Neutrinos to Gran Sasso

In a year that the Nobel prize highlighted the puzzling nature of neutrinos, preparations continued on the beam line and experiments for the CNGS project – CERN Neutrinos to Gran Sasso – which is scheduled to start up in 2006.

In 2002, American chemist Ray Davis was awarded a share of the Nobel prize for physics for his pioneering detection of neutrinos from the Sun, which in turn led to the discovery during the 1970s that too few solar neutrinos seemed to be detected on Earth. Thirty years on, this mystery seems to be almost certainly solved, as in June 2002 the Sudbury Neutrino Observatory presented unambiguous evidence that neutrinos can 'oscillate' – that is, change from one type to another. To investigate this phenomenon further, over a completely different range of energies and distances, CERN is preparing to supply a neutrino beam to the Gran Sasso underground laboratory, 730 kilometres away in Italy, where the ICARUS and OPERA detectors, currently in preparation, will be installed.

There are three types of neutrino, each in a sense the neutral relative of three charged particles – the electron, the muon and the tau. The Sun emits electron-neutrinos, which appear to be changing to another type before they are detected here on Earth. The CNGS beam by contrast will consist of muon-neutrinos, at much high energies than the neutrinos emitted by the Sun.

Civil engineering for CNGS

The CNGS neutrinos will be produced at CERN when protons from the SPS strike a target to create pions and kaons. The muon-neutrinos produced in the decays of these particles will form the beam directed at the Gran Sasso laboratory. At CERN the preparations have involved the excavation of some three kilometres of new tunnels plus several caverns. This excavation work was completed in December 2002, when the connection was made between the access gallery to the CNGS hadron (pion and kaon) stop area and the tunnel for the TI8 transfer line. Concreting is under way, and the huge target cavern, which is 115 metres long by 6.5 metres wide and required 2000 metres cubed of concrete, has been completed. These civil engineering works are expected to finish in summer 2003. A key component of the CNGS beam will be the one-kilometre-long, 2.45-metre-diameter vacuum tube, in which the particle decays produce the neutrinos. The contract for its construction and installation was signed in December 2002, and installation, which will take 8 months, will begin in autumn 2003.

The curtain rises for OPERA

The OPERA experiment (Oscillation Project with Emulsion-tRacking Apparatus) aims to observe oscillations of the CNGS muon-neutrinos to tau-neutrinos. The detector, which is being built by an international collaboration of some 170 physicists, combines photographic emulsion and electronic detector techniques to pinpoint the location of neutrino interactions and to detect the particles emerging from them.

During 2002 the OPERA collaboration completed the design, test and optimization stage for the detector, which

>The last metres of the CNGS decay tunnel, where the 730-kilometre-long neutrino beam begins, were completed in March 2002.

is to comprise two 'supermodules' of target and tracker sections, each followed by a muon spectrometer. The target part will consist of bricks of lead and emulsion interleaved with tracker modules of scintillator strips to reveal where interactions have occurred within the lead–emulsion bricks. The high-resolution information from the emulsion will reveal the signatures characteristic of any short-lived tau particles produced by neutrinos that have changed to tau-neutrinos. The main purpose of the target tracker is to identify the brick where an interaction is likely to have occurred. Construction of the detector began towards the end of 2002, with the production of the first 17-metre by 7.5-metre modules for the target tracker.

Successful tests for ICARUS

A second experiment proposed to exploit the CNGS beam at Gran Sasso is ICARUS (Imaging Cosmic And Rare Underground Signals). This would be the largest stage in an ongoing programme that began more than 12 years ago to develop liquid-argon time projection chambers for astroparticle experiments. A series of smaller detectors has proved the principle, and now the ICARUS collaboration, from Italy, Switzerland, China, Poland, Spain and the US, plans to build a detector for the CNGS beam with a total mass of 3000 tonnes.

At present a 600-tonne version, ICARUS T600, is being constructed at the University of Pavia, as two modules of 300 tonnes each. The first module was completed in 2001 and tested in a 100-day run with cosmic rays. During 2002 the assembly of the inner detector of the second module was completed and the data collected during the cosmic-ray run have been analysed. This analysis has shown the successful tracking of charged particles with tracks up to 20 metres long. Together with other tests, this demonstrates that the scaling up from smaller prototypes has been successful. The aim next year will be to install the full T600 detector at Gran Sasso, and to continue with the design and construction of 'clones' that will enable the full mass of the T3000 version to be installed by 2006.