# The architecture of DAQ system for the ARGO-YBJ experiment

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**Abstract:** The ARGO-YBJ experiment has now reached its final design configuration. The detector system consists of a full coverage array (about 6700 square meters) of Resistive Plate Chambers (RPCs). At the nominal threshold the system must be able to sustain a maximum transfer rate of the order of 15 Mbyte/s and an high peak data flow. Data are read out using a typical front-end acquisistion chain built around a custom bus. Specialized electronics have been designed and efficent software has been written to perform this task. In this paper we describe the architecture of the daq system of the Argo-YBJ experiment and its performances.

## Introduction

The Argo-YBJ experiment is a collaboration between Chinese and Italian groups. The apparatus is located at Yangbajing (Tibet, P.R. China) at 4300 meters above the sea level, about 90 km from Lhasa.

With Argo-YBJ detector it's possible to investigate many issues in gamma-astronomy and cosmic ray physics over a large energy range, owing to its ability to operate down to a few hundreds of GeV up to the PeV [1].
The telescope is optimized for the detection of small size air showers to study gamma-ray from galactic and extra-galactic sources. It monitors the northern hemisphere in the declination band $-10° < \theta < 70°$.

The apparatus consists of an array of dimension 74 x 78 $m^2$, with an active area of about 92%, made of a single layer of Resistive Plate Chambers (RPCs) operating in streamer mode, surrounded by a guard ring which extends the coverage to an area of up to 99 x 111 $m^2$.

The digital read-out of the RPC saturates when the energies reach a few hundreds of TeV. In order to extend the dynamic range, a charge read-out has been implemented.

The data acquisition system was designed to efficiently handle such event rates, and to combine the tasks of data logging with those of data quality control.
The DAQ system was designed to sustain a maximum trigger rate of about 10 kHz corresponding to 20 MB/s of throughput from the Front-End Electronics (FEE) to the online farm system.

## Daq System

### Daq requirements

The DAQ system requirements strongly depend on the trigger selection and shower topology. Our main interest is in $\gamma$ showers at low energies that can be triggered imposing a small threshold on the number of pads firing on the entire carpet [2]. The DAQ System must be able to: manage a trigger rate of the order of 10 kHz; collect a large number of sub-frames from the front-end channels spread around the entire detector, each one spanning an extremely wide range of event sizes from a few bytes to many hundreds of kbyte; sustain an average data transfer rate estimated to be of the order of 20 MB/s for the full instrumented detector (all the digital and analogic read-out); acquire data with a few percent of dead time. These estimates have been evaluated by Monte Carlo simulations and extrapolating from measurements done on the apparatus at several stages during its construction [3]. Moreover the design of the system should allow for easy scalability.

## Daq Architecture

The DAQ system (the front-end and the trigger electronics) permits currently to acquire data on all full central carpet.

The detector is structured in modules made up of 12 RPCs, called Clusters. The entire detector comprises 154 Clusters out of which 130 Clusters make up the central carpet. Each Cluster has its own modular read-out and local trigger electronics housed in a Local Station (LS) [4] [2]. In each Cluster the 120 pertaining pads are sampled with a time resolution of about 1 ns by digital, multi-hit TDCs. The pad signals are stretched to 150 ns in order to guarantee that signals from particles in the same shower can be put in coincidence. The trigger logic validates an event on the basis of the time distribution of the fired pads and their multiplicity on the carpet. The LS outputs a 6-bit Low Multiplicity (LM) weighted bus (when $\geq 1$, $\geq 2$,$\geq 3$, $\geq 4$, $\geq 5$, $\geq 6$ pads are fired). This read-out saturates when more than 6 pads fire in coincidence on the same Cluster.

