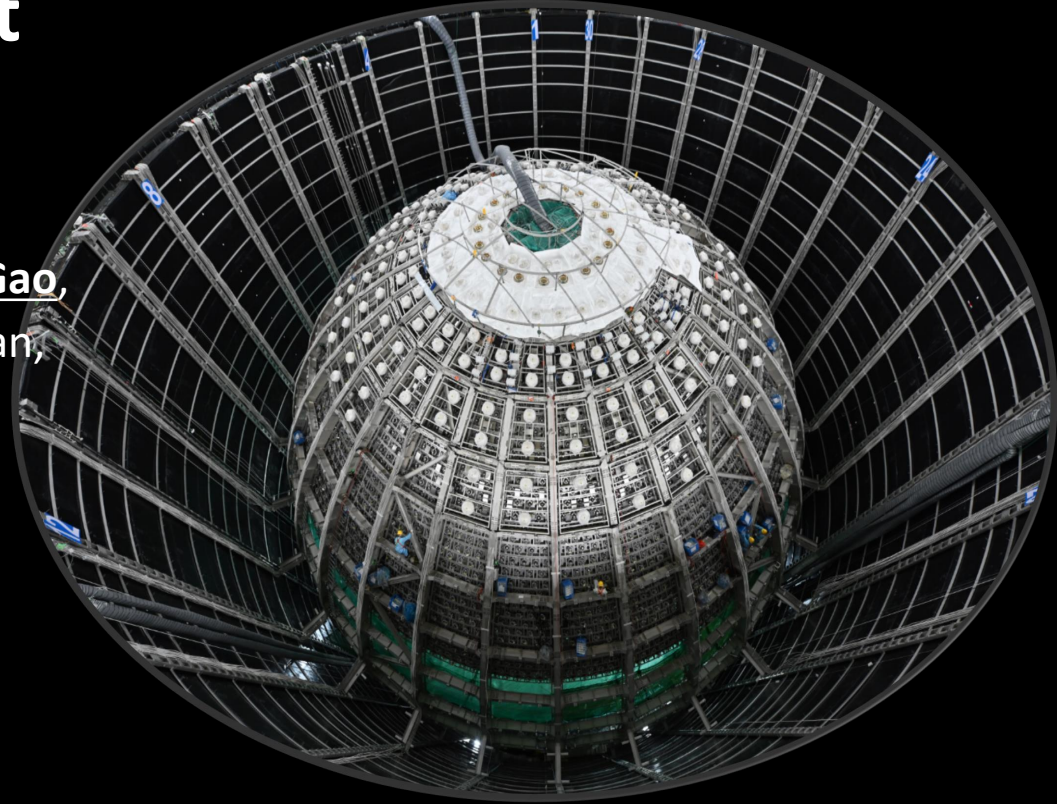# Testing of back-end card(BEC) for JUNO experiment

Barbara Clerbaux, Jianmeng Dong, **Feng Gao**,
Marta Colomer, Pierre-Alexandre Petitjean,
Yifan Yang

