Journal of Physics: Conference Series **1390** (2020) 012112 doi:10.1088/1742-6596/1390/1/012112

Studies of the Electromagnetic Calorimeter with projective geometry for the MPD/NICA

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Abstract. A projective geometry description of the MPD Electromagnetic Calorimeter (ECal) has been developed and implemented within the MpdRoot software framework. Using this package, characteristics of the detector were studied by Monte Carlo methods. Information about energy and spatial resolution as well as registration efficiency was obtained for different clustering procedures. One module of the detector, developed at JINR, was tested using electron beam at DESY. Energy scan for this prototype was carried out to estimate detector linearity. Results of the simulations and beam tests are presented.

1. Introduction

The main goal of the MPD/NICA is to study hot and dense baryonic matter. Experiment will be focused on the mixed phase investigation and search for the critical endpoint in heavy ion collisions. Very helpful instrument to study temperature evolution of the system from the formation time to thermal freeze-out and system sizes of the matter at the early stages, are electromagnetic probes. Electromagnetic calorimeter is going to measure the spatial position and energy of electrons and photons produced in heavy ion collisions [1].

2. ECal in MPD/NICA

2.1. The main tasks of ECal

One of the main tasks of the ECal in the MPD is to measure energy and spatial position of electrons and photons produced in heavy ion collisions. ECal will also participate in particle identification, measurements of the photons flux and reconstruction of certain decays with participation of the photons [2].

2.2. Basic requirements

To fulfill those tasks the ECal has to meet the following requirements: high segmentation, dense active medium with the small Moli'ere radius, adequate spatial resolution, small shower overlaps, the particle occupancy below 5%. The calorimeter must be able to operate in the magnetic field up to 0.5 T, time resolution should be at least below 1 ns.

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A heterogeneous calorimeter of the "Shashlik" type was chosen to satisfy these requirements. The calorimeter consists of active medium (scintillator) and absorber (lead), the light will be collected with the help of wavelength shifting (WLS) fibers [3].

3. ECal geometry

3.1. Design

ECal geometry will be projective in both planes: ϕ and θ. The basic unit of the ECal will be a tower with a transverse size of 4x4 cm^2 (Figure 1). Every tower will be shaped in ϕ and θ planes depending on its location in the ECal barrel. The tower consists ot 220 layers of lead (0.3 mm) and scintillatior (1.5 mm) plates. Total number of the towers is 43008 in the barrel part of the calorimeter. Sixteen towers (2 rows along ϕ and 8 towers along θ - Figure 2) are assembled into one module. Such a segmentation is not fundamentally important, this configuration was selected for easier organization of the electronics readout and ECal assembling [2, 3].

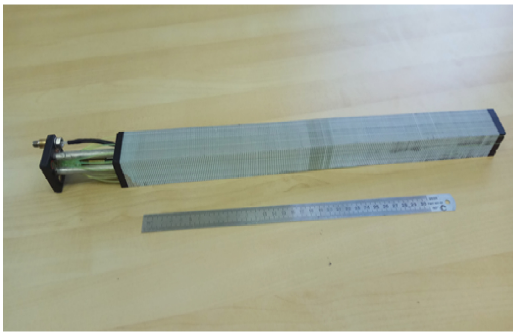

Figure 1. One ECal tower before cuts.

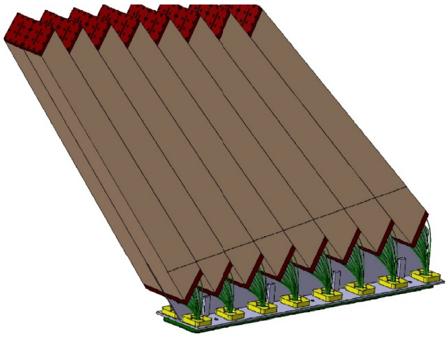

Figure 2. One module.

3.2. ECal geometry implemented in the MpdRoot

The ECal consists of two Chambers (at positive and negative Z-positions). Each Chamber consist of 8 sectors in ϕ direction (two of them with 24 towers and six of them with 48 towers - Figure 3). Every row in the sector is composed of 64 towers in θ direction (Figure 4). Each tower is fixed by two Kapton plates on top and bottom of the unit.

