JUNO Sensitivity to Neutrino Oscillation Parameters

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on behalf of the JUNO collaboration

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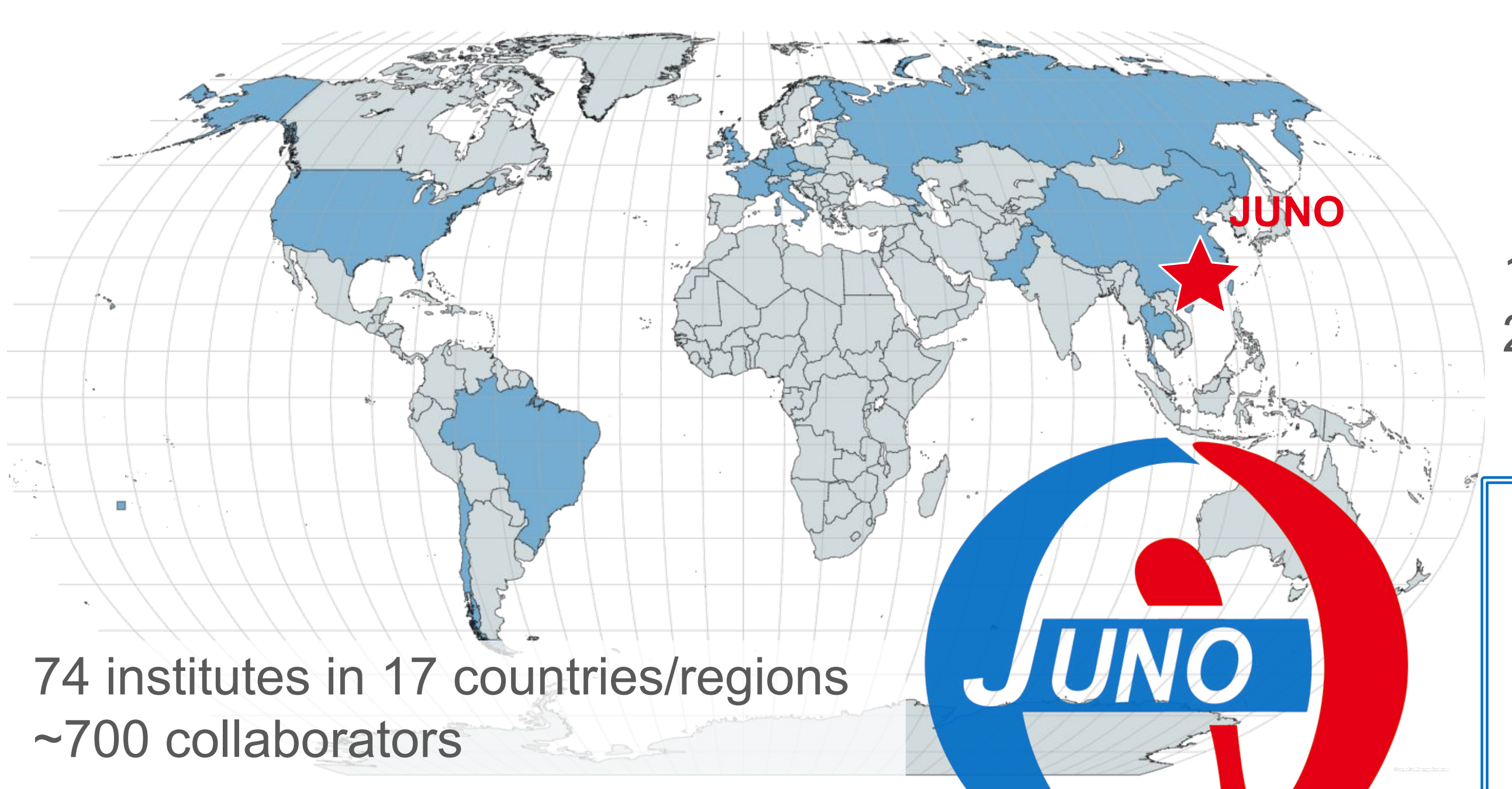
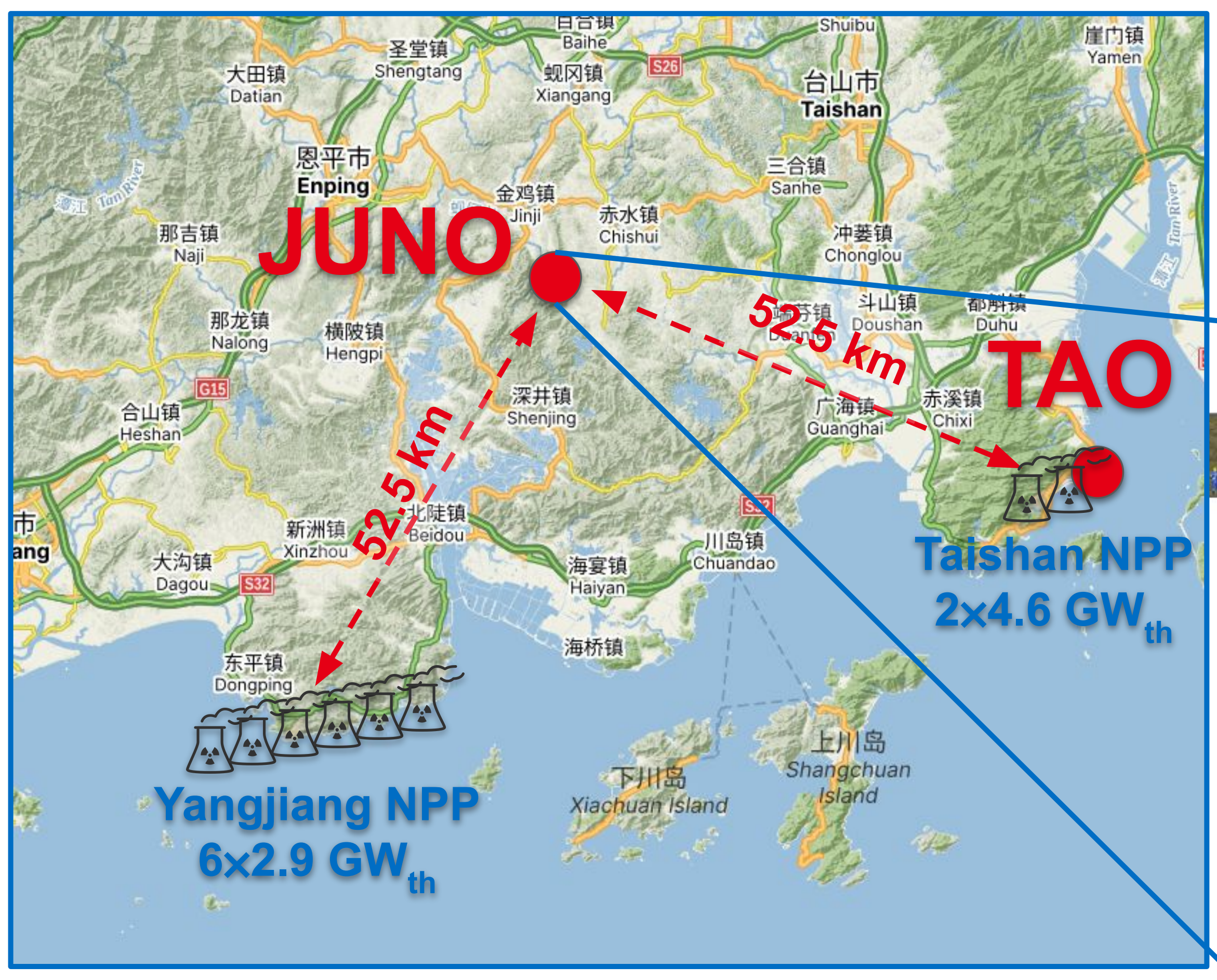


