Mass testing of Large-PMT electronics at Kunshan for the JUNO experiment

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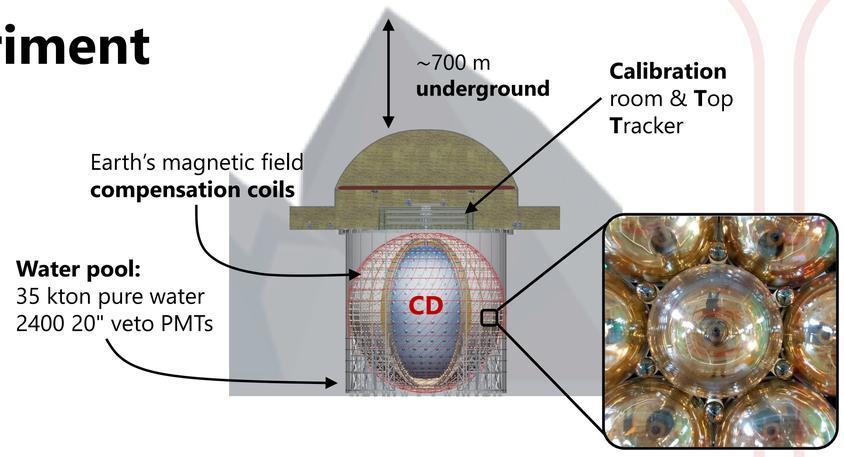
The JUNO experiment

The **Jiangmen Underground Neutrino Observatory** (**JUNO**) is a neutrino **medium baseline** experiment with an expected unprecedented energy resolution of 3% at 1 MeV, under construction in southern China [1,2].

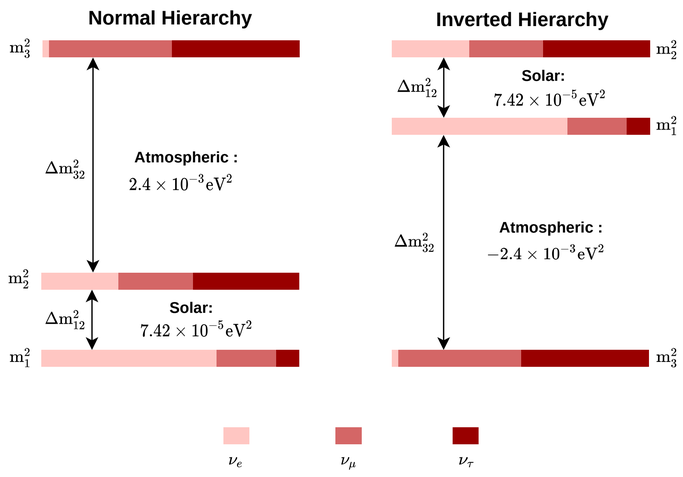


Extensive **neutrino physics and astrophysics program** [1]:

- **Reactor** $\bar{\nu}_e$: 60 IBD/day
- Supernovae burst: 5000 IBD + 2300 ES in 10 s (@ 10 kpc)
- DSNB: 2-4 IBD/year
- Solar ν: O(100)/year
- Atmospheric ν: O(100)/year
- Geo-ν: ~400/year

Central Detector (CD):
20 kton liquid scintillator (LS) inside an acrylic vessel (AV) (⌀ 35.4 m), supported by a stainless-steel latticed shell

PMT system:
~18000 20" (Large-)PMTs
~25600 3" (Small-)PMTs
photocoverage > 75%
~1300 pe/MeV expected

