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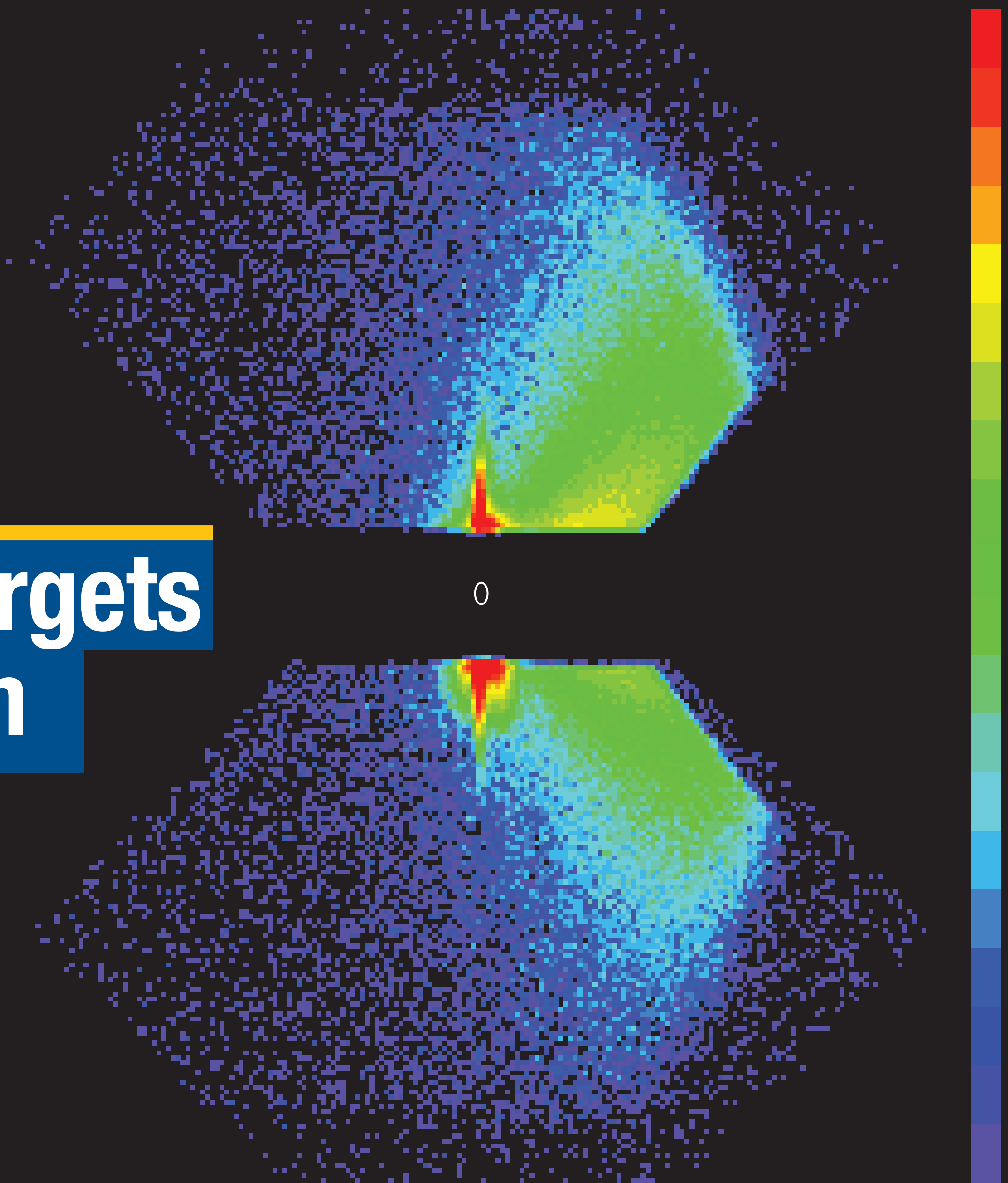

TOTEM targets the proton

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

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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:
Argonne National Laboratory (US) Cosmas Zachos
Brookhaven National Laboratory (US) P Yamin
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Publisher Susan Curtis
Production editor Jesse Karjalainen
Technical illustrator Alison Tovey
Group advertising manager Ed Jost
Recruitment advertisement manager Chris Thomas
Advertisement production Katie Graham
Marketing & Circulation Anastasia Ireland

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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E-mail: desypr@desy.de
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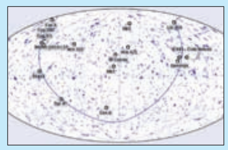
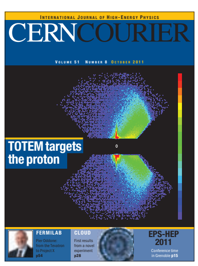




On the cover: A histogram of the intersection points of selected tracks with silicon detectors in Roman pots at 220 m from the interaction point in the TOTEM experiment at the LHC (p37). The white ellipse marks the 1σ beam profile. The tracks are indicated in the bottom silicon detectors at one side and in the top detectors at the other side of the interaction point, representing the proton–proton scattering configuration; elastic scatters are mainly in the red regions (see article for further explanation).

News

NEUTRINOS

Daya Bay experiment begins taking data

The nuclear power plant at Daya Bay. (Image credit: IHEP.)

The Daya Bay Reactor Neutrino Experiment has begun its quest to answer some of the puzzling questions that still remain about neutrinos. The experiment's first completed set of twin detectors is now recording interactions of antineutrinos as they travel away from the powerful reactors of the China Guangdong Nuclear Power Group, in southern China.

The start-up of the Daya Bay experiment marks the first step in the international effort of the Daya Bay collaboration to measure a crucial quantity related to the third type of oscillation, in which the electron-neutrinos morph into the other two flavours of neutrino. This transformation occurs through the least known neutrino-mixing angle, θ_{13}, and could reveal clues leading to an understanding of why matter predominates over antimatter in the universe.

The experiment is well positioned for a precise measurement of the poorly known value of θ_{13} because it is close to some of the world's most powerful nuclear reactors – the Daya Bay and Ling Ao nuclear power reactors, located 55 km from Hong Kong – and it will take data from a total of eight large, virtually identical detectors in three experimental halls deep under the adjacent mountains. Experimental Hall 1, a third of a kilometre from the twin Daya Bay reactors, is the first to start operating. Hall 2, about a half kilometre from the Ling Ao reactors, will come online in the autumn. Hall 3, the furthest hall, about 2 km from the reactors, will be ready to take data in the summer of 2012.

The Daya Bay experiment is a "disappearance" experiment. The detectors in the two closest halls will measure the flux of electron-antineutrinos from the reactors; the detectors at the far hall will look for a depletion in the expected antineutrino flux. The cylindrical antineutrino detectors are filled with liquid scintillator, while sensitive photomultiplier tubes line the detector walls, ready to amplify and record the telltale flashes of light produced by the rare antineutrino interactions. As a result of the large flux of antineutrinos from the reactors, the twin detectors in each hall will capture more than 1000 interactions a day, while at their greater distance the four detectors in the far hall will measure only a few hundred interactions a day. To measure θ_{13}, the experiment records the precise difference in flux and energy distribution between the near and far detectors.

The experimental halls are deep under the mountain to shield the detectors from cosmic rays and the detectors themselves are submerged in pools of water to shield them from radioactive decays in the surrounding rock. Energetic cosmic rays that make it through the shielding are tracked by photomultiplier tubes in the walls of the water pool and muon trackers in the roof over the pool so that events of this kind can be rejected.

After two to three years of collecting data with all eight detectors, the Daya Bay Reactor Neutrino Experiment should be well positioned to meet its goal of measuring the electron-neutrino oscillation amplitude – and hence $\sin^2 2\theta_{13}$ – with a sensitivity of 1%.

The start up of the experiment begins after eight years of effort – four years of planning and four years of construction – by hundreds of physicists and engineers from around the globe. China and the US lead the Daya Bay collaboration, which also includes participants from Russia, the Czech Republic, Hong Kong and Taiwan. The Chinese effort is led by project manager Yifang Wang of the Institute of High Energy Physics (IHEP), Beijing, and the US effort is led by project manager Bill Edwards of Lawrence Berkeley National Laboratory and chief scientist Steve Kettell of Brookhaven National Laboratory.

Sommaire en français

HEAVY IONS

ALICE measures the shape of head-on lead–lead collisions

One the many surprises to have emerged from studies of heavy-ion collisions at Brookhaven's Relativistic Heavy Ion Collider (RHIC) and now at CERN's LHC concerns the extreme fluidity of the dense matter of the nuclear fireball produced. This has traditionally been studied experimentally by measuring the second harmonic of the azimuthal distribution of emitted particles with respect to the plane of nuclear impact. Known as v_2, this observable is remarkably large, saturating expectations from hydrodynamic models, suggesting that the so-called quark-gluon plasma is one of the most perfect fluids in nature (*CERN Courier* April 2011 p7). Many assumed that the matter in the elliptical nuclear overlap region becomes smooth upon thermalization, rendering the Fourier coefficients other than v_2 negligible in comparison.

However, recently it was proposed that collective flow also responds to pressure gradients from the "chunkiness" of matter distributed within the initial fireball in random event-by-event fluctuations. These nonuniformities lead to anisotropy patterns beyond smooth ellipses: triangular, quadrangular, and pentangular flow are now being studied by measurements of v_3, v_4, v_5 and beyond at RHIC and the LHC.

The new measurements evoke comparisons with the vestigial cosmic microwave background (CMB) radiation, whose nonuniformities offer hints about the conditions at the universe's earliest moments. Just as the CMB anisotropy is expressed by multipole moments, the azimuthal anisotropy of correlated hadron pairs from heavy-ion collisions can be represented by a spectrum of Fourier coefficients $V_{n\Delta}$. In pair-correlation measurements, a "trigger" particle is paired with associated particles in the event to form a distribution in relative azimuth $\Delta\phi$. Over many events, a correlation function is produced, whose peaks and valleys describe the relative probability of pair coincidence.

The left side of the figure shows a correlation function measured by ALICE for the 2% most central (i.e. head-on) lead–lead collisions at the LHC, where the particle pairs are separated in pseudorapidity to suppress "near-side" jet correlations near $\Delta\phi = 0$. Even when this gap is imposed, a curious longitudinally-extended near-side "ridge" feature remains. Considerable theoretical effort has been devoted to explaining the source of this feature since its discovery at RHIC. In the correlation function in the figure, the first five $V_{n\Delta}$ harmonics are superimposed. The right side of the figure shows the spectrum of the Fourier amplitudes. Evidently in the most head-on collisions, the dominant harmonic is not the second elliptical term, but the triangular one, $V_{3\Delta}$; moreover, the Fourier coefficients here are significant up to $n = 5$. These results corroborate the idea that initial density fluctuations are non-negligible.

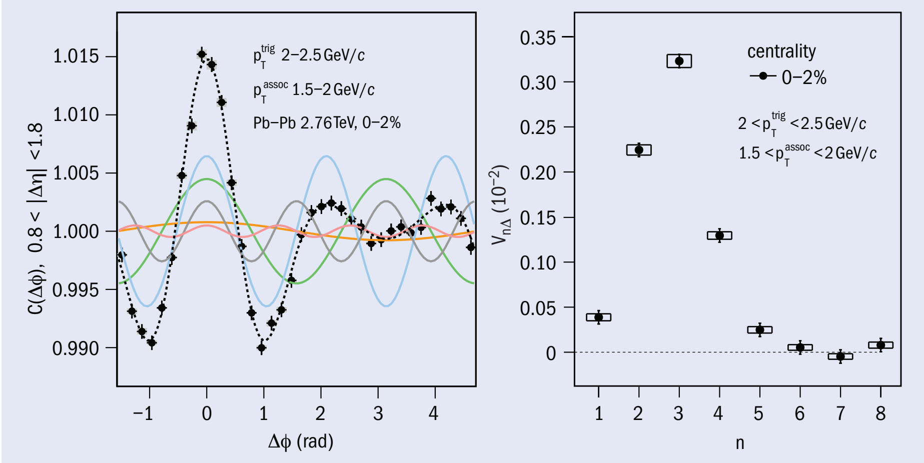


Fig. 1. Left: correlation function for charged hadron pairs from head-on Pb–Pb collisions. Right: corresponding spectrum of Fourier harmonic amplitudes vs n.

The intriguing double-peak structure evident on the "away side" (i.e. opposite to the trigger particle, at $\Delta\phi = \pi$) was not observed in inclusive (i.e. not background-subtracted) correlation functions prior to the LHC. However, in the hope of isolating jet-like correlations, the v_2 component was often subtracted as a non-jet background, leaving a residual double peak when the initial away-side peak was broad. This led to interpretation of the structure as a coherent shock-wave response of the nuclear matter to energetic recoil partons, akin to a Mach cone in acoustics. However, the concepts of higher-order anisotropic flow are now gaining favour over theories that depend on conceptually independent Mach-cone and ridge explanations.

These measurements at the LHC are significant because they suggest a single consistent physical picture, vindicating relativistic viscous hydrodynamics as the most plausible explanation for the observed anisotropy. The same collective response to initial spatial anisotropy that causes elliptic flow also economically explains the puzzling "ridge" and "Mach cone" features, once event-by-event initial-state density fluctuations are considered. Moreover, measuring the higher Fourier harmonics offers tantalizing possibilities to improve understanding of the nuclear initial state and the transport properties of the nuclear matter. For example, the high-harmonic features at small angular scales are suppressed by the smoothing effects of shear viscosity. This constrains models incorporating a realistic initial state and hydrodynamic evolution, improving understanding of the deconfined phase of nuclear matter.

Conference

Lepton Photon goes to Mumbai

The global nature of modern particle physics was clearly manifest at the biennial Lepton Photon conference that took place this year in India. The Tata Institute of Fundamental Research (TIFR), Mumbai, was host to the 25th International Symposium on Lepton Photon Interactions at High Energies – Lepton Photon 2011 – on 22–27 August.

The conference opened with a welcome from Mustansir Barma, director of TIFR, and speeches by Srikumar Banerjee, chair of the Atomic Energy Commission, Shri Prithviraj Chavan, the Chief Minister of the State of Maharashtra, and Patricia McBride, chair of the C11 Committee of the International Union of Pure and Applied Physics, under whose auspices the Lepton Photon conferences take place.

New results from the LHC and the latest news on searches for the Higgs boson were among the highlights, as at the EPS-HEP 2011 meeting held in Grenoble in July (*CERN Courier* September 2011 p5, p11). Thanks to the outstanding performance of the LHC, the experiments and the Worldwide LHC Computing Grid, some of the results were from analyses based on roughly twice the data sample presented in Grenoble. With the additional data analysed, the ATLAS and CMS experiments have now excluded the existence of a Higgs over most of the mass region 145–466 GeV with 95% confidence level. Moreover, the significance of hints of a Higgs signal has slightly decreased and it remains the case that the slight excess observed could be the effect of statistical fluctuations.

The Gateway of India monument located on the waterfront in South Mumbai provided a motif for the conference. (Image credit: Lepton Photon 2011.)

The talks covered a range of other physics that is being investigated by the LHC experiments. These included precision measurements in top-quark physics, for example, and in B physics, where results from the LHCb experiment on B mesons are becoming the most precise yet. There were also reports on the status and prospects of the LHC machine and, by CERN's direct general, Rolf Heuer, on the future of colliders after the LHC.

Reports on some of the results presented at the conference follow on the next two pages.

● For the conference programme and presentations, see: http://www.tifr.res.in/~lp11/.

Citizen science

LHC@home 2.0 attracts massive support

The public launch in August of a new application for CERN's volunteer-computing platform LHC@home produced an overwhelming response. The application Test4Theory, which runs Monte Carlo simulations of events in the LHC, was announced in a CERN press release on 8 August. Within three days, the number of registered volunteers swelled from a few hundred to nearly 8000. The application joins SixTrack, an accelerator beam-dynamics tool that has been used for LHC machine studies at CERN since 2004 and is now being prepared and extended in collaboration with the École polytechnique fédérale de Lausanne for studies of the LHC and its upgrade.

Given that the new application requires participants to install a virtual machine on their computer – not a trivial task – the level of enthusiasm is impressive. So, to avoid saturating the server that manages the project, there is now a waiting list for new participants. With the volunteer computing power at hand, nearly 20 billion events have already been simulated. According to CERN's Peter Skands, the physicist leading the simulation effort, when the number of active volunteers passes 40 000 – which could happen later this year – the system will become equivalent to a true "virtual collider", producing as many collisions per second as the real LHC.

Running part of a "virtual LHC" on their computers is clearly appealing to those who join LHC@home. The volunteers have not only dedicated a great deal of computing time to the project, but in many cases also provided expert assistance in debugging some of the software and managing the discussion forums that are part and parcel of a successful online citizen-science project (*CERN Courier* September 2011 p41).

● You can sign up to join the project at http://lhcathome.web.cern.ch/LHCathome/Physics/.

News

LEPTON PHOTON 2011

LHCb pins down the B_s mixing phase

The LHCb collaboration's presentation at Lepton Photon 2011 included one of the most eagerly awaited measurements in flavour physics: the CP violation phase in B_s–$\overline{B}$ mixing. This is the counterpart of sin 2β in the B^0 system, which was measured by the B-factory experiments BaBar and BELLE using the channel $B^0 \to J/\Psi K_s$. They provided the first measurement of CP violation in B^0 mixing, which is both large and now well measured, with $\sin 2\beta = 0.69 \pm 0.02$. In contrast, the Standard Model prediction for ϕ_s, the corresponding phase for the B_s meson, is extremely small and precise: $\phi_s = 0.036 \pm 0.002$ rad (Charles *et al.* 2005). It is therefore an interesting place to search for new physics beyond the Standard Model, which may enhance the value. Time-dependent analyses of B_s mesons were not accessible at the B-factories, so this remained a key measurement for hadronic machines, first at the Tevatron and now at the LHC.

The golden mode for this study is $B_s \to J/\Psi\, \phi_s$ where the J/Ψ decays to $\mu^+\mu^-$ and the φ decays to K^+K^-. The measurement is very challenging: the final state is not a pure CP eigenstate, so an angular analysis has to be made to separate the CP-even and CP-odd components. In addition, the fast B_s–$\overline{B}_s$ oscillation necessitates precise vertex reconstruction, and tagging of the production state (whether it was a B_s or $\overline{B}_s$) is also important. The result for ϕ_s is correlated to another quantity in the fit, $\Delta\Gamma_s$, the difference in width of the two B_s mass eigenstates. (It is the mass difference of these two states that determines the oscillation frequency.) $\Delta\Gamma_s$ can be positive or negative, but in the Standard Model is predicted to be $0.087 \pm 0.021\ ps^{-1}$ (Lenz and Nierste 2011). The uncertainties on ϕ_s and $\Delta\Gamma_s$ are correlated, and furthermore the fit turns out to be insensitive to the replacement $\phi_s \to \pi - \phi_s$ when $\Delta\Gamma_s \to -\Delta\Gamma_s$ so there are two ambiguous solutions. As a result, the measurements are usually plotted

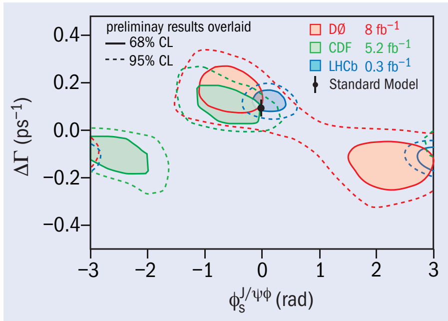


Fig. 1. Preliminary results for the width difference $\Delta\Gamma_s$ vs the mixing phase ϕ_s from DØ (Burdin 2011), CDF (CDF 2010) and LHCb (LHCb 2011a). The contours have been redrawn and overlaid for comparison here, the original plots can be found in the references.

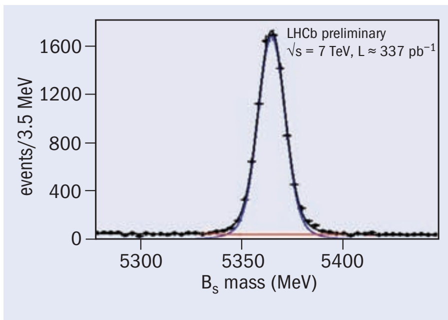


Fig. 2. Signal for $B_s \to J/\Psi\,\phi$ (LHCb 2011a). The line indicates the fitted background level.

as contours in the ϕ_s vs $\Delta\Gamma_s$ plane.

The CDF and DØ experiments at the Tevatron made the first measurements. Their early results agreed with each other and appeared, when combined, to indicate a large value for ϕ_s, about 3σ away from the Standard Model expectation. More recent updates have moved their preferred values somewhat closer to the Standard Model, but a hint of a possible discrepancy remained, as shown by the red and green contours in figure 1 (Burdin and DØ 2011, CDF 2010).

LHCb has now accumulated the largest sample of $B_s \to J/\Psi\,\phi$ decays in the world, over 8000 signal candidates with very high purity (figure 2). The resulting constraint is shown as the blue contour in figure 1 (LHCb 2011a). It is much more precise than the preceding measurements, with one of the two solutions being in good agreement with the Standard Model expectation – the hint of a discrepancy is not confirmed. This result also gives the first significant direct measurement of $\Delta\Gamma_s$, $0.123 \pm 0.029 \pm 0.008\ ps^{-1}$, where the first uncertainty is statistical and the second systematic.

Another related analysis presented by LHCb uses a different decay mode, $B_s \to J/\Psi\, f_0$, which should measure the same phase. Although the statistics are lower, the final state is CP-odd in this case, so the analysis is simpler (LHCb 2011b). It gives a consistent result to $B_s^0 \to J/\Psi\,\phi$, and the preliminary combined result from LHCb is $\phi_s = 0.03 \pm 0.16 \pm 0.07$ rad (LHCb 2011c). This result is statistically limited, but as data continue to pour in from the LHC there are good prospects for substantial further improvement. So, although LHCb has now ruled out a gross effect from new physics, the experiment should be able to measure the true value even if it is as small as predicted in the Standard Model – and test any subtle effects from new physics.

Further reading

S Burdin, DØ collaboration 2011 *EPS-HEP 2011*, Grenoble.
CDF collaboration 2010 CDF/ANAL/BOTTOM/PUBLIC/10206.
J Charles *et al.* (CKMfitter group) 2005 *Eur. Phys. J. C* **41** 1.
A Lenz and U Nierste 2011 arXiv: 1102.4274v1.
LHCb collaboration 2011a LHCb-CONF-2011-049.
LHCb collaboration 2011b LHCb-CONF-2011-051.
LHCb collaboration 2011c LHCb-CONF-2011-056.

Top precision at ATLAS

Measurements of top-quark properties were among the many new results shown by the ATLAS collaboration at Lepton-Photon 2011. The very large mass of this quark relative to the others leads many physicists to believe that it plays a special role in physics beyond the Standard Model.

At the luminosity recently achieved at the LHC, a top quark is produced on average approximately every second. Because of the large number of top quarks produced and the excellent detector performance, the ATLAS experiment is able to measure precisely the quark's properties, thereby providing stringent tests of the Standard Model as well as probing for the subtle effects of new physics. So far all measurements are consistent with the Standard Model, but further data will bring increased precision and with it greater sensitivity to new effects.

ATLAS has measured the production cross-section of top pairs in the single lepton decay channel to be 179±12 pb. This precision of 7% is better than the uncertainty on the theoretical prediction, providing an excellent testing ground for perturbative QCD. A combination of the measurements in the different channels will further increase the precision.

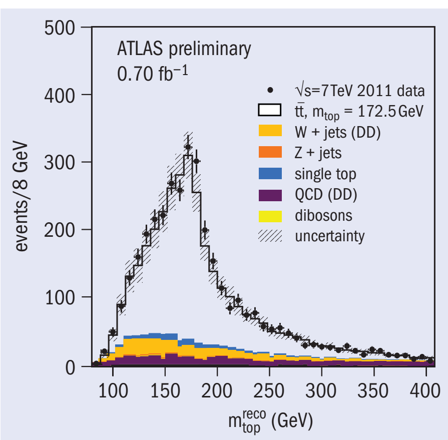
Electroweak production of single top quarks is sensitive to the element V_{tb} of the quark-mixing matrix and also to a potential flavour-changing-neutral current component in top-quark couplings. ATLAS has measured top production in the t-channel – first measured only a couple of years ago at the Tevatron – with a significance exceeding 7σ. ATLAS has also placed limits on the production of single top in the s-channel and the Wt final state, laying the groundwork for the eventual measurement of these processes.

As a result of the excellent calibration of the detector, ATLAS has also measured precisely the mass of the top quark at 175.9 GeV, with a total uncertainty of just 2.8 GeV. This precise measurement, together with the W mass and electroweak radiative corrections, implies that the Higgs boson is lurking at low mass – if it is indeed a Standard Model Higgs.

ATLAS has further probed for new physics with the most precise measurements to date of the fraction of longitudinally polarized W bosons in the decay of top quarks and of the degree of spin correlation. The results of these measurements are consistent with Standard Model expectations, as are those of production asymmetries similar to those recently reported to be anomalous at the Tevatron.

