

Investigation of the electromagnetic calorimeter response function by cosmic muons

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Abstract. In this work, the passage of cosmic muons in calorimetric modules was simulated. The coefficients for converting signal amplitudes into absorbed energy of a passing particle were obtained. The data collected during the exposure of the electromagnetic calorimeter to cosmic muons were analyzed. The results of the analysis were used to process the experimental data obtained in the interaction of carbon, argon and krypton at 3.5 GeV/nucleon energy with different targets.

1 Introduction

The electromagnetic calorimeter in the BM@N project makes it possible to measure the spatial position and energy of photons and electrons formed in heavy ion collisions. ECal is also important to identify particles due to the high time resolution. In addition, the photon detector will serve to measure the total energy flux, which largely reflects the initial conditions achieved in collisions of heavy ions at NICA. The first step to analyse the events is the search for mesons and subtraction hits associated with hadrons, from the full particles flux. The calculated charged tracks with the corresponding energy deposited in ECal will be identified as tracks e , π , K or p . In order to achieve the required sensitivity in the reconstruction of π^0 in a high photon beam, the photon energies must be measured with high accuracy [1].

To do this, after the accumulated data, it is necessary to analyse and calibrate the calorimeter. Many cells in the ECal are individual devices operating in the same spectrometer. These circumstances require coordination of all recorded signals, i.e. conversion of the recorded signal amplitude into energy units.

2 ECal design

The main element of ECal designs is the calorimetric modules. At the moment 56 modules located in one shoulder of the setup are used (Fig. 1). Each module consists of 9 towers and each tower contains 250 alternating Pb (0.275 mm) and plastic scintillator (1.5 mm) tiles (Fig. 1).

The length of the module having the 18 cm radiation length is about 40 cm. The cells of each tower are optically combined by 9 longitudinally penetrating wavelength shifting fibers for light collection. The light collected with 9 fibers is read out by MAPD units with 3×3 mm² sensitive areas.

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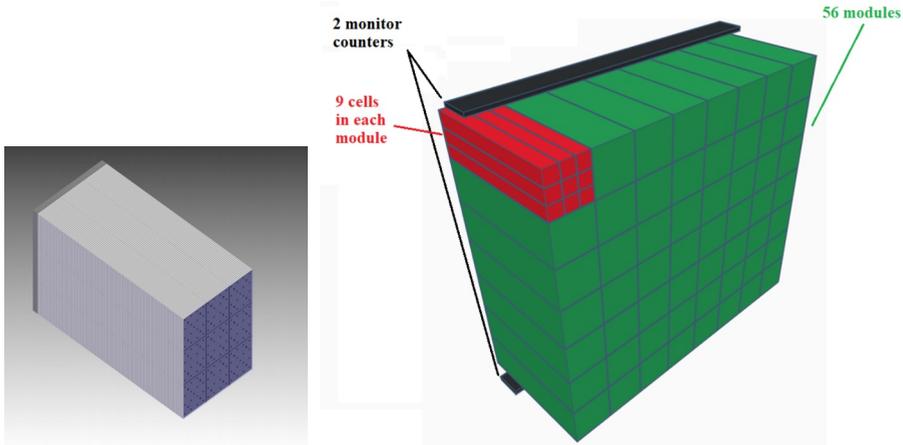


Figure 1: One Ecal module (left) and ECal setup (right)

3 Modeling

To explore the entire calorimetric setup requires a stable high-energy radiation source. This source is cosmic muons (intensity ~ 120 particles per second per m^2), which have the same energy release in the cells of the calorimeter during the passage of the particle, because the free path of the muons reaches several meters with slightly energy losses.

Before working with real data from cosmic muons, a simulation of the passage of cosmic muons through the ECal was carried out.

The simulation allows one to estimate the thickness of the muon path length in the volume of the electromagnetic module. Therefore, knowing the thickness of the path length, it is possible to determine the energy released by the particle. In the simulation it is assumed that the particle passes one of three paths at different angles (Fig. 2). The left part of Fig. 2 shows the filling of the electromagnetic calorimeter with space muons.

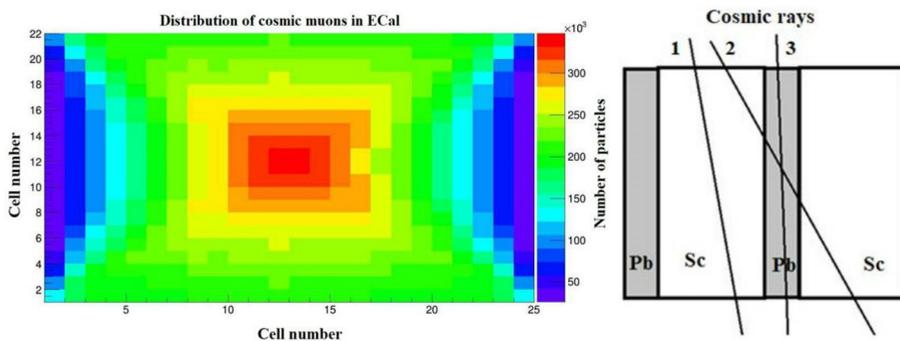


Figure 2: Distribution of cosmic muons in ECal (left) and muons paths (right)

Then for each cell, the dependence of the effective thickness of the scintillator on the ECal cell number during cross-scanning of cells by cosmic muons was obtained (Fig. 3).

