First neutrino oscillation results from JUNO

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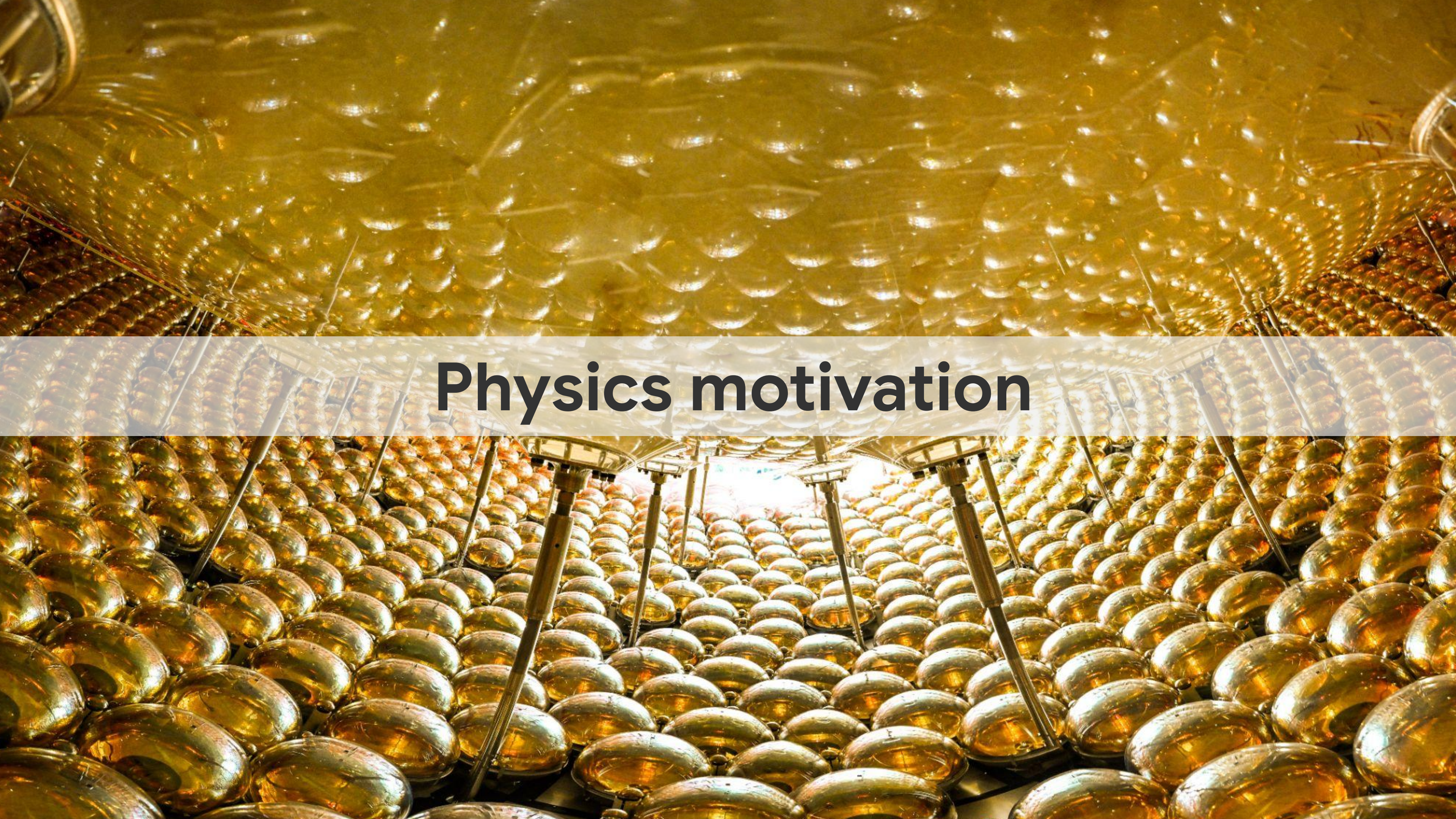
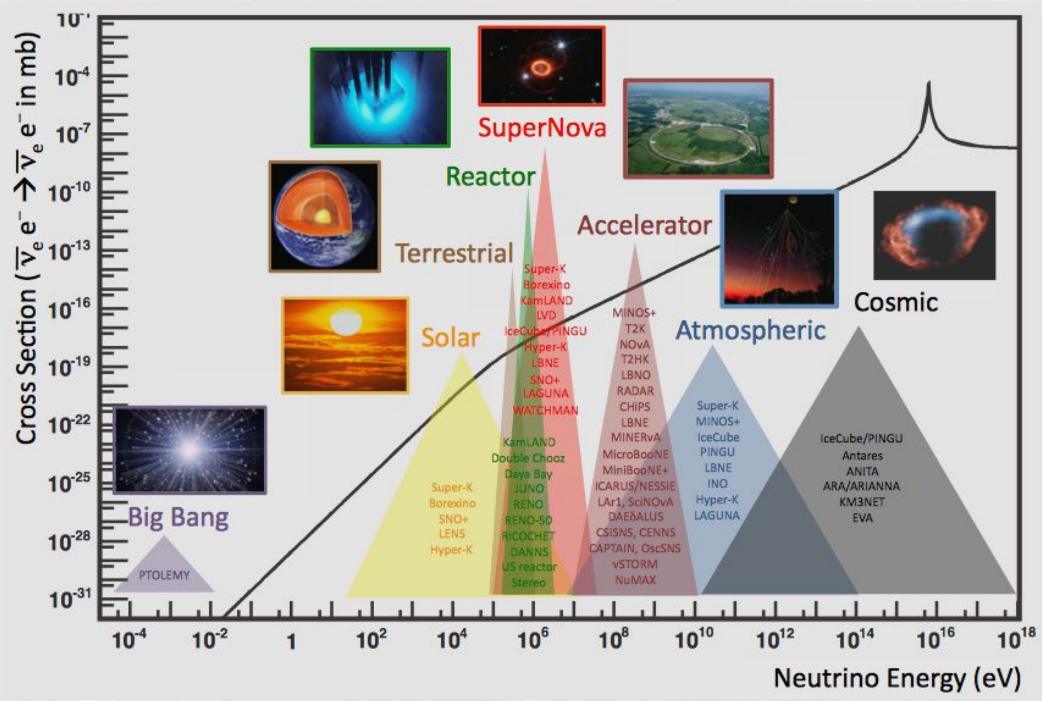
for the JUNO collaboration

BNL colloquium | May 5th, 2026

Physics motivation

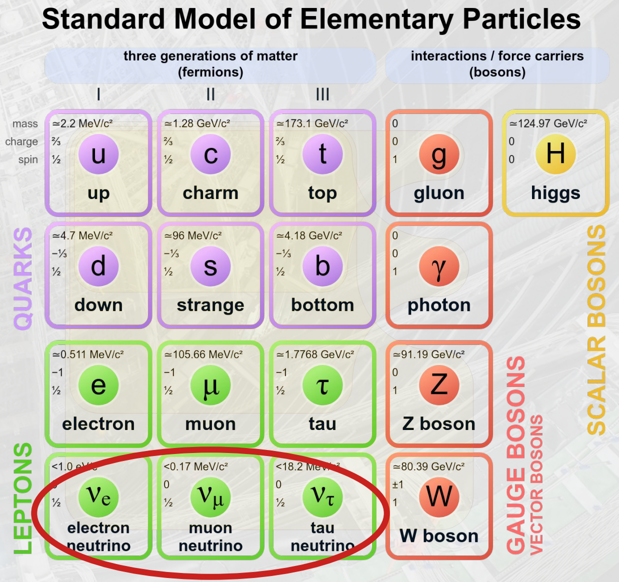


The ubiquitous neutrinos

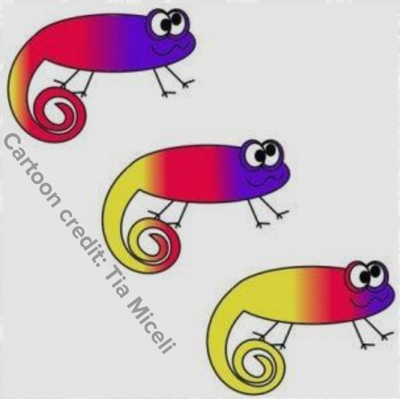


Study neutrinos with sources ⟷ Study sources with neutrinos

- Neutrinos are everywhere! Second most abundant particle in the universe
- Neutrinos are ~~weird~~ cool. Their behavior is beyond the Standard Model



The shape-shifting neutrinos



L

$$|\nu_\alpha\rangle = \sum_i U^*_{\alpha i}|\nu_i\rangle$$

How they interact (ν_e, ν_μ, ν_τ)

PMNS matrix

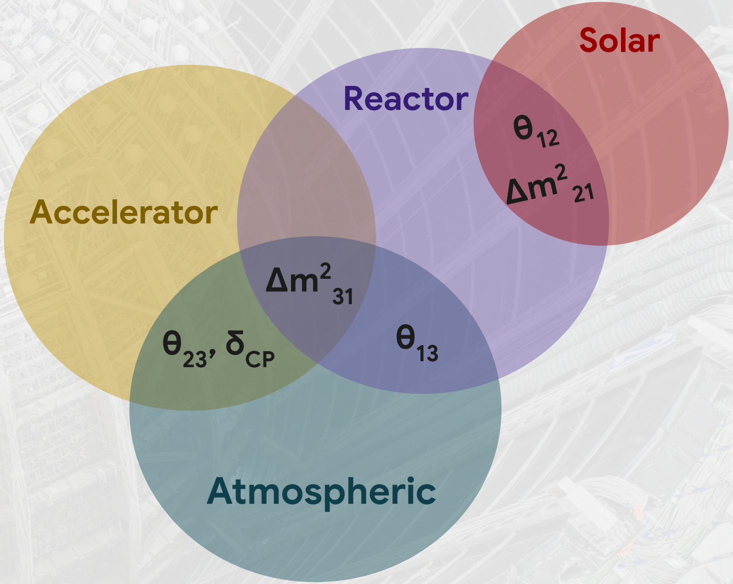
How they propagate (ν_1, ν_2, ν_3)

amplitude

frequency

$$P(\bar{\nu}_e \rightarrow \bar{\nu}_e) \cong 1 - \sin^2 2\theta_{13} \sin^2 \frac{\Delta m^2_{32} L}{4E}$$

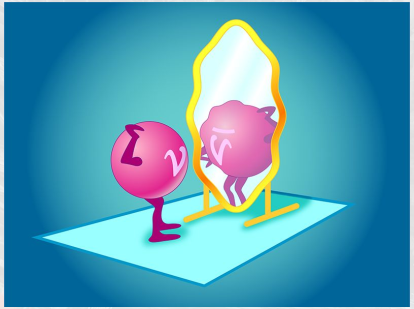
(a rough approximation)

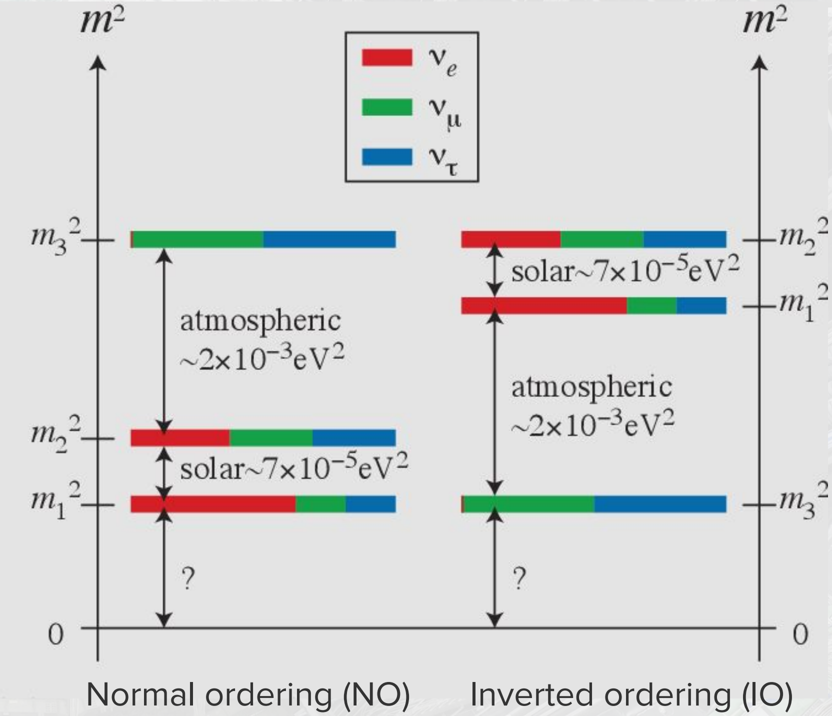


Various experiments studying different sources provide complementary measurements for a full picture of neutrinos

The mysterious neutrinos

- Neutrino mass ordering (NMO): How are the neutrino masses ordered?
- Do neutrinos violate CP symmetry?
- What is the octant of θ_{23}?
- What is the absolute mass of neutrinos?
- What is the origin of their mass?





Why do we need precision measurements?

- Is the 3-neutrino framework consistent?
    - Are there additional neutrino states?
    - Are there non-standard interactions
- Sharpen constraints on neutrino mixing & mass generation models
- Model-independent tests of the 3-neutrino framework (notably PMNS non-unitarity)
- Stringent cross-checks between different experiments

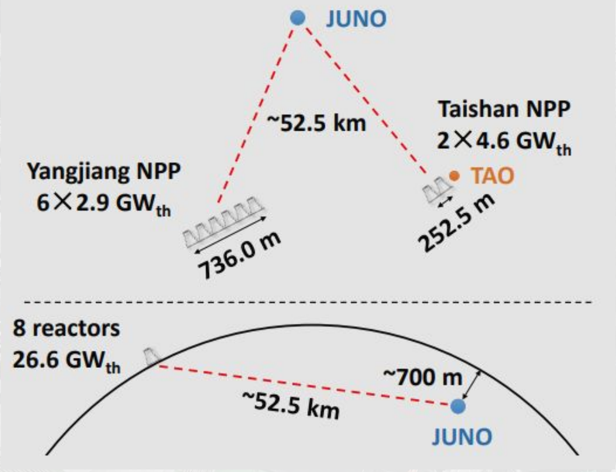
PDG 2025

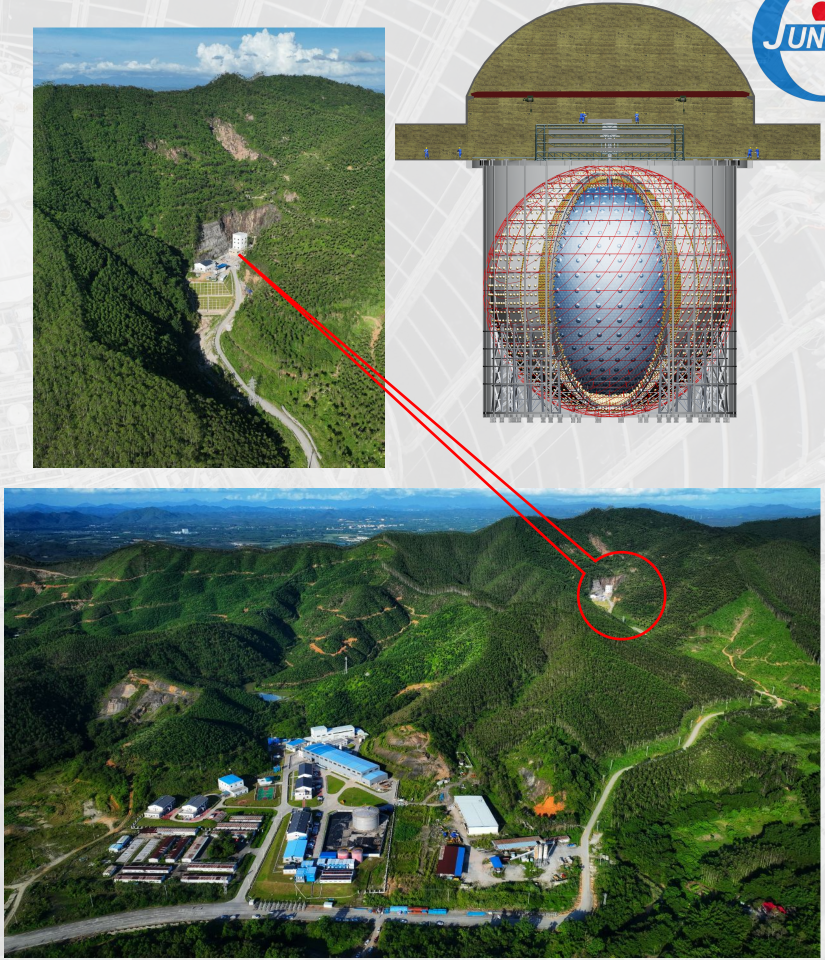
Δm^2_{21}	$(7.50 \pm 0.19) \times 10^{-5}$ eV^2	1.3%
Δm^2_{31}	$(2.527 \pm 0.034) \times 10^{-3}$ eV^2	2.5%
$\sin^2\theta_{12}$	0.307 ± 0.012	3.9%
$\sin^2\theta_{13}$	0.0216 ± 0.0006	2.8%
$\sin^2\theta_{23}$	$0.534^{+0.015}_{-0.019}$	3.2%

JUNO basics

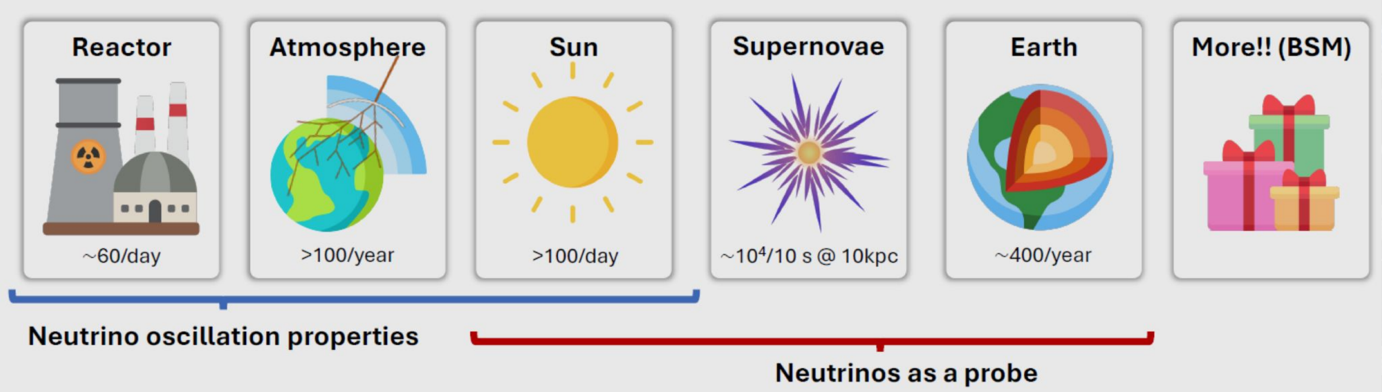
JUNO at a glance

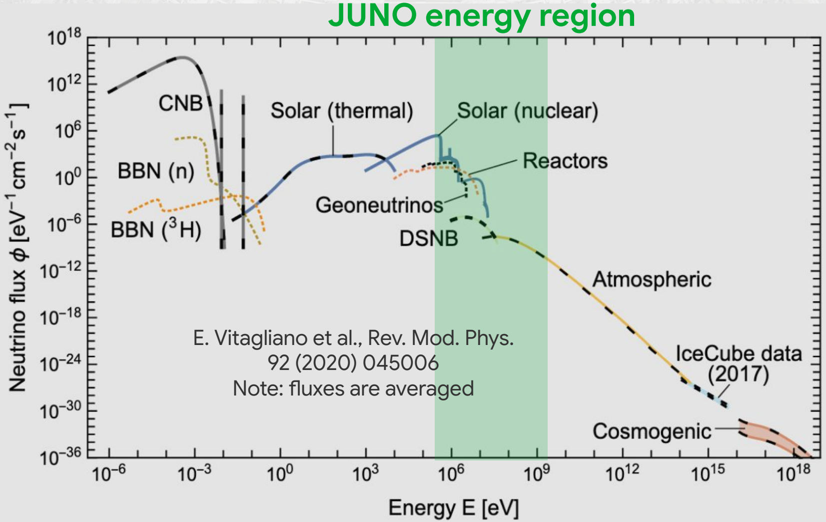
- The Jiangmen Underground Neutrino Observatory (JUNO), a large multipurpose experiment in China
- 35 m diameter sphere with 20 ktons of liquid scintillator (LS) surrounded by water Cherenkov detector
- Unprecedented energy resolution of 3% at 1 MeV





