Precise detector of JUNO-TAO experiment

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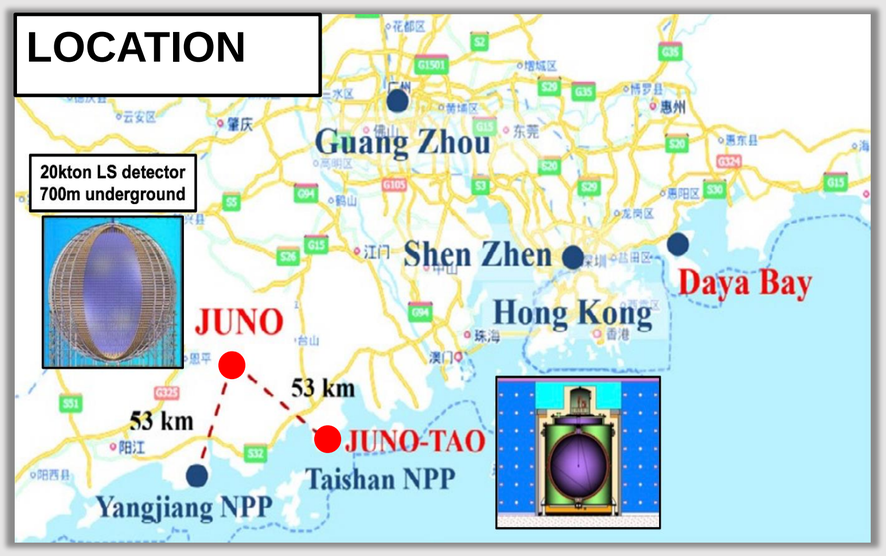
16th Pisa Meeting, 2024

JUNO & JUNO-TAO

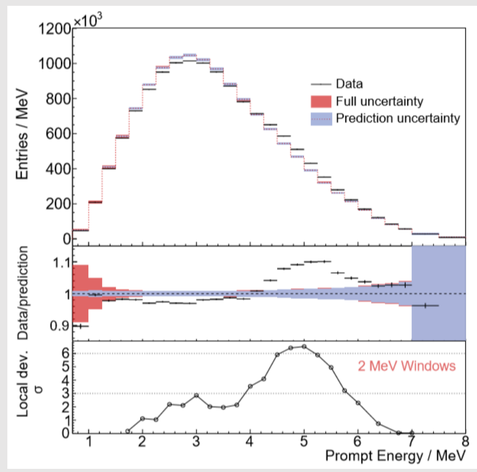
- The Taishan Antineutrino Observatory (TAO) is a satellite experiment of the Jiangmen Underground Neutrino Observatory (JUNO), located in the southern China, expected to start collecting data in 2024.
- TAO consists of a spherical ton-level Gadolinium-doped Liquid Scintillator (Gd-LS) detector (1.8 m diameter) at ~30 m from a reactor core of the Taishan Nuclear Power Plant (4.6 GW) in Guangdong.
- By means of 10 m² SiPM covering the spherical LS, the reactor antineutrino spectrum will be measured with a sub-percent energy resolution (≤ 2%/√E MeV, exp. ~4000 pe/MeV).
  - ✓ 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.

	Distance	Mass	Power	Eff.	Oscillation	Statistics
TAO / JUNO	$\frac{53^2}{0.03^2}$	$\frac{1\ ton}{20000\ ton}$	$\frac{4.6}{36}$	$\frac{0.5}{0.8}$	$\frac{1}{0.321}$	
Factor	3.1×10^6	0.5×10^{-4}	0.128	0.625	3	**36 X**