● Further reading

For ATLAS results presented at Mumbai, see https://twiki.cern.ch/twiki/bin/view/AtlasPublic/AtlasResultsEPS2011.



Reconstructed top mass in the muon channel comparing data (points) to simulated signal, with m_{top}=172.5 GeV, and estimated backgrounds (full lines).

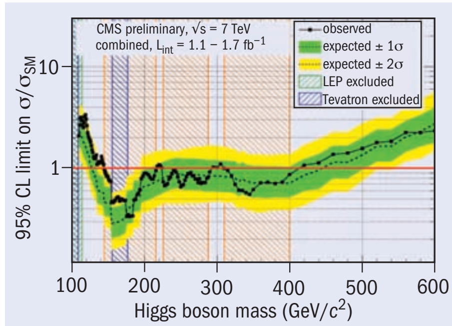
CMS updates its Higgs search

The CMS search for the Higgs boson is being carried out using a range of decay products: two photons; two τ leptons; two b quarks; two W bosons; and two Z bosons. Analysing all of these channels ensures that the search is sensitive to observing the Higgs irrespective of its mass. The CMS collaboration presented the first results from a combination of Higgs searches in these channels at the EPS-HEP 2011 conference in Grenoble at the end of July (*CERN Courier* September 2011 p11). For Lepton-Photon 2011, held in Mumbai a month later, they were able to update several key analyses, using additional data collected during the summer.

The CMS results presented in Mumbai were based on data-sets corresponding to 1.1–1.7 fb^{-1} (integrated luminosity), depending on the channel. The figure shows the result of all of the search channels combined. It indicates that CMS observes no convincing excess of events in the explored mass range of 110–600 GeV.

The analysis excludes, with a confidence level (CL) of 95% the existence of a Standard Model Higgs boson in three Higgs mass ranges: 145–216 GeV, 226–288 GeV and 310–400 GeV. For the quantity of data collected so far, the CMS collaboration would expect to exclude the Higgs boson in the range 130–440 GeV in the absence of a signal. The two gaps between the three excluded mass ranges observed in the data are consistent with statistical fluctuations. At 90% CL, the results exclude the Standard Model Higgs boson in the mass range from 144–440 GeV, without interruptions. All exclusion regions were obtained using CLs from the modified frequentist construction .

A modest excess of events is, however, apparent for Higgs boson masses below 145 GeV. With the data due to be collected in the coming months, CMS will be



Experimental limits on Standard Model Higgs production in the mass range 100–600 GeV. The solid curve from CMS (labelled observed) reflects the observed experimental limits, parameterized in units of the theoretically predicted cross-section (vertical axis) for the production of Higgs of each possible mass value (horizontal axis). All mass ranges for which the solid curve dips below the horizontal line at the value of $\sigma_{95\%}/\sigma_{SM}$ = 1 are excluded. The excluded regions are shown as hatched regions on the plot for CMS (orange) as well as for experiments at the Large Electron–Positron (LEP) collider and at the Tevatron. The dashed curve shows the expected sensitivity to the Higgs boson, based on simulations.

able to distinguish between the possible interpretations: either the production of a Higgs boson or a statistical fluctuation of the backgrounds. During the ongoing proton–proton data-taking period at the LHC, which is expected to terminate at the end of 2012, CMS will record substantially more data, leading to a significantly increased sensitivity to the Standard Model Higgs boson – if it exists – over the full range of possible masses.

More information can be found in CMS-HIG-11-011.

ν–$\bar{\nu}$ mass difference lessens

One of last year's surprise results came from the MINOS (Main Injector Neutrino Oscillation Search) experiment in the US, which suggested that neutrinos and their antimatter counterparts, antineutrinos, might have different masses – an idea that goes against most commonly accepted theories of how the subatomic world works. At Lepton-Photon 2011, however, the MINOS collaboration presented updated results. These constitute the world's best measurement of muon neutrino and antineutrino mass comparisons and bring the masses more closely together.

Since the result announced in June 2010, the experiment has nearly doubled its data set, from 100 antineutrino events to 197 events. While the new results are only about 1 σ away from the previous results, the combination rules out concerns that the previous result could have arisen from detector or calculation errors. Instead, the combined results point to a statistical fluctuation that has lessened as more data have been collected.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Sciencewatch

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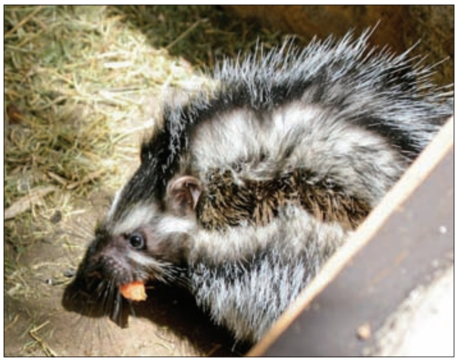
The rat that poisons its enemies

There are only a few examples of toxic mammals in existence, but an African crested rat has found a way to make itself poisonous without having evolved a means of producing its own poison.

Fritz Vollrath of the University of Oxford and colleagues have found that *Lophiomys imhausi* gets poison into its saliva by chewing on the bark of a plant, *Acokanthera schimperi*, which has toxins similar to those used traditionally in the manufacture of poison arrows. Over the course of a week, it repeatedly applies the poison to short hairs hidden under fur along its flank. The hairs have holes in them that allow the poison to enter. When attacked, the rat, rather than fleeing, can part the covering fur and expose the poisoned hairs.



Lophiomys imhausi – *look but don't touch. (Image credit: Susannah Rouse.)*

Even large animals such as jackals and lions that try to bite it – an event that the rat seems to have a decent chance of surviving thanks to an exceptionally thick skin and skull – will pull back, froth at the mouth and (often) drop dead. This is the first example of acquired lethal toxicity in a placental mammal.

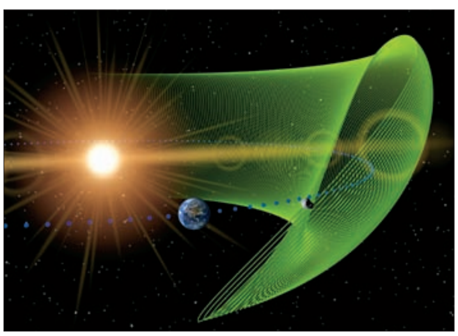
● **Further reading**
J Kindgon *et al.* 2011 *Proc. Roy. Soc. B* published online, doi: 10.1098/rspb.2011.1169.

Earth's Trojan asteroid

In 1772, Joseph-Louis Lagrange showed that a small object in space could be trapped in the orbit of a larger one if it were 60° ahead of or behind it. These positions are often labelled L_4 and L_5 and objects that sit in them are, by convention, called "Trojans". The first such object, found in 1906, was an asteroid in the Sun-Jupiter system. Similar ones have since been found elsewhere, but only now has one been found associated with the Earth.

Martin Connors of Athabasca University in Alberta and colleagues, using NASA's Wide-field Infrared Survey Explorer (WISE), discovered what appears to be a Trojan asteroid in Earth's orbit around the Sun. Named 2010 TK7, this asteroid is a few hundred metres across and its orbit is expected to be stable for at least 10 000 years.

● **Further reading**
M Connors *et al.* 2011 *Nature* **475** 481.



The path of 2010 TK7 (green) during one 195-year cycle. (Image credit: Paul Wiegart/ University of Western Ontario.)

Electronics less than skin deep

A new sort of electronic-circuit design could revolutionize how devices are carried by people. John A Rogers of the University of Illinois at Urbana-Champaign and colleagues have demonstrated what they call "epidermal electronics". Built by transfer printing, these are systems that match the physical properties of skin and can be attached to skin without adhesives, using van der Waals interactions alone.

The circuits flex and stretch with the skin and can include transistors, inductors, capacitors, diodes, strain sensors, physiological sensors, photodetectors and even light-emitting diodes. Not only could such devices be used to monitor physiological data for people, but – the authors note in the abstract – they could even be used as the basis for computer-game controllers.

● **Further reading**
Dae-Hyeong Kim *et al.* 2011 *Science* **333** 838.

Mixing colours for LCDs

While liquid-crystal displays (LCDs) require almost no power to operate, their typical lack of colour can be quite a limitation. Now, Yoshimitsu Sagara and Takashi Kato of the University of Tokyo in Japan have made a remarkable LCD system based on a two-component mixture with a single luminophore to give colour that can reversibly switch between three coloured states – something never achieved until now.

Various combinations of shearing and temperature change cause red, green and yellow phases of the mixture to be produced and so can be used to display colour images. With luck, the current generation of black-and-white e-book readers will one day be replaced by ones that can show colour images as well.

● **Further reading**
Y Sagara and T Kato 2011 *Angew Chem. Inter. Ed.* **50** 1.

Nanotubes in seconds

Typical methods of making nanotubes have been awkward and cumbersome. Now, Xinyu Zhang of Auburn University, Alabama, and colleagues have developed what they call the "Poptube" approach.

A precursor, for example ferrocene, is mixed with a conducting solid material such as a conductive polymer before being "zapped" in a conventional microwave oven. The conductive mixture then starts to arc – just as metal cutlery would. The high temperatures decompose the ferrocene into an iron catalyst and a source of carbon to make nanotubes and the process is off and running. All of this happens in air and initially at room temperature. Just 15–30 s later the nanotubes are ready – in record time and without any complicated equipment.

● **Further reading**
X Zhang 2011 *Chem. Commun.* **47** 9912.

Astrowatch

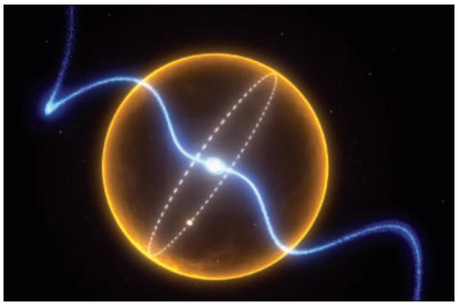
Compiled by Marc Türler, ISDC and Observatory of the University of Geneva

A diamond planet is found around a pulsar

"Remember when you were young, you shone like the Sun", opens the famous song *Shine On You Crazy Diamond*. Written as a tribute to Syd Barrett, Pink Floyd's lead musician until 1975, it could also refer to a newly discovered planet orbiting a pulsar. The planet was once a star but the pulsar robbed it of almost everything except for its innermost part of crystalline carbon (diamond) and oxygen.

The supernova explosion of massive stars usually leaves behind an ultradense neutron star formed by the collapse of the iron core of the former star. Like a giant atomic nucleus, neutron stars typically contain the mass of the Sun in a sphere of about only 10 km in radius. They often manifest themselves as pulsating stars, or "pulsars". The observed pulsation comes from the spin of the neutron star shining a beam of radiation from a magnetic pole towards the Earth at each rotation (*CERN Courier* September 2006 p13). The pulse duration corresponds to the spin period of the neutron star and ranges from about 1 ms to 10 s. Millisecond pulsars – the most rapidly rotating – are thought to have been spun-up via accretion of matter from a companion star (*CERN Courier* December 2010 p10). That about 30% are solitary suggests that some might have completely "eaten-up" their companion star, either via continuous accretion or by the merger of the binary system.

While extrasolar planets are continuously being discovered around normal stars (*CERN Courier* November 2010 p13), planets around pulsars are extremely rare.



Schematic view of the pulsar-planet system PSR J1719-1438 showing the pulsar with 5.7 ms rotation period in the centre, with the orbit of the planet in comparison to the size of the Sun indicated as a yellow bubble. (Image credit: Swinburne Astronomy Productions, Swinburne University of Technology.)

So far, an extrasolar planetary system has been found around only one pulsar, PSR B1257+12. It comprises two planets of about three times the mass of the Earth and a third body of lunar mass. The origin of these first detected exoplanets – back in 1992 – is still puzzling astronomers. Could the planets have survived the supernova explosion at the origin of the pulsar or did they form afterwards out of a remaining disc of matter?

The presence of an orbiting companion can be detected by a sinusoidal modulation of the arrival times of the pulses. Such a characteristic signal has now been detected among almost 200 TB of data processed by supercomputers as part of a systematic search for pulsars. The modulation observed by the 64 m radio telescope in Parkes, Australia, suggests the presence of a Jupiter-mass planet orbiting the newly discovered pulsar PSR J1719-1438. The period of the orbit is only 2.2 hours, corresponding to a distance between the planet and the pulsar of no more than the radius of the Sun.

This tight orbit gives strong constraints on the size of the planet. It must be much denser and hence smaller than Jupiter to prevent it from being ripped apart by the strong gravity of the neutron star. A minimal density of 23 g cm^{-3} was calculated by a team led by Matthew Bailes, of Swinburne University of Technology in Australia, together with colleagues from Europe, Australia and the US. This exceeds the density of any chemical element and suggests that the planet-like body is made of matter in extreme conditions similar to those found in white dwarfs.

Low-mass white dwarfs have already been found around millisecond pulsars, but this one is unique as it would have lost more than 99.9% of its original mass to the hungry pulsar. The remnant planet-mass body is most likely to be made mainly of carbon and oxygen and the density is such that it is certain to be crystalline, which means that a large part of the star may be similar to a diamond. To check how brilliant and transparent the planet really looks, one would have to travel 4000 light-years towards the constellation of Serpens.

Further reading

M Bailes *et al.* 2011 *Science Express*. doi: 10.1126/science.1208890.

Picture of the month

The little spot indicated with an arrow at the bottom of this image is the subject of much attention by astronomers all around the world. It is the light of a supernova explosion detected on 24 August 2011 by the Palomar Transient Factory (PTF) sky survey using the wide-angle 1.2-m Samuel Oschin Telescope in California. What makes this supernova, called PTF11kly, special is that it is in the nearby, face-on Pinwheel Galaxy and that it was detected within hours of ignition. (This spiral galaxy is located near the handle of the Big Dipper, or Plough). Moreover, the supernova is of Type Ia, the ones that are used as standard candles to measure the expansion rate of the universe and that provide evidence for the existence of dark energy (*CERN Courier* September 2003 p23). PTF11kly offers a unique opportunity to understand better the physics of these explosions. (Image credit: D Andrew Howell & B J Fulton, LCOGT, *et al.* / Faulkes Telescope North, LCOGT.)

CERN Courier Archive: 1968

A look back to CERN Courier vol. 8, October 1968, compiled by Peggie Rimmer

The EPS

Formation of the European Physical Society

On the afternoon of 26 September, the European Physical Society EPS was officially inaugurated in the Aula Magna of the University of Geneva, bringing to a successful conclusion discussions on an idea started at Bologna in November 1965 and carried forward at meetings in Pisa, CERN, London, Geneva and Prague. The seat of the Society is in Geneva and the Secretariat is located at the Institut Battelle in Carouge.

On 25 September a final discussion at CERN, under the Chairmanship of the Director General, Professor B Gregory, cleared the remaining points on the Constitution, and on the morning of 26 September more than 40 leading physicists in Europe and 18 National Physical Societies were enrolled in the EPS.

The Official Inauguration of the EPS in the Aula Magna of the University of Geneva; left to right, Professor G Bernardini (President of the Executive Committee of the Society), Dr. D van Berchem (Rector of the University of Geneva) and Mr. E Valloton (Head of the Scientific Section of the international department of the Swiss Ministry of Foreign Affairs).

The Constitution states: "The purpose of the Society is and shall be to contribute to and promote the advancement of physics, in Europe and in neighbouring countries, by all suitable means and in particular: a) by providing a forum for the discussion of subjects of common interest; b) by providing means whereby action can be taken on those matters which it appears desirable to handle on the international level.

"The Society will concern itself with such things as the co-ordination of Conferences and Summer Schools; the co-ordination of European physics journals and the publication of a Bulletin; the exchange of experience and information relating to physics teaching; the exchange of scientists between physics centres in Europe."

EPS membership is defined:

The following individual, legal persons or bodies may become Ordinary Members of the Society:

a) individuals who have shown by their contribution to European science, by their professional activity or otherwise, to the Council's satisfaction, that they can further the cause and object of the Society;

b) societies, groups or laboratories organized or existing under the laws of the State of their incorporation or of their seat and which, in the Council's opinion, make a significant contribution to European science;

c) individuals who are members of a society or group which has been accepted as an Ordinary Member of EPS and who fulfil the conditions laid down in the foregoing paragraph provided such individual membership in EPS is not precluded by the Constitution or by-laws of their society or group.

● Compiled from texts on pp238–239.

News from abroad

Superconducting accelerator programme at Stanford

The High Energy Physics Laboratory (HEPL) at Stanford University, USA, has for some years been the scene of an intensive attack on the challenging problem of a superconducting accelerator (SCA). The work, under the leadership of professors W M Fairbank and H A Schwettman, has advanced to the stage where a large SCA will be put together during the next few years with every hope of successful operation.

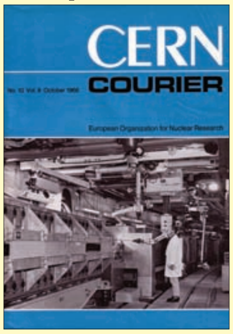
The feasibility of constructing a superconducting linear accelerator was examined at several centres (CERN, Rutherford Laboratory and Stanford University) in the early 1960s. It became obvious at that time that a severe research programme to achieve major technical advances would be needed to overcome the problems involved and only Stanford decided to confront the work.

Within the next few years all of the individual pieces of work done on various aspects of SCA technology will be brought together in the design, construction and operation of a superconducting electron linac 150 m long. If all goes well it could eventually lead to a superconducting conversion of the accelerator at the Stanford Linear Accelerator Center SLAC, a National Laboratory distinct from HEPL, which is a University Laboratory.

During this exciting stage of the work at Stanford, two CERN people will be working with the team – E Jones (who did research with the storage ring model, CESAR, at CERN) and P Bramham (a linac r.f. specialist from the ISR Division).

● Compiled from texts on pp239–241.

Compiler's Note



The idea of the SCA was to operate a linear accelerator at superfluid helium temperatures with resonant cavities made of superconducting niobium instead of copper. The machine was built and successfully used in several nuclear physics experiments between 1979 and 1981. Although the dream of converting the 3.2 km linear accelerator at SLAC was never realized, the SCA provided beams for the invention of the free-electron laser by John Madey in 1976, which has now evolved to operate across the spectrum from infrared down to hard X-ray wavelengths (*CERN Courier* December 2010 p17).

Superconductivity studies continue today at the Stanford Institute for Materials and Energy Science, a joint SLAC-Stanford institute, where researchers are working on the challenging problem of understanding high-temperature superconductors.

Great times in Grenoble

Impressive results from the LHC and so much more to come: this is the general feeling that participants took home from the EPS-HEP 2011 conference, held at the end of July. This report presents some of the many highlights.

The biennial meetings organized by the High Energy and Particle Physics division of the European Physics Society (EPS) aim to provide a global view of the state of the art in research in the field. This year's meeting, which took place in Grenoble on 21–27 July, attracted more than 800 participants – and certainly delivered. The International Europhysics Conference on High-Energy Physics, EPS-HEP 2011, was the first major international conference since CERN's LHC started to supply significant amounts of data in a new energy region. After only one year of data-taking, the LHC took centre stage, in both proton–proton and heavy-ion physics, thanks to the spectacular performance of the accelerator and the impressively fast data analysis by the experiments. In parallel, there were results based on near-final data samples from experiments at Fermilab's Tevatron and at the B factories, while hot news came from neutrino experiments and searches for dark matter. All in all, the conference was a real success, raising current knowledge up a huge notch across all searches for new physics.

All of the Tevatron and LHC experiments showed improved or new limits in searches, reaching mass limits close to or slightly above 1 TeV in simple supersymmetric models. Anyone who had hoped that the LHC would reveal supersymmetry early on may have been slightly disappointed, but as many theorists reminded the participants: new physics is guaranteed, all that is needed is patience. CERN's director-general, Rolf Heuer reinforced this point, stating that either finding the Higgs or excluding it will be a great discovery.

At the Tevatron, the CDF and DØ experiments – with data corresponding to an integrated luminosity of about 8 fb^{-1} – continue to extend their exclusion limits for a Higgs particle with a mass of around 160 GeV. After two decades of truly fruitful physics, the Tevatron was scheduled to shut down definitively at the end of September, leaving a total of more than 10 fb^{-1} of data ready to be analysed. Meanwhile, the CMS and ATLAS experiments at the LHC have already reached a sensitivity exceeding that of the Tevatron experiments. Both experiments have slightly better preliminary limits in the region covered by CDF and DØ, while also excluding a high-mass Higgs – in a region out of the reach of the Tevatron. Most amazingly, if the LHC continues to perform as well as it has so far, the experiments are guaranteed to find or exclude the Standard Model Higgs by the end of 2012.

Coffee and posters at EPS-HEP 2011: a traditional and vital part of any conference. (Image credit: Tomáš Ježo/LPSC.)

There was, however, already some intriguing news from the Higgs sector. Both the CMS and ATLAS collaborations revealed small excesses of events in their preliminary WW and ZZ analyses based on about 1 fb^{-1} of data (*CERN Courier* September 2011 p11). The most significant upward fluctuation over background was obtained in the Higgs → WW → lνlν channel. Both groups also see smaller excesses in the same mass region from the decay via ZZ to four leptons. All of these fluctuations fall in regions that are not yet excluded by the Tevatron or the LHC, and they made for some interesting discussions during the conference. If the Standard Model Higgs boson does indeed exist, this is exactly how it will manifest itself: a faint appearance above the distant horizon, which should grow with time as more data are analysed. Nonetheless, everyone agreed that it is far too early to tell what is happening unambiguously before ▷

After only one year of data-taking , the LHC took centre stage, in both proton–proton and heavy-ion physics.

EPS-HEP 2011

The EPS-HEP awards

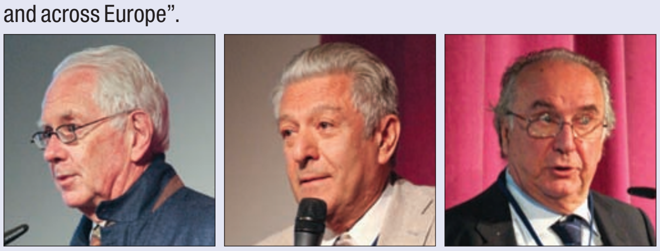
A key highlight was the presentations of prizes by the High Energy and Particle Physics Division of the EPS. This year the prestigious High Energy and Particle Physics Prize for an outstanding contribution to High Energy Physics went to Sheldon Lee Glashow of Boston University, John Iliopoulos of the Ecole Normale Supérieure, Paris, and Luciano Maiani from the University of Rome La Sapienza. They were rewarded "for their crucial contribution to the theory of flavour, presently embedded in the Standard Theory of strong and electroweak interactions which is still of utmost importance today". In 1970, they put forward a compelling argument for the existence of a fourth quark – charm – to solve a number of problems in particle physics. Their proposal, now known as the GIM mechanism, was spectacularly confirmed when particles containing the charm quark were unexpectedly discovered in 1974.

The Giuseppe and Vanna Cocconi Prize for an outstanding contribution (experimental or theoretical) to particle astrophysics and cosmology went to Paolo de Bernardis of the University of Rome La Sapienza and Paul Richards of the University of California, Berkeley, "for their outstanding contributions to the study of cosmic microwave background anisotropies with the balloon-borne experiments BOOMERanG and MAXIMA".

Davide Gaiotto of the Institute for Advanced Studies in Princeton, received the Gribov Medal for outstanding work by an early-career physicist in theoretical particle physics and/or field theory. He was rewarded "for his work on uncovering new facets of the dynamics of four-dimensional supersymmetric gauge theories and in particular for discovering a large class of four-dimensional superconformal theories and for finding with others important intricate relations between two-dimensional theories of gravity and four-dimensional gauge theories".

The Young Physicist Prize for outstanding work by one or more was awarded to Paolo Creminelli of the International Centre for Theoretical Physics, Trieste, and Andrea Rizzi of the Swiss Federal Institute of Technology, Zurich. Creminelli received his share of the award "for his contributions to the development of a solid field-theoretical approach to early-universe cosmology and for his studies of non-gaussianities in the cosmic-microwave background", while Rizzi was rewarded "for his contributions to the reconstruction software and physics program of the CMS experiment at the LHC".

Finally, the Outreach Prize for outstanding outreach achievement connected with high-energy physics and/or particle astrophysics went to Christine Kourkoumelis of the University of Athens and Sofoklis Sotiriou, director of the Ellinogermaniki Agogi Center for Science Teachers Training, for "building educational resources to bring the research process in particle physics and its results to teachers and students, both nationally and across Europe".



Left to right: Glashow, Iliopoulos and Maiani – GIM – in action in Grenoble. (Image credit: Tomáš Ježo/LPSC.)

more data are added and further rigorous checks made, because both experiments could be affected similarly by mis-modelling of the background or be victims of statistical fluctuations.

