Double Chooz Experiment Status

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Double Chooz Collaboration

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Web Site: www.doublechooz.org/
Outline

• Neutrino detection and $\theta_{13}$ measurement

• Overview of the Double Chooz detector

• DC far preliminary data

• Antineutrino anomaly and consequences for Double Chooz

• Summary and outlook
NEUTRINO DETECTION AND $\theta_{13}$ MEASUREMENT
Reactor Neutrino Detection Signature

- Reactors as neutrino sources:
  \[ N_\nu (s^{-1}) = 6 N_{\text{Fiss}} (s^{-1}) \approx 2 \times 10^{11} P (s^{-1}) \]

Chooz: \( P = 2 \times 4.25 \text{ GW}_{\text{th}} \Rightarrow N_\nu \sim 2 \times 10^{21} \text{s}^{-1} \)

Neutrino detection via inverse \( \beta \) decay

Target:
- Gd doped scintillator

1 g/l Gd in LS

Distinctive two-step signature:
- **prompt event**
  - Photons from \( e^+ \) annihilation
  - \( E_{e} = E_\nu + 0.8 \text{ MeV} + O(E_{e}/m_n) \)

- **delayed event**
  - Photons from \( n \) capture on dedicated nuclei (Gd)
  - \( \Delta t \sim 30 \mu s \quad E \sim 8 \text{ MeV} \)
Site in French Ardennes

300 mwe Hill topology

Started 12/10

Physics data taking 04/11

1115 m

998 m

351 m

465 m

115 mwe Flat topology

Start in early 2013

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The - New – Concept – 2 detectors

\[ P(\nu_e \rightarrow \nu_e) = 1 - \sin^2(2\theta_{13}) \sin^2(\Delta m^2_{31} L/4E) \]

![Survival probability for 3 MeV \(\nu_e\)](image)

- \(\Delta m^2_{13} = 2.4 \times 10^{-3}\)
- \(\theta_{13} = 9.6^\circ\)
- \(E = 3\) MeV

**Background reduction and calibration are very important**

- \(E = 1\text{-}8\) MeV
- Pure \(\nu_e\) flux

Nuclear Power Station

\(-\) \(\nu_e\)

400 m

Near detector

\(-\) \(\nu_{e,\mu,\tau}\)

Far detector

\(1050\) m

Far to near detector signal ratio will give information about \(\theta_{13}\)
Expected Neutrino Oscillation Signal

Two independent sets of information: Normalisation + Spectrum distortion

\[ \sin^2(2\theta_{13}) = 0.04 \]
\[ \sin^2(2\theta_{13}) = 0.1 \]
\[ \sin^2(2\theta_{13}) = 0.2 \]

Far Detector: ~
40 000 events/3y
- Reactor efficiency: 80%
- Detector efficiency: 80%

Near Detector: ~ 5 \times 10^5 events/3y
- Reactor efficiency: 80%
- Detector efficiency: 80%
- Dead time: 50%

\[ \Delta m^2_{atm} = 3.0 \times 10^{-3} \text{ eV}^2 \]

arXiv: hep-ex/0606025v4

J. Maricic - Double Chooz
Overview if the Double Chooz detector

4 concentric vessels

Neutrino target vessel in the center

http://doublechooz.in2p3.fr/

Courtesy of T. Lasserre
The detector design

Near and far detectors are IDENTICAL.

