JOINT INSTITUTE FOR NUCLEAR RESEARCH
Veksler and Baldin laboratory of High Energy Physics

FINAL REPORT ON THE
SUMMER STUDENT PROGRAM

Adaptation of Monte Carlo simulations of the BM@N detector to the experimental data

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Participation period:
July 18 – August 30

Dubna, 2021

Abstract

The BM@N (Baryonic Matter at the Nuclotron) is an experiment at the NICA (Nuclotron-based Ion Collider fAcility) accelerator complex. The first physics runs were carried out with the collection of experimental data in 2018. Initially, the experimental data was very noisy, therefore, for the physical analysis, the track selection procedures described in this article were implemented. On the other hand, the simulated data is too idealized and the characteristics of the tracks are very different from the experiment. In this regard, the realistic effects described in this work were added to the simulation algorithm.

Contents

Introduction

Modern physics, due to the collision of nuclei on accelerators, forms conditions of extreme temperature and density, forming quark-gluon plasma. Study of the properties of this matter will help scientists unravel the mysteries of the universe.

1.1 Megaproject NICA

The mega-science NICA Complex (Nuclotron-based Ion Collider fAcility, fig. 1.1), which is being created on the basis of the Joint Institute for Nuclear Research (Dubna, Russia), will make it possible to study the properties of baryonic matter under extreme conditions.

The main scientific task is to find out of the billions of interactions observed by the detector those events and particles that will indicate that a mixed state of nuclear matter has arisen in this system. To obtain new information about the fundamental properties of matter, it is necessary to reconstruct the real picture of what happened during the interaction of the beam with the target.

Thus, the problem of reconstructing the particle trajectories is very important, since it makes it possible to carry out a physical analysis of the matter formed after the interaction of the beam ions with the target nuclei.

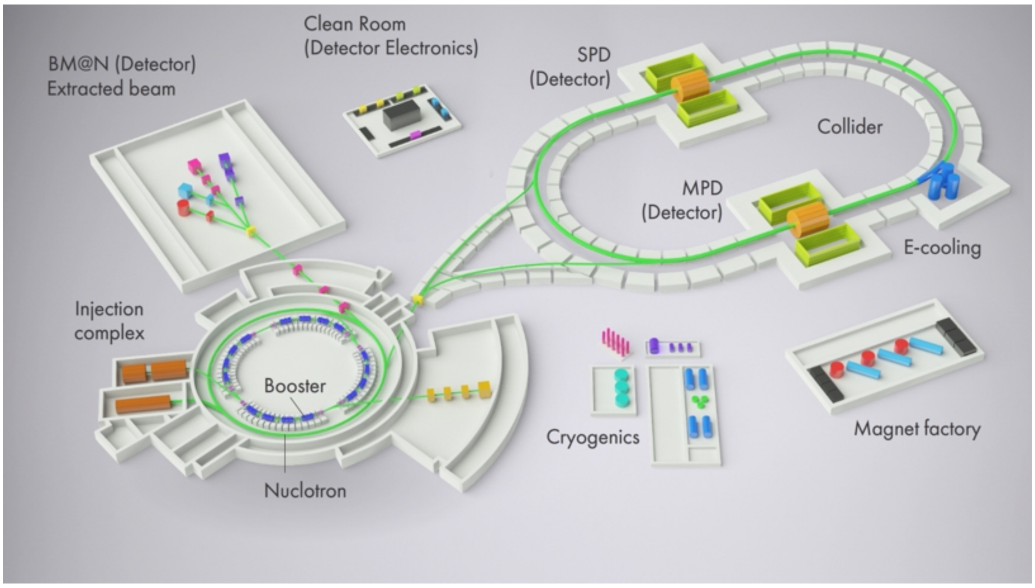


Figure 1.1: The scheme of the NICA accelerator complex

1.2 BM@N experiment

BM@N (Baryonic Matter at the Nuclotron, fig. 1.2) is the first experiment at the NICA accelerator complex, within the framework of which the physical launches of the installation were carried out with the collection of experimental data. Its characteristics allow the study of collision of particles and ions from the fixed target at energies up to 6 AGeV [2].

