Conference Paper

Tests of the Electromagnetic Calorimeter for HADES Experiment at GSI

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Abstract

Measurements of mass spectra of dilepton pairs in the HADES experiment in the energy domain of SIS18 and SIS100 (FAIR, Darmstadt, Germany) are very important for studing the excitation function of the virtual photon radiation from dense nuclear matter. A detail study of this phenomenon in the intermediate mass region (0.14 < M < 0.6 GeV/c^2) demands precise measurements of inclusive cross sections of π^0 and η-meson production by a new developed electromagnetic calorimeter (ECAL) on the basis of lead-glass Cherenkov detector modules. The ECAL will replace the currently existing HADES Pre-Shower detector, located at forward angles ($18^0 < \theta < 45^0$). An additional advantage of ECAL would be the improvement of the electron/pion separation at larger momenta (p > 400 MeV/c) as compared to the present situation. In this article we briefly present the main details of the detector layout, construction of the lead-glass Cherenkov detector modules and the support structure. The stand for test measurements of ECAL detector modules on cosmic rays is described in details and main results of cosmic test measurements are presented.

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1. Introduction

Results of measurements of dilepton pairs in the HADES experiment in the energy domain of SIS18 and SIS100 (FAIR, Darmstadt, Germany) are obligatory to establish a complete excitation function of the virtual photon radiation from dense nuclear matter. A large excess of the dilepton yield in the intermediate (0.14 < M < 0.6 GeV/c^2) mass region of dielectron pairs was found by the CERES collaboration at the SPS energies of 40 AGeV pointing to a strong source generated from the high density zone of HI collisions [1]. A detailed study of this phenomenon demands a precise knowledge of the hadronic cocktail, which is dominated by the η Dalitz decay. Precise measurements of dielectron spectra given by π^0 decay are also necessary for normalization.

It is proposed to perform precise measurements of inclusive cross sections of π^0 and η-meson production by an electromagnetic calorimeter (ECAL) based on lead-glass Cherenkov detector modules [2, 3]. An additional advantage of ECAL would be the improvement of the electron/pion separation at larger momenta (p > 400 MeV/c) as compared to the present situation. Beam tests have shown that the ECAL energy resolution is (5 − 6)% $E^{-1/2}$. Detailed simulations have determined that this enables the η-meson reconstruction in the forthcoming experiment on Ag+Ag collisions at 1.65 AGeV/c and in future measurements at SIS100 with Ni + Ni collisions at energy range 2 - 8 AGeV.

In this article we briefly present procedures and test results of ECAL detector modules on cosmic rays at GSI (Darmstadt, Germany).

