Online Scintillator Internal Radioactivity Investigation System

JUNO's Radiopurity Pre-Detector OSIRIS

Michael Wurm on behalf of the JUNO-OSIRIS Group
Johannes Gutenberg-University Mainz, Institute of Physics & Cluster of Excellence PRISMA^{++}

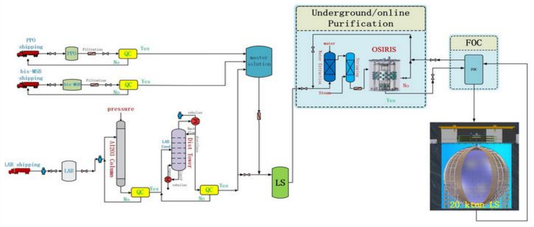
Overview

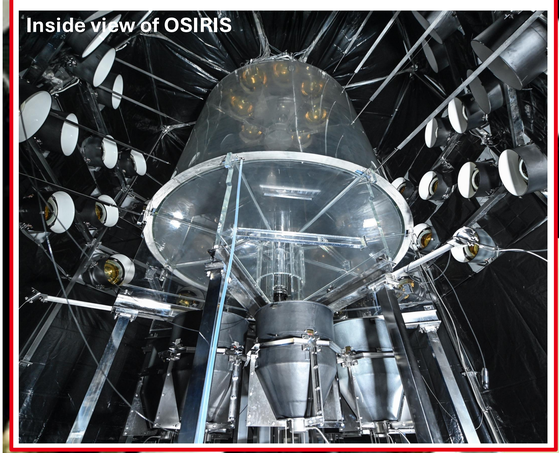
The OSIRIS detector is a subsystem of the liquid scintillator filling chain of the JUNO neutrino experiment. Before and during Central Detector filling, its purpose is

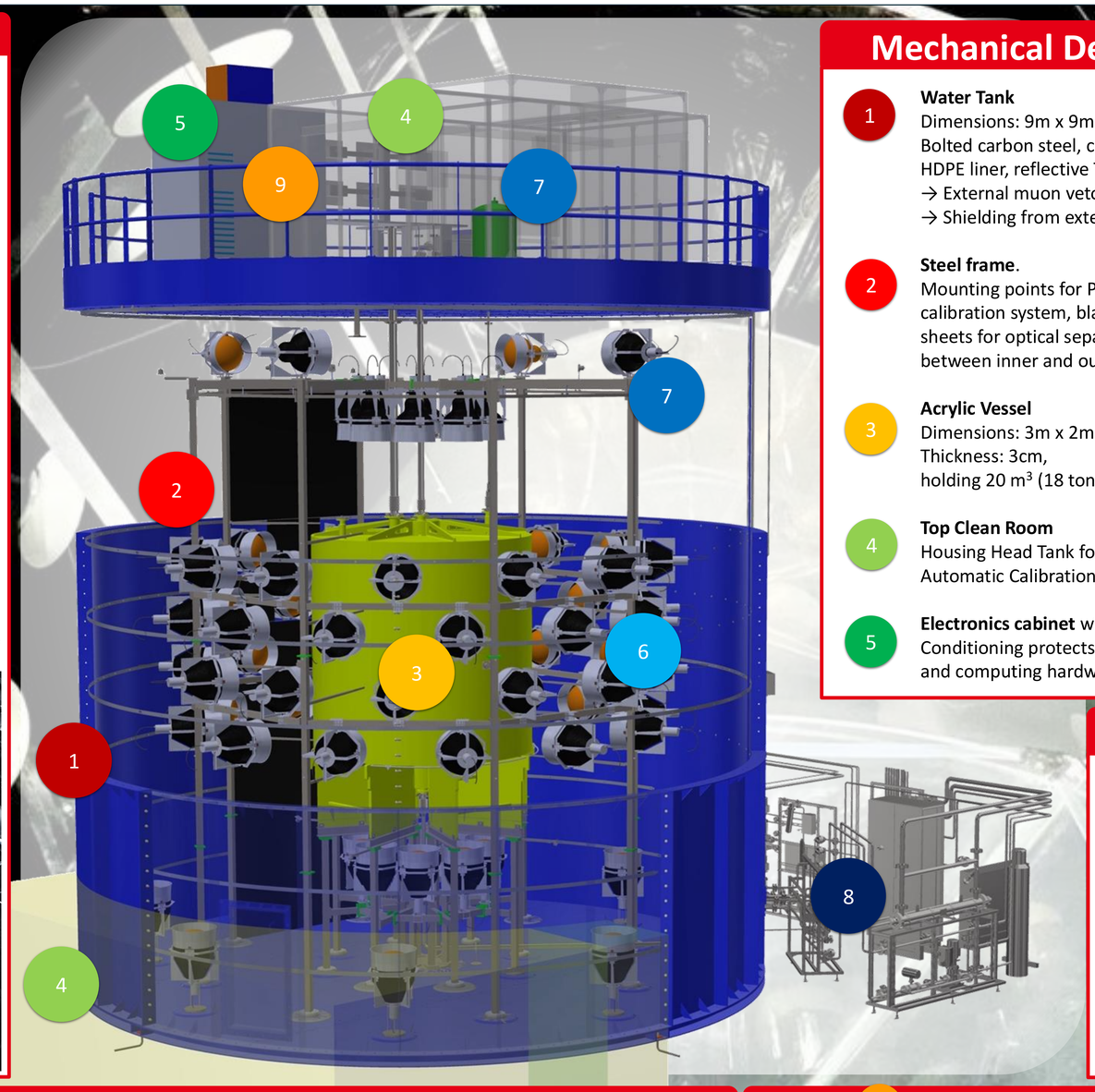
- ***To validate the radiopurity of the scintillator***
- ***To assure that all components of the JUNO scintillator system work to specifications and***
- ***To verify that only neutrino-grade scintillator is filled into the JUNO Central Detector.***

