*(C) G.Feofilov, Karlskirche, Vienna, 1992*

# Fast Beam-Beam Collisions Monitor for experiments at NICA

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***The NICA days 2019 and IVth MPD Collaboration Meeting,***
***21-25 October 2019, CZilTT, Warsaw***
***https://indico.cern.ch/event/802303/overview***
***Reported by Grigory Feofilov, Thursday, 24.10.2019 ,***
***Job is supported by RFBR grant #18-02-40097***

# Layout

- NICA complex
- General requirements to functionality of the beam-beam collisions monitoring at NICA
- MCP-based solutions for
  - Beam Position Monitor (BPM) and
  - Fast Beam-Beam Collisions counters (FBBC) for NICA
- First test results and prototyping
- Conclusions and plans

# NICA collider : from protons and polarized deuterons to very massive gold ions

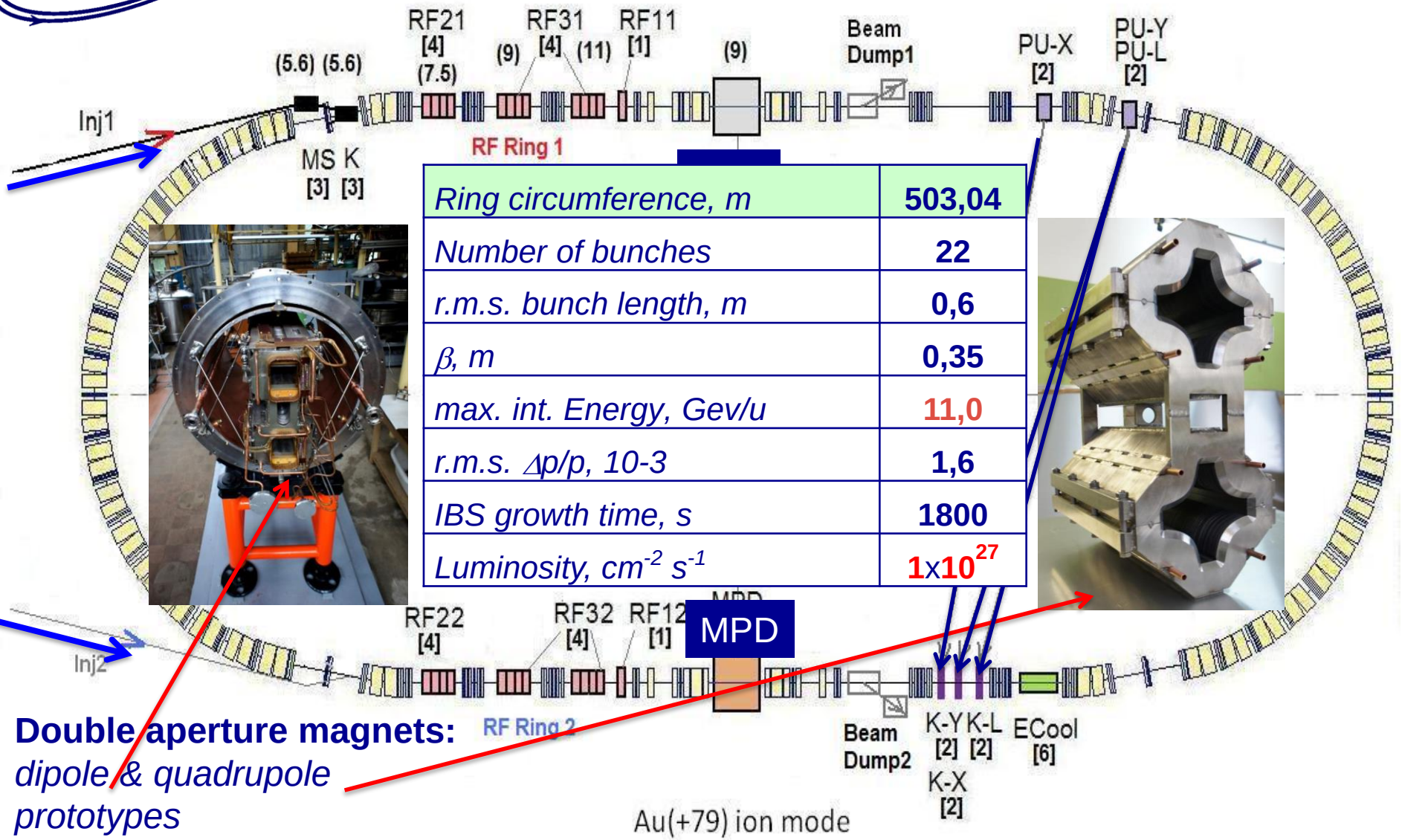
Heavy ions will be accelerated up to kinetic energy of 4.5 GeV per nucleon, the protons – up to 12.6 GeV.

Two interaction points are foreseen: one for heavy-ion studies with the MPD detector [1] and another for polarized beams for the SPD experiment [2].

[1] V. Golovatyuk, V. Kekelidze, V. Kolesnikov, O. Rogachevsky, A. Sorin, The Multi-Purpose Detector (MPD) of the collider experiment, Eur. Phys. J. A52 (8) (2016) 212. doi:10.1140/epja/i2016-16212-1.
[2] R.Abramishvili, et al., Spin Physics Experiments at NICA-SPD with polarized proton and deuteron beam. Letter of Intent, LoI-02.06.14 , JINR, Dubna.

# The Collider

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



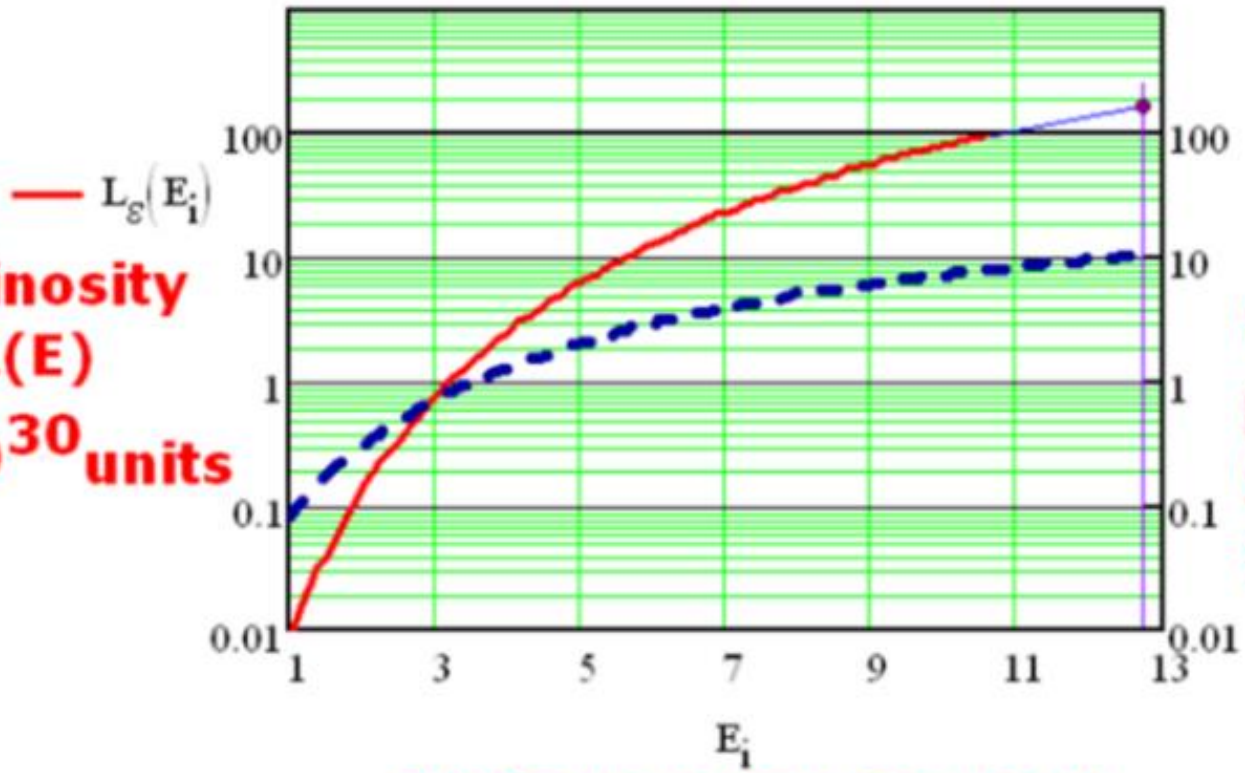

| | |
|---|---|
| *Ring circumference, m* | **503,04** |
| *Number of bunches* | **22** |
| *r.m.s. bunch length, m* | **0,6** |
| *$\beta$, m* | **0,35** |
| *max. int. Energy, Gev/u* | **11,0** |
| *r.m.s. $\Delta p/p$, 10-3* | **1,6** |
| *IBS growth time, s* | **1800** |
| *Luminosity, cm$^{-2}$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