2. High Acceptance DiElectron Spectrometer (HADES)

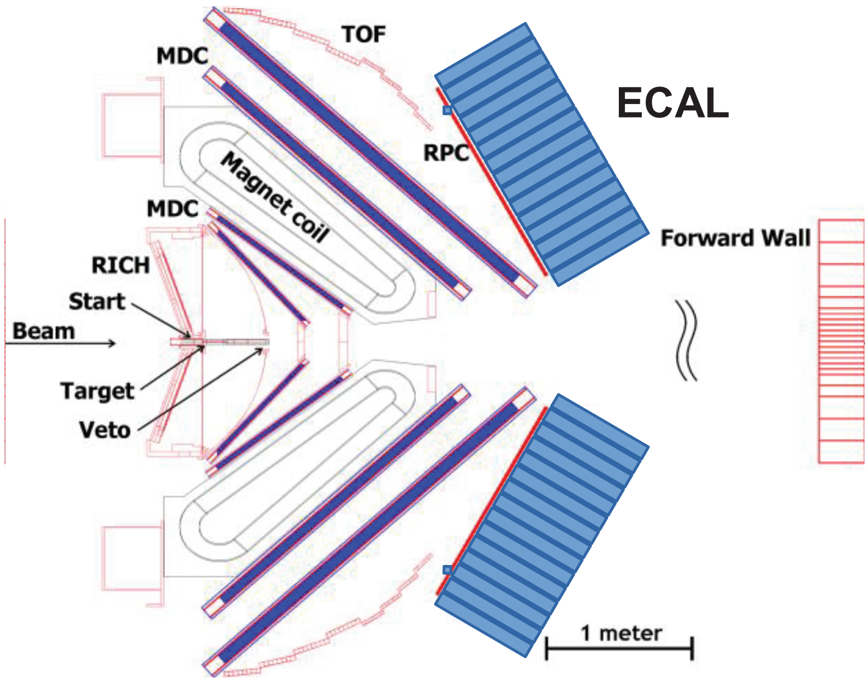

Figure 1: HADES layout.

HADES is multifunctional detector for a precise spectroscopy of electron-positron pairs (dielectrons) and charged hadrons produced in proton, pion and heavy ion reactions in a 1-3.5 GeV beam kinetic energy region. HADES also participates in the FAIR Compressed Baryonic Matter (CBM) experimental program at GSI. The main aim of the HADES experiment, in the framework of the international collaboration, is to measure properties of dense nuclear matter produced in heavy-ion collisions and learn about in-medium hadron properties (masses, decay widths). HADES consists of several main subsystems (see HADES layout in Fig.1):

- a diamond START and VETO system composed of two diamond sensors;
- a Ring Imaging Cherenkov (RICH) detector for the electron identification with the gas radiator and a position-sensitive photon detector covering the full azimuthal range;
- four sets of Multi-wire Drift Chambers (MDC) before and after the Superconducting toroidal magnet allow to reconstruct charged particle momenta with a resolution of 1 %;
- two time-of-flight walls: a scintillator based time-of-flight wall (TOF) at angles above 45^0 and RPC wall built with resistive plate chambers at angles below 45^0 together with ECAL form a multiplicity/electron trigger array. A Forward Wall allows to reconstruct the orientation of the reaction plane.

3. The electromagnetic calorimeter (ECAL)

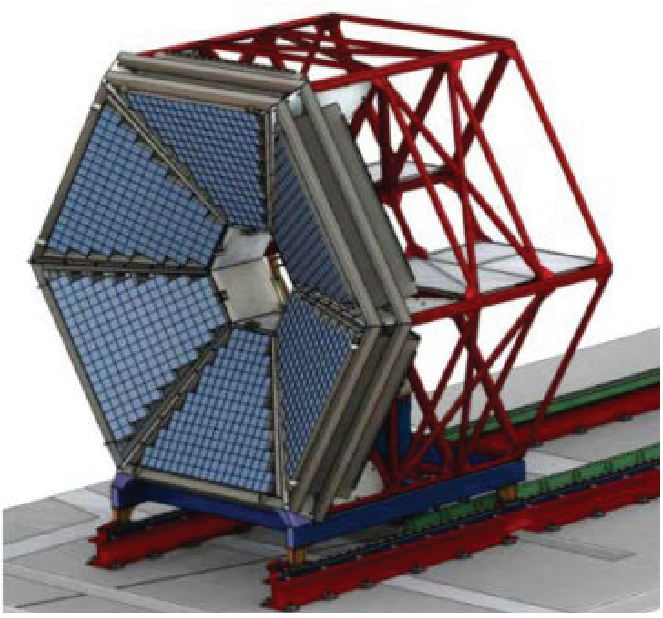

Figure 2: Basic design of the HADES Electromagnetic calorimeter ECAL.

