Repot by G.Feofilov at XV Vienna Conference on Instrumentation

Fast Beam-Beam Collisions Monitor for experiments at NICA

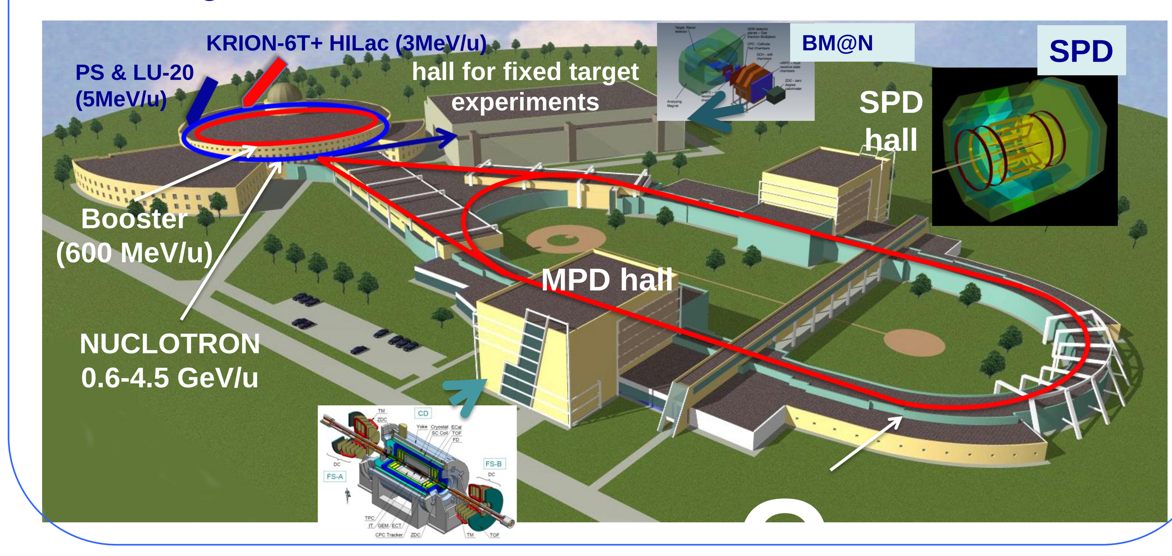
A.A. Baldin (1), G.A.Feofilov*(2), P.Har'yuzov (1), F.F.Valiev (2)
(1) JINR and Institute for Advanced Studies "OMEGA", Dubna, RF
(2) V.Fock Institute for Physics, Laboratory of Ultra-High Energy Physics, Saint-Petersburg State University
*E-mail: grigory-feofilov@yandex.ru

Main targets of the NICA project:
- study of hot and dense baryonic matter
- investigation of nucleon spin structure, polarization phenomena

Two interaction points are foreseen for beam intersections of NICA collider at JINR. The event-by-event monitoring of collisions is required both for the beam tuning and for event selection using the precise timing (T0) of the events for MPD and SPD experiments at NICA. Data on the reaction plane and on the event centrality of nucleus-nucleus collisions should be also obtained for physics analysis. The Beam-Beam Collisions (FBBC) monitor based on the Micro Channel Plates (MCPs) is proposed. New MCPs with the improved characteristics, such as small diameter (6μ) channels, low resistivity (100-500 MOhm), high gain (~10^7), short fast rise-time (~0.8ns) signals, will be used. The ultra-high vacuum (UHV) compatibility and low-mass compact design allow the application inside the vacuum beam line. The FBBC is also considered for the local polarimetry at the SPD to monitor the beam polarization during data taking.The FBBC uses the concept of the isochronous multi-pad readout and summation of short (~1ns) signals. The prototypes were developed and tested previously using the beams of MIPs both at JINR and CERN. Results of model simulations and tests of new prototypes of the fast MCP readout setups are presented and discussed.