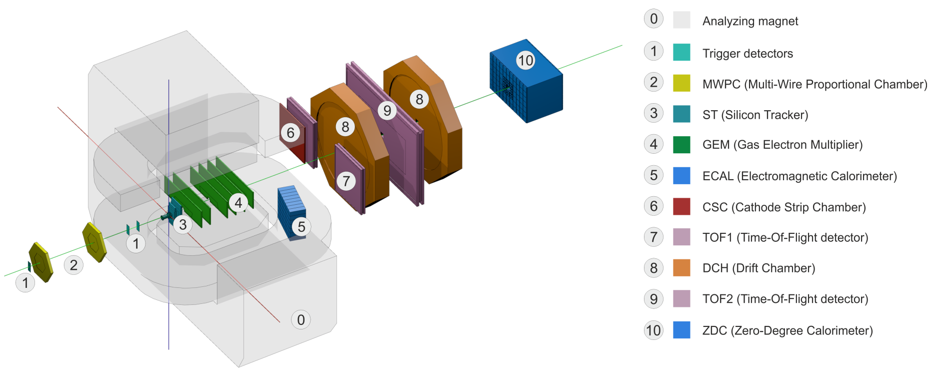


Figure 1.2: View of the BM@N experimental setup [3]

The central track system of the setup consists of three silicon detectors and six planes of gas electron multipliers located inside the magnet. When analyzing the experimental data, the reconstructed coordinates of the points created by the charged particle in the sensitive element of the detector are obtained.

The external tracking system is represented by DCH (Drift CHambers) and TOF (Time-of-Flight) detectors. The TOF400 and TOF700 cameras, located 400 cm and 700 cm from the target, determine the time it took for the particle to reach the detector. TOF400 detectors are positioned to the left and right of the direction of beam travel to record tracks with a smaller radius of curvature.

Experimental data processing

The track reconstruction algorithm in the BM@N experiment consists of two stages: reconstruction of trajectories in the central track system for detectors located inside the magnet, and combining the reconstructed trajectories with hits from detectors behind it.

However, the experimental data turned out to be too noisy for physical analysis (see fig. 1.3), so additional procedures were carried out to filter them.

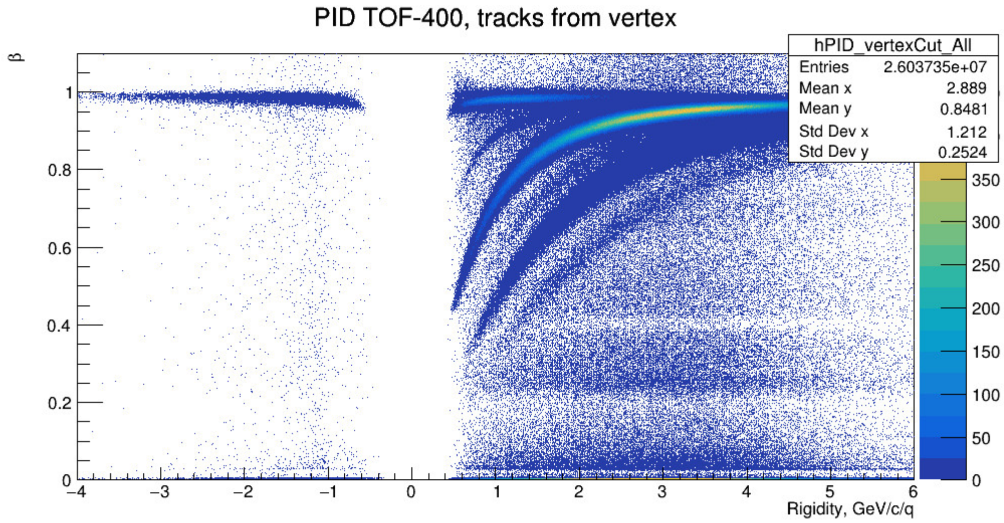


Figure 1.3: Dependence of particle velocity on magnetic rigidity

1.3 Additional conditions for selecting tracks

The implemented algorithm selects global tracks for which the reconstructed vertex is in a certain range. To determine the region in which the vertex is located, from all experimental files, the events of collision of an argon beam with target nuclei were considered and the coordinates of the vertex in each event were stored on the histogram. The distributions of the vertex coordinates are shown in fig. 1.4.