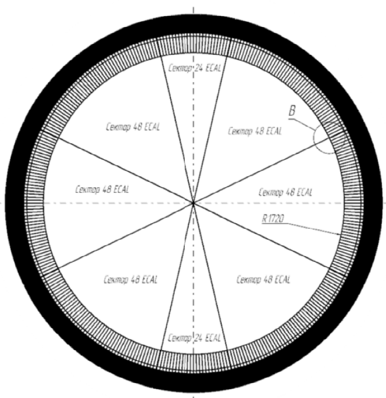

Figure 3. The ϕ plane of the ECal.

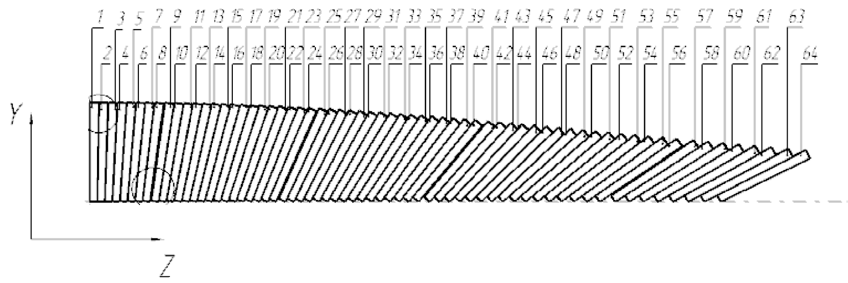

Figure 4. ECal sketch in the Z plane.

4. MC studies of the ECal with clustering algorithms

Two independent methods of digitization and clusterization were invented. They differ in the way how the points are collected. Both clustering methods take a hit with maximum energy deposition as a starting one, but one of them - ITEP method, creates a cluster using a fixed-size frame around this hit, while the second - AZ method, combines all hits which have a common border.

These two algorithms were tested by random photons with different energies and polar angles. The magnetic field of 0.5 T was used in the test and the hit threshold was set at 10 MeV.

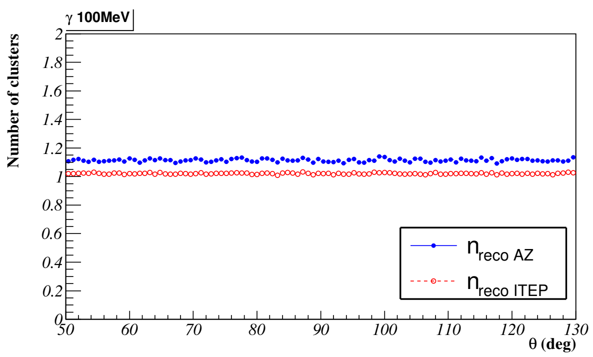

Figure 5. Number of clusters vs polar angle (γ with energy 100 MeV).

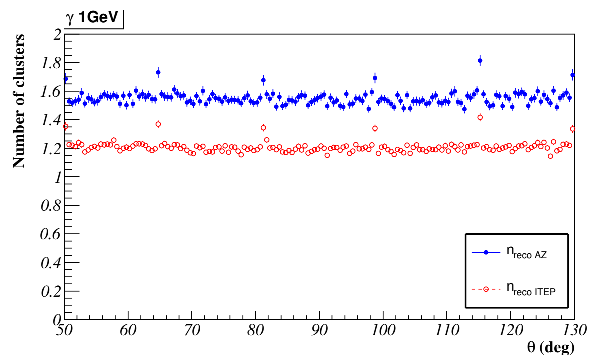

Figure 6. Number of clusters vs polar angle (γ with energy 1 GeV).

In Figures 5, 7, 9 results for 100 MeV photons are shown. Figures 6, 8, 10 present results for 1 GeV photons. In figures 5 and 6 one can see that AZ clustering algorithm finds somewhat more clusters as compared to the ITEP algorithm. Energy measured using the cluster with maximum energy deposition is comparable in the both algorithms (Figures 7 and 8).

Difference in the energy resolution about 2% was observed between ITEP and AZ algorithms for low energy (Figure 9). For 1 GeV photons, energy resolution (Figure 10) is very similar and equals to about 5%.

