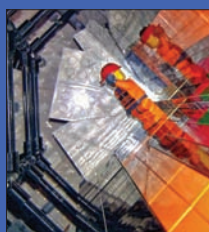


CERN COURIER

VOLUME 52 NUMBER 1 JANUARY/FEBRUARY 2012

All eyes are on the Higgs



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THE ARTS

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A BEAUTIFUL FUTURE

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

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

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

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

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

© 2012 CERN ISSN 0304-288X

IOP Publishing



CERN COURIER

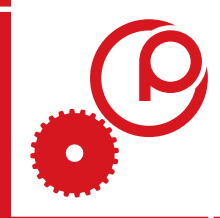
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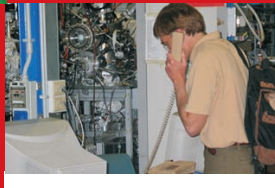
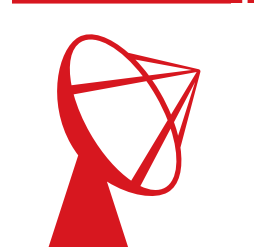
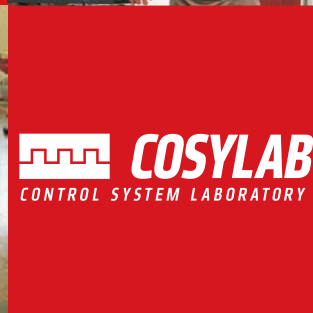
On the cover: CERN's auditorium was packed for presentations on the latest results on the search for the elusive Higgs boson (p6).

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Alan Jackson, former Technical Director of the Project (ASP)



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

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News

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Council solicits opinion to chart the future of European particle physics

During its December meetings, CERN Council announced that an Open Symposium will be held in Cracow on 10–13 September 2012 for the purpose of updating the European Strategy for Particle Physics. Council adopted Europe's current strategy for the field in July 2006 with an understanding that it be brought up to date at appropriate intervals of typically five years (*CERN Courier* September 2006 p29).

The Open Symposium is part of a process designed to get the maximum input from the particle-physics community, as well as from other stakeholders both inside and outside Europe, as Europe's strategy forms part of a global whole. Opinion will be solicited from the individual scientists who carry out the research, the communities that stand to benefit and the research ministries that will foot the bill. With help from the local organizing committee, the Open Symposium will be arranged by a preparatory group appointed by Council and provide an opportunity for the global particle-physics community to express its views on the scientific objectives of the strategy.

Submissions will be solicited for written statements from individual physicists, groups of scientists representing specific interests – such as an experiment or a topic of theoretical research – together



The historic city of Cracow will be the setting for the Open Symposium for updating the European Strategy for Particle Physics. (Image credit: Krzysztof Nahlik/dreamstime.com.)

the EU Council of Ministers meeting to be held at the same time.

• Further information on the update of the European Strategy of Particle Physics, including announcements and details for participation at the Open Symposium, may be found as it becomes available at <https://europeanstrategygroup.web.cern.ch/EuropeanStrategyGroup/>.

with contributions from institutions and organizations, such as funding agencies and science ministries. After discussion in the Open Symposium, these statements will be made available to the European Strategy Group tasked by Council with drafting the updated strategy document under the chair of the Scientific Secretary of the Strategy Session of Council.

Council will discuss the draft of the updated European strategy in March 2013 and will hold a special session in Brussels in early summer 2013 to adopt the updated strategy. It is also expected that the update of the strategy will become an agenda item for

the organization: Yugoslavia was a founder member state of CERN in 1954 and remained a member state until 1961. Serbian physicists have long been active in the ISOLDE facility and through the 1980s and 1990s were active in the DELPHI experiment at the Large Electron–Positron collider.

Serbia formally came back into the fold through a co-operation agreement in 2001, leading to involvement in the ATLAS and CMS experiments at the LHC. Serbian industry participated in the construction of both detectors and the country is also active in Grid computing.

Following notification of ratification, Serbia will join Israel as an associate member state of CERN. After a maximum period of five years, Council will decide on the admission to full membership.

Serbia set to join CERN as associate member state

At its 161st meeting at CERN on 16 December, the CERN Council unanimously voted to admit the Republic of Serbia to associate membership as the pre-stage to membership of CERN. This status will come into force following the signing of the related agreement by the two parties and notification to CERN of ratification by the Serbian parliament.

Serbian scientists have an involvement with CERN that dates back to the origins of

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News

LHC PHYSICS

Getting excited about the Higgs?

Tuesday 13 December 2011 is a day that many will remember. There was high anticipation of what the ATLAS and CMS collaborations would have to say about the latest results on the search for the elusive Higgs boson. Only senior management knew what the other collaboration was going to present, for the rest it was a well kept surprise.

From 8.30 a.m. onwards, physicists flocked into the main auditorium at CERN and by 10.30 a.m. the place was packed – three and a half hours before the talks even started – and no more people were being allowed in. The atmosphere was almost festive, maybe because the wireless network became saturated so that nobody could work. Similarly eager anticipation could be felt in a separate room where journalists representing the many news agencies and TV channels were able to share in the excitement.

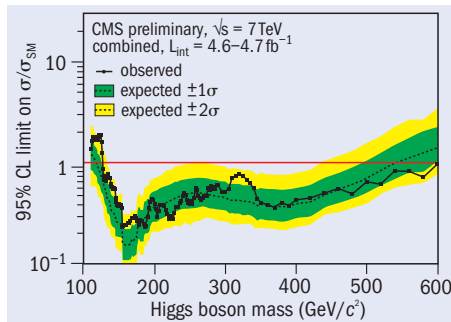
But what was all of the excitement about?

The short answer is that the presentations revealed that if the Higgs boson exists in the manner predicted by the Standard Model, then its mass is most likely between 115.5 and 127 GeV. To be more precise, the CMS collaboration rules out at 95% confidence level a Higgs boson with a mass larger than 127 GeV, while the ATLAS collaboration rules it out for masses below 115.5 GeV and larger than 131 GeV (with a small window of 237–251 GeV in mass not yet excluded by ATLAS). The upper limits on the exclusion region are 468 GeV for ATLAS and 600 GeV for CMS.

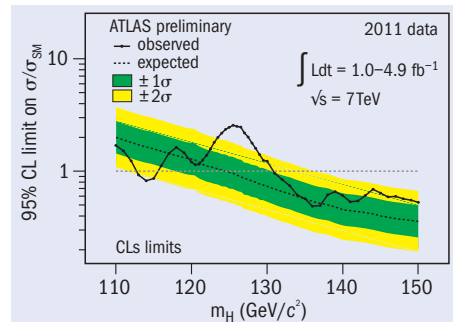
The ability to exclude the low-mass region was limited in both experiments by an excess of events around 120 GeV. Such excesses could be just background fluctuations or the first indications of a Higgs signal building up. These results are consistent with what is expected from the statistics accumulated so far, whether the low-mass Higgs exists or not.

The 2012 data campaign, during which the LHC is expected to deliver at least twice as many collisions as in 2011, should put to rest the 40-year quest for the Standard Model Higgs boson via either its discovery or its complete exclusion.

Only a month after the end of proton–proton collisions in 2011, both collaborations showed preliminary results using the full statistics of the year, corresponding to an integrated luminosity of 4.6–4.9 fb⁻¹ – almost twice that shown at the summer conferences. The results unveiled in the presentations in December demonstrate



Left: The expected (dashed line and coloured bands) and observed (black line) 95% confidence-level cross-section limits as a function of the Higgs boson mass over the full mass range from the CMS collaboration. Right: Similar plot from the ATLAS collaboration concentrating on the low mass range. The y-axes are normalized to the Standard Model cross-section, thus an observed value less than 1 corresponds to a mass that is excluded. The coloured bands show the 95% (yellow) and 68% (green) regions around the mean (dashed line) expected limit.



The main auditorium was packed, having reached its full capacity already three and a half hours before the presentations began.

the deep understanding achieved by each collaboration of detector performance and of the numerous backgrounds.

Both spokespeople, Fabiola Gianotti for the ATLAS collaboration and Guido Tonelli for the CMS collaboration, paid tribute in their presentations to the hundreds of physicists – most of them students and young post-docs – who have worked so hard in recent months to improve substantially the understanding of the detectors, in particular under the complex condition of ever increasing pile-up, where as many as 20 interaction vertices were reconstructed in a single event.

As a result of a coin toss by the director-general, Gianotti spoke first. The ATLAS collaboration had concentrated on updating the analyses in the channels that are most sensitive to the low-mass Higgs boson: $H \rightarrow \gamma\gamma$ and the “golden channel”, $H \rightarrow ZZ \rightarrow llll$, where l indicates an electron or a muon. An update of the $H \rightarrow WW$ search with the data collected for the summer

conferences was also shown. While in the first two channels the Higgs boson would be seen as a narrow peak on top of a broad background, the presence of the Higgs boson in the third channel would be seen as a more broad excess of events.

Tonelli then took the stage and presented a full array of CMS analyses – all including the full 2011 statistics – starting with the ones sensitive to the highest Higgs masses, $H \rightarrow ZZ \rightarrow (llqq), (ll\nu\nu), (ll\tau\tau)$, continuing with $H \rightarrow WW, H \rightarrow \tau\tau, H \rightarrow bb$ and finishing with $H \rightarrow \gamma\gamma$ and the golden channel $H \rightarrow ZZ \rightarrow llll$.

The energy and angular resolutions of the electromagnetic calorimeters are the key ingredients in the analysis of $H \rightarrow \gamma\gamma$, which is potentially the single-most sensitive mode in the low-mass region. The better the resolution, the narrower the peak in the invariant-mass distribution of the two photons and the easier it will be to see the Higgs, if it exists.

Despite having two different detector technologies – ATLAS uses a liquid argon sampling calorimeter, while CMS relies on crystals – the mass resolution obtained in both experiments in the channel with the best resolution is 1.4 GeV. For CMS, good mass resolution is possible thanks in particular to the major progress that has been achieved in understanding the calibration of the crystal calorimeter; in the central area of the calorimeter the performance is now close to nominal. The ATLAS calorimeter provides a similar mass resolution to that of CMS, despite intrinsically worse energy resolution. This is thanks to its capability to measure photon angles.

LHCb sees first evidence for CP violation in charm decays

The LHCb experiment was initially designed for the study of B physics (the “b” in its name stands for beauty, or



b quark). However, the LHC is also a copious source of particles that contain the charm quark, such as the D meson, which also makes the experiment well suited to their study. The rate at which data are selected by the LHCb trigger and written to storage was therefore increased last year by 50%, to 3 kHz, with the extra capacity dedicated to charm. This has now paid off spectacularly, with one of the most interesting (and unexpected) results to come from the LHC so far: evidence of CP violation in charm decays.

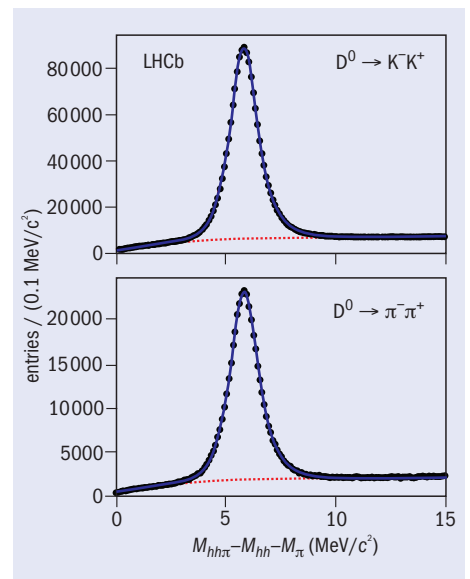
CP symmetry, the combination of charge-conjugation, C, and parity, P, is known to be violated in B and K decays. It is an important property to study because it is a necessary ingredient for explaining the matter–antimatter asymmetry in the universe. The CP violation observed so far in B and K decays is consistent with the predictions of the Standard Model but is far too small to explain the observed matter–antimatter asymmetry. The prediction for D mesons in the Standard Model is that they should have little CP violation, at the level of 10^{-3} or less, but this may be enhanced by new physics.

CP violation can be observed as a difference in the rate of D^0 decays to a given final state, compared with the rate of the antiparticle \bar{D}^0 decays to the same final

state. Because the effect being looked for is tiny, the LHCb collaboration performed its search by measuring the difference in the CP asymmetry for two final states, $D^0 \rightarrow K^-K^+$ and $D^0 \rightarrow \pi^-\pi^+$, which is denoted by ΔA_{CP} . In this way, systematic uncertainties in the production and detection of particles compared with antiparticles should cancel, while the CP asymmetry, which is expected to have opposite sign for the two modes, should remain visible.

$D^{*\pm} \rightarrow D^0\pi^\pm$ decays are used as the source of the neutral D-meson sample because the charge of the pion tags the produced particle as a D^0 or \bar{D}^0 (see figure). The experiment has collected more than a million of these decays, a total more than 10 times greater than in measurements by experiments at B-factories. It is also larger than the data sample used to obtain the previously most precise result, from the CDF experiment at Fermilab’s Tevatron, and benefits from the clean selection made possible by LHCb’s ring-imaging Cherenkov detectors.

LHCb measures the asymmetry to be $\Delta A_{CP} = (-0.82 \pm 0.21 \pm 0.11)\%$, where the first error is statistical and the second systematic. The significance of the measured deviation from zero is 3.5σ , giving the first evidence for CP violation in the charm sector, at a level that is higher than was expected. Establishing whether this result is consistent with the Standard Model, or the first hint of new physics, will require the analysis of additional data and improved theoretical understanding. LHCb



Mass-difference spectra for reconstructed $D^{*+} \rightarrow D^0\pi^+$ decays, with $D^0 \rightarrow K^-K^+$ (top) and $D^0 \rightarrow \pi^-\pi^+$ (bottom), showing the high-statistics samples of cleanly reconstructed decays in these suppressed modes.

has already collected almost a factor of two more data, with more to come this year, so this exciting first indication should be clarified soon.

● Further reading

LHCb collaboration 2011 arXiv:1112.0938 [hep-ex], submitted to *Phys. Rev. Lett.*

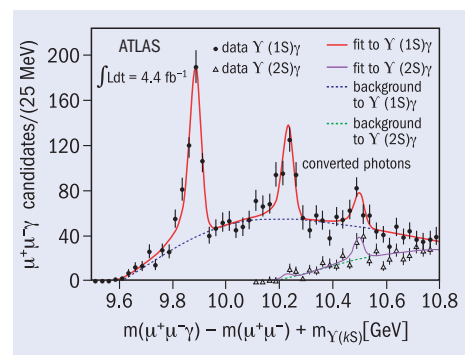
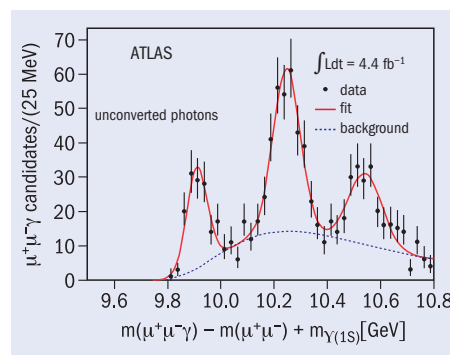
ATLAS discovers its first new particle

The ATLAS collaboration has announced the discovery of the $\chi_b(3P)$, which is a bound state of a bottom quark and bottom antiquark ($b\bar{b}$).



Bound states of a heavy quark and its antiquark – collectively called quarkonium – are the QCD analogues of the hydrogen atom, with each particle corresponding to a different energy level. For $b\bar{b}$ states, the S states are the well known Υ particles, while the P states are known as χ_b . As with the hydrogen atom, transitions between these states can be observed through the emission of a photon (γ).

The collaboration discovered the new state through the radiative transitions $\chi_b(3P) \rightarrow \Upsilon(1S) + \gamma$ and $\chi_b(3P) \rightarrow \Upsilon(2S) + \gamma$, followed by the decay of the Υ to two muons. The figure shows the spectrum of the χ states: the



The spectrum of the χ_b states observed in three different ways with peaks, from the left, for the $\chi_b(1P)$, the $\chi_b(2P)$ and the new $\chi_b(3P)$. The plot on the left shows the spectrum for decays involving unconverted photons, while the right-hand plot shows spectra for decays involving converted photons. In the right-hand plot, the upper (red) curve shows the spectrum for χ_b decays to $\Upsilon(1S)$, while the lower (brown) curve shows the spectrum for decays to $\Upsilon(2S)$. (Only the $\chi_b(3P)$ peak appears distinctly in the lower spectrum because it is the only χ_b state with decays involving enough energy to be detected in this study.)

News

leftmost peak is the $\chi_b(1P)$, the middle one the $\chi_b(2P)$ and the rightmost the new state, $\chi_b(3P)$. The photons were detected either by the electromagnetic calorimeter (in which case they remained unconverted) or, if they had interacted with material and converted to an e^+e^- pair, by the ATLAS tracking detectors.

Usually, a new particle is discovered in one or at most two channels, and the first observation is at the very edge of statistical significance. However, ATLAS has seen the $\chi_b(3P)$ with three different signatures,

in both the $\Upsilon(1S)$ and $\Upsilon(2S)$ channels, and the peaks are unmistakable. The outstanding performance of both the LHC and the ATLAS detector made such a clear observation possible.

Also in analogy with atomic physics, the visible peaks contain internal structure from hyperfine splitting among states of different angular momentum. These could be resolved with future data samples.

Studying the energy levels of quarkonium states provides information about the

forces that bind quarks together. One surprise is that the $\chi_b(3P)$ is slightly heavier than predicted, implying that the quark–antiquark pair is a little more loosely bound than expected. The $\chi_b(3P)$ is just at the very limit of being bound, so the quark and antiquark are about as far apart from each other as they can possibly be.

● **Further reading**

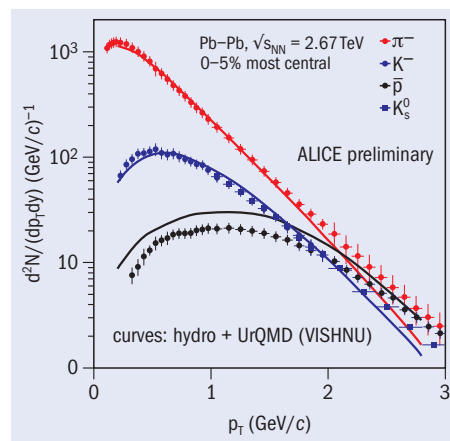
ATLAS collaboration 2011 <http://arxiv.org/abs/1112.5154> submitted to *Phys. Rev. Lett.*

Hadron spectra probe nature of matter in Pb–Pb collisions

In current understanding, the matter created in heavy-ion collisions – the quark–gluon plasma (QGP) – behaves as a nearly perfect liquid. The confirmation of this hydrodynamic behaviour, previously observed at Brookhaven’s Relativistic Heavy Ion Collider (RHIC), was one of the most eagerly awaited results from the first Pb–Pb collisions at the LHC. One of the crucial measurements for the characterization of the fireball produced in the collisions centres on the spectra of identified hadrons, which encode the collective expansion velocity in the QGP and hadronic stages. Moreover, their overall abundances are believed to be fixed at hadronization.

The ALICE detector was designed to perform these measurements with a unique combination of detectors for particle identification (PID): the silicon inner-tracking-system, the time-projection chamber and the time-of-flight detector. The collaboration has used these to measure the production of pions, kaons and protons in the range in transverse-momentum, p_t , where most of the particles are produced (0.1 to about 3 GeV/c).

The figure shows the results compared with the expectation from a hydrodynamic model, revealing a good agreement with the predicted shapes (Floris 2011). Together with the results on the azimuthal anisotropy also reported by ALICE and the other LHC experiments, this



The production of pions (red), kaons (blue) and protons (black) measured by ALICE in Pb–Pb collisions at the LHC. The theoretical curves are from a hydrodynamic model (Heinz et al. 2011).

represents the most direct confirmation of the hydrodynamic interpretation at the LHC. On an absolute scale, however, the model calculations shown in the figure significantly over-predict the production of protons – a surprise revealed by the first LHC data.

The production of soft hadrons ($p_t < 1\text{--}2$ GeV/c) is generally described in a statistical language: it is assumed that particles are created in thermal equilibrium. This idea, dating back to a classic 1950 paper by Enrico Fermi, has proved successful over a range of collision energies ($\sqrt{s} \sim 2$ GeV –

200 GeV) and provides a possible link to the temperature of the hadronization (or deconfinement phase transition).

At present, however, the yield ratios measured by ALICE seem to challenge both previous experiments and theory. While the K/π , Ξ/π and Ω/π ratios are compatible with the expectations from the thermal model with $T \approx 165$ MeV, as in previous observations, the p/π ratio points to a significantly lower temperature (see *CERN Courier* December 2011 p7 for the Ξ and Ω analysis). On the experimental side, there are indications of a similar effect at lower energies, which call for further investigations. On the theoretical side, a number of different possibilities are being investigated, none of them conclusive at the moment.

The unique PID capabilities of the ALICE experiment will continue to be crucial for the characterization of the deconfined matter produced in Pb–Pb collisions at the LHC. They also pave the way for a rich programme in proton–proton physics, especially in the soft physics domain, e.g. with the forthcoming measurement of fragmentation constraints with identified particles and spectra in high-multiplicity events.

● **Further reading**

M Floris for the ALICE collaboration 2011 *J. Phys. G* **G38** 124025.

U W Heinz et al. 2011 arXiv:1108.5323, to appear in the *AIP Conference Proceedings* for PANIC11 MIT 24–29 July 2011.

RARE ISOTOPES

New technique probes isovector transitions

A team at the National Superconducting Cyclotron Laboratory (NSCL) at Michigan State University has developed a new experimental technique for measuring (p, n) charge-exchange reactions at intermediate energies (~ 100 MeV/nucleon) on rare

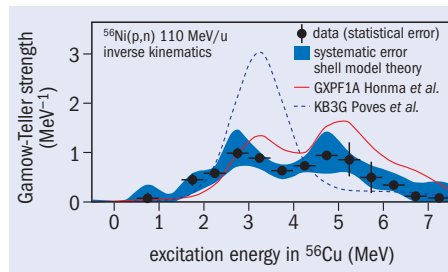
isotopes. The main virtue of the technique is that it can be applied to study the isovector response of rare isotopes of any mass and up to high excitation energies. Previously, charge-exchange experiments with rare isotopes were restricted to light isotopes and

final states at low excitation-energies.

The new technique has been applied first to study Gamow-Teller (GT) transitions from ^{56}Ni – an important case for modelling electron-capture rates of interest for the late evolution of core-collapse and

thermonuclear supernovae (Sasano *et al.* 2011 and Langanke 2011.) Nuclear charge-exchange reactions at intermediate energies have long been used to study the spin-isospin response of stable nuclei and weak reaction rates, in particular for astrophysical purposes.

To study the (p, n) reaction on the rare nickel isotope, the experiment was performed in inverse kinematics. A beam of ^{56}Ni particles at 110 MeV/u, produced by fast-fragmentation of ^{58}Ni particles from the NSCL coupled-cyclotron facility on a thick production target, was directed at a liquid hydrogen target, which provided the proton “probe”. The newly constructed Low-Energy Neutron Detector Array detected recoil neutrons, allowing the excitation energy of the ^{56}Cu reaction product and the centre-of-mass scattering angle to be deduced by measuring the neutron angle and energy. The S800 spectrograph detected heavy fragments



The GT strength for the $^{56}\text{Ni} \rightarrow ^{56}\text{Cu}$ transition, measured by the new technique involving inverse kinematics and a beam of rare isotopes, ^{56}Ni .

(^{56}Cu , or one of its decay products). After isolating the $\Delta L=0$ components of the excitation-energy spectrum via their distinct forward-peaked angular distribution, the team was able to extract the GT transition strength, using the well established proportionality between the differential cross-section at vanishing momentum

transfer and the GT strength.

The figure shows the extracted GT strength as a function of excitation energy and the comparison with two shell-model calculations based on different Hamiltonians. Because isospin symmetry-breaking effects are small and ^{56}Ni has isospin $I=0$, the strength distribution for the $^{56}\text{Ni} \rightarrow ^{56}\text{Cu}$ reaction is nearly identical to that for the $^{56}\text{Ni} \rightarrow ^{56}\text{Co}$ reaction. The latter is of relevance for electron captures in stellar environments, while ^{56}Ni plays a central role in the studies of weak reaction rates for supernovae. By benchmarking and improving the shell-model calculations for the $N=Z=28$ nucleus ^{56}Ni , more reliable calculations of electron-capture rates for many nuclei in the iron group will be possible.

● Further reading

M Sasano *et al.* 2011 *Phys. Rev. Lett.* **107** 202501.
K Langanke 2011 *Physics* **4** 91.

LHC

Meeting sets scene for LHC-luminosity upgrade

A design study for the High-Luminosity LHC (HL-LHC) project to upgrade the LHC has been launched with a meeting at CERN to bring together scientists and engineers from 20 institutes in Europe, Japan and the US. The goal is to prepare the ground for an LHC-luminosity upgrade scheduled for around 2020, which aims to take the LHC's luminosity to 200–300 fb⁻¹/year, a factor of 5–10 above the current design value. Upgrading the LHC for higher luminosity will involve a number of innovative technologies and

challenges. These include cutting-edge 12 T superconducting magnets, compact and ultraprecise superconducting cavities for beam rotation, as well as 300-m-long, high-power superconducting links with almost zero energy dissipation.

The meeting on 16–18 November marked the initial step in the HiLumi LHC Design Study, which is supported through the European Commission's Seventh Framework programme (FP7). Drawing on expertise from around the world, this 1st HiLumi LHC Collaboration Meeting included scientists and engineers from the well established CERN-KEK collaboration and US LHC Accelerator Research Program (LARP). Because it was a joint meeting with LARP, the first day was organized as a LARP collaboration meeting (LARP CM17), with a plenary session followed by two parallel sessions (Accelerator Physics

and Magnet R&D), where the accent was on the LARP programme and its results.

