JUNO Calibration with Natural Radioactivity

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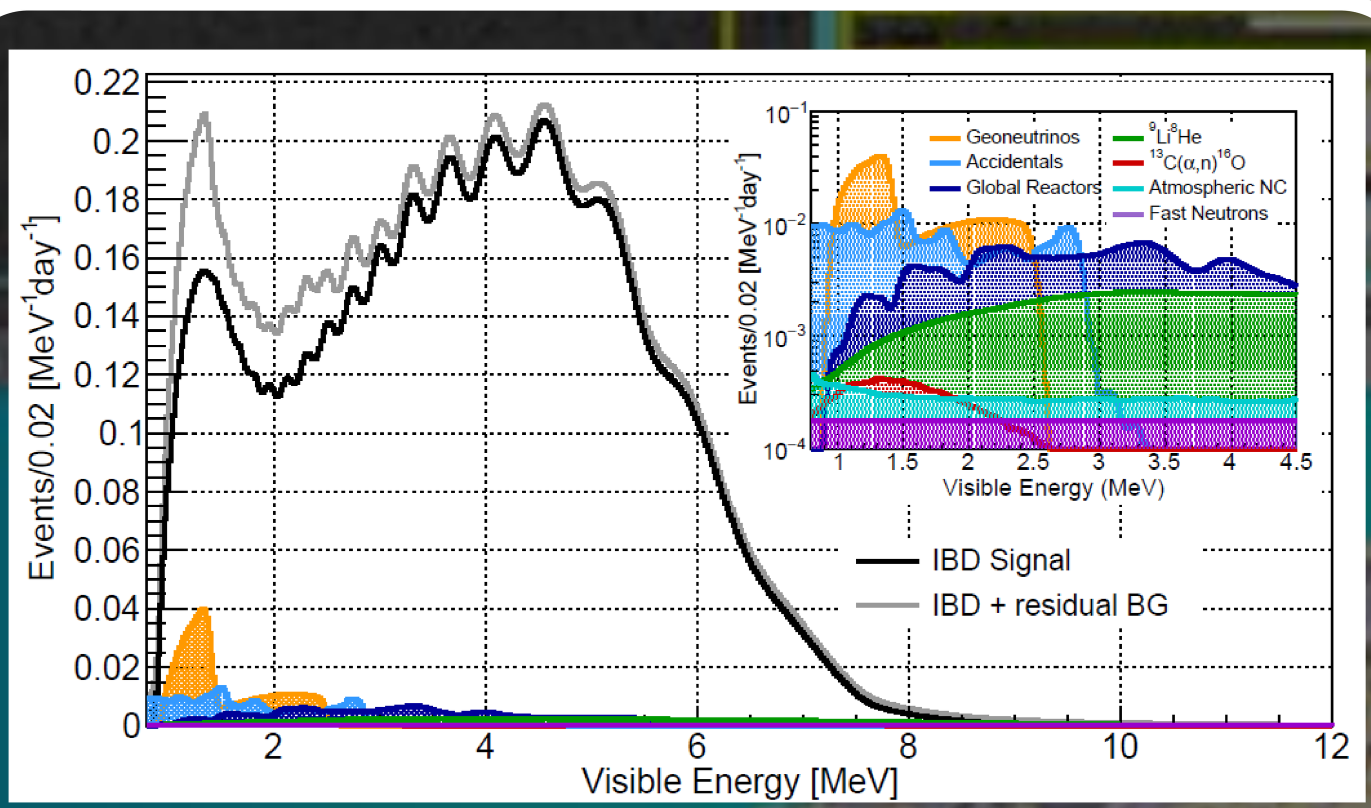
On behalf of the JUNO Collaboration

