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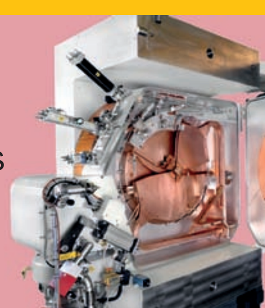

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Editor Christine Sutton
Editorial assistant Carolyn Lee
CERN, 1211 Geneva 23, Switzerland
E-mail cern.courier@cern.ch
Fax +41 (0) 22 785 0247
Web cerncourier.com

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

Laboratory correspondents:
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Publisher Susan Curtis
Production editor Jesse Karjalainen
Technical illustrator Alison Tovey
Group advertising manager Ed Jost
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Advertisement production Katie Graham
Marketing & Circulation Angela Gage

Head of B2B & Marketing Jo Allen
Art director Andrew Giaquinto

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

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Italy Loredana Rum or Anna Pennacchietti, INFN, Casella Postale 56, 00044 Frascati, Rome, Italy
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On the cover: Best known as an experiment to investigate subtle differences between matter and antimatter through the study of beauty particles containing b quarks, LHCb has a full programme of studies in electroweak physics (p34). The cover shows the VELO, which is the central tracking detector that aids studies of exclusive dimuon events.

News

CONFERENCE

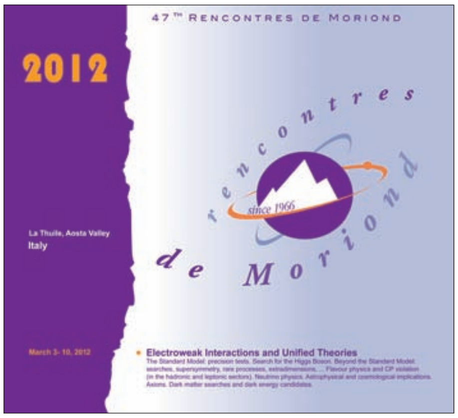
Much food for thought at Moriond

The first week of the 47th Rencontres de Moriond, devoted to weak interactions and unified theories, came to a close on 10 March, leaving participants not only impressed but also puzzled by the new results presented at the conference held in La Thuile. The focus this year was to look at the results on searches for the Higgs boson, exclusion limits, searches for dark matter, precision measurements, flavour and neutrino physics, and to assess their impact on theoretical models, in particular those based on supersymmetry (SUSY) and extra dimensions.

The first excitement came from new measurements of the branching ratio for the decay $B_s \to \mu\mu$ from the LHCb, CMS and ATLAS experiments at CERN's LHC. LHCb and CMS have a sensitivity within a factor of around two of the rate expected in the Standard Model for this extremely rare decay, where contributions from new physics could be detected. LHCb is setting the best limit to date, of less than 4.5×10^{-9}, barely above the Standard Model prediction of around 3.5×10^{-9}. This leaves little room for new physics. However, David Straub, a theorist affiliated with Scuola Normale Superiore and INFN in Pisa, showed that finding a branching ratio smaller than predicted by the Standard Model would also open the door to new physics, something that has previously received little attention but is now becoming possible with the increase in precision at the LHC.

The ATLAS and CMS collaborations showed updates to the results reported in December 2011 (*CERN Courier* January/February 2012 p6). These include further analyses of the full 2011 data sample. In the low-mass Higgs region, the ranges not excluded at 95% confidence level (CL) have shrunk a little more. For ATLAS, all possible Higgs masses below 122.5 GeV (except at 118 GeV) are now excluded, together with those from 129 GeV up to 539 GeV; for CMS all masses between 127.5 and 600 GeV are excluded. This leaves only a small range where the Higgs boson could still be found.

The small excesses reported in December are still there, coming mostly from $H \to \gamma\gamma$ for both experiments and also from Higgs $\to$ llll for ATLAS. Having analysed the whole 2011 data set and included new decay channels, CMS observes a 2.8 σ deviation at 125 GeV, while ATLAS has a 2.5 σ excess at 126 GeV. When the "look-elsewhere effect" is taken into account in the 110–145 GeV range, the significance of this excess goes down to about 2.1 σ.



The Rencontres de Moriond have been running since 1966, approximately the same time as the preferred mechanism for electroweak symmetry breaking, which came under much scrutiny with the new results present during the first week of the 47th meeting.

Fermilab's Tevatron experiments provided a surprise. Having analysed almost all of their data and greatly improved their analyses, the DØ collaboration sees a slight excess of events in the Higgs mass range of 115–145 GeV while CDF sees it for $m_H < 150$ GeV, coming mostly from the $H \to b\text{-}\bar{b}$ and $H \to WW$ channels. The combined effect corresponds to a 2.2 σ excess above the predicted background. In addition, CDF and DØ greatly improved the precision on the masses of the W boson and the top quark. Both play an important role in determining the consistency of the Standard Model. In particular, CDF has measured the W mass to be 80.387 ± 0.019 GeV, while DØ finds a mass of 80.375 ± 0.023 GeV. These recent measurements now confine the Higgs mass to $m_H = 94^{+29}_{-24}$ GeV.

While all four collaborations – ATLAS, CMS, CDF and DØ – insisted that it was too early to jump to conclusions about the Higgs boson, theorists have already been checking the effects of the mass of the Higgs and find that the currently allowed range is already putting constraints on SUSY models.

Away from the colliders, the announcement during the conference of the measurement of the neutrino mixing angle θ_{13} caused excitement (p8). Another highlight concerned the 8 σ annual modulation observed by the DAMA/LIBRA dark-matter experiment, which the collaboration interprets as a signal of dark matter. It has been suggested that the effect could be caused by cosmic muons, but new calculations show that the data are inconsistent with the cosmic muon hypothesis at 99% CL.

Possible signs of a Higgs boson with production cross-sections and branching ratios compatible with the Standard Model coupled with no signs of new physics despite extremely precise tests, left all of the participants of this first week of "Moriond" rather puzzled. Perhaps it is time to go back to the drawing board.

Sommaire en français

LHC NEWS

4 TeV: the goal for 2012

Running the LHC at 4 TeV per beam in 2012 was a key outcome of this year's LHC Performance workshop in Chamonix. Announcing this in his concluding statement, Steve Myers, CERN's Director for Accelerators and Technology, gave the main priorities for the year: delivering enough luminosity to the ATLAS and CMS experiments to allow them independently to discover or exclude the Higgs; the proton–lead-ion run; and a machine-development programme to target operation after the long technical shutdown (LS1) planned for 2013–2014. The 2012 integrated-luminosity target is to achieve more than 15 fb^{-1}, and LHC progress will be monitored carefully with two checkpoints in the year to see if a run extension is needed to meet this target.

These conclusions derived from week-long discussions in Chamonix, which had begun with a critical review of 2011. Looking back on an excellent year for the machine and its experiments, the workshop identified possible improvements to critical systems – such as beam instrumentation and machine protection – to maximize the performance of the 2012 run.

Last seen running with heavy ions before the technical stop started in December, the LHC is all geared up to run with protons at 4 TeV per beam in 2012.

The experiments provided their requirements for 2012, namely the need for at least 15 fb^{-1} either to discover the Higgs or to exclude it at 95% confidence level down to a mass of 115 GeV. Potential improvements to performance and machine availability include maximizing the time that the LHC delivers collisions to the experiments, as well as the potential of injectors to provide bunches with higher intensities and the smallest-possible beam size (translating directly into higher collision rates).

One of the big successes of 2011 was the "squeeze" – the reduction of the beam size at the interaction point – which was pushed in the latter part of the year. Further squeezing in 2012 might be possible in combination with the use of tighter collimator settings. This could give a peak luminosity of around $6 \times 10^{33}\ cm^{-2}s^{-1}$, to be compared with a maximum of $3.6 \times 10^{33}\ cm^{-2}s^{-1}$ in 2011. With a bunch spacing of 50 ns and a total of 1380 bunches (as in 2011), an integrated luminosity of 15 fb^{-1} seems to be in reach if the tighter collimator settings prove to be operationally robust and the impressive performance of the LHC's many hardware systems continues.

While discussions took place in Chamonix, the full maintenance programme of the winter technical stop was nearing completion. The long operational periods now in place at the LHC allow only a few short technical stops between beam runs. This meant that time was tight for the much needed maintenance and upgrades during this winter stop.

When the 2011 beam run ended on 7 December, the cryogenics team emptied the magnets of helium to work on their full programme of maintaining and improving the already good level of availability. In addition, there were planned interventions to the essential technical-infrastructure systems, such as electricity, cooling and ventilation. An impressive list of maintenance included enhancements to vacuum, power converters, RF, beam instrumentation, safety, collimation, the beam dump and injection. To improve machine performance, measures were taken to mitigate the effects of radiation on equipment in and around the LHC tunnel, including the installation of additional shielding in points 1 and 5, as well as the relocation of radiation-sensitive electronics to less exposed areas.

Additional work was required around Point 5 to repair RF fingers at the connection of two beam-vacuum chambers in CMS. The repair was completed successfully and the sector was then put under vacuum. The cool-down to 1.9 K of all LHC sectors, which had been floating at about 80 K over the Christmas break, took place in February so that powering and cryogenic tests could occur before the machine restart in March. The tests included electrical qualification of the superconducting circuit, to check insulation and instrumentation integrity, followed by powering tests aimed at pushing the performance of all LHC circuits to their operational level. The tests injected current through the superconducting circuits while checking the correct behaviour of the protection mechanisms – an essential element for the safe operation of the machine. Much attention is needed to power the main dipole and quadrupole circuits at a different current level for operation at 4 TeV.

Following this impressive progress, the machine is set to run at 4 TeV. After operating at 3.5 TeV per beam for two years, the LHC is now entering another domain at a new energy level.

● For regular updates on the LHC, see the *CERN Bulletin* http://cern.ch/bulletin/.

ANTIMATTER

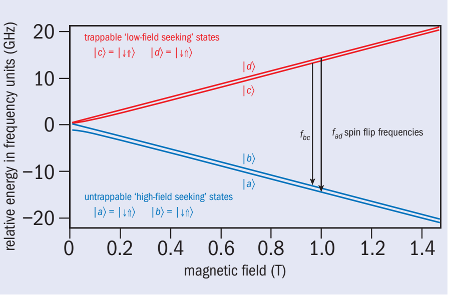
ALPHA's first antihydrogen spectroscopy

The ALPHA collaboration has reported the first-ever resonant interaction with the antihydrogen atom, observed in their experiment at the Antiproton Decelerator (AD) at CERN.

ALPHA synthesizes antihydrogen from cryogenic plasmas of antiprotons and positrons. While the charged constituents can be easily confined through their interactions with electric and magnetic fields, confining neutral antihydrogen is much more difficult. It can be held in a highly inhomogeneous magnetic field (a "minimum-B" configuration) because it has a magnetic dipole moment, but the interaction is so weak that only atoms with kinetic energy equivalent to 0.5 K or less in temperature can be trapped, using superconducting magnets. This is how ALPHA has already held antihydrogen atoms for up to 1000 s (*CERN Courier* March 2011 p13 and July/August 2011 p6).

Assuming that antihydrogen behaves like hydrogen, the 1s ground state will exhibit both hyperfine splitting (through the interaction between the spins of the positron and the antiproton) and splitting in a magnetic field (see figure). In a high magnetic field, these states are characterized by the direction of the spins of the antiproton and positron with respect to the field direction. The "low-field-seeking" states labelled |c⟩ and |d⟩ can be trapped, because their energy increases with magnetic field strength. Atoms that end up in the |a⟩ and |b⟩ states ("high-field-seekers") are expelled from the trap and annihilate in the surrounding apparatus.

In the latest experiment, a horn antenna directed microwaves into the atom trap so as to flip the spin of the positron in the stored atoms, thus driving the transitions |c⟩→|b⟩ and |d⟩→|a⟩. The experimental sequence was as follows: produce and trap antihydrogen (of the order of one trapped atom at a time on average); irradiate the trapped atom with microwaves resonant on either the |c⟩→|b⟩ or |d⟩→|a⟩ transition (these are excited alternately for 15 s each over a total of 180 s); look for evidence of "lost" antihydrogen. To conduct control experiments, it was repeated without microwaves or with microwaves at a shifted off-resonance frequency. Each sequence took about 10 minutes of real time.



The expected hyperfine energy levels (in frequency units) of antihydrogen in a magnetic field. For the state vectors, the single (double) arrow represents the positron (antiproton) spin.

The collaboration used two methods to look for evidence of ejected antihydrogen. At the end of each sequence, the atom trap is rapidly de-energized, the fields falling with a time constant of about 9 ms. Any antihydrogen remaining in the trap is released and detected by ALPHA's three-layer silicon detector over a 30 ms time window. It is then possible to compare the survival rate of anti-atoms for the three cases: no microwaves present, resonant microwaves present, or off-resonant microwaves present. The other detection measurement involves looking for direct annihilations from ejected antihydrogen during the times in which resonant microwaves are present; background (primarily cosmic rays) discrimination here is more challenging because of the longer observation time.

In both types of measurement, ALPHA finds a strong signal for resonant interaction. For example, in 110 trials with off-resonance microwaves, 23 annihilations were observed when the trap was de-energized; with microwaves on resonance, 2 annihilations were observed in 103 trials. (Detection efficiency is about 50% for both cases). The on- and off-resonance measurements localize the resonance to no better than 100 MHz in about 29 GHz; the collaboration has not yet attempted to scan the lineshape to further localize a resonant peak.

This measurement marks the beginning of anti-atom spectroscopy and illustrates that it is possible to make measurements on antimatter atoms using only a few atoms. In 2012 the ALPHA apparatus will give way to ALPHA-2, a new device that is further optimized for precision microwave and laser spectroscopy. ALPHA-2 will be commissioned during the upcoming run of the AD, from May to November.

● **Further reading:**

C Amole *et al.* 2012 *Nature*, doi: 10.1038/nature10942.

FUNDING

US high-energy physics faces budget cuts

On 13 February, US President Barack Obama unveiled his administration's budget request for fiscal year 2013, which begins on 1 October 2012. The budget for the Department of Energy's Office of Science would increase by 2.4 per cent to \$4.992 billion, but high-energy physics would be reduced by 1.8 per cent to \$777 million. In the next step, the two chambers of the US Congress will take up the negotiations to arrive at a final budget.

The proposed cuts in high-energy physics would hit two long-term programmes the hardest: the Long-Baseline Neutrino Experiment (LBNE) and the US R&D programme for the International Linear Collider (ILC). The budget for LBNE would drop to \$10 million from \$21 million in the current year. The collaboration had requested an increase to advance its plans to search for CP-violation in neutrino interactions by sending neutrinos from Fermilab to a detector in South Dakota (p12).

Funding for the US ILC R&D programme is eliminated in the request, a cut of \$20 million. While the current ILC R&D phase will end this year, the next phase would have helped to advance accelerator technologies that would benefit projects such as Fermilab's Project X proton accelerator and Berkeley's Next-Generation Light Source.

Some programmes would fare much better. Funding for non-accelerator physics programmes would increase by \$13 million to ramp-up engineering and design efforts for the Large Synoptic Survey Telescope camera project and R&D funding for next-generation dark-matter experiments. The US contribution to the upgrades of the Belle-II detector at KEK in Japan would remain on track, along with near-term neutrino and muon research programmes at Fermilab.

News

NEUTRINOS

Daya Bay experiment measures θ_{13}

The Daya Bay Reactor Neutrino Experiment, a multinational collaboration operating in the south of China, has reported its first results. The team has analysed tens of thousands of interactions of electron-antineutrinos caught by six massive detectors buried in the mountains adjacent to the powerful nuclear reactors of the China Guangdong Nuclear Power Group (*CERN Courier* October 2011 p5).

The copious data revealed for the first time a strong signal of the mixing angle θ_{13}, related to the type of neutrino oscillation in which electron-neutrinos morph into the other two flavours. This is the last mixing angle to be measured precisely and could reveal clues leading to an understanding of why matter predominates over antimatter in the universe. Once thought to be near zero, the first results indicate that $\sin^2 2\theta_{13}$ is equal to 0.092 ± 0.017.

The sensitive photomultiplier tubes, which line the Daya Bay detector walls, are designed to amplify and record the faint flashes that signify an antineutrino interaction.(Image credit: Roy Kaltschmidt/ Lawrence Berkeley National Laboratory.)

The Daya Bay experiment counts the number of electron-antineutrinos detected in the halls nearest the Daya Bay and Ling Ao reactors and calculates how many would reach the detectors in the Far Hall if there were no oscillation. The number that apparently vanish on the way (by oscillating into other flavours) gives the value of θ_{13}. Because of the near-hall/far-hall arrangement, it is unnecessary to have a precise estimate of the antineutrino flux from the reactors.

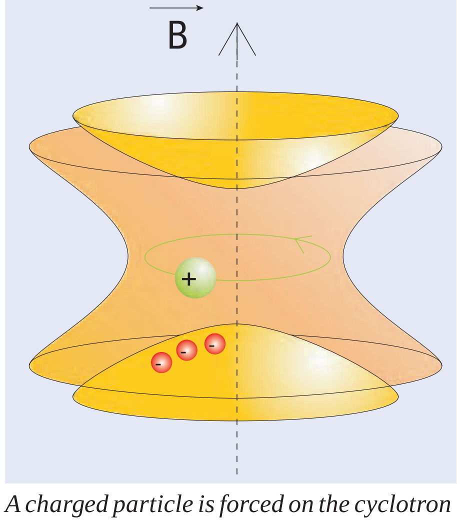
The initial results will in the coming months and years be honed by collecting more data and reducing statistical and systematic errors. Refined results will open the door to further investigations and influence the design of future neutrino experiments, including how to determine which neutrino flavours are the most massive and whether there is a difference between neutrino and antineutrino oscillations.

NUCLEAR PHYSICS

^{110}Pd: a new possibility for $\beta\beta0\nu$ decay

The search for the neutrinoless double-beta decay ($\beta\beta0\nu$ decay) aims to solve a long-standing question concerning the nature of neutrinos. The decay, in which a nucleus decays by emitting two electrons but no neutrinos, can occur only if the neutrino is its own antiparticle, i.e. a Majorana particle. If it occurs, it must be extremely rare, with a half-life greater than 10^{24} years. This poses an enormous experimental challenge regarding its unambiguous detection, with just a few nuclear isotopes offering a useful hunting ground (*CERN Courier* January/ February 2012 p28). Now an experiment at the ISOLDE facility at CERN has identified a new potential candidate, the palladium isotope ^{110}Pd.

The signature for $\beta\beta0\nu$ decay appears in the sum of the energies of the two emitted electrons, which should have a single peak at the Q value for the decay, i.e. at the energy corresponding to the mass difference between the initial and final nuclide. (In double-beta decay with neutrinos ($\beta\beta2\nu$), the emitted electrons have a broad energy spectrum.) Calorimetric experiments searching for $\beta\beta0\nu$ require detectors fabricated from sufficient quantities of the transmuting material to allow the detection of a decay within a reasonable amount of time. In addition, the energy of the decay peak must be known precisely if the detector is to have a high resolution at the correct energy.



A charged particle is forced on the cyclotron orbit by a magnetic field, B, and stored in a Penning trap by applying a voltage, U, to hyperbola-shaped electrodes.

With its high natural abundance, ^{110}Pd offers a promising alternative for double-beta decay searches, now that its Q value has been measured directly with unprecedented accuracy. An experiment using the Penning-trap mass spectrometer ISOLTRAP at ISOLDE has determined the Q value from the cyclotron frequency ratio of ^{110}Pd and its decay-product ^{110}Cd by manipulating a few, singly charged ions in an isolated environment (Fink *et al.* 2012).

In a Penning trap, a charged particle is bound radially on the cyclotron orbit by a homogeneous magnetic field, while an electrostatic potential between the hyperbola-shaped electrodes provides axial confinement (see figure). Since the ions are trapped in three dimensions, they exhibit three eigenmotions (only one of which is shown in the figure for simplicity). An applied radio-frequency field can modify the energy stored in the eigenmotions, resonantly enhancing the energy transfer when it reaches the exact eigenfrequency. This can be measured using a technique known as time-of-flight ion-cyclotron-resonance. Usually, fewer than 10 ions of one species are excited in the trap and the cyclotron frequency is determined. The other species is then loaded into the trap and excited. This measurement cycle is repeated many times in order to collect statistics and minimize systematic effects.

In this experiment, the Q value was determined after roughly two days of measurement to be Q = 2017.85(64) keV. This value is shifted by 14 keV compared with previous results and is 17 times more precise. While the shift leads to a new value for the ^{110}Pd half life, the lower uncertainty should enable future experiments on $\beta\beta0\nu$ decay to have higher resolution.

● **Further reading:**

D Fink *et al.* 2012 *Phys. Rev. Lett.* **108** 062502.

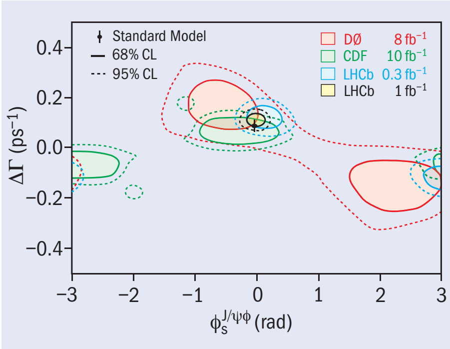
LHC PHYSICS

The heavier B_s meson state lives longer

The LHCb collaboration has determined the sign of the width difference in the B_s system, $\Delta\Gamma_s$, through the influence of quantum-mechanical interference. This shows for the first time that the heavier of the two B_s meson states has the longer lifetime, a result that is in agreement with the Standard Model expectation and similar to the situation in the kaon system.

The B_s meson, made up of a b quark and s antiquark, has some fascinating properties. Because it is neutral, it can mix with its antiparticle (which has a b antiquark and s quark), and this quantum-mechanical effect leads to the B_s system having two states with well defined mass, m_H and m_L (for "heavy" and "light" respectively). The B_s oscillates from its particle to antiparticle state, with a frequency that is proportional to the difference in those masses, $\Delta m_s = m_H - m_L$, a frequency that is now well measured. However, the two states are also expected to have different lifetimes, so that their widths (defined as the inverse of their lifetimes) should differ by $\Delta\Gamma_s \equiv \Gamma_L - \Gamma_H$. Until now, the sign of $\Delta\Gamma_s$ was not known.