**Double aperture magnets:**
*dipole & quadrupole prototypes*

[1] http://nica.jinr.ru/projects/collider.php

**Lpeak ≈**

**$1.8 \cdot 10^{32}$ cm**




**Luminosity L(E) in $10^{30}$ units**

particle numbe

per bunch in 10

maximum proto

in each ring – 2

**Proton energy E** in GeV

- IP parameters: **β** = 35 cm, bunch length **σ** = 60 cm (not optimi

**bunch number** – 22, collider perimeter **C** = 503 m

from I.N.Mesh
29/11/2012

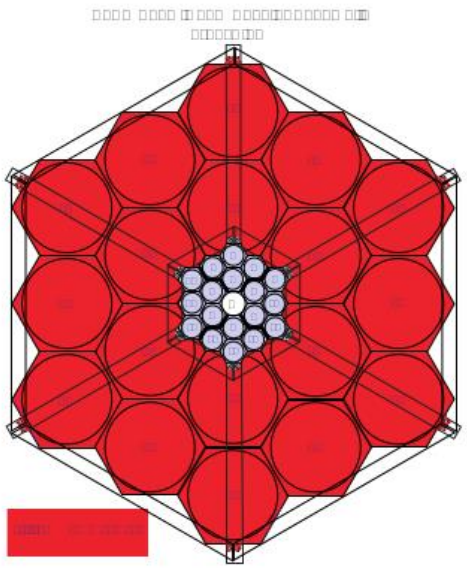
# General requirements to functionality of the beam-beam collisions monitoring at NICA

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
   - the multiplicity class relevant to the event centrality in nucleus-nucleus collisions
   - T0 --the collision time
   - Location of the Interaction Point (IP)
   - Possible application in local polarimetry

# 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 hits hits in the corresponding phototubes, imposed to avoid ambiguities in the azimuthal angle to assign to the event.

↑ (↓) --refer to the direction of the polarization of the particular bunch crossing.

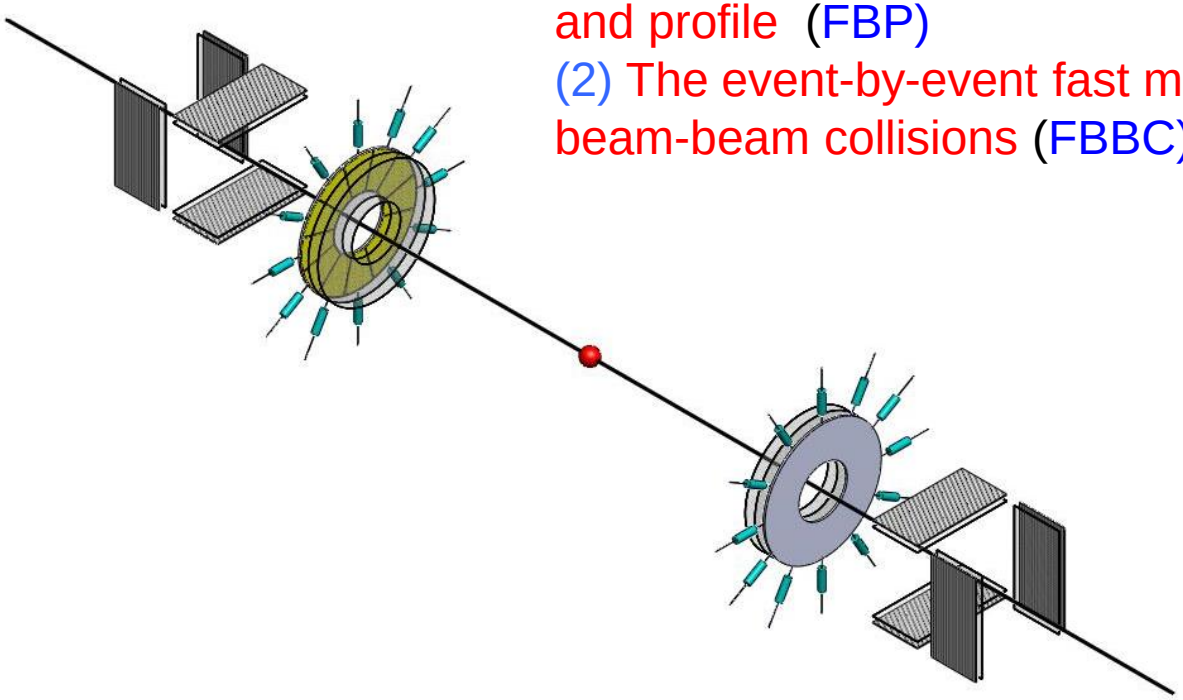
Fig.1 The STAR beam-beam counter as seen looking towards the interaction point from outside of the STAR magnet. ($2.2 < |\eta| < 5.0$) [1].

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

- See also report by Prof. Maria Elena Tejeda-Yeomans, 23.10.19 at the present NICA meeting.

# MCP-based solutions for Beam Position Monitor (BPM) and Fast Beam-Beam Collisions counters (FBBC) for NICA

(1) Fast monitoring of the beam position and profile (FBP)
(2) The event-by-event fast monitoring of beam-beam collisions (FBBC)



# Micro Channel Plates (MCPs) as a MIP detector

[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.

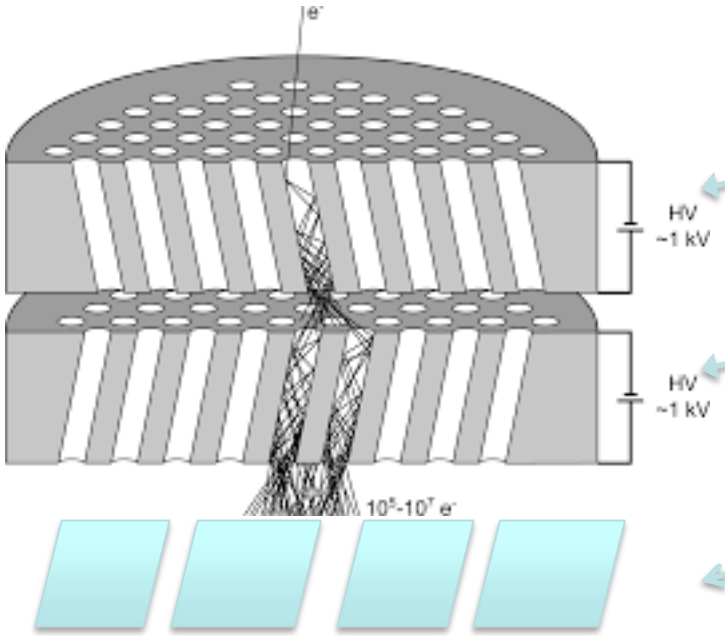
…

[3]V.Bondila, L.Efimov D.Hatzifotiadou, G.Feofilov, V.Kondratiev, V.Lyapin, J.Nysten, P.Otiougova, T.A.Tulina, W.H.Trzaska, F.Tsimbal, 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] G. Feofilov, V. Kondratev, O. Stolyarov, T. Tulina, F. Valiev, and L. Vinogradov, Development and Tests of MCP Based Timing and Multiplicity Detector for MIPs, ISSN 1547-4771, Physics of Particles and Nuclei Letters, 2017, Vol. 14, No. 1, pp. 150–159. © Pleiades Publishing, Ltd., **2017**.

# Micro Channel Plates (MCPs) as a MIP detector [1,2]



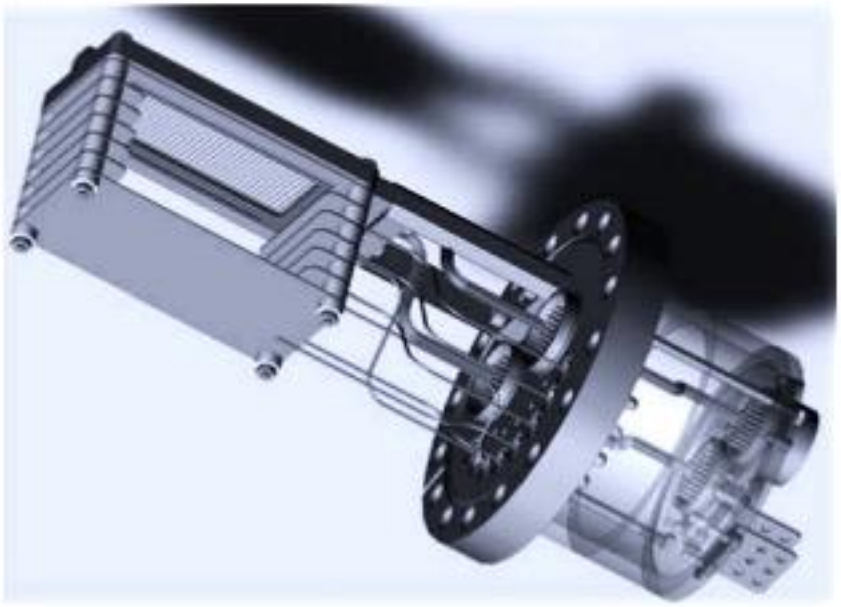

Active target-converter

MCP-Amplifier

Readout anodes

[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.

