PARTICLE PHYSICS

New Experiments Step Up Hunt for Neutrino Mass

TOKYO—Some of physicists' fondest hopes ride on the neutrino, a shadowy and seemingly massless particle. If the neutrino does have a trace of mass, swarms of them could account for some of the mass that cosmologists believe is missing from the universe as a whole. A massive neutrino might also point the way to a new theory of elementary particles and forces that would transcend the current Standard Model. Now experiments at underground laboratories around the world are striving to weigh the neutrino—without ever observing it.

The new experiments monitor a radioactive material with sensitive detectors, watching for an excruciatingly rare—perhaps nonexistent—process known as neutrinoless double beta decay. These are far from the only efforts to measure neutrino mass. Other researchers, for example, are trying to catch neutrinos in the act of "oscillating" from one of the three neutrino types—called flavors—to another, a transformation that would be a sure sign of mass. But while the oscillation experiments might be sensitive to neutrino masses as low as thousandths of an electron volt (eV), they can only reveal the difference in mass between two flavors. Neutrinoless double beta decay, in which the energy of electrons flung from a decaying radioactive nucleus is measured, will give an absolute value for the mass of the neutrino. That makes the experiments "an essential part of the program of modern particle physics," says astrophysicist John Bahcall of the Institute for Advanced Study in Princeton, New Jersey.

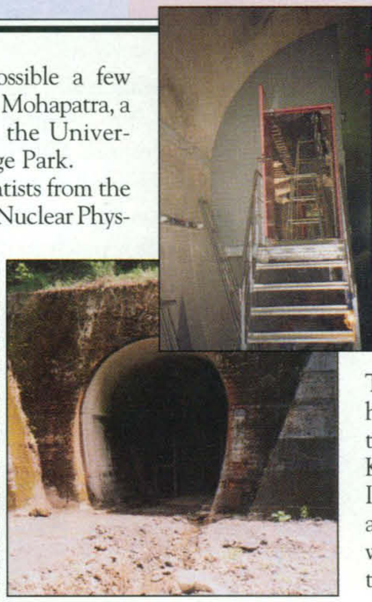
The catch is that so far, neutrinoless double beta decay has never been observed. Ordinary double beta decay is a rare, although regularly observed, process in which two neutrons in a radioactive nucleus decay into two protons, emitting two electrons, or beta rays, and two antineutrinos (antimatter counterparts of the neutrino). In the elusive neutrinoless form, other protons within the nucleus would absorb the antineutrinos as neutrinos, and only the electrons would escape. By comparing the measured energy of the electrons with the total energy of the process predicted by theory, researchers could calculate the energy—and therefore the mass—of the neutrinos.

Neutrinoless double beta decay can take place only if the neutrino has a nonzero mass. Its failure to appear in experiments so far means the process must be rare—and the neutrino mass minute. Current results already suggest a ceiling of roughly 1 eV—a tiny fraction of the mass of the electron. By monitoring larger quantities of radioactive material with more sensitive detectors while screening out sources of background radiation, the new generation of experiments aims to push the mass sensitivity as low as 0.1 eV. It's a level "people didn't think possible a few years ago," says Rabindra Mohapatra, a theoretical physicist at the University of Maryland, College Park.

PUTTING THE NEUTRINO ON THE SCALE

Name of experiment/ collaboration	Heidelberg-Moscow	ELEGANT V	NEMO-3
Institutions	Max Planck Institute for Nuclear Physics and Russian Science Center Kurchatov Institute	Osaka University Research Center for Nuclear Physics	CNRS; University of Bordeaux; University of Caen; Joint Institute for Nuclear Research, Dubna, Russia; *et al.*
Location of experimental setup	Gran Sasso Underground Laboratory, Italy	Oto Cosmo Observatory, Japan	Frejus Underground Laboratory, France
Emitter material	Germanium-76	Calcium-48	Molybdenum-100
Latest upper limit for neutrino mass	0.48 eV	Beginning operations	Planned opening in 1998
Target level	0.1 eV	0.6 eV	0.1 eV

Earlier this year, scientists from the Max Planck Institute for Nuclear Physics in Heidelberg, Germany, and the Russian Science Center Kurchatov Institute in Moscow reported lowering the upper limit of the possible mass of the electron neutrino to 0.48 eV. Mohapatra notes, however, that uncertainties in the "extremely complicated calculations" mean the results, from Gran Sasso National Laboratory in Italy's Apennines, could be off by a factor of 2.



RESEARCH CENTER FOR NUCLEAR PHYSICS, OSAKA U.

Tunnel vision. Japanese neutrino scientists are setting up shop in this railway tunnel south of Osaka.

Now Osaka University's Research Center for Nuclear Physics in Japan is setting up a double-beta-decay experiment in its new Oto Cosmo Observatory in a never-used railroad tunnel 100 kilometers south of Osaka. Hiro Ejiri, a physicist at Osaka, says that steady winds blowing through the tunnel at the new observatory help reduce its natural radon concentrations, which can result in background events. "We hope to get the sensitivity down to 0.6 eV," he says. That's no better than the Russian-German group has already claimed. But because the two groups are working with different isotopes (see table), Mohapatra and others say the Osaka experiment could provide independent confirmation of the recent Heidelberg-Moscow results.

A second European group, including scientists from France's CNRS, several French universities, and the Joint Institute for Nuclear Research in Dubna, Russia, wants to push the limits even lower. The collaboration, called NEMO, hopes by the end of 1998 to bring a new detector online in the Frejus Underground Laboratory in the Alps along the French-Italian border. Francis Laplanche, a physicist at the University of South Paris and a member of the team, says that the group intends to reduce the upper limit on neutrino mass to 0.1 eV by using a large mass of an isotope of molybdenum, cutting background radiation, and improving detection schemes. The Heidelberg-Moscow group, however, believes it will reach that level first. Hans Klapdor-Kleingrothaus of the Max Planck Institute says the goal is to achieve an upper limit of 0.1 eV within 5 years "just by letting the experiment run."

If any of the experiments actually pin down the mass of the neutrino, physicists would have their first clear clue to a theory beyond the Standard Model. The various Grand Unified Theories make different predictions for neutrino mass, and the results to date, by lowering the ceiling on neutrino mass, are casting doubt on some theories, says Moscow's Alexei Smirnov. "These bounds [on neutrino mass] could forbid some schemes," he says—not a bad payoff for an experiment that never sees its quarry.

–Dennis Normile