ID#198

Performance of 20-inch Potted PMTs for JUNO

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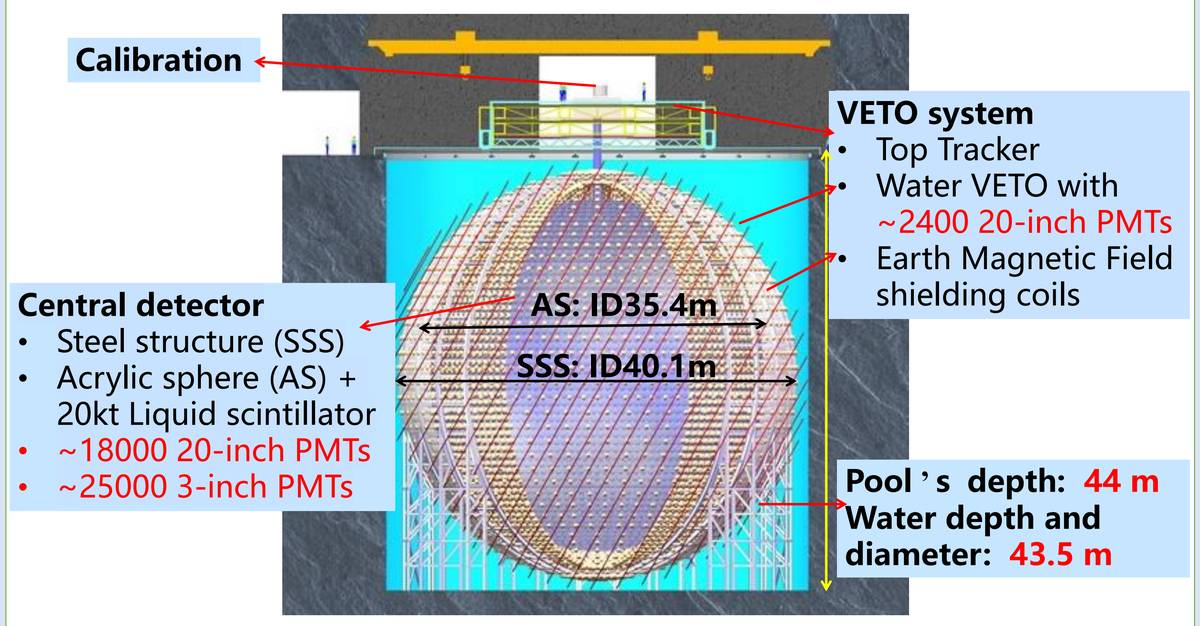
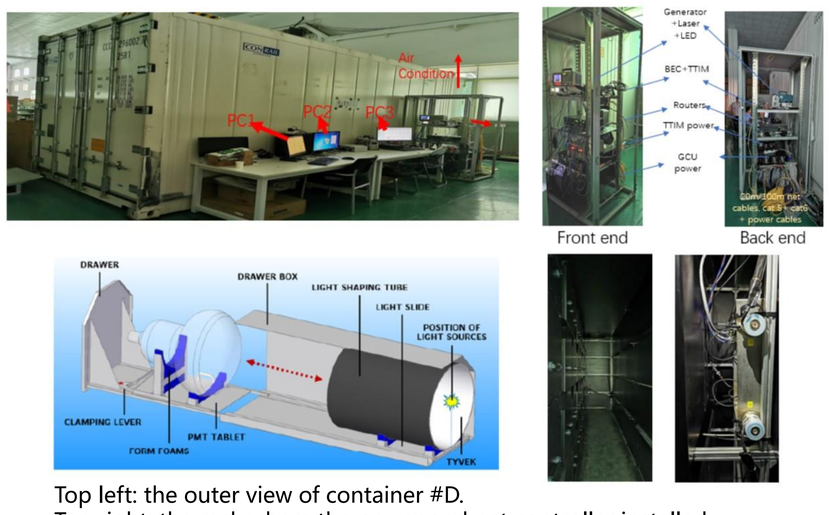
JUNO Detector

- **Main physics goal:** Determining neutrino mass ordering and making a sub-percent measurement of three oscillation parameters
- **High efficient PMTs:** Photon detection efficiency (PDE) ~30%
- **Very high PMT coverage:** 78%



