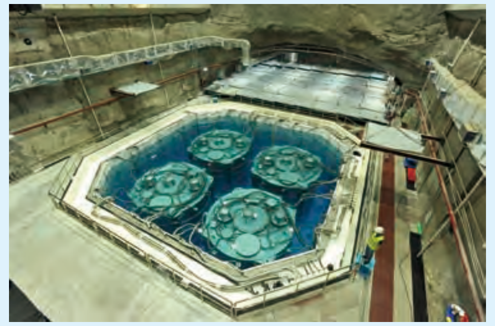
This born-in-China experimental result garnered much attention from the international community of physics, and was regarded as a milestone in the research of neutrino physics. It was selected as one of the top 10 scientific accomplishments of the year in 2012 by Science magazine.



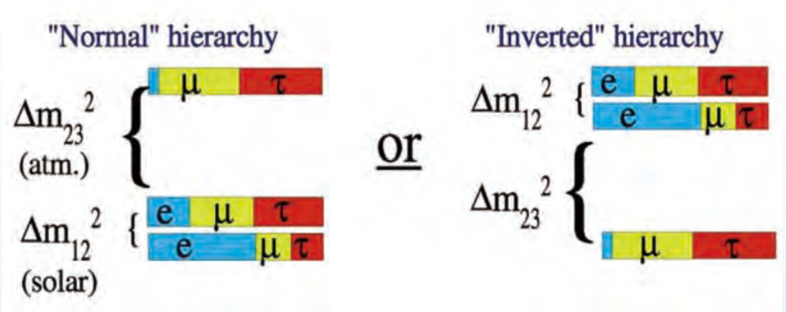
The result opens the door to further investigations and has an influence on the design of future neutrino experiments -- including how to determine which neutrino flavors are the most massive, whether there is a difference between neutrino and antineutrino oscillations, and, eventually, why there is more matter than antimatter in the universe. Because matter and antimatter 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.

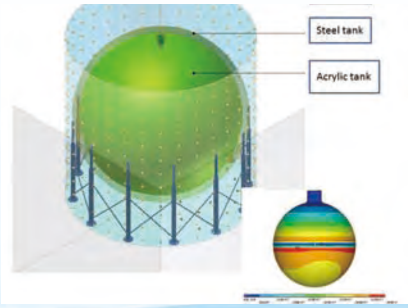
All eight detectors of the Daya Bay Reactor Neutrino Experiment have now been successfully installed, and data-taking started on October 19, 2012. This marked the completion of the experimental design and construction.

In the next three to five years, scientists will aim to improve the precision of the measurement of the mixing angle θ_{13} by a factor of four compared to the first results, and to start research on a precise measurement of the reactor antineutrino spectrum.

>> Jiangmen Underground Neutrino Observatory (JUNO)

The neutrino mass hierarchy is very important for our understanding of the evolution of the universe, the generation and propagation of Supernova neutrinos, and the oscillation of long baseline neutrinos. The precise measurements of 4 of the 6 neutrino mixing parameters also make it possible to check the unitarity of the neutrino mixing matrix and search for new physics.