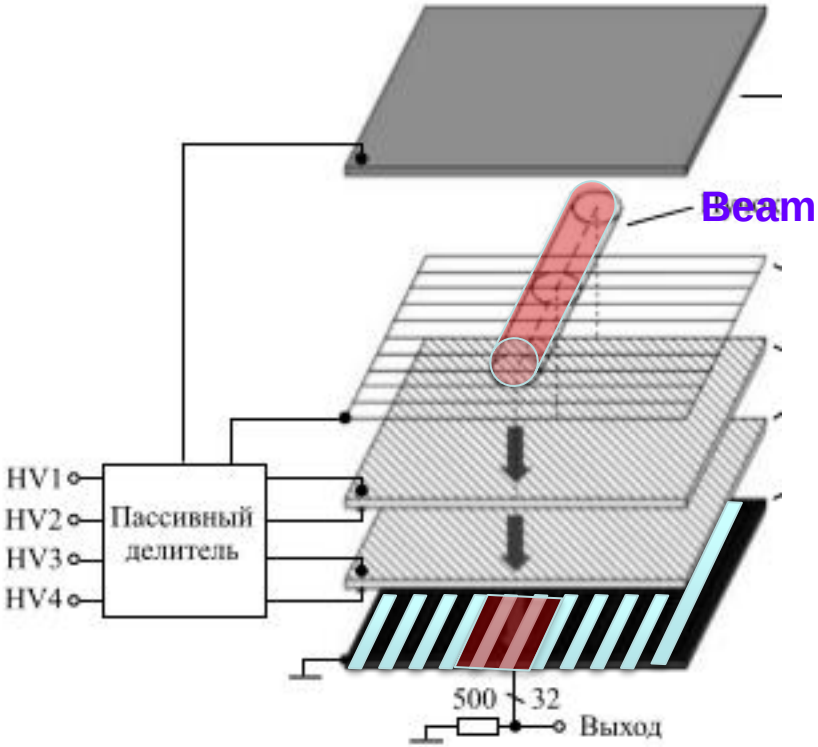
# First test results of the beam profile Monitoring



MCP-based device for fast monitoring of the beam profile (FBP) at the NUCLOTRON [1]

[1] A.Baldin, A.Berlev, I.Kudashkin, A.Fedorov, Space-time characteristics of the circulating beams, Letters to ECHAIA, 2014, vol.11, №2 (186), p.209-218

# Beam Position Monitor (BPM) [1].




Anode

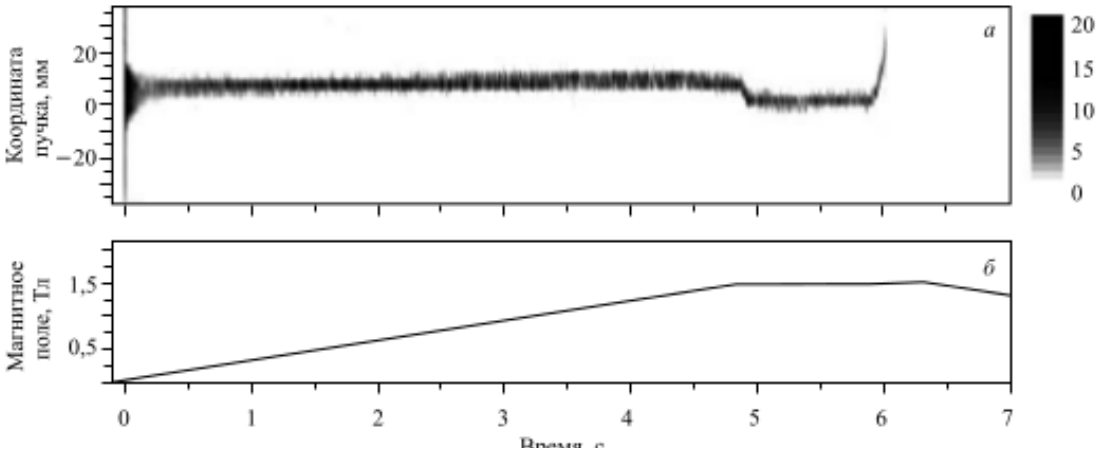
Gating grid

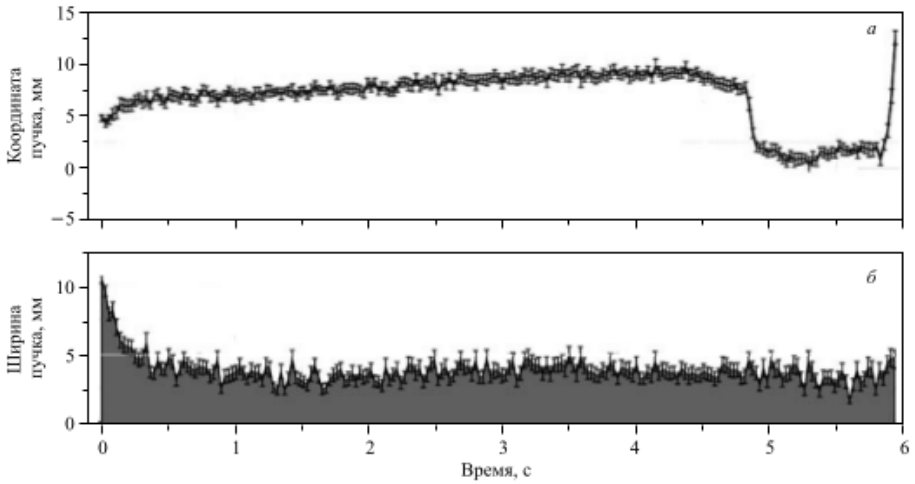
MCP-1
MCP-2

Strip readout

[1] A.Baldin, A.Berlev, I.Kudashkin, A.Fedorov, Letters to ECHAIA, 2014, vol.11, №2 (186), p.209-218

# Space-time characteristics of the circulating beams
# TESTS AT NUCLOTRON, JINR

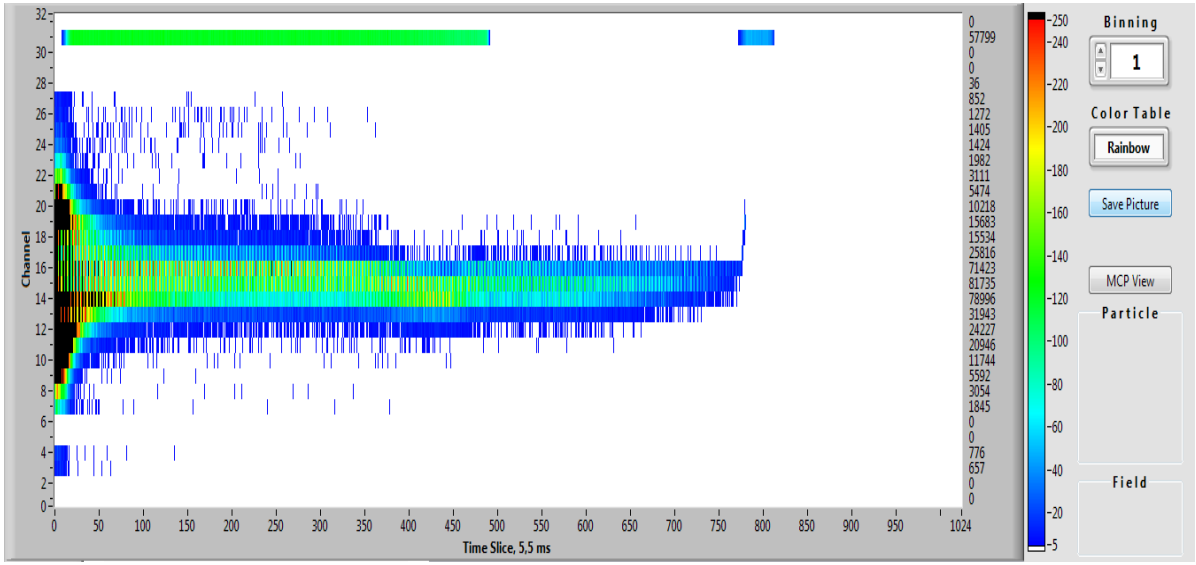



Example of the deutron beam position measurements by using the residual gas interaction MCP-based detector at the NUCLOTRON.
The energy of deutron beams was= 4GeV,
beam intensity -$10^{8}$,
Vacuum $10^{-8}$ Torrr.[1]

