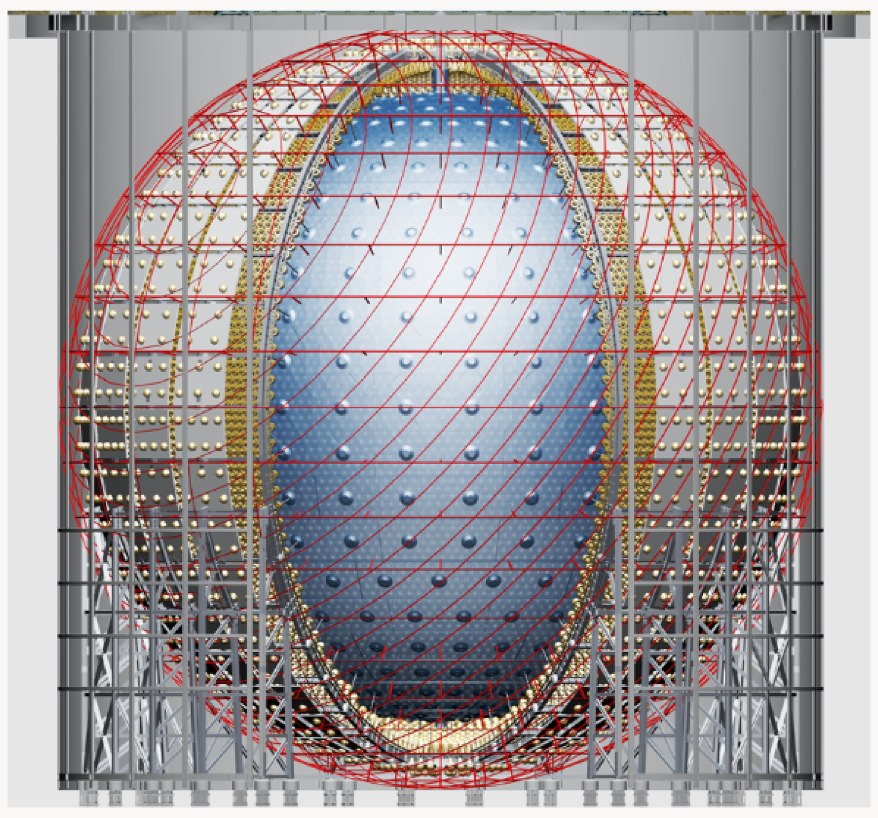
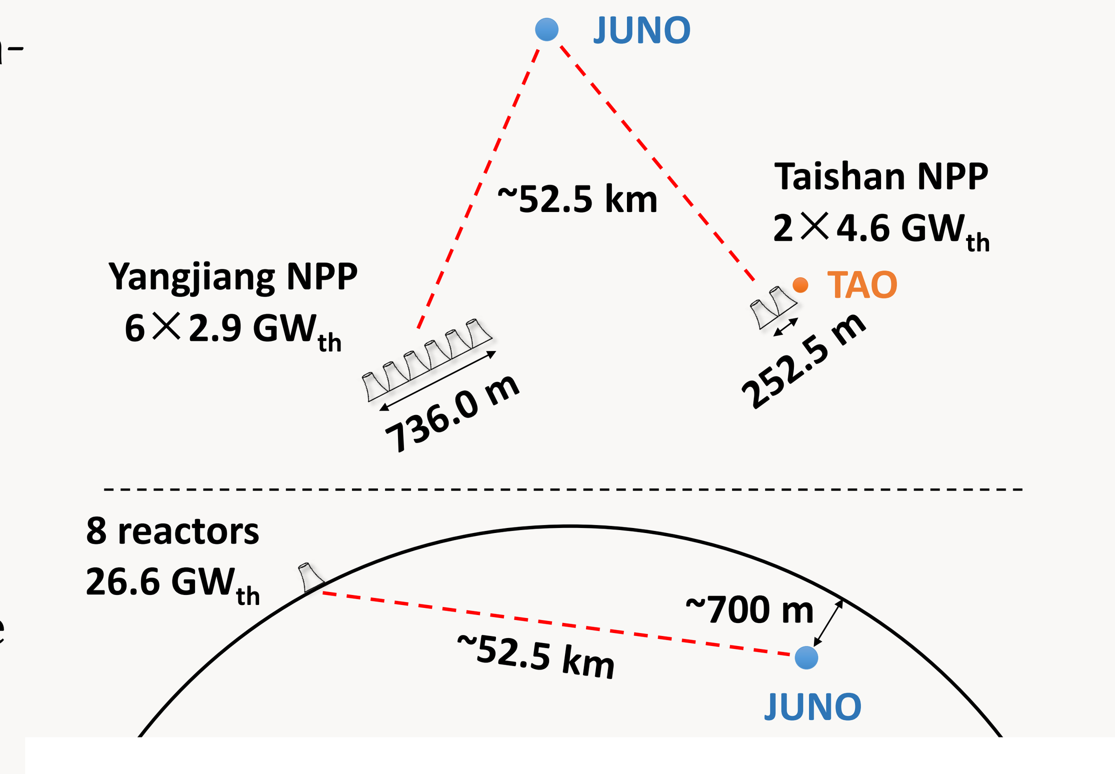
JUNO Neutrino Mass Ordering Sensitivity with Subdetectors

