



The Water Cherenkov detector of JUNO



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The Jiangmen Underground Neutrino Observatory (JUNO) is a 20 kton liquid scintillator detector with multi-purpose measurements. The detector will be built in a 700 m deep underground laboratory with primary physics goal of the neutrino mass hierarchy determination. Due to the low background requirement of the experiment, a multi-veto system for cosmic muon detection is required for background reduction. This poster is mainly focused on the Water Cherenkov detector progress.

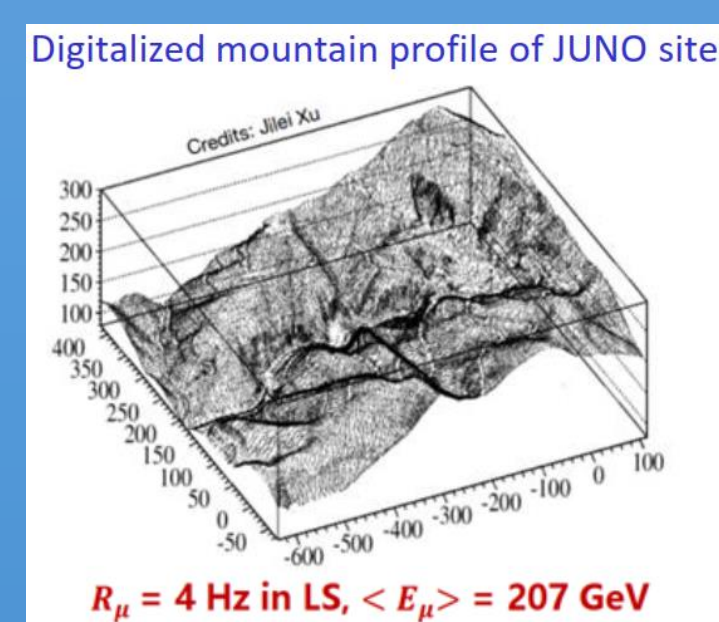
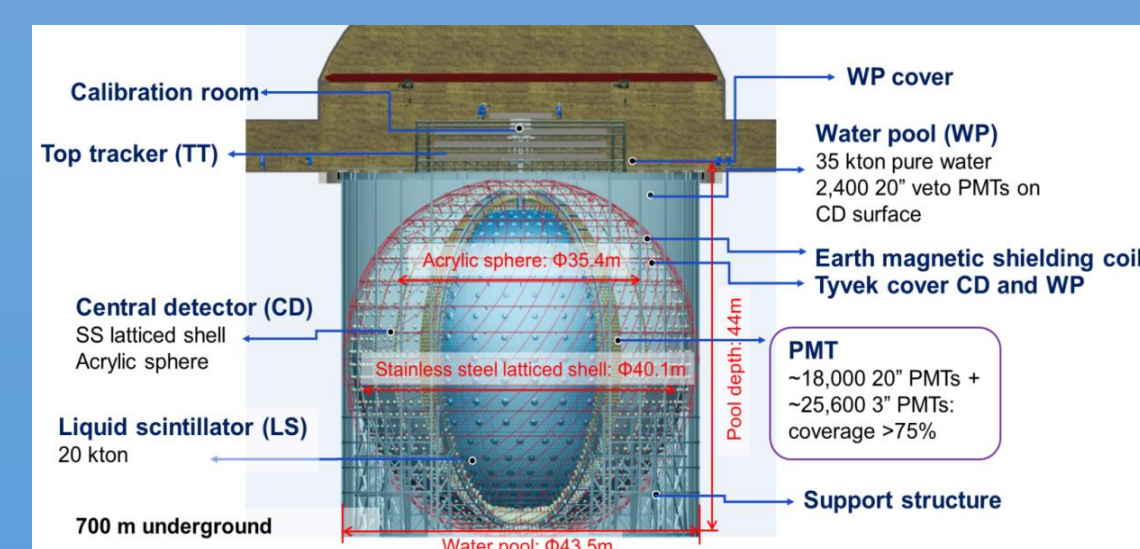
The JUNO experiment : a reactor anti-neutrino experiment

- Physics goals:**
 - Mass ordering (3σ with 6 years data taking)
 - Three oscillation parameters to $<1\%$ level.
 - Supernova neutrinos, geo-neutrinos, solar neutrinos, atmospheric neutrinos and other oscillation physics such as searches for proton decay, among others.

- Detector**
 - Central Detector: 20-kton liquid scintillator;
 - 17612 20" PMTs + 25600 3" PMT, High energy resolution $3\% @ 1\text{MeV}$.
 - Background reduction: Under 700 m deep underground for muon flux reduction.

