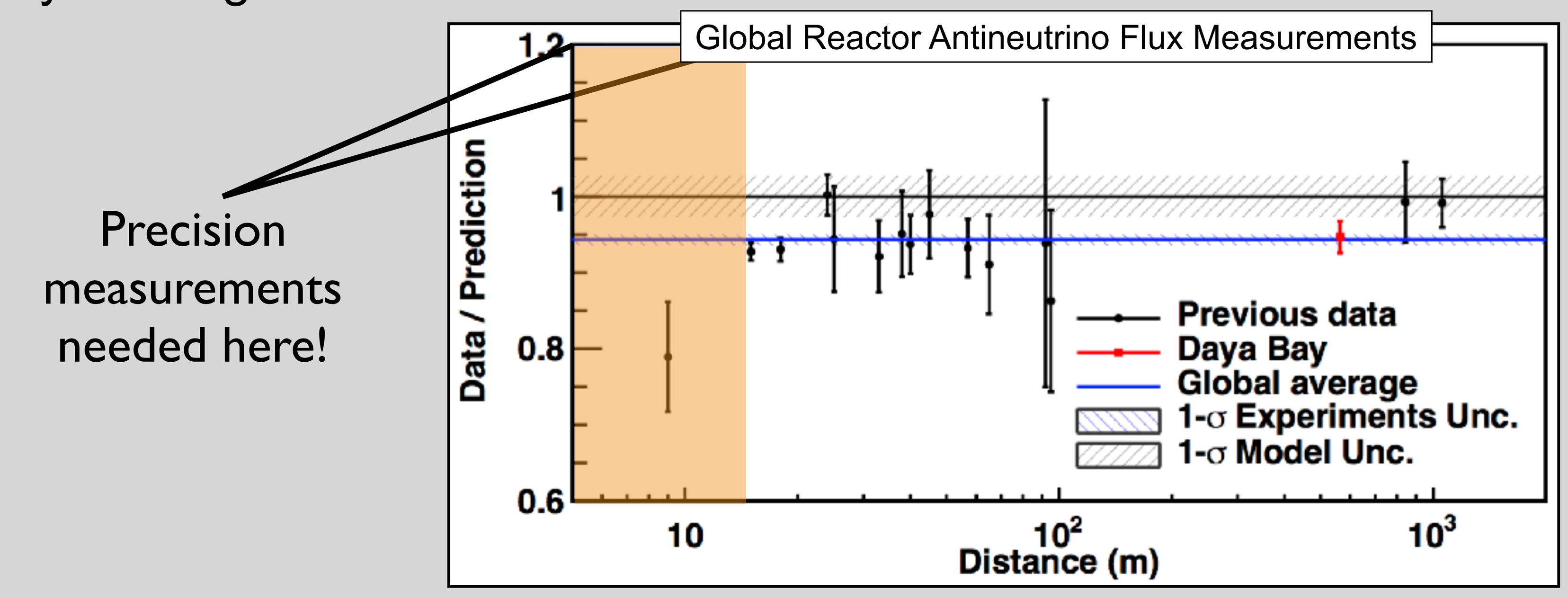
Searching For Sterile Neutrinos With PROSPECT

Bryce Littlejohn (Illinois Institute of Technology), on behalf of the PROSPECT Collaboration

PROSPECT's neutrino oscillation analysis uses target segmentation to look for differences in measured reactor antineutrino inverse beta decay (IBD) positron spectra at different positions in its detector. With a 7-9 m baseline coverage, the analysis probes sterile oscillations in the 1-10 eV^2 mass-splitting range, with sensitivities independent of the underlying flux model. This poster presents PROSPECT's oscillation analysis, including discussion of input signal and background datasets, estimation and implementation of absolute and relative systematic uncertainties, and statistical approaches in the oscillation fit.

