

ICHEP 2020 | PRAGUE



Status and progress of the JUNO detector



Jilei Xu

On behalf of the JUNO collaboration

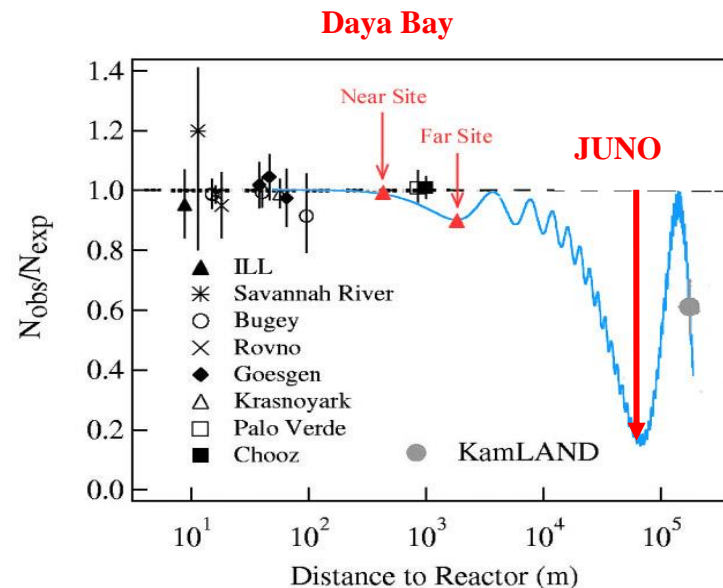
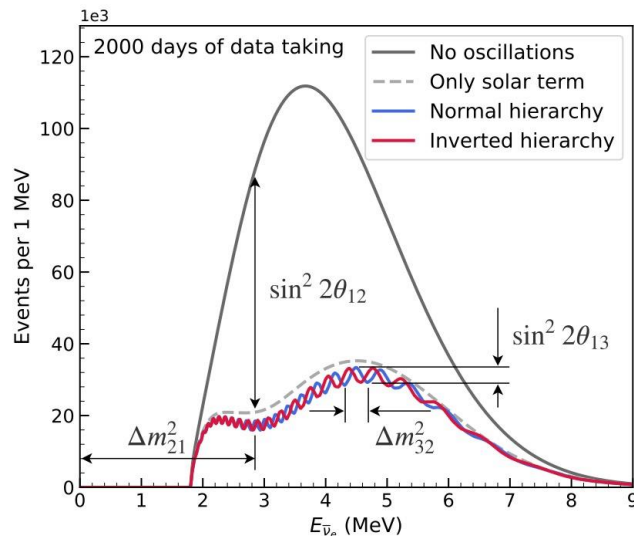
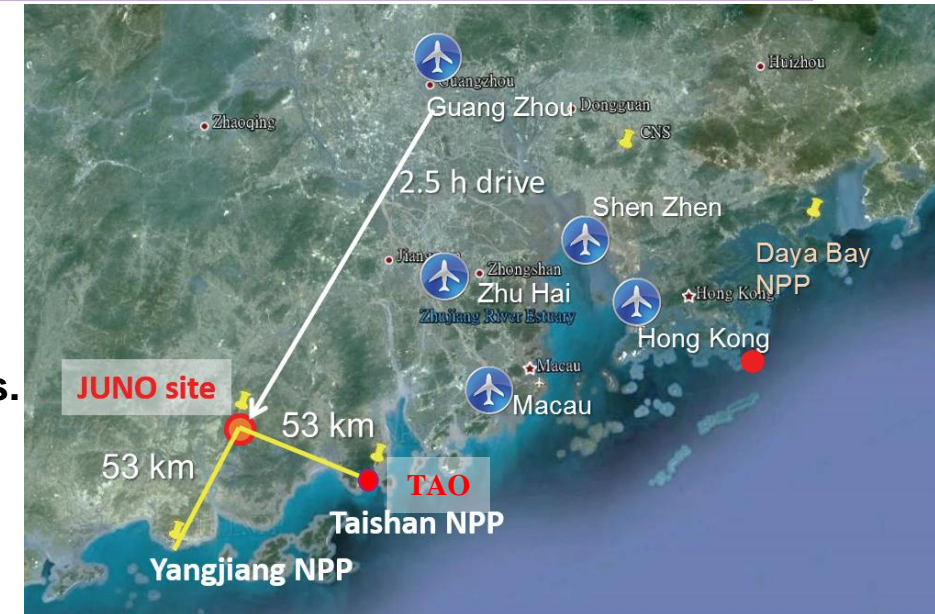
July 31, 2020

Content

- **JUNO introduction**
- **Physics prospects**
- **Sub-detectors and status**
- **Summary**

Jiangmen Underground Neutrino Observatory

- 20 kton liquid scintillator (LS), 3% @ 1 MeV energy resolution, under construction in southern of China.
- Main physics goal:
 - Determine neutrino mass ordering by reactor antineutrinos.
- Detector requirement:
 - High transparency LS, high coverage of PMTs and low backgrounds.
- The most challenging design in the reactor neutrino experiments throughout the world.



Yangjiang NPP	Taishan NPP
17.4 GW	9.2 GW

All six 2.9 GW cores in Yangjiang NPP and two 4.6 GW cores in Taishan NPP are in operation now.

