# Muon System in Daya Bay Neutrino Experiment

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On behalf of the Daya Bay Collaboration

# Outline

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- Purpose of Muon System
- Muon Induced Background
- Muon System Components
  - Resistive Plate Chamber (RPC)
  - Water Pool Cherenkov Detector
- Current Status of Muon System Installation

# Physics Goal of Daya Bay

- To search for the neutrino mixing parameter, $\sin^2 2\theta_{13}$ , with a sensitivity better that 0.01 (@ 90% C.L.) in three year run

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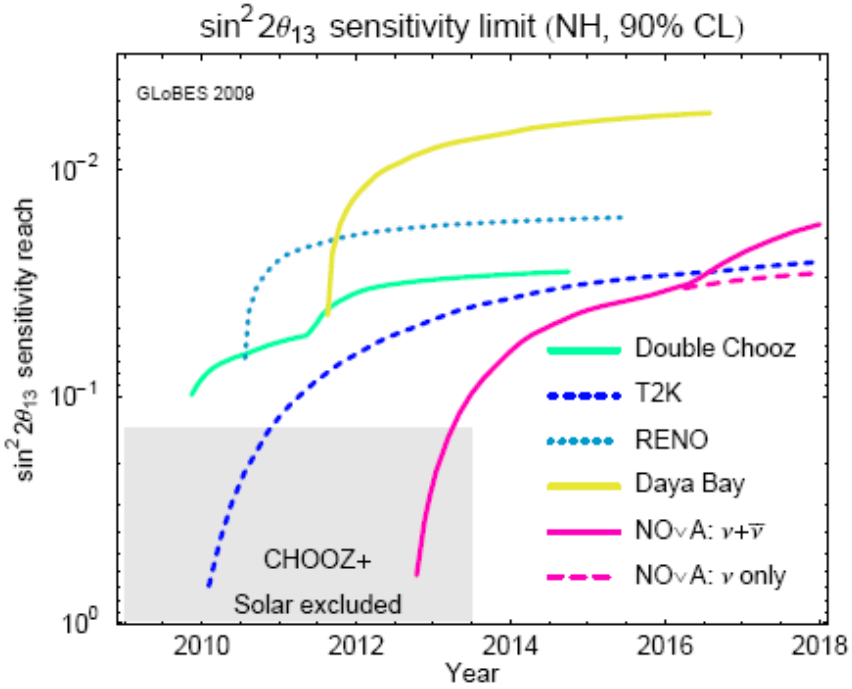
Oscillation probability:

$$P(\bar{\nu}_e \rightarrow \bar{\nu}_e) = 1 - \sin^2 2\theta_{13} \sin^2\left(\frac{\Delta m^2_{13} L}{4E_\nu}\right)$$

Daya Bay will start taking data this summer




Huber et al

# Purpose of Muon System

- To attenuate gamma rays and neutrons produced outside of the active detector volume

- To tag muons that pass close to the detector so that muon induced fast neutron backgrounds can be rejected and studied to keep the uncertainty on untagged fast neutron backgrounds below 0.1% of signal

# Background Summary

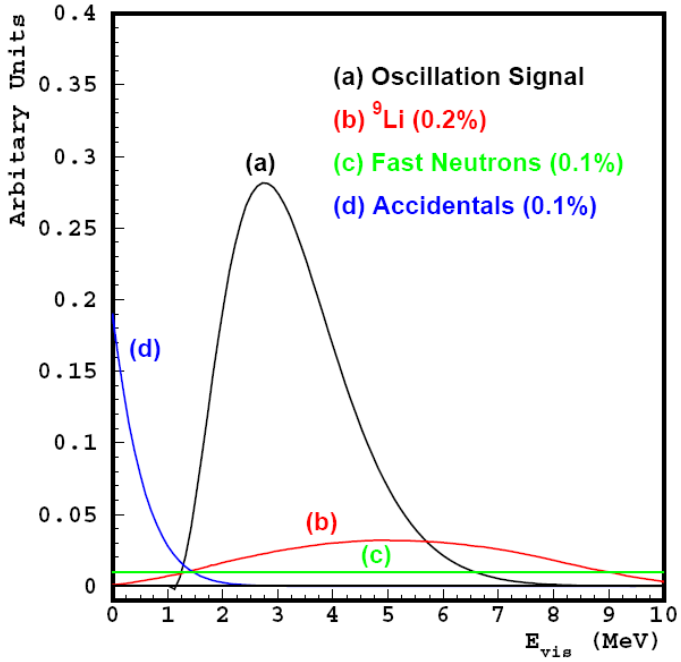
| | | DYB site | LA site | far site |
|---|---|---|---|---|
| (a) | Antineutrino rate (/day/module) | 840 | 740 | 90 |
| | Natural radiation (singles) (Hz) | <50 | <50 | <50 |
| | Single neutron (/day/module) | 18 | 12 | 1.5 |
| | $\beta$-emission isotopes (/day/module) | 210 | 141 | 14.6 |
| (d) | Accidental/Signal | <0.2% | <0.2% | <0.1% |
| (c) | Fast neutron/Signal | 0.1% | 0.1% | 0.1% |
| (b) | $^{8}He^{9}Li$/Signal | 0.3% | 0.2% | 0.2% |

