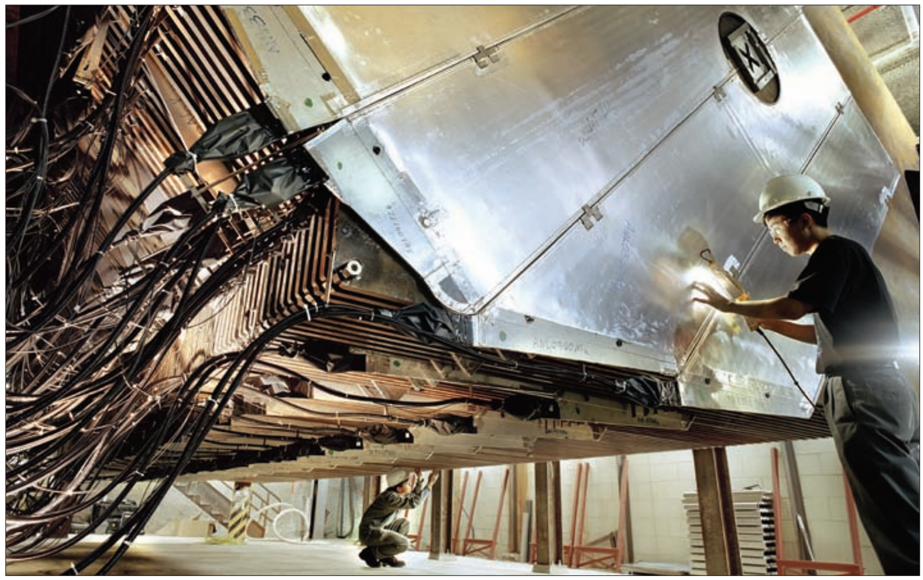
NEWS

NEUTRINOS

Muon neutrinos vanish on way to Minnesota

Muon neutrinos definitely disappear *en route* from Fermilab in Illinois to Soudan in Minnesota. This is the conclusion from the first results of the Main Injector Neutrino Oscillation Search (MINOS), presented at a seminar at Fermilab on 30 March, which showed that MINOS has observed the disappearance of a significant fraction of these neutrinos. The observation is consistent with the phenomenon of neutrino oscillation, in which neutrinos change from one kind to another, and corroborates earlier observations of muon-neutrino disappearance, made by the Super-Kamiokande and KEK-to-Kamioka (K2K) experiments in Japan.



The near detector of the MINOS neutrino experiment at Fermilab. (Courtesy Peter Ginter.)

The Fermilab side of the MINOS experiment comprises a beam-line in a 1220 m long tunnel pointing towards Soudan. The tunnel holds the carbon target and beam-focusing elements that generate neutrinos from protons accelerated by Fermilab's Main Injector accelerator. A neutrino detector, the MINOS "near detector" located 100 m underground on the Fermilab site, measures the composition and intensity of the neutrino beam as it leaves the laboratory. The Soudan side of the experiment features the 6000 tonne "far" detector about 700 m underground, which measures the properties of the neutrinos after their 725 km trip to northern Minnesota.

If neutrinos did not change as they travel away from Fermilab, the MINOS detector in Soudan should have recorded 177±11 muon neutrinos. Instead, the collaboration found only 92 muon-neutrino events – a clear observation of muon-neutrino disappearance. The deficit as a function of energy is consistent with the hypothesis of neutrino oscillations, which can occur only if different neutrino types have different masses. The MINOS observations yield a value of Δm^2, the square of the mass difference between two types of neutrinos, equal to 0.0031 ±0.0006 (statistical uncertainty) ±0.0001 (systematic uncertainty) eV^2.

In the oscillation scenario, muon neutrinos can transform into electron neutrinos or tau neutrinos, but alternative models – such as neutrino decay and extra dimensions – are not yet excluded. The MINOS collaboration will need to record much more data to test more precisely the exact nature of the disappearance process. Over the next few years, the experiment should collect about fifteen times more data, yielding more results with higher precision.

The MINOS neutrino experiment follows on from the K2K long-baseline neutrino experiment in Japan. From 1999–2001 and 2003–2004, K2K sent neutrinos created at an accelerator at the KEK laboratory to a detector in Kamioka, a distance of about 240 km. Compared with K2K, the distance in the MINOS experiment is three times longer, and both the intensity and the energy of the MINOS neutrino beam are higher. These advantages have enabled the MINOS experiment to observe in less than a year about three times as many neutrinos as K2K did in around four years. Later this year the CERN Neutrinos to Gran Sasso project will start delivering muon neutrinos to the Gran Sasso National Laboratory in Italy (*CERN Courier* March 2006 p6).

