Time-of-Flight system of the BM@N/NICA experiment.
Performance of the detector and particle identification results.

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BM@N (Baryonic Matter at Nuclotron) is the first experiment at the accelerator complex of the NICA. The Nuclotron will provide variety of beams from protons to gold ions with the kinetic energy of ions ranging from 1 to 6 GeV per nucleon. The main goal of the experiment is studying of baryonic matter at high density and temperature within collisions of relativistic heavy ions. The experiment combines high precision tracking with high performance time-of-flight measurements for particle identification. First physical data were obtained in spring 2018. The setup registered particles from collisions of Ar and Kr beams with the targets C, Al, Sn, Cu, Pb. The performance of the detectors and preliminary result of particle identification are presented in the poster.

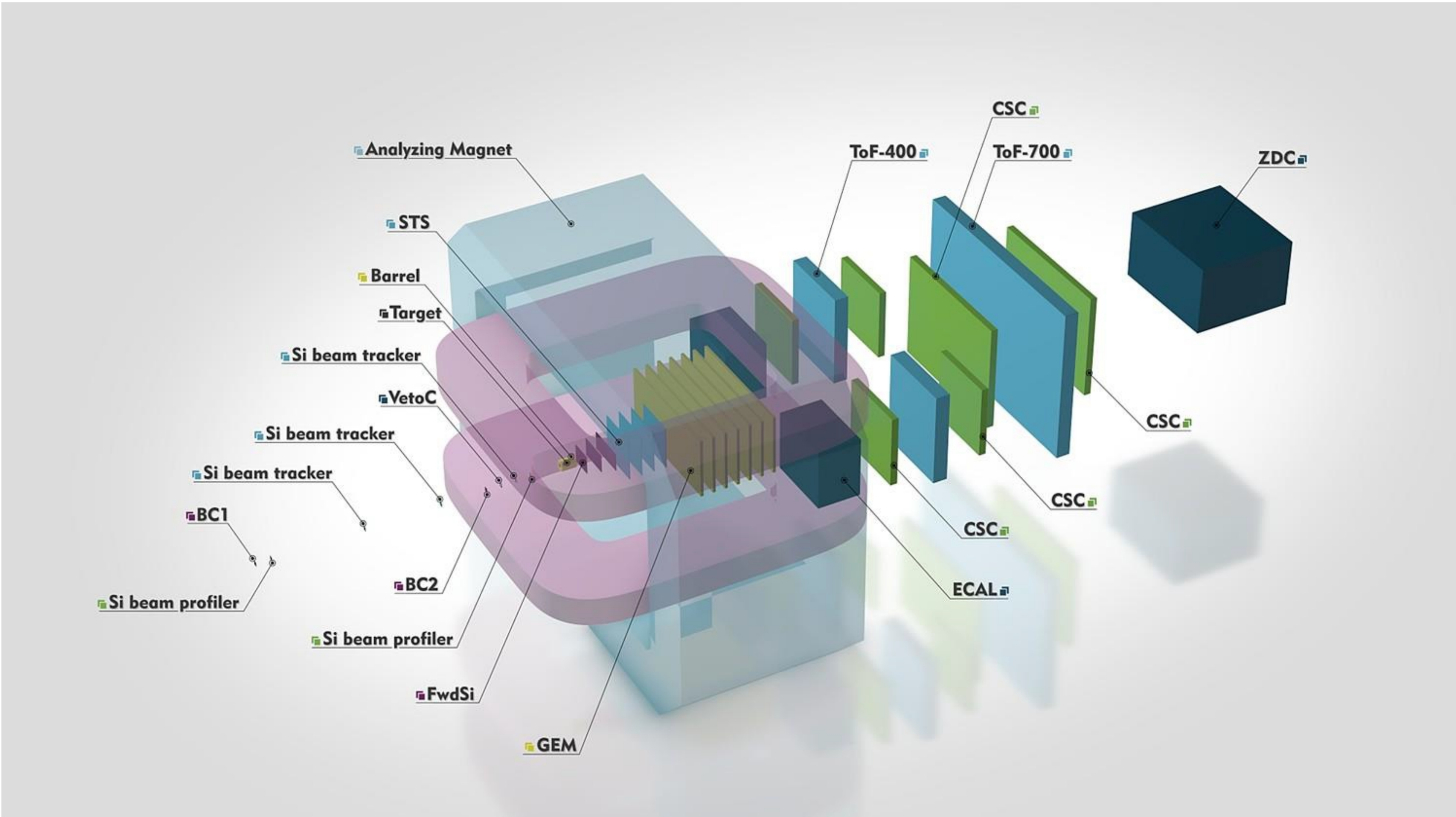

Fig. 1. Schematic view of the BM@N setup

BM@N (Baryonic Matter at Nuclotron) is fixed target experiment of the NICA Complex. The setup include a beam monitor system (Si beam profiler/tracker), Trigger and T0 system base on fast scintillator counters (BC1/2, VetoC, Barrel), precise tracking system in magnetic field (FwdSi, STS, GEM), outside tracking system (CSC), particle identification system based on time-of-flight measurements (ToF400 and ToF700), and calorimetry system (ZDC and Ecal). In March 2018, BM@N run with Ar and Kr beams on targets C, Al, Cu, Sn, Pb were held.

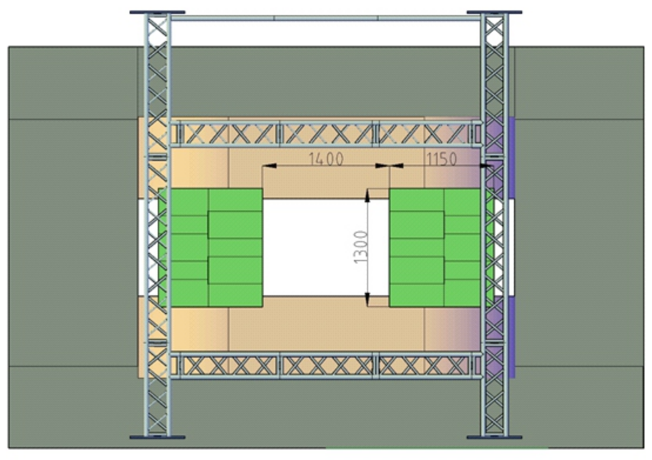

Fig. 2. ToF-400 wall schematic layout. Green squares are active area of MRPCs.

Active volume of one detector	300x600 mm^2
Operation voltage	11.5-12.5 kV
Number of FEE channels of one detector	96
Total number of detector	20
Total number of FEE	1920
Total active area of ToF-400	~3 m^2
Gas mixture	C2H2F4, i-C4H10, SF6 (90%/5%/5%)
Total gas volume	~0.3 m^2
Volume exchange/day	2
Radiation length	~13% X/X_0

Table 1. Main technical parameters of ToF-400

The ToF-400 wall consists of two part (left and right) are placed symmetrical to the beam. Every part consist of two gas boxes which content 5 MRPCs each. The active area of the MRPCs overlap on 50 mm inside the box. Overlap of gas boxes ensures crossing of active area of detectors 50 mm also. Size of every part is 1.15x1.3 m2 and defined to satisfy the geometrical acceptance of the tracking detectors. Separation pion/kaon up to 3 GeV/c requires better then 80 ps time resolution.

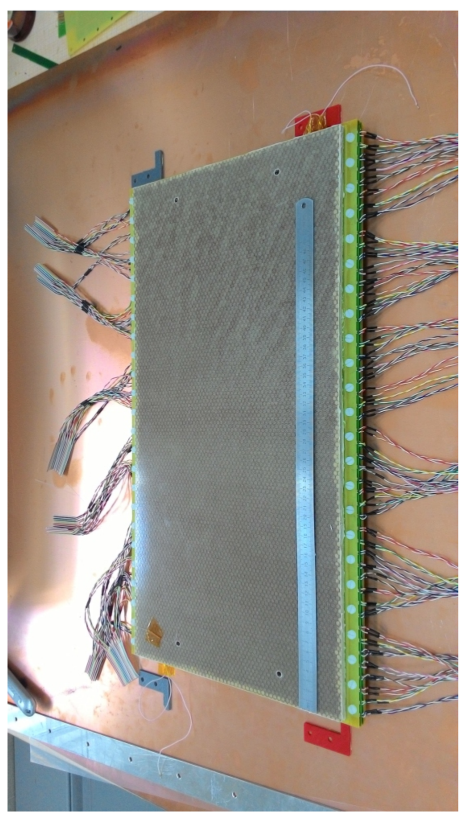

Fig. 3. Assembled MRPC.

