# Automatic test system of the back-end card for the JUNO experiment


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## Introduction

The Jiangmen Underground Neutrino Observatory (JUNO) is a neutrino medium baseline experiment in construction in China. The JUNO goals are to determine the neutrino mass hierarchy and perform precise measurements of several neutrino mass and mixing parameters [1].


Figure 1: JUNO site

The experiment uses a large liquid scintillator detector [2] aiming at measuring anti-neutrinos issued from nuclear reactors at a distance of 53 km. The neutrino detector consists of a large volume of liquid scintillator with a 20 kton fiducial mass, deployed in a laboratory 700 meters underground.

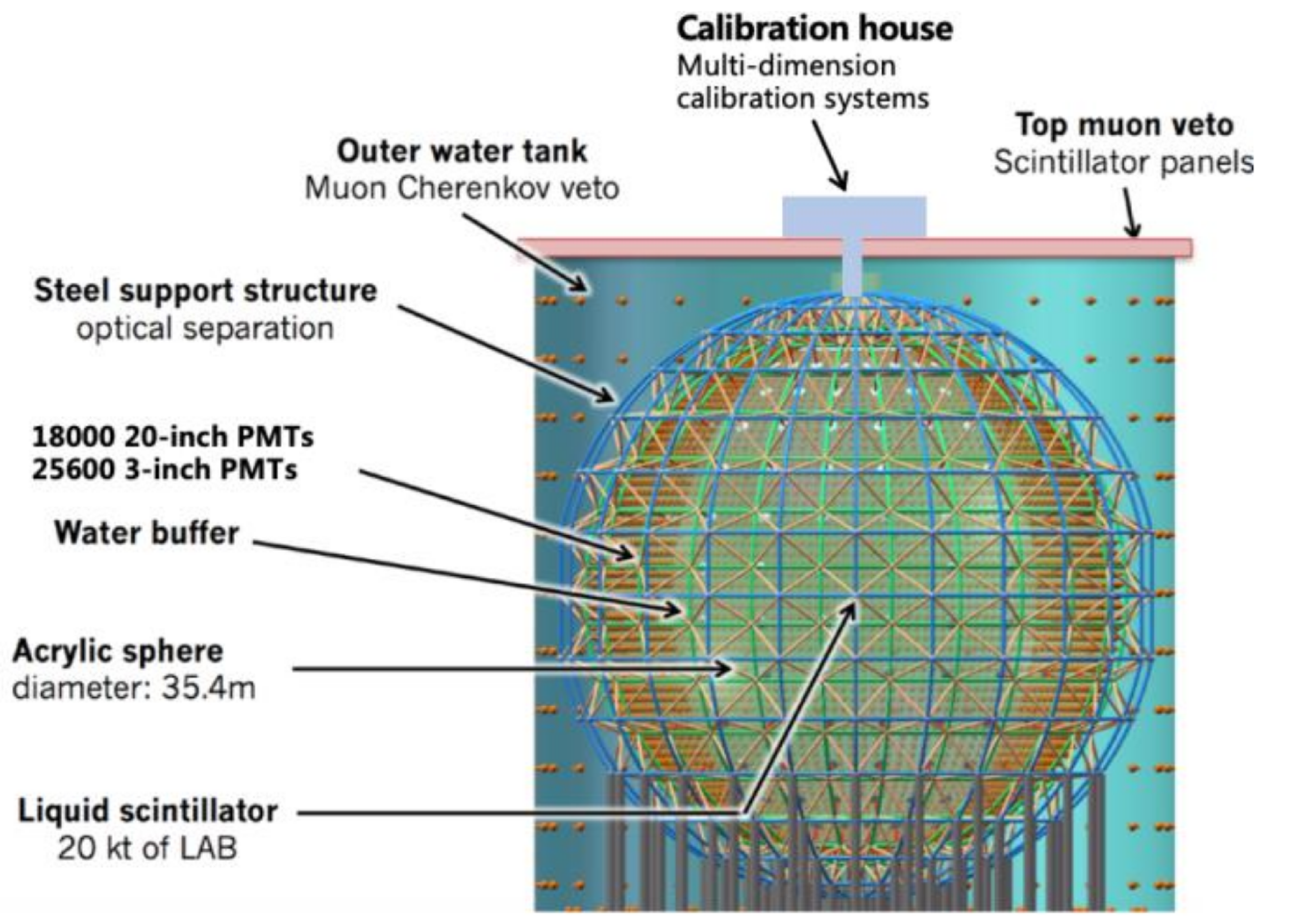


Figure 2: Schematic view of the detector

The JUNO readout electronics system will have to cope with signals of 18,000 photo-multiplier tubes (PMT) of the central detector, as well as 2,000 PMT installed in the surrounding water pool to detect the Cherenkov light from muons. To avoid signal loss due to long distance transmission, most parts of the electronics system will be located in the water, close to the detector body.

## JUNO electronics system

The JUNO electronics system can be separated into mainly two parts [3]:

1. the front-end electronics system performing analog signal processing (the underwater electronics), and after about 100 m cables,
2. the back-end electronics system, sitting outside water, consisting of the DAQ and the trigger.

Besides, power supply needs also to be delivered to underwater electronics from outside water. Figure 3 shows the scheme used for the JUNO trigger. Three PMT are connected to a Global Control Unit (GCU) through waterproof coaxial cable. The links for the data exchange between underwater electronics and back-end electronics are performed through Ethernet cables.

