Event reconstruction based on data from micro-strip detectors of the tracking system in the BM@N experiment

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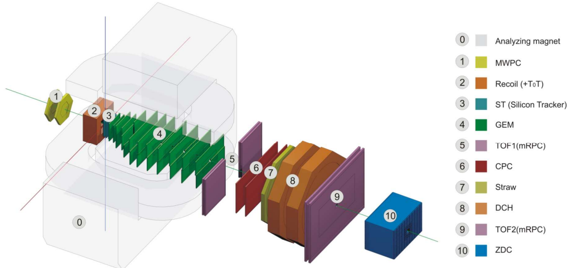
Introduction

BM@N (*Baryonic Matter at Nuclotron*) is a fixed target experiment at the NICA accelerator complex located at JINR (Dubna, Russia). The main goal of the experiment is to study interactions of relativistic heavy ion beams with an energy up to 6 AGeV.

The core of BM@N is a tracking system to register tracks of charged particles produced in primary interactions. Each track consists of a set of spatial points, named hits, in the 3D coordinate space of the experiment. On the basis of the parameters of the found tracks we have made the following physical analysis.

The main detectors of the tracking system in the BM@N experiment have the micro-strip readout. The key advantage of such a detector type is to use readout electronics, which are much easier to assemble through a smaller number of digital channels in comparison with, for example, pad-based or pixel-based detectors. However, this advantage is diluted by a significant shortcoming – false strip crossings, named fakes, resulting from the coordinate reconstruction procedure. It considerably complicates further track finding algorithms. With the increase in event multiplicity the number of fakes also increases. It leads to a reduction in the overall efficiency of the event reconstruction procedure.

In this poster we describe the main features of the hit reconstruction procedure as a step in the complete event reconstruction based on data from three types of micro-strip detectors used in the BM@N experiment in 2017-2018: GEM, SILICON, CSC. The software implementation of the simulation and data processing algorithms for the detectors is also described.

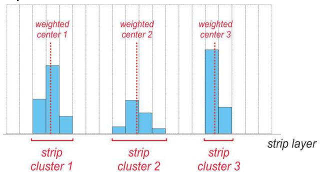


Hit reconstruction in detectors with micro-strip readout

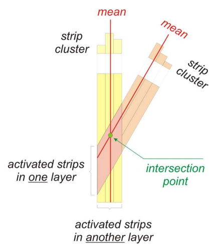
The mentioned tracking system in BM@N consists principally of micro-strip detectors. This type of detectors has a 2D-coordinate readout plane with two layers of strips. Each layer has a set of sensitive elements (parallel strips). The layers are rotated with a stereo angle with respect to each other. Through this layer orientation we have some crossings of strips to reconstruct XY-coordinates of hits.

Our hit reconstruction algorithm comprises two main stages:

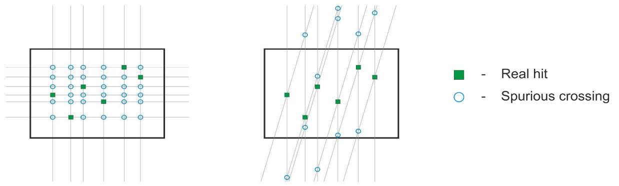
1. **Cluster finding**. It needs to recognize *strip clusters* in a strip layer and evaluate their parameters.



2. **Hit finding**. It needs to identify coordinates of the intersection points (hits) of strip projections for both layers. The resulting intersections determine spatial points of particle tracks registered by micro-strip detectors.

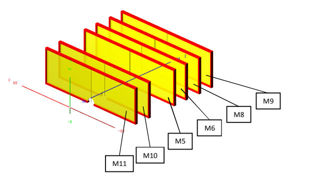


The activated strips of one layer crossing strips of another layer form intersections (hits). We deal with two types of intersections: the first of them are real points through which the charged particles pass. The second ones, named fakes, produce spurious coordinates of non-existent tracks of the particles. Fakes are the main disadvantage of using strips as a readout in track reconstruction problems. The case when strips of two layers cross at the right angle (orthogonal strips) gives us the largest number of fakes. One of the ways to decrease the number of fakes is to rotate strips of one layer on a small angle with respect to another layer. Such rotation removes the majority of fake crossings out of the sensitive area (although many of them are still left).