74 institutes in 17 countries/regions
~700 collaborators

A. Abusleme et al., **Sub-percent precision measurement of neutrino oscillation parameters with JUNO**, Chin. Phys. C 46 (2022)

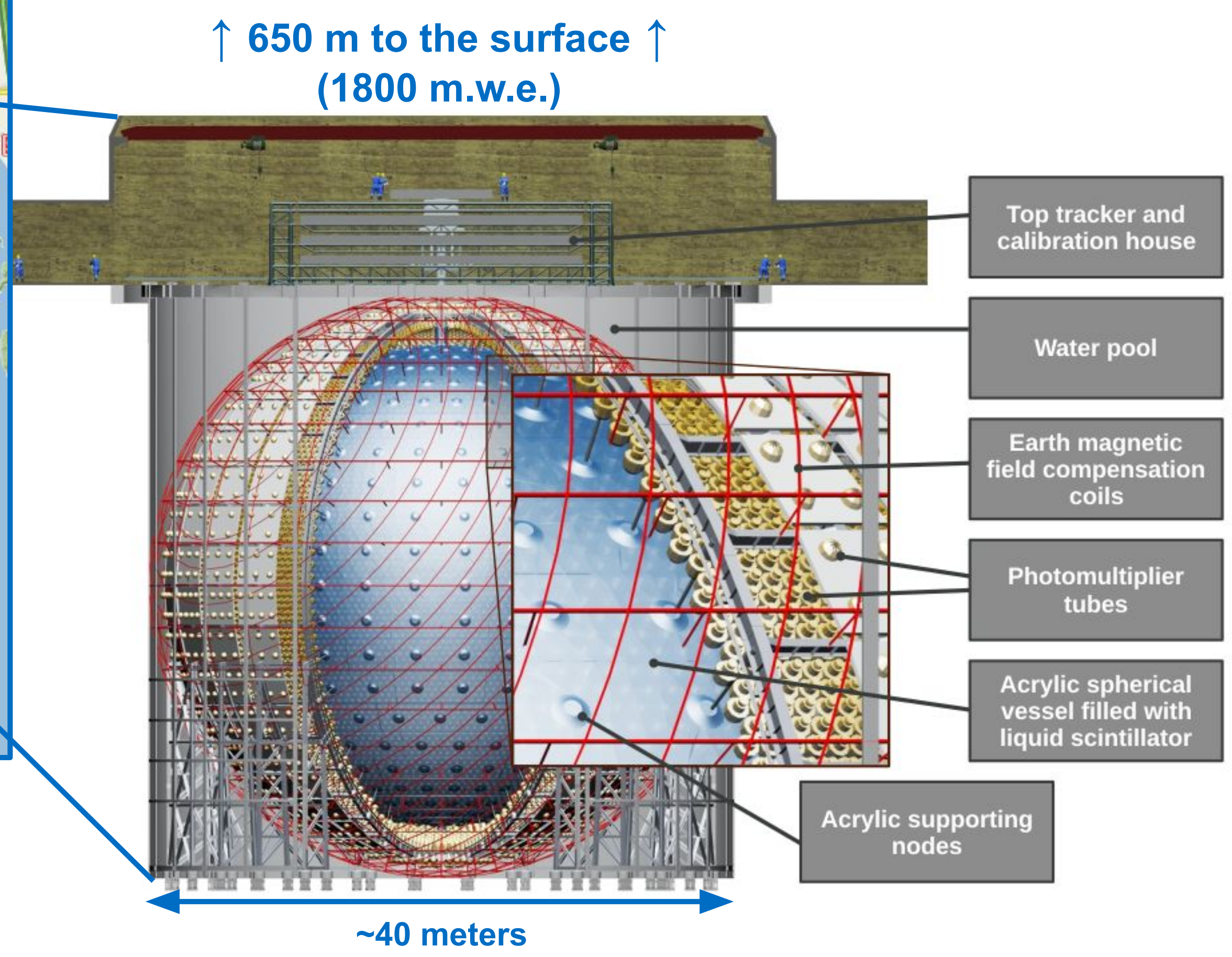
Jiangmen Underground Neutrino Observatory (JUNO) [1, 2], under construction in South China, is designed to resolve the neutrino mass ordering using the oscillatory pattern of the electron antineutrinos produced in nuclear reactor cores. With a baseline of 52.5 km and a fine energy resolution of 3% at 1 MeV, JUNO will allow for the observation of two neutrino oscillation modes simultaneously, collecting about 100,000 inverse beta decay events in six years with a 20 kton liquid scintillator target. This makes it possible to precisely measure the mixing angle θ_{12} and mass splittings Δm^2_{21} and Δm^2_{31} with unprecedented accuracy below 1%. The contribution covers details of the analysis and the final sensitivity results [3].

