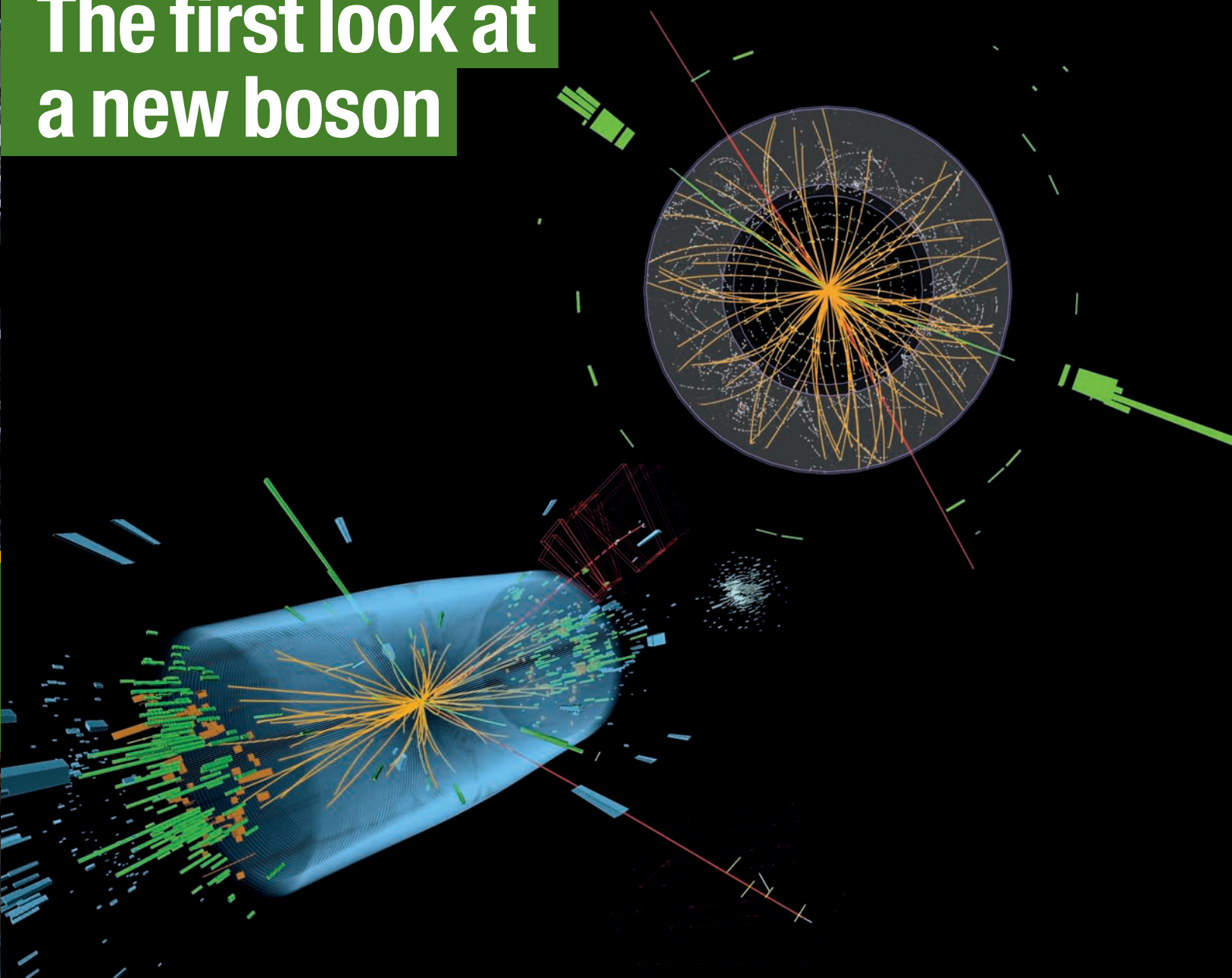


# CERN COURIER

VOLUME 52 NUMBER 7 SEPTEMBER 2012

## The first look at a new boson



### ICHEP2012

Melbourne hosts the summer's major conference  
**p53**

### SPACE SHUTTLE

Astronauts come to CERN  
**p63**



### PS BOOSTER HITS 40

A key machine continues to evolve  
**p33**

Source for trouble free Power Supply Design

## New VME395 series of WIENER VME/VME64x Mini Crates

FRONT TO REAR COOLING — WITH TCP/IP ETHERNET AND OPC SERVER  
**THE PERFECT CHOICE FOR SMALL SETUPS!**



- mechanics for 6U , 160mm VME modules, suitable either for 19" racks, as tower- or desktop box, ruggedized design
- 9 slot monolithic backplanes VME /VME64 or VME64x with optional P0 connector
- 1 or 2 cPCI power supplies (250W), with hot-swapping and redundant operation, voltage and current monitoring / control, rear side plugged in
- measurement and data logging system for remote monitoring and control, Ethernet and USB interface
- rear access for 6U /80mm transition modules (optionally 160 and 120mm)
- alphanumeric high-visibility LED display for voltages, currents, fan speed, temperatures and settings / programming, 4 status LED's

Crate Type	Backplane	Output voltages and currents				Total power AC Mains 90-265V
		+5V	+3.3V	+12V	-12V	
VME395-1	VME64	33A		6A	1.5A	250W
VME395-2	VME64	66A		12A	3A	500W
VME395x1	VME64x	33A	33A	6A	1.5A	250W
VME395x2	VME64x	66A	66A	12A	3A	500W
VME395x1P0	VME64x with P0	33A	33A	6A	1.5A	250W
VME395x2P0	VME64x with P0	66A	66A	12A	3A	500W



## Covering current developments in high-energy physics and related fields worldwide

CERN Courier is distributed to member-state governments, institutes and laboratories affiliated with CERN, and to their personnel. It is published monthly, except for January and August. The views expressed are not necessarily those of the CERN management.

**Editor** Christine Sutton  
**News editor** Kate Kahle  
**Editorial assistant** Carolyn Lee  
 CERN, 1211 Geneva 23, Switzerland  
**E-mail** cern.courier@cern.ch  
**Fax** +41 (0) 22 785 0247  
**Web** cerncourier.com

**Advisory board** Luis Álvarez-Gaumé, James Gillies, Horst Wenninger

**Laboratory correspondents:**  
**Argonne National Laboratory (US)** Cosmas Zachos  
**Brookhaven National Laboratory (US)** P Yamin  
**Cornell University (US)** D G Cassel  
**DESY Laboratory (Germany)** Till Mundzeck  
**EMFCSC (Italy)** Anna Cavallini  
**Enrico Fermi Centre (Italy)** Guido Piragino  
**Fermi National Accelerator Laboratory (US)** Katie Yurkewicz  
**Forschungszentrum Jülich (Germany)** Markus Buescher  
**GSI Darmstadt (Germany)** I Peter  
**IHEP, Beijing (China)** Tongzhou Xu  
**IHEP, Serpukhov (Russia)** Yu Ryabov  
**INFN (Italy)** Romeo Bassoli  
**Jefferson Laboratory (US)** Steven Corneliussen  
**JINR Dubna (Russia)** B Starchenko  
**KEK National Laboratory (Japan)** Youhei Morita  
**Lawrence Berkeley Laboratory (US)** Spencer Klein  
**Los Alamos National Laboratory (US)** Rajan Gupta  
**NCSL (US)** Ken Kingery  
**Nikhef (Netherlands)** Paul de Jong  
**Novosibirsk Institute (Russia)** S Eidelman  
**Orsay Laboratory (France)** Anne-Marie Lutz  
**PSI Laboratory (Switzerland)** P-R Kettle  
**Saclay Laboratory (France)** Elisabeth Locci  
**Science and Technology Facilities Council (UK)** Julia Maddock  
**SLAC National Accelerator Laboratory (US)** Farnaz Khadem  
**TRIUMF Laboratory (Canada)** Marcello Pavan

Produced for CERN by IOP Publishing Ltd  
 IOP Publishing Ltd, Temple Circus, Temple Way,  
 Bristol BS1 6HG, UK  
 Tel +44 (0)117 929 7481

**Publisher** Susan Curtis  
**Production editor** Jesse Karjalainen  
**Technical illustrator** Alison Tovey  
**Group advertising manager** Chris Thomas  
**Advertisement production** Katie Graham  
**Marketing & Circulation** Angela Gage

**Head of B2B & Marketing** Jo Allen  
**Art director** Andrew Giaquinto

**Advertising**  
 Tel +44 (0)117 930 1026 (for UK/Europe display advertising)  
 or +44 (0)117 930 1164 (for recruitment advertising);  
 E-mail: sales@cerncourier.com; fax +44 (0)117 930 1178

**General distribution** Courier Adressage, CERN, 1211 Geneva 23, Switzerland  
 E-mail: courier-adressage@cern.ch  
 In certain countries, to request copies or to make address changes, contact:  
**China** Keqing Ma, Library, Institute of High Energy Physics,  
 PO Box 918, Beijing 100049, People's Republic of China  
 E-mail: keqingma@mail.ihep.ac.cn  
**Germany** Veronika Werschner, DESY, Notkestr. 85, 22607 Hamburg, Germany  
 E-mail: desypr@desy.de  
**Italy** Loredana Rum or Anna Pennacchiotti, INFN, Casella Postale 56, 00044 Frascati,  
 Rome, Italy  
 E-mail: loredana.rum@inf.infn.it  
**UK** Mark Wells, Science and Technology Facilities Council, Polaris House, North Star  
 Avenue, Swindon, Wiltshire SN2 1SZ  
 E-mail: mark.wells@stfc.ac.uk  
**US/Canada** Published by Cern Courier, 6N246 Willow Drive,  
 St Charles, IL 60175, US. Periodical postage paid in St Charles, IL, US  
 Fax 630 377 1569. E-mail: creative\_mailing@att.net  
 POSTMASTER: send address changes to: Creative Mailing Services, PO Box 1147,  
 St Charles, IL 60174, US

Published by European Organization for Nuclear Research, CERN,  
 1211 Geneva 23, Switzerland  
 Tel +41 (0) 22 767 61 11. Telefax +41 (0) 22 767 65 55

Printed by Warners (Midlands) plc, Bourne, Lincolnshire, UK

© 2012 CERN ISSN 0304-288X

IOP Publishing



# CERN COURIER

VOLUME 52 NUMBER 7 SEPTEMBER 2012

- 5 **NEWS**  
 • Tevatron experiments observe evidence for Higgs-like particle • Proton run for 2012 extended by seven weeks • Auger determines pp inelastic cross-section at  $\sqrt{s} = 57\text{ TeV}$  • Heavy-ion jets go with the flow • New results cast light on semileptonic  $B_s$  asymmetry • XENON100 sets record limits • MoEDAL looks to the discovery horizon
- 12 **SCIENCEWATCH**
- 14 **ASTROWATCH**
- 16 **ARCHIVE**
- 18 **FEATURES**  
**CMS studies the quark–gluon plasma**  
*Results from a multifaceted heavy-ion programme.*
- 27 **Particle identification in ALICE boosts QGP studies**  
*How the experiment employs an arsenal of techniques.*
- 33 **The PS Booster hits 40**  
*The evolution of a key machine at CERN.*
- 39 **ECLLOUD12 sheds light on electron clouds**  
*Workshop brings the experts together.*
- 43 **Discovery of a new boson – the ATLAS perspective**  
 46 **4 July 2012: a day to remember**  
 49 **Inside story: the search in CMS for the Higgs boson**  
*ATLAS and CMS describe the analysis procedures presented in the seminar on 4 July, watched by scientists around the world.*
- 53 **Particle-physics fever in Melbourne**  
*A wave of optimism at ICHEP2012.*
- 63 **FACES & PLACES**
- 78 **RECRUITMENT**
- 85 **BOOKSHELF**
- 90 **VIEWPOINT**



**On the cover:** Candidate events consistent with the decay of a Standard Model Higgs boson for ATLAS (top) and CMS (bottom), as announced on 4 July (pp43–50). Both events have the characteristics expected from the decay to a pair of Z bosons, one of which decays to  $e^+e^-$  (green lines and towers), the other to  $\mu^+\mu^-$  (red lines). The events could also be from background processes.

# Exceptional high performance



Totally outclassing  
the competition



## nXDS

Discover more at  
[www.edwardsvacuum.com/nXDS](http://www.edwardsvacuum.com/nXDS)



nXDS - the great new shape of  
high performance dry vacuum pumping

## EDWARDS

Vacuum science... product solution.



FERMILAB

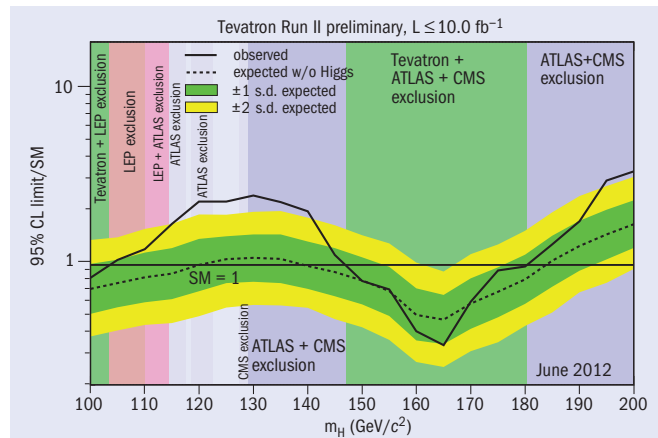
# Tevatron experiments observe evidence for Higgs-like particle

The CDF and DØ collaborations at Fermilab have found evidence for the production of a Higgs-like particle decaying into a pair of bottom and antibottom quarks, independent of the recently announced Higgs-search results from the LHC experiments. The result, accepted for publication in *Physical Review Letters*, will help in determining whether the new particle discovered at the LHC is the long-sought Higgs particle predicted in the Standard Model.

Fermilab's Tevatron produced proton-antiproton collisions until its shutdown in 2011 (*CERN Courier* October 2011 p20); the LHC produces proton-proton collisions. In their analyses, the teams at both colliders search for all potential Higgs decay modes to ensure that no Higgs-boson event is missed. While the Standard Model does not predict the mass of the Higgs boson, it does predict that the Standard Model Higgs boson favours decaying into a pair of b quarks if the mass is below 135 GeV. A heavier Higgs would decay most often into a pair of W bosons.

The CDF and DØ teams have analysed the full Tevatron data set – accumulated over the past 10 years. Both collaborations developed substantially improved signal and background separation methods to optimize their search for the Higgs boson, with hundreds of scientists from 26 countries actively engaged in the search.

After careful analysis and multiple verifications, on 2 July CDF and DØ announced a substantial excess of events in the data beyond the background expectation in the mass region between 120 GeV and 135 GeV, which is consistent with the predicted signal from a Standard Model Higgs boson. Two days later, the ATLAS and CMS collaborations announced the observation in



*The Tevatron results indicate evidence for a Higgs-like particle with a mass between 120 and 135 GeV.*

collisions at the LHC of a new boson with a mass of about 125 GeV.

At both of the Tevatron and the LHC, b jets are produced in large amounts, drowning out the signal expected when a Standard Model Higgs boson decays to two b quarks. At the Tevatron, the most successful way to search for a Higgs boson in this final state is to look for those produced in association with a W or Z boson. The small signal and large background require that the analysis includes every event that is a candidate for a Higgs produced with a W or Z boson. Furthermore, the analysis must separate the events that are most signal-like from the rest.

In the past two years, the CDF and DØ Higgs-search analysis teams improved the expected Higgs sensitivity of these experiments by almost a factor of two by separating the analysis into multiple search channels, adding acceptance for final decay products as well as developing innovative ways for improving particle-identification methods. Combined with a Tevatron data set of 10 fb<sup>-1</sup>, these efforts led to the

extraction of about 20 Higgs-like events that are not compatible with background-only predictions. These events are consistent with the production and decay of Higgs bosons created by the Tevatron. The signal has a statistical significance of 3.1  $\sigma$ .

#### ● Further reading

CDF and DØ collaborations 2012 arXiv:1207.6436v1 [hep-ex].

## Sommaire en français

Les expériences du Tevatron observent des indices d'une particule semblable au boson de Higgs	5
Sept semaines de prolongation pour l'exploitation 2012 du LHC avec protons	6
Auger mesure la section efficace inélastique pp pour $\sqrt{s} = 57$ TeV	6
Ions lourds : des jets qui interagissent avec le flux	7
L'asymétrie semi-leptonique $B_s$ mieux comprise	9
Le détecteur XENON100 fixe des limites record	9
MoEDAL : un potentiel de découvertes	10
Les lasers : vers une lumière nouvelle sur la gravité quantique	12
Des amas de galaxies reliés par un filament de matière noire	14

## A day to remember

On 4 July, particle physicists around the world eagerly joined many who had congregated early at CERN to hear the latest news on the search for the Higgs boson at the LHC (p46). It was a day that many will remember for years to come. The ATLAS and CMS collaborations announced that they had observed clear signs of a new boson consistent with being the Higgs boson, with a mass of around 126 GeV, at a significance of 5  $\sigma$ . In this issue of *CERN Courier* the two collaborations present their evidence (p43 and p49) and CERN's director-general reflects on broader implications (p90). There was further good news from Fermilab with new results on the search for the Higgs at the Tevatron, described above.

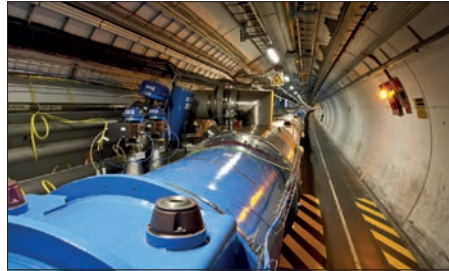


## News

## LHC NEWS

# Proton run for 2012 extended by seven weeks

An important piece of news that was almost lost in the excitement of the Higgs update seminar on 4 July is that the LHC proton run for 2012 is to be extended. On 3 July, a meeting between CERN management and representatives from the LHC and the experiments discussed the merits of increasing the data target for this year in the light of the announcement to be made the following day (p46). The conclusion was that an additional seven weeks of running would allow the luminosity goal for the



year to be increased from 15 to 20 fb<sup>-1</sup>. This should give the experiments a good supply of

data to work on during the LHC's first long shut-down as well as allow them to make progress in determining the properties of the new particle.

The original schedule foresaw proton running ending on 16 October, with a proton-ion run planned for November. In the preliminary new schedule, proton running is planned to continue until 16 December, with the proton-ion run starting after the Christmas stop on 18 January 2013 and continuing until 10 February.

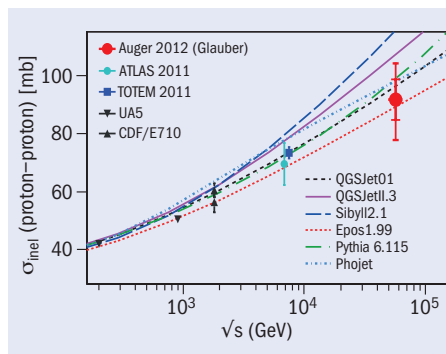
## COSMIC RAYS

# Auger determines pp inelastic cross-section at $\sqrt{s} = 57$ TeV

Ultra-high-energy cosmic-ray particles constantly bombard the atmosphere at energies far beyond the reach of the LHC. The Pierre Auger Observatory was constructed with the aim of understanding the nature and characteristics of these particles using precise measurements of cosmic-ray-induced extensive air showers up to the highest energies. These studies allow Auger to measure basic particle interactions, recently in an energy range equivalent to a centre-of-mass energy of  $\sqrt{s} = 57$  TeV.

The structure of an air shower is complex and depends in a critical way on the features of hadronic interactions. Detailed observations of air showers in combination with astrophysical interpretations can provide specific information about particle physics up to  $\sqrt{s} = 500$  TeV. This corresponds to an energy of  $10^{20}$  eV for a primary proton in the laboratory system.

The depth in the atmosphere at which a cosmic-ray air shower reaches its maximum size,  $X_{\max}$ , correlates with the atmospheric depth at which the primary cosmic-ray particle interacted. The distribution of the measured  $X_{\max}$  values for the most deeply penetrating showers exhibits an exponential tail, the slope of which can be directly related to the interaction length of the initiating



Auger's measurement of the pp inelastic cross-section at  $\sqrt{s_{NN}} = 57$  TeV, compared with predictions of various interaction models and measurements at the Sp $\bar{p}$ S, the Tevatron and the LHC.

particle. This, in turn, provides the inelastic proton-air cross-section. The proton-proton (pp) cross-section is then inferred using an extended Glauber calculation with parameters derived from accelerator measurements that have been extrapolated to cosmic-ray energies. This Auger analysis is an extension of a method first used in the Fly's Eye experiment in Utah (Baltrusaitis *et al.* 1984).

The composition of the highest-energy

cosmic rays – whether they are protons or heavier nuclei – is not known and the purpose of the Auger analysis is to help in understanding it. The analysis targets the most deeply penetrating particles and so is rather insensitive to the nuclear mix. As long as there are at least some primary protons, then it is their cross-section that is measured. Moreover, to minimize systematic uncertainties, the Pierre Auger collaboration has chosen the cosmic-ray energy range of  $10^{18}$ – $10^{18.4}$  eV ( $\sqrt{s_{NN}} \sim 57$  TeV) in which protons appear to constitute a significant contribution to the overall flux. The largest uncertainty arises from a possible helium contamination, which would tend to yield too large a proton inelastic cross-section.

The figure shows the experimental result, which is to be published in *Physical Review Letters* (Abreu *et al.* 2012). It confirms the cross-section extrapolations implemented in interaction models that predict a moderate growth of the cross-section beyond LHC energies and is in agreement with the  $\ln^2(s)$  rise of the cross-section expected from the Froissart bound.

### Further reading

P Abreu *et al.* 2012 *Phys. Rev. Lett.*, in press.  
R Baltrusaitis *et al.* *Phys. Rev. Lett.* **52** 1380.

**Les physiciens des particules du monde entier sont invités à apporter leurs contributions aux CERN Courier, en français ou en anglais. Les articles retenus seront publiés dans la langue d'origine. Si vous souhaitez proposer un article, faites part de vos suggestions à la rédaction à l'adresse [cern.courier@cern.ch](mailto:cern.courier@cern.ch).**

**CERN Courier welcomes contributions** from the international particle-physics community. These can be written in English or French, and will be published in the same language. If you have a suggestion for an article, please send proposals to the editor at [cern.courier@cern.ch](mailto:cern.courier@cern.ch).

## LHC PHYSICS

## Heavy-ion jets go with the flow



ALICE

The studies of central heavy-ion collisions at the LHC by the ALICE, ATLAS and CMS experiments show that partons traversing the produced hot and dense medium lose a significant fraction of their energy. At the same time, the structure of the jet from the quenched remnant parton is essentially unmodified. The radiated energy reappears mainly at low and intermediate transverse momentum,  $p_T$ , and at large angles with respect to the centre of the jet cone. The ALICE collaboration has studied this  $p_T$  region in PbPb collisions at a centre-of-mass energy  $\sqrt{s_{NN}} = 2.76$  TeV by using two-particle angular correlations, with some interesting results.

In the analysis, the associated particles are counted as a function of their difference in azimuth ( $\Delta\phi$ ) and pseudorapidity ( $\Delta\eta$ ) with respect to a trigger particle in bins of trigger transverse momentum,  $p_{T, \text{trig}}$ , and associated transverse momentum,  $p_{T, \text{assoc}}$ . With the aim of studying potential modifications of the near-side peak, correlations independent of  $\Delta\eta$  are subtracted by an  $\eta$ -gap method: the correlation found in  $1 < |\Delta\eta| < 1.6$  (as a function of  $\Delta\phi$ ) is subtracted from the region in  $|\Delta\eta| < 1$ . Figure 1 shows an example in one  $p_T$  bin: only the near-side peak remains, while by construction the away-side (not shown) is flat.

ALICE studies the shape of the near-side peak by extracting both its rms value (which is a standard deviation,  $\sigma$ , for a distribution centred at zero) in the  $\Delta\eta$  and  $\Delta\phi$  directions and the excess kurtosis (a statistical measure of the “peakedness” of a distribution). The near-side peak shows an interesting evolution towards central collisions: it becomes eccentric.

Figure 2 presents the rms as a function of centrality in PbPb collisions as well as the one for pp collisions (shown at a centrality of 100). Towards central collisions the  $\sigma$  in  $\Delta\eta$  (lines) increases significantly, while the  $\sigma$  in  $\Delta\phi$  (data points) remains constant within uncertainties. This is found for all of the  $p_T$  bins studied, from  $1 < p_{T, \text{assoc}} < 2$  GeV/c,  $2 < p_{T, \text{trig}} < 3$  GeV/c to  $2 < p_{T, \text{assoc}} < 3$  GeV/c,  $4 < p_{T, \text{trig}} < 8$  GeV/c (Grosse-Oetringhaus 2012).

The observed behaviour is qualitatively consistent with a picture where longitudinal flow distorts the jet shape in the  $\eta$ -direction (Armesto *et al.* 2004). The extracted rms and also the kurtosis (not shown here) are quantitatively consistent (within 20%) with Monte Carlo simulations with A MultiPhase

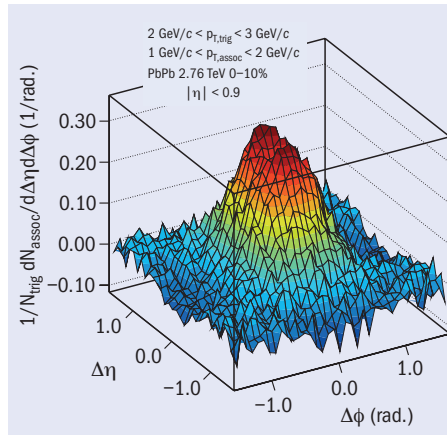


Fig. 1. Associated yield per trigger particle as a function of  $\Delta\eta$  and  $\Delta\phi$ .

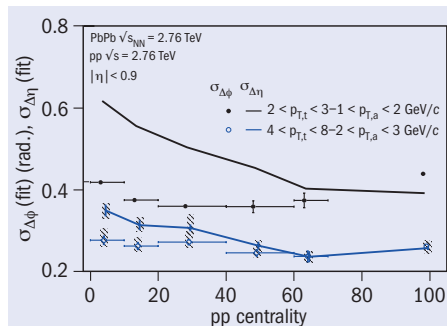


Fig. 2.  $\sigma$  of the near-side peak in  $\Delta\phi$  (data points) and  $\Delta\eta$  (lines) as a function of centrality for two different  $p_T$  bins (the rightmost point shows the result for pp collisions).

Transport Code (AMPT) (Lin *et al.* 2005). This Monte Carlo correctly reproduces collective effects such as “flow” at the LHC, which stem from parton–parton and hadron–hadron rescattering in the model.

This observation suggests an interplay of the jet with the flowing bulk in central heavy-ion collisions at the LHC. The further study of the low and intermediate  $p_T$  region is a promising field for the understanding of jet quenching at the LHC, which in turn is a valuable probe of the fundamental properties of quark–gluon plasma.

#### • Further reading

N Armesto *et al.* 2001 *Phys. Rev. Lett.* **93** 242301.  
JF Grosse-Oetringhaus for the ALICE collaboration 2012 “Hadron Correlations Measured with ALICE,” proceedings of Hard Probes 2012, Cagliari, Italy, arXiv:1208.1445 [nucl-ex].  
Lin *et al.* 2005 *Phys. Rev.* **C72** 06490.

## PHOTONIS

INDUSTRY | SCIENCE | MEDICAL

PHOTONIS is the leading manufacturer of high-speed particle and photon detection. Our products support a wide range of physics research applications, and are integrated in many laboratories where high energy, high-speed particle and photon detection is critical.

## PHOTON DETECTORS

Fast photon counters and single photon detectors for high-energy physics research applications.

- MCP-PMTs in Round or Square shapes with photocathode choices;
- Hybrid Photo Diodes for single photon counting with extremely low noise.



## BEAM PROFILE MONITORING

Fast photonic timing products for beam profile monitoring.

- Image Intensifiers in a wide range of custom photocathodes;
- Streak Tubes for a superior combination of spatial and temporal resolution;
- Electron Generator Arrays for a uniform, dense electron flux;
- Resistive Glass tubes to direct ion flow.



## ELECTRON MULTIPLICATION

PHOTONIS is the largest manufacturer of microchannel plates and electron multipliers.

- Microchannel Plates with custom sizes now with a low noise option;
- Channeltron® Electron Multipliers for single channel ion or electron detection.



## POWER TUBES

PHOTONIS offers a wide range of power tubes for use in particle accelerators.

- Large Power Triodes provide full RF amplification for pulsed service.



Call PHOTONIS for all your high-speed, high-energy physics detection needs. We are an established provider to CERN and other research laboratories globally.

## PHOTONIS

PHOTONIS France S.A.S.  
Avenue Roger Roncier  
19100 Brive La Gaillarde

T: +33 (0) 555 86 37 00  
E: sales@photonis.com  
W: www.photonis.com

A PASSION FOR PERFECTION

**PFEIFFER**  **VACUUM**



**PFEIFFER**  **VACUUM**



**adixen**  
by PFEIFFER VACUUM



## Perfect Vacuum Solutions!

### Two strong brands combined for your success

- Best-in-class products
- Leading vacuum technology know-how
- Worldwide sales and service support

**Are you looking for a perfect vacuum solution?  
Please contact us:**

**Pfeiffer Vacuum GmbH** · Headquarters/Germany  
T +49 6441 802-0 · F +49 6441 802-1202  
info@pfeiffer-vacuum.de

[www.pfeiffer-vacuum.com](http://www.pfeiffer-vacuum.com)





# New results cast light on semileptonic $B_s$ asymmetry

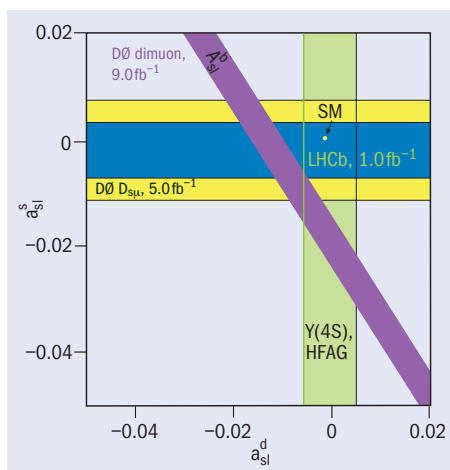


The LHCb experiment has made the most precise measurement to date of the asymmetry  $a_{sl}^s$ ,

which is a measure of a flavour-specific matter–antimatter asymmetry in B-mesons and a test for physics beyond the Standard Model.

In 2010, and with an update in 2011, the Fermilab DØ collaboration reported an asymmetry in the semileptonic decays of B mesons decay into muons, which they observed in the number of events containing same-sign dimuons (*CERN Courier* July August 2010 p6). The most recent result, using almost the full DØ data sample of  $9\text{ fb}^{-1}$ , gives an asymmetry of about  $-1\%$ , and differs by  $3.9\sigma$  from the tiny value predicted within the framework of the Standard Model (Abazov *et al.* 2011). If confirmed, it would indicate the presence of new physics.

Same-sign dimuons can be produced from the decay of pairs of neutral B mesons, which can mix between their particle and antiparticle states. Owing to the inclusive nature of the DØ measurement, the asymmetry, denoted  $A_{sl}^b$ , is a sum of contributions from the individual asymmetries in the  $B_d$  and  $B_s$  meson systems,  $a_{sl}^d$  and  $a_{sl}^s$  respectively. It is shown as the diagonal band in the plane of those



Results on the dimuon asymmetry in B mesons, with the latest measurement for LHCb (blue band).

asymmetries in the figure. The individual asymmetries characterize CP-violation in B-meson mixing, similar to the parameter  $\epsilon_K$  in the neutral kaon system.

One of the highest priorities in flavour physics has been to measure  $a_{sl}^d$  and  $a_{sl}^s$  separately to establish if there is a disagreement with the Standard Model – and, if so, whether it occurs in the  $B_d$  or  $B_s$  system. Previous measurements of  $a_{sl}^d$  by the

BaBar and Belle collaborations working at the  $\Upsilon(4S)$  resonance and of  $a_{sl}^s$  in an independent analysis by DØ have not been sufficiently precise to answer this question.

The new result from LHCb, based on the full 2011 data sample of  $1.0\text{ fb}^{-1}$ , and first presented at ICHEP2012 (p53), provides the most precise measurement to date of  $a_{sl}^s$ . The analysis uses  $B_s^0 \rightarrow D_s^- \mu^+ X$  (and charge conjugate) decays, with  $D_s^- \rightarrow \phi \pi^-$  and relies on excellent control of asymmetries in the  $\mu^\pm$  trigger and reconstruction. The result,  $a_{sl}^s = (-0.24 \pm 0.54 \pm 0.33)\%$ , which is shown as the horizontal blue band in the figure, is consistent with the Standard Model prediction (LHCb collaboration 2012). Updated results from DØ on both  $a_{sl}^d$  and  $a_{sl}^s$ , which were also presented at ICHEP2012, continue to leave the situation unclear; more precise measurements are needed (Stone 2012). With the recently announced extension of proton running at the LHC for 2012 (p6), the LHCb collaboration expects to more than triple its data sample, so updates on this topic will be most exciting.

## ● Further reading

VM Abazov *et al.* DØ collaboration 2011 *Phys. Rev. D* **84** 052007.

LHCb collaboration 2012 LHCb-CONF-2012-022.  
S Stone 2012 LHCb-TALK-2012-203.

## DARK MATTER

# XENON100 sets record limits

The XENON collaboration has announced the result of analysis of data taken with the XENON100 detector during 13 months of operation at INFN'S Gran Sasso National Laboratory. It provides no evidence for the existence of weakly interacting massive particles (WIMPs), the leading candidates for dark matter. The two events observed are statistically consistent with one expected event from background radiation. Compared with their previous result from 2011, the sensitivity has again been improved by a factor of 3.5. This constrains models of new physics with WIMP candidates even further and it helps to target future WIMP searches.

XENON100 is an ultrasensitive device. It uses 62 kg of ultrapure liquid xenon as a WIMP target and simultaneously measures ionization and scintillation signals that

are expected from rare collisions between WIMPs and the nuclei of xenon atoms. The detector is operated deep underground at the Gran Sasso National Laboratory, to shield it from cosmic rays. To avoid false events occurring from residual radiation from the detector's surroundings, only data from the inner 34 kg of liquid xenon are taken as candidate events. In addition, the detector is shielded by specially designed layers of copper, polyethylene, lead and water to reduce the background noise even further.

In 2011, the XENON100 collaboration published results from 100 days of data-taking. The achieved sensitivity already pushed the limits for WIMPs by a factor 5 to 10 compared with results from the earlier XENON10 experiment. During the new run, a total of 225 live days of data were

accumulated in 2011 and 2012, with lower background and hence improved sensitivity. Again, no signal was found.

The two events observed are statistically consistent with the expected background of one event. The new data improve the bounds to  $2.0 \times 10^{-45}\text{ cm}^2$  for the elastic interaction of a WIMP mass of 50 GeV. This is another factor of 3.5 compared with the earlier results and cuts significantly into the expected WIMP parameter region. Measurements are continuing with XENON100 and a still more sensitive, 100-tonne experiment, XENON1T, is currently under construction.

● The XENON collaboration consists of scientists from 15 institutions in China, France, Germany, Israel, Italy, the Netherlands, Portugal, Switzerland and the US.

## News

## LHC EXPERIMENTS

# MoEDAL looks to the discovery horizon

MoEDAL, the “magnificent seventh” LHC experiment, held its first Physics Workshop in CERN’s Globe of Science and Innovation on 20 June. This youngest LHC experiment is designed to search for the appearance of new physics signified by highly ionizing particles such as magnetic monopoles and massive long-lived electrically charged particles from a number of theoretical scenarios.

Philippe Bloch of CERN commenced the meeting, stressing CERN’s support for the MoEDAL programme. He spoke of the key role that smaller, well motivated “high-risk” experiments such as MoEDAL play in expanding the physics reach of the LHC and reminded the audience that “one cannot predict with certainty where the next discovery will be made”.

Nobel laureate Gerard ’t Hooft began the morning’s theory talks with a reprise of his work on the monopole in grand unified theories (GUTs), elegantly showing how the beautiful monopole mathematics plays an important role in QCD and other fundamental theories. Arttu Rajantie of Imperial College London deftly recounted the story of “Monopoles from the Cosmos and the LHC”, concentrating on more recent theoretical scenarios, such as that of the electroweak “Cho-Maison” monopole, which are detectable at the LHC because they involve particles that are much lighter than the GUT monopole, with masses in the range  $1 \text{ TeV}/c^2$ .

John Ellis and Nikolaos Mavromatos of King’s College London then changed the emphasis from magnetic to electric charge. Ellis described supersymmetry (SUSY) scenarios with massive stable particles (MSPs), such as sleptons, stops, gluinos and R-hadrons, which should be observable by MoEDAL. Mavromatos characterized the numerous non-SUSY scenarios that could give rise to MSPs, such as D-particles, Q-balls, quirks, doubly charged Higgs etc., all of which MoEDAL could detect.

In the afternoon, Albert de Roeck of CERN and Philippe Mermod of the



’t Hooft introduces the Dirac monopole. (Image credit: R Soluk, University of Alberta.)

University of Geneva laid out the significant progress made by CMS and ATLAS, respectively, in the quest for new physics revealed by highly ionizing particles. James Pinfold, of the University of Alberta and MoEDAL spokesperson, made the physics case for MoEDAL. He pointed out how its often-superior sensitivity to monopoles and massive slowly moving charged particles expanded the physics reach of the LHC in a complementary way. The MoEDAL collaboration, with 18 institutes from 10 countries, is still a “David” compared with the LHC “Goliaths” but its potential physics impact is second to none (*CERN Courier* May 2010 p19).

No workshop dealing with magnetic monopoles would be complete without an account of the search for cosmic monopoles. The two main experiments in this arena – MACRO, installed underground at the Gran Sasso National Laboratory in Italy, and the SLIM experiment, at the high-altitude Mount Chacaltaya Laboratory in Bolivia – were presented by Zouleikha Sahnoun of the SLIM collaboration. These two experiments still have the world’s best limits for GUT and intermediate-mass monopoles. Returning to Earth, David Milstead of Stockholm University described a project to search for trapped monopoles at the LHC.

Importantly, this initiative is complementary to that of both MoEDAL and the main LHC experiments.

Why has the monopole not been seen in previous searches at accelerators? Vincete Vento of the University of Valencia offered an ingenious explanation. Monopoles are hiding in monopolium, a bound state of a monopole and an antimonopole, a suggestion that Paul Dirac made in his 1931 paper. Vento went on to describe a couple of ways that MoEDAL might detect monopolium.

In the last talk of the workshop, John Swain of Northeastern University presented the remarkable speculation that at the LHC the neutral Higgs boson could predominantly decay into a nucleus–antinuclues pair. He sketched, and nimbly defended, a theoretical justification for this surprising suggestion. Certainly, such a decay mode would be easily detectable by MoEDAL.

The clear message of the workshop is that MoEDAL has a potentially revolutionary physics programme aimed exclusively at the search for new physics, with the minimum of theoretical prejudices and the maximum exploitation of experimental search techniques. After all, in the words of JBS Haldane: “... the universe is not only queerer than we suppose, but queerer than we can suppose.”

**Heinzinger®**  
power supplies  
supplies your world

HIGH PRECISION | HIGH CURRENT | HIGH VOLTAGE

*We have the power!*

high precision  
DC Power Supplies  
& more



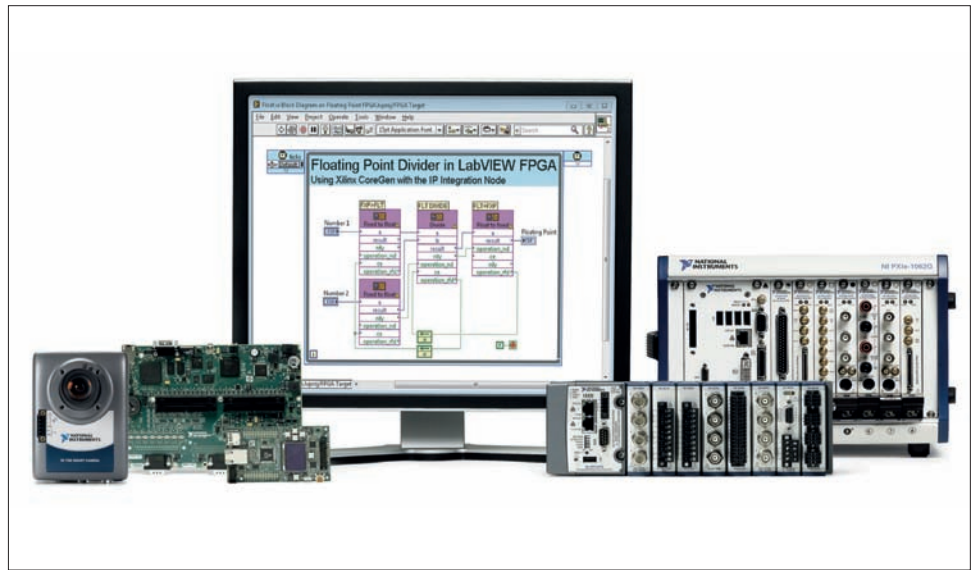
[www.heinzinger.com](http://www.heinzinger.com)

# Customized COTS for the LHC Collimator Collimation Control System

Particle accelerators need collimation systems to absorb energetic particles that fall outside the nominal beam core. With energies capable of melting 500 kg of copper, the Large Hadron Collider (LHC) is protected from uncontrolled beam losses by a collimation system consisting of more than 100 collimators, each equipped with two moveable jaws. The LHC collimation control system is responsible for the control of more than 500 stepper motor axes and the monitoring of more than 700 linear variable differential transformer (LVDT) positioning sensors. The collimators are distributed around the 27 km ring, and each of the motor axes needs to be synchronized within a maximum jitter of 10 ms over the 30-minute-long motion profiles of the motors while maintaining a position error of 20  $\mu\text{m}$  or less. If the axes are for the same jaw, then the maximum synchronization jitter needs to be at the microsecond level.

CERN needed a platform with the custom features that were essential but still available as commercial off-the-shelf (COTS) tools to keep the cost of developing custom hardware and software drivers down. This also would help reduce the manpower needed to complete the required system. By using an FPGA-based COTS system that was truly field programmable without having to send it back to the vendor for reprogramming, CERN could gain the benefits of both a custom and COTS design. Additionally, an FPGA offers true hardware parallelism to greatly improve performance and provides hardware reliability because FPGA circuitry is a “hard” implementation of program execution.

The CERN LHC team chose the National Instruments PXI platform, featuring the reconfigurable I/O (RIO) architecture with an FPGA at its heart, for the collimation control system. This platform delivers the small size, ruggedness, and cost savings that custom designs and VME- and PLC-based systems do not.



## RIO Architecture

CERN LHC team members can use the FPGA for advanced control algorithms as well as custom interfacing, timing, and triggering. In this specific application, they use the FPGA for tasks such as trajectory generation for motors, verification of lost steps, and ensuring synchronization. With the RIO architecture, team members can completely contain the entire control loop—input, control algorithm, and output—in the FPGA if needed and achieve very high loop rates and determinism as well as extremely low latency.

The microprocessor unit (MPU) in the NI RIO architecture can run different OSs such as real-time (VXWorks, Pharlap), Windows, and Linux OSs. The MPU communicates with the FPGA through a high-speed, typically PCI or PCI Express interface. CERN runs a real-time OS for the MPU to execute math algorithms for amplitude estimation and to obtain position information for the collimators. The MPU also acts as a “gateway” for all the data exchange from the top-level application via a standard CERN middleware server and establishes individual communication channels through the Data Interchange Management (DIM) system.

## Programming FPGAs and Real-Time Systems

The real differentiator for the NI RIO architecture is the graphical system design approach that includes NI LabVIEW system design software. The MPU, FPGA, and specialized I/O that make up the RIO architecture traditionally have been designed

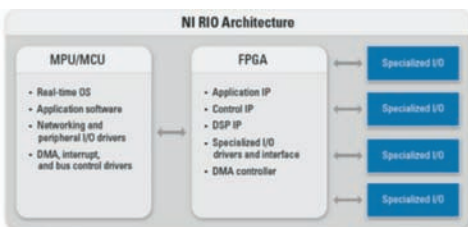
and programmed using a disparate collection of tools that require a multidisciplinary team to implement the design. A design team with this range of expertise can be difficult and expensive to assemble.

LabVIEW is an integrated design tool that offers a common language to program the MPU and the FPGA. A single design tool decreases the need for specialized software and hardware description language (HDL) expertise so that one engineer on the design team can implement application, DSP, measurement, and control software executing on both the MPU and FPGA. This blurs the lines between hardware and software engineering and creates the new role of system designer.

LHC collimation control system development team members took advantage of the RIO architecture and LabVIEW to design their system successfully. Over 120 PXI systems loaded with NI reconfigurable I/O modules are being used to control 108 collimators around the 27 km LHC ring. Since September 2008, the system has operated successfully while meeting all the stringent jitter, position tolerance, and synchronization requirements.

Control and diagnostic teams in various labs, research facilities, and the industry are increasingly taking advantage of the RIO architecture and graphical system design for their systems. Choosing the right system architecture in this technology-driven era allows teams to reap the best of both worlds: custom and COTS.

To learn more about the CERN collimation control system, visit [ni.com/newsletter/cern](http://ni.com/newsletter/cern).



The reconfigurable I/O (RIO) architecture can be used for diagnostic and control systems.



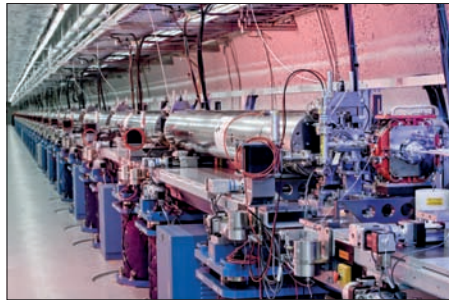
# Sciencewatch

COMPILED BY JOHN SWAIN, NORTHEASTERN UNIVERSITY

## Lasers could shine light on quantum gravity

Physics involving quantum mechanics and gravity need not involve the rather inaccessible Planck scale of  $10^{19}$  GeV. A new proposal by Gianluca Gregori of the University of Oxford and colleagues suggests using lasers to provide large accelerations that would mimic (via the equivalence principle) the effect of gravity on electrons.