The recent results from CDF, CMS and LHCb on the flavour-changing neutral-current decays $B_s \rightarrow \mu\mu$ provided another great conversation topic. The CDF collaboration reported a first measurement of this branching ratio at $(1.8 + 1.1 - 0.9) \times 10^{-8}$, which is higher than the Standard Model prediction of $(3.2 \pm 0.2) \times 10^{-9}$. On the other hand, CMS and LHCb both have preliminary limits, which when combined are lower than the CDF result (*CERN Courier* September 2011 p11). More data from all experiments will soon help to clear this ambiguity.

One analysis that has drawn considerable attention in the preceding months is CDF's observation of a possible signal of new physics in the final state W + 2 jets. The updated analysis, now based on 7.3 fb^{-1} of data, shows a clear excess of events with a dijet mass around 145 GeV. At more than 4σ, this is a significant excess, shared equally between the two channels $W \rightarrow e$ or μ. All eyes have thus turned to DØ, which is best positioned to look into this effect. The DØ team performed an important verification by artificially adding in a signal such as the one that CDF observed to confirm that DØ is indeed sensitive to such a signal. All efforts so far have turned up no excess above Standard Model backgrounds in a 4.3 fb^{-1} data sample, even when emulating the CDF selection criteria. A joint task force between the two experiments is now hard at work trying to resolve this discrepancy. Meanwhile, at the LHC, a similar signal would have to emerge amid larger backgrounds, so the sensitivity in this search may be diminished, depending on the nature of the new effect. Both CMS and ATLAS are actively combing through their data for signs of this effect, finding no evidence for the CDF signal thus far.

The DØ and CDF collaborations still see a deviation from the Standard Model in the forwards–backwards asymmetry of top–antitop production, opening the door to several possible explanations in terms of physics beyond the Standard Model. This effect is most pronounced at $t\bar{t}$ masses above 450 GeV. More studies are underway.

From QCD to neutrinos

The session on QCD showed great progress in the field, with updates on parton distribution functions from the experiments at DESY's HERA collider, which stopped running in June 2007, as well as several results from the LHC. These measurements are now challenging the precision of theoretical predictions and will contribute to further refinements of the Monte Carlo simulations.

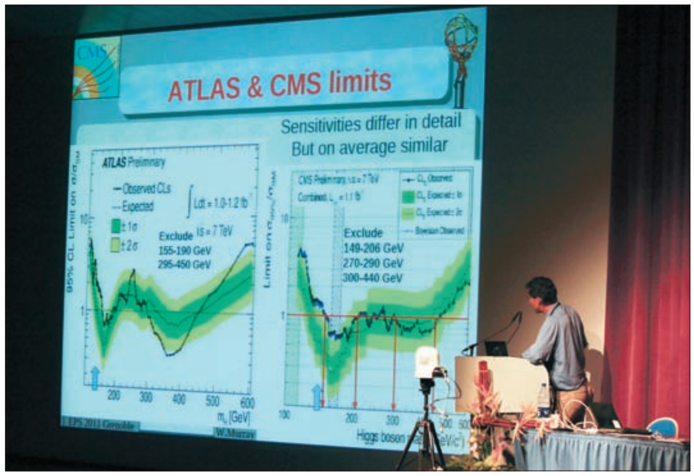
On the flavour front, there were as many as 25 new results from near-to-final datasets in the BaBar and Belle experiments at the B factories at SLAC and KEK, respectively, as well as new measurements from the Tevatron and LHC experiments, in particular LHCb. Together, they provide significant tests of the Standard Model, which still stands strong and unchallenged despite every attempt to uncover a flaw. Searches for charged-lepton flavour violation, electric dipole moments and the updated dilepton charge-asymmetries at the Tevatron continue to probe possible new effects. The BaBar collaboration showed impressive limits on rare decays with branching ratios reaching as low as 10^{-8}, while LHCb now has the most precise single measurement and first 5σ observation of CP violation at a hadron machine using B→Kπ decays (*CERN Courier* September 2011 p13).

Any deviation from the Standard Model predictions would reveal the existence of new physics, but such deviations now require even more stringent tests, hence more data are needed. To collect even larger data samples, a new generation of B factories is on its way. The Belle II experiment at SuperKEKB is well into the construction phase and will replace KEKB, which shut down definitively in June 2010. The SuperKEKB design luminosity of 8×10^{35} cm^{-2} s^{-1} is 40 times higher than the record for KEKB. Commissioning of the upgraded machine and experiment is planned for mid-2014. Meanwhile, the SuperB project has been approved in Italy (*CERN Courier* July/August 2011 p9). Parts of the BaBar detector will soon cross the ocean to be relocated in Rome at a new facility on the Tor Vergata University campus, to start a new life there in 2015.

As ever, conference participants eagerly anticipated news from the various direct searches for dark matter. While both the DAMA/LIBRA and CoGeNT experiments have tantalizing signs of light dark-matter candidates, these are now in contradiction with recent limits revealed by the XENON100 collaboration, whose null results exclude the first two results. Hence, the situation remains ambiguous, with much still to be elucidated. Efforts are ongoing to explain why the peaks of the modulation signals seen by DAMA/LIBRA and CoGeNT do not coincide. Further scrutiny is also being directed towards the unmodulated part of the DAMA/LIBRA signal, together with investigations of other possible backgrounds for the CoGeNT experiment – all with the aim of producing more convincing and irrefutable results. The whole community is hard at work collecting and analysing more data, while construction of larger detectors that will use a tonne or more of active material is underway. With new results and updates expected in a year or two, this topic will be among the highlights of the next EPS-HEP meeting in 2013.

The 295 km Tokai-to-Kamioka (T2K) long-baseline neutrino experiment in Japan, and the Fermilab-based Main Injector Neutrino Oscillation Search (MINOS) with a "far" detector 730 km away in the Soudan Mine, now have the first indications for a sizeable mixing angle between the electron and muon neutrinos (*CERN Courier* September 2011 p6). These measurements were discussed in view of their implications for the measurement of CP violation in neutrino mixing and for the design of future long-baseline neutrino projects. One of the proposed experiments, the Laguna Pyhäsalmi project, would have an underground 100 ktonne "far" detector in Finland, 2300 km from CERN. Its goal would be to measure neutrino oscillations, taking advantage of large enhancements from matter effects.

While the LHC is already looking back in time all of the way to the early universe, it will also take particle physics into the future, with plans established up to 2030 and beyond. Three long shutdowns are currently foreseen. The first will take place at the end of 2012 to allow improvements in the magnet interconnects and for the installation of new release-valves to ensure the prevention of further incidents like the one that brought the LHC to a halt in 2009. This will allow the machine to reach its design centre-of-mass energy of 14 TeV by the autumn of 2014. The following ▷



One of the highlights of the conference: the Higgs limits from CMS and ATLAS, as shown by Bill Murray on the last day. (Image credit: Jiří Kvita/CERN.)

Atsuko Suzuki, director of KEK, gave a moving thank-you for the support that the community gave following the earthquake and tsunami in Japan this spring. (Image credit: Jiří Kvita/CERN.)

Summing up the conference: concluding remarks by David Gross. (Image credit: Jiří Kvita/CERN.)

long shutdown in 2018 will be for several detector upgrades while the final planned shutdown, in 2022, will be used to prepare for the high-luminosity upgrade to the LHC (HL-LHC). Scenarios are also being considered for an upgrade to higher energies in the even more distant future.

A next-generation linear collider is still under study, with final design reports on the Compact Linear Collider (CLIC) and International Linear Collider (ILC) concepts planned for the end of this year. The physics outcome from the LHC experiments by the end of 2012 will provide crucial input to decide what kind of linear collider will best suit the future needs of particle physics.

On the theoretical front, participants heard of recent accomplishments using scattering amplitudes in quantum field theory. As well as updating the community on their progress with calculation techniques, the presentations by theorists served as a reminder that the questions that are currently unanswered by the Standard Model – from the existence of dark matter to the unexplained problem of particle "generations" – imply that new physics ought to be there, waiting to be discovered.

The closing session was devoted to an outlook for experimental and theoretical particle physics as a whole. Pier Oddone, Rolf Heuer and Atsuko Suzuki, the directors for Fermilab, CERN and KEK, respectively, presented their visions for the future of particle physics from the perspectives of the US, Europe and Asia.

Oddone laid out the many plans for Fermilab in the post-Tevatron era, spanning from searches for dark energy and dark matter, to neutrino physics with upgraded experiments MicroBoone and MINOS+, as well as projects for accelerator development of the ILC and a muon collider. He reminded participants that contributions to the LHC from the US – for both the accelerator and the detector – represented the largest single investment in high-energy physics that the US has made since the 1970s.

Suzuki warmly thanked the community for its extended support after the devastating earthquake and tsunami earlier this year and it was moving to hear about the efforts that Japanese colleagues are making to recover from the effects. The KEK laboratory suffered damage both at the Tsukuba and Tokai campuses. Nevertheless, the construction plans for SuperKEKB are still on schedule. Repairs are underway at Tokai, with the first power tests scheduled for November. In addition, Suzuki presented new projects underway in Asia, such as the Korea Neutrino Research Center, which was scheduled to start operation in August, and the Daya Bay experiment in China, which will study oscillations in reactor neutrinos. "Near" detectors at Daya Bay started data-taking in August, while "far" detectors in the nearby mountains should be operating by next summer.

Heuer stressed both the importance of international collaboration in establishing any future accelerator projects and how the results of existing facilities should be used to determine the needs for future accelerators. Results from the LHC will therefore be a key ingredient in determining which design is best for a new linear collider. In an effort to increase the collaborative spirit, CERN is already opening its door to new member states.

All of the great results presented at EPS-HEP 2011 could not have been fully appreciated without the impeccable organization provided by the local committee headed by Johann Collot of the University of Grenoble. Sometimes, however, success can bring trouble: interest in the conference following the news of intriguing reports on the Higgs boson nearly brought the conference website to a halt.

The local committee also spared no effort in treating the participants to local specialities, providing more than just food for thought. These included an impressive wine-and-cheese reception on the opening night, followed by "danced" lectures organized for the public. While local speakers explained the field of particle physics, dancers from the University of Grenoble's modern-dance company accompanied them on stage, seemingly surprising some of the speakers themselves. The evening ended with a beautiful "dance of the particles" to everybody's delight. The social programme also included a soccer tournament, a reception hosted by the City of Grenoble at the modern art museum, a Bel Canto concert and a gastronomic dinner – enough to suit everyone's taste.

This conference really marked the beginning of the LHC era. As David Gross, who received the Nobel Prize in Physics in 2004, concluded: "We have one inverse femtobarn of data in, and 2999 more to go. So be patient. The fun is just starting!" Now, even the unexpected can be expected.

● For the full programme and presentations, see the conference website at http://eps-hep2011.eu/. The next EPS-HEP conference will be held in Stockholm on 18–24 July 2013.

Résumé

D'excellentes nouvelles de Grenoble

Cet été, le LHC a tenu la vedette à Grenoble à la conférence EPS-HEP, qui comptait 800 participants. On retiendra les zones d'exclusion élargies pour le boson de Higgs venant du Tevatron et du LHC, avec un petit excédent autour de 145 GeV. Les mesures de $B_s \to \mu\mu$ *par CDF, LHCb et CMS ont alimenté bien des discussions, tout comme les limites dépassant le TeV pour différents modèles. Plusieurs théoriciens prônent la patience : la nouvelle physique se manifestera à coup sûr. Le prestigieux prix de l'EPS-HEP à été décerné à Sheldon Lee Glashow, John Iliopoulos et Luciano Maiani.*

Pauline Gagnon, Indiana University and CERN.

Collider physics

Long live the Tevatron

As the Tevatron closes down, the data analysis continues, but there are already many areas in which the experiments have delivered results of enduring importance. **Chris Quigg** surveys some highlights.

A quarter-century of experimentation is coming to a close at Fermilab's Tevatron collider, a pioneering instrument that advanced the frontiers of accelerator science and particle physics alike, setting the stage for the LHC at CERN. The world's first high-energy superconducting synchrotron, the Tevatron served as the model for the proton ring in the HERA collider at DESY and as a key milestone towards the development of the LHC. In its final months of operation the Tevatron's initial luminosity for proton–antiproton collisions at 1.96 TeV averaged more than $3.5 \times 10^{32}\ cm^{-2}s^{-1}$. The integrated luminosity delivered at 1.96 TeV approached $12\ fb^{-1}$, with approximately $10\ fb^{-1}$ recorded by the CDF and DØ experiments. A long line of innovations and much perseverance made possible the evolution of luminosity shown in figure 1 (Holmes *et al*. 2011).

The legacy of the Tevatron experiments includes many results for which the high energy of a hadron collider was decisive. Chief among these is the discovery of the top quark, which for 15 years could be studied only at the Tevatron. Exacting measurements of the masses of the top quark and the W boson and of the frequency of B_s oscillations punctured the myth that hadron colliders are not precision instruments. Remarkable detector innovations such as the first hadron-collider silicon vertex detector and secondary vertex trigger, and multilevel triggering are now part of the standard experimental toolkit. So, too, are robust multivariate analysis techniques that enhance the sensitivity of searches in the face of challenging backgrounds. CDF and DØ exemplify one of the great strengths of particle physics: the high value of experimental collaborations whose scientific interests and capabilities expand and deepen over time – responding to new opportunities and delivering a harvest of results that were not imagined when the detectors were proposed.

Early days

The CDF logbook records the first collision event in the Tevatron at 02.32 a.m. on 13 October 1985, at an energy of 800 GeV per beam. The estimated luminosity was $2 \times 10^{25}\ cm^{-2}s^{-1}$, more than seven orders of magnitude below the machine's performance in 2011. By the afternoon, the Tevatron complex was shut down for

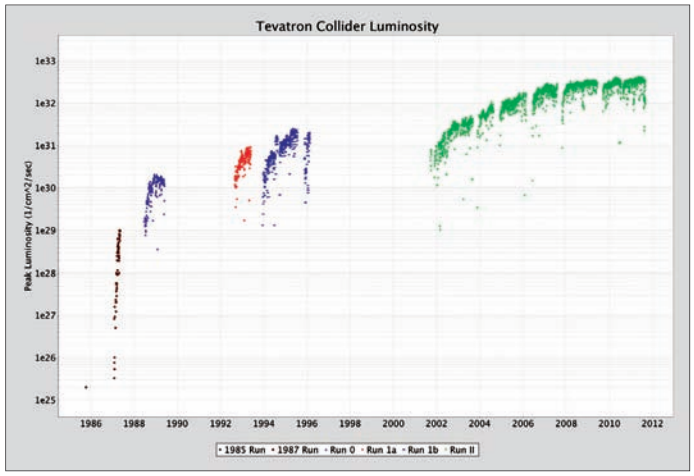


Fig. 1. Initial luminosity for all fills in the Tevatron collider. The peak luminosity reached $4.3 \times 10^{32}\ cm^{-2}s^{-1}$ – about 30 million collisions per second.

18 months to construct the DØ interaction region and complete the CDF detector. CDF's pilot run in 1987 yielded the first wave of physics papers, including measurements and searches. During 1988 and 1989 CDF accumulated $4\ pb^{-1}$, now at 1.8 TeV in the centre of mass. (Two special-purpose experiments also published results from this run. Experiment 710 measured elastic scattering and the total cross-sections; Experiment 735 sought evidence of a deconfined quark–gluon plasma.) The peak luminosity delivered to CDF surpassed $10^{30}\ cm^{-2}s^{-1}$ in collisions of six proton bunches on six antiproton bunches. Papers from these early runs are worth rereading as reminders of how little we knew, and how a tentative but growing respect for the Standard Model brought coherence to the interpretation of results. It is also interesting to see how the experimenters went about gaining confidence in their detector and their analysis techniques.

The legacy of the Tevatron includes many results for which the high energy of a hadron collider was decisive.

Both DØ and CDF took data at 1.8 TeV in the extended Run 1 between 1992 and 1996, recording $120\ pb^{-1}$. An important enabler of increased luminosity was the move to helical orbits, which eliminated collisions outside the two interaction regions. During this period, a small test experiment called MiniMax (T864) searched for disordered chiral condensates and other novel phenomena in the far-forward region. This was a time of high excitement, not only

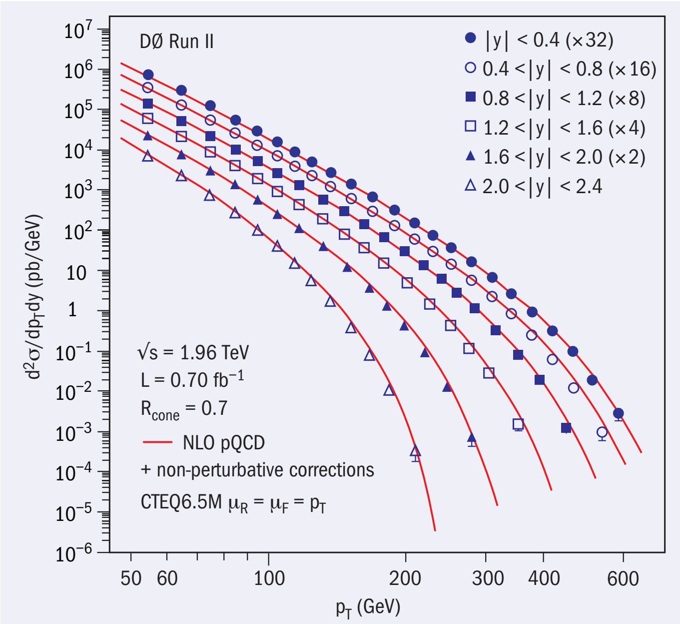


Fig. 2. The inclusive jet cross-section measured by the DØ collaboration in proton–antiproton collisions at 1.96 TeV as a function of transverse momentum in six rapidity bins. Solid curves show next-to-leading-order (one-loop) perturbative QCD predictions.

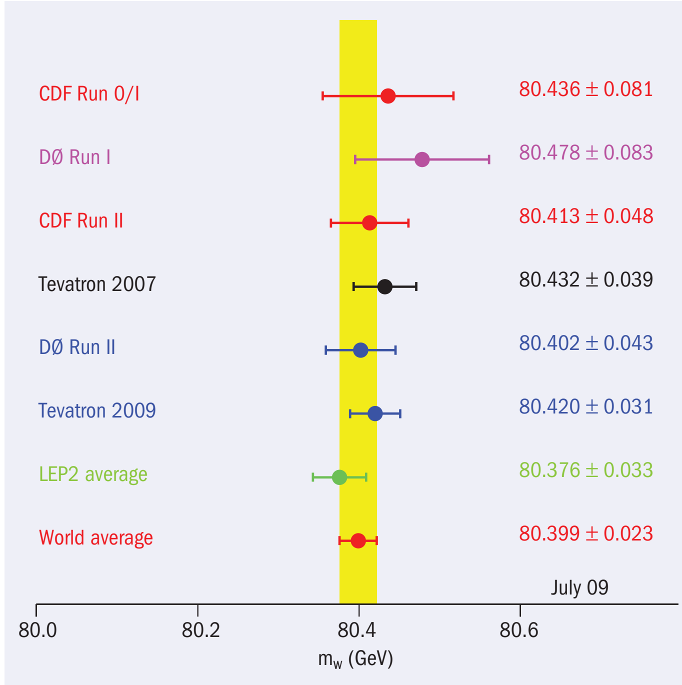


Fig. 3. Tevatron measurements of the W-boson mass, compared with the average from the four LEP experiments and the world average.

for the drama of the top-quark search, but also for the stimulating conversation between the teams on the Tevatron experiments and those at the Z factories at CERN and SLAC, and at the HERA electron–proton collider, all of which were breaking new ground.

Fermilab then constructed the Main Injector and Recycler in a new tunnel, while the experiments undertook ambitious detector upgrades. Improvements to the cryogenic system made it possible to lower the operating temperature of the superconducting magnets and so raise the collision energy to 1.96 TeV. CDF installed a new central tracker and improved silicon vertex detector and enhanced its forward calorimetry and muon detection. DØ added a solenoid magnet, a silicon vertex detector and a scintillating-fibre tracker and also improved the detection of forward muons. Run 2 began slowly in 2001, but attention to detail and many accelerator improvements – including 36-bunch operation and electron-cooling of antiprotons in the recycler – contributed to the outstanding performance of the mature machine.

Strong and electroweak physics

The Tevatron experiments have probed the proton with a resolution of about one-third of an attometer (10^{-18} m), greatly expanding the kinematical range over which we can test the theory of the strong interactions. Perturbative QCD is extremely well validated in studies of hadron jets and other observables. The jet cross-section displayed in figure 2 shows the agreement between calculation and observation over eight orders of magnitude in rate (e.g. Abazov *et al*. 2008, Aaltonen *et al*. 2008 and 2009). Such measurements established the importance of gluon–gluon scattering as a mechanism for jet production and helped constrain the parton distribution functions for the gluons. Values of the strong coupling constant extracted from jet studies exhibit the running behaviour characteristic of asymptotic freedom at higher scales than accessible in other experiments. The strong coupling at the Z-boson mass has been determined with an uncertainty of about 4%.

Other jet studies have not only tested QCD but also probed for physics beyond the Standard Model. Measurements of the angular distribution of dijet production confirm the Rutherford-scattering-like expectation of QCD and place upper bounds on the size of extra spatial dimensions. They also validate, at a resolution of nearly 1/(3 TeV), a key idealization that underpins the Standard Model – the working hypothesis that quarks are pointlike and structureless. Measurements of the dijet mass spectrum that extend beyond 1.2 TeV (roughly 2/3 of the centre-of-mass energy of the proton–antiproton collisions) are likewise in accord with next-to-leading-order QCD calculations. No evidence is seen for unexpected dijet resonances.

In the final data set of 10 fb^{-1}, each experiment should have approximately 5 million W bosons in each leptonic decay channel and perhaps 400 000 Z bosons. These large samples have made possible many important measurements. The production cross-sections agree with QCD predictions to such a degree that electroweak gauge-boson production is under study as a primary luminosity monitor for LHC experiments. Studies of Z production, with or without accompanying jets, are immensely valuable for testing simulations of Standard Model physics. The forward-backward asymmetry of the electrons or muons produced in W decay, which arises from the V–A structure of the charged weak current, provides important information about the up-quark and down-quark parton-distribution functions.

Given what we know from many sources, the masses of the ▷

Collider physics

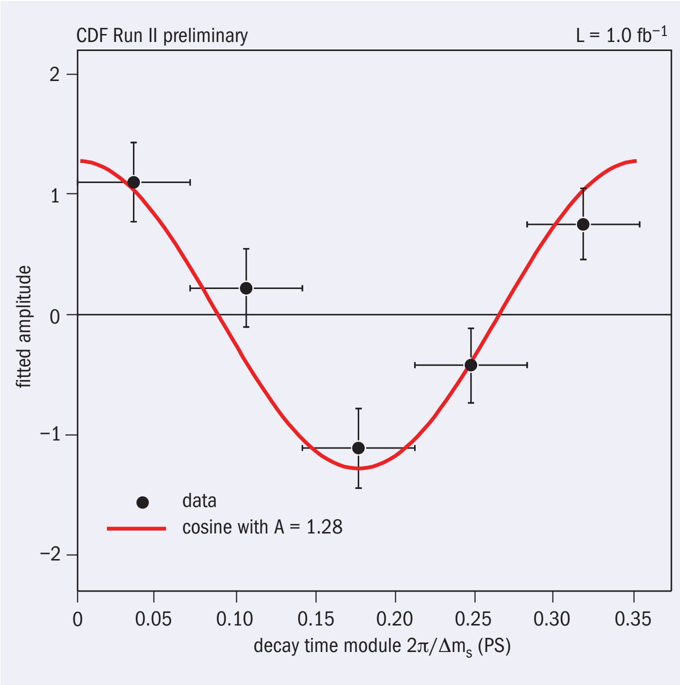


Fig. 4. CDF's $B_s - \bar{B}_s$ oscillation signal measured in five bins of proper decay-time modulo the measured oscillation period.

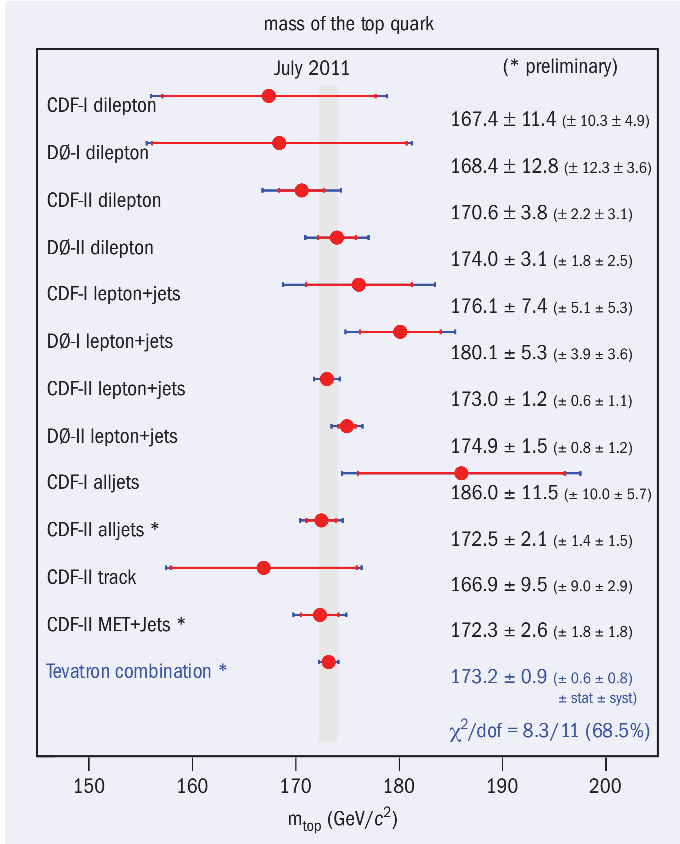


Fig. 5. Tevatron measurements of the top-quark mass.