● The MINOS experiment includes about 150 scientists, engineers, technical specialists and students from 32 institutions in six countries, including Brazil, France, Greece, Russia, the UK and the US. The US Department of Energy provides the major share of the funding, with additional funding from the US National Science Foundation and the UK's Particle Physics and Astronomy Research Council. For more information on the experiment see www-numi.fnal.gov/.

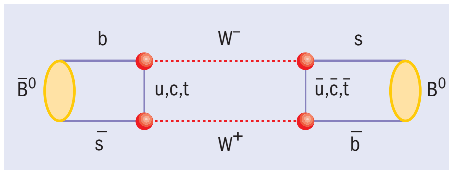
Sommaire

B PHYSICS

D0 provides precise results on B_s^0 oscillations

The D0 collaboration at Fermilab has published the first direct two-sided bound on the oscillation frequency of the B_s^0, the meson comprising a strange quark (s) and a bottom antiquark ($\bar{b}$). The result is consistent with what is expected from the Standard Model, within a 90% confidence level. The phenomenon in which a B_d^0 meson (with a down quark, d, instead of the strange quark) converts into its antiparticle $\bar{B}_d^0$ is well established, and its oscillation frequency Δm_d has been measured precisely (Heavy Flavour Averaging Group 2006). The value of the corresponding measure of the oscillation frequency of a B_s^0 meson into its antiparticle $\bar{B}_s^0$ – Δm_s – was until now much more poorly known.

The D0 collaboration is an international team of 700 physicists from 90 institutions and 20 countries working at Fermilab's Tevatron, which provides high-energy proton–antiproton collisions for two experiments, D0 and CDF. The data for the D0 result were taken from 1 fb^{-1} of total collision data, yielding more than a billion events (Abazov *et al.* 2006). The 90% confidence level means that the result does not qualify as a discovery, although it does provide a very strong indication. However, according to Rob Roser, co-spokesperson of CDF, within the next month or so the CDF collaboration should provide a result with greater precision.



A B_s mixing "box diagram" through which the B_s^0 is able to oscillate to the $\bar{B}_s^0$.

The D0 result already provides some interesting constraints on supersymmetry. "The D0 value of $17 < \Delta m_s < 21$ ps^{-1} limits the contributions to the oscillation process that could be made by supersymmetric particles," explains D0 co-spokesperson Terry Wyatt, from the University of Manchester. "The basic idea is that supersymmetric particles may be exchanged in the box diagrams that are responsible for B_s^0 mixing." Several theoretical models of supersymmetry predict a much faster oscillation of B_s^0, and the D0 result now disfavours these models.

Further reading

V M Abazov *et al.* D0 Collaboration 2006 http://arXiv.org/pdf/hep-ex/0603029.
Heavy Flavour Averaging Group 2006 http://arXiv.org/pdf/hep-ex/0603003.

FRASCATI

KLOE completes a successful run at the DAFNE collider

On 16 March, operation of the K Long Experiment (KLOE) detector ended after 23 months of continuous running at the DAFNE collider at Frascati. During this time the detector collected an integrated luminosity of 2.3 fb^{-1}, corresponding to the observation of some 6.2 billion ϕ decays. These data are in addition to the 450 pb^{-1} sample collected in shorter runs in 2000, 2001 and 2002.

DAFNE, the Frascati ϕ-factory, has been performing increasingly well, delivering 200 pb^{-1} a month by the end of 2005. The efforts by the DAFNE and KLOE teams to ensure good data-taking conditions have resulted in their collecting a large homogeneous data sample in terms of machine background, beam energy and detector performance. Smooth trigger and data-acquisition operations, and continuous running of detector calibration ensured high-quality data.

Members of the KLOE team with the detector.

KLOE has many unique aspects, in particular detector performance, the special environment at the ϕ factory, the unique possibility of kaon species tagging, an open trigger and complete recording of all data. These allow the physics investigated to include such varied topics as precision measurements of kaon properties, the study of scalar mesons and the measurement of the hadronic cross-section at less than 1 GeV, which is necessary for calculating the muon anomaly. The ϕ-meson decays are also a copious source of η and η' mesons.

With the analysis of 450 pb^{-1} of data, KLOE has reached accuracies of a fraction of 1% in the measurements of the kaon absolute branching ratios and lifetimes. The results have already removed a problem with the unitarity of the quark-mixing matrix that dates back more than 30 years. The new data set will lead to improvements of all published results, especially in the K_s sector, and to new measurements of the poorly known hadronic cross-section near threshold.

DAFNE will resume operation by the FINUDA collaboration in a few months to investigate hypernuclei. Plans to upgrade the collider to DAFNE2 and the detector to KLOE2 are being studied.

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.