JUNO's Physics Goals



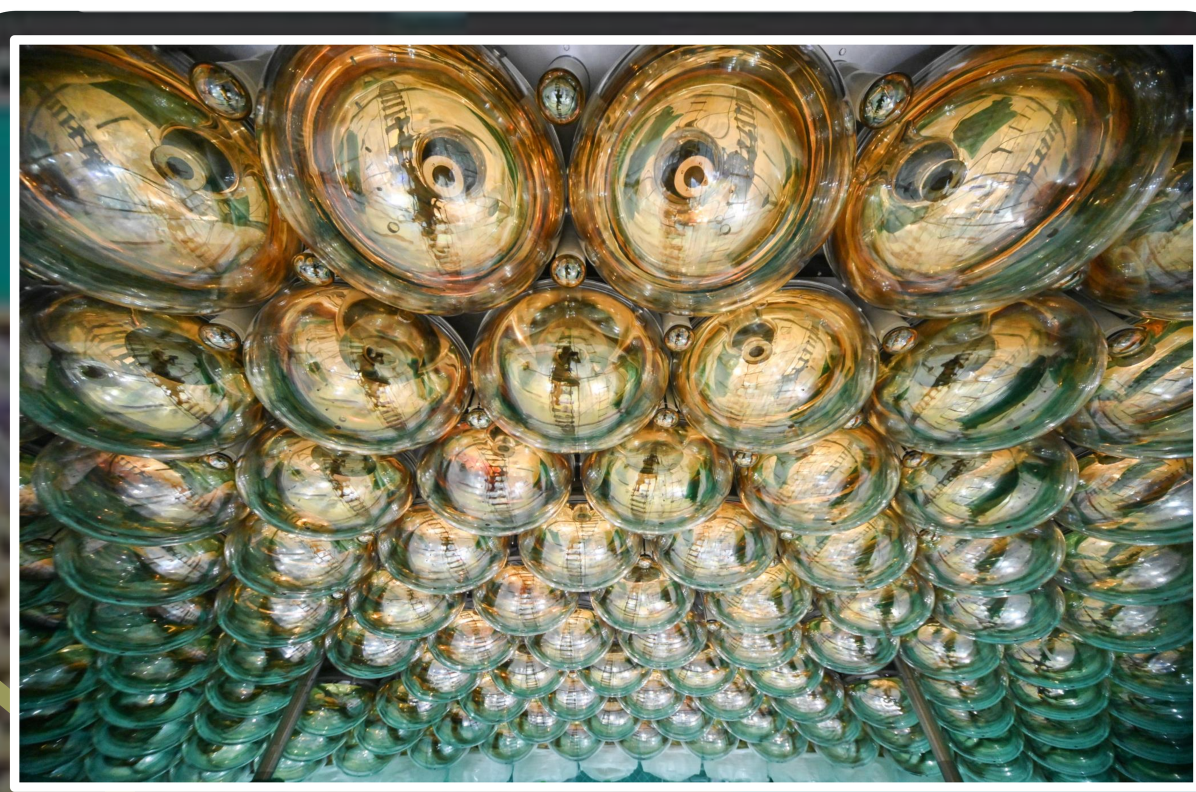
Reconstructed positron energy spectrum from reactor antineutrinos, with background expectations. [1]

Measure the fine structure in the oscillated energy spectrum from medium baseline nuclear reactors

- Separate Normal and Inverted mass ordering
- Precisely measure $\Delta m^2_{21}, \Delta m^2_{31}, \theta_{12}$

Extensive detector calibration is needed in order to achieve this level of precision.

The JUNO Detector



JUNO's installed 20" and 3" photomultiplier tubes

- 20-kiloton liquid scintillator detector
- 17,612 20" & 25,600 3" PMTs
- Highest photocathode coverage (78%) [2]
- Aiming for <3% energy resolution (1MeV)
- Low Energy threshold (~20keV)