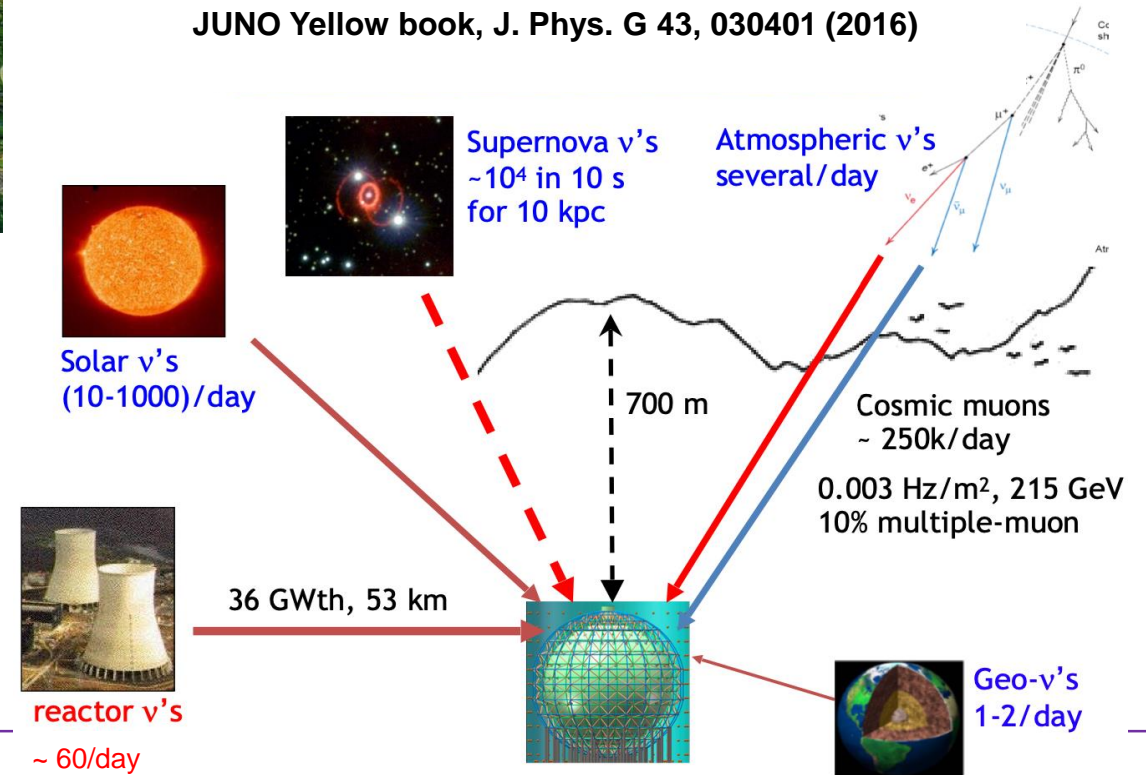
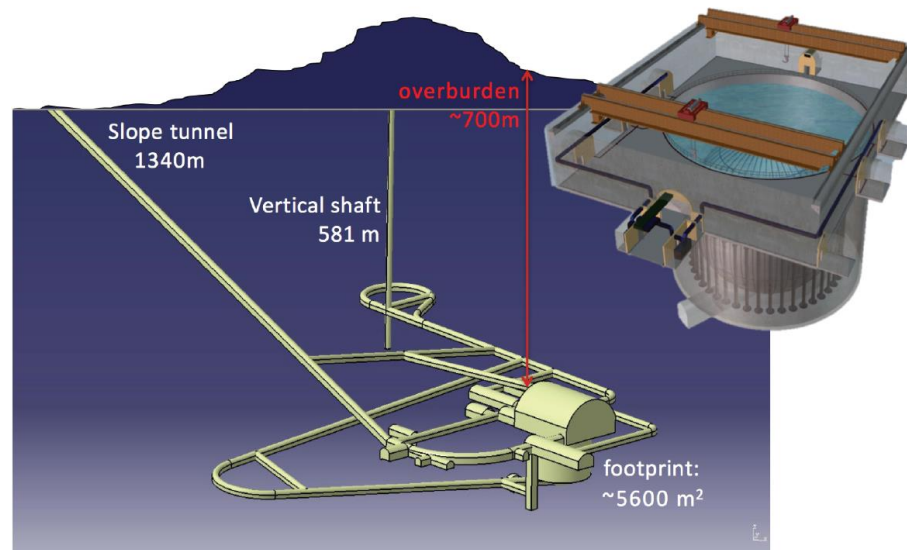


