TOF based on MRPC for the NICA experiments

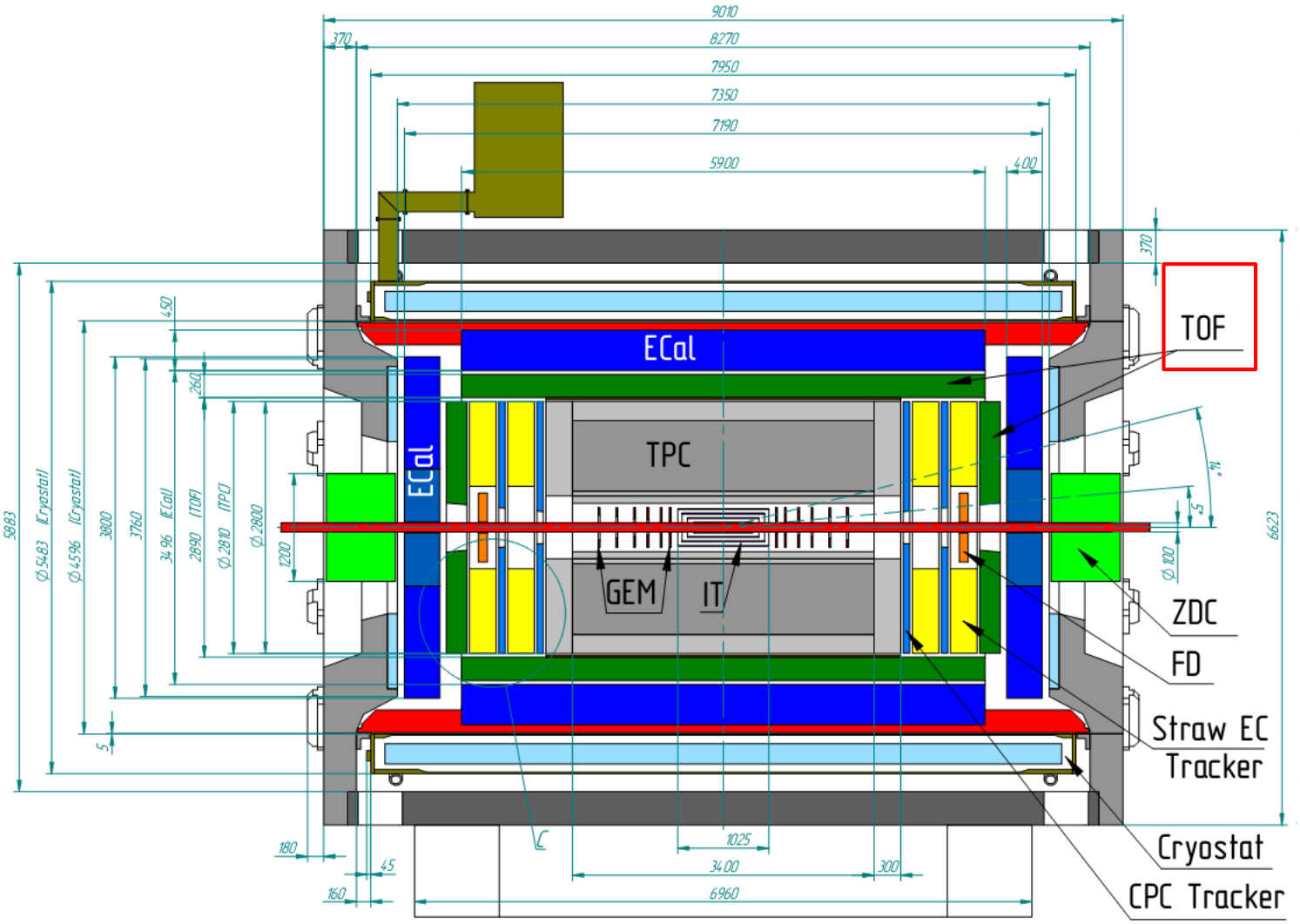
V. Babkin on behalf of the TOF group of the MPD & BM@N experiments

Abstract: The identification of hadrons in experiments on the study of hot and dense baryonic matter is an important and complex task. Particles identification in the MPD & BM@N is performed by a time-of-flight system based on multi-gap RPC.

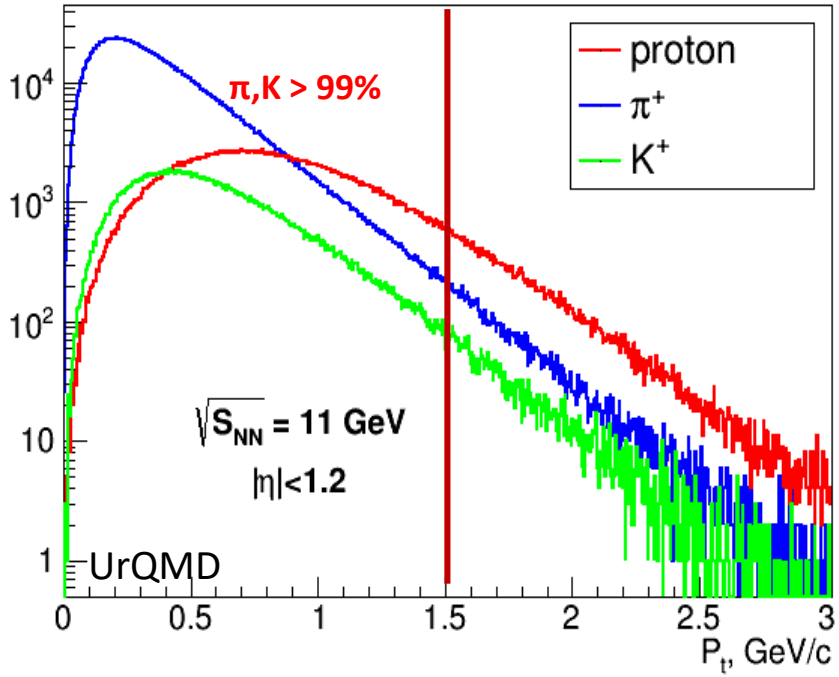
Outlines

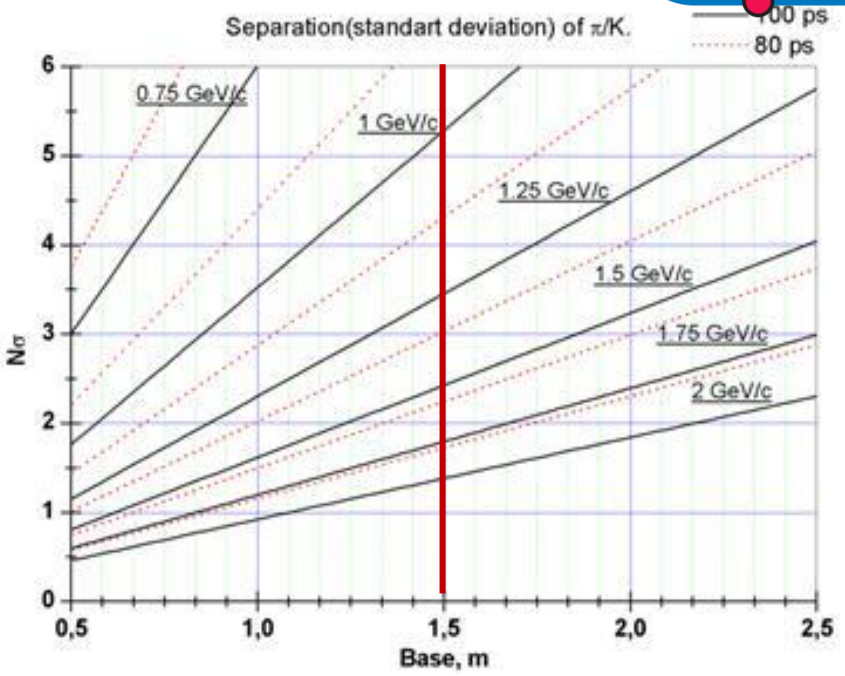
- Requirements to the MPD TOF system
- Design of the TOF barrel and MRPC
- Readout electronics
- Integration to the MPD & service
- Mass production & testing
- MRPC TOF at BM@N
- Conclusions

Two stages of the MPD experiment



Requirements to the TOF MPD





The basic requirements to the TOF system are:

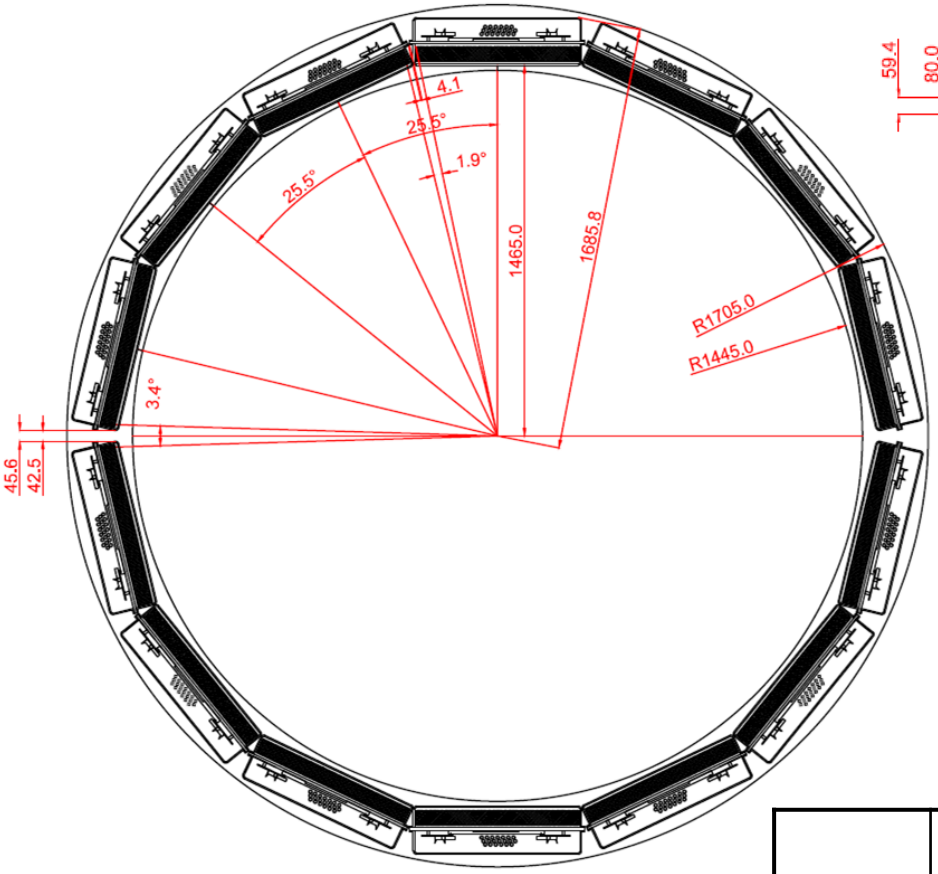
- large phase space coverage $|\eta| < 2$;
- large area coverage **~50 m²**
- time resolution of < **100 ps**;
- high granularity to keep the maximum occupancy <**15%**;
- high geometrical efficiency;
- identification of pions and kaons with up to $p_t < 1.5$ **GeV/c**;
- identification of (anti)protons with up to $p_t < 3$ **GeV/c**;

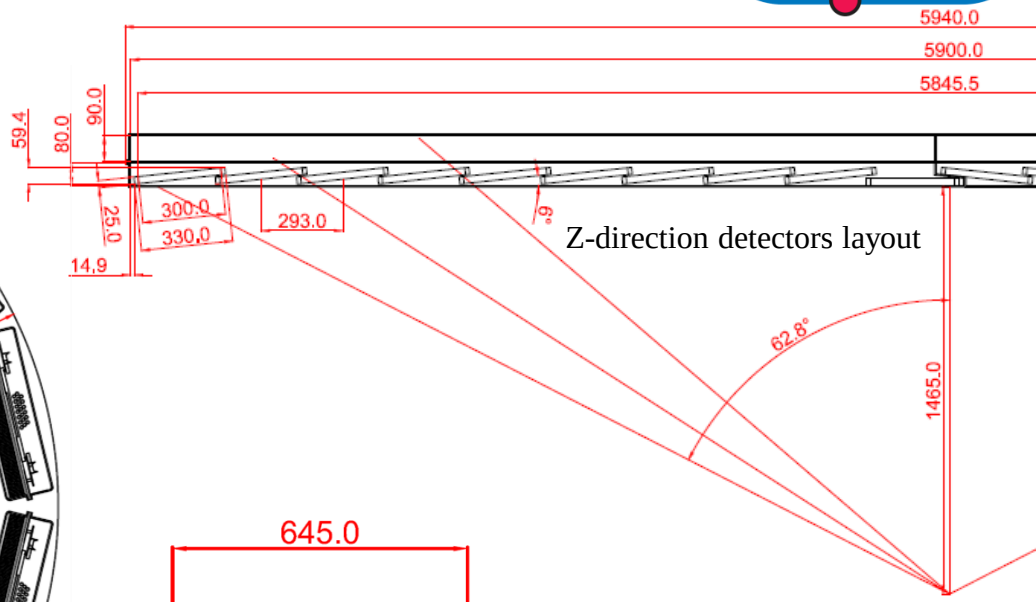
The best choice for this requirements is a Multigap Resistive Plate Chamber (**MRPC**).

