Overview of MRPC based ToF systems developed in JINR

Vadim Babkin on behalf of the TOF group of the MPD & BM@N experiments

1) Joint Institute for Nuclear Research, VBLHEP
2) NICA – (Nuclotron based Ion Collider fAacility)
3) History of MRPC R&D and testing in JINR
4) MRPC mass-production workshop in VBLHEP
5) ToF system of the BM@N experiment
6) Upgrade of the NA61 ToF system at SPS (CERN)
7) MPD experiment at NICA
8) Status of the TOF system for MPD
9) Plans and conclusions

Joint Institute for Nuclear Research

SCIENCE BRINGS NATIONS TOGETHER

The Joint Institute for Nuclear Research is an international intergovernmental organization established through the Convention signed on 26 March 1956 by 11 founding States and registered with the United Nations on 1 February 1957. JINR is situated in **Dubna, the Moscow Region, the Russian Federation**.

JINR has at present **16 Member States: Armenia, Azerbaijan, Belarus, Bulgaria, Cuba, Arab Republic of Egypt, Georgia, Kazakhstan, D. P. Republic of Korea, Moldova, Mongolia, Romania, Russia, Slovakia, Uzbekistan, and Vietnam.** Participation of Germany, Hungary, Italy, the Republic of South Africa and Serbia in JINR activities is based on bilateral agreements signed on the governmental level.

The Institute employs about **4500** people, including more than 1200 scientists, among whom there are full members and corresponding members of national academies of sciences, more than 260 Doctors of Science (Professor) and 560 Candidates of Science (PhD).

Joint Institute for Nuclear Research (Dubna, Russia)

7 JINR Laboratories, each being comparable with a large research institute in the scale of investigations performed

Dzhelepov Laboratory
of Nuclear Problem

Flerov Laboratory
of Nuclear Reactions

Veksler and Baldin Laboratory
of High Energy Physics (VBLHEP)

Frank Laboratory of Neutron Physics

Laboratory of Radiation Biology

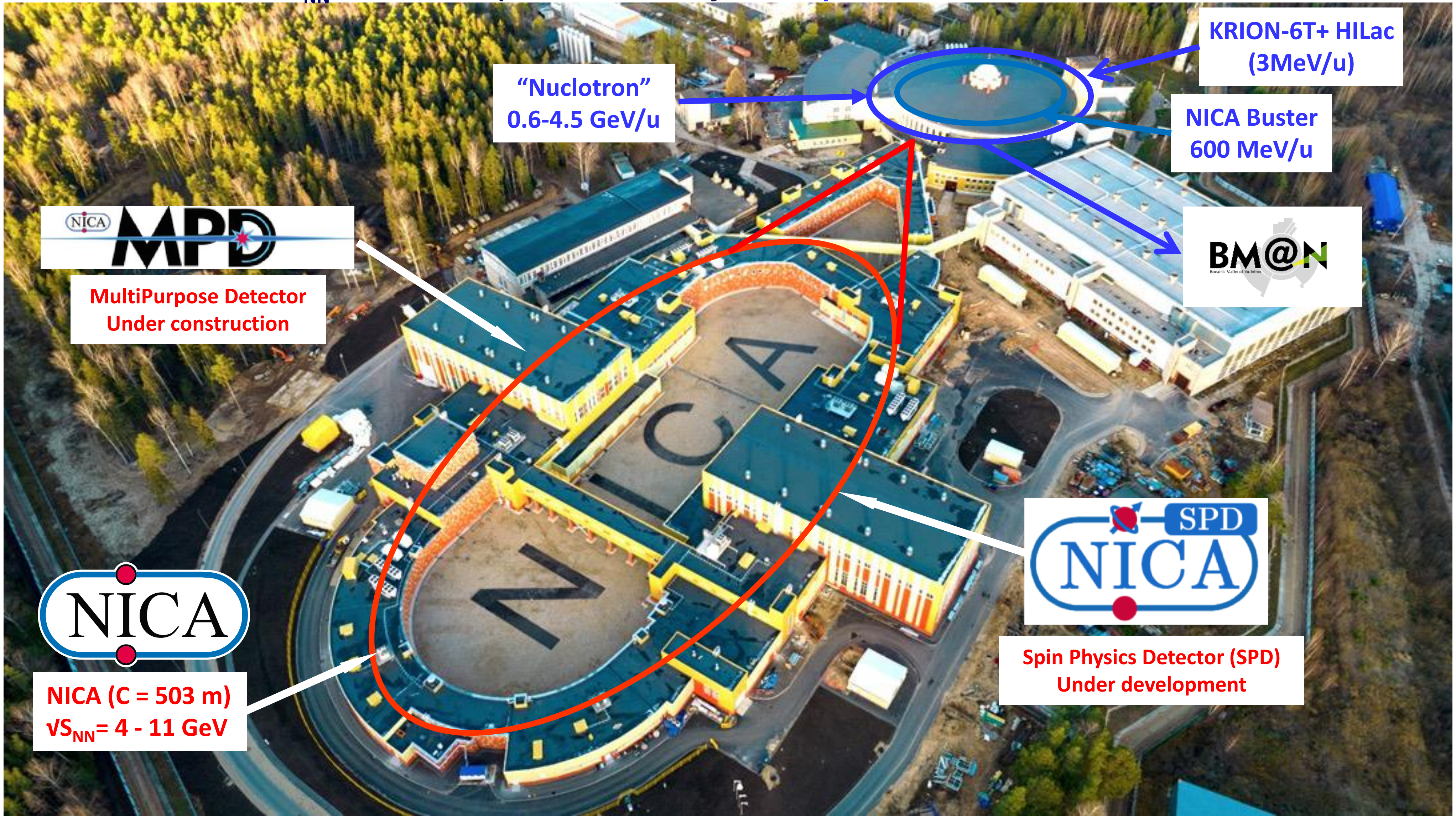
Bogolubov Laboratory
of Theoretical Physics

Mesheryakov Laboratory
of Information Technology

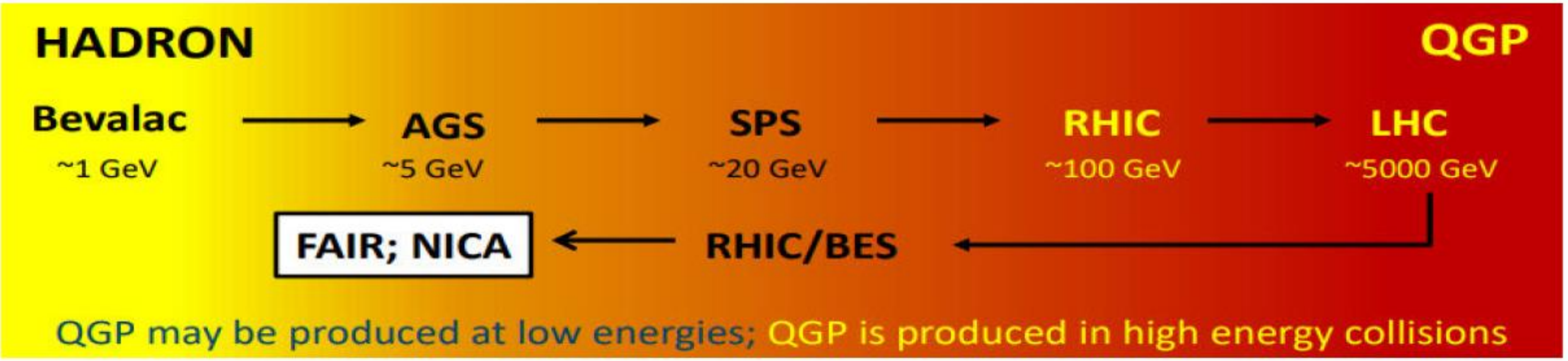
VBLHEP accelerator complex. NICA - Nuclotron based Ion Collider fAacility

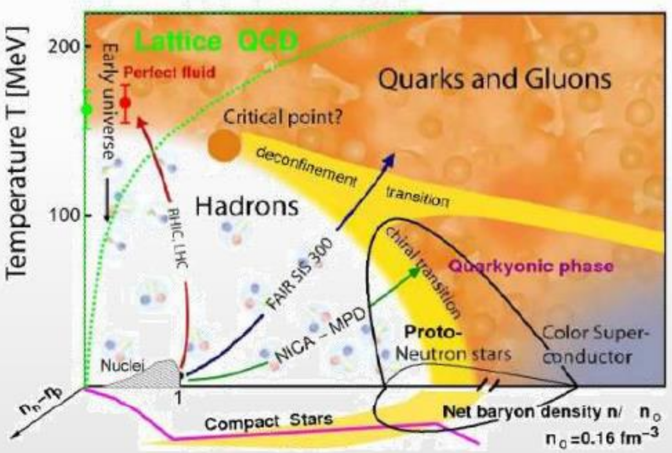
$\sqrt{s_{NN}}$ = **4 - 11** GeV; ***ion beams for MPD:*** from **p** to **Au** @ **L** ~ **10^{27}** cm^{-2} c^{-1} (for Au)

$\sqrt{s_{NN}}$ = **6 - 26** GeV; ***polarized beams for SPD:*** **p↑** and **d↑** @ **L** ~ **10^{32}** cm^{-2} c^{-1}

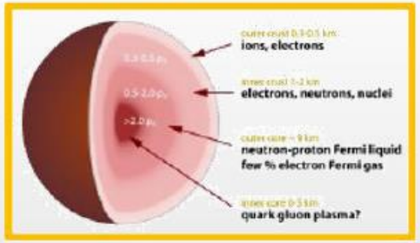


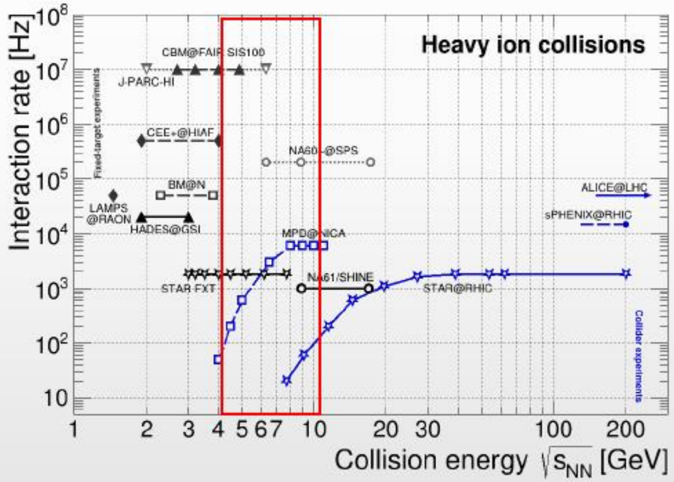
VBLHEP accelerator complex. NICA - Nuclotron based Ion Collider fAacility





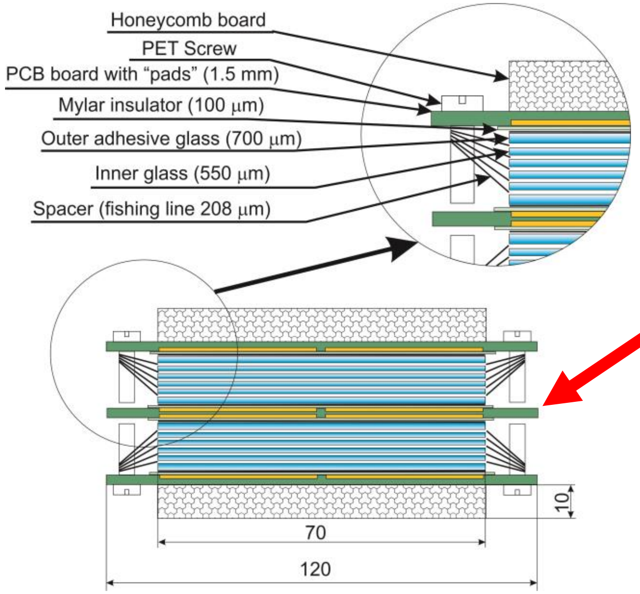
high baryon densities
→ inner structure of
compact stars

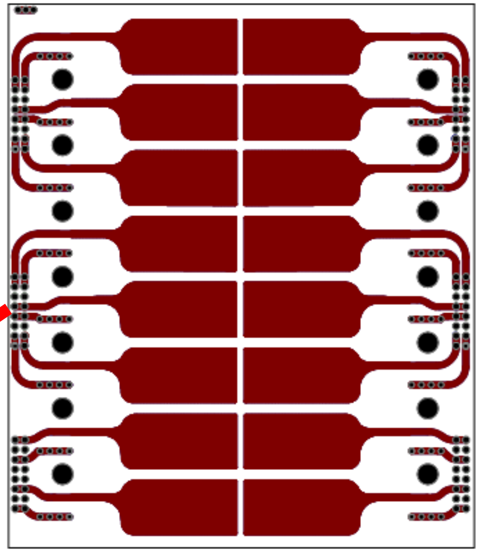


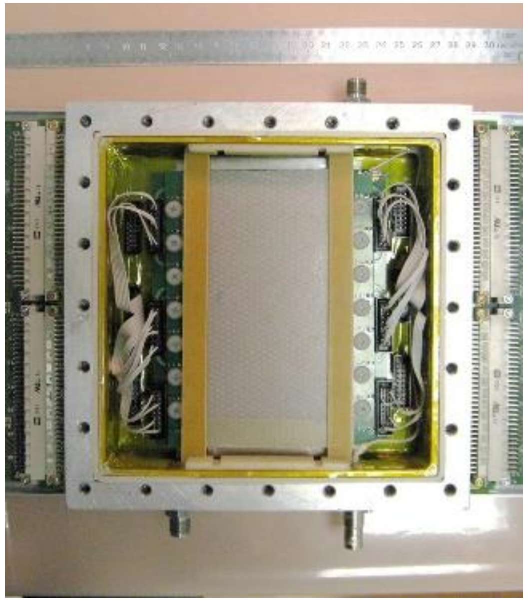


- At μ_B ~ 0, smooth crossover (lattice QCD calculations + data)
- At large μ_B, 1st order phase transition is expected → QCD critical point
- BM@N and MPD will study QCD medium at extreme net baryon densities
- Many ongoing (NA61/Shine, STAR-BES) and future experiments (CBM) in ~ same energy range

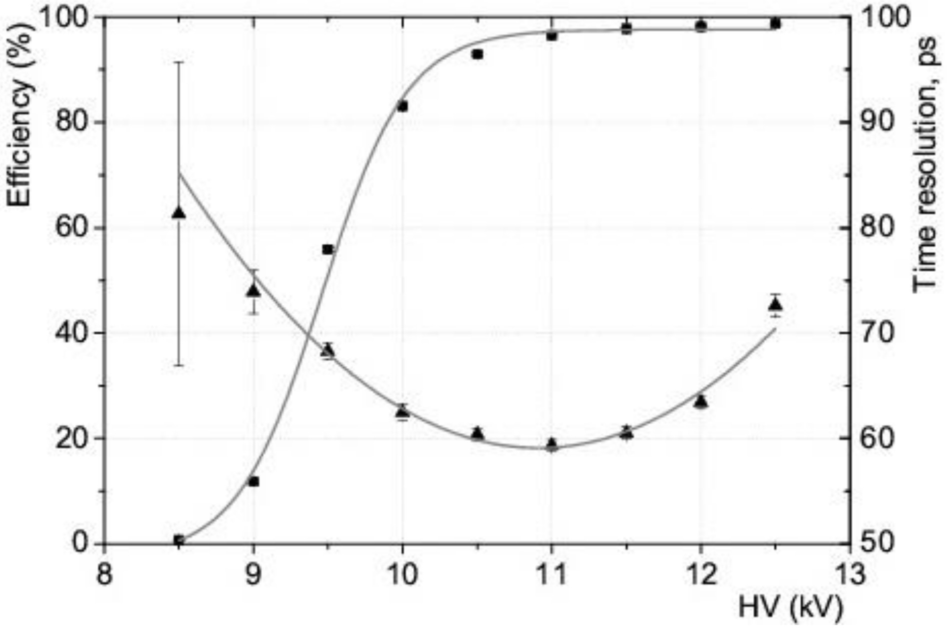
History. First multigap resistive plate chamber (MRPC) prototypes with pad readout (2008-2009).





