TWENTY-FIRST LOMONOSOV CONFERENCE ON ELEMENTARY PARTICLE PHYSICS

Status of the Time-of-Flight and ECal Particle Identification Systems of the MPD Experiment at the NICA Collider

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on behalf of the MPD TOF and ECal Group

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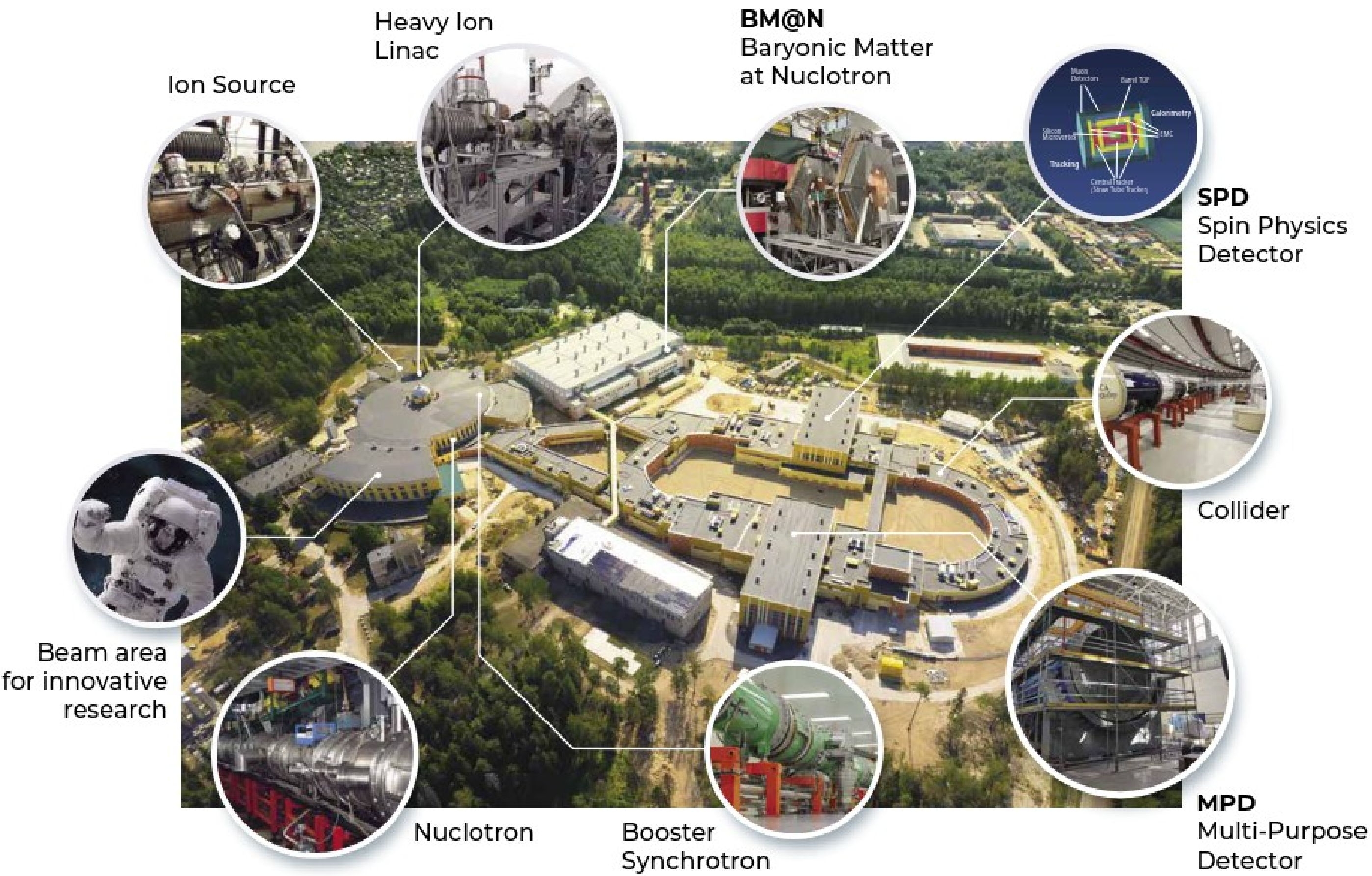
NICA (Nuclotron-based Ion Collider fAcility)

