Neutrino Experiment for Oscillation at Short Baseline

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for the NEOS collaboration
Reactor neutrino experiments

more...
Motivation — anomalies

\begin{itemize}
  \item LSND (2001)
  \item MiniBooNE (2013)
  \item Gallex/SAGE (2009)
  \item Mention (2011)
  \item Garziazzo (2016)
\end{itemize}

\textbf{\~{}1 \text{eV} sterile neutrino}

\textbf{white paper (2012)}
NEOS Sensitivity to 3+1 ν oscillation

\[ P(\bar{\nu}_e \rightarrow \bar{\nu}_e) \sim 1 - \sin^2 2\theta_{14} \sin^2 \left( 1.27 \frac{\Delta m^2 L}{E_\nu} \left[ \frac{\text{eV}^2 \cdot \text{m}}{\text{MeV}} \right] \right) \]

washed out by:

- **Baseline**
  size of reactor, detector
- **Detector**
  neutrino → prompt energy
- **Uncertainties in model**
  bin-to-bin (un)correlated
- **Statistics, background, …**

Single detector experiment:
- a decent model spectrum,
- detector simulation

Data / MC (3ν)

*illustration*

- 1
- Antineutrino energy (MeV)
- 1.8
- 10
- ≈1.0
- Reconstructed prompt energy (MeV)
- 10

\[ \sin^2 2\theta \]

\[ \Delta m^2 \]

- *RAA allowed*
- 90% CL
- 95% CL
- 99% CL

Detector Sensitivity
95% CL. (NEOS)
Experimental site

- Hanbit-5 reactor in Yeonggwang (霊光, ghost illumination), Korea
- Distance between neighboring reactor cores: 256 m
- Same reactor complex being used for the RENO experiment
Hanbit-5 reactor and tendon gallery

- OPR-1000, Thermal power: 2.8 GW
- Active core size: $\Phi 3.1$ m, H 3.8 m
- 177 fuel rods, 1/3 changes after a cycle
- LEU fuel: $\sim 4.x\%$ U-235 enrichment
- Detector-core distance: 23.7 m
- Overburden > 20 m.w.e.
Detector design & construction

- Simple / compact / homogeneous.
  - efficiency, energy resolution.
- 1000L of 0.5% Gd loaded LS.
- 2 x 19 8-inch PMTs.
- No γ-catcher buffer layer.
- LAB:UG-F = 9:1 for PSD.
- Source calibration through chimney.
- FADC 500 MS/s for waveform analysis
Detector responses & simulation

PSD

Non-uniformity

Quenching

Escaping γ’s

3d calibration

Non-linearity

α

β/γ

Cherenkov

Charge [pC]

Entries (/3 pC)

Data

Simulation

NEOS Preliminary

Co at radial border

60Co: 2.505 MeV

Work in progress

n-H capture: 2.223 MeV

212Po: 8.955 MeV

137Cs: 0.662 MeV

214Po: 7.833 MeV

239Po: 6.115 MeV

NEOS Preliminary

Co at Z-48cm

60Co at center

α

β

γ

cherenkov

Work in progress

PSD

Non-uniformity

Quenching

Escaping γ’s

3d calibration

Non-linearity

α

β

γ

cherenkov
Prompt energy spectrum

- 1976 IBD candidates/day (on), 85 /day (off); S/N~23.
- Negligible background change between on-off periods.
- Spectral anomaly observed (vs Huber-Mueller normalization).
- Small structural fluctuations.
- Reference spectra generated using detector response matrix, - energy escape due to detector size
Active-to-sterile oscillation

- Normalized with the Daya Bay shape
- Best fits at:
  $(1.73 \text{ eV}^2, 0.05), (1.30 \text{ eV}^2, 0.04)$
  with $\chi^2(3\nu)-\chi^2(4\nu) = 6.5$, $p$-value = 0.22
- Not a definitive answer for $3+1\nu$ oscillation or fine structures in reactor $\nu$ spectrum.

![Graph showing active-to-sterile oscillation results](image)
Recent Issues

“… sterile neutrino models fail to simultaneously account for all the $\nu_e \rightarrow \nu_e$ data, the $\nu_\mu \rightarrow \nu_e$ data and the $\nu_\mu \rightarrow \nu_\mu$ data. This conclusion is robust;” Maltoni @ v2018

+ fine structures in the flux spectrum > requires high resolution detector?
NEOS phase-II measurement

- Starts in September 2018:
  - one full burnup cycle (~500 days),
  - plus two maintenance (off) periods (>100 days, contributions from spent fuels?)
  - expecting ~1 M IBD events.
  - same reactor, same detector.

- Spectrum evolution with fuel component changes.
  - from a single LEU core,
  - absolute spectrum measurement,
  - decomposing spectra for different elements.
Detector refurbishment and preparation

- To make more stable detector for longer data taking.
- Producing fresh Gd-LS and its QC.
- Upgrading slow control/monitoring system - temperature / PMT gain.
- MC simulation upgrade, e.g. GEANT4 versions, n-Gd data.
Summary

• IBD prompt energy spectral shape has been successfully measured, using 2.8 GWt commercial reactor at 24 m distance.

• No strong sign of active-to-sterile neutrino oscillation for $\Delta m^2 \sim 1 \text{ eV}^2$, $\sin^2 2\theta \sim 0.1$.

• Similar spectral anomaly observed as mid-baseline experiments.

• Measurement will be resumed soon to see the evolution of the reactor neutrino flux/spectrum according to the fuel component changes.

Thank you.
B1. Recent limits

- NEOS 90%
- DANSS 90% (preliminary)
- PROSPECT 95% (33 days)
- STEREO 90% (66 days)