Status of event reconstruction

Alexander Zinchenko

Outline

1. TPC fast digitizer
2. TPC cluster finder
3. Track reconstruction
4. Vertex reconstruction in low-multiplicity events
5. Hyperon reconstruction (background from event mixing)
6. Tracking in the end-cap region

TPC fast digitizer

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Simulating the time projection chamber responses at the MPD detector using generative adversarial networks

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Abstract High energy physics experiments rely heavily on the detailed detector simulation models in many tasks. Running these detailed models typically requires a notable amount of the computing time available to the experiments. In this work, we demonstrate a new approach to speed up the simulation of the Time Projection Chamber tracker of the MPD experiment at the NICA accelerator complex. Our method is based on a Generative Adversarial Network – a deep learning technique allowing for implicit estimation of the population distribution for a given set of objects. This approach lets us learn and then sample from the distribution of raw detector responses, conditioned on the parameters of the charged particle tracks. To evaluate the quality of the proposed model, we integrate a prototype into the MPD software stack and demonstrate that it produces high-quality events similar to the detailed simulator, with a speed-up of at least an order of magnitude. The prototype is trained on the responses from the inner part of the detector and, once expanded to the full detector, should be ready for use in physics tasks.

1 Introduction

Computer simulations of high-energy physics experiments play a crucial role in a variety of relevant tasks, including detector geometry optimization [1,2], selecting best analysis strategies [3,4], and testing the Standard Model (SM) predictions and searching for new phenomena beyond the SM [5,6]. For a typical experimental data analysis, the number of simulated events usually translates directly to the uncertainty of the final physics result. The amount of computational resources spent on the simulations usually takes a notable fraction of the total computing capabilities of an experiment and is comparable with that spent on the real data processing [7,8]. Therefore, faster approaches to event generation and simulation are in great demand for the existing and future high energy physics experiments.

The MPD detector is one of the two experiments at the NICA accelerator complex – a new heavy ion accelerator facility being constructed at the Joint Institute for Nuclear Research and located in Dubna, Russia [9,10]. The complex is designed to study the properties of dense baryonic matter. For the tracking, MPD utilizes a time projection chamber (TPC) in the central barrel [11]. TPC simulation is very CPU-intensive [12], and hence a fast simulation approach for TPC is highly desirable.

A typical approach to constructing models for fast simulation of particle physics detectors is to use a simplified detector geometry and a simplified model of the interaction of particles with matter [13]. This approach is justified for subsystems with a flat sensitive volume, such as silicon trackers, that measure the two-dimensional coordinate of a passing particle. For systems with a large volume, such as calorimeters or TPC-based trackers, this approach makes it difficult to achieve a reasonable compromise between accuracy and simulation speed.

Another fast simulation approach is an analytical parameterization of the detector responses, as can be seen in shower shape parameterizations for calorimeters [14]. This approach can significantly speed up the calorimeter simulation, but it makes it difficult to achieve high quality simulated data. A common solution for calorimeters is also to use the so-called "frozen showers" [13] when detailed simulated system responses are stored as a response library for subsequent reuse.

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Generative Adversarial Networks for the fast simulation of the Time Projection Chamber responses at the MPD detector

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Abstract. The detailed detector simulation models are vital for the successful operation of modern high-energy physics experiments. In most cases, such detailed models require a significant amount of computing resources to run. Often this may not be afforded and less resource-intensive approaches are desired. In this work, we demonstrate the applicability of Generative Adversarial Networks (GAN) as the basis for such fast-simulation models for the case of the Time Projection Chamber (TPC) at the MPD detector at the NICA accelerator complex. Our prototype GAN-based model of TPC works more than an order of magnitude faster compared to the detailed simulation without any noticeable drop in the quality of the high-level reconstruction characteristics for the generated data. Approaches with direct and indirect quality metrics optimization are compared.

1. Introduction

Simulation of particle detectors is inevitable in the High Energy Physics (HEP) experiments. For a typical HEP data analysis, the limited size of simulated data samples often contributes directly to the uncertainty in the final result. Since the number of simulated events that one can afford to produce is constrained by the computational efficiency of the simulation algorithms, faster algorithms are always desired [1].

