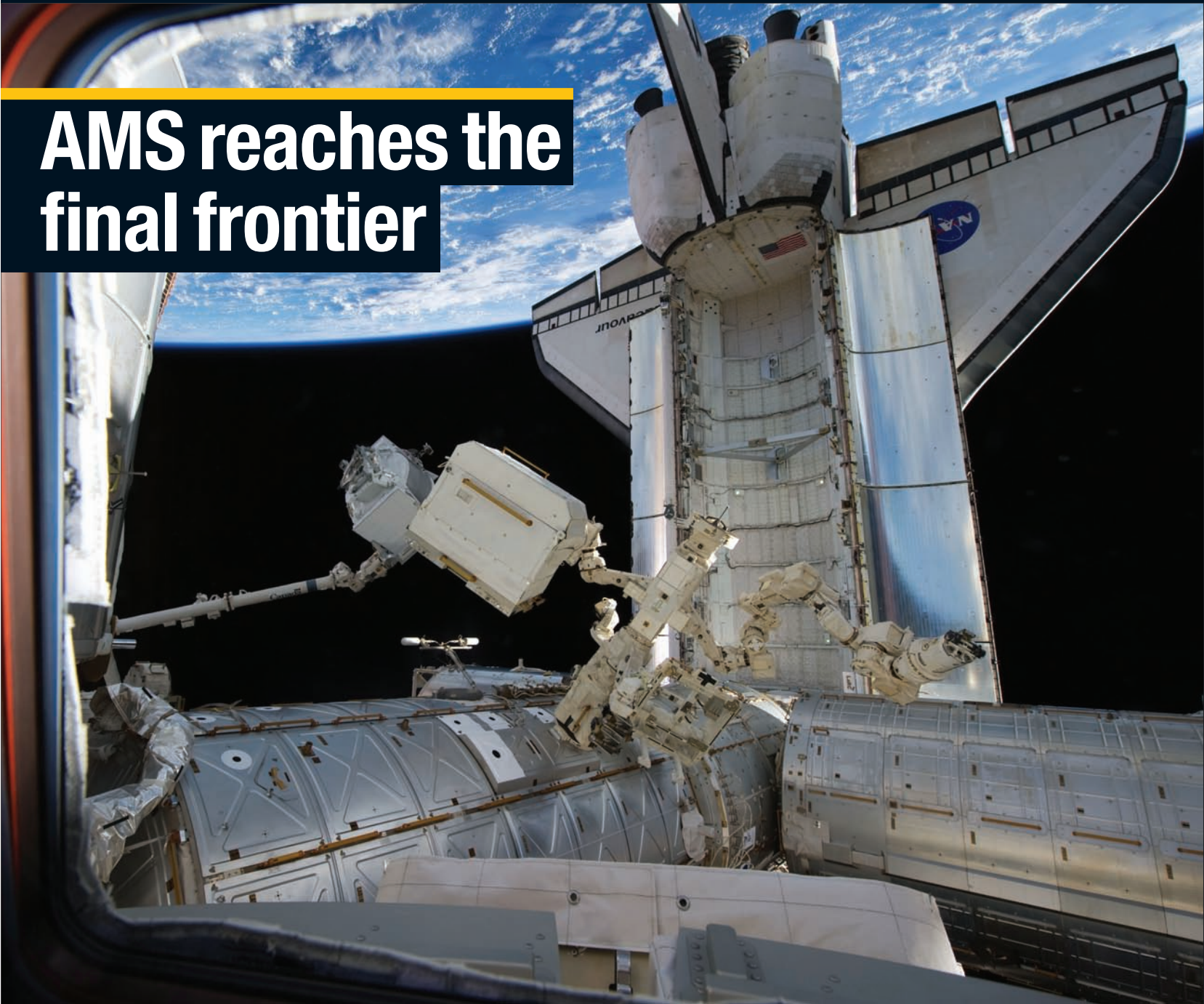


CERN COURIER

VOLUME 51 NUMBER 6 JULY/AUGUST 2011

AMS reaches the final frontier



INTERVIEW

A dream comes true for Sam Ting
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THE EPS

Luisa Cifarelli sees a bright future ahead
p45 & p58



BENEATH THE GRAN SASSO

The ICARUS detector is now in full flight **p30**

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On the cover: With the Earth in the background, the AMS (the grey block, centre left) is deployed from the loading bay of the space shuttle *Endeavour* to its location on the International Space Station. (Image credit: NASA.)

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News

CERN

LHC achieves 2011 data milestone

In June the LHC made good the promise of delivering an integrated luminosity of 1 fb^{-1} to the general-purpose detectors, ATLAS and CMS. This was the target for 2011 and it was achieved a little before the middle of the year. At the same time, making use of a technique known as “luminosity levelling”, the LHCb experiment had already recorded around 0.36 fb^{-1} , well on the way to achieving its 1 fb^{-1} by the end of the year.

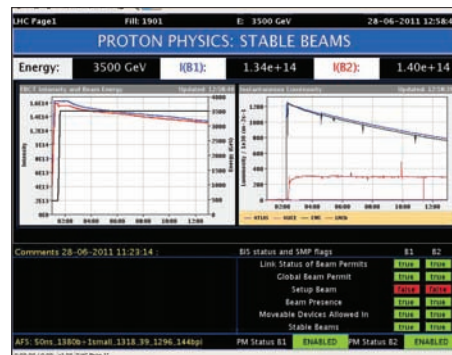
Reaching the luminosity milestone was the result of a programme of steady increments in the number of bunches of protons injected into the LHC, with 144 bunches added per beam per step (CERN Courier June 2011 p5). With each increment, the LHC provides three long “fills” of stable beams, before the next step. By the end of May, the number of bunches reached 1092 per beam, providing a peak luminosity of $1.25 \times 10^{33} \text{ cm}^{-2}\text{s}^{-1}$ and a total energy per beam of some 70 MJ. A few long-lived fills soon yielded more than 40 pb^{-1} at a time for the general-purpose detectors, nearly as much as the LHC delivered in all of 2010, so allowing the 2011 milestone to be reached by 17 June.

The step to 1236 bunches per beam followed on 24 June, with the successful increment only four days later to 1380 bunches per beam – the maximum for the current bunch spacing of 50 ns. Running during these last few days of June included one epic fill that was 19 hours long and delivered an integrated luminosity of 60 pb^{-1} .

At the same time, the technique of luminosity levelling has been employed to deliver a peak luminosity to the LHCb experiment of about $3 \times 10^{32} \text{ cm}^{-2}\text{s}^{-1}$. If the beams were allowed to collide head-on in the LHCb detector, this figure would be exceeded, so the beams are initially separated by about $15 \mu\text{m}$ in the vertical plane. Then, as the beam intensity decays during a fill, this separation is gently reduced to keep the luminosity constant at the acceptable maximum. The LHCb experiment has more specialized physics goals than ATLAS and CMS, and was designed to run at lower luminosity and low multiplicity, processing just one proton–proton interaction per bunch crossing. The decision to increase the bunch intensity in the LHC before increasing the number of bunches, as well as the excellent performance of the detectors, has inspired the collaboration



Screens show the record fill (no. 1900) achieved on 27 June, left, which lasted just over 19 hours. The following fill, right, on 28 June provided the first stable beams with 1380 bunches per beam, the maximum possible at 50 ns spacing.



to run with as many as six interactions per crossing. The successful implementation of luminosity levelling means that the physics output of LHCb can be maximized while staying within the limits of peak luminosity that the detector can handle.

As the total beam intensity of the LHC has been pushed up, the operators have encountered various problems, such as the “unidentified falling objects” (UFOs). These are thought to be dust particles falling through the beam, causing localized beam loss. The losses can push nearby beam-loss monitors over the threshold to dump the beam. This is more of an annoyance than a danger for the LHC, but it does reduce the operational efficiency.

A period of machine development began on 29 June, in which the operators made several investigations for further improvements in the LHC’s performance, including the next steps towards higher beam intensities. One test involved the successful injection of trains of 24 bunches with 25 ns spacing, with up to 216 bunches injected. In other tests, bunches at 50 ns spacing were filled to twice the nominal intensity, with 2.7×10^{11} protons per bunch, the highest intensity achieved. These studies thus offer different paths to higher luminosities in the LHC.

Meanwhile, with the bumper crop of data already in hand, the LHC experiments are now working hard to get results ready for the main summer physics conferences: the European Physical Society’s High Energy Physics conference, being held in Grenoble on 21–27 July, and the Lepton-Photon

conference, this year hosted by the Tata Institute in Mumbai on 22–27 August.

● For regular updates on the LHC, see the CERN Bulletin: <http://cdsweb.cern.ch/journal/CERNBulletin/>.

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ANTIMATTER

ALPHA traps antihydrogen for minutes

In November of 2010, the ALPHA collaboration at CERN's Antiproton Decelerator (AD) grabbed the world's headlines by trapping a handful of atoms of antihydrogen (*CERN Courier* January/February 2011 p7). The result demonstrated that it was, indeed, possible to produce trappable antihydrogen atoms. Now, the ALPHA team has shown that it can hold on to the trapped antiatoms for up to 1000 seconds and has succeeded in measuring the energy distribution of the trapped antihydrogen (ALPHA collaboration 2011).

Antihydrogen has been produced at CERN since 2002 by allowing antiprotons from the AD to mix with positrons in a Penning trap comprised of a strong solenoid magnet and a set of hollow, cylindrical electrodes for manipulating the particles. However, being neutral, the antiatoms are not confined by the fields of the Penning trap and annihilate in the apparatus. It has taken eight years to learn how to trap the antihydrogen, mainly because of the weakness of the magnetic dipole interaction that holds the antiatoms. The antihydrogen must be produced with a kinetic energy, in temperature units, of less than 0.5 K, otherwise it will escape ALPHA's "magnetic bottle". By contrast, the plasma of antiprotons used to synthesize the antihydrogen begins its time in ALPHA with an energy of up to 4 keV (about 50 million K).

The ALPHA antiatom trap consists of a transverse octupole magnet and two short solenoid or "mirror" coils – all fabricated at the Brookhaven National Laboratory (figure 1). This configuration produces a magnetic minimum at the centre of the device (*CERN Courier* March 2011 p13). Antihydrogen forms at the magnetic minimum and cannot escape if its energy is below 0.5 K. To see if there is any antihydrogen in the trap, the team rapidly shuts down the magnets (9 ms time constant). Any escaping antiatoms are revealed by their annihilation, which is registered in a three-layer, silicon vertex detector. In 2010, antiatoms were trapped for 172 ms, the minimum time necessary to make certain that no bare antiprotons remained in the trap, and the experiment detected 38 events consistent with the release of trapped antihydrogen.

The ALPHA team has subsequently worked to improve the trapping techniques,

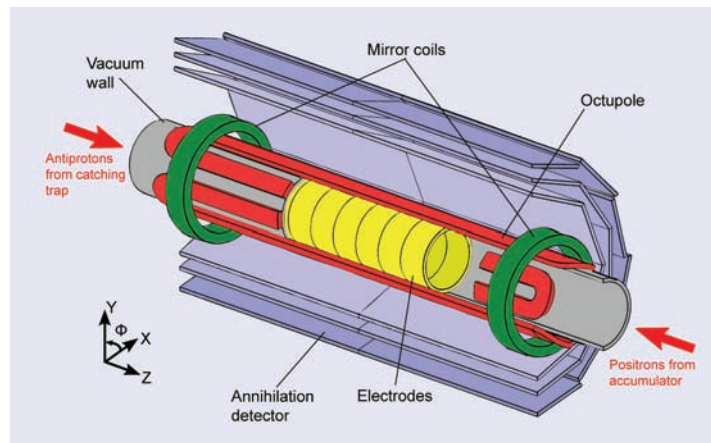


Fig. 1. Diagram of the ALPHA central apparatus showing the Penning trap electrodes, magnets for the atom trap and the silicon vertex detector.

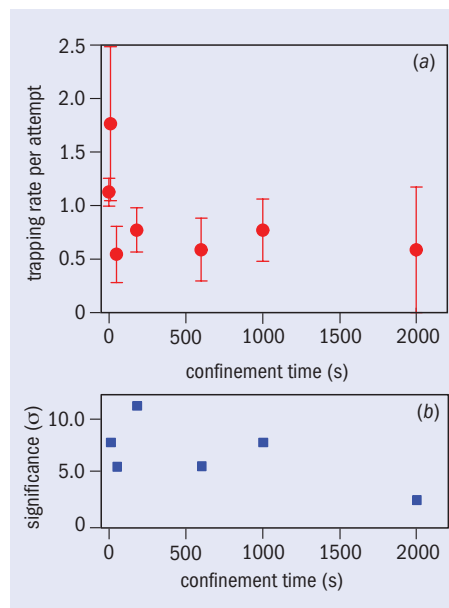


Fig. 2. a) The number of trapped antihydrogen atoms per attempt, as a function of confinement time. The error bars represent uncertainties from counting statistics only. b) The statistical significance of the observed signal against the (cosmic-ray) background-only hypothesis, expressed in terms of the number of Gaussian standard deviations for a one-sided limit. (The point for 0.4s ($\gg 20\sigma$) is off scale.) (ALPHA collaboration 2011.)

succeeding in particular in increasing by a factor of five the number of antiatoms trapped in each attempt; the total number trapped has now risen to 309. The improvements include the addition of evaporative antiproton cooling and optimization of the autoresonant mixing

that helps to produce the coldest-possible antiatoms. The team then made measurements in which they increased the time in the trap from 0.4 to 2000 s, yielding 112 detected annihilations in 201 attempts (figure 2). The probability that the detected events are background from cosmic rays is less than 10^{-15} (8σ) at 100s, and 4×10^{-3} (2.6σ) at 2000s. Calculations indicate that most of these trapped antiatoms reach the ground state – which is crucial for future studies with laser and microwave spectroscopy.

The distributions in space and time of the annihilations of the escaping antiatoms are already providing information about their energy distribution in the trap. This can be compared with a theoretical model of how the team thinks the antihydrogen is being produced in the first place.

The long storage time implies that the team can begin almost immediately to look for resonant interactions with antihydrogen – even if only one or two atoms occupy the trap at any given time. For example, resonant microwaves will flip the spin of the positron in the trap, causing a trapped atom to become untrapped, and annihilate. The ALPHA collaboration hopes to begin studies with microwaves in 2011, aiming for the first resonant interaction of an antiatom with electromagnetic radiation. In the longer term, the ALPHA2 device will allow laser interaction with the trapped antiatoms in 2012 – the first step in what the team hopes will be a steady stream of laser experiments with ever-increasing precision.

Further reading

ALPHA collaboration 2011 *Nature Physics*. doi:10.1038/nphys2025.

LHC EXPERIMENTS

ATLAS sheds light on new physics

Photons have an important role at the LHC, not only as tools for testing the Standard Model but also as heralds of new physics. The ATLAS collaboration has recently announced two measurements that in one case make use of photons as probes of QCD and in a second analysis use them to set limits on the production of the Higgs boson.

The production mechanism of photons in proton–proton collisions is sensitive to the density of the basic constituents within the colliding particles. This makes the measurement of their properties an excellent way to test the theoretical predictions of perturbative QCD, with a technique that is complementary to studies based on jets. One example is the new measurement made by the ATLAS collaboration of the inclusive production of isolated prompt photons.

The analysis uses the full 2010 data sample collected by ATLAS in LHC proton–proton collisions at 7 TeV, corresponding to an integrated luminosity of 35 pb^{-1} . The result extends the measurement of the cross-section up to a photon transverse momentum of 400 GeV (figure 1), thus covering a kinematic region similar to that achieved at Fermilab's Tevatron and by the CMS collaboration at the LHC. QCD calculations performed at next-to-leading order (NLO) predict cross-sections that are in good agreement with the measured data across five orders of magnitude. Below 25 GeV, where the NLO predictions are less accurate, the predicted cross-section is larger than that measured in the data.

Photons are also important signatures of new physics, a familiar example being the production of a Standard Model Higgs boson decaying into a photon pair. If nature has chosen the Standard Model

Higgs as the mechanism for electroweak-symmetry breaking, then about 10 000 Higgs bosons should already have been produced in ATLAS, assuming a light mass for the Higgs of about $120 \text{ GeV}/c^2$. In this mass region, the decay into two photons remains the most promising channel for discovery, despite the small branching ratio of about 0.2%.

Using an integrated luminosity of 209 pb^{-1} from the full 2010 data sample, and the first part of the data collected in 2011, the ATLAS collaboration has studied the di-photon invariant mass spectrum in the mass range 100–150 GeV/c^2 and looked for a possible excess of events that could be attributed to the decay of a new neutral particle. In this analysis, the different components associated to known processes were separated using the same data-driven technique as was used to measure the inclusive photon production cross-sections. The fluctuations observed in the di-photon invariant mass spectrum are compatible with the expected statistical fluctuations of the background. This translates into limits on the production cross-section of a Standard Model-like Higgs boson decaying into a pair of photons that range between 4 and 16 times the cross-section expected.

With the LHC delivering increasing amounts of data, both measurements are already set to improve.

● Further reading:

ATLAS collaboration 2011 *Phys. Rev. D* **83** 052005.

ATLAS collaboration 2011 ATLAS-CONF-2011-058.

CMS collaboration, <https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsQCD10037>.

ATLAS collaboration 2011 ATLAS-CONF-2011-085.

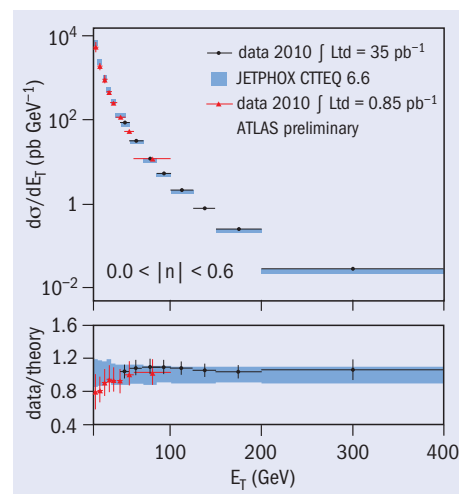


Fig. 1. Photon production cross-section as a function of the photon transverse energy. The recent ATLAS results (black points) are compared with a Monte Carlo prediction (blue bands) and to the first ATLAS photon results (red points). The lower plot shows the ratio of data to theory, demonstrating the good agreement of the predictions.

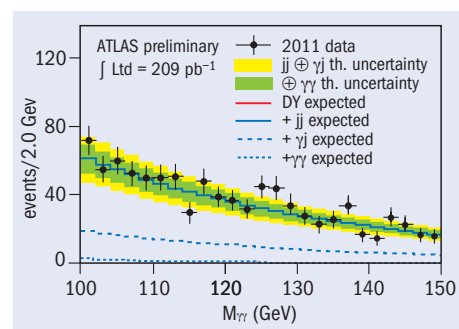


Fig. 2. Di-photon invariant mass spectrum in data (black) compared with empirical and theoretical expectations of the Standard Model backgrounds (blue/yellow bands).

ALICE and the charm of heavy-ion collisions

The ALICE collaboration has measured the production of the charmed mesons D^0 and D^+ in lead–lead collisions at the LHC. In central (head-on) collisions they find a large suppression with respect to expectations at large transverse momentum, p_t , indicating that charm quarks undergo a strong energy loss in the hot and dense state of QCD matter formed at the LHC. This is the first

time that D meson suppression has been measured directly in central nucleus–nucleus collisions.

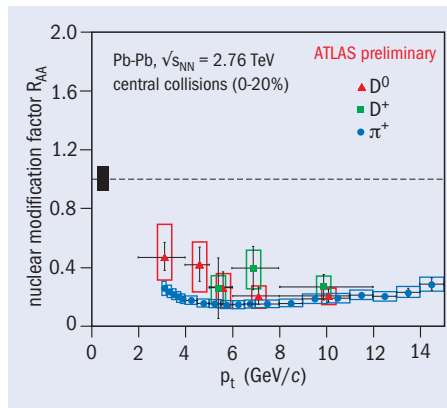
Heavy-flavour particles are recognized as effective probes of the highly excited system (medium) formed in nucleus–nucleus collisions; they are expected to be sensitive to its energy density, through the mechanism of in-medium energy

loss. The nuclear modification factor R_{AA} – the ratio of the yield measured in nucleus–nucleus collisions to that expected from proton–proton collisions – is well established as a sensitive observable for the study of the interaction of hard partons with the medium. Because of the QCD nature of parton energy-loss, quarks are predicted to lose less energy than gluons (which have

News

a higher colour charge); in addition, the so-called “dead-cone” effect and other mechanisms are expected to reduce the energy loss of heavy partons with respect to light ones. Therefore, there a pattern of gradually decreasing R_{AA} suppression should emerge when going from the mostly gluon-originated light-flavour hadrons (e.g. pions) to the heavier D and B mesons: $R_{AA}(\pi) < R_{AA}(D) < R_{AA}(B)$. The measurement and comparison of these different probes provides, therefore, a unique test of the colour-charge and mass dependence of parton energy-loss.

Experiments at the Relativistic Heavy Ion Collider at Brookhaven measured the suppression of heavy flavour hadrons indirectly in gold–gold collisions at 200 GeV through the R_{AA} of the inclusive decay electrons. Using data from the first lead–lead run at the LHC ($\sqrt{s_{NN}} = 2.76$ TeV), the ALICE collaboration has measured the production



Nuclear modification factor as a function of transverse momentum for D^0 , D^+ , and π^+ mesons in central lead–lead collisions at $\sqrt{s_{NN}} = 2.76$ TeV.

of prompt D mesons via the reconstruction of the decay vertex in the channels $D^0 \rightarrow K^-$

p^+ and $D^+ \rightarrow K^- p^+$. The results show a suppression of a factor 4–5, as large as for charged pions, above 5 GeV/c (see figure). At lower momenta, there is an indication of smaller suppression for D than for π mesons. Data with higher statistics, expected from the 2011 lead–lead run, will allow the collaboration to study this region with more precision and address this intriguing mass-dependence in QCD energy-loss.

The result implies a strong in-medium energy loss for heavy quarks, as also suggested by the suppression measured by the ALICE collaboration for electrons and muons from heavy flavour decays, and by the CMS collaboration for J/Ψ particles from B meson decays.

● **Further reading:**

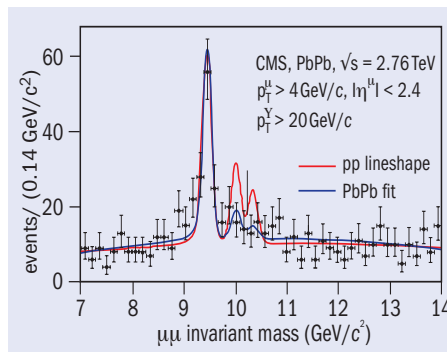
A Dainese *et al.* (ALICE collaboration) 2011 *Proceedings of Quark Matter 2011* arXiv:1106.4042 [nucl-ex].

CMS observes Υ suppression in lead–lead collisions

The heavy-ion collision data collected in November 2010 at the LHC continue to provide exciting new physics results. Recently, at the time of the Quark Matter 2011 conference, the CMS collaboration released the first results on the observation of a suppression of the excited Υ resonances in the lead–lead collisions at 2.76 TeV per nucleon pair. The suppression of heavy quarkonia is considered to be one of the “candle” signatures for the possible formation of a quark gluon plasma (QGP).

The Υ , a quarkonium system consisting of a bottom and an antibottom quark, exists in three states known as 1S, 2S and 3S, in decreasing order of how tightly the quarks are bound. The 1S is the ground state of the Υ , while the others are excited states. Because they are more loosely bound, the 2S and 3S states are less likely to survive in QGP matter. This means that the number of $\Upsilon(2S)$ and $\Upsilon(3S)$ particles observed relative to $\Upsilon(1S)$ in heavy-ion collisions is expected to be less than the corresponding numbers from proton collisions.

CMS studied pairs of muons that are part of the post-collision debris in the detector,



Comparison of the number of Υ produced in lead–lead collisions (blue line) and proton–proton collisions (red dashed line), showing the suppression of the excited Υ states (the smaller peaks). Note that a normalization factor was introduced to compare the results.

in which pairs of muons produced from the decays of particles such as the Υ will outnumber the pairs that are created by random processes. Thanks to the excellent momentum resolution of the CMS detector,

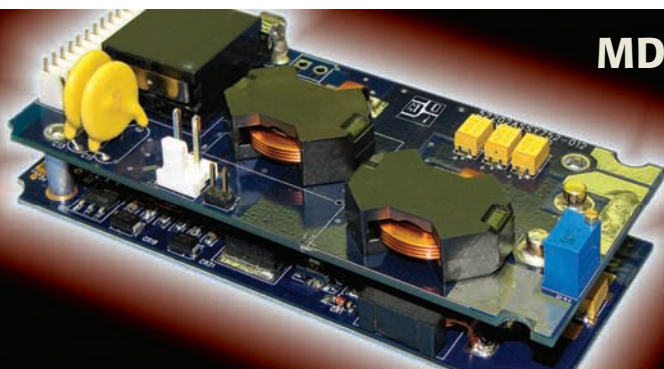
a spectrum can be produced from the masses of each pair, with clear peaks corresponding to the masses of the particles from which they decayed.

The results show a dramatic difference in the number of $\Upsilon(2S)$ and $\Upsilon(3S)$ produced in the heavy-ion and proton–proton collisions. From the data collected from both runs at 2.76 TeV, CMS has observed that the relative production of the excited states of the Υ particle in heavy-ion collisions is only about 30% that of the comparable rates from proton collisions, with an uncertainty of about 20% (see figure). The probability of obtaining the measured value, or a lower one, if the true double ratio of the heavy ion and proton results is unity, has been calculated to be less than 1%.

The CMS collaboration is looking forward to the next lead–lead run later this year when more data will allow study of the suppression of the excited Υ states with even higher statistics.

