Announcing the First Results from Daya Bay: Discovery of a New Kind of Neutrino Transformation

Brookhaven National Laboratory

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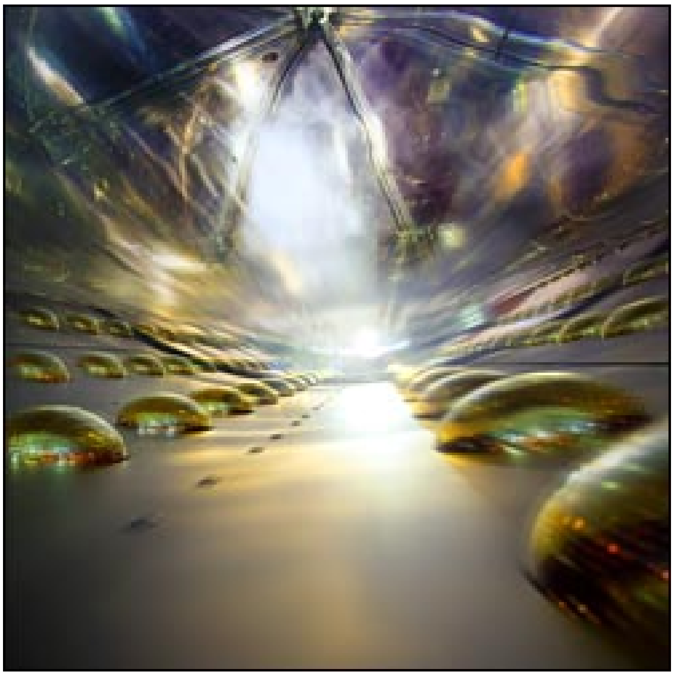
The following news release is being issued today by the Daya Bay Reactor Neutrino Experiment Collaboration, which is led by China and the United States. The U.S. Department of Energy's Brookhaven National Laboratory continues to play multiple roles in this international project, ranging from management to data analysis. In addition to coordinating detector engineering efforts and developing software and analysis techniques, Brookhaven scientists perfected the "recipe" for a special, very chemically stable liquid that fills part of Daya Bay's detectors and interacts with antineutrinos. This work builds upon a legacy of breakthrough neutrino research by Brookhaven Lab that has resulted in two Nobel Prizes in Physics. For more information about Brookhaven's role, visit the links listed after the news release or contact Justin Eure, jeure@bnl.gov [9], 631-344-2347, or Peter Genzer, genzer@bnl.gov [10], 631-344-3174.

Announcing the First Results from Daya Bay: Discovery of a New Kind of Neutrino Transformation



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+ENLARGE [11]Sensitive photomultiplier tubes line the Daya Bay detector walls, designed to amplify and record the faint flashes that signify an antineutrino interaction. (Courtesy of Roy Kaltschmidt, Lawrence Berkeley National Laboratory)

BEIJING; BERKELEY, CA; and UPTON, NY – The Daya Bay Reactor Neutrino Experiment, a multinational collaboration operating in the south of China, today reported the first results of its search for the last, most elusive piece of a longstanding puzzle: how is it that neutrinos can appear to vanish as they travel? The surprising answer opens a gateway to a new understanding of fundamental physics and may eventually solve the riddle of why there is far more ordinary matter than antimatter in the universe today.

Traveling at close to the speed of light, the three basic neutrino "flavors" – electron, muon, and tau neutrinos, as well as their corresponding antineutrinos – mix together and oscillate (transform), but this activity is extremely difficult to detect. From Dec. 24, 2011, until Feb. 17, 2012, scientists in the Daya Bay collaboration observed tens of thousands of interactions of electron antineutrinos, caught by six massive detectors buried in the mountains adjacent to the powerful nuclear reactors of the China Guangdong Nuclear Power Group. These reactors, at Daya Bay and nearby Ling Ao, produce millions of quadrillions of elusive electron antineutrinos every second.

