Study of the interaction trigger and beam ion fragmentation for Au+Au collisions in BM@N experiment

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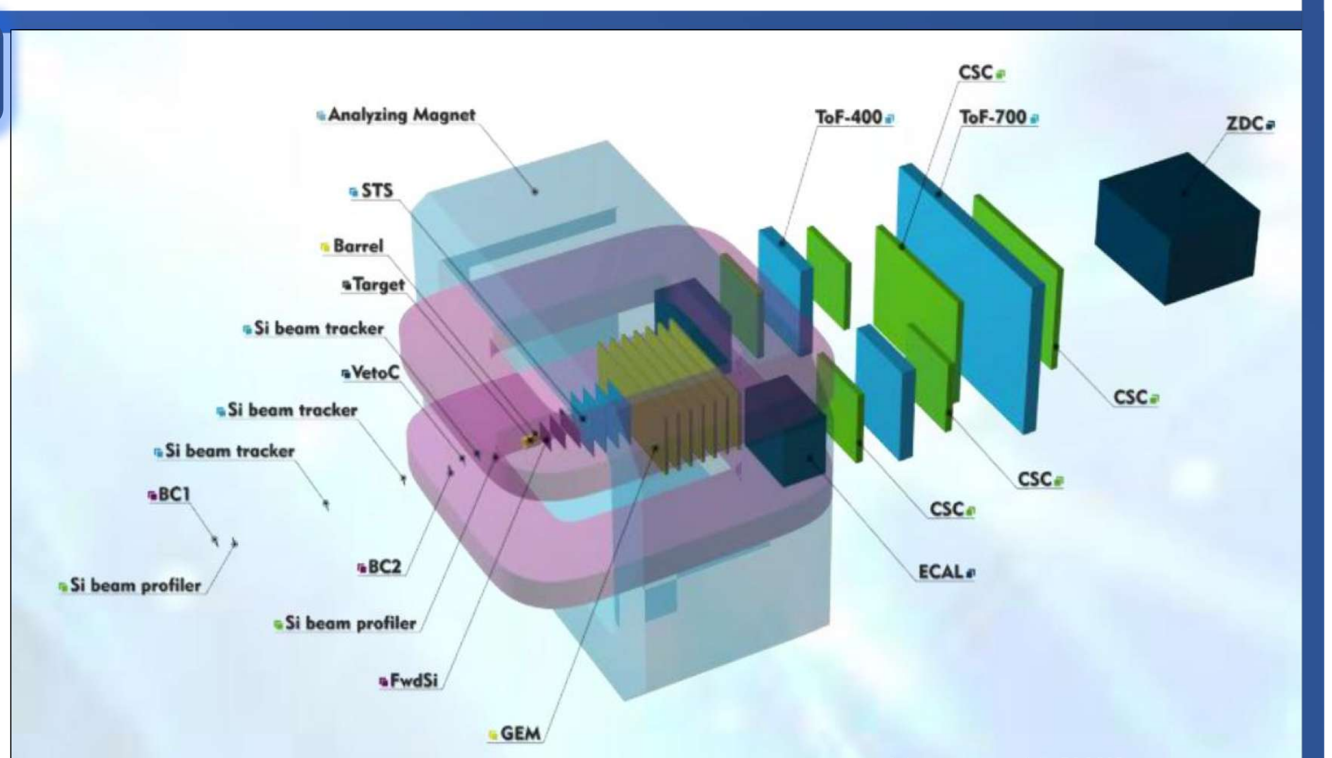
INTRODUCTION

Investigation of the properties of hot and dense nuclear matter formed in Au + Au collisions is the main focus of the BM@N [1-2] fixed target experiment. The trigger detector system consists of beam counters detecting each beam particle incident on the target, target area detectors – scintillation barrel and silicon multichannel detectors measuring multiplicity of secondary charged particles and forward detectors – Cherenkov detector of beam ion fragments and hadron calorimeter. The fast interaction trigger is based on information coming from the target area and forward detectors and it is used for effective selection of collision events in the BM@N target. Selection of the collisions on centrality is important option of the fast interaction trigger.

