OAK RIDGE National Laboratory

The PROSPECT reactor antineutrino Experiment: Highlights and future opportunities

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On behalf of the PROSPECT collaboration

March 23rd – P5 Town Hall at Fermilab and Argonne, 2023

ORNL is managed by UT-Battelle, LLC for the US Department of Energy

U.S. DEPARTMENT OF ENERGY

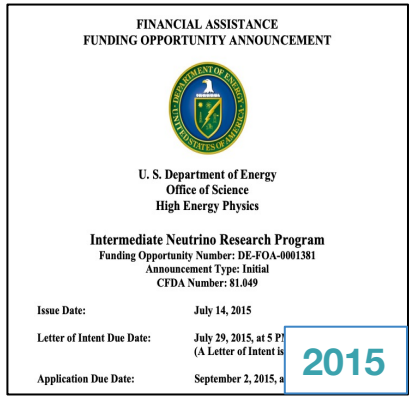
Physics Division

PROSPECT is a successful outcome of the last Snowmass / P5 cycle

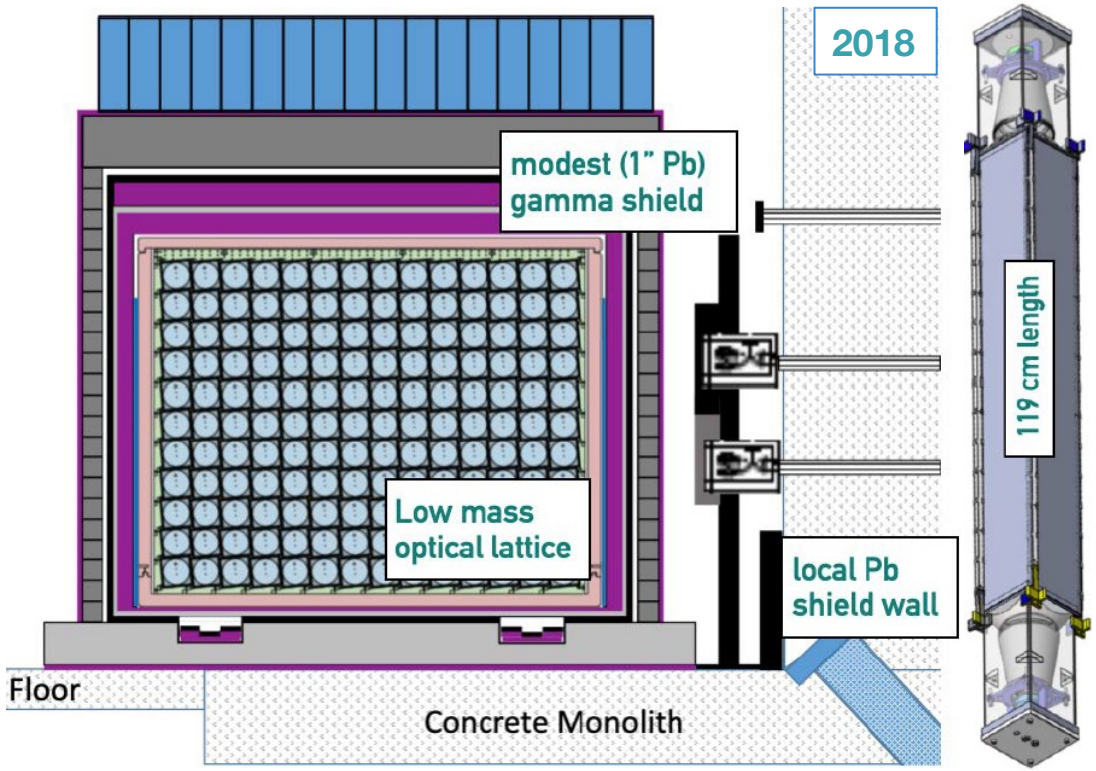
Recommendation 4: Maintain a program of projects of all scales, from the largest international projects to mid- and small-scale projects.

Recommendation 6: In addition to reaping timely science from projects, the research program should provide the flexibility to support new ideas and developments.

Recommendation 15: Select and perform in the short term a set of small-scale short-baseline experiments that can conclusively address experimental hints of physics beyond the three-neutrino paradigm. Some of these experiments should use liquid argon to advance the technology and build the international community for LBNF at Fermilab.

