Overview of the JUNO-TAO Experiment

Liang Zhan, Institute of High Energy Physics, Beijing
on behalf of the JUNO Collaboration

Abstract

The Taishan Antineutrino Observatory (TAO, also known as JUNO-TAO) is a satellite experiment of the Jiangmen Underground Neutrino Observatory (JUNO). The experiment consists of a ton-level liquid scintillator detector placed at 44 m from a 4.6 GWth reactor core of the Taishan Nuclear Power Plant. The main goal is to measure the reactor antineutrino spectrum with sub-percent energy resolution, providing a reference spectrum for JUNO as well as a benchmark for nuclear databases and other experiments. The detector design consists of a spherical acrylic vessel containing 2.8 ton gadolinium-doped liquid scintillator viewed by 10 m^2 Silicon Photomultipliers (SiPMs) with ~50% photon detection efficiency and providing around 95% photon coverage. The expected energy resolution is better than 2% at 1 MeV. The detector will operate at -50◦C to mitigate the impact of SiPM dark noise. About 1000 reactor antineutrinos will be collected per day. The detector is under construction and a prototype detector has been assembled and tested. The detector operation is expected to begin as soon as 2024.

Introduction

arXiv: 2005.08745

- The Taishan Antineutrino Observatory (TAO) is a satellite experiment of the Jiangmen Underground Neutrino Observatory (JUNO)
- TAO consists of a spherical ton-level Gadolinium-doped Liquid Scintillator (Gd-LS) detector (1.8 m diameter) at 44 m from a reactor core of the Taishan Nuclear Power Plant (4.6 GW) in Guangdong.
- By means of 10 m^2 SiPM coverage, the reactor antineutrino spectrum will be measured with an unprecedented energy resolution (≤ 2%/√E MeV)

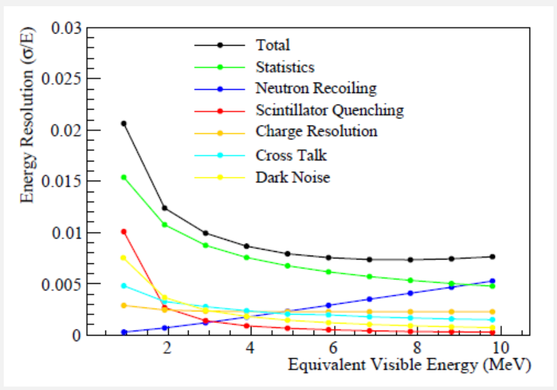


Fig. 1: The expected energy resolution of TAO detector

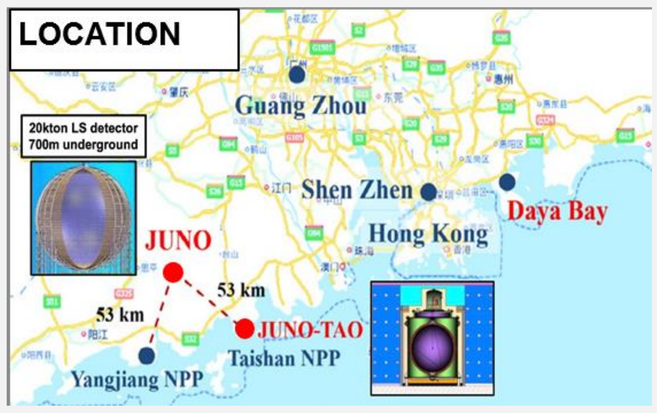


Fig. 2: The JUNO and TAO experimental sites

The Physics Goals

- Provide a model-independent reference spectrum for the JUNO neutrino mass-hierarchy measurement.
- Provide a new benchmark measurement to test nuclear databases.
- Reactor monitoring: status/fuel.
- Search for sterile neutrino

