Design and Integration of JUNO-OSIRIS

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JUNO Experiment Design

The Jiangmen Underground Neutrino Observatory (JUNO) is now under construction underground with 700 meters depth in the southern China, aiming to observe incoming neutrinos from several sources. The main objective is to determine the neutrino mass hierachy and neutrino oscillation parameters, and also other neutrino physics problems[1].

The central detector (CD) was constructed as an enomous acylic sphere with 35.4 meters in diameter, containing with over 20,000 tons of liquid scintillator (LS). This CD will be contructed and submerged in the cylindrical water pool with 35,000 ton of high purity water, as the VETO detector as shown in Figure 1 and 2. There will be over 17,600 20-inch photomultiplier tubes (PMTs) and 25,600 3-inch PMTs, installed all over the CD with an overall coverage of 77.9% to observe an interaction between incoming neutrinos and liquid medium according to the inverse beta decay (IBD) and another 2,400 20-inch PMTs used for the water Cherenkov VETO detector. With these impressive capabilities, the 20-inch PMTs[3] and liquid scintillator both play a crucial role for the JUNO experiment achieve an exceptional effective energy resolution of 3% at 1 MeV.

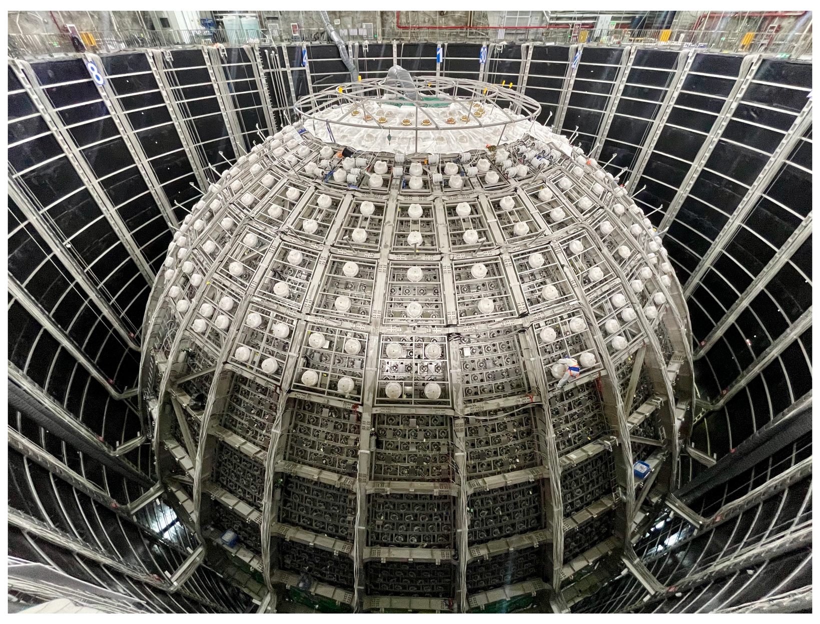

Figure 1: The JUNO central detector inside the cylindrical water pool under construction

