The status of the BEC (Back-end cards) for the JUNO experiment

Yifan Yang, Barbara Clerbaux, Feng Gao, Marta Colomer, Pierre-Alexandre Petitjean
Université libre de Bruxelles (ULB)

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Introduction

The Jiangmen Underground Neutrino Observatory (JUNO)[1] is a neutrino medium baseline experiment in construction in China, with the goal to determine the neutrino mass hierarchy and perform precise measurements of several neutrino mass and mixing parameters. The experiment uses a large liquid scintillator detector aiming at measuring antineutrinos issued from nuclear reactors at a distance of 53 km.

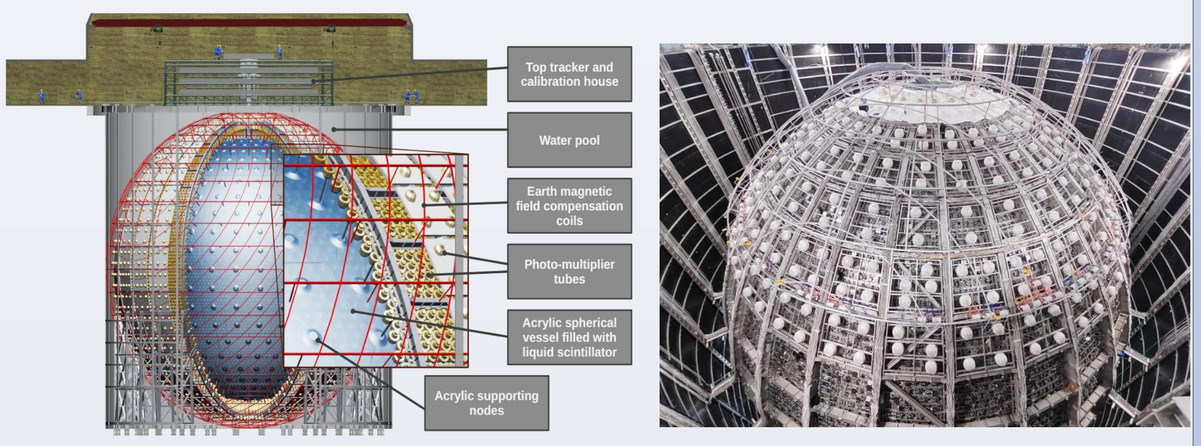


Figure 1: Schematic view of the JUNO detector (left) and picture of the detector in construction (right)

The JUNO detector:
- It is located 650 m underground
- Will be the largest liquid scintillator detector (20 kton)
- Two complementary sub-systems with >40k PMTs → 77.9% photo coverage

Readout system overview

The JUNO electronics system [2-3]:
- The front-end electronics system located Under Water (UW): reads and process the analog signal coming from the PMTs
- The back-end electronics system, sitting outside water, consisting of the DAQ and the trigger system

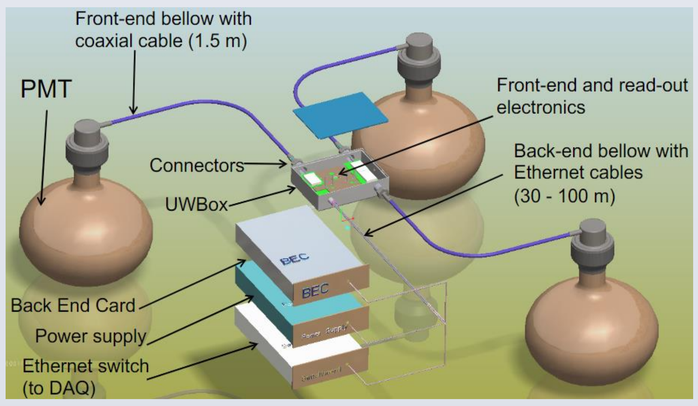
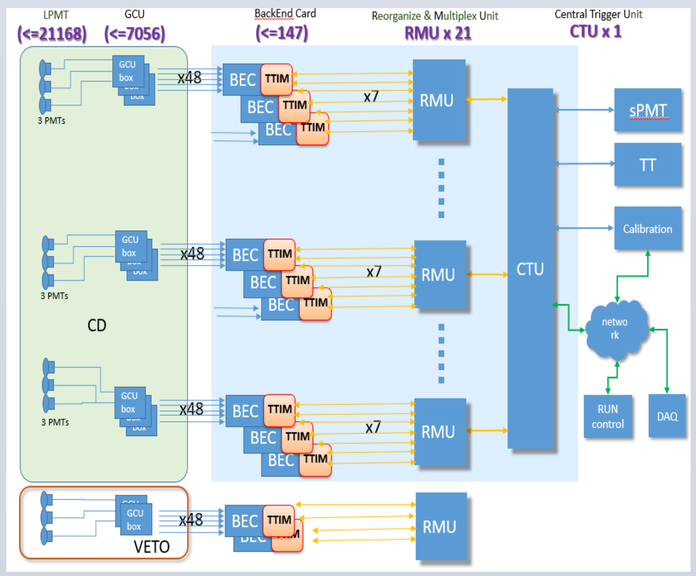


Figure 2: Schematic view of the JUNO electronics system

Data exchange between UW electronics and backend electronics includes:
- Synchronized data (trigger request and trigger accept running at 125 Mbps, 62.5 MHz system clock and IEEE1588 time synchronization protocol)
- Asynchronized data (1 Gb Ethernet packet with event data and slow control).