TIPP 2023-09-06

1

Outline

JUNO experiment

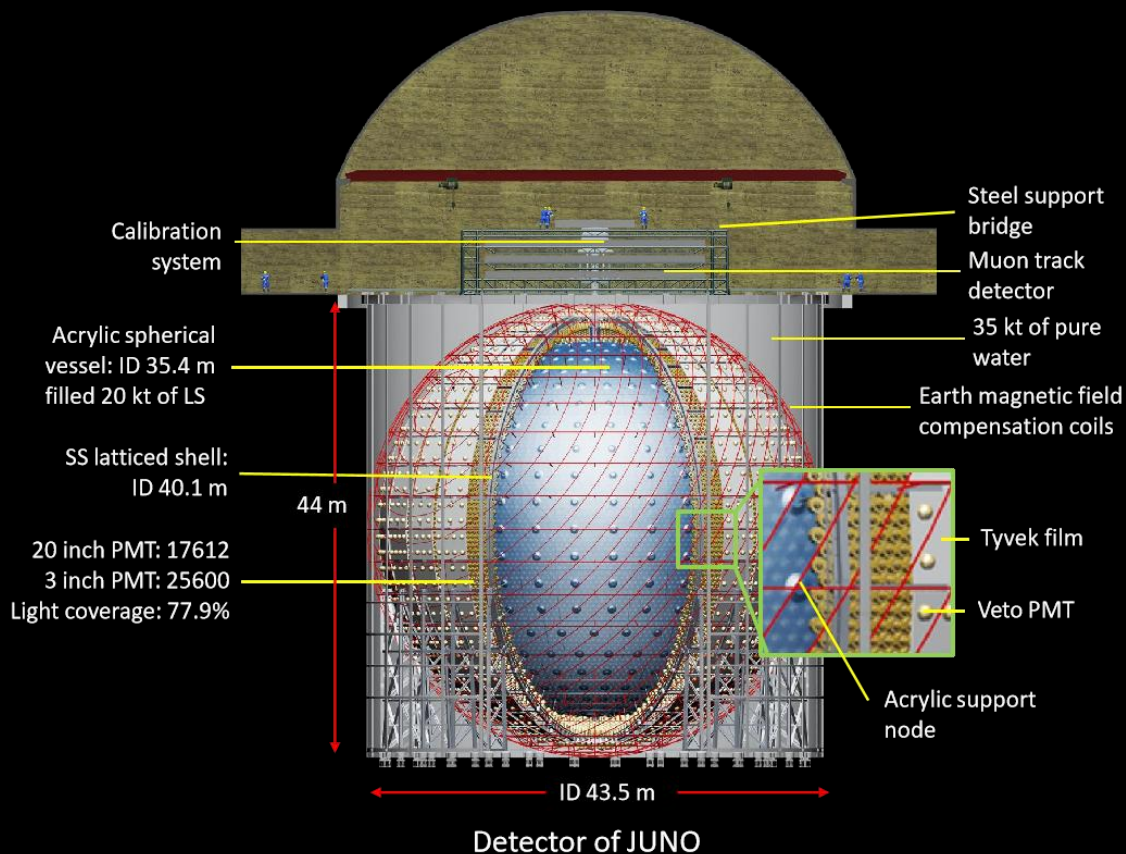Electronics system overview

Test of BEC

The status of BEC after installation

Jiangmen Underground Neutrino Observation (JUNO)

- JUNO is a medium baseline (53 km) reactor neutrino experiment, the primary goal: determination of neutrino mass ordering.
- Located in Guangdong Province, South of China. It is located 650 m underground.

~650 m rock overburden
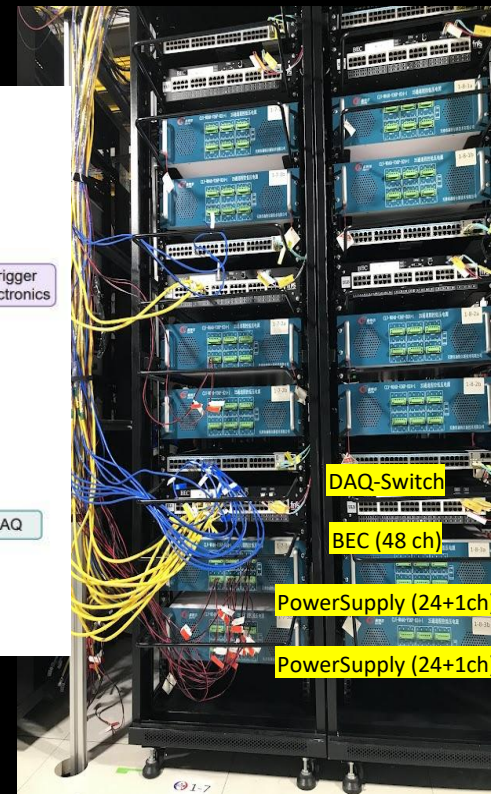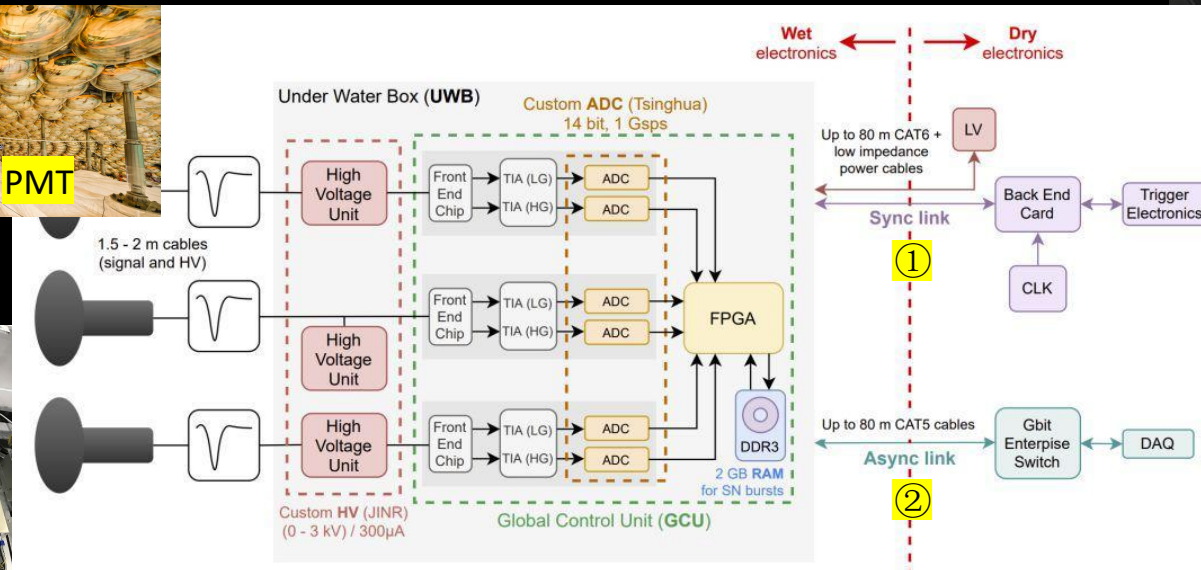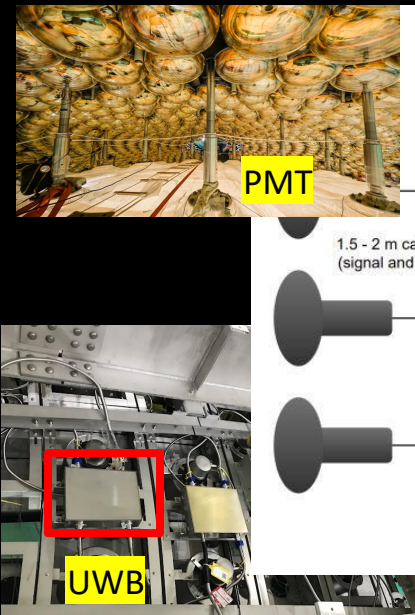
Slope tunnel: 1265 m with 42 degree