nica.jinr.ru



$\sqrt{S}$ = 4–11 GeV/N Energy | Collider ring circumference 503 m

NICA PARAMETERS

Range of nuclei:
from hydrogen to bismuth, including gold

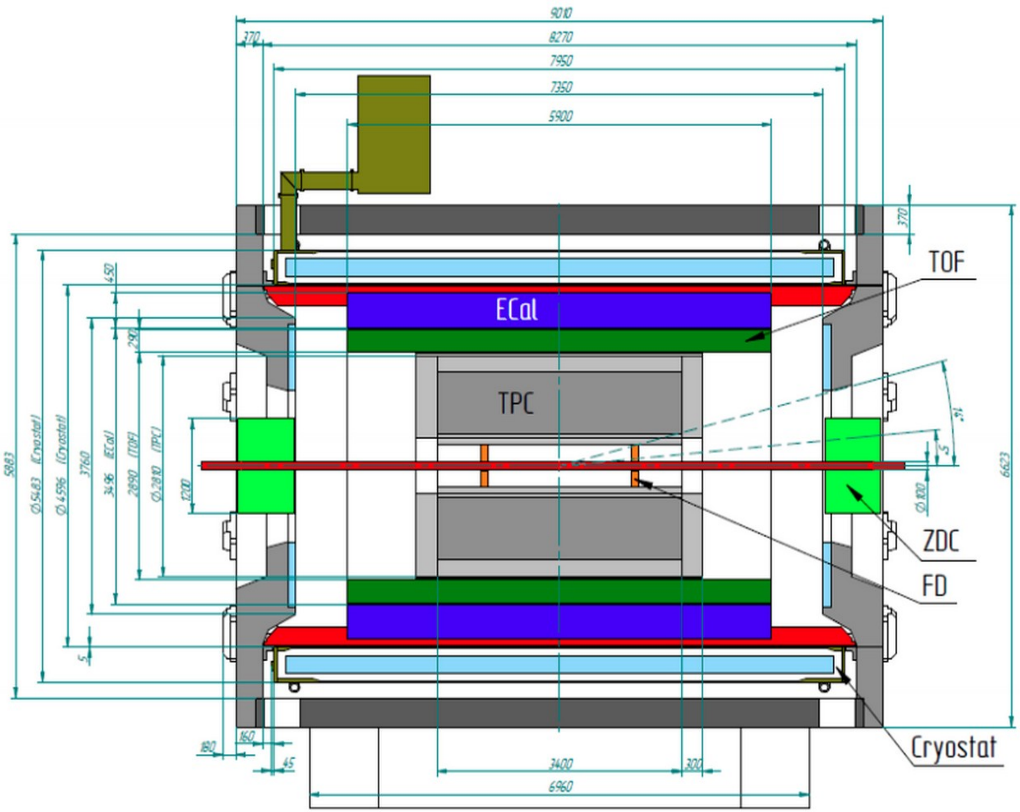
Energy of extracted beams:
up to **4.5 GeV/N**

Intensity (per second):
Heavy ions — **$5 \cdot 10^8$**
Protons — **10^{10}**

Designed luminosity:
Heavy ions — **10^{27} cm^{-2}/s^{-1}**

Light nuclei and polarised protons and deuterons — **10^{32} cm^{-2}/s^{-1}**

Multi-purpose detector MPD



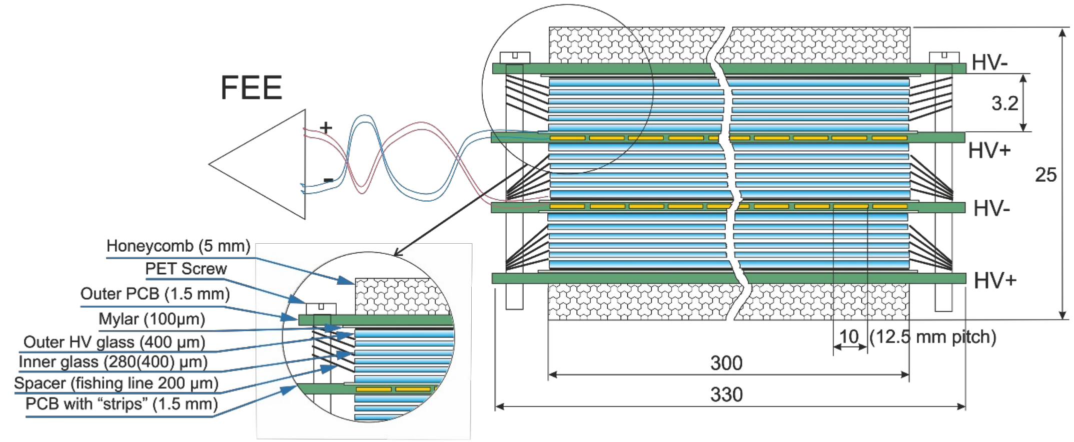
Structure of the MPD with main dimensions.

The MPD is capable of detecting photons, electrons and charged hadrons in collisions of heavy ions in the energy range of the NICA collider. The detector includes a 3-D tracking system and a particle identification system. Identification of charged hadrons in a wide range of momentum up to 3 GeV/c is achieved by combining of time-of-flight measurements and energy loss information (dE/dx) from the time-projection camera (TPC). The time of flight is measured using the TOF system of the same name, which is used to determine the «stop» time and the Forward Detector (FD), designed to measure the «start» time. The electromagnetic calorimeter ECal is part of the PID system and its main purpose is to identify electrons, photons and measure their energy with high accuracy.

