Searching for Sterile Neutrino Oscillations with the PROSPECT Experiment

Other PROSPECT Presentations:
- PROSPECT Overview, Assembly and Calibration - X. Zhang
- PROSPECT in a nutshell - J. Lu at New Perspectives

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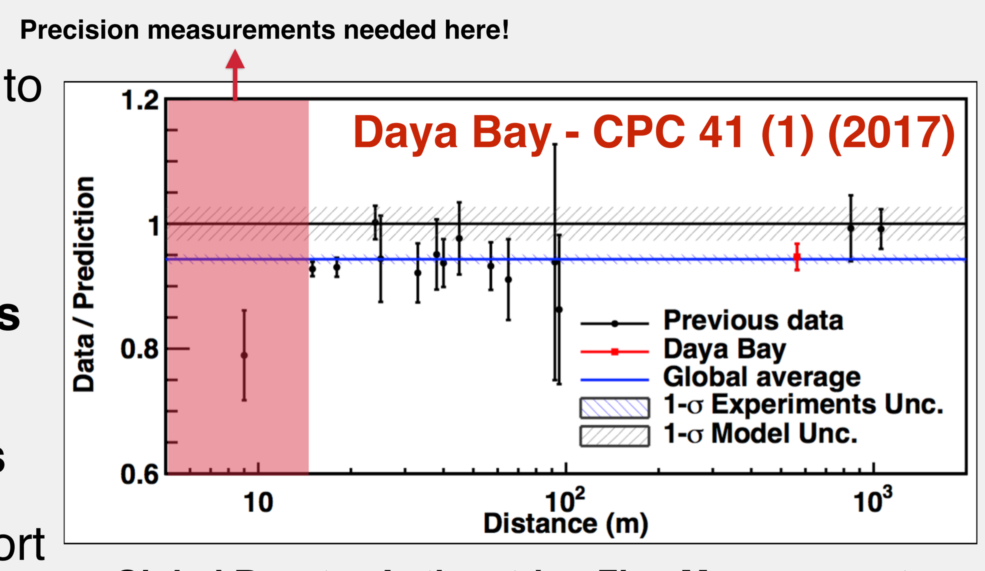
PROSPECT is a reactor antineutrino experiment consisting of a segmented liquid scintillator antineutrino detector designed to probe short-baseline neutrino oscillations and precisely measure the antineutrino spectrum of the primary fission isotope ^{235}U. PROSPECT's neutrino oscillation analysis utilizes target segmentation to look for differences in measured inverse beta decay (IBD) positron spectra at different positions in its detector. With a current baseline coverage of between 7 and 9 meters, the analysis will probe sterile oscillations in the ~1-10 eV^2 mass-splitting range, with sensitivities largely independent of the underlying reactor antineutrino flux. This poster will present the first oscillation result with 33 days of PROSPECT data, including discussion of input inverse beta decay signal selection, estimation and implementation of absolute and relative systematic uncertainties, and statistical approach used in the oscillation fit.

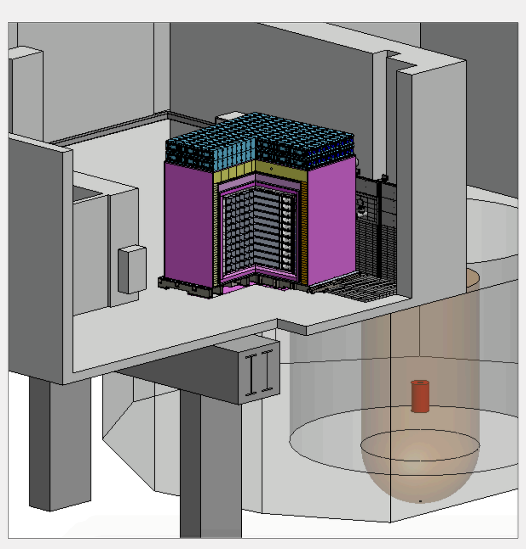
Motivation

- Reactor antineutrino experiments observe deficit in rates compared to the predictions
- Could be:
  - **Wrong reactor flux predictions**
  - **Electron antineutrinos oscillating to sterile neutrinos**
- New reactor measurements at short baselines can resolve this question