W boson and top quark are key elements in the Standard Model network that constrains the properties of the Higgs boson. A stellar accomplishment of the Tevatron experiments has been the determination of the W-boson mass as 80.420 ± 0.031 GeV, better than 4 parts in 10^4. Figure 3 summarizes the Tevatron measurements and their impact on the current world average. The combined uncertainty at the end of Run 2 may approach 15 MeV.

The growing data samples available at the Tevatron, along with the evolution of experimental techniques, have made it possible to observe cross-sections times branching ratios well below 0.1 pb. All of the electroweak diboson pairs (Wγ, Zγ, WW, WZ and ZZ) have been detected at the rates predicted by the Standard Model. Mastery of these channels is a prerequisite to the Higgs-boson search at moderate and high masses, but they carry their own physics interest as well: the possibility of validating the Standard Model structure of the triple-gauge couplings and searching for anomalous couplings incompatible with the Standard Model. So far, the three-gauge-boson interactions are consistent with electroweak theory in every particular.

From bottom to top

CDF and DØ have exerted a broad impact on our knowledge of states containing heavy quarks. Studies of the production and decay dynamics of quarkonium states have repeatedly challenged phenomenological models, while measurements of b- and t-quark production have made possible sharp tests of QCD calculations at next-to-leading order. The Tevatron experiments account for nearly all of our knowledge of the B_c meson, with precise measurements of the mass and lifetime. The Tevatron contributes world-leading measurements of masses and lifetimes of B mesons and baryons, and has been the unique source of information on many of the B-baryons. With CDF's recent observation of the Ξ_b^0, all of the spin-1/2 baryons containing one b quark have been observed at the Tevatron, except for the Σ_b^0 (*CERN Courier* September 2011 p8). We also owe to the Tevatron our knowledge of orbitally excited B and B_s mesons, constraints on the mass and quantum numbers of X(3872), important evidence on D^0–$\bar{D}^0$ mixing and high-sensitivity searches for rare decays into dimuons.

The Tevatron experiments met one of the key targets for Run 2 by determining the frequency of B_s–$\bar{B}_s$ oscillations. Following a two-sided limit published by DØ, the CDF collaboration determined the oscillation frequency as 17.77 ± 0.13 ps^{-1} (Abulencia *et al*. 2006). The oscillation signal is shown in figure 4. This beautiful measurement, in line with Standard Model expectations, constrains the manner in which new physics might show itself in B physics.

The discovery of the top quark by the Tevatron collaborations in 1995 was a landmark achievement (Abe *et al*. 1995, Abachi *et al*. 1995, Carithers and Grannis 1995). By 1990, searches by CDF had raised the lower bound on the top-quark mass to 91 GeV, excluding decays of W into t + b. A heavy top decays so swiftly that it cannot be observed directly, but must be inferred from its disintegration into a bottom quark and a W boson – both of which are themselves unstable particles. The hunt took off with the growing data-sets available to both CDF and DØ in 1992–1993 and soon the possibility of observing top was in the air. DØ subsequently raised the lower bound to 131 GeV. Moreover, a growing body of observations that probed quantum corrections to the electroweak theory pointed to a top-quark mass in the range 150–200 GeV. Finding top there emerged as a critical test of the understanding built up over two decades.

Eighteen months of deliciously intense activity culminated in a joint seminar on 2 March 1995, demonstrating that top was found in the reaction $p\bar{p} \rightarrow t\bar{t} + \text{anything}$. CDF gauged the top-quark mass at 176 ± 13 GeV, while DØ reported 199 ± 30 GeV. Since the discovery, larger event samples, improved detectors and sophisticated analysis techniques have led to a detailed dossier of top-quark properties (Deliot and Glenzinski 2010). Tevatron measurements of the top mass have reached 0.54% precision, at 173.2 ± 0.9 GeV, a level that demands scrupulous attention to the theoretical definition of what is being measured (Tevatron Electroweak Working Group 2011). A compilation of the Tevatron measurements is shown in figure 5. CDF and DØ now aim for an uncertainty of ± 1 GeV per experiment; to reach this level of precision will require a better understanding of b-jet modelling and of uncertainties in the signal and background simulations.

The $t\bar{t}$ production characteristics are in good agreement with QCD expectations for the total rate, transverse-momentum dependence and invariant-mass distribution. Tevatron studies support a top-quark charge of +2/3, and show that the tbW interaction is left-handed. Approximately 70% of the W bosons emitted in top decay are longitudinally polarized, while the rest are left-handed. The top-quark lifetime is close to 0.3 yoctosecond (10^{-24} s), as electroweak theory anticipates. Because top decays before hadronizing, it can be studied as a bare quark. Up to this point, exploratory studies of spin correlations among the $t\bar{t}$ decay products are in accord with the Standard Model. Both experi- ▷

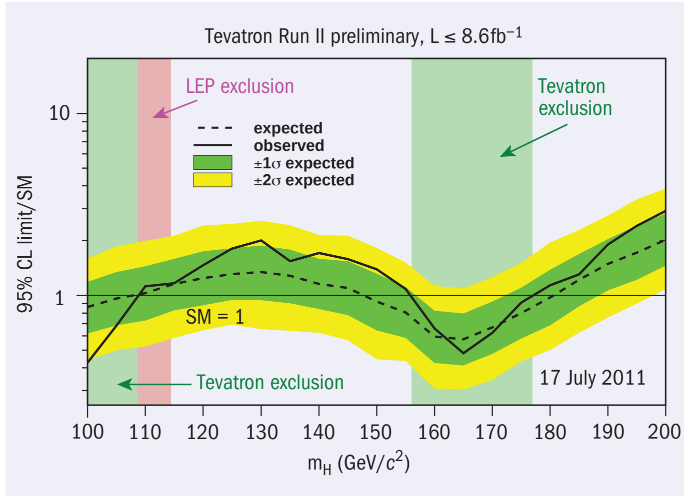


Fig. 6. Observed and expected 95% confidence level (CL) upper limits on the ratios to the Standard Model cross section, as functions of the Higgs boson mass for the combined CDF and DØ analyses. The bands represent 68% and 95% probability regions for fluctuations in the absence of signal.

ments have observed a forward-backward production asymmetry that is considerably larger than the Standard Model predictions, as currently understood (*CERN Courier* May 2011 p9). This tantalizing result – which could point to new physics – challenges theorists to create more robust, detailed and credible simulations of the Standard Model.

Important information about the weak interactions of top comes from the detection of single-top production through the decay of a virtual W boson or the interaction of an exchanged W boson with a b quark. Using an array of multivariate analysis techniques, CDF and DØ have observed single-top production at a rate consistent with the Standard Model. The DØ collaboration has succeeded in isolating the t-channel exchange process. These measurements allow a determination of the strength of the tbW weak coupling that is consistent with the Standard Model prediction of a value near unity, as well as with other indications that $t \rightarrow bW$ is the dominant decay mode of the top quark.

Higgs and other new phenomena

The search for the Standard Model Higgs boson is the ultimate challenge for the Tevatron. The straightforward strategy, to detect a light Higgs boson produced in gluon–gluon fusion that decays into the dominant $b\bar{b}$ mode, is foreclosed by the overwhelming rate of b-quark pair production by the strong interactions. Thus CDF and DØ have had to seek signals in several production channels and decay modes, as well as master many sources of background. Current searches consider gluon–gluon fusion, the associated production of a Higgs boson and W or Z boson and vector-boson fusion. The decay modes examined are $b\bar{b}$, W^+W^-, ZZ, $\gamma\gamma$ and $\tau^+\tau^-$.

So far, the Tevatron experiments have given information on where the Standard-Model Higgs boson is not. The combined analyses of summer 2011, based on up to 8.6 fb^{-1} of data, exclude Standard Model Higgs-boson masses between 156 and 177 GeV, as shown in figure 6 (The Tevatron New-Phenomena and Higgs Working Group 2011). Parallel work has restricted the allowed parameter space for the lightest Higgs boson of supersymmetric models. According to projections informed by current experience, the full Tevatron data-set should yield 95% confidence-level exclusion limits up to 185 GeV – should no signal be present – and "evidence" at the 3σ level below 120 GeV and in the range 150–175 GeV.

During more than two decades as the world's highest-energy machine, the Tevatron has had unparalleled capability to search for direct manifestations of physics beyond the Standard Model. Broad explorations and searches for specific hypothetical phenomena have been major activities for the experiments. The Tevatron constraints on conjectured extensions to the Standard Model are impressive in number and scope: CDF and DØ have set limits on supersymmetric particles, many varieties of extra spatial dimensions, signs of new strong dynamics, carriers of new forces of nature, magnetic monopoles and many more exotica. The null searches compel us to contemplate with greater intensity the unreasonable effectiveness of the Standard Model.

To be sure, some observations do not square with conventional expectations. In addition to the suggestion of a larger-than-foreseen forward-backward asymmetry in top-pair production noted above, it is worth mentioning two other surprising effects now in play. DØ reports an anomalous like-sign dimuon charge asymmetry in semileptonic decays of $b\bar{b}$ pairs that suggests unexpectedly large CP violation in the decays of b-hadrons. CDF sees a yield of jet pairs in association with a W boson that exceeds expectations in the dijet mass interval between 120 and 160 GeV (*CERN Courier* May 2011 p8). DØ does not confirm the excess, but the degree of disagreement remains to be quantified. We should find out soon, from further work at the Tevatron and from new analyses at the LHC, whether any of these results holds up and changes our thinking.

● Further reading

For more about all the results from the Tevatron experiments, see www-cdf.fnal.gov and www-d0.fnal.gov. An article about the Tevatron machine will appear in the November issue of *CERN Courier.*

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Résumé

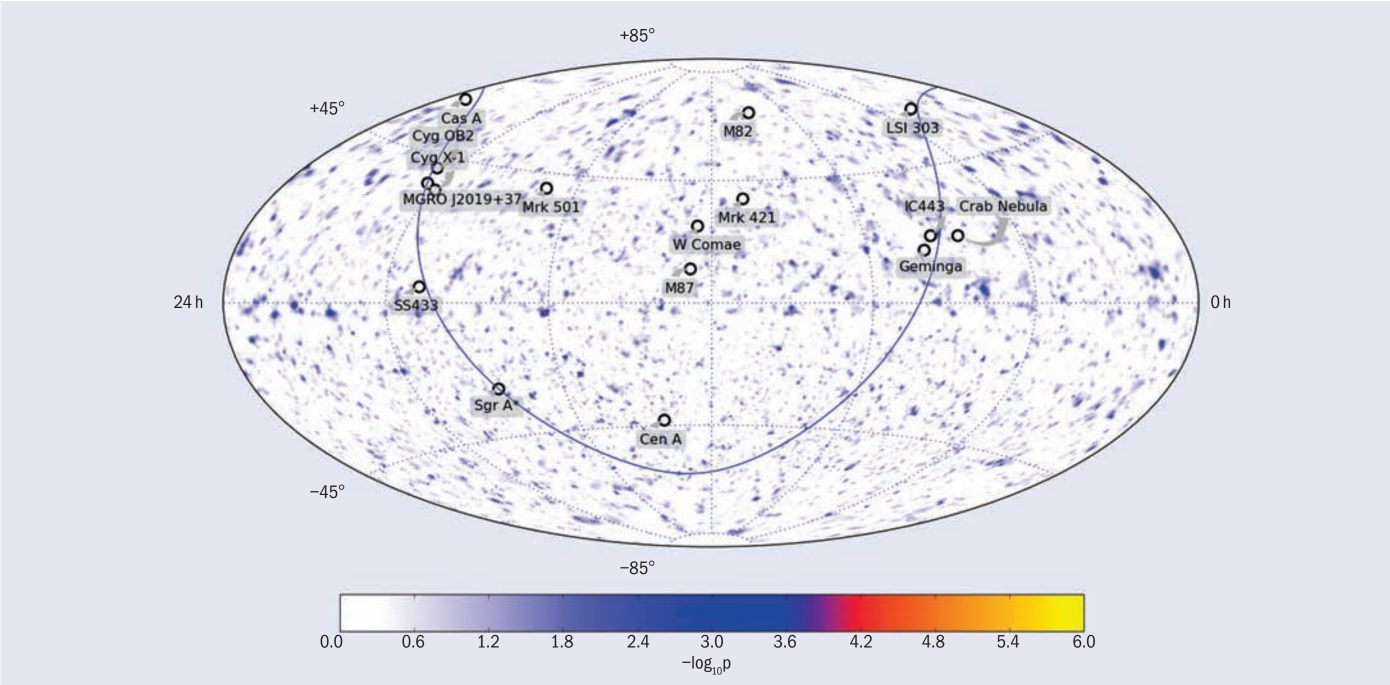
Longue vie au Tevatron

Vingt-cinq ans d'expérimentation s'achèvent pour le Collisionneur Tevatron du Laboratoire Fermi, un pionnier qui a fait reculer les frontières de la science des accélérateurs et de la physique des particules. On doit au premier synchrotron supraconducteur de haute énergie du monde de nombreux résultats inédits : découverte du quark top, mesures de précision des mésons B et des baryons, recherches approfondies de nouveaux phénomènes. Dans cet article, Chris Quigg, théoricien au Laboratoire Fermi, retrace son histoire. Même si les derniers événements ont été enregistrés, l'analyse et l'interprétation des données se poursuivent.

Chris Quigg, Fermilab.

A final thought

The last events have been recorded at the Tevatron collider but the interpretation of data, now enriched by conversation with LHC experiments, goes on. I would like to thank the CDF and DØ collaborators not only for the results they have put in the books, but also for the demands they have placed on theorists to calculate more processes ever more accurately, to make more reliable simulations and to think in new ways.



A neutrino sky map based on data taken with 40 and 59 strings in the IceCube detector. (Image credit: Juan Aguilar/IceCube.)

Looking at the neutrino sky

The NUSKY 2011 workshop on cosmic rays and cosmic neutrinos brought together many of the main players for talks and discussions on the latest news in the field as it enters the era of the cubic-kilometre-scale detector.

Astrophysical neutrinos are produced in the interactions of cosmic rays with an ambient medium of gas (protons) and photons of different energies. Once produced, these cosmic neutrinos can propagate cosmological distances and reach the Earth practically without interactions. They therefore carry unique information about the sources of cosmic rays, their acceleration and the composition of the most energetic phenomena in the universe.

The neutrino sky "seen" by experiments originates in the atmosphere, which shines day and night in neutrinos. One experiment alone, IceCube at the South Pole, has already detected more than 10^5 atmospheric neutrino events. However, the hope is to see "stars in broad daylight" through this atmospheric flux – that is, to observe neutrinos of cosmic origins. These include neutrinos from various point-like sources and some extended objects, as well as diffuse neutrino fluxes. The selection of the energy band – cosmic neutrinos should dominate at high energies – together with directional and time features, as well as correlations with known objects, emitting for instance in γ rays, are the main tools for distinguishing atmospheric and cosmic neutrinos.

The NUSKY 2011 international workshop on cosmic rays and cosmic neutrinos took place at the Abdus Salam International Centre for Theoretical Physics, Trieste, on 20–24 June. It attracted around 90 participants and featured some 40 talks by the main players in the field, covering all of the important aspects of the production, propagation and detection of high-energy cosmic neutrinos. Numerous discussions ensued, focusing on the implications of the latest experimental results, as well as on the status and perspectives of the field.

The workshop took place during a critical period for a field in which the working experiments have reached the sensitivity ▷

Astroparticle physics

necessary to probe realistic theoretical predictions. The results from IceCube – the first cubic-kilometre-scale detector ever built – thus played a prominent role in the discussions (*CERN Courier* March 2011 p28). Their preliminary results correspond to 40 and 59 detector strings (IC40 and IC59); data from IC79 are being analysed and the complete detector, IC86, is now running. So far, the various searches have found no cosmic-neutrino events.

Diffuse neutrino fluxes include the cosmogenic neutrinos generated in cosmic-ray interactions with the photons of the cosmic microwave background, as well as the integrated fluxes from remote, faint and unresolved objects. The IceCube collaboration finds no deviation of the reconstructed neutrino-energy spectrum from that for atmospheric neutrinos. This gives an upper bound on the neutrino flux in the 0.1–10 PeV energy range that is already below the Waxman-Bahcall limit, derived from the known cosmic-ray flux above 10^{19} eV.

As far as individual sources are concerned, the main suspects are objects that are relatively close, where the acceleration of cosmic rays probably occurs. These include supernova remnants (SNRs) in the Galaxy, as well as active galactic nuclei and gamma-ray bursters (GRBs). The IceCube all-sky maps show no statistically significant signal for steady or transient galactic or extragalactic sources. Nor has any neutrino been detected by IceCube (IC40 + IC59) in the so called stacking analysis of the GRBs (more than 100). The limit on the neutrino flux that emerges from this analysis is a factor of 5 below predictions, thus disfavouring the fireball model of GRBs.

The Pierre Auger Observatory in Argentina and ANITA, the balloon-bourne radio-interferometer that flew over Antarctica, are sensitive to the upper end of the cosmic-neutrino spectrum, the most relevant range for cosmogenic neutrinos (i.e. 10^{18} eV or 1 EeV). No neutrino-candidate events have been found in Auger data for periods equivalent to two years of the full array. ANITA-II has one candidate event, with one background event expected; cosmogenic models predict from 0.3 to 25 events.

The predictions for atmospheric neutrino fluxes depend on the properties of cosmic rays and on the physical conditions of the sources. In this connection, there are some new and interesting results. IceCube has found cosmic-ray anisotropies in the 20–400 TeV energy range, with a significant angular structure in the southern hemisphere. Anisotropy at higher energies, above 100 TeV, could reveal some connection to nearby SNRs. In addition, the KASCADE-Grande extensive air-shower array has observed structures in the "knee" region of the all-particle cosmic-ray spectrum.

Cosmic-ray origins

Turning to the question of the composition of ultra-high-energy cosmic rays (UHECRs), there had been somewhat contradictory results from the HiRes experiment and the Pierre Auger Observatory. In this connection, the possibilities for UHECR production by sources in the Galaxy (such as past GRBs), as well as a dominant contribution from Centaurus A, were discussed at the workshop. The basic principles of cosmic-ray acceleration in SNRs are well understood on the basis of the non-linear theory of diffusive acceleration at collisionless Newtonian shocks.

The neutrino–γ-ray connection was at the centre of many discussions as a result of the wealth of new information from γ-ray astronomy. The production of neutrinos should be accompanied by production of γ-rays from π^0–decay (the hadronic mechanism). However, ultrahigh-energy γs from extragalactic sources and γs of cosmogenic origin can interact with the medium (photons, electrons), giving rise to electromagnetic cascades. Hence, the whole γ spectrum shifts to lower energies in the giga- to tera-electronvolt range, where the Large Angle telescope (LAT) on the Fermi Gamma Ray Telescope gives important bounds. The Fermi-LAT results on the extragalactic γ flux can be translated into bounds on cosmic rays and cosmogenic neutrinos – the so-called "cascade" bound, based on the approximate equality of the energy released in neutrino production and in the electromagnetic cascade process. These data challenge the GRB origin of cosmic rays: if GRBs are the source of cosmic rays, then 10 events are predicted, while nothing appears in the diffuse bound.

One open question concerns the mechanism for the production of photons at the source. Tera-electron-volt γ-rays from transparent galactic sources can provide a direct indication of cosmic-ray acceleration sites. However, γs can be produced by accelerated electrons via the inverse Compton effect and by synchrotron radiation (both leptonic mechanisms). Fermi-LAT has measured γ spectra from a large number of SNRs and it turns out that both leptonic and hadronic γ-ray models work for SNRs on a source-by-source basis. In the case of GRBs, only bright GRBs are favoured by the Fermi-LAT data as the detectable sources. Nevertheless, bright nearby GRBs seem to be rare.

Features of neutrino propagation are a key element when the flavour of neutrino is taken into account in the detection process. The flavour composition and its dependence on neutrino energy are determined by conditions at the neutrino sources, in particular by the strength of magnetic field, the density distribution, etc. Flavour is also affected by neutrino oscillations and therefore depends on neutrino parameters. The expected composition ratio has the form $a:1:1$ with a around 1, its precise value depending on 1–3 mixing, the deviation of 2–3 mixing from maximal, the neutrino-mass hierarchy and CP-violation. Various effects typical of physics beyond the Standard Model, such as neutrino decay, non-standard neutrino interactions or the presence of new neutrino species, can also modify the ratio. Finally, the ratio is extremely sensitive to possible violations of fundamental symmetries, such as Lorentz symmetry or the equivalence principle, which lead to modifications in the dispersion relations.

The hope is that, with more data from IceCube, a discovery is on the horizon.

Another highlight of the workshop was the report on the first-year of data-taking by DeepCore, the inner detector of IceCube, which has a low energy threshold of 10 GeV. The rate of events, which include cascades induced by electron-neutrinos as well as neutral current muon-neutrinos, was shown. DeepCore will detect around 800 neutrino-induced cascades per year. The physics motivations for the Phased IceCube Next Generation

Upgrade (PINGU-I and PINGU-II) were also presented.

Neutrino observatories have now reached sufficient sensitivity to constrain multimessenger signals, γ-rays and UHECRs with minimal assumptions. That there is no evidence as yet for astrophysical neutrinos poses a problem for future projects because it means that IceCube will only scratch the surface of neutrino astronomy. The prime targets now are the transient sources.

There are several projects already under consideration or in progress. KM3NeT, a detector for neutrino astronomy under the Mediterranean Sea, which will have an instrumented volume of more than 5 km^3, is in its preparatory phase. It will search for neutrino point sources in the energy range 100 GeV – 1 PeV. The Cherenkov Telescope Array is a new instrument for very high-energy ($10–10^5$) GeV γ astronomy. JEM-EUSO will detect Cherenkov light coming from the atmosphere using a telescope on the International Space Station that will have an instantaneous aperture of up to 10^6 km^2. ANITA-III, approved to fly in 2013–2014, will search for ultra-high-energy neutrinos with 3–5 times higher sensitivity than ANITA-II. The Askaryan Radio Array is a ground-based antenna array at the South Pole covering an area of 100 km^2. The expected yield is 3–5 neutrinos per year above 10^{17} eV, below the bulk of the cosmogenic neutrino predictions.

The NUSKY 2011 workshop was held just as high-energy neutrino astronomy enters a new cubic-kilometre era. Current bounds already have important implications and any further improvement of data will have an impact on the picture of the neutrino sky, with important consequences. The hope is that, with progressively more data from IceCube, a discovery is on the horizon. As Francis Halzen, of the University of Wisconsin-Madison and IceCube, concluded, "Hess 1912… and still no conclusion [on the origins of cosmic rays]; now the instrumentation is in place… SNRs and GRBs are in close range!"

Résumé

Les yeux rivés sur le ciel neutrino

NUSKY 2011, l'atelier international sur les rayons et les neutrinos cosmiques, a rassemblé du 20 au 24 juin dernier les plus éminents spécialistes du domaine autour des questions essentielles que sont la production, la propagation et la détection des neutrinos cosmiques de haute énergie. Les débats ont notamment porté sur les conséquences des derniers résultats obtenus, ainsi que sur l'état de la discipline et ses perspectives d'avenir. L'atelier a eu lieu au moment où les expériences ont atteint la sensibilité nécessaire pour vérifier les prédictions réalistes en la matière. Les résultats d'IceCube, le premier détecteur d'un kilomètre cube jamais construit, étaient évidemment très attendus.

Daniel Hernández Díaz and **Alexei Smirnov**, The Abdus Salam International Centre for Theoretical Physics.

CERN

CLOUD: closing in on the init

At the end of August, the journal *Nature* published the first results from CLOUD, an experiment at CERN that aims to settle the question of whether or not cosmic rays have a climatically significant effect on clouds.

A view inside the 3-m chamber for the CLOUD experiment, which has been b

Studies of the effects on clouds of atmospheric ions from galactic cosmic rays extend as far back as C T R Wilson at the beginning of the 20th century, whose work on simulating ion-droplet processes led to a Nobel Prize in Physics for his development of the cloud chamber (*CERN Courier* May 2011 p38). Some 50 years later, laboratory studies beginning in the 1960s established ion-enhancement of aerosol nucleation at ion-production rates that are characteristic of the lower atmosphere (e.g. Vohra *et al*. 1984). Aerosols are tiny liquid or solid particles suspended in the atmosphere and – above a size of around 100 nm – they provide the seed particles for all cloud droplets; "nucleation" indicates that they are produced by the clustering (condensation) of trace atmospheric molecules rather than by direct emission into the atmosphere, such as sea-spray particles.