This parameter is intimately involved in the study of CP-violation in B_s mixing, where the phase of the B_s oscillations, ϕ_s, is measured. In the Standard Model, the phase is expected to be small but accurately predicted, $\phi_s = -0.036 \pm 0.002$ rad. It has been studied using the decays of the B_s to two lighter mesons, $B_s \rightarrow J/\psi\,\phi$. Because of correlations between $\Delta\Gamma_s$ and ϕ_s, the experimental searches have been presented until now as contours in the $\Delta\Gamma_s$ vs ϕ_s plane, as shown in the figure, which is an update of a previous measurement (*CERN Courier* October 2011 p8). However, because the sign of $\Delta\Gamma_s$ was unknown, there was an ambiguity in the solution, seen as two selected regions in the $\Delta\Gamma_s$ vs ϕ_s plane.



Constraints on the mixing parameters of the B_s meson, shown as contours in the $\Delta\Gamma_s$ vs ϕ_s plane. The results from the DØ and CDF experiments are shown in red and green respectively, and the previous result from LHCb in blue. For the latest result from LHCb the ambiguity in the solution has been resolved, leaving only the single solution shown in yellow. This is still consistent with the Standard Model expectation indicated by the black point.

The new analysis from LHCb uses the fact that, when the spin-1 ϕ meson is reconstructed in its decay to K^+K^-, a small admixture of spin-0 kaon pairs is also included in the selected events, because – at any given K^+K^- mass value – the two possible spin states are quantum-mechanically indistinguishable, interference effects can be observed in the data. The relative phase of these two components varies as a function of the reconstructed mass and the trend of that variation is to increase or decrease depending on the sign of $\Delta\Gamma_s$. The experimental data show clearly a decreasing trend, with 4.7 σ significance, demonstrating that $\Delta\Gamma_s$ is positive (LHCb 2012a). As a consequence, in the latest update of the CP-violation study there is only a single solution in the plane.

This new result was presented at the Moriond conference (p5) and uses the full data set collected by LHCb so far (LHCb 2012b). When combined with another channel ($J/\psi\, f_0$), the result is $\phi_s = -0.002 \pm 0.083$ (stat.) ± 0.027 (syst.) rad. While this is consistent with the Standard Model prediction, there is still room for contributions from new physics to this phase. Another exciting step forward is expected with the further doubling of the LHCb data set, expected this year.

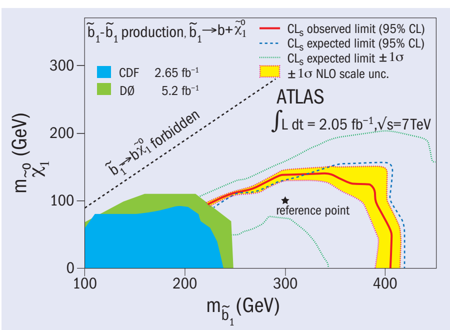
● Further reading:

LHCb collaboration 2012a arXiv:1202.4717, submitted to *Phys. Rev. Lett.*
LHCb collaboration 2012b LHCB-CONF-2012–002.

Supersymmetry in the third generation

Despite the current absence of direct experimental evidence, supersymmetry (SUSY) at the weak scale remains among the most motivated and studied extensions of the Standard Model.

A common feature of many models is that third-generation SUSY particles – the s-top ($\tilde{t}$), s-bottom ($\tilde{b}$) and s-tau ($\tilde{\tau}$), which are the partners of the third-generation quarks and of the τ lepton – are lighter than the partners of the first two generations. Hence, they can be produced at large rates via pair production or in the decay of gluinos, the scalar partners of gluons. Furthermore, they should decay to heavy quarks (t, b) or τ leptons, providing characteristic and striking experimental signatures. The ATLAS collaboration recently presented the results from several searches for third-generation SUSY particles based on 2 fb^{-1} of data (ATLAS 2012). Different strategies are used in each of these analyses, which rely on signatures with one



Results of the ATLAS search for direct $\tilde{b}$ production showing the observed (red curve) and expected (dashed blue curve) limits at 95% confidence level as a function of the $\tilde{b}$ and LSP ($\tilde{\chi}^0$) masses. The area below the red curve is excluded by this analysis. Limits from Tevatron experiments are shown as solid areas.

or two hadronic taus in $\tilde{\tau}$ searches, b-jets with a lepton veto in $\tilde{b}$ searches and two same-sign leptons or b-jets with a lepton in $\tilde{\tau}$ searches. In the models considered, each SUSY decay-chain ends with the production of a stable, lightest supersymmetric particle (LSP), which is only weakly interacting and escapes detection. Therefore, high missing transverse-momentum

News

is also required in all of these analyses.

The searches found no significant excess over the Standard Model background and provide the most stringent limits to date on models that are characterized by the decay of third-generation SUSY particles. The figure (p9) shows, as an example, that the exclusion limits obtained in the search for scalar bottom pair-production – using events with exactly two b-jets – extend the existing limits on the $\tilde{b}$ mass by about 150 GeV.

In the coming months and with increasing amounts of data, these analyses will probe unexplored regions, corresponding for example to high-LSP or gluino masses, and so may shed light on the existence of third-generation SUSY particles.

● **Further reading:**

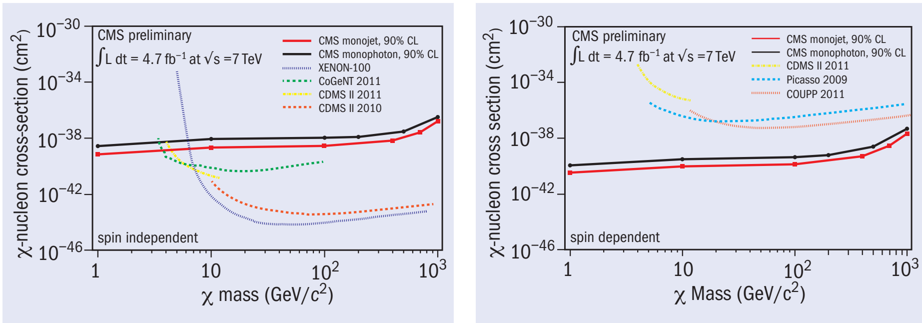
ATLAS collaboration 2012 arXiv:1112.3832v1, accepted by *Phys. Rev. Lett.*

Shedding light on dark matter

Dark matter may constitute 83% of the particles in the universe, but so far there has been no direct observation of its presence in experiments. With its high-energy collisions, the LHC is a promising hunting ground for this elusive form of "matter", either by producing dark-matter particles directly or new particles that decay into dark matter. Recently, the CMS collaboration completed a search for dark matter, sifting through the full 2011 data set of proton collisions at a centre-of-mass energy of 7 TeV.

Dark-matter particles produced at the LHC would presumably escape undetected, yielding "missing momentum" in the event. However, they could be accompanied by a jet or a photon, or some other particle. CMS has looked for evidence of these visible companions by studying "monojet" and "monophoton" data. Within the framework of a simple model for the production of dark matter, the CMS analysis significantly extends the sensitivity of direct searches, which look for tiny interactions of dark-matter particles in very sensitive detectors.

The way that the dark-matter particles (χ) are produced and interact depends on their spin. With respect to direct searches, CMS is sensitive in the low-mass region below 3.5 GeV if the spin of the produced particles is ignored, and it can set the world's best limits at all masses in the spin-dependent case.



The 90% CL upper limits from CMS on the χ-nucleon cross-section as a function of χ mass for spin-independent (left) and spin-dependent scattering (right). Also shown are limits from other experiments.

The monophoton search looks for single, isolated photons (γ) with transverse energy greater than 145 GeV and more than 130 GeV of missing transverse energy. Events with excessive hadronic activity (jets) are vetoed. After the application of selection criteria, 73 events remain, where 71.9 ± 9.1 would be expected in the absence of dark-matter particles. Standard Model background-events are expected mainly from pp → Zγ – where the Z decays to two neutrinos – and from events with misidentified jets or electrons, or from instrumental sources.

The monojet search requires at least one jet with transverse momentum greater than 110 GeV and more than 350 GeV of missing transverse momentum. Events with isolated leptons or more than two jets are vetoed. After event selection, 1142 events are found in data with an expectation from Standard Model processes of 1224 ± 101 events. Again, a contribution from "invisible" decays to neutrinos dominate this expectation, either from pp → Z+jets with the Z decaying to two neutrinos, or from pp → W+jets where the W escapes detection. There seem to be no signs of a new production mechanism for the two "mono-object" signatures analysed, so CMS can use the null results to place limits on the cross-section for dark matter. The limits depend on the presumed mass of the dark-matter particles and are presented as regions in the plane of cross section vs mass in the figures.

● **Further reading**

Detailed papers are being submitted to *Phys. Rev. Lett.* and *JHEP*.

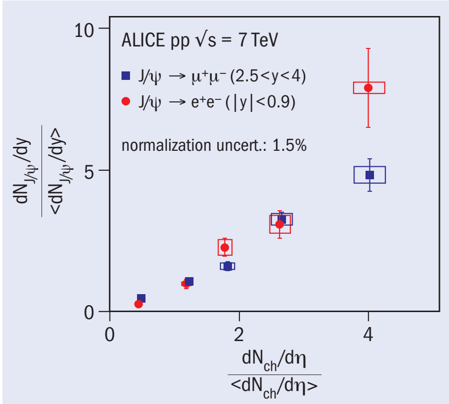
J/Ψ production in high-multiplicity pp collisions

The J/Ψ meson, a bound state of a charm and an anticharm quark, has always been an important testing ground for quantum chromodynamics (QCD). However, understanding J/Ψ production in proton–proton (pp) collisions remains a challenge. While the production of unbound $\bar{c}c$ pairs via partonic (quark and gluon) hard-scattering processes can be described within perturbative QCD, the subsequent formation of a colourless bound state, such as the J/Ψ, leaves much room for theoretical modelling. Recently, a new measurement by the ALICE collaboration at the LHC adds yet another challenge for theoretical models.

ALICE, which among the LHC experiments has the unique capability to identify J/Ψ at low transverse momenta, measured J/Ψ production in pp collisions at $\sqrt{s}$ = 7 TeV as a function of the charged-particle multiplicity ($dN_{ch}/d\eta$) of the underlying event. As the figure (p11) shows, this study revealed a remarkably linear increase of the J/Ψ yield with $dN_{ch}/d\eta$ (Abelev *et al.* 2012). Even though the charged-particle multiplicity is measured only at central rapidity, this increase is seen in not only this region but also at forward rapidities.

The charged-particle multiplicity is mostly the result of processes happening with a small momentum transfer, i.e. so-called soft processes. J/Ψ mesons, on the other hand, are expected to be produced in hard processes, as described above. The assumption has been that the two are not necessarily correlated. However, the measurement by ALICE shows that the yields of the heavy J/Ψ scale just like those of any other light hadron. Regardless of its high rest mass (3.097 GeV/c^2) the J/Ψ behaves just like a "light" particle.

The event multiplicity $dN_{ch}/d\eta$ could be directly related to the impact parameter of a given pp collision. This would be analogous to heavy-ion physics where, depending on the centrality of the reaction, different numbers of binary collisions occur between the nucleons. A similar situation could arise in pp collisions at LHC energies because the probability is high that many collisions take place between the quarks and gluons inside the protons. Most of these multiparton interactions are usually assumed to have a relatively low momentum-transfer and therefore to affect mainly soft-particle production. That J/Ψ production behaves similarly to the production of other charged particles might indicate that harder processes are also affected by multiparton interactions.



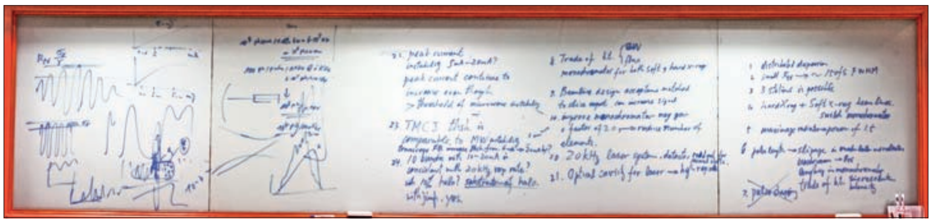
The J/Ψ yield ($dN_{J/\Psi}/dy$) as a function of the charged-particle multiplicity densities at mid-rapidity ($dN_{ch}/d\eta$) (Abelev et al. *2012). Both are divided by the corresponding averaged value for minimum-bias pp collisions ($<dN_{J/\Psi}/d\eta>$, $<dN_{ch}/d\eta>$). Measurements are shown at forward rapidities ($2.5 < y < 4$) and at mid-rapidity ($|y| < 0.9$).*

This measurement is an example of the new experimental opportunities that the LHC has opened up, allowing the correlation of observables on soft and hard scales. Further studies on the charged-particle multiplicity dependence of other hard processes, such as the production of Υ, open charm and beauty, should shed more light on the nature of this effect.

● **Further reading:**
B Abelev *et al.* (ALICE collaboration) 2012 arXiv:1202.2816 submitted to *Phys. Lett.* B.

LIGHT SOURCES

NSRRC considers ultrafast X-ray source



Notes from the discussion on how to improve the performance of laser slicing sources.

With a view to sustaining a large-scale facility at a time of worldwide economic crisis and soaring energy costs and to provide efficient use of beam time, the National Synchrotron Radiation Research Center (NSRRC) in Hsinchu has been exploring ways to make the most of its facilities. One possibility is an ultrafast X-ray source. This is being considered through a feasibility study and technological investigation aimed at gaining additional leverage for NSRRC's second accelerator, the Taiwan Photon Source (TPS), which is currently under construction (*CERN Courier* June 2010 p16). To this end, NSRRC held a mini-workshop on "Storage-ring ultrafast X-ray sources and their applications" on 16–17 January. Nearly 40 participants attended, including speakers invited to join discussions with NSRRC staff and the ultrafast-science research groups from neighbouring universities, including National Tsing Hua University and National Chiao Tung University.

Participants at the mini-workshop. (Image credits: NSRRC.)

On the first day, Shaukat Khan of the Technical University, Dortmund, offered a comprehensive overview of ring-based, ultrafast and coherent light-sources, including topics such as laser slicing, low-alpha lattice, coherent harmonic generation and echo-enabled harmonic generation. Gerhard Ingold of PSI introduced several topics: the operational performance of the FEMTO source at the Swiss Light Source at PSI; the proposed upgrade of beamline optics and the laser repetition rate from 2 kHz to 10 kHz (or even 20 kHz); and the study of the ultrafast structural dynamics in condensed matter. Karsten Holldack of the Helmholtz-Zentrum Berlin described the laser system of the femtoslicing facility at the BESSY II synchrotron, known as FEMTOSPEX, which was upgraded to a 6 kHz repetition rate in 2010. It has been over-booked by a factor of three, indicating the growing demand in this domain. At Brookhaven's National Synchrotron Light Source (NSLS) a feasibility study has been carried out on the NSLS II laser-slicing source with a 4.8 m modulator wiggler in response to users' requests, as Li Hua Yu of Brookhaven explained.

On the second day, Andreas Streun of PSI discussed in-depth the beam-dynamics issues involved in a high-repetition-rate

News

laser-slicing source, saying that noise caused by beam halo is a critical issue. In general, the side effects of laser slicing on storage-ring performance are mainly contributed by the modulator wiggler and chicane. In addition, a series of presentations by NSRRC team members covered the design requirements and considerations of a proposed beamline for the NSRRC TPS laser-slicing source and its potential applications. Yu also chaired a discussion about how to improve the performance of laser-slicing sources. Methods such as maximizing radiator length, reducing the loss of photon flux in the photon-beamline design, multiple slicing, increasing laser repetition rate and single-bunch current are considered essential for a state-of-the-art laser-slicing source.

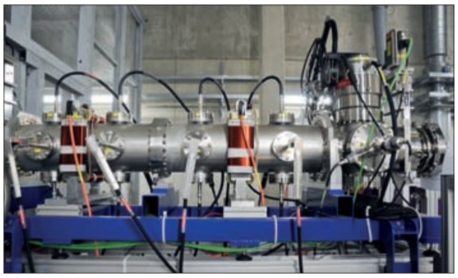
Based on input generated at the mini-workshop, the preliminary design of the TPS laser-slicing source with a modulator wiggler, one hard-X-ray radiator and one soft-X-ray radiator in three separate, 7-m straight sections, appears to be a feasible scheme and will provide 10 times more flux than the SLS FEMTO source. However, Ingold suggested a different scenario that requires only two straight sections, with a modulator wiggler and a hard-X-ray radiator in one 12-m-long straight section plus a soft-X-ray radiator in one 7-m-long straight section – and this is regarded as an attractive alternative.

NUCLEAR POWER

GUINEVERE: towards cleaner nuclear energy

A particle accelerator has been successfully coupled to a nuclear reactor for the first time at the Belgian Nuclear Research Centre (SCK•CEN). The demonstration model GUINEVERE is now in operation, showing the feasibility of an accelerator-driven system (ADS) for nuclear energy (p37). By using an ADS, the accelerator can be turned off to stop the reactor immediately. This system, known as subcritical, is safer than standard nuclear reactors.

GUINEVERE is a test installation of limited power to fine-tune the operation and control of future subcritical reactors. Unlike conventional reactor systems, it produces fast neutrons that can be used for the transmutation of high-level radioactive waste into less-toxic products with shorter life spans, helping to improve their geological disposal.



The accelerator used to produce fast neutrons. (Image credit: SCK•CEN. Used by permission.)

The GUINEVERE project involves a dozen European laboratories and the European Commission. The accelerator was built by the Centre National de la Recherche Scientifique in France. The French Commissariat à l'Energie Atomique et aux Energies Alternatives helped develop the concept and provided the reactor fuel. Following the inauguration of GUINEVERE in March 2010, the accelerator, as well as the ventilation and monitoring of the installation, were tested exhaustively. In February 2011 the reactor was started in critical mode and was subjected to a long series of tests. The accelerator and reactor have now been connected successfully, making the system subcritical.

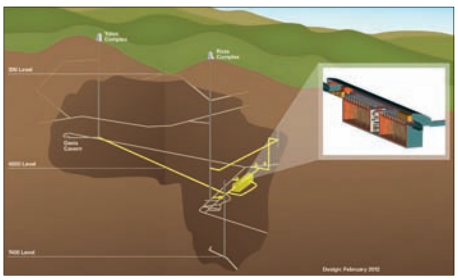
The successful launch of GUINEVERE is an important step towards MYRRHA, SCK•CEN's multipurpose research facility, which will become operational in 2023.

NEUTRINOS

Steps forward for new long-baseline experiment

The collaboration working to design the Long-Baseline Neutrino Experiment (LBNE) in the US has recently made major decisions about the experimental configuration, while the collaboration itself continues to grow. More than 600 researchers have now signed on to an experimental programme that will reach unprecedented sensitivity and precision for addressing the neutrino-mass hierarchy, CP-violation in neutrino mixing and the mixing angle θ_{13} – recently measured for the first time by the Daya Bay experiment (p8).

The first in the series of decisions involved the configuration of the neutrino beamline. The accelerator complex at Fermilab would be used to generate neutrinos for LBNE. The chosen configuration would send the beam up a small hill before it heads underground towards the LBNE far detector at the Homestake Mine in South Dakota. This configuration would make construction easier and more cost-effective, as well as protect the aquifer at Fermilab.



The current design for locating the far detector in the Homestake Mine. (Image credit: Fermilab.)

The collaboration then reached consensus on the depth of the facilities at the site of the far detector, choosing a depth of 4850 ft (1470 m). This is optimal for not only the LBNE scientific programme but for other experiments such as direct dark-matter and neutrinoless double-beta-decay searches.

The last crucial decision was the selection of the technology for LBNE's far detector. Liquid-argon and water-Cherenkov technologies had both been studied and were considered viable options, but either choice would require a significant scaling-up of existing technology to meet the needs of LBNE. While its scaling-up challenge is greater, liquid-argon has more potential because of the detailed information provided on each neutrino event. After an extensive process that involved physics studies and analysis of the technical feasibility of various configurations – as well as external reviews organized by the collaboration – the project manager made the final recommendation to base the far detector on liquid-argon.

Many steps remain before LBNE becomes reality, notably a decision by the US Department of Energy to proceed with detailed design and eventual construction of the project.

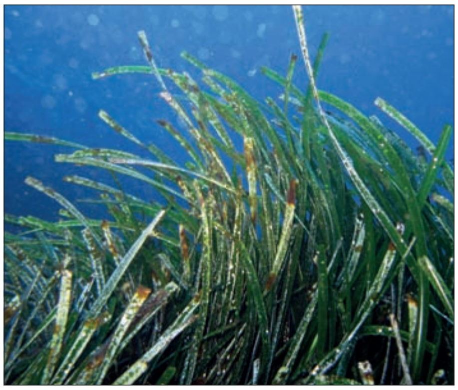
Sciencewatch

Compiled by John Swain, Northeastern University

The world's oldest living thing

When people think of the oldest living things they often think of trees, such as Great Basin bristlecone pine trees in California and Nevada, which are nearly 5000 years old. Recently, Sophie Arnaud-Haond of Ifremer, in Plouzané, France, and the Universidade do Algarve and colleagues sampled and sequenced DNA from *Posidonia oceanica* – a seagrass – at 40 sites along 3500 km of sea floor from Spain to Cyprus. This plant, like other seagrasses, reproduces by cloning, so it grows as one big organism comprised of genetically identical cells.

Based on the known (and slow) growth rate of this grass, the researchers estimate that the patch of genetically uniform plants along 15 km of coastline of the island of Formentera must be between 80,000 and 200,000 years old, making it the oldest living thing known on Earth.



Does the seagrass Posidonia oceanica *form the oldest living thing? (Image credit: planctonvideo/dreamstime.com.)*

Further reading

S Arnaud-Haond *et al.* 2012 *PLoS ONE* **7(2)**: e30454, doi:10.1371/journal.pone.0030454.

Compelling illusions

Illusions are usually thought of as tricks of the mind, but new research by Bruno Laeng and Tor Endestad of the University of Oslo shows that they can also cause direct physiological changes. They used infrared eye-trackers to monitor pupil size in people looking at drawings designed to give the illusion of a white region being brighter or dimmer, despite being objectively of equal brightness.

On glancing at the "brighter" images – despite not really being brighter at all – people's pupils rapidly contracted before gradually expanding as they adjusted to the true intensity. So, just thinking that something is bright seems to fool the eye itself and not just the brain, at least for a while.

Further reading

B Laeng and T Endestad 2012 *Proc. Nat. Acad. Sci.* **109** 2162.

A super hangover cure

Give rats the human equivalent of 15 to 20 beers in under two hours and they will pass out. Put them on their backs and they will need about an hour's rest before they are able to flip back over again. However, if they had taken some dihydromyricetin (DHM) with their booze they would roll over in just 15 minutes and have less of a hangover two days later, as measured by reduced anxiety and incidence of seizures.

