JUNO – Status and First Results

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On behalf of the JUNO Collaboration

Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

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Jiangmen Underground Neutrino Observatory (JUNO)

Designed as a **reactor neutrino** experiment to determine the **mass ordering**

Sloped tunnel

1266 m, 23°

Vertical shaft

564 m

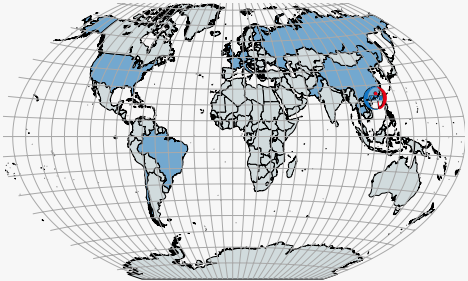
650 m overburden

$R_\mu \sim 0.004\,\mathrm{Hz/m^2}$

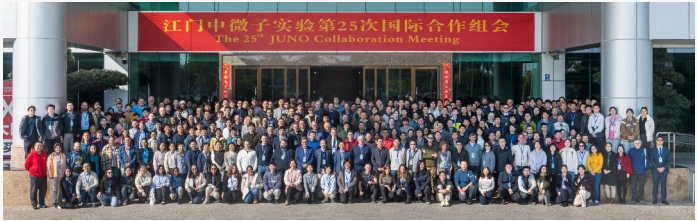
- Approved in 2013
- Construction 2015-2024
- Data taking since August 2025

20 kton LS detector

JUNO Collaboration



- 73 institutions
- 17 countries/regions
- $\sim$ 700 collaborators

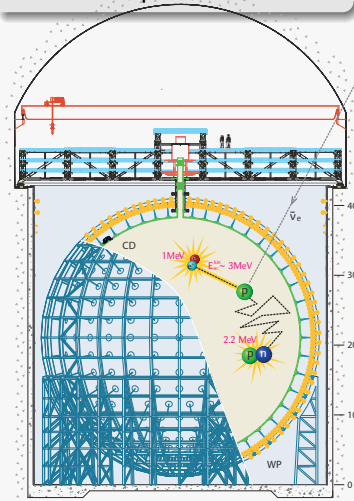


Working on a rich physics program

- **Reactor neutrinos** $\rightarrow$ mass ordering
- Solar neutrinos
- Supernova neutrinos, DSNB
- Atmospheric neutrinos
- Geoneutrinos
- Exotic searches, proton decay

Reactor Neutrinos at JUNO

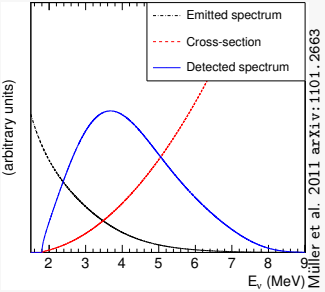
20 kton liquid scintillator



Inverse beta decay

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

- Prompt signal: e^+-annihilation
  $$E_p = E_{\bar{\nu}_e} - 0.784\,\text{MeV}$$
- Delayed signal: n-capture
  $$\sim 200\,\mu\text{s},\ 2.2\,\text{MeV}$$



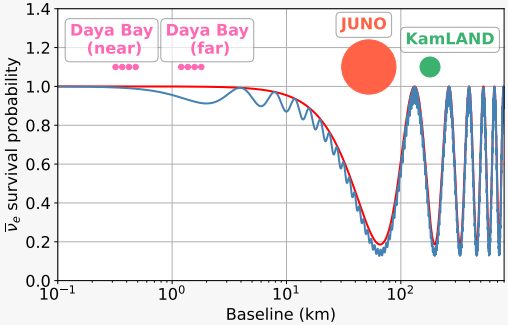
$\bar{\nu}_e$ Source

2 NPP at equal distance
Baseline 52.5 km
Thermal power 26.6 GW
Taishan 9.2 GW
Yangjiang 17.4 GW

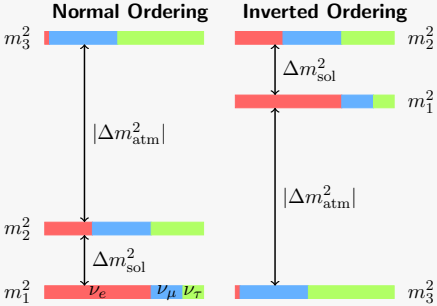
Reactor $\bar{\nu}_e$-Oscillations

$$P_{\bar{\nu}_e \to \bar{\nu}_e} = 1 - \sin^2 2\theta_{13}(\cos^2\theta_{12}\sin^2\Delta_{31} + \sin^2\theta_{12}\sin^2\Delta_{32}) - \cos^4\theta_{13}\sin^2 2\theta_{12}\sin^2\Delta_{21}$$

