Development of a Luminosity Detector for NICA MPD

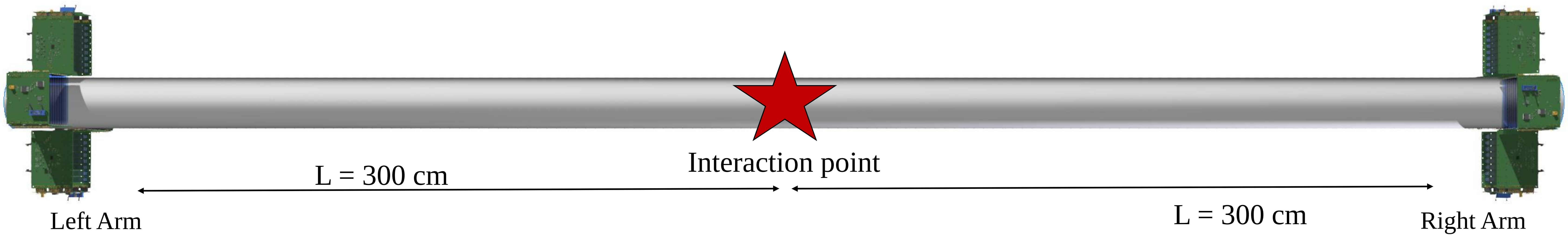
Mikhail Buryakov*, Sviatoslav Buzin, Genadii Milnov, Petar Dulov

Joint Institute for Nuclear Research

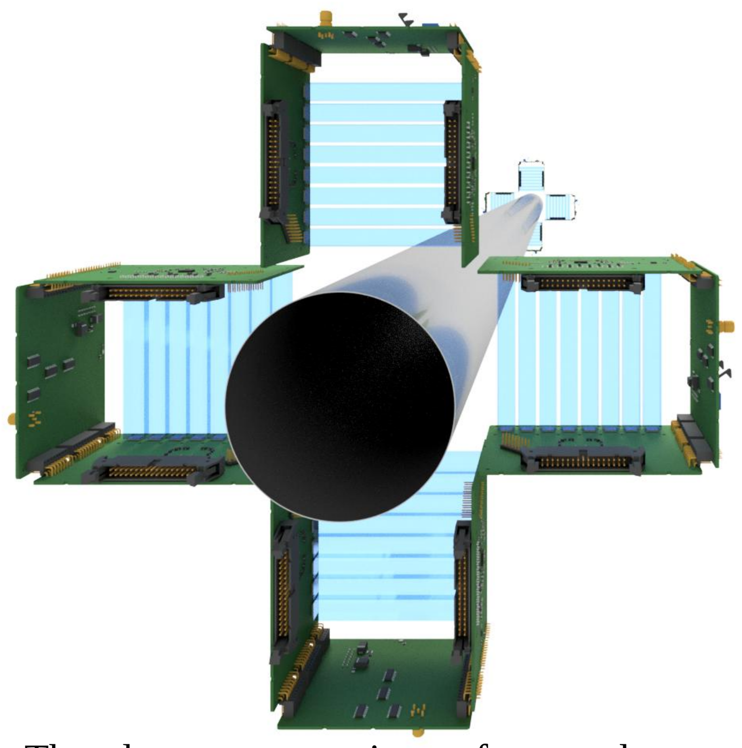
61th Meeting of the Programme Advisory Committee for Particle Physics, 2025

