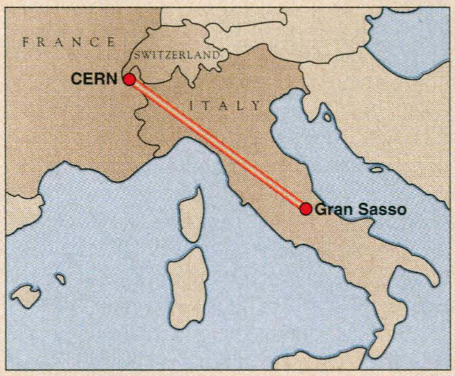
First Stop on the Neutrino Roadshow: CERN

In mid-April, CERN, Europe's particle physics lab in Geneva, will aim a beam of the elusive particles called neutrinos into two new detectors designed to spot one of the three types of neutrinos: the tau neutrino, the only member of the trio that has not yet been observed. The aim of the experiment, however, is not to prove that the tau neutrino exists—no one doubts that. Instead, the researchers hope to show that muon neutrinos can oscillate, or spontaneously transform, into tau neutrinos during their 1-kilometer flight from source to detectors.

The results of this experiment, the first concerted effort to look for neutrino oscillations, could bring the first breakthrough in the search for neutrino oscillations now being mounted at labs around the world (see main text). If the CERN detectors, known as CHORUS and NOMAD, do find a handful of taus amongst the flood of unchanged muon neutrinos, it will mean that the particles have mass, a result eagerly sought by many cosmologists and physicists. But even if this first experiment comes up empty, it will guide future experimenters by ruling out a neutrino mass in certain ranges. And it will provide an object lesson in the art of analyzing neutrino beams.



Cosmopolitan neutrinos. Route of a proposed CERN experiment.

To create its neutrino beam, CERN will use its 1970s-vintage Super Proton Synchrotron (SPS). A beam of protons will be diverted from the SPS and directed at a cluster of cigarette-sized beryllium rods. The impact creates pions (quarks paired with antiquarks), which fly down a 300-meter tunnel, giving them time to decay into a muon (a heavier counterpart of the electron) and a muon neutrino. At the end of the tunnel the muons as well as any remaining pions and protons slam into an iron block and stop dead, while the neutrinos continue on their way.

After travelling another 800 meters through the Earth, the neutrino beam will pass through the detectors, CHORUS and NOMAD. These two instruments go about spotting tau neutrinos in entirely different ways, which should provide a check on the results. CHORUS is essentially a giant camera containing 800 kilograms of silver bromide gel, much like black-and-white photographic film. The researchers will open the aperture to incoming neutrinos and wait for a year. Then they will remove some of the emulsion and examine it with a microscope fitted with a TV camera and steered by a computer that is attuned to the predicted signature of a tau neutrino colliding with a nucleus in the gel.

In contrast to CHORUS's simplicity, NOMAD aims to identify neutrinos by electronically recording the debris from their collisions. Showers of particles produced when neutrinos collide with matter in the detector will fly through drift chambers: gas-filled cavities in which particles create a trail of ionization, which electrodes arranged in the cavities pick up. The length and shape of the trails reveals the particles' identities, allowing investigators to infer which type of neutrino triggered the shower.

Even with two sophisticated detectors, the CERN researchers know their task will not be easy. Neutrino detectors are leaky nets, because the particles so rarely interact with matter. Of the 5×10^{16} neutrinos generated each year by the neutrino line, the two new detectors are likely to pick up only hundreds of thousands. All—or nearly all—will be muon neutrinos. If enough oscillations take place, the detectors might snare a few tens of tau neutrinos a year, says François Vannucci, head of the NOMAD team.

But even that tiny number may be an overestimate if the so-called mixing ratio (the proportion of neutrinos that oscillate from one type to another) is small. Or the neutrinos may be too light to oscillate at all during their short trip. Lighter neutrinos take longer to oscillate, so the distance between source and detector defines the lightest oscillating neutrino a detector can spot. The kilometer range of the CERN experiment means CHORUS and NOMAD will be sensitive only to neutrino masses of 1 electron volt or greater.

If this first experiment draws a blank, CERN's neutrino physicists will have to pin their hopes on a proposal to piggyback a longer-baseline experiment on the construction of the Large Hadron Collider (LHC), a massive new accelerator that is up for final approval this spring. The SPS ring will again act as pre-accelerator, and one of the proposed transfer lines between the two rings has a section that points almost directly at Italy's Gran Sasso underground laboratory, 732 kilometers away. There, physicists are planning to build a new detector called ICARUS, containing 15,000 tons of liquid argon. ICARUS is meant to record proton decay, but it could just as well detect neutrinos, such as ones beamed from CERN.

A proposal for future neutrino experiments at CERN notes that the transfer line would only have to be realigned slightly and its straight section extended for an extra kilometer to house the target, focusing magnets, and decay channel. "It would not cost much to dig the extra tunnel," says CERN physicist Jean-Pierre Revol. The same study also looked at a more challenging possibility: sending a beam through the earth to the Super Kamiokande detector in Japan, 8,752 kilometers away. That would re-quire superconducting magnets to bend the proton beam downwards by 43 degrees, and a tunnel dug 600 meters down into solid rock.

Vannucci, however, is betting that those more extreme measures will not be necessary to detect neutrino oscillations. "I'm a lucky person," he says, knowing he will need all the luck he can get.

–Daniel Clery