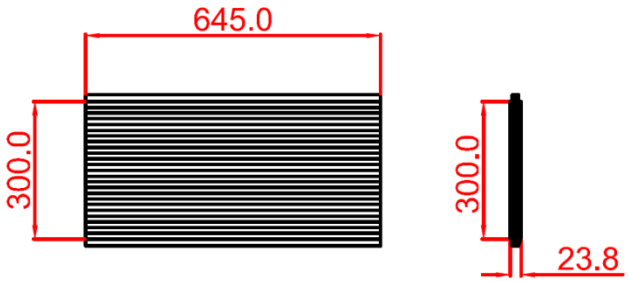
Mechanical design of the TOF barrel

Estimated mean occupancy ~10%

Estimated geometrical efficiency ~94%



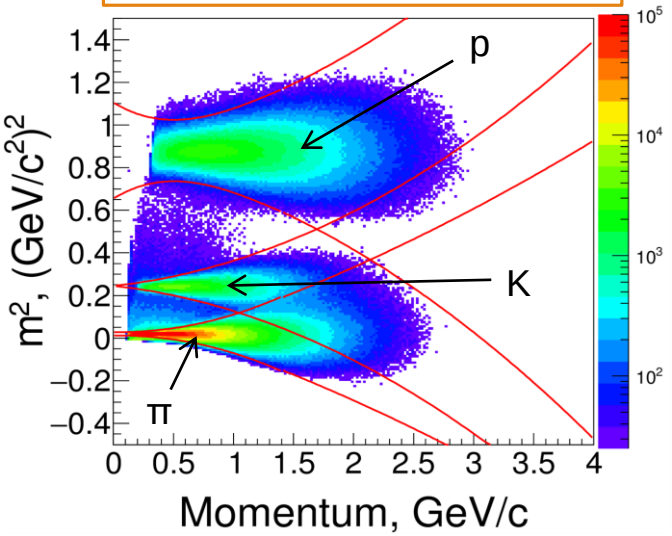




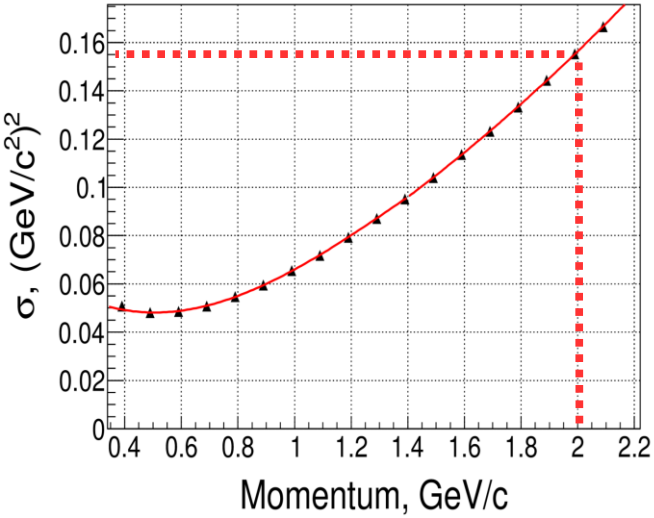
	Number of detectors	Number of readout strips	Sensitive area, m^2	Number of FEE cards	Number of FEE channels
MRPC	1	24	0.2	2	48
Module	10	240	1.85	20	480
Sector	20	480	3.7	40	960
Barrel	280	6720	51.8	560	**13440** (1680 chips)

Real PID simulation (MPDROOT)

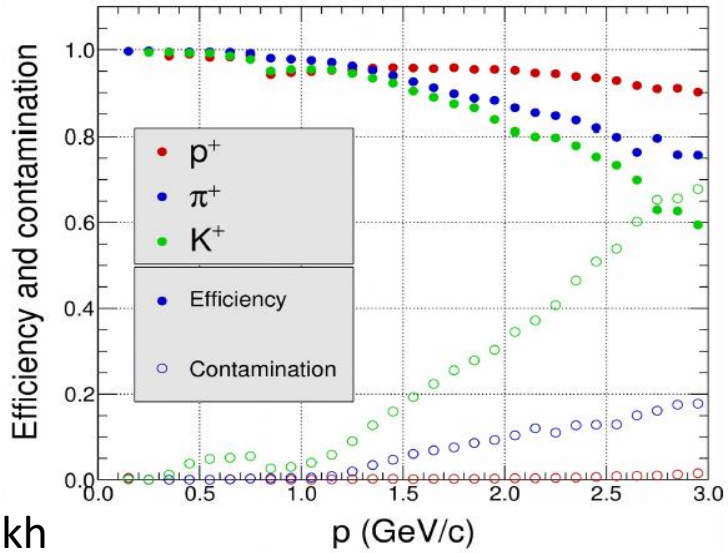
Red lines depict 3σ bands



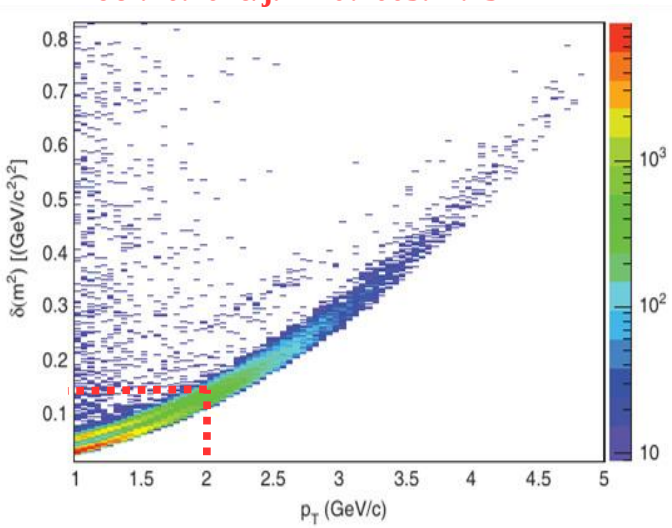
m² resolution (from MPD)