Calibration source

Calibration Approaches

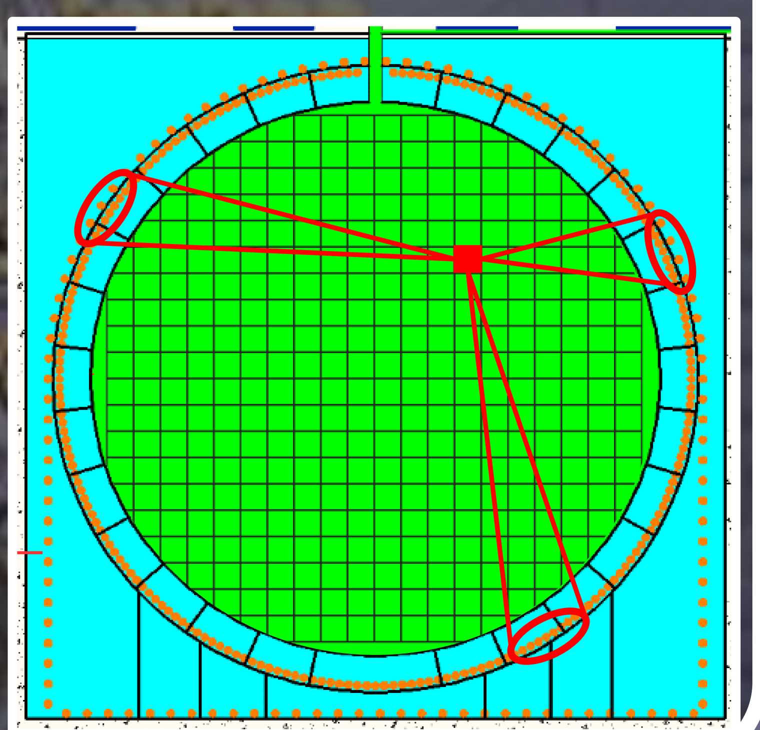
Deployable calibration sources

- High statistics, well-understood energy depositions across variety of energies
- Deployment around detector takes time, needs to be repeated if detector conditions change.

When life gives you lemons?

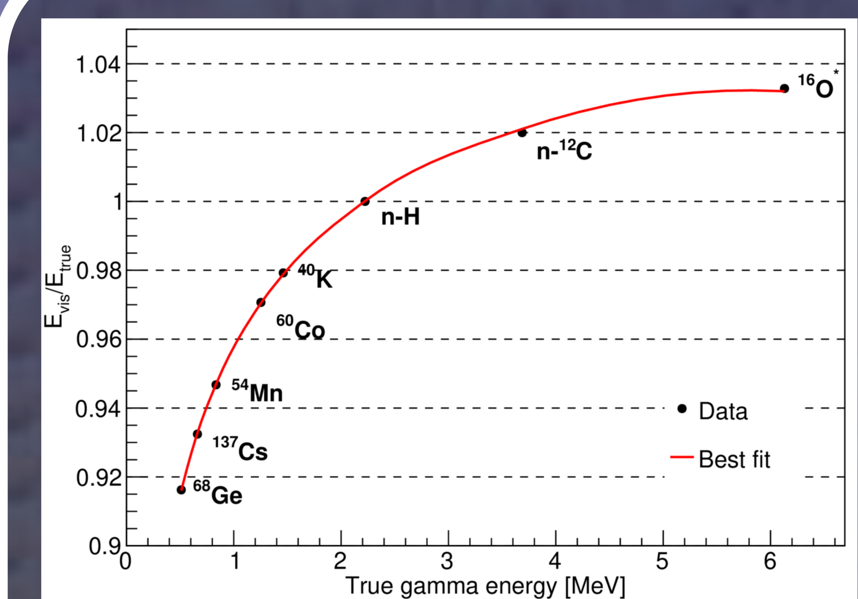
- Naturally occurring radioactivity within the detector are a background – use them for calibration!
- Similarly, cosmic ray muon followers background events will be used for calibration. See poster #285: "Neutron source-based event reconstruction in JUNO"

@ 10^{-15}gU/gLS (minimum IBD impurity level [3][4]): Expect to tag 20,600 pairs per day, with <1% impurities