The detector and interaction trigger performance for Au + Au collisions at energy of 4 A GeV was studied by Monte-Carlo simulation with a code DCM-QGSM [3] + GEANT4 [4].



Schematic view of the BM@N set up.

TARGET AREA DETECTOR PERFORMANCE

Target area detectors

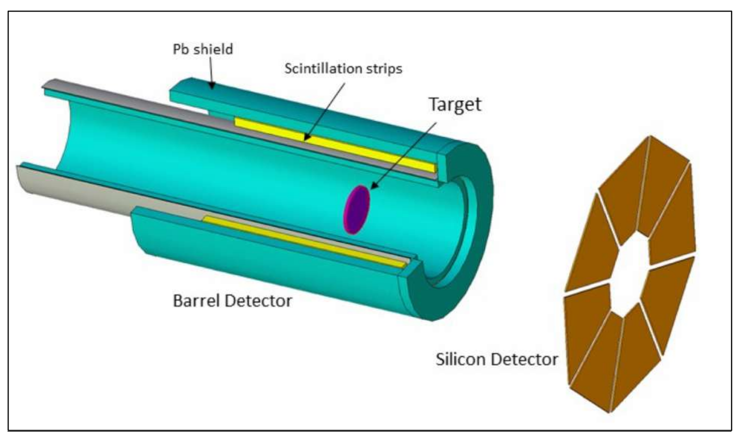
The BM@N target area with multichannel detectors – Barrel Detector (BD) and Silicon Detector (SiD) – is schematically shown in figure. The Au target with a thickness of 300 μm is placed inside the BD at a distance of 50 mm from the end of BD. The target area is located inside the BM@N magnet with a field of B = 0.9 T.

The BD consists of 40 scintillation strips 150 × 7 × 7 mm^3 with SiPM readout from one end of the strips. The inner radius of the strip cylinder is 46 mm. The SiPMs are from SensL (Ser. C) and have 6 × 6 mm^2 active area. A special Pb shield is applied around scintillation strips with the purpose to absorb the δ -electron background.

The BD covers a region of large polar angles and it detects the charged particles, mainly protons and pions, produced in nucleus – nucleus collisions.

The forward angle region is covered by the SiD with inner and outer radii of 25 and 93 mm respectively. The distance from the target to SiD is 120 mm. The SiD has a thickness of 525 and it consists of 64 trapezoidal strips.

Thus, the total granularity of the target area detectors is 40 + 64 = 104 channels. The granularity of the detectors is chosen to provide a possibility to select nuclear interactions with different impact parameters.



The geometry of the target area of the BM@N experiment.

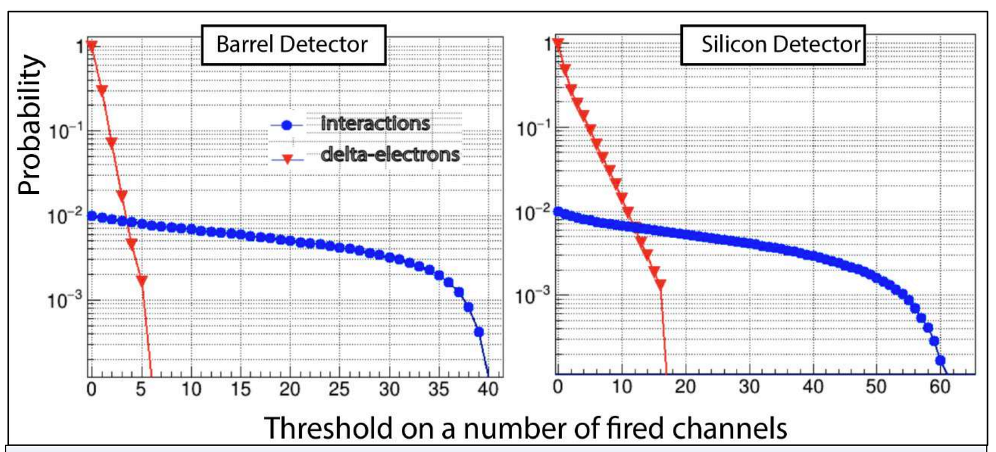
Background conditions

The δ -electrons produced by Au ions in the target can make an essential contribution to the number of fired channels in BD and SiD detectors. This background reduces the capability of the detectors to select the interactions in the target because trigger signals can be generated even when the incoming beam ion passes the target without interaction.

