Joint Institute for Nuclear Research Veksler and Baldin Laboratory of High Energy Physics

FINAL REPORT ON THE SUMMER STUDENT PROGRAM

GEM track and event reconstruction in Ar run

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Abstract

BM@N (Baryonic Matter at Nuclotron) is experiment of first stage of the NICA project at JINR(Dubna). The BM@N purposes and set-up are briefly presented. Event and track reconstruction results from the GEM(Gas Electron Multiplier) tracking system performance are reviewed from the first physical Ar run.

Contents

1 Introduction

Relativistic heavy ion collisions provide quite unique opportunities to experimentally approach the nuclear matter under extreme conditions of temperature and energy densities. The system produced in a heavy ion collision evolves in time and space. A huge amount of energy is concentrated in a small space-time region which lead to new phase. Different phase states of produced matter occupy different areas of the QCD phase diagram Figure 1. It is described in terms of temperature (T) and net baryon chemical(μ_B) potential.

At low T and low μ_B the hadron phase is realized. It is characterised by the fact that the chiral symmetry is spontaneously broken. In the very large μ_B region the color superconductor (CSC) is predicted by QCD. At enough high temperatures or densities new phase is appeared. It is state of the Quark-Gluon Matter(QGM).

Thus heavy ion collisions allow to research phase diagram, properties of different states of nuclear matter, explore and test QCD in its natural scale (λ_{QCD}), address the fundamental question of hadron confinement and chiral symmetry breaking, which are related to the existence and properties of QGM, study the parameters of the equation of state (EoS) of nuclear matter at high temperatures and densities.

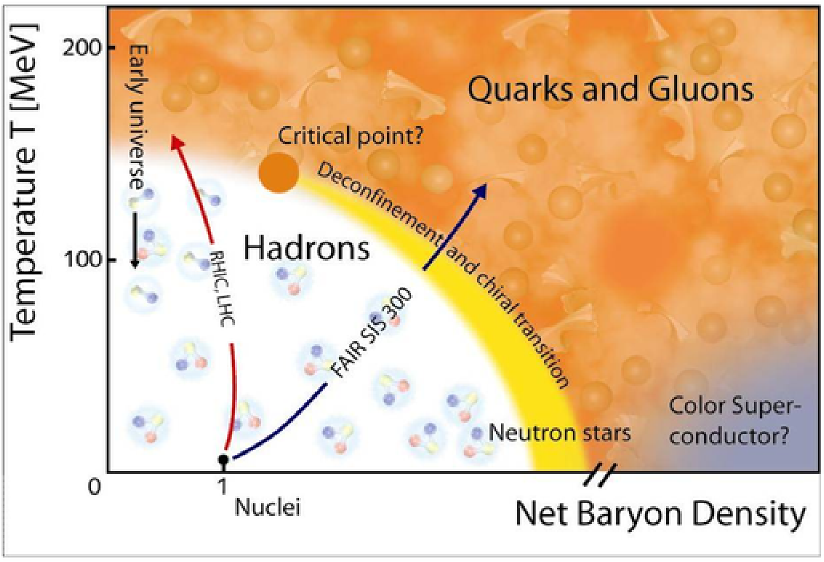

Figure 1: Phase diagram of QCD.

2 BM@N experiment

BM@N experiment (Barionic Matter at Nuclotron) is fixed target experiment at the accelerator complex of NICA-Nuclotron(JINR Dubna)[1]. The main aim of this experiment is to studying relativistic heavy ion interactions. The range of beam kinetic energies varies from 1 to 4.5 GeV. The tasks of this experiment are to investigate:

- the equation of state(EoS) for nuclear matter and the dynamics of nuclear collisions;
- the properties of hadrons in a dense medium;
- the production of cascade hyperons near the threshold and the production of hypernuclei due to the coalescence of lambda hyperons with nucleons.

The scheme of the NICA accelerator complex is shown in Figure 2. The schematic view of the BM@N experiment setup is shown in Figure 3. The BM@N setup consists of the following subsystems [2]:

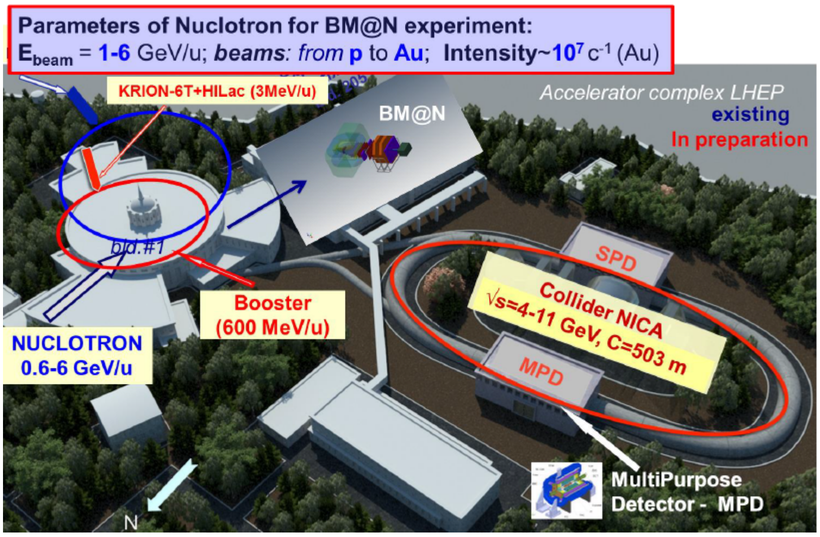

Figure 2: The schematic view of NICA complex.