Muon Outer-VETO:

- **ν-target**: 80% dodecane + 20% PXE + 0.1% Gd
  - Volume for ν-interaction (d = 2.3 m, h = 2.8 m)
- **γ-catcher**: 80% dodecane + 20% PXE
  - Extra-volume for ν-interaction

Acrylic vessels ➔ «hardware» definition of fiducial volume

Muon Inner-VETO: scintillating oil (78 8” PMTs)

Non-scintillating buffer: same liquid
  - Isolate PMTs from target

Shielding: steel 17 cm: >7λ(γ).
  ➔ Improved background reduction

PMT support structure: steel tank, optical insulation target/veto area (390 10” PMTs)

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Inner Detector
Inner Detector Lid
Background in Double Chooz

**Accidental bkg:**
- $e^+$-like signal: radioactivity from materials, PMTs, surrounding rock
  
  **Rate** = $R_e$
- n signal: n from cosmic $\mu$ spallation, thermalized in detector and captured on Gd ($R_n$)

  ⇒ Accidental coincidence
  
  **Rate** = $R_e \times R_n \times \Delta t$

**Correlated bkg:**
- fast n (by cosmic $\mu$) recoil on p (low energy) and captured on Gd
- long-lived ($^9\text{Li}$, $^8\text{He}$) $\beta$-decaying isotopes induced by $\mu$
CHOZ had a 1.6% absolute detector systematic uncertainty, the best to date. Total uncertainty 2.7%.

Bugey is the only experiment that has tried to build identical detectors. Result was 2.0% relative error. 5.0% total.

**Double Chooz goal is 0.6% relative uncertainty and less than 0.6% total.**

**Calibration sources:**
- Natural H n-capture peak
- Radioactive sources
- Laser and LED system

**Deployed in NT and GC:**

$^{137}\text{Cs}, \quad ^{60}\text{Co}, \quad ^{68}\text{Ge}, \quad ^{252}\text{Cf}$
Calibration - $^{68}$Ge in the guide tube

Example of calibration data: $^{68}$Ge in the guide tube.

Monte Carlo tuning is ongoing.
DC FAR PRELIMINARY PHYSICS DATA
Data Taking

- Data taking with far detector started on April 13, 2011
- >100 days physics data
- Trigger rate ~120 Hz
- Trigger threshold < 0.6 MeV
- 75% physics runs
- 10% calibration runs
Muons: rate and coincidence

- Inner veto 39 Hz
- Inner detector 11 Hz

- Michel electrons from stopped muons:
  - $\tau = 2.25 \pm 0.13 \, \mu s$

$\Delta t = \text{time between 2 muons in ms}$

$T_{ID} - T_{OD} = \Delta t = \text{time in } \mu s$
Muon correlated events

- $H \sim 2.2$ MeV
- $C \sim 3-5$ MeV
- $Gd \sim 8$ MeV
- Energy calibration is ongoing

Preliminary

![Graph showing PMT charge sum (a.u.) vs. events with peaks labeled H, C, Gd.](image)
Muon correlated neutron capture on H

- Muon correlated neutron capture in hydrogen energy window
- 1.9 – 2.5 MeV
Neutrino candidates selection

1) Apply muon veto cut $\sim 1$ ms
2) Prompt energy window 0.7 – 12 MeV
    - singles rate $\sim 10$ Hz
3) Delayed energy window 6 – 12 MeV
    - singles rate $\sim 0.1$ Hz
4) Coincidence window $\sim 100$ $\mu$s

Result: neutrino candidates (neutrinos + bkg)
Time and Space Distribution

- Timing distribution between prompt and delayed signal in Gd energy window (6-12 MeV) $\rightarrow \tau \sim 30 \mu s$.

- Spatial distribution between prompt and delayed signal – between 20-30 cm is expected.
Energy spectrum in delayed Gd window

- Energy distribution of delayed signals in the Gd energy window (6-12 MeV) → peak ~ 8.3 MeV
Position Reconstruction of neutrino candidates – delayed signal vertex

Detector top view

Gamma catcher

Detector side view
Daily Neutrino Rate

IBD Candidate Rate

1 reactor off data

~4000 neutrino candidates in 3 months → already exceeds CHOOZ statistics
Summary and Outlook

- Double Chooz is detecting neutrinos
- Backgrounds are low
- We will use Bugey-4 c-s for normalization
- Data analysis in progress
- T2K best fit will be addresses with this data set