DETECTOR



52.5 km baseline is optimal for resolving NMO and advantageous for measuring Δm^2_{21}, Δm^2_{31}, and $\sin^2\theta_{12}$.

Determination of **Neutrino Mass Ordering** (NMO) is the main goal of JUNO and drives the design.



High statistics thanks to

- 20 kt liquid scintillator target
- 26.6 GW$_{th}$ total NPP power

~100,000 reactor anti-ν_e events in 6 years

Unprecedented energy resolution thanks to

- High light yield of liquid scintillator: ~10,000 photons / MeV
- High transparency of liquid scintillator: ~20 m attenuation length at 430 nm
- High photo-coverage: ~75% with 17,612 20'' PMTs (high PDE) ~3% with 25,600 3'' PMTs

3% at 1 MeV

ANALYSIS STRATEGY

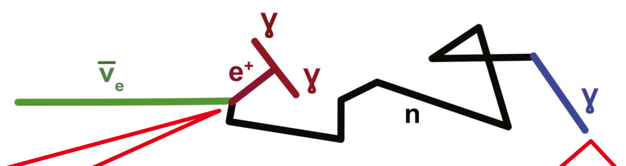
$$P_{\bar\nu_e\to\bar\nu_e} = 1 - \boxed{\cos^4\theta_{13}\sin^2 2\theta_{12}\sin^2\left(\frac{\Delta m^2_{21}L}{4E}\right)} - \boxed{\sin^2 2\theta_{13}\left[\cos^2\theta_{12}\sin^2\left(\frac{\Delta m^2_{31}L}{4E}\right)+\sin^2\theta_{12}\sin^2\left(\frac{\Delta m^2_{32}L}{4E}\right)\right]}$$