Abstract

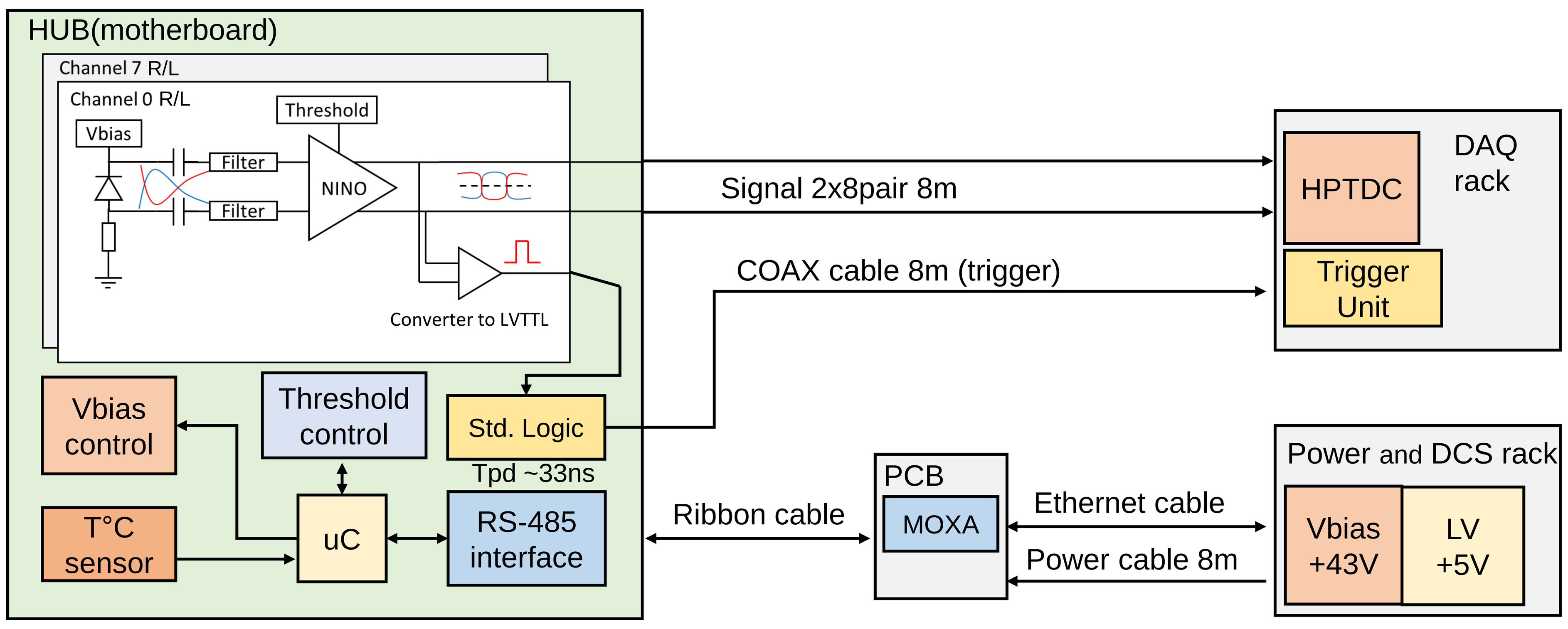
A luminosity detector (BMO) has been developed for the initial commissioning of the NICA collider at JINR, designed to efficiently register events during collisions of light nuclei bunches. Luminosity, a key parameter for particle colliders, is particularly challenging to measure accurately in hadron colliders. The detector supports beam alignment and luminosity monitoring at the MPD interaction point [1], enabling the control of the transverse beam profile and relative beam positions. Custom electronics based on NINO ASIC [2] were developed. Signals are transmitted to an HPTDC-based [3] DAQ via LVDS cables. Developed and tested detector demonstrates robust performance for luminosity measurements.

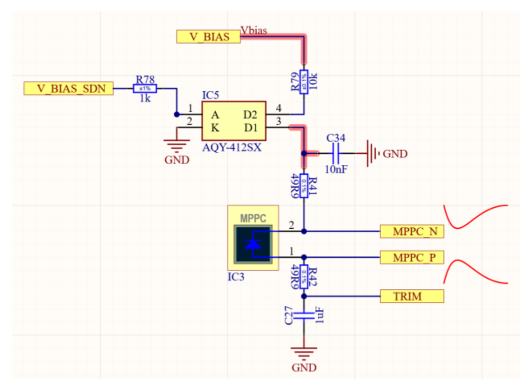


Introduction

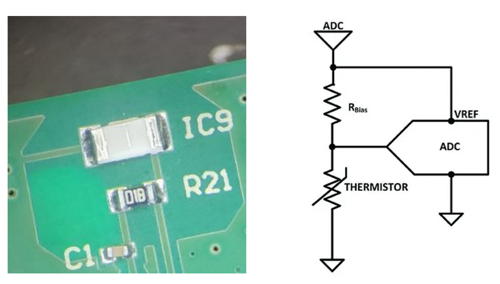


The detector comprises of two planes located 300 cm from the interaction point. Each plane collects data from four modules, each containing eight 10×10×95 mm³ scintillator bars (organic polystyrene with the addition of 1.5% p-terphenyl and 0.05% POPOP) with Hamamatsu S14160-6050HS SiPM at the edges.