The remarkable effects of this substance have been discovered by Jin Liang of UCLA and colleagues, who found it in an extract from the seeds of *Hovenia dulcis*, a plant known in traditional medicine for more than 1300 years as being a hangover cure. Even more remarkably, alcohol given with DHM does not seem to cause addiction. This is not to say that it makes drinking alcohol safe, because alcohol affects numerous systems in the body, but tests are planned on humans. Any volunteers?

Further reading

Y Shen *et al.* 2012 *Journal of Neuroscience* **32** 390.

Sea-urchin spines understood

Sea urchins have tough spines – hard but able to resist shock. Now, Helmut Cölfen of the University of Konstanz and colleagues have found out why. The team used X-ray scattering at the European Synchrotron Radiation Facility in Grenoble to show that the spines are made of nanometre-sized bricks of magnesium-calcite crystals aligned in parallel and glued together with non-crystalline lime made of almost pure calcite with a 0.1% admixture of protein.

This is the first detailed study of a biological mesocrystal and it opens the door for synthesizing novel strong materials that combine high degrees of hardness with resilience. It seems that sea urchins get the substance to crystallize from an amorphous precursor phase.

Further reading

J Seto *et al.* 2012 *Proc. Nat. Acad. Sci.*, doi: 10.1073/pnas.1109243109.

Tough urchin spines. (Image credit: LuciaPescaru |dreamstime.com.)

Non-exponential decays and carbon dating

Radioactive decay is often assumed exponential, and in many cases that turns out to be a good description. However, in radioactive carbon dating, there are disagreements between radiocarbon dates and dates from dendrochronology (counting tree rings). These have traditionally been attributed to variations in atmospheric carbon-14 levels, but Philip Aston of the University of Surrey points out that strictly exponential decay is impossible in quantum mechanics (using energy instead of time gives a non-normalizable Lorentzian); he also shows that predicted atmospheric affects that assume exponential decay do not match predictions from modelling.

For slowly decaying isotopes there is little direct experimental knowledge of the decay curves over long times, so dating based not only on carbon-14 but also on other isotopes may have to be revisited. Both theoretical and experimental input would be interesting.

Further reading

P J Aston 2012 *Euro Phys Letters* **97** 52001.

Astrowatch

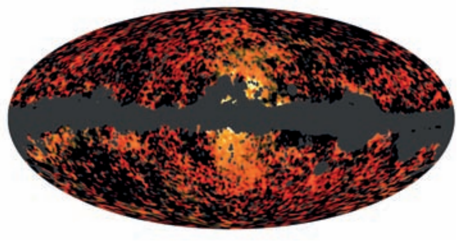
Compiled by Marc Türler, ISDC and Observatory of the University of Geneva

Planck reveals details across the Milky Way

While awaiting the Planck mission results on the Cosmic Microwave Background (CMB), the scientific community must be content with measurements on foreground sources. Those are nevertheless providing interesting and unexpected results, especially by mapping a mysterious haze in the central portion of the Milky Way, and by producing the first all-sky map of molecular clouds where stars are born.

It was a risky strategy for the European Space Agency to launch two prime missions of its scientific programme on 14 May 2009, Herschel and Planck (*CERN Courier* July/August 2009 p6), but the Ariane 5 rocket succeeded in sending both spacecraft into orbit around the second Lagrange point of the Sun–Earth system. Both missions use this prime location – 1.5 million kilometres away – to study the cold universe unaltered by the glow of the Earth and Moon. However, they each operate differently. Herschel is an observatory, in the sense that any astronomer can propose an observation of a source of interest and get data rights if their proposal is accepted. This approach does not apply to Planck – which is continuously scanning the sky, so the data have to be shared among the Planck collaboration as a whole.

The Planck data acquisition is slowly nearing completion. The spacecraft had enough helium-3 to cool down the high-frequency instrument (HFI) to 0.1 K for 30 months, about twice what was originally required. Since January, however, only the low-frequency instrument (LFI) continues to operate, mainly to refine the calibration. The data release of the nominal mission (the first 15.5 months) is planned for early 2013; the full data set will become public a year later. Both releases will be accompanied by scientific publications on the observed fluctuations of the CMB, which are the most anticipated by the scientific community. The Planck results will improve the determinations of the constituents, the history and the fate of the universe obtained by NASA's Wilkinson Microwave Anisotropy Probe (*CERN Courier* May 2008 p8).



Projected image of the whole sky as seen by Planck in radio waves. The main emission of the Galactic Plane – the horizontal band in the image – has been removed to reveal, as a yellowish glow, the faint Galactic Haze emitted around the Galactic Centre. (Image credit: ESA/Planck collaboration.)

The Planck CMB results have not yet been published because many Galactic and extra-Galactic foreground sources superimpose on the CMB, as illustrated by the all-sky image released in the summer of 2010 (*CERN Courier* September 2010 p11). Disentangling the various components from each other is a tricky task that requires a deep understanding of all foreground sources and instrumental effects. While some Planck scientists work on the CMB, others work on the removal and characterization of these foregrounds. A first set of early Planck results was released in January 2011, together with a catalogue of thousands of compact sources both in the Milky Way and in distant galaxies and clusters of galaxies. The next set of Planck results on foregrounds was presented at an international conference on 13–17 February 2012, in Bologna, and will be published in the coming months. This includes two unexpected results on the diffuse emission of the Galaxy.

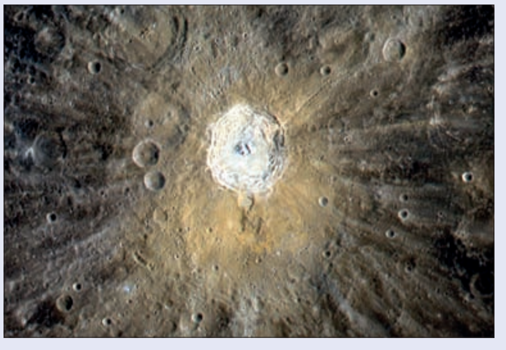
One surprise came from the detailed, all-sky map of carbon monoxide (CO) presented by Jonathan Aumont of the Institut d'Astrophysique Spatiale, Université Paris XI, Orsay. The CO molecule emits a number of narrow, rotational emission lines in the frequency range probed by Planck's HFI. The spectroscopic measurement of these lines is commonly used to probe the presence of cold molecular clouds from which new stars form. Because the CO lines are narrow compared with the broad spectral bands observed by Planck, it was not anticipated that it would be possible to measure their contribution and thus compete with spectroscopic surveys of CO.

Another unexpected result was presented by Krzysztof Gorski of the Jet Propulsion Laboratory, Caltech, Pasadena, and Warsaw University Observatory. He presented a map of the sky showing a distinct synchrotron emission that is roughly co-spacial with the giant gamma-ray bubbles detected by the Fermi Space Telescope (*CERN Courier* January/February 2011 p11). This suggests that the radio and gamma-ray emissions could come from the same population of relativistic electrons filling the bubbles – but their actual origin remains mysterious.

Further reading

Planck Intermediate Results, in preparation.

Picture of the month



A crater on the Moon? No, on Mercury – the innermost planet of the solar system. This image was taken by NASA's MESSENGER spacecraft. Contradicting intuition, plunging inside the solar system is not easier than going away from the Sun. Hence, MESSENGER took nearly seven years from launch on 3 August 2004 to orbit Mercury on 18 March 2011. This colourful crater is named after Gerard Kuiper (1905–1973), a Dutch-American pioneer of modern planetary science and famous for suggesting the existence of what is now called the Kuiper belt of asteroids beyond Neptune. He was also a member of the Mariner 10 mission, which flew past Mercury in 1975. A third mission to reach Mercury will be the European–Japanese BepiColombo spacecraft to be launched in 2015. (Image credit: NASA/Johns Hopkins University Applied Physics Laboratory/Carnegie Institution of Washington.)

CERN Courier Archive: 1969

A look back to CERN Courier vol. 8, April 1969, compiled by Peggie Rimmer

PARTICLES

Quarks are still elusive

An experiment at the CERN proton synchrotron PS has searched, unsuccessfully, for the elusive quarks. If, as is postulated, different combinations of more fundamental objects called quarks explain the orderly grouping of the observed particles, individual quarks must carry a charge ⅓ or ⅔ of the electron charge, providing an excellent handle to get hold of them if they exist.

The PS was operated at 27 GeV and the proton beam was directed onto a target in the magnet ring. The beamline was tuned to a 'supermomentum' of over 30 GeV/*c* so that particles carrying normal charge would not find their way through the beamline magnets. On the other hand, a particle of about 10 GeV/*c* carrying ⅓ charge would be guided to the detectors.

The experiment pushed detection techniques down to a production cross-section of about 10^{-39} cm^2, a hundred times lower than previously investigated. Advantage was taken of the fact that particles carrying ⅓ charge will produce ⅑ of the ionization of a normal particle. Scintillation counters were set to record only particles giving such low ionization and a streamer chamber was installed which gives tracks of a density depending on the ionization (the first use of a streamer chamber at the PS). Particles with charge of +⅓ and +⅔ were looked for but none was found.

A quark search has also been carried out by Soviet scientists at the higher energies available from the Serpukhov 76 GeV machine, but again without success. It can be concluded that the likelihood of observing quarks at existing accelerator energies is now very remote.

● Compiled from texts on p101.

EPS

European Physical Society inaugural conference

With a blaze of trumpets, announcing the Mayor of Florence, the inaugural conference of the European Physical Society EPS opened in the splendour of the Palazzo Vecchio on 8 April. More than 850 scientists attended and for five days Florence was the scene of reviews of "The Growth Points of Physics" by leading figures from European science. A plenary session on "Trends in High Energy Physics" was shared by L Van Hove and T D Lee.

Van Hove reported on interesting developments in evolving a systematic description of collisions of strongly interacting particles, using the "Veneziano model". This model has absorbed the ideas that 1) Regge trajectories could continue to higher masses well beyond the investigated region, populated by a limitless number of particles, and 2) some form of duality exists between the production of resonances and the exchange of particles.

G Bernardini, president of the EPS, addresses the inaugural session of the conference in the Palazzo Vecchio, Florence. Behind him are the heralds and standard of the Mayor, L Bausi (centre); on the right is C A Funaioli, representing the Italian government. (Image credit: Foto Torrini.)

Lee reported on latest developments in electromagnetic and weak interaction theories, concentrating in particular on problems arising in weak-interaction theory when the "first order" equations are extended to higher order. When, for example, the higher-order theory is used to calculate the mass difference between the charged and neutral pions, the result comes out as infinity.

Two of the highlights were brilliant talks by A Hewish (Cambridge) on "Pulsars" and by D W Sciama (Cambridge) on "The Recent Renaissance of Observational Cosmology". The dramatic experimental observations and fascinating thinking in the field of astronomy over the past few years make it the fastest "growth point of physics" at present.

In his talk on "The Old Days at the Cavendish" P M S Blackett pleaded that experimenters should have their eyes wide open for the "accidental" observation. Two of the most exciting recent observations in astronomy have been "accidents". One was the detection of the first pulsar (CP1919) in July 1967, when the Cambridge telescope picked up radio signals pulsing with remarkable regularity every 1⅓ second. By now about 40 pulsars are under investigation. They are believed to be beamed synchrotron radiation (a "lighthouse" effect) coming from spinning neutron stars, the remaining cores of super novae explosions.

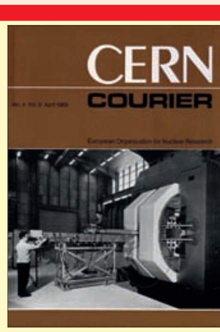
Another "accident" was the detection in 1965 of the background radiation of the universe. Radio telescopes can pick up this isotropic radiation, corresponding by now to a temperature of about 3 K, which lingers from the first tens of seconds of the mighty explosion 10^{10} years ago, at the origin of our universe. This has given heavy weight to the "big bang" theory as opposed to the "steady state" theory of the evolution of the universe.

Since, when dealing with cosmological phenomena, matter is being considered under extreme conditions such as are produced in high-energy particle collisions, research at accelerators is an important input to cosmological theories.

● Compiled from texts on pp106–107.

Compiler's Note

Existential studies and unexpected observations are ever the stuff of dreams. While physicists hunt for the elusive Higgs deep inside the LHC detectors, hominologists are searching remote corners of the Siberian wilderness for the elusive Yeti, faster-than-light neutrinos (to be confirmed) kindle fanciful notions of time travel and exoplanets recently discovered by NASA's Kepler telescope have given new impetus to the quest for ancient signals from extraterrestrial intelligence inhabiting the so-called Goldilocks Zones around distant stars. Who needs science fiction?




GAP

How the CMS collaboration orchestrates its success

New members of the top-level management talk to **Antonella Del Rosso** about the CMS model for running a large collaboration, as they prepare for the start of the LHC's run in 2012.

Trying to uncover the deepest mysteries of the universe is no trivial task. Today, the scientific collaborations that accept the challenge are huge, complex organizational structures that have their own constitution, strict budget control and top management. CMS, one of two general-purpose experiments that study the LHC collisions, provides a good example of how this type of scientific complexity can be dealt with.

The CMS collaboration currently has around 4300 members, with more than 1000 new faces joining in the past three years. Together they come from some 170 institutes in 40 countries and six continents. Each institute has specific tasks to complete, which are agreed with the management leading the collaboration. "The collaboration is evolving all of the time. Every year we receive applications from five or so new institutes that wish to participate in the experiment," says Joe Incandela of the University of California Santa Barbara and CERN, who took over as spokesperson of the CMS collaboration at the start of 2012. "The Collaboration Board has the task of considering those applications and taking a decision after following the procedures described in the CMS constitution. All of the participating institutes are committed to maintaining, operating, upgrading and exploiting the physics of the detector."

Once they become full members of the collaboration, all institutes are represented on the Collaboration Board – the true governing body of CMS. (In practice, small institutes join together and choose a common representative.) The representatives can also vote for the spokesperson every two years. "To manage such a complex structure that must achieve very ambitious goals, the collaboration has so far always sought a spokesperson from among those people who have contributed to the experiment in some substantial way over the years and who have demonstrated some managerial and leadership qualities," notes deputy-spokesperson Tiziano Camporesi of CERN . "We often meet film-makers or journalists who tell us that they want to feature a few people. They want to have 'stars' who can be the heroes of the show but we always tell them that the collaboration has literally thousands of heroes. I have often heard it said that we are like an orchestra: the conductor is important but the whole thing only works if every single musician plays well."

Although two years may seem to be a short term, Joao Varela – who is a professor at the Instituto Superior Técnico of the Technical University of Lisbon and also deputy-spokesperson – believes that there are many positive aspects in changing the top management rather frequently. "The 'two-years scheme' allows CMS to grant this prestigious role to more people over time," he says. "In this way, more institutes and cultures can be represented at such a high level. There is a sense of fairness in the honour being shared across the whole community. Moreover, each time a new person comes in, by human nature he/she is motivated to bring in new ideas."

As good as the idea is to rotate people in the top management, the CMS collaboration is currently analysing the experience already accumulated to see if things can be improved. "So far deputies have always been elected as spokespersons and this has ensured continuity even during the short overlap. I was myself in physics co-ordination, then deputy and finally spokesperson. Even so, I am learning many new things every day," points out Incandela.

At CMS the spokesperson also nominates his/her deputies and many of the members of the Executive Board, which brings together project managers and activity co-ordinators. "The members of the Executive Board are responsible for most of the day-to-day co-ordination work that is a big part of what makes CMS work so well," explains Incandela. "Each member is responsible for managing an organization with large numbers of people and a considerable budget in some cases. Historically, the different projects and activities were somewhat isolated from one another, so that members of the board didn't really have a chance or need to follow what the other areas were doing. With the start of LHC operations in 2008 this began to change and now people focus on broader issues." To improve communication among the members of the Executive Board, the new CMS management also decided to organize workshops. "These ▷

The conductor is important but the whole thing only works if every single musician plays well.

A small fraction of the CMS collaboration together with a full-scale photograph of the detector. (Image credit: Achintya Rao.)

LHC experiments

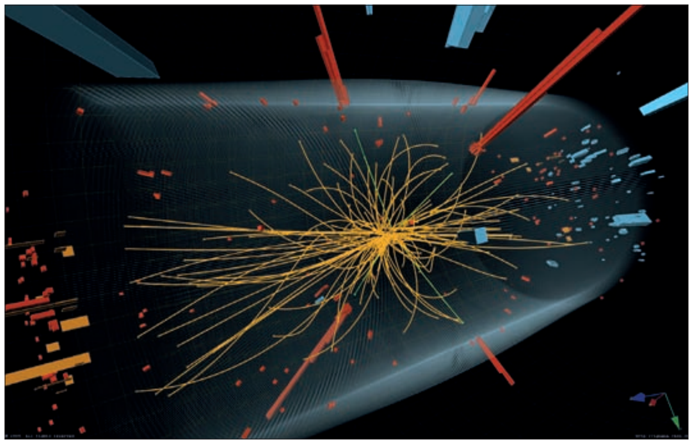
have turned out to be fantastic events," says Camporesi. "At the meetings, we discuss important and broad issues openly, from what is the best way to do great physics to how to maintain high morale and attract excellent young people to the collaboration."

To keep the whole collaboration informed about the outcomes of such strategic meetings and other developments in the experiment in general, the CMS management organizes weekly plenary meetings. "I report once a week to the whole collaboration: we typically have anywhere from 50 to 250 people attending, plus 100–200 remote connections. We are a massive organization and the weekly update is a quick and useful means of keeping everybody informed," adds Incandela.

The scientific achievements of CMS prove not only that a large scientific collaboration is manageable but also that it is effective. In January this year a new two-year term began for the CMS collaboration, which also renewed all of the members of top management. This is a historic moment for the experiment because many potential discoveries are in the pipeline. "This is my third generation of hadron collider – I participated in the UA2 experiment at CERN's SPS, CDF at Fermilab's Tevatron and now CMS at the LHC. When you are proposing a new experiment and then building it, the focus is entirely on the detector," observes Incandela. "Then, when the beam comes, attention moves rapidly to the data and physics. The collaboration is mainly interested in data and the discoveries that we hope to make. We must ensure the high performance of the detector while providing the means for extremely accurate but quick data analysis. However, although almost everything works perfectly, there are already many small things in the detector that need repairing and upgrading."

The accelerator settings for the LHC's 2012 run, decided at the Chamonix Workshop in February, will mean that CMS has to operate in conditions that go beyond the design target. "The detector will face tougher pile-up conditions and our teams of experts have been working hard to ensure that all of the subsystems work as expected. It looks like the detector can cope with conditions that are up to 50% higher than the design target", confirms Camporesi. "Going beyond that could create serious issues for the experiment. We observe that the Level1 trigger starts to be a limitation and the pixel detector starts to lose data, for instance." CMS is already planning upgrades to improve granularity and trigger performance to cope with the projected higher luminosity beyond 2014.

Going to higher luminosity may be a big technical challenge but it does mean reducing the times to discoveries. "The final word on the Higgs boson is within reach, now measurable in terms of months rather than years. And for supersymmetry, we are changing the strategy. In 2010–2011, we were essentially searching for supersymmetric partners of light quarks because they were potentially more easily accessible. This approach didn't yield any fruit but put



An event recorded in CMS with four high-energy electrons (red towers) that could be from the decay of two Z-bosons. While it shows characteristics expected from the decay of a Higgs boson, it is also consistent with background Standard Model processes.

significant constraints on popular models. A lot of people were discouraged," explains Varela. "However, what we have not ruled out are possible relatively light supersymmetric partners of the third-generation quarks. The third generation is a tougher thing to look for because the signal is smaller and the backgrounds can be higher. By increasing the energy of the collisions to 4 TeV one gains 50–70% in pair production of supersymmetric top, for instance, while the top-pair background rises by a smaller margin. Having said this, and given the unexplored environment, it is obviously important if we discover things. But it is also important if we don't see anything."

There is a long road ahead because the searches will continue at higher LHC energies and luminosities after 2014, but the CMS collaboration plans to be well prepared.

Résumé

CMS : comment faire fonctionner une grande collaboration

S'efforcer de dévoiler les mystères de l'Univers n'est pas chose facile. Aujourd'hui, les collaborations scientifiques qui acceptent ce défi sont d'énormes structures complexes qui disposent de leurs propres statuts, d'un contrôle budgétaire strict, et d'une direction centralisée. CMS, l'une des deux expériences généralistes qui étudient les collisions au LHC, constitue un bon exemple de la manière de gérer ce type de complexité scientifique. Dans cet article, les nouveaux membres de l'équipe de direction réfléchissent sur le modèle CMS d'organisation d'une grande collaboration, au moment où l'on prépare l'exploitation 2012 du LHC.

Antonella Del Rosso, CERN.

Industry

Medical-isotope cyclotron designs go full circle

Invented 80 years ago, the first cyclotrons were small. Now those being built for the production of medical isotopes are returning to the dimensions of their predecessors as they make use of the latest technologies.

The first cyclotron, built in 1930 by Ernest Lawrence and Stanley Livingston, was 4.5" (11 cm) in diameter and capable of accelerating protons to an energy of 80 keV (figure 1). Lawrence soon went on to construct higher-energy and larger-diameter cyclotrons to provide particle beams for research in nuclear physics. Eighty years ago this month, he and Livingston published a seminal paper in which they described the production of light ions with kinetic energies in excess of 1 MeV using a device with magnetic pole-pieces 28 cm across (Lawrence and Livingston 1932). By 1936 John Lawrence, Ernest's brother, had made the first recorded biomedical use of a cyclotron when he used the 36" (91 cm) machine at Berkeley to produce ^{32}P for the treatment of leukaemia. Since then, the physics design of the cyclotron has improved rapidly, with the introduction of alternating-gradient sector focusing, edge focusing, external ion-source injection, electron cyclotron-resonance sources, negative-ion acceleration, separated-sector technology and the use of superconducting magnets.

