



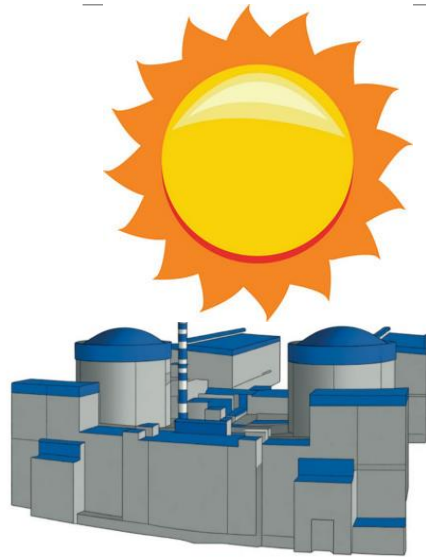
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Neutrino experiment JUNO and its first results

Tomáš Tměj

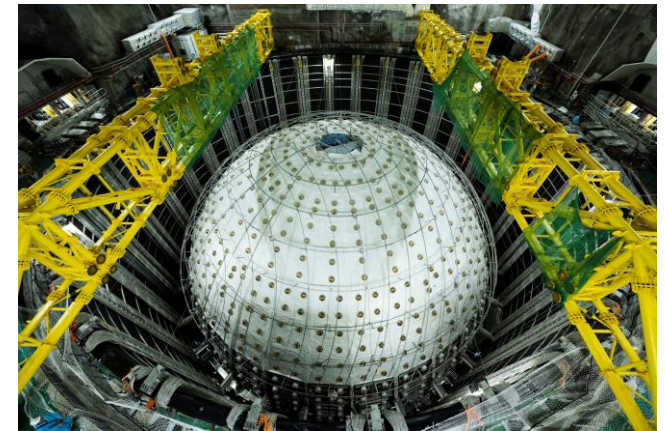
Neutrino oscillation



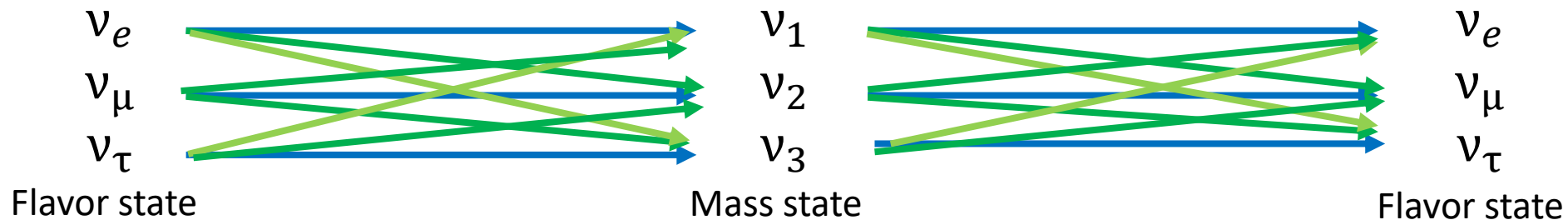
neutrinos are generated



neutrinos propagate through space



neutrinos are detected

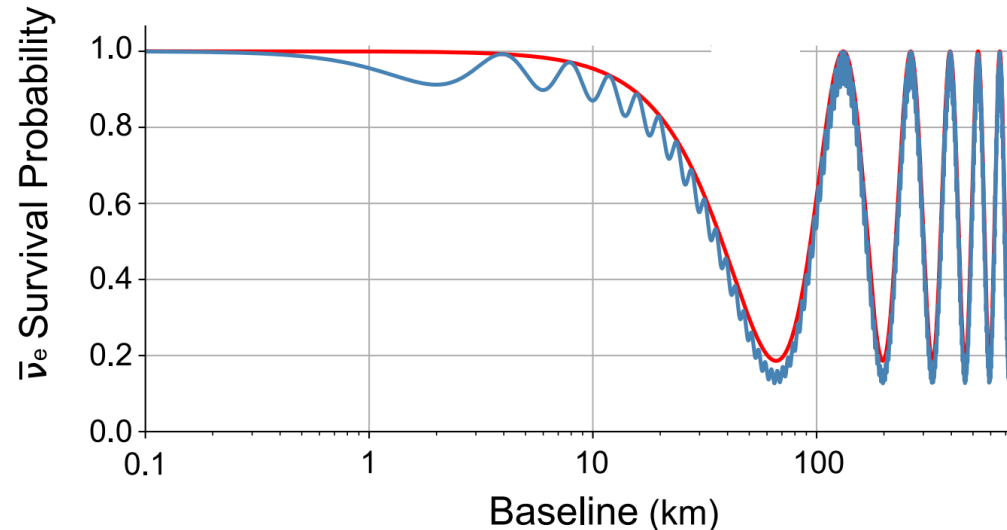
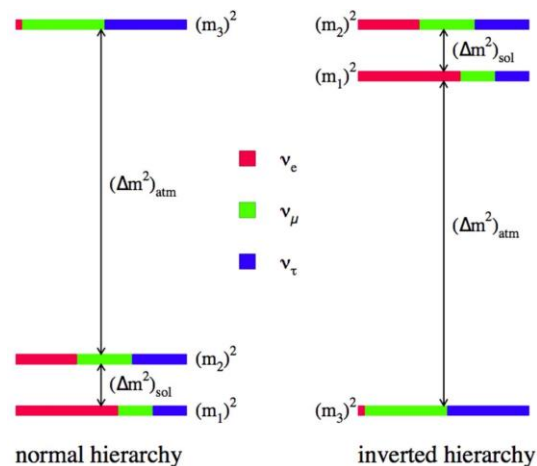