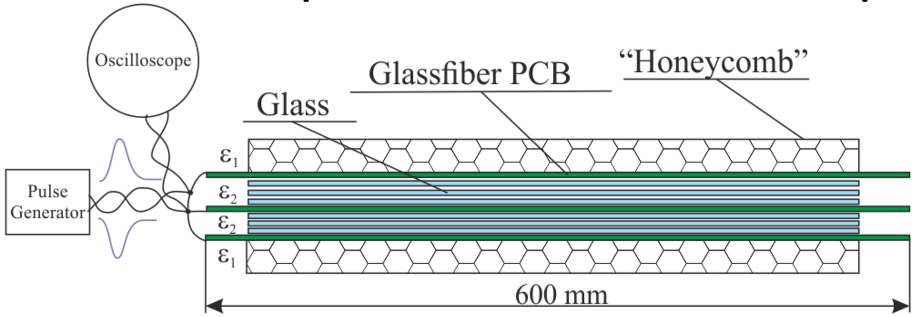


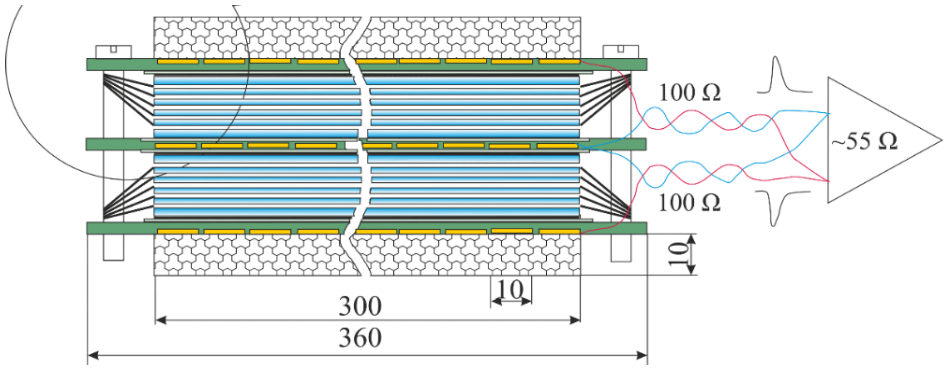
Pad MRPC prototype characteristics	
Overall dimensions	200x400 mm
Active surface	140x70 mm
Channel number	8x2 = 16
Pad's dimension	34x16 mm
Glass thickness (inner, outer)	550, 700 μm
Gap number (2 stacks)	2x5 = 10
Gap width	210 μm
Gas mixture	$C_2H_2F_4/iC_4H_{10}/SF_6$ (90/5/5)
Operating voltage	11,5 kV
Readout electronics	NINO + HPTDC

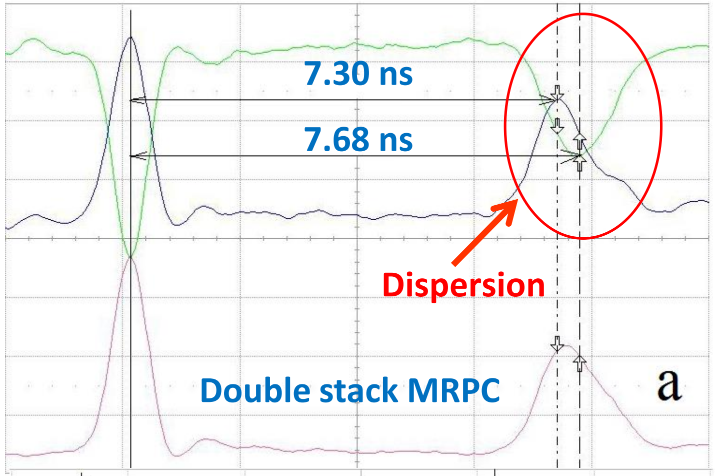


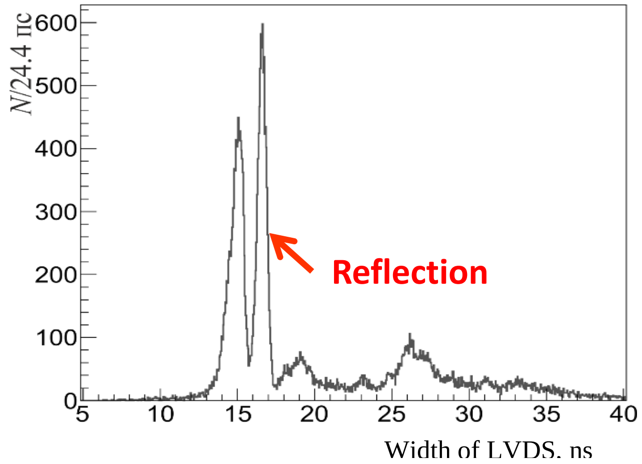
History. MRPCs with strip readout for NICA experiments.

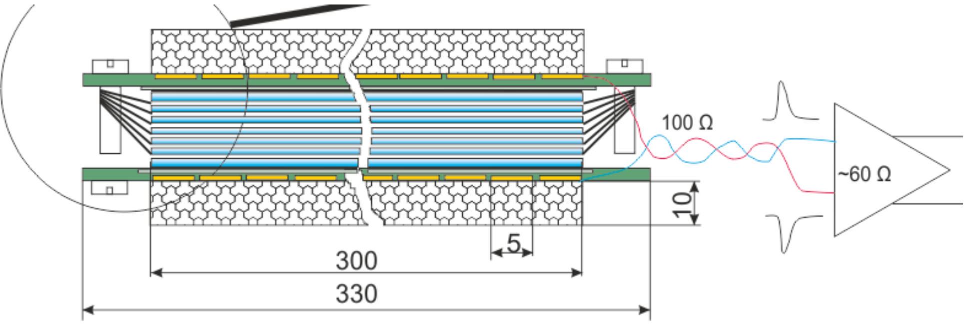
First double-stack strip MRPC assembled according to the principle of a pad prototype

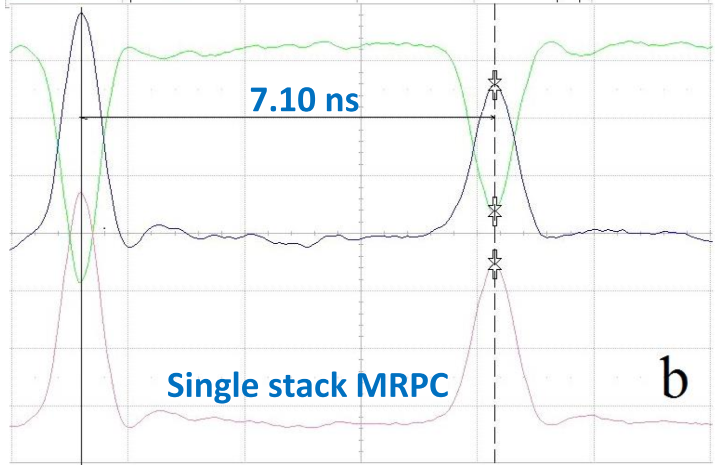


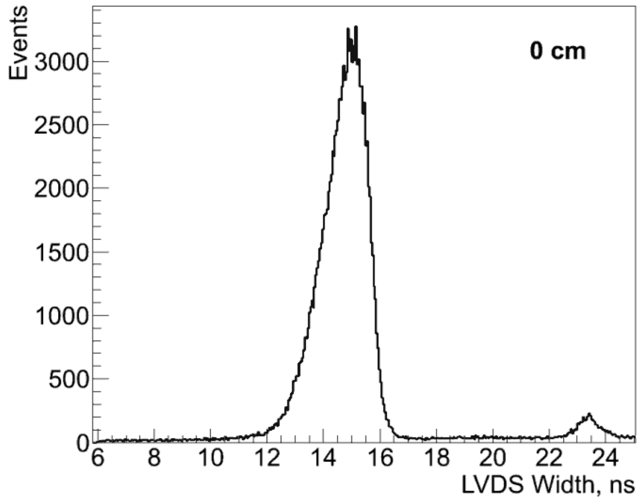




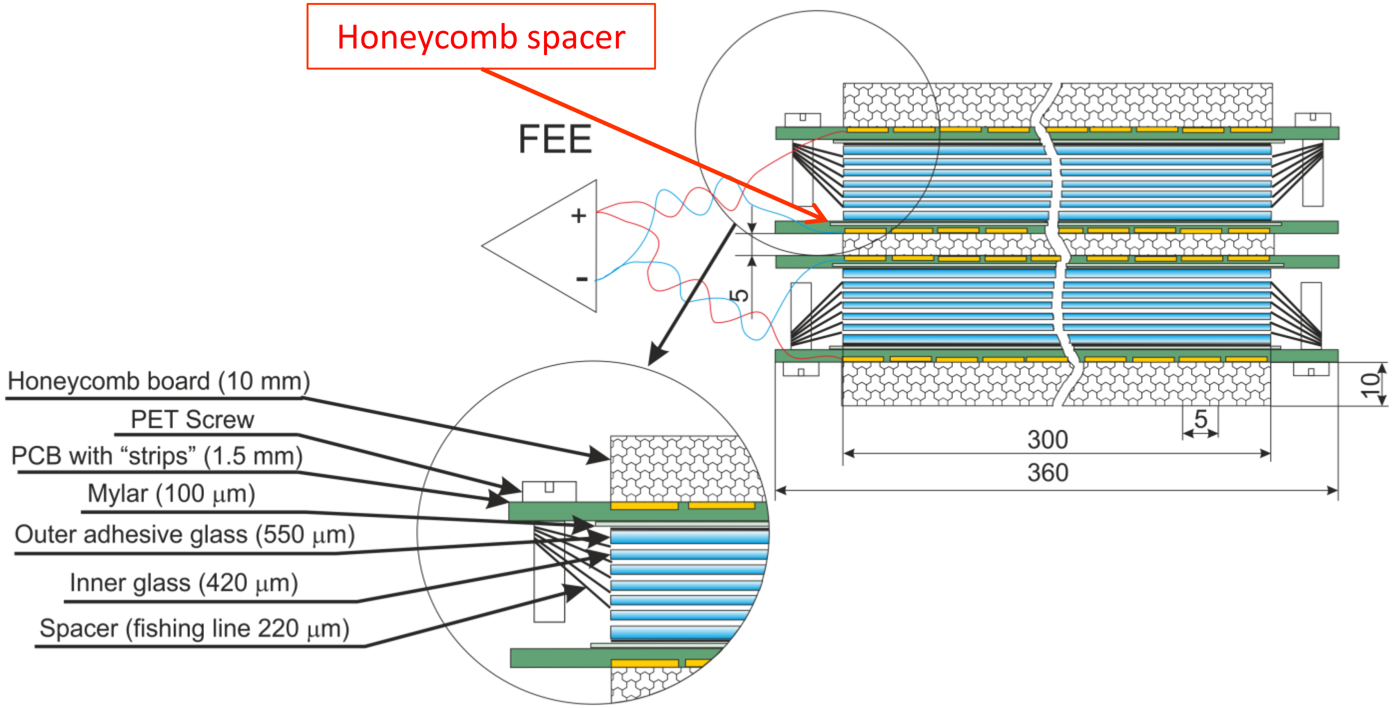


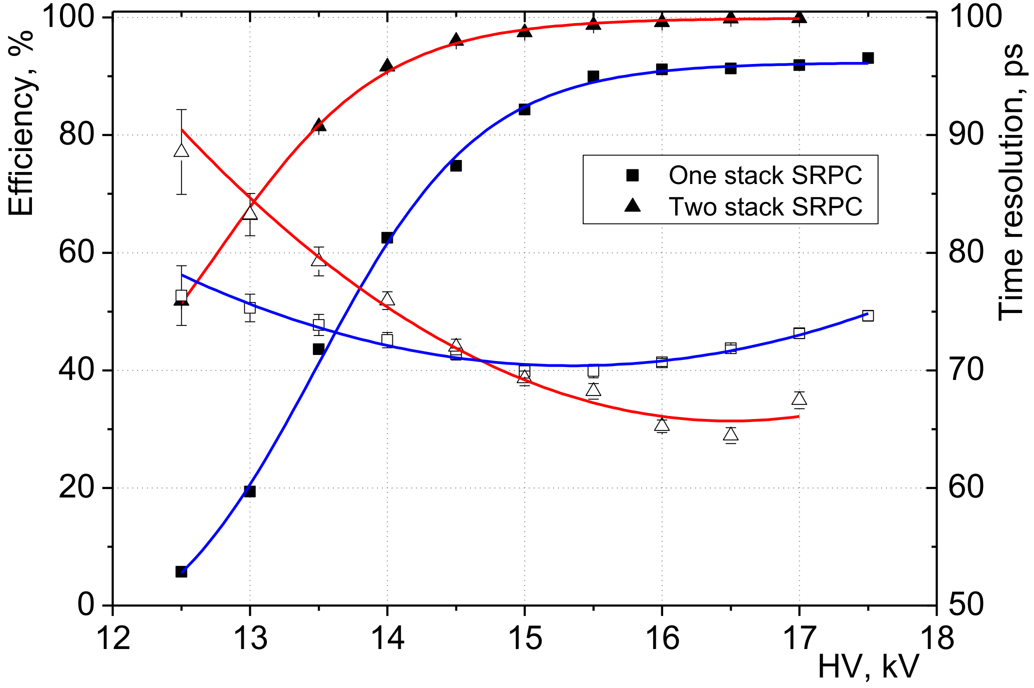






History. MRPCs with strip readout for NICA experiments.

