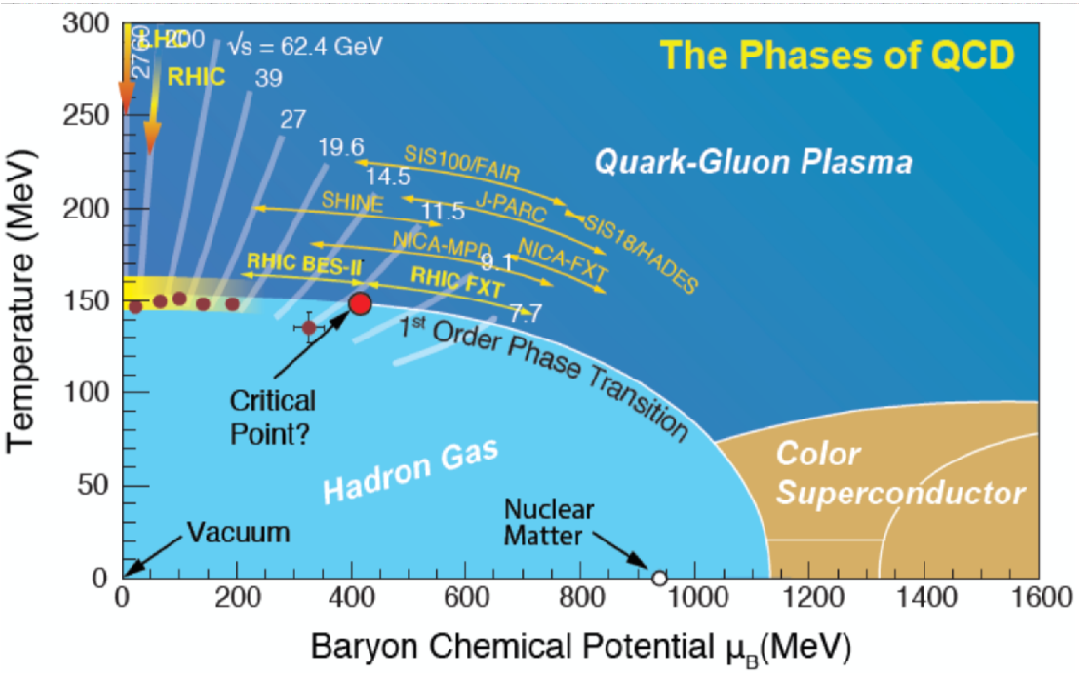
Time-of-flight system of the MultiPurpose Detector at NICA

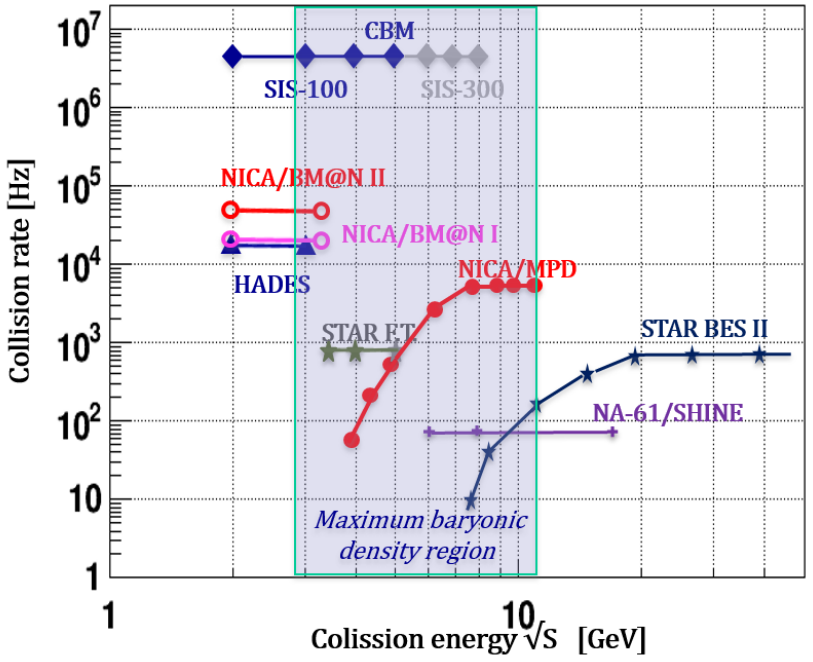
V. Babkin on behalf of the TOF group of the NICA/MPD experiment

Contents

- Physical goals of the MPD at I stage
- Requirements to the TOF system
- Design of the TOF barrel and MRPC
- Readout electronics
- MRPC test results
- TOF performance
- TOF mass production and testing
- Conclusions

The problem of studying hot and dense baryonic matter at NICA





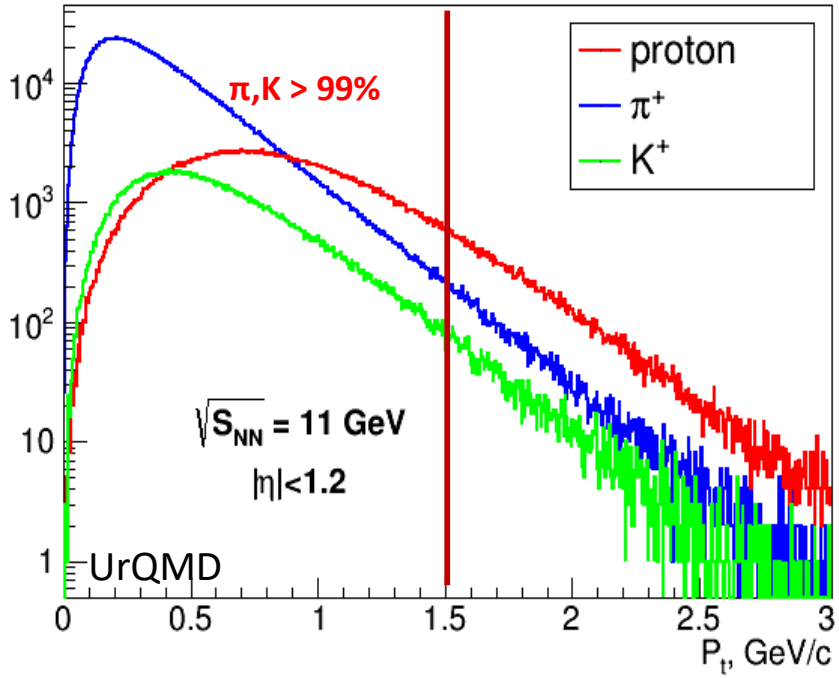
MPD/NICA heavy ion programm:

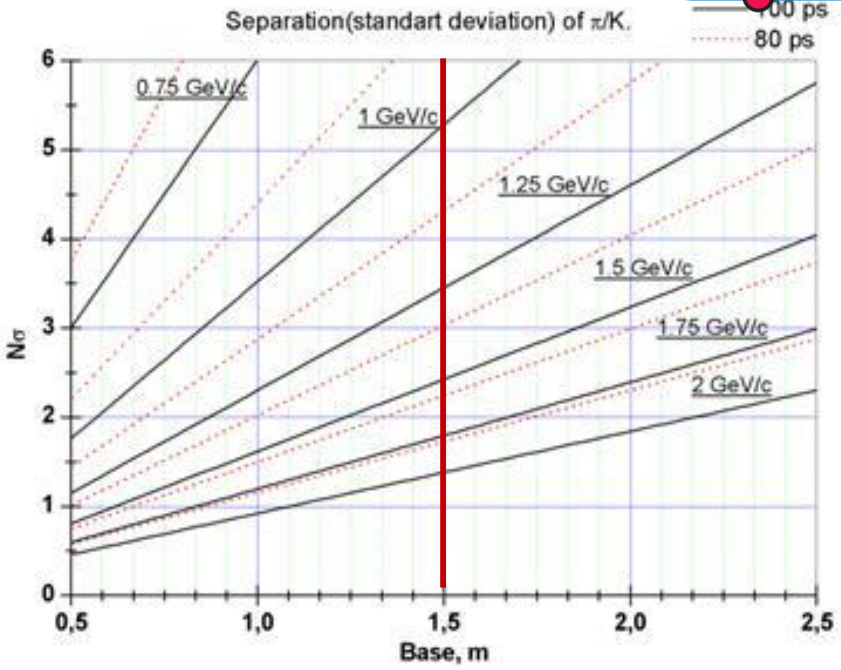
- **Main properties, EOS** – particle yields & spectra, ratios, femtoscopy, flow
- **In-Medium modification of hadron properties** – onset of low-mass dilepton enhancement
- **Deconfinement (chiral) phase transition at high ρ_B** – enhanced strangeness production
- **QCD Critical Point** – event-by-event fluctuations & correlations
- **Exotic (**hypernuclei, etc.)

To study properties of phase diagram it is important:

- to have possibilities of **fine scan** on collision energy;
- to have **variety** of beam nucleus.

