Simulation of NICA MPD trigger system for MPDRoot software

Моделирование триггерной системы NICA MPD для программного обеспечения MPDRoot

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Установка MPD комплекса NICA создается для изучения взаимодействия тяжелых ионов и должна обеспечивать точное определение позиций треков для корректной идентификации частиц. Функционирование установки MPD, как единого целого, обеспечивается триггерной системой. Ограничения аппаратных компонентов, а также скорости распространения сигнала, ведут к несинхронности срабатывания детекторов как друг относительно друга, так и непосредственно относительно события столкновения. Моделирование триггерной системы для ПО MPDRoot улучшает приближение и общее качество моделирования по отношению к реальному оборудованию. Работа посвящена исследованию влияния триггерной задержки на качество восстановления треков в детекторе MPD TPC.

The experiment MPD at the NICA accelerator complex is designed to study heavy ion collisions and should provide accurate information of track positions for correct identification of particles. Synchronization of all detectors of the MPD will be provided by a trigger system. Due to hardware limitations and signal propagation speed, the detectors are not triggered simultaneously between themselves and with respect to the moment of particle collision. Simulation of the trigger system with the MPDRoot software brings the quality of the detector response simulation closer to the real setup. The study demonstrates impact of including the trigger latency on tracks reconstruction for the MPD TPC detector.

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Introduction

The experiment MPD of the NICA project is designed to study hot and dense baryonic matter in collisions of heavy ions. The first stage of experimental MPD setup consists of 5 detectors: fast forward detector (FFD), time of flight system (TOF), forward hadron calorimeter (FHCal), time projection chamber (TPC) and electromagnetic calorimeter (ECal) (see Fig. 1). Two of them will be used only for data taking - TPC and ECal. The other three - FFD, TOF, FHCal - will be used not only for data taking, but also for event triggering.

The Time-Projection Chamber (TPC) is the main tracking detector of the experiment MPD. The design and structure of the MPD TPC are similar

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to those that were used in the STAR and ALICE experiments. The active gas volume of the TPC is bounded by coaxial field cage cylinders with a pad plane readout structure at both end-caps. The uniform electric field in the active volume is required for drifting of electrons. The field is created by a thin central high voltage (HV) electrode together with a voltage dividing network at the surface of the outer and inner cylinders and at the readout end-caps. Volume of MPD TPC is divided into two even halves by HV electrode [1].

The TPC is the slowest detector in terms of data taking. Readout chambers require some period of time between data collection of different events and must be provided with a trigger to initiate information reading.

Simulation of MPD trigger system

The MPD trigger system general design consists of 3 parts/stages (see Fig. 2). The first stage detects event collision by three trigger detectors and processes some fast information about event parameters. This stage takes a period of time that is needed for the slowest trigger detector to process its data. This time is expected to be ∼300 ns. The second stage is provided by central trigger module. The module has to process data from trigger detectors and makes a decision of event relevance. The module fires a trigger for TPC and ECal detectors to collect corresponding event data if the event is considered valuable. This stage takes no more than 50 ns. The third stage requires full data from all detectors and also includes time for spreading trigger signal to corresponding detectors. This stage takes ∼1150 ns for the TPC detector. The trigger system design peculiarity is that only trigger detectors and central trigger module clocks are synchronized by White Rabbit system [2]. TPC readout hardware has no link to White Rabbit synchronized global clock.

Cumulative trigger latency for MPD TPC is expected to be around 1.5 µs. Trigger latency leads to several effects in the data collected by TPC. The latency causes loss of data near the end-caps of the TPC and reduction of acceptance range. Also this latency results in offset of all data towards the end-caps (see Fig. 3). Electrons from track ionization continue to drift while trigger is still propagating to readout hardware. Therefore electrons near the end-caps reach them before readout hardware starts to collect data, and all other electrons have corresponding measured position offset along drift path. The more the trigger latency is, the more the effect will be. It is expected that MPD TPC pseudorapidity range is reduced by $\Delta\eta \simeq 0.1$ (1.05 instead of 1.15 at the corner of the TPC) and data are shifted by ∼8.3 cm for the electron drift velocity 5.5 cm/µs.

It is expected that MPD TPC trigger latency will be measured individually for each event to correct the latency effects. There is no available information about latency measurement quality before commissioning of real experiment. Hence, three methods to measure trigger latency with event