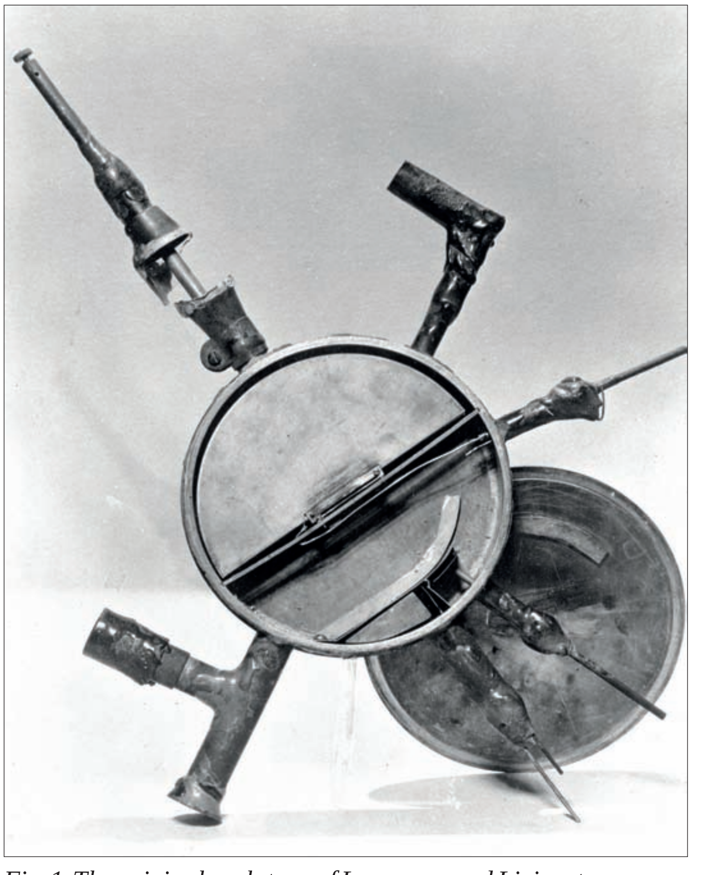


Fig. 1. The original cyclotron of Lawrence and Livingston was only 11 cm in diameter. (Image credit: LBNL.)

Historical developments

However, other accelerator designs were evolving even faster, with the construction of the synchrocyclotron, the invention of the synchrotron, of linear accelerators and of particle colliders that were capable of generating the extremely high energies needed by the particle-physics community. The usefulness of the cyclotron appeared to diminish but in 1972 the TRIUMF laboratory in Canada turned on the world's largest cyclotron, at 2000 tonnes with a beam-orbit diameter of 18 m and negative-ion acceleration. Two years later, in Switzerland, PSI brought into commission a large separated-sector, 590 MeV proton cyclotron. Both of these machines have contributed to isotope-production programmes. More recently, a superconducting ring cyclotron delivering a proton beam energy of 2400 MeV has been built in Japan at the Riken research institute.

Nevertheless, the value of the cyclotron as a method for producing medical isotopes had come under further pressure in the 1950s and early 1960s from the availability of numerous nuclear-research reactors that had high neutron fluxes, large-volume irradiation positions and considerable flexibility for isotope production. These attributes allowed the generation of important radioisotopes such as ^{99}Mo, ^{131}I, ^{35}S and even ^{32}P more easily and more cost effectively.

Nevertheless, there remained a few radionuclides with neutron-deficient nuclei that were important for medical imaging but could be produced only by particle accelerators. These included ^{123}I and ^{201}Tl, used for nuclear cardiology, and others such as ^{111}In. The production reactions needed were often of the type where a proton knocks out only a few neutrons, (p,xn) with x=1 or 2 or 3, so that the accelerator energy required was usually no more than around ▷

Industry

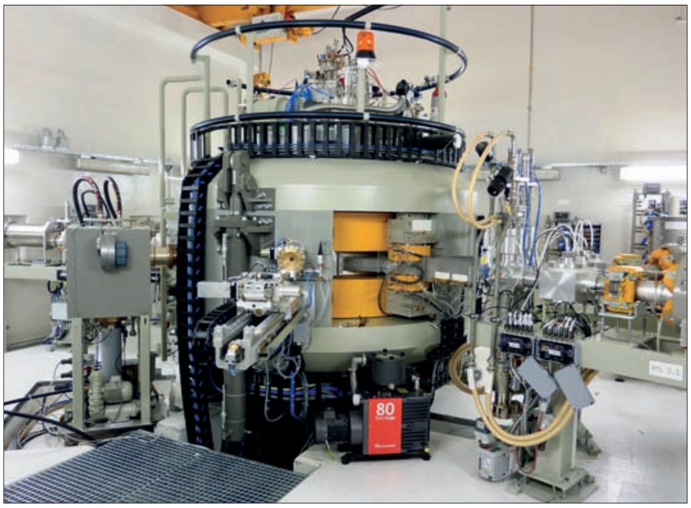


Fig. 2. The power-efficient Cyclone-30 isotope-producing cyclotron, 2.7 m in diameter and 2.8 m high. (Image credit: IBA.)

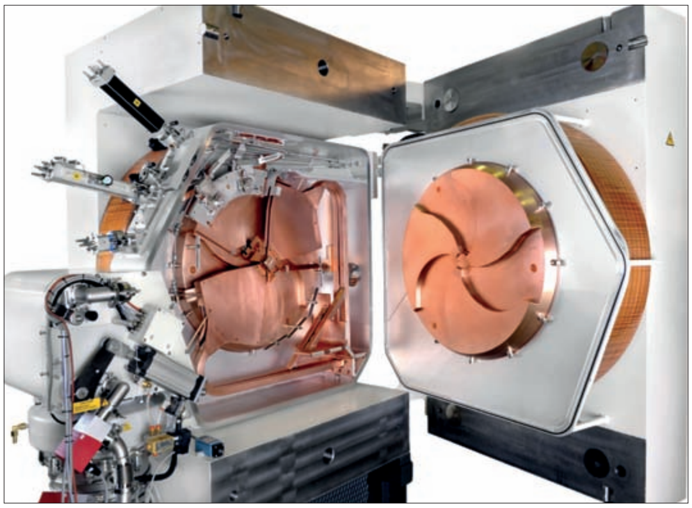


Fig. 3. The 1.2 m × 1.3 m 17 MeV PETTRACE cyclotron, with a height of 1.9 m. (Image credit: General Electric Healthcare).

30 MeV. Consequently the use of the medium-energy cyclotron was revived. The first dedicated medical-isotope cyclotron was designed and built at the Hammersmith Hospital in London in 1955 and was followed by dozens of research-based cyclotrons, often with their own bespoke designs.

The routine use of radioisotope-labelled medical products and the demand for radiopharmaceutical injections for patients led to the creation of a new sector of industry: to supply cyclotron systems capable of the production of medical isotopes. Commercial companies started to design, build and supply complete cyclotron systems specifically for this purpose. The first generation of these industrial cyclotrons was made available by companies such as Philips in the Netherlands and The Cyclotron Corporation (TCC) in the US, but these machines were usually complicated instruments requiring considerable physics expertise for operations and maintenance. Second-generation cyclotrons, with more compact designs and improved engineering, were developed later by Scanditronix in Sweden, Thompson CSF in France and Sumitomo and JSW in Japan, all with designs that led to lower radiation doses to the operators. Around 1980, the first negative-ion industrial cyclotron, the CP-42, became available from TCC, with 40 MeV proton extraction.

In 1988, a major step forward occurred with the development by Yves Jongen at the University of Louvain-la-Neuve, Belgium, of an industrial cyclotron customized for medical-isotope production – the Cyclone-30 (figure 2). This new cyclotron was power efficient, had a user-friendly control system and incorporated negative-ion acceleration and charge-exchange stripping for extraction, as developed earlier at the TRIUMF cyclotron. It spawned the start of a new accelerator company in Belgium, IBA SA, and this concept of an optimized industrial design was subsequently adopted by other companies, including Ebco Industries in Canada. Most of these isotope-producing cyclotrons were in the energy range of 20–40 MeV – some having an extracted beam capability of 500 μA or more – and several companies have made available a range of cyclotrons operating at different energies (Schmor 2010).

In addition, a range of positron-emitting, neutron-deficient radionuclides were found to be particularly effective for biomedical human imaging via positron-emission tomography (PET), i.e. ^{18}F, ^{11}C, ^{15}O and ^{13}N. The production energies required for these PET isotopes were lower – from around 5 MeV to 20 MeV – with ^{18}F being the most commonly used. Many of the same industrial companies designed even smaller cyclotrons at around either 17 MeV, for high-output ^{18}F production, or around 11 MeV, for lower, hospital-based ^{18}F production, and some cyclotron designs had radiation self-shielding arrangements. PET had long been an imaging technique used in research but by 1998, the medical regulator in the US – i.e. the Food and Drug Administration – had approved the use of PET imaging for several clinical indications. However, ^{18}F has a half-life of only two hours, which limits delivery to small geographic regions. This led to the building of numerous manufacturing facilities for lower-energy PET cyclotrons. It is estimated that by 2010 the world market for small PET cyclotrons was between 50 and 60 a year.

Although ^{18}F, in the form of ^{18}F-deoxyglucose or FDG, has remained the most commonly used radionuclide for PET, numerous other tracers labelled with ^{18}F are in advanced stages of clinical development and eventual commercialization. However, the process of their drug licensing has been particularly slow. Despite the considerable investment made in R&D and manufacturing of FDG by industry, there is a growing concern that the potential for its use in PET imaging and its implementation in personalized medicine has not been achieved fully. There also exist numerous other tracers that provide good images of the human body, many of which use ^{11}C as the radiolabel. However, ^{11}C has an extremely short half-life of only 20 minutes and it would have to be produced inside the facilities of the smallest general hospitals, as well as at larger research institutions.

The drive towards smaller, hospital-based cyclotrons dedicated to producing small quantities of injectable radioisotopes started back in 1989 when IBA, following on from the success of the Cyclone-30, designed the Cyclone 3D – a 3 MeV deuteron cyclotron for ^{15}O production. Some five models have been delivered, but unfortunately ^{15}O has remained a research tool used

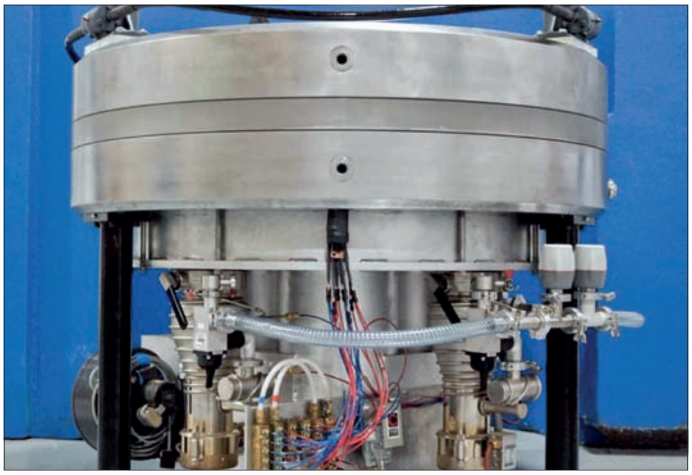


Fig. 4. The ABT Molecular Imaging cyclotron for single-patient doses is 1.2 m in diameter and 1 m high. (Image credit: ABT Molecular Imaging Inc.)

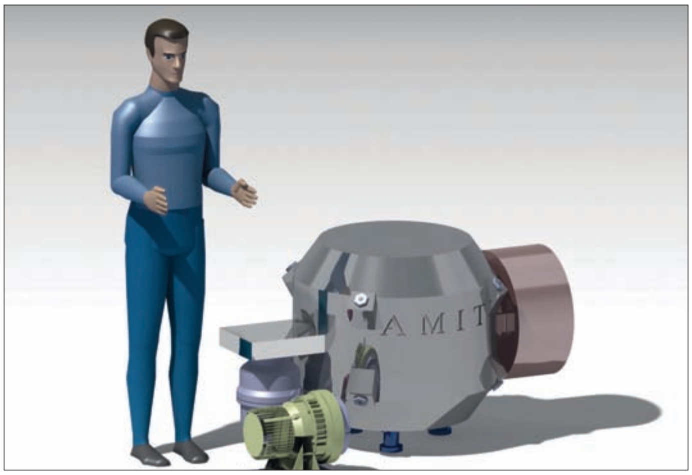


Fig. 5. Conceptual design for the CIEMAT/CERN superconducting cyclotron with a magnet only 0.8 m in diameter. (Image credit: CIEMAT.)

primarily for blood-flow studies rather than becoming a regular commercial product with its own pharmaceutical-marketing authorization licence.

Another approach towards reducing the size of the cyclotron was the OSCAR cyclotron, originally designed and delivered in 1990 by Oxford Instruments in the UK, and now distributed by EuroMeV. OSCAR is a 12 MeV, 100 µA superconducting cyclotron with an external ion source. Around eight models with this more complicated design have been delivered.

Latest trends

The concept of producing quantities of PET radionuclides that are suitable for one dose to a single patient was not really addressed until 2009, when Ron Nutt of ABT Molecular Imaging Inc developed a small cyclotron with 7.5 MeV energy, positive ion (i.e. proton) acceleration and an internal target for the production of unit doses of ^{18}F. This cyclotron was designed as a component of an integrated production system that also included targetry, a chemistry system based on microfluidic processing, an online chemistry quality-control system and a methodology for radiopharmaceutical product release. The physics of this cyclotron reverts to the more traditional method of proton acceleration and internal targets to reduce the radiation burden associated with stripping inside negative-ion cyclotrons. Nevertheless, this cyclotron system has established a new strategy of producing unit-patient doses of radionuclides with short half-lives. Moreover, the production can be located in smaller clinical facilities, possibly in remote and rural locations around the world.

The use of negative-ion acceleration, the ease of charged-particle stripping-extraction and the convenience of having external targets have been preferred by other developers. General Electric Healthcare has recently reported success in the development of a small, vertical cyclotron with a proton energy of around 8 MeV. In Spain, a public–private consortium has announced a development project called AMIT, which is funded by the Spanish Centre for Industrial Technology Development. Within this consortium, the accelerator institute CIEMAT in Madrid will be delivering a cyclotron with a low-energy proton beam. A collaboration has been set up between CIEMAT and CERN to design and build the smallest-possible cyclotron using superconducting technology with a proton energy of around 8 MeV, the objective being to produce single-patient doses of both ^{18}F and ^{11}C in particular. This collaboration with CERN will include the use of some of the accelerator technology and expertise used in building the LHC.

Figure 5 shows a schematic of this cyclotron. A trade-off exists between increasing the magnetic field with higher levels of Lorentz stripping of negative ions and associated increases in the neutral beam-radiation field against the requirement of increasing the size of the radiation shielding around the cyclotron periphery. The nominal extraction radius for this machine will be around 11 cm. In other words, the size of the latest industrial medical-isotope producing cyclotrons have reverted to dimensions close to those of Lawrence's first cyclotron developed over 80 years ago.

● Further reading

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Résumé

Cyclotrons pour isotopes médicaux : un air de déjà vu

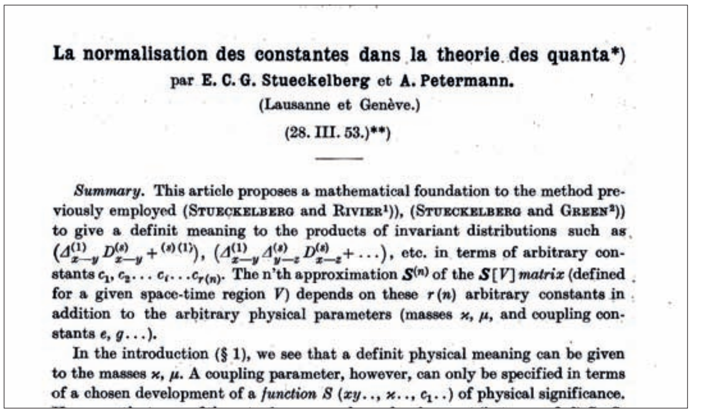
Inventés il y a 80 ans, les premiers cyclotrons étaient de petite taille. En raison d'un besoin d'atteindre de plus hautes énergies, les cyclotrons ont augmenté en taille, puis ont été supplantés par les synchrotrons et les collisionneurs pour la physique des hautes énergies. Toutefois, la nécessité de radio-isotopes à courte durée de vie pour la médecine a amené l'industrie à s'intéresser à la conception et à la production de petits cyclotrons destinés à être utilisés dans les hôpitaux. À présent, tirant parti des technologies les plus récentes, les cyclotrons construits pour la production d'isotopes médicaux reviennent aux dimensions de leurs ancêtres.

Dewi M Lewis, CERN, and **Uno Zetterberg**, General Electric Healthcare.

Tribute

Interactions with André Petermann

Antonino Zichichi recalls encounters with a major theorist at CERN, who died last summer.


La normalisation des constantes dans la theorie des quanta*)

par **E. C. G. Stueckelberg** et **A. Petermann.**

(Lausanne et Genève.)

(28. III. 53.)**)

Summary. This article proposes a mathematical foundation to the method previously employed (STUECKELBERG and RIVIER[1]), (STUECKELBERG and GREEN[2])) to give a definit meaning to the products of invariant distributions such as $(\Delta^{(1)}_{x-y} D^{(s)}_{x-y} + {}^{(s)(1)})$, $(\Delta^{(1)}_{x-y} \Delta^{(s)}_{y-z} D^{(s)}_{x-z} + \ldots)$, etc. in terms of arbitrary constants $c_1, c_2 \ldots c_i \ldots c_{r(n)}$. The n'th approximation $S^{(n)}$ of the $S[V]$ *matrix* (defined for a given space-time region V) depends on these $r(n)$ arbitrary constants in addition to the arbitrary physical parameters (masses $\varkappa$, μ, and coupling constants $e, g \ldots$).

In the introduction (§ 1), we see that a definit physical meaning can be given to the masses $\varkappa$, μ. A coupling parameter, however, can only be specified in terms of a chosen development of a *function* $S\,(xy \ldots, \varkappa \ldots, c_1 \ldots)$ of physical significance.

The seminal paper of 1953 by Stueckelberg and Petermann.

The first time that I heard of André Petermann, I was in Rome in 1954 at a seminar by Bruno Ferretti on hot topics in theoretical physics. Under discussion was the paper that André had written with Ernst Stueckelberg in which the electromagnetic coupling "constant" was losing its fundamental property of being constant. The audience was shocked to learn that electric charge had to change with energy.

The origin of this conceptual revolution was the work in which these two theoretical physicists discovered that all quantities such as the gauge couplings (α_i) and the masses (m_j) must "run" with q^2, the invariant four-momentum of a process (Stueckelberg and Petermann 1951). It took many years to realize that this "running" allows not only the existence of a grand unification and opens the way to supersymmetry but also finally produces the need for a non-point-like description of physics processes – the relativistic quantum-string theory – that should produce the much-needed quantization of gravity.

It is interesting to recall the reasons that this paper attracted so much attention. The radiative corrections to any electromagnetic process had been found to be logarithmically divergent. Fortunately, all divergencies could be grouped into two classes: one had the property of a mass; the other had the property of an electric charge. If these divergent integrals were substituted with the experimentally measured mass and charge of the electron, then all theoretical predictions could be made to be "finite". This procedure was called "mass" and "charge" renormalization.

Stueckelberg and Petermann discovered that if the mass and the charge are made finite, then they must run with energy. However, the freedom remains to choose the renormalization subtraction points. Petermann and Stueckelberg proposed that this freedom had to obey the rules of an invariance group, which they called the "renormalization group" (Stueckelberg and Petermann 1953). This is the origin of what we now call the renormalization group equations, which – as mentioned – imply that all gauge couplings and masses must run with energy. It was remarkable many years later to find that the three gauge couplings could converge, even if not well, towards the same value. This means that all gauge forces could have the same origin; in other words, grand unification. A difficulty in the unification was the new supersymmetry that my old friend Bruno Zumino was proposing with Julius Wess. Bruno told me that he was working with a young fellow, Sergio Ferrara, to construct non-Abelian Lagrangian theories simultaneously invariant under supergauge transformations, without destroying asymptotic freedom. During a nighttime discussion with André, in the experimental hall to search for quarks at the Intersecting Storage Rings in 1977, I told him that two gifts were in front of us: asymptotic freedom and supersymmetry. The first was essential for the experiment being implemented, the second to make the convergence of the gauge couplings "perfect" for our work on the unification. We will see later that this was the first time that we realized how to make the unification "perfect".

The muon g-2

The second occasion for me to know about André came in 1960, when I was engaged in measuring the anomalous magnetic moment (g–2) of the muon. He had made the most accurate theoretical prediction, but there was no high-precision measurement of this quantity because technical problems remained to be solved. For example, a magnet had to be built that could produce a set of high-precision polynomial magnetic fields throughout as long a path as possible. This is how the biggest (6-m long) "flat magnet" came to be built at CERN with

The audience was shocked to learn that electric charge had to change with energy.

the invention of a new technology now in use the world over (*CERN Courier* December 2005 p12). André worked only at night and because he was interested in the experimental difficulties he spent nights with me working in the SC-Experimental Hall. It was a great help for me to interact with the theorist who had made the most accurate theoretical prediction for the anomalous magnetic moment of a particle 200 times heavier than the electron. The muon must surely reveal a difference in a fundamental property like its g-value. Otherwise, why is its mass 200 times greater than that of the electron? (Even now, five decades later, no one knows why.)

When the experiment at CERN proved that, at the level of 2.5 parts in a million for the g-value, the muon behaves as a perfect electromagnetic object, the problem changed focus to ask why are there so many muons around? The answer lay in the incredible value of the mass difference between the muon and its parent, the π. Could another "heavy electron" – a "third lepton" – exist with a mass in the range of giga-electron-volts? Had a search ever been done for this third "lepton"? The answer was no. Only strongly interacting particles had been studied. This is how the search for a new heavy lepton, called HL, was implemented at CERN, with the Proton AntiProton into LEpton Pairs (PAPLEP) project, where the production process was proton–antiproton annihilation. André and I discussed these topics in the CERN Experimental Hall during the night shifts he spent with me.

The results of the PAPLEP experiment gave an unexpected and extremely strong value for the (time-like) electromagnetic form-factor of the proton, whose consequence was a factor 500 below the point-like cross-section for PAPLEP. This is how, during another series of night discussions with André, we decided that the "ideal" production process for a third "lepton" was (e^+e^-) annihilation. However, there was no such collider at CERN. The only one being built was at Frascati, by Bruno Touschek, who was a good friend of Bruno Ferretti and another physicist who preferred to work at night. I had the great privilege of knowing Touschek when I was in Rome. He also became a strong supporter of the search for a "third lepton" with the new e^+e^- collider, ADONE. Unfortunately the top energy of ADONE was 3 GeV and the only result that we could achieve was a limit of 1 GeV for the mass of the much desired "third lepton".

Towards supersymmetry

Another topic talked about with André has its roots in the famous work with Stueckelberg – the running with energy of the fundamental couplings of the three interactions: electromagnetic, weak and strong. The crucial point here was at the European Physical Society (EPS) conferences in York (1978) and Geneva (1979). In my closing lecture at EPS-Geneva, I said: "Unification of all forces needs first a supersymmetry. This can be broken later, thus generating the sequence of the various forces of nature as we observe them." This statement was based on work with André where in 1977 we studied – as mentioned before – the renormalization-group running of the couplings and introduced a new degree of freedom: supersymmetry. The result was that the convergence of the three couplings improved a great deal. This work was not published, but known to a few, and it led to the Erice Schools Superworld I, Superworld II and Superworld III.

