New analysis opportunities with PROSPECT

Cristian Roca Catala – 07.IX.2022

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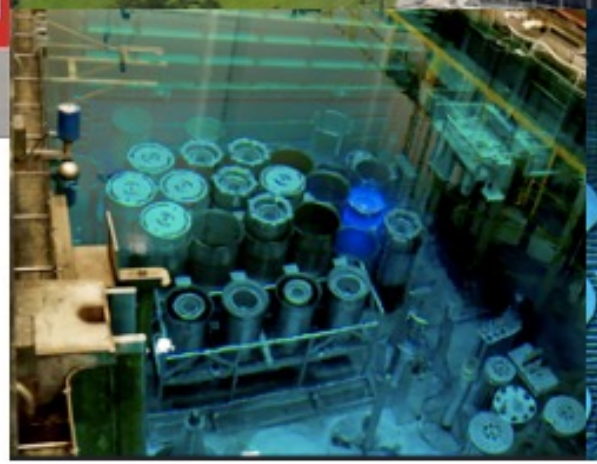
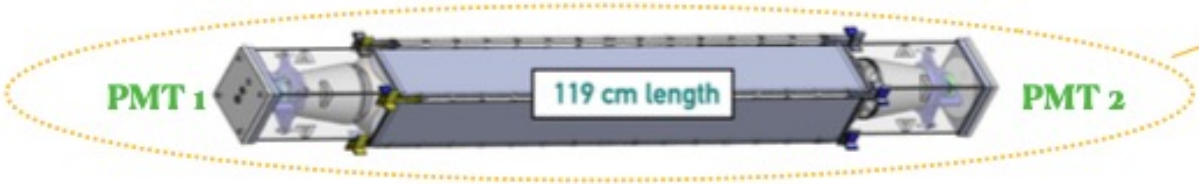


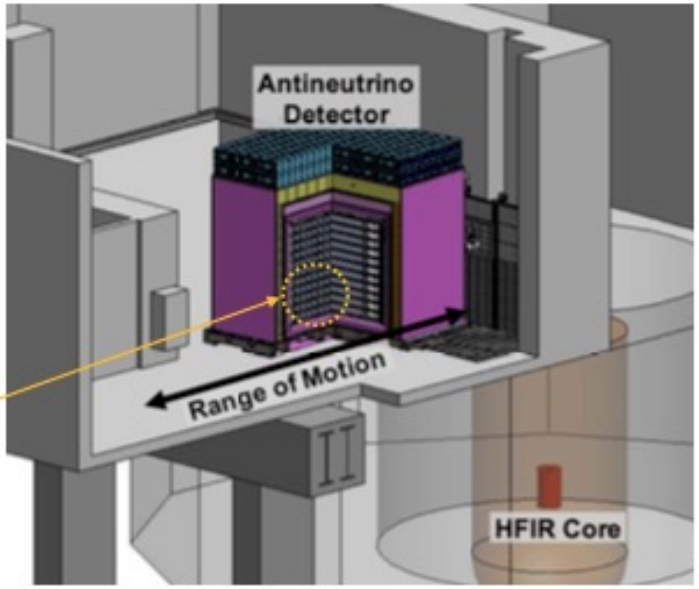
The High Flux Isotope Reactor - Oak Ridge

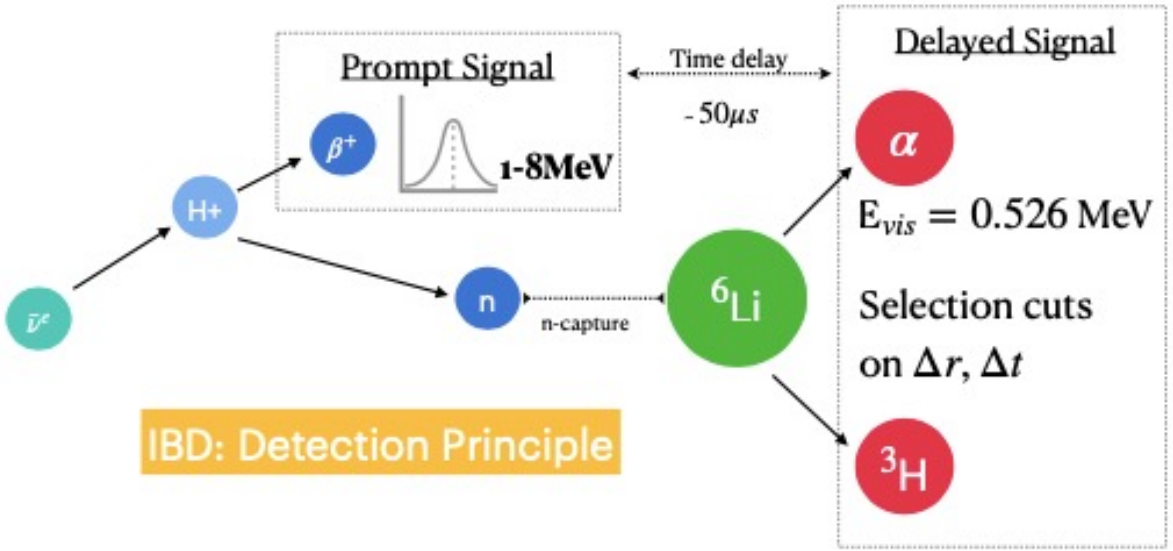
- Compact HEU core
- Pure U-235 fuel
- Research reactor ~ 85MW - 46% reactor up time

PROSPECT design

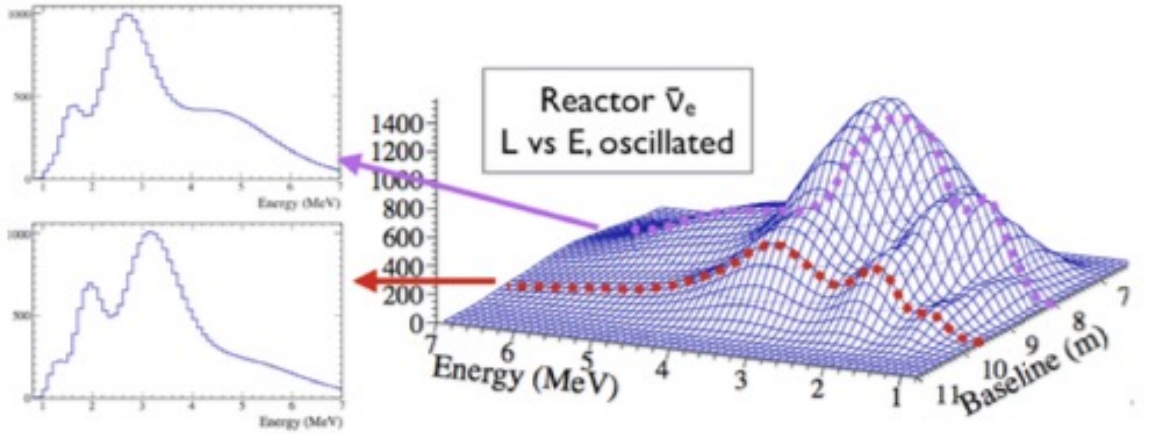
- **Liquid Scintillator** loaded to a mf of 0.08% ^6Li
- High-resolution **spectrum** at a range of **baselines (7-9 m)**
- 14x11 **Segmented** detector allows **topology selection** and **background rejection**
- **Double PMT** readout with light concentrators ~ 5% $\sqrt{E}$ energy resolution







