The status and the radioactive background control of JUNO's Water Cherenkov Detector

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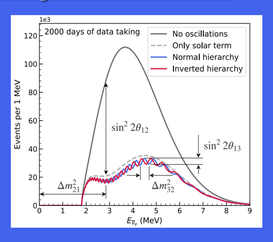
The Jiangmen Underground Neutrino Observatory (JUNO), a 20 kton multi-purpose low background liquid scintillator detector, was proposed primarily to determine the neutrino mass ordering. To suppress the radioactivity from surrounding rocks and tag the cosmic muons, the central detector is submerged in a water Cherenkov detector (WCD), which is filled with 35 kton ultrapure water and equipped with 2400 MCP-PMTs. To lower the accidental background in the central detector, the radon concentration in the ultra-pure water should be reduced to less than 10 mBq/m^3. This poster will introduce WCD's current status as well as the radon removal and online monitor system.

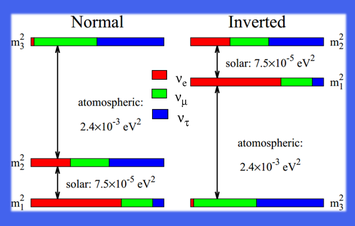
JUNO: A multi-purpose neutrino experiment [1]

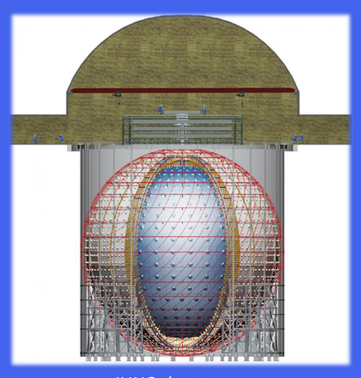
- Sources: reactor neutrinos, 26.6 GW_{th} total thermal power (Yangjiang: 6*2.9GW_{th}, Taishan:2*4.6GW_{th});
- Detecting method: inverse beta decay reaction;
- Baseline : 53km;
- Location: 700m underground for muon flux reduction;
- Detector: 20-kton liquid scintillator with 17612 20'' photomultiplier tubes (PMTs) and 25600 3'' PMTs.

JUNO location

Physics Goals



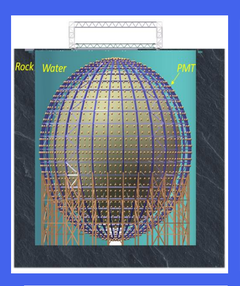




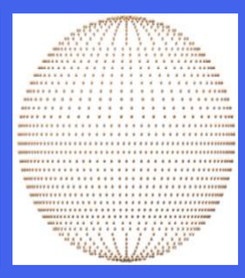
JUNO detector

- Determine neutrino mass ordering (major goal);
- Precise measurements of three neutrino oscillation parameters;
- Study supernova neutrinos、solar neutrinos、atmospheric neutrinos、 geo-neutrinos;
- Exotic searches, proton decay;

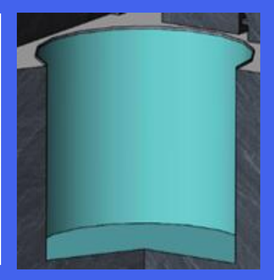
The water Cherenkov detector (WCD)