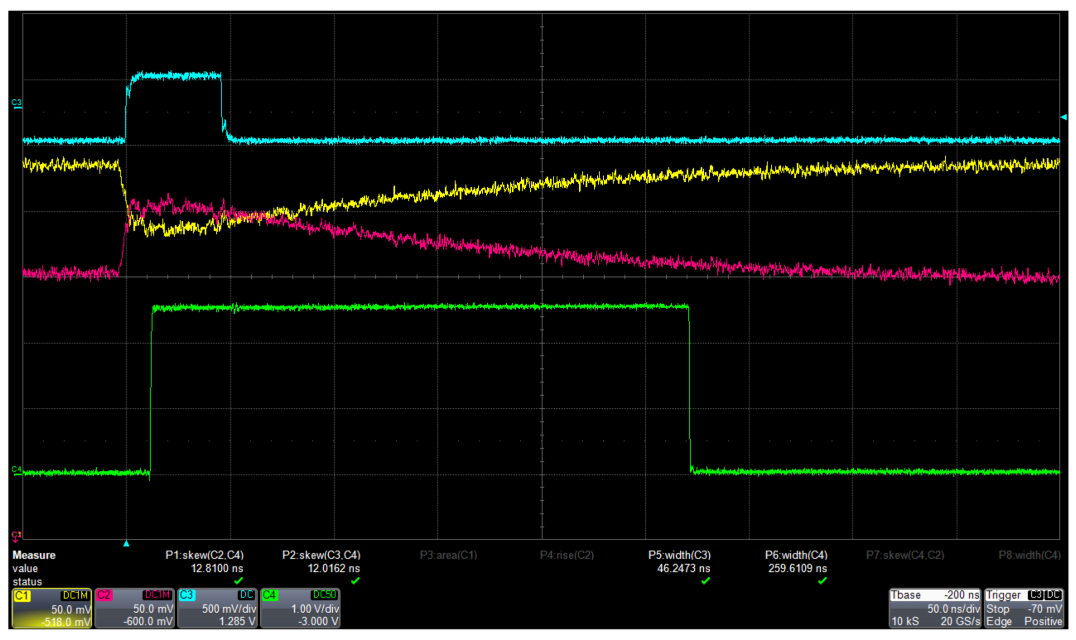


Biasing and readout circuits of SiPM

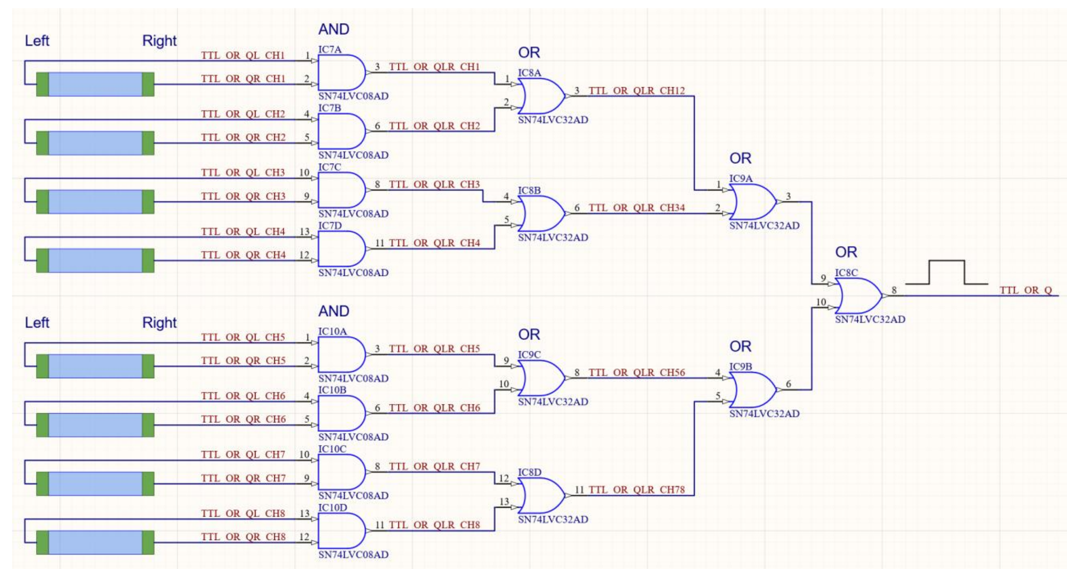


Temperature sensor connection and layout

An important part of the detector system is the moving system, which allows the detectors to be positioned at a distance of up to 130 mm perpendicular to the ion channel with a discrete step of 30 µm. The movement of the detectors is carried out with NEMA 11 type stepper motors, which drive a carriage moving along a guide rail through a screw gear (T-type trapezoidal helical sliding table, model T06). Expected to be used outside the MPD.



