The JUNO OSIRIS detector

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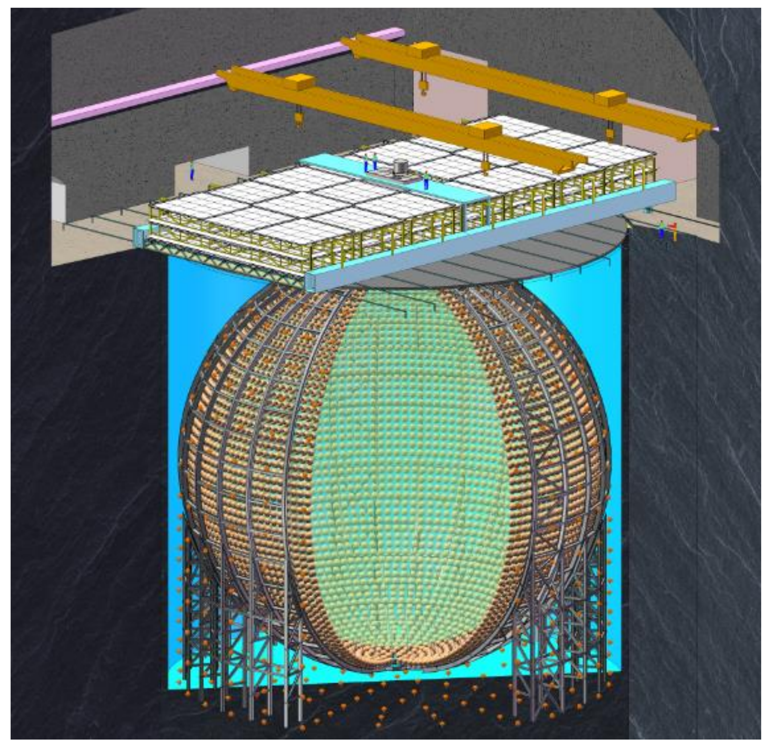
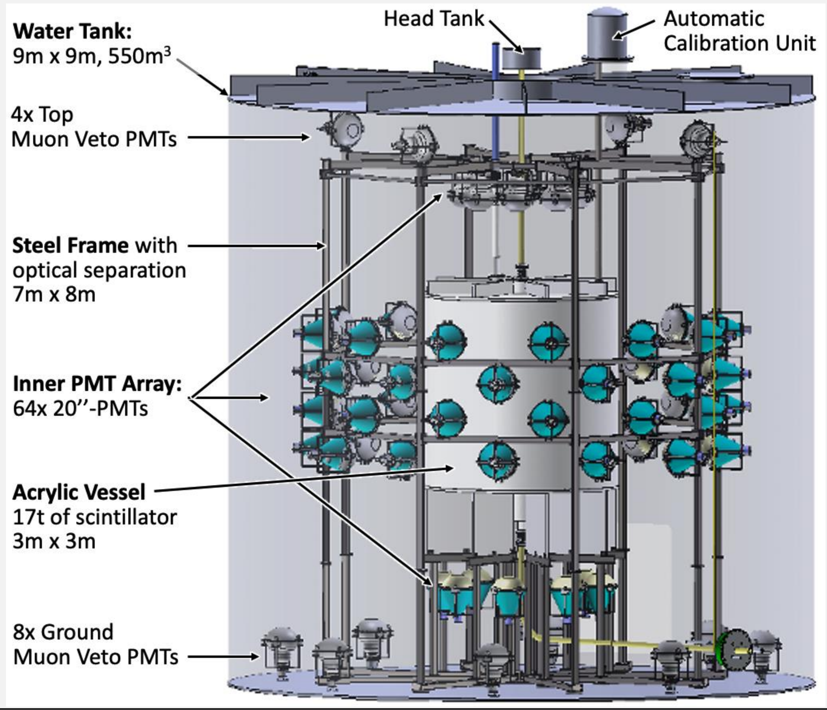
THE JUNO EXPERIMENT