$$\Delta_{ij} = \Delta m^2_{ij} L/(4E)$$



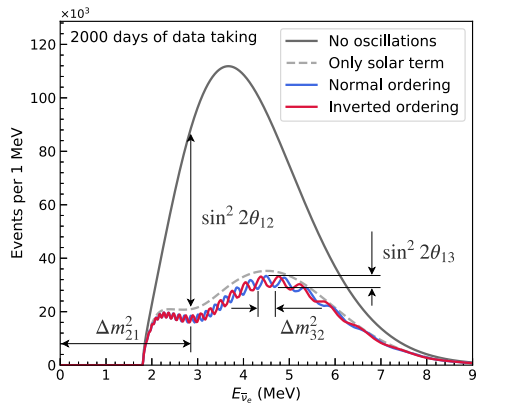
- slow **solar** mode: $\sin^2\theta_{12}$, Δm^2_{21}
- fast **atmospheric** mode: Δm^2_{31}



- Normal Ordering: $\Delta m^2_{31} > 0$
- Inverted Ordering: $\Delta m^2_{31} < 0$

▷ $\Delta_{32} = \Delta_{31} - \Delta_{21}$

Precision Measurements



Requirements

- High statistics ($\sim 10^5$ events in 6 years)
  - Large LS target
- Energy resolution: $\sim 3\%@1\,\text{MeV}$
  - High LS light yield and transparency
  - High PMT coverage and efficiency
- Energy scale uncertainty $< 1\%$
  - Calibration systems

- Near detector for precise measurement of reactor antineutrino spectrum (TAO)

- First experiment to observe both atmospheric and solar oscillations
- Access to $\sin^2\theta_{12}$, $\sin^2\theta_{13}$, Δm^2_{21} and Δm^2_{31}, independent of δ_{cp} and θ_{23}

JUNO Detector

Top Tracker

3 plastic scintillator layers

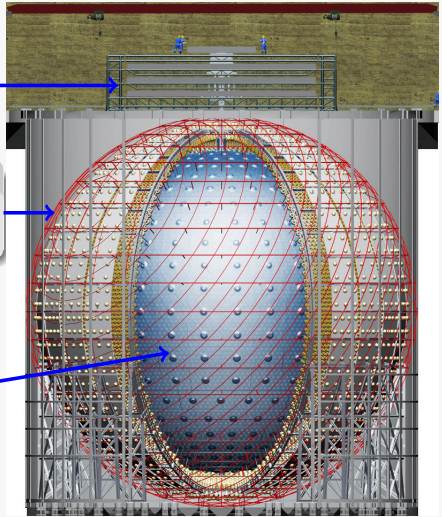
Central Detector

Acrylic vessel, $r = 17.7\,\mathrm{m}$
$20\,\mathrm{kton}$ LS target:
LAB + $2.5\,\mathrm{g/L}$ PPO + $3\,\mathrm{mg/L}$ bis-MSB
17612 20" PMTs
25600 3" PMTs