3.1. Basic design of the ECAL

The ECAL will replace the currently existing HADES Pre-Shower detector, located at forward angles ($18^0 < \theta < 45^0$) (Fig.1). The basic design of the ECAL (Fig.2a) is given

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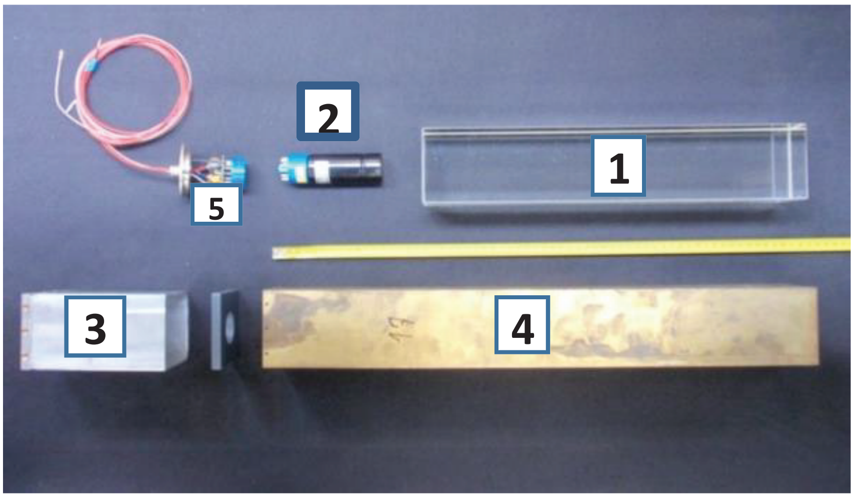

Figure 3: Cherenkov detector module of the ECAL: 1 – Lead glass CEREN25; 2 – PMT; 3 – Aluminum cover; 4 – Brass can; 5 – Optical LED- system.

by HADES geometry – six separate sectors covering polar angles between 12^0 and 45^0 with almost full azimuthal coverage. The total area of the proposed HADES calorimeter amounts to about 8 m^2. The ECAL consists of 978 lead glass modules (163 modules in each sector).

3.2. Construction and operation principle of ECAL lead-glass Cherenkov detector modules

Each ECAL module (Fig.3) consists of a radiator block of lead glass CEREN25 (1) of dimensions $92 \times 92 \times 420\ mm$ wrapped with Tyvek paper, PMT (2) protected by an aluminum cover (3), the brass can (4) and optical LED-system (5). The lead glass CEREN25 has main properties as following: radiation length (X_0) – 2.51 cm, refractive index – 1.708 (at λ = 400 nm) and Moliere radius – 3.6 cm.

When a relativistic particle passes through the lead glass radiator, an electromagnetic/hadronic shower is developing. Shower particles emit the Cherenkov light registered by PMT. The amplitude of the output signal is proportional to the energy of the primary particle (leptons/photons). As a readout system the PADIWA readout board is planned to be used.

ECAL modules are tested with PMTs Hamamatsu R6091 (3-inch photocathode) and PMTs THORN EMI 9903 (1.5-inch photocathode). EMI tubes are used in part of modules because of funding problems.

4. Tests of ECAL detector modules on cosmic rays

4.1. The main goals of ECAL cosmic tests:

- to choose the operating HV power supply at a mean value of the signal amplitude of about 1500 mV for each ECAL module under test by using cosmic rays and the Light Emission Diode (LED) system;
- to estimate the amplitude resolution of cosmic spectrum for each ECAL module;
- to define the defective ECAL modules and prepare them for repairing;
- to develop recommendations for the assembly of ECAL modules.

4.2. Stand for tests of ECAL detector modules on cosmic rays (muons)

A test stand for measurements of eight detector modules simultaneously on cosmic rays has been developed and used at the GSI Detector Laboratory.

Fig.4 shows one of the test frames with four testing channels for ECAL modules (1), scintillation trigger detectors (2) for creating of trigger signals from cosmic particles, HV power supply (3) for ECAL modules and trigger detectors, NIM-based electronics (4) which generates trigger signals.