The JUNO experiment is a multi-purpose neutrino observatory currently under construction in Jiangmen, China. Its main goal is the measurement of the neutrino mass ordering with a significance of **>3σ** after six years of measurements. To achieve this result, an energy resolution of **3%/$\sqrt{E_{vis}[\mathrm{MeV}]}$** was defined as a primary design goal of JUNO. Therefore, JUNO is using 20kt of liquid scintillator (LS) surrounded by 17612 20-inch PMTs and about 25600 3-inch PMTs. Since the radioactive purity of the liquid scintillator is of outmost importance to reach the desired energy resolution and background levels, a radiopurity monitor (OSIRIS) was developed. This pre-detector will be installed into the LS filling chain of JUNO, monitoring the radiopurity levels of the LS in either batch or continuous mode.

If you are looking for more information find Philipp Kampmann and his poster on the JUNO experiment.



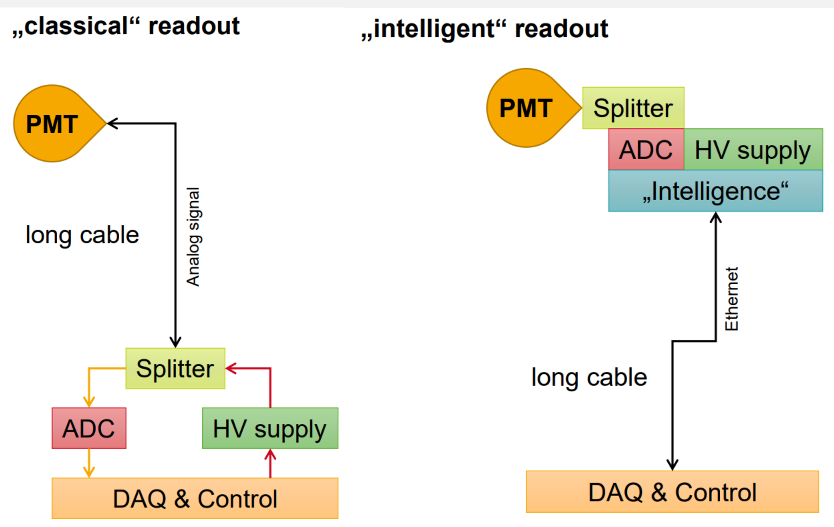
OSIRIS – THE ONLINE SCINTILLATOR INTERNAL RADIOACTIVITY INVESTIGATION SYSTEM



The Online Scintillator Internal Radioactivity Investigation System (OSIRIS) detector is the main liquid scintillator (LS) quality control device of JUNO. The main features are:

- Housed in a 9m x 9m water tank
- 3m x 3m central acrylic vessel
- LS capacity of 20t
- 64 + 12 20-inch "intelligent" PMTs (inner volume + veto)
- Inner and outer volume are optically separated
- Two independent calibration systems: Automated Calibration Unit + Laser calibration system -> calibration of timing/s.p.e. charge to improve energy and vertex reconstruction

THE "INTELLIGENT" PHOTOMULTIPLIER TUBES (iPMT)

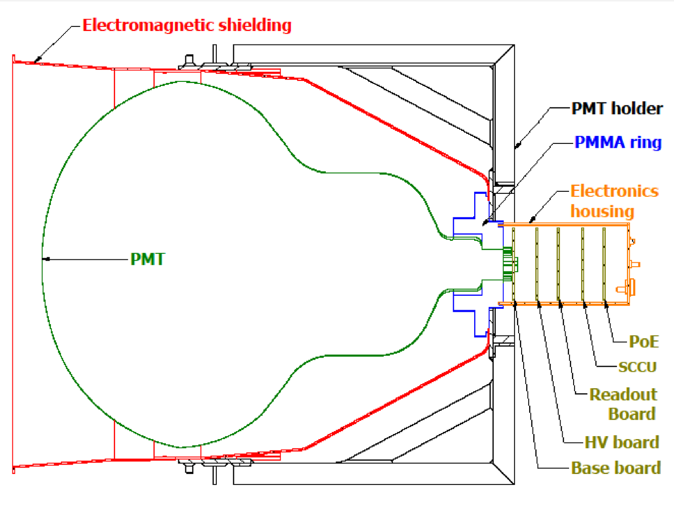


Difference between "classical" and "intelligent" PMT approach.

