The measurement of ϑ_{13} in Double Chooz

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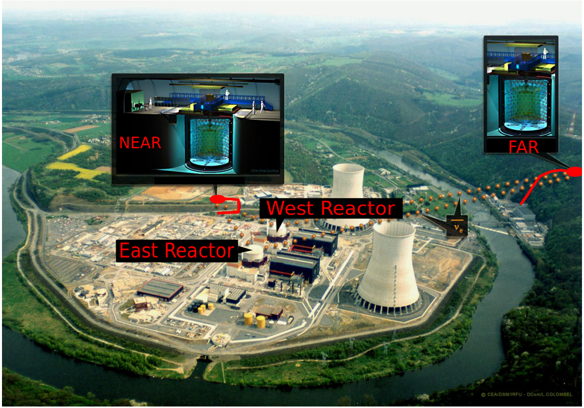
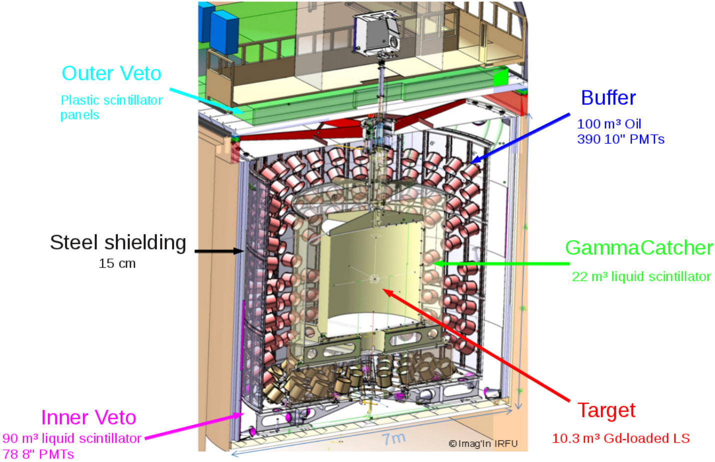
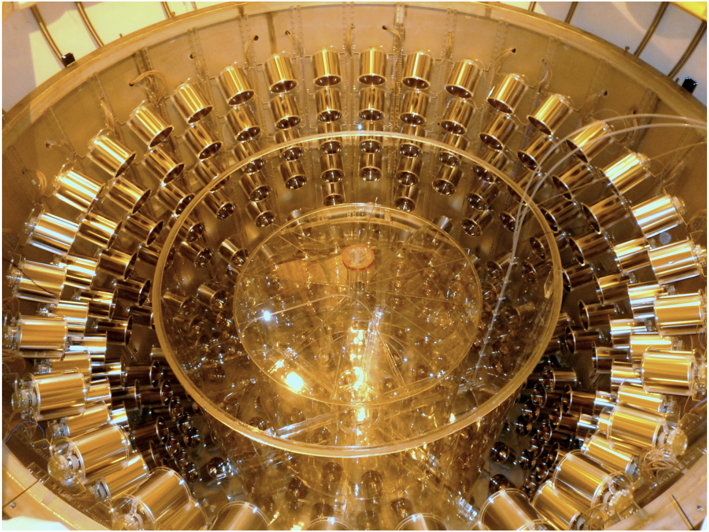
The Double Chooz Detector: Detector Site



The Double Chooz Detector: Cross Section



The Double Chooz Detector



Neutrino Detection: Inverse Beta Decay

Inverse Beta Decay

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

- Energy threshold: 1.8 MeV

$\Rightarrow$ $E_\nu = E_{vis} + 0.8\,\text{MeV}$

- Subsequent thermalization and capture of the neutron

Neutron Capture

$$n + Gd \rightarrow Gd^* \rightarrow Gd + \sum_i \gamma_i$$

$\Rightarrow$ Clear event signature

Neutrino Detection: Possible backgrounds

Correlated background

- Fast neutrons, especially after spallation reactions of untagged muons
- β-n-emitting cosmogenic isotopes like ^{9}Li or ^{8}He produced by muons in the scintillator
- Stopped muons entering the detector through the chimney
- (α,n)-reactions in the liquid scintillator

Accidental background

- Accidental coincidences between a positron-like prompt event and a neutron-like delayed event, which are correlated in space and time

Trigger rate and event classes

Far detector trigger rate: $\sim$120 Hz

- Instrumental light: PMT bases sporadically glowing ($\sim$60 Hz)
- Cosmic muons: $\sim$46 Hz
- Singles: mainly radioactivity ($\sim$10 Hz)
- Antineutrinos: $\sim 45\,\mathrm{d}^{-1}$