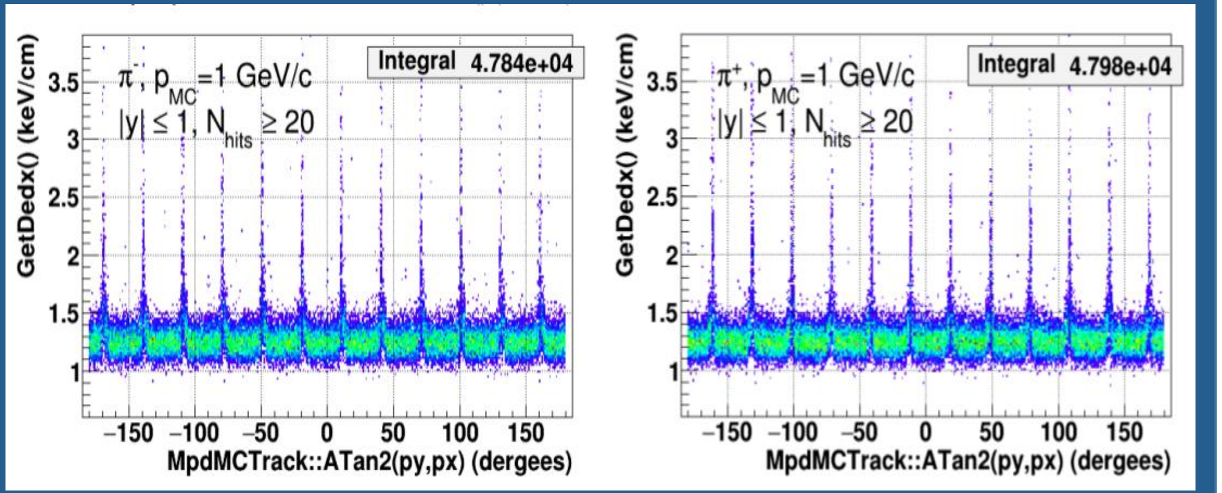
Computational efficiency of the detailed simulation is often limited by the fine granularity of the physics simulation steps being performed. Therefore, a speed-up may be achieved by aggregating a sequence of such steps with a single estimate of the probability distribution for the last step output parameters, conditioned by the first step inputs. An important requirement for such a probability distribution estimate is that it should allow for efficient sampling. Generative Adversarial Networks [2] are a good candidate for such a parametric estimate since they only require a forward pass through a neural network to generate new samples. In this work, we demonstrate an application of GANs for building a fast-simulation model of the Time Projection Chamber (TPC) detector at the MPD experiment at the NICA accelerator complex [3].

