Improving PROSPECT Neutrino Measurements with Single Ended Event Reconstruction

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For the PROSPECT Collaboration

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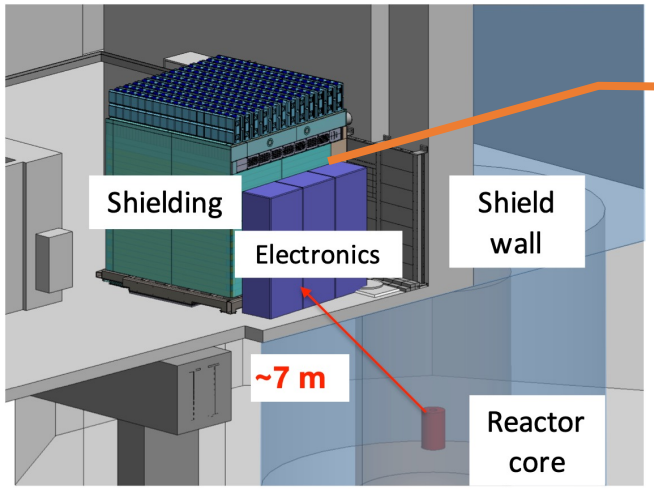
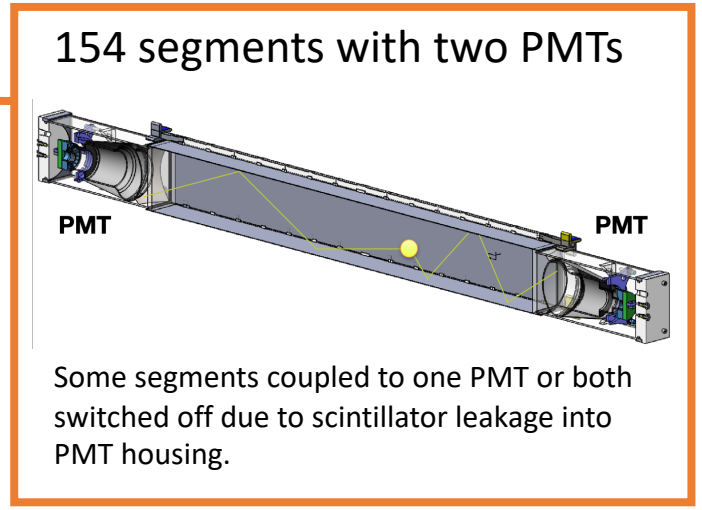
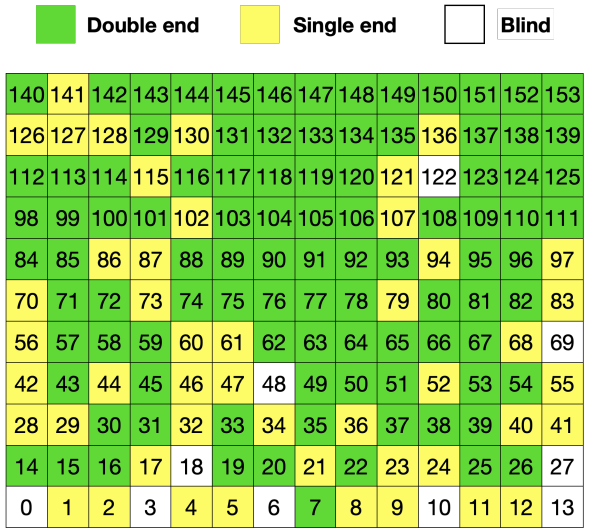
PROSPECT reactor neutrino measurement

- PROSPECT measures reactor neutrino spectrum in 7 to 9 m baseline from HEU reactor to:
  - Probe the sterile neutrino oscillation [PhysRevLett.121.251802]
  - Measure the reactor neutrino spectrum to test the correlation of ^{235}U contribution to the reactor spectrum discrepancy [PhysRevLett.122.251801]
- The latest published results [PhysRevD.103.032001] only included inverse beta decay (IBD) in 97 out of 154 scintillator segments. 47 single ended segments was excluded.
- We organized measurement with single ended event reconstruction (SEER) to improve the IBD statistics.