● **Further reading**

CMS collaboration 2011 arXiv:1105.4894 [nucl-ex], submitted to *Phys. Rev. Letts.*



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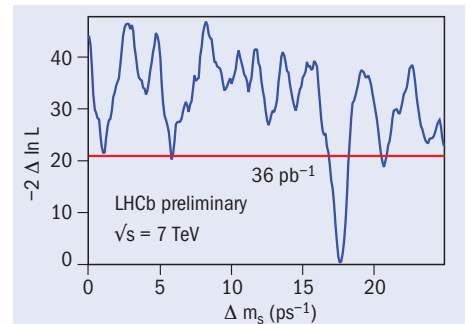
LHCb closes in on B_s oscillations

In analysing data from the 2010 running of the LHC, the LHCb collaboration has made some important measurements of the oscillation properties of B_s mesons.

In the B_s system, the B_s and the \bar{B}_s are mixtures of mass eigenstates that differ in mass by Δm_s and it is this difference that determines the frequency of the oscillations between the B_s and \bar{B}_s states. It also modifies the probability distribution for the proper time for B_s^0 decays. To measure Δm_s , the collaboration analysed some 1350 candidates for four decays of the kind $B_s^0 \rightarrow D_s^- \pi^+$ and $B_s^0 \rightarrow D_s^0 \pi^+$, which were selected from 36 pb^{-1} of data collected in 2010 at 7 TeV in the centre-of-mass. The team measured the proper decay times for these events, tagging them according to whether they corresponded to un-mixed or mixed decay, i.e. whether the production and decay flavour are the same or opposite, respectively. The preliminary result yields a result of $\Delta m_s = 17.63 \pm 0.11$ (stat.) ± 0.04 (syst.) ps^{-1} (LHCb collaboration 2011a). This is to be compared with the previous best

measurement in the world, from the CDF experiment at the Tevatron, of 17.77 ± 0.10 (stat.) ± 0.07 (syst.) ps^{-1} (CDF collaboration 2006).

The B_s can also decay to $J/\Psi\phi$, either by $B_s \rightarrow \bar{B}_s$ oscillation or directly, and the interference between these two decay modes gives rise to the CP-violating phase ϕ_s . The LHCb collaboration has made its first measurement of this phase using 836 $B_s \rightarrow J/\Psi\phi$ signal candidates from the same 2010 data sample used to determine Δm_s . In the Standard Model, ϕ_s is approximately equal to the angle $-2\beta_s$ from a unitarity triangle of the Cabibbo-Kobayashi-Maskawa matrix, and global fits to data give $-2\beta_s = (0.0363 \pm 0.0017)$ rad. The Tevatron experiments – CDF and DØ – have reported values for ϕ_s that are somewhat inconsistent with the Standard Model expectation, so this is a crucial measurement for LHCb. The first result from last year's data is consistent with the Tevatron results, but not yet as precise (LHCb collaboration 2011b). However, the LHCb experiment has already taken enough



The likelihood for Δm_s , shows the signal at 17.63 ps^{-1} . (The horizontal line is the likelihood for infinite mixing frequency.)

data this year to make a much more precise measurement, and will be able to clarify whether there is any sign of new physics in this decay.

● Further reading

CDF collaboration 2006 *Phys. Rev. Lett.* **97** 2423003.
LHCb collaboration 2011a LHCb-CONF-2011-005.
LHCb collaboration 2011b LHCb-CONF-2011-006.

FACILITIES

SuperB Factory set to be built at the University of Rome 'Tor Vergata'

Roberto Petronzio, president of INFN has announced that the SuperB Factory, will be built at the University of Rome 'Tor Vergata'. The facility tops the list of 14 flagship projects of the National Research Plan of the Italian Ministry for Education, Universities and Research (*CERN Courier* January/February 2011 p8).

The SuperB project involves the construction underground of a new asymmetric high-luminosity electron-positron collider. It will occupy approximately 30 hectares on the campus

of the University of Rome 'Tor Vergata' and be closely linked to the INFN Frascati National Laboratories, located nearby. The project, which will ultimately cost a few hundred-million euros, obtained funding approval for €250 million in the Italian government's CIPE Economic Planning Document. It has also attracted interest from physicists in many other countries. At the end of May, some 300 physicists from all over the world gathered on the island of Elba for a meeting that started the formal formation of the SuperB collaboration, a crucial milestone

on the road towards realization of the accelerator.

SuperB will be a major international research centre for fundamental and applied physics. The high design luminosity of $10^{36} \text{ cm}^{-2} \text{ s}^{-1}$ will allow the indirect exploration of new effects in the physics of heavy quarks and flavours through the studies of large samples of B, D and τ decays. The same infrastructure will also provide new technologies and advanced experimental instruments for research in solid-state physics, biology, nanotechnologies and biomedicine.

FELs

SACLA laser sets new record

RIKEN and the Japan Synchrotron Radiation Research Institute (JASRI) have successfully produced a beam of X-ray laser light with a wavelength of 0.12 nm. This was created using the SPring-8 Angstrom

Compact free electron LASER (SACLA), a cutting-edge X-ray free-electron laser (XFEL) facility unveiled by RIKEN in February 2011 in Harima. It opens a window into the structure of atoms and

molecules at a level of detail never seen before.

One of only two facilities in the world to offer this novel light source, SACLA has the capacity to deliver radiation one billion

News

times brighter and with pulses one thousand times shorter than other existing X-ray sources. In late March, the facility marked its first milestone, accelerating beam to 8 GeV and spontaneous X-rays produced at 0.08 nm.

Only three months later, SACLA has marked a second milestone. On 7 June,

operators successfully increased the density of the electron beam by several hundred times and guided it with a precision of several micrometres to produce a bright X-ray laser with a wavelength of only 0.12 nm (a photon energy of 10 keV). This matches the record of 0.12 nm set at the only other operational XFEL facility in the

world, the Linac Coherent Light Source at SLAC (*CERN Courier* December 2010 p17).

With experiments soon to commence and user operations at the facility to begin by the end of fiscal year 2011, this new record offers a taste of things to come with SACLA's powerful beam.

ACCELERATORS

EuCARD reviews progress at annual meeting

The second annual meeting of the European Co-ordination for Accelerator Research and Development (EuCARD) project took place on 11–13 May at the headquarters of the Centre National de Recherche Scientifique in Paris, attended by more than 120 participants. EuCARD is a four-year project co-funded by the European Union's Framework Programme 7 and involves 37 European partners (*CERN Courier* November 2009 p16).

Among the many results and issues discussed was the progress of the engineering design for a 13 T niobium-tin (Nb_3Sn) dipole. The first results on its high-temperature superconductor coil insert showed the need for a second iteration; the Nb_3Sn undulator also requires optimization with respect to instabilities. New materials have been identified for more robust collimators; intelligent collimators for the LHC and cold collimators for the Facility for Antiproton and Ion Research

are undergoing beam tests.

Linear collider technologies are on the move as well and new findings were reported on the origin of breakdowns in cavities. Stabilization to below 0.5 nm at 1 Hz has been demonstrated and there have been advances in instrumentation and femtosecond synchronization. Several superconducting bulk or coated cavities are in either final design, construction or test stages. These include crab cavities for both the LHC and the Compact Linear Collider study. Finally, novel concepts are progressing, including the new crab-waist crossing being tested at DAFNE, the commissioning of EMMA (the fixed-field alternating gradient machine at Daresbury) and the emittance measurement of tiny laser-driven, plasma-accelerated beams.

The networking activities in neutrino facilities, accelerator performance and RF technologies have confirmed their efficiency as exchange platforms. They

have made the case for their expansion in the EuCARD2 proposal, which is under preparation and will be submitted by November 2011. Transnational access to the UK Science and Technology Facilities Council's MICE facility (precision beams and muon-ionization cooling equipment) is continuing. HiRadMat at CERN, which offers pulsed irradiation, will open this autumn. Potential external users can benefit from financial support from the European Commission.

This year, the meeting dedicated one day to accelerator research and development in France, as well as to topics outside the scope of EuCARD, including the SuperB project (p9), neutrino facilities and Siemens medical accelerators. There was also a visit to the large accelerator platforms at the Institut de Physique Nucléaire d'Orsay and CEA-Saclay.

For further details about the EuCARD project, see <http://cern.ch/EuCARD>.

New European novel accelerator network formed

The European Network for Novel Accelerators (EuroNNAc) was formally launched at a workshop held at CERN on 3–6 May as part of the EuCARD project. The aim was to form the network and define the work towards a significant Framework Programme 8 proposal for novel accelerator facilities in Europe.

The workshop was widely supported, with 90 participants from 51 different institutes, including 10 from outside Europe, and had high-level CERN support, with talks by Rolf Heuer, Steve Myers and Sergio Bertolucci. There were also contributions from leading experts in the field such as Gerard Mourou of the Institute Lumiere Extreme and Toshi

Tajima of Ludwig Maximilians Universität, two senior pioneers in this field.

The field of plasma wakefield acceleration, which the new network plans to develop, is changing fast. Interesting beams of 0.3–1 GeV, with 1.5–2.5% energy spread, have now been produced in several places including France, Germany, the UK and the US, with promising reproducibility. Conventional accelerator laboratories are now interested to see if an operational accelerator can be built with these parameters. To avoid replication of work, a distributed test facility spread across many labs is envisaged for creating such a new device.

If a compact, 1 GeV test accelerator were pioneered, it could be copied for use around the world. Possible applications include tests in photon science or as a test beam for particle detectors. This could ease the present restrictions on beam time experienced by many researchers. These developments are currently being restricted

to electron accelerators because they can be useful even when not fully reliable. Proton machines for medical purposes would, however, need to be more reliable.

In addition to the R&D aspects, the network discussed plans to create a school on Conventional to Advanced Accelerators – possibly linked to the CERN Accelerator School – and to establish a European Advanced Accelerator Conference.

The network activities will be closely co-ordinated with the TIARA and ELI projects (*CERN Courier* June 2011 p28 and March 2009 p21). There is currently high funding support for laser science in Europe – about €4 billion in the next decade. EuroNNAc will help in defining the optimal way towards a compact, ultra-high-gradient linac. CERN will co-ordinate this work with help from the École Polytechnique and the University of Hamburg/DESY.

For further information, or to express an interest in participating, please contact Ralph Assmann, euronnac.coordination@cern.ch.

LIGHT SOURCES

NSRRC commissions linac system for new photon source

Only four months after the crates containing parts of the new electron linac system touched ground at the test site, the National Synchrotron Radiation Research Center (NSRRC) completed the commissioning of the linac system for its second synchrotron light source facility, the Taiwan Photon Source (TPS), on 6 May.

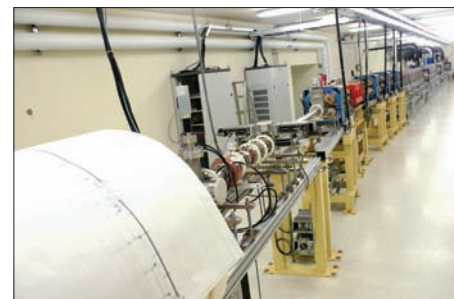
This is a major milestone in a challenging project that has had to contend with waves of worldwide recession, turbulent inflation, price fluctuations for raw materials, and unforeseen obstacles in civil construction. The contract to design and manufacture the single turn-key system, with a minimum output energy of 150 MeV, was awarded to RI Research Instruments GmbH, Germany, in November 2008. The basic design parameters stipulated 2997.924 MHz (S band) radio frequency, pulse duration of 1 ns and 200–1000 ns for short and long pulses respectively, and a maximum repetition rate of 5 Hz. The linac consists of an electron gun, a focusing and bunching section, and an accelerating section. The electron gun is capable of providing pulsed nanosecond electrons with an energy of 90 keV. Once produced, the electrons are further focused, longitudinally bunched and transferred to the 20-m long accelerating section. This has three acceleration structures equipped with three high-power microwave amplifiers, in which the electrons are accelerated to 150 MeV.

The linac is the first TPS subsystem to require many supporting subsystems in order to proceed in its testing. During the development, various unexpected situations were encountered and steps were taken to deal with them; these included the availability of the test site ahead of the completion of the building for the TPS storage ring. The establishment of a full-scale linac test site placed an additional workload on the TPS construction teams.

The construction of the linac test site and



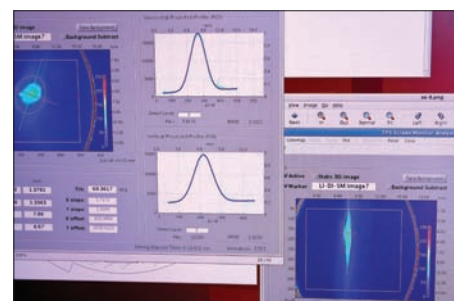
The linac system for the TPS, with the gun and bunching sections.



The linac system and diagnostic beamline sections. (Image credits: NSRCC.)

the process to obtain operating permission from the Atomic Energy Committee occupied the last four months of 2010. In January 2011, the TPS subsystem teams moved in and began working around the clock to set up the facility. Later they joined forces with the engineering teams from RI Research Instruments GmbH to install and test the linac. The effective collaboration between the different teams was a key factor in the smooth and successful commissioning of the linac. Having the TPS linac system up and running opens a number of channels for engineers to test their systems, especially those developed in house by the NSRRC staff including the control and instrumentation group.

The design of the linac system by the four-member linac team began in the spring of 2006 and by June 2008 it was made available for an open bid to vendors worldwide. In November 2008, the project was awarded to ACCEL Instruments GmbH (acquired by Bruker Energy & Supercon Technologies Inc in 2009). This gave RI Research Instruments GmbH, a spin-off division from ACCEL, 27 months to prepare the complete system for commissioning with beam. After the first parts arrived at the linac test site in January 2011, the TPS linac team geared up to prepare for the acceptance test. The intense schedule put linac staff on a 24-hour shift to work on the



Screens show profiles of the linac beam.

project, in particular on the high-power RF conditioning of the accelerating structures. This effort reached a conclusion on 5 May, with an output energy greater than 150 MeV and measurement of the major beam parameters.

The TPS will be equipped with a 3 GeV electron accelerator, 518.4 m in circumference, and a low-emittance synchrotron storage ring. As part of the major advanced scientific research projects under the National Science Council, the TPS is being built next to the NSRRC's first light source, Taiwan Light Source (CERN Courier June 2010 p16). The first official proposal of the TPS was submitted to governmental authorities in 2006 and the official ground breaking of TPS civil construction began on 7 February 2010.

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.

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Sciencewatch

COMPILED BY JOHN SWAIN, NORTHEASTERN UNIVERSITY

Biological cells bring laser to life

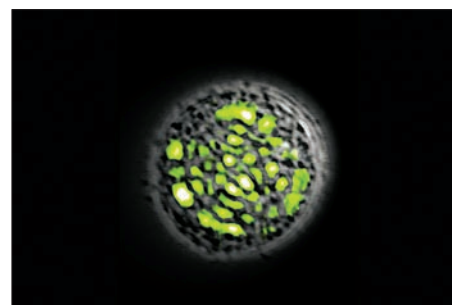
The latest in the ever-growing list of things that can be made to exhibit laser action is a single living cell. Malte C Gather and Seok Hyun Yun of the Wellman Center for Photomedicine, Massachusetts General Hospital in Boston (and other affiliations), genetically engineered human kidney cells to express green fluorescent protein (GFP). GFP, derived from a jellyfish, is often used as a marker in cell biology, but only via its incoherent fluorescence.

To make a laser, the researchers placed the cells one at a time between tiny mirrors each just 20 μm across. On illumination with blue

light, the cells became tiny lasers, emitting an intense green beam. The cells remain alive throughout the lasing process and in fact, as living things, constitute a self-healing laser, in that if GFPs are destroyed the cell will just make more. The work opens new possibilities for imaging where amplification of signal light could take place inside a biological system rather than in external devices.

● **Further reading**

Malte C Gather and Seok Hyun Yun 2011 *Nature Photonics*. doi:10.1038/nphoton.2011.99.



Genetic engineering leads to a living laser. (Image credit: Nature Photonics and the Wellman Center for Photomedicine.)

How round is the electron?

The typical mental image that many people have of an electron is as a spherically symmetric, spinning point charge. However, if an electron has an electric dipole moment (edm), this would represent a distortion of the usual image and the sphere would have to be thought of as stretched into an ellipsoid. Now, J J Hudson and colleagues of Imperial College, London, have set the lowest limit so far on such an edm, using ultracold molecules of ytterbium fluoride; the edm of the molecule reflects any possible dipole moment of an unpaired electron.

The team made the measurement using an interferometric technique, in which external electric and magnetic fields make two states that differ in energy by an amount proportional to the electron edm. The limit obtained, which is the world's best, is now less than 10.5×10^{-18} e.cm. The scales for any new physics involved are comparable to the tera-electron-volt scale and could spell trouble for supersymmetry, which typically predicts a non-zero value in this range. Plans are underway to improve this result by a factor of 10.

● **Further reading**

J J Hudson *et al.* 2011 *Nature* **473** 493.

Full spectrum tunable LED

Standard LEDs light up in just one colour, but now in a remarkable breakthrough Gyu-Chul Yi of Seoul National University and colleagues have demonstrated an LED that can be tuned continuously from red to blue. The device is based on gallium

nitride nanorods coated with layers of indium gallium nitride to form quantum wells – effectively, tiny artificial atoms. The thicknesses of the layers vary naturally when they are produced and, by changing the applied voltage, current can be pushed through different layers, giving rise to different colours of emitted light. The implications for display technology are as obvious as they are amazing.

● **Further reading**

Young Joon Hong *et al.* 2011 *Advanced Materials* online. doi: 10.1002/adma.201100806.



A specific protein makes a queen bee, as opposed to a worker bee. (Image credit: Ibezzeb/Dreamstime.com.)

The protein that makes a queen

Honey-bee larvae become queen bees if fed “royal jelly”, and now Masaki Kamakura of Toyama Prefectural University in Imizu, Japan, has found out how. Noting that royal jelly loses its effectiveness over time, he studied each component that could decay and identified a single, specific

The physics of venomous snake bites

“Hydrodynamics of reptilian envenomation” is part of the title of a recent paper by Bruce A Young of the University of Massachusetts, and colleagues. They studied why it is that in the majority of venomous snakes, venom is conveyed via an open groove on the fang rather than through a channel down the middle in the style of a hypodermic syringe.

Their key insight is that surface tension and non-Newtonian behaviour of venom – which they measured for the western diamondback rattlesnake and the red spitting cobra – play a dominant role. Venom can be held ready in the groove while the snake waits for its prey, and then once the snake has bitten, surface tension pulls the venom along the “tube” formed by the channel and the victim’s flesh.

● **Further reading**

Bruce A Young *et al.* 2011 *Phys. Rev. Letts.* **106** 198103.

protein – dubbed “royalactin” – that plays the role of queen-maker.

Royalactin works by switching on a gene, *Egfr*, found throughout the animal kingdom. So it seems likely that bee colonies started out “casteless” and only later developed queens and workers using a pre-existing signalling pathway.

● **Further reading**

M Kamakura 2011 *Nature* **473** 478.

Astrowatch

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

Swift witnesses a black hole devouring a star

Follow-up observations of an apparently normal gamma-ray burst (GRB) detected by NASA's Swift satellite have identified the event as a star being ripped apart by a massive black hole in a distant galaxy. Two articles in *Science* report on the observational investigations and the physical interpretation of this rare sight.

On 28 March 2011 at 12.57 UT, an outburst of gamma rays was detected by the Burst Alert Telescope (BAT) on the Swift satellite. Called GRB 110328A, the GRB looked like one of the hundreds that Swift has already detected since its launch in November 2004 (*CERN Courier* December 2005 p20). As always, the satellite pointed its narrow-field optical and X-ray telescopes towards the transient source to observe the decline of the GRB afterglow within minutes to hours (*CERN Courier* October 2005 p11, May 2007 p11). This time, however, the source remained bright and highly variable, with repeated outbursts triggering the BAT three more times in 48 hours. As the days passed with no major decline in X-rays, it became obvious that this source was not a usual GRB and it was thus dubbed Sw 1644+57.

Astronomers had begun ground-based follow-up observations soon after the burst. In one of the reports in *Science*, Andrew Levan of the University of Warwick and collaborators tell the detective story involved in the identification of the event. While the Gemini-North Telescope in Hawaii had poor weather conditions two hours after the burst, 11 hours later the Nordic Optical Telescope on La Palma in the Canary Islands detected



Artist's impression of the star about to be ripped apart by the black hole. (Image credit: University of Warwick/Mark A Garlick.)

a faint galaxy at the position of the burst. Subsequent spectroscopic observations determined a redshift of 0.35, indicating that the source is nearly four thousand million light-years away. The unusual characteristics of the event awoke the curiosity of the Hubble Space Telescope, which was able to pinpoint it to the very centre of the remote galaxy – a finding confirmed in radio observations by the Very Large Baseline Array.

Could the object be a quasar? Archival data show no sign of nuclear activity in this relatively small galaxy and, furthermore, the luminosity released by the event exceeds by a factor of 100 the flares from the most powerful active galactic nuclei. So what else can release the energy equivalent to 10% of the rest mass of the entire Sun in less than two weeks? A possibility is the disruption and swallowing of a star venturing too close to the event horizon of a black hole. At least

this is the conclusion reached by Joshua Bloom of the University of California, Berkeley, and colleagues, although they admit that Sw 1644+57 initially displayed none of the theoretically anticipated – nor observed – characteristics of such an event.

The poor observational and theoretical knowledge of tidal-disruption flares is a consequence of their rarity: they should occur only about 1 to 10 times every 100 000 years in a given galaxy (*CERN Courier* April 2004 p12). Because such an event would be so unlikely, theorists did not consider that a putative jet emitted from the black hole devouring a star would point right towards Earth. As unlikely as it seems, J Bloom and collaborators found strong evidence that this had to be the case for Sw 1644+57 because the observed luminosity would be too high for the inferred mass of the black hole – below 10 million solar masses – if it were not enhanced by relativistic beaming in a jet aligned with the line-of-sight. So everything points to the disruption of a star that has swiftly turned a dormant black hole into a luminous blazar (see, for example, *CERN Courier* June 2006 p14). The source was restless for the three following weeks, and so were the scientists who eagerly had to write the two papers and submit them jointly to *Science* on 18 April 2011!

● Further reading

A J Levan *et al.* 2011 *Science Express*. doi: 10.1126/science.1207143.

J S Bloom *et al.* 2011 *Science Express*. doi: 10.1126/science.1207150.

Picture of the month

This rare view of a space shuttle docked to the completed International Space Station (ISS) – with its impressive solar panels – gives a good idea of their relative sizes. Who took this picture? An astronaut floating around the ISS? Not quite, it was by astronauts leaving the ISS on 23 May 2011 in a Russian Soyuz TMA-20 supply ship, before landing in Kazakhstan the same day, after 159 days in space. The picture was taken during the penultimate shuttle flight, just four days after astronauts aboard the *Endeavour* successfully installed the Alpha Magnetic Spectrometer onto the ISS (p18). (Image credit: NASA.)



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Gianluca Chiozzi, Head of the Control and Instrumentation Software Department (ESO)

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A LOOK BACK TO CERN COURIER VOL. 8, JULY/AUGUST 1968, COMPILED BY PEGGIE RIMMER

NEWS FROM ABROAD

International Centre for Theoretical Physics

During the three weeks of 7–29 June, about 350 leading physicists from countries throughout the world gathered at the International Centre for Theoretical Physics (ICTP) in Trieste, Italy, for a major symposium to inaugurate the fine new building which has just become its permanent home.

Professor Abdus Salam, director of ICTP, described the aim of the meeting: “to review the whole spectrum of modern theoretical physics, to share the insights of different disciplines and to acquire, if possible, a deep sense of the scope and unifying nature of the subject.” Among the participants were Nobel prize winners MA Bethe, FC Crick, P A M Dirac, W Heisenberg, CH Townes, TD Lee, J Schwinger and EP Wigner.

In 1960 Professor Salam proposed the creation of ICTP to the International Atomic Energy Agency, a subsidiary body of the United Nations, particularly to help theoretical physicists from developing countries. Salam conceived the Centre as a place where scientists could come for brief periods to sharpen their minds by working alongside the most distinguished men in physics. The policy is to avoid specialization in any given area of theoretical physics and to be strictly inter-disciplinary. A major feature of each academic year is a blitz on particular topics during extended seminars (lasting four to ten weeks), when many scientific big guns are brought together at the Centre to bombard a specific problem.

In achieving his aim, Salam has had the invaluable help of Professor Paulo Budini,



Professor Abdus Salam, director, in discussion during the International Symposium on Contemporary Physics at the ICTP. (Image credit: Photos Rice, Trieste.)

who has been instrumental in securing the extensive support of the Italian government and the city and university of Trieste, which has been the mainstay of the Centre up to now.

- Compiled from texts on pp159–160.

LAMPF Users Meeting

On 20 June, the first Users Meeting for the Los Alamos Meson Physics Facility was held at the Los Alamos Scientific Laboratory; more than 100 scientists from outside the Laboratory attended. LAMPF will be a national facility with experimental time shared about equally between teams based at Los Alamos and teams from Universities and research centres throughout the USA.

LAMPF is an 800 MeV-proton linear accelerator to provide 1 mA average beam current with a 6–12% duty-factor. It will

produce meson beams about 10 000 times more intense than those at present available at comparable energies.

The construction schedule aims for a beam by July 1972; Dr L Rosen, leader of the project, reviewed progress. The injector components are well advanced. An acceptable ion source has been built and a 750 kV power supply is on order. The linac section to take the beam to 100 MeV, using a drift-tube structure, is also well in hand. The copper-clad steel is ordered and prototypes of the drift-tubes, quadrupoles and r.f. power supplies are coming together. The linac section for energies above 100 MeV will use the new concept of side-coupled cavities. An electron model (24 MeV, 1 mA) is working very well and is being used to identify any problems due to heavy beam loading and to develop a computer-based control system.

Dr Rosen concluded with what he called an “Orson Welles type of remark”: “Within the next five years, changes in computer technology may bring new management problems. Remote data links between an on-line computer at the site and a group 2000 miles away would allow a user some degree of participation in running an experiment without actually being close to his equipment. This might offer some real advantages, especially if one can transmit visual displays as well as voice and printed messages. We may yet have to worry about how much importance one attaches to suggestions relating to the strategy for an experiment in progress, made miles from the experimental site and perhaps while the strategist is sipping martinis.”