The copious data revealed for the first time the strong signal of the effect that the scientists were searching for, a so called "mixing angle" named theta one-three (written θ13), which the researchers measured with unmatched precision. Theta one-three, the last mixing angle to be precisely measured, expresses how electron neutrinos and their antineutrino counterparts mix and change into the other flavors. The Daya Bay collaboration's first results indicate that theta one-three, expressed as sin2 2 θ13, is equal to 0.092 plus or minus 0.017.

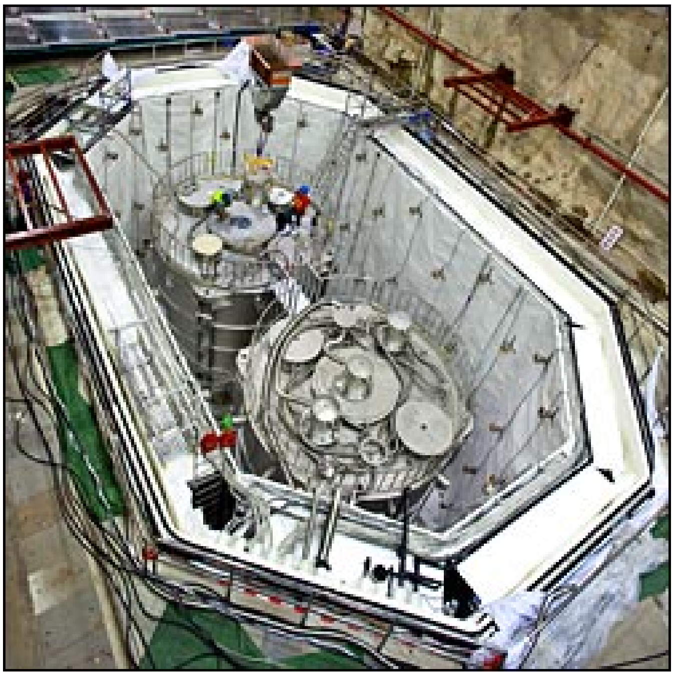
Brookhaven physicist Chao Zhang will give a presentation on the current status of the Daya Bay experiment with greater details on these new results at 3:00 p.m., Thursday, March 8, at Brookhaven Lab's Hamilton Seminar Room. A video of the talk will later be posted on WBNL [12].

"This is a new type of neutrino oscillation, and it is surprisingly large," says Yifang Wang of China's Institute of High Energy Physics (IHEP), co-spokesperson and Chinese project manager of the Daya Bay experiment. "Our precise measurement will complete the understanding of the neutrino oscillation and pave the way for the future understanding of matter-antimatter asymmetry in the universe."

Neutrinos, the wispy particles that flooded the universe in the earliest moments after the big bang, are continually produced in the hearts of stars and other nuclear reactions. Untouched by electromagnetism, they respond only to the weak nuclear force and even weaker gravity, passing mostly unhindered through everything from planets to people. The challenge of capturing these elusive particles inspired the Daya Bay collaboration in the design and precise placement of its detectors.

"Although we're still two detectors shy of the complete experimental design, we've had extraordinary success in detecting the number of electron antineutrinos that disappear as they travel from the reactors to the detectors two kilometers away," says Kam-Biu Luk of the U.S. Department of Energy's Lawrence Berkeley National Laboratory (Berkeley Lab) and the University of California at Berkeley. Luk is co-spokesperson of the Daya Bay Experiment and heads U.S. participation. "What we didn't expect was the sizable disappearance, equal to about six percent. Although disappearance has been observed in another reactor experiment over large distances, this is a new kind of disappearance for the reactor electron antineutrino."

The Daya Bay experiment counts the number of electron antineutrinos detected in the halls nearest the Daya Bay and Ling Ao reactors and calculates how many would reach the detectors in the Far Hall if there were no oscillation. The number that apparently vanish on the way (oscillating into other flavors, in fact) gives the value of theta one-three. Because of the near-hall/far-hall arrangement, it's not even necessary to have a precise estimate of the antineutrino flux from the reactors.



