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Response of a close to final prototype for the $\overline{\text{P}}$ANDA Electromagnetic Calorimeter to photons at energies below 1 GeV

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ABSTRACT

The response of two generations of prototypes of the $\overline{\text{P}}$ANDA Electromagnetic Calorimeter (EMC), PROTO60 and PROT120, to photons in the energy range between 50 MeV and 800 MeV was obtained. Furthermore, the performance of the pre-amplifier ASIC (APFEL) under real experimental conditions, the position dependence of the energy resolution within the crystal and the implementation of higher order energy correction algorithms with a 15 GeV/c positron beam were studied.

1. Introduction

The $\overline{\text{P}}$ANDA detector at the future FAIR facility will be used to study $p\overline{p}$ interactions with the aim to study the strong interaction within the charm sector, for example. The EMC of the target spectrometer with its expected excellent performance and efficiency for electromagnetic particles over a wide energy range from 10 MeV up to 15 GeV, respectively, will be one of the central components to achieve the physics goals. The barrel EMC will consist of more than 11,000 lead tungstate (PWO-II) crystals operated at $-25\,°C$ to achieve the required resolution and efficiency stated in the TDR of the $\overline{\text{P}}$ANDA EMC [2].

2. Prototypes

2.1. PROTO60

The PROTO60 consists of 60 tapered PWO-II crystals operated at $-25\,°C$. The readout is performed via a single 1 cm^2 quadratic large area avalanche photodiode (LAAPD) and a low-noise low-power preamplifier. Several beam tests were performed over a large energy range which fulfilled the required performance and have confirmed a sufficient energy, time and position resolution. Details can be found in [4]. At the highest energy a test was carried out at CERN SPS exploiting the 15 GeV/c positron beam. For charged particle tracking a prototype of the $\overline{\text{P}}$ANDA Microvertex-Detector was used, which allowed us to investigate higher order

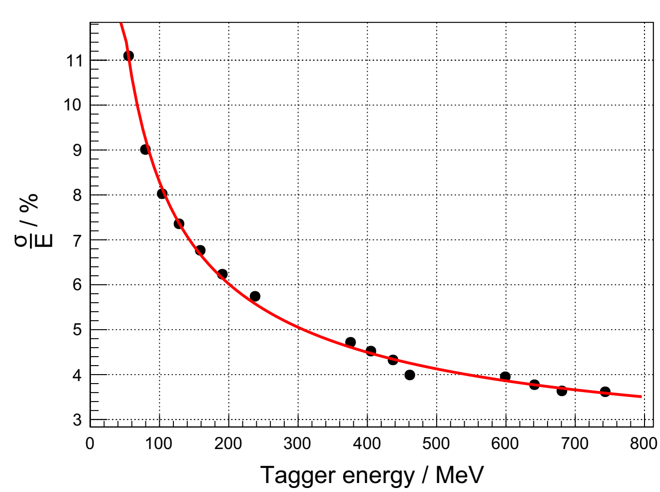

Fig. 1. Energy resolution of the PROTO120 as a function of the photon energy with an energy threshold of 3 MeV for the contributing detector module.

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energy corrections depending on the point of impact of photons (Section 3).

2.2. PROTO120

The most recent prototype PROTO120 represents a larger section of a barrel slice, containing the most tapered crystals and the close to final components. The readout is performed with two 1 cm^2 rectangular LAAPDs per crystal, which are read out separately via the custom made APFEL-ASIC, adapted to a large dynamic range of 10,000 (1 MeV to 12 GeV), with low power consumption of 55 mW/ch, a high rate capability up to 500 kHz and an optimized signal shaping. First tests with photons of energies up to 800 MeV provided by the tagged photon facility at MAMI (Mainz) show a sufficient energy resolution for a 3×3 crystal matrix. The resolution in Fig. 1 is obtained by summing the energy response of the relatively calibrated modules of the matrix

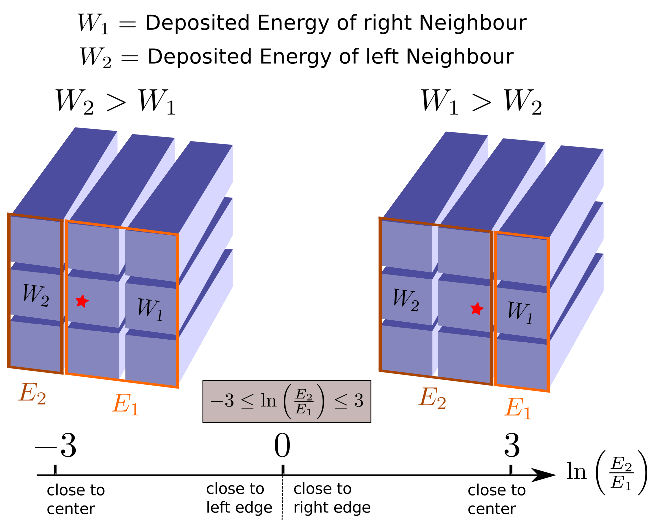

Fig. 2. $\ln(E_1/E_2)$-method for a 3×3 crystal matrix [3].

using the direct photon beam and fitting a Novosibirsk-Function [5], a commonly used function in particle physics as an estimator of the mode of a skewed Gaussian distribution, to the reconstructed line shapes.