Combined PID efficiency and contamination, 0 < |η| < 1.4

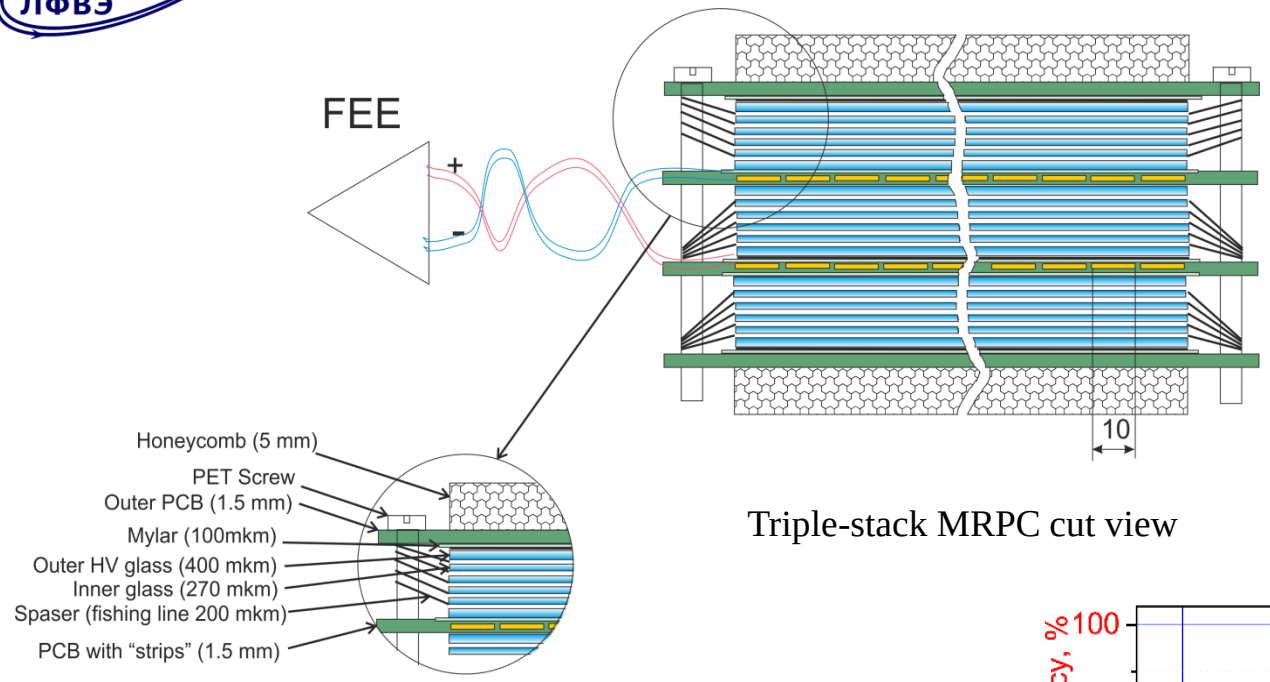


doi:10.1016/j.nima.2005.11.251



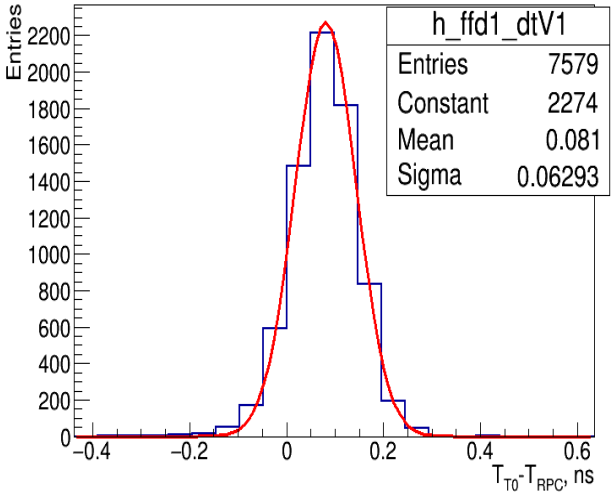
A. Mudrokh

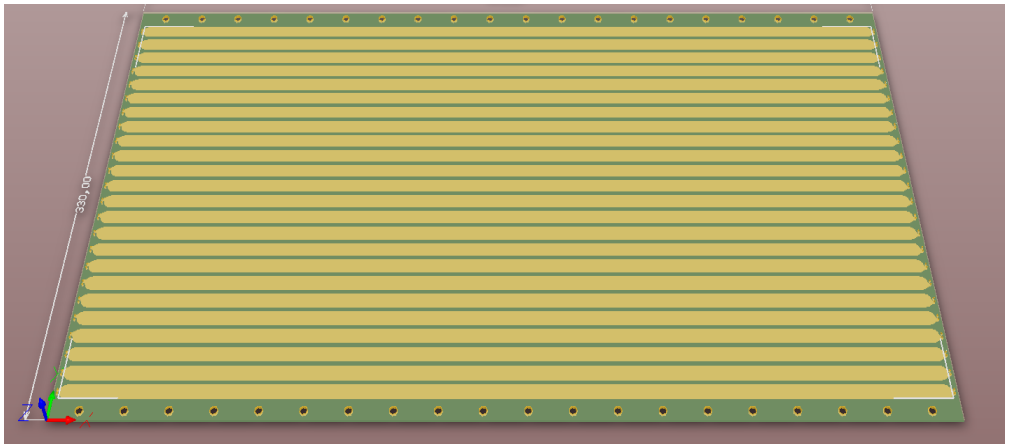
Triple-stack MRPC



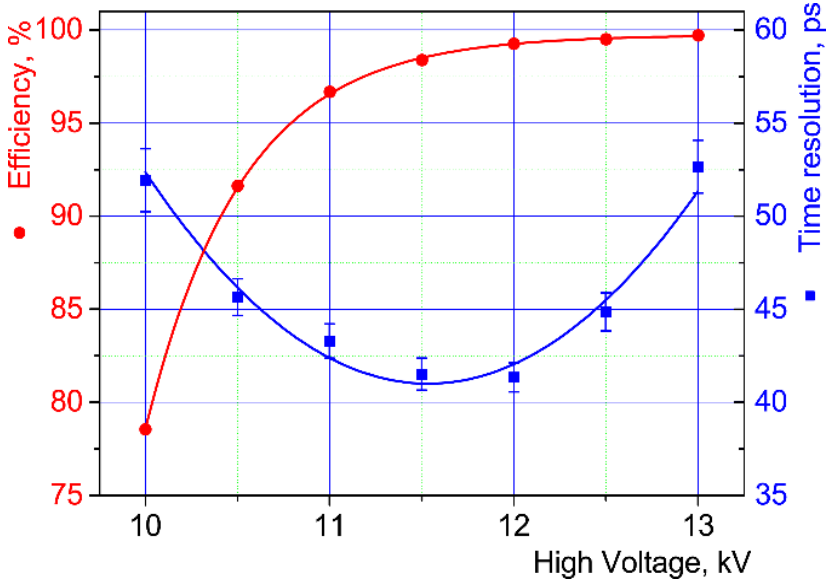
Triple-stack MRPC cut view

$$\sqrt{63^2 - 48^2} \approx 41\ \text{ps}$$





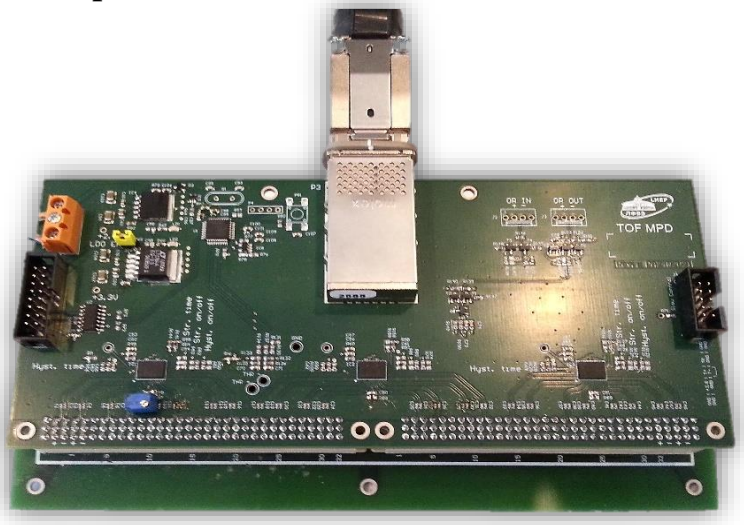
Inner readout board with strips

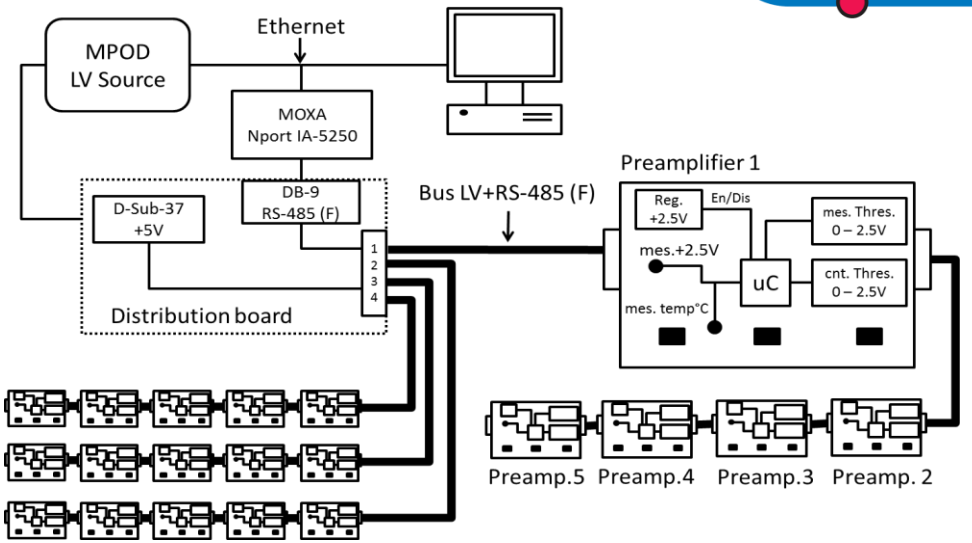


Efficiency and time resolution of the MRPC versus HV

Front-end electronics

NINO based 24-channels
preamplifier-discriminator board PA24N2V2I

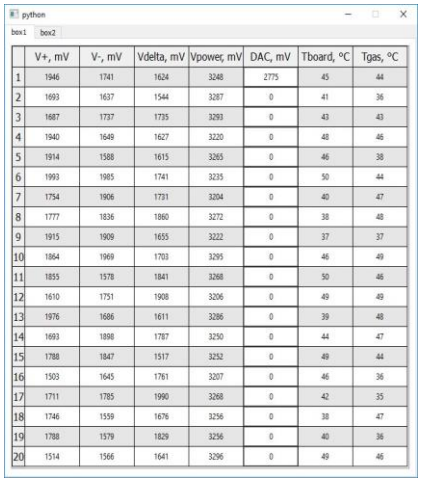




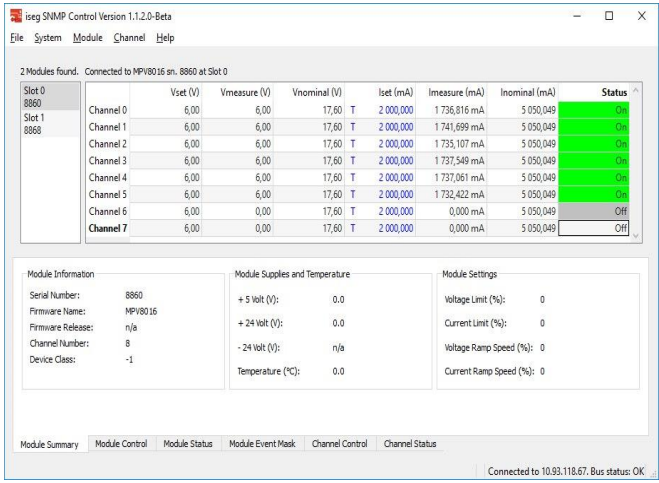
Powering preamplifier board and connection scheme.

- ✓ Stabilization of the voltage (+2.5V);
- ✓ Differential input (Zdiff = 55 Ohm);
- ✓ Inputs capacitors for two-end strip readout;
- ✓ CXP (InfiniBand) 100 Ω output connector;
- ✓ Series “or” output for 24 channels;
- ✓ Time jitter (RMS) for one channel ≈ 7 ps;
- ✓ “On board” slow control:

- voltage control & monitoring;
- preamplifier thresholds control;
- board temperature monitoring ±0.5 °C;
- gas volume temperature monitor.



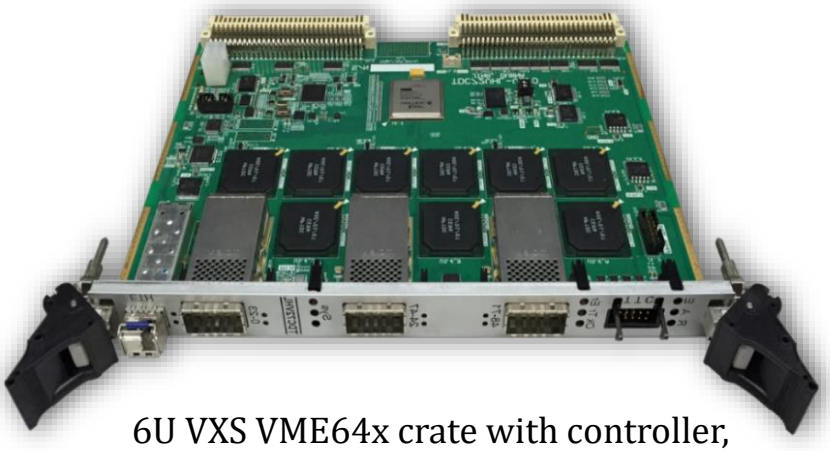
	V+, mV	V-, mV	Vdelta, mV	Vpower, mV	DAC, mV	Tboard, °C	Tgas, °C
1	1946	1741	1624	3248	2775	45	44
2	1693	1637	1544	3287	0	41	36
3	1687	1737	1735	3293	0	43	43
4	1940	1649	1627	3220	0	48	46
5	1914	1588	1615	3265	0	46	38
6	1993	1985	1741	3235	0	50	44
7	1754	1906	1731	3204	0	40	47
8	1777	1836	1860	3272	0	38	48
9	1915	1909	1655	3222	0	37	37
10	1864	1969	1703	3295	0	46	49
11	1855	1578	1841	3268	0	50	46
12	1610	1751	1908	3206	0	49	49
13	1976	1686	1611	3286	0	39	48
14	1693	1898	1787	3250	0	44	47
15	1788	1847	1517	3252	0	49	44
16	1503	1645	1761	3207	0	46	36
17	1711	1785	1990	3268	0	42	35
18	1746	1559	1676	3256	0	38	47
19	1788	1579	1829	3256	0	40	36
20	1514	1566	1641	3296	0	49	46



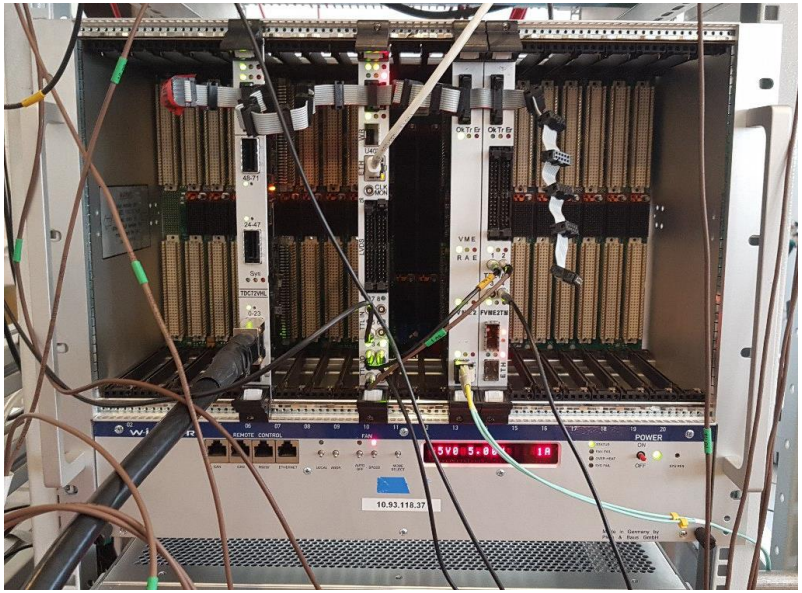
Slow control GUI clients (left side for FEE, right LV source)

Readout electronics (DAQ)

72-channels VME time-to-digital converter TDC72VHL

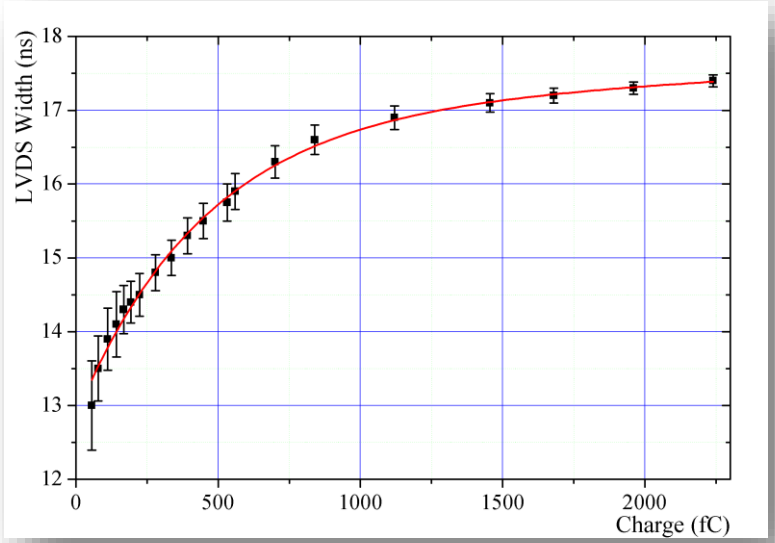


6U VXS VME64x crate with controller, trigger modules and TDC72VHL



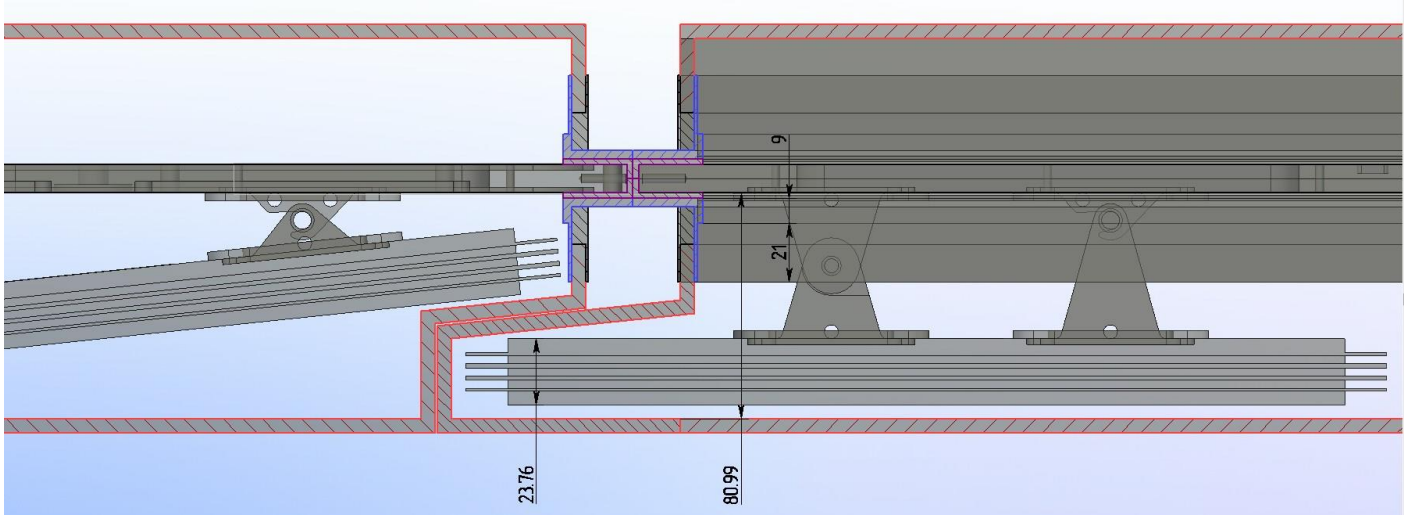
- ✓ VME64x interface with VXS;
- ✓ TDC type: timestamping HPTDC chip;
- ✓ Input: differential 100 Ω (LVDS);
- ✓ Resolution: 23.4 ps bin size ($\sigma_t \approx 18$ ps - measured);
- ✓ Power consumption: +5V/0.13A; +3.3V/5.6A;