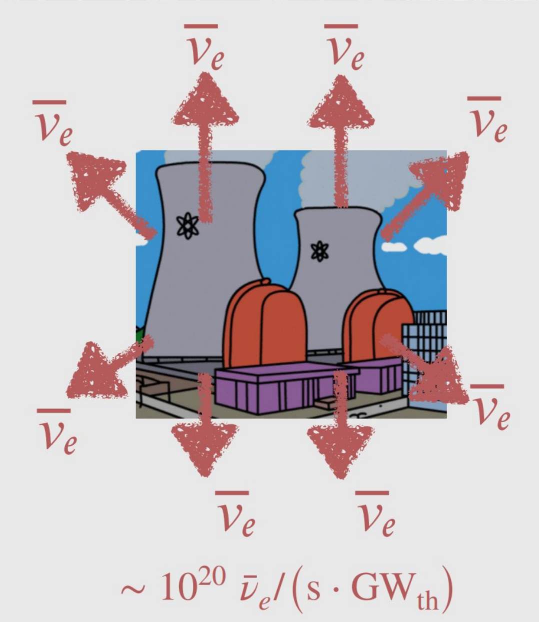
JUNO: a multipurpose observatory

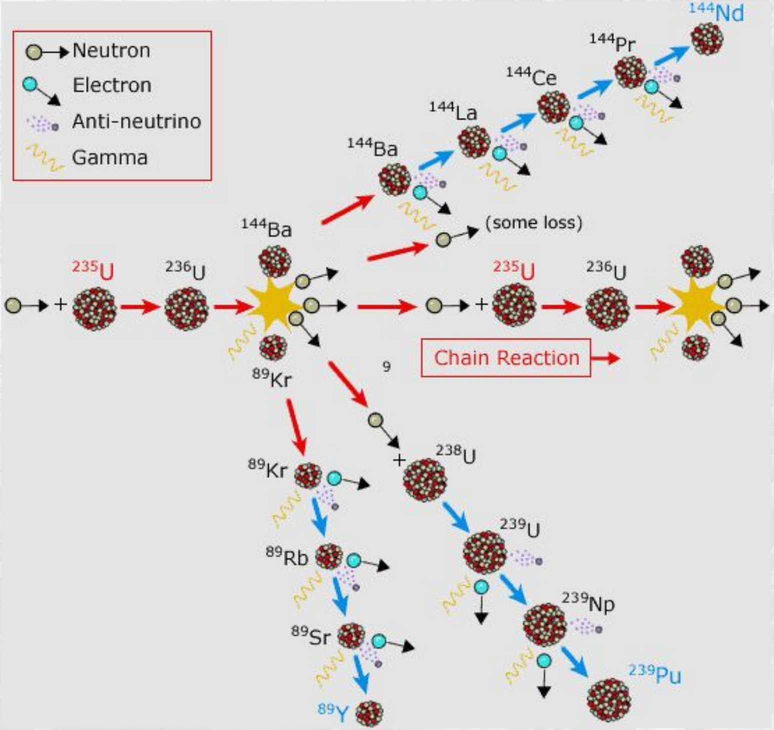




Reactor antineutrinos production

Nuclear reactors are a flavor-pure, widely available, cost-effective, extremely intense and well-understood source of electron antineutrinos

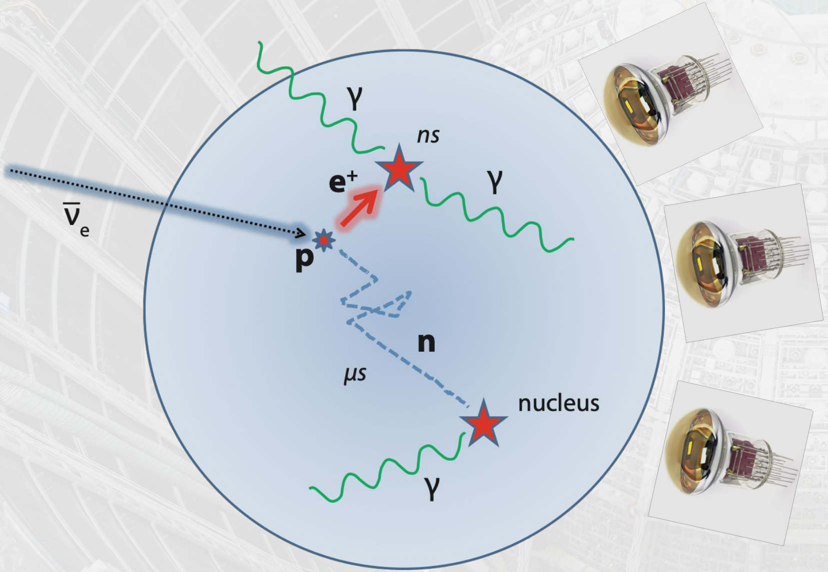




$$n \longrightarrow p + e^- + \bar{\nu}_e$$

Detection of reactor antineutrinos

Detection in LS via **Inverse Beta Decay (IBD)**



$$\bar{\nu}_e + p \rightarrow e^+ + n$$

Prompt: e^+e^- annihilation gammas (2 x 0.511 MeV) + K.E. loss of e^+

Delayed: n-capture on H (2.2 MeV) or other heavier nuclei

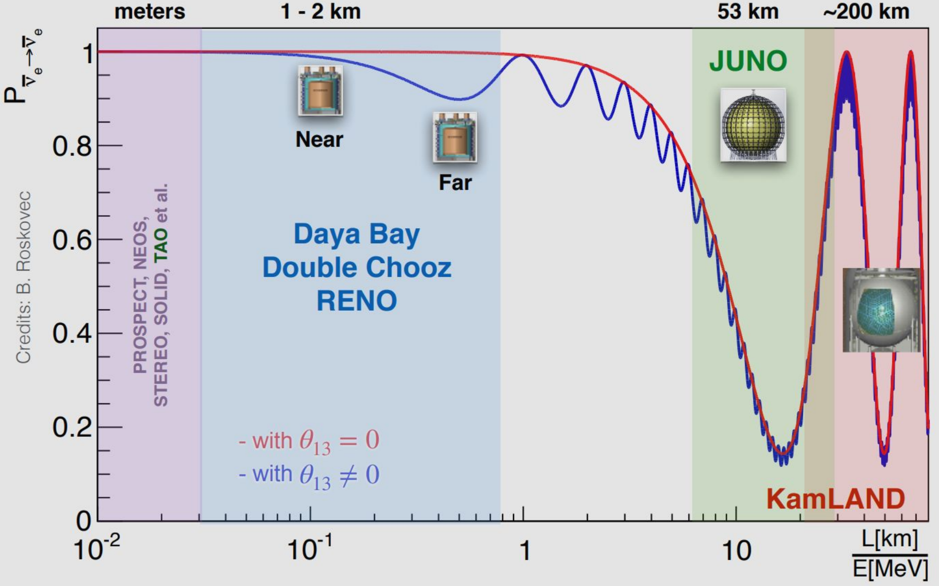
- Coincidence between prompt and delayed signals allows for powerful background rejection
- Energy of positron preserves information about energy of incoming $\bar{\nu}_e$

$$E_{vis}(e^+) \simeq E_\nu - 0.78 \text{ MeV}$$

Reactor antineutrinos oscillation probability at JUNO

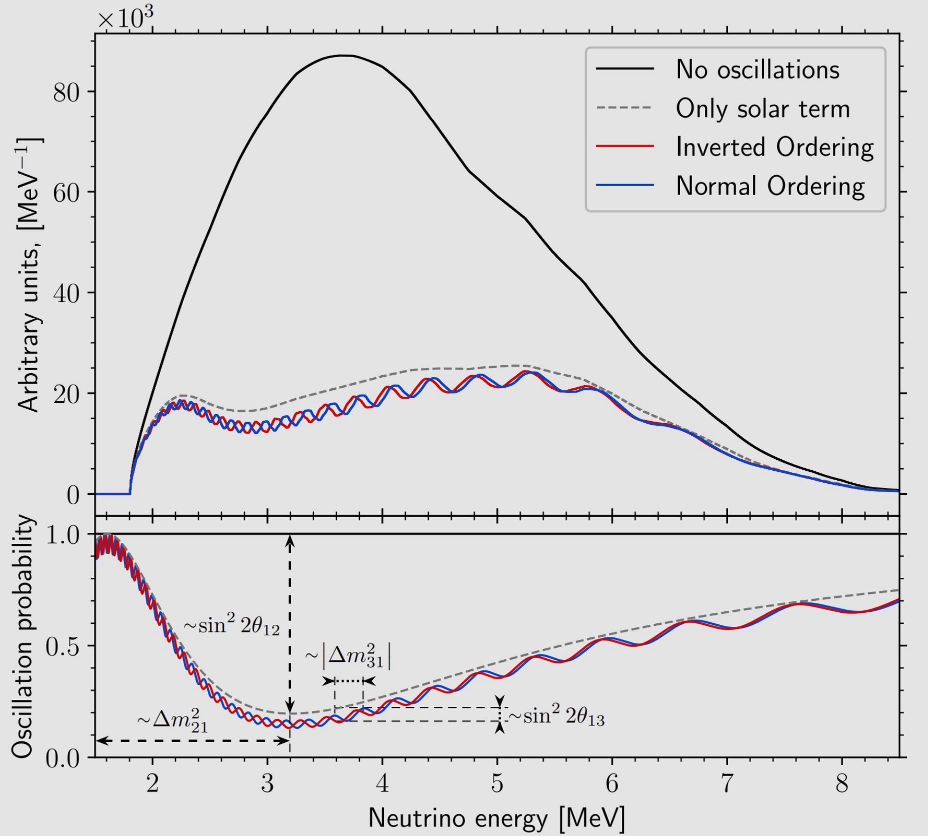
$$P_{\bar{\nu}_e \to \bar{\nu}_e}(L,E) = 1 - \sin^2 2\theta_{12} \cos^4\theta_{13} \sin^2\frac{\Delta m^2_{21} L}{4E} - \sin^2 2\theta_{13}\left(\cos^2\theta_{12}\sin^2\frac{\Delta m^2_{31}L}{4E} + \sin^2\theta_{12}\sin^2\frac{\Delta m^2_{32}L}{4E}\right)$$

- Reactor experiments study electron antineutrino survival probability
- First experiment to observe both "atmospheric" and "solar" oscillations



Reactor antineutrinos oscillation probability at JUNO

- Access to $\sin^2\theta_{12}$, $\sin^2\theta_{13}$, Δm^2_{21}, Δm^2_{31}, and NMO
- Mass ordering inferred through the interference pattern → need excellent energy resolution
- NMO is independent of δ_{CP} and θ_{23}, complemetary to accelerator and atmospheric experiments
- Unoscillated spectrum should also be known with good precision (TAO)



JUNO's journey


Installation of vertical shaft

2013 — Project start

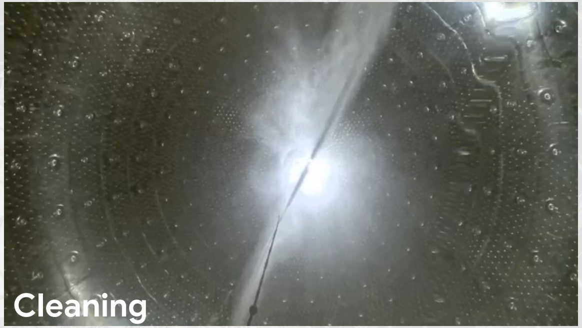
2015 — Start of civil construction

2022 — Beginning of detector installation

Dec 1, 2024 — End of detector installation

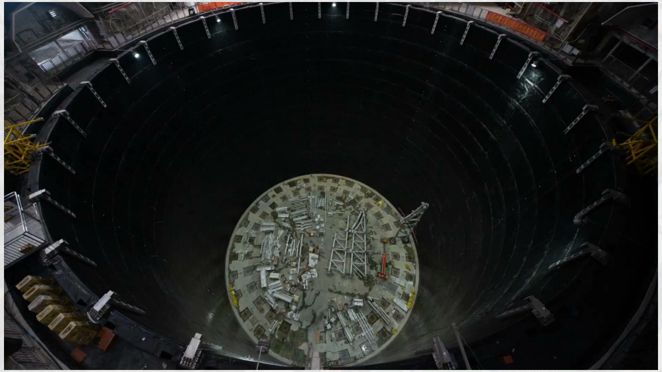
Dec 17, 2024

Cleaning & Installation of extra PMTs


Cleaning


Tunnel dig


Completion of acrylic vessel


Installation video

JUNO's journey

Dec 18, 2024 — Start of water filling

Calibration

Test runs

Feb 1, 2025 — End of water filling

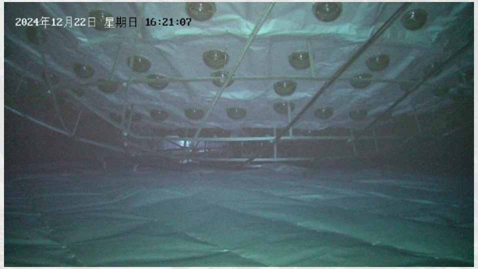
Water Phase

Feb 8, 2025 — Start of LS filling

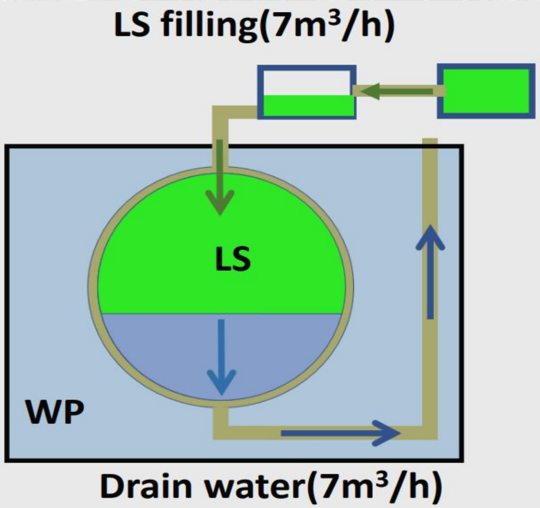
More calibration, radiopurity monitoring

Mixed phase

Aug 26, 2025 — Start of Physics Data-taking

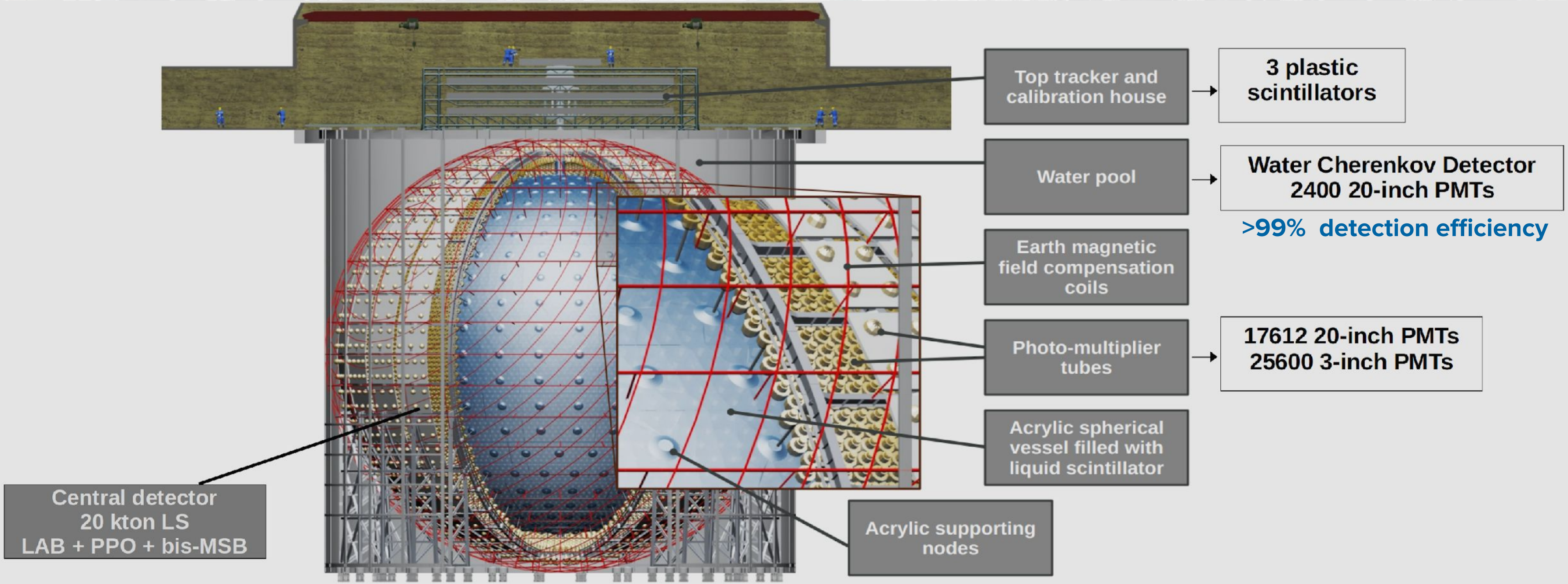


During water filling Dec 12, 2024



JUNO design features

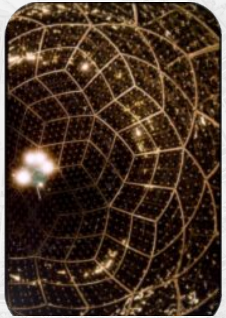
Detector design overview

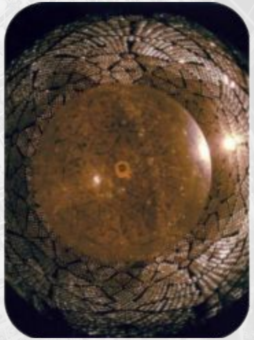


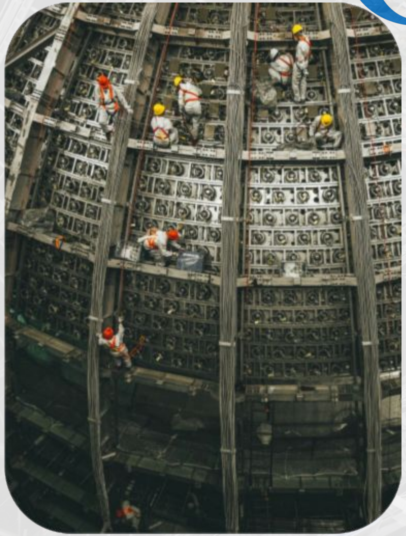
What it takes: go big!