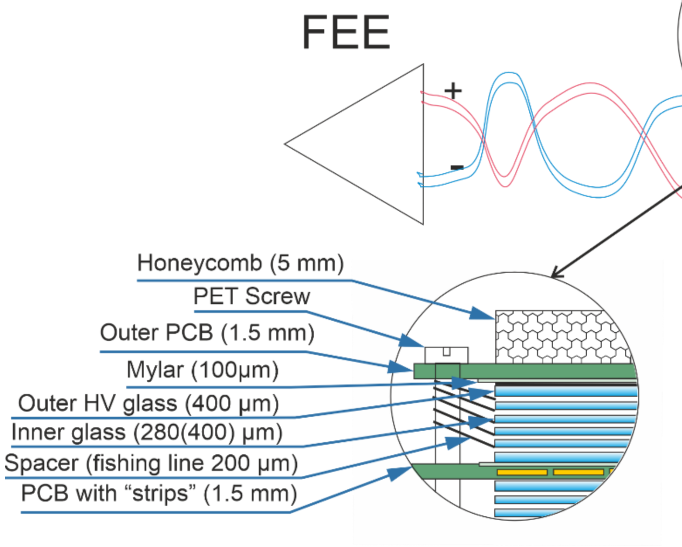


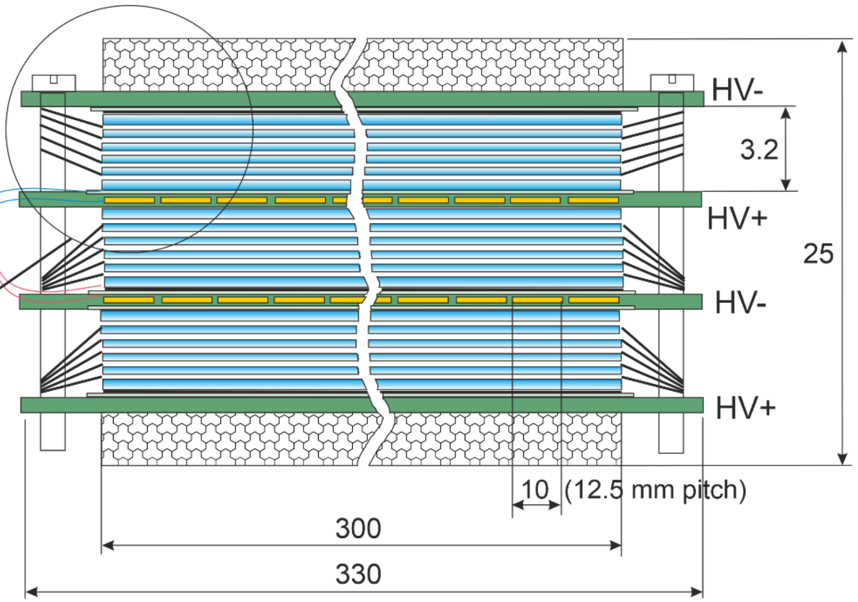


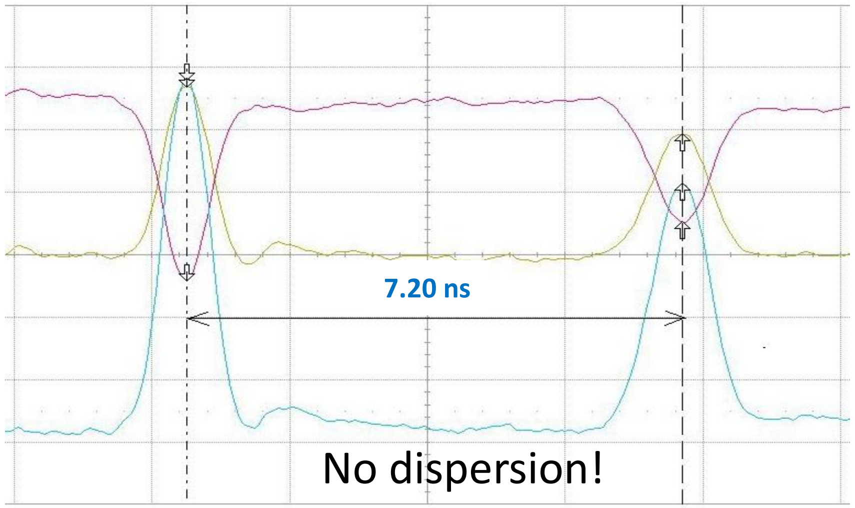
We need new construction of MRPC with symmetrical transmission line!

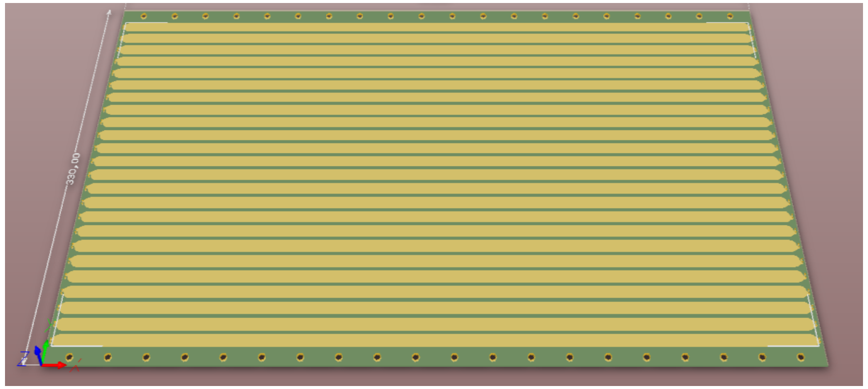
History. 3-stack 15-gap MRPC.

First MRPC with 280 um glass!

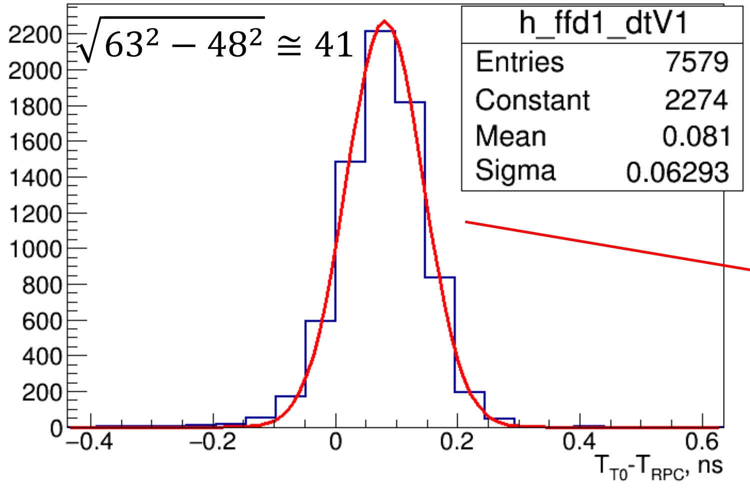


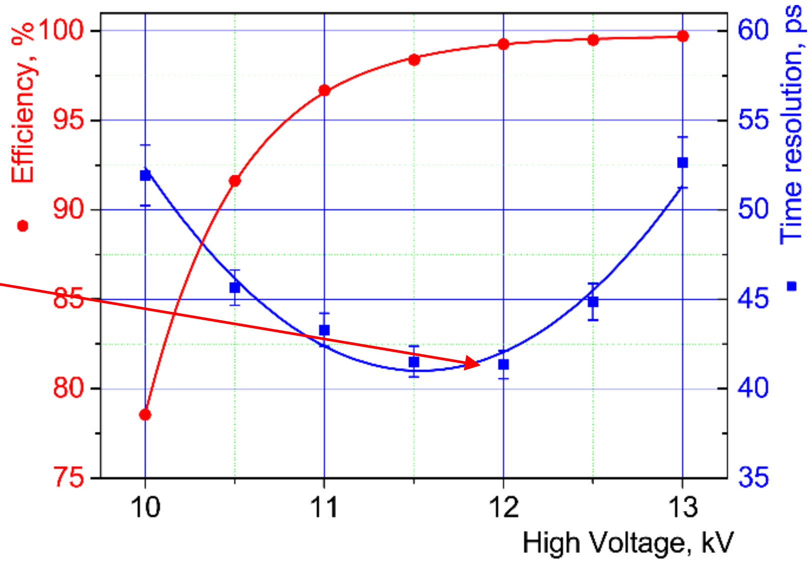






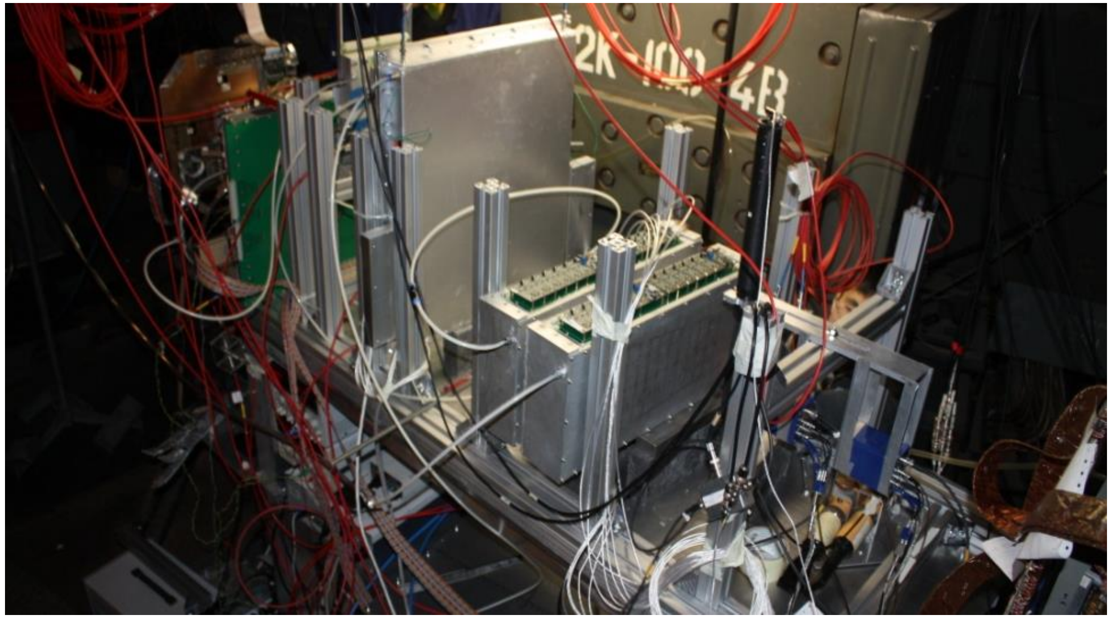
MRPC readout strips

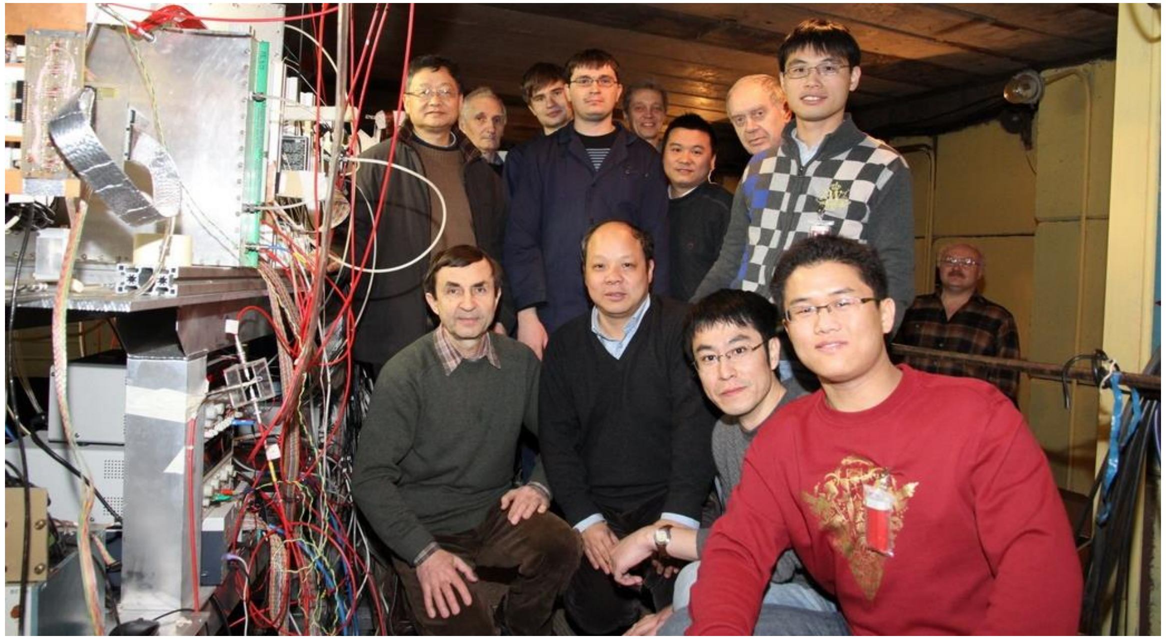




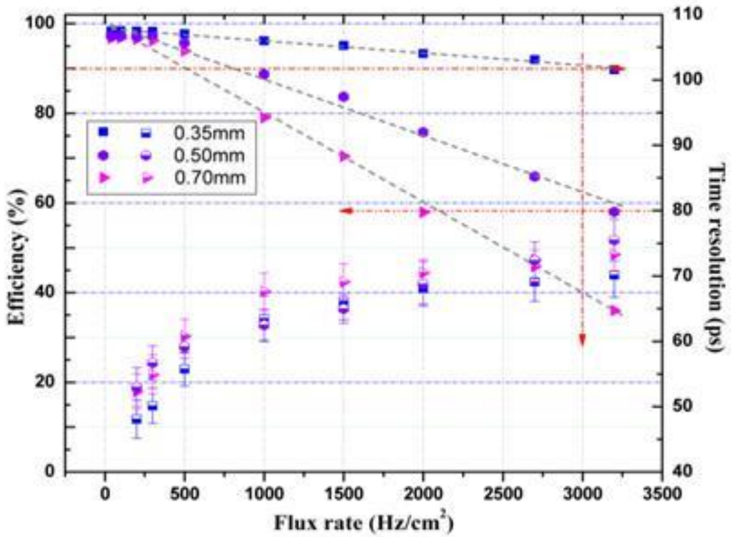
The best measured MRPC time resolution

High rate MRPC test in JINR with USTC & Tsinghua University groups (2011).