- Compiled from texts on pp190–191.

Compiler's Note



In 1954, Abdus Salam, himself to become a Nobel Laureate in 1979, was faced with the heartbreak of having to leave his own country, Pakistan, to pursue a research career in theoretical physics. Contrary to criticism that theoretical physics is the “Rolls Royce of sciences” and developing countries needed only bullock carts, Salam believed that such work – actually requiring no expensive equipment – was an obvious way to build up pure science in those countries. And, indeed, for almost half a century ICTP has been a major force in advancing scientific expertise in the developing world and stemming the brain drain from these regions.

With the first e-mail still three years in the future, Louis Rosen at LAMPF had almost 20/20 foresight of the shape of things to come in communications technology. Less clear, is whether his managerial misgivings were due mainly to a potential remoteness of physicists from experiments or proximity to drinks' cupboards!



Excavation work for the Los Alamos Meson Physics Facility, on a finger-shaped mesa bordered by canyons to the north and south. (Image credit: Photo Los Alamos.)

RENEWABLE ENERGY

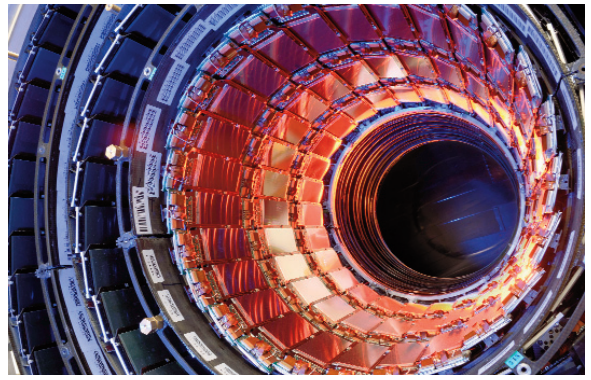


Thermonuclear fusion is one of the few truly sustainable forms of energy for the planet that will probably be available in the mid to long term. It is a technology that offers the prospect of safe, environment-friendly operation, combined with excellent fuel availability and procurement security.

ITER (originally an acronym for the International Thermonuclear Experimental Reactor, now used in the Latin sense of "itinerary") is an international project that will demonstrate the feasibility of a nuclear fusion reactor able to reproduce the physical phenomenon that occurs in stars in controlled conditions, for the purposes of generating clean energy in the future without the collateral effects typical of current fission technology (waste, contamination risk).

FUSION SUPERCONDUCTIVITY

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LHC HIGH ENERGY PHYSICS

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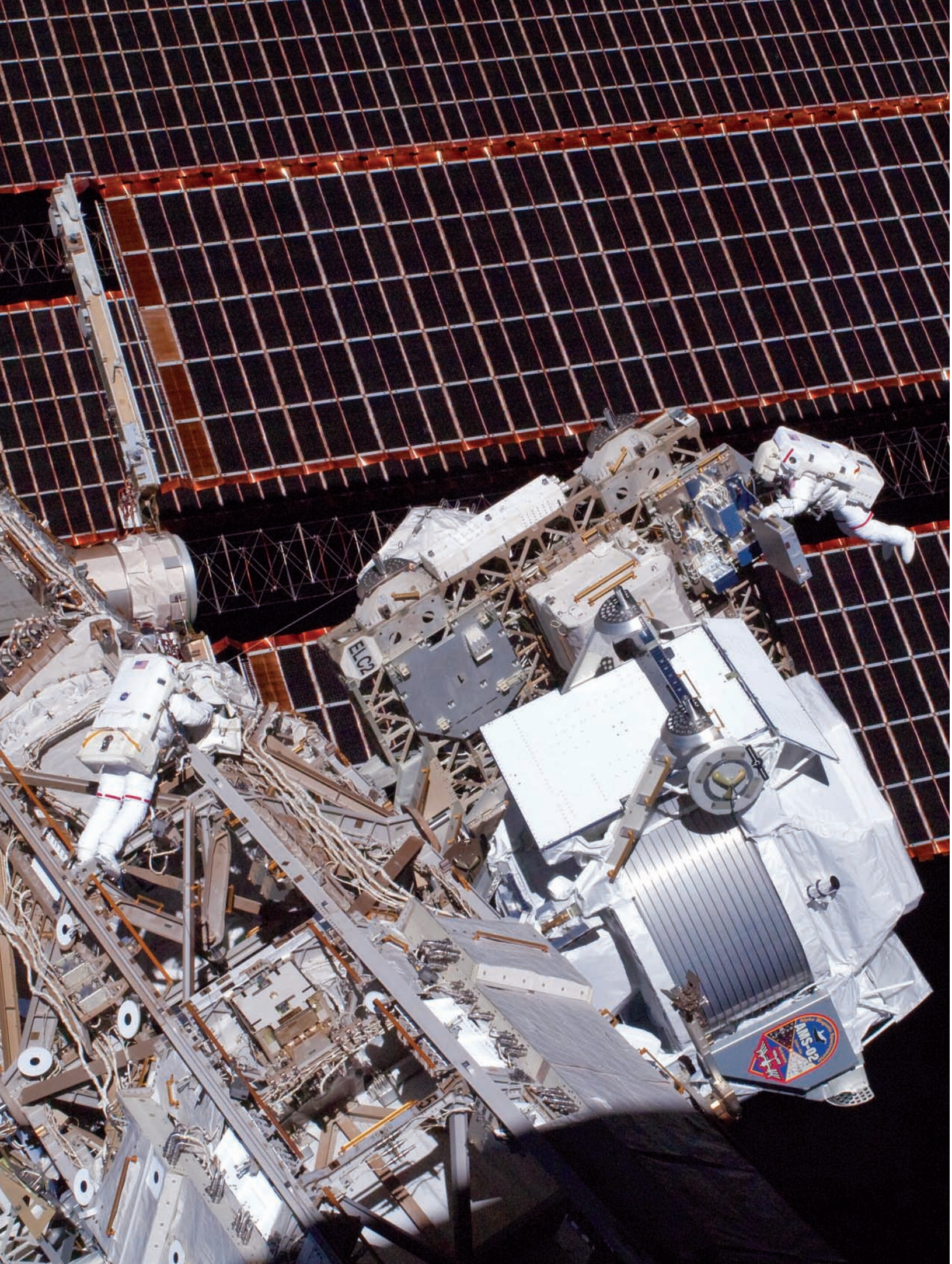
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AMS: the search for exotic matter goes into space

For the first time, a particle-physics detector will study cosmic rays from beyond the Earth's atmosphere in an experiment lasting many years. Aboard the International Space Station, the Alpha Magnetic Spectrometer (AMS-02) is seeking clues about both antimatter and the "dark side" of the universe.

25 May 2011, 08:56 EDT: The *Endeavour* space shuttle takes off for its final trip into space. In its payload bay, it is carrying the Alpha Magnetic Spectrometer (AMS-02), a large particle detector. For the 600 physicists and engineers who have been working on the AMS project for more than 15 years, it is a fantastic accomplishment, but the real excitement is only just beginning. Two days after take off, *Endeavour* will reach the International Space Station (ISS), where AMS-02 is installed. From this vantage point in space, the advanced detector will catch the tracks of cosmic rays for years to come.

Cosmic messengers

The Big Bang that gave rise to the universe about 13.7 billion years ago should have produced particles and antiparticles in equal amounts, as indeed happens in experiments at particle accelerators. So why is there no evidence of antimatter in the universe? This is one of the big questions of modern physics – one that the international AMS collaboration, led by Nobel laureate Sam Ting, is seeking to address. The mission will also join the search for dark matter in the universe and gather information on sources of cosmic rays.

Cosmic rays are energetic particles from outer space. Protons and the nuclei of helium together represent about 99% of the spectrum, while the remaining 1% is composed of heavier nuclei and electrons. The details of their origins remain unknown but they are probably produced in different cosmic objects, especially the most violent, such as supernova remnants. The sources must be powerful natural accelerators – more powerful than any achievable in laboratories on Earth.

Opposite: Astronauts inspect the installation of AMS-02 on the ISS. (Image credit: NASA.)

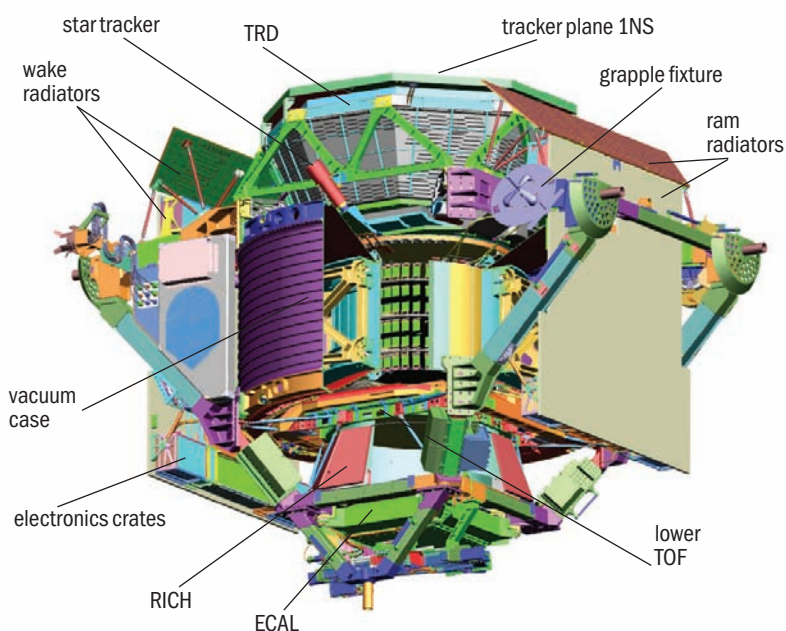


Fig. 1. The various particle detectors on board AMS-02.

AMS-02 is the first large magnetic spectrometer to fly into space for a long period of time, following on from its prototype, AMS-01, which flew aboard the space shuttle *Discovery* for 10 days in June 1998 (*CERN Courier* June 1999 p6 and July 1999 p16). It will allow the cosmic-ray spectrum to be measured with high precision. Such precise measurements are possible only from space, because the cosmic rays that bombard the Earth interact with the atmosphere. At the Earth's surface it is possible to detect only the cosmic-ray showers that they produce, as the Pierre Auger Observatory in Argentina does, for example (*CERN Courier* July/August 2006 p12). The magnetic fields in space mean that it is impossible to deduce the location of any source of the primary charged particles by measuring their direction. However, determining the composition of the cosmic rays precisely is a key to knowing where they come from. All of the natural elements are present in cosmic rays in approximately the same ratio as in the Solar System, so detailed differences could reveal crucial information about the nature of their source – rather like fingerprints – and make it possible to identify the sources indirectly.

The requirements for operating in space are challenging and AMS-02 has been designed specially for this hostile environment. It has to resist vibrations and large temperature variations; it ▷

Astroparticle physics



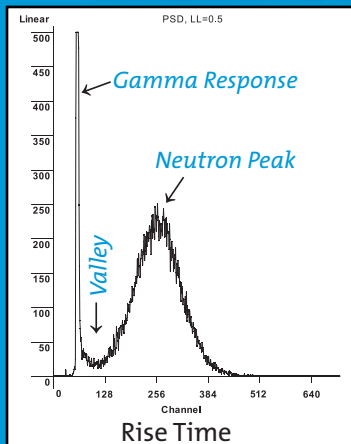
Working on AMS-02 in a clean room at CERN in July 2010.

must operate in the vacuum of space and in the absence of gravity. In addition, the electronics have to be resistant to radiation. Other vital constraints also had to be considered in designing the detector, such as its weight and electrical consumption, both of which were strictly limited.

At the heart of AMS-02 is a powerful, permanent magnet that bends charged particles and antiparticles in opposite directions. This “magic ring” is designed specifically to ensure that the magnet has a negligible net dipole-moment, so avoiding a coupling with the Earth’s magnetic field that would otherwise disturb the orbit of the ISS. Around this magnet, several layers of detectors work together to identify particles passing through (figure 1, p19). The silicon tracker measures the trajectory deflection of charged particles, the ring-imaging Cherenkov (RICH) detector estimates their velocity and the electromagnetic calorimeter (ECAL) measures their energy. In addition, the transition radiation detector (TRD) identifies light particles by the detection of the X-rays that they emit. The time-of-flight (TOF) system acts as a trigger, alerting the subdetectors to an incident cosmic ray. An anti-coincidence counter was also developed to sort the events in real time, rejecting cosmic rays traversing the magnet walls and keeping the significant ones that really cross the overall detector. As a whole, AMS-02 is able to digitize 300 000 channels of data some 2000 times a second.

AMS-02 can recognize one antiparticle among a billion particles. This represents an increase in sensitivity of three orders of

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CERN and AMS: a success story

The CERN convention mentions cosmic rays in its list of scientific interests. So it is not by chance that CERN is involved in the AMS experiment, even if it is not a CERN experiment in exactly the same way that the LHC experiments are.

CERN played a major role in making AMS happen. Where else could an international collaboration involving 14 countries – mainly from Europe – prepare such a particle detector? CERN is accustomed to managing large projects and it was therefore natural that it provided support for the AMS collaboration.

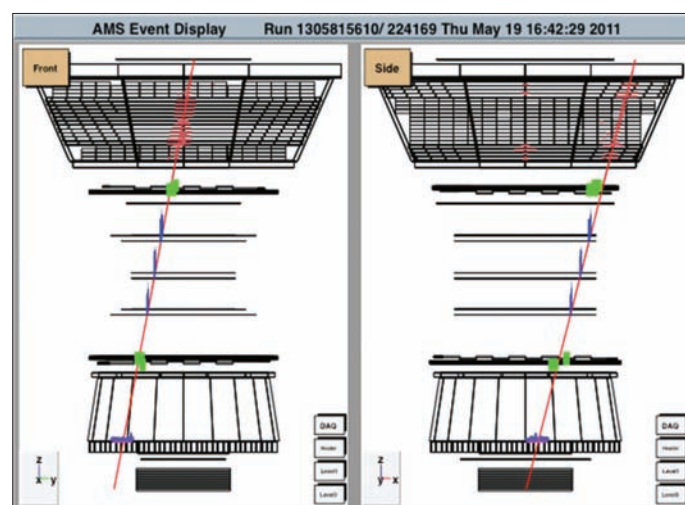
AMS is a CERN “recognized experiment” and has benefited from using the organization’s infrastructures and support for many years. A dedicated clean room, for instance, was built at CERN for assembling AMS-02 and the detector was calibrated at the laboratory’s test-beam facilities, to simulate the flux of cosmic rays. Last but not least, the AMS scientific operation centre will soon be inaugurated at CERN.

magnitude in comparison with previous experiments. With such precision, the detector will provide the composition of the cosmic-ray spectrum with unprecedented accuracy. This will enable the AMS collaboration to find either an explanation for the disappearance of antimatter or proof of its existence hidden away in a remote corner of the universe. The observation of just one antihelium nucleus would provide evidence for the existence of a large amount of antimatter somewhere in the universe – large enough for antiprotons to have undergone a process of nucleosynthesis. This matter could only have been generated soon after the Big Bang and would represent a real breakthrough in the current view of the universe.

Antiworlds and the dark universe

There are other puzzles about the universe that AMS can try to solve. Only 4% of the universe is accessible to telescopes and detectors through the radiation that it emits. The rest appears to be in the forms known as dark matter and dark energy, which account for about 23% and 73%, respectively, of the total matter and energy in the universe. In this case, AMS-02 is expected to play a key role by tracking possible signals from the annihilation of supersymmetric particles. One of the candidates for a dark-matter particle is the neutralino, a hypothetical particle that is predicted by supersymmetry. If neutralinos do indeed exist they could interact with each other, producing excesses of charged or neutral particles – creating anomalies in the overall cosmic-ray spectrum.

For this reason, AMS-02 has been eagerly awaited because it will probably be the only experiment able to confirm or invalidate results from other experiments that have recently been in the spotlight. In particular, two satellites, PAMELA and FERMI, as well as the ATIC balloon experiment flown above Antarctica, have all reported an excess of electrons and positrons in the cosmic-ray spectrum. Even though these different measurements are inconsistent with each other, they could all possibly fit with the scenario of dark-matter annihilation. Using a completely different approach, underground experiments such as Xenon, CDMS or Edelweiss, are currently providing strong competition in the



One of the first events seen by AMS-02, collected only moments after the detector was activated on 19 May. The particle is identified as a 42 GeV carbon nucleus. (Image credit: AMS-02.)

detection of dark-matter particles. Moreover, in parallel the LHC is producing data that could in the next two years provide the first exciting news on dark matter.

Particle physics, astroparticle physics and cosmology are certainly at a key moment in their history as AMS-02 enters the race. “Better to light a candle than to curse the darkness,” goes a Chinese proverb. All eyes are now focused on the AMS-02 experiment, hoping that it will precisely light the candle on both the dark universe and the antiuniverse.

AMS was built by an international collaboration involving large European participation from France, Germany, Italy, the Netherlands, Spain and Switzerland, together with China, Taiwan, Russia and the US. It has been supported by the national high-energy institutes INFN, IN2P3, CIEMAT, the US Department of Energy, Academia Sinica (Taipei), Swiss National Fund, and by the space agencies ASI, DLR, NASA, and ESA. The detectors were integrated at CERN by the collaborating groups. Space qualification was at the ESTEC facilities in ESA.

Résumé

Le 25 mai 2011 décollait à bord de la navette spatiale Endeavour le Spectromètre magnétique alpha: AMS-02

AMS-02 est un détecteur de particules qui va étudier les rayons cosmiques avec une sensibilité sans précédent, depuis la station spatiale internationale. Construit sous la houlette du Professeur Samuel Ting, lauréat du prix Nobel de physique et assemblé au CERN, AMS-02 pourrait apporter quelques réponses concernant les grandes énigmes de l'Univers que sont l'antimatière et la matière noire. Développer un détecteur de particules adapté aux contraintes spatiales a été un véritable défi pour les quelque 600 physiciens et ingénieurs qui ont conçu l'expérience. Après plus de 15 ans de préparation, les choses sérieuses commencent enfin pour la collaboration internationale AMS.

Arnaud Marsollier, CERN and IN2P3.

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Endeavour takes passion, precision and patience

It is 20 years since **Sam Ting** first conceived of sending a magnetic spectrometer into space. **Paola Catapano** was with him during the launch of AMS on the space shuttle.

“Most of our understanding of our cosmos up to now comes from measuring light. Besides light rays, there are charged particles, which have not been used nearly as much as light to understand the universe.” Samuel Ting, the principal investigator for the Alpha Magnetic Spectrometer (AMS-02) experiment, is talking to the assembled press at the 2.00 p.m. briefing in the crowded auditorium at the Kennedy Space Center, Cape Canaveral. His experiment is soon to fly on board the space shuttle *Endeavour*, prior to installation on the International Space Station (ISS). “AMS is the first detector to study charged particles from cosmic rays directly in space, thanks to its magnet – the first magnet in space – and it will do so for the next 20 years, for the space station’s entire lifetime,” he explains. “It is the only fundamental science experiment in the space station.”

This was the main argument that Ting, well known as a leading particle physicist and Nobel laureate, used to convince the US Congress in 2008 to request that NASA “shall take all necessary steps to fly one additional space shuttle flight to deliver the Alpha Magnetic Spectrometer and other scientific equipment and payloads to the International Space Station prior to the retirement of the space shuttle” (US government 2008). AMS-02 had been grounded in 2005, in response both to the accident of the space shuttle *Columbia* on re-entry in 2003 and to the decision to retire the shuttle by late 2010. Were it not for its primary payload, the 2011 launch of *Endeavour* might never have been scheduled.

Unexpected discoveries

The principal scientific goals of AMS-02 are to search for dark matter and antimatter (p18). However, AMS’s biggest discovery might come in a totally unexpected area. Ting points out that the major discoveries in particle physics over the past 50 years were made in areas of physics that had not been anticipated when building the facilities where the discoveries were made. Take, for example, neutral currents, which Ting regards as the first major discovery made at CERN’s Proton Synchrotron (*CERN Courier*



Sam Ting, left, with Saul Gonzalez of the US Department of Energy’s Office of High Energy Physics, at the Kennedy Space Center on launch day. (Image credit: Mike Struik.)

September 2009 p16). “When the Proton Synchrotron was built nobody thought about neutral currents,” he says. Likewise for the Brookhaven National Laboratory, which built the Alternating Gradient Synchrotron (AGS) during the same period. “The purpose was to study the nuclear force; instead it discovered a second kind of neutrino, CP violation and the J particle,” he explains. “So

What you predict and what you discover are often very different things

what you predict and what you discover are often very different things. With AMS, we are going to explore new territory with a precision instrument, and that is the key to discovery. What we will really see, nobody knows. This is how science advances.” This philosophy was also a key to his Nobel-prize-winning

experiment at the AGS, which opened up a new world of particle physics based on a fourth kind of quark, charm, in what has become known as the “November revolution” of 1974.

The story of the AMS experiment goes back nearly 20 years, to the cancellation of the Superconducting Supercollider project in 1993. It was then that Ting first had the idea to send a relatively large-scale particle detector into space. “I began to think maybe I should do something different, not necessarily with accelerators, and then I remembered that in early 1964 I did an experiment ▷

Interview

Eyewitness: the final countdown for Endeavour

Thursday 28 April, LD-1. It's launch-minus-one day at the Kennedy Space Center (KSC) in Cape Canaveral and so far it's "go" for tomorrow's 10-minute launch window at 3.47 a.m. EDT, the time set for space shuttle *Endeavour's* final lift-off. I am one of 1500 members of the international press accredited at the KSC and one of the expected half-a-million viewers to witness the launch.

Much of the attention surrounding this mission has focused on the fact that this will be the final flight of *Endeavour* and the penultimate mission of the entire space-shuttle programme, as well as that the mission commander, Mark Kelly, is married to Congresswoman Gabrielle Giffords, who is recovering from a shooting more than four months ago. And, according to the latest rumours among the press at KSC, the "first family" is expected to attend tomorrow.

It's T-11 hours and holding, one of the longest pauses (around 14 hours) built into the countdown procedure. I join the media registered for witnessing the removal of *Endeavour's* Rotating Service Structure (RSS). This is one of the important milestones performed in the T-11 hold in the countdown. Around midnight, the metallic gantry around the shuttle starts to move away under



Lightning threatens the Vehicle Assembly Building at the Kennedy Space Center on 28 April, the night before the scrubbed launch attempt. (Image credit: Mike Struik.)

the enthralled gaze of the press representatives who were brave enough to stay, revealing *Endeavour* in all of its splendour. Once the operation has been performed, there are still 11 hours and so many unknowns before lift-off. Moreover, the weather does not seem promising, with lightning threatening NASA's Vehicle Assembly Building and launch pad 39.

Friday 29 April, T-3 hours and... scrub. After a short night (the RSS removal took place after midnight), we wake up early not to miss another milestone in the countdown schedule – the astronauts' "walk-out" and departure for launch pad. We have to be early at the media

centre for the usual "K-9" controls (dogs checking for explosives). On the way, I stop at AMS's premises at KSC, which happen to be close to the Operations and Checkout building where all astronauts spend the night before launch, since the time of the *Apollo* missions. We see three of them jogging – their last chance for a while.

Walk-out takes place at 11.58 a.m. as planned. I barely manage to shout "Forza Roberto" to my compatriot Roberto Vittori, before my voice is drowned in the crowd of media and NASA staff cheering the STS-134 crew, as they proceed to the Airstream van (also used by all crews since *Apollo* times).

However, in the media bus taking us back to the press centre, we see the Airstream van backing up – a clear sign that something has gone wrong. At a press briefing we learn that, while the astronauts were on their way to the pad, the launch team identified a fault in the heaters of the auxiliary power unit that prevents the shuttle's fuel from freezing. This is enough to scrub the launch window.

Sunday 15 May, T-11 hours. I'm back at KSC for the second launch attempt and the legendary countdown clock is again on T-11 hours and holding. The faulty box in the shuttle's aft compartment that resulted in the launch postponement has been replaced and the entire system re-tested. The weather forecast for tomorrow's slot is "70% go". Countdown will resume soon.

Monday 16 May, T-9 minutes and counting. The Mission Management team has just given the final "go" for launch. In less than 9 minutes *Endeavour* will lift off with AMS cradled in its cargo bay. I am on the media-centre lawn, less than 5 km from the launch pad, one of the closest points to watch a launch at KSC. I'm grateful to Prof. Ting for the invitation. No words can convey the emotion; it's a lifetime experience not to be forgotten.

Paola Catapano

together with Professor Leon Lederman to show how an antiproton and an antineutron form an antideuteron. A similar experiment was also done by Professor Zichichi's group at CERN (*CERN Courier* March 2009 p17). So I began to think, maybe I should do an experiment in space. In the 1990s, together with a group of colleagues, we saw the ISS as an opportunity to mount an experiment to study cosmic rays. With support from NASA and the US Department of Energy, an international consortium started work on AMS, and we flew a precursor instrument on the STS-91 shuttle mission in 1998."

The key component of AMS-01 was the magnet, as in its successor, but the detector was much simpler. "It was intended as a proof of principle, proof that a magnet could go to space and it did so by

flying 10 days on the space shuttle *Discovery*," explains Ting. The test flight in June 1998 not only showed that everything worked, but also made some initial intriguing measurements of cosmic rays in space (*CERN Courier* July 1999 p6). This provided the ground work for AMS-02, which is intended to operate for 20 years. "It has greater, more precise subdetectors, with many channels, whose size, scope and precision are totally different from AMS-01," he says. "We made them as precise as we could manage."

So how does Ting feel to see AMS-02 finally being about to launch after the long journey that began with AMS-01? "I am actually very calm; I am confident everything will be OK. This detector spent two decades in the workshop: at CERN, we tested the detector twice with a beam from the SPS accelerator, then we tested it

Interview

in the thermovacuum chamber at ESA-ESTEC. We took it apart and re-assembled it three times, so we're quite familiar with what's going on inside. All of the subdetectors measure energy in a repetitive way, so I think everything will work."

