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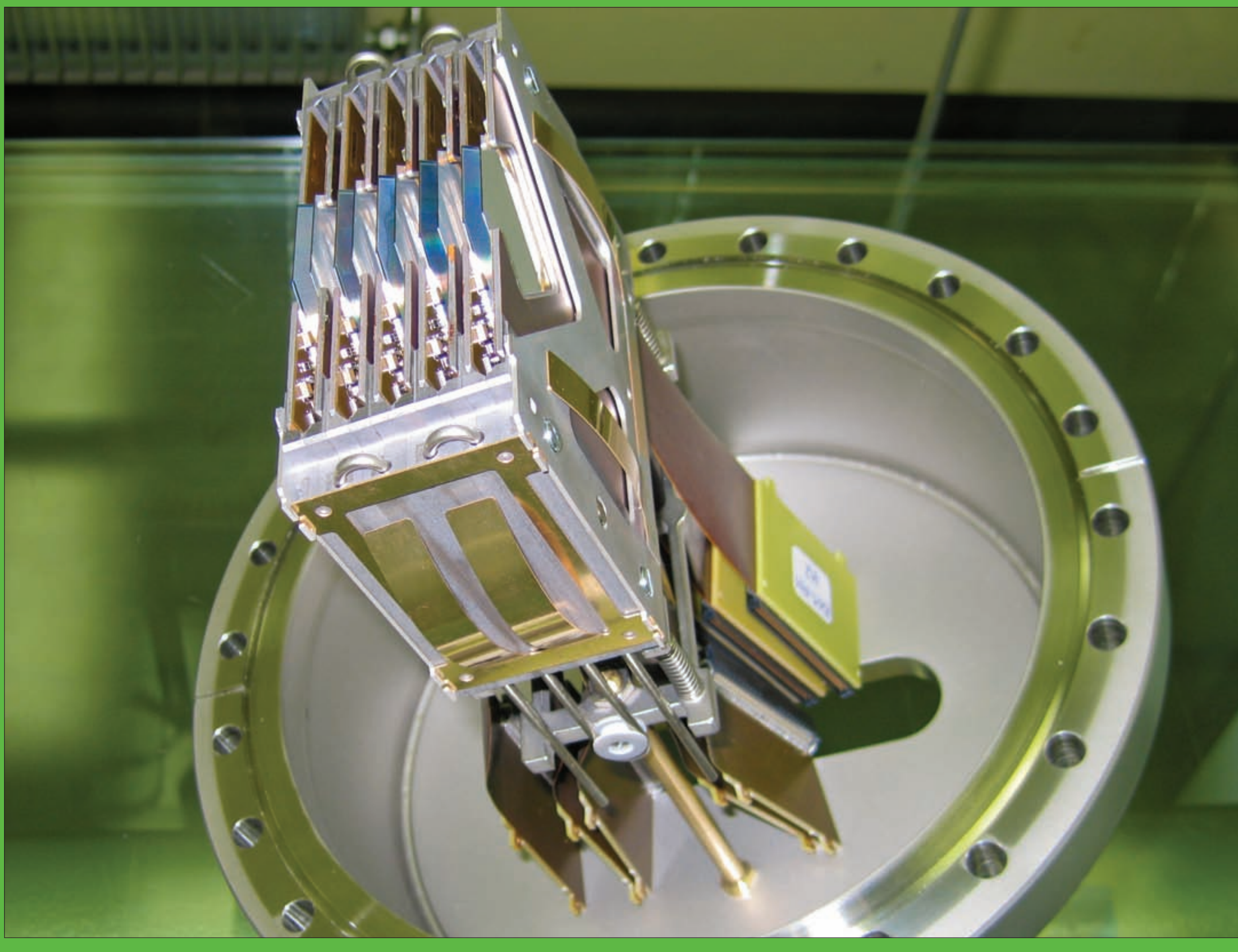

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Covering current developments in high-energy physics and related fields worldwide

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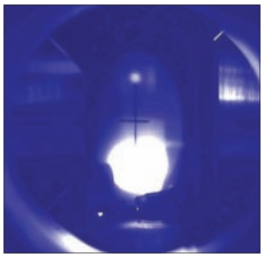
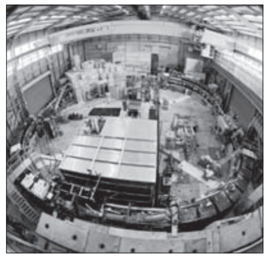


Anything but blue at PETRA III p6



Still cool after 30 years p13

Back to the future p29

Cover: The TOTEM experiment at the LHC will use innovative devices close to the beam line, such as these "edgeless" silicon detectors in a Roman Pot (p19). (Courtesy TOTEM.)

NEWS

LHC NEWS

Collisions to start at 3.5 TeV

The LHC will initially run at an energy of 3.5 TeV per beam when it starts up in November this year. This decision has comes after all tests on the machine's high-current electrical connections were completed at the end of July, indicating that no further repairs are necessary for safe running.

"We've selected 3.5 TeV to start," explained CERN's director-general, Rolf Heuer, "because it allows the LHC operators to gain experience of running the machine safely while opening up a new discovery region for the experiments. The LHC is much better understood than it was a year ago. We can look forward with confidence and excitement to a good run through the winter and into next year."

Following the incident of 19 September 2008 that brought the LHC to a standstill, testing has focused on the 10 000 high-current superconducting electrical connections of the kind that led to the fault. These consist of two parts: the superconductor itself, and a copper stabilizer that carries the current in case of a quench – when the superconductor warms up and stops superconducting. There is negligible electrical resistance across these connections when they are in their normal superconducting state, but in a small number of cases tests have revealed abnormally high resistances in the superconductor. These have been repaired. However, there remain a number of cases where the resistance in the copper stabilizer connections is higher than it should be for running at full energy.

The latest round of tests has looked at the resistance of the copper stabilizer. As a result, many copper connections showing anomalously high resistance were repaired.

A magnet interconnection being closed in Sector 5-6 at the end of June, following repairs to the copper stabilizers. Tests completed for all sectors show that the machine is safe to run in 2009–2010.

The tests on the final two sectors, which concluded at the end of July, revealed no further anomalies. This means that no more repairs are necessary for safe running this year and next.

The procedure for the 2009 start-up will be to inject and capture beams in each direction, take collision data for a few shifts at the injection energy, and then commission the ramp to higher energy. The first high-energy data should be collected a few weeks after the first beam of 2009 is injected. The LHC will run at 3.5 TeV per beam until a significant data sample has been collected and the operations team has gained experience in running the machine. Thereafter, with the benefit of that experience, the energy will be taken towards 5 TeV per beam. At the end of 2010, the LHC will be run with lead ions for the first time. After that, the LHC will shut down and work will begin on moving the machine towards 7 TeV per beam.

Earlier in July leaks of helium into the vacuum insulation were found in Sectors 8-1 and 2-3 while they were being prepared for the electrical tests on the copper stabilizers at around 80 K. In both cases the leak occurred at one end of the sector, where the electrical feedbox, DFBA, joins Q7, the final magnet in the sector. The end vacuum subsectors – a 200 m stretch of the LHC sealed off by vacuum barriers – will be warmed to room temperature in order to locate the leaks and repair them. Suspicion rests in both cases on flexible hose in the liquid-helium transport circuits; two years ago, a similar leak occurred during the first cool-down of Sector 4-5. Unfortunately, the repair necessitates a partial warm-up of both sectors, with a consequent impact on the schedule for the restart. It is now foreseen that the LHC will be closed and ready for beam injection by mid-November.

● CERN is publishing regular updates on the LHC in its internal Bulletin, available at www.cern.ch/bulletin, as well as via Twitter and YouTube at www.twitter.com/cern and www.youtube.com/cern.

Sommaire

LIGHT SOURCES

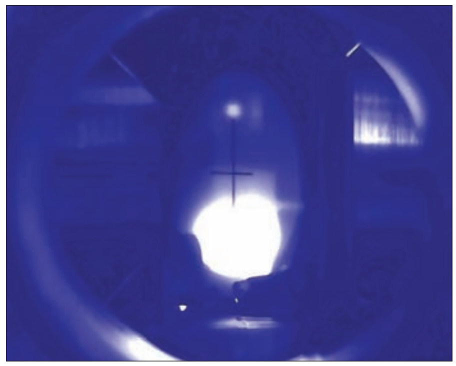
PETRA III generates first X-ray beam

DESY's new synchrotron radiation source PETRA III generated the first X-ray light for research on the weekend of 18–19 July. The electron storage ring, 2.3 km in circumference, went through a two-year upgrade costing €225 million, which converted into the world's most brilliant storage ring X-ray source. Following test runs of individual instruments, PETRA III will start regular user operation in 2010.

As the most powerful light source of its kind, PETRA III will offer excellent research possibilities, in particular to researchers who investigate ever smaller samples with ever finer details, or those who require tightly focused and very short-wavelength X-rays for their experiments. PETRA III first stored its first positron beam in April (*CERN Courier* June 2009 p8). Following this milestone, the undulators were put in place to force the beam to oscillate and emit the high brilliance synchrotron radiation.

PETRA was originally built as an electron–positron collider for particle physics and more recently was used as a pre-accelerator for the electron/positron–proton collider, HERA, which closed down in June 2007. In less than two years PETRA has been completely refurbished and modernised, the remodelling funded mainly by the German Federal Ministry of Education and Research, the City of Hamburg and the Helmholtz Association. A 300 m long experimental hall was built over the PETRA storage ring, to house 14 synchrotron beamlines and up to 30 experimental stations (*CERN Courier* September 2008 p19). To ensure that the samples under study are not affected by vibrations, the experiments will be installed on the largest monolithic concrete slab in the world.

The PETRA III team around DESY's director in charge of photon science, Edgar Weckert (centre), smiling happily as they see a monitor showing the first X-ray light. (Photos courtesy DESY.)



The spot of the first X-ray beam at PETRA III.

RARE ISOTOPES

New neutron-rich nuclei support 'island of inversion' theory

Researchers at the National Superconducting Cyclotron Laboratory (NSCL) at Michigan State University have succeeded in making and measuring the production rates of 15 new neutron-rich isotopes. Several of these rare isotopes were produced at significantly higher-than-expected rates. The results suggest the existence of a new "island of inversion" – a region of isotopes with enhanced stability in a sea of mostly fleeting and unstable nuclei at the edge of the nuclear map.

Motivation to explore this region of nuclides was provided in part by an earlier experiment at NSCL that produced and measured the production rates of three new isotopes of magnesium and aluminium (*CERN Courier* December 2007 p37). In particular, the aluminium isotope measured (^{42}Al) was beyond the limit of stability predicted by one of the leading theoretical models. It was therefore logical to ask: how well do existing theories describe the behaviour of heavier, neutron-rich nuclei?

Perhaps not so well, according to the results of continued studies at NSCL, which have investigated the nuclei of elements from chlorine to manganese. Most of the nuclei in this region were expected to be characterized by low binding energies, and thus be exceedingly unstable and difficult to produce. However, the experiments revealed unexpectedly higher production rates for several isotopes of potassium, calcium, scandium and titanium (Tarasov *et al.* 2009).

The results could imply the existence of a new island of inversion for neutron-rich nuclei. The island would be the result of changes in the interaction strength between protons and neutrons, which is already known to depend on the number of protons and neutrons inside the nucleus. Nearest the stable isotopes, the change is often small enough to go unnoticed, but in very neutron-rich nuclei the effects can be amplified in localized areas, leading to small groupings of isotopes with very distinctive properties.

Further reading

O B Tarasov *et al.* 2009 *Phys. Rev. Lett.* **102** 142501.

Element 112 is to be given the name 'copernicium'

The team that discovered element 112 at GSI Darmstadt has proposed naming it "copernicium", with the element symbol "Cp", in honour of the scientist and astronomer Nicolaus Copernicus. The International Union of Pure and Applied Chemistry (IUPAC) should officially endorse the new element's name in around six months, the period set to allow the scientific community to discuss the proposal.

Copernicus, who lived from 1473 to 1543, paved the way for the modern view of the universe when he firmly planted the Earth in orbit about the Sun in his famous work *De revolutionibus orbium coelestium*. With its planets revolving around the Sun on different orbits, the solar system became a model for other physical systems, in particular the atom, with electrons in orbit around the nucleus. Although this model of the atom soon became surpassed by quantum mechanics, it still provides a strong visual image. In an atom of the new element, 112 electrons surround the nucleus.

Element 112 was first observed 13 years ago but has only recently received official recognition from IUPAC (*CERN Courier* July/August 2009 p6). It is the heaviest element discovered so far in the periodic table, being 277 times heavier than hydrogen. Produced by nuclear fusion when bombarding zinc ions onto a lead target, the element rapidly decays so its existence can be proved only with the help of extremely fast and sensitive analysis methods. Twenty-one scientists from Germany, Finland, Russia and Slovakia were involved in the experiments at GSI that led to the discovery.

NEW PARTICLES

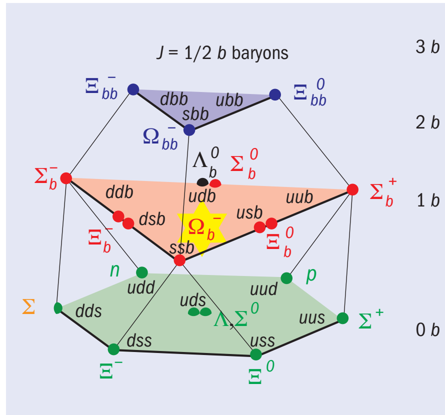
Fermilab's CDF experiment observes the Ω_b^- baryon

The CDF collaboration has announced the observation of a new particle, the Ω_b^- baryon, containing three quarks: two strange quarks and a bottom quark (ssb). The sighting of this "doubly strange" particle, predicted by the Standard Model, is significant because it strengthens physicists' confidence in their understanding of how quarks form matter. However, it conflicts with a result announced in 2008 by CDF's sister experiment, DØ.

The Ω_b^- is the latest entry in the "periodic table of baryons" illustrated in the figure. The Tevatron is unique in its ability to produce baryons containing the b quark, and the large data samples now available after many years of successful running have enabled experimenters to find and study these rare particles. The discovery of the Ω_b^- follows the first observations of two types of Σ_b baryons at the Tevatron in 2006 and the discovery there of the Ξ_b^- baryon in 2007 (*CERN Courier* July/August 2007 p6).

Combing through almost 5×10^{11} proton–antiproton collisions produced by the Tevatron, the CDF collaboration isolated 16 examples in which the particles emerging from collisions reveal the distinctive signature of the Ω_b^-, which travels only a fraction of a millimetre before it decays into lighter particles. CDF has performed the first ever measurement of the Ω_b^-'s lifetime and obtained $1.13 + 0.53 - 0.40$(stat.) ± 0.02(syst.) $\times 10^{-12}$ s.

In August 2008, the DØ experiment announced its own observation of the Ω_b^- based on a smaller sample of data from the Tevatron (*CERN Courier* November 2008 p7). Interestingly, the new observation from CDF conflicts with this earlier result. The CDF collaboration measures the mass of the Ω_b^- to be 6054.4 ± 6.8(stat.) ± 0.9(syst.) MeV/c^2, compared with DØ's findings of 6165 ± 10(stat.) ± 13(syst.) MeV/c^2. These two results are statistically inconsistent, leaving the teams from the two experiments wondering whether they are measuring the same particle. Furthermore, the experiments observed different rates of production for this particle. Perhaps most interesting is that neither experiment sees a hint of evidence for a particle at the mass value measured by the other.



The various three-quark combinations with J=1/2 that are possible using the three lightest quarks – up, down and strange – and the bottom quark. The CDF collaboration has observed the Ω_b^-, highlighted by the yellow star.

Although the latest result announced by CDF agrees with theoretical expectations for the Ω_b^-, both in the measured production rate and in the mass value, further investigation is needed to solve the puzzle of these conflicting results.

Further reading

CDF collaboration, T Aaltonen *et al.* 2009 http://arxiv.org/abs/0905.3123.

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

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

THEORY

Is quantum theory exact or approximate?

Quantum mechanics has puzzled the scientific community from the beginning. One of the major sources of difficulties comes from the measurement problem: why do measurement processes always have definite outcomes, despite the fact that the Schrödinger equation allows for superpositions of states? And why are such outcomes random (distributed according to the Born rule), while the Schrödinger equation is deterministic? New experiments and observations could help to answer such questions by providing a more precise idea of the possible limits of validity of quantum theory (Adler and Bassi 2009).

Most solutions to the measurement problem look for a reinterpretation of the formalism of quantum mechanics. Models in which the wave function collapses spontaneously, however, follow a different route. They purposely modify the Schrödinger equation by adding new nonlinear and stochastic terms, which break quantum linearity above a scale fixed by new parameters. Physically, the wave function is coupled (nonlinearly) to a white-noise classical scalar field, which is assumed to fill space.

By modifying the Schrödinger equation, collapse models make predictions that differ from those of standard quantum mechanics and that can be, in principle, tested. The scale at which deviations from standard quantum behaviour can be expected gives indications of the sensitivity that experiments should reach if they are to provide meaningful tests of collapse models and quantum mechanics.

There have already been experiments that directly or indirectly test collapse models against quantum mechanics and others are proposed for the future. Probably the best known are the diffraction experiments with macromolecules (C_{60}, C_{70}, $C_{30}H_{12}F_{30}N_2O_4$), which set an upper bound 13 decades above the most conservative value of the collapse parameter λ (related to the noise strength) and five decades above the strongest value suggested. Other tests include the decay of supercurrents and proton decay, but the upper bounds are even weaker than in the diffraction experiments. One interesting proposal is an experiment that includes a tiny mirror mounted on a cantilever, within an interferometer: it will set an upper bound of 9 (1) decades on the weakest (strongest) value of λ.

The strongest bound, however, comes from the spontaneous emission of X-rays from germanium-76, as predicted by the continuous spontaneous localization (CSL) model, the most popular collapse model. It sets an upper bound of only six decades on the weakest value of λ. The strongest value is disproved by these data, but the bound is weakened if non-white-noise is considered with a frequency cutoff. The data coming from spontaneous X-ray emission are very raw, and several contributions from known sources (e.g. gamma-ray contamination, double beta-decay) have not been subtracted. A dedicated experiment on spontaneous photon emission could set a much stronger upper bound and would represent the most accurate test of quantum mechanics against the rival theory. Such a project is under discussion between the University of Trieste and the INFN, Laboratori Nazionali di Frascati.

