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HIT FINDER AND TRACK RECONSTRUCTION ALGORITHMS IN THE MULTI-WIRE PROPORTIONAL CHAMBERS OF THE BM@N EXPERIMENT

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The BM@N experiment is a part of the NICA accelerator complex at the Joint Institute for Nuclear Research, Dubna. The main goal of the research program on this detector is to study the interactions of relativistic heavy ion beams with fixed targets. BmnRoot software is used to process both experimental and simulated data. Not all the detectors, however, are included in the reconstruction chain. One of them is the Multi-Wire Proportional Chamber (MWPC). Here we present the description of the MWPC detector geometry and the algorithms for digitizing, hit finding and track reconstruction. The results of simulation are given.

Keywords: BM@N, NICA, Multi-Wire Proportional Chamber, MWPC, track reconstruction, hit finder, digitizer, BmnRoot

1. Introduction

NICA (Nuclotron-based Ion Collider fAcility) [1] is a new accelerator complex designed at the Joint Institute for Nuclear Research (Dubna, Russian Federation) to study properties of dense baryonic matter. BM@N experiment (Baryonic Matter at Nuclotron) [2] has the purpose of studying the collisions of elementary particles and ions with a fixed target. The BM@N setup consists of the set of coordinate detectors for reconstruction of charge particle trajectories, time-of-flight detectors for particle identification and calorimeters for energy measurements (Fig. 1).

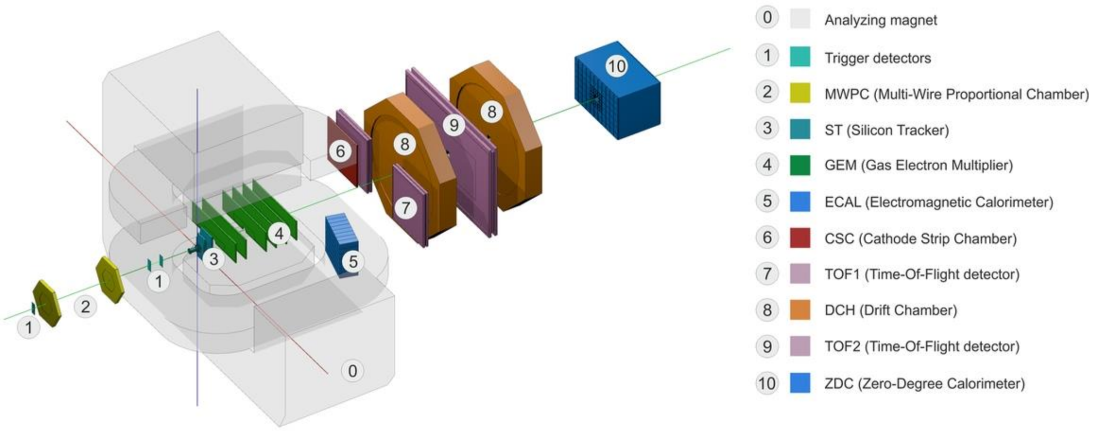


Figure 1. Three-dimensional view of the BM@N facility

BmnRoot framework [3] is used for the BM@N experiment data processing. It provides a powerful tool for detector performance studies, event simulation and development of algorithms for event reconstruction and physics analysis of experimental data registered by the BM@N facility. The BmnRoot is implemented in the programming language C++ and based on the ROOT [4] environment and the object-oriented framework FairRoot [5].

The detector inclusion in the simulation and reconstruction chain can be divided into several stages:

- creating the detector geometry to describe particle interactions with the detector;
- detector digitization – transformation of simulated data into detector signals;
- development of particle track reconstruction algorithms.

2. Multi-Wire Proportional Chamber

Multi-Wire Proportional Chambers are used to determine the trajectory of a particle beam. The detector is a chamber filled with a mixture of gases, in which anode wires are located between the cathode planes (Fig. 2). Upon entry, a charged particle causes ionization of the gas, and the generated electrons under the action of the electric field of the chamber trigger the wire closest to the particle's trajectory.

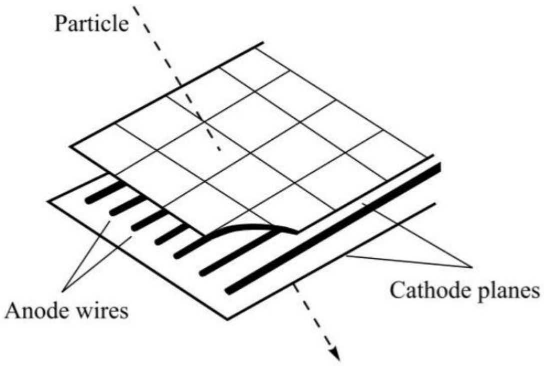


Figure 2. Structure of the MWPC detector

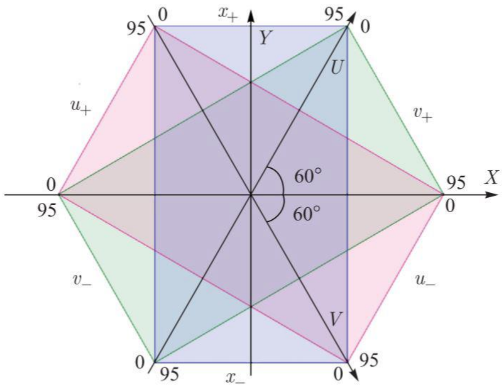


Figure 3. Coordinate system of the MWPC detector [6]