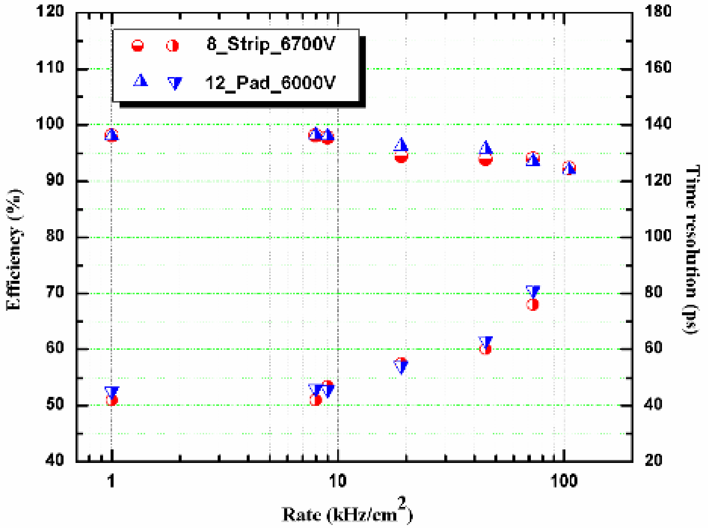




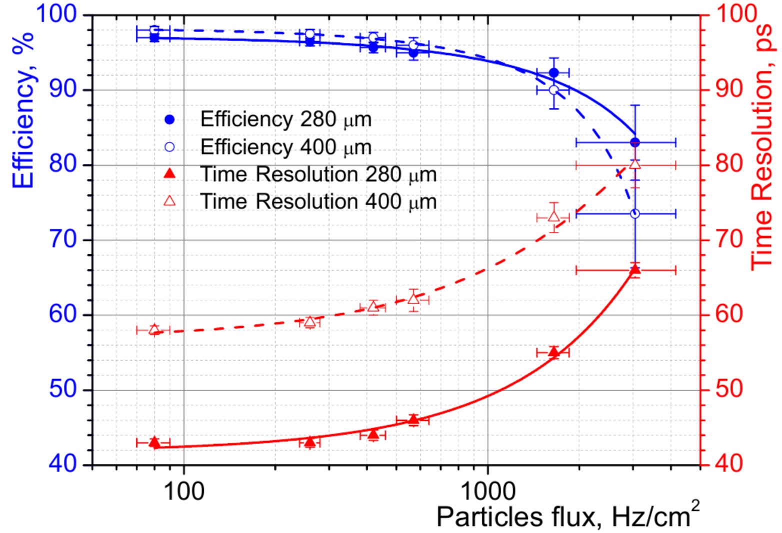
Test setup on the Nuclotron extracted beam of deuterium (2 GeV/u)



Different thickness glass rate capability



Semiconductor glass rate capability



Rate capability of our 3-stack MRPCs

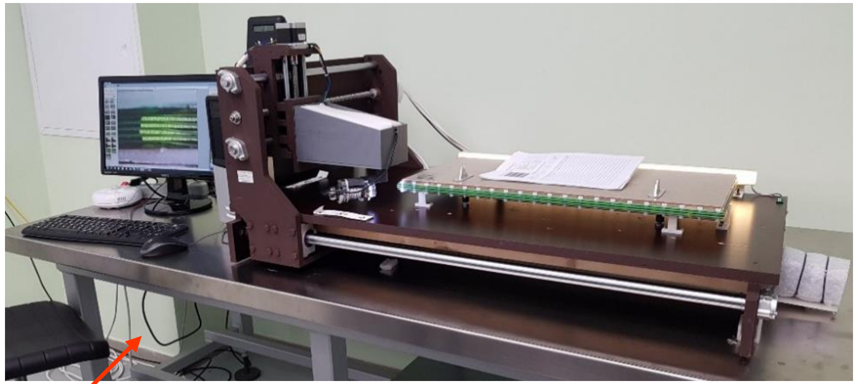
Mass production and quality control

Mass production staff: 4 physicists, 4 technicians, 2 electronics engineers

All procedure of detector assembling and optical control is performed in a clean rooms ISO class 6-7.

Glass cleaning with ultrasonic wave & deionized water

Automatic painting the conductive layer on glass

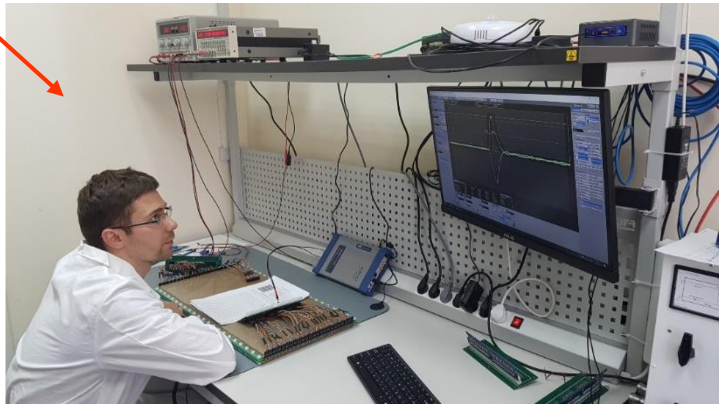


Check list

1) Optical control (gap uniformity, cracks in glass)
2) Primary HV testing (without gas) - up to 6 kV
3) Readout pins and cables break, short-circuit and reversed polarity control
4) Full HV testing (after fast pumping and filling with working gas mixture) – up to 12 kV
5) Transmission line impedance (reflection) control

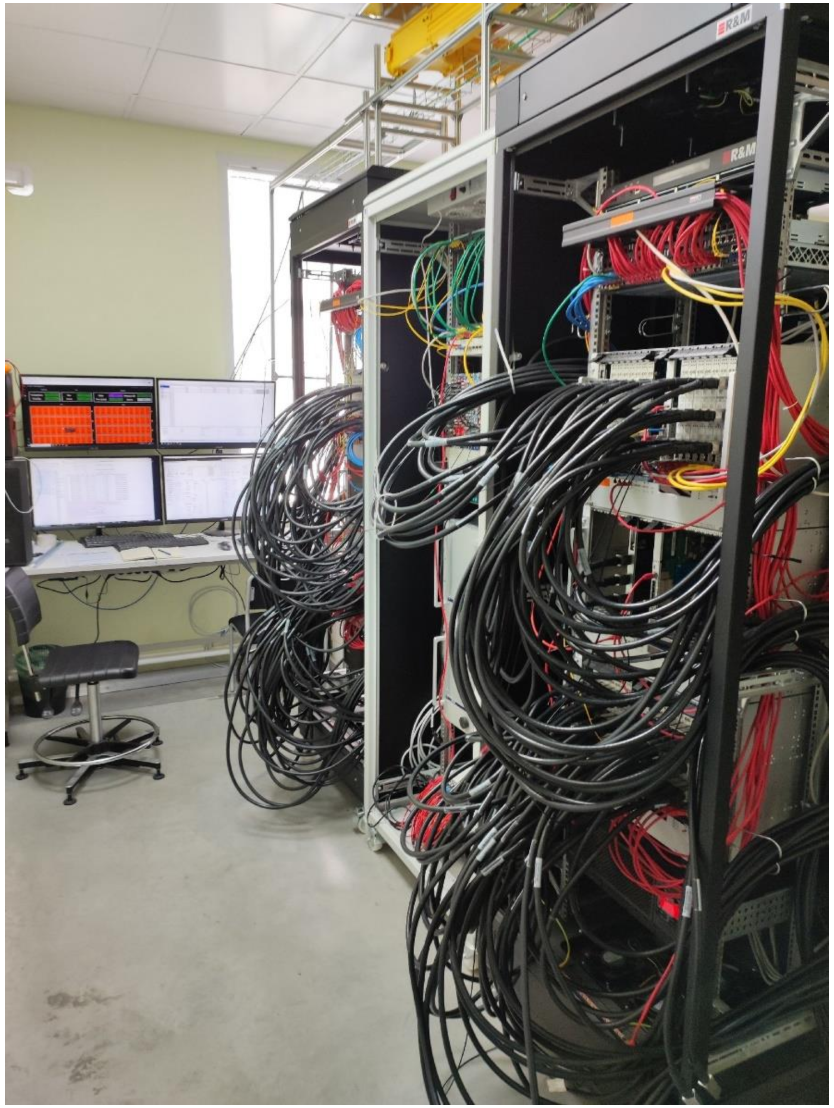
MRPC assembling

TOF modules assembling

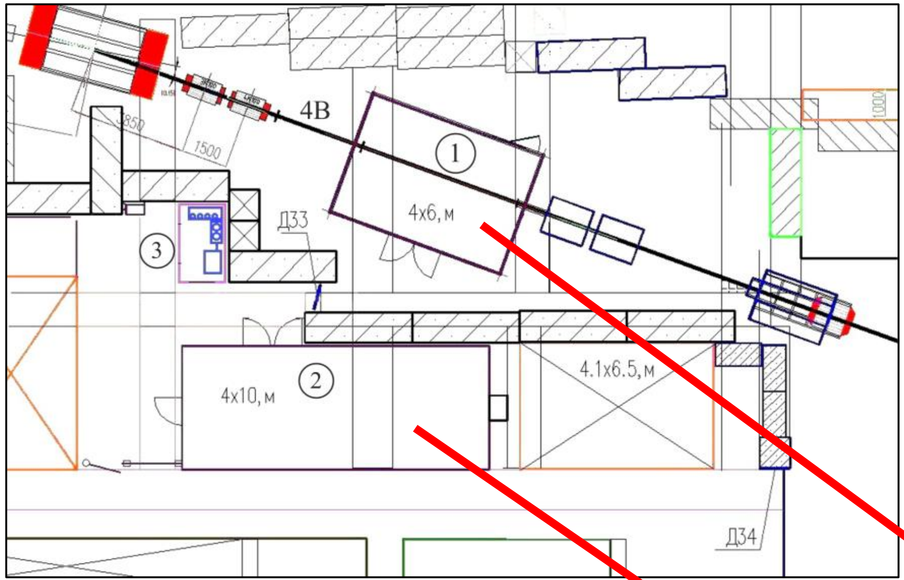


Cosmic rays test of TOF modules

Laboratory stand for testing TOF modules on cosmic rays operate since beginning of August 2021



MPD test stand at the extracted beams of Nuclotron



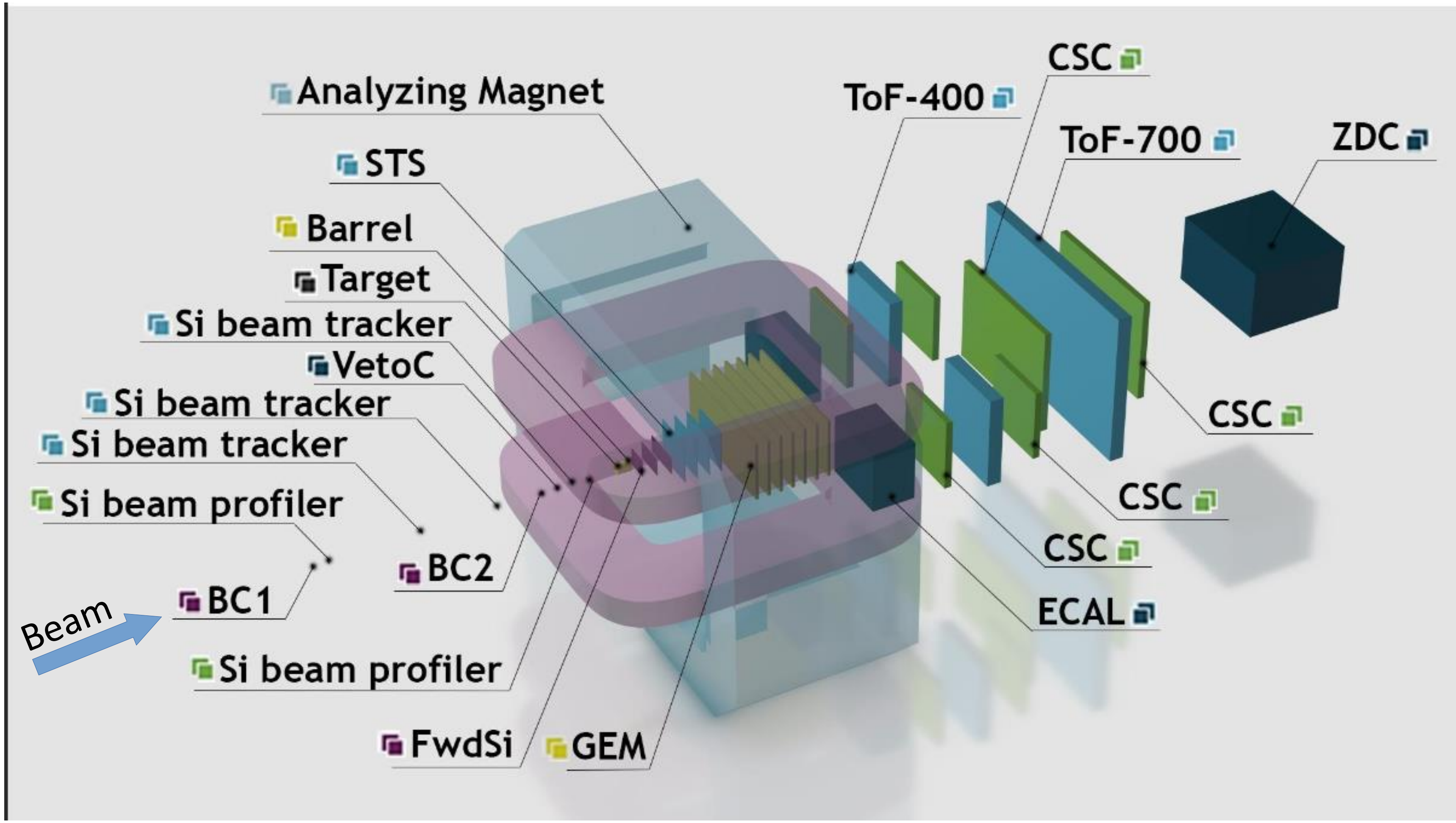
Particles	Energy, GeV/u	Maximum intensity at the setup, c^{-1}
p	0.2 – 4.5	$\sim10^{8}$
d	0.2 – 4.5	$\sim10^{7}$
^{12}C	1 – 3.5	$\sim10^{6}$

The main parts of stand:

- two platforms made of aluminum profile (total length - 5 m);
- the precision positioning device for detectors movement remotely;
- three multiwire proportional chambers with position resolution ~0.5 mm;
- two independent gas system with different gas mixtures (freons and inert gases);
- data acquisition system (DAQ) based on the VME and Ethernet.

