Study of performance of Fast Beam-Beam Collision monitor system with MC simulations and machine learning methods

Oral talk for NUCLEUS-2021

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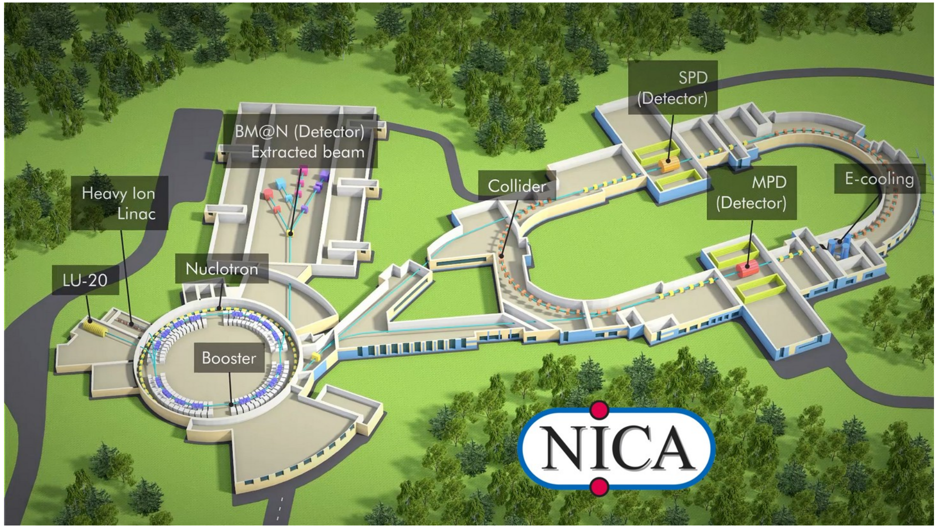
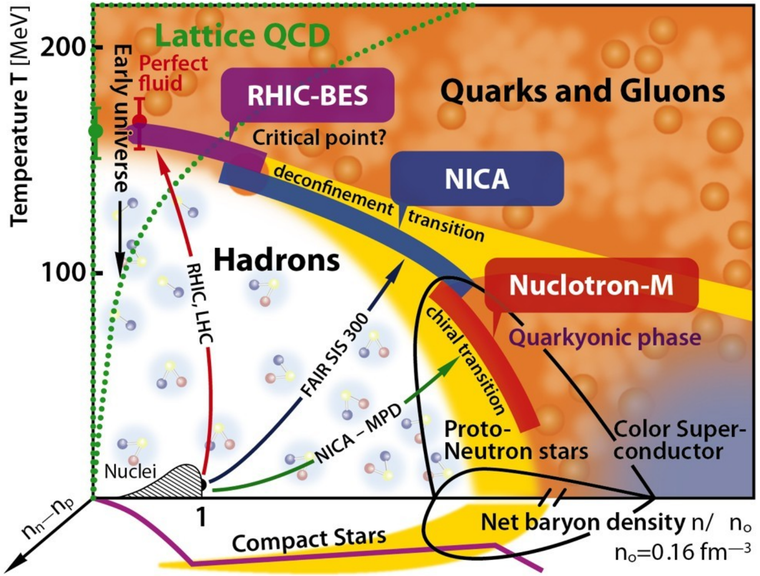
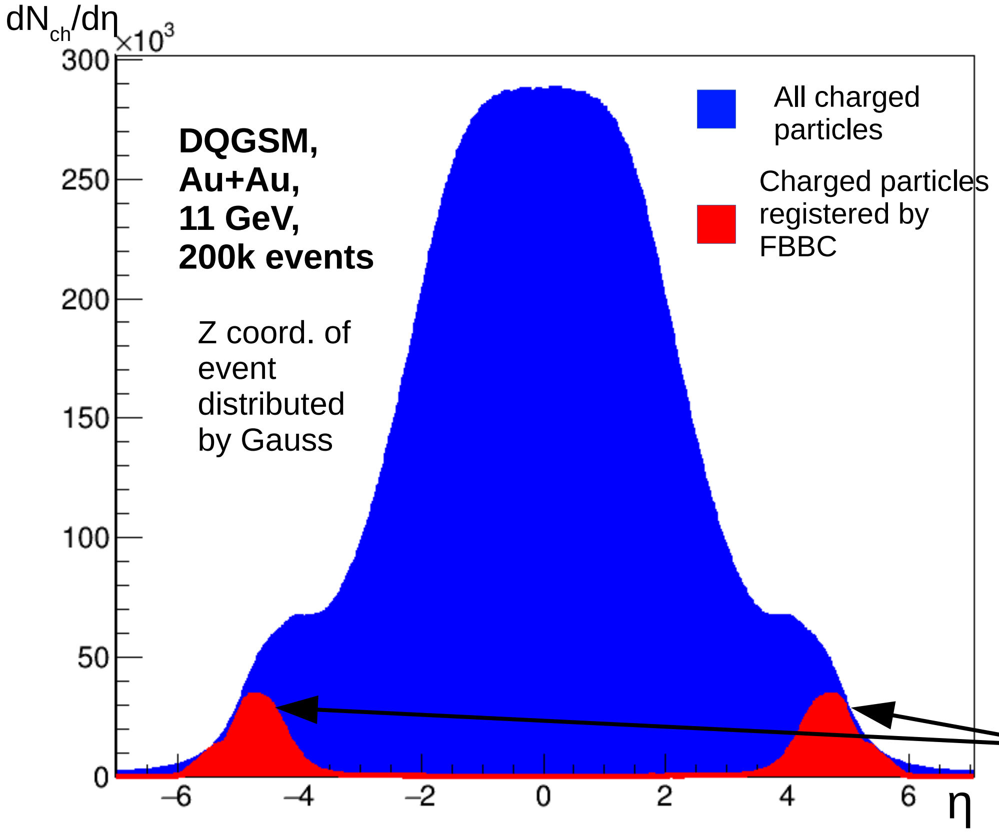




