Performances of JUNO's Small PMT subdetector during the 1st commissioning runs

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The JUNO experiment

The Jiangmen Undergound Neutrino Observatory (JUNO) is a **20 kilotons** liquid scintillator detector currently under construction in southern China. The light emitted by the liquid scintillator is detected by an array of **17 612 20-inch photomultiplier tubes (LPMTs)** and **25 600 3-inch PMTs (SPMTs)**.

The main goal is the determination of the **neutrino mass hierarchy** and the **precision measurement** of oscillation parameters by analysing the energy spectrum of reactor antineutrinos [1].

Small PMT system

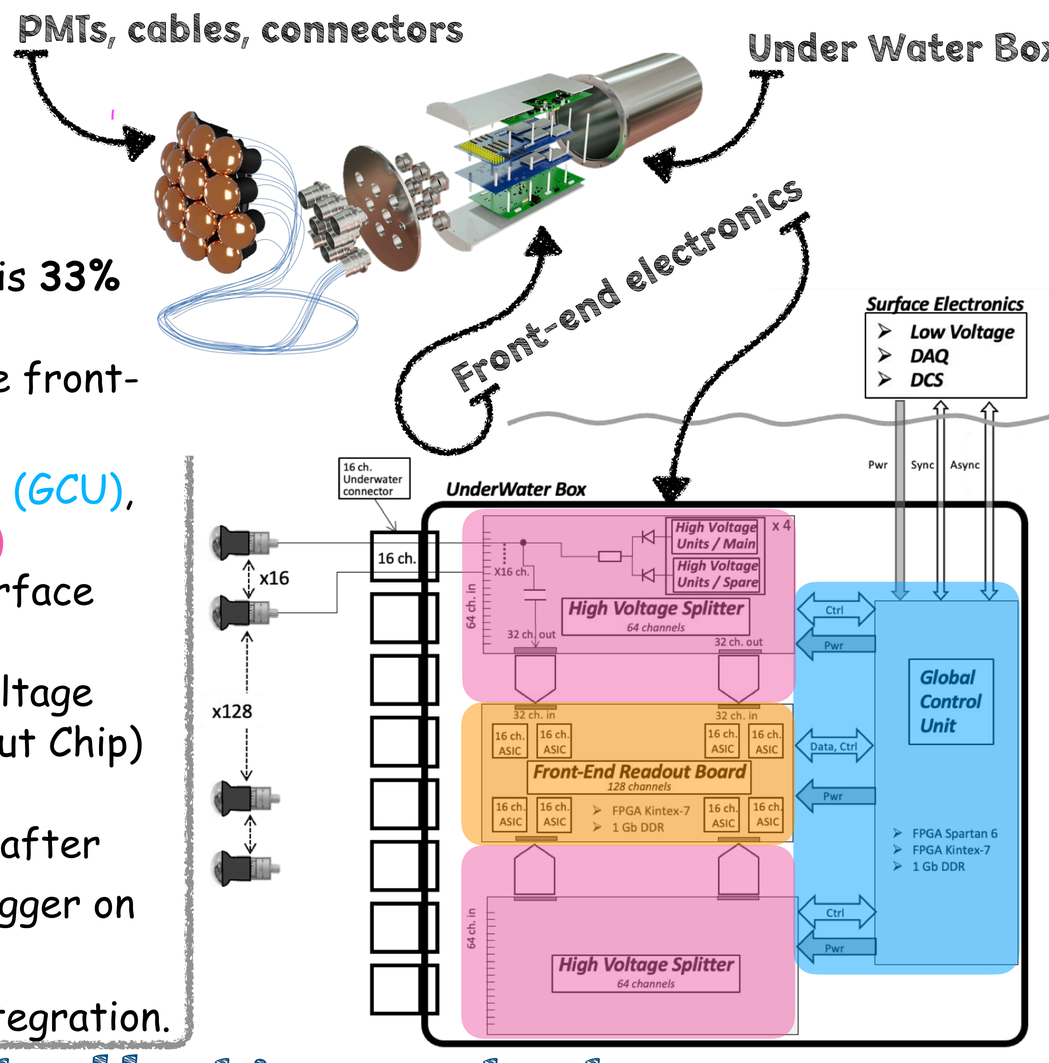
The 3-inch PMTs operate in photon-counting regime for energies below 10 MeV and will help calibrate the charge response non-linearity of the LPMTs.

