MC simulations of beam-beam collisions monitor for event-by-event studies at NICA

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MOTIVATION

https://nica.jinr.ru/physics.php

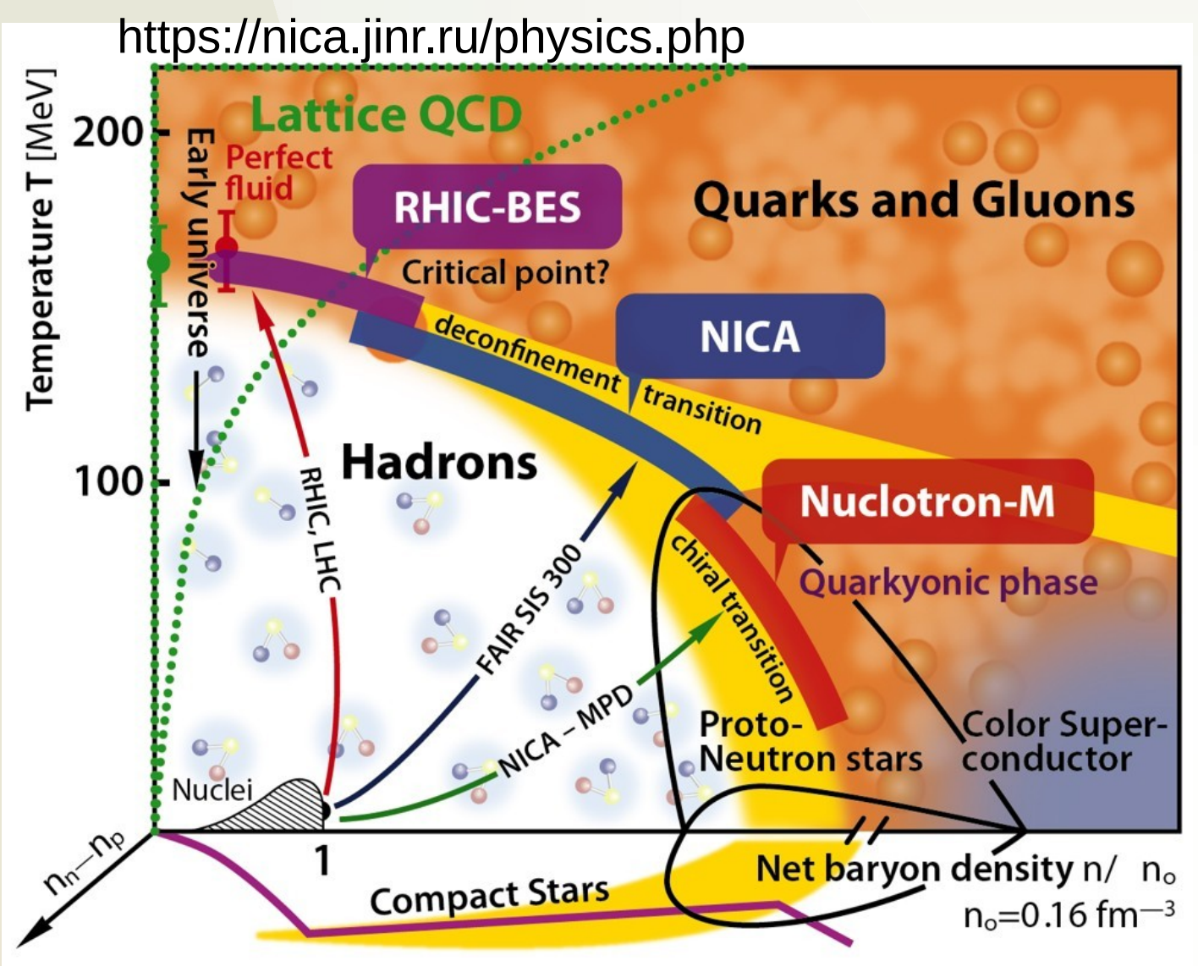

Fig.1. QCD phase diagram

Experiments to study the QCD phase diagram in the region of high baryon densities are planned at the NICA collider. For quantitative event-by-event analysis it is necessary to determine such event characteristics as *interaction point coordinates, multiplicity, centrality, azimuth distribution*, etc.
To meet the challenges of the fast monitoring of the beam-beam collisions of the high intensity NICA beams, **the compact MCP-based Fast Beam-Beam Collisions (FBBC) detector** with high timing properties was proposed in **[1]**. It is capable, in combination with the Beam Position Monitor (BPM), to provide the continuos monitoring of bunch-by-bunch crossing the beams location and their profilles, the collision intensity, the interaction point (IP) determination and the azimuthal distribution of particles produced.
In the present report we study by the MC simulations the options of detector layout and the timing distributions of the particles reaching the detectors. The general concept of the Fast Beam-Beam Collisions Monitor set-up is shown in the **Fig.4.**

