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# The Daya Bay Reactor Neutrino Oscillation Experiment

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The Daya Bay reactor neutrino experiment aims to measure the last unknown neutrino mixing parameter $\theta_{13}$ with a sensitivity of $\sin^2 2\theta_{13} < 0.01$ at 90% C.L. The experiment will measure the flux and energy spectrum of reactor antineutrinos through the inverse beta-decay reaction on protons with three sites at different distances from the reactor cores. This measurement will provide a better understanding of the neutrino mixing matrix and will also give direction to future experiments probing CP violation in the lepton sector and the neutrino mass hierarchy. An overview, current status, and schedule of the experiment is presented.

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## 1. Introduction

The observations of neutrino oscillations has demonstrated that the masses of neutrinos are nonzero and therefore that the Standard Model of particle physics is incomplete. The theory which explains the effect of neutrino oscillation introduces several parameters such as masses of neutrinos, mixing angles, and CP violating phase delta. Two out of three mixing angles are now very well known. The last one, $\theta_{13}$, still lacks precise measurement which would provide information on whether the parameter is zero or not.

The Daya Bay reactor neutrino experiment, [1], is aimed to measure this last unknown mixing angle $\theta_{13}$ which appears to be very small or vanishing. To achieve the planned unique sensitivity, $\sin^2 2\theta_{13} < 0.01$ (90% C.L.) several conditions have to be satisfied. Firstly, large number of events is needed and therefore one of the most powerful nuclear power plants, the Daya Bay nuclear power complex, is exploited as a prolific source of the electron antineutrinos. Secondly, the experiment needs to consider all possible background effects and suppress them in a defined level of uncertainty.

Most of the background events in experiments of the same type as the Daya Bay are caused by cosmic muons, which can penetrate through layers of a shielding right into detectors and subsequently produce there signals. To decrease a rate of such events, most of the experiments are built deep underground to provide extensive overburden reducing the flux of incoming cosmic muons.

In order to avoid a detection of signals from the rest of muons reaching the area of the detectors, various veto systems are usually employed. The main task of these systems is to efficiently tag all muons passing through.

## 2. Design of Daya Bay Experiment

The Daya Bay experiment is located by the Daya Bay nuclear power plant on the south-east coast of China, about 50 km straight-line distance from Hong Kong. The experiment will use the electron antineutrinos coming from beta decay of isotopes produced in fission processes in the reactor cores. The measurement of the flux will be done at three locations. Two sites employing two detectors each will be located nearby the reactor cores and one site with 4 detectors will be located about 2 km away from the cores. This setup will enable to do relative measurements at different locations allowing to reduce systematic uncertainties in the antineutrino flux.

### 2.1 Antineutrino Detectors

The antineutrino detector module, AD, is constructed in a form of three nested cylindrical zones partitioned with acrylic tanks and bounded by stainless steel vessel. The innermost region is filled with gadolinium-loaded organic liquid scintillator serving as an antineutrino target. The middle layer is filled with pure liquid scintillator and it is employed to catch all gammas escaping from the target volume. The scintillation light coming from both volumes is collected by photomultiplier tubes, PMT, mounted on the inner side of the steel tank and are surrounded with a layer of mineral oil, which provides shielding against gamma radiation of the material of PMTs and from the steel tank. The sizes of the volumes are 20 tons for each liquid scintillator and 40 tons for mineral oil.



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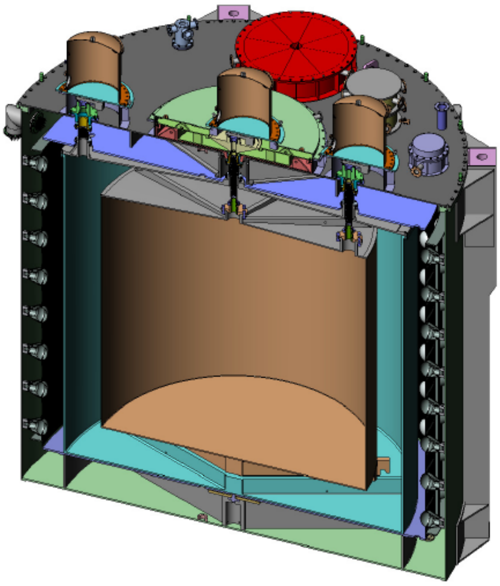

Figure 1: Cross section of antineutrino detector to be used in the experiment Daya Bay.The figure demonstrates the three-layer structure.