Collapse models also make predictions that have cosmological implications. The apparent violation of energy conservation arising from the interaction with the collapsing noise places important upper bounds. The strongest comes from the intergalactic medium: requiring that the heating produced by the noise remains below experimental bounds places an upper bound of 8 (0) decades on the weakest (strongest) value of λ.

Further reading

Stephen L Adler and Angelo Bassi 2009 *Science* **325** 275.
www.qmts.it/research/drm/main_drm.html.

GRID COMPUTING

STEP '09 sets new records around the world

After months of preparation and two intensive weeks of continuous operation in June, the LHC experiments celebrated the achievement of a new set of goals aimed at demonstrating full readiness for the data-taking with collisions expected to start later this year. The Scale Testing for the Experiment Programme '09 (STEP '09) was designed to stress the Worldwide LHC Computing Grid (WLCG), the global computing Grid that will support the experiments as they exploit the new particle collider. The WLCG combines the computing power of more than 140 computer centres, in a collaboration between 33 countries.

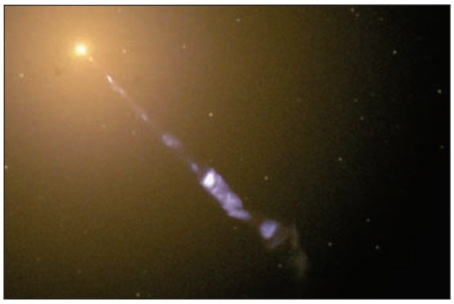
While there have been several large-scale data-processing tests in recent years, this was the first production demonstration to involve all of the key elements from data-taking through to analysis. This allowed different records to be established in data-taking throughput, data import and export rates between the various Grid sites, and in huge numbers of analysis, simulation and reprocessing jobs. The ATLAS experiment ran close to 1 million analysis jobs and achieved 6 GB/s of Grid traffic – the equivalent of a DVD's worth of data a second, sustained over long periods. This result coincides with the transition of Grids into long-term sustainable e-infrastructures that will be of fundamental importance to projects with the lifetime of the LHC.

With the restart of the LHC only months away, there will be a large increase in the number of Grid users, from several hundred unique users today to several thousand when data-taking and analysis commence. This will happen only through significant streamlining of operations and the simplification of end-users' interaction with the Grid. STEP '09 involved massive-scale testing of end-user analysis scenarios, including "community-support" infrastructures, whereby the community is trained and enabled to be largely self-supporting, backed a core of by Grid and application experts.

COSMIC RAYS

Telescopes pin down location of cosmic accelerator

Teams using imaging atmospheric Cherenkov telescopes to detect very high-energy gamma rays have joined forces with astronomers to reveal the precise location of particle acceleration in the nearby giant radio galaxy Messier 87 (M87). Collaborations on the High Energy Stereoscopic System (HESS), the Major Atmospheric Gamma-Ray Imaging Cherenkov (MAGIC) project and the Very Energetic Radiation Imaging Telescope Array System (VERITAS) have worked together with a team at the Very-Long Baseline Array (VLBA) radio telescope in an unprecedented, co-ordinated, 120-hour observational campaign. Their simultaneous observations at the lowest and highest ends of the electromagnetic spectrum indicate that the active galactic nucleus in M87 accelerates charged particles to very high energies in the immediate vicinity of the central black hole (V A Acciari *et al.* 2009).



M87 with its giant plasma jet. Combined observations from the extremes of the electromagnetic spectrum indicate that particle acceleration takes place very close to the central black hole that powers the galaxy. (Courtesy NASA and the Hubble Heritage Team STScI/AURA.)

M87 is a giant radio galaxy, 54 million light-years from Earth, with a jet structure – a huge outflow from the central region, which is probably fuelled by accretion of matter onto a massive black hole. In the jet, charged particles can be accelerated to very high velocities, with the inevitable accompanying production of high-energy gamma rays. The first indications for very high-energy gamma radiation from M87 were found in 1998 with the High-Energy Gamma-Ray Astronomy (HEGRA) telescope array – the predecessor of HESS and MAGIC (*CERN Courier* June 2009 p20). These observations were confirmed by HESS in 2006 and revealed a fast variability of the gamma-ray flux on a timescale of a few days, implying an exceptionally compact gamma-ray source.

To pinpoint the source more closely, HESS, MAGIC and VERITAS jointly observed M87 from January to May 2008, collecting 120 hours' worth of data. During this time the galaxy underwent two major outbursts of very high-energy gamma-ray emission. Over the same period, high-resolution radio observations by the 43 GHz M87 Monitoring Team at the VLBA, a system of radio telescopes spanning the US, indicated a strong increase of the flux from the innermost core of M87 in the immediate vicinity of the central black hole. The combination of observations at the two extremes of the electromagnetic spectrum indicate that the site of the high-energy gamma emission, and hence the particle acceleration, in M87 must lie close to the black hole.

Further reading

V A Acciari *et al.* 2009 *Science* **325** 444.

NUCLEON STRUCTURE

NuTeV anomaly supports new effect in bound nucleons

A new theoretical calculation of the effects of the nuclear medium may account for the "NuTeV anomaly", a puzzling experimental result that disagreed with the Standard Model (*CERN Courier* January 2002 p7). The solution may lie with the isovector nuclear force generated by excess neutrons or protons in iron, which produces a subtle change in the quark structure of all of the nucleons.

The NuTeV anomaly arose when the Neutrinos at the Tevatron (NuTeV) collaboration at Fermilab measured the ratio of neutral-current to charged-current reactions in the collisions of high-energy neutrinos (and antineutrinos) with a large steel target (Zeller *et al.* 2002). The measurements gave a value for the electroweak parameter $\sin^2\theta_W$ that was three standard deviations higher than predicted by the Standard Model. When analysing the data, however, the collaboration had to make a correction to compensate for the unequal numbers of protons and neutrons in the iron nuclei in the steel target. In the analysis, the effect of the extra neutrons was removed by subtracting the structure functions of a comparable number of free neutrons from the iron nucleus, assuming that the protons and neutrons bound inside the iron nucleus are identical to free protons and neutrons.

Changes in structure functions in bound nucleons are well known through the effect discovered by the European Muon Collaboration (EMC). Now theorists from Tokai University, the University of Washington and Jefferson Lab have revealed a novel isovector EMC effect, arising from a proton or neutron excess. This effect implies an additional correction, of a sign and magnitude that are essentially model independent, which removes at least half of the NuTeV anomaly (Cloët *et al.* 2009). Moreover, when the new effect is combined with the well known correction for charge symmetry violation in the nucleon itself, the NuTeV data turn out to be in excellent agreement with the Standard Model.

The NuTeV data may be seen as providing crucial evidence for a conceptual change in the understanding of nuclear structure, in which the quark structure of the bound nucleon is fundamentally modified by the medium. Independent experimental confirmation of the isovector EMC effect could be provided by charged-current studies on heavy nuclei at a future electron-ion collider and in parity-violating deep-inelastic scattering experiments at Jefferson Lab following the 12 GeV upgrade.

Further reading

G P Zeller *et al.* [NuTeV Collaboration] 2002 *Phys. Rev. Lett.* **88** 091802; erratum 2003 *Phys. Rev. Lett* **90** 239902.
I C Cloët, W Bentz and A W Thomas 2009 *Phys. Rev. Lett.* **102** 252301.

SCIENCEWATCH

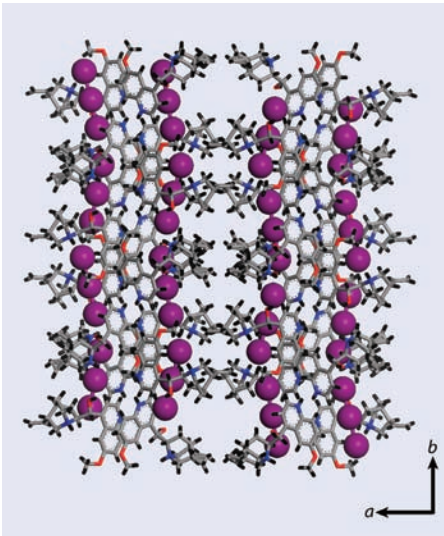
Compiled by John Swain, Northeastern University

Researchers finally uncover the structure of polaroid

A better understanding of the history of polaroid could lead to breakthroughs in nanotechnology, now that the detailed crystalline structure of the substance has been determined.

Polaroid is made from a crystalline material called herapathite, which was first discovered in 1852 when tincture of iodine was dropped into urine from a dog that had been fed quinine in the laboratory of toxicologist William Bird Herapath. He realized that the resulting crystals made excellent polarizers, however, it was not until the 1920s that Edwin Land, of Polaroid fame, ground the crystalline material into a fine powder and extruded it into polymers to make polarizing filters. Surprisingly, the structure of herapathite has only now been unravelled, thanks to Bart Kahr and colleagues of the University of Washington, Seattle.

Kahr has also discovered that Bernotar, an analogue of polaroid that was made independently by Ferdinand Bernauer (1892–1945) and marketed by Karl Zeiss, seems to be a single crystalline film of herapathite. This is just the kind of material needed for organic electronics these days, but nobody knows how Bernauer did it.



The crystal structure of herapathite. The purple spheres are iodine atoms. The absorbing axis that leads to the polarizing action of the crystals is vertical. Solvent molecules and sulphate ions have been removed for clarity.

Further reading

B Kahr *et al.* 2009 *Science* **324** 1407.
Jyllian Kemsley 2009 *Chemical and Engineering News* **June 22** 43.

The entropy of language

Archaeologists who find symbols inscribed on ancient objects are often faced with the difficult task of trying to decide if the "writing" corresponds to a language or not – that is, if they are simply a group of symbols rather than a proper piece of text. This was the case recently with a script from the Indus civilization, which existed in what is now eastern Pakistan and north-western India between about 2600 and 1900 BC.

The script has not yet been deciphered, but Rajesh P N Rao of the University of Washington and colleagues found that comparison of the conditional entropy yielded interesting results. The idea is that in a proper language symbols neither follow each other randomly nor are they always placed in the same order. Comparison of the Indus script places it much closer to natural linguistic systems such as English, Rig-Vedic Sanskrit and Old Tamil – and even programming code Fortran – than to non-linguistic systems such as human DNA or bacterial protein sequences.

So, the script from the Indus civilization appears indeed to be a language, and the fact that the conditional-entropy study places it close to Old Tamil might provide a clue to help decipher it one day.

Further reading

Rajesh P N Rao *et al.* 2009 *Science* **324** 1165.

Graphene displays an electrically tunable bandgap

The bandgap of a material determines, to a large extent, its electrical and optical properties and this is usually more or less fixed for any particular material. Moreover, some materials have no bandgap, which limits their use in electronics, for instance. Graphene, the 2D crystalline form of carbon, always appeared to be one of these – until now.

Feng Wang of the University of California at Berkeley and colleagues have demonstrated that a gated bilayer of graphene can have its bandgap manipulated electrically over a wide range, from 0 to 250 meV (corresponding to the near infrared). This opens the door to a whole new range of devices for the detection, generation and amplification of infrared light over an interesting frequency region.

Further reading

Y Zhang *et al.* 2009 *Nature* **459** 820.

The subtle science of reproducibility

Scientists usually try to describe their experiments as best they can so that others can reproduce the results, but sometimes small factors that might seem insignificant can make a big difference.

Stephen M Buchwald of MIT in Boston and Carsten Bolm of Aachen University have found that for some organic reactions that are long thought to be catalysed by iron salts, it might be mainly trace impurities of copper at the parts-per-million level that are doing the job. If the iron salt is too pure then the reaction does not work – while forgetting the iron altogether in favour of a trace of copper makes the reaction go well.

Their work serves as an important reminder that to repeat an experiment you may have to repeat everything with great care.

Further reading

Stephen L Buchwald and Carsten Bolm 2009 *Angewandte Chemie International Edition* **48** 5586.

Compiled by Marc Türler, ISDC and Observatory of Geneva University

Galactic positrons are not from dark matter

A new study on the propagation of positrons in the galaxy suggests that dark-matter annihilation or decay is not required to account for gamma-ray observations by ESA's INTEGRAL satellite. It shows that the observed characteristics of the positron emission can be fully accounted for by β+ decay of radionuclei produced by nucleosynthesis in supernova explosions and the wind of massive stars.

One of the main successes of the INTEGRAL gamma-ray satellite is its unprecedented characterization and mapping of positron annihilation in the galaxy. Early results from INTEGRAL's spectrometer showed that the 511 keV emission line from electron–positron annihilation is mainly emitted from a circular region that corresponds roughly to the central bulge of the Milky Way. As the galactic-disc emission could not be clearly detected, the data implied a bulge-to-disc ratio at least three times higher than for the production sites of positrons by β+ decay in supernova ejecta.

Dark matter soon emerged as an explanation for the positron excess in the bulge compared with the distribution in supernovae of type Ia (*CERN Courier* November 2004 p13). Researchers then realized, however, that the range of masses for the required lightweight dark-matter particle was severely limited by the deduced maximum energy of the positrons (*CERN Courier* December 2006 p14). Nevertheless, over recent years, more than 100 papers

Positron annihilation detected by INTEGRAL, the gamma-ray observatory launched in October 2002, is probably not of dark-matter origin. (Courtesy ESA.)

have been published on exotic dark-matter candidates that could explain the positron excess in the galactic bulge. These include new axions, superconducting strings, Q balls, sterile neutrinos, millicharged fermions, unstable branons and many more.

This proliferation of exotic ideas should stop with the recent publication of a paper in *Physical Review Letters* by Richard Lingenfelter and Richard Rothschild from the University of California San Diego and their colleague James Higdon at the Keck Science Center. Their letter is based on a detailed study that they published in the *Astrophysical Journal*, where they demonstrate that the assumption that positrons cannot propagate over large distances in the galaxy is wrong. They further show that positrons from the decay of the radionuclei ^{56}Ni, ^{44}Ti and ^{26}Al produced in supernova ejecta will preferably decay in the denser environment of the galactic bulge, where most of the molecular clouds are concentrated.

Lingenfelter and colleagues therefore argue that the observed bulge excess can be fully accounted for by identified astrophysical sources of positrons, mainly the supernova ejecta and the strong winds of massive stars. The easy propagation of the positrons before annihilation in the dense envelopes of molecular clouds also explains the high positronium fraction (94% ± 4%) deduced from the ratio of the 511 keV line flux to the three-photon continuum emission at lower energies. The study further suggests that the observed asymmetry of the positron annihilation between one side of the galactic plane and the other (*CERN Courier* March 2008 p12) could just result from the asymmetric distribution of the inner spiral arms of the galaxy as seen from the Earth.

In view of these results, it seems that the excitement about a possible dark-matter signal in the INTEGRAL measurements was premature and built on shaky ground. With the recent arguments against other dark-matter claims, this elusive matter looks even darker than ever (p16).

Further reading

J C Higdon *et al.* 2009 *ApJ* **698** 350.
R E Lingenfelter *et al.* 2009 *Phys. Rev. Lett.* **103** 031301.

Picture of the month

This spectacular "soap bubble" is actually a newly discovered planetary nebula. It is difficult to imagine that it could have remained unnoticed until a year ago in a region as scrutinized as the Cygnus constellation and just 0.5° away from NGC 6888, the Crescent Nebula. Its faintness over a relatively bright background explains the late discovery: without the excellent colour contrast of this image taken with the 4 m Mayall telescope of the Kitt Peak Observatory, the Cygnus bubble – now designated as PN G75.5+1.7 – would be barely discernible. Like other planetary nebulae, it is the remnant of a dying Sun-like star and will probably remain visible for about 10 000 years before fading away (*CERN Courier* July/August 2003 p13 and April 2007 p10). (Courtesy T A Rector/University of Alaska Anchorage, H Schweiker/WIYN and NOAO/AURA/NSF.)

A look back to *CERN Courier* vol. 6, September 1966, compiled by Peggie Rimmer

CPT

Breaking the laws of symmetry

Ten years ago (in October 1956) T D Lee and C N Yang pointed out that parity, P, which implies that if a particle interaction is possible then its mirror image is also possible, appears to be violated in the two- and three-meson decays of the K meson. They suggested that this breakdown was characteristic of interactions involving the weak force, which controls the slow decay of heavier particles into lighter particles. In December 1956 this prediction was confirmed by C S Wu in the case of the radioactive decay of nuclei.

Symmetry was reimposed by combining P and charge symmetry, C, which implies that the detailed behaviour of an interaction between particles should be the same as between their antiparticles. CP was held to be conserved in all weak interactions. This was found to be good until 1964, when a team from Princeton University, led by V L Fitch and A J Cronin, at the 33 GeV Brookhaven synchrotron looked at the weak decay of the long lived neutral K meson, K^0_L. If CP is conserved, this is allowed to decay into three pions. About once in 500 decays it went to two pions in violation of the symmetry.

Violation of C?

One idea was that what we are seeing is not really a violation of CP in weak interactions but a violation of C symmetry in the strong or electromagnetic interactions.

Experiments started at CERN, at the Rutherford Laboratory and then at Brookhaven, to look for C violation in the electromagnetic interaction. They all concentrated on the same particle, the eta meson, a neutral particle for which particle and antiparticle are the same. It can decay via the electromagnetic interaction into three pions; one positive, one negative and one neutral (also its own antiparticle).

We have the interaction $\eta^0 \rightarrow \pi^+ + \pi^- + \pi^0$ for which the C reflection is $\eta^0 \rightarrow \pi^- + \pi^+ + \pi^0$. If C symmetry is good, the behaviour of the positive and negative pions coming from the decay will be symmetrical. The experiments have looked to see whether the number of pions of a given energy is equally divided between positive and negative types.

The result from the Brookhaven team, led by P Franzini, of Columbia University, and his wife J Lee-Franzini, of State University Stony Brook, emerged first (*Physical Review Letters*, 27 June 1966). 435 000 photographs were taken at a bubble chamber filled with liquid deuterium and 1441 of them were accepted as genuine cases of eta production and its decay into three pions. In 724 events the positive pions were emitted with greater energy, compared with 627 events where the negative pions were more energetic. On the basis of this result the Americans announced violation of charge symmetry in the electromagnetic interactions, causing great excitement in sub-nuclear physics.