Similar concept to previous LS experiments, but much larger and more precise!

Reines & Cowan, 300 L
Discovery of neutrinos







Experiment	Daya Bay	Borexino	SNO+	KamLAND	JUNO
LS mass	8 x 20 ton	~300 ton	780 ton	~1 kton	20 kton
PMT coverage	~12%	~34%	~54%	~34%	~78%
Energy resolution	~8%	~5%	~4-5%	~6%	~3%
Light yield	~160 p.e./ MeV	~500 p.e./ MeV	~300 p.e./MeV	~250 p.e./MeV	> 1665 p.e./ MeV

What it takes: push the energy resolution limits

With 3% @ 1 MeV, JUNO is the LS detector with the best energy resolution in history

$$\frac{\sigma(E)}{E} = \sqrt{\frac{\sigma^2_{stoch}}{E} + \sigma^2_{non-stoch}}$$

stochastic term: depends on photostatistics

non-stochastic term: residual issues (stability, uniformity, linearity) after calibration

Improvements on multiple fronts to solve the challenge!

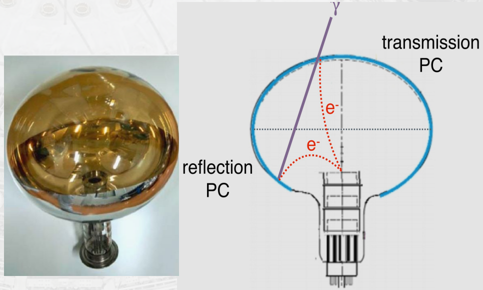
Property	KamLAND	JUNO	Relative Gain
Total light level	**250 p.e. / MeV**	**>1600 p.e. / MeV**	**>6**
Photocathode coverage	34%	~78%	>2
Scintillation fluor	1.5 g/l PPO	2.5 g/l PPO	>1.5
Attenuation length / R	15/16 m	20/35 m	~0.6
PMT QE×CE	20%×60% ~ 12%	~30%	>2

- **Lots of PMTs** (→ Total light level, >6)
- **Optimized LS** (→ Scintillation fluor >1.5; Attenuation length ~0.6)
- **More efficient PMTs** (→ PMT QE×CE, >2)

The Large PMT (LPMT) system

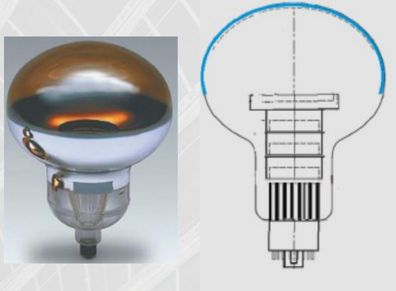
- Main detection device: 20-inch PMTs
- Arranged tightly: 3 mm clearance
- QExCE ~ 30%
- Two complementary and new technologies

Microchannel plate (MCP)-PMTs



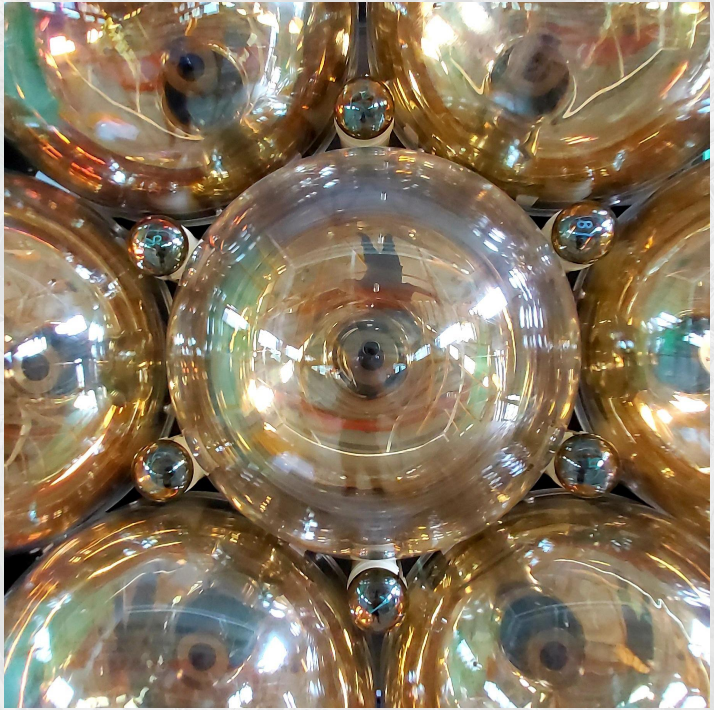
- Developed for/by JUNO (IHEP + NNVT)
- ~13,000 in CD + ~3000 in water tank

Dynode-PMTs

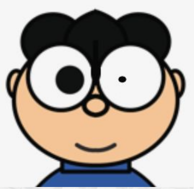


- R12860 from Hamamatsu
- New type of Bialkali supercathode
- ~5,000 in CD

The Small PMT (sPMT) system



XP72B22 NIM A 1005 (2021) 165347

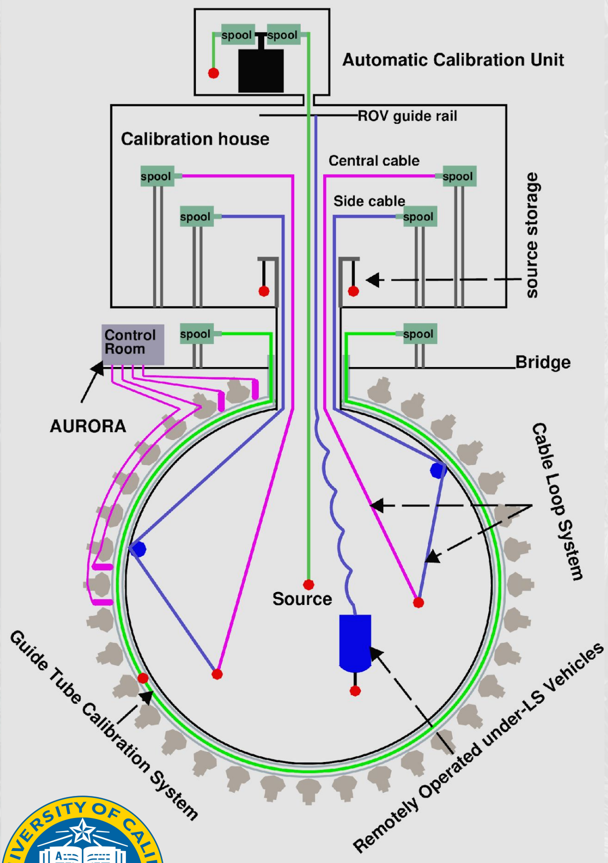


$$\frac{\sigma(E)}{E} = \sqrt{\frac{\sigma^2_{STOCH}}{E} + \sigma^2_{NON-STOCH}}$$

Less than 1%
Never achieved before!

- 26,000 3-inch PMTs predominantly in photon-counting mode. Custom-made for JUNO
- Principle: look at the same event with two sets of eyes with different systematics (eg. non-linearity)
- Aid position reconstruction and muon reconstruction

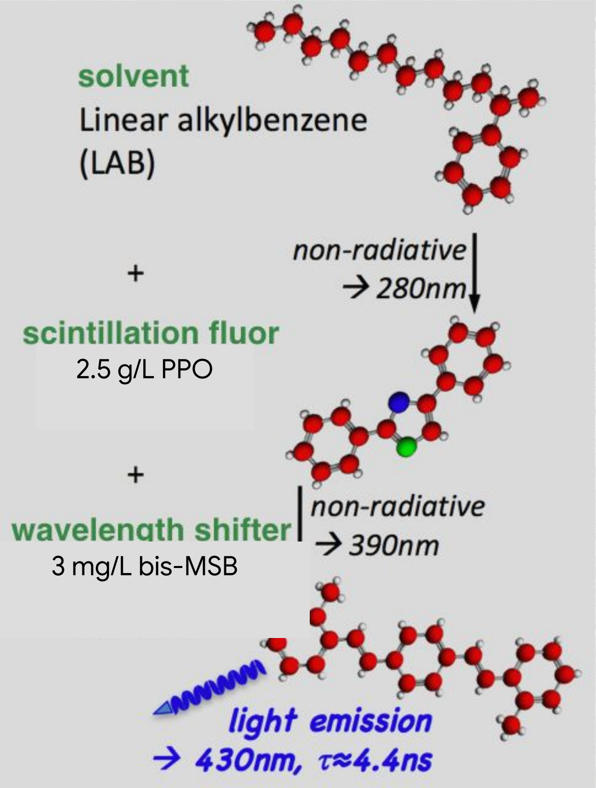
What it takes: comprehensive calibration



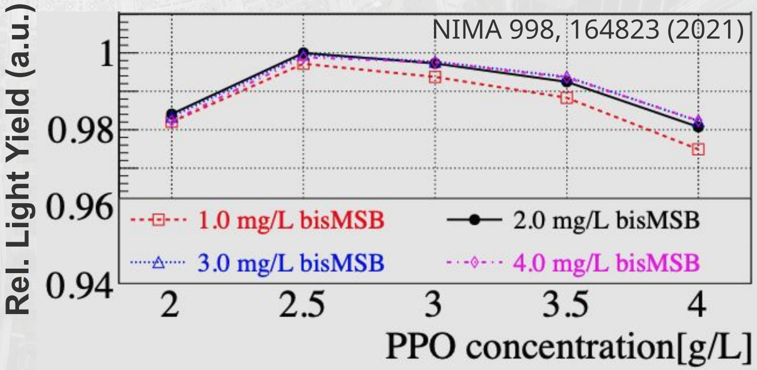
JHEP 2021, 04 (2021)

- A high light level of 1665 p.e. per MeV alone is not enough! Systematics should be kept under control (< 1% energy scale uncertainty)!
- In addition to sPMT, have a comprehensive calibration program consisting of 4 mutually complementary systems:
  - 1D: Automated Calibration Unit (ACU) deploys radioactive and laser (1 ns, keV-TeV range) sources along the central axis
  - 2D: Cable Loop System (CLS) to scan vertical planes
  - 2D: Guide Tube to scan the outer surface of the central detector (where the CLS cannot reach)
  - 3D: Remotely Operated Vehicle (ROV) operating inside the LS to scan the full volume

What it takes: optimized Liquid Scintillator (LS)



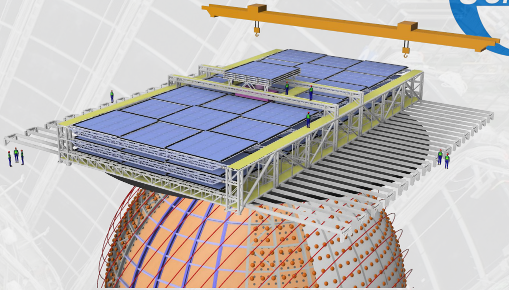
- LS requirements: High light yield, high transparency, high radiopurity
- Recipe optimized with a decommissioned Daya Bay detector whose results were extrapolated to JUNO size using a new optical model
- Attenuation length: 20.6 m @ 430 nm

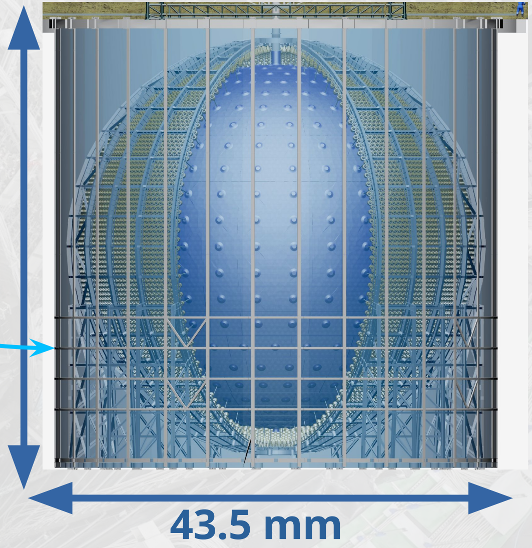


What it takes: low backgrounds!

Reduce **cosmogenics** + tag residual muons (>99.9% efficiency)

- ~650 m overburden
- Instrumented water pool
- Dedicated top tracker





What it takes: low backgrounds!

Radiopurity control:

- Material screening, production handling, clean room during installation, acrylic surface treatment
- ~1 order better than requirement:
  - ^{238}U: (7.5 +/- 0.7) x 10^{-17} g/g
  - ^{232}Th: (8.2 +/- 0.6) x 10^{-17}g/g
  - ^{210}Po: (4.3 +/- 0.2) x 10^{4} /day /kton

First results with 59 days of data

Energy reconstruction basics

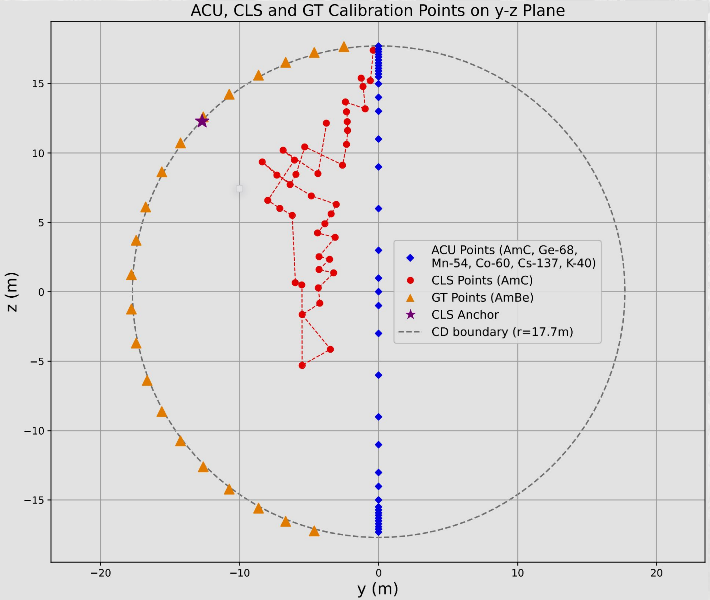
Number of photons
N_{ph}

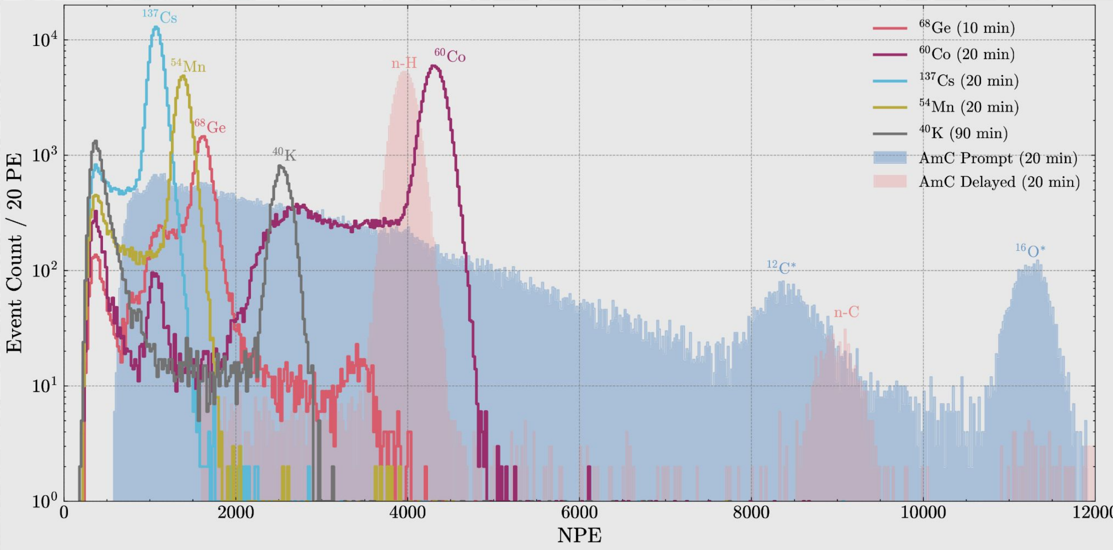
$E_{rec} \cong k\, N_{ph}$

Reconstructed energy
E_{rec} (MeV)

- Non-linearity (quenching, Cherenkov, instrumental)
- Non-uniformity of detector response

Calibration

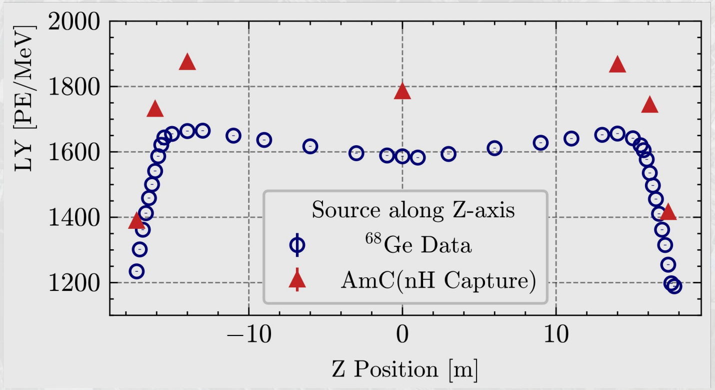




Multiple artificial calibration sources deployed around central axis (1D) and in 2D plane
\+ Natural sources (cosmogenic spallation products, natural radioactivity)

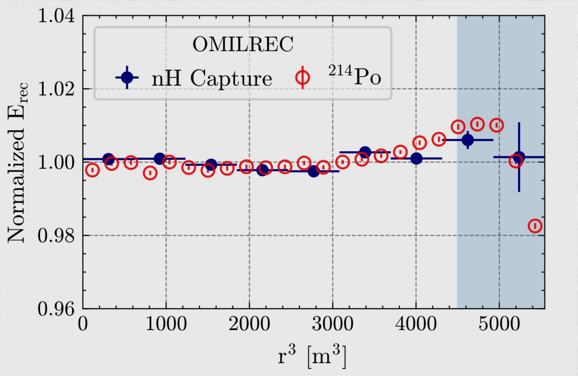
Light yield and residual non-uniformity

Effective light yield > 1600 PE



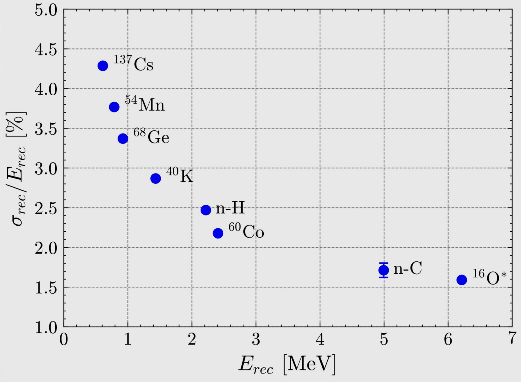
- AmC neutron source: 2.2 MeV γ from nH capture
- ^{68}Ge (e+): 2 x 511 keV γs

