HIGH-ENERGY PHYSICS

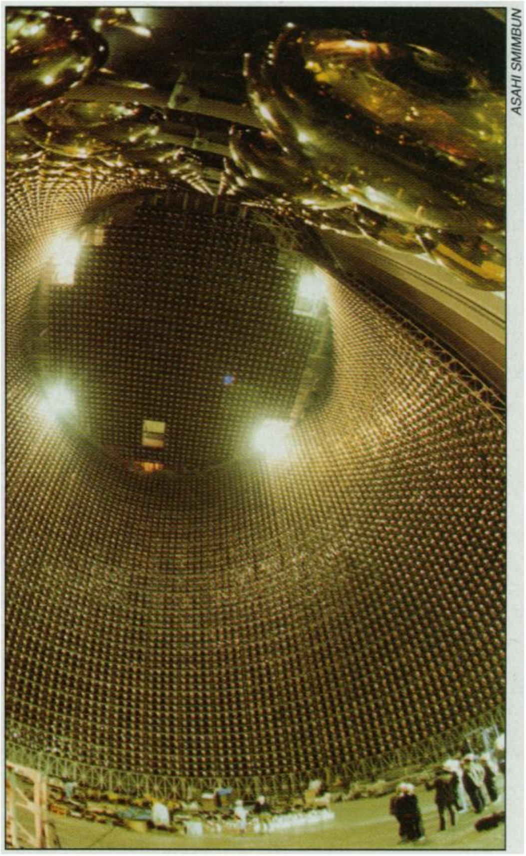
"Super" Japanese Site Gears Up to Solve Neutrino Puzzle

KAMIOKA, JAPAN—Ever since Wolfgang Pauli proposed the existence of neutrinos in 1930 to explain some puzzling features of the radioactive decay of certain atoms, experimentalists have labored hard to detect enough of the elusive particles to determine their properties. It took 26 years to prove that Pauli's particle even exists—a feat for which Frederick Reines of the University of California (UC), Irvine, won the Nobel Prize last month. Soon, however, physicists will be capturing neutrinos in unprecedented numbers in a 50,000-metric-ton tank that will fill with water starting next month. Researchers hope that this colossal waterbath will yield an answer to one of the most pressing questions in cosmology and high-energy physics: Do neutrinos have mass?

The $100 million experiment, called Super-Kamiokande, is located in a lead mine 300 kilometers west of Tokyo. The tank lies beneath 1 kilometer of earth and rock, which will screen out background radiation that would confound its 11,200 photomultiplier tubes. In this shielded environment, the detector should pick up the flashes of Čerenkov radiation emitted when one of the swarm of neutrinos collides with an electron or triggers a nuclear process spawning an electron. Super-Kamiokande is so much larger than other water detectors—its predecessor originally held only 3000 tons, and an older U.S. facility in an Ohio salt mine had a 8000-ton tank—that it will generate more data on solar and atmospheric neutrinos in 4 months than the cumulative production of all detectors to date. And that volume of data could start generating answers about neutrinos.

"We could get enough data to make a very strong statement [regarding neutrino mass] within 1 year," predicts Henry Sobel, a UC Irvine physicist and co-leader of a consortium of U.S. institutions collaborating on the project. Project director Yoji Totsuka, of the University of Tokyo's Institute for Cosmic Ray Research, is a bit more circumspect. He notes the large number of premature claims regarding neutrino mass and estimates it "could take 5 to 10 years to gather a convincing body of evidence."

Neutrino mass isn't the only item on Super-Kamiokande's plate, however. Scientists will also be watching for a pattern of Čerenkov radiation indicating the decay of the proton into charged particles. It would be the first experimental evidence of a phenomenon that University of Pennsylvania physicist Alfred Mann calls "the Holy Grail" of particle physics, and its observation would upset the established Standard Model of forces and particles, which holds that protons do not decay. At the same time, cosmologists are hoping that Super-Kamiokande will be lucky enough to record the paroxysms of a relatively close supernova, capturing enough neutrinos to answer questions about the mechanism of such exploding stars. "It's going to be a very important facility for elementary particle physics and astrophysics," says University of Tokyo cosmologist Katsuhiko Sato.



Dry run. Researchers inspect the bottom of Super-Kamiokande before its 50,000-ton fill-up.