- a tracking system;
- a time-of-flight system for identifying charged particles;
- detectors for determining the collision parameters.

The tracking system consists of a set of GEM (Gaseous Electron Multipliers) detectors, Double-Sided Silicon Detectors (DSSD) silicone detectors, located inside the analyzing magnet, and also drift (DCH) cameras behind the magnet. Time-of-flight detectors (TOF1,2), based on mRPC (multigap Resistive Plate Chambers) technology with strip reading, are used for efficient particle separation. The parameters of these detectors allow to identify particles up to pulses of the order of several GeV/c. To determine the centrality of a collision by measuring the energy of particle-beam fragments, the zero-angle calorimeter (ZDC) is used.To study processes with electro-magnetic probes (γ, e) in the final state, an electro-magnetic calorimeter(ECAL) is used. It is located behind the outer DCH chambers. Thus, the setup allows you to measure the parameters of tracks with high accuracy with the identification of particles, using time-of-flight information, and determine the centrality of the collision with the help of calorimeters. The magnetic field can reach 1.2 T for obtaining optimal acceptance and momentum resolution for various processes and beam energies.

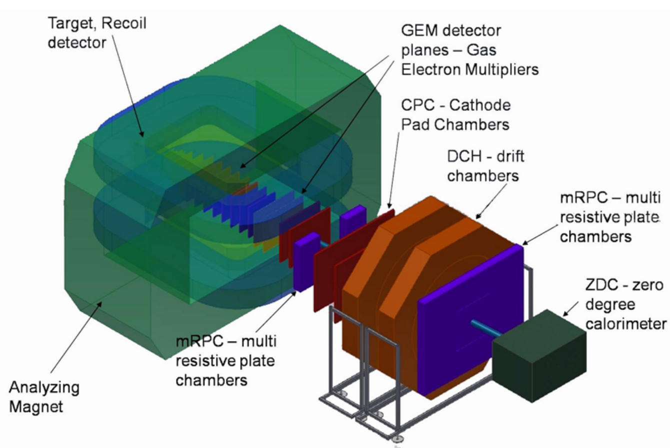

Figure 3: The schematic view of the BM@N setup.

3 The GEM detectors

The GEM detectors in the BM@N experiment is a set of chambers, filled with a gas mixture of ArCO2 (70/30), with microstrip information extraction. Their configuration in run 7 had presented 7 GEM chambers, located along the beam axis; but the third station was faulty. Therefore the working configuration includes 6 stations Figure 4. The black arrows show information about direction of reading strips, also information about the number of strips, alignment for each station is provided on Figure 4. Numbers indicate sector number. Even sectors (2,4) are called hot zones, odd ones (1,3) - main zones. The stations have a stripe pitch of 800 μm.

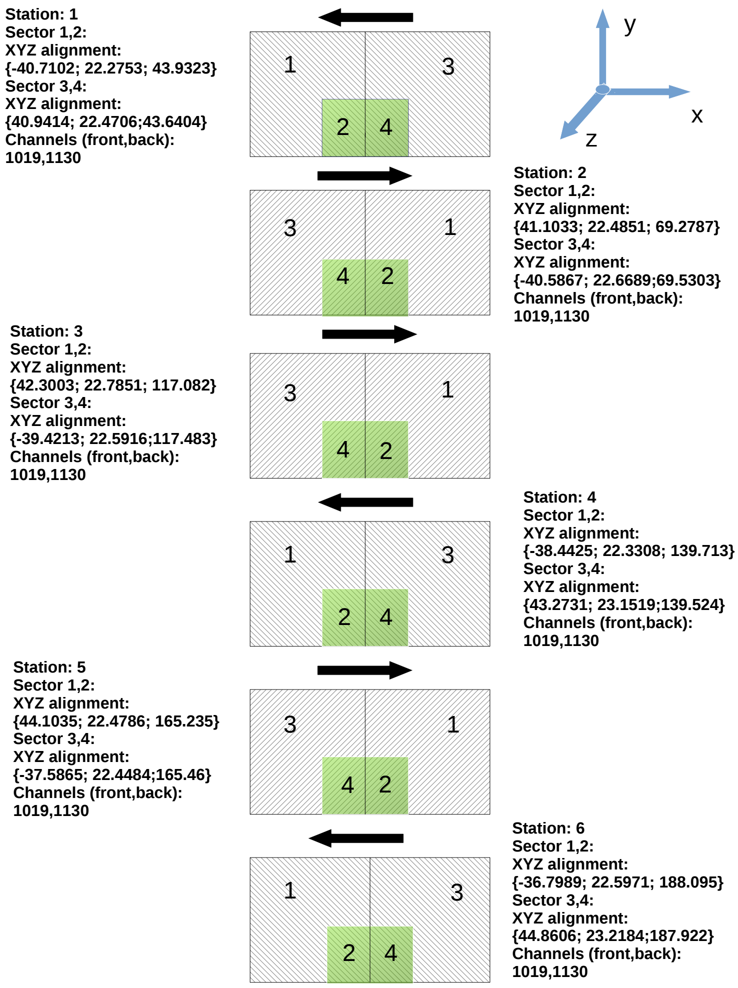

Figure 4: Configuration of GEM in run 7

The acceptance for the current configuration is shown in the Figure 5 in terms of tangent of angles relative to the beam axis. The first stations have wider acceptance, than last ones.