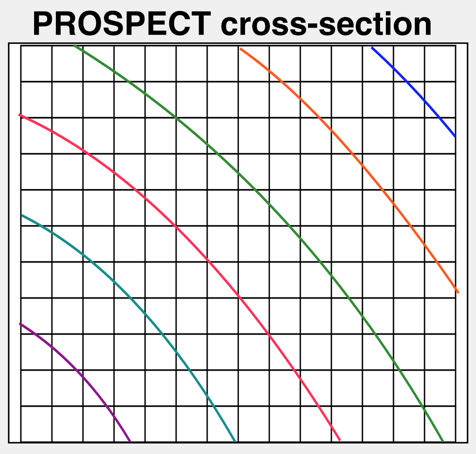


Global Reactor Antineutrino Flux Measurements

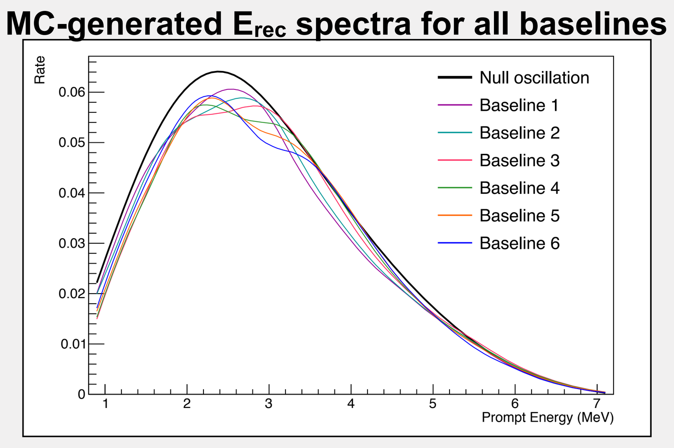
Oscillation Search Strategy



PROSPECT cross-section



MC-generated E_{rec} spectra for all baselines



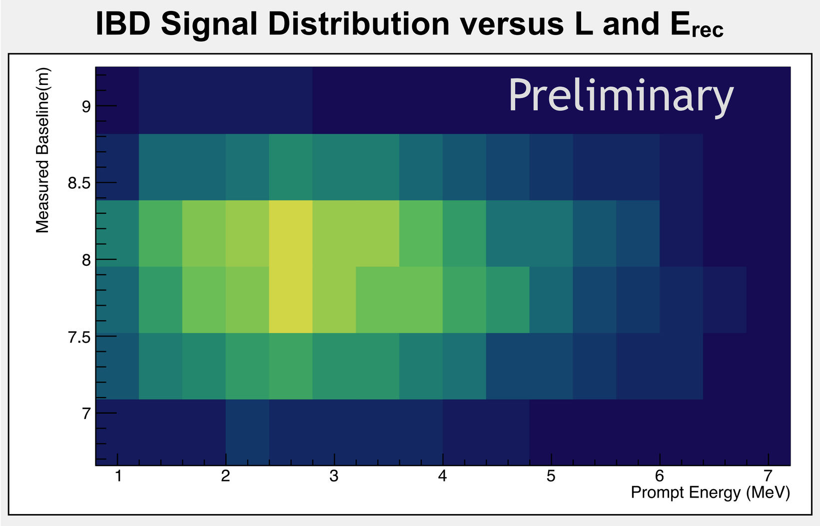
$$\chi^2 = \mathbf{\Delta}^{T} V_{tot}^{-1} \mathbf{\Delta}$$

$$\Delta_{l,e} = O_{l,e} - O_e \frac{E_{l,e}}{E_e} \qquad O_e = \sum_{l=1}^{L} O_{l,e},\ E_e = \sum_{l=1}^{L} E_{l,e} \qquad E_{l,e} = E_{l,e}^{null} \cdot \left(1 - \sin^2\theta_{new} \sin^2\left(1.27 \Delta m^2_{new} \frac{L}{E_\nu}\right)\right)$$