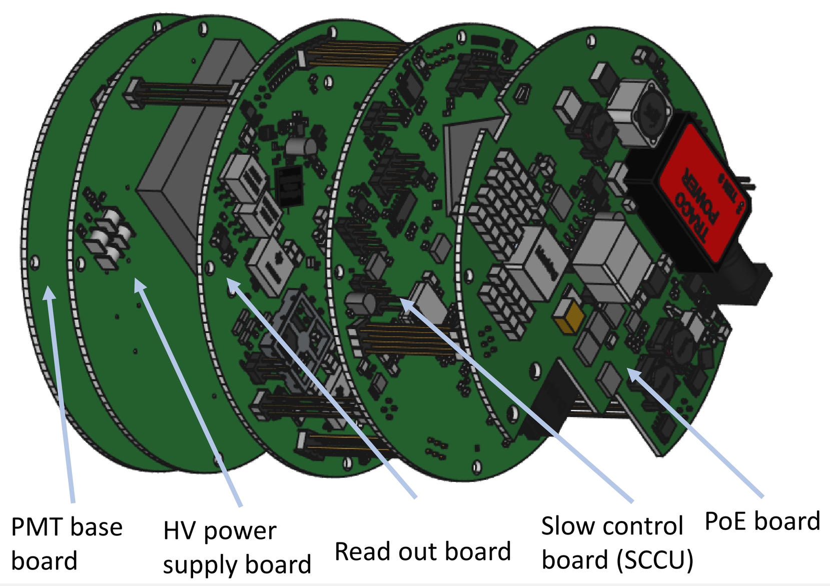
As a unique feature OSIRIS utilizes a new kind of photomultiplier tube, the "intelligent" PMTs. Each iPMT includes all necessary DAQ electronics in its base:

- ADC ("VULCAN")
- Power supply
- FPGA
- ARM core processors
- PoE, data I/O, control via single ethernet cable

Main benefits are lesser signal loss and less noise as well as reduced data transfers.