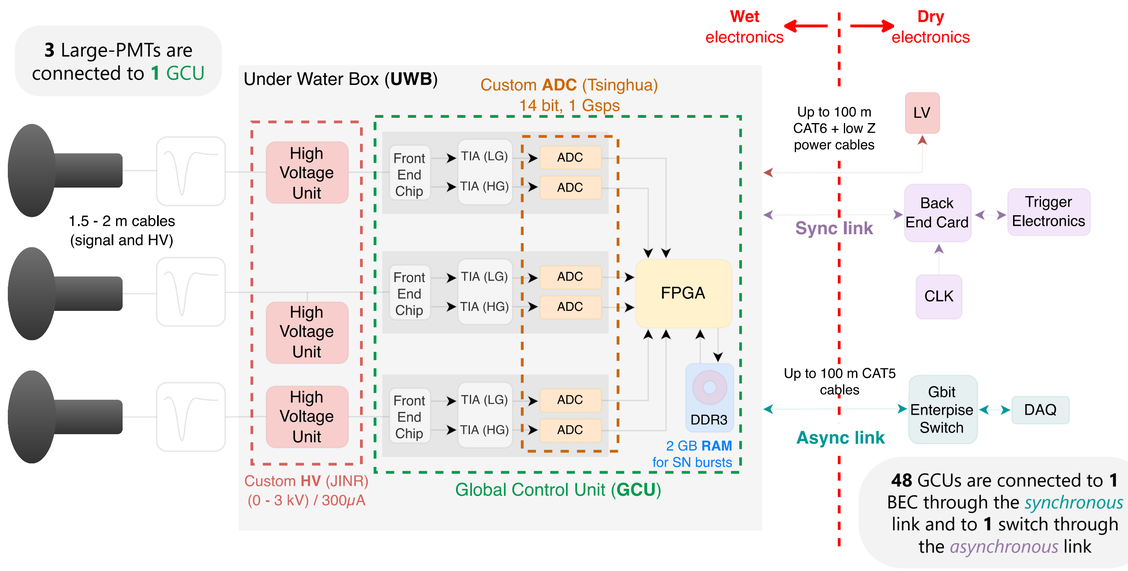


Main **physics goals**:

- neutrino mass **ordering** determination @ 3σ in 6 years
- measurement of three **oscillation** parameters with sub-percent precision

Large-PMT readout electronics

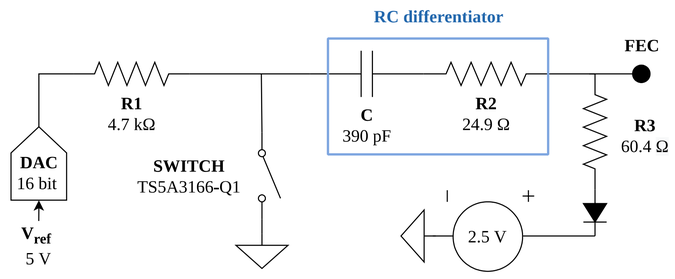
See poster by V. Cerrone, *Large-PMT electronics performance tests for the JUNO experiment*



GCUs are the **key component** in the processing of Large-PMT signals: a thorough characterization during mass production is required.

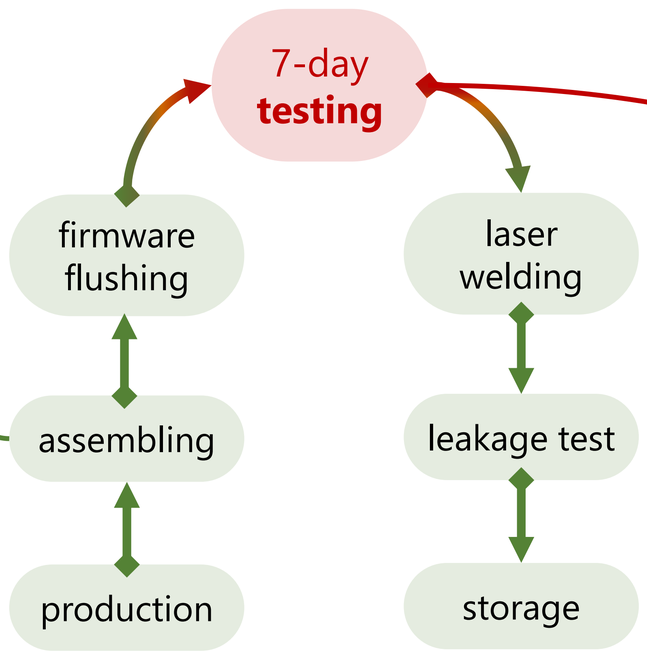
Each channel is equipped with an internal test pulse generator, or **calibration circuit**. The circuit is used to check that the channel is **working** and to **calibrate** it.

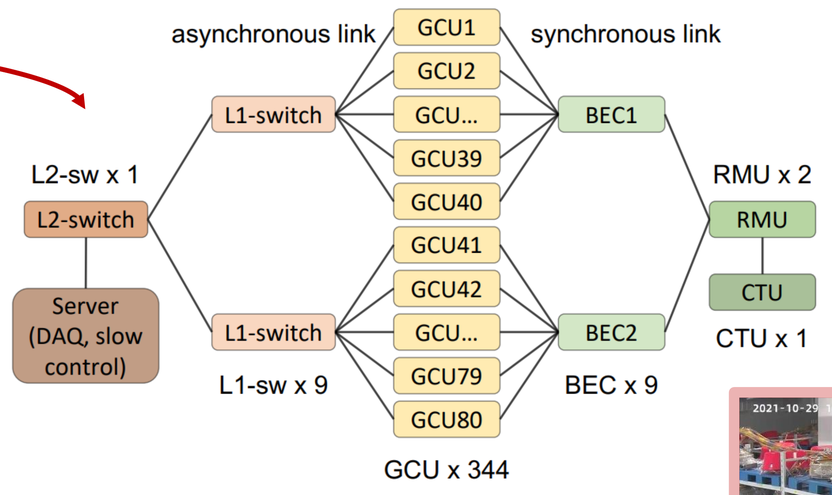
The amplitude of the pulse is set with a 16-bit Digital to Analog Converter (**DAC**). The pulse is generated with the help of a **switch** which is controlled via IPbus [4].



