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The distributed RPC read-out system for the ARGO-YBJ experiment

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Abstract. ARGO-YBJ is a full coverage layer of Resistive Plate Counters (RPCs) covering an area of about 5.800 m^2 to be installed at the YangBaJing Laboratory (Tibet, China) at 4.300 m a.s.l. The DAQ system is based on a Central Station which receives the detector information from distributed readout electronics (Local Station). Each Local Station reads out and digitizes the space and time information from 120 pick-up pads of 12 RPCs and gives out the pad multiplicity for trigger purposes. On trigger occurrence, each Local Station sends the collected data to the Central Station. Both the detector and the electronics allow 1 ns accuracy in time measurements. In this work a detailed description of the Local Station and its performance are presented.

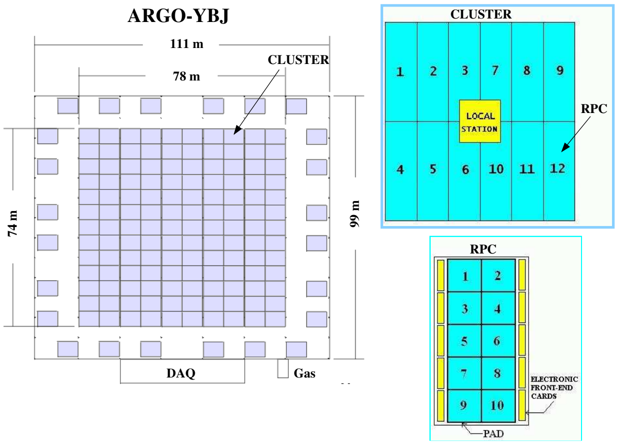

Fig. 1. Schematic view of the ARGO-YBJ detector

1 Introduction

The ARGO-YBJ experiment (Astrophysical Radiation Ground based Observatory at YangBaJing) is under construction at the YangBaJing High Altitude Cosmic Ray Laboratory (4300 m a.s.l. equivalent to 606 g/cm^2) 90 Km North to Lhasa (Tibet, China). This experiment will be devoted to a wide range of fundamental issues in cosmic ray and astroparticle physics, including γ-ray astronomy and γ-ray burst physics at energies $\geq 100\,GeV$ (Abbrescia, 1996).

The apparatus consists of a full coverage array of $74 \times 78\ m^2$ dimension which is realized with a single layer of RPCs (Resistive Plate Counters), $280 \times 125\ cm^2$ each. The area surrounding the central detector core, up to $\sim 100 \times 100\ m^2$ (see figure 1), is only partially instrumented with RPCs. This outer ring improves the apparatus performance, enlarging the fiducial area for the detection of showers with the core outside the full coverage carpet.

A 0.5 cm thick lead converter will cover uniformly the RPCs plane. In this way the number of charged particles will be increased by conversion of shower photons, thus lowering the energy threshold and reducing the particle time fluctuation on the shower front.

The basic element providing the time pattern of the shower is the logic PAD. It is defined as the fast-OR of 8 strips used to pick up the signals from the RPCs (Iacovacci, 2000). These logic PADs ($56 \times 62\ cm^2$) define the time granularity of the detector (there are 15600 PADs in the carpet, 10 for each RPC); the space granularity is defined by the strips (124800 in the carpet).

From the data acquisition point of view, the basic detection unit is the *cluster*, a set of 12 contiguous RPCs (see figure 1), which corresponds to the LOCAL STATION (LS) in the DAQ design. The Local Station provides the local pad multiplicity for trigger purposes and the event space-time information to the CENTRAL STATION (CS).