Residual non-uniformity better than +/- 1%



- nH capture from IBDs
- ^{214}Po (α), visible energy ~0.9 MeV

Energy resolution ~3.4% for ^{68}Ge

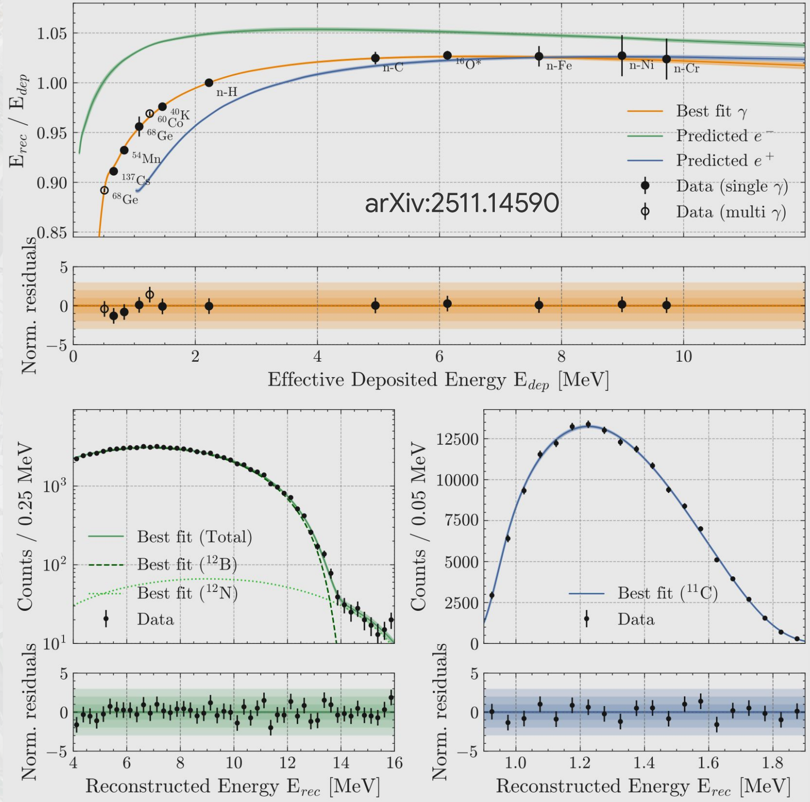


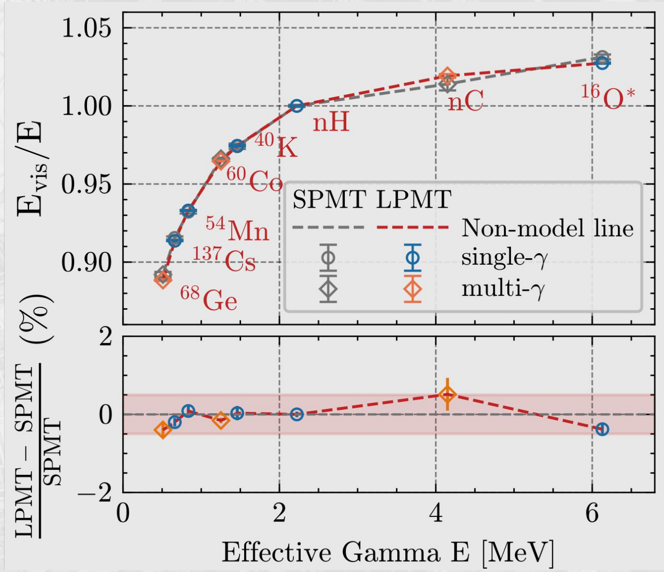
γ sources at the detector center

arXiv:2511.14590

Energy response and non-linearity

arXiv:2511.14590



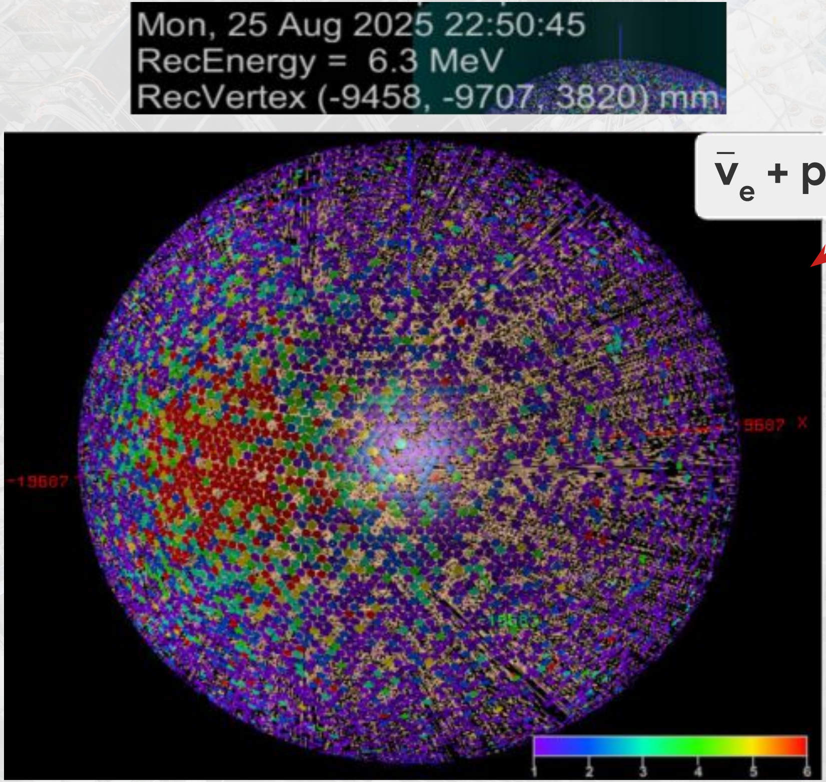


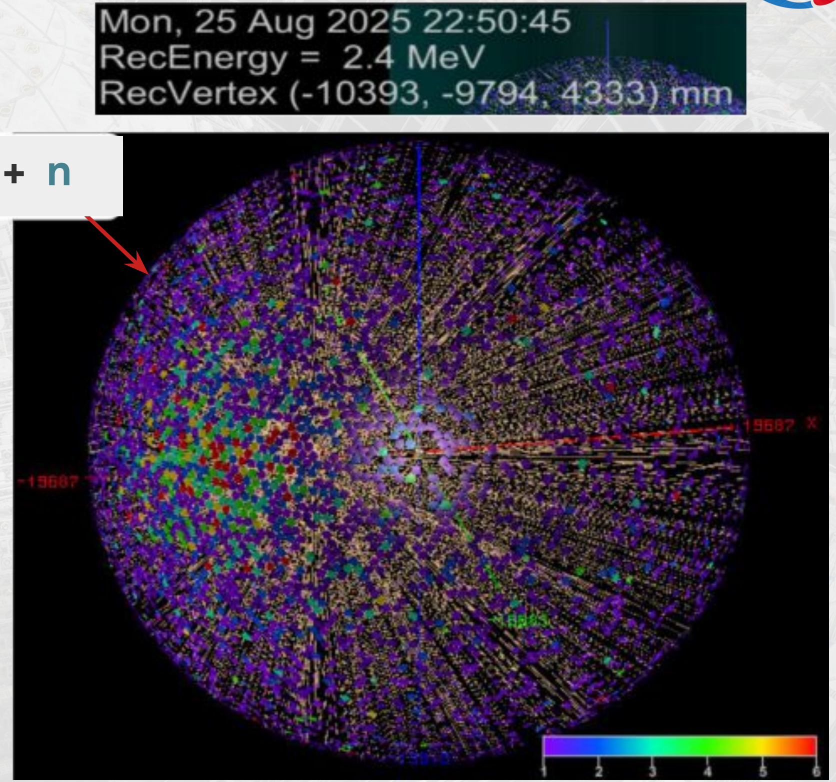
- Energy non-linearity (NL) characterized to better than 1% precision
- Good agreement between NL measured with LPMTs and sPMTs (which are virtually linear)

Event selection

First IBD candidate

$$\bar{\nu}_e + p \longrightarrow e^+ + n$$

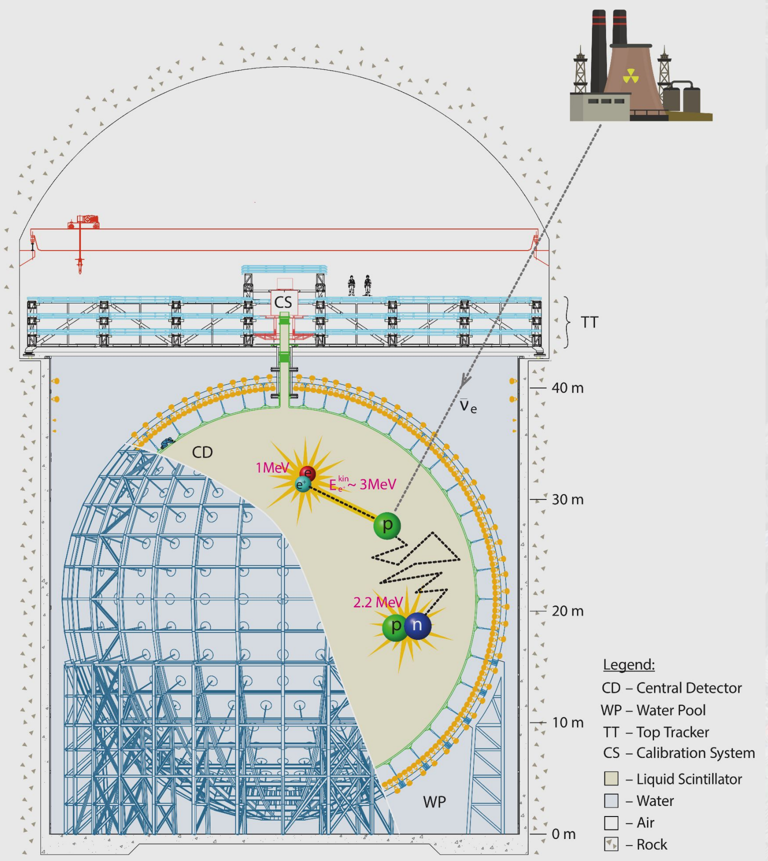




Event selection

$\bar{\nu}_e + p \rightarrow e^+ + n$

IBD selection: **prompt** e^+ annihilation signal + **delayed** nH-capture gamma (~200 μs later)

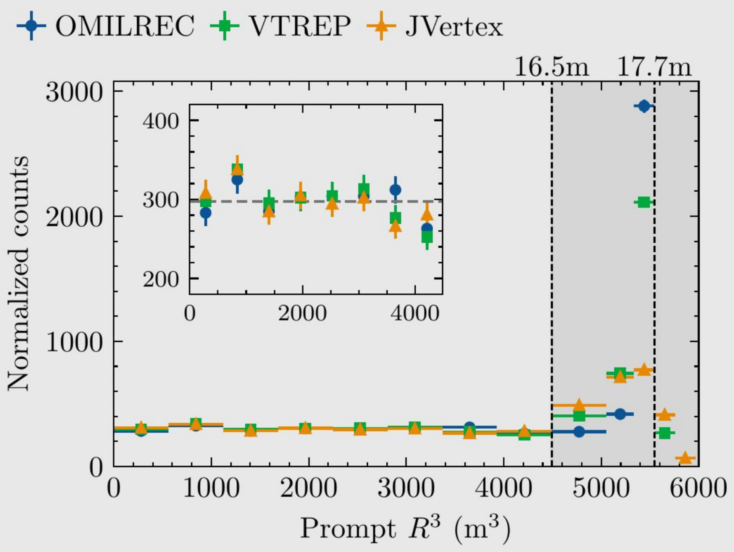


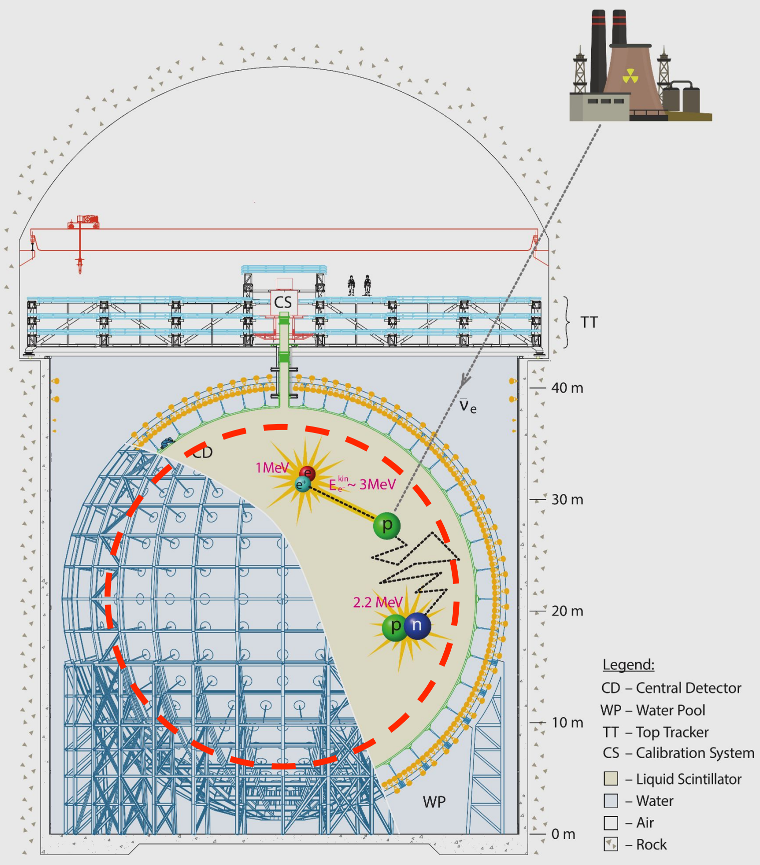
Event selection

$\bar{\nu}_e + p \rightarrow e^+ + n$

IBD selection: **prompt** e^+ annihilation signal + **delayed** nH-capture gamma (~200 μs later)

1. **Choose fiducial volume:** Reduce radioactive backgrounds and cosmogenic fast neutrons (r < 16.5 m)





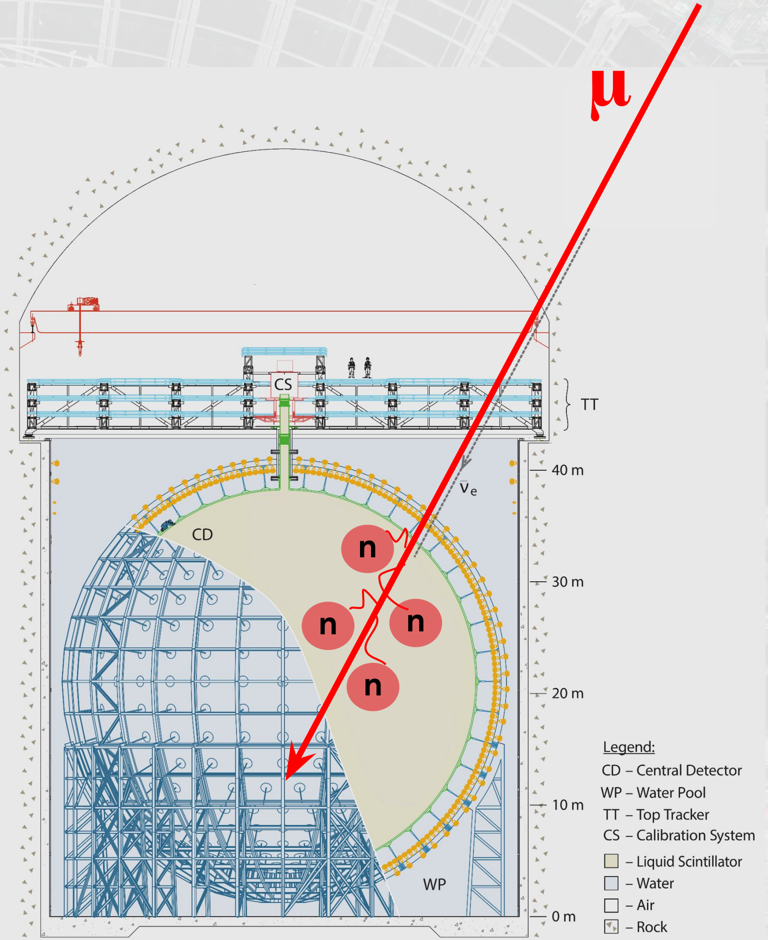
Event selection

$\bar{\nu}_e + p \rightarrow e^+ + n$

IBD selection: **prompt** e^+ annihilation signal + **delayed** nH-capture gamma (~200 μs later)

1. **Choose fiducial volume:** Reduce radioactive backgrounds and cosmogenic fast neutrons (r < 16.5 m)

2. **Cosmogenic vetoes:** Veto muons and other spallation products using Δt to muons + Δr to spallation neutrons
    - Veto events < 5 ms to muons to remove short-lived spallation products
    - Veto spherical regions of < 2 m around spallation neutrons for 1.2 s to suppress long-lived spallation products



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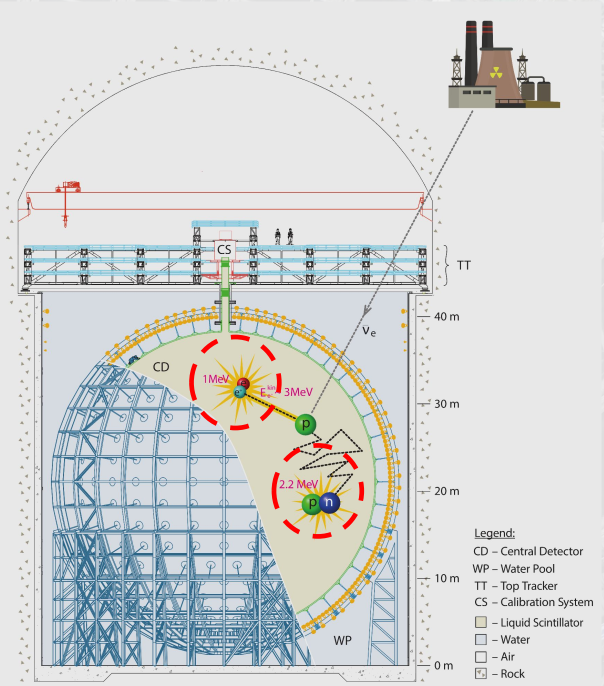
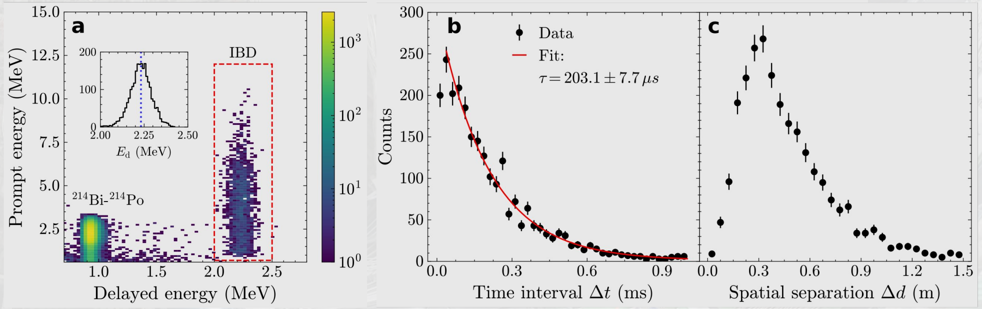
2. **Cosmogenic vetoes:** Veto muons and other spallation products using Δt to muons + Δr to spallation neutrons