Jiangmen Underground Neutrino Observatory (JUNO)



JUNO is multi-purpose liquid scintillator detector under construction in China [1]:

- Target mass of 20 kt of Liquid Scintillator (LS)
- Diameter of 35 m
- Energy resolution $<3\%/\sqrt{E(MeV)}$
- Energy scale uncertainty $<1\%$
- Baseline optimized for Neutrino Mass Ordering (NMO) determination
- 3σ sensitivity to NMO with ~6 yrs. × 26.6 GW_{th} exposure using reactor $\bar{\nu}_e$



Motivation

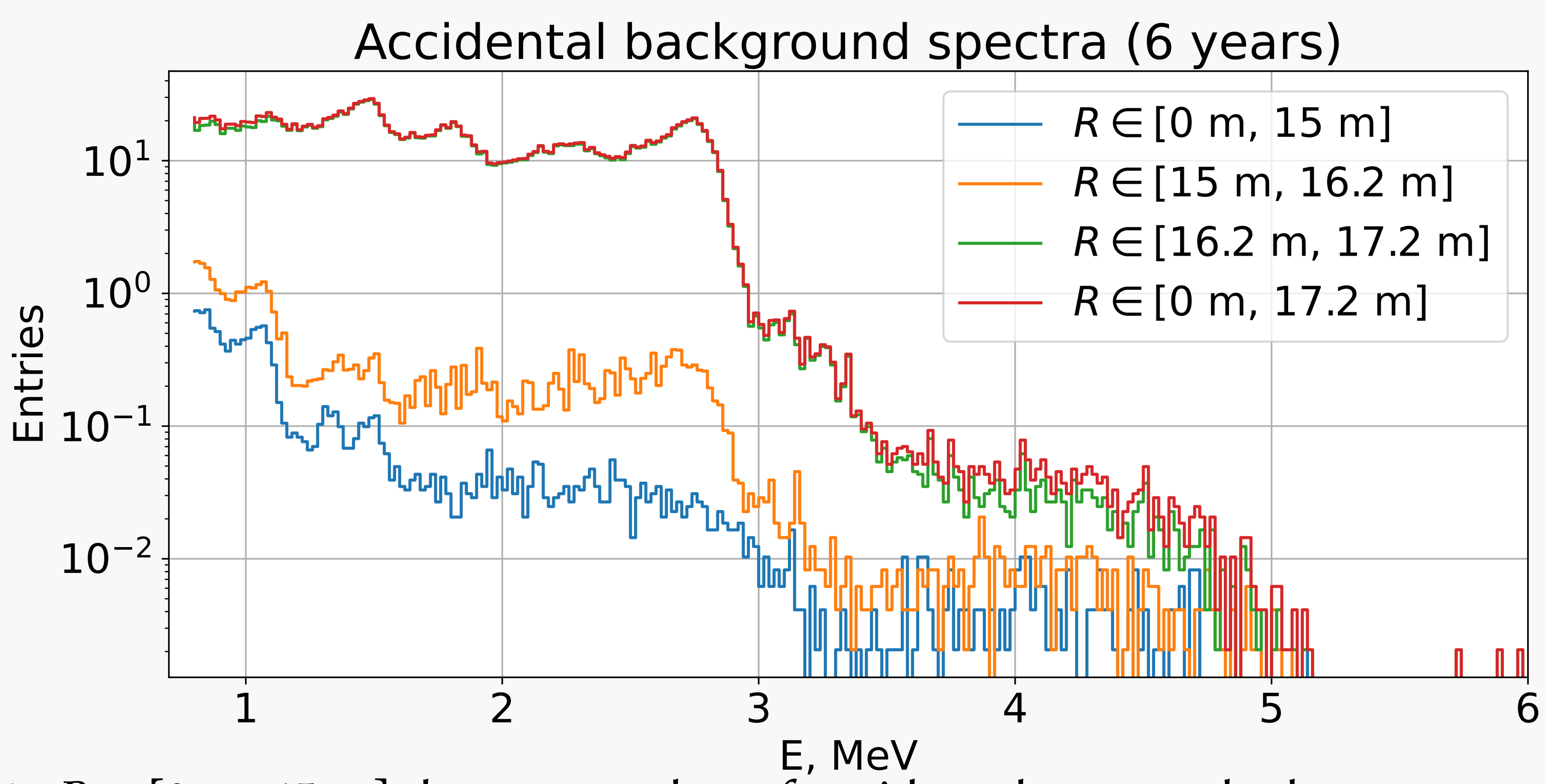
1. Sensitivity to NMO depends on the Fiducial Volume (FV) cut
2. Bigger cut leads to more statistics, but worse energy resolution and higher accidental background
3. Instead of choosing a specific FV, the entire detector volume may be divided into a few virtual subdetectors