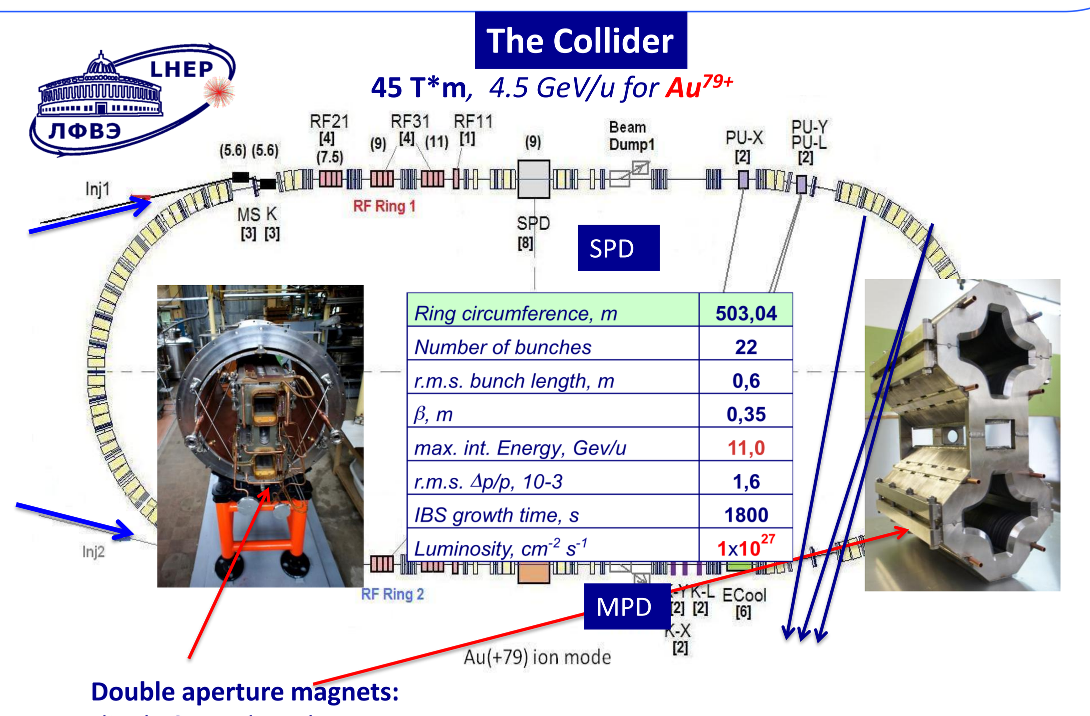
The NICA complex

existing facilities — *to be constructed*



The Collider

45 T*m, *4.5 GeV/u for* ***Au^{79+}***



Ring circumference, m	503,04
Number of bunches	22
r.m.s. bunch length, m	0,6
β, m	0,35
max. int. Energy, Gev/u	11,0
r.m.s. Δp/p, 10-3	1,6
IBS growth time, s	1800
Luminosity, cm^{-2} s^{-1}	$1x10^{27}$

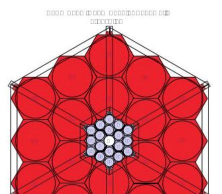
Double aperture magnets:
dipole & quadrupole prototypes

Polarized beams at NICA

- **p↑p↑** at $\sqrt{s_{pp}}$ **= 12 - 27 GeV, L_{av}** ≈ 10^{32} $cm^{-2}s^{-1}$
- **d↑d↑** at $\sqrt{s_{NN}}$ **= 4 - 13 GeV**
- *longitudinal and transverse polarization at SPD and MPD*

Beam-beam interaction and t0 counters at STAR [1]

To analyze the vertical component of polarization, the following spin asymmetry (ε) is formed:

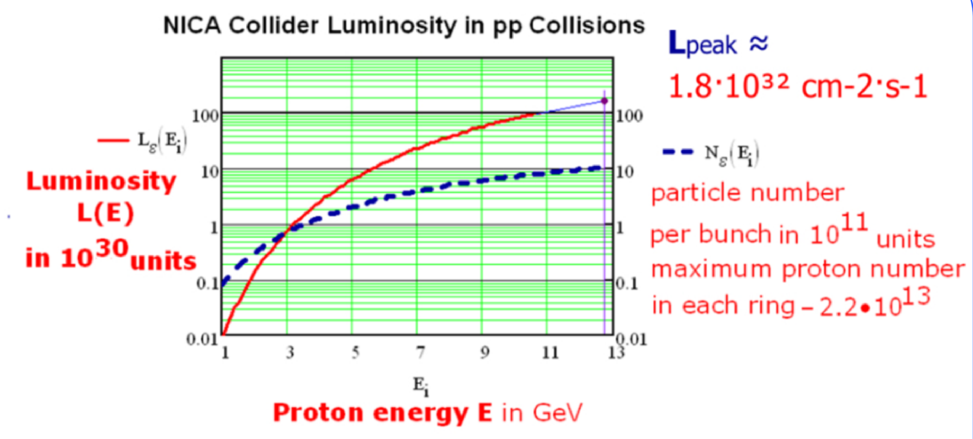


$$\epsilon = P_{beam} \times A_N = \frac{\sqrt{(L\cdot\overline{R})_\uparrow \times (R\cdot\overline{L})_\downarrow} - \sqrt{(L\cdot\overline{R})_\downarrow \times (R\cdot\overline{L})_\uparrow}}{\sqrt{(L\cdot\overline{R})_\uparrow \times (R\cdot\overline{L})_\downarrow} + \sqrt{(L\cdot\overline{R})_\downarrow \times (R\cdot\overline{L})_\uparrow}}.$$

The symbols R(L) refer to the condition of no hits in the corresponding phototubes, imposed to avoid ambiguities in the azimuthal angle to assign to the event. (Range in pseudorapidity 2.2 < |η| <

Fig.1 The STAR beam-beam counter as seen looking towards the interaction point from outside of the STAR magnet.

[1] L.C.Bland for STAR collaboration, STAR RESULTS FROM POLARIZED PROTON COLLISIONS AT RHIC, arXiv: hep-ex/0403012



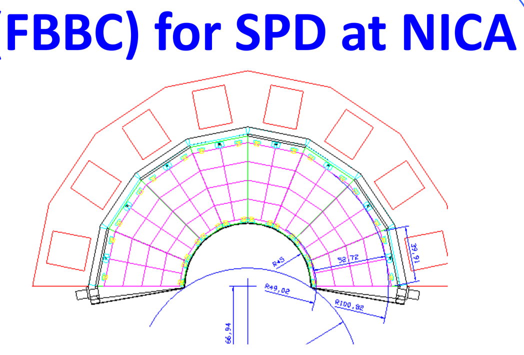
IP parameters: **β** = 35 cm, bunch length **σ** = 60 cm (not optimized), **bunch number** – 22, collider perimeter **C** = 503 m — from I.N.Meshkov 29/11/2012

Fast Beam-beam Collision counters (FBBC) for SPD at NICA

Options based on the MCP applications:

A) - Outside the beam-pipe (I)

Array of sector MCPs with multipad readout anodes



B) - Outside the beam-pipe (II)

Array of sector MCPs setup with fast multianode readout in thin-wall vacuum chambers with getter pumps

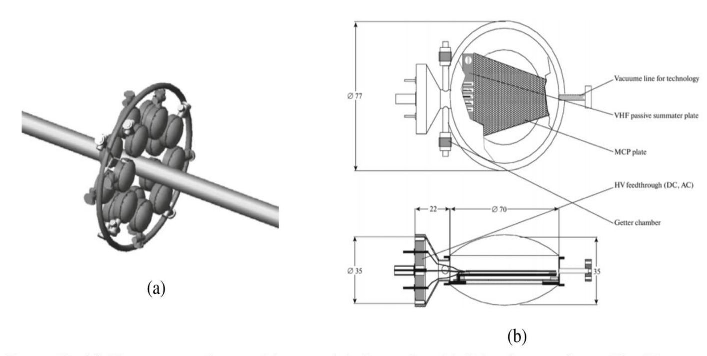
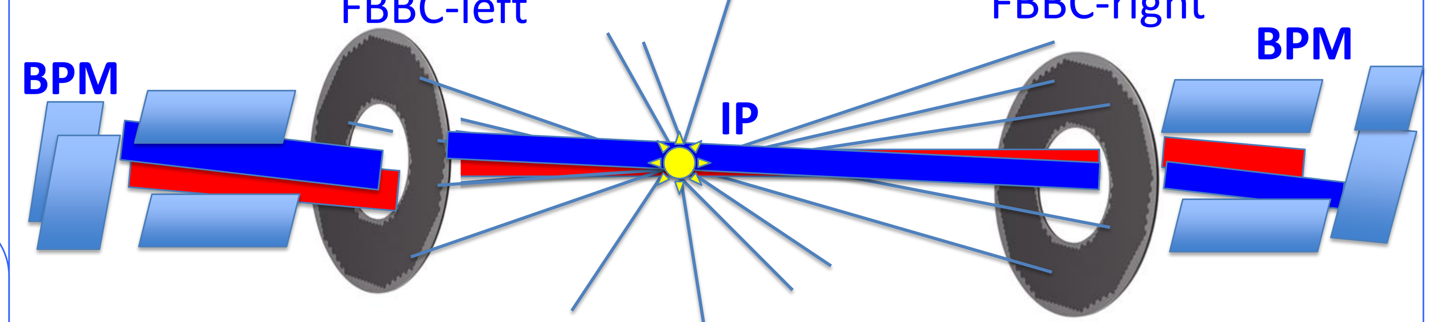