Robert Dickinson of the National Center for Atmospheric Research, Boulder, Colorado, was the first to postulate in detail a cosmic-ray-aerosol-cloud mechanism to explain solar-climate variability (Dickinson 1975). More than 20 years later, correlations between cosmic-ray changes and clouds were reported for the first time by two groups (Svensmark and Friis-Christensen 1997; Pudovkin and Veretenenko 1997). Since these initial observations, a large number of papers have been published that either dispute or support the presence of significant correlations between cosmic rays and clouds, so the atmospheric observations are not yet settled. Carefully controlled laboratory experiments provide the best way of understanding whether or not cosmic rays could affect Earth's clouds and climate because atmospheric measurements are affected by many uncontrolled sources of variability. This is precisely the aim of the CLOUD experiment at CERN.

In its first round of measurements, the CLOUD experiment is tackling one of the most challenging and long-standing problems in atmospheric science: to understand how new aerosol particles are formed in the atmosphere and the effect that these particles have on climate. Increases in the number concentration of atmospheric aerosol particles cool the climate both directly, by reflecting more sunlight, and indirectly, by forming additional cloud droplets, which makes clouds brighter and extends their lifetimes. The increased amount of aerosols in the atmosphere caused by human activities is thought to have offset a large fraction of the warming caused by greenhouse gases.

By current estimates, about half of all cloud droplets are formed on aerosol particles that were nucleated, so the nucleation process is likely to be important for climate. However, the physical mechanisms of nucleation are not well understood, so aerosol nucleation in current global-climate models is either based on theoretical calculations or adjusted to match observations. The CLOUD collaboration aims to understand the nucleation process and provide reliable aerosol physics for climate models. These data will help to quantify the direct and indirect radiative effects of aerosols on the climate, which are recognized as the largest source of uncertainty in climate forcing contributed by mankind.

CERN know-how has been key in achieving the technical requirements for CLOUD.

tial steps of cloud formation

n built to demanding specifications to keep contamination at low levels.

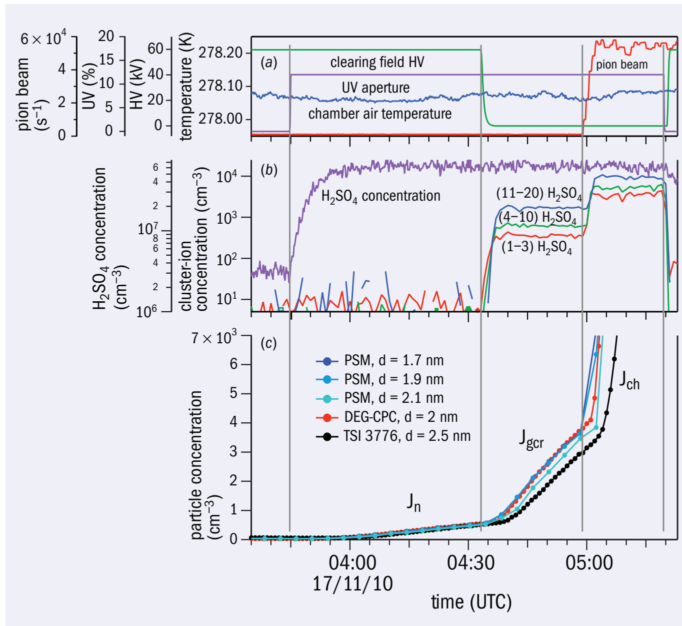


Fig. 1. Example of a typical CLOUD run sequence, as a function of Coordinated Universal Time (UTC), to measure a set of neutral, galactic cosmic ray (GCR) and charged (pion beam) nucleation rates: a) control parameters and chamber air temperature, b) sulphuric-acid and cluster-ion concentrations, and c) aerosol-particle number concentrations, measured by several instruments. The production of ions from GCRs and then, at higher rate, from the pion beam causes sharp increases in the cluster-ion concentrations (b) and particle-formation rates (c). The onset times are progressively delayed according to the number of H_2SO_4 molecules in the cluster (b) or the 50% detection-size threshold, d, of the particle counter (c).

To answer these questions, the CLOUD collaboration has built a 3-m stainless-steel chamber with much lower concentrations of contaminants than all previous experiments. This allows the measurement of nucleation from controlled amounts of selected trace gases without the complicating effect of undetected gases. CERN know-how has been key in achieving the demanding technical requirements for the CLOUD chamber and its gas and thermal systems: impurities of condensable vapours in the chamber must be kept below about 1 part per trillion; and the temperature stability of the chamber must be around 0.01 K. CLOUD uses a secondary beam from the CERN Proton Synchrotron (PS) to simulate the effects of cosmic rays with precise control of the "cosmic ray" intensity. The experiment has several other unique aspects, including the capability to create an ion-free environment with an internal electric clearing field, precise control of light-induced (photolytic) gas-phase reactions by means of ultraviolet (UV) illumination from a fibre-optic system, as well as highly stable operation at any temperature between 300 K and 183 K. During experimental runs, small amounts of the chamber atmosphere are extracted and passed through an array of state-of-the-art mass spectrometers and other instruments to measure the ultralow concentrations of atmospheric vapours and other important quantities.

The first results

In its first results published in *Nature*, the CLOUD collaboration reports on its measurements of the formation of new particles from sulphuric acid, ammonia and water vapours, which have long been thought to account for nucleation in the Earth's atmosphere (Kirkby *et al*. 2011). The experiment has also measured the enhancement of atmospheric aerosol nucleation from galactic cosmic rays and the report includes the first-ever measurements of the chemistry and growth, molecule-by-molecule, of newly-formed charged clusters from single molecules up to stable aerosol particles.

Figure 1 shows a typical sequence of online measurements ▷

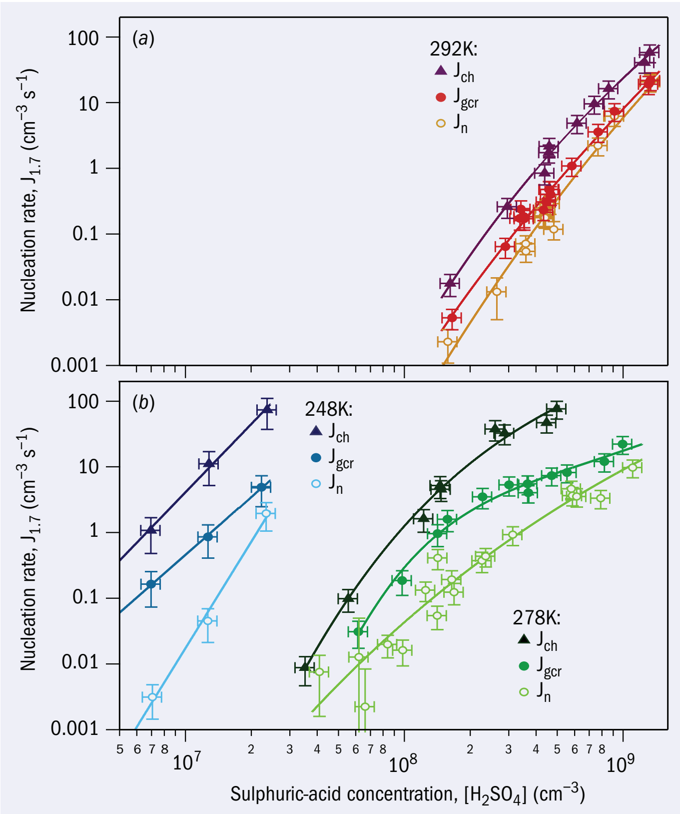


Fig. 2. Neutral, GCR and charged (pion beam) nucleation rates, J_n, J_{gcr} and J_{ch}, respectively, measured by CLOUD as a function of sulphuric-acid concentration at 38% relative humidity (RH) at a) 292 K, b) 248 K and 278 K. A clear enhancement is seen for the GCR and pion beam conditions, indicating the importance of ion-induced nucleation.

of the nucleation rates under different ionization conditions. High voltage is initially applied to the clearing-field electrodes to sweep ions from the chamber and suppress all effects of ionization (a). The run is started by opening the shutter of the UV system at a selected aperture, which rapidly establishes a chosen sulphuric-acid concentration in the chamber by photolytic oxidation of SO_2 in the presence of O_3 and H_2O – as occurs in the real atmosphere (b). Particles begin to appear in each aerosol counter after a time delay that depends on the particle growth rate and the detection size threshold (c). When the neutral nucleation rate, J_n, has been measured, the clearing field is turned off (a). This allows cosmic rays to generate ion pairs that remain in the chamber, as shown by the appearance of small ion clusters (b). The ions give rise to a distinct increase in the nucleation rate, J_{gcr}, resulting from ion-induced nucleation at ground-level cosmic-ray intensity (c). In the next step, a 3.5 GeV/*c* pion beam from the PS is turned on and passes through the chamber, producing a further sharp increase in the nucleation rate, corresponding to J_{ch}. Finally, the run is ended by closing the UV shutter and turning on the clearing field high-voltage, which starts to clear the chamber of aerosols in preparation for a new run under different conditions.

CLOUD has already made several important discoveries. First, the experiment has shown that the most likely nucleating vapours, sulphuric acid and ammonia, cannot account for the nucleation that is observed in the lower atmosphere. The nucleation measured in the chamber occurs at only 1/10–1/1000 of the rates observed in the lower atmosphere. It is clear from these first results from CLOUD that the treatment of aerosol formation in climate models will need to be revised substantially because all models assume that nucleation in the lower atmosphere is caused by these vapours and water alone. It is now essential to identify the additional nucleating vapours and whether their sources are mainly natural or from human activities. If the vapours have strong anthropogenic sources then there potentially exists a new climate-forcing agent from human activities. Alternatively, if the source is natural, then there is the potential for a new climate feedback that may affect the understanding of how the climate responds to radiative forcings.

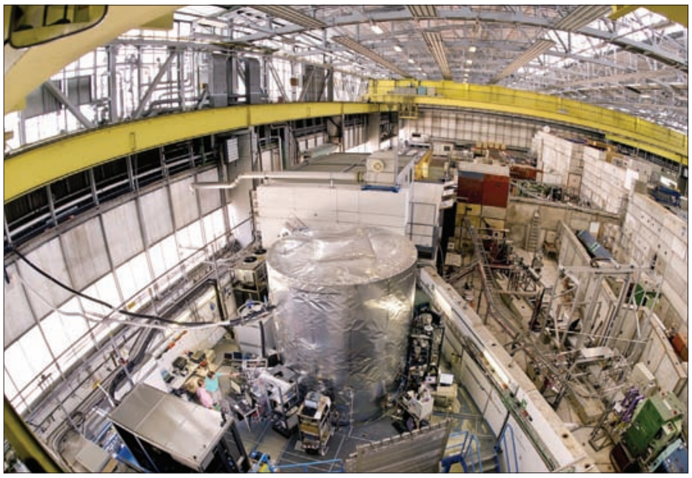
Second, CLOUD has found that natural rates of atmospheric ionization caused by galactic cosmic rays substantially enhance nucleation under the conditions studied so far – by up to a factor of 10. Ion-enhancement is particularly pronounced in the cool temperatures of the mid-troposphere (about 5 km altitude) and above. CLOUD has found that at these temperatures, sulphuric acid and water vapour can nucleate without the need for additional vapours. This result leaves open the possibility that cosmic rays could also influence climate. However, it is premature to conclude that cosmic rays have a significant influence on clouds and climate until the additional nucleating vapours have been identified, their ion enhancement measured and the ultimate effects on clouds have been confirmed. So far, CLOUD has only measured the formation rate of aerosols in the few-nanometre size range, which are far too small to seed clouds.

The next steps for the CLOUD experiment will be to investigate the role of biogenic organic vapours in atmospheric aerosol nucleation, to measure condensational growth of aerosols up to sizes sufficient to seed cloud droplets and to study the effect of cosmic rays on these processes. Also, during the next few months, a new fast expansion system will be installed on the CLOUD chamber to allow it to operate as a classical Wilson cloud chamber for the *in situ* creation of liquid and ice clouds. This will extend CLOUD's capability to study the effects of cosmic rays directly on cloud droplets and ice particles themselves.

When he visited the Ben Nevis Observatory in 1894 and 1895, Wilson was fascinated by the electrical and cloud condensation phenomena he witnessed. He returned to the Cavendish Laboratory at Cambridge determined to recreate clouds in the laboratory and study their physics. This led to his expansion cloud chamber, later described by Ernest Rutherford as "the most original and wonderful instrument in scientific history". After his Nobel prize in 1927, Wilson returned to his passion for meteorological phenomena and devoted the rest of his life to the study of atmospheric electricity and clouds. Today, a century after its invention, Wilson's cloud chamber remains "the most original and wonderful instrument"

It is clear that aerosol formation in climate models will need to be revised substantially

CERN



The CLOUD experiment in the East Hall at the PS at CERN.

for studying the link between cosmic rays and clouds.

● The CLOUD (Cosmics Leaving OUtdoor Droplets) experiment is conducted by an international and interdisciplinary collaboration of scientists from Austria (University of Innsbruck, University of Vienna), Finland (Finnish Meteorological Institute, Helsinki Institute of Physics, University of Eastern Finland, University of Helsinki), Germany (Johann Wolfgang Goethe University Frankfurt, Leibniz Institute for Tropospheric Research), Portugal (University of Beira Interior, University of Lisbon), Russia (Lebedev Physical Institute), Switzerland (CERN, Paul Scherrer Institut), the UK (University of Manchester, University of Leeds) and the US (California Institute of Technology). CLOUD has received invaluable support from CERN accelerator and technical teams including, in particular, PH-DT, EN-CV, EN-MME, EN-MEF and TE-VSC.

● Further reading

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Résumé

CLOUD : le mystère de la formation des nuages

L'expérience CLOUD du CERN vise à répondre à la question suivante : les rayons cosmiques ont-ils un effet sur les nuages et donc sur le climat ? À l'aide d'une chambre spéciale exposée à un faisceau de pions, elle a mesuré la formation de particules d'aérosol à partir d'acide sulfurique, d'ammoniac et de vapeurs d'eau ajoutés à de l'air. D'après les premiers résultats, ces vapeurs ne peuvent à elles seules expliquer la formation d'aérosols observée dans la basse atmosphère. CLOUD a aussi découvert que l'ionisation atmosphérique par les rayons cosmiques galactiques est un facteur favorisant, mais il est encore trop tôt pour dire si les rayons cosmiques ont une influence sur le climat.

Jasper Kirkby, CERN.

An artist's impression of the planned Med*Austron hadron therapy centre. (Image credit: Moser Architekten, Vienna.)*

Head-to-head technology transfer for hadron therapy

The development of the *Med*Austron project for a hadron therapy facility in Austria marks the first time that CERN has worked to set up an accelerator community in a member state through technology transfer.

The fall of the Berlin Wall in November 1989 and the subsequent disintegration of the Iron Curtain ended half a century of division for central Europe. Austria moved abruptly from being on the edge of two large political and economic powers to being at the centre of the reviving central European region. Anticipating the potential of the new situation, Meinhard Regler, of the Austrian Academy of Sciences Institute of High Energy Physics (HEPHY), started to campaign for a centre of excellence for scientific research with an international and multidisciplinary character that would stimulate new growth. In the first instance, the exact definition of the facility was left open. Among the possibilities were a synchrotron radiation facility, a centre for microelectronics and a computing centre, but whichever the final choice the aim was to equip the region with a tool for world-class research and to counter the "brain drain" of young scientists.

A commission chaired by Peter Skalicky, the Rector of the Technical University of Vienna, was set up under the patronage of the Austrian Academy of Sciences to study the project, provisionally called AUSTRON, that would fulfil this role. In spring 1991, at a meeting in Bratislava of the "Pentagonale" – a loose co-operation of states instigated by Austria in November 1989, which consisted of Austria, Czechoslovakia, Italy, Hungary and Yugoslavia – the decision was taken that AUSTRON should be a neutron spallation source. In October of that year the idea was developed further and endorsed by a panel of experts representing more than 50 research institutions, during a working week of the "Hexagonale" held at CERN (the addition of Poland to the Pentagonale in 1991 had created the "Hexagonale", later to become the Central European Initiative).

Neutrons were an attractive proposition. Apart from "ticking all of the boxes", neutron diagnostics were considered to be reaching a point where their use would increase sharply, as had been the case with synchrotron light some years earlier. There was also the so-called "neutron drought" that the pending closure of many nuclear reactors was likely to trigger. Carlo Rubbia, then CERN's director-general, strongly encouraged Austria and – because Austria did not have its own accelerator community – he promised the vitally needed technology transfer from CERN's accelerator experts.

By the end of December 1992, Erhard Busek, then minister for science and research, officially announced the support of the Austrian government. An international scientific advisory board was set up the following year under the chairmanship of Albert Furrer of the Paul Scherrer Institute (PSI) and a detailed study of the AUSTRON facility took place, hosted by CERN, with the resulting report published in November 1994. Upgrade studies continued into 1998 but sadly the project was faltering and was officially shelved in 2003. It seemed that CERN had lost the chance to stimulate the creation of a new accelerator community in a member ▷

state, but the ashes of AUSTRON contained the seed and fertilizer for a second project.

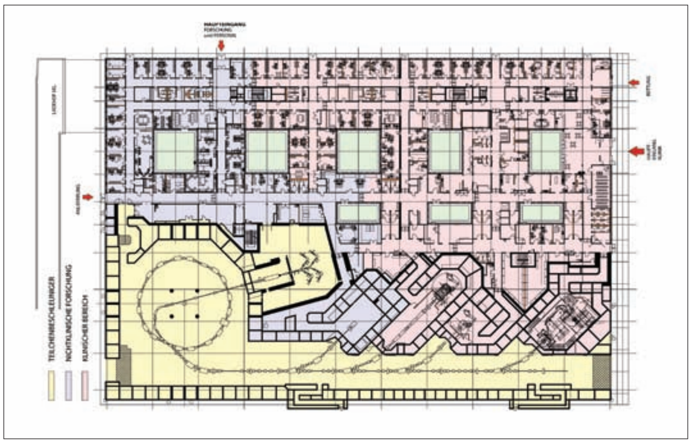
Well before AUSTRON, Robert R Wilson, who was working on cyclotrons at Lawrence Berkeley Laboratory (LBL), had written a paper in 1946 in which he proposed using the behaviour of protons at the Bragg peak (where they deposit most of their energy over a short distance at the end of their trajectory) for cancer therapy and in which he even had the foresight to mention carbon ions (*CERN Courier* December 2006 p24). LBL went on to pioneer hadron therapy, beginning with protons and helium ions and later, after the commissioning of the Bevalac in 1974, work started in earnest with heavier ion species. It continued for about 15 years until the world's first hospital-based proton treatment centre, Loma Linda, opened in California in 1990. The accelerator equipment for Loma Linda was built with the help of Fermilab and its director – Wilson. In Europe, the first treatment using protons was performed for a cervical cancer in 1957 at the University of Uppsala, which has continued to be a leading proton-based treatment centre.

Seeds for a new project

In 1988, a two-year study for the European Light Ion Medical Accelerator (EULIMA) began to design a European cyclotron for treating deep-seated tumours with 400 MeV/nucleon carbon ions. CERN participated in this study and contributed an alternative design based on a synchrotron. This alternative design, which investigated advanced ideas for gantries and incorporated expertise gained from the Low Energy Antiproton Ring (LEAR) at CERN, firmly set the synchrotron as the preferred machine for light-ion therapy to the present day. This work inspired Regler together with Horst Schönauer at CERN to include a radio-biological facility in the original AUSTRON design study, so providing the seed for a second project.

Towards the end of the AUSTRON initiative, CERN was under considerable pressure from its own project for the LHC, but there was still a feeling of lost opportunities. Inside AUSTRON, Regler was not ready to give up and was thinking about the medical option, which he called Med-AUSTRON. At the same time, in Italy there was the Terapia con Radiazion Adroniche (TERA) project led by the indefatigable Ugo Amaldi, who was also wondering if CERN could be persuaded to host another study, but this time for a synchrotron for cancer therapy. CERN was particularly well positioned for studying the synchrotron design in view of the extensive R&D that teams there had carried out on slow-extraction schemes in both LEAR and the Proton Synchrotron (PS). These studies ranged from classic quadrupole-driven configurations to exotic ultraslow extractions using stochastic noise. However, it was not a forgone conclusion that CERN would agree in the light of the effort required for the LHC, but the conviction and support of Kurt Hübner, who was then director of accelerators, succeeded in establishing the Proton Ion Medical Machine Study (PIMMS) in the PS Division.

The PIMMS group was formed following an agreement between Med-AUSTRON and the TERA Foundation and was headed by Philip Bryant with expert help from CERN staff. The study group was later joined by Oncology-2000 in the Czech Republic and had a close collaboration with GSI at Darmstadt. The brief was to design a synchrotron-based centre capable of sub-millimetre accuracy for the conformal treatment of complex-shaped tumours by active scanning. Although the centre was to be primarily for carbon ions, protons were to be included. The effort focused first on the theoretical understanding of slow extraction and the techniques to produce a smooth beam-spill. The PIMMS team started work in January 1996 and published their report four years later.



Engineering drawing of the Med*Austron centre showing: the accelerator complex (yellow); nonclinical offices, workshops and the first beam station devoted to research (blue); clinical areas and beam stations for cancer treatment, the last with a proton gantry (pink); space for natural light access (green). (Image credit: Moser Architekten, Vienna.)*

Rise of *Med*Austron

The acceptance and funding of a project is never a quick process. Unsurprisingly, MedAustron, which had lost its capital letters to stress its independence from AUSTRON, became the subject of a new design study under Thomas Auberger and Erich Griesmayer in Wiener Neustadt, which was published in 2004. By now the weight of the various studies and the excellent proof-of-principle experiments carried out by laboratories such as LBL, GSI and PSI using their own high-energy physics machines, together with the growing involvement of industry, had changed the hadron-therapy landscape. Ion Beam Applications SA in Belgium was already dominating the market for turnkey, cyclotron-based proton facilities and Siemens in Germany was associating with Danfysik in Denmark for the up-and-coming market in carbon-ion machines. Germany was the first European country to fund a carbon-ion centre, with the Heidelberg Ion Therapy Centre; Italy was next with its Centro Nazionale di Adroterapia Oncologica (CNAO) in Pavia; and in 2004 Austria followed suit with the political approval and partial funding of *Med*Austron (which had now gained an italic front-end) in Wiener Neustadt.

In 2004, the Austrian federal government, the government of Lower Austria and the city of Wiener Neustadt put forward a plan for funding the nonclinical research part of *Med*Austron and in February 2005, PEG *Med*Austron GmbH was created under the direction of Theodor Krendelsberger to look after this funding and search for industrial investment partners in a public/private-partnership model for the funding of the medical treatment part. This

Michael Benedikt, centre, describes work on the Med*Austron construction site to Steve Myers and members of CERN's accelerator management during a visit on 25 August 2011. (Image credit: Thomas Kästenbauer/Bildreport Austria.)*

did not work and the government of Lower Austria stepped forward and assumed the role of the main investor and created the EBG *Med*Austron GmbH in April 2007 under the direction of Martin Schima and later Bernd Mösslacher to oversee the construction (and future operation) of the facility.

With the conceptual design, funding and business plan in place, the need to formalize the technology transfer for the accelerator design was urgent because Austria had no accelerator community of its own. Discussions with CERN's director-general at the time, Robert Aymar, and Steve Myers, then Accelerators & Beams Department leader, led to a strategy with three pillars. First, CERN agreed to help by hosting and intensively training the *Med*Austron team in all aspects of the accelerator design and construction. Second, collaboration agreements were signed with CNAO and PSI, which allowed *Med*Austron to benefit from the experience of the more advanced Italian project concerning the accelerator complex, as well as from the wealth of knowledge in PSI concerning gantry design and all aspects of medical operation. Some six employees of EBG *Med*Austron are currently integrated into the PSI activities. Finally, a wider programme of contact and interchanges with strong international partners was set up. This strategy is now well advanced and strongly supported by the current director-general of CERN, Rolf Heuer. Commissioning is expected to start in 2013 and treatments in 2015.

This was not the first time that CERN had hosted a team starting a new facility. In the 1970s, the newly-formed European Southern Observatory was given its first home in CERN, followed in the 1980s by the European Synchrotron Radiation Facility. However, in the case of *Med*Austron, it was the first time that CERN had agreed not only to house a project but also to train the EBG staff by making a CERN staff member, Michael Benedikt, the Technical Project Leader. To date 35 young engineers have been hired by EBG *Med*Austron and are working with the experts at CERN to design the *Med*Austron accelerator complex. The rapid hiring phase was greatly facilitated by the Austrian doctoral student programme, which furnished a third of this intake. Without the doctoral programme, which is funded by the Austrian federal government and has operated in CERN since 1993, it would not have been possible to find so many highly-qualified engineers so quickly.