[1] A.Baldin, A.Berlev, I.Kudashkin, A.Fedorov, Letters to ECHAIA, 2014, vol.11, №2 (186), p.209-218

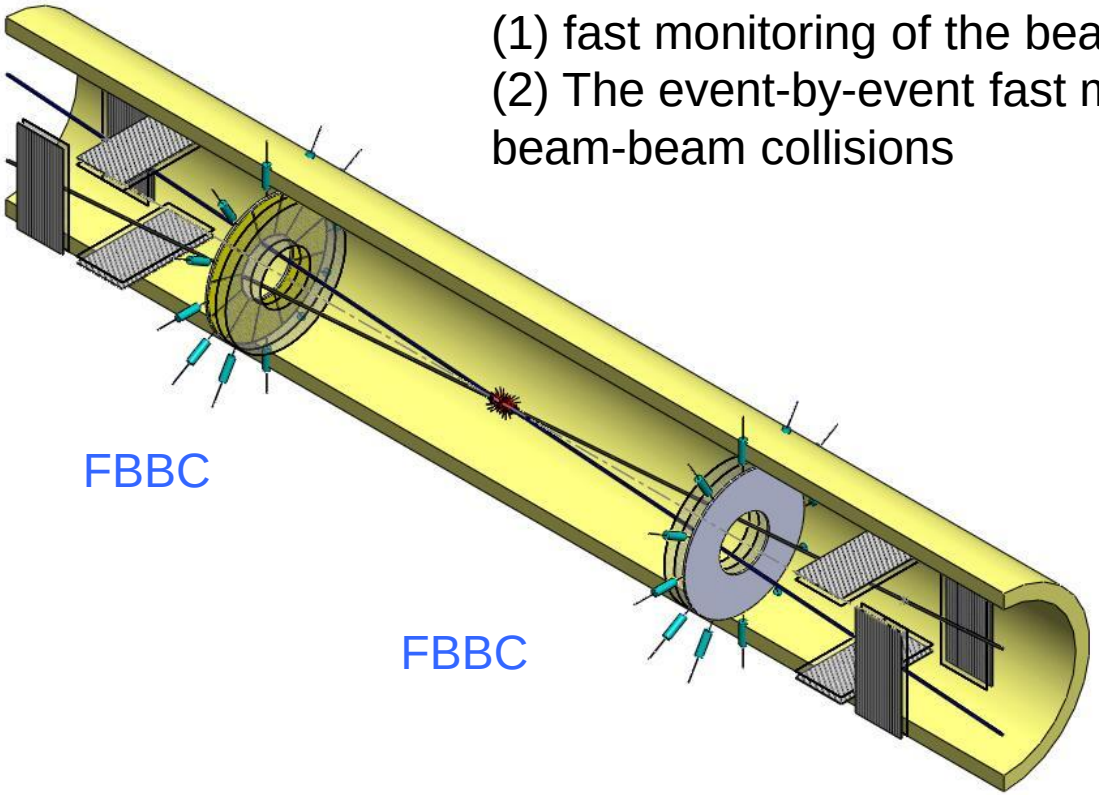
# Space-time characteristics of the circulating beams
# TESTS AT NUCLOTRON, JINR in February-April 2018




Dynamic profile of an accelerated krypton beam inside the NUCLOTRON accelerator ring (Vertical readings of the upper pattern in mm).
Example of the Kr beam position measurements at the NUCLOTRON. The energy of beams was 3.5GeV , beam intensity --$10^{6}$, vacuum { $10^{-8}$ Torrr. Time Slice = 5,5 ms. Y scale has 3 mm channel bin width.

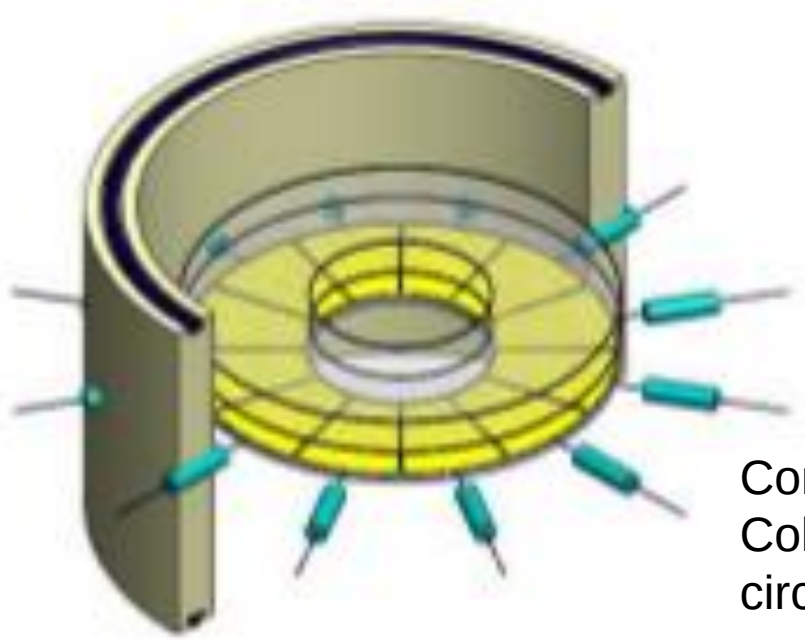
# Fast Beam-Beam Collisions monitoring (FBBC)

(1) fast monitoring of the beam profile (FBP)
(2) The event-by-event fast monitoring of beam-beam collisions




NIMA62154
DOI: 10.1016/j.nima.2019.04.108

# Fast Beam-Beam Collisions monitoring (FBBC) conceptual design



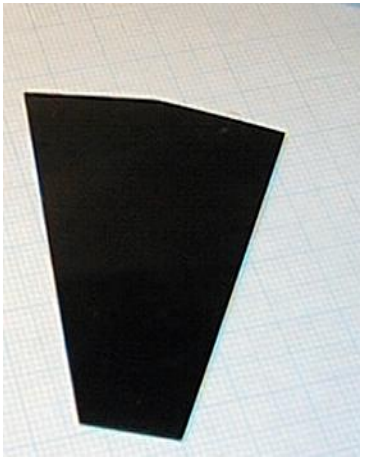
Compact module of the Fast Beam-Beam Collision Monitor (FBBC) based on the circular MCP chevron setup.

Sector cathode readout pads and two MCP set-ups are embedded into a vacuum flange with hermetic 50 Ohm signal and HV feedthroughs.

# Micro Channel Plates

**OPTIONS:**

1) High resolution rectangular 43x63 $mm^2$ MCPs
with 6-15 μm - channel diameter -- could be used for the **BPM**
2) Sector type MCPs with the multipad isochronous readout
of the MCP array--could be used for the **FBBC**
3) MCP 56-15ch 12-15 with 15 μm - channel diameter
--could be considered for **a very compact FBBC**
placed inside the vacuum beam pipe
(Dimensions: 24 mm center hole and
the outer diameteris 60 mm)



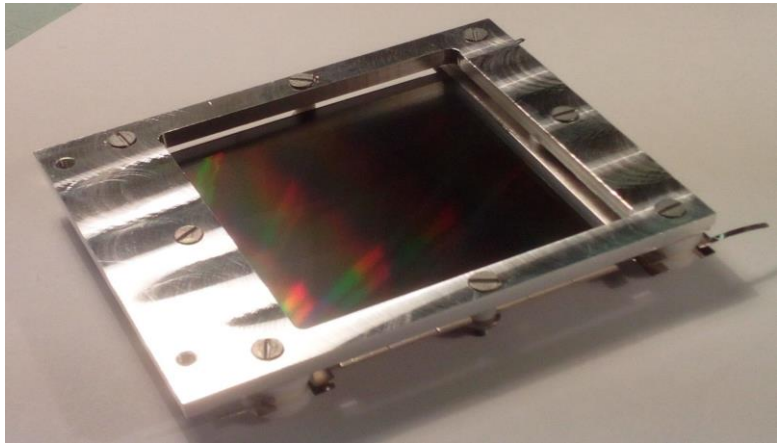
**OPTIONS:**

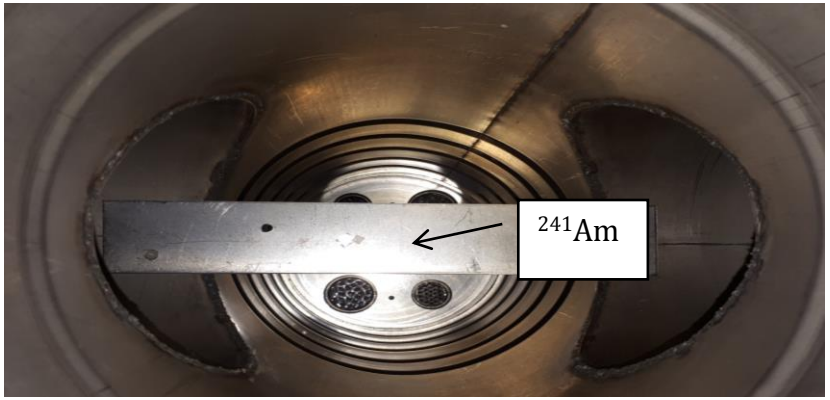
VTC "BASPIK" detectors with a gap clearance between MCPs (with separated power supply). **https://baspik.com/eng/news/456/**