Total expected background rates:

far site < 0.4 events/det/day

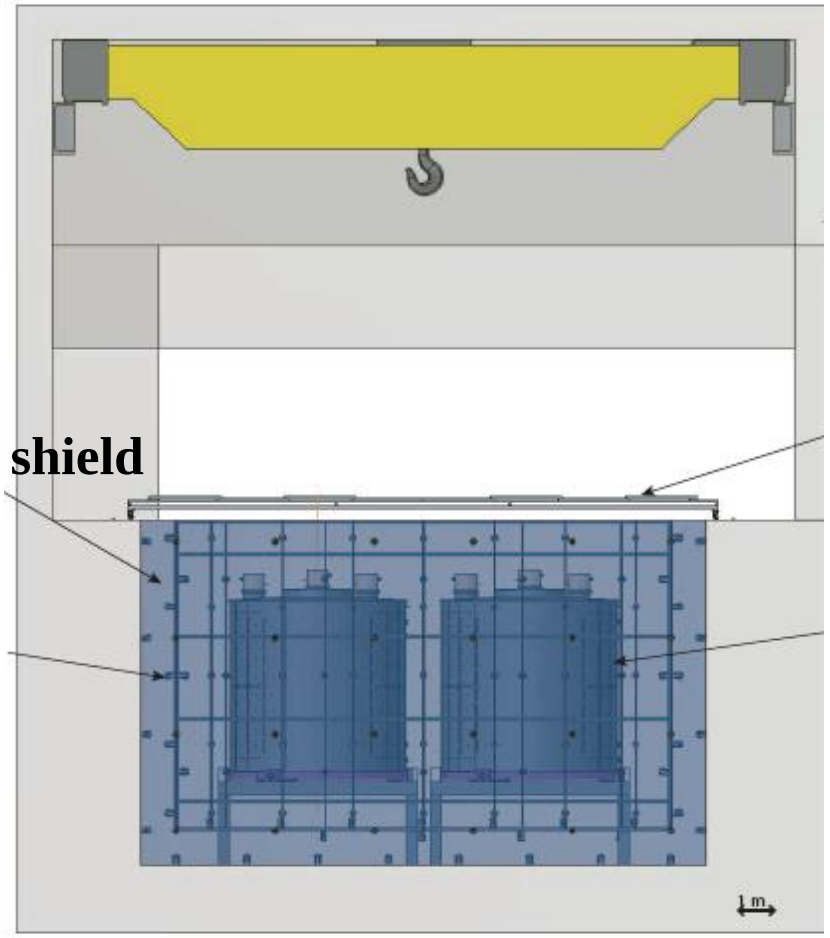
Daya Bay site < 6 events/det/day

Ling Ao site < 4 events/det/day

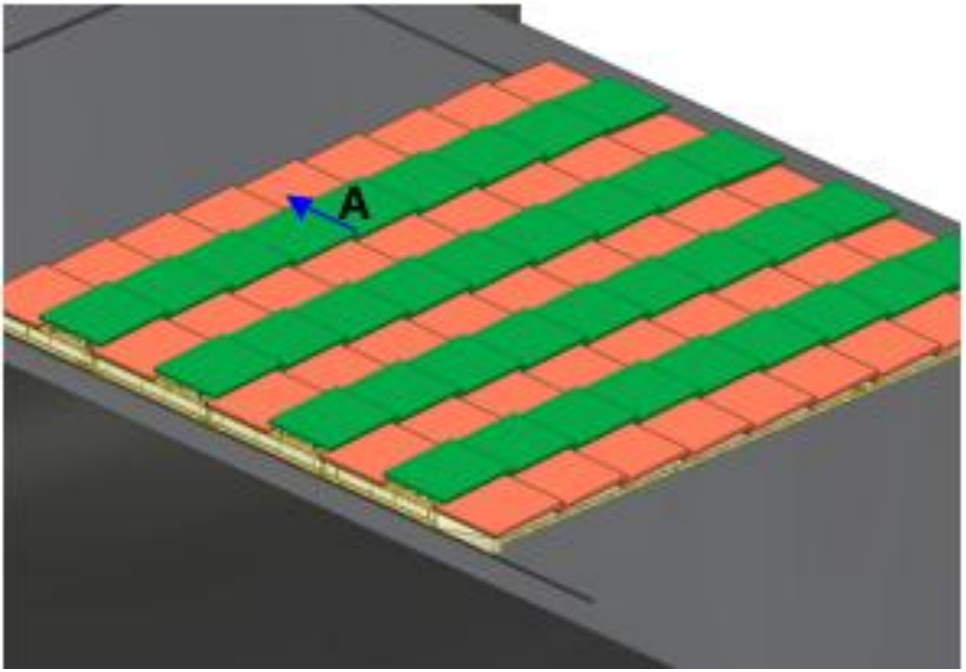


# Muon System

The Daya Bay muon system consist of two detector systems: a multi-layer RPC and a water pool (Cherenkov detectors)

