The Daya Bay Neutrino Experiment

Search for the disappearance of anti-electron neutrinos from a reactor to measure the mixing angle \( \theta_{13} \)

\[ P_{\bar{\nu}_e} \approx \sin^2 \theta_{13} \sin^2(1.27 \Delta m^2 \cdot L/E) \]

The Daya Bay experiment is located at the Daya Bay Nuclear Power Plant (Fig. 1) in Shenzhen, China. The experiment deploys eight identical antineutrino-detectors (AD) to detect antineutrinos from six 2.9 GW reactor cores, in three underground experimental halls at different distances as shown in Fig. 2. The target zone of each AD is filled with 20 tons of 0.1% Gd-doped liquid scintillator.

**Signal event: Inverse \( \beta \)-decay**

\[ \bar{\nu}_e + p \rightarrow e^+ + n \]

Prompt positron + delayed neutron capture

The main background to this measurement are induced by cosmic-ray muons.

<table>
<thead>
<tr>
<th>Overburden (m)</th>
<th>Daya Bay</th>
<th>Ling Ao</th>
<th>Far</th>
</tr>
</thead>
<tbody>
<tr>
<td>Muon Flux (Hz/m²)</td>
<td>1.16</td>
<td>0.73</td>
<td>0.041</td>
</tr>
<tr>
<td>( \mu ) Mean Energy (GeV)</td>
<td>50</td>
<td>60</td>
<td>138</td>
</tr>
</tbody>
</table>

Backgrounds produced by cosmic-ray muons
1) \( ^{13} \)\(^{6} \)\(^{4} \)\(^{0} \) Li: significant \( \beta \)-neutron emission decay branching -- Br(Li)~50%, Br(\(^{6} \)\(^{4} \)\(^{0} \) He)~16%, (cf. lifetime \(^{6} \)\(^{4} \)\(^{0} \) Li 0.18 sec, \(^{6} \)\(^{4} \)\(^{0} \) He 0.16 sec)
2) Fast neutrons: recoil proton gives prompt signal followed by neutron capture
3) Accidental: coincidence of neutron capture with natural radioactivity in the detector

**Expected Signal and Background rates**

<table>
<thead>
<tr>
<th>Background (rate/day/module)</th>
<th>DB</th>
<th>LA</th>
<th>Far</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antineutrino rate (day/module)</td>
<td>846</td>
<td>746</td>
<td>98</td>
</tr>
<tr>
<td>Natural radiation (Hz)</td>
<td>&lt;50</td>
<td>&lt;50</td>
<td>&lt;50</td>
</tr>
<tr>
<td>Single neutron (day/module)</td>
<td>15</td>
<td>12</td>
<td>15</td>
</tr>
<tr>
<td>( \beta )-emission isotopes (day/module)</td>
<td>210</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>Accidental/Signal</td>
<td>0.2%</td>
<td>0.2%</td>
<td>0.1%</td>
</tr>
<tr>
<td>Fast Neutron/Signal</td>
<td>1.5%</td>
<td>0.3%</td>
<td>0.4%</td>
</tr>
<tr>
<td>UTD/Signal</td>
<td>0.3%</td>
<td>0.2%</td>
<td>0.1%</td>
</tr>
</tbody>
</table>

**Water Cherenkov Detector**

Water pool surrounding the antineutrino detector
- The muon water pools (water Cherenkov detectors) are divided into inner and outer zones by reflective Tyvek sheets to increase the light yield in the water pools (shown in Fig. 9)
- The detector instrumented with 960 8-inch PMTs (Fig. 10), coverage of 0.8%
- 288 PMTs at Daya Bay/Ling Ao, 384 PMTs at Far
- The combined muon detection efficiencies from the inner and outer pools 98.8%
- Water Cherenkov + RPC combined \( \mu \) detection efficiency: 99.5%
- Calibration system consisting of LED enclosed in Teflon diffuser ball to monitor water quality (e.g. light attenuation), PMT gains and timing.

**Status of AD and Muon System**

- • Completed civil construction for Daya Bay near hall
- • The first AD assembled, and “Dry” detector test running
- • RPC support structure installation
- • Water Cherenkov detector PMT installation
- Schedule:
  - Spring 2011: Daya Bay near detector physics ready
  - Autumn 2012: all far site detectors physics ready

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**The Muon Veto System**

Water Cherenkov detector with RPCs

The Daya Bay muon veto system (Fig. 3 and Fig. 4) is a dual tagging system with multiple layers of resistive plate chambers (RPCs) on top of the water pool and water Cherenkov detector surrounding AD.

**Resistive Plate Chamber (RPC)**

4 layers of RPC (6 mm thick) in each modules
- RPC detectors cover the water pools (Fig. 7).
- Each module has four 2m x 2m layers of RPCs, each consisting of two bare chambers (Fig. 8). There are a total of 81 modules in the far hall and 56 each in the near halls.
- Non-flammable gas mixture of Ar/R134A/Isobutane/SF6 (65.5/30/4/0.5).
- \( \pm 8 \text{kV} \) voltage gap
- A muon is characterized by hitting 3 out of 4 RPC layer in a module and the efficiency of each layer is 98.6%.

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