The CERN experiment

The experiment at CERN used a negative pion beam from the 28 GeV proton synchrotron directed onto a hydrogen target to produce the interaction: pion plus proton gives neutron plus eta, $\pi^- + p \rightarrow n + \eta^0$. The two charged pions from the eta decay were observed in spark chambers, placed in an accurately known magnetic field. From 350 000 photographs, 10 600 were accepted as genuine eta events.

The experiment took about six weeks and the team consisted of five scientists from CERN, A M Cnops (Belgium), G Finocchiaro (Italy), J C Lassalle (France), P Mittner (Italy) and P Zanella (Italy), three from Eidgenossische Technische Hochschule, Zurich, J P Dufey, B Gobbi and M Pouchon, and A Muller from Saclay. The result, (announced at the 13th International Conference on High Energy Physics at the end of August, and in *Physics Letters*, 1 September) extracted from three times as many events as in all of the other published experiments combined, showed no evidence for C violation.

An identical experiment to the Franzini experiment has been performed by a team using the 7 GeV accelerator, Nimrod, at the Rutherford and a deuterium-filled 81 cm chamber from Saclay. They obtained 800 accepted eta events, about half of the American statistics, and detected no asymmetry.

Where are we now?

It is believed that the reflection of three symmetries together – charge, parity and time CPT – is a good symmetry, where time, T, says that if a sequence of events involving particles can occur, then exactly the reverse sequence is possible. If CPT symmetry is shaken, then it would undermine the foundations of modern theoretical physics.

In the weak interactions, P and C are violated and the combined CP seems to be violated in K^0_L decay. If CP is violated, then T must be also, so that CPT will be safe; thus T has a question mark under weak interactions. The recent eta experiments have questioned whether C, and thus CP, is good for the electromagnetic interactions and, again to preserve CPT, it puts a question mark under T.

The whole field is obviously in the melting-pot but one can hope that the intensive research on the various possibilities thrown up by the recent observations will soon clarify the present intriguing picture.

● Compiled from the article on pp171–174.

COMPILER'S NOTE

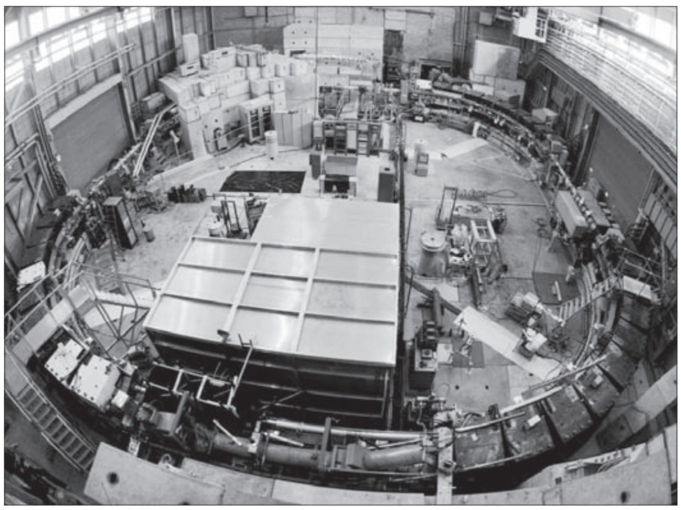
In a seminar given at CERN (in the early 1970s, I think), T D Lee suggested that beauty lies not in perfect symmetry but in slight deviations therefrom, illustrating this with pictures of some beautiful Greek vases. While CP symmetry violation may be a source of beauty for physicists, it also happens to be crucial to our very existence, playing an important role in today's dominance of matter over antimatter. The article "Why does CP violation matter to the Universe?" by John Ellis (*CERN Courier* October 1999 p24) is an excellent summary of the subject, still up to date on theory even if inevitably out of date on experiments, for example with LHCb "scheduled to start taking data at CERN's LHC collider in 2005".

ICE-cool beams just keep on going

Thirty years after CERN's first tests of electron cooling with the Initial Cooling Experiment – ICE – the original cooler continues its work in delivering dense antiproton beams and has provided valuable experience for future work with ion beams.

The quality of a charged particle beam is characterized by the product of its radius and divergence – the emittance – and by the momentum spread. Together they define the part of the phase space that is occupied by the particles in an accelerator. In 1966 Gersh Budker proposed a method that would allow the compression, or "cooling", of the occupied phase space in stored proton beams. His idea of electron cooling was based on the interaction of a monochromatic and well directed electron beam with the heavier protons circulating over a certain distance in a section of a storage ring. The electrons are produced continuously in an electron gun, accelerated electrostatically to a velocity equal to the average velocity of the circulating beam and then inflected into the beam. Both beams overlap for a distance, over which the cooling takes place, and then the electrons are separated from the ion beam and directed onto a collector.

The first successful demonstration of electron cooling took place in 1974 at the proton storage ring NAP-M at what is now the Budker Institute of Nuclear Physics (BINP) in Novosibirsk. A few years later CERN and Fermilab built dedicated facilities to study the cooling process, which was a prerequisite for the accumulation of antiprotons for the proposed conversion of proton accelerators to proton–antiproton colliders. The Initial Cooling Experiment (ICE) at CERN became operational in 1977 with the goal of determining which of two cooling methods would be more appropriate for high-energy antiprotons: electron cooling or the technique proposed by Simon van der Meer at CERN, namely, stochastic cooling. The tests on electron cooling took place in 1979 (see box, p15).



The storage ring of the Initial Cooling Experiment (ICE). The cooler is visible just behind the concrete blocks in the foreground.

From ICE to LEAR

As is well known, CERN chose stochastic cooling for the Antiproton Accumulator that was used to feed the SPS when operating as a proton–antiproton collider. However, the request by physicists for a programme with low-energy antiprotons allowed the ICE electron cooler to continue, with a new lease of life. Thirty years and two reincarnations later, essentially the same device is now used routinely to cool and deliver low-energy antiprotons to experiments on CERN's Antiproton Decelerator (AD).

In its first reincarnation, the ICE cooler was used on the Low Energy Antiproton Ring (LEAR). This decelerator ring was built to deliver intensities of a few thousand million (10^9) antiprotons in an ultra-slow extraction mode to up to three experiments simultaneously over many hours. Operation in LEAR required a static vacuum level less than 10^{-11} torr, which meant that the cooler needed a major upgrade of its vacuum system. The high gas load coming from the cathode and collector regions of the cooler had made its operation on ICE very problematic and the best obtainable vacuum was in the order of 10^{-10} torr. Higher pumping speeds and a careful choice of materials were therefore needed if there was to be any significant improvement in the vacuum.

A team from CERN and Karlsruhe carried out an extensive study of various vacuum techniques between 1981 and 1984, resulting in a new design for the complete vacuum envelope, which was built using high-quality AISI 316LN stainless steel. In addition, the whole system was designed to be bakeable at 300 °C *in situ* for ▷

24 hours, requiring permanent jackets to provide the necessary thermal insulation. The use of non-evaporable getter (NEG) strips developed for the Large Electron–Positron Collider provided an increase in pumping speed and three such modules were initially installed on the cooler. The choice of NEGs was evident as space limitations excluded any other type of pumping system, such as cryopumps or sputter ion pumps.

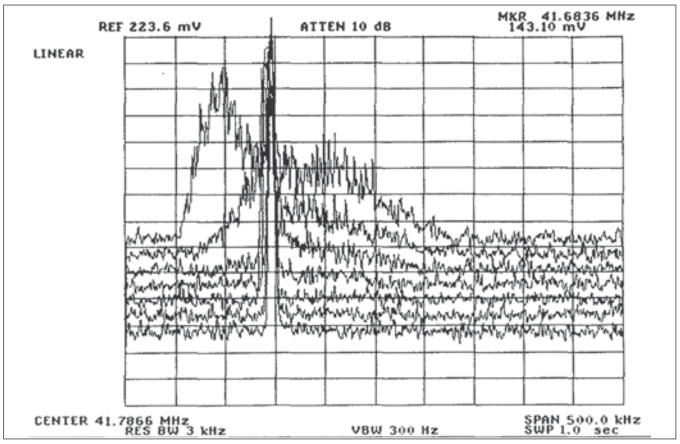
With this hurdle overcome preparations started for the integration of the cooling device with LEAR. To fit into one of the 8 m long straight sections of the machine, the interaction length of the cooler had to be reduced by half. Luckily the drift solenoid had been designed in two equal parts so removing one half was not a problem. The high voltage and the control systems of the device were also completely refurbished and a dedicated equipment building was erected close to the LEAR ring. The installation of the cooler took place during the summer of 1987 followed by the conditioning of the cathode and further tests to monitor the evolution of the LEAR vacuum in the presence of the electron beam. By the autumn of 1987 the cooler was ready to cool its first beam. The first cooling tests took place on a 50 MeV proton beam injected directly from Linac 1 and the initial results confirmed all expectations.

After protons the attention turned to antiprotons and the use of electron instead of stochastic cooling to improve the duty cycle of the deceleration in LEAR. To deliver high-quality antiproton beams to the different experiments in the South Hall, the operators applied stochastic cooling after injection at 609 MeV/*c* and then at various plateaus during the deceleration process. It would normally take around 20 minutes to obtain a "cold" beam at 100 MeV/*c*, the lowest momentum in LEAR. The use of electron cooling reduced this time to 5 minutes as cooling was needed for only 10 seconds on each of the intermediate plateaus, compared with 5 minutes per plateau with stochastic cooling. Hardware modifications required to render the operation of the cooler as reliable and effective as possible included the replacement of the collector with one that had a better collection efficiency (>99.99%), a new control system to synchronize the power supplies for the cooler with the LEAR magnetic cycle, and the implementation of a transverse feedback system (or "damper") to counteract the coherent instabilities observed with such dense particle beams.

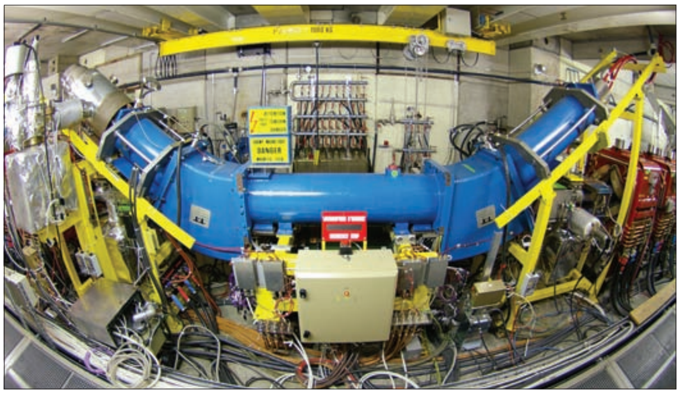
Apart from being the first cooler to be used routinely for accelerator operations, this apparatus was also the first to demonstrate the cooling and stacking of ions. In 1989 a machine experiment was devoted to studies on O^{6+} and O^{8+} ions coming from Linac 1. By applying electron cooling during the longitudinal stacking process this succeeded in increasing the intensity by a factor of 20. Later these ions were accelerated to an energy of 408 MeV/u and extracted to an experiment measuring the distribution of dose with depth in types of plastic equivalent to human tissue.

The years of operation on LEAR also allowed detailed studies of the cooling process. A full investigation into the influence of the machine's optical parameters demonstrated that cooling was not effective over the whole radius of the electron beam and that having a finite value of the dispersion function in the cooling section could enhance the process significantly. Before these studies it was believed that a circulating ion beam with transverse dimensions comparable to the electron beam size would produce stronger cooling.

In a separate study the electron beam was neutralized by



The first electron cooling of protons in LEAR is shown in this scan – a frequency analysis of the Schottky noise. The spectrum becomes narrower as the cooling process takes effect.



The electron cooler, which was upgraded to be operated on LEAR, in place in the ring of the Antiproton Decelerator at CERN.

accumulating positively charged ions using electrostatic traps placed at either end of the cooling section. By neutralizing the space charge of the electron beam, the induced drift velocity of the electrons would become negligible and hence the equilibrium emittances of the ion beam would be reduced further. Even though a neutralization factor of more than 90% could readily be obtained, it proved to be very difficult to stabilize this very high level of neutralization. Secondary electrons produced in the collector would be accelerated out of the collector region and oscillate back and forth between the collector and the gun. At each passage through the cooling section they would excite the trapped ions causing an abrupt deneutralization.

Another important modification to the cooler was the development of a variable-current electron gun. The gun inherited from ICE was of the resonant type and offered little operational flexibility. The new gun was of the adiabatic type with the peculiarity that it had been designed to operate in a relatively low magnetic field – a prerequisite for its integration in LEAR. Online control of the electron beam intensity was possible by simply varying the voltage difference between the cathode and the "grid" electrode.

Towards the end of the antiproton programme on LEAR, the cooler was paving the way for the conversion of this ring to the Low Energy Ion Ring (LEIR), which would cool and accumulate lead ions for CERN's new big accelerator, the LHC. A series of machine experiments using lead ions with various charge states (52+ to 55+) not

From the archives

Electron cooling tests started in the ICE (Initial Cooling Experiment) storage ring at CERN in May and the results obtained so far are very encouraging. Beam quality can be greatly improved (for example, the six-dimensional phase space density can be improved by a factor of 10^7), cooling times are short (0.3 s and 1.2 s in momentum spread and betatron amplitude, respectively) and beam losses are down to the level corresponding to scattering on residual gas.

The construction of the electron gun started at CERN in the summer of 1977. It was installed in the ring in April 1979 and the first test started in May. Cooling effects, both in longitudinal and transverse dimensions, were observed on the first day as soon as the electron and proton beams were aligned and their velocities matched. Further optimization was obtained by adjusting the gun parameters to minimize the microwave radiation produced by the electrons. Cooling was then strong enough to produce longitudinal bunching of the proton beam. Finally the betatron frequencies of the ICE ring were modified to move the transition energy above the operating energy. The bunching effect disappeared and the best cooling conditions were obtained. The proton beam reduced from 2 cm to less than 1 mm and the momentum spread from 2×10^{-3} to 4×10^{-5}.

● ***CERN Courier* October 1979 p309.**

only demonstrated the feasibility of the proposed scheme, but also brought to light an anomalously high recombination rate between the cooling electrons and the Pb^{53+} ions (which had initially been the proposed charge state) leading to lifetimes that were too short for cooling and stacking in LEAR. It was decided to use Pb^{54+} ions instead, as they are produced in equal quantities to the 53+ charge state.

On to the AD

After 10 years on LEAR, the cooler was moved to the AD in 1998 where it continues to provide cold antiprotons for the "trap" experiments in their quest to produce large quantities of antihydrogen. Recently the AD team attempted a novel deceleration technique using electron cooling. The idea is to ramp the cooler and the main magnetic field of the AD simultaneously to a lower-energy plateau. This allows the antiproton beam to be kept cold throughout the deceleration process avoiding the adiabatic blow-up that all beams experience when their energy is reduced. The first tests were very modest, decelerating 3.5×10^7 antiprotons from 46.5 to 43.4 MeV, but future experiments will concentrate on decelerating the beam below 5.3 MeV.

The experience gained with the upgraded ICE cooler on LEAR provided the stepping stones for the design of a new state-of-the-art cooler for the I-LHC project to provide ions for the LHC. This is the first of a new generation of coolers incorporating all of the recent developments in electron cooling technology (adiabatic expansion, electrostatic bend, variable density electron beam, high perveance and "pancake" solenoid structure) for the cooling and accumulation of heavy ion beams. High perveance, or intensity, is necessary to rapidly reduce the phase-space dimensions of a newly injected "hot" beam, while variable density helps to efficiently cool particles with large betatron oscillations and at the same time improve the

The new cooler for the LEIR ring to provide ion beams for the LHC.

lifetime of the cooled stack. Adiabatic expansion also enhances the cooling rate because it reduces the transverse temperature of the electron beam by a factor proportional to the ratio of the longitudinal magnetic field between the gun and the cooling section.

The new cooler, built in collaboration with BINP, was commissioned at the end of 2005 and has since been routinely used to provide high-brightness lead-ion beams required for the LHC. In parallel there have been studies to determine the influence of the cooler parameters (electron beam intensity, density distribution, size) on the lifetime and maximum accumulated current of the ions.

Electron cooling will certainly be around at CERN for quite a few more years. With the AD antiproton physics programme extended until 2016, the original ICE cooler will be nearly 40 years old when it finally retires. If the Extra Low ENergy Antiproton (ELENA) ring comes to life, it will require the design of a new cooler with an energy range of 50 to 300 eV to cool and ultimately decelerate antiprotons to only 100 keV. The possibility of polarized antiprotons at high energy in the AD will also require either an upgrade of the present cooler or the construction of a new one capable of generating a high-current electron beam at 300 keV. Of course the LEIR electron cooler will continue to deliver lead ions for the LHC and, with a renewed interest for a fixed-target ion programme, other ion species could also find themselves being cooled and stacked in LEIR.

Résumé

ICE : le refroidissment des faisceaux continue

Trente ans après les premiers essais de refroidissement des électrons avec l'expérience ICE, l'installation d'origine continue à livrer des faisceaux denses d'antiprotons. Après d'importantes améliorations, le dispositif a été installé en 1987 sur l'anneau d'antiprotons de basse énergie, et est devenu le premier « système de refroidissement » à être utilisé régulièrement pour l'exploitation d'accélérateurs. Il a également été utilisé pour des études approfondies du processus de refroidissement et, en 1989, a été le premier à faire la démonstration du refroidissement et de l'empilement des ions. Depuis 1998, il est utilisé sur le Décélérateur d'antiprotons (AD), auquel il fournit des antiprotons froids pour les expériences visant à produire de grandes quantités d'antihydrogène.

Gerard Tranquille, *CERN*.

Cosmic leptons challenge dark-matter detection

The interpretation of recent cosmic-ray data within particle-physics models of dark matter conflicts with physics that arises naturally beyond the Standard Model. This favours an astrophysical explanation, as **Pierre Brun** and **Timur Delahaye** explain.