A high-energy (100 J) laser would strike a gas jet, creating a channel of plasma about 0.2 mm long in which electrons would be accelerated by a second laser, in this case a high-intensity ( $10^{19}$  W/cm<sup>2</sup>) pulsed optical laser. Thomson scattering of X-rays



Could the Linac Coherent Light Source see tests of quantum mechanics in non-Minkowski space-time? (Image credit: Brad Plummer/SLAC.)

from a third laser – a free-electron laser providing 0.5 keV photons – would reveal via broadening the presence of an effectively non-Minkowski metric.

The requisite lasers are not yet available all in one place. Suggestions for a facility of this kind have already been made at both the Linac Coherent Light Source at Stanford and at the European XFEL at DESY. A laboratory test of quantum mechanics in non-Minkowski space-time might not be far off – with no black holes needed!

● **Further reading**

BJB Crowley *et al.* 2012 *Scientific Reports* 2 491.

### New spintronic transistor

A remarkable new spintronic transistor has been announced, with both the theory and experiment presented in the same paper. While traditional spintronic transistors manipulate the spin degrees-of-freedom of electrons via spin-orbit interactions, the new device from Dieter Weiss of the University of Regensburg and colleagues uses tunable Landau-Zener transitions.

The technique allows the adiabatic propagation of spin information in a cadmium-manganese-telluride diluted magnetic semiconductor quantum-well structure. The device carries information 10 to 100 times further than previous spintronic transistor designs.

This is a breakthrough in not just the storage but also the transport and processing of spin information. The full blossoming of spintronic technology seems closer than ever.

● **Further reading**

C Betthausen *et al.* 2012 *Science* 337 324.

### Fossil links

It looks like a good year for palaeontologists. A missing link in the fossil record of insect evolution has been found by Romain Garrouste of the Muséum national d'Histoire naturelle in Paris and colleagues. Dubbed *Strudiella devonica*, the 370-million-year-old fossil is the first complete Devonian insect fossil ever found. It is important because it fits in what has been called the “Hexapoda gap”, during which insect precursor organisms evolved into insects.

In addition, Walter Joyce of the University

### Tomatoes and taste

If you seem to remember an earlier time of uglier but tastier tomatoes, you may be remembering accurately. It turns out that tomatoes really are red for appearance at the expense of taste.

For decades breeders have selected tomatoes that develop a uniform light green colour before ripening, rather than having “green shoulders” (darkening more around the stem). Ann Powell of the University of California in Davis and colleagues have studied the genetics involved and found that this selection for visual appearance interferes with a gene *SIGLK2* and that doing so reduces the amount of sugar and other flavoured compounds within the popular red fruit.

● **Further reading**

ALT Powell *et al.* 2012 *Science* 336 1711.

of Tübingen and colleagues have analysed nine fossil male/female pairs of *Allaeochelys crassesculpta* turtles dating back 47 million years and found evidence in two that they were mating. Their report is in a paper with the delightful title, “Caught in the act: the first record of copulating fossil vertebrates.”

● **Further reading**

R Garrouste *et al.* 2012 *Nature* 488 82.  
WG Joyce *et al.* 2012 *Biol. Lett.*, doi: 10.1098/rsbl.2012.0361.

### Triple bonds for boron

It is not often that a brand-new type

of chemical bond is found but Holger Braunschweig and colleagues of Julian-Maximilians-Universität in Würzburg have coaxed two boron atoms to form a triple bond. Triple bonding, which occurs between carbon or nitrogen atoms, was not unexpected for boron. It had not been seen except, possibly, in highly unstable states.

The group used highly electron-donating chemical groups called N-heterocyclic carbenes to help coax electrons into a triple bond between two boron atoms. The green compound formed is stable up to 234°C if kept from air and promises the start of a new field of chemistry. The team has already taken a further step by forming a chain of four boron atoms bound to a metal.

● **Further reading**

H Braunschweig 2012 *Nature Chemistry* 4 563.

### Black holes and lithium

Standard Big Bang nucleosynthesis predicts well the relative abundances of hydrogen and helium, but predictions for lithium have always been too low. This is the so-called “lithium problem”. Now, Fabio Iocco of Stockholm University and Miguel Pato of the Technische Universität München make the problem worse by adding another source of lithium: synthesis in hot tori of matter from companion stars around black holes of stellar mass. They find that this source alone could be similar to the original pre-galactic lithium, thus worsening the lithium problem.

● **Further reading**

F Iocco and M Prato 2012 *Phys. Rev. Lett.* 109 021102.

# Agilent Vacuum: the UHV company

Agilent Technologies, spun-off from Hewlett-Packard in 1999, is today a world technology leader in life sciences, electronic measurement, and chemical analysis. In 2010 Agilent acquired Varian, Inc., a leading provider of analytical instrumentation and vacuum products. Varian's 60+ years of technology leadership and tradition of innovation in vacuum and leak detection became

come from Varian, now Agilent, from the first Diode Vaclon pump to the Triode, then to the StarCell series pumps, and the Vaclon Plus. Agilent supplies UHV solutions to all major academic and government labs, particle accelerators and synchrotrons, and large physics projects worldwide.



vacuum in several applications, ranging from research to industry, including particle accelerators, synchrotron light sources, medical accelerators, electron microscopes, surface analysis and focused ion beams. As a key enabling technology, ultra-high vacuum produced by Agilent ion pumps has been a critical and fundamental element of particle physics research from its early days to the recent milestone discovery of the Higgs boson on the Large Hadron Collider at CERN.

## Complete UHV Solutions

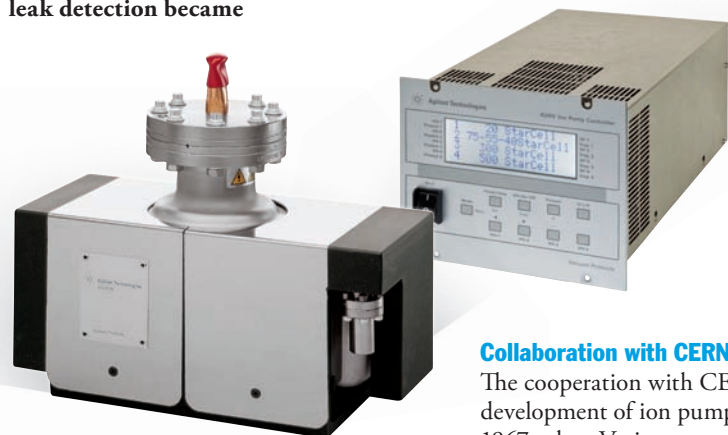
Agilent Vacuum is the leading UHV company, providing total oil-free solutions from atmospheric pressure to ultra-high vacuum. Agilent is the only vacuum supplier providing a complete range of pumps and accessories from dry scroll pumps, to high vacuum turbomolecular pumps, including the revolutionary TwisTorr, with proven best technical specifications on the market, up to the most advanced line of ultra high vacuum ion pumps, combined with the new Agilent 4UHV, the first true 4-channel ion pump controller.



Agilent VPD Plant, Torino, Italy



Toll free: 00 800 234 234 00  
[www.agilent.com/chem/vacuum](http://www.agilent.com/chem/vacuum)



a part of Agilent, the world's premier measurement company. Two of Silicon Valley's champions have combined to create a one-stop, truly global vacuum supplier, leader in High- and Ultra-High Vacuum solutions for physics research and scientific instrumentation.

## Technology leadership in UHV

Varian Vacuum, now Agilent Vacuum has always been at the forefront of vacuum technology, setting industry standards since 1957, with the invention of the ion pump that made UHV possible. The first sputter ion pump was developed to improve the life and performance of microwave tubes by continuous pumping with "appendage" ion pumps. The Varian invention of the sputter ion pump and of the ConFlat Flange (CFF) ushered in the era of ultra-high vacuum. The availability of vacuum systems that could routinely achieve pressures below  $10^{-11}$  mbar (Torr) enhanced R&D efforts in high energy physics. All of the major innovations in ion pump technology have



## Collaboration with CERN

The cooperation with CERN for joint development of ion pumps dates back to 1967, when Varian opened the Torino factory specifically for the manufacture of Ion Pumps designed to create ultra-high vacuum for the first CERN experiment. Since then, Varian, now Agilent, continues to supply High and Ultra-High Vacuum solutions to CERN. One of the first large installations of sputter ion pumps (300 pumps, with a pumping speed of 400 l/s) was the hadron collider ISR (Intersecting Storage Rings) that ran at CERN from 1971 to 1984. This was the start of a long history of ion pumps in Agilent's Torino plant, which today is the hub for ion pump development and manufacturing. It was also the start of an intensive collaboration between CERN and Varian (now Agilent). The StarCell ion pump, specifically designed to fulfill the vacuum requirement of the LEP project, was developed in Torino in 1983 and tested extensively by Varian and CERN engineers together on the CERN premises. As a result, more than 1,000 StarCell ion pumps have been built for the LEP project alone. The StarCell ion pump has proven to be the most important ion pump development and is the worldwide recognized standard for creating and maintaining ultra high



# Astrowatch

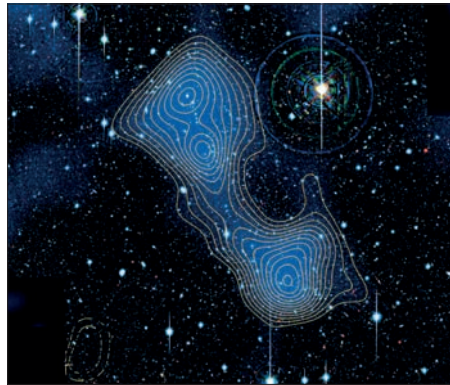
COMPILED BY MARC TÜRLER, ISDC AND OBSERVATORY OF THE UNIVERSITY OF GENEVA

## Dark-matter filament binds galaxy clusters

Numerical simulations of structure formation in the universe reveal how clusters of galaxies form at the intersection of dark-matter filaments. The presence of such a filament connecting the galaxy clusters Abell 222 and Abell 223 has finally been detected through its weak gravitational lensing effect on background galaxies.

With the advent of supercomputers it became possible to simulate the action of gravity over cosmic time starting from a rather uniform distribution of matter in the early universe (*CERN Courier* September 2007 p11). Time-lapse films based on these simulations show the evolution of structure formation in a large volume of the universe. While the universe expands globally, gravity tends to collapse small initial regions of over-density. Matter is therefore contracting locally while being stretched on large scales. The opposite effects of gravitational collapse and cosmic expansion result in a sponge-like structure with a web of filaments delimiting big voids. The densest regions are at the intersection of filaments and are the formation sites of clusters of galaxies. As time proceeds, matter flows along the filaments to the nearest cluster, making the filaments thinner and thinner.

This sponge-like distribution of matter in the universe has been confirmed by mapping the position of thousands of galaxies in the nearby universe for decades. According to the simulations, it is primarily cold dark matter that collapses to shape the filamentary skeleton of the universe; normal, baryonic matter follows the same route to form galaxies along these filaments. The detection of warm-hot intergalactic gas



*A bridge of dark matter is found to connect the two main clusters in the Abell 222 and Abell 223 galaxy clusters. The distribution of mass is shown with contours and a blue glow, on a background image obtained by the 8.2 m Subaru telescope on Mauna Kea, Hawaii. (Image credit: JP Dietrich et al. 2012.)*

along walls of galaxy over-densities was another piece of evidence for the validity of this scenario (*CERN Courier* July/August 2010 p14). What remained to be detected was the actual presence of dark matter in these filaments. This has now been achieved by Jörg P Dietrich of the University of Michigan and collaborators in Germany, the UK and the US, looking at the galaxy supercluster Abell 222 and Abell 223.

The technique used to map the distribution of dark matter in clusters of galaxies is always the same. It is called weak gravitational lensing and consists of measuring the small distortion of the shape of background galaxies induced by the presence of the invisible matter (*CERN*

*Courier* January/February 2007 p11). As mass distorts space-time locally, it changes the path of light from remote galaxies and thus alters their shape as observed from Earth. The problem is that the true shape of the individual galaxies is not known, so it is difficult to know how strong their distortion is. However, by analysing tens of thousands of galaxies, a global trend of distortion can emerge with statistical significance.

Dietrich and colleagues find a bridge of matter between Abell 222 and Abell 223 at the 96% confidence level. The derived surface density of this structure is unexpectedly high compared with dark-matter filaments in numerical simulations. This suggests that the filament is not seen from the side but almost along its major axis, thus increasing its projected mass. The red-shift difference between the two galaxy clusters does, indeed, suggest that they are at about 60 million light-years apart. The binding filament contributes as much as a complete galaxy cluster to the total mass of the supercluster. It is the site of an over-density of galaxies and includes hot intergalactic gas detected in X-rays. This gas contributes to about 9% of the total mass of the filament at most. The remaining mass would essentially be composed of dark matter. This discovery is new evidence that the basic assumptions of numerical simulations are valid; in particular, that cold dark matter is an essential ingredient governing the formation of large-scale structures in the universe.

### ● Further reading

JP Dietrich *et al.* 2012 *Nature* **487** 202.

## Picture of the month

Who is smoking in space? This delicate curl of smoke is blown away by a newborn star hiding in a cloud of dust. In the process of star formation, the infall of matter may form an accretion disc around the infant star, where magnetic fields are thought to funnel some of the incoming matter away in twin jets of gas ejected in opposite directions. Such stellar jets are the analogues of the extremely powerful jets of supermassive black holes in quasars (*CERN Courier* July/August 2006 p10). Herbig-Haro (HH) objects – so called in honour of George Herbig and Guillermo Haro, who studied these nebulosities in the 1940s – travel with speeds of several hundred kilometres a second. This jet of HH 110 has been captured beautifully by the Hubble Space Telescope in front of a background of distant spiral galaxies. (Image credit: NASA, ESA and the Hubble Heritage team (STScI/AURA).)





# Refrigerators for the cryogenic particle racetrack

*On 4 July 2012, the eyes of the world were firmly fixed on CERN in Geneva. It was on this day that the physicists at CERN announced their sensational discovery of a new particle that could be the Higgs boson. Linde Kryotechnik AG is proud to have played a part in this momentous occasion, providing the cutting-edge cryogenic technology for the accelerator's ring and detectors.*

## Outstanding achievement

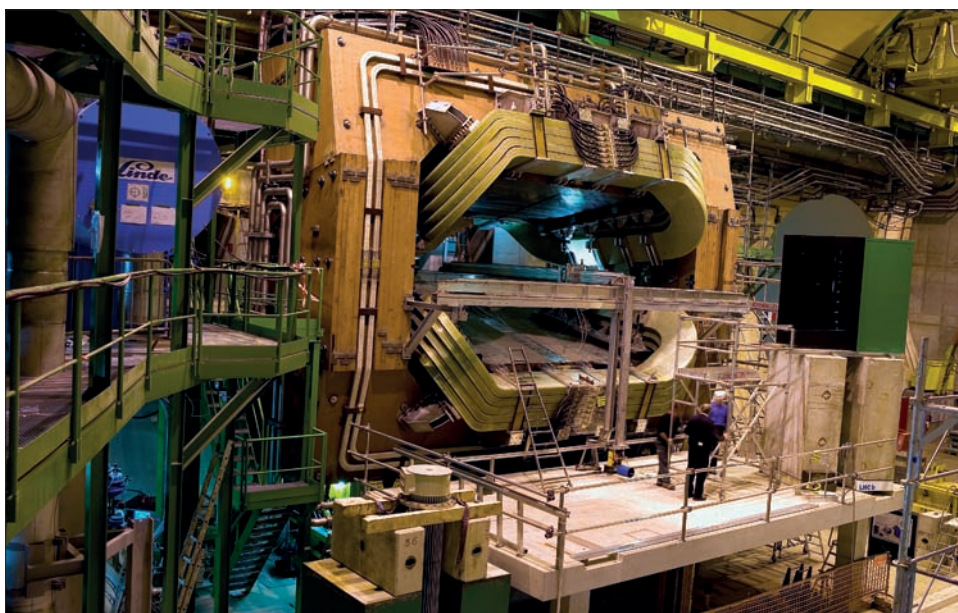
Two international teams conducting the ATLAS and CMS particle physics experiments at CERN have proven the existence of a particle that could be the Higgs boson – which would without doubt be one of the most important discoveries in particle physics, since the Higgs boson provides the key to explaining how elementary particles acquire mass.

Linde Kryotechnik would like to congratulate the physicists on their outstanding achievement. The findings once again highlight the ground-breaking work carried out at CERN. Linde Kryotechnik also expresses its thanks for the many years of successful collaboration with CERN. The cutting-edge cryogenic technology supplied by Linde Kryotechnik played a key role in keeping the CERN particle accelerator and detectors running smoothly in the long-standing search for the Higgs boson.

The Large Hadron Collider (LHC) has an operating temperature of just 1.8 K ( $-271.3^{\circ}\text{C}$ ), and is thus close to absolute zero. The superconducting magnets in the collider need this low temperature to generate intense magnetic fields for the ring. If the scientists at CERN used normal conducting magnets, the circumference of the particle accelerator would end up being 120 km long and energy consumption would rise thirty-fold.

The bending magnets have to be cooled using helium as this is the only element that remains liquid at this temperature. Together, the magnets have a combined weight of 37,000 tons, and 10,000 tons of liquid nitrogen is needed to cool this mass to 80 K. A further 130 tons of helium is used in the accelerator's closed cooling cycle, making the LHC the world's largest refrigerator.

Three consecutive phases are required to cool the LHC to these low temperatures. During an initial purification and cooling phase, liquid nitrogen brings the helium stream to a purity level of 99.9999 percent and a temperature of 80 K. This procedure has to be carried out after



Linde equipment (left) at LHCb, Point 8

complete warm-up of the accelerator, which takes place as scheduled every three to four years.

The preliminary cooling phase lasts two weeks. In the second cooling phase, helium expansion turbines cool the helium further, gradually reducing the temperature from 80 to 4.5 K – the boiling point of helium at an absolute pressure of 1.25 bar. The temperature of the helium is then reduced to 1.8 K during a third phase. This additional cooling is achieved by vaporizing the helium at an absolute pressure of 16 mbar. Multi-stage cold compressors with active magnetic bearings, variable speed and a sophisticated control system are used to recompress the vapour.

The temperature has to remain consistent at every point along the long proton racetrack. Cryogenic experts overcame this challenge by developing a complex distribution network comprising five different stations spread out along the entire accelerator ring. One or two cooling units are positioned at each station. Each unit delivers two helium streams, one gaseous flow at 50 K, and one supercritical flow at 4.5 K. The cryogenic helium streams are then pumped down to the ring elements at a depth of around one hundred metres. Here they flow through magnetizing coils, cooling jackets and cooling plates.

In recognition of the outstanding technology in Linde Kryotechnik's cooling solutions, CERN management honoured Linde Kryotechnik with the Golden Hadron Award in 2003.

CERN presented Linde Kryotechnik with a special honorarium in acknowledgement of the exceptional efficiency of its systems and publicly commended the design at the ICEC conferences in Beijing, China (2004) and Fukuoka, Japan (2012). CERN also lauded the extremely compact footprint and outstanding reliability of the solution.

Linde Kryotechnik also upgraded two existing refrigeration systems from the predecessor accelerator, LEP, equipping them with two new turbines. Linde's cryogenic technology is also being deployed in the ATLAS experiment to help cool the heat shield in the ATLAS detector to 40 K, and to cool the test bench for superconducting bending magnets to 4.5 K.

Linde Kryotechnik is proud to have been able to contribute to such a ground-breaking discovery and wishes CERN every success in its future research endeavours.

## Linde Kryotechnik AG

Daettlikonerstrasse 5  
8422 Pfungen  
Switzerland

Phone **+41.52.304-0555**

Fax **41.52.304-0550**

E-mail **info@linde-kryotechnik.ch**

Web **www.linde-kryotechnik.ch**

# CERN Courier Archive: 1969

A LOOK BACK TO CERN COURIER VOL. 8, SEPTEMBER 1969, COMPILED BY PEGGIE RIMMER

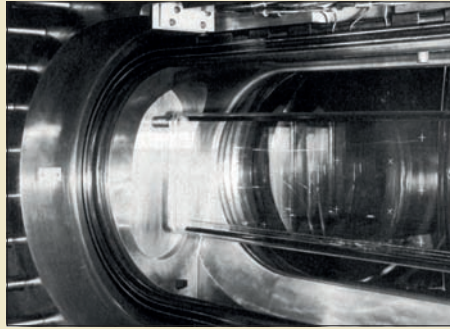
## RUTHERFORD LAB

# Successful tests on target technique

A new target technique has been successfully applied in the 1.5 m hydrogen bubble chamber at the Rutherford Laboratory. It involves the installation of a hydrogen target within a larger chamber containing a hydrogen neon mixture, to take advantage of the merits of both the hydrogen and the heavy-liquid bubble chamber.

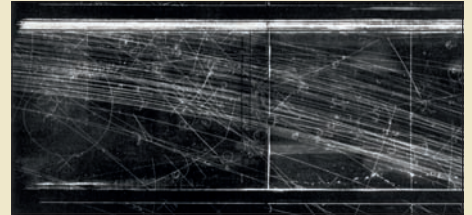
A perspex “bag” containing hydrogen runs the length of the 1.5 m chamber whilst the main volume is filled with a hydrogen neon mixture. The target bag has been developed and constructed in the Track Chambers Division at CERN on the basis of experience gained with similar devices for the DESY chamber and the CERN 1 m model.

The bag has plane walls parallel to the main chamber windows. It is constructed of perspex 2 mm thick and is 30 cm high by 4 cm deep. When the pressure system of the chamber is operated, the expansion is transmitted to the hydrogen in the bag



*The 1.5 m hydrogen bubble chamber at the Rutherford Laboratory showing the perspex bag which contains the target hydrogen. The bag runs the length of the chamber, with plane walls parallel to the chamber windows.*

due to the movement of the perspex walls. Since the expansion required is about 1%, the movement of each wall needs to be only about 0.2 mm.



*A photograph taken during the first test runs. Tracks appear in the hydrogen inside the bag and the hydrogen neon mixture outside with negligible track distortion going from inside to outside.*

Thus the two liquids are simultaneously sensitive, i.e. charged particle tracks can be produced inside and outside the bag. The first test run has shown that the Rutherford system, by far the biggest of its type yet to be assembled, works well and will be an excellent instrument for physics.

● Compiled from texts on pp270–271.

## CERN NEWS

### Fire in the PS tunnel

On the morning of Sunday 31 August, fire broke out in the outer tunnel in the south-east Proton Synchrotron PS area, which houses the k 11 low-momentum separated pion beam

and the neutrino beam which will feed the heavy-liquid bubble chamber, Gargamelle.

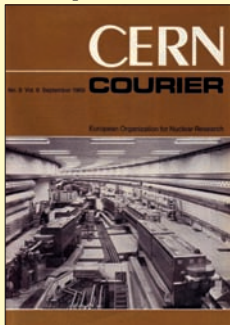
It took the CERN firemen over two hours to put out the blaze. Fortunately, no one was injured. However, a whole series of cables were burned out and the pulsed magnets,

vacuum system and beam control system were damaged by the intense heat and falling white-hot debris. The photograph gives some idea of the damage.

Every effort is being made to have the k 11 beam operating again as soon as possible after the annual PS shutdown and an investigation is under way to see how safety conditions can be improved before Gargamelle comes into operation.

● Compiled from texts on p267.

## Compiler's Note

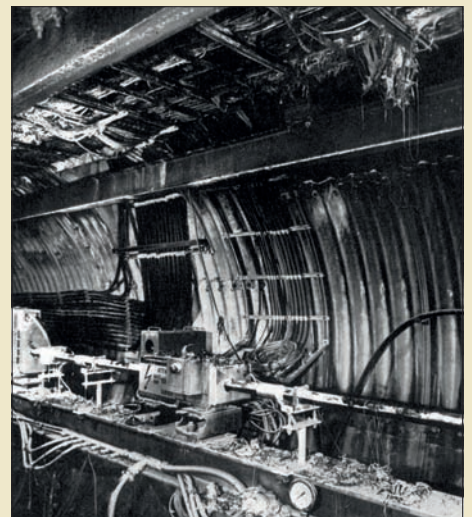


During the 1960s, earnest attempts were underway to develop a gauge theory of the weak interaction. Three carriers were postulated for the force – the charged and neutral vector bosons  $W^+$ ,  $W^-$  and  $Z^0$  – with the so-called “Higgs mechanism” formulated to solve the problem that the carriers had to be massive.

Experimental evidence was needed urgently. Bubble chambers were in their heyday and Gargamelle, built at Saclay, was installed in the PS neutrino beam at CERN in record time, despite the fire. In 1973, the collaboration announced the groundbreaking observation of a weak neutral current, a discovery that boosted activity on the Standard Model of unified electroweak interactions.

Throughout the next decade, bubble chambers gave way to electronic detectors and beam energies available from accelerators steadily increased, especially with the advent of storage rings. The heavy  $W^+$ ,  $W^-$  and  $Z^0$  bosons were detected in 1983 by the UA1 and UA2 experiments at CERN's Super Proton Synchrotron, converted to a proton–antiproton collider.

Now, the gargantuan detectors ATLAS and CMS at the LHC have recorded clear sightings of a new particle, consistent with being a/the boson of the hypothetical Higgs field. If these preliminary results are confirmed by the additional data currently being collected, then another chapter of the electroweak story will have been written by beams at CERN.



*Fire damage in the outer PS tunnel.*





SIEMENS



# SIMATIC WinCC Open Architecture

SCADA system for large applications and projects requiring a high degree of customized adaptability.

SCADA System

SIMATIC WinCC Open Architecture scales to requirements – from single-site systems to networked, redundant high-end systems with more than 10 Mio tags and for distributed systems up to 2048 servers. The SCADA system is available for Windows, Linux

and Solaris. SIMATIC WinCC Open Architecture provides a platform for OEM/customized developments. Furthermore it enables fast and effective creation of applications and customized solutions.

[www.siemens.com/wincc-open-architecture](http://www.siemens.com/wincc-open-architecture)

# Energize YOUR *Physics Research*

The collection of high energy physics titles from Wiley is written by eminent researchers in the field, each utilising the current findings in the most prominent topics.

For a full listing of titles available and to order, please visit [www.wiley.com/go/physics](http://www.wiley.com/go/physics)



Connect with us:

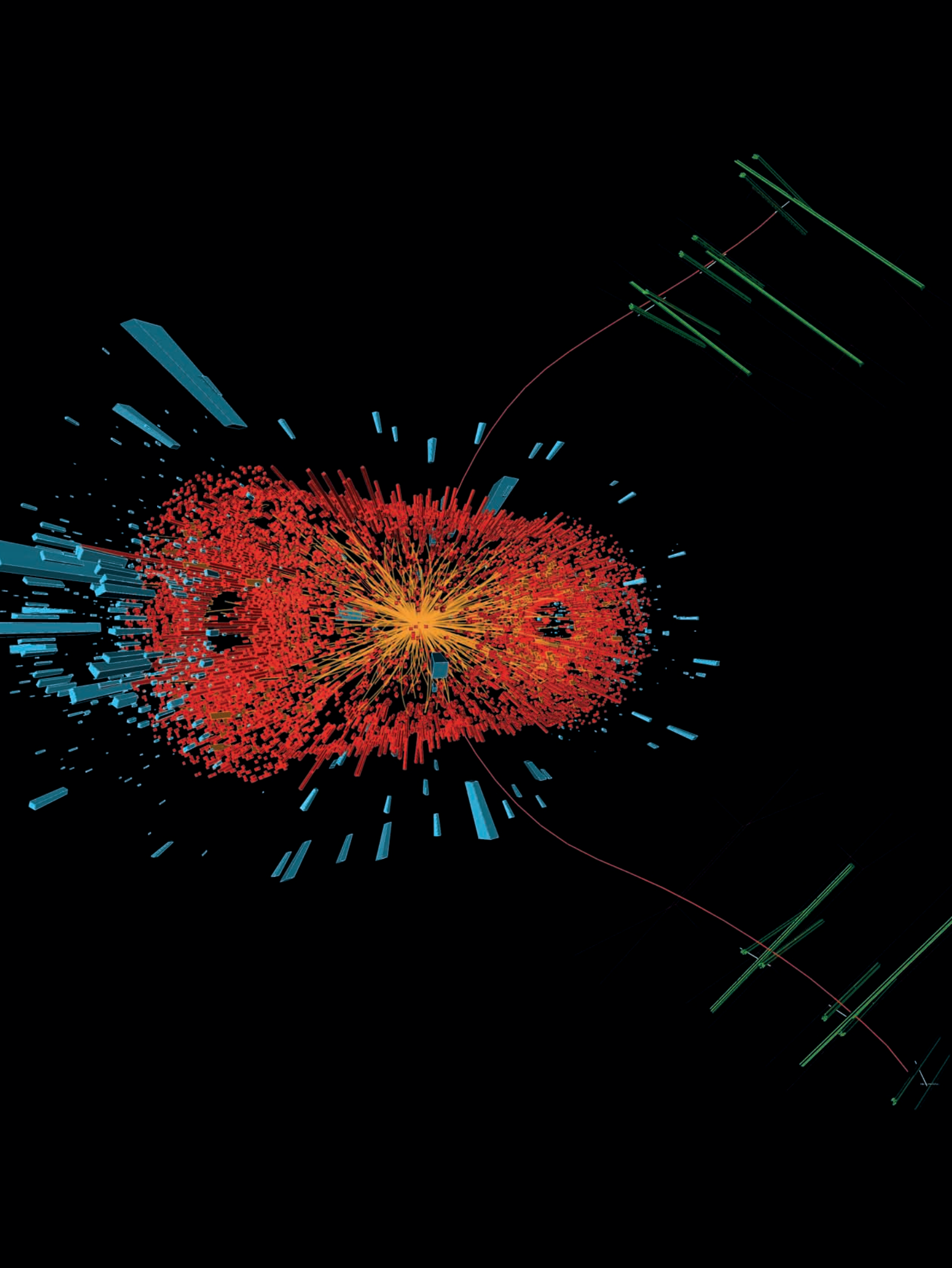
 /physicsbywileyblackwell

 @WB\_Physics

 WILEY

 WILEY-VCH





# CMS studies the quark–gluon plasma

Since the first collisions of lead ions in the LHC in November 2010, the CMS heavy-ion physics programme has been delivering exciting results at a steady pace, revealing more and more about the properties of nuclear matter at extremely high energy-density and temperature.

When atomic nuclei collide at high energies, they are expected to “melt” into a quark–gluon plasma (QGP) – a hot and dense medium made out of partons (quarks and gluons). At the LHC, many of the observed properties of the produced matter are consistent with this picture, similar to earlier findings by experiments at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory and at CERN’s Super Proton Synchrotron. The quantitative characterization of this medium is still far from complete, but with more than an order of magnitude increase in the collision energy, the LHC is providing a tremendous opportunity to extend the studies. In particular, the higher energy collisions create much greater abundances of rare probes of the hot matter – such as jets (groups of high transverse-momentum ( $p_T$ ) particles emitted within a narrow cone), or bound states of heavy quark–antiquark pairs.

With its flawless performance in the heavy-ion run, the LHC exceeded the projected luminosity for lead–lead (PbPb) collisions in 2011, allowing the CMS experiment to record an integrated luminosity of  $150 \mu\text{b}^{-1}$  at a nucleon–nucleon centre-of-mass energy of  $\sqrt{s_{\text{NN}}} = 2.76 \text{ TeV}$ , the luminosity being approximately 20 times more than in 2010. This new data set gives the CMS collaboration the opportunity to perform a detailed investigation of the medium using probes that are available for the first time in heavy-ion collisions, in a physics programme that partially overlaps but largely complements and extends the range of heavy-ion research conducted by the ALICE and ATLAS collaborations at the LHC. This article describes some of the heavy-ion results that CMS has obtained so far, with an

emphasis on unique findings from the high-luminosity data.

The CMS heavy-ion programme is multifaceted, based on the diverse capabilities of the CMS detector and the broad interests and expertise of the members of the collaboration. The key to its success lies in the careful planning, support, expertise and hard work of the entire CMS collaboration. A well optimized triggering strategy with robust algorithms was in place for the 2011 run, allowing CMS to take maximum advantage of the delivered luminosity. A detailed inspection of each heavy-ion event was performed by the level-1 and high-level trigger systems, and the most interesting events containing rare signals were written to tape.

## Properties of the bulk medium

Using the 2010 data, the LHC experiments were able to characterize the bulk properties of the partonic medium. The CMS collaboration performed detailed studies of soft-particle production by measuring the charged-particle multiplicity, transverse energy flow, azimuthal asymmetry in charged-particle and neutral-pion production, and two-particle correlations. The number of produced particles changes by orders of magnitude depending on whether the collision is “head-on” (central) or peripheral. The centrality of the PbPb collisions is characterized by the energy deposited in the forward calorimeters of the CMS detector, covering small polar angles with respect to the beamline (i.e. the pseudorapidity interval  $3 < |\eta| < 5.2$ ), with the most central collisions leaving the largest amount of energy in the detector. The events are then categorized based on this energy into percentile intervals of the total inelastic hadronic PbPb cross-section (the 0–20% centrality class meaning the 20% most central collisions, etc). Quantitatively, the centrality is usually characterized by the number of nucleons participating in the actual collision (i.e. those in the overlap zone of the two nuclei) denoted by  $N_{\text{part}}$ .

As experiments at RHIC had previously observed, the hot matter produced at the LHC exhibits strong collective-flow behaviour. In off-centre collisions the initial nuclear overlap zone is spatially asymmetrical with an approximately ellipsoidal shape. This asymmetry leads to instantaneous pressure gradients that are more effective in pushing particles out from the collision zone along the minor axis of the ellipse, rather than perpendicular to it. As a result, the matter produced in the collision undergoes anisotropic expansion, which is observed as a collective flow of particles with distinct azimuthal asymmetry. A Fourier analysis of the azimuthal angular  $\Delta$

*The decay of an  $\Upsilon$  state to  $\mu^+\mu^-$  (the long tracks), picked out in a lead–lead collision in CMS thanks to its excellent capabilities for muon detection. Measurements of the  $\Upsilon$  family provide a “window” onto the hot medium formed in the energetic collisions.*

## LHC physics

distribution of the final-state particles reveals important aspects of the collision dynamics, and provides constraints to the equation of state and the viscosity (resistance to flow) of the medium.

For head-on PbPb collisions, CMS estimates the energy density per unit volume to be about  $14 \text{ GeV}/\text{fm}^3$  at a time of  $1 \text{ fm}/c$  after the collision, which is about 100 times larger than the density of normal nuclear matter and 2.6 times greater than obtained at the highest RHIC energy. A significant increase of the mean transverse energy per particle is similarly observed. Despite this increase, the trends in the collective flow and correlation measurements show relatively modest changes compared with RHIC, indicating that the general properties of the matter produced at the LHC, as observed through the study of soft particles, are consistent with a strongly interacting partonic medium.

### Jet quenching

A key diagnostic tool that provides information about the density and composition of the medium produced in high-energy heavy-ion collisions comes from the measurements of high transverse-momentum jets. These “hard probes” result from relatively rare violent scatterings of the quarks and gluons that comprise the incoming nuclei. Since the production cross-sections of these energetic partons are calculable using the well established techniques of perturbative QCD, they have long been recognized as particularly useful “tomographic” probes of the hot medium.

The majority of the produced jets originate in the scattering of gluons or light quarks (up, down or strange), which are expected to lose energy while propagating through the medium. Less frequently the outgoing parton is a heavy charm or bottom quark that may also interact – although possibly less strongly – with the medium. Of particular interest are the events that produce hard-scattering probes that do not interact strongly, such as prompt photons or weak bosons, as they provide precise constraints on the energy of the recoiling parton and enable a controlled measurement of the parton energy loss in the medium. Multiple complementary measurements involving different probes can be performed using CMS, because of the detector’s high resolution, granularity, large acceptance, high-rate read-out capability and triggering.

The enormous energy loss of the partons propagating through the hot and dense medium became immediately apparent in the online event displays of the first PbPb collisions in the LHC, which revealed strikingly unbalanced dijet events and photon–jet events (figure 1). Subsequently, both ATLAS and CMS published detailed studies of the dijet transverse-momentum asymmetry. CMS expanded on this initial observation with a comprehensive set of measurements aiming not only to quantify the amount of lost energy, but also to answer the question: “Where does the lost energy go?”

The data from jet-track correlations indicate that the large

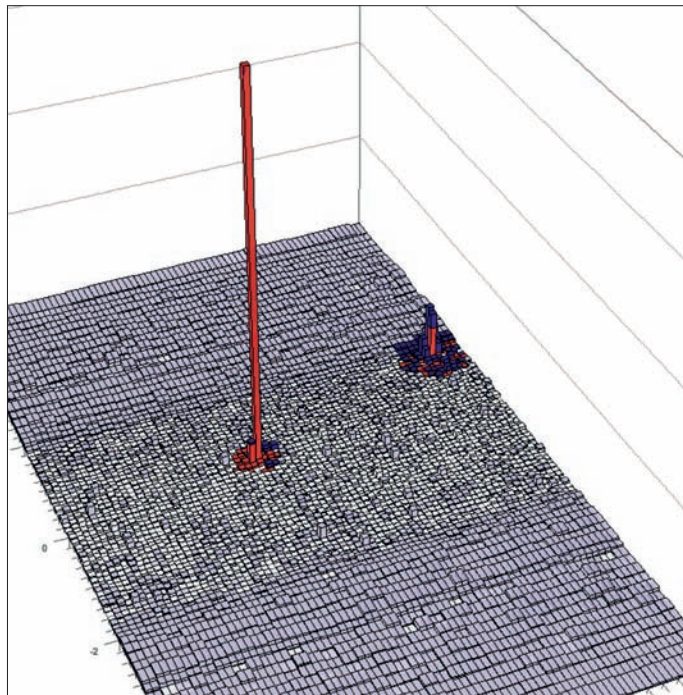


Fig. 1. An event display from CMS showing a photon ( $p_T = 191 \text{ GeV}/c$ ) and a jet ( $p_T = 98 \text{ GeV}/c$ ) with unbalanced transverse momenta.

energy lost by the partons is transferred to soft hadrons, which are scattered relatively far away in rapidity from the jet axis. To investigate the possible modifications of the jet structure, measurements of the jet shapes and fragmentation functions are also pursued. The high-luminosity data set collected in 2011 allows for further characterization of the dijet momentum-imbalance, by studying jets up to unprecedented values of transverse momenta. CMS has recently published a paper on this dijet momentum-imbalance, which is found to persist in central collisions up to the highest values of leading-jet transverse momenta studied – even the most energetic jets do not escape the medium unaltered.

Further tests of the jet-quenching hypothesis use control measurements involving probes that do not interact strongly, such as photons, Z and W bosons. The transverse-momentum spectra of charged hadrons and isolated photons are compared with their equivalents in pp collisions. Figure 2 shows the suppression factor,  $R_{AA}$ , of the production rates of high transverse-momentum particles, scaled to be unity if nuclear collisions are a simple superposition of pp collisions. As expected, a strong suppression is observed for charged particles ( $R_{AA} < 1$ ), but the yields of electroweak probes appear unaffected by the medium ( $R_{AA} \approx 1$ ). The measurement of b-decays to  $J/\Psi$  particles  $\triangleright$

**fug**

FuG Elektronik GmbH  
Rosenheim / Germany

Email: [info@fug-elektronik.de](mailto:info@fug-elektronik.de)  
Internet: <http://www.fug-elektronik.de>

### ► Highly stable power supplies

From low to high power  
for acceleration, bending, ion sources  
and a lot of further applications in science and industry





# Goodfellow

## Metals & Materials. Solutions for research and industry

Standard and custom made products in Pure Metals, Alloys, Polymers, Ceramics, as well as many Composites and Compounds in various forms including foil, rod, tube, wire, powder, etc. All available on our secure website – and with a 5% discount!

Goodfellow Cambridge Limited  
Ermine Business Park  
Huntingdon, PE29 6WR  
Tel: 0800 731 4653  
or +44 1480 424 800  
Fax: 0800 328 7689  
or +44 1480 424 900  
E-mail: [info@goodfellow.com](mailto:info@goodfellow.com)

[www.goodfellow.com](http://www.goodfellow.com)

Congratulations to all our customers at CERN on your breakthrough discovery.



## Innovative detectors for High Energy Physics Experiments

Hamamatsu's innovative customised detectors have enabled the world's leading High Energy Physics experiments such as CMS and ATLAS to continue to push the boundaries of science.

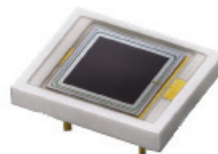
Our award winning design capabilities assure highly reliable solutions, suitable for mass production, ideal for even the largest and most demanding physics experiments.



■ Photomultiplier Tubes and Modules



■ Silicon PMT "MPPC" and Modules



■ Large Area APDs and Arrays



■ Silicon Strip Detectors

**HAMAMATSU**  
PHOTON IS OUR BUSINESS

[www.hamamatsu.eu](http://www.hamamatsu.eu) Freephone: Europe 00 800 800 800 88



## Together we make a difference

Luvata, supplier of hollow conductors and low-temperature superconductors, would like to congratulate CERN and all the contributors that make discoveries possible.

**People working for a better future.**

[www.luvata.com](http://www.luvata.com)

**LUVATA**  
Partnerships beyond metals



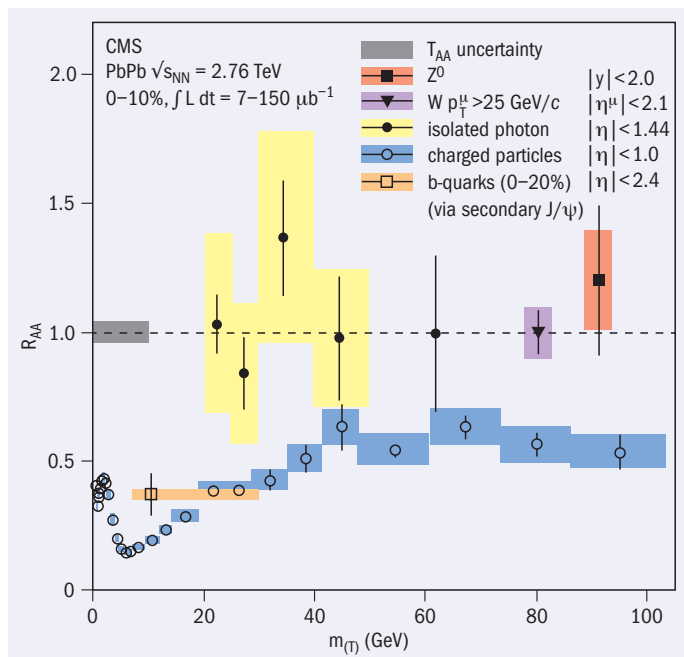


Fig. 2. CMS measurements of the nuclear-modification factor  $R_{AA}$  for a variety of hard probes denoted for the 10% of most central PbPb collisions, plotted as a function of the transverse mass of the particle ( $m_T$ ), where the pion mass was assumed for “charged particles”. The points for the Z and W are plotted at the rest mass of the particle. The error bars represent statistical uncertainties; shaded boxes show systematic uncertainties and, except for the Z and W, the width of the box indicates the bin-width in  $m_T$ .

shows clearly that b-quarks are also strongly suppressed.

Having seen that isolated photons do not suffer suppression in the medium, CMS took the study to the next level using the high-luminosity data from 2011. The first measurement of a photon–jet imbalance was performed by examining events containing an isolated photon ( $\gamma$ ) with  $p_T > 60$  GeV/c and an associated jet with  $p_T > 30$  GeV/c. The transverse momenta of the jet and the photon are compared by forming the ratio  $x_{j\gamma} = p_T(\text{jet})/p_T(\gamma)$ . Figure 3 shows the centrality dependence of the average momentum imbalance, as well as the fraction of isolated photons with an associated jet partner  $R_{j\gamma}$ . The measurements in PbPb collisions are compared with those in pp collisions at the same energy and simulations that do not include the jet-quenching effect. A significant decrease in  $\langle x_{j\gamma} \rangle$  and  $R_{j\gamma}$  compared with the simulation is observed for more central PbPb collisions, indicating a larger parton energy loss in the collisions where the volume of the medium is larger.

While the jet-quenching phenomenon is undoubtedly established from the data, a complete theoretical understanding of the underlying parton energy-loss mechanism is still lacking. The data sample with  $150 \mu\text{b}^{-1}$  integrated PbPb luminosity allows the study of the azimuthal anisotropy of charged-particle production up to high  $p_T$ , providing additional information on the path-length dependence of the in-medium parton energy loss. Since the initial nuclear overlap zone for off-centre collisions is azimuthally asymmetrical with approximately ellipsoidal shape, partons propagating in the direction of the minor axis of the ellipse are expected to lose less energy than those propagating along the major axis. This leads to a final particle distribution (at any given transverse momentum) that is not cylindrically symmetrical, but has a cosine-shaped modulation as a function of azimuthal angle (that is, the

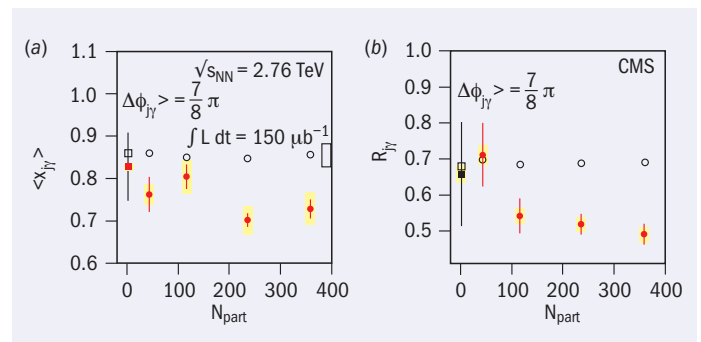


Fig. 3. a) Average ratio of jet transverse-momentum to photon transverse-momentum as a function of the number of nucleons participating in the collisions ( $N_{part}$ ), for PbPb collisions (solid circles), pp collisions (squares) and simulations (open symbols). The empty box at the far right indicates the correlated systematic uncertainty. b) Average fraction of isolated photons with an associated jet above 30 GeV/c as a function of  $N_{part}$ . In both plots, the yellow boxes indicate point-to-point systematic uncertainties and the error bars denote the statistical uncertainty.

rotation around the beamline). Figure 4 shows the half-amplitude of this cosine modulation, at different transverse-momenta and collision centralities. Nonzero elliptic anisotropy is observed even at high  $p_T$  (up to  $p_T \approx 40$  GeV/c) where most charged particles originate from the fragmentation of jets. These measurements are thus indirectly related to the amount of energy loss (and its dependence on the path length) of energetic partons inside the hot QCD medium.