- **Compare data to prediction using a covariance matrix approach:**
- For purely relative comparison between baselines, prediction is formed by scaling the detector-wide spectrum individually for each baseline bin according to the MC-predicted detector response and oscillation effects present at that baseline

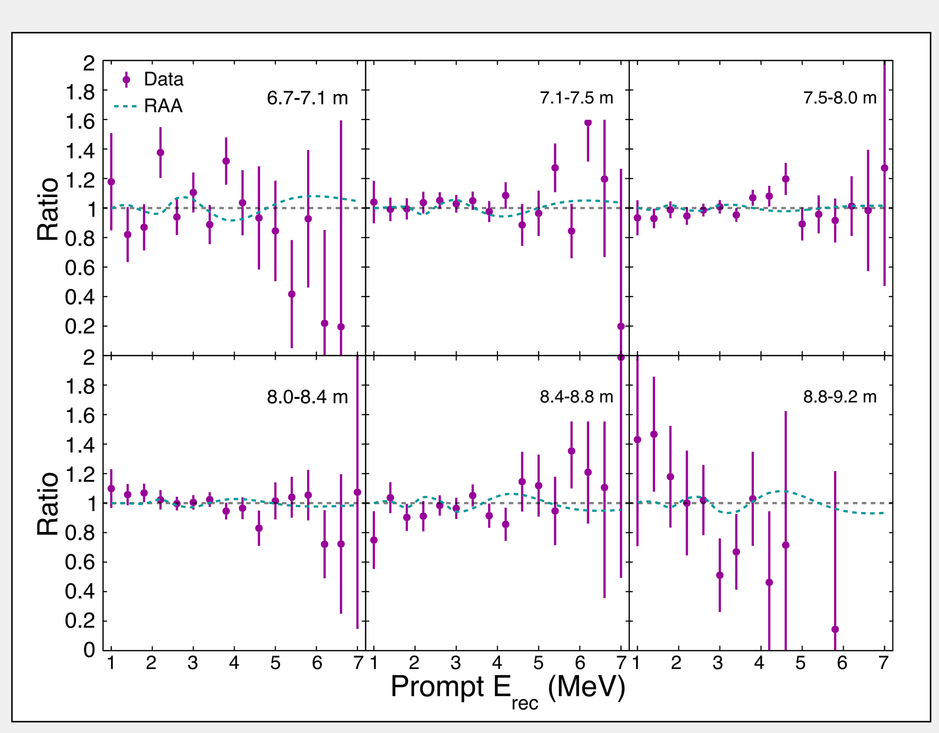
Dataset

IBD Signal Distribution versus L and E_{rec}



- Utilize 33 days of reactor-on data, 28 days of reactor-off data
- 43k IBD candidates
- 25k IBD signal events post bkg-subtraction
- Distributed signal into 6 baseline, 16 energy bins

- L vs E_{rec} spectrum for each baseline is formed by scaling the full detector spectrum
  - Accounts for relative efficiency and energy scale variations with position
  - Scaling factor obtained from full detector and reactor Monte Carlo
- Oscillation fitting is done by comparing measured L vs E_{rec} spectrum for each baseline to the predicted L vs E_{rec} spectrum

