Progress of JUNO commissioning and online reconstruction of PMT waveforms

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Introduction

The Jiangmen Underground Neutrino Observatory (JUNO)

- Neutrino source: mainly reactor neutrinos
- Target substance: 20 kton of liquid scintillator
- Photocathode coverage: high, with tens of thousands of 20-inch photomultiplier tubes (PMT)
- Physical goals: neutrino mass ordering, precise measurement of oscillation parameters, other physics such as supernova neutrino

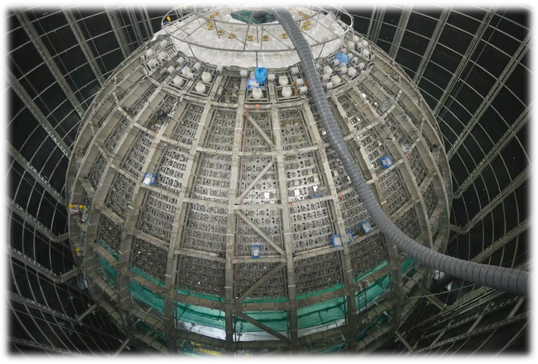

Figure 1. JUNO construction site

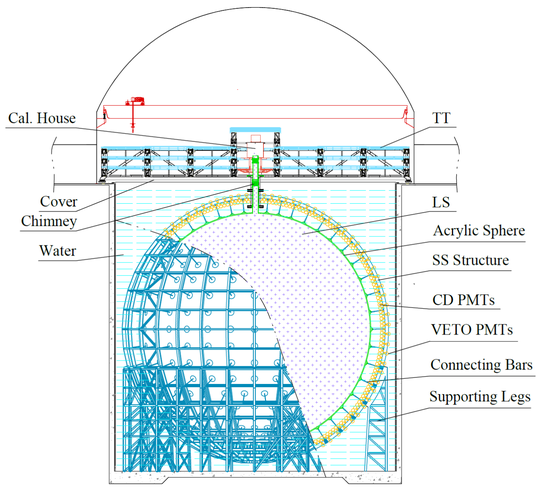

Figure 2. Schematic view of the JUNO detector [1]

Progress

- Under assembling
- > 50 % PMTs already installed
- Expected to be put into operation quickly after construction, so it's necessary to conduct commissioning during the construction

Online waveform reconstruction

A feature of electronics in JUNO, enables more efficient DAQ

Method

FPGA – continuous over threshold integral (COTI)
Offline – COTI, deconvolution, machine learning, ……

COTI algorithm

Baseline calculation, pulse searching, integral

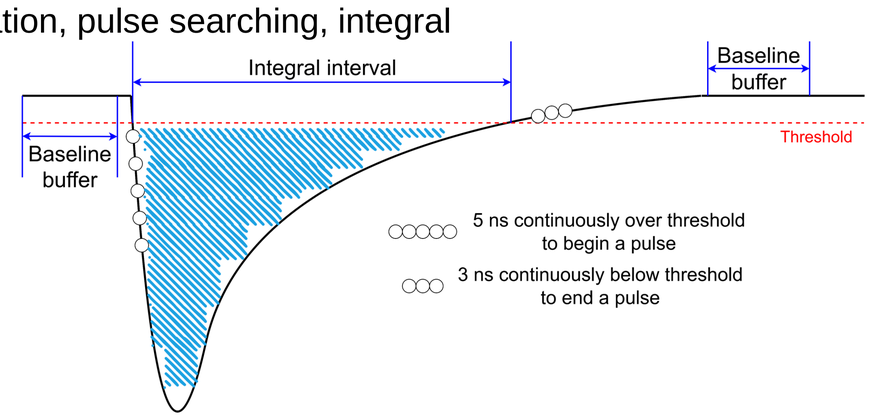

Figure 3. COTI algorithm

Validation

COTI algorithms in FPGA and offline give the consistent result
0.002% of the first pulses and ~0.12% of the second show difference
Reason is known: limited readout window