Requirements to the TOF MPD



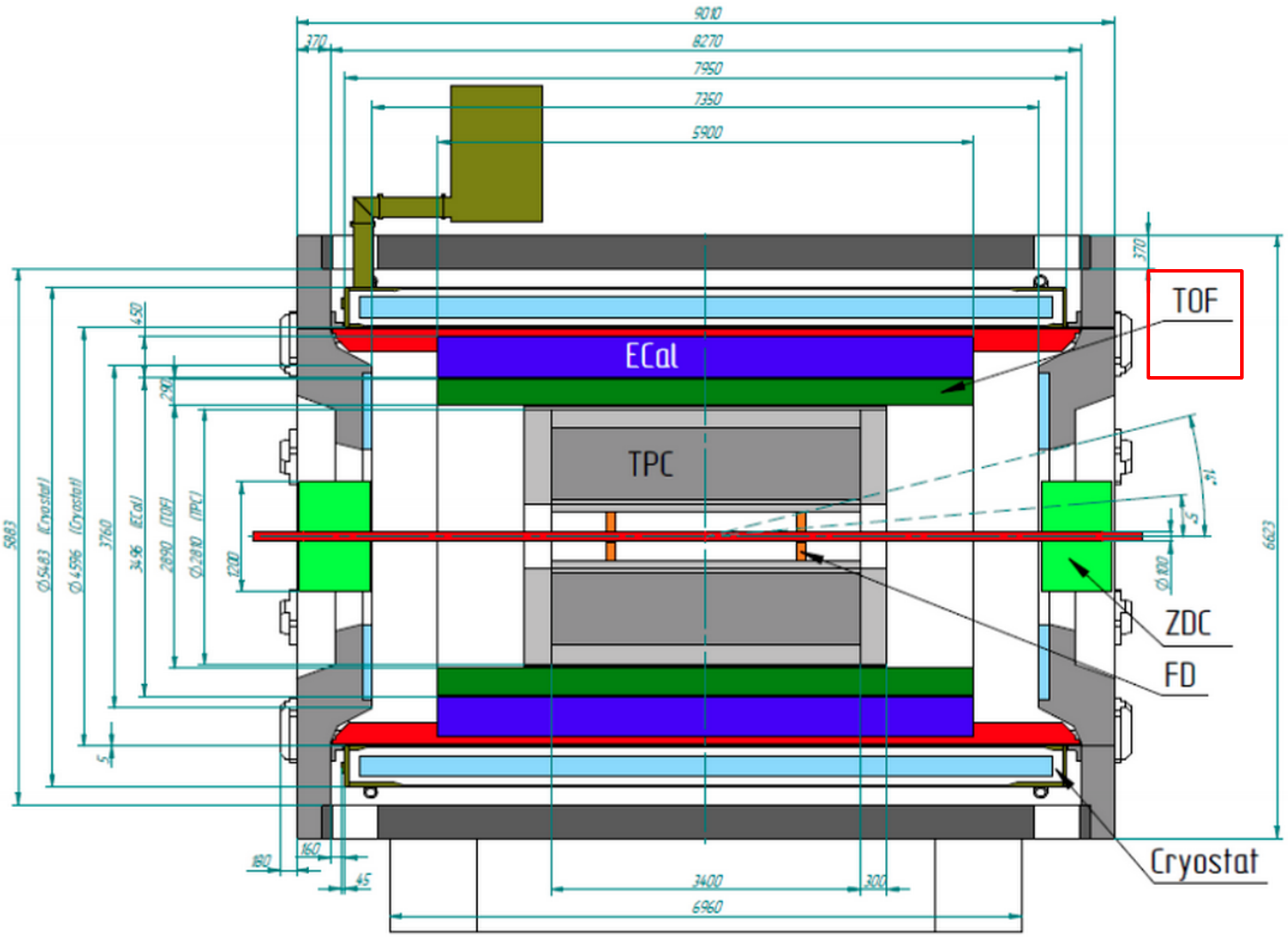


The basic requirements to the TOF system at Stage I of MPD are:

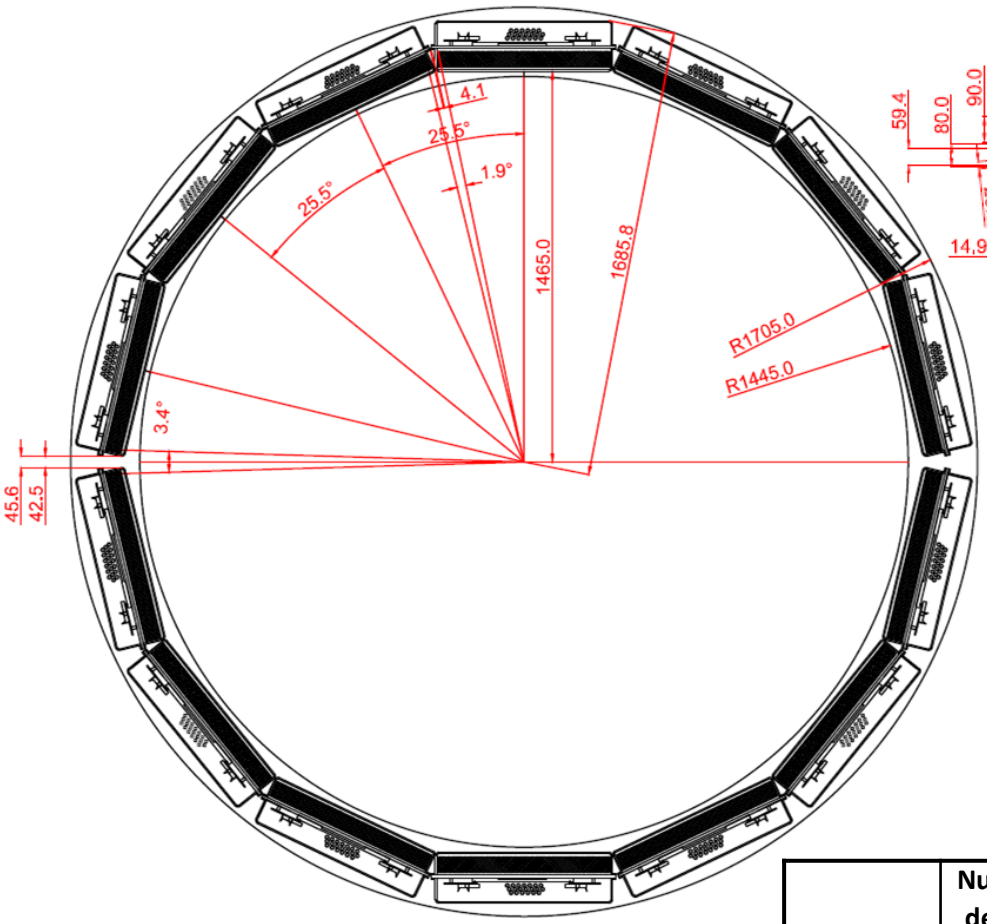
- phase space coverage $|\eta| < 1.4$;
- large area **~50 m²**
- time resolution of < **100 ps**;
- high granularity to keep the maximum occupancy <**15%**;
- high geometrical efficiency **>90%**;
- separation of pions and kaons with up to $p_t < 1.5$ **GeV/c**;
- separation of (anti)protons with up to $p_t < 3$ **GeV/c**;

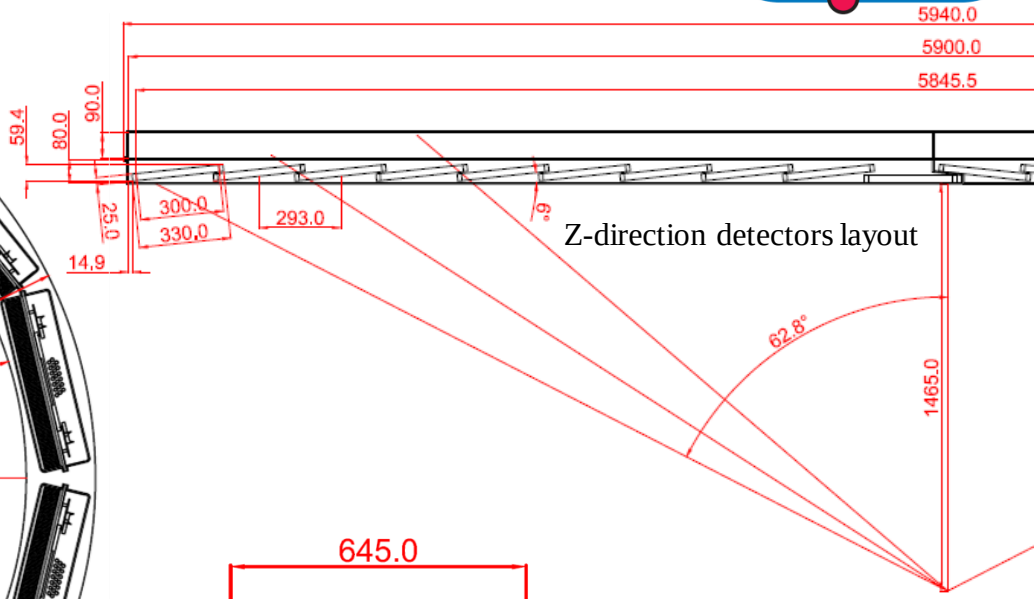
The best choice for this requirements is a Multigap Resistive Plate Chamber (**MRPC**).

