An Event Building scenario in the trigger-less PANDA experiment

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Abstract. The PANDA experiment will be running up to $2 \times 10^7$ antiproton-proton collisions per second at energies reaching 15 GeV. The lack of simple features distinguishing the interesting events from background, as well as strong pileup of events’ data streams make the use of a hardware trigger impossible. As a consequence the whole data stream of about 300 GB/s has to be analyzed online, i.e: tracking, vertex finding, particle identification and event building.

The GEM Tracker covers polar angles from 4 to 20 degrees in the forward direction, and can be used for the event building in a large fraction of events. In this work the analysis chain and the implemented algorithms will be presented. Moreover, the event builder prototype based on GEM Tracker data will be presented.

1. Introduction

antiProton ANnihilation at DArmstadt, or PANDA [1], is a future experiment at the Facility for Antiproton and Ion Research (FAIR), an international accelerator complex currently under construction at GSI.

The PANDA experiment will study antiproton annihilation with antiproton beam energies of up to 15 GeV, but collisions with heavier ions will also be conducted. The physics program of the PANDA experiment aims at very detailed spectroscopy and observation of extremely rare production channels. In order to observe such rare processes, with cross sections orders of magnitude below the background, high collision rate is essential. The average design event rate at the PANDA experiment will reach $2 \times 10^7$ collisions per second, which will cause data from different events to overlap. Furthermore, a large fraction of this data stream is uninteresting from the physics point of view and should not be stored. In most experiments a set of hardware triggers is responsible for such data stream reduction. However detailed study [1] proved that such simple trigger is not possible for the PANDA experiment. Moreover, it showed that for the majority of channels in order to distinguish the interesting events from background it will be necessary to perform the whole event reconstruction online, with track finding, vertex reconstruction and particle identification.

This poses challenges for the PANDA computing and requires development of new methods not only for data reconstruction, but also for simulation. Such methods are currently being implemented in FairRoot [2], a general framework for data simulation and analysis originally intended for the FAIR experiments. Meanwhile the tool, which provides, inter alia, run managers, IO communication, particle transport engines and parameter containers, is widely
Figure 1. Originally digitized data are stored organized by simulated events. While reading, they are stored in time-ordered buffer. The analysis tasks request data chunks according to time.

used, and one of its first users was the PANDA experiment. The PandaRoot software [3] contains descriptions of all PANDA detectors as well as reconstruction algorithms and allows realistic simulations and reliable data analysis. The next chapter of the work will briefly introduce the simulation of the time-based data stream based on one of the PANDA detectors. The reconstruction results will follow in the third section. The fourth section will summarize the event building example.

2. Time-based simulation
In order to properly simulate the undisrupted data flow with different events possibly mixed up, a time-based simulation [4] has been implemented in FairRoot. The time-stamped digitized data is stored originally in the ROOT TTree in separate leaves corresponding to simulated events. The data is read event-by-event and is stored in time-ordered buffers. The reconstruction task requests data from the filled buffers and obtains time slices of data, as presented schematically in Figure 1. Currently two methods of such data extraction are implemented: it is possible to retrieve all the data until a user-defined point in time, or each time slice is defined by gaps in the data stream. Decision about the usage of any of the two methods should be adapted to the expected fluctuations in the data stream. The time-based simulation algorithm implemented in FairRoot allows for relative flexibility and ensures that the data used in the time-based reconstruction is decoupled from the original simulated events’ structure.

Figure 2 shows a concrete example of such procedure using data from one of the PANDA detectors, the Gaseous Electron Multipliers (GEM) Tracker. The data in the top panel is color-coded according to corresponding simulated events. Different colors in the bottom panel represent different slices used for the reconstruction as obtained from the buffer. For the GEM Tracker, the time slices are defined by gaps in the data stream.
3. Reconstruction results

The reconstruction of the digitized data from the GEM Tracker includes finding of clusters, hits and eventually tracks. The algorithms, developed over the course of the last 5 years, were based on the event structure of the data. Large chunks of the code proved to be useful also in the time-based scenario, but some changes had to be introduced. In particular, the amount of data in each time slice is usually greater than in simulated events, which increases the combinatorial background. This effect can be partially balanced by matching data with a similar time stamp. The track finding, as compared to previous reconstruction stages, poses additional difficulty, as the hits belonging to one track may be spread over neighboring time slices. It is therefore important, at least in some reconstruction tasks, to store the input data in internal buffers for possible usage in the analysis of later time slices.

A track finding efficiency of 87% was achieved (see Figure 3), which is lower than the 95% efficiency obtained for the event-based reconstruction, mainly due to higher combinatorics, but also because of data spread between different time slices. The reconstructed track quality did not deteriorate and the momentum resolution amounts to 1% (see Figure 4) in the transverse direction and 4% in the longitudinal direction.

4. Event building

The reconstructed tracks contain also start time information, that can be used as an estimator of the event start time $T_0$. The GEM Tracker Event Builder analyses the time slices with reconstructed tracks and finds events (see Figure 5). The input tracks and found event candidates are stored in corresponding buffers. Consequently, the event buffer is analysed to extract events, which are old enough that no more tracks are expected to be added. Such events are stored together with corresponding tracks, in the output tree. In Figure 6 a comparison of the reconstructed events start time with the simulated events start time is presented. The obtained event start time resolution is 0.4 ns. Overall, 92% of the reconstructable events were reconstructed, with an impurity of ghost events below 2%. 

Figure 2. GEM Tracker’s digitized data versus time. Top panel shows different simulated events in different colors (vertical line indicates the beginning of a corresponding event), in the bottom panel different colors represent different time slices.
Figure 3. Momentum distribution of the simulated tracks (blue line) and reconstructed tracks (red line).

Figure 4. Difference between tracks reconstructed momentum and the corresponding simulated track momentum.

Figure 5. Event building scheme.

Figure 6. Difference between reconstructed ($T_{\text{reco}}^0$) and simulated ($T_{\text{MC}}^0$) event start time.

5. Summary
The presented work shows that within the FairRoot framework it is possible to simulate and reconstruct free streams of data. Meanwhile all detectors of the PANDA experiment can be simulated within the time-based framework, and some, including the GEM Tracker, developed algorithms for time-based reconstruction. The presented track finding results are good enough to allow reconstruction of originally simulated events. A set of abstract classes for easy implementation of event building tasks has been added to the FairRoot. A first implementation using the GEM Tracker reconstructed tracks has been finalized for the PANDA experiment. The concept may be now used by other detector groups to create their own algorithms of event building.

[1] The PANDA Collaboration 2009 Physics Performance Report for PANDA: Strong Interaction Studies with Antiprotons (arXiv:0903.3905 [hep-ph])
[2] Al-Turany M, Bertini D, Karabowicz R, Kresan D, Malzacher P, Stockmanns T and Uhlig F 2012 J. Phys.: Conf. Series 396 022001
[3] Spataro S (for the PANDA Collaboration) 2011 J. Phys.: Conf. Series 331 032031
[4] Spataro S 2012 J. Phys.: Conf. Series 396 022048