JUNO experiment

- A 20 kton liquid scintillator (LS) detector

- PMT coverage: 78%

- Energy resolution @ 1 MeV: 3%

Calibration system

Steel support bridge

Muon track detector

35 kt of pure water

Acrylic spherical vessel: ID 35.4 m filled 20 kt of LS

Earth magnetic field compensation coils

SS latticed shell: ID 40.1 m

20 inch PMT: 17612
3 inch PMT: 25600
Light coverage: 77.9%

44 m

Tyvek film

Veto PMT

Acrylic support node

ID 43.5 m

Detector of JUNO

4

Electronics system

5

Trigger system
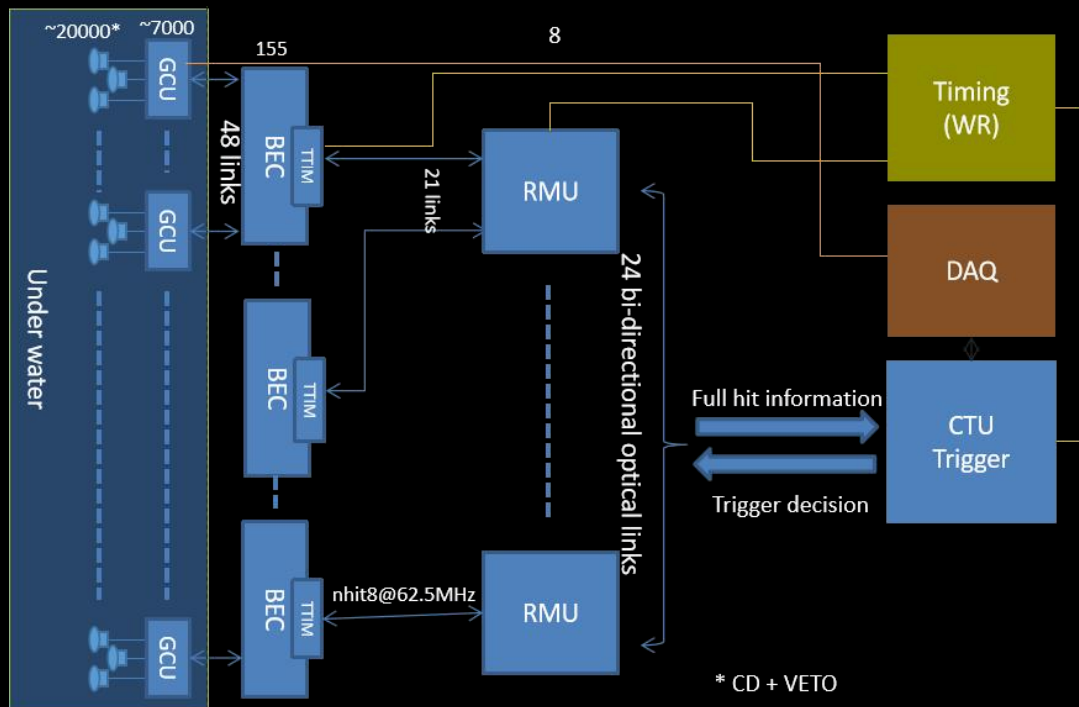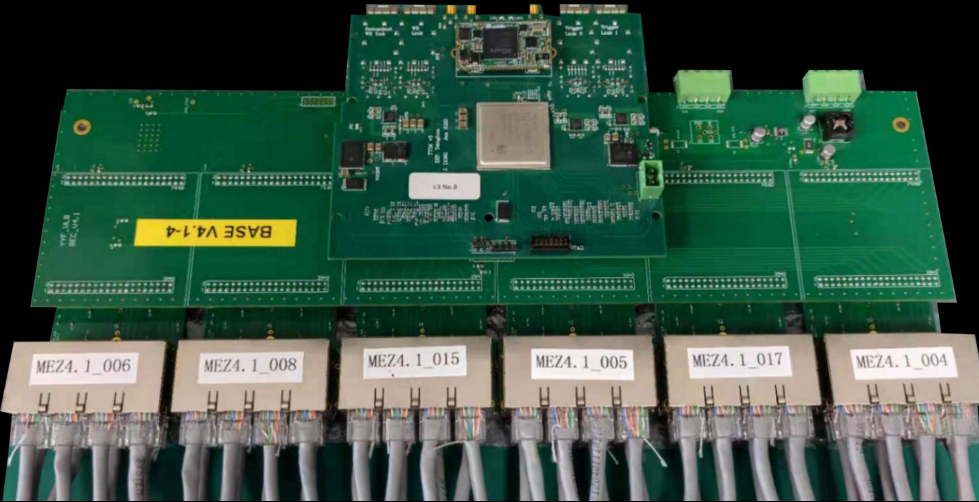

