Il rivelatore JUNO-TAO e il suo ruolo per JUNO

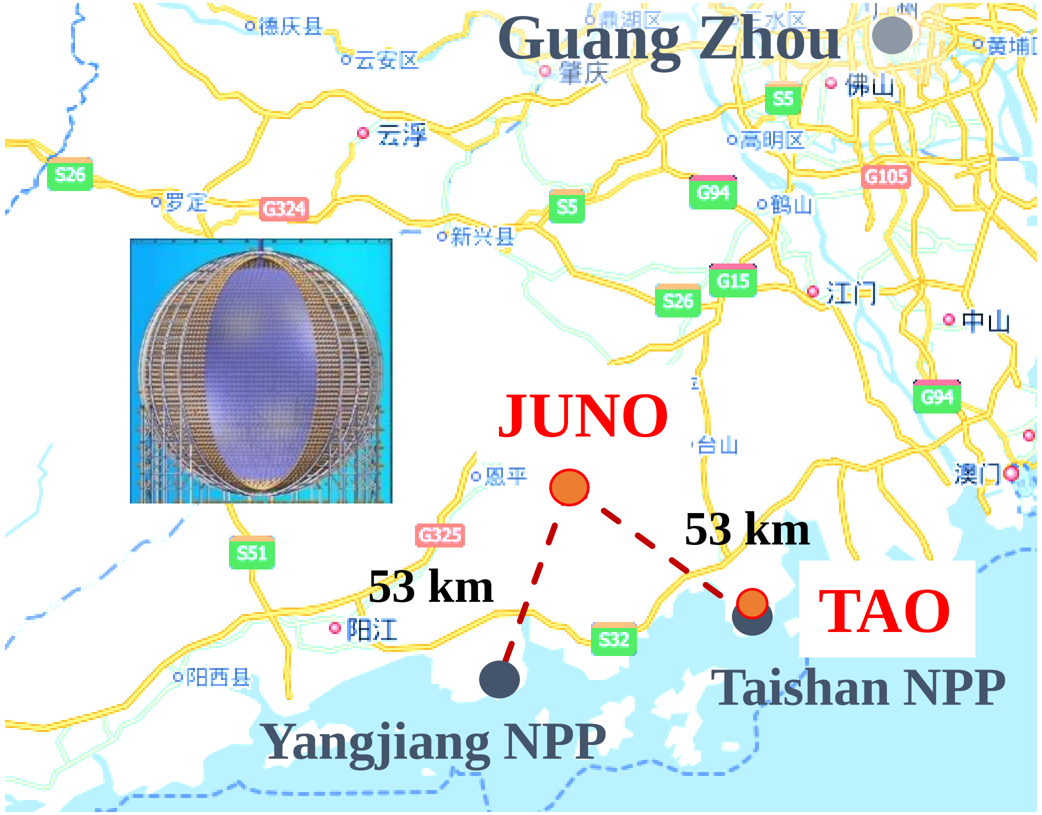
C. Lombardo[a,b] a nome della colloborazione JUNO

[a] Università di Catania

[b] INFN-Catania

Jiangmen Underground Neutrino Observatory

- JUNO is a medium baseline (53 km) reactor neutrino experiment, located in China and 650 m overburden.
- JUNO measures the neutrino flux from 8 reactor cores dispatched in two nuclear power plants (combined thermal power of 26.6 GW).
- In addition to the main detector JUNO will also have a second detector called JUNO-TAO placed near one of the reactor cores.
- JUNO is also sensitive to other neutrino sources.



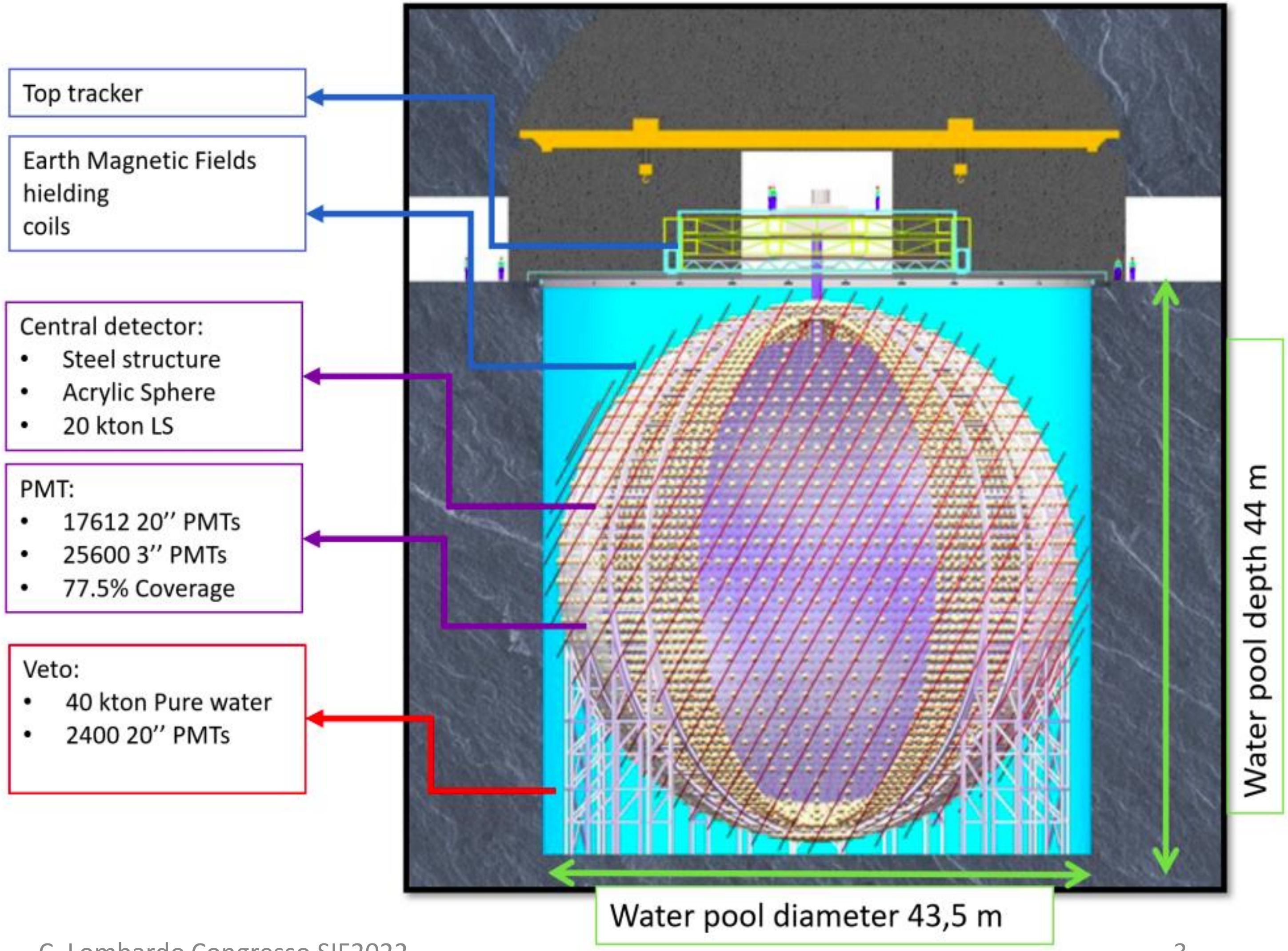
JUNO:Central Detector

- 20 kt of liquid scintillator based on LAB inside a 35.4 m acrylic vessel
- Surrounded by a water Cherenkov tank and a top muon tracker as veto
- 17612 20-inch PMTs + 25600 3-inch PMTs for dual calorimetry
- Primary goals: precise measurement of reactor neutrino oscillation parameters and Neutrino Mass Ordering (NMO) determination