2 Detector

One of the innovative aspects introduced by ARGO is the use of RPCs. These gaseous detectors have a wide use in elementary particle physics. Their good time resolution, low

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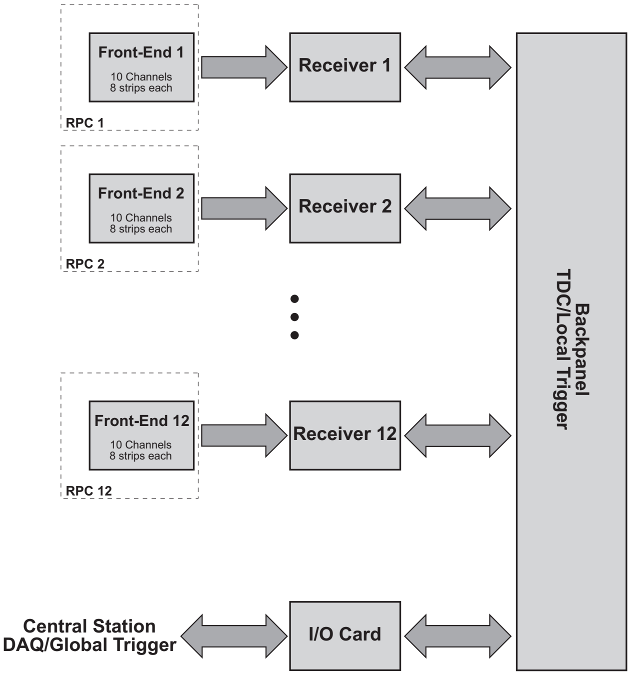

Fig. 2. Local Station schematic

cost and possibility to group them in a compact structure, make them extremely competitive to build a full coverage carpet for studing the EASs (Extensive Air Showers). The RPCs will operate in streamer mode. This mode delivers large amplitude saturated signals and it is less sensitive than the avalanche or proportional mode to electromagnetic noise, to changes in the environment conditions and to mechanical deformations of the detector. In 1998 a full coverage carpet of $\sim 50\,m^2$ has been put in operation in the YangBaJing Laboratory in order to investigate both the RPCs performance at 4300 m a.s.l. and the capability of the detector to sample the shower front of atmospheric cascades (Bacci, 2000).

The signal pick-up consists of strips $6.7\,cm$ wide and $62\,cm$ long glued on one side of $4\,mm$ thick foam sheet. On the opposite side of the foam sheet an aluminum ground plane shields the strips from the external noise. The separation between two adjacent strips is $3.0\,mm$. The strips are logically organized in pads of $56 \times 62cm^2$ area. The strips are connected to an 8 channel front-end electronic board. According to the pad geometry, the resulting strip-line impedance is about 25 Ω.

The front-end electronics is based on an 8-channel discriminator chip which is mounted on boards fixed at the edge of the readout panel (ATLAS, 1997). The length of the boards is tuned with the width of the strips so that each board input is essentially in contact with the corresponding strip and no wires are required. The input-to-output delay is the same for all the eight channels. Each channel consists of a voltage amplifier connected to a variable-threshold comparator. The circuit is implemented in a VLSI chip in GaAs technology. The amplifier frequency response is optimized for the typical time structure of the RPC avalanche signal. The amplifier output is bipolar, thus avoiding a possible dependence of the steady output voltage on the counting rate. The resulting frequency response has a maximum at 100 MHz and a 3dB bandwidth of 160 MHz. This chip has been successfully tested on board and also mounted on the detector for cosmic ray tests (Aielli, 1998).

3 Local Station

The digital signals originating from front-end elecronics are sent to receiver cards housed inside the Local Station crate.

Each receiver card collects the signals coming from 10 front-end cards and produces an output (FAST-OR) for each hit pad. FAST-OR signals are sent to TDCs and trigger logic both for time measurements and trigger definition (see fig. 2).