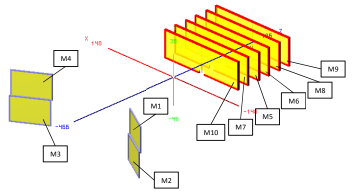


Micro-strip GEM detector

GEM (*Gas Electron Multiplier*) is a gaseous detector consisting of a set of gas-filled chambers with registering planes. The chambers in the BM@N experiment are placed inside a wide-aperture analyzing magnet. The GEM-configuration of the carried out runs of the experiment in 2017-2018 is presented below:



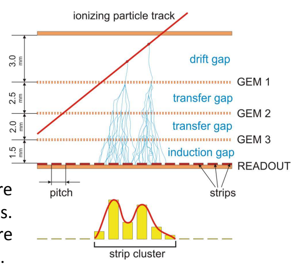
GEM configuration (run-7)



GEM configuration (run-7 SRC)

GEM chamber structure and working principle

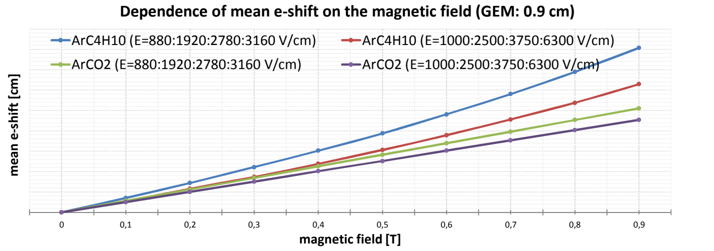
GEM chambers with three stages of electron amplification are used in the BM@N experiment. Each stage has a thick kapton foil covered in copper on both sides. The foil contains many microscopic holes (about 70 µm in the diameter). Large electric fields in the holes are created by voltage placed across two copper layers of the foil.



Thus, the primary electrons produced inside the drift gap are caught by the foil holes and generate electron avalanches. These avalanches drift towards to the readout board where they are registered as a signal (represented as a strip cluster).

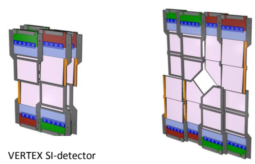
The gaseous mixtures used in the experiment in 2017-2018 were Ar-CO2 (70/30) и Ar-iC4H10 (80/20). The selection of the appropriate mixture was guided by the minimization of the Lorentz shift – some deviation of charge carriers (electrons) in the chamber caused by the electromagnetic force. It leads to a shift in the reconstructed X-coordinates. To evaluate this shift for various combinations of the magnetic field and gaseous mixtures we had a detailed simulation of the electron avalanche formation within the GEM chamber with the Garfield++ framework. It gave us some necessary dependencies such as the average shift of clusters versus the magnetic field. Taking into account the simulated data, we were able to improve the efficiency of experimental data processing.

Dependence of mean e-shift on the magnetic field (GEM: 0.9 cm)



Micro-strip SILICON detector

SILICON is a silicon-based semi-conductor detector with micro-strip readout elements. It is composed of si-modules, which form planes arranged along the beam axis of the experiment (Z-axis). The configuration of BM@N in 2018 included three silicon planes. As opposed to the "thick" GEM chamber, this detector has more precise coordinate resolution through a small pitch of strips (about 100 µm vs. 800 µm in GEM). The division of the plane into small independent modules, as well as a small stereo-angle between strips (2.5 degrees), prevents the appearance of the large number of fakes. Due to this, the silicon detector is placed in the area with the highest occupancy (near the target). Thus, the silicon detector is used as a vertex detector to increase the accuracy of the primary vertex reconstruction.



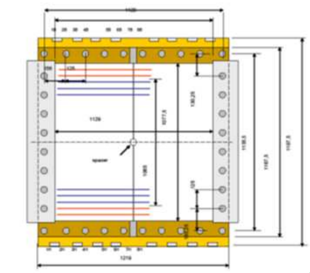
VERTEX SI-detector consisting of two planes (4 half-modules + 2 modules)

SI-detector consisting of 8 modules

Our silicon detector has a thin sensitive volume (300 µm vs. 9 mm in GEM). Due to the faster drift of charge carriers (electrons and holes) in the solid medium (in comparison with the gaseous medium) and small sensitive thickness, the Lorentz force is minimal.

Micro-strip CSC detector

CSC (*Cathode Strip Chamber*) is a micro-strip gas chamber used in the BM@N experiment as an additional plane of the outer tracker deployed outside the magnet. The large distance of the detector from the interaction point (more than 4 m) significantly reduces occupancy. It allows us to use strips with a wider pitch (2.5 mm vs. 0.8 mm in GEM). The stereo angle between the strips is similar to GEM and equals 15 degrees. In the spring run of the experiment in 2018 the detector was represented with one plane, which had a sensitive area of *1129 mm x 1078 mm*.

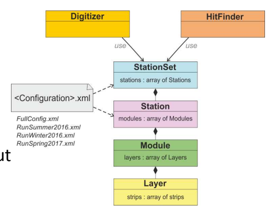


Software implementation

The algorithms of simulation, data processing and hit reconstruction for the described detectors have been implemented and embedded into the BMNROOT repository.

The common structure of the micro-strip detector software realization is presented on the right.

- **Digitizer** – a class for signal simulation on the strip readout from MC-points.
- **HitFinder** – cluster and hit finder algorithms.



Each detector (**StationSet**) consists of chambers (**Station**).
The station includes **modules,** which have sets of strip layers (**Layer**).