Cosmic background

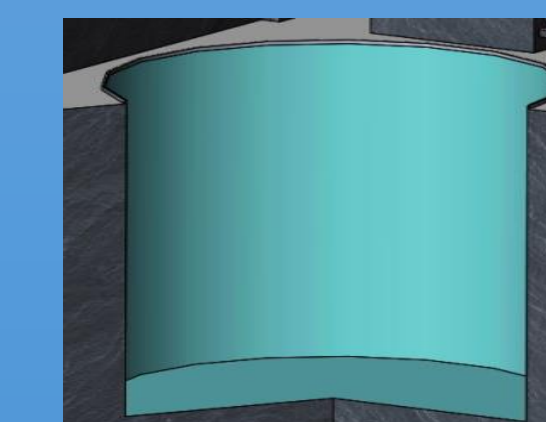
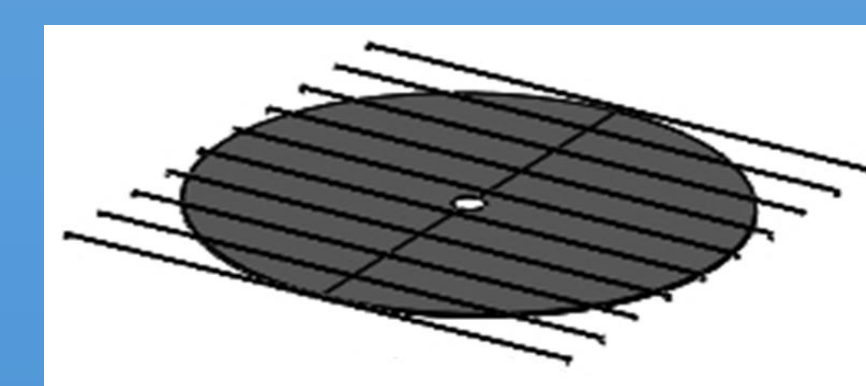
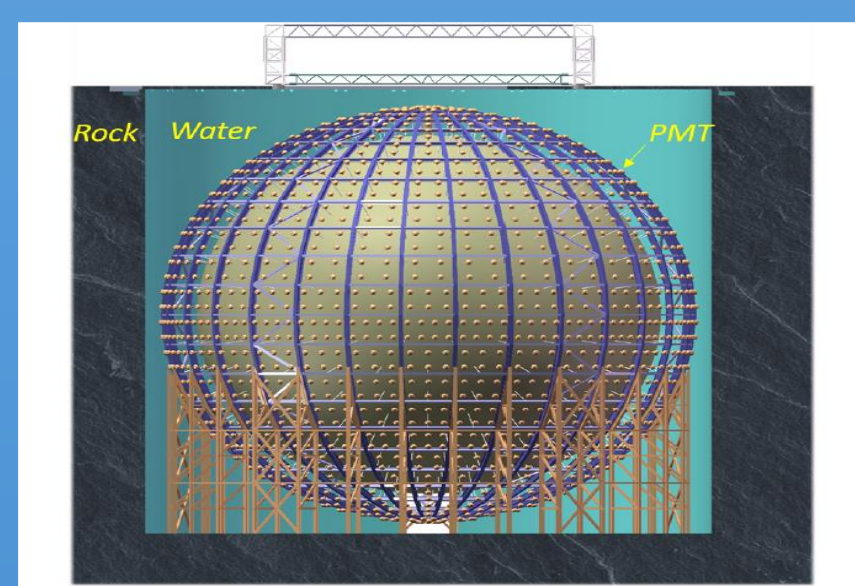
- ${}^9\text{Li}/{}^8\text{He}$ from muon spallation:
 - $\sim 127 {}^9\text{Li} + 40 {}^8\text{He}$ isotope/day (IBD signal $\sim 60/\text{day}$);
 - Untagged muon induced fast neutron background.
 - Reduce the background to low level:
- Good veto detector are required;**
 - Water Cherenkov Veto + Top Tracker detectors
- Water Cherenkov Veto:**
 - Fast neutrons background rejection
 - Muon tagging \rightarrow Control within 0.1/day.
 - Radioactivity from rock \rightarrow passive shielding by water
 - Cosmogenic isotopes reduction (${}^9\text{Li}/{}^8\text{He}$)
 - Requires a precise muon track reconstruction \rightarrow Top tracker



Background	Rate (day^{-1})
Geoneutrinos	1.2
World reactors	1.0
Accidentals	0.8
${}^9\text{Li}/{}^8\text{He}$	0.8
Atmospheric neutrinos	0.16
Fast neutrons	0.1
${}^{13}\text{C}(\alpha, n){}^{16}\text{O}$	0.05