Neutrino oscillation

- Described by U_{PMNS} matrix
- Probability depends on $\frac{L}{E}$, $|\Delta m_{ij}^2|$
- Mass hierarchy?

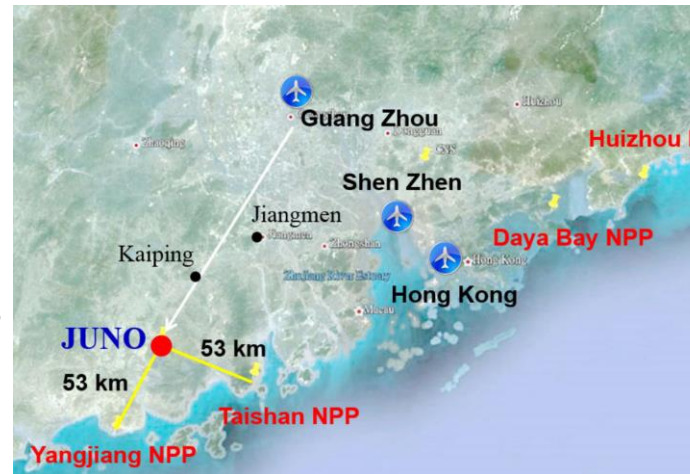
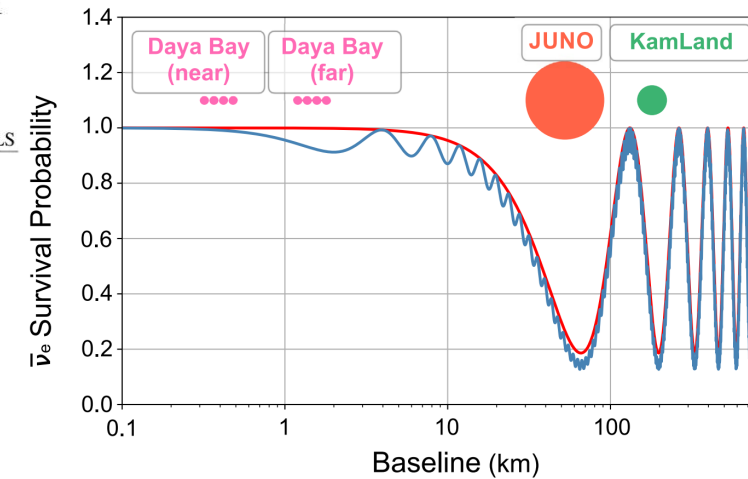
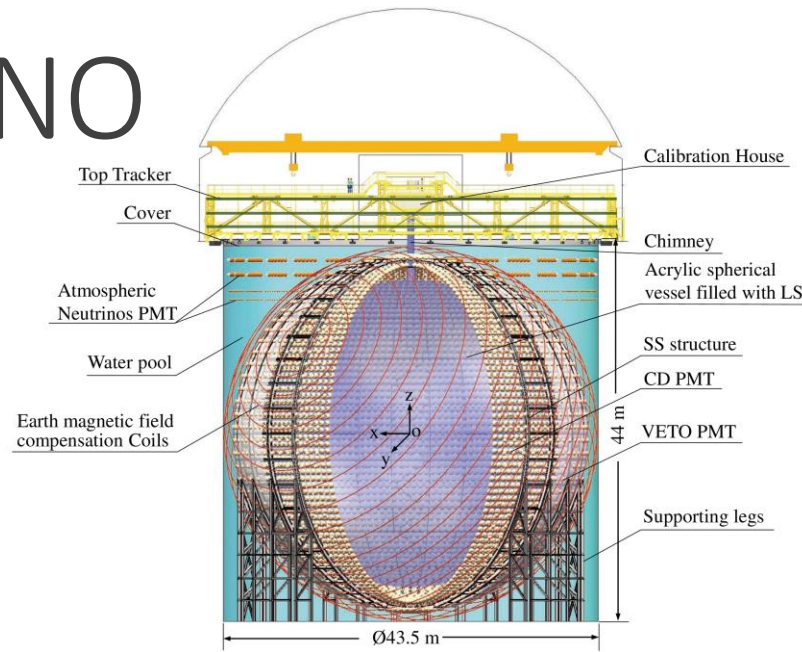
$$U_{PMNS} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & c_{23} & s_{23} \\ 0 & -s_{23} & c_{23} \end{pmatrix} \begin{pmatrix} c_{13} & 0 & s_{13} e^{-i\delta} \\ 0 & 1 & 0 \\ -s_{13} e^{i\delta} & 0 & c_{13} \end{pmatrix} \begin{pmatrix} c_{12} & s_{12} & 0 \\ -s_{12} & c_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