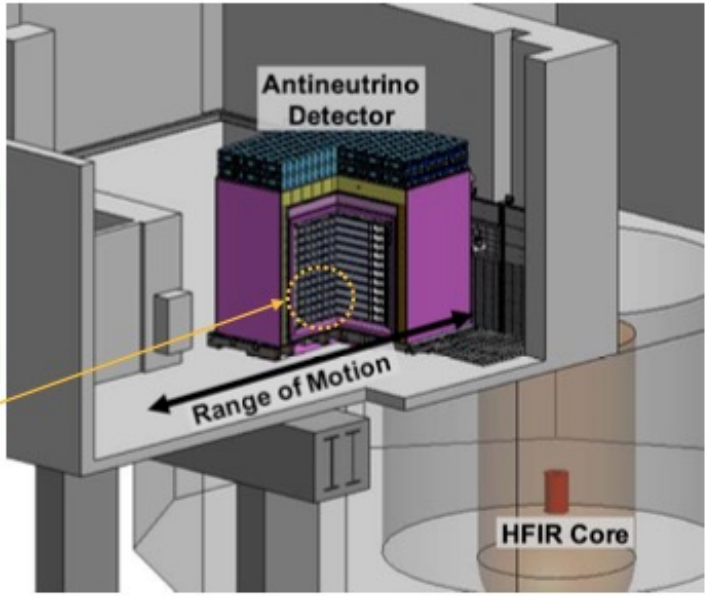
IBD: Detection Principle

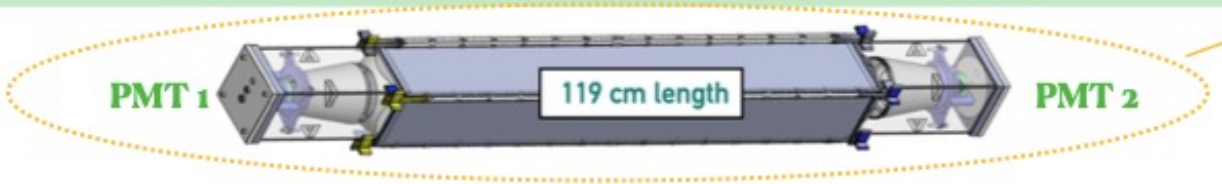


Search for relative spectral distortions within the detector volume

PROSPECT neutrino measurement

- Liquid Scintillator (**LS**) **ingress** in some of the **PMT housings** fatally affecting HV/signal dividing bases.
- The latest published results [PhysRevD.103.032001] only included IBDs from 97/154 segments w/ **Double Ended Event Reconstruction (DEER)**



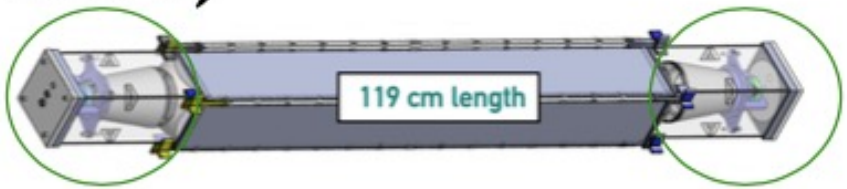


LS ingress increased over time

- **47** single ended segments were **excluded**
- **Single Ended Event Reconstruction (SEER)** has been developed to improve the **IBD statistics**
- **Data Splitting (DS)** into different **periods** would allow a more efficient and effective **active segment selection.**

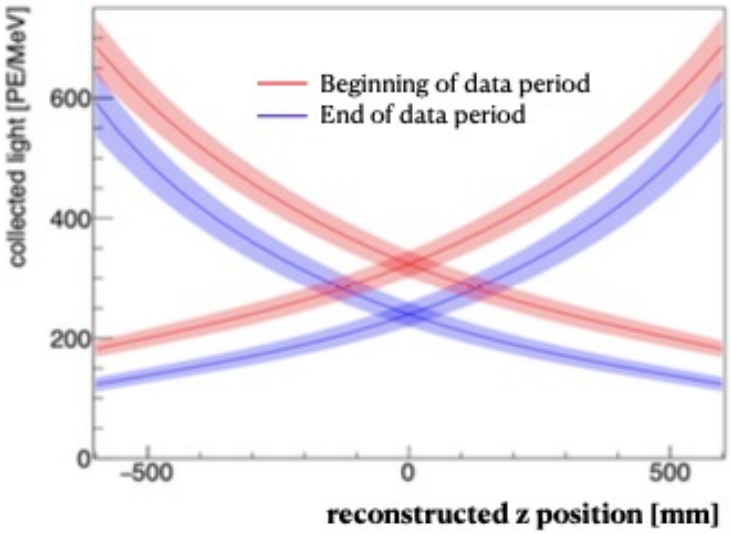
Double End Event Reconstruction (DEER)

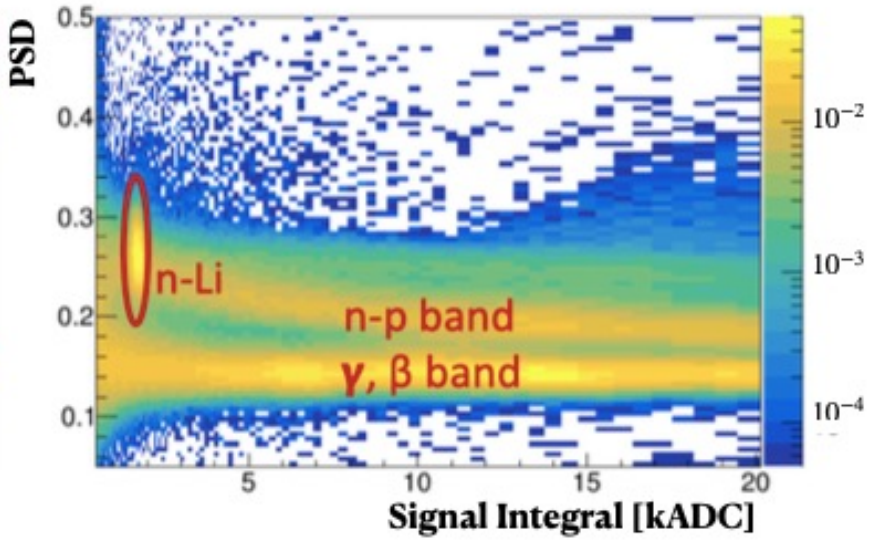
The standard route for event reconstruction in PROSPECT

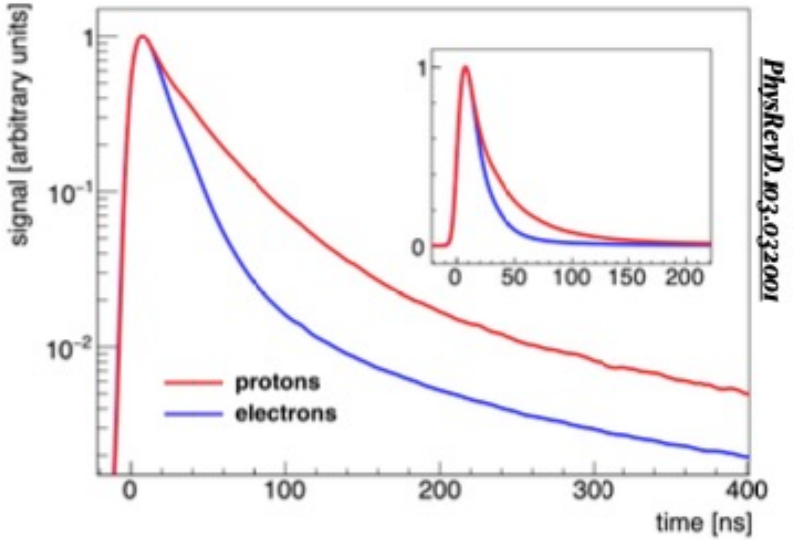


- Rely on the **waveform** pair collected by **both PMTs** of a segment
- **Event position** along a segment (z-position) **reconstructed** with **timing** and **integral** difference on the pulse pair.