MedAustron represents the most intensive "head-to-head" transfer of technology that CERN has ever undertaken. In many ways, it is the age-old system of master and apprentice and – as usually happens – the apprentice quickly overtakes the master who looks on proudly.

This is already apparent in the design refinements and new ideas that are being incorporated into the machine. The civil engineering has just started on the site in Wiener Neustadt and in one to two years the young team will fly from the nest at CERN to their new offices. This will be an exciting moment for all involved. For CERN it will mark the first time that an accelerator community has been set up in a member state through technology transfer, surely a reason to celebrate.

Résumé

Med*Austron : un projet de coopération inédit*

Med*Austron, le projet autrichien d'hadronthérapie, est l'aboutissement d'un long travail dans lequel le CERN s'est investi pour créer, par le biais du transfert de technologies, une communauté au service d'un accélérateur. L'article décrit l'évolution du projet : de sa naissance en 1989 après la chute du mur de Berlin, jusqu'aux premiers coups de pioche, il y a quelques mois. Le CERN, associé à toutes les phases du projet, s'est engagé dernièrement dans une étape essentielle : la formation intensive des équipes pour tous les aspects liés à la conception et à la construction de l'accélérateur.*

Michael Benedikt, CERN, and **Philip Bryant**, CERN (retired).

TOTEM probes new depths in pp elastic scattering

One of the smaller experiments at the LHC is finding out more about what the proton looks like in the new high energy region.

Forty years ago, the Intersecting Storage Rings (ISR) at CERN became the world's first proton–proton collider, transporting the study of particle physics to much higher energies than was otherwise achievable. Now, the same is happening again at CERN as the LHC begins to open up a new high-energy frontier and it is interesting to find out how phenomena discovered at the ISR develop as the collision energy increases.

One of the first discoveries at the ISR was that the total proton–proton (pp) cross-section rises with energy: rather surprisingly, the proton becomes both larger and more opaque (*CERN Courier* January/February 2011 p39). Later, measurements of pp elastic scattering showed further unusual behaviour, revealing a peculiar structure in the variation of the differential cross-section with t, the four-momentum transfer squared. Now, the TOTEM collaboration at the LHC has published its first results on pp elastic scattering, which confirm that the behaviour observed at the ISR continues towards much higher energies.

The differential cross-section measured at the ISR showed a sharp peak at small values of $|t| = (0.01–0.5)\ GeV^2$ that falls away exponentially to a dip, at about $1.4\ GeV^2$, followed by a broad local maximum that eventually decreases more or less as $|t|^{-8}$ (figure 1a). Measurements at different centre-of-mass energies in the range 23–62 GeV revealed that the sharp peak at low |t| appears to become narrower ("shrinks") with rising energies, with the dip moving towards smaller values of |t|, indicating that the radius of the proton ($r_p^2 \sim 1/|t|$) is, in effect, increasing with energy. However, the power-law dependence at larger |t| values appeared not to depend on energy.

The ISR was also the world's first proton–antiproton ($p\bar{p}$) collider and measurements there showed a similar behaviour for the elastic differential cross-section (figure 1b), but without the pronounced dip, which was replaced instead by a broad "shoulder". Between the ISR and the start-up of the LHC, the only measurement of pp elastic scattering was performed by the pp2pp experiment at Brookhaven's Relativistic Heavy Ion Collider at 200 GeV in the centre-of mass over a limited |t| range around $10^{-2}\ GeV^2$. For $p\bar{p}$, on the other hand, higher collision energies became available in ▷

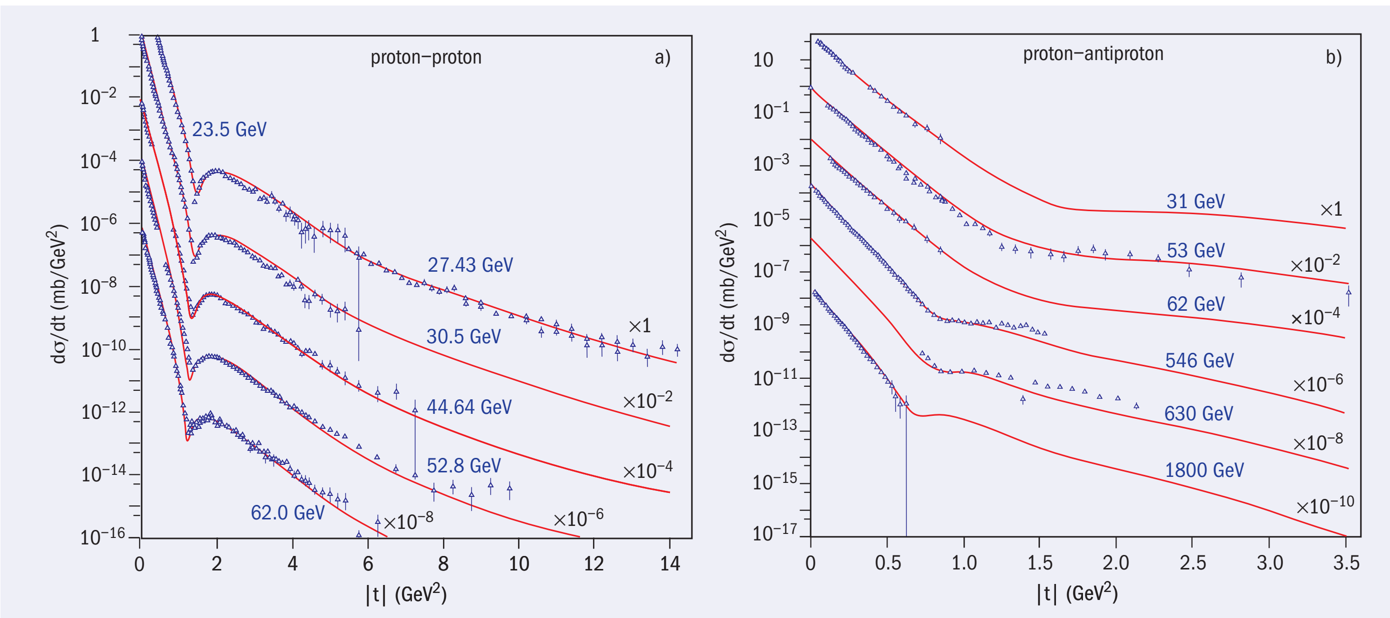


Fig. 1. (a) The differential cross-section for pp elastic scattering measured at the ISR showed a peak at small |t|, followed by a dip and then a broad maximum. (b) Measurements at the ISR and later machines showed that the dip does not appear in $p\bar{p}$ elastic scattering.

LHC physics

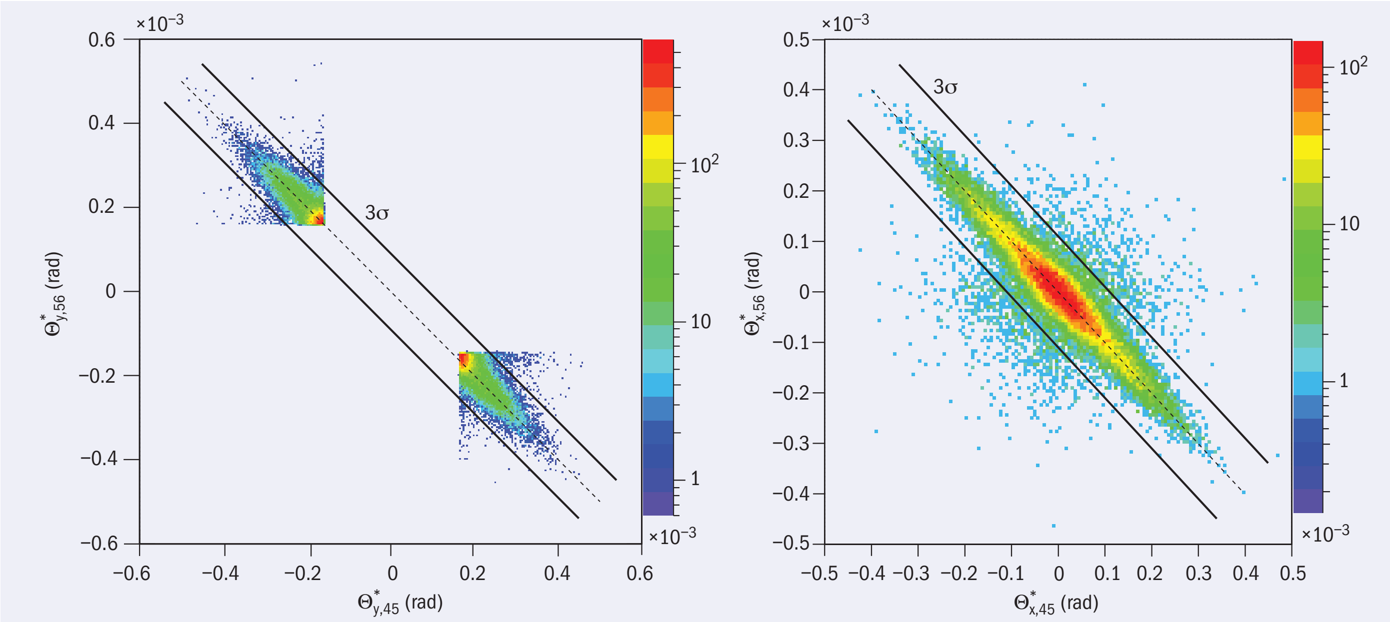


Fig. 2. The correlation between the reconstructed proton scattering angles Θ^*_y (left) and Θ^*_x (right) on both sides of the interaction point ("45" = to the left, "56" = to the right). The observed spread is in agreement with the beam divergence.

the 1980s; first at CERN's Super Proton Synchrotron (546 GeV) and then at Fermilab's Tevatron (up to 1.96 TeV). Measurements at these energies showed that the $p\bar{p}$ cross-section continued to exhibit a similar shape as at the ISR, but without a pronounced dip as observed in pp scattering.

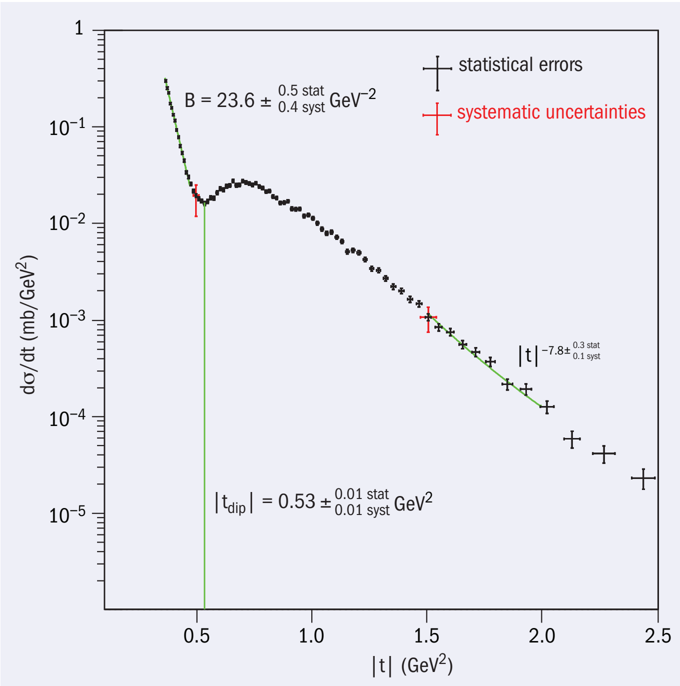
The LHC now presents the first opportunity to follow the behaviour observed at the ISR for pp scattering to higher energies, in particular with the experiment TOTEM, which stands for "TOTal cross-section, Elastic scattering and diffraction dissociation Measurement". TOTEM is optimized for measuring elastic pp scattering over values of |t| ultimately in the range 0.001–10 GeV^2. It can detect protons scattered at small angles by using silicon detectors in Roman Pots – movable insertions in the beam pipe that allow the detectors to be brought close to the beam (*CERN Courier* September 2009 p19). The experiment is located at point 5 on the LHC (together with CMS) and there are Roman Pot stations at distances of 147–149 m and 215–220 m from the interaction point. Each station contains two units that are 2–5 m apart and each consists of two pots in the vertical plane, which approach the beam from above and below, and one pot that moves horizontally. Each pot contains a stack of 10 specially designed silicon-strip detectors that have an insensitive region facing the beam of only a few tens of micrometres.

There are 512 strips per detector with 66 μm spacing and the detectors are oriented such that five of the 10 planes per pot are at +45° with respect to the edge near the beam, while the other five are at –45°. The trigger requires collinear hits in at least three of the five planes in each projection. This is implemented by programmable coincidence logic in integrated circuits that are mounted on the detectors and must therefore be radiation tolerant. Elastic candidate events require two reconstructed collinear diagonal tracks.

In a dedicated run of the LHC in October 2010, with only four proton bunches of 7×10^{10} protons per bunch, the TOTEM experiment acquired data for a total integrated luminosity of 6.1 nb^{-1} at a centre-of-mass energy of 7 TeV. The low-luminosity configuration of the LHC allowed the detectors to be brought in towards the centre of the beam to a distance of only seven times the 1σ width of the beam itself. The collaboration has analysed these data and in July published the first results on elastic pp scattering in the new high-energy region of the LHC (Antchev *et al*. 2011).

The figure on the front cover of this month's *CERN Courier* shows the histogram of the intersection points of the selected tracks in this data set with the Roman-pot silicon detectors at 220 m from the interaction point. The tracks are indicated in the bottom silicon detectors at one side and in the top detectors at the other side of the interaction point, representing the pp scattering configuration; the coloured scale shows the number of tracks on a log scale, from less than 10 in the dark blue to more than 10 000 in the red. The displacement in the vertical direction (less than 2 mm for the red region) is to a first approximation proportional to the vertical scattering angle. With the current LHC beam optics the horizontal scattering angle leads to only a small displacement in the x direction. However, protons that have lost momentum are shifted in the +x direction by the dispersion of the machine. This means that elastically scattered protons remain close to x=0, while those that are diffractively scattered are displaced in the positive x direction (the green region). Already in the raw data, the accumulation of elastic events close to x=0 and near the edge of the detectors is clearly distinguishable from the background mainly from diffractive events. Thus |x| <0.4 mm is the first criterion for selecting elastic candidates.

The LHC presents the first opportunity to follow the behaviour observed at the ISR.



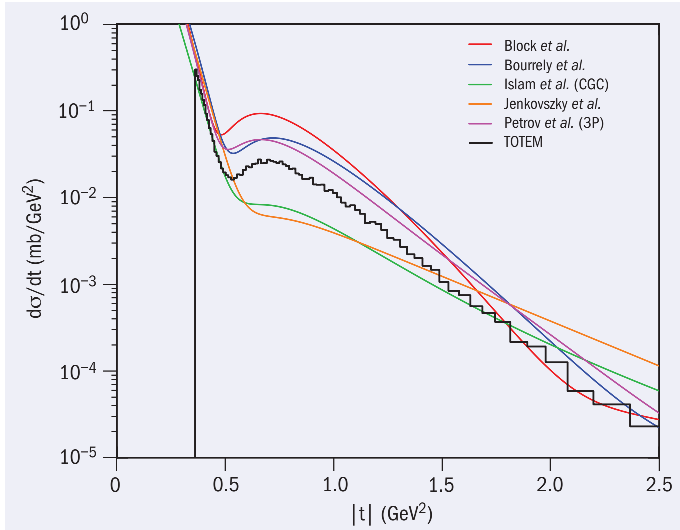


Fig. 3. (left) TOTEM's measured differential cross-section dσ/dt. (Antchev et al. *2011)*

Fig. 4. (above) The measured dσ/dt compared with the predictions of several models (see Antchev et al. *for further details).*

Vertical and horizontal scattering angles can be deduced from measurements of the track displacement in y and the track angle in x at the Roman pot stations. For collinear tracks on either side of the interaction point, these angles should be the same – as is impressively demonstrated in figure 2. Collinearity cuts at 3σ, as shown in the figure, provide another powerful tool to reduce background further.

From a total of 5.28×10^6 recorded triggers, 293×10^3 events had the required constructed tracks and elastic topology, of which 70.2×10^3 passed the cut in $|x|$ and 66.0×10^3 survived the final collinearity cuts. These events were then used to calculate the differential cross-section, the value of $|t|$ being derived from the measured scattering angle.

Figure 3 shows the differential cross-section that TOTEM has measured for elastic pp scattering in the $|t|$ range $0.36 < |t| < 2.5\ \text{GeV}^2$. It clearly exhibits the global features that were first seen at the ISR. At $|t| < 0.47\ \text{GeV}^2$ the data show an exponential decrease with a peak at low $|t|$ sharpening with energy and leading to a well pronounced diffractive minimum at $|t| = (0.53 \pm 0.01$ stat. ± 0.01 syst.) GeV², followed by a rounded peak that falls away as a power law, $|t|^{-n}$, where $n = 7.8 \pm 0.3$ stat. ± 0.1 syst. In particular, the data confirm the trend first observed at the ISR that the dip moves towards smaller values of $|t|$ with increasing collision energy. At the ISR the dip appeared at a value of $|t|$ around 1.4 GeV²; now, at a centre-of-mass energy of 7 TeV – some 100 times higher – TOTEM has found the dip to be near 0.5 GeV². Interpreting this within the optical model, the proton continues to become larger with energy and consequently the total cross-section should rise further.

These first measurements of elastic scattering at LHC energies already begin to differentiate between various models. As figure 4 shows the position of the dip and the slopes at smaller and larger $|t|$ agree with the predictions of some models but not with others. However, none of these models is capable of correctly predicting the measured size of the cross-section over the total $|t|$-range.

For the TOTEM collaboration this marks just the beginning. The experiment has already accumulated 5.8 pb⁻¹ of data in high-luminosity runs that will extend the range in $|t|$ to 4–5 GeV². Special LHC beam optics for dedicated runs are presently being commissioned to reach much smaller $|t|$ values down to below 0.01 GeV². This will allow a better extrapolation of the differential cross-section to $t = 0$. A measurement of the total pp cross-section with a luminosity-independent method based on the optical theorem will then be possible for the first time in this new high-energy region. The TOTEM collaboration is confident that this data taking will start soon and that first results will be available around the end of 2011. Furthermore, diffractive phenomena are on the list of investigations. There is much to look forward to – in more ways than one.

● Further reading

G Antchev *et al.* TOTEM collaboration 2011 *EPL* **95** 41001.

Résumé

TOTEM explore la diffusion élastique proton–proton

La collaboration TOTEM, au LHC, a publié ses premiers résultats sur la diffusion élastique proton–proton (pp) à une énergie de 7 TeV dans le centre de masse. Les mesures de section efficace différentielle étendent les études menées aux anneaux de stockage à intersections (ISR) du CERN (le premier collisionneur proton–proton du monde) à des énergies plus de cent fois plus élevées. Ces premiers résultats indiquent que le comportement qui avait été observé aux ISR se répète à ces hautes énergies. Les données permettent déjà une comparaison avec des modères théoriques.

Christine Sutton, CERN, together with the TOTEM Collaboration.

Faces & Places

Appointment

Matveev becomes JINR director

Victor Matveev took office as director of the Joint Institute for Nuclear Research (JINR) on 1 September, after being elected to the position in March.

After graduating in 1964 from St Petersburg State University, where he studied theoretical physics under Vladimir Fock, Matveev went on to work in the Laboratory of Theoretical Physics of JINR in Dubna. In 1978 he joined the Institute for Nuclear Research of the Russian Academy of Sciences (RAS) and has been the institute's director since 1987.

Matveev has made a number of important contributions in theoretical physics, including the development of methods of quantum field theory for studying high-energy scattering, the description of relativistic composite systems, the formulation of the quark theory of nuclear forces and studies of the effects of quark degrees of freedom in nuclei. He also introduced the notions of hidden colour and quark counting rules.

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

He succeeds Alexei Sissakian , who sadly died in May last year (*CERN Courier* June 2010 p32).

Victor Matveev takes the helm in Dubna. (Image credit: JINR.)

Collaboration

New links forged between Ecuador and CERN

A new protocol signed on 12 July in Quito is opening the way to stronger links between the Ecuadorian scientific community and CERN. The operational framework provided by the protocol will enable scientists from Ecuador to take part in CERN's projects, supported by the Ecuadorian authorities.

Ecuador's involvement with CERN dates back to 1999 when a first international co-operation agreement was signed. However, despite these early beginnings, only a few scientists from Ecuador, affiliated to non-Ecuadorian institutes, have since been directly involved in CERN's projects, in particular the CMS experiment at the LHC. That should change now with a new protocol that provides a better defined framework for the collaboration between CERN and Ecuador.

The new agreement will benefit both the scientific and the educational communities in Ecuador as it concerns not only physicists, engineers and specialized technicians from universities, but also high-school teachers and students. One teacher from Ecuador has already participated in the High-School Teacher programme at CERN and an Ecuadorian student participated this year in CERN's Summer Student programme.

The protocol also promotes the development of undergraduate and graduate programmes in physics at Ecuadorian universities. These courses should increase the number of qualified students who can participate in CERN's scientific activities. Scientists from Ecuador will be involved in all aspects of these activities, from theoretical and experimental physics to electronics and Grid computing.

During the signing ceremony at the National Secretariat of Higher Education, Science and Technology (SENESCYT), Quito, on 12 July. Left to right: Guillermo Solórzano, Minister for Coordination of Knowledge and Human Talent, René Ramirez Gallegos, National Secretary for Higher Education, Science and Technology, SENESCYT, Felicitas Pauss, CERN's head of international relations, and Jose Salicio, CERN's adviser for Latin American countries. (Image credit: SENESCYT.)

AWARDS

ICTP honours work in conformal theory

ICTP has awarded its 2011 Dirac Medal to Edouard Brézin of the École Normale Supérieure, Paris, John Cardy of the University of Oxford and Alexander Zamolodchikov of Rutgers University, New Jersey. The award recognizes "their independent pioneering work in field theoretical methods to the study of critical phenomena and phase transitions; in particular, their significant contributions to conformal field theories and integrable systems". Their research and the physical implications of their formal developments have had important consequences in both classical and quantum condensed-matter systems as well as in string theory.

ICTP's Dirac Medal, first awarded in 1985, is given in honour of Paul Dirac, who was one of the greatest physicists of the 20th century and a staunch friend of the centre. It is awarded annually on his birthday, 8 August, to scientists who have made significant contributions to theoretical physics.

MEETING

The 8th **Vienna Central European Seminar on Particle Physics and Quantum Field Theory** is to be held in Vienna on 25–27 November. This year's subject is "Particle physics and the LHC". There will be talks on the CMS, ATLAS, LHCb and ALICE experiments and on the LHC high-luminosity programme. There will also be theoretical physics lectures on heavy-ion physics, QCD, flavour physics, ultracold neutrons, electroweak symmetry breaking and new physics for the LHC. Nobel Laureate Frank Wilczek has accepted an invitation to give the "Boltzmann-Lecture" as part of the programme. For further details, see www.univie.ac.at/vienna.seminar/2011/.

CORRECTION

In the recent report "ATLAS takes a closer look at dibosons" (*CERN Courier* September 2011 p12), the error on the measured cross-section for ZZ production missed a decimal point. It should have read $8.4^{+2.7}_{-2.4}$ pb.

Also, in the report "Alice and the charm of heavy-ion collisions" (July/August 2011 pp7–8) the figure should read, "ALICE preliminary". Apologies to all concerned.

COLLABORATION

ISAPP: training for young astroparticle physicists

The International School on Astroparticle Physics (ISAPP) is a network of doctorate schools and institutes that started in 2002, with the aim of bringing together the particle-physics and astrophysics communities to help in building up a community of astroparticle physicists. The network's main means towards achieving this goal centres on international schools and summer institutes, organized as joint activities between the network members and aimed at PhD students and young researchers from different countries. These activities began with the first two international schools in 2003. Since then, 12 schools and one summer institute have been organized, including this year's schools in Heidelberg and Varenna.

The schools are neither workshops nor conferences; instead they provide real training courses for doctoral students. This spirit characterizes the organization from the start, including the choice of scientific programmes, the selection of teachers and the lectures themselves. Every school is preceded by 2–3 introductory days, with lectures on the Standard Model of particle physics, for the astrophysics community, and on the basic cosmic physics for the particle physicists. The schools, which have received endorsement from the Particle and Nuclear Astrophysics and Gravitation International Committee of the International Union of Pure and Applied Physics, are typically 8–12 days long and attendance is limited to about 60 students.

The subject of the schools is focused, in turn, on one or two of the following topics: neutrino physics and astrophysics, dark matter, dark energy, cosmic rays, cosmic microwave background (CMB), the large-scale universe, the early universe and gravitational waves. The school this year in Heidelberg on 8–15 July was on "The dark side of the universe", while the one in Varenna on 26 July – 5 August was on "Neutrino physics and astrophysics". Some 105 students attended in Heidelberg and about 50 in Varenna.