This unique feature helps to get amplification gain factor above $1 \times 10^7$

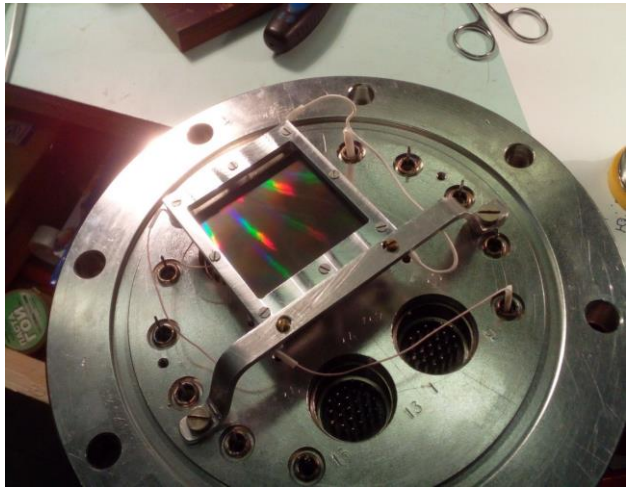
# For Test set-ups at JINR and SPbSU for Micro Channel Plates

MCPs: 43x63, 6mkm channel
https://baspik.com/eng/products/mkp/

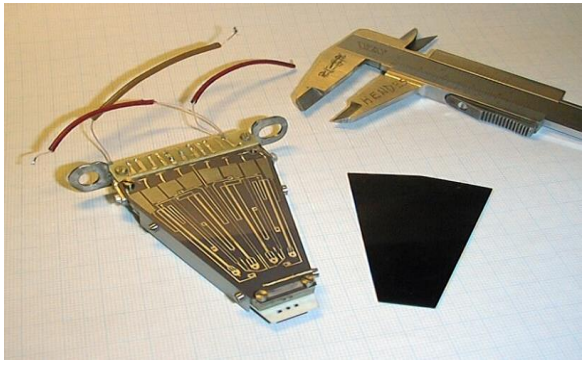


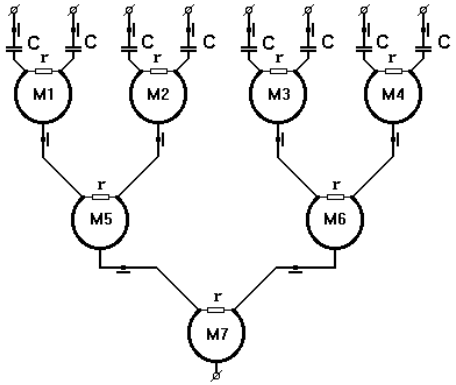



The ultra-high vacuum (UHV) compatibility and low-mass compact design.

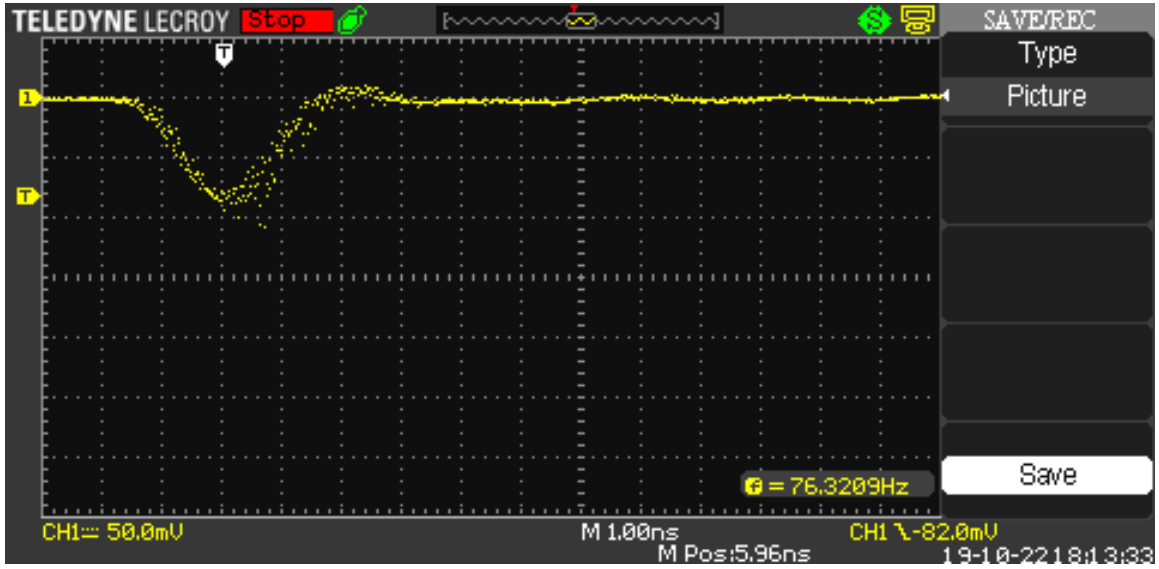


# MCP test bench at SPbSU



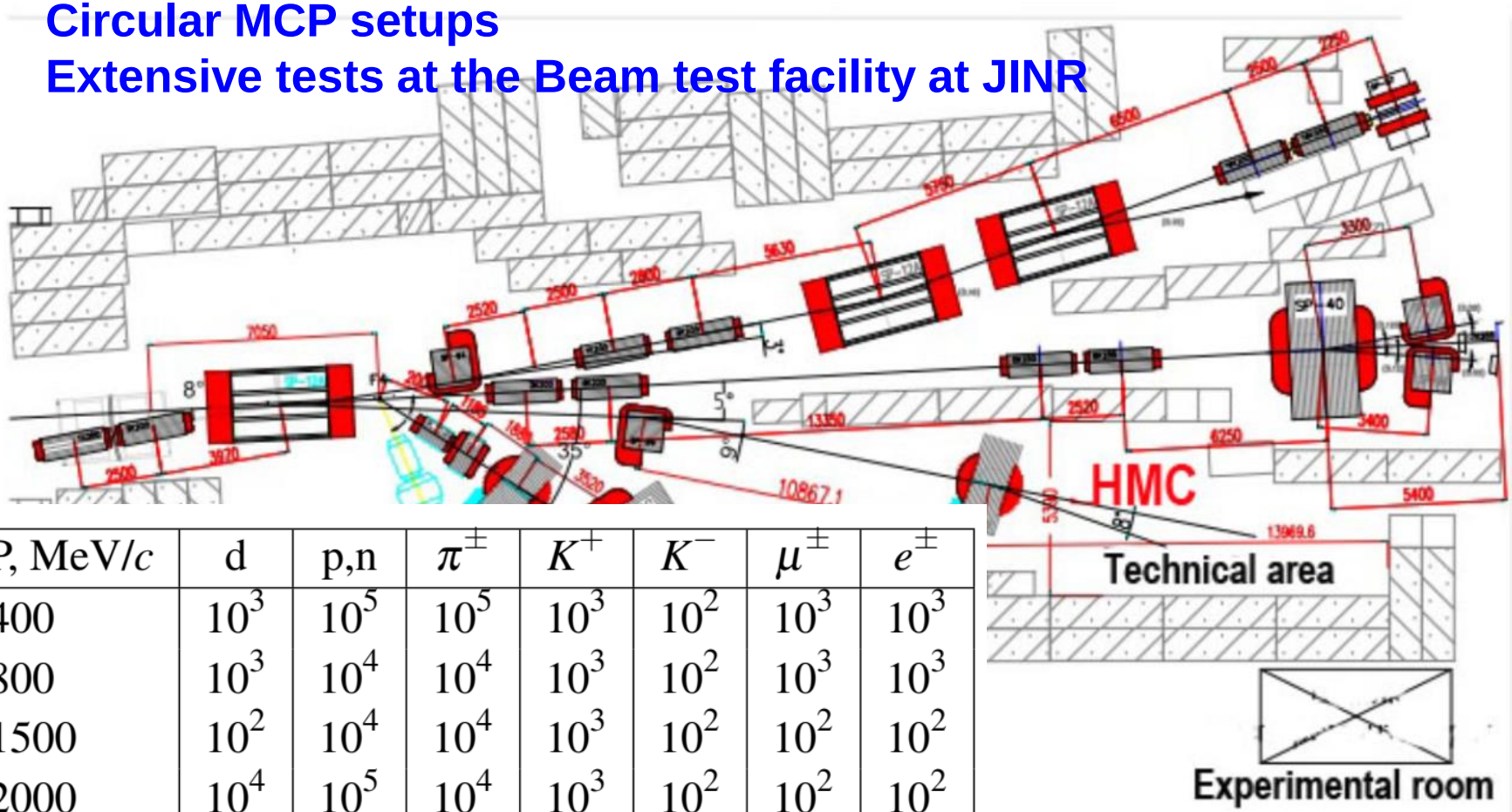



Passive summator based on circular bridges (UHF microelectronics design) assembled inside the test board. 8 inputs 50 Ohm , 1 coaxial 50 Ohm output, 8 charge outputs.



