JUNO Water Cherenkov Detector and Performance

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UCI Department of Physics & Astronomy
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The JUNO Experiment

Physics goals:

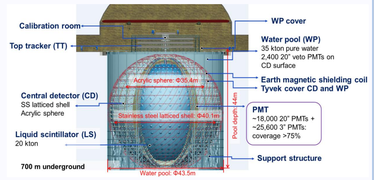
- Mass ordering (3σ with 6 years data taking)
- Three oscillation parameters precision to <1% level.
- Supernova neutrinos, geo-neutrinos, solar neutrinos, atmospheric neutrinos, and other topics(e.g. proton decay).

Good veto detector are required;

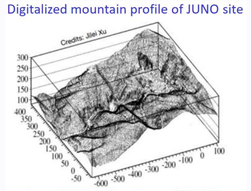
- **Water Cherenkov Veto + Top Tracker detectors**

Water Cherenkov Veto:

- Fast neutrons background rejection
  - Muon tagging ->Control within 0.1/day.
- Radioactivity from rock → passive shielding by water
- Cosmogenic isotopes reduction (^{9}Li/^{8}He)
  - Requires a precise muon track reconstruction ->Top tracker



Digitalized mountain profile of JUNO site



R_μ = 4 Hz in LS, $< E_\mu >$ = 207 GeV

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

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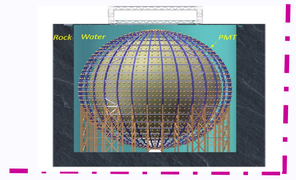
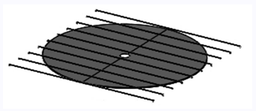
Detector Design

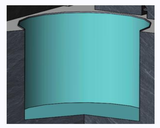
- **Water Cherenkov Detector and sub-systems**
  - Detector dimension:diameter and height 43.5 m × 44m;
  - 2400 20-inch MCP-PMT used for veto system;
  - PMTs put on the surface of the sphere and facing outside;
  - Tyvek reflector film coated on surface to increase light collection efficiency;
  -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



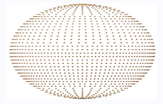
Pure water system, flow rate: ~100t/h



Cover & rail

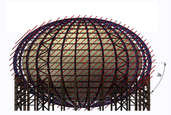


Pool liner



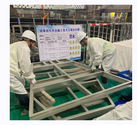
PMTs & Tyvek reflection film

Bird cage &Tyvek reflection film



EMF coils

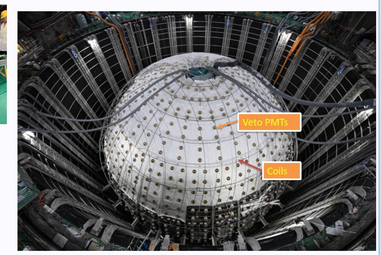
Veto PMT/electronics installation

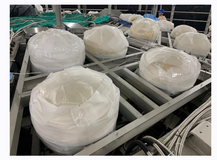


Veto module assemble exp. Hall

Install PMT/electronics box

Prepare for lifting module

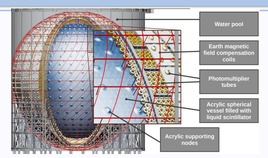


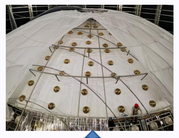


	Planned	Installed	Uninstalled
VETO	2400	2399 (MCP PMTs)	1 (MCP PMTs) due to space interference
Water Attenuation Length Module	5	5 (MCP PMTs)	

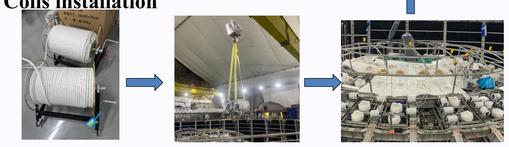
Compensation coils system

- 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.
  - A scheme using 32 shielding coils;
  - total cable length>30km;
- Coils performance
  - Residual EMF for CD PMT: max. < 0.1 Gauss (average ~0.05 Gauss); same as anticipation.
  - Residual EMF for Veto PMT: max. < 0.2 Gauss (average ~0.1 Gauss) ; same as anticipation.

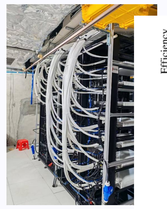


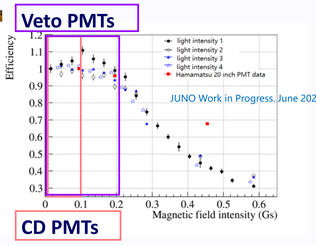


Coils installation



Resident intensity

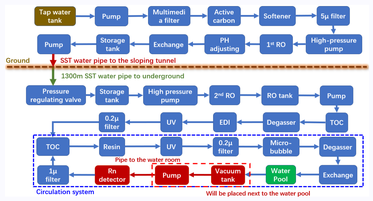




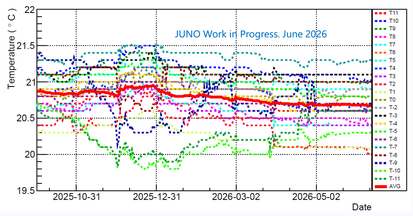
Water system

- **Water circulation**
  - Keep water quality good;
  - Keep temperature control within ~(21±1)℃ around acrylic vessel-> very important for acrylic safety;
- Output of the water system
  - Radon concentration in water <10 mBq/m^3
- Speed:100 t/h, 2-3 weeks one vlume;

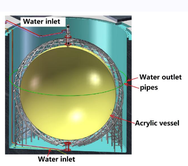
Water system chart



Water temperation in detector vs time



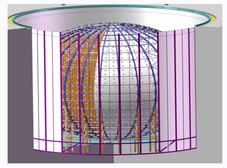
Water circulation



Water system (underground)

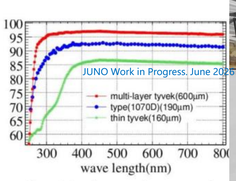
Tyvek reflection film

- Surface of the SS latticed shell
- Pool wall, bottom and top;



Tyvek reflector

Tyvek Reflectivity

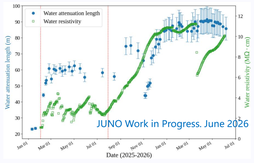


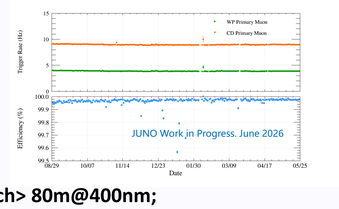
Reflectivity larger than 95% for wavelengths > 300nm

Tyvek installation

Detector performance

- **Dec.18,2024, whole detector installation finished and detector start filling.**
- **Aug.26. 2025, Start data taking.**





- **The water attenuation length now can reach> 80m@400nm;**
  - **Target 40m, better than anticipation.**
- **The CD muon, the detector achieves >99.5% detection efficiency with excellent stability.**

Summary

- **JUNO will measure neutrino mass ordering, and a rich physics potential with supernova neutrinos, geo-neutrinos, solar neutrinos,atmospheric neutrinos and other oscillation physics such as searches for proton decay, etc.**
- **JUNO water Cherenkov detector is designed for muon detection and background reduction.**
  - **The detector starting data taking last year. The results shows that the water Cherenkov detector has very good performance.**

Poster session (No. 325)