Motivation: The Reactor Anomaly

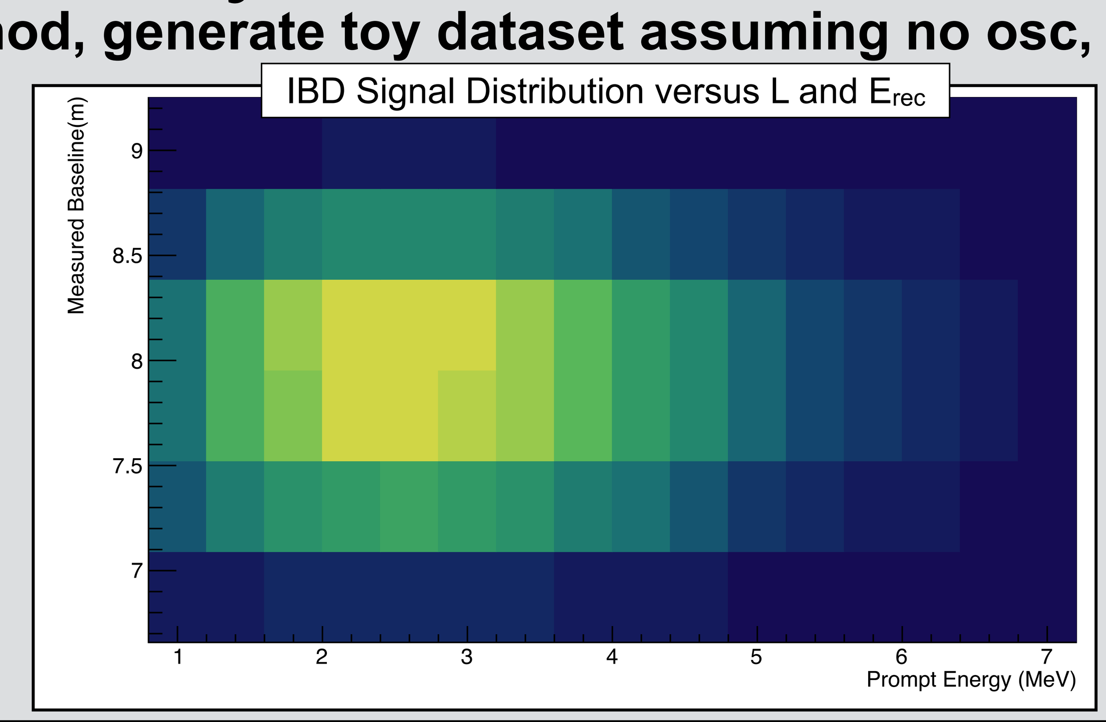
- State-of-the art reactor models predict more neutrinos than are observed by existing reactor antineutrino flux measurements



- **Are reactor flux predictions wrong? Or were electron antineutrinos oscillating to sterile neutrinos before reaching these detectors?**
- New reactor measurements at short baselines can resolve this question