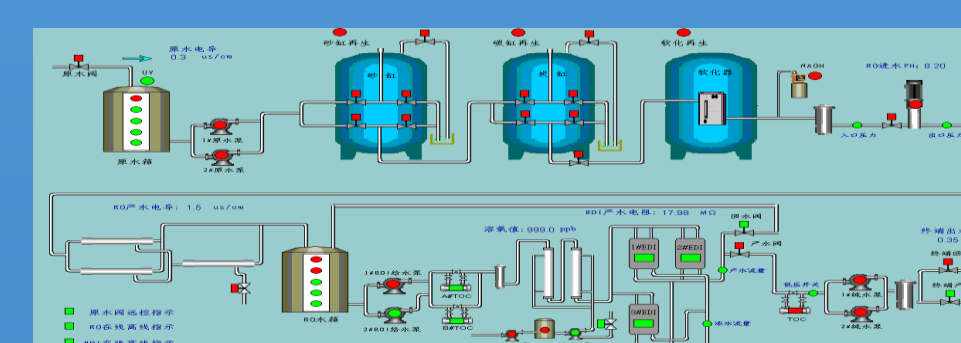
Water Cherenkov Detector and sub-systems

- Detector dimension: 43.5 m diameter * 44m height;
- 2400 20 inch MCP-PMT used for veto system;
- PMTs put on the surface of the sphere and facing outside
- Tyvek reflector film coated on surface to increase light collection efficiency
- 35 kton ultrapure water in the pool
- Detector efficiency is expect to be $> 99\%$.

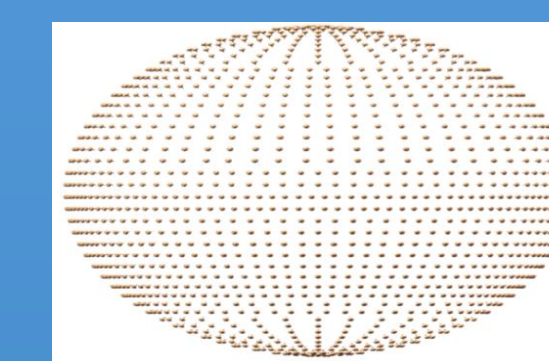


Cover & rail

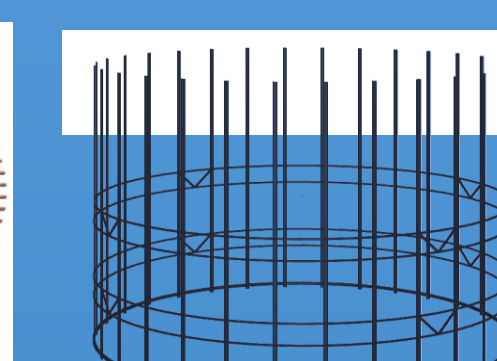
Pool liner



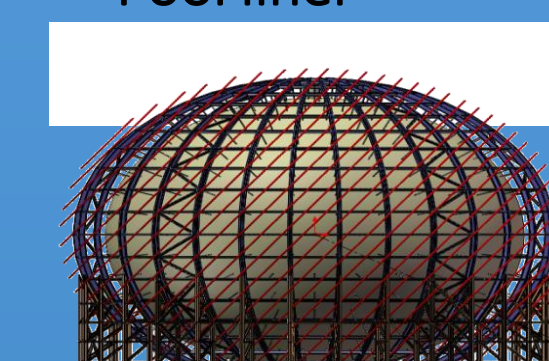
Pure water system, flow rate: $\sim 100\text{t/h}$