  ➡ **Energy** reconstructed by pulse area with **position correction**.
- Pulse shape discriminations (**PSD**) are used to **distinguish** gamma/beta events from heavy particle **interactions** (n-Li captures and n-p recoils).
- **Pulses without** matching **pair** are **excluded** from calibrated data analysis.





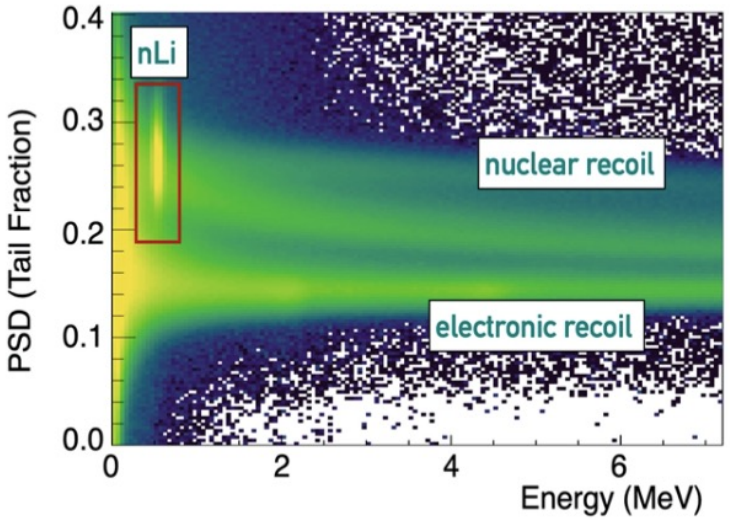


IBD Event Selection

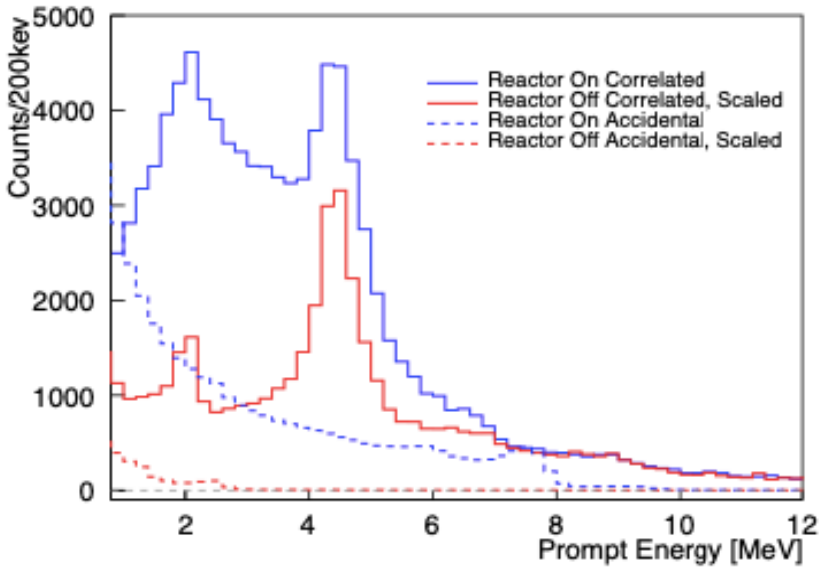
IBD Topology-based cuts:
- Neutron Capture region
- Prompt PSD
- Prompt-delayed Distance
- Prompt-Delayed Timing
- Fiducial z-cut

Veto cuts:
- Muon Veto Time
- Neutron Veto Time
- Recoil Veto Time

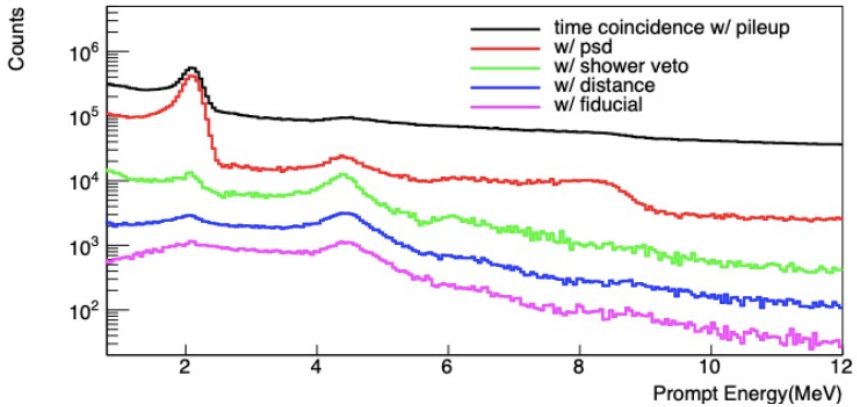
Prompt PSD Cut



Measured prompt energy spectrum of correlated IBD-like candidates



Prompt Energy Distributions Under Different Cuts



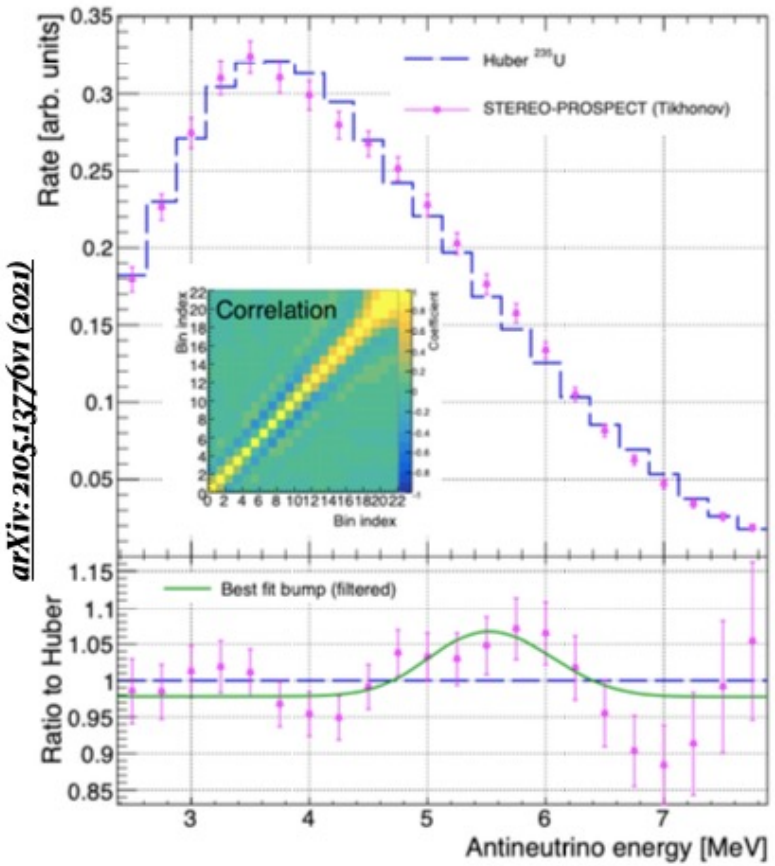
- 95.65 reactor-on calendar days, 73.09 reactor-off
- >50,000 IBD events
- Signal to background ratio > 1