A special Pb-shield was applied around the scintillation strips of BD with the purpose to absorb δ - electrons produced by Au ions in the target. The shield is made as inner and outer cylinders plus a layer closing the forward ends of the strips. The protection efficiency of this shield is an issue for study by the MC simulation.

Based on observations from this study, the 5 mm inner and 10 mm outer lead shields help to reduce the δ-electron background (see left figure). A threshold on fired channels of ~ 6 channels completely suppresses the background contribution to the probability of trigger generation.

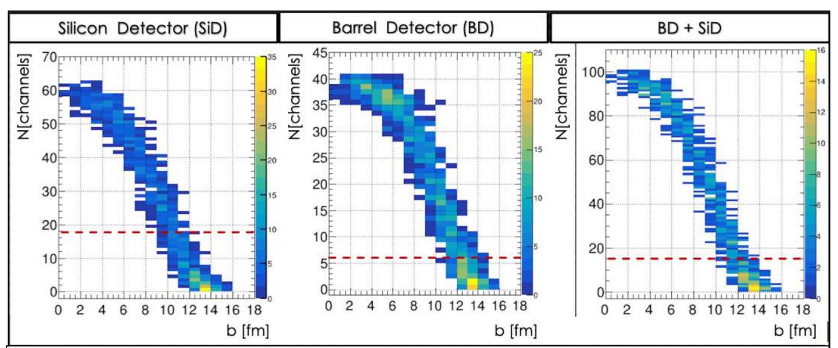
The simulation shows that a high magnetic field reduces the δ -electron background for SiD, and the background contribution to the detector response dramatically decreases with a distance from the target. The result obtained for the SiD position is shown in the right figure. The SiD detects only the interactions if the number of fired channels exceeds 17 channels.



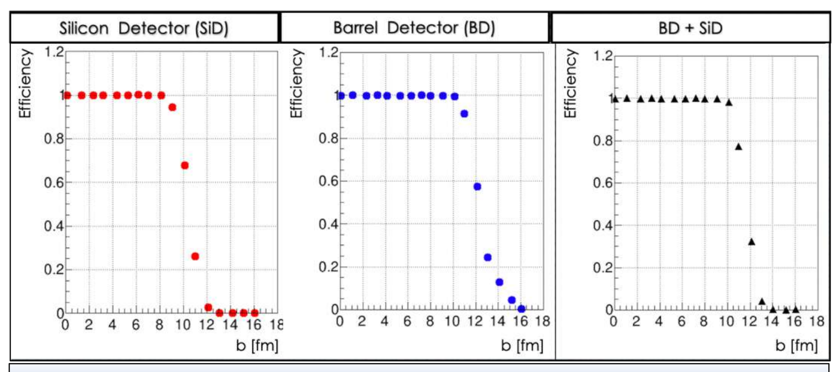
The probability of true (blue) and false (red) triggers in the registration of Au + Au collisions as a function of the threshold on the number of counts in BD (left) and SiD (right) detectors.

Efficiency of triggering Au+Au collisions

The study of the BD and SiD responses as a function of impact parameter of Au + Au collisions at 4 A GeV shows that in the central collisions the numbers of fired channels reach the total granularity in both detectors. The dashed red lines in the figures correspond to applied thresholds for suppression of the δ -electron background. For this condition the efficiency is 100% for central and semi-central Au+Au collisions as for the individual detectors as for sum of the detector responses.



The number of counts in the trigger detectors (SiD, BD, BD+SiD) in the registration of Au+Au collisions depending on the impact parameter.