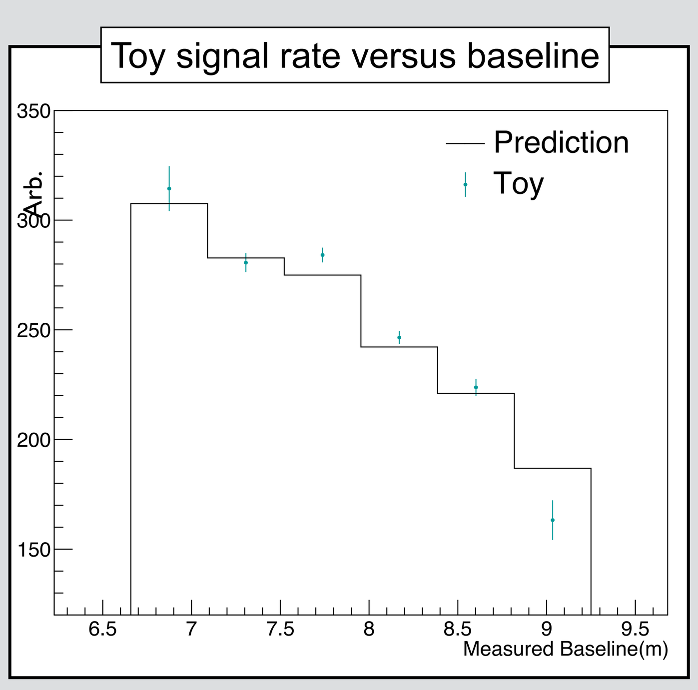
Input Toy Dataset

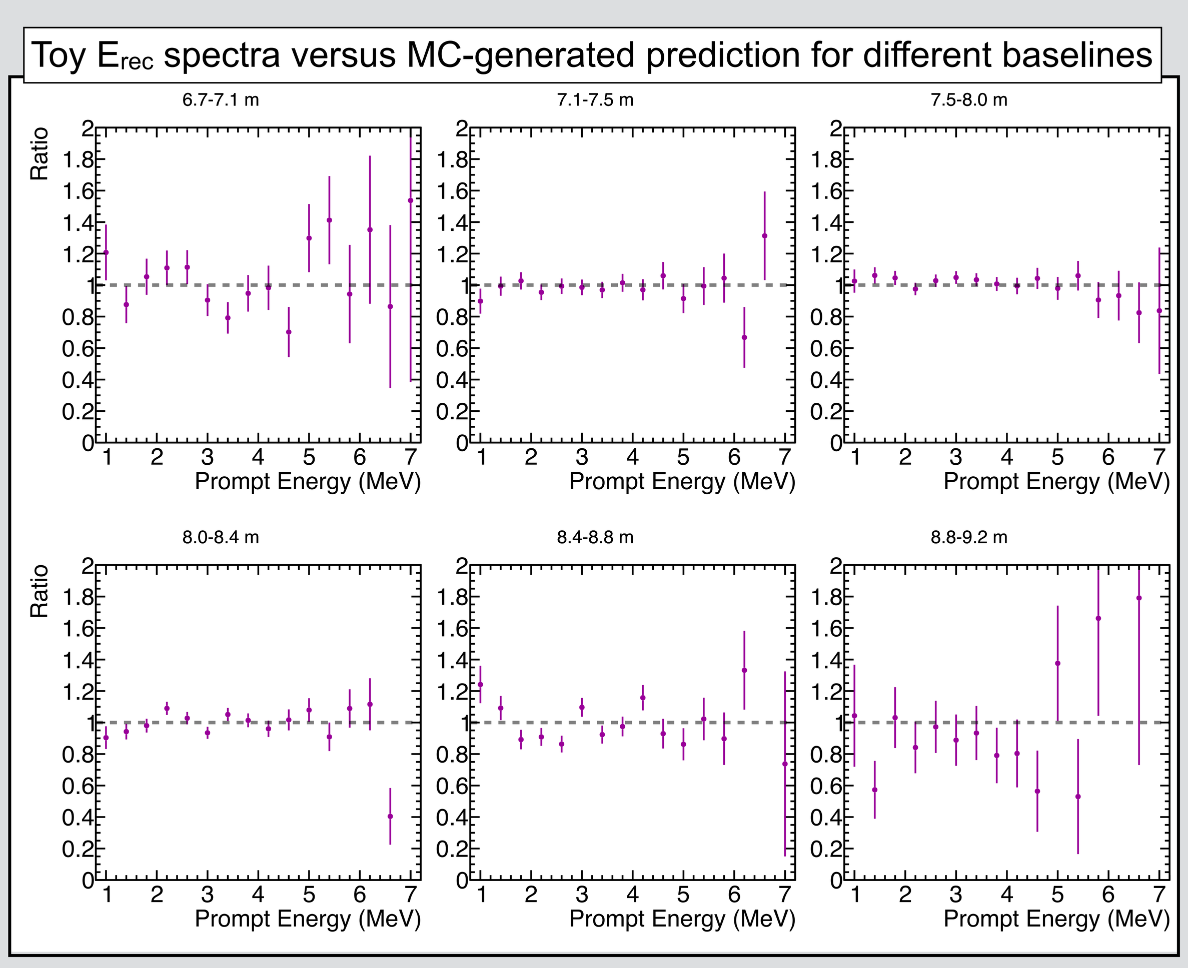
- **To demonstrate our method, generate toy dataset assuming no osc, stat/syst uncertainties**
- Utilize 26 days of reactor-on data, 23 days of reactor-off data
- 50k IBD candidates
- 25k IBD signal events post bkg-subtraction
- Distributed signal into 6 baseline, 16 energy bins