Requirements:

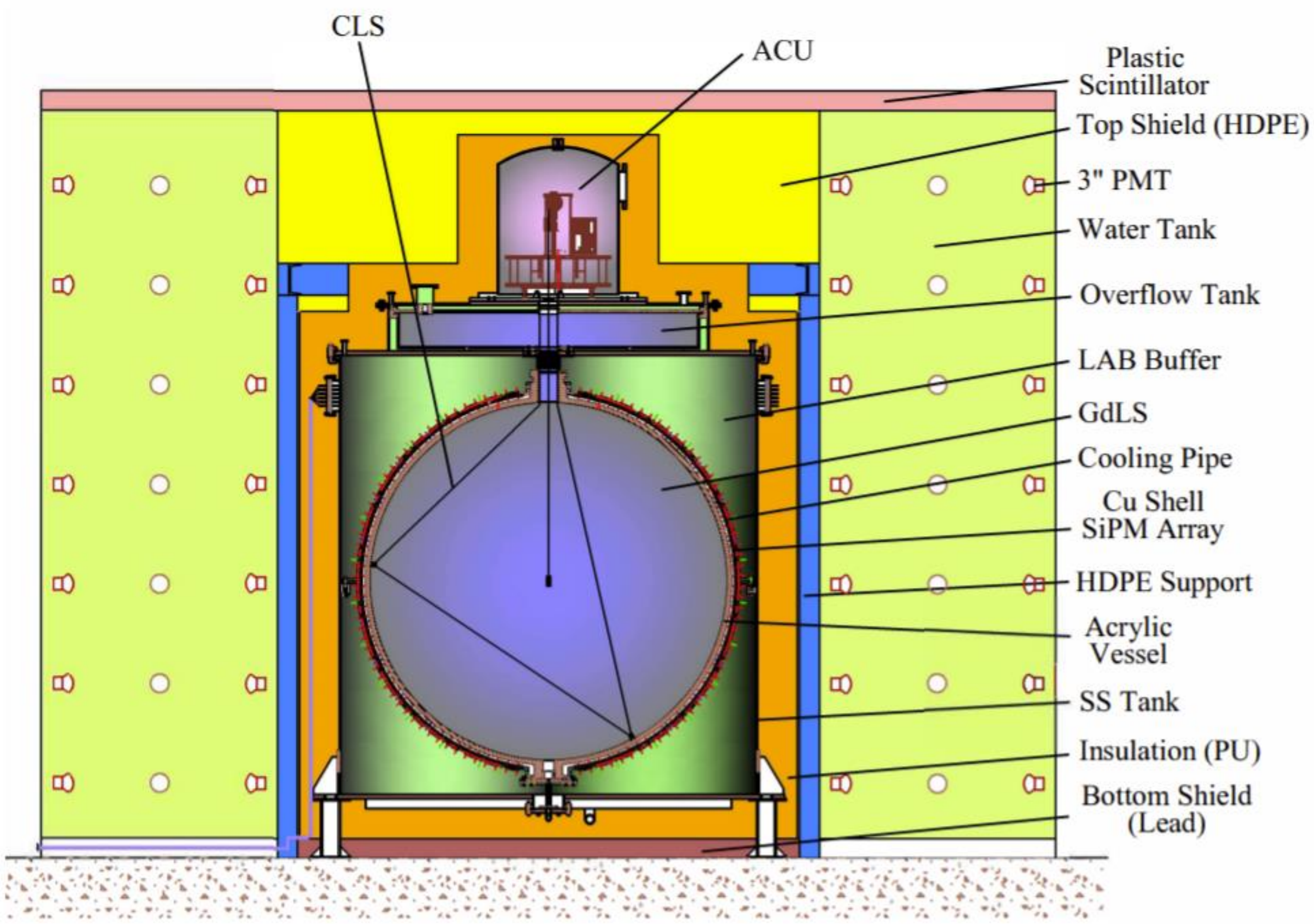
- High statistics ($\sim 10^5$events in 6 yr)
- Energy resolution: $\sim 3\%@1\text{MeV}$
- Energy scale uncertainty < 1%

arXiv:2104.02565



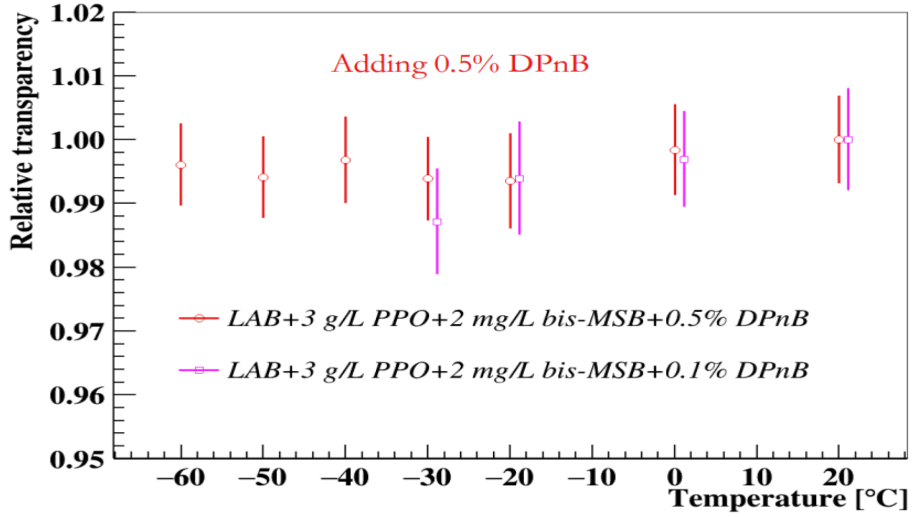
JUNO:TAO detector

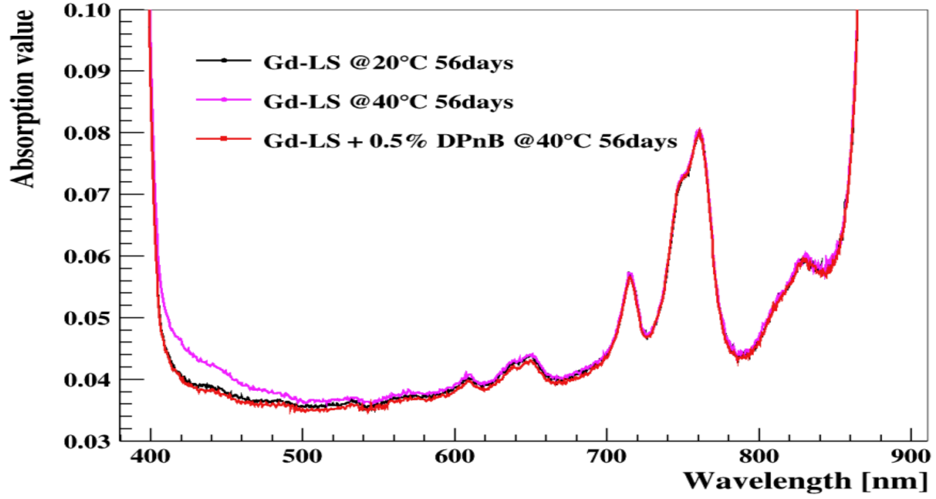
- 2.8 ton of Liquid Scintillator doped with Gadolinium (GdLS) in a spherical vessel with 1.8 m diameter
- Expected 4000 IBD/Day (2000 with 1-ton fiducial volume)
- $\sim 10\ m^2$ of SiPMs (more than 4000 4 x 8 SiPMs arrays)
- Operate at -50 °C to reduce SiPM dark noise
- From the center to the outside: GdLS → Acrilic vessel → SiPMs and support → LAB Buffer → Criogenic system → water and HDPE shield → muon veto
- High energy resolution : $\sim 1.5\%$@1MeV
- Prototype under construction in China