First (basic) stage of the MPD experiment

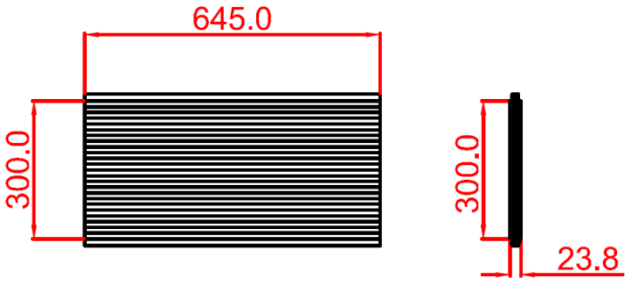


Mechanical design of the TOF barrel



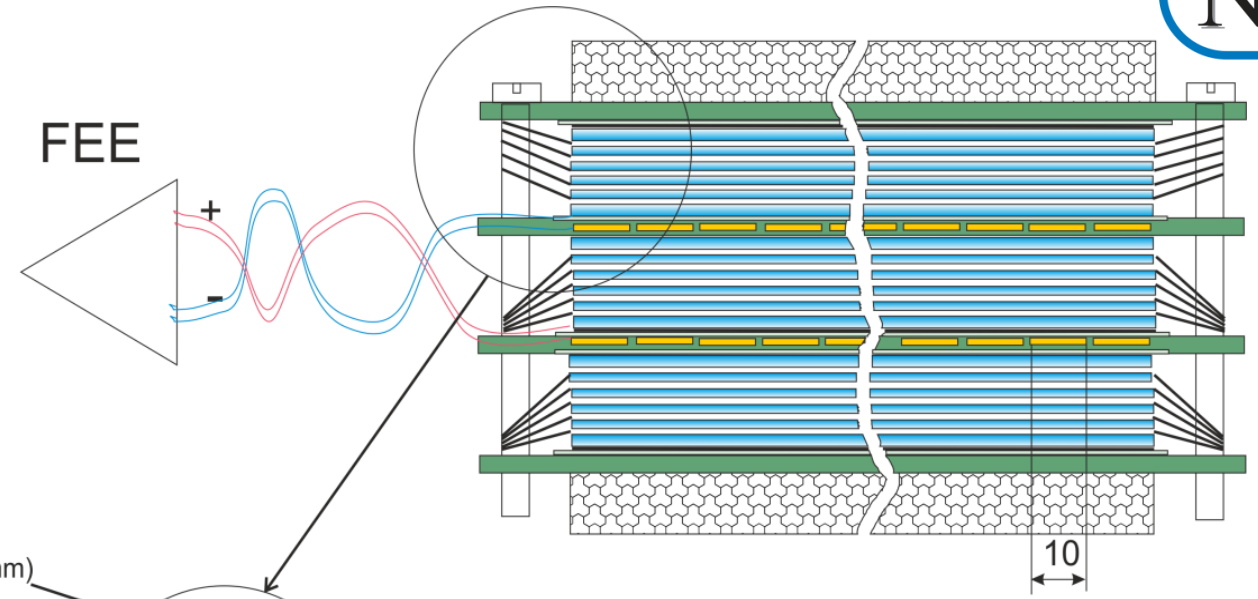


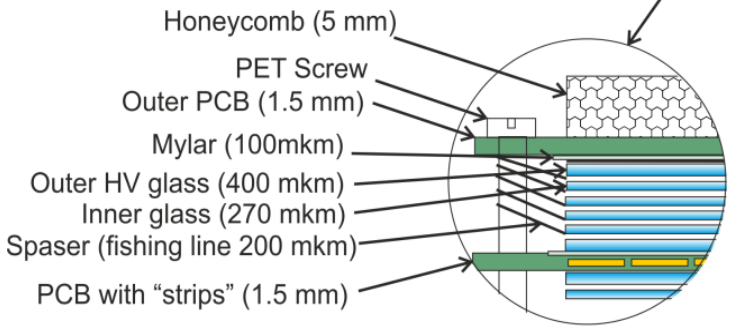
Z-direction detectors layout

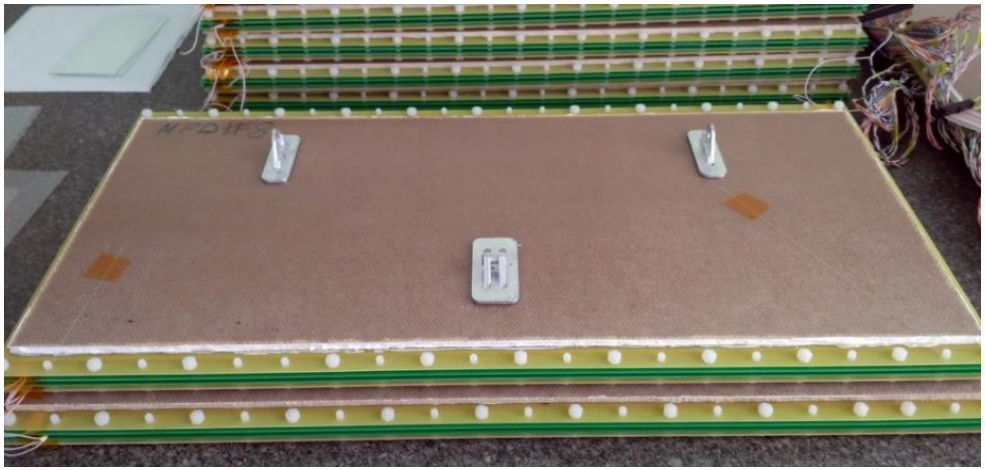


	Number of detectors	Number of readout strips	Sensitive area, m^2	Number of FEE cards	Number of FEE channels
MRPC	1	24	0.2	2	48
Module	10	240	1.85	20	480
Sector	20	480	3.7	40	960
Barrel	280	6720	51.8	560	**13440** (1680 chips)

Triple-stack MRPC

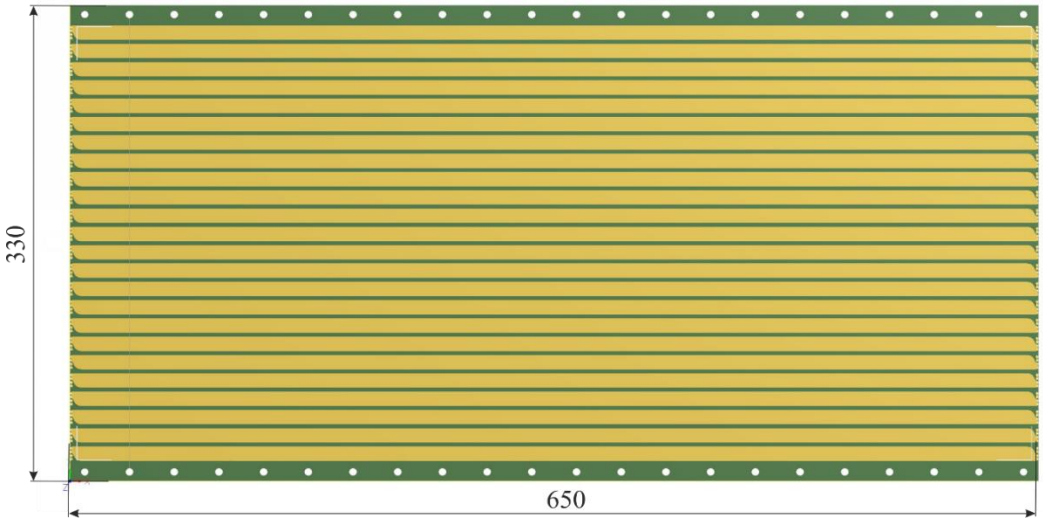




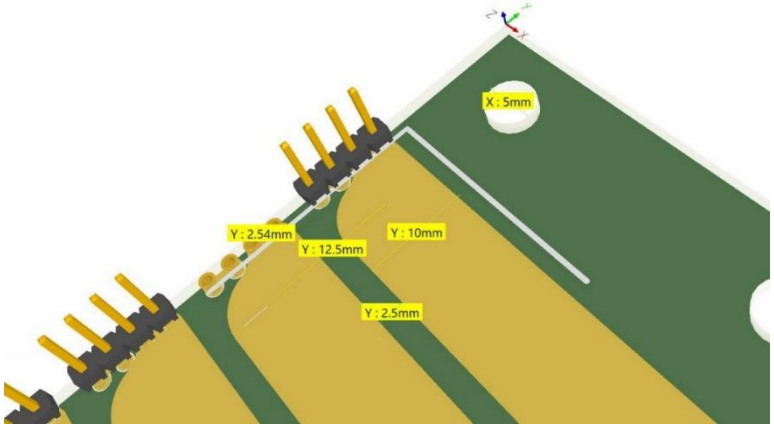


The same MRPC design successfully used at the BM@N experiment. Details is in poster #19 of Mikhail Rumyantsev