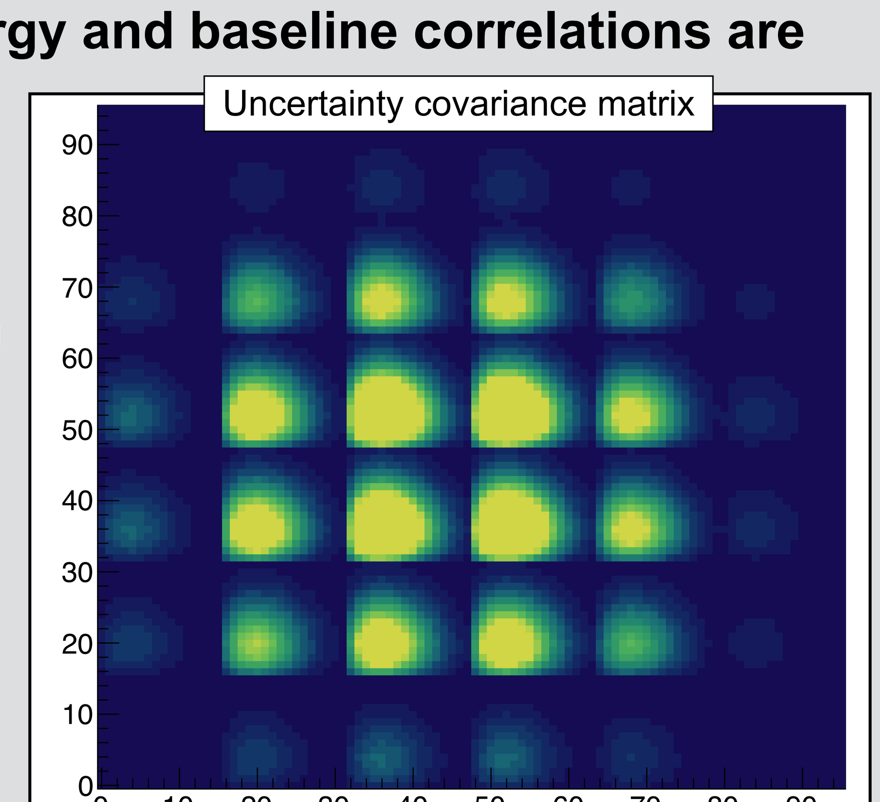
Predictions and Uncertainties

- Full reactor core and building model used to generate true baselines
- True IBD spectrum provided by Huber-Mueller, Vogel-Beacom.
- **Monte Carlo used to convert true baselines and energies to L and E_{rec}**
  - Accounts for relative efficiency and energy scale variations with position
  - Applies oscillation at the true antineutrino baseline/energy level
- **Osc-induced, MC-derived deficits versus L and E_{rec} are then applied to the data's total measured prompt spectrum to form a prediction.**
  - Results in limited dependence on the true underlying reactor model.