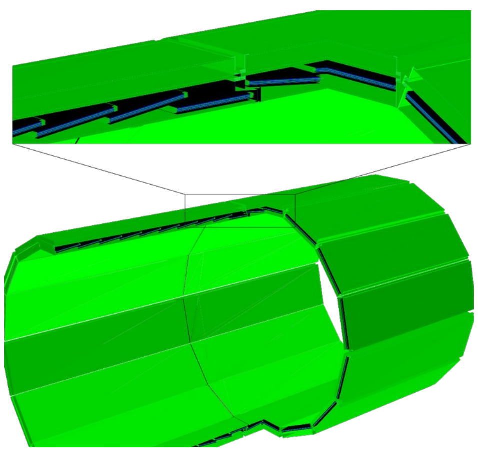
Time-of-Flight detector

Requirements for the Time-of-Flight system:

- large range of pseudorapidity |η| ≤ 1.2;
- high granularity in order to keep the overall system occupancy below 15% and minimize the decrease in efficiency due to double hits;
- good position resolution to ensure efficient matching of hits in the TOF detector with TPC tracks;
- high geometric efficiency and detection efficiency;
- identification of pions and kaons with $p_T < 1.5$ GeV/c;
- identification (anti)protons with $p_T < 3$ GeV/c;
- functioning of detector elements in a magnetic field of 0.5 T;
- time resolution of the entire system, including electronics, below 80 ps.



Structure of the MRPC detector.



Structure of the TOF detector.

	Number of detectors	Number of readout strips	Sensitive area, m^2	Number of FEE boards	Number of FEE channels
MRPC	1	24	0.192	2	48
Module	10	240	1.848	20	480
TOF	280	6720	51.8	560	13440

The main parameters of the TOF system.

TOF on-camera and readout electronics

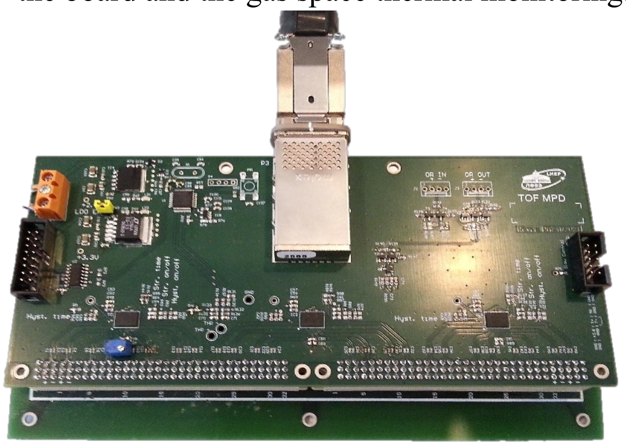
The features of the 24-channel preamplifier board based on ASIC NINO are as follows:

• there are capacitors at the inputs of the board, adapted for reading from both sides of the strip;

• the discrimination thresholds monitoring and control;

• the NINO integrated circuit voltage monitoring and control;

• the board and the gas space thermal monitoring.



NINO based 24-channel amplifier-discriminator with the Molex CXP connector.

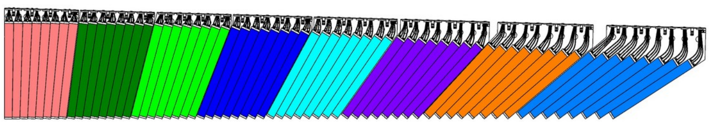
72-channel time-digital converter module TDC72VHL in the VME64x standard based on the HPTDC chip are used. The width of the TDC samples is ~ 23.4 ps.

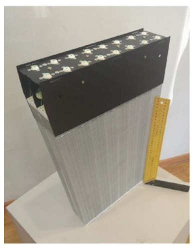
72-channel time-to-digital converter TDC72VHL v4 with CXP input connector.

The modules are connected to VME–VXS crates, each of which can accommodate up to 18 TDC72VHL, taking into account the trigger and synchronization module TTVXS. Synchronization of the TDC modules in one VME-VXS device is carried out over a high-performance VXS bus. Between the crates, time synchronization is carried out using the "White Rabbit" technology, which ensures synchronization accuracy better than 10 ps.

VME-VXS crate with TDC modules, trigger and synchronization module.

Electromagnetic Calorimeter





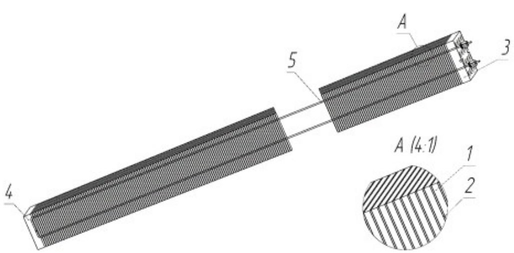
Top – evolution of ECal module shape from the center to the edge of MPD, bottom - modules of different types.