### Quarkonium suppression

The ultimate proof for the formation of QGP in heavy-ion collisions would be a measurement that demonstrates the presence of deconfined quarks and gluons. In the plasma state, the quark and gluon colour charges would be neutralized (or screened), similarly to the Debye screening of the electric charges of electrons and ions in an electromagnetic plasma. The colour-charge screening can be studied experimentally through the measurement of quarkonia, which consist of bound heavy quark–antiquark pairs (charm or beauty). In the QGP, the attractive force binding the pair together would be reduced, hindering the formation of the quarkonium states. Thus, observation of suppression in the production rate of these particles in comparison with the production rate in pp collisions is a signature of deconfinement, although other processes may obscure the effect.

CMS has excellent capabilities for muon detection and has measured the production rates of several particles ( $J/\psi$ ,  $\psi(2S)$ ,  $Y(1S, 2S, 3S)$ ) that have different radii and probe colour screening at different distance scales. The various quarkonium states are expected to “melt” in the QGP at different temperatures, corresponding to their respective binding energies. The measurement of the suppression pattern of several of these particles is thus needed to constrain the initial temperature in the collision and to demonstrate deconfinement.  $\blacktriangleright$



## LHC physics

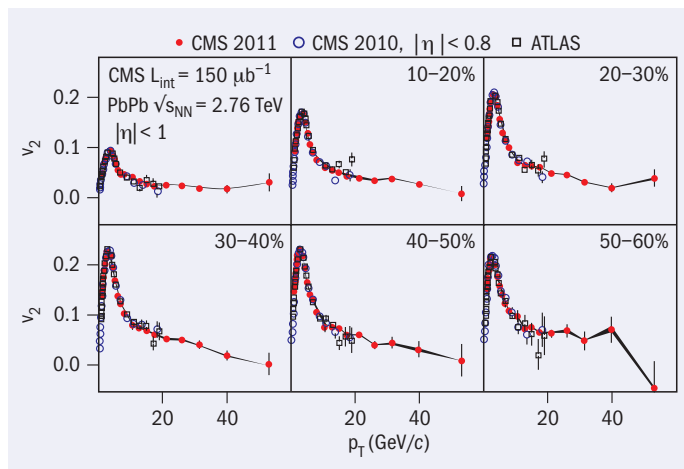


Fig. 4. The quantitative measure of the elliptic anisotropy of particle emission,  $v_2$ , as a function of  $p_T$  with  $|\eta| < 1$  for six centrality ranges in PbPb collisions at 2.76 TeV (2011 data). For soft particles ( $p_T$  below  $\approx 3$  GeV/c), the anisotropy is driven by the pressure gradients in the medium, while the high- $p_T$  particles are affected by the energy loss in the medium that is spatially asymmetrical. Error bars denote statistical uncertainties, while the grey bands correspond to systematic uncertainties. Results from ATLAS and CMS using data collected in 2010 are also shown. (The ALICE collaboration released data up to 20 GeV/c more recently.)

The suppression of the excited states of the  $\Upsilon$  family was already seen in the 2010 data, albeit with limited statistical precision. With the high-luminosity data from 2011 the effect has been confirmed and studied in much more detail. Figure 5 shows the dimuon invariant-mass distribution obtained in PbPb collisions compared with the distribution measured in pp collisions, and clearly reveals the strong suppression of the excited  $\Upsilon$  states. To quantify the effect, the yields of the  $\Upsilon(2S)$  or  $\Upsilon(3S)$  states are compared with the yield of the  $\Upsilon(1S)$  state in PbPb and pp collisions by forming a double ratio:  $[\Upsilon(nS)/\Upsilon(1S)]_{\text{PbPb}}/[\Upsilon(nS)/\Upsilon(1S)]_{\text{pp}}$ . The values of these double ratios are determined to be  $0.21 \pm 0.07$  (stat.)  $\pm 0.02$  (syst.) for  $n=2$  and less than 0.17 at 95% confidence level for  $n=3$ . The individual  $\Upsilon(1S)$  and  $\Upsilon(2S)$  states are suppressed, compared with pp collisions, by factors of about 2 and 10, respectively. CMS thus finds the expected melting pattern, with the suppression being ordered according to the binding energy of the respective quarkonium states. The  $\Psi(2S)$  state at high  $p_T$  also falls into this picture, although a hint of an intriguing opposite trend was recently observed at low  $p_T$ , but with limited statistical significance. More data are needed to confirm this observation, in particular a larger pp reference data set at the matching energy of 2.76 TeV.

By July 2012, the CMS heavy-ion programme had produced 16 papers submitted to refereed journals, of which 11 have already been published. More analyses are under way, and the collaboration is also preparing for the upcoming proton–lead collisions in the LHC, which will serve as a reference for normal nuclear effects. Such a control measurement, together with short, high-luminosity pp runs at 2.76 TeV and 5 TeV (to match the proton–lead collision energy) requested by CMS will complete the first round of pioneer-

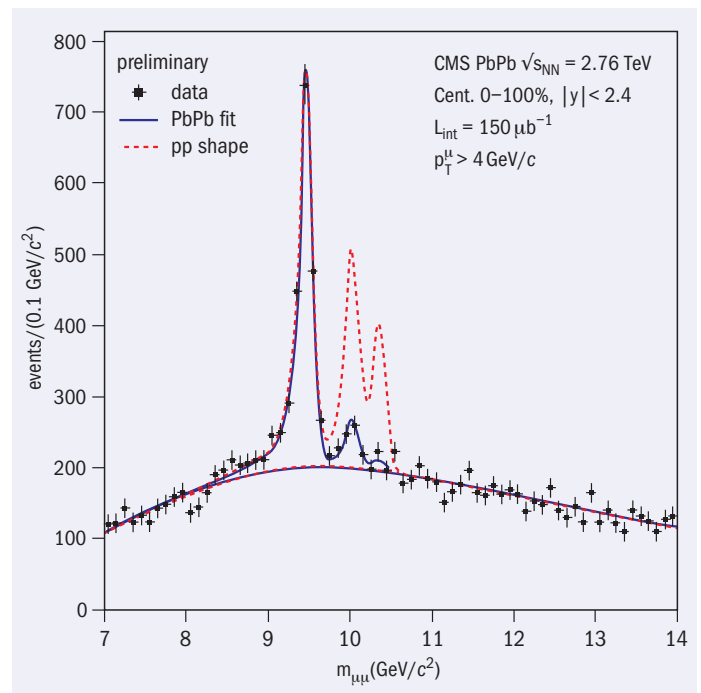


Fig. 5. The dimuon invariant-mass distribution from PbPb collisions at 2.76 TeV compared with a fit obtained from pp data measured at the same energy. The suppression of the  $\Upsilon(3S)$  and  $\Upsilon(2S)$  states in the PbPb data is clearly visible.

ing investigations into the extremes of strongly interacting matter. With these data, the first steps of a journey back to the state of the universe just a few microseconds after the Big Bang are being taken at the LHC, and the CMS experiment is one of the “time-machines” making this exciting journey possible.

#### • Further reading

For further information and details about these results and more, see the collection of public results on heavy-ion physics from CMS at <https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsHIN>.

#### Résumé

*CMS étudie le plasma quarks–gluons*

*Depuis les premières collisions d'ions plomb au LHC en novembre 2010, le programme de physique des ions lourds de CMS a fourni des résultats prometteurs à une cadence soutenue, dévoilant de nombreux aspects des propriétés de la matière nucléaire à des densités d'énergie et des températures très élevées. En particulier, l'ensemble de données à haute luminosité recueillies en 2011 permet à CMS de réaliser une étude détaillée du milieu chaud et dense créé, en utilisant des sondes disponibles pour la première fois dans les collisions d'ions plomb. L'article décrit certains des résultats obtenus jusqu'à présent par CMS, l'accent étant mis sur des résultats exceptionnels issus des données obtenues à grande luminosité.*

Julia Velkovska, Vanderbilt University, and Gabor Veres, CERN.

# WHAT POWERS YOUR ACCELERATOR?



## HV and RF Technology Innovations from L-3

L-3 Electron Devices is leading the technology revolution with powerful solutions like the 13 kW klystron for the 12 GeV Upgrade at the Thomas Jefferson National Accelerator Facility and the 90 kW IOT amplifier for Brookhaven National Lab's NSLS-II Booster RF Transmitter System. For high-voltage switching or stable and reliable RF power, L-3's thyratrons, klystrons, IOTs and TWTs are meeting the demanding requirements of many of the world's major accelerator systems, and we are working to produce the next generation of devices for tomorrow's new accelerators.

To learn more about L-3's innovative technology, visit [L-3com.com/edd](http://L-3com.com/edd) or email us at [wpt.marketing@L-3com.com](mailto:wpt.marketing@L-3com.com).

Electron Devices

L-3com.com

**HSR AG**  
FL-9496 BALZERS

**Established Know-How in Vacuum Technology**

www.hsr.li · info@hsr.li  
Fohrenweg 16 · 9496 Balzers · Liechtenstein  
Tel. 00423 388 09 90 · Fax 00423 388 09 99

## Research Grade Ultra High Vacuum Electron Guns

A Menagerie of Models and Sizes  
1 eV to 100 keV fA's to 100's of mA's

Source Cable

Differential Pumping Port CF 4.5

LaB6 Cathode

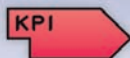
Instrumentation Port CF 2.75

60 keV Electron Gun  
High Currents / Current Densities  
Magnetic Focus / Deflection

**EGH-6210**

Electrons Out CF 2.75

- High Brightness Sources
- Ultra Stable Energies and Beam Currents
- Source Alignment During Full Operation
- Computer Control; Precision Metering
- Customer Replaceable Firing Units
- Custom Projects and Unique Applications

**KIMBALL PHYSICS**   
info@kimphys.com Wilton, NH USA 603-878-1616  
[www.KimballPhysics.com](http://www.KimballPhysics.com)





## A PIONEER IN SUPERCONDUCTIVITY SALUTES A MONUMENTAL ACHIEVEMENT IN SCIENCE

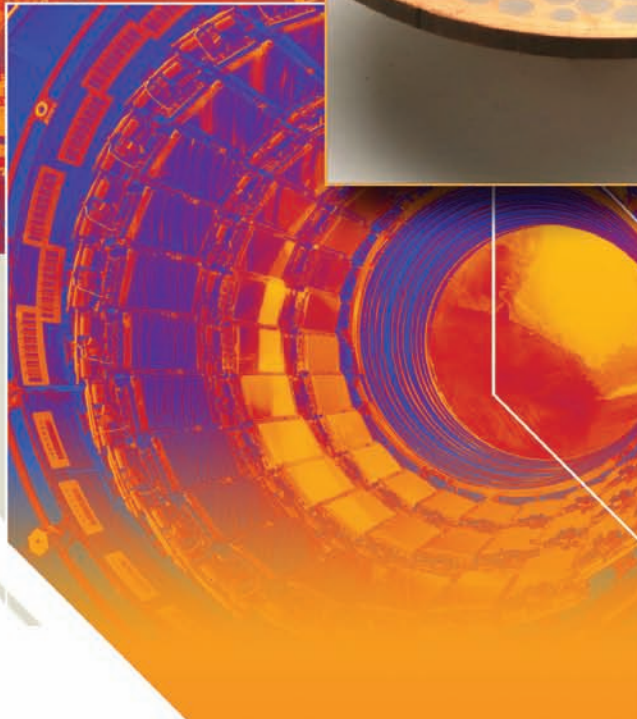
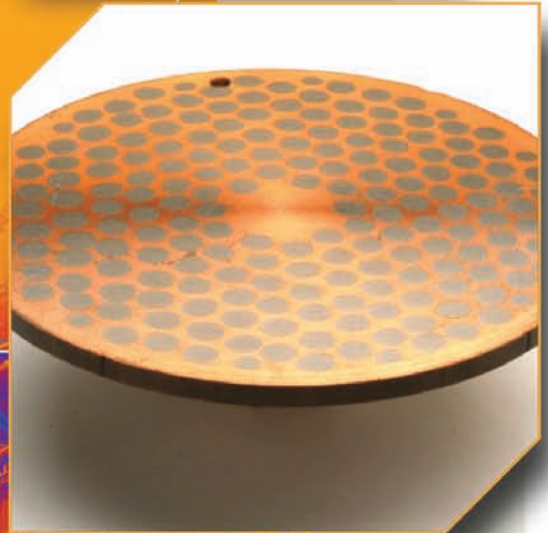
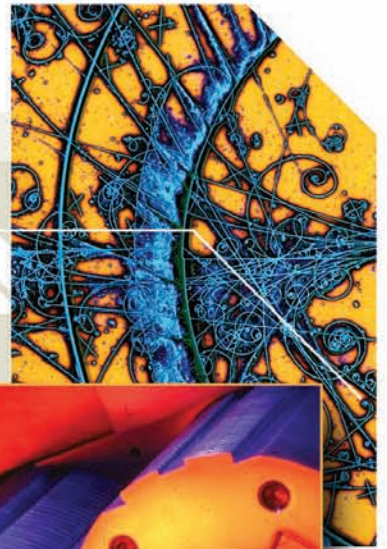
Scientists at CERN have made some ground breaking discoveries. And nothing was more momentous than the recent work in identifying the Higgs Boson particle, providing much-anticipated insight into particle physics theory.

For over 50 years ATI Wah Chang has played an integral part in the advancement of superconducting technology and research.

We were a proud contributor to the Large Hadron Collider (LHC) from the beginning, supplying over 1.2 million pounds of Nb47Ti alloy for superconducting magnet wire at CERN and were honored to receive one of the inaugural Golden Hadron Awards in 2002.

As work continues at CERN to explore the origins of our universe, ATI Wah Chang looks forward to our continued role in helping make those pioneering explorations possible.

[ATImetals.com](http://ATImetals.com)





# Particle identification in ALICE boosts QGP studies

An array of different detection techniques allows the precise identification of particles that emerge from deep within the hot dense matter produced in heavy-ion collisions.

Under extreme conditions of temperature and/or density, hadronic matter “melts” into a plasma of free quarks and gluons – the so-called quark–gluon plasma (QGP). To create these conditions in the laboratory, heavy ions (e.g. lead nuclei) are accelerated and made to collide head on, as was done at the LHC for two dedicated periods in 2010 and 2011. A key design consideration of the ALICE experiment at the LHC is the ability to study QCD and quark (de)confinement under these extreme conditions. This is done by using particles – created inside the hot volume as it expands and cools down – that live long enough to reach the sensitive detector layers located around the interaction region. The physics programme at ALICE relies on being able to identify all of them – i.e. to determine if they are electrons, photons, pions, etc – and to determine their charge. This involves making the most of the (sometimes slightly) different ways that particles interact with matter. This article gives an overview of the methods used for particle identification (PID) and their implementations in ALICE and describes how new technologies were used to push the state of the art.

## Penetrating muons

Muons can be identified by the fact that they are the only charged particles able to pass almost undisturbed through any material. This is because muons with momenta below a few hundred GeV/c do not suffer from radiative energy losses and so do not produce electromagnetic showers. Also, being leptons, they are not subject to strong interactions with the nuclei of the material that they traverse. This behaviour is exploited in muon spectrometers in high-energy-physics experiments by installing muon detectors either behind the calorimeter systems or behind thick absorber materials. All other charged particles are completely stopped, producing electromagnetic (and hadronic) showers.

The muon spectrometer in the forward region of ALICE features a thick, complex front absorber and an additional muon filter comprising an iron wall 1.2 m thick (*CERN Courier* December 2007 p30). Muon candidates selected from tracks penetrating

these absorbers are measured precisely in a dedicated set of tracking detectors. Pairs of muons are used to observe the full spectrum of heavy-quark vector-meson resonances ( $J/\Psi$ , ...). Their production rates can be analysed as a function of transverse momentum and collision centrality to investigate dissociation arising from colour screening (*CERN Courier* March 2012 p14). In addition, muons from the semileptonic decay of open charm and open beauty can also be studied with the muon spectrometer.

## Weighing particles

Hadron identification can be crucial for heavy-ion physics. Examples are open charm and open beauty, which allow the investigation of the mechanisms for the production, propagation and hadronization of heavy quarks in the hot and dense medium formed in the heavy-ion collisions. The most promising channel is the process  $D^0 \rightarrow K^- \pi^+$ , which requires efficient hadron identification owing to the small signal-to-background ratio (*CERN Courier* June 2012 p14).

Charged hadrons (in fact, all stable charged particles) are unambiguously identified if their mass and charge are determined. The mass can be deduced from measurements of the momentum and of the velocity. Momentum and the sign of the charge are obtained by measuring the curvature of the particle’s track in a magnetic field. To obtain the particle velocity there are four methods based on measurements of time-of-flight (TOF) and ionization, and on the detection of transition radiation (TR) and Cherenkov radiation. Each method works well in different momentum ranges or for specific types of particle. They are combined in ALICE to measure, for instance, particle spectra. Figure 1, for example, shows the abundance of pions in lead–lead (PbPb) collisions as a function of transverse momentum and collision centrality.

**All stable charged particles are unambiguously identified if their mass and charge are determined.**

## Kicking electrons from atoms

The characteristics of the ionization process caused by fast, charged particles passing through a medium can be used for PID. The velocity dependence of the ionization strength is connected to the Bethe-Bloch formula, which describes the average energy loss of charged particles through inelastic Coulomb collisions with the atomic electrons of the medium. ▷

## Detectors

Multiwire proportional counters (MWPCs) or solid-state counters are often used as the detection medium because they provide signals with pulse heights that are proportional to the ionization strength. Because energy-loss fluctuations can be considerable, in general many pulse-height measurements are performed along the particle track to optimize the resolution of the ionization measurement.

In ALICE this technique is used for PID in the large time-projection chamber (TPC) and in four layers of the silicon inner tracking system (ITS). A TPC is a large volume filled with a gas as the detection medium. Almost all of this volume is sensitive to the traversing charged particles but it features a minimum material budget. The straightforward pattern recognition (continuous tracks) makes TPCs the perfect choice for high-multiplicity environments, such as in heavy-ion collisions, where thousands of particles have to be tracked simultaneously. Inside the ALICE TPC, the ionization strength of all tracks is sampled up to 159 times, resulting in a resolution of the ionization measurement as good as 5%. Figure 2 shows the TPC ionization signal as a function of the particle rigidity for negative particles, indicating the different characteristic bands for various types of particle. A particle is identified when the corresponding point in the diagram can be associated with only one such band within the measurement errors. The method works well, especially for particles with low momenta up to several hundred MeV/c.

### Using a stopwatch

TOF measurements yield the velocity of a charged particle by measuring the flight time over a given distance along the track trajectory. Provided the momentum is also known, the mass of the particle can then be derived from these measurements. The ALICE TOF detector is a large-area detector based on multigap resistive plate chambers (MRPCs) that cover a cylindrical surface of 141 m<sup>2</sup>, with an inner radius of 3.7 m. The MRPCs are parallel-plate detectors built of thin sheets of standard window glass to create narrow gas gaps with high electric fields. These plates are separated using fishing lines to provide the desired spacing; 10 gas gaps per MRPC are needed to arrive at a detection efficiency close to 100%.

The simplicity of the construction allows a large system to be built with an overall TOF resolution of 80 ps at a relatively low cost (*CERN Courier* November 2011 p8). This performance allows the separation of kaons, pions and protons up to momenta of a few GeV/c. Combining such a measurement with the PID information from the ALICE TPC has proved useful in improving the separation between the different particle types, as figure 3 shows for a particular momentum range.

### Detecting additional photons

The identification of electrons and positrons in ALICE is achieved using a transition radiation detector (TRD). In a similar manner to the muon spectrometer, this system enables detailed studies of the production of vector-meson resonances, but with extended coverage down to the light vector-meson  $\rho$  and in a different rapidity region. Below 1 GeV/c, electrons can be identified via a combination of PID measurements in the TPC and TOF. In the momentum range 1–10 GeV/c, the fact that electrons may create TR

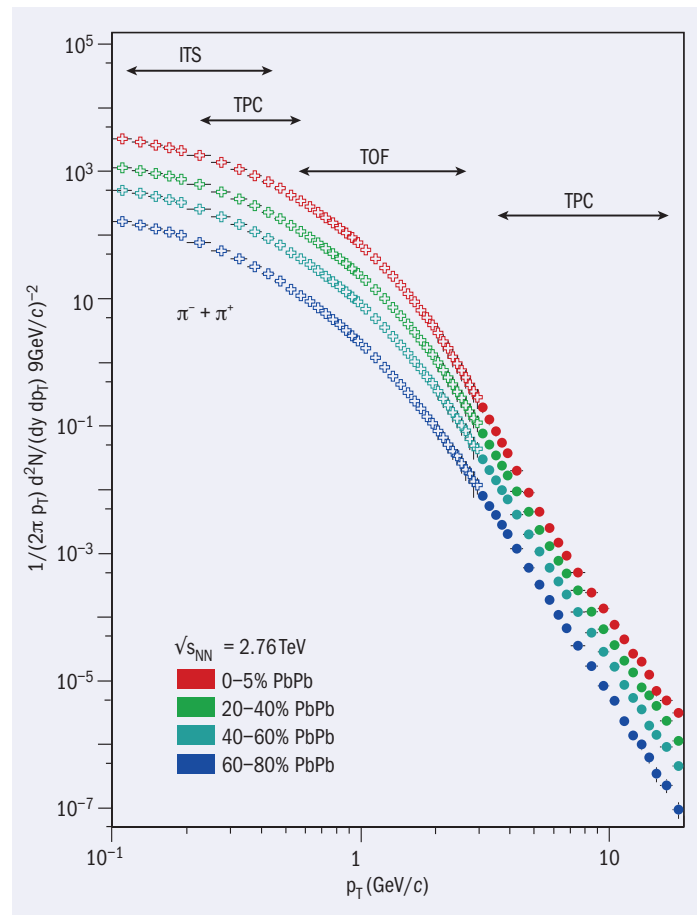


Fig. 1. Pion yield from PbPb collisions at centre-of-mass energy  $\sqrt{s_{NN}} = 2.76$  TeV for different collision centralities (0–5% corresponds to the most central) measured in ALICE. To cover the whole momentum range, data from different ALICE subdetectors are combined – in this plot the particle identification information comes from ionization (ITS and TPC) and time-of-flight (TOF) measurements.

when travelling through a dedicated “radiator” can be exploited. Inside such a radiator, fast charged particles cross the boundaries between materials with different dielectric constants, which can lead to the emission of TR photons with energies in the X-ray range. The effect is tiny and the radiator has to provide many hundreds of material boundaries to achieve a high enough probability to produce at least one photon. In the ALICE TRD, the TR photons are detected just behind the radiator using MWPCs filled with a xenon-based gas mixture, where they deposit their energy on top of the ionization signals from the particle’s track.

The ALICE TRD was designed to derive a fast trigger for charged particles with high momentum and can significantly enhance the recorded yields of vector mesons. For this purpose, 250,000 CPUs are installed right on the detector to identify candidates for high-momentum tracks and analyse the energy deposition associated with them as quickly as possible (while the signals are still being created in the detector). This information is sent to a global tracking unit, which combines all of the information to search for electron–positron track pairs within only 6  $\mu$ s.  $\blacktriangleright$



# Diamond Detectors for LHC

***“If I cannot see it, I cannot believe it, but there is plenty that I can see that I know I cannot believe”*** P.J. Bryant 2012

The LHC experiments at CERN are “our eyes” for looking into an incredibly small part of space on an incredibly fast time scale. About two decades of effort have gone into creating these artificial eyes and each experiment sports a bewildering array of monitors for “seeing” the beam particles as they escape from the circulating beams or flee the collision points. Just like our biological eyes these monitors give us the confidence “to know and to believe” what is happening and just like our biological eyes they can also lead us astray.

By virtue of its diamond detectors, **CIVIDEC Instrumentation** is proud to be one of the companies that has contributed to man’s ability “to see” clearly into the harsh and exacting environment surrounding the LHC beams and collision points. The “view” provided by diamonds extends over a wide spectrum for charged particles and photons and is characterized by a linear response from single-particle counting up to amperes of signal current, the ability to record detailed nanosecond time structures and, perhaps the most important of all, the capability to endure a harsh radiation environment.

## Cutting-edge technology

Born from the cutting-edge technology of CERN, CIVIDEC Instrumentation is a R&D company that focuses on the fabrication of radiation monitors based on CVD diamond detectors and, in particular, on low-noise high-speed electronics that fully exploit the intrinsic properties of the diamond material. The Company’s practical experience is firmly rooted in custom-tailored solutions for beam instrumentation for particle accelerators and dedicated readout systems.

These include :

- **A beam loss and analysis system for the LHC beams;** essential for the setting up of high quality beams for physics such as the Higgs search. This task is performed with a 1 ns



A Diamond Detector as provided by CIVIDEC Instrumentation, Austria

time resolution, 5 ns double-pulse resolution, 25 ns bunch-to-bunch loss detection, single-particle sensitivity, 160 dB dynamic range. The patented AC+DC measurement system affords AC measurement from 25 kHz to 2 GHz and DC loss measurement with a bandwidth of 1 Hz. The diamond material and the electronics are radiation tolerant up to 1 MGy.

- **ROSY, a dedicated readout system.** This system will be installed in the next LHC beam loss system upgrade. ROSY provides 4 channels, 5 GSPS and a bandwidth of 250 MHz. It has on-line dead-time-free signal processing and an Ethernet connection to control systems.
- **Neutron spectroscopy system.** This system affords a 5 keV energy resolution and a dynamic range of 20 MeV, direct neutron detection above 6 MeV, and indirect neutron detection via the  $n \rightarrow \alpha$  reaction for neutron energies below 6 MeV. An early pile-up problem was solved and patented.
- **A high-radiation monitor for LHC beam dump studies.** This system will operate with up to  $1E9$  particles per pulse on the detector for 144 consecutive pulses. The system applies a  $-60$  dB attenuation to the signal and shows no sign of saturation.

**CIVIDEC Instrumentation** is pleased to offer the sCVD and pCVD diamond diodes from 50  $\mu$ m to 500  $\mu$ m thickness. Standard transverse diamond sizes are limited to 10 mm x 10 mm with 8 mm x 8 mm electrodes for pCVD diamonds and 4.5 mm x 4.5 mm with 4 mm x 4 mm electrodes for sCVD diamonds. Custom elements can be made up to a maximum of 80 mm diameter for pCVD. Strip and mosaic detectors can be specified.

## Off-the-shelf electronics

Off-the-shelf electronics include: Broadband Current Amplifier: 40 dB, 20 dB, 1 MHz–2 GHz, low noise (5 dB). Fast Charge Amplifier: 10 ns FWHM, gain=4 mV/fC, 1000 electrons noise. Spectroscopy Shaping Amplifier: 180 ns FWHM, gain=8 mV/fC, 300 electrons noise.



*Erich Griesmayer is CEO of CIVIDEC Instrumentation and has been working at CERN for more than 20 years. He is associated professor at the Vienna University of Technology and Member of RD42, ATLAS, n\_TOF at CERN*

## Address

**CIVIDEC Instrumentation GmbH,  
Schottengasse 3A/1/41, 1010 Vienna, Austria  
E-mail office@cividec.at**

# Unprecedented speed, resolution and channel density.



## Agilent M9703A 12-bit High-Speed Digitizer

	Standard	Interleaving option (INT)
<b>Channel</b>	8 channels	4 channels
<b>Sampling Rate</b>	1.6 GS/s (with SR2) or 1 GS/s (with SR1)	3.2 GS/s (with SR2) or 2 GS/s (with SR1)
<b>Bandwidth</b>	DC to 2 GHz (with F10) or DC to 650 MHz (with F05)	DC to 1 GHz (with F10) or DC to 650 MHz (with F05)

The Agilent AXIe high-speed digitizer provides the ideal solution for advanced experiments in hydrodynamics, plasma fusion, and particle physics. With this module you can build a large number of synchronous acquisition channels with unprecedented measurement fidelity in the smallest footprint. Advanced IP design, state-of-the-art technology, and on-board real-time data processing are combined to achieve outstanding performance.



Scan QR code or visit <http://goo.gl/PwjgC> to see the AXIe digitizer video demo



Discover how to simplify your high-speed multichannel acquisition system  
[www.agilent.com/find/PhysicsAXIe](http://www.agilent.com/find/PhysicsAXIe)

© Agilent Technologies, Inc. 2012. Photos courtesy of CERN. © Copyright CERN.

Anticipate — Accelerate — Achieve



Agilent Technologies



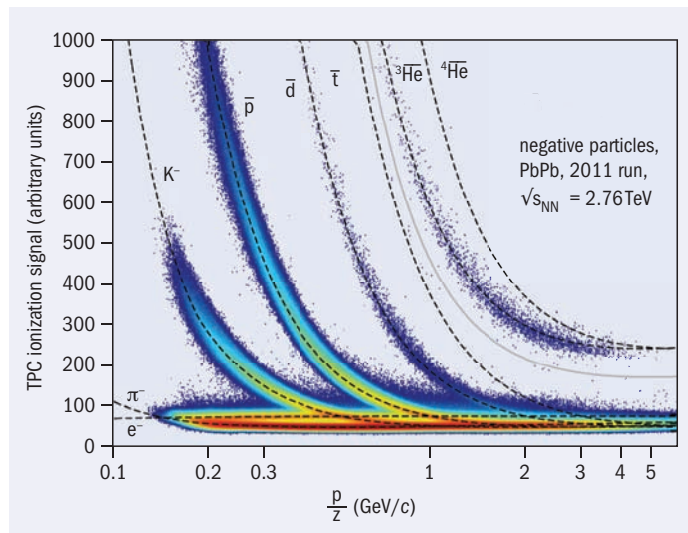


Fig. 2. Ionization signals in the ALICE TPC as a function of the particle momentum for PbPb collisions at  $\sqrt{s_{NN}} = 2.76$  TeV. An offline trigger was applied to enhance track samples with charges  $z < -1$ . The charged (anti)hadrons are well separated, in particular at low momentum. Electrons, antideuterons ( $\bar{d}$ ), antitritons ( $\bar{t}$ ) and anti- ${}^3\text{He}$  nuclei are visible as well. The dashed lines are parameterizations of the Bethe-Bloch curve.

### Measuring an angle

Cherenkov radiation is a shock wave resulting from charged particles moving through a material faster than the velocity of light in that material. The radiation propagates with a characteristic angle with respect to the particle track, which depends on the particle velocity. Cherenkov detectors make use of this effect and in general consist of two main elements: a radiator in which Cherenkov radiation is produced and a photon detector. Ring-imaging Cherenkov (RICH) detectors resolve the ring-shaped image of the focused Cherenkov radiation, enabling a measurement of the Cherenkov angle and thus the particle velocity. This, in turn, is sufficient to determine the mass of the charged particle.

If a dense medium (large refractive index) is used, only a thin radiator layer of a few centimetres is required to emit a sufficient number of Cherenkov photons. The photon detector is then located at some distance (usually about 10 cm) behind the radiator, allowing the cone of light to expand and form the characteristic ring-shaped image. Such a proximity-focusing RICH is installed in the ALICE experiment. The High-Momentum Particle IDentification (HMPID) detector is a single-arm array that has a reduced geometrical acceptance. Similar to the ALICE TOF, it can identify individual charged hadrons up to momenta of a few GeV/c but with slightly higher precision.

### Completing the picture

The ALICE detector also contains other components that can identify particles. A high-resolution electromagnetic calorimeter, the PHOS, which covers a limited acceptance domain at central rapidity, provides data to test the thermal and dynamical properties of the initial phase of the collision by measuring photons emerging directly from the collision. Last, a pre-shower detector, the PMD,

PbPb,  $\sqrt{s_{NN}} = 2.76$  TeV, 0–10% central  
 $2.0 < p < 2.5$  GeV/c,  $|y| < 0.5$   
 mass assumption: pion

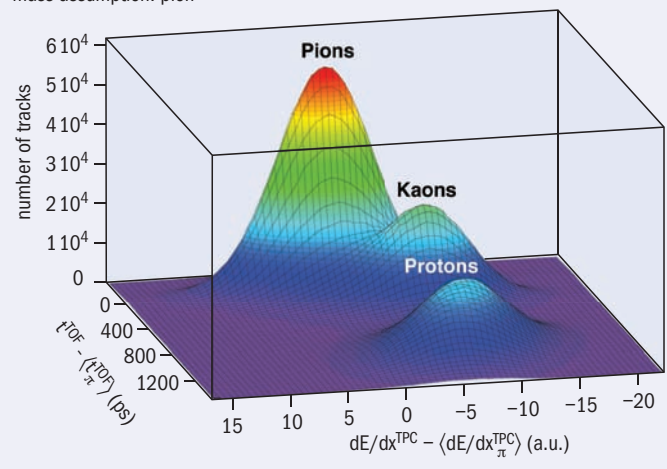


Fig. 3. In ALICE different PID measurements can be combined to achieve better separation of particle species. Here, for a certain momentum window, the time-of-flight information from the TOF detector is combined with ionization measurements ( $dE/dx$ ) in the TPC.

studies the multiplicity and spatial distribution of such photons in the forward region.

Each method described in this article provides a different piece of information. However, only by combining them in the analysis of the data produced by ALICE can the particles produced in the collisions be measured in the most complete way possible. In this way they can reveal the whole picture of what happens in the collisions.

### • Further reading

For more about PID in general and the ALICE experiment, see: C Lippmann 2012 *Nucl. Instr. Meth. A* **666** 148.  
 ALICE collaboration 2008 *JINST* **3** S08002.

### Résumé

*L'identification des particules à ALICE stimule les études QGP*

*L'expérience ALICE étudie, dans le cadre de la théorie de l'interaction forte, la chromodynamique quantique et la matière dans les conditions extrêmes créées dans les collisions d'ions lourds au LHC. Le programme de physique s'appuie sur la capacité d'identifier les particules produites au sein de la matière chaude et qui survivent suffisamment longtemps pour atteindre les détecteurs entourant la région d'interaction des faisceaux d'ions lourds. Pour cela, il faut tirer parti au mieux des différentes façons selon lesquelles les particules interagissent avec la matière des détecteurs. L'article présente les méthodes utilisées pour l'identification des particules et leur mise en œuvre dans ALICE, et décrit comment l'utilisation de nouvelles technologies a permis de faire progresser ces techniques.*

Christian Lippmann, GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt.

# Consultancy in Magnetics and Cryogenics

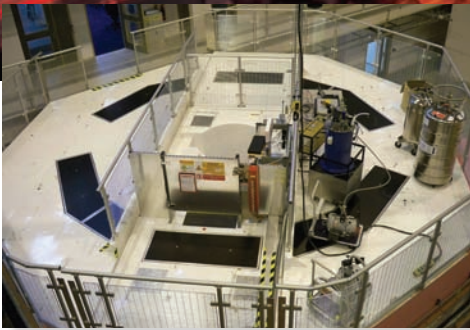
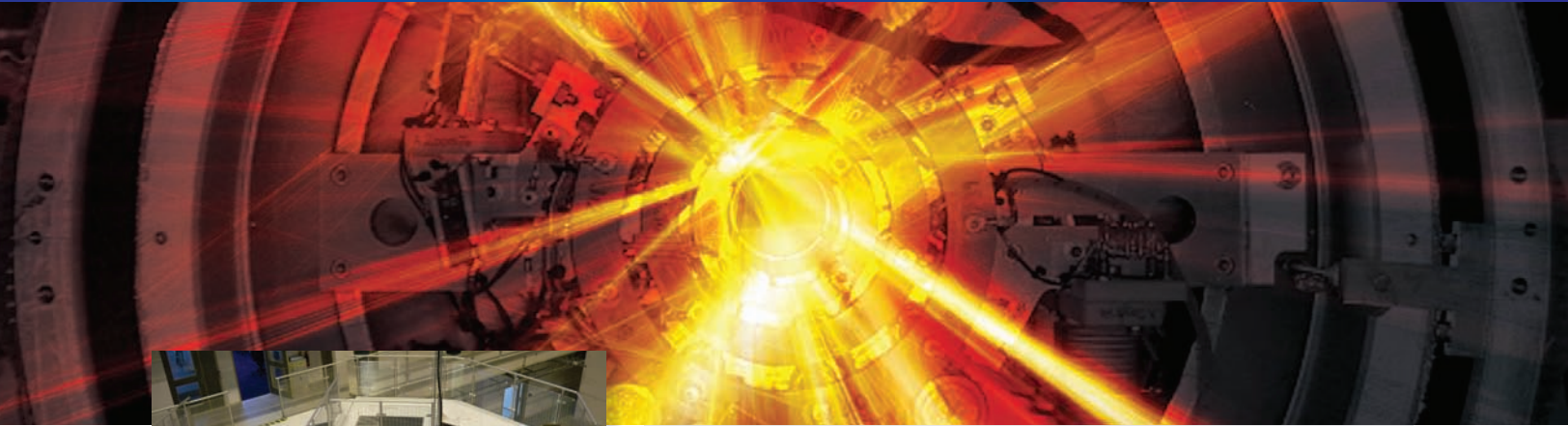


Photo courtesy of ISIS Neutron Source  
(STFC Rutherford Appleton Laboratory, Didcot).



Photo courtesy of  
Diamond Light  
Source, the  
UK's national  
synchrotron  
facility.

- Unrivalled expertise in modelling, design, engineering and programme management
- Feasibility studies, concept design and prototyping
- Beamline and target station systems: magnets, ultra-low-temperature, ultra high vacuum
- NbTi, Nb<sub>3</sub>Sn, Bi-2212 and YBCO materials
- Custom instrumentation: electronics, power supplies and diagnostics



For further information:  
[nanoscience@oxinst.com](mailto:nanoscience@oxinst.com)

[www.oxford-instruments.com/consultancy](http://www.oxford-instruments.com/consultancy)



*The Business of Science®*





# The PS Booster hits 40

Originally designed to boost the performance of CERN's Proton Synchrotron in the early 1970s, the PS Booster is still operating in the LHC era with its highest availability and flexibility – far beyond its original specifications.

On 26 May 1972, the PS Booster (PSB) accelerated its first protons to the design energy of 800 MeV. The running-in team, led by Heribert Koziol, had prepared for this event by already sending beam from the 50 MeV Linac1 through the PSB injection line while the geometers were still busy aligning the ring magnets. Just five months later, the team succeeded in accelerating at half of the design intensity. This achievement was a great relief for the entire staff of the then Synchrotron Injector (SI) division, led by Giorgio Brianti and his deputy, Helmut Reich. However, the path to full intensity proved unexpectedly tough.

The concept of the PSB dates from the mid-1960s, when CERN's 26 GeV Proton Synchrotron (PS) was getting into its stride and new and demanding clients – the Intersecting Storage Rings (ISR) and the Super Proton Synchrotron (SPS) – were on the horizon. By then, ideas to improve the performance of the PS by raising its output beam intensity from  $10^{12}$  to  $10^{13}$  protons per pulse (ppp) were already being considered.

## Boosting intensity

Particles in synchrotrons suffer from resonances generated by residual imperfections of the magnetic guide (dipole) and focusing (quadrupole) fields, in particular for certain values of the “tunes”  $Q_H$ ,  $Q_V$  (the number of horizontal/vertical oscillations per machine turn). Simple relations of the type  $mQ_H + nQ_V = p$ , with  $m$  and  $n$  small integers, are harmful “stop-bands” and must be avoided. In addition, high-intensity beams experience space charge, where the repulsive Coulomb force works against the external focusing and leads to a “Laslett tune-spread”,  $\Delta Q$ . Studies at the PS (and also at the Alternating Gradient Synchrotron at Brookhaven) established that intensities leading to  $\Delta Q > 0.25$  (“space-charge limit”) cannot be digested at injection because they do not keep clear of stop-bands up to order  $|m| + |n| = 4$ . At higher (relativistic) energies, the repulsive force becomes weaker while the beam also gets stiffer – so that  $\Delta Q$  shrinks with rising energy, scaling with  $1/\beta\gamma^2$ . Therefore, increasing the PS injection energy from 50 to 800 MeV would potentially boost its beam intensity by an order of magnitude.

After a study led by the late Werner Hardt of several variants, including a 200 MeV linac and a rapid-cycling synchrotron, a



*Fig. 1. One of the 16 magnet periods in the PSB tunnel. Right to left (following the beam): a bending magnet (dipole, green); an empty straight section with four superposed vacuum chambers; a bending magnet; a quadrupole triplet (focusing-defocusing-focusing, orange); a bending magnet; and RF equipment for beam acceleration (grey) in the next straight section.*

slow-cycling 800 MeV booster synchrotron consisting of four superposed rings was adopted. Its injection energy would still be 50 MeV but each of the four rings could be filled up to the same space-charge limit as the whole PS ring, yielding a factor of 4. In addition, slow cycling would allow for longer bunches, yielding a further factor of 1.5. Hence, the new machine would accommodate – at 50 MeV –  $10^{13}$  ppp rather than the  $1.6 \times 10^{12}$  ppp accelerated in the PS.

The four rings stacked on top of each other (figure 1), with a radius of 25 m (1/4 of the PS), consist of separate dipoles and quadrupoles (“separated function” magnets) – in contrast to the PS, which has “combined function” dipoles that incorporate gradients. Each of the 32 dipoles and 48 quadrupoles consists of a vertical stack of four magnets with a common yoke, enabling one main power supply to provide the current to all of them in series. An elaborate system of correction loops allows adjustment of the guide and focusing fields in each of the four rings. The 50 MeV beam from Linac1 is distributed vertically and multirun-injected into each ring. Originally, the RF system for the PSB accelerated five bunches per ring (RF harmonic number  $h=5$ ) to an ejection energy of 800 MeV. After being synchronized, the five bunches were horizontally extracted and recombined vertically to form a string of 20 bunches, corresponding to the harmonic number of the PS's RF system. The transverse optics (“lattice”) of the PSB ring, as well as the injection system and the recombination/transfer line (figure 2), were all designed by the late Claude Bovet.

Construction of the PSB started in 1968, with the centre of the ▷

# Vacuum Solutions from Pfeiffer Vacuum underpin the LHC

An important part of the successful operation of a particle accelerator is a high performance, reliable vacuum system. When it comes to the LHC, the vacuum requirements are even more demanding. The vacuum system needs to have a high reliability, be radiation resistant and the ease of maintenance should be assured. All these requirements have to be implemented in the solutions for vacuum generation, vacuum measurement and the analysis of the partial pressure. Thanks to a strong and successful collaborative partnership with CERN, Pfeiffer Vacuum delivered a solution, which satisfies all these requirements.

## Vacuum Generation

Pfeiffer Vacuum HiPace 300 turbopumps are used to rough pump the beam lines before activating the NEG (Non Evaporable Getter) coating. The second scope of application is to evacuate the insulation vacuum for the cryogenic system. HiPace 300 pumps provide a high pumping speed and an outstanding compression ratio for light gases. Both values are important for the generation of an excellent vacuum.

### Pumping Speed:

He: 255 l/s, Compression Ratio: He:  $> 10^8$

### Pumping Speed:

H2: 220 l/s, Compression Ratio: H2:  $> 5 \cdot 10^5$

The high vacuum pressure performance of a turbopump can be calculated according the following formula:

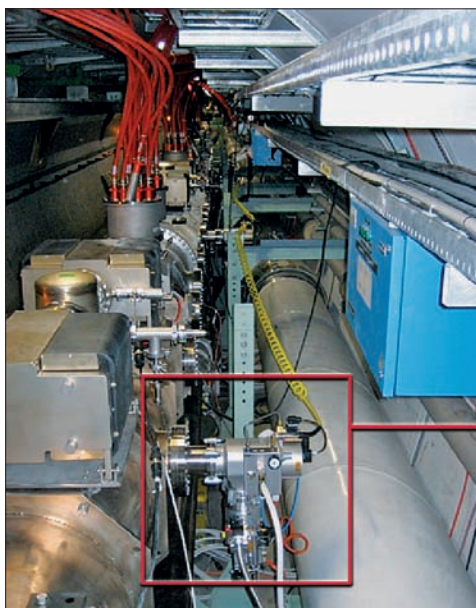
$$p_{HV} = \frac{Q}{S_{TMP,eff}} + \frac{P_{FVH_2}}{K_{0H_2}} + \frac{P_{FVHe}}{K_{0He}} + \frac{P_{FVG_3}}{K_{0G_3}} + \dots + \frac{P_{FVGn}}{K_{0Gn}}$$

$p_{HV}$  = high vacuum pressure,  $Q$  = gas load,  $S$  = pumping speed,  $P_{FV}$  = partial fore vacuum pressure (for different gases),  $K$  = compression ratio (for different gases)

## Turbopump applications can be divided into two main groups:

Applications with gas load and applications without gas load. For applications without gas load it is important to have a turbopump with a high compression ratio. As one can see in the formula, if the gas load is close to zero, which is normally the case in ultra high vacuum applications, the compression ratio becomes the determining factor. The compression ratio for light gases is important, since Hydrogen constitutes the majority of the residual gas. For gas load applications it is important to have a high pumping speed available. Again from the formula, if there is gas load, the pumping speed of a turbopump is the only factor that can reduce the high vacuum pressure significantly.

To be suitable for the operation on the LHC the turbopumps have to withstand a radiation dose up to 1.000 Gy/a. This high level of radiation prohibits



HiPace 300 in use at the LHC



the operation of any semiconductor components inside the pump. To overcome this problem Pfeiffer Vacuum developed together with CERN a new sensorless drive concept. This allows the complete removal of any electronics from the body of the pump. The electronics are installed outside the tunnel in radiation protected service galleries. These service galleries can be up to 1.000 m away from the pump. Although the electronics are placed far away from the pump, they can still notify the users of all the important status parameters of the turbopump.

Pfeiffer Vacuum HiPace turbopumps can be easily serviced. In case maintenance is necessary they do not need to leave the radiation area, all the maintenance work can be done on site inside the tunnel. Furthermore Pfeiffer Vacuum has ensured the pump electronics will have a long product life. All built in components are guaranteed to be available for a long period of time.

