Detector characterization and calibration for PROSPECT

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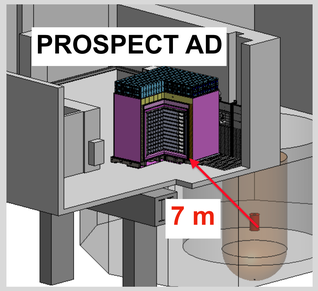
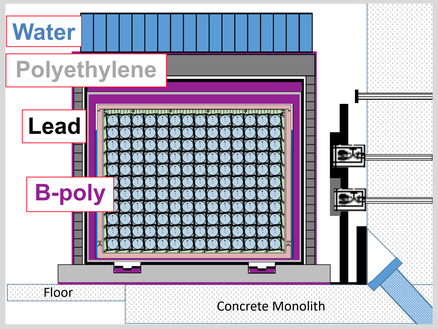
Neutrino 2020

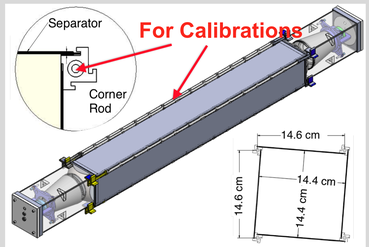
Compact segmented detector design provides uniform energy response

Antineutrino detector:

- Optically segmented into 154 cells.
- Li-6 doped liquid scintillator.
- Mass: ~4 ton.
- Overburden: 1 m.w.e.
- Each cell: 117.5 x 14.6 x 14.6 cm^3.



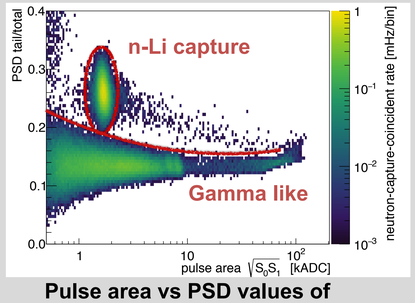




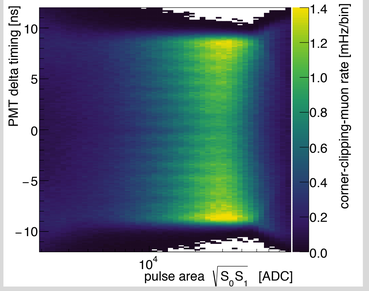
- **The segmented geometry of brings down the dimension of reconstruction from 3D to 1D, along each segment.**
- **The energy loss and signal collecting thresholds in all 154 segments brought unique challenge in understanding the detector response.**

Background sources provide continuous segment-to-segment response tracking

- **Passive calibration throughout the data taking period:**
  - Energy scale is passively calibrated based on presumed mean energy of the n-Li capture events induced by cosmogenic neutrons.
  - The Δt reconstructed position is calibrated with segment-corner-clipping muon tracks blocked by the tabs of the supporting rods.



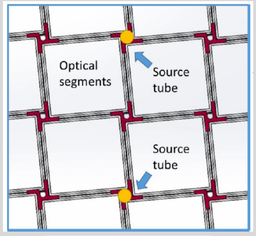
Pulse area vs PSD values of gamma and neutron like events



"Hobbles" effect caused by muon tracks blocked by the tabs

Energy scale of segmented detector characterized using numerous sources

- **Source calibration: motor driven gamma and neutron sources (absolute and relative E scale calibration, and neutron capture life time).**



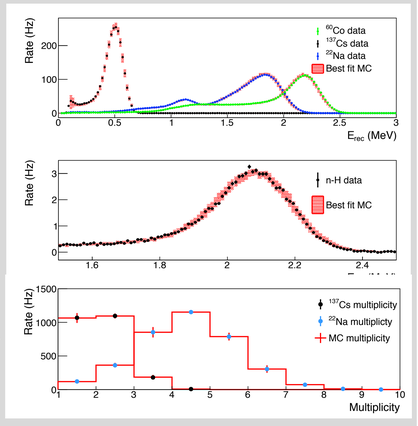
35 source tubes throughout AD

Source	Decay [keV]
^{22}Na	$e^+ \rightarrow$ 511 γ, 1274 γ
^{60}Co	1173 γ, 1332 γ
^{137}Cs	662 γ
^{252}Cf	Spontaneous fission → n
AmBe	Deexcitation 4430 γ

- **Ambient calibration:**
  - cosmogenic ^{12}B (β energy scale calibration)

Many observables from reconstructed events constrain the multi-parameter energy scale fit

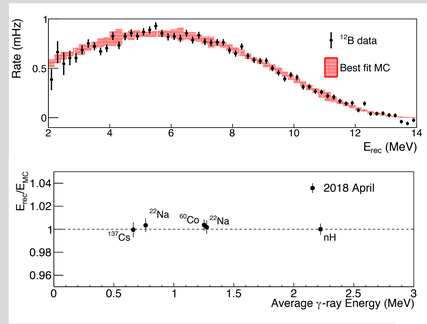
- **Energy scale calibration is vital to ensure correct oscillation sensitivity and spectral measurement of reactor neutrino.**
- **Energy scale calibration:**
  - Birks quenching, Cherenkov radiation and absolute energy scale are studied.
  - Comparing the Geant4 MC and calibration data simultaneously among the calibration gamma and ^{12}B spectra.
  - The gamma segment-multiplicities are also compared between MC and data to find the best fit energy response model.



E spectra and multiplicities of calibrations

Part of this work was performed under the auspices of the US Department of Energy by Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344. LLNL-POST-811577.

Achieve excellent data-MC agreement and energy scale uncertainty in a complex system

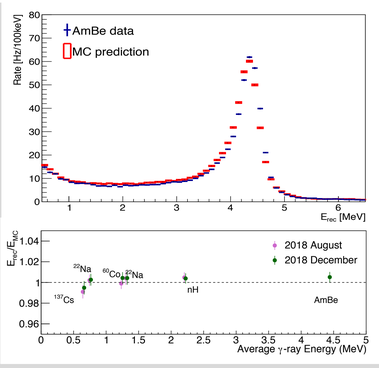


Only the ^{12}B spectrum and a single calibration campaign out of three was used to search for the best-fit detector energy response.

The uncertainty of the energy scale is ~0.5%.

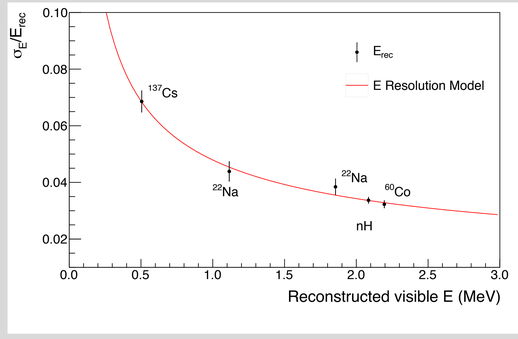
Two other independent calibration campaigns validates the stability of the E scale within the uncertainty.

The validation also shows good high energy gamma agreement by comparing the MC prediction and data with an AmBe source.



Energy resolution is 4.8% @ 1 MeV

- The stability of E resolution is ensured by tracking the photon detection efficiency during data taking.



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