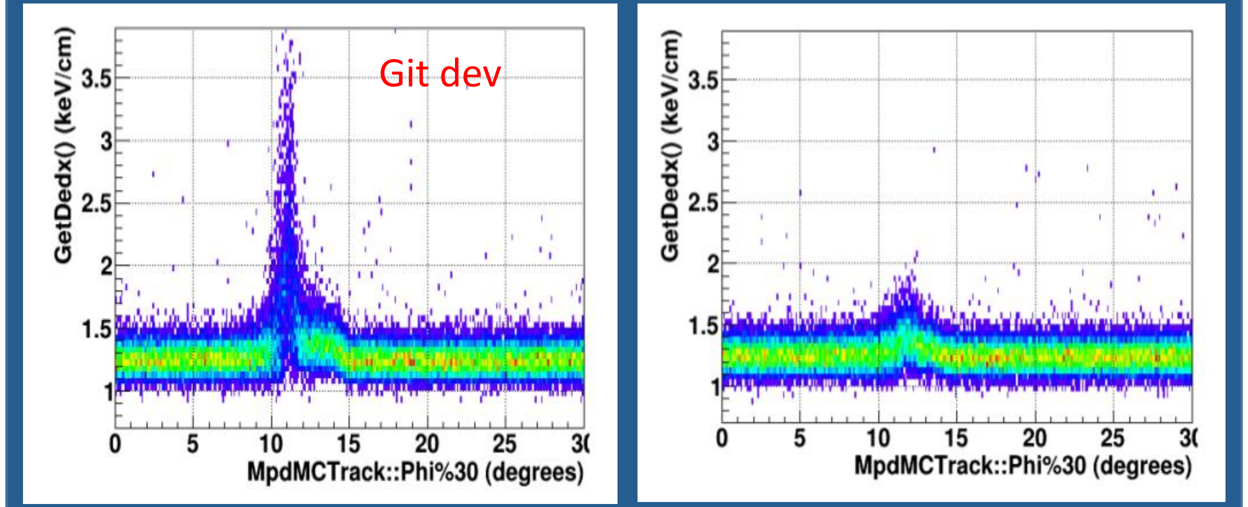
HSE team

TPC cluster finder

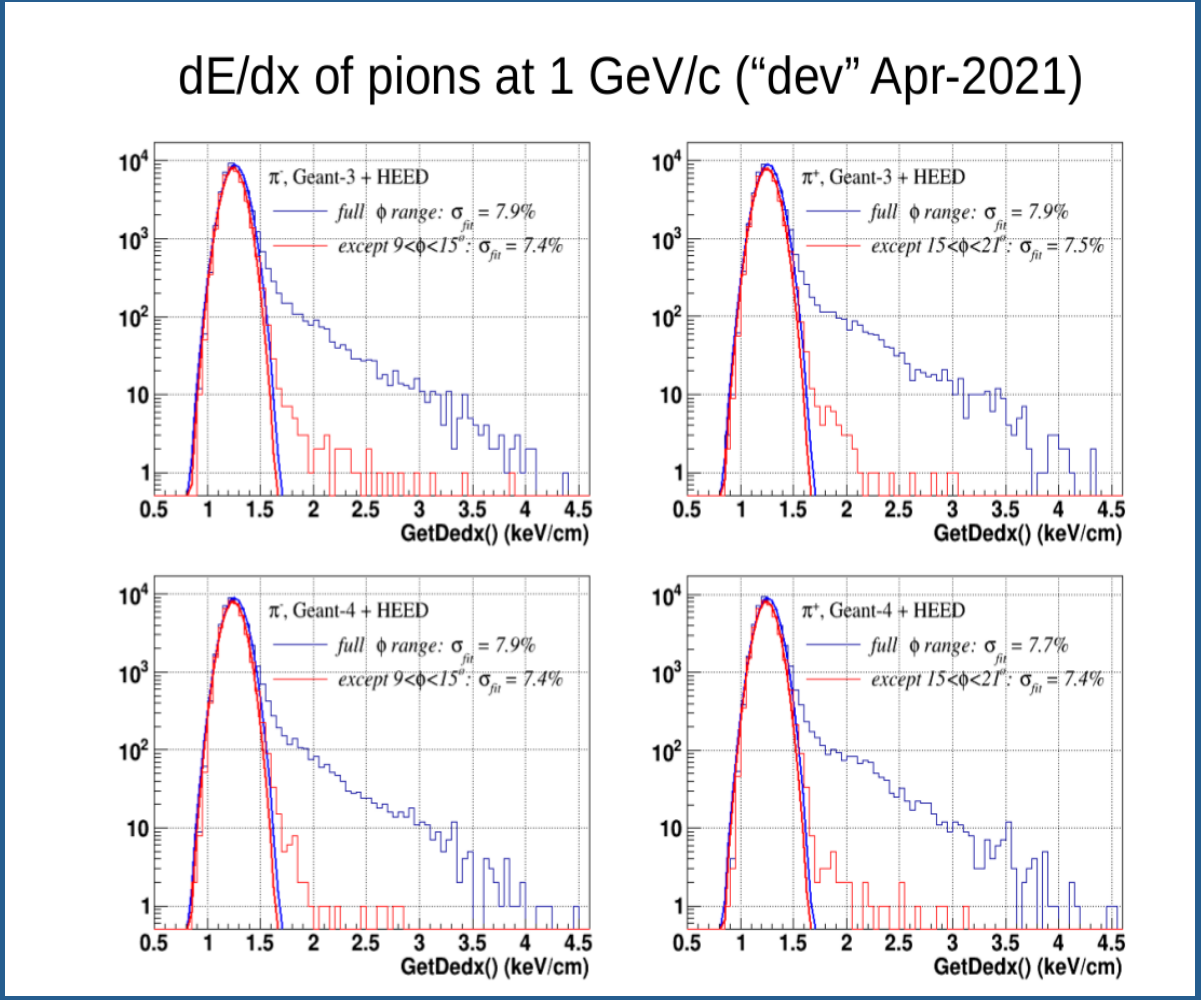
Tasks: two track separation (for femtoscopy) and cluster charge determination (for *dE/dx* identification)