Multipurpose experiment

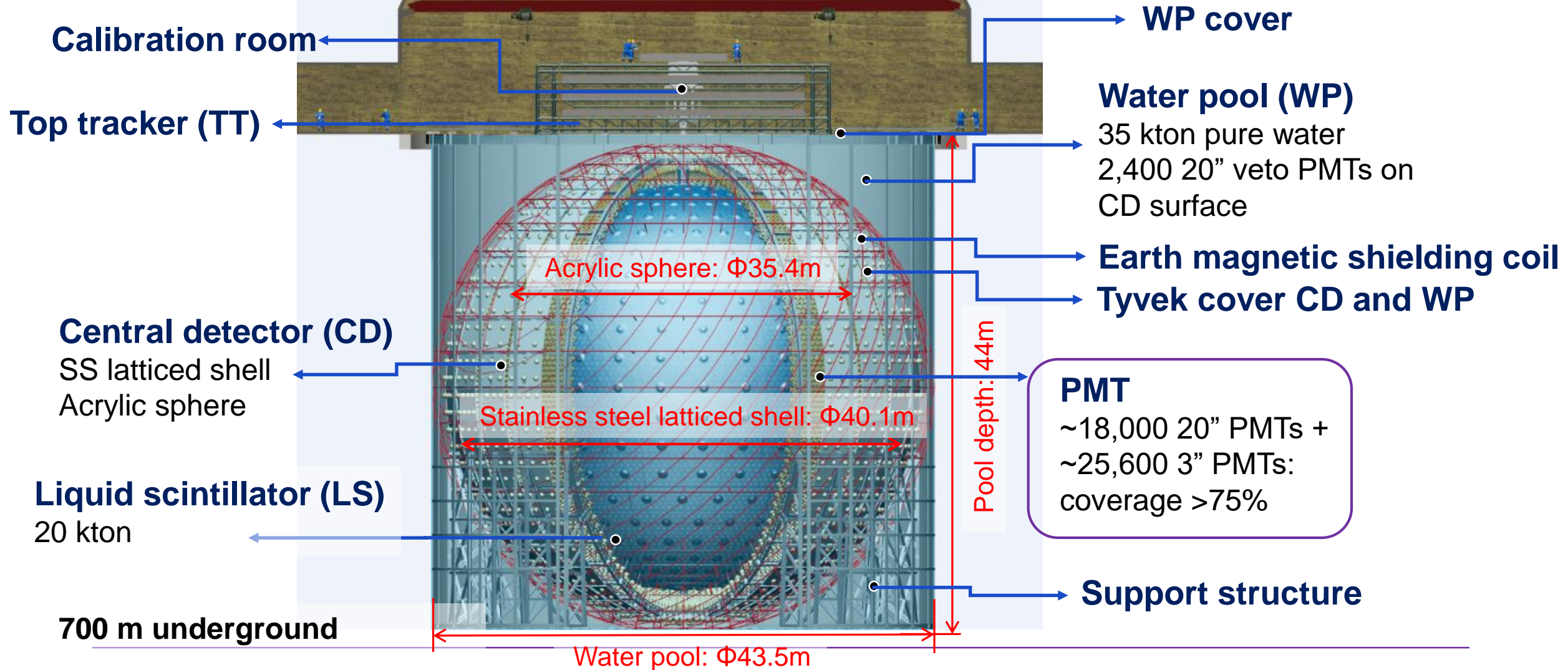


- Measure solar neutrino oscillation with highest precision ($<1\%$).
- Many neutrinos: Supernova, Geo-, solar, atmospheric, sterile,...
- Have a certain ability to detect proton decay

JUNO Yellow book, J. Phys. G 43, 030401 (2016)



JUNO detector



77 members, ~ 600 collaborators

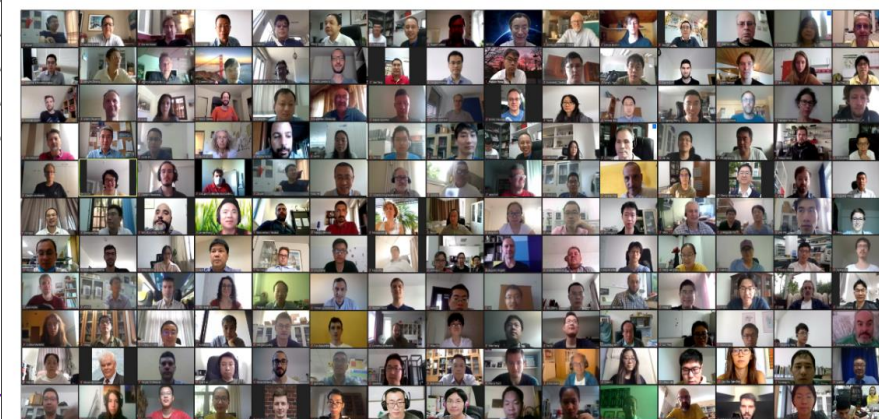


Country	Institute	Country	Institute	Country	Institute
Armenia	Yerevan Physics Institute	China	IMP-CAS	Germany	FZJ-IKP
Belgium	Universite libre de Bruxelles	China	SYSU	Germany	U. Mainz
Brazil	PUC	China	Tsinghua U.	Germany	U. Tuebingen
Brazil	UEL	China	UCAS	Italy	INFN Catania
Chile	PCUC	China	USTC	Italy	INFN di Frascati
Chile	UTFSM	China	U. of South China	Italy	INFN-Ferrara
China	BISEE	China	Wu Yi U.	Italy	INFN-Milano
China	Beijing Normal U.	China	Wuhan U.	Italy	INFN-Milano Bicocca
China	CAGS	China	Xi'an JT U.	Italy	INFN-Padova
China	ChongQing University	China	Xiamen University	Italy	INFN-Perugia
China	CIAE	China	Zhengzhou U.	Italy	INFN-Roma 3
China	DGUT	China	NUDT	Latvia	IECS
China	ECUST	China	CUG-Beijing	Pakistan	PINSTECH (PAEC)
China	Guangxi U.	China	ECUT-Nanchang City	Russia	INR Moscow
China	Harbin Institute of Technology	Croatia	UZ/RBI	Russia	JINR
China	IHEP	Czech	Charles U.	Russia	MSU
China	Jilin U.	Finland	University of Jyvaskyla	Slovakia	FMPICU
China	Jinan U.	France	LAL Orsay	Taiwan-China	National Chiao-Tung U.
China	Nanjing U.	France	CENBG Bordeaux	Taiwan-China	National Taiwan U.
China	Nankai U.	France	CPPM Marseille	Taiwan-China	National United U.
China	NCEPU	France	IPHC Strasbourg	Thailand	NARIT
China	Pekin U.	France	Subatech Nantes	Thailand	PPRLCU
China	Shandong U.	Germany	FZJ-ZEA	Thailand	SUT
China	Shanghai JT U.	Germany	RWTH Aachen U.	USA	UMD-G
China	IGG-Beijing	Germany	TUM	USA	UC Irvine
China	IGG-Wuhan	Germany	U. Hamburg		



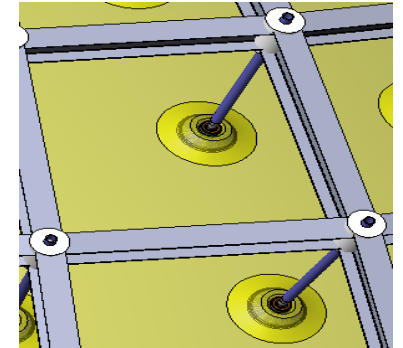
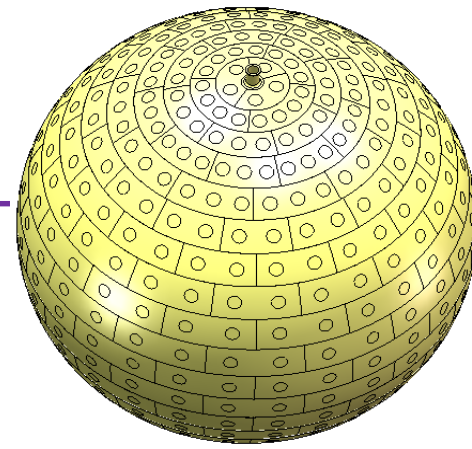
The 16th JUNO Collaboration Meeting