A schematic view of the test stand is presented in Fig.5. The ECAL module with the lead glass radiator is shown in the middle and cosmic particles pass through radiator in the vertical direction. Two trigger detectors on the top and bottom, made of scintillators and PMTs, are connected to the coincidence electronic circuit. Advantages of the test stand: 1) eight trigger separate channels and one common trigger signal; 2) data acquisition – analog signals (with dividers) are recorded and digitized with the CAEN DT5742 Digitizer; 3) the PADIWA readout system; 4) generator for LED-pulses.

5. Results of the cosmic tests of the ECAL modules

278 ECAL modules were assembled and cosmic tests were carried out in September 2016 – July 2017.

The operating HV-values for ECAL modules have been chosen. The example of the signal amplitude spectrum (1) and the integral charge spectrum (2) for one of the ECAL modules is shown in Fig.6. The operating HV was chosen based on the signal amplitude spectrum. In Fig.6 the mean value of spectrum (1) is –1500 mV.

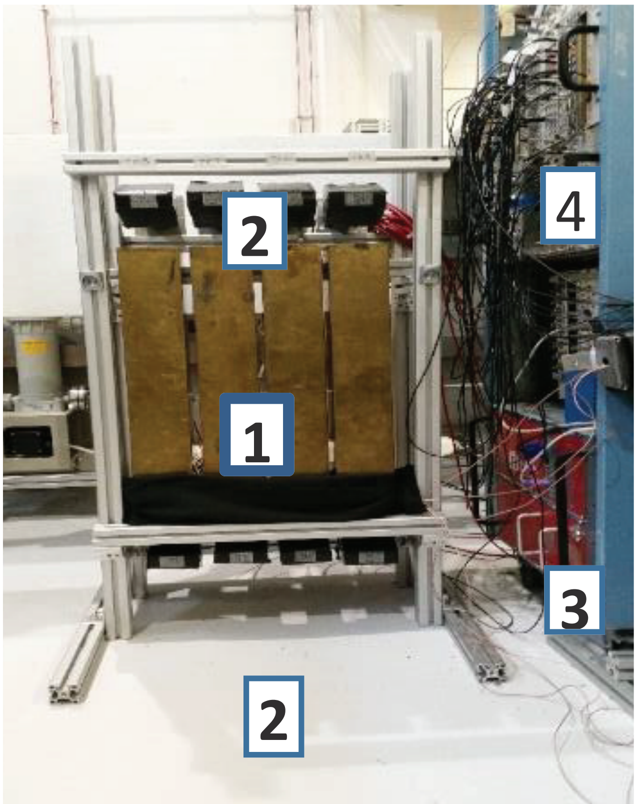

Figure 4: Stand for tests of ECAL detector modules on cosmic rays (muons) at GSI: (1) - testing channels for ECAL modules; (2) - scintillation trigger detectors; (3) - HV power supply; (4) - NIM-based electronics.

The energy resolution for cosmic rays was estimated from integral pulse spectra. The ECAL module energy resolution with 3-inch PMT is 8 – 9 % and the ECAL module energy resolution with 1.5-inch PMT is 11 – 19 % for integral spectra.

Fig. 7 shows the sector 3 on the ECAL mainframe with the installed 163 modules.

6. Conclusions

In this article we briefly presented procedures and results of ECAL detector modules tests on cosmic rays at GSI. Two ECAL sectors (163 x 2 = 326 modules) have been recently installed on the ECAL mainframe and the other two sectors will be installed at the beginning of 2018. The LED-system can be used for the amplitude calibration of individual modules with an accuracy of amplitude measurements (~1500 mV) of about 10 - 15 % for the most modules. It might be due to real difference between modules: different quality of connection of the optical fiber to the radiator or different reflectivity of the radiator's wrapping.