3. **Energy + time-space coincidence** of prompt and delayed
    - Prompt: 0.7-12 MeV
    - Delayed: 1.8-2.5 MeV
    - Δt < 1 ms
    - Δr < 1.5 m





arXiv:2511.14593

Event selection

arXiv:2511.14593

$\bar{\nu}_e + p \rightarrow e^+ + n$

IBD selection: **prompt** e^+ annihilation signal + **delayed** nH-capture gamma (~200 μs later)

1. **Choose fiducial volume:** Reduce radioactive backgrounds and cosmogenic fast neutrons (r < 16.5 m)
2. **Cosmogenic vetoes:** Veto muons and other spallation products using Δt to muons + Δr to spallation neutrons
3. **Energy + time-space coincidence** of prompt and delayed

Antineutrinos ($\bar{\nu}_e$) Candidates Summary		
DAQ live time (days)	59.1	
$\bar{\nu}_e$ candidates	2379	
Selection Efficiencies (%)	ε	σ_{rel}
Fiducial volume	80.6	1.6
PMT flasher rejection	>99.9	negligible
μ veto	93.6	negligible
Multiplicity	97.4	negligible
Prompt-delayed coinc.	95.1	0.13
Total efficiency (ε_{tot})	69.9	1.6
$\bar{\nu}_e$ signal (cpd[1])		
w/o ε_{tot} corrected	33.5 ± 1.7	
w/ ε_{tot} corrected	47.9 ± 2.6	
Non-oscillated $\bar{\nu}_e$	150.9 ± 2.7	

59.1 days of good data:

Aug 30th - Nov 2nd, 2025

Event selection

arXiv:2511.14593

$\bar{\nu}_e + p \rightarrow e^+ + n$

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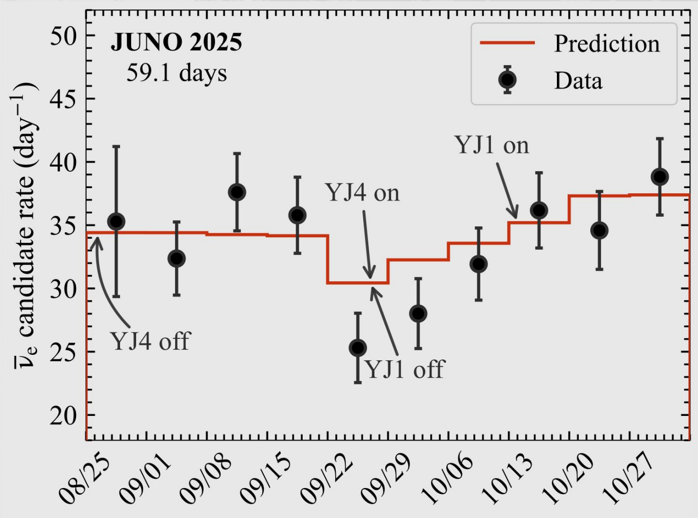
3. **Energy + time-space coincidence** of prompt and delayed

Good correlation between predicted and expected reactor IBD rate after background subtraction



Note: YJ stands for Yangjiang, a Nuclear Power Plant with 6 reactors seen by JUNO

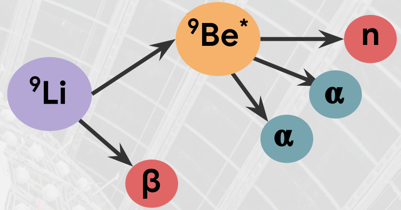
59.1 days of good data:

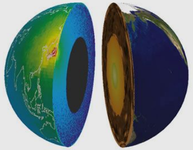
Aug 30th - Nov 2nd, 2025

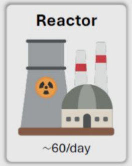
Backgrounds

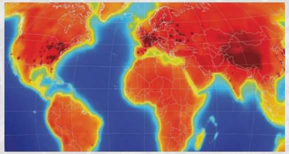
Backgrounds amount to ~14% of the total candidate sample

- β – n correlated signals from decay of long-lived ^{9}Li/^{8}He
- Geoneutrinos: emitted from the decay of U and Th in the Earth
- Neutrinos from other nuclear power plants (World reactors)





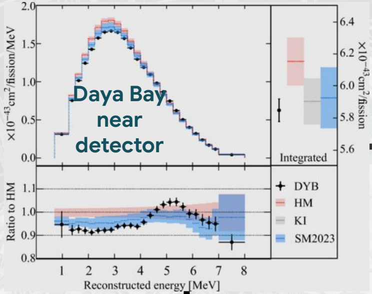


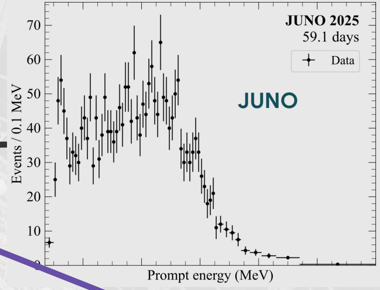


Backgrounds (cpd)	Pre-fit	Best-fit
^{9}Li/^{8}He	4.3 ± 1.4	3.9 ± 0.6
Geoneutrinos	1.2 ± 0.5	1.4 ± 0.4
World reactors	0.88 ± 0.09	0.88 ± 0.09
^{214}Bi-^{214}Po	0.18 ± 0.10	0.20 ± 0.10
^{13}C(α, n)^{16}O	0.04 ± 0.02	0.04 ± 0.02
Fast neutrons	0.02 ± 0.02	0.02 ± 0.02
Double neutrons	0.05 ± 0.05	0.07 ± 0.05
Atmospheric neutrinos	0.08 ± 0.04	0.07 ± 0.04
Accidentals ($\times 10^{-2}$)	4.9 ± 0.3	4.9 ± 0.3

arXiv:2511.14593

Oscillation fit





Huber-Mueller model

Reactor data (fission fractions, power, distance)

Energy non-linearity

Energy resolution

Data-driven or analytical/MC

Shapes

Rates

Unoscillated spectrum

Apply oscillations

$\sin^2\theta_{12}$, Δm^2_{21} free

Detector response

Backgrounds

Model

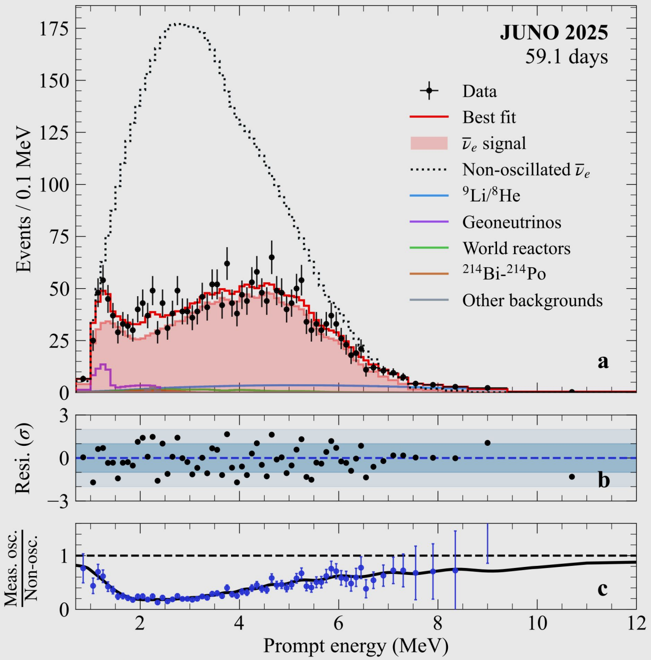
Data

Fit/ minimize

Oscillation fit results

- Consistent results from three independent analyses:
  - Own selections, reconstructions, background estimations, detector response characterizations, and fitting implementation
- Unoscillated spectrum constrained through joint fit with released Daya Bay data
  - Detector response accounted for individually for JUNO and Daya Bay
- Frequentist analysis with binned χ^2
- 1.6x factor improvement!

arXiv:2511.14593



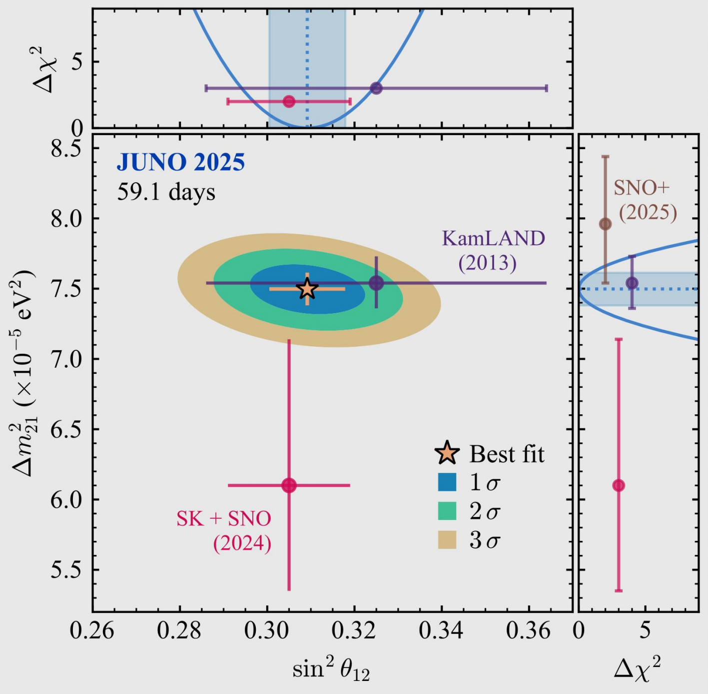
$$\sin^2\theta_{12} = 0.3092 \pm 0.0087\,,$$

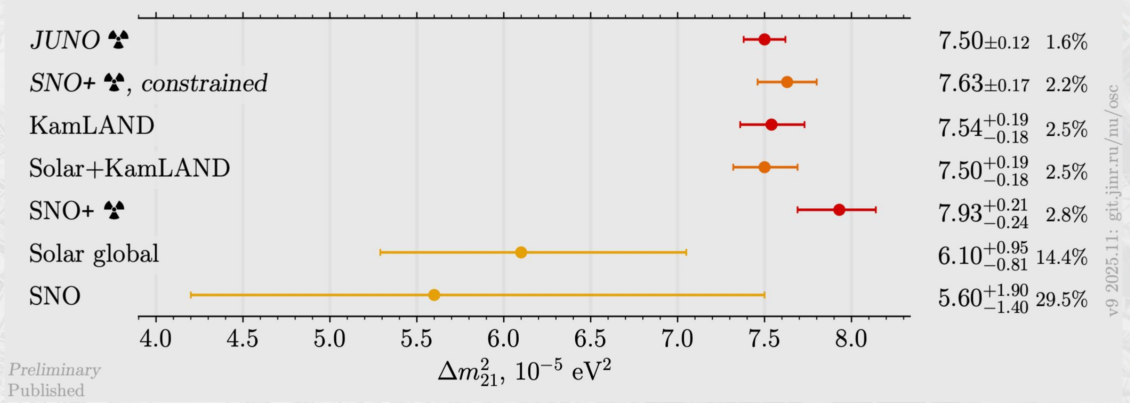
$$\Delta m^2_{21} = (7.50 \pm 0.12) \times 10^{-5}\ \mathrm{eV}^2$$

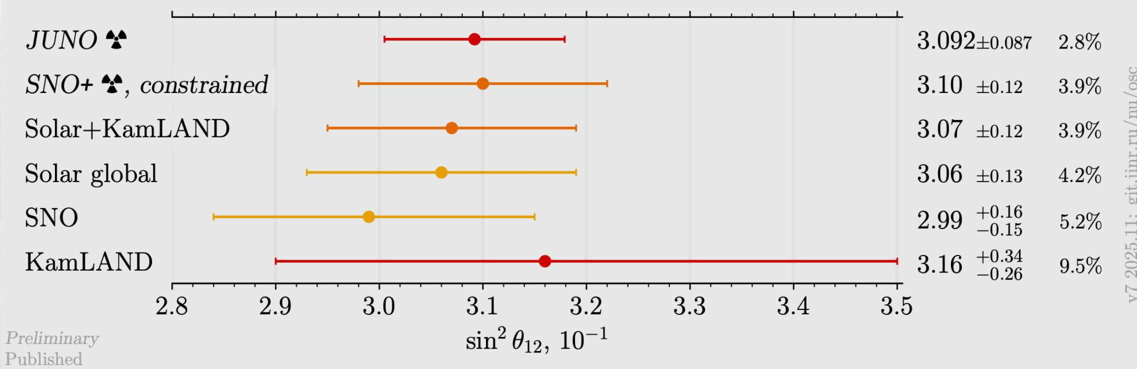
	Δm^2_{21}	$\sin^2\theta_{12}$
PDG 2025	2.5%	3.9%
JUNO	1.6%	2.8%

Comparison with the global landscape

arXiv:2511.14593



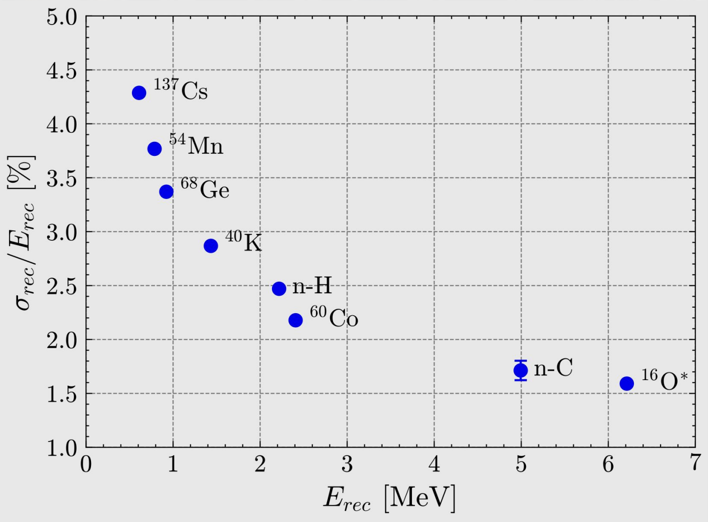


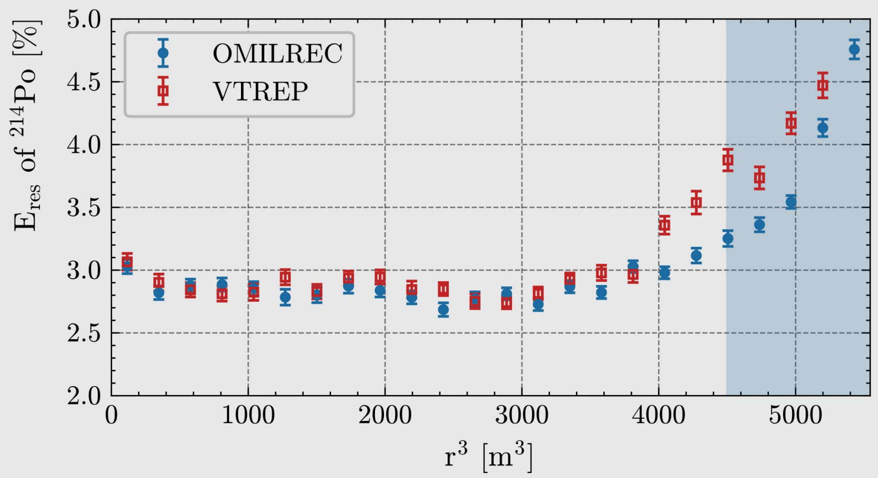


Good agreement with previous results!

Looking forward

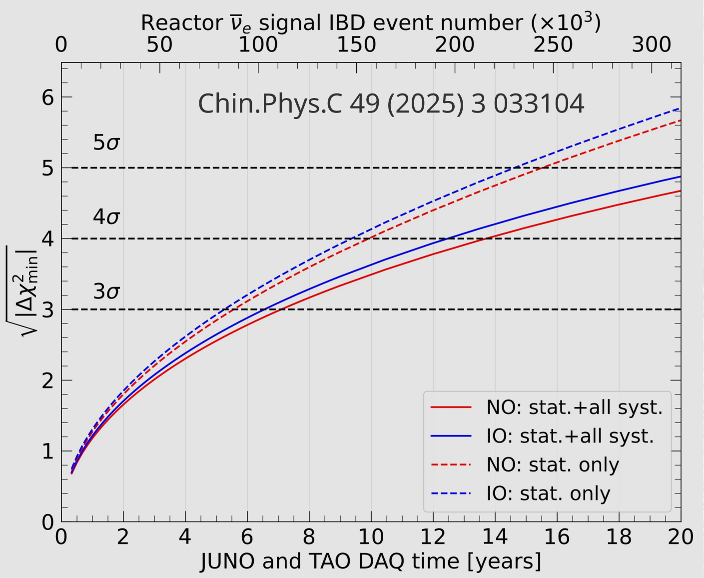
Energy resolution

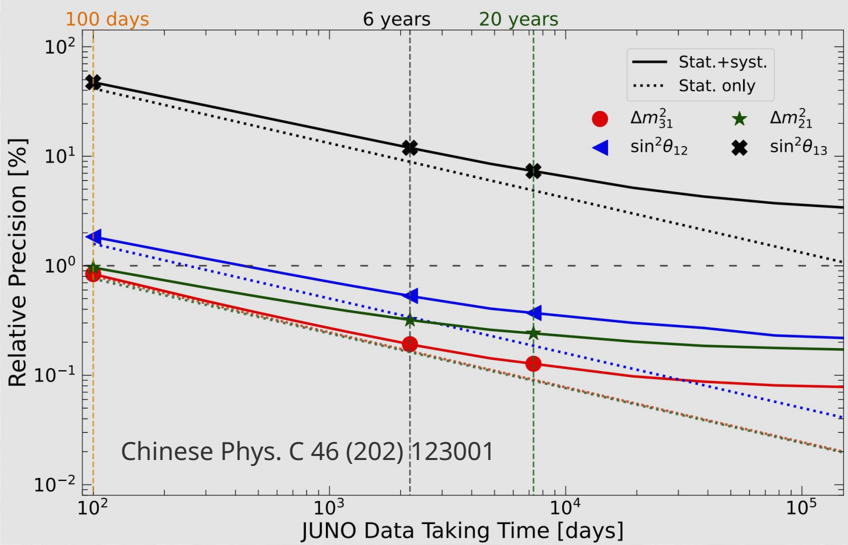




- Energy resolution is almost at design level
- Further improvements expected with better calibration and reconstruction!