Experiments to study the QCD phase diagram in the region of high baryon densities are planned at the NICA collider.

For qualitative event-by-event analysis it is necessary to determine such event characteristics as:
- *interaction point coordinates;*
- *multiplicity;*
- *centrality;*
- *time of event occurring;*
- *azimuth distribution, etc.*

For data collecting we have to build effective trigger system, which should be:
- *fast;*
- *precise;*
- *noiseless;*
- *radiation persistent;*
- *transparent.*

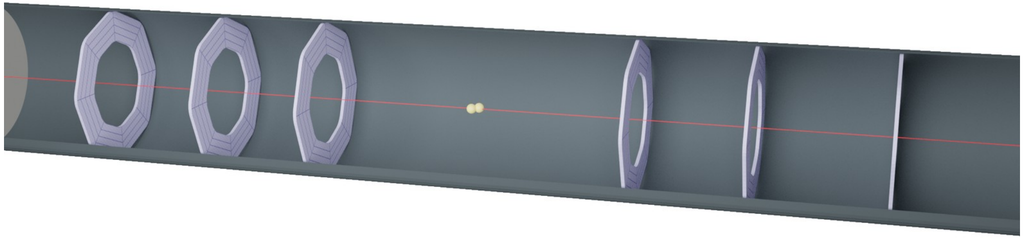


In the work [1] the system based on a few Microchanel plates located symmetrically on both sides of the main experimental facility (MPD or SPD), named Fast Beam-Beam Collision monitor system (**FBBC**).

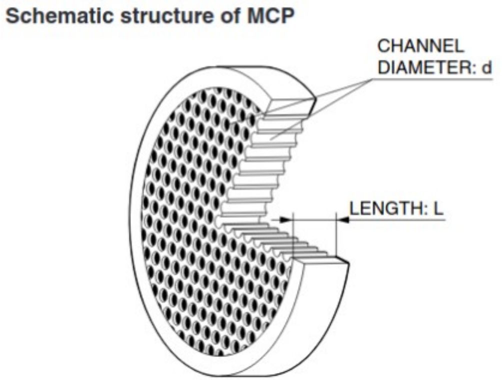
<u>In the present study we suggest next FBBC design:</u>