The second day included various parallel sessions organized for LARP and for the HiLumi LHC study, as well as the first HiLumi LHC Plenary Session, with presentations by the management and technical co-ordination. The first HiLumi LHC Collaboration Board also took place during a period of parallel sessions. The third day was devoted to a HiLumi LHC Public Session in CERN's Main Auditorium to review the HL-LHC programme and CERN's plans, as well as to discuss the US and Japanese involvement and the status of various work packages in the HiLumi LHC study.

For more about the meeting, see <http://hilumihc.web.cern.ch/HiLumiLHC/>. A more detailed report on the study will appear in the March issue of *CERN Courier*.

TECHNOLOGY TRANSFER

Events that match companies and researchers

Beam diagnostics, beam-profile measurements and quality-assurance methods are of the utmost importance for every accelerator or facility, and especially for radiotherapy beams. While researchers strive for better instruments and methods, industrial companies look towards the research

community for turning clever ideas and working prototypes into commercial products with improved accuracy and efficacy.

To foster the transfer of technologies based on high-energy physics, the HEPtech network has launched a series of workshops called “Industry – Academia matching events”. These include summary talks from both industry and the research community, with a poster gallery and live demonstrations. These are aimed at maximizing contact and collaboration between industrial companies and those researchers active in a particular field. The first event, on silicon photomultipliers, was held in February 2011

(*CERN Courier* June 2011 p33).

The second event, on the technology and the opportunities for beam instrumentation and measurement, took place on 10–11 November. It was held at GSI Darmstadt, home to much of the early work on heavy-ion radiotherapy. Some 84 participants, including representatives from 18 industrial companies, gathered at the new GSI Conference Building. The next event is planned to take place at DESY this spring and will focus on position-sensitive silicon detectors. It will be organized by the collaboration for Advanced European Infrastructures for Detectors and Accelerators (AIDA) with the support of HEPtech.

News

POLICY

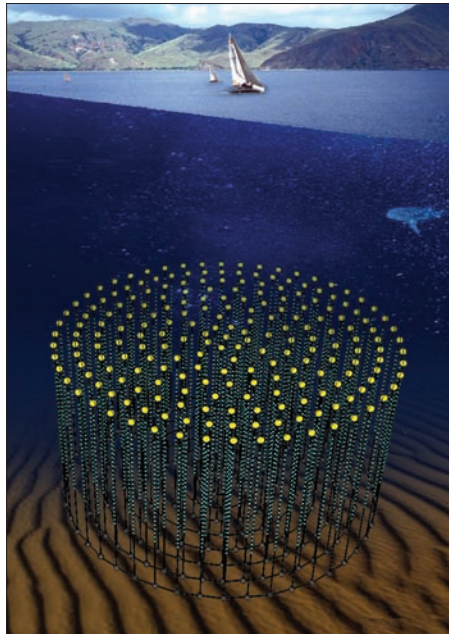
European funding agencies push forward large astroparticle-physics projects

European funding agencies have welcomed the priorities for the future of astroparticle physics defined by the scientific community and have accepted the recommendations included in the update of the European roadmap for astroparticle physics, published on 21 November 2011.

This update comes after the first ever European roadmap for astroparticle physics, published in 2008. The goal was to define the research infrastructures necessary for the development of the field: the “magnificent seven” of astroparticle physics (*CERN Courier* November 2008 p17).

The roadmap is the product of a collaboration between the ASroParticle European Research Area (ASPERA) network of European national funding agencies responsible for astroparticle physics and the Astroparticle Physics European Coordination (ApPEC). “The update of the roadmap provides a better picture of what will come first on the menu,” said Christian Spiering, chair of the ASPERA and ApPEC Scientific Advisory Committee that produced the roadmap. Funding for each project is still subject to national decision-making processes and the roadmap recognizes that not all funding agencies will necessarily support each project.

The strategy reaffirms the support required for current experiments and planned upgrades, in particular in the areas of gravitational waves, dark-matter



Artistic view of the KM3NeT undersea neutrino-telescope project, one of four big projects in the mid-term planning for the European roadmap in astroparticle physics. (Image credit: ASPERA/Nikhef/M Kraan.)

searches and the measurement of neutrino properties, as well as for underground and space-based infrastructures. The mid-term planning (2015–2020) includes four large projects to be constructed

starting from the middle of this decade.

In the domain of tera-electron-volt gamma-ray astrophysics the Cherenkov Telescope Array (CTA) is clearly the worldwide priority project. CTA is an initiative to build the next-generation ground-based, very high-energy gamma-ray observatory, combining proven technological feasibility with a guaranteed scientific perspective. Some 800 scientists from 25 countries have already joined forces to build it.

KM3NeT, the next-generation high-energy neutrino telescope in the Mediterranean Sea, is in its final stages of technology definition, with prototype deployment expected within the next 2–3 years. A project selected by the European Strategy Forum on Research Infrastructures, it is in an EU-funded preparatory phase, having obtained substantial regional funding.

LAGUNA is a megatonne-scale project for low-energy neutrino physics and astrophysics. It is at the interface with the CERN European Strategy update to be delivered in early 2013 and is currently the subject of an EU-funded design study.

Last, but not least, is a ground-based cosmic-ray observatory following in the footsteps of the Pierre Auger Observatory in Argentina. On longer time scales, similarly large infrastructures in the domain of dark energy or gravitational wave detection are being considered.

NEUTRINOS

First results from Double Chooz

Physicists at the Double Chooz experiment have found an indication of a disappearance of electron-antineutrinos that is consistent with neutrino oscillations.

The Double Chooz experiment, which detects antineutrinos produced in the

nearby nuclear reactor at Chooz in the French Ardennes, started data-taking in April 2011. The collaboration announced its first results seven months later at the 2011 LowNu conference held in Seoul, reporting new data consistent with short-range oscillations.

The result, on the disappearance of antineutrinos compared with the expected flux from the reactor, helps to determine the so-far unknown third neutrino-mixing angle, θ_{13} . The observed deficit indicates oscillation

with the following value: $\sin^2 2\theta_{13} = 0.086 \pm 0.041$ (stat.) ± 0.030 (syst.) or, at 90% CL, $0.015 < \sin^2 2\theta_{13} < 0.16$.

The measurement of this last mixing angle is important for future experiments aimed at measuring leptonic CP violation and relates indirectly to the matter–antimatter asymmetry in the universe.

● Further reading

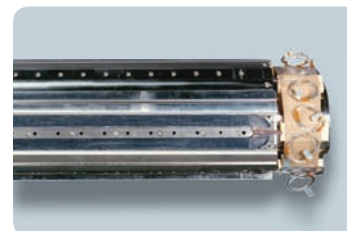
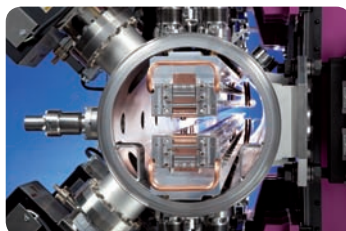
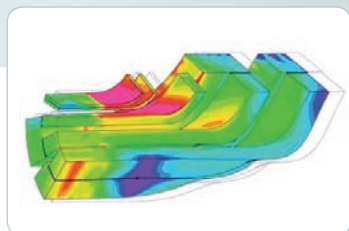
Y Abe *et al.* (Double Chooz collaboration) 2011 arXiv:1112.6353v1 [hep-ex].

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.

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

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Sciencewatch

COMPILED BY JOHN SWAIN, NORTHEASTERN UNIVERSITY

A 'snake oil' that really works

The term "snake oil" has long denoted any sort of quack medication, but recent studies suggest that at least one particular type of snake "product" may, indeed, offer remarkable medical benefits. Leslie A Leinwand of the University of Colorado, Boulder, and colleagues noted that Burmese pythons have a large increase in heart mass (40% within 2–3 days) after eating a large meal. This is accompanied by increased cardiac output, apparently to help support the increased metabolic requirements of digestions and nutrient transport.

Three fatty acids – myristic, palmitic



and palmitoleic – in the right proportions appear to be the trigger for these changes. Remarkably, the same stuff given to mice also increases the mass of their heart chambers – by 10% in a week. This surprising cross-species effect leads to hopes that something similar could help humans with heart trouble.

● Further reading

CA Riquelme *et al.* 2011 *Science* **334** 528.

The Burmese python could be good for you.
(Image credit: Anthonyata/dreamstime.com.)

Entangled diamonds

A remarkable new experiment has entangled the vibrational states of two macroscopic diamonds at room temperature. K C Lee of the University of Oxford and colleagues fired ultrafast (100 fs) laser pulses at a beam-splitter to hit two 3 mm diamonds.

Photons from the laser excited vibrational modes (phonons) in the diamonds, shared over 10^{16} atoms. Photons in a second pulse fired 350 fs later could recover the energy lost to the diamonds, something that would happen only half of the time if the diamonds were excited separately. However, this was not the case: instead, the second pulse of photons picked up the full energy. This showed that the diamonds were entangled, each in a superposition of being excited and not being excited, but correlated. While the decoherence time for such excitations in diamonds is short, the result is remarkable in that it shows entanglement between large objects at room temperature.

● Further reading

C Lee *et al.* 2011 *Science* **334** 1253.

Photons from the vacuum

The static Casimir effect, in which two parallel conducting plates are attracted as a result of vacuum fluctuations in the electromagnetic field, is well known and experimentally verified. Its less familiar cousin, the dynamical Casimir effect, predicts that if parallel conducting plates in the vacuum are moved closer and further apart, then real photons will be emitted. The effect is weak and requires plate motions

The shape of trees



An oak tree in winter shows off its branches.
(Image credit: B Preve/dreamstime.com.)

Long ago, Galileo Galilei noticed that "all of the branches of a tree at every stage of its height when put together are equal in thickness to the trunk". Traditional explanations based on the hydrodynamics of conserved fluid flow are unconvincing because only a small fraction of the branch cross-section is devoted to vascular transport; others involve somewhat artificial postulates of elastic similarity.

Now, Christophe Eloy of the University of California, San Diego, has proposed a surprisingly uncomplicated explanation that is borne out well in simple models. The observed regularity maximizes a tree's resistance to bending in the wind. Static loads from ice accumulation or fruit also lead to the same conclusion. In these days of excitement over exotic particles, it is good to keep in mind that simple things can still provide some interesting physics to think about.

● Further reading

C Eloy 2011 *Phys. Rev. Lett.* **107** 258101.

close to the speed of light, but it has now been seen for the first time.

CM Wilson of Chalmers University of Science and Technology in Gothenburg and colleagues have built a superconducting transmission line with a length that can be changed rapidly by modulating the inductance of a superconducting quantum interference device (SQUID) at high frequencies (above 10 GHz). The system models two oscillating parallel mirrors and as predicted pulls photon pairs out of the vacuum.

● Further reading

CM Wilson *et al.* 2011 *Nature* **479** 376.

Tractor beams

The science-fiction idea of a "tractor beam" seems rather unlikely to a physicist – light exerts radiation pressure and it is difficult to see how a beam of light could pull something. Now, however, S Sukhov and A Dogariu of the University of Central Florida have shown how it could be possible. The trick lies in arranging a beam with superposed waves so that as perpendicular components scatter forward they scatter such that the conservation of momentum makes the object move towards the illuminating source.

While this sounds incredible, even more amazing is the prediction that beams can be arranged to allow light to produce arbitrary translations and rotations of an object. Chalk up another one for science motivated by *Star Trek*.

● Further reading

S Sukhov and A Dogariu 2011 *Phys. Rev. Lett.* **107** 203602.

Astrowatch

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

'Supernova of a generation' reveals its nature

Astronomers have put under scrutiny the brightest and closest stellar explosion seen in the past 25 years. They have identified the supernova in the Pinwheel galaxy observed on 24 August 2011 as the explosion of a carbon-oxygen white-dwarf star triggered by mass accretion, most likely from a normal companion star.

Although a supernova – Latin for “super-new” – appears suddenly in the sky as a bright star, it is well known that the event marks the explosive demise of a star rather than its birth. Supernovae are rare, with a rate in the Milky Way of only about two per century (*CERN Courier* January/February 2006 p10). The majority of these stellar explosions (around 80%) are core-collapse supernovae, which result from the gravitational contraction of the central iron core of a star of more than about 10 solar masses that can no longer sustain nuclear fusion. While the core collapses into a neutron star or a black hole, the outer regions of the star are blown up in a gigantic explosion. Supernovae of type Ia are different. They are thought to be thermonuclear explosions of a white dwarf that result in complete disruption and leave no compact remnant. The historic supernovae of the years AD185, 1006, 1572 and 1604 have been identified to be of this type (*CERN Courier* December 2004 p15, May 2011 p12, December 2011 p12).

The event, PTF11kly, detected on 24 August 2011 in the nearby Pinwheel galaxy (Messier 101) was also soon identified as a type Ia supernova (*CERN Courier* October 2011 p12). Although the explosion was invisible to the unaided eye, it was bright enough (peak magnitude of 9.9) to trigger



The supernova SN 2011fe is clearly visible as the bright, bluish star in the upper, right portion of this image of M101 obtained with the Mayall 4-m telescope at Kitt Peak National Observatory. (Image credit: TA Rector (University of Alaska Anchorage), H Schweiker & S Pakzad NOAO/AURA/NSF.)

the interest of professional and amateur astronomers alike. The early detection of SN 2011fe, as it is called now, and its optimal location in a face-on spiral galaxy some 20 million light-years away, offered a rare chance for a better understanding of the progenitors of type Ia supernovae. The results of these investigations have now been published in two papers in *Nature*.

The first study, led by Peter Nugent of the Lawrence Berkeley National Laboratory and the University of California, is based on the early observations of SN 2011fe. It was detected only 0.5 days after ignition and the luminosity at that time allowed the researchers to constrain the size of the progenitor star to be less than one tenth that of the Sun. This is strong evidence that the exploding star was a white dwarf. These dense stars contain the mass of the

Sun within a size similar to the Earth and are the remnant cores of low-mass stars. Usually composed of carbon and oxygen, they maintain their structure via internal pressure from a degenerate gas of electrons. The star remains inert and stable as long as its mass does not reach the Chandrasekhar limit of 1.4 solar masses. When approaching this critical mass – for instance via accretion from a companion star – a runaway nuclear fusion of carbon ignites within the white dwarf and provokes the stellar explosion. The detection of the presence of carbon and for the first time also of oxygen in the spectrum of SN 2011fe confirms this scenario.

As for the nature of the companion star, there were basically three possibilities: a normal star; a much brighter red giant or helium star; or another white dwarf. Nugent and co-workers suggest a normal star based on the absence of the expected observational imprint that a white-dwarf merger of a giant star would leave. This is confirmed by the second study by Nugent's colleague of the University of California, Weidong Li and collaborators. They find no bright source at the position of SN 2011fe in archival images, thus ruling out luminous red giants and almost all helium stars as the mass-donor. The two studies confirm observationally the origin of type Ia supernova, a class of explosion that are similar enough to each other to be considered “standard candles” – a property that enabled the 2011 Nobel prize winners to discover the accelerating expansion of the universe (*CERN Courier* 2003 p23).

● Further reading

PE Nugent *et al.* 2011 *Nature* **480** 344.

WLi *et al.* 2011 *Nature* **480** 348.

Picture of the month

Is this a “celestial snow angel” or a “young star rebelling against its parent cloud”? The poetic view of the American press release contrasts with the more scientific European one. Both celebrate this new image by the Hubble Space Telescope, which witnesses the formation and not the demise of a star, although it resembles some planetary nebula (*CERN Courier* April 2007 p10). The “hourglass” shape of the nebula is created by strong ultraviolet radiation and the stellar wind from a massive new-born star enshrouded in a ring of gas. Called Sharpless 2-106, the nebula is located nearly 2000 light-years away in the direction of the constellation Cygnus. The colour scheme is rather misleading, however, because the usual pink colour of ionized hydrogen is shown here in blue, while red is used for infrared dust emission. (Image credit: NASA, ESA and the Hubble Heritage Team (STScI/AURA).)



CERN Courier Archive: 1969

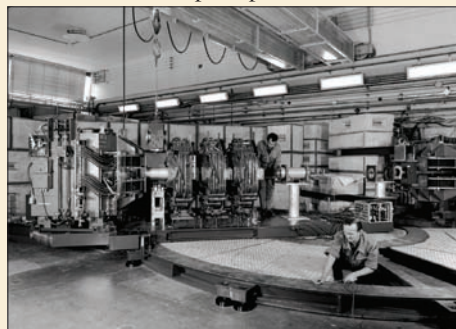
A LOOK BACK TO CERN COURIER VOL. 8, JANUARY/FEBRUARY 1969, COMPILED BY PEGGIE RIMMER

CERN

Meanwhile... at the synchrocyclotron

One of the major reasons for constructing the CERN 600 MeV synchrocyclotron SC was as a model for the more formidable task of constructing the 28 GeV proton synchrotron PS. Although the usefulness of the SC for intermediate energy physics (100–1000 MeV) was obvious at the time it was completed in 1957, the growing demand for use of the machine and the growing variety of its research programme was never anticipated. As things have turned out, it has played as notable a role in its field as the PS has at higher energies.

The machine yields pion beams in the energy range 80–300 MeV, high-purity muon beams in the energy range 50–200 MeV and an external proton beam of 595 MeV taken to an underground laboratory for work with ISOLDE, the Isotope Separator On-Line.



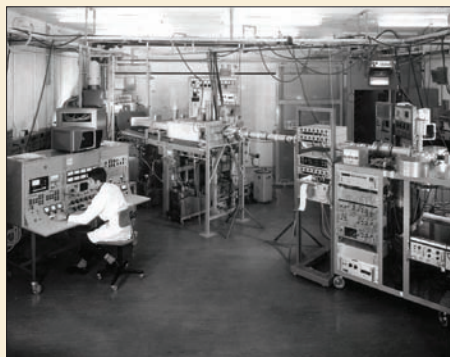
A double spectrometer used for pion-nucleon experiments at the SC.

In recent years, research in nuclear structure physics and radiochemistry have been added to elementary particle physics, plus some work in solid-state physics and radiobiology. As a bonus, the SC has also proved useful to test equipment intended for experiments at the PS.

There have been many outstanding achievements at the SC, including three important contributions to weak interaction physics:

- the discovery of the electron decay of the pion, which proved an important prediction of the weak interaction theory;
- the first exact measurement of the decay rate of the positive pion into a positron, neutrino and neutral pion;
- the most accurate measurement of the capture rate of muons in liquid and gaseous hydrogen.

The first precision measurement of



Part of the Isotope Separator On-line.

the magnetic moment of the muon, which extended the range over which electromagnetic theory is known to hold good, was also made at the SC.

The number of scientists involved in SC experiments has risen to 120; only 25 are CERN Staff, Fellows or CERN-paid visitors, 95 are based in about 26 universities and research centres throughout Europe. A recent investigation indicates that over the next two or three years, requests for machine time will rise by about 20%. Higher beam intensity will make possible a wide variety of experiments that are not feasible with the existing beam intensity, ensuring that European physicists continue to have a first-rate machine available for intermediate energy physics, particularly in the early 1970s.

- Compiled from texts on pp3–5.

Computer to Geneva

In February, a CDC 3800 computer left CERN for the University of Geneva. The machine came to CERN in September 1966

to sustain on-site computing capacity during the teething-troubles of the CDC 6600; the need for it was removed when the CDC 6400 arrived.

At that time, the Canton of Geneva was interested in acquiring a large computer for use by the university and the cantonal administration. CERN was able to offer the CDC 3800 on very favourable terms (4.9 million Swiss francs) and the Geneva authorities signed a purchase agreement in April 1968.

The CDC 3800 has a memory of 65 356 48-bit words, a capacity of approximately 1 100 000 operations per second, a reading speed of 1200 punched cards per minute, and 8 tape decks with a transfer speed of 120 000 characters per second.

- Compiled from texts on pp33–39.

Survey

Ten years ago, in August 1959, the first issue of *CERN COURIER* was published as a “house journal”, conveying news about CERN inside CERN. A few years later it also became one of the main channels for informing people outside about the work of CERN. More recently it has evolved to take in the work of related Laboratories.

In 1968, a readership survey was carried out. Of 2800 questionnaires sent to external readers (external distribution is now greater than internal distribution), 50% were completed and 86% of those who replied found the level “about right” – but maybe they would not take the *COURIER* if it were not about right.

- Compiled from text on p2.

Compiler's Note



The SC Counting Rooms were clustered around the small Control Room; the workshops were along the corridor leading to the experimental halls and to the machine itself. With typically a hundred or so physicists engaged in about a dozen experiments and a handful of machine operators known to one and all, this was research on a human scale. Forgive the nostalgia! Happily, the machine, decommissioned in 1990, is to become a tourist attraction; it is being prepared to welcome visitors to CERN in about two years' time.

When the SC closed, ISOLDE moved to the PS-Booster. For the past decade it has been delivering beams of radioactive ions, across the nuclear chart, for further acceleration in the Radioactive beam Experiment, REX-ISOLDE (p33).



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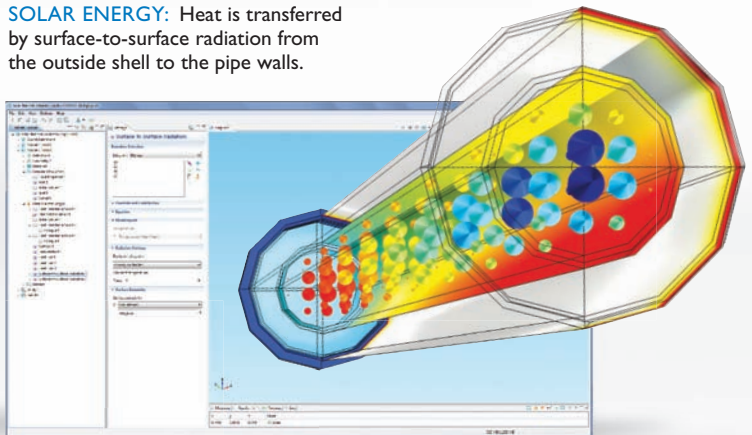


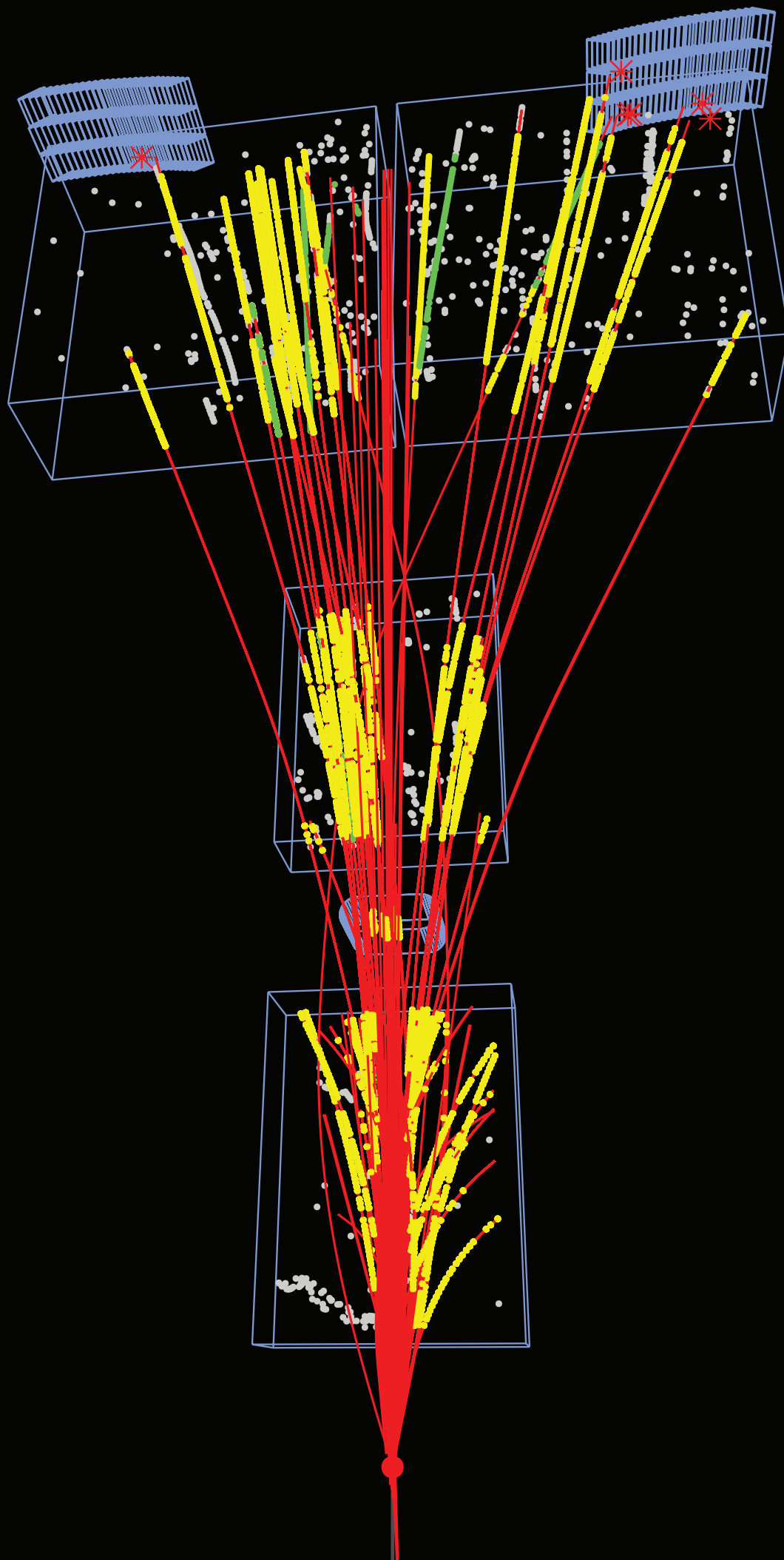
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Pursuit of deconfinement returns to the SPS

Marek Gazdzicki and Peter Seyboth follow the story of the discovery of the onset of deconfinement in heavy-ion collisions as it moved from the SPS to RHIC and the LHC – and now heads back to the SPS with the NA61/SHINE experiment.