Energy loss simulation in TPC

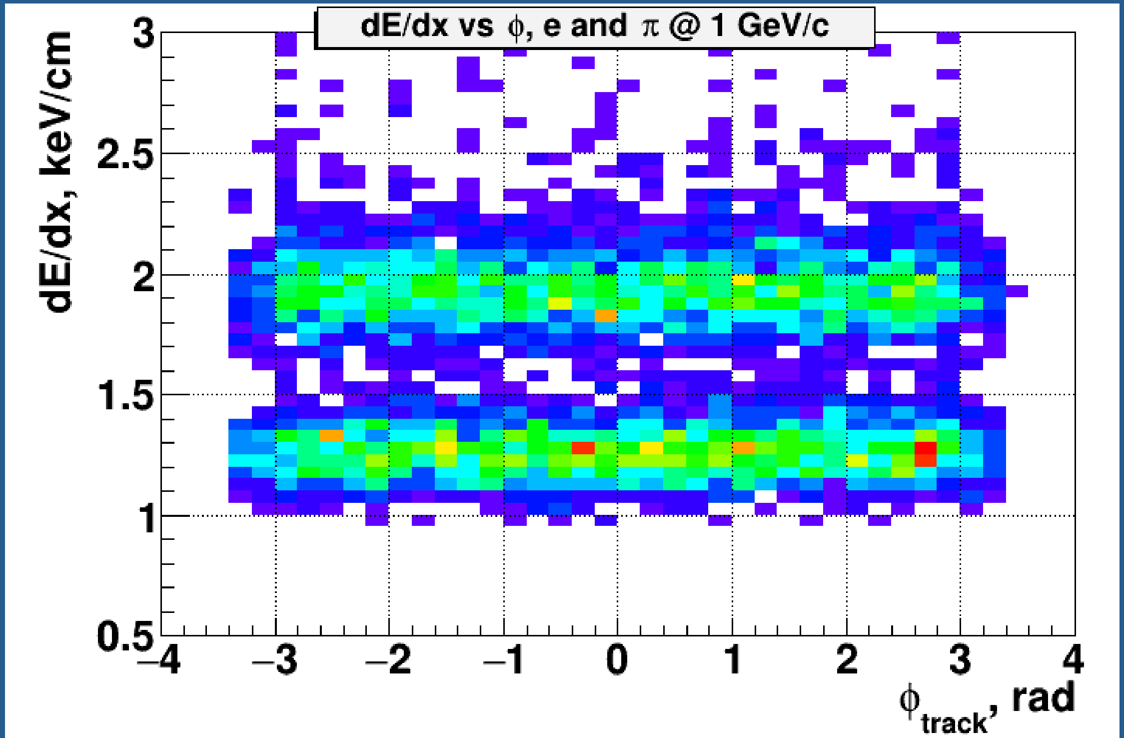


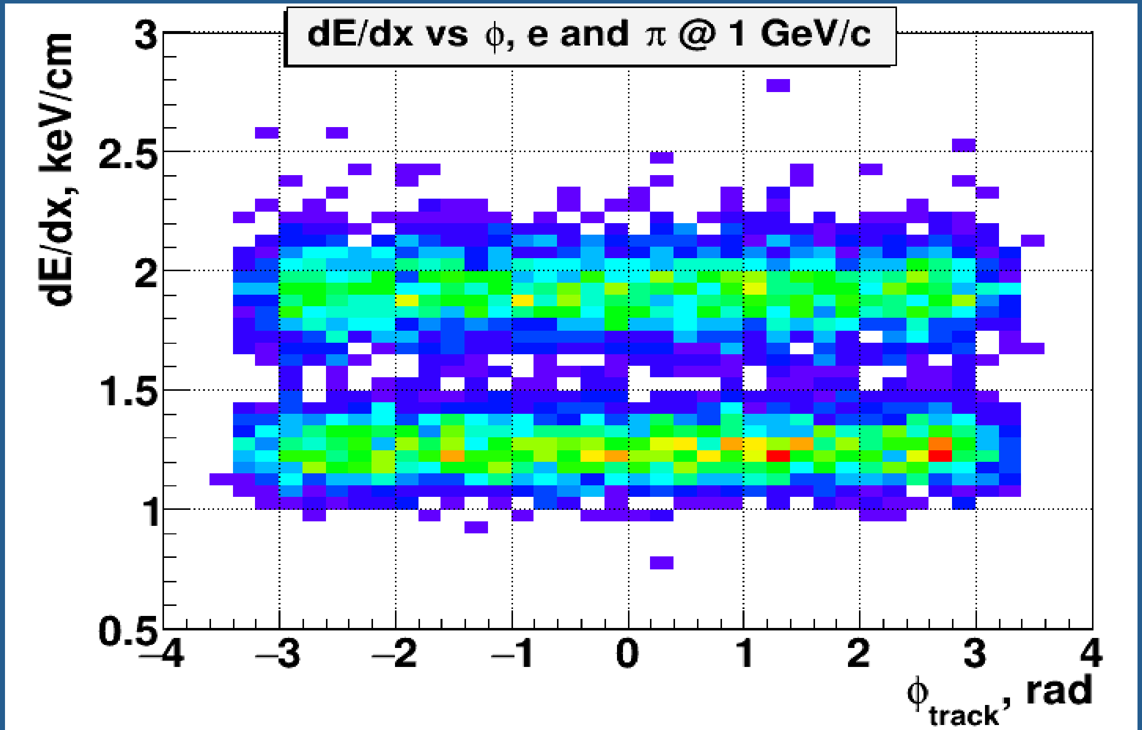


dE/dx in TPC

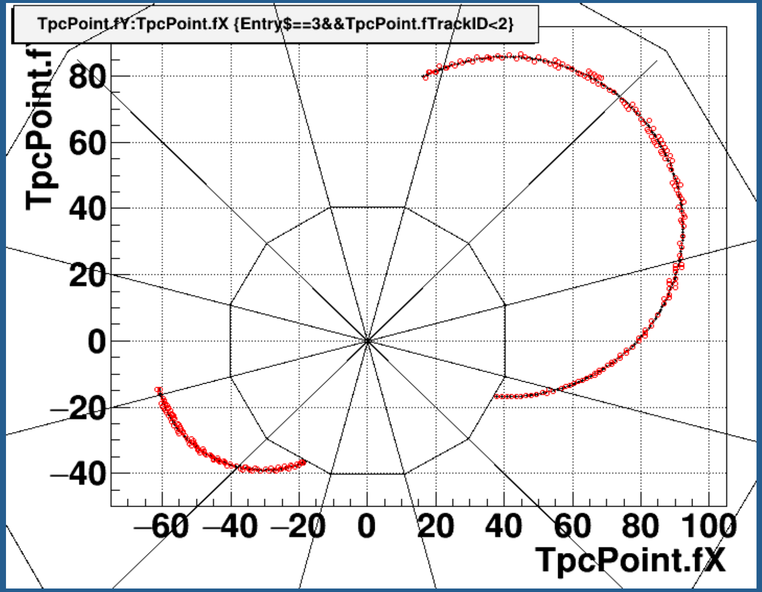


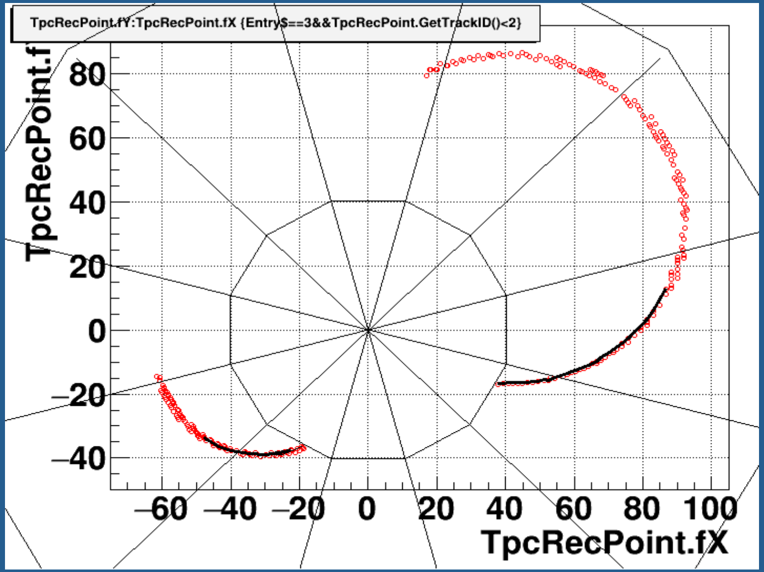
Energy loss simulation in TPC

