



Commissioning of new FHCAL at BM@N experiment

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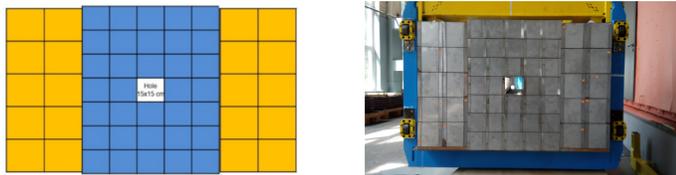
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The BM@N (Baryonic Matter at Nuclotron) is the fixed target experiment at NICA-Nuclotron (JINR, Dubna, Russia) accelerator complex. The main goal of the experiment is studying the properties of dense nuclear matter produced in ion-ion collisions. New Forward Hadron Calorimeter (FHCAL) with modular structure and a beam hole in the center has been developed and constructed to measure the collision centrality after the BM@N upgrade. The transverse and longitudinal segmentation of the FHCAL allows to perform calibration of the calorimeter with cosmic muons.

FHCAL modules have lead/scintillator sampling structure with longitudinal segmentation. Light signals from the sections are collected with MPPCs, amplified and read-out by ADC boards. Fast analog signals are collected for trigger system.

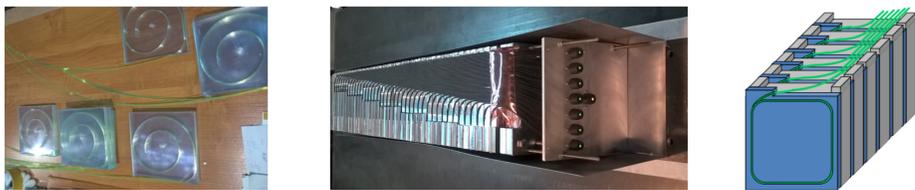
The status of development and construction of the new FHCAL calorimeter for the BM@N experiment will be presented. Performance of FHCAL front-end and readout systems will be discussed.

Modular composition



FHCAL was assembled and installed at the BM@N in 2019. It consists of 54 modules of two types and has a 15x15 cm² square beam hole in the center. 34 smaller modules have transverse size of 15x15 cm² and are identical to ones used in future NICA/MPD[1] experiment. 20 larger modules are 20x20 cm² and were designed for CBM experiment. Larger modules are placed on top of 2.5 cm thick steel support plates.

Module's internal structure

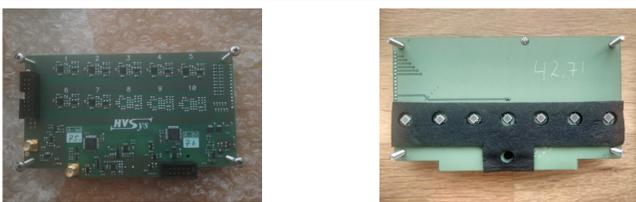


FHCAL modules contain interposed lead and scintillator plates compressed together by a steel band. Lead degrader plates are 16 mm thick. Scintillator tiles are 4 mm thick polystyrene-based plastic scintillators produced by Uniplast (Vladimir, Russia). They are wrapped in Tyvek reflector. Light is collected by wavelength shifting optical fiber. The fibers are glued into grooves in the scintillator plates. In the 20x20 cm² modules the grooves are circular, while in the 15x15 cm² modules the grooves are spiral and the end of the fiber is coated in reflective paint. Outside of the tiles fibers are optically shielded.

Every 6 consecutive scintillator tiles are combined into a section with one optical connector for a photodetector. Smaller modules have 7 of these sections, while larger modules have 10. Additional optical connector is used to propagate LED flash for photodetector calibration to all section optical connectors.

Modules are covered by spot-welded stainless steel cases.

Front-End Electronics



A Front-End Electronics assembly is mounted on every module. FEE consists of two PCBs. One board has 7 or 10 Hamamatsu MPPC photodetectors, a temperature sensor and is mounted on an aluminum heat sink. The other board contains signal preamplifiers with differential ADC driver output, individually adjustable voltage regulation circuits for the photodetectors, LED flash generation circuit with synchronization input and analog sum signal output. FEE boards are remotely controlled via HVSys System Module, which also supplies power. They were manufactured in JINR (Dubna, Russia).

