The radon and radium concentrations in water measurement systems for JUNO’s Water Cherenkov Detector

Cong Guo  On behalf of the JUNO collaboration

Institute of High Energy Physics, Chinese Academy of Science

The Veto detector

- JUNO will be equipped with two veto systems providing both an efficient background reduction towards the environmental radioactivity and the residual cosmic muon flux crossing the detector.
- Composition of the veto detector:
  - The Water Cherenkov detector (WCD): A pool filled with 35 kton of ultra-pure water and instrumented with 2400 Microchannel Plate Photomultipliers;
  - The top tracker detector: Plastic scintillator detector supplied by OPERA;

The water Cherenkov detector

- The muon tagging efficiency of WCD is larger than 99% and the fast neutron background from muon spallation can be reduced to ~0.1 event/day.
- An online water system will be used to provide ultra-pure water for the WCD.
- Main functions and requirements for the water system are:
  - Keep the overall detector temperature stable (±1 ± 1°C);
  - Keep the water quality good;
  - To get a long attenuation length;
  - Keep the intrinsic background low:
    - U/Th concentration should be less than 10⁻³ Bq/g;
    - The ²²²Rn concentration should be less than 10 mBq/m³;
    - The ²³⁸Ra concentration should be less than 10 mBq/m³.

The ultra-pure 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: Total Organic Carbon, this device can be used to remove the organic matters in the water;
- EDI: Electrodeionisation, can separate the dissolved ions from the water;
- Resin: Removes the dissolved ions;
- Micro-bubble: Loads gas into water for radon removal;
- Degasser: Removes the gas from water, including oxygen, nitrogen, radon and so on.

The ²²²Rn concentration in water measurement system

- Radon concentration measurement:
  - A semi-automatic measurement system for radon concentration in water has been developed;
  - Electromagnetic valves are used in the system;
  - Software has been developed for remote operation;
  - 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 ~3 mBq/m³;

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 ²²²Rn (²³⁸Ra) concentration in water with a sensitivity of 1 mBq/m³ (13 μBq/m³) have been developed;
- The installation of the sub-systems is steadily progressing;

References

[1] JUNO physics and detector, PNPY 123 (2022) 103927;