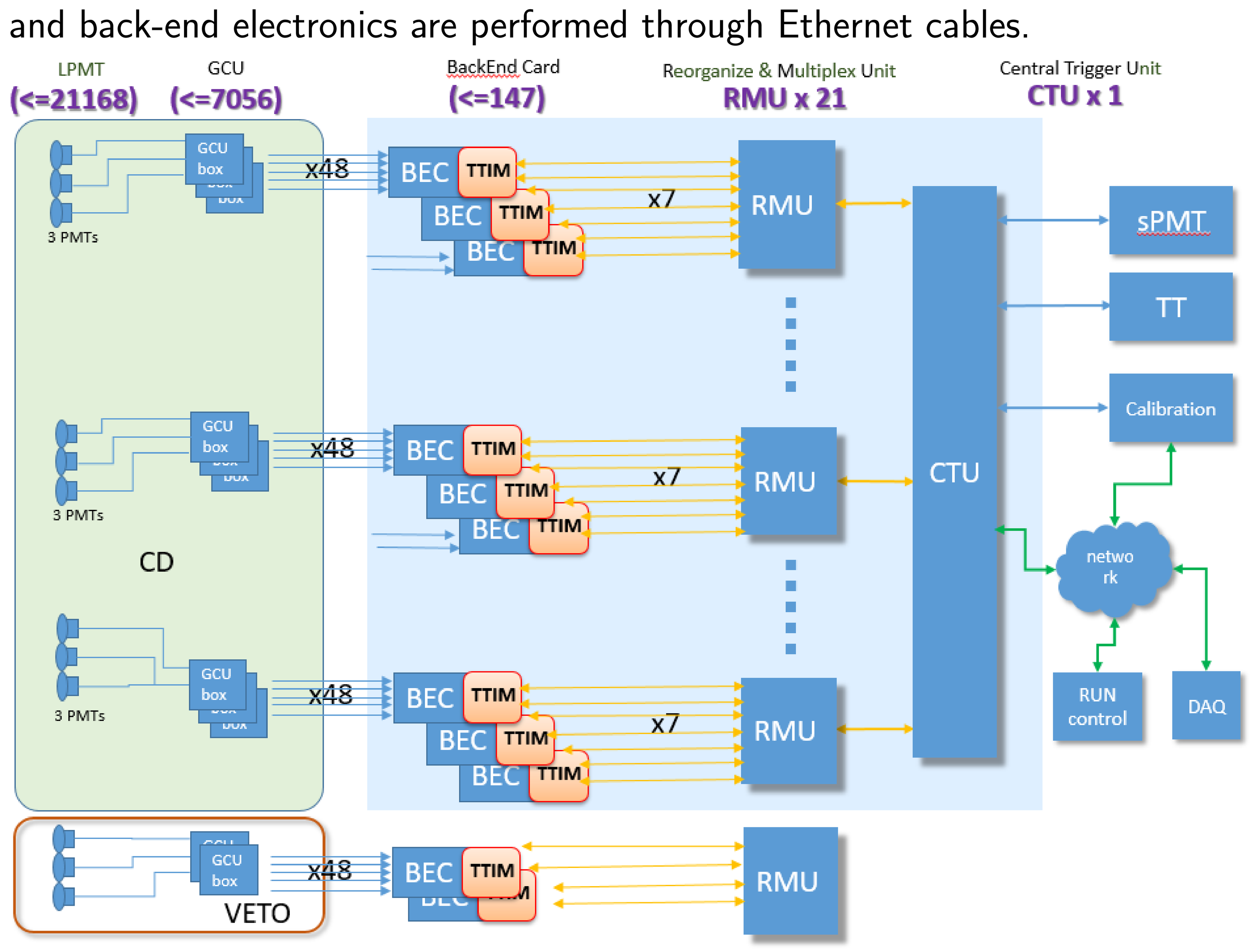


Figure 3: Schematic view of the JUNO trigger system

For the connection between the GCU and the back-end card (BEC), all the pairs of the cable are used. Table 1 resumes the BEC-GCU link. The 2 pairs out of 4 inside the Ethernet cable are used to transfer data from BEC to GCU (trigger and clock running at 125 Mbps and 62.5 MHz). The other 2 pairs are used to send data from the GCU to the BEC.

| 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 |

Table 1: Connection table of the BEC-GCU link

## Back-end electronics

Figure 4 shows the Trigger and Timing (TTIM) FMC mezzanine card (blue box) and the BEC. It connects the BEC to the trigger system. The BEC V4 is composed of 6 mezzanine cards (green box) and one baseboard (red box). We have chosen this design for different reasons:

- We chose small PCB card to have more mechanical robustness and ensure a better distribution of the power to the components.
- The mezzanines are plugged to the baseboard. So we have more flexibility to replace a defect one without changing all the BEC.
- We added different types of protections for each signal as well as power supply.

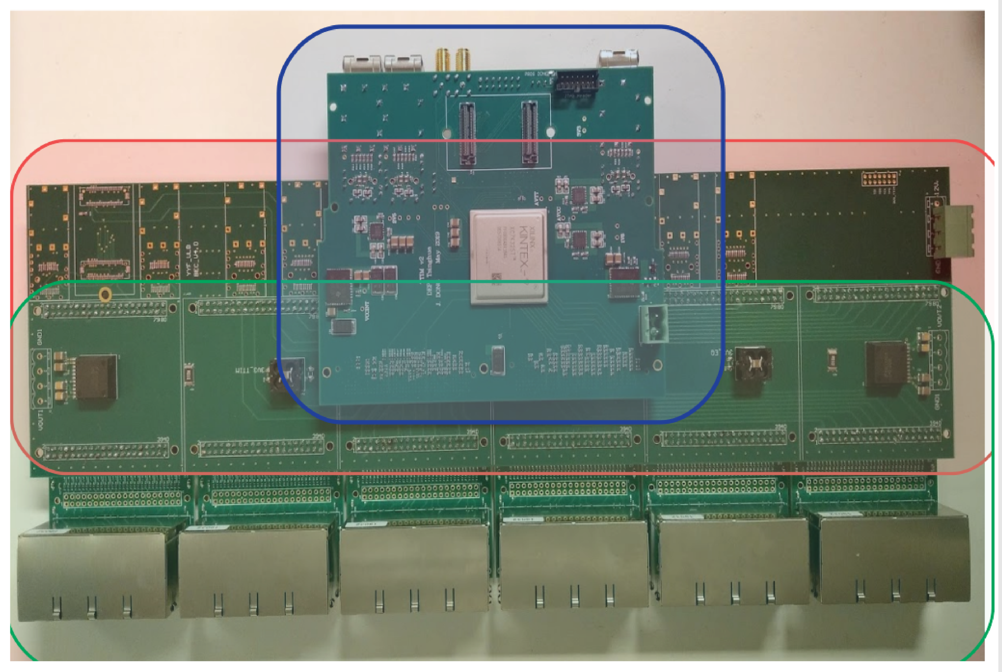

Figure 4: Picture of the back-end card version 4

Each mezzanine receives 8 Ethernet cables. One BEC receives maximum 48 Ethernet cables from 48 underwater boxes, corresponding to the signals of 144 PMT. At the moment only 44 ports will be used whole 4 will be left as spare. As we need to have some spare ports on the BEC, the actual BEC number planned to be built and tested is 154.