In the BM@N experiment, the MWPC detector incorporates six flat planes consisting of 96 wires each. Each plane is rotated by 60° relative to the previous one. The distance between the wires withinin one plane is d_w = 2.5 mm, and the inter-plane distance within in a chamber is 10 mm. In a Cartesian coordinate system the *z* axis is perpendicular to the planes. The coordinate system of the detector is shown in (Fig. 3). In this representation, the planes have the sign "+" or "−" depending on the increasing or decreasing numbers of the wires along the coordinate axis.

The detectors are located before the magnet, so straight lines can approximate particle trajectories.

3. Detector geometry

Simulations require a description of the detector geometry, its proportions, materials and location. The ROOT geometry package is used for this purpose. It is a tool to build, browse and visualize detector geometries. Previous version of MWPC geometry described only the active parts involved in the interactions, but the detector also contains frames and some additional materials where new particles may appear, and this should be taken into account (Fig. 4).

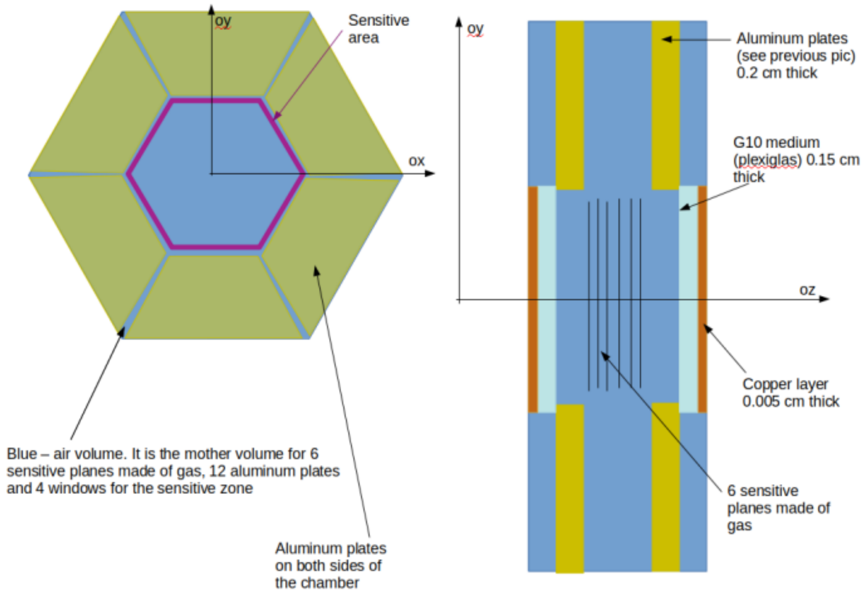
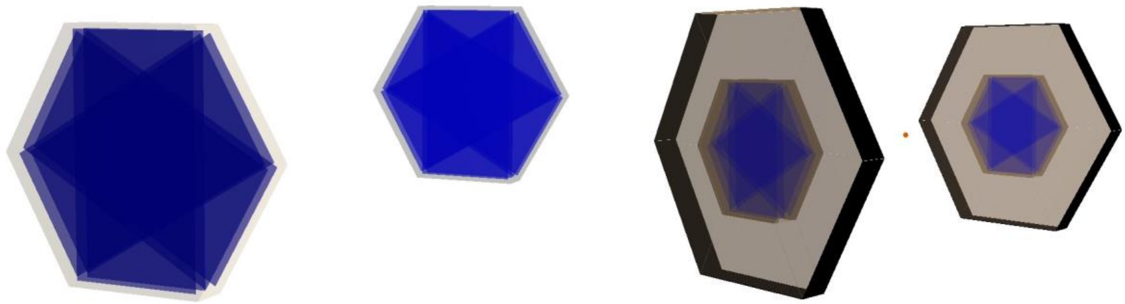


Figure 4. Schematic view of the MWPC detector

We have added aluminum frames around the detector and layers of copper and fiberglass on both sides of the stations to the new version of the geometry. The comparison between the detector models is presented in (Fig.5).