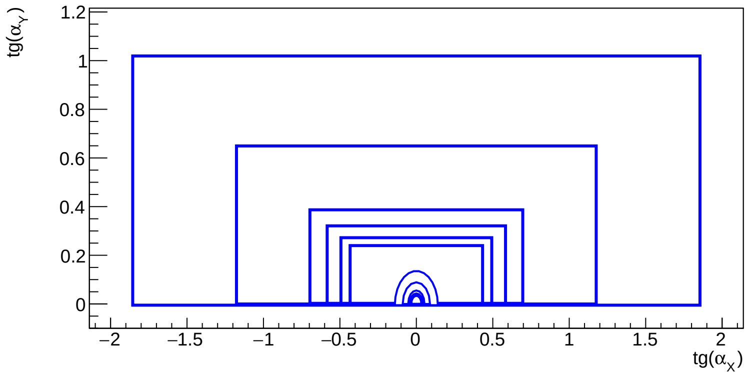

Figure 5: Acceptance of GEMs

4 Event and track reconstruction

Event and track reconstruction is very important initial stage of analysis. For this stage the data, given below, are used[3]:

Run number	Target	Energy, GeV	Magnetic field	Statistics
4648	Al (3.3 mm)	3.2	-	50K
4649	Al (3.3 mm)	3.2	+	50K

Only data with GEM detectors is used for analysis. Various histograms were obtained during the processing of data. The distribution of multiplicity for reconstructed tracks in run with magnetic field B=0T and B=0.6T is shown on Figure 6. The dependence number of hits, taking part in track reconstruction, and clusters, located on the front and back strips, on station number in run with magnetic field B=0T and B=0.6T are shown on Figure 7 (number of these hits>3). Number of clusters for back and front strips is roughly the same. Number of hits in zero magnetic field run is less than another run. The number of hits increases from the first stations to the last stations. It may be caused that the particles, flying at small angles, come out of the beam holes.

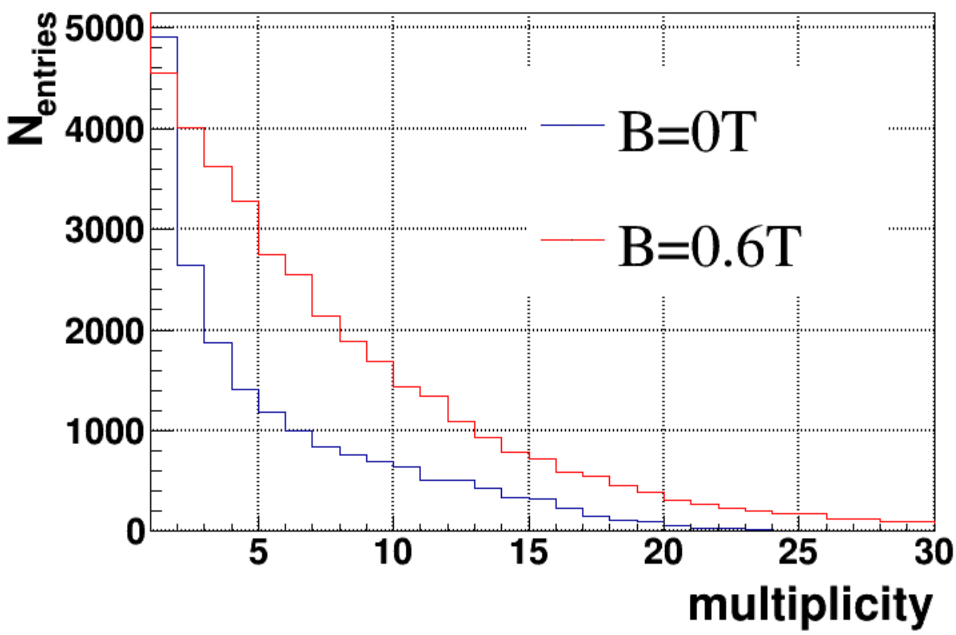

Figure 6: The distribution of multiplicity for reconstructed tracks in zero magnetic field run and run with magnetic field B=0.6T

The position distribution of clusters allows to do the same conclusion Figure 8. Cluster position is defined as mean strip number. The number of clusters increases for positions corresponding