## Test

The current test for the BEC is a loop test. We connect one port of the BEC to another through a Ethernet cable with different lengths. We use the TTIM FPGA as PRBS generator and send the signal trough the cable. Figure 5 shows the actual set-up. The BEC is powered by a redundant power module (R-PM in green) connected to the ATX power supply (ATX-PS in blue) and a programmable power supply (P-PS in red). To count the error we use the PRBS checker inside the FPGA. Then we read out the data from FPGA ILA and write it in a TXT file with a custom designed TCL code.

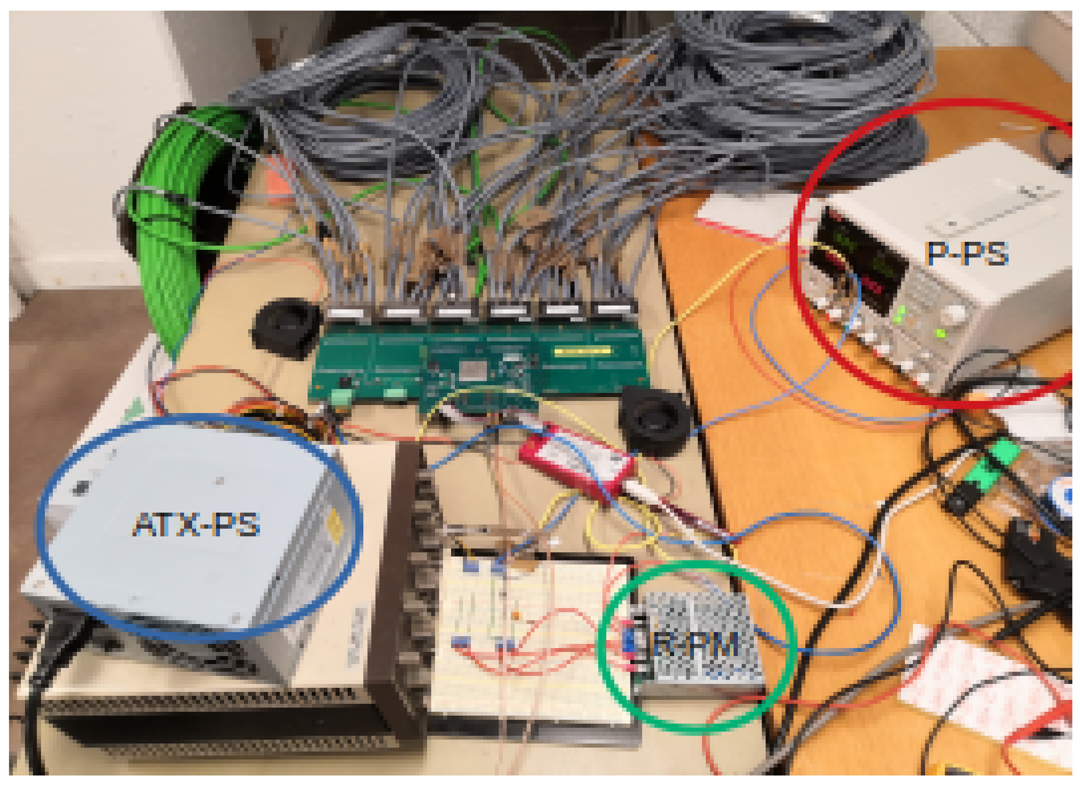


Figure 5: Set-up for the long-term test

Figure 6 shows the results for 48 channels for 28 days. The upper-left panel shows the results for the 41 channels that have no error for 28 days of running. The different colors correspond to different cables: dark blue is for 10 m CAT5E cables, light blue for 100 m CAT5 E cables and green is for CAT6 cables. We have 7 channels with errors (channel numbers 11,17,22,24,26,28,38). On top right panel we represented the channel number 26. Errors are appearing at different specific time, so the number of error is increasing with the time. To debug this error we have changed the cable and no more error was seen. The two lower panels show some examples of the 6 other channels where errors occur. For those channels error occurred only at a specific time. This type of error comes from an external noise.