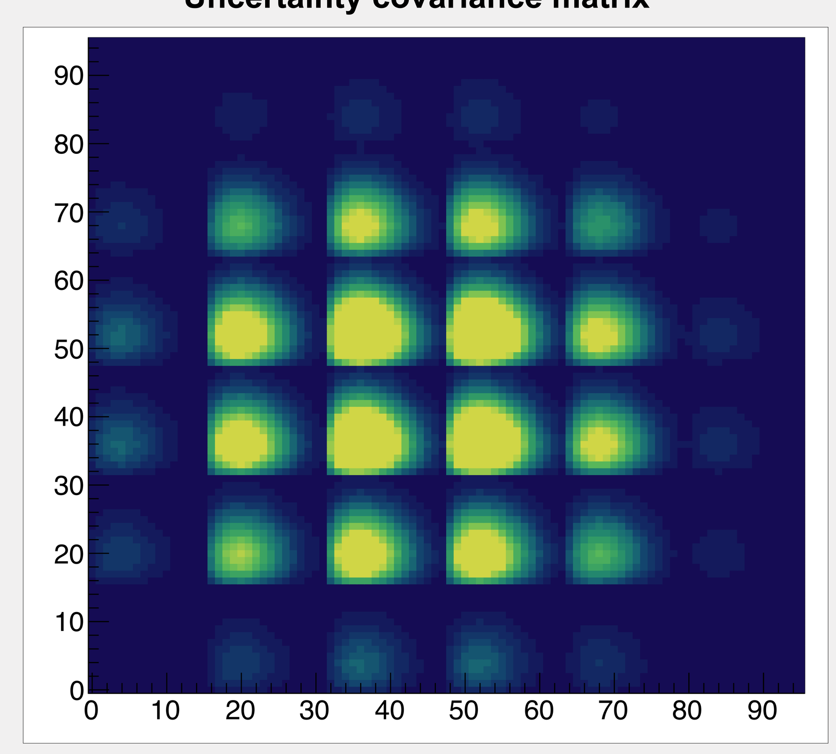


E_{rec} spectra versus MC-generated prediction for all baselines

Uncertainties

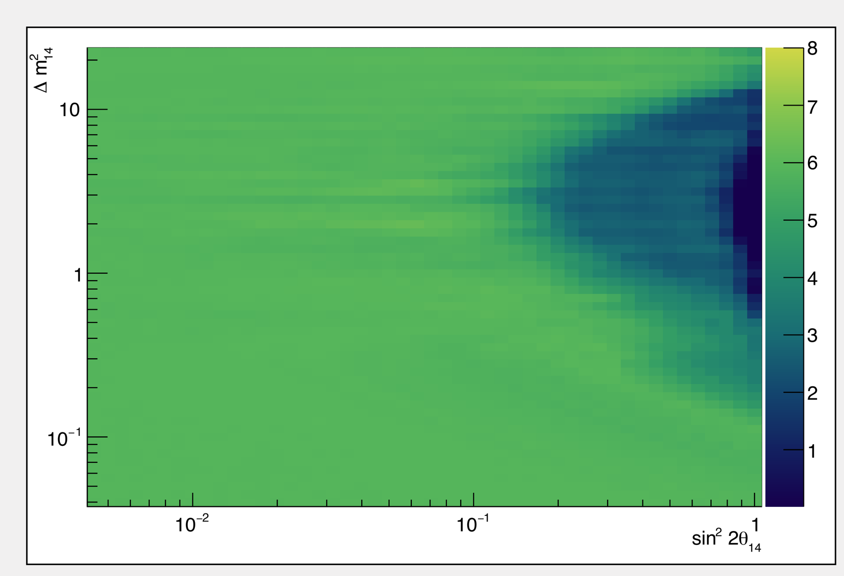
- **Complete uncertainties and their energy and baseline correlations are encapsulated in a covariance matrix**
  - IBD candidate statistics
  - Background measurement statistics
  - Reactor-Off background scaling uncertainty: 5%
  - Correlated baseline uncertainty: 10 cm
  - Segment-to-segment E_{rec} scale: 1%
  - Segment-to-segment efficiency: 5%
  - Absolute energy scale, leakage, and resolution uncertainty implemented in covariance matrix
  - Due to purely relative approach, reactor model and flux uncertainties are not relevant and not included.