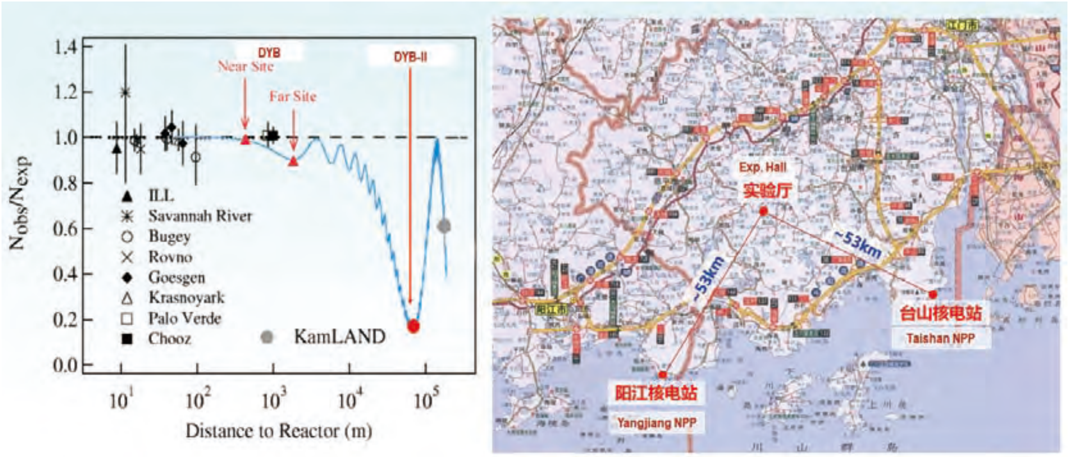




Conceptual design of the AD

The experimental goals of Jiangmen Underground Neutrino Observatory include the determination of the neutrino mass hierarchy; the measurement of 4 out of 6 neutrino mixing parameters to better than a 1% precision; the study of supernova neutrinos, geo-neutrinos, atmospheric neutrinos, sterile neutrinos, etc.

Jiangmen City of Guangdong Province is the best site for for Jiangmen Underground Neutrino Observatory. It is the home of the largest reactor complex in the world with 2.9X6 GW in the Yangjiang NPP and 4.6X4 GW in the Taishan NPP, which totals 35.8 GW. The experimental site will be located 53 km from both Yangjiang and Taishan NPP.



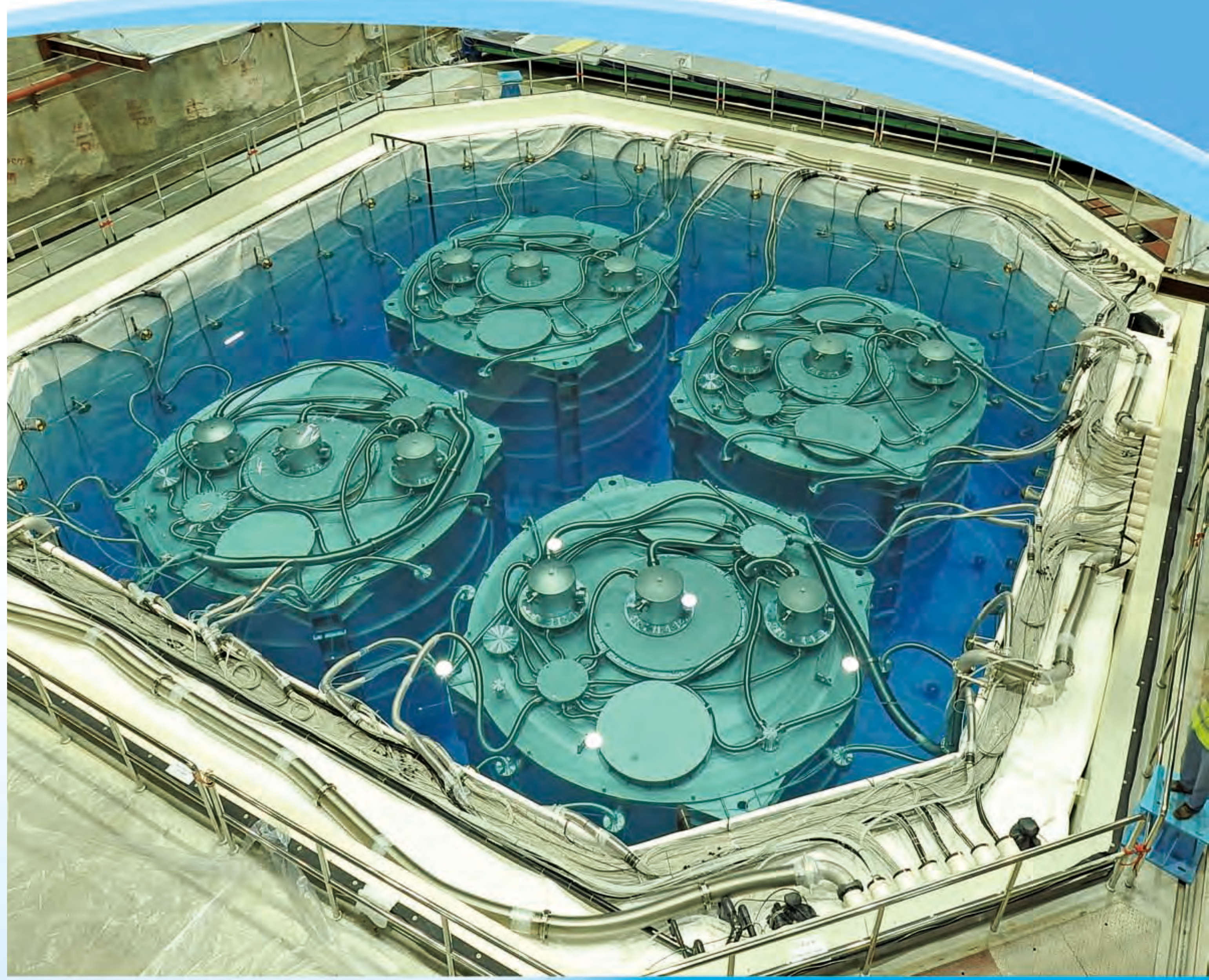
Jiangmen City of Guangdong Province is the best site for the Jiangmen Underground Neutrino Observatory.