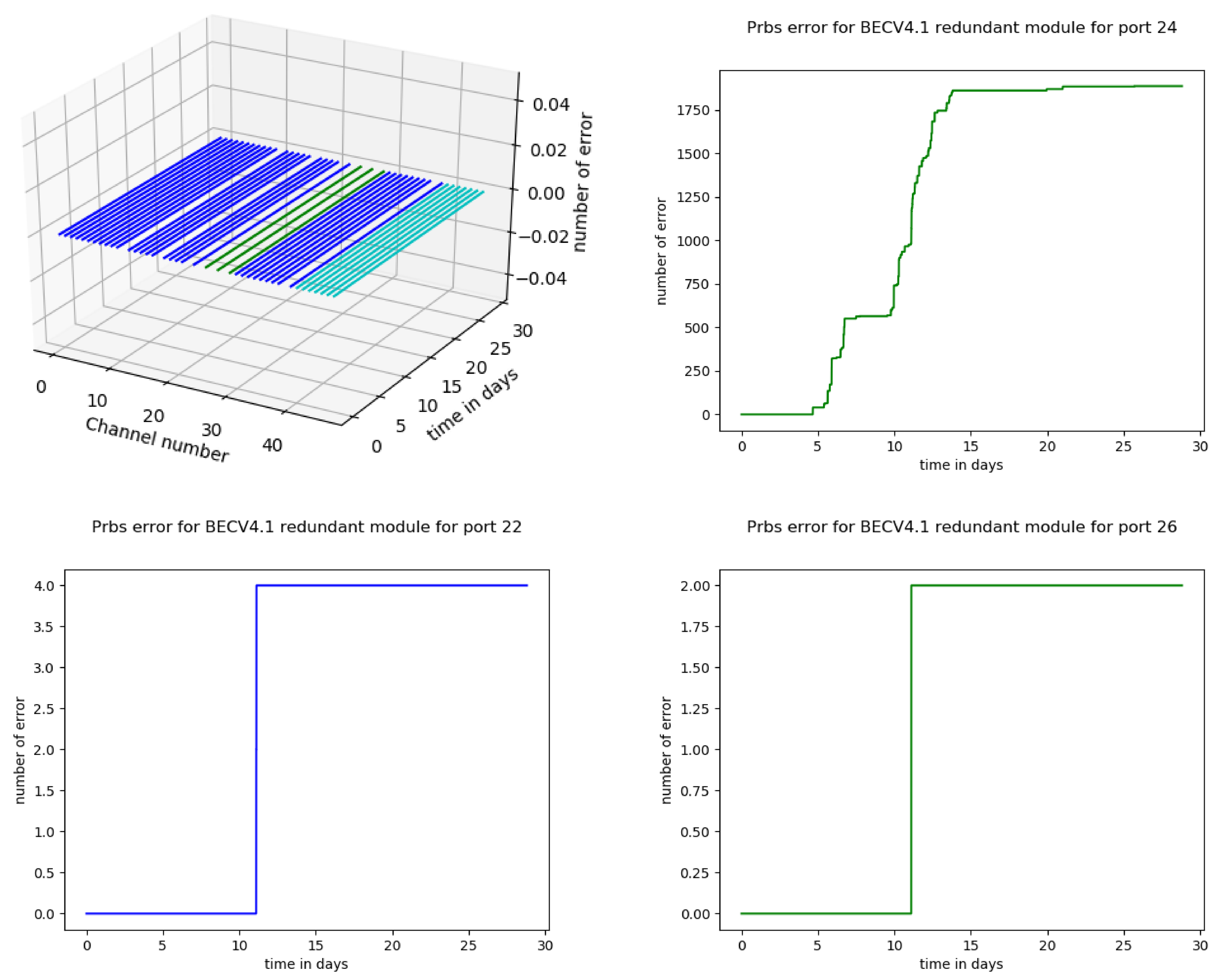


Figure 6: Test results for 28 days

## Conclusion and future plan

The current set-up is easy to operate and can be used for mass production test. A future work is to redo the tests with a better time resolution. To achieve this, we have as plan to use IPbus based firmware and Python scripts. Finally, we will redo the test on a set-up that includes the complete trigger chain.

## References


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