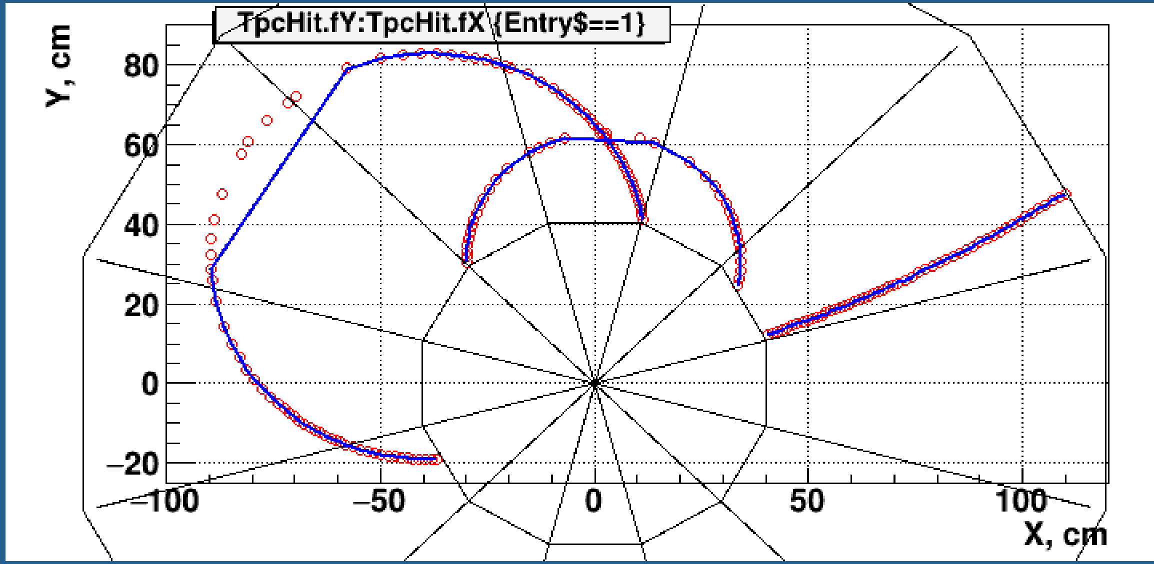




Track reconstruction: low-pT tracks



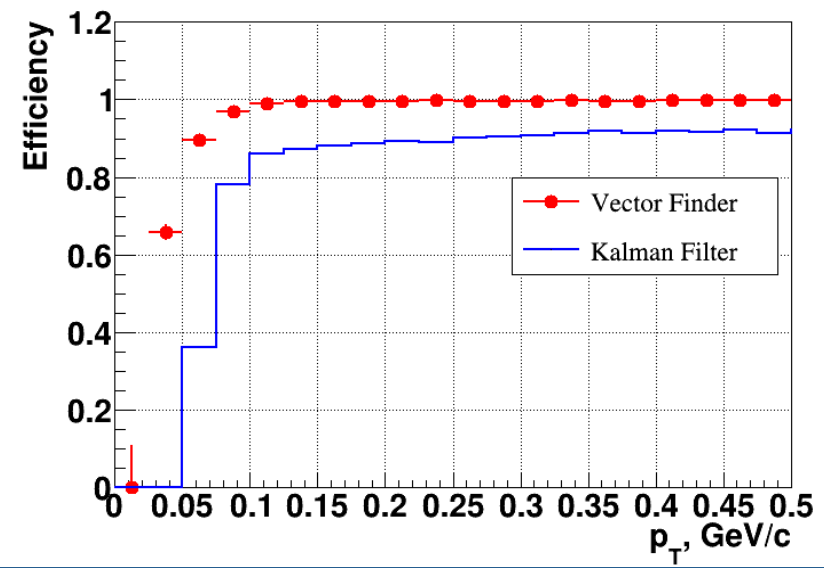


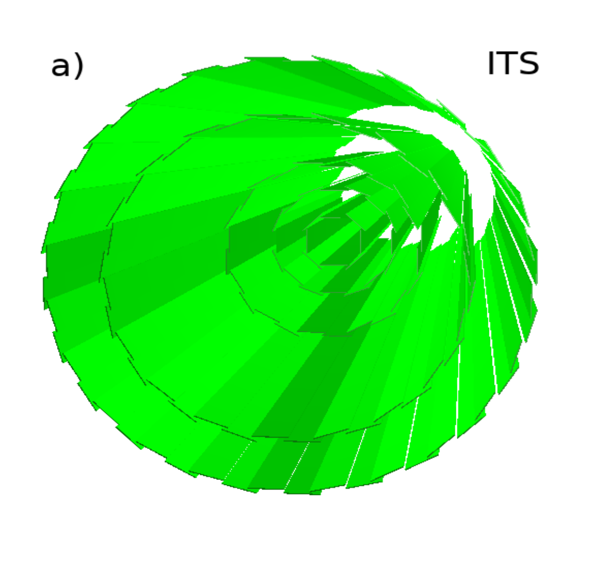


I. Tserruya, S.Rode

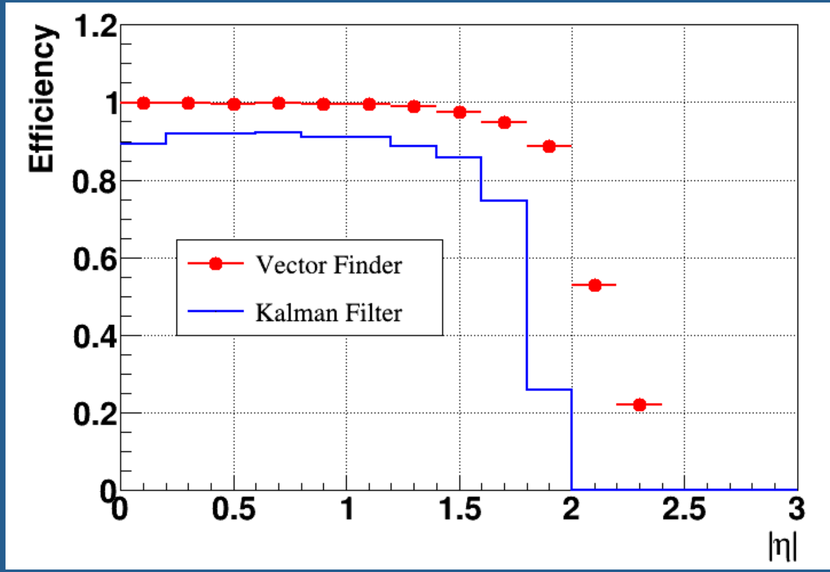