## Vacuum Measurement

For measuring the vacuum CERN relies on the ModulLine measuring system from Pfeiffer Vacuum. This measuring system consists of the gauge controller TPG 300 and a combination of passive pirani and cold cathode gauges. The passive design of the gauges without attached electronics ensures radiation resistance. All the electronics are located inside the gauge controller. The gauge controller was designed as a modular concept, with a basic chassis that can be equipped with measurement or interface boards. When the basic chassis was developed, Pfeiffer Vacuum ensured a long product life cycle, only components with long term availability have been used, and it has not been necessary to change the design in the last 25 years. The controller can be equipped with an interface board that allows communication with

a modern Profibus PLC. The gauge controller and the gauges are connected with special cables that have been evaluated in cooperation with CERN. A special triaxial cable for the cold cathode gauge allows the measurement of pressures down to  $10^{-11}$  mbar. A special ignition procedure ensures reliable ignition of the cold cathode gauge in the lower pressure range. All gauges are metal sealed, without elastomer seals, to guarantee high leak tightness.

## Analysis of the partial pressure

Residual gas analyses are made with Pfeiffer Vacuum quadrupole mass spectrometers. Vacuum annealed analysers with an annealed ion source and an annealed rod system provide very low outgassing rates. For ultra high vacuum applications, grid ion sources are used. These grid ion sources can be easily degassed via an integrated degas function. All these features lead to a very low background signal. For radiation applications it is possible to detach the electronics up to 6 metres away from the analyser.

The LHC and its vacuum system are outstanding. Pfeiffer Vacuum is proud to contribute to its success by delivering perfect vacuum solutions.

**Pfeiffer Vacuum GmbH**  
Headquarters/Germany  
Florian Henss, Market Management R&D

Phone +49 6441 802-1536  
Fax +49 6441 802-1300  
E-mail [florian.henss@pfeiffer-vacuum.de](mailto:florian.henss@pfeiffer-vacuum.de)  
Web [www.pfeiffer-vacuum.com](http://www.pfeiffer-vacuum.com)

**PFEIFFER**  **VACUUM**





Fig. 2. PSB injection (50 MeV) and transfer (1.4 GeV) lines. The beam coming from the linac (foreground) is distributed vertically to the four PSB levels. After acceleration, the four beams are recombined and transferred (from left to right in the picture) to the PS or ISOLDE.

machine lying exactly on the Swiss-French border. Many novel technological challenges had to be addressed, such as: unprecedented requirements on field quality and equality between the superposed magnet gaps; “kicker” magnets with rapid rise/fall times; and stable and reliable power converters operating directly from the grid. The ambitious aims for beam intensity and quality demanded special efforts for mechanical stability, beam diagnostics, vacuum equipment, radiation protection, assuring hands-on maintenance, and general reliability. Moreover, the PSB served as a “guinea pig” for the then innovative computer-control system aimed at monitoring all of the machine parameters.

### Design intensity – and beyond

While the quick initial success of the running-in testified to the soundness of the basic choices and the high quality of the construction work, major difficulties later hampered the progress towards design performance. The first was a strong energy-jitter of the beam from Linac1, which was eventually stabilized at the expense of the beam current (50 mA instead of the 100 mA that was specified). With the help of experienced accelerator physicists, Jacques Gareyte and the late Frank Sacherer, the obstacles were addressed one by one. The “working point” ( $Q_H$ ,  $Q_V$ ) was moved from around (4.8, 4.8) to (4.2, 5.3), mitigating transverse beam blow-up caused by repeated stop-band crossing arising from the synchrotron motion of the protons within the bunch. Furthermore, a fast change of the working point during acceleration proved beneficial, profiting from the shrinking  $\Delta Q$  (figure 3). Destructive coherent bunch-oscillations were stabilized by “Magnani shaking” and later by a coupled-bunch feedback system. A first pay-off came in 1973, when the search for neutral currents with the Gargamelle bubble chamber benefitted from the increased supply of protons from the PS with the PSB as injector. By 1974 the PS reached  $10^{13}$  ppp – the design performance of the upgrade programme.

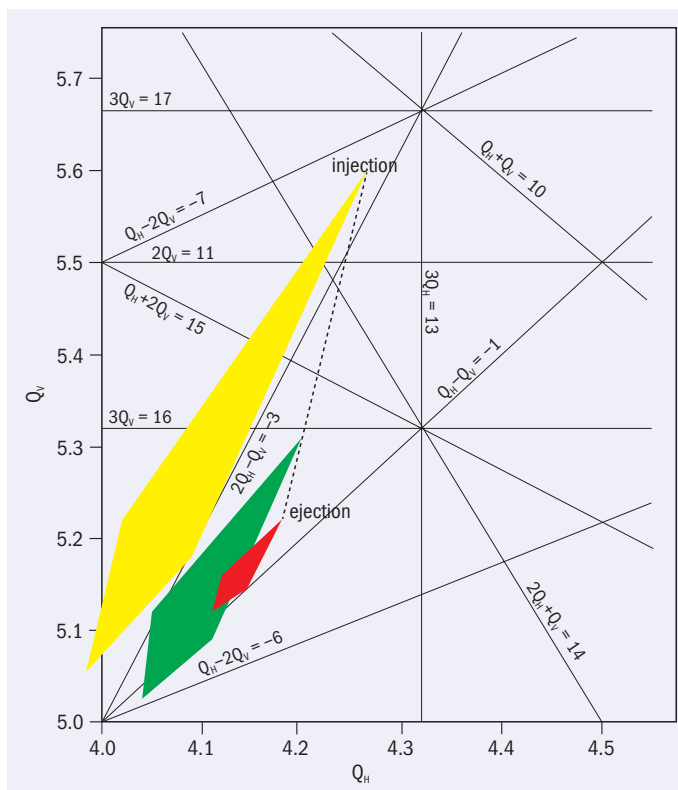


Fig. 3. Horizontal and vertical tunes  $Q_H$ ,  $Q_V$  and the space-charge tune-spread  $\Delta Q$  during acceleration in the PSB. The coloured areas depict  $\Delta Q$  at injection (yellow), after 120 ms acceleration (green) and after 400 ms at 1.4 GeV (red) for  $10^{13}$  protons in one ring. While  $\Delta Q$  is around 0.55 at injection, covering many stop-bands, it shrinks significantly during acceleration, enabling the working point to be moved rapidly to an area clear of harmful stop-bands.

However, this is not the end of the story. By 1978, the new Linac2 – still at 50 MeV but with 150 mA beam current – replaced Linac1 and dramatically increased the PSB’s potential, although it took a couple of years to exploit this improvement fully. Installing multipole correctors to eliminate stop-bands allowed intensities with larger tune-spread to be accommodated. The addition of “bunch-flattening cavities” in the PSB, fostered by the late George Nassibian, lowered the peak density of the bunches and thus  $\Delta Q$ , enabling an intensity some 25% higher to be accepted. Fast feedback systems compensating unwanted excitations by the bunches on the cavities (“beam loading”), as well as transverse dampers, also proved beneficial, culminating in the PSB’s acceleration of  $3 \times 10^{13}$  ppp by 1985. Now the PS was at pains to digest this beam at 800 MeV, in particular the high-density proton bunches for antiproton production, which were obtained by simultaneously ejecting two PSB rings and adding the bunches vertically in the recombination line, almost doubling their line density. To cope with this, the PSB was promoted to a 1 GeV machine after minor hardware modifications, increasing the PS space-charge limit by a further 25%.

Experiments involving light ions became popular in the early 1980s and the old Linac1 was successfully converted to accelerate oxygen and sulphur ions, deuterons and alpha particles. The PSB ▷

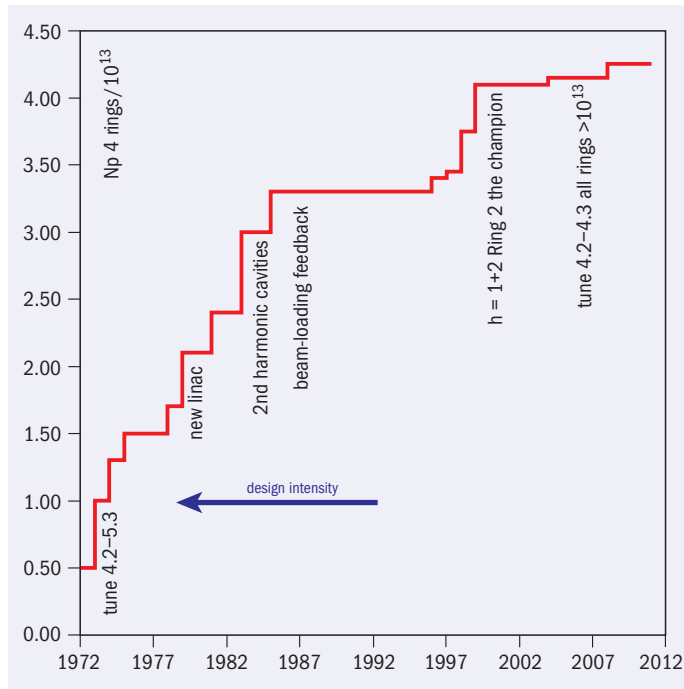


Fig. 4. The PSB peak intensity per pulse over the years (sum of the four rings).

followed suit. However, the issue now was not too high an intensity but one that was very low (by three orders of magnitude), which together with new acceleration frequencies challenged the beam diagnostics and RF systems. The low-intensity ion cycles had to be added to the supercycle – during which all beam parameters are modified from cycle to cycle to adapt to the requirements of the end-users. With the advent of a dedicated ion accelerator, Linac3, the PSB made its way up the periodic table to reach lead and, later, indium ions.

When CERN's first accelerator – the venerable 600 MeV Synchrocyclotron, by then feeding the ISOLDE online separator with protons – came to the end of its life after 33 years of meritorious services, ISOLDE looked for a new source. Following the suggestion to use the PSB's 1 GeV beam on the many spare cycles available, ISOLDE was relocated at the PSB in 1992: an experimental area of its own was the coming-of-age present for the Booster's 20th anniversary.

### Fit for the LHC

It is a CERN tradition that new machines use existing accelerators as injectors, and the LHC is no exception. Clearly, all of the accelerators of the proton-injector chain – Linac2–PSB–PS–SPS – had to undergo major upgrade programmes to be fit for the new machine. Among the requirements, the beam would have to fit into the tiny LHC aperture while having sufficient intensity to ensure high-luminosity operation. However, this implied a beam-brilliance at injection into the PSB that would lead to an unrealistic space-charge detuning of  $\Delta Q$  up to 1. This could be reduced to a more acceptable 0.5 by two-batch filling of the PS, but only if each batch could be squeezed into one half of its circumference. Accelerating one rather than five bunches in each PSB ring

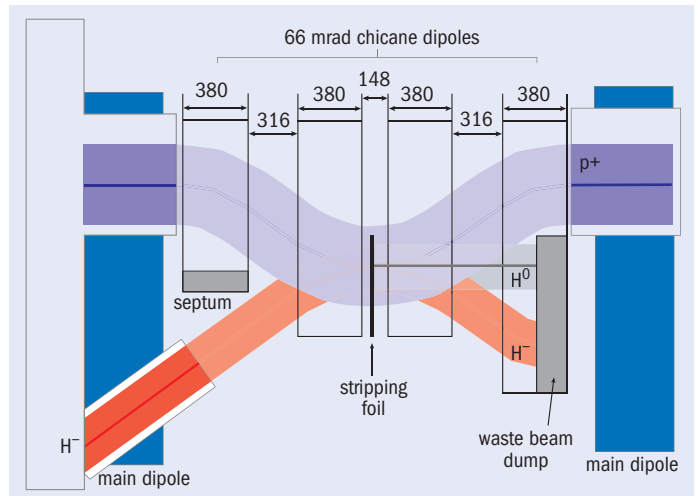


Fig. 5. The new charge-exchange injection scheme for the PSB. H<sup>-</sup> ions from Linac4 pass through a stripping foil and are converted into protons, which are then merged almost without losses with the proton beam already circulating in the machine.

and applying clever timing of the ejection/recombination kickers made this feasible, although the first batch in the PS has to dwell for 1.2 s on the 1 GeV “front porch”, proving vulnerable to space-charge effects.

A further improvement came from increasing the PSB–PS transfer energy to 1.4 GeV, reducing  $\Delta Q$  in the PS to 0.2, well below the space-charge limit of 0.25, owing to the  $1/\beta\gamma^2$  scaling. Upgrading a machine built for 800 MeV to 1.4 GeV was no minor task. It involved a new main power supply, increased water cooling and a partial renewal of the magnets and their power supplies in the transfer line to the PS. The rings had to be equipped with new  $h = 1$  (2 MHz) cavities and as well as recycled  $h = 2$  (4 MHz) cavities, the former accelerating one bunch in each ring, the latter for bunch flattening or accelerating two bunches a ring for some users. The lion's share of this upgrade was provided by Canada as part of its contribution to the LHC. Installation of the new hardware in both the PSB and the PS was completed by early 2000 and after a short running-in period the PS complex demonstrated its capability to supply the beams required by the LHC.

Owing to its unique four-ring structure, the PSB is a versatile machine that can deliver beams of different energy, intensity, density, shape or time-structure to many users, cycle after cycle. These are grouped in supercycles of various lengths that are adapted to the operation programme. Just for the LHC, some 10 different beams were prepared and made ready to work, all of them with their own intensity (over the range  $5 \times 10^9$ – $6.5 \times 10^{12}$  ppp) and emittance characteristics. Other cycles produce up to  $3.7 \times 10^{13}$  protons for ISOLDE, around  $2.5 \times 10^{13}$  protons for the CERN Neutrinos to Gran Sasso project,  $1.5 \times 10^{13}$  protons with small emittances for the Antiproton Decelerator or intensities as low as  $2 \times 10^{11}$  protons for slow extraction from the PS. In particular, the versatility of the recombination line enables the bunches from the four rings to be furnished with different distances between them to satisfy the requirements of the users.

By around 2003, two modifications to beam optics were



proposed and put into operation. First, the optics of the 50 MeV injection line were improved so that the dispersion and its derivative vanish at the injection point. This reduces the beam size and the losses in the last leg of the line (where the acceptance was limited) without perturbing the injection efficiency. Second, the working point of the machine was changed to avoid the systematic resonance  $3Q_v = 16$ , which limited the performance of the outer rings 1 and 4. The quadrant  $(Q_H, Q_v) = (4.2, 4.3)$  instead of  $(4.2, 5.3)$  proved able to accommodate the enormous tune-spread  $\Delta Q$  of 0.6 (using the same dynamic tune-change during the cycle) despite its apparent drawbacks: namely, the presence of the “Montague” coupling resonance  $2Q_H - 2Q_v = 0$  and the systematic resonances  $4Q_{H,V} = 16$ . As a result, the PSB reached a record of  $4.2 \times 10^{13}$  protons accelerated, with the four rings having similar performances (figure 4).

By 2006, when construction of the LHC was in full swing, the operation teams of all of the accelerators moved to a common control room – the CERN Control Centre – to increase the operational efficiency of the LHC and its injector chain (*CERN Courier* May 2006 p27). For the PSB team, this meant a change in culture owing to the larger distance between the PS complex and the new control room. However, the merging of the teams proved invaluable for the running-in and operation of the LHC, which uses all of the prepared beams.

### The future

The need for beams for the LHC with parameters even more demanding than what is provided today, together with the decision to operate the existing injector complex throughout the lifetime of the LHC, has triggered a major consolidation and upgrade project. As far as the PSB is concerned, the upgrade programme consists of two parts: modifications of the injection for 160 MeV charge-exchange injection from the new Linac4; and an energy upgrade of the PSB rings and extraction/transfer systems to 2 GeV.

The benefits of switching from Linac2 (50 MeV protons) to Linac4 (160 MeV  $H^-$ ) are twofold. With the increase of beam energy from 50 to 160 MeV, the relativistic  $\beta\gamma^2$  factor increases by a factor of two – doubling the intensity that can be accumulated within a given emittance and hence beam brilliance (ratio intensity/emittance). The other significant benefit is expected from changing the injection scheme to charge-exchange injection (figure 5). While the current multiturn injection is associated with a beam loss of up to 50% of the intensity on the injection septum, the new scheme will essentially be loss-free (apart from a few per cent owing to the stripping efficiency). Moreover, the new injection scheme will make it possible to tailor emittances by means of “phase-space painting” according to the needs of individual users.

The aim of the further energy upgrade of the PSB to 2 GeV is

to reduce space-charge effects at injection into the PS, removing once more this bottleneck in the LHC injector chain. This should increase the beam brilliance throughout the LHC injector chain so that the LHC can reach its ultimate luminosities. The expected gain can be deduced from the values of  $\beta\gamma^2$  at 2.0 GeV and 1.4 GeV; the factor of 1.63 corresponds to an intensity increase of 60% within given emittance values.

The upgrade to 2 GeV will be the third energy increase in the history of the PSB, having gone in steps from 800 MeV to 1 GeV and then to the current 1.4 GeV. The most important technical challenges will be the operation of the main magnets at field levels that are 30% higher than those at 1.4 GeV, together with the replacement of the main power supply, as well as the upgrade of the extraction and recombination system. Also, many components need modification or replacement to operate in the new parameter range. Following completion of the upgrade, the PSB will – in many parts – be a new machine, without losing its current versatility.

In its 40-year history, the PSB has undergone several upgrades and is today operating with its highest availability and flexibility, and far beyond its original design specifications. The ongoing consolidation and upgrade programme aims to operate the PSB throughout the lifetime of the LHC. This will ensure that it remains one of CERN’s backbone accelerators for the foreseeable future.

### • Further reading

C Bovet *et al.* 1973 *IEEE Trans. Nuclear Sci.* NS-20 825.

K Hanke (ed.) 2010 *PS Booster Energy Upgrade Feasibility Study*, first report <https://edms.cern.ch/document/1082646/3>.

J Poole (ed.) 2004 *LHC Design Report Vol III The LHC Injector Chain* CERN-2004-003.

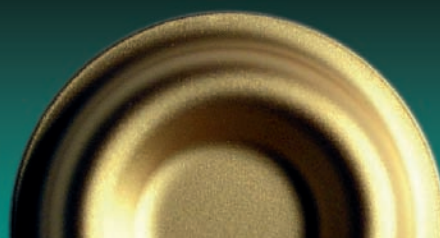
### Résumé

*Le Booster du PS fête ses 40 ans*

*Conçu pour renforcer la performance du Synchrotron à protons au début des années 1970, le Booster du PS fonctionne à présent bien au-delà de son cahier des charges initial, et son temps de disponibilité comme sa flexibilité sont sans exemple. Constitué d'un empilement de quatre anneaux, le Booster a accéléré ses premiers protons pour les porter à l'énergie nominale de 800 MeV en 1972. Depuis lors, il a connu de nombreuses modifications répondant à l'évolution du programme d'accélérateurs du CERN, la dernière en date visant à permettre l'obtention d'une intensité suffisante pour le LHC. La prochaine amélioration lui permettra de continuer à fonctionner pendant toute la durée de vie du LHC.*

**Klaus Hanke**, CERN, and **Michel Chanel**, **Karlheinz Schindl**, CERN (retired).

CONTROL THE SMALLEST LEAK  
WITH OUR GAS DOSING LEAKVALVE



 **nenion**  
www.nenion.at



# THE 13TH VIENNA CONFERENCE ON INSTRUMENTATION

11 - 15 February 2013

## SCIENTIFIC TOPICS

### **New Detector Developments in**

Particle physics / Astro-particle physics /  
Nuclear physics

Associated detector electronics  
and detector specific software

### **Applications in**

Biology / Medicine / Neutron scattering /  
Synchrotron radiation

Abstract Submission Deadline

**19 October 2012**

## ORGANIZING COMMITTEE

Institute of High Energy Physics of the Austrian Academy of Science

M. Kramer (chairman) T. Bergauer M. Dragicevic M. Friedl J. Hrubec

M. Jeitler W. Mitaroff M. Regler (honorary member)

Atominstytut, TU Wien G. Badurek





# E-CLOUD12 sheds light on electron clouds

A recent workshop reviewed the latest experiences with the phenomenon of electron clouds at the LHC and other accelerators.

Electron clouds – abundantly generated in accelerator vacuum chambers by residual-gas ionization, photoemission and secondary emission – can affect the operation and performance of hadron and lepton accelerators in a variety of ways. They can induce increases in vacuum pressure, beam instabilities, beam losses, emittance growth, reductions in the beam lifetime or additional heat loads on a (cold) chamber wall. They have recently regained some prominence: since autumn 2010, all of these effects have been observed during beam commissioning of the LHC.

Electron clouds were recognized as a potential problem for the LHC in the mid-1990s (*CERN Courier* July/August 1999 p29) and the first workshop to focus on the phenomenon was held at CERN in 2002 (*CERN Courier* July/August 2002 p15). Ten years later, the fifth electron-cloud workshop has taken place, again in Europe. More than 60 physicists and engineers from around the world gathered at La Biodola, Elba, on 5–8 June to discuss the state of the art and review recent electron-cloud experience.

## Valuable test beds

Many electron-cloud signatures have been recorded and a great deal of data accumulated, not only at the LHC but also at the CESR Damping Ring Test Accelerator (CesrTA) at Cornell, DAΦNE at Frascati, the Japan Proton Research Complex (J-PARC) and PETRA III at DESY. These machines all serve as valuable test beds for simulations of electron-cloud build-up, instabilities and heat load, as well as for new diagnostics methods. The latter include measurements of synchronous phase-shift and cryoeffects at the LHC, as well as microwave transmission, coded-aperture images and time-resolved shielded pick-ups at CesrTA. The impressive resemblance between simulation and measurement suggests that the existing electron-cloud models correctly describe the phenomenon. The workshop also analysed the means of mitigating electron-cloud effects that are proposed for future projects, such as the High-Luminosity LHC, SuperKEKB in Japan, SuperB in Italy, Project-X in the US, the upgrade of the ISIS machine in the UK and the International Linear Collider (ILC).

An international advisory committee had assembled an

exceptional programme for E-CLOUD12. As a novel feature for the series, members of the spacecraft community participated, including the Val Space consortium based in Valencia, the French aerospace laboratory Onera, Massachusetts Institute of Technology, the Instituto de Ciencia de Materiales de Madrid and the École Polytechnique Fédérale de Lausanne (EPFL). Indeed, satellites in space suffer from problems that greatly resemble the electron cloud in accelerators, which can be modelled and cured by similar countermeasures. These problems include the motion of the satellites through electron clouds in outer space, the relative charging of satellite components under the influence of sunlight and the loss of performance of high-power microwave devices on space satellites. Intriguingly, the “Furman formula” parameterizing the secondary emission yield, which was first introduced around 1996 to analyse electron-cloud build-up for the PEP-II B factory, then under construction at SLAC, is now widely used to describe secondary emission on the surface of space satellites. Common countermeasures for both accelerators and satellites include advanced coatings and both communities use simulation codes such as BI-RME/E-CLOUD and FEST3D. A second community to be newly involved in the workshop series included surface scientists, who at this meeting explained the chemistry and secrets of secondary emission, conditioning and photon reflections. Another important first appearance at E-CLOUD12 was the use of Gabor lenses, e.g. at the University of Frankfurt, to study incoherent electron-cloud effects in a laboratory set-up.

Several powerful new simulation codes were presented for the first time at E-CLOUD12. These novel codes include: SYNRAD3D from Cornell, for photon tracking, modelling surface properties and 3D geometries; OSMOSEE from Onera, to compute the secondary-emission yield, including at low primary energies; PyE-CLOUD from CERN, to perform improved and faster build-

up simulations; the latest version of WARP-POSINST from Lawrence Berkeley National Laboratory, which allows for self-consistent simulations that combine build-up, instability and emittance growth, and is used to study beam-cloud behaviour over hundreds of turns through the Super Proton Synchrotron (SPS); and BI-RME/E-CLOUD from a ▷

**Several powerful new simulation codes were presented for the first time at E-CLOUD12.**

## Accelerators



*ECLLOUD12 participants at La Biodola. (Image credit: Vinicio Tullio LNF/INFN.)*

collaborative effort of EPFL and CERN, to study various aspects of the interaction of microwaves with an electron cloud. New codes also mean more work. For example, the advocated transition from E-CLOUD to PyE-CLOUD implies that substantial code development done at Cornell and EPFL for E-CLOUD may need to be redone.

E-CLOUD12 could not solve all of the puzzles, and several open questions remain. Why, for example, does the betatron sideband signal – characterizing the electron-cloud related instability – at CesrTA differ from similar signals at KEKB and PETRA III? Why was the beam-size growth at PEP-II observed in the horizontal plane, while simulations had predicted it to be vertical? How can the complex nature of intricate incoherent effects be described fully? Which ingredients are missing for correctly modelling the electron-cloud behaviour for electron beams, e.g. the existence of a certain fraction of high-energy photoelectrons? How does the secondary-emission yield of the copper coating on the LHC beam-screen decrease as a function of incident electron dose and incident electron energy (looking for the “correct” equation to describe the variation of the primary energy at which the maximum yield is attained as a function of this maximum yield,  $\epsilon_{\max}(\delta_{\max})$  and the concurrent evolution in the reflectivity of low-energy electrons,  $R$ )? Does the conditioning of stainless steel differ from that of copper? If it is the same, then why should the SPS’s beam pipe be coated but not the LHC’s? Can the secondary-emission yield change over a timescale of seconds during the accelerator cycle (a suspicion based on evidence from the Main Injector at Fermilab)? Can the surface conditioning be speeded up by the controlled injection of carbon-monoxide gas?

As for the “electron-cloud safety” of future machines, E-CLOUD12 concluded that the design mitigations for the ILC and for SuperKEKB appear to be adequate. The LHC and its upgrades (HL-LHC, HE-LHC) should also be safe with regard to electron cloud if the surface conditioning (“scrubbing”) of the chamber wall progresses as expected. The situations for Project-X, the upgrade for the Relativistic Heavy Ion Collider, J-PARC

and SuperB are less finalized and perhaps more challenging.

E-CLOUD12 was organized jointly and co-sponsored by INFN-Frascati, INFN-Pisa, CERN, EuCARD-AccNet (*CERN Courier* November 2009 p16) and the Low Emittance Ring (LER) study at CERN. In addition, the SuperB project provided a workshop pen “Made in Italy”. The participants also enjoyed a one-hour football match (another novel feature) between experimental and theoretical electron-cloud experts – the latter clearly outnumbered – as well as post-dinner discussions until well past midnight. The next workshop of the series could be E-CLOUD15, which would coincide with the 50th anniversary of the first observation of the electron-cloud phenomenon at a small proton storage-ring in Novosibirsk and its explanation by Gersh Budker.

● For all of the presentations at E-CLOUD12, see <http://agenda.infn.it/conferenceOtherViews.py?view=standard&confId=4303>. *The E-CLOUD12 workshop was dedicated to the memory of the late Francesco Ruggiero, former leader of the accelerator physics group at CERN, who launched an important remedial electron-cloud crash programme for the LHC in 1997.*

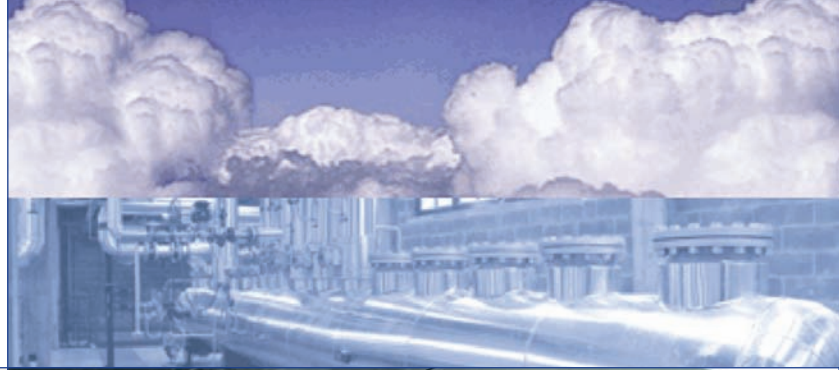
### Résumé

*E-CLOUD12 : en savoir plus sur les nuages d'électrons*

*Les nuages d'électrons produits dans les enceintes à vide peuvent avoir des effets sur le fonctionnement et la performance des accélérateurs. Ces phénomènes ont été reconnus au milieu des années 1990 comme pouvant présenter un problème pour le LHC, et le premier atelier consacré à ce phénomène a eu lieu au CERN en 2002. Dix ans plus tard, voici le 5<sup>e</sup> atelier sur les nuages d'électrons. Plus de 60 physiciens et ingénieurs du monde entier se sont réunis à l'île d'Elbe début juin, pour parler de l'état de la technique et évoquer l'expérience acquise récemment en matière de nuages d'électrons au LHC et dans d'autres accélérateurs.*

**Roberto Cimino**, LNF/INFN, and **Frank Zimmermann**, CERN, chairs of E-CLOUD12.





**DELTA-TI Impianti S.p.A.** was founded in 1975 on the basis of a solid family experience, dating back to the 1925 expertise of Demisto Biginelli and currently represented by our CEO. The long presence in the field of design and installation allows us to provide our customers with reliable, rational and functional products. We boast a large technical team specialized in design development, job management and coordination and a skilled workforce dedicated to the management of construction activities as well as personnel with appropriate qualifications. We invest in research and innovation to improve our performances in the design and installation phase.

Our company relies on qualified personnel dedicated to the Quality Management, SOA certifications and Personnel Safety. Thanks to the know-how passed on by our founder Demisto Biginelli we can design and realize:

- integrated systems for the production and distribution of energy (combined cycle power plants and cogenerating power plants)
- HVAC and fire protection plants
- electrical and electroinstrumental plants
- pipelines in general (overheated water, steam, compressed air, oil and fuels, natural gas, etc.)
- district heating networks and substations

Address: Via Albenga, 90/92 Rivoli (TO) ITALY  
Tel: +39 (0)11 957.15.97 – 957.36.62  
Fax: +39 (0)11 957.41.64  
Website: [www.delta-ti.com](http://www.delta-ti.com)  
E-mail: [info@delta-ti.it](mailto:info@delta-ti.it)



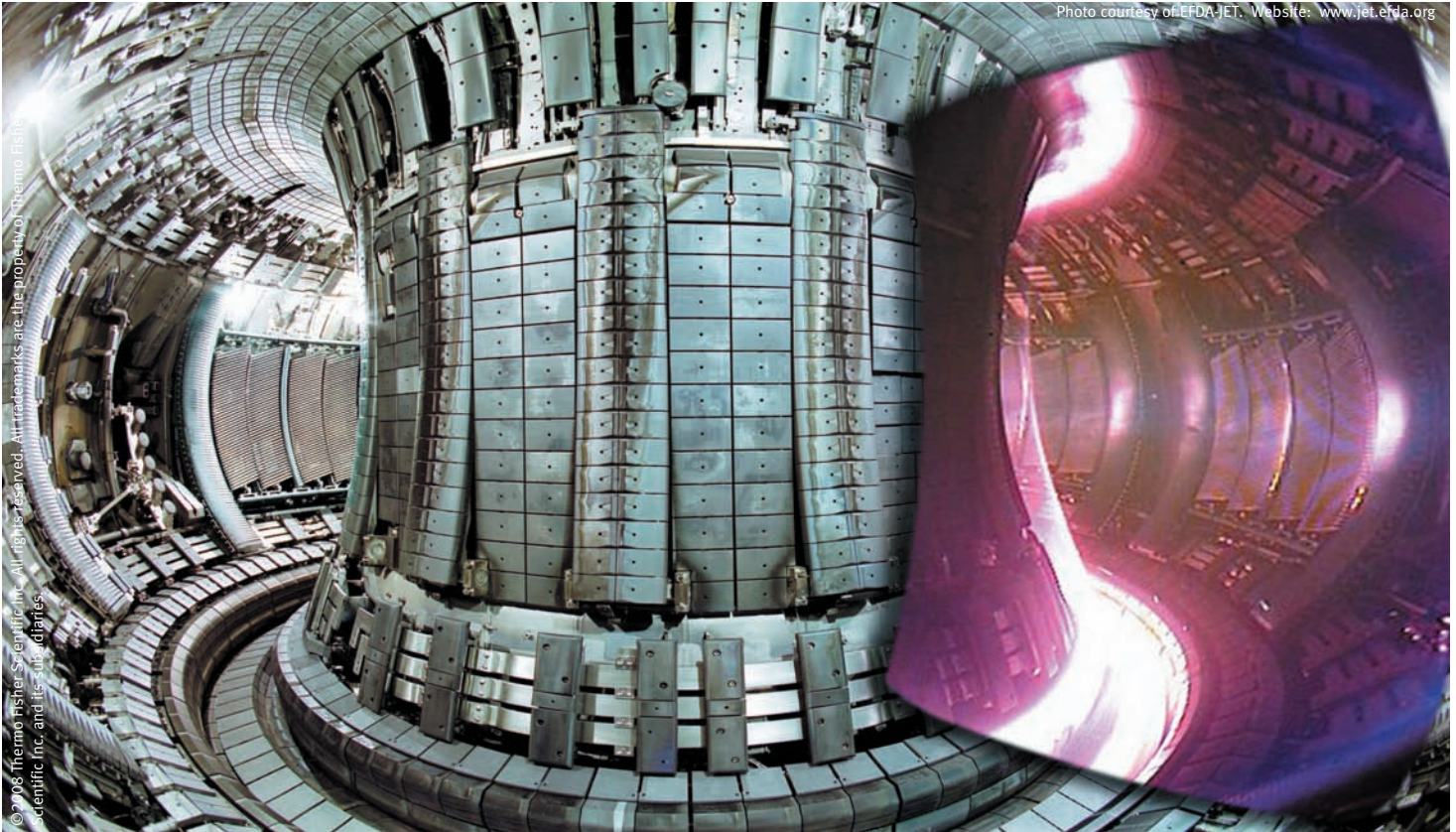


Photo courtesy of EFDA-JET. Website: www.jet.efda.org

© 2008 Thermo Fisher Scientific Inc. All rights reserved. All trademarks are the property of Thermo Fisher Scientific Inc. and its subsidiaries.

## Got Radiation? See what you've been missing

The Thermo Scientific MegaRAD series of radiation hardened CID imaging cameras are capable of operating in high dose environments and provide excellent image quality to total dose levels over 100 times the tolerance of conventional solid state cameras.

- Color and Monochrome imaging to beyond 3 MegaRAD
- High resolution CID imager technology
- Small remote detachable head

Look closer at the Thermo Scientific line of radiation hardened cameras. Visit [www.thermo.com/cidtec](http://www.thermo.com/cidtec) or contact us today about new innovative imaging products.

Tel: 1-315-451-9410 • Email: [sales.cidtec@thermo.com](mailto:sales.cidtec@thermo.com)



### **The world's only color rad hard camera**

Innovative Preamp per pixel CID design allows high radiation tolerance and excellent image quality even in low light conditions.



# Discovery of a new boson – the ATLAS perspective

With a well performing LHC and their sights on the major summer conference, the ATLAS analysis teams went into over-drive to provide a thrilling result for 4 July.

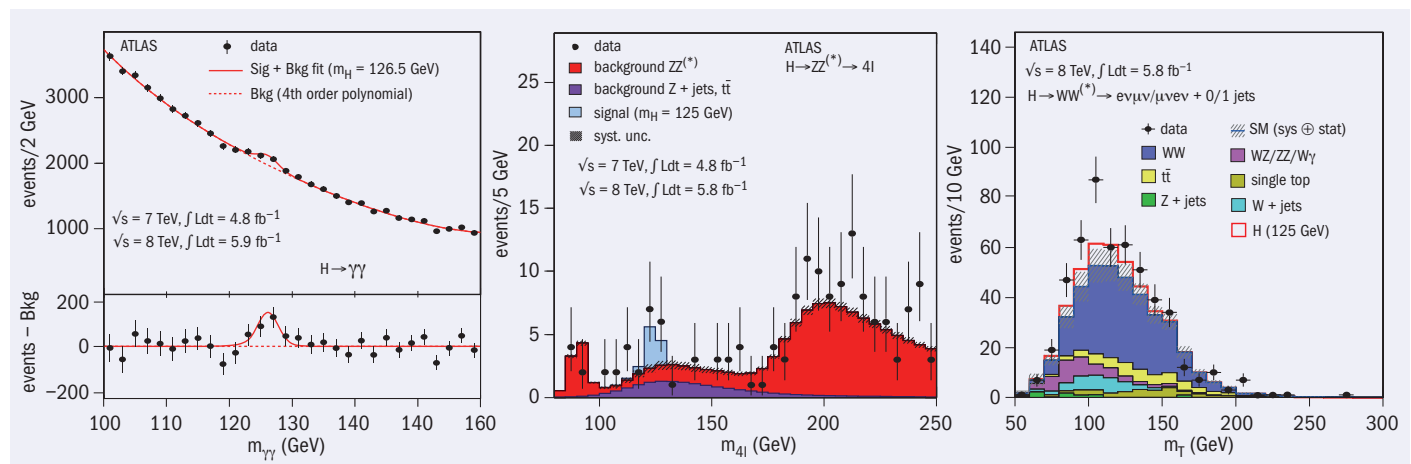
By the end of 2011, hopes for the discovery of the Higgs boson during 2012 were riding high on the back of tantalizing hints in the  $5 \text{ fb}^{-1}$  data sample. The aim was to quadruple the data set this year, with the added benefit that increasing the centre-of-mass energy from 7 TeV to 8 TeV brings a higher predicted rate of Higgs production. The first planned checkpoint was for the ICHEP 2012 conference (p53) and in the weeks preceding it the LHC performed better than ever, resulting in a total delivered luminosity of more than  $6 \text{ fb}^{-1}$  at 8 TeV. Thanks to the expertise and continued dedication of many people, the ATLAS detector was in great shape, and 90%

of the delivered data were recorded and passed the strict quality requirements to go forward for analysis.

## The strategy

The ATLAS strategy in preparation for the early ICHEP milestone was to focus first on the most sensitive decay modes, the decay of the Higgs boson to two photons ( $\gamma\gamma$ ), to two Z bosons or to two W bosons. The W and Z bosons are identified from their most clear final states. The two Zs decay to four leptons (llll), electrons or muons, and the W pair is identified in the mixed-flavour final state with an electron, a muon and two neutrinos:  $WW \rightarrow e\nu\mu\nu$ . The  $\gamma\gamma$  and  $ZZ \rightarrow \text{llll}$  modes have excellent mass resolution because the Higgs boson decays entirely into visible, well measured particles. However, they have quite different signal-to-background rates and features, requiring appropriate analysis strategies. By contrast, the presence of two invisible neutrinos means that the WW mode has low mass-resolution.

For each final state, the approach was not to look in the signal region of the 2012 data until the analysis procedure was frozen, to avoid any bias in tuning the event selection criteria. The  $\triangleright$



Left to right: Fig. 1a. Mass distribution of  $\gamma\gamma$  events. Upper panel: Data points show the invariant mass of  $\gamma\gamma$  events from both 2011 and 2012; dashed curve shows the fit to background only; solid curve shows the fit to signal plus background for a signal of mass 126.5 GeV. Lower panel: As above but with background subtracted. A peak in the distribution is seen at 126 GeV. Fig. 1b. Mass distribution of  $ZZ \rightarrow \text{llll}$  events. Data points show the 4l mass for events from both 2011 and 2012. Solid histograms show the expected backgrounds and the predicted signal of a Standard Model Higgs of mass 125 GeV. An excess of events over background is observed near 125 GeV. Fig. 1c. Transverse mass distribution of  $WW \rightarrow e\nu\mu\nu$  events. The data points show the transverse mass of events from 2012. Coloured histograms show the expected backgrounds, with the predicted signal of a Standard Model Higgs of mass 125 GeV added on top. A broad excess of events over background is seen.

## LHC discovery

selections were optimized using simulated samples and control regions in the data. These are samples of events with configurations that cannot come from a Higgs signal but which allow salient features of the data to be compared with simulation.

For the  $\gamma\gamma$  final state, the mass distribution of the photon pair in events with two energetic photons is shown in figure 1a (p43). The background to the Higgs signal is dominated by genuine  $\gamma\gamma$  events from known processes, plus events with one or two hadronic jets misidentified as photons. This background forms a smoothly falling spectrum on top of which there is a visible bump around 126 GeV. However, this distribution tells only part of the story. The potential significance of the signal is higher in subsets of the data that have better mass resolution. The resolution depends on whether the photons are in the central or forward parts of the detector, and also on whether one or both photons have “converted” by the process  $\gamma \rightarrow e^+e^-$ . Furthermore, the signal-to-background ratio also changes according to the number of additional hadronic jets in the event because this characterizes different Higgs-production mechanisms. The data were divided into 10 subsets, for each of which the background shape was derived by fitting the data themselves. By evaluating the probability that fluctuations of the smooth background could create the bump, the local significance at 126 GeV is found to be equivalent to 4.5 standard deviations ( $\sigma$ ).

Comparing the mass distribution from the two-photon sample with the distribution in figure 1b, where the mass is calculated from the four leptons in  $ZZ \rightarrow llll$  events, the situation is quite different. The predicted signal to background in the interesting mass range between 120 and 130 GeV is much larger for the  $ZZ$  final state, with about half of the background coming from genuine  $ZZ$  events and half from other processes. The background shape is more complicated than in the  $\gamma\gamma$  case but the expected features are well reproduced by simulation. The small peak in the distribution at 125 GeV has a local significance of  $3.4\sigma$ .

Combining the  $ZZ \rightarrow llll$  result with the  $\gamma\gamma$  result and with all of the channels measured in 2011 brings the local significance to the pivotal threshold of  $5.0\sigma$ , as was announced to cheers at the 4 July seminar. Moreover, the signal masses measured in these two high-resolution channels are consistent, with an overall best-fit mass of  $126.0 \pm 0.4$  (stat.)  $\pm 0.4$  (syst.) GeV.

The  $WW \rightarrow e\nu\mu\nu$  analysis was ready a few days after the seminar and is included in the publication. Although the mass cannot be calculated, a transverse-mass variable  $m_T$  can be formed from the measured electron and muon and the missing transverse energy in the event that arises from the unobserved neutrinos. Figure 1c shows the distribution of  $m_T$ , with the predicted broad signal from a 125 GeV Higgs boson superimposed on the known backgrounds. The visible excess of events over background lends further evidence for the presence of a signal, bringing the overall significance to  $5.9\sigma$ , corresponding to a one in 600 million chance that the known background processes could fluctuate to give such a convincing excess.

It came as something of a shock that the discovery threshold was reached so early in 2012. After more than 20 years of development, the detector has proved that it is capable of measuring leptons, photons, jets and missing energy with excellent precision, and it is

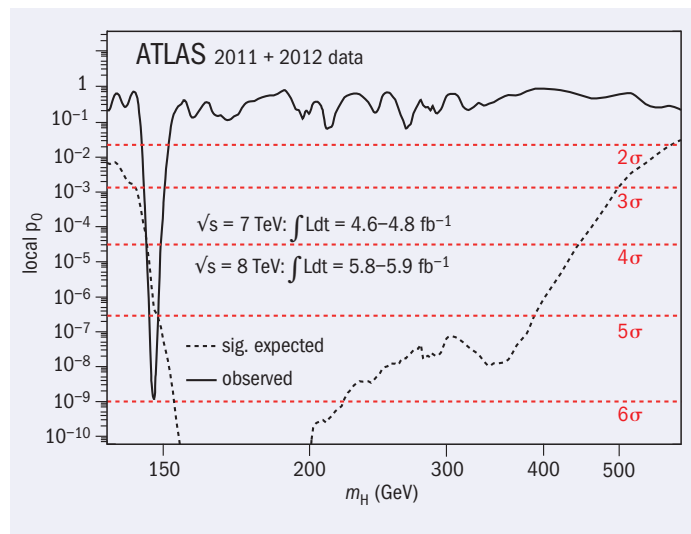


Fig. 2. Probability (local  $p_0$ ) for background processes to look like a signal as a function of mass. Solid curve is the observed probability, showing a sharp minimum at 126 GeV. The probability of background only producing this minimum is one in 600 million. Dashed curve shows the expected probability in the presence of a Standard Model Higgs signal for each possible value of Higgs mass.

### The excitement as the data were revealed for the first time was tangible.

operating with remarkable efficiency. This performance has been maintained even though the LHC is delivering higher luminosity than ever, with more proton–proton interactions per bunch crossing than foreseen. The trigger menus have been fine-tuned to select the most interesting events. The intricate process of reconstructing and distributing millions of events across the worldwide LHC Computing Grid in a matter of days runs smoothly; the ability to go from recording the last data to announcing a discovery just a couple of weeks later was incredible. In all aspects of the endeavour, people were prepared to work without sleep to ensure that the next step went without a hitch. The excitement as the data were revealed for the first time was tangible, and the thrill of the announcement on 4 July was shared by the collaboration around the world, from the lucky few in the CERN auditorium to collaborators at their home institutions and the attendees at the ICHEP conference in Melbourne.

The celebratory champagne has been drunk and the next stage of the work is beginning. The question on everyone’s lips now is whether this new particle has the features of the Standard Model Higgs boson. Undoubtedly, it is a brand-new boson, and we look forward to getting to know it better.

● For more, see the paper on these results from ATLAS, submitted to *Phys. Lett. B*, arXiv:1207.7214v1 [hep-ex].

**The ATLAS collaboration.**



# Oerlikon salutes LHC success

Oerlikon Leybold Vacuum supplied key vacuum components to CERN's Large Hadron Collider and ATLAS/CMS detectors.

## Oerlikon congratulates

Oerlikon congratulates the CERN scientists involved in the ATLAS (A Toroidal LHC Apparatus) and CMS (Compact Muon Spectrometer) experiments, which have revealed clear signs of a new elementary particle.

The discovery promises to be the elusive Higgs boson, which scientists have been searching for since it was predicted by the Standard Model of particle physics 50 years ago. This momentous achievement, which was made using the Large Hadron Collider (LHC) at CERN, could help to answer many of the remaining mysteries of particle physics.

The LHC – along with the four detectors used for ATLAS, CMS and other key experiments at CERN – requires ultrahigh vacuum conditions while they are being operated.

The strong radiation generated by the accelerated particles within the LHC, combined with the presence of very strong magnetic fields, present technical challenges for the design and operation of vacuum systems. Working alongside the scientific and technical collaborators who were responsible for various aspects of the experiments, Oerlikon designed systems which overcame these challenges and are absolutely unique to CERN.

