

# Calibrating a large hybrid detector

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Physics Opportunities of Large Liquid Scintillator Detectors II  
Mainz 2026/10/14



# Calibration is critical

... especially for rare event searches.

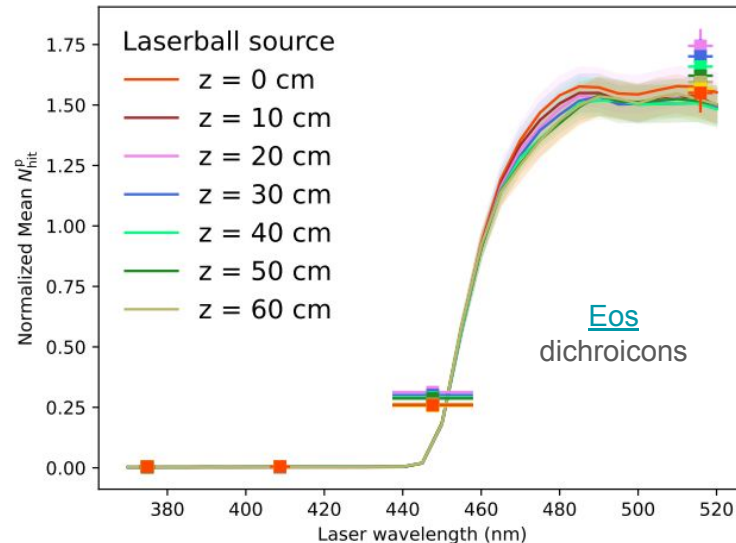
Need thorough evaluation of event reconstruction & classification, including tails of distributions  $\Rightarrow$  use tagged sources.

Excellent calibrations have been performed across many large optical detectors, but a next-gen hybrid detector should require finer evaluation of scintillation and Cherenkov signals, plus their relation.

1. More finely evaluate systematics on position, direction, energy, timing, and topology.
2. Evaluate Cherenkov directionality & topology in scintillator, and C/s relation vs.  $E$ .

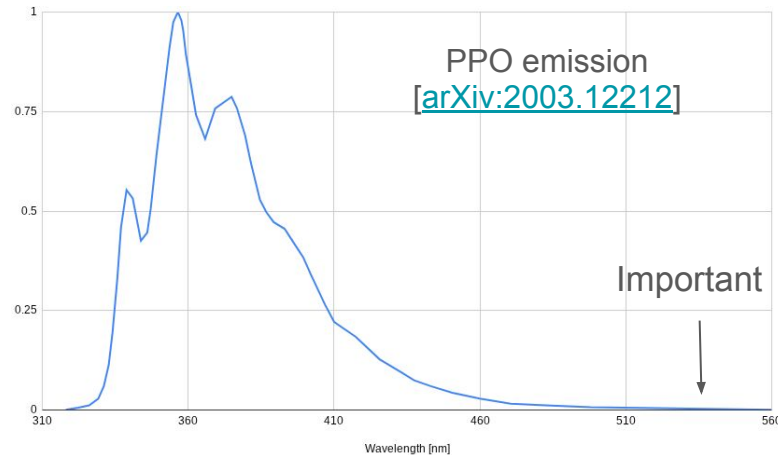
# Calibrations - detector components

- Photosensors plus optical components (e.g., dichroicons).
  - In-situ abilities of current generation sufficient.
  - New technologies need to be demonstrated.



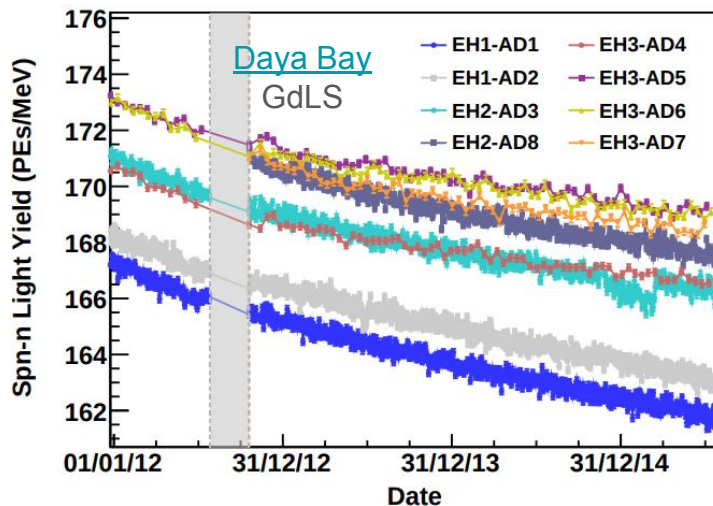
# Calibrations - detector components

- Ex-situ measurements of scintillator emission, timing (+in-situ), re-emission.
- Optical absorption & scattering (ex+in-situ).
  - Measured sufficiently well for existing experiments.
  - Need to measure emission tails well - overlap with Cherenkov.