The aspired sensitivity level of 10^{-15} g/g of ^{238}U and ^{232}Th requires a large (~20 m^3) detection volume and ultralow background levels.

OSIRIS is placed in the underground Scintillator Hall at the end of the scintillator purification line.







Mechanical Design

1. **Water Tank**
   Dimensions: 9m x 9m
   Bolted carbon steel, covered with HDPE liner, reflective Tyvek sheets
   → External muon veto detector
   → Shielding from external γ-rays

2. **Steel frame**.
   Mounting points for PMTs, calibration system, black&white sheets for optical separation between inner and outer detector

3. **Acrylic Vessel**
   Dimensions: 3m x 2m
   Thickness: 3cm,
   holding 20 m^3 (18 tons) of LS

4. **Top Clean Room**
   Housing Head Tank for filling and Automatic Calibration Unit

5. **Electronics cabinet** with air Conditioning protects electronics and computing hardware

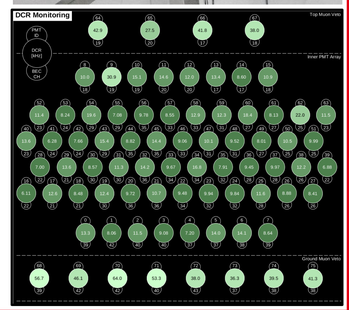
6 Photon Detection

Two separate PMT systems:

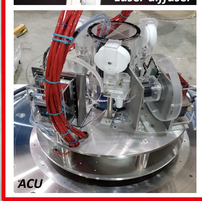
Inner PMT array for scintillation events in Acrylic Vessel
- 64 NNVT MCP-PMTs (20'')
- Optical coverage: 9%
- Photo det. efficiency: 25%
- Light yield: 230 p.e./MeV
- Time resolution: 8.4 ns
- Dark rate: ~10 kHz
- Individual magnetic shields from composite materials