TAO:GdLS

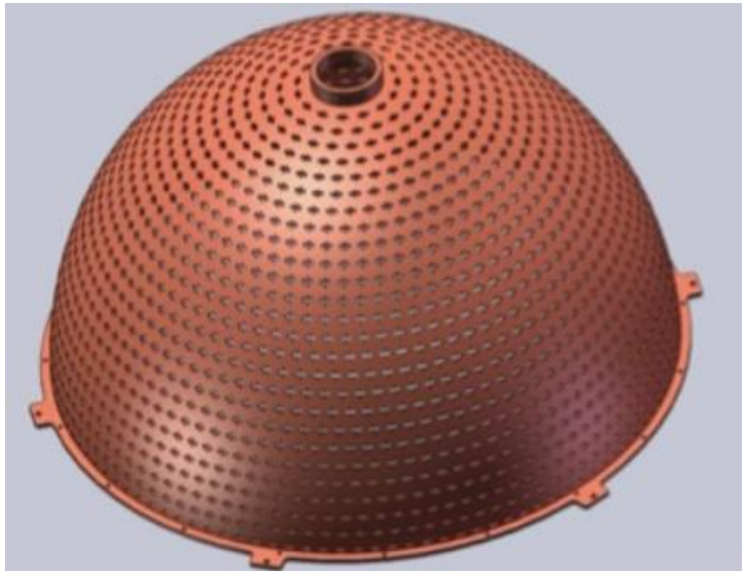
- Liquid scintillator composed by: LAB (Lynear Alkyl Benzene) doped with Gadolinium + 3 g/L PPO + 2 mg/L bis-MSB + 0.5% DPnB
  - High light yeld, flash point and transparency at -50 °C
- Plan to dope LAB buffer with Gd to reduce the neutron background
  - Compatibility with material at -50 °C confirmed
- A.L. (Attenuation Length) of GdLS >10 m (11 m at 430 nm)



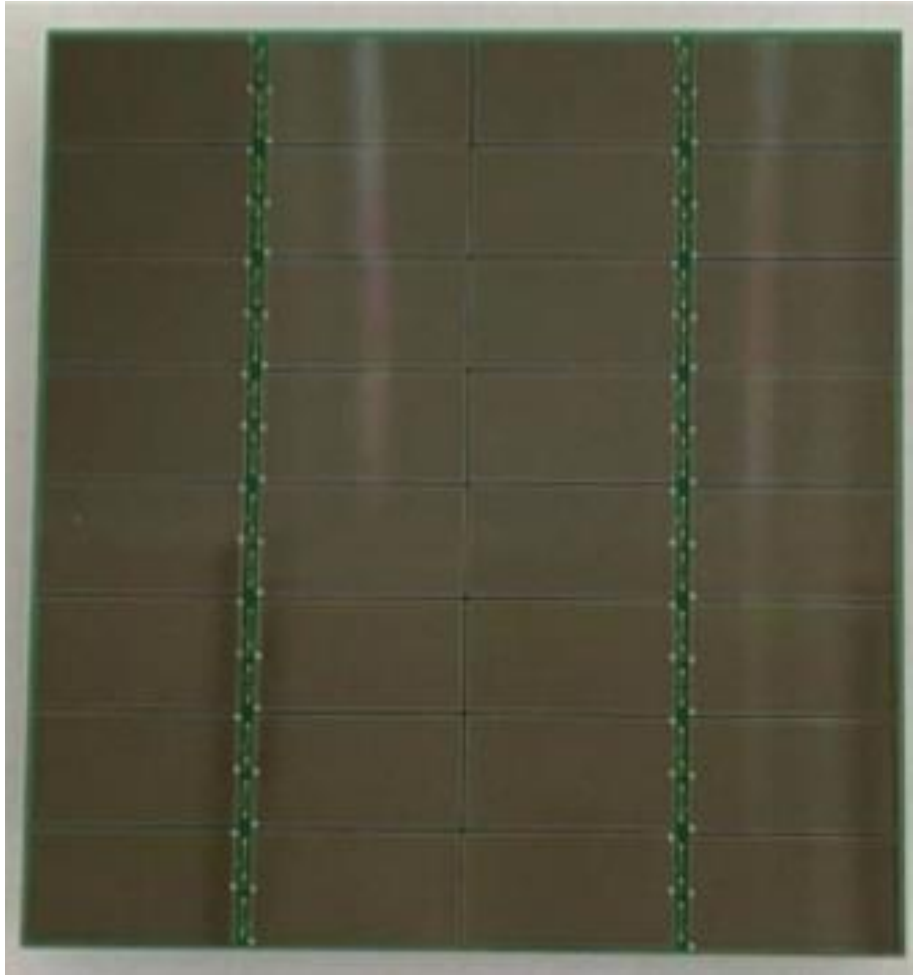


TAO: SiPM

- R&D on SiPMs conducted in the last years
- Strict requirements to reach the sensitivity goal
- 4024 tiles from HPK
- 8000 channels with ≤15 % charge resolution
- Cooled by the copper shell support
- Electronics ready to be produced