The quark model of hadron classification proposed by Murray Gell-Mann and George Zweig in 1964 motivated the opinion that a new state of matter, namely strongly interacting matter composed of subhadronic constituents, may exist. Soon thereafter, quantum chromodynamics (QCD) was formulated as the theory of strong interactions, with quarks and gluons as elementary constituents. As a natural consequence, the existence of a state of quasi-free quarks and gluons – the QCD quark–gluon plasma (QGP) – was suggested by Edward Shuryak in 1975. These events, together with the rapid development of particle-accelerator and detector techniques, mark the beginning of the experimental search for this hypothetical, subhadronic form of matter in nature.

First indications

The experimental efforts received a boost from the first acceleration of oxygen and sulphur nuclei at CERN's Super Proton Synchrotron (SPS) in 1986 ($\sqrt{s_{NN}} \approx 20$ GeV) and of lead nuclei in 1994 ($\sqrt{s_{NN}} \approx 17$ GeV). Measurements from an array of experiments were surprisingly well described by statistical and hydrodynamical models. They indicated that the created system of strongly interacting particles is close to at least local equilibrium (Heinz and Jacob 2000). Thus, a necessary condition for QGP creation in heavy-ion collisions was found to be fulfilled. The "only" remaining problem was the identification of unique experimental signatures of QGP.

Unfortunately, precise quantitative predictions are currently impossible to calculate within QCD and predictions of phenomenological models suffer from large uncertainties. Therefore, the results of the measurements were only suggestive of the production of QGP in heavy-ion collisions at the top SPS energy. The same situation persisted at the top energies of Brookhaven's Relativistic

Heavy Ion Collider (RHIC) and seems to be repeated at the LHC. Despite many arguments in favour of the creation of QGP at these energies, its discovery cannot be claimed from these data alone.

A different strategy for identifying the creation of QGP was followed by the NA49 experiment at the SPS and is now being continued by its successor NA61/SHINE, as well as by the STAR experiment at RHIC. The idea is to measure quantities that are sensitive to the state of strongly interacting matter as a function of collision energy in, for example, central lead–lead collisions.

The reasoning is based on simple arguments. First, the energy density of matter created at the early stage of heavy-ion collisions increases monotonically with collision energy. Thus, if two phases of matter exist, the low-energy density phase is created in collisions at low energies and the high-energy density phase in collisions at high energies. Second, the properties of both phases differ significantly, with some of the differences surviving until the freeze-out to hadrons and so can be measured in experiments. The search strategy is therefore clear: look for a rapid change of the energy dependence of hadron production properties that are sensitive to QGP, because these will signal the transition to the new state of matter and indicate its existence.

This strategy, and the corresponding NA49 energy-scan programme, were motivated in particular by a statistical model of the early stage of nucleus–nucleus collisions (Gazdzicki and Gorenstein 1999). It predicted that the onset of deconfinement should lead to rapid changes of the collision-energy dependence of bulk properties of produced hadrons, all appearing in a common energy domain. Data from 1999 to 2002 on central Pb+Pb collisions at 20A, 30A, 40A, 80A and 158A GeV were recorded and the predicted features were observed at low SPS energies (*CERN Courier* September 2003 p17; Alt *et al.* 2008, Gazdzicki *et al.* 2011).

The strategy is clear: look for a rapid change of energy dependence of hadron production properties

An independent verification of NA49's discovery is vital and calls for further measurements in the SPS energy range. Two new experimental programmes are already in operation: the ion programme of NA61/SHINE at the SPS; and the beam-energy scan at RHIC. Elsewhere, the construction of the ▷

Image left: Be+Be collision at 150A GeV/c recorded by NA61 in the 2011 run.

Heavy ions

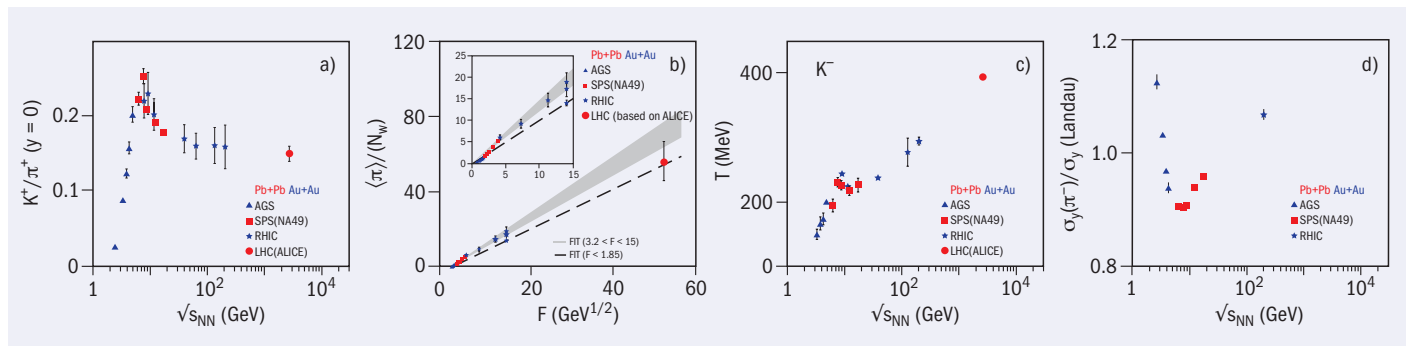


Fig. 1. Energy dependence of hadron production properties in central Pb+Pb (Au+Au) collisions, see text for details.

Nuclotron-based Ion Collider at JINR, Dubna, is in preparation. The basic goals of this experimental effort are the confirmation and the study of the details of the onset of deconfinement and the investigation of the transition line between the two phases of strongly interacting matter. In particular, the discovery of the hypothesized second-order critical end-point would be a milestone in uncovering properties of strongly interacting matter.

Four pointers

Last year rich data from the RHIC beam-energy scan programme were released (Kumar 2011, Mohanty 2011). Furthermore, the first results from Pb+Pb collisions at the LHC were revealed (Schukraft *et al.* 2011, Toia *et al.* 2011). It is therefore time to review the status of the observation of the onset of deconfinement. The plots in figure 1 summarize relevant results that became available in June 2011. They show the energy dependence of four hadron-production properties measured in central Pb+Pb (Au+Au) collisions, which reveal structures referred to as the “horn”, “kink”, “step” and “dale” – all located in the SPS energy range.

The horn. The most dramatic change of the energy dependence is seen for the ratio of yields of kaons and pions (figure 1a). The steep threshold rise of the ratio characteristic for confined matter changes at high energy into a constant value at the level expected for deconfined matter. In the transition region (at low SPS energies) a sharp maximum is observed, caused by the higher production ratio of strangeness-to-entropy in confined matter than in deconfined matter.

The kink. Most particles produced in high-energy interactions are pions. Thus, pions carry basic information on the entropy created in the collisions. On the other hand, entropy production depends on the form of matter present at the early stage of collisions. Deconfined matter is expected to lead to a final state with higher entropy than confined matter. Consequently, the entropy increase at the onset of deconfinement is expected to lead to a steeper increase with collision energy of the pion yield per participating nucleon. This effect is observed for central Pb+Pb collisions (figure 1b). When passing through low SPS energies, the slope of the rise in the ratio $\langle \pi \rangle / \langle N_p \rangle$ with the Fermi energy measure $F \approx \sqrt{s_{NN}}$ increases by a factor of about 1.3. Within the statistical model of the early stage, this corresponds to an increase of the effective number of degrees of freedom by a factor of about 3.

The step. The experimental results on the energy dependence of the inverse slope parameter, T , of K^- transverse-mass spectra for

central Pb+Pb (Au+Au) collisions are shown in figure 1c. The striking features of these data can be summarized and interpreted as follows (Gorenstein *et al.* 2003). The T parameter increases strongly with collision energy up to low SPS energies, where the creation of confined matter at the early stage of the collisions takes place. In a pure phase, increasing collision energy leads to an increase of the early-stage temperature and pressure. Consequently the transverse momenta of produced hadrons, measured by the inverse slope parameter, increase with collision energy. This rise is followed by a region of approximately constant value of the T parameter in the SPS energy range, where the transition between confined and deconfined matter with the creation of a mixed phase is located. The resulting softening of the equation of state “suppresses” the hydrodynamical transverse expansion and leads to the observed plateau or even a minimum structure in the energy dependence of the T parameter. At higher energies (RHIC data), T again increases with collision energy. The equation of state at the early stage again becomes stiff and the early-stage pressure increases with collision energy, resulting in a resumed increase of T .

The dale. As discussed above, a weakening of the transverse expansion is expected to result from the onset of deconfinement because of the softening of the equation of state at the early stage. Clearly, the latter should also weaken the longitudinal expansion (Petersen and Bleicher 2006). This expectation is confirmed in figure 1d, where the width of the π^- rapidity spectra in central Pb+Pb collisions relative to the prediction of ideal Landau hydrodynamics is plotted as a function of the collision energy. In fact, the ratio has a clear minimum at low SPS energies.

The results shown in figure 1 include new results on central Pb+Pb collisions at the LHC and data on central Au+Au collisions from the RHIC beam-energy scan. The RHIC results confirm the NA49 measurements at the onset energies while the LHC data demonstrate

that the energy dependence of hadron-production properties shows rapid changes only at low SPS energies. A smooth evolution is observed between the top SPS energy (17.2 GeV) and the current energy of the LHC (2.76 TeV). This strongly supports the interpretation of the NA49 structures as arising from the onset of deconfinement.

A smooth evolution is observed between the top SPS energy and the current energy of the LHC.

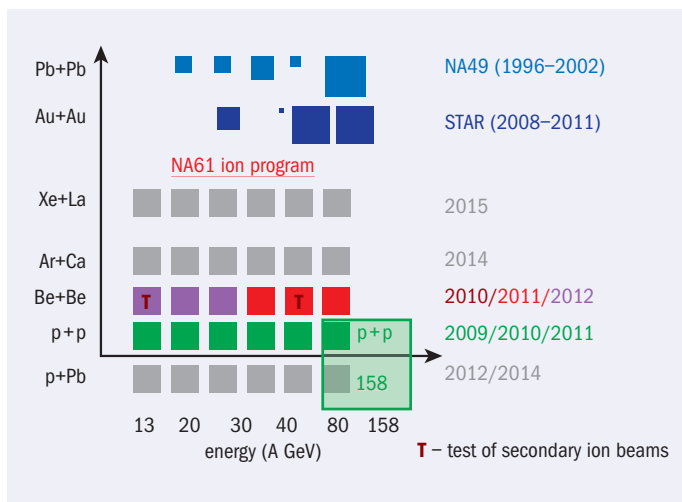


Fig. 2. The NA61 data-taking status and plans. For comparison, data collected by NA49 and STAR are also indicated.

Above the onset energy only a smooth change of the QGP properties with increasing collision energy is expected.

The first LHC data thus confirm the following expected effects:

- an approximate energy independence of the K^+/π^+ ratio above the top SPS energy (figure 1a);
- a linear increase of the pion yield per participant with $F \approx \sqrt{s_{NN}}$ with the slope defined by the top SPS data (figure 1b);
- a monotonic increase of the kaon inverse-slope parameter with energy above the top SPS energy (figure 1c).

The width of the π rapidity spectra in central Pb+Pb collisions should increase continuously from the top SPS energies to the LHC energies, as predicted by ideal gas Landau hydrodynamics. LHC data on rapidity spectra are required to verify this expectation.

The NA61/SHINE experiment

The confirmation of the NA49 measurements and their interpretation in terms of the onset of deconfinement by the new LHC and RHIC data strengthen the arguments for the NA61/SHINE experiment, which will use secondary proton and Be, as well as primary Ar and Xe beams in the SPS beam momentum range (13A–158A GeV/c). The basic components of the NA61 detector were inherited from NA49. Several important upgrades – in particular, the new and faster read-out of the time-projection chambers, the new, state-of-the-art resolution Projectile Spectator Detector and the installation of background-reducing helium beam pipes – allow the collection of data of high statistical and systematic accuracy. In parallel to the ion programme, the NA61/SHINE experiment is also making precision measurements of hadron production in proton- and pion-nucleus collisions for the Pierre Auger

Observatory's studies of cosmic rays and the T2K long-baseline neutrino experiment (*CERN Courier* December 2010 p41).

NA61 has already begun a two-dimensional scan in collision energy and the size of the colliding nuclei (figure 2). Data on proton–proton interactions at six collision energies were recorded in 2009–2011 and a successful test of secondary ion beams took place in 2010. The first physics run with secondary Be beams came in November/December 2011. Most important for the programme are runs with primary Ar and Xe beams, expected for 2014 and 2015, respectively. The collaboration between CERN and the iThemba Laboratory in South Africa is ensuring a timely optimization of the ion-source parameters. This all adds up to a future where the results from NA61 will allow a detailed study of the properties of the onset of deconfinement and a systematic search for the critical point of strongly interacting matter.

• Further reading

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Résumé

Déconfinement : retour au SPS

Les mesures issues de la première accélération de noyaux d'oxygène et de soufre au Supersynchrotron à protons (SPS) du CERN en 1986 et des noyaux de plomb en 1994 ont montré qu'une condition nécessaire à la création de plasma quarks-gluons dans les collisions d'ions lourds était remplie. Le « seul » problème restant était d'identifier des signatures uniques. La même situation a persisté aux énergies les plus élevées du Collisionneur RHIC de Brookhaven et semble se répéter au LHC. Une stratégie différente, adoptée par l'expérience NA49 au SPS, est actuellement poursuivie par NA61/SHINE ainsi que par l'expérience STAR à Brookhaven. L'idée est de mesurer des valeurs dépendant de l'état de la matière soumise à l'interaction forte en fonction des énergies de collision.

Marek Gazdzicki, Goethe-University Frankfurt and Jan Kochanowski University Kielce, and **Peter Seyboth**, Max-Planck-Institut für Physik Munich, and Jan Kochanowski, University Kielce.

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Agilent Technologies

SuperKEKB goes in hunt of flavour at the terascale

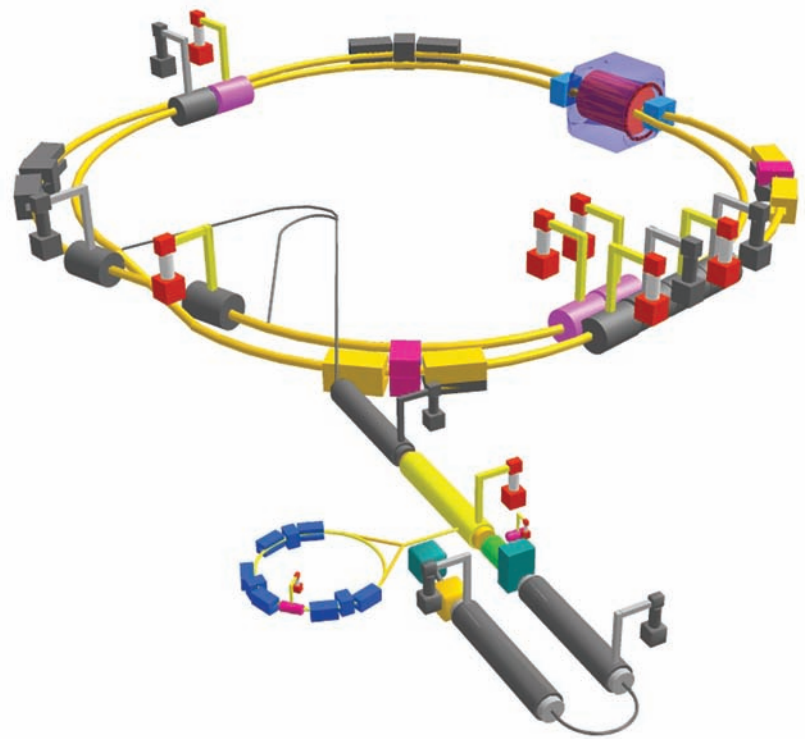
KEK is upgrading its B factory to provide a 40-fold increase in luminosity by using a large crossing-angle and squeezing the beams down to nanometres. The Belle experiment will also see a second incarnation.

What is dark matter? Why is there more matter than antimatter in the universe? These are some of the most fundamental puzzles in modern particle physics. The clues to the answers might reside in the physics of the symmetry breaking of electroweak forces at tera-electron-volt scale. Projects at the energy frontier, such as CERN's LHC, are complementary to the approach of flavour physics, where measurements of rare processes at lower energies can be sensitive to new types of interaction. SuperKEKB will provide a promising path to such new physics by enabling detailed studies of the decay processes of heavy quarks and leptons.

From 1998 to 2010, KEK, the Japanese High-Energy Accelerator Research Organization, operated its B factory, KEKB – an asymmetric electron–positron collider, 3 km in circumference – and achieved the world's highest luminosity of $2.11 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$, more than double the design value. There, the Belle experiment precisely analysed the characteristics of pairs of B and \bar{B} mesons produced in the collisions and confirmed the effect of CP-violation as indicated by the theory of Makoto Kobayashi and Toshihide Maskawa, who both received the Nobel prize in physics in 2008.

KEK has played a central role in flavour physics not only with the record-breaking KEKB but also with the world's first long-baseline neutrino oscillation experiment, KEK-to-Kamioka (K2K). Now, because large facilities are increasingly required for experiments in particle physics, a new style of international competition and co-operation has become necessary between institutes around the world. Together with the Japan Proton Accelerator Complex, which is a

SuperKEKB will provide a promising path to new physics via detailed studies of the decay processes of heavy quarks and leptons.



A schematic view of SuperKEKB. (Image credit: KEK.)

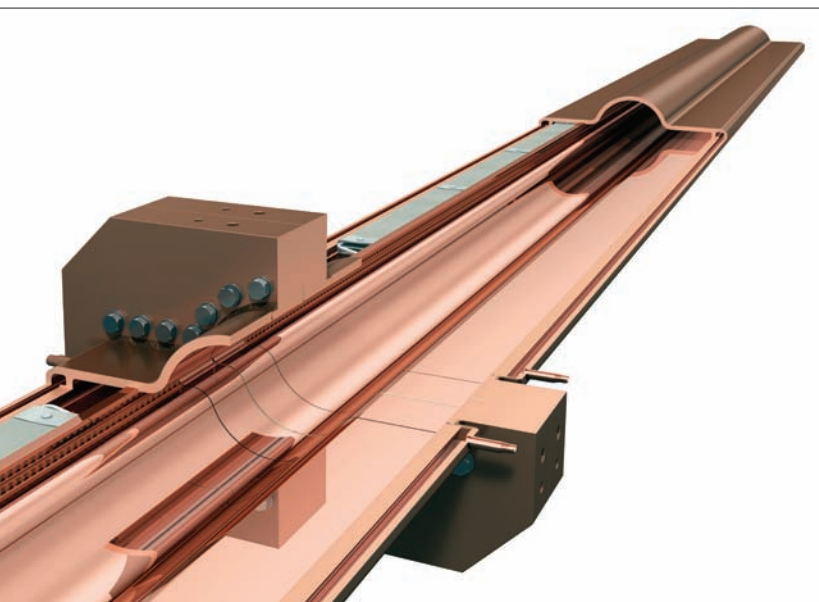
high-intensity proton facility built jointly with the Japan Atomic Energy Agency, KEK is continuing to play a leading role as one of the international focal points in flavour physics. As an international collaboration, SuperKEKB is open to the world and currently more than 400 physicists from 60 institutions from 17 countries and regions are working together to upgrade the Belle experiment to Belle II.

Forty times more collisions

SuperKEKB is essentially an upgrade project to increase the luminosity to $8 \times 10^{35} \text{ cm}^{-2} \text{ s}^{-1}$, or 40 times greater than at KEKB. Engineering a higher luminosity in a collider involves both increasing the beam current and reducing the beam size at the interaction point. The original approach for the upgrade was to increase the beam current and the beam–beam parameter – the “high current option”.

In March 2009 the SuperKEKB design changed course based on ideas from SuperB, using a large crossing-angle at the interaction point and beams squeezed to nanometre-scale to increase ▷

B factories



The antechamber reduces the effect of electron cloud in the positron beam pipe. (Image credit: Rey Hori.)

luminosity – the “nano-beam option”. The scheme has the advantage of reaching $8 \times 10^{35} \text{ cm}^{-2} \text{ s}^{-1}$ with only the double the current, but that is not to say that there are no other challenges.

The high current (3.6 A in the 4 GeV positron ring, 2.6 A for the 7 GeV electron ring) will lead to “electron cloud” effects in the positron ring when synchrotron radiation hits the walls of the beam pipe. To counteract such phenomena, SuperKEKB will use a special vacuum chamber for the positron ring with two small “antechambers”, one on the outside of the main beam pipe and one on the inner side. One suppresses the formation of electron clouds and the other contains vacuum pumps. In addition, the chambers between magnets will be wrapped with solenoid coils to reduce the effect of secondary electrons. Test antechambers developed at KEK from a prototype produced in collaboration with a team at the Budker Institute of Nuclear Physics have already been tried out in sections of the KEKB ring.

Further changes

The new design will be based on a larger crossing-angle (4.8°), requiring a redesign of the final-focus with eight higher-gradient quadrupole magnets placed nearer the interaction region to squeeze the beam to nanometre scale. These are unusually small superconducting quadrupole magnets, whose inner diameters are only 4–8 cm, or one-sixth the diameter of the KEKB quadrupoles. These magnets require current controls to protect them from quenches because the current density in the superconductor can go beyond 2000 A/mm^2 and on quenching the temperature will rise to more than 1000 K within around 50 ms. In addition, the accelerator design demands much smaller fabrication errors to ensure a quadrupole field quality of a few 10^{-4} .

Therefore, while SuperKEKB will be based on KEKB, various parts of the accelerator will be replacements. Others will be new. A new positron source and a flux concentrator will help in generating a high-current positron beam and a new damping ring (135 m

Ground-breaking ceremony



Ground-breaking ceremony participants joined together in opening one eye of the Daruma doll, a Japanese tradition for starting a new project. (Image credit: Sonja Blaschke.)

More than 200 physicists, government officials and national representatives from around the world gathered at KEK on 18 November to celebrate the official ground-breaking ceremony of SuperKEKB, held in the Kobayashi Hall.

KEK’s director-general, Atsuto Suzuki, addressed the assembled guests, describing the project as an important milestone towards the understanding of new physics at the high-intensity frontier, in a complementary role to the LHC at the high-energy frontier.

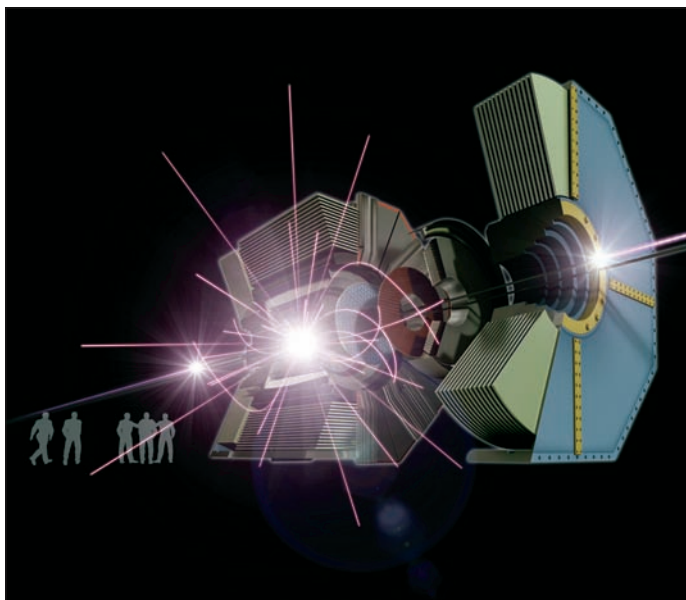
His speech was followed by words from: Peter Krizan, professor at the University of Ljubljana and Jozef Stefan Institute and Belle II spokesperson; Hiroaki Aihara, professor at the University of Tokyo and chair of the Belle II executive board; Takao Kuramochi, director-general of the Research Promotion Bureau, MEXT; Michael Procaro, director of the Facilities Divisions, Office of High Energy Physics, of the US Department of Energy; and Takashi Tachibana, a prominent Japanese journalist. Video messages followed from Rolf Heuer, director-general of CERN, and Piermaria Oddone and Young-Kee Kim, director and deputy-director of Fermilab, respectively.

The ceremony concluded with remarks by Katsunobu Oide, director of the Accelerator Laboratory, KEK, and a Daruma doll ceremony. This is a traditional Japanese ritual in which one eye is drawn on the doll, to wish for the ultimate achievement of a big project, when the second eye will be completed.

in circumference) will be added to reduce the emittance of the positron beam. Moreover, as well as changing the beam pipe in the main positron ring for one with “antechambers” as described above, the dipole magnets in this ring will be replaced. A new RF system will also help in accelerating high-current beam.

Because the SuperKEKB accelerator will produce electron–positron collisions at a much higher rate, the detector will also need to be upgraded. The aim is to accumulate an integrated luminosity

B factories



Artistic impression of Belle II. (Image credit: Rey Hori.)

of 50 ab^{-1} by 2021, which is 50 times more data than the previous Belle detector acquired. Thus the Belle II detector will also be an upgrade. The data-acquisition system will be redesigned with a network of optical fibres. Trigger electronics will be replaced with a new system. A pixel detector will be added for better resolution of particle tracking and a silicon vertex detector will cover a larger solid angle. A central tracking chamber, a time-of-propagation chamber and an aerogel ring-imaging Cherenkov detector are also being newly built.