All the electronic Local Station modules are housed in a 9U 16 inch standard crate (see fig.3). The crate contains twelve RECEIVER cards (one for each CLUSTER RPC), one IN/OUT card for the data communication with the Central Station, one active BACKPLANE where each card is inserted and the TDCs and the local trigger circuitery are located, two low voltage power supply and one fan unit. The Central Station receives Local Station pad multiplicity information for trigger purposes; when the trigger conditions are satisfied, a Common Stop signal is generated and distributed on fast cables to each Local Station to store the data. Once the Common Stop is received, data are sent to the Central Station for the successive disk storage. Due to the TDC features (Passaseo, 1995) the convertion time is zero and the total acquisition dead time, caused by the transmission time, depends only from the event size. Data are transferred at a rate of 200 $Mbit/s$ (16 bit word in 80 ns) on a 75 m long copper cable.

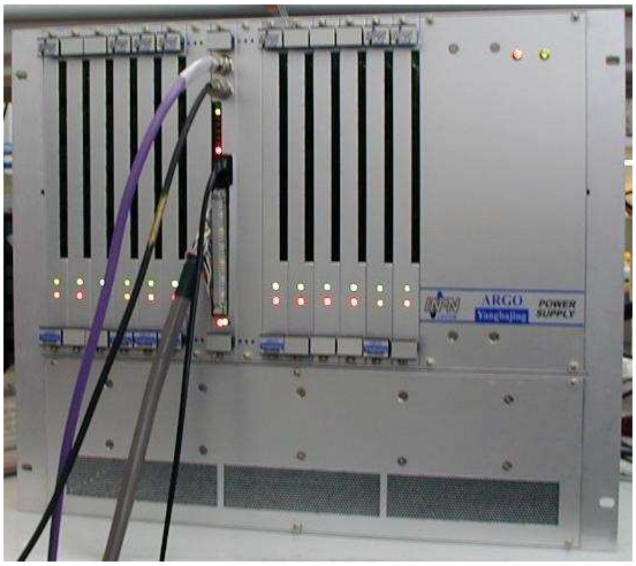

Fig. 3. Local Station

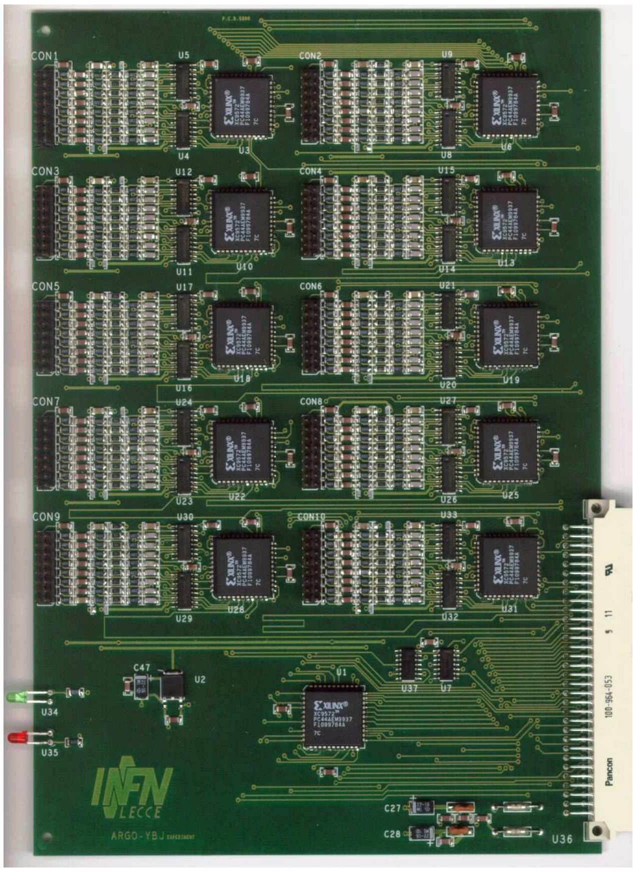

Fig. 4. The Receiver card

3.1 Receiver Card

The Receiver card, which reads data from one RPC, is a standard double Euro Card (see fig. 4). This card is logically divided into 2 sections: One contains the formation circuitery and logic, and the other is devoted to the communication with the backplane. In the first section, the ECL digital signals from each FRONT-END card are converted in 50 ns TTL signals.