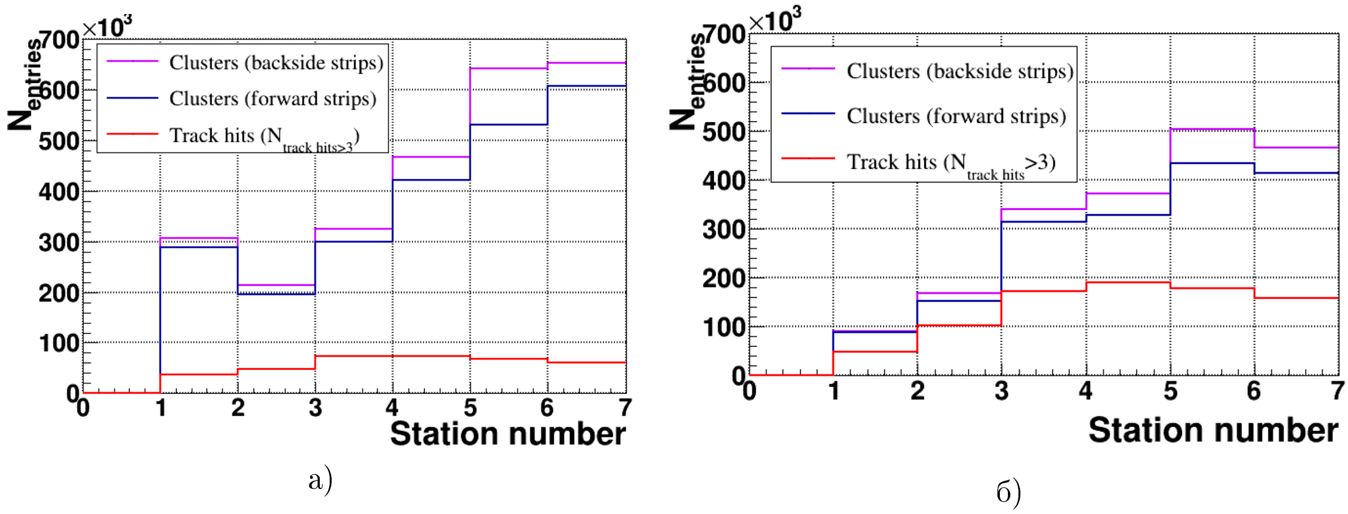

Figure 7: Dependence of number of hits and forward/backside strip clusters from station number in run with magnetic field a) B=0T b) B=0.6T

to the centers of stations. The distribution has a shift for run with the zero magnetic field configuration. To check this conclusion, the tracks, reconstructed from 4 hits, located on the last

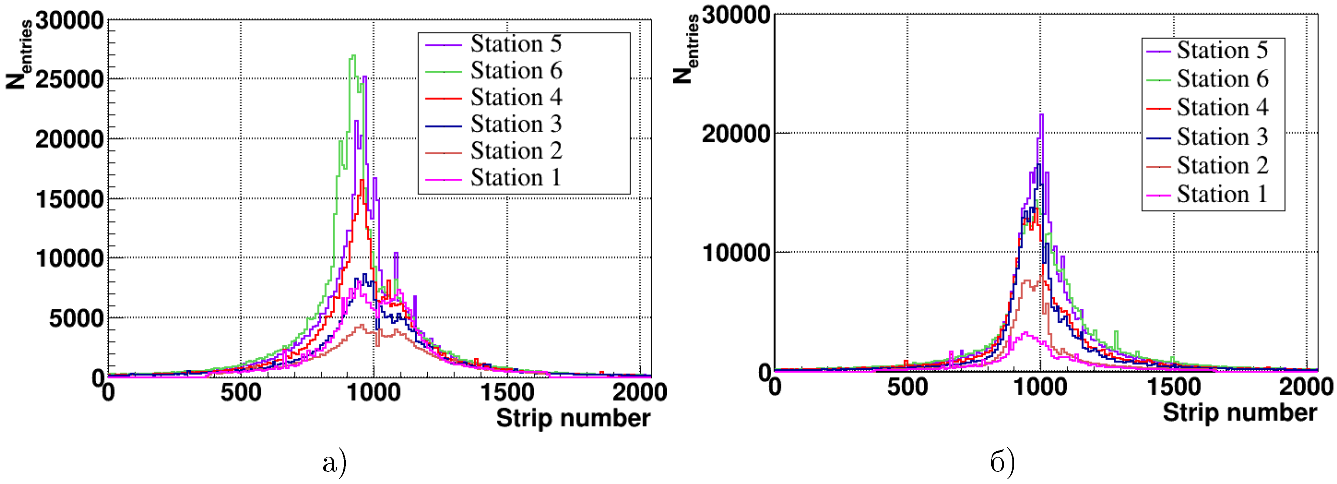

Figure 8: The position distribution of clusters for different stations in run with magnetic field a) B=0T b) B=0.6T

four stations, are extrapolated on two the first stations Figure 9 - Figure 10. The total number of tracks does not change, the number of tracks in the hole decreases in run with B=0T. Thus tracks are gradually coming out of the hole, which causes an increase in the number of clusters with an increase in the station number.

Magnetic field smears the picture Figure 10. Number of tracks increases at the transition from the first station to the second one, slight decrease of tracks in the hole is observed.