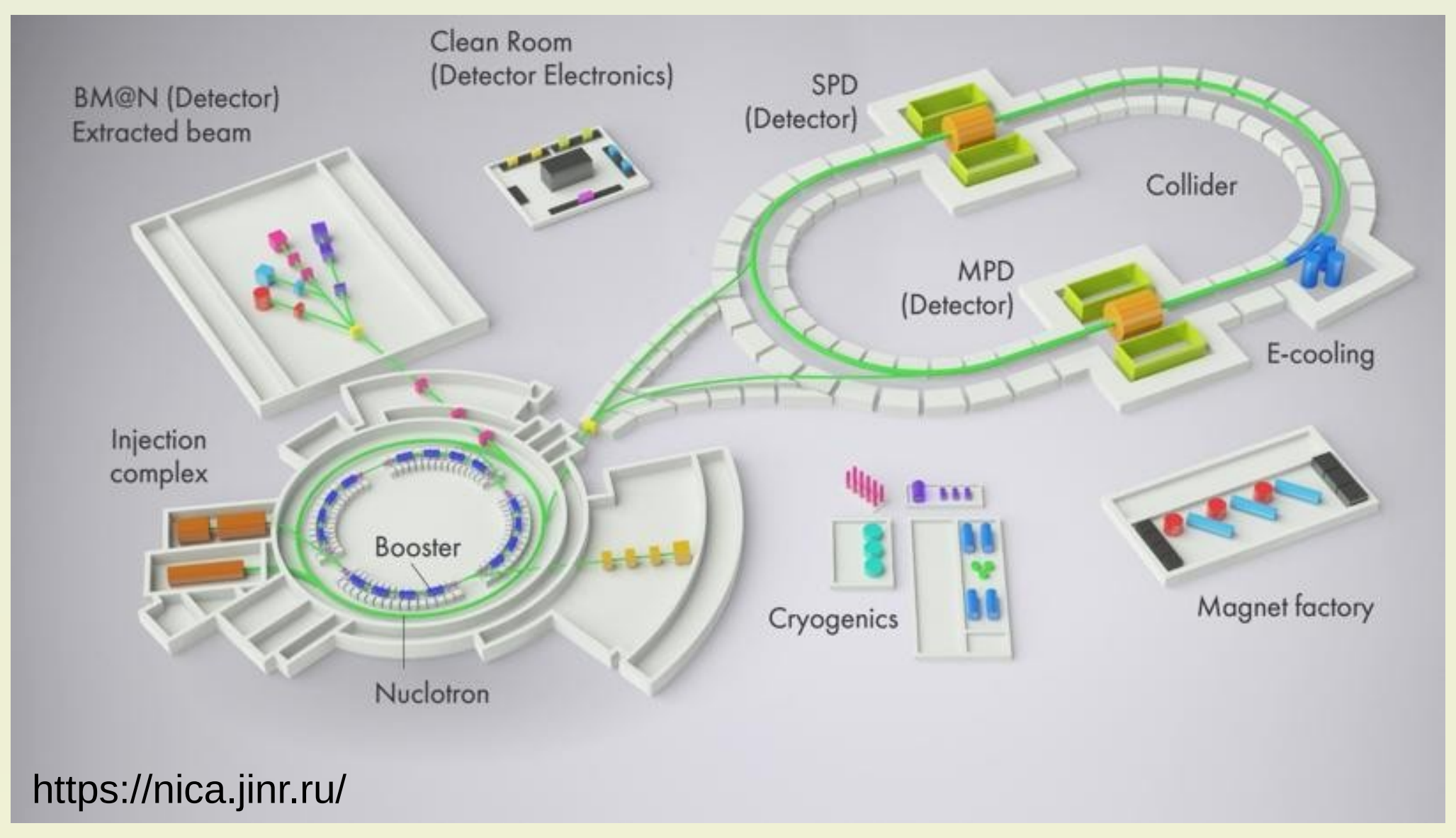

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Fig.2. NICA complex

MICROCHANEL PLATES DETECTORS

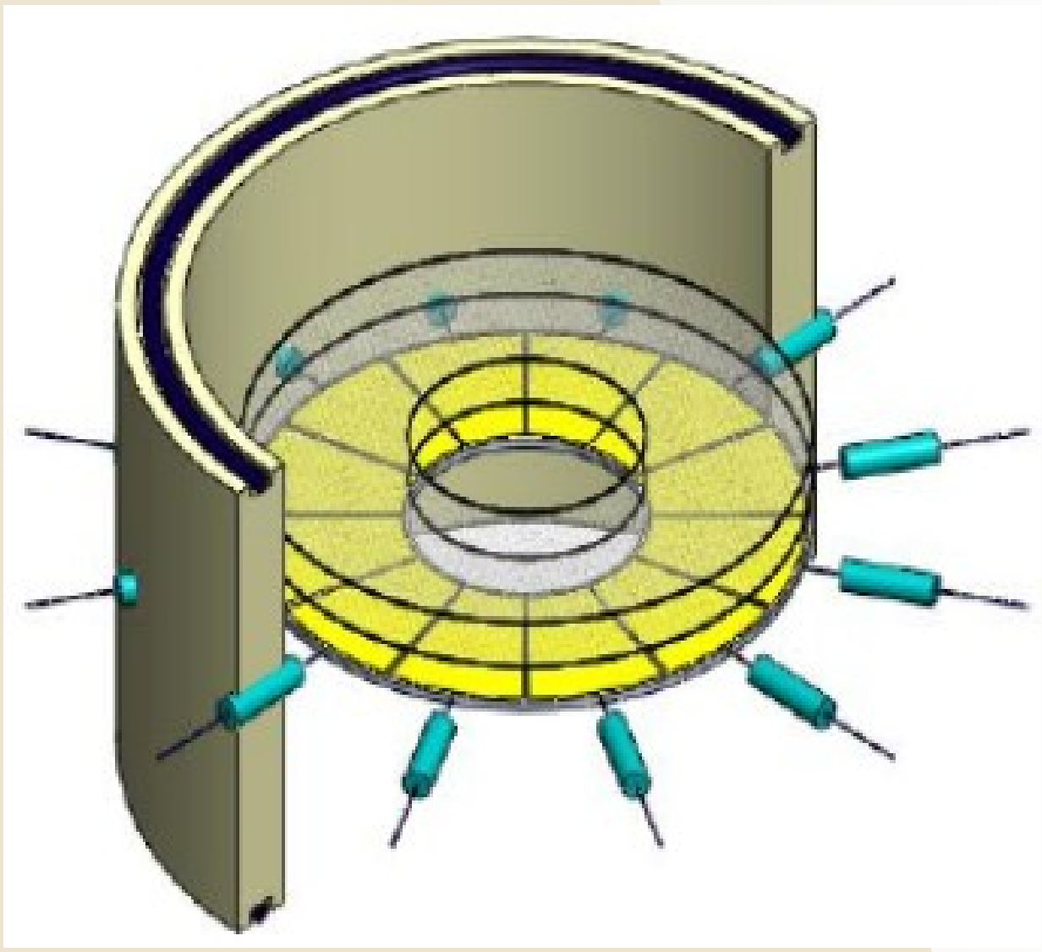

Fig.3. Concept of the compact module of the FBBC based on the circular MCPs [1].

The FBBC is based on the application of **Microchannel plate detectors** (**Fig.3**) for the precise determination of arrival times of charged particles produced in the nucleus-nucleus collisions at NICA. New MCPs with the improved characteristics, such as small diameter (8μ) channels, low resistivity (100-500 MOhm), high gain (~10^7), short (~1ns) MCP signals, fast rise-time (~0,8 ns) signals, will be used.
We suggest to use the MCP detectors in MPD and/or SPD experiments at NICA as the system for the fast collision trigger signal generation and bunch-by-bunch monitoring of the collision intensity, for the IP determination and for measurements of the TOF and azimuthal distributions of particles produced in the very forward/backward regions .