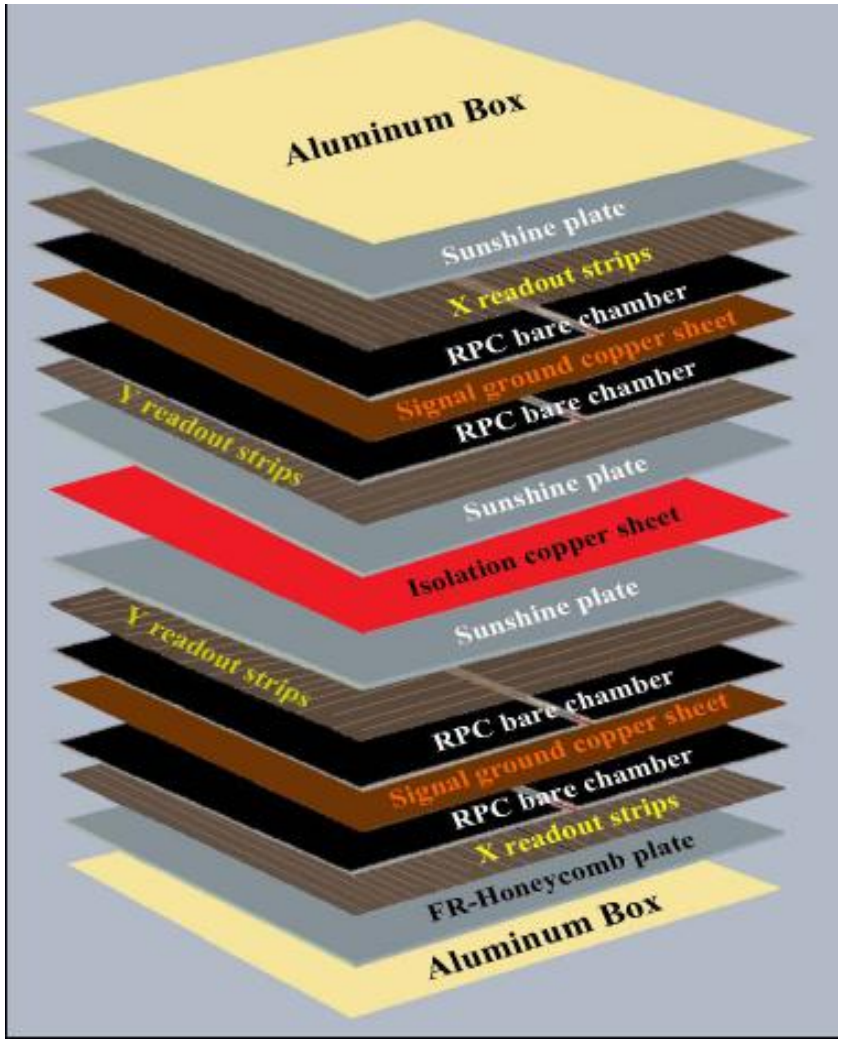


# Resistive Plate Chamber



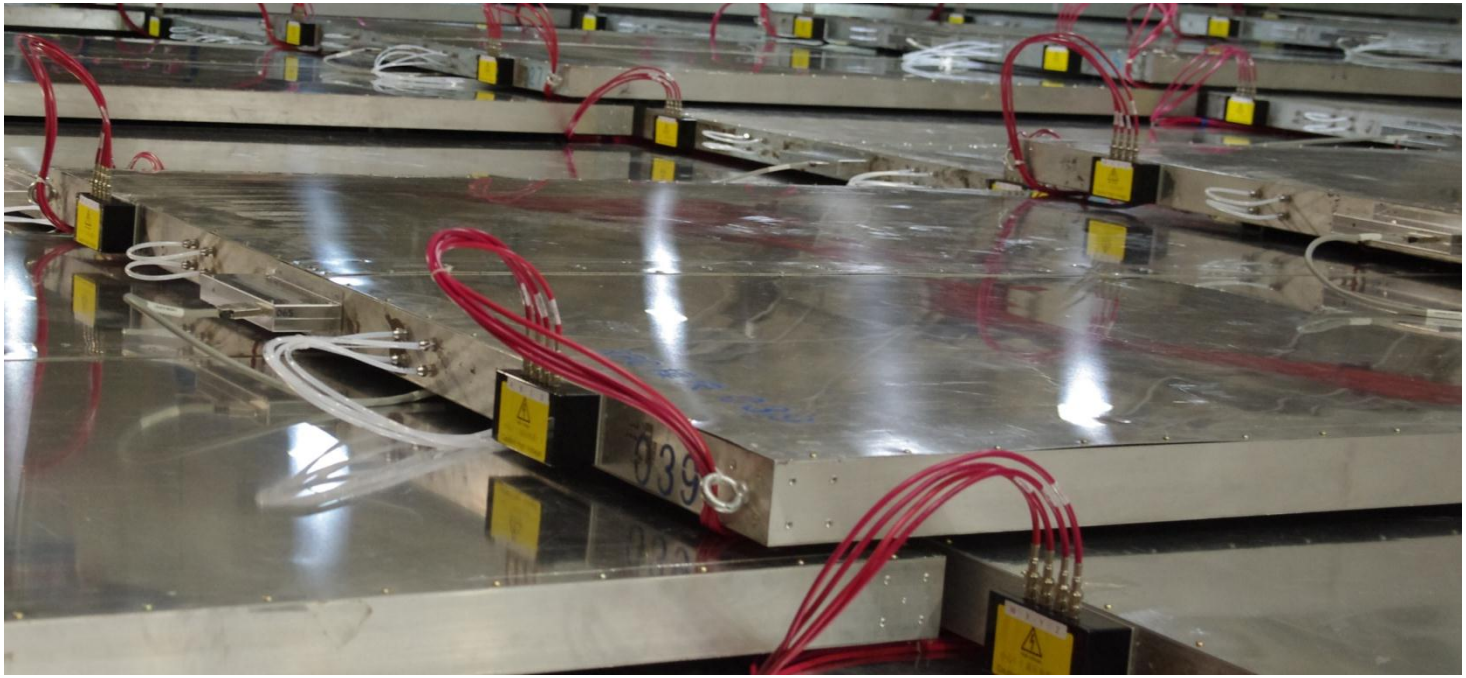

RPC layers covering water pool

54 RPC modules in each near site
81 RPC modules in far site




RPC module inner structure