Oerlikon Leybold Vacuum equipped the LHC and the large ATLAS detector with special vacuum systems, and then designed and installed two special pump systems for the CMS detector system, for which Oerlikon Leybold Vacuum received a CMS Gold Award in 2008. This award, presented by the CMS Collaboration, recognizes outstanding technological contributions.

**Andreas Widl**, CEO of Oerlikon Vacuum, said: "We are proud and excited for the ATLAS and CMS teams after the breakthrough announcement. This experiment has significant importance for a better understanding of the world of physics. It is the result of the hard and creative work of exceptional teams. We at Oerlikon Vacuum congratulate those teams and feel honoured to have made a small contribution to this success."

**Dr. José Miguel Jimenez**, Head of CERN's Vacuum, Surfaces and Coatings group in the Technology Department, added that in order to meet this amazing challenge, CERN was pleased to find in Oerlikon a partner capable

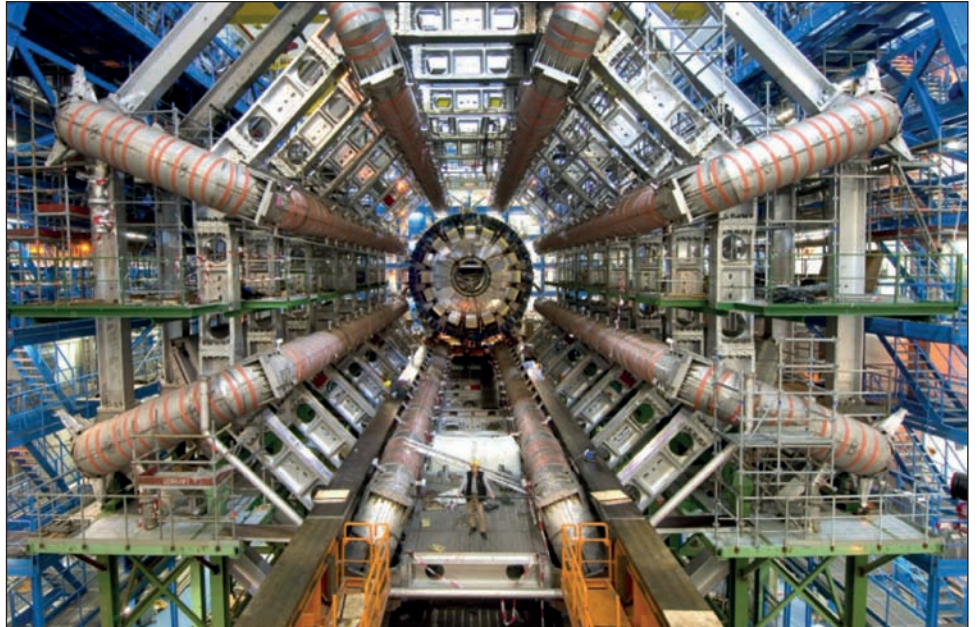


Photo: Installing the ATLAS calorimeter © 2005 CERN

of collaborating in the development of vacuum systems for the LHC and its injectors. This key partnership really made Oerlikon a part of the story.

## The CMS coil vacuum pumping system: design and installation

This system creates the vacuum inside the 40 m<sup>3</sup> volume of the coil cryostat. The vacuum system is fully instrumented and equipped with a PLC-based control process.

It consists of two double primary pumping stations, equipped with two rotary vane pumps and two roots pumps, located in the service cavern. These pumps provide the fore vacuum,

## In 2008, Benoit Curé, engineer at CERN's PH division, described the critical nature of the operation:

*"Pumping is the first step in the count-down for commissioning the solenoid, which can last 8 to 12 weeks. Once the operating vacuum is reached, cooling down takes over. Albeit essential, this is only one function of the pumps. In fact, during operations, the whole system is constantly on the alert; the oil-diffusion pumps get into action to prevent condensation on the surfaces. Reliability is the key feature of the system CMS has chosen and we were pleased to find a partner capable of collaborating with us in its design and construction."*

through vacuum ducts, to the two oil diffusion pumps located in the experimental cavern, and connected to the coil cryostat via the current leads chimney and the helium phase separator.

The rotary vane pumps have a pumping speed of 280 m<sup>3</sup>/h while the two roots pumps have a flow of 1000 m<sup>3</sup>/h. The biggest oil diffusion pump, installed via a DN 400 flange on the current leads chimney, has a nominal flow of 8000 l/s at 10<sup>-4</sup> mbar of fore vacuum. The smallest one delivers 3000 l/s at the phase separator.

The solenoid is inserted into two tanks with welded flanges forming the vacuum vessel. The complex cooling system of superconducting coils is known as the "cold mass", essentially the superconducting external cylinder to which the liquid Helium cooling system is attached. An ultrahigh vacuum is essential to start cooling down to 4° Kelvin. The process of pumping down the 40m<sup>3</sup> tank can last a couple of months, and the target temperature is usually reached within four weeks.

## Contact

E-mail [media.vacuum@oerlikon.com](mailto:media.vacuum@oerlikon.com)

Tel +49 221 347 1261

Web [www.oerlikon.com/leyboldvacuum](http://www.oerlikon.com/leyboldvacuum)

**oerlikon**  
leybold vacuum

## LHC discovery

Particle physicists around the world linked with CERN to hear the latest news on the search for the Higgs boson at the LHC.

It's 2 a.m. in Chicago, 9 a.m. in Geneva and 5 p.m. in Melbourne. Around the world, particle physicists in labs, lecture theatres and in their homes are full of anticipation. They are all waiting to hear the latest update in the search for the Higgs boson at the LHC, following the tantalizing hints presented on 13 December (*CERN Courier* January/February 2012 p6). Everyone knows that something exciting is in the air. The seminar has been rapidly scheduled to align with the start of the 2012 International Conference of the High-Energy Physics in Melbourne. It will be webcast not only to an audience in Melbourne but to the many teams around the world who have contributed over the years.

The news has its roots in the 1960s. The work of Robert Brout, François Englert, Peter Higgs, Gerald Guralnik, Carl Hagen and Tom Kibble in 1964 was to become a key piece of the Standard Model, giving mass to the W and Z bosons of the electroweak force. From the 1970s, searches for the so-called Higgs boson progressed as particle accelerators grew to provide beams of higher energies, with experiments at Fermilab's Tevatron and CERN's Large Electron-Positron providing the best limits before the LHC entered the game in 2010.

It was a day that many will remember for years to come. Englert, Higgs, Guralnik and Hagen were all in the audience at CERN to hear the news directly. (Sadly, Brout died last year and Kibble was unable to attend.) The ATLAS and CMS collaborations announced that they had observed clear signs in the LHC's proton-proton collisions of a new boson consistent with being the Higgs boson, with a mass of around 126 GeV.

The adjoining articles (p43 and p49) give some insight into the analysis procedures behind these latest results from the ATLAS and CMS experiments.

### Résumé

*Une journée mémorable*

*Le 4 juillet, au matin, le CERN a accueilli des physiciens des particules du monde entier, impatients de connaître les dernières nouvelles sur la recherche du boson de Higgs au LHC. Cette journée restera gravée dans les esprits. Les collaborations ATLAS et CMS ont annoncé qu'elles avaient observé des indices probants de l'existence d'un nouveau boson aux caractéristiques compatibles avec celles du boson de Higgs, au voisinage de 126 GeV. Les articles correspondants donnent un aperçu des analyses qui ont conduit aux résultats obtenus par les deux expériences.*

# 4 July 2012: a da



*More than two hours before the seminar was due to start, there were long queues of people waiting for the doors of CERN's main auditorium to open.*



*Dan Green, of CMS, gives a toast at Fermilab. (Image credit: Fermilab Visual Media Services.)*



*Watching the seminar from DESY in Germany. (Image credit: DESY.)*



# Day to remember



*Joseph Incandela, left, and Fabiola Gianotti, spokespersons of the CMS and ATLAS collaborations, respectively, join in the applause after their presentations at CERN.*



*François Englert, left, and Peter Higgs, two of the names behind the seminal work of 1964.*



*Some of the enthusiastic audience at Fermilab. (Image credit: Fermilab Visual Media Services.)*



*Carl Hagen, of the University of Rochester, speaks at the seminar.*



*Gerald Guralnik, of Brown University, is happy to hear the news.*

# Precision magnetic measurement: from CERN to industry and back

*Magnets are key elements of the Large Hadron Collider (LHC), and the success of the LHC must in large part be attributed to the fabulous work of the CERN team that characterized these thousands of magnets. Since the tools for this exacting job were not available, most were developed at CERN. Continuing a symbiotic relationship that has endured more than 25 years, Metrolab Technology SA has licensed some of this technology, improving it and making it available to industry and other laboratories. The following is a brief retrospective.*

## NMR Precision Teslameters

In 1985, **Metrolab's** first product was a high precision magnetometer based on the Nuclear Magnetic Resonance (NMR) effect – using a design licensed from CERN. Metrolab turned a delicate piece of scientific equipment, capable of measuring magnetic field strengths to within parts per million, into a tough industrialized instrument that could be operated by any technician. The chief beneficiary was the then-nascent industry for Magnetic Resonance Imaging (MRI), which has since become one of medicine's most important imaging modalities.

That NMR magnetometer went on to become the world's standard method for measuring strong fields to a very high degree of precision. Its direct successor, the Precision Teslameter PT2025, continues to be manufactured today (see *Figure 1*). It is only now that an all-new digital model, the PT2026, is preparing to replace CERN's original design. Its benefits include better resolution, greater measurement range, better performance in inhomogeneous fields, modern interfaces and much greater versatility.

## Digital Integrators

The pattern repeated itself a few years later, when Metrolab licensed CERN's design for a Precision Digital Integrator (PDI). The PDI integrates the voltage of a moving coil, using Faraday's Law to compute the field strength at well-known positions, with a precision of roughly one part in  $10^5$ . This very integrator, coupled with a sophisticated rotating-coil system, was used to characterize the LHC dipoles.

Metrolab industrialized this instrument by adding, for example, programmable-gain amplifiers and a flexible trigger facility. Thus was born Metrolab's Precision Digital Integrator PDI5025, which became the accepted standard at accelerator laboratories and magnet suppliers throughout the world – and remained so for over 20 years (see *Figure 2*).

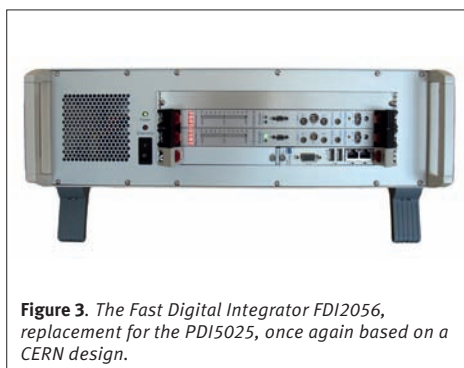
In 2007, CERN presented a successor to the PDI, designed to work with a fast rotating-coil



**Figure 1.** Metrolab's NMR Precision Teslameter PT2025, today's "gold standard" for magnetometry, originally based on a design licensed from CERN.



**Figure 2.** Metrolab's Precision Digital Integrator PDI5025, for decades the accepted standard for high-speed integrators, also based on a CERN design.



**Figure 3.** The Fast Digital Integrator FDI2056, replacement for the PDI5025, once again based on a CERN design.

system. One of this system's primary objectives was to study transient effects observed in large superconducting magnets like the LHC dipoles. To match the fast rotating-coil system, the new Fast Digital Integrator (FDI) was designed to provide a 100x speed- and 100x resolution improvement over its predecessor.

Once again, Metrolab decided to license this new CERN design, introducing it in 2010 as the Fast Digital Integrator FDI2056. Based on internal testing and customer feedback, Metrolab decided to undertake a number of improvements. Again, a major improvement was the flexible trigger

facility, notably enabling the FDI2056 to accept all commonly available rotational and linear position encoders as trigger source.

Other low-level modifications include improved noise performance and linearity, synchronized acquisition on multiple channels, improved time resolution and trigger rate, and miscellaneous bug fixes. The most important improvement, however, is the transition from a board-level to a system-level product. The non-standard, low-level PCI interface has been replaced by a PDI5025 compatibility interface, as well as a "native" interface based on an Ethernet connection and industry-standard VXI-11, IEEE 488.2 and SCPI protocols (see *Figure 3*).

## Two-way street

Metrolab has reaped tremendous benefits from its relationship with CERN, but so has the high-energy physics community. CERN itself has become an excellent customer of Metrolab's PT2025 – for example to calibrate the LHC rotating-coil systems – thus gaining access to a fully industrialized version of its own technology.

More generally, Metrolab has served to distribute CERN-developed technology to other accelerator laboratories. But rather than just distributing technology, Metrolab actually improves on it. Not to awaken latent rivalries between scientists and engineers, let us attribute these improvements primarily to a difference in perspective: CERN designs an instrument to respond to a specific need, whereas Metrolab aims to satisfy as broad a clientele as possible.

In fact, although the bulk of our product palette is no longer driven by high-energy physics applications, Metrolab has made a conscious effort to stay "plugged into" this community, for example by participating in conferences such as the Particle Accelerator Conferences (PAC, EPAC and IPAC) and the International Magnetic Measurement Workshop (IMMW).

The industrialization of CERN's magnetic measurement technology illustrates how the transfer of such specialized technology can, and should, work. Patent lawyers are not particularly useful: their cost is only amortized in large markets like smartphones. Incentives encouraging technology transfer are not particularly useful either: a durable symbiotic relationship should be incentive enough. What is useful is a platform to exchange ideas, similar to the IMMW conferences – plus a little bit of imagination.

## Contact

**Claude Thabuis**  
Sales and Production Manager  
E-mail [contacts@metrolab.com](mailto:contacts@metrolab.com)  
Tel +41 22 884 3311  
Fax +41 22 884 3310  
Web [www.metrolab.com](http://www.metrolab.com)



# Inside story: the search in CMS for the Higgs boson

The exciting results announced on 4 July were first dreamt of by the founders of CMS more than 20 years ago. Now, their vision has borne magnificent fruit.

9.35 a.m. 4 July 2012. In front of an expectant crowd packing CERN's main auditorium, Joseph Incandela shows a slide on behalf of the CMS collaboration; its subject, the combination of the two search channels with the best mass resolution,  $H \rightarrow \gamma\gamma$  and  $H \rightarrow ZZ \rightarrow 4$  leptons (llll). The slide shows a clear excess that corresponds to  $5\sigma$  above the expected background, signalling the discovery of a new particle. The audience erupts into applause. These decay modes not only give a measure of the mass of the new particle as  $125 \pm 0.6$  GeV but also reveal that it is, indeed, a boson, meaning a particle with integer spin; the two-photon decay mode further implies that its spin must be different from 1 (figure 1).

The search for the Standard Model Higgs boson, the missing keystone of the current framework for describing elementary particles and forces, has been going on for some 40 years. The ideas that led to the 4 July announcement were seeded more than 20 years ago: in 1990, at the Aachen workshop where people first heard the term "Compact Muon Solenoid", and where people such as Michel Della Negra and Tejinder Virdee – the founding fathers of the CMS collaboration – presented quantitative ideas on how the Higgs boson, if it existed, could be found at the LHC (CERN Courier October 2008 p11). They aimed to provide coverage down to the region of low mass, which required precision tracking and electromagnetic calorimetry.

A measure of the performance of CMS, its hardware, software, distributed computing, analysis systems and the inventiveness of the people doing the analysis, can be gauged by the fact that a discovery of a Higgs-like boson has been made at half of the design energy of the LHC, using one-third of the integrated luminosity and under fiercer than the design "pile-up" conditions that were foreseen in the pre-data-taking estimates for reaching such a significance. This success is a real tribute to the thousands of CMS physicists and several generations of students who have turned CMS from a proposal on paper to a scientific instrument, *hors du commun*, producing frontier physics.

On 4 July the CMS collaboration presented searches for the Standard Model Higgs boson in five distinct decay modes:

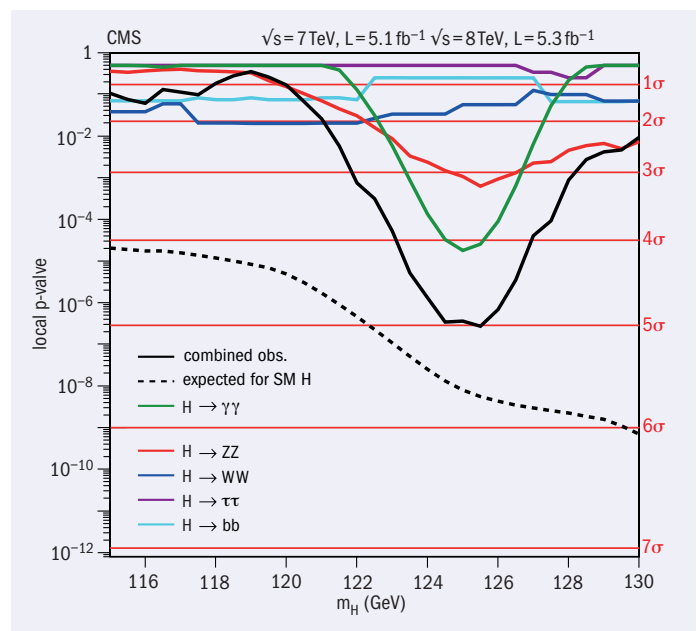


Fig. 1. Measured significance for the various decay modes and their combination.

$\gamma\gamma$ ,  $ZZ \rightarrow llll$ ,  $WW \rightarrow l\nu l\nu$ ,  $\tau\tau$  and  $bb$ , the so-called high-priority analyses. The 2012 data-taking campaign and physics analyses had been under preparation since the end of 2011. The CMS collaboration had been pushing to go to 8 TeV collision energy and, assuming that this would happen, started the data simulation at 8 TeV in December. The collaboration identified 21 high-priority analyses, including the ones for the Higgs searches. The reconstruction software was improved and the trigger menus prepared to select with high efficiency the events necessary for the search. The software and computing resources were for the most part dedicated to the high-priority analyses.

The limits on the Higgs boson mass, established by experiments at CERN's Large Electron-Positron collider and Fermilab's Tevatron, and by the LHC campaign in 2011, showed that the Standard Model Higgs boson, if it existed, would most likely inhabit the mass range 114.4–127 GeV. Another important strategic decision was to re-optimize and improve the analyses using the expected sensitivity as the driving criterion. The entire analysis procedure in each individual analysis was assessed on the basis of maximizing sensitivity without looking into the above-mentioned mass region – in other words, they were "blind". This would inevitably lead >

## LHC discovery

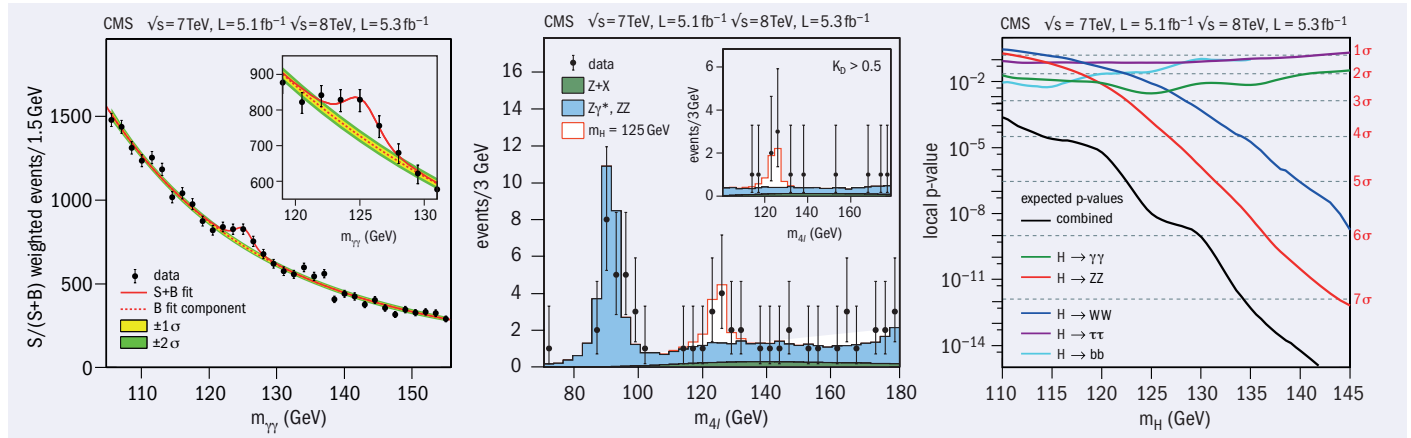


Fig. 2. Two-photon mass for the  $H \rightarrow \gamma\gamma$  decay mode: the main plot shows the weighted sum of the various analysis categories using  $S/(S+B)$  as a weight (where  $S$  and  $B$  are the expected signal and expected background). The insert shows a zoom on the signal region. Fig. 3. Four-lepton mass for the  $H \rightarrow ZZ \rightarrow llll$  decay mode. The insert shows the events passing a kinematic discriminant that selects Higgs-like decay topologies. Fig. 4. Expected significance for a SM Higgs boson in the various decay modes and their combination.

to a day of high drama when the “unblinding” was to take place, on 15 June.

The unblinding procedure, defined before 2012 data-taking, was to proceed in two steps:

- The performance of the analyses would be evaluated and pre-approved by the collaboration based on the first  $3 \text{ fb}^{-1}$  of data that had been collected and fully certified. On 15 June, the results in the blinded region would be shown. The deadline of 15 June arrived and all analyses were declared ready by the analysis review committees and on seeing the results from the high mass-resolution channels most of the hundreds present at CERN or connected via videoconferencing were astounded – there were the first clear signs that a new particle could be coming into view. The indications seen in the 2011 data not only remained, but were strengthened. A day of excitement indeed!
- From 15 June onwards the analyses would be – and were – simply topped-up, once the data quality-certification process was completed. They would eventually include all of the data available up until the technical stop of the LHC planned for late June.

Expectations started to increase, especially when observing the fantastic performance of the LHC, which was delivering collisions at a record rate. At the same time, the considerable increase in sensitivity of all five analyses, compared with those of 2011, meant that a discovery became a real possibility. In particular, the  $H \rightarrow \tau\tau$  channel had improved in sensitivity by more than a factor of two and  $H \rightarrow b\bar{b}$  was also starting to contribute. All of the analyses had integrated multivariate analysis methods for selection and/or reconstruction to optimize use of the full event information, leading to improved sensitivity. The channels with high mass-resolution,  $H \rightarrow \gamma\gamma$  and  $H \rightarrow ZZ \rightarrow llll$ , achieved close-to-design resolutions, e.g. for the best categories of events,  $1.1 \text{ GeV}$  and  $<1 \text{ GeV}$  for diphoton and four-lepton states, respectively (figures 2 and 3). The anticipated number of standard deviations ( $\sigma$ ) for the expected significance came out close to  $6 \sigma$  (median) using  $5 \text{ fb}^{-1}$  from each of the 7 TeV and 8 TeV data sets (figure 1). A higher (lower) observed significance would indicate an upwards (downwards) fluctuation of this expectation.

All of the five high-priority analyses were performed indepen-

dently at least twice. Furthermore, improvements in the definition and selection of the physics objects were subjected to scrutiny and formal approval before deployment.

As every new batch of certified data was added, the analysts eagerly looked forward to updates. The final word would belong to the team responsible for combining the results from the five high-priority analyses, the combination procedure having been validated before the unblinding.

The combination of these five analyses reveals an excess of events above the expected background, with a maximum local significance of  $5.0 \sigma$  at a mass of  $125.5 \text{ GeV}$ . The expected significance for a Standard Model Higgs boson of that mass is  $5.8 \sigma$ . The signal strength  $\sigma/\sigma_{\text{SM}}$  was measured to be  $0.87 \pm 0.23$ , where  $\sigma/\sigma_{\text{SM}}$  denotes the production cross-section multiplied by the relevant branching fraction, relative to the Standard Model expectation.

Having clearly seen a new particle, considerable attention was then devoted to measuring properties such as mass, spin if possible, and its couplings to bosons and fermions. All in all, the results presented by CMS are consistent, within uncertainties, with expectations for a Standard Model Higgs boson. With the recent decision to extend the 2012 data-taking by 55 days, the collaboration is now eager to accumulate up to three times more data, which should enable a more significant test of this conclusion and an investigation of whether the properties of the new particle imply physics beyond the Standard Model.

This will prove to be the discovery of a particle *sans precedent*. If it is confirmed to be a fundamental scalar (spin 0) then it is likely to have far-reaching consequences on physicists’ thinking about nature. It would be the first fundamental scalar boson. It is known that fundamental scalar fields play an important role not only in the presumed inflation in the early instants of the universe but also in the recently observed acceleration of its expansion. There can be no doubt that exciting times lie ahead.

- For more, see the paper on these results from CMS, submitted to *Phys. Lett. B*, arXiv:1207.7235v1 [hep-ex].

**The CMS collaboration.**



# L A K E S H O R E MODEL 350 ULTRA LOW CRYOGENIC TEMPERATURE CONTROLLER

Ideal for use with He-3 systems and other ultra-low temperature refrigeration platforms down to 100 mK

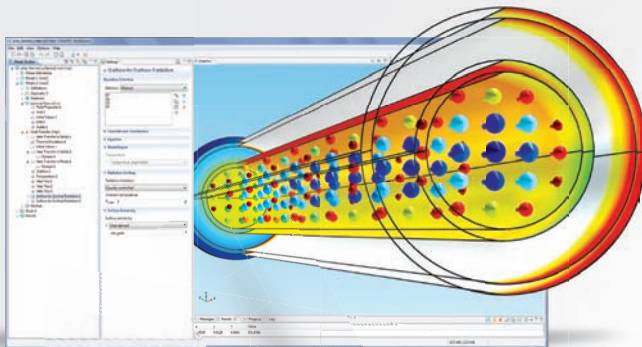
NOW  
AVAILABLE

- Optimized performance with Cernox™ RTDs
- Patented low-noise input circuitry enables super low excitation power for minimal self-heating and high resolution measurement
- 4 independent control loops and a broad range of I/O configurations can eliminate need for additional instrumentation



 **LakeShore**  
Phone: (614) 891-2244 Fax: (614) 818-1600  
info@lakeshore.com www.lakeshore.com

## Verify and optimize your designs with COMSOL Multiphysics®



**SOLAR ENERGY:** Heat is transferred by surface-to-surface radiation from the outside shell to the pipe walls.

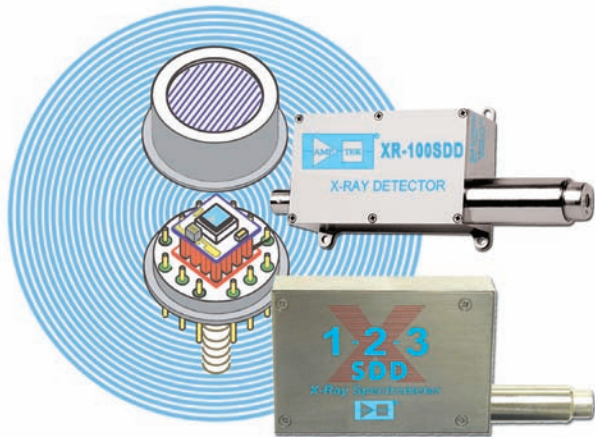
Multiphysics tools let you build simulations that accurately replicate the important characteristics of your designs. The key is the ability to include all physical effects that exist in the real world. Order a free CD containing 700 multiphysics presentations at [www.comsol.com/confcd](http://www.comsol.com/confcd)



# Silicon Drift Detector

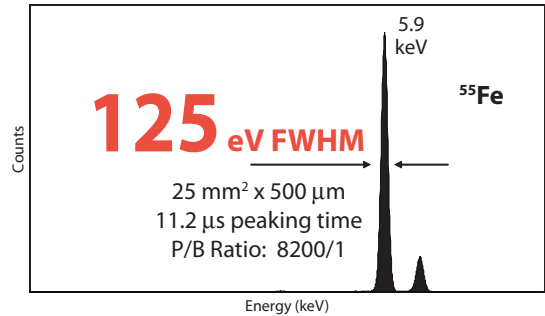
No Liquid Nitrogen  
Easy to Use

Solid State Design  
Low Cost

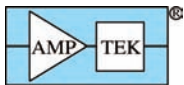


**XR-100SDD** X-Ray Detector and  
**X-123SDD** Complete X-Ray Spectrometer with X-ray  
detector and preamplifier, digital pulse processor,  
MCA, and power supply

## SUPER SDD



Please see web site for vacuum applications



**AMPTEK Inc.**

E-mail: [sales@amptek.com](mailto:sales@amptek.com)  
[www.amptek.com](http://www.amptek.com)



**Zoppas Industries**  
Heating Element Technologies



Image credit: CERN



# Particle-physics fever in Melbourne

Starting with the announcement of the discovery of a new boson at CERN, ICHEP2012 resonated to a wave of optimism, despite the continued absence of long sought-after signs of new physics.

Never before did the International Conference on High-Energy Physics (ICHEP) start with such a bang. Straight after registering on 4 July in Melbourne, participants at ICHEP2012, the 36th conference in the series, were invited to join a seminar at CERN via video link, where they would see the eagerly anticipated presentations of the latest results from ATLAS and CMS. The excitement generated by the evidence for a new boson sparked a wind of optimism that permeated the whole conference. Loud cheers and sustained applause were appropriately followed by the reception to welcome more than 700 participants from around the world, where they could discuss the news over a glass of delicious Australian wine or beer.

As usual, ICHEP consisted of three days of six parallel sessions followed by a rest day and then three days of plenary talks to cover the breadth and depth of particle physics around the world. This article presents only a personal choice of the highlights.

## All eyes on the new boson

Talks on the search for the Higgs boson drew huge crowds in the parallel sessions. The discovery of something that looks very much like the Higgs boson raises two pressing questions: what kind of boson was found; and what kind of limits does this discovery impose on the existing models? While the answer to the first question will come only when more data are available, it is already possible to start answering the second question.

Sara Bolognesi of Johns Hopkins University presented some interesting preliminary work based on a recently published study in which helicity amplitudes are used to reveal the spin and parity of the new boson. These can be measured through the angular correlations in the decay products. For example, in  $H \rightarrow WW$  decays, when both  $W$ s decay into leptons, the angular separation in the



Enthusiastic applause in Melbourne welcomes the new boson via webcast. (Image credit: Claudia Marcelloni/ATLAS.)

transverse plane can help not only to reduce the background but also to distinguish between spin-parity  $0^+$  and  $2^+$ . Likewise, the parity of a spin-0 boson can be inferred from the distribution of the decay angles of  $H \rightarrow ZZ \rightarrow llll$ . Bolognesi and her colleagues developed a Monte Carlo generator that allows the comparison of any hypothesized spin with data and have made the full analytical computation of the angular distributions that describe the decays  $H \rightarrow WW, ZZ$  and  $\gamma\gamma$ . All that is needed is more data – and the nature of the new particle will be revealed.

Another approach to determine the spin of the new boson consists of studying which decay modes are observed. A Standard Model Higgs boson has spin 0, so it should couple to fermions and vector bosons. Spin 1 is already excluded for the new boson because it could not produce two photons ( $\gamma\gamma$ ), each with spin 1. A spin 2 boson could decay into  $b\bar{b}$  (with an extra spin 1 gluon on board) but not to two  $\tau$  leptons. So, it was puzzling to hear from Joshua Swanson of the University of Wisconsin Madison that CMS does not observe  $H \rightarrow \tau\tau$  after having analysed the  $10 \text{ fb}^{-1}$  at hand from 2011 and 2012. The current analysis is consistent with the background-only hypothesis, yielding an exclusion limit that  $\triangleright$



Melbourne is famous for its trams. (Image credit: J Karjalainen.)

## ICHEP 2012

is 1.06 times the Standard Model production cross-section for  $m_H = 125$  GeV. Needless to say, this will be closely monitored as soon as more data become available.

Meanwhile, many theorists and experimentalists are already speculating on the possible impact of the discovery on the current theoretical landscape. Several people showed the effect of all known measurements in flavour physics, direct limits and the new boson mass on existing models. Nazila Mahmoudi of CERN and Clermont-Ferrand University reminded the audience that there is more to supersymmetry (SUSY) than the constrained minimal supersymmetric model (CMSSM). She showed that, assuming that the new particle is a Higgs boson, its mass has a huge impact on the allowed parameter space. Already, several constrained models such as the mSUGRA, mGMSB, no-scale and cNMSSM are severely limited or even ruled out. This impact is, in fact, complementary to direct searches for SUSY. Mahmoudi stressed the importance of going back to unconstrained SUSY models, pointing out that there is still plenty of space for the MSSM model.

### So many searches, such little luck

In the search for direct detection of new phenomena, both for exotics and for SUSY, the results were humbling despite the numerous attempts. In the parallel sessions, more than 30 talks were given on SUSY alone, sometimes covering up to five different analyses. Andy Parker of the University of Cambridge, who reviewed this field, showed how these searches have already covered all of the most obvious places. However, as he reminded the audience, there are still two big reasons to believe in SUSY. First, it provides a candidate for dark matter that has just the right cross-section to be consistent with today's relic abundance. Second, a light Higgs particle needs this kind of new physics to stabilize its mass. Parker also pointed out that only the third generation of SUSY particles, namely stops and staus, need to be light, a point that Riccardo Barbieri of Scuola Normale Superiore and INFN also stressed in his conference review. For these particles, the current model-independent limits are still rather low, well below 1 TeV, but should improve rapidly with more data.

SUSY could also be hidden if the mass-splitting between gluinos and neutralinos is rather small. In that case there would be very little missing transverse energy (MET), when most analyses have been looking towards large MET. This is the idea behind various scenarios with compressed mass spectra. Or it might be that the SUSY particles are so long lived that they require an adapted trigger strategy because they decay beyond the first layers of the detectors. Searches have been made in all of these directions but without any success so far.

Nevertheless, with the discovery of a new boson, there is much more optimism than a year ago during the European Physical Society conference on High-Energy Physics (EPS HEP 2011), where Guido Altarelli had commented that given no sign for SUSY yet, it was too early for despair but enough for depression. The word of caution that Parker raised, echoing Mahmoudi, provides room for optimism. It is of utmost importance to stay away from the hypotheses of constrained models and to aim instead for the broadest possible scope. SUSY is far from being dead yet and there is plenty of unexplored parameter space, with much of it still containing

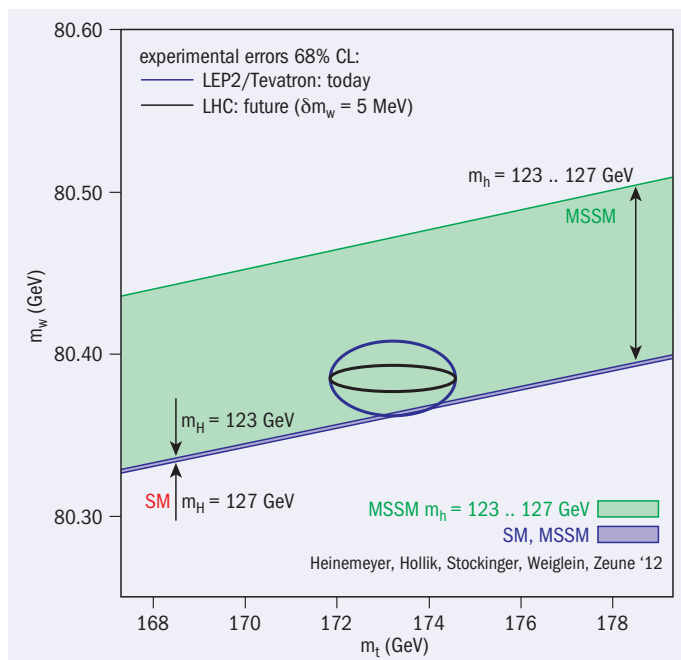


Fig. 1. Electroweak consistency check on whether the new boson is the Standard Model Higgs boson (thin blue line) or a minimal supersymmetric (MSSM) one (green band). The blue ellipse shows the current knowledge on  $m_t$  and  $m_W$ , whereas the black ellipse depicts what will happen if  $m_W$  becomes known to 5 MeV.

particles of low mass. As Raman Sundrum of the University of Maryland remarked: “We must not only look for what’s left but rather, what’s right.”

Testing the consistency of the Standard Model with the so-called electroweak fit has been a tradition for all major conferences for the past decade or two and in this ICHEP proved no different – except for a major twist. For the first time, the mass of the newly found boson was used to test if all electroweak measurements (W and Z boson masses, the top-quark mass, single and diboson production cross-sections, lepton universality etc.) could fit together. All of these measurements were reviewed by Joao Barreiro Guimaraes da Costa of Harvard University, culminating with the overall electroweak fit in terms of W-mass versus top-mass space in figure 1. This allows testing of how consistently all of these parameters fit together under the hypothesis that the new boson is the Standard Model Higgs boson (thin blue line) or one associated with MSSM (green band). The blue ellipse shows the current status of the

experimental measurements of  $m_t$  and  $m_W$ , whereas the black ellipse depicts what will happen if the LHC brings the uncertainty on  $m_W$  down to 5 MeV – although this will be a great challenge. If the central value remains unchanged, it would bring the Standard Model into difficulty, whereas there will still be plenty of room for the MSSM parameters. One  $\triangleright$

**In the search for direct detection of new phenomena, the results were humbling.**



The world's leading supplier of thermal processing services.....



...proud to provide ongoing support for CERN's research

Heat Treatment

Hot Isostatic Pressing (HIP)

Metal Joining

Surface Technology

Operating an international network of quality-accredited facilities, Bodycote is the world's largest provider of thermal processing— a vital part of the manufacturing process which includes a variety of techniques and specialised engineering processes that improve the properties of metals and alloys and allow production of complex components.

#### Bodycote

Parc Technologique de Lyon ILENA PARK – Bât B2  
117 Allée des Parcs 69792 SAINT PRIEST CEDEX – France  
Tél.: +33 04 37 23 82 00 • [www.bodycote.com](http://www.bodycote.com)  
[sales.france@bodycote.com](mailto:sales.france@bodycote.com)



#### MPIF Design Excellence Award – Grand Prize 2007

Awarded to Bodycote for Neat-net-shape powder metallurgy to create Dipole Cryomagnet End Covers for the LHC

#### Bodycote brazing

A 20 years know-how for scientific instrumentation, Brazing under vacuum, hydrogen, argon, nitrogen

#### BODYCOTE VILLAZ

PAE de la filière d'en Haut, 175 Route des Futaies 74370, VILLAZ (France)

Tél.: 04 50 60 23 60

Contact: Eric BUCZKOWSKI

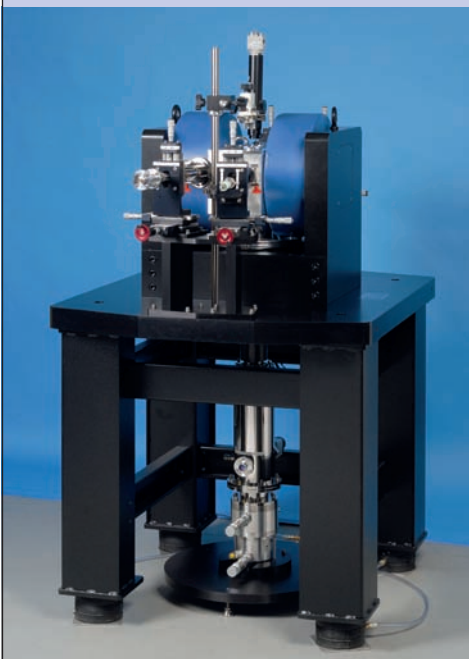
Email:

[eric.buczowski@bodycote.com](mailto:eric.buczowski@bodycote.com)



# CERN COURIER

## WEBINAR SERIES



Vacuum and Cryogenic (3 K to 675 K) Probe Stations: A versatile tool for materials and device characterization

**JOIN US FOR THIS FREE WEBINAR**

**Thursday 27 September 2012, 2.30 p.m. BST**

Join Scott Azer for a live discussion on implementing vacuum probe stations as tools to characterize different materials and devices. We will focus on describing probe stations used to study MEMS, MOSFETS, organic electronics, solar cells, graphene and quantum dots.

The speaker will take questions at the end of the webinar.

Sponsored by

**JANIS**

Register now at [cerncourier.com/cws/go/webinar](http://cerncourier.com/cws/go/webinar)

## ICHEP 2012

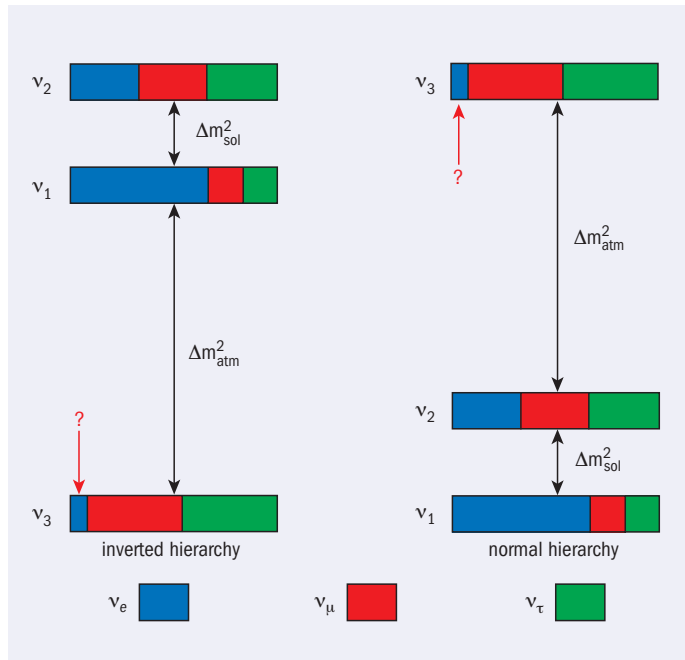


Fig. 2. Which neutrino mass eigenstate is the lightest? Is there a normal or an inverted hierarchy? This still remains unknown.

noteworthy result of this global fit is the prediction of the Standard Higgs boson mass at 125.2 GeV when all electroweak parameters are taken into account. Only the direct exclusion limits from the Large Electron–Positron collider and the Tevatron were included.

### Dark matter, light neutrinos

“No theories, just guesses for dark matter.” These were the words with which Neal Weiner of New York University summarized the situation on the theory front for dark matter. He explained that, unlike for the Higgs boson, there is currently no theory that allows predictions experimentalists could try to verify. The field is faced with a completely open slate.

If weakly interacting massive particles (WIMPs), a generic class of dark-matter candidates, exist with a mass of around 100 GeV, then some 10 million would go through a person’s hand every second, as Lauren Hsu of Fermilab pointed out during her comprehensive review of direct searches for dark matter. Nevertheless, in contrast to the clarity of Hsu’s presentation, the situation remains extremely confusing. She first reminded the audience of the basics. A WIMP could scatter elastically off a nucleon and the scattering cross-section can be broken into two terms: a spin-independent term (SI), which grows as the square of the atomic mass  $A$ ; and a spin-dependent term (SD) that scales with the spin of the nucleon.

Currently, xenon-based and cryogenic germanium experiments dominate the field for the SI measurements, while superheated liquid detectors such as Picasso and COUPP are competitive for SD measurements. The XENON100 collaboration’s results for 2011 exceed the sensitivity of other experiments over a range of WIMP masses (new results with 3.5 times better sensitivity appeared just after the conference, see p8). SuperCDMS, a germanium-based detector, started operation in March 2012 but first results have still to be released.



The conference took place on the south-west bank of the Yarra River, which runs through the wine country to Melbourne and out into the bay. (Image credit: Nevereverro/Dreamstime.com.)

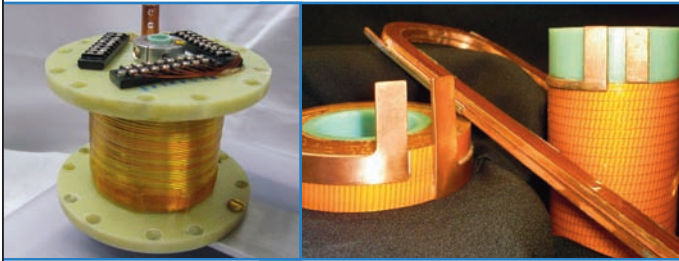
Several inconsistencies remain unexplained. In 2008, the DAMA/LIBRA collaboration first reported an annual modulation in event rate that was consistent with dark matter with a statistical significance that now reaches  $8.9\sigma$ . This modulation peaks in summer and is at its lowest in winter, making some people suspect backgrounds that are modulated by seasonal changes. COUPP and KIMS, two experiments that use iodine as DAMA/LIBRA does, have now been running for some time. However, their data are not consistent with elastic scattering of WIMPs off iodine, so the mystery continues in terms of what DAMA/LIBRA is seeing. Finally, DM-ICE is a new effort underway in which about 200 kg of sodium-iodide crystals will be deployed within the IceCube detector at the South Pole. One interesting point is that any background tied to seasonal effects will modulate with a different phase in the southern hemisphere.

This is not the only ongoing discrepancy. Two collaborations, CoGeNT and CRESST-II, announced the observation of an annual modulation in low-energy events, with the CRESST-II excess being at  $4.2\sigma$ . This contradicts many other results (from CDMS, XENON100, EDELWEISS, ZEPLIN, etc.) where no modulation is observed in low-energy data. The CoGeNT observation was particularly hard to reconcile with the CDMS results because both CoGeNT and CDMS are germanium-based detectors. However, now that the CoGeNT collaboration has modified its background estimates, the data from these two experiments are no longer in conflict. The CRESST team is working on reducing its background, which could help resolve this discrepancy.

Moving on to the field of neutrino physics, Takashi Kobayashi of KEK reminded the audience that the mere fact that neutrinos have mass proves that there is physics beyond the Standard Model. These masses induce mixing – in that the different flavours of neutrinos are linear combinations of mass eigenstates. Neutrino mixing is now described by the Pontecorvo–Maki–Nakagawa–Sakata (PMNS) matrix and until recently it remained to be seen if all three flavours participated in the mixing.

Without a doubt the biggest news in neutrino experiments this year came from the Daya Bay experiment’s measurement of the mixing angle between the first and third neutrino-mass  $\triangleright$





**SuperPower** Inc.

A Furukawa Company

superior performance. powerful technology.