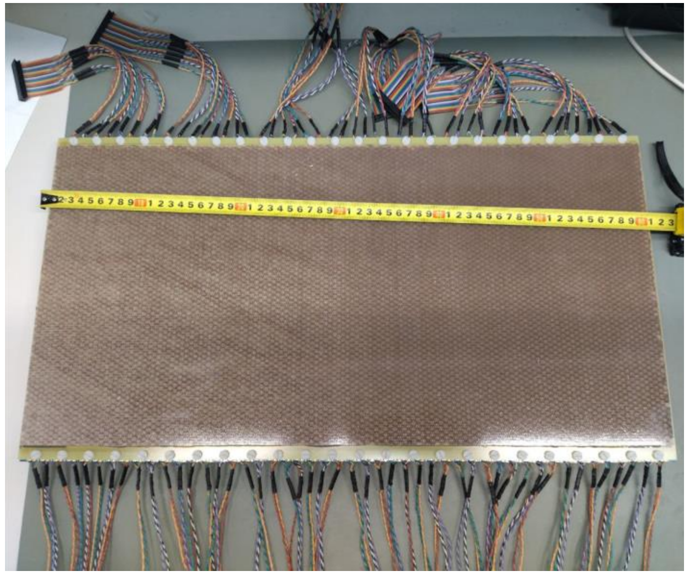
Barionic Matter at Nuclotron (BM@N) experiment

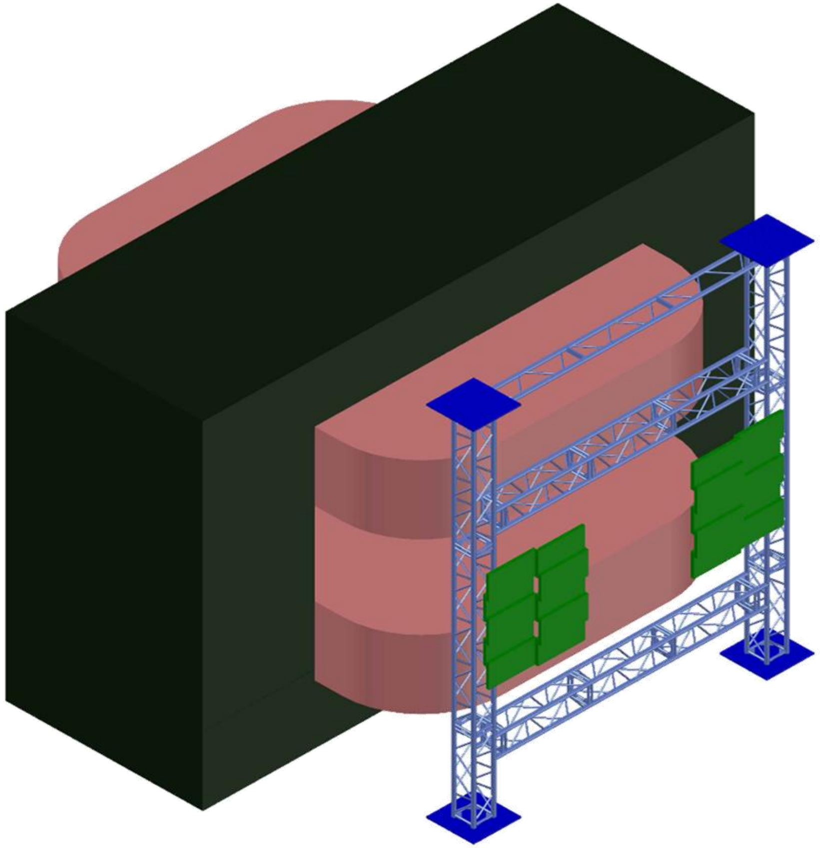
The BM@N is fixed-target experiment with the final goal to perform a research program focused on the production of strange matter in heavy-ion collisions at beam energies between **2** and **6** GeV/u.
Colaboration: 3 Countries, 10 Institutions, 184 participants.



- Beam monitor system: Si beam profilometers and tracker.
- Trigger sustem: BC1, BC2 and Veto counters, Barrel detector around target.
- Inner tracking system: STS and GEM in magnetig field up to 0.9T.
- Other tracking system: CSC detectors.
- TOF400+TOF700 system for PID
- ZDC for centrality determination.
- ECAL(optional)

Barionic Matter at Nuclotron (BM@N) experiment





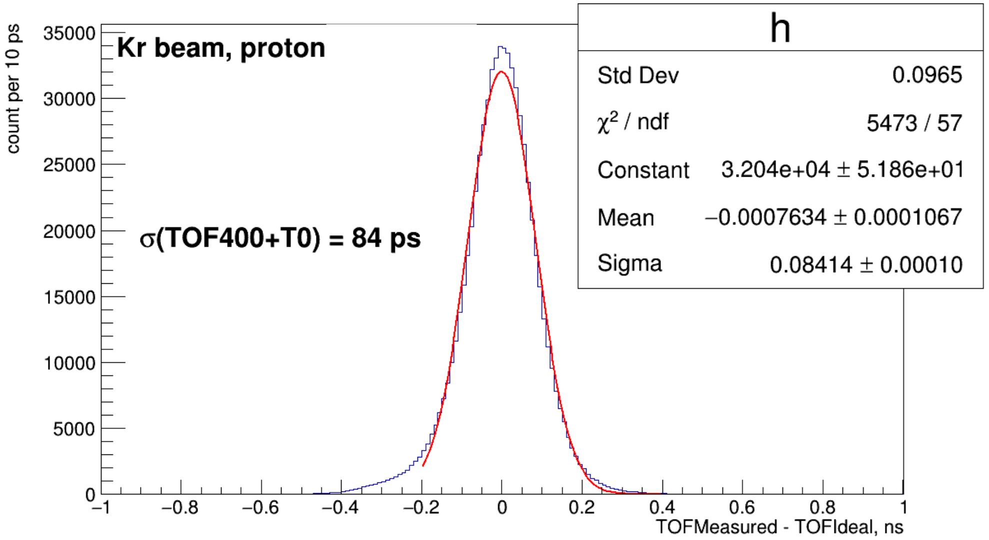
Full mounted ToF-400 system

BM@N ToF-400 MRPC characteristics	
Active area	600x300 mm^2
Channel number	48 (with both side readout)
Strip dimension	300x10 mm (12.5 mm pitch)
Glass thickness (inner, outer)	280, 400 µm
Gap number (3 stacks)	3x5 = 15
Gap width	200 µm
Gas mixture	$C_2H_2F_4/iC_4H_{10}/SF_6$ (90/5/5)
Operating voltage	11,5 kV
Readout electronics	NINO + HPTDC

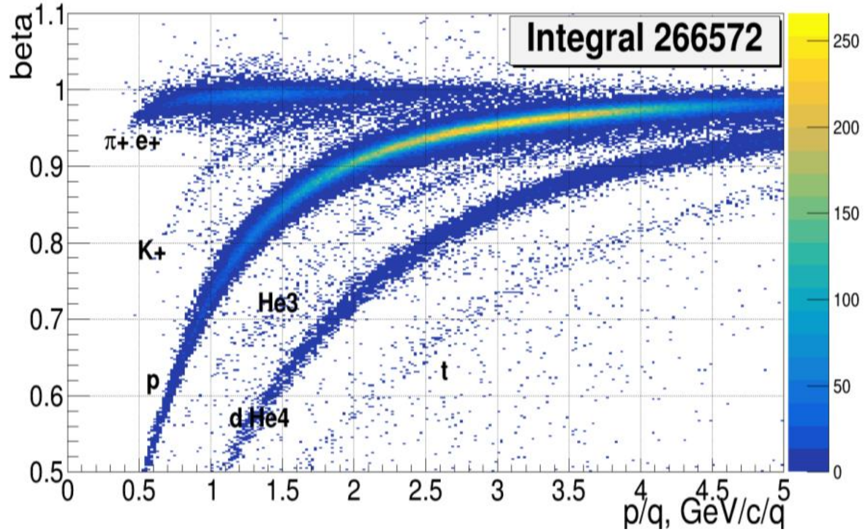
FEE channels of one detector	96
Total active area of ToF-400	**~3 m^2**
Total number of detectors	20
Total number of FEE	1920

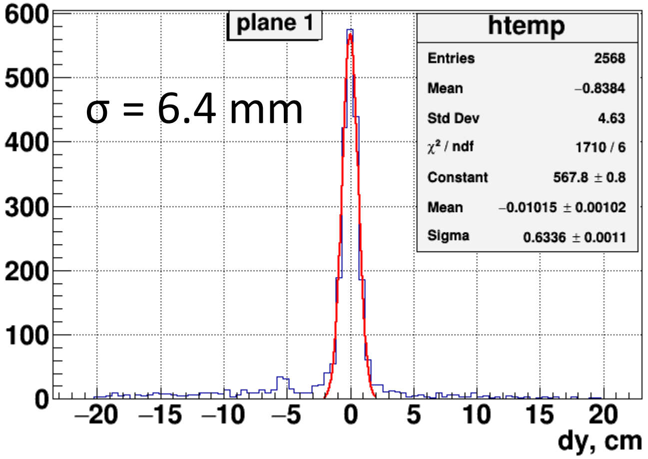
Barionic Matter at Nuclotron (BM@N) experiment

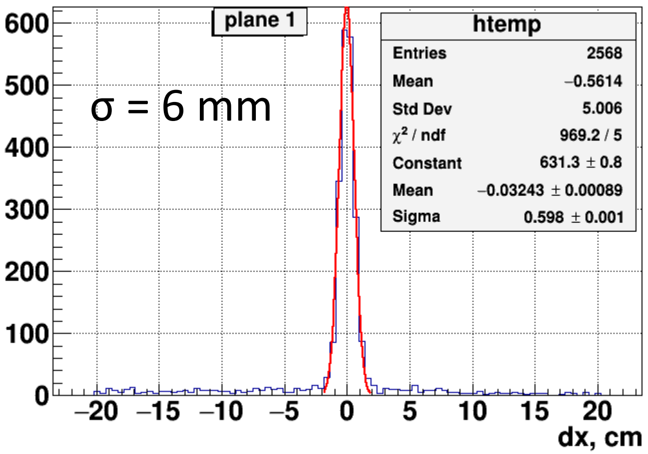
The result of data analysis of Kr+target(C, Cu, Pd, or Sn) interaction collected in 2018.