Based on the data obtained, the following coordinate ranges were selected

$$V_x \in (-1, 2),\ V_y \in (-5, -2),\ V_z \in (-4, 2).$$

At the first step, the selected tracks are extrapolated using the Kalman filter through the hits in the planes of the silicon detector and gas electron multipliers that belong to this track.

At the second step, the track from the TOF detector is extrapolated to the vertex through all the hits found, and at the same time its length is calculated. If, during back extrapolation, the trajectory falls within the specified range for the vertex, then its parameters are saved for further physical analysis.

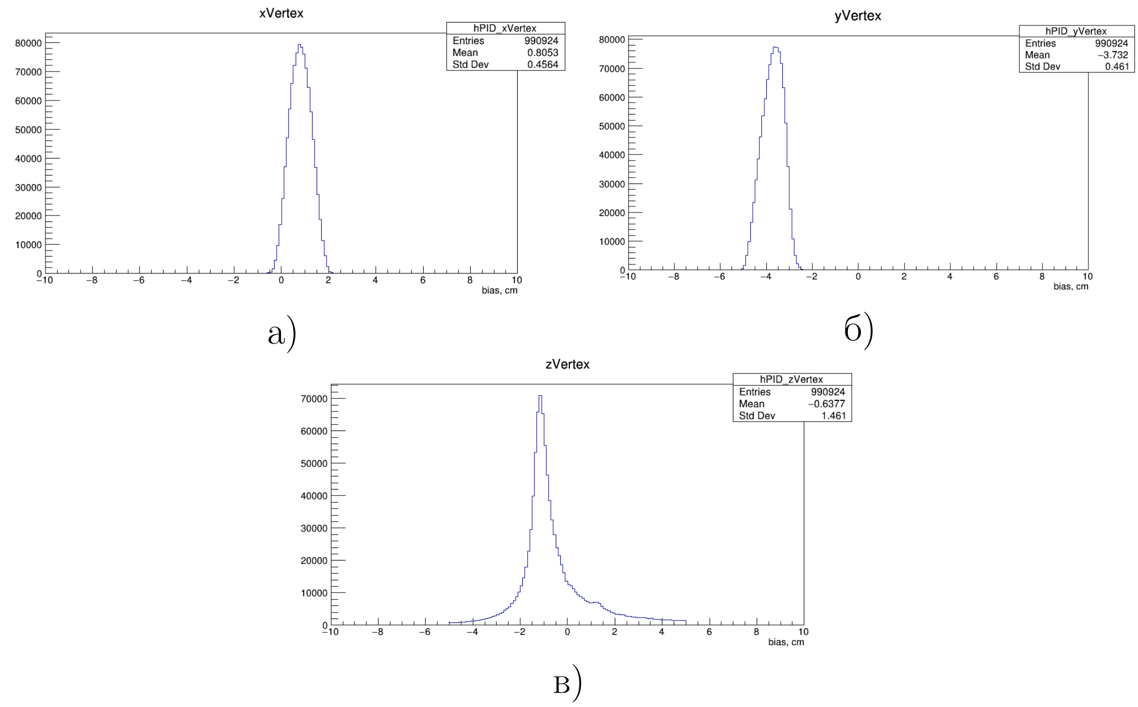


Figure 1.4: Vertex range by coordinate a) x; б) y; в) z

After the track selection procedures, the data quality improved significantly. The experimental curves for particles are shown in fig. 1.5.