# Future plans:

- Fast front-end readout electronics design
- Model simulations
- Circular MCP setups
- Extensive tests at the Beam test facility at JINR

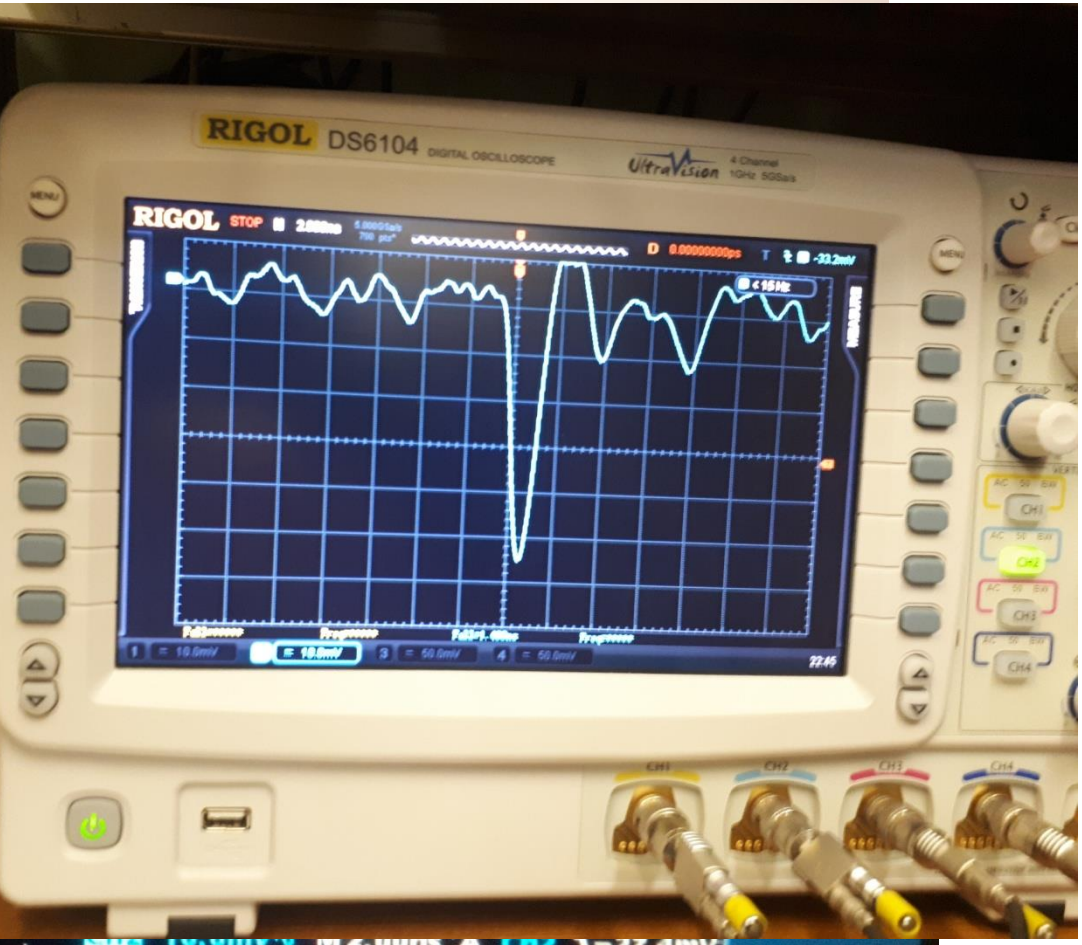


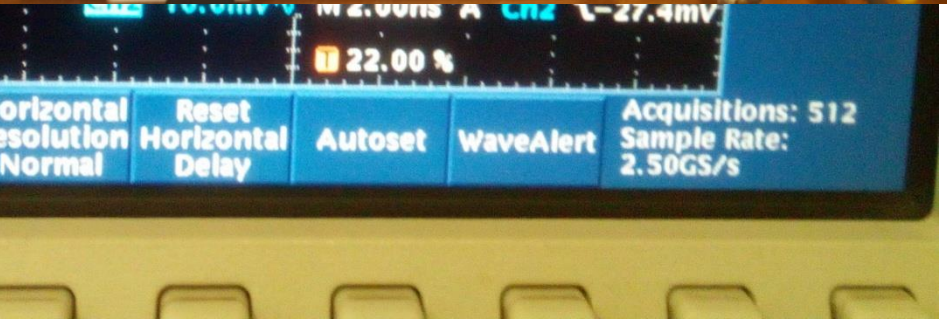

| P, MeV/$c$ | d | p,n | $\pi^{\pm}$ | $K^{+}$ | $K^{-}$ | $\mu^{\pm}$ | $e^{\pm}$ |
|---|---|---|---|---|---|---|---|
| 400 | $10^3$ | $10^5$ | $10^5$ | $10^3$ | $10^2$ | $10^3$ | $10^3$ |
| 800 | $10^3$ | $10^4$ | $10^4$ | $10^3$ | $10^2$ | $10^3$ | $10^3$ |
| 1500 | $10^2$ | $10^4$ | $10^4$ | $10^3$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