As a result of the simulation, we obtain the energy spectrum of the average losses for all cells of the electromagnetic calorimeter, which can be used to recalculate the amplitude of

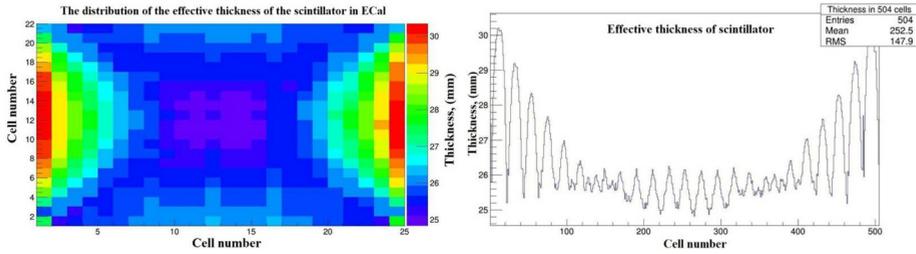


Figure 3: Effective thickness scintillator in 2d plot (left) and 1d plot (right)

the output signal (Fig. 4). The formula for calculating the energy is as follows:

$$E = \frac{dE}{dx} * \rho * d,$$

where ρ is the density of the material, d is the thickness of the scintillator.

The density of the applied lead is 1.032 g/cm^3 , specific energy losses are equal to 1.936 MeV/g/cm^2 .

To apply the simulation results to the real data, it is possible to obtain signal amplitude conversion coefficients for each cell of the calorimeter.

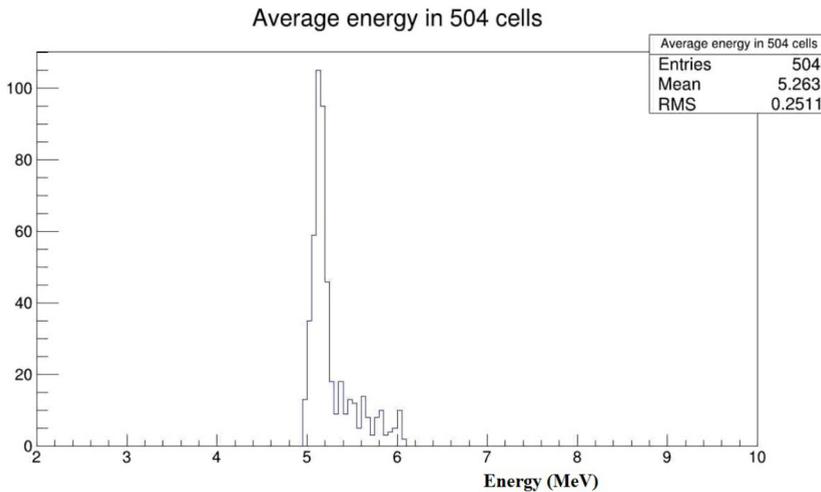


Figure 4: Average energy of cosmic muons in ECal

4 Data analysis of the cosmic muons

ECAL monitoring system based on cross-scanning of cells by cosmic rays. The four-fold coincidence of signals from two counters uses as a start-up signal for the front-end electronics of the calorimeter (Fig. 5) [2]. Other events have not been taken into account.

The block diagram of the monitoring system is placed on the calorimeter 8×7 modules (24×21 cells). Cosmic data were obtained at different positions of the monitor counters. At a distance of 80, 160 and 290 mm from the opposite side of the electronics (Fig. 6).