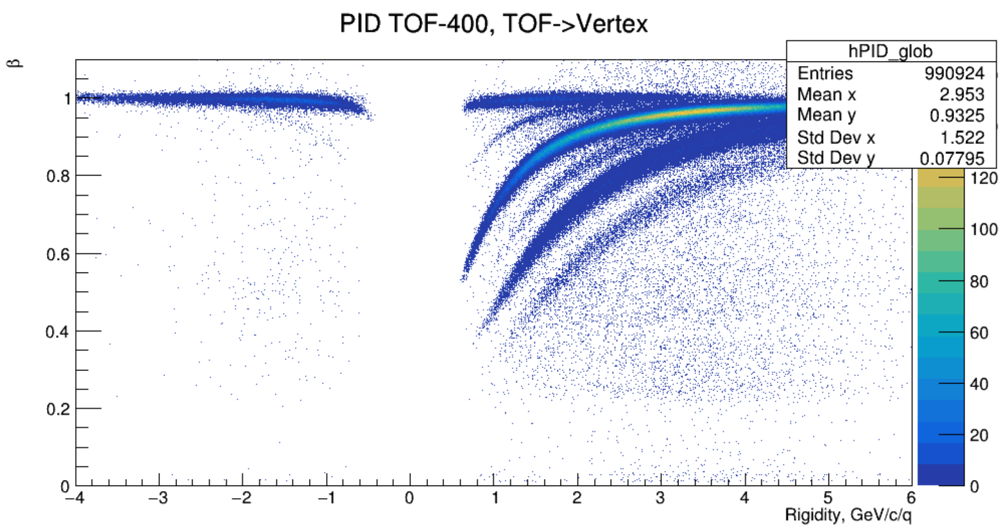


Figure 1.5: Dependence of particle velocity on magnetic rigidity

An additional condition reliability track is the number of hits. Fig. 1.6 shows histograms of tracks with at least 1 hit in silicon and more than 3 hits in gas electron multipliers. In the future, these tracks will be selected for physical analysis.

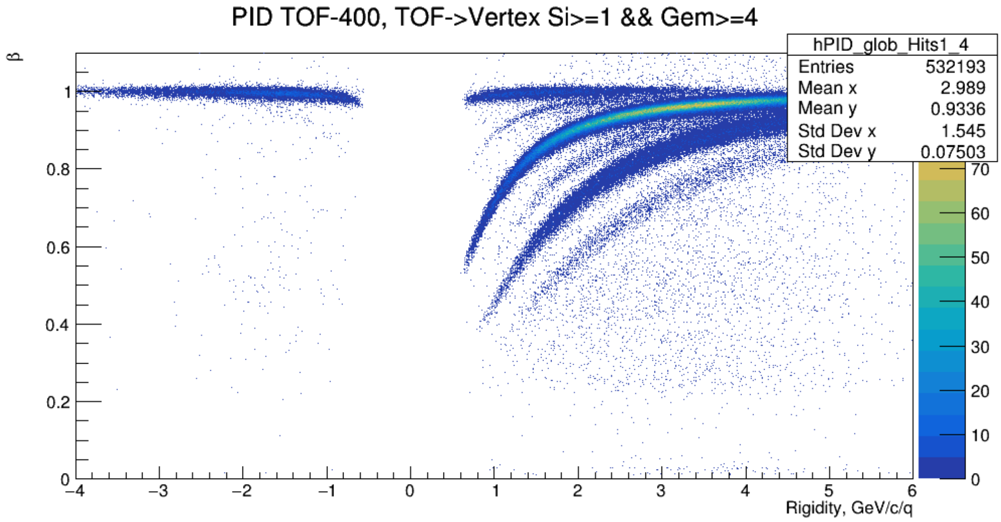


Figure 1.6: Dependence of particle velocity on magnetic rigidity

Monte Carlo data processing

For simulation the events, the DCMSMM was used [4]. It generated collision of an argon beam with a Pb target with an energy of 3.2 AGeV. The histograms of the dependence of the velocity on the magnetic rigidity for the simulated data are shown in figure 1.7.

It follows from the figure presented that the distribution of the velocity from the momentum, in contrast to the experimental data, slightly