It is not surprising that CERN's facilities were used in testing AMS-02. Ting's relationship with the laboratory goes back nearly half a century, his first day at CERN being on 13 March 1963, as a Ford Foundation Fellow. "There, I had the good fortune to work with Giuseppe Cocconi at the Proton Synchrotron, and I learnt a lot of physics from him," he recalls. Particle physics and CERN have certainly both evolved a great deal since then. "When I first came to CERN, high-energy physics was dominated by the US," he says. "Most people at CERN were looking at what was done at Brookhaven and tried to do similar experiments. Now the picture has completely changed. Most US particle physicists come to CERN, and CERN now really has become the centre of high-energy physics in the world."

With all of the current interest in CERN and particle physics, Ting has some serious, practical advice for young people aspiring to become physicists. "If you want to be a scientist, whether it is a physicist, mathematician or biologist, you need to remember that you're doing this only for interest, not for fame or glory, because only very few people in their lifetime accomplish what they really want," he explains. "Physics is a very difficult thing; particle physics involves large groups of people working together. Unless you think that physics is the most important thing in your life, you should not do it. It takes passion, precision, patience."

Patience is a quality that Ting certainly has, waiting for this "last Endeavour" for his AMS project and never giving up hope. So when does he expect the first important results? "We have no competition," he says. "We are going to do this very slowly, very carefully. We won't publish any preliminary results; we'll only publish the data that we're absolutely sure about." Whatever AMS discovers, the final answers, like much that Ting has achieved, will be the result of passion, precision and patience.

• Further reading

US Government 2008 PUBLIC LAW 110-422—OCT. 15 2008.

Résumé

À bord d'Endeavour, des années de passion, de précision et de patience

L'idée d'envoyer un spectromètre magnétique dans l'espace trottait dans la tête de Samuel Ting depuis 20 ans. Après l'abandon du projet de supercollisionneur supraconducteur en 1993, il s'agissait de concevoir des expériences sans accélérateur. Avec le soutien de la NASA et du ministère de l'Énergie des États-Unis, un consortium international a commencé à travailler sur le Spectromètre magnétique alpha (AMS), et un prototype a été envoyé à l'occasion d'une mission de la navette spatiale en 1998. Cette année, Samuel Ting était présent en Floride pour assister au lancement d'AMS-02. Il a fait part à Paola Catapano de ses espoirs concernant cette mission, et de sa conception de la recherche scientifique en général.

Paola Catapano, CERN.



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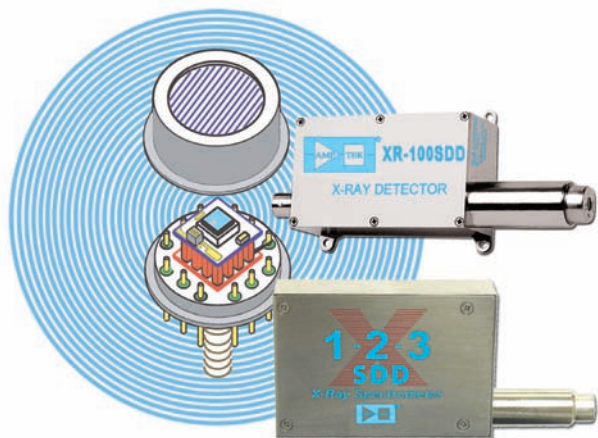
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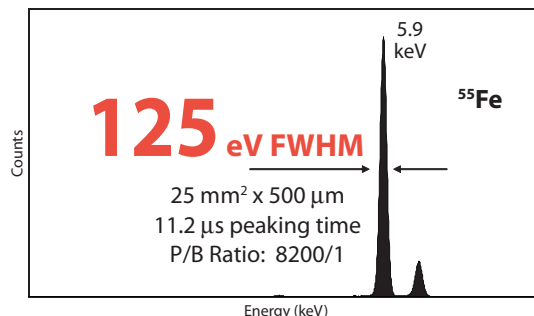
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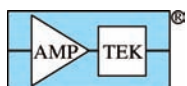


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LHC physics meets philosophy

It was not a clash of cultures but more a case of fruitful controversy when philosophers, historians of science and physicists met at the first Spring School on Philosophy and Particle Physics, held in Germany earlier this year.

At the end of March, the first Spring School on Philosophy and Particle Physics took place in Maria in der Aue, a conference resort of the archbishopric of Cologne in the rolling hills of the area called Bergisches Land, between Cologne and Wuppertal. It was organized by the members of the Deutsche Forschungsgemeinschaft's interdisciplinary research project, "Epistemology of the Large Hadron Collider", which is based at the Bergische Universität Wuppertal. Part of the time was reserved for lecture series by distinguished representatives of each field, including: Wilfried Buchmüller, Gerardus 't Hooft, Peter Jenni and Chris Quigg from physics; Jeremy Butterfield, Doreen Fraser and Paul Hoyningen-Huene from philosophy; and Helge Kragh from the history of science. The afternoons were devoted to five working groups of philosophy and physics students who discussed specific topics such as the reality of quarks and grand unification. The students then presented their results at the end of the school.

The large number of applications – more than 100 for 30 available places – from PhD students and young post-docs from all over the world demonstrated the strong interest in this interdisciplinary dialogue. There was an almost equal share of applicants from physics and philosophy. The pairing of students and lecturers from such different backgrounds made the school a great success. Almost all of the students rated it "very good" or "excellent" in their evaluations.

Theory and reality

The diverse academic backgrounds of the participants stimulated plenty of discussions during the lectures and working groups, as well as late into the night over beer. They centred on the main lecture topics: the reality of physical theories and concepts, experimental and theoretical methods in particle physics, and the history and philosophy of science.

For example, one of the working groups was concerned with the question, "Are quarks real?" Most physicists would, of course, answer "yes". But then again, the existence of quarks is inferred



Participants take a break from physics and philosophy for the group photo session, with Nobel laureate Gerardus 't Hooft, centre front. (Image credit: IZWT-Wuppertal.)

in a way that is indirect and theory laden – much more than for, say, chairs and tables. Are there different levels of reality? Or are quarks just auxiliary constructs that will be superseded by other concepts in the future, as happened with the ether in the 19th century, for example? A comprehensive picture of philosophical attitudes towards the reality content of physical theories was discussed by the philosopher Hoyningen-Huene of the University of Hannover. His lecture series also presented critically other aspects of the philosophy of science, focusing on the classic ideas of Karl Popper and Thomas Kuhn: What qualifies as a scientific theory? Are physical theories verifiable? Are they falsifiable? How do physical theories evolve over time?

Fraser, of the University of Waterloo, and Butterfield, of the University of Cambridge, discussed the scope and applicability of particle and field concepts in the interpretation of quantum field theory (QFT), an area that is certainly one of the most successful achievements in physics. However, Fraser pointed out that the need for renormalization in QFT, as used in particle physics, reflects a conceptual problem. On the other hand, the more rigorous algebraic QFT does not allow for an interpretation in terms of particles, at least in the traditional sense.

Another topic that has attracted the attention of philosophers in recent years concerns gauge theories and spontaneous symmetry breaking, as Holger Lyre, of Otto-von-Guericke-Universität ▷

Physics and philosophy

Magdeburg, discussed in his lecture. He asked whether it is justified to speak of “spontaneous breaking of a gauge symmetry” given that gauge symmetries are unobservable, a theme that was also discussed in a working group. Again, most physicists would take the pragmatic view that it is justified as long as all physical predictions are observed. Philosophers, however, look for the aspects of gauge theories that can count as being “objectively real”.

The contrarian attitudes between physicists and philosophers were put in a nutshell when a renowned physicist was asked whether he considers the electron to be a field or a particle, and the physicist replied: “Well, I usually think of it as a small yellow ball.” Pragmatism – motivated by a remarkably successful theoretical and experimental description of particle physics – clashed with the attempt to find unambiguous definitions for its basic theoretical constructs. It was one of the goals of the school to understand each other’s viewpoints in this context.

The physics lectures covered both experiment and theory. On the experimental side, Jenni, of CERN, and Peter Mättig, of the University of Wuppertal, discussed methods and basic assumptions that allow us to deduce the existence of new particles from electronic detector signals. As also discussed in one of the working groups, the inference from basic (raw) detector signals to claiming evidence for a theory is a long reach. The related philosophical question is on the justification of the various steps and their theory-ladenness; i.e. in which sense do theoretical concepts bias experimentation, and vice versa. Close to this is the additional question addressed in the discussion as to what extent the LHC experiments are fit to find any new particle or interaction that may occur.

The theory lectures of Robert Harlander, of the University of Wuppertal, Michael Krämer, of RWTH Aachen, and Quigg, of Fermilab, focused on the driving forces for new theories beyond the Standard Model. Apart from cosmological indications – comprehensively reviewed by DESY’s Buchmüller in one of the evening sessions – there is no inherent need for such a theory. Yet, almost everyone expects the LHC to open the door to a more encompassing theory. Why are physicists not happy with the Standard Model and what are the aims and criteria of a “better” theory? One of the working groups discussed specifically the quest for unification as one of the driving forces for a more aesthetic theory.

A current, highly valued guiding principle for model building is the concept of “naturalness”. To what extent are small ratios of natural parameters acceptable, such as the size of an atom compared with the size of the universe? As Nobel laureate ’t Hooft discussed in an evening talk, again there is no direct physics contradiction in having arbitrarily small parameters. But the physicists’ attitude is that large hierarchies are crying out for an explanation. Naturalness requires that a small ratio can arise only from a slightly broken symmetry. This is the background for many models that increase

the symmetry of the Standard Model to justify the smallness of the weak scale relative to the Planck scale. Another idea that ’t Hooft discussed is to invoke anthropic arguments fuelled, for example, by the discovery of the string landscape consisting of something like 10^{500} different vacua.

Closely related to the philosophy of science is the history of science. The development of the Standard Model was the subject of one of the working groups and was also comprehensively discussed by Kragh, of the University of Aarhus. Looking at the sometimes controversial emergence of the Standard Model revealed lessons that may well shape the future. Kragh reminded the audience that what is considered “certain” today only emerged after a long struggle against some “certain facts” of former times.

At first glance, philosophical questions may not be directly relevant for our day-to-day work as physicists. Nevertheless, communication between the two fields can be fruitful for both sides. Philosophy reminds us to retain a healthy scepticism towards concepts that appear too successful to be questioned. In return, the developments of new experimental and theoretical methods and ideas may help to sharpen philosophical concepts. Looking into the history of physics may teach us how sudden perspectives can change. Coming at the brink of the possible discovery of new physics at the LHC, the school was a great experience, reflecting about what we as physicists take for granted. The plan is to have another school in two years.

• Further reading

For more details, visit www.springschool-2011.uni-wuppertal.de.

Résumé






La physique du LHC à la rencontre de la philosophie

Ce ne fut pas le choc des cultures, mais bien plutôt un débat constructif. À l’occasion de la première École de printemps consacrée à la question « philosophie et physique des particules », philosophes, historiens des sciences et physiciens ont pu entamer un dialogue interdisciplinaire. Si les questions d’ordre philosophique ne présentent pas d’intérêt direct pour le travail quotidien du physicien, la communication entre ces deux disciplines peut être profitable pour tout le monde. Organisée au moment où le LHC est peut-être en passe de découvrir une nouvelle physique, l’École a été une expérience formidable. La philosophie rappelle aux physiciens qu’il est bon de garder un certain scepticisme à l’égard de concepts à première vue indiscutables. Réciproquement, le développement de nouvelles idées et de nouvelles méthodes en physique peut amener à affiner certains concepts philosophiques.

Robert Harlander and **Peter Mättig**, Bergische Universität Wuppertal.



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Detectors

ICARUS takes flight be

The world's largest liquid-argon time-projection chamber is now up and running successfully beneath the Gran Sasso massif, where it records the interactions of neutrinos from CERN and searches for proton decay with remarkable resolution.

Historically, imaging detectors have played a crucial role in particle physics. In particular, bubble-chamber detectors – such as Gargamelle at CERN – were an incredibly fruitful tool, permitting the visualization and measurement of particle interactions in an unprecedented way and providing fundamental contributions, in particular in neutrino physics. However, in the search for rare phenomena, bubble chambers are limited mainly by the impossibility to scale their size to larger masses and by their duty cycle, which is intrinsically limited by the mechanics of the expansion system.

The concept of the liquid-argon time-projection chamber (LAr-TPC) was conceived more than 30 years ago: it allows the calorimetric measurement of particle energy together with 3D track reconstruction from the electrons drifting in an electric field in sufficiently pure liquid argon (Rubbia 1977). The LAr-TPC successfully reproduces not only the imaging features of the bubble chamber – its medium and spatial resolution being similar to those of heavy-liquid bubble chambers – but it also has the further achievement of being a fully electronic detector, which is potentially scalable to multikilotonne masses. In addition, it provides excellent calorimetric measurements, with the big advantage of being continuously sensitive and self-triggering.

The ICARUS LAr-TPC

The ICARUS T600, the largest LAr-TPC ever built, contains 760 tonnes of liquid argon (LAr). It represents the state of the art of this technique and marks a major milestone in the practical realization of large-scale LAr detectors. Installed in Hall B of the underground Gran Sasso National Laboratory (LNGS) of the Istituto Nazionale di Fisica Nucleare (INFN), it is collecting neutrino events from the beam of the CERN Neutrinos to Gran Sasso (CNGS) project. Produced at CERN, the neutrinos reach Gran Sasso after a journey of around 730 km (*CERN Courier* November 2006 p20). The detector also acts as an underground observatory for atmospheric, solar and supernovae neutrinos. In addition it will search for proton decay (in particular into exotic channels) in one of its 3×10^{32} nucleons, with zero background.

The ICARUS T600 detector consists of a large cryostat that is

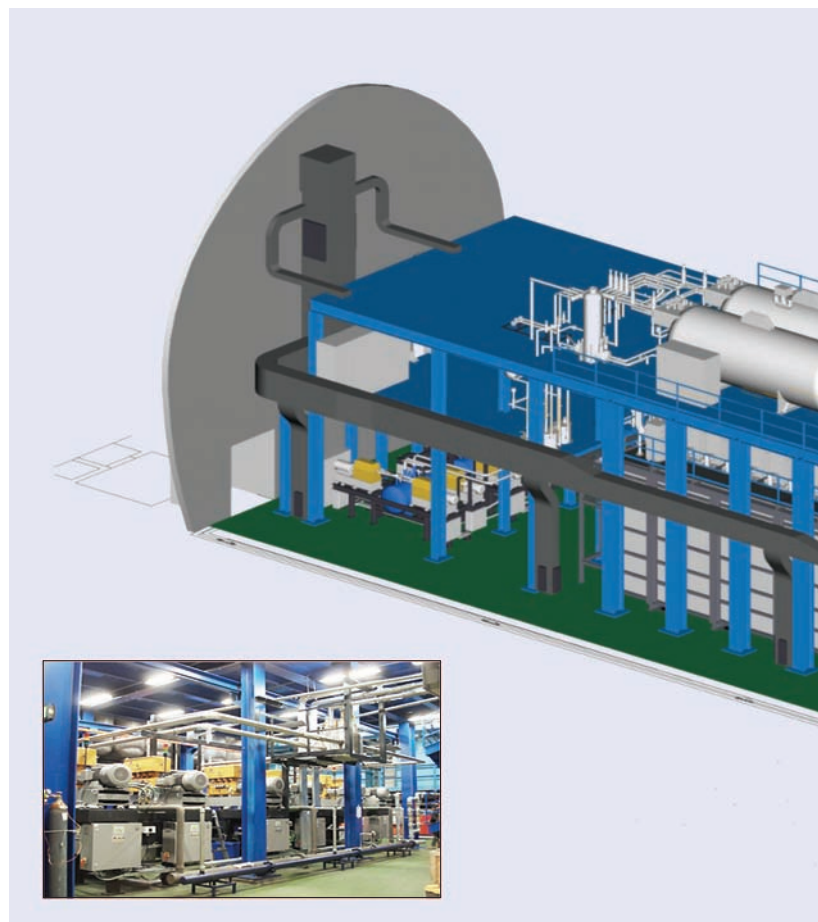


Fig. 2. Centre: Schematic view of the whole ICARUS T600 plant in Hall-B at detector installation. Bottom-right: details of the cryo-coolers plant.

split into two identical, adjacent half-modules (with internal dimensions of $3.6 \times 3.9 \times 19.6 \text{ m}^3$), which are filled with ultrapure liquid argon (Amoruso *et al.* 2004). Each half-module houses two TPCs separated by a common cathode, with a drift length of 1.5 m. Ionization electrons, produced by charged particles along their paths, are drifted under a uniform electric field ($E_D = 500 \text{ V/cm}$) towards the TPC anode made of three parallel wire planes that face the drift volume (figure 1). A total of approximately 54 000 wires are deployed with 3 mm pitch, orientated on each plane at a different angle (0° , $+60^\circ$ and -60°) with respect to the horizontal direction. By appropriate voltage biasing, the first two planes (the induction-1 and induction-2 planes) provide signals in a non-destructive way; finally, the ionization charge is collected and measured on the last plane (the collection plane).

The relative time of each ionization signal, combined with the electron drift-velocity information ($v_D \sim 1.6 \text{ mm}/\mu\text{s}$), provides the position of the track along the drift coordinate. Combining the wire coordinate on each plane at a given drift time, a 3D image of the

beneath the Gran Sasso

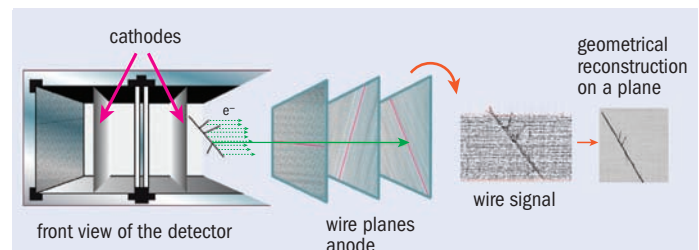
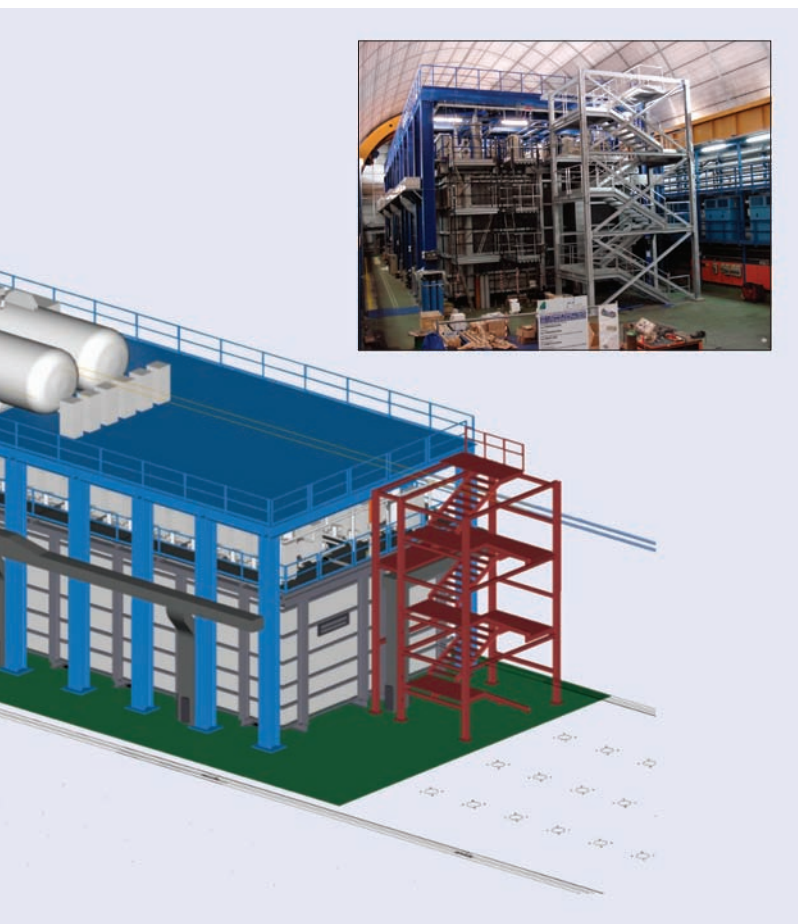


Fig. 1. Illustration of the ICARUS T600 working principle: left to right, from the ionization path of a charged-particle in liquid argon to its geometrical reconstruction.

operation in 2001 and tested with cosmic rays at the Earth's surface. To meet safety and reliability requirements for underground operation in Hall B at LNGS, the ICARUS T600 module – illustrated in figure 2 – was equipped with dedicated technical infrastructures. Assembly of the complete detector was achieved in the first months of 2010 and it was finally brought into operation with its subsequent commissioning.

Operation at LNGS

In the spring of 2010, the detector was filled with ultrapure LAr and activated immediately. Events from the CNGS neutrino beam and cosmic rays were observed with a trigger system that relied on both the scintillation light signals provided by the internal PMTs and the CNGS proton-extraction time. The “early warning” signal, sent from CERN to LNGS some 80 ms before the first proton spill extraction, allows the opening of two gates of around 50 μ s, corresponding to the predicted extraction times. The first observed CNGS neutrino event is shown in figure 3 (p32, top); other beautiful events with a muon crossing both chambers of a module and two neutral pions are shown in the middle and bottom parts of figure 3, respectively.

LAr purity is monitored continuously by measuring the charge attenuation along the tracks of ionizing cosmic muons that cross the full drift path. With the liquid recirculation turned on, the LAr purity steadily increased, the value of the free-electron lifetime exceeding 6 ms in both half-modules after a few months of operation (figure 4, p32). This corresponds to a maximum free-electron yield attenuation of 16%. Sudden degradations of purity owing to periodic pump stops for maintenance are always recovered promptly within a few days.

The performance of LAr-TPCs has been studied progressively over the past two decades by exposing different detectors to cosmic rays and neutrino beams, culminating in the successful achievement of the T600 operation. The high resolution and granularity of the detector imaging allow the precise reconstruction of event topology, which is completed by a calorimetric measurement.

Particles are identified by studying both the dE/dx versus Δ

ionizing event can be reconstructed with a remarkable resolution of about 1 mm³. The absolute time of the ionizing event is provided by the prompt UV-scintillation light emitted in the LAr and measured through arrays of photomultiplier tubes (PMTs), installed in the LAr behind the wire planes.

The electronics for data acquisition allow continuous read-out, digitization and independent waveform recording of signals from each wire of the TPCs. The electronic noise is 1500 electrons r.m.s. to be compared with around 15 000 free electrons produced by a minimum-ionizing particle in 3 mm.

To permit electrons produced by ionizing particles to travel “unperturbed” from the point of production to the wire planes, electronegative impurities (mainly O₂, H₂O and CO₂) in the LAr must be kept at a low concentration level (below 0.1 ppb). Therefore, both gaseous and liquid argon are continuously purified by recirculation through standard Hydrosorb/Oxysorb filters.

Preassembly of the ICARUS T600 detector began in 1999 in Pavia and one of the two 300-tonne half-modules was brought into

Detectors

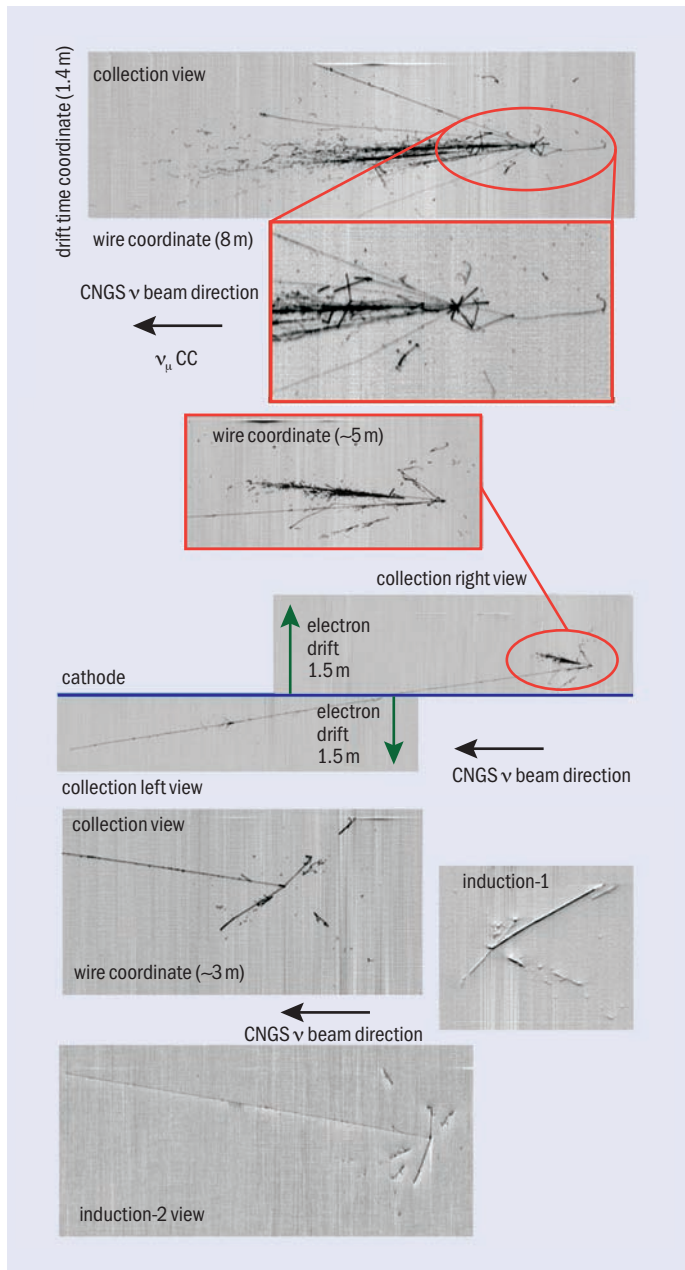


Fig. 3. (Left) First CC interaction from the CNGS beam as recorded by ICARUS-T600 (collection view, top) together with a ν_μ CC interaction with a 18 m-long muon (middle) and a nice ν_μ CC interaction with a clean π^0 signature as recorded in the collection, induction-1 and induction-2 views (bottom).