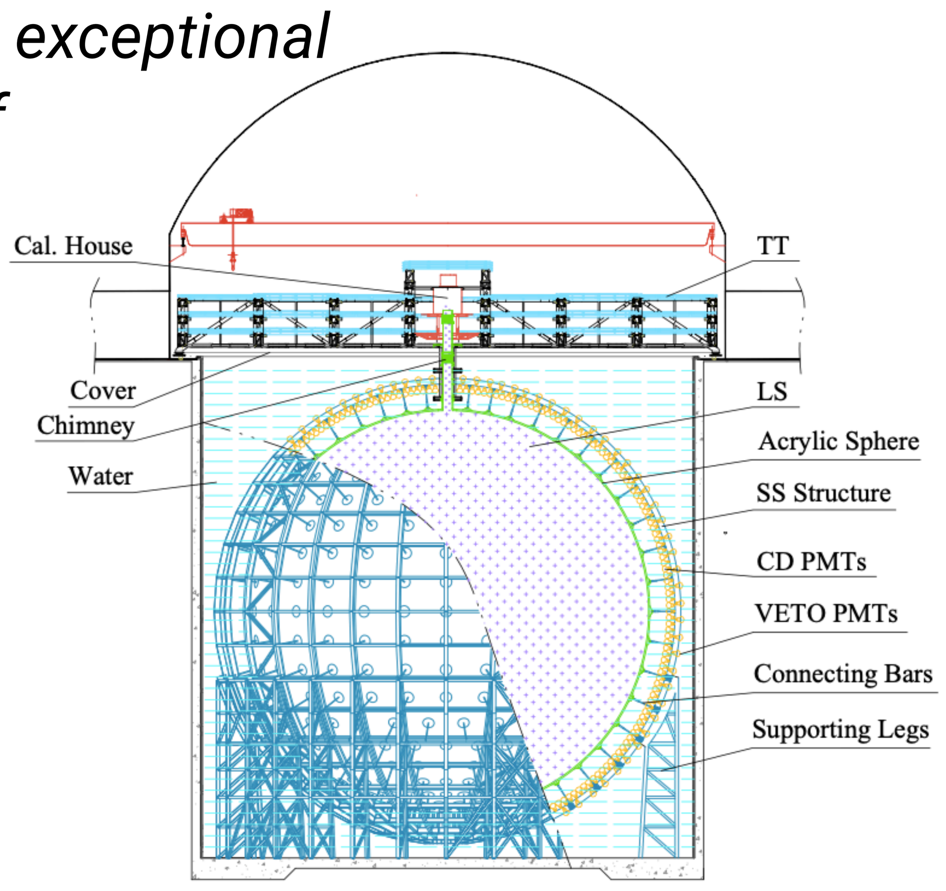

Figure 2: The overall scheme of the JUNO detector[1]

Tons of LS in this experiment, contains three components: Linear Alkyl Ben- zene (LAB), 2,5-diphenyloxazole (PPO), and 1,4-bis(2-methylstyryl)benzene (bis-MSB) , which requires the U/Th purity of 1×10^{-15} g/g for the reactor neutrino studies and 1×10^{-17} g/g for the solar neutrino studies. These liquid will be prepared by the LS processing system after several stages distributed on the ground, and transferred to underground for testing the contamination with the water extraction and gas stripping systems before transferring to the Online Scintillator Internal Radioactivity Investigation System (OSIRIS) detector.