The first beam of SuperKEKB is expected in 2014 and the physics run will start in 2015. Ultimately, Belle II should collect 40 times more B-meson samples per second than its predecessor – roughly $800 \text{ B}\bar{\text{B}}$ pairs per second. This will allow the Belle II collaboration to examine the effects of unknown particles in a higher energy region in the search for clues to new physics. Belle II at SuperKEKB will form one of the international focal points for particle physics in the coming decade.

Résumé

Le SuperKEKB part en chasse à l'échelle du téra

Le KEK procède actuellement à une amélioration de son usine à B, afin d'arriver à une luminosité 40 fois plus élevée. La nouvelle configuration prévoit un grand angle de croisement et des faisceaux comprimés à l'échelle du nanomètre (option « nano-faisceau »). La machine atteindra une luminosité de $8 \cdot 10^{35} \text{ cm}^{-2} \text{ s}^{-1}$, pour une intensité double seulement. L'angle de croisement plus grand ($4,8^\circ$) a nécessité une nouvelle conception de la focalisation finale, avec huit aimants quadripôles supraconducteurs à gradient plus élevé. L'intensité plus élevée nécessite une chambre à vide spéciale pour l'anneau à positons, ainsi qu'une nouvelle source positons et un nouveau système RF. L'expérience Belle connaîtra également une deuxième incarnation.

Youhei Morita, KEK.

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B factories

The SuperB approach to high luminosity

The next-generation B factory to be built in Italy will reach new levels in luminosity by employing the innovative crab-waist scheme at the beam collision point.

In 2010 the Italian government gave the green light for SuperB – a next-generation B factory based on an asymmetric electron-positron (e^+e^-) collider, which is to be constructed on the Tor Vergata campus of Rome University (figure 1). The intention is to deliver a peak luminosity of $10^{36} \text{ cm}^{-2} \text{ s}^{-1}$ to allow the indirect exploration of new effects in the physics of heavy quarks and flavours through studies of large samples of B, D and τ decays. Building on the wealth of results produced by the previous two B Factories, PEP-II and KEKB, and their associated detectors, BaBar and Belle, SuperB will produce an unprecedented amount of data and make accessible a range of new investigations.

The SuperB concept represents a real breakthrough in collider design. The low-emittance ring has its roots in R&D for the International Linear Collider (ILC) and could be used as a system-test for the design of the ILC damping ring. The invention of the crab-waist final focus could also have an impact on the current generation of circular colliders.

The SuperB e^+e^- collider will have two rings with a 1.25 km circumference, one for electrons at 4.18 GeV and one for positrons at 6.7 GeV. There will be one interaction point (IP) where the beams will be squeezed down to a vertical size of only 36 nm rms. The design results from a combination of knowledge acquired at the previous B factories as well as the concepts developed for linear colliders.

The innovative crab-waist principle, which has been successfully tested at Frascati's Φ factory – the DAΦNE e^+e^- collider – will allow SuperB to overcome some of the requirements that have proved problematic in previous e^+e^- collider designs, such as high beam currents and short bunches. While SuperB will have beam currents and bunch lengths similar to those of its predecessors, the use of smaller emittances and the crab-waist scheme for the collision region should produce a leap in luminosity from some $10^{34} \text{ cm}^{-2} \text{ s}^{-1}$ to an unprecedented level of $10^{36} \text{ cm}^{-2} \text{ s}^{-1}$, without increasing the background levels in the experiments or the machine's power consumption.

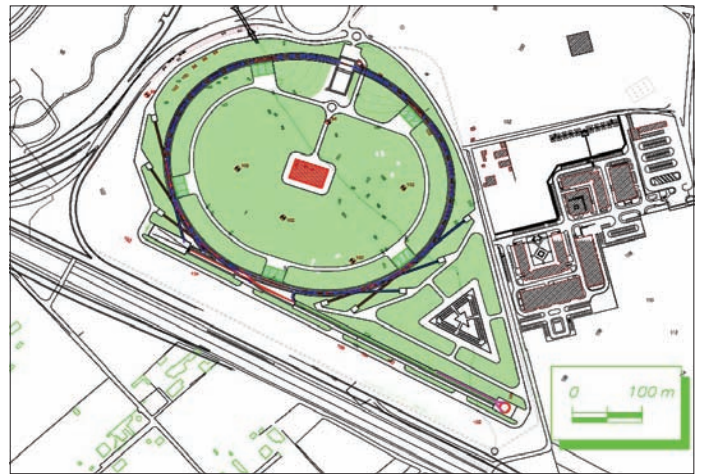


Fig. 1. Plans for the SuperB facility, which is to be built on the Tor Vergata campus of Rome University.

High luminosity in particle colliders not only depends on high beam-intensity, it also requires a small horizontal beam size and horizontal emittance (a measure of the beam phase space) and a very small value for the vertical β function at the IP, β_y^* . (The β function in effect gives the envelope of the possible particle trajectories and has a parabolic behaviour around the IP.) However, β_y^* cannot be made much smaller than the bunch length without running into trouble with the “hourglass” effect, in which particles in the bunch-tails experience a much higher β_y^* and a loss in luminosity.

Unfortunately it is difficult to shorten the bunch length in a high-current ring without exciting instabilities and therefore paying in radio-frequency voltage. One way to overcome this is to make the beam crossing-angle relatively large and the horizontal beam size small, so that the region where the two colliding beams overlap is much smaller than the bunch length. In addition, in the crab-waist scheme, two sextupoles at suitable phase-advances from the IP are used to rotate the waist in the β function of one beam such that its minimum value is aligned along the trajectory of the other beam, so maximizing the number of collisions occurring at the minimum β (figure 2). This technique can substantially increase luminosity without having to decrease the bunch length. A crab-waist scheme was tested at the DAΦNE in 2008 allowing a peak luminosity three times higher than the previous record for similar currents in the two rings.

The combination of large crossing-angle and small beam sizes,

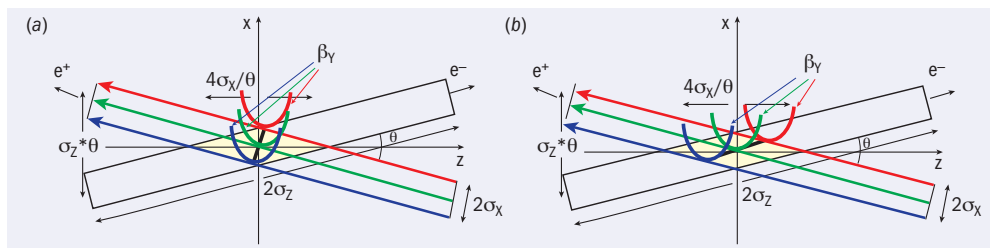


Fig. 2. The crab-waist collision scheme, showing the effect with the sextupoles off (a) and on (b). The straight lines in colour show the directions of motion for particles at different points in the positron bunch (e^+); the curved lines show the vertical β function (β_y).

emittances and beam angular divergences at the IP in the SuperB design will also be effective in decreasing the backgrounds present at the IP with respect to the previous B factories. A limited beam current also contributes to keeping these levels very low at SuperB. However, luminosity-related backgrounds are still relevant and impose serious shielding requirements.

The high luminosity of SuperB, representing an increase of nearly two orders of magnitude over the current generation of B factories, will allow exploration of the contributions of physics beyond the Standard Model to the decays of heavy quarks and heavy leptons. Indeed, new physics can affect rare B-decay modes through observables such as branching fractions, CP-violating asymmetries and kinematic distributions. These decays do not typically occur at tree level, so their rates are strongly suppressed in the Standard Model. Substantial variations in the rates and/or in angular distributions of final-state particles could result from the presence of new heavy particles in loop diagrams, providing clear evidence of new physics. Moreover, because the pattern of observable effects is highly model-dependent, measurements of several rare decay modes can provide information regarding the source of the new physics.

The SuperB data sample will contain unprecedented numbers of charm-quark and τ -lepton decays. Such data are of great interest, both in a capacity to improve the precision of existing measurements and in sensitivity to new physics. This interest extends beyond weak decays; the detailed exploration of new charmonium states is also an important objective. Limits on rare τ decays, particularly lepton-flavour-violating decays, already provide important constraints on models of new physics and SuperB may have the sensitivity to observe such decays. The accelerator design will allow for longitudinal polarization of the electron beam, making possible uniquely sensitive searches for a τ electric dipole moment, as well as for CP-violating τ decays.

Studies of CP-violating asymmetries are among the primary goals of SuperB. In addition to known sources of CP, new CP-violating phases arise naturally in many extensions of the Standard Model. These extra phases produce measurable effects in the weak decays of heavy-flavour particles. The detailed pattern of these effects, as well as of rare-decay branching fractions and kinematic distributions, will be made accessible by SuperB's high luminosity. Such studies will provide unique constraints in, for example, ascertaining the type of supersymmetry breaking or the kind of extra-dimensional model behind the new phenomena. A natural consequence of such detailed studies will be an improved knowledge of the unitarity triangle to the limit allowed by theoretical uncertainties.

In addition to pursuing important research in fundamental phys-

ics, SuperB is also taking up the challenge to combine it with a rich programme of applied physics: the synchrotron light emitted by the machine will have a high brightness and will be suitable for studies in life sciences and material science. Current proposals include: the creation and exploitation of beamlines for laser ablation on biomaterials (a technique that, by modifying the surface of the material with a laser, allows the creation of patterns of biological systems); femtochemistry studies (a field that includes the structural study of small numbers of molecules); and the development of new phase-contrast imaging techniques to improve the reconstruction of morphological information related to tissues and organs.

The construction of SuperB, which is funded by the Italian government and supported by a large international collaboration that includes scientists from Europe, the US and Canada, is planned to take about six years. The newly established "Nicola Cabibbo Laboratory" Consortium will provide the necessary infrastructure for the exploitation of the new accelerator. In November, the Consortium appointed Roberto Petronzio as director with an initial three-year mandate. The machine will reuse several components from PEP-II, such as the magnets, the magnet power-supplies, the RF system, the digital feedback-system and many vacuum components. This will reduce the cost and engineering effort needed to bring the project to fruition.

The exciting physics programme foreseen for SuperB can only be accomplished with a large sample of heavy-quark and heavy-lepton decays produced in the clean environment of an e^+e^- collider. The programme is complementary to that of an experiment such as LHCb at a hadron collider. Indeed, a "super" flavour factory such as SuperB will, perforce, be a partner together with experiments at the LHC, and eventually at an ILC, in ascertaining exactly what kind of new physics nature has in store.

Résumé

SuperB et haute luminosité

En 2010, le gouvernement italien a donné le feu vert pour la construction du SuperB – « usine à B » de la prochaine génération – sur le campus Tor Vergata de l'Université de Rome. L'objectif est que le nouveau collisionneur électron-positon asymétrique délivre une luminosité de crête record de $10^{36} \text{ cm}^{-2} \text{ s}^{-1}$ au moyen d'un dispositif innovant (« crab waist ») au point où les faisceaux entrent en collision. De la sorte, le SuperB pourra procéder à l'exploration indirecte d'une nouvelle physique par l'étude d'un grand nombre de désintégrations de particules B, D et τ et donner lieu à toute une série de nouvelles recherches.

Antonella Del Rosso, CERN.

Accelerating sustainability in large-scale facilities

Scientific research centres and large-scale facilities are intrinsically energy intensive, but can big science improve its energy management? A recent workshop brought experts together to share their know-how and ideas for the future.

The United Nations General Assembly has designated 2012 the international year of sustainable energy for all. With leadership from UN Secretary-General Ban Ki-moon, a coordinating group of 20 UN agencies (UN-Energy) will tackle the crucial challenges of sustainable access to energy, energy efficiency and renewable energy at the local, national, regional and international levels. So what can big science do for global climate and energy challenges?

Catherine Césarsky, High Commissioner for Atomic Energy and member of the CERN Council, believes that research infrastructures (RIs) in particular are appropriate tools for addressing these challenges scientifically, validating and providing scientific knowledge and in this way contributing to the decision-making process. When it comes to technical solutions, large-scale RIs, being intrinsically energy intensive, can provide their know-how in improving energy management and share their mid- and long-term strategies for reliable, affordable and sustainable carbon-neutral energy supply.

Act now, save later

It was with this message that Césarsky opened the first Joint Workshop on Energy Management in Large Scale Research Infrastructures, which was organized by CERN, the European Spallation Source (ESS) and the European Association of National Research Facilities (ERF). It took place in Lund, where the ESS will be built as the first carbon-neutral research facility, and brought international experts on energy together with representatives from research laboratories and future large-scale research projects all over the world. The objective was to identify the challenges and best practice for energy efficiency, optimization and supply at large

research facilities and to consider how these capabilities could be better oriented to respond to this general challenge for society.

The quality of energy required and the levels of consumption mean that RIs have a considerable, unique expertise regarding energy savings and efficiency approaches, ranging from research in materials sciences to demonstrators/prototypes of energy efficiency. In particular, the workshop helped to identify several key points:

- The development and demonstration of co-generation (combined heat and power) plus renewable energy go hand in hand with the improvement in the quality of electrical power and a better use of transmission lines (in peak-shaving methods to reduce power drawn at peak times and in storage), while decreasing instrumental black-outs.
- It is important to maximize the re-use of thermal energy generated in various systems, both for heating and cooling (e.g. with heat pumps and absorption refrigerators), thus decreasing the use of primary energy.
- The design of systems should allow the recovery of heat at higher temperatures than in usual design standards, to allow a better re-use and an interaction with local communities to develop district heating if not yet available.
- While new RIs are in the position to introduce energy-saving approaches, there is a need for special support to allow existing RIs to re-fit and increase efficiency; this could be a driver for improved returns to the hosting territory, through increased technology and knowledge transfer.

RIs employ some of the best technicians and applied researchers in the world, who are trained continuously in cutting-edge technology by responding to the technical challenges brought to them by the best researchers. RIs could be the test-bed for completely innovative research-based solutions, such as the use of superconduct-

ing lines to manage different energy flows, the installation of superconducting magnetic-energy storage for energy quality control, the transformation of energy between radio frequency and direct current, and other novel schemes involving advanced concepts.

An increase in efficiency in the use of energy will be the major contributor to limiting carbon emissions at large-scale



Research infrastructures have considerable expertise regarding energy savings and efficiency approaches.

facilities. Energy efficiency will be driven by introducing and demonstrating appropriate methods and breakthrough technologies, including the recycling of waste heat into useful applications.

A recurrent theme of discussion during the workshop was the importance of evaluating the different energy options both in the design of new research facilities and in the upgrade of existing ones. The inclusion of energy-efficiency and recycling requirements at the design stage opens many possibilities and initiatives to all of the stakeholders. For example, high-temperature waste water can be recovered with high efficiency, but equipment manufacturers are rarely asked if high-temperature cooling water can be used to cool their equipment.

As recommendations, the workshop proposed that:

- The design and the construction of facilities should aim at optimizing scientific performance while including the best approach to energy use.
- The optimal balance between investment and operation costs must have a long-term view. A total “cost of ownership” approach is required.
- A clear and objective assessment of overall energy consumption – equipment, buildings and associated information and communication technologies – must be available.
- The use of relatively fine-grained monitoring and active feedback-control tools (including modelling), as well as the specific role of an energy manager, are required.

Towards renewables

In addition to technical aspects, the workshop tackled socioeconomic issues in parallel sessions. These advised investigation and a long-term approach in matters such as: government legislation (tax exemptions, permits and licenses), contracts with energy suppliers, innovative financing, understanding of the energy-load profile, contracts for steady-state and peaks, socioeconomic and environmental impacts and benefits at the host site.

Renewable energies will be important as future sustainable energy sources for RIs. In turn, the RIs can be instrumental in supporting renewable-energy research and technological development through, for example, new and improved materials (for photo-voltaic, fuel cells, improved motors and turbines etc.), the development of environmentally friendly biofuels, and new and safe methods of carbon capture.

Large-scale RIs are able to generate innovative solutions that can be used profitably elsewhere and be at the base of “win-win” partnerships with industries. Their capabilities and staff could also be mobilized for large international projects, e.g., the development of solar power generated in the sun-rich regions of North Africa and the Middle East (MENA). This could supply up to 15% of Europe’s energy needs by 2050 as advocated by the DESERTEC

foundation. Technologies to exploit this potential, such as concentrated solar power, exist and are proven. Realizing such ambitious projects, however, will require a new energy and science partnership between Europe and MENA and a closer integration of MENA into the European Research Area.

The workshop showed that several RIs are already mobilizing their unique resources and technical skills to respond to the “energy grand challenge”. They can act as a test-bed for implementing appropriate energy-supply and procurement schemes as well as efficient

RIs can be particularly effective in training young researchers, operators and managers to face the upcoming energy challenges.

energy-use. RIs can also be particularly effective in training young researchers, operators and managers to face the upcoming energy challenges in order to co-operate on R&D, exchange best practices and provide know-how. Planned by Frédéric Bordry (head of CERN’s Technology Department), Thomas Parker (ESS energy manager) and Carlo Rizzuto (chair of ERF and president of Sincrotrone Trieste – Italy), the workshop attracted 150 participants, indicating a clear requirement for this type of initiative.

The unanimous consensus on such a need was supported by CERN with the proposal to host a second workshop in 2013.

For the full programme and presentations, see <http://ess-scandinavia.eu/energyworkshop>.

Résumé

Développement durable et installations de grande envergure

Les centres de recherche et les installations scientifiques de grande envergure sont par nature de grands consommateurs d’énergie. Est-il possible dans ce contexte d’améliorer la gestion de l’énergie ? Un récent atelier a rassemblé des experts pour réfléchir à cette question et proposer des idées pour l’avenir. L’objectif était de recenser les problèmes et les bonnes pratiques au niveau des grandes installations de recherche et de voir comment, grâce à leurs capacités, celles-ci peuvent apporter des réponses à ce problème général de la société. L’atelier a montré que les grandes infrastructures de recherche disposent de ressources et de capacités techniques utiles. Ils peuvent servir de bancs d’essai pour la mise en œuvre de systèmes appropriés pour la production et la distribution de l’énergie, ainsi que pour son utilisation efficace.

Frédéric Bordry and **Marina Giampietro**, CERN.

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Neutrinos

NEMO 3: the goals,

With its unique capability to measure all the relevant observables, the NEMO 3 experiment has taken big strides in the study of double beta decay.

Located under 1700 m of rock in the Modane Underground Laboratory (LSM) at the middle of the Fréjus Rail Tunnel, the NEMO 3 experiment was designed to search for neutrinoless double beta decay, with the aim of discovering the nature of the neutrino – whether it is a Majorana or Dirac particle – and measuring its mass. The experiment ran for seven years before it finally stopped taking data in January 2010. While the sought-after decay mode remained elusive, NEMO 3 nevertheless made impressive headway in the study of double beta decay, providing new limits on a number of processes beyond the Standard Model.

Standard double beta decay ($\beta\beta 2\nu$) involves the simultaneous disintegration of two neutrons in a nucleus into two protons with the emission of two electrons accompanied by two antineutrinos, $(A, Z) \rightarrow (A, Z+2) + 2e^- + 2\bar{\nu}$. It is a second-order Standard Model process and for it to occur the transition to the intermediate nucleus accessible by normal beta decay, $(A, Z) \rightarrow (A, Z+1) + e^- + \bar{\nu}$, must be forbidden by conservation of either energy or angular momentum. In nature, there are 70 isotopes that can decay by $\beta\beta 2\nu$ and experiments have observed this process in 10 of these, with half-lives ranging from 10^{18} to 10^{21} years. However, $\beta\beta 2\nu$ decay is not sensitive to the nature or mass of the neutrino, unlike double beta decay with no emitted neutrinos ($\beta\beta 0\nu$). This process, $(A, Z) \rightarrow (A, Z+2) + 2e^-$, is forbidden by the Standard Model electroweak interaction because it violates the conservation of lepton number ($\Delta L = 2$). Such a decay can occur only if the neutrino is a Majorana particle (a fermion that is its own antiparticle). Non-Standard Model processes that can lead to $\beta\beta 0\nu$ decay include the exchange of a light neutrino, in which case the inverse of the $\beta\beta 0\nu$ half-life depends on the square of the effective neutrino mass. Other possible processes involve a right-handed neutrino current, a Majoron coupling or supersymmetric particle exchange.

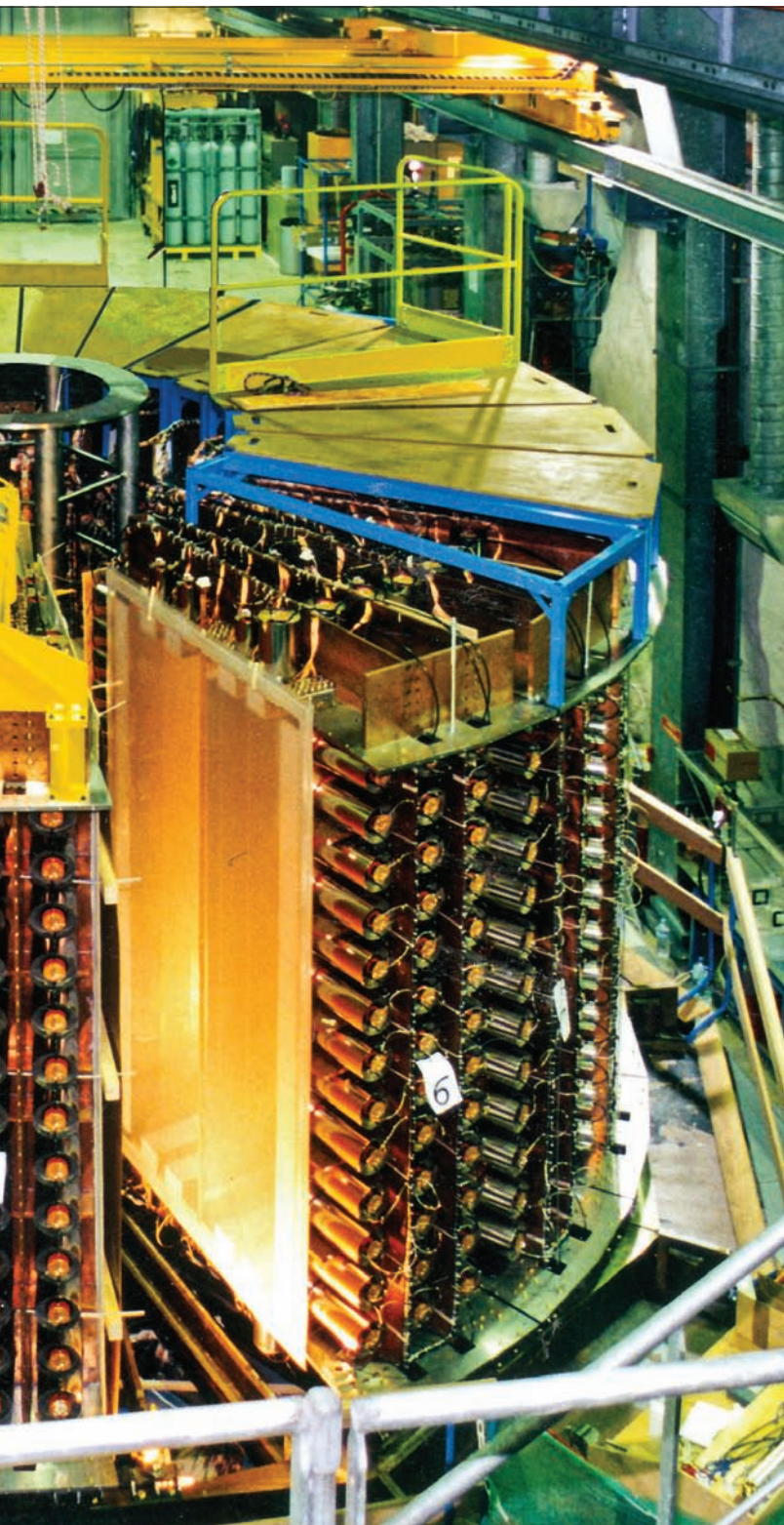
The experimental signature for double beta-decay processes appears in the sum of the energy of the two electrons. For $\beta\beta 0\nu$ decay, this would have a peak at the $Q_{\beta\beta}$ transition energy (typically 2–4 MeV), while for $\beta\beta 2\nu$ decay it takes the form of a continuous spectrum from zero to $Q_{\beta\beta}$. There are also two other observables: the angular distribution between the two electrons and the individual energy of the electrons. These two variables can distinguish which process is responsible for $\beta\beta 0\nu$ decay, if it is observed.

The NEMO collaboration – where NEMO stands for the Neutrino Ettore Majorana Observatory – has been working on $\beta\beta 0\nu$



Fig. 1. The NEMO 3 detector, installed in the Modane Underground Laboratory.

results and legacy



laboratory. (Image credit: CNRS and CEA.)

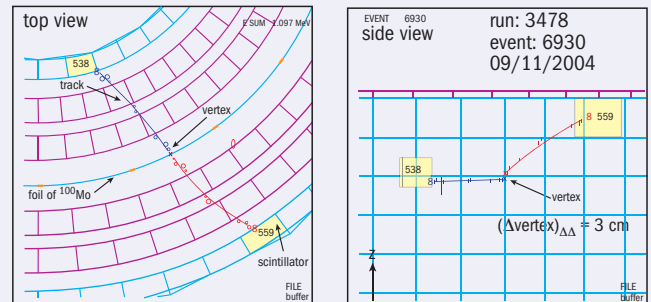


Fig. 2. Top view and side view of a typical $\beta\beta$ event in NEMO 3. The two electrons are emitted from the source foil (pink line), the circles correspond to the tracker information, the red curved lines are the fitted tracks and the red rectangles show the hit calorimeter cells.

decay since 1989. The design of the NEMO 3 detector, which evolved from two prototypes, NEMO 1 and NEMO 2, began in 1994 and construction started three years later. The method uses a number of thin source foils of enriched double beta-decay emitters surrounded by two tracking volumes and a calorimeter.

