Recent Reactor $\bar{\nu}_e$ Results From the PROSPECT Experiment

December 5, 2019

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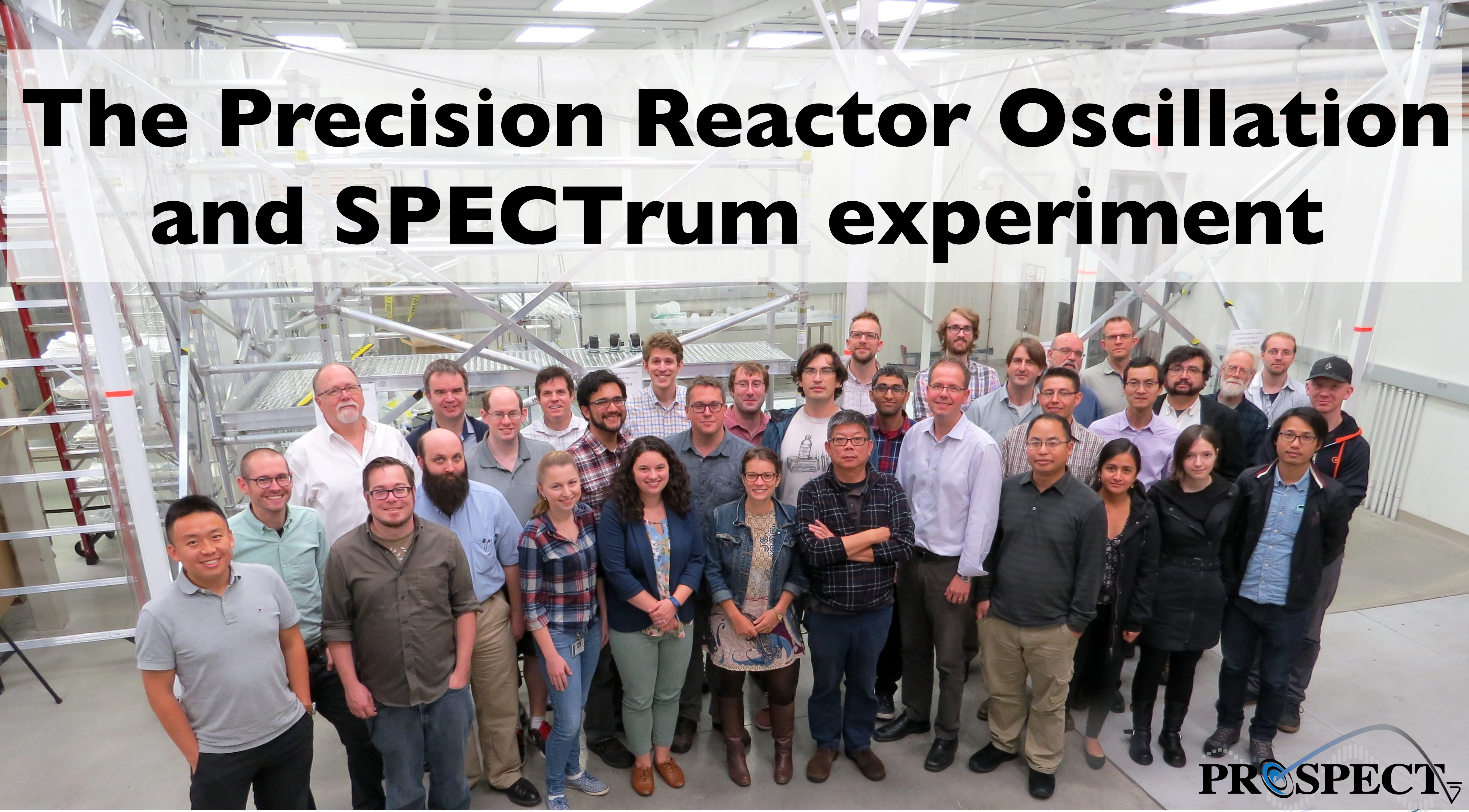
Illinois Institute of Technology

Present Issues, Summarized

- Flux predictions don’t match global measurements
  - Hypothesis 1: Electron antineutrinos are oscillating away
  - Hypothesis 2: Predicted fluxes are just wrong for some (all?) isotopes
- Spectrum predictions don’t match global (LEU) measurements
  - Can’t be from oscillations.
  - Likely a model problem. Is one isotope’s prediction wrong? Or all isotopes?
- Thus far, PROSPECT has worked to tackle the two highlighted questions using a segmented detector deployed at the ^{235}U-burning HFIR reactor
- In performing physics measurements, we also perform valuable AAP R&D by demonstrating on-surface reactor antineutrino detection capabilities

The Precision Reactor Oscillation and SPECTrum experiment

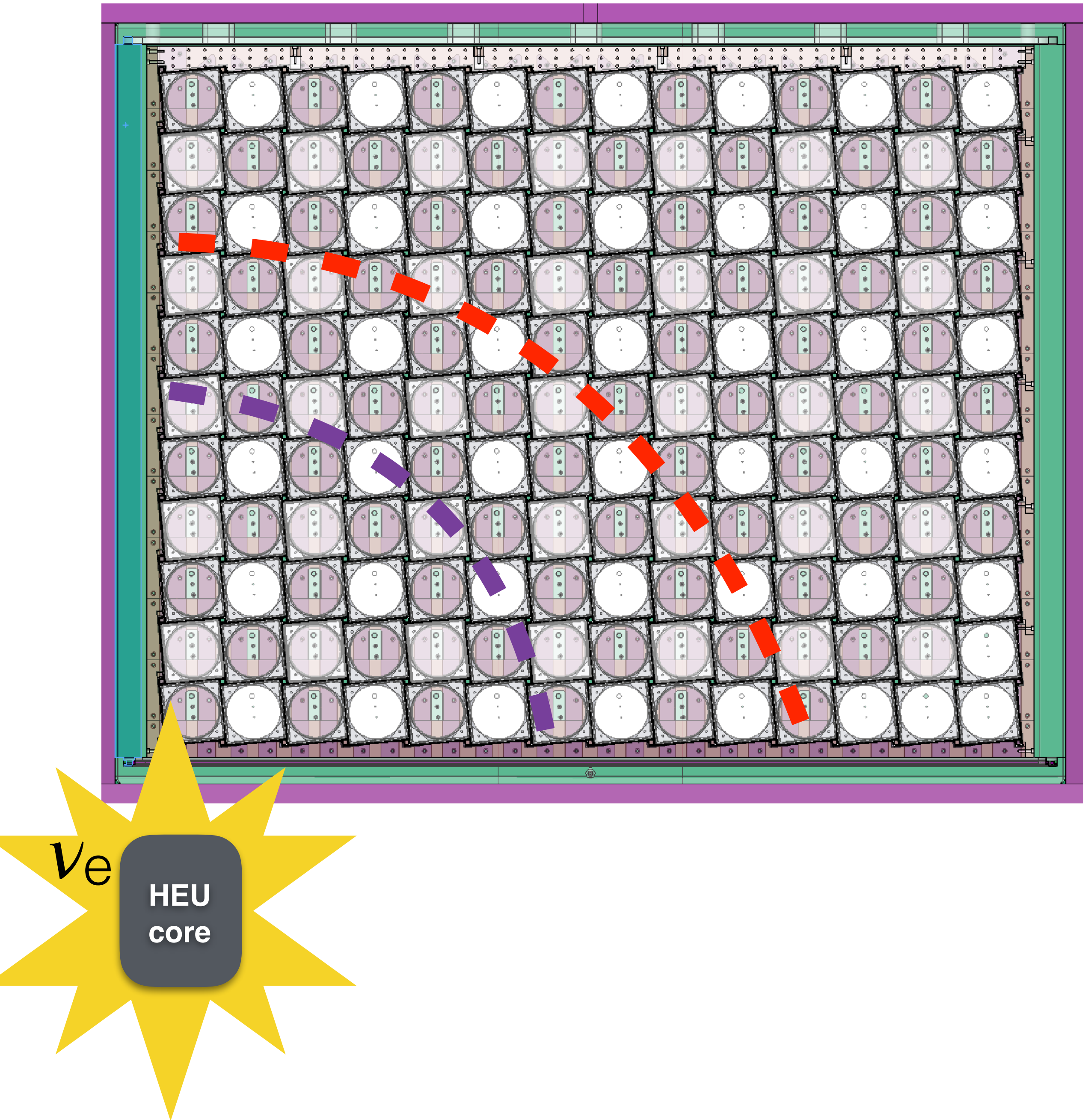


University of Waterloo
Temple University
W&M
Georgia Tech
Le Moyne College
HFIR
Drexel University
Lawrence Livermore National Laboratory
Brookhaven National Laboratory
NIST
Oak Ridge National Laboratory
Yale

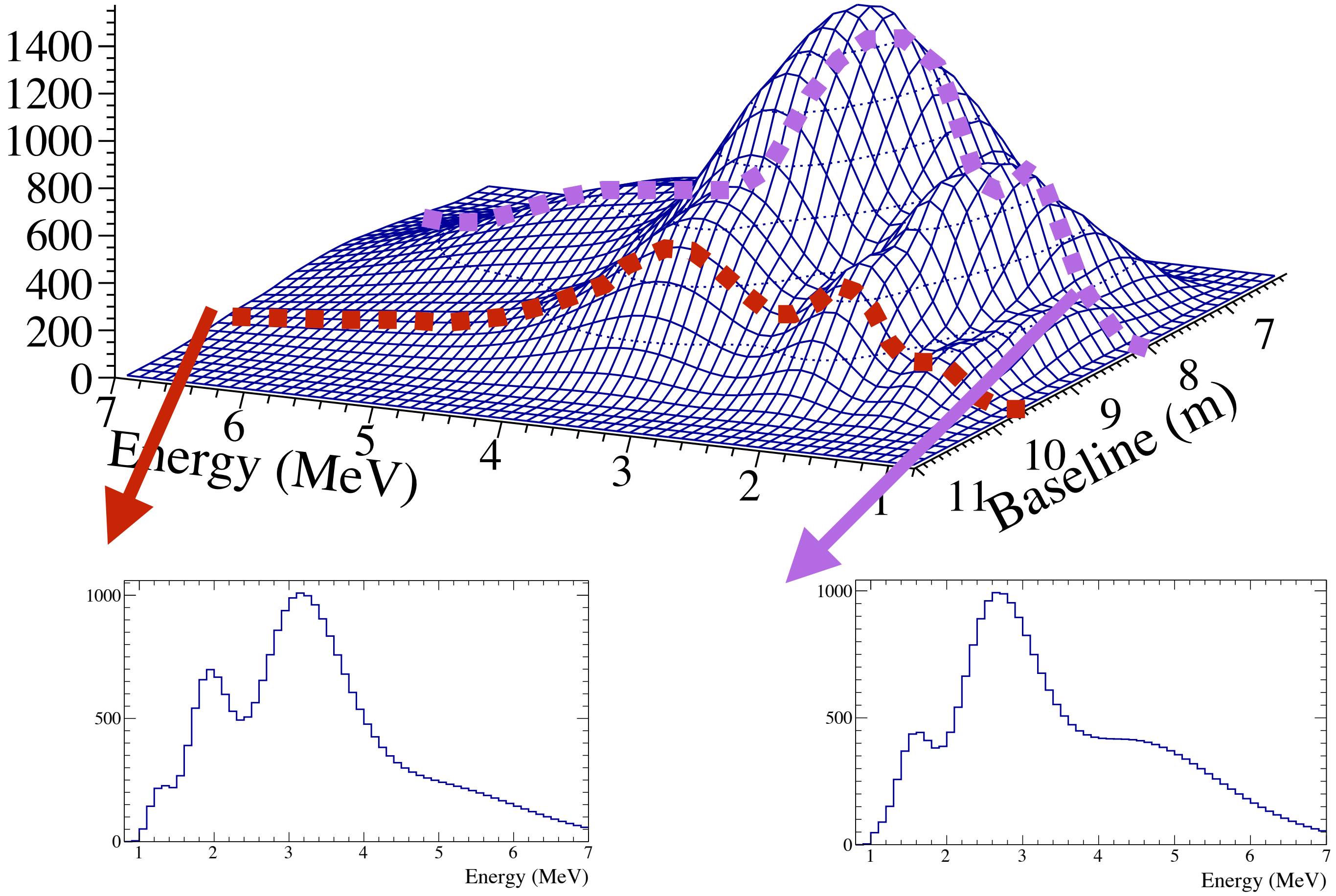
Flux-Independent Sterile Osc Search

- Search for baseline-dependent energy spectrum distortion inside a stationary, segmented, short-baseline detector

100s of detectors in 1!



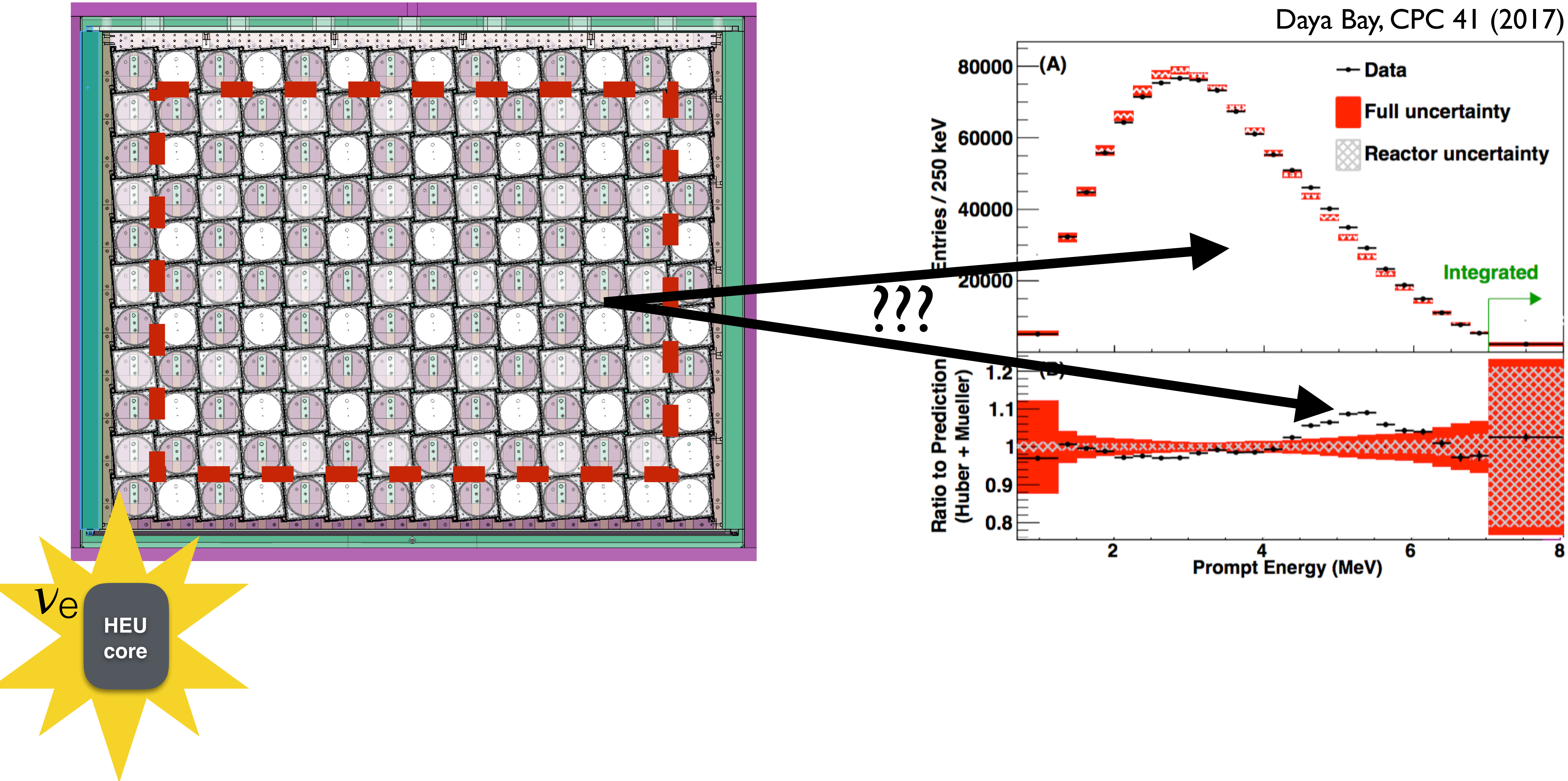
L vs E, oscillated



$$sin^2(2\theta)sin^2(1.27\Delta m^2\frac{L}{E_\nu})$$

^{235}U $\bar{\nu}_e$ Energy Spectrum Measurement

- Measure energy spectrum of ^{235}U $\bar{\nu}_e$ using an HEU reactor
- Then ask: how do results differ for HEU and LEU reactors?
  - Can give a clue which isotopes are poorly predicted



Daya Bay, CPC 41 (2017)

PROSPECT Experiment Overview

Scientific Goals

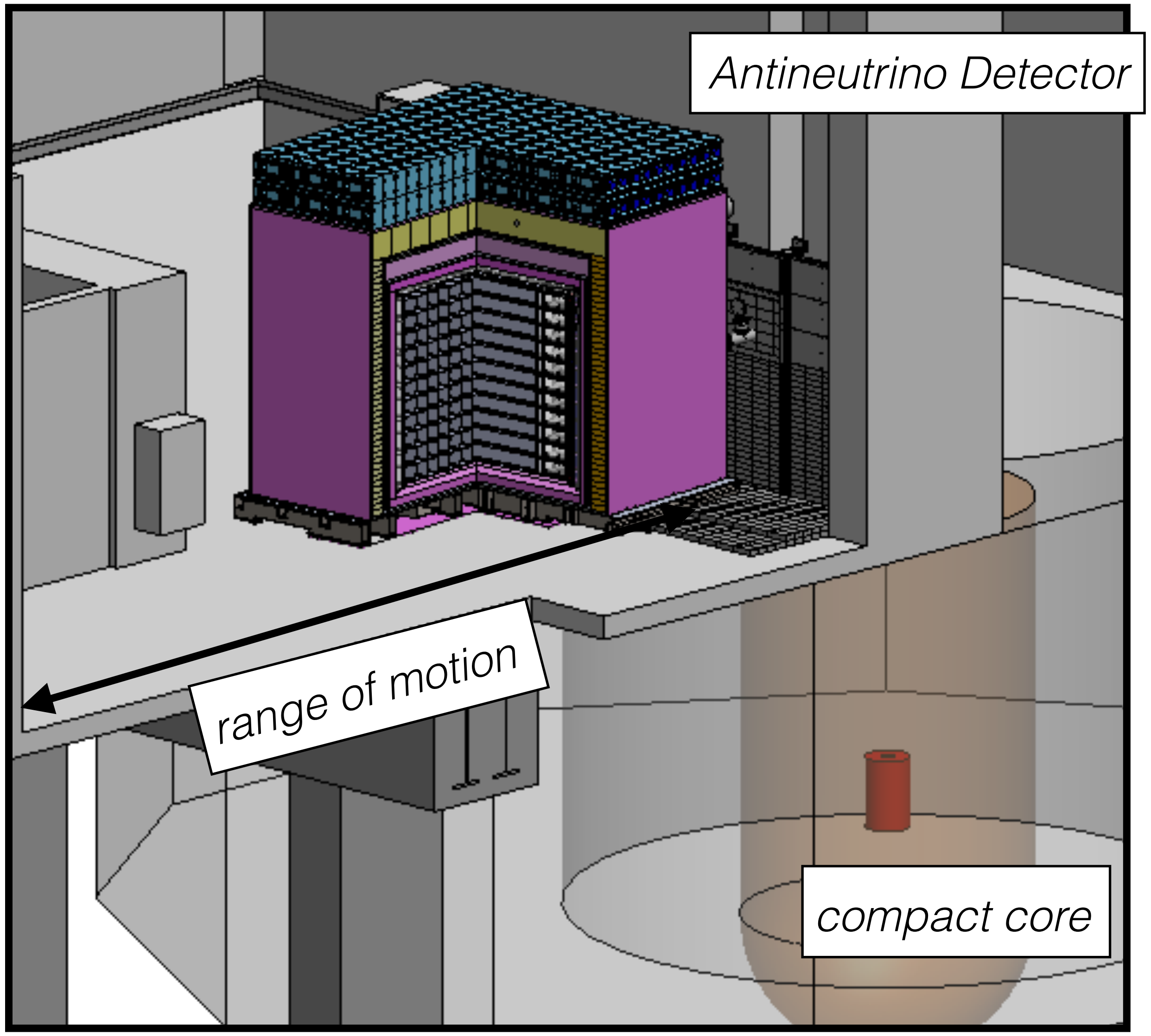
1. model independent search for eV-scale sterile neutrinos at short baselines
2. measure ^{235}U-only antineutrino spectrum to address spectral deviations

Close proximity to reactor (< 10m)

- search for sterile oscillations throughout the detector (segmented)
- high statistics for precision spectrum
- possible at research reactors, allows us to isolate a single isotope ^{235}U

Challenges at HFIR near-surface site

- backgrounds: cosmogenic fast neutrons and reactor gammas
- limited space: compact calorimeter
- current detector technology not well-matched for this environment

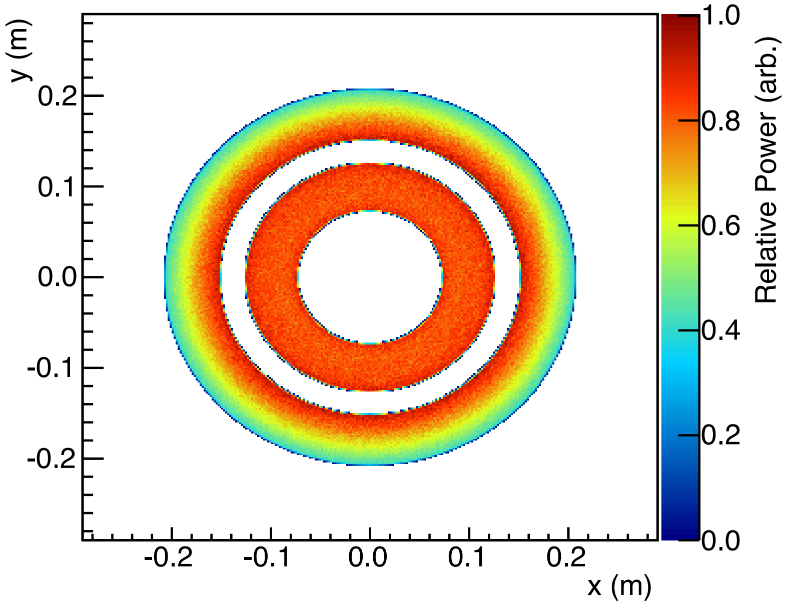


@ High Flux Isotope Reactor (HFIR),
Oak Ridge National Laboratory

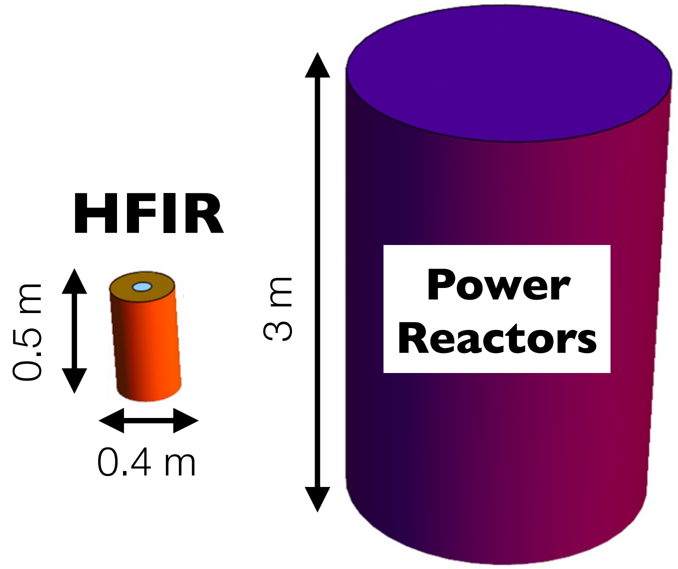
High Flux Isotope Reactor (HFIR)

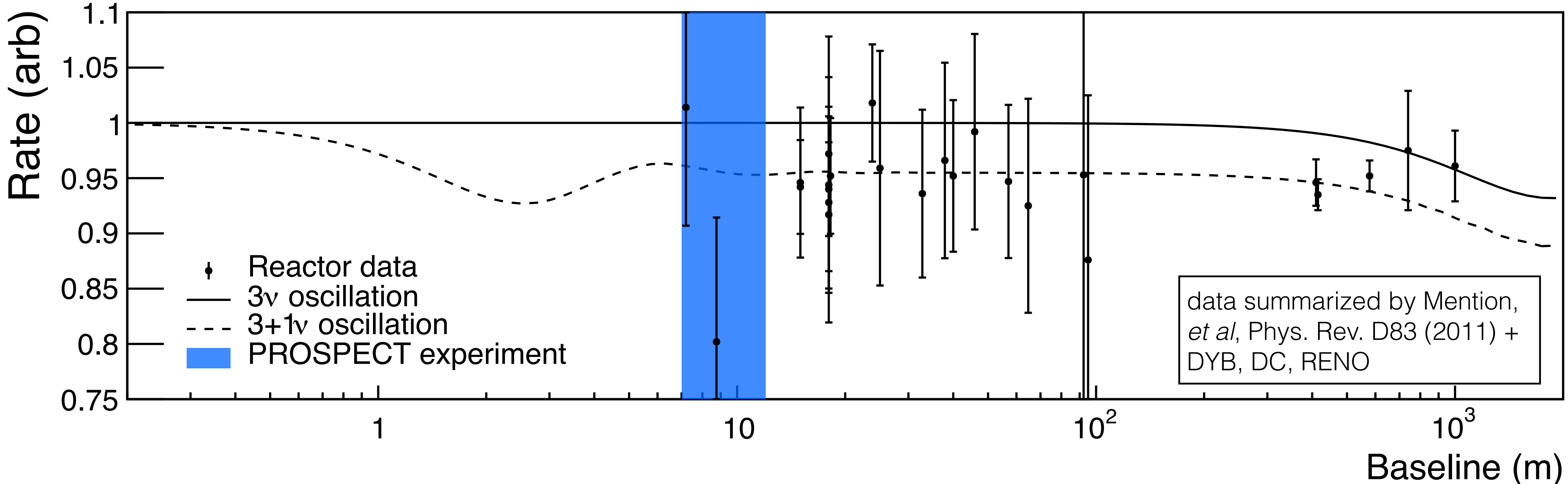
- 85MW highly enriched uranium reactor
- >99% of ν from ^{235}U, ~no isotopic evolution
- 24-day cycles, 46% RxOn; RxOff: measure background
- Compact cylindrical core: 0.2m radius, 1m height
- Baselines 7-12m within mobile detector

Power density



Reactor Sizes





data summarized by Mention, *et al*, Phys. Rev. D83 (2011) + DYB, DC, RENO

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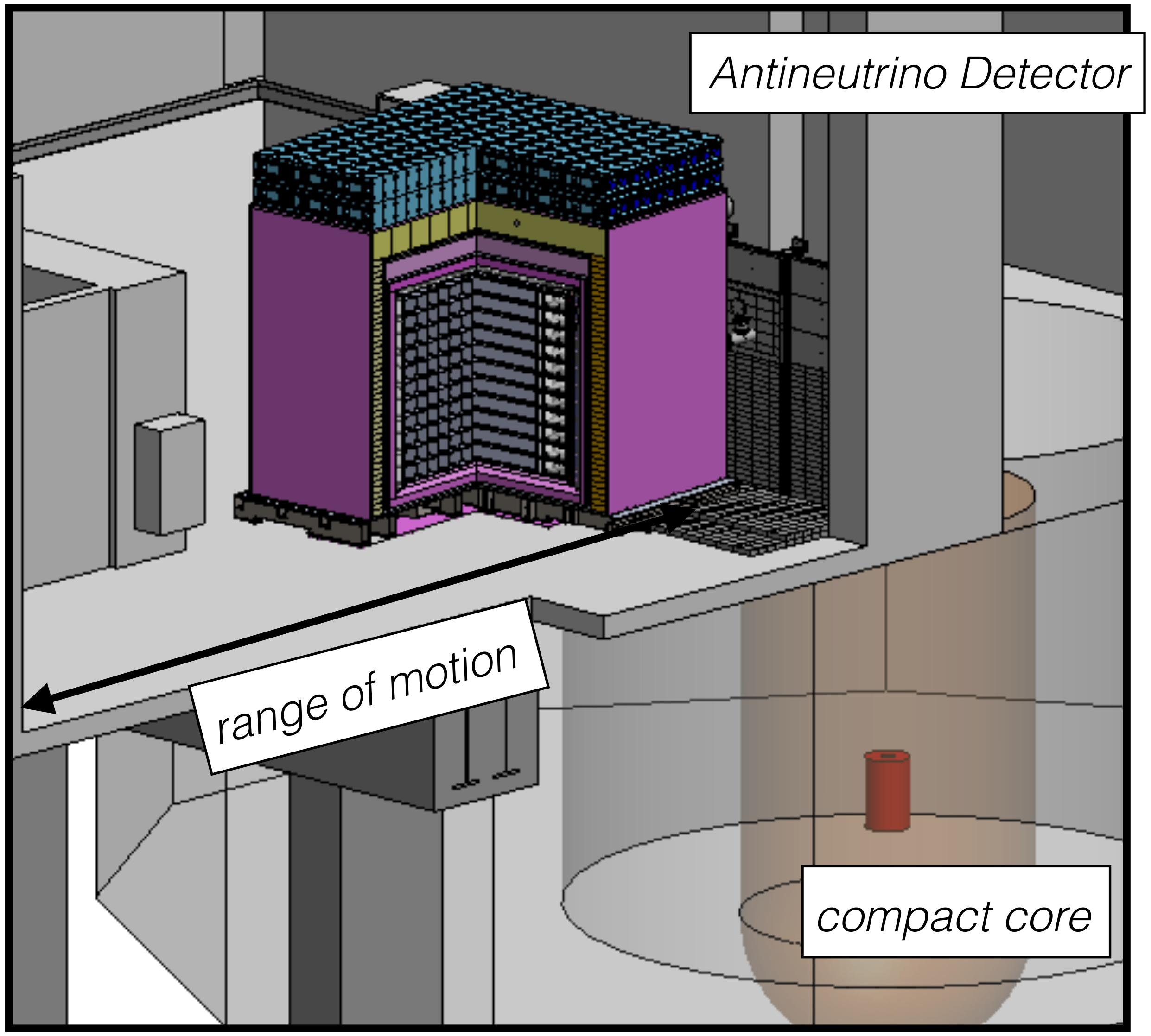
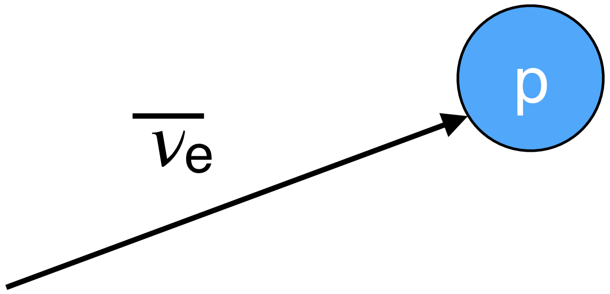


@ High Flux Isotope Reactor (HFIR),
Oak Ridge National Laboratory

IBD Detection in ^{6}Li-doped LS

IBD: $\overline{\nu}_e + p \rightarrow \beta^+ + n$



- develop new liquid scintillator to detect IBDs near-surface reactor environment