Yellow (C1) and Red (C2) – signals from SiPM; Blue (C3) – LVDS output from discriminator; Green (C4) – Trigger output.



The standard logic arrangement in the module.

Structure of the Detector Module:
- Composed of three printed circuit boards.
- Two boards, arranged mirror-symmetrically, contain the readout electronics (SiPM and ToT discriminator) and HUB board.

HUB Board Functions:
- Distributes power across the system.
- Generates logical signals when at least one scintillation bar is triggered.

Outputs:
- 16 LVDS outputs.
- 1 LVTTL trigger output.

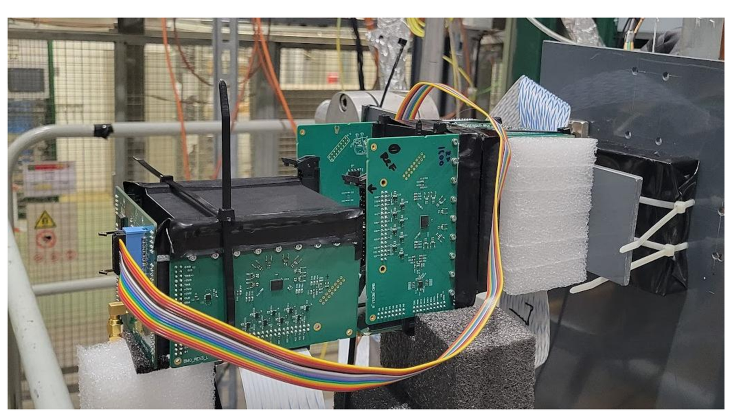
Signal Processing:
- Signals from SiPMs are read-out differentially by NINO ASIC discriminator via decoupling capacitors and filters.
- Discriminator outputs (LVDS standard) are transmitted through 8-meter differential cables to a DAQ system rack with TDC64VLE [4] time-to-digital converters based on HPTDC (25 ps resolution).

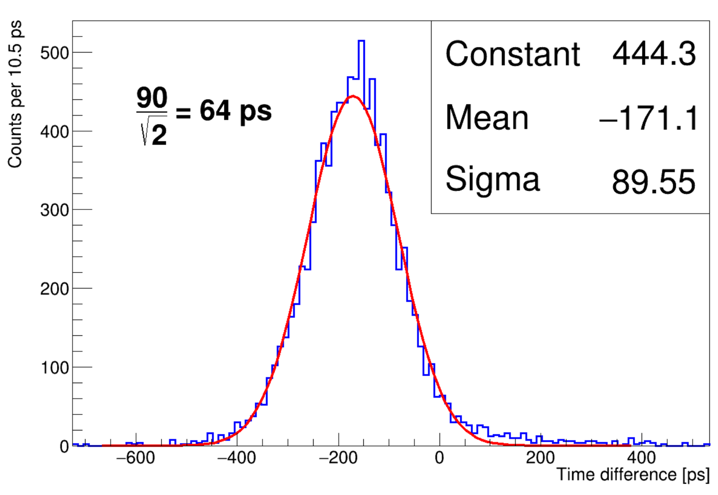
Logical Signal Formation:
- LVDS-to-LVTTL level converters are used on each signal bus output.
- Logical signals are processed with "AND" and "OR" circuits on the HUB board.
- Time from flash detection to trigger signal generation: **33 ns**.

Control and Communication:
- Discriminator thresholds and SiPM bias voltage are managed via the HUB board using an STM8L microcontroller, discrete DACs, and an external temperature sensor.
- Communication is conducted through an RS-485 interface in half-duplex mode.

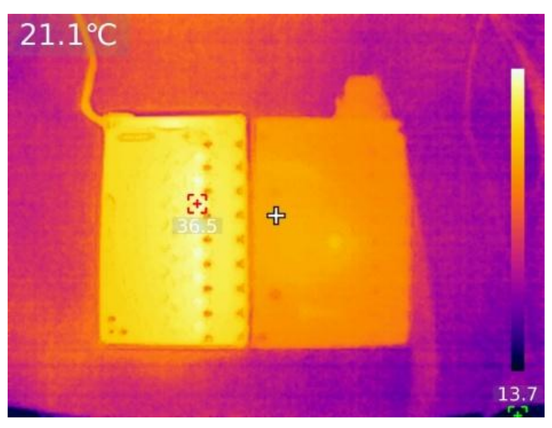
Power Consumption:
- Less than **1.6 W** (+5 V × 0.32 A).
- Vbias for SiPM +43V × 50 uA (0-3V adj.)

