

Trans-Alps Neutrino Beam Gets CERN Go-Ahead

A longtime plan to shoot neutrinos from the European Laboratory for Particle Physics (CERN) near Geneva through the Alps to the Gran Sasso National Laboratory near Rome was approved by the CERN council on 17 December. Two huge detectors at the Italian lab are being designed to check whether neutrinos change flavor—from muon to tau—on their 730-km journey.

The evidence for flavor changes, or oscillation, is mounting—most compelling are the 1998 results with atmospheric neutrinos from Super Kamiokande in Japan (see *PHYSICS TODAY*, August 1998, page 17). Scheduled to start taking data in 2005, the Gran Sasso experiments—like projects already in the works in Japan and the US—are intended to extend those findings by exploiting the higher intensity of man-made neutrinos; at Gran Sasso, scientists hope to get the first-ever glimpse of the tau neutrino.

If neutrinos do oscillate, then theory says they must have mass. The mass would be much less than that of an electron, the next lightest particle, but taken together, the plentiful neutrinos could account for the large discrepancy between theoretical calculations and estimates of the mass of the universe.

Waiting for neutrinos

A neutrino beam such as the one now planned has been on Gran Sasso's wish list all along. In 1979, Antonino Zichichi, then the president of Italy's National Institute for Nuclear Physics (INFN), which runs Gran Sasso, put the idea to the Italian government (see his sketch). Recent results from Super Kamiokande and elsewhere have increased the urgency for having a neutrino beam, says Enzo Iarocci, the current INFN head and a member of the CERN council.

Italy will put up two-thirds of the roughly \$46 million needed for constructing the neutrino source; additional cash contributions have so far been promised by Belgium, France, Germany, and Spain; and CERN will provide people, time, and \$14 million worth of existing equipment.

The neutrino beam at CERN will be created by smashing high-energy protons against a target. Pions from the collisions will be focused by magnets down a kilometer-long evacuated

▶ Europe's new neutrino experiments probably won't be the first to confirm neutrino oscillation, but they could be the first to see the tau neutrino.

pipe pointing toward the detectors. Muon neutrinos from pion decay will emerge from the pipe and zip at nearly the speed of light

to (and mostly through)

Gran Sasso in 2.5 msec. Neutrinos are neutral and interact so rarely that only a few thousand of the quintillion (10^{18}) a year that are supposed to come from CERN will be spotted.

An unambiguous signal

The two detectors planned for the CERN–Gran Sasso neutrino beam are called OPERA and ICANOE.

In OPERA, photographic emulsion and lead sheets will be layered so that particles resulting from neutrinos hitting lead nuclei can be tracked in the emulsion. Tau leptons, which come from tau neutrinos, will travel