LHC DETECTORS

CMS tracker sees first cosmic muons

The tracker for the CMS experiment at CERN passed an important milestone in March when the first cosmic-muon tracks were observed in one of the end caps. CMS is one of the two large multi-purpose detectors being constructed at the Large Hadron Collider. Its tracker system, comprising a barrel detector and two end caps, contains 25 000 silicon-microstrip sensors covering 210 m^2, with 9.6 million electronic readout channels. Its construction involves teams from the whole of Europe and the US, with the final assembly at CERN.

The two tracker end caps (TECs) feature silicon-strip modules mounted on wedge-shaped carbon-fibre support plates, or "petals". Up to 28 modules are arranged in radial rings on both sides of these plates; one eighth of an end cap is populated with 18 petals and is called a "sector".

One of the muon events recorded in the first sector of the TEC+, under test in Aachen. The display shows the individual silicon-strip modules in the 18 "petals" that make up the sector.

One of the TECs, TEC+, is being constructed at the RWTH (Rheinisch-Westfälische Technische Hochschule) Aachen and testing began earlier this year. A total of 400 silicon-strip modules are read out simultaneously, using close-to-final readout and power-supply components and data-acquisition software. The first sector has already been thoroughly tested, demonstrating a channel efficiency of less than 1% and common-mode noise of only 25% of the intrinsic noise.

To understand the behaviour of the TEC sector better, including the response to real particles, basic functionality testing was followed by a run with cosmic muons. Thousands of tracks have been recorded and will be used to study tracking performance and to exercise various track-alignment algorithms.

The next important step will be to test the first sector under CMS operating conditions, with the silicon modules working at a temperature of less than −10 °C. The remaining seven sectors will then be assembled and in autumn the TEC+ will be delivered to CERN.

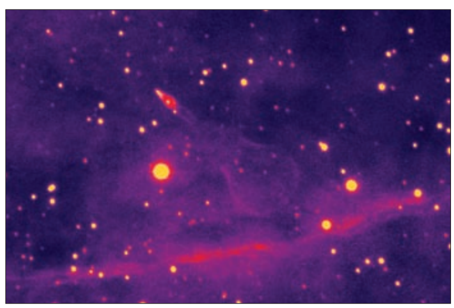
ASTROPARTICLES

Sterile neutrinos unravel astrophysics

Almost every current theoretical model of neutrino masses introduces sterile ("right-handed") fields, which mix with the ordinary ("left-handed") neutrinos. Ordinary neutrinos have no electrical charge and interact through the weak force, but there may also exist rogue sterile neutrinos that feel only gravity. Most models make these new particles very heavy, while also trying to explain the small masses of ordinary neutrinos. Now Peter Bierman of the Max Planck Institut for Radioastronomy, Bonn, and Alexander Kusenko of University of California, Los Angeles, have suggested that if some of the sterile neutrinos are relatively light, they could resolve several astrophysical puzzles. In particular, sterile neutrinos with kilo-electron-volt (keV) masses could account for dark matter, the origin of the rapid motion of observed pulsars and re-ionization of the universe (Bierman and Kusenko 2006).

These relatively light sterile neutrinos were the topic of a recent workshop, Sterile Neutrinos in Astrophysics and Cosmology, held in Crans Montana in March. The meeting looked not only at how keV sterile neutrinos can solve a variety of problems in astrophysics, but also at how their existence might be detected.

Dark-matter sterile neutrinos could decay into a lighter neutrino and an X-ray photon, and this seems to be the most promising path to discovery. The workshop brought together particle physicists and X-ray observers, who presented the current limits and discussed ways to search for dark-matter neutrino decays. One important feature of dark matter in the form of the sterile neutrinos is the smoothing of structures on small scales. This "warm" dark matter – in contrast with the "cold" and "hot" alternatives – would be indistinguishable from cold dark matter on large scales, but it would yield stellar structures with the smallest size relative to the dark-matter particle mass. Recent studies of dwarf spheroid satellite galaxies have reported seeing the minimal halo size, indicative of warm dark matter.



The Guitar Nebula is formed by the wake of a neutron star moving through the interstellar medium at 1600 km/s. If keV sterile neutrinos exist, they could explain this extraordinarily rapid motion. (Courtesy S Chatterjee and J M Cordes, Cornell University/Palomar Observatory.)

The same decays into X-ray photons happening in the early universe could have produced enough ionization to catalyse a rapid production of molecular hydrogen, which is the most important cooling agent for primordial gas. Enriched with molecular hydrogen, haloes of gas would cool and collapse, forming the first stars. These stars could have re-ionized the universe, in agreement with observations of the Wilkinson Microwave Anisotropy Probe (p12).

The role of sterile neutrinos in pulsars originates in supernova explosions, where sterile neutrinos with a mass of several keVs from the cooling nascent neutron star would be emitted preferentially in one direction, set by the star's magnetic field. Although the neutrinos would not interact with the magnetic field, they would scatter off fermions polarized along the magnetic field in the neutron star. The anisotropy of sterile-neutrino emission would be sufficient to give the neutron star a recoil velocity of hundreds of kilometres a second. This agrees with observations of pulsars – magnetized rotating neutron stars – all of which have very large velocities. The origin of these velocities is a long-standing puzzle, which would have a simple explanation if sterile neutrinos exist.