Used cuts for antineutrino search (I)

- Prompt signal:
  - **Instrumental light:** MQTQ < 0.09 && RMS(T_s) < 40 ns
- Delayed signal:
  - **Instrumental light:** MQTQ < 0.06 && RMS(T_s) < 40 ns

Used cuts for antineutrino search (I)

- Prompt signal:
  - **Instrumental light:** MQTQ < 0.09 && RMS(T_s) $< 40\,$ns
  - **Muon cut:** time difference to closest muon $> 1000\,\mu$s
- Delayed signal:
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Used cuts for antineutrino search (II)

- Prompt signal:
  - **Instrumental light:** MQTQ < 0.09 && $\mathrm{RMS}(T_s) < 40\,\mathrm{ns}$
  - **Muon cut:** time difference to closest muon $> 1000\,\mu\mathrm{s}$
  - **Energy cut:** $0.7\,\mathrm{MeV} < E < 12.2\,\mathrm{MeV}$
- Delayed signal:
  - **Instrumental light:** MQTQ < 0.06 && $\mathrm{RMS}(T_s) < 40\,\mathrm{ns}$
  - **Muon cut:** time difference to closest muon $> 1000\,\mu\mathrm{s}$
  - **Energy cut:** $6.0\,\mathrm{MeV} < E < 12.0\,\mathrm{MeV}$
  - **Time cut:** $2\,\mu\mathrm{s} < \Delta t < 100\,\mu\mathrm{s}$
  - **Multiplicity cut:** No additional valid trigger in a time window [-100 μs, 400 μs] around the prompt event.
  - **No spatial cut**

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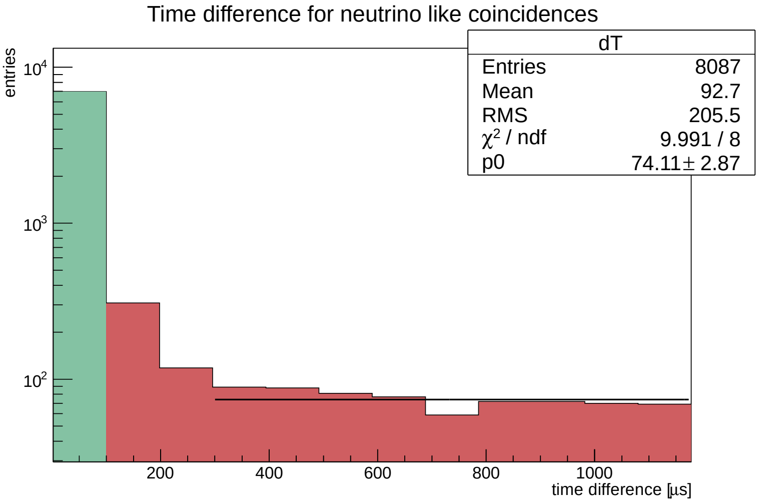
Estimation of accidental background



(design goal: <1 event per day)

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$\Rightarrow$ In total $(3.46 \pm 1.26)\,\mathrm{d}^{-1}$ background events; confirmed with one day reactor off-off data (3 events found)

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- Systematic error: 2.1% detector + 1.8% reactor

$\Rightarrow$ No oscillation hypothesis excluded at 94.6% (for $\Delta m^2 = 2.4{\cdot}10^{-3}\,\mathrm{eV}^2$)

The mixing angle ϑ_{13}

Rate analysis

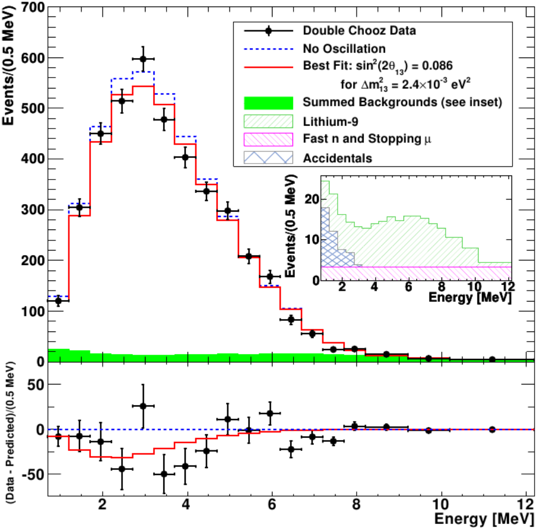
$$\sin^2(2\vartheta_{13}) = 0.104 \pm 0.030(stat) \pm 0.076(syst)$$