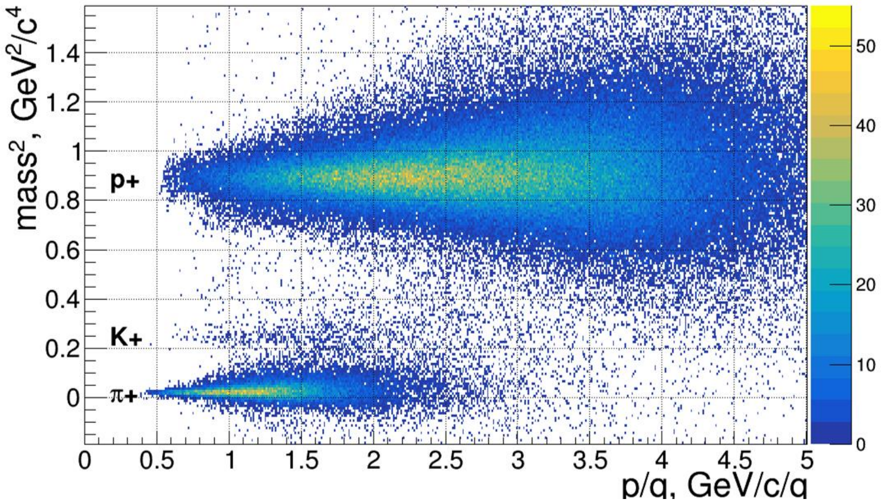
ToF-400 full time resolution (from identified protons)





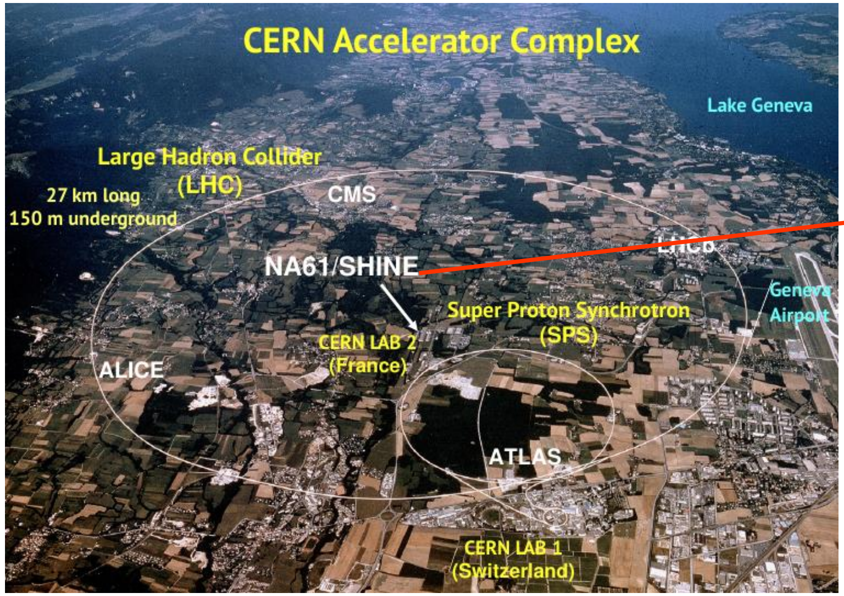


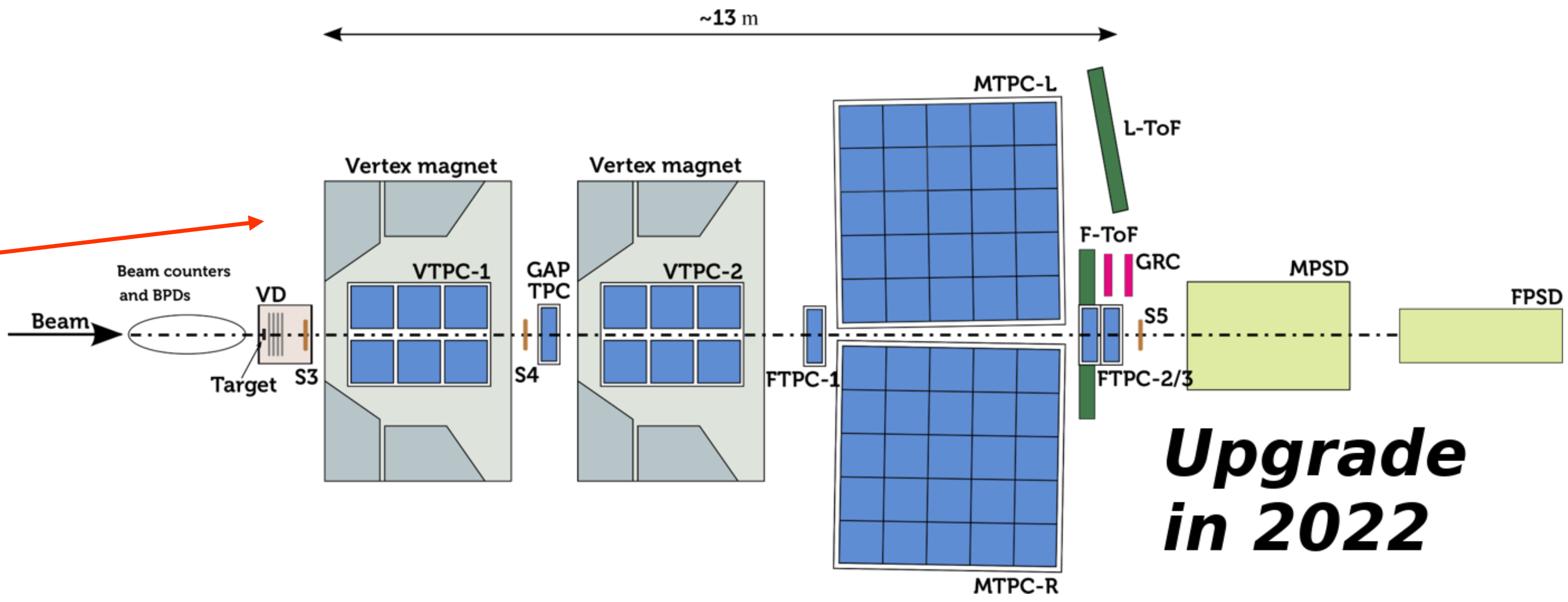
Residuals for refited GEM+CSC track extrapolated to ToF400

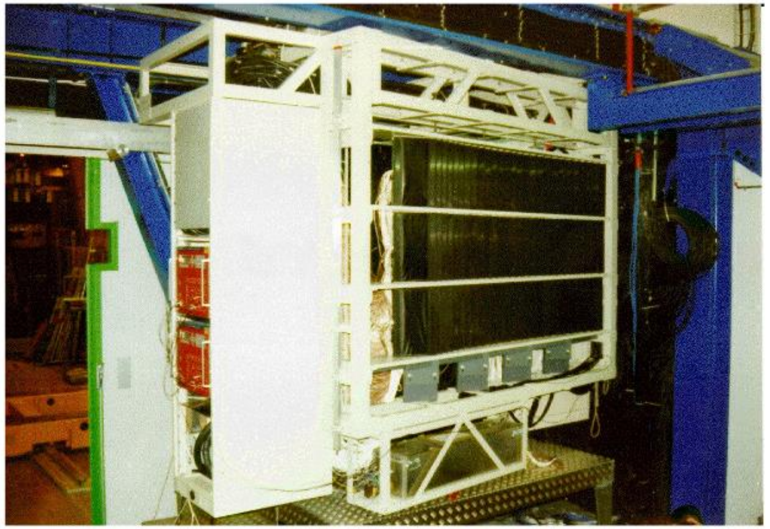


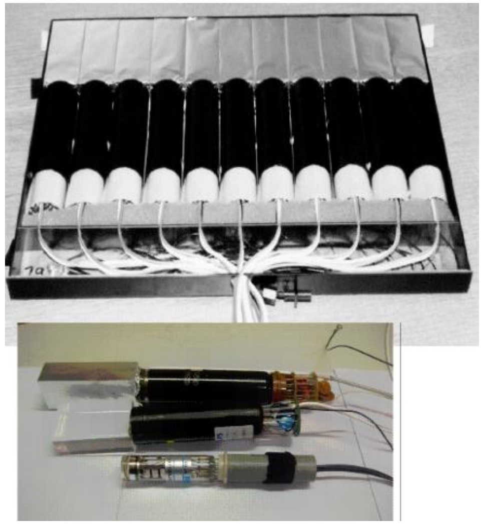
Particles separation by the ToF-400 system

Upgrade of the L-ToF system of NA61 at SPS (CERN)





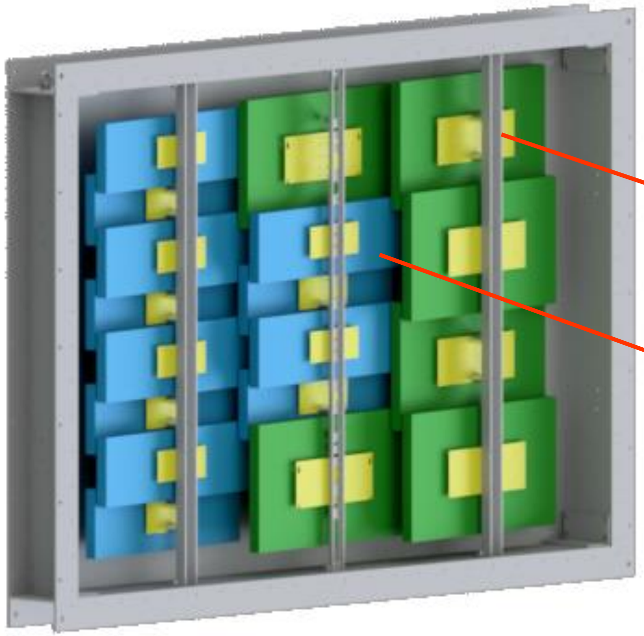


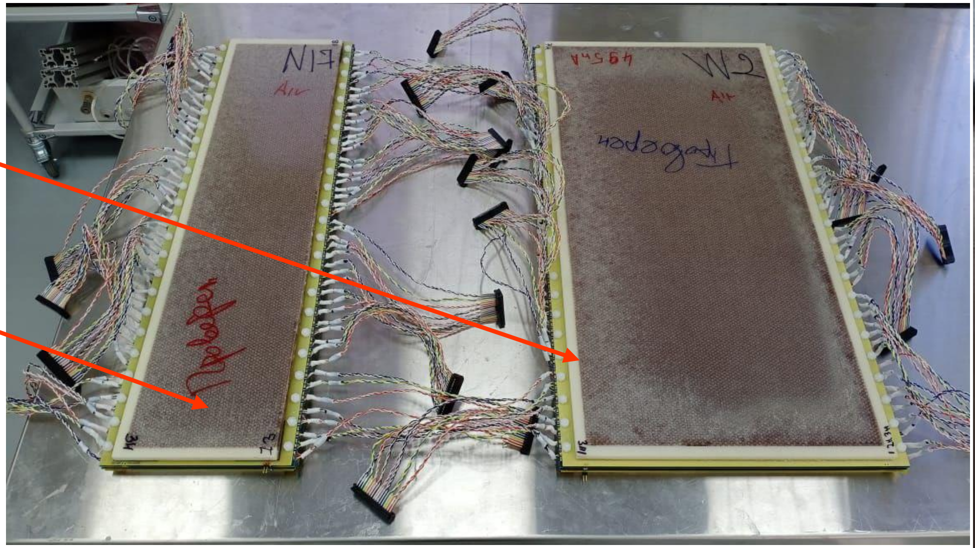


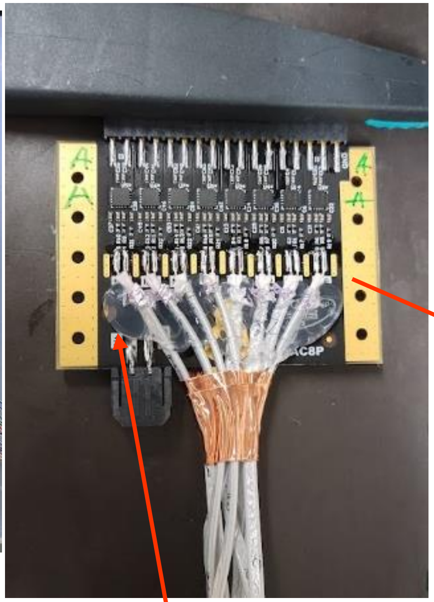
Predecessor of MRPC ToF NA61/SHINE:

- 2 x 891 scintillator counters
- TOF-L (JINR contribution) put into operation in 1995-96
- Time resolution: ~ 76 ps
- Distance from target L = 13-15 m

Upgrade of the L-ToF system of NA61 at SPS (CERN)

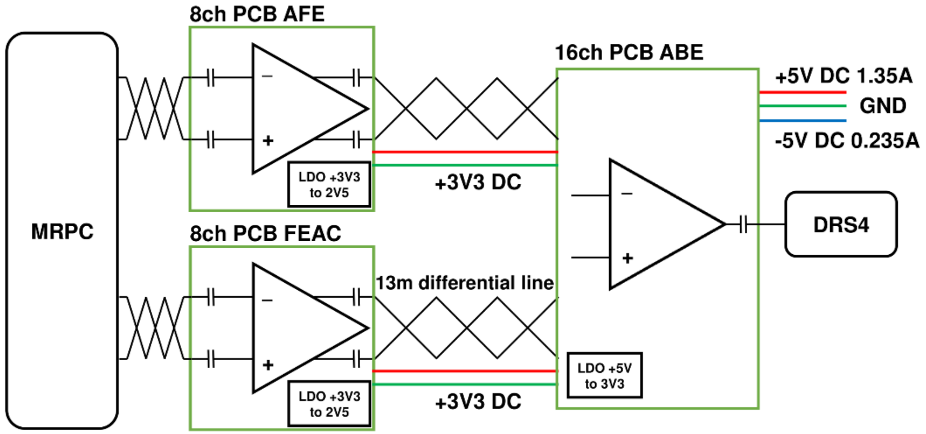






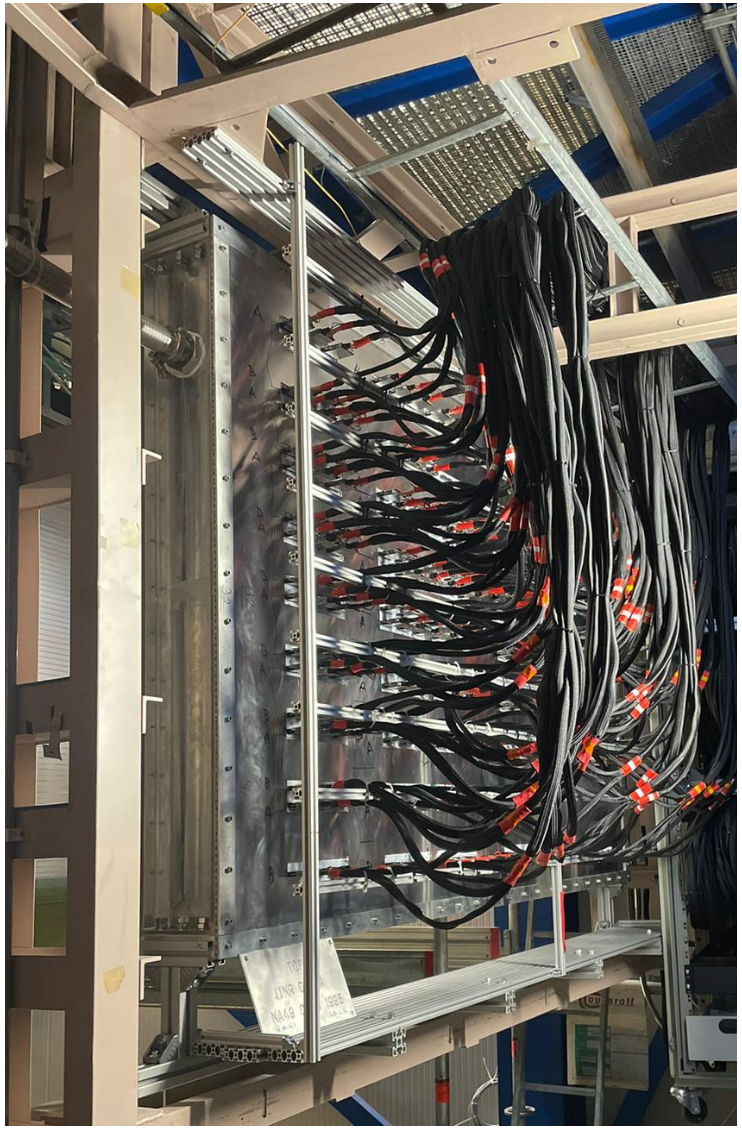
18 MRPCs of two sizes
1728 channles in total
MRPC-L (JINR contribution) put into operation in 2021-2022
Time resolution: ~ 52 ps
Distance from target L = 14 m

