Conference Paper

The construction and parameters of Forward Hadron Calorimeter (FHCAL) at MPD/NICA

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Abstract

Forward hadron calorimeter (FHCAL) at MPD/NICA experimental setup is intended for the measurements of the geometry of heavy ions collisions, namely, the collision centrality and the orientation of the reaction plane. FHCAL consists of two identical arms placed at the left/right sides from the beam collision point. This is a modular lead-scintillator compensating calorimeter designed to measure the energy distribution of the projectile nuclei fragments (spectators) and forward going particles close to the beam rapidity.

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1. Introduction

Forward hadron calorimeter (FHCAL) is one of the basic detectors of the MPD experimental setup at NICA (Dubna, Russia) [1] together with Time Project Chamber (TPC), Time-Of-Flight (TOF), Electromagnetic Calorimeter (Ecal) and Fast Forward Detector (FD), see Fig.1

The main design requirements to the FHCAL at NICA are (a) sufficient energy resolution to allow for collision centrality determination and (b) granularity in the plane transverse to the beam direction which is needed for the reaction plane reconstruction. The centrality dependence of the energy deposited in the FHCAL is non-monotonous in case of a beam hole in the central module. This is an obvious effect of the acceptance loss for forwardly emitted fragments. As a result, it is not possible to discriminate central and peripheral collisions using FHCAL detected energies alone.

To resolve the ambiguity in centrality determination, an additional information on the angular spectator distribution at the FHCAL surface is used.The subdivision of the calorimeter into two, inner and outer parts (see Fig.1), and the calculation of the energy depositions $\mathbf{E}_{in}$ and $\mathbf{E}_{out}$ separately in these calorimeter parts allows the construction of new observable, energy asymmetry:

$$\mathbf{A}_E = (\mathbf{E}_{in} - \mathbf{E}_{out})/(\mathbf{E}_{in} + \mathbf{E}_{out}).$$

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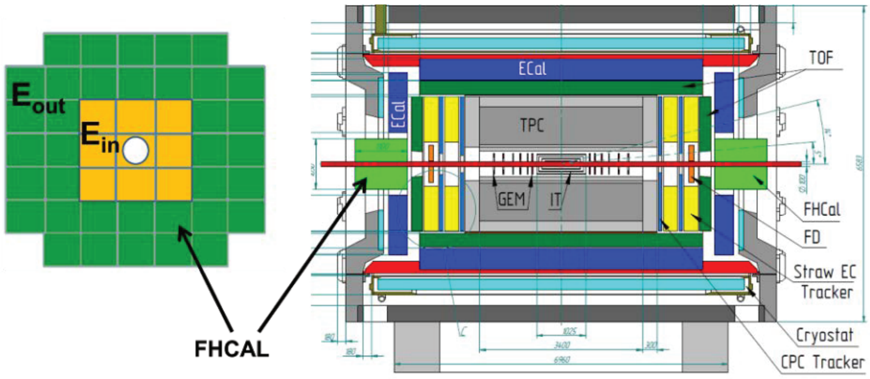

Figure 1: Schematic structure of FHCAL calorimeter (left) and its position in MPD setup (right). FHCAL is subdivided into two, inner and outer parts for the measurements of centrality.

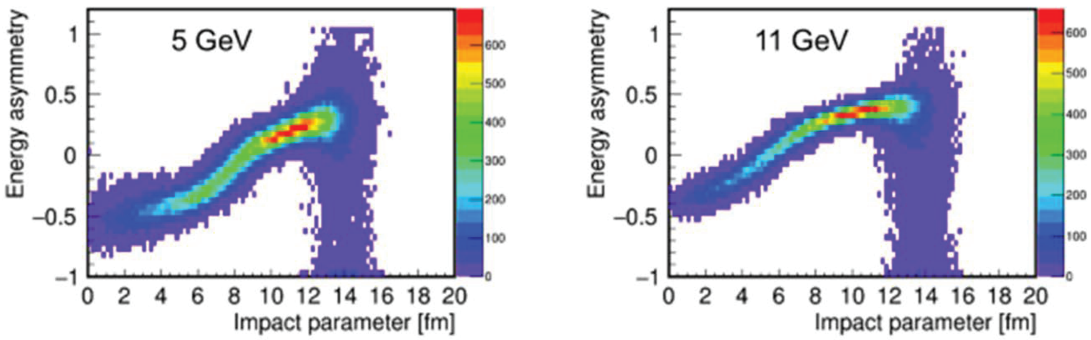

Figure 2: Dependence of the energy asymmetry on impact parameter for two collision energies.