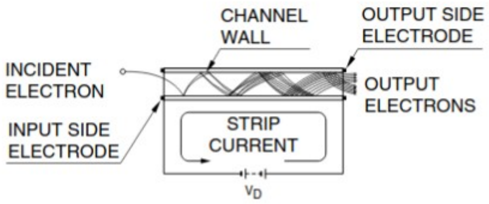
- **6 MCPs (3 right + 3 left)** installed into beam pipe
- MCPs are placed at distances **90 cm, 150 cm and 250 cm** from the center of the main facility

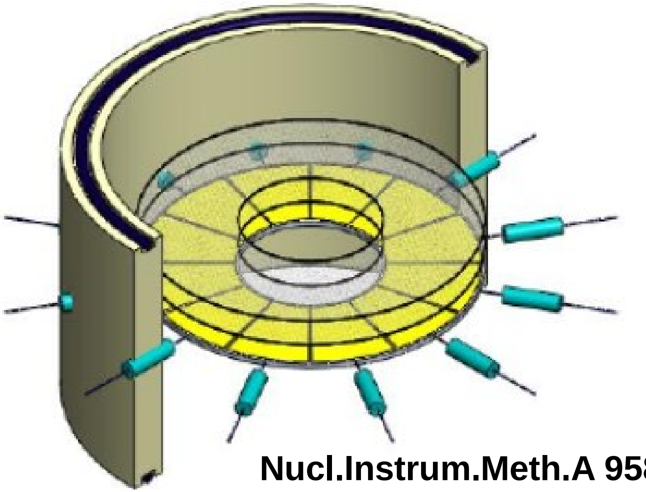
Such MCPs configuration should cover the pseudorapidity intervals **3.9 ⪝ |η| ⪝ 5.5**



[1] A.A. Baldin, G.A. Feofilov, P. Har'yuzov, F.F. Valiev. Nucl.Instrum.Meth.A 958 (2020) 162154





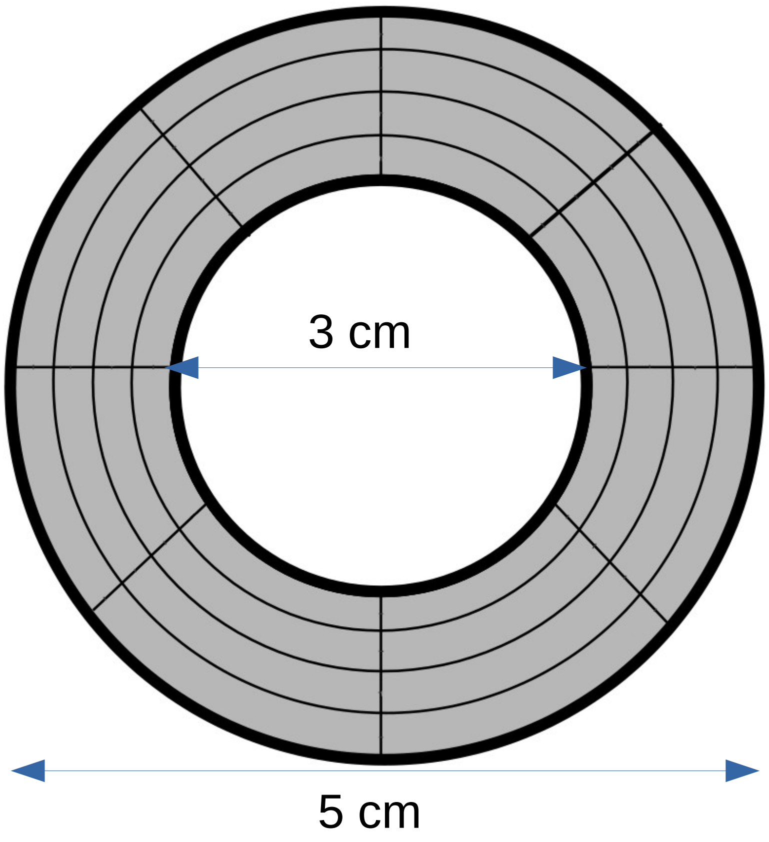


Nucl.Instrum.Meth.A 958 (2020) 162154

We suggest a detectors on **MicroChannel Plates (MCP)** as the system for trigger signal generation, finding of interaction point and, perhaps, centrality class determination in MPD and/or SPD experiments.