## A New Generation of SuperPower'd™ Magnets

Ultra-high field magnets using SuperPower® 2G HTS Wire is enabling increasingly powerful magnetic fields for advancements in high energy physics (accelerators & colliders), condensed matter physics (high-resolution NMR & EPR spectroscopy), biology and chemistry research, materials sciences, and physiology.

Benefiting demanding coil applications; enhanced by expert engineering.

- **Advanced Pinning Wire:** enhanced performance over various operating fields and temperature ranges (4.2 K to 77 K)
- **Flexible:** suitable for both pancake and layer wound coil types (tensile and bend strains >0.4% without performance degradation)
- **Critical Current:** high  $I_c$  available in long lengths



Contact us today  
about our **Quick-Ship** program

450 Duane Ave. ■ Schenectady, NY 12304 ■ USA  
Tel: 518-346-1414 ■ Fax: 518-346-6080  
www.superpower-inc.com ■ info@superpower-inc.com



**GRUPPO  
DIMENSIONE**

DIMENSIONE S.p.A.  
Filiale in France  
75, Rue Louis et Auguste Lumière  
Technoparc - St. Genis Pouilly  
69138 St. Genis Pouilly Cedex  
Siège opératif et administratif  
Via VII Marzo, 8 - 10093 Grugliasco (Italia)  
e-mail: gara@gruppodimensione.com  
www.gruppodimensione.com





UNIVERSITY of  
**ROCHESTER**

The University of Rochester  
Congratulates

**Professor Carl Richard  
Hagen**

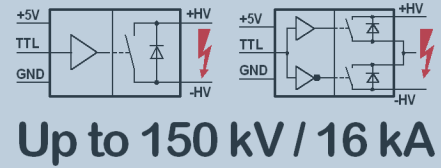
and the other winners of the  
2010 Sakurai Prize

**Robert Brout, François Englert,  
Gerald Guralnik, Peter Higgs and  
Thomas Kibble**

*upon the confirmation of their  
1964 prediction of the  
scalar boson*



# FAST HIGH VOLTAGE SOLID-STATE SWITCHES



- Operating voltages from 1 to 150 kV
- Peak currents from 15 A to 16 kA
- Nanoseconds rise & fall times, high di/dt
- Very stable operation and low jitter
- AC, DC & push-pull switching modules
- MOSFET, IGBT and SCR technology
- Easy control by TTL compatible inputs
- Galvanic isolation for highside switching
- Various housing and cooling options
- Custom designed switches & pulsers
- Highly reliable design, 5 years warranty



**electronica 2012**  
Munich 13.-16. Nov. / Booth A3.530



[www.behlke.com](http://www.behlke.com)

Behlke Power Electronics LLC, 5 Alexander Rd, Billerica, MA 01821, USA  
Behlke Power Electronics GmbH, Am Auernberg 4, 61476 Kronberg, DE

Over 300 standard models available!



**BEHLKE**  
HIGH-TECH IN HIGH VOLTAGE



Refractory Metals | Advanced Ceramics

## High Performance Solutions for Particle Accelerators

H.C. Starck offers product solutions for particle accelerators from tungsten heavy metal alloys with outstanding high density properties. Our production facilities in Germany, China, and the U.S. can produce fully machined parts from 1 gram to 1.5 tons of tungsten high density materials for collimator and radiation shielding applications.

- > Beam Blockers
- > Targets
- > Shielding Parts
- > Collimators

Value-added product solutions made of Mo, W, Nb, and Ta:

- > Sheet
- > Tube
- > Plate
- > Fabricated Parts
- > Bar

H.C. Starck supplied the tungsten slugs used in the FCAL Section of the Atlas Detector for the Large Hadron Collider (LHC).

For more information, email [info@hcstarck.com](mailto:info@hcstarck.com) or visit [www.hcstarck.com](http://www.hcstarck.com)

**H.C. Starck**  
Empowering High Tech Materials

## CAMAC

Still using CAMAC? You're in good company, lots of people all over the world do. CAMAC can't be beat for ease of use. But working with obsolete equipment can be stressful! An upgrade can change that.

Start with the CMC100 USB FASTCAMAC crate controller. It does everything that your venerable type A controller can do and a lot more. Its faster, up to 100 nsec per data word into its 1 Megaword buffer memory. Then transfer at 40 MegaBytes per second over USB 2.0 into the host computer. It's smarter too, with its built in LAM grader and fast list processor. Store programs in the 512 word list memory and trigger with a LAM or NIM pulse. And it's easy to use. Just plug it into any USB port. With the free EZcamac software you can be collecting useful data in hours, not days or weeks.

The CMC080 is a 16 channel, triple range charge integrating ADC. It's sensitive, as low as 25 fC lsb. And it's fast, with gates as short as 10 nS, and dead time as low as 4 µsec. It has a sliding scale for zero DNL.

Need something special? Have a DAQ control problem? The CMC206 ULM can be anything you can dream up using a Xilinx 3S1500, 4MB of fast memory and both NIM and diffECL I/O. It's been used as a trigger module, a precision multiscaler and a TDC.

Use FERA? Add the CMC203 Fera Driver. It replaces your aging 4301 and adds lots of new features. Its 1Mword memory can be a FIFO buffer or an histogram memory.

See details, manuals and much more at [www.CMCCAMAC.com](http://www.CMCCAMAC.com)

**Cheesecote Mountain CAMAC**  
24 Halley Drive, Pomona, NY 10970  
845-364-0211, [info@cmccamac.com](mailto:info@cmccamac.com)



eigenstates,  $\Theta_{13}$  (*CERN Courier* May 2012 p6). This is the last ingredient needed to allow future tests of CP-violation in the neutrino sector. T2K had reported the first evidence of  $\nu_e$  appearance in 2011, which already implied a non-zero value for  $\theta_{13}$  (*CERN Courier* September 2011 p6). Jun Cao of the Institute of High-Energy Physics, Beijing showed how T2K was then followed by MINOS, Double Chooz, Daya Bay and now RENO, with a first result showing a  $4.9\sigma$  deviation from zero for  $\theta_{13}$  (*CERN Courier* June 2012 p8). The Daya Bay group has achieved the best measurement, now with  $\sin^2 2\theta_{13} = 0.089 \pm 0.010$ , a  $7.7\sigma$  deviation from zero.

One big remaining area of questions concerns the neutrino-mass hierarchy. Which mass eigenstate is the lightest? Do we have a normal or an inverted hierarchy (figure 2)? As always, much still remains to be done in neutrino physics but, as in the past, it is bound to bring interesting or even surprising results.

### Great theoretical developments

Unnoticed by most experimentalists, there have been tremendous developments in the past eight years with scattering amplitude theory. “While experimentalists were busy building the LHC experiments, theorists were improving their understanding of perturbative scattering amplitudes,” said Lance Dixon of SLAC in his overview talk. This has allowed them to “break the dam”, leaving impossibly complex Feynman-diagram-based calculations behind in performing computations at next-to-leading order (NLO). The unprecedented precision achieved has led to the description of complex multijet events, such as those observed in collisions at the Tevatron and the LHC.

These new techniques were developed within the context of the maximally supersymmetric Yang-Mills theory ( $N=4$  SYM), an exotic cousin of QCD. Currently, complete calculations are possible only for events producing  $W/Z$  + jets, which involve at most 110 1-loop diagrams. However, this new technique can tackle the equivalent of 256,265 diagrams. Feynman diagrams are still used but only for the simpler, tree-level processes. One major advantage of scattering amplitudes is that they can recycle tree processes into loops, bringing much simplification to the calculations. This is bringing amazing precision into the new calculations, as Dmitry Bandurin of Florida State University revealed. Now, QCD-inclusive jet cross-sections agree with recent theoretical calculations over 8–9 orders of magnitude and up to jet momenta of 2 TeV, as measurements by the CMS collaboration show (figure 3).

ATLAS showed the first inclusive jet data at 8 TeV, confirming the expected increase in jet-production rates and reach in transverse momentum. The current level of understanding in jet identification, systematics and jet-energy scale leads in many cases to experimental uncertainties similar to or lower than the theoretical uncertainties. The sensitivity to parton density functions (PDFs) sets the strongest constraint on the gluon PDF and the extraction of the strong coupling constant  $\alpha_s$ . It also tests  $\alpha_s$  running up to 400 GeV. The inclusive Z and W results extensively cross-check perturbative QCD calculations, leading to a triumph of NLO, matrix element and parton-shower Monte Carlo predictions. Studies of multiple parton interactions at the Tevatron and the LHC are leading to improved phenomenological nucleon models. All of these results are important for searches for new physics at

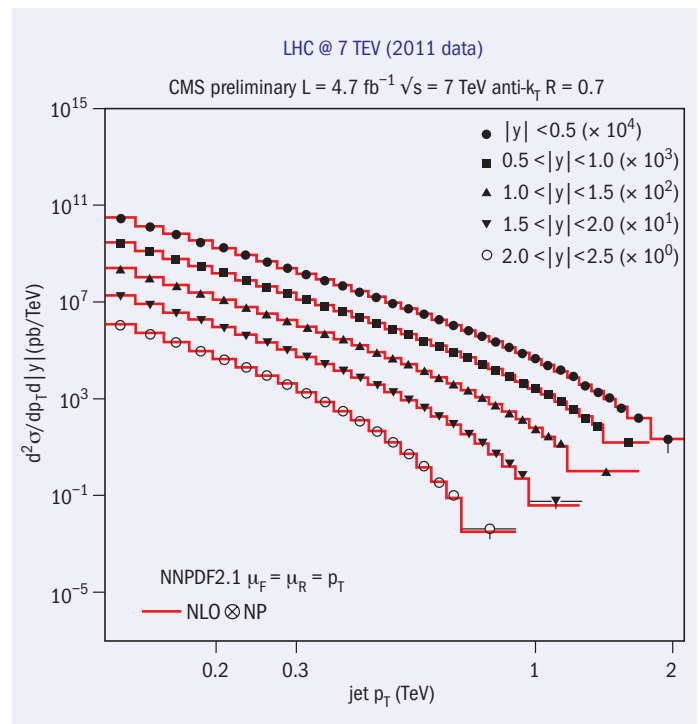


Fig. 3. Jet-production rates at different rapidity measured by the CMS collaboration in 7 TeV data. New theoretical developments allow agreement between data and predictions across 8–9 orders of magnitude.

high energies. The participants witnessed the impressive amount of work accomplished in measuring PDFs, cross-sections, diffractive processes and deep-inelastic scattering, all of which are much needed building blocks for the groundwork that underpins discoveries.

Last summer at EPS-HEP 2011, the LHCb and CMS collaborations created a stir when they presented their first precise search for  $B_s \rightarrow \mu\mu$  decay – a channel that is sensitive to new physics. Now, combining all of the 2011 data for CMS, ATLAS and LHCb, the 95% CL upper limit on this branching fraction is  $4.2 \times 10^{-9}$ , closing in on the Standard Model prediction of  $(3.2 \pm 0.2) \times 10^{-9}$ . This new LHC result increases the tension with the result from the CDF experiment at the Tevatron of  $13_{-7}^{+9} \times 10^{-9}$ , which is slightly reduced after including all  $10 \text{ fb}^{-1}$  of data.

The LHCb collaboration reported the first observation of a decay with a  $b \rightarrow d$  transition involving a penguin diagram, which makes

**This new technique can tackle the equivalent of 256,265 diagrams.**

$B^+ \rightarrow \pi\mu\mu$  the rarest B decay ever observed. In the Standard Model, it is 25 times smaller than similar decays involving  $b \rightarrow s$  transitions. With  $1 \text{ fb}^{-1}$  of collision data, the LHCb experiment obtained  $25.3_{-6.4}^{+6.7}$  signal events – a result that is  $5.2\sigma$  above background and consistent with the predictions of the Standard Model. The collaboration also reported on the  $\Delta$

## ICHEP 2012

first measurement of CP violation in charmless decays.

At the Tevatron, both the CDF and  $D\bar{0}$  experiments still see a significant forwards-backwards asymmetry in  $t\bar{t}$  production in all channels with a strong dependence on  $m_{t\bar{t}}$ , which conflicts with the Standard Model. No such asymmetry is seen by either ATLAS or CMS at the LHC, where it is defined as the asymmetry in the widths of the  $t$  and  $\bar{t}$  rapidity distributions.

### Looking towards the future

CERN's director-general, Rolf Heuer, concluded the conference by reviewing the future for high-energy-physics accelerators, stating how the LHC results will guide the way at the energy frontier. The current plans for CERN include a long shutdown in 2013–2014 to increase the centre-of-mass energy, possibly to the design value of 14 TeV. This will be followed by two other shutdowns: one in 2018, for upgrades to the injector and the LHC to go to the ultimate luminosity; and one in 2022 for new focusing magnets and crab cavities for high luminosity with levelling, with the humble goal of accumulating about  $3000 \text{ fb}^{-1}$  by 2030.

Numerous other plans are in the air, such as a linear collider, where Heuer stressed the importance for the international community to join forces on a single project. "We need to have accelerator laboratories in all regions of the globe planned in an international context, and maintain excellent communication and outreach to show the benefits of basic science to society," he stressed.

There was not a dull moment at the ICHEP conference in Melbourne, thanks to the efforts of the organizers and their crew. Everyone who joined one of the many possible conference tours on Sunday was treated to views of incredibly beautiful coastlines and native wildlife. The overall experience was well worth the journey.

### • Further reading

For more about ICHEP2012, see [www.ichep2012.com.au](http://www.ichep2012.com.au).  
S Bolognesi 2010 *Phys.Rev.* **D81** 075022.

### Résumé

*La fièvre de la physique des particules s'empare de Melbourne*

*La 36<sup>e</sup> Conférence internationale de la physique des hautes énergies a commencé en beauté à Melbourne avec l'annonce, en direct du CERN, de l'évidente présence d'un nouveau boson. Cette nouvelle généra un vent d'optimisme qui imprégna toute la conférence malgré l'absence toujours flagrante des premiers signes de supersymétrie, matière noire ou tout autre phénomène révélateur de nouvelle physique. Des progrès énormes ont été rapportés en particulier sur le front théorique (n=4 SYM), en chromodynamique quantique et sur l'étendue des recherches de nouvelle physique.*

Pauline Gagnon, Indiana University and CERN.



METROLOGY AND POSITIONING



## High performance hexapods for your precision positioning

### JORAN Hexapod

#### HEXAPOD ADVANTAGES

- 6 degrees of freedom
- payload capacity: 1 500 kg
- resolution: 0.1  $\mu\text{m}$  / 0.5  $\mu\text{rad}$
- high stability & stiffness
- configuration of the rotation centre in software

For other hexapod sizes,  
consult us...



Contact: +33 (0)4 66 29 43 88 or [info@symetrie.fr](mailto:info@symetrie.fr)  
Discover our whole range: [www.hexapod-system.com](http://www.hexapod-system.com)





**NEW 48 CHANNEL  
HIGH VOLTAGE MODULE**

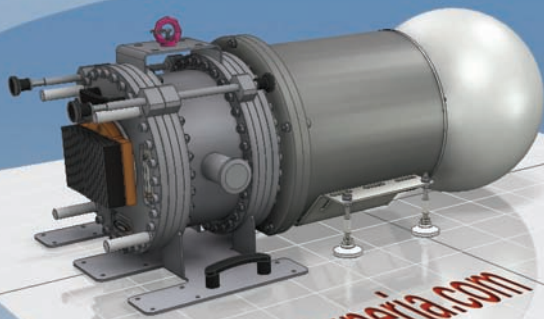
- low ripple & noise (typ. <math>5\text{ mV}\_{pp}</math>)
- 500 V / 3 kV (max. 1.5 W per channel)
- 48 HV distributed channels
- independent voltage control for each channel (between 0 and  $V_{nom}$ )
- current measurement per channel
- customer specific modifications on request e.g. EDS - Super-Kamiokande edition (12,000 channel HV-system)

**REDUCE YOUR COST PER CHANNEL**



**Design & Prototype Manufacturing**

- |                                      |                           |
|--------------------------------------|---------------------------|
| Conceptual Design with 3-D Rendering | Manufacturing Support     |
| Cost Estimation                      | Assembly Support          |
| Project Management                   | Design Documentation      |
| FEA Analysis                         | Risk Analysis             |
| 2-D Drafting and 3-D Modeling        | Maintenance Documentation |



**sigmaingegneria.com**

Sigma Ingegneria s.r.l.  
via Acquacalda, 220 - 55017 - Lucca (LU) - Italy  
Tel +39 0583 1861320 - Fax +39 0583 1861321  
www.sigmaingegneria.com  
e-mail: info@sigmaingegneria.com



**Sigma Ingegneria**



**www.treking.com**

**High-Voltage Amplifiers**

- Voltage Range to  $\pm 60\text{ kV}$
- Slew Rates to  $1500\text{ V}/\mu\text{s}$
- Current to 10 A
- Bandwidth to 3 MHz



**Currently Under Development:**

- $\pm 5\text{ kV}$  @ 450 mA – for decelerator applications
- $\pm 17.5\text{ kV}$  @ 700 mA – for high-voltage component testing

(t): 585-798-3140 • (f): 585-798-3106 • sales@treking.com  
TREK, INC. 11601 Maple Ridge Road, Medina, NY 14103 USA

# MBS

**OUR STATE OF THE ART  
ARPES SYSTEM  
MBS A-1 SYS  
GIVES YOU POWER!**

**Launched Products**

**Sub-meV ARPES System: MBS A1SYS**  
**Sub-meV PES analyser: MBS A-1**  
**Super intense Low Energy Photon Source:  
MBS T-1**  
**He lamp: MBS L-1**  
**Spin detector: MUSPIN etc.**

For Detailed Information **Please Contact Us:**

## **MB SCIENTIFIC AB**

Seminariegatan 29B,  
SE-752 28, Uppsala,  
SWEDEN

Tel: +46 18 290960

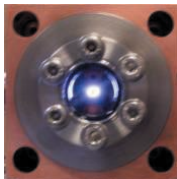
Fax: +46 18 572683

[info@mbscientific.se](mailto:info@mbscientific.se)

[www.mbscientific.se](http://www.mbscientific.se)



MBS T-1



**INIZIATIVE INDUSTRIALI SRL SU  
for GRUPPO COSMI**

**Your reliable services  
throughout the  
industrial plant life-cycle**

[www.gruppocosmi.com](http://www.gruppocosmi.com)

Advertising feature

## **A long term partnership in the ultra-high vacuum technology between SAES Getters Group and CERN**

**SAES Getters Group** has been pioneering the development and manufacturing of special getter materials in a variety of vacuum devices since more than 70 years. Thanks to a close technical cooperation, many SAES getters pumping solutions have been tested and used by CERN since more than 30 years, paving the way to a larger diffusion of getter technology to meet UHV-XHV challenges in particle accelerators. Today, SAES Getters Group is supplying the new generation of getter vacuum pumps NEXTorr®, that combine high sorption speed for all the gasses in a compact volume: the unique characteristics of NEXTorr® will enable improved vacuum performances in particles accelerators as well as reduced footprint and savings in the maintenance area.

SAES Getters Group is also licensee of the not evaporable getter (NEG) film coating technology developed in the 90s' at CERN. SAES Getters Group supplied NEG coated chambers to a the most important particles accelerators in Europe, US and Asia. This technology nicely complements the getter pumps product line, thus allowing SAES Getters to offer a complete portfolio of solutions for Particle Accelerators and High Energy machines.



**saes  
getters**

[www.saesgetters.com](http://www.saesgetters.com)

email: [neg\\_technology@saes-group.com](mailto:neg_technology@saes-group.com)



# Faces & Places

CERN

## AMS experiment marks one year in space

On 25 July, CERN celebrated the first year in space for the Alpha Magnetic Spectrometer (AMS) with a visit from the crew of the shuttle mission, STS-134, who successfully delivered AMS to the International Space Station (ISS) last year. Launched on 16 May 2011, the experiment was already sending data back to Earth by 19 May (*CERN Courier* July/August 2011 p18 and p23). The data are received by NASA in Houston and then relayed to the AMS Payload Operations Control Centre (POCC) at CERN for analysis. A second POCC has recently been inaugurated in Taipei.

STS-134 was the last flight for the *Endeavour* space shuttle, crewed by commander Mark Kelly, pilot Gregory Johnson, mission specialists Gregory Chamitoff, Michael Fincke, Andrew Feustel and European Space Agency (ESA) astronaut Roberto Vittori. During the celebrations at CERN, the astronauts unveiled a commemorative plaque on the lawn outside the POCC to mark the occasion and later gave a public lecture at CERN.

The AMS detector's first year in space has been a learning curve: data have been used to calibrate the detector and understand fully its performance in the extreme thermal conditions encountered in space. However, it has already collected some 17 billion cosmic-ray events and has been able, for the first time, to identify electrons with energies exceeding 1 TeV before they enter the atmosphere. "This holds great promise for the AMS research programme that's now getting underway," says AMS spokesperson Samuel Ting.



STS-134 astronauts (left to right) Andrew Feustel, Gregory Chamitoff, Gregory Johnson, Michael Fincke and Mark Kelly in the AMS Payload Operations Centre at CERN. (Image credit: Anna Pantelia/CERN.)



Left to right: Johnson, Kelly and Vittori stand with the EPS plaque at the site of the former cosmic-ray research lab, Les Cosmiques. (Image: Mike Struik/CERN.)

Two days before the event at CERN, three of the astronauts also laid a commemorative plaque for the EPS at Les Cosmiques, a former high-altitude laboratory on one side of Mont Blanc, the highest mountain in Western Europe, to mark 100 years of research into cosmic rays. Johnson, Kelly and Vittori laid the plaque, which marks an EPS Historic Site Laboratory.

The French National Centre for Scientific Research founded the laboratory to study cosmic rays in 1943, at a site 3613 m above sea level. Les Cosmiques was officially inaugurated in 1946 in the presence of Irène Joliot-Curie and stayed operational until 1955.

● To view the astronauts' public lecture at CERN, see <http://cdsweb.cern.ch/record/1464066>.

AWARDS

## Lebrun receives Kamerlingh Onnes Medal

Philippe Lebrun of CERN has received the Kamerlingh Onnes Medal from the Royal Dutch Association of Refrigeration (KNVvK) in recognition of his ground-breaking contributions to the field of cryogenic science and technology that made the LHC possible. Erik Hoogendoorn, the chair of the KNVvK, presented him with the award on 25 June in Delft, during the 10th IIF/IIR Gustav Lorentzen conference on natural refrigerants.



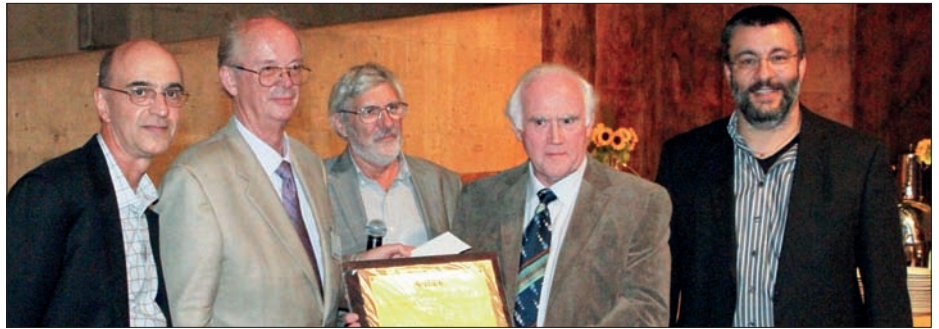
Philippe Lebrun. (Image credit: Anna Pantelia/CERN.)

The Kamerlingh Onnes Award was established in 1948, at the 40th anniversary of the KNVvK. It is awarded for excellent contributions to the development or application of refrigeration in the broadest sense. Lebrun led CERN's Accelerator Technology department during the construction of the LHC, which uses several thousand high-field superconducting magnets operating in superfluid helium below 2 K.

## Faces & Places

# IEEE-NPSS honours Chris Parkman ...

The Computer Applications in Nuclear and Plasma Sciences (CANPS) award of the Institute of Electrical and Electronics Engineers/Nuclear and Plasma Science Society (IEEE-NPSS) has been given to Chris Parkman who worked at CERN for more than 40 years. He received the award for his “outstanding development and user support of modular electronics for the instrumentation in physics applications” during the 18th IEEE-NPSS Real Time Conference, held in Berkeley on 11–15 June.



Left to right: Sergio Zimmermann, Jean-Pierre Martin (CANPS award chair), Patrick Le Dû, Chris Parkman and Stefan Ritt (CANPS chair). (Image credit: IEEE-NPSS-CANPS.)

Parkman joined CERN in 1970, designing computer interfaces and read-out modules for experiments at the Proton Synchrotron. He went on to work for many experiments at subsequent machines, in particular the Large Electron–Positron (LEP) collider, and most recently the LHC, as a member

of the ATLAS electronics group. He was instrumental in establishing the use of the VME bus in the LEP experiments and in the specification of VME standards. He was also for many years a key member of the ESONE Committee for the standardization of modular electronics.

# ... and achievements in accelerator development

The IEEE-NPSS has also honoured Hasan Padamsee of Cornell University and Vitaly Yakimenko of Brookhaven National Laboratory (BNL). They received the Particle Accelerator Science and Technology Award on 24 May at the 2012 International Particle Accelerator Conference (IPAC) in New Orleans. This award, which is granted at each occurrence of the Particle Accelerator



Hasan Padamsee. (Image credit: Cornell.)

Conferences (PAC or IPAC) held in North America, recognizes individuals who have made outstanding contributions to the development of particle-accelerator science and technology.

Padamsee, who joined Cornell’s Superconducting RF group in 1973 and was its head between 1987 and 2009, was



Vitaly Yakimenko. (Image credit: BNL.)

selected “for contributions to the science and technology of RF superconductivity”. Yakimenko, who became the director of Brookhaven’s Accelerator Test Facility in 2005, was selected “for contributions to high-brightness electron beams and to their application to advanced accelerators and light sources”.

# IOP medals: from particles to the cosmos

Studies at the smallest and the largest scales in the universe are among the areas of research recognized in the 2012 awards from the UK’s Institute of Physics.

The Dirac Medal for outstanding contributions to theoretical physics goes to Graham Ross, University of Oxford, “for his theoretical work in developing both the Standard Model of fundamental particles and forces and theories beyond the Standard Model that have led to many new insights into the origins and nature of the universe”. In a career spanning



Left: Graham Ross, who receives the Dirac Medal. (Image credit: Oxford University.) Right: Martin Rees, recipient of the Isaac Newton Medal. (Image credit: Cambridge University.)



## Scalable Readout System (SRS)

Manufacturing by Prisma Electronics SA

### Minicrate

3U  
2k channels



ADC



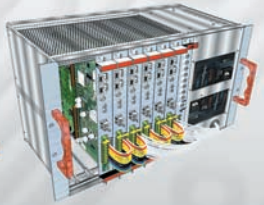
ATX



FEC

### Eurocrate

6U  
14k channels



Designed by the RD51 Collaboration  
Distribution through CERN Store



www.prisma.gr

# HELPING YOU CREATE THE FUTURE

## 2D/3D BEAM OPTICS & CHARGED PARTICLE TRAJECTORY ANALYSIS

Lorentz has been rewritten from the ground up. The bottom line is improved productivity.

For users familiar with Lorentz, the flow of the program is now quite intuitive with many new options readily available.

For new users, the speed, accuracy and ease-of-use have to be seen.

## ANALYZE AND MODEL:

BEAMS

IONS

CHARGED  
PARTICLES

BEAM  
OPTICS

ELECTRON  
GUNS

## PUT OUR SOFTWARE TO THE TEST

Send us your model, whatever the level of complexity. We will show you how to get results from your exact design – no canned demos.

Contact us for an evaluation and start improving productivity today. A live demo is also available.

BEM & FEM available  
in the same package



[www.ventacid.hu](http://www.ventacid.hu)



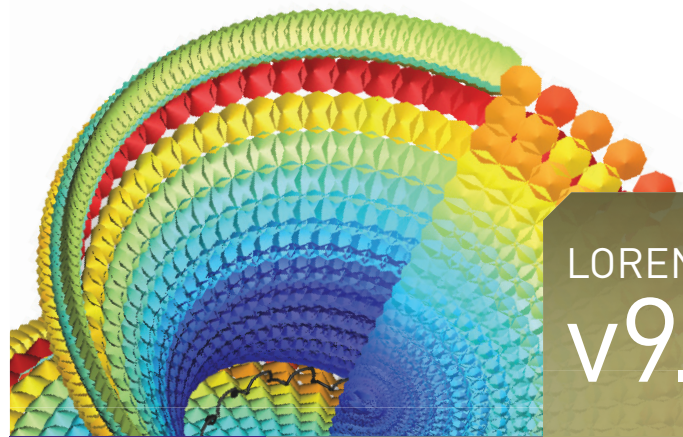
Prompt supplier needed? A Market Leader Hungarian Manufacturer

Founded in the year 2000 **Ventacid Hungaria Ltd** is working on the field of the environmental protection. As part of the french Europe Environnement Group **VENTACID** provides turn-key air treatment systems and plastic tanks even in ATEX-proof version. The company is **certified** for manufacturing plastic welded installations and tanks containing **dangerous liquids** having suitable technical and personal conditions documented procedure specifications and operates a quality management system with reference to **ISO 9001:2008**.

As the **most important Hungarian** manufacturer of plastic welded installations **VENTACID** made significant investments in the recent years: 2,500 m<sup>2</sup> indoor production hall as well as modern plastic welding machines some of them **unique in Hungary**. Due to its machines and well trained specialists **VENTACID** managed to join the European technical construction-commercial processes. The company's annual revenues from domestic and export now reaches one and a half million euros.

Following **CERN Procurement services'** approval, the firm is registered into **CERN database**.

Contact: dir. Laszlo ORBAN email: orban@ventacid.hu



LORENTZ  
v9.0



**INTEGRATED**  
ENGINEERING SOFTWARE

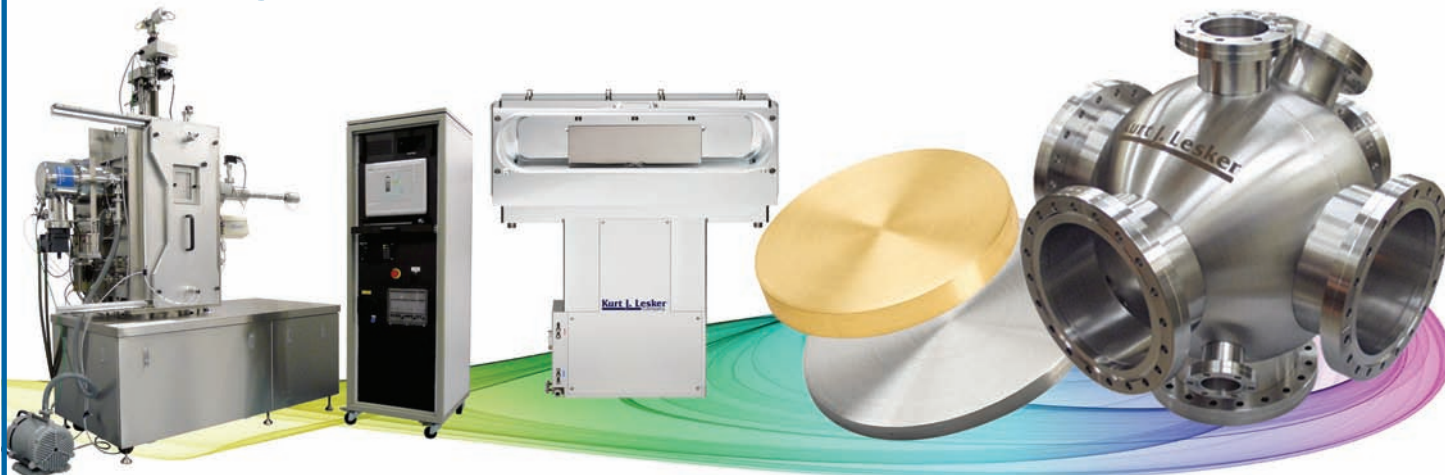
Call +1 204.632.5636

email [info@integratedsoft.com](mailto:info@integratedsoft.com)

or visit [www.integratedsoft.com/products/lorentz](http://www.integratedsoft.com/products/lorentz)



## All Things Vacuum



### PROCESS EQUIPMENT™ DIVISION

- Tools for: Sputtering & Evaporation
- Electron Beam & Thermal Evaporation
- OLED, OPV & Organic Electronics

### VACUUM MART™ DIVISION

- KJLC® Hardware
- Vacuum Pumps & Fluids
- KJLC® Feedthroughs
- KJLC® Valves & Gauges

### MATERIALS™ DIVISION

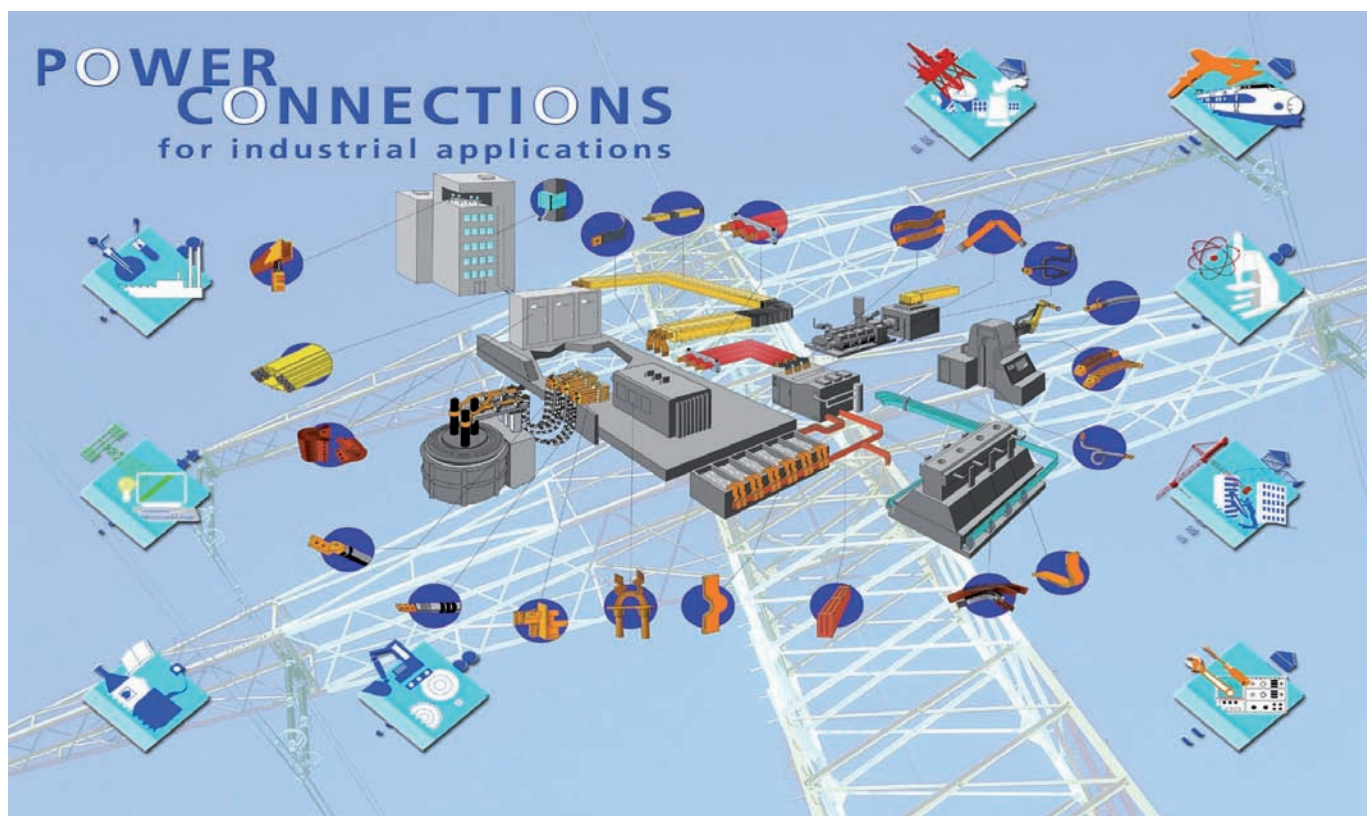
- Sputter Targets
- Evaporation Materials
- Precious Metals

### MANUFACTURING™ DIVISION

- 3D Modelled Designs
- Structural & Thermal Analysis
- Cleaning & Inspection
- Assembly & Test Facilities

[www.lesker.com](http://www.lesker.com)

12-088



[www.vision-electric.com](http://www.vision-electric.com)



[www.ems-power.com](http://www.ems-power.com)



[www.sps-standard.com](http://www.sps-standard.com)



40 years, Ross has consistently worked at the frontiers of the subject and made many seminal contributions. He was, for example, a pioneer of supersymmetry theory and phenomenology, and more recently he has developed fundamental theories of neutrino mass and mixing parameters.

A fellow theoretician, David Lyth of Lancaster University, receives the Hoyle Medal and Prize “for his contributions to particle cosmology, in particular to the origin of the structure of the universe”. This

prize is awarded for distinguished research in astrophysics, gravitational physics or cosmology. Cosmology is also recognized in the awarding of the Isaac Newton medal this year to Martin Rees (Lord Rees of Ludlow) of Cambridge University. This medal is awarded regardless of subject area, background or nationality, for outstanding contributions to physics.

On the experimental side, the Rutherford Medal and Prize for distinguished research in nuclear physics or nuclear

technology goes to Peter Butler of the University of Liverpool. He is honoured for his “outstanding work in the field of experimental nuclear physics and his dynamic contributions to the future direction of the field”. Last, the Kelvin Medal and Prize, for outstanding contribution to public engagement within physics, goes to Graham Farmelo of Churchill College, Cambridge. He is cited in particular for his biography of Paul Dirac (*CERN Courier* September 2009 p39).

## EPS announces Lize Meitner Prize winners

The European Physical Society (EPS), through its Nuclear Physics Division, has awarded the Lize Meitner Prize 2012 jointly to Karlheinz Langanke of GSI and TU Darmstadt, and to Friedrich-Karl Thielemann of the University of Basel, for “their seminal contributions to the description of nuclear processes in astrophysical environments that have changed our modern understanding of stellar evolution, supernovae explosions and nucleosynthesis”. Their work represents a bridge between the nuclear-physics and astrophysics communities and has decisively contributed to shaping the research programme at current and future radioactive-beam facilities.

The Lize Meitner Prize is given every two years for outstanding work in the fields of



experimental, theoretical or applied nuclear science. Langanke and Thielemann will receive the award in a special session at



the 25th International Nuclear Physics Divisional Conference of the EPS, on 20 September.

*Left: Karlheinz Langanke. (Image credit: G Otto/GSI.) Right: Friedrich-Karl Thielemann. (Image credit: All rights reserved.)*

### SPAIN

## International meeting eyes the future

The International (Winter) Meeting on Fundamental Physics (IMFP), held in Spain every year since 1973, celebrated its 40th edition when 140 researchers from national and foreign research institutes gathered at the Centro de Ciencias de Benasque Pedro Pascual in Benasque on 24 May – 3 June.

The idea behind the IMFP grew out of the aim to foster collaboration among the members of the Spanish scientific community and to explore possible mechanisms for the sustainable development and consolidation of high-energy physics, which it was felt at the time urgently required the return of Spain to CERN – after the country’s withdrawal in 1969 – as well as participation in research programmes



*Participants at the 40th IMFP, outside the Centro de Ciencias de Benasque Pedro Pascual in Benasque. (Image credit: A Sahún.)*

at other large international laboratories. Funded by the Institute of Nuclear Studies of the Junta de Energía Nuclear (JEN), with strong support from CERN, the IMFP was launched as the result of an initiative by Manuel Aguilar and Juan Antonio Rubio of JEN and the CIEMAT research centre in Madrid, Lucien Montanet of CERN and Francisco Ynduráin of the Universidad Autónoma de Madrid.

One of the main goals was to set up a

forum at which prestigious researchers, mostly from abroad, would present the most relevant scientific advances in the field to the young and much reduced community of Spanish physicists working in the discipline. Forty years on, IMFP has largely met its initial goals and become both a reference at the national level and a widely appreciated international event.

Discussions took place at one of the earliest meetings to identify the most effective ways

## Faces & Places

to facilitate Spain's return to CERN, which finally happened in 1983. Initially, JEN was in charge of the organization and funding of the IMFP series. After the return of Spain to CERN and thanks to the steering plan for high-energy physics that was approved in 1983 – two important events in which JEN played an essential catalytic role – newly formed experimental groups acquired a growing visibility and responsibility in the organization of IMFP. As a result, the meeting moved round Spain to take place in most of the regions that host research teams in particle, astroparticle and nuclear physics.

Appropriately, the 40th IMFP was held at the Centro de Ciencias de Benasque Pedro Pascual, which honours the memory of the distinguished theoretical physicist Pedro Pascual, who was highly instrumental in the development of science in Spain and

in particular basic research during the last decades of the 20th century. The programme included a workshop on flavour physics and on the relevance and opportunity of the “super” B factories that are under construction or under discussion, together with sessions on neutrino physics, physics at the Canfranc Underground Laboratory, cosmic rays and ultrahigh-energy gamma rays, dark matter and dark energy, gravitational waves and physics at Fermilab's Tevatron and at CERN's LHC.

The future of the LHC and its ambitious experimental programme and the scientific perspectives of the electron–positron colliders under consideration (the International Linear Collider and the Compact Linear Collider studies) were the subject of long scientific sessions of great interest. The last part of the meeting was

devoted to presenting the plans to develop the European Strategy for Particle Physics and to assessing the situation in Spain (excellent from the scientific point of view, but worrying in terms of the evolution of resources) and the possible contributions from the Spanish scientific community.

This meeting was extremely well organized by the Instituto de Fisica Corpuscular (IFIC), a joint centre of the Consejo Superior de Investigaciones Cientificas and the University of Valencia, under the efficient leadership of Francisco Botella, Juan Fuster and Carmen García. It was funded by the National Centre for Particle, Astroparticle and Nuclear Physics (CPAN), the National Programme for Particle Physics, IFIC, CIEMAT, the Consolider project Multidark and the Centro de Ciencias de Benasque Pedro Pascual.

### VISIT



Google Science Fair winner **Shree Bose** could not have picked a better time to visit CERN. Judges chose her as the top young scientist out of more than 10,000 submissions from 13- to 18-year-old students all over the world. Part of her prize was a trip to CERN and she was there on 4 July, the day the laboratory announced the discovery of a Higgs-like particle (p46).

Bose's prizewinning project demonstrated a link between a certain enzyme and drug-resistance in ovarian cancer cells, as well as a way to counter the effect. She did the research the summer before her junior year of high school under the supervision of Alakananda Basu at the University of North Texas Health Science Center in Fort Worth. In August, Bose will go to Harvard University to study cellular and molecular biology.

### QCD

## School looks forward to ep and eA colliders

The International Spring School “QCD prospects for future ep and eA colliders”, organized in the framework of the “Groupement de Recherche Chromodynamique Quantique et Physique des Hadrons”, took place at the Laboratoire de Physique Théorique, Orsay, on 4–8 June. The aim was to bring together PhD students, postdocs and tenured physicists, both theoreticians and experimentalists, whose main interest relates to the strong interaction in nuclear and particle physics and its fundamental theory, QCD. A total of 64 participants came from Europe (Belgium,

Italy, France, Germany, Spain) and the US and – as intended – an informal atmosphere generated fruitful exchanges between the lecturers, students and postdocs, as well as between experienced physicists.

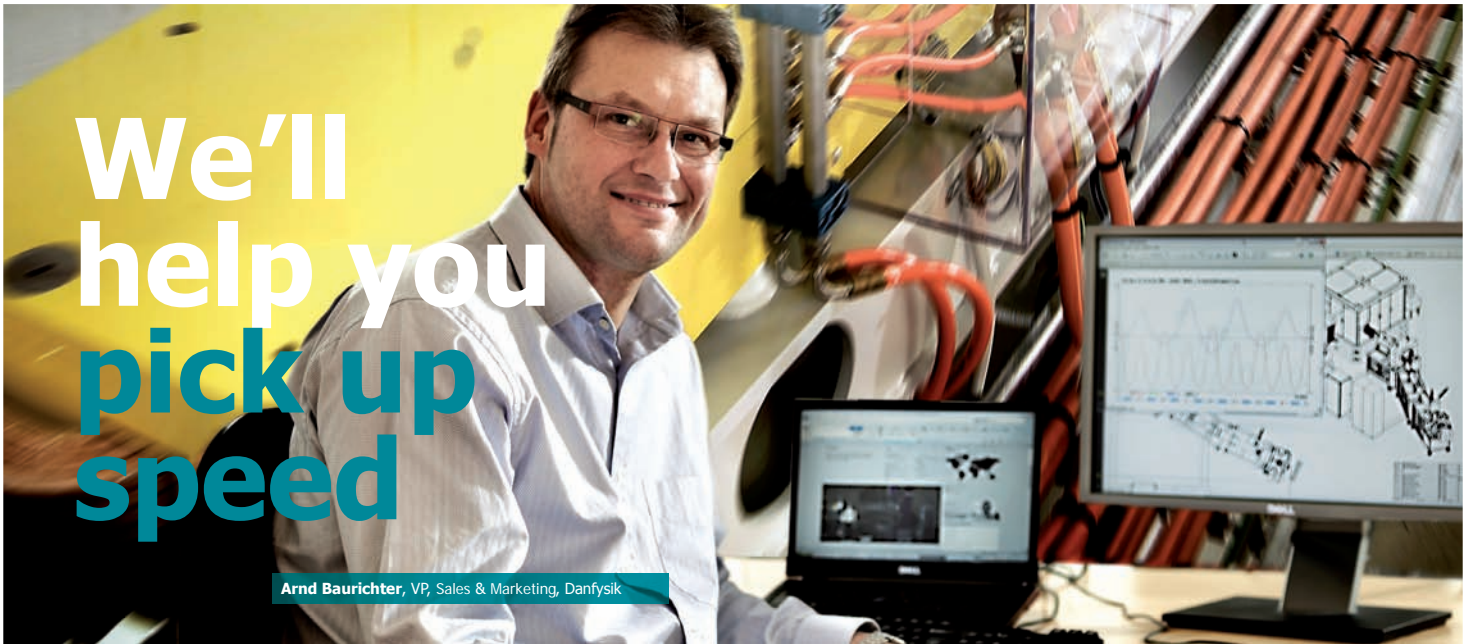
The scientific programme was constructed with a view to developing the skills of the students and postdocs in mastering the various theoretical and experimental challenges raised by the different electron–proton and electron–ion collider projects that are currently under study in Europe and the US. To do this, it focused on several key topics, in the spirit of an ideal machine that would combine a high centre-of-mass energy, high luminosity and beam-polarization facilities. Although covering mainly phenomenological and theoretical issues, the programme also touched on the experimental aspects of the different projects.

