Software system for data acquisition and real-time analysis operating the ATLAS-TPX network

Benedikt Bergmann, Jakub Begera, Petr Burian, Josef Janecek, Petr Manek, Stepan Polansky, Stanislav Pospisil *Senior Member, IEEE*

***Abstract*—TODO**

I. Introduction

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II. Timepix Detector

Each ATLAS-TPX device consists of two Timepix [1] readout chips with silicon sensor layers of thicknesses 300 μm and 500 μm facing each other. They are interlaced by a set of neutron converters. The Timepix ASIC (application specific integrated circuit) divides the sensor area into a square matrix of 256×256 contiguous pixels with a pixel dimension of 55 μm. It allows a configuration of each pixel in either of the three modes of operation:

- In the spectroscopic Time-over-Threshold (ToT) mode the energy deposition in the sensor material is measured.
- In the Time-of-Arrival (ToA) mode the time from an interaction with respect to the end of the exposure is recorded (precision up to 25 ns).
- In the counting mode, the number of interactions with energies above 5 keV during the exposure time are counted.

Data are taken in so-called frames, representing the counter contents of all individual pixels after an adjustable exposure time (often also referred to as frame acquisition time). In each frame, interacting quanta of ionizing radiation can be seen as tracks on the pixel matrix, which have characteristic shapes, depending on the particle range in silicon, its deposited energy, angle of incidence, and particle type.

III. Hardware Architecture

A read-out interface is a special dedicated hardware device that reads data and controls acquisition of the detector. [2] Given the harsh radiation environment within the ATLAS machine, the ATLASPIX interface was developed by modifying a regular FITPix interface. [3]

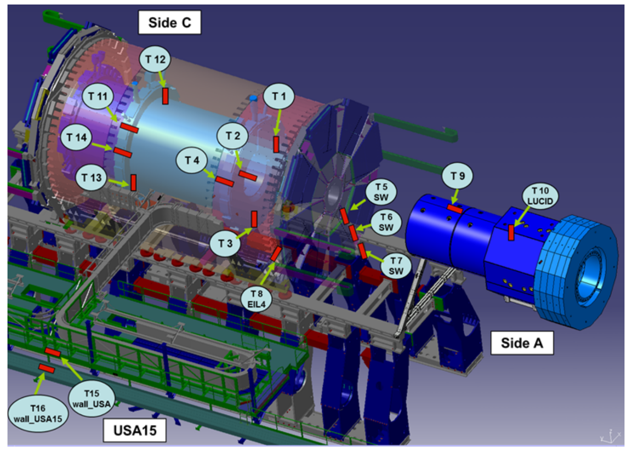

Fig. 1. Artistic view of the device positions of the ATLAS-TPX network in the ATLAS experiment.

The interface has two parts connected by four cables. The detector itself is positioned and oriented within the ATLAS machine, whereas the rest of the interface is placed in a nearby server room, shielded against ionizing radiation. Cables connect both parts, allowing protected hardware to control detectors remotely[1] during operation of the machine. To manage multiple detectors simultaneously, a computer is directly connected to all read-out interfaces. This computer, also known as *the control PC*, gathers all measured data and forwards commands from the system operator to the detectors through the ATLASPIX interface. This configuration is shown in Figure **??**.

At the time of writing this work, the control PC is being operated manually from a remote location. The automation of the operation is under investigation (for more information, see Section **??**).

IV. Acquisition & Control Software

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V. Data Analysis Subsystem

The data analysis subsystem is comprised of virtual machines hosted at CERN Meyrin data center and managed by OpenStack private cloud. Each machine provides multitude of *worker nodes* responsible for parallel execution of queued *jobs* – mutually independent operations that interact with data files.

[1]The software used to control and process results of data acquisition is fundamentally similar to the software used in the MPX network. [4]

B. Bergmann, J. Begera, P. Burian, J. Janecek, P. Manek, S. Polansky, S. Pospisil are with the Institute of Experimental and Applied Physics, Czech Technical University in Prague, Horska 3a/22, 128 00 Praha 2-Albertov, Czech Republic.