The challenge for any search for $\beta\beta 0\nu$ decay is the control of the backgrounds from cosmic rays, natural radioactivity, neutrons and radon. The background comes from any particle interactions or radioactive decays that can produce two electrons in the source foils. Because the signal level is so low, even third- and fourth-order processes can be a problem. Cosmic rays are suppressed by installing the experiment in a deep underground laboratory, as at the LSM. Natural radioactivity is reduced by material selection and purification of the source isotopes: the source foils in NEMO 3 had a radioactivity level a million times less than the natural level of radioactivity (around 100 Bq/kg). Neutrons and high-energy γ -rays are suppressed by specially designed and adapted shielding.

The NEMO 3 detector

The principle of NEMO 3 was to detect the two emitted electrons and to measure their energy as well as their angular distribution and their individual energies. The identification of the electrons reduces drastically the background compared with the calorimetric techniques of other experiments. The price of this advantage is a rather modest energy resolution, partly as a result of the electron's energy loss in the source foils. However, the experimental sensitivity for $\beta\beta 0\nu$ depends on the product of the energy resolution and the number of background events. The source foils in NEMO 3 had a thickness of around 100 μm , which corresponded to a compromise between the amount of radioactive isotope and the electrons' energy losses.

Another advantage of this experimental technique is the possibility of using different isotopes. The double beta-decay source \triangleright

Neutrinos

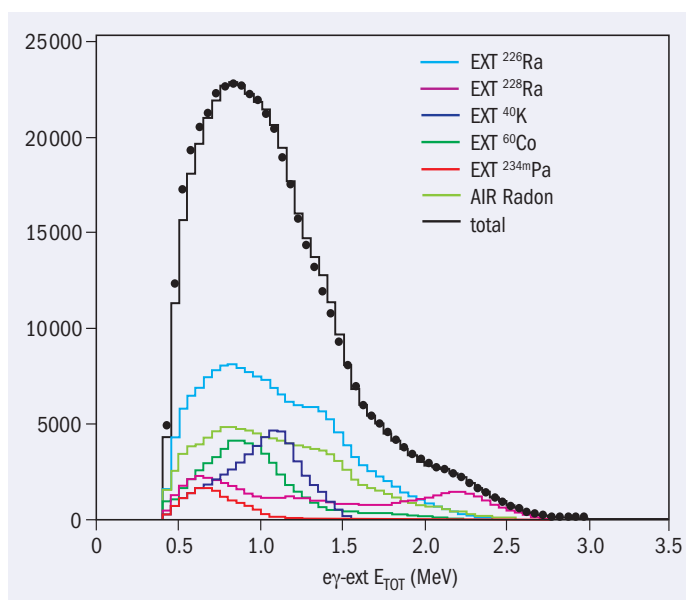


Fig. 3. Components of external background measured in the electron-gamma ($e\gamma$) channel.

inside NEMO 3 had a total mass of 10 kg, which was shared as follows: 6.914 kg of ^{100}Mo , 0.932 kg of ^{82}Se , 0.405 kg of ^{116}Cd , 0.454 kg of ^{130}Te , 37.0 g of ^{150}Nd , 9.4 g of ^{96}Zr and 7.0 g of ^{48}Ca . These isotopes were enriched in Russia. In addition, two ultrapure sources of copper (0.621 kg) and natural tellurium (0.491 kg) were used to measure the external background. It is the first time that a detector has measured seven different double beta-decay emitters at the same time.

The NEMO 3 detector was made of 20 identical sectors. The tracking volume consisted of 8000 drift chambers working in Geiger mode. The volume was filled with a mixture of helium, 4% alcohol, 1% argon and a few parts per million of water to ensure the stable behaviour of the chamber. Electrons could be tracked with energy down to 100 keV with an efficiency of greater than 99%. The calorimeter was made of 2000 plastic scintillators coupled to low-radioactivity Hamamatsu phototubes. The choice of plastic scintillator was driven by the low Z to reduce back scattering, the low radioactivity and the cost. The calorimeter allowed measurements of both the energy ($\sigma=3.6\%$ at 3 MeV) and the time of flight ($\sigma=300$ ps at 1 MeV).

A coil created a magnetic field of 0.003 T to enable the identification of the sign of the electrons. The shielding was made of 20 cm of iron to reduce γ -ray background and 30 cm of water to reduce the neutron background. A tent flushed with air containing just 15 mBq/m³ of radon surrounded the whole detector.

The unique feature of the NEMO 3 experiment was its ability to identify electrons, positrons, γ -rays and delayed α -particles. Figure 2 (p29) shows a typical double beta-decay event in NEMO 3 with two electrons emitted from a source foil, with the track curvature in the magnetic field identifying the charge and the struck scintillator blocks measuring the energy and the time of flight. The timing is important to distinguish a background electron crossing the detector ($\Delta t=4$ ns) from two electrons coming from a source foil ($\Delta t=0$ ns).

The experiment has measured the background through various

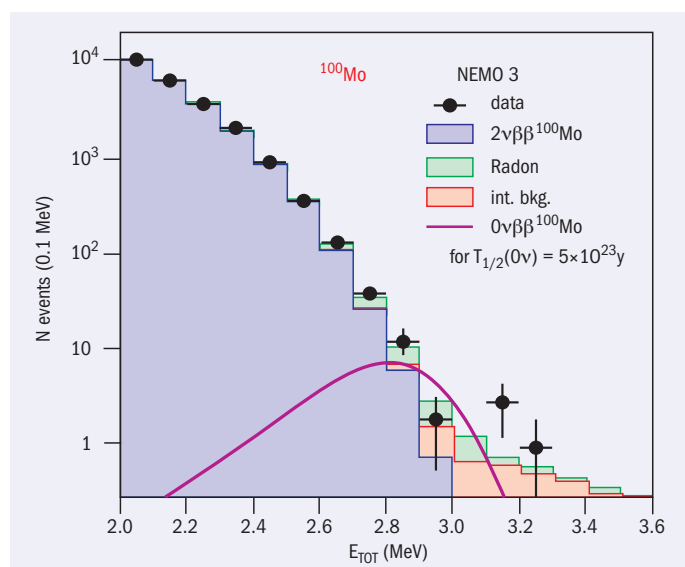


Fig. 4. Sum of the electron energy for 7 kg of ^{100}Mo after 4.5 years of data-taking, zoomed to the region where the $\beta\beta 0\nu$ decay is expected.

analysis channels: single e^- , $e^- + \gamma$, $e^- + \alpha$, $e^- + \alpha + \gamma$, $e^- + \gamma + \gamma$, $e^- + e^+$ and so on. This allows measurements to be made of the actual backgrounds from residual contamination of the source foils as well as from the surrounding materials. Figure 3 demonstrates the ability of the experiment to identify the many sources of external background in the $e\gamma$ channel (as an example) for the ^{100}Mo source foil.

NEMO 3 has produced an impressive list of results. The main result is, of course, related to the search for $\beta\beta 0\nu$ decay. Figure 4 shows the sum of the electron energy for 7 kg of ^{100}Mo after 4.5 years of data-taking, zoomed into the region where the signal for $\beta\beta 0\nu$ decay is expected. The measurement of all of the kinematic parameters and the identification of all of the sources of background allows a 3D likelihood analysis to be performed. The result is a limit on the half-life of $T_{1/2} > 1 \times 10^{24}$ years, corresponding to a neutrino mass limit $\langle m_\nu \rangle < 0.3 - 0.9$ eV. The range corresponds to the spread associated with the different nuclear matrix-element calculations that must be used to extract the effective neutrino mass. This limit obtained with 7 kg of ^{100}Mo is one of the best limits, together with the result of $\langle m_\nu \rangle < 0.3 - 0.7$ eV from the Cuoricino experiment (12 kg of ^{130}Te) and of $\langle m_\nu \rangle < 0.3 - 1.0$ eV from the Heidelberg-Moscow experiment (11 kg of ^{76}Ge).

One possible scenario for $\beta\beta 0\nu$ involves the emission of the Majoron, the hypothetical massless boson associated with the spontaneous breaking of baryon-number minus lepton-number (B-L) symmetry. NEMO 3 has obtained the best limit so far for the Majoron-neutrino coupling, with $g_M < (0.4 - 1.8) \times 10^{-4}$. The experiment has also set a limit on the λ parameter in models where a right-handed current exists for neutrinos, with $\lambda < 1.4 \times 10^{-6}$. These limits were obtained by analysing the angular distributions of the decay electrons and they are therefore unique to NEMO 3.

In addition, NEMO 3 has measured the half-lives for seven $\beta\beta 2\nu$ decays, providing a high-precision test of the Standard Model and nuclear data that can be used in theoretical calculations. In seven years, more than 700 000 events were recorded for $\beta\beta 2\nu$ emission

Neutrinos

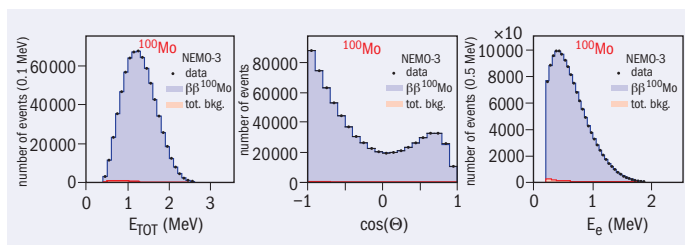


Fig. 5. Left to right: The energy spectrum, angular distribution and single energies measured for the two-neutrino double beta decay of ^{100}Mo .

from ^{100}Mo . Figure 5 shows the energy spectrum, angular distribution and single energies measured for ^{100}Mo . The first direct detection of $\beta\beta 2\nu$ decay to the 0^+ excited state has also been measured for this nucleus and the first limit on the bosonic component of the neutrino has been obtained.

The NEMO 3 detector has demonstrated a powerful method for searching for neutrinoless double beta decay, with the unique capability of measuring all kinematic parameters of the decay. The next step for the NEMO collaboration is to build the SuperNEMO detector, which will accommodate 100 kg of source foil (^{82}Se , ^{150}Nd or ^{48}Ca) to reach a sensitivity of 50 meV on the effective mass of the neutrino. A demonstrator module is under construction in several laboratories around the world and will start operation in 2013 in the LSM, with 7 kg of ^{82}Se . The main improvement in this larger detector over NEMO 3 will be the energy resolution ($\sigma=1.7\%$ at 3 MeV) and the reduction of the background by a factor of 10. This demonstrator will improve the current limit on the effective neutrino mass and is expected to reach the goal of a zero-background experiment for 7 kg of source and two years of data-taking, which has never been done before. With this demonstration, the collaboration will be ready to build more Super NEMO modules up to the maximum source mass possible.

- The NEMO and SuperNEMO collaboration is formed by laboratories from France, the UK, Russia, the US, Japan, the Czech Republic, Slovakia, Ukraine, Chile and Korea. The LSM is operated by the CNRS and the CEA.

Résumé

NEMO 3 : ses buts, ses résultats, ses apports

Avec sa capacité exceptionnelle de mesurer toutes les observables pertinentes, l'expérience NEMO 3 a réalisé de grandes avancées dans l'étude de la désintégration double bêta. Située dans le Laboratoire souterrain de Modane, l'expérience a été conçue pour la recherche de la désintégration double bêta sans émission de neutrinos, avec le but de découvrir la nature du neutrino – particule de Majorana ou de Dirac ? – et de mesurer sa masse. L'expérience a fonctionné pendant 7 ans, avant la fin de la prise de données en janvier 2010. Même si le mode de désintégration recherché n'a pas été trouvé, NEMO 3 a apporté néanmoins de nouvelles limites concernant plusieurs processus au-delà du Modèle standard.

Fabrice Piquemal, Centre d'Etudes Nucléaires de Bordeaux Gradignan, and **Jenny Thomas**, University College London.

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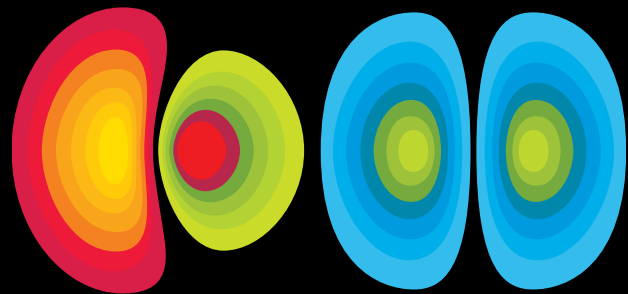
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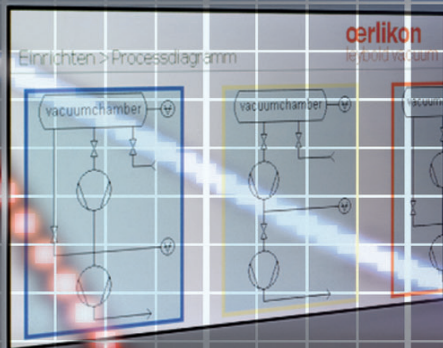
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Isotope toolbox turns 10

REX-ISOLDE, one of CERN's most compact accelerators, has just celebrated its 10th anniversary. The machine's versatility provides radioactive ion beams across the range of nuclear isotopes.

The evolution of nuclear structure through the list of stable nuclear isotopes was well established by the late 1960s. During the following decades, however, the discovery of more and more short-lived nuclei expanded the nuclear chart – revealing several surprises. For example, the nuclear shells, which give the classical “magic numbers” along the line of stability, have been seen to change position and sometimes even to dissolve in highly unstable (exotic) nuclei. Only now is the field approaching a fundamental understanding of how nuclear shells evolve. To follow these changes in nuclear structure, nuclei must be probed in many complementary ways. Therefore the leading nuclear-physics facilities not only give access to many different isotopes but also allow a variety of experiments to be performed.

The introduction of REX-ISOLDE at CERN's ISOLDE facility a decade ago (Kester *et al.* 2000) allowed a major step forward, as ions produced in the Isotope On-Line (ISOL) facility could be accelerated to a completely new energy region. Before the introduction of REX-ISOLDE, the experiments at ISOLDE took place at low energy (up to 60 keV) via decay studies, ion-beam measurements or manipulation. The natural extension of these techniques was to include reaction studies such as Coulomb excitation, capture reactions and transfer reactions. The challenge was to devise a universal, fast, efficient and cost-effective acceleration scheme that would take full advantage of the large range of isotopes available at ISOLDE.

The idea for the REX-ISOLDE “post-accelerating” scheme emerged in 1994, the acronym coming from “Radioactive beam EXperiments at ISOLDE”. The added accelerator had to increase the beam energy to a few million electron-volts per atomic mass unit (MeV/u). Its key ingredient is an innovative scheme for preparing ions that combines a Penning trap with an electron-beam ion source (EBIS) – REXTRAP and REXEBIS, as illustrated in figure 1. The semi-continuously released radioactive 1^+ ions from the ISOLDE target, produced by the impact of 1.4 GeV protons from the Proton Synchrotron Booster, are accumulated and phase-space cooled in the buffer-gas-filled Penning trap, before being sent in a bunch to REXEBIS. So called “charge breeding” takes place inside the EBIS, i.e. the conversion of the ions from 1^+ to q^+

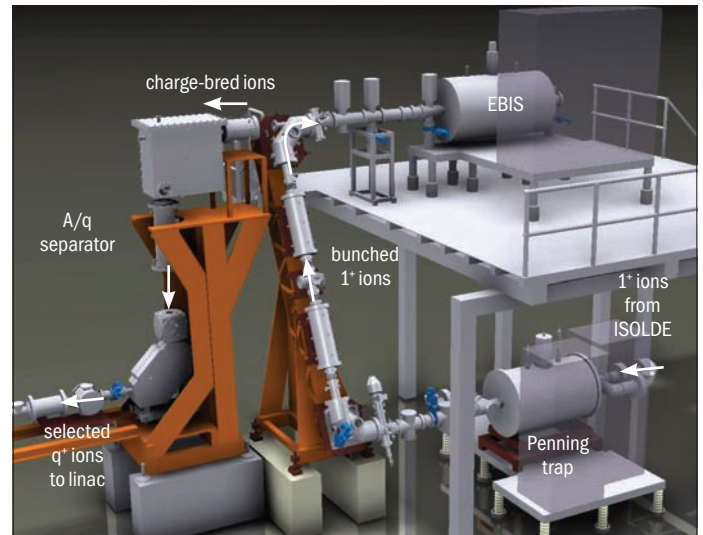


Fig. 1. Schematic diagram showing the voyage of the ions in the low-energy part of REX-ISOLDE. (Image credit: V Barozier.)

by bombardment with a dense, energetic electron beam. The highly charged ions, now with a reduced mass-to-charge ratio ($A/q < 4.5$), are extracted and separated before being post-accelerated in a room-temperature linear accelerator (linac). The high charge state allows for efficient acceleration in the compact linac. REX-ISOLDE pioneered this charge-breeding scheme for radioactive ions and now several facilities around the world are replicating the concept (Wenander 2010).

Versatile acceleration

Although REX-ISOLDE has a modest final beam energy compared with other CERN accelerators, it compensates by being agile and flexible. It was initially designed to perform post-acceleration of neutron-rich Na and K isotopes, all with masses below $A = 50$. Since then the mass range has been extended and radioactive elements from light ^8Li to heavy ^{224}Ra have been accelerated for experiments. To accelerate the heavier elements, high charge states – for example, above 50^+ for Ra – have to be achieved to fulfil the A/q requirement of the linac. Neither stripping foils nor gas-jet stripping can be used to obtain such charge states at low energies, so the challenging task falls entirely on the charge breeder. By increasing the breeding time, sometimes up to 300 ms, REXEBIS can nevertheless efficiently convert the ions to the required high charge states.

Because REX-ISOLDE also has the ability to cover the high mass-range for ions it is possible to make full use of ISOLDE's capability to produce heavy radioactive elements by spallation processes in targets of uranium carbide. This is a unique ▷

Nuclear physics

feature that so far no other radioactive ion-beam facility can challenge. The combination of a Penning trap and EBIS has also proved capable of accepting almost all chemical elements produced by ISOLDE because the ions are kept within the traps without any surface contact.

The duration of the cooling and the charge breeding is of secondary importance for radioactive elements with long half-lives. On the other hand, some radioactive isotopes of interest have short half-lives, potentially leading to decay losses of the rare ions. By optimizing the cooling and the breeding, even elements such as ${}^{11}\text{Li}$ ($t_{1/2} = 8.5$ ms) and ${}^{12}\text{Be}$ ($t_{1/2} = 23.6$ ms) have been post-accelerated successfully. To reduce the decay losses further, continuous injection from the ISOLDE target-ion source into REXEBIS – without prior bunching and cooling in REXTRAP – can be performed at the expense of a slightly lower transmission efficiency.

The purity of the radioactive ion beams is an important factor. Because there are often only a few thousand ions per second, corresponding to subfemtoampere beams, there is a real interest in suppressing as much contaminating beam components as possible. The excellent vacuum of REXEBIS is one of the requirements for good beam purity. Still, even with a vacuum of better than 10^{-11} mbar, the residual gas ions – such as C, N, O, Ar and Ne (the latter being the buffer gas in the Penning trap) – usually dominate the beam extracted from the EBIS. In the A/q spectrum shown in figure 2, the residual gas ions appear in discrete peaks, while the background between the peaks is very clean. Thus, by correctly choosing the A/q value of the radioactive beam – in this case abundantly injected ${}^{129}\text{Cs}$ – the contaminating beam components can be avoided. By adjusting the time the radioactive ions are trapped within the EBIS, and therefore the time ions are exposed to the electron-impact ionization process, the charge state and hence the A/q of the extracted ions is changed.

The low-energy side of REX is a toolbox full of means for beam-manipulation exercises. One of the latest tools to be added is the “in-trap decay” method, used for producing elements that are not readily available from ISOLDE for chemical reasons, such as Fe. A short-lived isotope of abundantly produced Mn is taken from ISOLDE, injected into the EBIS and kept there for a few hundred milliseconds until the major fraction has decayed to Fe, before being accelerated to the experiment. This method can be used to access isotopes of several elements new to ISOLDE, such as B, Si, Ti and Zr.

Another tool, aimed at improving the beam purity and suppressing isobaric contaminants from ISOLDE, for instance Rb superimposed on Sr, is the molecular sideband method. Instead of extracting the ions of interest as atomic 1^+ ions from ISOLDE, a carrier gas – in this case CF_4 – is introduced and the ions are extracted as SrF^+ . Because of the electron configuration, the Rb contaminant does not form an RbF^+ molecule and can therefore be suppressed in the ISOLDE separator. Inside the EBIS, the SrF^+ is broken up and the Sr charge bred in the normal way before being accelerated to the experiment.

Yet another method of beam purification is to make use of the inherent mass-selectivity of the Penning trap. The injected ion cloud from ISOLDE, containing both the ion of interest and the isobaric contamination, is excited to a large radius inside the 3 T magnetic field of REXTRAP. Thereafter, a mass-selective cool-

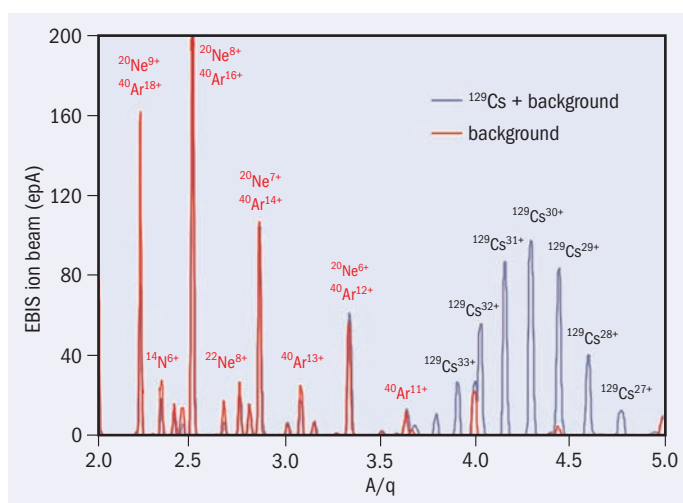


Fig. 2. Extracted beams from REXEBIS as function of A/q showing residual gas peaks and charge-bred ${}^{129}\text{Cs}$. The blue (red) trace is with (without) ${}^{129}\text{Cs}$ being injected.

ing mechanism is applied, re-centring only the ions of interest, while the contamination is lost on extraction. A mass resolution in the order of 30 000 – a factor six times higher than with the High-Resolution Separator at ISOLDE – has been demonstrated for ions with mass number A in the range of 30 to 40.

Selected results

At the start, REX-ISOLDE made use of five room-temperature accelerating cavities to reach a maximum energy of 2.2 MeV/u. In 2004, a 9-gap interdigital H-type cavity was added to the linac, which boosted the final energy to approximately 2.9 MeV/u. Through stepped activation of the six accelerating cavities, the energy of the ion beam can be varied from 300 keV/u (the energy of the RF quadrupole cavity) up to the maximum energy.

The demand for beam time by the experiments is high, and many different beams – up to 10 elements and 20 isotopes plus several stable calibration beams – have to be delivered every year. This has to be done efficiently, in terms of both set-up time and beam transmission, because the exotic ions are difficult to produce. Until now, REX-ISOLDE has accelerated close to 100 isotopes of 30 different elements (P Van Duppen and K Riisager 2011).

A major theme in the experiments performed so far has been the tracking of the evolution of nuclear shells. The first hints for the breaking of the classical magic numbers came from experiments at CERN on neutron-rich nuclei with about 20 neutrons, in what is now called the “island of inversion”. Several REX experiments have contributed to clarifying the structure in this region. One of the latest combined a radioactive ${}^{30}\text{Mg}$ beam with a radioactive tritium target to do two-neutron transfer to two 0^+ states in ${}^{32}\text{Mg}$, the data being consistent with the closed-shell configuration in the excited state rather than the ground state (CERN Courier September 2011 p29).