The detection of small size showers is one of the main tasks of the Argo-YBJ experiment. An inclusive trigger able to record a minimum number of hits has been implemented, based on a four-level coincidence scheme which correlates only signals pertaining to adjacent areas.
Shower events are selected using a simple but powerful algorithm, by just summing the multiplicities of all Clusters across the entire carpet in a time window of $\sim$400 ns. When the total number of hits exceeds a programmed threshold the event is selected for acquisition. The spurious signals from the detector ($\sim$400 Hz/pad) represent the noise for the shower events [5].
Besides this channel there are other triggers designed to select showers with dense core region, with cluster data frame much bigger than the first one.

The Argo-YBJ DAQ [3] is built on a two-layer read-out architecture implementing an event-driven data collection by using two custom bus protocols, based on VME-bus. In figure 1 a schematic view of the DAQ system it's shown.

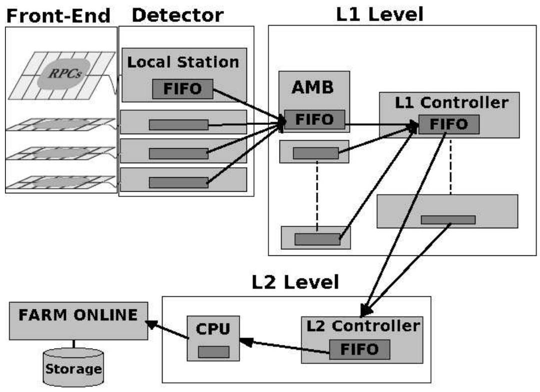


Figure 1: Schematic view of the architecture of DAQ system.

When a trigger occurs, a signal is forwarded to the LS where it acts as a common stop for all the TDCs. The LS assembles a local data frame containing an incremental event number, the addresses of the fired strips, all the timing information in the TDCs and transfers this frame to the Central Station at a rate of 160 Mbit/s. The frame is pushed into a FIFO memory placed in the Argo Memory Board (AMB) [6] which is part of the Level-1 read-out system. The Level-1 environment is based on crates equipped with a VME and a custom bus (AUXbus) [7] that uses the lines undefined by the VME standard [8]. Each AMB can manage 4 LS channels and each Level-1 crate contains up to 16 AMB boards.
A Level-1 read-out controller (ROCK [9]) in each VME crate collects the front-end data via the AUXbus. It implements hardware block transfer capability and its peak throughput is 50 MB/s. The Level-1 controller builds data frames consisting of an event number, data frames from the AMB boards and a parity word. Up to 8 Level-1 controllers can be daisy-chained and acquired by one Level-2 controller (ROCKM [10]) through a fast one-directional custom-bus (CBUS) sustaining up to 40 MB/s [11]. The Level-2 controller collects the data frames relevant to a given event number from all the Level-1 boards.

A decoupling fifo is hosted on both the L1 and the L2 controllers to buffer the data. The L2 controller fifo is read by a CPU hosted on the same VME bus and the data are sent to the online farm system through gigabit ethernet connection.
The VME CPU currently in use is a Motorola model MVME6100 running at 1.3 GHz, with 1 GB of RAM memory and 2 ethernet 100/1000 interfaces.

All the DAQ VME crates provide a slow commercial bidirectional bus (VIC-bus) whose bandwidth is 4 MB/s, that is used to initialize the DAQ chains, to check the status of the electronics and to manage the run condition.

To improve scalability, the system can be split in several chains by adding more L2 controllers each one having its own VME processor board [3].

## Farm Online system

The online farm consists of a Blade Center by IBM. The blade center chassis can host up to 14 blade server boards allowing fast and easy maintenance and redundancy.
The blade center chassis is equipped with two switches to which all blade servers are internally connected: one for the ethernet protocol (10/100/1000 Mbs) and one for a fiber channel protocol.

The present configuration provides full redundancy since six boards are installed out of which only three are used: one for the farm system that receives the data from the MVME6100 CPU with a 1000 Mbs ethernet connection; one for the control of the DAQ system (a software named "Argo Run Control" permits to manage the DAQ system); one for managing/archiving/transfering the data files. The online software is presented in [3].