This is how we arrived at 1991 when it was announced that the search for supersymmetry had to wait until the multi-tera-electron-volt energy threshold would become available. At the time, a group of 50 young physicists was engaged with me on the search for the lightest supersymmetric particle in the L3 experiment at CERN's Large Electron Positron (LEP) collider. If the new theoretical "predictions" were true then there was no point in spending so much effort in looking for supersymmetry-breaking in the LEP energy region. Reading the relevant papers, André and I realized that no one had ever considered the evolution of the gaugino mass (EGM). During many nights of work we improved the unpublished result of 1977 mentioned above: the effect of the EGM was to bring down the energy threshold for supersymmetry-breaking by nearly three orders of magnitude. Thanks to this series of works I could assure my collaborators that the "theoretical" predictions on the energy-level where supersymmetry-breaking could occur were perfectly compatible with LEP energies (and now with LHC energies).

Finally, in the field of scientific culture, I would like to pay tribute to André Petermann for having been a strong supporter for the establishment of the Ettore Majorana Centre for Scientific Culture in Erice. In the old days, before anyone knew of Ettore Majorana, André was one of the few people who knew about Majorana neutrinos and that relativistic invariance does not give any privilege to spin-½ particles, such as the privilege of having antiparticles, all spin values having the same privilege. In all of my projects André was of great help, encouraging me to go on, no matter what the opposition could present in terms of arguments that often he found to be far from being of rigorous validity.

• Further reading

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Résumé

Interactions avec André Petermann

André Petermann, l'un des premiers membres de la division Théorie, est décédé en août dernier, dans sa 89e année. André Petermann inventa, avec son patron de thèse Ernst Stueckelberg, le groupe de renormalisation, qui fut l'un des fondements de la théorie moderne des transitions de phases et de la liberté asymptotique en théorie quantique des champs, et aussi de la quête de l'unification de toutes les interactions de particules. Antonino Zichichi se remémore ses échanges stimulants avec Petermann sur des sujets tels que la mesure du moment magnétique anormal du muon et la recherche d'un nouveau lepton lourd.

Antonino Zichichi, CERN, Geneva, Enrico Fermi Centre, Rome, INFN and the University of Bologna.

Interview

Saul Perlmutter: fron

Paradoxically, work on "light candles" led to the discovery that the universe is much darker than anyone thought. **Arnaud Marsollier** caught up with Saul Perlmutter recently to find out more about this Nobel breakthrough.

Saul Perlmutter surrounded by the press on the day that he learnt he had rec

Saul Perlmutter admits that measuring an acceleration of the expansion of the universe – work for which he was awarded the 2011 Nobel Prize in Physics together with Brian Schmidt and Adam Riess – came as a complete surprise. Indeed, it is exactly the opposite of what Perlmutter's team was trying to measure: the decelerating expansion of the universe. "My very first reaction was the reaction of any physicist in such a situation: I wondered which part of the chain of the analysis needed a new calibration," he recalls. After the team had checked and rechecked over several weeks, Perlmutter, who is based at Lawrence Berkeley National Laboratory and the University of California, Berkeley, still wondered what could be wrong: "If we were going to present this, then we would have to make sure that everybody understood each of the checks." Then, after a few months, the team began to make public its result in the autumn of 1997, inviting scrutiny from the broader cosmology community.

Despite great astonishment, acceptance of the result was swift. "Maybe in science's history, it's the fastest acceptance of a big surprise," says Perlmutter. In a colloquium that he presented in November 1997, he remembers how cosmologist Joel Primack stood up and instead of talking to Perlmutter he addressed the audience, declaring: "You may not realize this, but this is a very big problem. This is an outstanding result you should be worried about." Of course, some colleagues were sceptical at first. "There must be something wrong, it is just too crazy to have such a small cosmological constant," said cosmologist Rocky Kolb in a later conference in early 1998.

According to Perlmutter, one of the main reasons for the quick acceptance by the community of the accelerating expansion of the universe is that two teams reported the same result at almost the same time: Perlmutter's Supernova Cosmology Project and the High-z Supernova Search Team of Schmidt and Riess (*CERN Courier* November 2011 p5). Thus, there was no need to wait a long time for confirmation from another team. "It was known that the two teams were furious competitors and that each of them would be very glad to prove the other one wrong," he adds. By the spring of 1998, a symposium was organized at Fermilab that gathered many cosmologists and particle physicists specifically to look at these results. At the end of the meeting, after subjecting the two teams to hard questioning, some three quarters of the people in the room raised their hands in a vote to say that they believed the results.

What could be responsible for such an acceleration of the expanding universe? Dark energy, a hypothetical "repulsive energy" present throughout the universe, was the prime suspect. The concept of dark energy was also welcomed because it solves some delicate theoretical problems. "There were questions in cosmology that did not work so well, but with a cosmological constant they are solved," explains Perlmutter. Albert Einstein had at first included a cosmological constant in his equations of general relativity. The aim was to introduce a counterpart to gravity in order to have a model describing a static universe. However, with evidence for the expansion of the universe and the Big Bang theory, the cosmological constant had been abandoned by most cosmologists. According to George Gamow, even Einstein thought that it was his "biggest blunder" (Gamow 1970). Today, with the discovery of the acceleration of

m light into darkness

eceived a share in the 2011 Nobel Prize in Physics. (Image credit: LBNL.)

Geometers of the universe

To measure the rate at which the universe is expanding, physicists need to find the best tools to allow them to gauge the size of the universe both today and in the past. Type Ia Supernovae are known for their uniform brightness, which makes them accurate tools for measuring astronomical distances. This is why they are commonly called "standard candles".

By comparing how bright the explosion appears with how bright it should be, cosmologists can evaluate the distance of the supernova. In addition, the ongoing expansion of the universe stretches the wavelengths of the light propagating from any cosmic body, shifting it to the redder end of the spectrum. By combining the measurements of distance (and hence how far back in time the supernova occurred) and of the red shift (indicating how much the universe has stretched since that time) for many supernovae, it is possible to evaluate the evolution of the universe's expansion.

the expansion of the universe, the cosmological constant "is back".

Since the discovery, other kinds of measurements – for example on the cosmic microwave background radiation (CMB), first by the MAXIMA and BOOMERANG balloon experiments, and then by the Wilkinson Microwave Anisotropy Probe satellite – have proved consistent with, and even made stronger, the idea of an accelerating expansion of the universe. However, it all leads to a big question: what could be the nature of dark energy? In the 20th century, physicists were already busy with dark matter, the mysterious invisible matter that can only be inferred through observations of its gravitational effects on other structures in the universe. Although they still do not know what dark matter is, physicists are increasingly confident that they are close to finding out, with many different kinds of experiments that can shed light on it, from telescopes to underground experiments to the LHC. In the case of dark energy, however, the community is far from agreeing on a consistent explanation.

When asked what dark energy could be, Perlmutter's eyes light up and his broad smile shows how excited he is by this challenging question. "Theorists have been doing a very good job and we have a whole landscape of possibilities. Over the past 12 years there was an average of one paper a day from the theorists. This is remarkable," he says. Indeed, this question has now become really important as it seems that physicists know about a mere 5% of the whole mass-energy of the universe, the rest being in the form of dark matter or, in the case of more than 70%, the enigmatic, repulsive stuff known as dark energy or a vacuum energy density.

Including a cosmological constant in Einstein's equations of general relativity is a simple solution to explain the acceleration of the expansion of the universe. However, there are other possibilities. For example, a decaying scalar field of the kind that could have caused the first acceleration at the beginning of the universe or the existence of extra dimensions could save the standard cosmological model. "We might even have to modify Einstein's general relativity," Perlmutter says. Indeed, all that is known is that the expansion of the universe is accelerating, but there is no clue as to why. The ball is in the court of experimentalists, who will have to provide theorists with more data and refined measurements to show precisely how the expansion rate changes over time. New observations by different means will be crucial, as they could show the way forward and decide between the different available theoretical models.

"We have improved the supernova technique and we know what we need to make a measurement that is 20 times more accurate," he says. There are also two other precision techniques currently being developed to probe dark energy either in space or from the ground. One uses baryon acoustic-oscillations, which can be ▷

Interview

seen as "standard rulers" in the same way that supernovae are used as standard candles (see box, previous page). These oscillations leave imprints on the structure of the universe at all ages. By studying these imprints relative to the CMB, the earliest "picture of the universe" available, it is possible to measure the rate at which the expansion of the universe is accelerating. The second technique is based on gravitational lensing, a deflection of light by massive structures, which allows cosmologists to study the history of the clumping of matter in the universe, with the attraction of gravity contesting with the accelerating expansion. "We think we can use all of these techniques together," says Perlmutter. Among the projects he mentions, are the US-led ground-based experiments BigBOSS and the Large Synoptic Survey Telescope and ESA's Euclid satellite, all of which are under preparation.

However, the answer to this obscure mystery – or at least part of it – could come from elsewhere. The full results from ESA's Planck satellite, for instance, are eagerly awaited because they should provide unprecedented precision on measurements of the CMB. "The Planck satellite is an ingredient in all of these analyses," explains Perlmutter. In addition, cosmology and particle physics are increasingly linked. In particular, the LHC could bring some input into the story quite soon. "It is an exciting time for physics," he says. "If we just get one of these breakthroughs through the LHC, it would help a lot. We are really hoping that we will see the Higgs and maybe we will see some supersymmetric particles. If we are able to pin down the nature of dark matter, that can help a lot as well." Not that Perlmutter thinks that the mystery of dark energy is related to dark matter, considering that they are two separate sectors of physics, but as he says, "until you find out, it is still possible".

Further reading

George Gamow 1970 *My World Line: An Informal Autobiography* (Viking Press).

Résumé

Saul Perlmutter : de l'ombre à la lumière

Lorsque Saul Perlmutter avec son équipe a mesuré l'accélération de l'expansion l'univers, il s'est d'abord demandé d'où pouvait provenir l'erreur. Récompensé par le prix Nobel de physique 2011 qu'il partage avec Brian Schmidt et Adam Riess, il avoue que cette découverte a été une complète surprise et raconte comment elle a été admise en quelques mois. Un peu plus de dix ans après, l'énergie noire, une sorte de « substance répulsive » qui expliquerait cette accélération, reste une énigme qui défie les physiciens ; elle représenterait pas moins de 70% de l'ensemble du bilan masse-énergie de l'Univers. Des mesures plus fines devraient bientôt permettre de choisir entre les différentes théories développées pour rendre compte de la nature de cette mystérieuse énergie noire.

Arnaud Marsollier, CERN and IN2P3.

The ALICE computing project

Federico Carminati describes how the ALICE collaboration responded to changes in the computing environment in particle physics, dealing with object-oriented programming and the vision of the Grid.

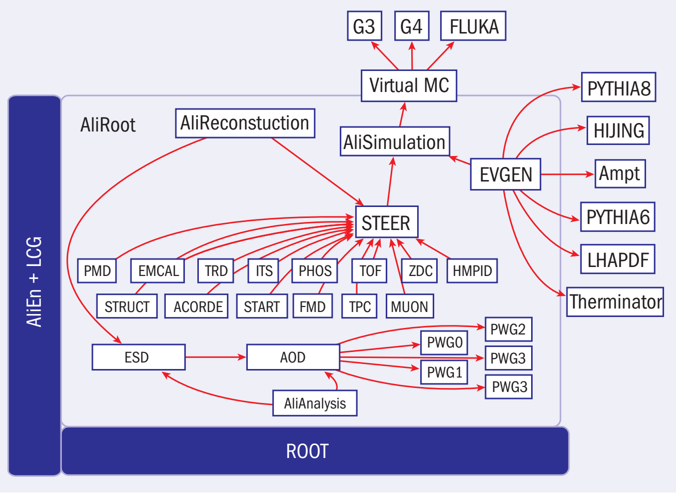


Fig. 1. The structure of the ALICE offline framework, AliRoot.

The ALICE software environment (AliRoot) first saw light in 1998, at a time when computing in high-energy physics was facing a challenging task. A community of several thousand users and developers had to be converted from a procedural language (FORTRAN) that had been in use for 40 years to a comparatively new object-oriented language (C++) with which there was no previous experience. Coupled to this was the transition from loosely connected computer centres to a highly integrated Grid system. Again, this would involve a risky but unavoidable evolution from a well known model where, for experiments at CERN, for example, most of the computing was done at CERN with analysis performed at regional computer centres to a highly integrated system based on the Grid "vision", for which neither experience nor tools were available.

In the ALICE experiment, we had a small offline team that was concentrated at CERN. The effect of having this small, localized team was to favour pragmatic solutions that did not require a long planning and development phase and that would, at the same time, give maximum attention to automation of the operations. So, on one side we concentrated on "taking what is there and works", so as to provide the physicists quickly with the tools they needed, while on the other we devoted attention towards ensuring that the solutions we adopted would lend themselves to resilient hands-off operation and would evolve with time. We could not afford to develop "temporary" solutions but still we had to deliver quickly and develop the software incrementally in ways that would involve no major rewrites.

The rise of AliRoot

When development of the current ALICE computing infrastructure started, the collaboration decided to make an immediate transition to C++ for its production environment. This meant the use of existing and proven elements. For the detector simulation package, the choice fell on GEANT3, appropriately "wrapped" into a C++ "class", together with ROOT, the C++ framework for data manipulation and analysis that René Brun and his team developed for the LHC experiments. This led to a complete, albeit embryonic, framework that could be used for the experiment's detector-performance reports. AliRoot was born.

The initial design was exceedingly simple. There was no insulation layer between AliRoot and ROOT; no software-management layer beyond a software repository accessible to the whole ALICE collaboration; and only a single executable for simulation, calibration, reconstruction and analysis. The software was delivered in a single package, which just needed GEANT3 and ROOT to be operational.

To allow the code to evolve, we relied heavily on virtual interfaces that insulated the steering part from the code from the 18 ALICE subdetectors and the event generators. This proved to be a useful choice because it made the addition of new event generators – and even of new detectors, easy and seamless.

The effect of having this small, localized team was to favour pragmatic solutions.

To protect simulation code by users (geometry description, scoring and signal generation) and to ease the transition ▷

from GEANT3 to GEANT4, we also developed a "virtual interface" with the Monte Carlo simulator, which allowed us to reuse the ALICE simulation code with other detector-simulation packages. The pressure from the users, who relied on AliRoot as their only working tool, prompted us to assume an "agile" working style, with frequent releases and "merciless" refactorizations of the code whenever needed. In open-source jargon we were working in a "bazaar style", guided by the users' feedback and requirements, as opposed to the "cathedral style" process where the code is restricted to an elite group of developers between major releases. The difficulty of working with a rapidly evolving system while also balancing a rapid response to the users' needs, long-term evolution and stability was largely offset by the flexibility and robustness of a simple design, as well as the consistency of a unique development line where the users' investment in code and algorithms has been preserved over more than a decade.

The design of the analysis framework also relied directly on the facilities provided by the ROOT framework. We used the ROOT tasks to implement the so called "analysis train", where one event is read in memory and then passed to the different analysis tasks, which are linked like wagons of a train. Virtuality with respect to the data is achieved via "readers" that can accept different kinds of input and take care of the format conversion. At ALICE we have two analysis objects: the event summary data (ESD) that result from the reconstruction and the analysis object data (AOD) in the form of compact event information derived from the ESD. AODs can be customized with additional files that add information to each event without the need to rewrite them (the delta-AOD). Figure 1 (p31) gives a schematic representation that attempts to catch the essence of AliRoot.

The framework is such that the same code can be run on a local workstation, or on a parallel system enabled by the "ROOT Proof" system, where different events are dispatched to different cores, or on the Grid. A plug-in mechanism takes care of hiding the differences from the user.

The early transition to C++ and the "burn the bridge" approach encouraged (or rather compelled) several senior physicists to jump the fence and move to the new language. That the framework was there more than 10 years before data-taking began and that its principles of operation did not change during its evolution allowed several of them to become seasoned C++ programmers and AliRoot experts by the time that the detector started producing data.

AliRoot today

Today's AliRoot retains most of the features of the original even if the code provides much more functionality and is correspondingly more complex. Comprising contributions from more than 400 authors, it is the framework within which all ALICE data are processed and analysed. The release cycle has been kept nimble. We have one update a week and one full new release of AliRoot every six months. Thanks to an efficient software-distribution scheme, the deployment of a full new version on the Grid takes as little as half a day. This has proved useful for "emergency fixes" during critical productions. A farm of "virtual" AliRoot builders is in continuous operation building the code on different combinations of operating system and compiler. Nightly builds and tests are automatically performed to assess the quality of the code and the performance parameters (memory and CPU).

Fig. 2. Live monitoring of the nodes in the ALICE Grid.

The next challenge will be to adapt the code to new parallel and concurrent architectures to make the most of the performance of the modern hardware, for which we are currently exploiting only a small fraction of the potential. This will probably require a profound rethinking of the class and data structures, as well as of the algorithms. It will be the major subject of the offline upgrade that will take place in 2013 and 2014 during the LHC's long shutdown. This challenge is made more interesting because new (and not quite compatible) architectures are continuously being produced.

An AliEn runs the Grid

Work on the Grid implementation for ALICE had to follow a different path. The effort required to develop a complete Grid system from scratch would have been prohibitive and in the Grid world there was no equivalent to ROOT that would provide a solid foundation. There was, however, plenty of open-source software with the elements necessary for building a distributed computing system that would embody major portions of the Grid "vision".

Following the same philosophy used in the development of AliRoot, but with a different technique, we built a lightweight framework written in the Perl programming language, which linked together several tens of individual open-source components. This system used web services to create a "grid in a box" – a "shrink-wrapped" environment, called Alice Environment or AliEn – or implement a functional Grid system, which already allowed us to run large Monte Carlo productions as early as 2002. From the beginning, the core of this system consisted of a distributed file catalogue and a workload-management system based on the "pull" mechanism, where computer centres fetch appropriate workloads from a central queue.

AliEn was built as a metasystem from the start with the aim of presenting the user with a seamless interface while joining together the different Grid systems (a so-called overlay Grid) that harness the various resources. As AliEn could offer the complete set of services that ALICE needed from the Grid, the interface with the different systems consisted of replacing

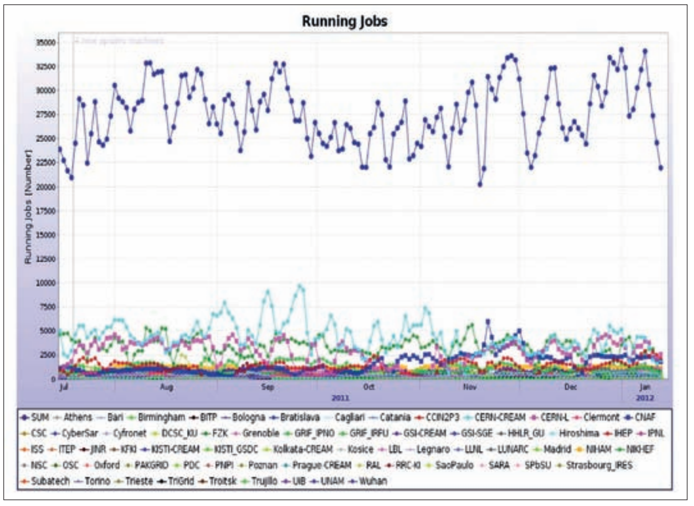


Fig. 3. A screenshot of jobs executing on the ALICE Grid during the second half of 2011.

as far as possible the AliEn services with the ones of the native Grids.

This has proved to be a good principle because the Advanced Resource Connector (ARC) services of the NorduGrid collaboration are now integrated with AliEn. ALICE users access transparently three Grids (EGEE, OSC and ARC), as well as the few remaining native AliEn sites. One important step was achieved with the tight integration of AliEn with the MonALISA monitoring system, which allows large quantities of dynamic parameters related to the Grid operation to be stored and processed. This integration will continue in the direction of provisioning and scheduling Grid resources based on past and current performance, and load as recorded by MonALISA.

The AliEn Grid has also seen substantial evolution, its core components having been upgraded and replaced several times. However, the user interface has changed little. Thanks to AliEn and MonALISA, the central operation of the entire ALICE Grid takes the equivalent of only three or four full-time operators. It routinely runs complicated job chains fully automated at all times, totalling an average of 28 000 jobs in continuous execution on 80 computer centres in four continents (figure 3).

The next step

Despite the generous efforts of the funding agencies, computing resources in ALICE remain tight. To alleviate the problem and ensure that resources are used at the maximum efficiency, all ALICE computing resources are pooled into AliEn. The corollary is that the Grid is the most natural place for all ALICE users to run any job that exceeds the capacity of a laptop. This has put considerable stress on the ALICE Grid developers to provide a friendly environment, where even running short, test jobs on the Grid should be as simple and fast as running them on a personal computer. This still remains the goal but much ground has been covered in making Grid usage as transparent and efficient as possible; indeed, all ALICE analysis is performed on the Grid. Before a major conference, it is not uncommon to see more than half of the total Grid resources being used by private-analysis jobs.

The challenges ahead for the ALICE Grid are to improve the optimization tools for workload scheduling and data access, thereby increasing the capabilities to exploit opportunistic computing resources. The availability of the comprehensive and highly optimized monitoring tools and data provided by MonALISA are assets that have not yet been completely exploited to provide predictive provisioning of resources for optimized usage. This is an example of a "boundary pushing" research subject in computer science, which promises to yield urgently needed improvements to the everyday life of ALICE physicists.

It will also be important to exploit interactivity and parallelism at the level of the Grid, to improve the "time-to-solution" and to come a step closer to the original Grid vision of making a geographically distributed, heterogeneous system appear similarly to a desktop computer. In particular, the evolution of AliRoot to exploit parallel computing architectures should be extended as seamlessly as possible from multicore and multi-CPU machines – first to different machines and then to Grid nodes. This implies both an evolution of the Grid environment as well as the ALICE software, which will have to be transformed to expose the intrinsic parallelism of the problem in question (event processing) at its different levels of granularity.

Although it is difficult to define success for a computing project in high-energy physics, and while ALICE computing certainly offers much room for improvement, it cannot be denied that it has fulfilled its mandate of allowing the processing and analysis of the initial ALICE data. However, this should not be considered as a result acquired once and for all, or subject only to incremental improvements. Requirements from physicists are always evolving – or rather, growing qualitatively and quantitatively. While technology offers the possibilities to satisfy these requirements, this will entail major reshaping of ALICE's code and Grid tools to ride the technology wave while preserving as much as possible of the users' investment. This will be a challenging task for the ALICE computing people for years to come.