THE UNIVERSE YOURS TO DISCOVER
INTERNATIONAL YEAR OF ASTRONOMY 2009

Recent measurements of cosmic-ray leptons – electrons and positrons – have generated a buzz because they might point to unknown astrophysical or exotic cosmic phenomena. A new measurement of the cosmic-ray positron fraction, $e^+/(e^-+e^+)$, by the satellite-borne PAMELA detector shows an unambiguous rise between 10 GeV and 100 GeV (*CERN courier* May 2009 p12). This confirms previous claims by the High-Energy Antimatter Telescope (HEAT) and AMS-01 collaborations (figure 1). At the same time, the Advanced Thin Ionization Calorimeter (ATIC), Fermi Gamma-Ray Telescope and HESS collaborations have published new results on the sum e^-+e^+ at higher energies, up to a few tera-electron-volts. Although there are still discrepancies between these three experiments they could indicate the presence of a feature in the energy spectrum of e^-+e^+ between 600 GeV and 1 TeV. Whether it is a bold peak, as ATIC claims, or a more shy bump, as the Fermi data indicate, is still unclear (figure 2). Further work and crosschecks are necessary to reach a definite answer. Another issue concerns whether this feature arises from electrons only or from both electrons and positrons.

There is nevertheless the hint of a signal in this energy range, which is quite challenging to reproduce with conventional cosmic-ray models. A workshop held in Paris in May, "Testing Astroparticle with the New GeV/TeV Observations. Positrons And electRons: Identifying the Sources (TANGO in PARIS)", provided the opportunity to discuss and confront the possible interpretations of these results.

Conventional cosmic-ray production

The current understanding is that most cosmic rays are produced in the remnants of supernovae – what is left after the cataclysmic ends to the lives of many stars. Some cosmic-ray species (positrons, antiprotons, boron etc.) do not exist in stars but are instead produced by the spallation reaction of other cosmic rays with the interstellar medium. Once made, cosmic rays diffuse in the galactic magnetic field; they lose energy, are convected and eventually reach Earth.

Even taking into account the uncertainties underlying the state-of-the-art cosmic-ray transport modelling it is not possible to reproduce the PAMELA data, as figure 1 shows (T Delahaye *et al.* 2009). One solution is that the model for standard astrophysical positrons is mistaken in some way. For instance, the source distribution in the galaxy might be more complex than generally believed and positron production by spallating proton cosmic-rays on interstellar matter

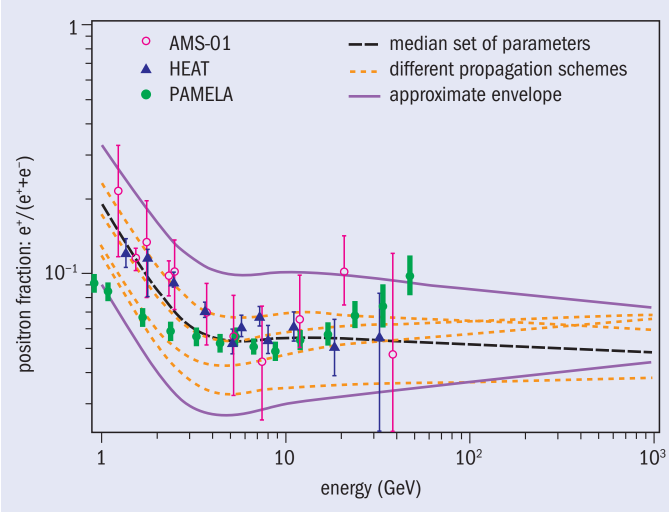


Fig. 1. Positron fraction as measured by PAMELA, together with an estimation of the conventional background (the electron contribution is a fit from an independent dataset). Note that none of the background shape can accommodate the rise in the positron fraction.

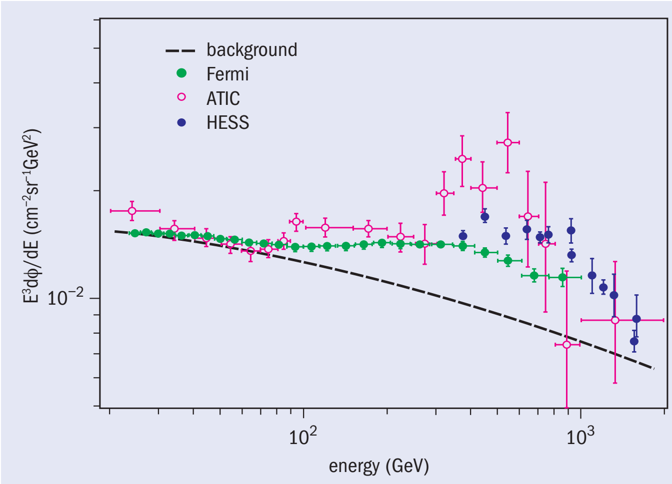


Fig. 2. Electron flux as measured by Fermi, ATIC and HESS. Systematic errors are not represented here and may lead to shifts in the normalization of the spectra.

might be higher than expected. Such an effect could arise from a local over-density of proton sources (the spiral arms) or of interstellar matter around supernova remnants. However, in these models, it is difficult at the same time not to over-produce other cosmic-ray species, such as antiprotons or boron.

Another solution is that supernovae and spallating cosmic rays are not alone in the significant production of high-energy charged particles, so that other astrophysical objects also contribute. As electrons and positrons lose a lot of energy as they propagate in the galaxy, one single nearby source could explain the observed feature. Pulsars seem to be a good candidate for such an effect because they may produce electrons and positrons evenly, thus enriching the surrounding positron fraction. Unfortunately, the way that pulsars could produce electron–positron pairs and release them in the galaxy is not yet clear – making predictions difficult. Nevertheless, recent observations from Fermi have revealed that pulsars are more numerous than expected, so there is a high chance that we are missing many of them. Hence explaining the PAMELA/ATIC feature with pulsars is feasible.

The most exciting solution would be that these excesses arise from the effects of dark matter, so allowing a first insight into physics beyond the Standard Model. Indeed, in such a scenario, the mass of our galaxy would be dominated by new non-standard particles, which would annihilate or decay into standard particles, contributing to the cosmic-ray flux.

While it is extremely appealing, the dark-matter solution is puzzling. The natural way to agree with constraints from cosmology (freeze-out of the dark-matter particles in the early universe) is to have a new particle with mass and couplings of the order of the electroweak scale. If this particle could annihilate or decay into Standard Model particles then the corresponding cosmic-ray production rate would be small, which would not allow the reproduction of features as significant as the ones seen by PAMELA, ATIC, Fermi and HESS. To account for them, the dark-matter signal must be magnified with respect to the standard picture in some way, by a factor ranging from 100 to 1000, depending on the model. This is a well known fact – which the models make possible either with some particle-physics effect (for dark-matter particles of masses typically larger than a few tera-electron-volts or so) or as a consequence of local enhancements of the signal caused by dark-matter substructures.

Trouble appears when confronting this interpretation with channels where corresponding excesses should appear, such as cosmic antiprotons and photons. PAMELA recently published fresh measurements of the antiproton flux up to 100 GeV (figure 3, p18), which show no specific feature (*CERN Courier* April 2009 p7). Antiprotons are interesting because the theoretical uncertainty associated with the background estimate is lower than for that of positrons – and most models with new physics expect annihilations or decays of dark matter to produce antiprotons. It is therefore possible to put an upper limit to the signal enhancement necessary to explain the leptonic data (Donato *et al.* 2009). It eventually appears that the antiproton data are incompatible with the large enhancements that are required by leptons for conventional dark-matter candidates.

The only way out is to have either a very heavy particle (of mass larger than 10 TeV) or to suppress the hadronic annihilation or decay modes of the dark-matter particle. In the first case, an excess of antiprotons should appear in future higher-energy data; in the second, no hadrons are produced by this so-called "leptophilic" dark ▷

matter. In both cases the properties of the new particle are different from those usually expected. Within minimal supersymmetric dark-matter models, for instance, large masses imply a loss of naturalness and direct electron/positron production in the annihilation is suppressed. In addition, when confronting models that survive the antiproton constraints to photon observations, the net tightens even more. Indeed, all of these electrons and positrons should also be produced in places where large magnetic fields are present (e.g. at the galactic centre) and consequently produce sizable radio emission, which is in general above the measured values (at least in the most standard galactic models).

The previous considerations assume a particle-physics type enhancement – i.e. an overall enhancement of the production of exotic cosmic leptons – regardless of the location in the galaxy. However, one could ask if these cosmic-ray features are the same everywhere in the galaxy. An interesting possibility is that a nearby clump of dark matter is responsible for some local excesses (Brun *et al.* 2009). In this case, the antiproton constraints may be less stringent and the ones from photon observations are totally avoided. The main feature responsible for the local lepton anomalies would then be a nearby (closer than a few kiloparsecs), bright clump. (As electrons and positrons do not propagate over large distances, just one massive clump could contribute sufficiently). In fact, dark-matter haloes are expected to form by successive mergers of small structures. Large haloes, such as the one of our galaxy, should contain a lot of smaller subhaloes (up to 20% of the total halo mass). Large numerical simulations can model the formation of these structures and calculate the probability of finding a configuration that fulfils the requirements to account for the lepton excesses in a halo of the size of the Milky Way. Unfortunately, this probability is found to be extremely low; usually fewer than 1% of the simulations exhibit such a favourable scenario. If such a clump does exist, however, the gamma-ray satellite Fermi has enough sensitivity to detect the associated gamma-ray emission.

Epilogue?

It is definitely possible to reproduce the observed cosmic-ray data with the help of dark-matter signals. Within this hypothesis, however, there will always be some tension between the different channels and observables or quite a high level of fine tuning. It could be that we are circling the properties of dark-matter particles but it is more likely that the bulk of the observed leptons come from a nearby astrophysical source that produces a large fraction of electron–positron pairs. In this case, the signal would constitute an additional background for indirect searches for dark matter through lepton channels that had not previously been accounted for.

A big step forward will be the measurement of the small anisotropy in the arrival directions of the cosmic-ray leptons, if any. If it is observed and points towards a known pulsar, then the conclusion will be clear. It is also urgent to separate electrons from positrons at higher energies and to increase statistics in all channels. Future results from PAMELA, and especially AMS-02, on leptons and also on fluxes of all nuclei will be of great help in feeding the cosmic-ray propagation models. The indirect searches for dark matter through charged channels can then continue, in particular looking for fine structure in the spectra. It will then be interesting (and challenging) to interpret future data and weigh them against results from the LHC and direct-detection experiments.

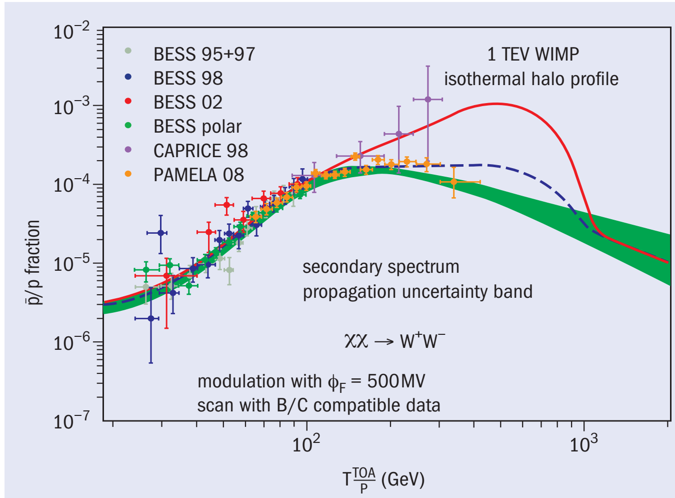


Fig. 3. Antiproton-to-proton ratio, compared with the background estimates and its uncertainty (green band). The solid red and dashed blue lines are hypothetical dark-matter signals (Donato et al. *2009).*

Whatever the nature of the source, we might be witnessing the first direct observation of a nearby source of cosmic rays with energies in the range of giga- to tera-electron-volts. These are exciting times and we might have to wait a little longer for the solution to this cosmic puzzle. The answer(s) will certainly come from a convergence of information from different messengers. Thanks to its large field of view, the Fermi telescope should reveal something about a nearby source, should it be a pulsar or something more exotic. Eventually, future large neutrino and gamma-ray observatories (such as KM3NeT and the Cherenkov Telescope Array) will certainly offer a great opportunity to take a deeper look into this brainteaser.

● The presentations slides and videos the TANGO talks are available at http://irfu.cea.fr/Meetings/TANGOinPARIS.

Further reading

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Résumé

Leptons cosmiques et matière noire

Des mesures récentes de leptons (électrons et positons) de rayons cosmiques pourraient révéler des phénomènes astrophysiques ou cosmiques inconnus à ce jour. La solution la plus intéressante serait que les caractéristiques observées s'expliquent par certains effets de la matière noire, ce qui donnerait un premier aperçu de la physique au-delà du modèle standard. Toutefois, s'il est possible de reproduire les données obtenues des rayons cosmiques à l'aide des signaux de la matière noire, plusieurs difficultés surgissent. Il semble plus vraisemblable que l'essentiel des leptons observés proviennent d'une source astrophysique produisant une grande proportion de paires électrons–positons.

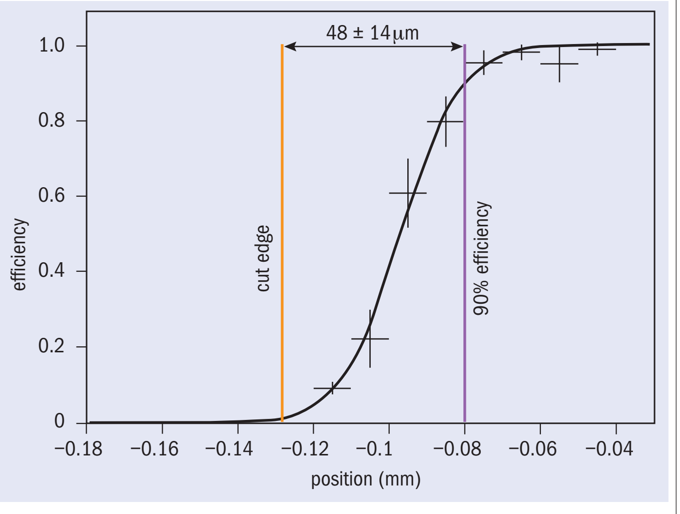
Pierre Brun, *IRFU, CEA Saclay, and* **Timur Delahaye**, *LAPTh Annecy and University of Torino.*

A small experiment with a vast amount of potential

The TOTEM experiment is one of the smallest at the LHC, but it uses innovative detectors to explore physics that is largely beyond the reach of its giant siblings.

While most of the LHC experiments are on a grand scale, the subdetectors for TOTEM, which stands for TOTal cross-section, Elastic scattering and diffraction dissociation Measurement at the LHC, are not longer than 3 m, although they extend over more than 440 m. Despite reduced dimensions, TOTEM's potential resides in making some unique observations. In addition to the precise measurement of the proton–proton interaction cross-section, TOTEM's physics programme will focus on the in-depth study of the proton's structure by looking at elastic scattering over a large range of momentum transfer. Many details of the processes that are closely linked to proton structure and low-energy QCD remain poorly understood, so TOTEM will investigate a comprehensive menu of diffractive processes – the latter partly in co-operation with the CMS experiment, which is located at the same interaction point on the LHC.

The measurement of the total proton–proton interaction cross-section with a luminosity-independent method requires a detailed study of elastic scattering down to small values of the squared four-momentum transfer, together with the measurement of the total inelastic rate. Early measurements at CERN's Intersecting Storage Rings (ISR), which were confirmed at CERN's Sp$\bar{p}$S collider and at the Tevatron at Fermilab, revealed that the proton–proton interaction probability increases with collider energy. However, the nature of the correct growth with energy remains a delicate and unresolved issue. A precise measurement of the total cross-section at the world's highest-energy collider should discriminate between the different theoretical models that describe the energy dependence. The value of the total cross-section at LHC energies is also important for the interpretation of cosmic-ray air showers. All of the LHC experiments will use TOTEM's measurement to calibrate their luminosity monitors, in order to calculate the probability of measuring rare events.



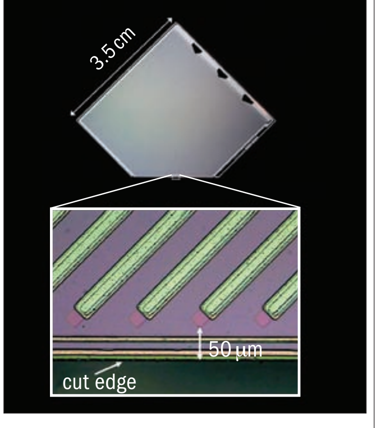


Fig. 1. A microstrip edgeless silicon detector for TOTEM. The magnification shows the narrow gap between the detector structure and the edge. The plot above shows the efficiency of one of these detectors at the edge. The left-most vertical line indicates the position of the cut edge, from which the efficiency rises to 100% within 50 µm.

Fig. 2. Four Roman Pot detector packages with their edgeless silicon sensors. (Courtesy TOTEM.)

Sophisticated detectors

The study of physics processes in the region close to the particle beam, which is complementary to the programmes of the LHC general-purpose experiments, requires appropriate detectors. In the case of elastic and (most) diffractive events, intact protons in the final state need to be detected at a small angle relative to the beam line, therefore special proton detectors must be inserted into the vacuum beam pipe of the LHC. The TOTEM Collaboration had to invest heavily in the design of sophisticated detectors characterized by a high acceptance for particles produced in the busy region close to the beam pipes (The TOTEM Collaboration, G Anelli *et al.* 2008). All of the three subdetectors – Roman Pots and two particle telescopes, T1 and T2 – will detect charged particles emitted ▷

by the proton–proton collisions at interaction point 5 (IP5) on the LHC and will have trigger capabilities to allow an online selection of specific events.

The Roman Pots are special movable devices that are inserted directly into the beam pipe by bellows, which are compressed as the pots are pushed towards the beams circulating inside the vacuum pipe. They are called "Roman" because they were first used by a group of Italian physicists from Rome, in the early 1970s, to study similar physics at the Intersecting Storage Rings, the world's first high-energy proton–proton collider (*CERN Courier* July/August 2009 p21). They are known as "Pots" because the vessels that house the delicate detectors, which can localize the trajectory of protons passing within 1 mm of the beam (with a precision of around 20 μm), are shaped like a vase.