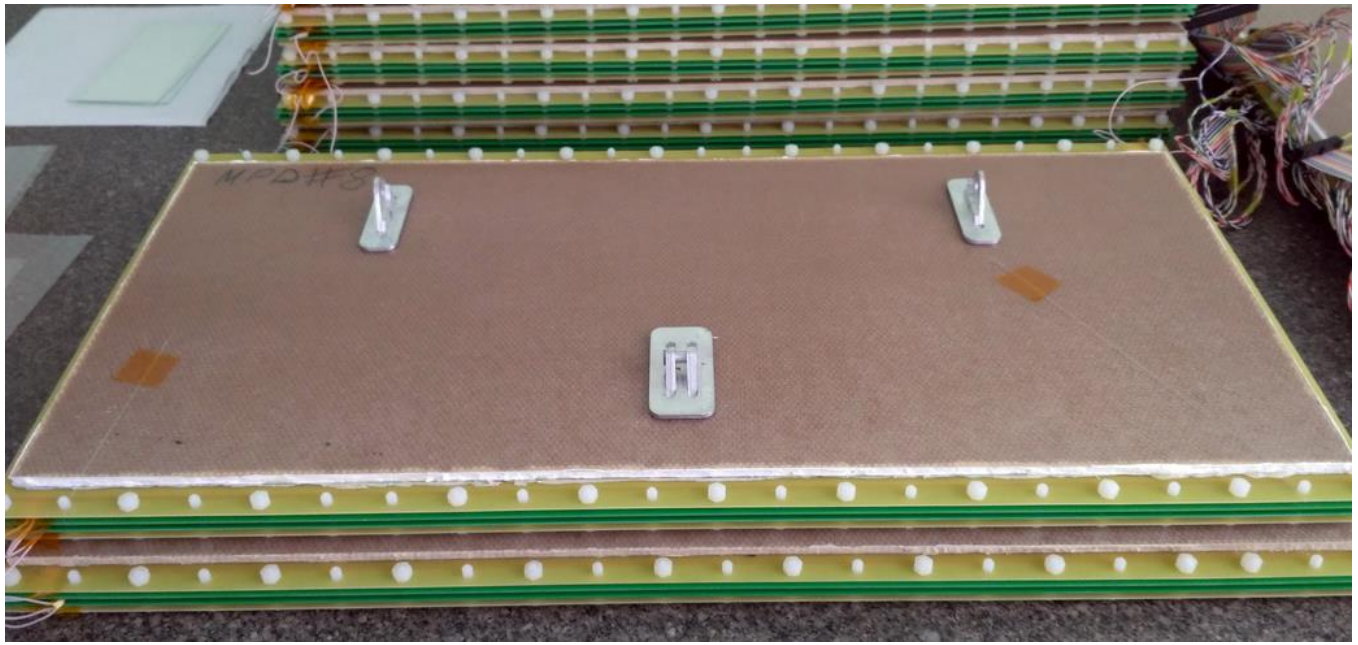
  Standalone mode:
- ✓ Ethernet data transfer;
- ✓ Time synchronization by the White Rabbit.



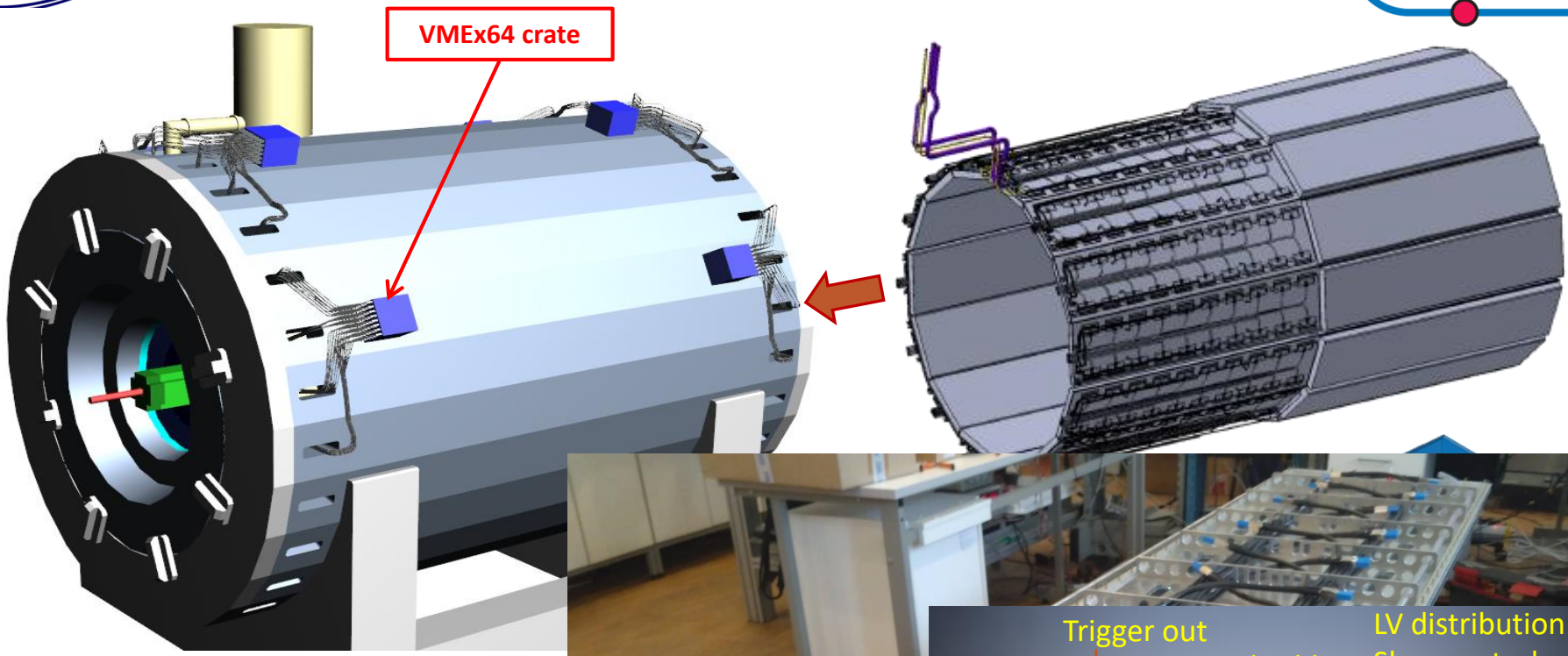
Gas & FEE aluminum box

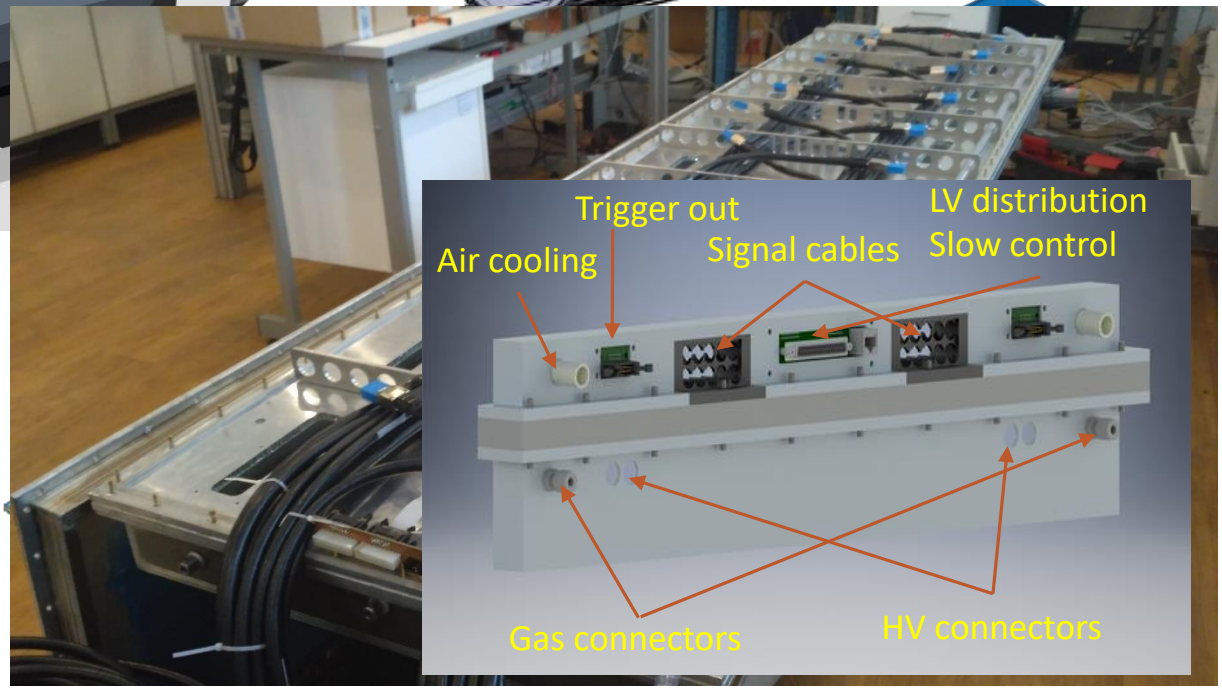
Fixation of detectors inside the box





Cabling and readout electronics location



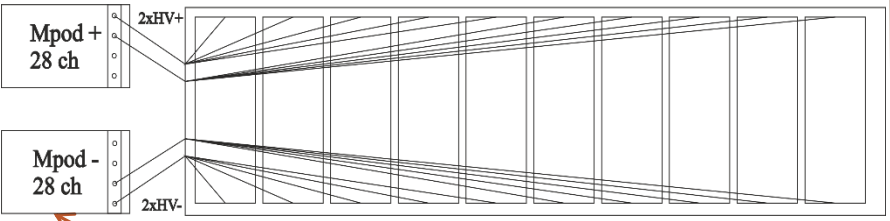


Total cabling:
14 VME crates
196 TDC72VHL => 14 per crate
560 cables Molex CXP => 40 per crate
Cable lengths: 4 - 8 m
About 70 cm^2 in each technical hole for cables and tubes.
Low heat dissipation inside the barrel! ~10 W/m^2

Power systems of the MPD TOF

HV system requirements:

Minimum number of differential "±" channels: **56 (280)**
Voltage range (one polarity): **8000 V**
Total current through the whole system **(~150 μA)**
Precision of the current monitoring: **~10 nA**
Multichannel structure
Remote control

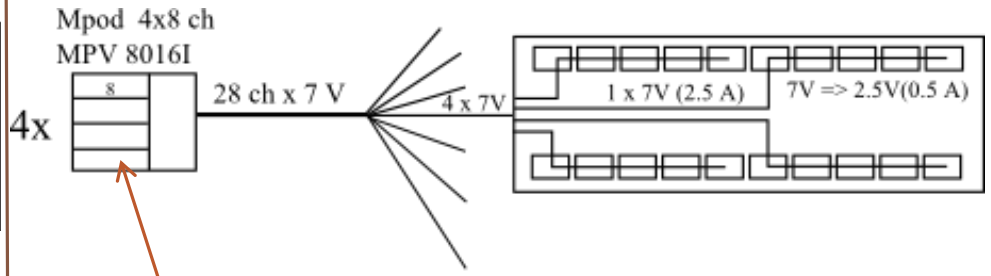


HV distribution scheme

WIENER Mpod system and iSeg EHS 4080p(n) module

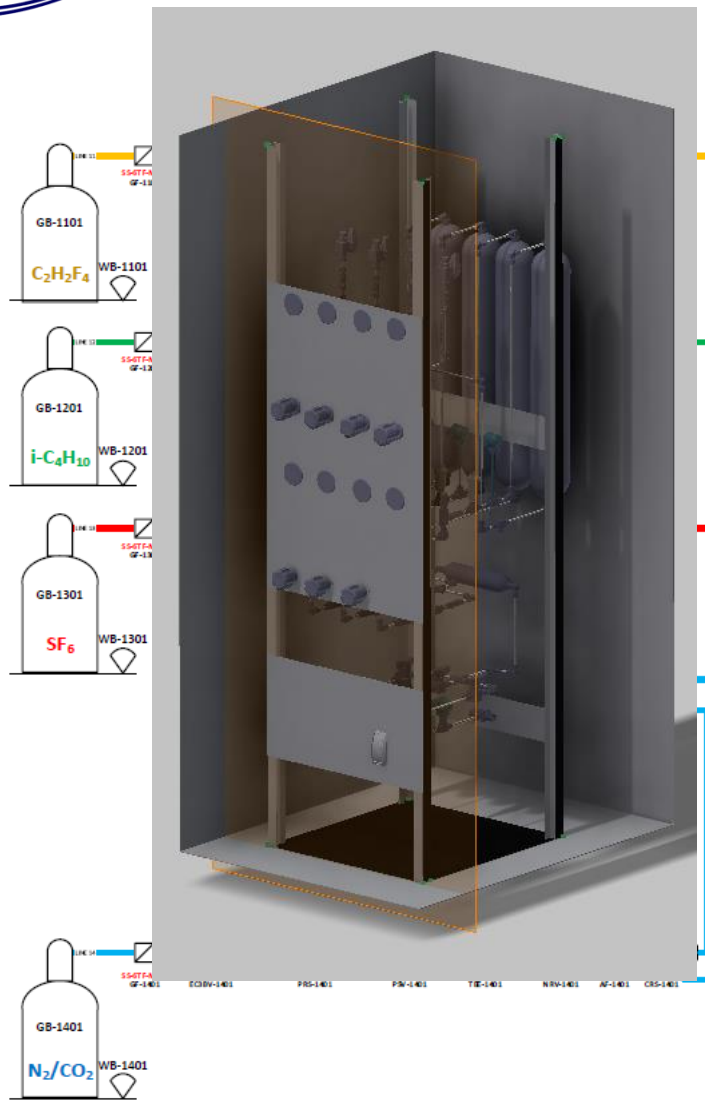
LV system requirements:

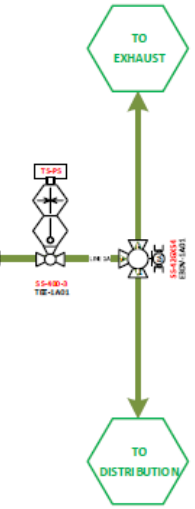
560 (1120) NINO preamplifier-discriminator boards
Minimum number of LV channels (1 ch per 5 amp): **112**
Supply voltage: **2.5V&3.3 V (<0.5 A/board, 2.5 A/LVch)**
Maximum power consumption **2 kW**
Multichannel structure
Remote control



1 LVch per 5 boards (2.5 A)
560 boards = 112 LVch (280 A)

Gas system





GSS Gas Supply System					
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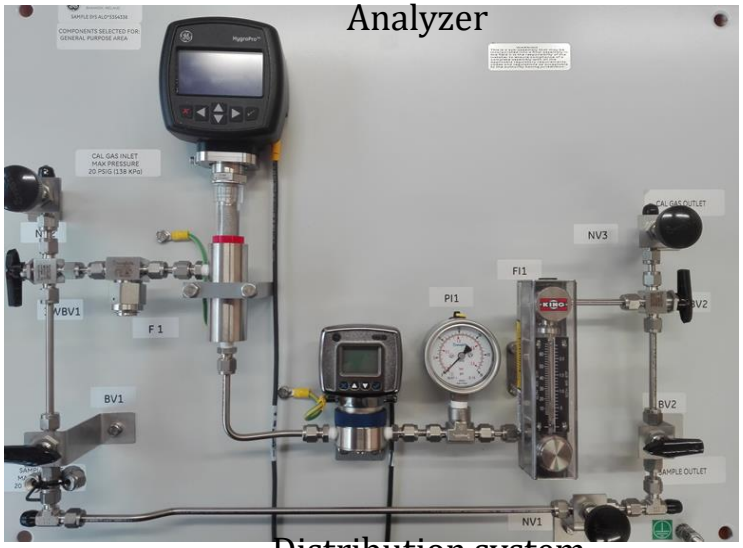
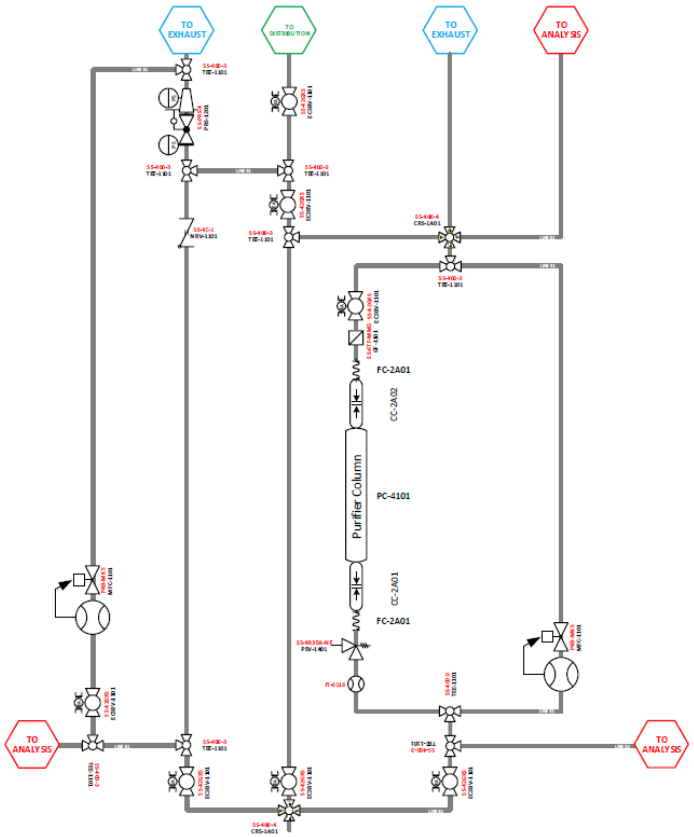
Scale: 1: 1	Sheet: 1 Z 6	Last modified: 12/03/2018	DATA 07/08/2017		
Drawn by:	MAREK PERYT; marekperyt@if.pw.edu.pl				
File Name:	SC_V_GAS_SYSTEM_MPD_180312.VSDX				
Version: 1.1	Drawing number: 0001	Format: A-4	Logo: NICA-MPD JINR V&BLHEP		

Gas system (analyzer, purifier, distributor)

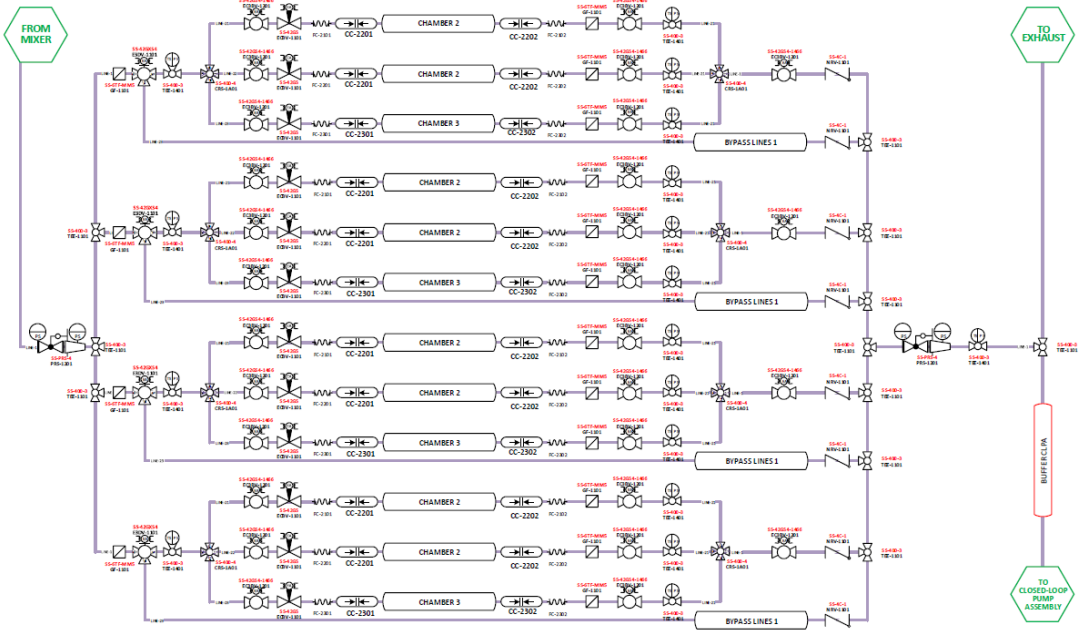
Analyzer



Purification system



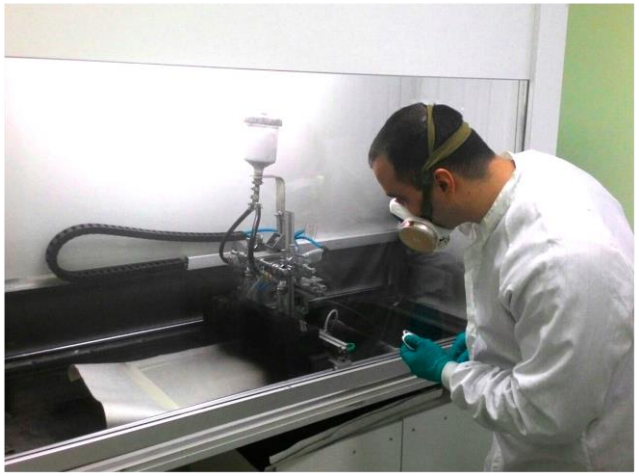
Distribution system



Mass-production of the TOF modules

Workshop staff: 3 physicists, 5 technicians, 2 electronics engineers
Productivity: ~ 1 detectors per day (1 module/2 weeks).