Several trigger sources:
- 179 Vertex fitting trigger with compressed trigger window (48ns).
- Normal multiplicity trigger with wide window (300ns, configurable).
- SN alert
- Periodic trigger
- External trigger
- ......

Back-End Card

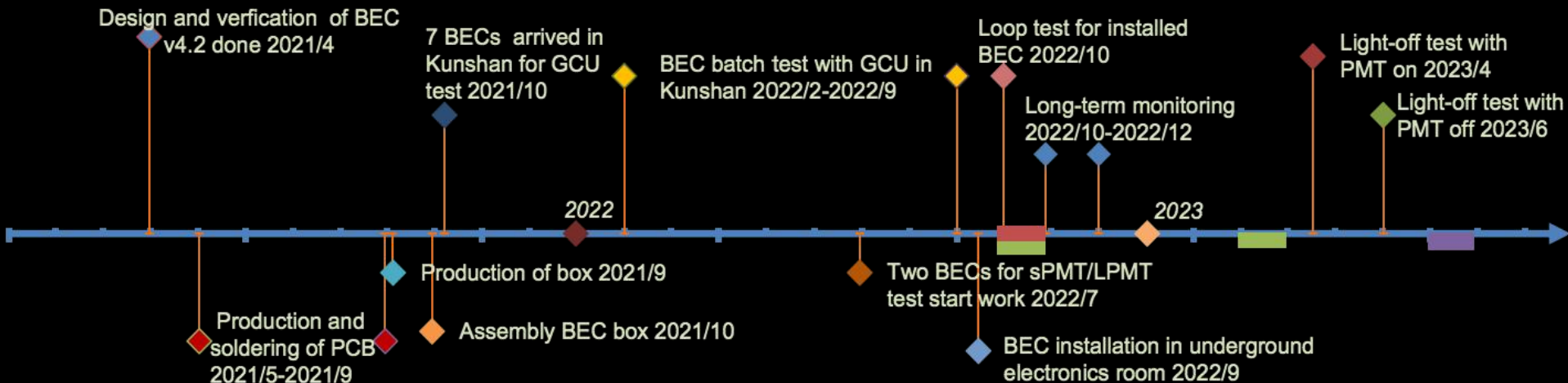The BEC is in direct communication with the underwater electronics

- One base board
- 6 mezzanines, each of them interface with GCU through 8 RJ45
- One trigger/time interface mezz (TTIM) carry a FPGA , provide time and clock from the white rabbit, collect full hit information.

Name	Type of signals	origin to destination
Pair 1-2:	62.5 MHz clock	BEC → GCU
Pair 4-5:	125 Mbps data	BEC → GCU
Pair 3-6:	125 Mbps data	GCU → BEC
Pair 7-8:	125 Mbps data	GCU → BEC

Part II: Test of the BEC

Timeline of BEC test

Design and verfication of BEC v4.2 done 2021/4

7 BECs arrived in Kunshan for GCU test 2021/10

BEC batch test with GCU in Kunshan 2022/2-2022/9

Loop test for installed BEC 2022/10

Long-term monitoring 2022/10-2022/12

Light-off test with PMT on 2023/4

Light-off test with PMT off 2023/6

2022

2023

Production of box 2021/9

Assembly BEC box 2021/10

Production and soldering of PCB 2021/5-2021/9

Two BECs for sPMT/LPMT test start work 2022/7

BEC installation in underground electronics room 2022/9

9

Test of the BEC

To check the physics chain of BEC, two test methods were presented

- BEC self-loop test

- Combine test of BEC and GCUs

BEC test item	self test	combine test	Trigger system(CTU-RMU-BEC-GCU)
Afterproduction	√		
after assembly	√		
BEC test in Kunshan	√	√	√
BEC self-test after installation in electronics room	√	—	—
BEC test with electronics system *	√	√	will be done