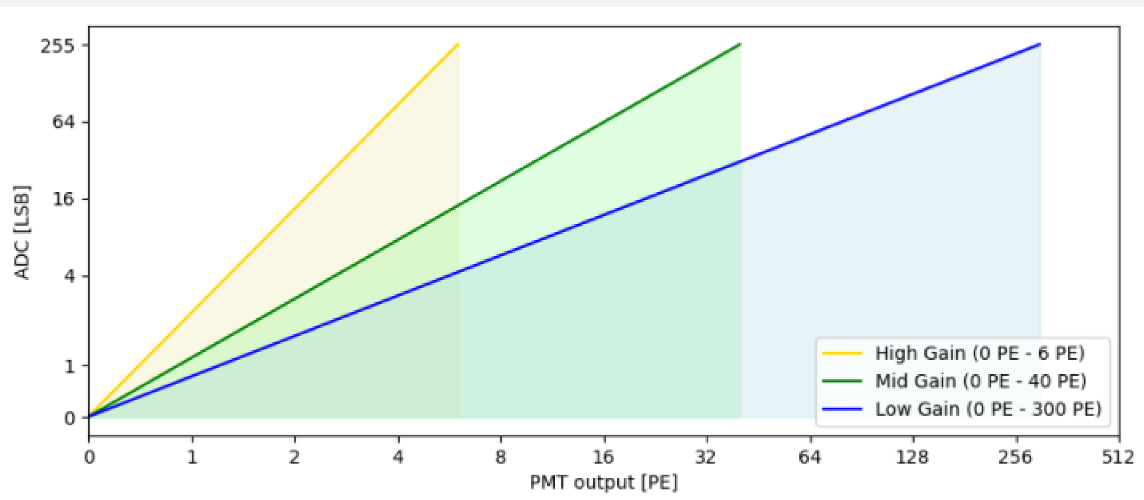


Scheme of the iPMTs of OSIRIS

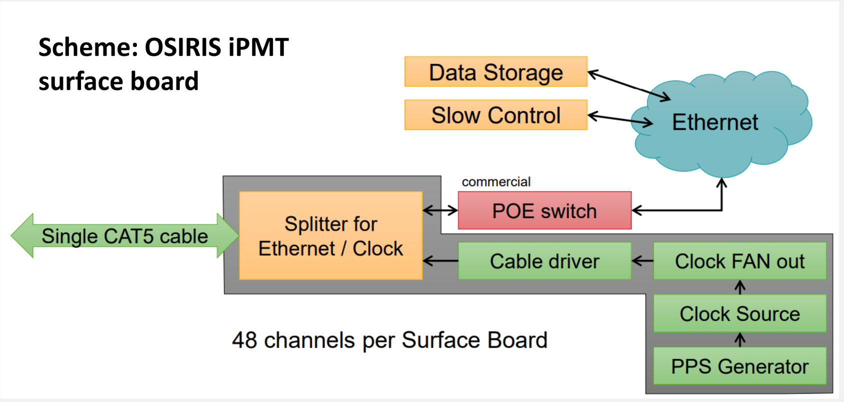


The electronics stack is located at the base of each PMT and consists of five PCBs:

- **PMT base**: Connects the PMTs dynode pins to the electronics stack
- **HV power supply**: Converts the 24V supply voltage to the desired PMT HV
- **Read out**: Contains the VULCAN ADC and ZYNQ SoC (FPGA + ARM core processor)
- **Slow control**: Ethernet bridge for control and configuration (e.g., clock distribution, RS485,…)
- **PoE**: Detaches PoE and signal, generates intermediate voltages (5V) for the other boards

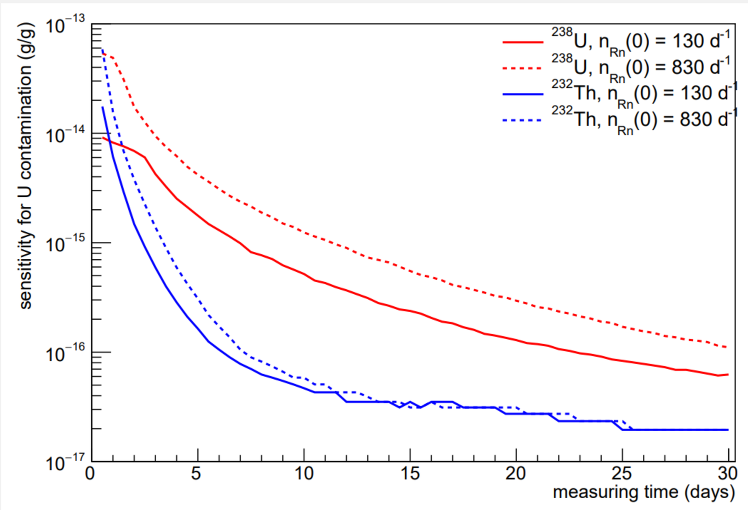


The VULCAN ADC chip consists of three independent 8bit ADCs with a sampling rate of 500 MS/s featuring three different gains. Incoming signals will be sampled in parallel, a selection of valid samples with the highest gain is done in the chip. In result, VULCAN can cover a wide dynamic range with decreasing resolution. The output of VULCAN is connected to the ZYNQ SoC for further processing.



All iPMTs are connected to one of two surface boards, which serve as pass-through for the PoE/data signal and provide a synchronization of the iPMTs. To assure identical clocks, the internal clock of one of the boards is used by both surface boards. The top-level control of the whole system is performed by the general run control of OSIRIS.