Ultrasonic wave glass cleaning

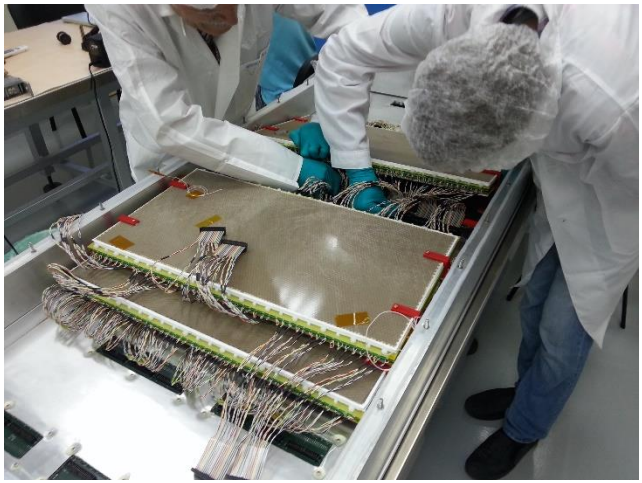


Painting of the HV conductive layer

MRPC assembling

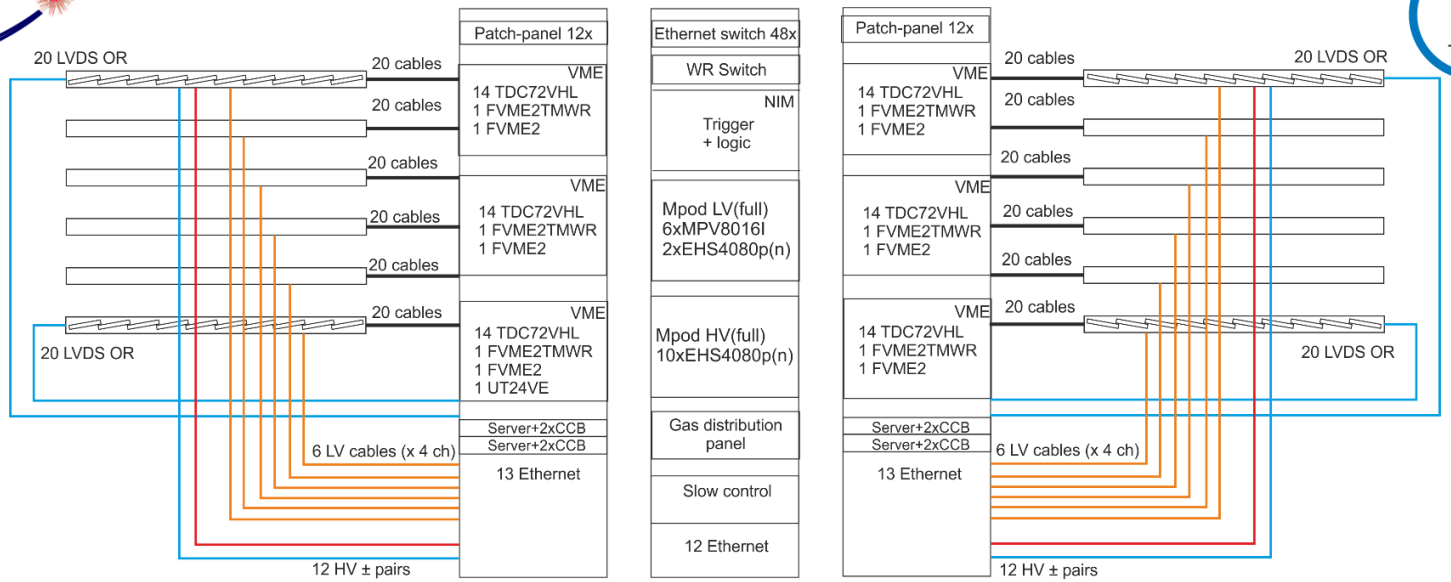
Optical quality control

Cables and connectors soldering

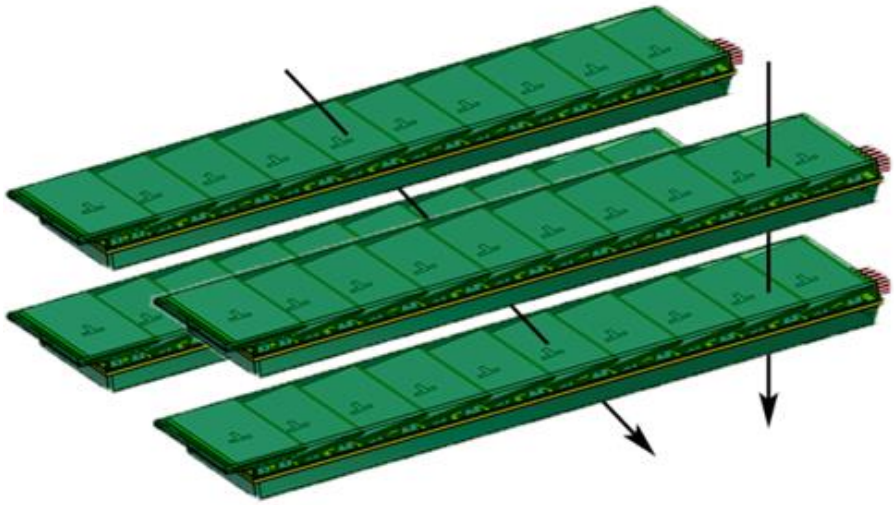


Detectors installation to the TOF box

Cosmic stand for testing of the TOF modules

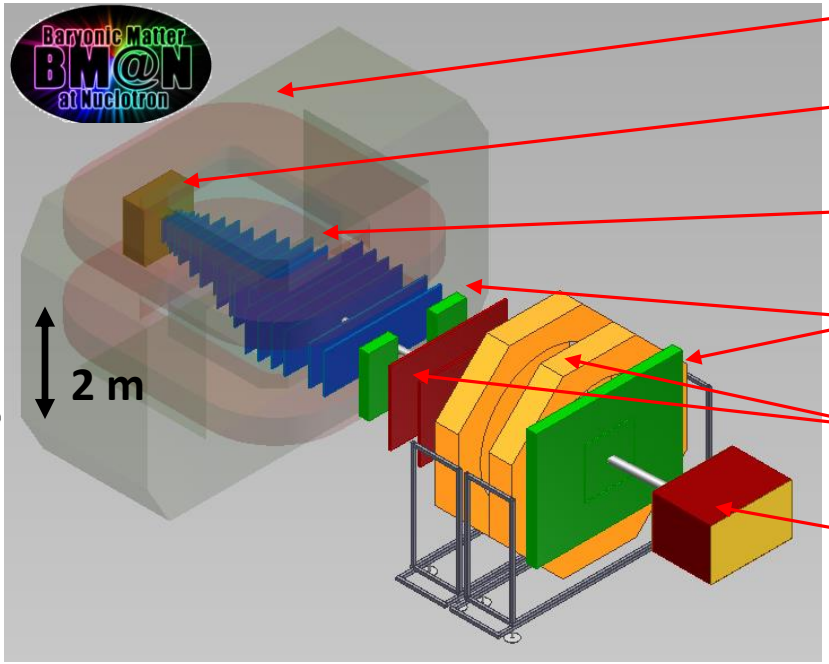


1 stand = 6 modules = 60 detectors (120 preamps + 40 TDC)



Baryonic Matter at Nuclotron (BM@N)

First BM@N & SRC physics run took place on March-April 2018



- Large aperture analyzing magnet SP-41
- Target and detectors to form T0, L1 centrality trigger and beam monitors
- Central tracker (SSD, GEM) inside analyzing magnet to reconstruct AA interactions
- ToF system based on MRPC and T0 detectors to identify low momentum hadrons
- Outer tracker (DCH, CSC) behind magnet to link central tracks to ToF detectors
- ZDC calorimeter to measure centrality of AA collisions and be used in a trigger
- Electromagnetic calorimeter (ECal) for γ, e+e- identification (optional)

Physics:

- ✓ multi strange hyperon and hypernuclei production
- ✓ hadron femtoscopy
- ✓ in-medium effects for strange & vector mesons in dense barionic matter
- ✓ electromagnetic probes (with Ecal)

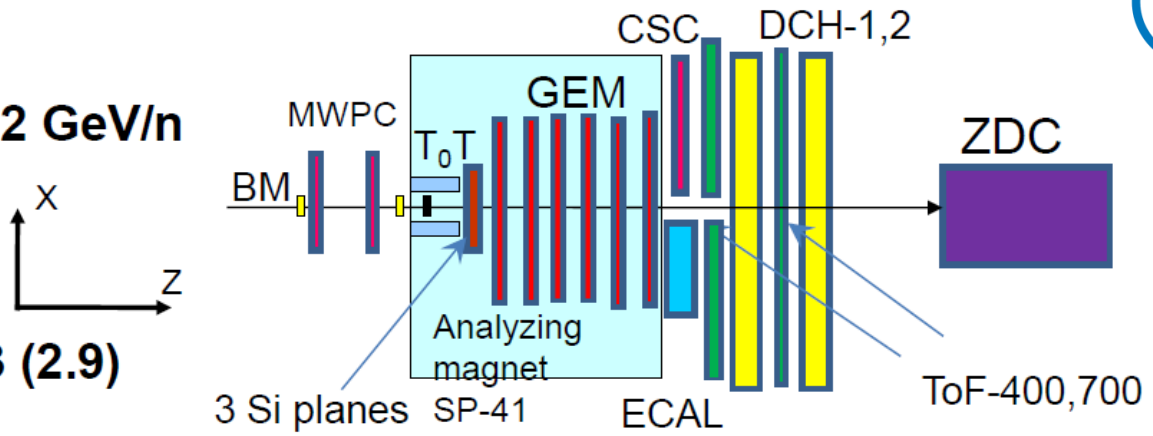
Expression of interest from scientists:

INP, SINP MSU, IHEP + S-Ptr Univ. (RF);
GSI, Frankfurt U., Gissen U. (Germany):
+ CBM-MPD IT-Consortium
+ SRC group (Israel, USA, Germany…)

First BM@N & SRC physics run on March-April 2018

Ar beam, T_0= 3.2 GeV/n

Kr beam, T_0= 2.3 (2.9) GeV/n



- Central tracker inside analyzing magnet → 6 GEM detectors 163 x 45 cm^2 and 3 forward Si strip detectors for tracking
- Full ToF-400, ToF-700, T0 + Trigger barrel and Si detectors, full ZDC, part of ECAL, CSC and DCH chambers as outer tracker

Program:

- Measure inelastic reactions Ar (Kr) + target → X on targets Al, Cu, Sn, Pb

→ Hyperon production measured in central tracker (Si + GEM)

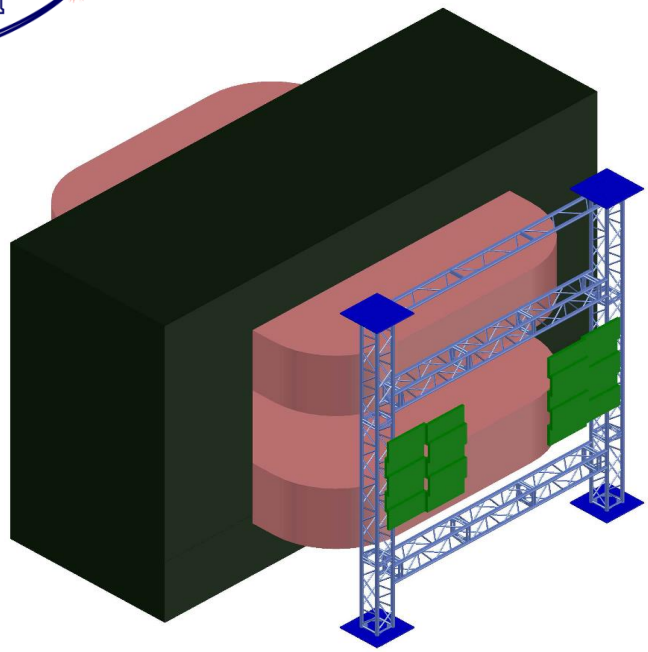
→ Charged particles and nuclear fragments identified with ToF-400,700

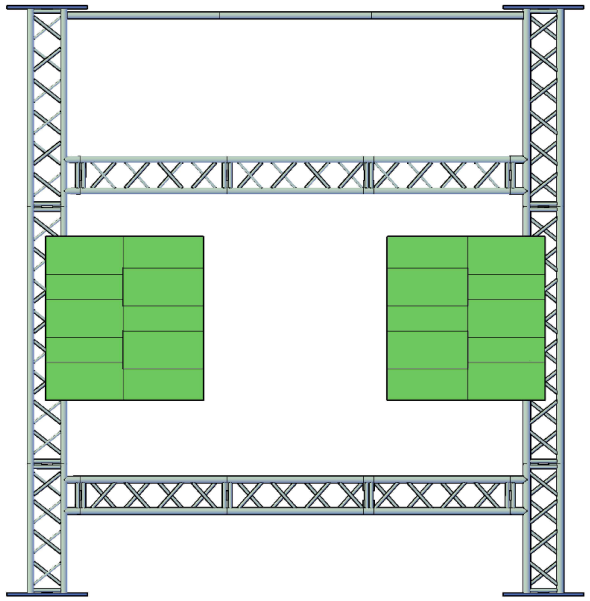
→ Gamma and multi-gamma states identified in ECAL

→ 130 M events in Ar beam, 50 M events in Kr beam

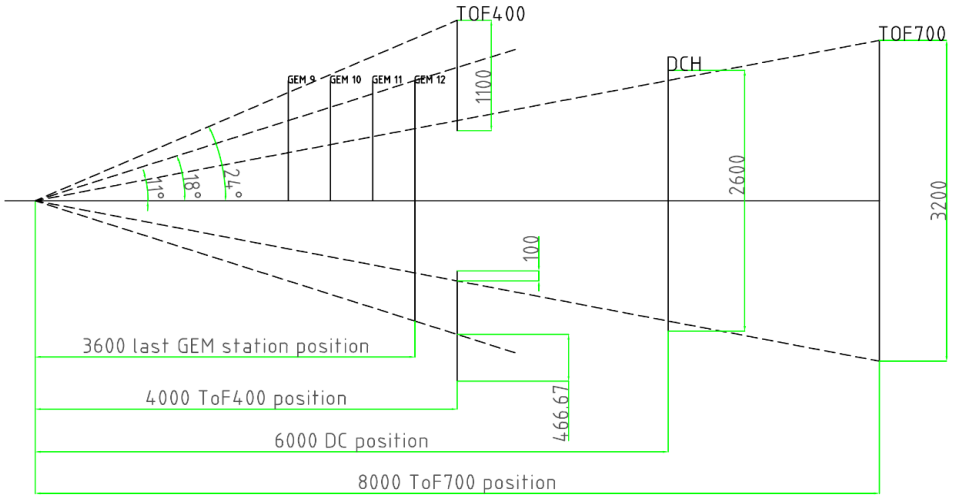
+ analyze data from previous technical runs with Deuteron and Carbon beams of 3.5 - 4.6 GeV/n performed in December 2016 and March 2017

BM@N TOF-400 system

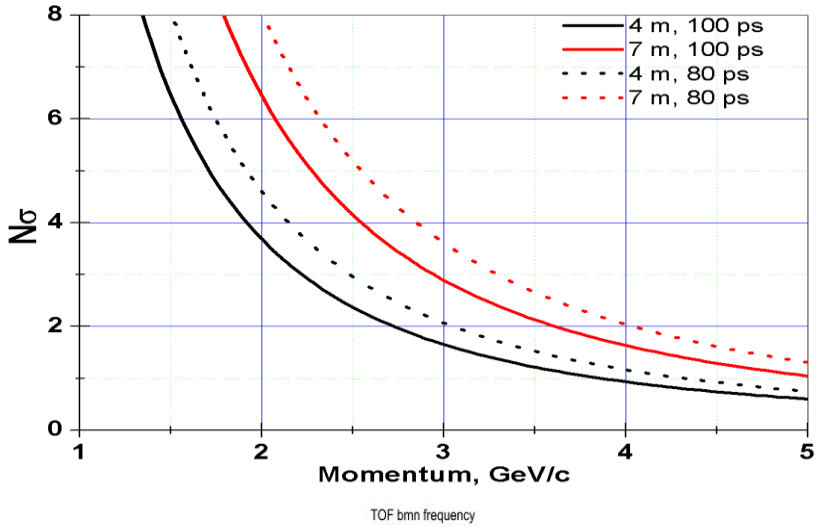


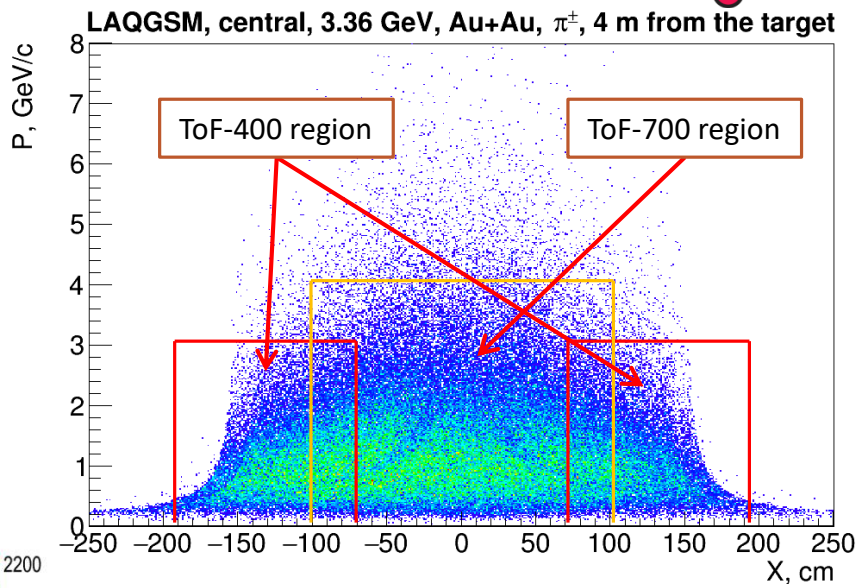


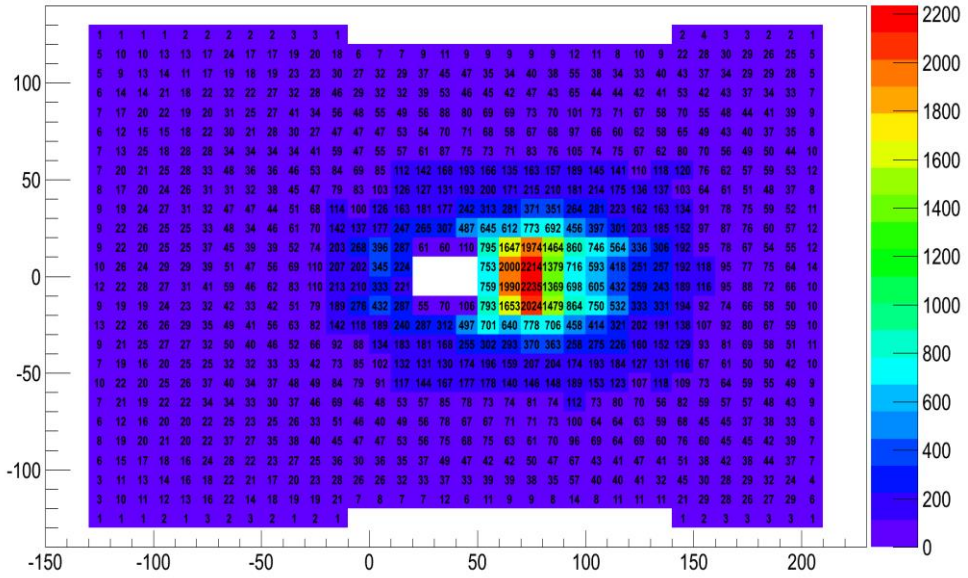
# Detectors	20
# Strips (300*10 mm^2)	960
# FEE	1920
Area total	~2,42 m^2
# LV channels	20 (4 FEE card on 1ch, 5V 2A)
# HV channels	20 (20"+" and 20"-") 1ch on 1MRPC