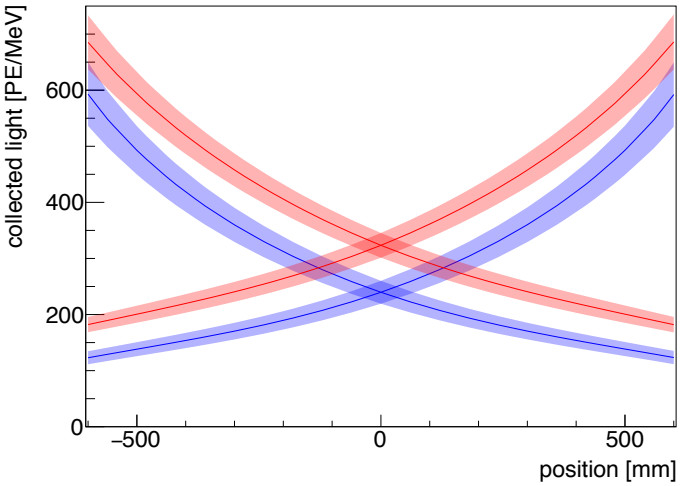




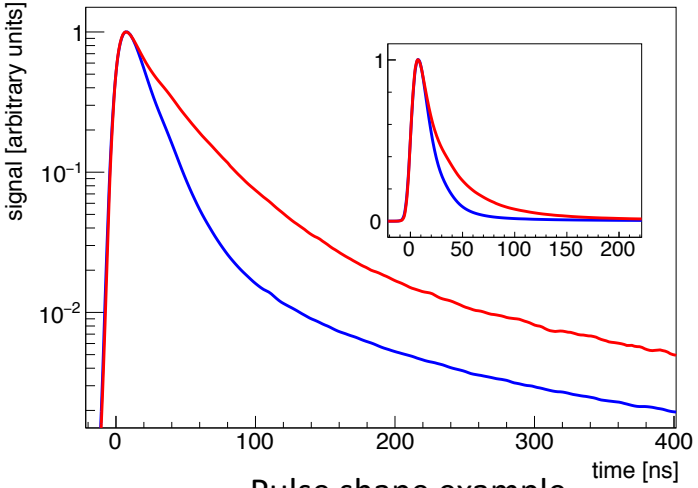
Double end event reconstruction (DEER)

PhysRevD.103.032001

- Past PROSPECT event reconstruction 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 of the pulse pair.
  - Energy reconstructed by pulse area with position correction.
  - Pulse shape discrimination (PSD) are used to distinguish gamma and beta events from heavy particle interactions (n-Li captures and n-p recoils).



