PROCEEDINGS OF SCIENCE

OSIRIS – The Online Scintillator Internal Radioactivity Investigation System of JUNO

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The Online Scintillator Internal Radioactivity Investigation System is an 18-ton pre-detector of JUNO, currently under commissioning in south-west China. During the 6-month filling phase of the JUNO main detector, it will be responsible for the monitoring of the radiopurity of the liquid scintillator filled into the JUNO central detector. Fast $^{214/212}$Bi/$^{214/212}$Po coincidences serve as a main measurement channel for OSIRIS' high sensitivity to ^{238}U/^{232}Th contaminations in the liquid scintillator. In addition, contamination measurements of ^{85}Kr and ^{14}C are also foreseen. OSIRIS is located 700m underground in the JUNO laboratory near the central detector. Its cylindrical central vessel is surrounded by 64 JUNO 20-inch PMTs and embedded into a water Cherenkov muon veto. Calibration of the detector will be done by an automated calibration unit featuring radioactive sources and a fast pulsed LED, as well as by a pico-second laser calibration system responsible for time- and charge calibration. After OSIRIS' main purpose of monitoring the liquid scintillator has been fulfilled, a consecutive physics phase addressing solar neutrinos and $0\nu\beta\beta$ decay is foreseen.

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1. The JUNO experiment

The Jiangmen Underground Neutrino Observatory (JUNO) is a large scale liquid scintillator neutrino detector currently under commissioning in south-west China (see figure 1, left). The main detector of JUNO will feature 20kt of liquid scintillator (LS) encased in a acrylic sphere with a diameter of 35m. This vessel is surrounded by 45'000 photomultiplier tubes (20" and 3") [1]. In addition, two veto systems are available: A top tracker system inherited from the OPERA experiment and a water muon Cerenkov veto [2] (see figure 1, right).
The main goal of JUNO is the determination of the neutrino mass ordering, however, a broad physics program is available including geo-neutrinos, solar neutrinos, supernova neutrinos, proton decay, etc [3].

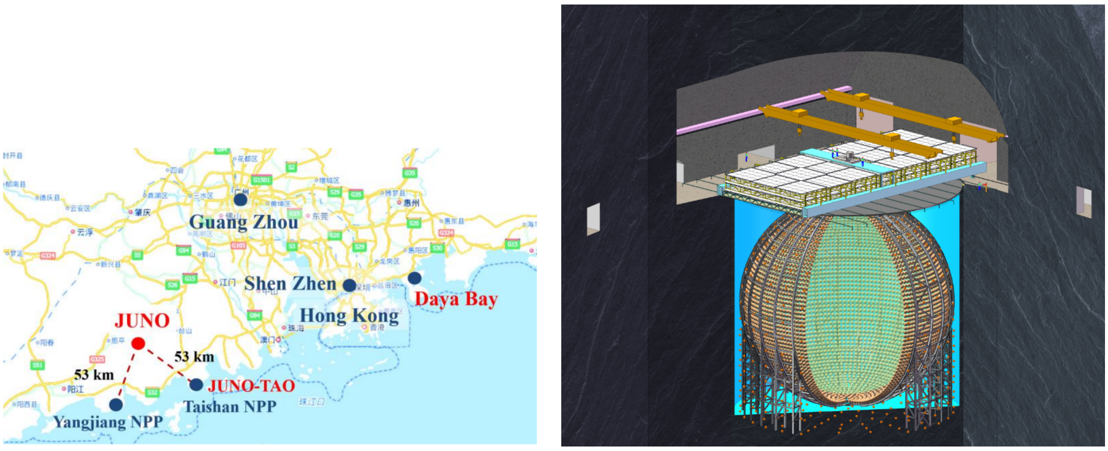

Figure 1: Left: Location of the JUNO experiment in southwest China. Right: 3D view of the JUNO central detector.

2. The Online Scintillator Internal Radioactivity Investigation System

2.1 Motivation

To achieve the scientific goals of JUNO, a focus on the radiopurity of all detector components is necessary [4]. Especially, the liquid scintillator needs to follow stringent limits of ^{238}U, ^{232}Th, ^{210}Po, ^{40}K and ^{14}C (see table 1). These limits differ for the two main detection modes of JUNO (inverted beta decay (IBD) for reactor electron anti-neutrinos and solar neutrinos) and are also caused differently. In the case of reactor anti-neutrinos ^{210}Po mimics the IBD via ^{13}C^{16}O reactions whilst ^{14}C pile-up with prompt events will distort both, energy scale and resolution. Looking at the detection of solar neutrinos, ^{238}U and ^{232}Th will create an additional background for elastic scattering on electrons via α and β decays of the chains. Additionally, ^{40}K leads to β (and connected γ) events that creates a background that is not connected to the ^{238}U and ^{232}Th and therefore hard to calculate.

Table 1: Limits for different radioactive isotope concentrations in JUNO. Marked in red are the main limits that are the focus of OSIRIS.

Isotope	JUNO IBD $\left[\frac{g}{g}\right]$	JUNO solar $\left[\frac{g}{g}\right]$
^{238}U	1×10^{-15}	1×10^{-16}
^{232}Th	1×10^{-15}	1×10^{-16}
^{210}Po	-	1×10^{-24}
^{40}K	1×10^{-16}	1×10^{-17}
^{14}C	1×10^{-17}	1×10^{-17}

2.2 The Detector

The OSIRIS detector [5] (see figure 2) is located in the JUNO underground liquid scintillator hall and acts as a radiopurity monitor. After distillation, filtration, water extraction and stripping, OSIRIS is the last device in the LS production chain of JUNO. Defined main goals are on the one hand the monitoring of the LS during the six months long filling phase of JUNO, on the other hand the support of the commissioning of the whole LS production chain of JUNO. OSIRIS will feature two different operation modes: batch and continuous. In batch mode, the whole volume of the vessel will be exchanged and monitored for several days or weeks, whilst in continuous mode the LS will traverse OSIRIS within a day, which allows for a steady monitoring of the produced LS.
The detector will be calibrated by two independent systems, an automated calibration unit (ACU) and laser calibration system (LCS). In the case of the ACU, three different sources can be used for continuous monitoring (^{40}K source), vertex calibration (high activity source made of ^{137}Cs, ^{65}Zn and ^{60}Co) and timing/charge calibration (410nm pulsed LED). The LCS features 24 diffused 420nm ps-laser injection points distributed in the detector and allows a precise timing and charge calibration of all PMTs used in OSIRIS.