Although the ISAPP schools are organized by the member institutions in the network, they are open to students from anywhere in the world. Fellowships, including living expenses and also travel if needed, are available to students from countries and institutions that have limited resources. The selection is based on the students' CVs. Students come mainly from western Europe, but the presence of students from eastern Europe, the US and Canada, Central and South America and Asia is steadily increasing.

Students listen intently at the first school this summer, which was held in Heidelberg in July. (Image credit: ISAPP.)

Four schools are already being planned for 2012 (in Spain and France) and 2013 (in Sweden and Israel). They will be on, respectively: CMB and high-energy physics: from the early universe to clusters of galaxies and large-scale structure; Multimessengers in high-energy astroparticle and astrophysics; Dark-matter composition and detection; From LHC to IceCube: implications for astroparticle physics. In addition, a summer institute on underground experiments will be organized at the Gran Sasso Laboratory.

The schools are not the only activity of the network. ISAPP organized its first summer institute at the Karlsruhe Institute of Technology in 2009, on "Phenomenology and detector techniques in astroparticle physics" and many doctoral theses have been prepared in co-tutelage between institutions in the network. There are also exchanges of visitors, teachers and students, which are organized on the basis of an agreement signed by all of the members of the network.

Meanwhile, the ISAPP network continues to grow. It now includes 33 institutions from 10 European countries, including Russia and Israel, and is open to new entrants.

● For more about ISAPP, see www.mi.infn.it/ISAPP/.

WORKSHOP

Casting light on the dark

More than 70 scientists from all over the world met on Mykonos, the Greek "island of the light", to discuss current knowledge about the dark universe at the 7th PATRAS workshop on Axions, WIMPs and WISPs on 26 June – 1 July. As in previous meetings in the series, PATRAS 2011 brought together experimentalists and theorists to discuss the status of the field in an inspiring and friendly atmosphere.

The two major pillars of these meetings are the two best motivated candidates for particle dark matter – the axion and the weakly interacting massive particle (WIMP). Inspired by the possibilities that are opening up in ongoing axion searches and triggered by theoretical developments, particles with related properties have also become a focus of the workshop, so axion-like particles (ALPs) or more general, very weakly interacting slim (light) particles (WISPs) were covered in the range of presentations.

The light shines on the participants at the 7th PATRAS workshop on the island of Mykonos, Greece. (Image credit: Marc Schumann.)

A few introductory talks set the scene. Pierre Sikivie of the University of Florida discussed axion dark matter and the special behaviour of this subelectron-volt particle. In particular, if axion dark-matter forms a Bose-Einstein condensate, it could lead to observable features in cosmological structures. This possibility sparked a lively discussion on how these features fare in the light of N-body simulations and observations. Such simulations are a speciality of Ben Moore of the University of Zurich, who determined the "frequency of elephants in the Galaxy" (or the number of Earth–Moon-like systems). Gianfranco Bertone, also currently at Zurich, focused on WIMP dark matter and explained that to pinpoint experimentally its major properties, mass and cross-section, with high precision, direct detection signals and signatures from collider experiments are necessary. This demonstrated that we truly live in exciting times as both direct-detection experiments and the LHC are delivering data at an astonishing rate. Jihn Kim of Seoul National University, one of the inventors of high-scale axion models, ventured beyond axions and showed how everything could be embedded into the bigger picture.

Direct dark-matter searches are a traditional focus of the workshop and there were presentations on the status of the EDELWEISS, XENON, CDEX/TEXONO, XMASS, CDMS, CRESS and DARWIN experiments and on their recent results. It became clear that the race to discover WIMP dark matter is on and it remains open as to whether the first hints will be from direct detection or the LHC. Indeed some direct detection experiments already report excess events, so one discussion session was devoted to the current situation, where signal claims of low-mass WIMPs by several experiments are challenged by the non-observations by several others. To resolve these issues, more efforts should go into co-ordinated background studies, a point that Priscilla Cushman of the University of Minnesota emphasized.

Experimental searches are developing rapidly for subelectron-volt (axion) dark matter and other particles, such as hidden photons and chameleons, which might provide a solution to the problem of dark energy as Philippe Brax, of Saclay, pointed out. This was evident in talks about several experiments – CAST, ADMX, the Yale cavity experiment, ALPS, GammeV, SHIPS and BMV/XAX – that in one way or another try to observe "light-shining through a wall" or even to convert dark matter into light. There are many more new and interesting ideas and experiments to shed light on very weak interactions, such as experiments with ultracold neutrons or, at somewhat higher energy scales, with electrons fired at fixed targets. Talks on laboratory searches were complemented by presentations on astrophysical bounds on light particles, for example from the Sun or white dwarfs; the latter even provide a hint that such particles could be just around the corner.

The PATRAS programme traditionally also features recent results, new theoretical ideas, and exciting projects in particle and astroparticle physics, beyond the main focus of the conference. This year, there were several talks about the neutrino and in particular about the recent measurement of the last missing mixing angle by T2K (*CERN Courier* September 2011 p6), searches for electric dipole-moments and recent highlights from the ATLAS and LHCb experiments at the LHC.

As well as the inspiring talks and in-depth discussions, the beautiful venue, the delicious Greek food, an excursion to the famous ruins on the neighbouring island, Delos, and a memorable conference party, all made this workshop surpass the expectations of the participants and the organizers.

● The workshop was supported by CERN, DESY, the University of Patras, the Institute for Particle Physics Phenomenology (Durham University), and the University of Zurich. Further information and the slides of the presentations can be found at http://axion-wimp.desy.de. The next workshop will be held in Chicago in summer 2012.

CULTURE

Creative collisions in Linz and beyond

Take one of the world's most prestigious digital arts organizations, Ars Electronica, collide it with CERN, and what do you get? The first official cultural partnership under CERN's new cultural policy, Great Arts for Great Science. This special collision's mission: to detect and display creativity and the human imagination, elements that are even more invisible to the human eye than particles .

The launch of the partnership at the Ars Electronica Festival in Linz, marked the beginning of a three-year relationship between the two organizations. Both share a common purpose: to create cultural innovation and new knowledge – in CERN's case, through its science, engineering and technology; in Ars Electronica's, through developing new technologies and designs in heady artistic fusions. Bring the two organizations together and creative collisions will happen across art, science, technology and society.

The first manifestation of this cultural fusion was the six-day Ars Electronica Festival on 31 August – 6 September. "Origin – How it All Begins" was inspired by CERN's quest for fundamental knowledge courtesy of the collaboration between scientists from some 580 institutions in more than 100 countries around the world. The festival focused on investigating the importance of fundamental research in the modern short-term, applied-driven age to generate new ideas and innovation – and more. In the words of the festival's artistic directors, Christine Schopf and Gerfried Stocker, the festival concentrated on "taking a fresh look at the true significance of places and facilities like CERN. It could very well be that they are not only models for spaces conducive to perception and invention that are indispensable for scientists, but also for the development of designs for a viable, sustainable society that humankind needs so urgently now."

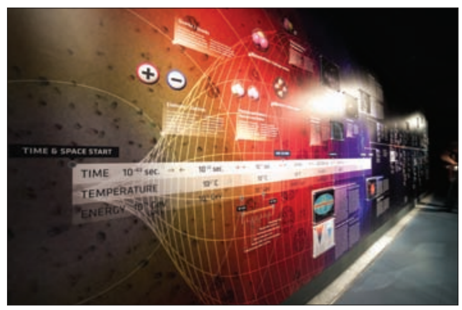
For six days throughout Linz, more than 35 000 visitors from around the world were thrilled by a packed programme of talks, concerts, installations, interventions, exhibitions, performances, videos and presentations of new inventions, technologies and artists' works. Joao Pequenao, of the ATLAS experiment, demonstrated his 3D holographic model of the detector in full data flow; in the great Brucknerhaus concert hall, CERN's director-general, Rolf Heuer,

LED strips mounted behind the glass panes illuminate the façade of the Ars Electronica Centre in Linz. (Image credit: Nicolas Ferrando, Lois Lammerhuber.)

and Jochi Ito, the new director of MIT Media Lab, discussed innovation; Carsten Nicolai's extraordinary piece visualizing the soundtrack of the effect of magnetic fields on a beam of electrons grabbed the eyeballs; and children at Create Your Own World and during the Kinder Uni cross-examined top scientists and thinkers from different fields. Even sacred spaces such as St Mary's Cathedral were not immune, with the great explorer of the audio comos, Sam Aiunger, enticing audiences "to think with their ears".

The festival was also the occasion for the unveiling of another CERN initiative. On the gala night of the Prix Ars Electronica – the digital and media arts equivalent of the Oscars – CERN and Ars Electronica announced that there was to be an addition to the prizes, which are also known as the Golden Nicas. The Prix Ars Electronica Collide@CERN will be an annual prize for the next three years. The prize is an open call to artists in any art form who work in the digital domain to win a joint residency of up to three months in total both at CERN and with the transdisciplinary Futurelab team at Ars Electronica, thanks to the funding given to the project by external funders and donors.

This was the first of a series of open calls in the Collide@CERN Artists Residency Programme for artists in different fields to apply to win a place as an artist in residence



The exhibition, Origin – How it All Begins, *at the Ars Electronica festival this year. (Image credit: Florian Voggeneder.)*

at CERN. The next will be announced later this year in the field of dance and performance, with prize money from the City of Geneva and the creative period of three months at CERN funded by the Canton of Geneva. The health group UNIQA Assurances Switzerland is sponsoring of all the artists' insurance for the entire programme.

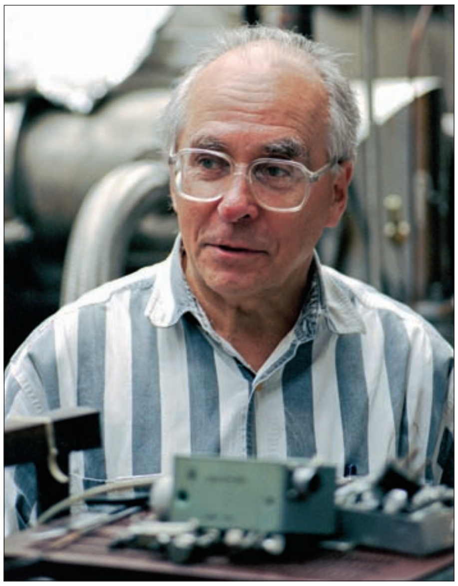
Behind the whole programme is the belief that: arts + science = culture. Both are expressions of what it is to be human, they are just expressed differently. Put them together, colliding the minds of scientists with the imaginations of artists, and who knows what innovations will happen through these creative collisions.

Obituaries

Vladimir Lobashev 1934–2011

Vladimir Lobashev, who was well known in the field of nuclear and elementary particle physics, passed away on 3 August, after a long illness. He made important contributions to fundamental studies in parity and CP violation, to neutron and neutrino physics, and to medium-energy physics.

The early part of Lobashev's scientific career, at St Petersburg Nuclear Physics Institute of the Russian Academy of Sciences, was dedicated mainly to the weak interaction physics. His discovery of parity-violating effects in nuclear electromagnetic transitions was instrumental in establishing the universality of weak interactions. He was awarded the Lenin Prize for this work in 1974. In the course of this research he discovered and made the first measurements of a new effect in QED – the rotation of the polarization plane of gamma-rays in propagating through polarized electrons. He also designed novel methods of dealing with ultracold neutrons and obtained a limit on the CP-violating neutron electric-dipole moment, which was the best in the world at the time.



Vladimir Lobashev. (Image credit: INR.)

In 1972 Lobashev moved to the Institute for Nuclear Research of the Russian Academy of Sciences, Troitsk, where he played a major role in designing and supervising the construction of the complex of intense beams of the Moscow Meson Factory. His most significant recent result is an invention of a new type of spectrometer for beta-decay electrons and an experiment to make a direct measurement of the mass of the electron-neutrino in tritium beta-decay, which together with the Mainz experiment produced the best limit on the neutrino mass.

Lobashev's research was highly appreciated in Russia and all over the world. He was a member of the Russian Academy of Sciences and received many government awards, including the title of Honorary Citizen of the city of Troitsk.

His passing is a great loss to Russian science. He will always be remembered by his numerous former students and colleagues as a great researcher who devoted all of his life to science.

We express our deep sorrow to his relatives and close friends.

● *Friends and colleagues.*

Ryszard Gokieli 1947–2011

Ryszard Gokieli, a highly valued high-energy physicist and computing expert, passed away on 20 July, after a two-month struggle to recover from a serious heart attack.

Usually seen late at night in his office, with a laptop and a cup of coffee, Gokieli was known to his colleagues and friends as a brilliant researcher, unusually competent and tireless in his work. His friends remember talking to him as a pleasure, enjoying the correctness of his judgements and his specific, subtle sense of humour. His younger colleagues will always recall how helpful he was in both physics and computing matters.

Born in 1947, Gokieli graduated from the University of Warsaw. For most of his career he was employed by the Soltan Institute for Nuclear Studies and was involved in a series of large experiments on the particle colliders at CERN. In the 1970s he worked in the Split Field Magnet Collaboration at the Intersecting Storage Rings, where the production of hadrons at large transverse momenta was observed for the first time, providing evidence for the quark nature of hadronic matter. Then, for about 15 years beginning in late 1980s, he was a member of the DELPHI collaboration at the Large Electron–Positron collider. There his competence in computing was recognized and he became leader of the DELPHI Central Computing effort.

Ryszard Gokieli. (Image credit: Jerzy Nomańczuk.)

With the advent of the LHC era, Gokieli gradually increased his commitment to the CMS experiment, as a member of the Warsaw group. Once again seduced by the challenges of data processing, he started developing computing Grids. In 2005 he became a member of the CERN-led project, Enabling Grids for E-science, and soon afterwards became the Polish representative in the Worldwide LHC Computing Grid initiative. Setting up a pan-European and worldwide grid for high-energy physics was a major success, but also Gokieli's personal success. Its importance can only be appreciated now that the LHC is gaining impetus and discoveries are round the corner.

In 2009 Gokieli took on yet another big task in organizing and building national computing infrastructure and services for nuclear power plants in Poland. As deputy director he recently devoted most of his enthusiasm to this project – the Computing Centre Świerk – in work that has now been sadly and terminally interrupted.

● *Wojciech Wiślicki, Soltan Institute for Nuclear Studies.*

Visits

Mamphono Khaketla, minister of education and training for the Kingdom of Lesotho, second from left, came to CERN on 8 July. The delegation, which included, from left to right, **Motsoakapa Makara**, principal secretary for the ministry of education and training, **Mefane Lintle**, Lesotho delegate, and **Moshe Anthony Maruping**, Lesotho ambassador, visited the ATLAS visitor centre with **Peter Jenni**, former ATLAS spokesperson.

On 2 August **Kassym-Jomart Tokayev**, director-general for the United Nations Office at Geneva, centre right, toured the LHC superconducting magnet test hall at CERN with **Frédérick Bordry**, left, head of CERN's technology department. While at CERN, Tokayev also visited the ATLAS visitor centre and UNOSAT (UNITAR's operational satellite-applications programme).

Director-general, ministry of higher education, science and technology for the Republic of Slovenia, **Jana Kolar**, left, was welcomed to CERN on 18 July by CERN's director-general, **Rolf Heuer**. During her visit she toured the ATLAS visitor centre, the LHC superconducting magnet test hall and CERN's exhibition the *Universe of Particles* in the Globe of Science and Innovation.

Faces & Places

New products

Highland Technology has released its latest industrial/aerospace VME module, the V210 relay board. The V210 features 64 SPDT electromechanical power relays under VME register control. Features include relay state readback, VME activity and error LEDs, and jumper-free configuration. Relays are rated for 2 A, 240 VAC, and 60 W maximum. The module is switch-selectable to operate in conventional or latching-relay modes, and is a drop-in replacement for all versions of the VMIC VMIVME-2210 relay module. For further details, tel +1 415 551 1700, e-mail info@highlandtechnology.com, or visit www.highlandtechnology.com.

MKS Instruments Inc has introduced the elite RF Power Generator for amorphous Si PV, LED and MEMS applications. The elite generator's integrated, single PCBA design offers exceptional reliability, and its air cooled, compact, light-weight design provides a cost-effective, easy-to-install solution for RF deposition and etch needs. It is available in 2U full rack and 3U half rack enclosures to allow for rack mounting, and is available in power levels of 300 W, 600 W and 750 W. For more information, contact MaryAnn Naddy, tel +1 978 645 5538, e-mail MaryAnn_Naddy@mksinst.com, or see www.mksinst.com.

National Instruments has unveiled NI LabVIEW 2011, the 25th anniversary version of its system design software. LabVIEW 2011 has new engineering-specific libraries and can interact with the new multicore NI CompactRIO controller and NI PXIe-5665. NI has also announced new 1-slot NI Compact DAQ chassis that support wireless, USB and Ethernet buses. The NI cDAQ-9191, cDAQ-9181 and cDAQ-9171 support all NI C series modules for the NI CompactDAQ platform and can be used in conjunction with the existing 4- and 8-slot chassis. For further details, tel +44 1635 523 545, e-mail info.uk@ni.com, or visit www.uk.ni.com.

Southern Scientific has introduced a hands-free, personnel contamination monitor that provides a cost-effective solution for contamination monitoring in controlled areas. Handhound is wall-mounted, housed in a stainless steel enclosure, and because its operation is entirely hands-free, all risk of equipment contamination is removed. A scan is automatically initiated when a user places their hands under the detector and accurate voice recognition allows them to select their name from a pre-programmed list and commence measurement. For more information, visit www.southernscientific.co.uk.

Unitemp has introduced the LC1000, a new low-cost capacity temperature chamber for the testing and monitoring of semiconductors and other products. The chamber is "eco-friendly" with a low current consumption of 13A. The temperature range is –20°C to 80°C with an accuracy of ±1 degree and heat dissipation of 350 W continuous. Designed from high-quality stainless steel, the cabinet has internal measurements of 1300 × 650 × 1100 mm and is fitted with double doors. For further details, contact Paul Brown, tel +44 1628 850 611 or see www.unitemp.co.uk.

ZTEC Instruments has released the ZT8540 I/Q Digitizer, which functions as a baseband vector signal analyser (VSA) from DC to 300 MHz. The new VSA provides signal fidelity and real-time processing capabilities that enable a broad set of RF and wireless test techniques, such as performing error vector magnitude, adjacent channel leakage ratio, and third-order intermodulation distortion measurements. The ZT8540 I/Q includes two 14-bit 400 MS/s ADCs, 512 MB deep memory, programmable I/Q input gain of 0 dB to 30 dB and an on-board digital downconverter with fractional re-sampling. For more information, tel +1 505 342 0132, e-mail marketing@ztecinstruments.com, or see www.ztecinstruments.com.

Antimatters

Antihydrogen matters

The past year's results on trapping antihydrogen at CERN have not only brought many plaudits for the scientists involved, but have also sparked the public imagination.

The latest honour from the scientific community is from the American Physical Society (APS) whose 2011 John Dawson Award for excellence in plasma-physics research goes to members of the ALPHA collaboration. William Bertsche (Swansea), Paul Bowe (Aarhus), Michael Charlton (Swansea), Joel Fajans (University of California, Berkeley), Makoto Fujiwara (TRIUMF), Jeffrey Hangst (Aarhus), Niels Madsen (Swansea), Francis Robicheaux (Auburn), Daniel Silveira (RIKEN), Dirk Van der Werf (Swansea) and Jonathan Wurtele (University of California, Berkeley) will received the award at a ceremony at the APS Division of Plasma Physics Annual Meeting in November.

News of the trapping of antihydrogen for 1000 s in June caused quite a stir (*CERN Courier* July/August 2011 p6). Following articles that appeared in the French press, Jeffery Hangst, spokesperson for the ALPHA collaboration, was delighted to receive a congratulatory note from François de Rose, one of the founding fathers of CERN, a non-scientist now in his 100th year (*CERN Courier* January/February 2011 p44). The same news also reached a wider audience, inspiring, for example the poem and cartoon, reproduced here.

This cartoon by Vicky Woodward first appeared in The Xplanationblog *(http://blog.xplana.com) and is reproduced with their kind permission.*

Does antimatter matter?

The scientists at CERN
with artifice sublime
have trapped some anti-hydrogen
a thousand seconds at a time.

They cooled some anti-protons
with a neg-magnetic yield
then squeezed the stuff together
with a strong magnetic field.

The thousand seconds over
came the end of their creation.
Magnetic field turned off caused
anti-stuff's annihilation.

The scientists are hopeful
that they will learn one day
why, when next to simple matter,
anti-matter vanishes away.

These mysteries of science
they really make you think
If matter rules our universe
could it vanish in a wink?

– John Treneman

● Taken from "some perverse verse" (volume 5) and reprinted by kind permission of the author, John Treneman.

Recruitment

Postdoctoral Research Positions
LIGO Laboratory

California Institute of Technology (Caltech)
Massachusetts Institute of Technology (MIT)

The Laser Interferometer Gravitational-Wave Observatory (LIGO) has as its goal the development of gravitational wave astronomy. The LIGO Laboratory is managed by Caltech and MIT, and is sponsored by the National Science Foundation. It operates observatory sites equipped with laser interferometric detectors at Hanford, Washington and Livingston, Louisiana. The initial detectors, and an enhanced version, have achieved design sensitivity and data sets spanning almost two years of coincidence operation has been collected. Analysis is ongoing, with extensive participation by the LIGO Scientific Collaboration (LSC). A major upgrade (Advanced LIGO) is now underway which will increase the sensitivity of the detectors by tenfold. In addition, a vigorous R&D program supports the development of enhancements to the detectors as well as future capabilities.

The LIGO Laboratory may have several postdoctoral research positions at Caltech, MIT and at the two LIGO observatory sites. Successful applicants will be involved in the operation of LIGO itself, analysis of data, both for diagnostic purposes and astrophysics searches, as well as the R&D program for future detector improvements. Expertise related to astrophysics, modeling, data analysis, electronics, laser optics, vibration isolation and control systems is desirable. Most importantly, candidates should be broadly trained physicists, willing to learn new experimental and analytical techniques, and ready to share in the excitement of building, operating and observing with a gravitational-wave observatory. Appointments at the post-doctoral level will initially be for one-year with the possibility of renewal for up to two subsequent years.

Applications for post-doctoral research positions with LIGO Laboratory should indicate which LIGO site (Caltech, MIT, Hanford, or Livingston) is preferred by the applicant. Applications should be sent to **HR@ligo.caltech.edu** (Electronic Portable Document Format (PDF) submittals are preferred).

Applications should include curriculum vitae, list of publications (with referred articles noted), and the names, addresses, email addresses and telephone numbers of three or more references. Applicants should request that three or more letters of recommendations be sent directly to **HR@ligo.caltech.edu** (Electronic Portable Document Format (PDF) submittals are preferred. Consideration of applications will begin December 1, 2011 and will continue until all positions have been filled.

Caltech and MIT are Affirmative Action/Equal Opportunity Employers
Women, Minorities, Veterans and Disabled Persons are encouraged to apply
More information about LIGO available at www.ligo.caltech.edu

20 July 2011

University at Buffalo
The State University of New York

Department of Physics
Tenure-track assistant professor position in experimental particle physics

The Physics Department of the State University of New York at Buffalo invites applications for a tenure-track assistant professor position in experimental particle physics to begin in the fall of 2012. We seek candidates with a strong background in particle physics experiment who are prepared to play a leadership role in the community and show promise in supervision and teaching. Faculty in the Physics Department are expected to teach at the Undergraduate and Graduate levels, advise and mentor graduate students, maintain a robust program of research, and provide service to the Department, University, and community at large.

Review of applications will start November 1, 2011. For full consideration, all application materials must be received by December 1, 2011. The application must include a letter describing current and planned research and teaching activities, a curriculum vita, list of publications, and at least three letters of reference. Applications and reference letters must be submitted online at https://www.ubjobs.buffalo.edu/applicants/Central?quickFind=54421. Informal inquiries can be sent to the Search Committee via physearc@buffalo.edu.

The current experimental particle physics group consists of two faculty members, three postdocs, three graduate and several undergraduate students. We are conducting research at the Tevatron/D0 and LHC/CMS, and enjoy close collaboration with other faculty members working on theoretical particle physics and cosmology. Information about the group can be found at www.physics.buffalo.edu/hepcos/.
Applications are particularly encouraged from those who would extend and strengthen our group's efforts.

SUNY at Buffalo is an Affirmative Action/Equal Opportunity employer committed to diversity and inclusion.

Florida Institute of Technology
High Tech with a Human Touch™

FACULTY POSITION IN EXPERIMENTAL PARTICLE PHYSICS

The Department of Physics and Space Sciences at Florida Institute of Technology invites applications for a full-time faculty position to begin in spring or fall 2012 contingent upon the availability of funds. Appointments at all academic ranks will be considered. Applications are welcome from candidates with a Ph.D. degree in physics and working in experimental high-energy particle physics.