PMTs & Tyvek reflection film

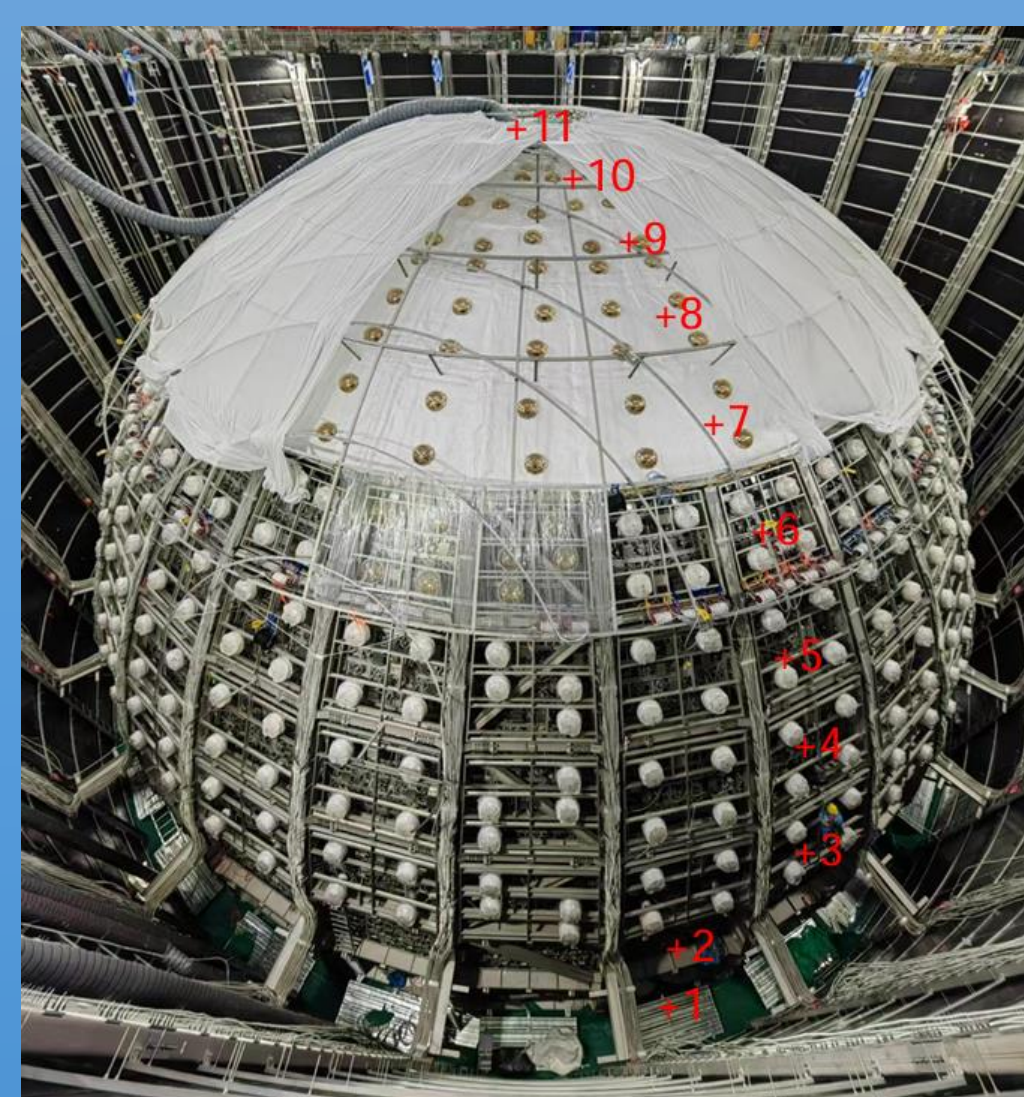
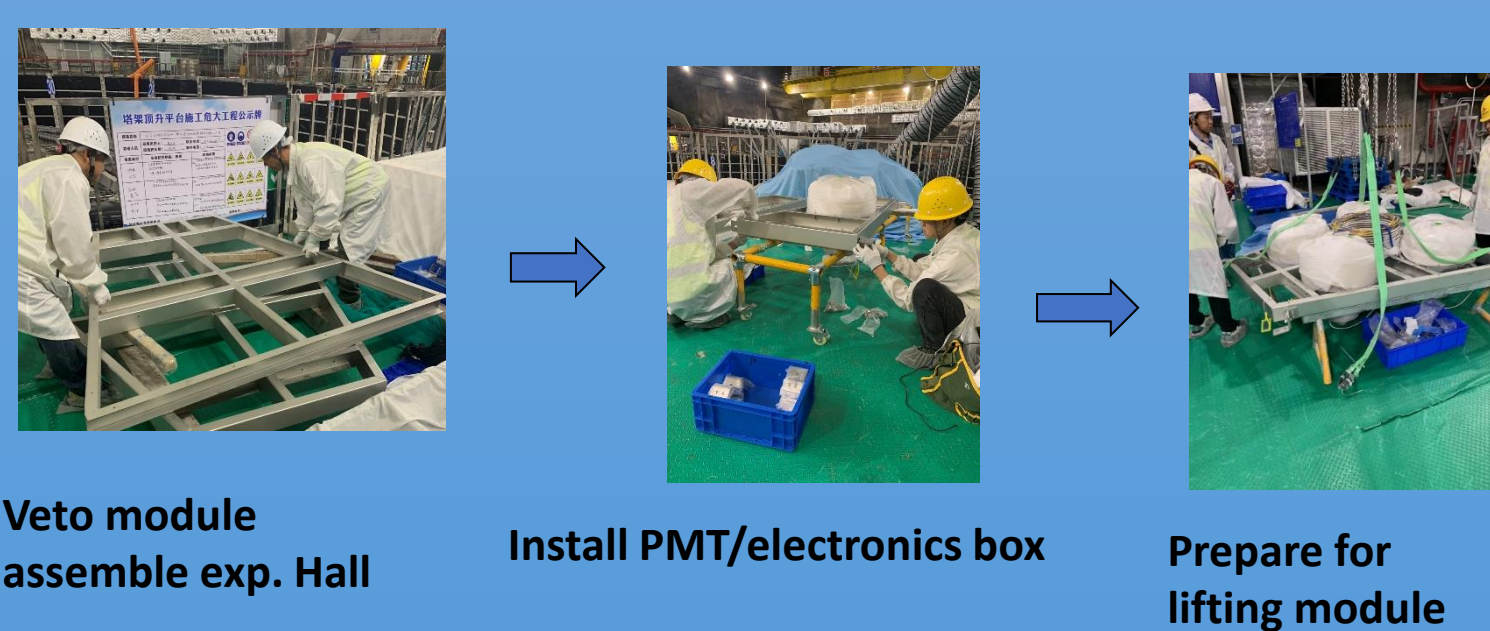