$$P_{ee}(L, E) = 1 - \sin^2(2\theta_{12}) c_{13}^4 \sin^2\left(\frac{|m_2^2 - m_1^2| L}{4E}\right) - \sin^2(2\theta_{13}) \left[c_{12}^2 \sin^2\left(\frac{|m_3^2 - m_1^2| L}{4E}\right) + s_{12}^2 \sin^2\left(\frac{|m_3^2 - m_2^2| L}{4E}\right) \right]$$



Experiment JUNO

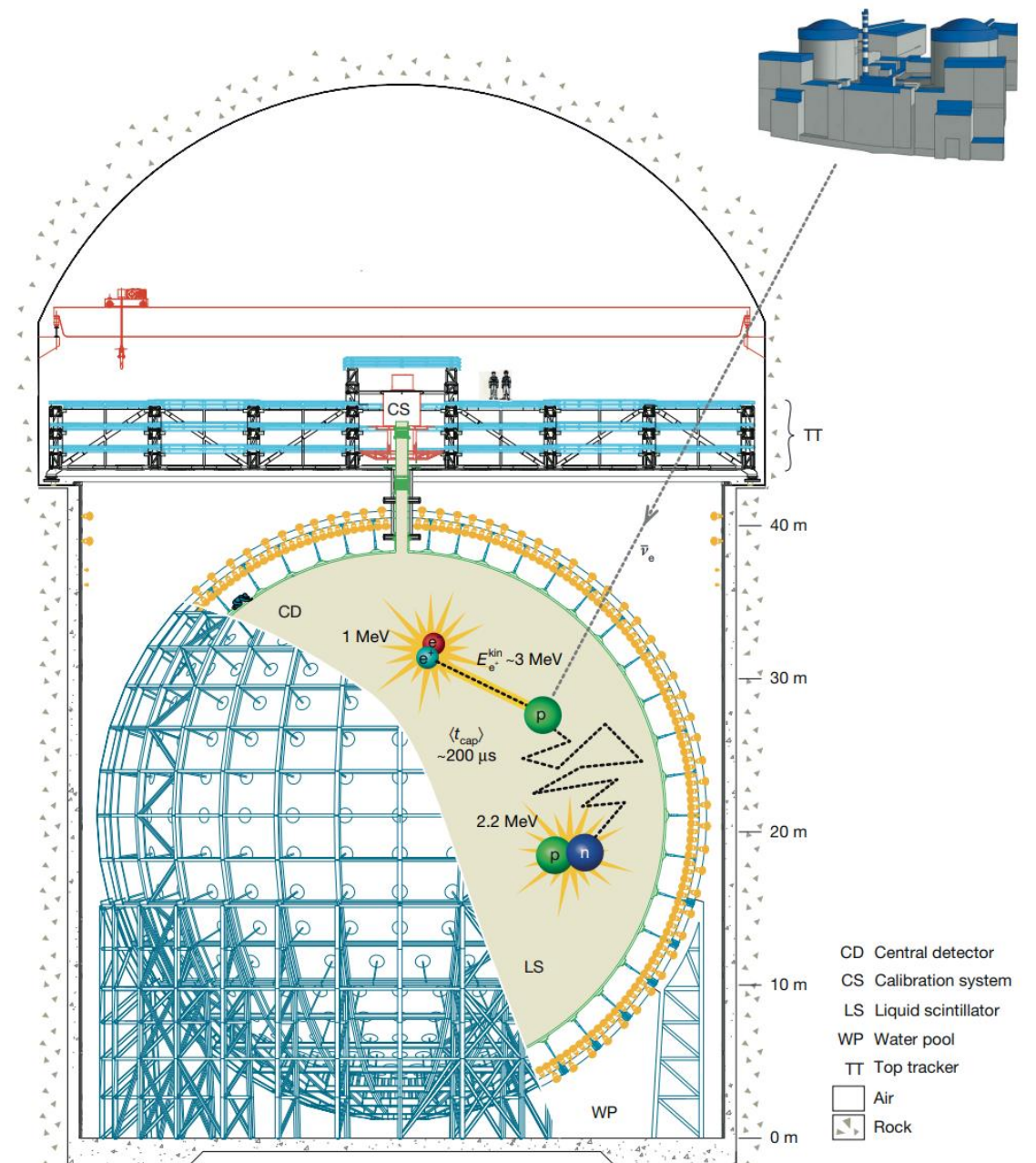
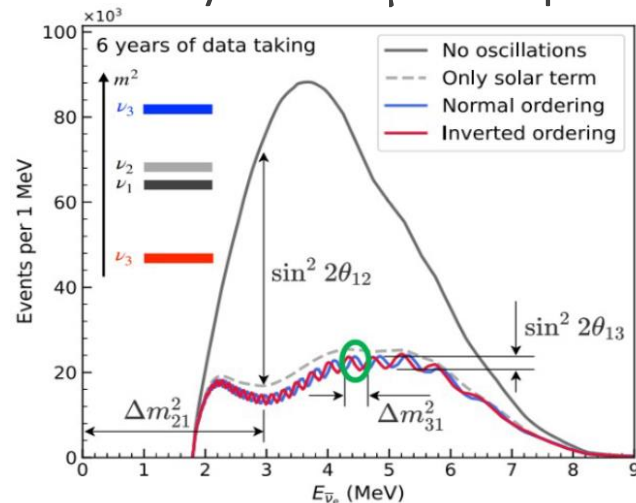
- Collaboration of 67 institutions, 717 people
- 700 m underground
- 20 kton liquid scintillator
- 17 596 20-inch PMTs
- 25 587 3-inch PMTs
- Veto and calibration systems
- 2 nuclear power plants 53 km away
 - Planned overall thermal power 36 GW
 - One power plant is not completed yet
 - Current overall thermal power 27 GW
- Other subsystems
 - JUNO Tao (near detector)
 - OSIRIS
- Example of its goals
 - Neutrino mass hierarchy
 - Precise measurement of the oscillation parameters