<u>MCP advantages:</u>

- high timing precision (~ 50 ps);
- fast signal rise time (< 1ns);
- low level of noise;
- ability to work in strong magnetic fields;
- high radiation persistent;
- low amount of matter (transparency) .



<u>We suggest the next MCP design:</u>

Geometry form: ring
Inner radius: 15 mm
Outer radius: 25 mm

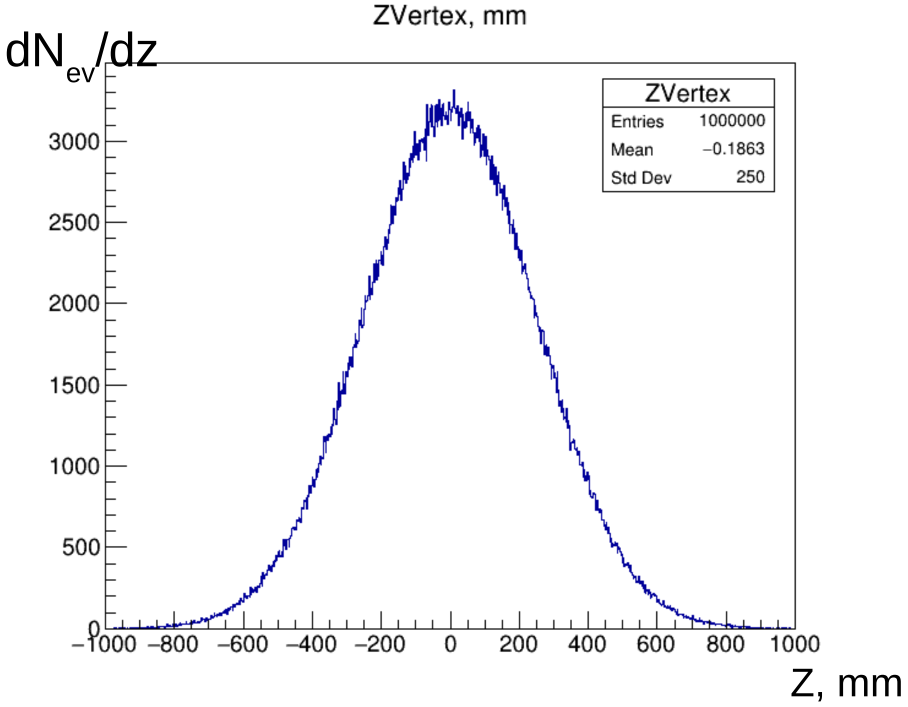
4 equal radial sectors and 8 equal azimuth sectors = 32 sectors (read-out channels)

MC simulations: main details

- **Used MC generators:** DQGSM + FBBClib
- **Collisions:** Au+Au, √s = 11 GeV per NN pair
- **1 mln. events**
- **Number of plates:** 3 right + 3 left;
- **L1, L2, L3** = [90 / 150 / 250] cm