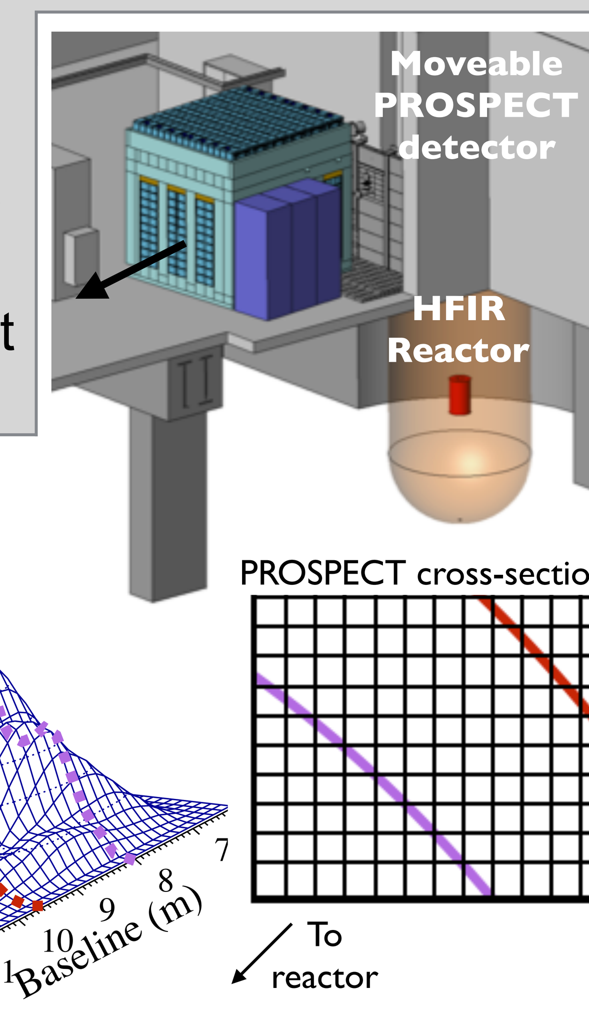


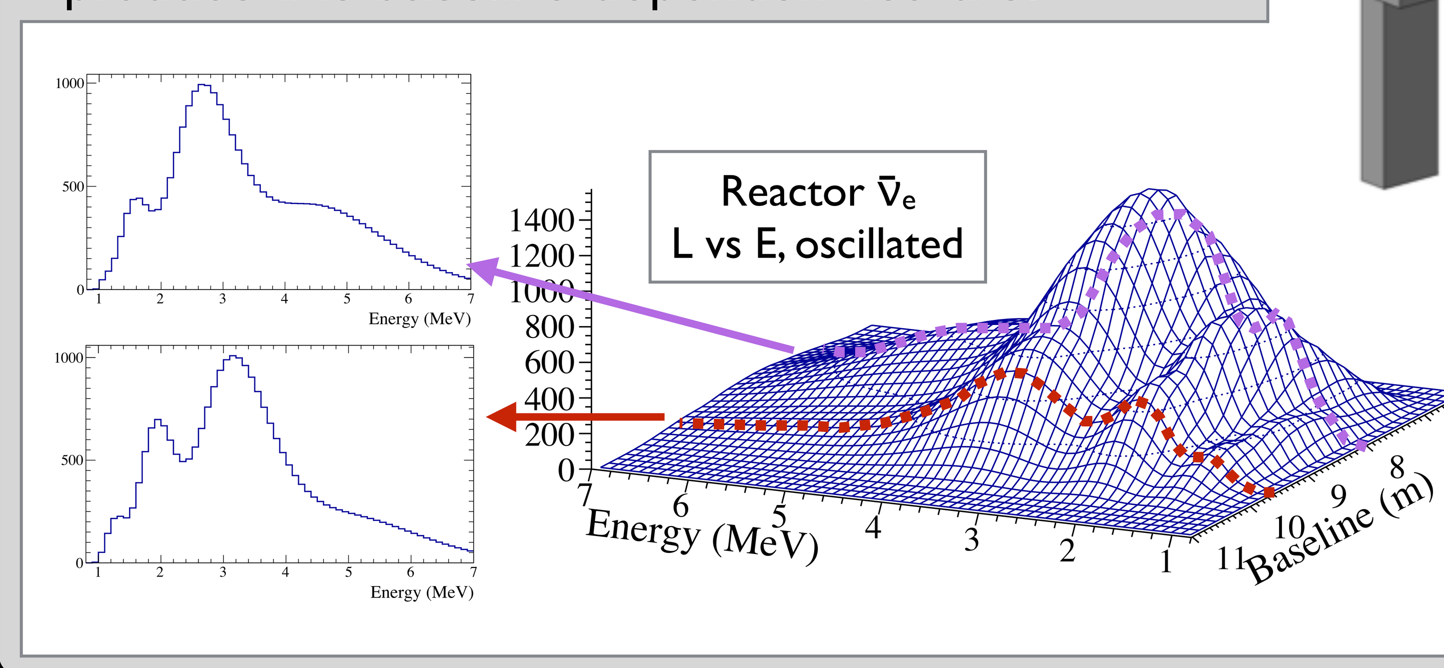
- **Complete uncertainties and their energy and baseline correlations are encapsulated in a covariance matrix**
  - IBD candidate statistics
  - Background measurement statistics
  - RxOff bkg scaling uncertainty: 5%
  - Correlated baseline uncertainty: 10 cm
  - Segment-to-segment E_{rec} scale: 1%
  - 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.