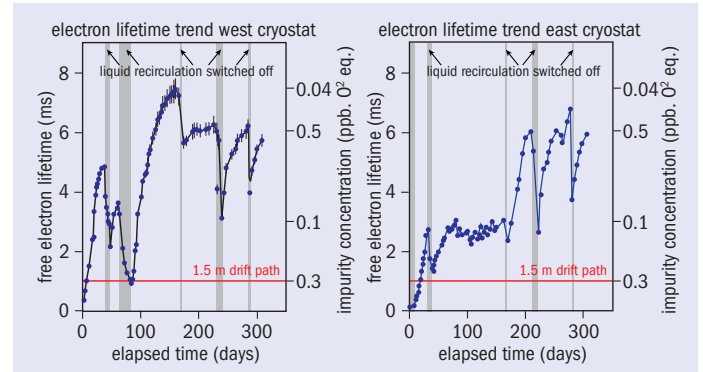


Fig. 4. Free-electron lifetime evolution in the west (left) and east (right) cryostats as a function of the elapsed time for the first 330 days of operation of the T600 detector.

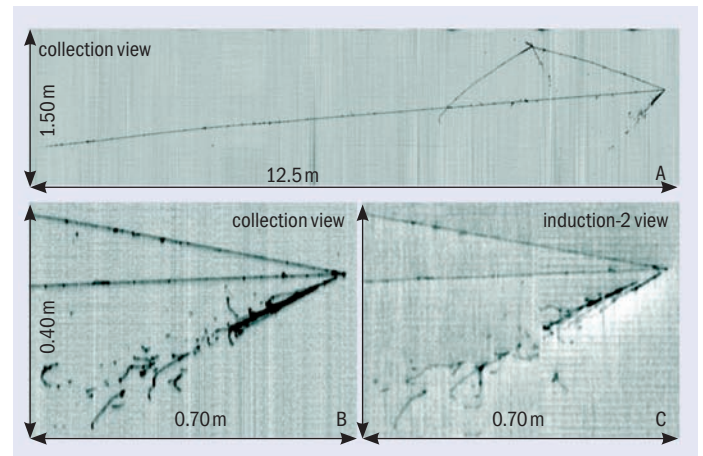


Fig. 5. An example of ν_μ CC interaction from the CNGS beam in collection view (A); together with close-up views of the primary vertex for the collection (B) and induction-2 (C) projections, which allow a complete solution of the event topology.

range and the decay/interaction topology. Electrons are identified by the characteristic electromagnetic showering, being well separated from π^0 via $\gamma\gamma$ reconstruction, dE/dx signal comparison and the π^0 invariant mass measurement at the level of 10^{-3} . This feature guarantees a powerful identification of the charged current (CC) electron-neutrino interactions, while rejecting neutral-current (NC) interactions to a negligible level. The electromagnetic energy resolution $\sigma(E)/E = 0.03/\sqrt{E(\text{GeV})} \oplus 0.01$ is estimated in agreement with the $\pi^0 \rightarrow \gamma\gamma$ invariant mass measurements in the sub-giga-electron-volt energy range, while $\sigma(E)/E = 0.30/\sqrt{E(\text{GeV})}$ has been inferred for hadronic showers.

For long muon tracks that escape the detector, momentum is determined by measuring the displacements arising from multiple scattering along the track. The procedure, implemented through a Kalman filter algorithm and validated on stopping muons, allows

a resolution of $\Delta p/p$ that can be as good as 10%.

During the 2010 CNGS run, the T600 acquired neutrino interaction events with steadily increasing efficiency, a live time of up to 90% and increasing quality. In the last 2010 period, about 100 neutrino CC events were collected and classified, in agreement with expectations.

As an example of the detector capabilities, figure 5 shows a CNGS ν_μ CC event with a 13 m-long muon track, together with zoomed projections on the collection and induction-2 planes. The use of two different views allows the recognition of two distinct electromagnetic showers pointing to – but detached from – the primary vertex. Even though the two photons overlap in the collection view it was possible to determine the associated invariant mass $m_{12}^* = 125 \pm 15 \text{ MeV}/c^2$, which is compatible with the π^0 mass. The initial ionization of the closer photon amounts to 2.2 minimum ionizing particles. This is a

Detectors



Fig. 6. The two half-module cryostats of ICARUS T600 just after they arrived in hall B at LNGS in December 2004. (Image credit: Francesco Arnedo LNGS-INFN.)

clear signature for pair conversion, thus confirming the expected e/π^0 identification capabilities of the detector.

The momentum of the long muon track in figure 5 has been measured to be via the multiple-scattering method $p_\mu = 10.5 \pm 1.1$ GeV/c. The other primary long track is identified as a pion that interacts to give a secondary vertex. A short track from the secondary vertex is identified as a kaon, decaying in flight into a muon. From the decay topology and energy deposition, the kaon momentum can be evaluated as 672 ± 44 MeV/c.

The capability for identifying and reconstructing low-energy kaons is a major advantage of the LAr-TPC technique for proton-decay searches. In the event described, the kaon momentum is not far from the average (300 MeV/c), for instance in the $p \rightarrow \bar{\nu} K^+$ channel. Also, the ability to identify π^0 s, as in this event, is effective for many nucleon-decay channels, as well as for the discrimination of NC events when looking for $\nu_\mu \rightarrow \nu_e$ oscillations.

The missing transverse-momentum reconstructed is 250 MeV/c. Despite the non-full containment of the event, this value is consistent with the theoretical expectation from the Fermi motion of target nucleons. The reconstructed total energy is 12.6 ± 1.2 GeV, well within the energy range of the CNGS beam (Bailey *et al.* 1999).

• Further reading

S Amoruso *et al.* 2004 *Nucl. Instr. Meth. A* **516** 68.

C Rubbia 1977 CERN-EP/77-08.

R Bailey *et al.* 1999 *The CERN Neutrino beam to Gran Sasso* (NGS) (Addendum to report CERN 98-02, INFN/AE-98/05) CERN-SL/99-034(DI), INFN/AE-99/05.

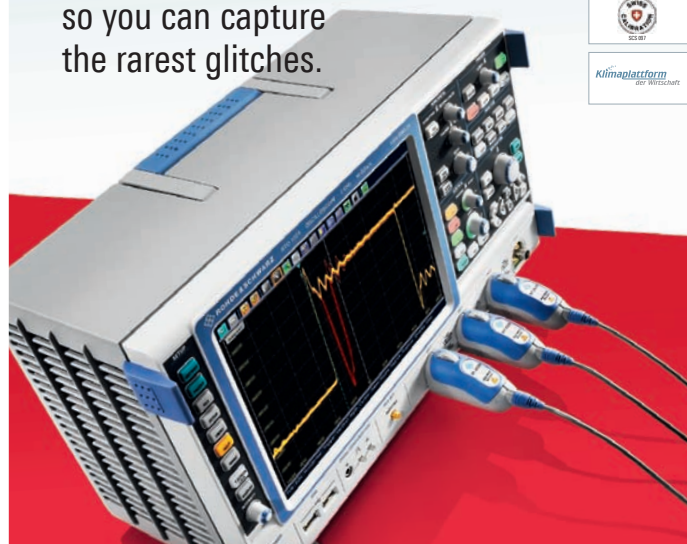
Résumé

ICARUS déploie ses ailes sous le Gran Sasso

En 1977, Carlo Rubbia a eu l'idée d'une chambre à projection tridimensionnelle à argon liquide, dispositif qui non seulement posséderait la même résolution que la chambre à bulles, mais serait également un détecteur entièrement électronique, capable de s'adapter à des masses de plusieurs milliers de tonnes. Le détecteur ICARUS T600, qui contient 760 tonnes d'argon liquide, est le plus grand appareil de ce type jamais construit. Il se trouve à la pointe de l'innovation et représente un véritable tournant dans la réalisation de détecteurs à argon liquide de grandes dimensions. Installé dans le hall B du Laboratoire national du Gran Sasso, situé sous terre, il enregistre à présent des événements neutrinos dans le cadre du projet CNGS (Neutrinos du CERN vers le Gran Sasso).

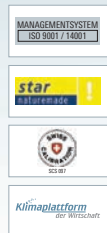
Carlo Rubbia, on behalf of the ICARUS collaboration.

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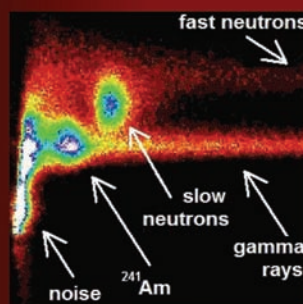


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Hildred Blewett: a life with particle accelerators

The centenary of **Hildred Blewett's** birth provides an occasion to look back at the career of a person whose very real legacy helps women to continue their careers in physics.

One of the most generous schemes to support women returning to physics – and possibly the most valuable to result from a personal bequest – is the M Hildred Blewett Fellowship of the American Physical Society (APS). When Hildred died in 2004, she left nearly all that she had to the APS to set up the scholarship, which funds a couple of women a year in the US or Canada to the tune of up to \$45 000. So far, nine recipients have benefited from the bequest, including two in nuclear and particle physics – not far removed from Hildred's own field of work in accelerator physics. Indeed, she played an important role in the design of accelerators on both sides of the Atlantic, as well as in the organization of their exploitation.

Hildred Hunt was born in Ontario on 28 May 1911. Her father, an engineer who became a minister, supported her interests in mathematics and physics, although the family did not have much money and Hildred had to take a time out from college – a factor that appears to have influenced the future bequest. Nevertheless, by 1935 she had graduated from the University of Toronto with a BA in physics and maths. Stints of research followed, first at the University of Rochester, New York, and then at Cambridge's Cavendish Laboratory – which was still under Ernest Rutherford – together with her husband John Blewett, who had also studied in Toronto. After returning to the US, in 1938 Hildred joined Cornell University as a graduate student, with Hans Bethe as her thesis supervisor. Writing in *APS News* more than 60 years later, physicist Rosalind Mendell recalled Hildred saying that as John was working on magnetrons at General Electric (GE) “she had gone back for her doctorate because she loved physics and could no longer endure life as a ‘useless’ company wife” (Mendell 2005). Rosalind had arrived at Cornell in 1940, when she was just short of 20 years old, joining 50 men plus Hildred – “the cheerful, confident and breezy Canadian blonde”. Hildred took the younger woman under her wing, a characteristic that was seen later with other junior colleagues and was also reflected in her final bequest.

The entry of the US into the Second World War changed eve-



Hildred Blewett in the 1940s. Her bequest supports women returning to physics. (Image credit: Blewett family.)

rything and by the summer of 1942, Bethe was working with Robert Oppenheimer in California on some of the first designs for an atomic bomb. In November Hildred joined GE's engineering department; her thesis work was left behind, never to be fulfilled. While at GE she developed a method of controlling smoke pollution from factory chimneys. However after the war, a bright

Her father, an engineer who became a minister, supported her interests in mathematics and physics

future opened up for scientific research in the US and in 1947 both Blewetts were hired by the newly established Brookhaven National Laboratory to work on particle accelerators. Hildred's forte was in theoretical aspects, while John had already worked with betatrons at GE.

The Blewetts were part of the team that worked on the design and construction of a new accelerator that would reach an energy of 3 GeV, an order of magnitude higher than in any previous machine and in the range of cosmic-ray energies, hence the name of “Cosmotron”. The machine came ▷

Centenary



Kjell Johnsen, left, shows Willi Jentschke and Hildred Blewett some of the emerging results from the ISR in January 1971.

into operation in 1952 and Hildred edited a special issue of *Review of Scientific Instruments*, which contained articles on many key aspects, some of which she also co-authored (Blewett 1953a).

Birth of the PS

That same year saw the emergence of the alternating gradient or “strong-focusing” technique, which offered the possibility for an accelerator to go up to much higher energies and gave birth to the Alternating Gradient Synchrotron (AGS) at Brookhaven. The idea was also conveyed to a group of physicists from several European countries who visited Brookhaven in the summer of 1952 to learn about the Cosmotron and how they might build a similar but somewhat larger machine for the nascent organization that would become CERN. Following the visit, and a busy period of study, the decision was indeed taken to build a strong-focusing machine of 25–30 GeV, the future Proton Synchrotron (PS). The group invited the two Blewetts and Ernest Courant – one of the inventors of the principle of strong focusing – to Europe to help plan the new laboratory.

By the end of March 1953, the provisional Council had agreed to build the strong-focusing machine, but as CERN did not yet officially exist, the work was split among groups in several European institutions. On six months’ leave from Brookhaven, the Blewetts went to Odd Dahl’s institute in Bergen, where they contributed to the initial design of the PS. The arrangement turned out to be more complex than initially thought, and they pushed to have everything moved to Geneva, once the site had been selected and ratified by the cantonal referendum in June 1953. The advance guard of the PS group, including the Blewetts, arrived there at the beginning of October. At the end of the month Geneva hosted a conference on the theory and design of an alternating-gradient proton synchrotron; Hildred edited the proceedings (Blewett 1953b).

Both Blewetts were full members of the PS group, engaged in



Hildred at an interdivisional board to select CERN fellows in November 1975. She joined CERN in 1969.

all aspects, from theoretical research to cost estimates, and their collaboration continued, even after they returned to the US. By January 1954, the decision had been taken to build the 33 GeV AGS at Brookhaven, so the collaboration between the US and Europe was important to both. Hildred commented later that there were even times when “in many ways Brookhaven got more from the co-operation than CERN did” (Krige 1987). She returned to Geneva to attend accelerator conferences in 1956 and 1958, and visited CERN for three months in 1959, when the PS was near completion. Well known photos record her presence in the PS control room on the magical evening of 24 November when the “transition” took place; her written recollections still bring the day vividly to life (*CERN Courier* November 2009 p19).

Back in Brookhaven Hildred made major contributions to the design of the AGS, in particular she “presided over the design of the magnets” (Blewett 1980). Courant also recalls that she devised an elaborate programme to make detailed field measurements of each of the 240 magnets, which enabled the team to assign the positions of the magnets in the ring so as to minimize the effects of deviations from the design fields.

The AGS began operation in 1960, a few months after the PS at CERN. Alan Krisch, then a graduate student at Cornell, worked on a large-angle proton–proton scattering experiment, which was one of the first to be approved. Hildred “sort of adopted” him and he remembers her as a “formidable woman from whom he learnt much”. She was the one, for example, who suggested that the Cornell group acquire a trailer to provide a cleaner environment where they could collect their data near their AGS experiment. “It was a great idea,” he says, “and soon everyone had trailers.”

The Blewetts split up around that time, as professional divergences increased. These included, Krisch recalls, a disagreement about whether the AGS should add a high-intensity linac or colliding beams. After the divorce, Lee Teng, a colleague and friend,

invited Hildred to the Argonne National Laboratory, where he had become director of the Particle Accelerator Division. “I remembered that at Brookhaven she got along very well with and was respected by all of the AGS users,” he says, so he suggested that Hildred become the liaison with the users of Argonne’s Zero Gradient Synchrotron (ZGS). She took on the work with characteristic dedication, bringing all of her experience from Brookhaven, taking care of the needs of the users. One of these was Krisch, who at 25 was a newly appointed assistant professor at the University of Michigan and spokesperson for one of the first experiments on the ZGS. Under Hildred, the experimental areas worked well, “probably the best of any place I’ve worked at”, he says. During this time at Argonne, papers by Hildred show that she continued to work on magnet design, as well as on costings for experimental facilities.

By 1967, on leave from Argonne, she was already involved with the 300 GeV project at CERN, for example as co-ordinator of utilization studies across the member states to look into the exploitation of the machine that would become the Super Proton Synchrotron (ECFA 1967). She joined the CERN staff in 1969 and collaborated in the Intersecting Storage Rings (ISR), which started up in 1971 (*CERN Courier* January/February 2011 p27). That same year she was heavily involved in the organization of the 8th International Conference on High-energy Accelerators in Geneva, nearly a quarter of a century after the conference (also in Geneva) that had foreshadowed the PS. She ran the finances of the ISR Division, keeping a careful eye on how resources were spent, as well as being secretary of the ISR Committee (ISRC), serving the new community of users at CERN. Again, the users included Krisch, this time as the first US spokesperson on a CERN experiment, together with a trailer flown over from Argonne; and again Hildred’s expertise proved invaluable, advising on how to run the cabling etc. By the time she retired she had been secretary for 60 meetings of the ISRC and left behind her a perfect organization, in the words of her successor.

She retired in August 1976, but remained at CERN until July 1977 as a scientific associate. During this final year, reports were published on the concept for a 100 GeV electron–positron machine and on studies of 400 GeV superconducting proton storage rings – the future Large Electron–Positron collider and Large Hadron Collider, respectively – both of which involved Hildred (Bennet *et al.* 1977 and Blechschmidt *et al.* 1977). She also organized the 1st International School of Particle Accelerators “Ettore Majorana” in Erice, which laid the foundations for the CERN Accelerator School.

The recollections of some of the people who knew Hildred not only paint a picture of a strong woman who cared a great deal for others, but also give some insight into her interests beyond physics. Mendell remembers that they walked together on the Physics Department hikes at Cornell and Courant recalls that she was “an avid folk dancer”, organizing weekly classes in which he and his

wife participated enthusiastically. Krisch recalls that during his third encounter with Hildred at CERN, she invited him to Geneva’s English Theatre Club to see her star as the Bulgarian heroine in George Bernard Shaw’s *Arms and the Man*.

After a few years in Oxford, which suited her interests in music, amateur dramatics and fine arts, Hildred returned to Canada to be closer to her brother and his family. She died in Vancouver in June 2004, at the age of 93. Her career was characterized by her concern that others too should be able to make the most of their time in the field she clearly enjoyed – from the young people she mentored to the user communities she served in several major laboratories and to the beneficiaries of her generous bequest.

● Further reading

For more about the APS M Hildred Blewett Fellowship, see www.aps.org/programs/women/scholarships/blewett/.

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Résumé

Hildred Blewett : une vie dédiée aux accélérateurs

Hildred Blewett, décédée en 2004, a légué presque tous ses biens à l’American Physical Society pour fonder une bourse d’études, d’un montant annuel pouvant aller jusqu’à 45 000 dollars, destinée aux femmes reprenant une carrière de physicienne interrompue. Le centenaire de sa naissance nous donne l’occasion de revenir sur la carrière de cette pionnière dans le domaine des accélérateurs, carrière menée aussi bien au CERN qu’au laboratoire de Brookhaven. Après avoir participé, des deux côtés de l’Atlantique, à la conception des premiers synchrotrons à protons à focalisation forte, elle a joué un rôle clé dans l’exploitation de plusieurs machines en aidant leurs utilisateurs. Ce fut notamment le cas pour les anneaux de stockage à intersection du CERN, qui ont occupé l’essentiel des dix dernières années de sa longue carrière de physicienne.

Maria Fidecaro and **Christine Sutton**, CERN. The authors would like to thank Marion Heimerle of BNL and Anne Marie Bugge, formerly CERN, for their help with this article, in addition to those quoted in the text.



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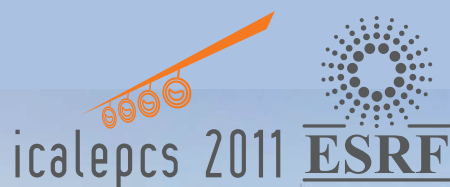
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The ISR's totally unexpected results

Forty years after the first results from the ISR were presented at an international summer conference, **Antonino Zichichi** looks at the legacy of some major surprises from the world's first proton–proton collider.

Our understanding of QCD continues to depend on the contributions from totally unexpected results found at the Intersecting Storage Rings (ISR). Some of the most relevant of these also represent an interesting frontier for research at the LHC. In particular, the “effective energy” remains the basic parameter for revealing the features of universality in the multiparticle hadronic systems that are produced, while the “leading” effect is still present at LHC energies, with all of its consequences, such as the total independence of the two hemispheres of the interaction.

Effective energy

The perceived wisdom, up to the moment when the first unexpected results came from the ISR, was that each pair of strongly interacting particles produces its own final state. The properties of these final states were measured to be all different, as shown by a remarkable number of well established quantities, namely: the fractional momentum distribution $d\sigma/dx_F$ (where x_F is Feynman x); the average number of charged particles $\langle n_{ch} \rangle$; the ratio of the average energy in the charged channel to the total energy $\langle E_{ch} \rangle / \langle E_{total} \rangle$; the transverse-momentum distributions $d\sigma/dp_T^2$; the normalized transverse-momentum distribution $d\sigma/(d\sigma/p_T / \langle p_T \rangle)$; the event planarity; the two-particle correlations; and the scale-breaking effects.

Out of these eight quantities, the most popular is the average number of charged particles, $\langle n_{ch} \rangle$. It was taken for granted that different pairs of interacting particles – πp , Kp , pp , $\bar{p}p$, etc. – had to give different values for $\langle n_{ch} \rangle$. That the other seven quantities were different for different pairs of interacting particles was considered a natural consequence of the fact that different initial states have to produce different final states. This perceived wisdom was shown to be wrong when the effective energy was discovered at the ISR.

At the ISR, and at any other collider, the quantity $\sqrt{s} = \sqrt{(q_1^{inc} + q_2^{inc})^2} = 2E_{inc}$ was considered to be the total energy available in the

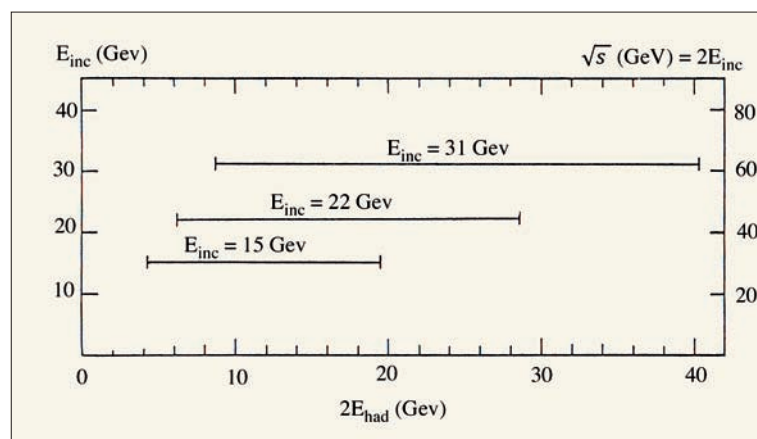


Fig. 1. The effective hadronic energy $2E_{had}$ available for particle production as a function of ISR beam energy, E_{inc} (left) and the total nominal energy $\sqrt{s} = 2E_{inc}$ (right).

centre-of-mass system (E_{inc} being the incident energy of each colliding proton). The Bologna-CERN-Frascati (BCF) group proved that this is not true: the quantity \sqrt{s} should be considered as the “nominal”, not the “effective”, value for the total energy available.

The key point is that in a pp collision, such as at the ISR, the total energy available for particle production is not $(\sqrt{s})_{pp} = 2E_{inc}$. In fact, the incoming proton can carry a large fraction of the primary energy away into the final state.

Our understanding of QCD continues to depend on totally unexpected results found at the ISR

If you examine the final state of a pp interaction, in 90% of the cases you find in each hemisphere a “leading” particle: $q_1^{leading}$ and $q_2^{leading}$. On average, they carry 50% of the nominal energy, $2E_{inc}$. The hadronic system produced in each hemisphere has at its disposal the quadrimomentum $q^{had} = q^{inc} - q^{leading}$, which gives rise

to the quantity $2E_{had}$. This is the effective energy.

The BCF group measured the detailed features of 10^5 pp collisions, on an event-by-event basis, to identify the effective energy of each collision. Once this quantity is taken as the correct energy for a given process, the eight quantities quoted above are the same, no matter what the nature of the pairs of interacting particles or the type of interaction. The leading effect is a very general \triangleright

Anniversary

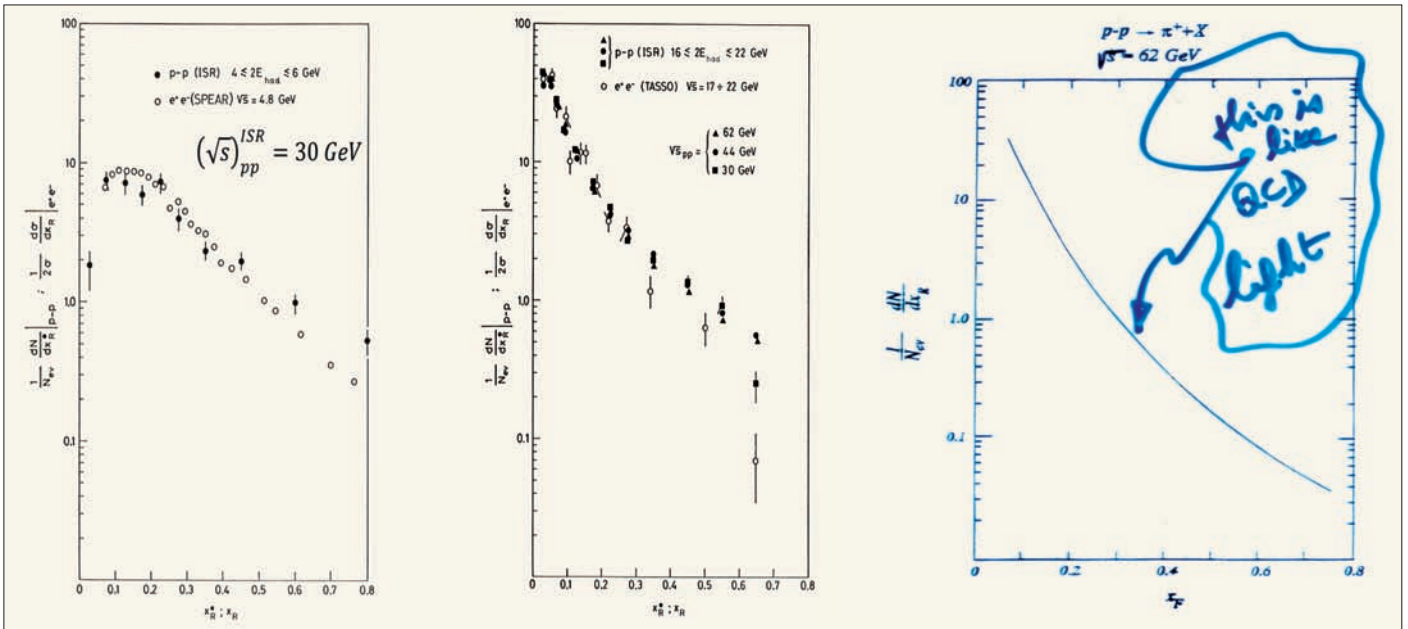


Fig. 2. Examples of inclusive single-particle fractional-momentum distributions obtained at the ISR in different ranges of $2E_{had}$ at different \sqrt{s}_{pp} show the remarkable agreement with e^+e^- data from the low energies of Mark I at SPEAR (left) to TASSO at PETRA (centre). At the right is the sum of the distributions measured at $\sqrt{s}_{pp} = 62$ GeV, which Gribov called the “QCD light”.

phenomenon that is present when a hadron interacts – whether strongly, electromagnetically or weakly (Basile *et al.* 1981a and 1981b). When a hadron in the final state shares energy with all other particles produced in this highly privileged way, the effect must be accounted for correctly to compare the properties of the multiparticle hadronic system produced in the interaction. This is how we found the first evidence for universality features between pp and e^+e^- data using pp interactions at the nominal ISR energy, $(\sqrt{s})_{pp} = 62$ GeV (Basile *et al.* 1980).