Outer PMT array forming an active muon veto
- 12 NNVT MCP-PMTs (20'')
- Veto efficiency for muons crossing LS: >99.98%

JUNO readout electronics
- groups of 3 PMTs connect to common underwater Global Control Unit (GCU)
- GCU provide High Voltage, forwards hit information to BEC for trigger formation, digitizes waveforms



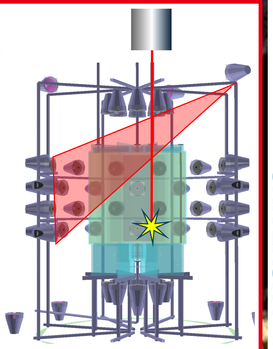
7 Calibration



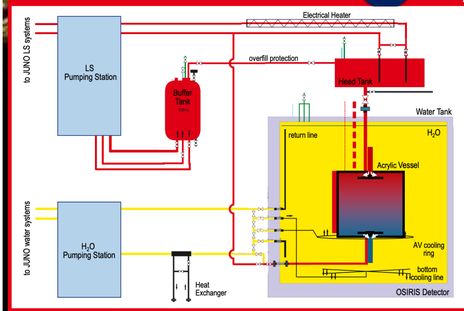
Laser System: picosecond laser distributes photons through fibers to diffusers on steel frame
→ PMT spe charge calibration and timing synchronization

Automatic Calibration Unit (ACU) lowers weak radioactive sources into scintillator volume, off-axis
→ energy scale and resolution, position reconstruction

In-situ monitoring of spe calibration using low-multiplicity events

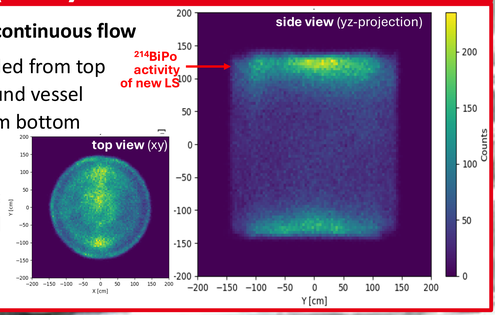


8 Liquid Handling System (LHS)

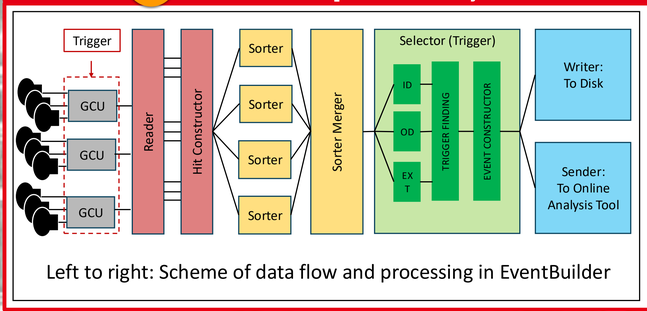


LHS provides two operation modes: **batch/continuous flow**

- new pre-heated (by 2-5°C) scintillator added from top
- outside, cooled water flows upwards around vessel
- old cooled-down scintillator removed from bottom
- acrylic diffusers redirect inflow to horizontal direction
  → formation of stable temperature layers
- has been verified with thermometers and by tracking propagation of fast ^{214}Bi-Po coincidences in scintillator volume



9 Data Acquisition, Event Builder, Slow Control



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

Readout scheme adapted from standard JUNO DAQ

- GCUs forward digitized hits to **Back-End Card (BEC)**
  → majority (physics) or external (calib) trigger
  → system capable to run at 6kHz during calibration
- GCUs provide status data (e.g. dark rate display)
- Online EventBuilder sorts PMT waveforms into events
- OnlineMonitor realized via RootSorter performs live-tracking of event distributions and ^{214}Bi-Po rates
- Offline analysis performed by same framework