a) Old geometry b) New geometry

Figure 5. Comparison of detector models

4. Monte Carlo data digitization and hit reconstruction

The main purpose of the reconstruction procedure is to process the experimental data. For further tests of track reconstruction, however, processing the simulated data is also important. It should be brought to the same form with the experimental data. For this purpose the BmnMwpcDigitizer class has been developed and incorporated into BmnRoot framework. The coordinate data obtained during the simulation must be digitized, that is, presented as a discrete set of wire numbers and detector planes. Based on the geometry of the detector, this can be done by rounding to integers the following expressions for different planes: $n_{x_+} = \frac{x}{d_w} + 47.5$, $n_{u_+} = \frac{u}{d_w} + 47.5$, $n_{v_-} = 47.5 - \frac{v}{d_w}$, $n_{x_-} = 47.5 - \frac{x}{d_w}$, $n_{u_-} = 47.5 - \frac{u}{d_w}$, $n_{v_+} = 47. + \frac{v}{d_w}$.

The next step is creating three-dimensional reconstructed points - hits, on which tracking will be built. The BmnMwpcHitMaker class has been developed and incorporated into BmnRoot framework. Tracks are built based on three hits obtained from six values of the detector wire numbers, one from each plane.

The intersections of wires in planes 0-1, 2-3 or 4-5 are converted into a hit, the *z* coordinate of which is taken as the average between the coordinates of the planes, and the remaining coordinates are calculated based on the detector geometry.

Hit 1	Hit 2	Hit 3
$x = (n_{x_+} - 47.5)d_w$ $u = (n_{u_+} - 47.5)d_w$ $y = \frac{2u - x}{\sqrt{3}}$	$v = (47.5 - n_{v_-})d_w$ $x = (47.5 - n_{x_-})d_w$ $y = \frac{x - 2v}{\sqrt{3}}$	$u = (47.5 - n_{u_-})d_w$ $v = (n_{v_+} - 47.5)d_w$ $x = u + v$ $y = \frac{2u - x}{\sqrt{3}}$

5. Track reconstruction algorithm

The particle tracks are built on three hits. This is being performed by the BmnMwpcTracking classthat we have developed. At first, the data read from the BmnMwpcHits branch is sorted into three planes corresponding to different *z* coordinates. Further, all the hit combinations from different planes are approximated by straight lines using the least squares method and the best ones are selected from them by the chi-squared test.

The following functional is being minimized:

$$\sum_i \frac{d_i^2}{\sigma^2} \rightarrow min$$

where d_i is the difference between the hit coordinates and the approximated coordinates in the i-th plane, $\sigma = d_w/\sqrt{12}$ = 0.072 cm is the standard deviation.

If more than 60% of the hits in a track refer to the same simulated track, then the reconstruction is considered correct. The efficiency of the algorithm for track reconstruction for 1, 2, and 3 simulated tracks in an event as a function of the polar angle θ is presented in (Fig. 6).

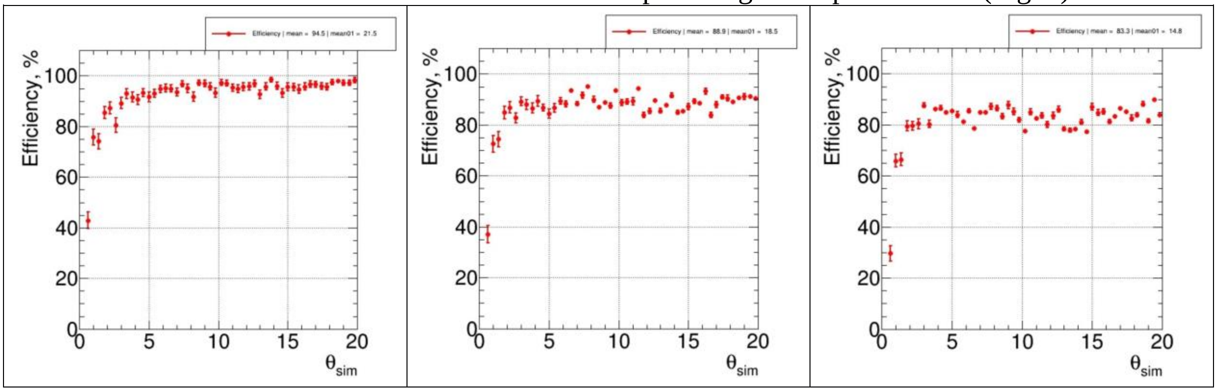


Figure 6. Efficiency of track reconstruction for 1, 2 and 3 particles in event

6. Conclusion

The realistic geometry of the MWPC detector that includes the surrounding materials is described. It turned out that the material around the detector has a small effect on the appearance of new particles in it. Classes for digitizing the simulated data and finding reconstructed hits on which tracking is built is developed and incorporated into BmnRoot framework. Track reconstruction algorithm and an algorithm for merging tracks in a two chamber system have been developed.

7. Acknowledgement

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