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The JUNO experiment and its readout electronics system

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The main goal of the Jiangmen Underground Neutrino Observatory (JUNO) under construction in China is to determine the neutrino mass hierarchy. The detector consists of 20 ktons of liquid scintillator instrumented by 17612 20-inch photomultiplier tubes, and 25600 3-inch small PMTs, with photocathode coverage of 77%. The electronics system is separated into two main parts. The front-end system, sitting under water, performs analog signal processing. The backend electronics system, sitting outside water, consists of the DAQ and the trigger. The design of the electronics system as well as the current production status will be reported in the presentation.

Summary (500 words)

The Jiangmen Underground Neutrino Observatory (JUNO) is a neutrino medium baseline experiment in construction in China. This experiment will look for neutrino mass ordering (NMO) and neutrinos from a wide variety of natural sources. The JUNO detector consists of 20 ktons of liquid scintillator contained in a 35 m diameter acrylic sphere, instrumented by 17612 20-inch photomultiplier tubes (PMTs), and 25600 3-inch small PMTs, accounting for a total photocathode coverage of about 77%. The required energy resolution to measure the NMO at a 3-4 sigma in about 6 years of data taking is of 3% at energy of 1 MeV.

JUNO's physics goals place stringent requirements on the electronics: an excellent photon's arrival time measurement for good vertex reconstruction, large dynamic range, and negligible dead time. The following specifications have been defined: to provide a full waveform digitization with a high speed, and a high resolution on the full dynamic range. The main risk concerns the reliability of the underwater electronics, which will not be accessible after the installation. The reliability requirement is to have less than 1% PMT and underwater electronics failure over 6 years.

The JUNO electronics system is separated into two main parts: underwater and outside water, which are connected through 100-meter Ethernet cables and power cables. The first contains the PMTs, the second hosts the backend electronic cards (BECs) and consists of the DAQ and the trigger. This scheme was adopted to get very precise PMT signal measurement required by JUNO's physics goals, but it poses strong requirements on electronics reliability.

First, the analog signals from the PMTs are processed and digitized by frontend electronics located underwater and protected by stainless-steel boxes. For large PMTs, three of them are connected to one Global Control Units (GCUs) which power the PMT and digitize the digitize the signal. This set-up is chosen to optimize the ratio between power consumption and reliability. Then, the digitized signal is processed by FPGA. The digital signal and the trigger information are forwarded to the dry electronics through 100 m Ethernet cables chosen over optical fibers for their price and reliability.

At this point, the signal reaches the back-end electronics, where the BECs collect and equalize the incoming trigger request signals, which are handled by FPGA mezzanine card. Each BEC receives 48 Ethernet cables from the 48 underwater boxes and distributes the clock signal to the GCU's. The signals from the various BECs are sent to 21 RMU (Reorganize & Multiplex Unit) cards and then send to the central trigger unit.

The electronics for small PMT is a bit different. On the underwater side, they are grouped by 128 over an underwater junction box where all the front-end electronics belongs. The readout and digitization of the 128 channels will be operated by single electronics board called ABC board. The small PMT share the design of large PMT for back-end electronics.

The talk will describe the full electronics system which has been developed for JUNO and will give an update on the production state.

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