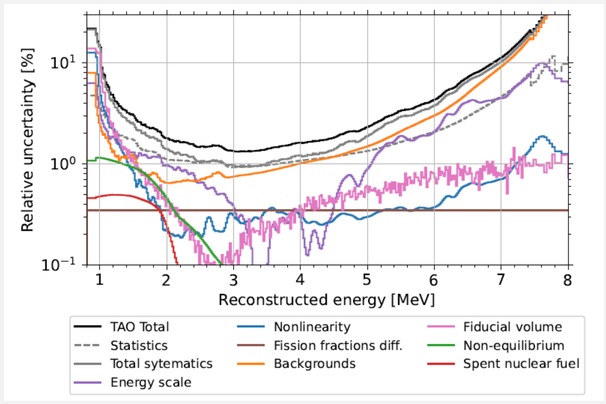


Fig. 2: The expected energy spectral uncertainty of TAO detector

arXiv: 2405.18008

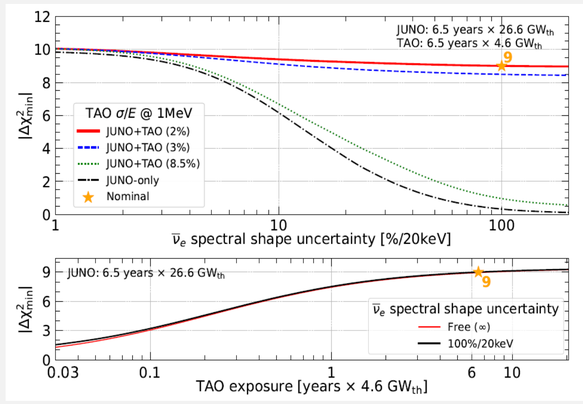


Fig. 2: The impact of the TAO experiment on the determination of the neutrino mass ordering for JUNO experiment

TAO Detector

Highlights

- Energy resolution <2%@√E MeV
- SiPM PDE >50% (~4000 p.e./MeV)
- SiPM coverage: 94% of ~4π, ~10m^2
- SiPM DCR: <100 Hz/mm^2 @-50℃
- Dewatering Low-temperature LS : <10ppm

Top tracker

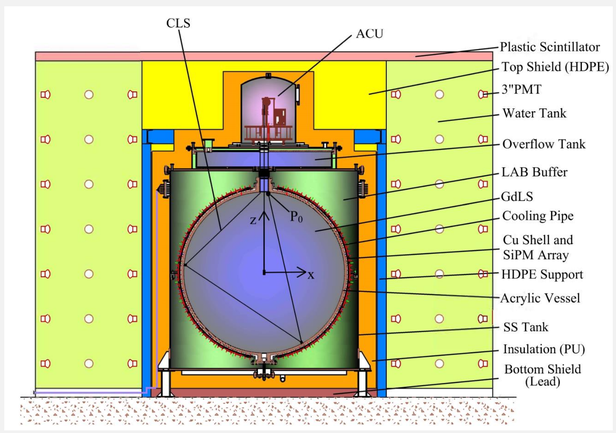
4-Layer PS+WLS fiber, 160 strips
2 m × 20 cm × 2 cm/strip

Water tank

3 irregular water tanks
~300 3" PMT

Central detector (CD)

- Acrylic sphere: 1.8 m inner diameter (ID), 2.8 t low temperature GdLS
- Copper shell: 1.886 m (ID), holding 4024 pieces of 50*50 mm^2 SiPM tiles
- SS tank: 2.09m (ID), 10mm thickness with 3.2 t LAB/Gd-LAB
- Cryogenic system: 4.5kW cooling power and 150 mm-thick melamine foam full covering to keep -50℃ running condition



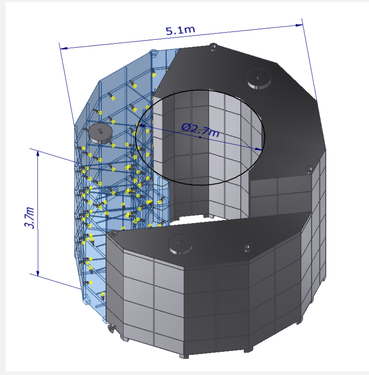
Veto System

Water Cherenkov

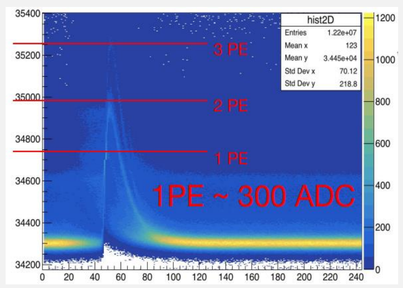
- Tank contract signed
- sPMT electronics tested on prototype

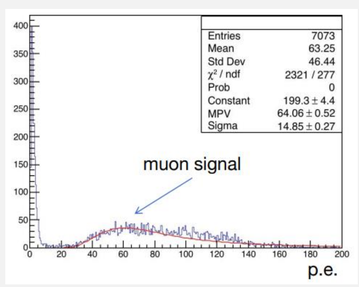
Top Veto Tracker

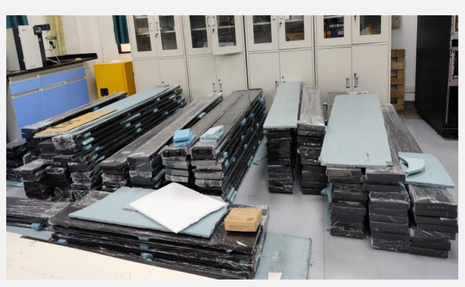
- All PS strips passed QA
- Module test with SiPM + electronics
- 1st Integration and overall test finished