M. Andriamirado et al. (PROSPECT Collaboration), Phys. Rev. D 103, 032001 (2021).

Recent published analyses

PROSPECT's combined analyses

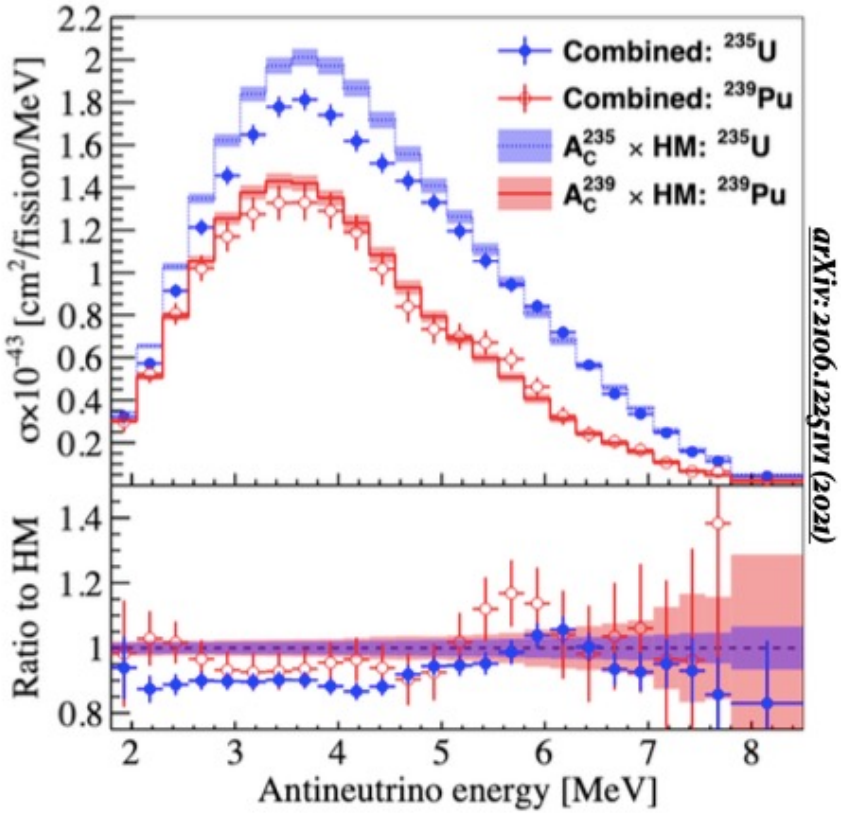
PROSPECT + STEREO



arXiv: 2105.13776v1 (2021)

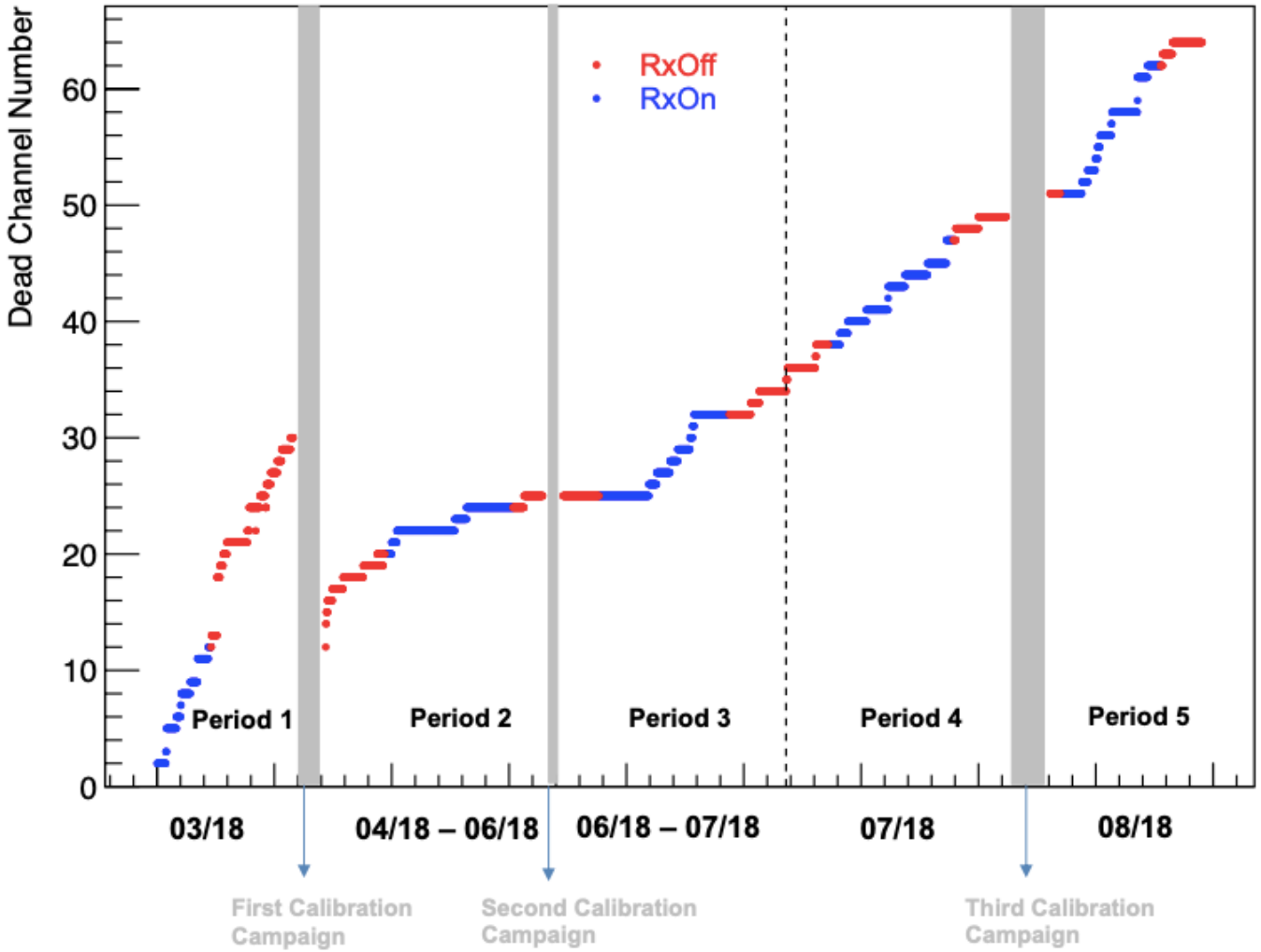
- **Comparison** to **H-M** performed in unfolded/**neutrino energy space**.
- Unfolding techniques: **Tikhonov regularization** and **WienerSVD** .
- Stronger **confirmation** of **excess** between 4-6 MeV area.
- **Improved uncertainty** of the **U235** spectral shape.
- **Proof of concept**: combining HEU/LEU experiments is possible and very positive.

PROSPECT + DAYA BAY



arXiv: 2106.12251v1 (2021)

New analysis: Data Splitting (DS)



Previously:

- Single data period processed using single analysis configuration.
- Configuration conservatively chosen to represent final detector status.

New goals:

- Leverage dead channel evolution to enhance recovery of statistics from earlier dates.