In the region of the classical neutron magic number 50, a campaign of experiments has probed how shells evolve towards ${}^{78}\text{Ni}$, presumably still a double magic nucleus. Both transfer- and Coulomb-excitation experiments have been performed, the lat-

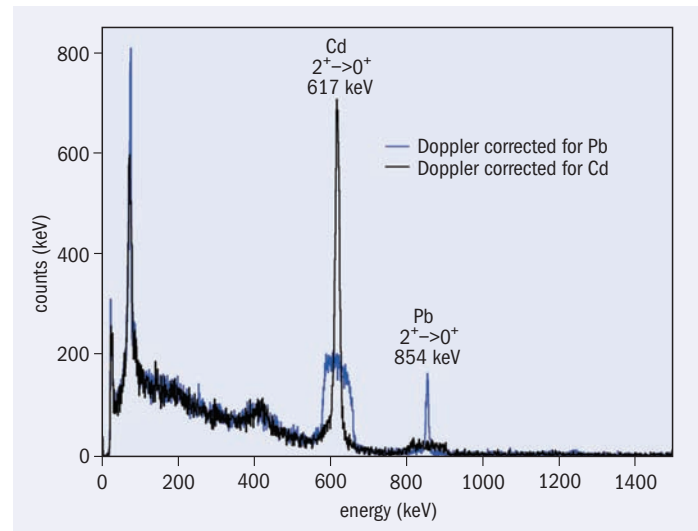
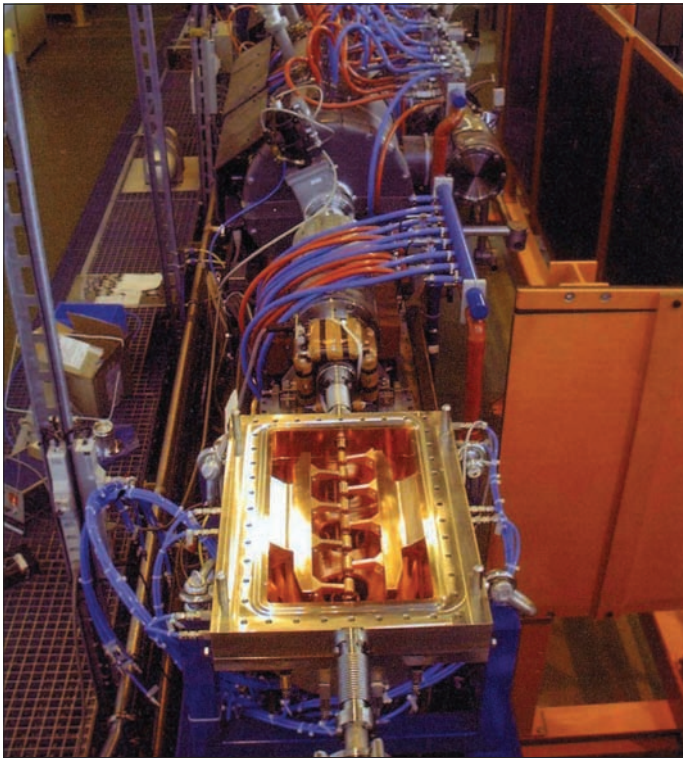


Fig. 4. The gamma-spectrum recorded for Coulomb excitation of ^{192}Pb on a Cd target at small scattering angles. By Doppler correction to the beam or target frame it is possible to identify excitations in each nucleus. (Image credit: J Pakarinen.)

Fig. 3. The REX-ISOLDE linac during the installation of the 9-gap interdigital H-type cavity (which is open in the photo).

ter including one that made use of another speciality of ISOLDE: isomeric beams (*CERN Courier* December 2005 p31). ISOLDE's laser ion source can in certain cases – such as the heavy Cu isotopes – produce beams of an isotope that is mainly in either its ground state or in a long-lived (isomeric) state. This extra selectivity helps greatly in interpreting complex spectra that result when these beams react.

In the light mass region REX experiments are also testing the extent of shell-breaking in the nucleus ^{12}Be (neutron number 8), but the physics implications are broader because the accelerated isotope in this case, ^{11}Be , is a halo nucleus with an unusually large spatial extent. The halo structure implies that continuum degrees of freedom play an important role. An extreme example of this is the neighbouring halo nucleus ^{11}Li that is bound although its subsystem ^{10}Li is particle unbound. The structure of ^{10}Li has also been studied in transfer experiments at REX.

As a final example, at the other end of the nuclear chart several experiments are tracking the sizeable changes in shape that are known to take place systematically among light isotopes of elements around Pb (*CERN Courier* October 2007 p19). Coulomb excitation favours transitions among collective states and has allowed the identification of different shapes in nuclei from ^{182}Hg to ^{204}Rn .

Apart from these nuclear physics examples, the REX-ISOLDE accelerator has also been used for physics-application studies. These include the calibration of plastic foils of polyethylene terephthalate (PET), for use as solid-state nuclear track detectors, and for development work on diamond detectors.

REX-ISOLDE is a machine undergoing constant development to fulfil the changing requests of the experiments. Currently, the possibility of producing polarized nuclear beams with the tilted

foil method is being investigated. The beam energy will also be increased in a few years' time – first to 5 MeV/u and ultimately to 10 MeV/u – within the framework of the High Intensity and Energy ISOLDE project, HIE-ISOLDE. This will be achieved by adding superconducting cavities to the accelerating linac (Pasini *et al.* 2008). The increased energy range will open up a wide field of reaction studies and keep REX-ISOLDE fully booked for at least another decade.

• Further reading

O Kester *et al.* 2000 *Hyperfine Interactions* **129** 43.

M Pasini *et al.* 2008, A SC upgrade for the REX-ISOLDE accelerator at CERN, Proceedings of Linac'08.

P Van Duppen and K Riisager 2011 *J. Phys. G: Nucl. Part. Phys.* **38** 024005.

F Wenander 2010 *J. Instrum.* **5** C1004.

Résumé

Les dix ans de REX-ISOLDE

REX-ISOLDE (Radioactive beam Experiments at ISOLDE) vient de célébrer son dixième anniversaire. Le défi initial était de concevoir un système « post-accelération » universel, rapide, efficace et économique tirant pleinement parti de la large gamme d'isotopes disponible à ISOLDE. Cette machine, qui est l'un des accélérateurs les plus compacts du CERN, a une énergie de faisceau modeste, compensée toutefois par une grande flexibilité. Elle a permis de grandes avancées dans les études de physique nucléaire, puisque les ions produits dans l'installation ISOLDE peuvent être accélérés pour atteindre une région d'énergie complètement nouvelle.

Fredrik Wenander, CERN, and **Karsten Riisager**, Aarhus University.

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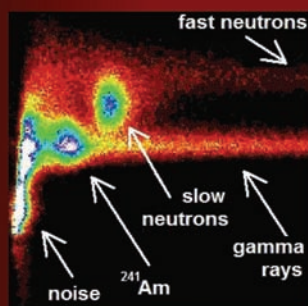
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Faces & Places

AWARDS

EPS, France, Japan and the US honour physicists

The European Physical Society (EPS) has awarded the Lise Meitner Prize 2010 to Juha Äystö of the University of Jyväskylä for his “accurate determination of nuclear fundamental properties by the invention of innovative methods of ion guidance and its applications to radioactive beams”.

One of Äystö’s innovative breakthroughs has been an ingenious method of gas-guidance for ion beams in which the ions are thermalized in a noble buffer gas, thus resetting the ions’ charge-states to unity. The singly charged ions are rapidly extracted and transported by an ultrasonic jet. When combined with an isotope separator, both the speed of the technique – which takes only milliseconds – and its selectivity make it an ideal tool for investigating short-lived exotic nuclides. Äystö has further exploited the possibilities by combining the technique with novel research instruments such as laser-spectroscopy and ion-trap set-ups at the IGISOL-facility at Jyväskylä.

Äystö is well known at CERN, having been the ISOLDE group leader (1999–2002) and chair of the ISOLDE and Neutron Time-of-flight Committee (2003–2005).

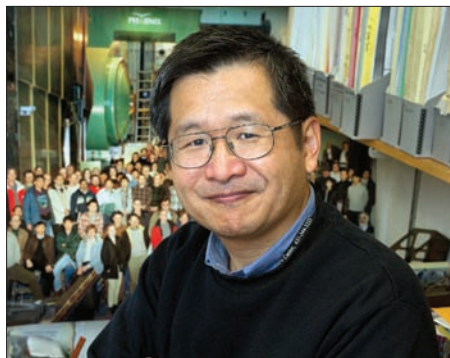
In France, Cécile DeWitt-Morette has been promoted to officer in the National Order of the Legion of Honour. Emeritus professor of physics at the University of Texas, Austin, she is well known for her role in founding the Les Houches Physics School in the French Alps in 1951, which quickly grew to become a place for students to learn in intense sessions at an advanced level. She was first received into the Legion as a knight in 2007, in recognition of the role that the Les Houches school played in the revival of theoretical physics after the Second World War.

The promotion to officer recognizes DeWitt-Morette’s continuing contribution to French science and culture. She received the medal with its rosette on 18 November at the Institut des Hautes Études Scientifiques (IHES). It was presented to her by fellow physicist Yvonne Choquet-Bruhat, who was the first woman to be elected to the French Academy of Sciences and is a grand officer of the Legion. DeWitt-Morette played an important role in the creation of IHES and has been on the board of directors since 1996.

DeWitt-Morette has many scientific publications to her name, including some important books, most recently *The Pursuit*



Juha Äystö speaks at the award ceremony. (Image credit: CSIC.)



Yasuyuki Akiba of Brookhaven and RIKEN. (Image credit: BNL.)

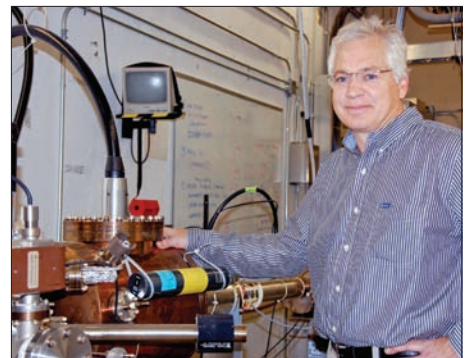
of Quantum Gravity: Memoirs of Bryce DeWitt from 1946 to 2004, in memory of her husband (CERN Courier November 2011 p51).

Yasuyuki Akiba, experimental group leader of the RIKEN BNL Research Center at the Brookhaven National Laboratory (BNL) and vice-chief scientist at the RIKEN Nishina Center in Japan has been awarded the 2011 Nishina Memorial Prize. Yoshi Nishina originated the study of nuclear physics in Japan and trained many young Japanese scientists in the field. The prize is awarded to young physicists for their achievements in the field of atomic and subatomic physics by the Nishina Memorial Foundation, which was established in 1955 to commemorate Nishina.

Akiba, who is also deputy-spokesperson of the PHENIX collaboration, receives the prize for his research at Brookhaven’s Relativistic Heavy Ion Collider, in particular, on lepton-pair production. He shares the prize with Akihide Fujisawa of Kyushu University and Katsumi Ida of the National



Cécile DeWitt-Morette, left, receives the medal and rosette from Yvonne Choquet-Bruhat. (Image credit: IHES.)



Matt Poelker, honoured by the DOE. (Image credit: Jefferson lab.)

Institute for Fusion Science, who are honoured for the “experimental identification of intrinsic electromagnetic field structures in high-temperature plasmas”.

In the US Matt Poelker, a scientist with Jefferson Lab’s accelerator division, is one of nine winners of a 2011 Ernest Orlando Lawrence Award. This prestigious national award from the US Department of Energy (DOE) recognizes outstanding contributions in research and development supporting the DOE and its missions. Poelker receives the award for leading a transformative effort to achieve production of electron beams that possess remarkable properties for advancing parity-violation and polarization-transfer experiments, which are now yielding key information on nucleon quark–gluon structure.

Poelker leads Jefferson Lab’s Center for Injectors and Sources. The group develops and maintains the sources of electron beams for the Continuous Electron Beam Accelerator Facility (CEBAF) and has made great strides in providing highly polarized electron beams of record currents.

Faces & Places

APPOINTMENT

Ent becomes associate director at Jefferson Lab

Rolf Ent has been appointed associate director for experimental nuclear physics at Thomas Jefferson National Accelerator Facility.

Ent earned his PhD at the Free University Amsterdam/Nikhef in 1989, before a year of postdoctoral research at CERN (with the University of Virginia) that was connected with the development of a polarized solid-state target used in measurements of the spin structure-functions of the proton and neutron. In 1990 he began research at Massachusetts Institute of Technology, focusing on a broad programme of scattering measurements, usually with polarized targets, at Bates Lab, Indiana University Cyclotron

Facility, Nikhef and SLAC. He also served as associate director for experimental research at the Nuclear/High-Energy Physics Research Center of Excellence at Hampton University.

Since joining Jefferson Lab as a staff scientist in 1993 to take charge of commissioning of Hall C, Ent has served in a number of leadership positions. These included leading roles in the 12 GeV upgrade project and the design project for the lab's proposed electron-ion collider. He has served on organizing and review committees and as spokesperson for many experiments, particularly in the study of the transition between quark-gluon and hadronic degrees of freedom.



Rolf Ent. (Image credit: Jefferson Lab.)

COLLOQUIUM

CERN celebrates the 'Rutherford centenary'

CERN marked the centenary of the discovery of the atomic nucleus, as published in Ernest Rutherford's famous paper of 1911, with its Rutherford Centennial Colloquium, held on 15 November in the presence of John Adank, New Zealand's ambassador to the World Trade Organization in Geneva.

After an introduction by CERN's director-general, Rolf Heuer, the speakers covered topics ranging from Rutherford's early life in New Zealand, presented by his great grand-daughter Mary Fowler, through to his role as an inspiration to young scientists in his homeland, as seen by New Zealander Mark Kruse, who is now at Duke University and a member of the ATLAS collaboration. Fellow New Zealander, John Campbell, spoke about Rutherford's road to discovery of the nuclear atom, in a similar



Left to right: Jerome Friedman, John Campbell, Mark Kruse, Rolf Heuer, John Adank, Mary Fowler, Ian Hinchliffe, Emmanuel Tsesmelis, who organized the colloquium, and Sean Freeman.

vein to his article in *CERN Courier* on the occasion of the centenary (May 2011 p20).

Rutherford's scientific legacy in nuclear physics was covered by Sean Freeman, appropriately from Manchester University, where the famous scattering experiment took place. Jerome Friedman delved deeper into matter with his talk detailing the scattering experiments at SLAC that first pin-pointed

quarks within nucleons and led to the Nobel Prize in Physics in 1990, which he shared with Henry Kendall and Richard Taylor. Ian Hinchliffe of Berkeley brought the physics up to date, discussing QCD and related studies at the LHC.

● For all of the presentations, see <http://indico.cern.ch/conferenceDisplay.py?confId=147420>.

POLAND

Merger creates new institute for nuclear research

On 25 October, Grzegorz Wrochna was appointed director of the National Centre for Nuclear Research (NCBJ) in Świerk/Otwock, near Warsaw, for a 4-year term. The

new institute came into operation on 1 September as the result of a decision by the Polish government to merge the POLATOM Institute for Atomic Energy and the Sołtan Institute for Nuclear Studies (IPJ) in Świerk. With approximately 1000 employees, NCBJ is now the largest research institute in Poland.

The centre is to continue basic research in physics in co-operation with various



organizations, including CERN. Its strategic tasks also include support for the Polish nuclear-power programme and the construction of hi-tech devices (mainly accelerators and detectors) for research, industry and medicine.

Participation in the LHC programme at CERN remains a major priority of NCBJ. Its predecessor, IPJ, participated in the construction of straw tubes for the LHCb tracker, the ALICE electromagnetic calorimeter and the CMS muon trigger.

Wrochna participated in this effort at CERN, co-ordinating activities on the CMS muon trigger in 1991–1998. Now, NCBJ is producing π -mode accelerating structures for Linac4 at CERN to provide a high-intensity proton beam for the LHC. NCBJ is also involved in neutrino experiments, including ICARUS and T2K, and is supporting the proposal of LAGUNA, a new-generation experiment, which could be located in the Sieroszowice mine in Poland.

NCBJ will also continue the tradition of nuclear physics. Over the past couple of years, its theorists published several widely cited papers explaining experimental results on the structure of nuclei and their interactions. Experimental groups have already started preparation for research at the Facility for Antiproton and Ion Research in Darmstadt.

One new direction for NCBJ is astroparticle physics. Experience with trigger systems and on-line processing of large data streams in particle-physics experiments led to the idea of the “Pi of the Sky” experiment (with the Institute of Theoretical Physics PAS and the Faculty of Physics, University of Warsaw), which detected the brightest γ -ray burst ever seen, GRB 080319B (*CERN Courier* June 2008 p12). Long experience with scintillating crystals is now paying off in the development of γ -ray detectors for satellite missions such as POLAR.

NCBJ participates actively in the construction of large research infrastructures, not only at CERN. This effort includes higher-order-mode absorbers for the XFEL linac in Hamburg, elements of neutral beam injection for the W-7X

stellarator in Greifswald, co-operation with the European Spallation Source in Lund and the Solaris synchrotron in Cracow. In applications-related activities at NCBJ, the HITEC department exports medical accelerators for cancer radiotherapy and industrial accelerators for radiography of engineering structures, while the POLATOM Radioisotope Centre manufactures radioisotopes, mainly radiopharmaceuticals for medical diagnostics. Two large projects currently under development in NCBJ Świerk are the CIŚ Świerk Computing Centre, and the Świerk Science and Technology Park. The CIŚ Centre with its computing power of about 100 teraflops is going to start operations at the end of this year. The park is already accepting its first business customers.

SCIENCE AND ART

First artist in residence at CERN starts in March

The first Prix Ars Electronica Collide@CERN has been awarded to Julius von Bismarck, a 28-year-old German artist. He will start his two-month residency at CERN in March, followed by a one-month residency with the transdisciplinary team at Futurelab at Ars Electronica, Linz. The work and experience of this joint collaborative residency will be showcased at the Ars Electronica Festival later this year.

The Prix Ars Electronica Collide@CERN is the digital-arts strand of the three-year Collide@CERN programme, initiated by CERN in 2011. It marks a three-year science/arts cultural partnership and creative collaboration between CERN and Ars Electronica, which began with CERN's co-operation at Origin, the 2011 Ars Electronica Festival (*CERN Courier* October 2011 p43). The award was made following the jury meeting to assess 395 entries from more than 40 countries – received during the seven-week open call that was announced at the festival in September.

With a growing international reputation for his diverse and experimental artistic practice, von Bismarck received the award for “his proposal and work which manipulates and criticizes our notions of reality in unpredictable ways, often with inventive use of video, objects and public interventions”. His works are also characterized by his fascination with complex philosophical and scientific ideas.

The artistic fields of the entries ranged from experimental sound work and music, architecture and sculpture to social-media



Julius von Bismarck with the Golden Nica award of the Prix Ars Electronica he won in 2008. (Image credit: Ars Electronica.)

projects that explore how people relate to science and technology. In recognition of the

high level of interest and participation in the competition, as well as the quality and range of ideas shown by the international artists, the jury created an additional category of Honorary Mentions, which were awarded to the new-media artist Natasa Teofilovic, from Serbia; the interdisciplinary music theatre collaboration between composer Arnoud Noordegraaf, from the Netherlands, and writer Adrian Hornsby, from the UK; and the generative artist Eno Henze, from Germany.



Feeling Material XXXIV (2008) by Antony Gormley hangs over the stairwell in the entrance of CERN's Main Building. Donated to CERN by the award-winning artist, it was formally unveiled by Sarah Gillett, the UK ambassador to the Swiss Confederation in a ceremony on 7 December. Gormley, winner of the Turner Prize in 1994, creates sculptures that explore the relation of the human body to space at large.

Faces & Places

CELEBRATION

Greenberg reaches 80 as Matveev passes 70

Oscar Wallace “Wally” Greenberg, the theoretician best known for introducing the hidden three-valued colour charge carried by quarks, will celebrate his 80th birthday on 18 February. He continues as an active, full-time faculty member of the University of Maryland in College Park, where he has been since 1961.

Greenberg proposed the idea of colour in 1964 – soon after quarks were introduced – to resolve the paradox that quarks in the supermultiplet of ground-state baryons seemed to violate the Pauli exclusion principle. Because fractionally charged particles had not been observed, quarks with fractional charges seemed highly speculative at the time. Greenberg’s suggestion that quarks have a hidden three-valued charge, in addition to having fractional electric charge, seemed completely wild.

Undeterred by the scepticism of many physicists, to provide an experimental test for his proposal Greenberg calculated the pattern of excited states of baryons on the basis of the baryons having Fermi statistics. It took 10 years for data on excited states of baryons to show that his predictions were correct, thus establishing colour charge. Greenberg’s work, together with the gauging of the colour charge by Yoichiro Nambu and Moo-Young Han in 1965, provided the foundation for quantum chromodynamics, the current theory of strong interactions and an important component of the Standard model.

Greenberg is also known for proving that



Oscar “Wally” Greenberg. (Image credit: University of Maryland.)

local and relativistically covariant quantum field theories must also obey CPT symmetry. He made a systematic analysis of possible quantum statistics in three or more space dimensions and of parastatistics with AML Messiah. He also invented “quons”, a type of quantum statistics that interpolates between Bose and Fermi statistics, to provide a theory that can violate the usual statistics in three space-dimensions.

Viktor Matveev, director of the RAS Institute for Nuclear Research and director of the Joint Institute for Nuclear Research (Dubna), celebrated his 70th birthday on 11 December.

Matveev has made a number of important contributions in theoretical physics, including the development of methods of quantum field theory for studying



Viktor Matveev. (Image credit: JINR.)

high-energy scattering, the description of relativistic composite systems, the formulation of the quark theory of nuclear forces and studies of the effects of quark degrees of freedom in nuclei. He also introduced the notions of hidden colour and quark-counting rules.

As director of INR, Matveev played an important role in the realization of the Baksan and Baikal neutrino observatories and the Moscow Meson Factory at Troitsk. He also actively supports the integration of Russian physics programmes with international ones. He is a member of the Particle and Neutrino Astrophysics and Gravitation International Committee of IUPAP and serves as the chair of the Russia and Dubna Member States Collaboration Board in the CMS project at LHC at CERN.

SCHOOLS

New school series in Asia-Pacific region

The first Asia-Europe-Pacific School of High-Energy Physics (AEP-SHEP) will take place in Fukuoka, Japan, on 14–27 October 2012. This new series of schools is to be held in the Asia-Pacific region every two years, in even-numbered years. It will cater for students at a similar level to the annual CERN-JINR European School of High-Energy physics, and the CERN Latin-American School of High-Energy Physics (also held every two years, in



The location of the first school in the new series. (Image credit: Luigans Spa & Resort.)

odd-numbered years). AEP-SHEP will build on the experience from these schools and also from the successful France-Asia Particle-Physics School.

The purpose of the school is to provide young physicists with an opportunity to learn about recent advances in elementary-particle physics from world-leading researchers. It also aims to encourage communication

between young researchers in Europe, Asia and the Pacific region. It will teach high-energy physics from an experimental and phenomenological perspective, with a focus on accelerator-based programmes in Europe and Asia, and will include related fields such as astroparticle physics and cosmological aspects of particle physics.

The programme will be at a level appropriate for PhD students in experimental particle physics but students working on particle-physics phenomenology (if not too far from experiment) may also be accepted. It will also be open to junior post-docs (typically less than two years after completing their PhD) and advanced MSc students provided that their prior knowledge is comparable to that of the principal target audience. It is expected that up to 100 students will attend the School.

The new school’s international organizers

include representatives from Australia, China, France, India, Japan, Korea, Russia, Taiwan and CERN. The local organization of the 2012 school is being supported strongly by KEK and Kyushu University, with involvement of some other universities in Japan. Students from countries in

the Asia-Pacific region and Europe are particularly invited to apply to the school, but applications from other regions will also be considered.

More information and the application form are available on the AEPSHEP website, <http://aepshep.org>.

School-time in Heidelberg

The Wilhelm and Else Heraeus School on “Diffractive and Electromagnetic Processes at High Energies” took place in Heidelberg on 5–9 September. Sixteen invited lecturers reviewed the lessons learnt at the HERA and the Tevatron colliders, and presented the first results from the LHC experiments: ALICE, ATLAS, CMS, LHCb and TOTEM. Participating students had the opportunity to present the results of their research in seminars or by poster.

Alan Martin of the Institute of Particle Physics Phenomenology at Durham University gave the introductory lecture on diffraction and Krzysztof Piotrkowski of the Université Catholique de Louvain in turn introduced photon–photon physics at high energies. Parton saturation and diffractive processes were presented by Krzysztof Golec-Biernat of the Institute of Nuclear Physics, Cracow.

Review talks on diffraction at HERA and the Tevatron were given by DESY’s Henry Kowalski and Christina Mesropian of Rockefeller University, respectively. The prospects of the diffractive-physics programme at the LHC were addressed by many lecturers. Wolfgang Ochs of the Max-Planck Institute discussed current understanding of the production and decay of glueballs from the theoretical side, summarized the results from CERN’s Large Electron–Positron collider on leading systems in gluon jets and proposed strategies for similar searches at the LHC. Suh-Urk Chung of the Brookhaven National Laboratory reviewed the evidence for exotic mesons from the E852 experiment at Brookhaven and COMPASS at CERN. This stimulated a discussion on the analysis of exotic mesons in central diffractive production at LHC energies. Exclusive Higgs and dijet production formed the topic for the lecture by Antoni Szczurek of the Institute of Nuclear Physics in Cracow.

First results on sensitivities to diffractive channels and on rapidity-gap studies by the ATLAS collaboration were presented by Per Grafström of CERN. Igor Katkov



Participants in front of a “small” wine barrel during a tour of Heidelberg castle. (Image credit: Krzysztof Golec-Biernat.)



CERN’s Per Grafström wears an origami flower made by a student during one of the dinners. (Image credit: Rainer Schicker.)

of the Karlsruhe Institute of Technology summarized the status of studies by CMS of diffractive and electromagnetic physics channels. The ongoing activities of LHCb were presented by Ronan McNulty of University College, Dublin, and Frigyes Nemes of the Eötvös Loránd University, Budapest, described TOTEM’s first results on proton–proton elastic scattering. Results from ALICE on central meson-production and on cosmic-ray physics were summarized by Rainer Schicker of the University of Heidelberg and by Arturo Fernando Tellez of Puebla University, respectively. The prospects for measurements with tagged protons at the LHC were outlined by Marek Taševský of the Physics Institute, Prague.

Prizes for the best posters were awarded to Erik Brucken of the Helsinki Institute of Physics and Wenbo Li of Peking University. The 38 participants from 18 countries had the opportunity to socialize during dinners, as well as during a boat trip on the Neckar.

● For more information, see <http://school-diff2011.physi.uni-heidelberg.de>.

VISITS



Alejandro Cruz, Costa Rican minister of science and technology, right, visited CERN on 27 October. He was welcomed by **Sergio Bertolucci**, CERN’s director for research and scientific computing, and presented with a gift of a temperature-sensitive mug that depicts the history of the universe. During his visit the minister also saw the ATLAS visitor centre and UNITAR’s operational satellite applications programme, UNOSAT.