slow "solar" component

fast "atmospheric" component

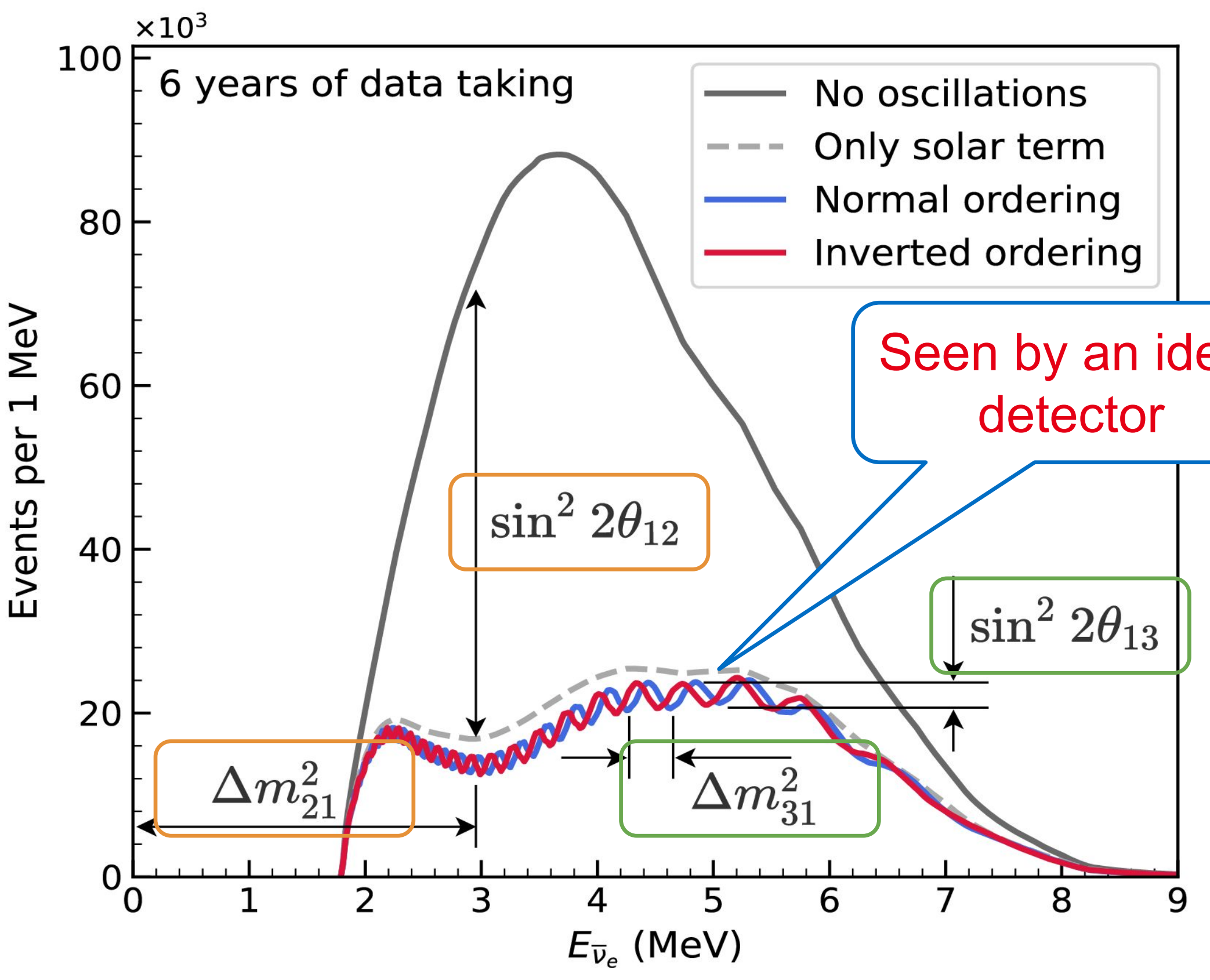
Detection channel: Inverse Beta-Decay (IBD)

