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Status and perspectives of large PMT electronics of the JUNO experiment

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Summary. — In this work, after a brief introduction on the JUNO experiment, the requirements of the JUNO electronics will be pointed out. To fulfill all the requirements a new scheme, called 1F3, for the JUNO electronics was proposed on July 2017. In the 1F3 scheme the voltage divider will be directly connected and potted with the PMT. The signal, coming from the base, will be connected to an electronics underwater box in which there will be the HV voltage supply units and the processing electronics. The current status of all the JUNO electronics boards (GCU, ADU, power board, HV units and BEC) will be described.

1. – The JUNO experiment

The JUNO (Jiangmen Underground Neutrino Observatory) experiments is the reactor neutrino experiment under construction in the South of China [1, 2] and it is placed at around 53 km from two different nuclear power plants. Its aim is the neutrino mass hierarchy determination. Furthermore, with the JUNO experiment, some neutrino oscillation parameters (such as $\sin^2(\theta_{12})$, Δm^2_{12} and Δm^2_{ee}) can be measured with a precision better than 1%. The JUNO detector has to have a large active mass, for this reason 20 kton of LAB liquid scintillator inside a sphere of 35 m of diameter will be used. Moreover, to achieve the neutrino mass hierarchy determination an excellent energy resolution is also required. The energy resolution of 3% at 1 MeV is foreseen due to a high light yield (1200 p.e./MeV) and a high optical cover (78% provided by two independent PMT (PhotoMultiplier Tube) systems). The JUNO detector will be composed by the central detector (the sphere with the liquid scintillator), the top tracker, the water pool to be used as Cherenkov veto detector. To collect the scintillation light two independent PMT systems are foreseen: the first one composed of 20000 large PMTs (20″ in diameter, optical coverage around 70%) and the second one composed of 25000 small PMT (3″ in diameter, optical coverage around 3%).

2. – The 1F3 scheme of JUNO electronics

In this work the readout electronics for the large PMTs of the JUNO experiment will be described. The requirement (sect. **2**˙1) and the new electronics scheme status (sect. **2**˙2) for the electronics will be explained.

2˙1. *The requirements of the JUNO electronics.* – The JUNO experiment electronics will not be accessible after the installation; for this reason it has to fulfill a lot of requirements. The large PMT will be underwater in the Cherenkov pool and to improve the signal-to-noise ratio, the digitizer has to be placed as near as possible to the PMT, so also the electronics will be underwater. The cost and the dissipated power per channel (the maximum power per channel has to be 10 W) has to be minimized due to the fact that the channel will be 20000 and the dissipated power can increase the water temperature a lot. The number of waterproof cables and connectors has to be minimized, to improve the reliability of the system. The reliability is, in fact, a crucial parameter for the electronics, because we would like to have less than 0.5% channels broken in 6 years. Moreover, the dimension of the electronics boards has to be small because they has to be placed in an underwater box undergone to a pressure of 0.5 MPa. Last but not least, to preserve the PMT signal characteristics fast digitizers (1 GS/s) with a good resolution (14 bit) are necessary to disentangle a small signal (0.1 p.e.) to the noise.

2˙2. *The JUNO electronics status.* – To fulfill all the requirements, the electronics scheme was changed from the so-called BX scheme to the 1F3 scheme. In the BX scheme there was an electronics channel for each PMT directly potted at the base of PMT, but the reliability and the dissipated power requirements were not respected. In the new 1F3 scheme the signals of three PMTs are brought, using a cable of 1.5 m, to an underwater box in which there is one electronics channel, as shown in fig. 1. In the underwater box there are 3 HV supply units, a board, called GCU (Global Control Units), for the distribution of the power, the signal processing and peripheral control and 3 boards with the ADCs (analog-to-digital converter). In the 1F3 scheme only the voltage divider is directly potted on the PMT. To bring the signal out of the water, two ethernet cables

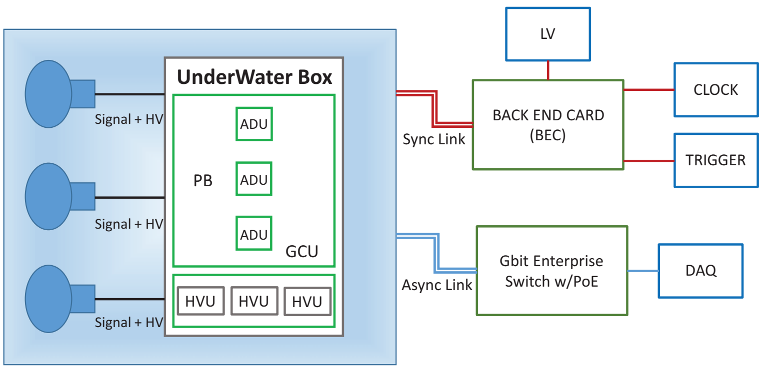

Fig. 1. – The 1F3 scheme of the JUNO electronics is shown. On the left there are three PMTs connected to the underwater box in which the electronics is placed. Inside the underwater box there are three HVUs and the GCU with the power part and the three ADU boards. The signal is brought out of the water through two ethernet cables, one from the synchronous part to the BCE board and the other one for the asynchronous part connected to an enterprise switch.

will be used: one for the asynchronous transmission (data and Power over Ethernet PoE) and the other one for the synchronous transmission (clock and trigger signal). The two cables will be connected to a back end card that is connected with the trigger system of the JUNO experiment.

The HV supply unit principal characteristics are i) positive polarity, ii) working range 1500 V–3000 V, iii) variation on the high voltage value of 0.5 V, iv) ripple of 0.11 V peak to peak, v) stability of 0.05%, vi) the maximum current id 300 μA. The HV supply unit will be remote controlled by RS485. The pre-production tests are ongoing and there will be a mass production soon.

The GCU is the intelligence of the electronics, it accommodates two FPGAs, one for the main function of the board and one to be able to reprogram the main FPGA from the outside. On the GCU there will be the power distribution part from the 48 V coming from the PoE to all the other values necessary for the other components. All the power lines have the following characteristics: i) they are controlled in a independent way, ii) they have a threshold both on the higher and the lower value of voltage, iii) they have a limitation and a block in current. There will be, on the GCU, also the space to include three ADU (analog to digital unit) boards using the castellated edge technique. The design, the routing and the integrity simulation were finished and the first prototypes are in the production phase.

The ADU is composed by a front end chip, trans-impedance amplifier, two ADCs developed in Tsinghua university, phase-locked loop and other support components. The prototypes of the new ADU board for the 1F3 scheme were produced and are under test. The BEC is used to bring the reference clock signal to the GCU and to communicate to GCU and trigger system. The BEC receives the signal from 48 PMTs. The new version of the BEC is now under test.

3. – Conclusions

The JUNO electronics scheme was change to 1F3 to fulfill the requirements, such as high reliability, low cost, low power dissipation. In the 1F3 scheme the voltage divider is directly connected and potted to the PMT, while the signals of 3 PMTs are brought by a 1.5 m cable to the underwater box in which an electronics channel is placed for the 3 signals processing. The new scheme and all the boards that will be in the underwater box were explained in detail and the actual status of each board was discussed. Some of the boards are in the prototypal production phase, others in the testing phase and others in pre-mass production testing phase. The mass production of the JUNO experiment electronics is foreseen in 2019.

The verification that the 1F3 electronics scheme fulfills all the requirements is ongoing but it can be completely verified when all the boards will be completely tested.

REFERENCES

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