>> International cooperation

The Daya Bay experiment is supported in part by the Ministry of Science and Technology of China, the Chinese Academy of Sciences, the National Natural Science Foundation of China, the Guangdong provincial government, the Shenzhen municipal government, the China Guangdong Nuclear Power Group, the United States Department of Energy and other foreign institutes. Serving as an excellent example of cooperation and innovation, the experiment is China's largest international project in the field of basic research.

The Daya Bay Reactor Neutrino Experiment is a China-based multinational particle physics project studying neutrinos. The multinational collaboration includes over 250 scientists from China, the United States, Hong Kong, Taiwan, Russia, and the Czech Republic. The Chinese scientists in the mainland mainly come from the Institute of High Energy Physics, Tsinghua University, Shanghai Jiao Tong University, Shandong University, China Institute of Atomic Energy, etc.

Daya Bay Reactor Neutrino Experiment



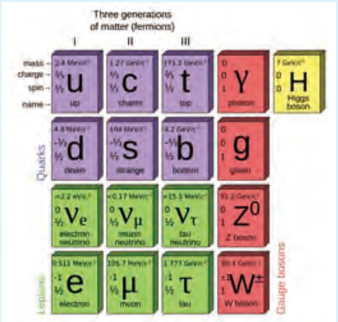
Institute of High Energy Physics

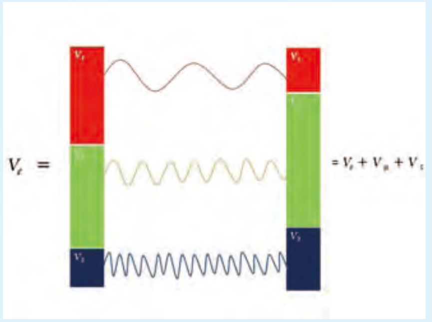
>>What is a neutrino?

Our world is made of matter, which consists of 12 fundamental particles, 6 quarks and 6 leptons, according to the Standard Model of particle physics. Leptons can be further divided into three kinds of charged leptons (electron, muon, tau) and three kinds of neutrinos (electron neutrinos, muon neutrinos and tau neutrinos).

The neutrino is denoted by the Greek letter ν, and it does not carry electric charge. All evidence suggests that neutrinos have mass, but their mass is tiny, even by the standards of subatomic particles. Neutrinos can happily pass through a wall of lead several hundred light-years thick. In nature, neutrinos bump into other particles only once in a blue moon. Neutrinos are one of the fundamental particles that make up the universe. They are also one of the least understood. Neutrinos are created as a result of certain types of radioactive decay, or in nuclear reactions, such as those that take place in the sun, in nuclear reactors, or when cosmic rays hit atoms.