In the TOTEM experiment, there are four Roman Pot stations, each composed of two units, separated by a distance of a few metres. Each unit consists of two pots in the vertical plane, which approach the beam from above and below, and one pot that moves horizontally. They are placed on both sides of the interaction point, at distances of 147 m and 220 m.

The proton detectors in the Roman Pots are silicon devices designed by Vladimir Eremin, Nikolai Egorov and Gennaro Ruggiero with the specific objective of reducing the insensitive area at the edge facing the beam to only 50 μm (figure 1, p19). This can be compared with a dead area typically more than 10 times larger for silicon detectors currently used elsewhere. High efficiency up to the physical border of the detector is an essential feature to maximize the experiment's acceptance for protons scattered elastically or diffractively at polar angles down to a few microradians at the interaction point. Radiation-hardness studies indicate that this edgeless detector remains fully efficient up to a fluence of about 1.5×10^{14} protons/cm^2.

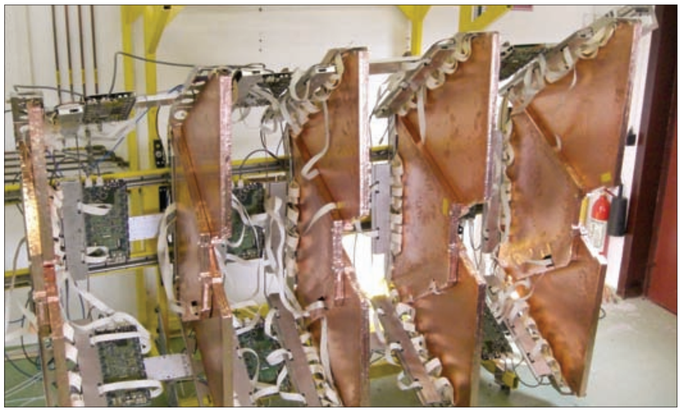


Fig. 3. A T1 quarter under test. (Courtesy TOTEM.)

The inelastic rate is measured by the telescopes T1 and T2. These are two charged-particle trackers situated close to the beam pipes in the CMS cavern at distances of about 10.5 m and 13.5 m on either side of the interaction point; indeed, T1 is within the CMS end-cap. By providing a full azimuthal coverage around the beam line, these

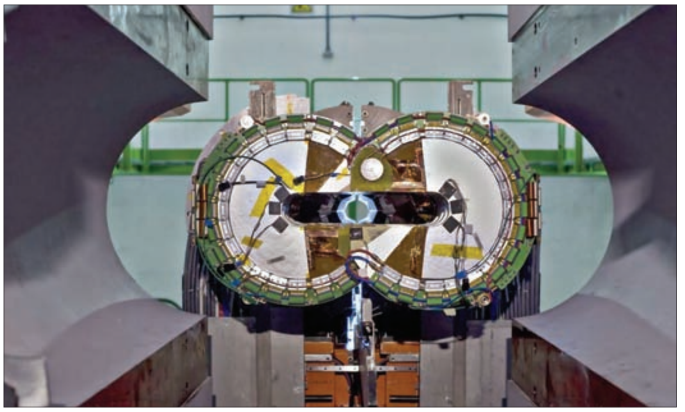


Fig. 4. One arm of the T2 telescope during installation in IP5.

telescopes will be able to reconstruct the tracks of charged particles coming from the proton–proton collisions and so allow the determination of the primary interaction vertex.

Each T1 tracker is made up of five subdetector planes perpendicular to the beam line. Each plane consists of six cathode-strip chambers (CSCs) – multiwire proportional chambers filled with a gas mixture, with cathode layers segmented into parallel strips. The advantages of this kind of detector are that it utilizes a well proven technology, provides a simultaneous measurement of three spatial co-ordinates (one from the anode wire plane and two from the cathode-strip planes) and uses a safe gas mixture ($Ar/CO_2/CF_4$). As T1 is installed in a high-radiation environment, the chambers have been tested in the gamma-irradiation facility at CERN. They have shown stable performances at doses several times higher than those expected for the design running conditions and exposure time. Tests with cosmic rays and muon beams have shown performances as expected.

The T2 tracking chambers are based on the gas electron multiplier (GEM) technology, invented by Fabio Sauli and Leszek Ropelewski at CERN, which combines a good spatial resolution with a high rate capability and a good resistance to radiation (*CERN Courier* June 2006 p37). In each T2 arm, 20 semi-circular GEM planes, with overlapping regions, are interleaved on both sides of the beam vacuum chamber to form 10 detector planes with full azimuthal coverage. In GEM detectors, in contrast to CSCs, the signal is collected on thin polyimide foils covered by a thin layer of copper on both sides. These foils, densely pierced and contained between two electrodes, are able to achieve high amplification and performance. GEM technology was chosen for T2 for the radiation hardness of the chambers and the flexibility of the read-out geometry. The read-out plane in the T2 chambers has been designed with strips that give a good resolution on the pseudo-rapidity co-ordinate, while pads give the phi co-ordinate for tracking and trigger purposes. Assembled "quarters" were tested with cosmic rays before the installation at IP5 and precommisioning tests have shown a good efficiency and resolution, matching the expected values (figure 5).

The read-out of all TOTEM sub-systems is based on the custom-developed digital Very Forward ATLAS–TOTEM (VFAT) chip, which also contains trigger capability. The data acquisition (DAQ) system is designed to be compatible with the CMS DAQ to make common data-taking possible at a later stage.

The collaboration has recently completed the installation of the Roman Pot stations at 220 m and the subdetector T2. T1 is going to be installed in autumn. In the future two more Roman Pot stations will be put in place at 147 m. The first measurements of the LHC luminosity and individual cross-sections will be performed by TOTEM as soon as the LHC collider becomes operational. The collaboration is looking forward to having adequate data to carry out their first new physics analyses and to having results to announce in 2010.

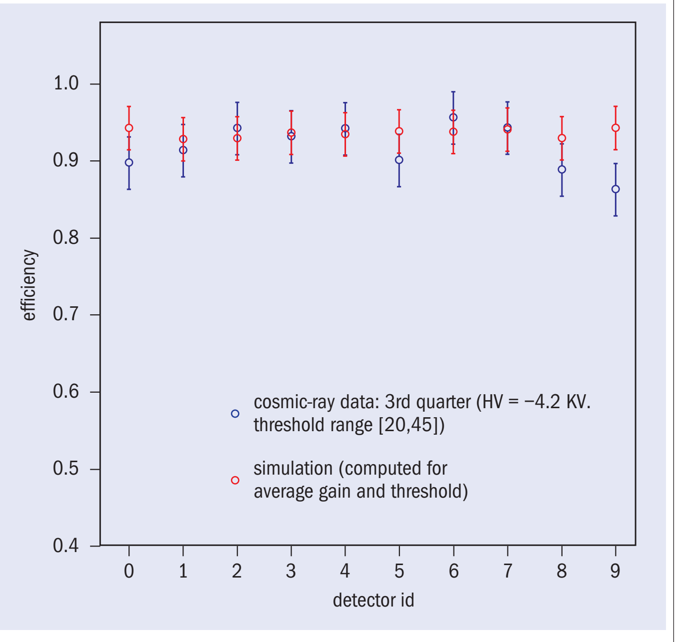


Fig. 5. The expected efficiency of each plane of a T2 quarter (blue triangles) compared to the simulated efficiency (red squares). The high voltage was set to a nominal gain of 4.2 kV.

● The TOTEM Collaboration has about 100 members from 10 institutions in seven countries. Karsten Eggert from CERN is the spokesperson; Angelo Scribano, from the University of Siena and INFN Pisa, is the chair of the Collaboration Board; and Ernst Rademacher from CERN is the technical co-ordinator.

Further reading

The TOTEM Collaboration, G Anelli *et al.*, 2008 *JINST* **3** S08007.

Résumé

Une petite expérience au grand potentiel

Alors que la plupart des expériences du LHC sont de grande échelle, les sous-détecteurs de TOTEM (TOTal cross section, Elastic scattering and diffraction dissociation Measurement – Mesure de la section efficace totale, de la diffusion élastique et de la dissociation diffractive), mesurent moins de 3 m, bien qu'ils se répartissent sur plus de 440 m. Cependant, malgré ses dimensions réduites, ce détecteur pourrait permettre des observations inédites. Outre la mesure précise de la section efficace d'interaction proton–proton, le programme de physique de TOTEM sera essentiellement consacré à une étude approfondie de la structure du proton se basant sur une analyse détaillée des phénomènes de diffraction, en partie réalisée en coopération avec l'expérience CMS.

Beatrice Bressan *and* **Virginia Greco**, *CERN, for the TOTEM Collaboration.*

Steven Weinberg: master bu

During his recent visit to CERN, Nobel laureate **Steven Weinberg** took time to talk to

It was no surprise that the audience arrived early in CERN's Globe of Science and Innovation for the colloquium on 7 July. Steven Weinberg is well known for his work on the Standard Model of particle physics and for his skill in writing carefully crafted books about particle physics and cosmology. His life in physics, like that of CERN, has spanned more than 50 years of discoveries and breakthroughs. In 1979 he received the Nobel Prize in Physics together with Sheldon Glashow and Abdus Salam, for "contributions to the theory of the unified weak and electromagnetic interaction between elementary particles, including inter alia the prediction of the weak neutral current". The latter had already been discovered at CERN by the Gargamelle collaboration in 1973 (p25). A decade later, in 1984, the UA1 and UA2 experiments at CERN were to discover the intermediate bosons, W and Z, with the masses predicted by the electroweak theory.

Weinberg first visited Europe after graduating from Cornell University, just as the provisional CERN became the fully fledged European Organization for Nuclear Research in 1954. Following advice from Dick Dalitz on where a young theorist should go for a study year in Europe, he joined the Institute of Theoretical Physics in Copenhagen, which at the time was home to CERN's nascent theory group. He returned to Europe for a second year in 1961, this time at Imperial College, London, and in July 1962 he visited CERN's Meyrin site for the first time, to attend the 11th "Rochester" Conference on high-energy physics (*CERN Courier* July/August 2005 p11). It was, he recalls, the beginning of an extraordinarily exciting period that extended until the mid-1980s. "There was a wonderful interplay between theory and experiment, with current algebra, electroweak theory and then QCD – and the brilliant experiments at CERN." To the discoveries of neutral currents and the W and Z, he adds the success of the Large Electron–Positron collider in showing how many types of quarks and lepton there are. By the end of the 1980s, "so many things became clear that had seemed murky", he explains, adding that at last "you could give a rationally organized course in particle physics". The Standard Model of particle physics had arrived.

From particle physics to cosmology

Since then, he feels that the field of particle physics has not been so exciting. "The discovery of neutrino mass is the only new thing," he says, pointing out that even this is not so new because the first signs were already there in the late 1960s in the results from Ray Davis's solar-neutrino experiment. Instead, the past 20 years or so have been marked by what Weinberg acknowledges as "heroic efforts" to go beyond the Standard Model, for example with string theory. In his view, while these ideas are more mathematically profound than the Standard Model, they have little contact with observation. The problem facing particle physics is that "the Standard Model worked too well!".

Back in the 1960s, Weinberg threaded his way through the theoretical jungle, reaching his unified description of weak and electromagnetic interactions in terms of an exact but spontaneously broken symmetry in 1967. This is the work for which he received the Nobel prize in 1979 and for which he is known far and wide (Weinberg 1967). He tells its story with his characteristic eloquence in the acceptance speech he gave in Stockholm (Weinberg 1979). Less universally well known is his work on chiral dynamics and effective field theories, in which he takes pride because he developed a point of view that became widely accepted. It resulted from some 15 years of work that took him from current algebra to effective field theory, with around 20 significant published papers. Together these form "a coherent body of work that changed the way people look at things", Weinberg explains, and which has relevance to areas from low-energy hadron theories to superconductivity and gravitation. "I'm very proud of that," he adds.

Weinberg often writes papers because he is trying to learn something. "Therefore they're unimportant papers," he comments. By contrast the books for which he is well known in the physics community represent the final crystallization of what he taught himself in a subject over the years, for example in the masterful three volumes on *The Quantum Theory of Fields* (*CERN Courier* April 2000 p37) and

Weinberg speaks at CERN in 1979, the year of his Nobel prize, ...

With Peter Jenni, the former spokesperson of the ATLAS collaboration.

ilder of the Standard Model

o *CERN Courier* about the changing face of particle physics and his hopes for the LHC.

... and visits 30 years later for another colloquium and a tour of ATLAS.

CERN's director-general, Rolf Heuer (left), welcomes Weinberg to CERN.

most recently *Cosmology* (*CERN Courier* May 2009 p43). He says that he never sees the books as an end in themselves – it is a bonus if they are valuable to others and he will be pleased if they become classics. Non-physicists – and probably many aspiring physicists – are no doubt more familiar with his lucid writing for the general public, for example in *The First Three Minutes*, which became a classic in science writing in the 1970s. Aficionados will be looking forward to his next publication, *Lake Views: This World and the Universe* (Harvard University Press), a compilation of essays that he has written on a wide variety of topics, from cosmology to religion.

Towards asymptotic safety

In line with his own experience in the particle physics of the 1960s, Weinberg believes that aspiring physicists should choose fields that are "messy and confusing". Ten years ago he would have recommended students to go into cosmology. "It's still having a wonderful run," he says, "and it will continue to be exciting...but with the LHC, maybe it's time for particle physics again." His advice now would be to master both subjects – with the aid of his books, of course.

Weinberg's current work continues to reflect his interest in both particle physics and cosmology. One aspect that he is pursuing concerns cosmological applications of "asymptotic safety" – that is, the idea of a theory that is safe from having its couplings blow up asymptotically, rather akin to the requirement of renormalization. This is leading to an approach to general relativity at very high energies that he feels is starting to look promising; the goal is an asymptotically safe quantum field theory of gravity with no problems at infinite energy. He presented these ideas in his colloquium at CERN on "The quantum theory of fields: effective or fundamental". Beginning with a look at the fluctuating popularity of quantum field theory, he went on to pose the question: is quantum field theory fundamental or does it arise from some deeper theory, such as string theory? His recent work suggests that perhaps it is possible to have a quantum theory of gravity without strings. "I don't want to discourage string theorists," he says, "but maybe the world is what we've always known: the Standard Model and general relativity."

Looking forward to the restart of the LHC and to the physics results to come, Weinberg acknowledges that he expects it to reveal the Higgs boson. "I have a stake in that," he admits, referring to his 1967 paper on electroweak unification, which contained the first serious prediction of the essential scalar boson as a real particle. "The real hope is to restore the exciting environment of particle physics that we remember from the 1960s and 1970s," he says.

● For the video of Weinberg's colloquium at CERN, see http://cdsweb.cern.ch/record/1188567/.

Further reading

S Weinberg 1967 *Phys. Rev. Lett.* **19** 1264.

S Weinberg 1979 http://nobelprize.org/nobel_prizes/physics/laureates/1979/weinberg-lecture.pdf and *Nobel Lectures, Physics 1971–1980*, ed. Stig Lundqvist, World Scientific.

Résumé

Steven Weinberg : le maître d'œuvre du modèle standard

Steven Weinberg est célèbre pour son travail sur le modèle standard de la physique des particules et pour ses talents d'auteur dans les domaines de la physique et de la cosmologie. A l'image du CERN, il a été un témoin actif des découvertes et des progrès réalisés en physique depuis plus de 50 ans. Il a reçu en 1979 le Prix Nobel de physique conjointement avec Sheldon Glashow et Abdus Salam pour sa contribution à la théorie de l'interaction électrofaible. A l'occasion d'une récente visite au CERN, il a donné une conférence sur ses travaux les plus récents, et a également pris le temps d'accorder un entretien à CERN Courier *sur l'évolution de la physique des particules et les espoirs qu'il fonde dans le LHC.*

Christine Sutton, *CERN.*

Gargamelle: the tale of a giant discovery

The discovery of neutral currents in the Gargamelle bubble chamber at CERN has been honoured with many prizes to members of the collaboration, including most recently the EPS High Energy and Particle Physics Prize. The key results were published in September 1973 after an intense period of work that had begun nearly two years earlier.

On 3 September 1973 the Gargamelle collaboration published two papers in the same issue of *Physics Letters*, revealing the first evidence for weak neutral currents – weak interactions that involve no exchange of electric charge between the particles concerned. These were important observations in support of the theory for the unification of the electromagnetic and weak forces, for which Sheldon Glashow, Abdus Salam and Steven Weinberg were to receive the Nobel Prize in Physics in 1979. Their theory became a pillar of today's Standard Model of particles and their interactions, but in the early 1970s, it was not so clear that it was the correct approach and that the observation of neutral currents was a done deal.

The story of the discovery has been told in many places by many people, including in the pages of *CERN Courier*, notably by Don Perkins in the commemorative issue for Willibald Jentschke, who was CERN's director-general at the time of the discovery, and more recently in the issue that celebrated CERN's 50th anniversary, in an article by Dieter Haidt, another key member of the Gargamelle Collaboration (*CERN Courier* October 2004 p21).

The huge bubble chamber, named Gargamelle after the giantess created 400 years earlier in the imagination of François Rabelais, took its first pictures in December 1970 and a study of neutrino interactions soon started under the leadership of André Lagarrigue. The first main quest, triggered by recent hints from SLAC of nucleon structure in terms of "partons", was to search for evidence of the hard-scattering of muon-neutrinos (and antineutrinos) off nucleons in the 18 tonnes of liquid Freon inside Gargamelle. Charged-current (CC) events in which the neutrino transformed into a muon would be the key. So the collaboration, spread over seven institutes in six European countries, set to work on gathering photographs of neutrino and antineutrino interactions and analysing them for CC events to measure cross-sections and structure functions.

The priorities changed in March 1972, however, when the collaboration saw first hints that hadronic neutral currents might exist. It was then that they decided to make a two-prong attack in the search for neutral-current (NC) candidates. One line would be to seek out potential leptonic NC events, involving the interaction with an electron in the liquid; the other to find hadronic neutral currents in which the neutrino scattered from a hadron (proton or neutron). ▷

Fig. 1. The first example of the leptonic neutral current. An incoming muon-antineutrino knocks an electron forwards (towards the left), creating a characteristic electronic shower with electron–positron pairs.