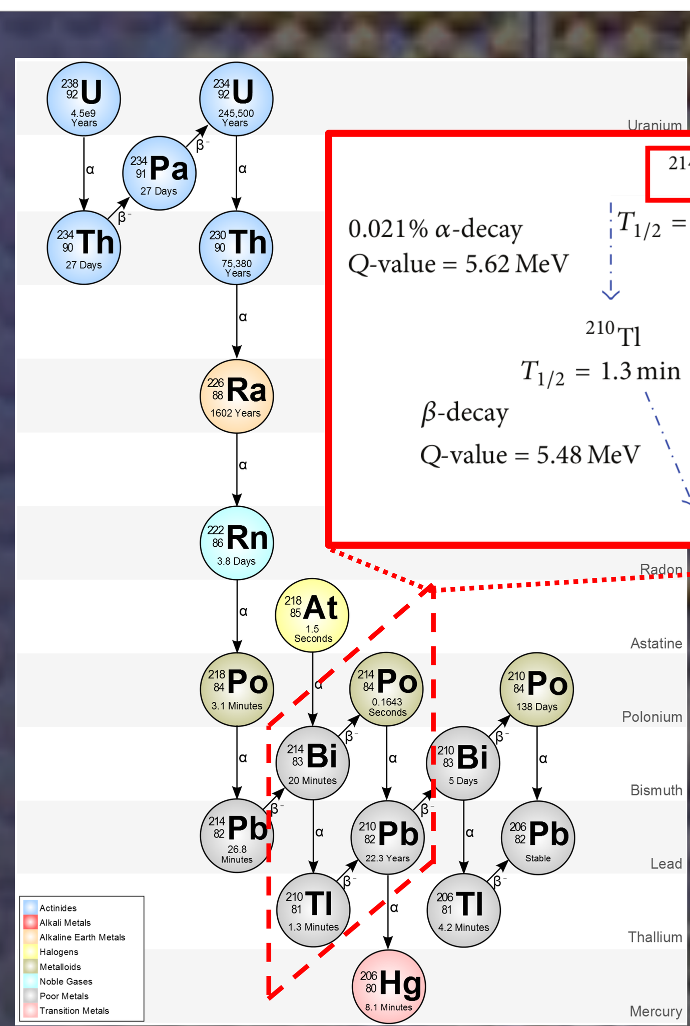


Sketch of the division of the detector into "voxels". The expected PMT charge collection can be calculated for each.

Measurables from Radioactivity



Calibration source energies used to measure non-linearity [5]

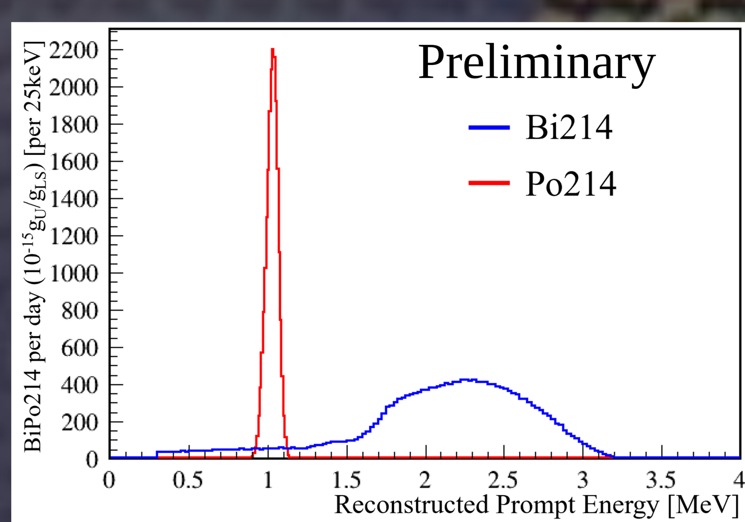


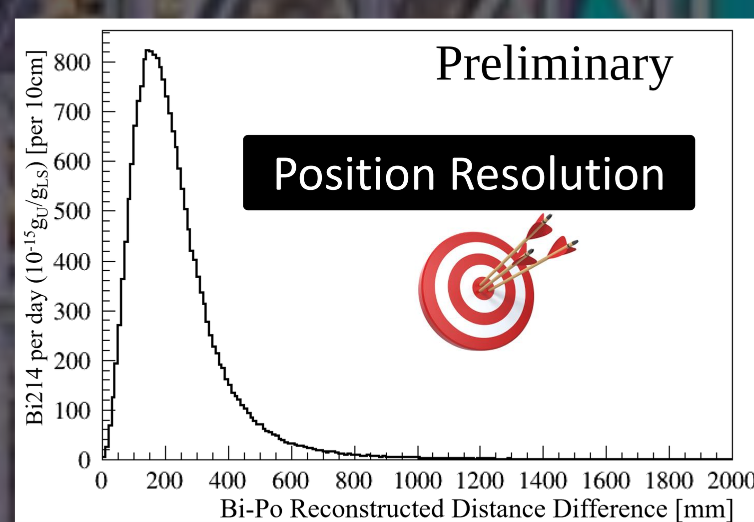
Naturally occurring ^{238}U decay chain, focused on Bi-Po 214 coincident decays [6][7]