Bird cage & Tyvek reflection film



EMF coils

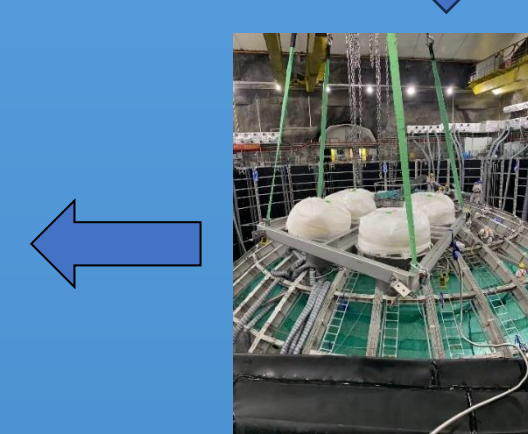
Veto PMT/electronics installation



- Installation status:**
 - +11 \sim +3 layer finished
 - 250 modules (40% of 620)
 - 730 PMTs (30% of 2400)



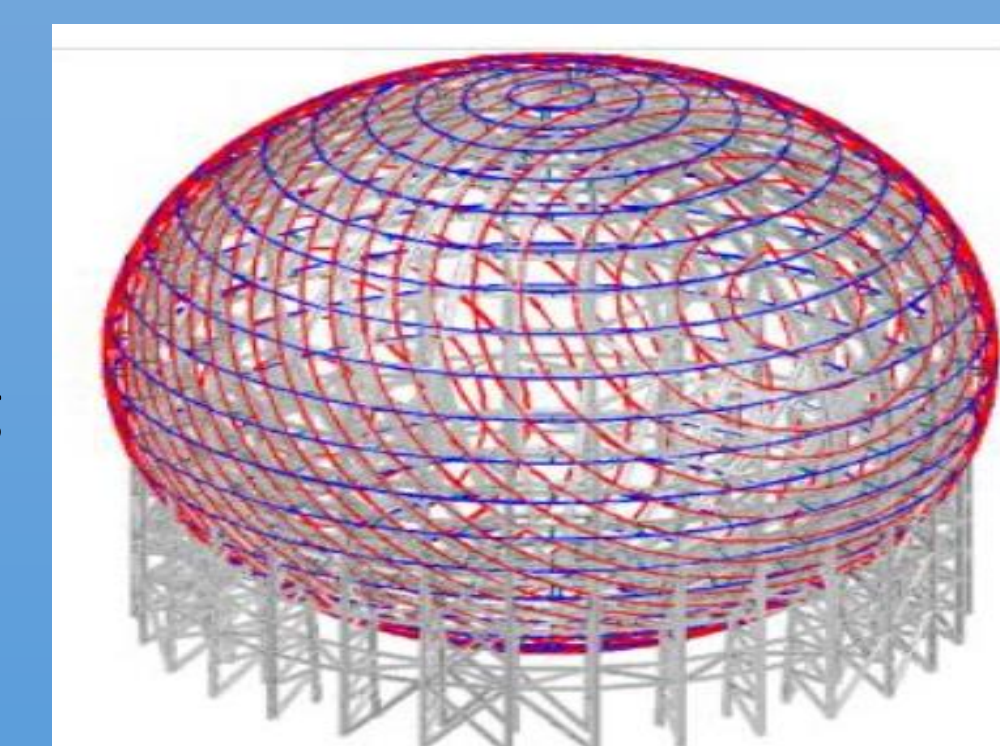
fixation



lifting

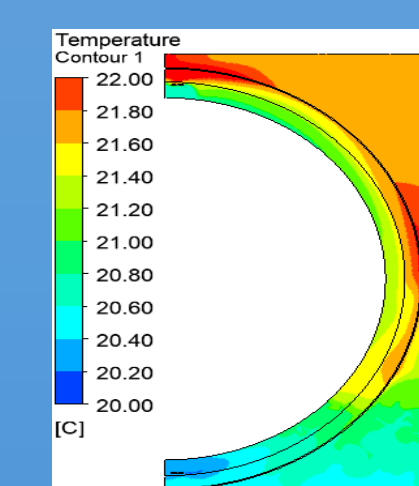
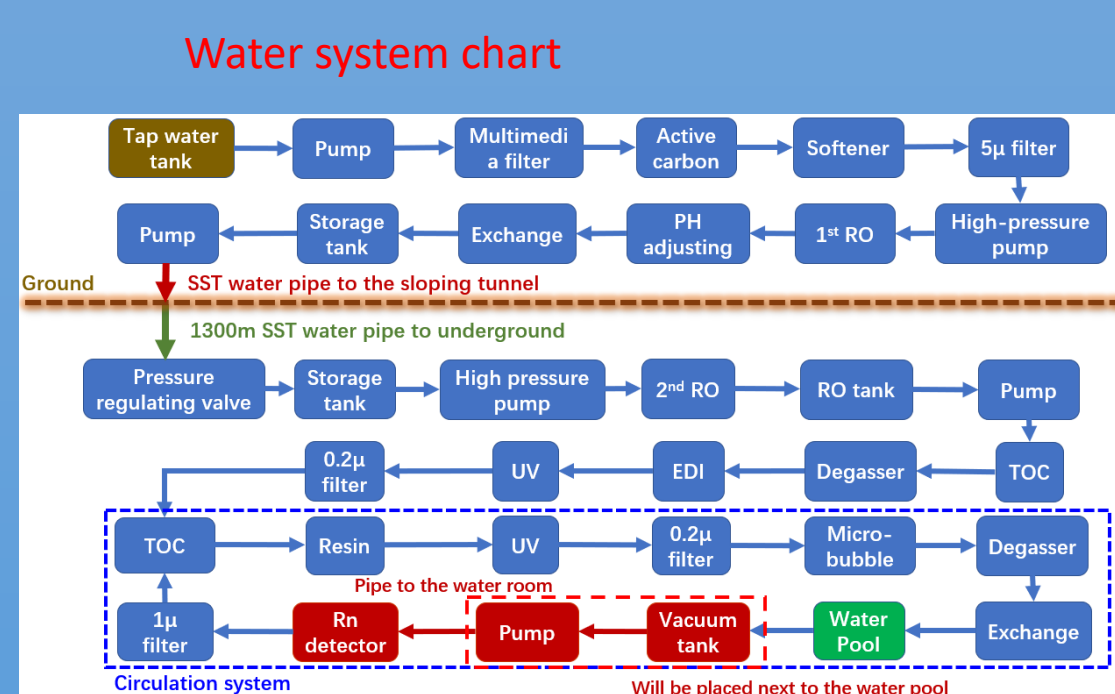
Compensation coils system

- Earth Magnetic Field (EMF) intensity (0.45Gs)
 - Big effect on the 20 inch PMT performance and need shielding system for compensation EMF.
- One set coils generate the opposite direction of the geomagnetic field to compensate EMF.
 - 32 coils shielding coils scheme
- Coils uniformity in CD $< 0.05\text{G}$.