$$\bar\nu_e + p \to e^+ + n$$

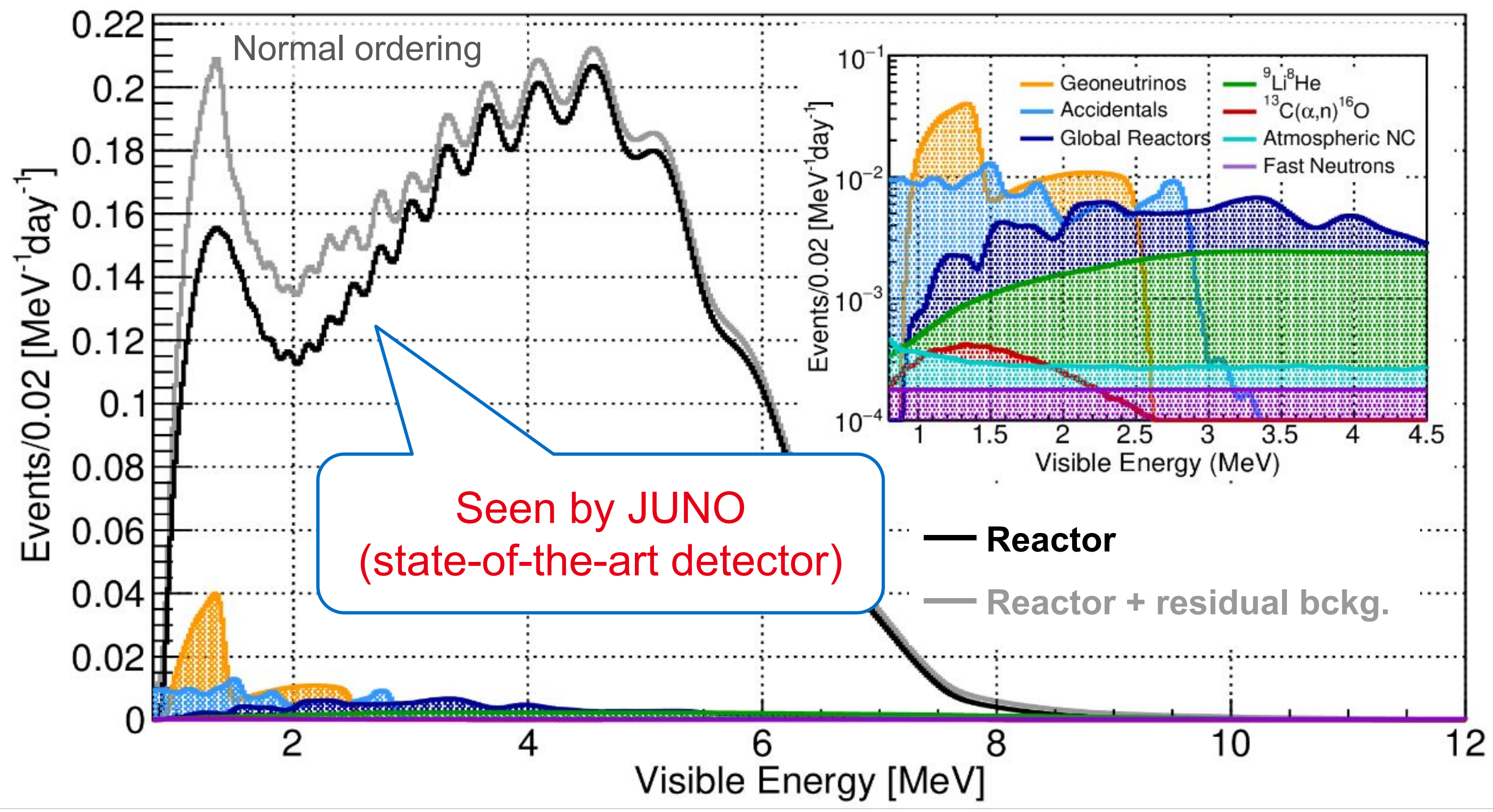


Prompt signal:
handle for energy
$E_\nu \simeq E_{e^+} + \Delta m_{n-p} + T_n$

Delayed signal:
