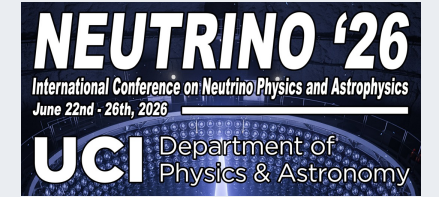




Energy Reconstruction in JUNO

Guihong Huang¹ · Wenjie Wu² — for the JUNO Collaboration¹Wuyi University, Jiangmen, China · ²Institute of Modern Physics, CAS, Lanzhou, China**20kton**

Liquid-scintillator central detector, 650 m deep

52.5km

Reactor baseline for the NMO measurement

1785PE/MeVLight yield at center (2.223 MeV n-H γ)**3.5%**Resolution, central ⁶⁸Ge (0.511 MeV $\gamma\gamma$)**±1%**

Energy uniformity within R < 17.2 m

1 Motivation

JUNO is a **20-kton liquid-scintillator** detector ~650 m underground; physics data taking began **26 Aug 2025**.

It resolves the **NMO** from the reactor- $\bar{\nu}$ spectrum at a **52.5 km** baseline.

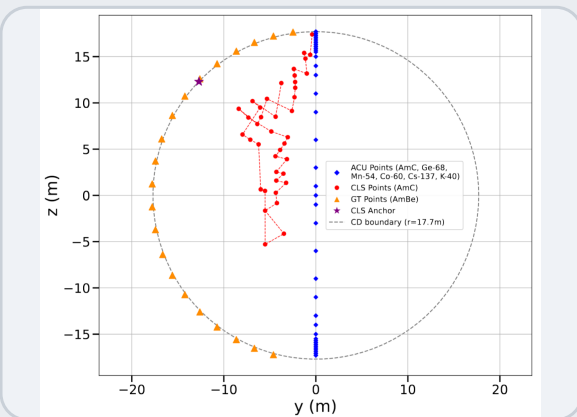
Resolving the fine spectral structure needs **good resolution, a stable energy scale and low non-uniformity**.

2 Calibration

Energy scale anchored by **nH capture γ at 2.223 MeV**.

Inputs: deployed ⁶⁸Ge γ & AmC neutron sources, and other sources.

Deployed by **ACU · CLS · GT** across the central detector.



Coverage. Sources spanning the volume to r = 17.7 m.

3 OMILREC

Data-driven **maximum-likelihood** fit of vertex \mathbf{r} and visible energy E_{vis} , jointly, from large-PMT Q & T.

Combined charge + time likelihood

$$\mathcal{L} = \prod_{j \in \mathcal{U}} e^{-\mu_j} \prod_{i \in \mathcal{F}} \left(\sum_{k \geq 1} P_Q(q_i | k) P(k | \mu_i) \right) \prod_{i \in \mathcal{T}} P_T(t_{i,r} | \mathbf{r}, d_i, \mu_i)$$

Expected light at PMT i

$$\mu_i(\mathbf{r}, E_{\text{vis}}) = E_{\text{vis}} \hat{\mu}_i^L(\mathbf{r}) c_i + \mu_i^D$$

Charge fixes the energy scale.

Timing uses the first-photon residual time $\mathbf{t}_{i,r} = \mathbf{t}_i - \mathbf{t}_0 - \text{TOF}_i(\mathbf{r})$ — the primary vertex handle.

Dynode & MCP PMTs modeled **separately**; staged fit **QMLE → TMLE → QTMLE**.

4 VTREP

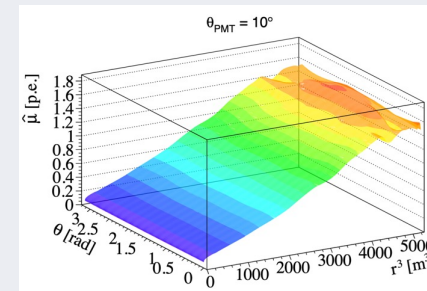
Independent reconstruction — vertex = where the **TOF-corrected hit-time** distribution is sharpest (barycenter seed, late hits down-weighted).