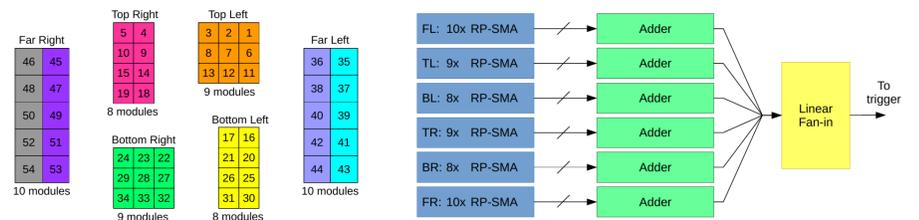
ADCs and data readout



46	45	5	4	3	2	1	36	35
48	47	10	9	8	7	6	38	37
50	49	15	14	13	12	11	40	39
52	51	19	18	17	16		42	41
54	53	24	23	22	21	20	44	43
		29	28	27	26	25		
		34	33	32	31	30		

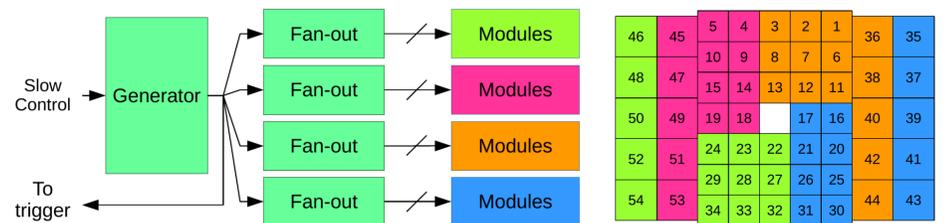
FHCAL uses eight ADC64s2[2] boards produced at JINR (Dubna, Russia) for signal readout. They are 64 channel 12 bit ADCs with sampling rate of 62.5 MS/s and memory depth of up to 1024 points per event. ADC64s2 has Lemo connectors for trigger and XOff signals, is capable of time synchronization via White Rabbit network, provides per-channel zero suppression function with adjustable threshold and can operate in self-triggered or externally triggered modes. FHCAL ADCs are fully integrated into the BM@N data acquisition system which provides trigger signals, busy logic, White Rabbit network and data readout connections. Power for FHCAL ADCs is supplied by a remotely controlled Wiener crate. FEE assemblies are connected to the ADCs by twisted pair ribbon cables via adapter boards with one ADC reading up to 9 7-section modules or up to 6 10-channel modules.

Analog trigger



Custom 12 channel analog sum modules were produced at JINR (Dubna, Russia) for the FHCAL. These adders have individually adjustable channel attenuation and are powered by an HVSys System Module. Six modules are connected to the FEE assemblies, one more adder acts as a second stage linear fan-in to produce total FHCAL response signal. For standalone runs and cosmic calibration this signal was connected to the BM@N DAQ system via a discriminator. This setup can be easily reconfigured for integration into the BM@N trigger system.

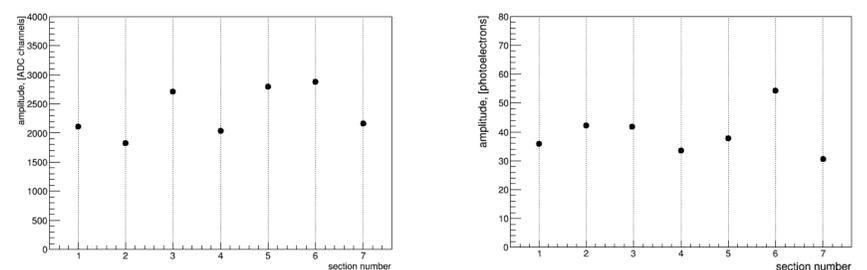
LED flash calibration



Custom LED flash synchronization modules with 16 outputs were produced at JINR (Dubna, Russia). One module has an MCU controlled from HVSys System Module and can generate logical NIM synchronization with a frequency of up to 1 kHz. Four other modules have an input connector and can propagate these signals. All modules are supplied power from the HVSys System Module.

One output of the generator is connected to the BM@N DAQ system to provide trigger for the LED flash calibration runs. Statistical analysis of data collected for various flash amplitudes allows to estimate the relation between the signal amplitude in ADC counts and number of photoelectrons produced in the MPPC.

Cosmic calibration



Since muon beams are unavailable at the BM@N setup, energy calibration of the FHCAL can only be performed using cosmic particles. Several data taking runs on cosmic muons were conducted. Longitudinal and transverse segmentation of the calorimeter allows for limited track reconstruction[3], which was used to compensate for track length variation in the scintillator tiles due to varying track orientation of the cosmic particles. Energy response values for every calorimeter section were obtained. Using data from LED calibration runs these values were converted to energy response in photoelectrons.

Acknowledgments

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