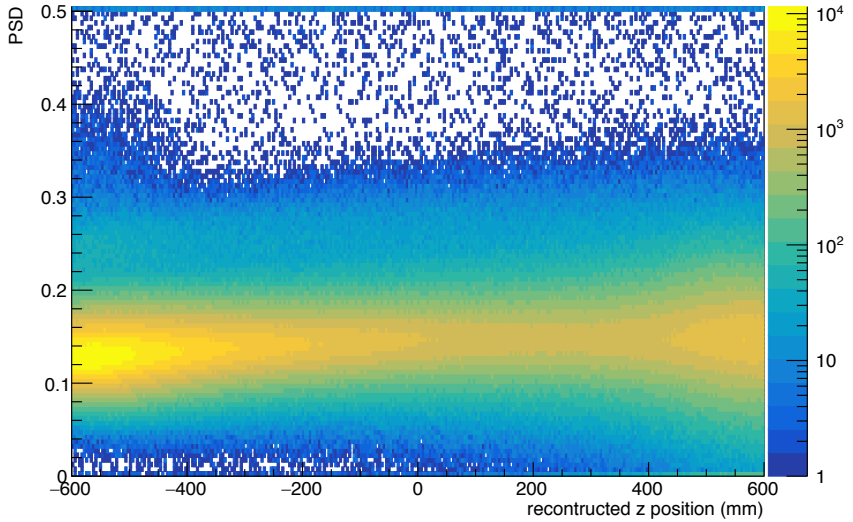
Position dependent signal amplitude



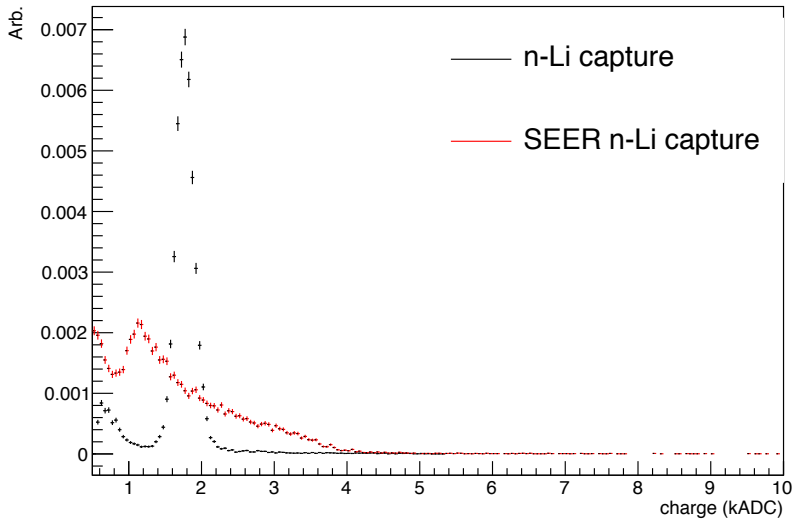
Pulse shape example

SEER for position and energy reconstruction

- SEER lacks the ability to reconstruct position because of no counterpart pulse comparison.
- Correlation between PSD and particle position is not strong to locate the event.
- Energy reconstruction depends on position, therefore not applicable in IBD analysis.



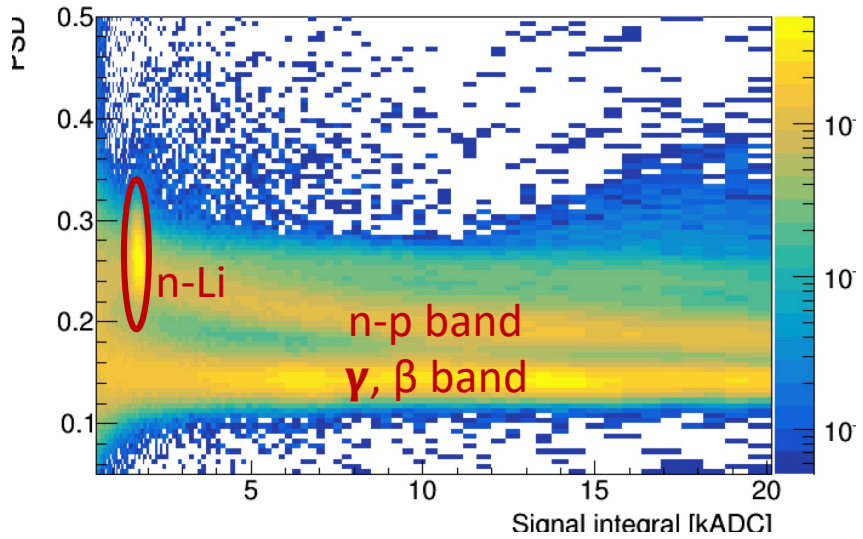
SEER PSD vs Z position



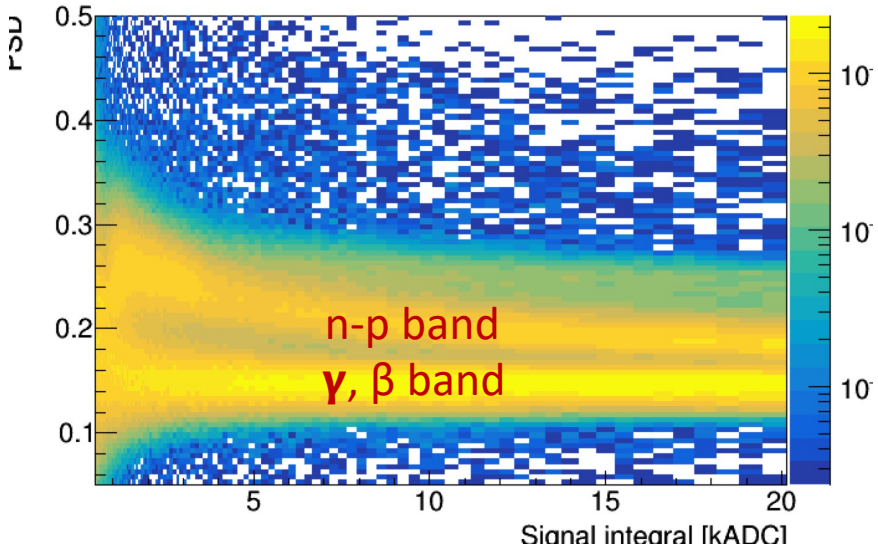
Signal aplitude of DEER and SEER n-Li capture events