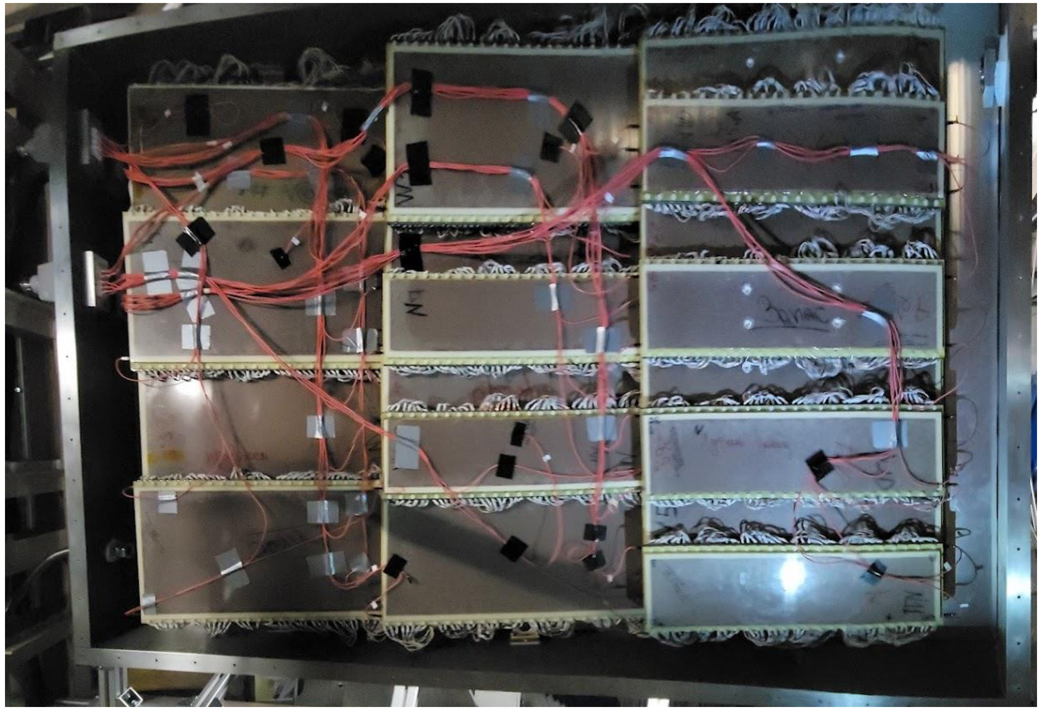
NA61 L-ToF MRPC characteristics	
Active area	600x300(150) mm^2
Channel number	48 (with both side readout)
Strip dimension	300(150)x10 mm
Glass thickness (inner, outer)	280, 400 μm
Gap number (3 stacks)	3x5 = 15
Gap width	200 μm
Gas mixture	$C_2H_2F_4/iC_4H_{10}/SF_6$ (90/5/5)
Operating voltage	11,5 kV
Readout electronics	AnalogFE + DRS4

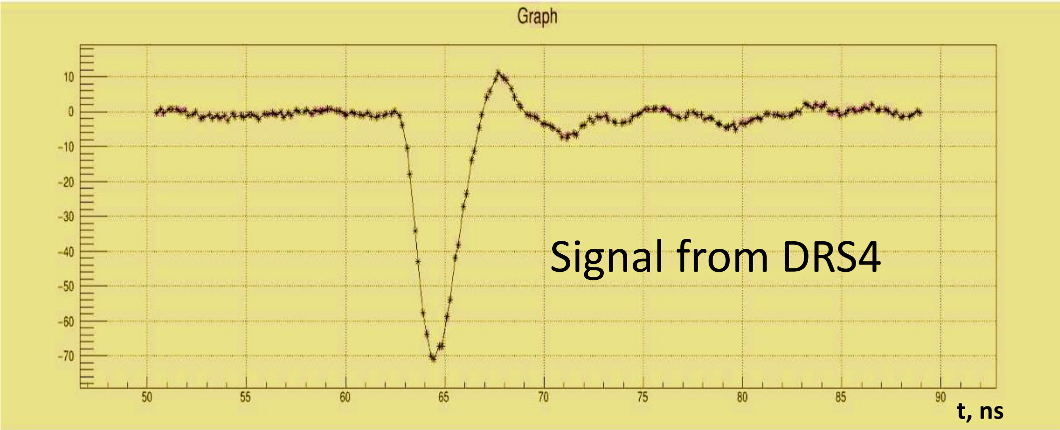


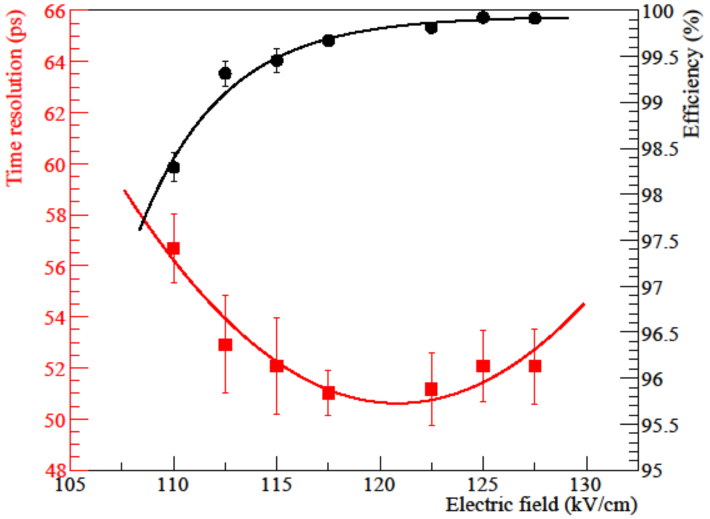
New self-maid of analog readout board.

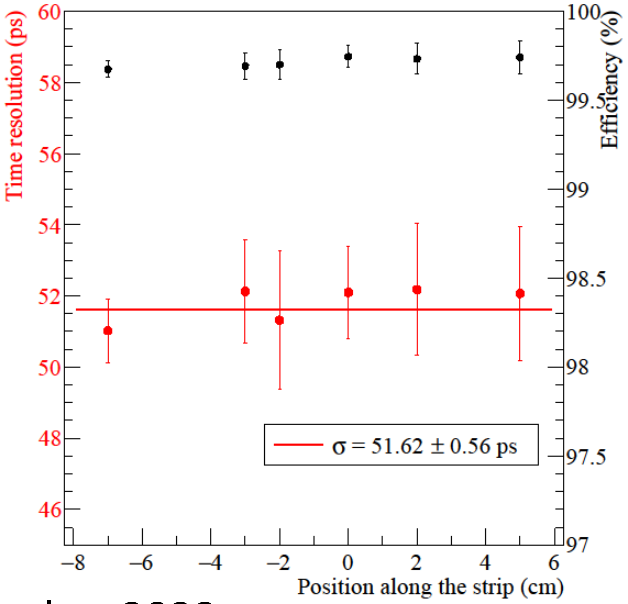
Upgrade of the L-ToF system of NA61 at SPS (CERN)









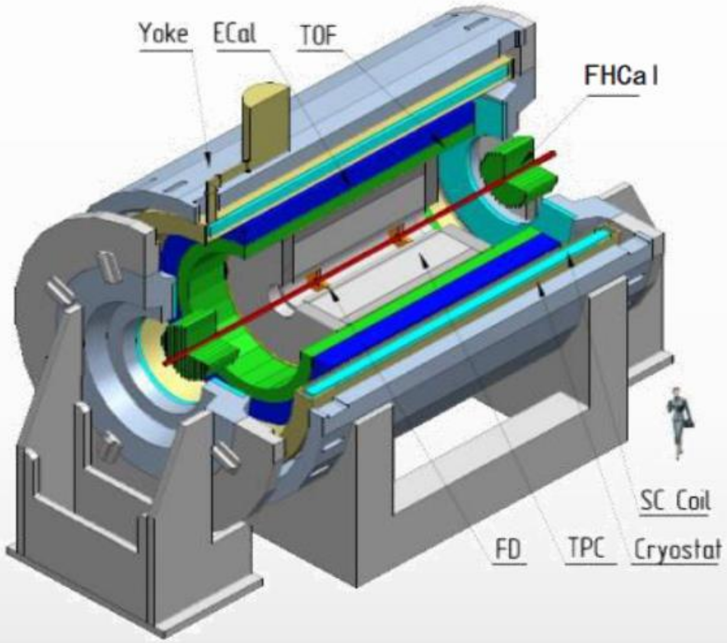


The first physical Run of NA61 with new L-ToF took place in September-October 2023

MPD (First stage)

MPD International Collaboration was established in **2018** to construct, commission and operate the detector