July 8-10, 2020, Online



Acrylic spherical vessel and SS structure

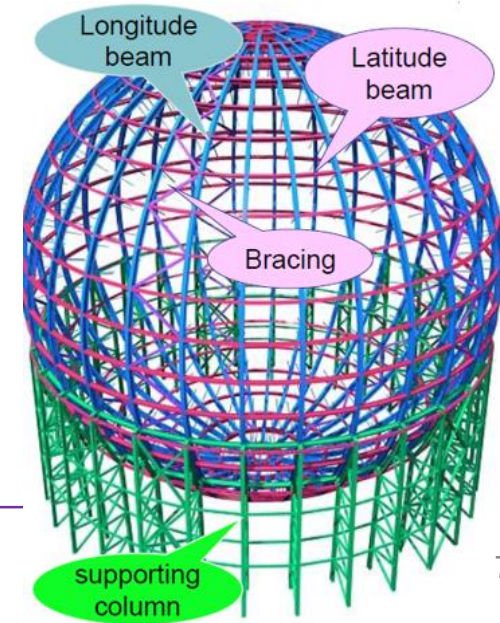
- The largest acrylic spherical vessel and SS structure.
 - Φ 35.4 m acrylic spherical vessel, acrylic sheets: 8 m \times 3 m \times 12 cm
 - Supporting bar to hold the Acrylic tank
 - Solved all technical problems: No standards for construction, high precision curved sheet, anti-seismic, transparency, low bkg, fast bonding and annealing.
- Acrylic vessel panels and SS structure are in production.



Pre-assembly in the manufacturer

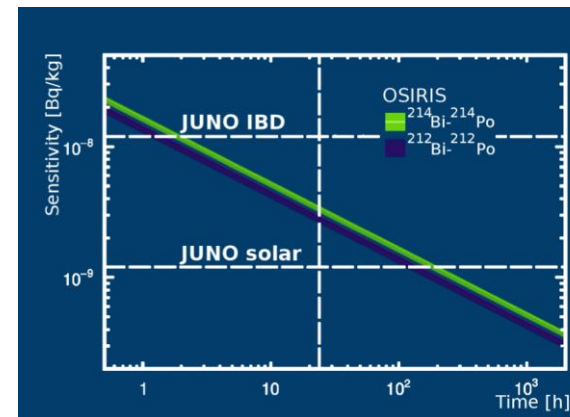
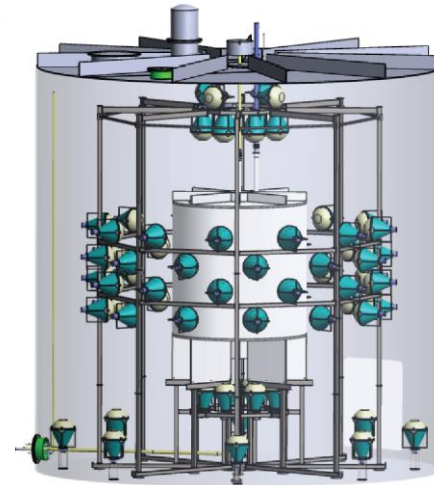
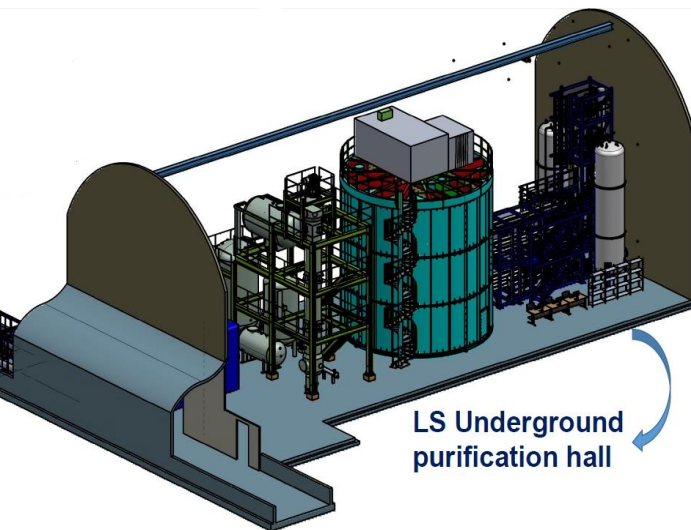
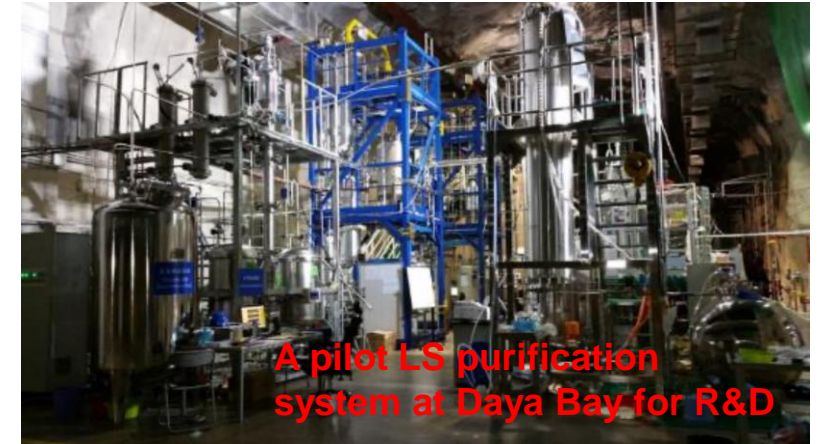


Bonding test of one ring acrylic



High transparent liquid scintillator

- Highest possible light yield and low radioactivity for JUNO
 - 2.5 g/L PPO + 3 mg/L Bis-MSB
 - 10^{-15} g/g for reactor antineutrinos
 - 10^{-17} g/g for solar neutrinos
- OSIRIS: **O**nline **S**cintillator **I**nternal **R**adioactivity **I**nvigation **S**ystem
 - 20 t LS and water tank 9 m x 9 m
 - Sensitivity of 10^{-15} g/g per day.
- Purification plant to achieve (attn. > 20 m)
 - Al_2O_3 filtration (Onsite installation this year)
 - Distillation
 - Steam stripping
 - Water extraction