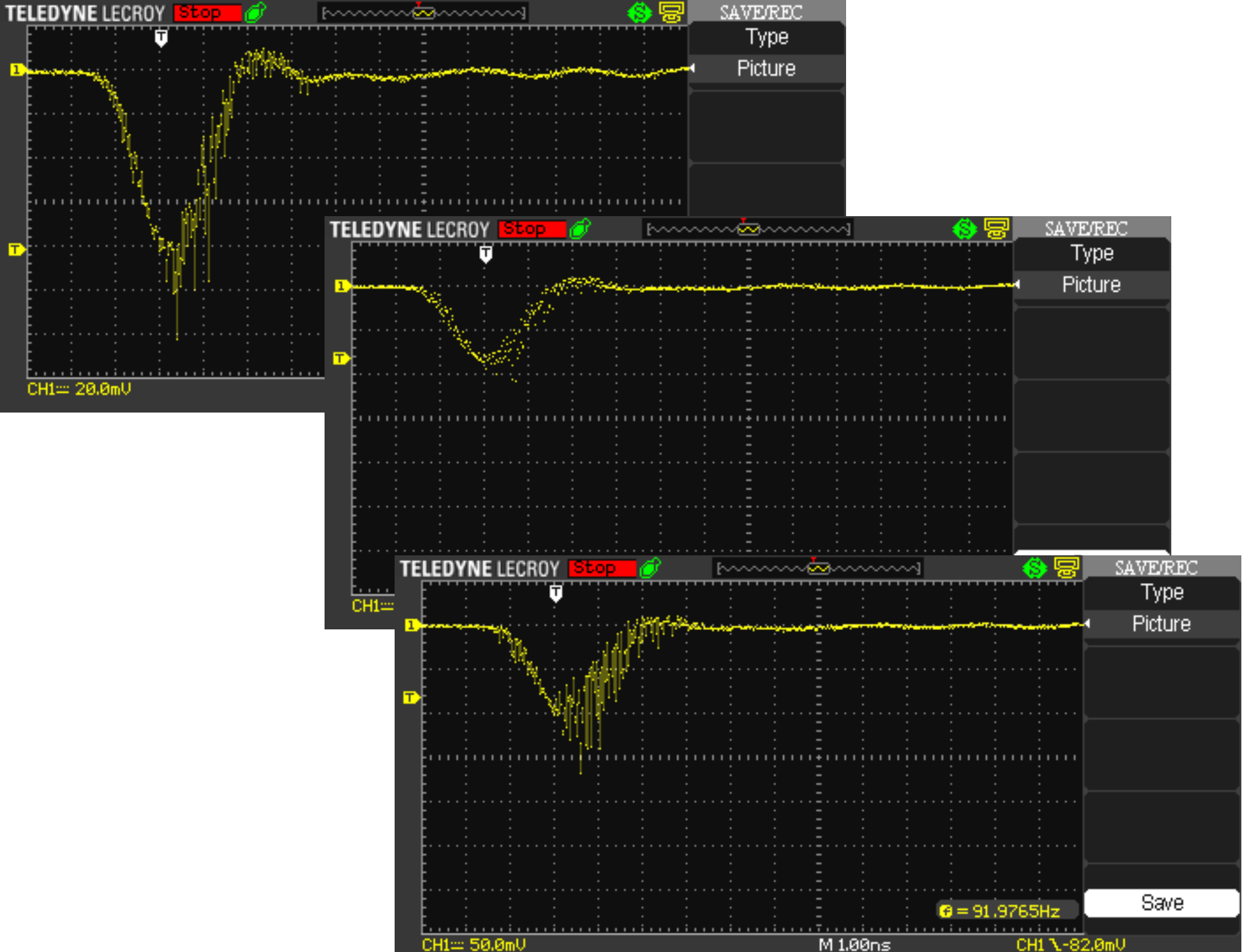
# Conclusions

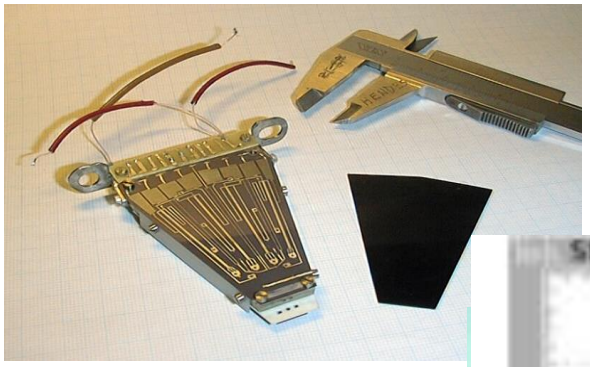
- MCP-based solutions for Beam Position Monitor (BPM) and Fast Beam-Beam Collisions counters (FBBC) for NICA are proposed with the account of the wide functional request that could be provided.
- The concept of the MCP-based Beam Position Monitor (BPM) was succesfully tested at the NUCLOTRON beams
- New MCPs with the improved characteristics, such as small diameter (6μ) channels, low resistivity (3-10 MOhm), high gain (~$10^7$), short fast rise-time (~0.8ns) signals, could be used. The ultra-high vacuum (UHV) compatibility and low-mass compact design allow the application inside the vacuum beam line.
- The first prototypes were prepared in the UHV design and the in-lab test started showing subnanosecond rise time
- The FBBC may also use 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.)
- The work is in progress with main focus on the future fast front-end multichannel electronics design for the readout of 1ns signals.

# BACK-UP SLIDES


RIGOL
DS6104
DIGITAL OSCILLOSCOPE
UltraVision
RIGOL
STOP
CH1
CH2
CH3
CH4


22.00 %
Horizontal
Resolution
Normal
Reset
Horizontal
Delay
Autoset
WaveAlert
Acquisitions: 512
Sample Rate:
2.50GS/s


TELEDYNE LECROY
Stop
SAVE/REC
Type
Picture
CH1 20.0mV
TELEDYNE LECROY
Stop
SAVE/REC
Type
Picture
CH1
TELEDYNE LECROY
Stop
SAVE/REC
Type
Picture
Save
F = 91.9765Hz
CH1 50.0mV
M 1.00ns
CH1 -82.0mV



General scheme of Circular Bridges Summator for 8 input channels.