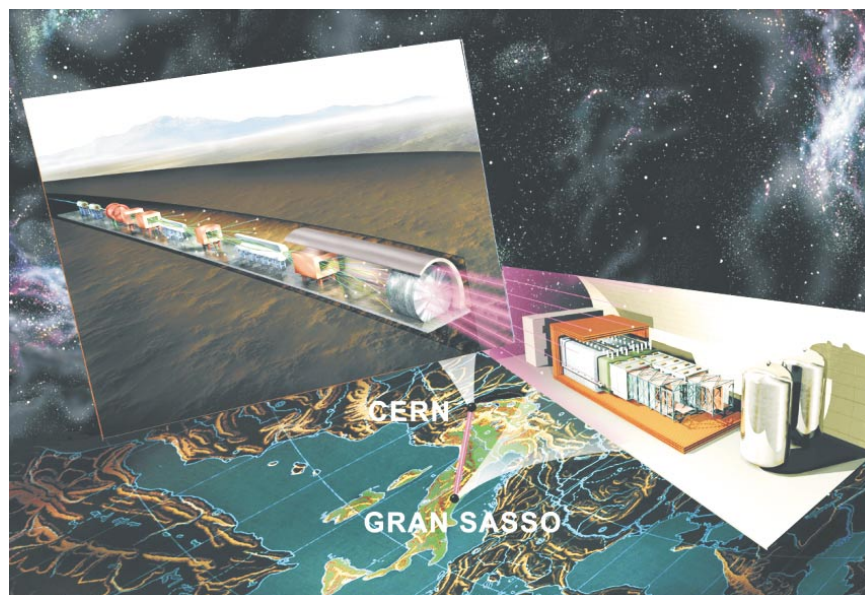
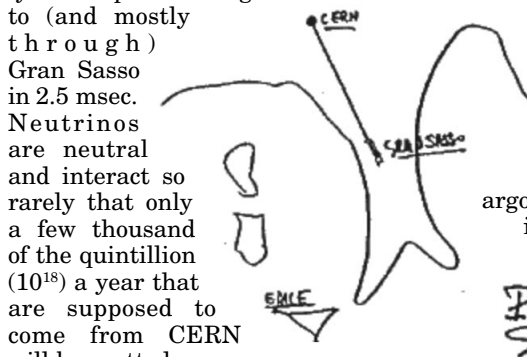
only a millimeter or so before decaying into other particles, whose tracks “would be an unambiguous signal,” says Francesco Pietropaolo, one of the beam designers. OPERA is expected to cost about \$55 million.

ICANOE, on the other hand, is intended to be more of a general-purpose detector, able to catch all flavors of neutrinos, from both man-made and naturally occurring sources.

It will couple liquid argon with sandwiches of iron and scintillator. The flavor and energy of incoming neutrinos will be deduced by reconstructing the collisions with argon nuclei, with the scintillator intended as a cross-check. In addition, by magnetizing the iron in the sandwiches to bend the paths of muons, scientists will be able to infer the momentum and energy of the parent muon neutrinos.

The argon detector has so far been tested in miniature, and a 600-ton prototype is under construction. “In principle, it's a splendid detector,” says Lorenzo Foa, a physicist at Pisa's Scuola Normale Superiore and a former director of research at CERN. “In terms of the physics, there

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ARTIST'S RENDERING OF THE NEUTRINO PIPE (left inset) at CERN that will feed detectors (right inset) at the Gran Sasso National Laboratory near Rome.

LUCA CESARO FOR INFN

is no problem. But in terms of the technology, you must prove that you can handle scaling up.” The final detector is expected to have about five kilotons of argon, and a price tag of \$71 million.

The tau of neutrinos

Why bother with OPERA and ICANOE, what with the Main Injector Neutrino Oscillation Search in the US expected to go on-line about two years earlier? MINOS isn’t designed to look directly for the tau neutrino. Instead, scientists will compare the number of muon neutrinos spewed out by Fermilab’s Main Injector to the number arriving at Minnesota’s Soudan Mine—coincidentally 730 km away. Any shortfall will be chalked up to oscillation into tau neutrinos.

Indeed, there are scientists on both sides of the Atlantic who believe that the European neutrino beam is a waste of resources, and that the two teams should have joined forces. As CERN physicist Friedrich Dydak puts it, “The CERN–Gran Sasso experiments will confirm what we do not know now, but what we will know long before they give results. Therefore, they will not give new insights unless other experiments fail. Should we build on the anticipation of the failure of others?” But Foa argues that the experiments are complementary: “As somebody said, ‘In order to prove a murder, you need to exhibit the body.’ Here, you need not only to verify that you have disappearance, you need to see the product of the oscillations.”

In fact, the parameters that govern oscillation haven’t yet been pinpointed. We may see a lot of oscillations, notes Pietropaolo, “but if we are not lucky, then we will see only a few events,” and a higher-intensity beam, a more massive detector, or a longer path would be needed to catch neutrinos changing flavor.

Says Luciano Maiani, CERN’s director general, “This is the kind of physics that should be done in several places—the experiments are relatively small.” And, he adds, “If neutrinos really oscillate, then we should start to think about a global facility—a plausible next step involving the whole world.” Foa agrees: “An interesting possibility would be to shoot neutrinos from CERN to Soudan, and from Fermilab to Gran Sasso.” In both cases, that’s about 7000 km.