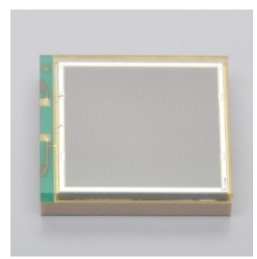
Requirements for the electromagnetic calorimeter:

- measurements of the spatial position, as well as the energy of photons and electrons;
- high spatial resolution and separation of overlapping electromagnetic showers;
- reliable reconstruction of photons and electrons;
- energy resolution of at least 5% for 1 GeV photons;
- the particle population should not exceed 5% for effective particle recovery;
- the time resolution should be below 1 ns, to eliminate noise and other overlaps, while close to 100 ps, so that particles can be identified by the time-of-flight method;
- the calorimeter must be capable of operating in a magnetic field up to 0.5 T.

To detect scintillation light, a SiPM (silicon photomultiplier) is used, currently a Hamamatsu S13360-6025 device.

Construction of tower without WLS.
1 –scintillator plate,
2 - lead plate,
3 and 4 - pressure plates,
5 - pressure string.



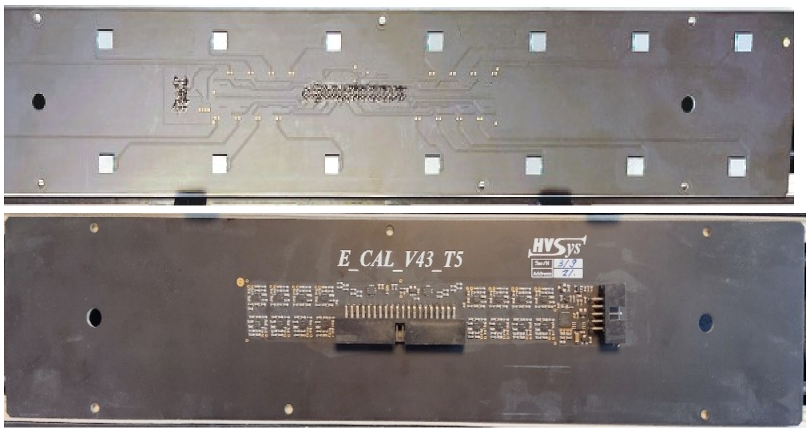


HAMAMATSU S13360-6025PE.

Type no.	Measure-ment conditions	Spectral response range λ (nm)	Peak sensitivity wavelength λp (nm)	Photon detection efficiency PDE*4 λ=λp (%)	Dark count*5 Typ. (kcps)	Dark count*5 Max. (kcps)	Terminal capaci-tance Ct (pF)	Gain M	Break-down voltage VBR (V)	Crosstalk probability (%)	Recom-mended operating voltage Vop (V)	Tem-perature coefficient at recom-mended operating voltage ΔTVop (mV/°C)
S13360-1325CS	Vover =5 V	270 to 900		25	70	210	60	7.0 × 10^5		1	VBR + 5	
S13360-1325PE		320 to 900										
S13360-3025CS		270 to 900			400	1200	320					
S13360-3025PE		320 to 900										
S13360-6025CS		270 to 900			1600	5000	1280					
S13360-6025PE		320 to 900										

Parameters HAMAMATSU S13360-6025.

ECal FE and readout electronics



HV board.

	Number of modules	Number of readout channels / towers	Sensitive area, m^2	Number of ADC64ECAL
4 module	4	64	~ 0.1024	1
Sector	96	1536	~ 2.4576	24
ECal	2400	38400	~ 61.44	600

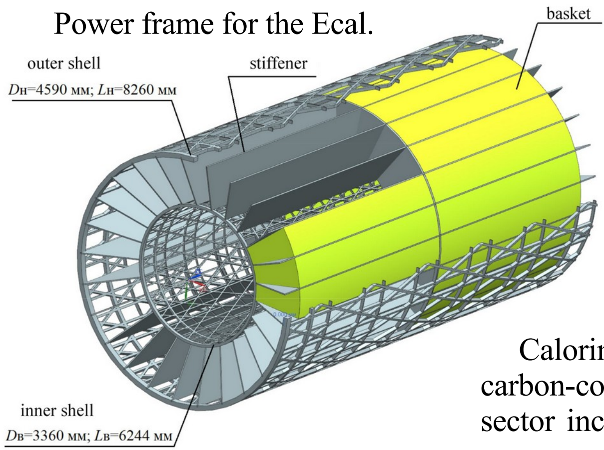
The main parameters of the electromagnetic calorimeter.

An ADC64ECAL board with 64 channels developed at JINR is used as an analog-to-digital converter. The zero suppression logic is based on baseline estimation and threshold value, while signal shaping is performed digitally using finite impulse response (FIR) filters. The ring type memory allows for the read back of the last 30 μs of waveforms, setting the trigger latency limit to this value. ADC board allows to be integrated to the White Rabbit system. White Rabbit provides sub-nanosecond accuracy.