- The EMF direction change every year ($< 0.2\text{deg/y}$).
 - Set a compensation angle when the coils are installed.
 - Make the angle change < 1 degree within 10 years.
- Installation status:**
 - +11 \sim +6 layer finished
 - Finished 20 coils (20 of 32 coils)



Water system

- Water circulation
 - Keep water quality good;
 - Keep temperature control within $(21 \pm 1)^\circ\text{C}$ around acrylic vessel \rightarrow very important for acrylic safety;
 - Simulation results show $20^\circ\text{C} < T < 22^\circ\text{C}$;
- Radon control in water
 - Radon concentration in water for JUNO prototype: $< 1 \text{ mBq/m}^3$



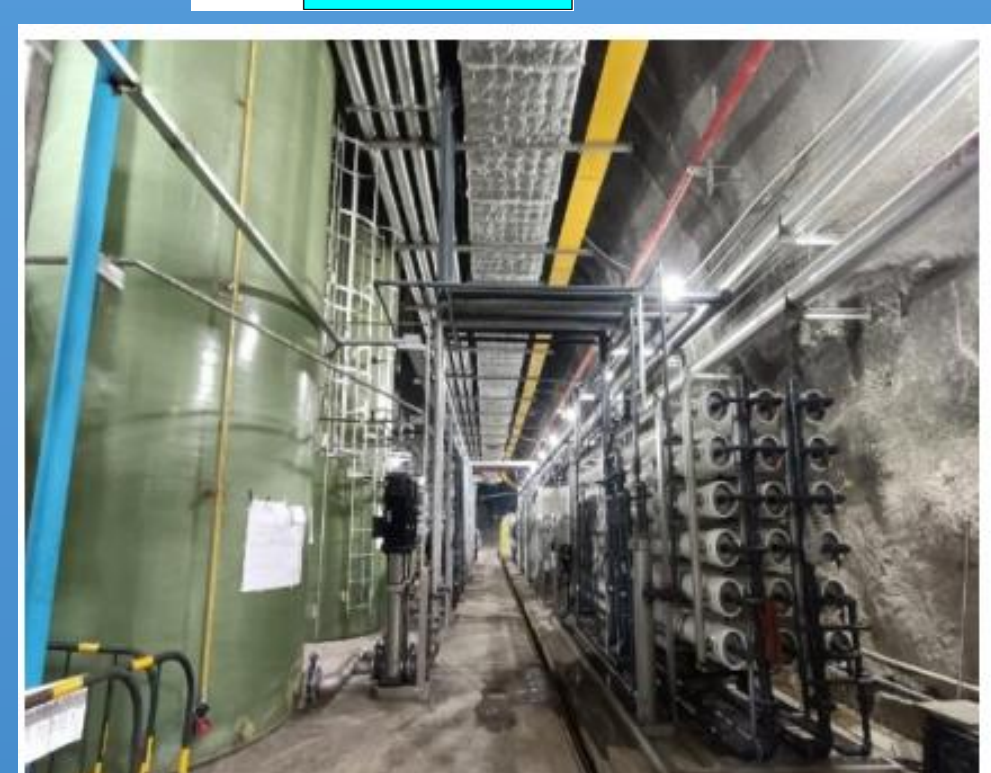
Temperature distribution around acrylic vessel