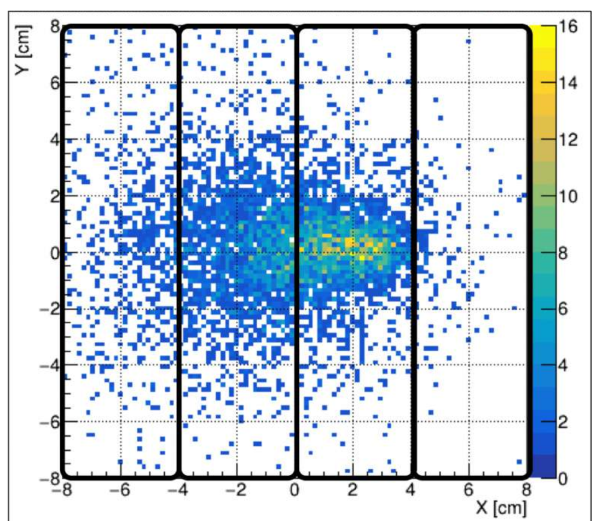


.Efficiency of the trigger detectors (SiD, BD, BD+SiD) in the registration of Au+Au collisions as a function of the impact parameter

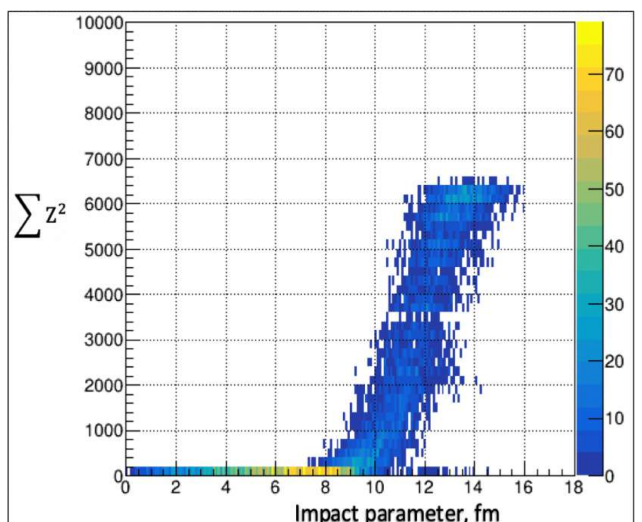
FORWARD DETECTOR PERFORMANCE

Fragment Detector

In order to suppress the background from δ -electrons and to reduce radiation damage to the detectors during the experiments with high intensity heavy ion beams, the region around the beam line will be covered by a vacuum pipe extended up to the position of the calorimeter HCal (replacement of ZDC). Fragment Detector (FD) with transverse dimensions 160x160 mm^2 will be placed after the vacuum pipe in front of the calorimeter. The FD will consist of 4 quartz plates 160x40x6 mm^3. Each of the plates is viewed from both sides by two groups of SiPMs sensitive to the Cherenkov light produced in the quartz radiators by the beam Au ions or by fast fragments. Simulation results demonstrate that nearly all heavy (Z > 6) fragments will be detected by the FD (left picture). The amplitude of the summed signal from the FD can be used for vetoing non-interaction events, for generating a trigger on central and semi-central collisions, and for additional offline characterization of peripheral collisions (right picture).



Distribution of charged fragments in the forward detector. (Z > 6).

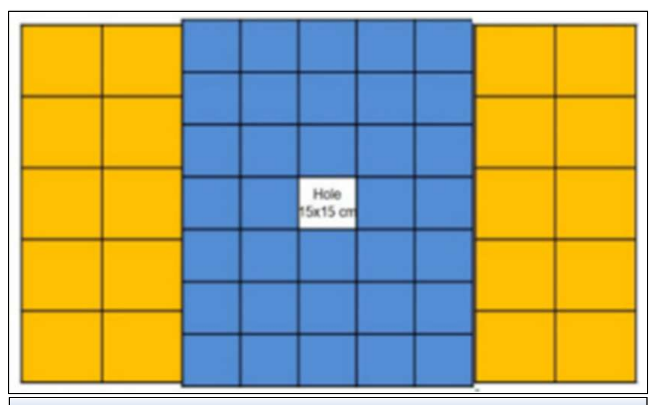


The square sum of the charges as a function of the impact parameter.

