Search for $\theta_{13}$ at the Daya Bay Reactor Neutrino Experiment
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The neutrino mixing (MNS) matrix
- The MNS matrix relates the mass eigenstates ($\nu_1$, $\nu_2$, and $\nu_3$) to the flavor eigenstates ($\nu_e$, $\nu_s$, and $\nu_x$).
- It can be described by three 2D relations:
  - $U_{\nu_{1e}}^2 = \frac{1}{2} (1 - \sin^2 \theta_{13})$
  - $U_{\nu_{2e}}^2 = \sin^2 \theta_{13} - \sin^2 \theta_{23}$
  - $U_{\nu_{3e}}^2 = 1 - U_{\nu_{1e}}^2 - U_{\nu_{2e}}^2$
- If $\sin^2 \theta_{13}$ is zero, there is no CP violation in neutrino mixing.

Existing limit on $\theta_{13}$

Measuring $\theta_{13}$ with reactor antineutrinos
- Reactor anti-neutrinos survival probability:
  - $P_{\nu_e} = \sin^2 2\theta_{13} \sin^2 \frac{1}{2} \Delta m_{31}^2 L^2 / E$.

Nuclear reactors as antineutrino source
- Fusion process in nuclear reactor produces huge number of low-energy antineutrinos.
- A typical commercial reactor, with 3 GW thermal power, produces $6 \times 10^{20} E^0_{\nu_e}$.
- Daya Bay reactors produce 11.6 GW, now 17.4 GW, in 2011.
- The observable antineutrino spectrum is the product of the flux and the cross section.

GdLS stability in 4-ton test batch production
- Daya Bay experiment uses 200 ton 0.1% gadolinium-loaded liquid scintillator (GdLS).

Antineutrino Detector (AD)
- Three-zone cylindrical design:
  - Target: 20 ton 0.1% Gd-loaded liquid scintillator (GdLS)
  - Gamma catcher: 20 ton LS
  - Buffer: 40 ton (mineral oil)
- 192 low-background $\beta^+$ PMTs
- Reflectors at top and bottom
- AD sits in a pool of ultra-pure water

Site preparation

Muon veto system

Fabrication and delivery of detector components
- GdLS will be produced in multiple batches but mixed in reservoir on-site, to ensure identical detectors.

Antineutrino event signature in AD
- Two peak consistence is crucial for background reduction.
- Neutron capture on Gd provides a secondary burst of light approximately 10 $\mu$s later.

Signal, background and systematic uncertainties
- Daya Bay sensitivity to $\sin^2 2\theta_{13}$
  - 2002 start detector with $3\times$ experiment nominal running period 5 years