Figure 48: (a) The conceptual general layout of timing and multiplicity detector formed by 16 sectors of MCP placed inside the independent thin wall Ti vacuum chambers around the beam line. (b) General design of the MCP prototype detector embedded into a thin-wall (200 μm) Ti lens-type chamber.

C) - Inside the beam-pipe (III)

Compact MCP circular setup with fast multianode readout



Compact FBBC is based on the MCPs with center-hole. It is used in the ToF measurements and asymmetry event-by-event analysis. The colliding beams go through the MCP's center hole, while the outer edges capture particles from the interaction point (**IP**).
Fast BPM – is the MCP-based beam position monitor

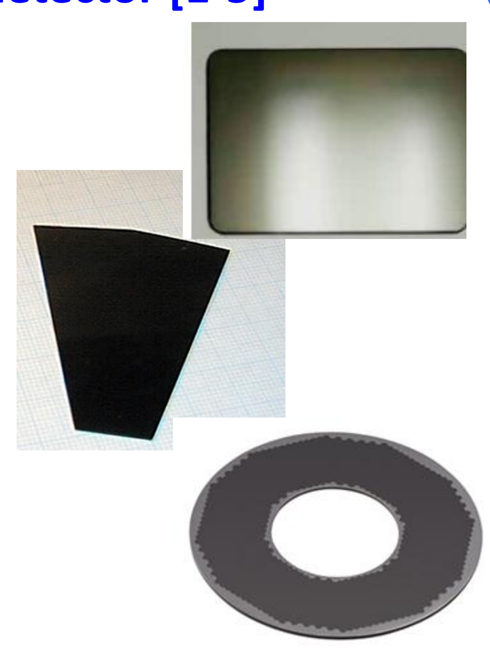
Requirements to functionality of the beam-beam counter

1) To provide the event-by-event measurements of:
   - beam location
   - 3D-beam profile (2 dimensional + time structure)
   - luminosity monitoring

2) Additional functionality in determination:
   - of the reaction plane
   - of the the event centrality in nucleus-nucleus collisions
   - T0 --the collision time
   - Location of the Interaction Point (IP)
   - Possible application in local polarimetry

Micro Channel Plates as MIPs detector [1-5]

1) High resolution rectangular 43x63 mm^2 MCPs with 15 µm - channel diameter (or with 6µ-channel diameter and enhancing timing response). -- could be used for the compact beam profile (BPM) detector
2) Sector type MCPs for multipad isochronous readout of large area MCP array--could be used for the **FBBC detector**
3) MICROCHANNEL PLATE MCP 56-15ch 12-15 15 µm - channel diameter (with 24 mm center hole and outer diameter of 60 mm)--could be considered for a **very compact FBBC** detector placed inside the vacuum beam pipe