Splitting Criteria:

- Each period starts immediately after a new calibration campaign.
- Each period contains one full RxOn period preceded and followed by RxOff periods.
- Keep RxOn/RxOff data between 50-70%

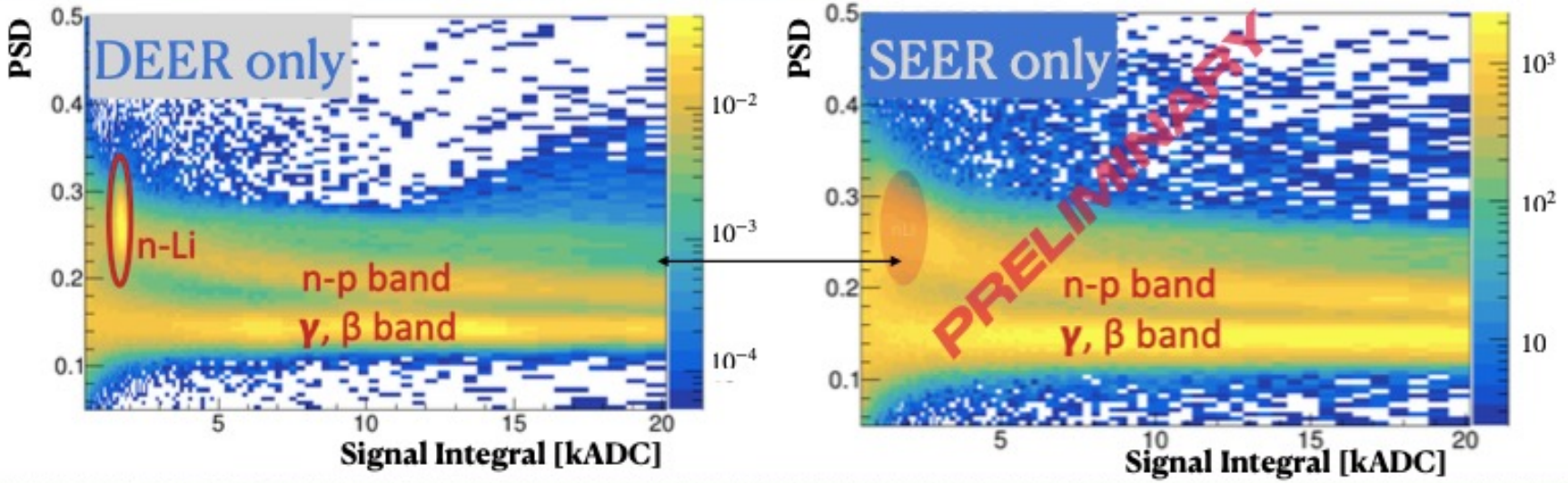
New analysis: Single-Ended Event Reconstruction (SEER)

Position and energy reconstruction

- **SEER lacks** the ability to reconstruct **position** because of no counter part pulse comparison (**1 PMT** available).
- **Energy reconstruction** depends on position, therefore **not applicable** as IBD selection cut.

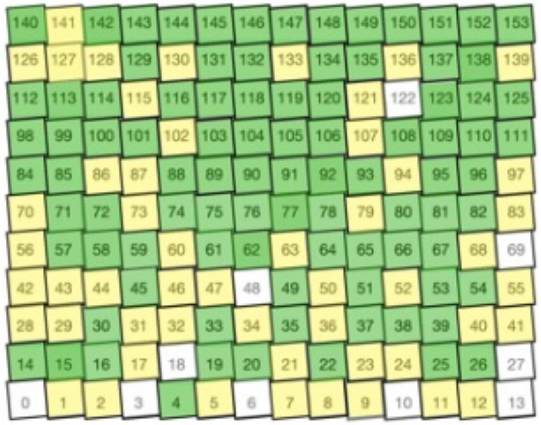
Particle Identification (PID)

- **PSD** capability with **single PMT** readout is applicable for **PID**
- **SEER** PSD **lacks** the ability to **distinguish n-Li capture** from n-p recoil events.
- **More** active **segments** from SEER+DEER allow for **better IBD selection** and bkg rejection.



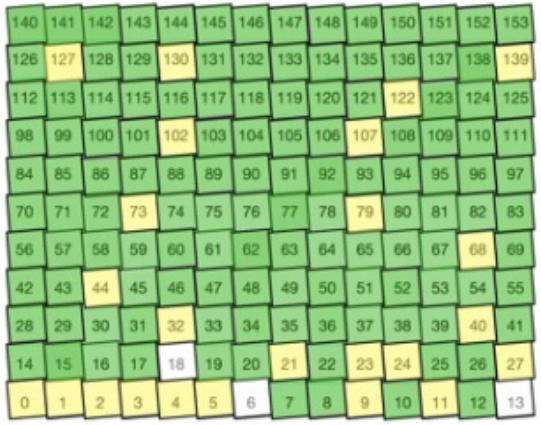
New analysis: Detector configuration for each period

Detector Configuration Used for Previous Analysis

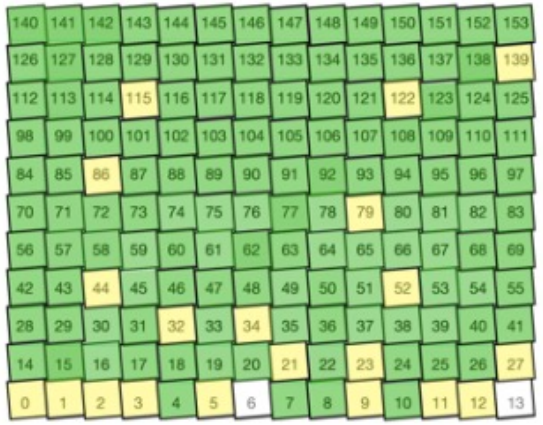


- Previous analysis did not make use of single ended segments.
- This new method takes full advantage of all the data collected by the PROSPECT detector

