Joint Search for Light Sterile Neutrino Oscillations by PROSPECT, STEREO, and Daya Bay

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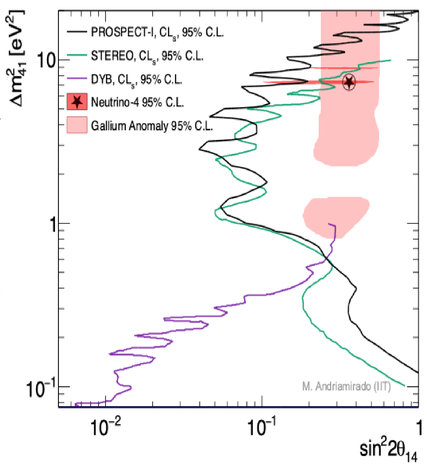
PHYSICS MOTIVATION

The Reactor-Gallium Tension

- Early reactor measurements showed a ~6% deficit in $\bar{\nu}e$, dubbed the "Reactor Antineutrino Anomaly."
- Updated flux predictions have since absorbed most of this deficit, leaving only a few percent of unexplained disappearance in reactor data.
- Gallium source experiments (GALLEX, SAGE, BEST), however, still see disappearance exceeding 10% at comparable baselines.

Open Questions

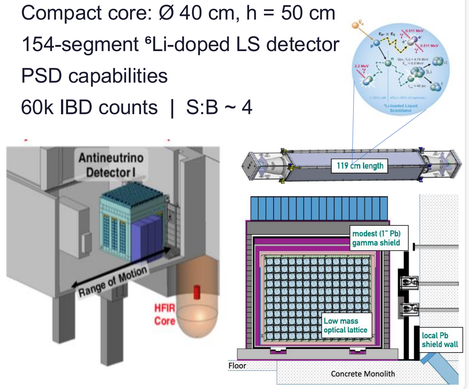
- Can a single sterile neutrino explain the Gallium anomaly without violating tighter reactor constraints? Daya Bay, PROSPECT, and STEREO each individually find results consistent with the null hypothesis. A joint search combining all three achieves greater sensitivity than any one alone.



THE THREE EXPERIMENTS

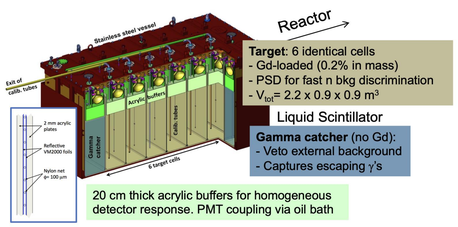
PROSPECT — *HFIR, Oak Ridge, USA*

- 85 MWth HEU reactor (>99% ^{235}U)
- Compact core: Ø 40 cm, h = 50 cm
- 154-segment ^{6}Li-doped LS detector
- PSD capabilities
- 60k IBD counts | S:B ~ 4



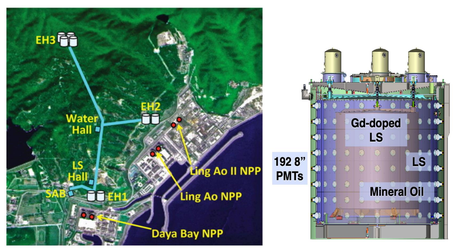
STEREO — *ILL, Grenoble, France*

- 58 MWth HEU reactor (>99% ^{235}U)
- Compact core: Ø 40 cm, h = 80 cm
- 6-cell Gd-doped LS detector
- PSD capabilities
- ~107k IBD counts | S:B ~ 1



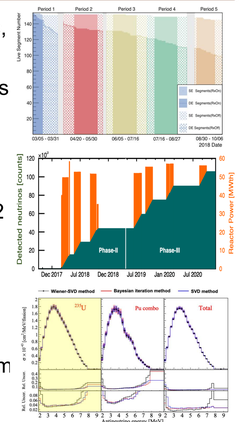
Daya Bay — *Daya Bay, China*

- 6 × 2.9 GWth LEU reactors
- Evolving fuel mixture
- 8 detectors, 20 kL fiducial volume
- Baseline: 360–1900 m | Gd-LS
- 5.55 × 10^{6} IBD counts | bg/sig < 2%



Analysis inputs

- PROSPECT: 5 periods, 6 baseline bins [6.94–8.94 m], 33 energy bins [0.8–7.4 MeV]
- STEREO: 2 periods, 6 baseline bins [9.4–11.2 m], 11 energy bins [1.62-7.12 MeV]
- Daya Bay: 1 unfolded ^{235}U reference spectrum (antineutrino space)



ANALYSIS METHOD

Joint CNP Multi-Period Framework

PROSPECT's covariance-based framework is extended to incorporate STEREO and Daya Bay data simultaneously.

Method 1 — Relative shape (PROSPECT + STEREO)

$\chi^2_{rel} = \Delta^T V^{-1}_{rel} \Delta, \quad \Delta_{l,e} = M_{l,e} - P_{l,e}\,(M_e/P_e)$

- Model-independent: no absolute flux assumption.