IBD Detection in ^{6}Li-doped LS

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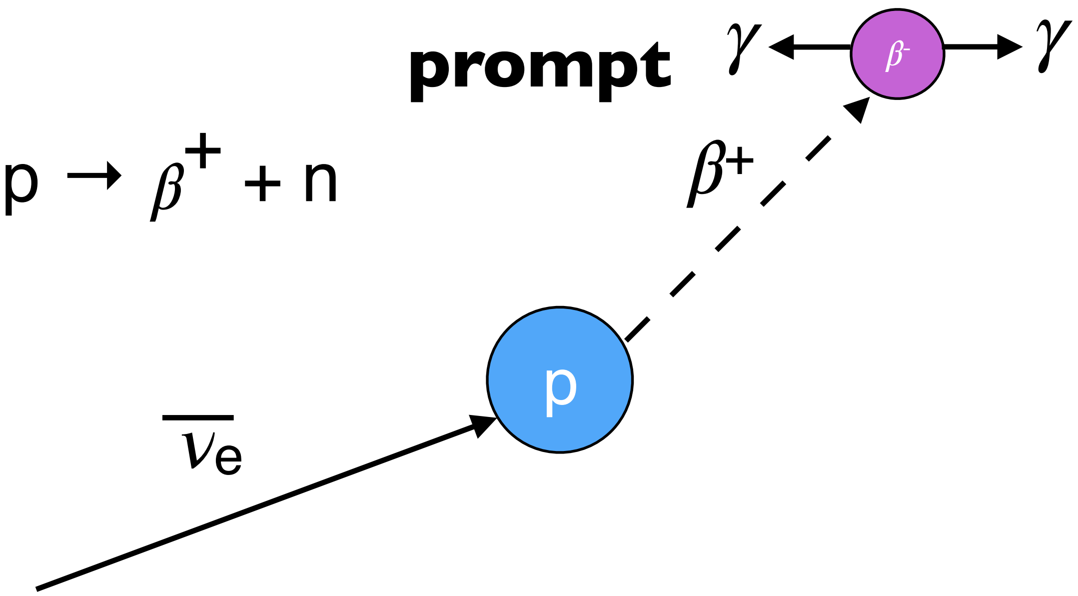

E = 1-10 MeV

- develop new liquid scintillator to detect IBDs near-surface reactor environment
- prompt (or detected) energy: positron ionization is a proxy for neutrino energy

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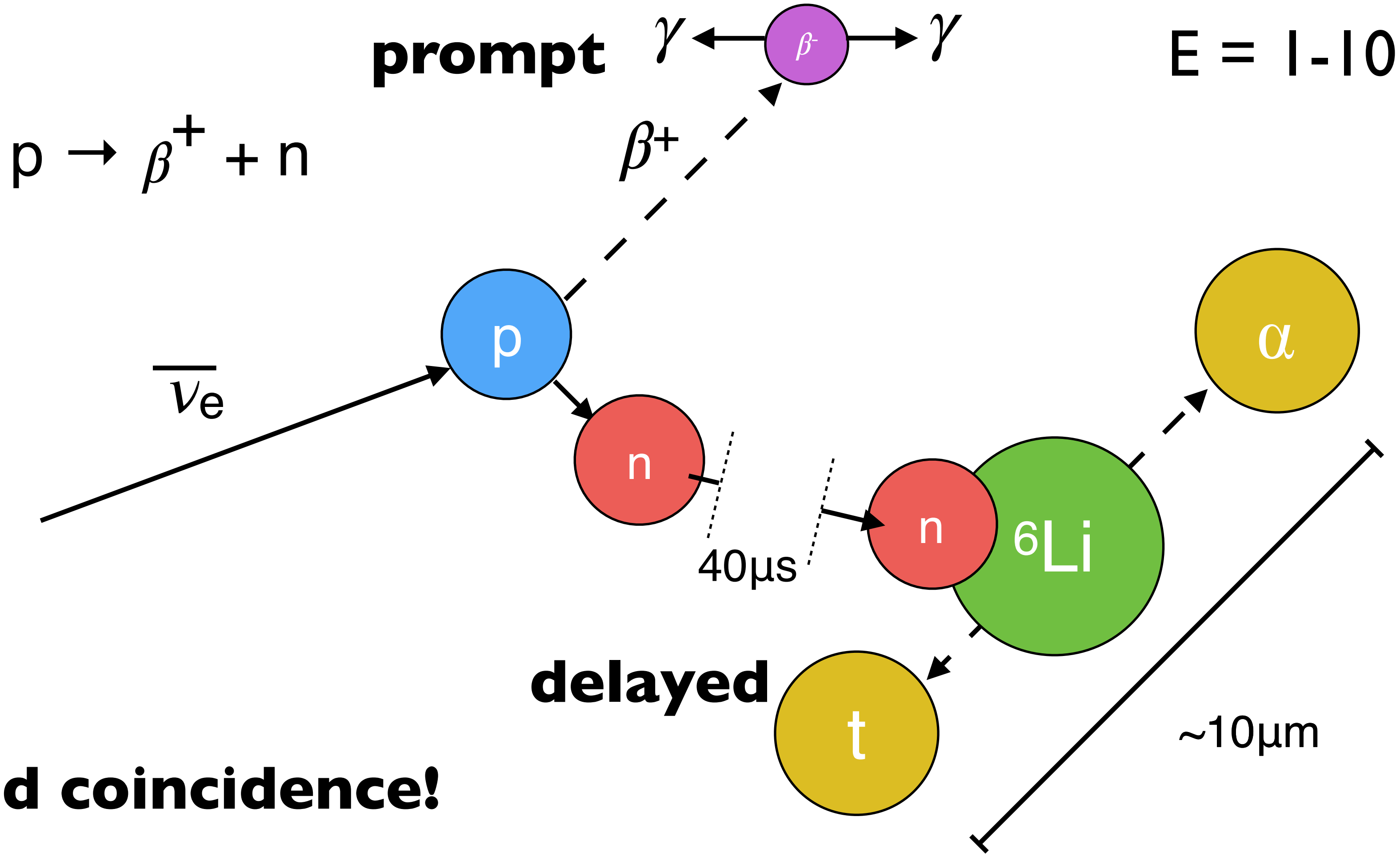


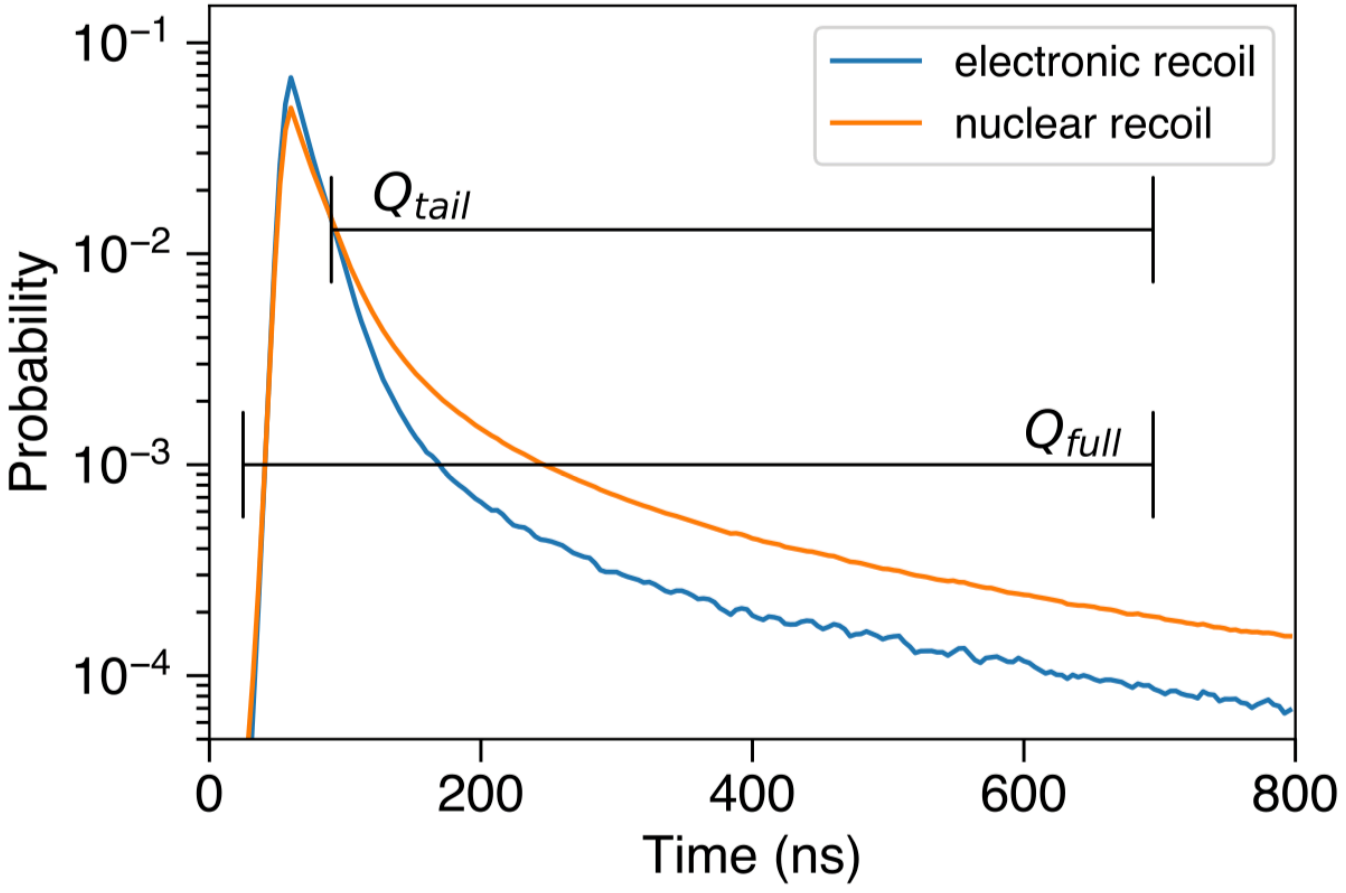
correlated coincidence!

- develop new liquid scintillator to detect IBDs near-surface reactor environment
- prompt (or detected) energy: positron ionization is a proxy for neutrino energy
- development of ^{6}LiLS for neutron tag needed in compact detector as decay is highly localized in space.. within a PROSPECT segment

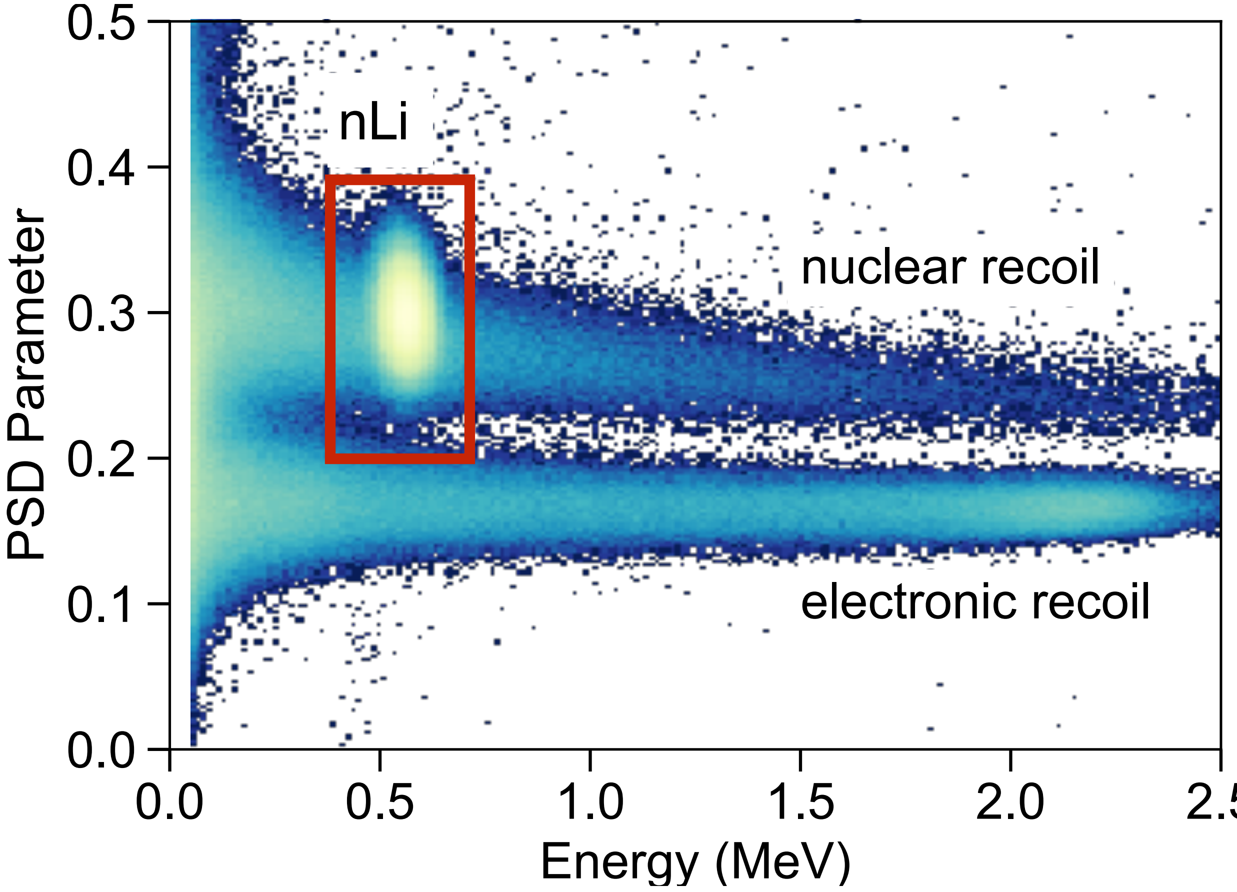
^{6}LiLS ideal for neutrino identification in compact, near-surface detector

Pulse-Shape Discriminating ^{6}LiLS

- Developed ^{6}LiLS with capabilities to distinguish particles through their scintillation timing profile (ionization density).
- PSD adds powerful information to identify IBD and reject backgrounds
- A multi-year R&D effort to optimize PSD, geometry, optics, etc.



PROSPECT two-segment prototype



PSD = Qtail/Qfull

PROSPECT, JINST 13 P06023 (2018)

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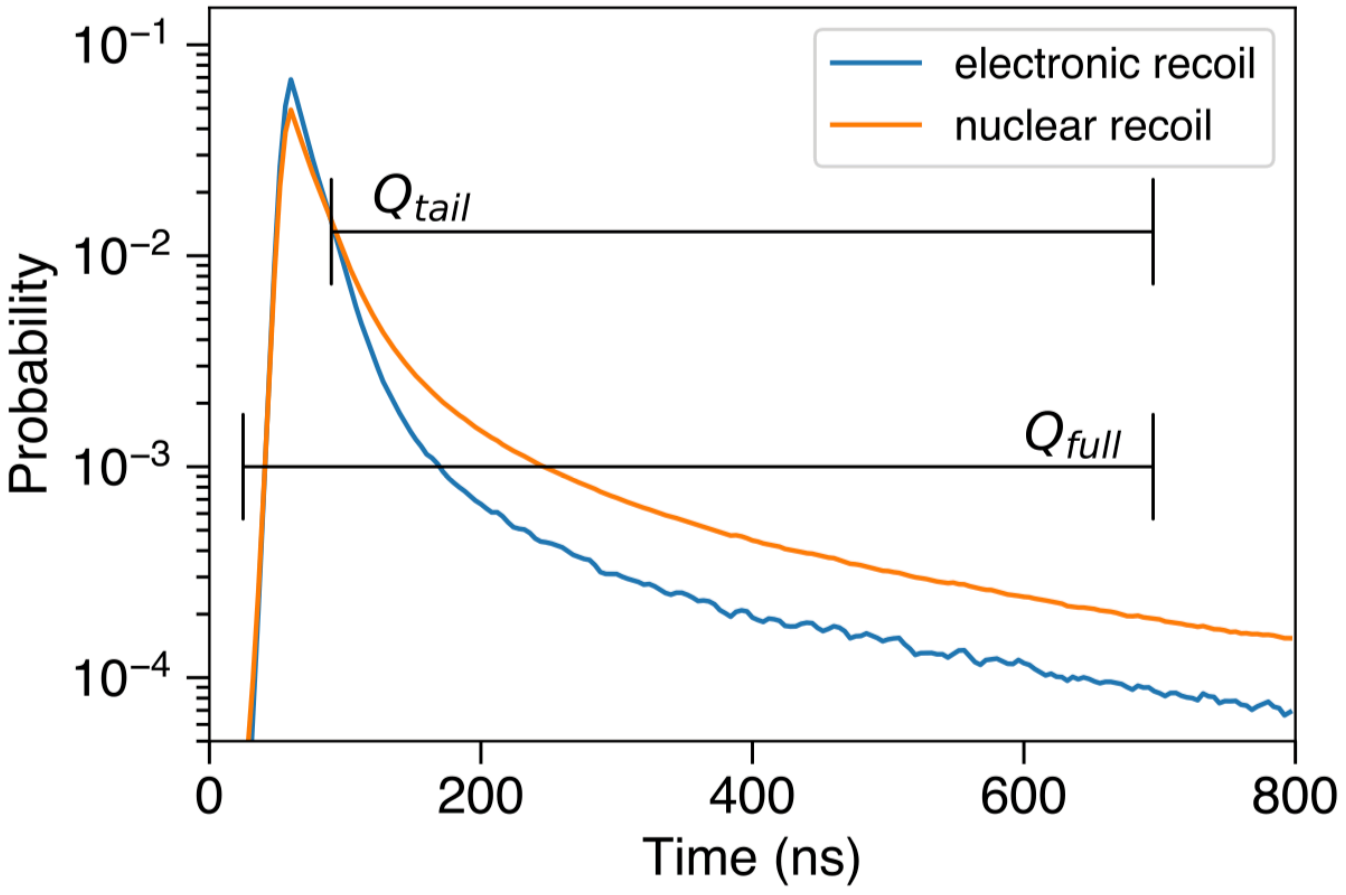

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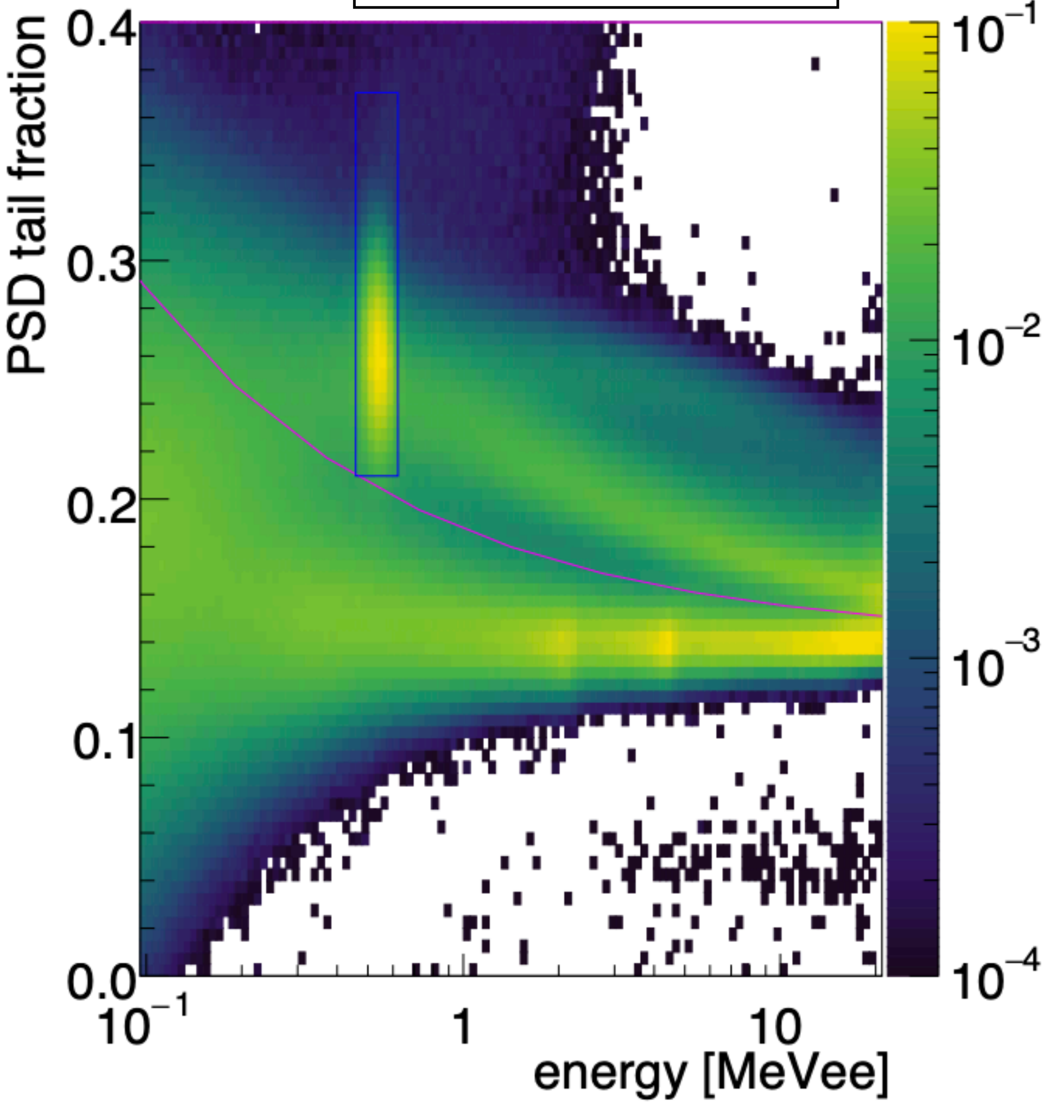
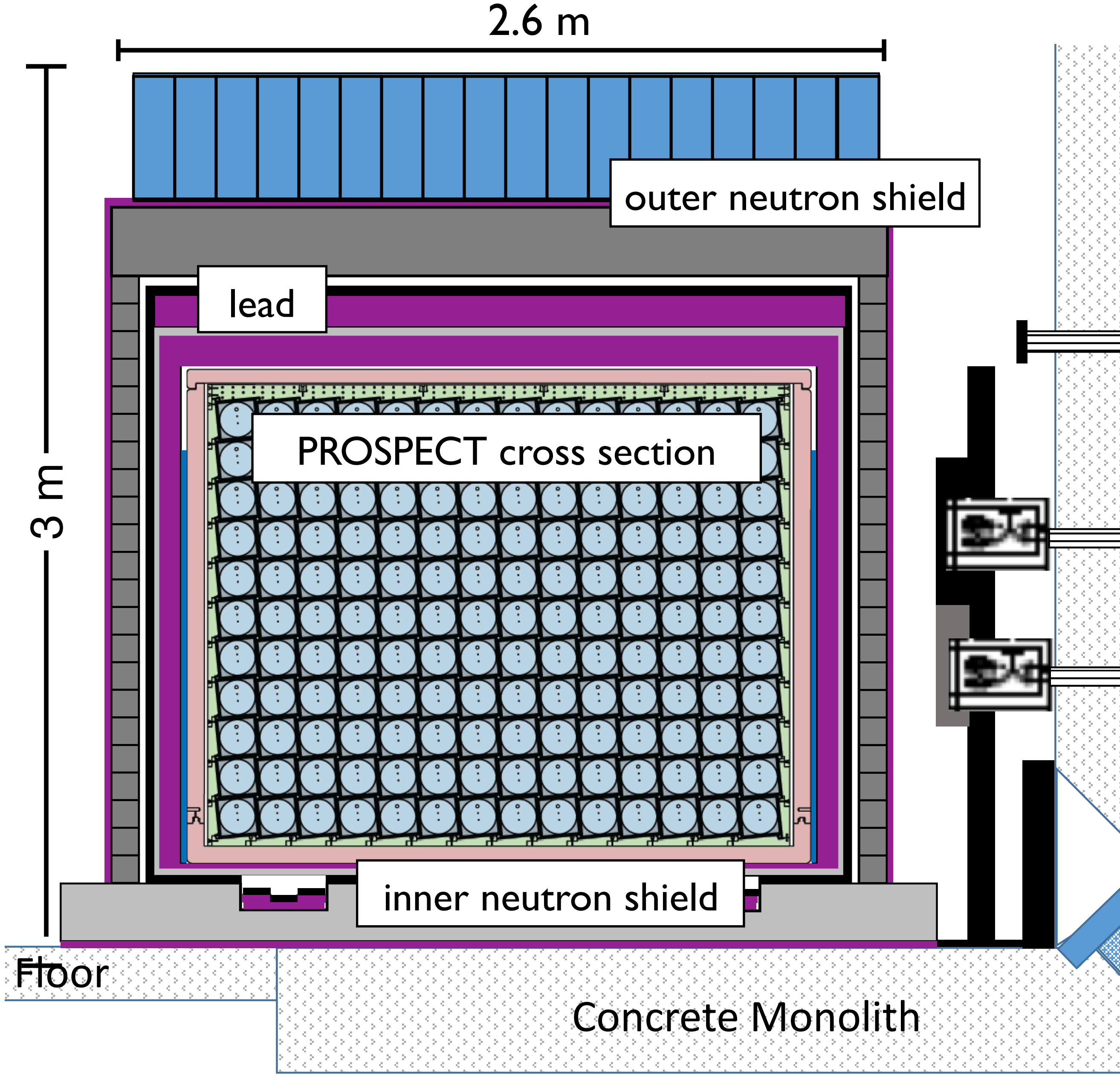
real PROSPECT data

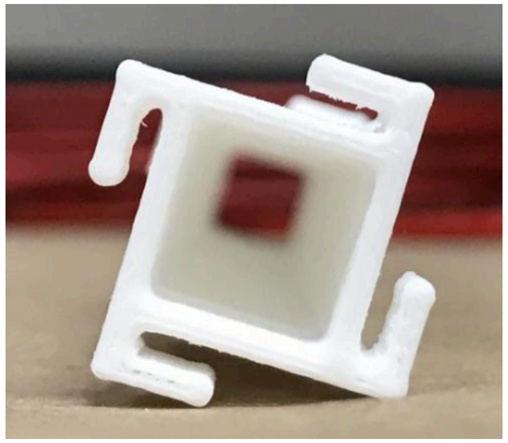


PROSPECT, NIM A806 401 (2019)

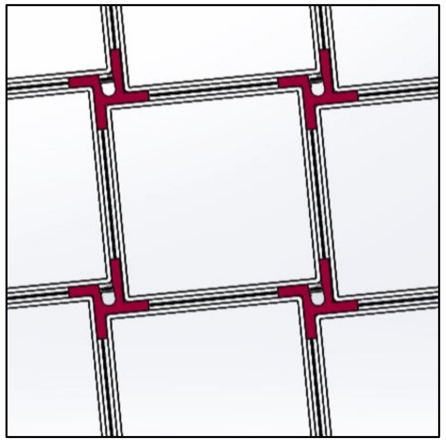
PROSPECT Segmented Detector Design

- 4 tons ^{6}Li-loaded liquid scintillator
- 154 segments, 119cm × 15cm × 15cm
- thin (1.5mm) highly reflective optical panels held in place by 3D printed support rods
- calibration access along each segment
- 3D position reconstruction (X,Y) with (Z) from double-ended PMT readout
- optimized shield for backgrounds at the surface and reactor