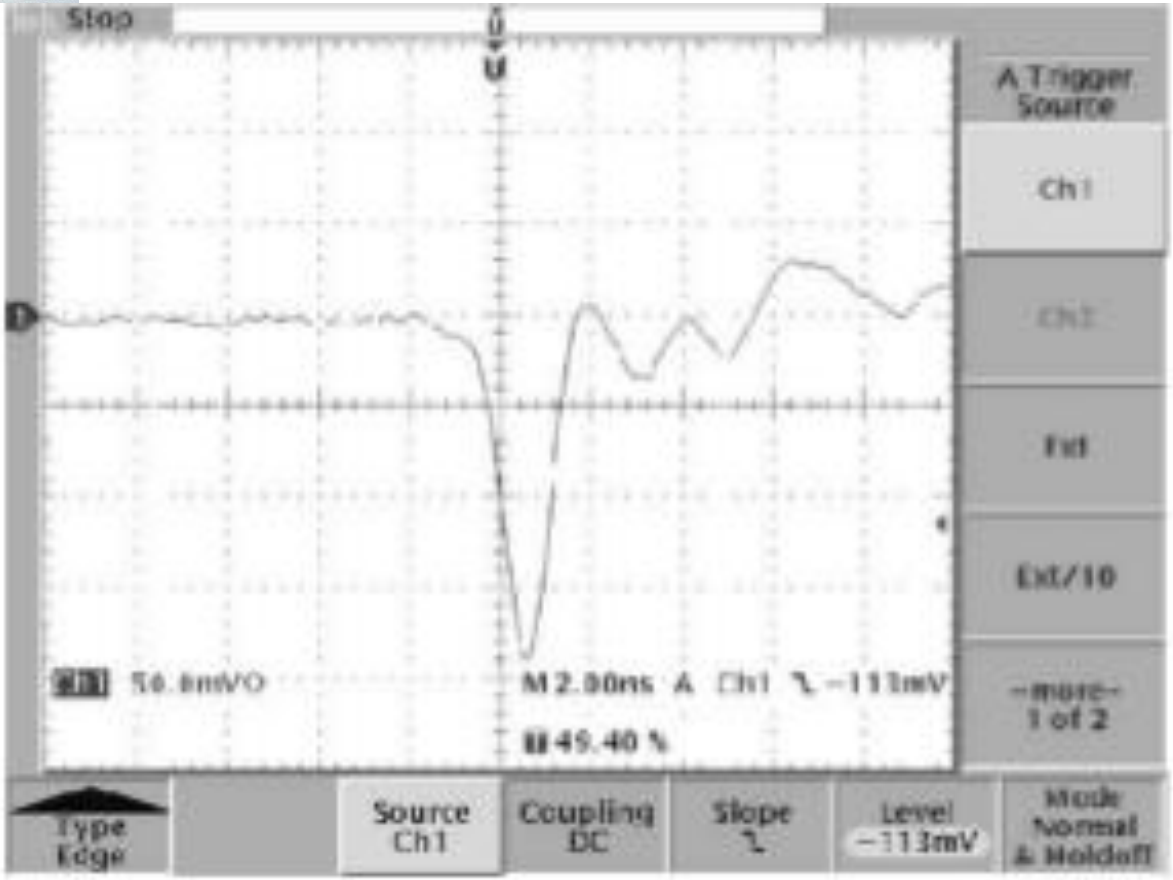
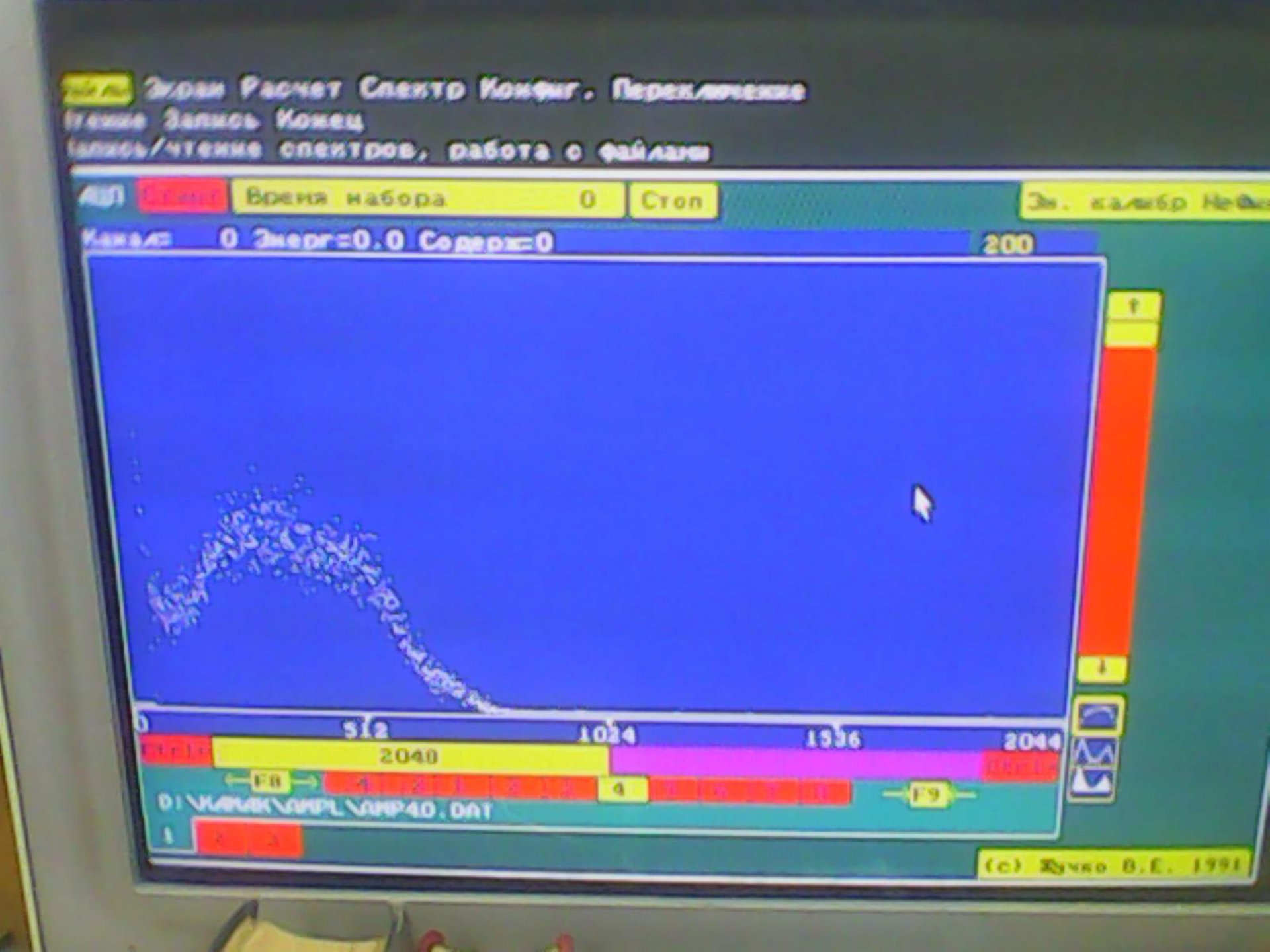
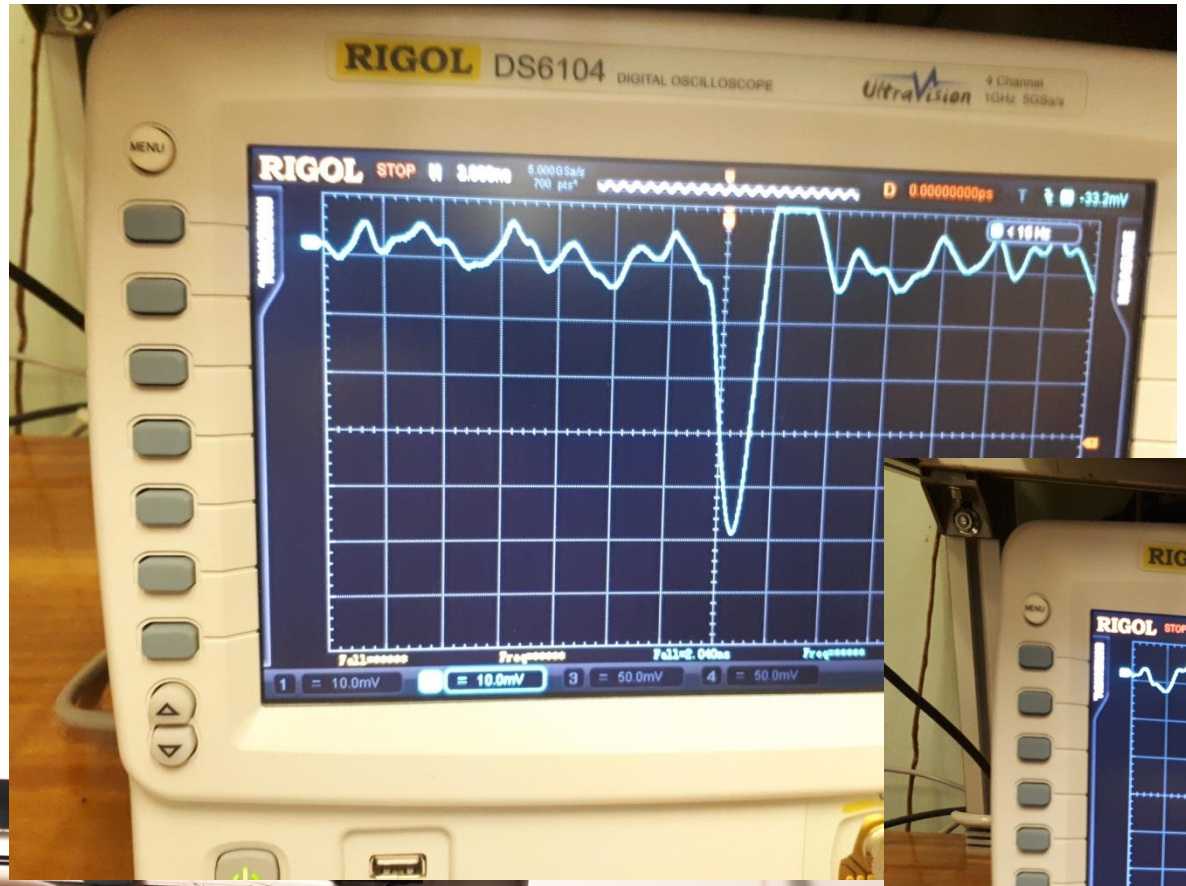
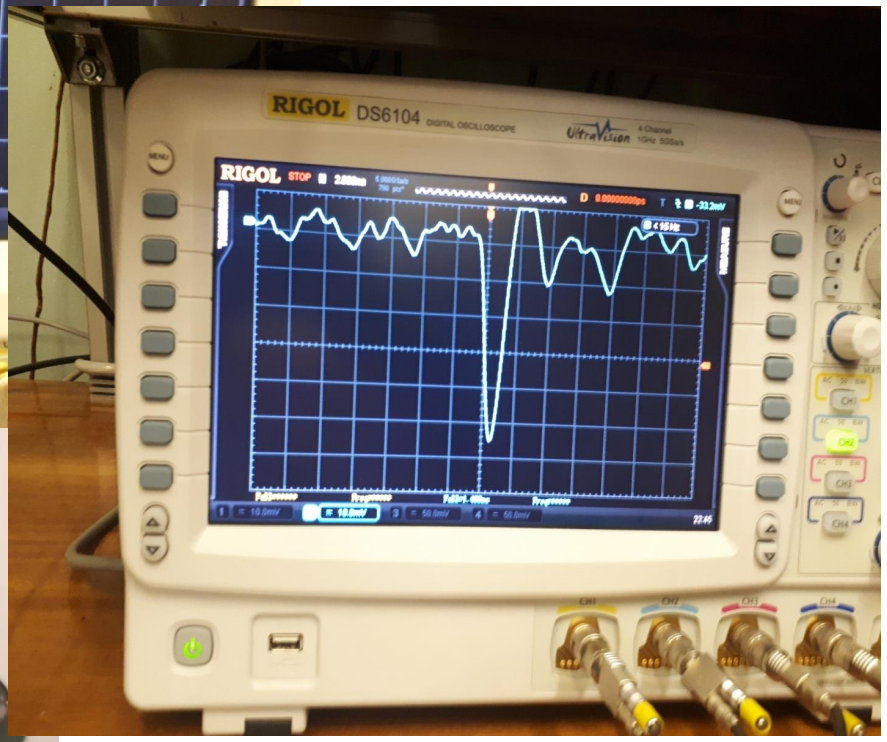



Fig. 2. Signal obtained from the MCP sector detector after the fast preamplifier.


Эдрон Расчет Спектр Конфиг. Переключение
Чтение Запись Конец
Запись/чтение спектров, работа с файлами
Время набора 0
Стоп
Эн. калибр
0 Энерг=0.0 Содерж=0
200
512
1024
1536
2044
2048
F8
F9
D:\KAMAK\AMPL\AMP40.DAT
(c) Жуко О.Е. 1991


RIGOL DS6104 DIGITAL OSCILLOSCOPE
UltraVision
MENU
RIGOL STOP
1 10.0mV
10.0mV
3 50.0mV
4 50.0mV


RIGOL DS6104 DIGITAL OSCILLOSCOPE
UltraVision
RIGOL STOP