Container System[1]

- **Six alternating layers of silicon-iron:** Shielding the external fields with the residual magnetic field less than 4.7 μT

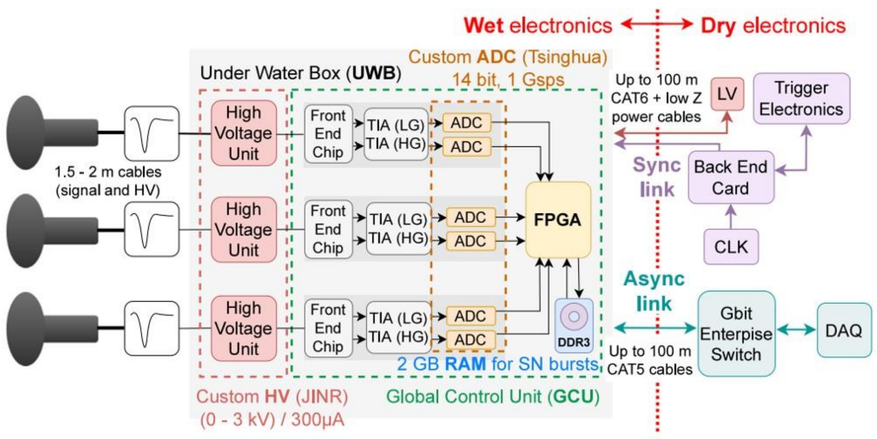


Top left: the outer view of container #D.
Top right: the rack where the power and net controller installed.
Bottom left: the schematic view of a drawer box.
Bottom right: the internal view of the container and an installed box of 1F3 electronics. between the drawers.

- **32 independent working channels (drawers)**
- **Stabilized LED light source with 420 nm wavelength**
- **A HVAC (heating, ventilation, and air conditioning) unit:** Controlling the measurement environment inside the containers (23°C for the container #D)
- **JUNO 1F3 electronics prototype:**
  - **High voltage unit (HVU):** Providing the bias voltage to PMTs
  - **Global control unit (GCU):** Analog-digital conversion and waveform acquisition
- **A DAQ system based on Linux[2]:** Initialization, configurations of HVU and electronics, control waveform readout, temperature and DCR monitoring

More detailed introduction can be found in the paper[3].

Global Control Unit

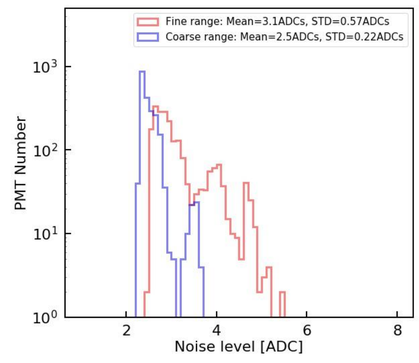


- **One GCU has 3 channels**
- **One channel has two ranges**
  - **Fine Range** (range1, High gain): 1ADC=0.122 mV 0-128 p.e.
  - **Coarse Range** (range0, Low gain): 1ADC= 0.832 mV 0-1000 p.e.

More detailed introduction can be found in the paper[4].

Results from the Container System

- **Noise level of electronics**
  - Fine range: **3.1 ADCs (4% for SPE)**
  - Coarse range: **2.5 ADCs**



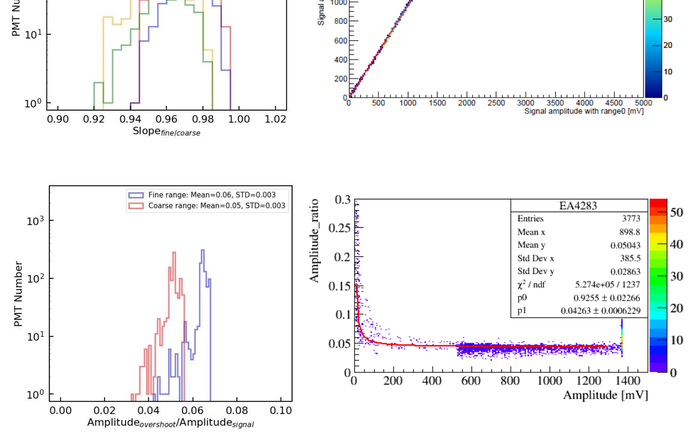
- **Performance of LPMT with SPE model**
  - The amplitude threshold for DCR measurement is around **1.8 mV**.
  - The amplitude threshold for waveforms analysis is **3 mV**.
  - The charge integration window is [-20ns,+50ns] for peak.
  - The amplitude of SPE is about **8 mV**.