OSIRIS detector sensitivity

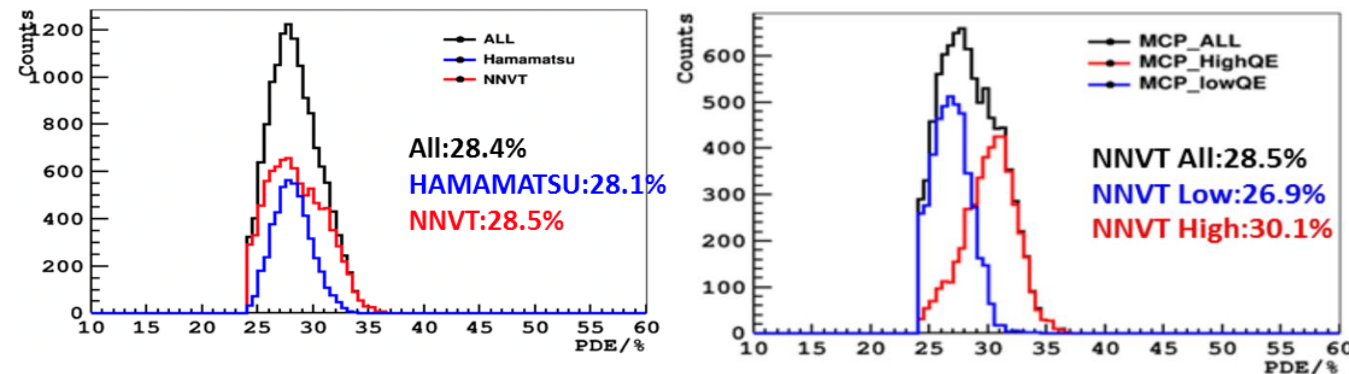
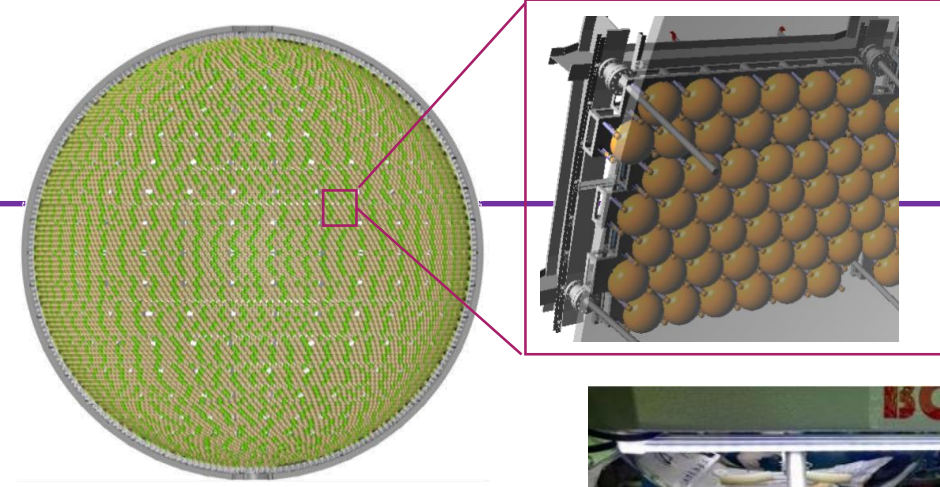


Purification system @ JUNO surface

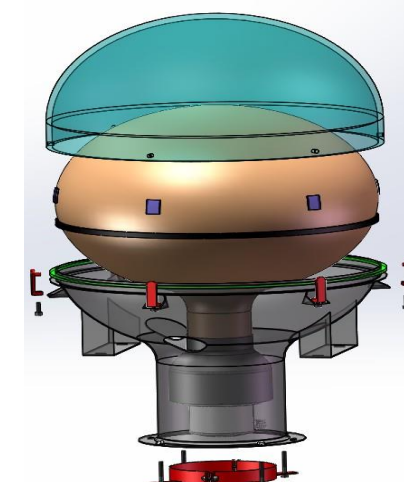
20-inch PMTs



- The largest coverage ($>75\%$)
 - Micro-channel plate (MCP) PMT ($\sim 13,000$ from Northern Night Vision Technology (NNVT) company)
 - Dynode PMT ($\sim 5,000$ from Hamamatsu company)
- Almost all bare PMTs are delivered, acceptance test going well.
- Mass potting is on going (36%) and in good shape.
- Implosion protection cover mass production started.



The photon detection efficiency (PDE) of new MCP-PMT is $> 30\%$.



Cover

3-inch PMTs

- 25,600 3-inch PMTs from Hainan Zhanchuang (HZC) photonics company.
- Make double calorimetry, calibrate non-uniformity and non-linearity of Large-PMTs
 - Reduce energy scale uncertainty
 - Improve energy resolution (non-stochastic term)
- Increase optical coverage (~3%)
 - Improve energy resolution (stochastic term)
- Extend energy measurement for muon physics
- Independent system for supernova and solar neutrino oscillation parameter measurement.
- In good progress:
 - ~26,000 PMTs were produced.
 - Others (HV divider, potting, cable, connector, HV splitter, electronics, under water box) are all going well.

