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Introduction to PANDA Data Acquisition System

H.Xu[a]*, Z-A.Liu[a], Q.Wang[a], W.Kuehn[b], S.Lang[b], M.Liu[b]

for PANDA Collaboration

[a]*Institute of High Energy Physics, Chinese Academy of Sciences, 100049, Beijing, China*
[b] *II.Physikalisches Institut, Justus-Liebig-Universitaet, 35392, Giessen, Germany*

Abstract

Due to the anti-proton annihilation at Darmstadt (PANDA) experiment has rich physics studies with different event selection criteria and very high interaction rate of $2x10^7$ /s and data rates of 200 GB/s and more, a high performance and high bandwidth data acquisition system without hardware trigger has been proposed. The data from various sub-detector systems are tagged by a very precise timestamp in front-end electronics. Event selection based on real time feature extraction, filtering and high level correlations will be executed on Advanced Telecommunications Computing Architecture (ATCA) compliant compute nodes. As a key element, the compute node that features high bandwidth connectivity and large memory for data buffering will be detailed. A demonstrator system for the electromagnetic calorimeter has been built to set up a basic system that can be interfaced to front-end electronics.

Keywords: PANDA, DAQ, ATCA, Compute Node, Trigger

1. Introduction

PANDA is a general purpose hadron spectrum to be installed in the high energy storage ring of the Future Anti-proton and Ion Research facility-FAIR [1], in Germany. It employs the high quality cooled

E-mail address: xuhao@ihep.ac.cn.

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anti-proton beam to hit fixed target to do research on strong interaction, weak interaction, exotic states of matter, hadron structure and so on.

The PANDA detector, see Fig 1, will be composed of two magnetic spectrometers [2]: the Target Spectrometer (TS) and the Forward Spectrometer (FS). The target spectrometer that will be used to measure at high angles comprises a superconducting solenoid, silicon tracking devices, a central tracker (either TPC or straw tube based), a high quality electromagnetic calorimeter, BaBar-style DIRC and a muon detector. The forward spectrometer for small angle tracks is based on a large normal conducting dipole magnet, drift chambers, Cherenkov detectors and electromagnetic and hadronic calorimeters.

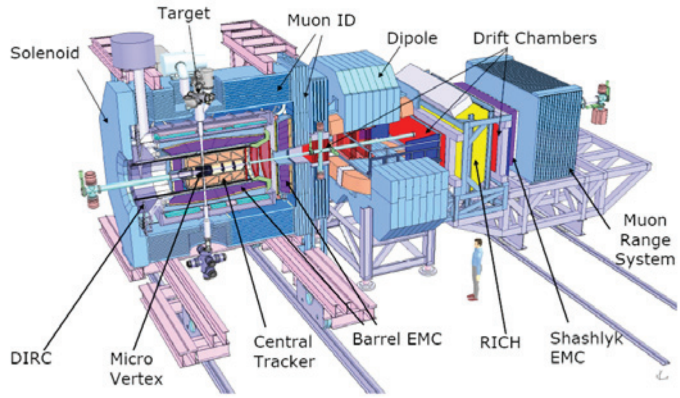

Fig.1. the PANDA detector

PANDA has a comprehensive physics program which includes charmonium spectroscopy, the search for QCD exotica, hypernuclear physics as well as the study of charmed hadrons in nuclear matter. This rich and diverse physics program requires high luminosity experiments with interaction rates of up to 3 x 10^7/s.

2. Requirements for Data Acquisition System

Since the physics of PANDA is frontier physics, high statistics is needed to detect rare processes or small deviations in physical distributions. the PANDA experiment plans to operate at interaction rates up to 30MHz, typical event sizes of 4 - 20 kB lead to data rates after front end pre-processing of 40GB/s - 200 GB/s. The pre-processing involves digital signal processing, zero and noise suppression, calibration and local feature extraction. We propose a hardware trigger-less DAQ system which features a continuously sampling system where the various subsystems are synchronized by a precision time stamp distribution system. Event selection is based on real time feature extraction, filtering and high level correlations [3].

The detector front-end electronics (FEE) reads and digitizes the data, then performs the first level of data reduction by determining valid hits, combining them to physical information like clusters, energies or tracks. The data is tagged with a precise timestamp which allows the association of information belonging to one interaction. Each interaction corresponds to a detector specific time slice in the data stream.

The data of a detector are either buffered or passed directly to a network of compute nodes depending on the settings of the respective physics measurements. These are supposed to extract a first simple physical signature that allows a decision on which time slices have to be transferred to the next processing level. The decision is broadcast through the network so that the next level's compute nodes can address the relevant buffered data of other detectors. The general structure of the data acquisition system is shown in Fig 2.