Filling a gap. Super-Kamiokande will extend the work of its comparatively pint-sized predecessor, Kamiokande, still running in a cavern just up the tunnel. Kamiokande, which opened in 1983, helped to detect the 1987A supernova, as well as prove that protons, if they decay at all, do not decay as quickly as some theories predicted. It also corroborated results from an earlier experiment that point to a solar neutrino gap—a puzzling deficit in the number of neutrinos measured compared with the levels that theory predicts are streaming from the sun.

One explanation proposed for the deficit is that some solar neutrinos originate as electron neutrinos but change, or oscillate, into one of two other flavors—tau and muon—that water Cerenkov detectors like Super-Kamiokande are unable to see. If so, neutrinos would have some mass, because the laws of quantum mechanics rule out oscillations in massless particles.

While researchers at other facilities plan to study neutrinos in other energy ranges (using heavy water or chemical soups) or use streams of neutrinos of known energy levels from other sources, the Super-Kamiokande group believes that it will be able to see the signature of neutrino oscillation directly in the large number of events it will be monitoring. The increased volume of water, more densely packed tubes, and more highly filtered water are expected to generate 30 events a day, compared with 0.3 for Kamiokande. Researchers will be sifting through this mass of information to compile two measures: an energy profile of solar neutrinos in a certain energy range and the distribution of the angles at which incoming atmospheric neutrinos enter the detector.

The energy profile should tell researchers whether the neutrinos they are detecting fit the characteristics expected in neutrinos generated by the decay of boron-8 in the sun. Boron-8 emits neutrinos in a range of energies, and a graph plotting flux and energy creates a characteristic curve that, in theory, should be independent of the absolute number of neutrinos. If oscillation is occurring, then the curve generated from Super-Kamiokande's data will differ from that yielded by electron neutrinos produced by the decay of boron-8. If there is no oscillation, the shape of the two curves should match. This would indicate there may not be a neutrino deficit and that models of the sun's inner workings must be revised to explain the neutrino gap.

The question of distribution applies to neutrinos generated when cosmic rays bombard Earth's atmosphere. These neutrinos should be created uniformly around Earth. But those generated on the far side of the planet will have farther to travel to reach the detector—and have more time to undergo oscillation. So, if the number of observed electron neutrinos varies by angle of incidence, it will strongly suggest that oscillation is occurring.

Yoichiro Suzuki, a physicist with the Cosmic Ray Institute, says there just hasn't been enough neutrino data in the past to investigate either effect. Now there will be. "We will be able to determine whether oscillation is occurring just with the Super-Kamiokande data," he says.

A global race. Super-Kamiokande will also be facing competition from facilities in Europe and the United States with links to an accelerator or nuclear power plant (*Science*, 18 February 1994, p. 916). Detecting flavors of neutrinos not produced at the source would be additional evidence of oscillation and, thus, of mass. Most of the experiments are still in the planning stage; Super-Kamiokande, for example, hopes to work with a proposed new accelerator 250 kilometers away at the Institute for High-Energy Physics in Tsukuba.

Whichever group succeeds in collecting evidence of mass first, there will be plenty for others to do. Pennsylvania's Mann says a determination of nonzero mass for the neutrino will "open up a cottage industry of investigations." Among the most important issues to resolve would be the mass of each flavor of neutrino and the conditions under which each one oscillates.

For now, however, Japanese neutrino scientists are grateful for the support they have received from the central government for the project, which was approved in 1991 by the Ministry of Education, Science, Sports, and Culture. Masatoshi Koshiba, a former professor of physics at the University of Tokyo and the godfather of Kamiokande, says the international attention garnered by Kamiokande mightily impressed governmental decisionmakers. The decision was made easier by the lack of competing proposals in Japan, unlike in the United States (*Science*, 29 September, p. 1813).

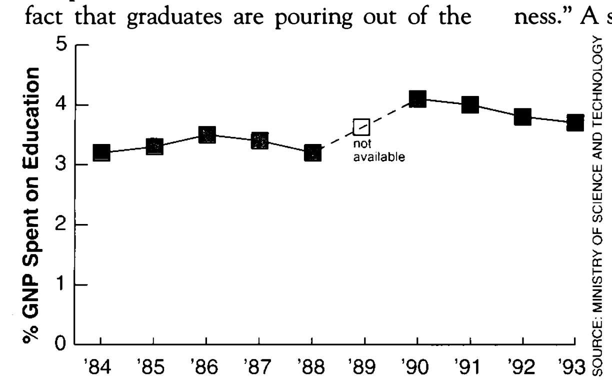
On 11 November the politicians will see what their $100 million has bought when they attend a ceremony at the mine site to mark the official end of construction. "The people from the ministries are all happy to see this project completed," Suzuki says. "But for us, it's just the beginning."