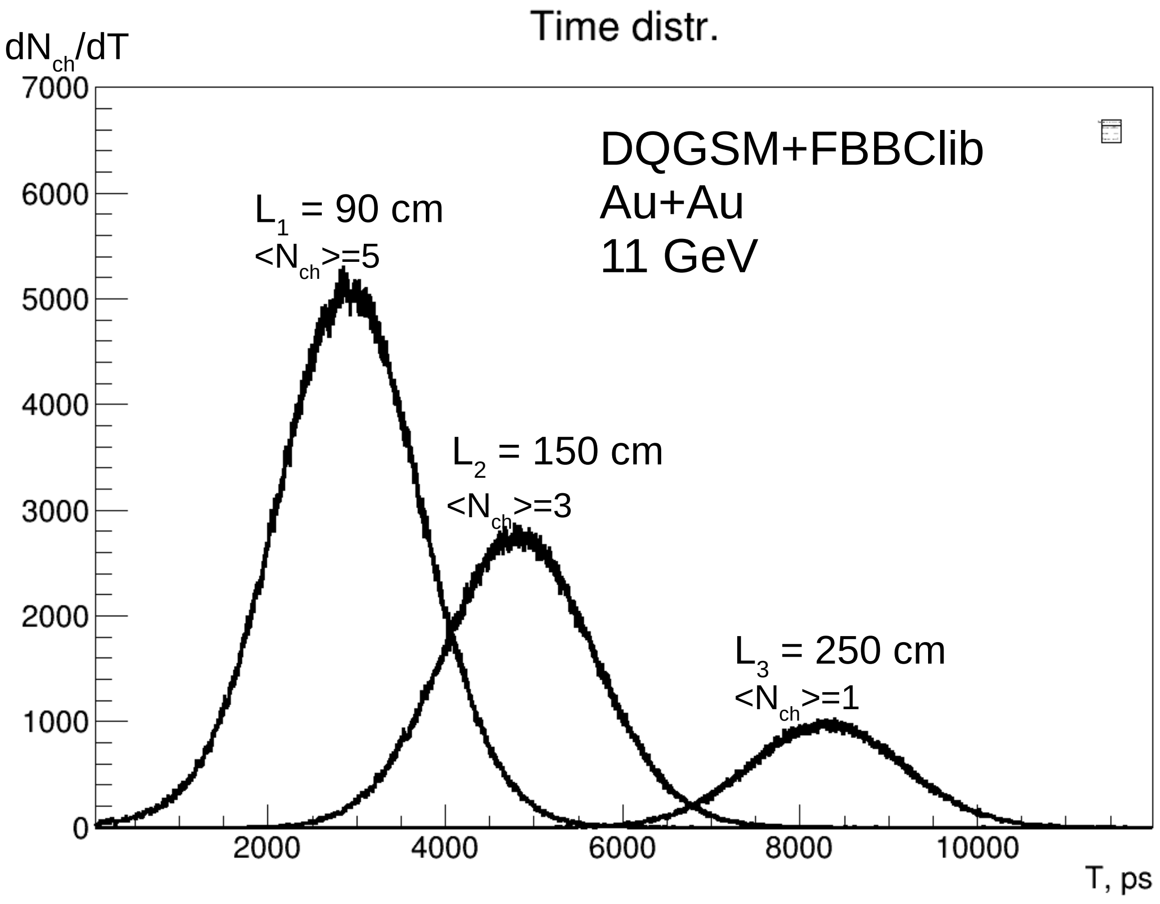
Covered pseudorapidity region: 3.9 ≲ |η| ≲ 5.5