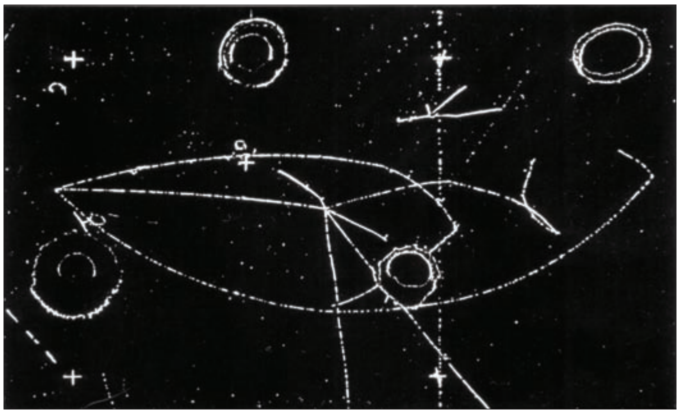


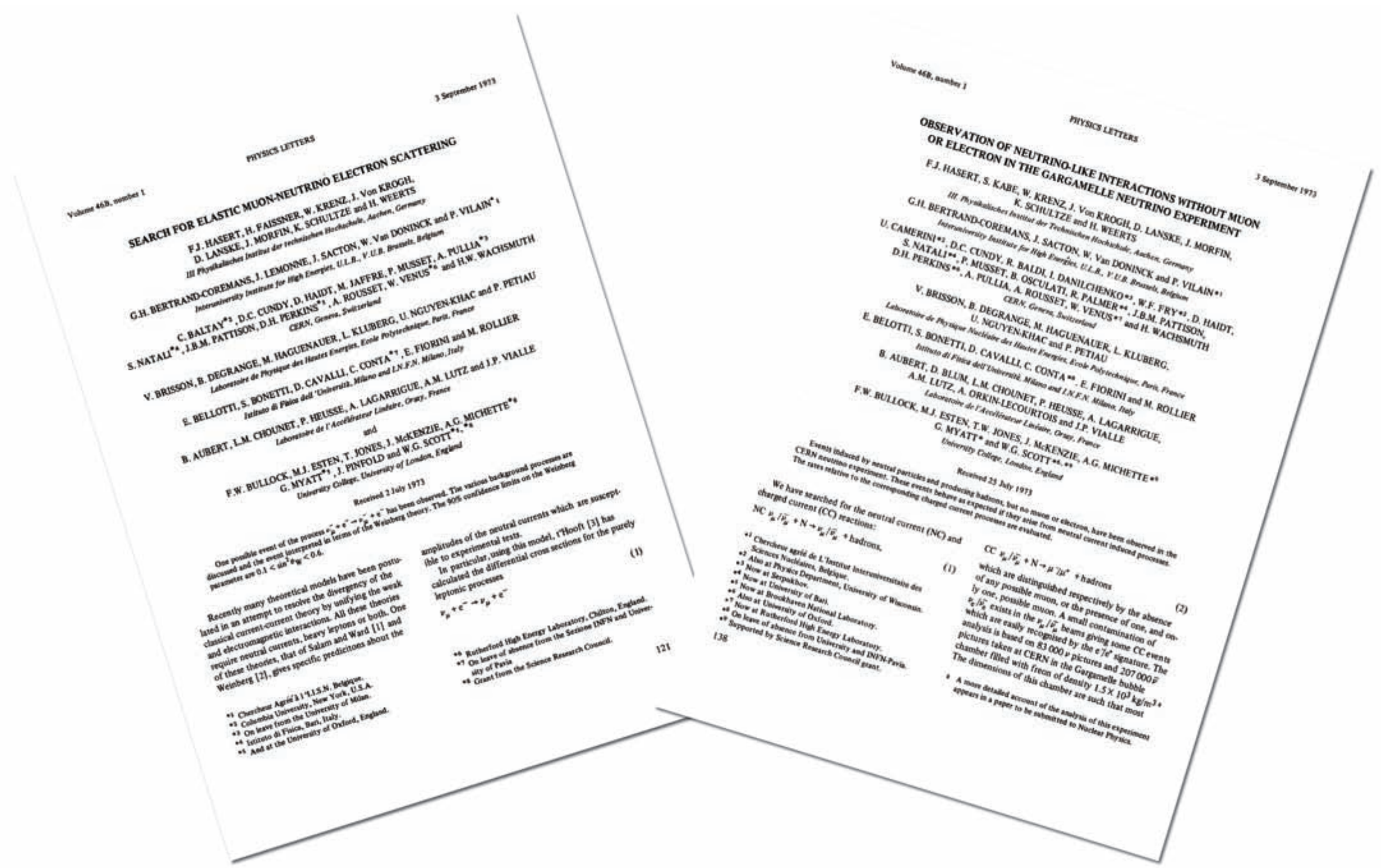
Fig. 2. A beautiful hadronic neutral current event, where the interaction of the neutrino coming from the left produces three secondary particles, all clearly identifiable as hadrons, as they interact with other nuclei in the liquid. There is no charged lepton (muon or electron).

In both cases the neutrino enters invisibly, as usual, interacts and then moves on, again invisibly. The signal would be a single electron for the leptonic case, while for hadronic neutral currents the event would contain only hadrons and no lepton (figures 1 and 2).

The leptonic NC channel was particularly interesting because previous neutrino experiments had shown that the background was very small and also because Martin Veltman and his student Gerard 't Hooft had recently demonstrated that electroweak theory was renormalizable. 't Hooft was able to calculate exactly the cross-sections for NC interactions involving only leptons, with the input of a single free parameter, $\sin^2\theta_W$, where θ_W is the Weinberg angle. Theorists at CERN – Mary K Gaillard, Jacques Prentki and Bruno Zumino – encouraged the Gargamelle Collaboration to hunt down both types of neutral current.

Such leptonic NC interactions would, however, be extremely rare. By contrast hadronic NC events would be more common but it was not yet clear how the theory worked for quarks. In this case the process was not easy to calculate, although Weinberg published some estimates during 1972. In addition there was the problem of a background coming from neutrons that are produced in CC interactions in the surrounding material and could imitate a neutral current signal.

Over the following year various teams carefully measured and analysed candidate events from film produced previously in several runs. The first example of a single-electron event was found in December 1972 by Franz-Josef Hasert, a postgraduate student at Aachen. Fortunately he realized that an event marked by a scanner as "muon plus gamma ray" was in fact something more interesting: the clear signature of an electronic NC interaction written in the tracks of an electron knocked into motion by the punch of the unseen projectile (figure 1, p25). This was a "gold-plated" event because it was found in the muon-antineutrino film in which any background is extremely small. Its discovery gave the collaboration a tremendous boost, strengthening the results that were beginning to roll in from the analyses of the hadronic NC events. However it was only one event, while by March 1973 there were as many as 166 hadronic NC candidates (102 neutrino events and 64 antineutrino events) although the question of the neutron



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SEARCH FOR ELASTIC MUON-NEUTRINO ELECTRON SCATTERING

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OBSERVATION OF NEUTRINO-LIKE INTERACTIONS WITHOUT MUON OR ELECTRON IN THE GARGAMELLE NEUTRINO EXPERIMENT

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The two papers from the 23 September 1973 issue of Physics Letters *together showed that Gargamelle had discovered weak neutral currents.*

background still hung over their interpretation.

Members of the team then began a final assault on the neutron background, which was finally conquered three months later, as Haidt and Perkins describe in their articles in *CERN Courier*. On 19 July 1973, Paul Musset presented the results of both hadronic and leptonic analyses in a seminar at CERN. The paper on the electron event had already been received by *Physics Letters* on 2 July (FJ Hasert *et al*. 1973a); the paper on the hadronic events followed on 23 July (FJ Hasert *et al*. 1973b). They were published together on 3 September.

It was an iconoclastic discovery, leaving many unconvinced. This was mainly because of the stringent limits on strangeness-changing neutral currents and the lack of understanding of the new electroweak theory. Gargamelle continued to increase the amount of data and by the summer of 1974, after the well known controversy described by Haidt and Perkins, several experiments in the US confirmed the discovery. From this time on the scientific community recognized that the Gargamelle Collaboration had discovered both leptonic and hadronic neutral currents.

Thirty-six years later the European Physical Society (EPS) has decided to award its 2009 High Energy and Particle Physics Prize to the Gargamelle Collaboration for the "Observation of weak neutral currents" (p31). However, it somewhat confounded the collaboration in citing only the authors of the hadronic neutral-current paper, even more so as the two author lists differed by only four physicists. Though the collaboration is honoured to receive the prize, its members feel that the award should not rewrite history. They feel, and rightly so, that the two papers were of equal importance in the discovery of neutral currents. Also, like many other physicists and the EPS prize committee, they feel that it was perhaps the greatest discovery of CERN. The prize was collected on behalf of the collaboration at the EPS HEP 2009 Conference in Krakow by Antonino Pullia and Jean-Pierre Vialle. Sometime in September the medal will be attached to the Gargamelle chamber, which now stands in CERN's grounds, and a reunion dinner for the collaboration will follow.

Further reading

FJ Hasert *et al*. 1973a *Phys. Lett.* **46** 121.
FJ Hasert *et al*. 1973b *Phys. Lett.* **46** 138.

Résumé

Gargamelle : histoire d'une découverte géante

La découverte des courants neutres dans la chambre à bulles Gargamelle, au CERN, au début des années 70, a valu de nombreux prix aux membres de la collaboration, y compris, tout récemment, le prix de physique des hautes énergies et physique des particules de la Socété européenne de physique. Après une période de travail intensif commencée près de deux ans plus tôt, les principaux résultats ont été publiés en septembre 1973, sous la forme de deux articles du même numéro de Physics Letters, l'un sur les courants neutres leptoniques et l'autre sur les courants neutres hadroniques. Le présent article se penche sur le contexte de ces deux publications, également importantes dans l'annonce de cette grande découverte réalisée au CERN.

Donald Cundy, *CERN/Torino IFSI, and* **Christine Sutton**, *CERN.*

LABORATORIES

Water in Homestake drops to the 4850 Level

After more than a year of continuous effort at the former Homestake gold mine in Lead, South Dakota, on 13 May pumps brought the water level down to below the historic 4850 ft level (1478 m underground). This event paves the way to re-open the site of the world's first solar-neutrino detector. Ray Davis began the original experiment in 1965; it ran for almost three decades and brought him a share of the 2002 Nobel Prize in Physics (*CERN Courier* December 2002 p15).

The State of South Dakota is investing $121 million to convert Homestake into a dedicated science and education centre – initially through the activities of the Sanford Underground Laboratory at Homestake, which plans a major experiment in the same cavern used by Davis. This will be followed by a proposed investment of $550 million for the national Deep Underground Science and Engineering Laboratory (DUSEL), currently being developed by the US National Science Foundation (NSF). DUSEL is set to become the largest, deepest underground laboratory in the world and will more than double the world's current underground-laboratory space (*CERN Courier* September 2007 p9).

When the Homestake Mining Company announced in September 2000 that the 125-year-old mine would shut down, scientists were quick to suggest converting it into a multidisciplinary underground laboratory for physics, geology, hydrology and biology. Progress was slow, however, and when the owners turned off the pumps in 2003 the water level gradually rose to 1380 m below ground.

It took a $10 million federal grant, $41 million from the South Dakota Legislature and a $70 million donation from local philanthropist, T Denny Sanford, to get the pumps started again in 2008, under the auspices of the South Dakota Science and Technology Authority (SDSTA). They will continue to pump until they reach Homestake's deepest level, 2500 m below ground. Several experiments are planned at various depths in the cosmic-ray-shielded, low-background-radiation environment.

The SDSTA has already begun to refurbish the "4850 Level" and clean out the Davis cavern for the Sanford laboratory's new dark-matter experiment, the Large Underground Xenon (LUX) detector. Other experiments planned for the 4850 Level, which will be one of DUSEL's main "campuses", include the search for neutrinoless double-beta decay – indicating that neutrinos are their own antiparticles – and a high-current, low-energy ion accelerator to study astrophysical nuclear reactions. Some of these experiments anticipate additional installations at the laboratory's 7400 Level (2256 m underground), which offers added shielding from backgrounds.

Planning for DUSEL is being led by the University of California, Berkeley, and the Lawrence Berkeley National Laboratory (LBNL), in collaboration with other institutions including the South Dakota School of Mines & Technology (SDMST) and Black Hills State University. Kevin Lesko, of Berkeley and LBNL, and Bill Roggenthen, of SDMST, are the project's joint principal investigators. "Regaining access to the 4850 Level is critical for DUSEL," says Lesko. "It allows the re-introduction of physics experiments into Homestake – the birthplace of neutrino astrophysics." Funding for the construction of DUSEL could come as early as 2012.

The biggest experiment intended for the 4850 Level is the Long Baseline Neutrino Experiment proposed by the US Department of Energy. For this the NSF plans to excavate one or more vast cavities, each holding 100 000 tonnes of ultrapure water and large enough to house nearby Mount Rushmore whole. Fermilab, 1300 km to the east of Homestake, would generate the neutrino beam aimed at the huge detectors, while the Brookhaven National Laboratory would build the instrumentation. In March this year the governor of South Dakota, Mike Rounds, and representatives of SDSTA, NSF, and DUSEL – including Lesko and Roggenthen – welcomed the laboratory directors, Pier Oddone of Fermilab and Sam Aronson of Brookhaven for a tour of the Sanford Laboratory.

Meanwhile, research has already begun at the Sanford Underground Laboratory. Roggenthen, a geologist, has installed a 3D seismic array with sensors at several levels. Preliminary experiments are also under way in biology and hydrology, and the mine is being surveyed for a gravity-wave detector. Members of the LUX collaboration will install their dark-matter experiment later this year.

South Dakota governor, Mike Rounds (right), and businessman/philanthropist, T Denny Sanford, shake hands at the plaque dedicating the Sanford Underground Science and Engineering Laboratory, in a ceremony at the 4850 Level of the former Homestake gold mine on 22 June.

The workshop area on the 4850 Level is now free of water. (Photos courtesy Bill Harlan, Sanford Underground Laboratory.)

FACILITIES

New X-ray, light-source and rare-isotope projects get underway in Europe and US

On 21 July federal research minister Annette Schavan, Hamburg's science senator Herlind Gundelach and Schleswig-Holstein's research minister Jörn Biel met at the DESY research centre in Hamburg to sign an agreement for participation in the European XFEL X-ray facility. With €90 million, the federal states Hamburg and Schleswig-Holstein will cover nearly 16% of Germany's contribution to the project (*CERN Courier* July/August 2007 p9).

The three politicians cemented this investment symbolically by laying the cornerstone for a test hall. In 2011 the new hall will be the site for intense functional tests of the facility's superconducting accelerator modules at –271°C. After the tests, the 12 m-long modules, each weighing 10 tonnes, will be transferred to the main tunnel of the X-ray facility to be assembled into a 1.7 km-long electron accelerator.

In the US, a month earlier, senators Charles Schumer and Kirsten Gillibrand, and congressman Tim Bishop joined representatives from the Brookhaven National Laboratory, the US Department of Energy (DOE), Battelle, and Stony Brook University on 15 June as they put shovels to the ground to commemorate the start of construction for the National Synchrotron Light Source II (NSLS-II) at Brookhaven. The project received $150 million earlier this year through the American Recovery and Re-investment Act to speed up the construction of the state-of-the-art research facility, which will create jobs and stimulate the local economy.

With construction now underway, the NSLS-II is scheduled to start operating in 2015. It will provide researchers with extremely bright beams of X-ray, ultraviolet and infrared light to study the ultrasmall structures and properties of a variety of materials and biological samples for studies in energy, environmental science and medicine among many other fields.

Michigan State University (MSU) announced the signing of a co-operative agreement with the DOE on 6 June concerning the Facility for Rare Isotope Beams (FRIB). The pact, an important milestone towards establishing the FRIB project, provides the instrument for the DOE Office of Science to provide financial assistance for MSU to design and establish the new facility.

The FRIB will be a DOE National User Facility within the department's Office of Nuclear Physics portfolio, located on the MSU campus. The centrepiece of the new facility will be a superconducting linear accelerator that will produce rare-isotope beams (*CERN Courier* July/August 2008 p15). While the FRIB is under construction, MSU will continue to operate the National Superconducting Cyclotron Laboratory as a National User Facility, funded by a co-operative agreement with the National Science Foundation.

Federal research minister Annette Schavan applies the mortar while Hamburg's science senator Herlind Gundelach holds a brick, in the company of Schleswig-Holstein's research minister Jörn Biel (left) and DESY's director, Helmut Dosch (behind). (Courtesy DESY.)

Rapper Alpinekat is helping put the science behind the FRIB (see main text) on the map with a new rap about nuclear physics commissioned by MSU. The physics alumnus from MSU made headlines last year with her LHC rap, which has already been seen more than 5 million times on YouTube. (Courtesy MSU.)

● For the "Rare-isotope rap", see www.youtube.com/watch?v=677ZmPEFIXE.

Gleaming shovels at Brookhaven. Left to right: Michael Holland, DOE; Shirley Strum Kenny, SUNY Stony Brook; Frank Crescenzo, DOE; Steve Dierker, BNL; Patricia Dehmer, DOE; Senator Kirsten Gillibrand; Senator Charles Schumer; Sam Aronson, BNL director; Ron Townsend, Battelle. (Courtesy BNL.)

COLLABORATION

John Adams Institute teams up with CERN

The John Adams Institute for Accelerator Science (JAI), a joint venture between the University of Oxford and Royal Holloway University of London, signed a collaboration agreement with CERN on 14 July. It will provide for co-operation between the JAI and CERN on a range of projects, from the LHC upgrade and the Compact Linear Collider Study to improved methods of treating cancer using protons and light ions.

The JAI is named after CERN's former director-general and renowned accelerator engineer, John Adams. Established in 2004, it provides a focal point for scientists and companies in the UK to develop leading concepts and technologies for major accelerator projects, as well as facilities and infrastructure for research and training in accelerator science and engineering.

The agreement was signed by CERN's director-general, Rolf Heuer, and the director of the JAI, Ken Peach. After the ceremony, visitors from the two universities toured the LHC accelerator, the ATLAS experiment and the respective control rooms.

CERN's director-general, Rolf Heuer (left), and Ken Peach, director of the JAI, seal the agreement.