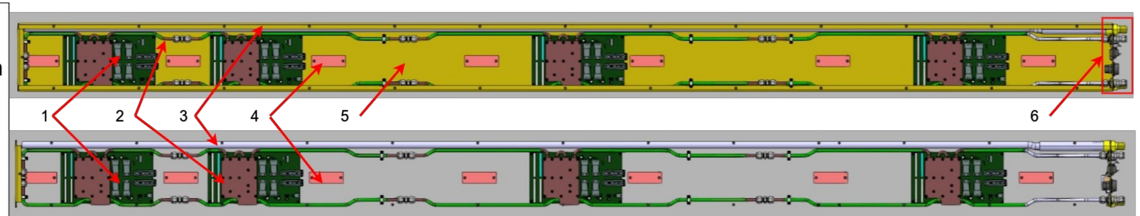
ADC64ECAL board.

ECal frame and cooling system

Power frame for the Ecal.



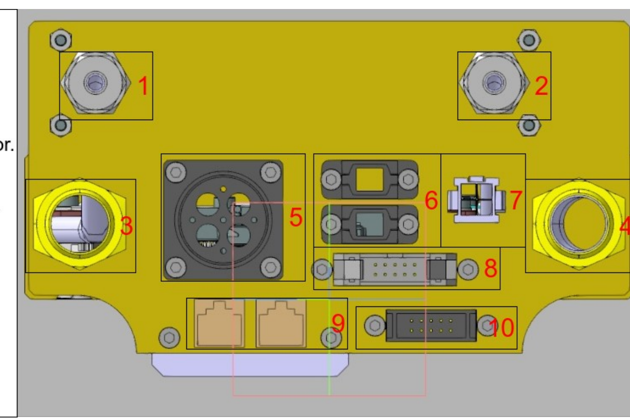
1. ADC64ECAL
2. Water system
3. Air system
4. Hole for channels
5. Box
6. Side panel



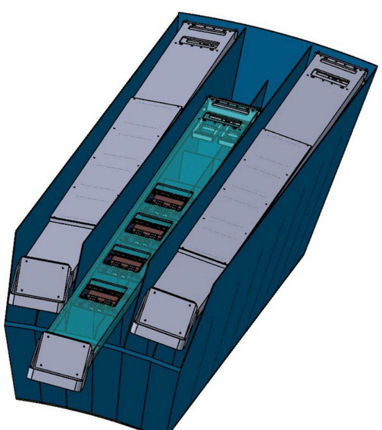
Box with cooling system and electronics.

Calorimeter half-sectors are placed in a carbon-composite power MPD frame. Each half-sector includes ECal readout electronics, which are supported by 3 boxes 3 meters long. 48 HV boards, preamps and control electronics are located in each half-sector, while the ADC boards are located inside heat-insulated boxes to minimize their impact on photodetectors. To ensure stable operation of the calorimeter, we use two types of cooling systems: liquid and air. The air cooling system has two circuits. One is for cooling the box with the ADC boards, the second is for cooling the space under the box in which the boards with photodetectors are located.

1. Water cooling in fitting.
2. Water cooling out fitting.
3. Air cooling in fitting.
4. Air cooling out fitting.
5. ADC64ECAL power connector.
6. ADC64ECAL optical connectors.
7. Voltage monitoring connector ADC64ECAL.
8. ADC64ECAL backup connector.
9. LED connection connector.
10. HV connection connector for boards with SiPM photodetectors



Side panel of box with cooling system and electronics..



Half-sector container (basket).

TOF and ECal testing setups

TOF testing setups.

ECal testing setups.

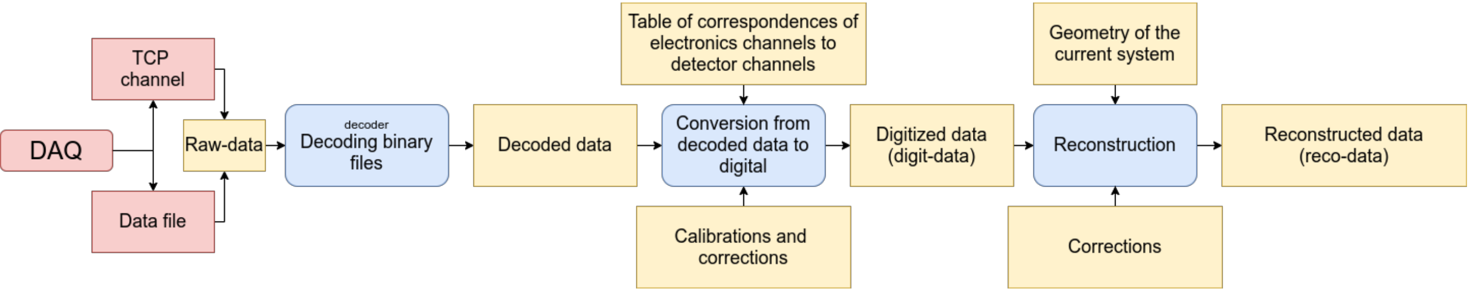
Special setups were created in the JINR Laboratory of High Energy Physics to test the TOF modules and the ECal half-sectors. Each of the installations includes service systems, data acquisition system and support structure on which detectors. The main tasks of the installations:

- checking the operability of all channels of detectors and electronics;
- checking the long-term stability of the operating parameters;
- measuring the efficiency of all detector and electronics channels;
- preliminary calibration of detectors and electronics and measurement of some system parameters.