Water Pool

$35\,\mathrm{kton}$ ultrapure water
2400 $20\,\mathrm{inch}$ PMTs

78% photo-coverage

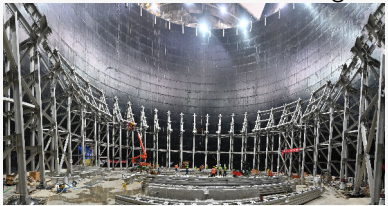


Building the Detector

2013: Project start

2015:
Start of civil construction

2022: Detector installation begins

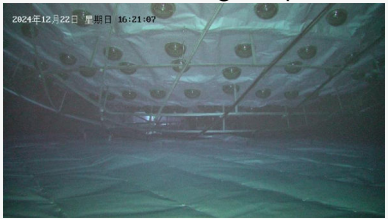


Dec 18 2024: Water filling starts

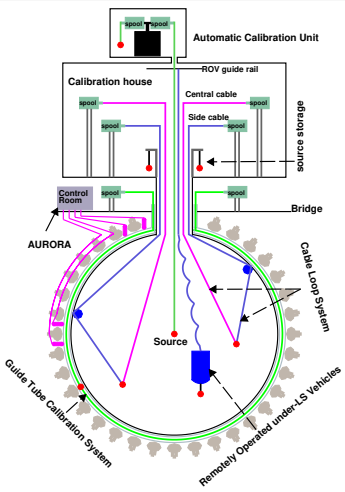
August 2025: End of LS filling

Dec 2024: Installation complete

Feb 1st 2025: Filling complete



Calibration



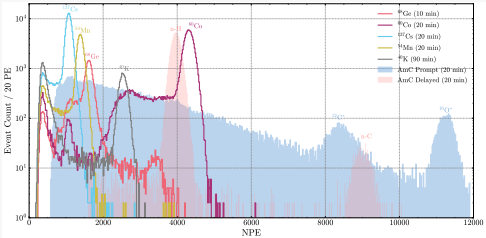
arXiv:2104.02565

Intensive calibration campaign

- Multiple sources
- Laser
- Natural radioactivity

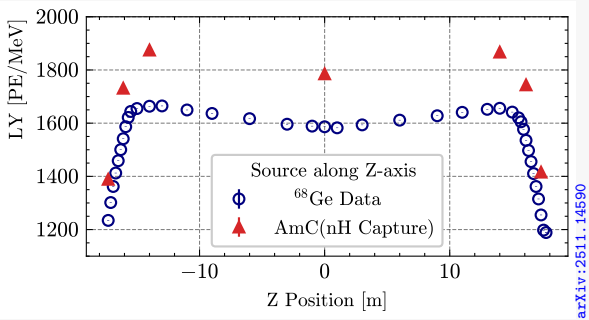
Calibration sources

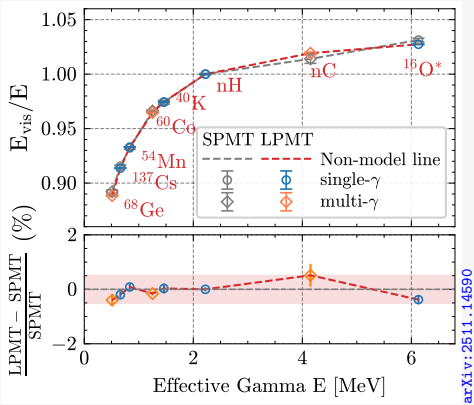
^{68}Ge, ^{137}Cs, ^{54}Mn, ^{60}Co, ^{40}K, ^{241}AmC



arXiv:2511.14590

Initial Performance

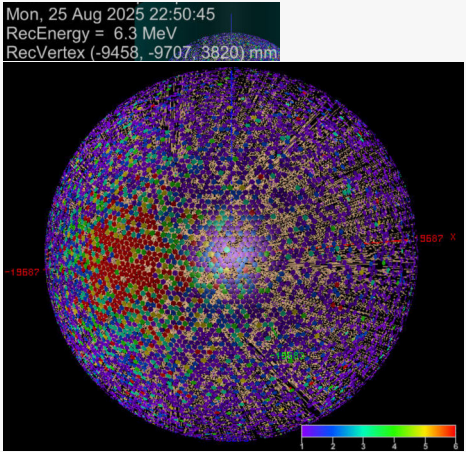


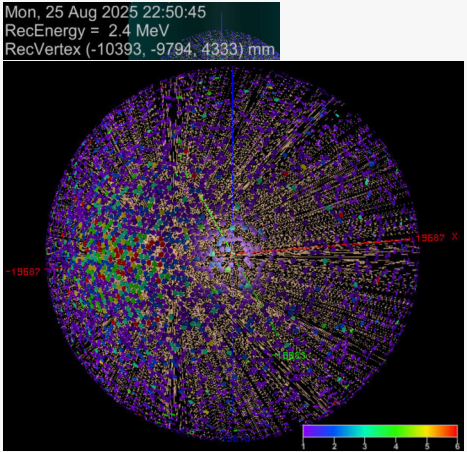


- 1600 PE/MeV with ^{68}Ge
- 1780 PE/MeV for nH capture
- Better light yield than expected
- Energy resolution $\sim 3.4\,\%$ for ^{68}Ge