neutron capture on H:
2.2 MeV within ~200 μs



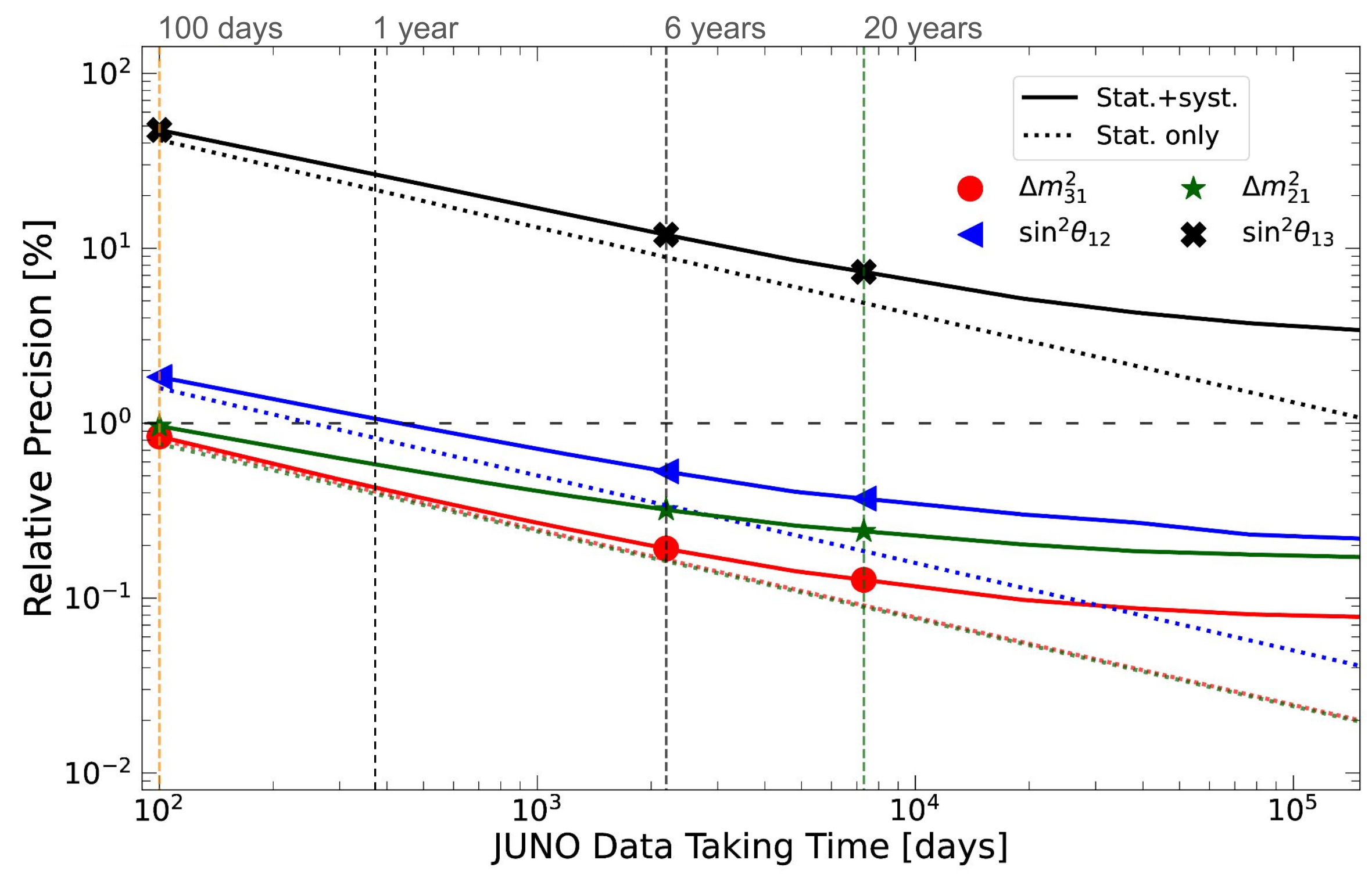
Seen by an ideal detector



Seen by JUNO (state-of-the-art detector)