10

Combine test with GCU in Kunshan

40 GCUs with cables were connected to 1 BEC via an additional extension cable.

- By checking the idle packet on the slow control link, a partial check of the synchronous link can be performed.
- Each slow control packet has been coded with hamming coding. By checking the correctness of the hamming coding, we can detect the error in the link.
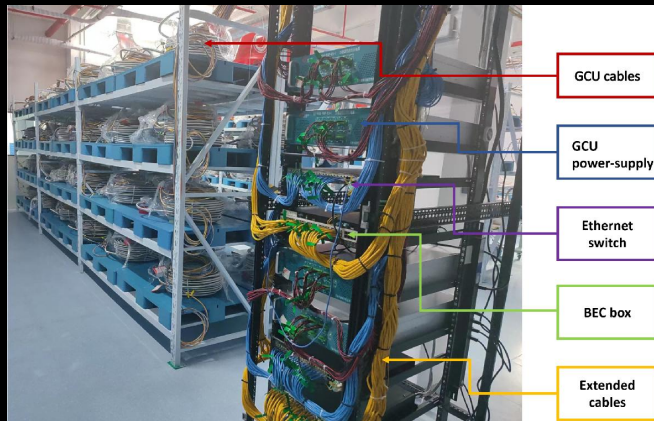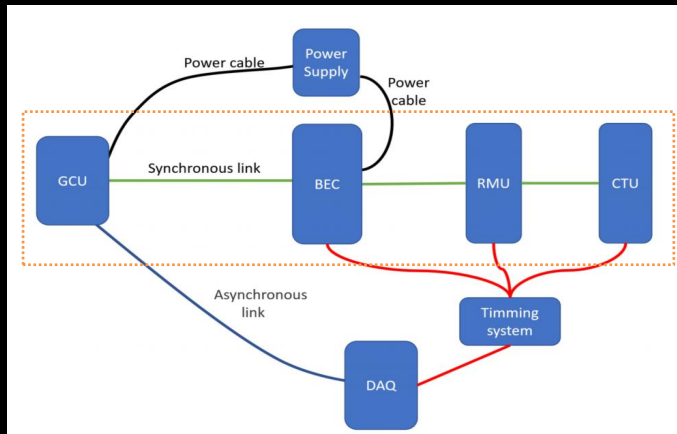
Combine test with GCU in Kunshan

176 BECs have been tested in Kunshan.

- One BEC are tesed for few times (test longer than 40 minutes are analyzed). In every run, if all runs of one channel stays with error, then this channel didn't pass.

Table 59: Table for BEC number 68.

- **Pass :** This channel pass the test.
- **Err :** This channel didn't pass the test and future investigation is needed.
- **4259:** TTC data are not available but temperature data are available.
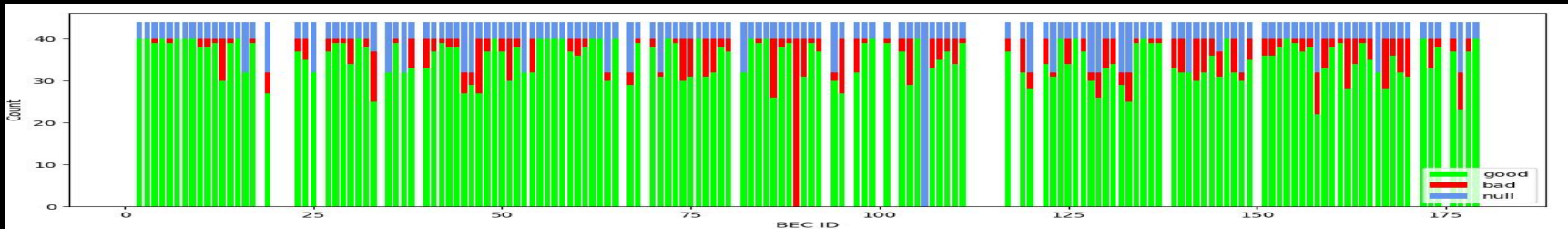
Self test (without extra cable)

The Pseudo Random Binary Sequence (PRBS) test is performed, while it is a standard feature to verify the link quality.

- Each port of the BEC is a sender and a receiver
- The FPGA on TTIM generates PRBS signal and also does the check.

Due to the tight schedule, less than 100 BECs were self-tested in Kunshan, but all the BECs used have been tested on site.
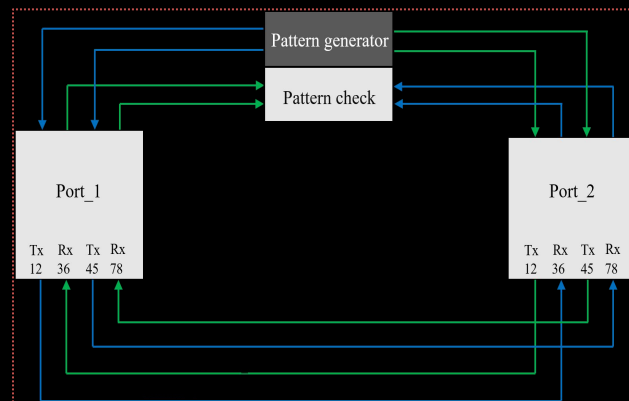
Self test result - short term