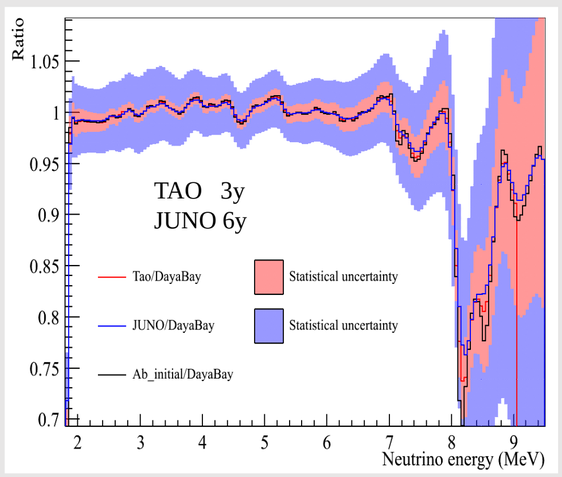


Compare w/ JUNO	1200pe/MeV
Cov. 75%→100%	X 1.33
PDE 27% → 50%	X 1.85
LS temp. at -50℃	X 1.25
Less absorption	X 1.4
1.4% photo-statistics	X4.3
TAO expected	~4000 pe/MeV

~2000 IBD/day @ fiducial volume



Daya Bay PRL123.111801 vs Huber-Mueller



M. Estienne, et al. PRL123, 022502

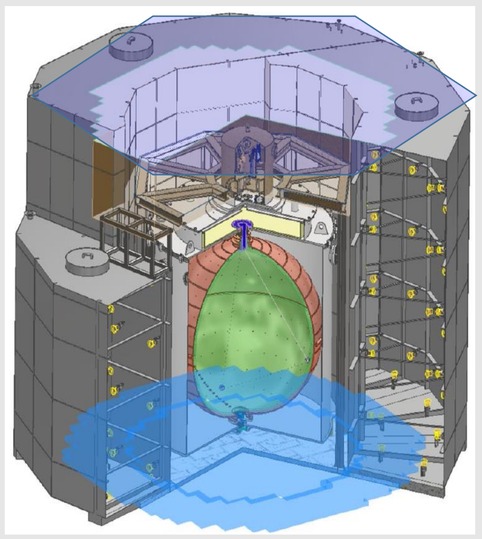
TAO detector

◆ 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

◆ Central detector (CD)

- **Acrylic sphere** 1.8m (ID), 20mm-thick with 2.8 t Low-T Gd-LS
- **Copper shell** 1.886m (ID), 12mm-thick with 4024 pieces of 50*50mm^2 SiPM tiles
- **SS tank** 2.09m(ID), 10mm-thick with 3.2 t LAB/Gd-LAB
- **Cryogenic system** with 4.5kW cooling power and 150mm-thick melamine foam full covering keeping -50℃ running condition



◆ Top Veto Tracker (TVT)

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

Top Shield(HDPE)

