Online Scintillator Internal Radioactivity Investigation System

OSIRIS

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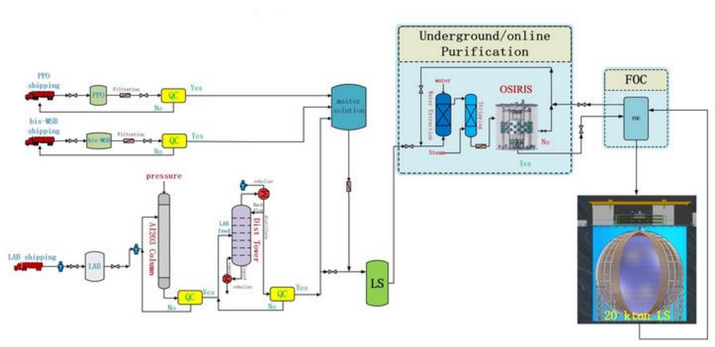
Overview

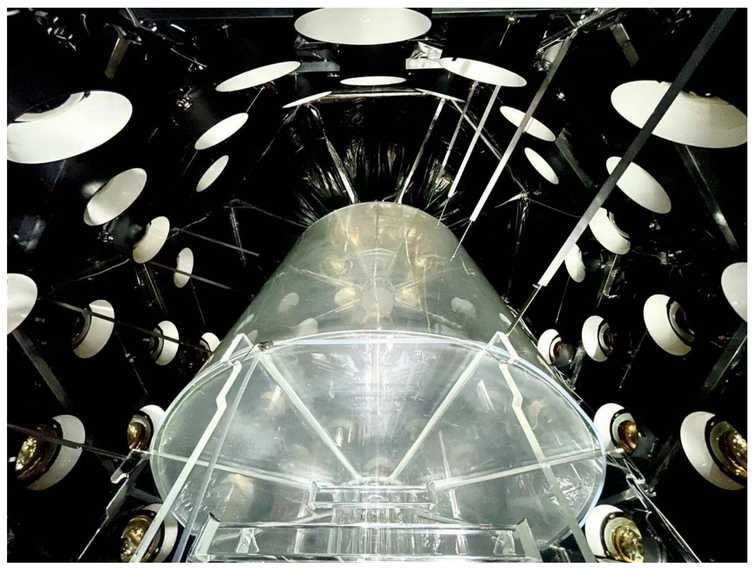
The OSIRIS detector is a subsystem of the liquid scintillator filling chain of the JUNO neutrino experiment. Its purpose is

- ***To validate the radiopurity of the scintillator***
- ***To assure that all components of the JUNO scintillator system work to specifications and***
- ***To verify that only neutrino-grade scintillator is filled into the JUNO Central Detector.***

The aspired sensitivity level of 10^{-16} g/g of ^{238}U and ^{232}Th requires a large (~20 m^3) detection volume and ultralow background levels.

OSIRIS's is placed at the end of the purification line of the liquid scintillator.