Experiment JUNO

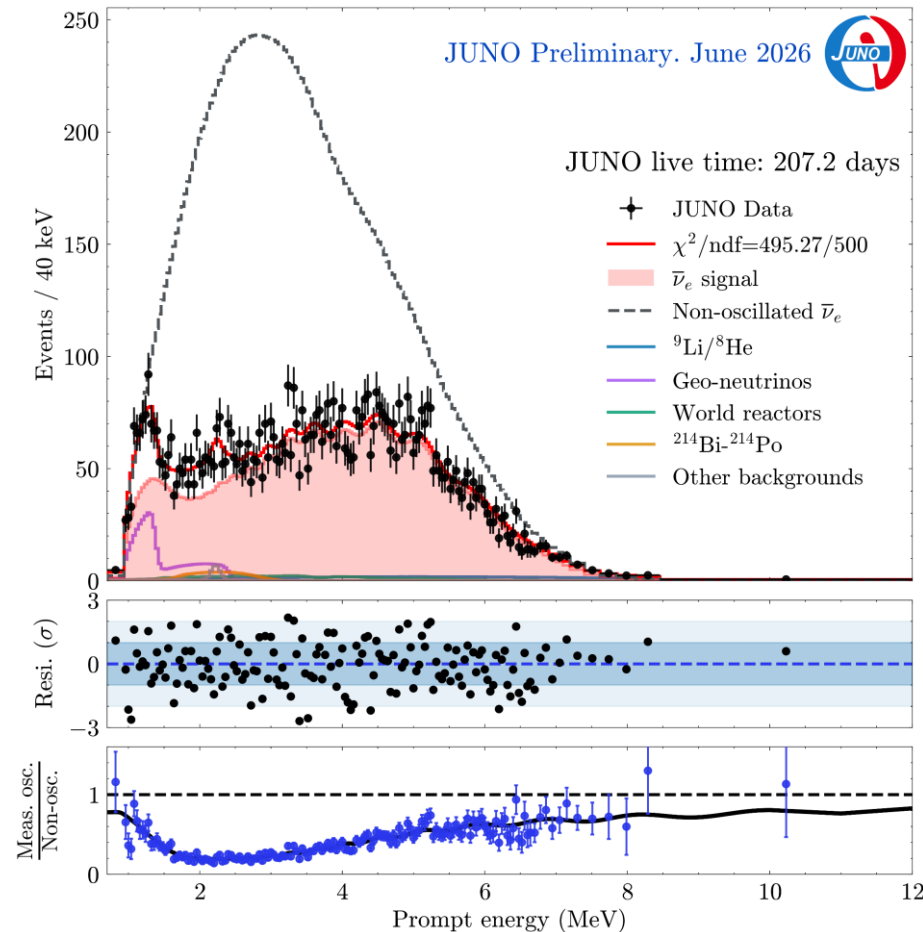
- An antineutrino is caught by inverse beta decay

$$\bar{\nu}_e + p \rightarrow e^+ + n$$
- The positron slows down and disperses its energy into the scintillator and annihilates with an electron
- The neutron with delay of 200 μs is captured by a proton



Reactor neutrino spectrum

- Taking data since August 2025
- Now: Results for 207 days of measurement
- Already published: Results for 59 days of measurement



Antineutrinos ($\bar{\nu}_e$) Candidates Summary		
DAQ live time (days)	207.2	
$\bar{\nu}_e$ candidates	8294	
Selection Efficiencies (%)	ϵ	σ_{rel}
Fiducial volume	87.12%	0.96%
PMT flasher rejection	> 99.9%	Negligible
μ veto	93.67%	0.02%
Multiplicity cut	95.94%	negligible
Prompt-delayed coinc.	95.50%	0.32%
Correlated discriminator	98.99%	0.15%
Total efficiency (ϵ_{tot})	74.01%	1.02%
$\bar{\nu}_e$ signal (cpd)		
w/o ϵ_{tot} corrected	36.02 ± 0.62	
w/ ϵ_{tot} corrected	48.67 ± 1.08	
Backgrounds (cpd)	Pre-fit	Best-fit
$^9\text{Li}/^8\text{He}$	1.05 ± 0.27	1.41 ± 0.26
Geoneutrinos	Free	2.12
World reactors	0.92 ± 0.09	0.92 ± 0.09
$^{214}\text{Bi}-^{214}\text{Po}$	0.42 ± 0.31	0.57 ± 0.34
$^{13}\text{C}(\alpha, n)^{16}\text{O}$	0.05 ± 0.02	0.05 ± 0.02
Fast neutrons	0.02 ± 0.02	0.02 ± 0.02
Double neutrons	0.10 ± 0.10	0.13 ± 0.10
Atmospheric neutrinos	0.09 ± 0.04	0.11 ± 0.05
Accidentals	0.07 ± 0.01	0.07 ± 0.01