◆ Water Tank

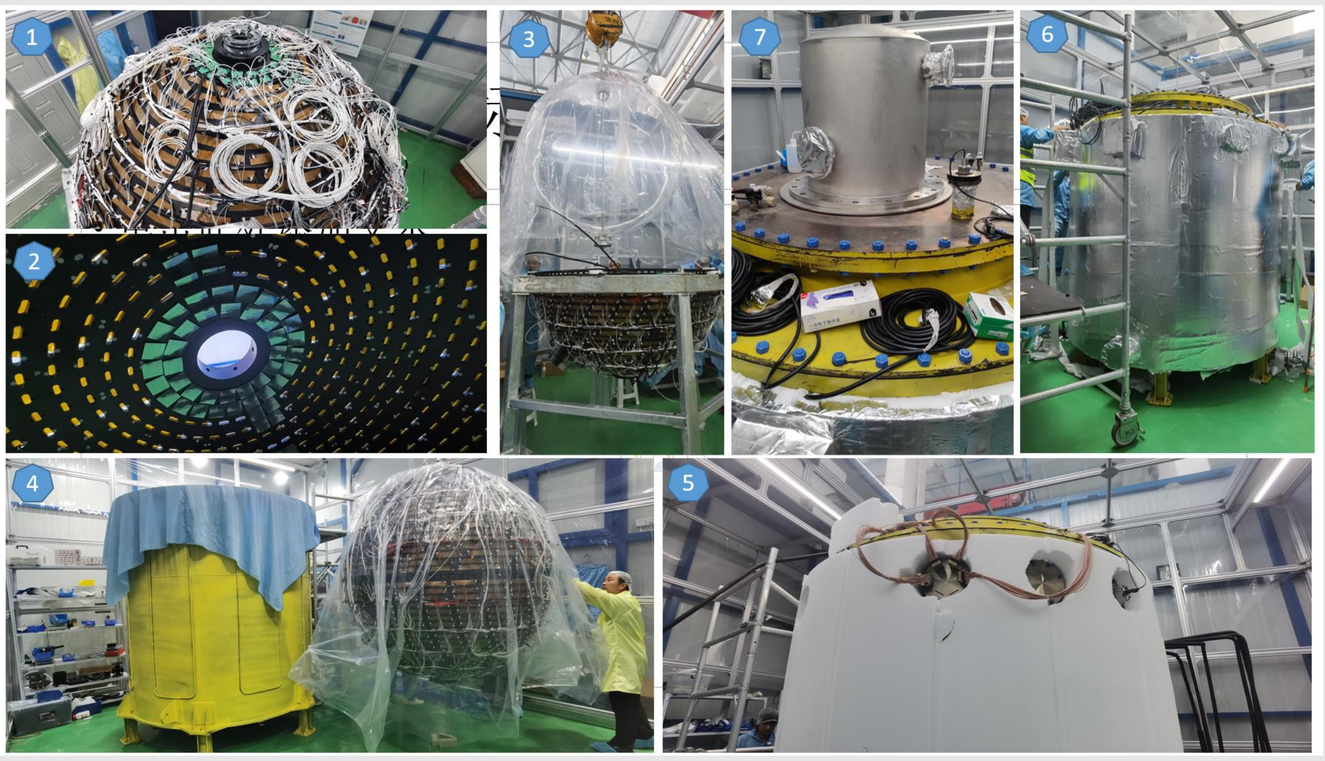
- 3 irregular water tanks
- ~300 3" PMT

◆ ACU & CLS

- 6 types of exemption sources

Overflow Tank
Cu Shell
SiPM Array
Acrylic Vessel
SS Tank
Insulation (MF) Bottom
Shield(Lead)

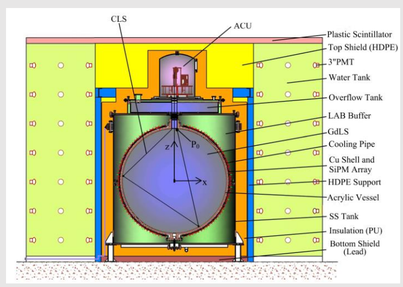
1:1 CD prototype

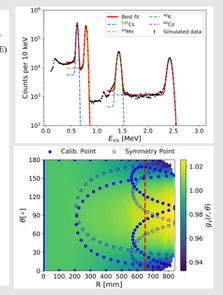


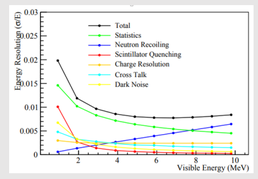
Calibration & Photon sensor

◆ ACU & Cable Loop System (CLS)

Xu, H., Abusleme, A., Anfimov, N.V. *et al.* Calibration strategy of the JUNO-TAO experiment. *Eur. Phys. J. C* **82**, 1112 (2022). https://doi.org/10.1140/epjc/s10052-022-11069-3