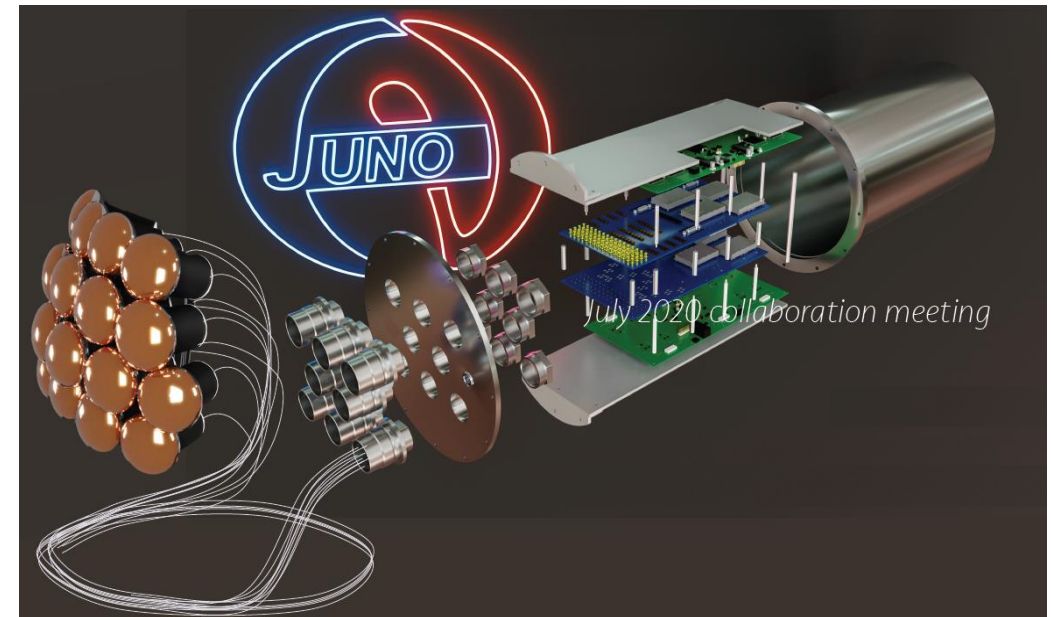
XP72B22



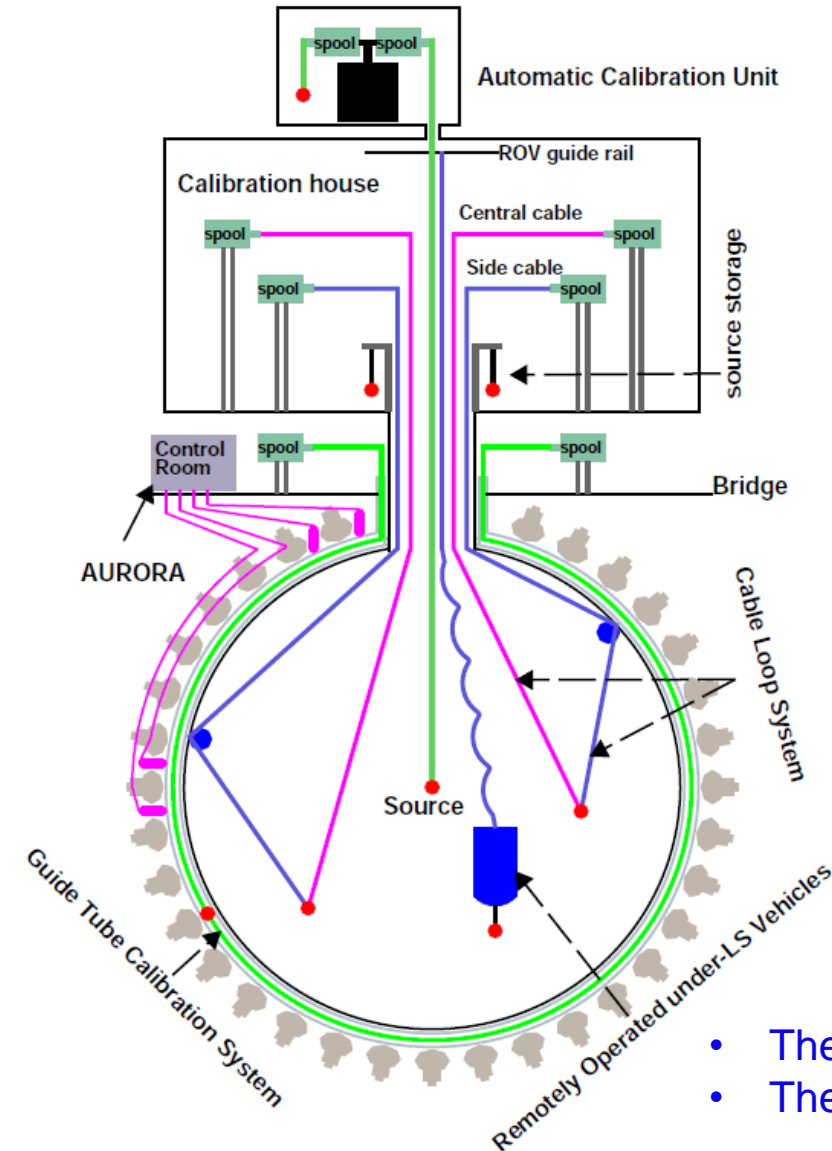
HZC Photonics
Custom 3-inch PMTs
for JUNO