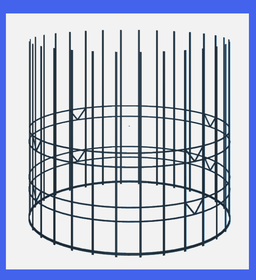
35kton ultra-pure water



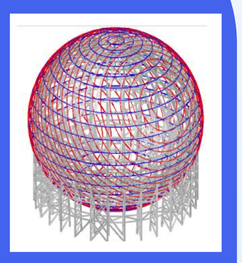
2400 20inch PMT & Tyvek



5mm HDPE lining

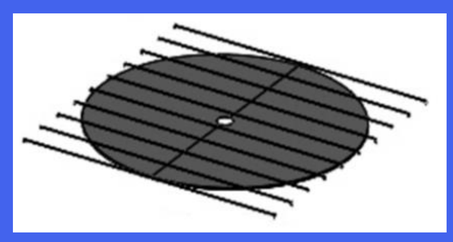


Bird cage & Tyvek



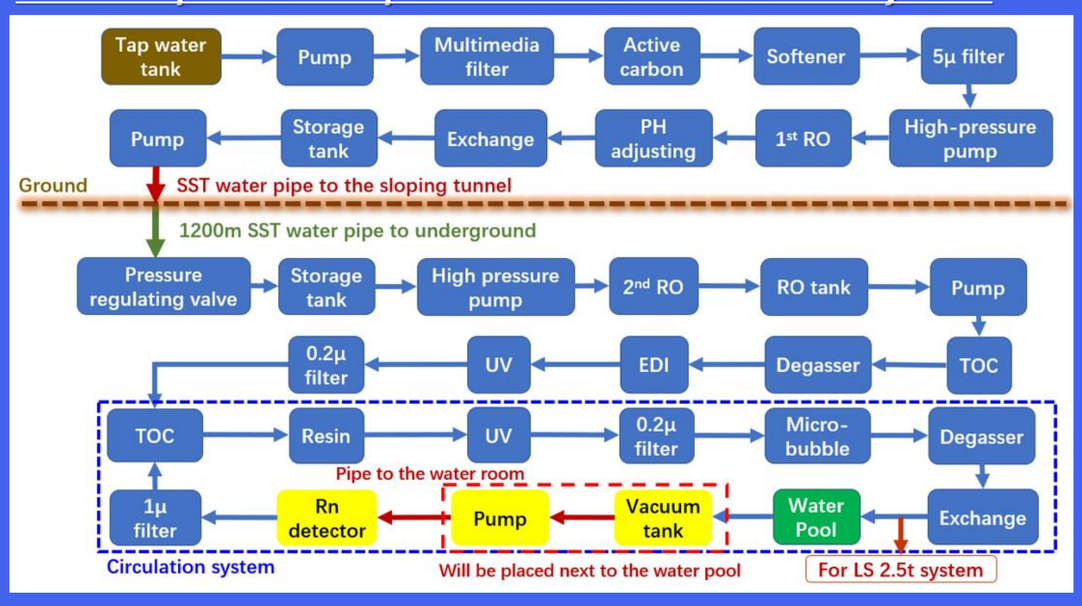
EMF Coil

- Composition:
  - ✓ Ultra-pure water + PMT: Muon tagging & Passive shielding:
  - ✓ HDPE lining: ~6000 m^2, serve as Rn barrier;
  - ✓ Tyvek reflector: Improve the light collection efficiency;
  - ✓ EMF coil: Shield the detector from the earth's magnetic field;
  - ✓ Cover: Gas tight for the detector;
  - ✓ Bird Cage: Supporting structures;
  - ✓ 100t/h water system: Ultra-pure water production;
- Radio-active requirements:
  - ✓ Rn/Ra concentration in water: <10mBq/m^3;



Cover & Rail

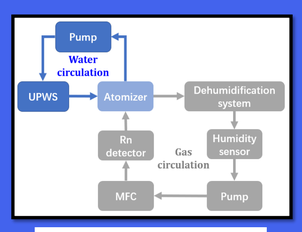
The ultrapure water production and circulation system



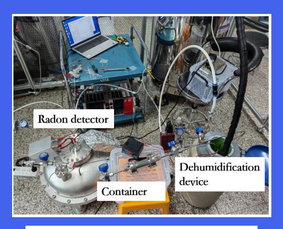
- RO: Reverse Osmosis, can be used to remove the dissolved ions as well as the suspended species in water, including bacteria;
- TOC remove: TOC is short for total organic carbon, this device can be used to remove the organic matters in the water;
- EDI: Electrode ionization, can separate the dissolved ions from the water ;
- Resin: Remove the dissolved ions ;
- Micro-bubble： Load gas into water for radon removal;
- Degasser: Remove the gas from water, including oxygen, nitrogen, radon and so on.

The Rn/Ra concentration in water measurement system[2,3]

Radon concentration in water measurement system



Schematic diagram of the measurement system

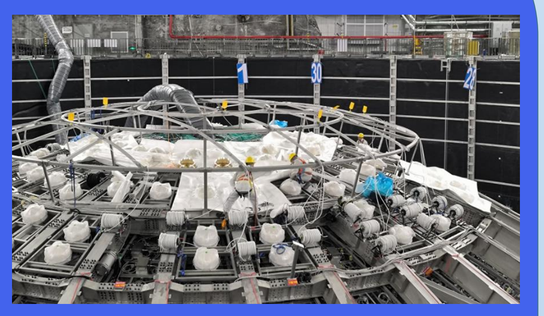


Radon emanation measurement system

Radium extraction devices

- Radon concentration measurement:
  - ✓ A semi-automatic radon concentration in water measurement system has been developed;
  - ✓ Electromagnetic valves are used in the system;
  - ✓ Software has been developed for remote operating;
  - ✓ The atomizer can transfer radon from water into gas;
  - ✓ A radon detector based on electrostatic collection is used for radon concentration determination;
  - ✓ The sensitivity of the system is ~1mBq/m^3;
- Radium concentration measurement:
  - ✓ Mn-fiber is used to extract radium from water, Mn-fiber is polyurethane fiber with MnO_2 attached;
  - ✓ The background of Mn-fiber is：~20μBq/g;
  - ✓ ^{226}Ra activity is determined by its gaseous daughter ^{222}Rn;
  - ✓ The amount of water treated by Mn-fiber and the adsorption efficiency of Ra were calibrated with Ra solution:
  - ✓ 5g Mn-fiber can extract radium from 10m^3 water;
  - ✓ The Ra extraction efficiency is ~88%;
  - ✓ The sensitivity of the system is ~13μBq/m^3;

Status of the WCD



- Detector installation is undergoing
  - ✓ HDPE lining of the side wall is finished;
  - ✓ The installation of the bird cage is finished;
  - ✓ The 100t/h water system is finished, but still working on the connection of the water pipes;
  - ✓ The installation of the EMF coil, the PMTs, and the Tyvek reflector are still ongoing;
  - ✓ The cover is under production;

Summary

- JUNO is a multi-purpose neutrino experiment and its main physics goal is to determine neutrino mass ordering;
- A water Cherenkov detector is used as passive shielding and muon veto;
- Several sub-systems have been developed to realize its physical functions;
- To lower the accidental background in the center detector, the radioactivity of the water should be well controlled;
- Two setups for measuring ^{222}Rn (^{226}Ra) concentration in water with a sensitivity of 1 mBq/m^3 (13 μBq/m^3) have been developed;
- The installation of the sub-systems is steadily progressing;

References

[1] Neutrino Physics of JUNO, arXiv:1507.05613;

[2]Y.P. Zhang, et al., The development of ^{222}Rn detectors for JUNO prototype, RDTM(2018)2:5;

[3] L.F. Xie, et al., Developing the radium measurement system for the water Cherenkov detector of the Jiangmen Underground Neutrino Observatory, NIM A 976 (2020) 164266;

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