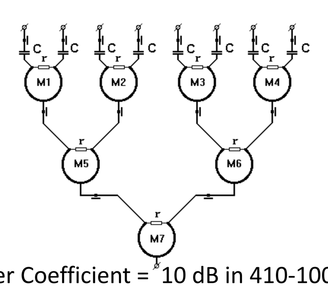


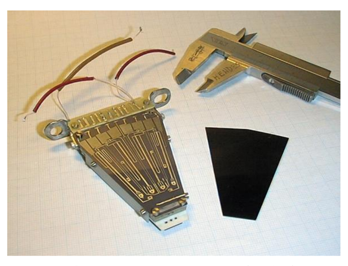
OPTIONS: VTC "BASPIK" detectors with a gap clearance between MCPs (with separated power supply).
https://baspik.com/eng/news/456/
This unique feature helps to get amplification **gain factor above 1×10^7** (in chevron fabrication) and above 1×10^9 (in Z-fabrication)

UHV-UHF technologies for fast readout

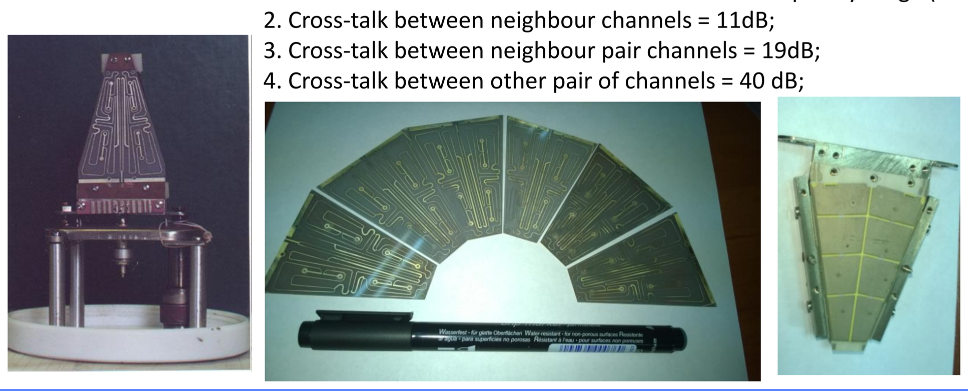
Sector detectors of approximately 20 cm^2 sensitive area are composed of micro-channel plates stack and **multipad readout anodes** integrated with a microelectronics designed **UHF passive summator**.

General scheme of Circular Bridges Summator for 8 input channels. Passive summator based on circular bridges (UHF microelectronics design) assembled inside the test board. 8 50 Ohm inputs, 1 coaxial 50 Ohm output, 8 charge outputs.

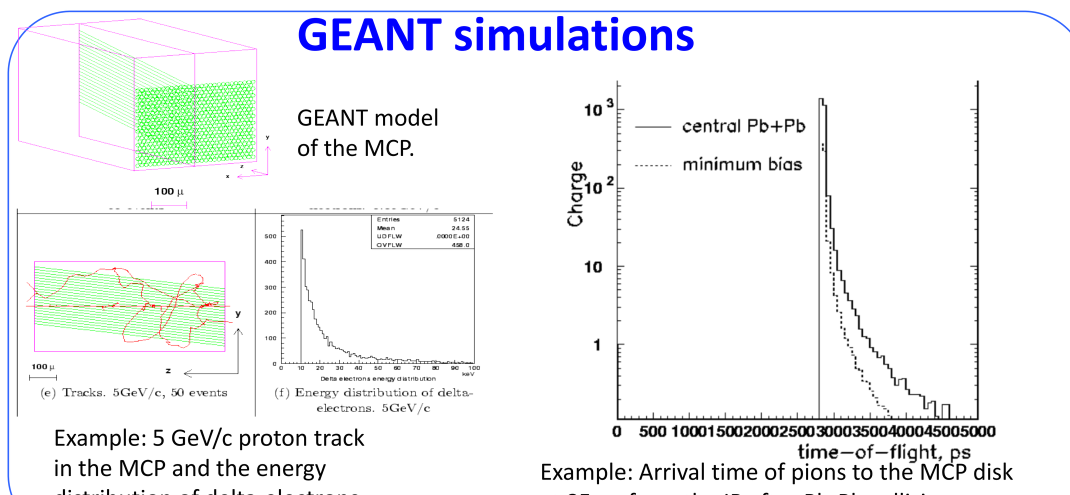




1. Transfer Coefficient = 10 dB in 410-1000MHz frequency range (6dB)
2. Cross-talk between neighbour channels = 11dB;
3. Cross-talk between neighbour pair channels = 19dB;
4. Cross-talk between other pair of channels = 40 dB;