P. Burian is also with the Faculty of Electrical Engineering, University of West Bohemia.
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E-mail: jakub.begera@cvut.cz, petr.manek@cvut.cz

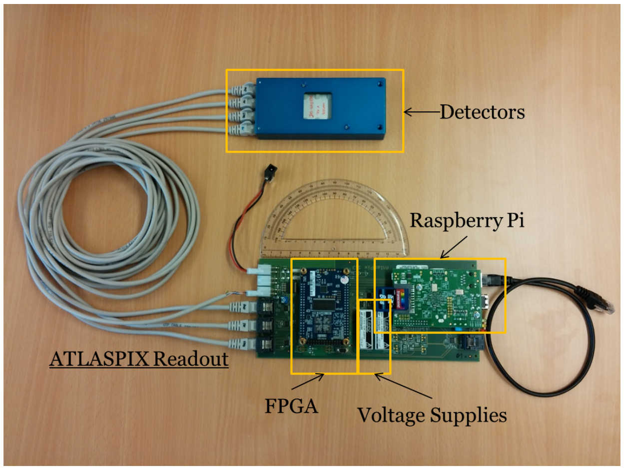

Fig. 2. ATLAS-TPX device, connected to its readout system through three Ethernet cables. The readout system consists of an FPGA, handling the device settings and operation, and a Raspberry Pi minicomputer for sending the data to the control PC in human readable format. Two voltage supplies are used for feeding the proper bias to each of the sensor layers.

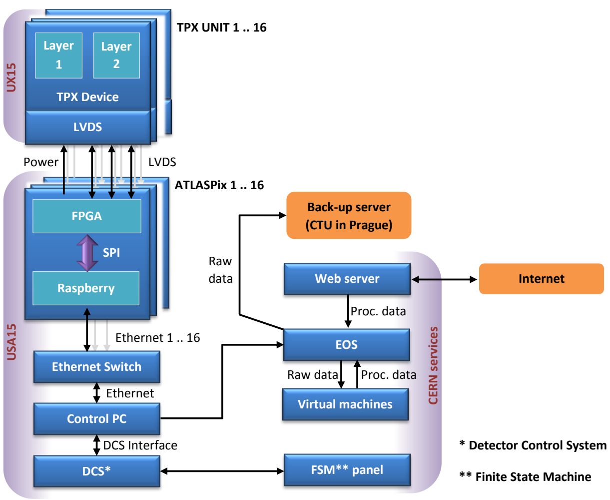

Fig. 3. Scheme of the readout, detector control, and data flow.

Scheduling and completion of jobs as well as the heartbeat and load of workers is continuously tracked by a *manager node*, which indirectly communicates with workers through shared PostgreSQL database cluster.

Primary purpose of the subsystem is to provide reliable infrastructure for automated data evaluation. This task is performed asynchronously with respect to the incoming data. Frames taken by TPX detectors are temporarily cached at the Control PC, then transferred to the EOS disk pool storage in 1-hour batches. Once in EOS, data files are discovered by the manager node, which schedules series of verification jobs, which are designed to detect known faults and data inconsistencies.

If the data is confirmed to be valid and no detector malfunctions are suspected, the manager schedules a full processing job. In the course of this operation, frames are subject to cluster analysis [5] and measurements are combined with energy calibration data. [6] Outputs are stored back in EOS in format

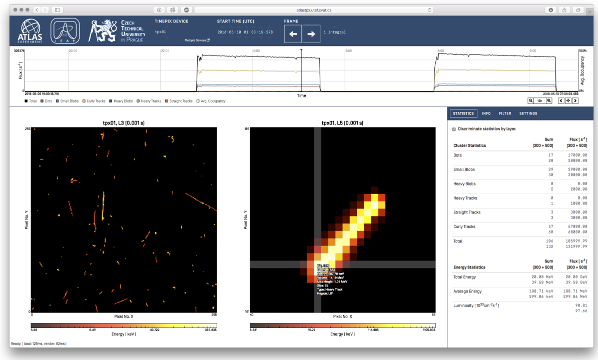

Fig. 4. Screenshot of the Data Visualization Application. [8] Top chart shows flux of characteristic traces in frames in specified time range, bottom charts show pixel matrices at a specified time.

compatible with the ROOT Data Analysis Framework. [7] The produced files serve as a starting point for data visualization and other subsequent analysis tasks such as activation analysis, noisy pixel detection or luminosity monitoring. The original data files are compressed and downloaded to a backup medium for archivation.

VI. Visualization Application

Processed data can be examined directly from the ROOT files or by means of the Data Visualization Application. [8] This application features a simple web interface capable of displaying frames given specific detector, date and time. In addition, the application is capable of plotting fluxes of characteristic traces in specified time periods. See Fig. 4.

Since the data is visualized on client-side using modern rendering techniques, the application can also offer basic data operations such as cluster filtering, pixel masking, data aggregation, integral view and logarithmic scale.

The application serves mainly as a tool of manual inspection of the network operation history. It is openly available to the scientific community upon request.

VII. Conclusion

The presented software can successfully control detector acquisition and retrieve, analyze and display frames from the ATLAS-TPX network. All components of the system are fully operational. The Data Visualization Application is publicly available to the scientific community upon request.

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