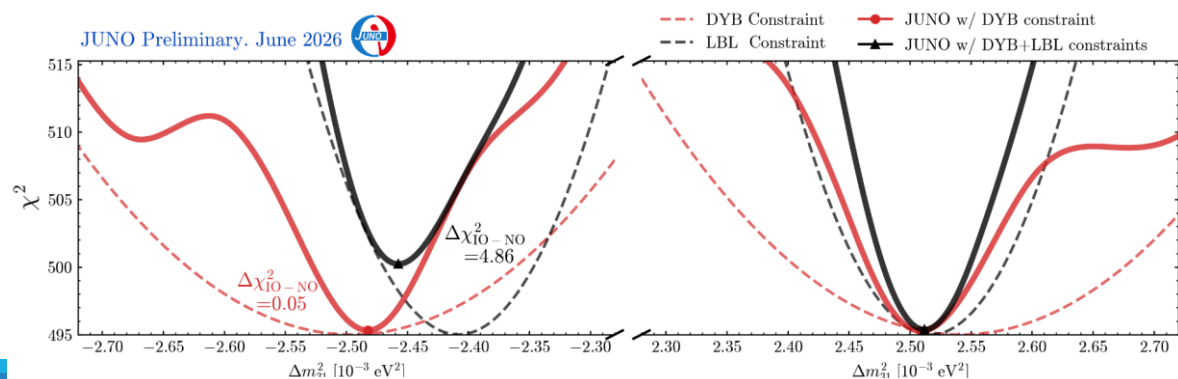
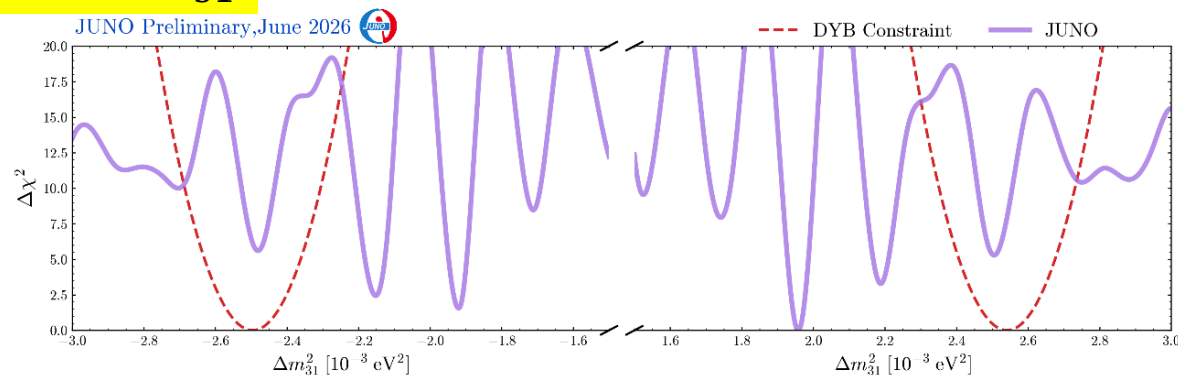
Measured mixing parameters

Improved: $\Delta m_{21}^2, \sin^2 \theta_{12}$

$$\Delta m_{21}^2 = (7,388 \pm 0,078) \times 10^{-5} \text{eV}^2 \quad (1,60\% \rightarrow 1,06\%)$$

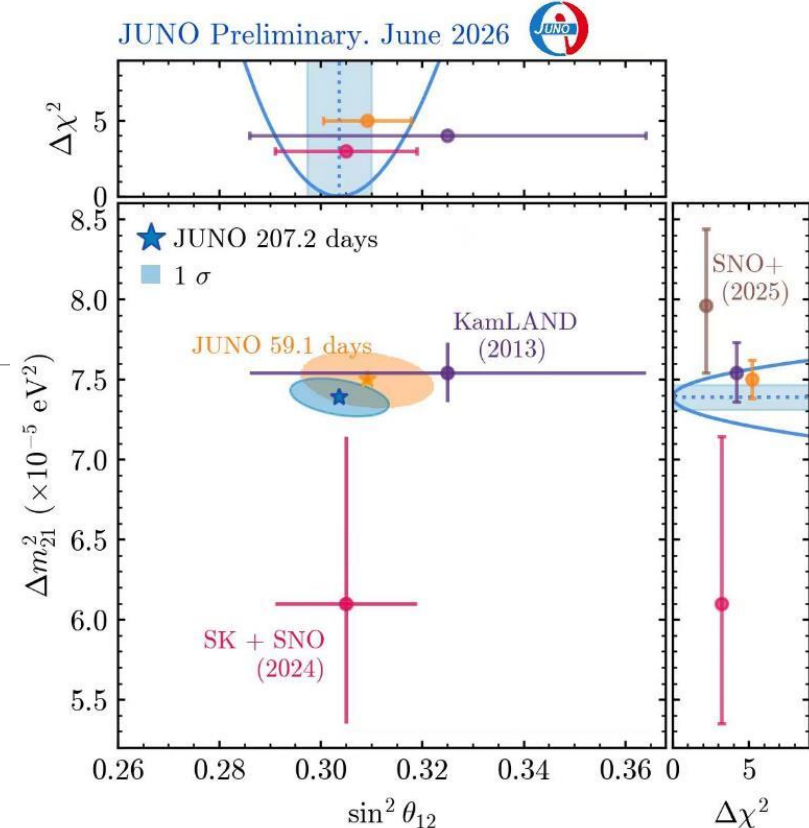
$$\sin^2 \theta_{12} = 0,3036 \pm 0,0064 \quad (2,8\% \rightarrow 2,1\%)$$