The typical parameters of potted dynode and MCP PMTs in container #D with 1F3 electronics[5].

Parameters	ALL PMT	Dynode PMT	MCP PMT	High-QE PMT	Low-QE PMT
Number of PMT	1969	738	1231	576	655
HV /V	1799	1929	1722	1701	1745
Gain /10^6	10.0	9.9	10.0	9.9	10.1
DCR /kHz	26.5	16.6	32.4	31.0	33.9
Resolution /%	30.5	28.0	32.0	32.7	31.2
P/V	3.8	3.6	3.9	3.9	3.9
FWHM /ns	10.5	10.8	10.3	10.4	10.1
S/N	14.3	14.2	14.3	14.2	14.4
Rise Time /ns	4.8	6.4	3.9	4.0	3.9
Fall Time /ns	11.9	8.9	13.6	14.1	13.1
Relative TTS /ns	8.8	6.2	10.3	10.3	10.4
Amplitude /mV	8.1	7.9	8.1	7.9	8.4

The results are consistent with this paper[1].

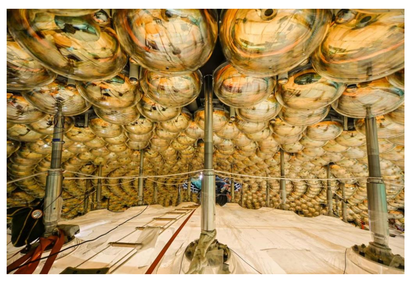
- **Comparison of two ranges in electronics with self trigger mode**



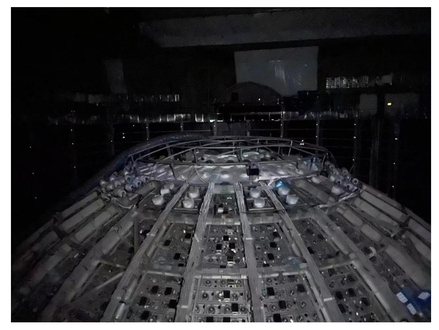
➢ The amplitude and charge agreement of the two ranges are approximately **97%** and **96%**, respectively.

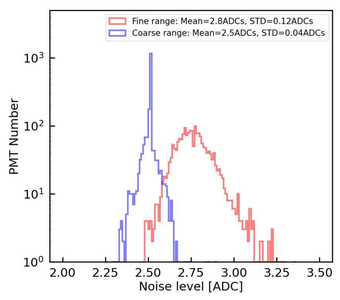
➢ The amplitude between signal and overshoot of the two ranges are about **6%** and **5%**.

Light-off Test of JUNO Detector



Light off





- **Noise level of electronics without HV**
  - As of June, a total of 651 GCUs had been tested for electronic noise.
  - Fine range: **2.8 ADCs (4% for SPE)**
  - Coarse range: **2.5 ADCs**

References

[1] Abusleme A, Adam T, Ahmad S, et al. Mass testing and characterization of 20-inch PMTs for JUNO[J]. The European Physical Journal C, 2022, 82(12): 1168.
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[3] B. Wonsak et al. A container-based facility for testing 20’ 000 20-inch PMTs for JUNO. Journal of Instrumentation, 16(8):T08001, August 2021. doi: 10.1088/1748-0221/16/08/T08001.
[4] Coppi A, Jelmini B, Bellato M, et al. Mass testing of the JUNO experiment 20-inch PMT readout electronics[J]. Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, 2023, 1052: 168255.
[5] Liu C, Li M, Wang Z, et al. Check on the features of potted 20-inch PMTs with 1F3 electronics prototype at Pan-Asia[J]. Journal of Instrumentation, 2023, 18(02): P02003.