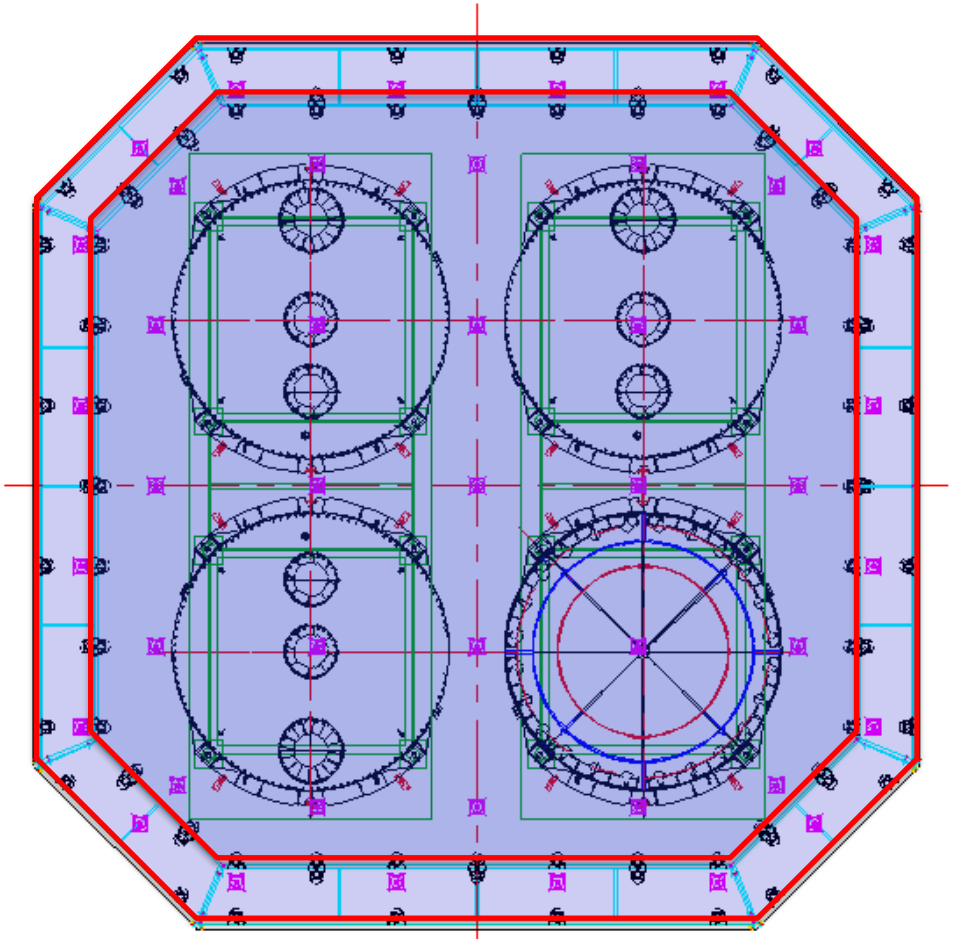
# Resistive Plate Chamber



RPC Module

- **Gas system**: gas mixture Ar/R134A/Isobutane/$SF_6$(65.5/30/4/0.5)
- **HV system**: CAEN HV mainframe provides 8kV for each layer
- **Readout system**: FEC(Front End Card)