Water tank prototype







Calibration System & Photon Sensor

Calibrate the detector response with multiple sources (energies) at deployed positions frequently
Installed and tested at the TAO prototype

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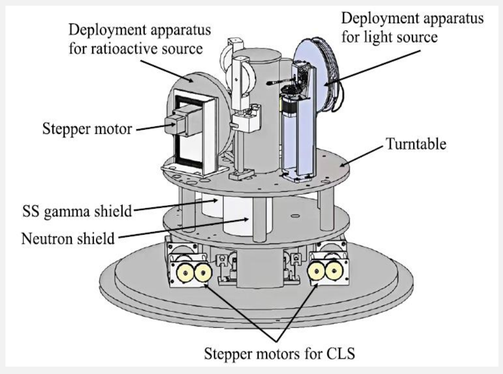
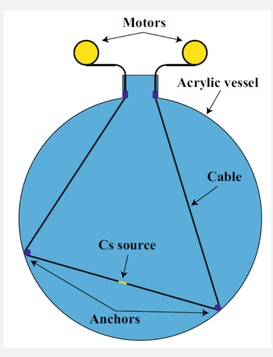
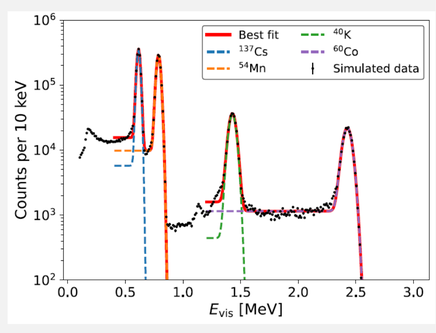




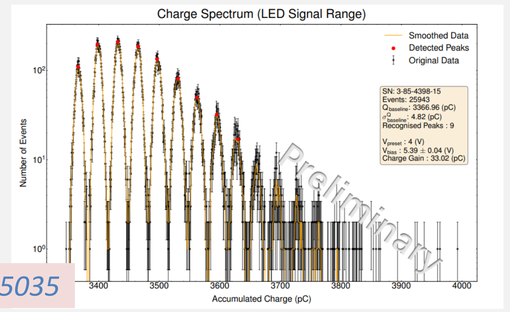


SiPMs as photon sensor

- All QA finished

4051 tiles checked, 178 with too large DCR, 115 too large Vbd non-uniformity

- High PDE feature also confirmed (52.5% at optimized overvoltage)

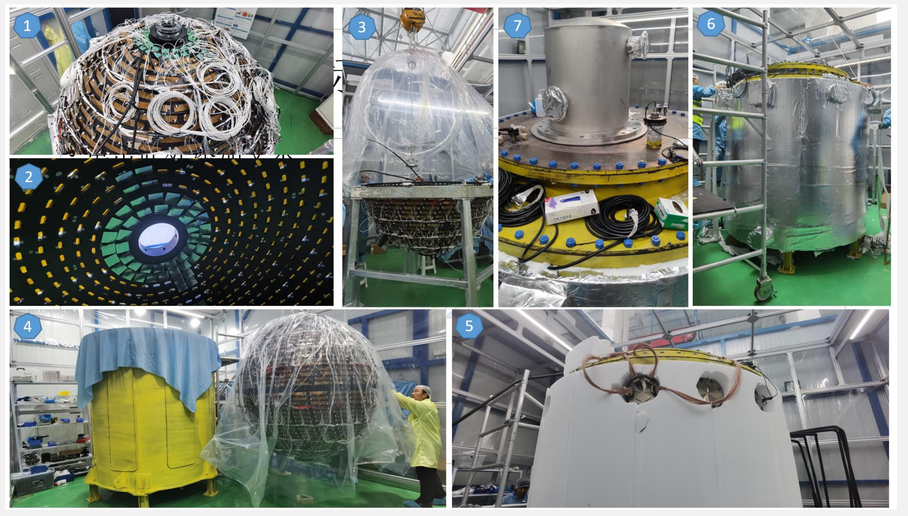


Poster #279, SiPM mass testing

JINST 19 (2024) 05, P05035

TAO CD prototype (1:1)

- CD is running stably at -50 °C
- Several tens of SiPM tiles are installed and their parameters are calibrated (dark noise, gain, PDE, after pulse, cross talk, etc..)
- Data is taken with Co-60 source, LED source, and cosmic muons
- Results will be released



Conclusion

- TAO detector will start data taking at similar time as JUNO
- TAO prototype will be dissembled and the major components will be shipped to Taishan reactor power plant in 2024
- With an unprecedented energy resolution, TAO will provide a precision reference antineutrino spectrum for JUNO

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