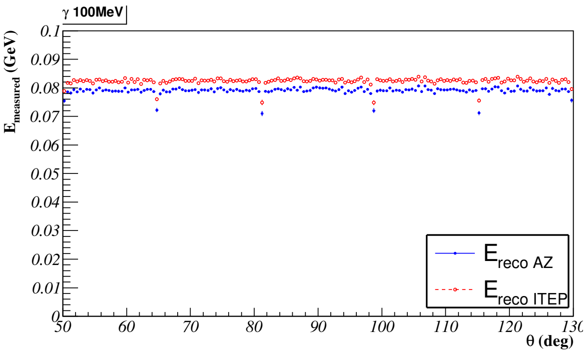

Figure 7. Reconstructed energy vs polar angle (γ with energy 100 MeV).

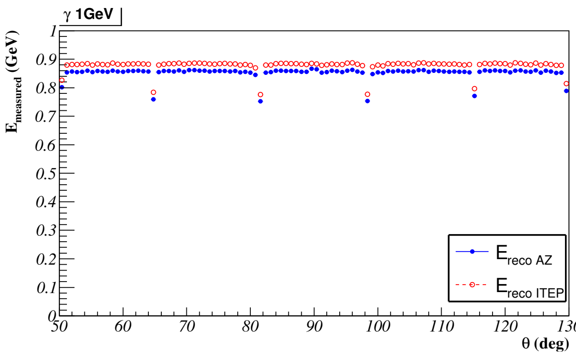

Figure 8. Reconstructed energy vs polar angle (γ with energy 1 GeV).

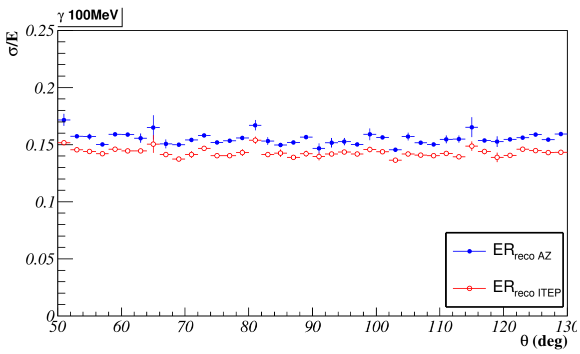

Figure 9. Energy resolution vs polar angle (γ with energy 100 MeV).

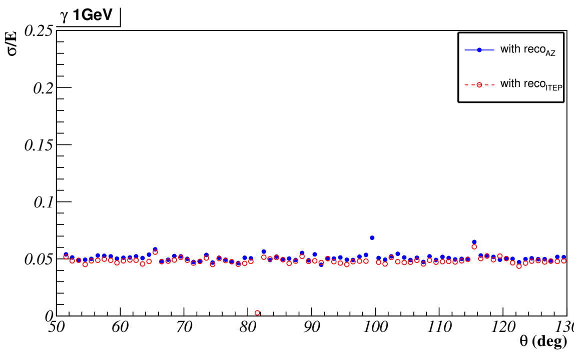

Figure 10. Energy resolution vs polar angle (γ with energy 1 GeV).

5. Beam test of the ECal prototype module

One module (2x8 channels) was produced in Dubna.

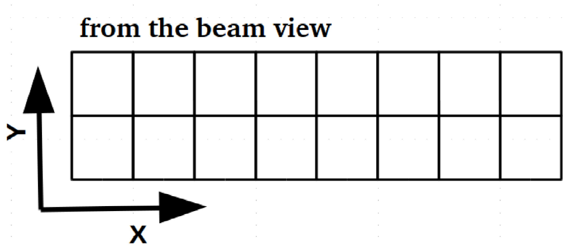

Figure 11. Schema of the module position during the experiment.

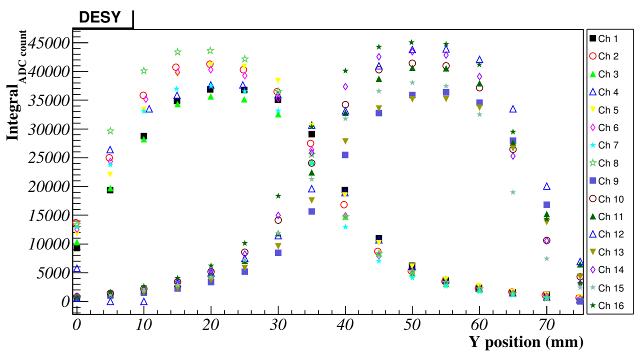

Figure 12. The signal value distribution, for different beam hit positions.