GOALS AND SENSITIVITY OF OSIRIS



Sensitivity to U/Th in the presence of an initial radon contamination Rn(0). An upper limit on the constant U/Th-supported term is derived from a time fit to the observed Bi-Po-rate, taking the known decay profiles of 222Rn/220Rn into account.

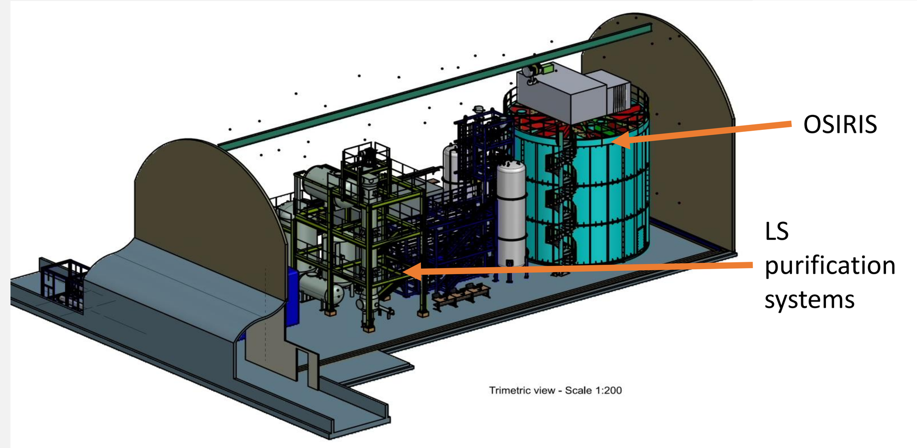
OSIRIS will be able to measure the contamination level of the LS with uranium and thorium chain elements in the range of $\leq 10^{-15}$ g/g for IBD and $\leq 10^{-16}$ g/g for solar neutrino measurements. Including the several expected background elements OSIRIS will be sensitive to the pollution of the LS of ^{14}C, ^{40}K, ^{210}Po, ^{232}Th and ^{238}U.

The time needed for those measurements depends on the desired level (IBD or solar) and ranges from several days (IBD) to several weeks (solar).

LIQUID HANDLING

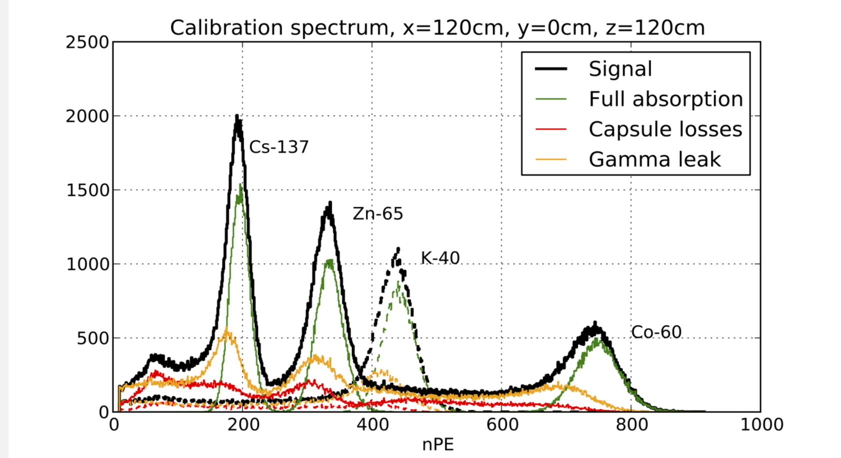
OSIRIS is included in the liquid handling chain of JUNO and located in the underground liquid handling hall together with the underground LS purification systems. A part of the LS (roughly 1/7) is passed from the stripping to OSIRIS to be checked in one of two modes:

- **Batch mode:** a single sample of 20m^3 of LS is measured for a long time period (several weeks), allowing for maximum sensitivity for U/Th impurities
- **Continuous mode**: Part of the produced LS is fed continuously to OSIRIS, traversing slowly with the use of a temperature gradient -> a real time observation is possible