Required some changes of the Kalman filter main engine. Some additional modifications will be benefitial. Some extra tuning is needed.

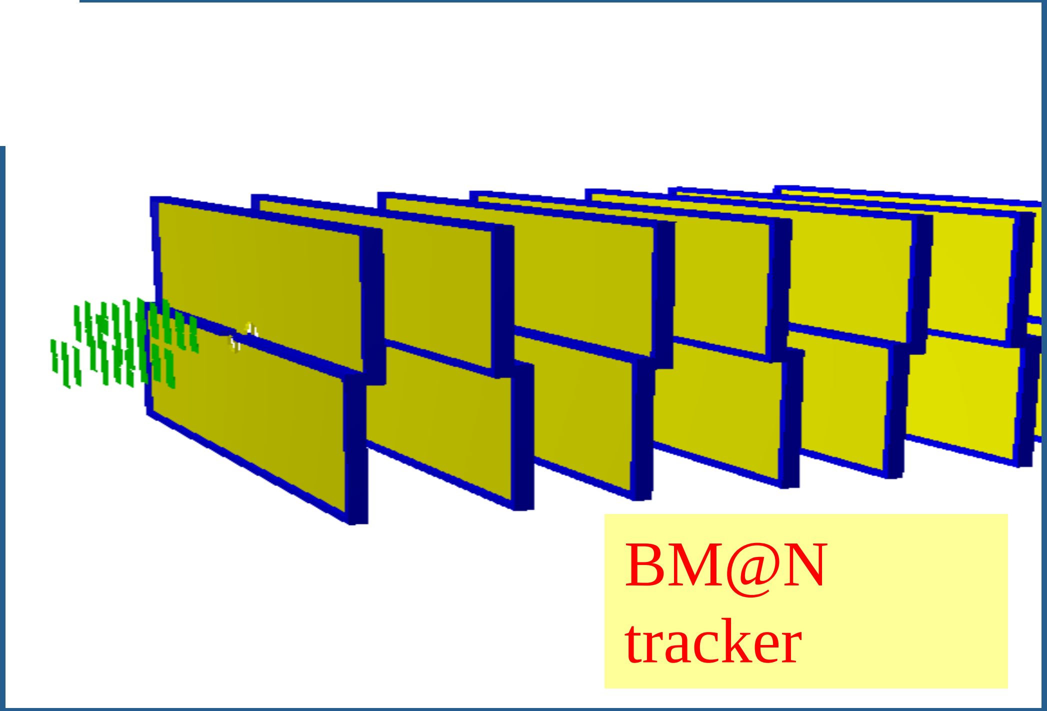
Track reconstruction: Vector Finder for ITS