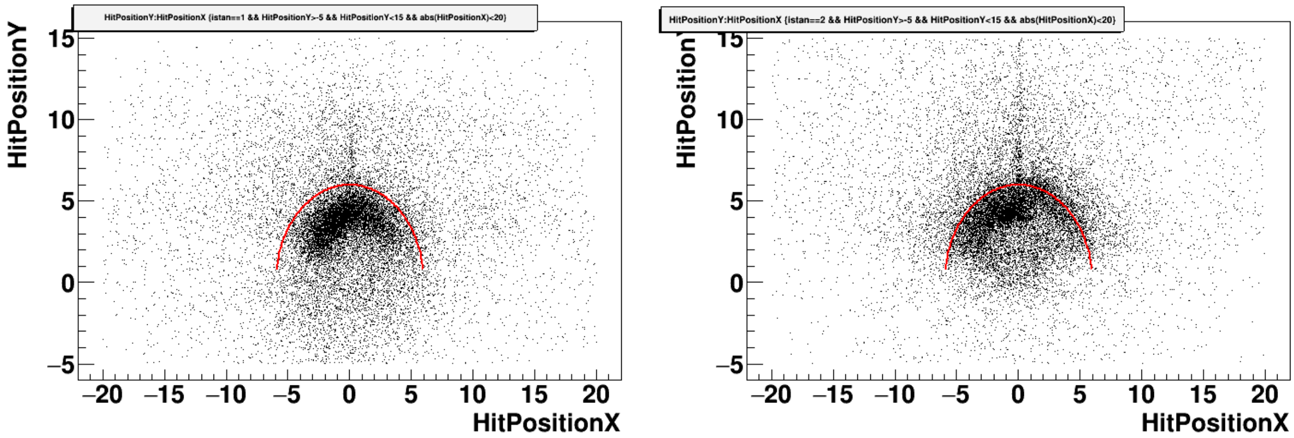

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Figure 9: The position (XY) distribution of hits, obtained by extrapolation of the track on a) 1-st station b) 2-d station in run with magnetic field B=0T (red line - GEM hole border)

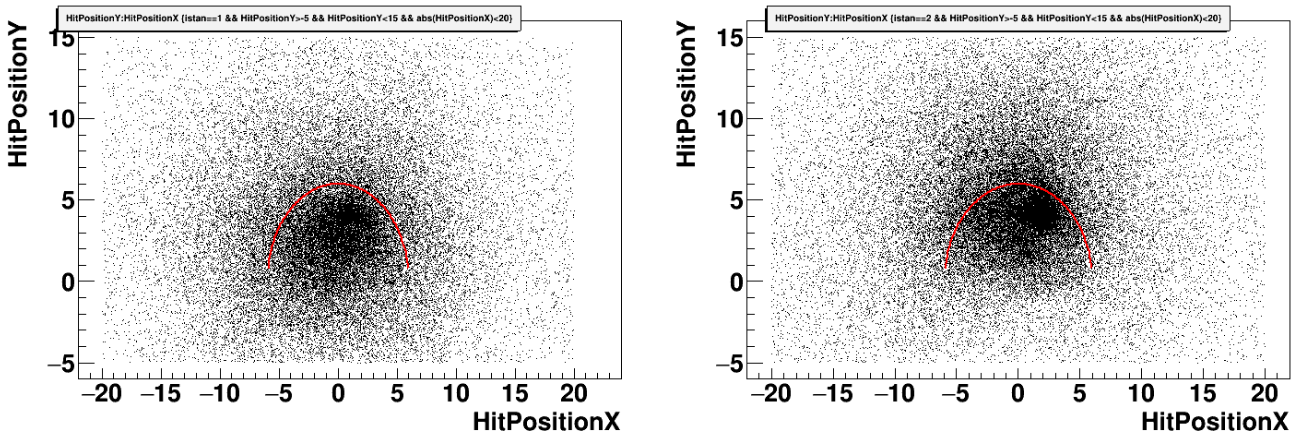

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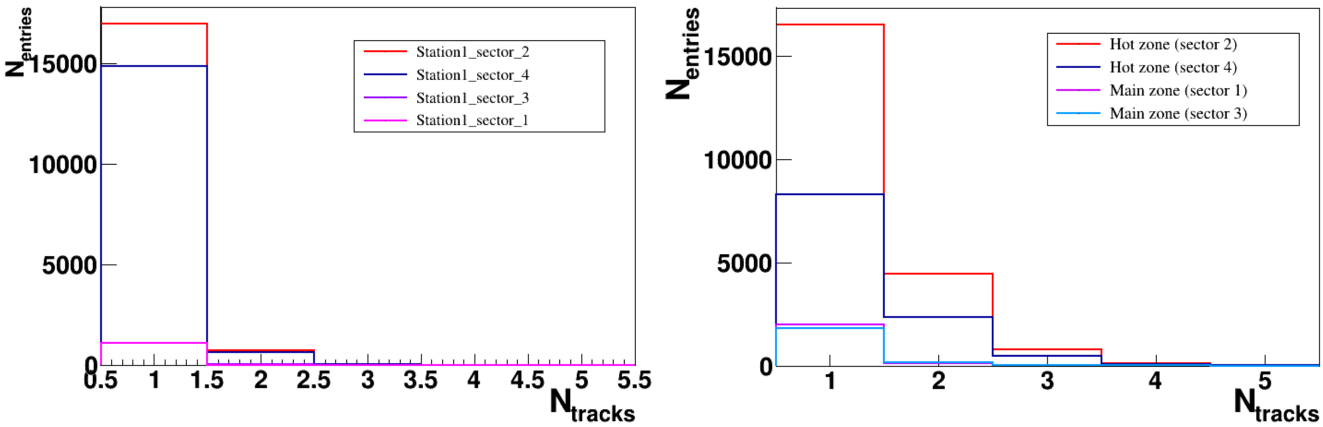
Figure 10: The position (XY) distribution of hits, obtained by extrapolation of the track on a) 1-st station b) 2-d station in run with magnetic field B=0.6T (red line - GEM hole border)