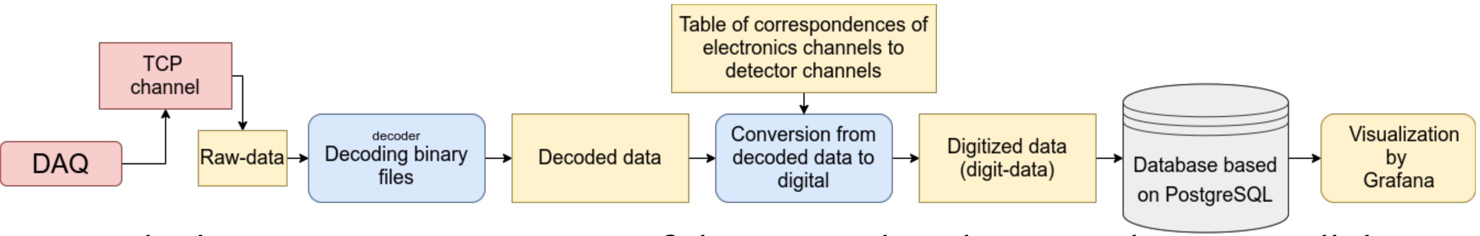
TOF modules are tested on cosmic radiation. The half-sectors and other elements of the ECal can be tested on cosmic radiation and using LEDs.

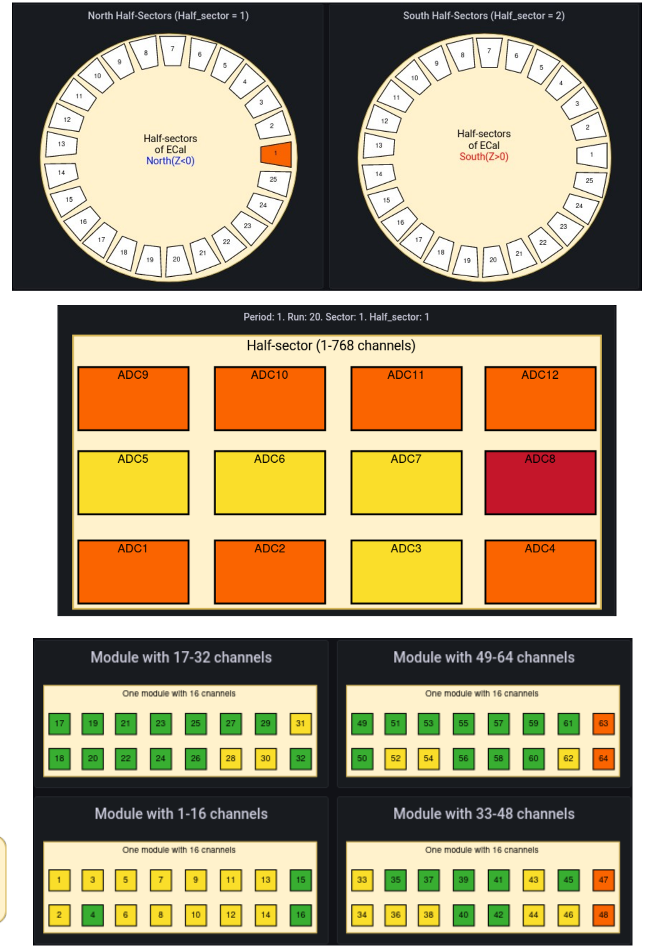
Software for processing of experimental data obtained at TOF and ECal testing setups

To process the experimental data, a software package was created within MPDRoot, the schematic diagram of which is shown in figure:



This whole data processing chain is already applicable to the TOF detector. In addition, procedures for obtaining and applying calibration of integral non-linearity (INL) of channels TDC, calibration of individual time delays in each channel and corrections using the Time-Over-Threshold (ToT) method and time correction during synchronization modules were developed and implemented. As for the ECal, here we stopped at digitized data and are actively working further. So online monitoring was developed and implemented to check the stability of the detector. Visualization has a hierarchical structure: all half-sectors, one half-sector, one ADC board. It was implemented in Grafana using various plugins.