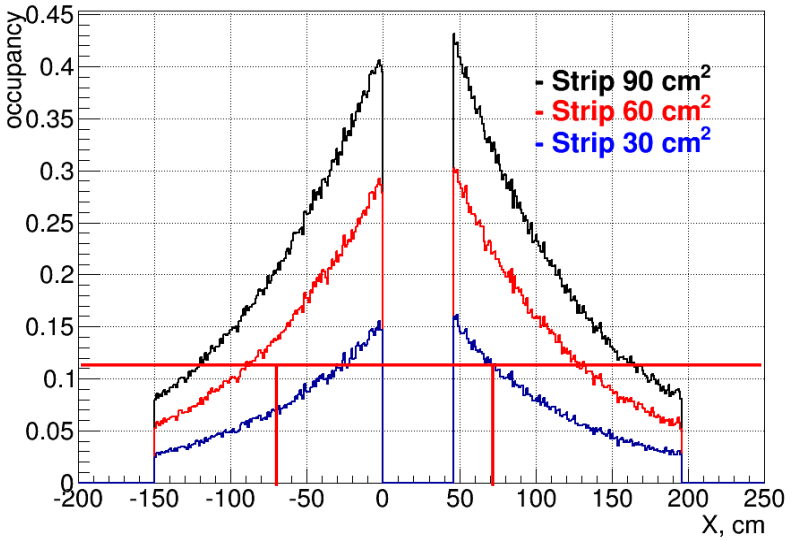
BM@N detector performance





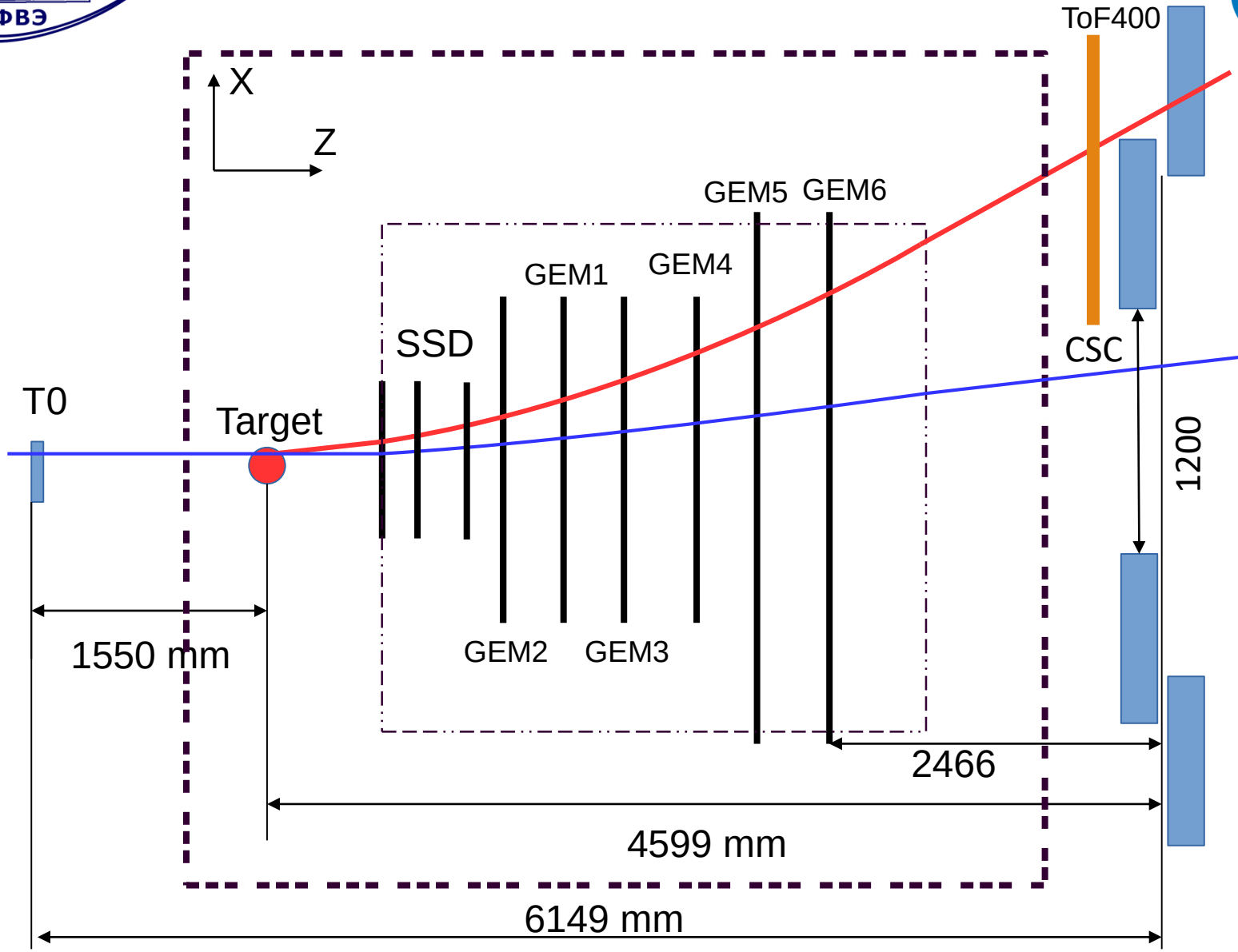


Mean particle flux in different regions of the TOF surface

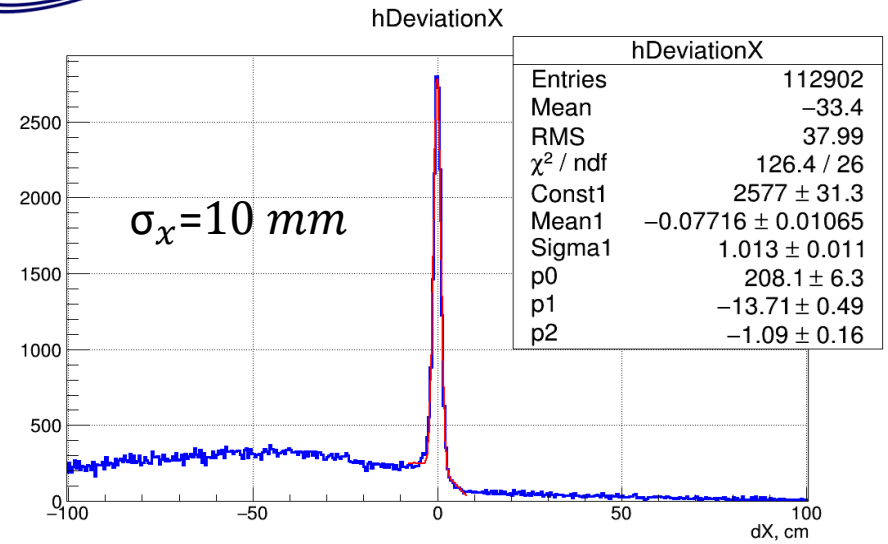


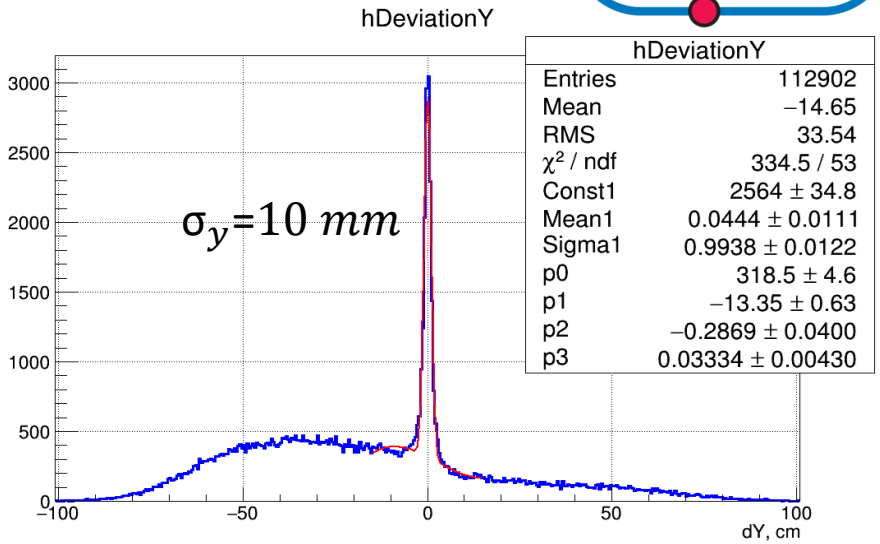
Estimated occupancy for central 3.36 GeV/u Au-Au