Uncertainty covariance matrix



Confidence Intervals

- **Use a frequentist approach to assign confidence intervals to the obtained χ^2**
- At each (Δm^2,θ) grid point, run 1000 toys with full statistical, systematic variations
- Use these to form critical $\Delta\chi^2$ PDF at each (Δm^2,θ)
- Use PDF to determine a p-value describing the compatibility of the data with that specific (Δm^2,θ) grid point

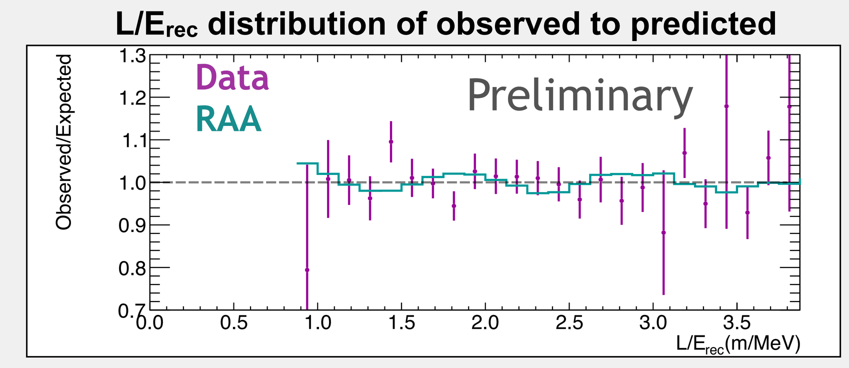


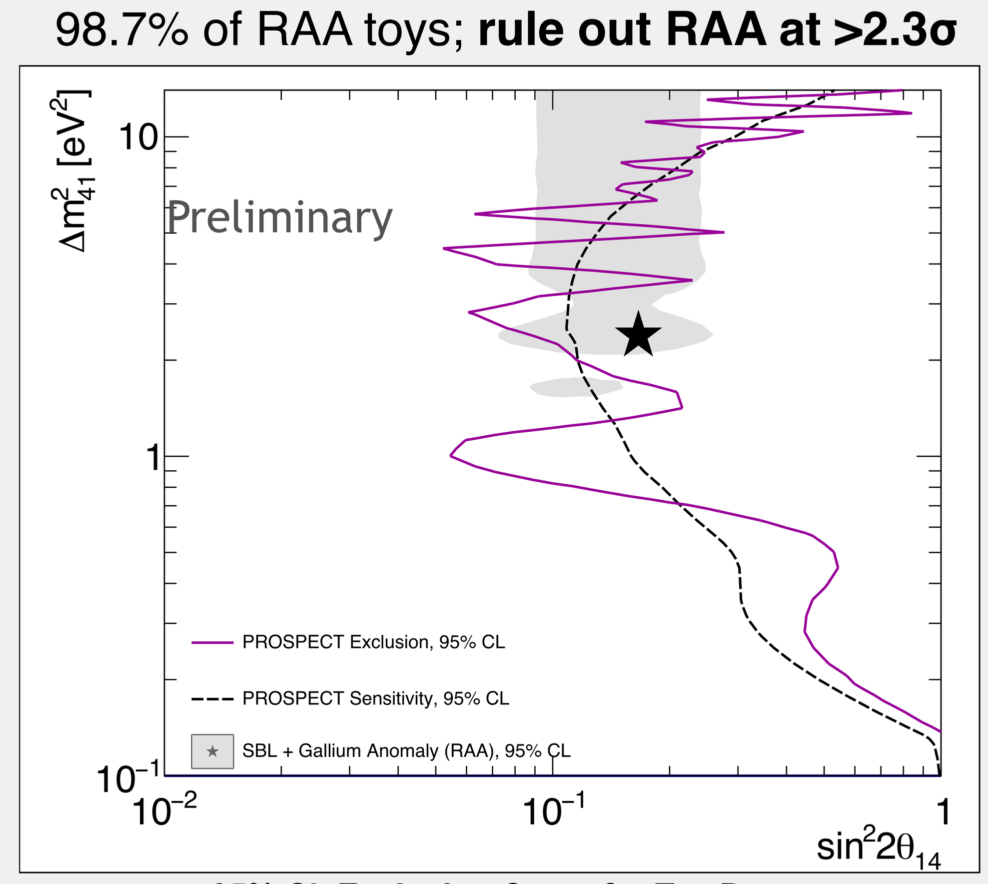
Map of critical $\Delta\chi^2$ indicating 95% CL exclusion