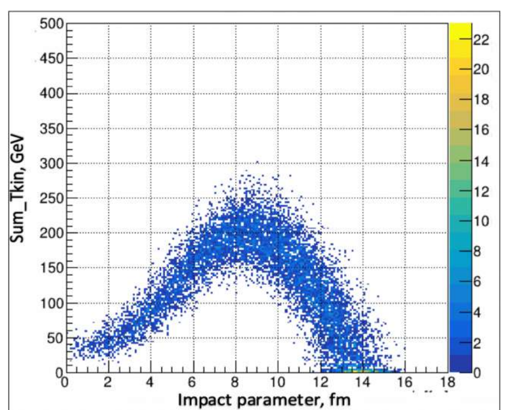
Hadron Calorimeter

In future BM@N runs the new HCal [5] will replace the ZDC at the end of the beam line at a distance of 9 m from the target. The HCal has a hole in the beam area, and consists of two types of modules for inner and outer regions (upper picture) with transverse size 150x150 mm^2 and 200x200 mm^2, respectively.

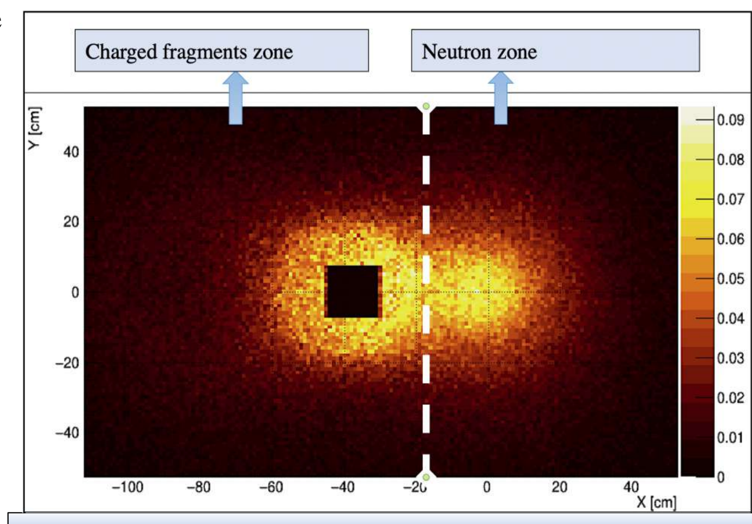
In the current study, the MC simulations were used to explore the possibility to include the signals from the HCal in the trigger. Two zones were considered as potentially important for forming trigger signals, the first one, dominated by the hits from charged fragments, the second - from neutrons (bottom right picture). Distribution of total kinetic energy of neutrons, which produce hits in the selected "neutron zone", shows strong dependence on the impact parameter (bottom left picture), indicating that a combined signal from calorimeter modules in this zone can be used for selecting centrality of the collisions.



Proposed geometry of new FHCal BM@N.



The total kinetic energy of neutrons as a function of the impact parameter.



Estimation of the average energy of the interaction products per event in the FHCal area.[GeV].