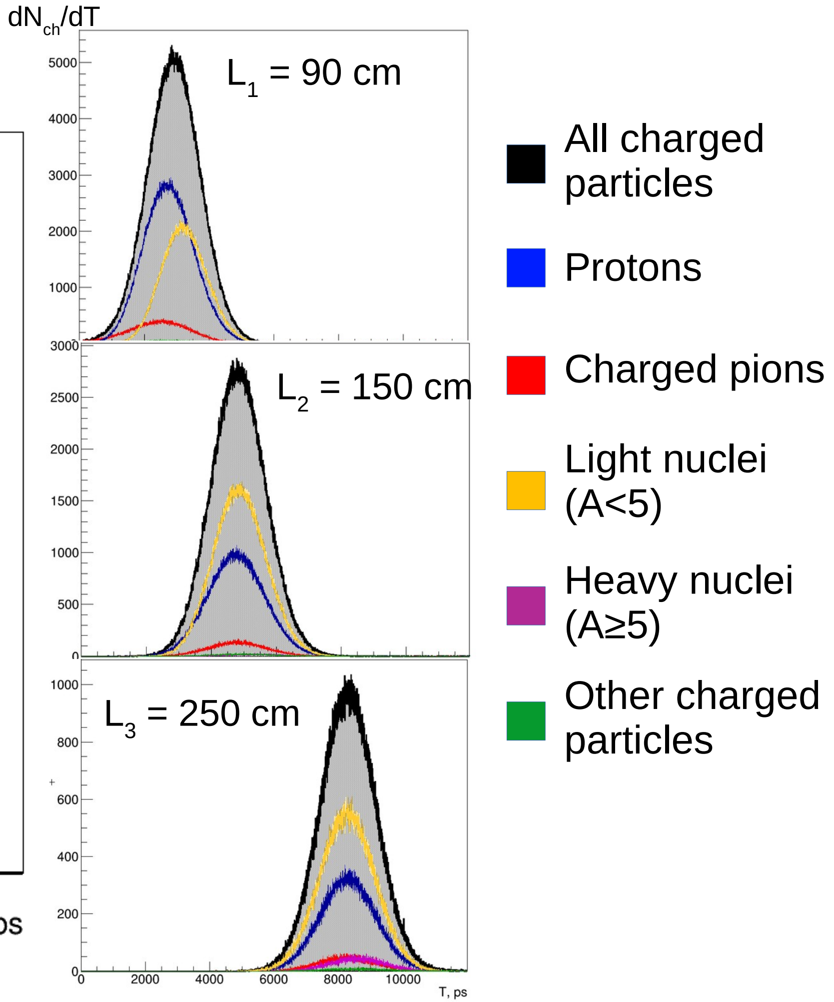
- **Charged particles** only
- **Efficiency of particle registration:** 90%
- **Timing precision:** 50 ps
- **Z vertex** distributed by Gauss distr. with σ = 30 cm



For detector processing simulation the C++ library **FBBClib** was created.