New: Δm_{31}^2

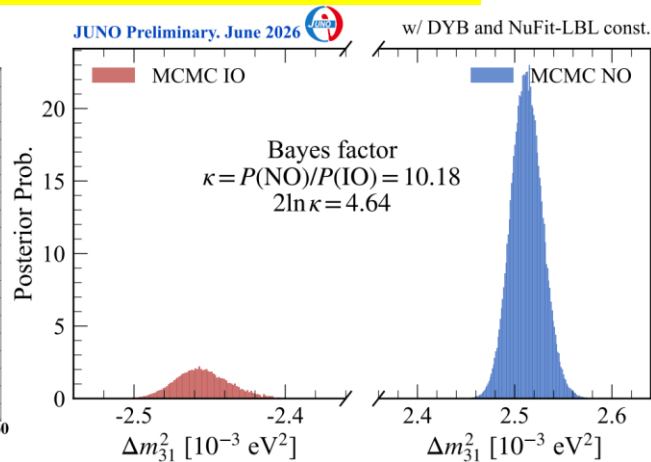
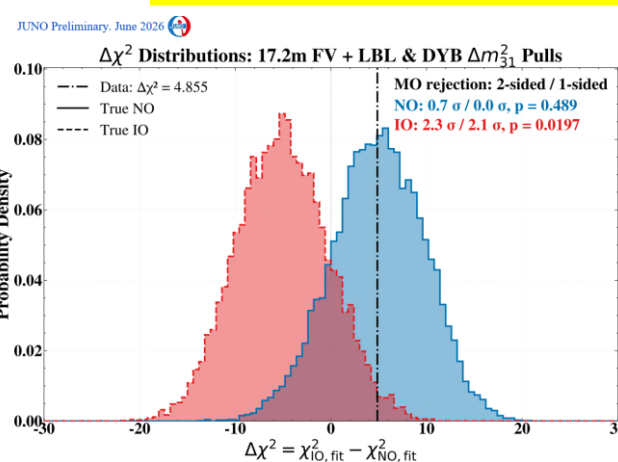


$$\Delta m_{31}^2 = (-2,482^{+0,025}_{-0,026}) \times 10^{-3} \text{eV}^2 \quad \Delta m_{31}^2 = (2,509^{+0,027}_{-0,025}) \times 10^{-3} \text{eV}^2$$

59 days 207 days



New: Normal mass ordering is favored by 2,3σ

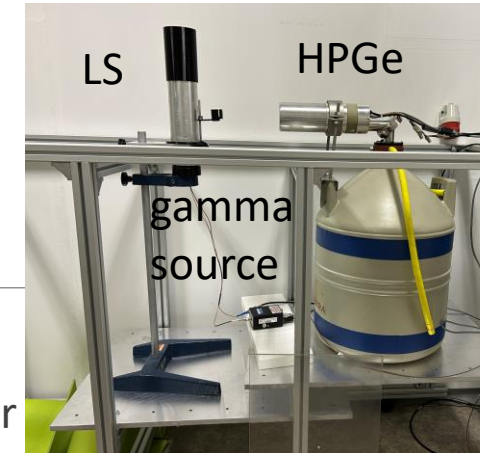


Our (Prague) contribution

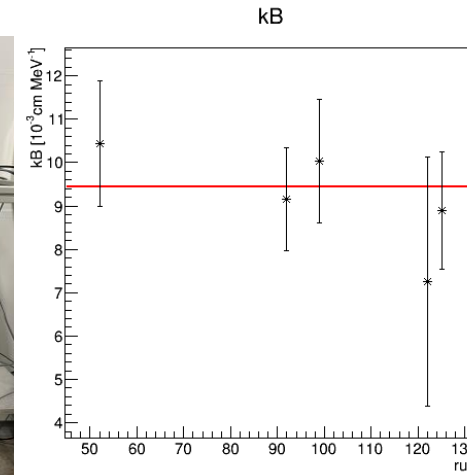
- Liquid scintillator nonlinearity measurement
 - Important for determination the deposited energy in the scintillator
 - Described by Birk's quenching constant kB
 - 6 different groups are working on it
 - 3 in laboratories, 3 using the Central detector data
 - Our (Prague) $kB = (9,4 \pm 0,7) \times 10^{-3} \frac{\text{cm}}{\text{Mev}}$
- LED flasher system in the water pool
 - Used for the water attenuation measurements at the bottom
 - Used for the time calibration of the PMTs in the Water pool