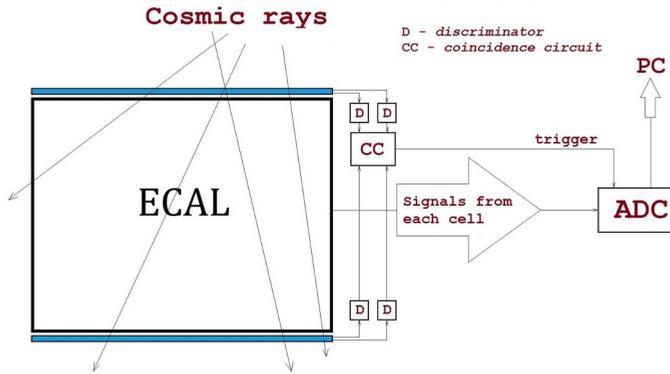


Figure 5: ECal monitoring system

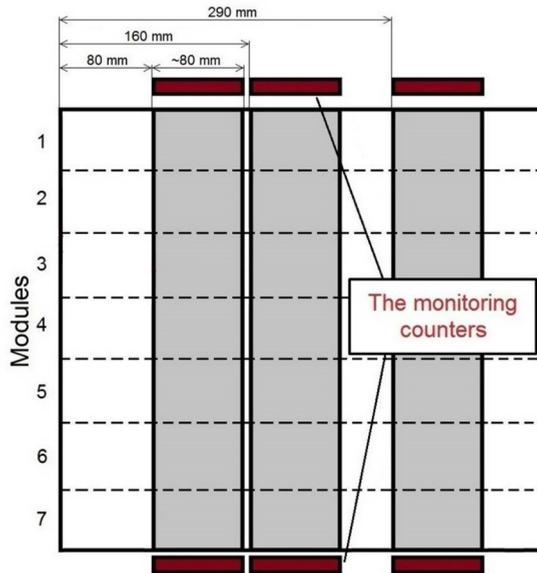


Figure 6: Block diagram of the monitoring system

The area of cosmic muons passing, which corresponds to the maximum energy release of electromagnetic shower, developed in the module of the calorimeter at a distance of 5-6 radiation length (this corresponds to about 12 cm), and occupies about 1-2 radiation length [3]. Three sets of calibration coefficients were obtained (Fig. 7). The light output for the three positions is different. The farther from electronics (Fig. 8) is, the less energy is. The difference of the coefficients between the first and last positions is about 20%.

As a result of this analysis, a correction has been made for the calibration coefficients.

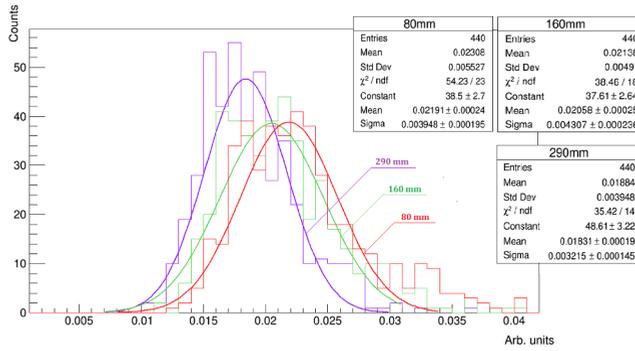


Figure 7: Calibration coefficients with different position of monitoring counters

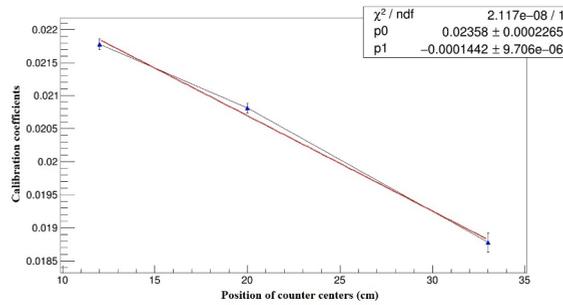


Figure 8: Calibration coefficients in different position of the counters

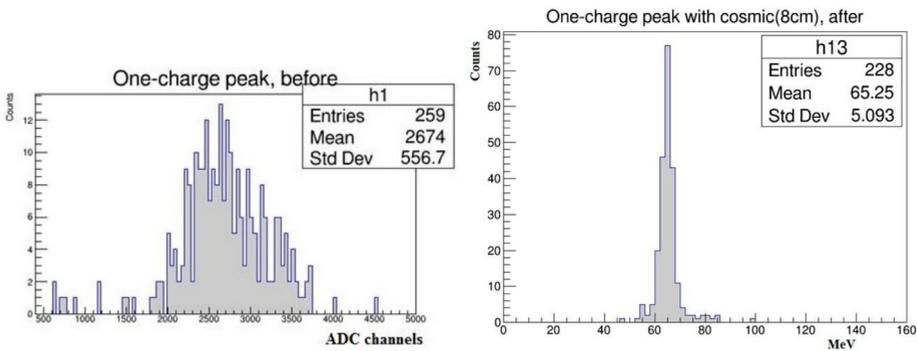


Figure 9: One-charge peak position

5 Calibration of beam data

Calibration on cosmic muons allows one to reconsider the problem with different positions of calorimeter cells in respect to the beam-axis. Fig. 9 shows the result of applying calibration coefficients to the real data of the 55th run of BM@N, with a carbon beam to the MIP signal.

The results of this calibration play an important role in the further reconstruction of π^0 . So, the next step is to reconstruct the pions from the experimental data using an electromagnetic calorimeter.

References

- [1] *The Multi Purpose Detector – MPD*,
http://mpd.jinr.ru/wp-content/uploads/2016/04/MPD_CDR_en.pdf
- [2] *ECAL - BM@N monitoring system with optic light fiber for working in a magnetic field*,
<http://uzmu.phys.msu.ru/file/2018/3/1830204.pdf>
- [3] *Electron Energy Reconstruction in the ATLAS Electromagnetic End-Cap Calorimeter using Calibration Hits*, <http://hepexp.ft.uam.es/atlas/DEA/DEA-Nebot.pdf>