New dawn. The measurement of a key parameter at the Daya Bay Nuclear Power Plant in China presages an exciting future for neutrino physics.

PARTICLE PHYSICS

Key Neutrino Measurement Signals China's Rise

New Year's Day on the traditional lunar calendar is the biggest holiday in China and marks the beginning of a 15-day festival. But there was no break this year for physicists working with China's Daya Bay Reactor Neutrino Experiment 70 kilometers northeast of Hong Kong. Racing to beat competitors around the world to make a key measurement, they worked through the 23 January holiday and surrounding festivities. "Those of us working on the data analysis didn't take time off," says Yifang Wang, co-spokesperson for the Daya Bay collaboration and director of the Institute of High Energy Physics (IHEP) in Beijing. "We were determined to do this."

They succeeded. On 8 March at a seminar at IHEP, the Daya Bay team announced the measurement of a crucial parameter describing the behavior of neutrinos, nearly massless subatomic particles that hardly interact with anything else. The parameter's value suggests that future neutrino experiments, some of which may help explain why the universe contains so much more matter than antimatter, will prove even more fertile than physicists had hoped. "It's not just a parameter; it's a gateway," says Robert Plunkett of Fermi National Accelerator Laboratory (Fermilab) in Batavia, Illinois.

Neutrinos are the chameleons of the subatomic world. The particles come in three different types, or "flavors": electron neutrinos, which are born in nuclear reactions; muon neutrinos, which emerge from the decay of particles called pions; and tau neutrinos, which have been generated in particle collisions at accelerator labs. For more than a decade, physicists have known that neutrinos of one type can morph into another type as the particles zip along at near–light speed. For example, electron neutrinos born in the sun change into other flavors so that fewer reach Earth than would be expected otherwise. Similarly, muon neutrinos created when cosmic rays strike the atmosphere change stripes before they reach underground detectors. Those oscillations prove that neutrinos have mass, as they can occur only if the particles have different masses.

In experiments with underground detectors, particle accelerators, and reactors, researchers had measured all but one of the five parameters needed to describe the oscillations theoretically: the two mass differences among the three neutrinos and three abstract "mixing angles" that determine how much one flavor mixes into another. Now, the 250 physicists working with the experiment at the Daya Bay Nuclear Power Plant and two neighboring plants in Shenzhen, China, have measured the last of the three mixing angles, known as θ_{13}.

Researchers measured the flux of electron antineutrinos produced by the six 2.9-gigawatt reactors at the site using three 100-tonne detectors near the reactors and three identical detectors 1.7 kilometers away. They looked for a decrease in the rate at which the antineutrinos reached the distant site, a sign that the particles were oscillating into flavors the detectors could not sense. To measure θ_{13}, researchers had to tease apart two superimposed oscillations: a larger, slower one of the type that accounts for the disappearance of solar neutrinos and reveals a different mixing angle and a smaller, faster one that had not been conclusively observed before. They found that θ_{13} equals 8.8°, give or take about 0.8°.

Daya Bay researchers needed only 55 days' worth of data taking to sew up the measurement. They edged out four other teams racing to make a definitive observation. Last June, physicists working with an accelerator-based neutrino experiment in Japan called T2K, which involves firing a beam of muon neutrinos from a laboratory in Tokai to the subterranean Super-Kamiokande neutrino detector 295 kilometers away, produced a result with a much larger error. Ten days later, researchers working with the MINOS experiment at Fermilab, which fires muon neutrinos 735 kilometers to a detector in the Soudan Mine in northern Minnesota, produced a similar result. In November, researchers with the Double Chooz reactor experiment in France followed suit. The Reactor Experiment for Neutrino Oscillations (RENO) in South Korea is also measuring the angle.

It's no accident that the Daya Bay team leapfrogged the competition, Wang says. By using more detectors with a greater total mass, the researchers could tally neutrinos faster than teams at other reactors could, he says. "One month of our data is comparable to 3 months of RENO's data and 4 months of Double Chooz's," Wang says. Happenstance also played a role, however. The T2K experiment was interrupted on 11 March last year, when the Tohoku earthquake hit Japan. It resumed taking data only in January. Had T2K run as planned, it might have produced an equally precise measurement by now, Wang says.

The fact that θ_{13} turned out to be larger than some scientists had feared also helped to speed up the measurement. And it implies that neutrino physics could be particularly rich

CREDIT: ROY KALTSCHMIDT, LAWRENCE BERKELEY NATIONAL LABORATORY in the decade ahead. For example, researchers in Japan, the United States, and Europe have plans to search for a slight asymmetry between the oscillations of neutrinos and antineutrinos, called CP violation, that might help explain why the infant universe grew to contain so much matter and so little antimatter. Those plans would have been for naught if θ_{13} had turned out to be zero. "All these CP-violating effects vanish if θ_{13} is zero," says Paul Langacker, a theorist at the Institute for Advanced Study in Princeton, New Jersey.