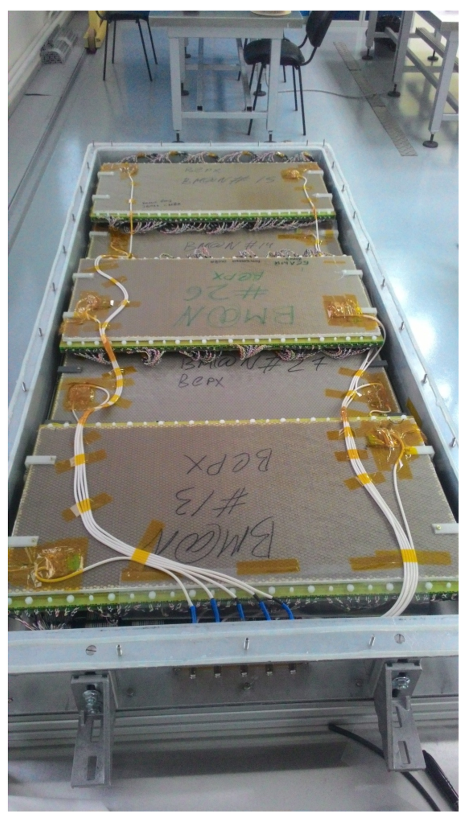

Fig. 4. One Box of ToF system.

Fig. 5. View of ToF system on BM@N.

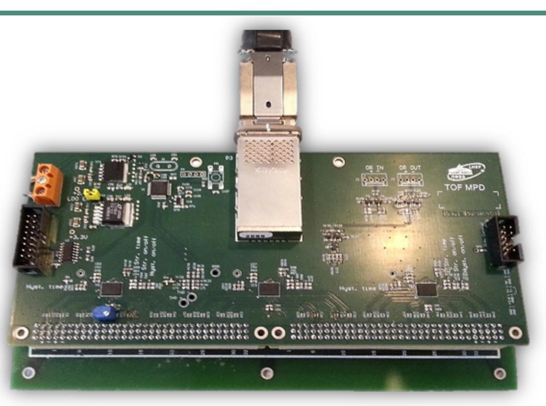

Fig. 6. 24 –channel amplifier –discriminator board based on NINO ASIC

Fig. 7. View of the TDC72VHL module

The fast front-end preamplifier discriminator chip NINO[3] are used for Time-of-Flight system. The 24-channel FEE board was developed in LHEP JINR[4]. The output signal in LVDS standard has time jitter less than 7 ps and its pulse width is dependent of input signal charge.

72-channel time-to-digital converters (TDC72VHL[5]) based on HPTDC chip [6] were developed and produced for digitization of LVDS signals and data acquisition. Time resolution of one channel is about 20 ps.