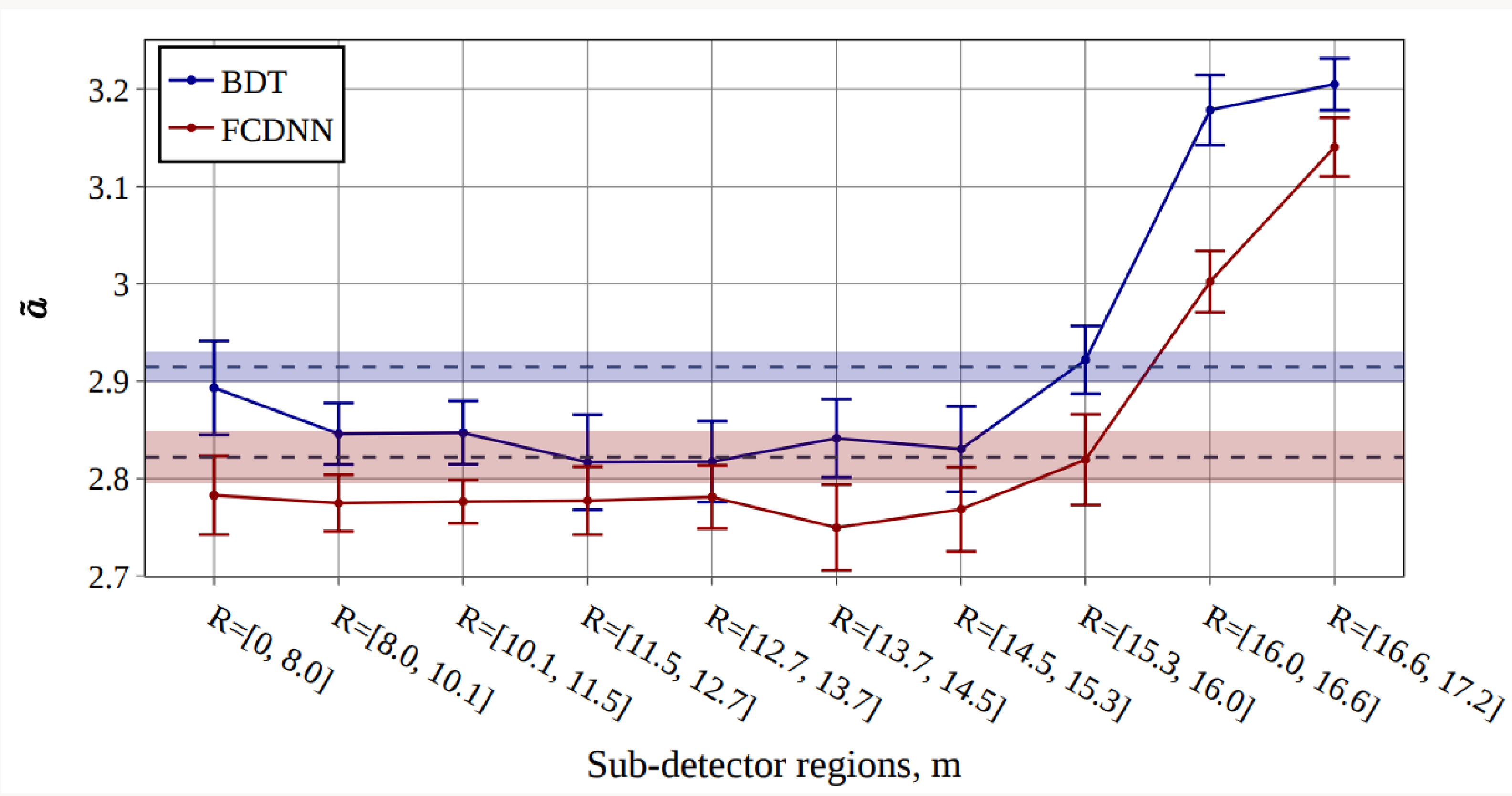
Requirements

To perform subdetector analysis one needs:

- ✔ Fractions of Inverse Beta Decay (IBD) and backgrounds events in every subdetector and their correlations
- ⌛ Energy scale for the subdetectors. By now all subdetectors use the same energy resolution and liquid scintillator non-linearity curve (LSNL)

Subdetector edges choice





1. $R \in [0\text{ m}, 15\text{ m}]$: lowest number of accidental events, the best energy resolution, 66.3% of FV [2]
2. $R \in [15\text{ m}, 16.2\text{ m}]$: low number of accidental events, slightly worse energy resolution, 17.2% of FV
3. $R \in [16.2\text{ m}, 17.2\text{ m}]$: biggest number of accidental events, worst energy resolution, 16.5% of FV

Fractions of events

	Event type	Rate [/day]
Uniform events	Reactor $\bar{\nu}_e$	47
	Geo-ν's	1.2
	Fast-n	0.1
	$^{9}Li/^{8}He$	0.8
	$^{13}C(\alpha, n)^{16}O$	0.05
Non-Uniform	Accidentals	0.8