The current Florida Tech HEP research program is centered on multi-TeV proton-proton collider physics with the CMS experiment at CERN, as well as detector development with the RD51 collaboration and grid computing. The department is seeking an outstanding candidate to strengthen our CMS research program. For more information on HEP at Florida Tech see www.fit.edu/pss or contact Professors Marc Baarmand (baarmand@fit.edu) and Marcus Hohlmann (hohlmann@fit.edu).

The successful candidate will be expected to conduct a vigorous, externally funded research program and must be committed to excellence in graduate and undergraduate education. To apply, please email in a single pdf file your CV, list of publications, description of current research and future plans, teaching philosophy, and contact information for five references to Professor Terry Oswalt, Department Head (email: HEPsearch@fit.edu). Applications will be reviewed beginning October 3, 2011 and will be accepted until the position is filled. Florida Institute of Technology is an Equal Opportunity/Affirmative Action Employer. Women and minorities are encouraged to apply.

Cornell Laboratory for Accelerator-based Sciences and Education (CLASSE)

Associate SRF Group Leader
Sr. Research Associate, Cornell University

CLASSE (Cornell Laboratory for Accelerator-based Sciences and Education) has an opening for the position of Associate Group Leader of the Superconducting Radio Frequency (SRF) Group. The SRF Group conducts a wide variety of activities based on superconducting RF technology. These include development, design, fabrication, and testing of accelerator components for the Energy Recovery Linac, the International Linear Collider, the Cornell Electron Storage Ring (CESR), for high-current CW Linacs like Project-X and for a Muon collider as well as R&D for new SRF materials. The group maintains and operates a large complement of facilities necessary for accelerator development.

The Associate Group Leader will be responsible to the SRF Group Leader for coordinating the manpower, resources, and facilities available to achieve the goals of SRF-based accelerator projects.

This Sr. Research Associate position requires a doctoral degree in physics, applied physics, or engineering sciences, a significant publication list, and at least 7 years of related experience. The candidate must have demonstrated leadership and supervisory experience in managing accelerator or similar projects. A broad range of knowledge of SRF components, design, fabrication, and testing techniques is highly desirable.

Applicants should arrange their CV, list of publications, and three letters of recommendation be sent to the following address:

Dr. Georg Hoffstaetter, Chair, Associate SRF Group Leader Search Committee, Newman Laboratory, Cornell University, Ithaca, NY 14853 USA.

Electronic submissions and inquiries may be addressed to search-classe@cornell.edu.

Cornell is an equal-opportunity/affirmative action employer.

Albert-Ludwigs-Universität Freiburg

UNI FREIBURG

The Faculty of Mathematics and Physics of the University of Freiburg / Germany invites applications for a

Junior Professorship (W1) with Tenure-Track-Option (W3)

in the field of **Theoretical Particle Physics** in research and teaching with emphasis on the phenomenology of elementary particle physics performed at accelerators. Expected are outstanding scientific achievements and a close collaboration with the Research Training Group 'Physics at Hadron Accelerators', especially in the domain of LHC physics. Teaching is also anticipated in all areas of theoretical physics.

Formal employment conditions are based on § 51 Abs. 2 and 3 LHG and include an outstanding doctoral University degree and pedagogical skills as well as the ability to pursue independent research in Theoretical Physics. The tenure track position is offered for an initial four year period. After a positive evaluation the position can be extended for another two years. The decision on the Tenure-Track-Option (W3) will be made before the sixth year.

The University of Freiburg is seeking to increase the number of female faculty members and therefore especially encourages suitably qualified women to apply. Applicants with a physical handicap will be given preference over other candidates provided they are equally qualified. Applications (with curriculum vitae, copies of degree certificates, list of publications and teaching records) should be sent by 15.11.2011, to the Dekan der Fakultät für Mathematik und Physik, Eckerstr. 1, D-79104 Freiburg, Germany.

ess EUROPEAN SPALLATION SOURCE

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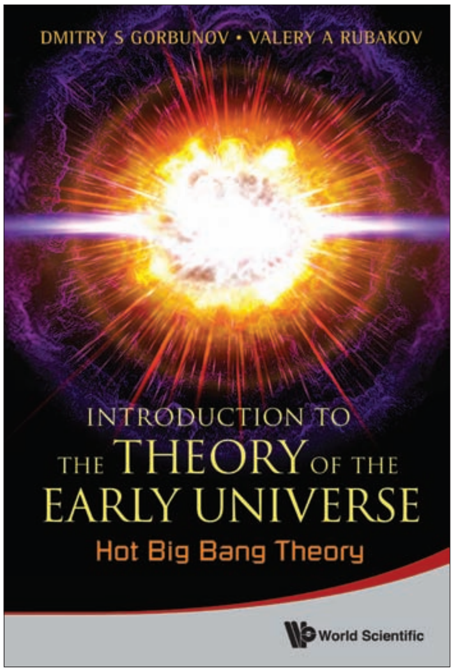
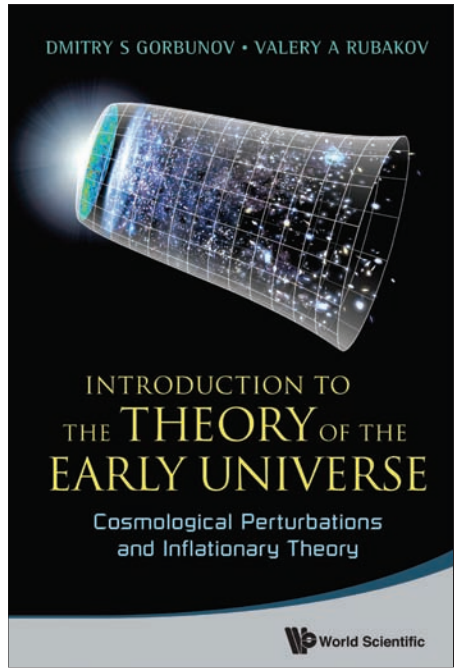
Bookshelf

Introduction to the Theory of the Universe: Hot Big Bang Theory
By Dmitry S Gorbunov and Valery A Rubakov
World Scientific
Hardback: £103 $158
Paperback: £51 $78
E-book: $200

Introduction to the Theory of the Universe: Cosmological Perturbations and Inflationary Theory
By Dmitry S Gorbunov and Valery A Rubakov
World Scientific
Hardback: £101 $156
Paperback: £49 $76
E-book: $203





When a field is developing as fast as modern particle astrophysics and cosmology, and in as many exciting and unexpected ways, it is difficult for textbooks to keep up. The two-volume *Introduction to the Theory of the Early Universe* by Dmitry Gorbunov and Valery Rubakov is an excellent addition to the field of theoretical cosmology that goes a long way towards filling the need for a fully modern pedagogical text. Rubakov, one of the outstanding masters of beyond-the-Standard Model physics, and his younger collaborator give an introduction to almost the entire field over the course of the two books.

The first book covers the basic physics of the early universe, including thorough discussions of famous successes, such as big bang nucleosynthesis, as well as more speculative topics, such as theories of dark matter and its genesis, baryogenesis, phase transitions and soliton physics – all of which receive much more coverage than is usual. As the choice of topics indicates, the approach in this volume tends to be from the perspective of particle theory, usefully complementing some of the more astrophysically and observationally oriented texts.

The second volume focuses on cosmological perturbations – where the vast amounts of data coming from cosmic-microwave background and large-scale structure observations have transformed cosmology into a precision science – and the related theory of inflation, which is our best guess for the dynamics that generate the perturbations. Both volumes contain notably insightful treatments of many topics and there is a large variety of problems for the student distributed throughout the text, in addition to extensive appendices on background material.

Naturally, there are some missing topics, particularly on the observational side, for example a discussion of direct and indirect detection of dark matter or of weak gravitational lensing. There are also some infelicities of language that a good editor would have corrected. However, for those wanting a modern successor to *The Early Universe* by Edward Kolb and Michael Turner (Perseus 1994) or John Peacock's *Cosmological Physics* (CUP 1999), either for study of an unfamiliar topic or to recommend to PhD students to prepare them for research, the two volumes of *Theory of the Early Universe* are a fine choice and an excellent alternative to Steven Weinberg's more formal *Cosmology* (OUP 2008).

● *John March-Russell, Oxford University.*

The Poetry of Physics and the Physics of Poetry
By Robert K Logan
World Scientific
Hardback: £42 $64
Paperback: £30 $43
E-book: $83

Robert Logan is a physicist who since 1971 has taught an interdisciplinary course, "The Poetry of Physics and the Physics of Poetry", at the University of Toronto. In this book, which grew out of the course, he introduces the evolution of ideas in physics by first briefly recalling the ancient science of Mesopotamia, Egypt and China before addressing in detail the revolutions that started in the 16th century and the more modern advances, including the birth of the Standard Model of particle physics. Sprinkled with quotations from leading physicists of the respective times, the book reports in an interesting way the historical connections that lead from one discovery to another and the impact physics had on (and received from) other branches of science, philosophy, arts, theology, etc. Thus he hopes to convey not only the poetry or beauty of physics but also how physics has influenced the humanities.

The word "physics" derives from the Greek word *phusis*, meaning "nature", and Logan wonders what physics would be without the ancient Greek philosophers. However, even with them, interest in science declined as theology became the dominant concern of the day. It was mainly thanks to René Descartes, who refused to accept past philosophical truths that he could not verify for himself ("Cartesian doubt"), and to other contemporary philosophers, that a change in attitude towards science began to develop in the beginning of the 17th century. During that period, Galileo Galilei, Johannes Kepler and several other scientists uncovered many mysteries of nature, which eventually led to Isaac Newton's breakthroughs. In return, the philosophy of the British (Locke, Berkeley, Hume) and French (Voltaire, Condillac, Diderot, Condoret) movements was heavily influenced by Newton's physics:

Bookshelf

their reflections were based directly on the scientific method.

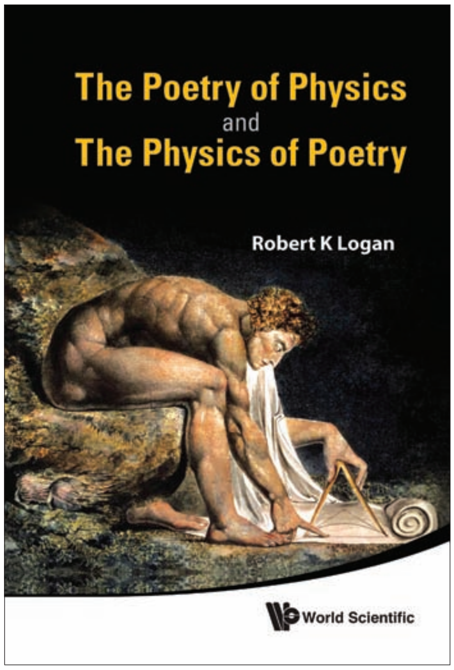
Moving on, the scientific advances of the 20th century would not have been possible without the abstract mathematical concepts developed in the 19th century or technological breakthroughs such as the invention of the vacuum pump, which paved the way for the study of all gas-discharge experiments and led to the discovery of X-rays and the electron. Logan connects these and other discoveries very naturally, claiming along the way that the distinction between physics and chemistry is artificial and a "historic accident".

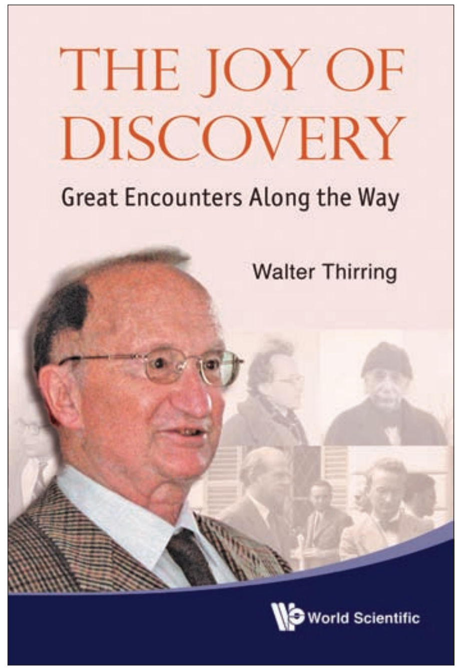
Breakthroughs in science are based on the gift of abstract thinking, astronomy being one of the earliest examples. It is interesting to realize that the structure of certain languages is intimately connected to abstract thinking. According to the Toronto school of thought in communication theory, to which Logan has contributed, "the use of a phonetic alphabet and its particular coding led the Greeks to deductive logic and abstract theoretical science". This was probably one of the main reasons that "abstract theoretical science is a particular outgrowth of Western culture" – as opposed to Eastern cultures, which use a much more complex alphabet.

Apart from discussing major physics discoveries, Logan also triggers readers (or at least his students) to acquire a critical attitude, quoting thinkers such as Thomas Kuhn and Karl Popper: "Science cannot prove that a hypothesis is correct. It can only verify that the hypothesis explains all observed facts and has passed all experimental tests of its validity." After all, a physics course is more than just conveying acquired knowledge.

I can gladly recommend this book to anyone wanting to refresh their physics basics or who would like to learn about the implications that physics has for other disciplines, and *vice versa*. I certainly enjoyed reading it and nostalgically recalled several moments from my undergraduate studies. It is a pity that there are many misprints and some unclear sentences.

● *Hermine K Wöhri, CERN.*





The Joy of Discovery: Great Encounters Along the Way

By Walter Thirring

World Scientific

Hardback: £30 $48

E-book: $62

Walter Thirring's reflections on his life are extremely interesting in all respects, both historical and scientific. Indeed, it is difficult to review his book without simply repeating its contents: the list of extremely impressive physicists who are quoted, as well as the list of extremely important topics in theoretical and experimental physics that are touched upon.

The account begins with the history of an Austrian family who never accepted the Nazi system. Walter's father had to retire from his position of physics professor at the University of Vienna; his elder brother had to enrol in the German army and, after having witnessing atrocities committed by the Ustashi in Russia, never returned from the Eastern Front. As for Walter, what probably saved his life is that during an exercise in the German army he was wounded in one of his arms and could not be sent to the front. He also made a dangerous mistake in a letter that he tried to send to his brother, but fortunately the Allied troops arrived at the right moment.

In the family, it had been agreed that the elder brother would follow a scientific career, while Walter would be allowed to be musician. After his brother's death, Walter agreed to become a physicist like his father. At some stage he met Helga, a typical product of the central European melting pot (during a meeting of the pontifical academy, she spoke in Polish to John Paul II). Helga became his wife and later also saved his life, when he had a stroke on the steps of the Budapest Opera.

Walter followed a rather complicated scientific trajectory. After studying in Vienna he went to Dublin, Glasgow, Gottingen, Zurich, Bern, Princeton, Bern, Massachusetts Institute of Technology, Seattle, Bern again, Vienna and CERN, then back to Vienna. During these travels he had the occasion to meet the best physicists in the world. It is impossible even to list them, so I shall concentrate on a few who are not so well known. However, I must begin with Albert Einstein whom Walter met in 1954 in Princeton. Everybody knows that Einstein did not like quantum mechanics, even though he contributed much to its foundation. One day Walter made the provocative statement that, in a strong gravitational field, particle–antiparticle pairs could be produced. Einstein refused to believe this; yet it was what became known as Hawking radiation around 1974.

I was interested by what Walter says about his compatriot, Bruno Touschek, the inventor of storage rings, to whom we owe so much. In Bern, Walter also met Fritz Houtermans, who was persecuted by both the Germans and the Russians and who, among other things, first proposed using plutonium for a bomb. (The only other person I have heard speaking about Houtermans is the late Charles Peyrou; unfortunately nobody tried to convince him to write down his recollections). The parts about Arnold Sommerfeld, Guido Beck and Felix Ehrenhaft are also fascinating.

I recommend reading the part where Walter was a member of the directorate at CERN. The decision had been taken to build the Super Proton Synchrotron (SPS); the question was where to build it? The member states of CERN were all fighting with each other to get it, but John Adams in secret elaborated a project to build it at CERN, underground. When he presented this idea to the CERN Council, it was a shock but it was accepted. Now we know that it was an excellent idea. The SPS worked so well that it could be transformed into a collider, producing W and Z particles; then the Large Electron–Positron (LEP) collider was also constructed on the CERN site. Now LEP has been replaced by the LHC, which is working well, despite not yet being at the design energy.

I see that I have not said a word yet about Walter's scientific achievements. They appear throughout the book: general relativity, field theory, dispersion relations, the Thirring model, the quark model and rigorous quantum mechanics (a domain where I learnt much from him and his students, Harald Grosse, Fred Bertelmann, and Bernhard Baumgartner), including his remarkable work on the stability of matter with Elliott Lieb. Among his students, the best was the late Julius Wess. In addition, with the help of Heide Narnhofer and others, Walter founded the Erwin Schrödinger Institute, which is a great success and will, we all hope, continue to receive funds.

Finally, the normal black-on-white text in the book can be read by anyone, except perhaps for the last part on entropy. The grey shaded "boxes" are reserved for experts. This is an excellent idea.

● *André Martin, CERN.*

Books received

Chaos: The Science of Predictable Random Motion
By Richard Kautz
Oxford University Press
Hardback: £55 $98.50
Paperback: £24.95 $44.95

Based on only elementary mathematics, this engaging account of chaos theory bridges the gap between introductions for the layman and college-level texts. It develops the science of dynamics in terms of small time-steps, describes the phenomenon of chaos through simple examples and concludes with a close look at a homoclinic tangle - the mathematical monster at the heart of chaos. The presentation is enhanced by many figures, animations of chaotic motion (available on a companion CD) and biographical sketches of the pioneers of dynamics and chaos theory. To ensure accessibility to high-school students, care has been taken to explain advanced mathematical concepts simply, including exponentials and logarithms, probability, fractals and transfinite numbers.

The Light Fantastic: A Modern Introduction to Classical and Quantum Optics (2nd edition)
By Ian R Kenyon
Oxford University Press
Hardback: £70 $126
Paperback: £35 $62.95

Kenyon's text book is a thorough introduction to modern classical and quantum optics, appropriate for advanced undergraduates or beginning graduates. The emphasis is on building an understanding in straightforward steps. Digital cameras, LCD screens, laser welding and the optical-fibre-based internet illustrate the penetration of optics in 21st-century life: many such modern applications are presented from first principles. This thoroughly revised and updated edition includes new coverage of photonic crystals and Bloch waves, as well as quantum dots and microcavities.

Viewpoint

From the Tevatron to Project X

As the Tevatron era ends, **Pier Oddone** looks at past success, as well as future promise, at Fermilab.

Pier Oddone, director, Fermilab.

The end of September marks the end of an era at Fermilab, with the shut down of the Tevatron after 28 years of operation at the frontiers of particle physics (*CERN Courier* March 2011 p5). The Tevatron's far-reaching legacy spans particle physics, accelerator science and industry. The collider established Fermilab as a world leader in particle-physics research, a role that will be strengthened with a new set of facilities, programmes and projects in neutrino and rare-process physics, astroparticle physics and accelerator and detector technologies.

The Tevatron exceeded every expectation ever set for it. This remarkable machine achieved luminosities with antiprotons once considered impossible, reaching more than $4 \times 10^{32}\, cm^{-2}s^{-1}$ instantaneous luminosity and delivering more than 11 fb^{-1} of data to the two collider experiments, CDF and DØ. Such luminosity required the development of the world's most intense, consistent source of antiprotons. The complex process of making, capturing, storing, cooling and colliding antiprotons stands as one of the great achievements by Fermilab's accelerator team.

As the world's first large superconducting accelerator, the Tevatron developed the technology that allowed later accelerators – including CERN's LHC – to push beam energy and intensity even higher. But beyond its scientific contributions, an enduring legacy to mankind is the role it played in the development of the superconducting-wire industry. The construction of the accelerator required 135 000 lb of niobium-titanium-based superconducting wire and cable at a time when annual world production of these materials was only a few hundred pounds. Fermilab brought together scientists, engineers and manufacturers who developed a large-scale manufacturing capability that quickly found huge demand in another emerging field: MRI machines.

The life of the Tevatron is marked by historic discoveries that established the Standard Model. Tevatron experiments discovered the top quark, five B baryons and the B_c meson, and observed the first τ neutrino, direct CP violation in kaon decays, and single top production. The CDF and DØ experiments measured top-quark and W-boson masses, as well as di-boson production cross-sections. Limits placed by CDF and DØ on many new phenomena and the Higgs boson guide searches elsewhere – and continuing analysis of Tevatron data may yet reveal evidence for processes beyond our current understanding. Chris Quigg's article in this issue gives further details on the Tevatron's scientific legacy and results still to come (p20).

As we bid farewell to the Tevatron, what's next for Fermilab? Over the next decades, we will develop into the foremost laboratory for the study of neutrinos and rare processes – leading the world at the intensity frontier of particle physics.

Fermilab's accelerator complex already produces the most intense high-energy beam of neutrinos in the world. Upgrades in 2012 will allow the NOνA experiment to push neutrino oscillation measurements even further. The Long-Baseline Neutrino Experiment, which will send neutrinos 1300 km from Fermilab to South Dakota, will be another leap forward in the quest to demystify the neutrino sector and search for the origins of a matter-dominated universe.

The cornerstone for Fermilab's leadership at the intensity frontier will be a multimegawatt continuous-beam proton-accelerator facility known as Project X. This unique facility is ideal for neutrino studies and rare-process experiments using beams of muons and kaons; it will also produce copious quantities of rare nuclear isotopes for the study of fundamental symmetries. Coupled to the existing Main Injector synchrotron, Project X will deliver megawatt beams to the Long-Baseline Neutrino Experiment. A strong programme in rare processes is developing now at Fermilab with the muon-to-electron conversion and muon g-2 experiments. A strong foundation for Project X exists at Fermilab, with expertise in high-power beams, neutrino beamlines, and superconducting RF technology.

Project X's rare-process physics programme is complementary to the LHC. If the LHC produces a host of new phenomena, then Project X experiments will help elucidate the physics behind them. Different models postulated to explain the new phenomena will have different consequences for very rare processes that will be measured with high accuracy using Project X. If no new phenomena are discovered at the LHC, the study of rare transitions at Project X may show effects beyond the direct reach of particle colliders. Project X could also serve as a foundation for the world's first neutrino factory, or – even further in the future – as the front end of a muon collider.

In parallel with the development of its intensity frontier programme, Fermilab will remain a strong part of the LHC programme as the host US laboratory and a Tier-1 centre for the CMS experiment, as well as through participation in upgrades of the LHC accelerator and detectors. Fermilab will also continue to build on its legacy as the birthplace of the understanding of the deep connection between cosmological observations and particle physics. The Dark Energy Survey, which contains the Fermilab-built Dark Energy Camera, will see first light in 2012. Better detectors are in development for the Cryogenic Dark Matter Search, and the COUPP dark-matter search is now operating a 60 kg prototype at Fermilab.

As Fermilab's staff and users say goodbye to the Tevatron, we look forward to working with the world community to address the field's most critical and exciting questions at facilities in the US, at CERN and around the world.

● *Pier Oddone, director, Fermilab.*

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x724	VME	8	100	14	0.5 / 2.25 / 10	SE / D	40	0.5 / 4	PHA
	Desktop/NIM	4 / 2				SE			
x720	VME	8	250	12	2	SE / D	125	1.25 / 10	CI, PSD
	Desktop/NIM	4 / 2				SE			
x721	VME	8	500	8	1	SE / D	250	2	no
x731	VME	8 - 4	500 - 1000	8	1	SE / D	250 / 500	2 / 4	no
x730 COMING SOON	VME	8	500	12	2	SE / D	250	1.25 / 10	PSD
	Desktop/NIM	4 / 2				SE			
x751	VME	8 - 4	1000 - 2000	10	1	SE / D	500	1.8 / 14.4 - 3.6 / 28.8	PSD
	Desktop/NIM	4 - 2				SE			
x761	VME	2	4000	10	1	SE / D	TBD	7.2 / 57.6	no
	Desktop/NIM	1				SE			
x740	VME	64	62.5	12	2 / 10	SE	30	0.19 / 1.5	no
	Desktop/NIM	32							
x742	VME	32+2	5000 (2)	12	1	SE	600	0.128 / 1 (3)	no
	Desktop/NIM	16+1							

(1) The x in the model name is V1 for VME, VX1 for VME64X, DT5 for Desktop and N6 for NIM
(2) Sampling frequency of the analog memory (switched capacitor array); A/D conversion takes place at lower speed (dead-time)
(3) The memory size for the x742 is 128/1024 events of 1024 samples each
(4) The indication *"size 1/ size 2"* denotes different options
(5) Digital Pulse Processing (DPP) firmware:
DPP-PHA: Pulse Height Analysis (Trapezoidal Filters), DPP-CI: Charge Integration (digital QDC), DPP-PSD: Pulse Shape Discrimination

Limited budget? Visit our web site for special offer or refurbished modules (1 years warranty) at an heavily discounted products.

Warranty extention available up to 5 years

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Small details Great differences

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October 23 - 29, 2011