Track Reconstruction in the BM@N Experiment

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Abstract. The BM@N experiment (Dubna, JINR) within the NICA complex is a running fixed target experiment. This paper mainly discusses the software support of the experiment and presents the status of the development and testing algorithms to be used for the reconstruction of heavy-ion collisions. Algorithms of reconstruction are described and tested with Monte Carlo input demonstrating a reasonable level of quality assurance. First results on particle identification being a good probe to estimate quality of reconstruction are also mentioned.

1 Introduction

BM@N (Baryonic matter at Nuclotron) [1] is one of the experiments performed at the NICA complex [2]. It aims at studying the interaction of heavy ion beams with fixed targets. The experiment includes high-precision measurements of particle trajectories and Time-Of-Flight (TOF) measurements that allow particle identification. The last experimental run was performed on spring 2018 with argon and krypton beams.

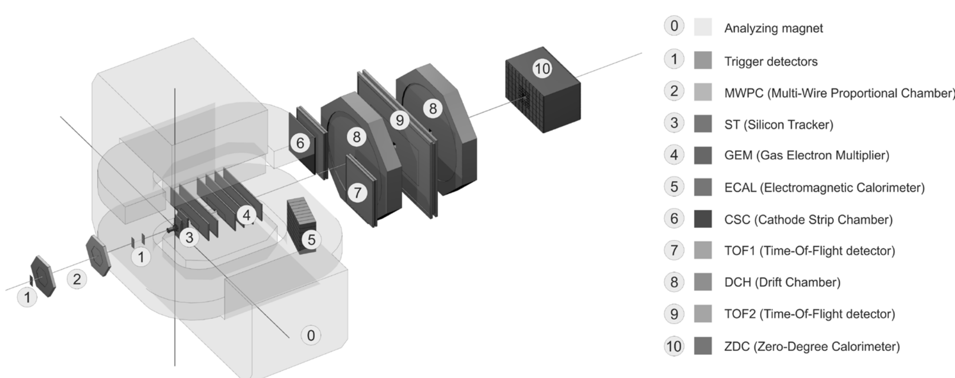

Figure 1. BM@N experimental setup for technical run on spring 2018 [6].

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The reconstruction of charged particle trajectories is one of the most important and time consuming tasks in the event reconstruction procedure. An algorithm used to this aim should be quite flexible and fast. Moreover, taking into account the different sets of detectors used in the experimental runs already performed and the fact that the last run comprised two configurations of the experimental setup, BM@N, and the Short Range Correlation Program (SRC) at BM@N, a candidate for the algorithm should fulfil a set of requirements. The following list of options to be selected automatically within the algorithm is obligatory:

- The configuration of the experimental setup to be used, BM@N or SRC.
- The list of detectors to be included into the reconstruction procedure.
- The input data type, e.g., Monte Carlo or experimental.
- Presence or absence of appropriate magnetic field, target etc.

Another important thing is related to the scalability of the algorithm. Indeed, the possibility to extend the algorithm for future configurations of the experimental setup with minimal modification, in particular, in the sense of the mentioned options, is considered as a benefit. When searching for a candidate for the algorithm, a huge work has been done. Finally, an algorithm based on cellular automaton [3] was chosen. Once chosen and tested, it was incorporated into the **`BmnRoot`** software [4, 5] to be used for its main purpose.

2 Description of the algorithm

Cell is considered as a base element of the algorithm. It is defined as a line segment connecting two hits pertaining to different planes of inner tracker consisting of GEM and silicon trackers (see Fig. 1). To get a more detailed description of the algorithm one is referred to [6], but, nevertheless, its main steps are given here:

1. cells creation,
2. cell states calculation,
3. track-candidates creation,
4. parameters of candidates smoothing,
5. candidates sorting,
6. tracks selection.

3 Testing of the algorithm

The developed algorithm is applicable to the reconstruction of curved tracks in magnetic field as well as straight ones when there is no magnetic field. A set of quality assurance tests performed with the Monte Carlo input containing minimal bias interactions of argon beam with kinetic energy of the order of 3.2 AGeV with lead target showed reasonable values of tracking efficiency of the order of 80 % for a wide momentum range and momentum resolution (see Fig. 2).

A visible decrease of efficiency observed in the momentum region over 3 GeV/c could be explained by the larger number of fragments as compared to the lower momentum values. The fragments cross the detector just in a narrow spatial cone, thus it does not help one to understand why the maximal efficiency is not higher than 80 %. Probably, it could be explained within the existing readout structure of the GEM detectors.

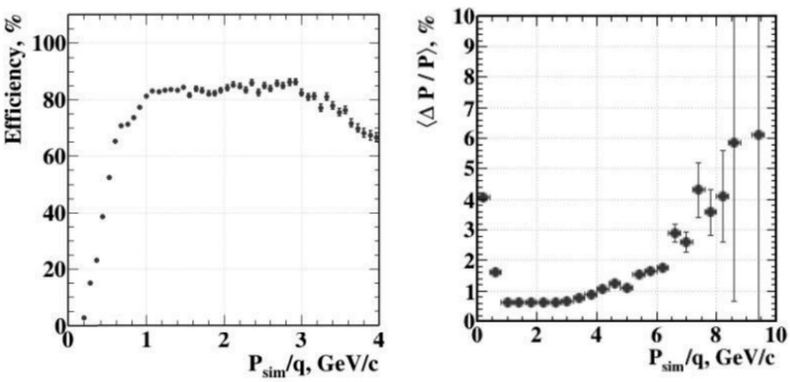

Figure 2. Left panel: tracking efficiency as a function of momentum. Right panel: momentum resolution as a function of momentum.