Reactor antineutrinos oscillation physics

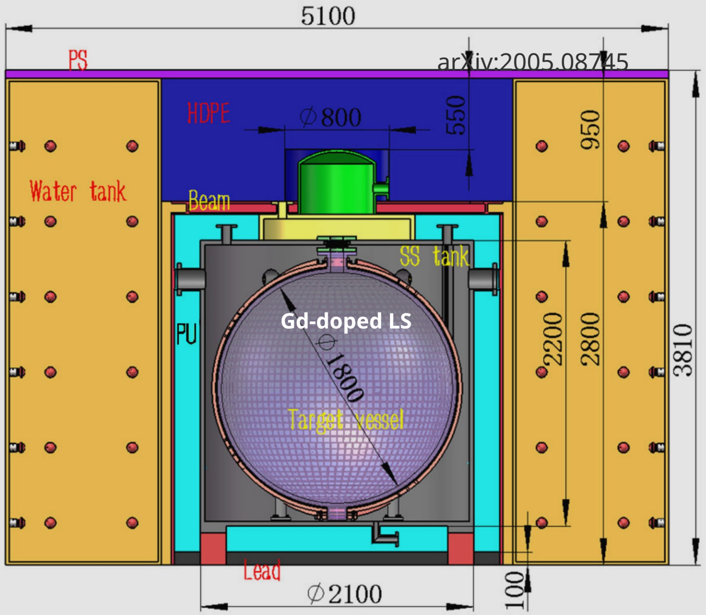




- ~7years: 3σ determination of NMO (earlier if combined with accelerator/ atmospheric experiments)
- ~6 years: Δm^2_{21}, Δm^2_{31}, and $\sin^2\theta_{12}$ ~an order of magnitude better precision than current values

	Δm^2_{21}	Δm^2_{31}	$\sin^2\theta_{12}$	$\sin^2\theta_{13}$
PDG 2025	2.5%	1.3%	3.9%	2.8%
JUNO 59 days	1.6%	-	2.8%	-
JUNO 6 years	0.3%	0.2%	0.5%	12.1%

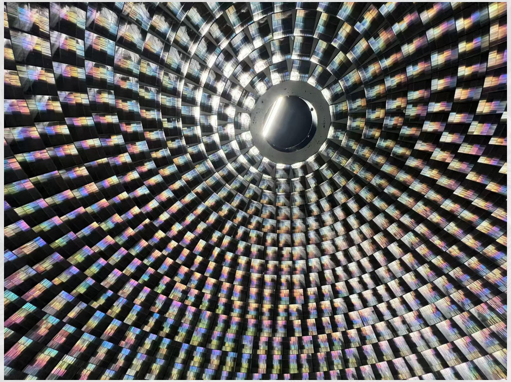
The Taishan Antineutrino Observatory (TAO)



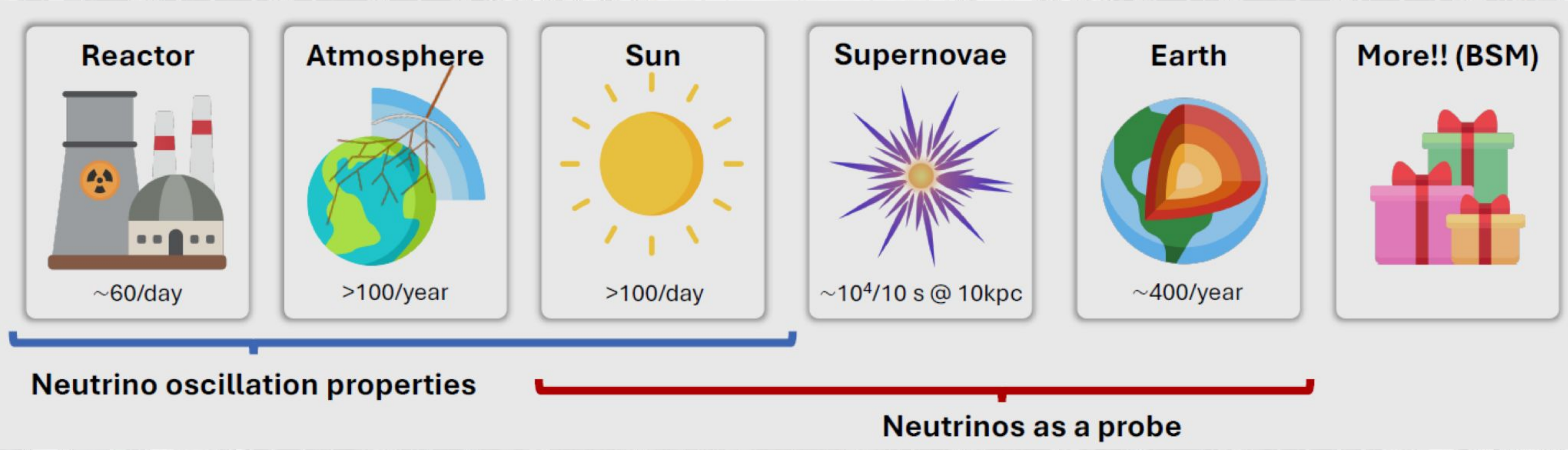
Satellite detector: provide precise measurement of reactor antineutrino spectrum

- ~40 m from one of Taishan 4.6 GW_{th} reactor core
- 1 ton fiducial volume with Gd-LS
- 30x JUNO event rate

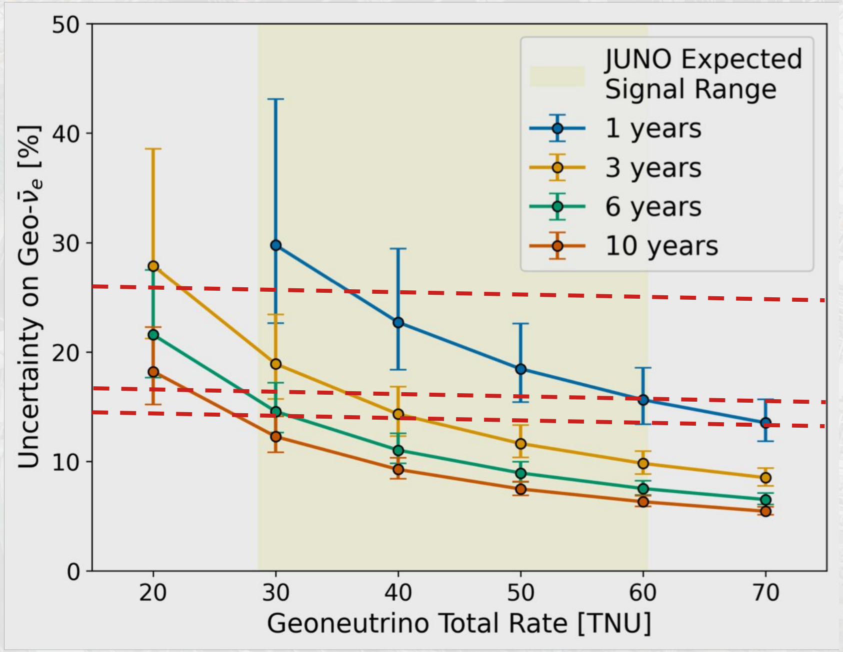
Physics data-taking just started as of Feb 12th, 2026 after a successful commissioning period!



Non-reactor neutrino physics



Geoneutrinos



$$^{238}\text{U} \rightarrow {}^{206}\text{Pb} + 8\alpha + 8e^- + 6\bar{\nu}_e + 51.7\text{ MeV}$$

$$^{235}\text{U} \rightarrow {}^{207}\text{Pb} + 7\alpha + 4e^- + 4\bar{\nu}_e + 46.4\text{ MeV}$$

$$^{232}\text{Th} \rightarrow {}^{208}\text{Pb} + 6\alpha + 4e^- + 4\bar{\nu}_e + 42.7\text{ MeV}$$

$$^{40}\text{K} \rightarrow {}^{40}\text{Ca} + e^- + \bar{\nu}_e + 1.31\text{ MeV } (89.3\%)$$

$$^{40}\text{K} + e^- \rightarrow {}^{40}\text{Ar} + \nu_e + 1.505\text{ MeV } (10.7\%)$$

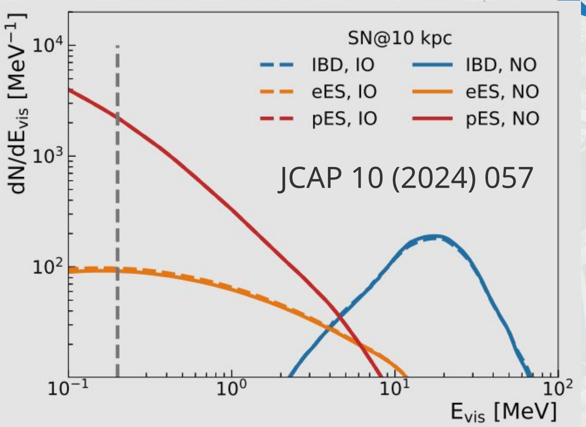
- Geoneutrinos give us information about the abundance of radioactive elements inside the crust and mantle, as well as the amount of heat emitted from them
- High statistics: more events in one year (~400) than global geoneutrino sample accumulated to date
- Expect a measurement soon!

Yesterday's background is today's signal!

Supernova neutrinos

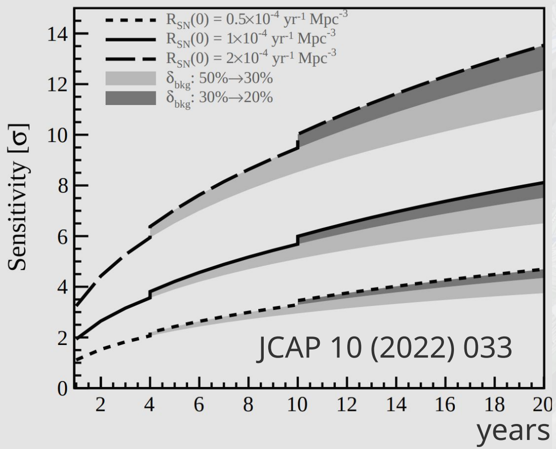
Core-collapse Supernova (SN) in our vicinity:

- Large SN neutrino sample with high energy resolution and low threshold (~0.02 MeV with multi-messenger trigger)
- 3 detection channels sensitive to all flavors, ~5k IBDs for SN @ 10 kpc
- Capability to detect pre-SN neutrinos from close SN-candidates: ~1.6 (0.9) kpc for normal (inverted) ordering



Diffuse Supernova Background (DSNB):

- DSNB: flux of neutrinos reaching the Earth from all the core-collapse supernovae in the universe
- Potential to observe DSNB with ~3σ significance in ~3 years assuming a nominal reference model



Summary & Conclusions

- JUNO is a multipurpose neutrino observatory with a rich program in neutrino physics and astrophysics
  - Neutrino mass ordering, oscillation parameters, supernova, solar, atmospheric, geoneutrinos, and other searches

- JUNO is pushing the limits in liquid scintillator detection technology
  - New solutions in terms of PMT technology, liquid scintillator properties and detector construction

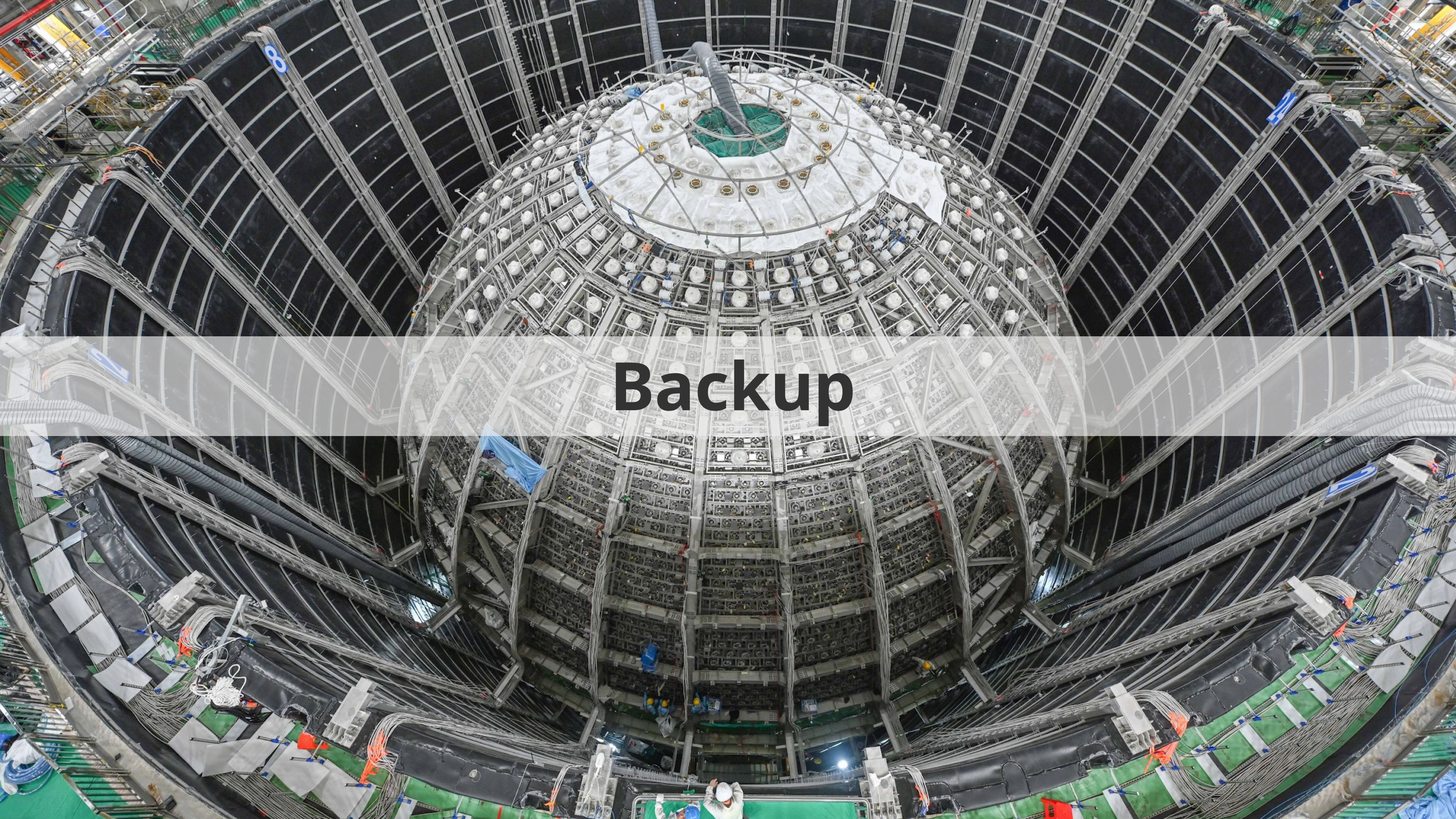
- First measurement using 59 days of data released
  - World-leading precision on Δm^2_{21} and $\sin^2\theta_{12}$ (1.6x factor improvement)
  - Excellent detector performance overall, sometimes exceeding expectations

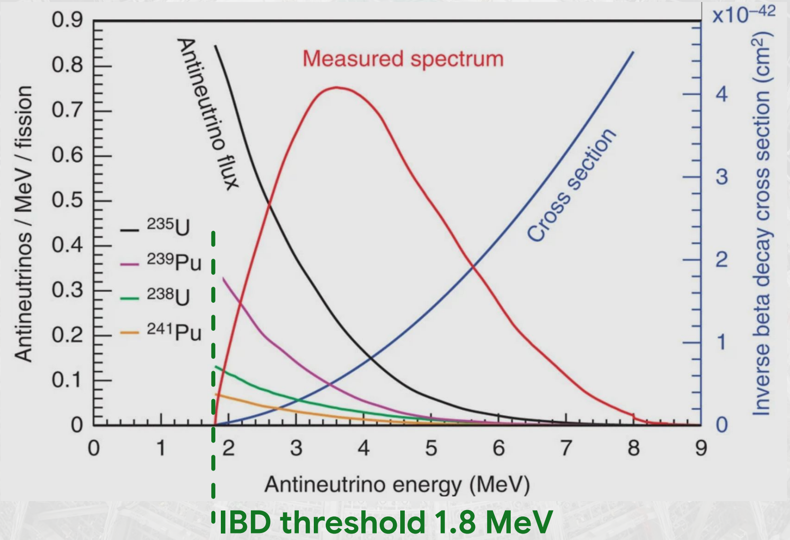
- **Anticipate some exciting results (and maybe some surprises?)**

Support from NSF is gratefully acknowledged

Thank you!