Since the fragments are detected mostly near the beam axis, the energy asymmetry for peripheral events must be maximum, see Fig.2. Taking the two-dimensional correlation between the energy asymmetry, $\mathbf{A}_E$ and full energy deposition in calorimeter one would be possible not only to resolve the ambiguity in the centrality determination but also to improve the centrality resolution for the central events [2].

2. FHCAL module construction

The FHCAL module transverse sizes of 15x15 cm^{2}were chosen to match the size of the hadron showers. Each module of hadron calorimeter consists of 42 lead-scintillator tile sandwiches with the sampling ratio 4 : 1 (thickness of the lead plates and scintillator tiles are 16 and 4 mm, respectively) that satisfies the compensation condition. Light readout is provided by the WLS-fibers embedded in the grooves in scintillator plates that ensures high efficiency and uniformity of light collection over the scintillator tile within a very few percent. WLS-fibers from each 6 consecutive scintillator tiles are collected together and viewed by a single photodetector at the end of the module. The

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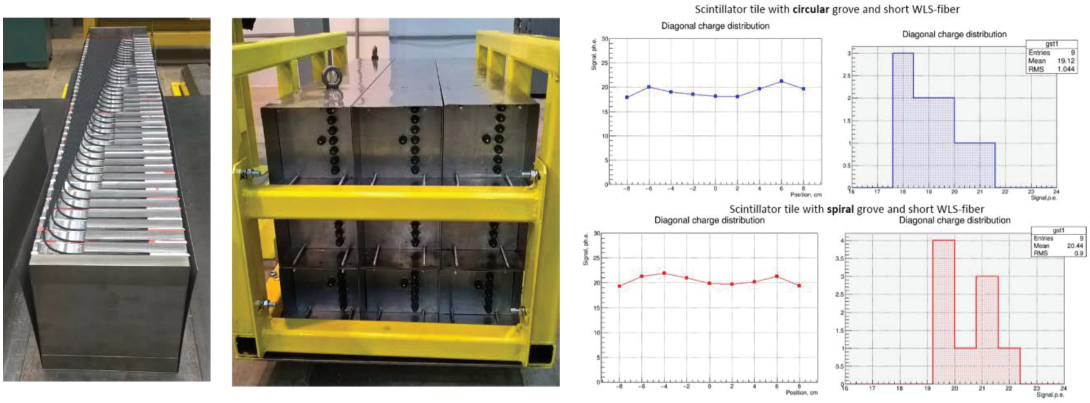

Figure 3: Left – photos of the FHCAL module during the assembling and array of 9 assembled modules. Right – measurements of the light yield along the diagonal of scintillators with different types of the grooves: up – scintillator with circular groove and down – scintillator with spiral groove.

longitudinal segmentation in 7 sections ensures the uniformity of the light collection along the module. The photos of assembled modules are presented in Fig.3 (left).

Longitudinal segmentation of the calorimeter modules requires 7 compact photodetectors coupled to the end of WLS-fibers at the rear side of the module. The use of micropixel avalanche photodiodes, (or silicon photomultipliers, SiPMs) is an optimum choice due to their remarkable properties as high internal gain, compactness, low cost and immunity to the nuclear counter effect and magnetic field.

To optimize the light collection efficiency from the scintillators some R&Ds on the groove shapes were performed. Namely, a few types of the scintillator tiles were produced with circular and spiral grooves. The tests of all tiles were performed with electron ^{90}Sr -source and trigger counter below the scintillator tile to detect the electrons passed through the scintillator. The outer end of WLS fiber was glued into special optical connector that was viewed by Hamamatsu MPPC. The measurements of the light amplitude were done with the step of 2 cm along the diagonal of the scintillator.

The results of measurements are shown in Fig.3, right. One can see, that both, circular and spiral grooves give similar results with the light yield of about 20 photoelectrons with 5% average space nonuniformity in the light collection. The spiral grooves provide slightly better parameters and were selected for the final design of FHCal modules.