It can be found on https://github.com/vsandul/FBBClib

Distribution of times of particle arrival: MC simulation results





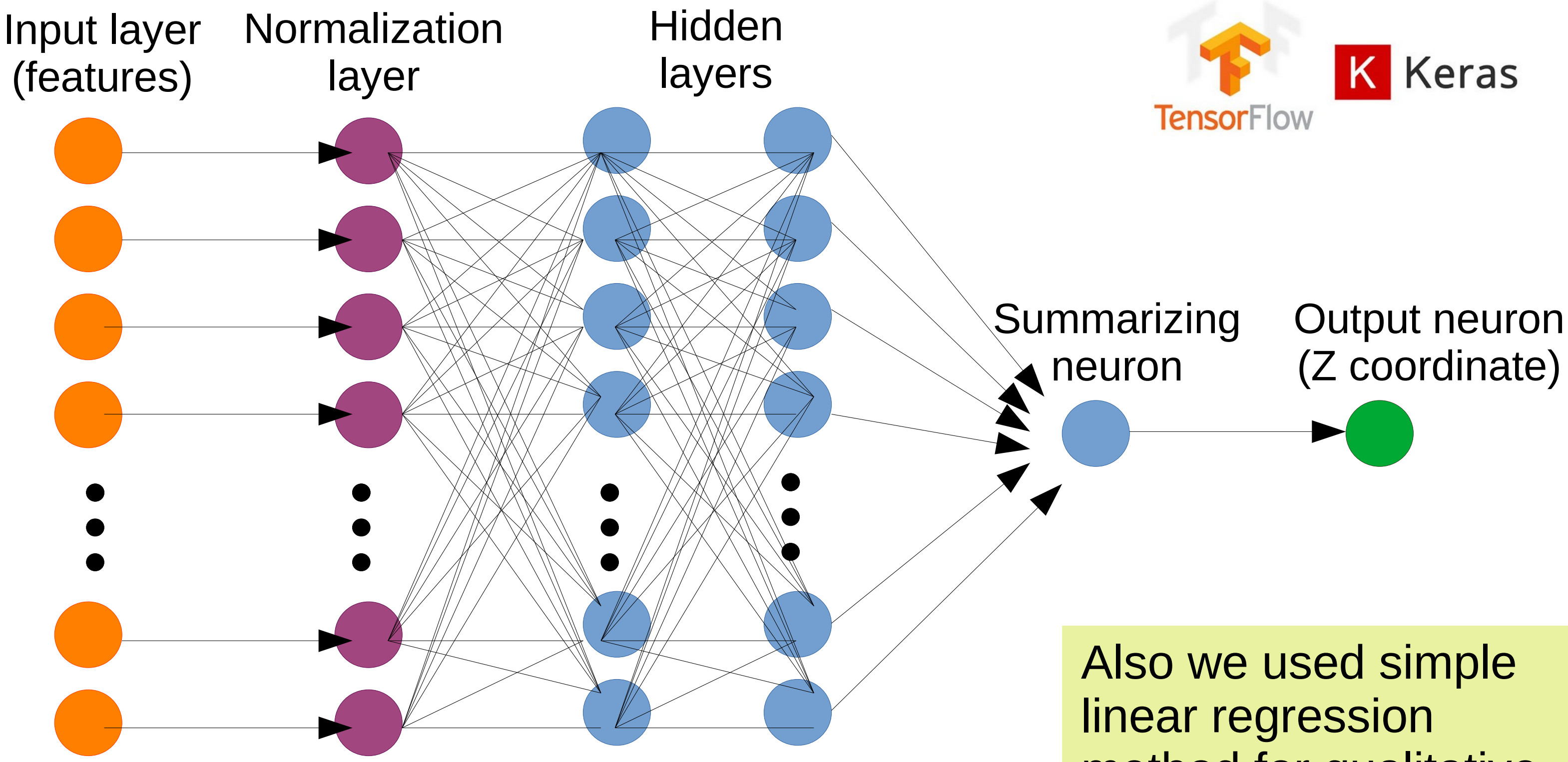
IP determination: neural network architecture