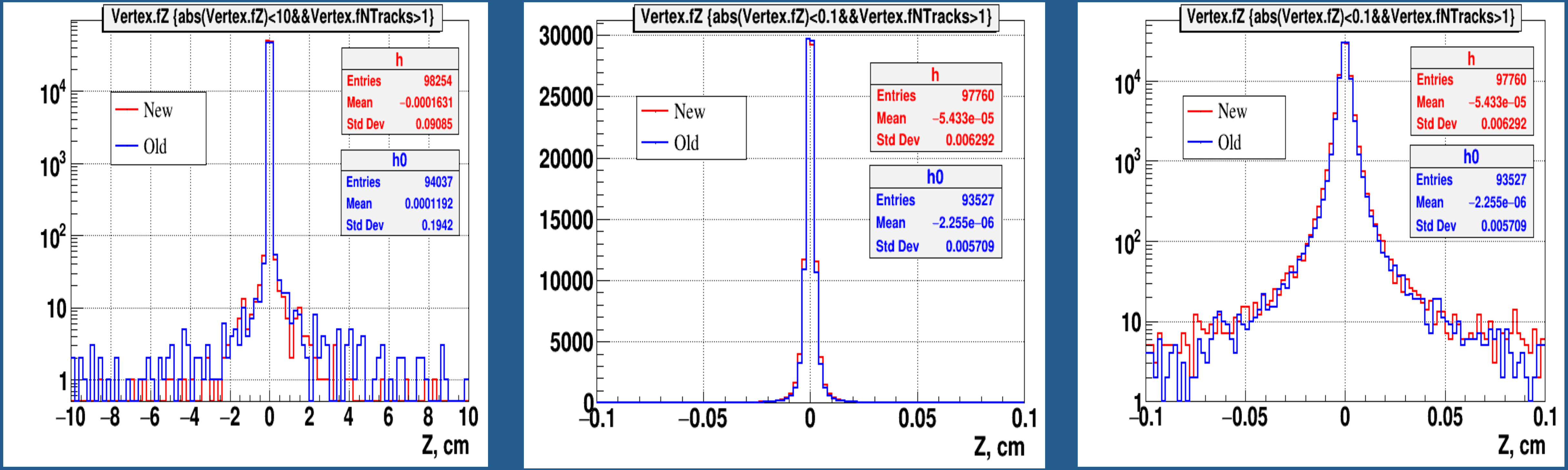
D. Zinchenko





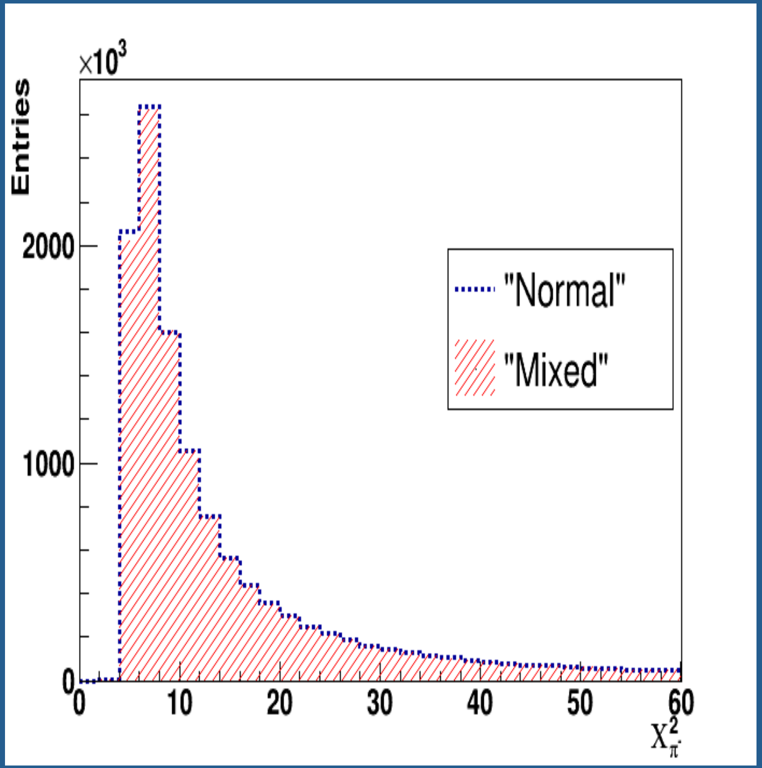
BM@N
tracker

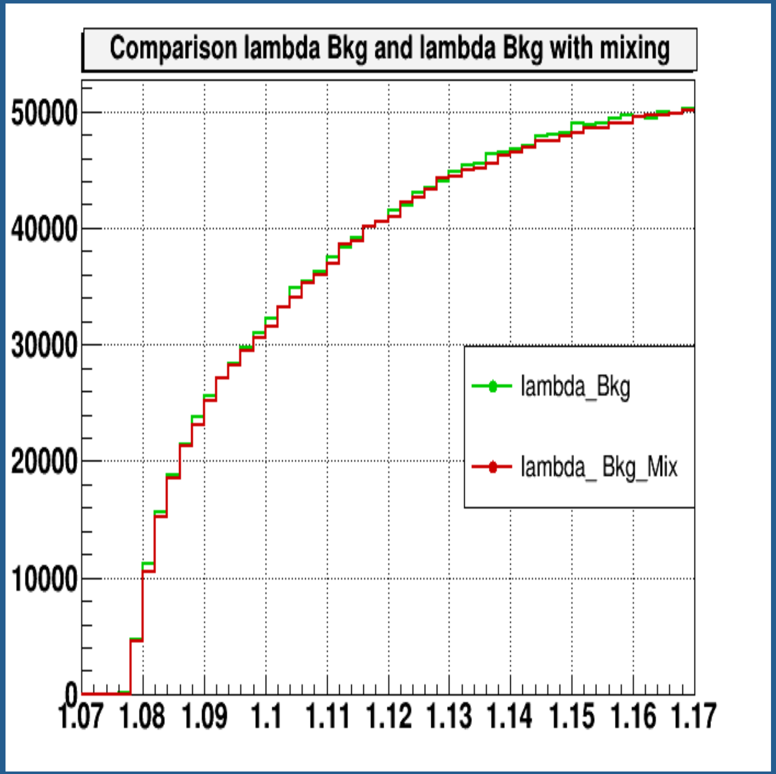
Vertex reconstruction in low-multiplicity events

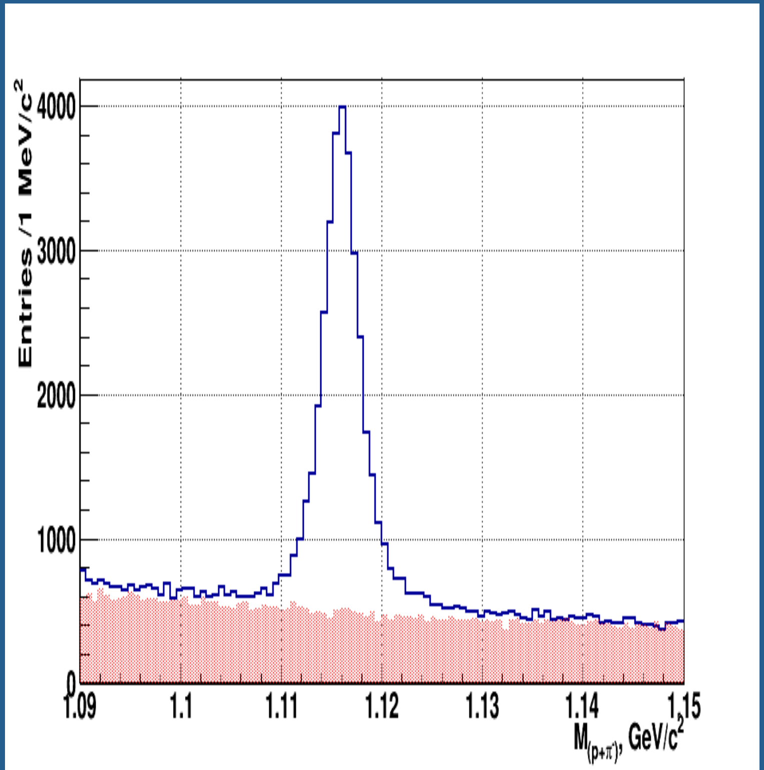


p+p @ 25 GeV
with ITS

Hyperon reconstruction (background from event mixing)







D. Suvarieva

Tracking in the end-cap region

MpdRoot classes related to the end-cap region have been removed

Summary / Outlook

- There are several active tasks on reconstruction