AWARDS

Prize time in Krakow at EPS HEPP 2009

The European Physical Society High Energy and Particle Physics (EPS HEPP) prize for 2009 has been awarded to the Gargamelle Collaboration "for the observation of the weak neutral-current interaction". This is the first time that the prize has been given entirely to a collaboration. The prize committee, for this purpose, identified the Gargamelle Collaboration with the authors of the first paper on the observation of neutral-current interactions in the hadronic channel. Antonino Pullia and Jean-Pierre Vialle accepted the prize on behalf of the collaboration on 20 July, at the 2009 Europhysics Conference on High Energy Physics in Krakow. The medal is to be attached to the Gargamelle bubble chamber, which now stands in the grounds at CERN.

The discovery of neutral currents came through investigations of neutrino interactions in Gargamelle during the early 1970s (p25). Neutrinos also featured in the award of the EPS HEPP Young Physicist prize in Krakow, which went to Maurizio Pierini of CERN and Niki Saoulidou of Fermilab. Saoulidou is rewarded for her contribution to neutrino physics; in particular she has worked on the DONUT and MINOS neutrinos experiments at Fermilab. Pierini receives his share of the prize for his contributions to the study and analysis of B mesons on the BaBar experiment at SLAC. The 2009 Gribov medal for outstanding work by a young physicist in theoretical particle physics and/or field theory goes to Freddy Cachazo of the Perimeter Institute, Canada,

The EPS HEPP High Energy and Particle Physics prize goes to Gargamelle. (Courtesy Per Osland.)

"for his research with others that led to significant simplifications in the calculation of scattering amplitudes in both gauge theories and gravity ones".

The 2009 EPS HEPP Outreach prize goes to Herbi Dreiner and Michael Kortmann of Bonn University "for the idea and realization of a physics show performed by university students and especially for the realization and sustainment of a particle-physics show within this framework". Dreiner performed one of the experiments from the show after the award ceremony, but it is usually students from Bonn who develop and perform the show (*CERN Courier* October 2007 p54).

At the same conference, Mick Storr and Andrzej Siemko of CERN received the Medal of the Commission of Polish National Education in recognition of their outstanding contributions to the organization of the Programme for Polish Teachers.

N N Bogoliubov prize goes to Paton and Shirkov

The N N Bogoliubov Prize of the Joint Institute for Nuclear Research (JINR) for the years 2006–2008 is to be awarded to Boris Yevgenievich Paton, president of the National Academy of Sciences of Ukraine, and Dmitri Vasilievich Shirkov, academician of the Russian Academy of Sciences and honorary director of JINR's Bogoliubov Laboratory of Theoretical Physics.

Patron receives the prize for his outstanding contribution to science and the development of international co-operation, while Shirkov is honoured for his outstanding contribution to theoretical physics, in particular for the development of new methods in quantum-field theory. The prize was instituted in 1995 by the JINR Committee of Plenipotentiaries and is awarded once every three years to two scientists from different countries.

Winners Shirkov (left) and Paton. (Courtesy JINR.)

IOP honours contributions to particle physics, cosmology and outreach

The UK's Institute of Physics (IOP) has awarded Tejinder "Jim" Virdee of Imperial College London with the 2009 Chadwick medal for distinguished research in particle physics. Virdee, the current spokesperson for the CMS collaboration at CERN, receives the award "for his crucial role in the design and construction of CMS".

The Moseley medal (formerly the Boys medal) is intended to recognize physicists early in their careers. The 2009 award goes to Matthew Wing of University College London, which he receives "for his outstanding contributions to the experimental programme of the HERA collider at DESY ... In particular, his work has led to a deeper understanding of the strong force and will have important applications to the LHC and future colliders".

Particle physics also features prominently in the award of the 2009 Bragg medal to Becky Parker, of Simon Langton Grammar School, "for her work to energise generations of pupils to take up the study of physics".

Jim Virdee receives the 2009 Chadwick medal from the IOP for his work during the design and construction of the CMS detector at CERN.

Among many achievements, she founded the National Cosmic Ray Grid, which is integral to the CERN@school project to develop simple and robust detectors that are suitable for use in schools. She has also devised methods to use the CERN Medipix chip in the Langton Ultimate Cosmic-ray Intensity Detector.

The IOP has bestowed its international award, the 2009 Isaac Newton medal, on Alan Guth of the Massachusetts Institute of Technology. This award is made to any physicist, regardless of subject area, background or nationality, for outstanding contributions to physics. Guth receives it "for his invention of the inflationary-universe model, his recognition that inflation would solve major problems confronting then-standard cosmology and his calculation, with others, of the spectrum of density fluctuations that gave rise to structure in the universe".

British cosmologist John Barrow of Cambridge University is honoured with the Kelvin medal for outstanding contributions to the public understanding of physics. He receives the award "for the promotion and explanation of physics and astronomy to young people and the general public through many books, lectures, broadcasts and drama with special reference to their wider cultural and historical importance".

University of Technology Dresden bestows honorary degree on Dorfan

In a ceremony on 6 July, SLAC's former director Jonathan Dorfan was honoured by the University of Technology (TU) Dresden with the degree *Doctor rerum naturalium honoris causa*. The award recognizes his merits in planning, constructing and operating the electron–positron collider PEP-II and the experiment BaBar, which have led to the discovery of the asymmetry between matter and antimatter in the decays of b quarks.

The particle-physics group of TU Dresden was the first German group to join SLAC's project for a B-meson factory, followed later by university groups from Bochum, Rostock, Dortmund, Heidelberg, Karlsruhe, Berlin and Mainz. The ceremony included a welcome address by Michael Kobel on behalf of the Faculty of Science and the laudation by Klaus Schubert – both of whom are members of the BaBar Collaboration.

The rector of TU Dresden, Hermann Kokenge, hands the award document to Jonathan Dorfan (left). (Courtesy TU Dresden.)

NIM A awards go to young scientists

Stefan Rossegger of TU Graz and CERN and Yusuke Uchiyama of the International Center for Elementary Particle Physics, Tokyo University, received Nim A Young Scientist awards for the best presentations at the 11th Pisa Meeting on Advanced Detectors. Rossegger, who works on the ALICE experiment, presented a poster on "An analytical approach to space-charge distortions for time-projection chambers" (TPCs). His solution for the given TPC geometry is faster and more accurate than finite-element analysis.

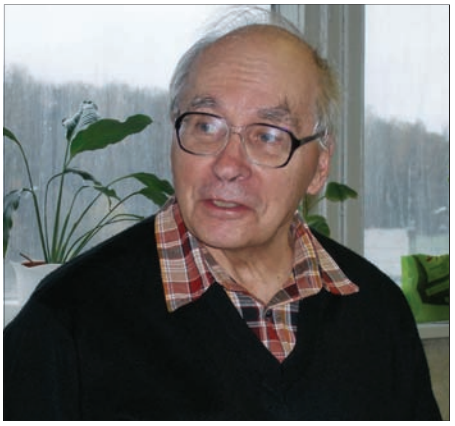
Uchiyama works on the MEG experiment at PSI, which is searching for lepton-flavour violation in muon decay. His poster was on "Gamma-ray reconstruction with liquid-xenon calorimeter for the MEG Experiment". It described reconstruction methods and techniques for background rejection.

CELEBRATIONS

Vladimir Lobashev reaches 75th birthday

Vladimir Lobashev, experimentalist in nuclear and particle physics, celebrated his 75th birthday on 29 July.

The early part of his scientific career, at St Petersburg Nuclear Physics Institute of the Russian Academy of Sciences, was dedicated mainly to fundamental neutron physics. His discoveries of several parity-violating effects in nuclear reactions with polarized thermal neutrons were instrumental in establishing the universality of weak interactions. He also designed novel methods of dealing with ultracold neutrons and obtained a limit on the neutron-dipole moment, which was the best in the world at the time.



Vladimir Lobashev. (Courtesy INR RAS.)

In 1972 he moved to the Institute for Nuclear Research of the Russian Academy of Sciences, Troitsk, where he played a major role in designing the complex of intense beams of the Moscow Meson Factory. Lobashev is perhaps the best known for his experiment, Troitsk-NM, on the direct search for the mass of the electron–neutrino in tritium beta-decay, which together with the Mainz experiment produced the best limit on the neutrino mass. A co-inventor of the idea of the method used, he still leads the Troitsk-NM experimental team. The same idea is now being realized in the Karlsruhe Tritium Neutrino Experiment (KATRIN).

Cyclotron centre bids adieu to Bikash Sinha

Kolkata's Variable Energy Cyclotron Centre (VECC) celebrated its foundation on 16 June – 32 years to the day since the first beam from the room-temperature machine was extracted in June 1977. The occasion was made more special as members of staff, both of the cyclotron centre and the adjoining Saha Institute of Nuclear Physics, bid adieu to Bikash Sinha in a fitting farewell. He has contributed significantly to these two institutions over the years. Sinha, who was director of the Saha Institute for 17 years and director of the VECC for the past 25 years, retired from his post at the end of June.

Sinha completes a remarkable quarter century, particularly with the recent sighting of the internal beam of the superconducting cyclotron and, more significantly, the collaboration with CERN at the SPS and now at LHC, as well as with Brookhaven National Laboratory. The success of the Photon Multiplicity Detector (PMD) at the SPS, at RHIC at Brookhaven and in the ALICE experiment at the LHC, has made the PMD and the dimuon spectrometer significant landmarks of Indo–CERN collaboration.

A special workshop, "25 years with professor Bikash Sinha", was organized to commemorate this unique occasion. The meeting consisted of talks on topics that have been the focus of his interest, covering a broad area, including: the quark–gluon plasma, nuclear physics, the anomalous helium abundance from thermal springs, cyclotrons (especially superconducting cyclotrons), the radioactive ion-beam project and radiation medicine.

Left to right: Rakesh K Bhandari, executive director of VECC; Bikash Sinha; Gopal Krishna Gandhi, governor of West Bengal; and Anil Kakodkar, chairman of India's Atomic Energy Commission.

During the workshop, the governor of the State of West Bengal, Gopal Krishna Gandhi (a grandson of Mahatma Gandhi) delivered a fascinating lecture on climate change. In the fourth Raja Ramanna memorial lecture at the cyclotron centre Anil Kakodkar, chairman of India's Atomic Energy Commission, outlined the need of the appropriate technology for a better tomorrow. Jürgen Schukraft of CERN, Hans Gutbrod of GSI and Tim Hallman of Brookhaven were present alongside an array of distinguished Indian scientists. Rakesh Bhandari, executive director of VECC and project director of the Superconducting Cyclotron, welcomed the guests and staff.

Rakesh K Bhandari and Bikash Sinha (back row fourth and fifth from left) in front of the VECC Superconducting Cyclotron, Kolkata. (Photos courtesy VECC.)

VISITS

The Cypriot minister of education and culture, **Andreas Demetriou** (right), was welcomed to CERN by the director-general, **Rolf Heuer**, on 11 June. During his visit, Demetriou learnt about the LHC Computing Grid project and applications of CERN's technology in the life sciences and medicine, as well as opportunities in education and training.

The presidents of Argentina, Mozambique and Poland visited CERN on 15 June while in Geneva for the International Labour Organization's summit on the Global Jobs Pact, held on 15–17 June. **Cristina Fernández**, President of Argentina (right) toured the ATLAS experiment and also visited the ATLAS control room, as well as meeting Argentine staff at CERN. Mozambique's president, **Armando Guebuza** (below, right), visited the CMS experiment together with CERN's co-ordinator for external relations, **Felicitas Pauss** (centre) and CMS spokesperson, Jim Virdee. Polish president Lech Kaczyński and First Lady **Maria Kaczyńska** (bottom right) also visited the CMS experiment and met Polish CERN staff.

PUBLISHING

EPL offers Open Access for high-energy physics papers

EPL, the letters journal of the European Physical Society (EPS), is now offering Open Access publication free of charge for papers from nuclear and particle physics. For some time, *EPL* (formerly *Europhysics Letters*), has offered Open Access to individual articles in its online edition (www.epljournal.org) against a fee charged to the authors. This fee is now being waived for papers from PACS groups 10 (high-energy physics) and 20 (nuclear physics).

This offer is a transitional measure in anticipation of when EPL joins the Sponsoring Consortium for Open Access to all Particle Physics Publications (SCOAP^3) and to express the support of the EPS for the SCOAP^3 initiative, launched by CERN in 2007. In addition, to broaden the expertise of the EPL Editorial Board in nuclear physics, relativistic heavy-ion physics and particle physics, during the past year four representatives of these fields have joined as co-editors. They are Peter Jacobs (Berkeley), Rüdiger Voss (CERN), Dieter Zeppenfeld (Karlsruhe) and Vladimir Zelevinsky (Michigan).

● For more information about the SCOAP^3 initiative, see www.scoap3.org.

MEETING

The **6th Vienna Central European Seminar on Particle Physics and Quantum Field Theory** is to be held in Vienna on 27–29 November. The title this year is "Effective Field Theories" and topics include chiral perturbation theory, soft collinear-effective theory, non-relativistic QCD and hadronic atoms, as well as effective field-theory methods in electroweak symmetry breaking. For more information, see www.univie.ac.at/vienna.seminar/2009/index.html.

NEW PRODUCTS

Aitech Defense Systems Inc now offers the S950-02, an enhanced, 1 GHz version of its S950-3U CompactPCI radiation-tolerant, single-board computer. Designed for space applications, the computer provides a low single-event upset rate, incorporating 128 MB of triple-redundant SDRAM to protect on-board memory from radiation. For more information, see www.rugged.com/s950.htm.

Bull has launched bullx, an environmentally friendly, ultradense and ultrahigh-performance family of supercomputers. Built around high-density blade servers, the range offers scalability and low power consumption and is designed to deliver from several teraflops to petaflops. For further information, see www.bull.com/extremecomputing.

Thermo Fisher Scientific Inc has introduced Integration Manager, a flexible and powerful data-transformation tool for automated data acquisition and distribution. Integration Manager can collect and store data from a range of instruments and deliver data in the formats appropriate for various recipients. For more information, call +1 866 463 6522 or see www.thermo.com/informatics.

CORRECTION

The obituary for James Allaby (*CERN Courier* July/August 2009 p50) contained an unfortunate error. The name of his son is Mark, as several readers have noted. Many apologies to all concerned.

RECRUITMENT

For advertising enquiries, contact *CERN Courier* recruitment/classified, IOP Publishing, Dirac House, Temple Back, Bristol BS1 6BE, UK.
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Information on the Institute can be found under http://www.mpp.mpg.de. Further information may be obtained from Prof. Wolfgang Hollik (hollik@mpp.mpg.de). Applicants should submit an application letter, a statement of research interests, a curriculum vitae, a list of publications, and arrange for three letters of support to arrive no later than September 30, 2009 at

Max-Planck-Institut für Physik
(Werner-Heisenberg-Institut)
c/o Ms. R. Jurgeleit
Föhringer Ring 6, D-80805 München
Germany

MAX-PLANCK-GESELLSCHAFT

Chamberlain Fellowship
Lawrence Berkeley National Laboratory

The Lawrence Berkeley National Laboratory's Physics Division invites outstanding recent Ph.D. recipients to apply for the Owen Chamberlain Fellowship in experimental particle physics and cosmology. Students who expect to receive their Ph.D. degree by the spring of 2010 are also invited to apply.

The Chamberlain Fellow is appointed for three years, with a possible two year extension. The Chamberlain Fellow is given time to review the Division's research program, and participate in any aspect of it, subject to funding limitations. He/she may also pursue new initiatives within experimental particle physics or cosmology subject to approval by the division director. In addition to salary, the Chamberlain Fellow receives a $5,000 annual research supplement.

Apply online at: **http://jobs.lbl.gov/LBNLCareers/details.asp?jid=23352&p=1** and follow the on-line instructions to complete the application process. In addition you must arrange to have at least three letters of reference and copies of your resume or CV, statement of research interests and publication list sent via email to: **Chamberlain-Fellow2009@lbl.gov** by October 17, 2009.

For information on the LBNL Physics Division's research program, please consult: **http://www-physics.lbl.gov**.

Berkeley Lab is an affirmative action/equal opportunity employer committed to the development of a diverse workforce.

BERKELEY LAB

The Enrico Fermi Institute – The University of Chicago

Tenure-track faculty appointment in Theoretical High Energy Physics

The Physics Department and the Enrico Fermi Institute at the University of Chicago invite applications for a tenure-track faculty appointment in Theoretical High Energy Physics. We are encouraging applications from candidates with recognized accomplishments in areas such as: physics of the standard model and beyond; collider physics; and particle cosmology. The successful candidate must have a doctoral degree in physics or a related field, and is expected to establish an independent research program while effectively contributing to the Department's undergraduate and graduate teaching programs. The appointment is expected to be at the Assistant Professor level. Appointment at the level of Associate Professor or Full Professor is possible for exceptionally well qualified candidates.

Applicants must apply online at The University of Chicago academic jobs website https://academiccareers.uchicago.edu. Applicants must upload a curriculum vitae, a list of publications and a brief research statement. Applicants must also arrange for three recommendation letters to be uploaded electronically in pdf format (each up to 10 MB) to http://enricofermi.uchicago.edu/phenom. The letters should be addressed to: **Prof. Simon Swordy, Director, Enrico Fermi Institute, The University of Chicago, Chicago, IL 60637**. Enquiries should be addressed to Ms. Sandy Heinz at ccsheinz@uchicago.edu

Review of applications will start in the fall, 2009, and will continue until the position is filled. To ensure full consideration, all application materials (including recommendation letters) should be received no later than November 1, 2009.

The University of Chicago is an equal opportunity, affirmative action employer.

POST-DOCTORAL FELLOWSHIPS FOR NON ITALIAN CITIZENS IN THE FOLLOWING RESEARCH AREAS

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Fellowships are intended for young post-graduates who are under 35 years of age by **November 15, 2009.**

Each fellowship, initially, is granted for one year and then, may be extended for a second year.

The annual gross salary is EURO 28.000,00.

Round trip travel expenses from home country to the INFN Section or Laboratory will be reimbursed, also lunch tickets will be provided for working days.

Candidates should choose at least two of the following INFN sites, indicating their order of preference.

