A data-driven calibration procedure for the HADES electromagnetic calorimeter*

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In its present configuration the HADES detector system is not able to detect photons. The proposed lead-glass electromagnetic calorimeter (EMC) [1] will, besides improving the electron-pion separation, enable the identification of the neutral pseudoscalar mesons (π^0, η) via their decay into two photons and their Dalitz decay[1]. The exclusive reconstruction of π^0 and η is achieved by analyzing the invariant mass spectrum (IMS) of the detected photons. The interpretation of the signal from the EMC is a complex process, which involves multiple steps. An algorithm, capable of reconstructing the initial photons hitting the EMC, has been developed [1]. Mostly due to energy losses inside the EMC this algorithm delivers systematical errors to the reconstructed momenta of the photons. A calibration procedure able to eliminate these systematical effects is, therefore, required.

The analysis of simulated data has shown that for photons the inaccuracy in the energy reconstruction is much larger than the errors in the reconstruction of polar and azimuthal angles [2]. Thus it is sufficient to calibrate only the energies of the single photons, in a first step this can be achieved by applying a correction to the energy using the equation:

$$E_C = E \times f\left(E, \theta, \varphi\right), \qquad (1)$$

where E_C and E are the calibrated and reconstructed energies, respectively, and f is a calibration function. A convenient general form of the function f is [2-3]:

$$f(E, \theta, \varphi) = \exp\left(\sum_{i=0}^{n} A_i \ln^i E\right), \qquad (2)$$

where A_i are calibration coefficients, which need to be determined. The summation limit n is usually set to 2 or 3 [2]. The coefficients A_i are determined using the likelihood function $\mathcal{L}$, which is defined as [3]:

$$\mathcal{L} = \sum_{j=1}^{N} \left[\ln M_{\gamma\gamma j} - \ln m_{\pi^0}\right]^2. \qquad (3)$$

Here the summation is over all photon pairs in the data sample, $M_{\gamma\gamma j}$ is the invariant mass of the j-th photon pair and m_{π^0} is the reference mass value, which is the mass of π^0. If the summation is performed only over photon pairs with invariant masses $M_{\gamma\gamma}$ in the range $M_{\pi^0} \pm \sigma_{M_{\pi^0}}$, then the likelihood function $\mathcal{L}$ should converge towards zero. Thus the calibration coefficients A_i can be determined by minimizing $\mathcal{L}$ with respect to A_i. The minimization of $\mathcal{L}$ and calculation of the coefficients A_i is performed numerically. A distinctive feature of this approach is that no prior knowledge of the calorimeter response is required: the calibration is based solely on measured data. Figure 1 shows the performance of the calibration procedure on the IMS of a simulated data sample.

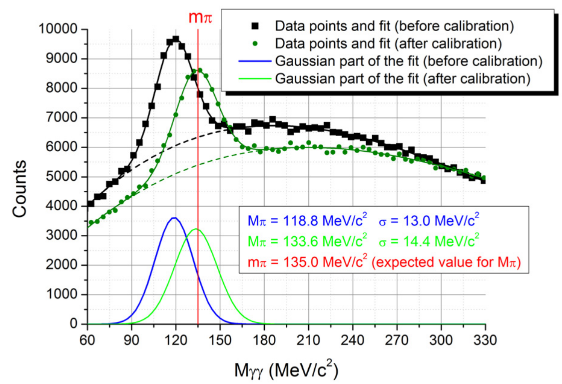

Figure 1: Two-photon invariant mass spectra showing π^0-peaks before and after calibration. The data are full-scale simulations of Ni+Ni collisions at 8 AGeV [2].

From Fig. 1 follows that the developed calibration procedure is accurate in the mass region of interest for the HADES experiment.

The calibration procedure was implemented in a standalone C++ program that uses only standard C++ and ROOT libraries [2] and can be, therefore, used for a broad class of electromagnetic calorimeters.

References

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