The statistics for these distributions are given in the table:

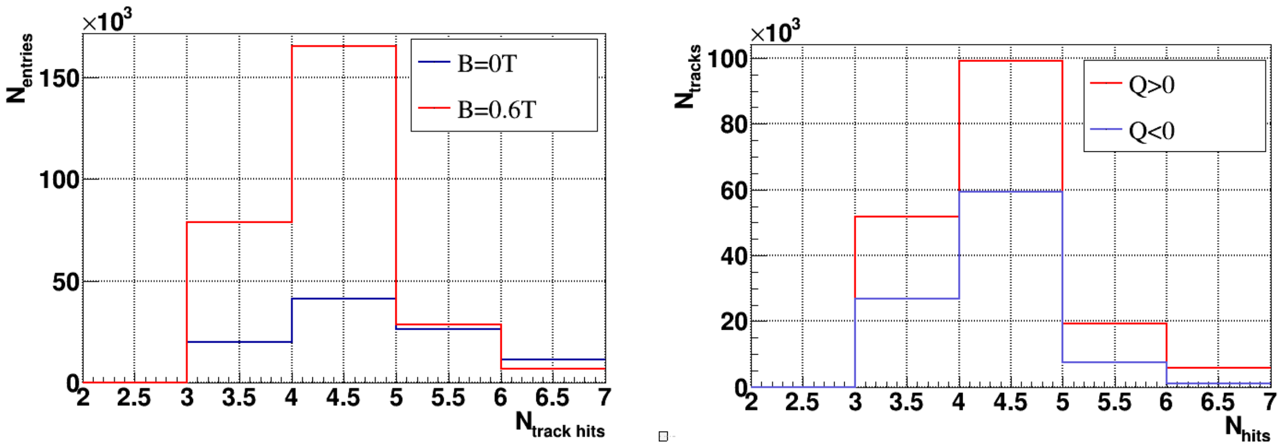
Magnetic field(B),T	Station number	Number of hits	Number of hits in hole zone
0.6	1	47003	24397
0.6	2	52173	24263
0	1	19405	13001
0	2	19426	11123

For understanding of track reconstruction procedure, the distribution of number of tracks, passing through the same cluster, is observed (Figure 11). Several tracks can pass through the same cluster. Most tracks go through the hot zone. Number of tracks, passing through the same cluster, increases significantly for magnetic field run.



a) б)

Figure 11: Distribution of number of tracks, passing through the same cluster, in run with magnetic field a) B=0T b) B=0.6T (for station 1)



a) б)

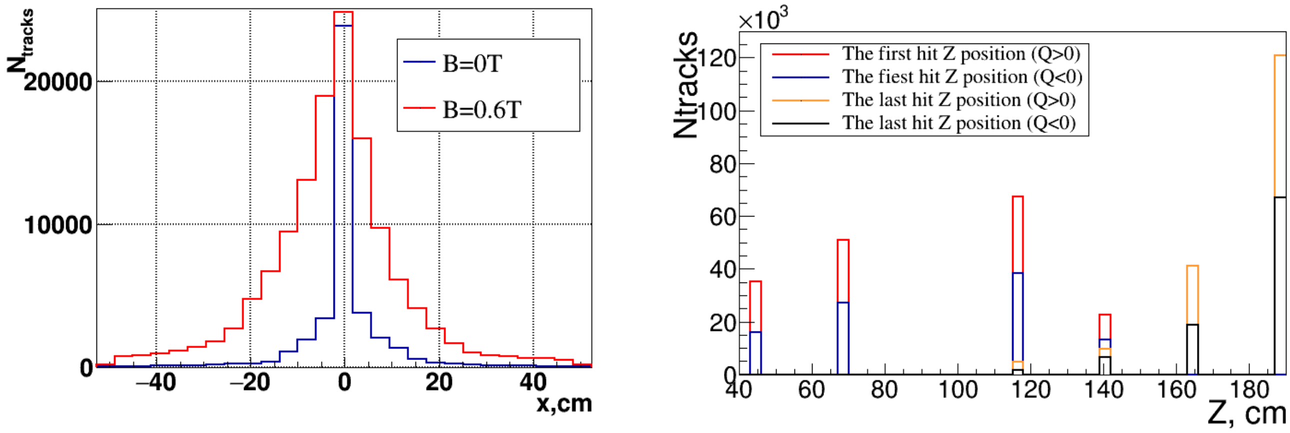
Figure 12: Distribution of number of hits for track reconstruction in run with magnetic field a) B=0T and B=0.6T for all particles b)B=0.6T positively and negatevely charged particles

Such track reconstruction may be reason an excess of the number of tracks in run with B=0.6T as compared to one with B=0T. The distribution of number of hits for track reconstruction on figurename 12 (a) demonstrates it. Most of the tracks are reconstructed from 4 hits. The distribution of number of hits for track reconstruction in run with B=0.6T for positively (Q>0) and negatevely (Q<0) charged particles is shown on figurename 12 (b). The number of positively charged particles exceeds the number of negatively one.