20-inch and 3-inch PMTs interleaving



Comprehensive calibration system

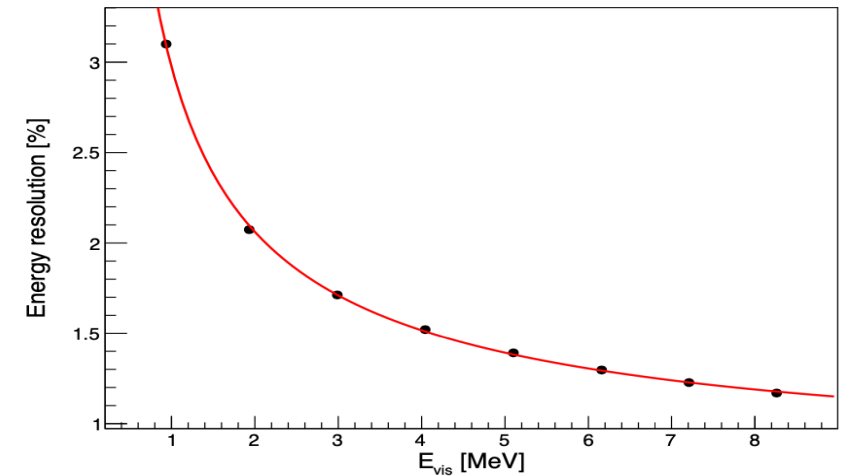
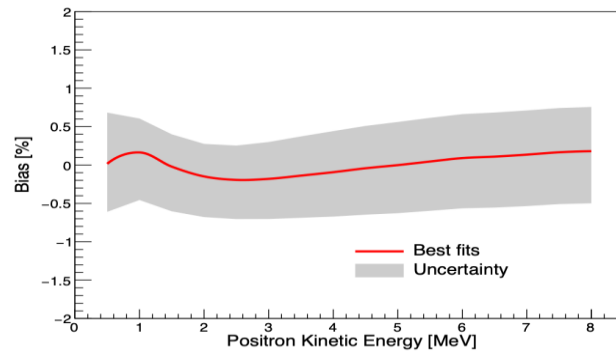
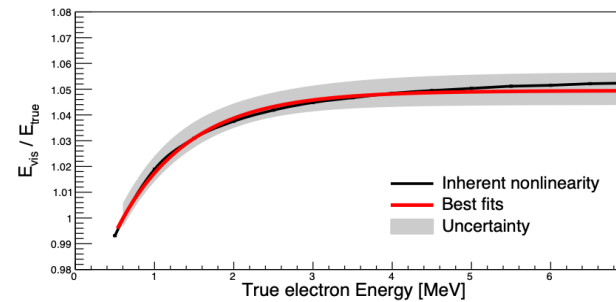


1D: Automatic Calibration Unit (ACU)

2D: Cable Loop System (CLS) and Guide Tube Calibration System (GTCS)

3D: Remotely Operated Vehicle (ROV)

Auxiliary systems: Calibration house, Ultrasonic Sensor System (USS), CCD and A Unit for Researching Online the LSc tRAnsparency (AURORA)



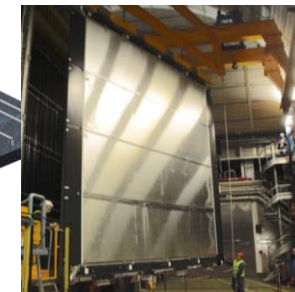
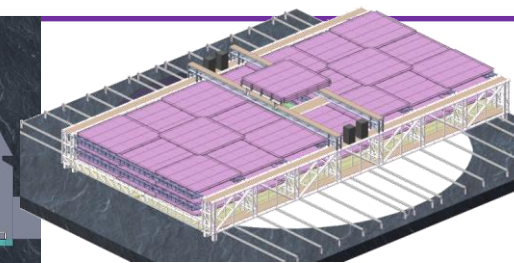
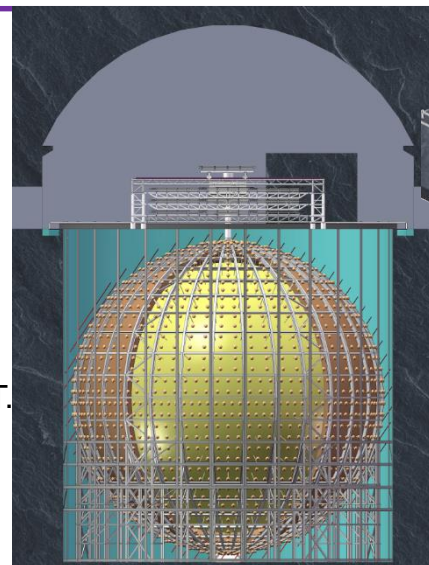
- The bias in the reconstructed energy is expected to be less than 1%.
- The effective energy resolution is expected to be less than 3.0% between 1 MeV and 8 MeV.

Veto system (Water Pool + Top Tracker)



Water Pool

- 35 kton ultrapure water
 - Passive shielding for rock neutrons and for material radioactivity
 - Active veto for muon that goes through LS and water pool.
- 2400 20-inch MCP-PMTs on CD surface toward outside.
- Earth magnetic shielding coils
 - Residual B <10% of local earth magnetic field for CD PMT, <20% for Veto PMT.
- 5 mm thickness HDPE lining
 - Prevent diffusion of Radon from rocks and keep water clean.
- Water circulation in good shape, control in $(21 \pm 1)^\circ\text{C}$
- Tyvek, good quality and technology, separate CD and WP, increase PE collection.



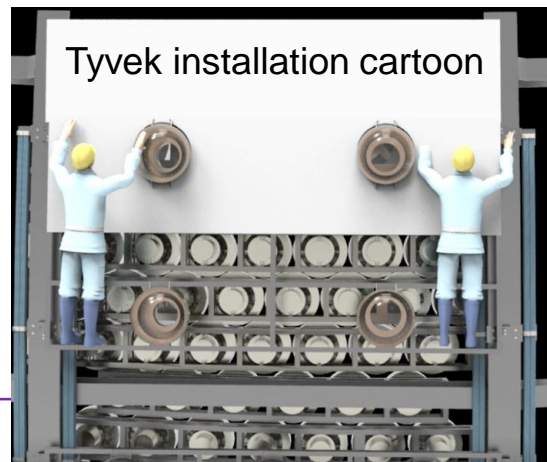
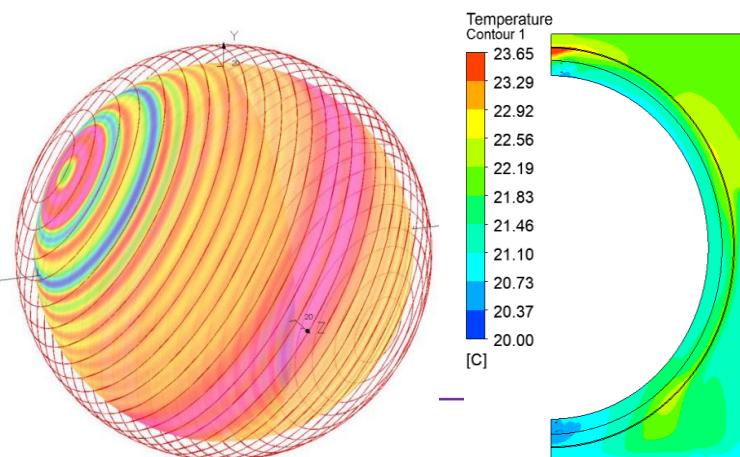
Concentrator Board