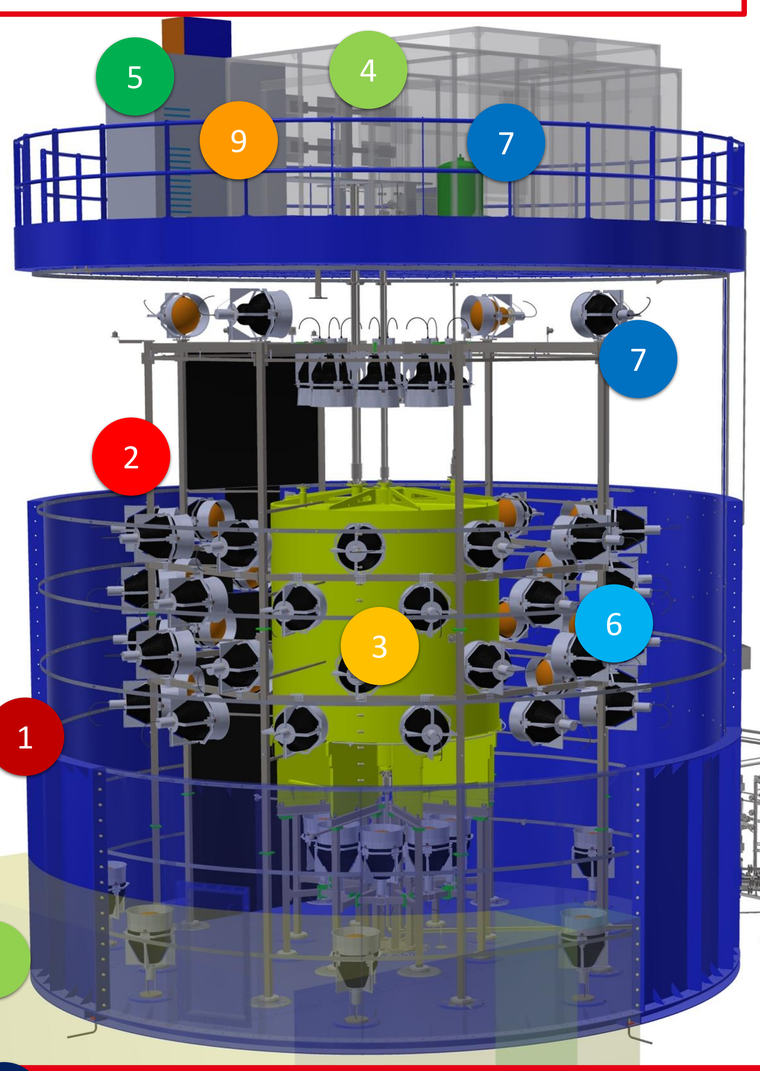




Inside view of OSIRIS shortly before closing the detector to the outside.

Mechanical Design

1. **Water Tank**, bolted carbon steel, inside covered with HDPE liner, works as a muon veto detector and providing shielding against external gammarays
2. **Steel frame** providing mounting points for photodetectors, calibration system and optical separation between inner and outer detector
3. **Acrylic Vessel** holding the ~20 ton scintillator sample
4. **Top and bottom cleanrooms** provide clean environment for detector instrumentation
5. **Electronics cabinet** with air conditioning holds the electronics and computing hardware



6 Photon Detection

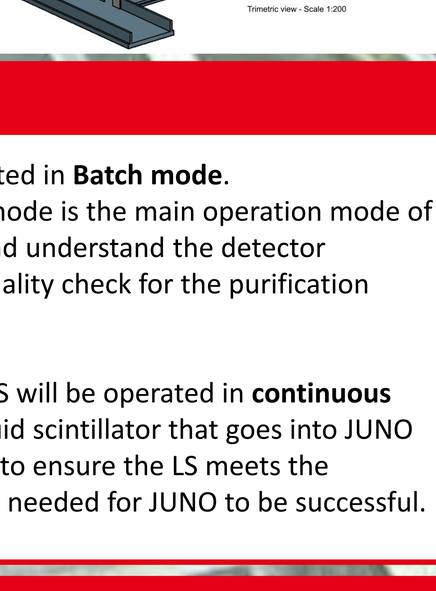
Light will be detected by 20-inch PMTs arranged in two optically separated subdetectors:

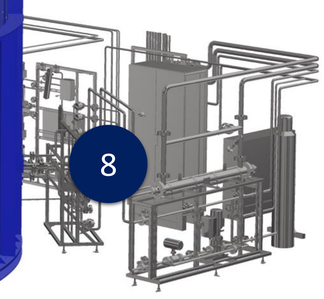
- **Inner array (64 PMTs) looking toward Acrylic Vessel**
- **Outer array (12 PMTs) acting as muon veto detector**
- PMTs are Multichannel plate (MCP) based
- Mean photo detection efficienty of 28.9%
- Mean time resolution ~ 8,4 ns
- JUNO readout electronics with 3 PMTs connecting to 1 underwater Global Control Unit (GCU) (see No. 9)

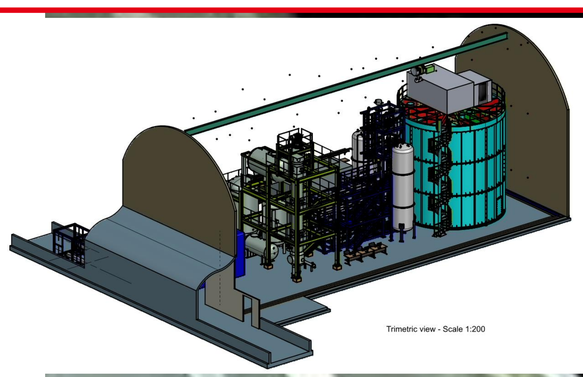
7 Calibration

Energy calibration is done by lowering weak radioactive sources from automatic calibration unit (ACU) to the scintillator.