# Water Pool Cherenkov Detector

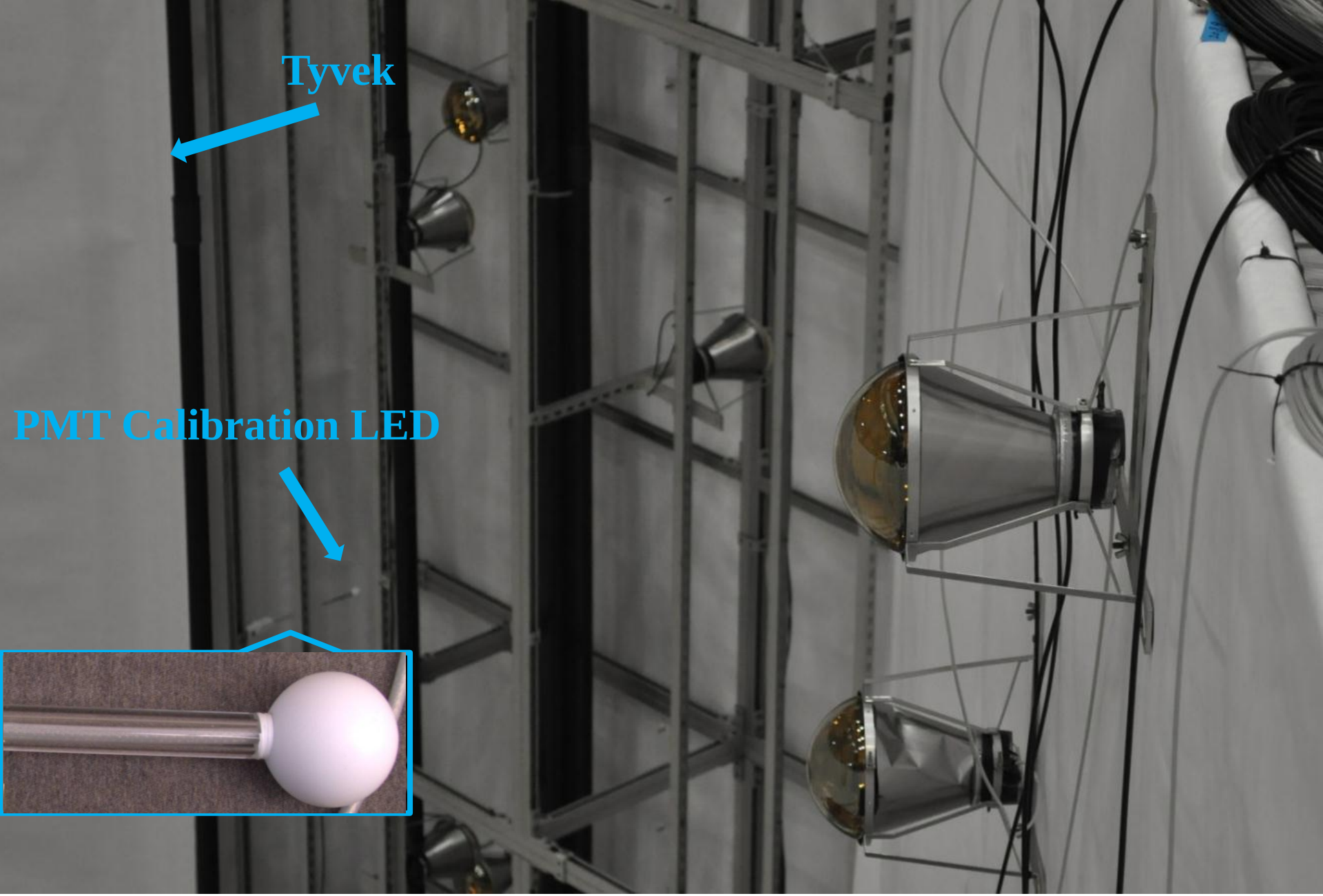


Plan view of far water pool

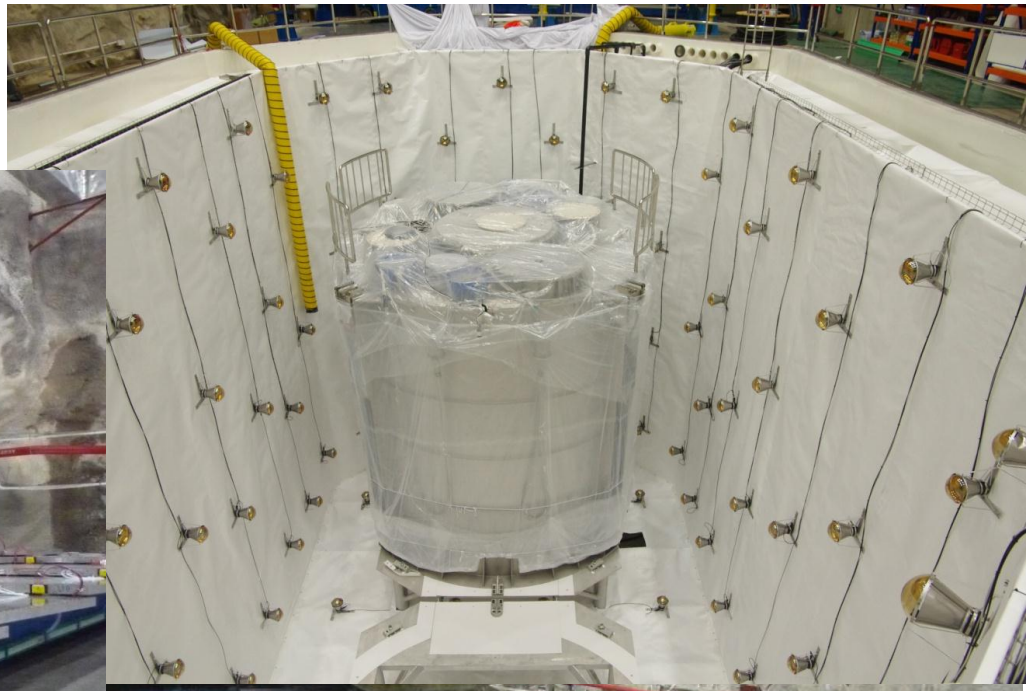
A light tight layer of Tyvek divides the pool into inner and outer zones. This segmentation improves detection efficiency and spatial reconstruction