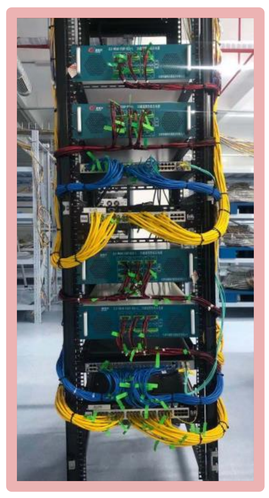
Mass testing at production site in Kunshan, China

Assembled Under Water Box (**UWB**)

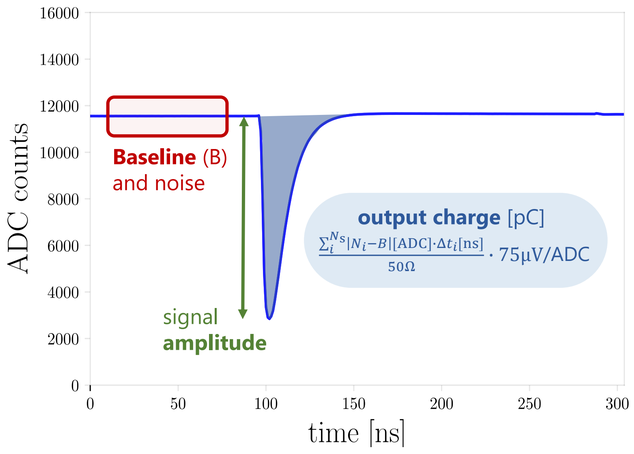




344 GCUs are tested **at the same time** at the Kunshan facility



Digitized **waveform** generated from the calibration circuit:



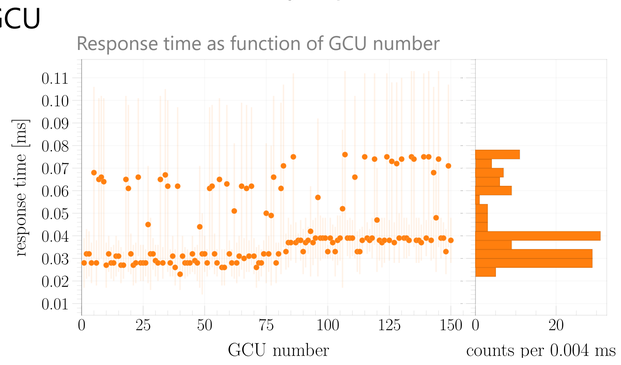
Waveform length and position of waveform can be changed online via **IPbus protocol** [4].
The current **window** for the waveform is 304 ns.

Waveform **properties** that we have to check:

- baseline
- noise
- trigger stability
- integrated charge
- packet size validity
- timestamp vailidty

Test Protocol

1. Ping Test: check **connection** of the GCU to the network; send 100 56-Byte packtes in 1 seconds to each GCU



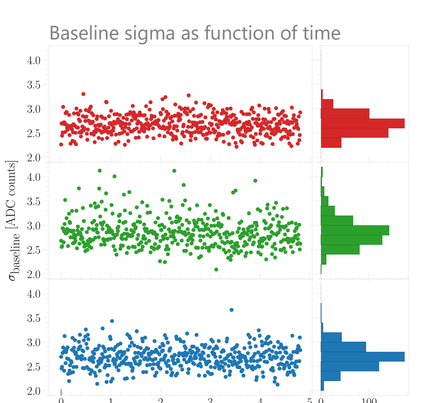
2. Linearity Test: **calibrate** each channel, evaluate gain for **High** Gain and **Low** Gain ADCs; short runs at various test pulse amplitude

3. Stability Test: check **stability** of parameter over time; e.g., baseline, baseline sigma, integrated charge; long run at fixed test pulse amplitude

4. Slow control monitoring: quantities are read through the *asynchronous* link via **IPbus** protocol [4]; e.g.,

- FPGA temperature
- HVU temperature
- PMT high voltage
- internal voltages and currents

5. DDR3: check **storage** capabilities and **event loss** rate



References:
[1] JUNO Collaboration, *JUNO Physics and Detector*, 2021, arXiv:2104.02565
[2] JUNO Collaboration, *Neutrino Physics with JUNO*, J. Phys. **G43**, 3, 030401 (2016) [arXiv:1507.05613]
[3] JUNO Collaboration, *JUNO CDR*, 2015, arXiv:1508.07166 (chapter 7)
[4] C. Ghabrous Larrea et al., *IPbus: a flexible Ethernet-based control system for xTCA hardware*, JINST **10** (2015) no.02, C02019