Backup



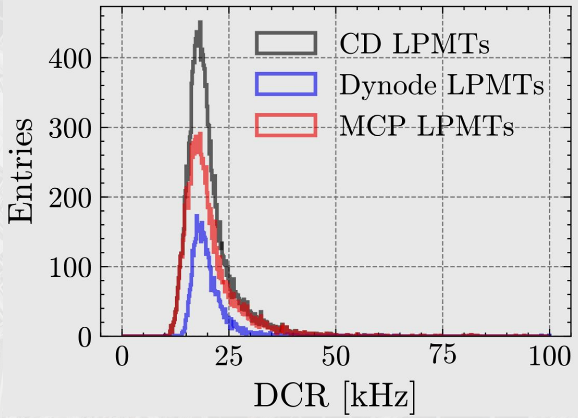


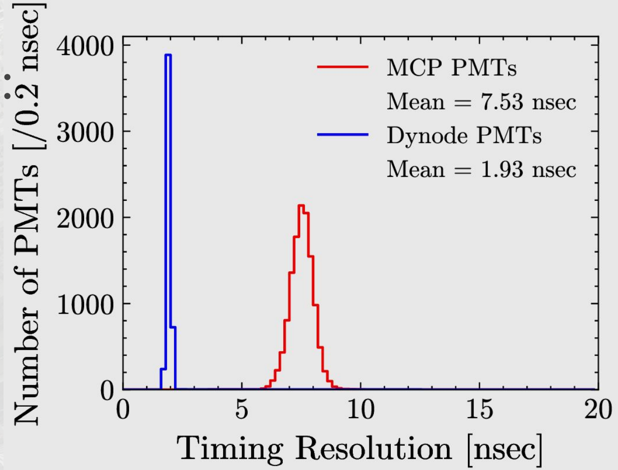
$E_{vis}\,(e^{+}) \simeq E_{\nu} - 0.78$ MeV

Low-level detector performance

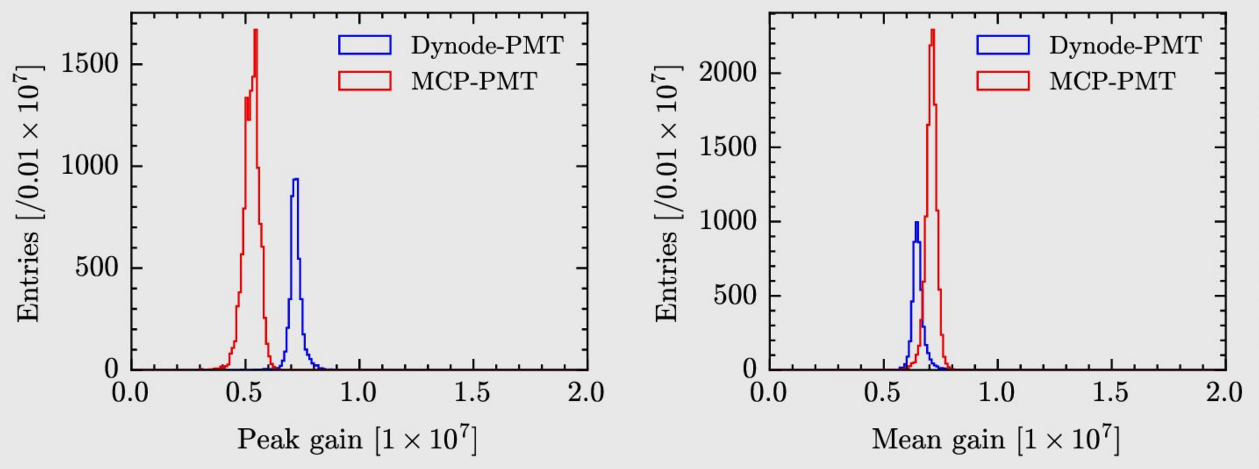
arXiv:2511.14590

- Large PMTs:
  - Lost ~0.1%
  - ~2-3% flashing at any given time
  - Few ns time resolution
  - ~20-23 kHz of Dark Count Rate (DCR)
- Electronics:
  - Low noise levels (roughly 0.055 PE)
  - Threshold at 0.2-0.3 PE
- Radiopurity (~order better than requirement):
  - ^{238}U: (7.5 +/- 0.7) x 10^{-17} g/g
  - ^{232}Th: (8.2 +/- 0.6) x 10^{-17}g/g
  - ^{210}Po: (4.3 +/- 0.2) x 10^{4} /day /kton
- Trigger threshold at 200 keV

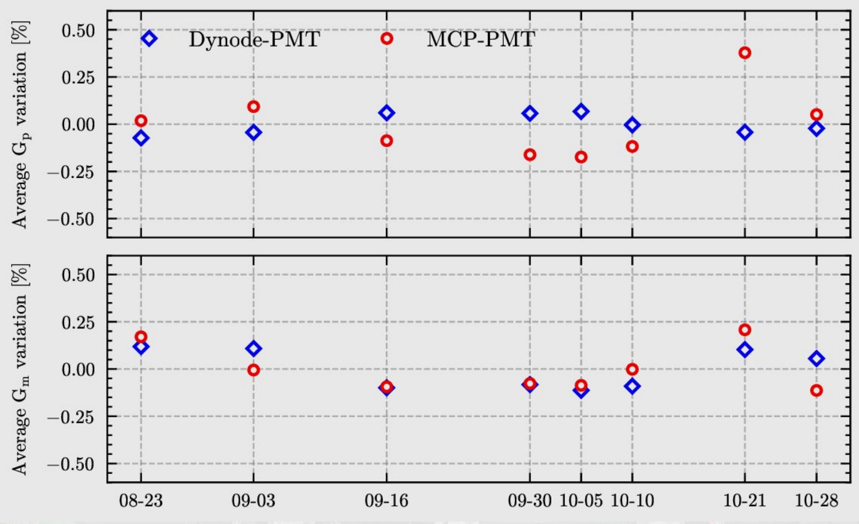




LPMT gains

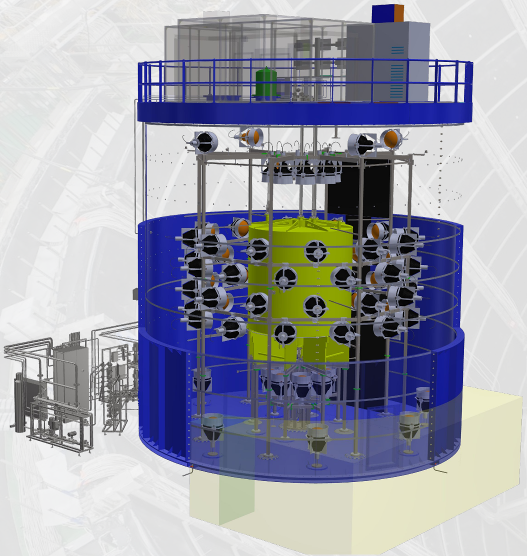


Dynode-PMT
MCP-PMT
Entries [/0.01 × 10^7]
Peak gain [1 × 10^7]
Mean gain [1 × 10^7]
0.0
0.5
1.0
1.5
2.0
0
500
1000
1500
2000



Dynode-PMT
MCP-PMT
Average G_p variation [%]
Average G_m variation [%]
0.50
0.25
0.00
−0.25
−0.50
08-23
09-03
09-16
09-30
10-05
10-10
10-21
10-28

OSIRIS



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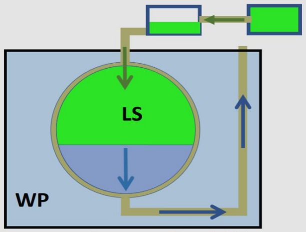
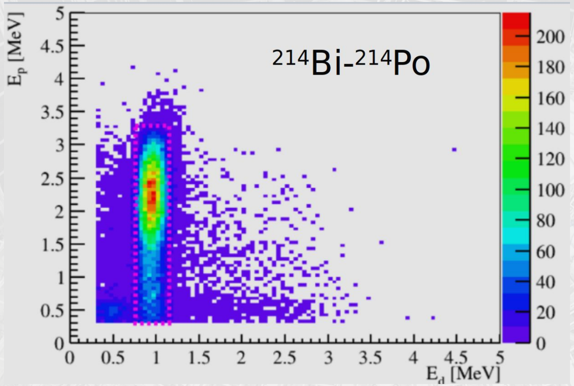
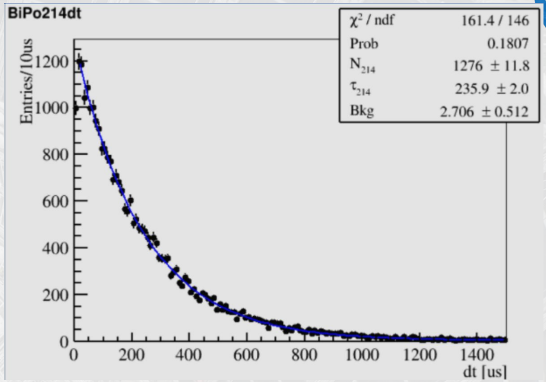
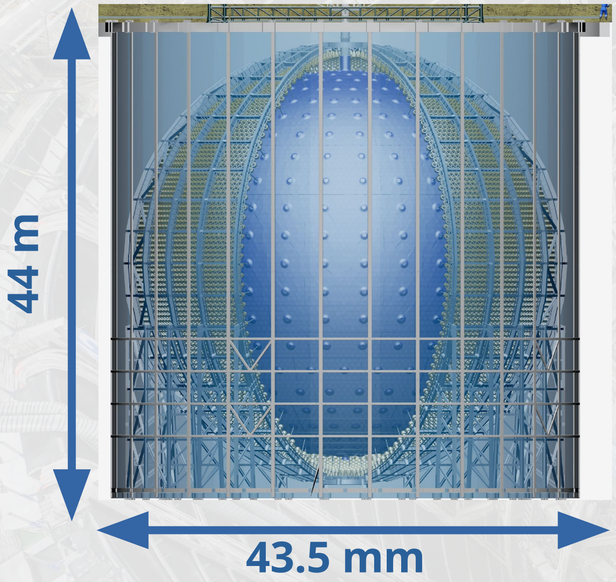


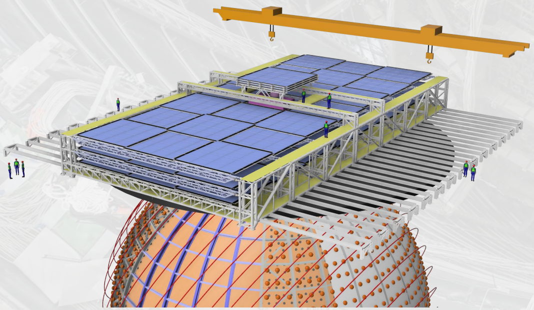




- Online Scintillator Internal Radioactivity Investigation System
- 3 m x 3 m acrylic vessel, 76 MCP-PMTs, 3 m of water shielding
- U/Th estimation by ^{214}Bi-^{214}Po and ^{212}Bi-^{212}Po coincidence tagging
- Analysis for other isotopes (e.g. ^{14}C, ^{210}Po) in progress

The muon veto system

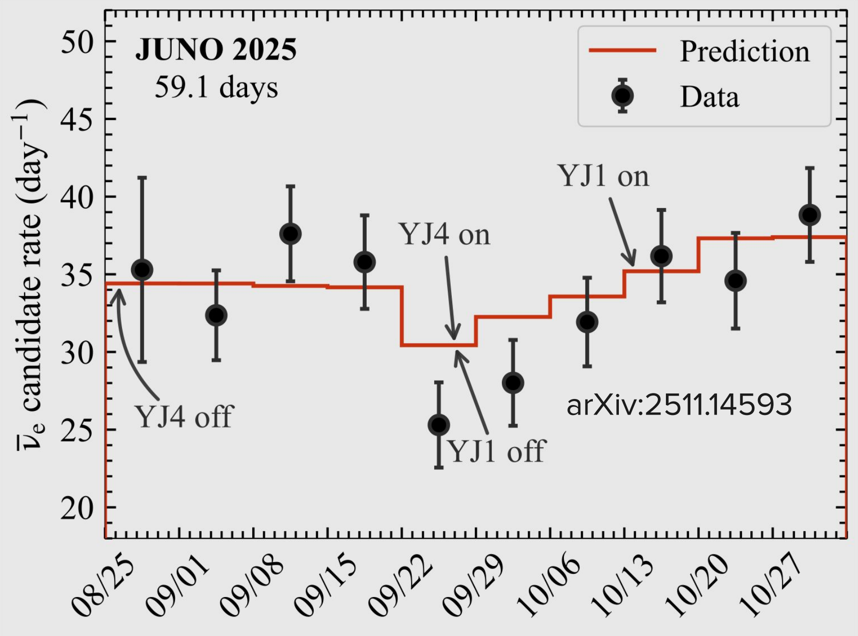




- The CD is be immersed in a cylindrical, instrumented water pool
- 35 kton ultrapure water with a circulation system U/Th/K < 10^{-14} g/g, attenuation length > 40 m
- Shield from radioactivity, cosmic neutrons, and veto cosmic muons
- 2400, 20-inch PMTs, high-density polyethylene lining to stop Rn from rock
- Detection efficiency > 99%
- Additional top tracker with 3 layers of plastic scintillator (reuse of OPERA's target tracker)
- Electromagnetic field (EMF) compensation coil around the detector to reduce effect of geomagnetic field of PMT light collection efficiency

Observed candidates and systematics

Good correlation between predicted and expected reactor IBD rate after background subtraction



Note: YJ stands for Yangjiang, a Nuclear Power Plant with 6 reactors seen by JUNO

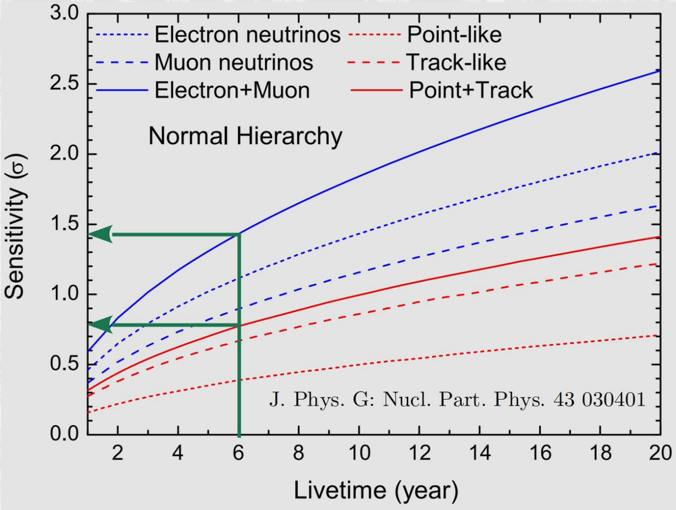
Current measurement is statistics dominated

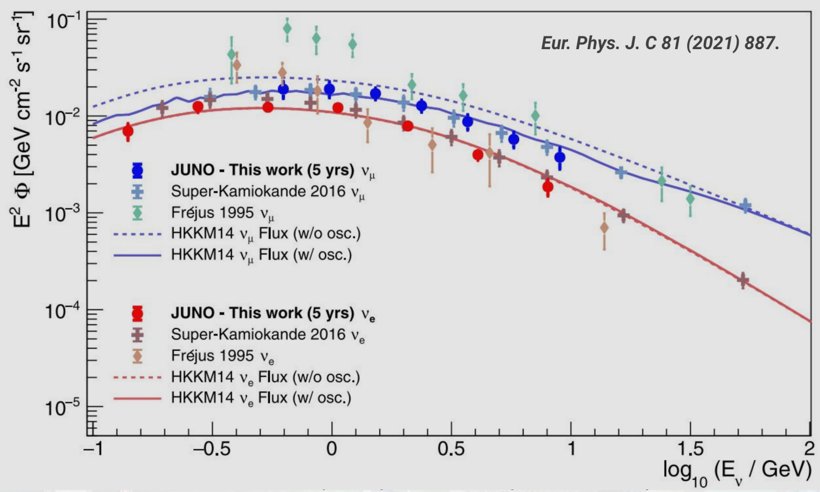
Source	Uncertainties
Target protons	1.0%
Reference spectrum	1.2%
Thermal power	0.5%
Fission fraction	0.6%
Spent nuclear fuel	0.3%
Non-equilibrium	0.2%
Different fission fraction	0.1%

Note: Decreasing order of uncertainty on each systematic shown. Does not reflect order of systematic contribution on solar parameters

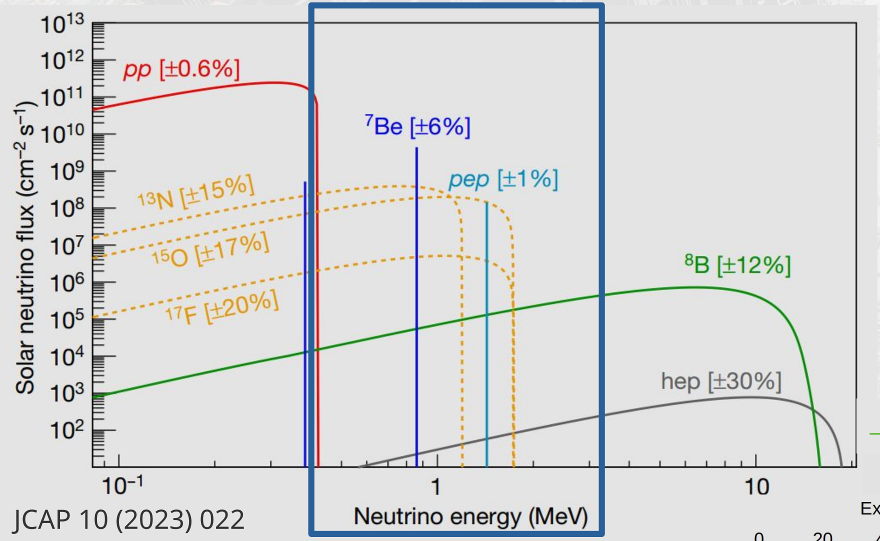
Atmospheric neutrinos

- Complementary to reactor neutrino NMO analysis using matter effects from atmospheric neutrinos crossing the Earth (~0.7-1.4 σ with ~6 years exposure)
- ~10° angular resolution at ~3 GeV
- Re-evaluation of sensitivity in progress!
- Will be the first measurement in LS
- Have good ability to reconstruct spectrum, very good performance in the"low energy"region (100 MeV - 10 GeV) ➔ provide important constraints to models





Solar neutrinos: intermediate energy



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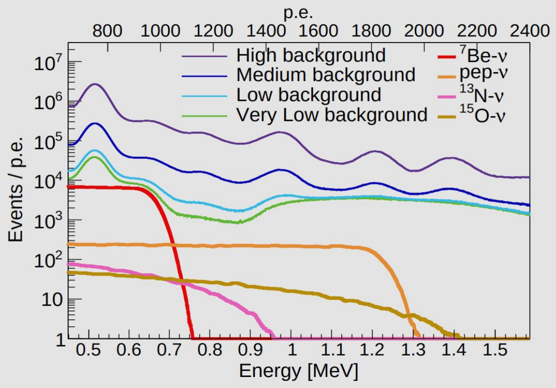
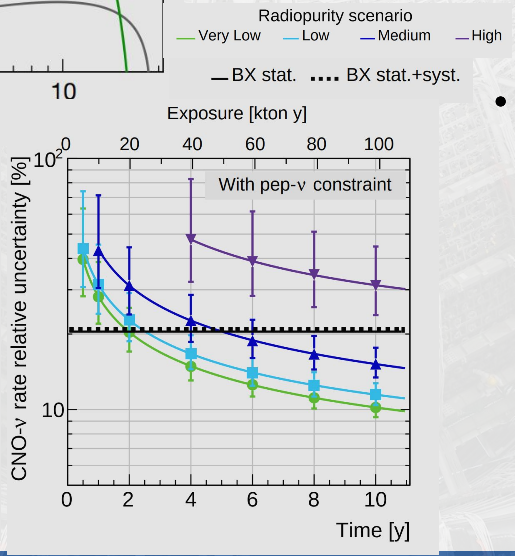
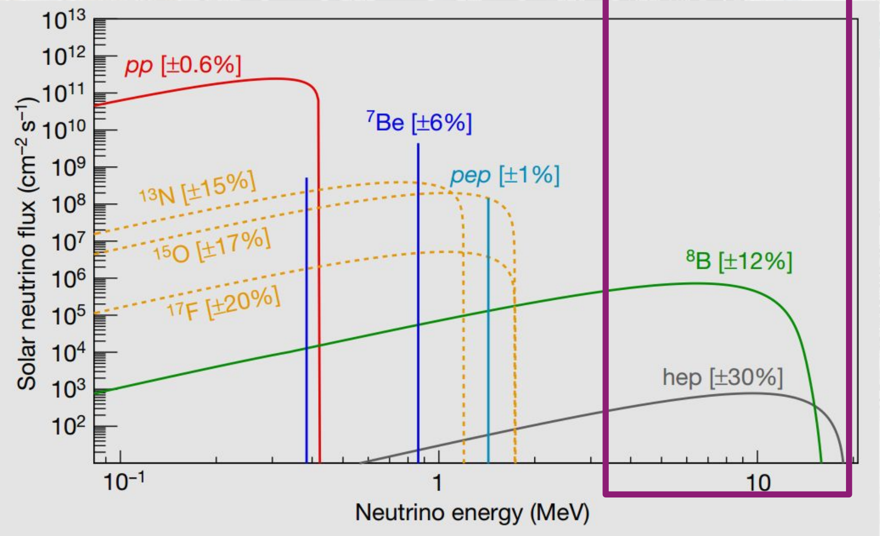
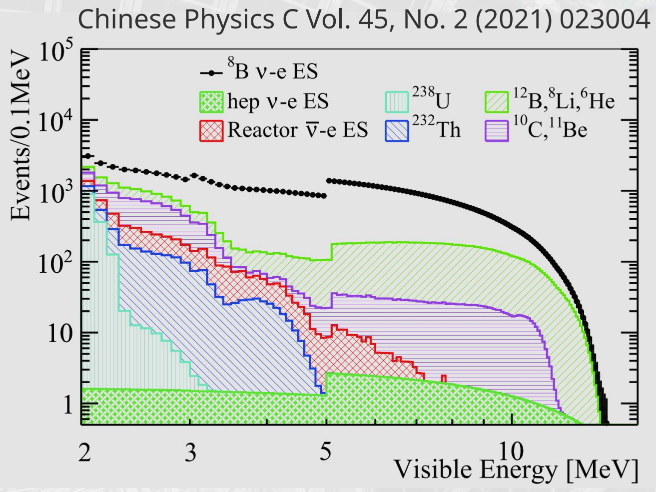