• Further reading

For more about the evolution of computing in high-energy physics, see: *From the Web to the Grid and Beyond. Computing Paradigms Driven by High-Energy Physics* by René Brun, Federico Carminati and Giuliana Galli Carminati (eds.) 2012 Springer.

Résumé

L'informatique d'ALICE

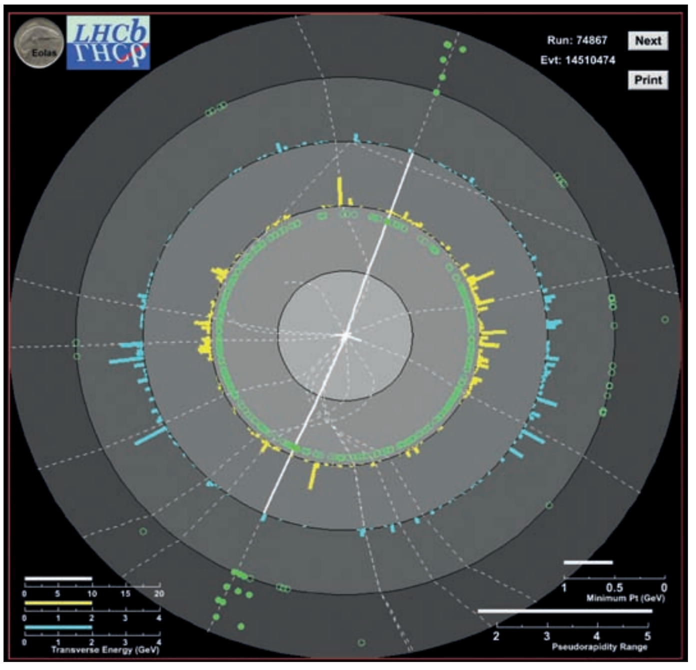
L'environnement logiciel d'ALICE (AliRoot) a vu le jour en 1998, à un moment où le calcul pour la physique des hautes énergies devait affronter une mission difficile. Une communauté de plusieurs milliers d'utilisateurs et de développeurs devait abandonner un langage de procédure (FORTRAN) utilisé depuis 40 ans pour adopter un langage à objets (C++) dont elle n'avait pas l'expérience. En même temps, il fallait faire la transition pour passer de centres de calcul plus ou moins reliés à un système de grille fortement intégré. Dans cet article, Federico Carminati décrit comment la collaboration ALICE a répondu à ces changements.

Federico Carminati, CERN.

LHCb looks forward to electroweak physics

Best known as an experiment to investigate subtle differences between matter and antimatter, LHCb also has a full programme of studies in electroweak physics that will test the Standard Model with high precision.

LHCb is one of the four large experiments at the LHC. It was designed primarily to probe beyond the Standard Model by investigating CP violation and searching for the effects of new physics in precision measurements of decays involving heavy quarks, b quarks in particular. At the LHC, pairs of particles (B and $\bar{B}$ mesons) containing these quarks are mainly produced in the direction of the colliding protons, that is, in the same forward or backward cone about the beam line. For this reason, LHCb was built as a single-arm forward spectrometer that covers production angles close to the beam line with full particle detection and tracking capability – closer even than the general-purpose experiments, ATLAS and CMS. This gives LHCb the opportunity to study the Standard Model in regions that are not easily accessible to ATLAS and CMS. In particular, the experiment has an active and rapidly developing programme of electroweak physics that is beginning to test the Standard Model in several unexplored regions.



The decay of a Z boson to two muons (thick white lines) in the LHCb experiment. The green dots show where the particles pass through the muon chambers. Electroweak physics at LHCb includes measurements of the production of Z and W bosons.

Closer to the beam

Particle production at collider experiments is usually described in terms of pseudorapidity, defined as $\eta = -\ln(\tan\theta/2)$, where θ is the angle that the particle takes relative to the beam axis. The particles tend to be produced in the forward direction: that is crowded into small values of θ, while in terms of η, they are spread more uniformly. The inverse relationship means that the closer a particle is to the beam line, the larger its pseudorapidity. LHCb's forward spectrometer is fully instrumented in the range $2 < \eta < 5$, a portion of which ($2 < \eta < 2.5$) is also covered by ATLAS and CMS. However, the forward region at $\eta > 2.5$ – roughly between 10° and 0.5° to the beam – is unique to LHCb, thanks to its full complement of particle detection.

LHCb can explore electroweak physics through the production of W and Z bosons, as well as virtual photons. The experiment can trigger on and reconstruct muons with low momentum $p_\mu > 5$ GeV and transverse momentum $p_{T\mu} > 1$ GeV, giving access to low values of the muon-pair invariant mass $m_{\mu\mu} > 2.5$ GeV. Specialist triggers can even explore invariant masses below 2.5 GeV in environments of low multiplicity. Coupled with the forward geometry, this reconstruction capability opens up a large, previously unmeasured kinematic region.

Figure 1 (overleaf) shows the kinematic regions that LHCb probes in terms of x, the longitudinal fraction of the incoming proton's momentum that is carried by the interacting parton (quark or gluon), and Q^2, the square of the four-momentum exchanged in the hard scatter. Because of the forward geometry, the momenta of the two interacting partons are highly asymmetric in the particle-production processes detected at

LHCb has a programme of electroweak physics that is testing the Standard Model in unexplored regions.

LHCb. This means that LHCb can simultaneously probe not only a region at high-x that has been explored by other experiments but also a new, unexplored region at small values of x. The high rapidity range and low transverse-momentum trigger thresholds for muons allow potential exploration of Q^2 down to 6.25 GeV^2 and x down to 10^{-6}, thus extending the region that was accessible at HERA, the electron–proton collider at DESY.

The aim is to probe and constrain the parton-density functions (PDFs) – basically, the probability density for finding a parton with longitudinal momentum fraction x at momentum transfer Q^2 – in the available kinematic regions. The PDFs provide important input to theoretical predictions of cross-sections at the LHC and at present they dominate the uncertainties in the theoretical calculations, which now include terms up to next-next-to-leading order (NNLO).

Using data collected in 2010, the LHCb collaboration measured the production cross-sections of W and Z bosons in proton–proton collisions at a centre-of-mass energy of 7 TeV, based on an analysis of about 36 pb^{-1} of data (LHCb collaboration 2011a). Although only a small fraction of W and Z bosons enter the acceptance of the experiment (typically 10–15%), the large production cross-sections ensure that the statistical error on these measurements is small. The results are consistent with NNLO predictions that use a variety of models for the PDFs. With greater statistics, the measurements will begin to probe differences between these models.

The uncertainty in luminosity dominates the precision to which cross-sections can be determined, so the collaboration also measures ratios of W and Z production, which are insensitive to this uncertainty, as well as the charge asymmetry for W production, $A_W = (\sigma_{W+} - \sigma_{W-} / \sigma_{W+} + \sigma_{W-})$. Figure 2 shows the results for A_W overlaid with equivalent measurements by ATLAS and CMS. It illustrates how the kinematic region explored by LHCb is complementary to that of the general-purpose detectors and extends the range that can be tested at the LHC. It is also apparent that LHCb's acceptance probes the region where the asymmetry is changing rapidly, so the measurements are particularly sensitive to the parameters of the various PDF models.

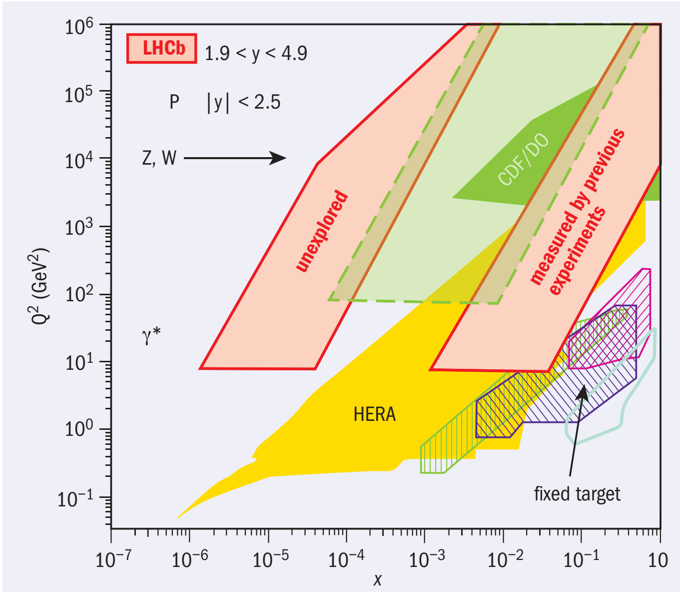


Fig. 1. The x-Q^2 kinematic region explored by the LHCb experiment (pink), compared with ATLAS and CMS (light green), as well as previous measurements.

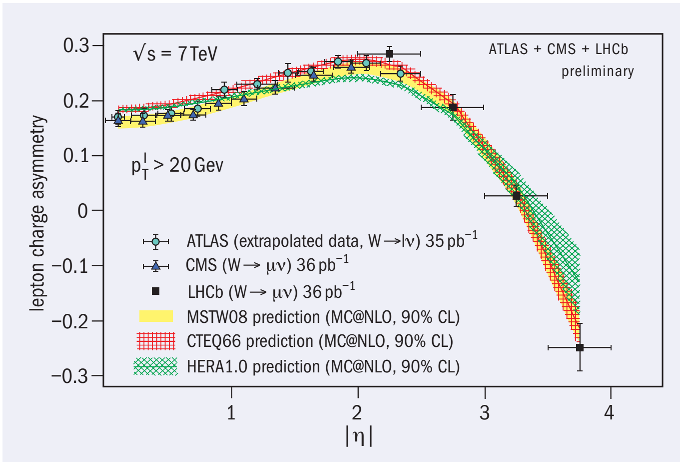


Fig. 2. LHCb's measurement of W charge asymmetry, shown as a function of lepton pseudorapidity, compared with next-to-leading order (NLO) predictions, including results from the ATLAS and CMS experiments.

Low-momentum muons

The LHCb collaboration also plans to increase the probing power of the cross-section measurements by improving the uncertainty in the luminosity itself. Work is ongoing to measure the exclusive production of pairs of muons, a QED process that should ultimately yield a more precise indirect measure of integrated luminosity. Although instrumented in the forward region, LHCb has some tracking coverage in the region $-1.5 < \eta < -4$ because the proton–proton collision point lies a little way inside the main tracking detector. The measurement exploits this acceptance, LHCb's ability to trigger on muons with low momentum and the low pile-up environment of collisions at LHCb, which allows the identification of these low multiplicity, exclusively produced events. First measurements based on 2010 data show that the measurement is feasible (LHCb collaboration 2011b). Updated measurements based on the 2011 data set are underway.

In high-energy hadron–hadron scattering the production of Z and W bosons, which decay into lepton pairs, occurs as a Drell-Yan process in which a quark in one hadron interacts with an antiquark in the other hadron to produce a W or a Z or a virtual photon, which then produces a lepton pair of opposite charges. With its ability to trigger on and identify muons with low transverse-momentum, LHCb can measure the production of muon pairs from Drell-Yan production down to invariant masses approaching 5 GeV. As figure 1 shows, these measurements probe values of x around 10^{-5} and can be used to improve knowledge of the behaviour of gluons inside the proton, building on the knowledge gained at HERA.

These and other production studies are being updated for the upcoming 20th International Workshop on Deep-Inelastic Scattering that takes place in Bonn on 26–30 March. The first measurements using electron final-states will also be available soon, as will those on the production of Z bosons in association with jets. The ▷

latter will open the way to more direct probes of the PDFs, once the jets can tagged by flavour (for example, a measurement of the production of a W boson together with a charm jet will allow constraints to be placed on the behaviour of the strange quark inside the proton).

The forward acceptance of LHCb also provides unexpected advantages for other measurements. The further forward in pseudorapidity that final states are produced, the more likely they are to arise from interactions between a valence quark in one proton and an antiquark in the "sea" of the other proton. This is in contrast to the ATLAS and CMS experiments, which experience predominately sea–sea collisions. The measurement of the forwards–backwards asymmetry of Z bosons, which is sensitive to the electroweak mixing angle, $\sin^2\theta_W$, benefits from this ability to define a "forward" incoming-quark direction. Studies show that LHCb can identify this correctly in more than 90% of events that have boson rapidities above 3 (McNulty 2011). PDF uncertainties are also reduced in this region. This gives the LHCb experiment the potential to reach the precision of a typical measurement of $\sin^2\theta_W$ at the Large Electron–Positron collider, even with the data set of 1 fb^{-1} already recorded.

Studies of the production of the top quark could also benefit from LHCb's detection system. Although the production rate for top inside LHCb is small at 7 TeV, at 14 TeV the rate should be large enough to make measurements viable. At this centre-of-mass energy, top-pairs are produced by quark–antiquark annihilation twice as often inside the forward region of LHCb's acceptance as they are in the central region. A measurement of the $t\text{-}\bar{t}$ asymmetry with LHCb could give a direct and comparable cross-check of the recent result from Fermilab's Tevatron.

Electroweak physics at LHCb may not have been part of the original programme, but the future prospects are bright.

● Further reading

LHCb collaboration 2011a LHCb-CONF-2011-012; LHCb-CONF-2011-039; LHCb-CONF-2011-041.

LHCb collaboration 2011b LHCb-CONF-2011-022.

R McNulty 2011 https://indico.cern.ch/conferenceOtherViews.py?view=standard&confId=118357.

Résumé

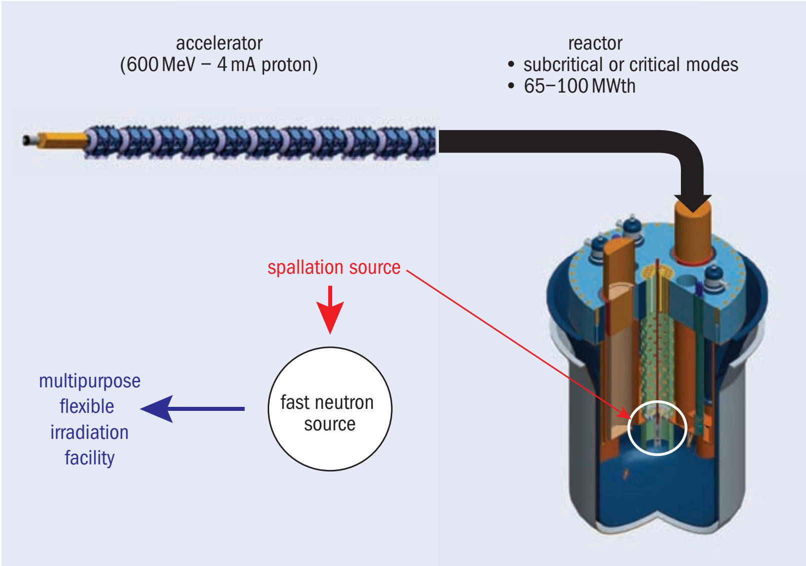
LHCb se tourne vers la physique électrofaible

S'intéressant à la production de mésons B au LHC, l'expérience LHCb a été conçue pour couvrir les angles de production de particules à proximité de la ligne de faisceaux, avec une capacité de détection de particules et de trajectographie complète. L'expérience travaille au plus près du faisceau, et de ce fait, elle a la possibilité d'étudier le Modèle standard dans des régions qui ne sont pas facilement accessibles aux deux grandes expériences généralistes, ATLAS et CMS. En particulier, LHCb mène à bien un programme vigoureux, et en plein développement, de physique électrofaible, qui commence à tester le Modèle standard dans plusieurs régions encore inexplorées.

Tara Shears, University of Liverpool, on behalf of the LHCb collaboration.

Mumbai engages ADS for nuclear energy

Researchers gathered in India recently to review the progress and outlook in accelerator-driven systems for power generation and nuclear-waste management.



The principle behind the MYRRHA project is to build a €960 million subcritical research reactor at the Belgian Nuclear Research Centre, SCK•CEN, to demonstrate the ADS concept. (Image credit: MYRRHA.)

On 11–14 December, the city of Mumbai was the setting for the Second International Workshop on Accelerator Driven Sub-Critical Systems and Thorium Utilization. Only a month later, a team in Belgium announced the first successful operation of GUINEVERE, a prototype lead-cooled nuclear reactor driven by a particle accelerator – one of the milestones in progress towards the type of accelerator-driven system (ADS) envisioned in Mumbai.

Today's nuclear reactors are based on a core with fissile fuel configured such that neutrons emitted in the fission process can maintain a chain reaction. In an ADS, by contrast, the neutrons necessary to establish a sustainable fission chain reaction are knocked out of a spallation target by high-energy protons from an accelerator. Because these neutrons are produced externally from the core, an ADS reactor has a great deal of flexibility in the elements and isotopes that can be fissioned. Indeed, the ADS – long advocated by Nobel laureate Carlo Rubbia – is increasingly seen as offering promise for nuclear-waste transmutation and for generating electricity from thorium, uranium or spent nuclear fuel (Clements 2012 and *CERN Courier* November 2011 p54).

Setting the scene

The Mumbai workshop attracted 160 researchers from nine countries to discuss developments in this burgeoning field. Srikumar Banerjee, chair of India's Department of Atomic Energy, opened the workshop by welcoming all of the participants and providing an overview of India's efforts in ADS research. He described several thrusts in the country's R&D programmes: development of a low-energy (20 MeV) accelerator front end; design studies for a 1 GeV, 30 mA superconducting RF (SRF) linac; and development of a spallation neutron source. He also emphasized the importance of thorium in India's three-phase, long-term development strategy for nuclear power, as well as the key role of the ADS concept both for power production and for management of minor actinides and used nuclear fuel.

Kumar Sinha, director of the Bhabha Atomic Research Centre (BARC) in Mumbai, which hosted the workshop, also spoke during the opening session. He discussed some of the challenges facing the ADS scientific community and stressed the value of international collaboration in large-scale projects of this kind, where it is important to co-ordinate efforts and optimize the use of financial and human resources.

The workshop convener, K C Mittal of BARC, outlined the overall context of the meeting – in particular the wish of India to exploit a thorium-based ADS to enhance the sustainability, safety and the proliferation resistance of nuclear-power generating systems. He noted that researchers worldwide have proposed innovative physics concepts and that several laboratories have succeeded in the design and construction of the new generation of accelerator required. Mittal underlined SRF accelerating technology and noted the potential importance of ▷

An ADS reactor has a great deal of flexibility in the elements and isotopes that can be fissioned.

Accelerators

Ingot-niobium cavity sets world record

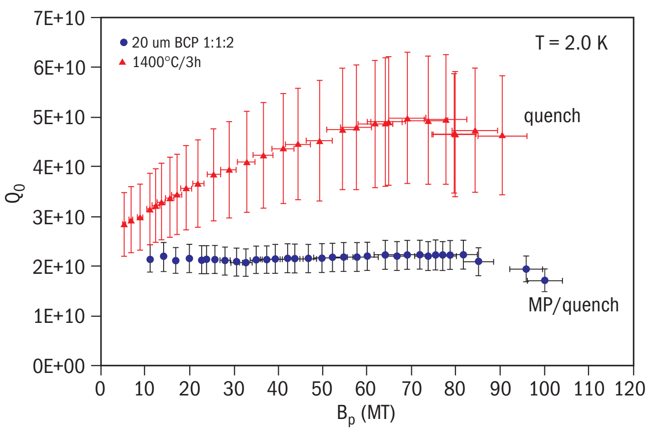
Linear arrays of SRF accelerating-cavities that are expensive and difficult to produce could constitute the heart of a future ADS. At December's workshop in Mumbai, Ganapati Rao Myneni – representing several scientific organizations and universities in Virginia in the US – discussed a cost-reducing approach to production of the cavities: fabrication directly from ingot niobium. Just two months later, in February, a laboratory test at Jefferson Lab using a cavity built from medium-purity ingot niobium reached a world record for the cavity quality factor Q_0.

The implications are enhanced accelerator performance with substantially lower costs because the high Q reduces the cost of the cryogenic plant and halves the operating cost.

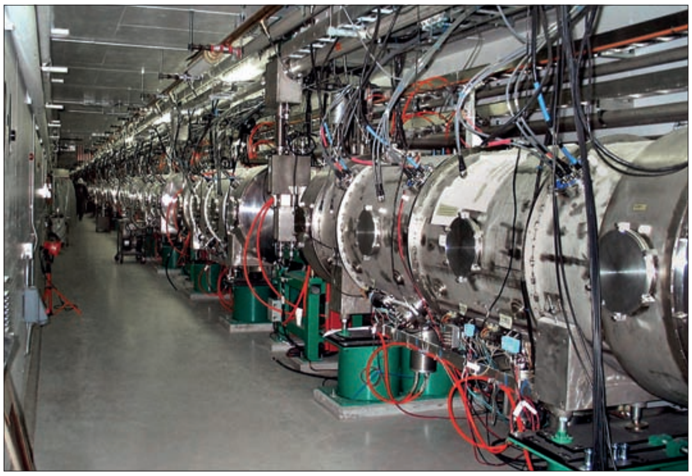
The cavity that was tested has a single cell of the shape originally used in the five-cell SRF cavities in the CEBAF machine at Jefferson Lab. CBMM, a company in Brazil, supplied the ingot niobium, which was of medium purity and had a residual resistivity ratio (RRR) of around 200 and a high tantalum content (about 1375 wt. ppm). The cavity was heat-treated in an ultrahigh-vacuum (UHV) induction furnace at 1400°C for three hours, followed by a high-pressure rinse with ultrapure water. Tested at 2.0 K, it reached a world-record Q_0 of 4.63×10^{10} at a peak surface-magnetic field (B_p) of about 90 mT, equivalent to an accelerating gradient of some 20 MV/m.

The team of researchers says that, to their knowledge, this is the highest Q_0 measured at that temperature and field. The measured value is about four times higher than, for example, the average Q_0 (2.0 K, 70 mT) of the "C100" cavities for the 12 GeV upgrade to CEBAF. The surface resistance was measured as a function of temperature at low field (with B_p around 10 mT) and a residual resistance of 1.0 ± 0.2 nΩ was obtained.

The researchers believe that the test shows an important proof of principle. It shows that to minimize cryogenic RF losses, fine-grain (ASTM 5) niobium of high purity (RRR > 300) and low tantalum content (< 600 wt. ppm) – properties that increase the price significantly – are not necessary. It also indicates that high-temperature heat treatment in a clean UHV furnace reduces the RF losses.



Results from the SRF cavity tests at Jefferson Lab in February. The results in blue are for ingot-niobium cavities processed by established methods; the red results show that the cavity quality factor Q nearly doubled with heat treatment to reach a world-record value.