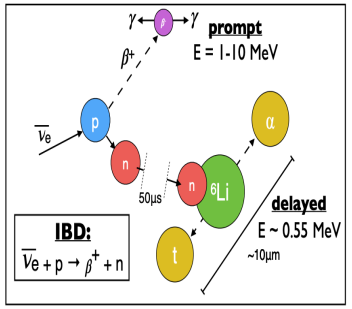


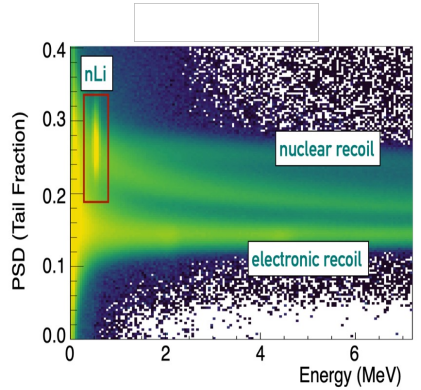
PROSPECT Detector



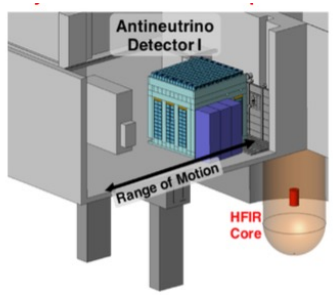
Antineutrino Detection:

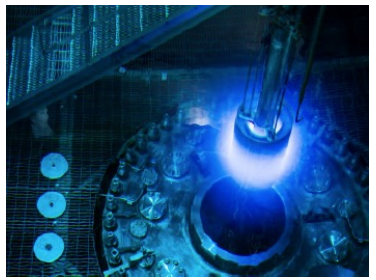
- PROSPECT detects antineutrinos via the Inverse Beta Decay (IBD) interaction
- Time-position correlation between prompt and delayed signal
- 14x11 array of 6LiLS (~4ton)
- Baseline: 6.7-9.2 m





Experiment Site:
High Flux Isotope Reactor (HFIR)

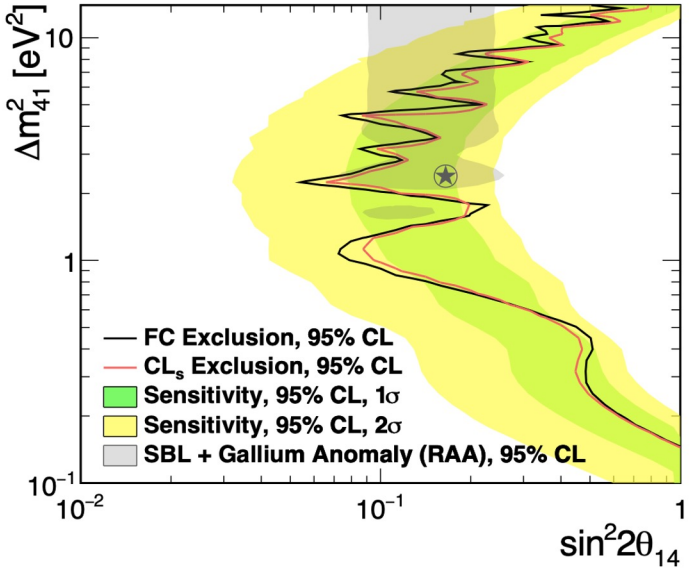


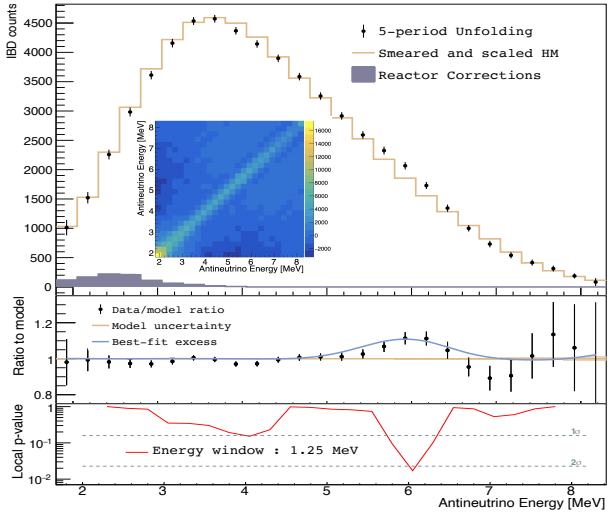


- 93% 235U Fuel
- 85 MW thermal power
- Compact core
- Huge flux in the few MeV range
- ~50% duty cycle for BG measurements

Results and plans from PROSPECT-I

2011 RAA paper & SNAC workshop,
2012 white paper motivated search for eV-scale sterile neutrinos,
2018 first physics limits from PROSPECT





- Performed direct test of the Reactor Antineutrino Anomaly,
  - RAA best-fit excluded: 98.5% CL
  - Data is compatible with null oscillation hypothesis (p=0.57)
- Helped establish new constraints on the origin of the data-model disagreement observed between 5-7 MeV
  - Likely due to an equal mismodeling of all fissile isotopes
- Led joint analyses with other experiments
  - STEREO and Daya Bay

First Oscillation Search
Phys. Rev. Lett. **121**, 251802 (2018)

First Spectrum Result
Phys. Rev. Lett. **122**, 251801 (2019)

Non-fuel reactor neutrinos
Phys. Rev. C **101**, 054605 (2021)

Improved Osc. + Spectrum
Phys. Rev. D **103**, 032001 (2021)

Boosted Dark Matter Search
Phys. Rev. D **104**, 012009 (2021)