GEANT simulations



Example: 5 GeV/c proton track in the MCP and the energy distribution of delta-electrons

Example: Arrival time of pions to the MCP disk at 85cm from the IP after Pb-Pb collision

Tests at CERN beams[3]

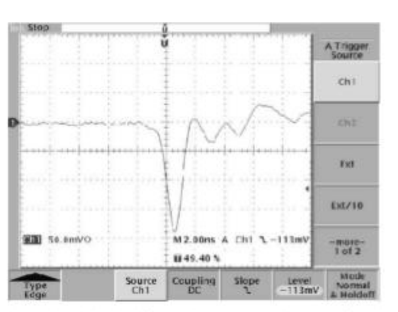
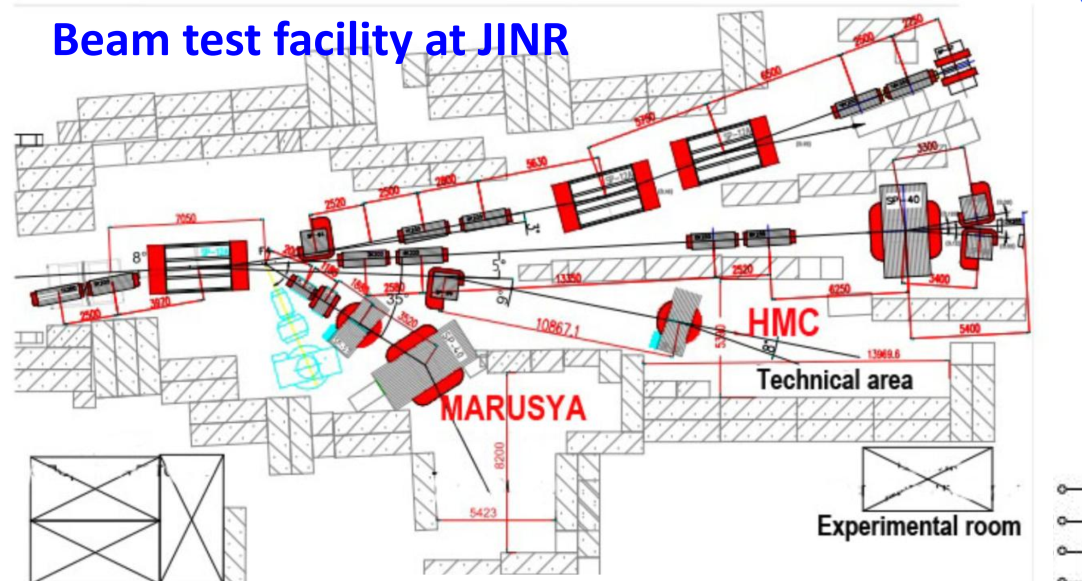


Fig. 2. Signal obtained from the MCP sector detector after the fast preamplifier.