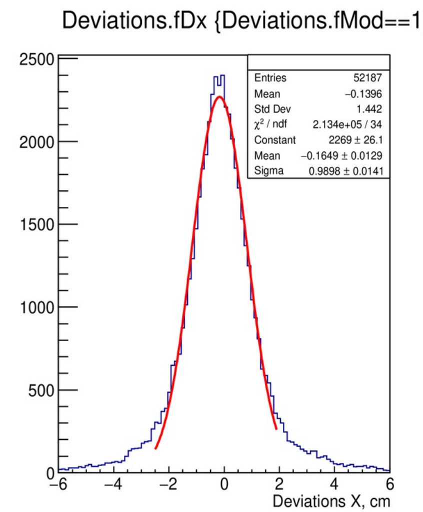
Hierarchical structure of visualization.

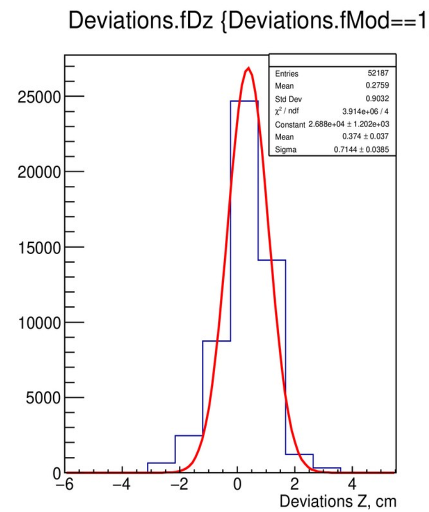
Baryshnikov V.

Current TOF status

The production of MRPC detectors has been completed. In total, we have 300 (107%) fully tested MRPC detectors. To date, 26 out of 28 TOF MPD modules have already been assembled.

In addition, estimates of the coordinate and time resolution of TOF modules were performed. To do this, an algorithm was implemented for matching 4 hits and 3 hits into one track. Each of the hits belongs to a separate module. 4 modules are located one above the other on one arm of the TOF testing setup. So for the first module, the deviations are $\sigma_x \approx 0.98$ cm and $\sigma_z \approx 0.71$ cm using vertical tracks.



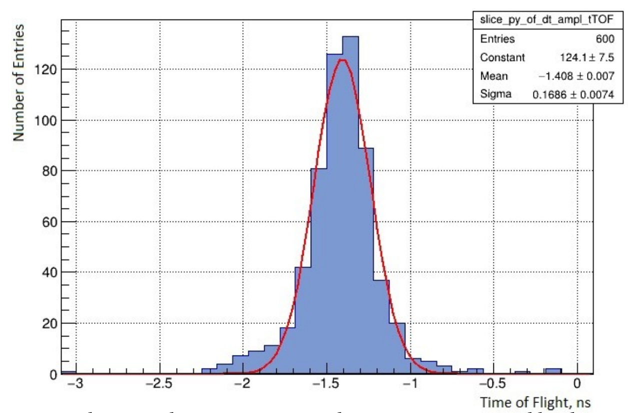


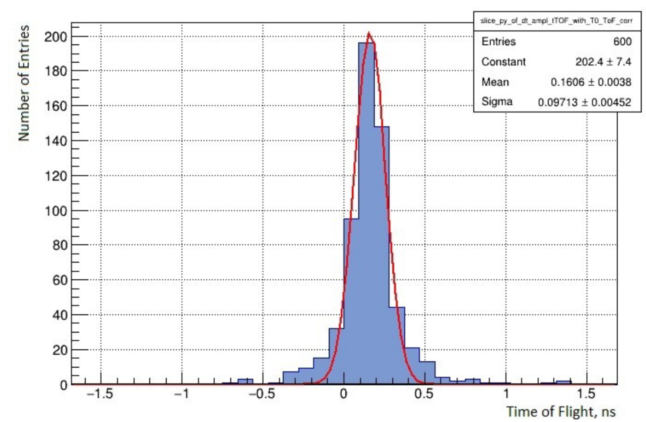
To obtain an estimate of the time-of-flight resolution, only vertical tracks with hits belonging to strips with the same number from MRPC with the same number were selected by one MRPC detector. This is done so that the same strip is responsible for the start time. The time resolution of such a system is $\sigma_t \approx 169$ ps without ToT correction and with - $\sigma_t \approx 97$ ps.

$$\sigma_t = \sqrt{\sigma_{TOF}^2 + \sigma_{FD}^2 + \sigma_{TOF\ \ FEE}^2 + \sigma_{FD\ \ FEE}^2 + \sigma_{TOF\ \ TDC}^2 + \sigma_{FD\ \ TDC}^2 + \sigma_{sync}^2},$$

$$\sigma_t = \sqrt{2\,\sigma_{MRPC}^2 + 2\,\sigma_{TOF\ \ FEE}^2 + 2\,\sigma_{TOF\ \ TDC}^2}, \quad \sigma_{MRPC\ with\ electrionic} = \frac{\sigma_t}{\sqrt{2}}$$