4 Fake hits

The existing readout structure of the inner tracker results in a large number of false strip intersections (called further "fake hits") due to the charged particles passing through the detector very close to each other (see Fig. 3).

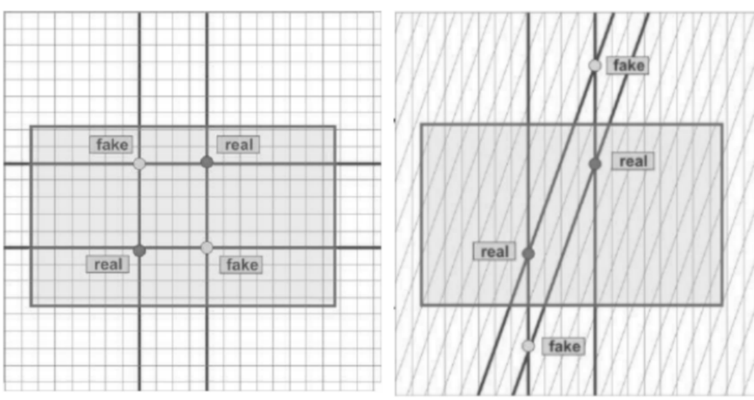

Figure 3. Scheme of fake hits production.

For n real hits and orthogonal strips the number of fake hits is calculated as $n^2 - n$. One way to decrease their number is to rotate strips of one layer at a relatively small angle (5°–15°) with respect to the other layer. In this case the number of fake hits is given by $(n^2 - n)\sin\alpha$, where α is the angle between strips.

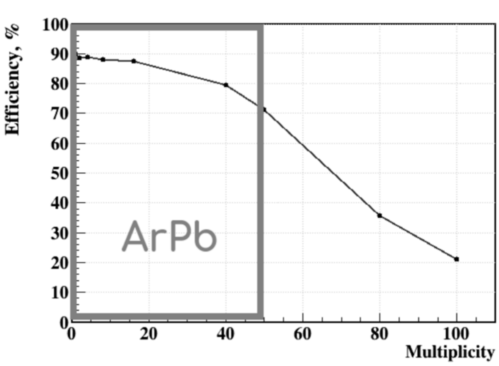

Figure 4. Dependence of the tracking efficiency on the particle multiplicity in events.

Taking the Monte Carlo sample used for testing the tracking algorithm, one can estimate the average number of charged particles (having at least 4 hits) to be reconstructed in an event (multiplicity) equal to 50. Such “real multiplicity” produces a huge number of hits in the detector, close to 2000. Surely, they contain an essential fraction of fake hits resulting in reconstructed tracks not presented in the Monte Carlo sample.

In Fig. 4 the mean efficiency of the track reconstruction as a function of different numbers of charged particles per event is shown. The framed region corresponds to ArPb-collisions. The tracking algorithm in its current state is able to process such charged multiplicities for tracks consisting of real and, of course, fake hits, but for the well known future upgrade of the experimental setup and use of gold ions in the collisions planned to be studied, the algorithm needs further improvements. As mentioned in Sections 1 and 2, the ideas for its future implementations will be sufficient to this aim.

5 Particle identification

The dependence of the particle velocity on the particle momentum could be a good probe of the quality of the track segment matching from the inner tracker and the Time-Of-Flight system. A current estimation of track parameters in the inner tracker used for matching segments with the TOF shows a set of well distinguished lines for different types of particles (see Fig. 5).

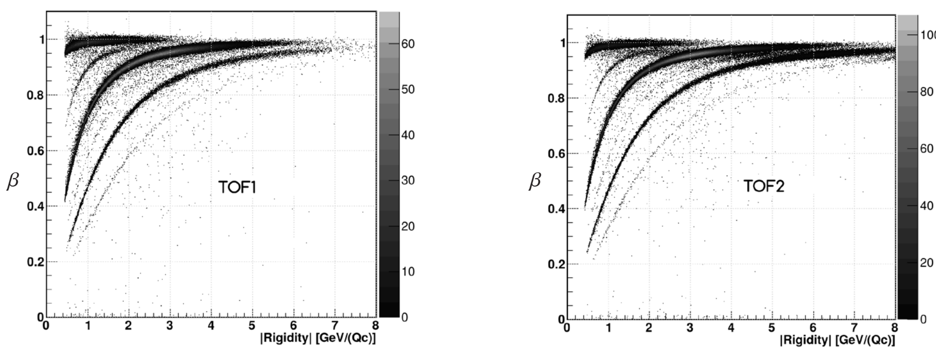

Figure 5. Dependency of particle velocity ($\beta = v/c$) on particle rigidity.

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References

[1] D. Baranov et al., KnE Energ. Phys. **3**, 291–296 (2018)
[2] V. Kekelidze, JINST, **12**, 06012 (2017)
[3] R. Glattauer et al., `arXiv:1202.2761`
[4] M. Al-Turany et al., J. Phys.: Conf. Ser., **396**, 022001 (2012)
[5] K. Gertsenberger et al., Eur. Phys. J. A., **52**, 16214 (2016)
[6] P. Batyuk et al., EPJ Web of Conferences **204**, 7012 (2019)
[7] A.V. Baranov, N.A. Balashov, N.A. Kutovskiy, R.N. Semenov, Physics of Particles and Nuclei Letters **13** (5), 672 (2016)