The experiment using electron beam was held in August at DESY. We performed two calibrations: voltage calibration [2] and detector response calibration. We did a scan along Y axis (Figure 11) in 8 X positions (hit in the X center of the channel), to find maximum response of each channel (Figure 12). Using average value from the 16 channels as a reference, we found the correction coefficients for each channel. Figure 13 shows distribution of those coefficients.

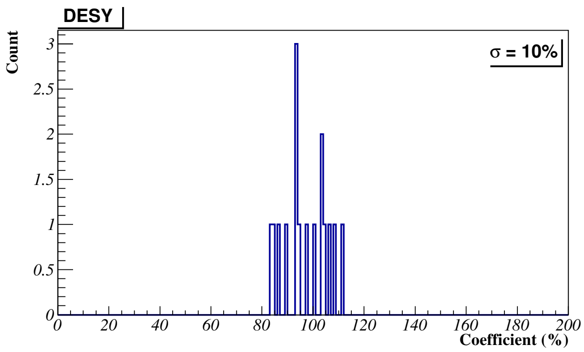

Figure 13. Distribution of the obtained coefficients.

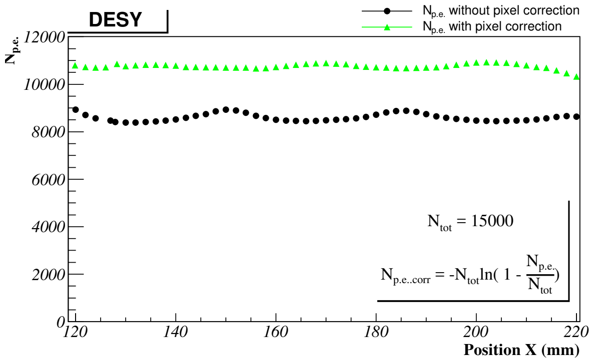

Figure 14. $N_{p.e.}$ from the whole module for different beam hit positions.

Using coefficients obtained for each channel, we did a scan along X axis (sum of all channels), shown in Figure 14. The primary distribution (marked in black) is not flat - peaks corresponds to the beam position between two towers. The photodetector HAMAMATSU [4] is used for light collection and it has a limited number of pixels [2, 3]. The photodetector saturation occurs when there is a large number of registered photoelectrons. This saturation can be described by the formula in Figure 14. After applying pixel correction we reduced this effect, as can be seen in the same Figure, marked in green. In Figure 15 one can see a response of the detector with (marked in black) and without (marked in red) pixel correction. Using this correction we obtained a linear detector response, which was one of our main goals.

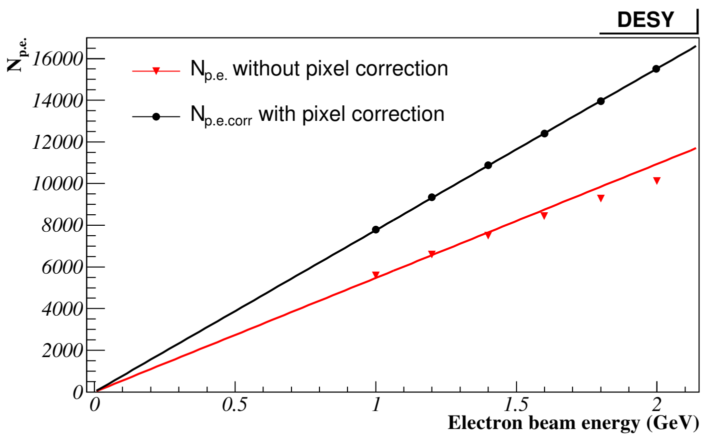

Figure 15. Detector response to the incoming electrons of different energies.

6. Conclusion

The software package for the MPD ECal simulation was created within the MpdRoot software framework with the test results presented above. The AZ and ITEP cluster reconstruction methods were studied and proven to work correctly.

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One module of the ECal produced in Dubna was tested on the electron beam. After pixel correction we got the linearity of the detector response. The results from the new projective module confirmed the expectations.

7. Acknowledgments
This work was supported by the Ministry of Education and Science of the Russian Federation under Contract No.05.615.21.0005 in the framework of the project RFMEFI61518X0007.

8. References
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