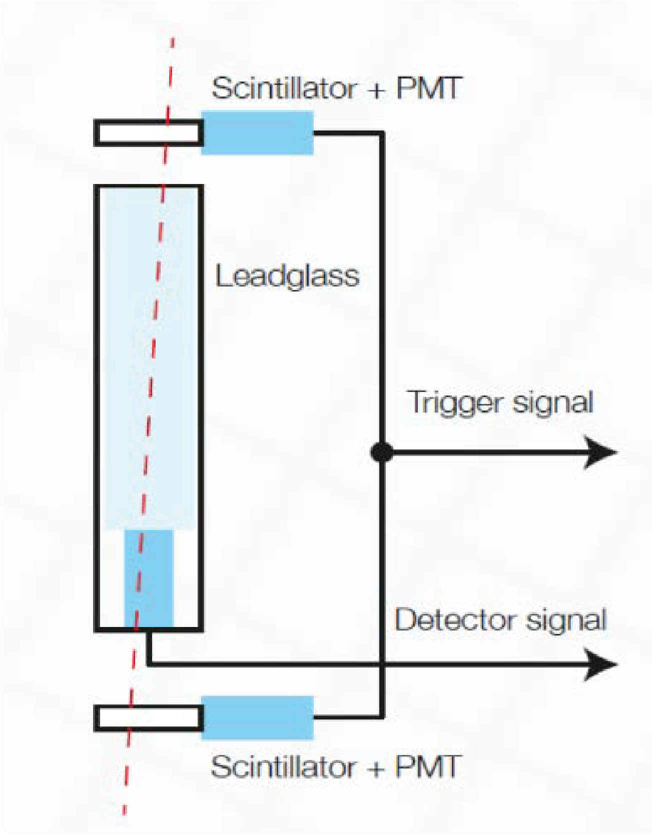

Figure 5: Schematic view of the test stand.

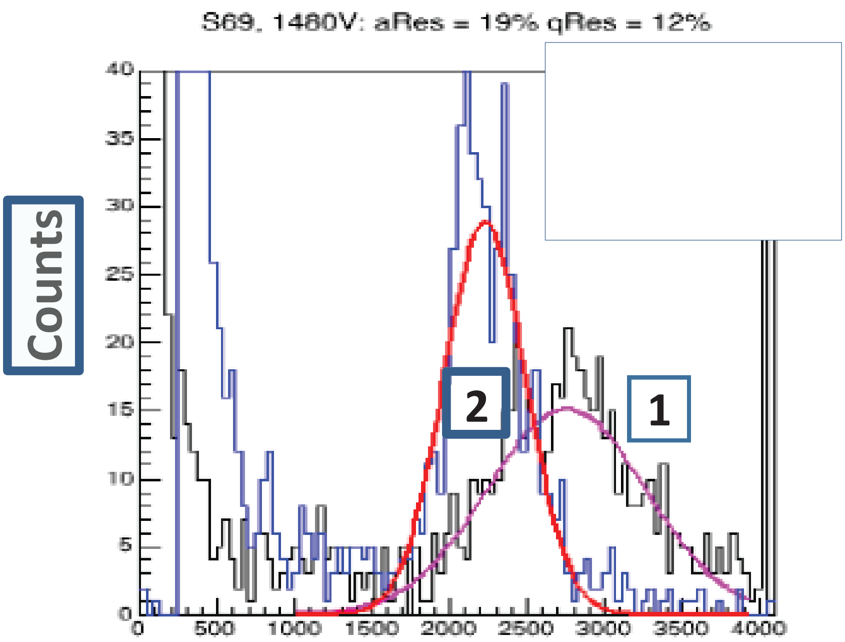

Figure 6: Example of the signal amplitude (1) and integral charge (2) spectra for one of the ECAL modules.

Figure 7: Sector 3 on the ECAL mainframe with the installed 163 modules.

Acknowledgments

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References

[1] Marin A *at al* 2007 Dilepton measurements with CERES *PoS* **CPOD07** 034

[2] Svoboda O, Blume C, Czyżycki W *at al* 2014 Electromagnetic calorimeter for the HADES@FAIR experiment Journal of Instrumentation 9 C05002

[3] Czyżycki W *at al* 2011 Electromagnetic Calorimeter for HADES *arXiv:* **1109.5550**