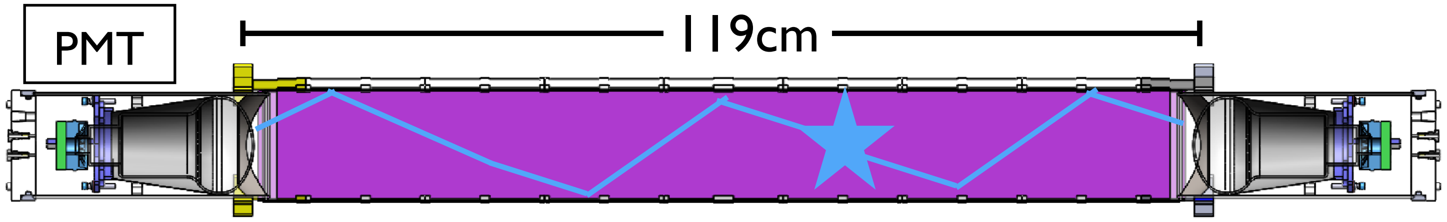




3D printed support rod



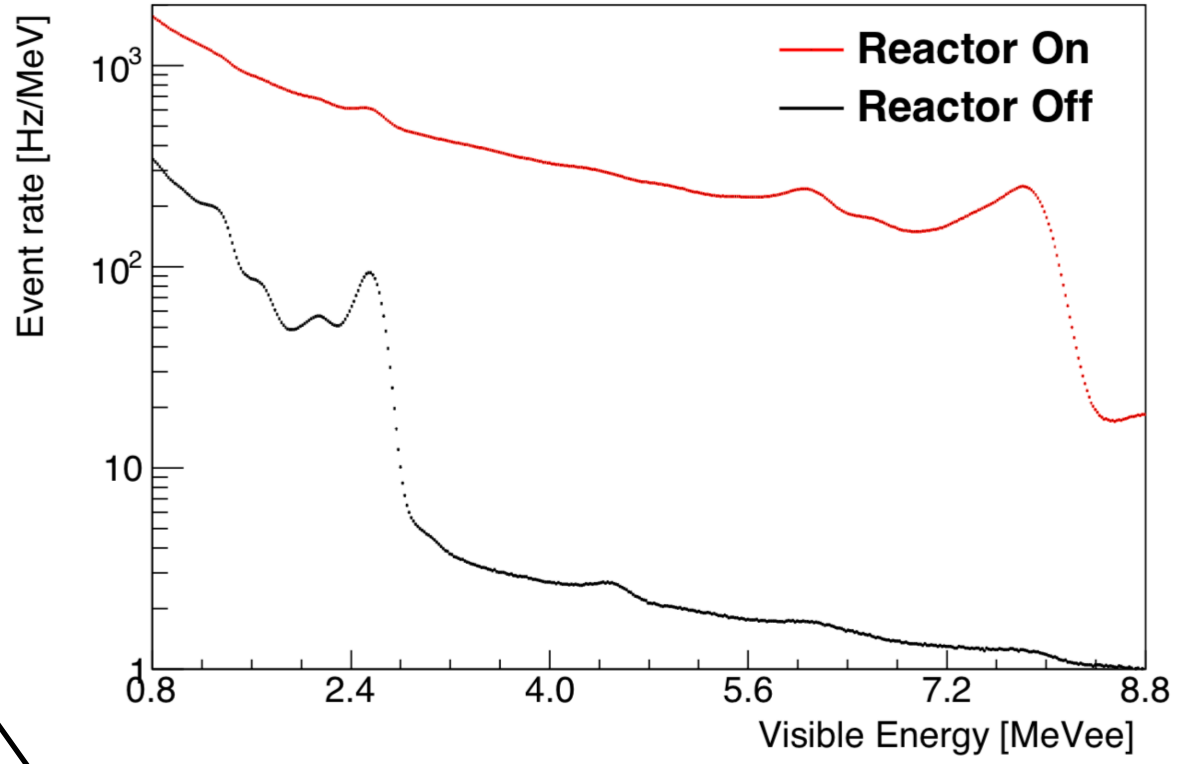
tilt for calibration access

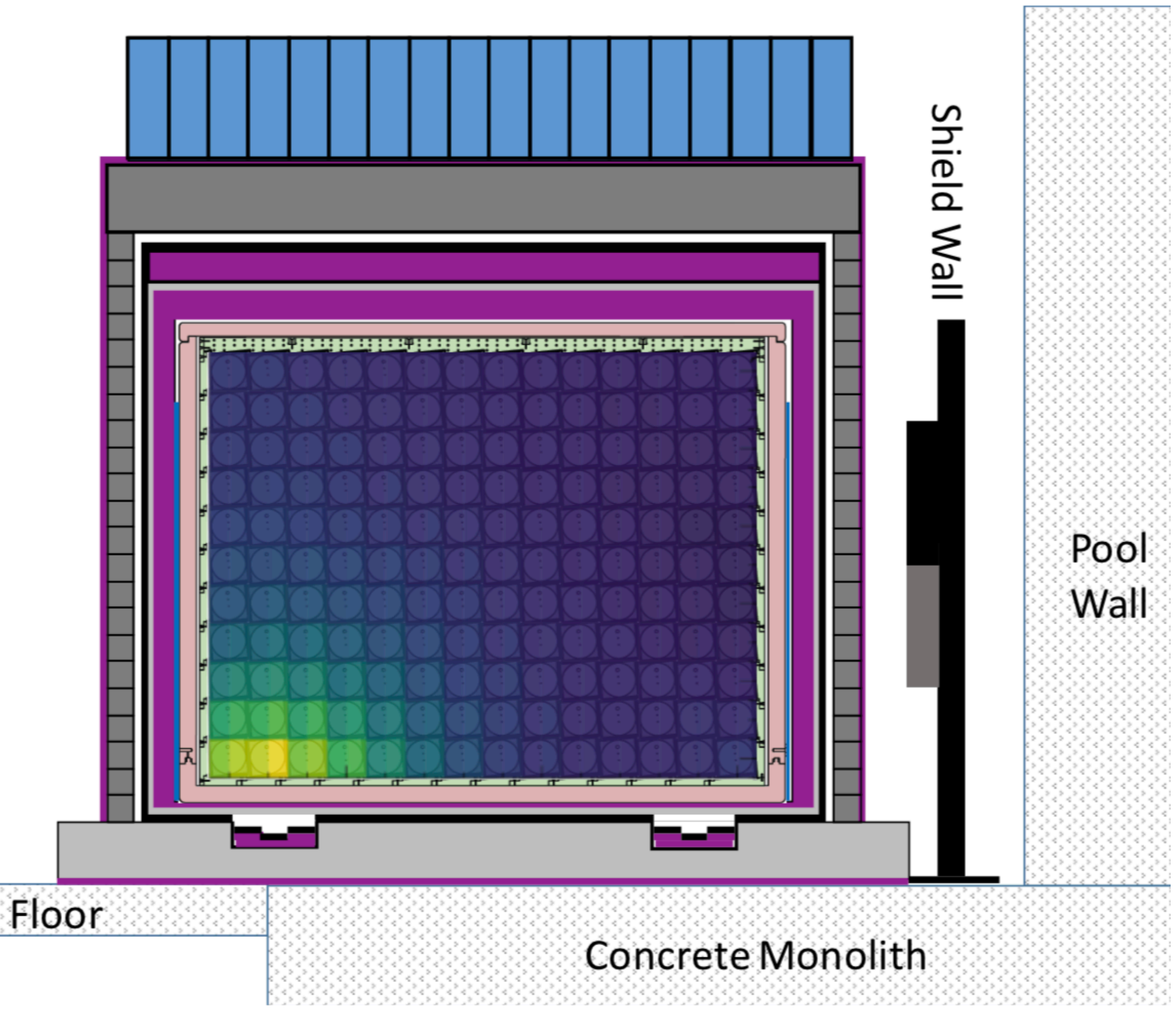


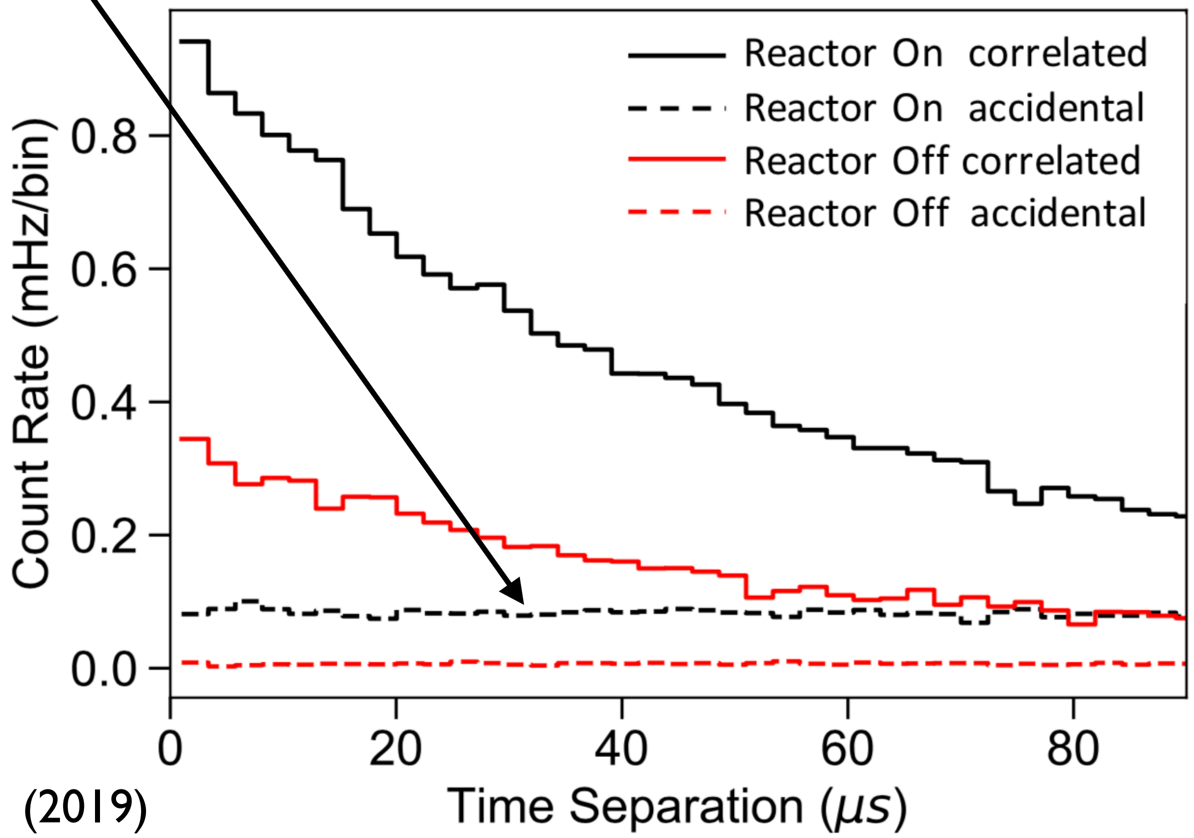
Liquid Scintillator Volume

Ambient Backgrounds

- Event rates in PROSPECT are substantially elevated during reactor-on data-taking periods
- Unique nLi signature, segmentation enable sub-dominant reactor-related accidental backgrounds



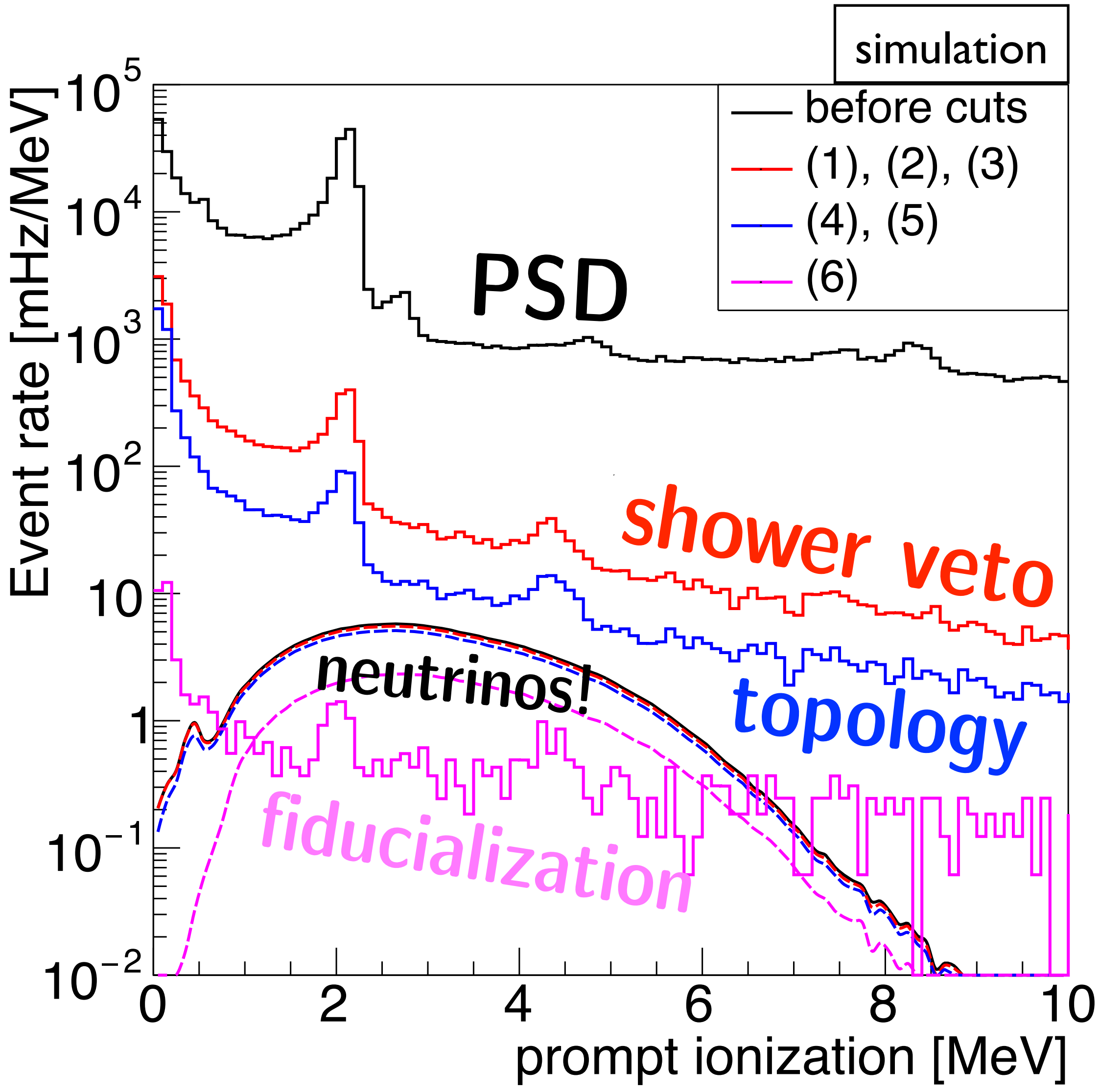




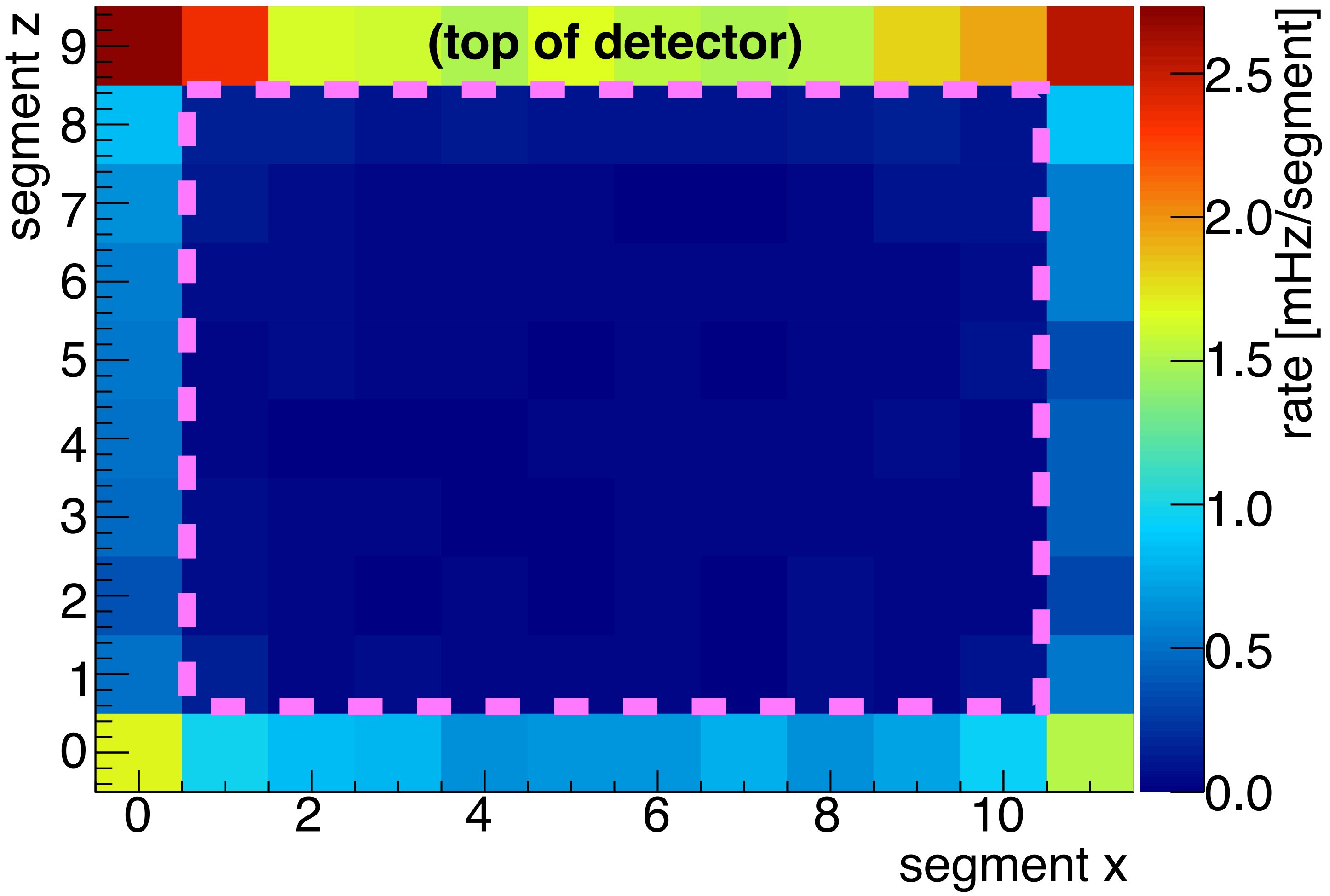
PROSPECT, NIM A806 401 (2019)

Combatting Backgrounds On-Surface

- Near-surface backgrounds: cosmogenic fast neutrons, reactor gammas
- Combination of segmentation, ^{6}Li liquid scintillator, particle ID powerful
- **PSD**, **shower veto**, **topology**, and **fiducialization** cuts provide >10^4 active background suppression (signal:background > 1)



PROSPECT, J. Phys. G 43 (2016)



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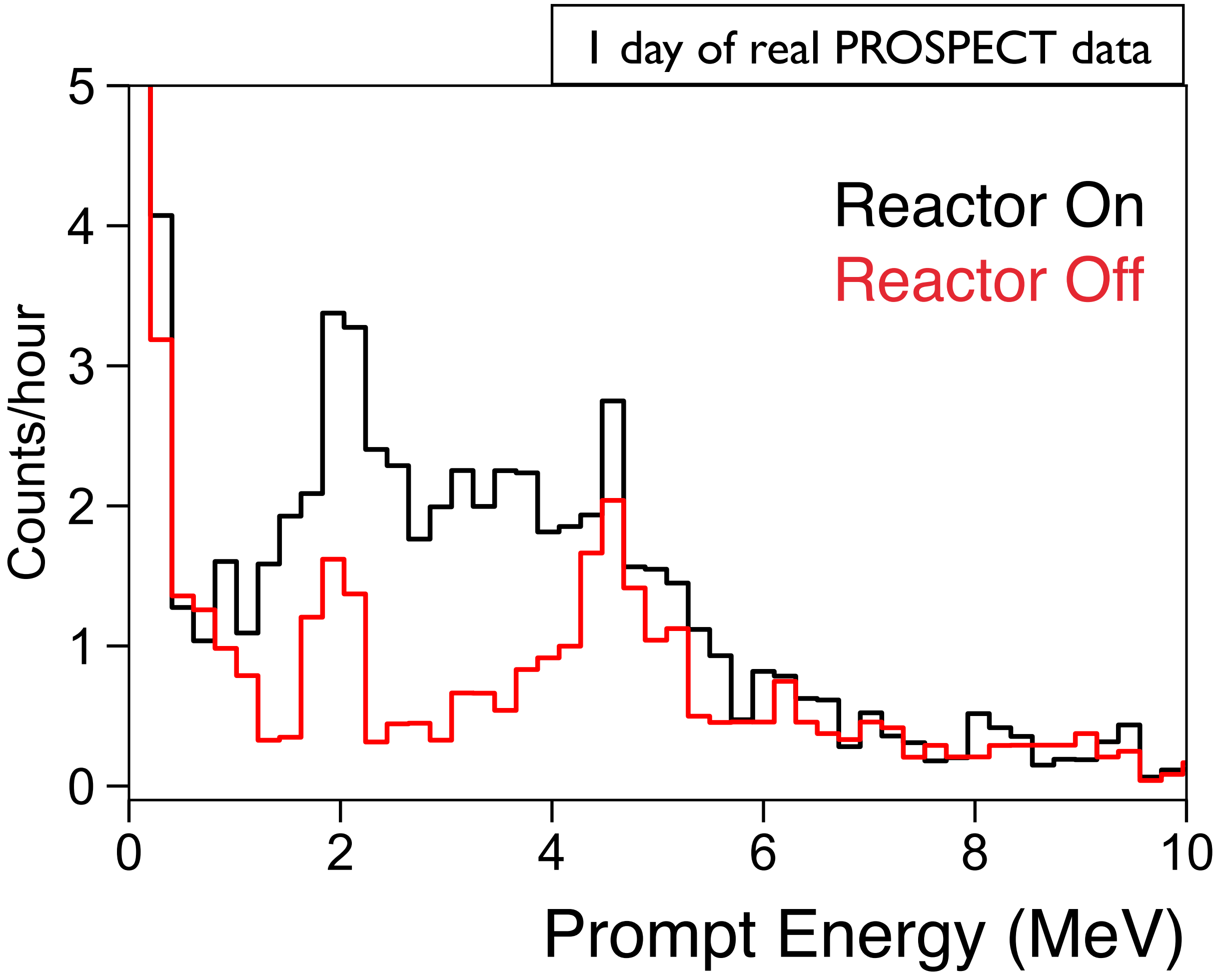

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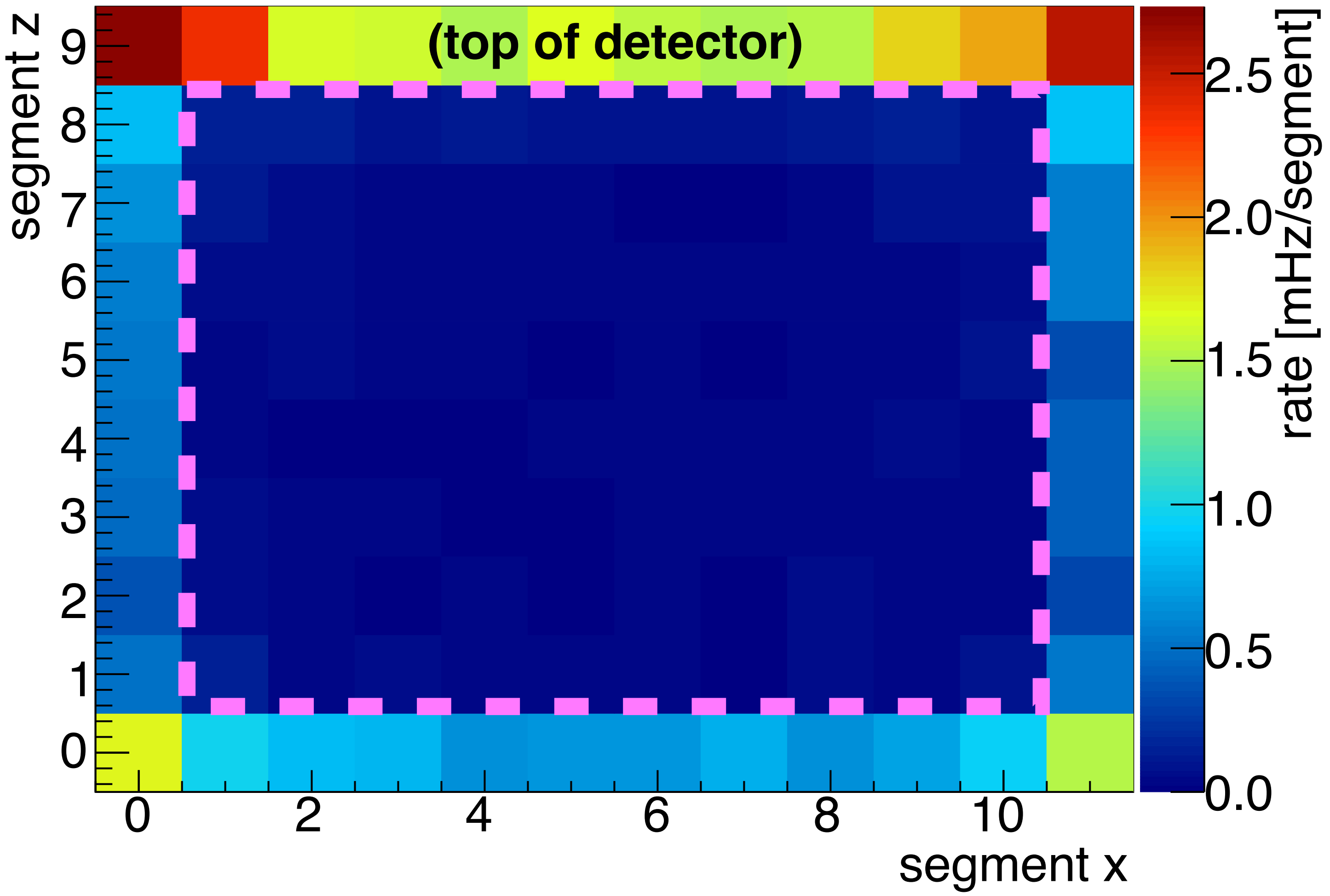
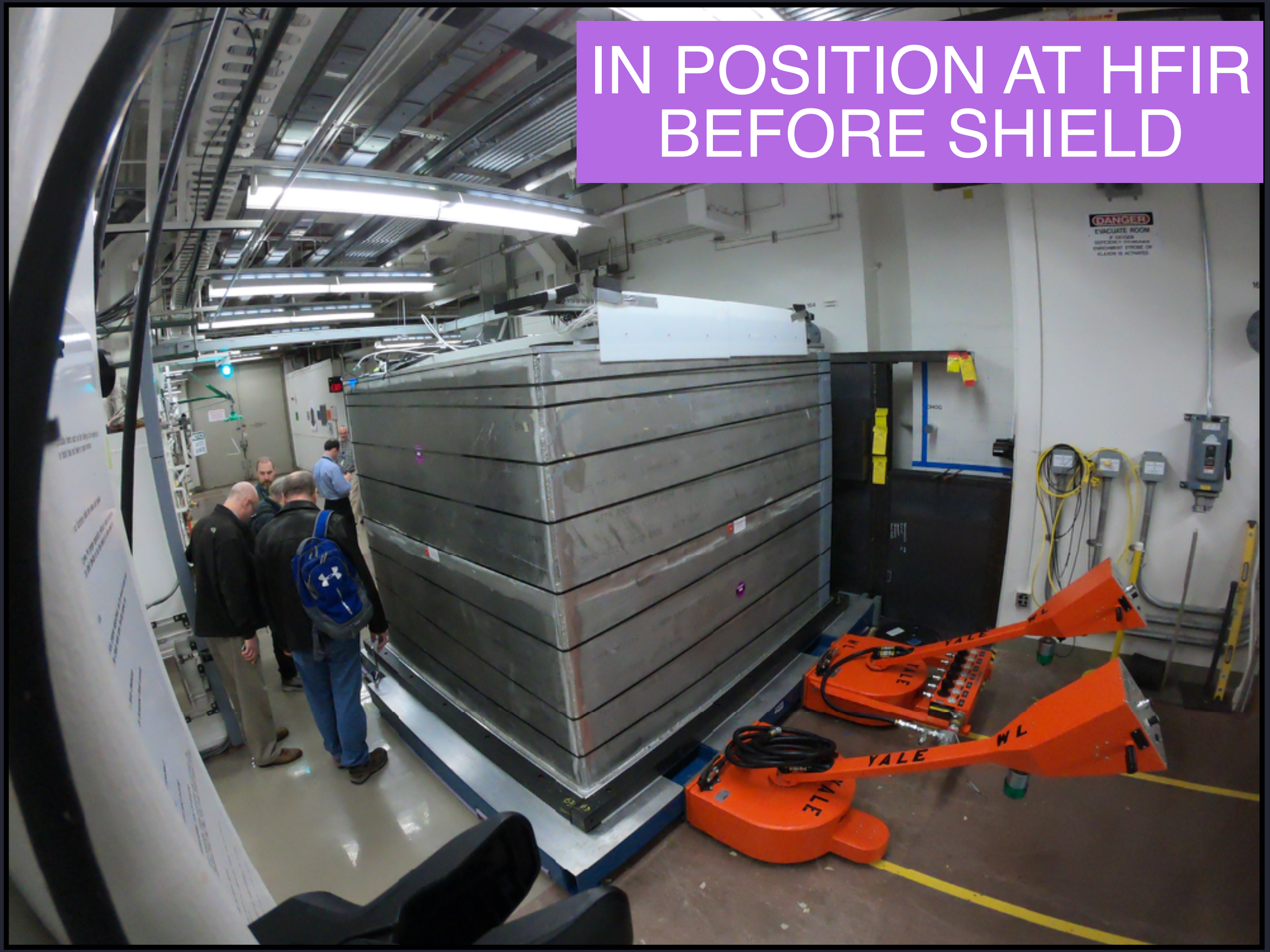


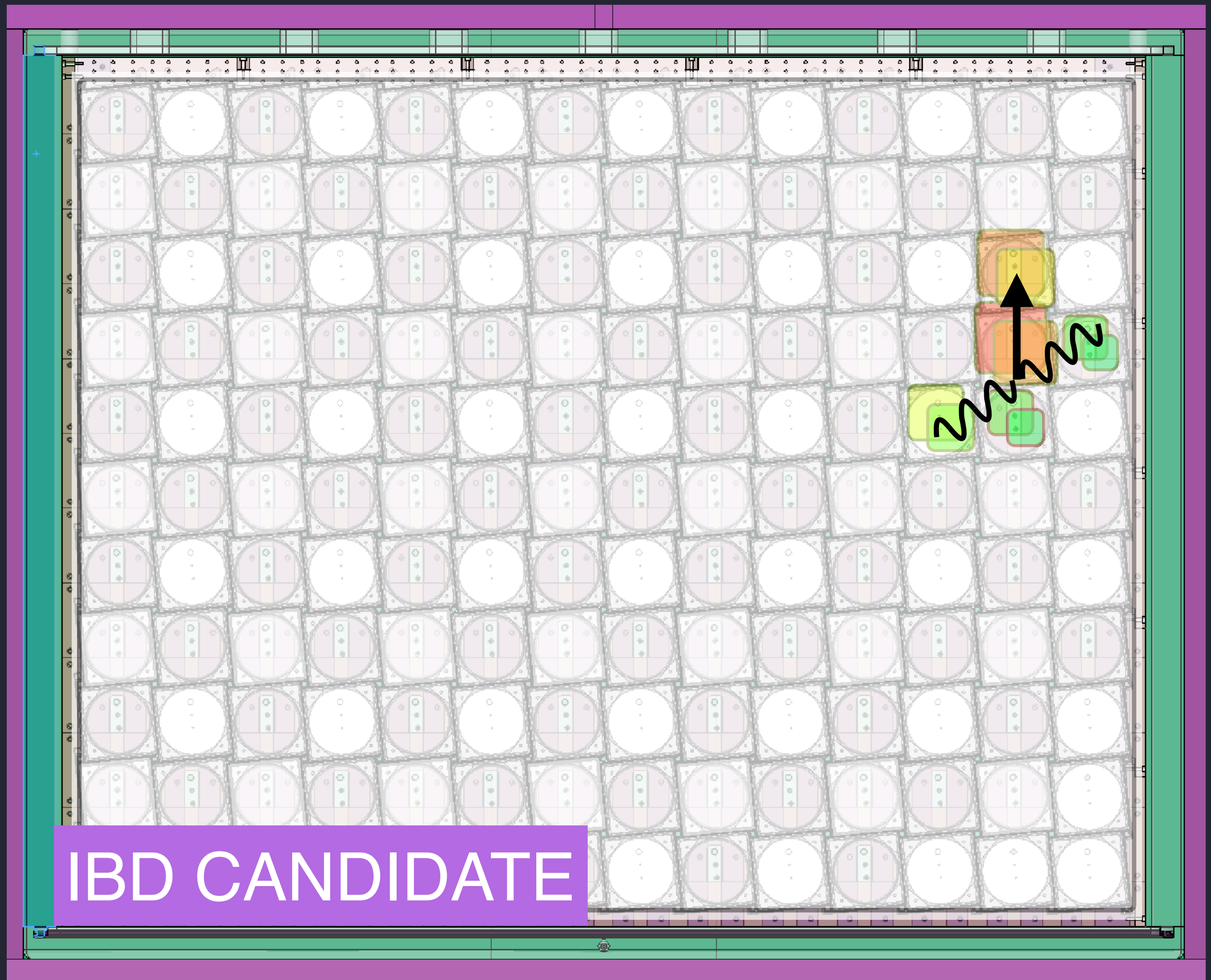
PROSPECT, J. Phys. G 43 (2016)