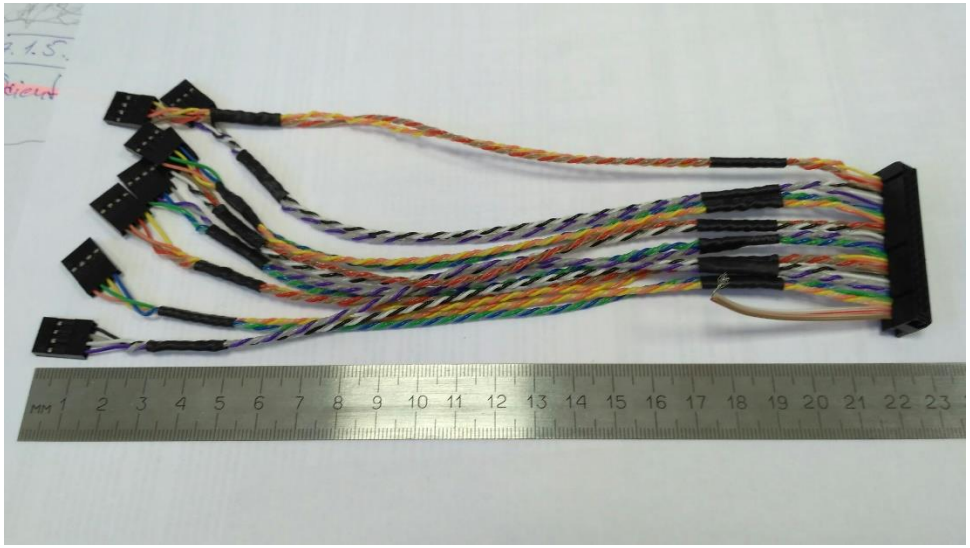
Signal readout



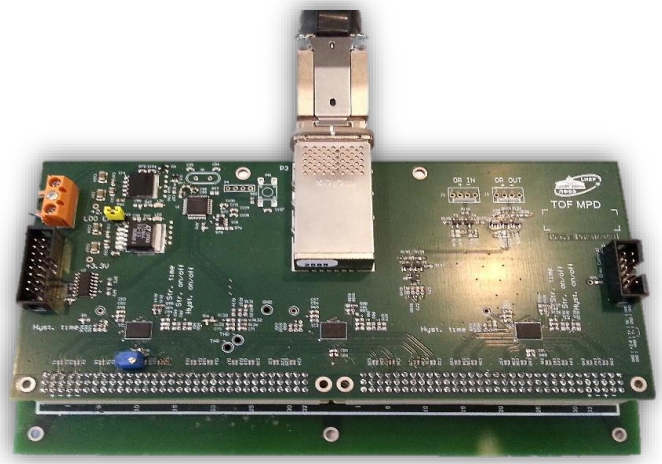
Overall dimensions of the readout board with strips



Signal connectors on the PCB



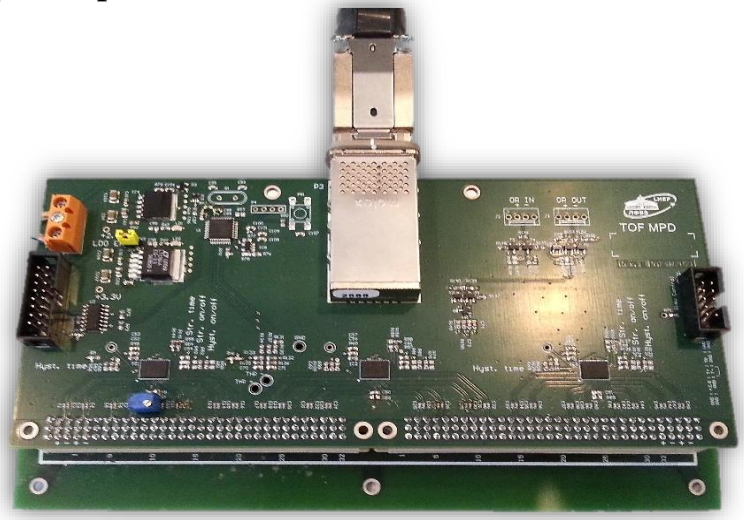
Doubled twisted pair cable for transferring signal to the preamp

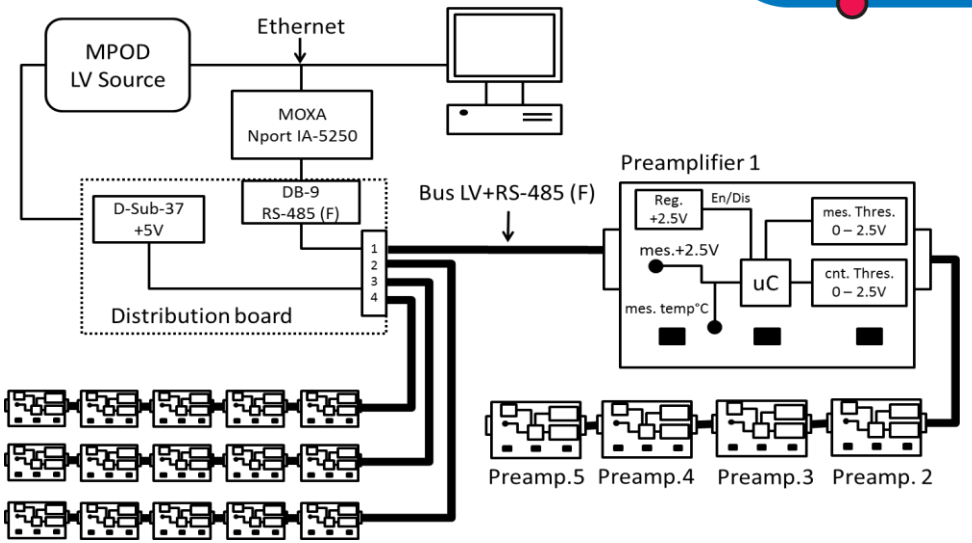


NINO based 24-ch preamplifier-discriminator PA24N2V2I with adapter board

Front-end electronics

NINO based 24-channels preamplifier-discriminator board PA24N2V2I

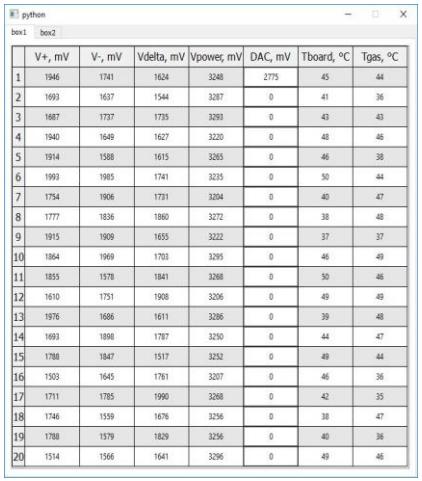




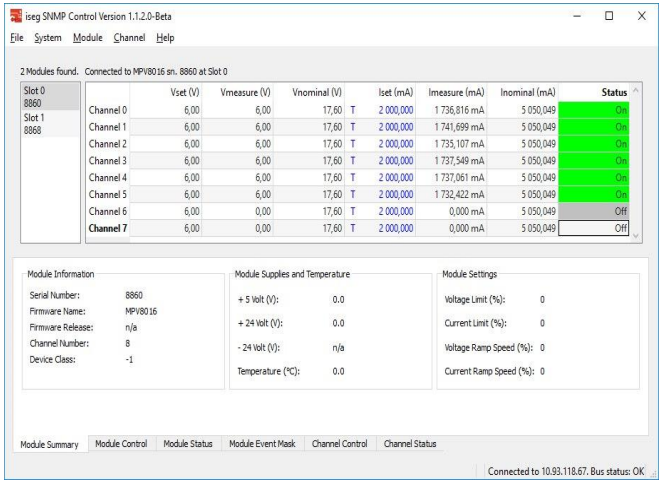
Powering preamplifier board and connection scheme.

- ✓ 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.



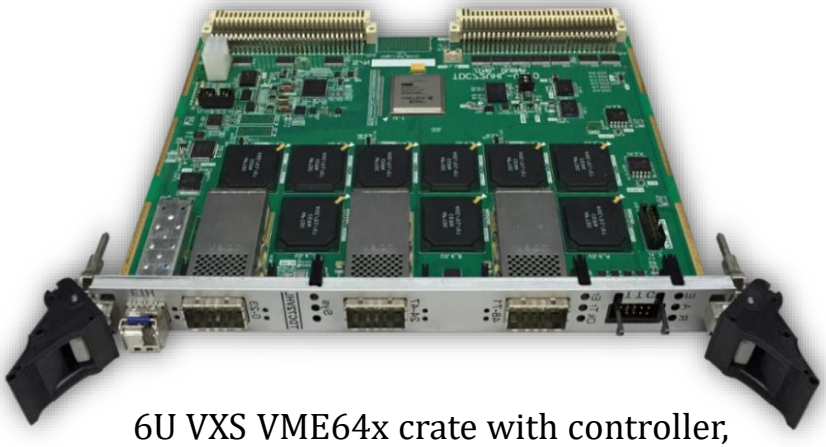
	V+, mV	V-, mV	Vdelta, mV	Vpower, mV	DAC, mV	Tboard, °C	Tgas, °C
1	1946	1741	1624	3248	2775	45	44
2	1693	1637	1544	3287	0	41	36
3	1687	1737	1735	3293	0	43	43
4	1940	1649	1627	3220	0	48	46
5	1914	1588	1615	3265	0	46	38
6	1993	1985	1741	3235	0	50	44
7	1754	1906	1731	3204	0	40	47
8	1777	1836	1860	3272	0	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 TDC72VXS