The blade center has also fiber optics connections to a disk server and to a tape library.
The disk server is an IBM model DS4100 providing a total buffer disk space of about 3.2 TB. The buffer disk capacity is enough to store all the data acquired by the DAQ over a period of one week: in normal condition this provides the "Data Mover" application [12] with enough time to move the data to the Collaboration computing centers. Should any problem arise with the network transfer, date files are migrated to tape and removed from the buffer.
All the blade servers share this disk space using the General Parallel File System (GPFS), the high-performance shared-disk filesystem from IBM. GPFS allows parallel applications the simultaneous access to a set of files (or even a single file) from any node that has the GPFS file system mounted while providing a high level of control over all file system operations.
In the current configuration of the farm system we measured a disk write throughput of about 45 MB/s, when at the same time another machine was reading data files at about 35 MB/s.

In the farm online system it's also present an efficient software component that reformats the data coming from the L2 CPU before writing them to disk, called RDS (Redundant Data Scan). This component allows to reduce the data size by a factor of 3 by removing redundant information like repeated board addresses or event numbers.

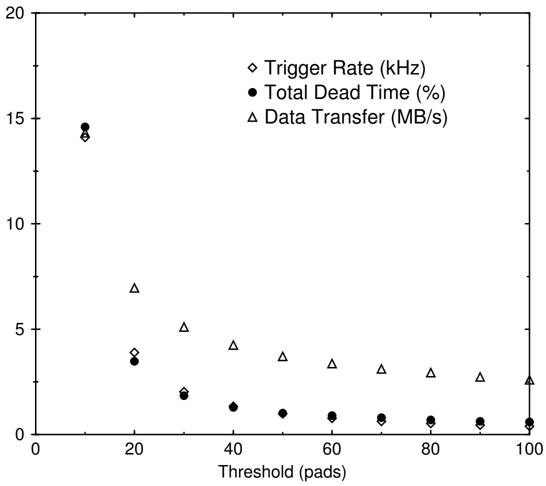


Figure 2: Trigger rate, total dead time and data transfer of the DAQ system versus the trigger threshold.

## DAQ system performance

The DAQ performance was measured analyzing the latest available data set relevant to the configuration with 130 clusters (the central carpet zone) in acquisition and with only 42 clusters fully instrumented with both digital and analog readout.

In this set-up the data transfer rate and dead time were measured as a function of the trigger threshold. We are particulary interested in the DAQ system performace in the case of low trigger thresholds where the trigger rate becomes high. Fig. 2 shows the trigger rate, the dead time and the data transfer dependences on the trigger threshold.

The measurements have been performed by decreasing the trigger threshold up to 20 pads on the whole carpet: the imposed threshold value allows us to study Gamma-Ray astronomy events while maintaining a good rejection of noise triggered events. Moreover, a measurement was done for 10 pads to check the system performances under stressed conditions.

When the threshold value is 20 the trigger rate is as high as 4 kHz, the data transfer is about 7 MB/s (before RDS) and the dead time is about 3%.

The Total Dead Time is the logical-OR of all dead time components, in particular through the DAQ chain these are: Dead Time on Transfer asserted by each LS during the data transfer to the FEE; L1 and L2 dead time that comes from the L1 and L2 controller FIFOs when they are almost full.

When extrapolating to the final configuration it has to be noted that the guard ring clusters are not part of the trigger system, so their inclusion is not going to affect the trigger rate. Fully instrumenting the analog read-out will only increase the total data throughput, as well. The measured performance thus enables us to say that the DAQ requirements are fully met in terms of the trigger rate sustainable at a small level of dead time.

The expected data flow in the final design should be less than 20 MB/s (before RDS). In case of a detector upgrade the DAQ System can be split into multiple chains with a measured throughput of about 20 MB/s per chain [3]: the present configuration of the online farm can easily sustain at least two DAQ chains.

## Conclusion

In this work a novel efficient setup for the DAQ system was realized, all the installed components allow us to have very high performances. The measurements of the DAQ performances demonstrate that the system is capable to sustain a good trigger rate with a very low dead time. Furthermore, the system is also scalable to effectively cope with possible future upgrades.

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