# Calibrations - detector components

- Loading/doping can increase probability of change in light yield and attenuation.
- Contamination can occur (un)expectedly.
  - ⇒ Monitor and control.
  - Regular calibration + mitigation (cover gas, additives,  $T$ , etc.)

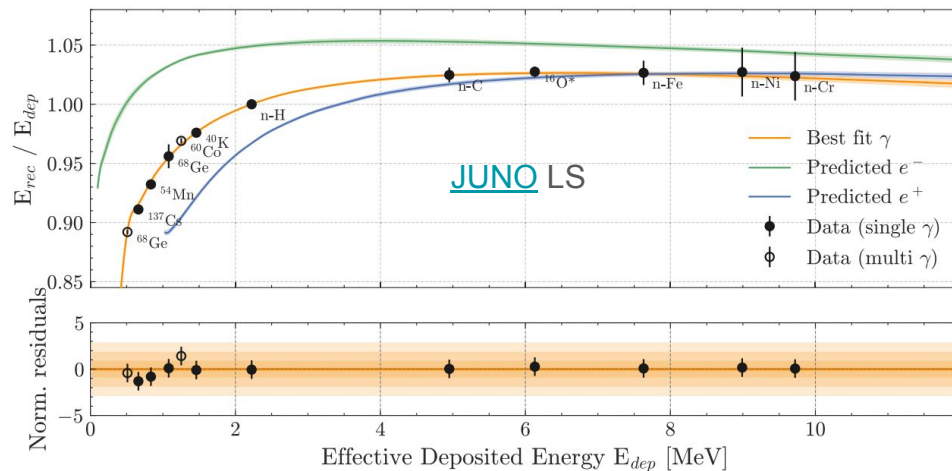


Daya Bay (Gd)LS  
LY and attenuation length  
decreased at 1%/year.

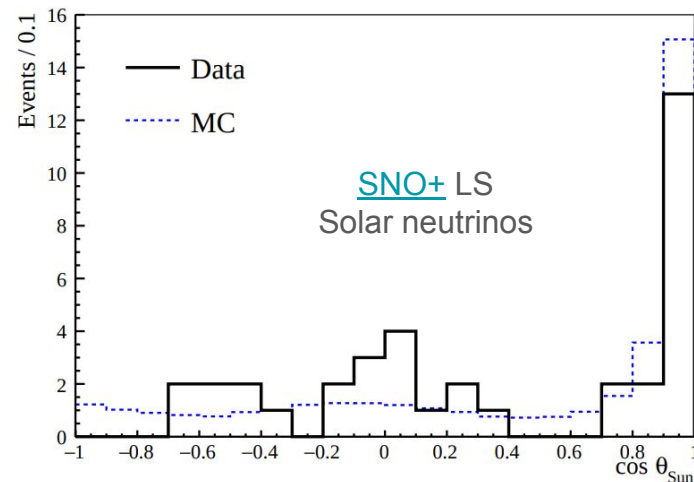
# Calibrations - low energy

1. Finely evaluate reconstruction & classification with deployed sources:  
*position, direction, energy, timing, and topology.*

Energy known to  $<1\%$  across volume.  
Likely sufficient.



Event-by-event directionality  
above a few MeV.



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*position, direction, energy, timing, and topology.*

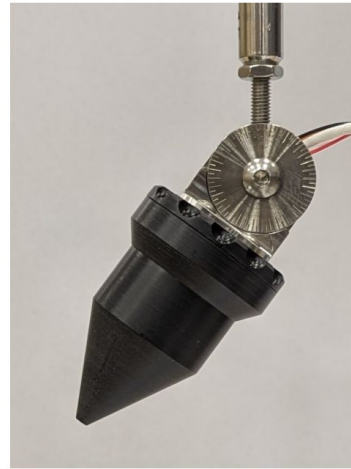
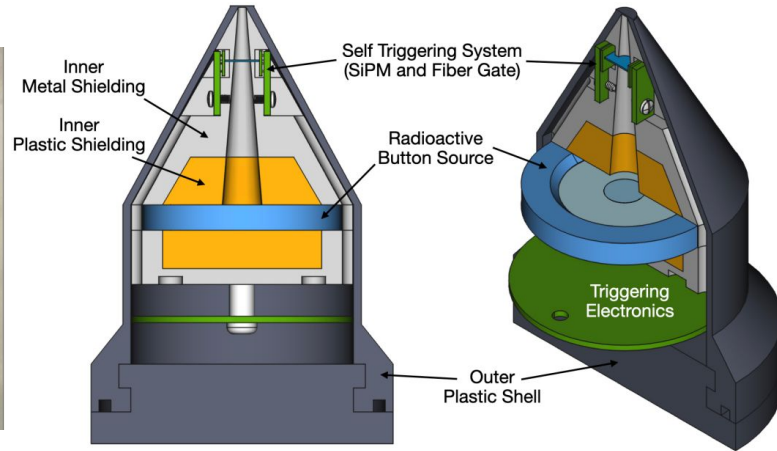
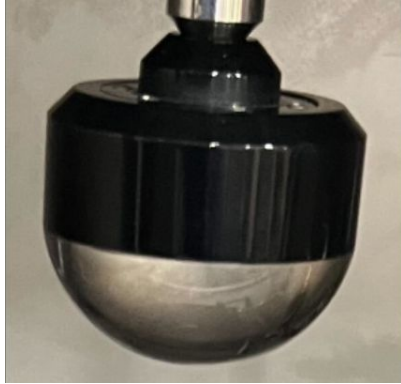
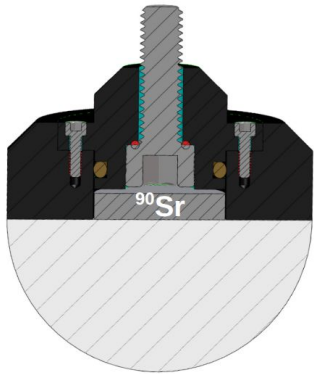
Want finer evaluations for some → use additional sources for