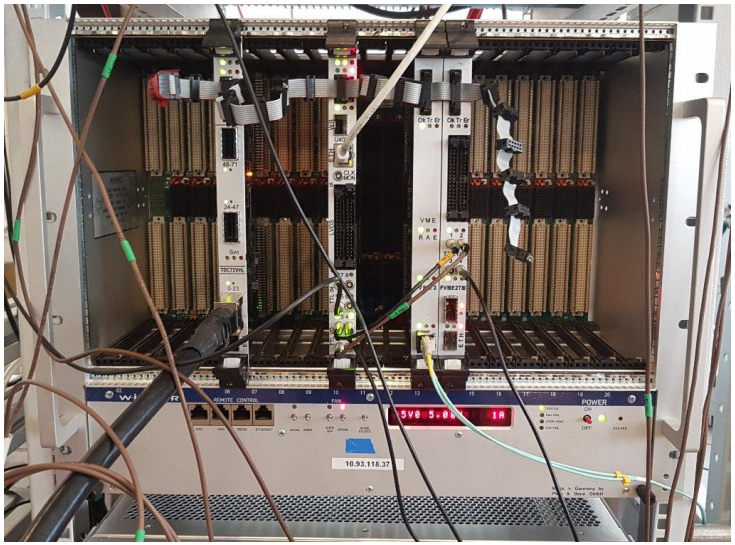


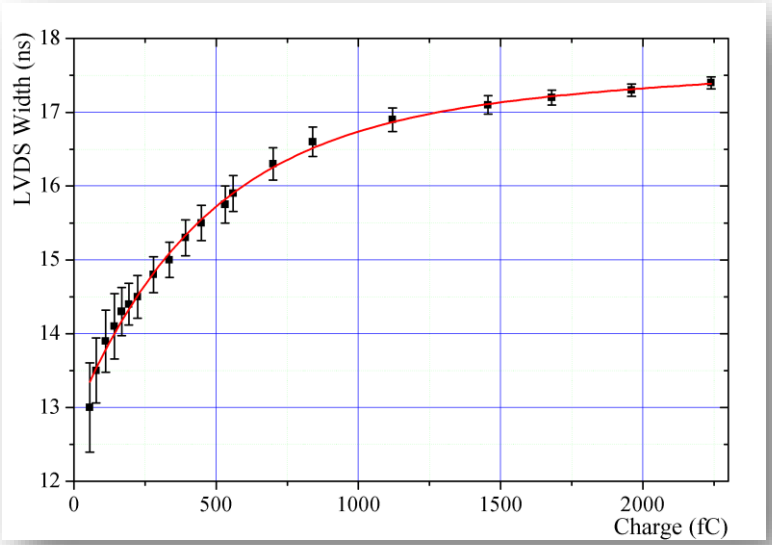
- ✓ VME64x interface with VXS;
- ✓ TDC type: timestamping HPTDC chip;
- ✓ Input: differential 100 Ω (LVDS);
- ✓ Resolution: 23.4 ps bin size ($\sigma_t \approx 18$ ps - measured);
- ✓ Power consumption: +5V/0.13A; +3.3V/5.6A;

Standalone mode:

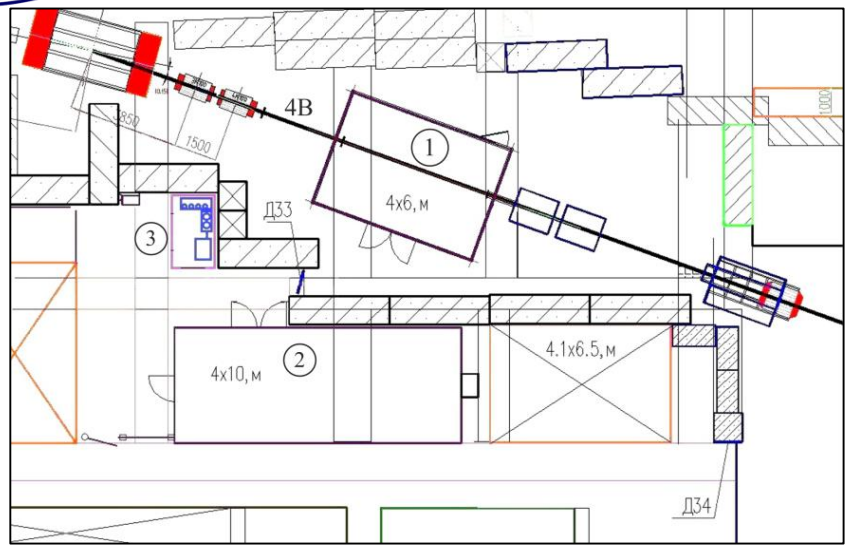
- ✓ Ethernet data transfer;
- ✓ Time synchronization by the White Rabbit.

6U VXS VME64x crate with controller, trigger modules and TDC72VXS



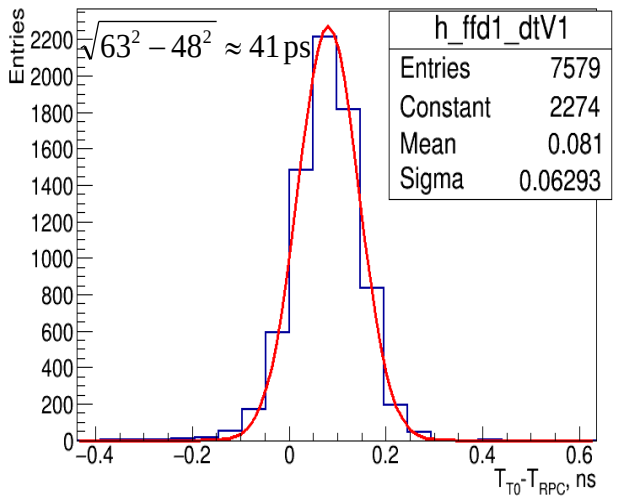


MPD test beam at the Nuclotron

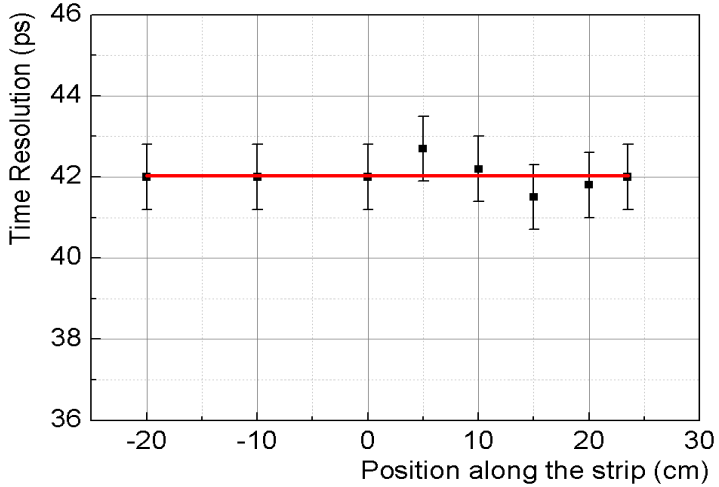


- two platforms made of aluminum profile;
- the precision positioning device (PD);
- three proportional chambers (MWPC 1, 2, 3) with an accuracy of determination of coordinate <1 mm;
- trigger scintillation counters (S1-S3);
- two independent gas system for various gas-filled detectors with different gas mixtures;
- data acquisition system (DAQ) based on the VME and Ethernet.