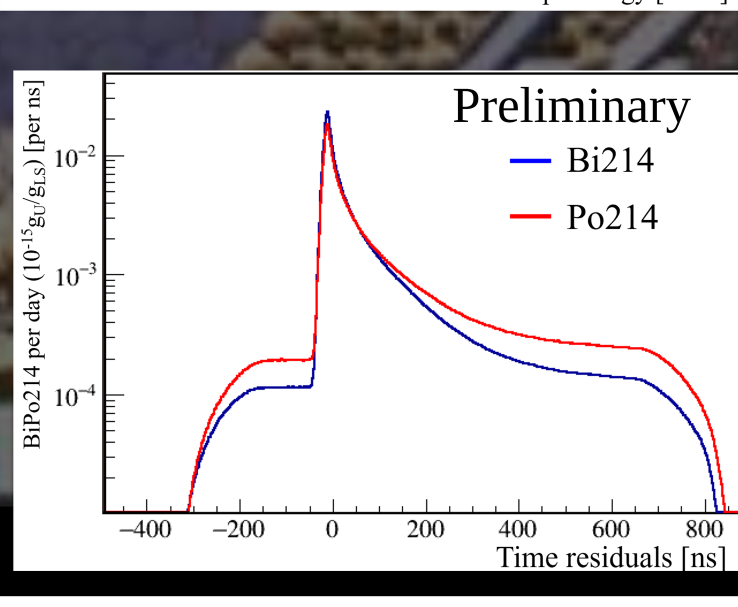
Scintillation Light Yield + Quenching

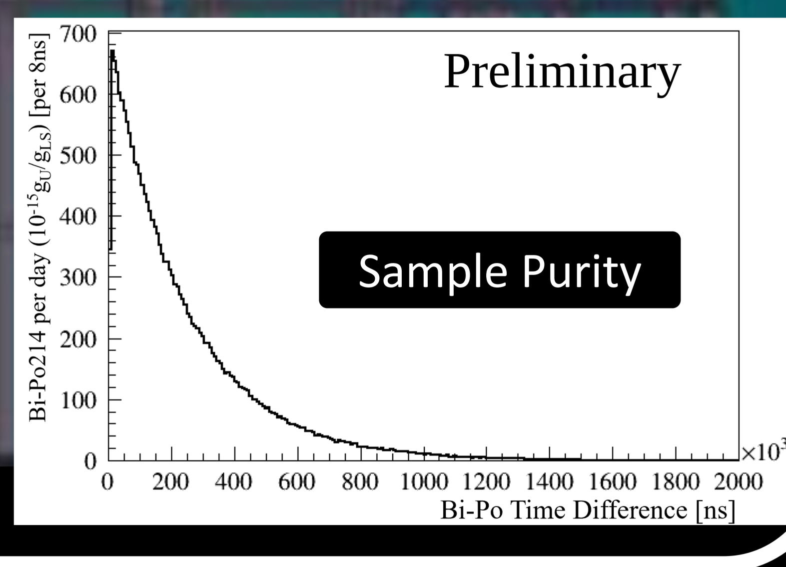
Expected PMT charge

Scintillation Timing – Particle ID









References

[1] The JUNO collaboration. 'Sub-Percent Precision Measurement of Neutrino Oscillation Parameters with JUNO'. Chinese Physics C, vol. 46, no. 12, Dec. 2022

[2] The JUNO Collaboration, "Potential to Identify the Neutrino Mass Ordering with Reactor Antineutrinos in JUNO", arXiv:2405.18008v1

[3] The JUNO collaboration, "The design and sensitivity of JUNO's scintillator radiopurity pre-detector OSIRIS", Eur. Phys. J. C 81 (2021) .

[4] The JUNO collaboration, "JUNO sensitivity to 7Be, pep, and CNO solar neutrinos ", arXiv:2303.03910v1

[5] The JUNO collaboration. 'Calibration strategy of the JUNO experiment'. J. High Energ. Phys. 2021, 4 (2021).

[6] Decay file:decay chain of thorium.svg search. https://commons.wikimedia.org/wiki/File:Decay_Chain_of_Thorium.svg. Accessed: 2024-05-15

[7] S. Andringa et al. Current Status and Future Prospects of the SNO+ Experiment. Advances in High Energy Physics, 2016:1–21, 2016.