Wherever it leads, the result puts Chinese particle physics on the map, researchers say. "This is arguably the most important physics result ever to come out of China," says Robert McKeown, a Daya Bay team member from the Thomas Jefferson National Accelerator Facility in Newport News, Virginia.

Over the past decade, the Chinese government has ramped up funding for physics and Chinese researchers are returning home from the West, says Wang, who once worked at Stanford University in Palo Alto, California. Still, Chinese researchers must pick their spots, he says. The Daya Bay experiment cost between \$30 million and \$40 million, with China bearing two-thirds of the cost and the rest split among the United States, Taiwan, Russia, and the Czech Republic. "If it cost \$300 million, I don't think we could have afforded it," Wang says.

Over the next 3 to 5 years, Daya Bay researchers will continue to hone the precision of their measurement. After that, they have preliminary plans to build detectors 60 kilometers from the reactors and try to determine the precise ordering of the neutrinos' masses, which should be easier now that θ_{13} is known to be sizable. (Right now, scientists know only the sizes of the differences in the particles' masses.) Of course, rivals such as T2K and the NOνA experiment, under construction at Fermilab, will try to do that first. Given their performance in measuring θ_{13}, don't be surprised if Chinese physicists give the competition a run for their money.

–ADRIAN CHO

DRUG DISCOVERY

New Institute Aims to Help Academics Make Medicines

The pharmaceutical industry is trying to shake itself out of drug-discovery doldrums. One company's latest attempt made its debut this week with the launch of a new nonprofit research institute to help academics turn their basic biology insights into drug compounds ready for human tests. The California Institute for Biomedical Research (CalIBR) is being backed by the German pharmaceutical giant Merck, which is committing \$42 million over the first 3 years and possibly as much as \$90 million over the first 7 years.

In return, if CalIBR's collaborations with an outside academic group lead to any drugs ready to move to the clinic, Merck would have the first right to negotiate a deal with the group. If the deal doesn't come together or Merck isn't interested, the academics are free to make a deal with a different pharma partner or spin off their own company.

Peter Schultz, a chemist at The Scripps Research Institute in San Diego, California, and former head of the Genomics Institute of the Novartis Research Foundation, will lead the new institute. Schultz says CalIBR leaders have already begun hiring staff, which he expects to grow to about 150 scientists. The institute is leasing lab space in Torrey Pines, near Scripps and the Salk Institute, but will probably build its own building in the future, Schultz says.

Schultz says the new nonprofit organization is needed to fill a growing gulf between basic biological discoveries made by academic researchers and the work done by pharmaceutical companies to shepherd compounds through human clinical trials to the market. "What we're trying to do is build a bridge that links the novel biology to something that is real," he says. Companies typically put candidate drug compounds through batteries of tests to optimize their effectiveness and limit side effects, but "academic labs often lack the tools and resources to be able to do that," says Steve Kay, dean of biological sciences at the University of California (UC), San Diego, who is also helping to spearhead the CalIBR effort.

"What we're trying to do is build a bridge that links the novel biology to something that is real."

—PETER SCHULTZ, THE SCRIPPS RESEARCH INSTITUTE

"One thing I really like about this idea is that at each step in the process we are playing to people's strengths."

—PETER KIM, MERCK RESEARCH LABORATORIES

CREDITS (TOP TO BOTTOM): SCHULTZ LAB/THE SCRIPPS RESEARCH INSTITUTE; MERCK

Schultz envisions an academic group approaching CalIBR after it identifies a new disease pathway or drug target, such as a novel protein involved in osteoarthritis. The collaboration would then identify potential compounds that could be honed into a drug to block or bolster the osteoarthritis protein. If successful, the collaboration would then make a deal with a pharma company and split the proceeds 50–50.

"I think it's very forward-thinking," says Kevan Shokat, a chemical biologist at UC San Francisco, who has launched companies of his own in hopes of commercializing basic research discoveries in his lab. If nothing else, the institute will give emerging therapies "more time to percolate" to see whether they can indeed make a difference in patients, Shokat says.

The launch of the new institute comes at a time when pharmaceutical companies around the globe are scrambling in search of a new model for research and development, says Kenneth Kaitin, who heads the Center for the Study of Drug Development at Tufts University in Boston. With the explosion of genomics, proteomics, and other novel science endeavors over the past 2 decades, R&D costs for pharma companies have doubled to nearly \$50 billion annually since 2000, according to the Pharmaceutical Research and Manufacturers of America. Meanwhile, the number of new small-molecule drugs approved for sale every year has leveled off. This combination

Published by AAAS