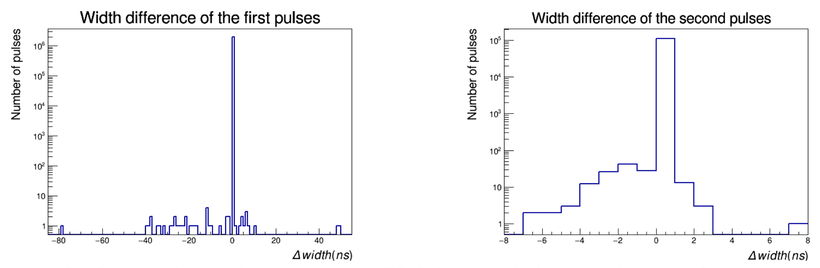

Figure 4, 5. Comparison of results from FPGA and offline. $\Delta width = 0$ means the same

Commissioning

Purpose

- To provide opportunities to test the installed PMTs
- To learn about the detector response
- To jointly debug the data processing

Multiple groups involved

- Installation
- Electronics, trigger, DAQ, DCS
- Analysis, software, physics

Good installation quality known from the light-on and light-off tests

Light-off test	Dec. 9, 2022	Apr. 17, 2023	Jun. 18, 2023	Sept. 4, 2023	May. 26, 2024
	57 LPMTs	700 LPMTs	0 LPMTs	~ 5,200 LPMTs	6868 LPMTs
	0 SPMTs	600 SPMTs	3,183 SPMTs	~ 7,000 SPMTs	>10 k SPMTs
Light-on test	Apr. 10-16, 2023		Jun. 19-25	Mid-Aug.	Nov., 2023
	230 GCUs		400 GCUs	1,300 GCUs	1,783 GCUs

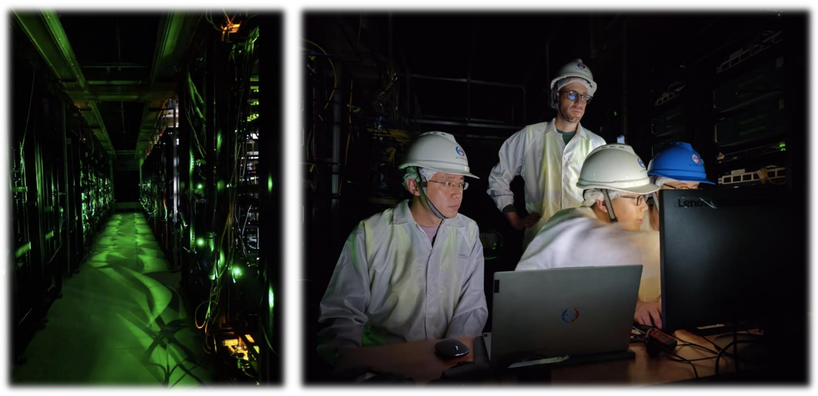

Figure 6. Light-off test in progress. Working in the electronics room with all light sources in experiment hall off

Online data flow

Online	Offline
Electronics	Event classification (fine)
Data acquisition	Reconstruction
Online event classification (fast)	Physical analysis