11 Countries, **>500** participants, **35** Institutes and **JINR**

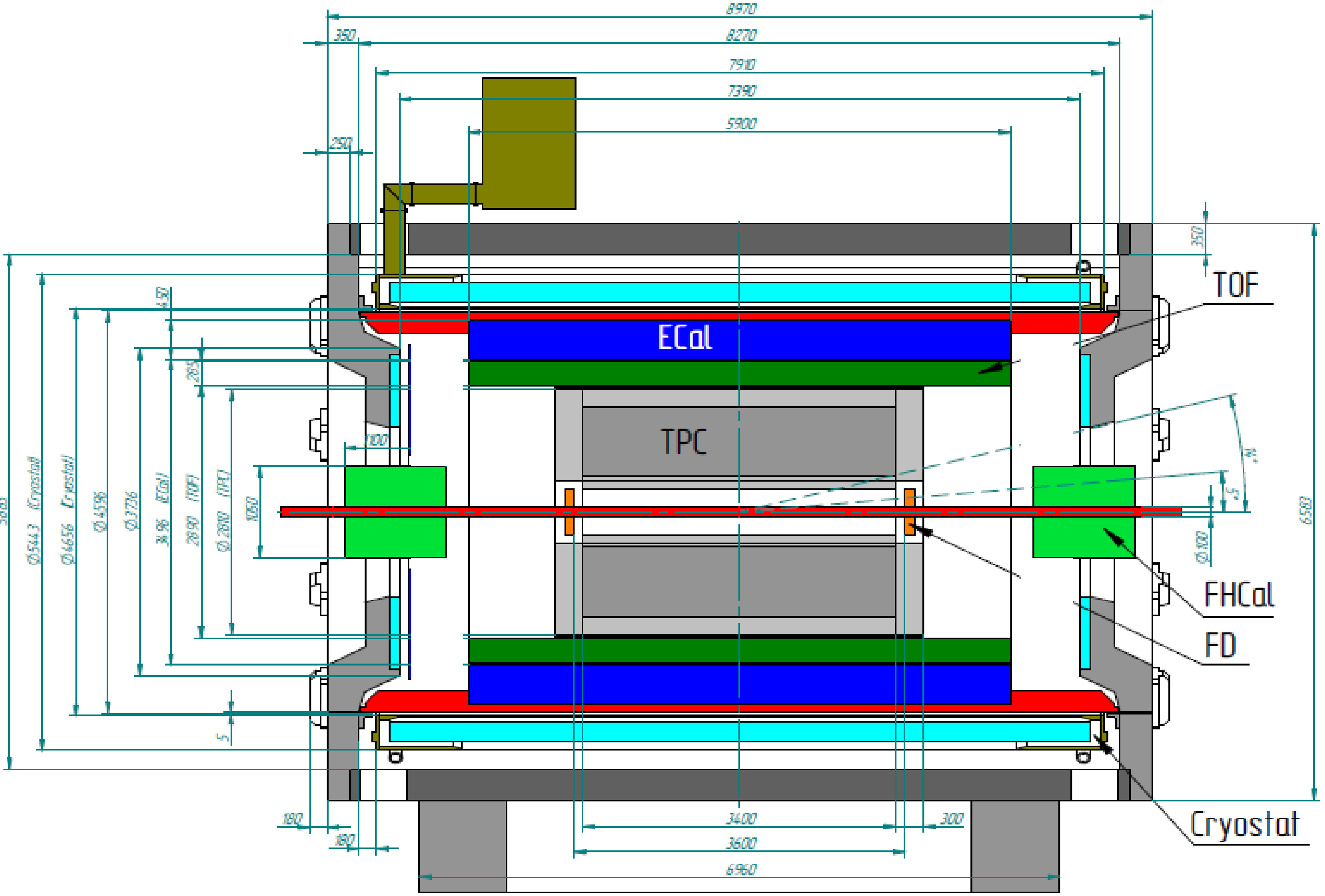


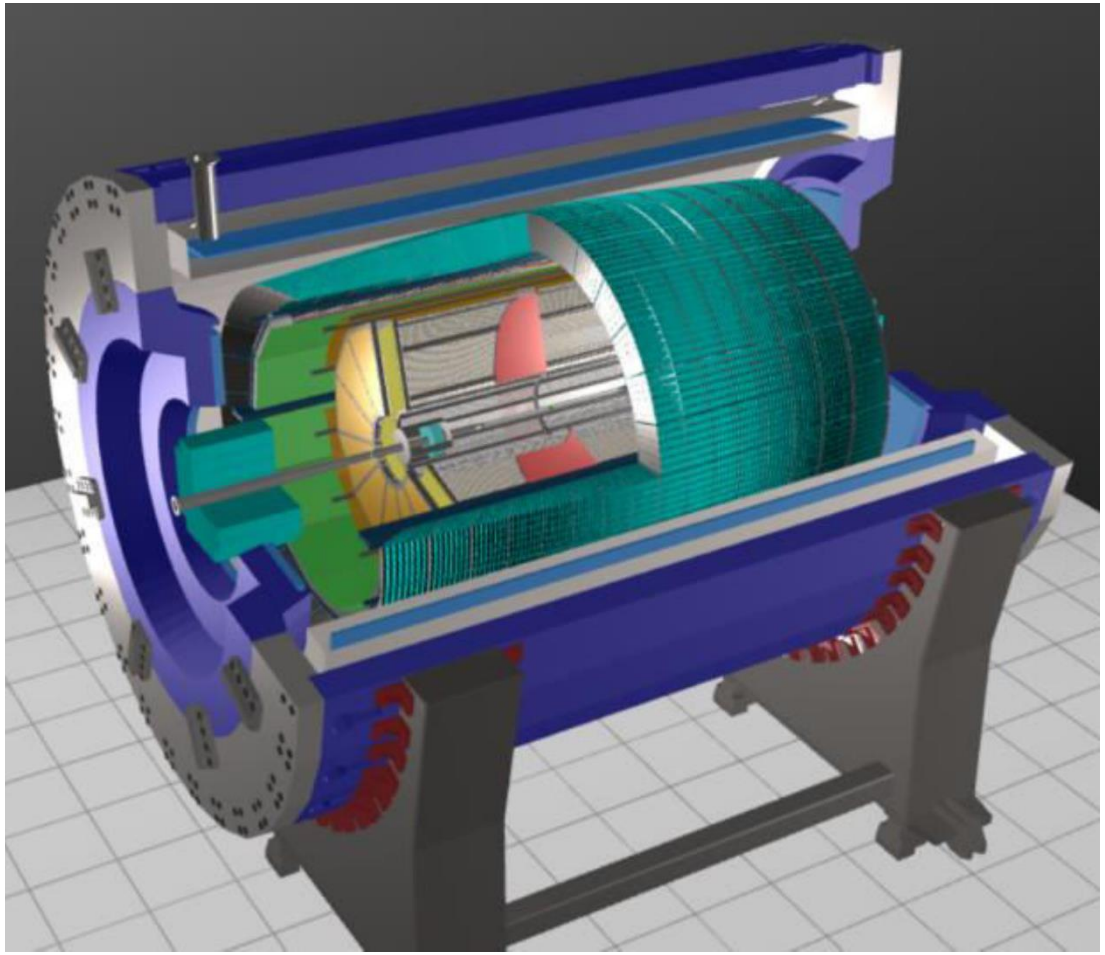
Organization

Acting Spokesperson:	**Victor Riabov**
Deputy Spokespersons:	**Zebo Tang, Arkadiy Taranenko**
Institutional Board Chair:	**Alejandro Ayala**
Project Manager:	**Slava Golovatyuk**

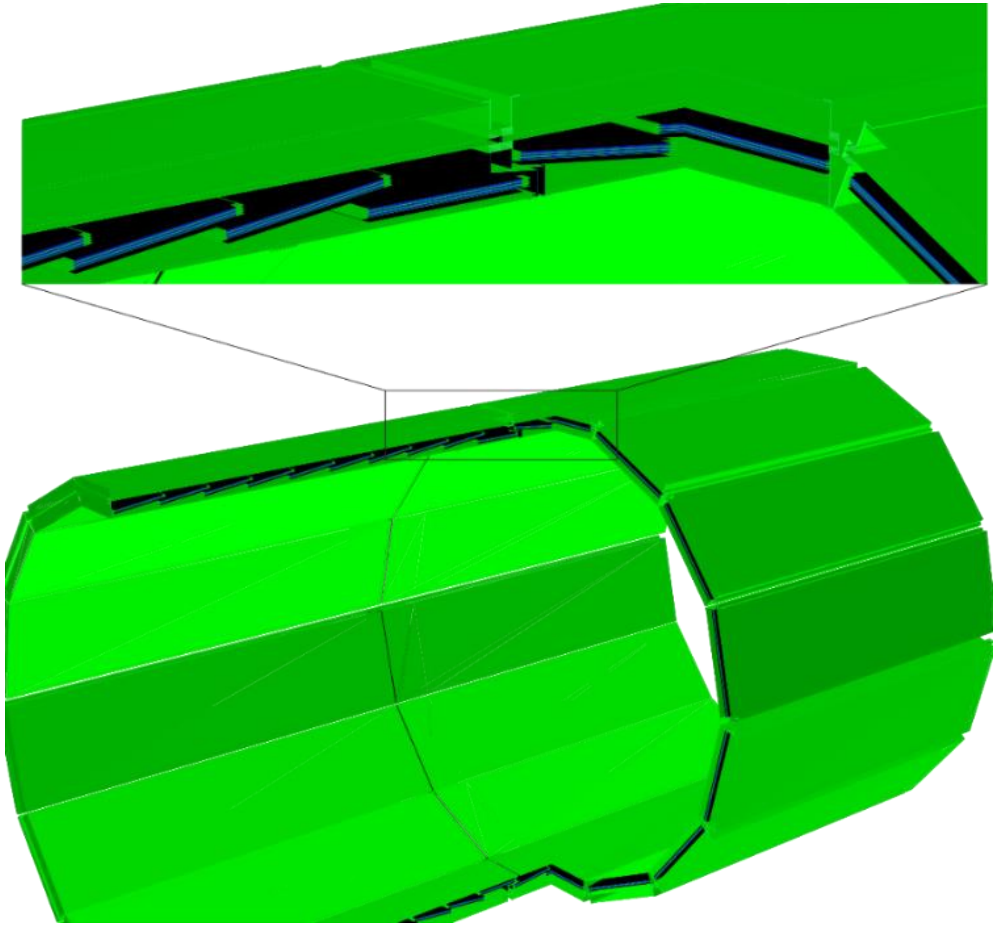
Joint Institute for Nuclear Research;
A.Alikhanyan National Lab of Armenia, Yerevan, **Armenia;**
University of Plovdiv, **Bulgaria;**
Tsinghua University, Beijing, **China**;
University of Science and Technology of China, Hefei, **China**;
Huzhou University, Huzhou, **China**;
Institute of Nuclear and Applied Physics, CAS, Shanghai, **China**;
Central China Normal University, **China**;
Shandong University, Shandong, **China**;
University of Chinese Academy of Sciences, Beijing, **China**;
University of South China, **China**;
Three Gorges University, **China**;
Institute of Modern Physics of CAS, Lanzhou, **China**;
Tbilisi State University, Tbilisi, **Georgia**;
Institute of Physics and Technology, Almaty, **Kazakhstan**;
Benemérita Universidad Autónoma de Puebla, **Mexico**;
Centro de Investigación y de Estudios Avanzados, **Mexico**;
Instituto de Ciencias Nucleares, UNAM, **Mexico**;
Universidad Autónoma de Sinaloa, **Mexico**;
Universidad de Colima, **Mexico**;
Universidad de Sonora, **Mexico**;
Institute of Applied Physics, Chisinev, **Moldova**;
Institute of Physics and Technology, **Mongolia**;
Belgorod National Research University, **Russia**;
Institute for Nuclear Research of the RAS, Moscow, **Russia**;
National Research Nuclear University MEPhI , Moscow, **Russia**;
Moscow Institute of Science and Technology, **Russia**;
North Osetian State University, **Russia**;
National Research Center "Kurchatov Institute", **Russia**;
Peter the Great St. Petersburg Polytechnic University Saint Petersburg, **Russia**;
Plekhanov Russian University of Economics, Moscow, **Russia**;
St.Petersburg State University, **Russia**;
Skobeltsyn Institute of Nuclear Physics, Moscow, **Russia**;
Petersburg Nuclear Physics Institute, Gatchina, **Russia**;
Vinča Institute of Nuclear Sciences, **Serbia**;
Pavol Jozef Šafárik University, Košice, **Slovakia**

MPD (First stage)



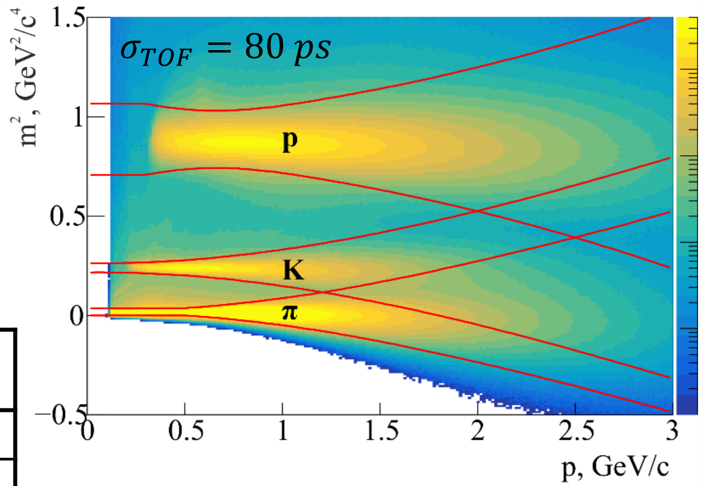


Time-of-Flight system on the first stage of MPD

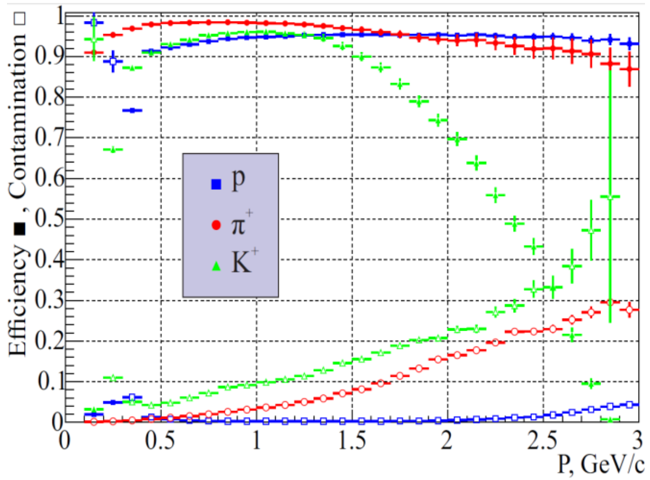


TOF Barrel

	Number of detectors	Number of readout strips	Sensitive area, m²	Number of FEE cards	Number of FEE channels
MRPC	1	24	0.192	2	48
Module	10	240	1.848	20	480
Barrel	**280**	6720	**51.8**	560	**13440**



Squared mass of particles from TOF (simulation in MPDRoot)



TOF PID efficiency

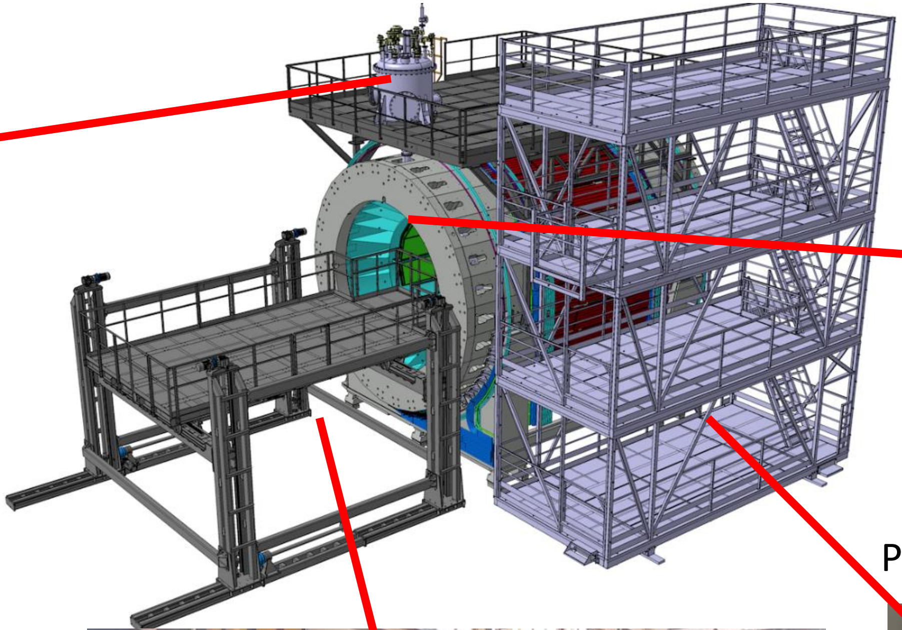
Progress of the TOF detectors and modules assembling

The production of MRPC detectors has been completed. Totally, to date, 300 (107%) MRPC detectors were produced. All 28 (100%) TOF MPD modules are already assembled, tested and stored. We have time to recheck and upgrade previously assembled modules. We are currently planning to make several additional spare modules.

We are ready for TOF installation into the MPD power frame

MPD assembling status

Cryogenic platform with Satellite refrigerator and Control Cryostat



Power Frame for ECal, TPC and TOF installation

The magnet consists of Solenoid inside Iron Toke and two correction coils inside of Endcaps

Lifting platform for detectors installation

Containers with electronics on the Platform

Plans and conclusions

Milestones of MPD assembling in 2023-2025

Year 2023	
Jan 15 - April 15	Preparation for Vacuum test of Solenoid with Cryostat
April 20 - May 15	Vacuum tests
June 15 – September 15	Activities in the MPD Hall are stopped for painting works
October – December	Cooling down solenoid to the Liquid N2 and further down to He temperature (-4K)
Year 2024	
January - February	Supplying the current to the Solenoid and Correction coils, testing the hit evacuation system
March - May	Magnetic Field measurements
June 1 - June 10	Support Frame installation
June 20 – August 30	Installation ECal sectors
September	Installation TOF modules, FHCal into poles
Oct 1st - Nov 30	TPC installation
Sept 18 - Nov 30	Cabling
Dec 4 - Dec 25	Installation of beam pipe
Year 2025	
Jan 10 - Feb	Move the MPD on Collider beam line, Commissioning

Plans for near future

- Upgrade of the ToF-400 system of BM@N to expand acceptance
- Assembling of R-ToF of the NA61 experiment
- Installing and commissioning of the MPD TOF system
- We are open for any new experiments ☺

We invite you to cooperate in the field of hardware and software development

E-mail: babkin@jinr.ru
vbabkin@cern.ch

Thank you for the attention!