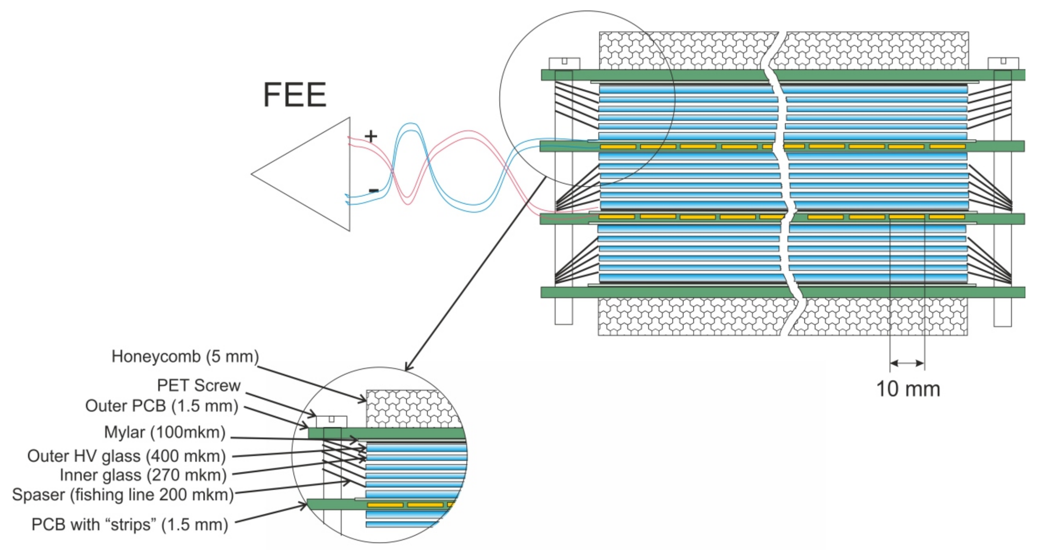

Fig. 8. Schem of the MRPC

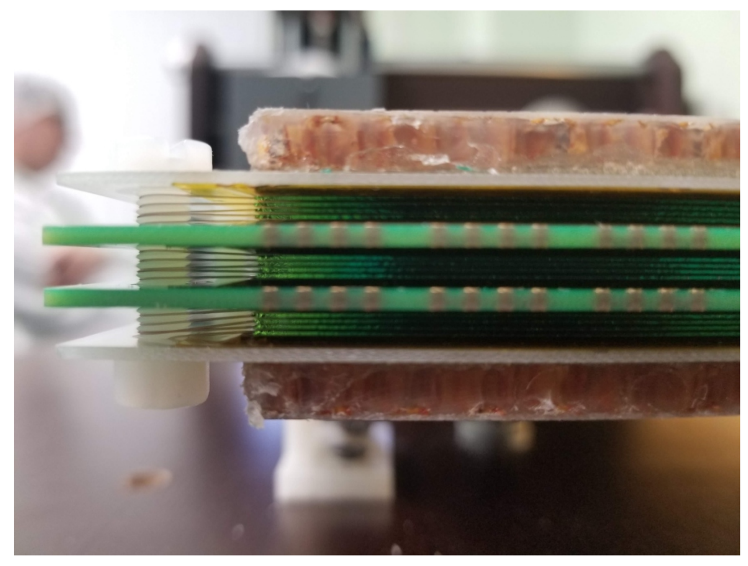

Fig. 9. Assembled MRPC

The MRPC[2] scheme is presented on Fig. 8. The detector consists of three stacks of 5 gas gaps each. As resistive electrodes we used common float glass. The outer glass electrodes have thickness 0.42 mm. The internal glass electrodes have thickness 0.27 mm. The fishing line as a spacer defines the 200 um gap between all resistive electrodes. The pickup electrodes look like strips and made on the PCB board. Differential analog signal from strip is transferred by twisted pair cable to front-end electronics. Signal is reading out from both ends of the strip. It provides better time resolution and determination of the coordinate of a particle along strip. Dimension of active area of one MRPC is 300*600 mm^2. It has 48 readout strips, 10 mm wide and 300 mm long.