- The nominal PMT's charge resolution for single photo-electrons (PE) is **33%** and the transit time spread is **1.6 ns**

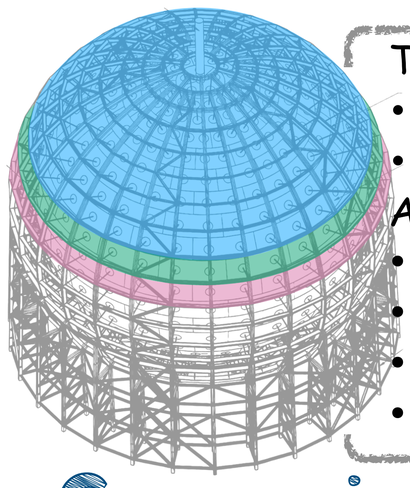
The 25 600 PMTs are handled by 200 Underwater boxes containing the front-end electronics →128 channels per set of electronics.

- The front-end electronics is composed of 1 global control unit board (GCU), 1 front-end readout board and 2 high-voltage splitter boards (HVS)
- The GCU handles the communication between the boards and the surface electronics
- The HVS power the PMTs and decouples the signal from the high-voltage
- The front-end board contains 8 CATIROC (Charge and Time Read Out Chip) each one measuring the time and integrated charge of 16 PMTs
- CATIROC has a time resolution of O(100 ps), a dead time of ~70 ns after trigger, 2 hits in a ~10 μs window can be digitised and it can self-trigger on charge as low as ~0.16 pC (1/3 PE at gain 3×10^6) [2]

All CATIROCs and boards have been characterised in lab and during integration.



Installation status

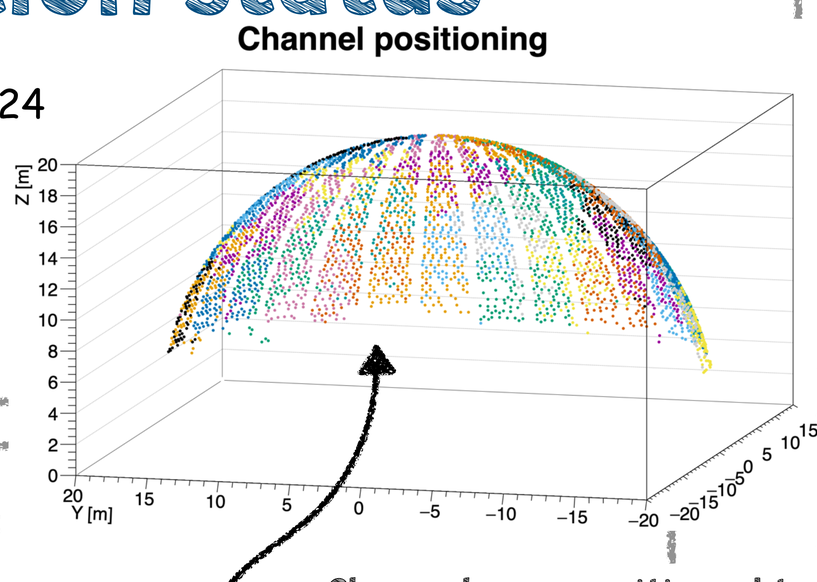


The installation is ongoing:

- From 80 to 160 PMTs are installed per day
- The installation is scheduled for completion by the end of 2024

As of February 2024:

- 86 (~43%) Underwater boxes are installed on the sphere
- 11 008 (~43%) SPMTs are installed on the sphere
- 8 672 (34%) SPMTs are connected to their electronics
- <1% channels lost during installation