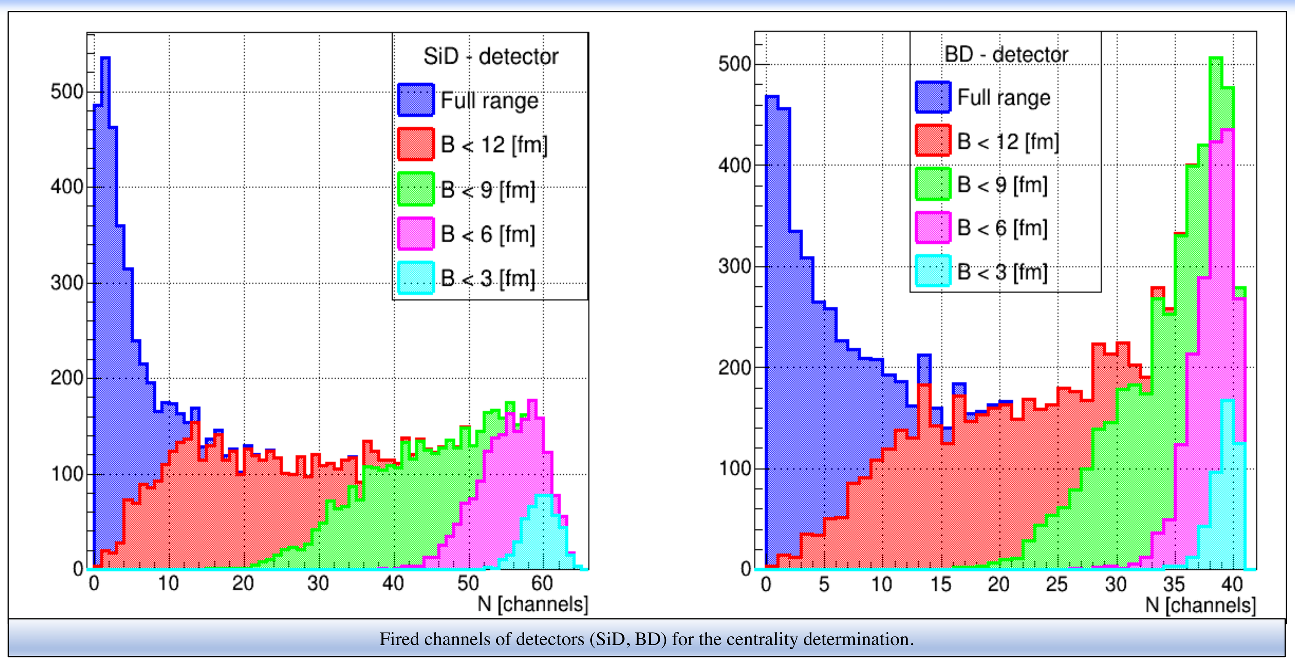
INTERACTION TRIGGER CONCEPT

Taking into account the considered results of MC simulation the following concept of the interaction trigger for Au+Au collisions can be realized:

- Min. Bias – FD + HCal:
- Central and semi-central collisions – BD + SiD + HCal;

The first option (Min. Bias) is realized by setting a high threshold on FD pulse height close to Au-ion peak with a low threshold on HCal response.

The second option is selection events on the centrality of Au + Au collisions and it is realized by setting the corresponding thresholds on number of fired channels in the BD and SiD, and threshold on HCal pulse height. More central collision means larger responses of BD and SiD and lower response of HCal.



Fired channels of detectors (SiD, BD) for the centrality determination.

References:

[1] M Kapishin 2016 The fixed target experiment for studies of baryonic matter at the nuclotron (BM@N), Eur. Phys. J. A 52 (2016) 213.
[2] V I Yurevich, O I Batenkov, G N Agakichiev, V A Babkin, S N Basilev, D N Bogoslovsky, L G Efimov, S P Lobastov, I A Philippov and A A Povtoreyko, Beam tests of Cherenkov detector modules with picosecond time resolution for start and L0 trigger detectors of MPD and BM@N experiments 2015 Phys. Part. Nucl. Lett. 12 (2015) 778.
[3] V D Toneev , K K Gudima, Particle Emission In Light And Heavy Ion Reactions // Nucl. Phys. A. 1983. V. 400, P. 173-190.
[4]J Apostolakis, M Asai, A G Bogdanov, H Burkhardt, G Cosmo, S Elles, G Folger, V M Grichine, P Gumplinger, A Heikkinen et al., 2009 Geometry and physics of the Geant4 toolkit for high and medium energy applications Radiation Physics and Chemistry, 78 859-873
[5] F. Guber, D. Borisenko, D. Finogeev, M. Golubeva, A. Ivashkin, N. Karpushkin, S. Morozov, and A. Senger, New forward hadron calorimeter for centrality and reaction plane determination at BM@N heavy ion experiments.