To find the reason of exceeding for number of tracks from 3 and 4 hits for data with B=0.6T, tracks, reconstructed from 4 hits, are extrapolated on target (Z=0). The extrapolated track position distribution for X coordinates in run with B=0.6T and B=0T is shown on Figure 13 (a). Statistics for tracks from 4 hits with B=0T is 41K, for ones with B=0.6T Figure 12 is 165,6K. Most of the tracks for data with B=0.6T don't start from a target. Such tracks may be fake.

On Figure 13 (b) the distribution of Z position for the first and last hit of track (B=0.6T) is shown. Most of the reconstructed tracks have the first hit in the third station and the last hit on the last one. It also may indicate on exit small angle particles from beam hole.

For reconstructed tracks residuals are build. Residual(dx) is a distance from hit to point, received by extrapolation of track on the same station, where hit is located, making assumptions about the absence of this hit. Dependence of residual dx from x coordinate of hit for hot and main zones of different stations is shown on Figure 14 - Figure 15. Special condition is set for building this distribution. Track, having a hit at the given station, must have hits at all nearby stations to this. Large residuals are observed in hot zones, especially in a zones, located close to the area



a) б)

Figure 13: a) Distribution of position(X) for tracks, extrapolated on target, in run with magnetic field B=0T and B=0.6T b) Distribution of the first and the last hit position(Z) of track for positively and negatively charged particles (B=0.6T)

of beam penetration. It can be caused by belonging of the same clusters to different tracks.

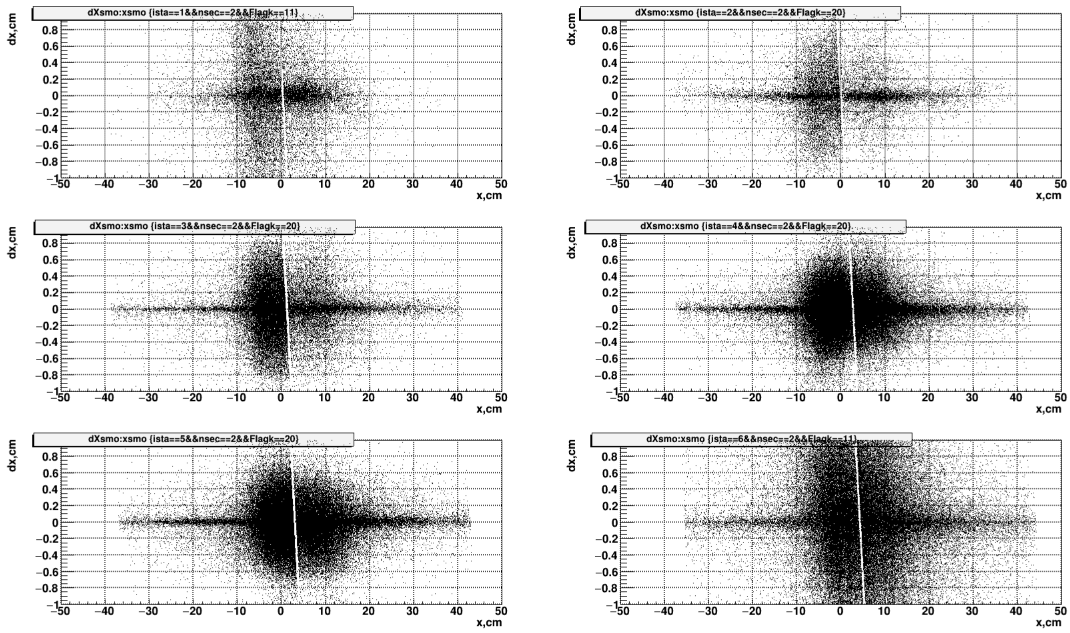


Figure 14: Dependence of residual from x coordinate of hit for hot zones (B=0.6T)

As a final result, efficiency ϵ for each GEM station is determined. Each GEM station is divided by a chosen grid into a certain number of zones. For each zone efficiency is defined as:

$$\epsilon = \frac{N_{hits}}{N_{hits} + N_{extrapolated\ points}}$$

, where N_{hits} is number of hits for given zone of station,$N_{extrapolated\ points}$ is number of points, received by extrapolation of track, which doesn't have hit on considered station, to this station. To calculate the efficiency, collision system Ar+Sn($E_{kin} = 3.2GeV$) with statistics 1.4M is used. Only events with number tracks more 2 and distance between experimental and reconstructed primary vertex less 5 cm are chosen. And also tracks with number hits more 3 are considered. Grid (X*Y) 2cm*1cm is set. Efficiency distribution for different stations for magnetic field runs is shown on Figure 16.