Daya Bay/PROSPECT Joint Spectrum Analysis
Phys. Rev. Lett. **128**, 081801 (2022)

PROSPECT/STEREO Joint Spectrum Analysis
Phy. Rev. Lett **128**, 081802 (2022)

Final PROSPECT-I Spectrum
arxiv:2212.10669

New Analysis Techniques

- **'Final' PROSPECT-I Oscillation**
- **Absolute Flux Analysis**
- **Correlated Background Study**
- **Antineutrino Directionality**

- **PROSPECT has served as a fantastic professional development and training program for young scientists.**
  - **10 Ph.D. Theses**
  - **2 M.S. Theses**
  - **Multiple Postdocs and undergraduates as well**

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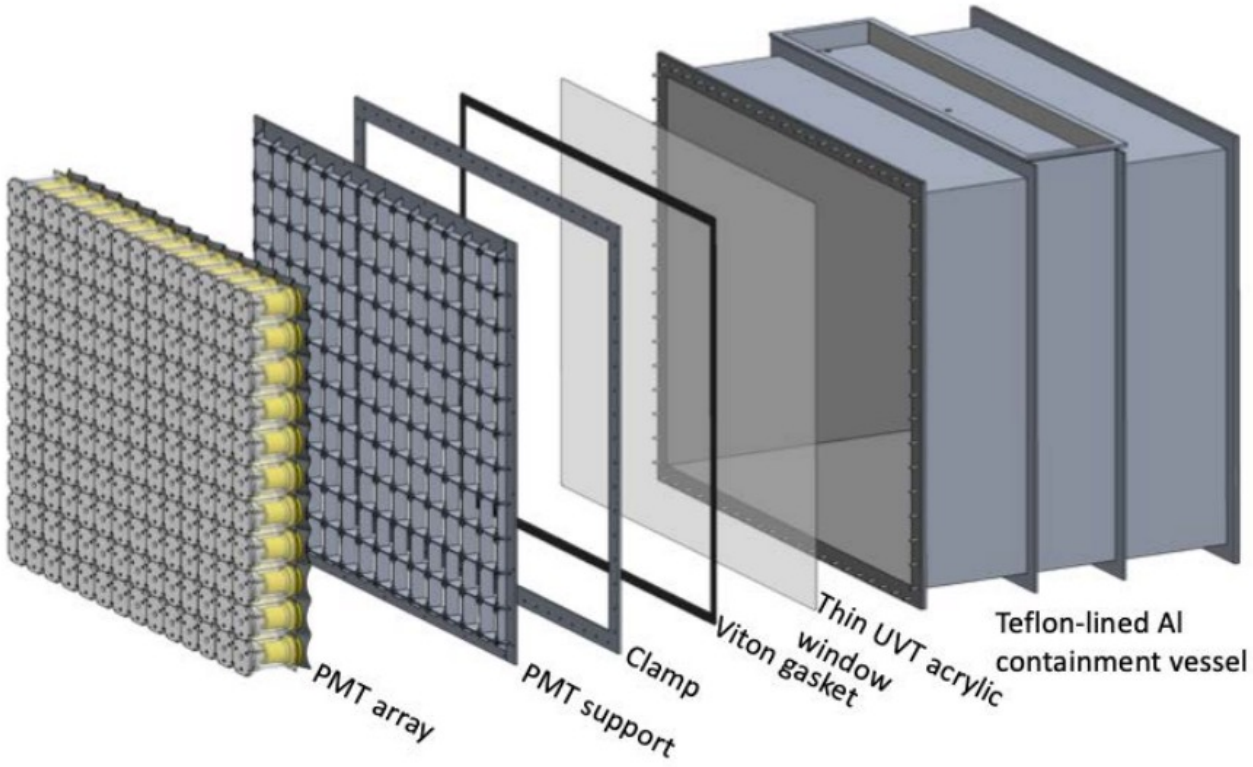
Next Phase of PROSPECT



High ~ 4:1 signal:background ratio

Planned ~2 year deployment at HFIR, ORNL

~50% reactor on-time

PROSPECT II

Retains successful elements of PROSPECT-I

- 14x11 optically segmented ^{6}Li-doped liquid scintillator with minimal shielding
- Located 7-9m from HEU core of HFIR (+ possible LEU site)

Moves PMTs out of liquid scintillator volume to avoid contact with other materials

Increases signal collection capacity with 20% longer segments, 20% increased ^{6}Li loading, longer data-taking period -> 10x effective statistics at HFIR

External calibration system instead of calibration tubes inside active volume, simplifies design

Designated to deploy at multiple sites

Physics opportunities:

- New HEU spectrum measurement with uncertainties at the level of model predictions
- Possible HEU/LEU measurement would mitigate the effect of systematic uncertainties
- Exclusion of the remaining Gallium Anomaly, RAA sterile neutrino oscillation phase space below ~10eV^2
- Test the claim made by Neutrino-4 at high Δm^2
- Address ambiguities in long-baseline physics