Results

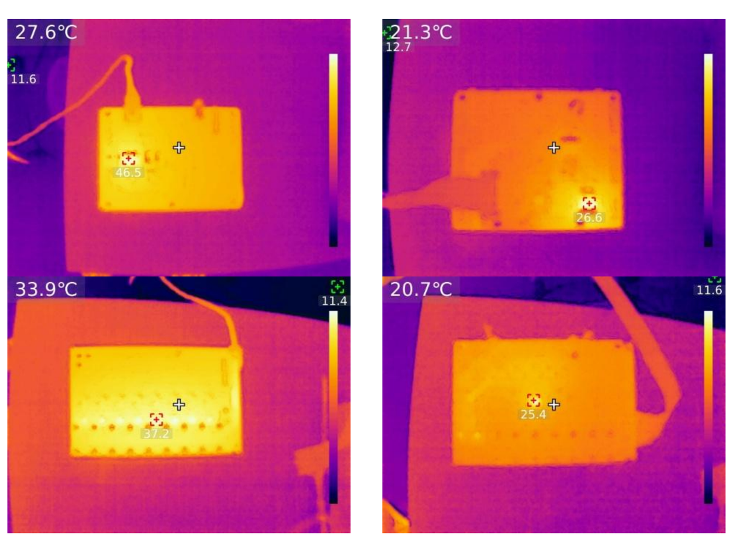




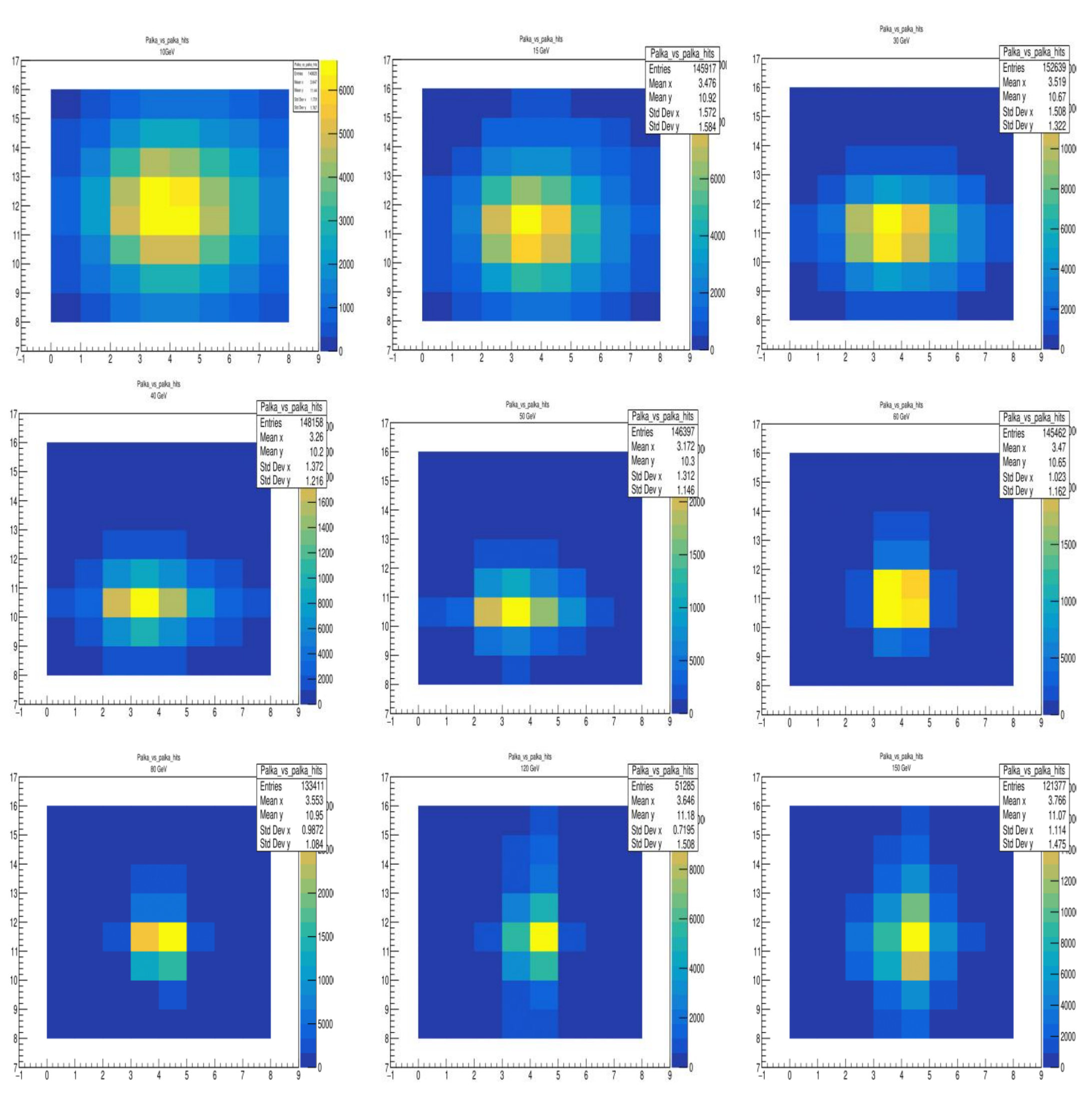
Time resolution was achieved from distribution of time difference between two bars of scintillators. Time was taken as average time from left and right SiPM.