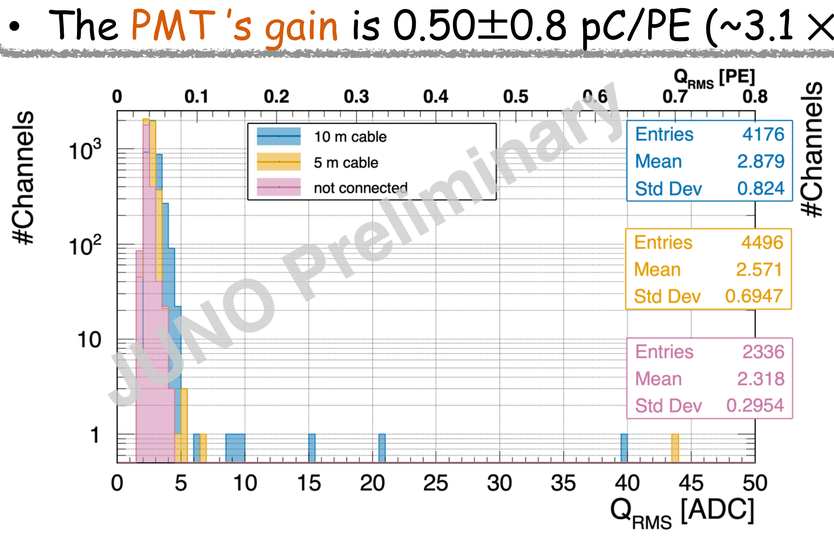
Commissioning performances

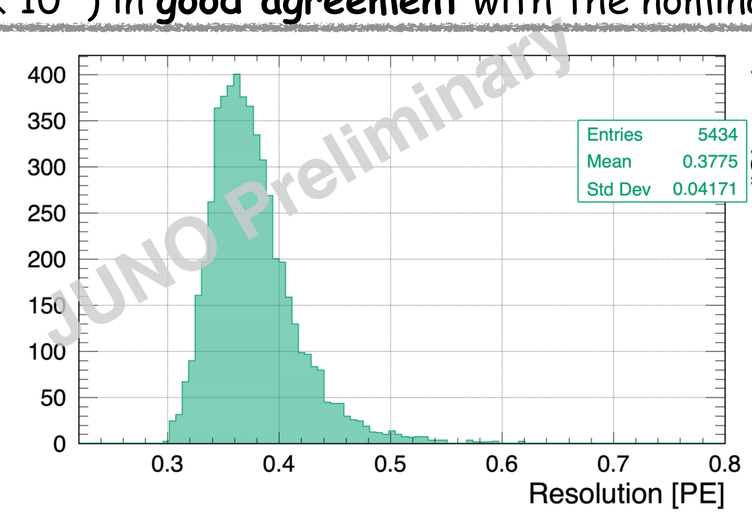
The electronic noise has been measured on **86** sets of electronics (11 008 channels):

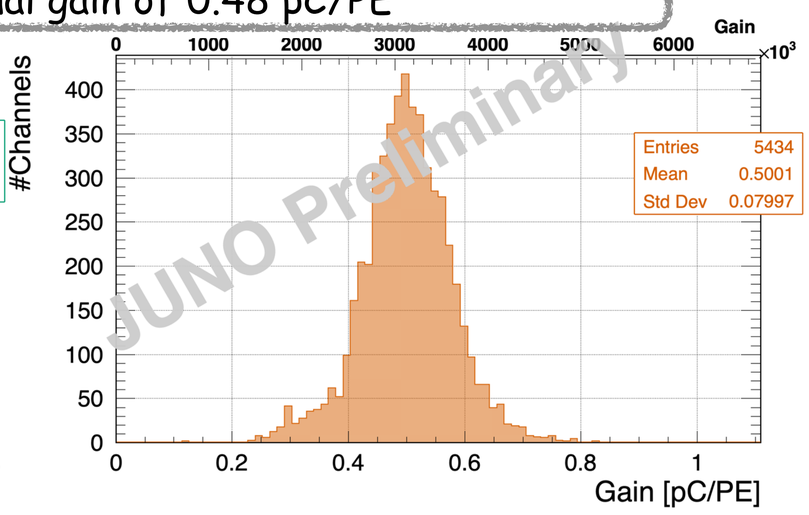
- The mean noise is ~2.5 ADC equivalent to ~0.05 PE this is much lower than the trigger threshold of 0.33 PE which demonstrates a **low electronic noise** and **good grounding**. A few noisy channels (> 15 ADC) due to badly connected cables have been identified and fixed.

The PMT 's gain and resolution have been measured on **43** sets of electronics (5434 channels):

- The PMT 's resolution is 38±4% in **good agreement** with the nominal resolution of 33%
- The PMT 's gain is 0.50±0.8 pC/PE (~3.1×10^6) in **good agreement** with the nominal gain of 0.48 pC/PE







[1] Prog.Part.Nucl.Phys. 123 (2022), 103927

[2] JINST 16 (2021) 05, P05010