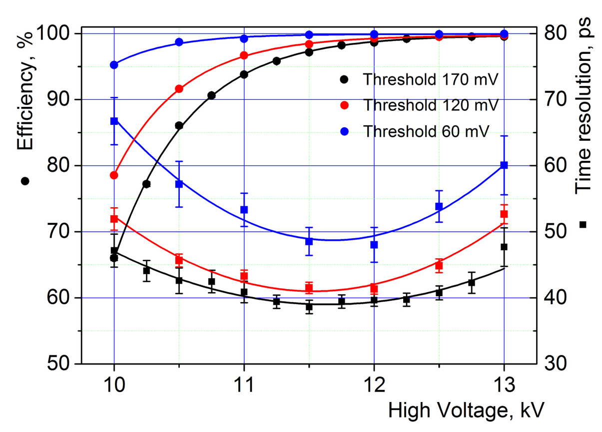

Fig 10. Time resolution and afficiency of the MRPC depending of HV

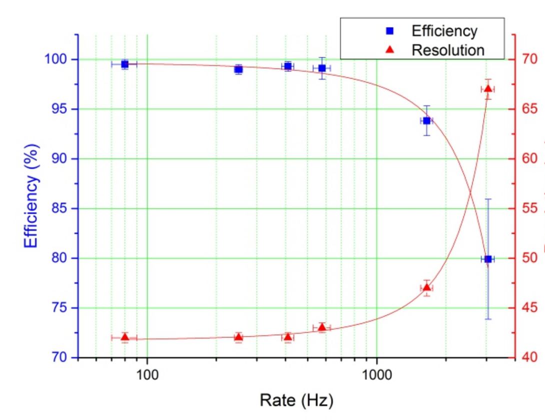

Fig 11. Time resolution and afficiency of the MRPC dependin of intensity

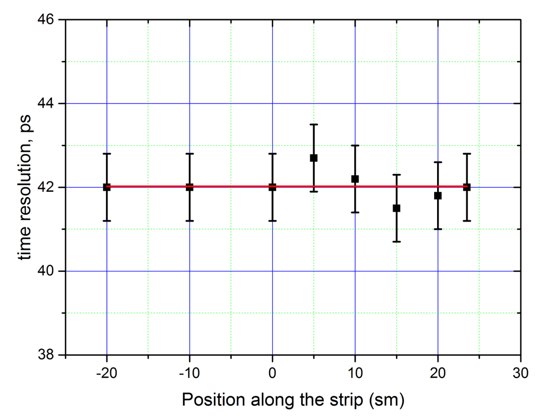

Fig 12. Dependence of the time resolution from position of particles along strip

The full scale MRPC was tested on the Nuclotron beam at LHEP. Result of efficiency and time resolution are present on the figure 10. The efficiency is higher than 98 % and time resolution is below 50 ps for different threshold of NINO. Working point is 11.5 kV at 120 mV of threshold. Results of high rate test are presented on figure 11. Particle flux on ToF-400 is not more then 1.5 kHz/cm^2 in BM@N, so time resolution of less than 50 ps and efficiency more than 90% are good results for MRPC made from float glass. The time resolution along strip measured by moving MRPC in horizontal direction (Fig. 12). All results including the contribution of all the front-end and DAQ electronics.

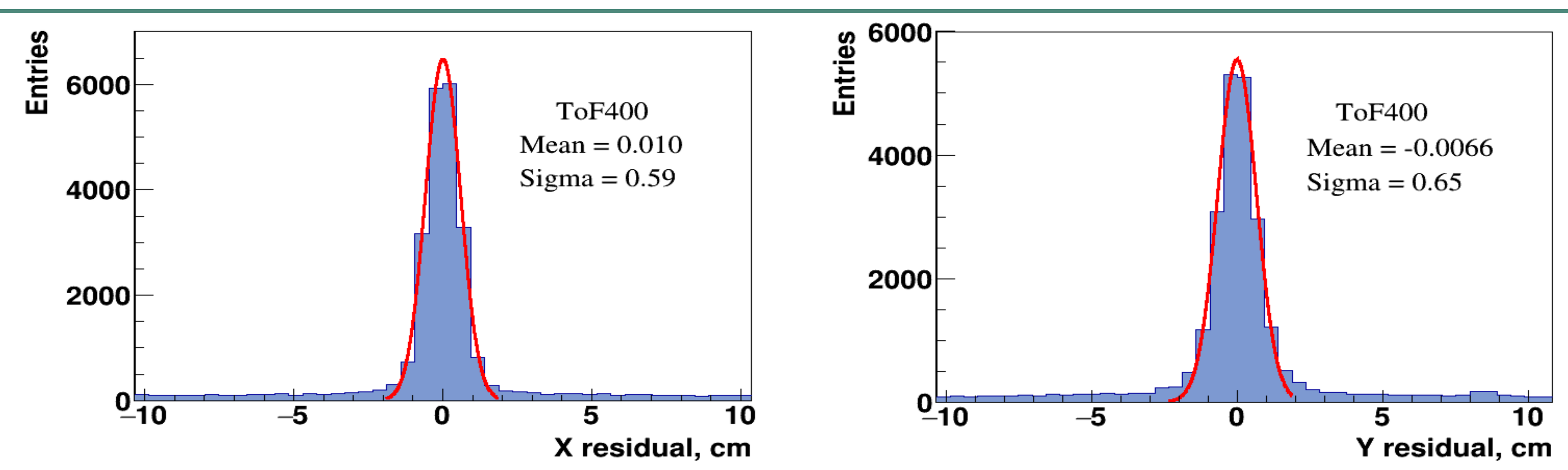

Fig. 13. Residues of X and Y of MRPC are shown above. The X resudial depend from readout strip pitch. The Y resudial determined by difference of time of signal arriving on both sides of the strip and depend from time resolution. This numbers are used for track matching.