SUPPOSED DETECTOR DESIGN

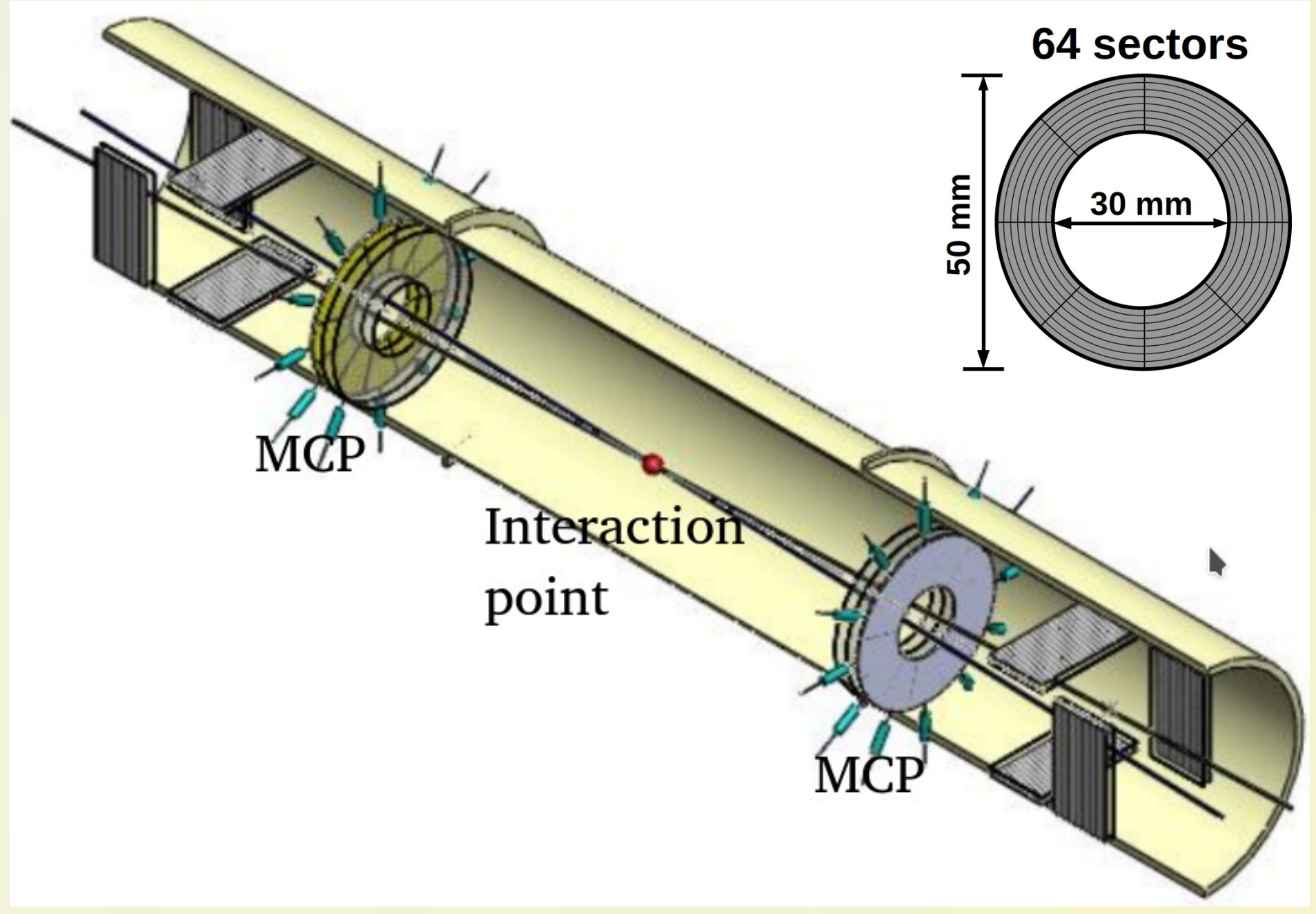

Fig.4. Supposed FBBC design [1]

We supposed FBBC as a two sets of MCPs placed on the left and right sides symmetrically from IP (**Fig.4**). The number of MCPs on the single side is optional, and we assume it equals 3-5 MCPs. We suppose every single MCP as a ring with inner diameter 30 mm and outer diameter 50 mm. MCP separated on some amount of sectors, which one of them is connected to read-out electronic channel. In this study we consider MCPs, separated on 8 angle and 8 radial sectors (total 64 read-out sectors) (**Fig.4**).