Neutrino oscillation is a quantum mechanical phenomenon whereby a neutrino created with a specific lepton flavor (electron, muon or tau) can later be measured to have a different flavor.





Neutrino oscillation is a quantum mechanical phenomenon whereby a neutrino created with a specific lepton flavor (electron, muon or tau) can later be measured to have a different flavor.

The Super-Kamiokande Collaboration announced the first evidence for neutrino oscillations (that one type can transmute into another type) in 1998. That was the first experimental observation supporting the theory that the neutrino has non-zero mass, a possibility that theorists had speculated for tens of years. Another two experiments (SNO and KamLAND) also observed clear evidence that neutrinos oscillate.

There are still many mysteries surrounding neutrinos, including their absolute mass, their Dirac or Majorana nature, their mass hierarchy, CP violation, the existence of sterile neutrinos, etc.

>> Measuring the mixing angle θ_{13} using reactor neutrinos

In the neutrino mixing matrix, all but two parameters have been measured: the smallest mixing angle, θ_{13}, and the value of the CP-violating phase, δ_{CP}. The CP-violating phase is related to matter-antimatter asymmetries, and thus may explain why our universe contains so little antimatter. The magnitude of θ_{13} has implications for the CP-violating phase since all the physical effects associated with CP violation contain a factor of $\sin\theta_{13}$. The size of θ_{13} also defines the physics potential of future accelerator-based experiments. The observation of reactor neutrinos at a baseline of 2 km allows a precise determination of the mixing angle θ_{13} without ambiguities.

The layout of the Daya Bay Experiment.

In October 2007, the Daya Bay Experiment celebrated its groundbreaking.

>> Daya Bay and Ling Ao Nuclear Power Plants (NPP)

The Daya Bay nuclear reactor complex includes the reactors of the Daya Bay, Ling Ao, and Ling Ao-II Nuclear Power Plants. The reactor complex has a total thermal power of 17.4 GW, one of the largest in the world.

The complex directly abuts a mountain range that can afford protection from cosmic rays, the main source of background in the experiment. Tunnels in the mountain can provide between 100 m (mean depth of 270 meters of water equivalent) and 400 m (mean depth of 1200 mwe) of granite overburden to shield the detectors from cosmic rays for distances of 250 m and 2 km from the reactor cores, respectively. This makes Daya Bay an ideal site for the θ_{13} measurement.

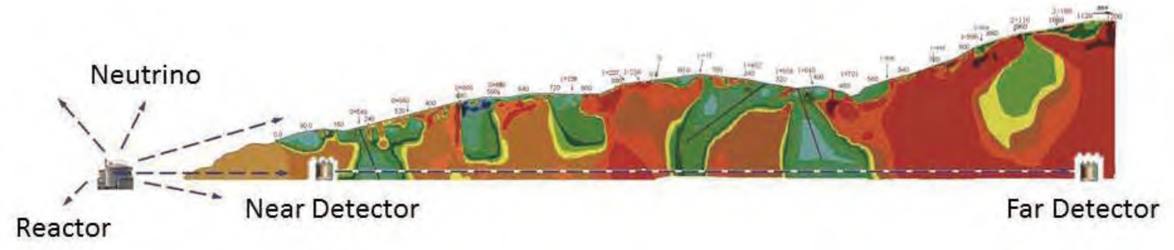
>> The scheme of the experiment

The accurate measurement of θ_{13} is of great importance to future physics research. In 2003, 7 countries in the world put forward 8 experimental proposals to measure it. Three of them, the Daya Bay Reactor Neutrino Experiment in China, the Double Chooz experiment in France, and the RENO experiment in Korea, were approved.

In the Daya Bay experiment, two halls were built near the nuclear reactors (near halls) and one hall is located far from the nuclear reactors (far hall). The halls are connected by horizontal tunnels. The two near halls are located one hundred meters underground, and the far hall is 350 meters underground. Identical antineutrino detector modules were placed in the experimental halls, two at each near site and four at the far site. Two functional halls were built for the production of liquid scintillator and water purification.