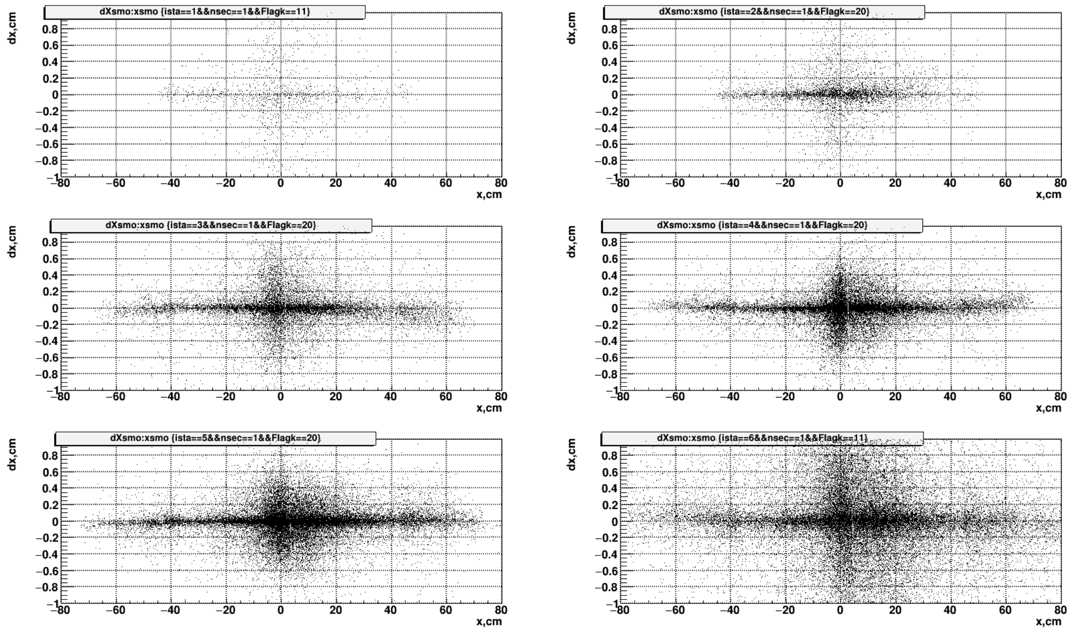


Figure 15: Dependence of residual from x coordinate of hit for main zones (B=0.6T)

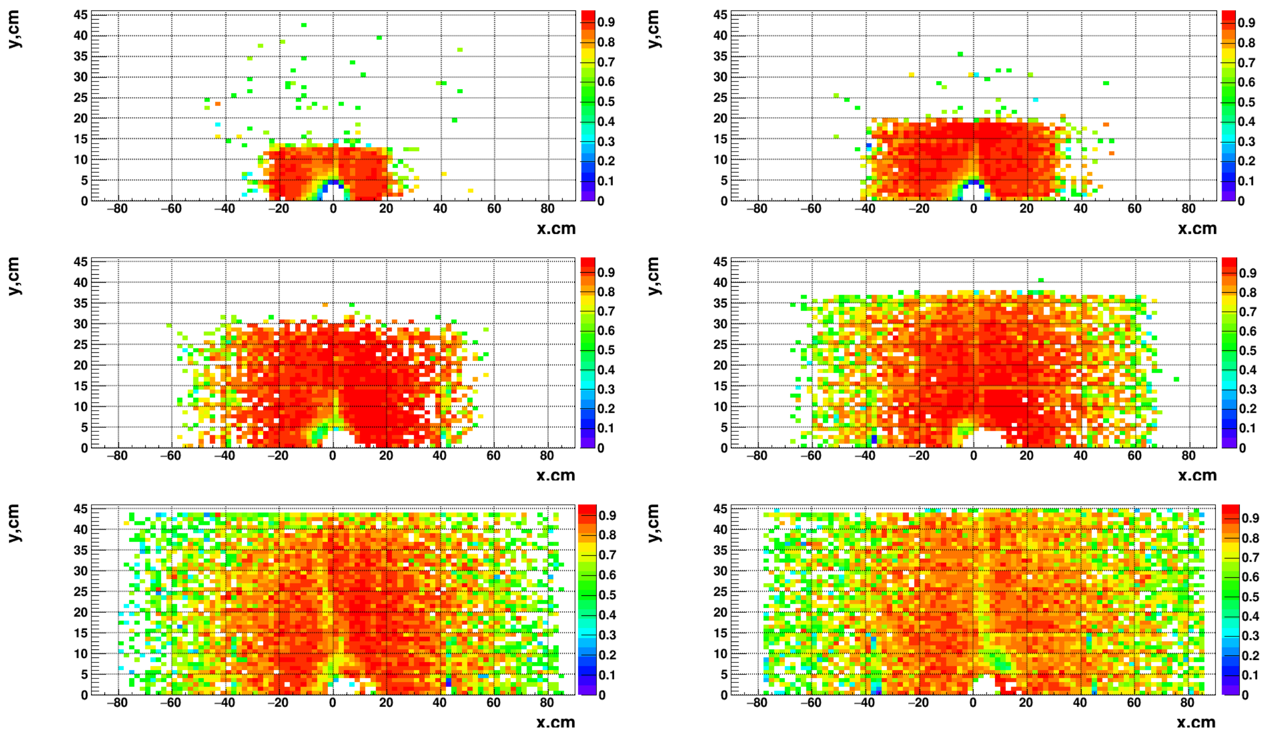


Figure 16: Efficiency distribution for different stations for magnetic field runs

5 Conclusion

In this paper, track and event reconstruction in Ar run (run 7) are received, using only information from GEM. Significantly larger reconstructed track multiplicity in magnetic field could be due to fake tracks. It may be caused by new degree of freedom for particles in the magnetic field, what can be reason of increasing for number of tracks, passing through the same cluster. The situation should improve when silicon detectors are activated in tracking. They should also help to better tune track reconstruction procedure parameters. The number of clusters increases with the station number and a large fraction of tracks begin at more dowmstream stations than station 1. It can be interpreted as due to small-angle particles coming out from the beam hole. To check the conclusions, the Monte Carlo simulation will be run soon.

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