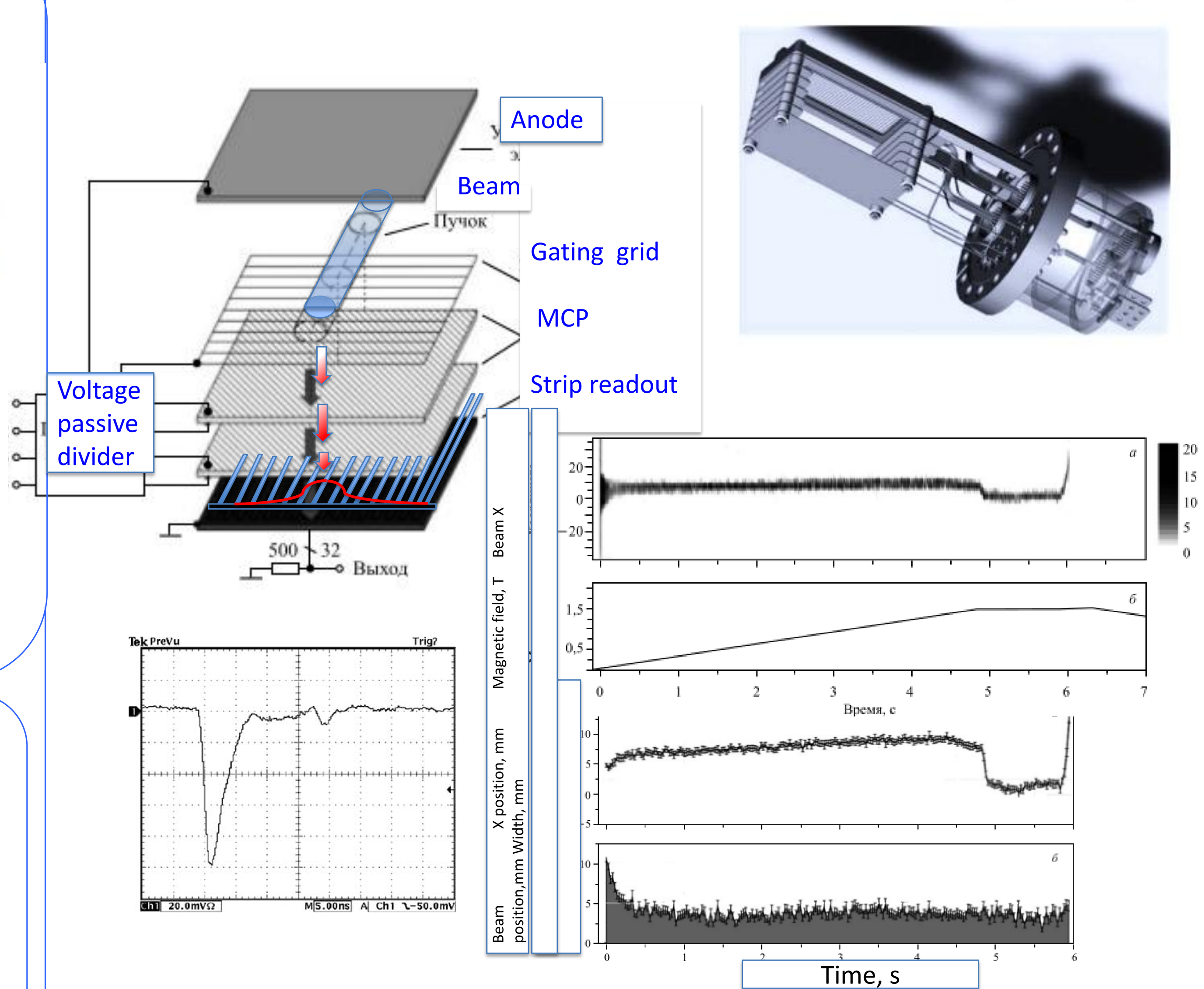
The in-beam tests of the detector prototypes and electronics at CERN GIF area (150 GeV/c muons) and at the T10 area of the CERN PS beams (7.5 GeV/c). The detector to be tested was positioned between 4 fast scintillation counters which determined the charged particle trajectories and were included in the trigger. The detector output signal passed the fast (1 GHz), low-noise preamplifiers and was then sent (see Fig. 2) to the fast timing electronics. The dynamic range of the signals applied was from 30 mV to 1:5V [3].The best experimental in-beam results obtained previously with chevron MCP detector was in 75 ps timing resolution obtained at 75% efficiency for the registration of a single MIP [3].