- INFN Laboratories: Laboratori Nazionali di Frascati (Roma), Laboratori Nazionali del Gran Sasso (L'Aquila), Laboratori Nazionali di Legnaro (Padova), Laboratori Nazionali del Sud (Catania);

- INFN Sections in the universities of: Bari, Bologna, Cagliari, Catania, Ferrara, Firenze, Genova, Lecce, Milano, Milano Bicocca, Napoli, Padova, Pavia, Perugia, Pisa, Roma La Sapienza, Roma Tor Vergata, Roma Tre, Torino, Trieste.

The research programs, must be focused on the research fields of the Section or Laboratory selected (http://www.infn.it).

Applications, in electronic form, must be sent to INFN no later than **November 15, 2009.**

To register, candidates must use the website http://www.ac.infn.it/personale/fellowships/

The application form requires:
- statement of research interests;
- curriculum vitae;
- three reference letters (specifying name, surname and e-mail of each referee).

Theoretical fellowships must start from September to December 2010. Requests for starting earlier accepted.

Experimental fellowships must start no later than April 2010. Requests to posticipate accepted.

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- Application including a resume and the usual documents (curriculum vitae, list of publications and copies of university degree)
- Three letters of reference shall be arranged to be sent to the DESY Human Resources Department

DESY-Fellowships are awarded for a duration of 2 years with the possibility of prolongation by one additional year.

DESY operates flexible work schemes. Handicapped persons will be given preference to other equally qualified applicants. DESY is an equal opportunity, affirmative action employer and encourages applications from women. There is an English-speaking Kindergarten on the DESY site.

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Human Resources Department | Code: 87/2009
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Phone: +49 40 8998-3392 | E-mail: personal.abteilung@desy.de
Deadline for applications: 30 September 2009
www.desy.de

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HELMHOLTZ | GEMEINSCHAFT

ATLAS post-doctoral research position
at the Niels Bohr Institute, Copenhagen University

The Experimental High Energy Particle Physics group at Niels Bohr Institute, Copenhagen University (http://hep.nbi.dk/wiki) invites applications for a post-doctoral research position in the ATLAS experiment, starting November 1st 2009.

The successful applicant will participate in the exciting task of analyzing the first data from the LHC at CERN. The post-doc position is for two years, with possibility of extension. The annual pensionable and taxable salary is approx. 500.000 DKK.

The successful applicant must have completed a PhD degree in particle physics and be interested in joining the tau physics activities in our group and, at wish, teaching and supervision of students.

Applications (details of which can be found on our listing at http://cerncourier.com/cws/job/J000004298) should be sent by e-mail only to Dr. Stefania Xella, xella@nbi.dk, until September 21, 2009.

BOOKSHELF

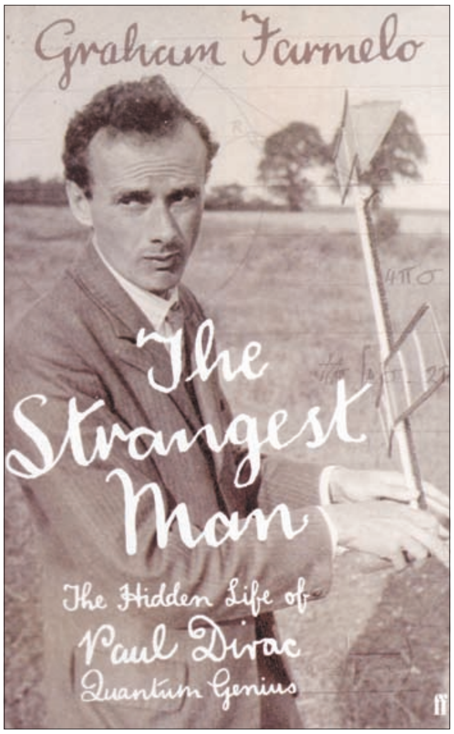
The Strangest Man: The Hidden Life of Paul Dirac, Quantum Genius by Graham Farmelo, Faber. Hardback ISBN 9780571222780, £22.50.

On 13 November 1995 the president of the Royal Society, Sir Michael Atiyah, unveiled a plaque in the nave of Westminster Abbey in London commemorating the life of Paul Dirac. Speaking at the ceremony, Stephen Hawking summed up Dirac's life: "Dirac has done more than anyone this century, with the exception of Einstein, to advance physics and change our picture of the universe." The plaque depicted Dirac's equation in a compact relativistic form and the man himself would no doubt have appreciated its terse style. At the time of his passing in 1984 Dirac ranked among the greatest physicists of all time. With the publication of Graham Farmelo's book *The Strangest Man*, we have an account of Dirac's life that is a *tour de force*.

Dirac's Swiss father, Charles, taught French at the Merchant Venturers' Technical College in Bristol and married Florence Holten in 1899. They had three children, Beatrice, Reginald (who committed suicide in 1924) and Paul, who was born on 8 August 1902 – the same year that Einstein started work at the patent office in Bern and Planck initiated the quantum theory of matter and light. This was the start of the modern era in which classical physics was revolutionized by two great advances – special relativity and quantum mechanics.

Dirac's early years were overshadowed by his domineering father and a browbeaten, needy mother. "I never knew love nor affection when I was a child," Dirac once remarked. Certainly, his difficult childhood seems to have deeply influenced the development of his "strange" character. Farmelo also explores another explanation for Dirac's introversion, literality, rigid behaviour patterns and egocentricity: perhaps Dirac, like his father, was autistic. Nonetheless, in his thirties, Dirac met and married Manci Balázs, an extroverted and passionate woman – his "antiparticle". Farmelo's candid and sympathetic account of the couple's improbable life together makes compelling reading. Yet, according to Farmelo, Dirac only cried once in his life, and that was when Einstein died.

Dirac's seminal contribution to physics was the unification of Heisenberg and Schrödinger's quantum mechanics with



Einstein's special relativity, which allowed him to write down a relativistic equation for the electron – the famous Dirac equation. With it he revealed the concept of spin and predicted the existence of antiparticles, subsequently discovered in studies of cosmic rays. In 1933, aged 31, he shared the Nobel prize with Schrödinger.

Dirac was also the creator of quantum electrodynamics and one of the chief architects of quantum-field theory. For him, the beauty of mathematical reasoning and physical argument were instruments for discovery that, if used fearlessly, would lead to unexpected but valid conclusions. Perhaps the single contribution that best illustrates Dirac's courage is his work on the magnetic monopole, the existence of which would explain the quantization of electric charge. The monopole's story is still far from complete and more revelations could be forthcoming.

Farmelo succeeds brilliantly in unifying all of the shadowy and contradictory perspectives of Dirac's character with his life as a scientific genius, and creates a complete picture of the man who played a leading role in the growth of modern physics. The book reveals how Dirac, although aloof and unworldly, was deeply affected by the turbulent and troubled history of the 20th century.
James Pinfold, University of Alberta.

Lust am Forschen: Lebensweg und Begegnungen by Walter Thirring, Seifert Verlag. Hardback ISBN 9783902406583, €22.90.

This biography of a physicist not only covers his life but reflects many interesting aspects of European history during the 20th century. Walter Thirring grew up in the tumultuous 1930s when Austria was united with Germany and when his father – also a well known physicist – had to leave the university because of his opposition to the Nazis. During the war Thirring, aged only 16, was called to the air-defence troops as part of the last reserve (*Flakhelfer*). He describes in an objective but moving way the cruelties of war by including the experiences of his brother and the difficult time after the war with hunger and hard work. I was really moved when I read this historical part because it awoke many experiences of my own life; I wonder how much the current generation can learn from this terrible past experience.

Thirring studied at Innsbruck under difficult conditions and received his PhD in 1949 at Vienna. He later worked with Schrödinger at Dublin, with Heisenberg at Göttingen, with Einstein at Princeton and met many other founders of modern physics and interesting personalities, who he describes vividly in humorous anecdotes.

He devotes a large part of the book to his scientific work, much of which now carries his name, e.g. the Thirring model and the Lieb-Thirring inequality. Being a mathematical theorist, his topics are unavoidably abstract and although he goes to great pains in trying to explain his work to the non-scientist, it will not be easy going for the general reader. (The more difficult parts are relegated to special boxes, which can be skipped.) The most fascinating chapters are those where he describes the highs and lows in the mental struggle that a theorist has in converting a rough idea into an acceptable theory. The ultimate reward is the feeling of happiness to have discovered something that nobody knew before – this is "the pleasure of research".

After his stay in the US, Thirring returned to Europe in 1958 and finally to Vienna where he followed his father as professor of physics and director of the Institute for Theoretical Physics. He accepted this offer after long negotiations, having decided that physics had gone through a positive transition in Europe, thanks mainly to the foundation of

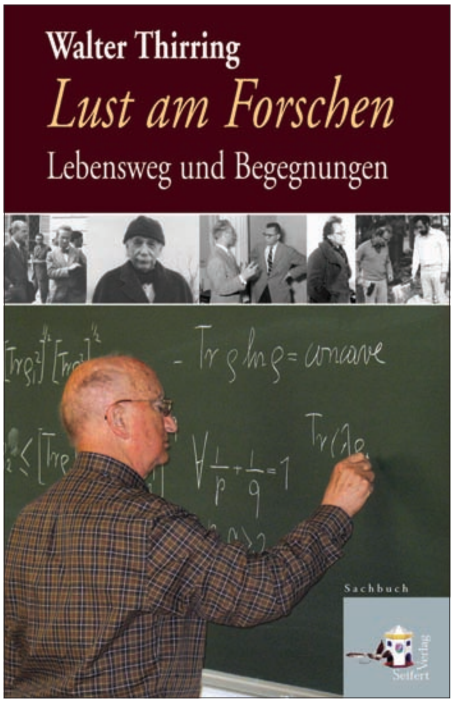
CERN. However, the working conditions at the institute were dreadful and Thirring had to become a manager to improve the situation. The building had to be renovated (including the provision of toilet paper), additional funds had to be found to employ scientists and the courses in theoretical physics had to be organized and updated. These beginnings resulted in a renowned institute.

Following in the Austrian tradition, Thirring in the 1970s started establishing contacts with colleagues in eastern Europe. This led to the foundation of the Erwin Schrödinger Institute in 1993, where scientists from eastern Europe are invited to meet and collaborate with colleagues from western Europe. More than 100 scientific visitors a year now benefit from this institution.

It is unavoidable that errors crept into the narrative, some of which I mention for historical accuracy. Thirring says that the Nobel prize was awarded to Wu, Yang and Lee for parity violation; while theorists Lee and Yang received it, regrettably C S Wu, who led the experiment that proved their idea correct, was not included. During Thirring's time in the CERN directorate in the early 1970s, the next big accelerator that was planned and approved was not LEP, but the SPS. He also gives the impression that Heisenberg was against the construction of the ISR, the first proton collider to be built; in discussions with me, Heisenberg explained that he was all in favour of this epoch-making facility, but against the more conventional SPS.

Thirring's second life was music. Had his elder brother not been killed in the war, Walter would probably have become a musician. He studied music with Anton Webern and also composed. The book comes with a CD with recordings of a few pieces of his chamber music, which sound astonishingly harmonious for modern music and pleasing to the ear.

For non-physicists the scientific elaborations might be difficult to digest, but this book provides a marvellous insight into the motivations, satisfaction and disappointments of being a scientist. Written in "Austrian



German", it has a poetic and eloquent style; a translation into other languages would probably spoil most of its charm.
Herwig Schopper, CERN.

Books received

Quantum Aspects of Life edited by Derek Abbott, Paul C W Davies and Arun K Pati, Imperial College Press. Hardback ISBN 9781848162532, £61 ($104). Paperback ISBN 9781848162679, £35 ($58).

Does quantum mechanics play a non-trivial role in biology? The burgeoning fields of nanotechnology, biotechnology, quantum technology and quantum information processing are now converging. The living cell is an information-replicating and processing system replete with naturally evolved nanomachines, which at some level require a quantum-mechanical description. As quantum engineering and nanotechnology meet, increasing use will be made of biological structures – or hybrids of biological and fabricated systems – for producing novel devices for information storage and processing and other tasks. An understanding of these systems at a quantum mechanical level will be indispensable. This volume sets out a timely quantum-biology agenda.

Lectures on Quantum Field Theory by Ashok Das, World Scientific. Hardback ISBN 9789812832856, £61 ($104). Paperback ISBN 9789812832863, £43 ($72).

These lectures for a two-semester course on quantum-field theory are presented in an informal and personal manner. They start with relativistic one-particle systems and go on to develop the basics of quantum field theory. Later lectures cover canonical quantization, covariant quantization of gauge theories, the Higgs phenomenon and the Standard Model of electroweak interactions. Regularization, (BPHZ) renormalization of field theories and gauge theories are all discussed in detail. This book will suit graduate students and researchers in theoretical physics.

Mesons and Baryons: Systematization and Methods of Analysis by A V Anisovich, V V Anisovich, M A Matveev, V A Nikonov, J Nyiri and A V Saransev, World Scientific. Hardback ISBN 9789812818256, £86 ($146).

This book is devoted to the investigation of strongly interacting hadrons — to a quark model operating with effective colour particles, constituent quarks, massive effective gluons and diquarks. The study of strong interactions based on effective constituent particles requires a solid ground of experimental data, which now exists. In this volume the authors rely on experiment and restore the effective Hamiltonian on the basis of QCD on the one hand and of the spectral integral method on the other. Baryon–baryon and antibaryon–baryon interactions are investigated with the purpose of unambiguous applications of the formulae to the interpretation of experimental data —the observation of new meson and baryon resonances.

'OK, I've finished my job now'

Emilio Picasso talks about the early days of the LEP project and the start-up 20 years ago.

On 14 July 1989 beam circulated for the first time in CERN's Large Electron–Positron (LEP) collider and a month later the experiments saw their first Z particles, created as the particles and antiparticles met at just the right energy. By 20 September the machine was ready for serious physics. It was a period of enormous satisfaction for the teams that had worked together to bring the project to fruition, and especially so for the project leader Emilio Picasso.

Picasso joined CERN as a physicist in 1964. Twenty years later he found himself immersed not just in accelerator design and construction but in project management and civil engineering, as the 27 km tunnel for LEP began to take shape. Appointed project leader in 1980 by the new director-general Herwig Schopper, he was well known in particular for his work on the g-2 experiments at CERN. These had involved a storage ring 40 m in circumference, but LEP was something on an entirely different scale.

This was precisely what made Picasso decide to accept the challenge of being project leader. "Everything that is new is attractive," he says, an outlook that has guided his career from cosmic-ray studies with balloons, through bubble chambers and g-2. So he set about learning how to run a major project, starting with advice from John Adams who had masterminded the construction of the SPS.

Moving mountains

His first task was to set up a management board with the best people available: Gérard Bachy on installation; Roy Billinge for the PS; Franco Bonaudi on experimental halls; Giorgio Brianti as head of accelerators; Bas de Raad for the SPS; Andrew Hutton on machine parameters; Henri Laporte for civil engineering; Günther Plass as deputy leader; Hans Peter Reinhard on vacuum; Lorenzo Resegotti for the magnets; and Wolfgang Snell for the RF. Schopper joined in regularly, mainly only to observe. "I was like the conductor of an orchestra," Picasso recalls. "It was a good team. We all knew each other well and respected each other."

The then director-general, Herwig Schopper (centre), with Henri Laporte (right) in charge of civil engineering, and LEP project leader Emilio Picasso inside a mock-up of the LEP tunnel in 1983.

Civil engineering was the main aspect of the project in which Picasso had no experience. One of the first important issues concerned the exact siting of the tunnel, which in the initial plans was to pass 12 km under the Jura mountains with some 1000 m of water-bearing limestone above. This allowed the tunnel to avoid the larger communities in France and Switzerland. Laporte advised that this would be a major challenge, so Picasso and Brianti went with him to meet tunnelling expert Giovanni Lombardi, whose advice was "to get out of the Jura or get out of the project".

One solution was to downsize, but to keep the ring as big as possible Picasso decided to look into moving it away from the mountains, towards the towns. "I had this idea", he remembers, "I cannot talk to the Jura, but I can talk to the people." So they talked to the people, setting up regular meetings with the local communes, and by moving the position of the tunnel to pass for only 3.3 km under the Jura, the team was able to reduce the greatest height above the ring to 200 m, and with it the maximum water pressure.

The final design for LEP was approved in December 1981 and, following a standard public enquiry in France, construction of the tunnel started in 1983. The mountains had not had their final say, however. The part under the Jura had to be blasted because the mixture of rock was not suitable for the tunnelling machines used elsewhere. For the first 2 km all went well and Schopper had commented to that effect, Picasso recalls, but "two days later, the mountain answered". Water burst into the tunnel, forming an underground river that took six months to eliminate. The smooth planning for construction and installation now became a complex juggling act.

A momentous start

By June 1987 part of the tunnel was complete and ready for installation, when Jacques Chirac, then French prime minister, visited CERN with Swiss president Pierre Aubert. Asked to arrange an event for the visitors, Picasso proposed that they position the first magnet. Not surprisingly, Chirac asked when the machine would be ready. At the time, there was no definite date, so Picasso decided there and then, answering "14 July 1989 – the 200th anniversary of the storming of the Bastille." Chirac responded: "Very good." But Picasso's colleagues were less impressed: "Is Emilio crazy? How will we be ready?" By July 1988, however, the first sector was completely installed and a test with beam by the LEP operations team led by Steve Myers proved that the machine was indeed well designed. A year later Picasso's prediction was confirmed, when the first beam went round the ring at 11.00 p.m. on 14 July 1989.

A month later there was great jubilation as the first collisions occurred. "For a long 10 minutes, Steve Myers and I didn't know whether the beams were colliding or not," Picasso recalls, "and then Aldo Michelini called: 'We have the first Z^0.' It was a beautiful moment. Steve had done an excellent job – and I thought, OK, I've finished my job now."

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724	8	4	2	100	40	14	0.5/4	Ready	NEW	NEW	COMING SOON
720	8	4	2	250	125	12	1.25/10	Ready	NEW	NEW	COMING SOON
721	8	-	-	500	250	8	2	Ready	-	-	-
731	8-4	-	2-1	500-1000	250/500	8	2-4	Ready	-	-	COMING SOON
740	64	32	-	65	30	12	0.19/1.5	Ready	NEW	NEW	-
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