Status

- Both ground and underground system installation are finished;
- Ready for tuning and commissioning



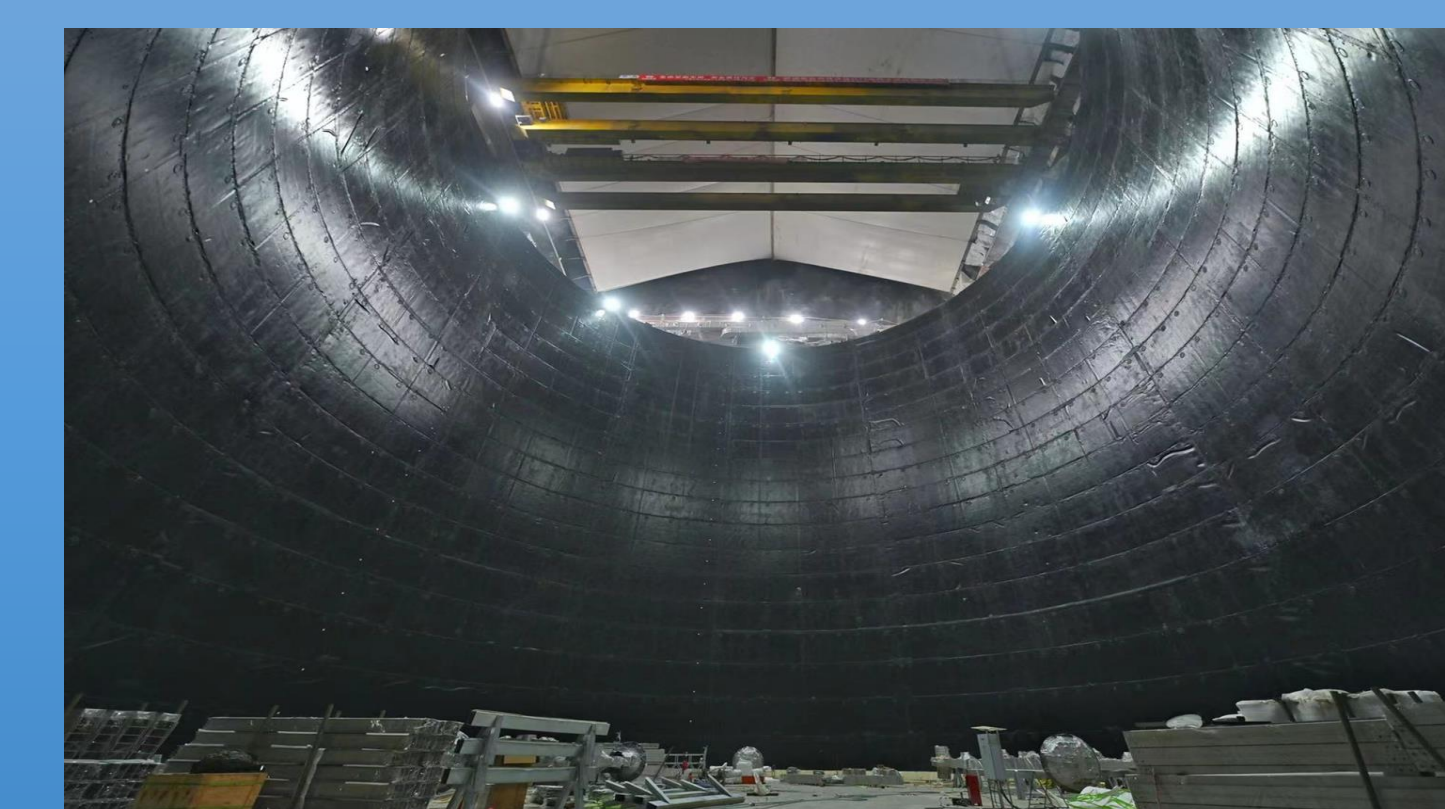
Water system (ground)