As figure 1 (p39) indicates, this fixed, nominal energy corresponds to a set of effective energies available for particle production, $2E_{had}$, in a range of about 5–40 GeV. We collected data at three ISR energies, $(\sqrt{s})_{pp} = 30, 44,$ and 62 GeV for the following reason. It was crucial to show that the multiparticle hadronic systems produced in pp interactions with the same values of $2E_{had}$, but with different values of E_{inc} , had the same properties in terms of the eight quantities mentioned above.

Let us take one example. The BCF group discovered that the fractional momentum distribution, $d\sigma/dx_F$, of a pion produced in the reaction $pp \rightarrow \pi^+ + X$ at the nominal total energy $(\sqrt{s})_{pp} = 62$ GeV is the sum of the fractional momentum distributions at different effective energies (figure 2). This is why Vladimir Gribov liked to call the pion spectrum the “QCD-light”.

The effective energy also dismantled another myth, the one that gave a special role to “high” transverse-momentum phenomena. We found at the ISR that the multiparticle systems (jets) produced at high p_T and at low p_T show the same universality features (Basile *et al.* 1988).

The leading effect

The discovery of effective energy was the driving force to study in detail the leading effect, which is a basic non-perturbative QCD

phenomenon. In another impressive set of totally unexpected results, the BCF group at the ISR established the following five properties of the effect, which need to be explained by QCD.

1. *The leading effect depends on the quantum number flow.* For example, if in the initial state there is a proton (uud) that goes into the final state, the probability of having the same “proton” (uud) with more energy-momentum than all the other particles is very high. The proof is in figure 3a, which shows how the number of quarks that go from the initial to the final state varies with the value of a function, L, which is proportional to the probability of having the particle in the privileged leading status with respect to all other particles in the final state. The leading effect decreases with the number of propagating quarks from the initial to the final state. For example, when the process is $p(uud) \rightarrow p(uud)$, all three quarks of the initial state go into the final state and $L \simeq 3$. However, in both $p(uud) \rightarrow \Lambda^0(uds)$ and $p(uud) \rightarrow \Sigma^+(uus)$ there are two propagating quarks and $L \simeq 1$. For $p(uud) \rightarrow \Sigma^0(dds)$ there is only one propagating quark and $L \simeq 0.5$. The minimum value of L is when there are no quarks going from the initial to the final state.

2. *The leading effect is flavour independent.* The neutron, produced in the process $p(uud) \rightarrow n(udd)$, seems to indicate some deviation from the other cases with two propagating quarks in figure 3a. To study if there is a flavour dependence in the leading effect, we extended our research to all heavy flavours. This is how we discovered the leading production of Λ_c^+ (Basile *et al.* 1981c) and found for the first time the Λ_b^0 , which at the time was the heaviest particle known (Basile *et al.* 1981d). The search for the Λ_b^0 proved that the leading production mechanism is also valid also for the Λ_b^0 and that the same leading-baryon effect is present in the Λ_b^0, Λ_c^+ and Λ_s^0 production mechanisms. So, despite the large mass difference between the strange (s), the charm (c), and the beauty (b) quarks, the production of these differently flavoured baryonic states shows the same leading

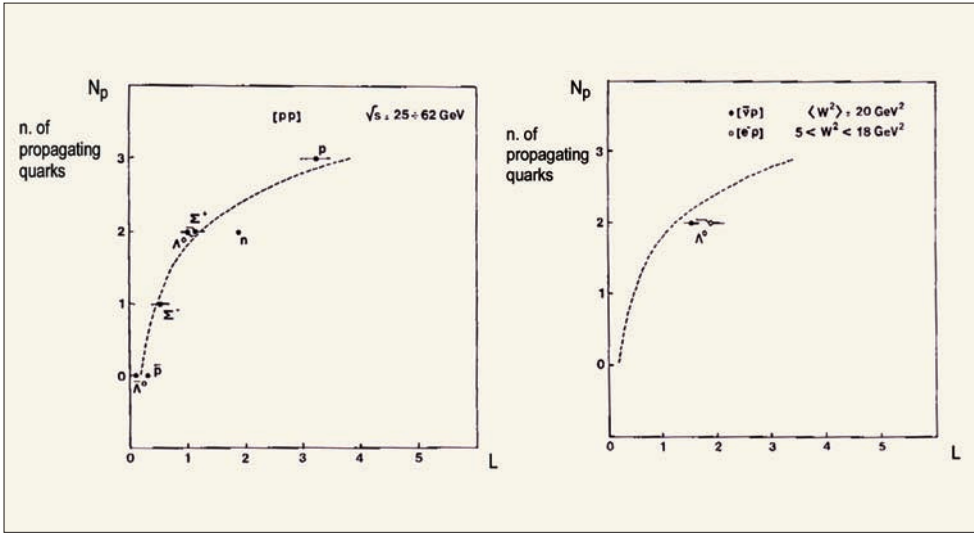


Fig. 3. (a) Left: The “leading” quantity L for different types of baryons produced in pp collisions at the ISR as a function of the number of propagating quarks. The centre-of-mass energy ranges from 25 to 62 GeV. The dashed curve was obtained by using a parametrization of the single-particle inclusive cross-section (Basile *et al.* 1981a). (b) Right: The “leading” quantity L for the Λ^0 produced in $\bar{\nu}p$ and e^-p interactions, where the number of propagating quarks is two.

effect (Basile *et al.* 1981e). The conclusion is that there is no mass-dependence in the leading effect and that it is flavour-invariant.

3. The leading effect is present in deep inelastic scattering (electromagnetic and weak). Figure 3b shows two examples of deep inelastic scattering: one is electromagnetic (e^-p) and the other is weak ($\bar{\nu}p$). In both cases the leading effect is present. Taking into account the results previously reported, where the interactions were all strong, the data prove that no matter if the interaction is strong, electromagnetic or weak, the leading effect is there and depends on the flow of quantum numbers from the initial to the final state.

4. The leading effect also exists when there are no hadrons in the initial state, as in e^+e^- annihilation. The fractional momentum distribution measured by the TASSO experiment of the particles produced in e^+e^- annihilation at $\sqrt{s} = 34.4$ GeV at the PETRA collider deviated markedly from the expected spectrum when a leading D^* was present in the final state. Using pp data from the ISR at effective energies in the range 10–16 GeV, the TASSO data showed excellent agreement (figure 4). The only correction needed was the subtraction of the D^* leading effect.

5. There are no long-range correlations in the leading effect. For many years experimental data have given evidence for a correlation between the two ISR hemispheres. The same problem needs to be studied at the LHC. The BCF group proved that these correlations disappear when the data are analysed in terms of the effective energy. The best proof came from the study of $p_{1,2}^{inc} + p_{1,2}^{inc} \rightarrow p_1^{leading} + p_2^{leading} + \text{anything}$, where $p_{1,2}^{inc}$ indicate the two incident protons, and $p_{1,2}^{leading}$ the two leading protons. The data-taking was performed using unbiased events to have a set of genuine inclusive pp interactions. The results, shown in figure 5, prove that the two hemispheres are totally independent and – contrary to what had been believed before – there are no long-range correlation effects.

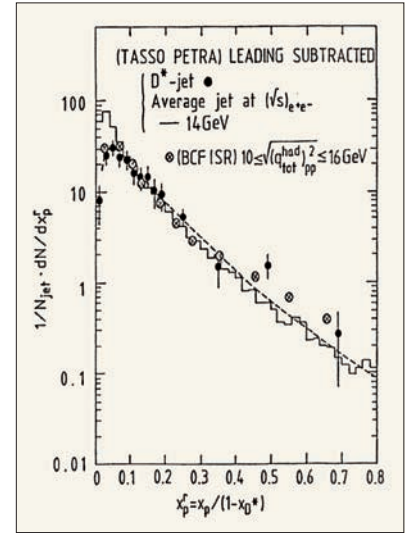


Fig. 4. Data from the BCF analysis at the ISR of proton–proton interactions with effective energy in the range 10–16 GeV show excellent agreement with the e^+e^- data at $\sqrt{s} = 14$ GeV.

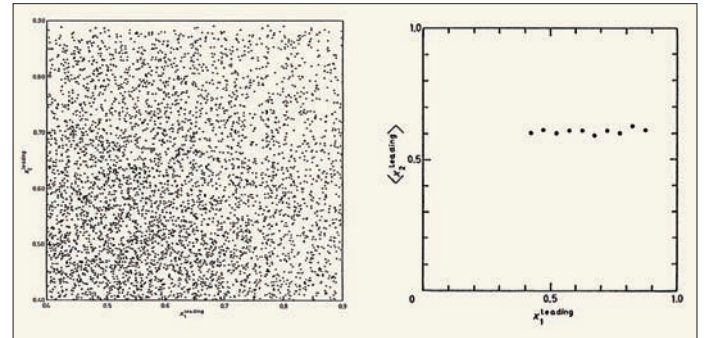


Fig. 5. Left: Scatter plot of the fractional energies of the two leading protons, $x_{1,2}^{leading} = E_{1,2}^{leading}/E_{1,2}^{inc}$, in the range $0.4 < x_{1,2}^{leading} < 0.9$, at the pp centre-of-mass energy $\sqrt{s} = 62$ GeV. Right: The average value $\langle x_2^{leading} \rangle$ for fixed $x_1^{leading}$ against $x_1^{leading}$. The value of $\langle x_2^{leading} \rangle$ is obtained from the scatter plot.

Two final remarks should be made on the leading effect. First, when there is no quantum number flow from the initial to the final state, the leading effect depends on the probability that the fragmentation products recombine themselves into one leading particle. From high- p_T data at the ISR we have: $\sigma(\text{single particle}) E_T^{inclusive}/\sigma(\text{jet}) E_T^{inclusive} \approx 10^{-2}$ for $E_T \approx 5\text{--}10$ GeV; from e^+e^- annihilation the results are: $\sigma(e^+e^- \rightarrow D^* + \text{other particles})/\sigma(e^+e^- \rightarrow C + \text{other particles}) \approx 10^{-2}$. We can deduce that if a single particle carries a large part of a certain available energy, it must “pay” a factor of around 10^{-2} . How this recombination into one leading particle can be possible is a problem for non-perturbative QCD theorists.

A second point is that in pp interactions at ISR energies, about 20 mb of cross-section is in the leading effect. At the ISR this effect is dominated by the quantum number flow. In e^+e^- there is no quantum number flow from the initial to the final state and only about Δ

Anniversary

1% of the total cross-section is in the leading effect. For an explanation we must wait until non-perturbative QCD can give the correct “predictions”.

In conclusion

The ISR were the source of a series of totally unexpected results. The effective energy with its universality features plays a fundamental role in all QCD processes. The leading effect is flavour independent, has no long-range correlation and exists no matter whether the process originates in a strong, electromagnetic or weak interaction. The next frontier is to find out if these properties are still valid at LHC energies.

Further reading

For the complete set of results at the ISR from the BCF Collaboration see *The Creation of Quantum Chromodynamics and the Effective Energy: In Honour of A Zichichi on the Occasion of the Galvani Bicentenary Celebrations* by V N Gribov, G 't Hooft, G Veneziano, V F Weisskopf and LN Lipatov (ed.) 2000 *World Scientific Series in 20th Century Physics* **25** 343.

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M Basile *et al.* 1981d *Lettere al Nuovo Cimento* **31** 97.

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Résumé

Les résultats inattendus des ISR

La compréhension de la chromodynamique quantique repose sur les résultats surprenants obtenus aux Anneaux de stockage à intersections (ISR). Certains de ces résultats font encore aujourd'hui l'objet de recherches de pointe au LHC. En particulier, l'« énergie effective » demeure le paramètre fondamental révélant les caractéristiques d'universalité dans les systèmes hadroniques multi-particules produits, tandis que l'on continue d'observer la présence d'une « particule prépondérante » aux hautes énergies obtenues au LHC, avec toutes les conséquences que cela implique, comme l'indépendance totale des deux hémisphères de l'interaction. Quarante ans après la présentation, lors d'une conférence d'été, des premiers résultats obtenus aux ISR, Antonino Zichichi revient sur ces surprises de taille.

Antonino Zichichi, University and INFN, Bologna, and Enrico Fermi Centre, Rome, on behalf of the Bologna-CERN-Frascati collaboration.



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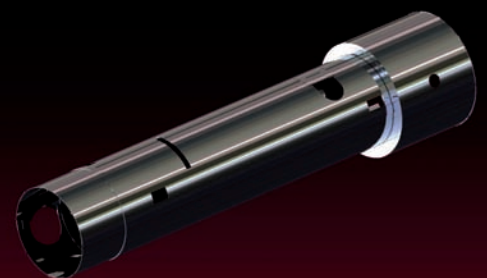
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Faces & Places

CELEBRATION

Robert Aymar honoured at CERN

On 24 May, Robert Aymar, CERN's director-general from 2004 to 2008, was awarded the National Order of the Legion of Honour of the French Republic in recognition of his outstanding scientific career. A renowned French physicist, he was director of the superconducting tokamak Tore Supra from 1977 to 1988, director of material sciences at the French Atomic Energy Commission (CEA) in 1990–1994 and director of the ITER project in 1994–2003. During his term of office at CERN he oversaw the commissioning and start-up of the LHC, which he inaugurated on 21 October 2008 (*CERN Courier* December 2008 p23).

Aymar was presented with the award during a colloquium held at CERN in honour of his 75th birthday. After an introduction by the current director-general, Rolf Heuer, a series of presentations from leaders in the various fields recalled many of Aymar's important contributions from the early days at Tore Supra to the completion of the LHC. Catherine Cesarsky, high commissioner for atomic energy, provided a contribution by video. Bernard Bigot, chairman of the CEA, presented Aymar with the medal of the Legion of Honour, during his contribution towards the end of the colloquium.



Above: Robert Aymar, right, was presented with the medal of the Legion of Honour by Bernard Bigot, chairman of the CEA, left.

Right: Aymar enjoys a presentation during the colloquium in honour of his birthday.



For the full programme and presentations, see <http://indico.cern.ch/conferenceDisplay.py?confId=134627>.

AWARDS

Suzuki and Petcov receive the 2010 Pontecorvo Prize

The Pontecorvo Prize for 2010 has been awarded to Yoichiro Suzuki, of the University of Tokyo and director of the Kamioka Observatory, and Serguey Petcov of SISSA, Trieste. Suzuki receives the prize for his "outstanding contribution to the discovery of atmospheric and solar neutrino oscillations in the Super-Kamiokande experiments", while Petcov is honoured for his "fundamental contribution to the investigation of neutrino propagation in matter, $\mu \rightarrow e\gamma$, $\mu \rightarrow 3e$ processes and Majorana properties of the neutrino".

The awards ceremony was held on 18 February at the 109th session of the JINR Scientific Council. Mikhail Itkis, acting director of JINR, and Alexander Olchevsky, director of the Dzhelepov



Yoichiro Suzuki, left, with Mikhail Itkis, centre, and Alexander Olchevsky.



Serguey Petcov, left, with Itkis. (Image credits: JINR.)

Laboratory of Nuclear Problems and chair of the international prize jury, presented the awards. The new director-elect of JINR,

Victor Matveev, and the Scientific Council warmly greeted the new laureates, who both gave presentations on their work.

Faces & Places

EPS Accelerator Group announces 2011 prizewinners

The European Physical Society Accelerator Group (EPS-AG) has announced the winners of the EPS-AG/IPAC'11 Accelerator prizes, to be presented at the International Particle Accelerator Conference, IPAC'11, which will take place on 5–9 September in San Sebastián.

Shin-ichi Kurokawa of KEK receives the Rolf Wideröe Prize for outstanding work in the accelerator field (without age limit). He is rewarded for “demonstrating excellent leadership over many years [making] significant contributions to the automated control and performance of high-energy colliders, as well as to international collaboration in the field of particle accelerators”. He was responsible for the design, construction and operation of the control system for KEK’s TRISTAN collider – the first full computer control for a large accelerator in Japan – and set up and led the team that brought the KEKB B-factory into being.

The Gersch Budker Prize, for a recent significant, original contribution to the accelerator field, with no age limit, also recognizes Japanese work with the award to Yasushige Yano, senior adviser and former director of the RIKEN Nishina Center. He was “responsible for turning the RIKEN Cyclotron Laboratory into the world’s most powerful source of cw radioactive isotope beams for all elements from helium to



uranium. [This was] based on an ambitious plan involving a new ECR ion source and RFQ injector, followed by a chain of three rings that required the... construction of the world’s first superconducting sector-magnet cyclotrons.”

The Frank Sacherer Prize, for an individual in the early part of his or her career, having made a recent significant, original contribution to the accelerator field, goes to CERN’s Rogelio Tomás García. “Among many significant contributions in a relatively short career, he is particularly well known for his innovative work in measuring resonance driving terms and the localization of lattice errors, for optics design including non-linear properties of beamlines with applications to the final focus of linear colliders, and for his contributions to the LHC operations and its upgrades.”

Clockwise: Shin-ichi Kurokawa. (Image credit: KEK). Yasushige Yano. (Image credit: RIKEN.) Rogelio Tomás García.



INR awards the 2011 Markov prizes

The Institute for Nuclear Research (INR) of the Russian Academy of Sciences in Moscow has awarded the 2011 M A Markov Prize to Alexey Kurepin and Igor Zeleznykh, of the Institute for Nuclear Research of the Russian Academy of Sciences, and Aston Komar of the Lebedev Physical Institute of the Russian Academy of Sciences. They received the awards at the 9th Markov Readings in Moscow on 13 May.

Kurepin is recognized for his “great contribution to researches in the field of relativistic nuclear physics and discovery of new properties of nuclei and nuclear matter”; Zeleznykh for “proposals and developments of new methods for detecting neutrinos and



The 2011 Markov prize laureates, left to right: Igor Zeleznykh, Aston Komar and Alexey Kurepin. (Image credit: INR.)

other elementary particles”; and Komar for his “great contribution to theoretical and experimental studies in elementary particle physics”.

The M A Markov Prize, which is awarded for essential contributions to theoretical and experimental studies in the field of

elementary particle physics, nuclear physics and neutrino astrophysics, was established by INR in memory of Moisey Alexandrovich Markov (1908–1994), who was one of the founders of the institute. The Markov Readings are held each year on 13 May to commemorate his birthday.

LEARNED SOCIETIES

Cifarelli and Stachel rise to the top

The European Physical Society (EPS) has its first woman president, since Luisa Cifarelli of the University of Bologna and INFN took over from Maciej Kolwas, at the close of the EPS Council meeting held on 1–2 April. She was elected president by the EPS Council at the meeting held on 19–20 March 2010 and will serve a two-year term, before becoming a vice-president for a further year.

Cifarelli studied at the universities of Rome and Bologna, where her thesis supervisor was Antonino Zichichi. Her research work has taken her to CERN, DESY and the Gran Sasso National Laboratory. For the past 10 years she has been involved in the design, construction and running of the huge time-of-flight detector of the ALICE experiment at the LHC, which is based on multigap resistive plate chamber technology. She has served on a number of councils, committees and commissions, including CERN Council and the INFN Board of Directors.

Johanna Stachel, professor of physics at the University of Heidelberg and a member of the ALICE collaboration at the LHC, has been elected as the next president of the



Luisa Cifarelli, the first woman president of the EPS. (Image credit: Mike Struik.)

Johanna Stachel with the first supermodule of the ALICE TRD ready for installation in 2006. (Image credit: A Saba/CERN.)

German Physical Society (DPG). She will be the first female president of the society when she takes over from Wolfgang Sander in 2012. Founded in 1845, the DPG is the world's oldest physical society and also the largest, with 59 000 members.

Stachel received her PhD from the



University of Mainz before conducting research with Stony Brook University and the Brookhaven National Laboratory. She has received many research awards, including the Federal Cross of Merit in 1999. Within ALICE, she is project leader of the transition radiation detector (TRD).

Herwig Schopper becomes honorary member of EPS

The European Physical Society (EPS) has elected Herwig Schopper to honorary membership. Schopper was director-general of CERN from 1981–1998, a period that saw the approval and construction of the Large Electron-Positron collider in the 27 km tunnel now occupied by the LHC. He is honoured for his scientific contributions to

the development of optics, thin metal layers, nuclear physics, elementary particle physics, detector development and accelerator technology (*CERN Courier* November 2009 p36). The EPS also recognizes Schopper for his successful work as the society's president, in transferring the headquarters to Mulhouse.



Schopper at CERN in 2009.

Venetian academy honours CERN theorist

In a ceremony at the Doge's Palace in Venice on 29 May, Gian Giudice of the theory unit at CERN, was nominated academician of the Istituto Veneto di Scienze, Lettere ad Arti (IVSLA) "for his outstanding contributions to the field of particle physics, and the development of supersymmetry and theories with extra dimensions".

The institute is an academy that promotes

the advancement of mathematical, physical and natural sciences, as well as the humanities and arts. Past members of the academy include the mathematicians Tullio Levi Civita and Gregorio Ricci Curbastro, the scientists Guglielmo Marconi and Luis Pasteur, the writers Alessandro Manzoni and Ezra Pound, and the sculptor Antonio Canova.



Gian Giudice, left, at the ceremony with president of the Academy, Gian Antonio Danieli. (Image credit: IVSLA.)

Faces & Places

VISITS



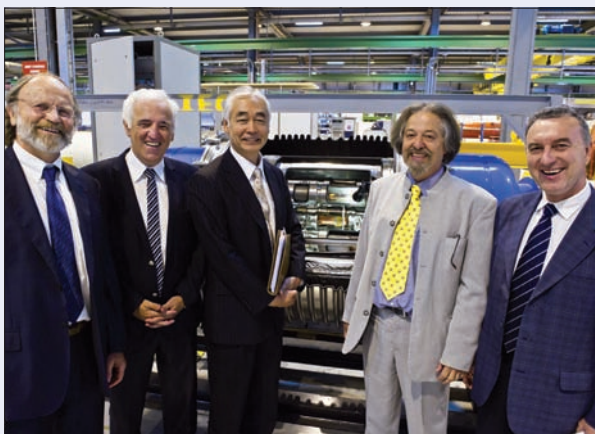
Carlos Martinez-Riera, general-director of international co-operation and institutional relations, ministry of science and innovation for Spain, right, visited the CMS control room with **Maria Chamizo-Llatas**, CMS deputy run co-ordinator, CIEMAT, when he came to CERN on 11 May. He also saw the CMS underground experimental area and the LHC superconducting magnet test hall.

Minister of natural resources for the Kingdom of Lesotho, **Monyane Moleleki**, left, toured the ATLAS visitor centre together with **Ketevi Assamagan**, ATLAS Collaboration member from Brookhaven National Laboratory, during a visit to CERN on 17 May. He was also invited to see the LHC superconducting magnet test hall.



Enrique T Ona, secretary of health for the republic of the Philippines, left, was welcomed to CERN on 20 May, by **Sergio Bertolucci**, CERN's director for research and scientific computing, here presenting a temperature-sensitive mug depicting the history of the universe. During his visit, Ona heard about life sciences at CERN and toured several facilities.

The director-general of ITER, **Osamu Motojima**, centre, visited CERN on 24 May. Here he is in the LHC superconducting magnet test hall with, from left to right, **Jean Jacquinet**, scientific adviser to the French high-commissioner for atomic energy, **Frédéric Bordry**, head of CERN's technology department, **Jean-Pierre Koutchouk**, of CERN's International Relations Office, and **Lucio Rossi**, deputy-head of the technology department.



PUBLISHING

EPS launches electronic newsletter

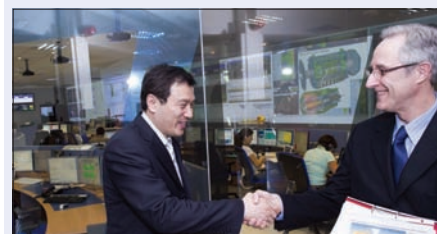
At the beginning of May, the European Physical Society (EPS) launched *e-EPS*, a monthly online digest of information and facts. It contains not only timely announcements and information about the EPS and its members, but also news on physics, events and other issues relevant to the European physics community. Also available in a printable PDF version, its aim is to complement *Europhysics News*, the bi-monthly magazine of the EPS.

The newsletter was launched at the start of the mandate of the new EPS president, Luisa Cifarelli, who also heads the editorial team.

● Read the newsletter at www.epsnews.eu.