During commissioning **we should adjust,**

- Time latency and sync
- Trigger configuration
- Traffic of data
- ……

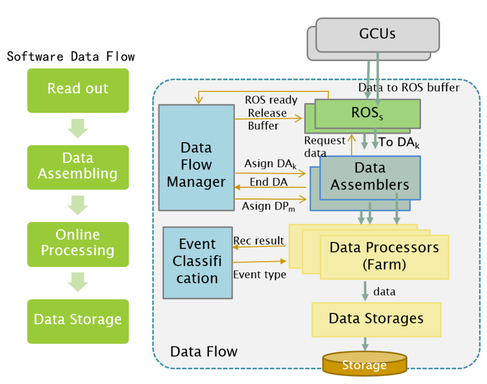

Figure 8. DAQ workflow. Readout from GCUs

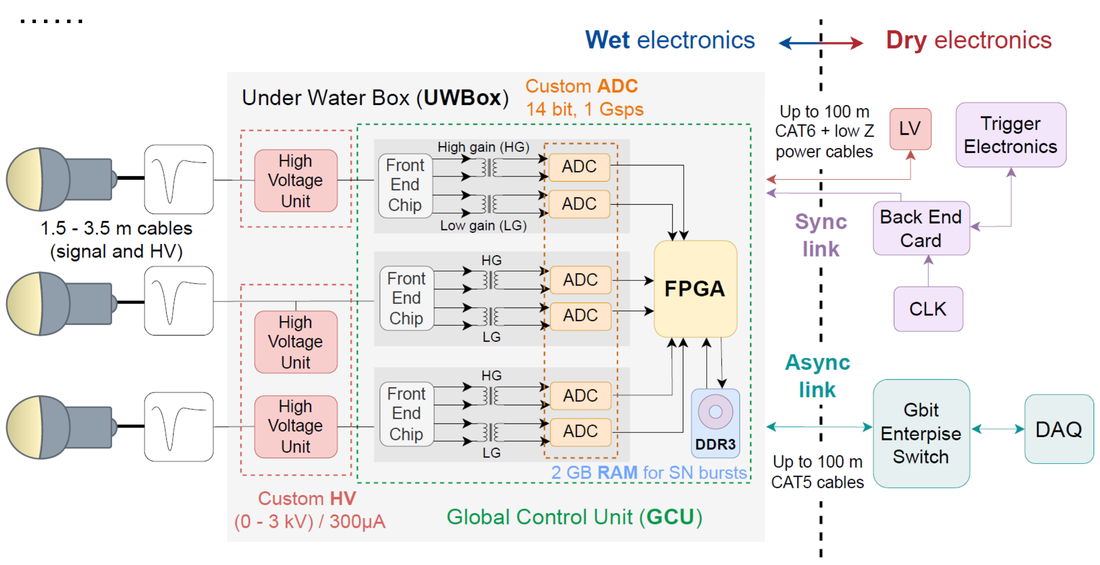

Figure 7. Electronic structure. GCU is in a box under water.
FPGA T/Q is essential to supernova burst analysis [2]

Result

Method + dataset

Electronic noise level (2023)

- Measured by RMS of the flat intervals in waveforms

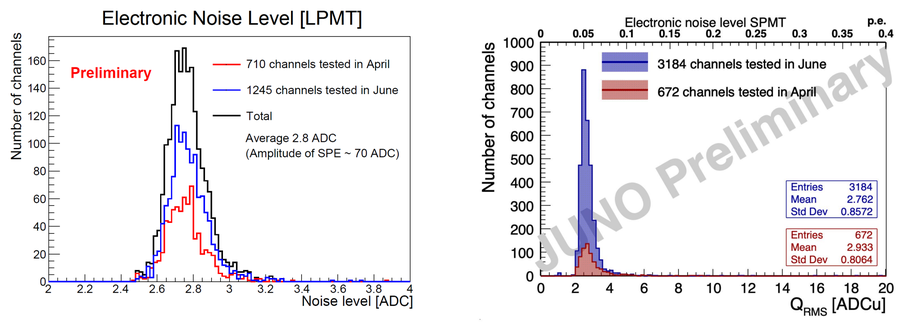

Figure 9, 10. Electronic noise level of LPMT and SPMT tested in commissioning. Result of LPMT is given by COTI algorithm

Dark noise rate

- Found to be higher if not fully cooled down after light exposure
- High DCR region (red in Figure 11.) – actually a potential light source

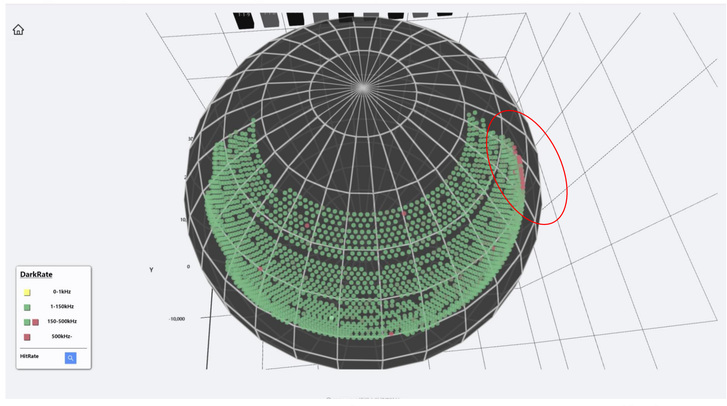

Figure 11. DCR monitoring. Each point represents an installed PMT

Reference

[1] JUNO physics and detector. JUNO Collaboration • Angel Abusleme (Chile U., Catolica) et al. Prog.Part.Nucl.Phys. 123 (2022), 103927
[2] Mass testing and characterization of 20-inch PMTs for JUNO. JUNO Collaboration • Angel Abusleme (Chile U., Catolica and Unlisted, CL) et al. Eur.Phys.J.C 82 (2022) 12, 1168