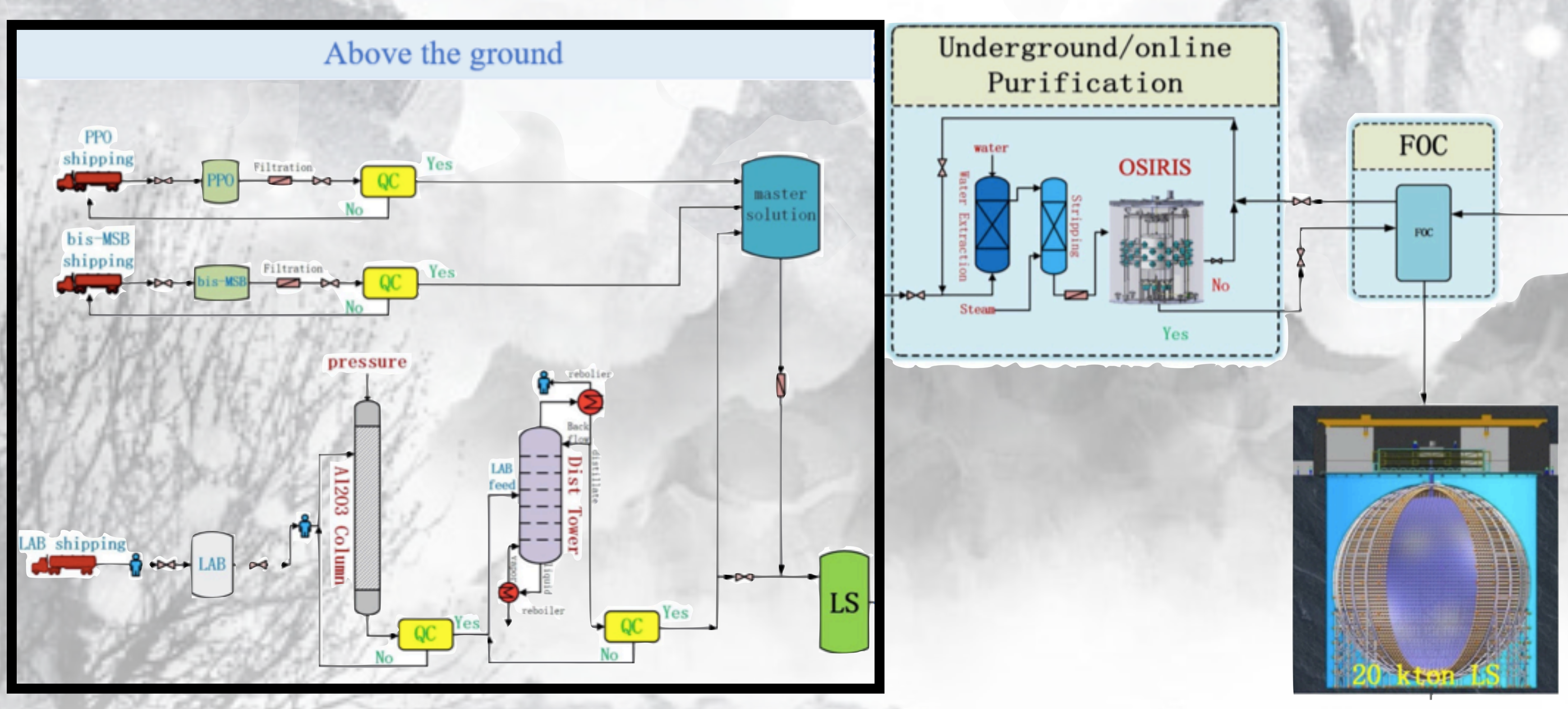

Figure 3: Flowchart of the liquid scintillator processing system[2]

OSIRIS Detector

The Online Scintillator Internal Radioactivity Investigation System (OSIRIS) serves as a precursor detector, tasked with monitoring and examining the LS purity prior to its transfer to the JUNO Fluid Connection and Control System (FOC) and CD. The OSIRIS detector is constructed with a 3-meter diameter cylindrical acrylic vessel designed to hold 18 tons of LS as shown in Figure 4. It is situated within a 9-meter height cylindrical tank filled with 550 tons of pure water. This detector was specifically engineered to search for the fast coincidence decays of ^{214}Bi − ^{214}Po and ^{212}Bi − ^{212}Po in the decay chains of ^{238}U and ^{232}Th, respectively. The projected sensitivity is 10^{-16} g/g, sufficient to test radiopurity levels for reactor (and even solar) neutrino detection. Additionally, 64 20-inch microchannel plate (MCP) PMTs were positioned around the LS vessel to observe incoming interactions, along with an additional 12 MCP PMTs for the water Cherenkov muon veto system[2]. All the PMTs is designed by a passive magnetic shielding and a front cylinder reflector.

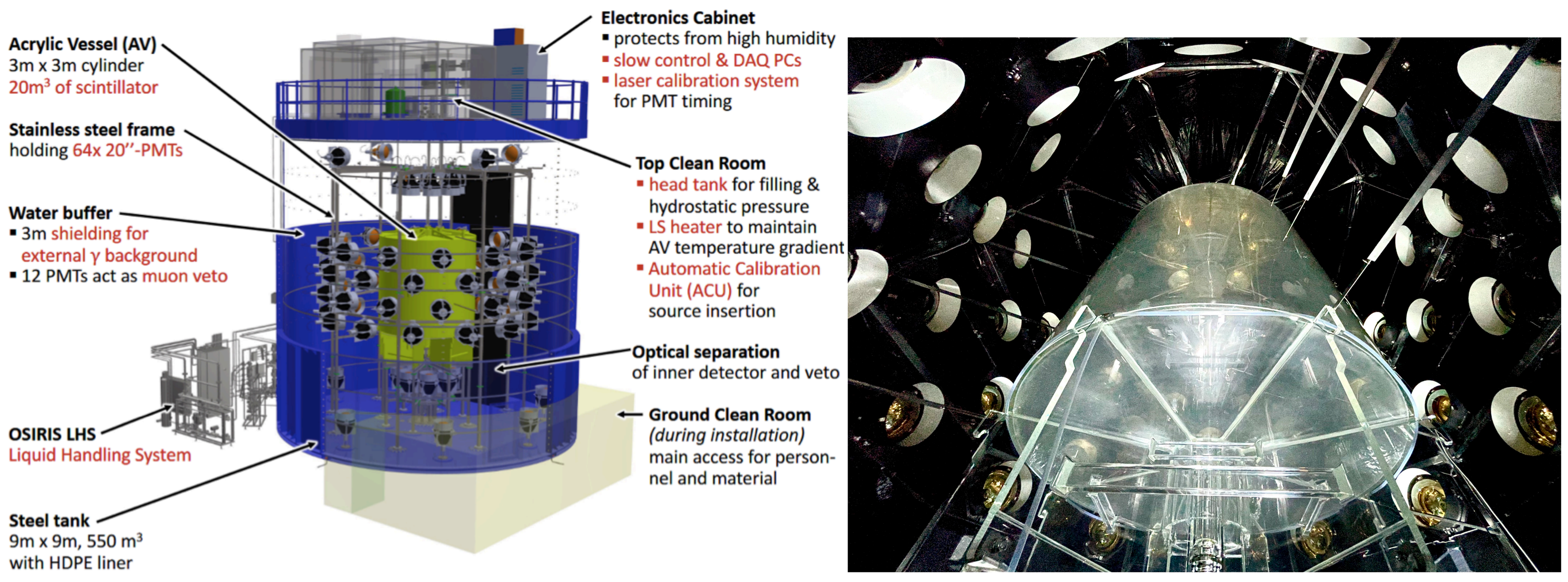

Figure 4: The overall OSIRIS detector scheme (left)[2] and an inside of OSIRIS detector with cylindrical acrylic vessel surrounded by 20-inch PMTs (right)