SiPM support

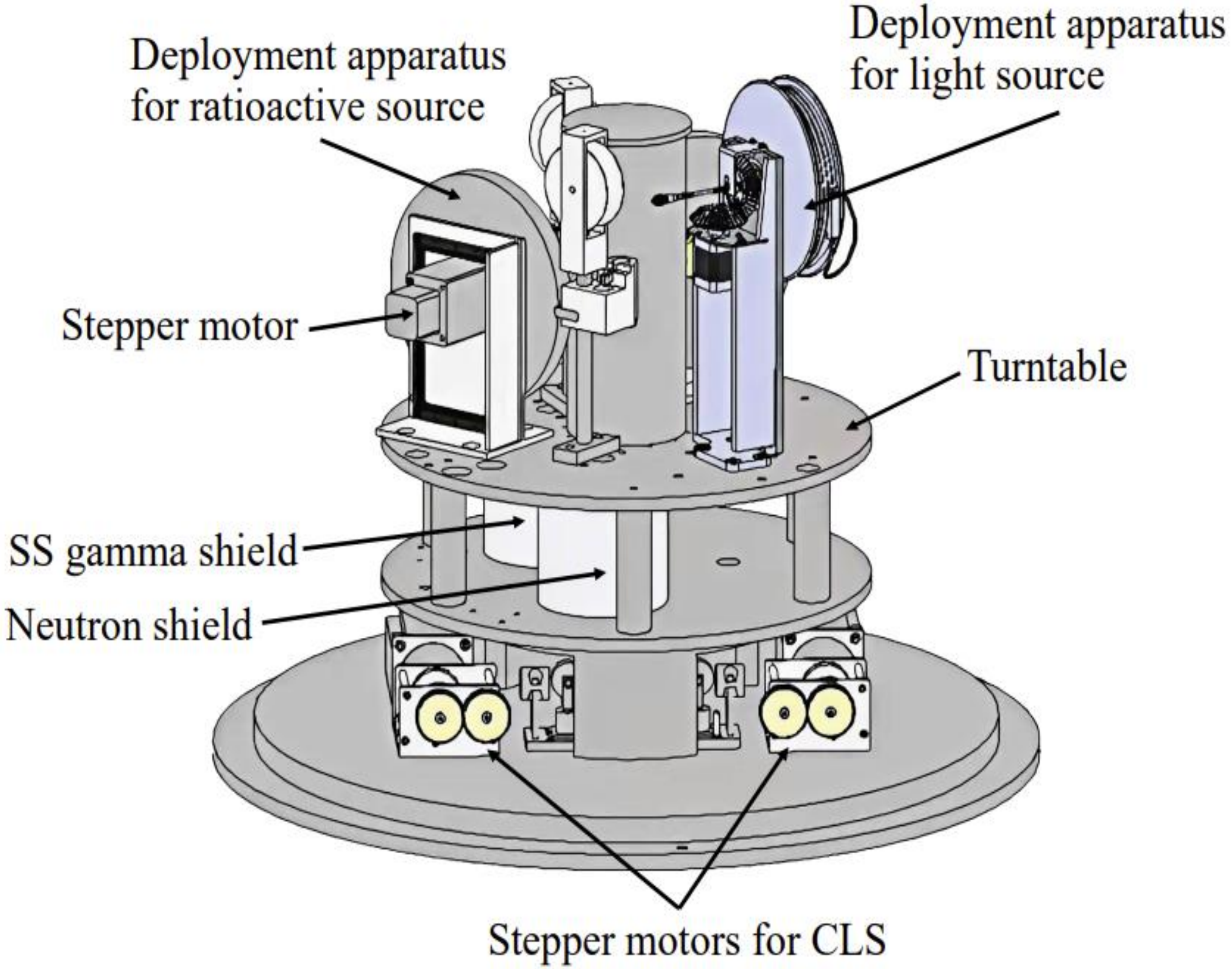


SiPM tile

TAO: calibration

JUNO-TAO calibration system is composed by:

- Automated Calibration Unit (ACU)
  - Can deploy 3 different sources inside the detector alongside the z-axis while a turntable revolves to a specific angle
    - An ultraviolet (UV) light source
    - a ^{68}Ge source
    - a combined source that contains multiple gamma sources and one neutron source
- Cable Loop System (CLS)
  - Designed with a single radioactive source, that can be deploy to off axis position



ACU System

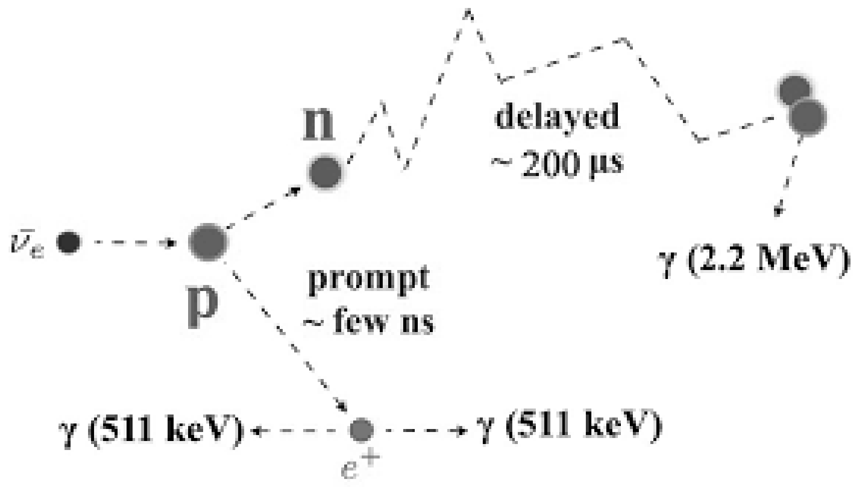
arXiv:2204.03256 (2022)

TAO: Neutrino Detection

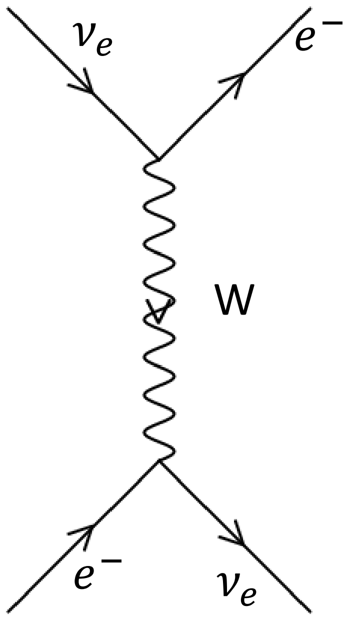
(Anti-)neutrinos are observed by:

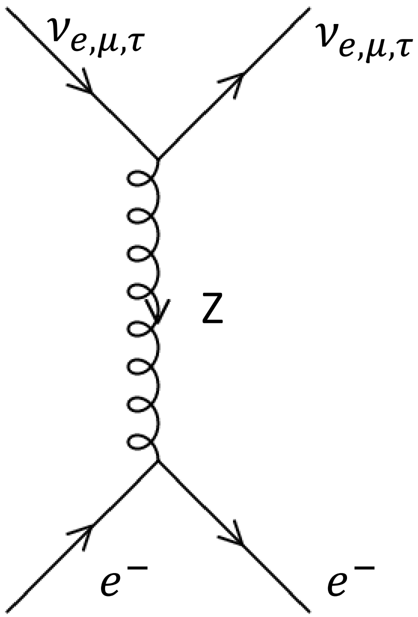
- **Inverse Beta Decay (IBD)** via the positron signal (1) and the following neutron capture:

$$\overline{\nu}_e + p \rightarrow e^+ + n \qquad (1)$$

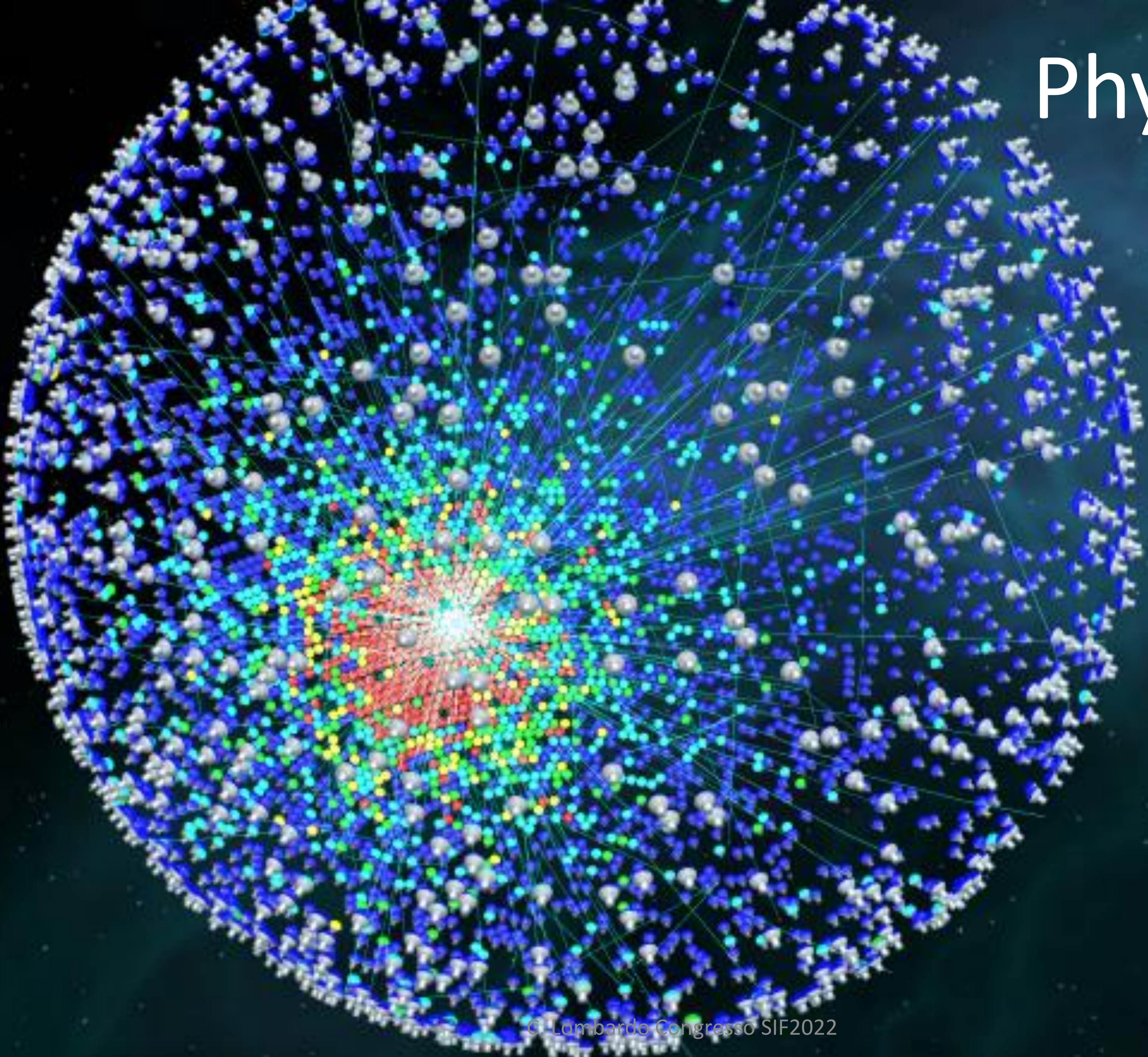


- **Elastic scattering (ES)** on e^- **,** CC and NC interactions:

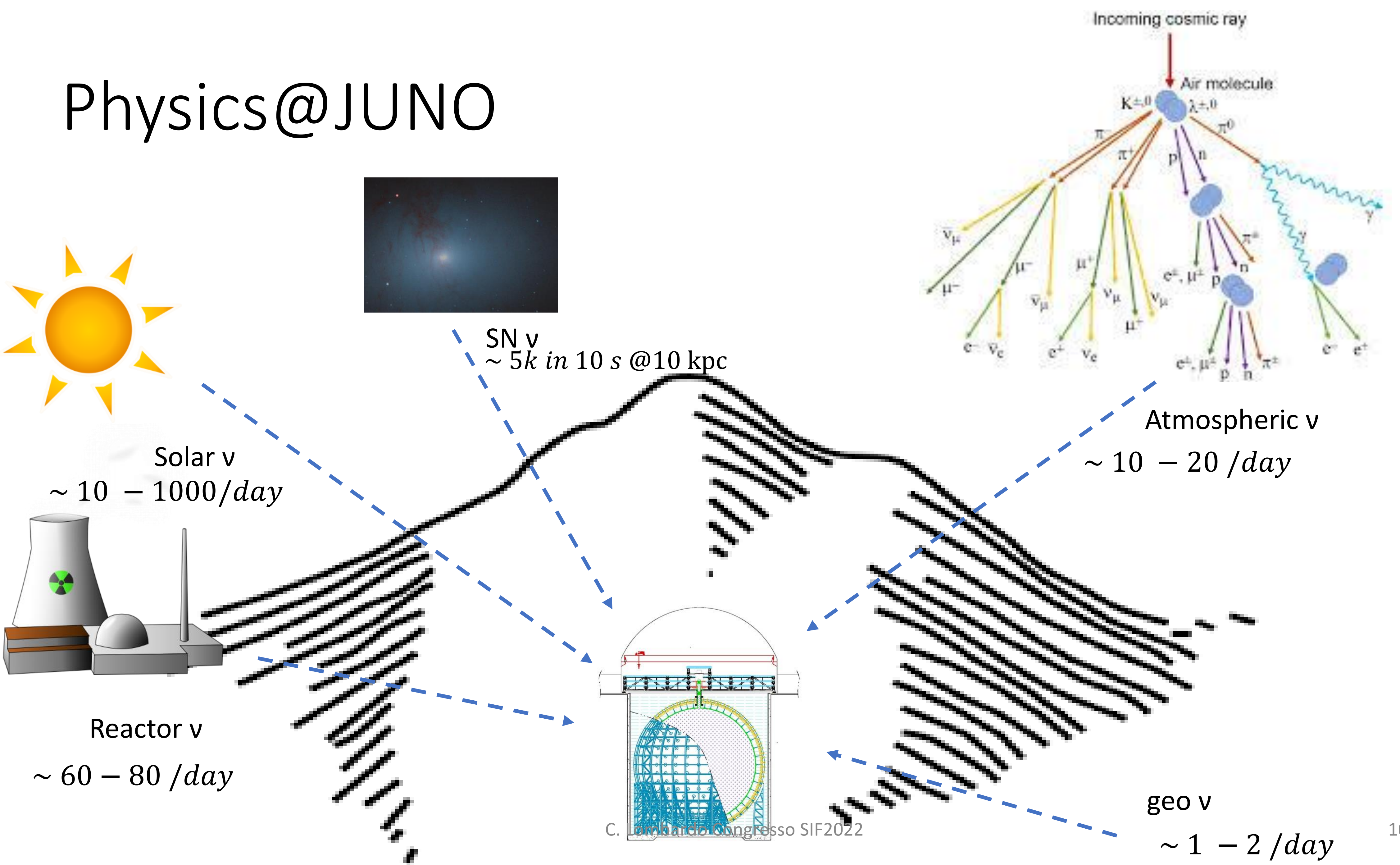




Physics@JUNO



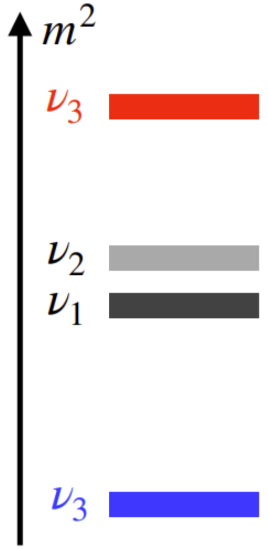
Physics@JUNO



Physics@JUNO

- Reactor Neutrino Oscillations
  - Sub-percent precision measurement of the oscillation parameters (arXiv: 2204.13249 accepted by Chin. Phys. C)
  - Determination of the neutrino mass ordering
- Solar Neutrinos
  - Sensitivity of ^{7}Be, ^{8}B, pep, and CNO neutrinos (Chin. Phys. *C* **45** 023004)
- Diffused SuperNova Background
  - Few events/year after energy cut and PSD analysis (arXiv:2205.08830)
- SuperNova neutrinos
  - Light curve, all flavour spectrum, direction
- Atmospheric Neutrinos
  - independent measurements and systematics to boost NMO sensitivity
  - Flux measurements (EPJ-C 81 (2021))
- Geoneutrinos
  - $\bar{\nu}_e$ from ^{238}U and ^{232}Th decay chains in Earth (Chin. Phys. C 40 (2016).