288 PMTs in each near site
368 PMTs in far site

PMT


Tyvek
PMT Calibration LED

# Installation Status



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# Thank you

# Backup

$$\begin{pmatrix} \nu_e \\ \nu_\mu \\ \nu_\tau \end{pmatrix} = \begin{pmatrix} U_{e1} & U_{e2} & U_{e3} \\ U_{\mu 1} & U_{\mu 2} & U_{\mu 3} \\ U_{\tau 1} & U_{\tau 2} & U_{\tau 3} \end{pmatrix} \begin{pmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \end{pmatrix}$$

With three neutrinos the mixing is governed by the MNS matrix which relates the mass eigenstates ($n_1$, $n_2$ and $n_3$) to the flavor eigenstates.

$$U_{MNS} = \underbrace{\begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\theta_{23} & \sin\theta_{23} \\ 0 & -\sin\theta_{23} & \cos\theta_{23} \end{pmatrix}}_{\text{Atmospheric}} \underbrace{\begin{pmatrix} \cos\theta_{13} & 0 & e^{i\delta}\sin\theta_{13} \\ 0 & 1 & 0 \\ -e^{i\delta}\sin\theta_{13} & 0 & \cos\theta_{13} \end{pmatrix}}_{\text{Reactor}} \underbrace{\begin{pmatrix} \cos\theta_{12} & \sin\theta_{12} & 0 \\ -\sin\theta_{12} & \cos\theta_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix}}_{\text{Solar}} \underbrace{\begin{pmatrix} 1 & 0 & 0 \\ 0 & e^{i\alpha} & 0 \\ 0 & 0 & e^{i\beta} \end{pmatrix}}_{\text{Majorana Phases}}$$

# Daya Bay: Experimental setup

- 8 identical anti-neutrino detectors ( two at each near site and four at the far site) to cross-check detector efficiency
- Two

**Far site**
Overburden: 355 m

**9 different baselines under the assumption of point size reactor cores and detectors**

**Ling Ao Near**
Overburden: 112 m

**Ling Ao II cores (Starting 2011)**

**Ling Ao cores**

**Daya Bay Near**
Overburden: 98 m

**Daya Bay cores**

| Cores \ Halls | Daya Bay Near (m) | Ling Ao Near (m) | Far (m) |
|---|---|---|---|
| Daya Bay | 363 | 1347 | 1985 |
| Ling Ao I | 857 | 481 | 1618 |
| Ling Ao | 1307 | 526 | 1613 |

# Relative measurement & disappearance probability

$$\frac{N_{\mathrm{f}}}{N_{\mathrm{n}}} = \left(\frac{N_{\mathrm{p,f}}}{N_{\mathrm{p,n}}}\right)\left(\frac{L_{\mathrm{n}}}{L_{\mathrm{f}}}\right)^2\left(\frac{\epsilon_{\mathrm{f}}}{\epsilon_{\mathrm{n}}}\right)\left[\frac{P_{\mathrm{sur}}(E, L_{\mathrm{f}})}{P_{\mathrm{sur}}(E, L_{\mathrm{n}})}\right]$$

Ratio of measured event rate from far and near site detectors

Ratio of number of protons in Gd-LS. Obtained by mass flow measurements

Ratio of the detector efficiency Obtained by calibration

Probability ratio determine $\sin^2(2\theta_{13})$