Results

- L/E_{rec} plot shows no notable oscillatory features
- Best χ^2/NDF = 66.5/78 at (Δm^2,$\sin^2 2\theta$)=(5.02, 0.14)
- Null oscillation χ^2/NDF = 70.1/80
- 23% of null oscillation toys have higher $\Delta\chi^2$; **consistent with no sterile neutrinos**
- χ^2 of 77.8/78 at RAA best-fit, larger than 98.7% of RAA toys; **rule out RAA at >2.3σ**

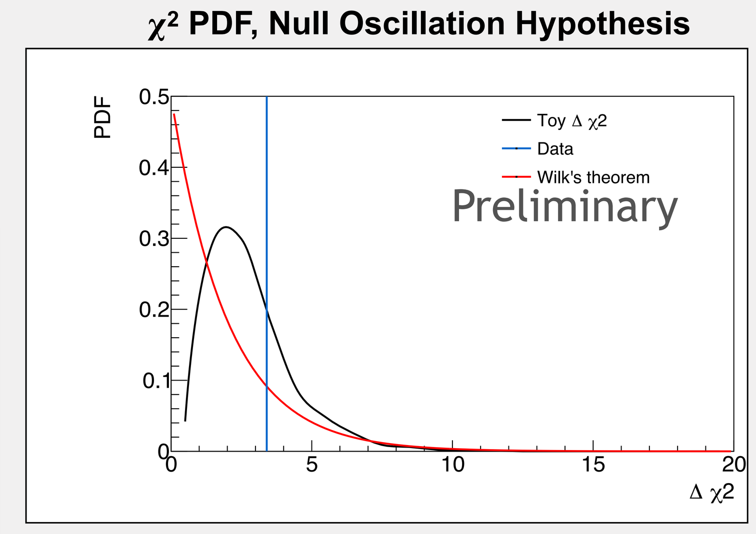
L/E_{rec} distribution of observed to predicted

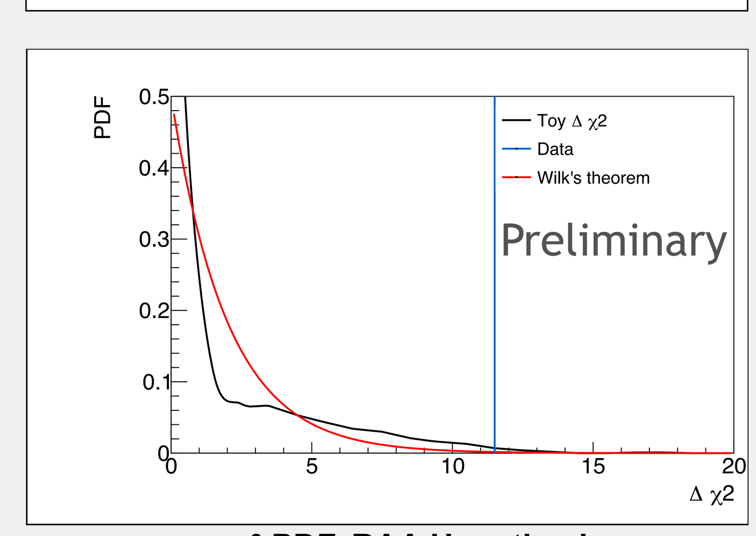




95% CL Exclusion Curve for Toy Data

χ^2 PDF, Null Oscillation Hypothesis





χ^2 PDF, RAA Hypothesis

Acknowledgements

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Reference:
First search for short-baseline neutrino oscillations at HFIR with PROSPECT, arXiv:1806.02784