3. Calibration of FHCAL modules with cosmic muons

The individual calibration of longitudinal sections is essential for the monitoring of the light yield behavior. After the module assembling, the light yield of all longitudinal sections was measured by using the cosmic muons crossing all 7 sections in single module. Nevertheless, the low statistics of horizontal muons initiated the selection

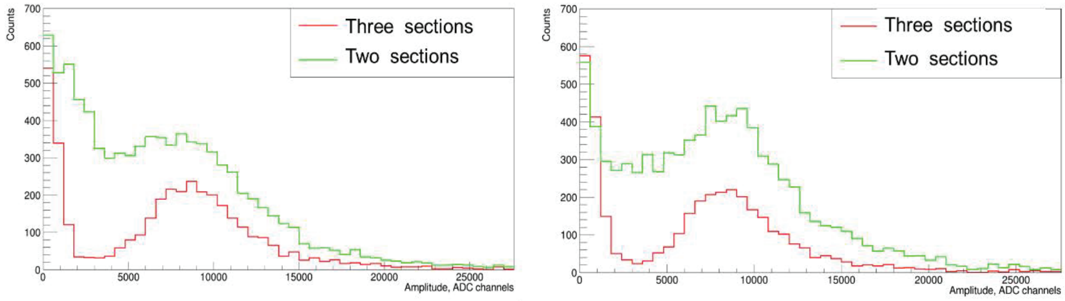

Figure 4: Amplitude spectra for the events with muons crossed two (green lines) or three neighbor sections (red lines) in module. Left and right pictures correspond to different longitudinal sections in module.

of other events with muons crossed two or three neighbor sections in module. The amplitude spectra for these two groups of events are shown in Fig.4. One can see, that the peaks are more visible in case of muon cross three sections because the pass lengths of muon in the scintillator tiles are less spread.

Light yield distribution in the longitudinal sections of FHCAL module for the muons crossed all (horizontal) or three neighbor sections in module is shown in Fig.5. As seen, muon deposits of about 50 photoelectrons/section. Horizontal muons deposit in each longitudinal section about 5 MeV of visible energy. Therefore, the normalized light yield of FHCAL corresponds to about 10 photoelectrons/MeV.

High light yield makes possible the energy calibration of the FHCAL modules with the cosmic muons during the calorimeter operation in MPD setup.

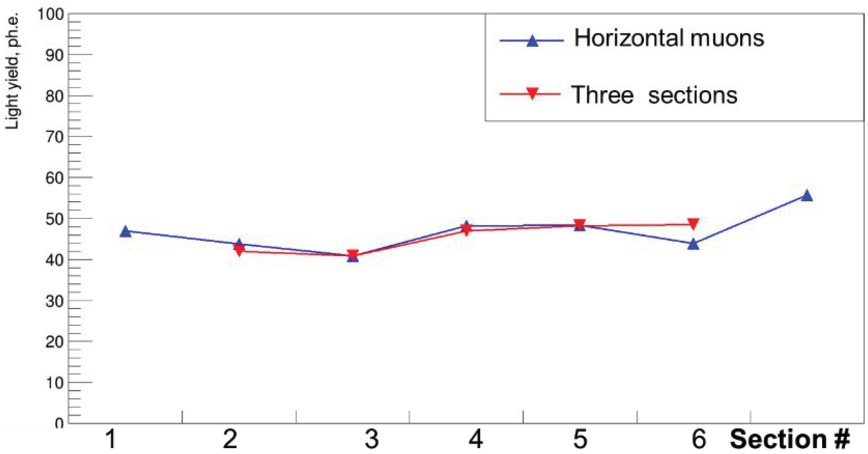

Figure 5: Light yield distribution (photoelectrons) in the longitudinal sections of FHCAL module for the muons crossed all sections (horizontal muons) or three neighbor sections in module.

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4. Conclusions

FHCAL is a key detector for the determination of the collision geometry at MPD/NICA. It has fine segmentation in both transverse and longitudinal directions. The FHCAL modules have 7 longitudinal sections with full length of about 4 interaction lengths. That is enough for the detection of the spectators with energies up to 6 GeV. The procedure of the energy calibration of the modules with cosmic muons was elaborated. The light yield of each longitudinal section is about 50 photoelectrons per minimum ionizing particle or 10 photoelectrons/MeV for visible energy.

References

[1] http://nica.jinr.ru

[2] M Golubeva et al., 2017, J. Phys.: Conf. Ser. 798 012074