Period 1



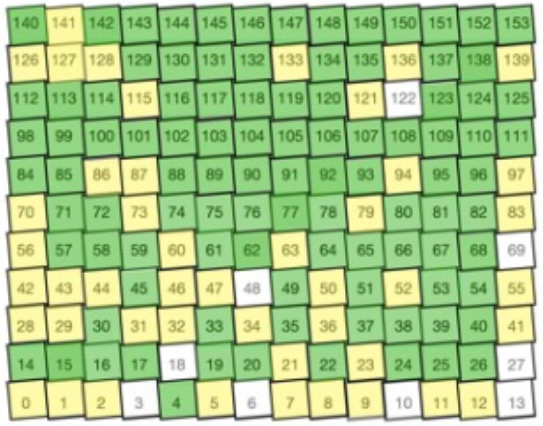
Period 2



Period 3

Period 4

Period 5



DE Segment

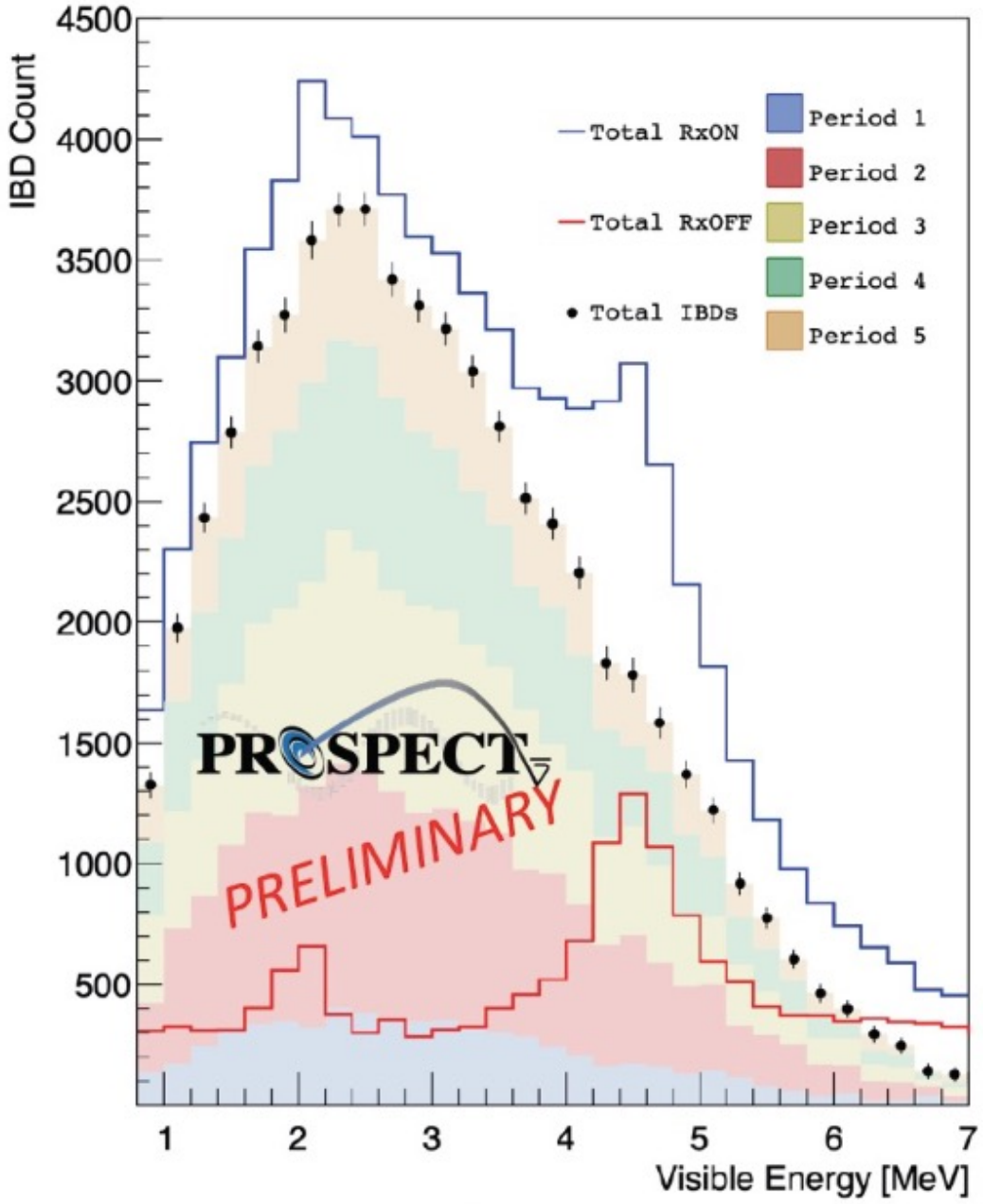
SE Segment

Blind Segment

New analysis: preliminary results and summary

Achieved Improvements:

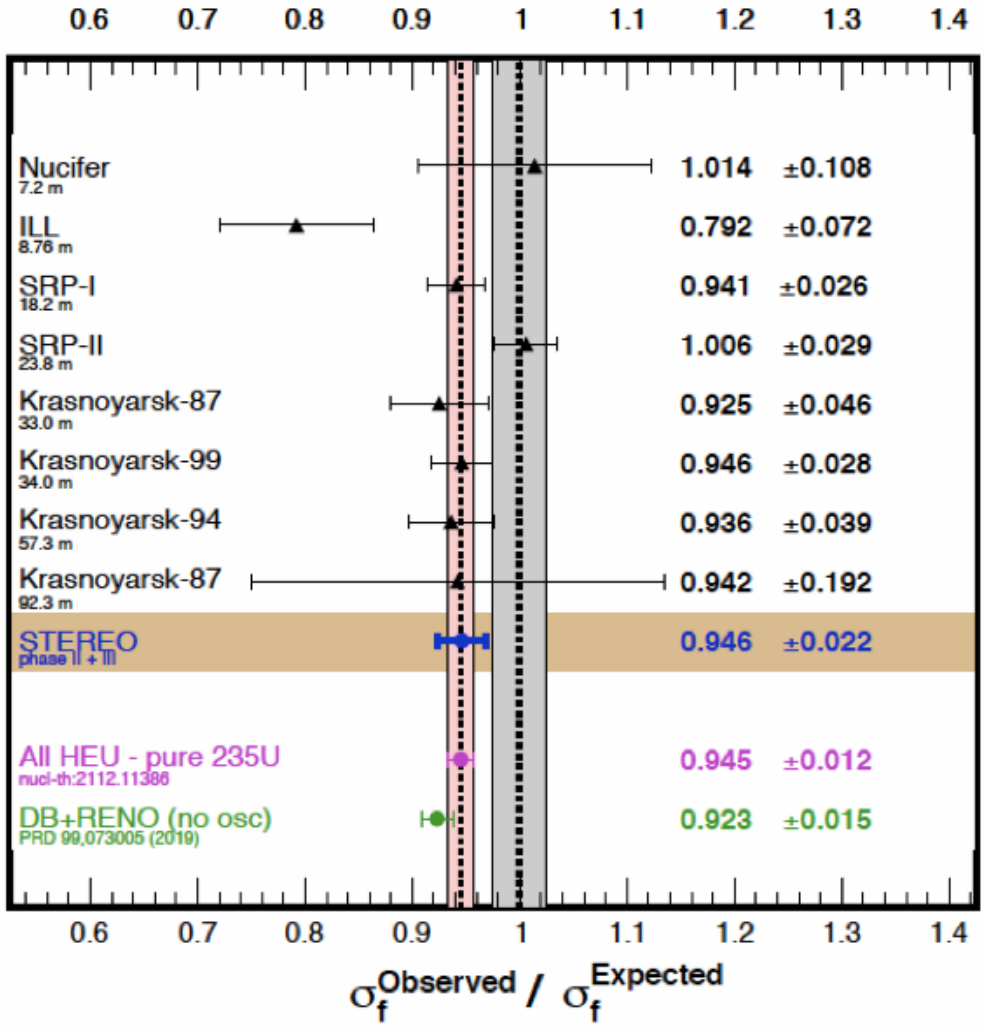
- IBD counts (x1.2)
- Eff. IBD counts (x 2)
- Signal to cosmogenic background (x 2.8)
- Signal to accidental background (x 2.4)



New analysis: motivation for flux analysis

Flux anomaly might be better understood than ever (Kopeikin 2021). Still, a PROSPECT flux analysis is still relevant:

- Updated and more precise measurement relative to flux predictions. Benchmarking.
- Controlled flux uncertainties for a precise spectra comparison analysis.
- Reactor power monitoring for verification and safeguards.