Dataset size:
from 10 000 to 300000 (depends on MCP configuration)

Data split ratio:
70% - train set
30% - validation set

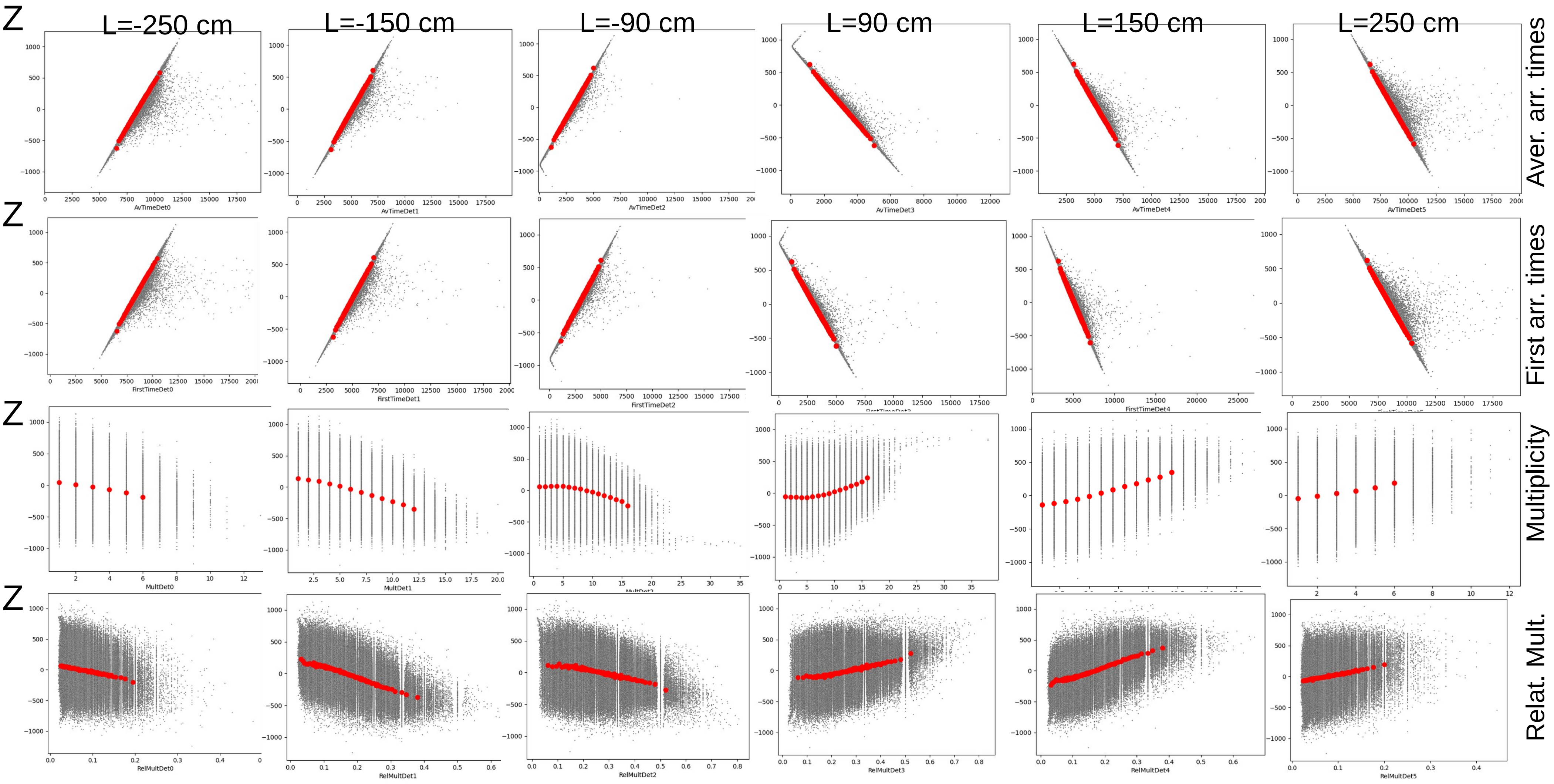
Metrics: MSE

Tensorflow Keras package was used for NN building and application



Also we used simple linear regression method for qualitative comparison

IP determination: features for ML



IP determination: results

🟢 At least 1 particle was registered by MCP

🔴 No particle was registered by MCP

MCP config.	Freq. of config.	σ, NN	σ, lin. regr.
🟢🟢🟢 🟢🟢🟢	31.6 %	3 mm	12 mm
🟢🟢🟢 🟢🟢🔴	10.4%	4 mm	26 mm
🔴🟢🟢 🟢🟢🟢	10.4%	4 mm	18 mm
🔴🟢🟢 🟢🟢🔴	6.6 %	6 mm	36 mm
🔴🔴🟢 🟢🟢🔴	2.5 %	9 mm	46 mm
🔴🟢🟢 🟢🔴🔴	2.5 %	10 mm	41 mm
🟢🟢🟢 🟢🔴🔴	2.2 %	6 mm	34 mm
🔴🔴🟢 🟢🟢🟢	2.2 %	8 mm	31 mm
🔴🟢🟢 🔴🔴🔴	1.8 %	7 mm	20 mm
🔴🔴🔴 🟢🟢🔴	1.8 %	7 mm	20 mm
Overall	72 %	**4.5 mm**	20.9 mm

The IP determination results for 10 most common MCP configurations are presented at the table.

Neural networks provide us with a very good quality of IP Z-coordinate determination.

Linear regression give us significantly worse results in comparison with NN

Summary

- We explore the ability of earlier suggested based on MicroChanel Plates Fast Beam-Beam Collision monitor system (**FBBC**) for the on-the-fly **reconstruction of Z position** of the event interaction point (and FBBC usage as a trigger system)
- We propose the FBBC as 6 MCP rings (3 right + 3 left) installed inside beam pipe and placed at the distances of 90 cm, 150 cm and 250 cm from the center of the main facility
- For this purposes special C++ library for FBBC processing simulation was written (**FBBClib**). Using **MC data** passed through virtual FBBC detector and **machine learning methods** (neural networks, linear regression), we obtained the possibility to reconstruct Z position of interaction point **with the precision σ = 4.5 mm**

- **The possibility of FBBC for event centrality determination is also under our interest (see Kirill Galaktionov's report "Neural network application to event-wise estimates of the impact parameter", today in 16:40 MSK)*

We would like to emphasize the acknowledgments to the RFBR grant №18-02-40097/19 for supporting this study

Thank you for attention!