Israeli deputy minister of foreign affairs, **Daniel Ayalon**, centre, was welcomed to CERN on 6 December by **George Mikenberg**, member of the ATLAS collaboration, and **Felicitas Pauss**, CERN’s head of international relations, where they toured the LHC superconducting magnet test hall. The deputy minister also took the opportunity to see the ATLAS visitor centre and the CERN Control Centre.



On 8 December **Archibald Lesao Lehohla**, deputy prime minister and minister of home affairs and public safety, and of parliamentary affairs for the Kingdom of Lesotho, right, visited CERN, where he was welcomed by **Rüdiger Voss**, CERN’s adviser for the Kingdom of Lesotho in the international relations office.

Faces & Places

OBITUARIES

Kei-Ichi Kuroda 1930–2011

Experimental physicist Kei-Ichi Kuroda, who participated in many experiments at CERN and had a special interest in developing new detectors, especially position-sensitive photomultipliers (PSPM), passed away on 16 September 2011.

After finishing a graduate course in Japan, where he was born in 1930, Kuroda started his career as a high-energy physicist with a PhD from the Institut de Physique Nucleaire (Orsay). In 1968, when most of the experimental facilities in France had stopped because of the general strike, he started his first trials of PSPMs. Applying an axial magnetic field to a venetian-blind photomultiplier tube, he illuminated different points on the photocathode, letting the secondary electrons spiral round the magnetic field lines. This allowed the gain to vary with position, a dependence that he observed successfully. With the aid of many computer calculations he was able to design a PSPM with the most appropriate dynode shape and a segmented anode, and he went on to produce the first prototype in collaboration with Hamamatsu Photonics Co.

After moving in 1976 from Orsay to the newly founded Laboratoire d'Annecy-le-Vieux de Physique des



Kei-Ichi Kuroda. (Image credit: D Drijard.)

Particules (LAPP), he promoted the development work of the RD-17 (FAROS) collaboration at CERN using a test beam on the Proton Synchrotron in collaboration with physicists from Kyoto Sangyo University and the Institute for High Energy Physics, Protvino. This effort pursued not only the development of the PSPM itself but also that of hodoscopes with PSPMs combined with scintillating fibres.

Although the research was fruitful, CERN threatened to end the work of RD-17 unless a “user” of the detector be found soon. Lucien Montanet introduced the work to Leonid Nemenov who was keen to carry out what was to become the DIRAC experiment, which needed exactly the detector that RD-17 was developing.

This happy marriage gave birth to a detector that played an essential role in this experiment, with a spatial resolution of 60 μm (comparable to wire chambers), a time resolution of about 330 ps and an efficiency of higher than 99% in a beam flux of 10⁸/s. It enabled the detection of charged-particle pairs produced in the target among a large number of backgrounds and has contributed to the success of DIRAC. Detectors based on the same concept are now being used in other high-energy physics experiments, for example COMPASS at CERN, as well as in other fields such as neutron imaging and medical diagnosis.

Even after early 2010, when a cancer was found in his lungs, Kuroda continued to come to his office at CERN and contributed to the success of the experiment. We greatly miss this unique physicist with his strong character.

● *His experimentalist colleagues.*

Per Dahl 1932–2011

Per Fridtjof Dahl, physicist, artist and historian of modern physics, died on 1 October 2011.

Per Dahl was born in Washington, DC, in 1932. The son of Odd Dahl (who was instrumental in the decision to use strong focusing in CERN's Proton Synchrotron), he grew up in Bergen between the ages of 4 and 17. He then returned to the US where he served three years in the army. Taking after his father, Per was interested in science and physics from an early age. After leaving the army he entered the University of Wisconsin and obtained his PhD in physics in 1960 before taking up post-doctoral work at the Niels Bohr Institute in Copenhagen.

In 1963 Per moved to Brookhaven National Laboratory (BNL), arriving at a time when superconductors were beginning to move from being laboratory curiosities to industrial production, leading to the development of accelerator magnets using NbTi and Nb₃Sn. Per became involved in the



Per Dahl. (Image credit: Brookhaven National Laboratory.)

design of these magnets and acquired a good understanding of both the materials and their application. He was exceptionally talented in explaining magnets and superconductors,

an activity that also revealed his skills as an artist. When CERN started to develop superconducting magnets it was through his mentoring that important technology could be rapidly transferred.

Per began working on the Superconducting Super Collider (SSC) in 1987, where his activity included documenting the magnet programme. When the SSC effort moved from the design location, Berkeley, to the laboratory location in Texas, Per expanded his work to include that of publishing the *SSC News* in support of the SSC mission. Following the termination of the project in 1993, he moved to the Accelerator and Fusion Research Division at Lawrence Berkeley National Lab (LBNL). In the following years he served as programme officer for the Office of High-Energy Physics, as well as helping BNL to define the magnet system for the Relativistic Heavy Ion Collider. He retired from LBNL in 1996 but kept contact with the lab as a visiting

scientist and through work at the Office for the History of Science and Technology at the University of California, Berkeley, until 2005. He was a fellow of the American Physical Society.

Not only was Per the author of numerous scientific papers, he also wrote several

books. These included *Heavy Water and the Wartime Race for Nuclear Energy* and *From Nuclear Transmutation to Nuclear Fission, 1932–1939* (CERN Courier December 1999 p38 and November 2002 p59.)

Throughout his life, Per was able to pursue his love for physics, for art and for his family.

While at Brookhaven, he was president of the BNL Art Society for several years. He is survived by his devoted wife of 45 years, Eleanor, and two sons, Erik and Thomas, and two grandchildren, Emily and Alex.

● *Eleanor Dahl, Peter Wanderer and Tom Taylor.*

OUTREACH

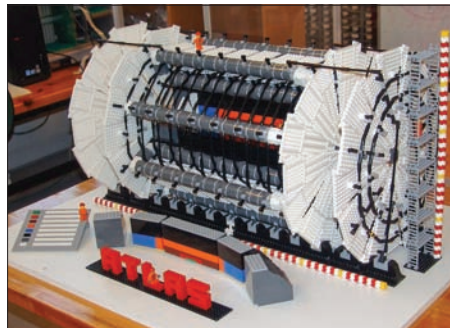
The building blocks of physics at CERN

Denmark is the birthplace of Lego, so it is appropriate that as part of an outreach project, Sascha Mehlhase, a post-doc at the Niels Bohr Institute in Copenhagen, should decide to design a model of the ATLAS experiment built from the famous building bricks. Using software available from Lego, it took Mehlhase some 48 hours to create the 3D design based on 9500 pieces.

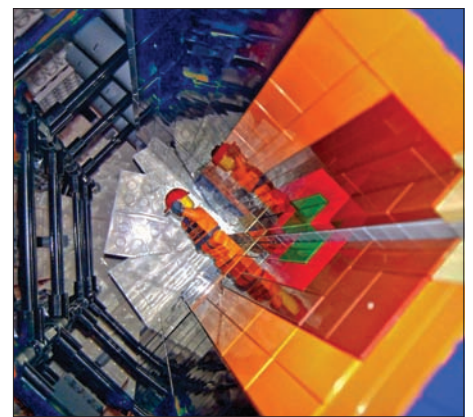
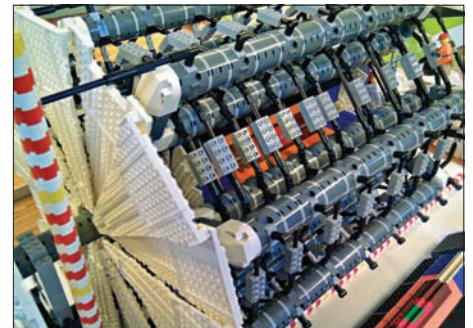
The next step was to order the bricks. And once delivered in 17 boxes it took Mehlhase and his colleagues several hours just to sort them out. Then it was time for the construction phase, which took approximately 33 hours spread over several weekends and evenings. It was not plain sailing because the effects of gravity, for example, meant that building with real bricks was not quite the same as designing in 3D.

Built to a scale of approximately 1:50, the final model measures 1 m × 0.5 m × 0.5 m, which is about the same scale as the Lego people. It illustrates all of the important details, from the muon and magnet system to the silicon tracker at the heart of the detector.

The total cost – about €2000 – was paid by the high-energy physics group at the Niels



Clockwise: The final model was built with 9500 pieces; spot the Lego physicists, who are to scale! Details include the toroid magnet system and muon wheels and the colour-coded inner detector layers. (Image credit: Sascha Mehlhase.)



Bohr Institute as part of their outreach effort.

For enthusiasts who have neither the time nor the money to build a similar large model, Mehlhase has also designed a smaller version with just 493 pieces, which might soon be available as an ATLAS souvenir.

To find out more, see <http://atlas-model.mehlhase.info>.

MEETINGS

ICTR-PHE 2012, the International Conference on Translational Research in Radiation Oncology & Physics for Health in Europe, takes place at the International Conference Centre Geneva, on 27 February – 2 March. The conference brings together two major events in the interdisciplinary field at the intersection of medicine, biology and physics: the ICTR medical conference and CERN's Physics for Health workshop. For details of the programme, see the associated website, <http://ictr-phe12.web.cern.ch/ICTR-PHE12/>.

HIAT2012, the 12th Heavy Ion Accelerator Technology Conference, will be held on 18–21 June and hosted by Argonne National Laboratory (ANL) at the Chicago History Museum, Chicago. Dedicated to heavy-ion accelerators and their components, its focus

includes experience at existing facilities, progress on new projects and upgrades, as well as trends in the proposal and design of future accelerators. The conference will be followed by an optional tour of the ATLAS accelerator at ANL on 22 June. The deadline for registration is 1 March. For further information, see www.phy.anl.gov/hiat12.

ICHEP 2012, the 36th International Conference on High Energy Physics, is to take place at the Melbourne Convention and Exhibition Centre on 4–11 July. In addition to presenting all of the latest findings from the LHC at CERN, the conference will herald developments in every area of experimental and theoretical high-energy physics, including flavour physics, dark matter, strong interactions, heavy ions, neutrinos, particle

astrophysics and cosmology, mathematical physics and string theory. For further information, see www.ichep2012.com.au.

EXON-2012, the 6th International Symposium on Exotic Nuclei, will be held on 1–6 October at the Far Eastern Federal University, Vladivostok. Organized by centres for the study of exotic nuclei – namely, GSI (Darmstadt), GANIL (Caen), FLNR JINR (Dubna), RIKEN (Wako-shi) and FRIB MSU (Michigan) – the symposium will be devoted to the investigation of nuclei in extreme states, in particular at the limits of nuclear stability (from very light neutron- and proton-rich nuclei up to superheavy nuclei). For details of registration (deadline 10 April) and other information, see <http://exon2012.jinr.ru> on e-mail exon2012@jinr.ru.

Faces & Places

NEW PRODUCTS

Aerotech has announced the new MPS75SL miniature linear positioning stages series, which are just 75 mm wide and available in four travel ranges from 25 mm to 100 mm. The small footprint and low-profile stage design is optimized in the use of miniature 1 mm-pitch precision ball screws, high-resolution encoders and anticreep crossed roller bearings for ultrasmooth velocity and reduced error motion. For further details, contact Simon Smith, tel +44 118 940 9400, e-mail ssmith@aerotech.com or visit www.aerotech.com.

Delta Tau has introduced the Power PMAC CPU, which delivers computing and data-processing features within a half-rack footprint to create a powerful heart for machine control systems. The new CPU has a dynamic range and resolution and support for very large memory, including 1 GB or 2 GB DDR RAM in a SO-CDIMM module with error correction. There is also 64 MB of MOR flash for standard firmware and 1 GB or 2 GB built-in NAND flash for code/settings on board. For further details, contact

Stirling Morley, tel +44 1376 333 333, e-mail stirling@micromech.co.uk or see www.micromech.co.uk.

Oxford Instruments has announced its new MercuryITC cryogenic temperature controller. This controller is used to control the temperature of a sample whose properties are being investigated. Customers configure the system as they need and can adapt it by adding plug-and-play expansion cards. For further details, tel +44 1865 393 349, e-mail sophie.walker@oxinst.com or visit www.oxford-instruments.com.

Pfeiffer Vacuum has introduced adixen backing pumps. The HiCube Pro turbo pumping station is available with a dry, multi-usage ACP roots pump for the adixen range. The HiCube Pro pumping station's special characteristic is its modular concept. For further details, contact Nicole Ackermann, tel +49 6441 802 169, e-mail nicole.ackermann@pfeiffer-vacuum.de or see www.pfeiffer-vacuum.com.

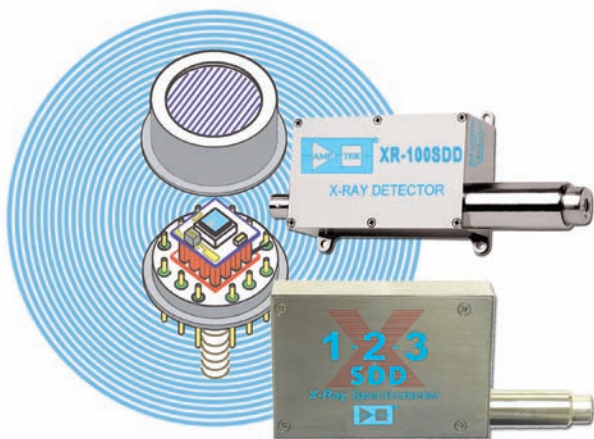
Trek, Inc has announced the Model 50/12, a DC-stable, high-voltage power amplifier designed to provide precise control of output voltages in the 0 to ± 50 kV DC range or peak AC with an output current range of 0 to ± 12 mA DC or peak AC. The amplifier is configured as noninverting with a fixed gain of 5000 V/V. For further details, tel +1 585 798 3140, e-mail sales@trekinc.com or visit www.trekinc.com.

Ultravolt, Inc has announced the extension of its EFL series of enhanced floating "hot-deck" isolated power supplies. EFL Series units can now achieve up to 30 kV of isolation. The EFL Series of "hot-deck" isolated system modules are already known for simplifying designs that have electronics highly isolated and/or truly floating on high voltage. The new 30EFL maintains the EFL Series performance, which includes analogue channel initial offset error of $< \pm 2$ mV, gain error of $< \pm 0.2\%$, linearity error of $< \pm 0.5\%$ and a temperature coefficient of $< \pm 10$ ppm. For further details, tel +1 631 471 4444 or visit www.ultravolt.com.

Silicon Drift Detector

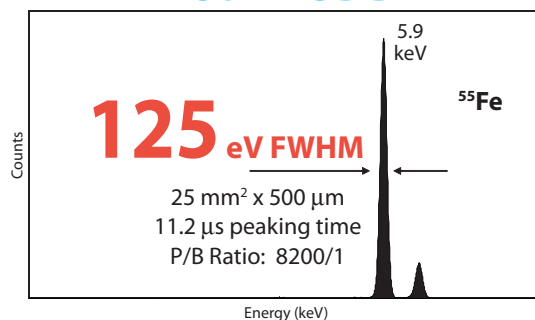
No Liquid Nitrogen
Easy to Use

Solid State Design
Low Cost

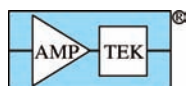


XR-100SDD X-Ray Detector and
X-123SDD Complete X-Ray Spectrometer with X-ray detector and preamplifier, digital pulse processor, MCA, and power supply

SUPER SDD



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The Partners of the Consortium are:

UNIVERSITE DE NICE - SOPHIA ANTIPOLIS, France (Co-ordinating institution), SHANGHAI ASTRONOMICAL OBSERVATORY, China, FREE UNIVERSITY OF BERLIN, Germany, AEI - POTSDAM, Germany, TARTU OBSERVATORY, Estonia, STOCKHOLM UNIVERSITET, Sweden, UNIVERSITY OF FERRARA, Italy, UNIVERSITY OF ROME - LA SAPIENZA, Italy, BRAZILIAN CENTRE FOR PHYSICS RESEARCH, Brazil, OBSERVATORY OF THE CÔTE D'AZUR, France, INDIAN CENTRE FOR SPACE PHYSICS, India, INTERNATIONAL CENTER FOR RELATIVISTIC ASTROPHYSICS NETWORK, Italy, UNIVERSITY OF SAVOIE, France

Director of the course: Prof. Remo Ruffini

PhD students will receive a very competitive salary (gross salary 2800 Euros per month and a 7500 Euro installation grant for non-European students), computing facilities and support for travel, and comprehensive benefits including paid vacation, health care insurance and retirement benefits. To be eligible, applicants should have obtained a Masters degree in astronomy, astrophysics, theoretical physics or a related field. We encourage applications from the best candidates irrespective of nationality, gender or background. Student research will be carried out in the framework of the IRAP PhD Consortium.

Consult the web page : <http://www.irap-phd.eu> for details and application instructions. All inquiries should be directed to Prof. Pascal Chardonnet, Erasmus Mundus Joint Doctorate Coordinator: chardonnet@lapp.in2p3.fr.

Applicants are requested send a curriculum vitae, an application form, a list of all university courses taken and transcripts of grades obtained, brief statements of research interests and experience, and the contact information for at least two referees. Applications received by the deadline of February 19, 2012 will receive full consideration.



RICE Tenure Track Position in Experimental Heavy Ion Physics

The Department of Physics and Astronomy at Rice University invites applications for a tenure-track assistant professor position in experimental heavy ion physics. The successful candidate is expected to teach and to conduct a vigorous research program that will enhance Rice's on-going efforts involving the STAR experiment at RHIC and the CMS experiment at the LHC. A PhD in physics or related field is required.

Applicants should send a dossier that includes a curriculum vitae, statements of research and teaching interests, and a list of publications, and they should arrange for at least three letters of recommendation to be sent to

B. Paul Padley, Chair, Experimental Heavy Ion Search Committee, Department of Physics and Astronomy –MS 61, Rice University, 6100 Main Street, Houston, TX 77005 or by email as a single PDF file to vcall@rice.edu with the subject line "HI Search".

Applications may be considered until the position is filled, but those received by February 1, 2012 will be assured full consideration. The appointment is expected to begin July 2012. Rice University is an affirmative action/equal opportunity employer; women and under-represented minorities are strongly encouraged to apply.

Accelerators | Photon Science | Particle Physics

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POSTDOC IN NEUTRINO ASTROPHYSICS.

DESY, Zeuthen location, is seeking: Postdoc (m/f)

DESY

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

The neutrino astrophysics group is involved in operation of the IceCube neutrino telescope at the South Pole and in the analysis of its data. The research goals of the group range from neutrino astrophysics to the investigation of neutrino properties. The group is part of the Brandenburg-Berlin Cluster for astroparticle physics and the Helmholtz Alliance for Astroparticle Physics.

The position

The work will include the exploitation of IceCube for the study of neutrino oscillations and other medium-energy phenomena. This includes design studies for further low-energy extensions of IceCube. Additionally, the successful applicant will have the opportunity to do astrophysical or particle physics research exploiting the data of the IceCube neutrino telescope. The successful candidate will work in an international research environment.

Requirements

- PhD in physics or astronomy
- Experience in conducting modern experiments in particle or astroparticle-physics and their interpretation
- Working experience with modern software tools (C++)
- Hardware experience is an advantage
- Good command of English
- Applications should include a CV, a statement of research interests, a list of publications, and the names of 2 references.

For further information please contact Christian Spiering, +49 33762-77218, christian.spiering@desy.de.

The position is limited to 2 years with a possible extension up to 3 years. Salary and benefits are commensurate with those of public service organisations in Germany. DESY operates flexible work schemes. Handicapped persons will be given preference to other equally qualified applicants. DESY is an equal opportunity, affirmative action employer and encourages applications from women.

Please send your application quoting the reference code, also by e-mail to:

Deutsches Elektronen-Synchrotron DESY

Human Resources Department | Code: 201/2011

Notkestraße 85 | 22607 Hamburg | Germany

Phone: +49 40 8998-1589 | E-mail: personal.abteilung@desy.de

Deadline for applications: until the position is filled

www.desy.de

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OPEN POSITIONS WITHIN THE OPAC PROJECT

The optimization of the performance of any particle accelerator critically depends on an in-depth understanding of the beam dynamics in the machine and the availability of simulation tools to study and continuously improve all accelerator components. It also requires a complete set of beam diagnostics methods to monitor all important machine and beam parameters with high precision and a powerful control and data acquisition system.

Within the oPAC project these aspects will be closely linked with the aim to optimize the performance of present and future accelerators that lie at the heart of many research infrastructures.

The network is currently aiming to recruit a pool of talented, energetic, strongly motivated, early stage researchers with a degree in physics, electrical engineering or a closely related field. Possibilities for enrolling into a PhD program exist. Women are especially encouraged to apply.

Deadline for applications:

March 9th 2012

Each researcher will benefit from a wide ranging training program that will take advantage of both local and network-wide activities, as well as of schools, conferences, and workshops. Excellent salaries will be offered. Most positions are for starting in summer 2012.

You will find more information about oPAC, all research projects and the application details at:

<http://www.liv.ac.uk/opac>

Contact and further detail:

Prof. Carsten P. Welsch
Cockcroft Institute of Accelerator
Science and Technology
University of Liverpool
Department of Physics
L69 7ZE Liverpool, UK
carsten.welsch@quasar-group.org



Diamond Light Source is the UK's national synchrotron science facility. Located at Harwell Science and Innovation Campus in Oxfordshire, we enable world-leading research across a wide range of scientific disciplines and industrial applications.

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Ref: DIA0679/TH

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Full time, 2 year fixed term

The Detector Group is responsible for the construction, installation, commissioning, and operation of the detector systems at Diamond. In order to provide the best detectors, the group is committed to a number of detector development and evaluation projects.

A Postdoctoral Research Associate is required to develop theoretical models of detectors and for their validation with appropriate experimental tests. Detector models are essential to determine the correct detector parameters for specific applications and to interpret the data provided by novel detector systems.

You will join a highly dynamic group working at the cutting edge of detector technology. The availability of a test beamline at Diamond allows the Detector Group to evaluate the performance of innovating detector technologies and their application to synchrotron X-ray experiments. Close cooperation with the Rutherford Appleton Laboratory enables access to other world-class facilities as well as the interaction with world-leading detector developers.

Candidates should have an appropriate PhD degree or equivalent qualification and knowledge of the principles of radiation-matter interaction. Experience in using Monte Carlo codes for the simulation of the interaction of radiation with matter e.g. MCNP, GEANT4 is desirable.

The position is offered for an initial appointment of two years. However there is the possibility of an extension.

Diamond is committed to equality of opportunities for all, and offer a competitive salary (dependent upon skills, qualifications and experience), comprehensive benefits, an index-linked pension scheme and flexible working hours.

For an application form and further information including work permit and visa requirements for non-EU nationals please visit our website at www.diamond.ac.uk or telephone our recruitment line on 01235 778218 or write to us at the address below, quoting the appropriate reference number.

Closing date: 19th February 2012.

www.diamond.ac.uk



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Accelerators | Photon Science | Particle Physics

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ASTROPARTICLE PHYSICS.

**DESY, Zeuthen location, is seeking:
Postdoc (m/f)**

DESY

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

The DESY neutrino astrophysics group in Zeuthen is involved in operation of the IceCube neutrino telescope at the South Pole and in the analysis of its data. The research goals of the group range from neutrino astrophysics to the investigation of neutrino properties. In addition the group is active in the development of novel detection technologies for neutrinos at highest energies. The group is part of the Brandenburg-Berlin Cluster for astroparticle physics and the Helmholtz Alliance for Astroparticle Physics which supports the opening of this position.

The position

- Detector R&D
- Detector and experiment simulation
- Data analysis
- Supervision of students

Requirements

- PhD in experimental particle physics or astroparticle physics
- Some experience in particle detector development and simulation
- Good programming skills (C,C++)
- Teamwork abilities
- Good knowledge of English

For further information please contact Rolf Nahnauer, +49 33762-77346, rolf.nahnauer@desy.de.

The position is limited to 2 years with a possible extension up to 5 years. Salary and benefits are commensurate with those of public service organisations in Germany. DESY operates flexible work schemes. Handicapped persons will be given preference to other equally qualified applicants. DESY is an equal opportunity, affirmative action employer and encourages applications from women.

Please send your application quoting the reference code, also by e-mail to:

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Human Resources Department | Code: 202/2011

Notkestraße 85 | 22607 Hamburg | Germany

Phone: +49 40 8998-1589 | E-mail: personal.abteilung@desy.de

Deadline for applications: February 15th, 2012

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PHOTO INJECTOR.

**DESY, Zeuthen location, is seeking:
Several Postdocs (m/f)**

DESY

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

The operation of Free-Electron Lasers like FLASH and the European XFEL requires electron sources with excellent beam quality. For the development of such electron guns a test facility for RF photo injectors, PITZ, is operated and upgraded at Zeuthen (near Berlin). Further improvement of the photo injector performance is foreseen with advanced photo cathode laser pulse shaping and new applications of the photo injector are studied in the frame of the new Accelerator R&D program supported by the German Federal Ministry of Education and Research.

The position

- Participation in the photo injector optimization at PITZ
- Beam dynamics simulations for special laser pulse shapes, applying the setups of PITZ and the European XFEL injector
- Participation in commissioning the upcoming photo cathode laser system with special pulse shaping and characterization of the upgraded electron source
- Simulation and experimental studies on the generation of ultra short bunches and particle driven plasma acceleration
- Participation in the shift operation at PITZ

Requirements

- University degree in physics or engineering including a PhD in physics
- Good knowledge and experience in accelerator physics and technology of high brightness electron beams or plasma physics
- Skills and experience in beam dynamics simulations, especially in the area of photo injectors are highly desirable
- Experience in laser pulse shaping techniques is of advantage

For further information please contact Dr. Mikhail Krasilnikov, phone: +49 33762-77213, mikhail.krasilnikov@desy.de or Dr. Frank Stephan phone: +49 33762-77338, frank.stephan@desy.de.