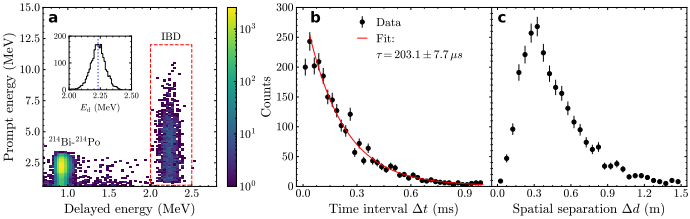
- Energy non-linearity characterized to better than 1%

First IBD Event



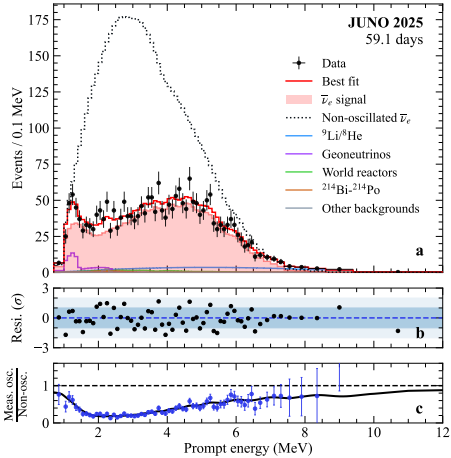


IBD Selection and Antineutrino Spectrum



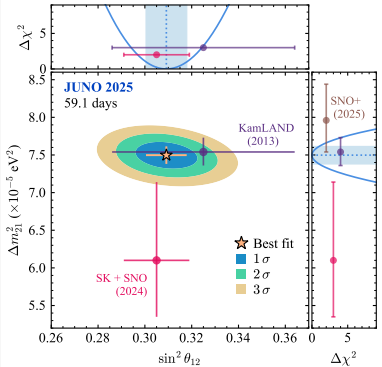
Antineutrinos ($\overline{\nu}_e$) Candidates Summary		
DAQ live time (days)	59.1	
$\overline{\nu}_e$ candidates	2379	
Selection Efficiencies (%)	ε	σ_{rel}
Fiducial volume	80.6	1.6
PMT flasher rejection	>99.9	negligible
μ veto	93.6	negligible
Multiplicity	97.4	negligible
Prompt-delayed coinc.	95.1	0.13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

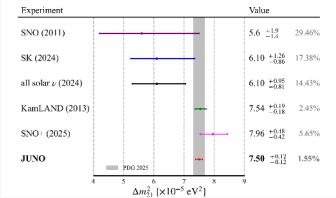
- 59.1 days of good data
- First results released in November

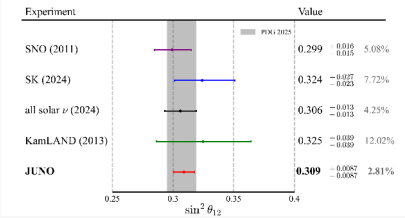


arXiv:2511.14593

Oscillation Parameters after 59 Days







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

$$\Delta m^2_{12} = (7.50 \pm 0.12) \times 10^{-5}\,\mathrm{eV}^2$$

- JUNO reaches world's best precision in $\sin^2\theta_{12}$ and Δm^2_{21} in 59.1 days
- Good agreement with previous results, improvement of precision by a factor of 1.6

arXiv:2511.14593

Summary and Outlook

- JUNO has successfully started data taking
- Most precise measurements of $\sin^2\theta_{12}$ and Δm^2_{21} have been released after 59.1 days of data taking
  - Factor 1.6 improvement
  - Excellent detector performance
- JUNO-TAO will further improve knowledge of reference $\bar{\nu}_e$-spectrum
- Rich neutrino program, also beyond reactor neutrinos
  - Mass ordering and oscillation parameters
  - Solar, supernova, atmospheric, geoneutrinos and other