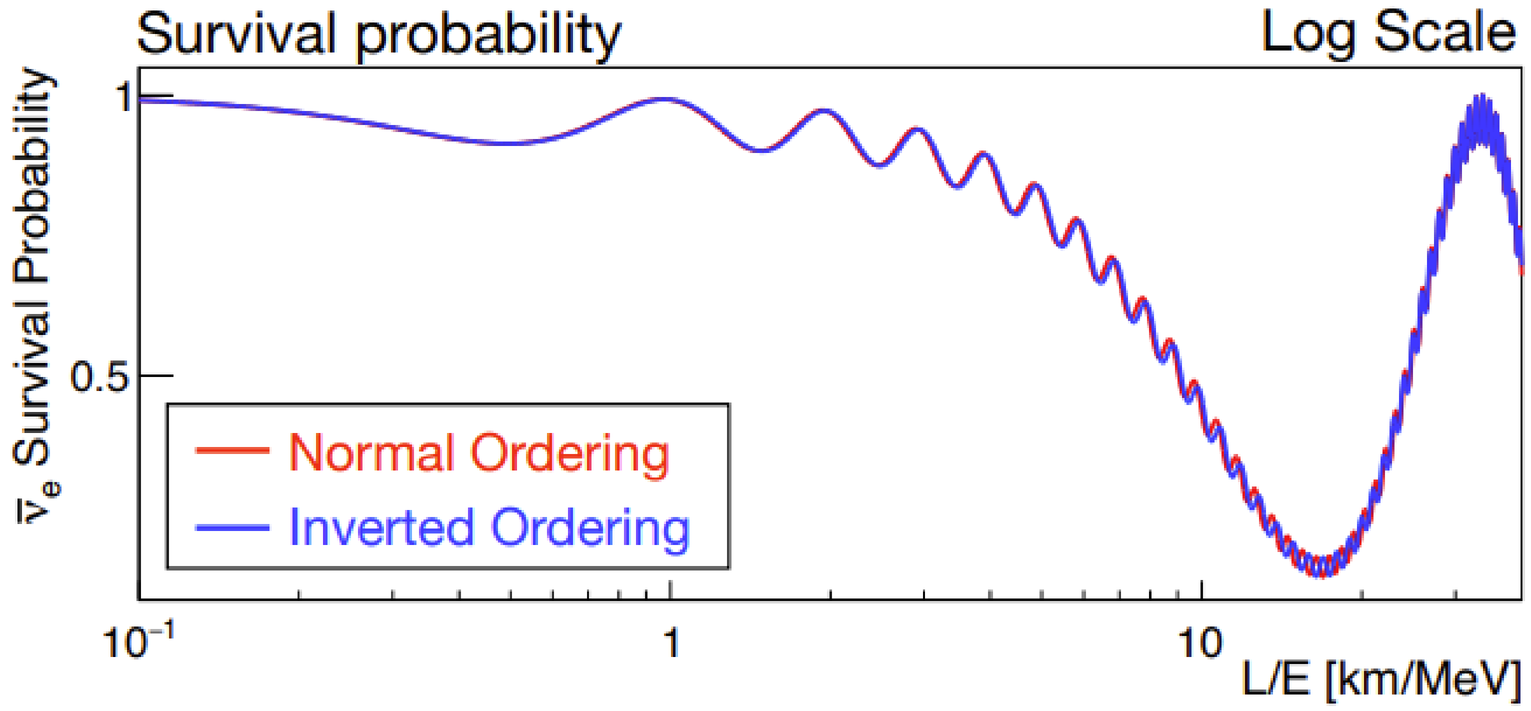
Mass Ordering@JUNO



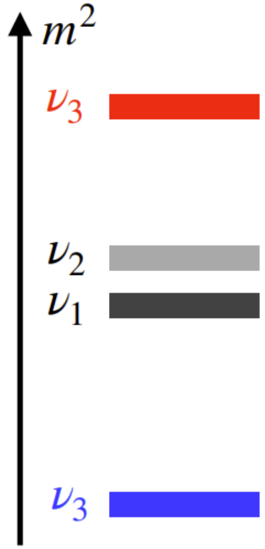
$m_2^2 > m_1^2$, but $\mathrm{sign}(\Delta m_{32}^2)$ not conclusively known

Is m_3^2 the heaviest (normal ordering) or the lightest (inverted ordering)?

$\bar{\nu}_e$ survival probability has this information embedded



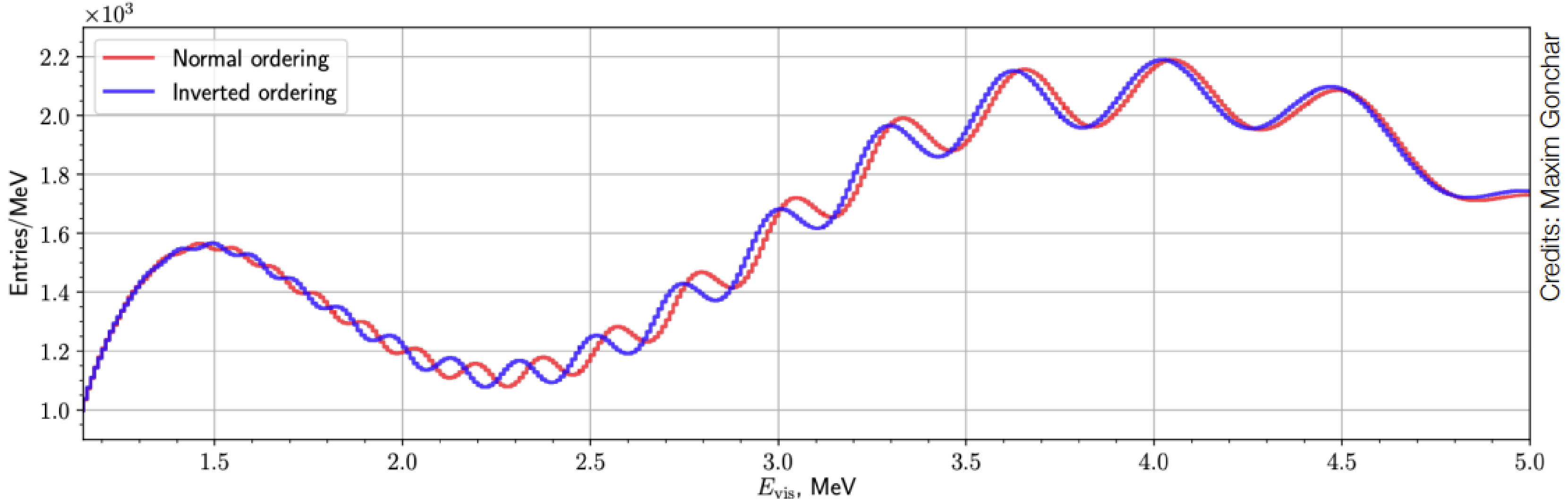
Mass Ordering@JUNO



$m_2^2 > m_1^2$, but $\mathrm{sign}(\Delta m_{32}^2)$ not conclusively known

Is m_3^2 the heaviest (normal ordering) or the lightest (inverted ordering)?