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Korean Neutrino Observatory Axed

In 1997 the government of South Korea announced an ambitious \$20 million experiment to detect neutrinos. This past June, just 18 months and about \$290 000 later, the High-Energy Astrophysics Neutrino Laboratory (HANUL) was canceled, largely because of infighting among project participants.

HANUL was definitely a worthwhile project, says University of Wisconsin–Madison physicist Francis Halzen, who works on AMANDA, a neutrino observatory far beneath the South Pole (see *PHYSICS TODAY*, March 1999, page 19). “The key was whether they could demonstrate that they could do the physics at [Earth’s] surface. It would have been the experiment that put Korea on the map worldwide.”

HANUL—Korean for “sky”—would have been the first-ever above-ground neutrino telescope. As with other experiments that hunt for the abundant, chargeless particles that may make up much of the universe’s unidentified mass, HANUL would have detected muons arising from collisions of neutrinos with matter. However, unlike other neutrino detectors, which are placed deep underground to minimize cosmic background radiation, HANUL was supposed to combine time-of-flight measurements and Čerenkov radiation to pick out the signatures of neutrinos that have passed through Earth, and reject the ten billion times more prevalent signals coming from atmospheric muons raining down from above.

Rejection of background radiation would have been helped by applying a magnetic field. The idea was to bend the muons’ paths so as to extract their charge, momentum, and energy, and then, working backward, to determine whether a given incident neutrino had originated in Earth’s core, the Sun, the atmosphere, or somewhere outside the Galaxy. Says Columbia University’s Wonyong Lee, one of HANUL’s masterminds, “By combining tracking chambers with magnets, one could in principle get rid of background [radiation].” Having the experiment at the surface would have been much cheaper than running it underground, he adds. “And we could have done gamma-ray physics in addition to neutrino physics.”

Spreading blame

So why was the project axed? Fingers point in all directions—at the scientists, at the science, and at the fund-

ing agency. The official explanation is that the Korea Science and Engineering Foundation (KOSEF, a counterpart to the US National Science Foundation) cut off HANUL’s funding because it didn’t expect the scientists to meet a deadline for building a prototype.

But the real reason, says Lee, was that the principal investigator (PI)—Gyeongsang National University’s Jin Sop Song—refused to resign after project leaders insisted they couldn’t work with him. “He was doing whatever he wanted. The group was not discussing physics, and money was not being distributed. We couldn’t communicate well,” Lee says, adding that before the project got started, he’d been warned that “PIs in Korea act like dictators.” KOSEF’s rules should be changed “to be more democratic and transparent, so everyone knows what’s going on,” he adds. For his part, Song says he was doing his best to make the project successful, that decisions were made by committee, and that it would have been “unreasonable” for him to step down. There was almost no progress on the work Lee was overseeing, he adds.

There is broad agreement that tensions ran high between the experiment’s Korean and Korean–American participants. News of HANUL’s cancellation gained wide attention this past November after an angry letter originally published by the Korean Physical Society’s monthly magazine *Physics and High Technology* was reprinted in English in the on-line newsletter *Korean American Science and Technology News*. Written by Chungnam National University’s Haeshim Lee, who had been the leader of HANUL’s theory group, the letter accused foreigners—that is, the Korean–Americans involved—and their supporters of arrogance, politicking for jobs in Korea, and bad science. “Even the site of the lab could not be agreed upon,” Haeshim Lee wrote. “In my opinion, those who proposed and supported the project seemed to lack basic understanding of both the cosmic ray physics and astrophysics.”

Song also points to the “deep intervention” of KOSEF, and says the funding agency bears “an essential responsibility for the demise of the project.” Joo Sang Kang, a high-energy physicist at Korea University, who, although not directly involved in HANUL, is active in South Korean science policy, agrees: “Yes, the schedule did slip. Yes, HANUL members