SEER for particle identification (PID)

- PSD capability with single PMT readout is applicable for PID.
- The resolution of SEER PSD is reduced because of the reduction of total light collection.
- SEER PSD lacks the ability to distinguish n-Li capture and n-p recoil events.



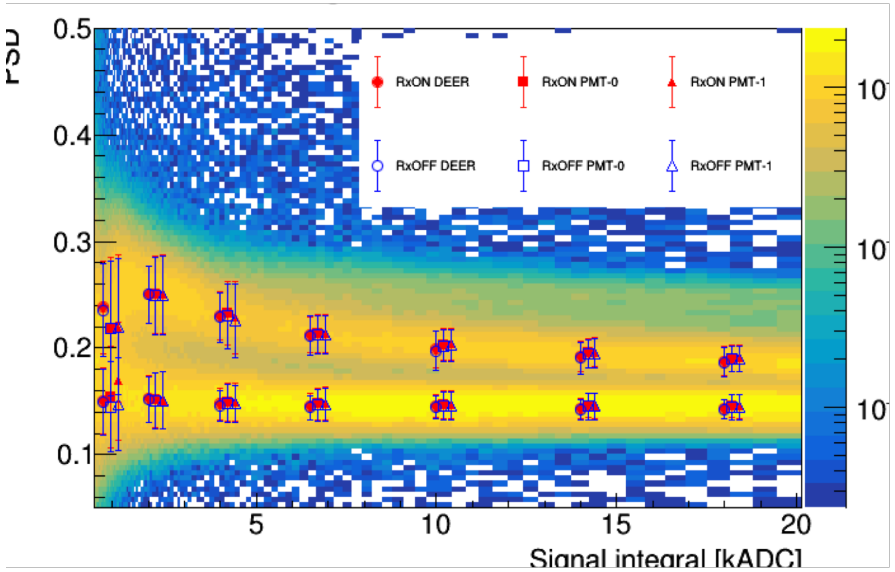
PSD and energy distribution of DEER signals



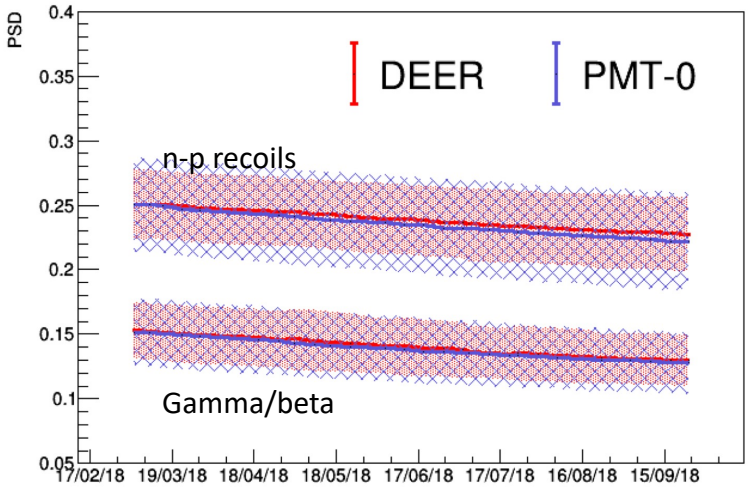
PSD and energy distribution of SEER signals

Calibrating SEER PSD

- PSD distribution of SEER and DEER events are fitted with Gaussian on slices of signal amplitude.
- SEER PSD indicates good discriminating power at energy above 2 kADC (0.55 MeV n-Li peak).
- The evolution of SEER PSD distribution is consistent with DEER, can be characterized with for IBD analysis.