OSIRIS Water Filling Process

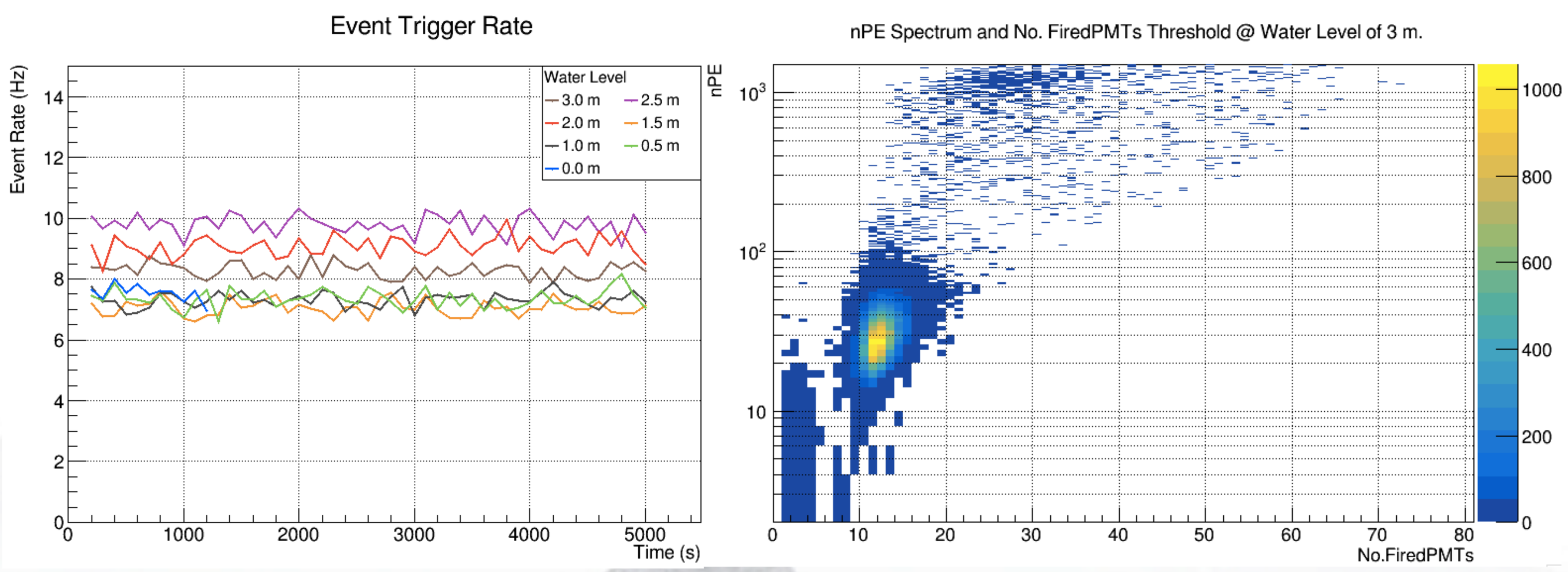

Figure 5: The preliminary results of the event trigger rate with different water level (left) and the nPE spectrum with different No.FiredPMTs threshold (right)

Late of November 2023, we started to fill the detector with the first pure water batch of 185 tons, reaching about 3 meters, just lower than the bottom of the acrylic vessel or one third of the detector which 16 PMTs were under water. We run the data taking with a threshold of 11 PMTs fired in 64 ns out of 76 PMTs in total, to observe the event waveform (also another triggerless data stream only with (T,Q) pair) during this process and observed the event rate of 7-10 Hz as shown in Figure 5 (left), and also calculated the classified muon event rate of ~0.3 which is basically consistent with the pre-estimated muon rate ~0.0030 Hz/m^2 [1]. We also applied the number of FiredPMTs as threshold to determine the nPE spectrum correlation (Figure 5, right). Most number of FiredPMTs dedicated is about 12 PMTs, fired in general events and radioactivity background. However, there were also some events with over 100 PE dedicated, which could be classified as muon events.

Reference
[1] JUNO collaboration. (2022). JUNO physics and detector. Progress in Particle and Nuclear Physics, 123, 103927.
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[3] Abusleme, A., Adam, T., Ahmad, S., Ahmed, R., Aiello, S., ... & Hou, S. (2022). Mass testing and characterization of 20-inch PMTs for JUNO. The European Physical Journal C, 82(12), 1168.