MC SIMULATION: DETAILS

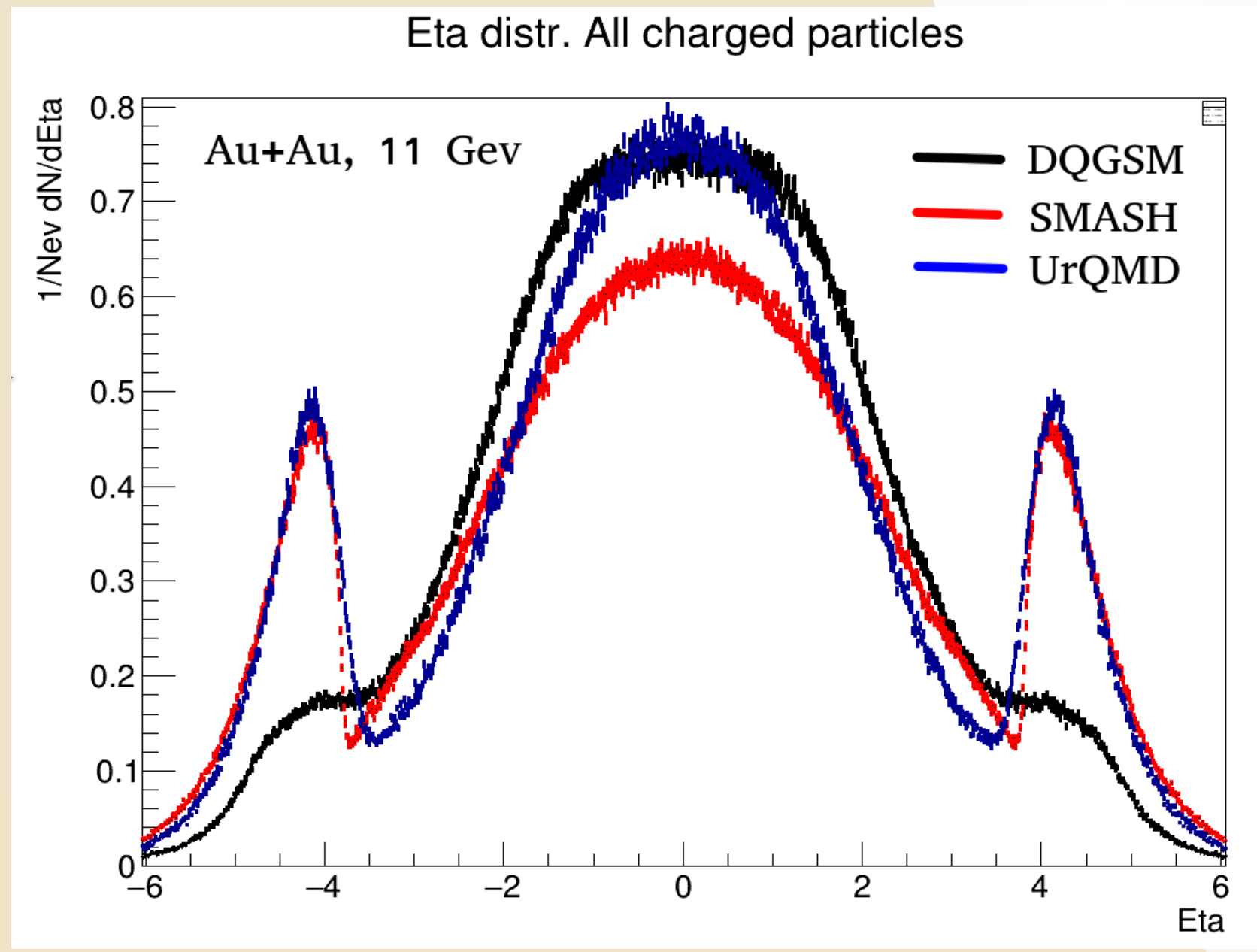

Fig.5. Charged particles pseudorapidity distributions: MC simulations

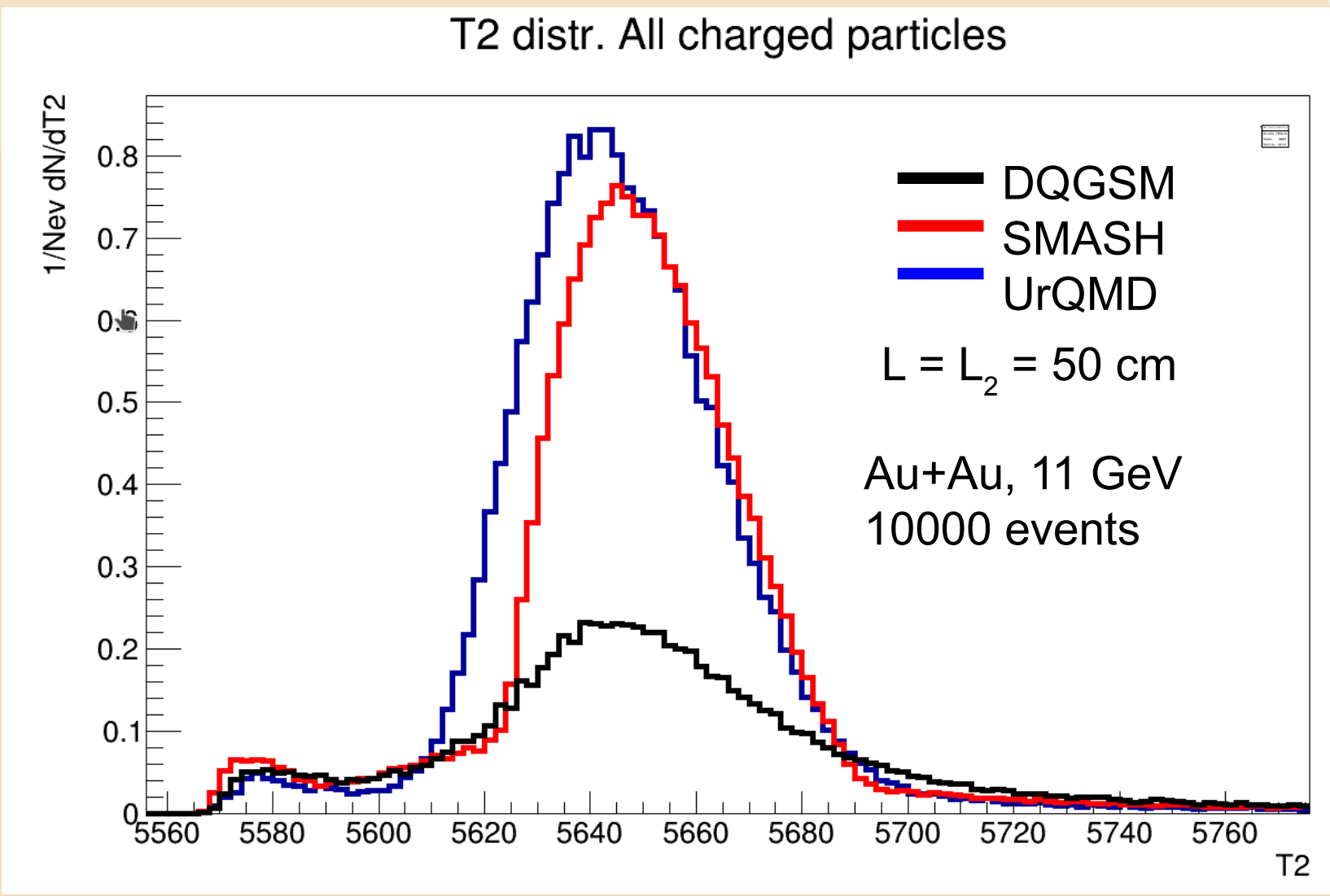

Fig.6. Charged particles time-of-flight distributions: MC simulations

For Monte-Carlo simulations we used 3 event generators: DQGSM **[2]**, SMASH 1.8 **[3]** and UrQMD 3.4 **[4]**. We didn’t use GEANT for experimental facility simulation yet – it will be done at the next stage of the study.

We simulated about 10000 Au+Au collisions with energy √s=11 GeV and impact parameter from 0 fm to 14 fm for every MC generator. Only charged particles are considered.

It was revealed that SMASH and UrQMD are unable to distinguish final state ions from bulks of separated nucleons, which leads to overestimating final multiplicity of protons (**Fig.5, Fig.6**). Thats why in the further part of the study we use DQGSM results mainly.