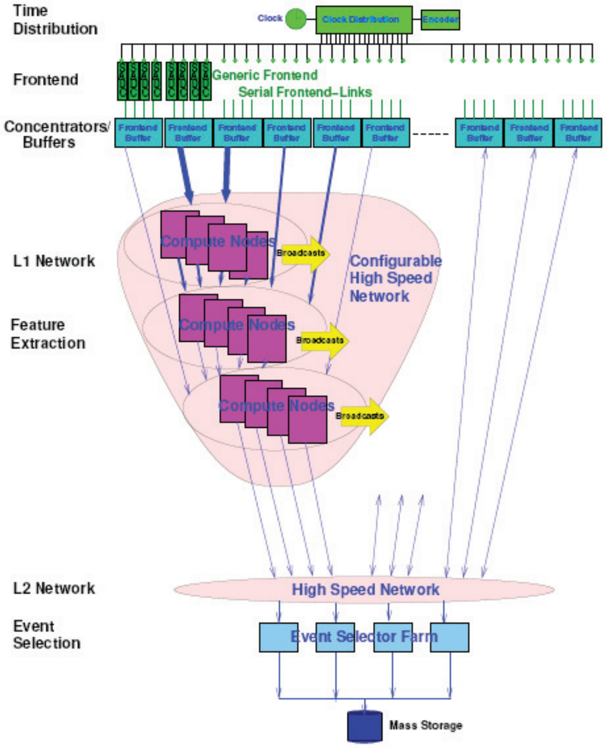

Fig.2. DAQ system for PANDA experiment

Many advanced technologies are required for the PANDA DAQ system: high speed serial links (10Gb/s per link and beyond), high-density FPGA with large numbers of programmable gates and real time embedded systems. To build a continuously sampling data acquisition in which event selection takes place in programmable processing units, we propose some key elements as following:

- Intelligent front-end modules, which are capable of autonomous hit detection and data preprocessing.
- A very precise time distribution system, to provide a clock from which all timestamps can be derived.
- Concentrators/buffers, to provide point-to-point communication, typically via optical links, buffering and on-the-fly data manipulation.
- Compute nodes, to aggregate large amounts of computing power in a specialized architecture rather than through commodity PC hardware.

Sophisticated online event filtering and selection is performed by a high-speed network of FPGA based Compute Node (CN) [4].

3. ATCA-based Compute Nodes

Event selection based on real time feature extraction, filtering and high level correlations will be executed on ATCA compliant FPGA-based Compute Nodes in two stages: At the first stage, the dedicated sub-detector information will be processed in the sub module. Some online feature extraction algorithms will be employed to extract particle information like energy, position, momentum and so on.

Some kind of particle identification will be done for charged particles. The results from the first stage will be combined together in the second stage to make a preliminary reconstruction for physics events. Then the event selection will be done based on the research topics of PANDA experiment and the result will be sent to the offline PC farm for further processing.

The structure of CN is shown in Fig 3. Each CN features 5 Xilinx Virtex-4 FX60 FPGA chips and up to 10 GBytes DDR2 memory. 3 Gbps bandwidth per channel and total of 50Gbps connectivity is provided by 8 front panel optical and 13 backplane electrical links using RocketIO ports. Five gigabit Ethernet links are provided for output transmission.

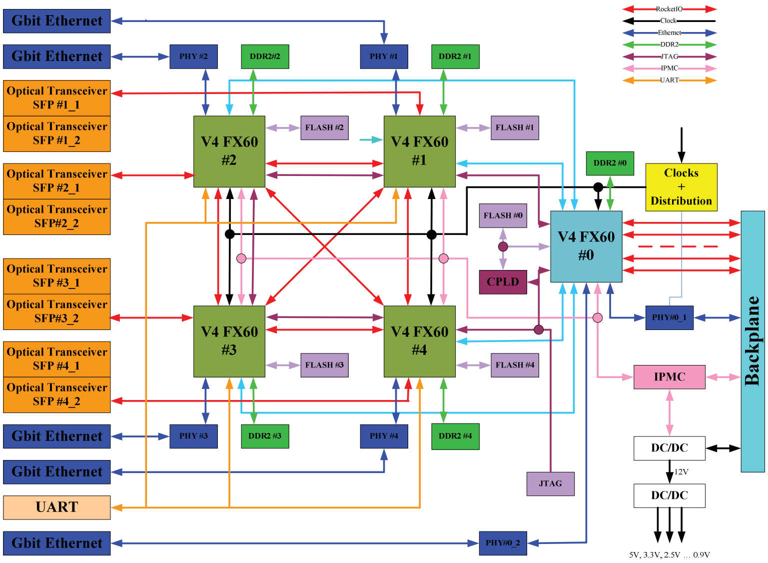

Fig.3. schematic of Compute Node

To accelerate large system design, a system on programmable chip design topology is implemented. A general purpose embedded system is built using the embedded PowerPC405 hardcore and some open source IP cores. An open source Linux system is ported to the platform for slow control, TCP/IP stack processing and other not time critical tasks. The event filter, event selection and other algorithms are designed as custom processing units with FPGA fabric resource. These customized processing units are combined with other general purpose modules to build a large system on chip [5].