PROSPECT Measurement Concept

- **PROSPECT can resolve this anomaly by probing its L/E nature**
- HFIR core provides pure ^{235}U flux
- Measure IBDs at many baselines with one segmented liquid scintillator target
- Baseline-dependent changes in prompt spectrum would be clear indication of sterile oscillations
- Uncertainties in reactor flux or spectrum could not produce this baseline-dependent feature.





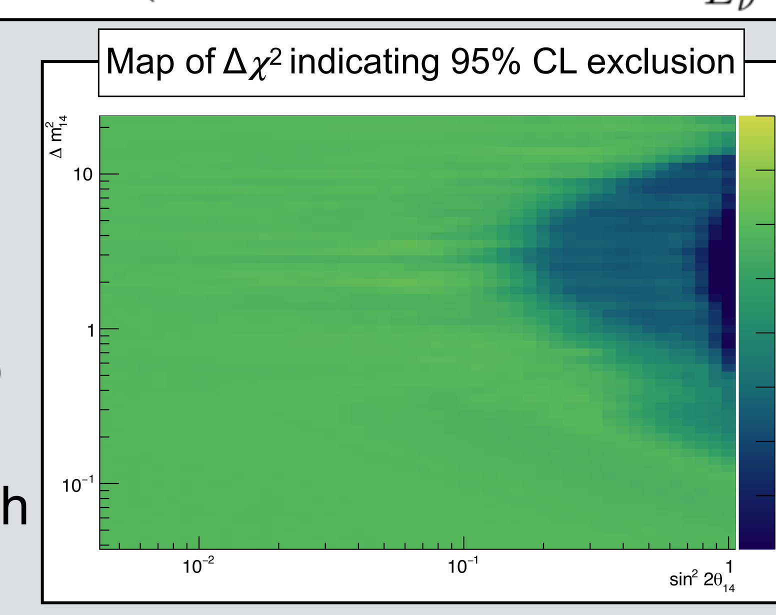
Oscillation Fit Approach

- **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:

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

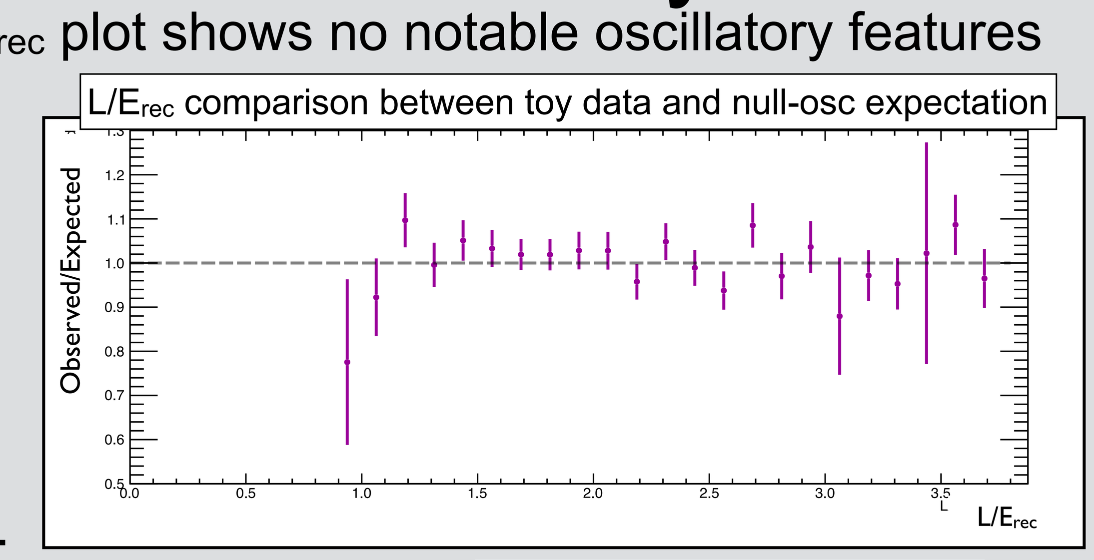
$$\Delta_{l,e} = O_{l,e} - O_e \frac{E_{l,e}}{E_e} \quad O_e = \sum_{l=1}^{L} O_{l,e},\ E_e = \sum_{l=1}^{L} E_{l,e} \quad E_{l,e} = E_{l,e}^{null} \cdot \left(1 - \sin^2\theta_{new}\sin^2\left(1.27\Delta m^2_{new}\frac{L}{E_\nu}\right)\right)$$

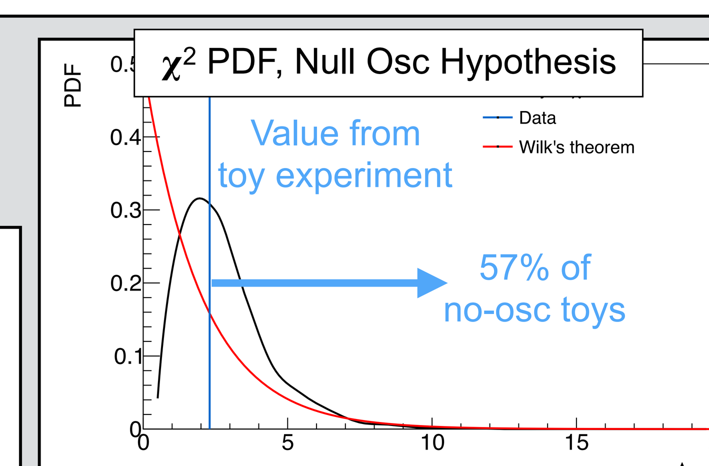
- **Use a frequentist approach to assign confidence intervals to obtained χ^2**
- At each (Δm^2,θ) grid point, run 1000 toys with full statistical, systematic variations
- Use these to form χ^2 PDF at each (Δm^2,θ)
- PDF can be used to determine a p-value describing the compatibility of the data with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