MEETING

The Balkan Summer Institute in physics, BSI2011, will take place on 19 August – 1 September in Serbia. The institute comprises three events: a seminar for teachers “Trends in modern physics”, held in Niš on 19 August – 1 September; the school “Cosmology and particle physics beyond the standard models” held in Donji Milanovac on 21–27 August; and two workshops, “Scientific and human legacy of Julius Wess” on 27–28 August and “Particle physics from TeV to Plank scale” on 28 August – 1 September, also in Donji Milanovac. For further information about all of the events, see <http://bsw2011.seenet-mtp.info>.



On 18 May, the visit to CERN of the deputy director-general of the state administration of foreign experts affairs for the state council of China, **Ming Lu**, left, included a tour of the ATLAS visitor centre with deputy spokesperson, **Andy Lankford**. Lu also met Sergio Bertolucci, CERN's director for research and scientific computing.



The spring meeting at the Karlsruhe Institute of Technology attracted almost 1400 participants. (Image credit: KIT.)

GERMANY

The LHC results blossom at spring meeting in Karlsruhe

The annual Spring Meeting of the Particle Physics, Mathematical Physics and Gravitational Physics Divisions of the German Physics Society (DPG) took place this year at Karlsruhe Institute of Technology (KIT) on 28 March – 1 April. With almost 1400 participants, a large majority of them particle physicists, this conference is the largest of its kind, and once again the number of presentations (1001) reached an all-time high. The increase can be justly attributed to interest in the first year of LHC operation, which was also the focus of both the “ceremonial” session, where Rolf Heuer, CERN’s director-general, gave the plenary lecture presenting the start of a new era of particle physics, and of the evening talk for the general public by the meeting’s organizer Thomas Müller from KIT.

The meeting featured 17 plenary and more than 100 parallel sessions, in which mainly graduate students and young scientists presented both a broad overview of the present state of the field and of future projects stimulated by the development of innovative technologies in particle detection, software algorithms and accelerator techniques.

The eagerly awaited measurements from the LHC experiments after the first year of operation were a major highlight. Since there is a separate division of the DPG (Hadrons and Nuclei) that covers heavy-ion collisions, results “only” from proton–proton collisions at up to 7 TeV in the centre of mass were presented in Karlsruhe. Although no discoveries were announced, presentations covered a large number of measurements and analyses that test the Standard Model at unprecedented energies at the LHC. The participants heard how, despite the integrated luminosity being more than 100 times smaller, the LHC has already outpaced Fermilab’s Tevatron in searches for supersymmetry, high-mass objects and compositeness scales. On the other hand, the precision measurements from the Tevatron and from heavy-flavour factories continue to pin down the Standard Model in an independent way. There was also a focus on progress in theoretical modelling, especially in the field of Higgs and flavour physics as well as in extensions to the Standard Model.

In the field of astroparticle physics, highlights included the inauguration of the neutrino telescope, IceCube, and the

completion of both the GERDA experiment, which searches for neutrino-less double beta decay, and the reactor-based neutrino experiment Double Chooz. There is great progress towards the direct measurement of neutrino mass in the near future with the Karlsruhe TRITium Neutrino experiment (KATRIN). The newest developments in direct searches for dark matter were exemplified with presentations on the experiments XENON100, EDELWEISS and CRESSTII, the latter claiming a 4.6 σ excess in their data that would fit to a weakly interacting massive particle with the relatively light mass of 13 GeV/ c^2 . In their development of multimessenger astronomy, German groups are also using gamma astronomy and cosmic-ray measurements to open a window deep into the universe.

Highlights of the ceremonial event included a lecture by Gunter Wolf from DESY, this year’s recipient of the Stern-Gerlach medal of the DPG, and the talk by CERN’s director-general. The president of the DPG, Wolfgang Sandner, took part in awarding the 2011 thesis prizes, and also thanked the more than 100 helpers of the local organizing team from KIT.

COLLABORATION

Alushta welcomes CMS physicists

Physicists of the Russia and Dubna Member States (RDMS) collaboration in CMS and colleagues from the wider CMS collaboration gathered in Alushta, Ukraine,

on 22–27 May for the 15th RDMS CMS Conference. Organized by the National Science Center – Kharkov Institute of Physics and Technology – and JINR, the meeting was hosted at JINR’s “Dubna” holiday house on the picturesque coast of the Black Sea in the Crimea. Some 50 talks, many by RDMS members, covered all aspects of physics at CMS – from the latest results on the Standard Model to signals of new physics, including the hunt for the Higgs boson. They also looked at analysis problems for the whole dataset for 2010 and the issues

of the detector upgrade.

In the spirit of the RDMS CMS meetings, the conference provided an important opportunity for young physicists, in particular from the RDMS countries, to attend and present their latest results. Sessions this year covered the direct search for heavy flavours and the top-quark (including single top-quark production), Higgs-boson hunting, the study of exotic objects, new heavy states and new symmetries, the latest results from the heavy-ion runs in 2010 and from the

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beginning of 2011 operation of the LHC, in particular the jet-quenching phenomenon, which is a possible signature of the quark-gluon phase transition. Intense meetings and discussions between experimentalists and theorists followed the talks and were particularly important for young physicists.

The conference opened with a review by Roberto Tenchini of the University of Pisa, who concentrated on the main results obtained so far by CMS. Progress has been tremendous, but more important results and discoveries are still expected. The presentations on the future physics programme started with a broad-brush review by Joseph Incandela of the University of California, the spokesperson-elect of the CMS collaboration. He focused on the challenges faced in the current and future physics and in the upgrades to CMS. These themes were continued in more detail in the review talks on topics that included searches for exotica beyond the current LHC, issues in supersymmetry searches, searches for the Higgs in weak boson associated-production and benchmark studies in high pile-up.

In confronting the Standard Model, the measurements by CMS provide stringent



Participants at the conference in Alushta on the Black Sea. (Image credit: JINR.)

tests of fundamental symmetries and there were several talks on these issues. These covered the extraction of the relevant physics aspects at CMS, the detection of tagged jets for Higgs production in vector-boson fusion, vector-boson scattering, the measurement of the single top t-channel cross-section, the angular distribution and asymmetries in rare flavour-changing neutral current decays of B-mesons, the first CMS results on di-muon physics and systematic effects in the charged neutral-current Drell-Yan process. Searches for new physics at CMS require the deep understanding of electroweak processes as much as for those that are related to strong interactions and they were the subject of

several review talks.

The collective flow effects in multiparticle production processes both in proton-proton and heavy-ion collisions were high on the conference agenda. In particular, Vladimir Korotkikh of the Skobel'tzyn Institute of Nuclear Physics at Moscow State University reviewed the two-particle correlations at CMS, including both elliptic flow and the "ridge" effect. There were also reports on the first CMS results on lead-lead collisions.

A number of presentations reported on the status of CMS performance. Talks on perspectives for the CMS upgrade included the hadronic and electromagnetic calorimeters, the tracker and muon systems, the calorimetry taskforce, R&D for a CMS high-precision spectrometer and work for the CMS test beams over the next 10 years.

In his summary talk, the spokesperson of RDMS CMS, Igor Golutvin from JINR, underlined that the lively research programme at CMS will be added to with the forthcoming detector upgrade—and raise the discovery potential for new physics in CMS in the near future.

For more details, see <http://rdms2011.kipt.kharkov.ua/rdmses/agenda>.

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OBITUARIES

Robert Brout 1928–2011

Born in New York in 1928, Robert Brout obtained his PhD from Columbia University in 1953, before becoming an associate professor in Cornell and a well-established expert on statistical mechanics. There he met François Englert, who was visiting as a postdoctoral researcher; this was the beginning of a life-long scientific collaboration. In 1961 Brout took the bold step to resign his position at Cornell and move with his family to Brussels, where he eventually became professor at the Université Libre de Bruxelles, and co-directed with Englert the Service de Physique théorique.

In 1964, Brout and Englert started a revolution with a famous three-page article, which offered the possibility to give mass to vector gauge bosons, the vectors of fundamental interactions. It proved to be the key to the unification of the weak and electromagnetic interactions in the Standard Model. This short article described the mechanism in various contexts, offering different possible realizations (with or without a fundamental scalar, in a “spontaneous” or “dynamical way”). Shortly afterwards this work was complemented by Peter Higgs, using an alternative mathematical approach. The work was recognized by the European Physical Society prize, the Wolf prize, and later the Sakurai prize.

The Brout–Englert–Higgs mechanism was later established by the discovery of the Z and W bosons and by the detailed field-theoretic computations that confirm the electroweak theory within its suspected domain of validity. The goal of the LHC is to investigate



Robert Brout, the “gardener of Eden”.
(Image credit: Katherine Graham.)

its precise realization, either through finding a new, fundamental scalar boson or (for instance) through some other new dynamics.

It was characteristic of Brout’s attitude in physics to rely heavily on his intuition, often gained from his expertise in statistical mechanics (the above example is typical in this regard); the mathematical developments would then follow. He would often present his ideas with impressive gusto, mimicking enthusiastically the physical situations. His warm personality gained the admiration of many students, who later perpetuated his approach around the world.

In his personal life, he was close to nature. His devotion to gardening inspired the title of his festschrift, the “gardener of Eden”, an expression that also conveys his gentlemanly manners in science and in life. He was clearly seduced by the European way of life

and indeed eventually opted for Belgian nationality.

Brout produced invaluable contributions to diverse domains of theoretical physics. His basic paper on irreversibility in 1956 initiated the “Brussels School” approach to irreversible processes. His contributions to the statistical theory of phase transitions, to fundamental interaction physics and to cosmology address basic questions. His pioneering work in cosmology, in which the whole Brussels group was eventually involved, introduced what is now known as inflation and relates the exponential expansion to the emergence out of a quantum fluctuation of the universe, a scenario that may well turn out to be basically the correct one.

In the early 1970s, when quantum field theory and gauge theories started to revolutionize particle physics (in no small part as a result of his work), Brout undertook itinerant courses in the Belgian universities (notably Leuven and Louvain-la-Neuve). This teaching – and the exceptional warmth of his personality – had a strong influence on the respective theory groups, affecting successive generations of theorists to this day. For this reason, the loss of this fatherly figure is felt with sadness in the Belgian physics community, which he greatly helped to unify.

Robert Brout died on 3 May in his house, in Linkebeek, Brussels, a small heaven surrounded by the blossoming flower beds that he had planted.

● François Englert and Jean-Marie Frère,
Université Libre de Bruxelles.

William (Bill) Galbraith 1925–2011

In 1952, armed with a rubbish bin (painted black on the inside) from the UK Atomic Energy Research Establishment at Harwell, a recycled 25 cm searchlight mirror and a 5 cm phototube, Bill Galbraith and his colleague John Jelley set out to measure flashes of Cherenkov light in the night sky. They observed a count rate of about one pulse per minute, so confirming Patrick Blackett’s assertion that Cherenkov light from charged cosmic rays traversing the atmosphere should contribute to the overall night-sky intensity. In 1953, with improved



Bill Galbraith. (Image credit: D Galbraith.)

apparatus at the Pic du Midi, the pair successfully demonstrated that the light signals they recorded had the polarization and spectral distribution characteristic of Cherenkov radiation. These experiments also revealed the correlation of the amplitude of the light signal with shower energy. The first steps towards Cherenkov astronomy had been taken.

Born in Renfrew, Scotland, Bill left school at the outbreak of the Second World War. His passion for science and engineering resulted in his working as a student assistant in the

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research laboratories of GEC. His BSc from Birkbeck College, the University of London, was achieved via study at evening classes, while his “day job” involved the development of pre-production versions of vacuum tubes for airborne and naval radar. Bill then joined the nuclear physics division at Harwell in 1948, measuring spontaneous fission rates of uranium and plutonium isotopes. This led to a PhD as an external student at the University of London.

After moving to the Lawrence Radiation Laboratory in 1958, Bill worked on $K \rightarrow \mu$ decay at the Berkeley Bevatron. Upon his return to the UK he was involved in the construction and operation of NIMROD, the 7 GeV proton synchrotron for the

newly-established Rutherford High Energy Laboratory. He also worked at CERN and Brookhaven on CP violation in K^0 decay, observations that narrowly post-dated and confirmed work by James Cronin and Val Fitch. Bill was appointed chair of high-energy physics at the University of Sheffield in 1966, where he worked in collaborations at the UK Daresbury Laboratory – where he was one of the founders of research activities using the newly constructed NINA electron synchrotron – and on a series of experiments in the West Area at CERN using the Omega Spectrometer.

Bill was an excellent mentor of undergraduates, postgraduates and young academics. His sense of fair play earned him

great respect among his university peers and he was appointed as dean of faculty of pure science and served as a pro-vice-chancellor shortly before his retirement.

Music played a great part in Bill’s life, from participation in choral societies in both Wantage and Sheffield to a love of attending concerts. He and his wife Elizabeth were keen supporters of the arts in general and music in particular. In Sheffield, Bill’s influence in his support of activities, such as the Sheffield Festival and of local musicians including the Lindsay String Quartet and Opera North promoted the city’s status as a centre for arts and music.

● *Lee Thompson, the University of Sheffield, on behalf of Bill’s colleagues and friends.*

Daniel Simon 1937–2011

Daniel Simon, leader of CERN’s PS Division from 1994 to 1999, died on 2 June at the age of 74, in Nancy. CERN owes to him a great number of developments of the experimental areas around the PS and the existence of the Antiproton Decelerator (AD).

Daniel came to CERN in 1962 from the University of Nancy. He first worked in the Nuclear Physics Apparatus Division on the electrostatic separators for the secondary beams at the PS, a subject that he also chose for his thesis. Then, as a member of the PS Division, he designed a variety of beamlines, including those providing protons and antiprotons to the Initial Cooling Experiment – the decisive experiment that allowed CERN to launch the antiproton project on the basis of stochastic cooling. His contributions to the initial layout and further evolution of the experimental areas of the Low Energy Antiproton Ring (LEAR) were essential for the success of the LEAR programme. Thereafter, Daniel drove the decision and the effort for the conversion of LEAR into the Low Energy Ion Ring (LEIR) for the provision of lead ions to the LHC.



Simon, as PS Division Leader in 1993.

He was one of the leaders of the relocation of ISOLDE to the PS-Booster, which saved this marvellous and now flourishing facility from closure when the 600 MeV Synchrocyclotron was shut down in 1990. However, Daniel’s most significant achievement was undoubtedly the AD, which

now is one of CERN’s cherished facilities despite its modest size and beam energy. It was he who, in close contact with the physics community, pushed for this project, as he could not accept the demise of low-energy antiproton physics at CERN when LEAR was to be closed and the SuperLEAR project was not accepted. This was a tough undertaking, at a time when the Large Electron–Positron collider was operating full steam and financing of the LHC was not yet assured.

Although a member of an accelerator division, Daniel had a strong affection for experimental particle physics. With a clear view of what CERN ought to do and the conviction that a broad base was indispensable, he fought valiantly and successfully for the small experiments around the PS complex and kept close contact with their users, whom he helped wherever he could. His friends and colleagues remember him as an enthusiastic physicist, an exacting and able manager, and a loyal friend.

● *His colleagues and friends.*

Stanislav Mikheyev 1940–2011

Stanislav Mikheyev, an outstanding experimentalist in the field of neutrino and underground physics and one of the inventors of the Mikheyev–Smirnov–Wolfenstein (MSW) effect, passed away suddenly on 23 April in Moscow, after a heart attack.

Mikheyev was born in Moscow on 11 October 1940 to the family of an expert in deep mining, Paul Kail. Influenced by his

uncle S Strelkov, a professor of physics, he decided to become a physicist. He entered Moscow State University in 1959 and in his final year studied nuclear physics in JINR, Dubna, where he met and was inspired by Bruno Pontecorvo.

In 1965 he began his postgraduate studies in the Lebedev Physical Institute under Aleksandr Chudakov, whose team of young

scientists, including Mikheyev, developed a prototype scintillator neutrino detector. Soon, Mikheyev became a leader of the neutrino experiments and together with V Bakatanov and A Voevodsky developed a time-of-flight method to determine the direction of the muon. This method was the basis of the Baksan Underground Scintillator Telescope, to which Mikheyev made

substantial contributions.

Mikheyev joined the newly created Institute for Nuclear Research (INR) in Moscow in 1970. At the suggestion of Pontecorvo his PhD thesis, defended in 1983, was promoted to a thesis for the higher degree of doctor of science because of its fundamental importance. The main results included the first measurements of the zenith-angle distribution of upward-going muons, searches for oscillations of atmospheric neutrinos, the first bound on oscillation parameters, the tightest upper limit on the diffuse flux of cosmic neutrinos, and resolution of the problem of horizontal events. These pioneering results substantially determined Mikheyev's further work and, to a large extent, the developments of the field.

In 1984 Mikheyev realized the importance of Wolfenstein's paper on neutrino oscillations for the analysis of atmospheric neutrino data. Thus began the collaboration with Alexei Smirnov, which led to the "invention" of the MSW effect and the discovery of two different phenomena in neutrino propagation in matter: resonance enhancement of neutrino oscillations and adiabatic flavour-conversion. The latter was proposed as an explanation of the deficit of solar neutrinos and 20 years later the MSW large-mixing-angle solution was established as the solution to the solar neutrino problem. Various applications of the MSW effect, in



Stanislav Mikheyev. (Image credit: INR.)

particular to supernova neutrinos, were also developed in 1984–1987.

During the same period Mikheyev created and led the experimental group that made further steps in understanding neutrino and muon interactions, performed searches for cosmic neutrinos from local sources, as well as neutrinos from the annihilation of dark-matter particles accumulated in the Sun and the Earth.

In 1991 Mikheyev joined the MACRO experiment in the Gran Sasso underground laboratory, where his expertise made him a principal member of the collaboration.

He returned to Moscow in 1999 and since then was involved in experiments in Russia and elsewhere. As well as being the scientific leader of the Baksan Telescope, he participated in the K2K experiment in Japan, which observed oscillations of accelerator neutrinos for the first time. He also became one of the principal investigators in experiments at the Baikal Deep Underwater Neutrino Telescope NT200 and NT200+ and its extension to the gigatonne-scale.

Mikheyev was a versatile researcher with a deep understanding of theory and a remarkable ability to solve sophisticated computational problems with his own creative computer programs. With his wisdom and human friendliness he was a scientific guide and source of inspiration for many young researchers. In 2006, together with Smirnov and Wolfenstein, he was awarded the Bruno Pontecorvo Prize, and in 2008 shared with Smirnov the M Markov Prize and the JJ Sakurai Prize for Theoretical Particle Physics.

Mikheyev will be remembered by his friends and colleagues for his quiet character, his modest personality, his precise style of communication with others, his impressive speed of understanding things and his deep physics intuition. His memory and lessons will remain with us.

● *G Domogatsky, V Gavrin, P Lipari, V Matveev, A Smirnov, O Suvorova and colleagues, INR, Moscow.*

NEW PRODUCTS

Micromech has announced the Delta Tau release of the GeoBrick LV-PC product range, aimed specifically at high-end applications. The multi-axes format, incorporating drives that are software configurable for any type of motor technology, is a perfect match for synchrotron and FEL beamlines, adaptive optics on telescopes, etc. The bricks offer easy control of goniometers, slits, and multiple feedback devices. For further details, e-mail stirling@micromech.co.uk or see www.micromech.co.uk.

Murata Power Solutions has introduced three new series of surface mount inductors aimed at high current applications where low loss characteristics are essential. The 3700, 3800 and 3900 series are flat-coil inductors that provide a range of inductance values from 0.15 to 10 μH with DC current ratings up to 19.5 A. These compact surface mount devices are available with DC resistance values ranging from 0.9 to 20.3 m Ω . Murata has also announced the DIU4CS frontend 2100 W DC/DC power supply in a compact 1U unit, designed to deliver bulk power to

54 VDC distributed power applications. A 5 VDC, 0.75 A standby output is also provided. For more information, e-mail sutherby@murata-ps.com or visit www.murata-ps.com.

Optical Surfaces Ltd has introduced aspheric lenses for demanding applications. These diffraction-limited aspheric lenses are up to 600 mm in diameter with low f-number. To meet the demands of high-power laser focusing, LINDAR and laser launch telescopes, the aspheric lenses are made with a surface finish of 20/10 scratch/dig and surface roughness of 1 nm rms. A range of high-power laser coating is available to maintain high transmission and enable the lenses to operate at the ultra-high energy thresholds of terawatt lasers. For further details, e-mail sales@optisurf.com, or see www.optisurf.com.

Resolve Optics Ltd has introduced optical systems designed to operate in hostile environments where radiation, extremes of temperature, pressure, high levels of vibration or shock, and contact with

corrosive liquids and gases would render standard products unusable. These optical systems will operate up in temperatures up to 950°C without cooling and can withstand radiation doses of up to 10⁹ rads without degradation of performance. For further details, e-mail sales@resolveoptics.com or see www.resolveoptics.com.

XP Power has announced the VFT series of low-cost 150 W single output AC/DC power supplies aimed at high-volume cost-sensitive applications. Packaged within the industry standard 3" x 5" format and measuring 1.4" high, the VFT150 series can provide a full 150 W output when force-cooled and up to 100 W with convection cooling. XP Power has also introduced the ECS65 series of single output open-frame AC/DC power supplies. Capable of delivering 65 W, these convection-cooled units are rated at up to 90% efficiency. The ECS65 series has a no-load power consumption of less than 0.5 W and a wide operating temperature range from -20 to +70°C. For more information, e-mail thead@xppower.com or visit www.xppower.com.

Recruitment

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Imperial College London and will be based in the High Energy Physics Group of the Department of Physics and will work closely with the Department of Surgery and Cancer. The successful candidate will be expected to contribute to the particle accelerator research programmes both at the Department of Physics of Imperial College and at the Cockcroft Institute, spending roughly equal amounts of time at the two institutions. The successful candidate will develop a joint research programme encompassing the development of accelerator techniques for particle-beam therapy and contribute to the development of capability in the provision of pulsed proton beams towards various sub-atomic sciences. A key research initiative will be the development of the clinical applications of Hadron and Laser Therapy. The successful candidate will have an international reputation for research and innovation in Accelerator Physics or a related field, combined with the potential to raise significant external research funding from UK and EU sources to support

research activities in accelerator R&D. In addition the successful candidate will have a good honours degree and doctorate (or equivalent) in a relevant subject area in addition to the ability to teach at undergraduate or masters level.

Within Imperial College, the successful candidate will be expected to work closely with the Department of Physics, the CRUK Centre, collaborating in particular with those studying the effects of radiation on cellular processes such as cell division and DNA repair, and the Radiotherapy Department of Imperial College Healthcare NHS Trust. In the longer term, the successful candidate will be expected to join a team to study these effects in vivo, with the aim of developing the clinical applications of particle beam therapy. The successful candidate will also be expected to interact closely with postgraduate students and postdoctoral research associates and will have some involvement with undergraduate education.

Closing Date: 31 August 2011

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Email: NP-EPP@physics.ucla.edu (preferred) or Office of the Chair
Attn: Experimental NP-EPP Search
UCLA Department of Physics and Astronomy
475 Portola Plaza, Rm. 2-707 PAB
Box 951547
Los Angeles, CA 90095-1547

The deadline is September 30, 2011. However, the search will remain open until the position is filled. Please refer to Tracking #1000-1112-01 in all correspondence.

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Postdoctoral position in experimental particle physics

Physics Institute III A

Our Profile:

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Your Profile:

Applicants must hold a doctoral degree.

The applicant must hold a PhD degree in experimental physics and have experience in international high energy particle physics experiments, with special qualifications in physics data analysis. A team-oriented work style is expected.

Your duties and responsibilities:

The applicant is expected to take a leading role in data analysis in the area of Supersymmetry, or Top quark physics with the CMS experiment. An active commitment in teaching is expected in addition.

Postdoctoral position in astroparticle physics

Physikalisches Institut III A

Our Profile:

The research program of the institute is experimental particle physics and astroparticle physics at the highest energies. We participate in the data analyses and upgrade programs of the CMS experiment (Switzerland) and the Pierre-Auger-Observatory (Argentina).

Your Profile:

Applicants must hold a doctoral degree.

Applicants must hold a PhD degree in experimental physics and have experience in international astroparticle physics experiments, with special qualifications in physics data analysis. A team-oriented work style is expected.

Your duties and responsibilities:

The applicant is expected to take a leading role in data analysis in the area of Cosmic Ray Physics with the Pierre-Auger-Observatory. An active commitment in teaching is expected in addition.

Our offer:

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Your contact person:

For further information, please contact Prof. Dr. Thomas Hebbeker

Tel.: +49 (0) 241 80 27330, Fax: +49 (0) 241 80 22189, Email: hebbeker@physik.rwth-aachen.de or Dr. Markus Merschmeyer
Tel.: +49 (0) 241 80 27330, Fax: +49 (0) 241 80 22189, Email: merschmeyer@physik.rwth-aachen.de

You can also obtain further information from our websites: physik.rwth-aachen.de/institute/institut-iiiia/

Please send your application by 31 July 2011 to Prof. Dr. Thomas Hebbeker
Physikalisches Institut III A Physikzentrum

Otto-Blumenthal-Str. Turm 26 D-52056 Aachen Germany or submitted via mail to Prof. Thomas Hebbeker hebbeker@physik.rwth-aachen.de

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High Energy Physics: www.birmingham.ac.uk/staff/excellence/fellows/areas/high-energy-physics.aspx

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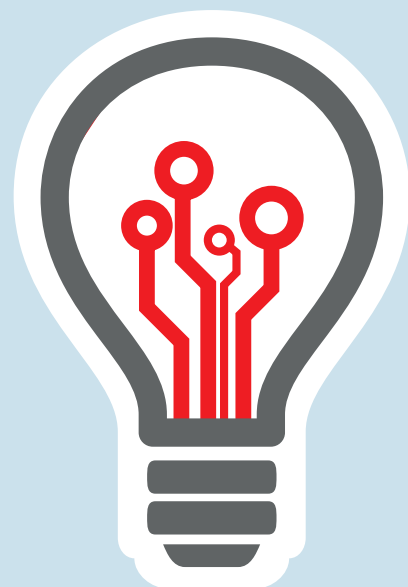
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The jobs site for physics
and engineering

Bookshelf

Summer Bookshelf

Summer for physicists is the season of conferences, with holidays squeezed in where possible. This year many particle physicists are no doubt already working hard on preparing the latest results from the LHC, based on the bumper crop of data already achieved.