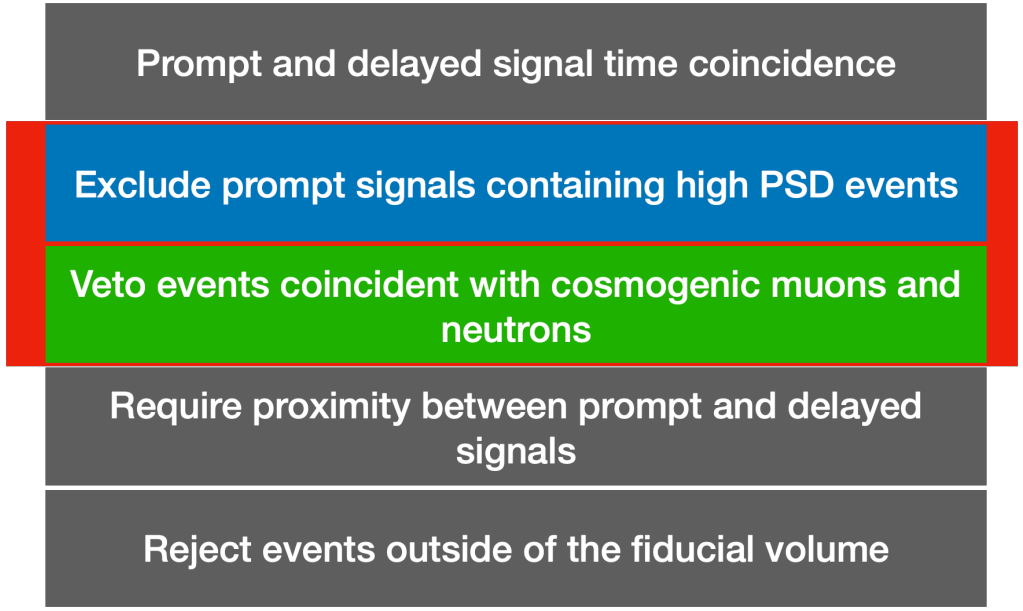
Gaussian fitted PSD distribution of DEER and SEER. (error bar represents 1σ width)

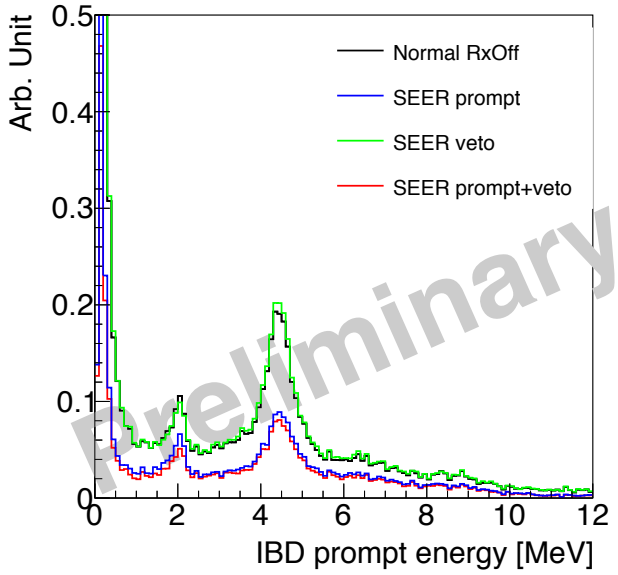


Width and mean of the DEER and SEER PSD distribution over time.

IBD selection with SEER

- IBD event selection: (avoids requirement of E and Z reconstruction)