3. Higher order energy corrections

A photon impinging centrally on a crystal deposits most of its energy within the crystal. Even in that case, there is a significant lateral energy leakage into neighboring crystals, which strongly depends on the point of impact. The energy sum of a crystal matrix as a function of the point of impact position is depicted in Fig. 3 (left) which shows an energy loss at the crystal border ($x_S = 0$ mm). It was shown by the ECAL-group of the CMS experiment at LHC [1] that the so-called $\ln(E_1/E_2)$-method is a sensitive algorithm to correct the energy reconstruction taking into account the lateral spread of the electromagnetic shower. The method is illustrated in Fig. 2. Two sub-arrays with energies E_1 and E_2 are assigned via the comparison of the energy deposited into the right and left neighboring crystals of the crystal

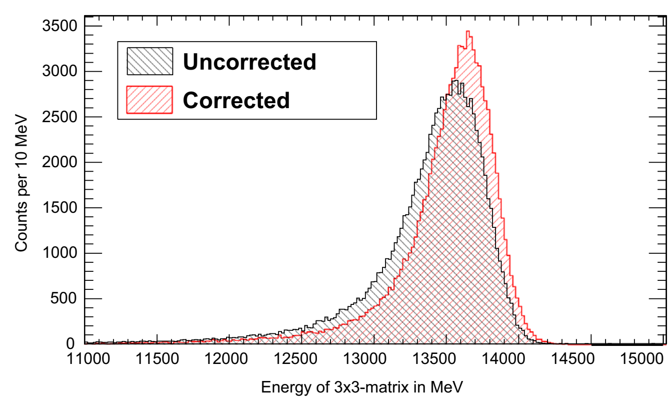

Fig. 4. Uncorrected and corrected line shapes of a 3×3 matrix measured at 15 GeV/c positron energy [3].

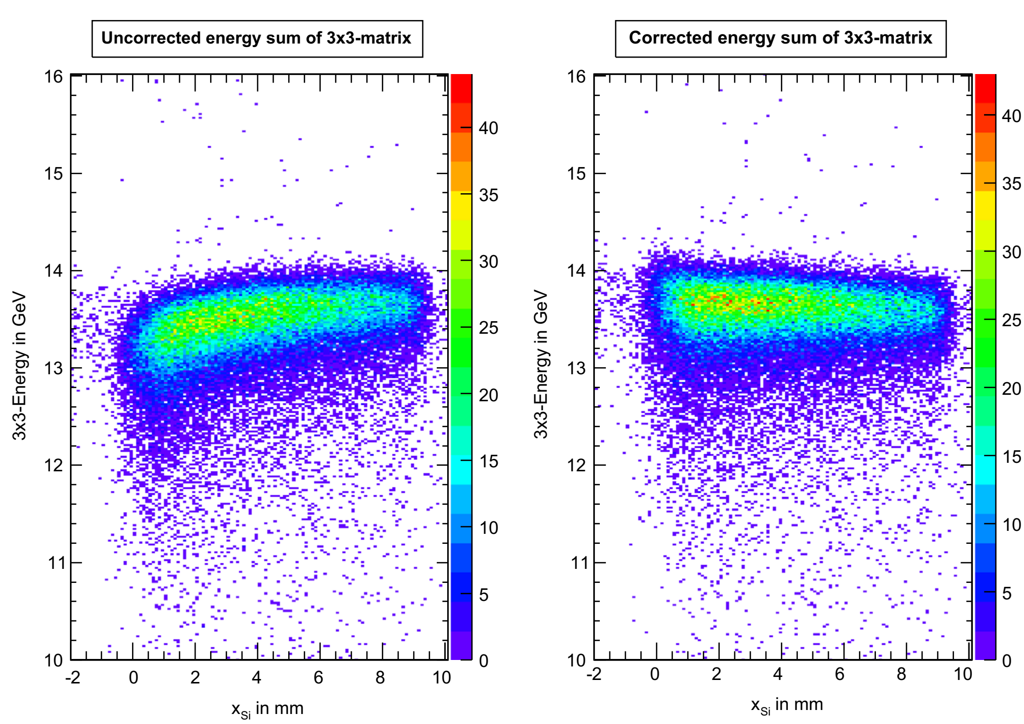

Fig. 3. Uncorrected (left) and corrected (right) energy of a 3×3 matrix as function of the tracked horizontal position coordinate [3].

showing the maximum energy deposition. The distribution of $\ln(E_1/E_2)$ is subdivided into equal slices in the range from -3 to 3. For events within a slice which fulfill $0.12 \cdot i - 3 \le \ln(E_1/E_2) < 0.12 \cdot (i+1) - 3$ with $i \in \{0, 1, 2, \ldots, 49\}$, the deposited energy of the 3×3 matrix is fitted with a Novosibirsk-Function. To obtain a correction function $f(x)$ with $x = \ln(E_1/E_2)$, the mean parameter of the Novosibirsk-Function is normalized, plotted as a function of $\ln(E_1/E_2)$ and fitted with a polynomial of fifth order. Finally, the corrected energy information is obtained by dividing the original energy information by $f(x)$.

The corrected energy of the 3×3-matrix as a function of the tracked x-coordinate (Fig. 3) shows a significant enhancement in particular at the crystal border which leads to a more homogenous behavior of the detector. The line shapes in Fig. 4 show that the width of the reconstructed line shape becomes narrower and the mean value increases by a value of 40 MeV. The correction procedure leads to an improvement of 0.3% in energy resolution [3].

4. Summary

The response of the $\overline{\text{P}}$ANDA EMC prototypes fulfills the requirements of the TDR. Furthermore, higher order energy corrections deliver an additional improvement on the homogeneity of energy deposition in between crystals correcting for dead material and leakage.

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