These signals are applied to the 10 acquisition PLDs (one for each pad) which make the logic OR (FAST-OR). These FAST-OR, stretched to 120 ns, are sent to both the TDCs and the local trigger logic on the backplane. Each channel could be masked for killing bad channels purposes.

3.2 Backplane

The active backplane collects all the Local Station electronic RECEIVER cards and it can be physically divided in three sections (see fig. 5). The first section contains only the 15 connectors for the various Local Station cards (12 receivers, one In/Out card and two free slots for future purposes). In the second section 4 TDCs are grouped to collect the fast-or signals from the receiver cards for the relative time measurement. In the third section, 5 FPGAs define the local trigger information by calculating the hit pad multiplicity. An additional FPGA manages all the described operations.

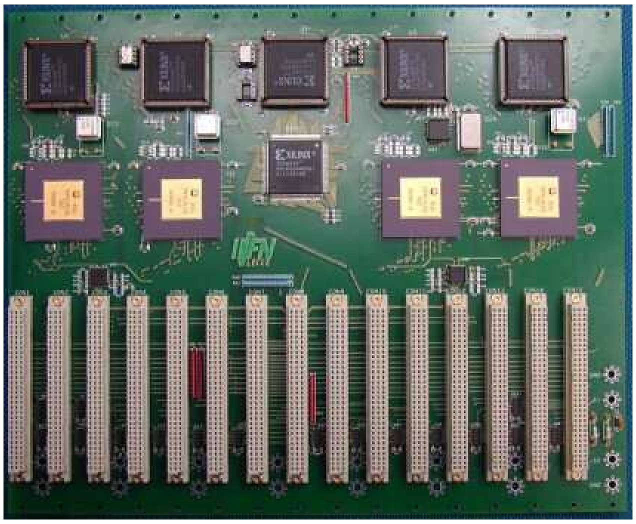

Fig. 5. The Backplane

The signals coming from the receiver cards are split in two ways: one way goes to the TDCs that store the data and start counting until the Common Stop from the central trigger arrives or 2μs elapse, the other one goes to the local trigger section where the actual mutiplicity is calculated and sent to the central trigger module.

3.3 In/Out Card

The IN/OUT card is devoted to the communication between the Local Station and the Central Station (see fig.6). This card is inserted in the central slot of the backplane. Three different kinds of lines are used for several purposes. Two 75 Ω shielded coaxial lines receive the distributed Common Stop and test signals with high precision.

Two 4 channel telephonic cables are used to receive and retransmit in a daisy chain data for initialization, such as bad channel kill mask, reset mask, etc. Finally 32 twisted pair channels are used to transmit data to the Central Station, and to receive the reset signal and another test signal.

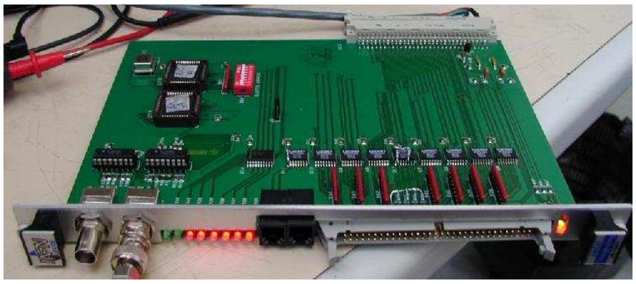

Fig. 6. in-out card

4 Conclusions

The distributed read-out system for ARGO-YBJ, a large cosmic ray detector has been described. It is made by a large number of Local Stations for the front-end readout, local pad multiplicity definition and data collection. Such information is sent to the Central Station for global trigger definition and data storage. An overall accuracy of 1 ns in time resolution has been achieved. This precision is fundamental to get a sufficient angular accuracy for physical goals. Design and prototyping of all the Loca Station components have been completed. At present, all the electronic boards are under contruction to istrument 40 CLUSTERs at the end of 2001. The first data taking has been planned by the spring of 2002.

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