>> Civil construction of the tunnel and experiment halls

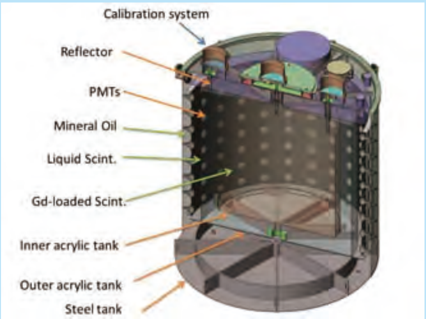
The tunnel and the experimental halls were designed by the Yellow River Engineering Consulting Co., Ltd., and the civil construction was carried out by the China Railway 15^{th} Bureau Group Corporation. Through the end of 2012, more than 3,000 blasts were conducted, which all met the security requirements of the National Nuclear Safety Administration. A 3,000-meter-long tunnel and five underground experimental halls were built.



>> Detector system

Each detector site has a water pool that is 16 meters long, 10 meters wide (16 meters for the far hall) and 10 meters high, and contains 2,000 tons of purified water. The antineutrino detector modules were submerged in the water pools, which provide greater than 2.5 meters of shielding to reduce cosmogenic neutrons and radioactive backgrounds from the rock. The water pools also serve as Cherenkov detectors to veto cosmic muons. Outside the water pool, there is another muon veto detector, consisting of a Resistive Plate Chamber (RPC). The combined veto efficiency is expected to be > 99.5%.

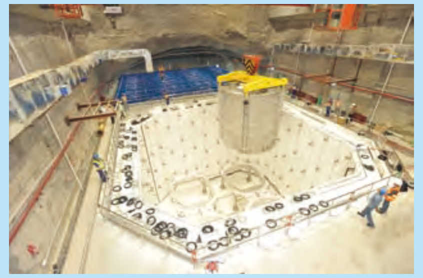
The detecting system



Section of Anti-neutrino detectors

>> Antineutrino detectors

Each antineutrino detector is a cylinder having an outer diameter of 5 meters, a height of 5 meters and weighing 110 tons. The liquid scintillator and photomultiplier tubes are the core parts of the detector. When an antineutrino interacts with a proton inside the detector, it produces a positron and a neutron. The energy from the positron is deposited in the scintillator, which creates a burst of light. An average of 30 microseconds later, a second burst of light is produced as the gadolinium captures the neutron. Photomultiplier tubes record the light produced in this reaction, which signals the presence of a neutrino. Each antineutrino detector contains three layers. In the center, they are filled with 20 tons of organic liquid scintillator that contains gadolinium, a heavy metal. Next is a layer of liquid scintillator without gadolinium. The outer layer uses mineral oil to act as shielding. 192 photomultiplier tubes were lined along the mineral-oil-filled outer detector tank. Three automated calibration units, fully automated robotic system responsible for the energy and time calibration, were installed on top of the detector.



In Experimental Hall 3, a 110-ton antineutrino detector was being installed in a 10-meter water pool.

>> Discovery of a new kind of neutrino transformation

On March 8, 2012, the Daya Bay Collaboration announced that the Daya Bay Reactor Neutrino Experiment had measured a nonzero value for the neutrino mixing angle θ_{13} with a significance of 5.2 standard deviations. The paper was published in Physical Review Letters on April 27 (Physical Review Letters, Vol. 108, No. 17).

The Daya Bay experiment counts the number of electron antineutrinos detected in the two halls nearest to the reactors and calculates how many would be observed by the detectors in the far Hall if there were no oscillations. The number of electron antineutrinos that apparently vanish on the way (oscillating into other flavors) reveals the value of θ_{13}. θ_{13} ,the last mixing angle to be precisely measured, expresses how electron neutrinos (and their antineutrino counterparts) mix and change into other flavors.