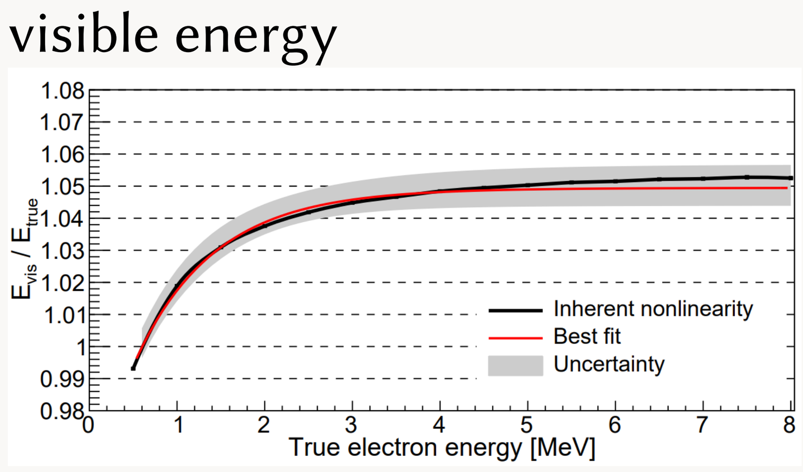
- JUNO spatial resolution of about 15 cm leads to interchange between subdetector events (i.e. correlations between subdetectors)
- Two sets of event fractions and their correlations were obtained:
  1. For uniform events
  2. For accidental background
- Uncertainties of fractions are within $10^{-3} - 10^{-4}$

LSNL

LSNL curve shows dependence of the amount of scintillation light on the energy deposited [3]:

$$f_{LSNL} = E_{vis}/E_{dep},$$

where E_{dep} is the e^+ deposited energy, E_{vis} is the expected visible energy

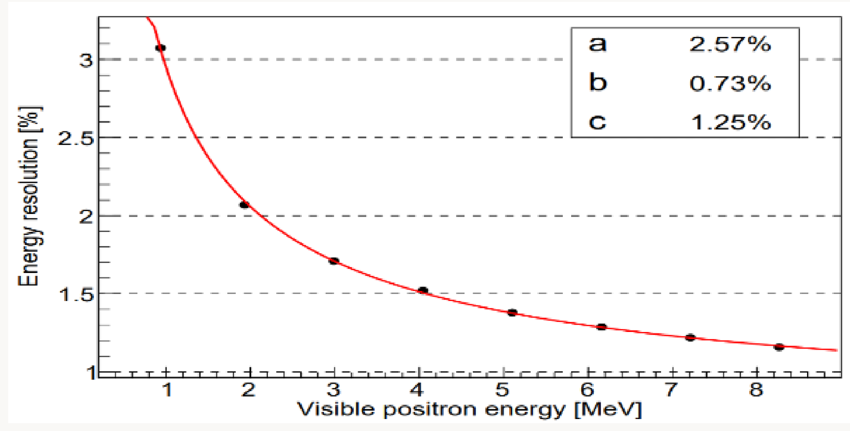


Energy resolution

Relative energy resolution can be parameterized as:

$$\frac{\sigma}{E_{vis}} = \sqrt{(a/\sqrt{E_{vis}})^2 + b^2 + (c/E_{vis})^2},$$

where a – statistical term, b – depends on detector uniformity, and c – represents dark noise



Current results and future plans

Subdetector NMO sensitivity analysis was performed:

- ~ 0.53% sensitivity increase for Normal Ordering case
- ~ 0.60% sensitivity increase for Inverted Ordering case

Next step:

- Estimate both LSNL and energy resolution for every subdetector that may lead to better results

References

[1] Angel Abusleme et al. "JUNO physics and detector". In: *Prog. Part. Nucl. Phys.* 123 (2022), p. 103927. DOI: 10.1016/j.ppnp.2021.103927. arXiv: 2104.02565 [hep-ex].

[2] Arsenii Gavrikov, Yury Malyshkin, and Fedor Ratnikov. "Energy reconstruction for large liquid scintillator detectors with machine learning techniques: aggregated features approach". In: *Eur. Phys. J. C* 82.11 (2022), p. 1021. DOI: 10.1140/epjc/s10052-022-11004-6. arXiv: 2206.09040 [physics.ins-det].

[3] Angel Abusleme et al. "Calibration Strategy of the JUNO Experiment". In: *JHEP* 03 (2021), p. 004. DOI: 10.1007/JHEP03(2021)004. arXiv: 2011.06405 [physics.ins-det].

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