There are many advantages in using ATCA [6]. It is an industry standard, delivers -48V@200 W/slot with adequate cooling. Furthermore, Full-mesh backplane provides high speed point-to-point serial connectivity. It is scalable, so we can easily expand the algorithms and components to multiple shelves using the external optical links. The ATCA base interface with gigabit Ethernet connectivity is available for interfacing with the PC farm. Shelf management for remote configuration and monitoring via the integrated intelligent platform management controller interface can be used for slow control tasks.

10 boards small production for performance test and example firmware development has been done since last year. All CN boards work well during our performance test and demonstrator system test.

4. DAQ Demonstrator System for EMC

To set up a basic system that can be interfaced to FEE, we have built a demonstrator system for electromagnetic calorimeter (EMC). The system insists of Network File System (NFS) server, interface card and Compute Node. NFS server serves as data source and online processor, and the interface card is used as FEE transmitter. First, Monte Carlo data are written to the interface card from the server terminal. Second, the data are transmitted to Compute Node via optical fibers. Then, the processed data are sent to online processor through gigabit Ethernet.

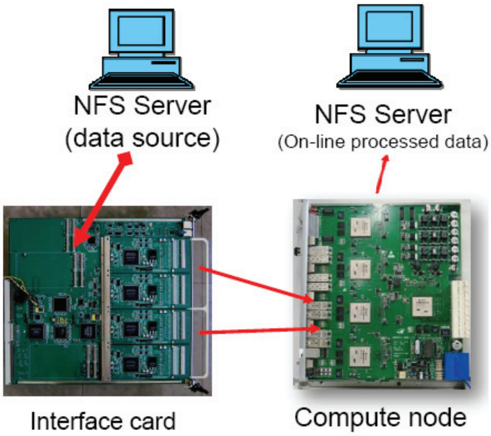

Fig.4. set up of DAQ demonstrator system for EMC

The EMC employs PWOII crystals featuring fast time response, high density and improved light yield. It will be used to measure the energy of photons and electrons. The electromagnetic photons or electrons create clusters of detector hits. Each crystal in such a cluster detects only part of the total energy. The goal of the cluster finding algorithm is to obtain the position and total energy of the photon or electron showers. The algorithms which are being developed are desired to run on the Compute Node platform.

About 10000 gamma simulations at each selected energy point we used with geometry restriction to the barrel part. The energy distribution of clusters found by the online algorithm is compared with the offline algorithm as shown in Fig 5 [7]. The main peak is considered as the contribution of valid clusters while the tail at low energy is considered to be fake clusters contributions. For the main peak part, these two algorithms agree with each other very well while the online algorithm has a smaller tail.

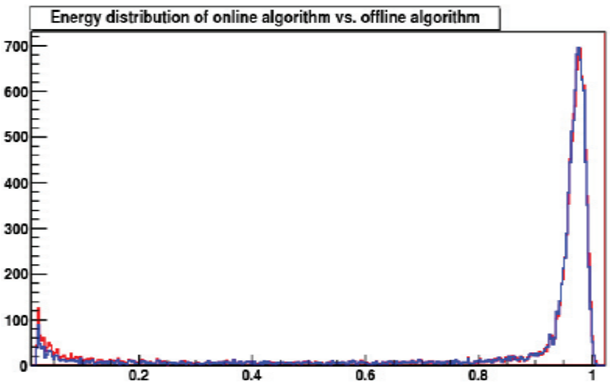

Fig.5. energy distribution of online and offline algorithm

The system ran for a long time. It is confident that the demonstrator system for EMC is stable and it is ready for other development.

5. Conclusion

To meet the requirements from PANDA experiment, a hardware trigger-less data acquisition system with high performance has been proposed. The system is scalable and suitable for a variety of applications requiring high data throughput, large amounts of buffer memory and high speed connectivity via optical links and gigabit Ethernet. As a key element, an ATCA-based compute node has been developed. Small production has been done for algorithms development and performance test. A demonstrator system for EMC is built and it is ready for other development.

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