FEBRUARY 2018 ARRIVAL AT ORNL



IN POSITION AT HFIR BEFORE SHIELD

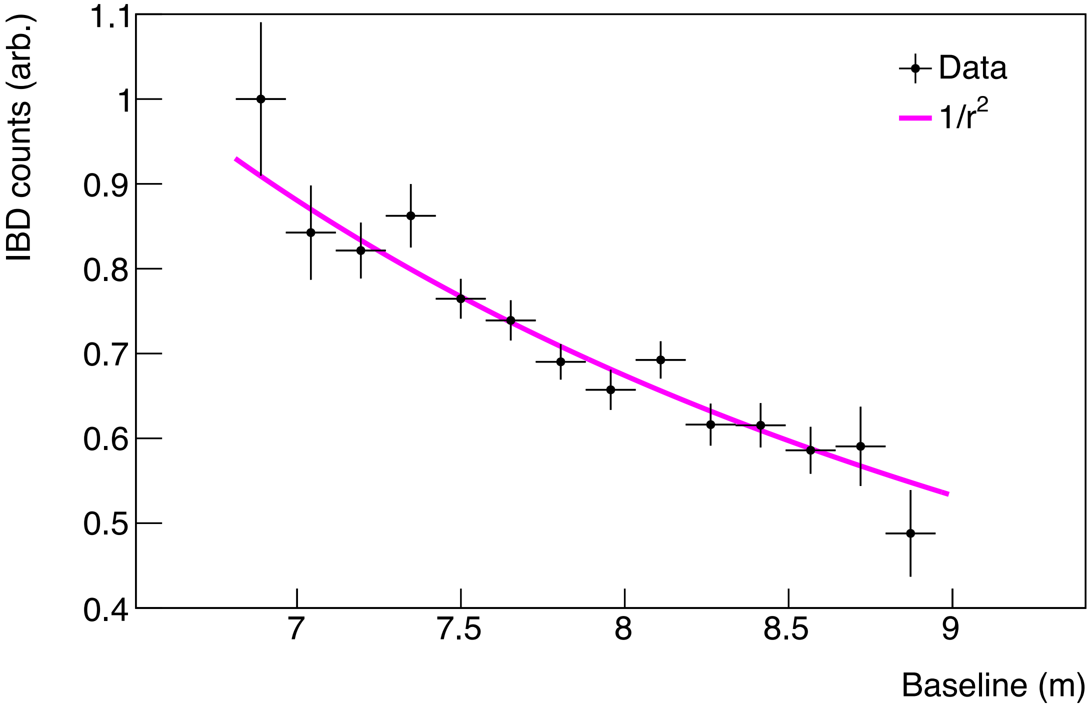
FILLING FROM MIXING TANK

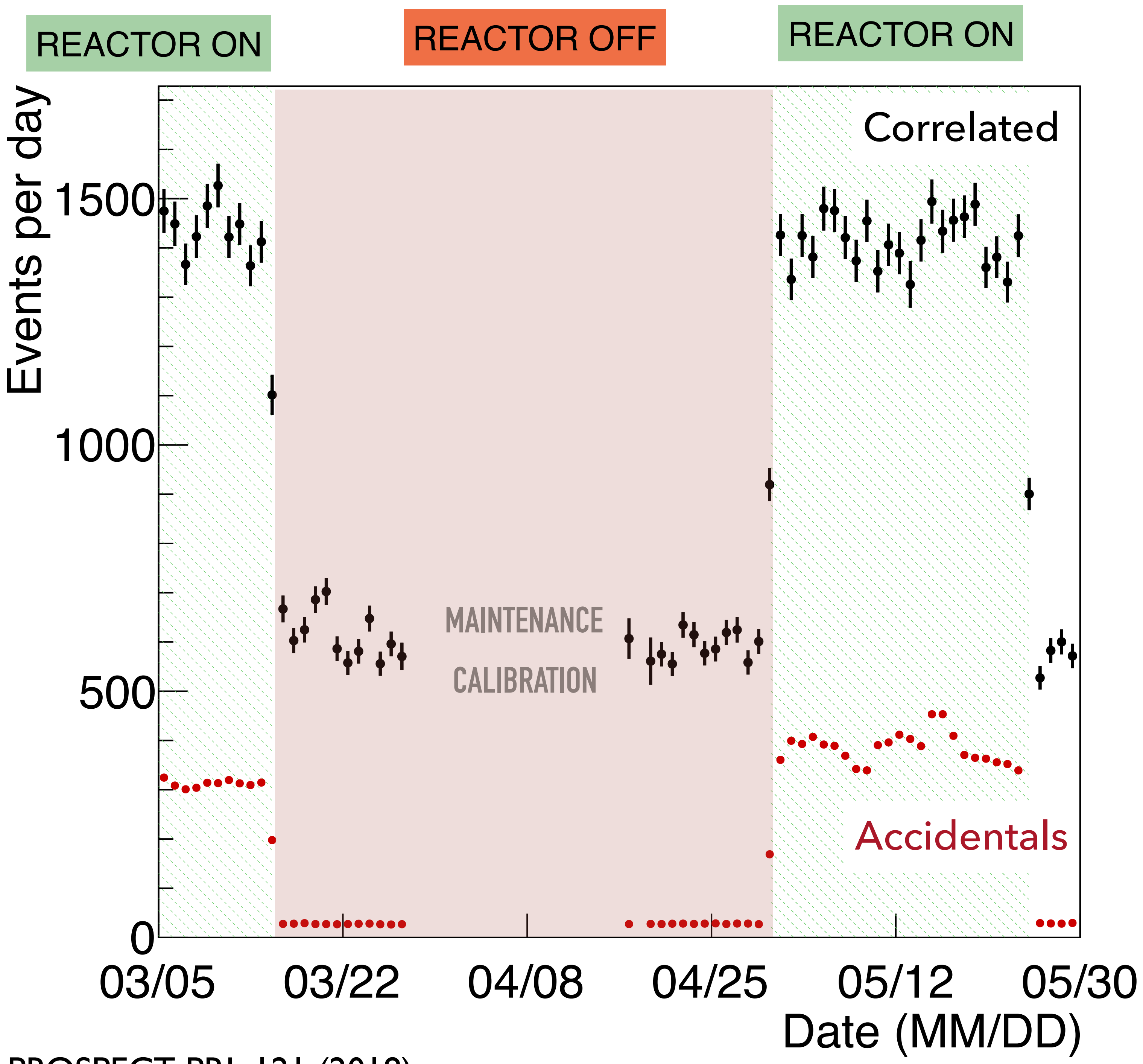


IBD CANDIDATE

Review: Sterile Oscillation Dataset

- 33 days of Reactor On
- 28 days of Reactor Off
- From 0.8-7.2 MeV prompt:
  - ~25,000 IBD interactions
  - average of ~770 IBDs/day
  - **correlated S:B = 1.32**
  - **accidental S:B = 2.20**
  - IBD selection defined and frozen on 3 days of data
- Segment-to-segment 1/r² drop-off clearly visible





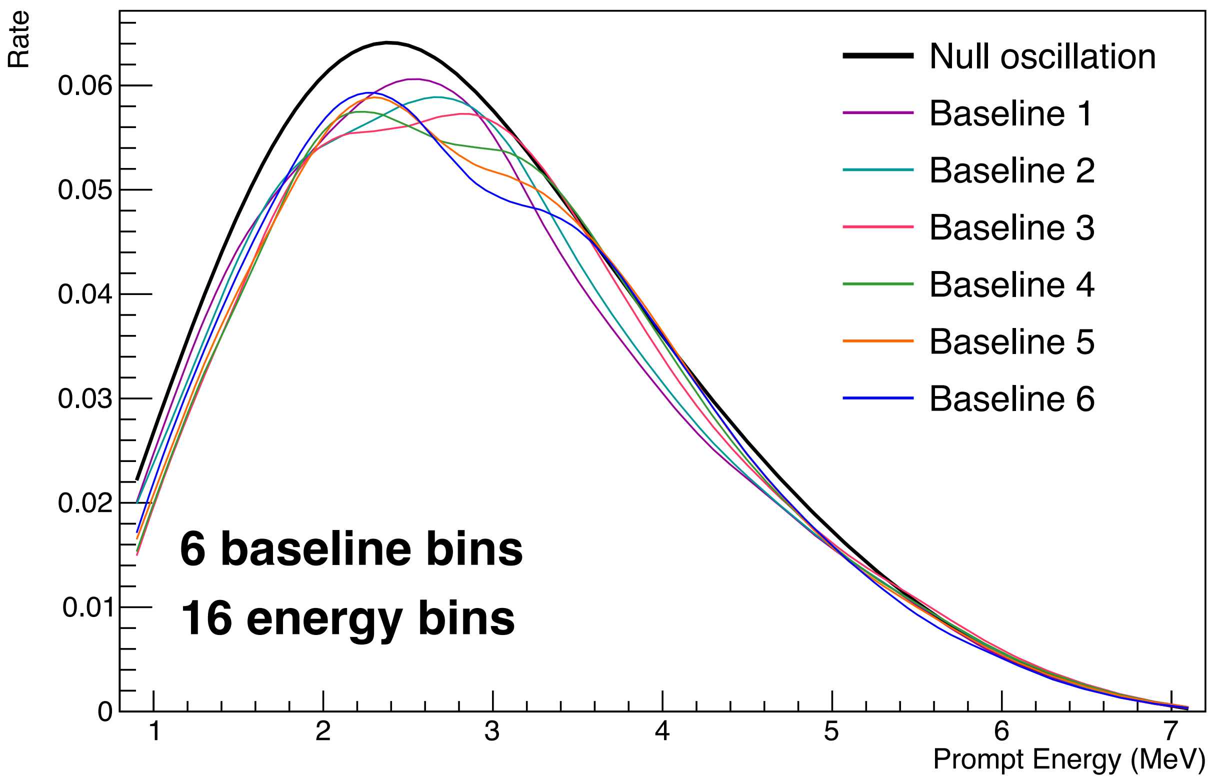
PROSPECT, PRL 121 (2018)

Sterile Oscillation Patterns

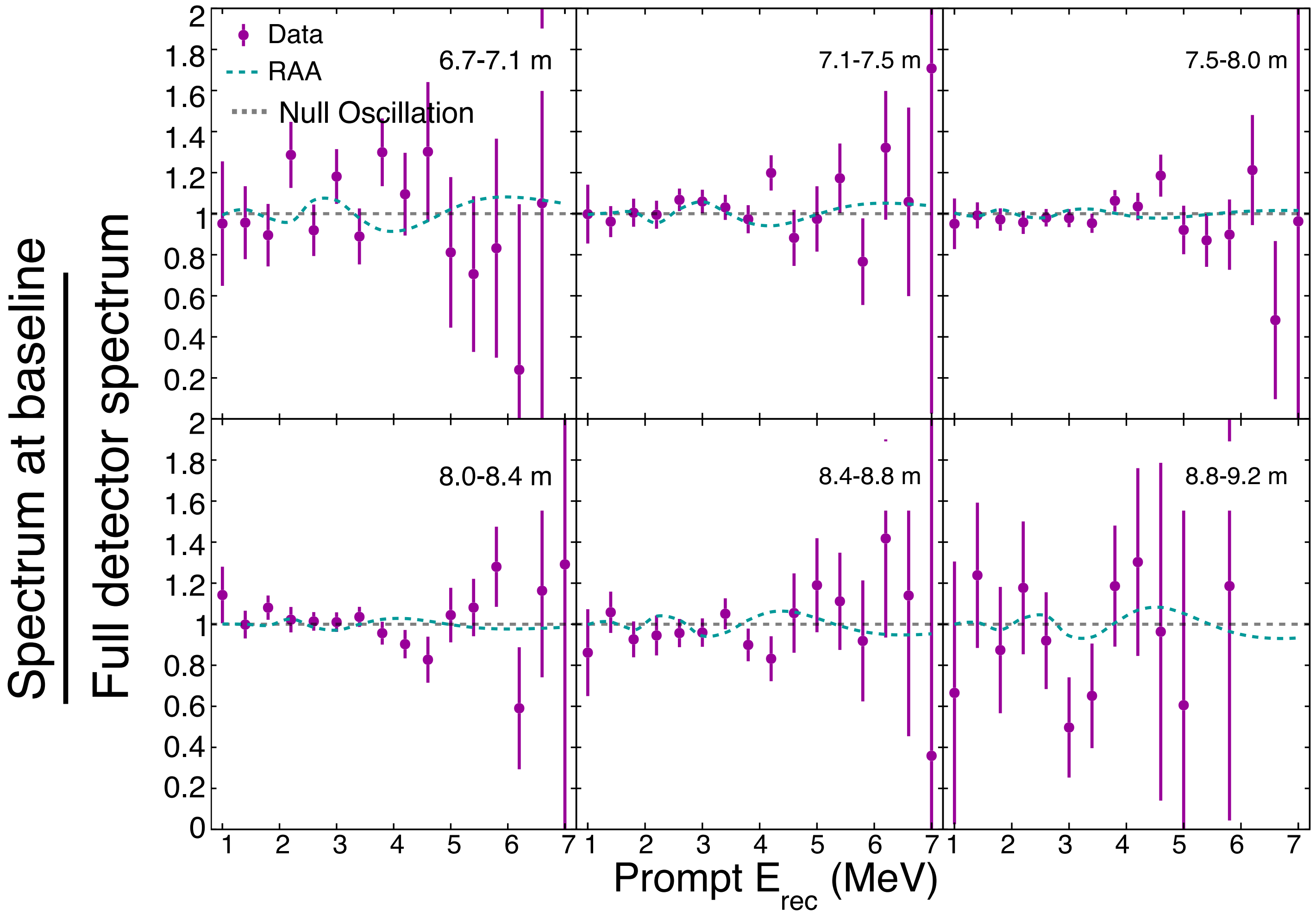
- Combine data into 16 energy, 6 baseline bins
- Divide each baseline's measured energy spectrum by the full-detector measured energy spectrum
- Compare this to predicted ratio for different (Δm^2_{41}, $\sin^2 2\theta_{14}$):

$$\chi^2_{min}(\Delta m^2, \sin^2 2\theta) = \mathbf{\Delta}^{\mathrm{T}} \mathbf{V}_{\mathrm{tot}}^{-1} \mathbf{\Delta}$$

illustration of baseline-dependent oscillation

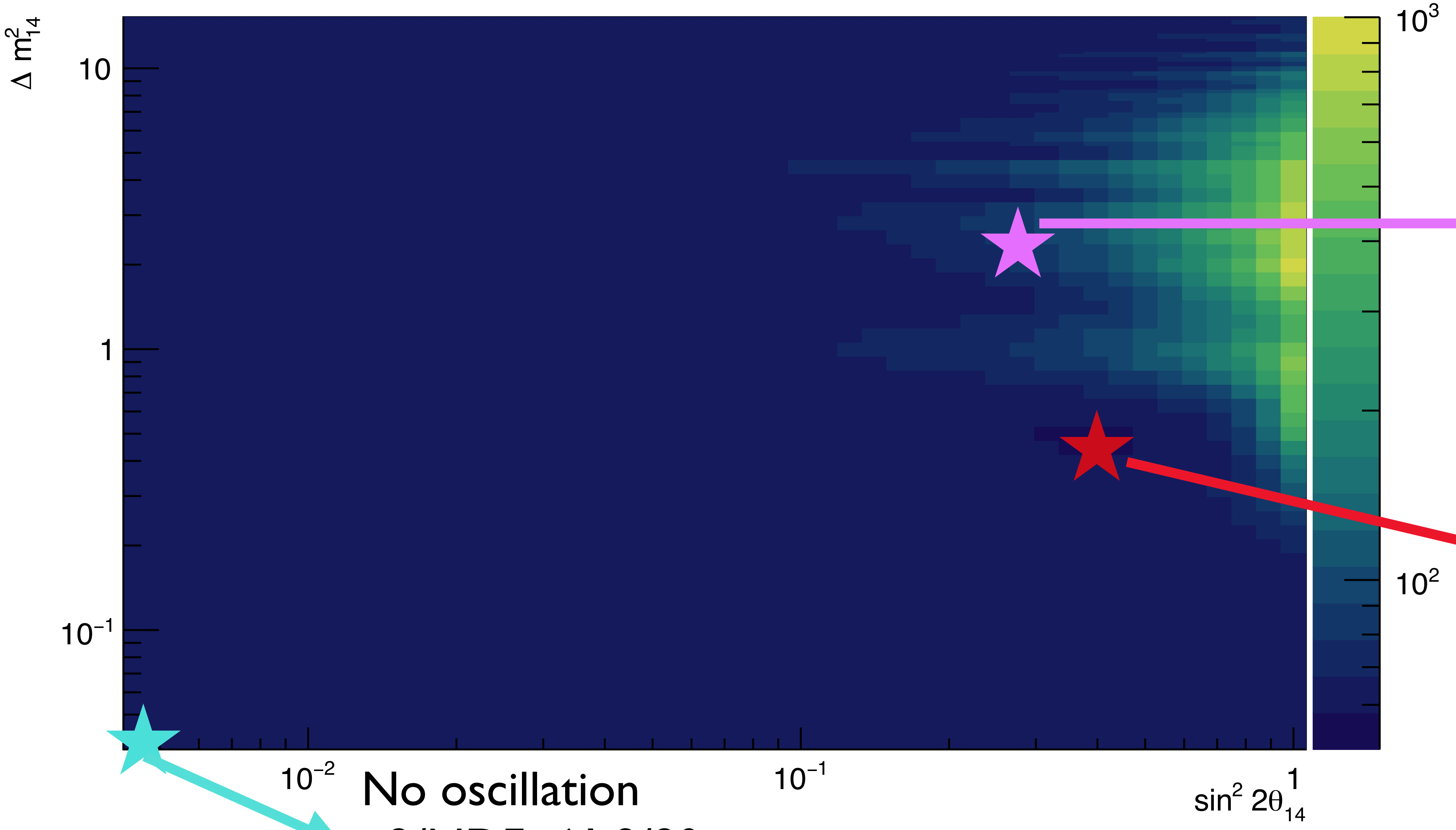


PROSPECT, PRL 121 (2018)



Sterile Oscillation Fit Results

- Best-fit χ^2 of 57.9/78
  - Null (reactor flux anomaly) oscillation is 4 (10.8) higher in χ^2
- What does this mean?
  - Do we rule out null oscillations? Or the osc-only flux anomaly best-fit?



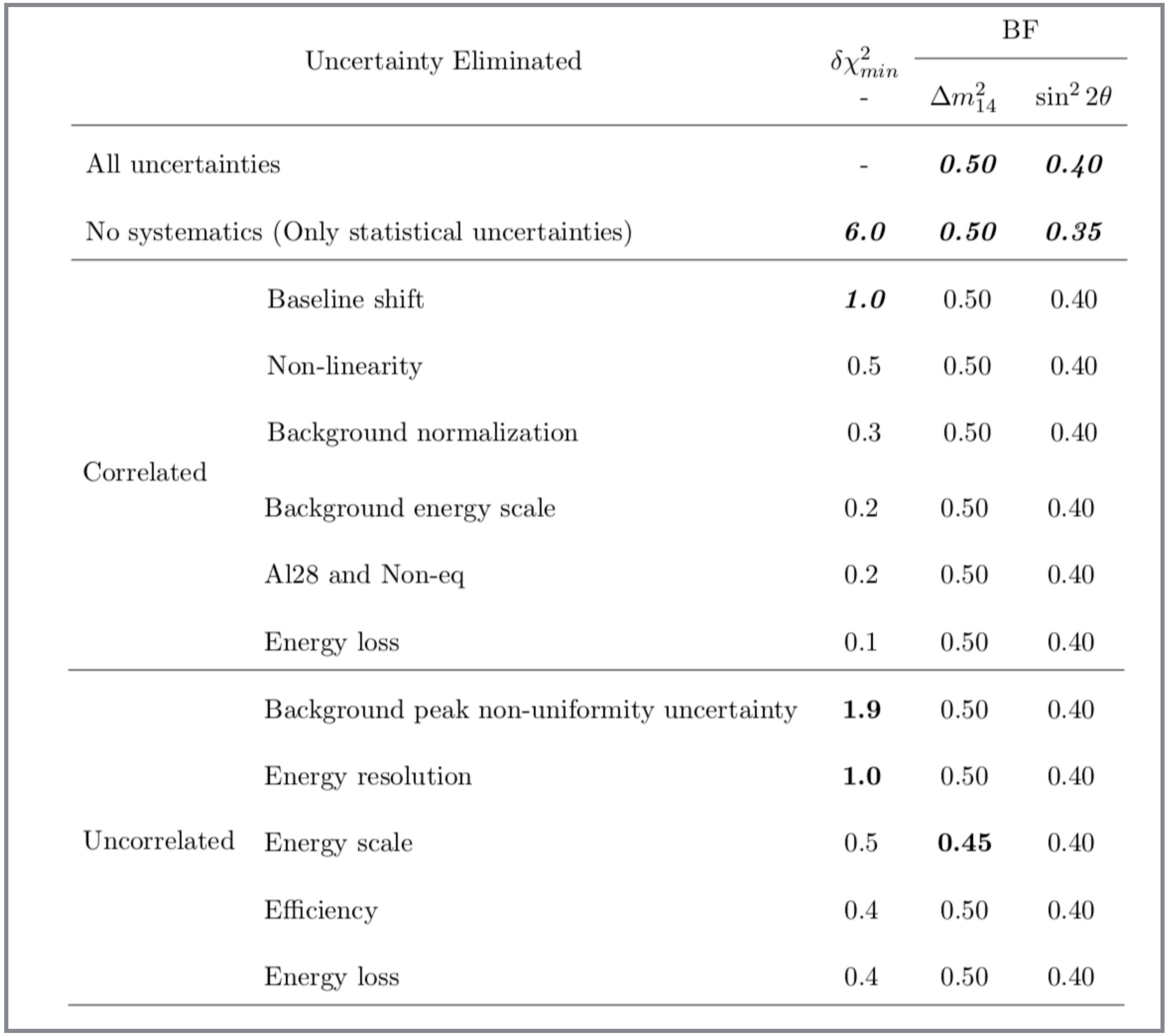
Flux anomaly best fit
χ2/NDF=68.7/78

Best-fit
χ2/NDF=57.9/78

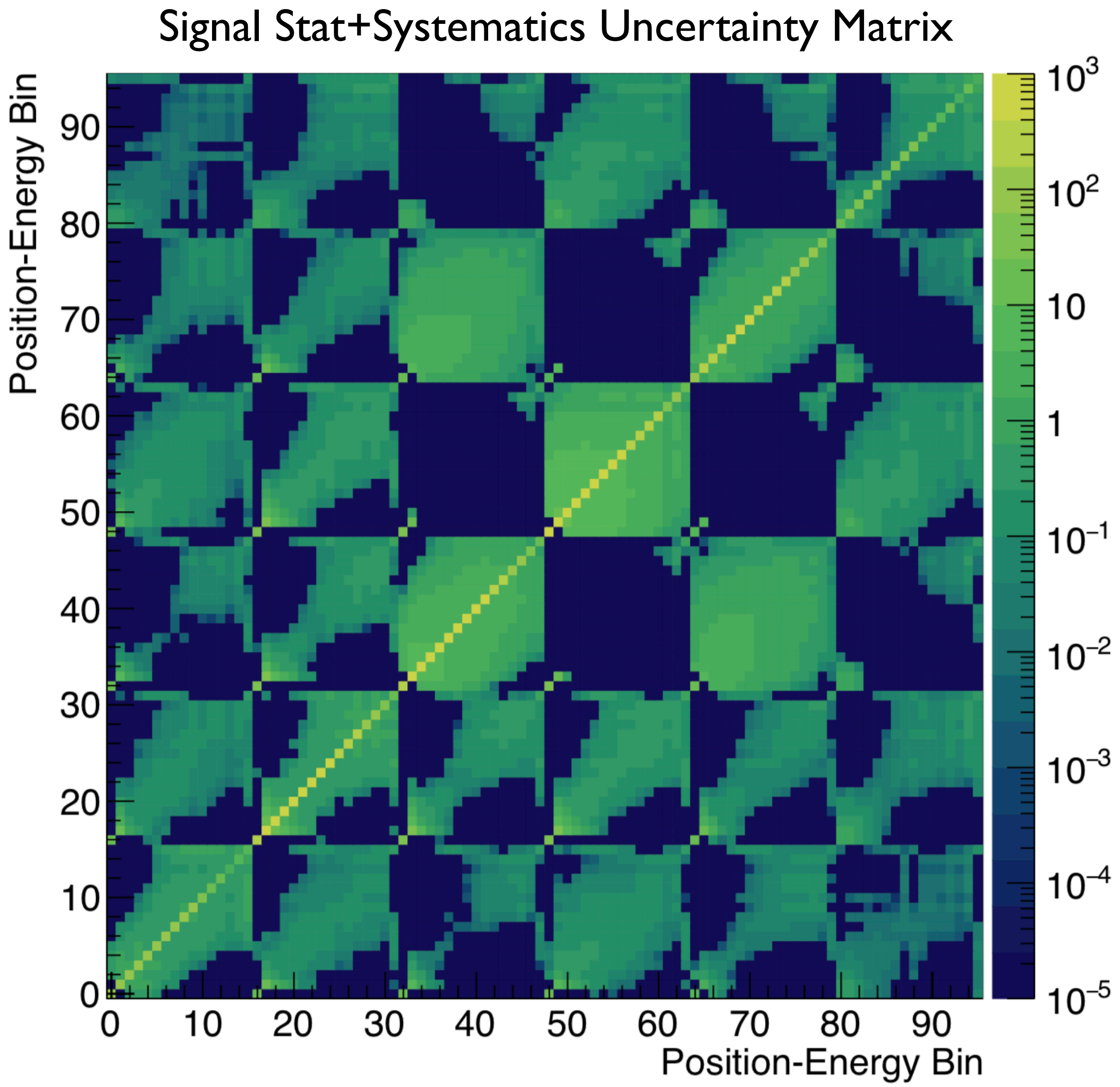
No oscillation
χ2/NDF=61.9/80

Sterile Oscillation Systematics

- Must define uncertainties $\mathbf{V}_{\mathbf{tot}}$ $\chi^2_{min}(\Delta m^2, \sin^2 2\theta) = \mathbf{\Delta}^{\mathrm{T}}\mathbf{V}_{\mathrm{tot}}^{-1}\mathbf{\Delta}$
  - Measurements have more than just statistical errors! $\mathbf{V}_{\mathbf{tot}}$, and exclusion curve, are ill-defined without them — especially if the dataset is very large!



	Uncertainty Eliminated	$\delta\chi^2_{min}$	BF	
		-	Δm^2_{14}	$\sin^2 2\theta$
All uncertainties		-	***0.50***	***0.40***
No systematics (Only statistical uncertainties)		***6.0***	***0.50***	***0.35***
Correlated	Baseline shift	***1.0***	0.50	0.40
	Non-linearity	0.5	0.50	0.40
	Background normalization	0.3	0.50	0.40
	Background energy scale	0.2	0.50	0.40
	Al28 and Non-eq	0.2	0.50	0.40
	Energy loss	0.1	0.50	0.40
Uncorrelated	Background peak non-uniformity uncertainty	**1.9**	0.50	0.40
	Energy resolution	**1.0**	0.50	0.40
	Energy scale	0.5	**0.45**	0.40
	Efficiency	0.4	0.50	0.40
	Energy loss	0.4	0.50	0.40

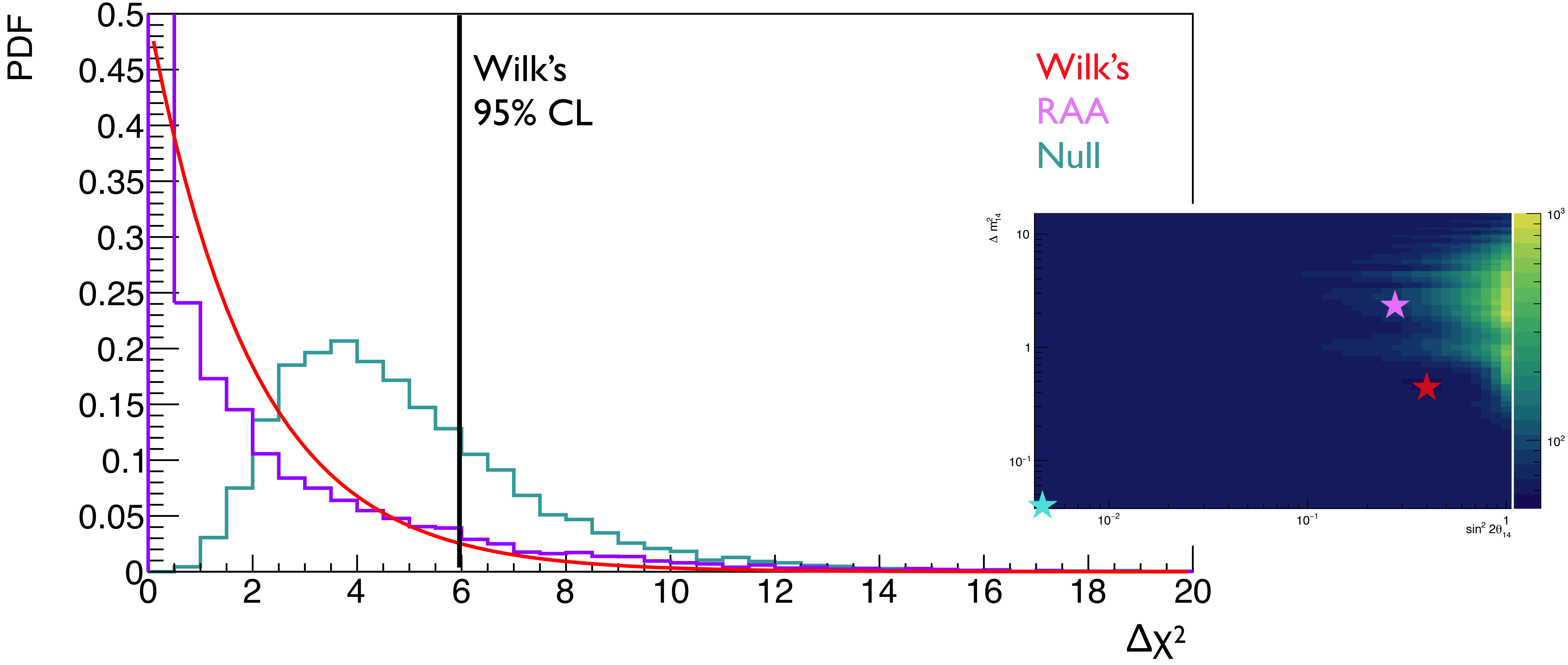


Signal Stat+Systematics Uncertainty Matrix

P.T. Surukuchi, PhD Thesis, IIT, 2019

Sterile Oscillation Confidence Intervals

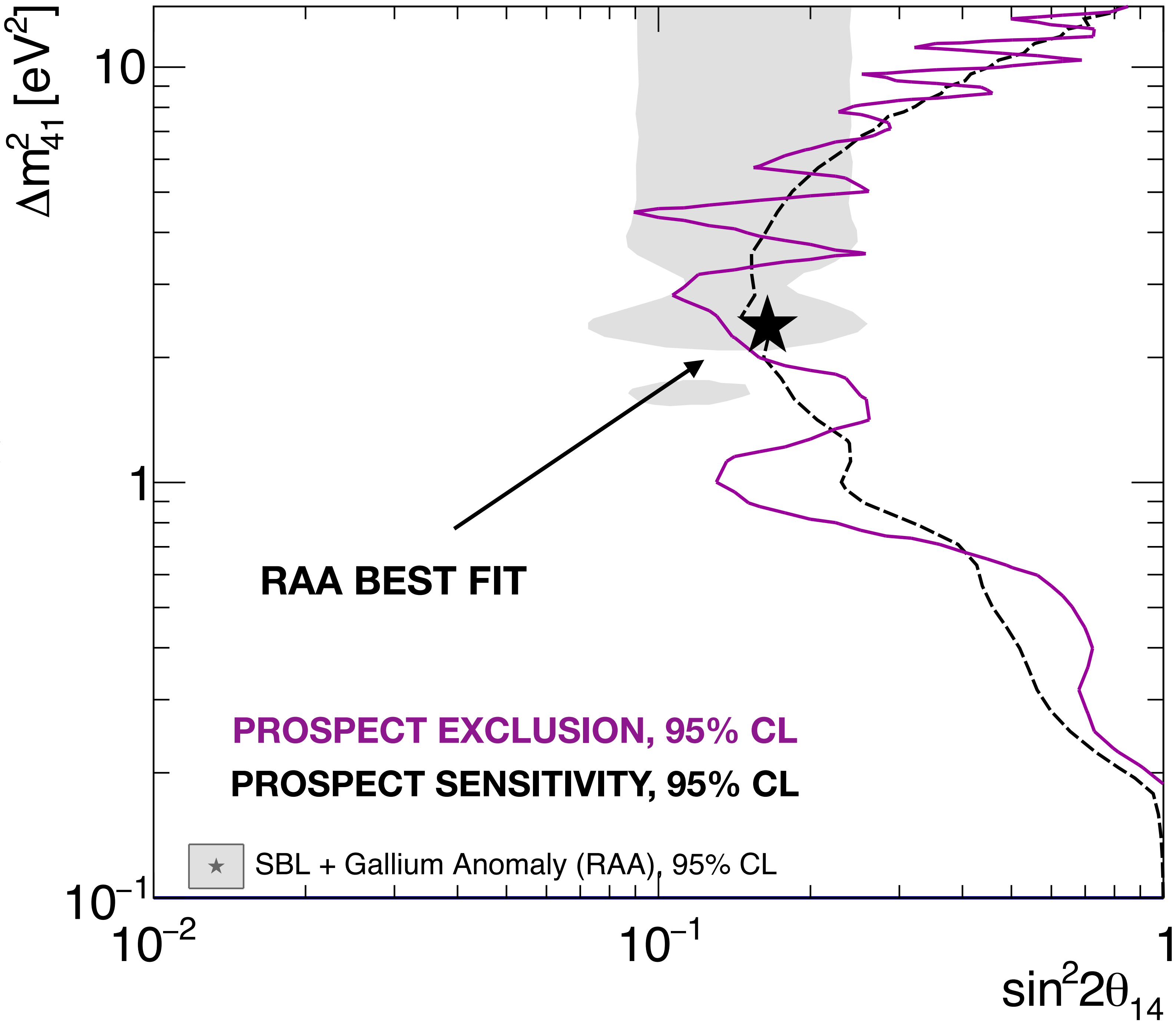
- To change $\Delta\chi^2$ to p-value preference (Nσ exclusion), usually assume that $\Delta\chi^2$ follows a χ^2 distribution
  - Generation of toy PROSPECT datasets show that this is not true for short-baseline reactor measurements with ~small osc signatures
  - Must establish confidence intervals with frequentist (Feldman-Cousins) method