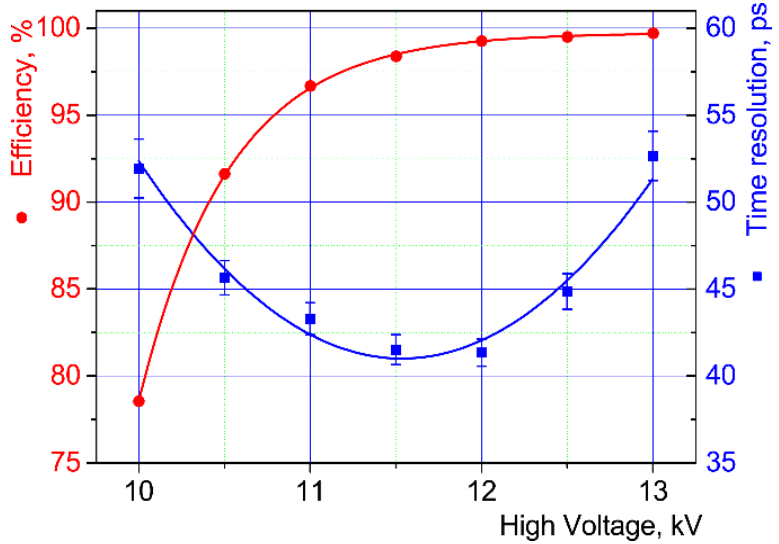
Triple-stack MRPC test results



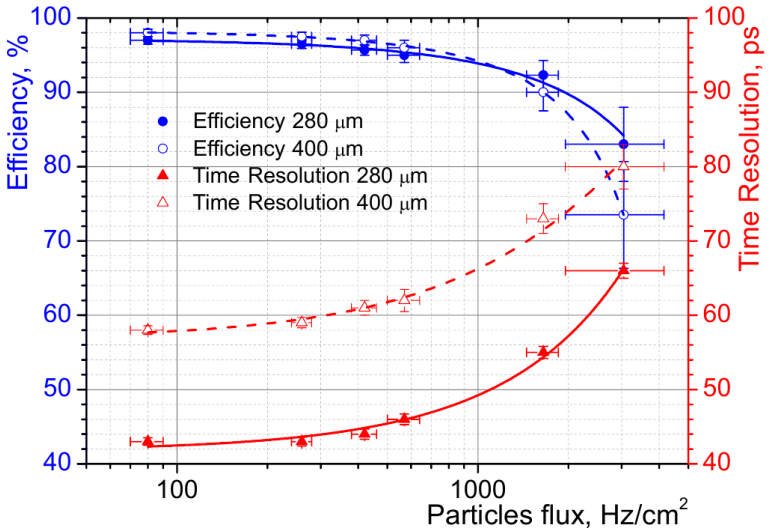
Time distribution between T0 and MRPC



Time resolution along the strip of the MRPC

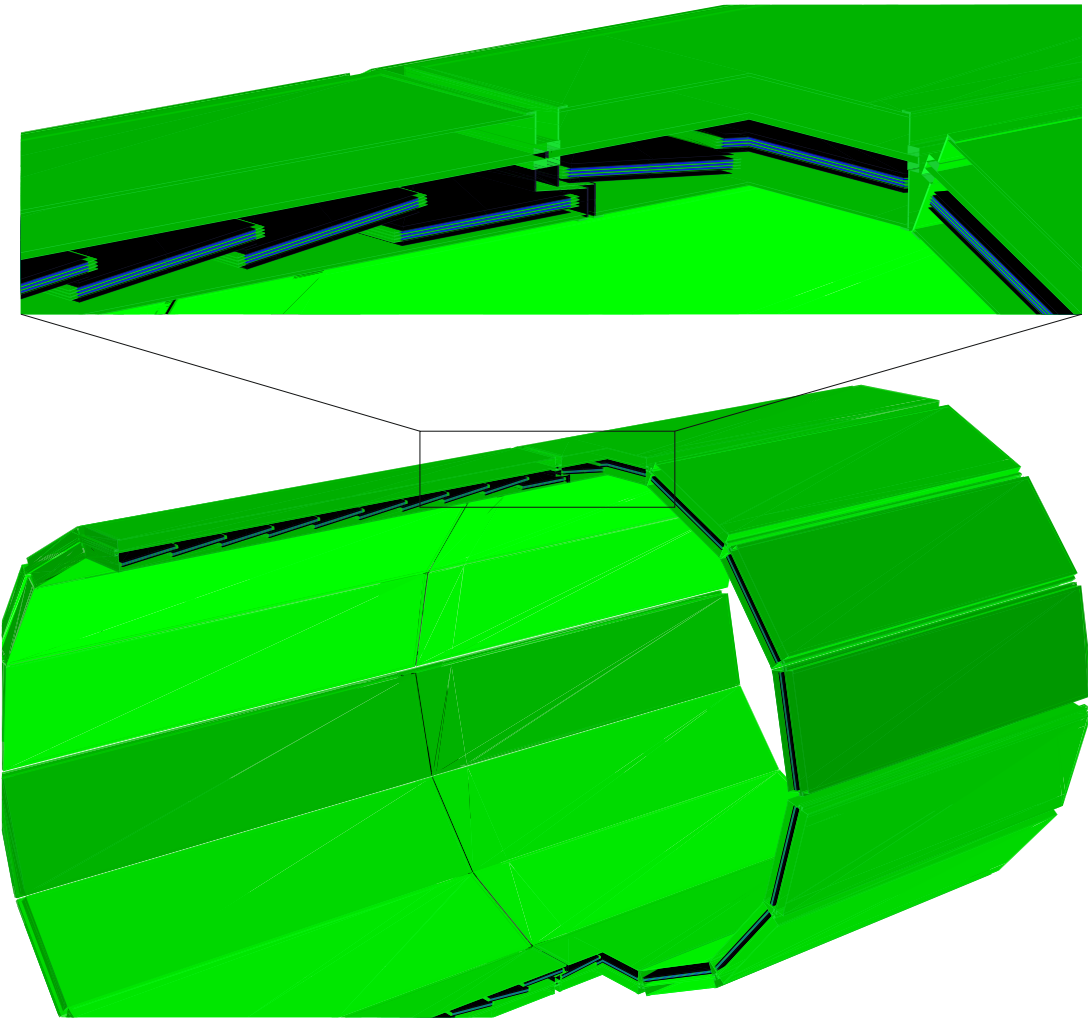


Efficiency and time resolution of the MRPC versus HV

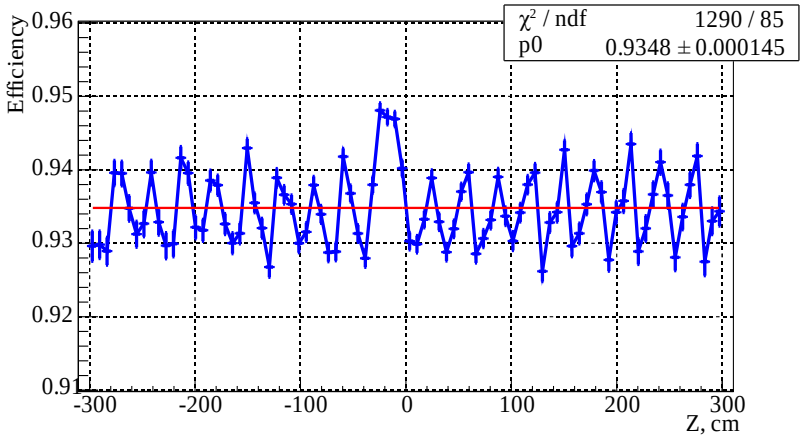


Efficiency and time resolution of the MRPC versus particles flux

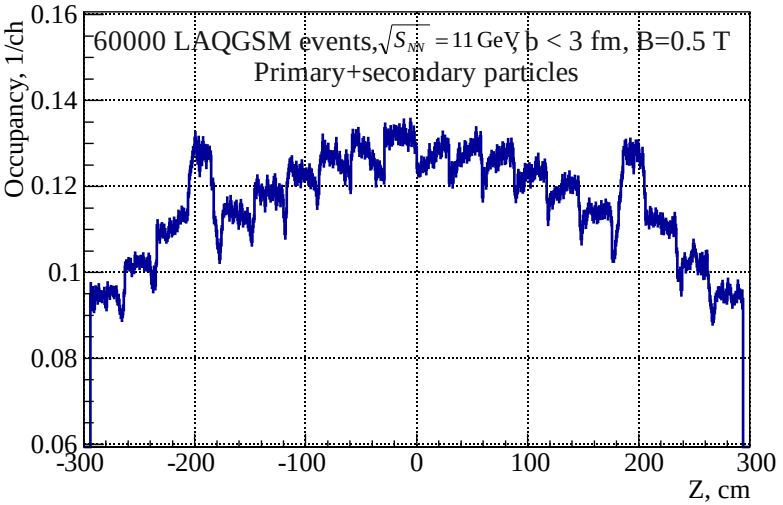
Detail geometry of the TOF for MPDRoot



Latest geometry of the TOF in the MPDRoot framework

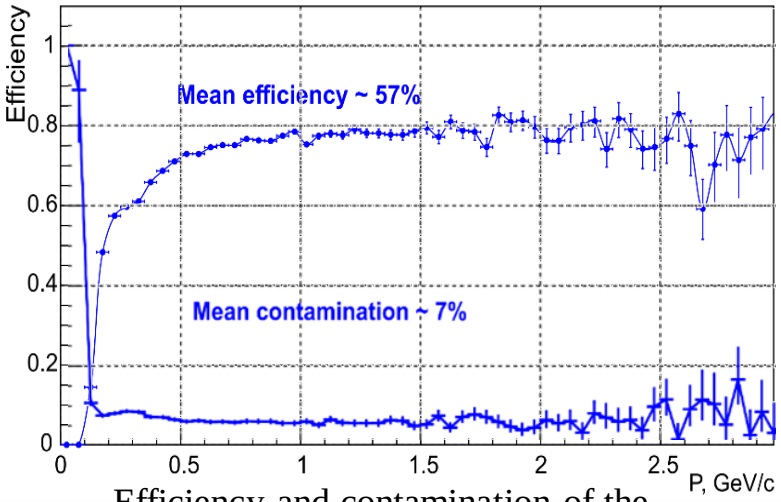


Geometrical efficiency along the TOF cylinder

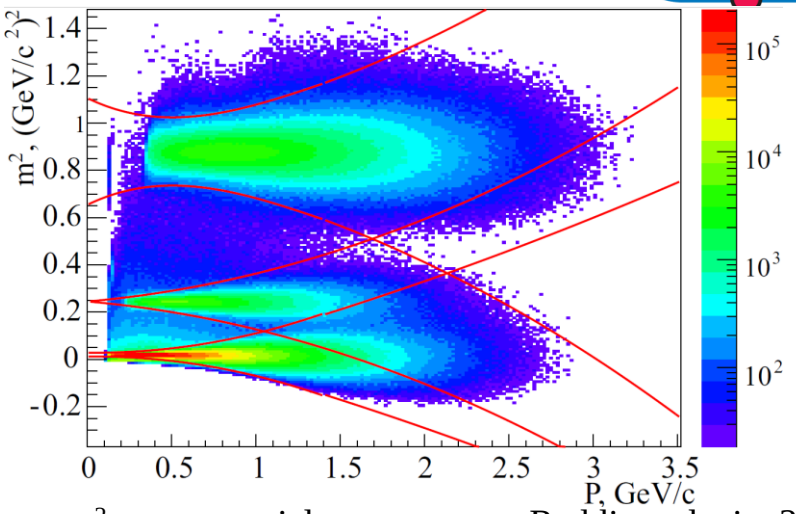


Differential occupancy along the TOF cylinder
Mean occupancy ~12%

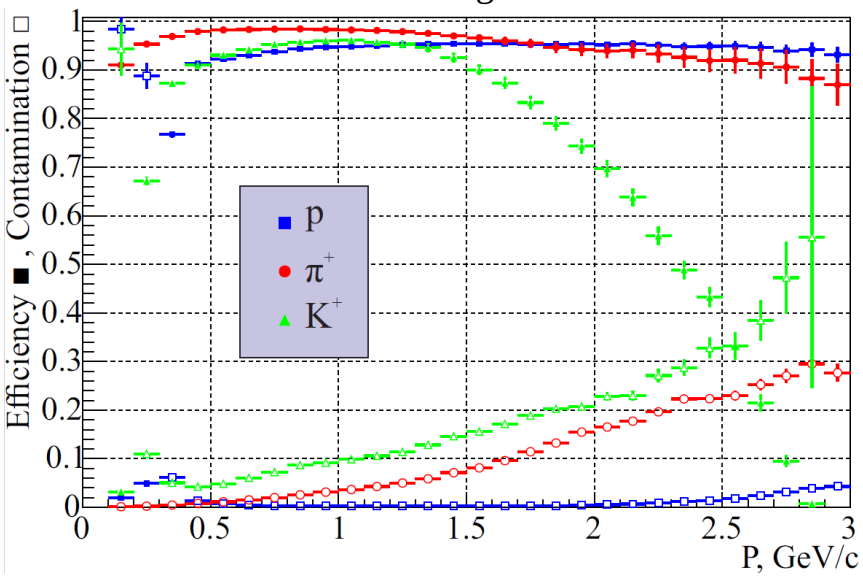
MPD TOF performance (realistic PID)



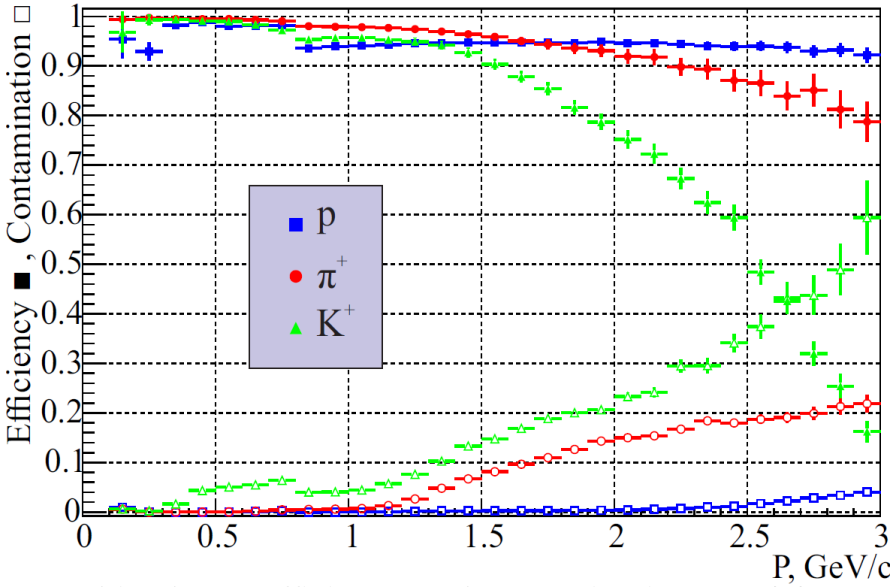
Efficiency and contamination of the TPC tracks matching with TOF hits