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+ENLARGE [13]Two antineutrino detectors in the first Daya Bay hall, shown here before the center chamber was filled with ultrapure water. (Courtesy of Roy Kaltschmidt, Lawrence Berkeley National Laboratory)

“Even with only the six detectors already operating, we have more target mass than any similar experiment, plus as much or more reactor power,” says William Edwards of Berkeley Lab and UC Berkeley, the U.S. project and operations manager for the Daya Bay Experiment. Since Daya Bay will continue to have an interaction rate higher than any other experiment, Edwards explains, “it is the leading theta one-three experiment in the world.”

The first Daya Bay results show that theta one-three, once feared to be near zero, instead is “comparatively huge,” Kam-Biu Luk remarks, adding that “Nature was good to us.” In coming months and years the initial results will be honed by collecting far more data and reducing statistical and systematic errors.

“The Daya Bay experiment plans to stop the current data-taking this summer to install a second detector in the Ling Ao Near Hall, and a fourth detector in the Far Hall, completing the experimental design,” says Yifang Wang.

Refined results will open the door to further investigations and influence the design of future neutrino experiments – including how to determine which neutrino flavors are the most massive, whether there is a difference between neutrino and antineutrino oscillations, and, eventually, why there is more matter than antimatter in the universe – because these were presumably created in equal amounts in the big bang and should have completely annihilated one another, the real question is why there is any matter in the universe at all.

“It has been very gratifying to be able to work with such an outstanding international collaboration at the world's most sensitive reactor neutrino experiment," says Steve Kettell of Brookhaven National Laboratory, the chief scientist for the U.S. effort. "This moment is exciting because we have finally observed all three mixing angles, and now the way is cleared to explore the remaining parameters of neutrino oscillation."

"This is really remarkable," says Wenlong Zhan, vice president of the Chinese Academy of Sciences and president of the Chinese Physical Society. "We hoped for a positive result when we decided to fund the project, but we never imagined it could come so quickly!"

"Exemplary teamwork among the partners has led to this outstanding performance," says James Siegrist, Associate Director for the Office of Science for High Energy Physics at the U.S. Department of Energy. "These notable first results are just the beginning for the world's foremost reactor neutrino experiment."

The Daya Bay collaboration consists of scientists from the following countries and regions: China, the United States, Russia, the Czech Republic, Hong Kong, and Taiwan. The Chinese effort is led by co-spokesperson, chief scientist, and project manager Yifang Wang of the Institute of High Energy Physics, and the U.S. effort is led by co-spokesperson Kam-Biu Luk and project and operations manager William Edwards, both of Berkeley Lab and UC Berkeley, and by chief scientist Steve Kettell of Brookhaven.

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The collaborating institutions of the Daya Bay Reactor Neutrino Experiment are Beijing Normal University, Brookhaven National Laboratory, California Institute of Technology, Charles University in Prague, Chengdu University of Technology, China Guangdong Nuclear Power Group, China Institute of Atomic Energy, Chinese University of Hong Kong, Dongguan University of Technology, Joint Institute for Nuclear Research, University of Hong Kong, Institute of High Energy Physics, Illinois Institute of Technology, Iowa State University, Lawrence Berkeley National Laboratory, Nanjing University, Nankai University, National Chiao-Tung University, National Taiwan University, National United University, North China Electric Power University, Princeton University, Rensselaer Polytechnic Institute, Shandong University, Shanghai Jiao Tong University, Shenzhen University, Siena College, Tsinghua University, University of California at Berkeley, University of California at Los Angeles, University of Cincinnati, University of Houston, University of Illinois at Urbana-Champaign, University of Science and Technology of China, Virginia Polytechnic Institute and State University Blacksburg, University of Wisconsin-

Madison, College of William and Mary, and Sun Yat-Sen (Zhongshan) University.

For more information, visit
http://dayawane.ihep.ac.cn/twiki/bin/view/Public/WebHome [18]

Related Links

- Daya Bay Today: BNL and Collaborators Enable Next Step in Neutrino Research [19]
- The Daya Bay Reactor Neutrino Experiment Begins Taking Data [19]
- Team of Physicists Win 1988 Nobel Prize for Discovery of the Muon Neutrino at Brookhaven's AGS [19]
- Brookhaven Lab's Raymond Davis Jr. Wins 2002 Nobel Prize for Detection of Solar Neutrinos [19]

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