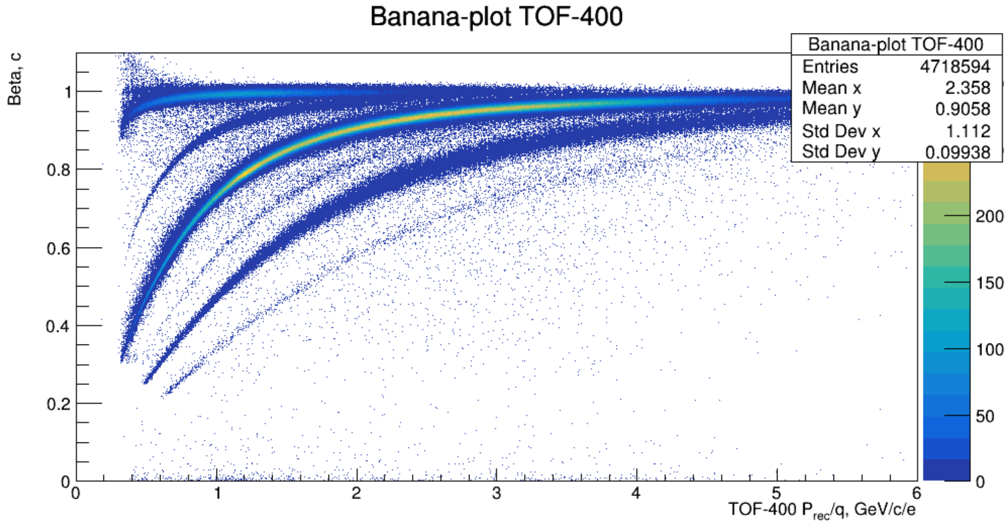


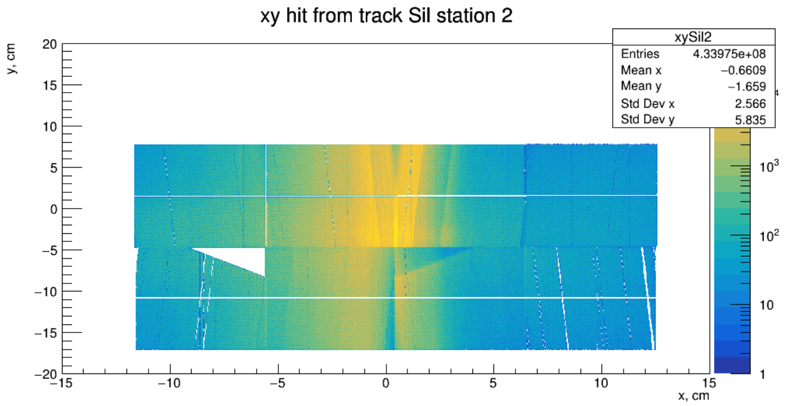
Figure 1.7: Dependence of particle velocity on magnetic rigidity

differs from the theoretical curve. Therefore, additional realistic effects must be added to the simulated data.

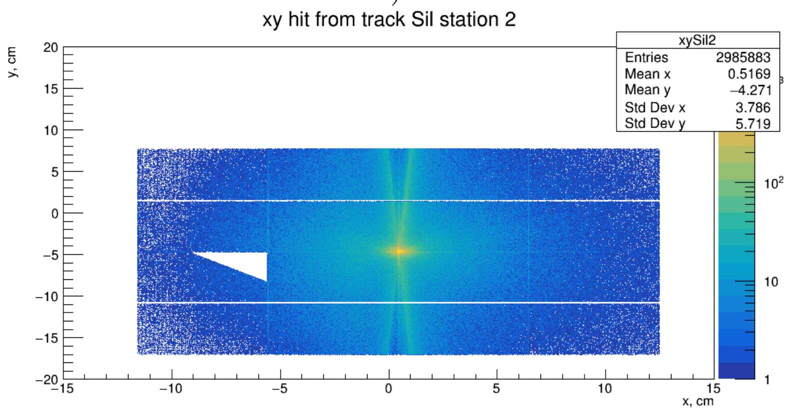
1.4 Adding realistic effects

The efficiency of reconstruction of experimental events is lower, since some zones of the readout electronics may not work. Figures 1.8a, 1.9a show the distributions of hits in the experimental data for a silicon station and a gas electron multiplier. These histograms clearly show non-working zones.

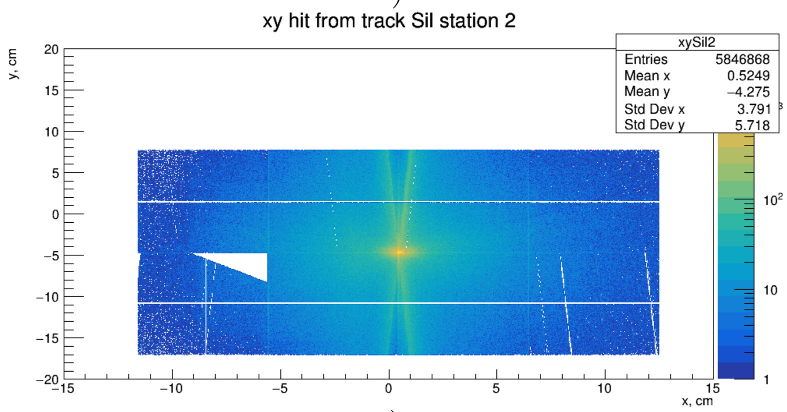
For Monte Carlo data, these effects do not appear (see fig. 1.8b, 1.9b). Therefore, the ability to turn off the strip if it worked less than a certain threshold value in the experiment was added to the modeling process. The obtained distributions of hits by stations for simulated data with masking of idle strips are shown in fig. 1.8c, 1.9c.