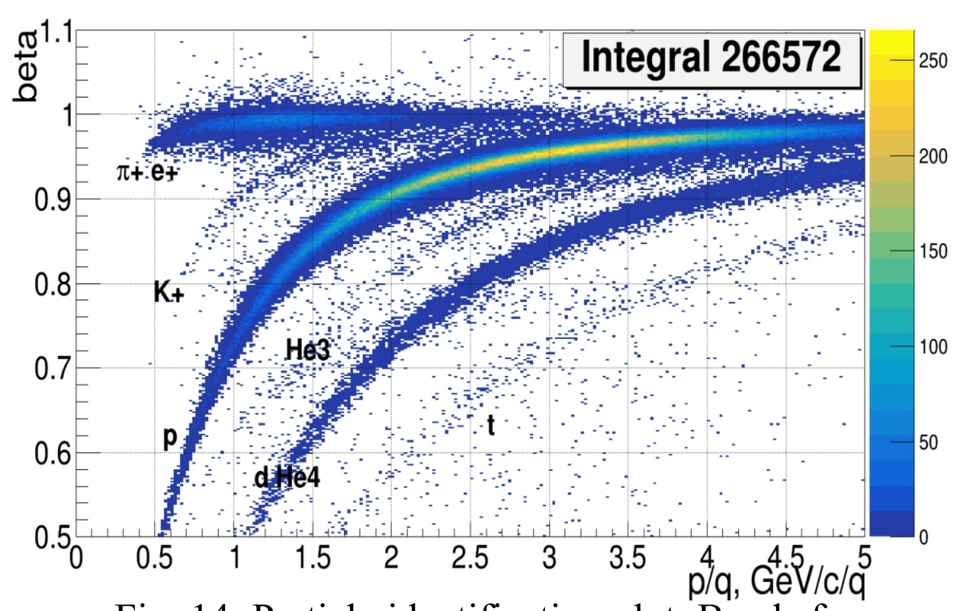

Fig. 14. Particle identification plot. Bands for π+, K+, p, He3, d/He4 and t are clearly visible

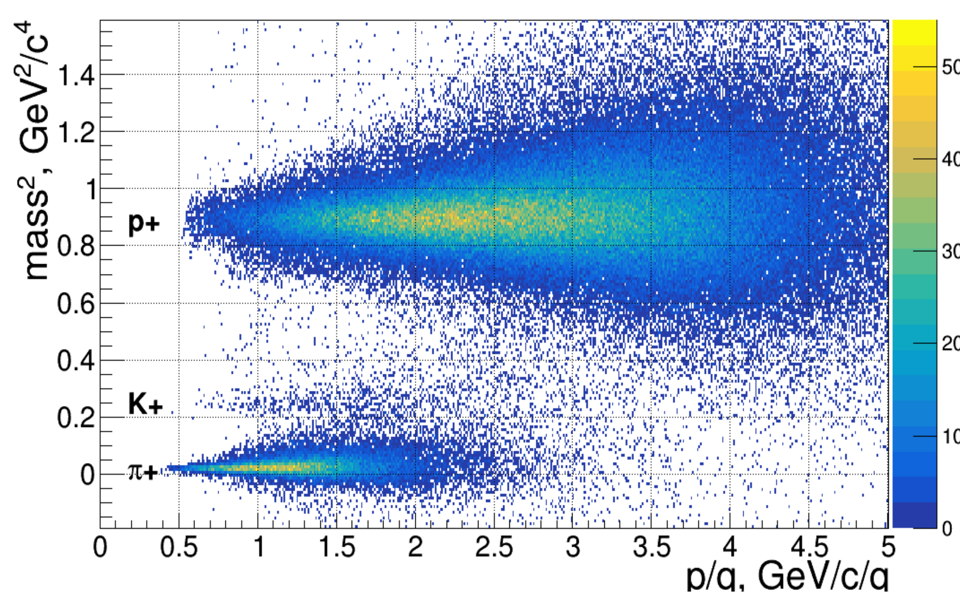

Fig. 15. m^2 versus momentum plot. The K+/π+ separation are possible up to 2 Gev/c

