Daya Bay Reactor Neutrino Experiment
On behalf of the DayaBay collaboration

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1 YuenKeung, Hor Virginia Tech. Daya Bay collaboration APS SouthEast meeting 2009
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Physics Goal

Angra, Brazil
Diablo Canyon, USA
Krasnoyarsk, Russia
Double Chooz, France
Daya Bay, China
RENO, Korea

$\sin^2 2\theta_{13} \approx 0.03$
$\sin^2 2\theta_{13} \approx 0.01$

8 proposals
4 cancelled
3 in progress
Physics Goal

Determine $\theta_{13}$ better than any past experiments

$$\left( \begin{array}{ccc}
1 & 0 & 0 \\
0 & \cos \theta_{23} & \sin \theta_{23} \\
0 & -\sin \theta_{23} & \cos \theta_{23}
\end{array} \right) \times \left( \begin{array}{ccc}
\cos \theta_{13} & 0 & e^{-i\delta_{CP}} \sin \theta_{13} \\
0 & 1 & 0 \\
-e^{i\delta_{CP}} \sin \theta_{13} & 0 & \cos \theta_{13}
\end{array} \right) \times \left( \begin{array}{ccc}
\cos \theta_{12} & \sin \theta_{12} & 0 \\
-\sin \theta_{12} & \cos \theta_{12} & 0 \\
0 & 0 & 1
\end{array} \right) \times \left( \begin{array}{ccc}
1 & 0 & 0 \\
0 & e^{i\alpha/2} & 0 \\
0 & 0 & e^{i\alpha/2 + i\beta}
\end{array} \right)$$

$\theta_{23} \sim 45^\circ$
Super K + Accelerator  
+ atmospheric CP-phase + small $\theta_{13}$
DayaBay
Double Chooz

$\theta_{12} \sim 35^\circ$
KamLand + Solar

Neutrinoless double beta decay

PMNS Matrix Parameterization: $\nu_\alpha = \sum_{i=1}^{3} U_{\alpha,i} \nu_i$
Relative measurement & disappearance probability

\[ P_{ee} \approx 1 - \sin^2 2\theta_{13} \sin^2 \left( \frac{\Delta m_{31}^2 L}{4E_\nu} \right) \]

- **near detectors** measure \( \nu_e \) flux and spectrum to reduce reactor-related systematic uncertainties
- **far detector** at the oscillation maximum provides the highest sensitivity
Relative measurement & disappearance probability

\[
\frac{N_f}{N_n} = \left( \frac{N_{p,f}}{N_{p,n}} \right) \left( \frac{L_n}{L_f} \right)^2 \left( \frac{\epsilon_f}{\epsilon_n} \right) \left[ \frac{P_{\text{sur}}(E, L_f)}{P_{\text{sur}}(E, L_n)} \right]
\]

- 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 detector efficiency Obtained by calibration
- Probability ratio determine \(\sin^2 (2\theta_{13})\)

Distance \(L \sim 1.8\ km\)
Baseline & detector design

- Currently running at **11.6 GW**
- One of the top five most powerful by 2011 (17.4 GW)
- Adjacent to mountain, easy to construct tunnels to reach underground labs with sufficient overburden to suppress cosmic rays

**Ling Ao II NPP:**
- **2 × 2.9 GW$_{th}$**
- Ready by 2010-2011

**Ling Ao NPP:**
- **2 × 2.9 GW$_{th}$**

1 GW$_{th}$ generates $2 \times 10^{20}$ $\bar{\nu}_e$ per sec
Deep down the mountain to suppress cosmogenic background.

Deploy identical detectors in all sites to isolate systematic uncertainties.

Optimize baseline distance for disappearance oscillation.
Baseline & detector design

Antineutrino Detector (AD)

- Automatic calibration system
- Top and bottom reflectors
- 192 8” PMTs
- Three-zone design:
  - Gd-doped LS, 20 tons
  - Inner acrylic vessel
  - LS as Gamma Catcher, 20 tons
  - Outer acrylic vessel
  - Mineral oil as buffer, 40 tons
  - Stainless steel tank
Baseline & detector design

Muon tagging
Shielding of background radiation
RPC as muon veto on top of water Cherenkov

2.5m water shield

Resistive plate chambers (RPC)

8” PMTs

289 PMTs in near site
384 PMTs in far site
Sensitivity

\[ \Delta m^2(\times 10^{-3} \text{eV}^2) \]

- **Chooz**
- **Daya Bay 3 y**

**Rapid convergence**

\[ \Delta m_{31}^2 = 2.5 \times 10^{-3} \text{eV}^2 \]

**Goal**

\[ \sin^2 2\theta_{13} < 0.008 \text{ @ } 90\% \text{ CL} \]

after 3 years of data taking
Sensitivity

Sensitivity Comparison

\[ \sin^2 2\theta_{13} < 0.008 \ @ \ 90\% \ CL \]

after 3 years of data taking

Current status, schedule and dates

- CD-0 (DOE Mission Need): 11/2005
- Daya Bay proposed at OHEP Briefing 4/2006
- Successful Physics Review 10/16/06
- CD-1 site selection approved 9/2007
- Groundbreaking for civil construction 10/2007
- CD-2 & 3a Baseline approved 3/2008
- CD-3b Construction start 8/2008
- Occupancy of SAB 3/2009

- Occupancy of first underground halls, 2009
- Expected start of first operations, 2010
- Full operations start, 2011
Current status, schedule and dates
Current status, schedule and dates

- LS Hall is ready
- Near Hall #1 will be ready in Nov 2009

Red indicates current construction progress.
DayaBay experiment is the most sensitive $\theta_{13}$ experiment under construction

Specifically designed to achieve the sensitivity of $\sin^2 (2\theta_{13})$ down to 0.01 (goal) at 90% C.L. and 0.008 (projected) in three years of data taking

It is now on track to take initial data in the next year and become fully operational in 2 years
The End

Thank You
<table>
<thead>
<tr>
<th>Source of uncertainty</th>
<th>Chooz (absolute)</th>
<th>Daya Bay (relative)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Baseline</td>
</tr>
<tr>
<td># protons</td>
<td>0.8</td>
<td>0.3</td>
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<tr>
<td>Detector Efficiency</td>
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<tr>
<td>Energy cuts</td>
<td>0.8</td>
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<td>Position cuts</td>
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<td>H/Gd ratio</td>
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<tr>
<td>n multiplicity</td>
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<td>0.05</td>
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<tr>
<td>Trigger</td>
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<td>0.01</td>
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<td>Live time</td>
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<td>&lt;0.01</td>
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<tr>
<td>Total detector-related uncertainty</td>
<td>1.7%</td>
<td>0.38%</td>
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</tbody>
</table>
Accidental coincidence:

- Natural radioactivity
- Neutrons from cosmic muons

Correlated events:

- Fast neutron capture + recoil proton
- Beta + neutron decay from Helium & Lithium
Energy spectrum of two processes in inverse-beta decay

\[ \nu_e + p \rightarrow e^+ + n \text{ (prompt)} \]

- 0.3 barn

\[ \rightarrow + p \rightarrow D + \gamma(2.2 \text{ MeV}) \text{ (delayed)} \]

- 50,000 barn

\[ \rightarrow + Gd \rightarrow Gd^* \rightarrow Gd + \gamma's(8 \text{ MeV}) \text{ (delayed)} \]