The cable containing the synchronized data connects from GCUs (Global Control Unit) to the back-end cards and then to the trigger system. The cable containing the asynchronized data connects from GCUs to a commercial switch and then to the DAQ system.
Power supply is delivered to UW electronics from a dedicated power cable.



LPMT: Large Photo Multiplier Tube

GCU: Global Control Unit

BEC: Back-End Card

RMU: Reorganize and Multiplex Unit

CTU: Central Trigger Unit

Figure 3:
Schematic view of the JUNO trigger system

One BEC receives 48 Ethernet cables from 48 underwater boxes, 4 pairs out of 4 inside one cable are used to transfer synchronized data. The BECs connect to the trigger system through a FMC mezzanine card named TTIM (Trigger, Timing, Interface Mezzanine).
Data transfer requirement : 125 Mbps bi-directional per channel, 2 channels per port.

[1] JUNO coll., "JUNO physics and detector", Progress in Particle and Nuclear Physics, 2022, 123: 103927
[2] B. Clerbaux, S. Hang, P-A Petitjean et al., "Automatic test system of the back-end card for the JUNO experiment", IEEE Transactions on Nuclear Science, 2021, 68(8): 2121-2126:2301.04379, 2023
[3] A. Coppi, B. Jelmini, M. Bellato et al., "Mass testing of the JUNO experiment 20-inch PMTs readout electronics", preprint arXiv:2301.04379, 2023

BEC final design

One BEC consists of one base board, one concentrator and six extenders (placed in 1U rack):
- Base board: power supply for whole system, interface with extenders and concentrator
- Extenders: direct interface with 8 Ethernet cables coming from 8 underwater boxes, equipped with 16 equalizers to handle 16 input channels
- Concentrator : TTIM, concentrate trigger information from 6 extenders which equal to 48 underwater boxes and forward it to next trigger processing level

Figure 4: Top view (left) and the front view (right) of the BEC system

Mass production and quality control

1. Testing of PCB
- PCB manufacture
- PCB testing
- PCB assembly (base and mezzanine)
- PCB testing

2. Testing after assembly
- BEC electronics assembly (base and mezzanine and TTIM)
- BEC self testing
- BEC mechanical assembly
- BEC self testing

3. Testing in Kunshan
- BEC self testing
- BEC test with GCUs

4. Testing after installation
- BEC self testing
- BEC long term monitoring

Installation and Commissioning

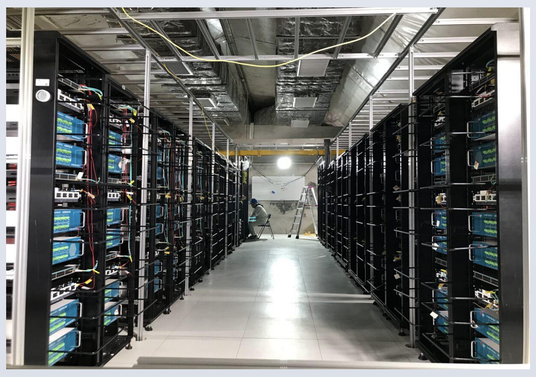


Figure 5: One of the two underground electronics rooms

BECs for the JUNO center detector:
- 164 BECs have been installed in the two underground electronic rooms in September 2022
- BEC self tests have been done
- Combine tests between installed BECs and GCUs are ongoing, and showed good results up to now
- The test of the links between BECs and the center trigger unit (CTU) is ongoing

Electronics commissioning for the JUNO center detector:
- Electronics commissioning is ongoing, LPMT/sPMT(w/wo HV) + electronics + trigger + DAQ + other electronics have been tested with light off
- Two trigger decision levels have been used: BEC-level & CTU-level
- The trigger modes include: global trigger(nhits/periodic/external), external/self trigger
- Periodic trigger to 305 GCUs from 14 BECs are tested with 250 Hz
- 1763 GCUs and 59 BECs attended commissioning using CTU-level trigger. Periodic trigger, external trigger and nhits trigger algorithm are tested

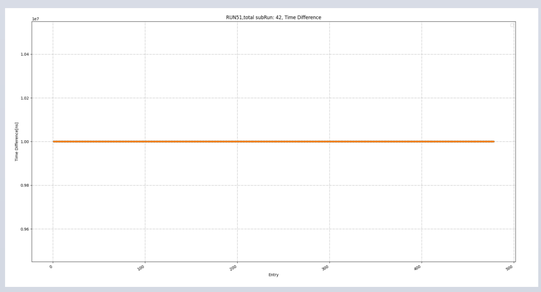


Figure 6: JUNO CTU level global period trigger: Time difference between two continue triggers

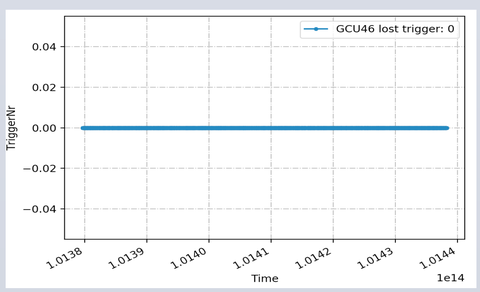


Figure 7: OSIRIS BEC level global nhits trigger: Trigger lost from BEC for OSIRIS is 0

BEC for OSIRIS (Online Scintillator Internal Radioactivity Investigation System):
- OSIRIS has almost same electronics as the JUNO detector
- One BEC has been installed and tested
- During commissioning, 27 GCUs and the BEC are synchronized, no trigger lost using global trigger with 40-60 Hz trigger rate