$$\frac{dL}{dx} = \frac{A}{1 + kB \frac{dE}{dx}} \frac{dE}{dx}$$

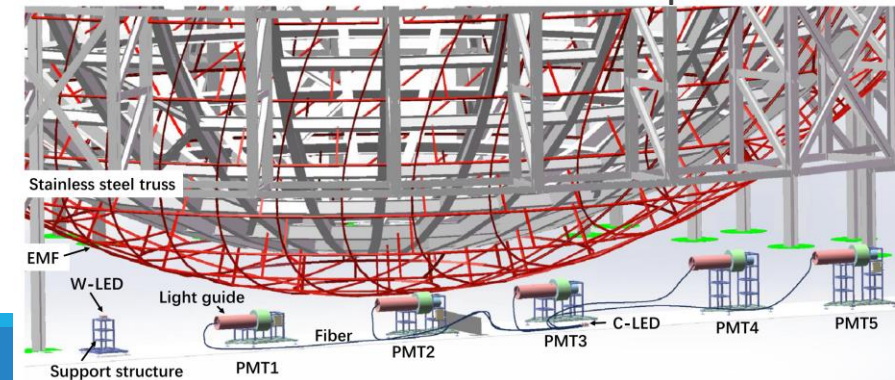
Birk's quenching formula



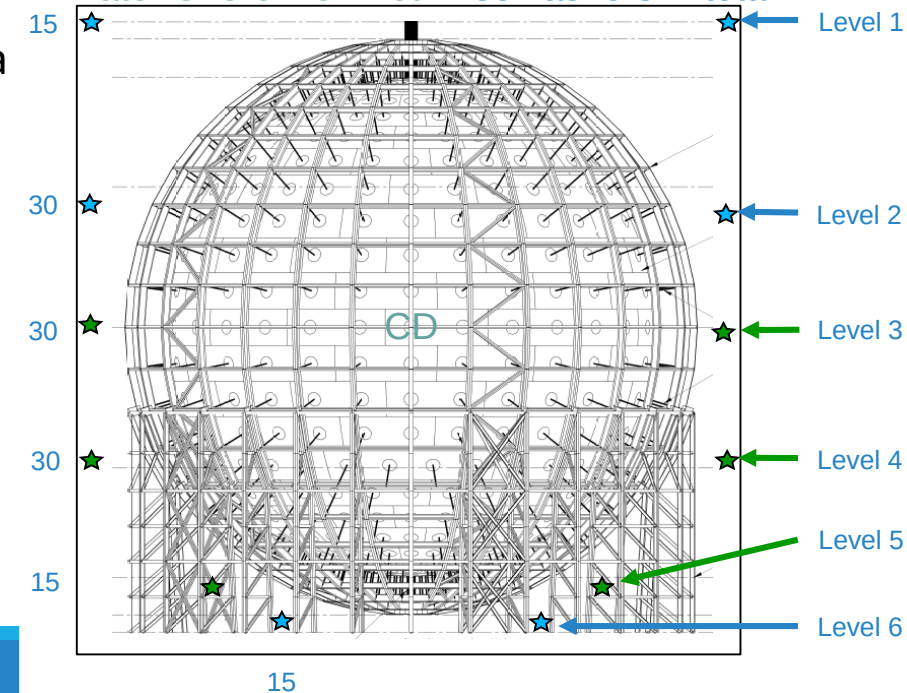
Prague laboratory setup



kB from different measurements



Water Cherenkov Det.: 135 flashers in total



Summary

- JUNO is a large underground neutrino observatory in southern China with a rich physics program
- JUNO is taking data since August 2025
- Neutrino oscillation is observed
- First updates of the parameters Δm_{21}^2 , $\sin^2 \theta_{12}$ and Δm_{31}^2
- Normal mass ordering is favored by $2,3\sigma$