Beam test facility at JINR



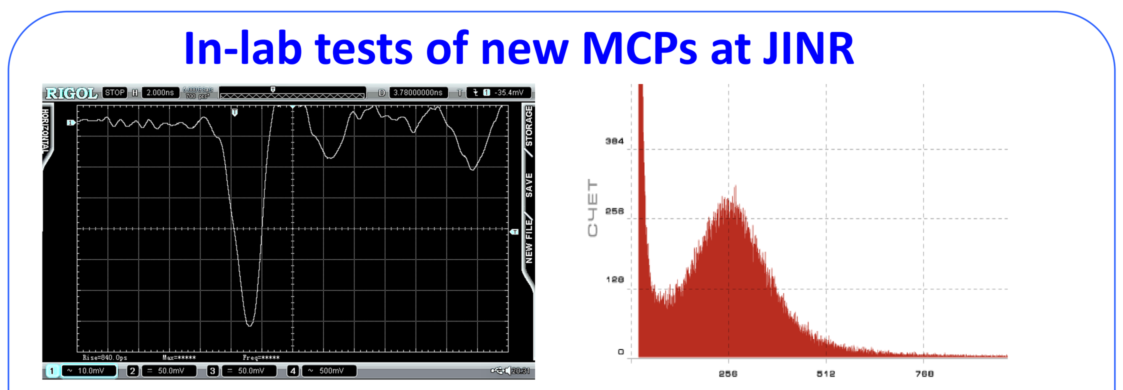
P, MeV/c	d	p,n	$\pi^{\pm}$	K^{+}	K^{-}	$\mu^{\pm}$	$e^{\pm}$
400	10^3	10^5	10^5	10^3	10^2	10^3	10^3
800	10^3	10^4	10^4	10^3	10^2	10^3	10^3
1500	10^2	10^4	10^4	10^3	10^2	10^2	10^2
2000	10^4	10^5	10^4	10^3	10^2	10^2	10^2
7000	10^4	10^6	10^3	10^3	10^2	10^2	10^2

MCP-based beam position monitor (BPM) at JINR[1]



Signal (left) and timing of the beam location and width (right) in the beam-tests at JINR Nuclotron [1]
[1] A.Baldin et al., Physics of Particles and Nuclei Letters, 2014, vol.11, №2 (186), p.209-218.

In-lab tests of new MCPs at JINR



Left: Signal shape from 8µ-channels MCP setup (<2ns FWHM, 0.84 ns rise-time).
Right: Spectrum of amplitudes (Sr-90 beta source, chevron **8µ-channels MCP** setup)

References:

1]A.Baldin,G.Feofilov,F.F.Valiev et al., Microchannel plates as a detector for 800 MeV/c charged pions and protons.
// JINR Rapid Communications. 1991. No 4/50/-91. p.27-36.
[2] A.A.Baldin, G.Feofilov,Yu.Gavrilov, A.Tsvinev,F.Valiev, Proposals for a new type of microchannel-plate-based vertex detector// NIM A323. 1992. p. 439-444.
[3] M.Bondila L.Efimov D.Hatzifotiadoud G.Feofilov V.Kondratiev V.Lyapin J.Nysten P.Otiougovf T.A.Tulina W.H.Trzaska F.Tsimbalf L.Vinogradov C.Williams, Results of in-beam tests of an MCP-based vacuum sector prototype of the T0/centrality detector for ALICE, NIM A, Volume 478, Issues 1–2, 1 February 2002, Pages 220-224
[4] Feofilov, G., Kondratev, V., Stolyarov, O., Tulina, T., Valiev, F., Vinogradov, L. Development and tests of MCP based timing and multiplicity detector for MIPs // Physics of Particles and Nuclei Letters, **2017**. Vol. 14, № 1. P. 150-159
[5] A.Baldin, A.Berlev, I.Kudashkin, A.Fedorov, Physics of Particles and Nuclei Letters, 2014, vol.11, №2 (186), p.209-218.
[6] R. Abramishvili, et al., LoI-02.06.14 Spin Physics Experiments at NICA-SPD with polarized proton and deuteron beam. Letter of Intent.

Summary:

1) A compact setup of two detectors with high timing capabilities based on the MCP applications -- the Fast Beam-Beam Collision counters (FBBC) and the Beam Position Monitor (BPM), is proposed to meet the wide set of requirements of the future physics programme with the polarized beams in the SPD at NICA
2) The feasibility of the event-by-event monitoring of the beam-beam interactions at NICA is confirmed both by the previous developments of the UHF-UHV technology and by the beam tests at JINR and CERN of the prototype detectors and electronics, as well as by the in-lab tests of new 8µ-channels MCPs with the improved characteristics.
3) The new R&D efforts will be focused on the development and the in-beam tests of the next generation of compact fast MCP-based FBBC prototypes using the beam-test facility at JINR.