Osc Parameter Sensitivity and Exclusion

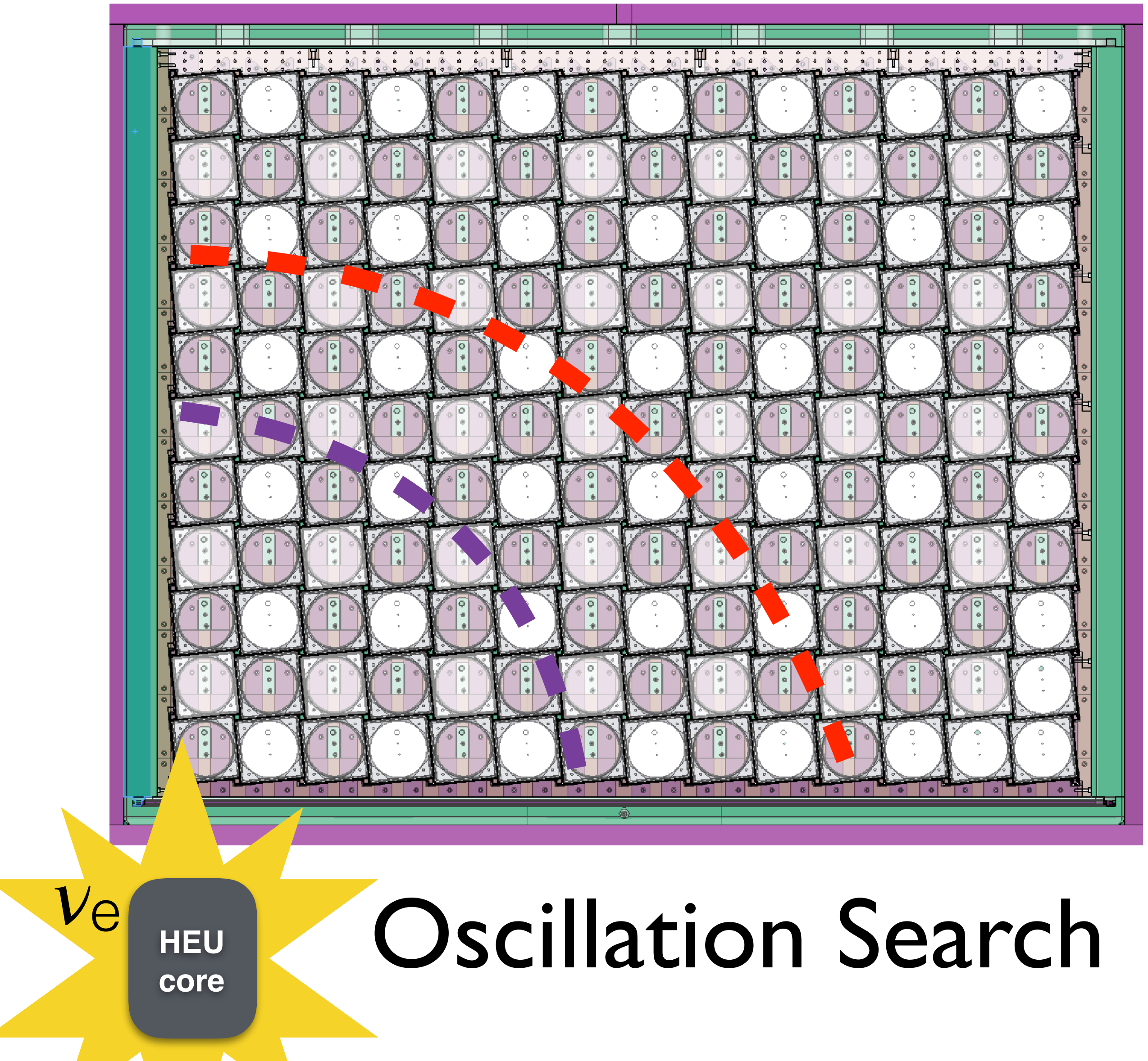
- With 33 days of reactor-on data-taking we excluded new interesting regions of $\sin^2 2\theta_{14}$ parameter space.
  - Short-baseline reactors currently do the best in constraining this active-sterile mixing parameter
  - Rule out best-fit of the osc-only solution to the flux anomaly at 2.2σ
  - Result is statistics limited; additional data in the can

PROSPECT, PRL 121 (2018)



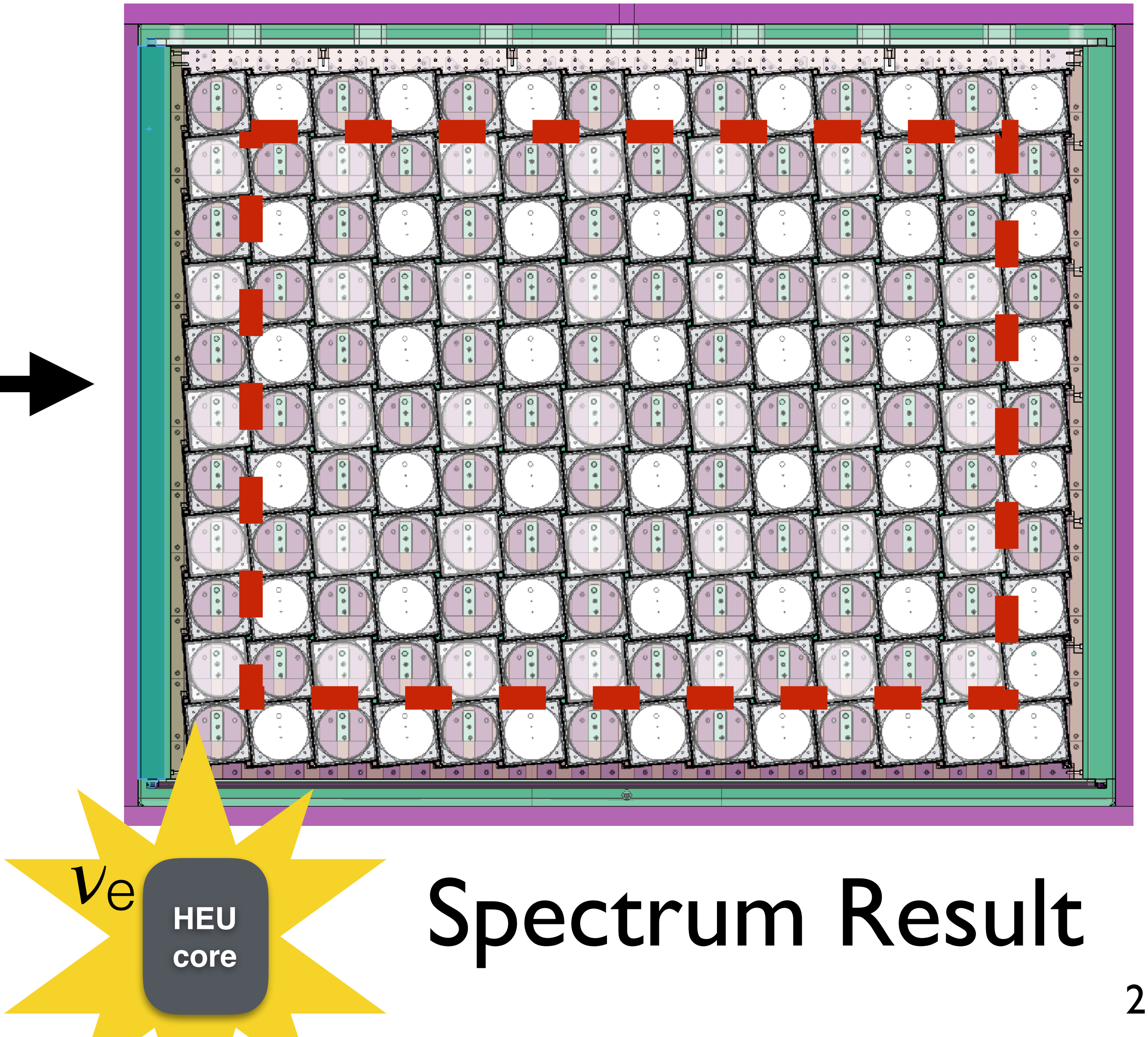
New to AAP: HEU Spectrum Results

- Look at absolute spectrum observed in the baseline-integrated fiducial detector volume.
  - Datasets largely similar: 40 (33) reactor-on days for osc (spectrum) result
  - Spectrum dataset: 31,000 IBDs detected, 1.7:1 signal:background



Oscillation Search

→

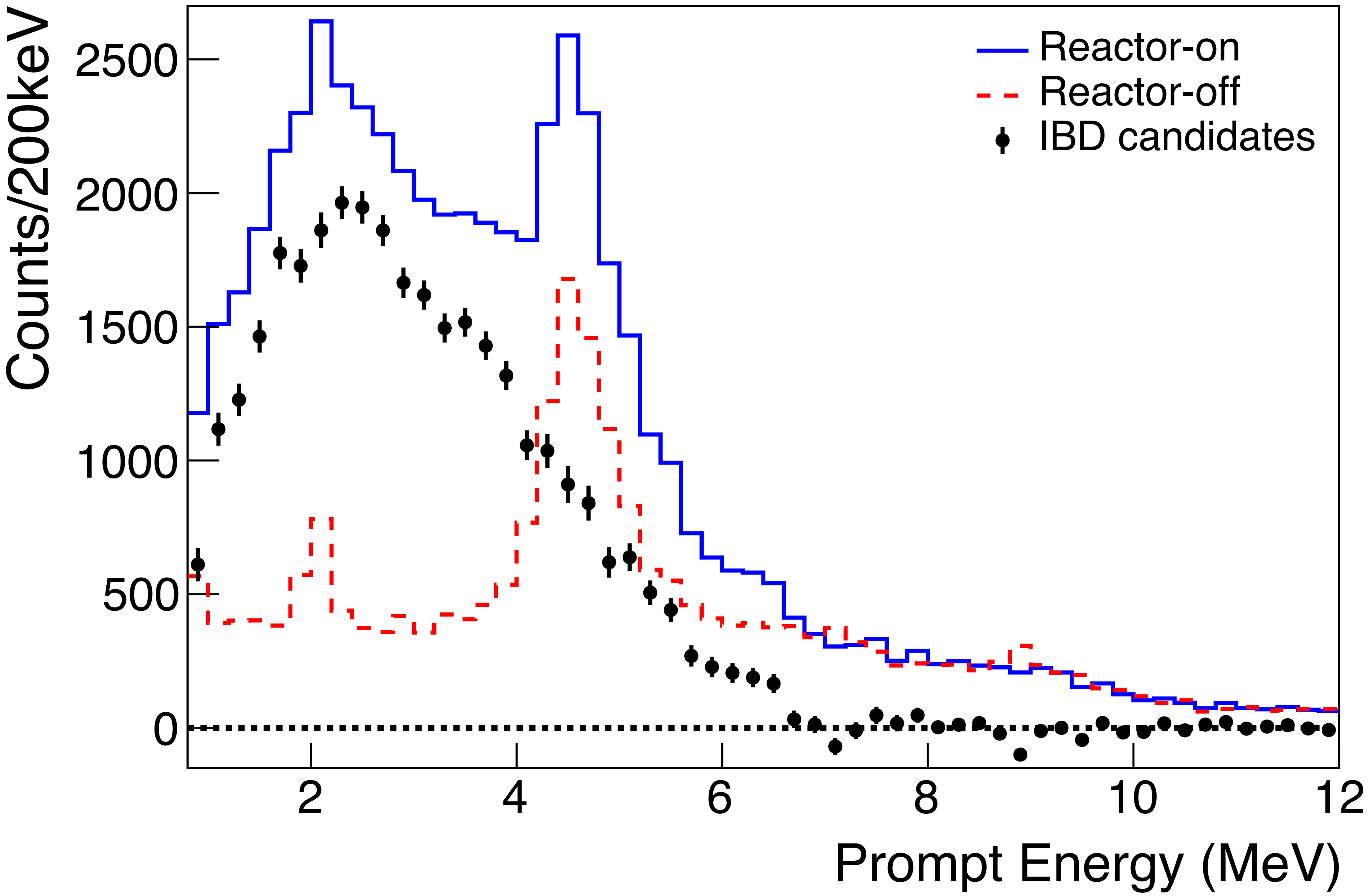


Spectrum Result

Neutrino and Background Datasets

- Look at reactor-on and reactor-off data in a different way: energy spectrum before and after on-off subtraction
  - Subtraction looks complete in high-energy sideband (good!)
  - Expected background peaks at ~2 and ~4.5 MeV cosmogenic neutrons

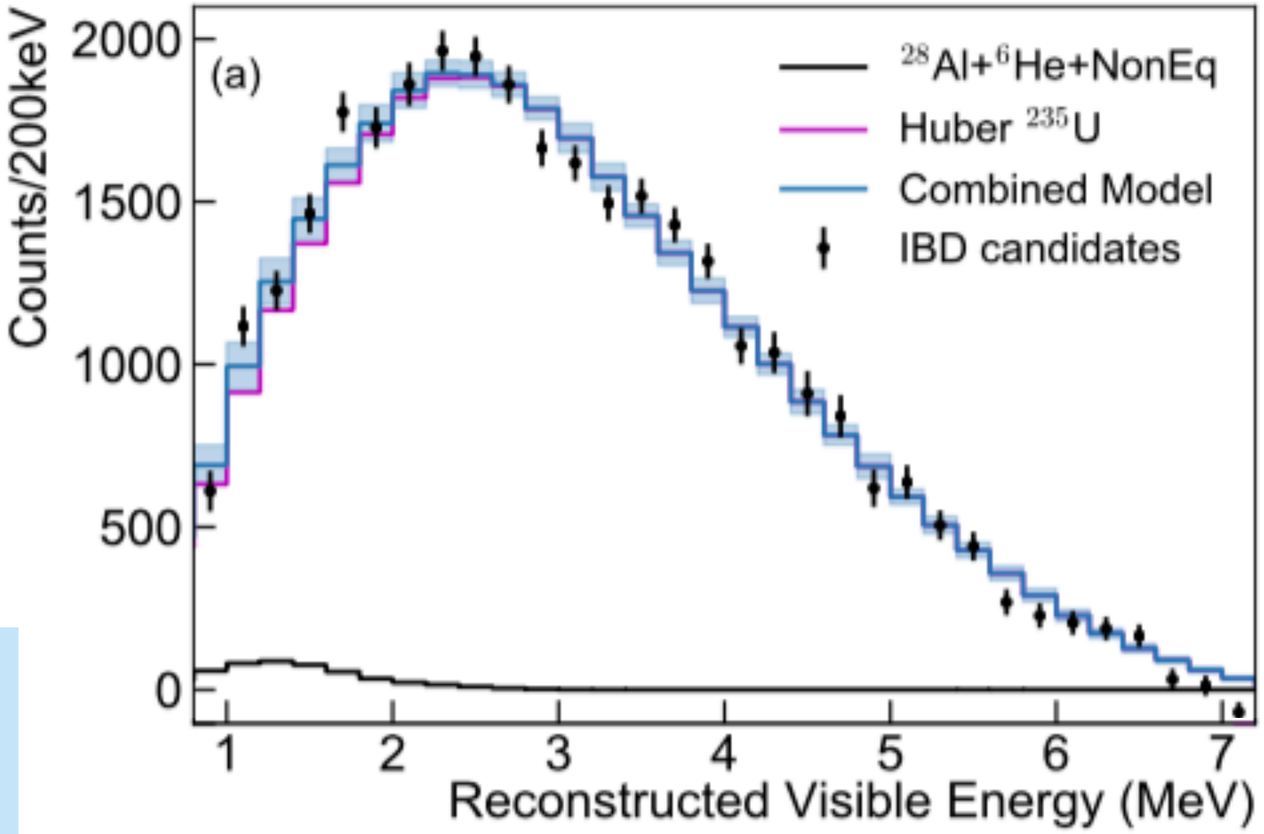
PROSPECT, PRL 122 (2019)



PROSPECT ^{235}U Spectrum Result

- Background-subtracted ^{235}U spectrum result
  - Compare to the Huber beta conversion prediction
  - Small neutrino contribution from activation of reactor components
  - Small correction for time-dependent effects in reactor fuel
- General agreement in broad spectrum features

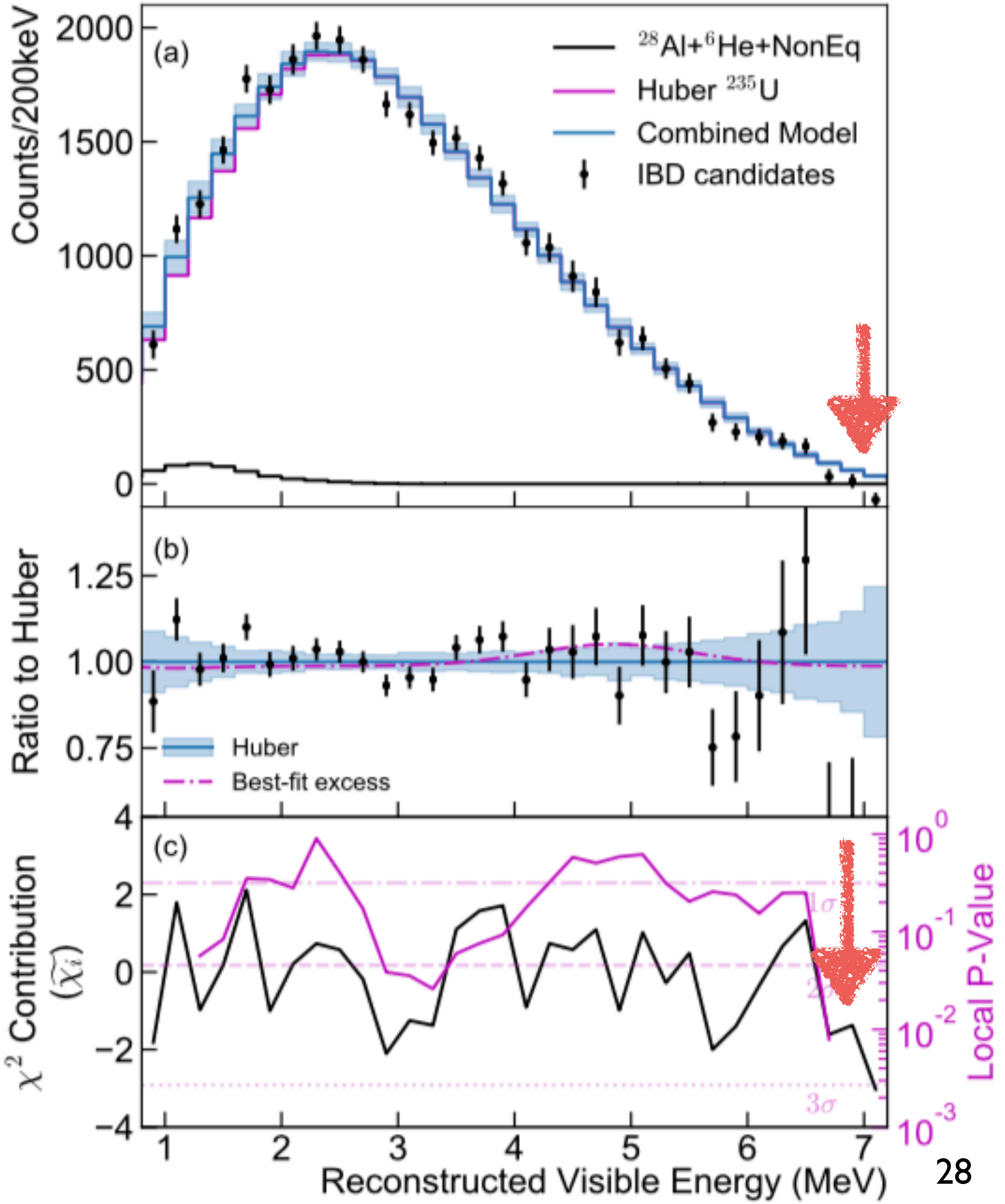
PROSPECT, PRL 122 (2019)



PROSPECT ^{235}U Spectrum Result

- Background-subtracted ^{235}U spectrum result
- Is PROSPECT consistent with Huber's ^{235}U model?
  - χ^2/ndf = 52.1/31; p-value = 0.01
  - So Huber broadly agrees with PROSPECT, but not a great fit
  - Worst offender is high energy; fit is OK otherwise.
    - Bkg issue? Unlucky statistics? Need more stats to know for sure.
    - Note: stats still dominate overall uncertainties across the spectrum

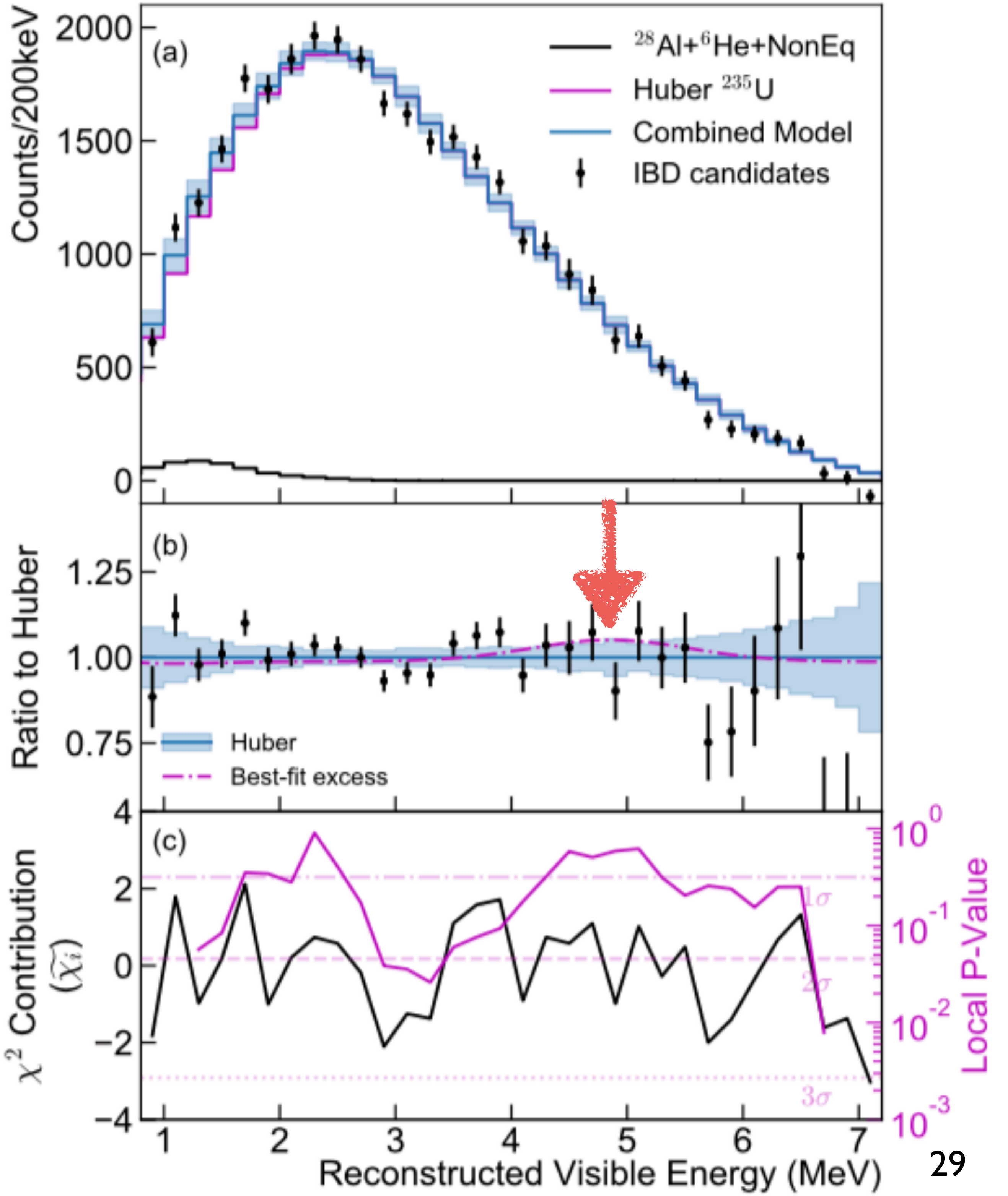
PROSPECT, PRL 122 (2019)



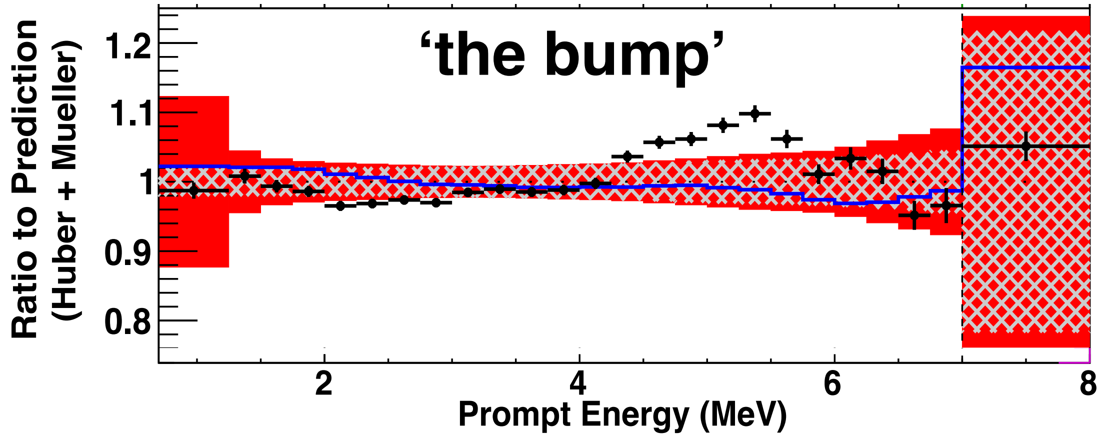
PROSPECT ^{235}U Spectrum Result

- Background-subtracted ^{235}U spectrum result
- How does PROSPECT compare to 'bump' in LEU θ_{13} experiments?
  - PROSPECT relative bump size WRT to Daya Bay: 69% ± 53%
  - ~consistent with 'no bump' (0%) and 'DYB-sized bump' (100%)
  - 'Big bump' (178%) if ^{235}U is the sole bump contributor
    - Disfavored at 2.1σ

PROSPECT, PRL 122 (2019)



Daya Bay, CPC 41 (2017)



Update: Current Analysis Status

- PROSPECT began running in March 2018 PROSPECT, NIM A806 401 (2019)
- Oscillation PRL used data through May 2018 PROSPECT, PRL 121 (2018)
- ^{235}U Spectrum PRL used data through July 2018 PROSPECT, PRL 122 (2019)
- We have reactor-on data in the can through October 2018
  - Limited by HFIR reactor availability: see next slide
  - This data includes ~2x the IBD statistics of the previous analyses
- Currently are working on a detailed PRD-style physics paper
  - Will likely provide updates to both spectrum and oscillation analyses
  - Will present in-depth descriptions of data and analysis
  - Will include extensive supplementary materials useful for comparison of PROSPECT data to other models and experiments

Update: Detector and Reactor Status

- PROSPECT began running in March 2018, and completed ~1 year of successful data-taking.
- From November 2018 to November 2019, the HFIR reactor did not operate.
  - Nov 2018: elevated radiation levels were detected in primary coolant
  - Issue was with core production; took ~year to identify a solution and a core production QA procedure to ensure no similar problems in the future
  - PROSPECT was obviously unable to accrue IBD statistics during this time
- Through 2019, PROSPECT developed an unacceptable number of non-functioning PMT channels.
  - The issue is briefly described in PROSPECT PRL publications
  - PROSPECT has been emptied and is presently being moved to Yale
  - At Yale, it will be de-constructed and repaired/upgraded in preparation for re-deployment

Update: Future Plans

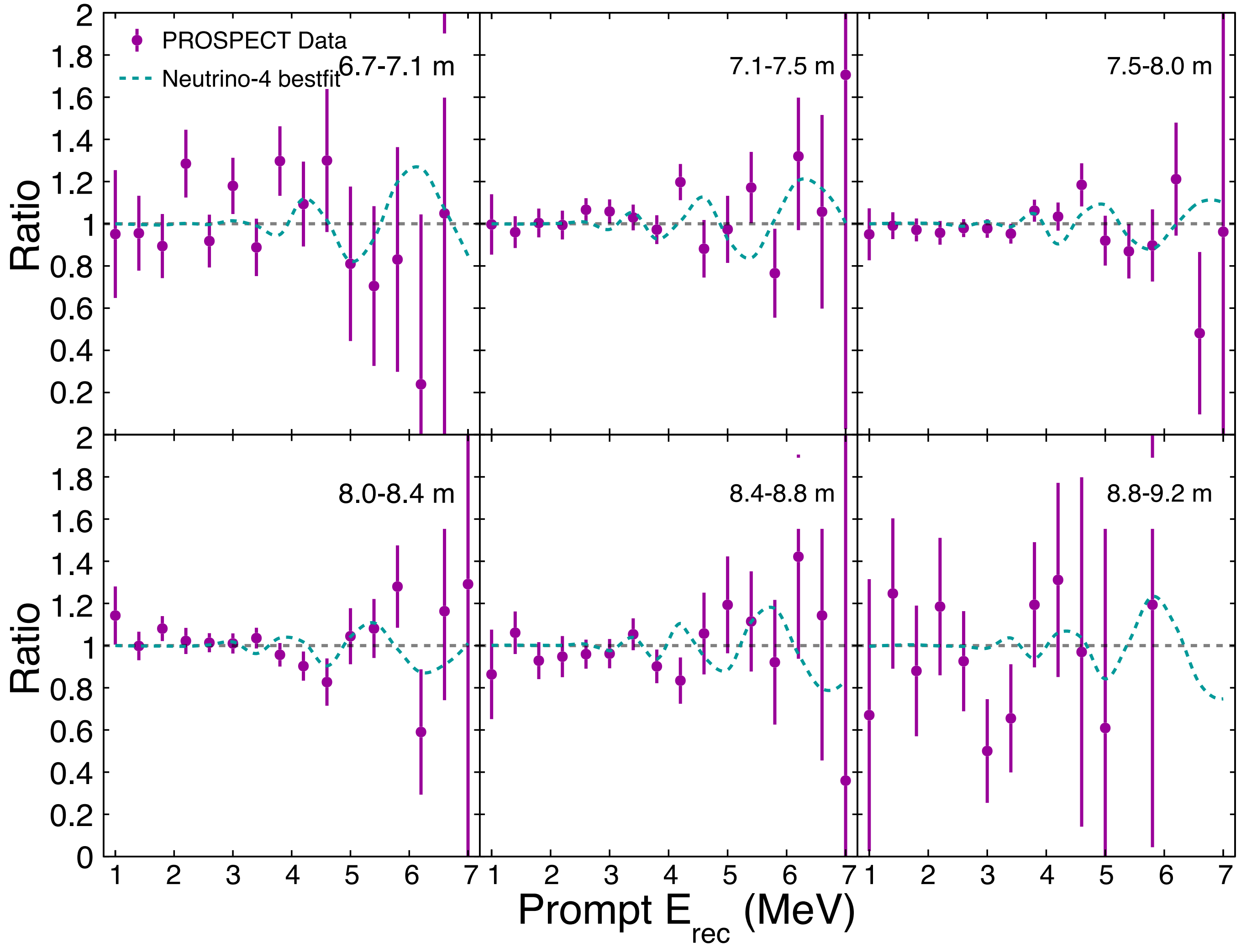
- PROSPECT plans to perform an upgrade of its detector while it is at Yale
  - Deconstruct detector
  - Repair or replace non-functioning PMT bases and PMT housings
  - Re-assemble with improved design features, aimed at improving ease of assembly and repair, portability, and longevity.
- Planning for re-deployment at HFIR in 2021, to perform multiple additional years of HEU data-taking
  - This dataset will greatly improve PROSPECT's HEU spectrum and sterile neutrino search physics deliverables.
  - Improved detector design aimed at enabling detector movement to other reactor sites (LEU reactor)
  - Studies are currently underway to quantify the gains of additional HEU or new LEU data-taking with PROSPECT