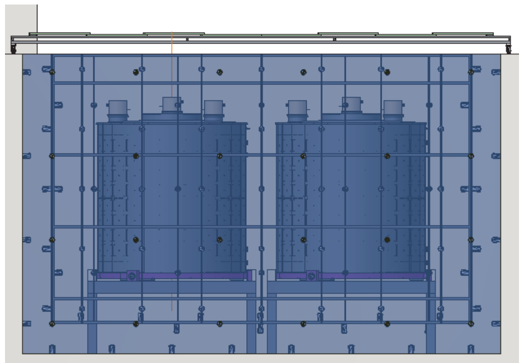

Figure 2: Schema of the muon system water pool with 2 AD modules submerged inside and PMTs mounted on sides. A layer of RPC modules is also visible on the top of the pool.

The diameter and height of the stainless steel vessel are both 5 m. The figure 1 shows a cross section through the AD module.

The aim of the detector is to detect inverse beta decay reaction of incoming antineutrino, triggering on two signals in a coincidence in a specified time window. First, prompt, signal comes from produced positron, the second one, delayed, is caused by an outgoing neutron which is captured on Gadolinium in the target region.

The conservatively estimated uncertainty of the detector efficiency is 0.38%.

### 2.2 Muon Veto System

The detectors at each site will be submerged in water pools which will serve both as an effective shielding from radioactivity of surrounding rock and as a Čerenkov counter providing a muon tagging system. There will also be a layer of RPC (Resistive Plate Chambers) modules over the top of the pools. The overall efficiency of cosmic muon detection is planned to be higher than 99.5%. Schematic picture of the water pool with submerged AD modules, and with the layer of RPC modules on top is shown in figure 2.

### 2.3 Backgrounds

There are three important sources of backgrounds in the Daya Bay experiment. Fast neutrons as spallation products of cosmic muons, $^{8}$He/$^{9}$Li produced mainly in muonic showers, and natural

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| Fast neutrons/signal | 0.1% | 0.1% | 0.1% |
| $^{9}$Li, $^{8}$He/signal | 0.3% | 0.2% | 0.2% |
| Accidentals/signal | $<$0.2% | $<$0.2% | $<$0.1% |

Table 1: Summary of expected contribution of three dominant sources of background events to the signal.

radioactivity from the surrounding material and from rock. The expected contribution to the signal is summarized in table 1.

## 3. Status and Plans

Currently, excavation of access and assembly tunnels is underway and more than 1,700 m of rock has been excavated to date. A prototype's stainless steel vessel has been assembled with outer, 4 meters in diameter, acrylic vessel and support ladders which are designed to hold PMT detectors.

We are getting ready for the first test of antineutrino detectors in this autumn. The so called Dry Run is aimed to test the detectors assembled with all electronics without being filled with any fluid.

The first measurements with fully assembled antineutrino detectors at the Daya Bay near site are planned for the summer 2010, providing first data on neutrino flux from the reactors. In the summer 2011, the far hall is scheduled to be ready for the first data taking, accomplishing the full setup of the experiment.

The experiment is planned to reach the sensitivity 0.01 in $\sin^2 2\theta_{13}$ at 90% C.L. in 3 years of data taking.

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## References

[1] Daya Bay Collaboration, *A Precision Measurement of the Neutrino Mixing Angle $\theta_{13}$ using Reactor Antineutrinos at Daya Bay*, `arXiv:hep-ex/0701029v1`