The superconducting RF proton linac at the SNS at Oak Ridge National Laboratory is providing valuable experience for a future ADS accelerator. (Image credit: ORNL.)

using ingot niobium for cost savings (see box). He also highlighted the continued ADS-related developments in India and China, at Belgium's Multi-purpose hYbrid Research Reactor for High-tech Applications (MYRRHA) and for the European Spallation Source (ESS), which is being built in Lund, Sweden.

Hamid Aït Abderrahim spoke about MYRRHA, the project to build a €960 million subcritical research reactor at the Belgian Nuclear Research Centre SCK•CEN (Studiecentrum voor Kernenergie, Centre d'Etude de l'énergie Nucléaire), which is scheduled to become operational in 2023. The centre is also the site of the GUINEVERE demonstration model, which is seen as a key step for developing procedures for regulating and controlling the operation of future subcritical reactors such as MYRRHA. The objectives for MYRRHA are to demonstrate the ADS concept at a significant power level and to prove the technical feasibility of transmuting minor actinides and long-lived fission products. Belgium welcomes international participation in the MYRRHA consortium, with eligibility based on a balanced in-cash/in-kind contribution to the project.

The technological advances for neutron spallation sources, such as the ESS, have obvious relevance for an ADS. Each type of facility requires a high-power, high-intensity linac to provide a proton beam for generating neutrons by spallation. A big difference, however, is the relative stringency of requirements for reliability, as measured by the rate at which faults trip the accelerator off-line. Colin Carlile reported on the outlook for ESS, noting that there are five spallation sources in four countries but, unlike the others, the ESS will produce neutrons in millisecond-scale bursts rather than on the microsecond scale. The linac will operate at 2.5 GeV, with 50 mA peak and 2 mA average current for 5 MW of proton-beam power with a 357 kJ/pulse. The ESS has 17 partners and expects to be the world's best source of slow neutrons. They aim to begin producing neutrons in 2019.

The Spallation Neutron Source (SNS) at Oak Ridge National Laboratory in Tennessee in the US has an SRF proton linac that is sometimes seen as being close to a proof of principle for an ADS accelerator. The SNS now has two years of experience at the megawatt level, having reached 1 MW within three years of operation. John Galambos of Oak Ridge summarized information on SNS operation that is pertinent to an ADS. He said that initial proton experiments indicate a favourable beam loss for an ADS and that although the SNS was never designed for low trip rates, the declining trip rate seems encouraging. Data from 2008, which are still considered current and applicable, indicate that four of the world's neutron facilities have roughly similar performance: many tens of trips a day lasting more than a minute, with far fewer than one trip a day lasting more than three hours.

Not all of ADS approaches call for SRF linacs. Swapan Chattopadhyay of the Cockcroft Institute in the UK told workshop participants about research into an ADS using a novel fixed-field, alternating-gradient driver. Collaborators in this effort represent PSI in Switzerland, Fermilab in the US, the International Atomic Energy Agency in Vienna, the Japan Proton Accelerator Research Complex, MYRRHA, ESS and BARC. In Japan itself, meanwhile, efforts are focusing on SRF, as Akira Yamamoto of KEK explained – but overlap with R&D for a future International Linear Collider and for energy-recovering linacs. KEK foresees building an in-house SRF fabrication and test facility.

As of early 2012, no government-funded ADS initiatives for nuclear-waste disposal or power generation are underway in the US. Nevertheless many of the country's scientists and engineers are actively working in ADS-related efforts. Two high-power accelerators, both built by Jefferson Lab, already operate with SRF technology: the SNS at Oak Ridge and Jefferson Lab's own Continuous Electron Beam Accelerator Facility (CEBAF). A third project, the SRF-based Project X, is in the design and prototyping stage at Fermilab and is foreseen to serve several scientific purposes with 3 GeV, 3 MW protons.

CEBAF pioneered the large-scale application of SRF when it became operational for nuclear-physics experiments in the mid-1990s at 4 GeV (*CERN Courier* May 2003 p35). It progressed to operate at 6 GeV and 1 MW through incremental improvements in technology. Researchers there have sought to reduce RF trips and develop tools to characterize them. A consortium of Virginia universities, industrial partners and Jefferson Lab has been established to pursue ADS R&D while preparing to host an ADS facility.

The efforts of the Virginia consortium fall in line with the sentiments of the September 2010 white paper written by 13 scientists from laboratories in the US and Europe, which was published by the US Department of Energy's Office of Science: 'Accelerator and Target Technology for Accelerator Driven Transmutation and Energy Production' (Aït Abderrahim *et al.* 2010). The paper notes that many of the key technologies required for industrial-scale transmutation requiring tens of megawatts of beam power, including front-end systems and accelerating systems, have already been demonstrated. The report also points out, however, that demonstration is still required for other components, such as those that enable improved beam quality and halo control, as well as highly reliable subsystems.

At Mumbai, an informal international collaboration to attack these and other ADS challenges continued to coalesce. Participants recognized the magnitude of the challenges that must be overcome for an ADS scheme to be completely successful: well thought-out, long-term development plans and international collaboration are going to be indispensable for its realization. One of the strengths of the workshop was that it gathered experts from the various subfields relevant to an ADS and gave them the opportunity to discuss the different struggles that they each face while still achieving optimization for the overall system. With this in mind, participants decided to meet again next year for a third International Workshop on Accelerator Driven Sub-Critical Systems, probably in Europe.

		transmutation demonstration	industrial-scale transmutation	power generation
front-end system	performance	green	green	green
	reliability	yellow	yellow	red
accelerating system	RF structure development and performance	green	green	green
	linac cost optimization	green	yellow	yellow
	reliability	yellow	yellow	yellow
RF plant	performance	green	green	green
	cost optimization	green	yellow	yellow
	reliability	yellow	yellow	red
beam delivery	performance	green	green	green
target systems	performance	green	yellow	yellow
	reliability	yellow	yellow	yellow
instrumentation and control	performance	green	yellow	yellow
beam dynamics	emittance/halo growth/beam loss	green	yellow	yellow
	lattice design	green	yellow	yellow
reliability	rapid SCL fault recovery	yellow	red	red
	system reliability engineering analysis	yellow	red	red

Assessment of the readiness of the technology required for an ADS system as presented in the white paper in September 2010 (Aït Abderrahim et al. *2010). Green indicates "ready", yellow indicates "may be ready, but demonstration or further analysis is required", red indicates "more development is required".*

• Further reading

For more about the workshop and presentations, see www.ivsnet.org/ADS/ADS2011/.

H Aït Abderrahim *et al.* 2010, http://science.energy.gov/~/media/hep/pdf/files/pdfs/ADS_White_Paper_final.pdf.

E Clements 2012 *Symmetry* **9** no. 1 p22.

A European report can be found at www.nea.fr/ndd/reports/2002/nea3109.html.

Résumé

Atelier de Mumbai : des accélérateurs pour l'énergie nucléaire

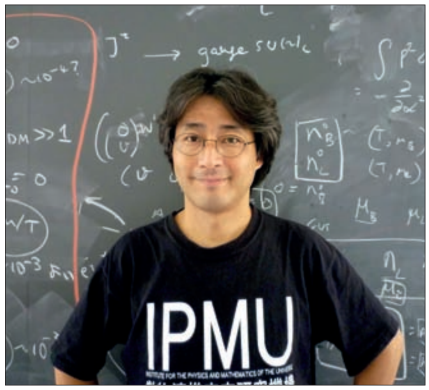
Les réacteurs nucléaires d'aujourd'hui fonctionnent avec un cœur de combustible fissile, dans lequel les neutrons émis dans le processus de fission peuvent maintenir une réaction en chaîne. Au contraire, dans un système par accélérateur, les neutrons nécessaires pour la réaction en chaîne sont extraits d'une cible par des protons de haute énergie issus d'un accélérateur. Ces systèmes sont vus, de plus en plus, comme prometteurs pour la transmutation des déchets nucléaires et pour la production d'énergie à partir de thorium, d'uranium ou de combustible nucléaire usagé. Un atelier sur ce thème, tenu à Mumbai du 11 au 14 décembre, a rassemblé 160 chercheurs en provenance de plusieurs pays, qui ont pu confronter leurs expériences dans ce domaine en plein développement.

Sama Bilbao y León, Virginia Commonwealth University.

Faces & Places

JAPAN

IPMU joins the Kavli family of institutes



The Kavli IPMU building, left, and director Hitoshi Murayama, who is delighted that the endowment will help sustain the research programme. (Image credit: Kavli IPMU.)

The University of Tokyo has announced the establishment of an endowment by the Kavli Foundation for the Institute for the Physics and Mathematics of the Universe (IPMU). The institute, which will now be known as the Kavli IPMU, probes the mysteries of modern cosmology through collaborative research conducted by a range of scientists, including mathematicians, theoretical physicists, experimental physicists and astronomers. Together they focus on topics such as dark matter, dark energy and the possibility of a single unified theory that can explain the cosmos at the smallest and largest scales.

The Kavli Foundation, based in Southern California, sponsors research in astrophysics, nanoscience, neuroscience and theoretical physics at institutes in countries across the globe, including China, the Netherlands, Norway, the UK and the US. Kavli IPMU is the foundation's 16th institute, its sixth in astrophysics, third in theoretical physics and the first to be established in Japan.

The Kavli IPMU, housed on the Kashiwa campus, outside Tokyo in the Chiba prefecture, has a team of around 200 researchers from 15 fields, with almost half coming from outside Japan. The director is Hitoshi Murayama, a particle physicist from the University of California, Berkeley, who works on subjects ranging from developing strategies for new particle-collider experiments to dark-matter theory and models of physics beyond the standard explanation for the nature of the universe. Deputy directors include Hiroaki Aihara, a particle physicist who is working on a new survey of distant galaxies to learn about the nature of dark energy, and Yoichiro Suzuki, who is heavily involved in an underground experiment to detect dark matter.

IPMU was established in 2007 as part of the World Premier International (WPI) Research Center Initiative, a programme by the Japanese government to promote interdisciplinary science in Japan, its international visibility and the globalization of Japanese universities. Proposed as part of the University of Tokyo, the IPMU was one of six research proposals around the country to win sponsorship from the ministry of education, culture, sports, science and technology. Other WPI institutes are involved in materials research, cell biology, immunology, nanotechnology and alternative-energy development.

Although it receives funding support from the government and the university, IPMU must eventually identify other sources of support for it to become a permanent research centre. "The endowment income will help sustain the research programme at the Kavli IPMU beyond the current initiative by the Japanese government," Murayama said. "Now we can press on to attack the most basic and biggest mysteries of the universe."

APPOINTMENT

Rossi named deputy associate director for nuclear physics at Jefferson Lab

Patrizia Rossi will become the deputy associate director for experimental nuclear physics at Thomas Jefferson National Accelerator Facility in May.

Rossi received a degree from the University of Rome in 1986 and a fellowship from INFN in 1988, before joining the Laboratori Nazionali di Frascati (LNF-INFN) as a staff researcher in 1990. Her research has focused on studying the structure of the nucleon and the strong force, which are areas of major emphasis at Jefferson Lab. In addition to working at Jefferson Lab and laboratories in Italy, Rossi also has conducted experiments at DESY and the European Synchrotron Radiation Facility in Grenoble.

Since 2003 she has served as co-spokesperson and LNF co-ordinator of Italian participation at Jefferson Lab and became a member of the laboratory's Program Advisory Committee in March 2010. She has collaborated on more than 160 refereed journal papers and has served as a member of numerous conferences and workshops.

Patrizia Rossi to become deputy associate director. (Image credit: Jefferson Lab.)

AWARDS

French Physical Society honours Daniel Fournier

Daniel Fournier, of the Laboratoire de l'Accélérateur Linéaire, has been awarded the Jean Ricard prize by the French Physical Society (SFP). He was presented with the award by Martial Ducloy, president of the SFP, in a ceremony at Orsay on 17 February, attended by many of his friends and colleagues. Fournier worked on the CELLO experiment at DESY and on NA31 and ATLAS at CERN, where he designed the "accordion" liquid-argon electromagnetic calorimeter for ATLAS.

The Jean Ricard prize is the SFP's most prestigious award and has been awarded to an experimental high-energy physicist only a few times since its creation in 1970. The former recipients in experimental high-energy physics are Georges Charpak, Paul Musset, Marcel Banner, Yves Declais and Alain Blondel.

Daniel Fournier, middle, with Ken Peach, former chair of CERN's scientific policy committee, left, and Martial Ducloy, president of the SFP, right.

OUTREACH

All you need to know in three minutes

Boris Lemmer, a PhD student at the Georg-August-Universität Göttingen on the ATLAS experiment, has moved a step nearer to international fame by winning the Geneva semi-final of the Swiss FameLab, following his victory in a recent "science slam" in Hanover (*CERN Courier* December 2011 p46). Twenty-two young scientists participated in the FameLab semi-final at CERN's Globe of Science and Innovation on 4 February, supported by a large audience and by more than 100 fans following via webcast. A panel of judges chose Lemmer and four other candidates to join five other semi-finalists at the national finals in Zurich on 30 March.

FameLab is an international competition to find the new voices of science and engineering. It was started in 2005 by the Cheltenham Science Festival in partnership with the National Endowment for Science, Technology and the Arts, and has grown to include 20 countries. In the competition, young scientists have three minutes to present their research in an entertaining and original way, understandable to a broad audience. Switzerland is participating this year for the first time.

Boris Lemmer wins the Geneva semi-final of the inaugural Swiss FameLab.

● For a video of the Geneva semi-final, see http://cdsweb.cern.ch/record/1421673.

Fabiola Gianotti, spokesperson of the ATLAS collaboration, was awarded the degree of Doctor Honoris Causa *at Uppsala University on 27 January. She received the degree, which was conferred by Tord Ekelöf, for her distinguished research career in experimental elementary-particle physics research at CERN's particle colliders and for her outstanding scientific leadership.*

Gianotti has conducted research at CERN at the Super Proton Synchrotron running as a proton–antiproton collider and at the Large Electron–Positron collider. She is now with the ATLAS experiment at the LHC. Researchers at Uppsala University form one of the 167 groups around the world that are members of the ATLAS collaboration. (Image credit: Uppsala University.)

Faces & Places

Schools

Singapore and CERN collaborate in winter school

A three-week school on Particle Physics, Cosmology and Implications for Technology took place in January, organized by the Institute of Advanced Studies (IAS) at Nanyang Technological University (NTU), in Singapore, with the participation of CERN. The participants ranged from undergraduates to graduates, postdocs and research faculty. More than 90 students attended, including 59 overseas and 33 local participants; of these, 18 were female students. Among the overseas participants, 27% came from mainland China and Taiwan, 20% from India, 12% each from Thailand and Indonesia, 7% each from Iran and Malaysia, and the remainder from Vietnam, the Philippines, Hong Kong, Russia, Korea and the US.

The school was designed to fill the need of many of the young students and researchers who have returned to their home countries to keep up with the latest discoveries and advances in the field. Major research centres have traditionally organized summer and winter schools to fill this need – for example, at Boulder, Colorado, in the US and at CERN, Les Houches and Erice in Europe. The winter school in Singapore is the first such advanced school to be held at the IAS.

In addition to lectures, tutorial sessions in the afternoon allowed the students – including undergraduates – to ask probing questions of the experts. The spirit was to reflect the effort at Lindau and the International Science Youth Forum to bring inquiring young minds into contact with frontier scientists. Lecturers included John Ellis, Harald Fritzsch, Ignatios Antoniadis, Serguey Petcov, Albert DeRoek, Barbara Jacak, Philip Burrows, Henry Tye, Emmanuel Tsesmelis, Ngee Pong Chang, Xiangdong Ji and Josef Nir.

Two public talks were also organized during the school. Ellis gave an evening lecture to a packed audience on "The Large Hadron Collider: answering Gauguin's questions about the universe"; and Fritzsch delivered an interesting lecture on his autobiography, "Escape from Leipzig".

Princess Maha Chakri Sirindhorn of Thailand agreed to act as the patron for the school, which was opened by Singapore's Deputy Prime Minister Teo Chee Hean in a ceremony on 9 January. Teo is confident that the move will boost Singapore's plans for science and technology. "The IAS School takes the collaboration between NTU and CERN to a higher level, and helps position NTU as the Asian research hub in the global network of scientific institutions that focus on high-energy physics," he said. The school was chaired by K K Phua, director of the IAS, and co-chaired by Ngee Pong Chang from City University New York and Emmanuel Tsesmelis of CERN.

The success of the school has encouraged the IAS, with participation from CERN, to organize another workshop in 2013 and another school in 2014.

John Ellis, sporting a CERN T-shirt while he lectures at the school.

Lecturers and students attending the school. (Image credits: IAS.)

OBITUARY

André Petermann 1922–2011

André Petermann, one of the first members of CERN's Theory Division, passed away last August in his 89th year. He pioneered, together with his adviser Ernst Stueckelberg, the renormalization group, one of the fundamental ideas in quantum field theory, which underlies the modern theory of phase transitions as well as asymptotic freedom and the quest for unification of all of the particle interactions.

André was among the first staff members of CERN, which at the beginning consisted of a small group of theorists at the Niels Bohr Institute in Copenhagen, headed by Bohr himself. When the group moved to Geneva they first occupied a set of barracks in Cointrin, next to the airport, before moving to the University of Geneva and then finally settling on the Meyrin site. For CERN's theoreticians, André was the last direct contact with these nomadic origins.

The importance of André's early work on the renormalization group was recognized by Kenneth Wilson, when he was awarded the Nobel Prize in Physics for his work on applying the renormalization group to critical phenomena. Wilson kindly acknowledged a congratulatory letter from André by paying tribute to his joint paper with Stueckelberg for initiating the whole renormalization-group effort.

A young André Petermann.

Another of André's important contributions to field theory and particle physics was his pioneering calculation of the next-to-leading order correction to the anomalous magnetic moment of the muon. This was key to the interpretation of CERN's famous experimental measurement of this quantity and is still a reference today, at a time when the theoretical interpretation of this quantity is much debated.

André's scientific interests ranged far and wide, extending in later years to include grand unification and the study of superstring compactifications. Long after his formal retirement, he would often be encountered browsing preprints late at night and many of us recall with fondness long telephone calls from André, quizzing us about some recent publication.

André was a special person, somebody with great purity of vision, breadth of interest and integrity. He had a deep understanding of physics and mathematics, and was an exceptional man whose manifold contributions to physics will live on. CERN's theory group is grateful to him: we feel deeply his passing.

● *Luis Álvarez-Gaumé, Ignatios Antoniadis, John Ellis and André Martin.*

MEETINGS

CIPANP 2012, the **11th Conference on the Intersections of Particle and Nuclear Physics**, will take place in St Petersburg, Florida, on 28 May – 3 June. The conference is designed to explore areas of interest to scientists working in elementary particle physics, nuclear physics, astrophysics, particle astrophysics, nuclear astrophysics and cosmology. Topics include theory, experiment and instrumentation, as well as facilities needed for the study of fundamental interactions, elementary particles, nucleons and nuclei, astrophysical phenomena and cosmic rays. CIPANP 2012 encourages participation by scientists of diverse backgrounds, in particular the participation of younger scientists. For more details, see http://cipanp2012.triumf.ca.

The **12th Heavy Ion Accelerator Technology Conference**, HIAT2012, will be held on 18–21 June in Chicago, hosted by Argonne National Laboratory. This international conference is dedicated to the design, construction, development and operation of heavy-ion accelerators and their components. It focuses on the operational experience of existing facilities, achievements in heavy-ion accelerator physics and technology, progress on the implementation of new projects and infrastructure upgrades, trends in the proposal and design of heavy-ion accelerators, as well as their main systems and components. A tour of the ATLAS facility at Argonne, including the Accelerator Development Facilities, is planned, as well as a one-day, add-on workshop on the status and techniques for production of high-mass radioactive-ion beams. For further information, see www.phy.anl.gov/hiat12.

The **International Workshop on Neutrino Factories, Super Beams and Beta Beams**, NUFACT 2012, will take place on 23–28 July, in Williamsburg, Virginia. The NUFACT workshops are now established as one of the important yearly neutrino conferences with an emphasis on future projects. The main goal is to review the progress – and share the challenges – in the studies of future neutrino-oscillation facilities that could discover and study the mass hierarchy of neutrinos, CP violation in the leptonic sector and possible new phenomena. The workshops combine the skills of experimenters, theorists and accelerator physicists. For further details, see http://wwwold.jlab.org/conferences/nufact12/reg.html.

CORRECTIONS

An error occurred in the November 2011 issue in the distance from Fermilab to the Soudan Underground Laboratory (p28). This should be 730 km (not 370 km).

In the December 2011 issue, in the article "A bumper year nears its end" (p5), the 2011 data objective was revised upwards to 5 fb^{-1} (rather than 1.2 fb^{-1}) and by the end of proton running the LHC had delivered 5 pb^{-1} to ALICE (rather than 5 fb^{-1}).

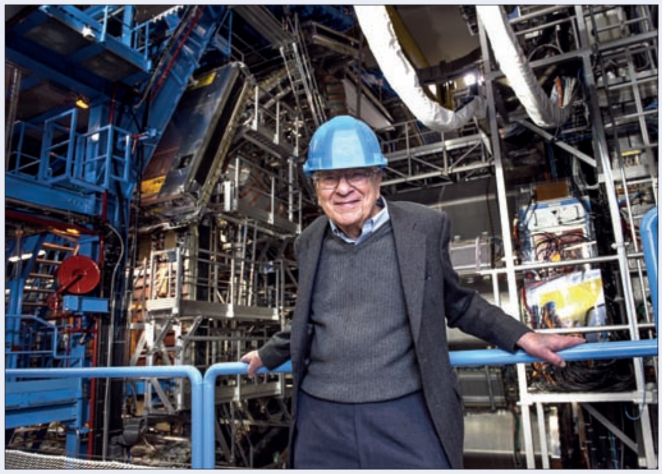
Apologies to all concerned.

Faces & Places

Visits

On 15 February, **Helge Reinhold Braun**, left, parliamentary state secretary, federal ministry of education and research (BMBF), of the Federal Republic of Germany, was welcomed to CERN by the director-general, **Rolf Heuer** (here demonstrating the temperature-sensitive coffee mug that depicts the history of the universe). Braun toured the ATLAS underground experimental area and visitor centre, as well as the LHC tunnel, before meeting German staff at CERN.

Murray Gell-Mann, well known for proposing the quark model and as a recipient of the Nobel Prize in Physics in 1969, came to CERN on 23 January. During his visit he gave a theoretical physics seminar on decoherent histories in quantum mechanics. He also toured ATLAS – where he is seen here – and CMS. (For an interview with Gell-Mann, see http://cdsweb.cern.ch/record/1421671.)