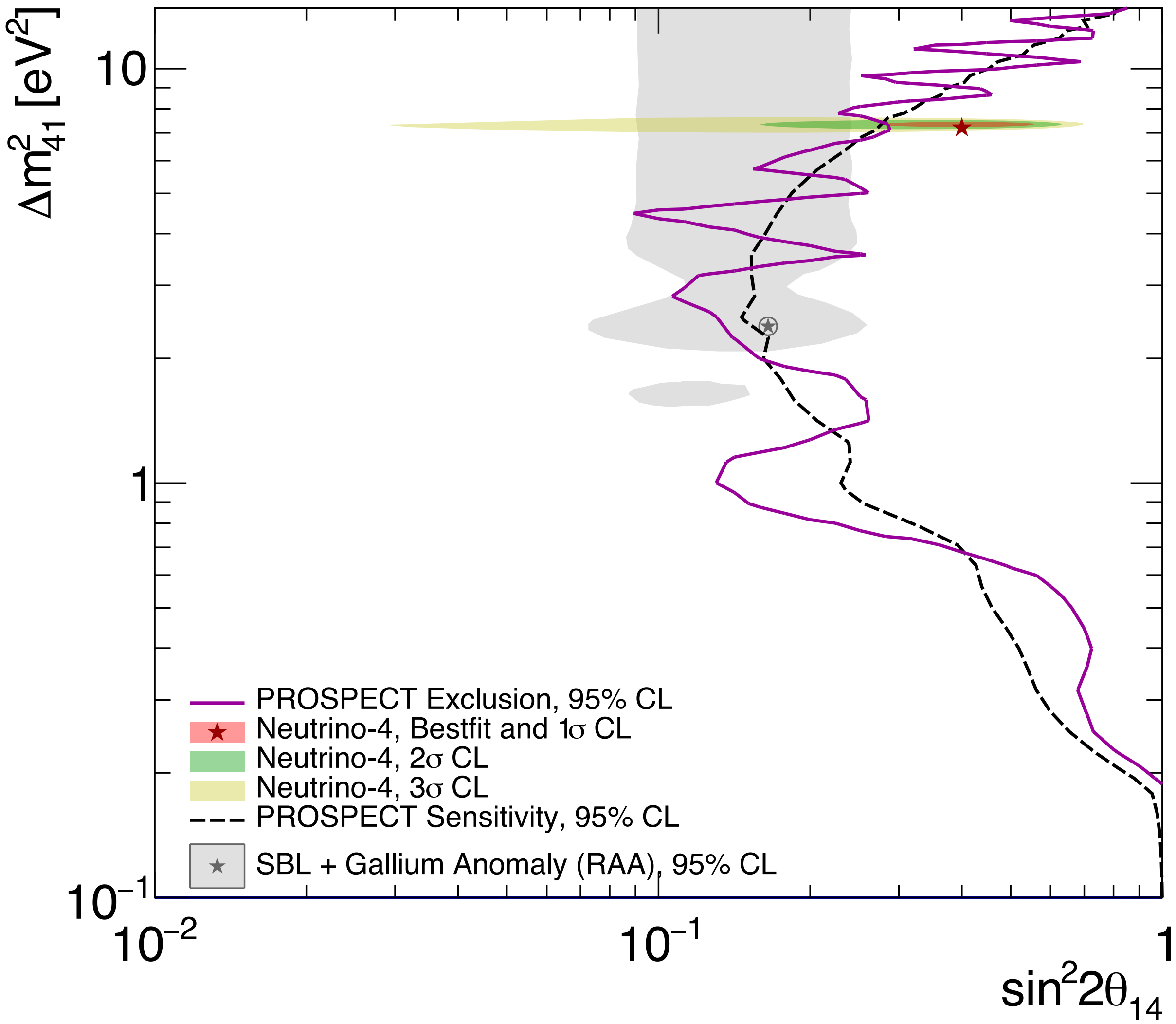
Summary

- PROSPECT has demonstrated that low-background on-surface reactor antineutrino detection is achievable.
- PROSPECT has set new limits on active-sterile neutrino mixing
  - PROSPECT and other reactor experiments will continue to lead global sensitivity to $\sin^2 2\theta_{14}$ in the eV-scale regime for the foreseeable future
- PROSPECT has performed the best-ever measurement of the ^{235}U ν_e spectrum
  - Lack of a 'large bump' in PROSPECT data with respect to prediction: indicates ^{235}U is not the sole producer of 'bumps' in LEU measurements
- Additional statistics will improve both of these PROSPECT measurements in the near future.
- PROSPECT's detector is currently being deconstructed, in preparation for an upgrade and re-deployment at HFIR.

BACKUPS

Comparison to Neutrino-4





Active-Sterile Osc Formalism

Giunti and Lasserre, hep-ph[1901.08330]

- With 1 additional (sterile) neutrino, new PMNS matrix:

$$U = \begin{pmatrix} c_{12}c_{13}c_{14} & s_{12}c_{13}c_{14} & c_{14}s_{13}e^{-i\delta_{13}} & s_{14}e^{-i\delta_{14}} \\ \cdots & \cdots & \begin{matrix} c_{13}c_{24}s_{23} \\ -s_{13}s_{14}s_{24}e^{i(\delta_{14}-\delta_{13})} \end{matrix} & c_{14}s_{24} \\ \cdots & \cdots & \cdots & c_{14}c_{24}s_{34}e^{-i\delta_{34}} \end{pmatrix}$$

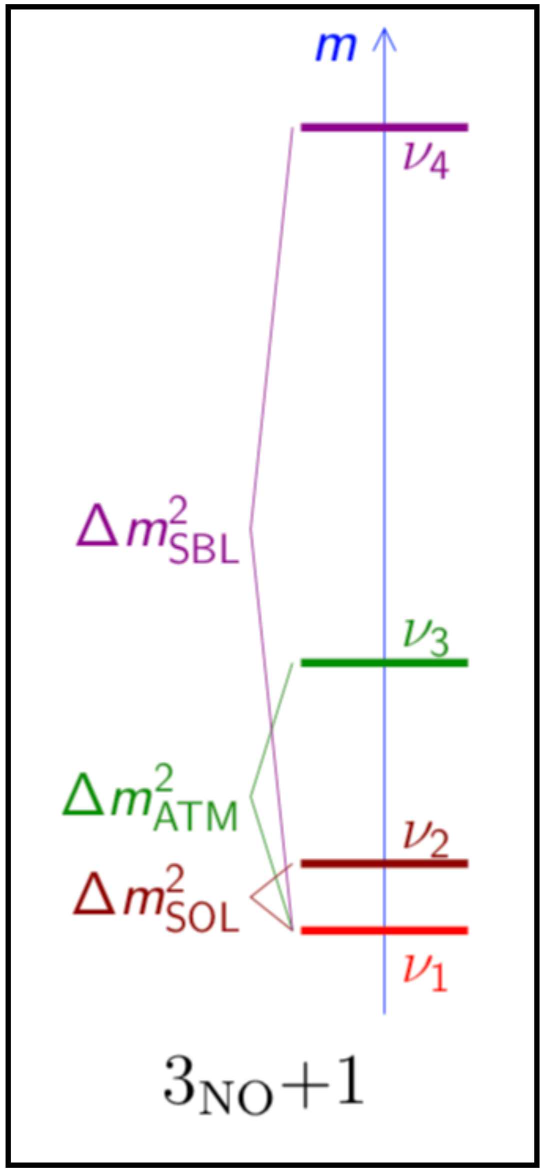
- Short-baseline oscillation looks like this:

$$P^{\mathrm{SBL}}_{\overset{(-)}{\nu}_{\alpha}\to\overset{(-)}{\nu}_{\beta}} = \left|\delta_{\alpha\beta} - \sin^2 2\vartheta_{\alpha\beta}\sin^2\left(\frac{\Delta m^2_{41}L}{4E}\right)\right|,$$

where $\Delta m^2_{41} = \Delta m^2_{\mathrm{SBL}}$, and

$$\sin^2 2\vartheta_{\alpha\beta} = 4|U_{\alpha4}|^2\left|\delta_{\alpha\beta} - |U_{\beta4}|^2\right|.$$

- For numu, nue experiments:



$$\sin^2 2\vartheta_{e\mu} = 4|U_{e4}|^2|U_{\mu4}|^2 = \boxed{\sin^2 2\vartheta_{14}}\boxed{\sin^2\vartheta_{24}}$$

LSND/mB/uB

$$\sin^2 2\vartheta_{ee} = 4|U_{e4}|^2\left(1-|U_{e4}|^2\right) = \boxed{\sin^2 2\vartheta_{14}}$$

PROSPECT / short-baseline reactor

$$\sin^2 2\vartheta_{\mu\mu} = 4|U_{\mu4}|^2\left(1-|U_{\mu4}|^2\right) = \sin^2 2\vartheta_{24}\cos^2\vartheta_{14} + \sin^2 2\vartheta_{14}\sin^4\vartheta_{24} \simeq \boxed{\sin^2 2\vartheta_{24}}$$

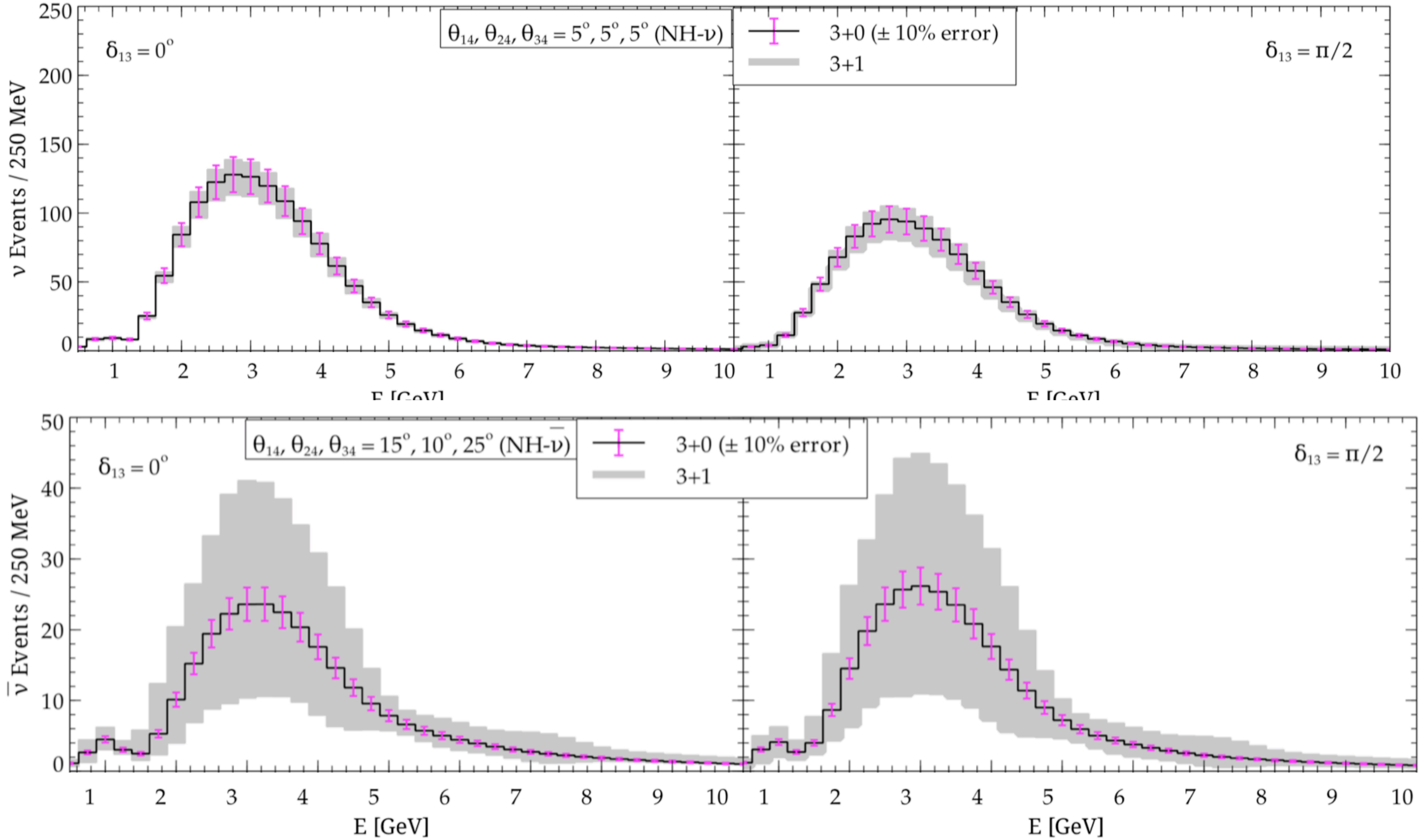
MINOS+

Active-Sterile Osc and LBL CP-Violation

- To avoid obscuring LBL CP-violation interpretation, would be best to have O(5%) constraints on $\sin^2 2\theta_{x4}$

Dutta, Gandhi, Kayser, Masud, and Prakash, JHEP 2016:122

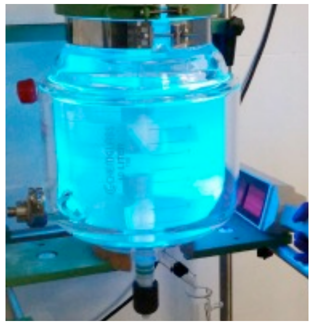
B. Kayser, 2016 PITT PACC SBN Workshop

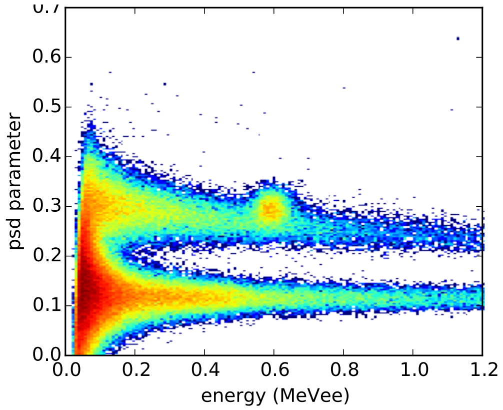


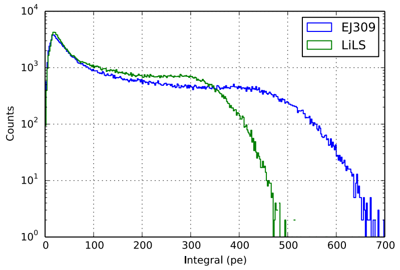
Path to segmented ^{6}LiLS detector with particle ID

PROSPECT-0.1
Develop LS
Characterize LS
Aug 2014-Spring 2015

5cm length
0.1 liters
LS, ^{6}LiLS







PROSPECT-2
Background studies
Dec 2014 - Aug 2015

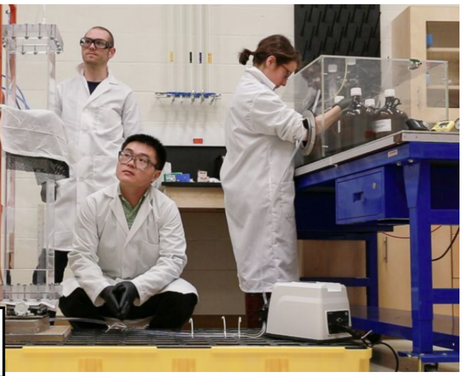
12.5 length
1.7 liters
^{6}LiLS

PROSPECT: NIMA A806 (2016) 401

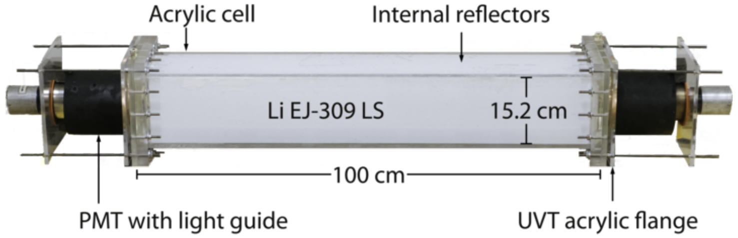
light guides
low mass reflectors

PROSPECT-20
Segment optics
Component design
Spring/Summer 2015

1m length
23 liters
LS, ^{6}LiLS



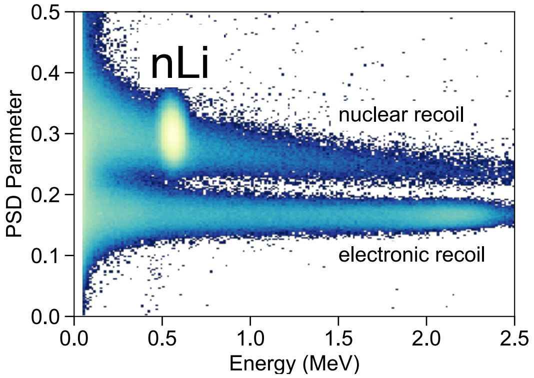
PROSPECT: JINST 10 P11004 (2016)



PROSPECT-50
Performance validation
Subsystem testbed
Simulation benchmark
2017-2018

1x2 segments
1.2m length
50 liters
LS,^{6}LiLS

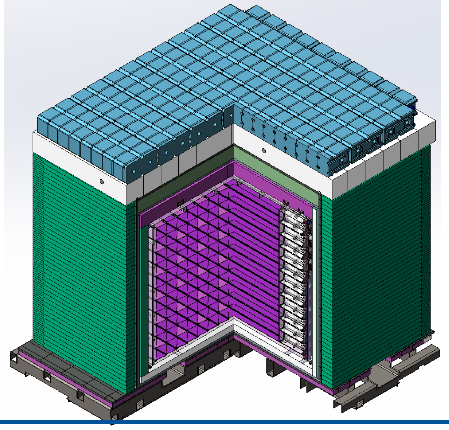
PROSPECT: JINST 13 P06023 (2018)



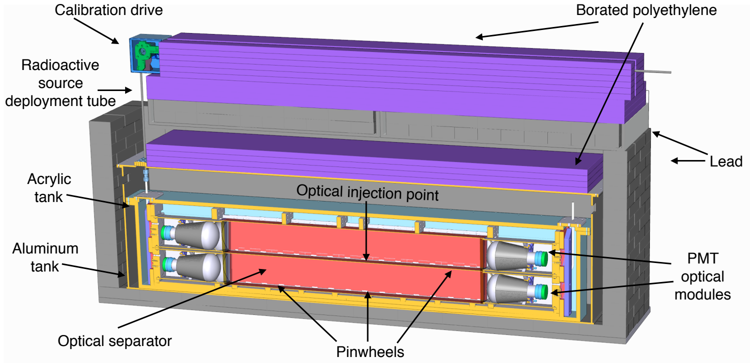
light collection
energy resolution
PSD performance

PROSPECT AD
Physics measurement
data taking 2018

11x14 segments
1.2m length
4 tons
^{6}LiLS



PROSPECT: arXiv:1808.00097

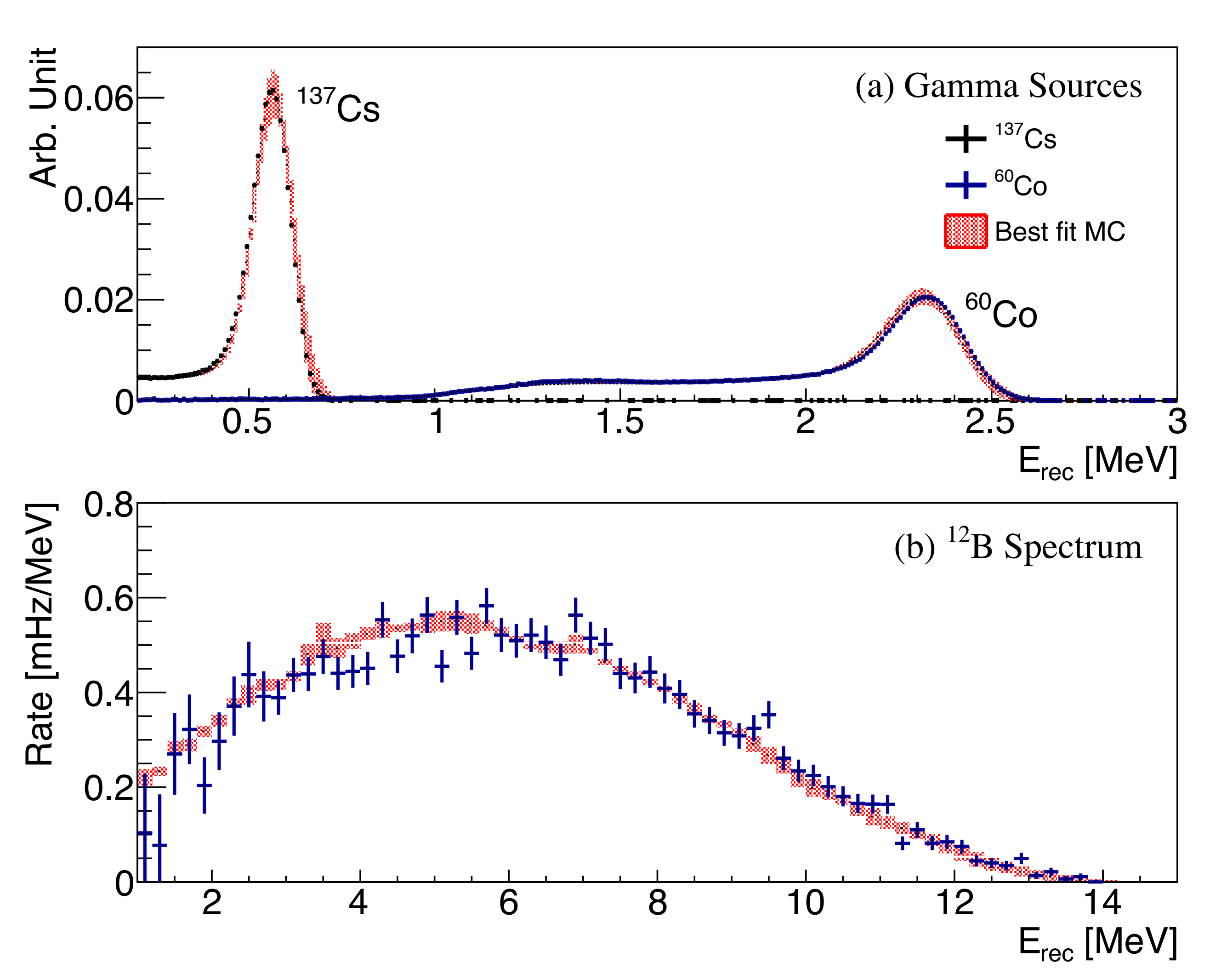


Energy Calibration

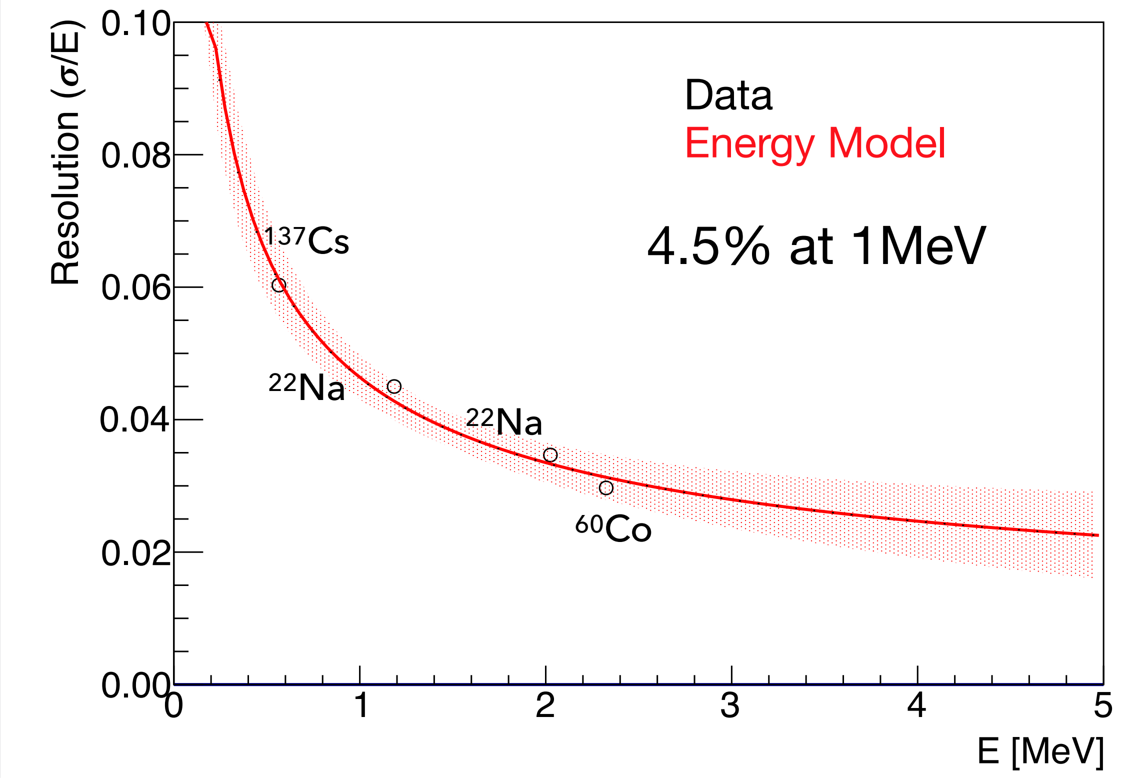
Gamma sources (^{137}Cs, ^{60}Co): Deployed throughout the detector

Fast-neutron tagged ^{12}B: High-energy beta spectrum calibration

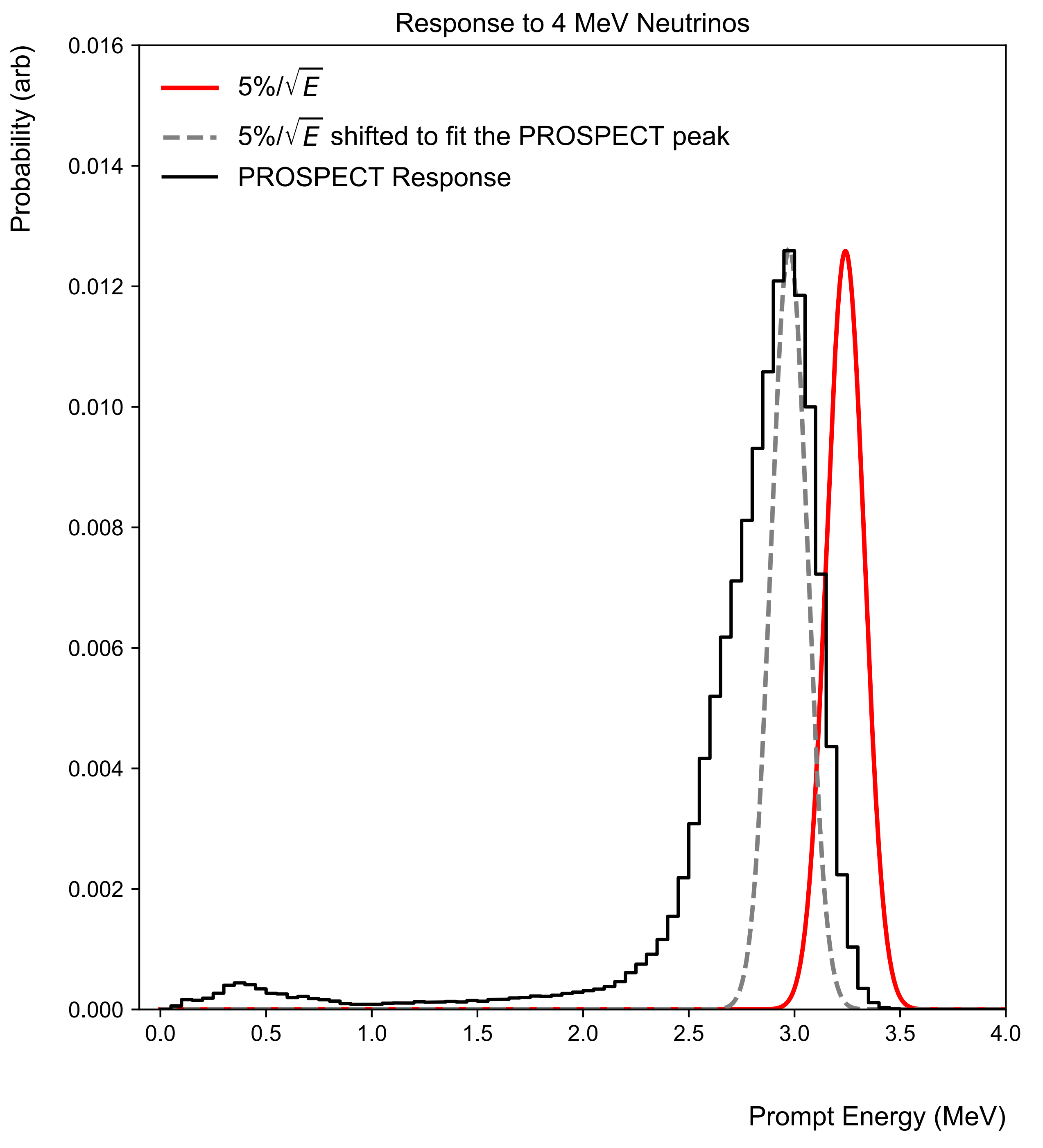
Full-detector E_{rec} within 1% of E_{true}