The position is limited to 3 years.

Salary and benefits are commensurate with those of public service organisations in Germany. DESY operates flexible work schemes. Handicapped persons will be given preference to other equally qualified applicants. DESY is an equal opportunity, affirmative action employer and encourages applications from women.

Please send your application quoting the reference code, also by e-mail to:

Deutsches Elektronen-Synchrotron DESY

Human Resources Department | Code: 183/2011

Notkestraße 85 | 22607 Hamburg | Germany

Phone: +49 40 8998-1589 | E-mail: personal.abteilung@desy.de

Deadline for applications: February 29th, 2012

www.desy.de

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Karlsruhe Institute of Technology (KIT) is the result of the merger of the University of Karlsruhe and the Research Centre Karlsruhe. It is a unique institution in Germany, which combines the mission of a university with that of a large-scale research centre of the Helmholtz Association. With 8000 employees and an annual budget of EUR 650 millions, KIT is one of the largest research and education institutions worldwide.

The Physics Department at the Karlsruhe Institute of Technology invites applications for the newly established position of a

Professor (W3) of Theoretical Astroparticle Physics

at the KIT-Centre Elementary Particle and Astroparticle Physics. The position should be filled as soon as possible.

We are looking for an expert in the area of theoretical astroparticle physics. Candidates with broad scientific competence and innovative research spanning the areas of astrophysics, elementary particle physics or cosmology will be considered.

The position offers an excellent research environment with opportunities for collaboration within the Department of Physics and with other structures of KIT. This includes the KIT Center of Elementary Particle and Astro-Particle Physics (KCETA), the Transregional Collaborative Research Center SFB/TR9 Computational Particle Physics and the Research Training Group GRK 1694 Elementary Particle Physics at Highest Energy and Precision. Further important assets are the Helmholtz Alliance for Astroparticle Physics and the Helmholtz Programme Astroparticle Physics, which should be strengthened by original contributions of the selected candidate.

Teaching duties include education of physics students as well as of students majoring in other natural sciences or engineering.

Applicants must have the degree of Habilitation or demonstrate equivalent scientific qualification as well as experience in teaching.

KIT is pursuing a gender equality policy. We encourage qualified women to apply. If qualified, handicapped applicants will be preferred.

Applications with standard documentation, including a summary of past teaching, a research plan as well as a list of the five most important publications, should be sent by **February 28th, 2012** to: **Karlsruher Institut für Technologie (KIT), Dekan der Fakultät für Physik, Campus Süd, 76128 Karlsruhe**

KIT - University of the State of Baden-Württemberg and National Laboratory of the Helmholtz Association



EUROPEAN SPALLATION SOURCE

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- NEUTRON OPTICS
- BEAM DIAGNOSTICS

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Consortium for Construction, Equipment and Exploitation of the Synchrotron Light Laboratory

The ALBA synchrotron light source is opening three positions:

The Director of the Facility The Head of the Accelerator Division The Head of the Experimental Division

The Consortium CELLS – jointly owned by the Spanish and Catalan Administrations – is responsible for the operation and future development of ALBA, a 3 GeV third generation synchrotron light facility. At present, the construction is finished and the accelerator complex and the seven state of the art beamlines covering a variety of research fields are finalizing their commissioning. The first call for users is going on and the first users are expected for April 2012. Details may be found at www.cells.es.

ALBA is located in Cerdanyola del Vallès, at some 20 km from Barcelona, in a metropolitan region of about 4.5 million people, a zone of improving scientific and technological level, with several international schools, universities and scientific and technological parks and with very good international communications.

The Consortium is looking for:

- A Director of the facility. The Director is responsible for the scientific and technical exploitation of ALBA, for the definition of short and long term development strategies and must report to the Governing Bodies of the consortium (an Executive Commission and a Rector Council whose delegates are appointed by the Owner Administrations).
- A Head of the Accelerator Division. His/her responsibility is the proper working of the machine and the implementation of new elements in order to achieve the nominal parameters: 400 mA, 4.6 nm-rad emittance, high flux and good stability.
- A Head of the Experimental Division. His/her responsibility is to achieve the best performance of the beamlines in order to attract good research projects and prepare the second phase of the beam lines.

Candidates must have experience in research institutes or similar facilities, a solid experience with accelerators and synchrotron light research and have qualifications for Directorship. The working language at Alba is English. Knowledge of Spanish and or Catalan is an asset.

They will be offered a full time contract according to the Spanish law. Employment conditions and salaries can take into account the needs of professionals and their families. The incorporation date to the position is expected in summer 2012

Applications should be sent to the Chairman of the Executive Commission of ALBA; Carretera BP 1413 de Cerdanyola a Sant Cugat, km 3.3; E 08290 Cerdanyola del Vallès; Spain. Candidates should send a letter of motivation and their CV to the Chairman of the Executive Commission of ALBA Prof. Ramon Pascual (pascual@cells.es).

Deadline for receiving applications: 15th March 2012.



Scientist for sample environment techniques (f/m)

The European X-Ray Free-Electron Laser Facility GmbH (European XFEL GmbH) is a multi-national non-profit company. It will make available X-rays of unique quality for studies in physics, chemistry, life sciences, materials research and other disciplines.

For the development of sample environment techniques we are seeking to employ a (f/m)

Scientist for sample environment techniques

The position

- plan and perform R&D on methods and devices for sample environment at FEL sources
- design and specify fixed target manipulation systems and/or liquid jet sources

Requirements

- PhD degree in experimental physics or chemistry or equivalent academic experience
- previous post-doc or PhD experience in instrumentation and research for synchrotron or FEL-based spectroscopy or imaging
- experience in the preparation of surfaces or liquids in vacuum; experimental skill and experience in mechanics and basic electronics

For additional information please contact Joachim Schulz (joachim.schulz@xfel.eu).

Application: Please apply online via our homepage www.xfel.eu (reference number **S-059**).

Duration: This appointment is initially limited to three years.

Deadline for application: 15 February 2012

European XFEL GmbH | Albert-Einstein-Ring 19 | 22761 Hamburg
Germany | Mailing address: Notkestr. 85 | 22607 Hamburg | Germany

www.xfel.eu



Cornell Laboratory for
Accelerator-based Sciences
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Tenure-track Faculty Appointment in Experimental Physics – Cornell University

The Department of Physics at Cornell University invites applications for a tenure-track faculty appointment in experimental physics. We encourage applications in experimental particle physics, accelerator physics, and astrophysics. Candidates should complement the existing research program in the Laboratory for Elementary-Particle Physics; expanding the LHC component of the laboratory program is not a priority of this search. The search will focus at the assistant professor level, although more senior candidates may be considered. The successful candidate will be expected to conduct an outstanding research program and be an effective teacher in the undergraduate and graduate instructional program of the Physics Department.

Please send the application, including a curriculum vita, a publication list, and a statement of research interests, to <http://academicjobsonline.org/ajo/jobs/1299>.

Applicants should arrange to have three letters of reference sent to the same address. Applications completed by Jan. 31, 2012 will receive full consideration.

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brightrecruits.com



IAEA
International Atomic Energy Agency

Nuclear Physicist

The International Atomic Energy Agency (IAEA), an independent United Nations organization headquartered in Vienna, Austria, with more than 150 Member States and a staff of 2300, serving as the global focal point for international cooperation in the safe and peaceful use of nuclear technology, is seeking a Nuclear Physicist for its Physics Section. This individual will be: (1) a planner and coordinator, who formulates, develops, organizes and implements the IAEA's activities on accelerators and nuclear instrumentation including related training and education; (2) a facilitator, who helps the Member States to establish cooperation among accelerator laboratories and nuclear education institutions, mainly in developing countries and main facilities and laboratories working on the application of accelerators; (3) a scientific secretary/technical expert, who plans and leads Technical Meetings; (4) a technical and project officer, who evaluates Technical Cooperation (TC) projects, and promotes, co-ordinates and evaluates moderately complex Research Projects (CRPs).

The successful candidate should have at the minimum:

- PhD in nuclear physics or a closely related field
- At least 7 years of relevant research experience; preferably 3 years at international level and proven ability in working with international projects or multinational teams
- Up-to-date knowledge of and experience in particle accelerators of various energy ranges and their use in research and industry
- Profound knowledge of particle and radiation detectors and their use in research and industry.

To apply for this position, please submit an on-line application at <http://www.iaea.org/About/Jobs> before 29th February 2012, selecting vacancy notice no. 2011/147.

Benefits: The IAEA offers a stimulating multicultural working environment in the beautiful and culturally rich city of Vienna, Austria. The post offers: tax free remuneration; rental subsidy; 6 weeks annual leave; medical insurance coverage; a staff retirement plan; full coverage of removal expenses for staff member, family, and personal effects; additional allowance for installation expenses; assistance with finding housing and schools in Vienna; financial assistance with the education of dependent children; and paid travel to the home country for the staff member and family every other year.

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The Institute of Particle Physics Research Scientist

Applications are invited for a position as a Research Scientist with the Institute of Particle Physics in Canada, IPP (<http://www.ipp.ca>). Candidates should preferably have at least three years of postdoctoral experience and a demonstrated record of accomplishment in experimental particle physics. The Research Scientist appointment is associated with an academic research position at a Canadian university and includes the right to hold research grants and to supervise graduate students. Such an appointment may be made permanent following a review after three years of employment.

The current program of IPP includes the following experiments:

- p-p collisions at the LHC (ATLAS);
- Long baseline neutrino studies at JPARC (T2K);
- Double-beta-decay searches with the SNO+ and EXO detectors;
- Dark Matter searches with the DEAP and PICASSO experiments;
- Precision pion decay studies at TRIUMF (PiENU);
- Very-high-energy gamma-ray astronomy (VERITAS).

The choice of experiment and university affiliation will be determined by mutual agreement between the candidate and the IPP. The position will be available as early as September 1, 2012.

Send curriculum vitae, statement of research interests and arrange for letters of recommendation from at least three referees, to be received by February 3, 2012 at:

Prof. W.Trischuk, Director
Institute of Particle Physics
Department of Physics
University of Toronto
60 Saint George Street,
Toronto, ON M5S 1A7
Canada
email: william@physics.utoronto.ca



All qualified candidates are encouraged to apply, however, in accordance with immigration regulations, Canadians and permanent residents will be given priority.

Bookshelf

The Infinity Puzzle: How the quest to understand quantum field theory led to extraordinary science, high politics and the world's most expensive experiment

By Frank Close

Frank Close

Hardback: £16.99

Frank Close is a prolific author – *Neutrino, Antimatter, Nothing, The New Cosmic Onion, Void, The Particle Odyssey, Lucifer's Legacy* and more, have already appeared this century. *The Infinity Puzzle* is his ingenious name for the vital but recondite procedure called “renormalization” in physics-speak, but his latest book covers much more ground than just this.

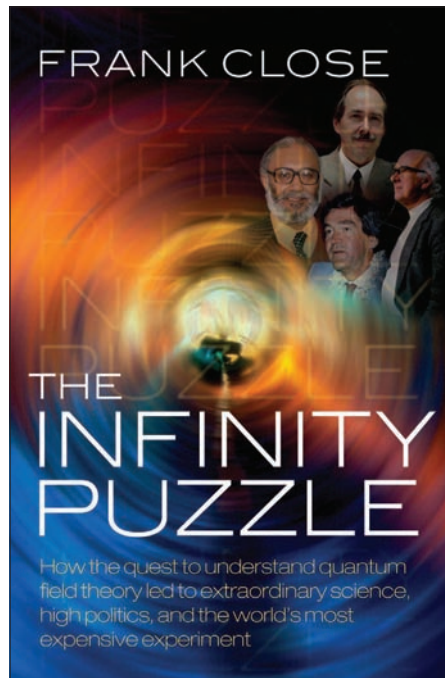
Setting off to trace the evolution of quantum field theory in the 20th century, Close needs to run, leaping from Niels Bohr to Paul Dirac without pausing at Erwin Schrödinger and Werner Heisenberg. However, he occasionally pauses for breath: his descriptions of difficult ideas such as gauge invariance and renormalization are themselves valuable. Equally illuminating are the vivid portraits of some of the players, many major – Abdus Salam, Sheldon Glashow, Gerard 't Hooft and John Ward – as well as others, such as Ron Shaw, who played smaller roles. Other key contributors, notably Steven Weinberg, appear on the scene unheralded.

The core of the book is the re-emergence in the 1960s of field theory, which had lapsed into disgrace after its initial triumph with quantum electrodynamics. Its new successes came with a unified electroweak theory and with quantum chromodynamics for the strong interactions.

Embedded in this core is a scrutiny of spontaneous symmetry breaking as a physics tool. Here Close presents the series of overlapping contributions that led to the emergence of what is now universally called the “Higgs mechanism”, together with the various claims and counterclaims.

Electroweak unification gained recognition through the Nobel Prize in Physics twice: in 1979 with Glashow, Salam and Weinberg; and in 1999 with 't Hooft and Martinus Veltman. Having assigned credit where he sees fit, Close also confiscates much of that accorded to Salam, stressing the latter's keen ambition and political skills to the detriment of enormous contributions to world science. (His International Centre for Theoretical Physics in Trieste was launched with initial support from IAEA, not from UNESCO, as stated in the book.)

In this electroweak saga, Close gives

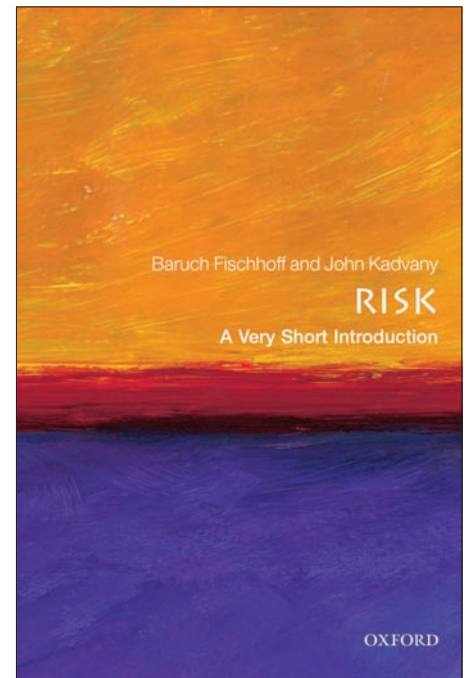


an impression that understanding weak interactions was at the forefront of people's minds in the mid-1960s, when many were, in fact, initially blinded by the dazzle of group theory for strong interactions and the attendant quark picture. In those days, spontaneous symmetry breaking became muddled with ideas of approximate symmetries of strong interactions. Many struggled to reconcile the lightness of the pion with massless Goldstone bosons. Close mentions Weinberg's efforts in this direction and the sudden realization that he had been applying the right ideas to the wrong problem.

As the electroweak theory emerged, its protagonists danced round its renormalization problems, whose public resolution came in a 1971 presentation in Amsterdam by 't Hooft, carefully stage-managed by Veltman, which provides a dramatic prologue to the book. For the strong interactions, Close sees Oxford with Dick Dalitz as a centre of quark-model developments but there was also a colourful quark high priest in the form of Harry Lipkin of the Weizmann Institute.

With the eponymous puzzle resolved, the book concludes with discoveries that confirmed the predictions of field theory redux and the subsequent effort to build big new machines, culminating in the LHC at CERN. The book's end is just as breathless as its beginning.

The Infinity Puzzle is illustrated with numerous amusing anecdotes, many



autobiographical. It displays a great deal of diligent research and required many interviews. At some 400 pages, it is thicker than most of Close's books. Perhaps this is because there are really two books here. One aims at the big audience that wants to understand what the LHC is and what it does, and will find the detailed field-theory scenarios tedious. On the other hand, those who will be enlightened, if not delighted, by this insight will already know about the LHC and not need explanations of atomic bar codes.

● *Gordon Fraser, author of Cosmic Anger, a biography of Abdus Salam that is now available in paperback.*

Risk – A very short Introduction

By Baruch Fischhoff and John Kadvanly

Oxford University Press

Hardback: £7.99

Amazing. A book that should be read by everyone who is still thinking of investing in hedge funds or believing that the stock market is rational. The subject is well explained, covering risk types that we are all familiar with, as well as some that most of us probably never think of as risk. What I especially like is the large number of recent events that are discussed, deep into the year 2011.

The range of human activity covered is vast, and for many areas it is not so much risk as decision making that is discussed. There are many short sentences that were

Bookshelf

perfectly clear to me but still unexpected such as “people are [deemed] adequately informed when knowing more would not affect their choices”.

The language is clear and pleasant to read, though here and there I sensed that the authors struggled to remain within the “very short” framework. That also means that you should not expect to pick up the 162-page book after dinner and finish it before going to bed. Much of it invites reflection and slow savouring of the ideas, effects and correlations that make risks and deciding about them so intimately intertwined with our human psyche.

A very pleasant book indeed.

- Robert Cailliau, *Prévešin*.

Books received

Dark Energy: Theory and Observations

By Luca Amendola and Shinji Tsujikawa

Cambridge University Press

Hardback: £45

Introducing the relevant theoretical ideas, observational methods and results, this textbook is ideally suited to graduate courses on dark energy, as well as supplement advanced cosmology courses. It covers the cosmological constant, quintessence, k-essence, perfect fluid models, extra-dimensional models and modified gravity. Observational research is reviewed, from the cosmic microwave background to baryon acoustic oscillations, weak lensing and cluster abundances.

Neutron Physics for Nuclear Reactors: Unpublished Writings by Enrico Fermi

By S Esposito and O Pisanti (eds.)

World Scientific

Hardback: £76 \$111

E-book: \$144

This unique volume gives an accurate and detailed description of the functioning and operation of basic nuclear reactors, as emerging from previously unpublished papers by Enrico Fermi. The first part contains the entire course of lectures on neutron physics delivered by Fermi at Los Alamos in 1945, as recorded in notes by Anthony P French. Here, the fundamental physical phenomena are described comprehensively, giving the appropriate

physics underlying the functioning of nuclear piles. The second part contains the patents issued by Fermi (and co-workers) on the functioning, construction and operation of several different kinds of nuclear reactor.

Measurements and their Uncertainties: A Practical Guide to Modern Error Analysis

By Ifan Hughes and Thomas Hase

Oxford University Press

Hardback: £39.95 \$85

Paperback: £19.95

This hands-on guide is primarily intended to be used in undergraduate laboratories in the physical sciences and engineering. It assumes no prior knowledge of statistics and introduces the necessary concepts where needed. Key points are shown with worked examples and illustrations. In contrast to traditional mathematical treatments, it uses a combination of spreadsheet and calculus-based approaches, suitable as a quick and easy on-the-spot reference.

The Nucleon–Nucleon Interaction and the Nuclear Many-Body Problem: Selected Papers of Gerald E Brown and T T S Kuo

By Gerald E Brown et al. (eds.)

World Scientific

Hardback: £87 \$140

E-book: \$182

These selected papers provide a comprehensive overview of some key developments in the understanding of the nucleon–nucleon interaction and nuclear many-body theory. With their influential 1967 paper, Brown and Kuo prepared the effective theory that allowed the description of nuclear properties directly from the underlying nucleon–nucleon interaction. Later, the addition of “Brown-Rho scaling” to the one-boson-exchange model deepened the understanding of nuclear matter saturation, carbon-14 dating and the structure of neutron stars.

Weaving the Universe: Is Modern Cosmology Discovered or Invented?

By Paul S Wesson

World Scientific

Hardback: £45 \$65

E-book: \$85

Aimed at a broad audience, *Weaving the Universe* provides a thorough but short

review of the history and current status of ideas in cosmology. The coverage of cosmological ideas focuses on the early 1900s, when Einstein formulated relativity and when Sir Arthur Eddington was creating relativistic models of the universe. It ends with the completion of the LHC in late 2008, after surveying modern ideas of particle physics and astrophysics – weaved together to form a whole account of the universe.

Symmetries and Conservation Laws in Particle Physics: An Introduction to Group Theory for Particle Physics

By Stephen Haywood

Imperial College Press

Hardback: £36 \$58

Paperback: £17 \$28

Group theory provides the language for describing how particles (and in particular, their quantum numbers) combine. This provides understanding of hadronic physics as well as physics beyond the Standard Model. The book examines symmetries and conservation laws in quantum mechanics and relates these to groups of transformations. The symmetries of the Standard Model associated with the electroweak and strong (QCD) forces are described by the groups U(1), SU(2) and SU(3). The properties of these groups are examined and the relevance to particle physics is discussed.

Primordial Cosmology

By Giovanni Montani, Marco Valerio Battisti,

Riccardo Benini and Giovanni Imponente

World Scientific

Hardback: £123 \$199

E-book: \$259

In this book the authors provide a self-consistent and complete treatment of the dynamics of the very early universe, passing through a concise discussion of the Standard Cosmological Model, a precise characterization of the role played by the theory of inflation, up to a detailed analysis of the anisotropic and inhomogeneous cosmological models. They trace clearly the backward temporal evolution of the universe, starting with the Robertson–Walker geometry and ending with the recent results of loop quantum cosmology on the “Big Bounce”.

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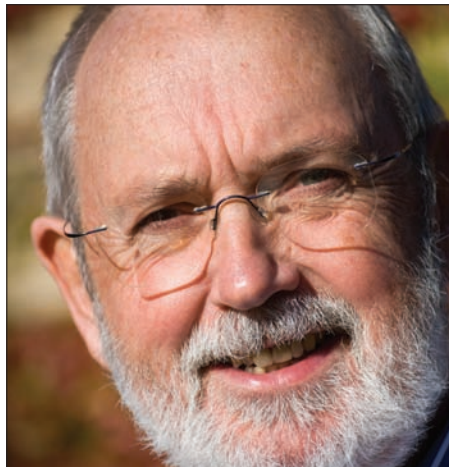
Towards a more confident future

Colin Carlile argues the case for collaboration and science as drivers of confidence – something that is surely needed in 2012.

Gloom and despondency about the economic climate fill the newspapers to saturation point. The eurozone is, once again, destined to fragment and disappear – there is a depressingly strong sensation that many people never wanted it to thrive in the first place and would be delighted (not openly of course) should it disappear. Interestingly, the issue of the real climate has fallen off the radar screens for the moment. There is no doubt that these issues and many others – most notably the atrocious inequality of living standards worldwide – are of immense importance as we enter another new year. As one year follows another, are we, as a society, content to accept that these problems are insoluble and, if not, how are we – international scientists, engineers and administrators – able to contribute best?

In my view there is a strong element of lack of confidence floating around but confidence is what is needed now. Science has, in the past and increasingly so today, often been the source of inspiration, meaning and confidence in people's lives. The moon landing is an obvious example – vision creates the confidence and the confidence creates the reality. The all-important and necessary details follow from the vision and not the other way around as many people today believe.

When we stand back and look at big-science facilities today we are justified in feeling awed. The LHC has been a lesson in determination and belief. Well done to all! The space telescopes as well as the ground-based telescopes provide



(Image credit: Roger Eriksson/ESS AB.)

breathtaking images and insights, and move the whole human race away from superstition towards a more realistic and healthy view of our place in the universe.

Today, the fragmentation of science into different disciplines, which was very evident in the second and third quarters of the previous century, is in reverse. Collaboration across these boundaries is today evident and productive, and this will surely continue. When I went to the Institut Laue-Langevin in Grenoble in 1999 I came into contact with the incipient grouping of the then seven large European science laboratories, which became EIROforum. Not the snappiest name in the universe, it has to be said, but a surprisingly effective and egalitarian organization in which not only the minnows certainly benefited but also the big-hitters gained. In many ways the international organizations mirror the national/international dilemma of the EU's Directorate-General for Research and there was a natural affinity, which opened doors, increased influence and created togetherness between the different players. I was a big fan of EIROforum and remain so. It has added an extra dimension.

However, the European Spallation Source (ESS), which I now head up, is not yet ready

to join this group of eight laboratories. The ESS sits plum in the middle of the size-scale between the cosmic scale of the telescopes and the submicroscopic scale of the LHC; it deals with materials science in all of its complexity and in all of its diversity. The ESS is not yet operational and it will not be such until the end of this decade when it will be the world's most intense source of slow neutrons for the investigation of materials – from bio membranes and drug-delivery mechanisms to magnetic structures and metallurgical properties. But, crucially, the ESS is driven by the same engine that drives the LHC: a high-intensity proton linear accelerator, with its superconducting niobium accelerating cavities. And collaboration between the ESS and CERN is thriving.

Costs are important, however, and the spending of taxpayers' contributions to scientific endeavours carries with it immense responsibility. This also, it must be said, applies to the spending of investors' contributions in private companies. Not before time it is becoming increasingly recognized that there are not two distinct colours of money in our economies. The capital cost of the ESS (€1.5 bn) could be funded comfortably from the bonuses awarded to US bankers – for 24 days! (All in 2008 values.)

To put this figure into context with other public building projects – the proposed 160 km high-speed rail link between London and Birmingham is expected to cost €20 bn. Travellers would barely have reached the outskirts of London before the cash registers had exceeded the €1.5 bn figure for the ESS.

So let us keep matters in perspective and press our governments to stand by their promises made in Lisbon in 2000 and in Barcelona to lift the percentage of European GDP spent on science from the 1.85% then to 3% (by 2010). The figure remains below 1.9% today. Science has a role in society!

● Colin Carlile is director-general of the European Spallation Source, which is to be built in Lund as the first carbon-neutral research facility (p26).

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.

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

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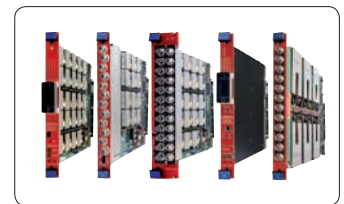


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