Further reading

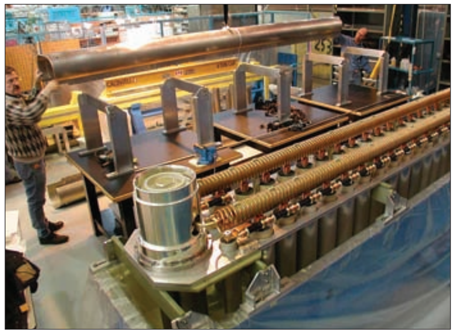
Peter L Bierman and Alexander Kusenko 2006 *Phys. Rev. Letts.* **96** 091301.

TRIUMF

Canadian modules take up position at LHC

As the many pieces of the Large Hadron Collider (LHC) and its experiments come together at CERN, Canada's contributions to the project are moving into their final positions. One of the hadronic end-cap calorimeters built at the Tri-University Meson Facility (TRIUMF) was recently installed in the ATLAS detector, and the first of the resistive twin-aperture quadrupoles for the "beam cleaning" regions in the LHC, designed at TRIUMF and built by Alstom Canada Inc, should be installed in the tunnel in June. However, the pulse-forming networks (PFNs) for the LHC injection kickers will soon become the first components from Canada to be completely installed.

The LHC will have fast-pulsed magnet systems – the kickers – to inject the two proton (or heavy-ion) beams into the main ring. Two pulsed systems are required, each comprising four magnets, four PFNs and four high-voltage thyratron-based switches. Each PFN consists of two 28 cell, 10 Ω lines connected in parallel at their ends. To kick the beam buckets from the Super Proton Synchrotron into the LHC ring, each system must produce a magnetic field pulse of 1.3 T.m strength, with a rise time of not more than 900 ns, an adjustable flattop duration up to 7.86 μs, and a fall time of not more than 3 μs. The total ripple in the field must be less than ±0.5%.



Gary Wait (left) and Michael Barnes complete the assembly of a PFN module at TRIUMF.

One of the PFN modules installed in the LHC.

The energy in a PFN is provided by a resonant-charging power supply (RCPS), which is used to reduce as much as possible the number of untriggered discharges of the thyratrons. The performance of the electrical circuit of the complete system, including a 66 kV RCPS and a 5 Ω PFN, was carefully simulated, and components were selected for the PFN on the basis of theoretical models in which a ripple of less than ±0.1% was attained.

As part of the Canadian contribution to the LHC, TRIUMF has built and tested in-house five RCPSs and nine PFNs. After shipment to CERN, the RCPSs and PFNs are thoroughly tested before insertion into the tunnel sections where injection into the LHC will occur. Installation began in May 2005, and the final systems should be installed this spring.

DESY

First results for the VUV-FEL radiation source

The first measuring period for external users at the vacuum ultraviolet free-electron laser (VUV-FEL), the new ultraviolet and X-ray radiation source at DESY, ended successfully on 27 February. Now the facility is gearing up for its second run in May.

The facility's centre-piece is the 300 m long FEL, which is the world's first – and until 2009, only – source of intense laser radiation at VUV and soft X-ray wavelengths. In January 2005, it generated its first laser pulses with a 32 nm wavelength, the shortest wavelength ever achieved with a FEL, and then started up for users in August. It is available for research groups from all over the world for experiments in areas such as cluster physics, solid-state physics, plasma research and biology. Four experimental stations are currently available, at which different instruments can be operated alternately.

Since the official start-up in August, a total of 14 research teams from 10 countries have carried out experiments ranging from generating and measuring plasmas to the first investigations of experimental methods for studying complex biomolecules, which will later be used at the European X-ray FEL (XFEL). As expected, the laser pulses of the VUV-FEL are shorter than 50 fs. This allows researchers to trace various processes on extremely short time scales by taking time-resolved "snapshots" of the reaction process. Investigating such time-resolved processes with radiation of short wavelengths is one of the most important new applications of this kind of X-ray laser.

The beams of DESY's new radiation source, the VUV-FEL, serve a range of experiments.

Before user experiments resume in May, the DESY team is carrying out machine studies to improve the stability of the facility, increase the energy of the laser pulses, and shorten the wavelength of the radiation to around 15 nm. At the same time, various studies are being done to prepare for the planned XFEL, which will be 3.4 km long and generate even shorter wavelengths, down to 0.085 nm, when it comes into operation in 2013. The VUV-FEL should produce its shortest wavelength of 6 nm in 2007, after an additional accelerator module is installed.