For those who can find time for reading something other than drafts of their latest papers and preprints with new results, this Bookshelf reviews a few less technical books for more relaxed reading – or for recommending to family and friends while the hard work continues.

The Quantum Story

By Jim Baggott

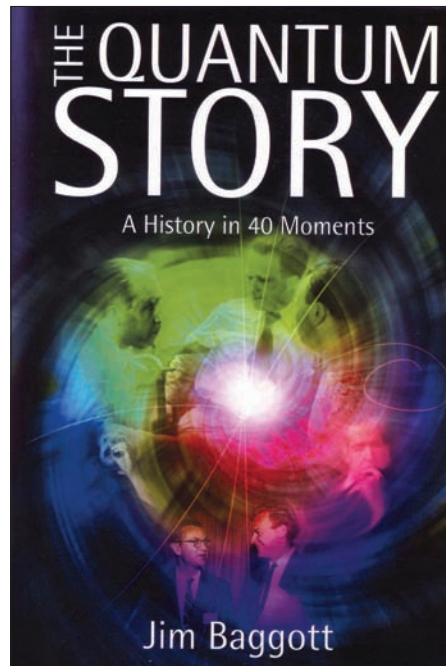
Oxford University Press

Hardback: £16.99 \$29.99

The Quantum Story provides a detailed “biography” of the 111-year-old quantum physics, from its birth with Planck’s quantum of action all of the way up to superstrings, loop quantum gravity and the start of the LHC – a machine that is expected to put physics back on the right track, with experimental measurements forcing some “figments of the theoretical mind” to confront reality.

The first chapters are simply delicious and ideally suited for summer reading on a sunny, late afternoon with a fresh drink close by. I was pleased to revisit most of the stories and characters I met as a teenager when reading books by or about Einstein, Bohr, Pauli, Heisenberg, de Broglie, Schrödinger, Dirac and many other universal heroes. Baggott explains the basics and wonders of quantum physics in a surprisingly clear way, despite its intrinsically “unsettling” and “wholly disconcerting” nature. A multitude of advances and a fair share of dead ends are exposed with excitement and suspense, almost as in a detective story, and the pace of the action is such that I was often reminded of Dan Brown’s novels. You begin to wonder if some of the main characters ever slept, such as during the Solvay conference in 1927, when each breakfast time Einstein would attack with a new *gedankenexperiment*, which Bohr would counter throughout dinnertime in Brussels’ “Hotel Britannique”.

We all know about Einstein’s “year of miracles” when, perhaps inspired by not having a respectable position to lose in the academic world, he revolutionized



physics with an incredible succession of amazing papers. It is less known that he also wrote several “unpublished papers”, some of which influenced new and important ideas, such as Born’s probabilistic view of Schrödinger’s wavefunctions, submitted for publication in June 1926. This “hastily written” paper was followed one month later by a second one giving a “more considered” perspective, complemented by a note added to the proofs of the first, mentioning that the probabilities are proportional to the *square* of the wavefunctions.

Somehow, it had not crossed my mind that even in those days many physicists were in a hurry to get their ideas in print. The “publish or perish” motto has long applied. Pauli submitted a paper deriving Balmer’s formula from matrix quantum mechanics just five days before Dirac did the same; maybe Dirac’s delay was caused by his proverbial perfectionism with clear language. Baggott mentions other notes added by the authors in the proofs of their papers, as when Heisenberg writes that: “Bohr has brought to my attention that I have overlooked essential points in the course of several discussions in this paper [on uncertainties].” Ouch... this must have hurt. It continues: “I owe great thanks to Professor Bohr for sharing with me at an early stage the results of these more recent investigations of his.” The Copenhagen interpretation did not have an easy birth.

The topic of quantum reality strikes

back later in the book, in chapters 30 to 35, where the reader needs a higher level of concentration to follow detailed developments regarding the topics of hidden variables, Bell’s and Leggett’s inequalities, entanglement and the surprisingly accurate experimental work recently made in this area. In chapters 18 to 29, the reader learns the crucial steps in the development of quantum field theories, quantum electrodynamics, quantum chromodynamics, quark asymptotic freedom and infrared confinement, the J/Ψ revolution, the discovery of the intermediate vector bosons, etc. This must be the nicest introduction to the Standard Model that I have read so far.

Given the style (and target audience) of the book, the almost complete absence of mathematics is quite understandable and I should say that the author succeeds remarkably well in explaining many leading-edge physics topics without the help of equations. It is true that “modern theoretical physics is filled with dense, impenetrable, complex mathematical structures”, which often obscure the deep meaning of what is being done. Nevertheless, and with the confidence gained after reading the 410 pages of main text plus several end-of-book notes, I dare to express the wish of seeing this book reprinted in a “special illustrated edition” (following the nice examples of Bill Bryson’s *A Short History of Nearly Everything* and Stephen Hawking’s *A Brief History of Time*), with more diagrams, pictures and equations.

In summary, this is a truly exceptional book, which I highly recommend. It will be enjoyable reading for many professional physicists as well as for bright high-school students waiting for something to trigger a decision to follow a career in physics.

● Carlos Lourenço, CERN.

Present at the Creation: The Story of CERN and the Large Hadron Collider

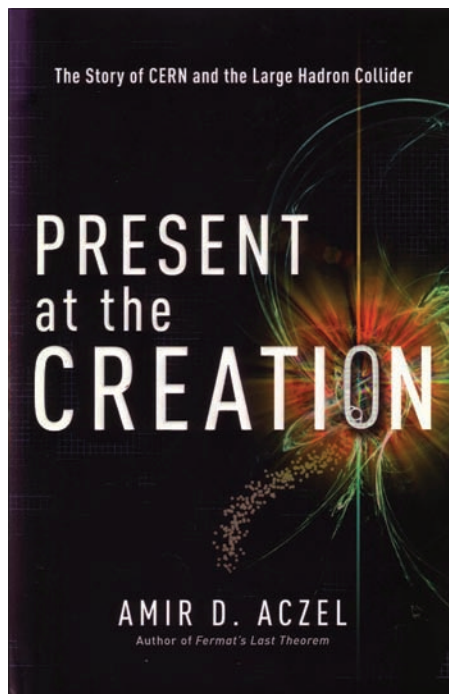
By Amir D Aczel

Crown

Hardback: £15.73 \$25.99

Mathematician and science writer Amir D Aczel is well known for his factually convincing and captivating story of *Fermat’s Last Theorem*. His recent book on CERN follows a similar recipe for writing a gripping story: impressions from several visits to the laboratory – notably witnessing the LHC restart from the CERN Control

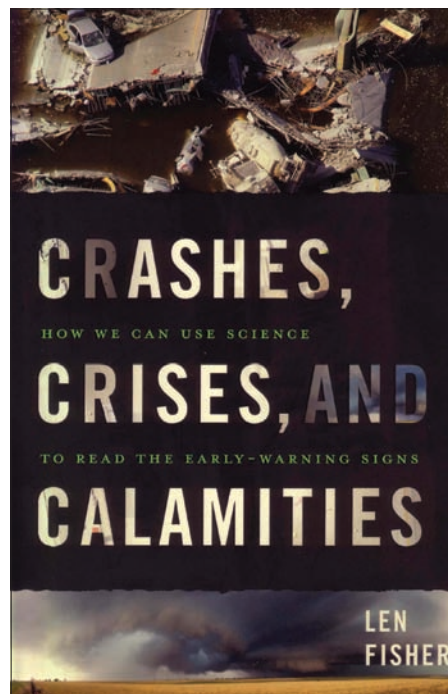
Bookshelf



Centre on 5 March 2010 and from the CMS Control Centre earlier in the day – as well as interviewing respective experts and leading physicists, including 13 Nobel laureates.

The story develops in 14 chapters that are illustrated with colour photographs, black-and-white line drawings, photographs and tables. An afterword, notes and a bibliography complete the picture, together with three more “technical” appendices: how an LHC detector works; particles, forces and the Standard Model; and the key physics principles used in the book. Aczel covers the LHC and its potentialities and risks, the four big detectors, symmetries of nature and Yang–Mills theory, the Standard Model, the Higgs particle, string theory, dark matter, dark energy and the fate of the universe. The result is a splendid effort to inform a wider public of CERN’s achievements set in an appropriate context.

As would be expected, Aczel is at his best when explaining mathematical theories such as that of Yang and Mills. Given the breadth of the material covered, it is not surprising that there are some lacunae and even errors. What struck me as an accelerator physicist was the erroneous explanation for the PS Booster synchrotron in the accelerator chain that feeds the LHC, which he attributes to the limited increase of particle velocity in a given synchrotron. In fact, the need for the Booster arose from the luminosity requirements of the Intersecting Storage Rings (and successive storage rings) – that is higher beam intensity and (phase space) densities or, in other words,



limited transverse and longitudinal beam emittances. It would have been helpful if Aczel had been able to interview the late Nobel laureate Simon van der Meer.

Altogether, however, it is a book that can be highly recommended to anybody who wants to know “everything” about CERN and who likes a narrative style. I would personally be interested to know how much a complete newcomer understood after a first reading.

● *Helmut Reich, formerly CERN.*

Crashes, Crises, and Calamities: How We Can Use Science to Read the Early-Warning Signs

By Len Fisher

Basic Books

Hardback: £13.99 \$23.99

When I received the book, I was eager to start reading it, particularly because of its subtitle: *How We Can Use Science to Read the Early-Warning Signs*. How can we? In fact, after reading the book, the conclusion is that we cannot.

Although realizing it caused some disappointment, I can confirm that, even without the million-dollar answer, the book is an interesting read. Len Fisher is an experienced writer, capable of explaining difficult concepts with simplified – but never simplistic – language. The book talks about equilibrium states, physical and mathematical models, negative feedback etc. When you study such topics in textbooks, you can quickly become bored that

everything seems so obvious. However, the mathematics that formalizes all of this is far from being obvious; and the million-dollar question has no answer precisely because of this.

Fisher’s writing is engaging because it moves the hard concepts into everyday life, giving them a framework that makes the reader forget about the complex physics and mathematics behind them. Thus, the equilibrium states that remain theoretical in textbooks, are here explained in real and contextual situations, so that the reader learns about the evolution of biological species, the main facts that determine the solidity of a newly constructed bridge (but it could be your house) and even the factors that lead the dynamics between two people who become a couple.

I found this enjoyable reading and the disappointment of the missing conclusion was partly compensated for by the genuine attention that the author pays to the reader’s entertainment. I recommend the book to a non-scientific readership, which, I believe, will greatly profit from Fisher’s explanation of how and why things work, or, conversely, why they don’t work and can break down.

● *Antonella Del Rosso, CERN.*

Le vrai roman des particules élémentaires

De François Vannucci

Éditions Dunod

Broché: €18

Version numérique: €14.99

De l’identification des atomes, à la fin du XIX^{ème} siècle, à la (incessamment sous peu ?) mise en évidence du boson de Higgs, la physique des particules est une aventure palpitante. Dans ce livre, le physicien François Vannucci dévoile les dessous des grandes avancées dans ce domaine trop peu populaire, et guide les amateurs de science, physiciens ou non, dans le monde des particules élémentaires. Le lecteur découvrira ainsi comment « les progrès de l’exploration de l’infiniment petit ont franchi les étapes successives de la molécule, de l’atome, du noyau, pour aboutir finalement aux constituants élémentaires ».

Si certains passages ardues nécessitent quelques prérequis, et s’il faut parfois s’accrocher pour ne pas s’égarer dans les méandres de la terminologie, la lecture de cet ouvrage reste dans l’ensemble très agréable et relativement accessible à un large public. En effet, plus qu’un véritable livre de physique, il s’agit d’un roman d’aventures – humaines et scientifiques – à travers lequel les amateurs de science au sens large peuvent revivre les moments clés de cette discipline : le lecteur en ressort

avec une bonne vue d'ensemble des grandes étapes qui ont marqué le monde de la physique des particules, qu'il s'agisse de la mise en évidence de nouvelles particules ou de la construction d'accélérateurs toujours plus puissants. Le texte est accompagné de quelques photographies historiques ainsi que de nombreux schémas. Malheureusement, ces illustrations restent trop souvent obscures au profane, faute de légendes suffisamment étayées.

En annexe, une frise chronologique retraçant les découvertes majeures et les Prix Nobel – de la découverte des rayons X par Wilhelm Röntgen en 1895 aux études sur la symétrie brisée de Yoichiro Nambu, Makoto Kobayashi et Toshihide Maskawa, nobélisés en 2008 – permet de (re)découvrir, en quelques pages, les grands noms de la physique des particules.

● *Anais Schaeffer, CERN.*

Decoding Reality: The Universe as Quantum Information

By Vlatko Vedral

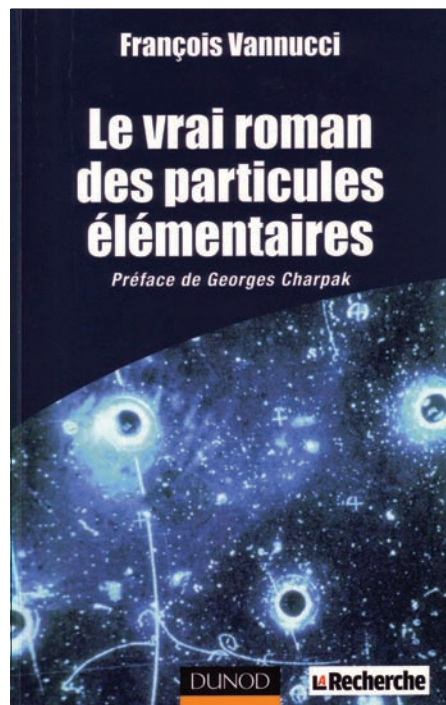
Oxford University Press

Hardback: £16.99

When I picked up this “engaging, non-technical exploration of what the new theory of quantum information and computation tells us about life, the universe and everything” (David Deutsch, quantum computation pioneer, author of *The Fabric of Reality* and, like Vedral, an Oxford University professor) I was hoping to get to grips with arcane topics such as entanglement and teleportation. When I reached the end of the book I was suffering from information overload, the point at which life ends according to Vedral.

The author begins by describing many aspects of “observed reality” in terms of classical information theory, from natural selection and global warming to poker playing and racial segregation. He then dives into the “real world” of quantum mechanics, where bits morph into qubits and nothing is as it seems. Part three is almost entirely speculative – how to get rid of God – and there I finally wilted.

The book is untidy, repetitive and in need of some error correction; 10^{100} divided by 10^{17} is not “about 10^{90} ”, or did I miss something? It is replete with the work of great thinkers, many of them Nobel laureates, so there are tough ideas to be absorbed, yet Vedral explains how to calculate 70% of 60%, and tells us that an unknown unknown is something we don't know we don't know. Well, er, yes... Discursive anecdotes and irritating bursts of whimsy often obscure the message, making



it easy for the reader to lose the plot.

Decoding Reality certainly contains an abundance of interesting facts but I didn't manage to get to grips with quantum information. The opinion of well-known scientist and communicator, Paul Davies, that it “is the finest treatment (he has) read of the weird interplay of quantum reality, information and probability”, leaves me wondering which book to pick up next.

● *Peggie Rimmer, Satigny and Oxford.*

Books received

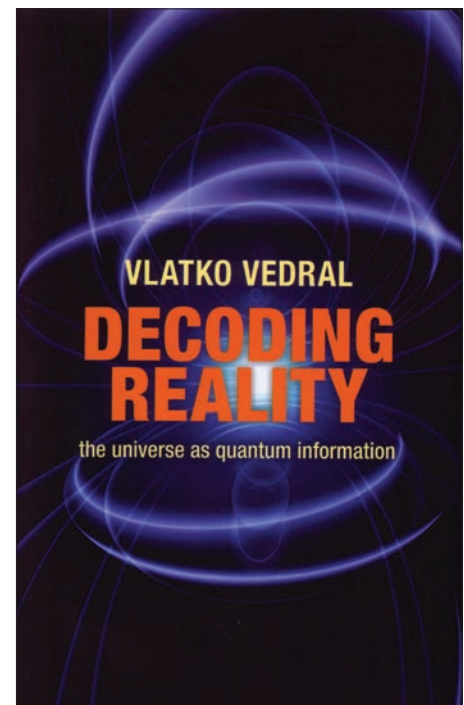
Energy, the Subtle Concept: The discovery of Feynman's blocks from Leibniz to Einstein

By Jennifer Coopersmith

Oxford University Press

Hardback: £29.95 \$55

In tracking the history of energy, this book is filled with the thrill of the chase, the mystery of smoke and mirrors, and presents a fascinating human-interest story. Moreover, following the history provides a crucial aid to understanding: this book describes the intellectual revolutions that were required to comprehend energy—revolutions as profound as those stemming from relativity and quantum theory. Using only a minimum of mathematics, the book recounts the emergence of the modern concept of energy, in all its forms, including Hamilton's mechanics and how it shaped 20th-century physics, and the meaning of kinetic energy, potential energy, temperature, action, and entropy. It is as much an explanation of



fundamental physics as a history of the fascinating discoveries.

Consciousness and Quantum Mechanics: Life in Parallel Worlds, Miracles of Consciousness from Quantum Reality

By Michael B Mensky

World Scientific

Hardback: £74 \$107

E-book: \$139

The phenomenon of consciousness includes mysterious aspects that provide a basis for many spiritual doctrines (including religions) and psychological practices. These directions of human knowledge are usually considered to contradict the laws of science. However, quantum mechanics — in a sense, the mysterious direction of science — allows us to include the phenomena of consciousness and life in the sphere of science. Wolfgang Pauli, one of the pioneers of quantum mechanics, together with psychologist Carl Gustav Jung, guessed about the relation between quantum mechanics and consciousness at the beginning of the 20th century, but only the “many-worlds” interpretation of quantum mechanics, proposed in 1957 by Hugh Everett III, gave the real basis for the systematic investigation of this relation. In this book, Michael Mensky of the PN Lebedev Institute elaborates what he calls the Extended Everett's Concept, which allows the derivation of the main features of consciousness and super-consciousness (intuition, or direct vision of truth) from quantum mechanics.

Viewpoint

CERN and the EPS: a joint endeavour

Luisa Cifarelli, president of the EPS, looks to the society's future and a closer collaboration with CERN.

The European Physical Society (EPS) was founded at CERN in 1968. Today it represents more than 100 000 physicists through its 41 national member societies and it provides a scientific forum for more than 3000 individual members from all fields of physics.

Around 50 universities, research institutes, laboratories and enterprises that are active in physics research are also present as EPS associate members. CERN was the first to join and has supported the EPS since the very beginning. Many leading personalities from CERN have been EPS presidents: Gilberto Bernardini, the founder and first president of the EPS, who at the time was CERN's research director; Antonino Zichichi; Maurice Jacob and Herwig Schopper.

The EPS is a non-profit association whose purpose is to promote physics in Europe and across the world. In 1968, when European integration was still rather vague, the establishment of the EPS was, to quote Bernardini's inaugural address in the CERN Council Chamber, "a demonstration of the determination of scientists to make their positive contribution to the strength of European cultural unity."

Today the EPS continues to play an important role in fostering the scientific excellence of European physicists, through high profile activities, in enhancing communication among physicists in Europe and across the world, and in bringing major issues in physics, and science in general, to the attention of the public and policymakers.

So how is the EPS organized? EPS members decide the priorities of the society, allocate resources for its activities and hold positions of responsibility. The scientific activities of the EPS segment into divisions and groups, which are governed by boards. Such activities include renowned topical

conferences, seminars and workshops.

The divisions and groups also develop outreach activities, for students and for the general public, and support measures to help physicists from less-favoured regions of Europe and from scientifically emerging countries worldwide to participate in EPS initiatives.

A number of prestigious prizes are awarded by the EPS divisions and groups in recognition of outstanding achievements in all fields of physics. These often anticipate the Nobel awards.

The EPS has 11 divisions, covering specific fields of physics research: Atomic, Molecular and Optical Physics, Environmental Physics, High Energy and Particle Physics, Nuclear Physics, Physics in Life Sciences, Plasma Physics, Quantum Electronics and Optics, Solar Physics, Statistical and Nonlinear Physics.

In addition there are seven groups that look at questions of common interest to all physicists, such as: Accelerators, Energy, and Technology; but also the History of Physics and Physics for Development. Finally, a number of committees deal with social questions: European Integration, Gender Equality in Physics, Mobility, Physics and Society and Young Minds.

Like all learned societies the EPS publishes a letters journal (*Europhysics Letters*), a scientific bulletin (*Europhysics News*) and, more recently, an electronic newsletter (*e-EPS*). These are produced in partnership with a number of member societies and their respective publishing houses.

As a consequence of its expansion and evolution over the past 40 years, the EPS has undergone several revisions to assess and define its two-fold role of learned society and federation of national societies, so that it can act as an authoritative, scientific opinion-maker.

In 2010 the society sketched out its new strategy plan and identified new guidelines. The EPS needs to gain more visibility, to strengthen and highlight the activities of its divisions and groups and to generate a greater spirit of belonging and cohesion among its members. It also needs to bring added value and provide a louder common voice to its member societies and associate



Luisa Cifarelli became president of the EPS in April. (Image credit: EPS.)

member institutions. It should increase its potential for co-operation and solidarity with less-favoured countries.

The preservation of the quality of European publications, in particular EPS journals and those related to or recognized by the EPS, and their integration into the context of global publishing is another main objective. Finally, establishing and strengthening links with other scientific societies worldwide – physical, astronomical and chemical – is among the new EPS priorities.

In this perspective, further intensifying the good relations and privileged interactions between CERN and the EPS would be highly desirable. Both institutions are on the same wavelength, share the same vision and support excellency in joint fundamental and applied research. They are concerned with technology transfer and industry's involvement in physics research and they care deeply about education matters, outreach, knowledge dissemination and public awareness.

As CERN's director-general Rolf Heuer repeatedly emphasizes, "We must bring science closer to society." A tighter collaboration between the unique European research laboratory that is CERN and the EPS could serve this common goal; moreover CERN could help considerably to boost the future of the EPS.

● Luisa Cifarelli, University of Bologna.

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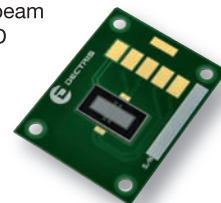
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- This units are an excellent mix of performance and high density (32/16 ch) of Data Acquisition Channels in one single board.
- Based on the PSI (Paul Scherrer Institute) switched capacitor array “**DRS4-Domino**”
- The analog input signals are continuously sampled by the DRS4s in a circular analog memory buffer; 1024 storage cells per channel (200 ns recorded time per event @ 5GSample/s)
- Programmable sampling frequency is **5GS/s, 2.5GS/s and 1GS/s**

761 Interleaved Digitizer series

VME/V1761 (2ch), Desktop/DT5761 (1ch), NIM/N6761 (1ch)

10 bit 4 GS/s Waveform Digitizer

- Clock In/Out, Triggers and 16 GPIOs available on the Front panel for multi-board synchronisation
- Memory buffer: 7.2 or 57.6 MSample/channel divided in 1 to 1024 independent read/write buffers

Available in VME, NIM and Desktop Form Factors

- Innovative and revolutionary daisy chainable Optical Link :
 - One PCI card A2818 (1 Optical Link) can control up to 8 ADC boards (e.g. 256 channels of model 742)
 - One PCIe card A3818 (4 Optical Links) can control up to 32 ADC boards (e.g. 1024 channels of model 742)
- USB2.0 port for NIM and Desktop boards
- Drivers, Libraries (C and LabView), Demos and Software tools for Windows and Linux

Digitizers Selection Table

Model ⁽¹⁾	Form Factor	N. of ch. ⁽⁴⁾	Max. Sampling Frequency (MS/s)	N. of Bits	Input Dynamic Range (Vpp) ⁽⁴⁾	Single Ended / Differential Input	Bandwidth (MHz)	Memory (MS/ch) ⁽⁴⁾	DPP firmware ⁽⁵⁾
x724	VME	8	100	14	0.5 / 2.25 / 10	SE / D	40	0.5 / 4	TF
	Desktop/NIM	4 / 2				SE			
x720	VME	8	250	12	2	SE / D	125	1.25 / 10	CI, NG
	Desktop/NIM	4 / 2				SE			
x721	VME	8	500	8	1	SE / D	250	2	no
x731	VME	8 - 4	500 - 1000	8	1	SE / D	250/500	2/4	no
x751	VME	8 - 4	1000 - 2000	10	1	SE / D	500	1.8 / 14.4 - 3.6 / 28.8	NG
	Desktop/NIM	4 - 2				SE			
x761	VME	2	4000	10	1	SE / D	TBD	7.2 / 57.6	no
	Desktop/NIM	1				SE			
x740	VME	64	65	12	2 / 10	SE	30	0.19 / 1.5	no
	Desktop/NIM	32							
x742	VME	32+2	5000 ⁽²⁾	12	1	SE	500	0.128/1 ⁽³⁾	no
	Desktop/NIM	16+1							

(1) The x in the model name is V1 for VME, VX1 for VME64X, DT5 for Desktop and N6 for NIM

(2) Sampling frequency of the analog memory (switched capacitor array); A/D conversion takes place at lower speed (dead-time)

(3) The memory size for the x742 is 128/1024 events of 1024 samples each

(4) The indication “size 1/size 2” denotes different options

(5) DPP-TF: Pulse Height analysis (Trapezoidal Filters), DPP-CI: Charge Integration (digital QDC), DPP-NG: γ -n Discrimination

Meet us at the following events:

EPS-HEP 2011 - International Europhysics conference on High Energy Physics

July 21 - 27, 2011

IPAC'11 2nd International Particle Accelerator Conference

September 5 - 9, 2011

PAV11 - Parity Violation to Hadronic Structure and more..

September 05 - 09, 2011

FUNFI - Fusion for Neutrons and Sub-critical Nuclear Fission

September 12 - 15, 2011

XCVII Congresso Nazionale Società Italiana di Fisica

September 19 - 23, 2011