160+4 backup BECs have been installed on site, after a transportation of 1700km from Kunshan to Jiangmen and 1.3km from surface to underground , all installed BECs have been re-tested. Each test was carried out for 10min. Only 1/48 channel of one BEC didn't pass the test, that will not be used to connect any GCU.
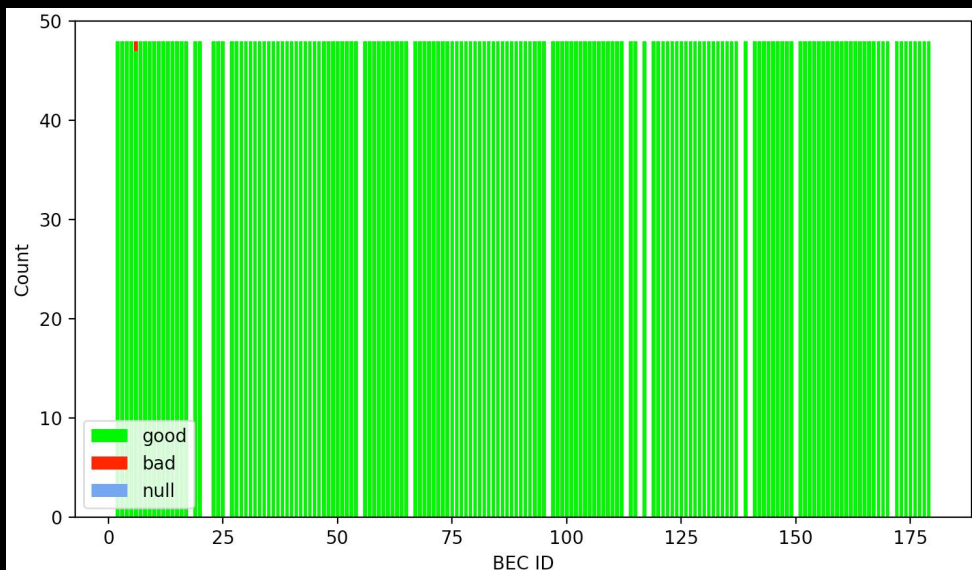
Self test result - long term

- A long-term monitoring of 97 BECs was conducted as well to check their longterm work status, with each run taking 48 hours and lasting a period of 1 month.

- The error was caused by environment noise. The worse error rate is 2.03e-12 smaller than the requirement* of 2.67e-11.

BEC-ID	time of 1st error happen	error rate
2 et .al	0 in 48h	4.63E-14
98 (7th,Nov)	6.38h	3.48E-13
132 (7th,Nov)	6.39h	3.48E-13
53 (19th,Nov)	1.46h	1.53E-12
137 (19th,Nov)	2.45h	9.08E-13
123 (19th,Nov)	3.72h	5.98E-13
123 (19th,Nov,2nd times)	1.09h	2.03E-12
123 (28th,Nov)	1.22h	1.82E-12

*calculated from the combine test time of BEC and GCU
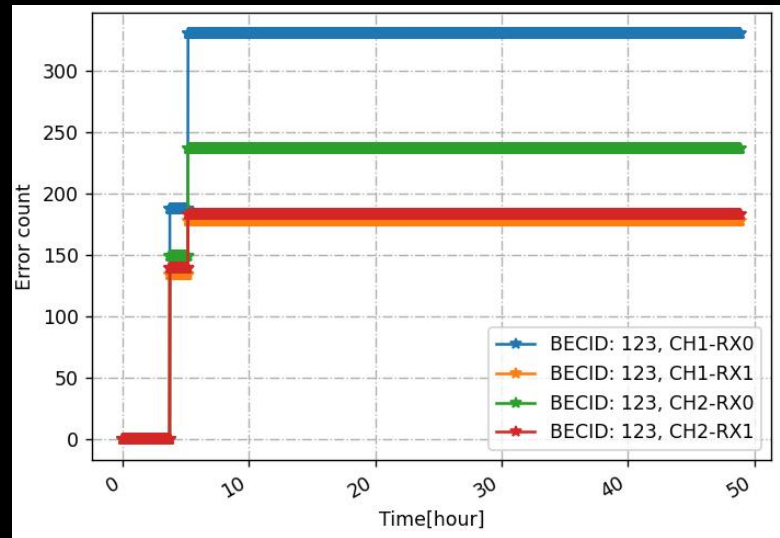
Part III: Current status of the BEC

BECs for JUNO CD

All 160+4 backup BEC have been installed in electronics rooms. After the partial installation of PMTs and UW boxes,

- A joint test with LPMT/sPMT + electronics + trigger + DAQ + DCS was performed using a BEC-level trigger in the detector commissioning, which provided a good result. All clock from BEC to GCU link worked well.
- The final test of the connection between GCU and BEC were successful.
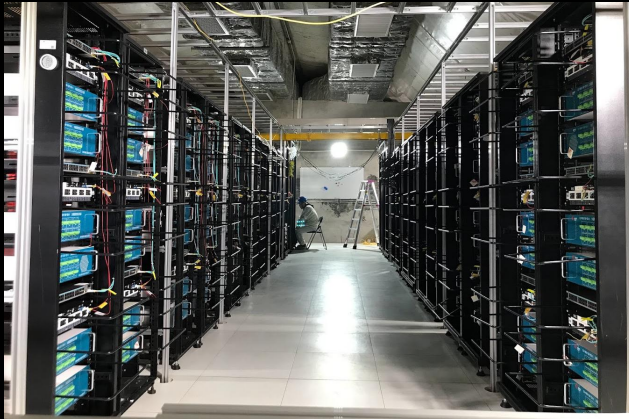
BEC for OSIRIS