STEREO (R. Rogly), Moriond-EW 2022 & PRL 125, 201801 (2020)

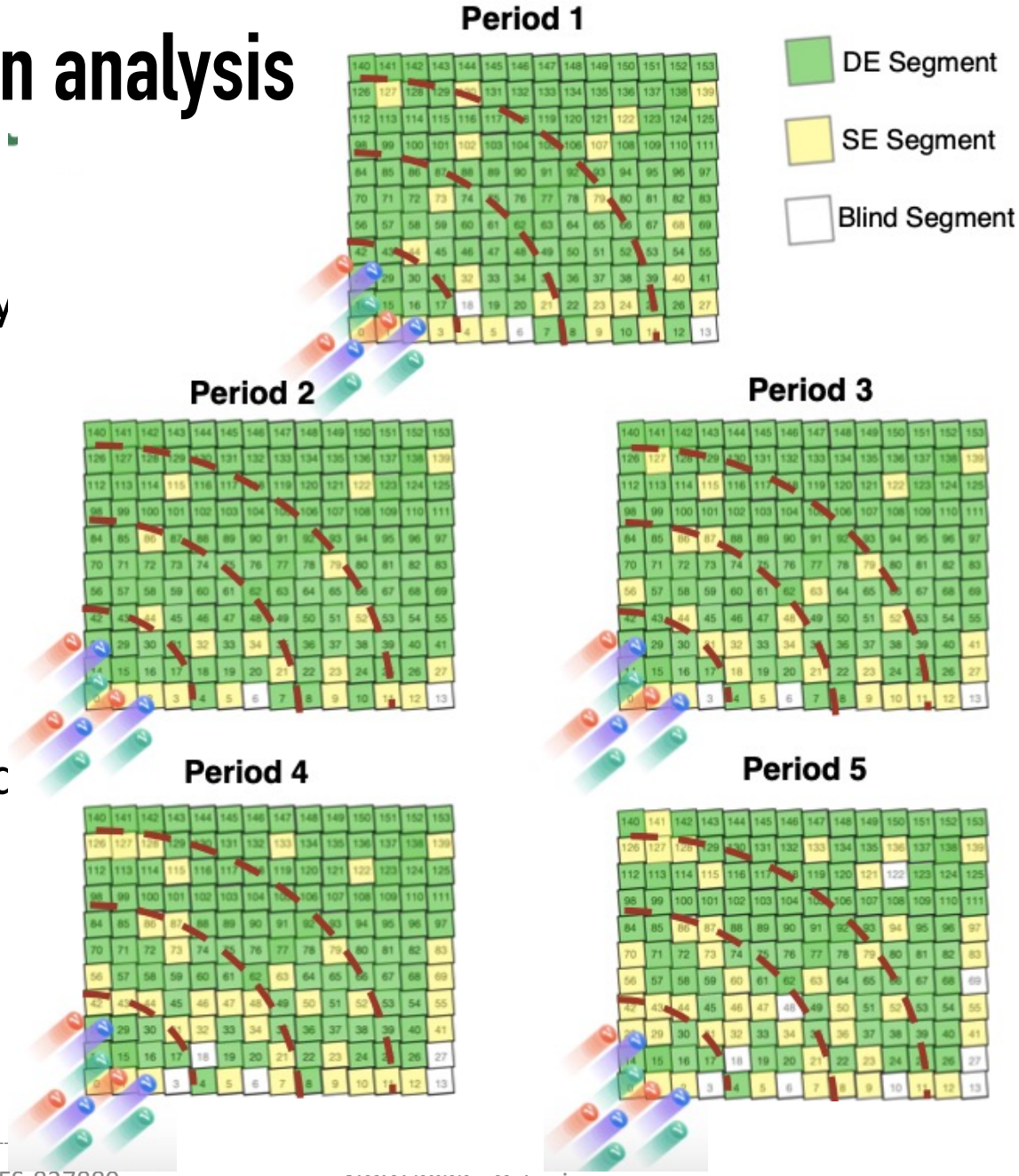
New analysis: multi-period oscillation analysis

- Previous oscillation measurement was statistics-limited. Increase in effective statistics (x2) will improve current sensitivity

- Multi-period analysis allows for the use of additional baseline bins which result in a sensitivity gain.

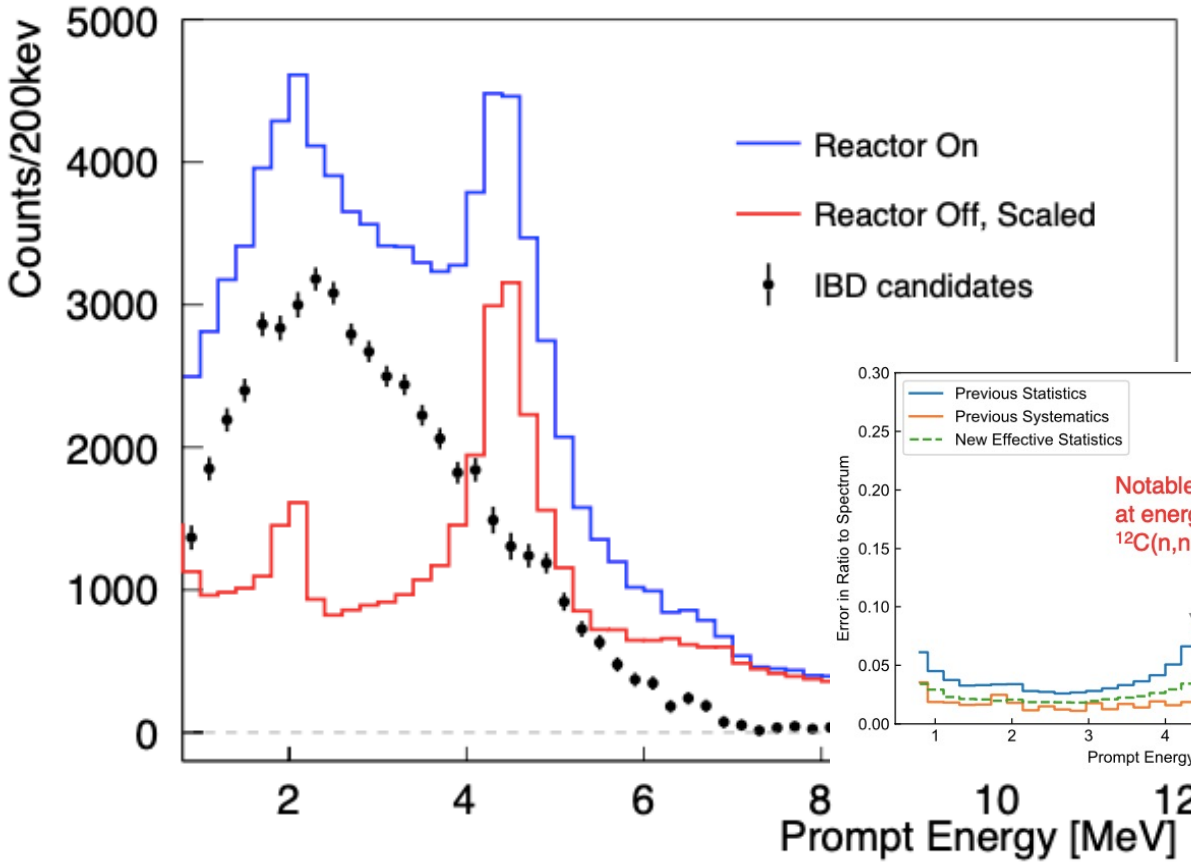
- A new framework capable of producing a joint oscillation analysis for each data perioc is being developed