High light collection: 795±15 PE/MeV



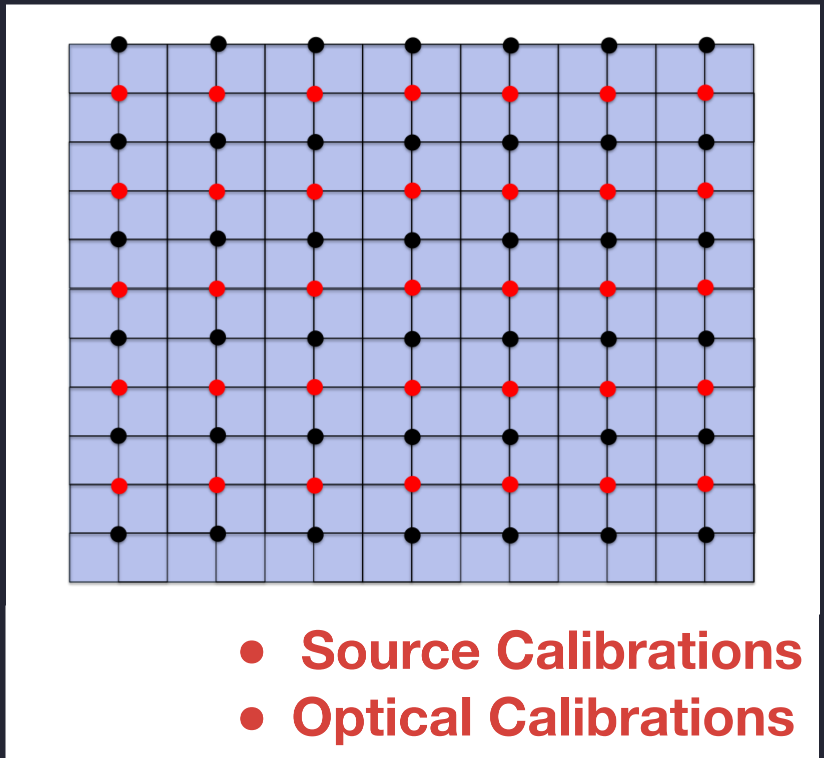
PROSPECT Response



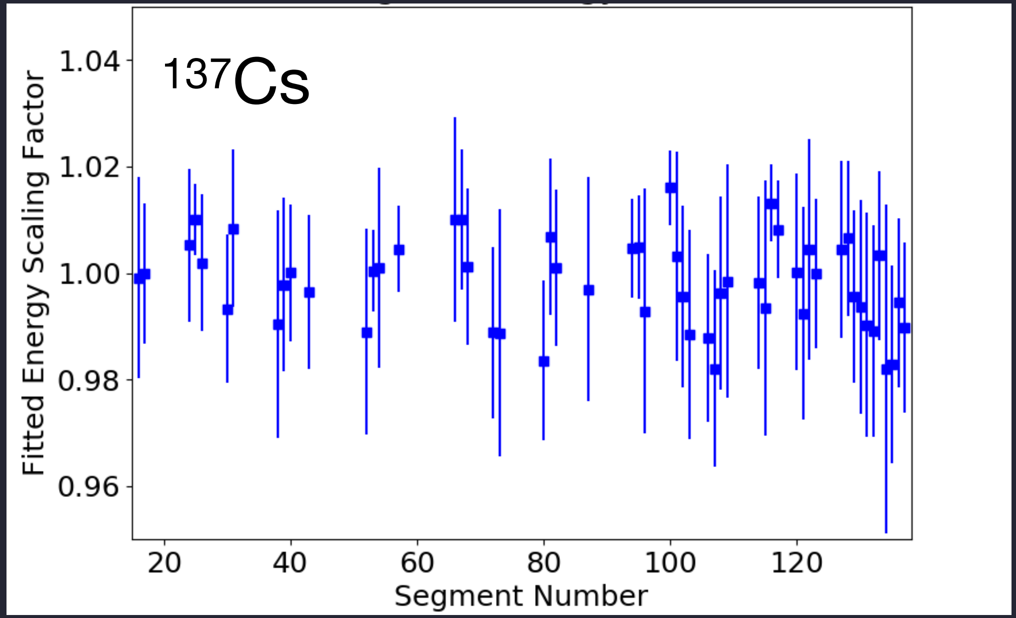
- PROSPECT detector is **compact** with a **limited gamma catcher volume** and **modest inactive volume**
- Escaping gammas and the energy lost in the inactive volume makes the response complicated
- Additionally a small contribution of reconstructed events at ~0.5 MeV arises from IBDs originating in the inactive volume whose gammas and neutrons are detected in the active volume
- Monte Carlo-generated response matrix is used in PROSPECT to handle this complicated response
- Response matrices are similarly **required** to be able to properly model energy response of other **compact detectors**

Energy Stability and Uniformity

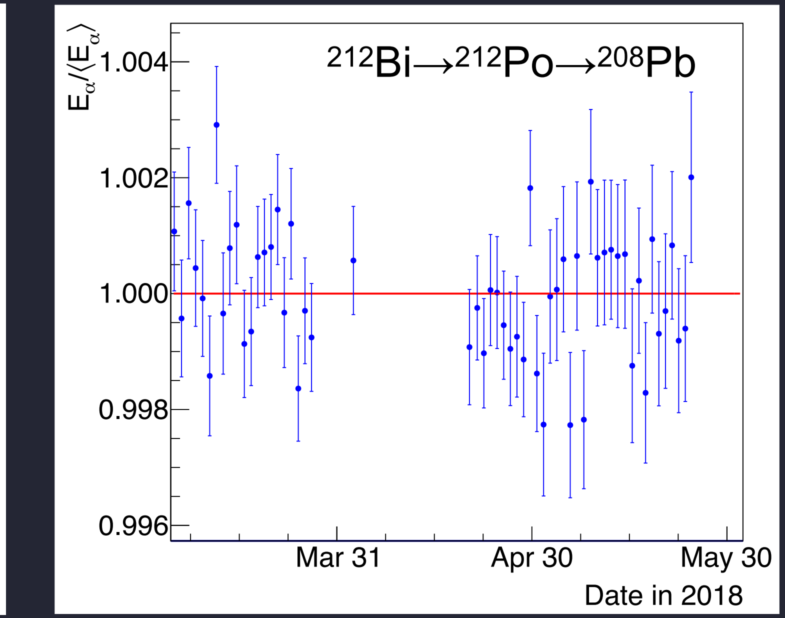
Calibration position map



Energy uniformity

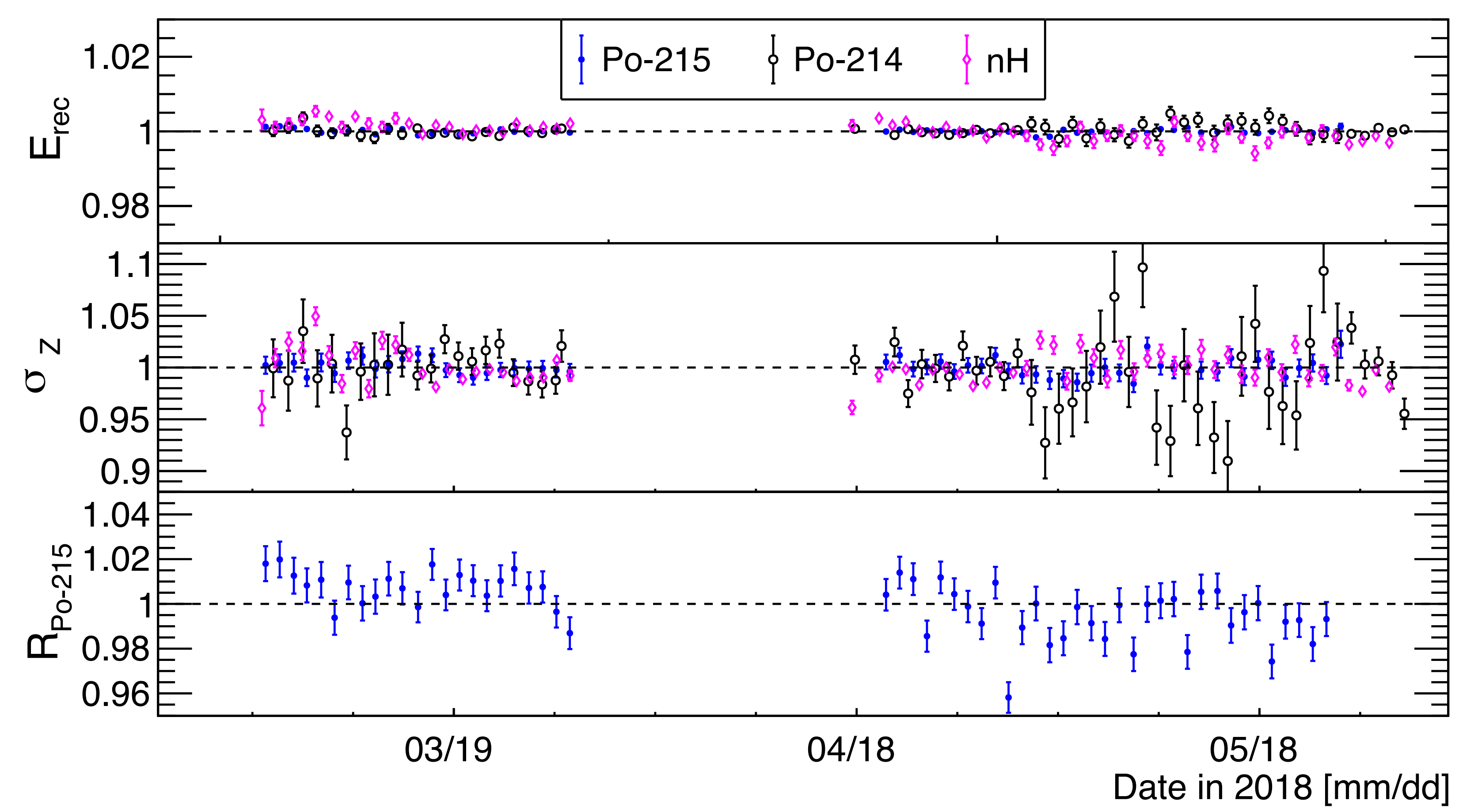


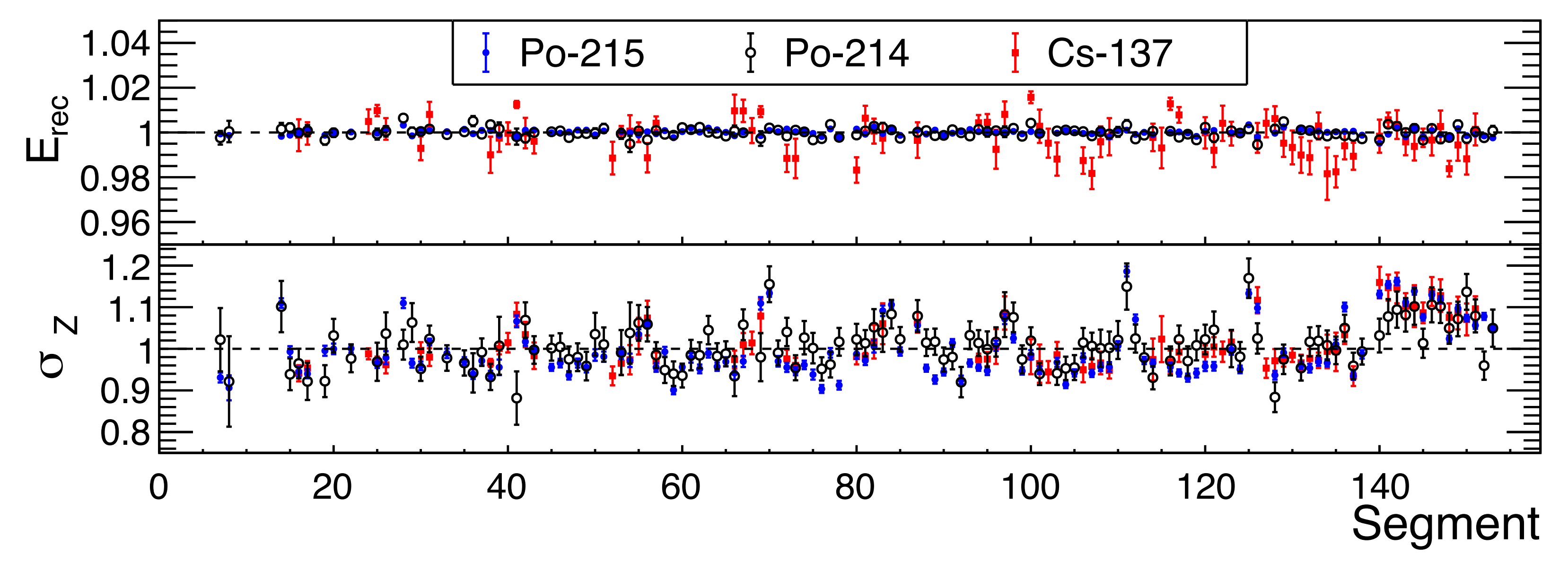
Energy stability



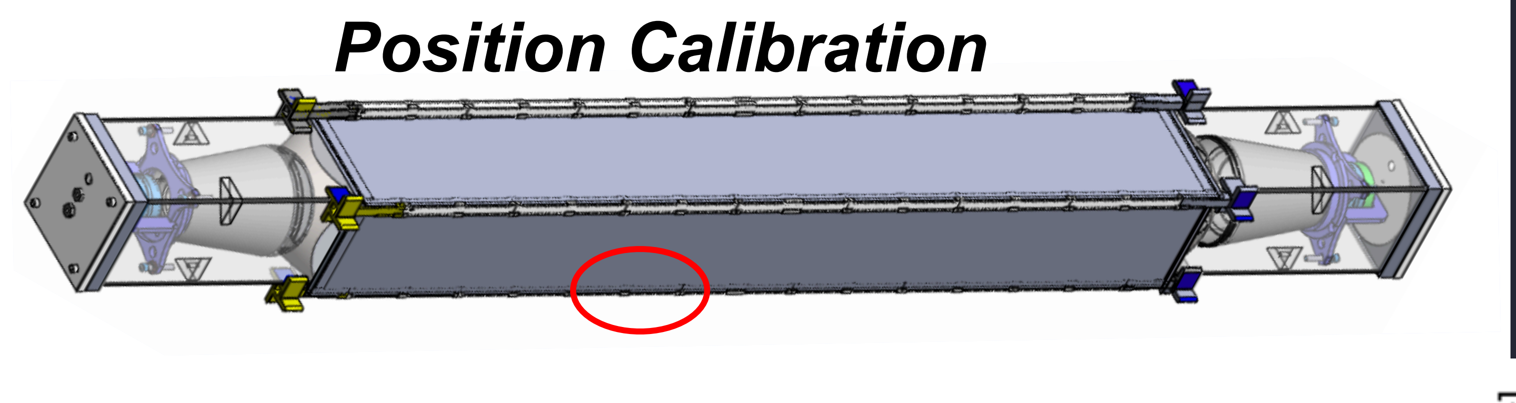
- 35 calibration source tubes throughout detector to map energy response
- Uniform segment to segment response
- Stability in reconstructed energy over time

Energy Stability and Uniformity

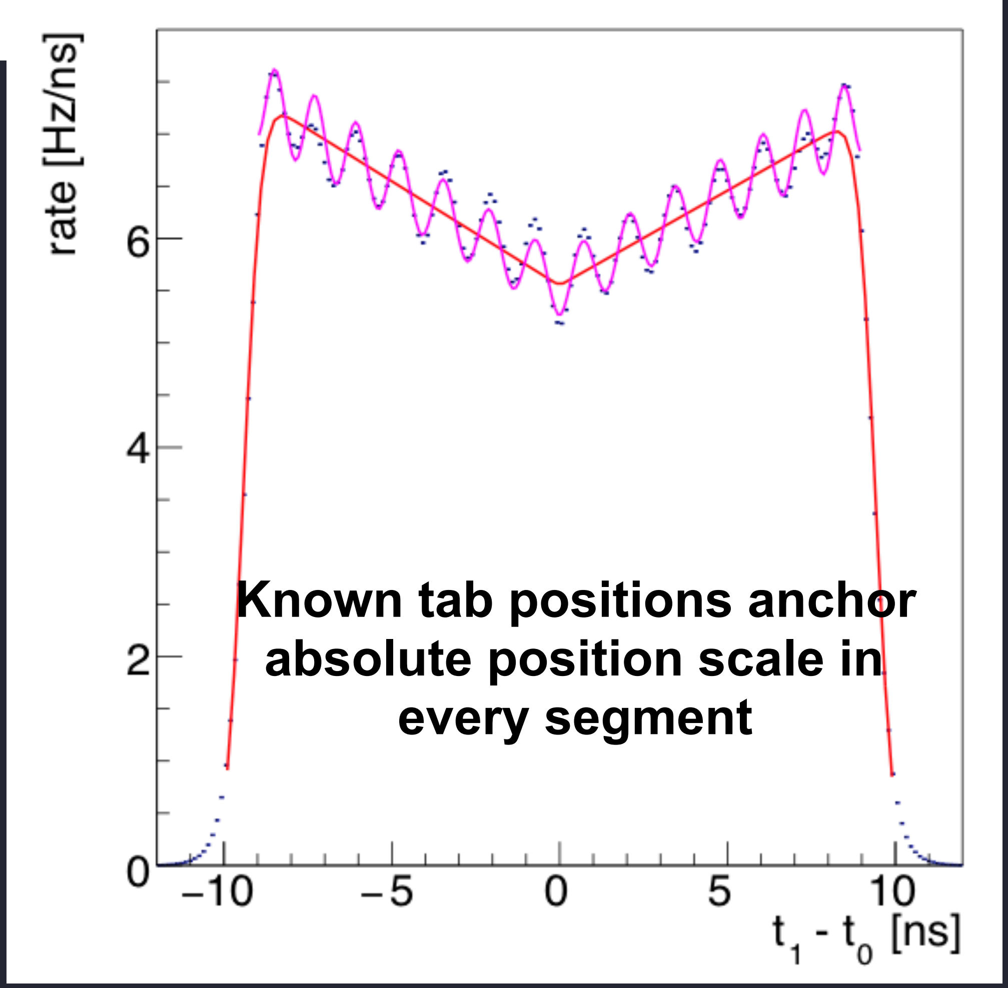




Position Calibration



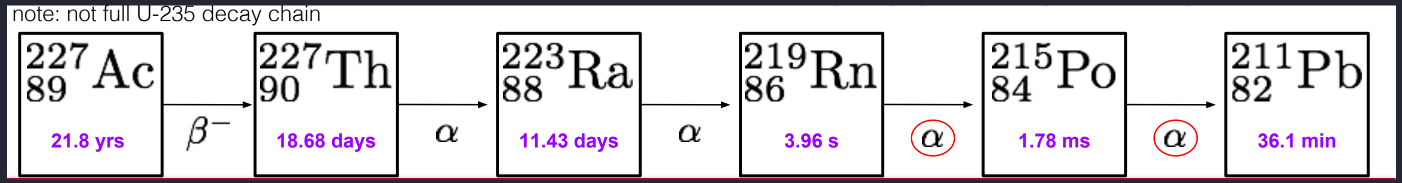
Pinwheel tabs alter local light transport, causing ‘tiger stripes’



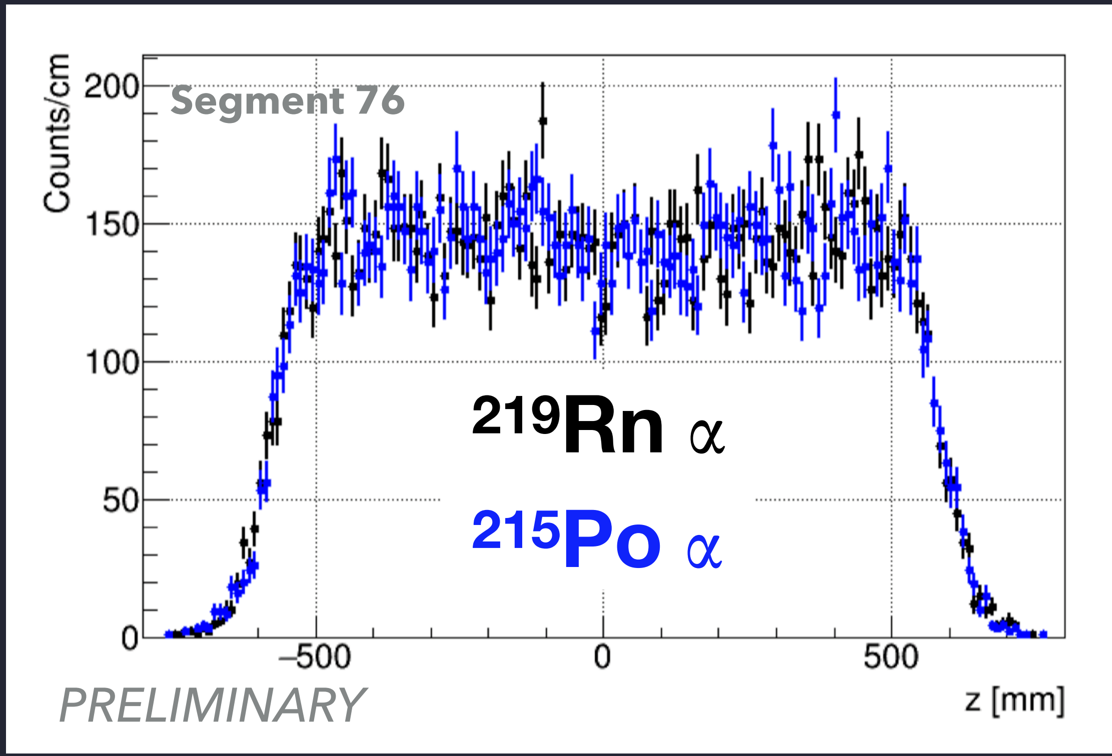
Known tab positions anchor absolute position scale in every segment

Relative Segment Volume Calibration

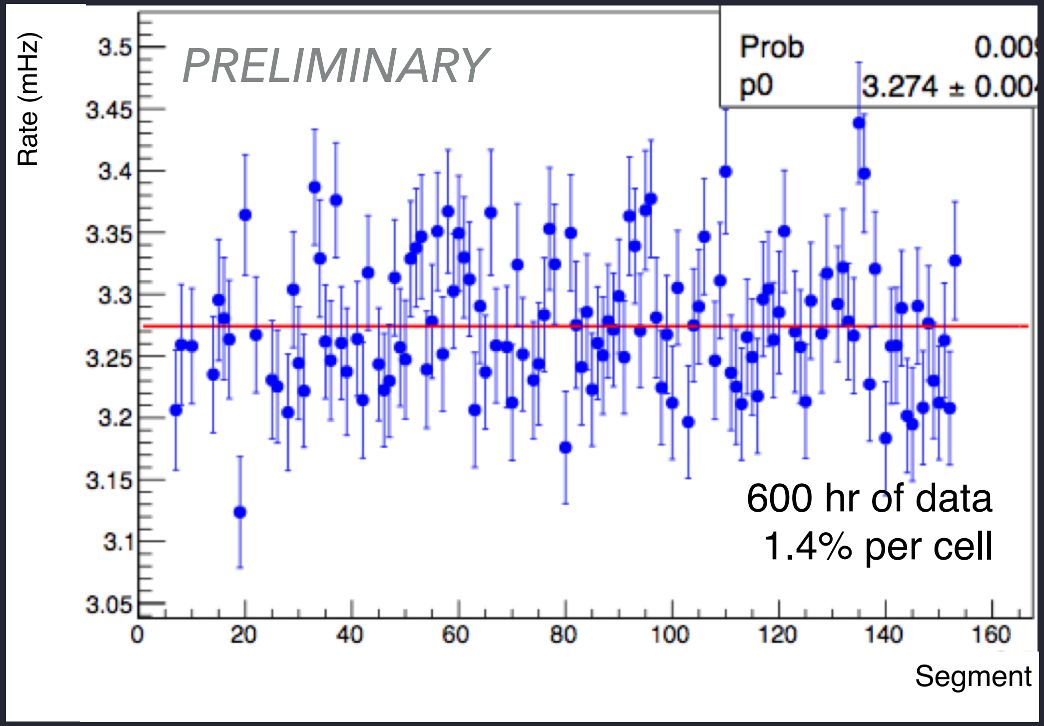
- Relative mass vital for oscillation search
- Survey during assembly: < 1% variation



- ^{227}Ac added to LS prior to filling
- Double alpha decay (^{219}Rn→^{215}Po→^{211}Pb), highly localized, 1.78ms half-life, efficient selection straightforward,
- Measured absolute z-position resolution of < 5cm
- Direct measurement of relative target mass in each segment



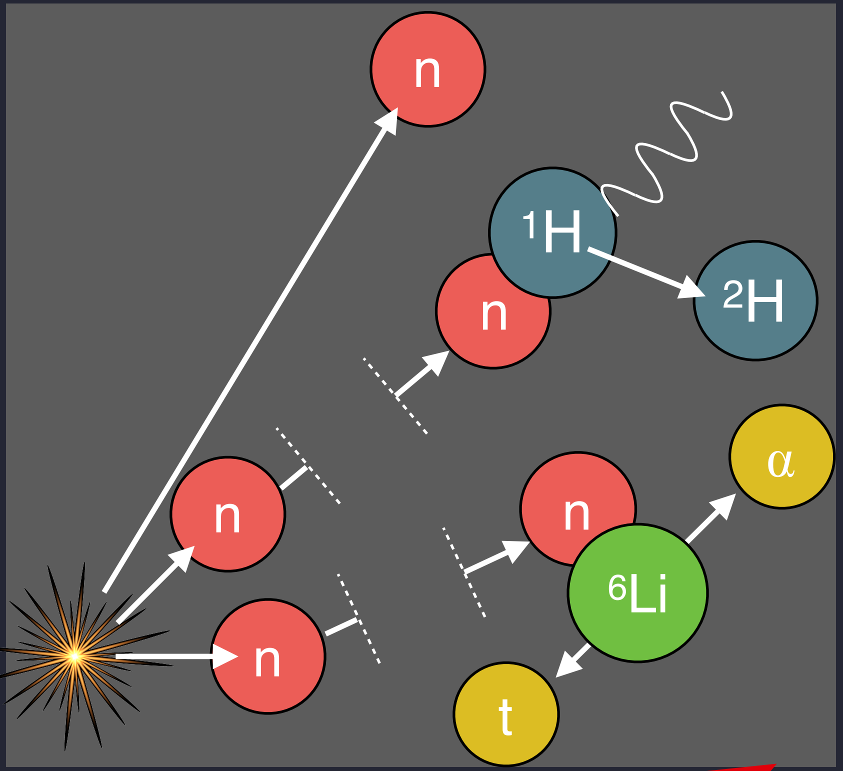
Uniformity in rates within segment



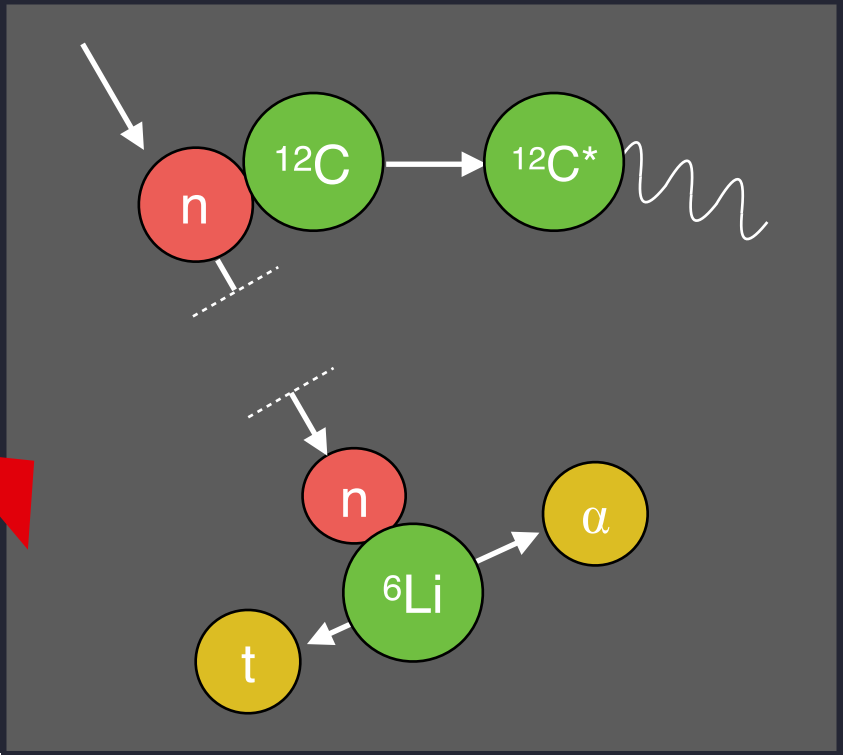
Uniformity in rates between segments

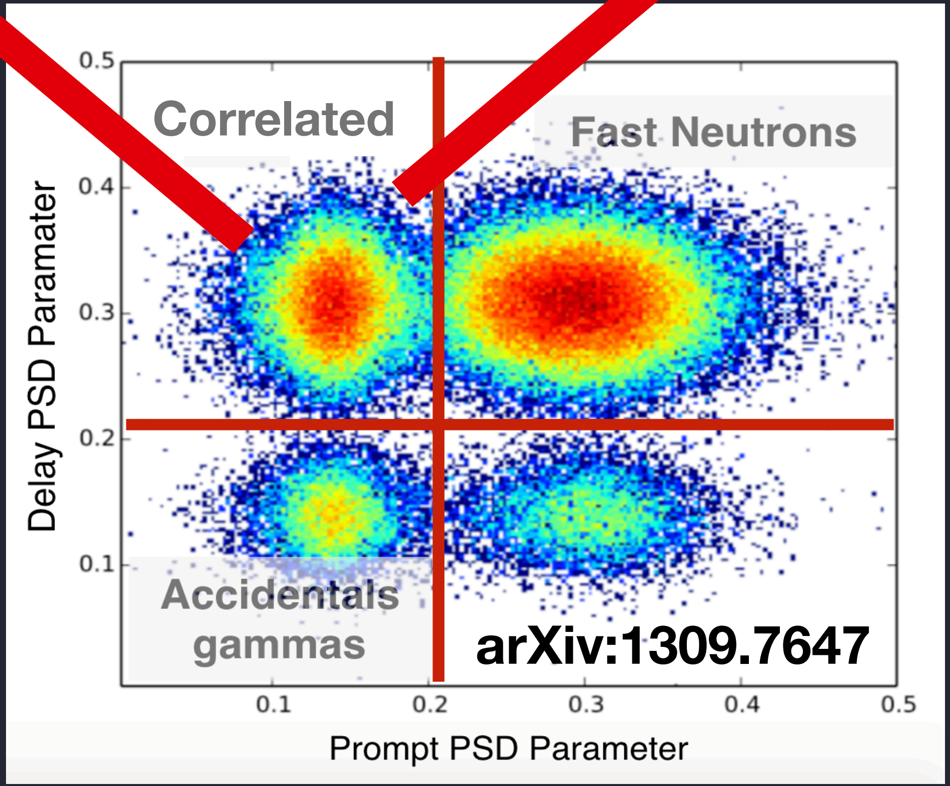
Other Backgrounds

Correlated nH followed by nLi



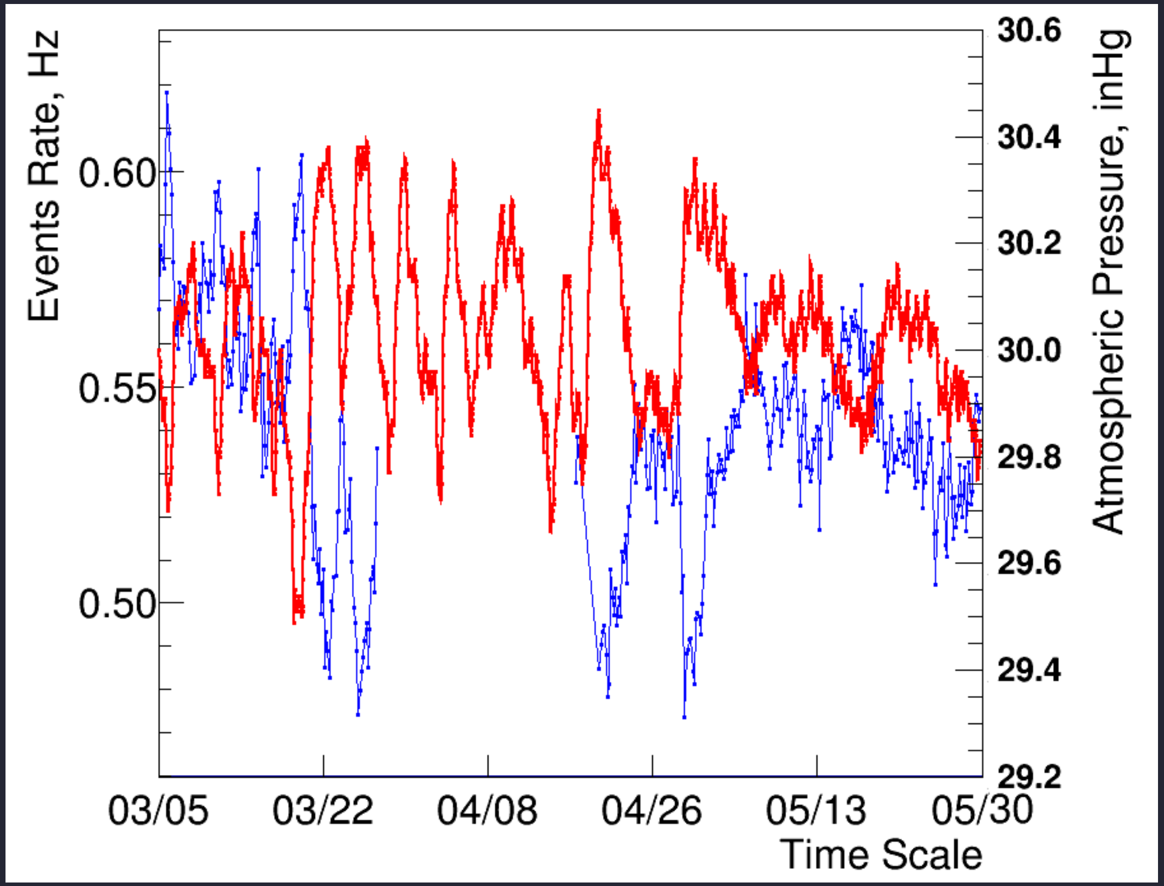
Correlated inelastic scattering on ^{12}C followed by nLi