m^2 versus particle momentum. Red lines depict 3σ bands



Efficiency and contamination of PID using only the TOF



Combined PID efficiency and contamination, $0 < |\eta| < 1.4$

Mass-production of the TOF modules

Workshop staff: 3 physicists, 5 technicians, 2 electronics engineers

Productivity: ~ 1 detectors per day (1 module/2 weeks)

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

Ultrasonic wave glass cleaning

Painting of the HV conductive layer

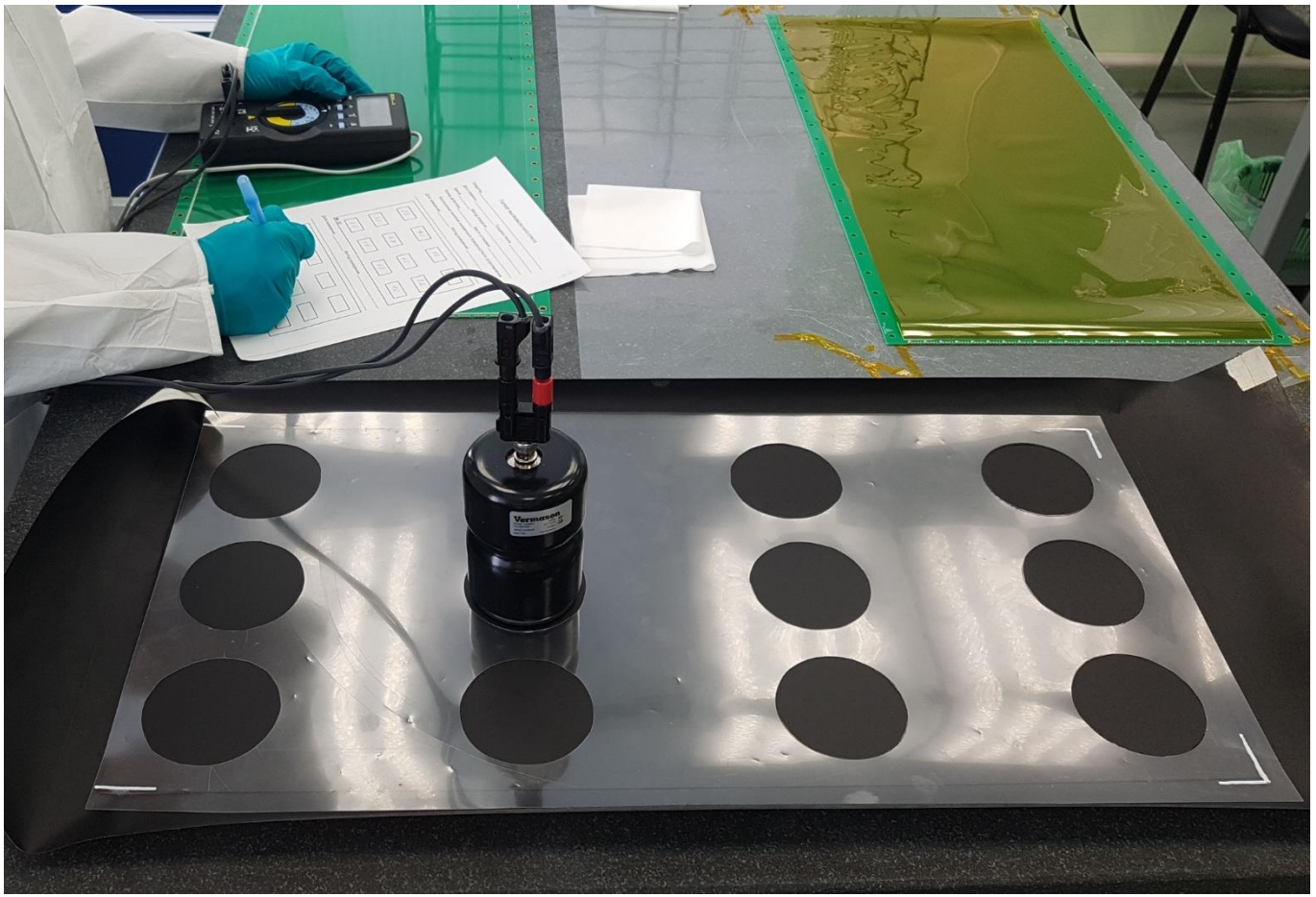
MRPC assembling

Cables and connectors soldering

MRPC detectors quality control

Preliminary materials control (before assembling):

- ✓ glass integrity & thickness
- ✓ honeycomb & PCB flatness
- ✓ HV layer surface resistivity



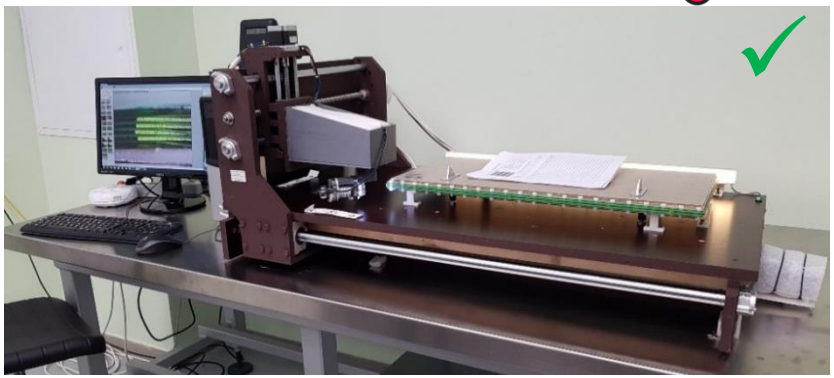
MRPC detectors quality control

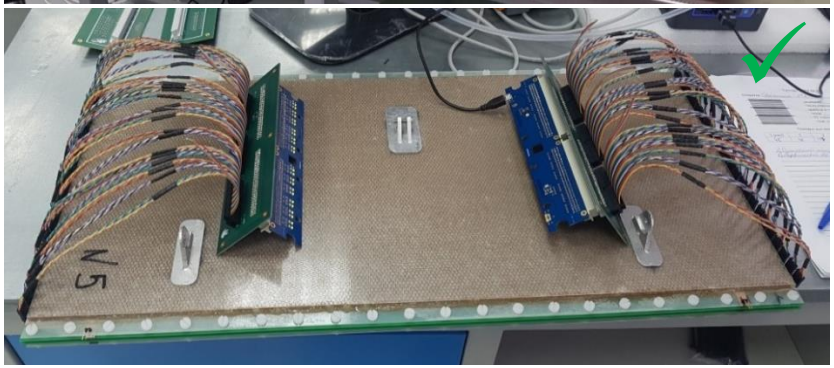
The quality control of the assembled detectors takes place in 5 stages.