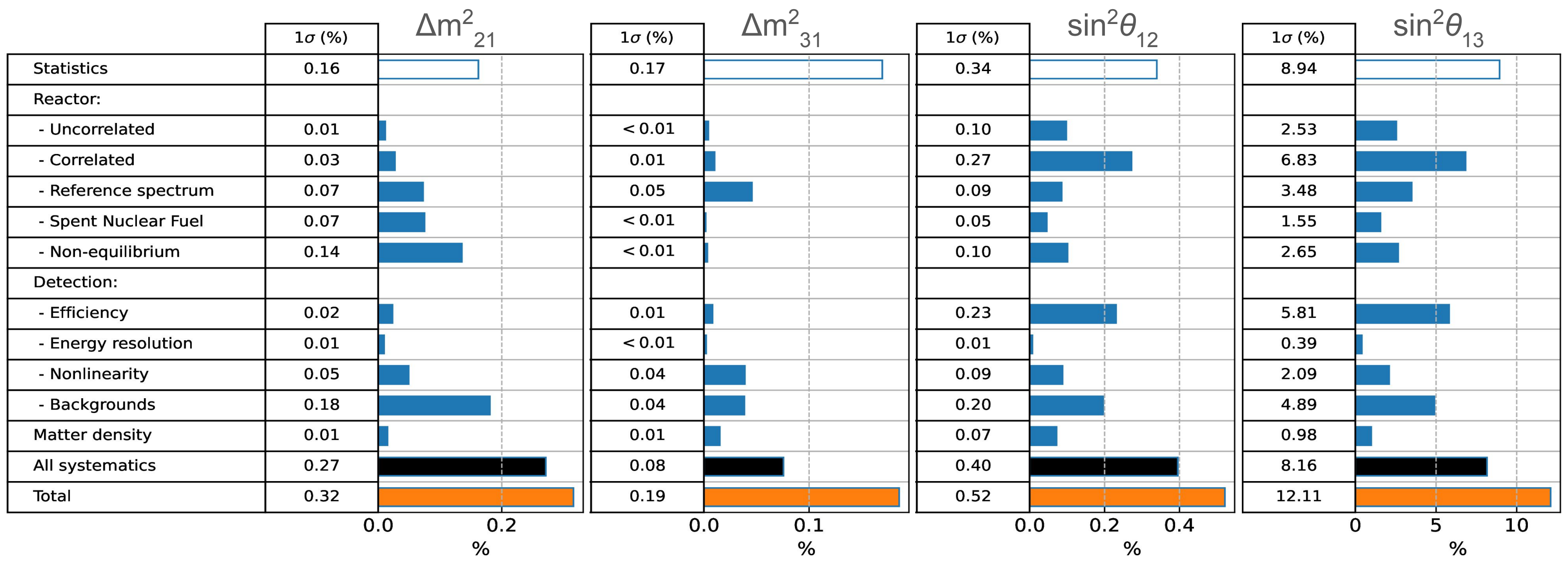
	[day^{-1}]
Signal:	
Reactor neutrinos	47.1
Backgrounds:	4.1
Geoneutrino	1.2
World reactors	1.0
Accidentals	0.8
^{9}Li / ^{8}He	0.8
Atmospheric ν	0.16
Fast neutrons	0.1
^{13}C(α,n)^{16}O	0.05

SENSITIVITY ESTIMATION



Exceptional sensitivity to Δm^2_{21}, Δm^2_{31}, and $\sin^2\theta_{12}$ [3]:

- Improvement of the current precision with a year of data
- Sub-percent precision level after a few years of data taking



	Δm^2_{21} 1σ (%)	Δm^2_{31} 1σ (%)	$\sin^2\theta_{12}$ 1σ (%)	$\sin^2\theta_{13}$ 1σ (%)
Statistics	0.16	0.17	0.34	8.94
Reactor:				
- Uncorrelated	0.01	< 0.01	0.10	2.53
- Correlated	0.03	0.01	0.27	6.83
- Reference spectrum	0.07	0.05	0.09	3.48
- Spent Nuclear Fuel	0.07	< 0.01	0.05	1.55
- Non-equilibrium	0.14	< 0.01	0.10	2.65
Detection:				
- Efficiency	0.02	0.01	0.23	5.81
- Energy resolution	0.01	< 0.01	0.01	0.39
- Nonlinearity	0.05	0.04	0.09	2.09
- Backgrounds	0.18	0.04	0.20	4.89
Matter density	0.01	0.01	0.07	0.98
All systematics	0.27	0.08	0.40	8.16
Total	0.32	0.19	0.52	12.11

	PDG2023 [4]	JUNO 6 y
Δm^2_{21}	$7.53\cdot10^{-5}$ eV^2 ± 2.4%	0.3%
Δm^2_{31}	$2.5283\cdot10^{-3}$ eV^2 ± 1.3%	0.2%
$\sin^2\theta_{12}$	0.307 ± 4.2%	0.5%
$\sin^2\theta_{13}$	0.022 ± 3.2%	12.1%

References:

[1] *F. An et al.*, J. Phys. G 43 030401 (2016).

[2] *A. Abusleme et al.*,Progr. Part. Nucl. Phys. 123 103927 (2022).

[3] *A. Abusleme et al.*, Chin. Phys. C 46 123001 (2022).

[4] *R.L. Workman et al.*, Prog. Theor. Exp. Phys. 083C01 (2022) + 2023 update.

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