2.3 First Air Run Data

Since OSIRIS is already in commissioning state, several detector parameters have already been evaluated, including run time measurements, majority trigger studies in air, dark count threshold studies etc. (see figure 3). A final comprehensive calibration of the detector will be performed after filling in fall 2023.

2.4 Future Physics Program

An extensive physic program of OSIRIS after the filling phase of OSIRIS is foreseen, see proceeding "Upgrade of OSIRIS for Future Liquid Scintillator Studies" by Kai Loo for detail.

3. Acknowledgements

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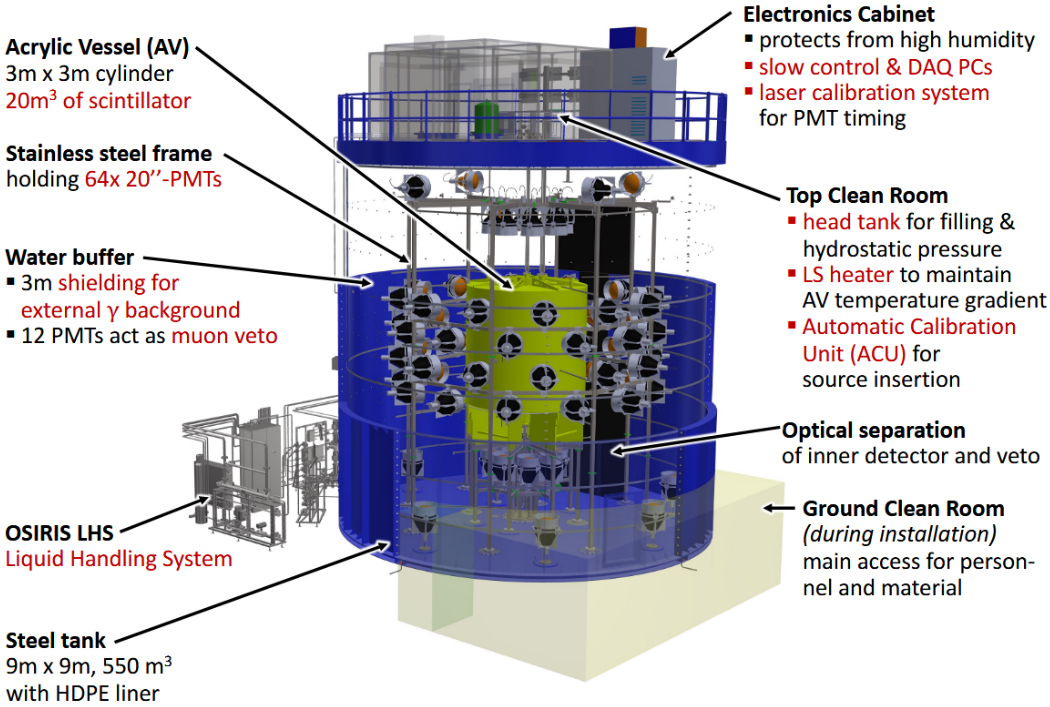

Figure 2: The OSIRIS detector as installed in the underground liquid handling hall of JUNO.

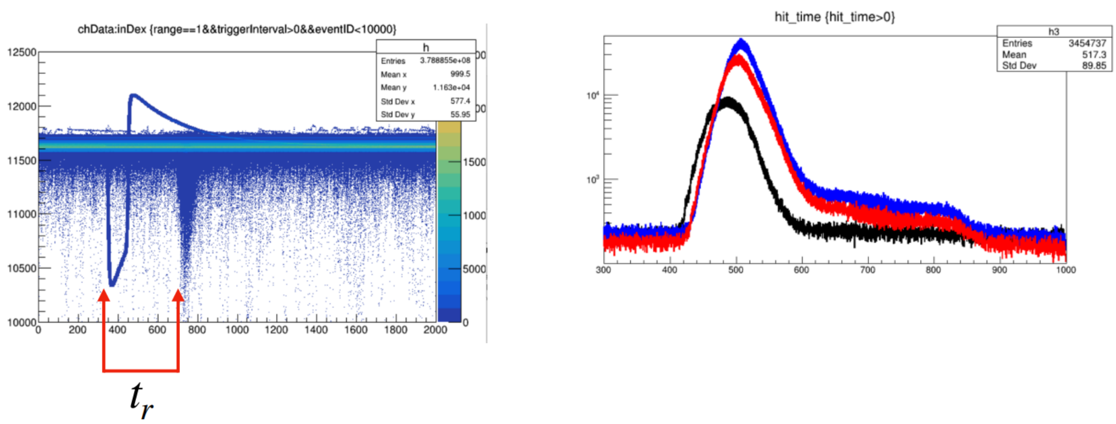

Figure 3: Left:Raw waveforms together with the trigger of the optical calibration systems. Marked is the run time between trigger and the acquired PMT pulse. Right:Hit time study of the detector with a small volume of LS encased in a glass bulb positioned at different heights (red and blue) inside the detector vs. natural radioactivity (black).

References

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