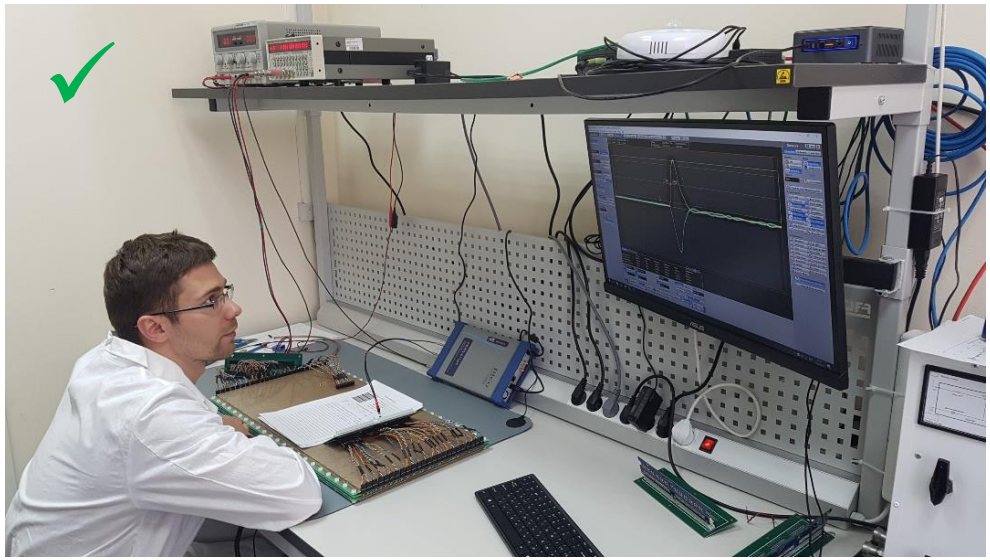
Check list

- ✓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

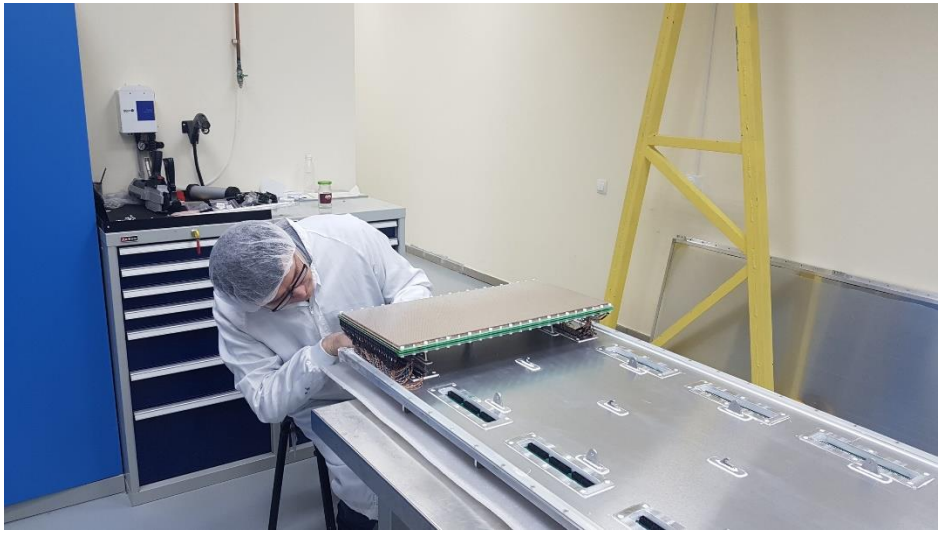
✓Ready for installation!





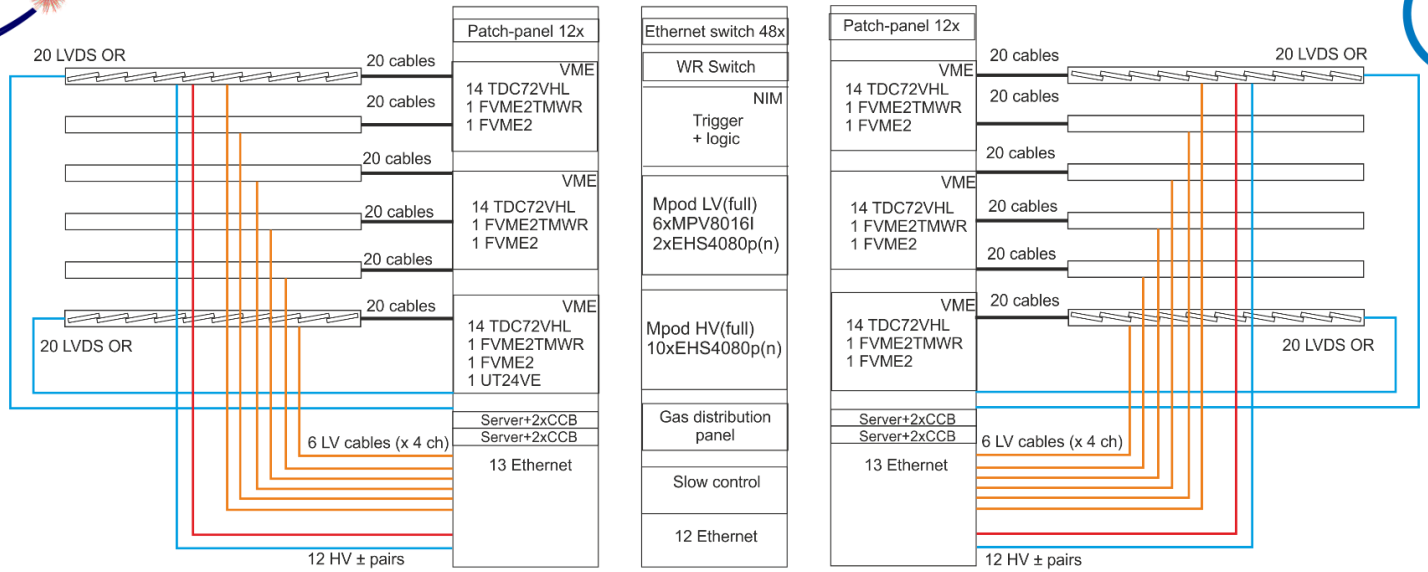


TOF modules assembling

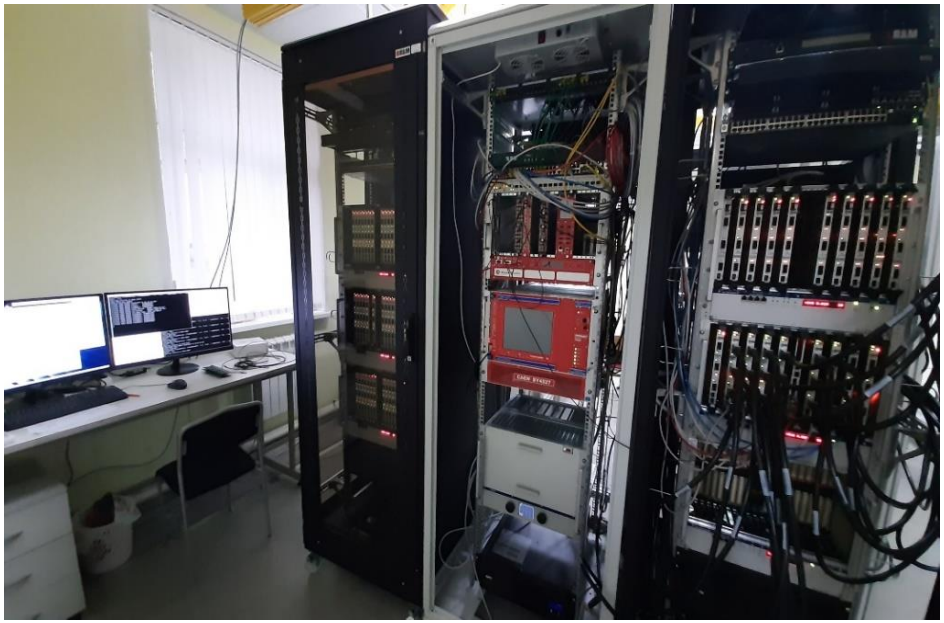


Basic requirement is leakage of gas mixture <0.5 cm^3/min per module (153 l)

Cosmic stand for testing TOF modules



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



Conclusions

- The technical design of the MPD TOF system is complete.
- All the materials for the TOF production purchased in full for the entire system. Mass-production started in 2019. At the moment we already produced 90 MRPCs (~33% of total).
- 3 TOF modules are assembled. One of them tested on the cosmic stand.
- The development of the readout electronics is complete. Mass production of front-end boards is finished last year. 50% of readout TDCs are produced and tested.
- Service subsystems (LV, HV and gas system) purchase is complete.
- We plan to finish production and commissioning of the MPD TOF at the end of 2020.

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Thank you for the attention!