$\bar{\nu}_e$ survival probability has this information embedded



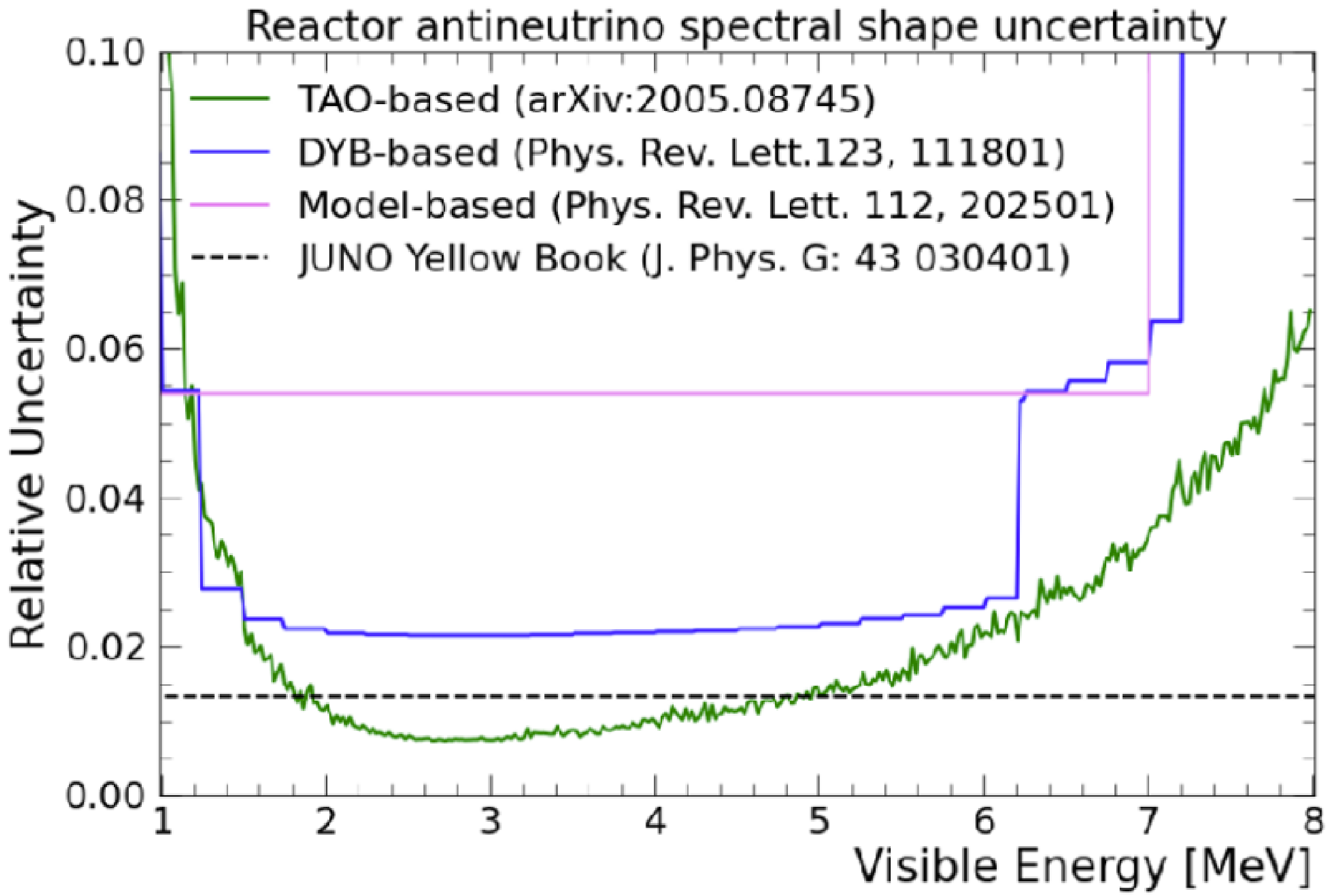
What is the role of TAO?

TAO: physics goal

- Measuring the energy spectrum of reactor-$\bar{\upsilon}_e$ to reduce the impact from reactor flux model uncertainties and improve JUNO capability to discover the Mass Ordering
- Providing a benchmark spectra to short-lived isotopes to nuclear database
- Searching for light sterile neutrino
- Reactor monitoring