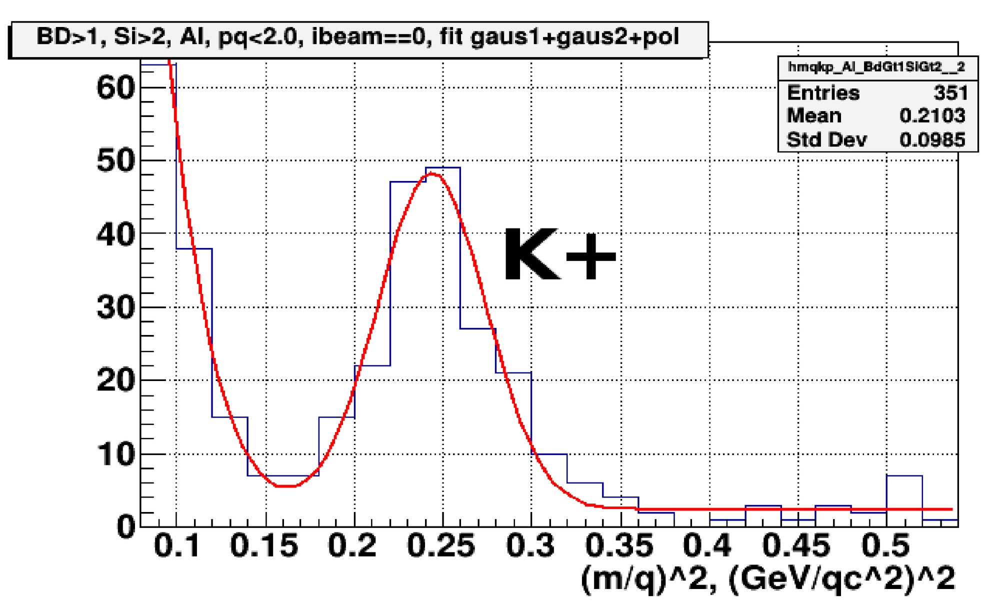

Fig. 16. Peak of K+ from Ar+target data collected over about one weeks

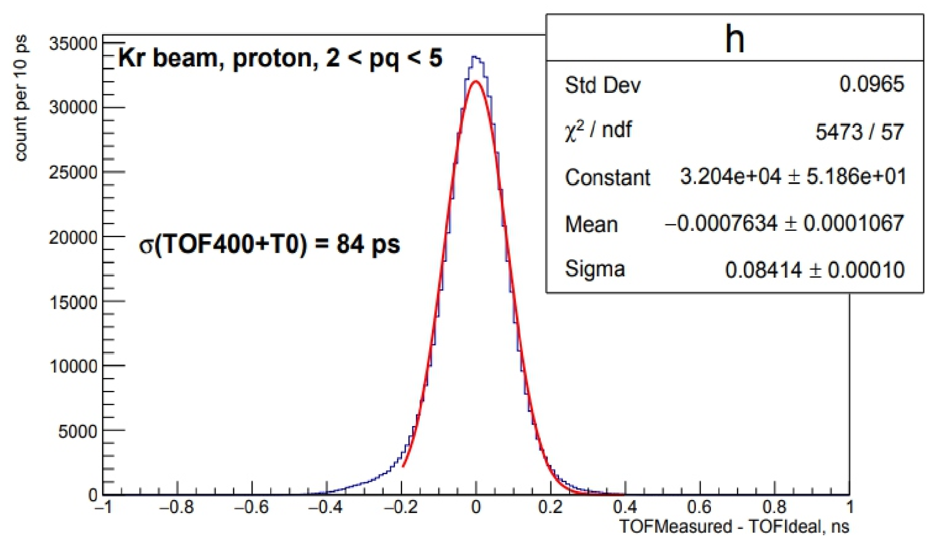

Fig. 17. Time resolution of T0+ToF400 system obtained by proton band

Reference:
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5. https://afi.jinr.ru/TDC72VHL
6. J. Christiansen. HPTDC. High Performance Time to Digital Converter. Version 2.2, March 2004.