New products

Highland Technology has announced the release of the V230 64-channel VME analogue input module. The V230 provides high channel-count data acquisition for dense monitoring applications. Data are presented in real time as a simple array of 64 values with no handshakes, interrupts or driver calls required. The 64 channels are individually programmable for both input range and filtering, with input ranges of ±102.4 mV, ±1.024 V or ±10.24 V. For further details, tel +1 415 551 1700, e-mail info@highlandtechnology.com or visit www.highlandtechnology.com.

Micromech-Yaskawa has announced the Sigma-5 EtherCAT C that provides real-time Ethernet interface for an EtherCAT communication network. The SGDV-OCA01A network module is an add-on board, which is compatible with the Sigma-5 series command option attachable amplifiers SGDV with the communication protocol CANopen. The EtherCAT network module offers a range of functions based on the IEC 61158 Type12, IEC 61800-7 CiA 402 drive profile. For more information, contact Karen Hicks, fax +44 1376 551 849 or see www.micromech.co.uk.

National Instruments Corporation has introduced the Multisim 12.0 with specialized editions for circuit design and electronics education. Multisim 12.0 Professional Edition is based on industry-standard SPICE simulation and is optimized for usability. Engineers can improve design performance to fit their applications by minimizing errors and prototype iterations with Multisim simulation tools that include both customizable analyses developed in NI LabVIEW graphical-system design software and standard SPICE analyses and intuitive measurement systems. For additional information, tel +44 1635 523 545, e-mail info.uk@ni.com, or see www.uk.ni.com.

Recruitment

For advertising enquiries, contact *CERN Courier* recruitment/classified, IOP Publishing, Temple Circus, Temple Way, Bristol BS1 6BE, UK.
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KIT
Karlsruhe Institute of Technology

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 missions of a university with those of a large-scale research centre of the Helmholtz Association. With 9.000 employees KIT is one of the largest research and education institutions worldwide.

The Faculty of Physics at the Karlsruhe Institute of Technology invites applications for the position of a

Professor (W3) of Theoretical Particle Physics

(successor of Prof. J. H. Kühn)

at the Institute for Theoretical Particle Physics. The tentative start date is April 1, 2013.

We seek an excellent scientist working on the phenomenology of elementary particles. The successful candidate shall in particular use the expected results of the LHC and modern precision experiments to explore new laws of nature within and beyond the Standard Model of elementary particle physics. Topical overlaps with the experimental programs in terrestrial elementary particle physics and links with our astroparticle physics groups are desirable. The appointed professor will have access to the resources of the KIT Center Elementary Particle and Astroparticle Physics (KCETA), the DFG-funded Research Training Group "Elementary particle physics at highest energy and precision" and the KIT's "Strukturiertes Promotionskolleg". We expect that the successful candidate participates in the organisation and management of KCETA and the Faculty of Physics.

Teaching duties include the participation in lecture courses covering basic and advanced theoretical physics at the undergraduate and graduate level. Since our courses for the core curriculum are usually held in German, the new professor is expected to learn German within two years after her or his appointment.

Applicants must have a junior faculty position, possess the degree of Habilitation, or demonstrate an equivalent academic qualification through their scientific record. Experience in teaching is further desirable.

KIT aims to increase the number of female professors and especially welcomes applications from women. Handicapped persons with equal qualifications will be preferred.

Applications with the usual resumé (including a summary of teaching experience, a research plan and a list of the five most important publications), should be sent by **April 13th, 2012** to: **Karlsruher Institut für Technologie (KIT), Dekan der Fakultät für Physik, Campus Süd, 76128 Karlsruhe, Germany**

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

EUROMAGNET CALL FOR PROPOSALS FOR MAGNET TIME

The next deadline for applications for magnet time at the **LABORATOIRE NATIONAL DES CHAMPS MAGNETIQUES INTENSES** (www.lncmi.cnrs.fr) the **HIGH FIELD MAGNET LABORATORY** (www.ru.nl/hfml/) and the **HOCHFELD LABOR DRESDEN** (www.hzdr.de/hld) is May 15th, 2012.

Applications can be done through an on-line application form on the website: http://www.euromagnet.org from April 15th, 2012.

Scientists of EU countries and Associates States* are entitled to apply under FP7 for financial support according to the rules defined by the EC.
*listed on ftp://ftp.cordis.europa.eu/pub/fp7/docs/third_country_agreements_en.pdf

For further information concerning feasibility and planning, please contact the facility of your choice.

ÖAW Austrian Academy of Sciences

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HBAR-HFS – Hyperfine Structure of Antihydrogen

(PI: Prof. E. Widmann)

is to be performed at the Antiproton Decelerator of CERN, Geneva, Switzerland.

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Prof. Dr. Eberhard Widmann
Stefan Meyer Institute for Subatomic Physics
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Vienna, Austria
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Applications are invited to fill a permanent position as

Professor (W3) in Physics (chair)

(Succession Prof. Dr. Ch. Stegmann)

at the Department of Physics in the Faculty of Sciences starting as soon as possible.

The successful candidate is expected to pursue research in experimental astroparticle physics and to join the Erlangen Centre for Astroparticle Physics (ECAP). Current core research areas of ECAP are gamma-ray and neutrino astronomy. We seek a scientist with an international standing in either gamma-ray astronomy or a field of experimental astroparticle physics that is not yet represented at ECAP. Teaching duties include lecturing in experimental physics at the B.Sc. and M.Sc. level. The Department also offers courses for students who have physics as a minor.

Prerequisites for the professorship include a university degree, a doctorate, excellent teaching skills as well as a post-doctoral habilitation or similar academic qualifications.

The University of Erlangen-Nuremberg pursues a policy of intense student mentoring and therefore expects a continuous presence of professors at the university during the lecture periods.

Applications including a CV, a list of publications, conference talks and courses taught, together with copies of degrees and any other relevant documents (please refrain from submitting reprints of publications) should be sent not later than **April 27, 2012** (date of stamp), to: The Dean, Faculty of Science, University of Erlangen-Nuremberg, Universitätsstraße 40, D-91054 Erlangen, Germany.

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ASTA R&D/User Facility Program Director (Scientist II)

A new accelerator science user facility – the Advanced Superconducting Test Accelerator (ASTA) at Fermilab – is scheduled to be constructed in 2012-13 with a goal to begin the first beam physics experiments in 2013. The ASTA will be a state-of-the-art electron linear accelerator facility based on International Linear Collider (ILC) technology providing 40 MeV to 1 GeV high-power high-peak and high-average brightness electron beams to several experimental areas.

Fermilab's Accelerator Physics Center (APC) seeks a Scientist of international stature and a proven record of accomplishment in the field of accelerator physics for this position. The ASTA will enable a collaborative R&D program, hosted by Fermilab, which engages United States Department of Energy (DOE) laboratories, universities, and companies with an interest in Advanced Accelerator R&D (AARD) and technologies. The Program Director is expected to provide leadership and vision for the scientific program; to lead the AARD activities at the ASTA; and to play a strategic role in shaping the accelerator R&D landscape at Fermilab and in the US.

This position requires a Ph.D. in physics or relevant discipline; significant leadership and project management experience with excellent knowledge and international renown in the field of accelerators for particle physics research; proven experience in leading large collaborative projects; ability to envision, persuade and empower and to interact successfully with the relevant scientific communities; proven record of success in handling responsibilities at a senior level in accelerator projects; and ability to travel by automobile and/or commercial air carrier both domestically and internationally.

In addition to completing the online resume profile at http://fermi.hodesiq.com for Job Code 120042, candidates with relevant experience and qualifications must also send a curriculum vitae, a publication list, a description of their most relevant achievements and the names of at least three (3) references to Dr. Stuart D. Henderson, Search Committee Chair, at stuarth@fnal.gov. All materials must be received by no later than April 15, 2012. Applications will be treated in strict confidence and only applicants being seriously considered for this position will be contacted.

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Weimar Culture and Quantum Mechanics: Selected Papers by Paul Forman and Contemporary Perspectives on the Forman Thesis

By Cathryn Carson, Alexei Kojevnikov and Helmuth Trischler (eds.)
World Scientific
Hardback: £98 $150
E-book: $195

This collection reprints Paul Forman's classic papers on the history of the scientific profession in Germany after the First World War and the invention of quantum mechanics. The Forman thesis became famous for its demonstration of the cultural conditioning of scientific knowledge, in particular by showing the historical connection between the culture of Weimar Germany – known for its irrationality and antiscientism – and the emerging concept of quantum acausality. In 2007, participants at a conference in Vancouver discussed the implications of the Forman thesis for contemporary historiography. Their contributions are also in this volume.

Cosmic Rays for Particle and Astroparticle Physics: Proceedings of the 12th ICATPP Conference

By S Giani, C Leroy and P G Rancoita (eds.)
World Scientific
Hardback: £137 $210
E-book: $273

The 12th ICATPP conference was aimed at promoting contacts between scientists involved in solar-terrestrial physics, space physics, astroparticle physics and cosmology from both the theoretical and the experimental approaches. The conference was devoted to physics and the physics requirements; a survey of theoretical models and performances of detectors; astroparticle physics; astrophysics research; and the space environment. It also covered the use of cosmic rays to extend the scientific research experience to teachers and students with air-shower arrays and other techniques.

International Seminar on Nuclear War and Planetary Emergencies: 43rd Session

By R Ragaini (eds.)
World Scientific
Hardback: £112 $170
E-book: $221

This volume in *The Science and Culture Series: Nuclear Strategy and Peace Technology*, edited by Antonino Zichichi, is the proceedings of a seminar focusing on planetary emergencies that was held in Erice in August 2010. Talks ranged from "The Evolving Nuclear Weapon Threat to Society" by Richard L Garwin to "Carbon Dioxide, Friend or Foe" by William Happer. Scientists in all fields, politicians and decision-makers in ministries of foreign affairs, science and interior and security, as well as international organizations, will find this an interesting resource.

Neutrino Physics, Second Edition

By Kai Zuber
CRC Press
Hardback: £82
E-book: $129.95

When Kai Zuber's text on neutrinos was published in 2003, the author correctly predicted that the field would see tremendous growth in the immediate future. Now, revised and expanded to include the latest research, conclusions and implications, *Neutrino Physics, Second Edition* delves into neutrino cross-sections, mass measurements, double-beta decay, solar neutrinos, neutrinos from supernovae and high-energy neutrinos, as well as new experimental results in the context of theoretical models. It also provides an entirely new discussion on the resolution of the solar-neutrino problem, the first real-time measurement of solar neutrinos below 1 MeV, geoneutrinos and long-baseline accelerator experiments.

Modern Perspectives in Lattice QCD: Quantum Field Theory and High Performance Computing. Lecture Notes of the Les Houches Summer School: Volume 93, August 2009

By Laurent Lellouch, Rainer Sommer, Benjamin Svetitsky, Anastassios Vladikas and Leticia F Cugliandolo
Oxford University Press
Hardback: £47.50 $85.50

This book is based on the lectures delivered at the XCIII Session of the École de Physique des Houches, held in August 2009. The aim of the event was to familiarize the new generation of PhD students and postdoctoral fellows with the principles and methods of modern lattice field theory, which aims to resolve fundamental, non-perturbative questions about QCD without uncontrolled approximations. The emphasis is on the theoretical developments that have shaped the field and turned lattice gauge theory into a robust approach to the determination of low-energy hadronic quantities and of fundamental parameters of the Standard Model.

Introduction to Black Hole Physics

By Valeri P Frolov and Andrei Zelnikov
Oxford University Press
Hardback: £55 $98.50

For many years, black holes have been considered interesting solutions of the theory of general relativity with a number of amusing mathematical properties. Now, following the discovery of astrophysical black holes, Einstein's gravity has become an important tool for their study. This text combines physical, mathematical and astrophysical aspects of black-hole theory. It also contains "standard" material on black holes as well as new subjects, such as the role of hidden symmetries in black-hole physics, and black holes in space–times with large extra dimensions.

Relativistic Quantum Physics: From Advanced Quantum Mechanics to Introductory Quantum Field Theory

By Tommy Ohlsson
Cambridge University Press
Hardback: £38 $65
E-book: $52

Quantum physics and special relativity theory were two of the greatest breakthroughs in physics during the 20th century and contributed to paradigm shifts in physics. This book combines these two discoveries to provide a complete description of the fundamentals of relativistic quantum physics, guiding the reader from relativistic quantum mechanics to basic quantum field theory. It gives a detailed treatment of the subject, beginning with the classification of particles, the Klein–Gordon equation and the Dirac equation. Exercises and problems are featured at the end of most chapters.

Quantum Engineering: Theory and Design of Quantum Coherent Structures

By A M Zagoskin
Cambridge University Press
Hardback: £45 $80
E-book: $64

Quantum engineering has emerged as a field with important potential applications. This book provides a self-contained presentation of the theoretical methods and experimental results in quantum engineering. It covers topics such as the quantum theory of electric circuits, the quantum theory of noise and the physics of weak superconductivity. The theory is complemented by up-to-date experimental data to help put it into context.

Viewpoint

Authors and supporters

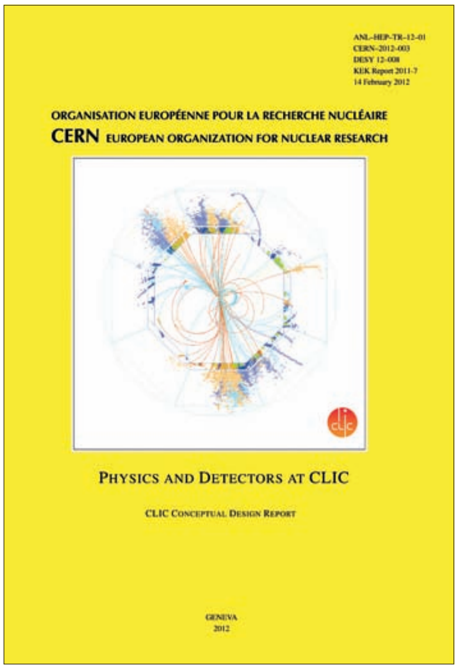
Lucie Linssen and **Steinar Stapnes** examine the question of authoring long-term development projects for particle physics.

The first "high-energy" accelerators were constructed more than 80 years ago. No doubt they represented technological challenges and major achievements even though, seen from a 2012 perspective, the projects involved only a few people and small hardware set-ups. For many of us, making a breakthrough with just a few colleagues and some new equipment feels like a dream from a different era. Nowadays, frontier research in particle physics requires huge infrastructures that thrill the imagination of the general public. While people often grasp only a fraction of the physics at stake, they easily recognize the full extent of the human undertaking. Particle-physics experiments and accelerators are, indeed, miracles of technology and major examples of worldwide co-operation and on-site teamwork.

Looking ahead

Studies on future accelerators and particle-physics experiments at the energy or luminosity frontier now span several decades and involve hundreds, if not thousands, of participants. This means that, while progress is made with the technical developments for a future facility, the physics landscape continues to evolve. The key example of this is the way that current knowledge is evolving quickly thanks to measurements at the LHC. As a result, it is impossible to predict decades in advance what the best machine option will be to expand our knowledge. Pursuing several options and starting long-term R&D well in advance is therefore essential for particle physics because it allows the community to be prepared for the future and to make informed decisions when the right moments arise.

For the post-LHC era, several high-energy accelerator options are already under study.



Physics and Detectors at CLIC*: a new concept in authoring.*

Beyond high-luminosity extensions of the LHC programme, new possibilities include: a higher-energy proton collider in the LHC tunnel, as well as various electron–positron colliders, such as the International Linear Collider (ILC) and the Compact Linear Collider (CLIC); and a muon collider. There is typically much cross-fertilization and collaboration between these projects and there is no easy answer when it comes to identifying who has contributed to a particular project.

When, some months ago, we were discussing the authoring of the CLIC conceptual design report, we faced exactly such a dilemma. The work on the CLIC concept has been ongoing for more than two decades – clearly with a continuously evolving team. On the other hand, the design of an experiment for CLIC has drawn heavily on studies carried out for experiments at the ILC, which in turn have used results from earlier studies of electron–positron colliders. Moreover, we also wanted both the accelerator studies and the physics and detector studies to be authored by the same list.

We looked at how others had dealt with this dilemma and found that in some cases, such as in the early studies for LHC experiments, protocollaborations were taken as a basis for authoring, while others, such as the TESLA and Super-B projects, have invited anyone who supports the study to sign. For the CLIC conceptual design report we opted for a list of "signatories". Those who have contributed to the development are invited to sign alongside those wishing to express support for the study and the continuation of the R&D. Here non-exclusive support is meant: signing-up for CLIC is not in contradiction with supporting other major collider options under development.

The advantage of the signatories list is that it provides the opportunity to cover a broader range of personal involvements and avoids excluding anyone who feels associated or has been associated with the study. The drawback of our approach is that the signatories list does not pay tribute in a clear way to individual contributions to the study. This recognition has to come from authoring specialized notes and publications that form the basis of what is written in the report.

The signatories list covers both the CLIC accelerator and the report for the physics and detector conceptual design. Already exceeding 1300 names in February, it demonstrates that – even if all eyes are on LHC results – simultaneous R&D for the future is considered important.

Are there better ways of doing this? As the projects develop, the teams are becoming more structured and this helps – at least partly – towards creating appropriate author lists. The size of the teams and the particular timescale of the projects will, however, remain much larger than the first accelerator projects in our field, and it is likely that striking the right balance between openness and inclusiveness and, on the other hand, restrictions and procedures in this matter will continue to be a difficult subject.

● **Further reading**

See https://indico.cern.ch/conferenceDisplay.py?confId=136364, with links to both CLIC conceptual design reports.

● *Steinar Stapnes is CERN's Linear Collider study leader and Lucie Linssen leads CERN's Linear Collider Detector project.*

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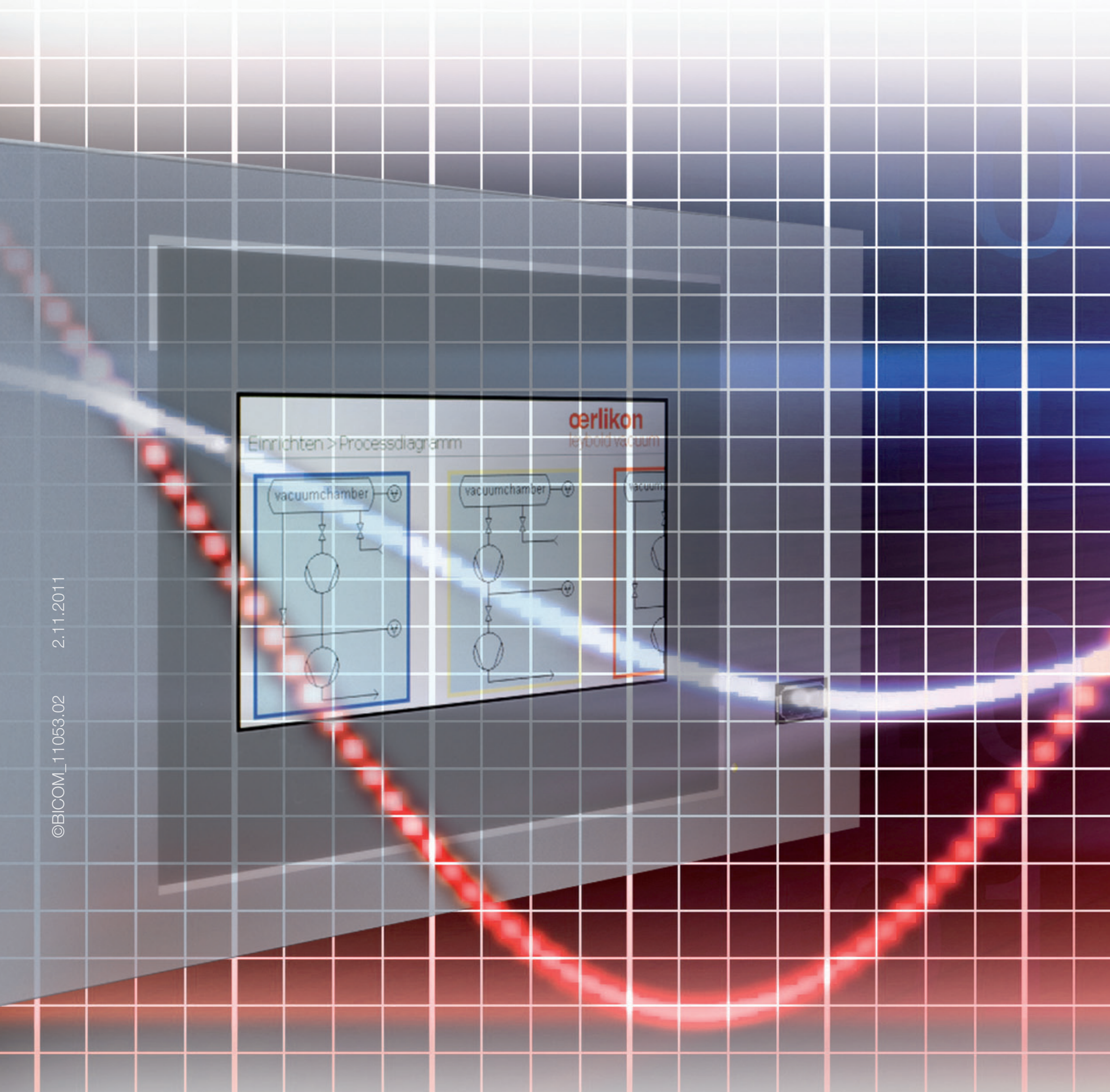

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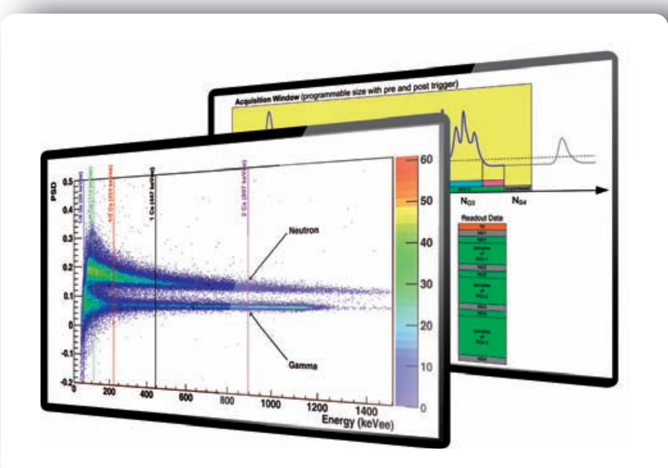

Digital Pulse Processing

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