Rate + shape analysis

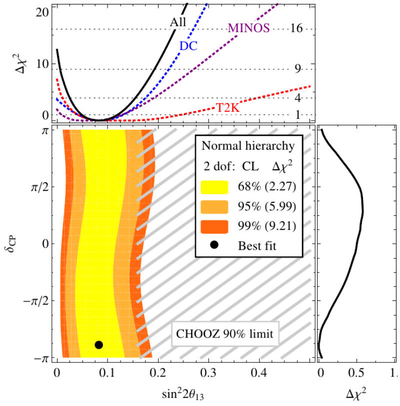
$$\sin^2(2\vartheta_{13}) = 0.086 \pm 0.041(stat) \pm 0.030(syst)$$

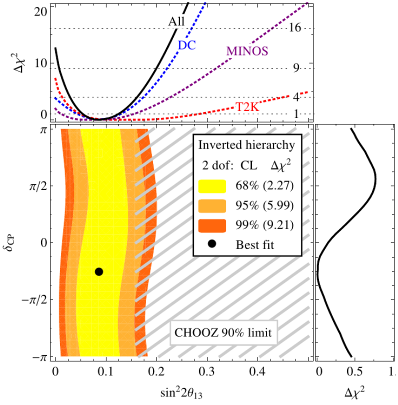
Y. Abe et al. PRL 108, 131801 (2012)

Spectral analysis



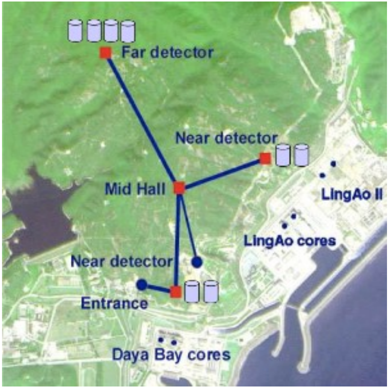
Combined analysis





P.A.N. Machado et al. arXiv:1111.3330v2

Daya Bay


Far detector
Near detector
Mid Hall
LingAo II
LingAo cores
Near detector
Entrance
Daya Bay cores

RENO

Reactor neutrino experiments

Daya Bay (rate only)

$$\sin^2(2\vartheta_{13}) = 0.092 \pm 0.016(stat) \pm 0.005(syst)$$

F.P. An et al. PRL 108, 171803 (2012)

RENO (rate only)

$$\sin^2(2\vartheta_{13}) = 0.113 \pm 0.013(stat) \pm 0.019(syst)$$

S.-B. Kim et al. arXiv:1204.0626v2

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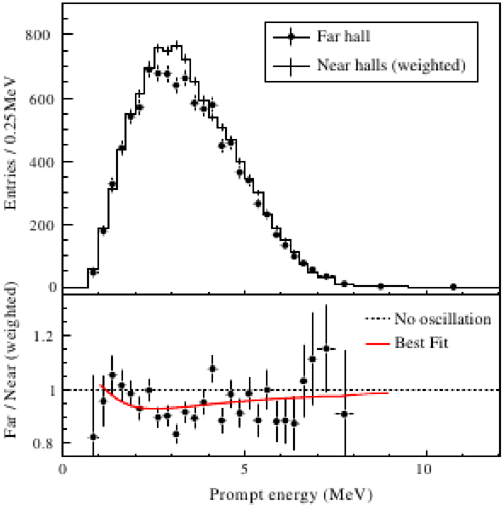
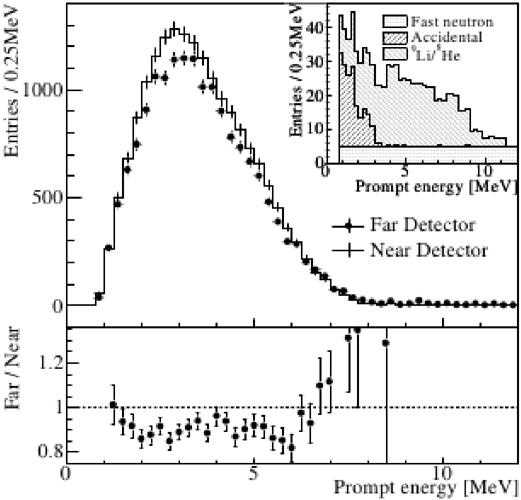
Backup Slides

Daya Bay results



RENO results



Neutrino Detection: Event signature