Read Out & Front End Boards installed in the End Cap

Top Tracker

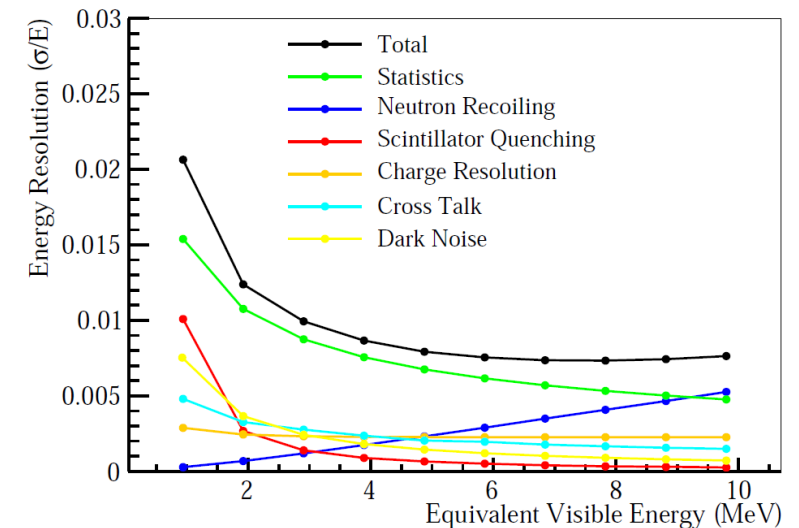
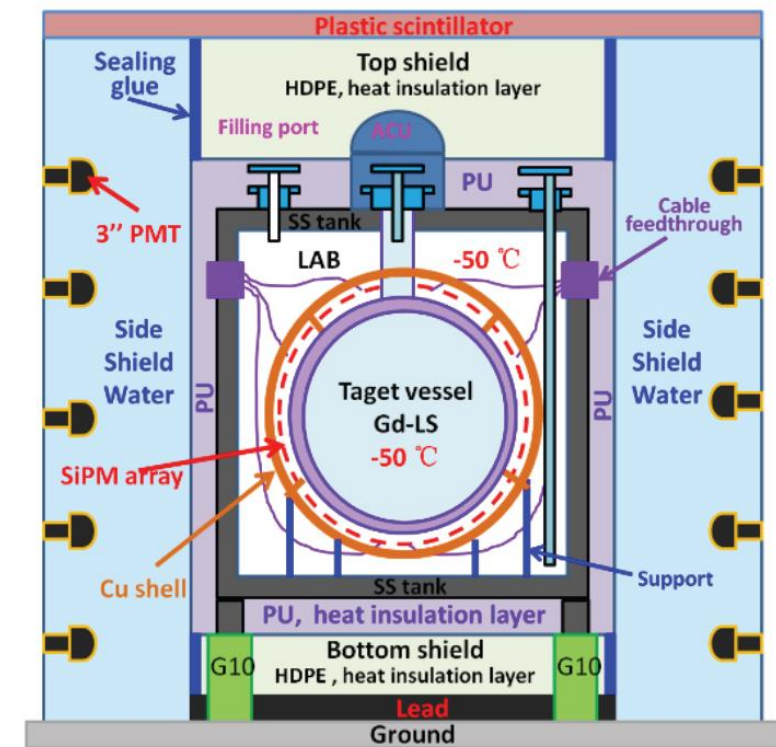
- Reuse the target tracker walls of the OPERA experiment
- 3-layers XY plastic scintillator modules are already at JUNO site
- Front End Boards are all produced and other boards in production and test well.
- Not only for veto, but also for muon tracking validation.



JUNO-TAO

- **Taishan Antineutrino Observatory (TAO)**, a ton-level, high energy resolution LS detector at 30 m from one of the Taishan reactor cores, a satellite exp. of **JUNO**.
- Measure reactor neutrino spectrum with sub-percent energy resolution for $E > \sim 2 - 3$ MeV.
 - Model-independent **reference spectrum** for JUNO
 - A benchmark for investigation of the **nuclear database**
- **Detector Design:**
 - 2.8 ton Gadolinium doped liquid scintillator
 - 10 m² **95% coverage** with SiPM
 - Photon detect efficiency > 50%
 - Operate at **-50 °C** (SiPM dark noise)
 - 4500 p.e./MeV
 - 2000 reactor antineutrinos / day

TAO start operation in 2022



Summary

- A multipurpose experiment: mass ordering, solar oscillation parameters, supernova neutrinos, solar neutrinos, geo-neutrinos, atmospheric neutrinos, nucleon decay, etc.
- Detector component production is in good progress.
- Start data taking in 2022.

- **Related talks:**

- Cecile Jollet, 31/07/2020, 08:00: [JUNO Physics](#)
- Qian Sen, 28/7/2020, 15:30: [The MCP based Large Area PMTs for Neutrino Detector](#)

- **Posters:**

- Kangfu Zhu, 29/07/2020, 13:39: [The JUNO Calibration Strategy and its Simulation](#)
- Thilo Birkenfeld, 29/07/2020, 13:45: [Detector Simulation and Reconstruction of Supernova Neutrinos with JUNO](#)
- Ziyuan Li, 30/07/2020, 13:45: [Vertex Reconstruction and Deep Learning Applications in JUNO](#)
- Guihong Huang, 30/07/2020, 13:48: [Energy and vertex reconstruction in JUNO](#)
- Yuhang Guo, 30/07/2020, 13:48: [Prospects for Proton Decay Searches in JUNO](#)
- Joao Pedro, 30/07/2020, 13:51: [Status of the Veto System of JUNO](#)
- Cecile Jollet, 30/07/2020, 13:54: [3-inch Photomultiplier System of the JUNO Experiment](#)

Thanks! (谢谢!)