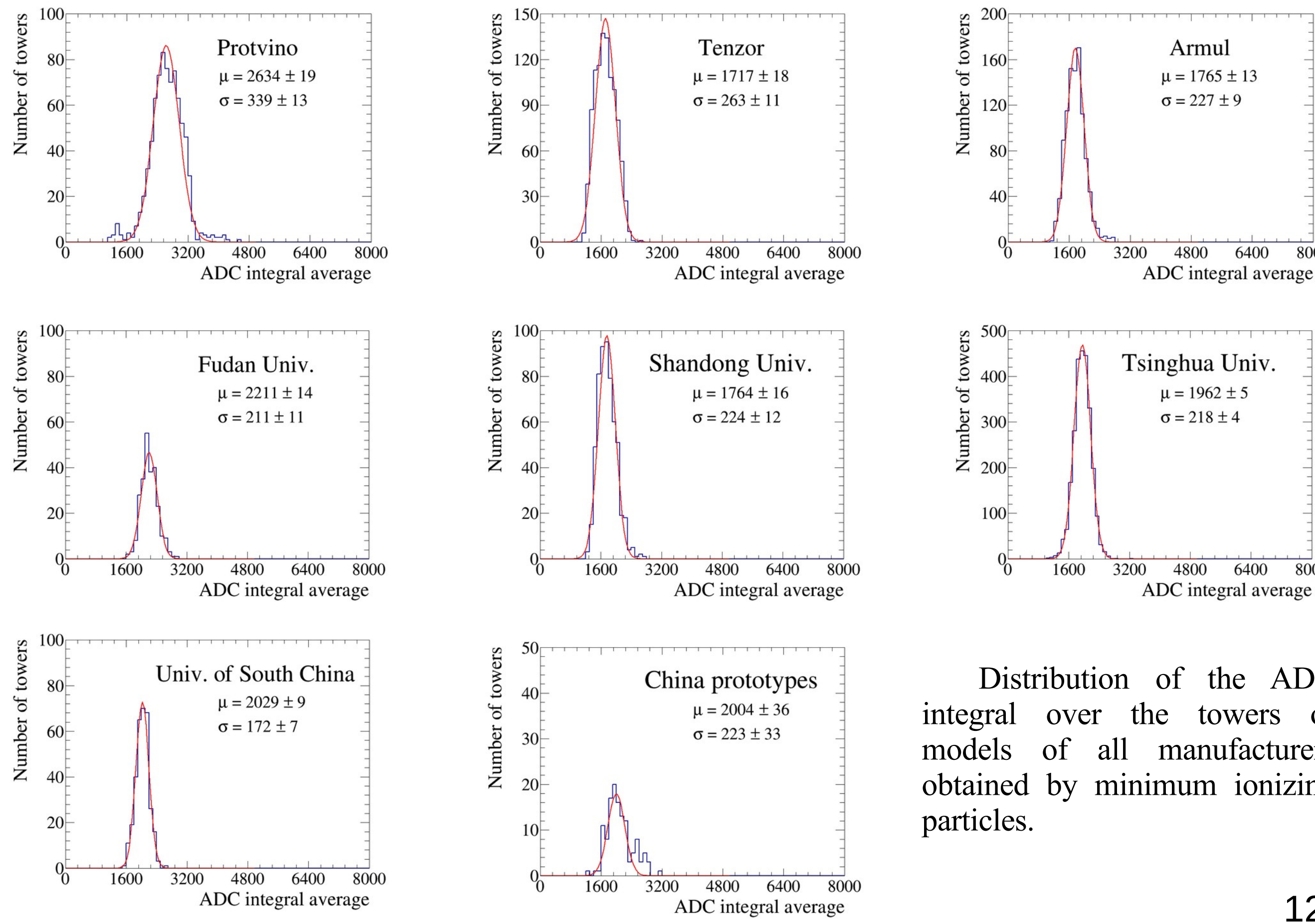
The time resolution of the MRPC together with the electronics is ≈ 69 ps. This is somewhat worse than the declared characteristics of the TOF system due to experimental data collected using cosmic rays with a wide range of momenta.





Current ECal status

At the moment we have 1600 modules out of 2400 for the electromagnetic calorimeter. Of these, 1600 modules together with 600 HV boards have been tested and calibrated. The remaining 800 modules will be produced in Russia and China. During the transportation of modules or during their operation, fiber optics were damaged, cracked or completely broken. This leads to a deterioration in the amount of light received at the photodetectors. Such problems were solved by gluing the break points, if possible, or by completely replacing the fiber bundles on the towers. Problems related to the violation of the geometric parameters of the modules were rare. As a result, all modules are operational, but differ slightly from each other within the acceptable range. Figure shows the light output distributions of all tested modules obtained using cosmic MIPs. 27 half-sectors are assembled, 8 of them have HV boards.



Distribution of the ADC integral over the towers of models of all manufacturers obtained by minimum ionizing particles.

Thank you for your attention.