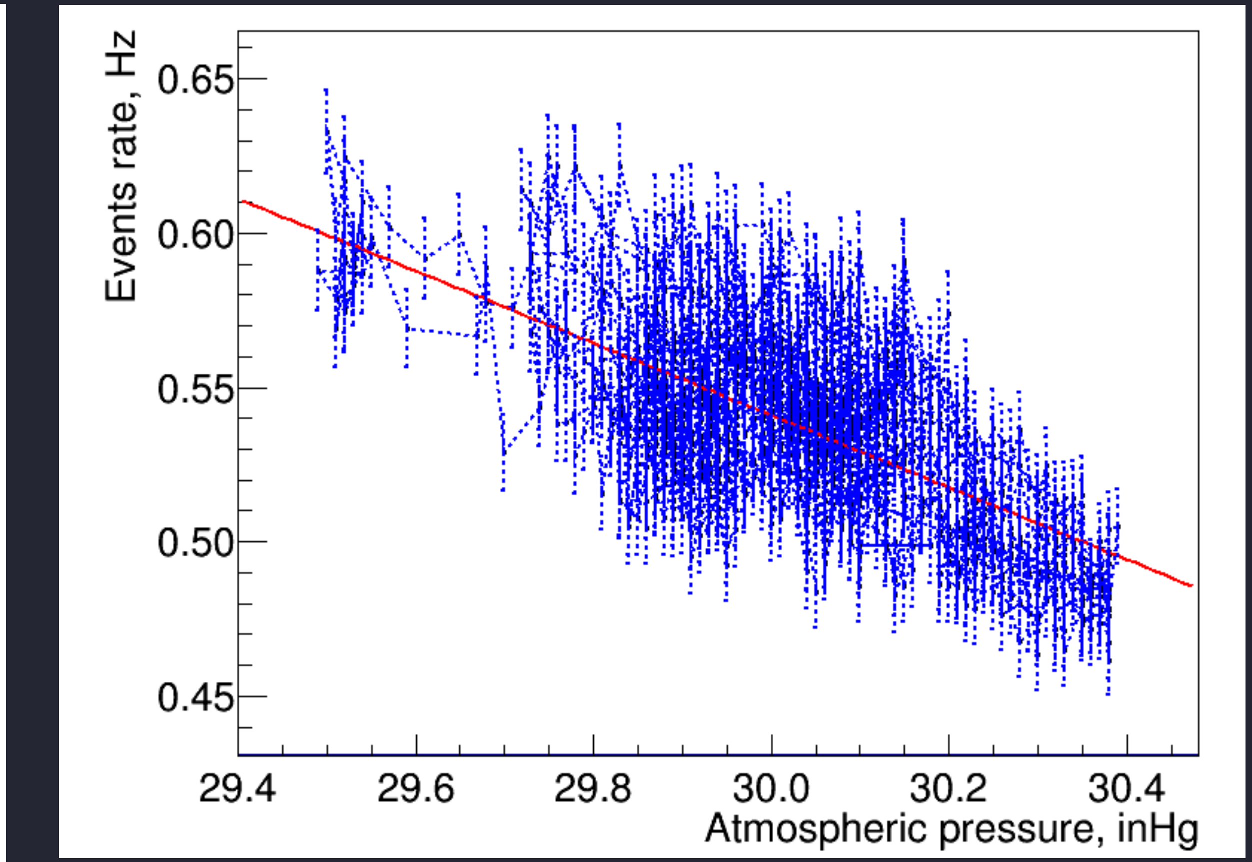




Cosmogenics are the main source for these two background classes

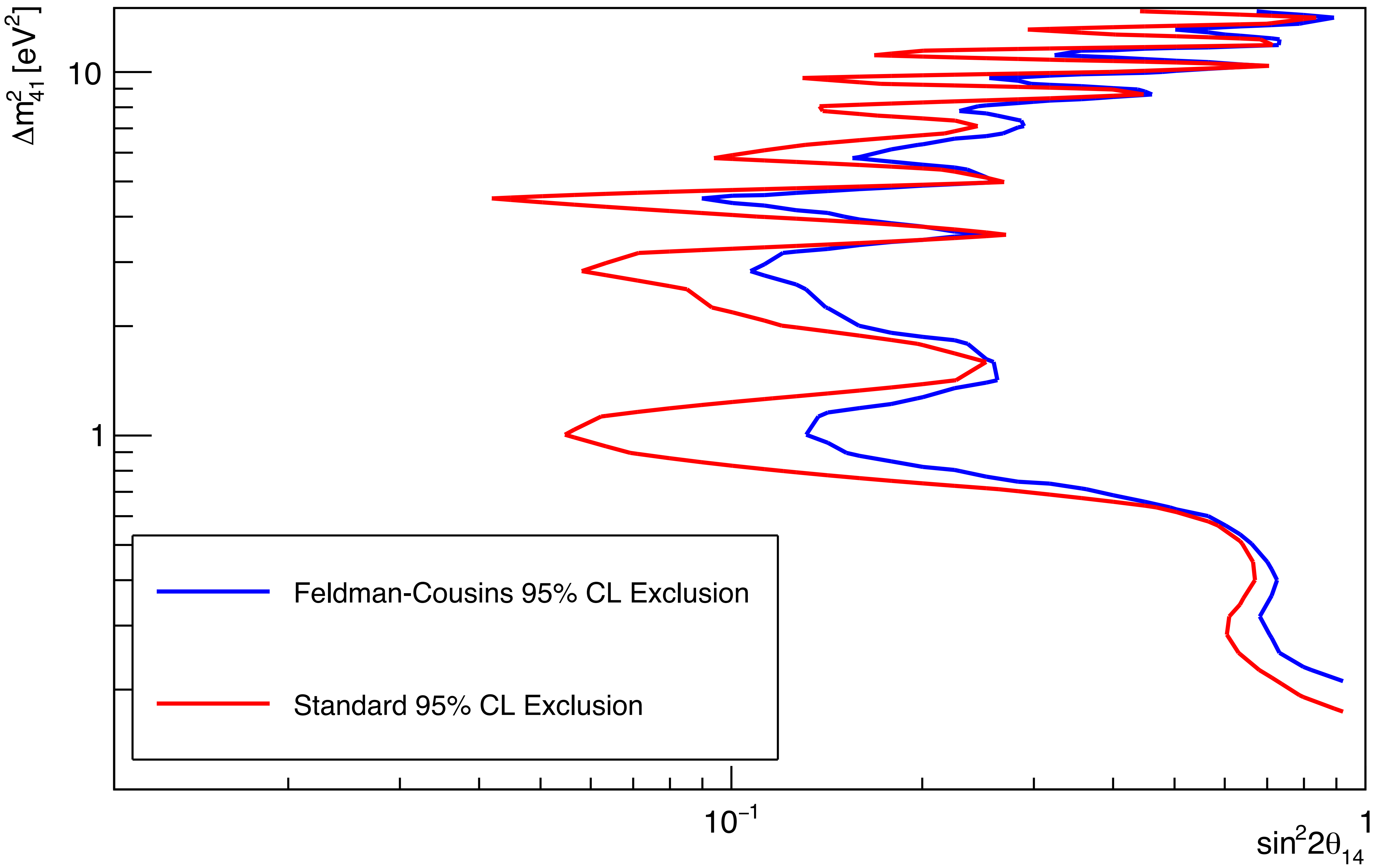
Cosmogenic Background Variations



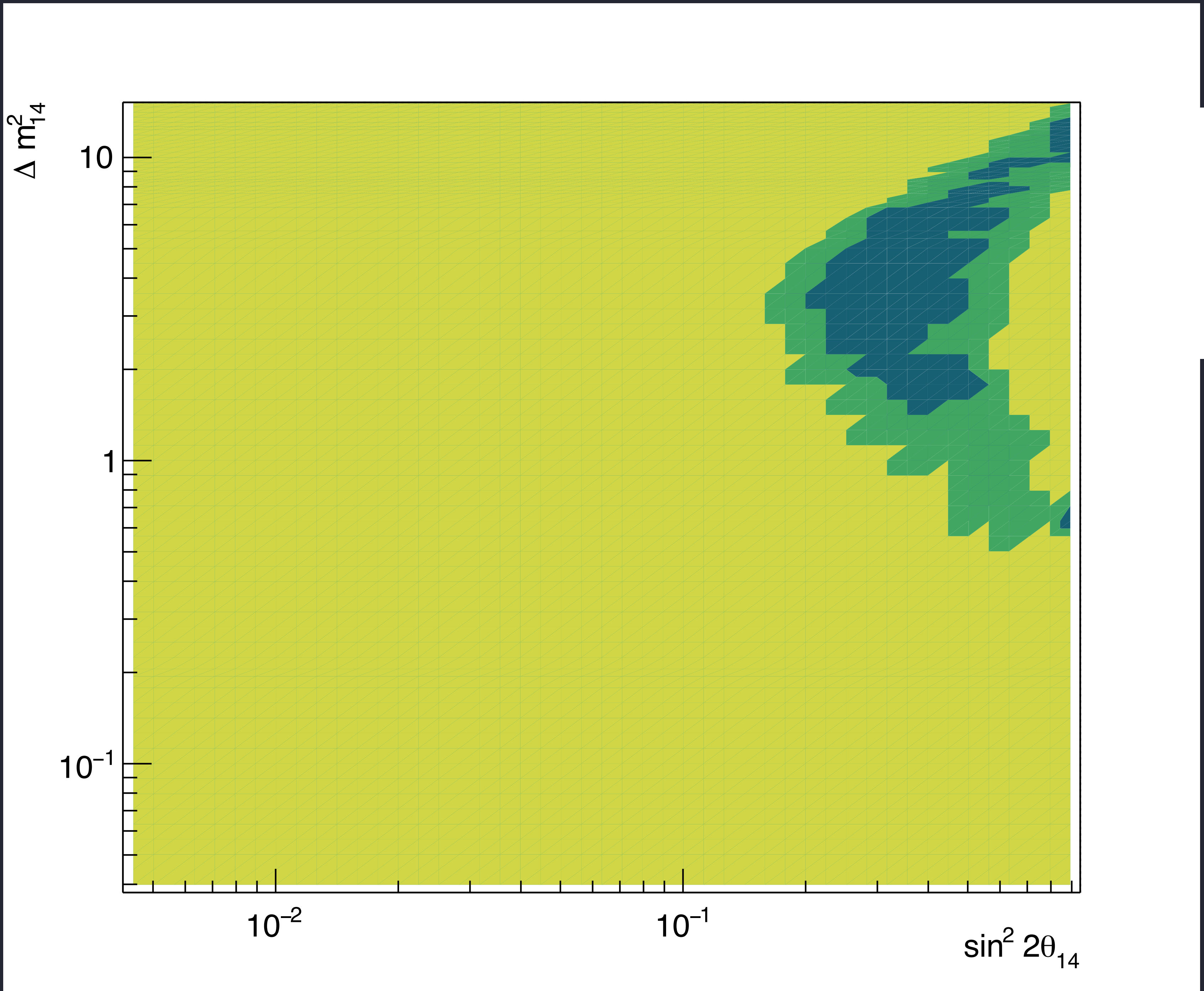


- Cosmogenic backgrounds are slightly dependent on the atmospheric pressure
- Measure correlation between pressure and background rates during reactor-off time
- Scale the backgrounds during reactor-off time using this correlation

Why use FC ?


Δm^2_{41} [eV^2]
10
1
10^{-1}
1
$\sin^2 2\theta_{14}$
Feldman-Cousins 95% CL Exclusion
Standard 95% CL Exclusion

Why use FC ?



Correct coverage

Undercoverage

Overcoverage

- If probability contained in the Wilk's theorem-defined chi2 values <(>) 0.95 then that point is undercovered (overcovered)
- Chi2 = +/- 1 taken as threshold to define the right coverage
- => undercoverage **if P(6.99) < 0.95** and
  overcoverage **if P(4.99) >0.95**

Neutrino-4

Feldman-Cousins Approach

☐ Standard (incorrect) method does not handle boundary features such as bounded nature of $sin^2 2\theta$ (0,1) or cases when oscillation frequency approaches energy bin size. Feldman-Cousins method solves those problems

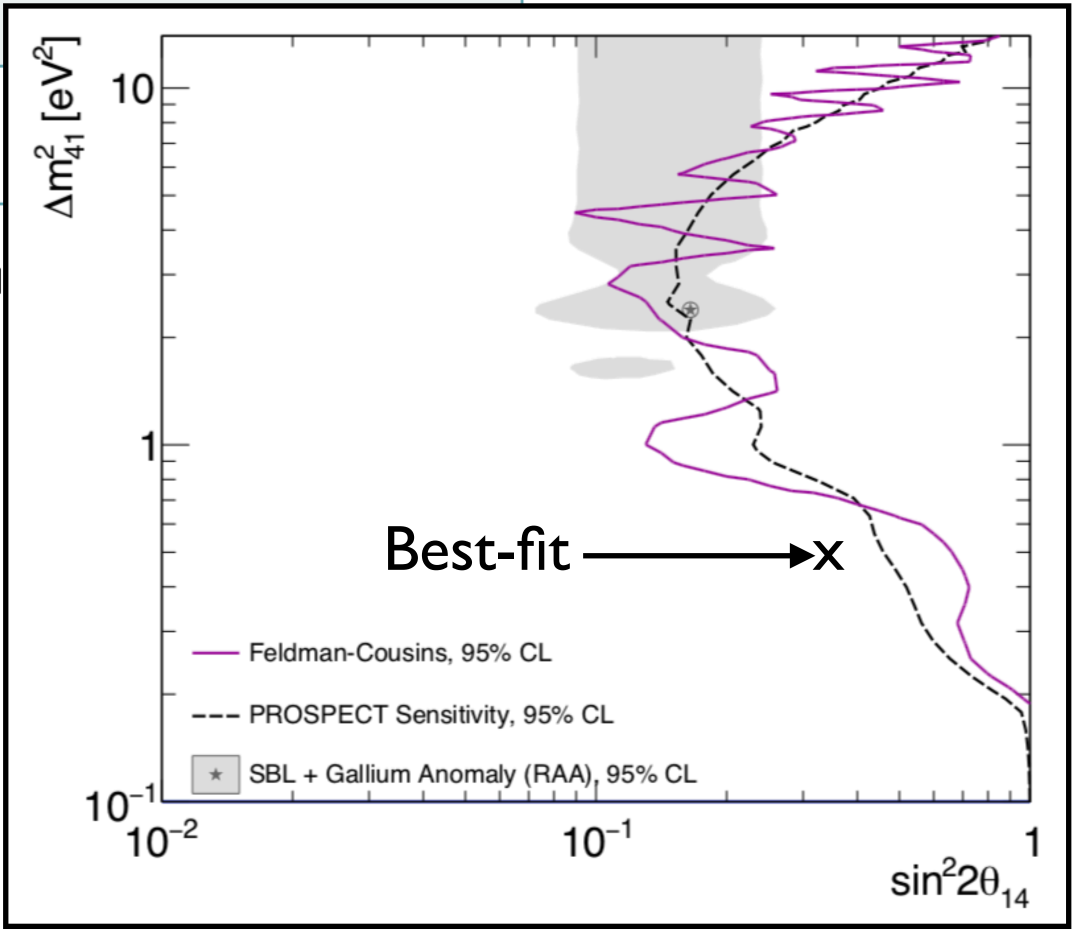
☐ Comparing p-values for Feldman-Cousins and standard (incorrect) methods:

P-values	3ν-oscillation hypothesis	RAA sterile ν oscillation hypothesis
Feldman-Cousins	0.58	0.013
Standard (incorrect) confidence intervals assignment	0.14	0.005

☐ If standard (incorrect) confidence levels used instead of Feldman-Cou

- We say 3ν is less compatible with data than it actually is

☐ Illustrates an importance of using Feldman-Cousins

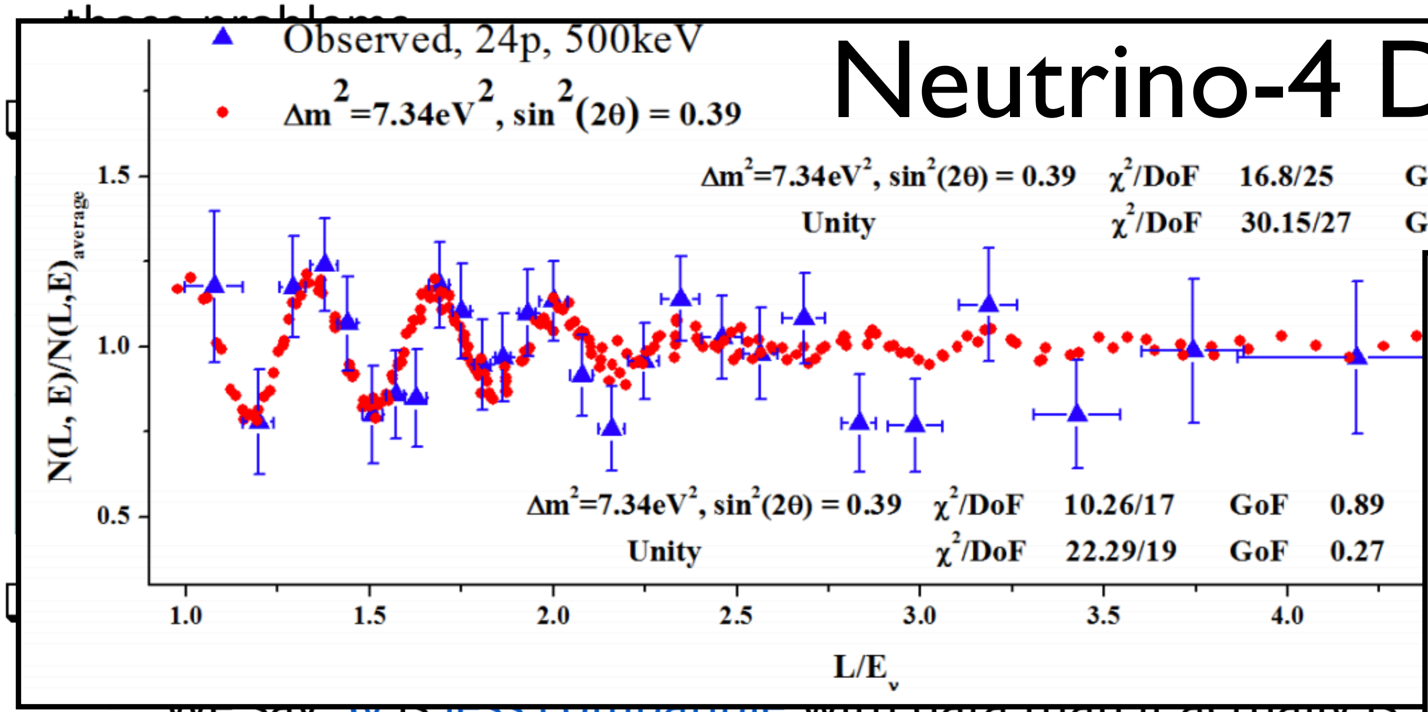


Best-fit → x

Neutrino-4

Feldman-Cousins Approach

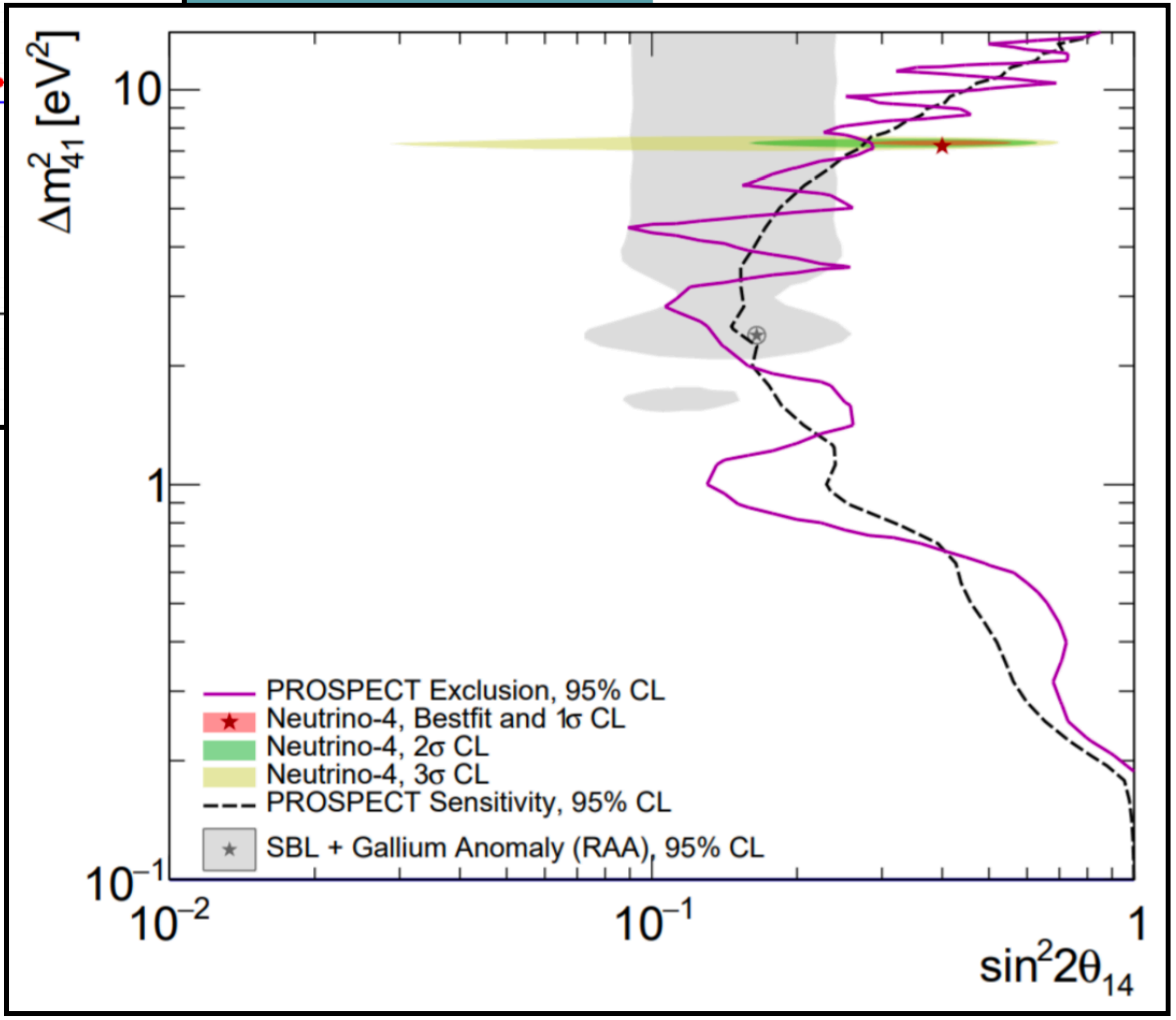
- ❑ Standard (incorrect) method does not handle boundary features such as bounded nature of $sin^2 2\theta$ (0,1) or cases when oscillation frequency approaches energy bin size. Feldman-Cousins method solves these problems



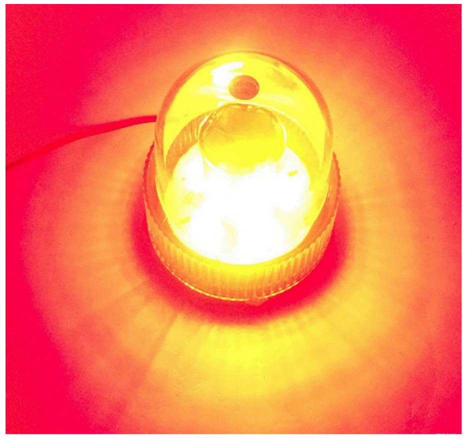
thods:

ile ν oscillation

We say 3ν is less compatible with data than it actually is

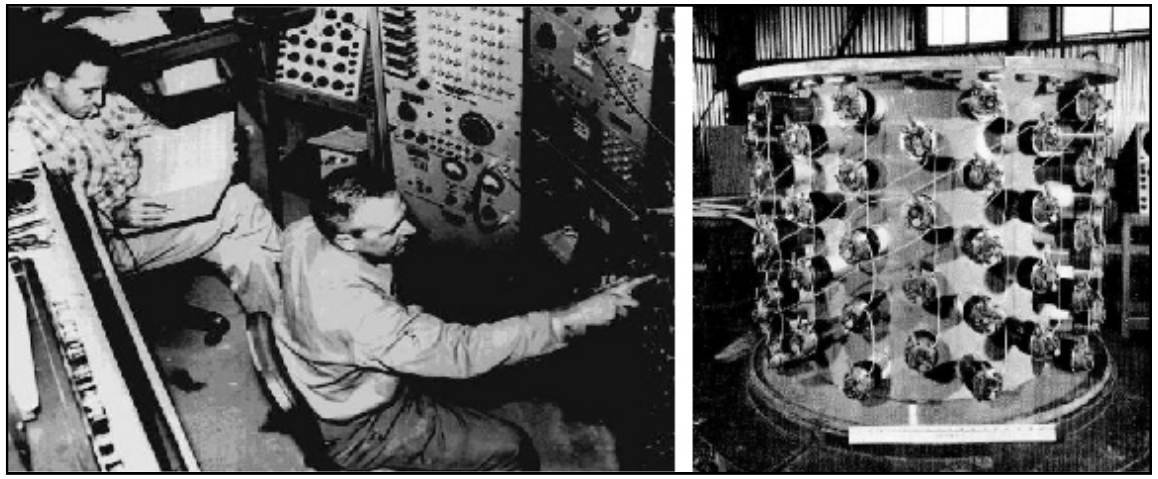


- ❑ Illustrates an importance of using Feldman-Cousins

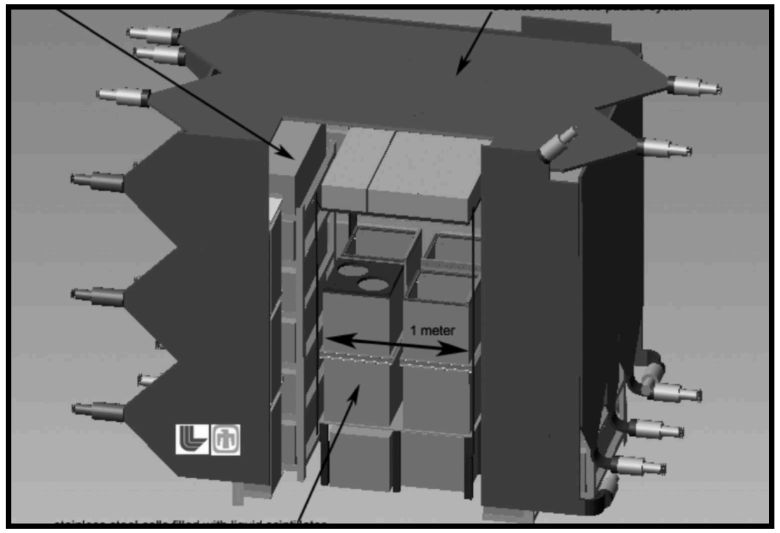


Reactor Neutrino Monitoring Advances

- Last few decades have brought major advances in realized tech:

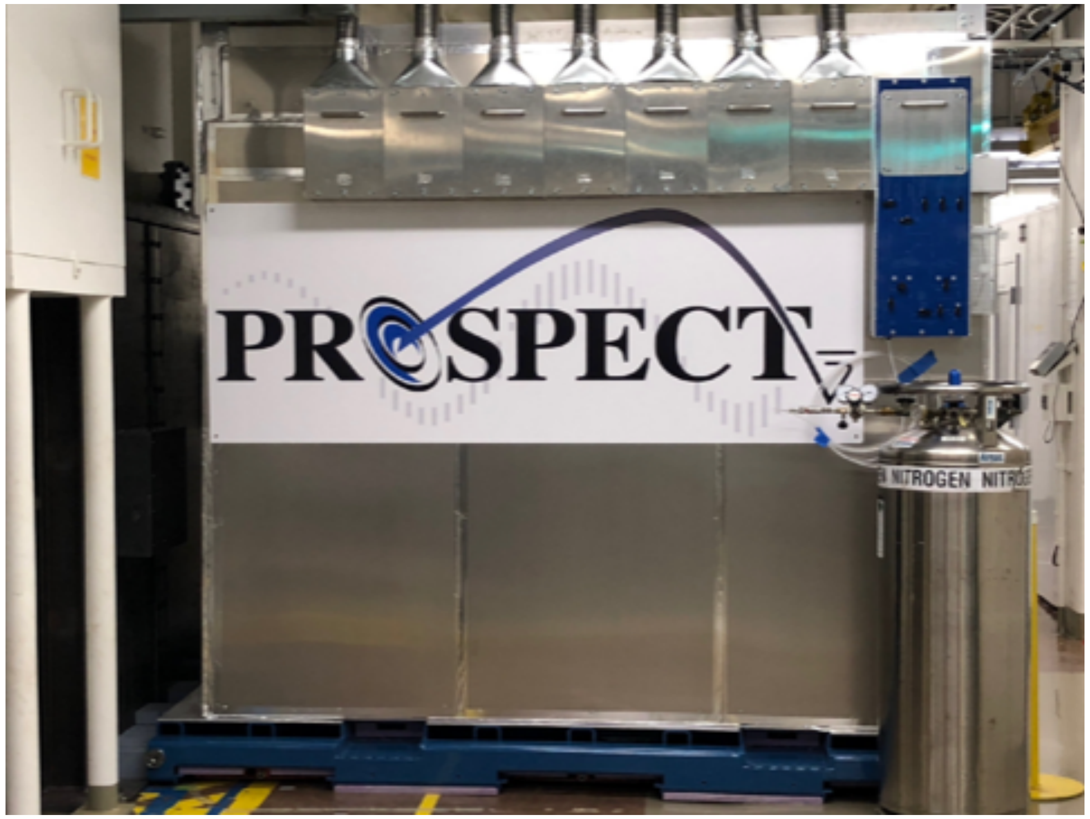


1950s: First Detection; ~1000 counts in 1 month; 5 background counts per 1 antineutrino count (S:B 1:5)



2000s: SONGS: ~230 counts per day, 25:1 S:B, but must be underground. 'semi-safe' detector liquid

1980s: Bugey: ~1000 counts per day, S:B 10:1, but only underground. flammable/corrosive solvent detector liquids



NOW: PROSPECT detector: ~750/day from only 80MW reactor, S:B 1:1 on surface, 'safe' plug-n-play detector