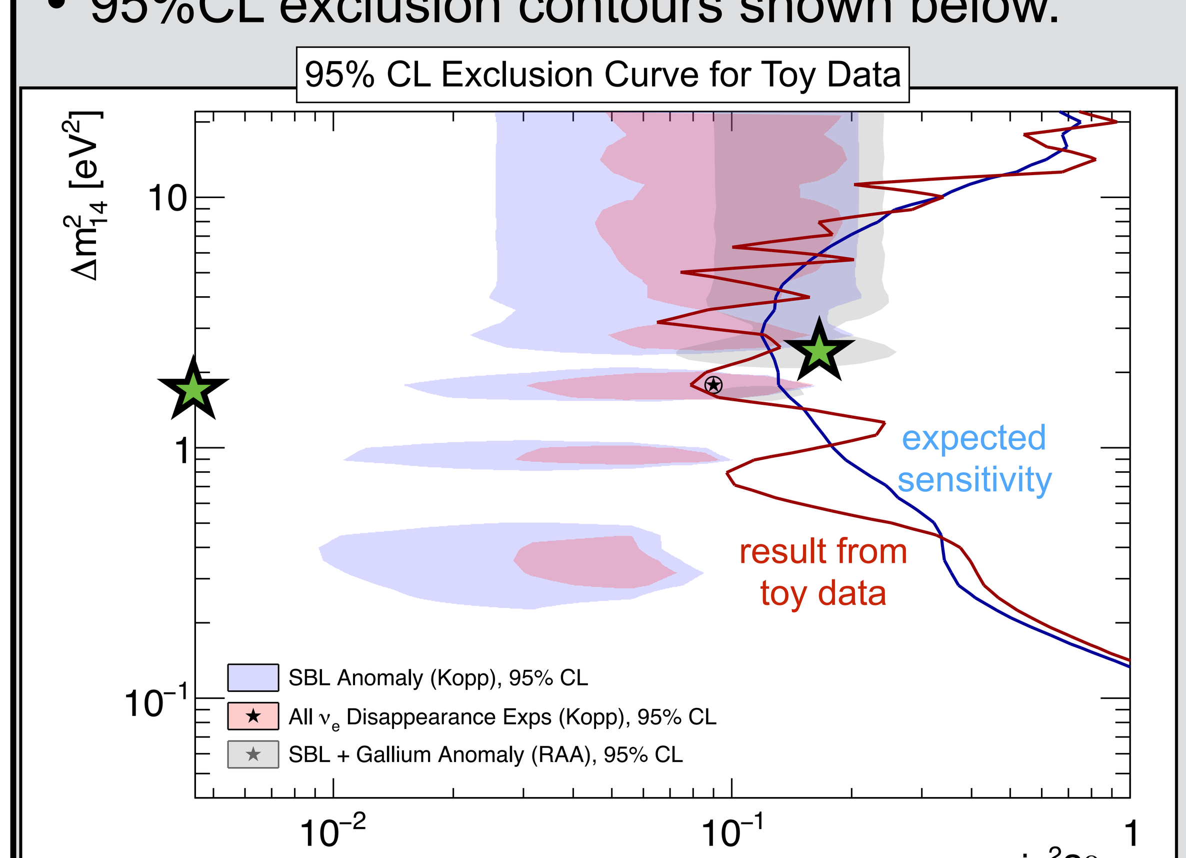


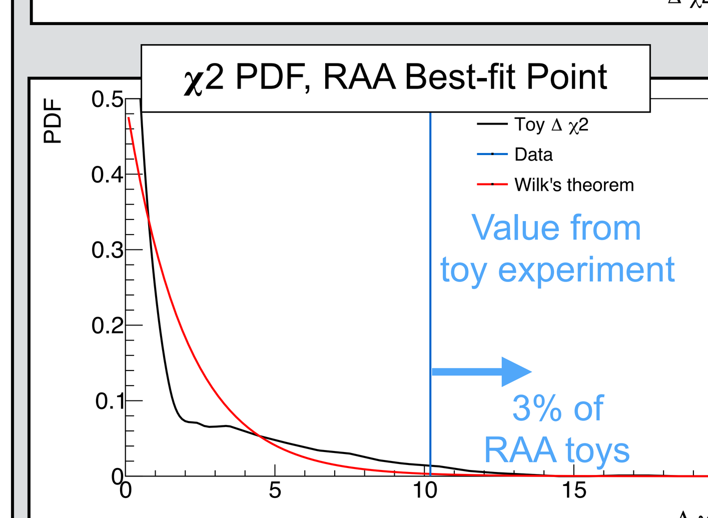
Oscillation Results From Toy Data

- Qualitative demonstration: L/E_{rec} plot shows no notable oscillatory features
- Best χ^2/NDF at (Δm^2,$\sin^2 2\theta$) = (1.26,0.11) of 109.1/94
- No-osc χ^2 of 111.3; 57% of no-osc toys have higher $\Delta\chi^2$; consistent with no steriles.
- χ^2 of 119.3 at RAA best-fit, larger than 97.2% of RAA toys; rule out RAA at >2σ
- 95%CL exclusion contours shown below.









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