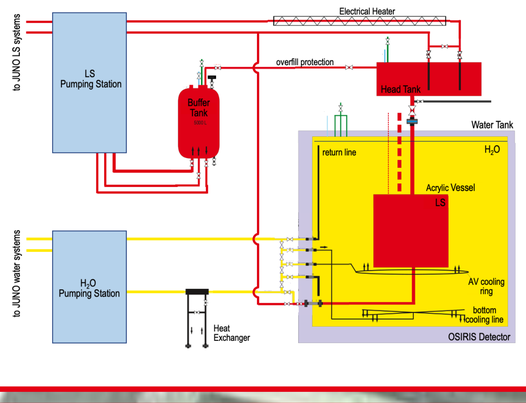
For the **timing calibration** of the PMT subsystems and DAQ electronics, picosecond laser pulses are sent to several diffusers mounted to steel frame.







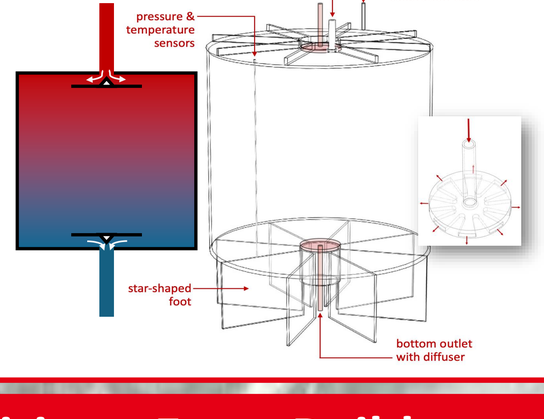
8 Liquid Handling System



LHS provides two operation modes: **batch** and novel **continuous flow mode.**

In continuous mode LS is heated before insertion to establish temperature gradient. To maintain continuous filling:

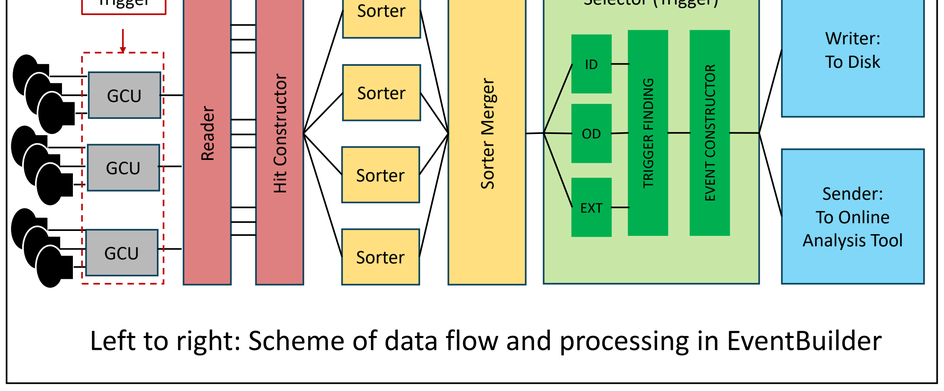
- **Diffusers** redirect inflowing LS into a horizontal direction
- Temperature profile monitoring with **ThermoRod**
- **Temperature control** of outside water



Currently OSIRIS is operated in **Batch mode**. Unitl JUNO filling batch mode is the main operation mode of OSIRIS to get first data and understand the detector properties as well as a quality check for the purification chain.

During JUNO filling OSIRIS will be operated in **continuous mode** to monitor the liquid scintillator that goes into JUNO during the filling process to ensure the LS meets the radiopurity requirements needed for JUNO to be successful.

9 Data Acquisition : EventBuilder



Left to right: Scheme of data flow and processing in EventBuilder

GCUs:
- Connects to 3 PMTs each
- Connects to hardware trigger module & DAQ
- Houses ADC with 1GS/s and HV module

Reader:
- Initializes connections
- Loops over HW and receives data in blocks
- Channel-by-channel buffering of data

Hit Constructor:
- Process data from Reader buffers
- Finds header and trailer to construct waveform
- Checks data validity

Sorter & Merger:
- Uses std::multiset
- Time sorts the waveforms
- Merges outputs from different sorter buffers into one buffer

Selector:
- Finds trigger
- Assigns trigger type
- Constructs hits close in time to Events

Sender & Writer:
- Writes to disk in binary format
- Sends events to online analysis PC over network

EventBuilder
EventBuilder is the DAQ software used in OSIRIS and uses a multithreaded, hit-by-hit processing of digitized data from the PMTs. With the current hardware, EventBuilder is capable of processing trigger rates of up to 6 kHz per PMT.

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