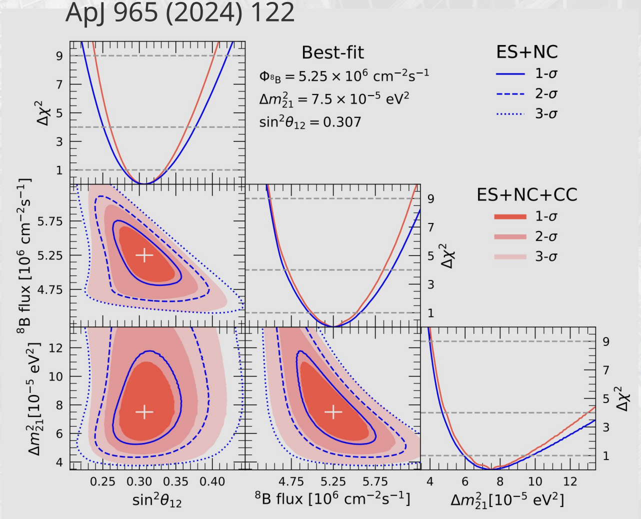


- ^{7}Be and *pep* neutrino flux uncertainties may be significantly improved w.r.t. current precision levels after a few years of data taking in all background scenarios
- CNO neutrino flux precision may exceed current precision at ~6 years levels with a *pep*-constraint, given sufficient background control

Solar neutrinos: high energy

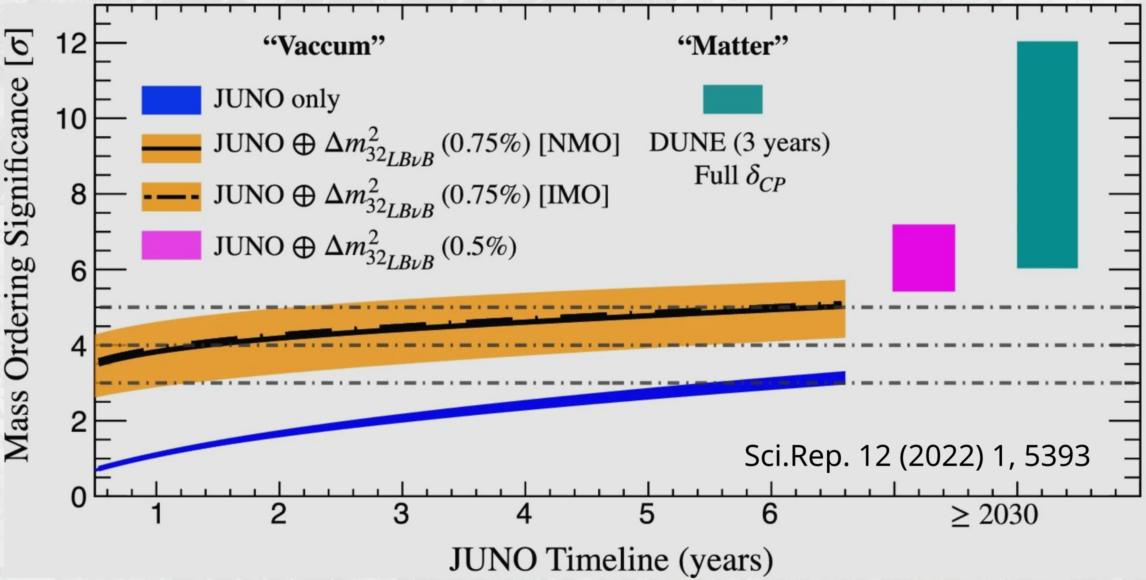






- Simultaneous measurement of ^{8}B solar neutrinos, Δm^2_{21}, and $\sin^2\theta_{12}$
- ^{8}B flux can be measured with ~5% precision using ES+NC+CC channels in 10 years. $\sin^2\theta_{12}$: 8%, Δm^2_{21} : 20%

NMO sensitivity with other experiments



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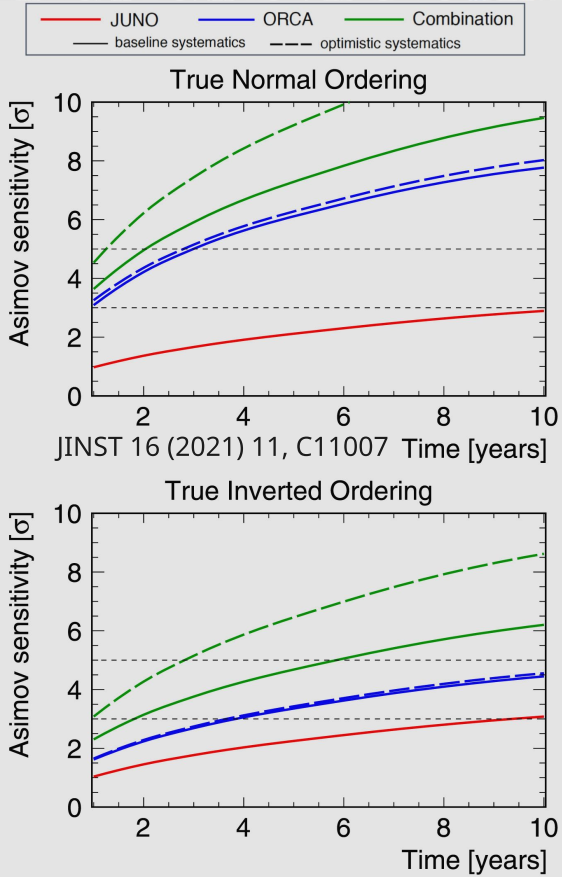

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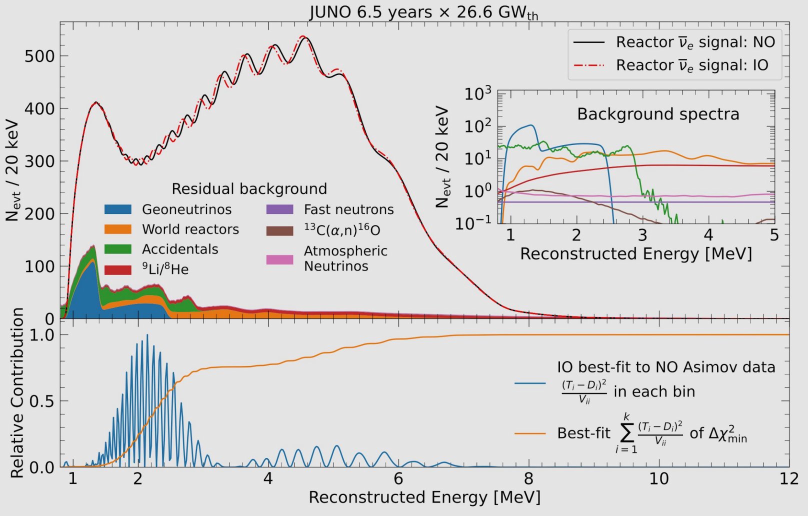
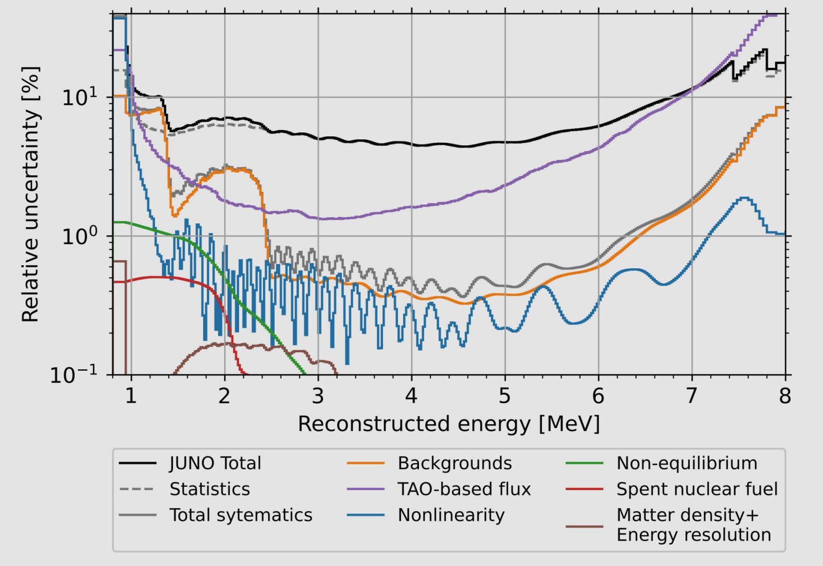
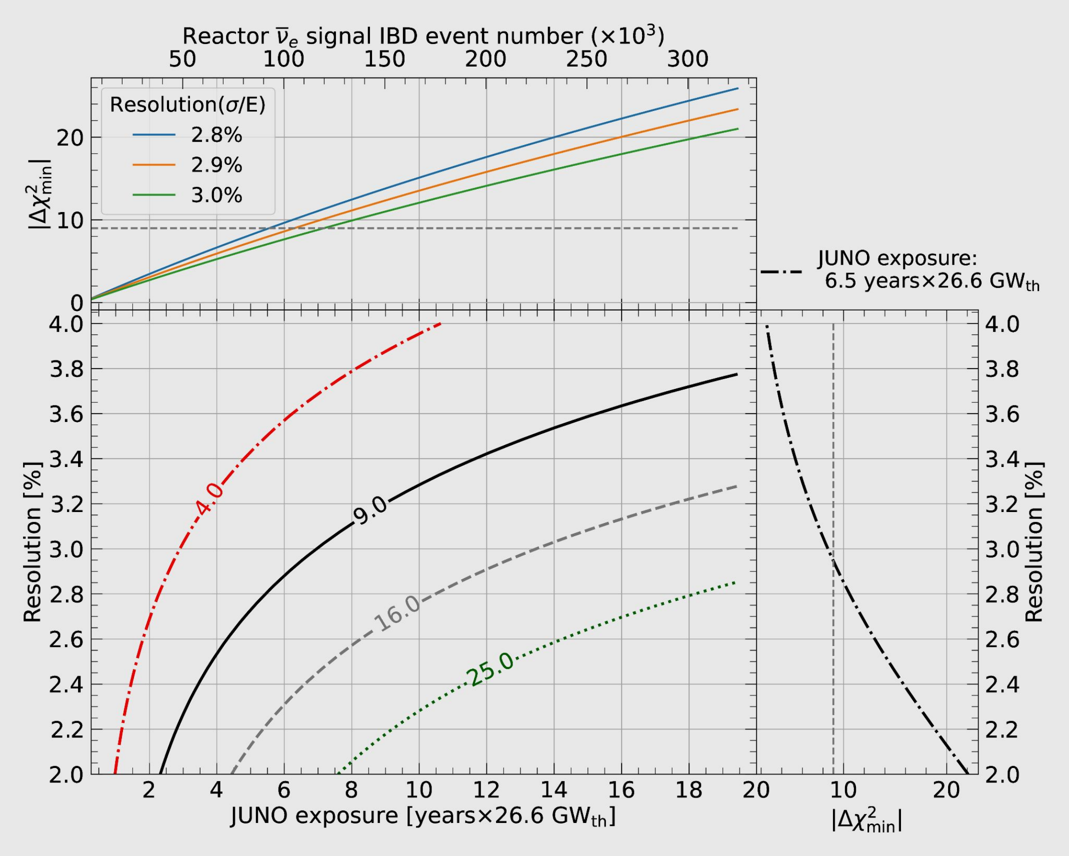
NMO sensitivity





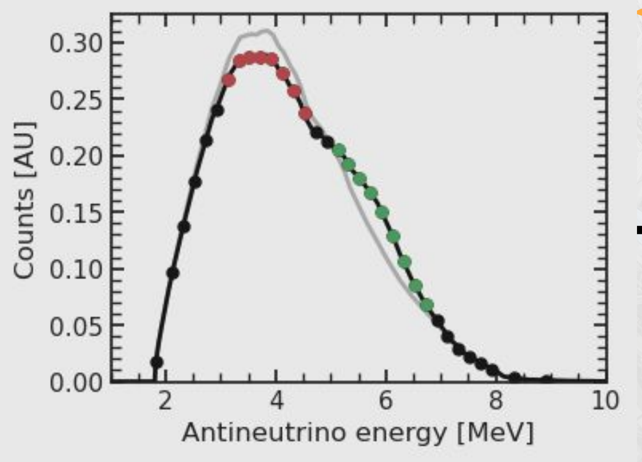
NMO vs energy resolution



Unoscillated spectrum

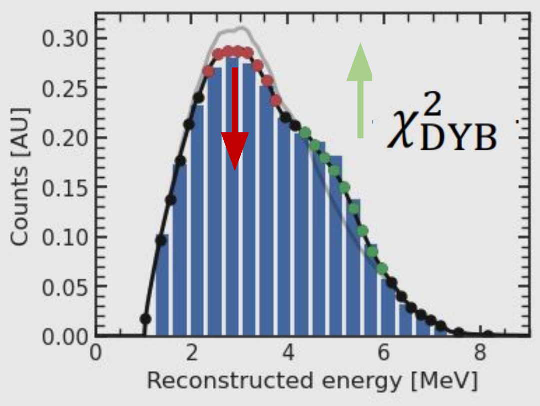
χ^2_{DYB} info

Shared reactor model

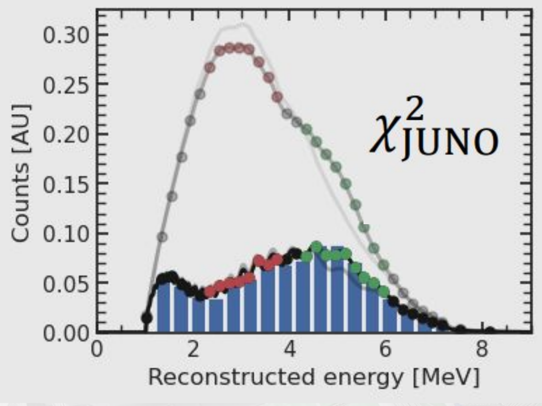


Daya Bay response

JUNO response



Daya Bay data

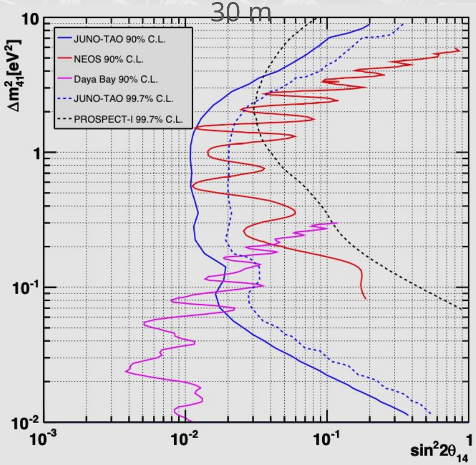


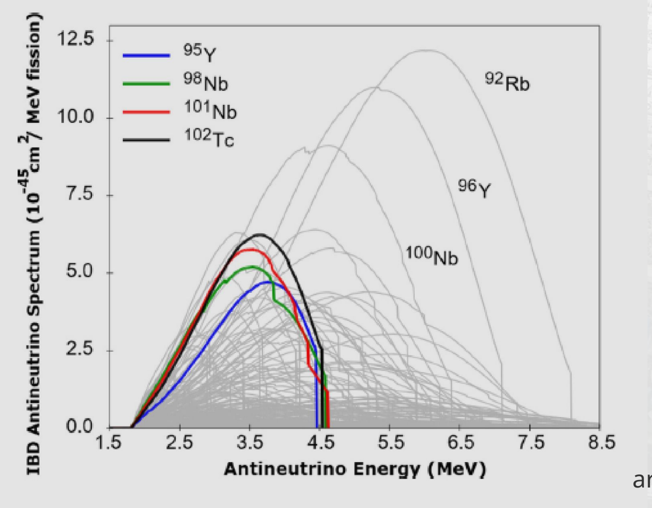
JUNO data

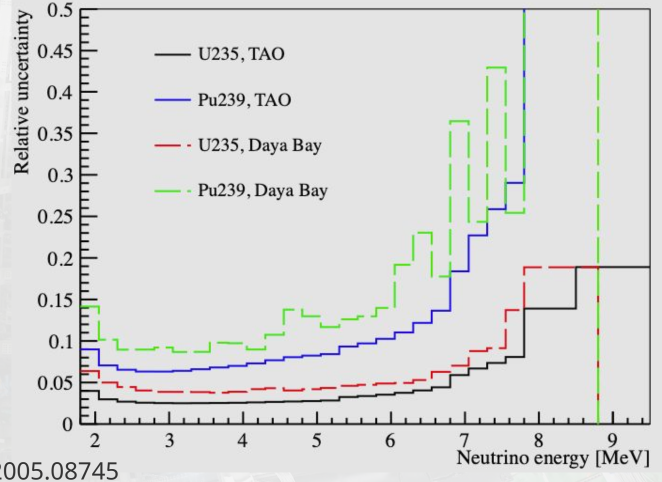
Physics with JUNO+TAO

Note: needs to be re-assessed with new TAO baseline of 44 m instead of 30 m

- See fine structure due to Coulomb corrections
- Serve as benchmark for JUNO, other experiments, and nuclear databases
- Search for sterile neutrinos
- Study reactor neutrino flux and spectrum shape with fuel composition evolution & decompose isotopic spectra







arXiv:2005.08745