Discrete components were replaced with ASIC, which reduced power dissipation by four times while maintaining performance.



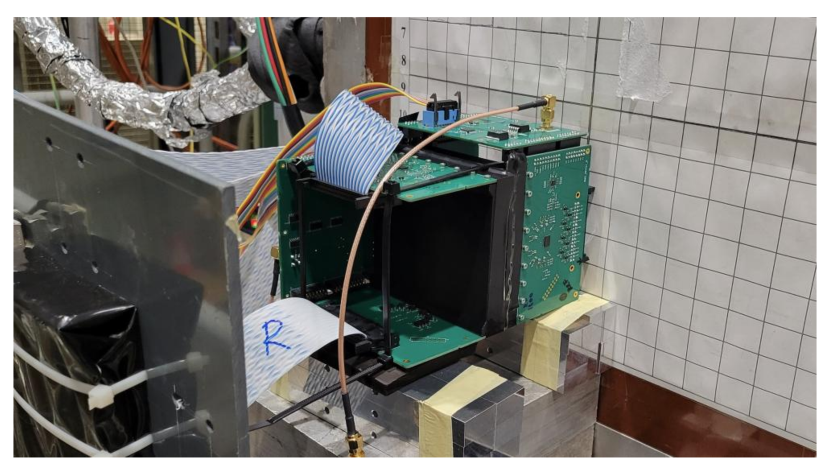
Rev.2 = 6,6W => Rev.3.1 = 1,6W



Reconstructed beam profiles for different energies

Achievements

- Time resolution < 64ps
- Efficiency ~ 99%
- Tdp <1,6W @+5V



BMO module was tuned and tested on H2 beam SPS CERN [5]. It was used as trigger and beam profilers for prototype of ALICE PHOS [6] calorimeter. During this test BMO worked at wide range of particle energy (from 10 GeV to 150 GeV). All systems worked as predicted.

References

[1] K. O.S. “Topical Problems of Beam Dynamics in the NICA Collider”. In: Physics of Particles and Nuclei 53.5 (Oct. 2022), pp. 1021–1049. DOI: 10.1134/S1063779622050057.

[2] F. Anghinolfi. “NINO: an ultra-fast and low-power front-end amplifier/discriminator ASIC designed for the multigap resistive plate chamber”. In: NIM in Physics Research 533.1 (2004), pp. 183–187. DOI: https://doi.org/10.1016/j.nima.2004.07.024.

[3] J. Christiansen. HPTDC High Performance Time to Digital Converter. Tech. rep. Version 2.2 for HPTDC version 1.3. Geneva: CERN, 2004.

[4] A. Electronics. AFI Electronics website. URL:https://afi.jinr.ru/.

[5] Lucie Linssen “Overview on CERN Test Beam Facilities”. In: (2009).

[6] H. Torii and (. A.-P. Collaborations). “The ALICE PHOS calorimeter”. In: Journal of Physics: Conference Series 160.1 (Apr. 2009), p. 012045. DOI: 10.1088/1742-6596/160/1/012045.