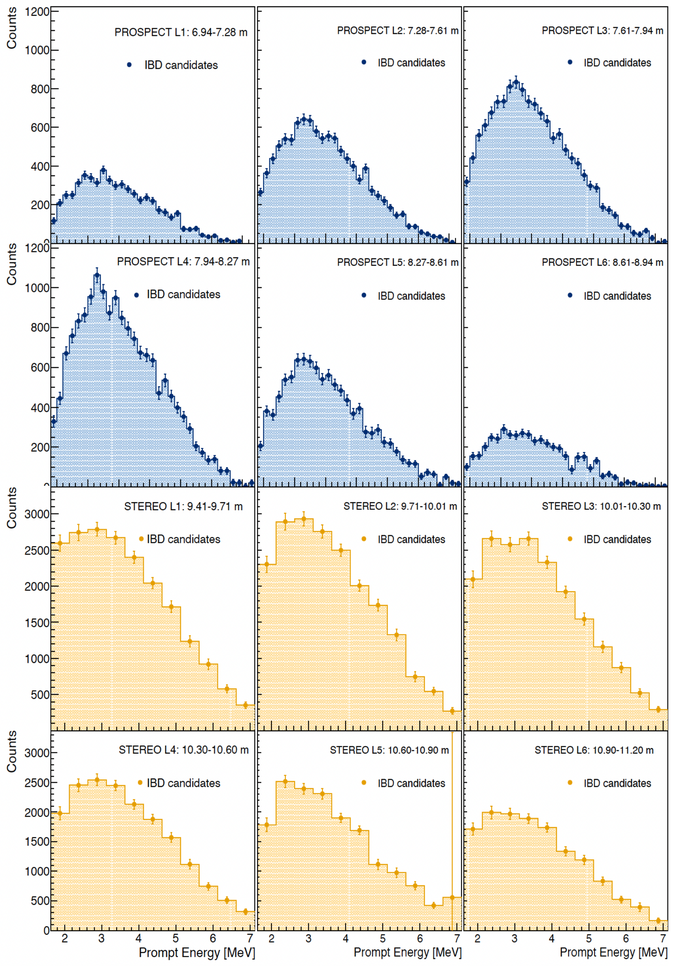
Method 2 — Absolute shape (+ Daya Bay)

$\chi^2_{abs} = \delta^T V^{-1}_{abs}\,\delta, \quad \delta_{l,e} = M_{l,e} - P_{l,e}$

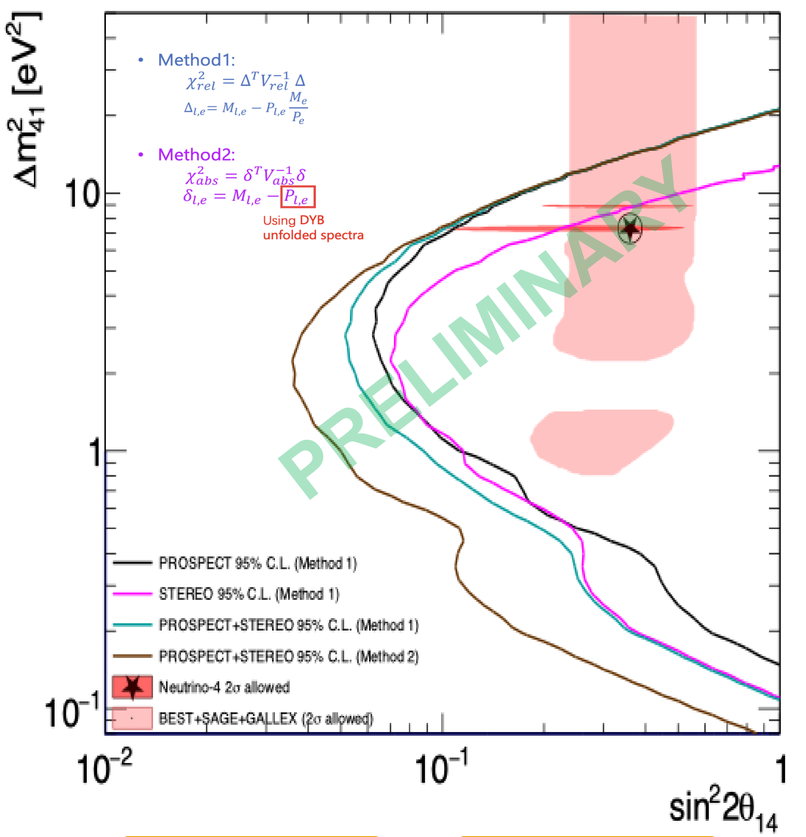
- Incorporates DYB's unfolded ^{235}U spectrum — improves sensitivity at $\Delta m^2_{41} < 10^{-1}$ eV².

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

- Spectral distortions are searched for across detector baseline bins.



MEDIAN SENSITIVITY PROJECTIONS



PROS+STE joint exclusion improved vs. individual experiments

Δm^2_{41} below 10 eV² largest gain with Daya Bay

SUMMARY

1. **New joint oscillation framework**
   PROSPECT's CNP multi-period framework has been extended to incorporate inputs from STEREO and Daya Bay, enabling the first combined short-baseline sterile neutrino search across three reactor experiments.
2. **Enhanced combined sensitivity**
   PROSPECT+STEREO improves exclusion for $\Delta m^2_{41} \in [10^{-1}, 10]$ eV². Adding Daya Bay's unfolded ^{235}U spectrum yields the largest improvement below 10 eV².
3. **Targeting open anomalies**
   The joint analysis directly probes the Neutrino-4 claimed signal (~8 eV²) and the allowed region from BEST, SAGE, and GALLEX; the primary physics targets of this joint analysis.
4. **Final fit in progress**
   Full fit incorporating all systematics is underway. Results expected soon.

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