BEC for OSIRIS (Online Scintillator Internal Radioactivity Investigation System)

- OSIRIS has almost same electronics as the JUNO detector
- BEC is the only trigger device.
- With 40-60Hz trigger rate, 27 GCU and the BEC are syncronized, no trigger lost using global trigger
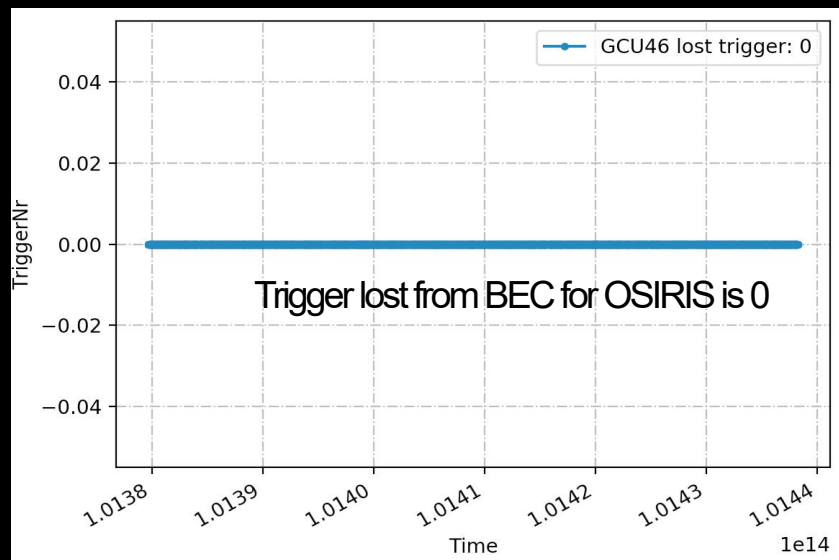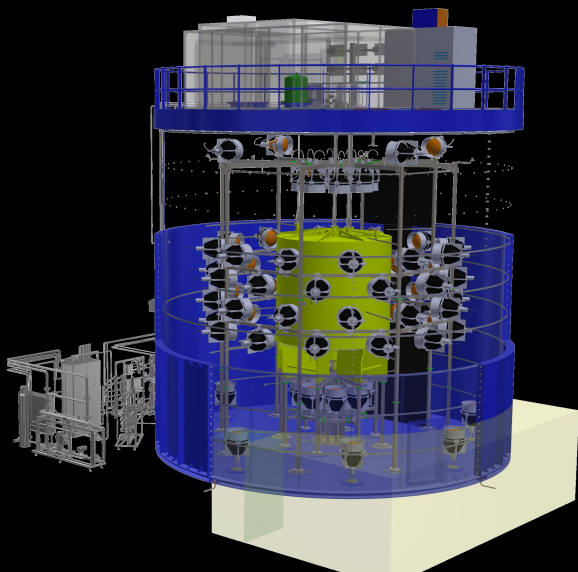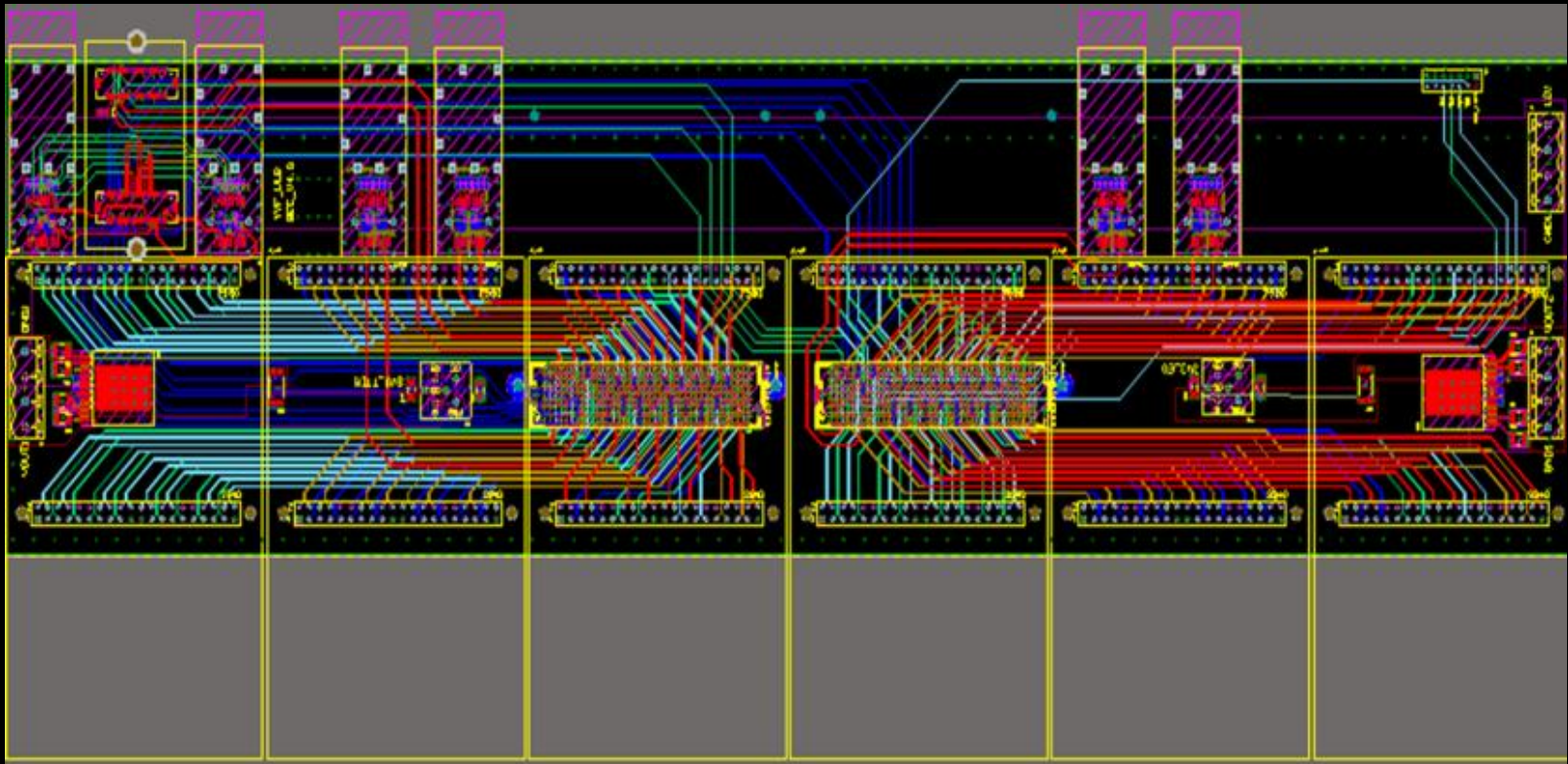
Summary