- Future joint-oscillation analysis with other reactor experiments

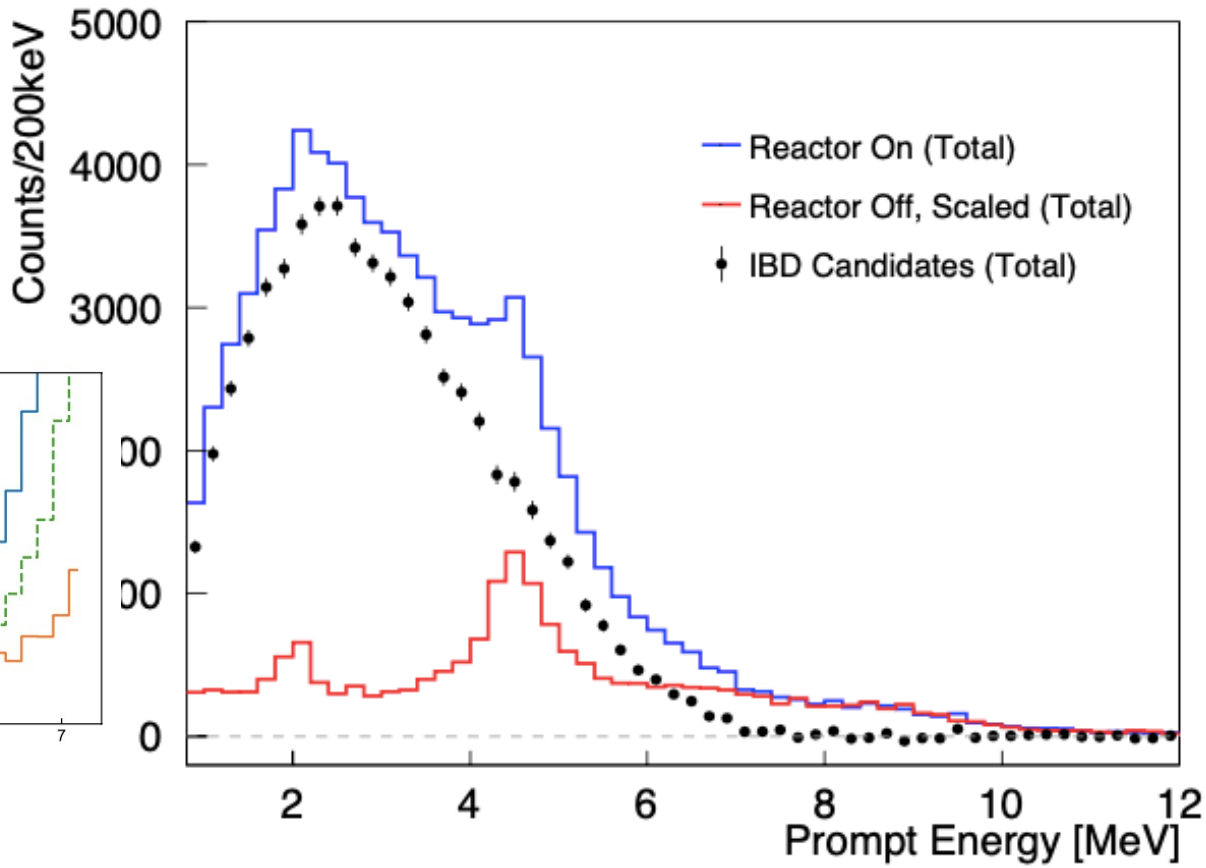


New analysis: multi-period spectrum analysis

Previous PROSPECT analysis



New SEER+DS multi-period analysis

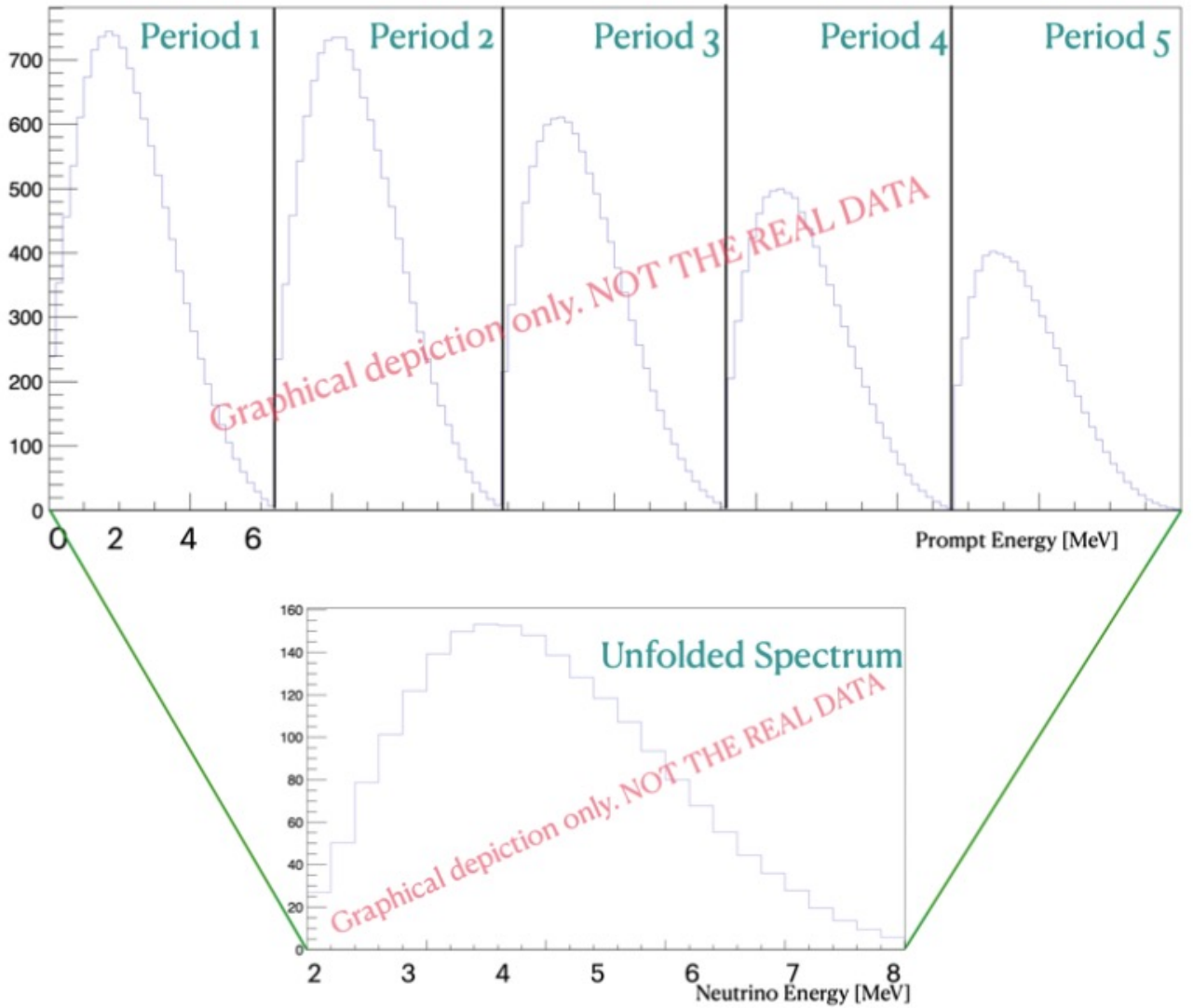


New analysis: multi-period spectrum analysis

- The implementation of a period-by-period analysis allows for the treatment of each period as an independent experiment.

- Following the work done during the joint spectrum analysis, a new unfolding framework has been developed to jointly unfold the prompt spectrum from each period into one final antineutrino energy spectrum

- This new framework paves the way for multi- experiment and multi-reactor joint antineutrino energy unfolding



Summary

- PROSPECT-I data still presents a fantastic opportunity to obtain world-class physics results.

- Increase in effective statistics caused by new DS+SEER analysis will have a significant impact on new efforts such as spectrum and oscillation measurements

- Multi-period analysis motivated the development of frameworks that will facilitate joint studies between different reactor-based experiments

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