TIME-OF-FLIGHT DISTRIBUTIONS: DQGSM RESULTS

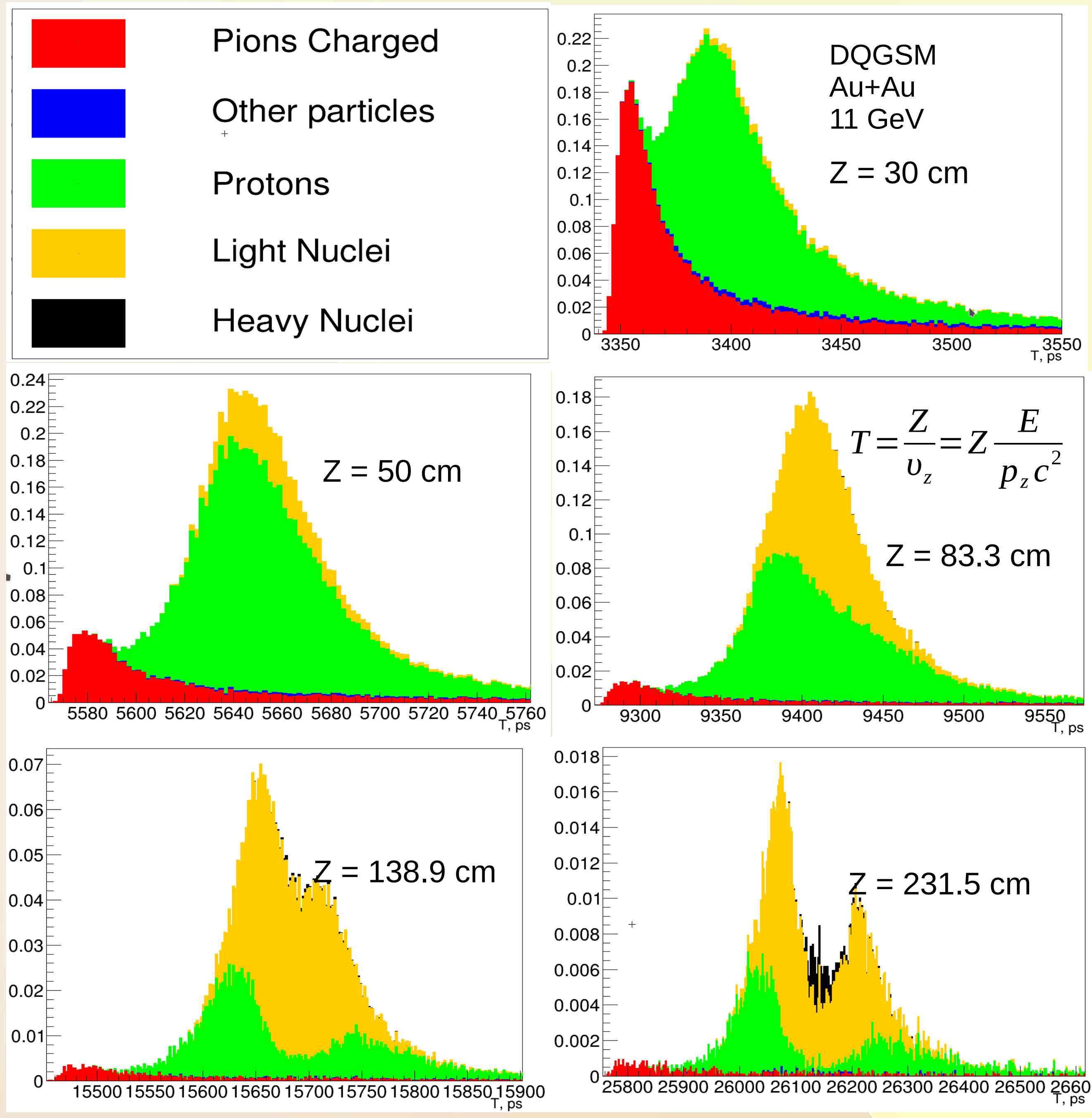

Fig.7. Time-of-flight distributions for different particle types: DQGSM simulations.

Here are the TOF distributions for several selected distances Z from the IP to the detector planes calculated by the DQGSM MC event generator for the different type of particles. One can see the changes in different particle types ratios: while distance increases, number of pions and protons decreases, and number of light nuclei increases. Also in the last 2 pictures we can see the appearance of heavy nuclei and unpredicted separation of protons and light nuclei into 2 groups.

EFFICIENCY OF PARTICLE COUNTING AND INTERACTION POINT DETERMINATION

Distance from IP to detector	30 cm	50 cm	83.3 cm	138.9 cm	231.5 cm
Covered η range	3.2 – 3.7	3.7 – 4.2	4.2 – 4.7	4.7 – 5.2	5.2 – 5.7
Average number of ch.part, passed through MCP in single event	9.6	8.7	7.5	4.1	1.4
Efficiency ($N_{counted}/N_{all\ passed\ through}$)	0.94	0.94	0.95	0.98	0.99
$\sigma(Z_{true}-Z_{calc})$	11 mm	13 mm	20 mm	56 mm	75 mm