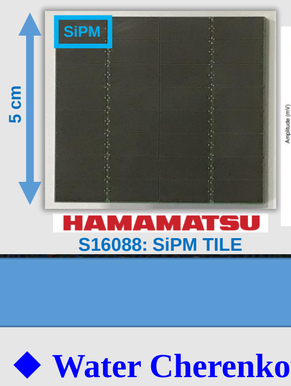


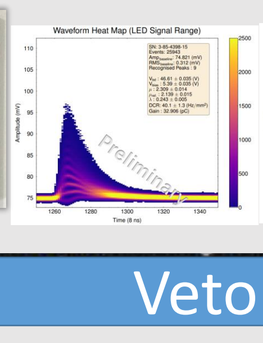


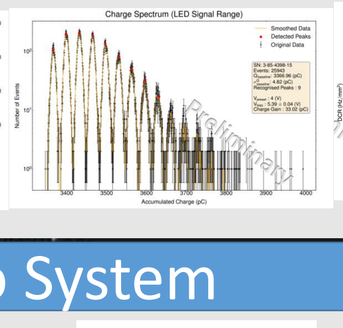
Source or process	Type	Radiation	Activity [Bq]	half life
^{137}Cs (ACU)	γ	0.662 MeV	50	30.1 years
^{54}Mn	γ	0.835 MeV	50	0.85 year
^{60}Co	γ	1.173 MeV + 1.333 MeV	10	5.27 years
^{40}K	γ	1.461 MeV	10	1.25×10^9 years
^{68}Ge	e^+	annihilation 0.511 MeV + 0.511 MeV	500	0.74 year
^{241}Am-^{13}C	n,γ	neutron + 6.13 MeV (^{16}O*)	2 (neutron)	432 years
$n(p,\gamma)d$	γ	2.22 MeV	2 (neutron)	
^{137}Cs (CLS)	γ	0.662 MeV	500	30.1 years
^{12}B	e	13.4 MeV (end point energy)		20.2 ms

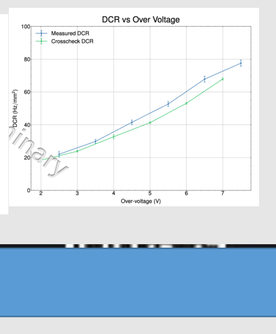
◆ SiPM

- All QA finished
  - 4051 tiles checked, 178 with too large DCR, 115 too large Vbd non-uniformity
- DCR issue carefully xchecked by IHEP and HPK
  - IHEP used a 2nd measurement system, HPK's results agree with us
- High PDE feature also confirmed (52.5% at optimized overvoltage)









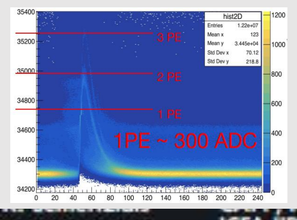
Veto System

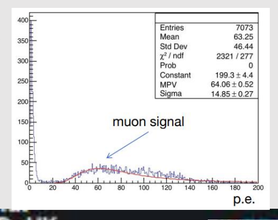
◆ Water Cherenkov

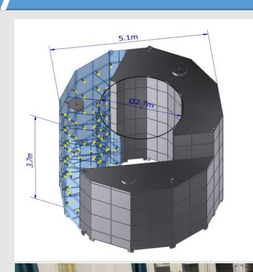
- Tank contract signed
- sPMT electronics tested on prototype

◆ Top Veto Tracker

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







Water tank prototype

Conclusion

- ***TAO will be placed 30 m away from one core of the Taishan NPP to measure the un-oscillated reactor neutrino spectrum***
- ***Unprecedented energy resolution of TAO detector is expected due to symmetrical construction, low temperature scintillator and cooled photon sensors together with comprehensive active and passive shielding.***
- ***These features open a way for precise reactor antineutrino flux and spectrum measurement which making TAO detector a promising tool to contribute greatly to applied antineutrino physics and open a possibility for industrial tool development.***
- ***1:1 prototype is testing***
- ***Expected time for TAO be online ~ end of 2024***

Acknowledgement

This work was supported partially by the National Natural Science Foundation of China (Nos. 11875282, 11475205 and 12022505), the Strategic Priority Research Program of the Chinese Academy of Sciences (No. XDA10011200), and the Youth Innovation Promotion Association of CAS.