- direction (see next slide),
- multi-site, ... and
- multi-direction ( $^{60}\text{Co}$  is a great candidate source for these last two).

# Calibrations - low energy

2. Evaluate Cherenkov directionality & topology in scintillator, and C/s relation vs.  $E$ .

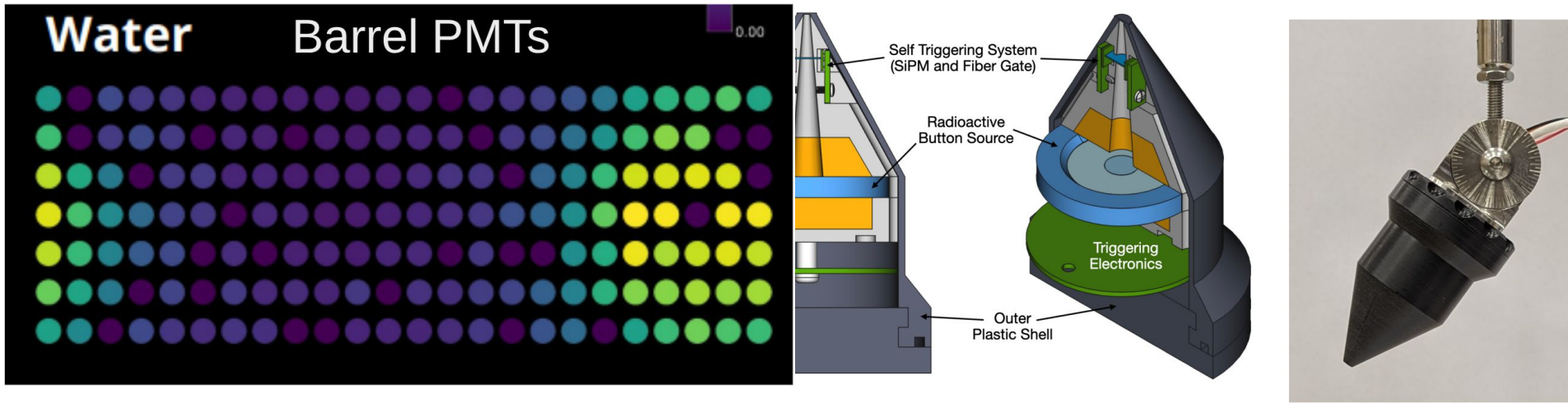
Development and demonstration in Eos (Cherenkov, directional, and  $^{60}\text{Co}$  sources):



# Calibrations - low energy

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# Calibrations - high energy (for a GeV beam)

For high light yield scintillator, can use a dual photosensor system like JUNO.

- Muons - Cherenkov ring studies, fixed energy-loss benchmark.
- Fast neutrons - proton scintillator time profile,  $n$  capture  $\gamma$ 's.
- Michel electrons - 20 kt @ SNOLAB gives 1.0-1.5k Michels/yr - other decay products are likely too few.
- T2K used atmospheric neutrinos to constrain detector performance at relevant energy range and event topologies (requires large dataset).

# Risks

Maybe the only significant risk is contamination introduced by deploying sources.

# Future tests

Deploying novel sources in SuperK-Gd, JUNO, and Hyper-K would demonstrate the source technologies at a larger scale.

At the end of an experiment (or detector phase), like SNO+ or JUNO, consider dissolving a very high concentration of short-lived isotopes into the scintillator to quantify traces of longer-lived isotopes or any other contaminants.

- This could provide additional low energies and particle types across the full volume.

# Summary

Calibration technology is critical for rare events searches and well in hand for Cherenkov and scintillation detectors.

For a next-gen hybrid detector, finer evaluations and novel source ideas are important.

- These are being developed & demonstrated in current projects, with room for more.
- Could deploy novel sources in current large-scale experiments.

Contamination risks from deployment are low, but end-of-experiment calibration campaigns and isotope dissolution could be tested by current generation experiments like SNO+ and KamLAND2-Zen, or JUNO.