Energy from a charge likelihood over fired + unfired PMTs, with refraction at the acrylic boundary; response built mainly from uniform ²¹⁴Po.

OMILREC response PDFs

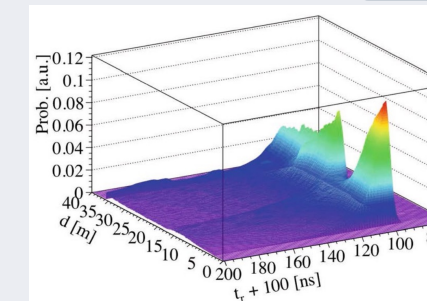
Built data-driven from ACU ⁶⁸Ge and uniform ²¹⁴Po — minimal optical-model dependence.

nPEMap · $\hat{\mu}^L(\mathbf{r})$ illustrative



Expected charge map. $\langle \text{p.e.} \rangle$ per PMT vs viewing angle — near-uniform at center, forward-peaked near the boundary.

Residual-time PDF · P_T illustrative

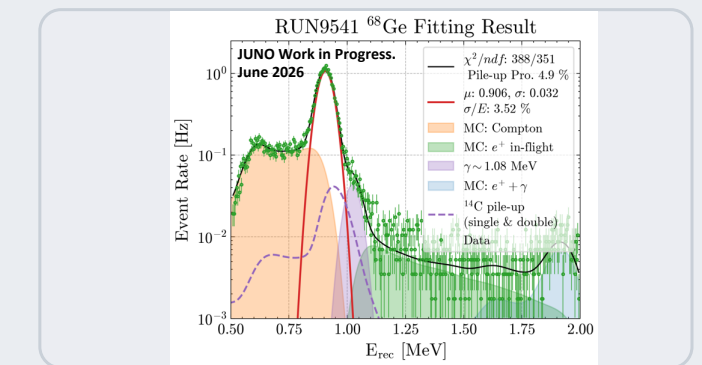


Timing PDF. Sharp leading edge + scattering / re-emission tail; the MCP transit-time spread is broader than the dynode.

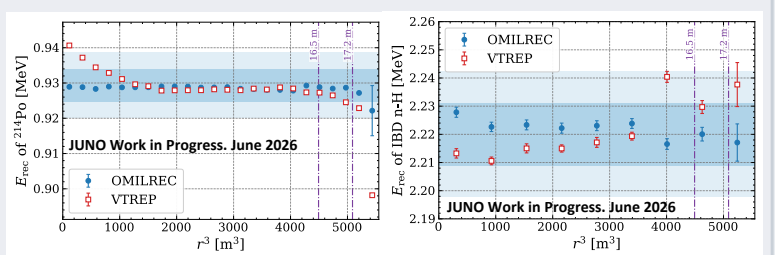
Cross-checks

Direct OMILREC ↔ VTREP comparison.

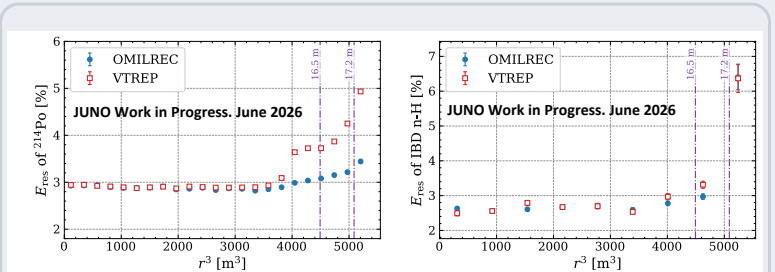
5 Results



Resolution. Two 0.511 MeV $\gamma \rightarrow \sigma/E \approx 3.5\%$.



Uniformity. Distributed ²¹⁴Po and IBD delayed IBD-nH: energy uniform to **±1%** within R < 17.2 m for both methods.



Resolution stability. Stable in the central region, degrading toward the boundary.

SUMMARY

OMILREC and VTREP **agree** across the fiducial volume — the central-detector response is stable. These results underpin precision reactor- $\bar{\nu}$ spectroscopy and JUNO's future **neutrino mass-ordering** measurement.