–Dennis Normile

UNDERGRADUATE EDUCATION

India Proposes Private Universities

NEW DELHI—Heidi Dewan, an undergraduate computer science major at the Jaynarayan University in Jodhpur, Rajasthan, has a common complaint about her education. She's worried that it won't prepare her for a job. "It leaves me with a lot of bookish, obsolete knowledge that is way behind what is actually going on in the world of software development in India today," says Dewan, who is halfway through her 4-year course of study. Her potential employers echo her complaints: Indian industrialists bemoan the fact that graduates are pouring out of the country's universities poorly equipped for high-tech occupations.



Shrinking support. Private schools could ease pressure on government to fund higher education.

Now these complaints have resonated within the government. Last month it introduced a bill into Parliament that would permit the formation of the country's first private universities. The bill, drafted by the Human Resources Development Ministry, would allow companies and other organizations to exert much greater control over curricula and other academic matters in the universities they help establish. The measure is not just intended to make universities more responsive to market needs, however: It may also ease the financial burden on the government, which now supports the entire system of higher education in India.

The proposal has ruffled the country's academic and scientific community. Critics worry that it will generate a flood of profitable "teaching shops." Officials of the faculty union at the University of Delhi fear the effect on public education of "captains of industry being put in charge of vital sectors like information and knowledge." Even supporters of the bill, like Vegesna Satyanarayana Raju, director of the Indian Institute of Technology (IIT)–Delhi, acknowledge that "there is the danger that the whole thing might become one business." A similar reaction greeted a proposal last year by Indians living abroad to create a National Science University funded by nongovernmental sources. That idea is still pending before policy-makers.

On the other hand, other academic administrators say that fears of a corporate takeover of Indian higher education are unfounded. "Some of the best teaching and research institutions all over the world are privately funded," notes Pratap Narain Srivastava, a radiation biologist and former vice chancellor of New Delhi's prestigious Jawaharlal Nehru University.

India has a chronic oversupply of highly trained technical and scientific personnel. In 1993, for example, the country's 183 universities awarded roughly 5000 Ph.D.s in the sciences, including medicine and engineering, but only about 1000 of them found jobs in industry that made use of their skills. A smaller number entered academia, with the rest settling for something outside their field.

Business leaders say that hiring rates are low because most students require extensive and costly retraining before they can function well in industrial R&D labs. "The mindset of a student must be tuned to the practical functioning of business and industry, rather than just theory," says Sanjay Dalmia, chair of one of India's big industrial houses, which has just given $300,000 to IIT-Delhi to support research on comparative management practices in Asia. The bill would help to narrow that gap. "A private university will make this interaction easier," he says, "and better trained students will make industry perform better."

Private institutions are also expected to offer a broader range of higher quality courses, as well as boosting salaries and improving working conditions for faculty. The existence of such institutions could also lead to improvements among public universities. "Excellence is the child of competition," says IIT-Delhi's Raju, "of which there is not much in the existing university system."

Many academic leaders also see the government's proposal as a useful platform for a broader discussion of higher education in India. Armaity Desai, chair of the University Grants Commission (UGC), which oversees academic research funding, feels that the bill reflects an inexorable trend in which the private sector will play a larger role in higher education. Although Desai applauds the bill's plan to preserve UGC's oversight of the system, she says that the real issue is the quality of the education imparted, not whether students are taught at a private or public school.

Although no companies have publicly said they would finance such a private university, there is believed to be considerable interest in the idea. The next step for the bill is a hearing before a joint committee of both houses of Parliament. Supporters are hoping for speedy passage, noting that the government would like to clear the measure before the national elections in July 1996.

In the meantime, Jaynarayan University's Dewan says that revising her curriculum to fit the needs of the computer industry would greatly improve her chances of finding a good job when she graduates. And she hopes that the prospect of competition from private universities will spur her institution into action.

–Pallava Bagla

Pallava Bagla is a science writer in New Delhi.