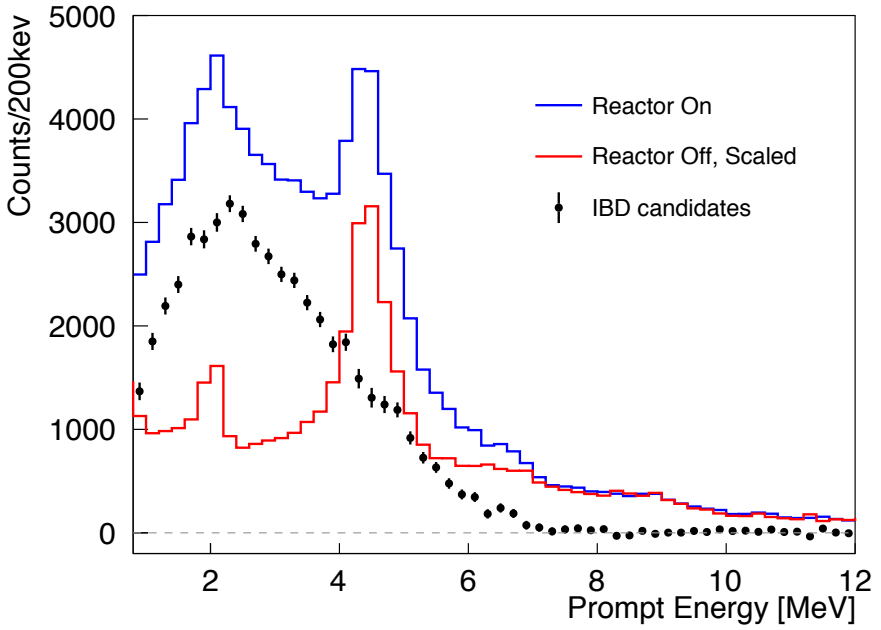


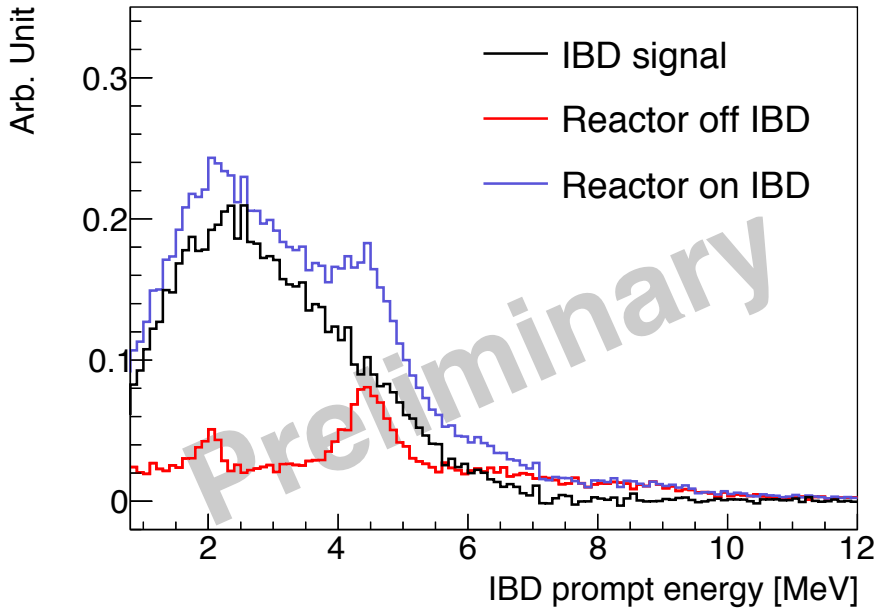


- Fake IBD signals are reduced due to greater detector volume is used to identify prompt IBD signal mixed with heavy particle recoil.

Improve IBD measurement with SEER

- **PRELIMINARY** SEER IBD spectrum hints significantly improved S:B.
- Improve PROSPECT's spectrum precision at target E range (4-6 MeV) of the spectrum discrepancy.





PhysRevD.103.032001

Summary

- PROSPECT's reactor neutrino measurement can be improved by adding event collected by single PMT segments.
- The SEER analysis is powerful to identify particles but has very limited ability to reconstruct position and energy.
- Using SEER to reduce background is efficient to improve PROSPECT effective IBD statistics.
- Be prepared to see the improved PROSPECT analysis with SEER!

Thank you!

Related talks:

B13.00001: The Design and Expanded Physics Reach of the PROSPECT-II Detector Upgrade

B13.00003: Joint Isotope-Dependent Analysis of the Daya Bay and PROSPECT Reactor Antineutrino Spectra

B13.00004: A Joint Analysis of the PROSPECT and STEREO ^{235}U Antineutrino Spectra

E18.00004: Optical Photon Tracking in GEANT-4 for the PROSPECT-II Detector Upgrade

E18.00005: Calibration system for PROSPECT-II

E18.00006: Machine Learning Analysis of PROSPECT Data

Y18.00006: PROSPECT's latest results

X10.00007: Cosmic ray boosted dark matter at PROSPECT—theory and propagation

X10.00008: Cosmic ray Boosted Dark Matter at PROSPECT – Experimental Analysis