a)

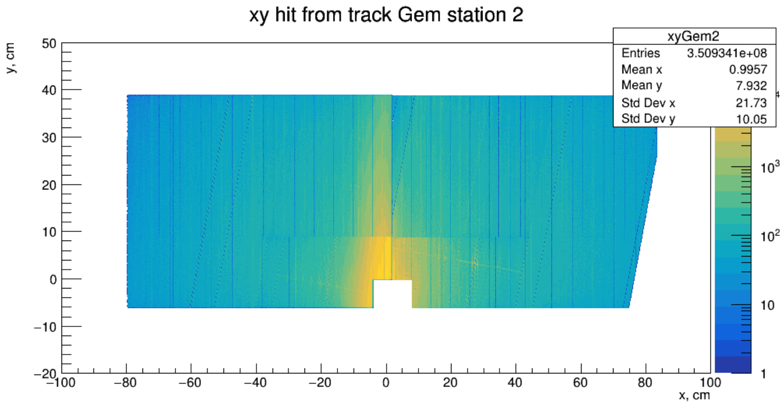


b)

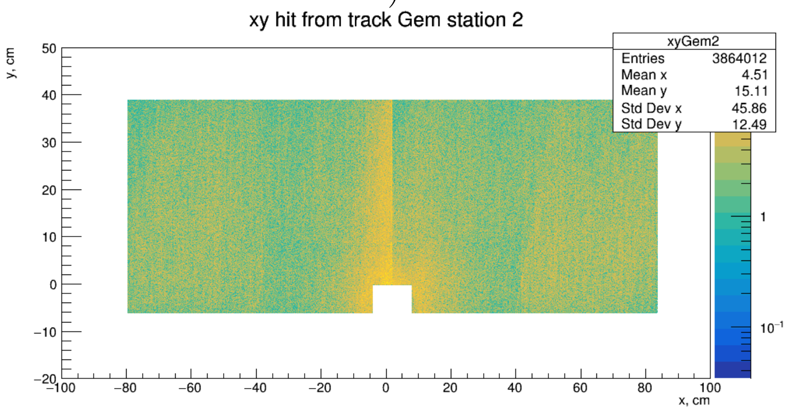


c)

Figure 1.8: Distribution of hits in a silicon station for a) experimental data; b) simulated data; c) modified Monte Carlo data



a)



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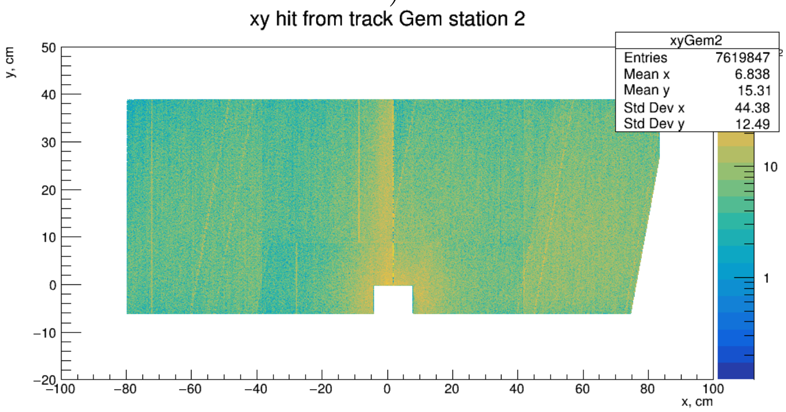

c)

Figure 1.9: Distribution of hits in a gem station for a) experimental data; b) simulated data; c) modified Monte Carlo data

Summary

During the summer practice, important tasks were completed, necessary for the physical analysis. At the first stage of the work, algorithms were implemented and parameters were selected that select only reliable physical events from the experimental data. At the second stage, realistic effects that were present in the experiment were added to the process of generating simulated events. The realized algorithms will be further used to identify particles from selected experimental events and to evaluate the efficiency of reconstruction obtained from modified Monte Carlo data.

Bibliography

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