The four main lecturers, some of the leading experts in the field, were given a

substantial amount of time to cover the various topics of this multifaceted domain in an extensive way. George Sterman of Stony Brook University gave his vision of the factorization of hard processes in QCD. In a dense and rather demanding series of lectures, the audience explored with him the fascinating aspects of pinching singularities and their physical meaning, from scalar to Yang–Mills theories, including the use of Ward identities. Some aspects in particular were covered in an advanced school for the first time.

Alfred Mueller of Columbia University gave an overview of the most striking effects of QCD dynamics at asymptotical energies in which he emphasized the saturation of quarks and gluons. He relied particularly on his dipole model, a multicolour version of QCD formulated in the light-cone perturbation theory, which has a rich dynamics with an illuminating physical content.





# We'll help you pick up speed

Arnd Baurichter, VP, Sales & Marketing, Danfysik



With nearly five decades' worth of experience serving the particle accelerator community, we are better placed than anyone to deliver the technologies you need to secure a competitive edge.


**Our core competencies:**

Magnets, Electrostatics, Power supplies, Insertion devices, Accelerator Systems, Beam Instrumentation, Management of complex projects.

Find out more about what we could do for you – please visit [www.danfysik.com](http://www.danfysik.com)








**Electronic Engineering**



- Integrated Schematic Capture and PCB design
- DFM analysis
- Peer review of electronic project documentation
- Design and development of electronic systems
- Design of Analogue and Digital circuits
- Firmware and Embedded Coding


**Electronic Production**

- PCB sourcing up to HDI
- Procurement and purchasing
- PCB population and testing
- Fast turnaround for small and medium series

 find us at [facebook.com/exatronik](https://facebook.com/exatronik)

 [comercial@exatronik.pt](mailto:comercial@exatronik.pt)  
 +351 234 315 500



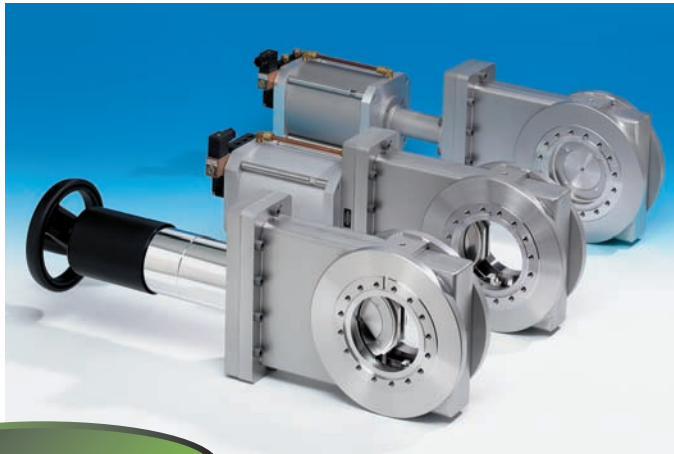
Electrical Cables and Conductors  
for Transport and Distribution of  
Electrical Energy

[www.solidal.pt](http://www.solidal.pt)



## All-metal Gate Valves

Series 48 for extreme UHV or aggressive media



Compact • Reliable • Unique

- The worldwide proven standard, industrially manufactured (ISO 9001)
- Full range from DN 16 to 320
- Many options available, specials on request

**Swiss Headquarters**  
Tel ++41 81 771 61 61  
CH@vatvalve.com

**VAT Benelux**  
Tel ++31 30 6018251  
NL@vatvalve.com

**VAT France**  
Tel 01 69 20 69 11  
FR@vatvalve.com

**VAT Germany**  
Tel (089) 46 50 15  
DE@vatvalve.com

**VAT U.K.**  
Tel 01926 452 753  
UK@vatvalve.com

**VAT USA**  
Tel (781) 935 1446  
US@vatvalve.com

**VAT Japan**  
Tel (045) 333 11 44  
JP@vatvalve.com

**VAT Korea**  
Tel 031 662 68 56  
KR@vatvalve.com

**VAT Taiwan**  
Tel 03 516 90 88  
TW@vatvalve.com

**VAT China**  
Tel 021 5854 4300  
CN@vatvalve.com

**VAT Singapore**  
Tel 0065 6252 5121  
SG@vatvalve.com

[www.vatvalve.com](http://www.vatvalve.com)



# BB Electronics is proud to be a supplier to CERN

### BB ELECTRONICS offers:

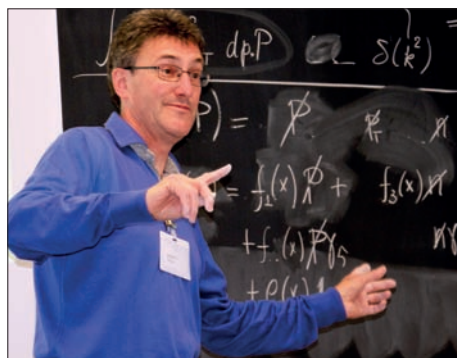
- Electronics Manufacturing Services from design to delivery
- High Quality certified production of PCBA and finished electronics products
- Cost reduction of existing products
- Shorter time to market through effective industrialisation
- Timely global deliveries and after sales service
- Engineering and manufacturing sites in Europe and Asia
- Value for money and a long term partnership

Contact us for more information or a competitive offer.  
BB Electronics A/S, EMS - from idea to solution.  
Ane Staunings Vej 21 • DK-8700 Horsens • Denmark  
Office: +45 7625 1000 • Fax: +45 7625 1010  
[www.bbelectronics.dk](http://www.bbelectronics.dk)

**BB** | **ELECTRONICS**  
EMS - from idea to solution



## Faces & Places



Piet Mulders presents the concept of transverse-momentum-dependent parton distributions. (Image credit: Samuel Wallon.)

Piet Mulders of VU University, Amsterdam, presented the new concept of transverse-momentum-dependent parton distributions (TMDs) and their interest for gaining access to the spin content of the nucleon. He emphasized the factorization properties of processes such as semi-inclusive deep-inelastic scattering in terms of these TMDs. The issues of potential breaking of factorization with universal time-odd TMDs were discussed at length.

Last, Marc Vanderhaeghen of the University of Mainz covered various theoretical and phenomenological aspects of the spatial structure of hadrons and generalized parton distributions. These non-diagonal parton distributions occur

naturally in deeply virtual Compton scattering. In particular, he gave a comprehensive overview of the physical picture that is now available of the internal structure of hadrons, thanks to the combined efforts of the experimental and theoretical community over the past decade.

Two shorter lectures on the projects for the Electron–Ion Collider and the Large Hadron–electron Collider were given by Franck Sabatié of l’Institut de Recherche sur les lois Fondamentales de l’Univers (Irfu) and Néstor Armesto of the University of Santiago de Compostela. They showed clearly that these challenging projects could have a major impact on the understanding of hadron structure, at both a qualitative and a quantitative level, with complementary aspects related to the medium- and high-energy ranges that the colliders would cover. A lecture on jet physics by Leandro Almeida of l’Institut de Physique Théorique, Saclay, completed the programme and some of the PhD students and postdocs gave seminars on their recent work.

The school was financially supported by the Labex P2IO, the GDR PH-QCD, the Université Paris Sud, the CNRS, the CEA/Irfu and the Joint Research Activity “Study of Strongly Interacting Matter” HP3. Thanks to this support, several PhD student obtained a partial cover of their expenses.

• For more information about the school, see <http://indico.in2P3.fr/event/QCD-ep-eA-colliders>.

### APPOINTMENT

## Caterina Biscari to head ALBA facility

Caterina Biscari has been appointed director of the CELLS consortium, which constructed and now operates ALBA, the third-generation synchrotron light source near Barcelona. Appointed by the consortium’s governing council, she takes over from acting director Gastón García from September. The ALBA facility has been in operation since March this year, providing synchrotron light for a range of experiments (CERN Courier November 2008 p31).

Biscari was previously technology director and scientific deputy of the Accelerators Division at INFN’s National Laboratory of Frascati. She has worked in several laboratories around the world, including



Caterina Biscari. (Image credit: INFN.)

CERN and most recently at the Centro Nazionale di Adroterapia Oncologica in Pavia. Now a fellow and executive committee member of the of the European Physical Society, she has also been chair of the society’s Accelerator Group and is a member of the Machine Advisory Committee for the LHC.

## BROCKHAUS MEASUREMENTS

# The new Gauss meter

magnetic field measurement

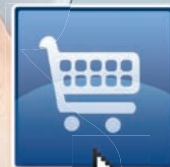
unmatched accuracy  
slimmest probes  
intuitive touch-screen



MADE IN GERMANY

Now available worldwide!

Find out more and order at our webshop:  
BROCKHAUS.COM/SHOP



Measuring Technology for Hard and Soft Magnetic Materials

Dr. Brockhaus Messtechnik GmbH & Co. KG  
Gustav-Adolf-Str. 4 · D-58507 Lüdenscheid  
Germany  
Phone: +49 (0) 2351 3644-0  
Fax: +49 (0) 2351 3644-44  
measurements@brockhaus.com

WWW.BROCKHAUS.COM

## Faces &amp; Places

## DETECTORS

# Calorimetry aficionados meet in Sante Fe

The XVth International Conference on Calorimetry in High Energy Physics, CALOR2012, took place in Santa Fe, New Mexico, on 4–8 June. This series of conferences started in 1990 at Fermilab and has been the premier event for calorimeter aficionados, a trend that CALOR2012 upheld. This year, several presentations focused on the status of major calorimeter systems, especially at the LHC. Discussions on new and developing techniques in calorimetry took a full day. Excellent updates on uses of calorimeters or ideas that are deeply rooted in particle-physics calorimetry in astrophysics and neutrino physics were followed by talks on algorithms and special triggers that rely on calorimeters. Last, discussions of promising current developments and ongoing R&D work for future calorimeters capped the conference. The field is alive and well, as demonstrated by the more than 100 attendees and the excellent quality of the 80 presentations.

The first day of the conference was dedicated to the LHC. In two invited talks, CERN's Guillaume Unal and Tommaso Tabarelli de Fatis of INFN/University of Milano-Bicocca discussed the critical role of the electromagnetic calorimeters in the hunt for the Standard Model Higgs boson in the ATLAS and CMS experiments, respectively. With much of the higher mass-region excluded for the Standard Model Higgs, the enhanced sensitivity for light Higgs in the two-gamma decay channel render electromagnetic calorimeters indispensable. Both of the speakers reported exceptional performance and overall control of detector systematics, even in the increasingly harsh environment at 8 TeV in the centre of mass. In the case of CMS, for example, precise intercalibration of towers, stabilization of environmental effects and corrections for uniform response in more than 75,000 lead-tungstate crystals result in much less than 1% constant term in energy

resolution. The measurement of missing transverse energy and jet energy-scale corrections in ATLAS and CMS were also presented in several talks.

Calorimetry is extremely diverse: many different techniques may be employed in building the detector and also in extracting information from it. The topics of the Calorimeter Techniques sessions included high-rate liquid-argon calorimeters, silicon photomultiplier sensors, highly granular digital calorimeters, new crystals and beam-test and simulation results. Don Groom of Lawrence Berkeley National Laboratory presented an intriguing study on why a homogenous dual-read-out calorimeter is unlikely to work.

Although natural media such as water would hardly be choice absorbers in accelerator-based experiments, they are nevertheless successfully exploited in searches for new phenomena. Members of the Telescope Array (Utah air), ANTARES

ET Enterprises  
electron tubes

## New Photomultiplier HV Base

Using photomultipliers is now even easier with a new range of compact, low noise, HV Bases from ET Enterprises.

Incorporating socket, voltage divider and HV supply, they are suitable for use with a wide range of photomultipliers operating in analogue, pulse counting or photon counting modes.

- range of input voltage (5V to 15V)
- output voltage adjustable from 100V to 2000V
- very low power
- high stability

Visit our new website for further information.

ET Enterprises is now your single source for 'Electron Tubes' and ADIT photomultipliers, including many Photonis replacements.

Use our new interactive website to search our complete range of products or follow the contact links to discuss your application.



ET Enterprises Limited, Riverside Way,  
Uxbridge, UB8 2YF, UK  
Phone: +44 (0)1895 200880  
Fax: +44 (0)1895 270873  
sales@et-enterprises.com  
www.et-enterprises.com

ADIT Electron Tubes, 300 Crane Street,  
Sweetwater, Texas 79556, USA  
Phone: (325) 235 1418  
Fax: (325) 235 2872  
sales@electron tubes.com  
www.electrontubes.com



## Charge sensitive preamplifiers

perfect for radiation detection!

Gaussian shaping amplifiers



all product specifications can be found online at:

<http://cremat.com>

Cremat's charge sensitive preamplifiers (CSPs) can be used to read out pulse signals from radiation detectors as diverse as semiconductor detectors (e.g. Si, CdTe, CZT), scintillator-photodiode detectors, avalanche photodiodes, gas-based detectors such as ionization chambers and proportional counters, microchannel plate detectors, and photomultiplier tubes (PMTs).

Our CSPs and shaping amplifiers are epoxy sealed plug-in modules less than 1 in<sup>2</sup> in area. Evaluation boards are available on which you can test these modules for use in your instrumentation.

Assembled instrumentation is also available.

**cremat**  
45 Union St  
Watertown, MA  
02472 USA  
+1(617)527-6590  
info@cremat.com



(Mediterranean water) and ARA, ARIANNA, ANITA and other (Arctic ice) collaborations discussed their use in several talks. Invited speaker, Philippe Bruel of the Laboratoire Leprince-Ringuet, Ecole Polytechnique, gave an overview of the gamma-ray sky above 20 MeV using the Fermi Gamma-ray Space Telescope and the role of the hodoscope array of the CsI(Tl) calorimeter. In a second invited presentation, Sylvie Rosier-Lees of the Laboratoire d'Annecy-le-Vieux de physique des particules described the design of the electromagnetic calorimeter (Pb/scintillating fibre sandwich) for the Alpha Magnetic Spectrometer (AMS-02), which has been operating in the International Space Station since May 2011 (p63) and has already collected more than 15 billion events.

In addition to making advances in calorimeter design, hardware and front-end electronics, particle physicists are increasingly finding themselves inventing new algorithms to reconstruct physics objects that use the detector information to its maximum capacity. Several presentations provided details on the reconstruction and trigger of jets, missing transverse energy, electrons, photons and  $\tau$  leptons. Pile-up, anomalous signals and noise-mitigation techniques were also discussed in the conference.

The last day saw the presentations of several future R&D initiatives, in particular for a future linear collider. The highly granular CALICE project, with different



Don Groom speaking at CALOR2012. (Image credit: N Akchurin.)

technology options, and plans for the dual-read-out DREAM project, were the main topics. Although these approaches are quite different conceptually, future experiments will certainly benefit from their innovations.

Several events allowed participants to share their interest in other topics. A rare astronomical event – the transit of Venus – coincided with the second day of the conference. The participants enjoyed viewing Venus' trail across the Sun with a solar telescope (H-alpha line at 656 nm). In Santa Fe, the interior ingress was at 16:23:04 MST (GMT-7) and reached centre at 19:27:04 MST. The last transit occurred in 2004 and the next one will happen in 2117.

The environs of Santa Fe have long

been considered sacred by the indigenous Americans and have been a source of inspiration for generations of artists, writers and scientists. Robert Oppenheimer's love of this area played no small role in establishing, during the Second World War, what is now the nearby Los Alamos National Laboratory. On the third day of the conference, some participants visited the lab after an awe-inspiring trip to the Bandelier National Monument, where canyons and mesas show evidence of a human presence going back 11,000 years.

In the 1980s, scientists mainly from Los Alamos set up the Santa Fe Institute, famed for its interdisciplinary research. Geoffrey West of the institute gave the keynote address. His talk, "Universal scaling laws from cells to cities – a physicist's search for quantitative, unified theories of biological and social structure and dynamics", inspired many interesting questions from the audience both after the talk and throughout the week during informal conversations.

CALOR2012 concluded with remarks by the chair of the organizing committee, Nural Akchurin of Texas Tech University. He summarized the highlights of the conference and invited proposals to host the CALOR2014 conference in Europe. The conference venue rotates between the Americas, Europe and Asia every two years. ● The CALOR12 presentations can be found at [calor2012.ttu.edu](http://calor2012.ttu.edu) and the proceedings will be published by IOP (*Journal of Physics Conference Series*) in the autumn.

## LETTER

### Concrete vs concrete

Although the catch phrase "concrete magnets" applies to both developments, there was actually little in common between the concrete-potted coils developed at the Rutherford Laboratory and the dipole magnets for the Large Electron-Positron (LEP) collider referred to in the recent archive page (*CERN Courier* June 2012 p13). The coils of the LEP dipoles were

single-turn aluminium bars (thus suppressing the need for inter-turn insulation), ground-insulated by glass-fibre and epoxy "gutters". It was the yokes of these magnets that were made of iron laminations interspaced with concrete, thus justifying the name of "concrete magnets". The prime rationale for this design, invented by Jean-Pierre Gourber and Renzo Resegotti, was neither radiation resistance

nor cost, but linearity of the excitation curve at the required low field (the LEP dipoles operated at less than 10% of the field of conventional accelerator magnets). Cost (there are few materials cheaper than iron, but concrete is one!), weight and rigidity (the yokes were in fact prestressed iron-and-concrete beams) came only as secondary benefits. *Philippe Lebrun, CERN.*

## JINR calls for nominations for Flerov prize

The Joint Institute for Nuclear Research, Dubna, has announced the contest for the 2013 GN Flerov Prize for outstanding achievements in nuclear physics, which will be awarded in March 2013, on the centenary of the birth of the eminent Russian physicist, Georgy Nikolaevich Flerov. The prize was established in 1992 in memory of Flerov and rewards contributions to nuclear physics

related to his interests. The contest is for individual participants only.

For the centenary year, in which two prizes will be awarded, the Flerov Prize board invites both individual submissions and nominations by the former winners of the prize and by distinguished scientists in low-energy heavy-ion physics, nuclear chemistry and applied nuclear research.

Entries for the 2013 prizes should include a CV, an abstract of research and copies of major contributions. These should be sent by 1 February 2013 to: Sergey Sidorchuk, Scientific Secretary of the Flerov Laboratory of Nuclear Reactions, Joliot Curie str. 6, 141980, Dubna, Moscow Region, Russia; or by e-mail to [sid@nrmail.jinr.ru](mailto:sid@nrmail.jinr.ru).

## Faces &amp; Places

## OBITUARIES

## Friedhelm Brasse 1929–2011

Friedhelm Brasse, one of the leading physicists in the early days of lepton–hadron deep-inelastic scattering, passed away in October 2011.

After his studies at the University of Bonn, Friedhelm received his PhD at the Max-Planck Institute for Iron Research in Düsseldorf. From 1959 he worked at the DESY synchrotron in its early years on the slow extraction of electron beams, interwoven with a short period at the Cambridge Electron Accelerator.

In 1963, Friedhelm began work to make measurements of nucleon form-factors using a magnetic spectrometer situated in the DESY ring. The first paper from the experiment concerned a search for heavy electrons and was followed by precise measurements of the proton and deuteron form-factors. Early results were obtained in collaboration with a group from Karlsruhe led by Herwig Schopper. Eager to explore the really unknown, Friedhelm and his group turned their attention to the inelastic kinematic region. They measured large cross-sections, which in hindsight can be seen as first indications of the partonic substructure of the nucleon and, which, when later measured at the higher energies available at SLAC, were unambiguously interpreted as the discovery of partons as constituents of hadronic matter. Subsequently in 1969, the combination of data from DESY and SLAC was shown to be consistent with these partons having spin  $1/2$ .

In the first international collaboration at DESY with Collège de France, Friedhelm investigated the electroproduction of  $\pi^0$  mesons at the lowest pion–nucleon resonance. Improvements to his



*Friedhelm Brasse on the occasion of his retirement. (Image credit: DESY.)*

spectrometers continued to be made, enabling measurements of higher-mass nucleon resonances and of the inelastic continuum.

The muon beam at CERN's Super Proton Synchrotron (SPS) made it possible to extend the kinematic reach of deep-inelastic scattering experiments. Friedhelm made important contributions to the design of the muon beam and also played a leading role in the experiments of the European Muon collaboration (EMC). His group at DESY contributed large drift chambers, a programmable trigger matrix and the active iron target, which turned out to be important for the discovery of the "EMC effect". He was elected EMC spokesperson at a

time when the NA9 extension of the EMC project was about to be installed, in which further substantial detectors were added to the experiment – most notably a streamer chamber.

In the early 1980s, work began at DESY on the preparation of the HERA experiments. Once the H1 collaboration had formed, Friedhelm led the prototype tests of the liquid-argon calorimeter modules in test beams at CERN – an experiment in its own right. It was then only natural that he be nominated as the first technical co-ordinator of the H1 experiment in 1986. His exceptional technical competence and strong determination to get things done on time and in the right way meant that H1 was ready to take cosmic-ray data with all detectors operational several months before the first electron and proton beams were even available. Friedhelm continued as technical co-ordinator until his retirement in 1994, successfully leading H1 through the first data-taking periods at HERA.

Friedhelm had a strong personality coupled with a determination always to complete what he felt should be done next. He never hesitated to take far-reaching and sometimes difficult decisions. Like most strong characters, working with him was not always comfortable but it was always productive and stimulating. Everyone with whom he worked in his various collaborations, including a large number of PhD students, benefited from, acknowledged and appreciated his dedication, his competence, the thoroughness that he brought to all his work and the success that almost always followed.

● *His colleagues and his friends.*

## Michael J Losty 1943–2012

Physicist Mike Losty passed away suddenly at home in Vancouver on 31 May.

A true Londoner, Mike started his physics studies at Imperial College and obtained a BSc in 1965. Following his MSc at the University of Pennsylvania, he returned to London and completed a PhD in 1971. At that time, Imperial College was already active in the relatively new field of bubble-chamber experiments. Mike made his thesis on nuclear-resonance production, combining data from 16 GeV/c pp and 10 GeV/c K<sup>-</sup>p experiments performed with

the 2 m bubble chamber at CERN. This early link to CERN would shape Mike's entire physics career. In the context of ever bigger international collaborations, he became a well known figure in data-taking, analysis and computing.

Moving to CERN in 1971, he joined the Track Chamber Division and became a member of Lucien Montanet's group, investigating  $\pi$  p collisions at 3.9 GeV/c in the 2 m chamber. A few years later, the groups of Montanet and Rafaël Armenteros joined forces to mount the first high-statistics

run of the 2 m chamber (3 million pictures) to look at the production of strange particles in 4.2 GeV/c K<sup>-</sup>p collisions. The wealth of new data, especially in meson and baryon spectroscopy, was probably the catalyst for Mike to become a member of the Particle Data Group (PDG), a position that he held from 1976 until 1984. In his recent memoirs, Matts Roos remembers Mike as the person who started the tradition of celebrating each new PDG review at a nice restaurant across the French border from CERN.

In 1977, Mike left CERN and took up a





a quality and technology global network

# Fabrication and assembling inspection of components for the LHC



- In Service Inspection
- Engineering NDT
- Notified Body

## Faces & Places

temporary position at Lawrence Berkeley Laboratory, which allowed him to continue his major contribution to the meson compilation for the PDG. Last, he obtained a permanent position in Canada in the high-energy physics group of the National Research Council (NRCC) in Ottawa. He spent several years in the early 1980s working on tagged-photon experiments at Fermilab – first on experiment E516, then on its highly successful successor E691. On E516 he combined the best features of two competing attempts at charged-track reconstruction, thus improving the overall tracking and physics potential.

When Canada joined the OPAL experiment at CERN's Large Electron–Positron (LEP) collider, the two Ottawa groups – NRCC and Carleton University – became the initial thrust in what became a major contribution involving four additional Canadian groups. Mike took responsibility for the track reconstruction of the Canadian Z-chambers. He was always a pleasure to work with at OPAL; skilled in data handling, fitting, etc,



Mike Losty. (Image credit: Steve Losty.)

he was also always ready to get his hands dirty and to advise other collaborators. He

subsequently served two one-year terms at CERN as overall software co-ordinator for OPAL.

At the end of LEP, Mike moved to TRIUMF in Vancouver in 2000, where he remained until his retirement in 2008. There, he worked on the construction of the ATLAS hadronic endcap calorimeters, maintaining the complex construction database that tracked all of the materials used, and he continued to make regular visits to CERN to attend software and calorimeter meetings. He remained an active member of ATLAS after his retirement, going in to TRIUMF several times a week to read papers and have lunch with former colleagues.

Mike leaves behind a loving extended family as well as a close group of friends and colleagues at TRIUMF, CERN and across the Canadian and international high-energy physics community. He will be greatly missed.

● *Vladi Chaloupka, Peter Dornan, Penny Estabrooks, Richard Hemingway, Hans Mes, Peter Schmid, Isabel Trigger.*

## NEW PRODUCTS

**Kepeco** has announced its new series KLN 750 W power supply. This low-profile, automatic crossover, programmable power supply delivers 750 W of stable DC power in a 1U, half-rack package. Eleven models ranging from 0–6 V, 0–100 A to 0–600 V, 0–1.25 A are offered. Programming of voltage, current and their limits may be achieved from the front panel controls, by remote analogue means or by RS 485 digital control. GPIB or LAN interfaces are factory-installed options. For further details, contact Saul Kupferberg, tel +1 718 461 7000, e-mail [saulk@kepecopower.com](mailto:saulk@kepecopower.com) or visit [www.kepecopower.com/kln.htm](http://www.kepecopower.com/kln.htm).

**Megatech** has introduced a new multipurpose cryogenic refrigeration system for ultralow temperature cooling. Based on the industry standard PFC series it can be used in conjunction with most vacuum equipment. The closed loop system is capable of providing up to 4000 W of cooling. Water vapour and other condensable substances can be captured by freezing them onto a cold surface. Capable of cooling in a temperature range of –98°C to –130°C, with cryocondensation of water vapour in the vacuum systems at speeds of up to 220,000 l/s. For more information, contact Peter White, tel +44 1543 500 044 or e-mail [peterw@megatechlimited.co.uk](mailto:peterw@megatechlimited.co.uk).

**Narda Safety Test Solutions** has equipped the frequency-selective field-measuring

instrument SRM-3006 with an LTE option. The instrument measures the electromagnetic fields emanating from LTE wireless communications stations in their entirety as well as according to cells and their antennas. The instrument can also extrapolate the results to determine the emission that would occur when transmission capacity is fully utilized. The SRM-3006 can cover all LTE bandwidths from 1.4 MHz to 20 MHz or select individual frequency channels down to 15 kHz. For more details, tel +49 – (0) 7121/97 32 – 0, fax +49 – (0) 7121/97 32 – 790 e-mail: [support@narda-sts.de](mailto:support@narda-sts.de) or see [www.narda-sts.de](http://www.narda-sts.de).

**Ortec Products Group** of Ametek Advanced Measurement Technology has launched the latest addition to its Detective Series of high-purity germanium radioisotope-identifiers. The Detective-200 is designed to be compact, highly sensitive and portable to achieve mobile nuclide identification. It is fully supported by the latest versions of the Detective-Remove software application, which manages multiple instruments and provides a mode to integrate into a single composite detector module. For further details, tel +1 865 482 4411 or +1 800 251 9750, fax +1 865 483 0396 or see [www.ortec-online.com](http://www.ortec-online.com).

**UltraVolt Inc** has introduced its latest high-voltage power systems, the HV Rack Advanced AC and HV Rack Advanced

AC 3Phase Series. These systems are fully adjustable AC sources with up to three phases and offer currents up to 600 A per phase. The manually adjustable frequency range is between 0.1 Hz and 2000 Hz and the standard model provides a voltage range of 0–300 VAC at a power range of 250 VA to 45 kVA. UltraVolt has also extended the V and M Series of microsize, micropower products. Both series are now offered at 0–2 kV, 0–2.5 kV and 0–3 kV, with 5, 12 and 24 V inputs. They offer programmable regulated output, high accuracy, and low ripple (0.01% peak to peak). For further details, tel +1 631 471 4444 or visit [www.ultravolt.com](http://www.ultravolt.com).

**XP Power** has announced two new families of compact metal-cased 15 W DC-DC converters. Available in an industry-standard 24-pin DIP measuring 31.75 × 20.32 × 10.16 mm, the JCG15 and JTF15 series offer a power density of up to 37.5 W per cubic inch with an efficiency of up to 91%. Providing nominal inputs of +12, +24 or +48 VDC, the JCG15 series accommodates 2:1 input ranges of 9–18 VDC, 18–36 VDC and 36–75 VDC, with the JTF15 series accepting 4:1 inputs of 9–36 VDC and 18–75 VDC. The converters operate from –40°C to +100°C for the JCG series and +105°C for the JTF series. For more information, contact Steve Head, tel +44 118 984 5515 or e-mail [shead@xppower.com](mailto:shead@xppower.com).



**IOP**corporate

# Article Packs



- Exclusive to researchers in industry
- The easy way to pay-per-view

Choose from more than **400,000** relevant, important scientific articles. With IOPcorporate Article Packs, you can download exactly what you need, when you need it, to maintain your competitive edge.

### **Fast and convenient**

- Provide access for every researcher at your corporation.
- Select a download limit that fits your unique needs.
- Download articles from any year, back to 1874.
- Go at your own pace – article packs don't expire, which means that you can keep downloading until your limit is reached.
- Start (and finish) at any time, and then simply renew.

**For more information, e-mail [iopcorporate@iop.org](mailto:iopcorporate@iop.org)**

- Current subscriptions must be maintained.
- The full list of content covered by IOPcorporate Article Packs is available upon request.



Scan here  
to search using  
your specific  
keywords



# Recruitment

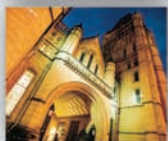
FOR ADVERTISING ENQUIRIES, CONTACT *CERN COURIER* RECRUITMENT/CLASSIFIED, IOP PUBLISHING, TEMPLE CIRCUS, TEMPLE WAY, BRISTOL BS1 6BE, UK.  
TEL +44 (0)117 930 1264 FAX +44 (0)117 930 1178 E-MAIL SALES@CERN Courier.COM  
PLEASE CONTACT US FOR INFORMATION ABOUT RATES, COLOUR OPTIONS, PUBLICATION DATES AND DEADLINES.

## The Cockcroft Institute . . .

Innovating amazing beams of particles and light...  
to interrogate nature

Apply Now

**Cockcroft Post Doctoral Fellows** for investigations in an advanced Free Electron Laser test facility CLARA at Daresbury Laboratory, UK and in superconducting microwave beam electro-dynamics in the European Spallation Source (ESS) at Lund, Sweden



The Cockcroft Institute, a unique collaboration between the Universities of Liverpool, Manchester, Lancaster, the Science and Technology Facilities Council and industry, brings together the best accelerator scientists, engineers, educators and industrialists to conceive, design, construct and use innovative instruments of discovery and to lead the UK's participation in flagship international experiments. It has major collaborations with CERN, DESY, RIKEN, Jefferson Lab, FNAL, LBNL, SLAC, VECC and world leading universities such as UC Berkeley, Stanford, Cornell, MIT, Cambridge, Imperial College, Strathclyde and IISc (Bangalore). The Institute has been involved in the development of the UK's first Free Electron Laser (FEL) on the ALICE accelerator test facility and is contributing towards development of an advanced FEL test facility (CLARA) to advance worldwide FEL research. The institute is also in collaboration with the ESS at Lund, Sweden in studying various accelerator structures and radiofrequency sources.

As founding members of the Cockcroft Institute, the Universities of Liverpool and Manchester are seeking to appoint two post-doctoral research associates to contribute to the ongoing development of CLARA and ESS. The CLARA FEL research involves investigations of novel concepts for the production of ultra-short FEL pulses of varying colours for the next generation of FELs. There will also be opportunities to take part in experiments aimed at optimising and enhancing the ALICE FEL performance. The ESS research associate, will use state-of-the-art computer codes for modelling rf cavities and studying beam dynamics in multi-cavity systems. Both posts will involve analysis, simulation and experimental research in close collaboration with institute members in other universities as well as in Daresbury and Rutherford Appleton Laboratories.

Applicants must have a Ph.D. in accelerator physics, particle physics, electrical engineering or a related discipline. Informal inquiries about the institute may be made to Professor Swapan Chattopadhyay ( [swapan@cockcroft.ac.uk](mailto:swapan@cockcroft.ac.uk)), about the ESS position to Professor Roger Jones ( [r.m.jones@cockcroft.ac.uk](mailto:r.m.jones@cockcroft.ac.uk)) and about the CLARA FEL position to Dr. David Newton ( [D.Newton@liverpool.ac.uk](mailto:D.Newton@liverpool.ac.uk)).



The Cockcroft Institute  
of Accelerator Science and Technology



### Professor Fellowship in Theoretical Nuclear Physics

The International Institute of Physics is offering a long term visiting Professor Fellowship in Theoretical Nuclear Physics. Prospective candidates should demonstrate expertise and research abilities in a variety of fields of Hadron Physics such as (large Nc) QCD, few and Many Body Nuclear Systems, Hadronic Matter at High Temperature and/or Density, Ultracold Atoms and Nuclei, Graphene, etc. Preference will be given to candidates whose research interests potentially overlap with those of the group at the IIP, which include String Theory and Applications of AdS/CFT Correspondence to Nuclear Physics and Condensed Matter, Quantum Information Theory, Statistical Field Theory and Strongly Correlated Electron Systems.

To apply, candidates should send by email ([professorship\\_applications@iip.ufrn.br](mailto:professorship_applications@iip.ufrn.br)), a CV with list of publications and a Research Plan. The position entitles the successful candidate to a monthly net income of R\$ 8.000,00 (US\$ 4.000,00) a return ticket, and an installation allowance of R\$8.000,00 upon arrival). **Application Window: from August 20 to September 30, 2012.** For more information access our web page on [www.iip.ufrn.br](http://www.iip.ufrn.br)

### Five postdoctoral positions in the fields of Condensed Matter Physics, Theoretical Nuclear Physics, Quantum Information Theory, Statistical Field Theory and String Theory

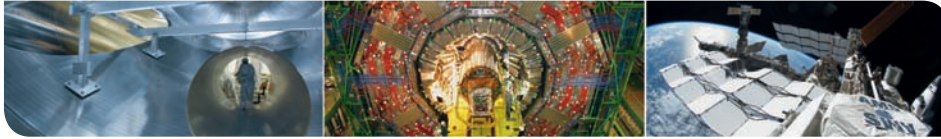
The International Institute of Physics is expecting to fill five postdoctoral positions in the fields of Condensed Matter Physics, Theoretical Nuclear Physics, Quantum Information Theory, Statistical Field Theory and String Theory, starting on November, 2012.

Prospective candidates should send by email ([postdoctoral\\_applications@iip.ufrn.br](mailto:postdoctoral_applications@iip.ufrn.br)), a CV with the list of publications, a statement of research interests and two letters of reference.

The position entitles the successful candidate to a monthly net income of R\$5.000,00 (US\$ 2.500,00) a return ticket, and an installation allowance of R\$5.000,00 upon arrival). **Application Window: From August 20 to September 30, 2012.**



# KSETA Karlsruhe School of Elementary Particle and Astroparticle Physics: Science and Technology



The KIT-Center Elementary Particle and Astroparticle Physics KCETA is a major institution in elementary particle and astroparticle physics and technological

**KSETA has open positions for doctoral researchers in elementary particle physics, astroparticle physics and advanced technologies**

developments. Our topics include cosmic rays, Dark Matter, quantum field theory, collider physics, flavour physics, neutrino physics and computational physics. We combine fundamental research – in theory and experiment – with the development of related modern technologies like superconducting detectors with terahertz bandwidth, analog and digital electronics, optical data transmission technology and parallel signal processing on FPGAs and GPUs. KCETA is a major contributor to leading-edge large-scale research projects such as AMS, Auger, Belle, CMS, EDELWEISS, JEM-EUSO and KATRIN; we host the German Tier-1 center GridKa and coordinate the Helmholtz Alliance for Astroparticle Physics.



The Graduate School KSETA has been established in the framework of the German Excellence Initiative; it will be in full operation from November 2012. We offer an inspiring interdisciplinary environment, international networking with research visits abroad, tailor-made course programs and career promotion.

#### Partner network:

- CERN (Switzerland)
- Fermilab and LBNL (USA)
- KEK (Japan)
- UNSAM and ITeDA (Argentina)

Visit [www.kseta.kit.edu](http://www.kseta.kit.edu)



KIT – University of the State of Baden-Württemberg and National Research Center of the Helmholtz Association

[www.kit.edu](http://www.kit.edu)

## Chief Scientist to lead a new laboratory in Nuclear Physics, RIKEN, JAPAN

RIKEN invites applications for the position of Chief Scientist (Laboratory Director) to lead a new laboratory in experimental nuclear physics using the RI Beam Factory (RIBF) of RIKEN Nishina Center for Accelerator-Based Science.

The present position is a permanent appointment, subject to RIKEN's mandatory retirement age of 60. RIKEN expects that the successful applicant will be able to take up this position on April 1st, 2013.

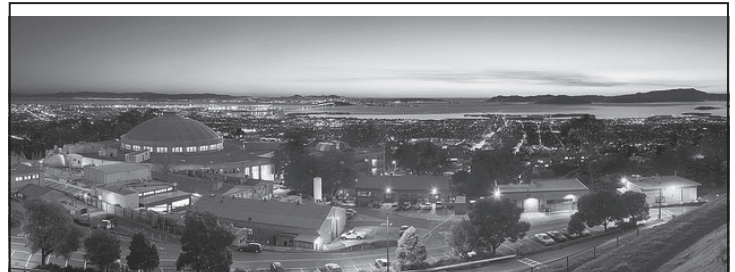
Applicants should send a full curriculum vitae and photograph; list of publications; one copy each of five key publications; a statement (about five pages A4 sized paper) explaining former research experience, and proposals for research at RIKEN; and the names and addresses of three referees.

**All applications should reach RIKEN by September 24th, 2012.**

Applicants should address all correspondence to: Dr. Hiroyoshi Sakurai, Chair of the Chief Scientist Search Committee, RIKEN Nishina Center for Accelerator-Based Science, 2-1 Hirosawa, Wako, Saitama 351-0198, JAPAN (E-mail address: sakurai@ribf.riken.jp)

For more information, please visit:

[http://www.riken.jp/engn/r-world/info/recruit/k120924\\_e\\_rnc.html](http://www.riken.jp/engn/r-world/info/recruit/k120924_e_rnc.html)



### LBNL Divisional Fellow - Experimental Particle Physics

The Physics Division at Lawrence Berkeley National Laboratory (LBNL) invites applications for a scientist with a record of accomplishment, creative ability, and outstanding promise in the field of experimental particle physics to work on the ATLAS experiment at the Large Hadron Collider.

The Divisional Fellow position is a five-year appointment with the expectation of promotion to a career position as a Senior Staff Scientist, and is similar to a tenure track junior faculty position at a university.

Candidates should have several years of experience in experimental particle physics beyond the Ph.D. and have demonstrated leadership and original achievements in research, or overall equivalent experience.

Please apply at <http://go.lbl.gov/df-epp>

For full consideration, please submit application materials by November 12, 2012.

For inquiries, please contact: Amy Pagsolingan (AVPagsolingan@lbl.gov)

[www.lbl.gov](http://www.lbl.gov)



AA/EEO

Accelerators | Photon Science | Particle Physics  
 Deutsches Elektronen-Synchrotron  
 A Research Centre of the Helmholtz Association



# PARTICLE PHYSICS.

## DESY has openings for: DESY-Fellowships (m/f)

### DESY

DESY is one of the world's leading centres for the investigation of the structure of matter. DESY develops, runs and uses accelerators and detectors for photon science and particle physics.

### The position

Fellows in experimental particle physics are invited to participate in DESY's particle physics research.

- Analysis and detector-upgrade in the LHC experiments ATLAS and CMS
- Preparation of the International Linear Collider ILC (accelerator and experiments)
- Cooperation in the Analysis Centre of the Helmholtz Alliance "Physics at the Terascale"
- Participation in experiments like ALPS and OLYMPUS
- Cooperation in the BELLE II experiments
- Analysis of HERA data

### Requirements

- Ph.D. completed within the last 4 years
- Experience in experimental particle physics

DESY-Fellowships are awarded for a duration of 2 years with the possibility of prolongation by one additional year.

Please submit your application including a resume and the usual documents (curriculum vitae, list of publications and copies of university degrees) to the DESY human resources department. Please arrange for three letters of reference to be sent before the application deadline to the DESY human resource department.

Salary and benefits are commensurate with those of public service organisations in Germany. Classification is based upon qualifications and assigned duties. DESY operates flexible work schemes. Handicapped persons will be given preference to other equally qualified applicants. DESY is an equal opportunity, affirmative action employer and encourages applications from women. There is a bilingual kindergarten on the DESY site.

Please send your application quoting the reference code, also by E-Mail to:

#### Deutsches Elektronen-Synchrotron DESY

Human Resources Department | Code: EM100/2012  
 Notkestraße 85 | 22607 Hamburg | Germany | Phone: +49 40 8998-3392 |  
 E-Mail: [personal.abteilung@desy.de](mailto:personal.abteilung@desy.de)

**Deadline for applications: 30 September 2012**  
[www.desy.de](http://www.desy.de)

The Helmholtz Association is Germany's largest scientific organisation.  
[www.helmholtz.de](http://www.helmholtz.de)



## The Excellence Cluster for Fundamental Physics

'Origin and Structure of the Universe'



## RESEARCH FELLOWS in Astrophysics, Cosmology, Nuclear and Particle Physics

The Excellence Cluster "Origin and Structure of the Universe" was established at the Technische Universität München (TUM) in October 2006 within the framework of the Excellence Initiative. The interdisciplinary research project unifies the physics faculties of TUM and Ludwig-Maximilians-Universität (LMU) as well as University Observatory of the LMU, several Max-Planck-Institutes (MPA, MPE, MPP, IPP) and the European Southern Observatory (ESO). The main goal of the Universe Cluster is to solve fundamental questions of physics, astrophysics, cosmology as well as nuclear and particle physics.

As part of our **FELLOWSHIP PROGRAM** we are looking for excellent young scientists on the postdoc level. Fellows will have the opportunity to work independently and potentially pursue an interdisciplinary research program in any research area of the Universe Cluster (theoretical or experimental). Fellowship appointments will be for a 3-year term and come with a budget of EUR 5K/year.

### APPLICATION

Candidates should send a cover letter, a complete curriculum vitae, a list of publications, a PhD certificate, a brief statement of research accomplishments and a research plan. Please upload these separate documents in the job section of the Cluster website [www.universe-cluster.de](http://www.universe-cluster.de). Please also arrange for 3 letters of recommendation to be sent to [job@universe-cluster.de](mailto:job@universe-cluster.de).

Applications from women and candidates with disabilities are especially encouraged and will be given preference to other applicants with equal qualifications. The application deadline is **October 31, 2012**.

### CONTACT

Technische Universität München · Excellence Cluster Universe  
 Dr. Andreas Müller · Boltzmannstrasse 2  
 85748 Garching · Germany

High Energy Physics Group  
 Dept of Physics & Astronomy



### Lectureship in Particle Physics (UCL Reference: 1260289)

Applications are invited for a lecturer post in the High Energy Physics Group in the Department of Physics and Astronomy at UCL.

The successful candidate will be expected to take a leading role in the ATLAS upgrade project, to publish research from the current ATLAS data and to raise the funds to support their research programme. They will also be expected to participate in the Department's teaching programme at undergraduate and graduate level including: lecturing, problem-solving tutorials, laboratory demonstrating and dissertation supervision.

Depending on experience, the salary will be in the Lecturer Grade 8 range: £39,818 to £46,972 per annum inclusive of London Allowance.

More details about the application procedure, the position, the UCL ATLAS group, the High Energy Physics Group, the Department of Physics and Astronomy, and UCL can be found at [http://www.hep.ucl.ac.uk/positions/lectureship\\_2012.shtml](http://www.hep.ucl.ac.uk/positions/lectureship_2012.shtml)

The closing date for applications is 5pm on Monday, 3 September 2012.



# KAVLI IPMU INSTITUTE FOR THE PHYSICS AND MATHEMATICS OF THE UNIVERSE



**“The universe is written in the language of mathematics.”** These words of Gallileo, who lived at the dawn of cosmology in the 16th to 17th century, give an important foresight to the strategy we must take at the Kavli Institute for the Physics and Mathematics of the Universe to answer big questions we face today.

**Kavli IPMU probes the deep mysteries of the universe** through collaborative research conducted by a range of scientists, including mathematicians, theoretical physicists, experimental physicists and astronomers.

**The institute was established in 2007** as one of Japan's five elite World Premier International Researcher Centers. It became the first member institute of the newly created Todai Institutes for

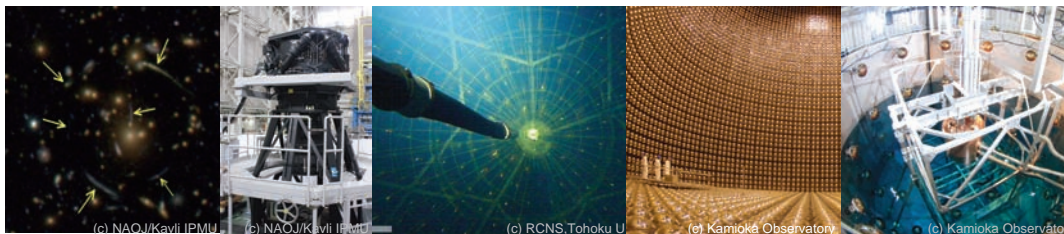
Advanced Study of the University of Tokyo in 2011. In April 2012, the IPMU became the Kavli IPMU by accepting the donation from the Kavli Foundation, a southern California based philanthropic organization devoted to the promotion of four scientific fields including astrophysics and theoretical physics.

**Kavli IPMU** has about 85 core researchers. **More than half of them come from overseas.** Including affiliate members and students, it is an international research center for some 200 researchers.