Water system (underground)

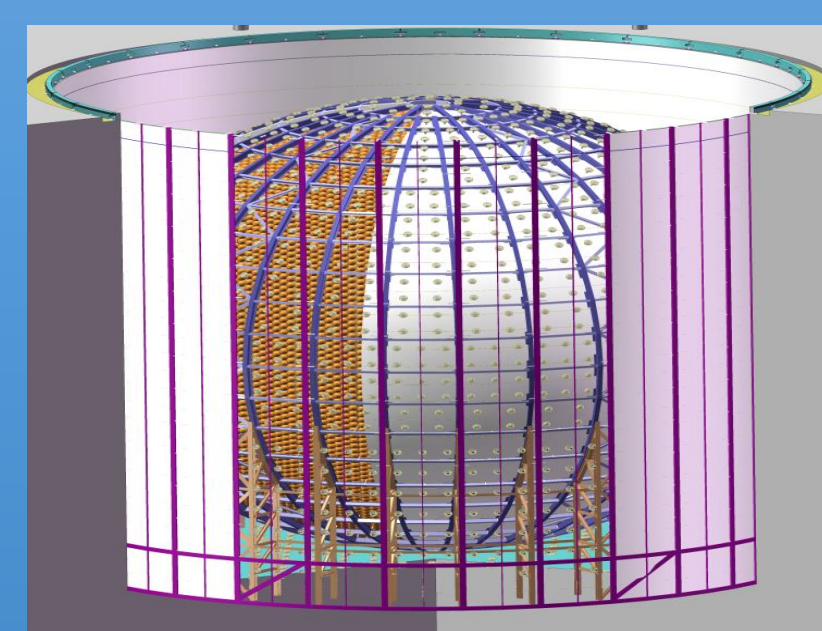
Pool lining

- High Density Polyethylene (HDPE)
 - To separate pure water from rock
 - To prevent rock radon diffusing into the pool.
 - Thickness 5 mm.
- The side wall lining installation was finished.
 - dimension: 43.5 m diameter * 44m height;
 - $> 6000 \text{ m}^2$ lining.

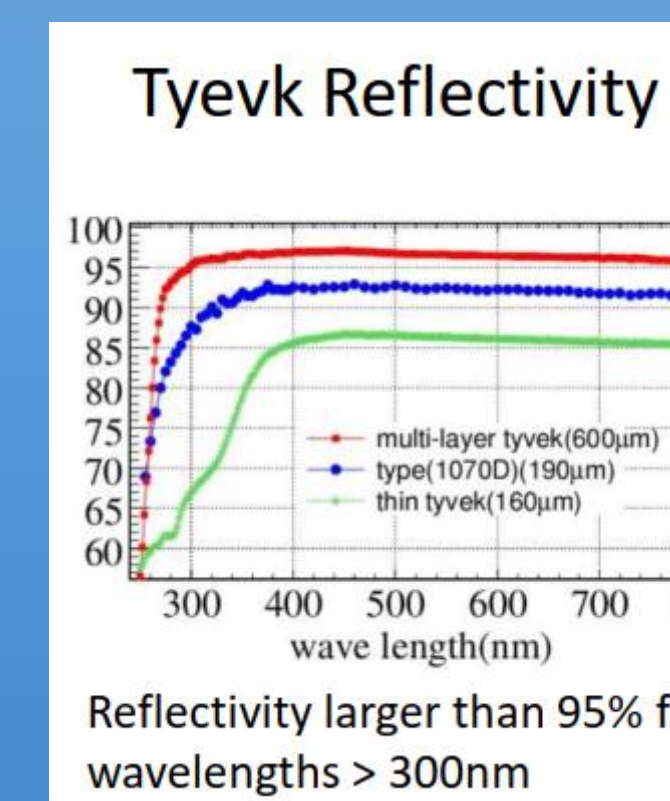


Tyvek reflection film

- To be installed on
 - Surface of the SS latticed shell;
 - Pool wall, bottom and top;
 - Start production soon.



Tyvek reflector



Reflectivity larger than 95% for wavelengths $> 300\text{nm}$

- Installation status:**
 - +11 \sim +7 layer finished



Status & Plan

- JUNO will determine the neutrino mass ordering at 3σ with 6 years of data taking and precisely measure the three oscillation parameters to $< 1\%$ level.
- JUNO water Cherenkov detector is designed for muon detection and background reduction.
- The detector assembly/installation is progressing smoothly and is expected to finish by end of this year.