- 164 BECs have been installed and passed the self loop-tests at the JUNO site, the combined tests between BEC and GCU are undergoing. The final tests between installed GCUs and BECs show a good result.

- Part of the BEC has been used. It plays an important role in the commissioning of the whole detector.

- In OSIRIS, BEC is working and works well.

Thank you for your attention!

Backup

To GCU

From base4

To base4

- 103 cm × 63 cm
- 8 layers
- 32 differential pairs with impedance control
- All equalizer inputs route in stripline covered by solid GND and VCC
- Use multi-channel design for all the equalizers

- 100 cm × 383 cm, 10 layers
- Supply power to TTIM and mezzanine separately, 10 A each
- 192 differential pairs with impedance control
- Minimum space between differential pairs is 4.5 times larger than the pitch

Error capture

- Pink: original PRBS signal(delayed for 500 ns)
- Blue: received signal(before equalizer)
- Yellow: received signal(after equalizer)
- Green: error out from prbs checker

- Glitch observed on received signal both before and after equalizer

- No glitch on original signal

- This error was due to external noise coupled on the cable

24
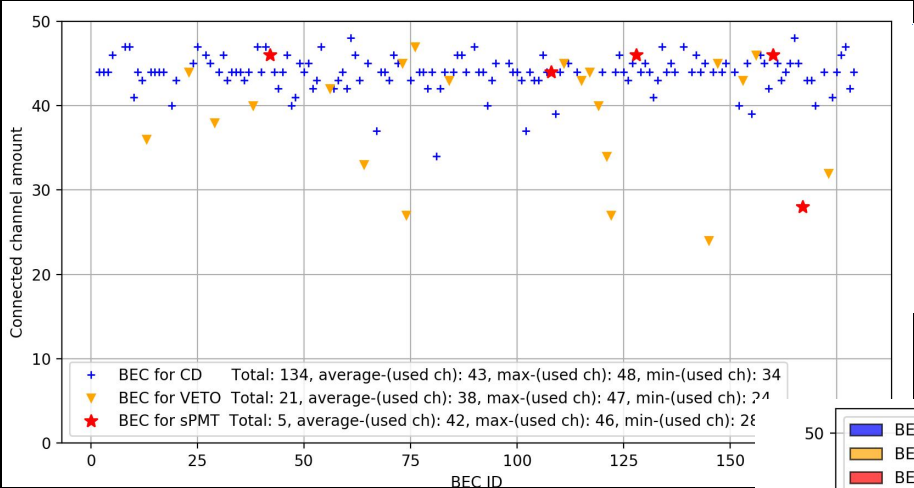
used channl	*Total BECs*	min	average	max
CD	*134*	34	43	48
Veto	*21*	24	38	47
sPMT	*5*	28	42	46