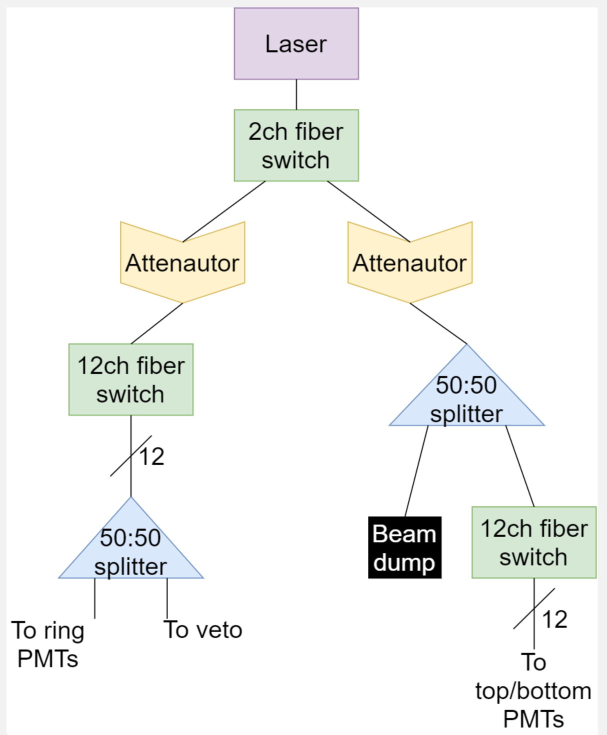


CALIBRATION SYSTEMS

The Automated Calibration Unit (ACU, left) is located on top of OSIRIS and able to deploy both optical and radioactive calibration sources. It was inherited from the Daya Bay experiment and adopted to the needs of OSIRIS. As an independent method to cross-check positions of the sources, two cameras are installed in the water tank to create an additional calibration capsule monitoring system.
To estimate the calibration performance, several Monte Carlo simulations have been carried out. The ACU is bound to do calibration runs at least on a weekly basis.



example of a simulated calibration spectrum with all available radioactive isotopes

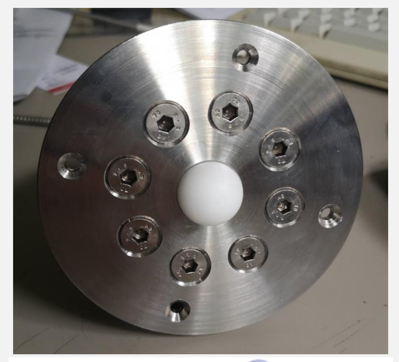


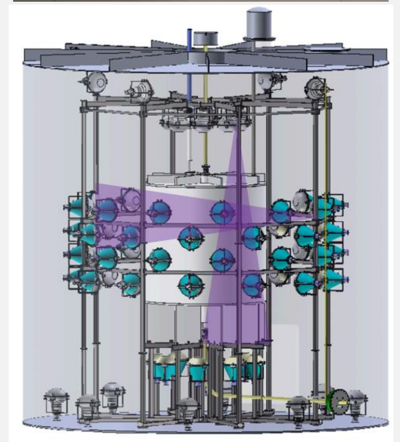
Light routing scheme of the Laser calibration system

The Laser calibration system features diffused light injection points, distributed in both inner volume and veto. The main features are:

- Pulse width ≈ 80ps
- 24 injection points (8 veto + 8 PMT ring + 8 above/below the acrylic vessel)
- Targeted timing alignment: 25ps (1σ)
- Required pulses: 2 x 10^5 (2 x 10^3 from statistics, leading to the result with taking the low light intensity into account)
- Measurement time per diffusor: 20s@10kHz trigger frequency

Due to this short measurement time and the overall system design the laser calibration can be done with minimal disturbance of the general measurements. The Laser system will be used for daily calibration runs.





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