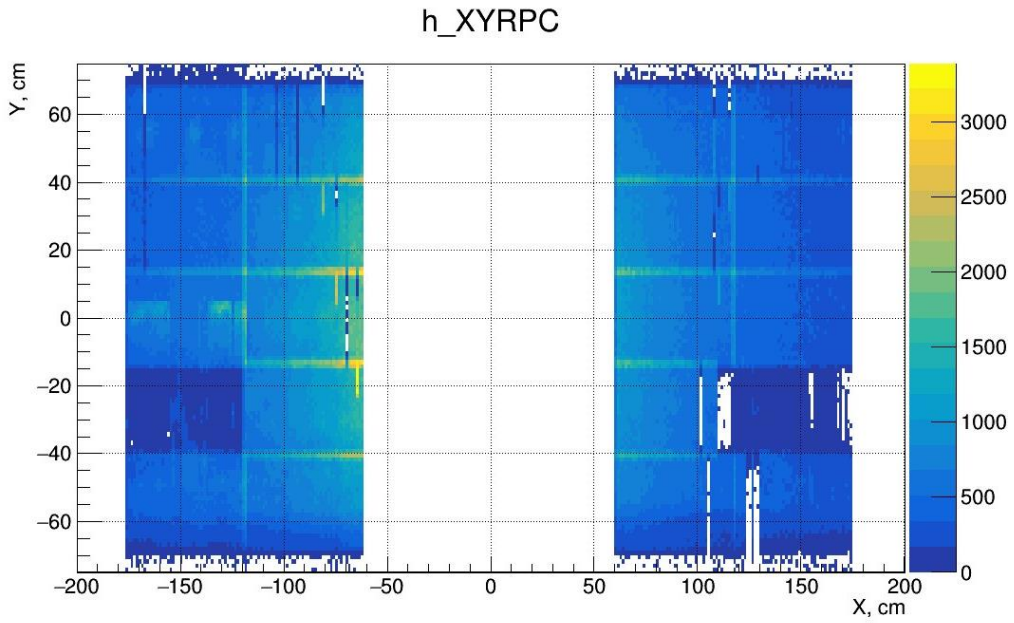
TOF-400 and tracker in March 2018

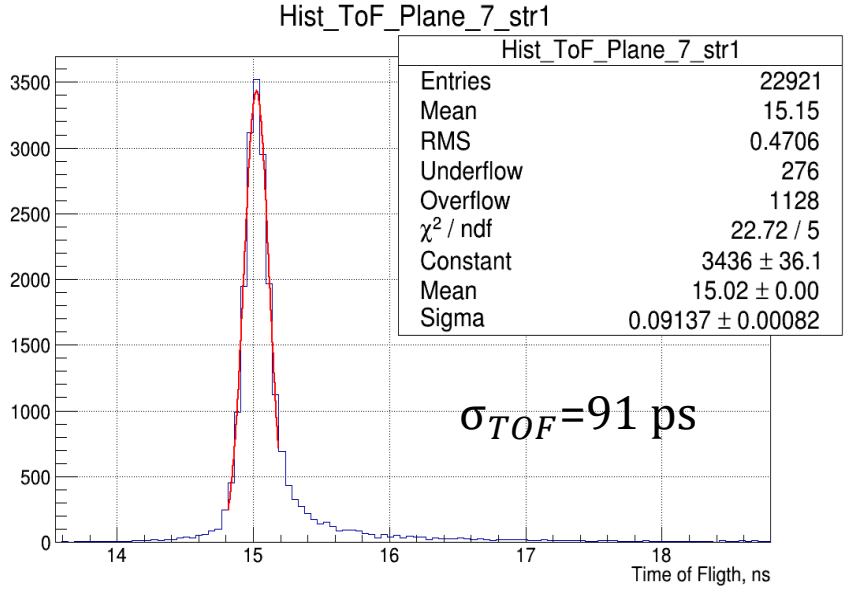


Time and spatial resolution of the TOF-400 MRPCs





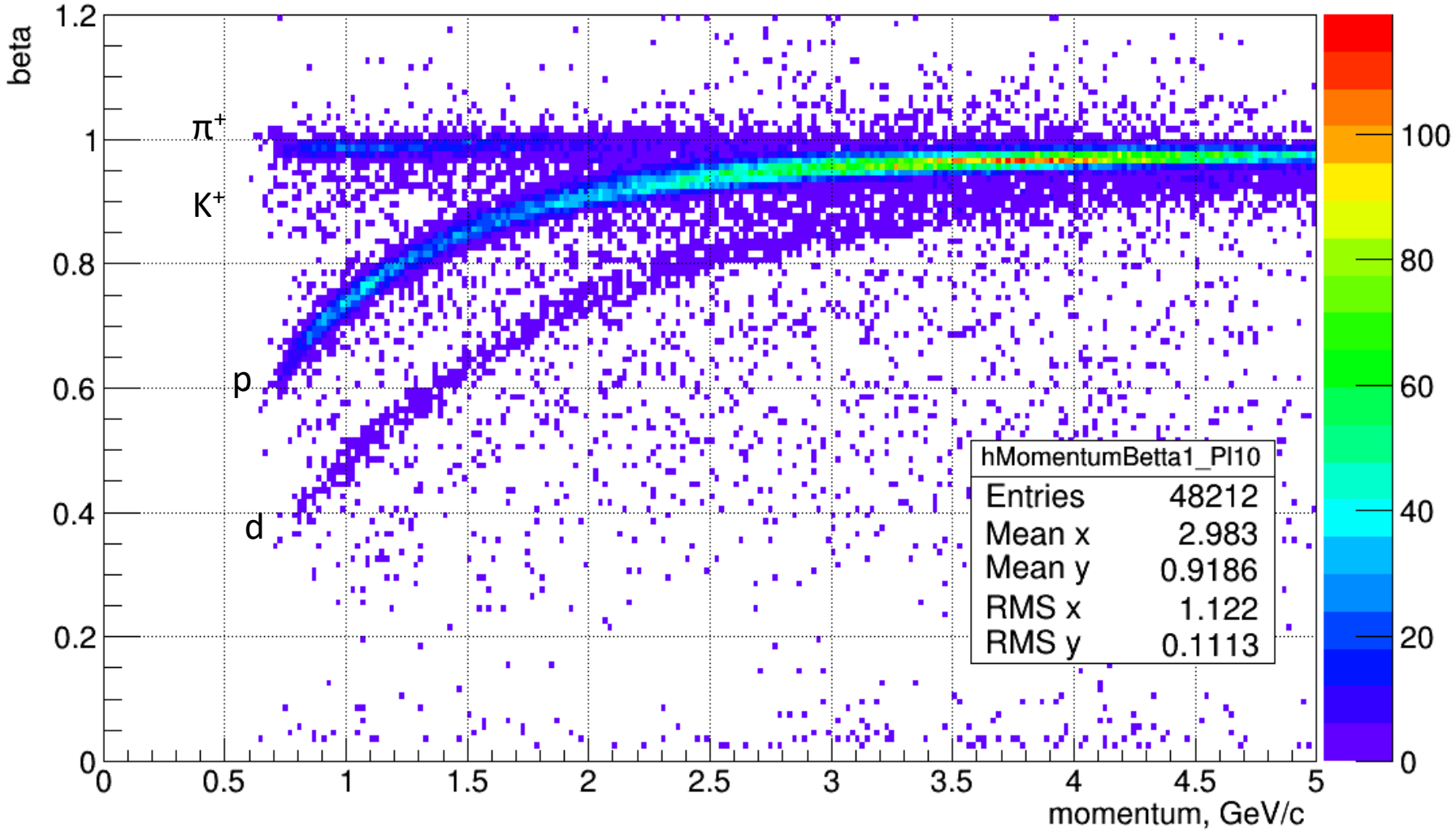




Time-of-Fligth (T0-ToF400)

Hadrons identification with TOF-400 (Run of March 2017)

C(3.5 GeV/c) + Al, 1M Events



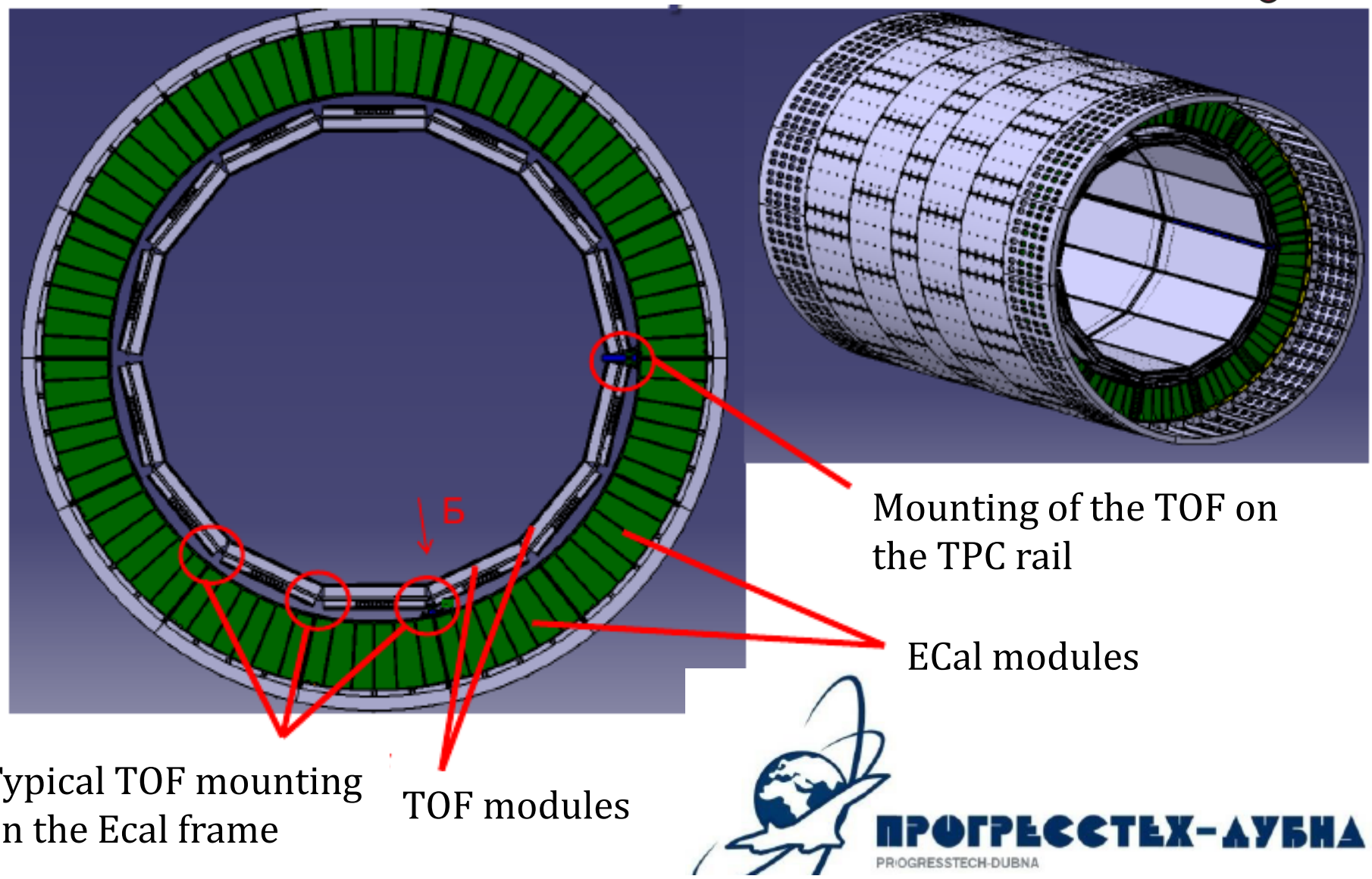
Conclusions

- Technical design of the MPD TOF system is complete.
- All materials purchased. Mass production will be started this summer.
- Development of the readout electronics is complete now. Mass production began last year. At the moment we already have 30% of preamplifier boards and +100% purchased.
- Service systems are in development and purchase state.
- Setup for testing of the MPD TOF modules with cosmic rays should be commissioned this year.
- BM@N TOF-400 system is commissioned and works well.

Thank you for the attention!

Extra slides

TOF modules integration into the MPD



Mounting of the TOF on the TPC rail

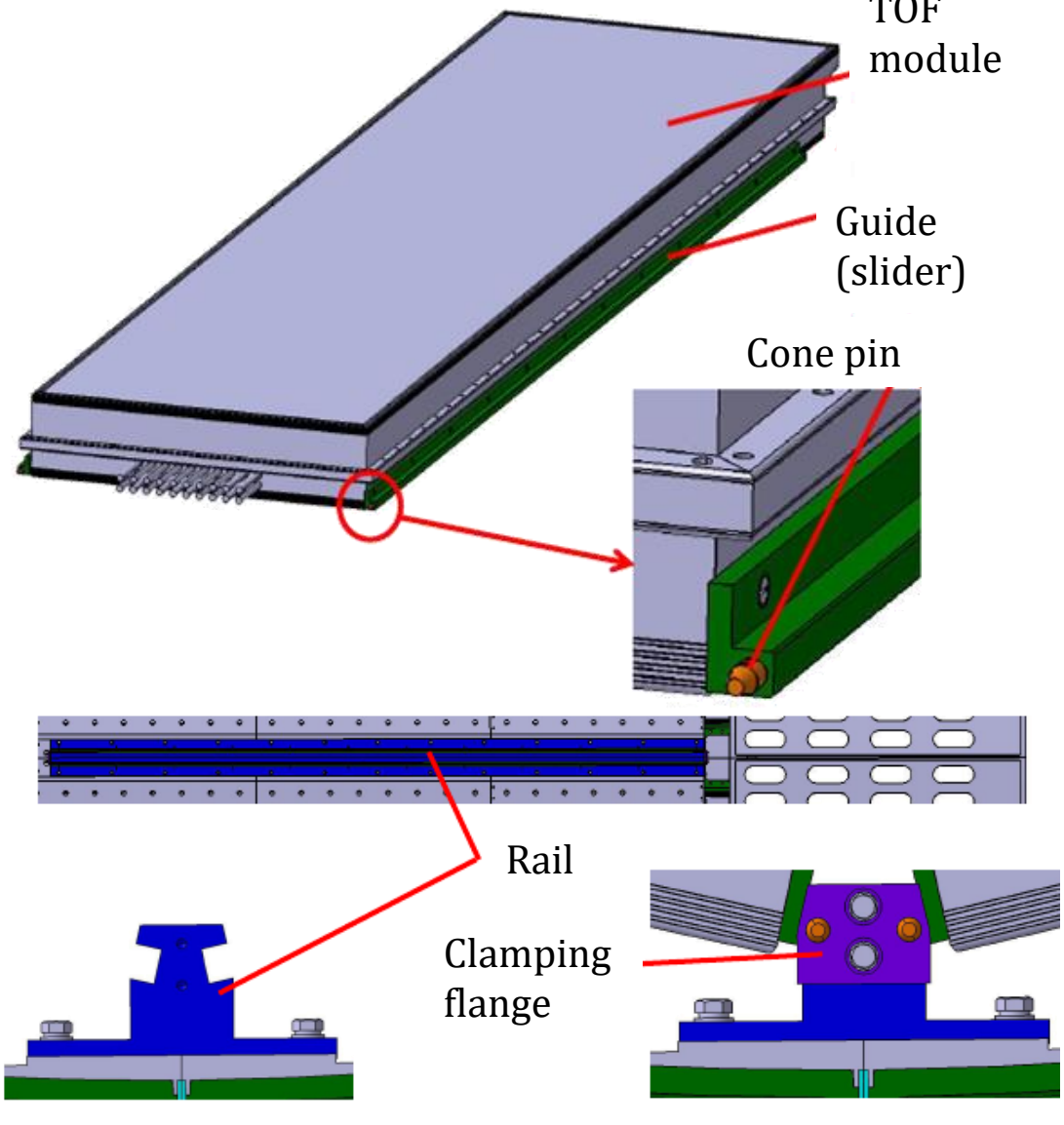
ECal modules

Typical TOF mounting on the Ecal frame

TOF modules

ПРОГРЕССТЕХ-ДУБНА
PROGRESSTECH-DUBNA

TOF modules integration into the MPD



New “Artmash”(Minsk) guides with rollers