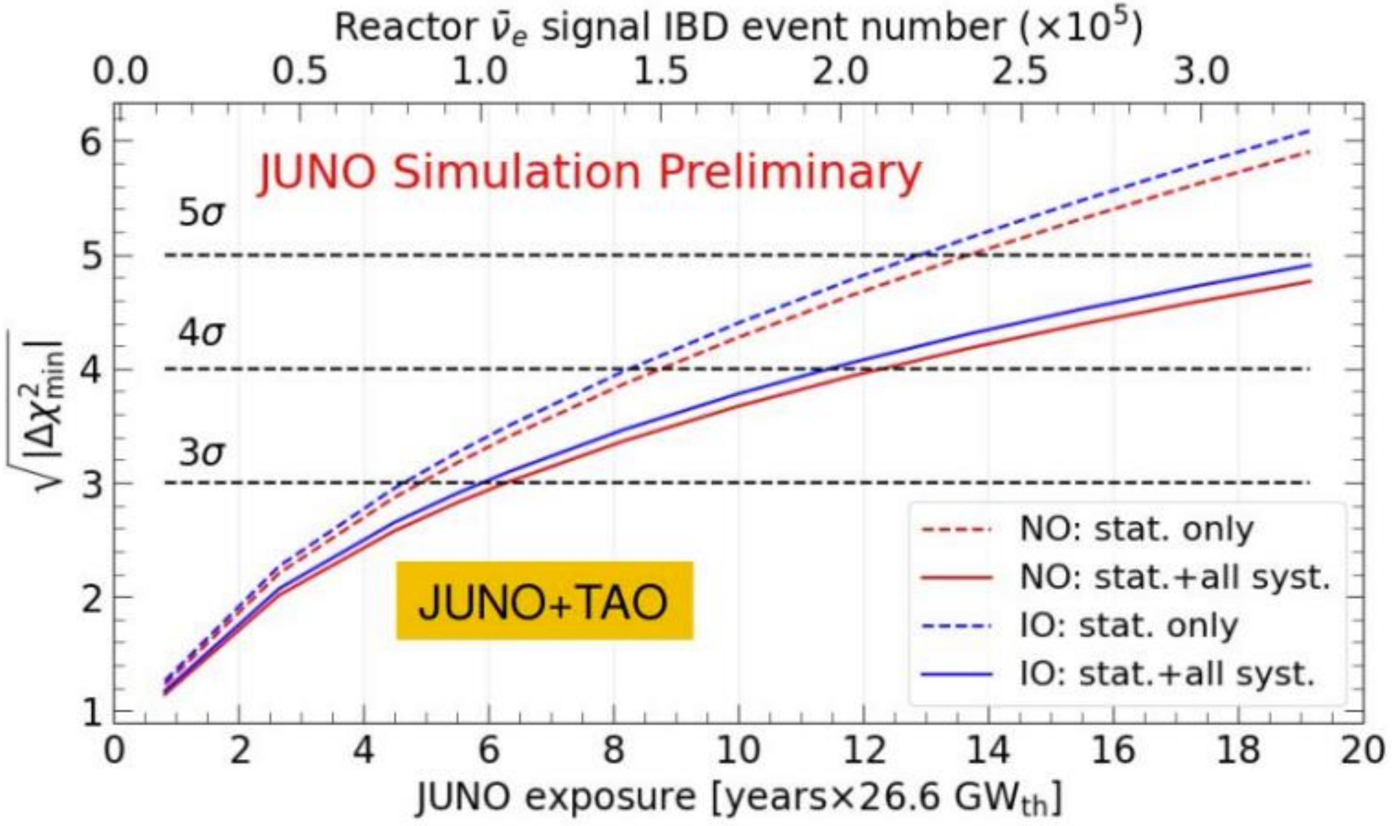
TAO: physics goal

Measuring the energy spectrum of reactor-$\bar{\nu}_e$ to reduce the impact from reactor flux model uncertainties and improve JUNO capability to discover the Mass Ordering



TAO: physics goal

Measuring the energy spectrum of reactor-$\bar{\upsilon}_e$ to reduce the impact from reactor flux model uncertainties and improve JUNO capability to discover the Mass Ordering



Future Prospects

- A prototype 1:1 is under construction in China
- SiPM mass testing will start in October 2022
- Will measure the reactor neutrinos spectrum with high energy resolution
- Will improve JUNO NMO analysis

Thanks for your attention!

Neutrino Mass

ν_1, ν_2 and ν_3 are the mass eigenstates while ν_e, ν_μ and ν_τ are the weak eigenstates.

$$\begin{pmatrix} \nu_e \\ \nu_\mu \\ \nu_\tau \end{pmatrix} = \begin{pmatrix} U_{e1} & U_{e2} & U_{e3} \\ U_{\mu 1} & U_{\mu 2} & U_{\mu 3} \\ U_{\tau 1} & U_{e\tau 2} & U_{\tau 3} \end{pmatrix} \begin{pmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \end{pmatrix}$$

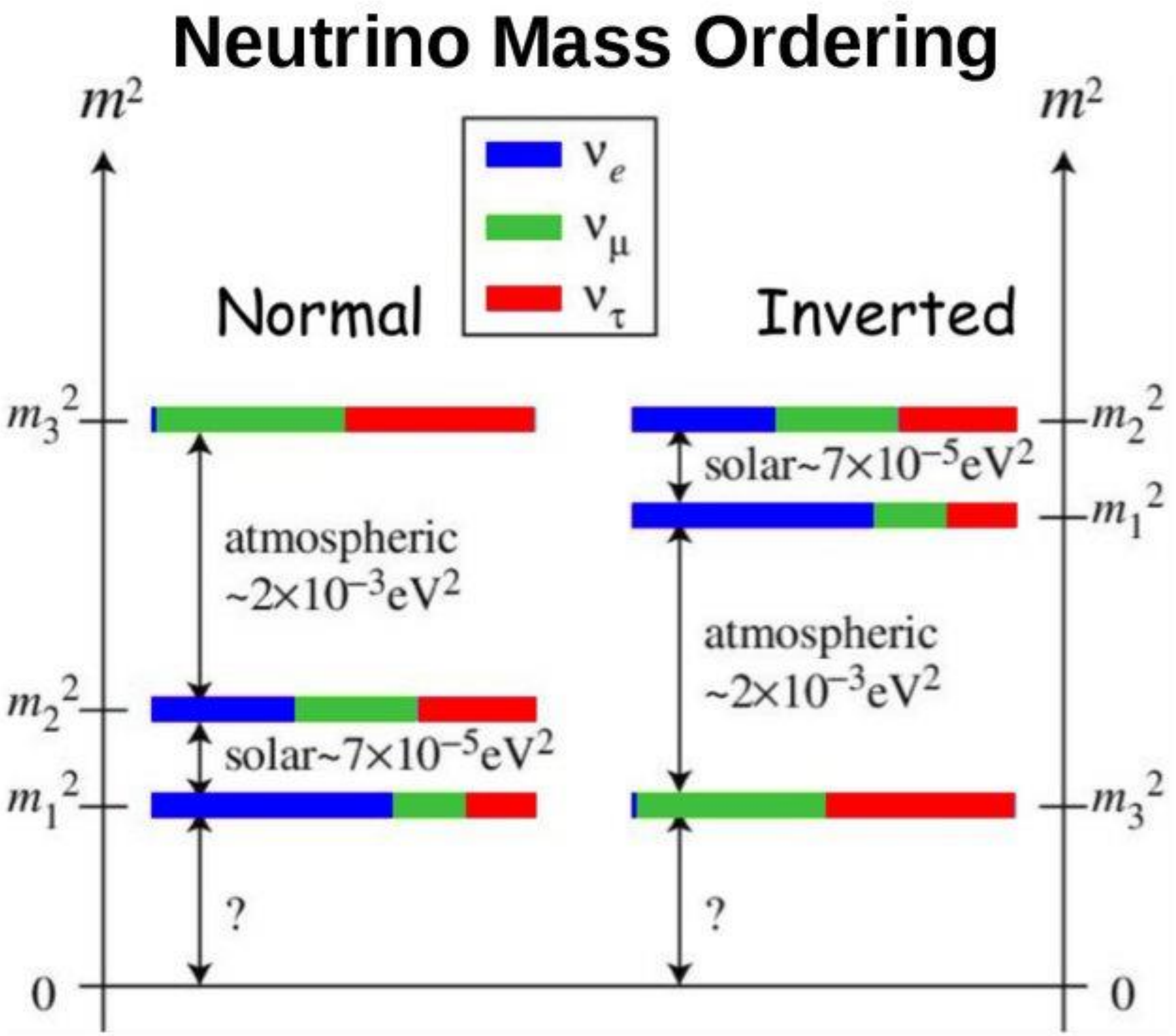
Neutrinos are produced and interact as weak eigenstates.

The weak eigenstates are linear combinations of the fundamental mass eigenstates.

The mass eigenstates are the free particle solutions to the wave-equation and will be taken to propagate as plane waves.

Neutrino Mass

The weak eigenstates are linear combinations of the fundamental mass eigenstates.
From the measurements on oscillations parameter there are two possible scenarios: Normal Hyerarchy and Inverted Hierarchy.



Fernández, Pablo. "Recent results from the long-baseline (LBL) neutrino oscillation experiments." SciPost Physics Proceedings 1 (2019): 029.