Tab. 1. Characteristics of MCP for different distances from IP

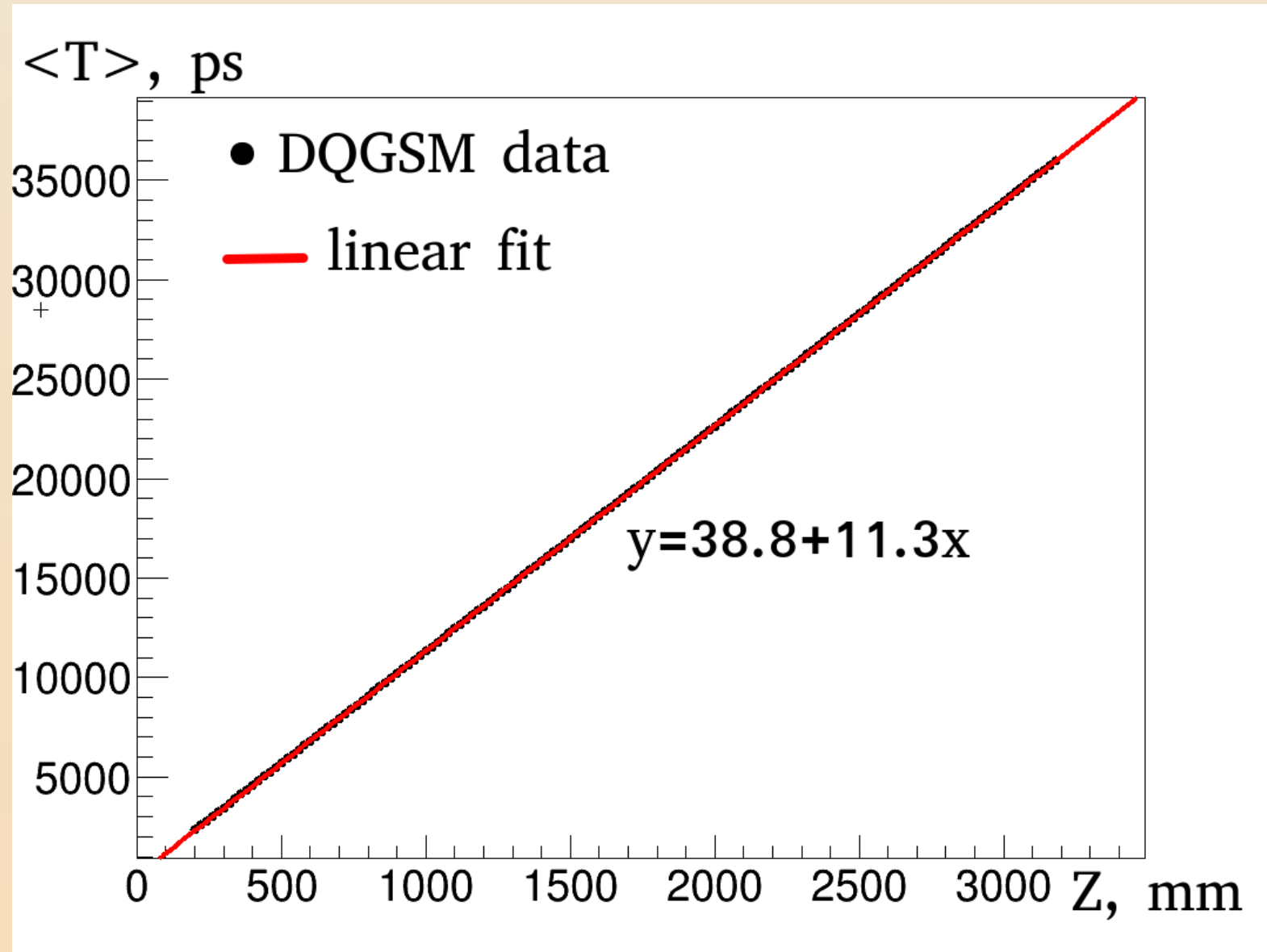

Fig. 8. Gauge plot of dependency <T> on Z

We calculated some characteristics of MCPs for different distances from IP (**Tab.1**), such as: pseudorapidity region, covered by single one MCP; event-by-event average number of charged particles in this pseudorapidity region; efficiency of particle counting, which is ratio of counted particles to all particles in the pseudorapidity region covered by the MCP.

Also we checked the possibility to reconstruct IP coordinate Z via the information about average arrival time of particles <T>. We make a gauge plot <T>(Z) (**Fig.8**) using DQGSM data, then we use the information from MCP about <T> in the single event and estimate coordinate Z_{calc} by gauge plot. The standard deviations of the quantity ($Z-Z_{calc}$) shown in the **Tab.1**.

CONCLUSIONS

- Fast compact detectors with high timing capabilities based on the MCP applications were proposed in **[1]** for the beam-beam collisions monitoring for NICA experiments at JINR.
- It is assumed that the particle beams pass through the central opening of the circular MCP setup, and the secondary particles produced in the collision are registered after fllying some definite distance from IP. Signals are recorded by sector cathodes and their arrival times are digitized along.
- The DQGSM MC event generator simulations show that for values of charged particles multiplicity expected in the high rapidity forward/backward regions at NICA energies, it will be sufficient to use a limited number of channels for the MCP disk detector (32 or 64).
- The DQGSM MC event generator simulations show also that with the timing resolution at the level of 50 ps one may expect to collect information on the arrival time distributions of different type of particles, including fragments.

REFERENCES

1. A.A. Baldin, G.A. Feofilov, P. Har'yuzov, F.F. Valiev, NIMA, v.958, 1 (2020), 162154
2. K.K. Gudima, S.G. Mashnik, A.G. Sierk, Report LA-UR-01-6804. Los Alamos. (2001)
3. J. Weil, V. Steinberg, J. Staudenmaier et al., Phys. Rev. C 94 (2016) 5, 054905
4. S.A. Bass, M. Belkacem, M. Bleicher, et al., Prog. Part. Nucl. Phys. 41 (1998) 225-370

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