**Openings** for faculty and postdoc positions are announced in October each year.

Visit our website:

<http://www.ipmu.jp/job-opportunities>



Kavli Institute for the Physics and  
Mathematics of the Universe  
5-1-5 Kashiwanoha  
Kashiwa, 277-8583 Japan  
<http://www.ipmu.jp/>  
e-mail: [inquiry@ipmu.jp](mailto:inquiry@ipmu.jp)



## IceCube Computing Facilities Manager

The **University of Wisconsin-Madison** is seeking candidates to manage the computing facilities for the IceCube project. UW-Madison is responsible to the National Science Foundation and the IceCube Collaboration for maintenance and operations of the IceCube Neutrino Observatory, a kilometer-scale neutrino detector at the South Pole. The collaboration includes scientists from over thirty research institutions worldwide who collectively participate in studies of high-energy neutrinos from cosmic sources and a range of scientific topics in Astroparticle Physics.

The IceCube Computing Facilities Manager is responsible for computing facilities located within the Wisconsin IceCube Particle Astrophysics Center (WIPAC), other UW-Madison campus locations, and at the South Pole. The manager also has responsibility to the IceCube Collaboration to provide timely access to IceCube data and upgrades to computing systems.

The IceCube data center includes approximately 3 PB of disk storage, over 1500 CPUs, and various tape storage facilities, including a 1.2 PB HSM. Computing systems at the South Pole consist of ~200 servers in various configurations for data reduction and storage.

A master's degree or higher in Physics, Computer Science, Electrical Engineering, or related field will be considered, Ph.D. is preferred.

Highly qualified candidates will have at least five years of direct experience managing large computing facilities used in a collaborative scientific research environment.

**Pay range is USD \$90,000 – \$130,000 depending on qualifications, plus excellent benefits.**

To view the full Position Vacancy Listing (PVL), go to  
[http://www.ohr.wisc.edu/pvl/pv\\_073267.html](http://www.ohr.wisc.edu/pvl/pv_073267.html)

Applicants should email their CV and cover letter referring to:  
PVL #73267 to [hr@icecube.wisc.edu](mailto:hr@icecube.wisc.edu).

RUPRECHT-KARLS-  
UNIVERSITÄT  
HEIDELBERG



## 6 Junior Research Positions in Experimental, Theoretical and Astrophysics

The Department of Physics and Astronomy at Heidelberg University invites applications for 6 junior research group leaders in experimental or theoretical physics or astrophysics. The positions are open in the context of the **Heidelberg Graduate School of Fundamental Physics**, granted in the framework of the “Excellence Initiative” of the German Federal and State Governments. The areas of research in fundamental physics at Heidelberg University encompass particle physics and cosmology, astronomy and cosmic physics, quantum dynamics and complex quantum systems, complex classical systems, mathematical physics and environmental physics.

Applicants must hold a Ph.D. and have a strong international research record in one of the six research directions of the school, to complement existing expertise. Successful candidates will be supported in building up independent research groups including associated doctoral positions and significant startup funding for experimental groups. They are expected to supervise doctoral projects in their field and contribute to the Graduate School's teaching programme.

Heidelberg University is an equal opportunity, affirmative action employer and encourages applications from female scientists.

The positions are limited to 5 years. Applications including the usual professional documentation should be sent until **15th October 2012** to the Spokesperson of the Graduate School, **Prof. Dr. Markus Oberthaler, Heidelberg Graduate School of Fundamental Physics, Central Office, INF 226, 69120 Heidelberg, Germany.**



**Thinking about the Future of Basic Science.**

**IBS/RISP has openings for:  
Accelerator Scientists/Engineers**

The Institute for Basic Science (IBS) was established by the Korean government in November 2011 with the goal to create a world-class research institute in the basic sciences. IBS/RISP is to develop scientific and technical expertise and capabilities for the construction of a rare isotope accelerator complex (Rare Isotope Science Project, RISP) for nuclear physics, and medical and material science and applications.

The IBS/RISP is seeking for qualified applicants to work for Rare Isotope Science Project (RISP) at its headquarters office in Daejeon, Republic of Korea. The positions are at the level of research fellow, and postdoctoral research associates and accelerator engineers. Persons with high-level research achievement, extensive experience in large scale accelerator facility construction are given higher priority. The starting date is as soon as possible.

The successful candidates will participate in the R&D and construction of accelerator systems for RISP.

If you have the appropriate skills and are looking for a diverse and interesting employment opportunity we encourage you to apply. IBS/RISP is an equal opportunity employer; all applicants will be considered on their merit. Salary and benefits will be decided upon negotiations with the Director of RISP and will become effective upon signing the contract.

Please send your application including CV and introduction to

**Ms. Y.H. LEE, RISP Director's Office at the Institute for Basic Science, 70 Yuseong-daero 1689-gil Yusung-gu, Daejeon, Korea, 305-811**  
or e-mail to [leeyh@ibs.re.kr](mailto:leeyh@ibs.re.kr).

Applicants should arrange to have three letters of references sent to address or e-mail.

Application deadline is August 31, 2012.

Further information can be obtained by sending mail to [leeyh@ibs.re.kr](mailto:leeyh@ibs.re.kr).

Deadline for applications: 31 August 2012

<http://risp.ibs.re.kr>

**EXTRAORDINARY  
JOB  
OPPORTUNITIES**

Unique opportunity to be involved in defining and implementing the state-of-the-art laser technology and construction of a new EU science facility.



[www.eli-beams.eu/cooperation/jobs/](http://www.eli-beams.eu/cooperation/jobs/)

**CERN**

From software engineers to administrators, from fire fighters to health and safety officers - every kind of thinking is welcome here.  
Take your career somewhere special.  
Take part [cern.ch/career](http://cern.ch/career)



## European XFEL SEIZE THE CHANCE

European XFEL is a multi-national non-profit company that is currently building an X-ray free-electron laser facility that will open up new areas of scientific research. When this facility is completed in 2015, its ultrashort X-ray flashes and unique research opportunities will attract scientists from all over the world to conduct ground-breaking experiments. We are a rapidly growing team made of people from more than 20 countries. Join us now!

### EXCITING OPPORTUNITIES

Find out more about our exciting opportunities for scientists, engineers and graduate students. Help develop X-ray instrumentation and other systems. Help create a research facility of superlatives that will provide X-rays of unique quality for cutting-edge research in physics, chemistry, the life sciences and materials science.

### WORKING AT EUROPEAN XFEL

English is the working language. We offer salary and benefits similar to those of public service organisations in Germany, a free-of-charge company pension scheme, generous relocation package and support, international allowance for non-German candidates hired from abroad, training opportunities etc.

### JOIN OUR NETWORK

Join our network of international research institutions, programmes and collaborations. Discuss problems and solutions with colleagues from all over the world.

### COME TO HAMBURG

Economically and culturally, Hamburg is the centre of Northern Germany. With its long history in trade, Hamburg has always been an outward-looking city and one of Germany's gateways to the world. Work and live in Hamburg, one of the most beautiful and interesting cities in Europe!

European XFEL GmbH, Albert-Einstein-Ring 19, 22761 Hamburg, Germany  
Mailing address: Notkestr. 85, 22607 Hamburg, Germany

[www.xfel.eu](http://www.xfel.eu)



University  
of  
St Andrews

School of Physics and Astronomy

## Lecturers x 3 & Chairs/Readers x 3

Lecturers – £37,012 - £45,486 per annum  
Readers – £46,846 - £52,706 per annum  
Chairs – salary negotiable

As part of the second phase of the Scottish Universities Physics Alliance (SUPA), we are seeking to expand our activities by appointing outstanding researchers to six faculty positions: three at Professorship/ Readership level, and three at a Lecturership level. Applicants for the Lecturer positions should have a strong track record in publishing internationally leading research, and a clear vision of how their work would complement our existing experimental and theoretical research strengths. Applicants for the Chair/Reader positions should have, in addition, strong records of scientific leadership and a proven ability to secure major research-funding awards and to establish and sustain national and international collaborations.

Applications are welcomed from theoretical and experimental physicists in the broad areas of condensed matter physics and photonics (including biophotonics). Applications should include a covering letter stating the level of appointment being sought, a one-page summary of research achievements to date, a one-page statement of the applicant's vision for his/her research at St Andrews and a full curriculum vitae including a list of refereed publications together with contact details for three referees.

We will begin processing applications on Monday 17th September 2012 and so applications should be received by Friday 14th September 2012.

Please quote ref: SK2934

Closing date: 14 September 2012

We encourage applicants to apply online, but if you are unable to do this, please call +44 (0)1334 462571 for an application pack.

The University of St Andrews is a charity registered in Scotland (No SC013532).

University of St Andrews

The University is committed to equality of opportunity

[www.st-andrews.ac.uk](http://www.st-andrews.ac.uk)



**brightrecruits.com**

WEBINAR SERIES

## PhD opportunities at IMT Lucca, Italy

Every year IMT Institute for Advanced Studies Lucca invites highly motivated students to apply for its PhD programmes in a range of disciplines that offer great potential for real-world applications, such as computer, decision and systems sciences; image analysis; economics; management; and development of cultural heritage and political history.

Register for this free webinar to find out more about IMT Lucca, the opportunities that are available to its PhD students and how to apply.

**Our free recruitment webinar is now available to view on demand**

Institutions  
Markets  
Technologies

**IMT**  
INSTITUTE  
FOR ADVANCED  
STUDIES  
LUCCA

Presented by

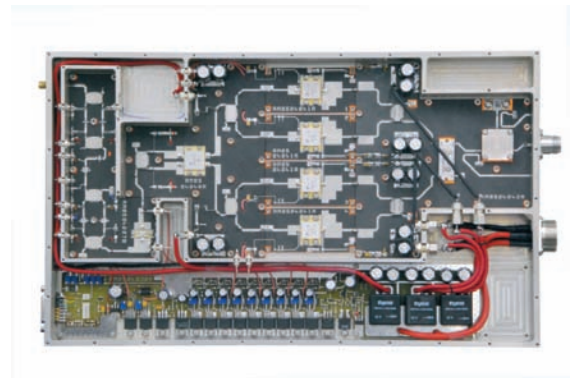
Register now at [brightrecruits.com/webinars](http://brightrecruits.com/webinars)

# RF Power Amplifiers

Amplifiers for HEP applications – Klystron & IOT drivers, Buncher & Cooling PA's

## Solid-state LDMOS, GaN & GaAs FET power amplifiers:

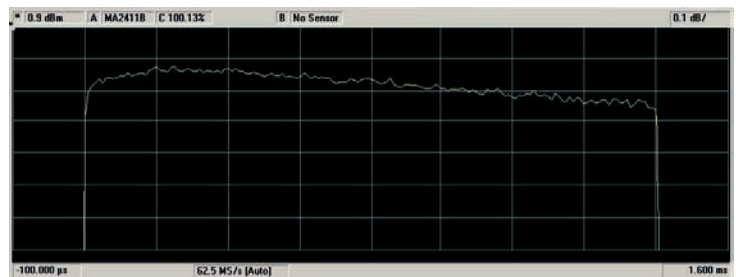
- High efficiency LDMOS, GaN & GaAs FET designs
- Pulsed power & CW models
- Output power to 4kW
- Low distortion
- High amplitude & phase stability
- Fast response times



Solid state designs offer advantages principally in terms of amplitude and phase stability as they are unaffected by the high voltage power supply variations affecting Klystrons and IOTs. Particularly so when an SSPA is used to drive electrically short IOTs, since system phase pushing and amplitude sensitivity is much reduced in comparison with higher gain Klystrons. The overall flexibility the SSPA offers in terms of frequency, amplitude and phase control, coupled with reliability factors including graceful degradation and a hot switching ability, make the use of SSPAs increasingly attractive in HEP RF system design.



AM86 1kW 1.3GHz PA



Typical 1.6mS 1kW pulse @ 1.3GHz

[www.maltd.com](http://www.maltd.com) **Microwave Amplifiers Ltd** [sales@maltd.com](mailto:sales@maltd.com)



# Bookshelf

## Time Machines

By Stanley Greenberg;

Introduction by David C Cassidy

Hirmer Verlag

Hardback: €39.90 SwFr53.90 £39.95 \$59.95

The American photographer Stanley Greenberg travelled 130,000 km over five years to create the 82 black-and-white photographs included in this large-format book. They are a record of the extraordinary and sometimes surreal complexity of the machinery of modern particle physics. From a working replica of an early cyclotron to the LHC, Greenberg covers the world's major accelerators, laboratories and detectors. There are images from Gran Sasso, Super-Kamiokande, Jefferson Lab, DESY and CERN, as well as Fermilab, SLAC and LIGO, Sudbury Neutrino Observatory, IceCube at the South Pole and many more.

The LUNA experiment at Frascati is like a giant steel retort-vessel suspended in the air; a LIDAR installation at the Pierre Auger Cosmic Ray Observatory in Argentina is a fantastically hatted creature from outer space bearing the warning "RADIACION LASER"; and the venerable 15-foot bubble chamber sits on the prairie at Fermilab like a massive space capsule that landed in the 1960s. (Who knows where its occupants might be now?)

Not a single person is seen in these beautiful images. They are clean, almost clinical studies of ingenious experiments and intricate machines and they document a world of pipes, concrete blocks, polished steel, electronics and braided ropes of wires. Greenberg has said that his earlier books, such as *Invisible New York* – which explores the city's underbelly, its infrastructure, waterworks and hidden systems – are "about how cities and buildings work", whereas *Time Machines* is about "how the universe works". More accurately, perhaps, it is about the things that we build to help us understand how the universe works – but here the builders are invisible, like the particles that they are studying.

In a book whose photographs clearly demonstrate the global nature of particle physics, David Cassidy, author of an excellent biography of Werner Heisenberg, includes a one-sided introduction, concentrating on US labs and achievements. Accelerators are "prototypically American" and his main comment on the LHC is that the US has contributed half a billion dollars to it and that Americans form its "largest national group". There are also inaccuracies: electroweak theory was confirmed by



the discovery of the W and Z bosons at CERN in 1983, not 1973; and the top quark discovery was announced in 1995, not 2008. The introduction does not do justice to Greenberg's excellent and wide-ranging photography but, fortunately, nor does it detract from it.

● Michael Marten, *Science Photo Library*.

## Pierre-Gilles de Gennes: A Life in Science

By Laurence Plévert

World Scientific

Paperback: £32

E-book: £41

Pierre-Gilles de Gennes obtient le prix Nobel de physique en 1991 « pour avoir découvert que les méthodes développées dans l'étude des phénomènes d'ordre s'appliquant aux systèmes simples peuvent se généraliser à des formes plus complexes, cristaux liquides et polymères ». Ni invention ni découverte, c'est un curieux intitulé. Le comité semble honorer un homme plus qu'une contribution identifiée. De fait, la vie de de Gennes se lit comme une épopée. Il naît en 1932 d'une famille alliant la banque et l'aristocratie. Ses parents se séparent, il est doublement choyé. La guerre éclate, c'est l'occasion de vacances alpestres. Cette enfance hors du commun lui apprend discipline et curiosité et lui donne une grande confiance en lui.

Attiré par les sciences à 15 ans, il surmonte les années difficiles de la classe préparatoire en jouant dans un orchestre de jazz. Reçu premier à l'École normale supérieure, il commence la vie libre de normalien, se mariant et devenant papa avant l'agrégation. Il se passionne pour la mécanique quantique et la théorie des groupes, qu'il décortique dans les livres. Feynman est son modèle. L'intuition doit

rester souveraine, et il l'applique aussi en politique où il rejette les modes de l'époque. Il vit une révélation avec l'école d'été des Houches, où il rencontre Pauli, Peierls... Les deux mois les plus importants de sa vie, dit-il. Sa vocation pour la physique s'y confirmera, mais quelle voie suivre ? La physique nucléaire ? « J'ai l'impression que personne ne sait décrire une interaction sinon en ajoutant des paramètres de manière ad hoc ».

Sorti de l'ENS, il intègre la division théorique de Saclay. Après son service militaire, il devient professeur à Orsay à l'âge de 29 ans. On lui laisse carte blanche, il s'attaque à la supraconductivité, montant un laboratoire à partir de rien. Se laissant guider par l'imagination, il mélange expérience et théorie. Aux plus jeunes, il insufflé l'enthousiasme, son charisme opère sur tous.

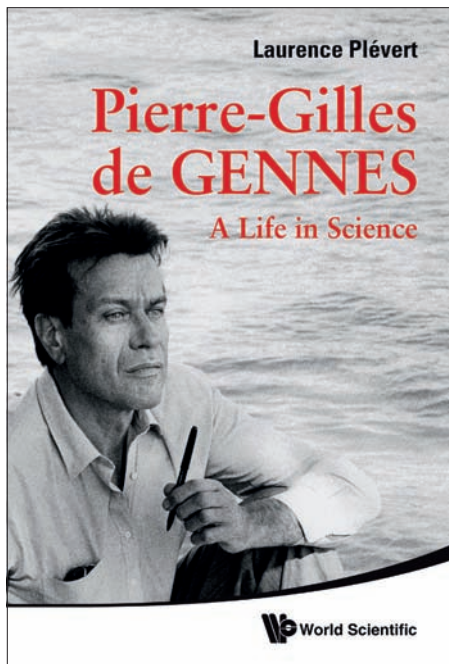
Il quitte Orsay en 1971, appelé au prestigieux Collège de France, pour y créer son propre laboratoire. Il y développe la science de « la matière molle », comprenant les bulles et les sables, les gels, les polymères... Théoricien du pratique, il prône une forte collaboration avec l'industrie. Pluridisciplinaire avant la lettre, il exploite les analogies suggérées par sa grande culture scientifique.

Dans son parcours sans faute, une hésitation apparaît. « Au milieu du chemin de sa vie », il sent le défi de l'âge. Il le relève allègrement fondant une seconde famille, en maintenant un bon rapport avec la première où vivent trois grands enfants. Sa femme ne s'insurge pas. Sa vie privée est aussi fertile que sa carrière, et trois nouveaux enfants naîtront.

Arrive l'heure des distinctions. Il est élu à l'Académie des Sciences, il reçoit la médaille d'or du CNRS, la Légion d'honneur, on lui propose un ministère. Tout en demeurant au Collège de France, il est appelé à la direction de l'ESPCI, qu'il remodèle à son goût, il s'y fait une réputation de despote. C'est un grand patron qui assume sa fonction. De fait, son autorité naturelle suscite chez ses collaborateurs une crainte sacrée. L'apothéose que représente le prix Nobel lui permet d'appliquer ses idées avec encore moins de retenue. Grand communicateur, il popularise ses idées à la télévision.

Un cancer se déclare, il s'accroche à ses activités. Retraité du Collège de France, il poursuit sa vie de recherche à l'Institut Curie dans le domaine des neurosciences. Il meurt en 2007 après une dure bataille.

## Bookshelf

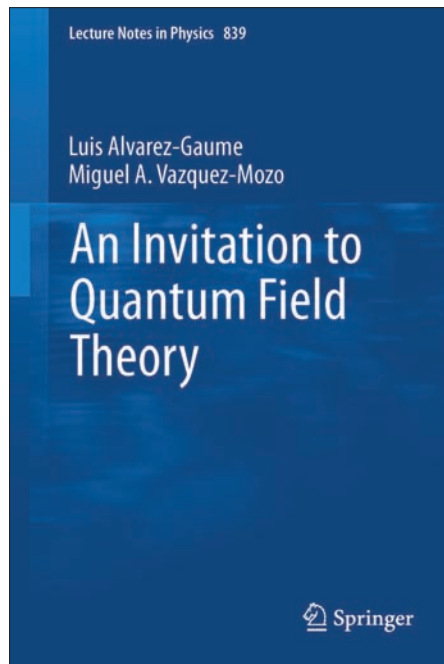


Pierre-Gilles de Gennes fut un homme de convictions. Parfois décrié pour ses prises de position, il ne craint pas de secouer les habitudes en s'attaquant aux structures sclérosées : « L'université a besoin d'une révolution. » Autre cheval de bataille : la « Big Science » ; il s'oppose au laboratoire de rayonnement synchrotron Soleil et au projet ITER. Humaniste, il publie un délicieux tableau de caractères à la manière de la Bruyère, et il avoue : « J'ai tendance à croire que notre esprit a des besoins autant rationnels qu'irrationnels. »

Bouillonnant d'idées, auteur de 550 publications, homme d'influence qui s'exprime de manière franche, il ose dire : « Il faut accélérer la mort lente de champs épuisés comme la physique nucléaire », et il remarque : « Quand j'ouvrais PRL en 1960, je trouvais chaque fois une idée révolutionnaire, aujourd'hui j'arrive à 2 ou 3 idées par an, dans un journal devenu 5 fois plus épais. » Il est vrai que les idées neuves se font rares. Nous vivons sur l'acquis d'anciennes avancées théoriques, et le Higgs découvert récemment a été postulé il y a 50 ans. D'où le le sentiment dérangeant que le progrès avance plus laborieusement.

Pierre-Gilles de Gennes fut un esprit fertile et passionné, mais il vécut aussi dans une période favorable, offrant des domaines vierges permettant de multiplier les recherches. Une carrière comme la sienne semble impossible aujourd'hui, les spécialités poussées à l'extrême étouffant les initiatives individuelles.

La biographie, très bien écrite par la journaliste Laurence Plévert, est truffée



d'anecdotes, elle se lit comme un roman qui emplit le lecteur d'un optimisme renouvelé sur les potentialités de l'aventure humaine et de la recherche fondamentale.

« Renaissance man », dit la quatrième de couverture ; j'oserai comparer Pierre-Gilles de Gennes à un monarque éclairé façon condottiere, ce qui ne contredit pas l'aphorisme d'un journaliste résumant l'attrait de l'homme : « Il est quelqu'un qu'on aimerait avoir comme ami, pour partager le privilège de se sentir un instant plus intelligent. »

*This book is a translation of the original French edition Pierre-Gilles de Gennes. Gentleman physicien (Belin, 2009).*

● François Vannucci. University of Paris 7 and LPNHE/APC.

### An Invitation to Quantum Field Theory

By Luis Alvarez-Gaumé and Miguel A Vázquez-Mozo

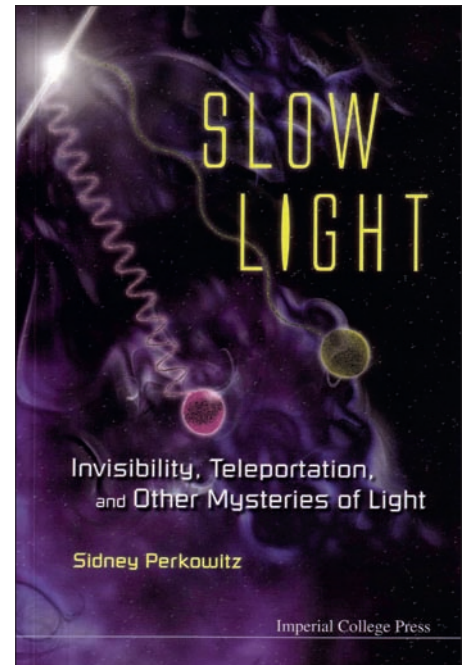
Springer

Paperback: £40.99 \$59.96 €48.10

E-book: £38.99 \$47.99 €42.99

The authors of this book have done a huge service in providing, in an easily readable book of fewer than 300 pages, a genuine invitation to quantum field theory. Its requirements are minimal: special relativity, quantum mechanics and electromagnetism are enough. It starts with simple physical arguments, showing how relativistic quantum mechanics applied to single-particle physics will not work and that quantum field theory is inevitable.

While many books on quantum field theory and introductory particle physics have appeared over the past few years,



this one is unique. Despite starting from an elementary level, quantum field theory is not reduced to Fock-space descriptions of particle states and Feynman diagrams. Path integrals, semiclassical limits and the structure of the quantum vacuum – including instantons and the strong CP problem – are discussed early on. Emphasis is placed on the subtle aspects of symmetries, both local and global, including explicit and spontaneous symmetry-breaking and anomalies, with many applications and heuristic explanations.

The full Standard Model is introduced with a careful discussion of fermion masses – both Majorana and Dirac and an exceptionally thorough discussion of discrete symmetries – the CPT theorem and the spin-statistics theorem. The calculus of Feynman diagrams is brought up without recapitulating the usual list of standard processes. Instead, Compton scattering at low energies is worked out in detail and applied to the polarization of the cosmic background radiation.

The treatment of higher-order corrections, infinities and renormalization is exceptionally clear and modern. It is carried out in detail, making connections between the position-space renormalization group in statistical mechanics and the momentum-space one more often used in particle physics. Effective field theories, naturalness and the decoupling of heavy particles are all explained with deep physical insight. A final chapter on special topics includes the non-perturbative production of particles by classical fields via the



Schwinger mechanism and an introduction to supersymmetry.

This book is not a replacement for longer texts but nor is it meant to be. It is a soaring and also deeply insightful overview that will inspire students to study the field in more detail. Having seen lectures given at various CERN Latin American schools based on the material that it contains, I can personally attest to the great enthusiasm with which they were received by young high-energy physicists. Experienced physicists will also find it a pleasant read. It is likely to provide novel insights into phenomena that they had already known about, but in a new light.

● John Swain, *Northeastern University*.

### Slow light: Invisibility, Teleportation and Other Mysteries of Light

By Sidney Perkowitz

Imperial College Press

Paperback: £13 \$19

E-book: £17 \$25

In many ways the simplest of things, light, is also among the most puzzling. Behaving both as a particle and as a wave, and setting a universal speed limit,  $c$ , when it travels through empty space, light is central to some famous paradoxes. There is – pardon the pun – more to light than meets the eye, as Sidney Perkowitz reveals in this fascinating little book.

Take slow light, for example. In early physics classes we learn that light slows down in matter, leading to the phenomenon of refraction. But just how slow can light go? As slow as you like, it seems, if you send pulses of laser light into a Bose–Einstein condensate; right down to a standstill, before starting again. Slow light, stopped light, fast light and even backwards light are all real results of tailoring highly dispersive media in which the group refractive index (the ratio of  $c$  to the group velocity) is not restricted to the standard values in the range 1–2, but can be less than 1 and even less than 0. Creating such seemingly unphysical values of refractive index also underlies the first practical examples of “invisibility cloaks”, formed only in the past few years with structures known as “metamaterials” (*CERN Courier* December 2006 p13).

With an elegant and clear style, Perkowitz takes the reader through the reality of these remarkable phenomena, including the strange quantum effects related to entanglement. In each case he states simply what is known through experiments, dwelling little on unproved theoretical whims. Here is an author who is keen to show that what we know is already amazing, without having to pour over the purely hypothetical. At the same time, he brings

in examples from a range of literature, from William Shakespeare’s *Tempest* to, inevitably, J K Rowling’s Harry Potter books, for example, in the chapter on invisibility. The broad range of references is impressive without being daunting, and goes well beyond the best known realms of fantasy and science fiction.

What is most remarkable is that this is done in so few pages (137), including an excellent section on further “reading, surfing and viewing”, which covers scientific papers as well as non-technical treatments alongside the many fictional references. While clearly targeted at non-physicists, *Slow Light* should entertain anyone wanting to come quickly and smoothly up to speed on some fascinating modern physics.

● Christine Sutton, *CERN*.

## Books received

### From Nuclei To Stars: Festschrift in Honor of Gerald E Brown

By Sabine Lee (ed.)

World Scientific

Hardback: £96 \$145

E-book: £125 \$189

In one way or another, Gerry Brown has been concerned with questions about the universe – its vast expanse as well as its most fundamental – throughout his entire life. In his endeavours to understand the universe in many manifestations from nuclei all of the way to the stars, he has been influenced by some of the most prominent physicists of the 20th century, and he himself, in turn, has influenced many others. This collection of articles dedicated to Gerry on his 85th birthday contains discussions of many of the issues that have attracted his interest over the years.

### Neutrino Physics (2nd edition)

By Kai Zuber

Taylor & Francis

Hardback: £82

When Kai Zuber’s text on neutrinos was published in 2003, the author correctly predicted that the field would see tremendous growth in the immediate future. In that book, he provided a comprehensive and self-contained examination of neutrinos, covering their research history and theory, application to particle physics, astrophysics, nuclear physics, and the broad reach of cosmology. Revised to be up to date, this second edition delves into neutrino cross-sections, mass measurements, double-beta decay, solar neutrinos, high-energy neutrinos and neutrinos from supernovae, as well as new experimental results in the context of theoretical models.

### Problems and Solutions in Quantum Computing and Quantum Information (3rd edition)

By Willi-Hans Steeb and Yorick Hardy

World Scientific

Hardback: £63 \$95

Quantum computing and quantum information are two of the fastest-growing and most exciting research fields in physics. Entanglement, teleportation and the possibility of using the non-local behaviour of quantum mechanics to factor integers in random polynomial time have also added to this new interest. This book supplies a collection of problems in these fields that should be invaluable to students and researchers. All of the important concepts and topics are included, ranging in difficulty from elementary to advanced. Most of the problems are self-contained and the solutions solved in detail.

### The Dreams That Stuff is Made Of: The Most Astounding Papers of Quantum Physics and How They Shook the Scientific World

Introduction by Stephen Hawking

Running Press

Hardback: \$30

*The Dreams That Stuff is Made Of* collates the essential works from the scientists who sparked the paradigm shift that changed the face of physics and pushed understanding of the universe to a new level. With an introduction by Stephen Hawking, this anthology includes works by Niels Bohr, Max Planck, Werner Heisenberg, Max Born, Erwin Schrödinger, J Robert Oppenheimer and Richard Feynman.

### Quantum Mechanics: Its Early Development and the Road to Entanglement and Beyond (2nd edition)

By Edward G Steward

Imperial College Press

Hardback: £73 \$110

Paperback: £45 \$69

This explanation of the origin of quantum mechanics provides a descriptive survey of developments up to the present day, with the mathematics presented in a digestible form yet following the original approach. The second edition presents two new chapters – “Interpretations of Quantum Mechanics” and “A Reflective Interlude”, which looks at the origin and early years of wave–particle duality – and a new appendix “Planck Units”. It will interest students of physics and those studying the history of science.

### Accelerator Physics (3rd edition)

By S Y Lee

World Scientific

Paperback: £45 \$68

## Bookshelf

Intended as a graduate or senior undergraduate textbook in accelerator physics and science, this book covers historical accelerator development, transverse betatron motion, synchrotron motion, linear accelerators and synchrotron radiation phenomena in low-emittance electron storage rings. It also introduces topics such as the free-electron laser and beam–beam interaction. Attention is paid to derivation of the action-angle variables of the phase space – important for understanding advanced topics such as the collective instability and nonlinear beam dynamics. Each section has exercises that are designed to reinforce concepts and solve realistic accelerator-design problems.

### Advanced Quantum Mechanics (2nd edition)

By Freeman Dyson, translated and transcribed by David Derbes

#### World Scientific

Hardback: £61 \$92

Paperback: £26 \$39

E-book: £79 \$120

In the 1940s, Freeman Dyson was responsible for demonstrating the

equivalence of the two formulations of quantum electrodynamics – Richard Feynman’s diagrammatic path-integral formulation and the variational methods developed by Julian Schwinger and Sin-Itiro Tomonoga – showing the mathematical consistency of QED. This volume comprises the legendary lectures on quantum electrodynamics that Dyson first gave at Cornell University in 1951. This 60th anniversary edition includes a foreword by science historian David Kaizer and notes from Dyson’s lectures at the Les Houches Summer School of Theoretical Physics in 1954.

### String Theory and Its Applications: TASI 2010 – From meV to the Planck Scale: Proceedings of the 2010 Theoretical Advanced Study Institute in Elementary Particle Physics

Edited by Michael Dine, Thomas Banks and Subir Sachdev

#### World Scientific

Hardback: £169 \$260

E-book: £223 \$338

This book is based on lectures given at the TASI summer school of 2010. It aims

to provide advanced graduate students, postdocs and senior researchers (and be useful to early postdocs etc) with a survey of important topics in particle physics and string theory, with emphasis on applications of methods from string theory and quantum gravity in condensed matter physics and QCD, especially heavy-ion physics.

### The Mathematical Language of Quantum Theory: From Uncertainty to Entanglement

By Teiko Heinosaari and Mário Ziman

#### Cambridge University Press

Hardback: £50 \$85

This book presents a clear and detailed exposition of the fundamental concepts of quantum theory: states, effects, observables, channels and instruments. It introduces several up-to-date topics, such as state discrimination, quantum tomography, measurement disturbance and entanglement distillation. The theory is illustrated with numerous examples, reflecting recent developments in the field. The treatment emphasizes quantum information, but its general approach makes it a useful resource for graduate students and researchers in all subfields of quantum theory.

# SUPERCON, Inc.

## Superconducting Wire and Cable

Standard and Specialty designs are available to meet your most demanding superconductor requirements.

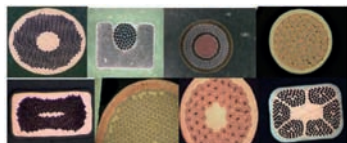
SUPERCON, Inc. has been producing niobium-based superconducting wires and cables for half a century. We are **the original SUPERCON** – the world’s first commercial producer of niobium-alloy based wire and cable for superconducting applications.

### Standard SC Wire Types

NbTi Wires  
 Nb<sub>3</sub>Sn —Bronze  
 Nb<sub>3</sub>Sn —Internal Tin  
 CuNi resistive matrix wires  
 Fine diameter SC Wires  
 Aluminum clad wire  
 Wire-in-Channel  
 Innovative composite wires

### Product Applications

Magnetic Resonance Imaging  
 Nuclear Magnetic Resonance  
 High Energy Physics  
 SC Magnetic Energy Storage  
 Medical Therapeutic Devices  
 Superconducting Magnets and Coils  
 Crystal Growth Magnets  
 Scientific Projects



**“We deliver superconductivity!”**

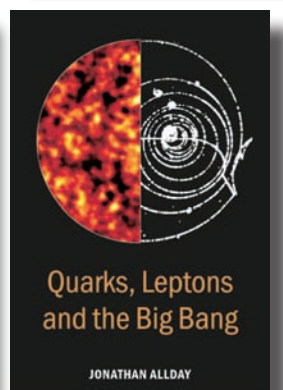
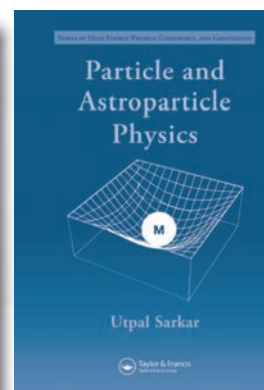
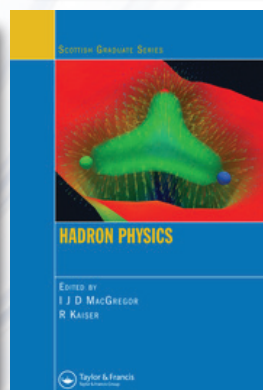
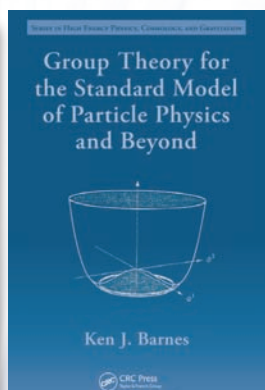
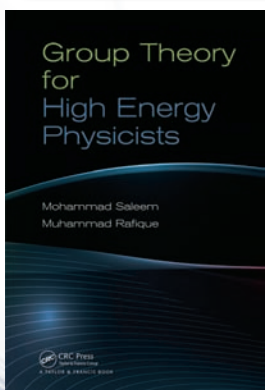
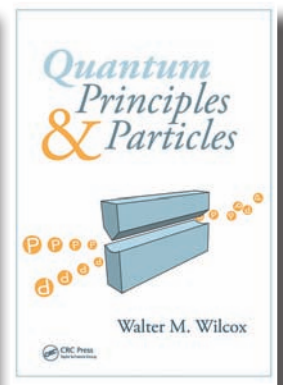
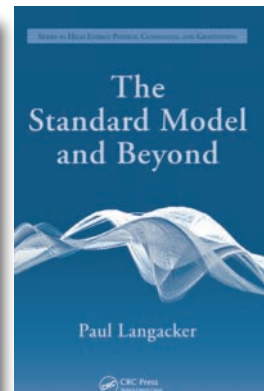
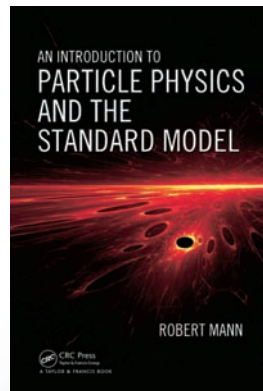
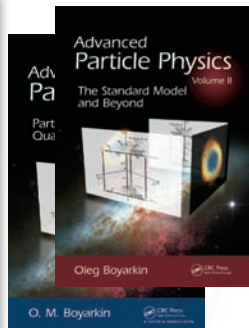
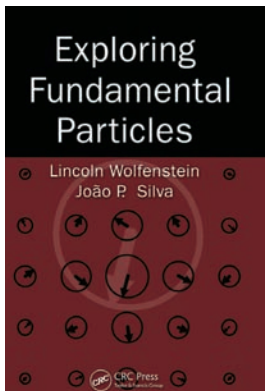
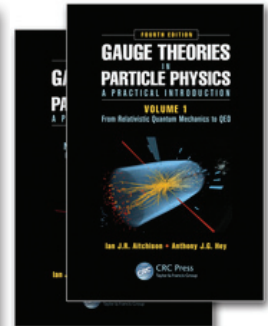
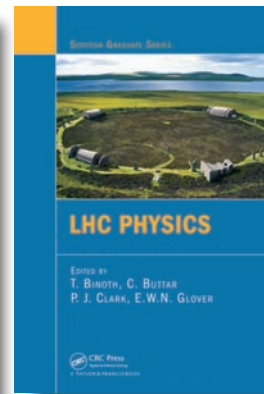
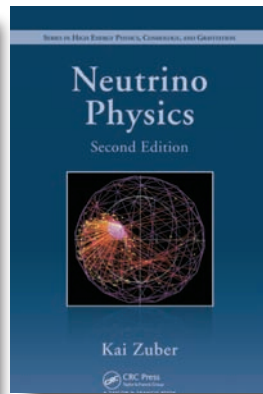
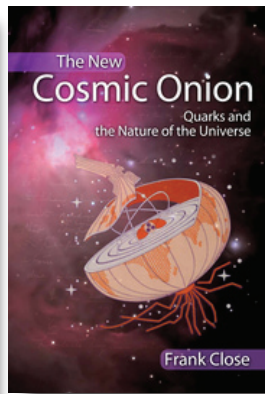
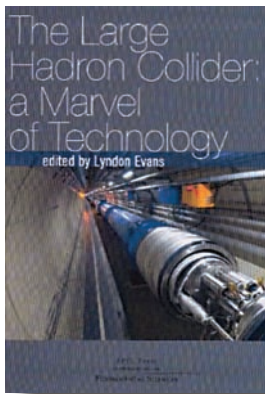
Contact us at [sales@supercon-wire.com](mailto:sales@supercon-wire.com)

[www.SUPERCON-WIRE.com](http://www.SUPERCON-WIRE.com)





# GET UP TO SPEED ON THE LHC AND PARTICLE PHYSICS!



Order online at [www.crcpress.com](http://www.crcpress.com)  
and enter **Promo Code HKL07** at checkout to **SAVE 20%** off  
your entire order.  
*Standard Shipping is always FREE.*

# Viewpoint

## An important day for science

CERN's director-general, Rolf Heuer, looks beyond the results announced on 4 July to a wider significance.

On 4 July 2012, particle physics was headline news around the world thanks to a scientific success story that began over 60 years ago. It was a great day for science and a great day for humanity: a symbol of what people can achieve when countries pool their resources and work together, particularly when they do so over the long term.

This particular success story is called CERN, a European laboratory for fundamental research born from the ashes of the Second World War with support from all parties, in Europe and beyond. The headline news was the discovery of a particle consistent with the long-sought after Higgs boson, certainly a great moment for science. In the long term, however, the legacy of 4 July may well be that CERN's global impact endorses the model established by the organization's founding fathers in the 1950s and shows that it still sets the standard for scientific collaboration today. CERN's success exemplifies what people can achieve if we keep sight of the vision that those pioneers had for a community of scientists united in diversity pursuing a common goal.

CERN is a European organization, founded on principles of fairness to its members and openness to the world. Accordingly, its governance model gives a fair voice to all member states, both large and small. Its funding model allows member states to contribute according to their means. Its research model welcomes scientists from around the world who are able to contribute positively to the laboratory's research programmes. Through these basic principles, CERN's founding fathers established a model of stability for cross-border collaboration in Europe, for co-ordinated European engagement with the rest of the world, and they laid down a blueprint for leadership in the field of particle physics. The result is that today, CERN is undisputedly



*The eagerly anticipated seminar on 4 July (top) was watched by members of the particle physics community the world over, from Fermilab in the US (left) to Tokyo University in Japan (right). (Image credits: left, Fermilab; right, University of Tokyo.)*

the hub of a global community of scientists advancing the frontiers of knowledge. It is a shining example of what people can do together.

This fact has not been lost on other fields and over the years several European scientific organizations have emulated the CERN model. The European Space Agency (ESA) and European Southern Observatory (ESO), for example, followed CERN's example and have also established themselves as leaders in their fields. Today, those thinking of future global science projects look to the CERN model for inspiration.

Scientific success stories like this are now more important than ever. At a time when the world is suffering the worst economic crisis in decades, people – particularly the young – need to see and appreciate the benefits of basic science and collaboration across borders. And at a time when science is increasingly estranged from a science-dependent society, it is important for good science stories to make the news and encourage people to look beyond the headlines. For these reasons, as well as the discovery itself, 4 July was an important day for science.

● Rolf Heuer, director-general, CERN.



# ACCELERATE ULTRA-HIGH VACUUM PERFORMANCE

Confidence means knowing the vacuum technology accelerating your lab's performance has been proven by the most powerful physics experiment ever built, CERN's Big Bang machine. Since 1967, Agilent's line of ultra-high vacuum ion pumps have been there—from the engineering to the experiments—to the remarkable discovery of the Higgs boson particle.

Combine Agilent's leading UHV solutions to accelerate your results:

- Agilent Diode, Noble Diode and StarCell pumps' UHV versatility
- Agilent 4UHV, the first true 4 channel ion pump controller
- Agilent TwisTorr turbo pumps' leading speed and compression
- Agilent Dry Scroll pumps' clean oil-free vacuum

Learn more: [www.agilent.com/chem/vacuum](http://www.agilent.com/chem/vacuum)

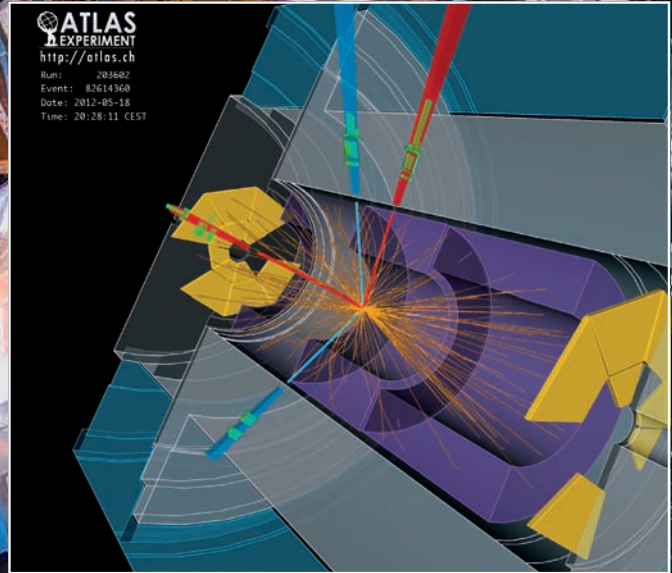
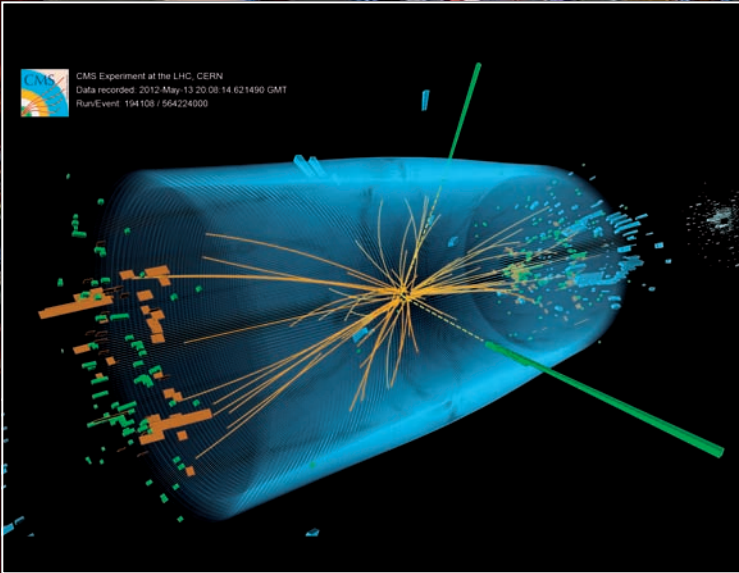
The Measure of Confidence





# CAEN & LHC EXPERIMENTS

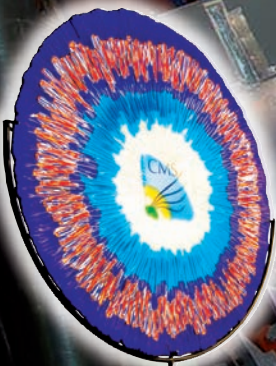
## SYNERGY FOR SUCCESS



Background photo ©CERN

July 4th, 2012: CMS and ATLAS announce the discovery of a new particle consistent with the Higgs Boson.

CAEN, proud supplier of CERN since 33 years congratulates with all CERN researchers for the discovery marking our time.



[www.caen.it](http://www.caen.it)

Artwork: A tribute to CERN COURIER for 10 years of Advertising Campaigns



Joint efforts achieve top performance

CMS Crystal Award of the year 2009

# - HIGH RELIABILITY

*Even in Extreme Conditions*

**DELIVERED PRODUCTS**  
*DESIGNED FOR HOSTILE ENVIRONMENT*

- 6.500 electronic units
- 1.3% global failure rate
- 190.000 sub-boards
- 0.1% global failure rate