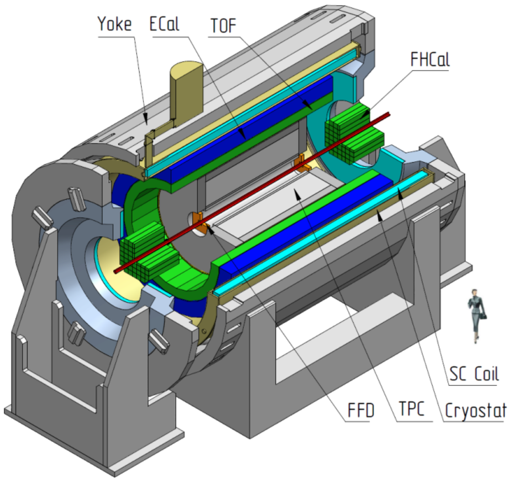

Fig. 1: NICA MPD 1-st stage setup

data only are proposed. All simulations and algorithms implementations were made for MPDRoot software environment [3]. The first one is a method based on summarization of raw data signal from each half of the TPC and slope detection in summarized signal (the slope is a position of a HV electrode, see Fig. 4). Calculation of average trigger latency is provided through matching the slope and position of HV electrode. This method is extremely rough and depends on selected threshold for the slope position detection. The second one is a method based on linking of not reconstructed tracks crossing HV electrode. Such tracks provide reconstructed point with almost same position near the HV electrode in both halves of the TPC. Searching and linking such pairs of track points provide information about trigger latency (see Fig. 5). This method is also very crude. It demands significant adjustments to provide similar to reasonable results because track points nearest to HV electrode always have some offset from HV electrode position that hard to be measured. The third one is a method based on comparison of two vertices reconstructed independently with data from each half of the TPC assuming that these two are a single one vertex. Distance between these two vertices provides information about trigger latency. This is the most and only reasonably precise method, but it has significant drawbacks of applicability only for single vertex events and also doubles the reconstruction time (see Fig. 6).

Summary

The study shows that knowledge of trigger latency is necessary for proper event reconstruction. Without this information it is impossible to link TPC data and also information from other detectors to a single image and provide event reconstruction. Only one from three proposed trigger latency calculation algorithms for MPD TPC provides quite accurate results with some restrictions and drawbacks.

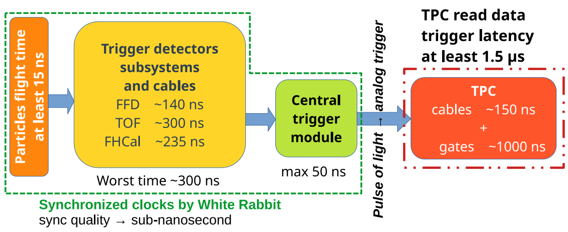

Fig. 2: MPD trigger flow diagram

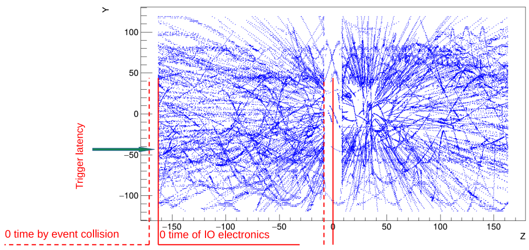

Fig. 3: MPD TPC effects of lack of knowledge of trigger latency

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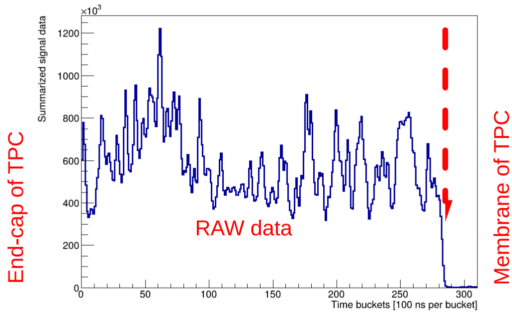


Fig. 4: Position of HV electrode on summarized raw data signal

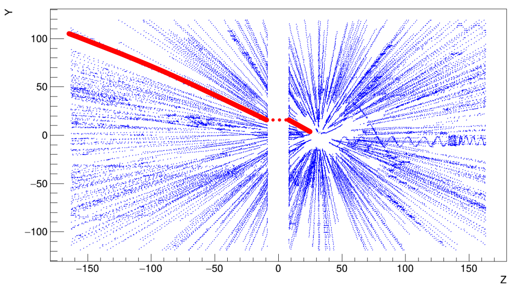
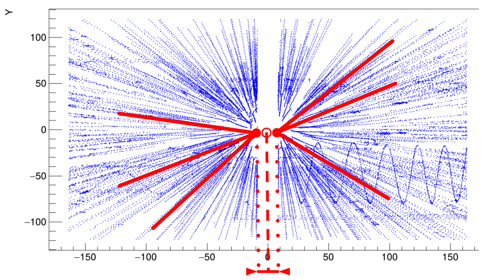
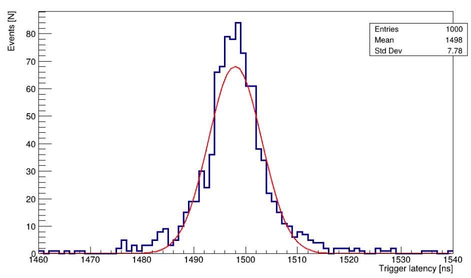


Fig. 5: Explanation of the algorithm of trigger latency calculation based on linking of tracks crossing HV electrode



(a) Explanation of the algorithm



(b) Quality of calculations (expected latency 1.5 μs)

Fig. 6: Trigger latency calculations based on determination of vertex position