Beam test data analysis of the ALICE FoCal-E pad prototype

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The ALICE FoCal-E detector[1)] is an electromagnetic sampling calorimeter with a total depth of 20 radiation length (X_0), which aims to measure the direct photons produced by quark-gluon Compton scattering to explore the small-x parton structure of nucleons and nuclei. It is composed of 18 low-granularity silicon pad layers, with a cell size of 1×1 cm^2 for energy measurement, and 2 high-granularity silicon pixel layers, with a cell size of 30×30 μm^2 for position measurement and photon shower separation because the direct photons should be distinguished from those decayed from π^0. All layers have the tungsten sheets with a thickness of 1 X_0 followed by silicon layers.

FoCal-E has been developed since 2016 to be used for physics data collection in 2029. Now, we are studying the detector performance to write a technical design report and optimize the final design. A FoCal-E prototype with a transverse dimension of 9×8 cm^2 was prepared and tested using high-energy electron beams from 20 to 350 GeV at CERN-SPS in September and November 2022. In this article, we report the status and plan of the pad data analysis.

FoCal-E pad will use the HGCROC chip, which is being developed by the CMS experiment for a high-granularity calorimeter.[2)] It provides ADC for signals up to 100 Minimum Ionizing Particles (MIP), which is used for energy calibration of each pad and time-over-threshold (TOT), which is fired from 100 MIP for large signals to measure photon energy up to 2 TeV. TOT is a technique that obtains the energy by measuring the pulse width of the digital output. Although it allows us to measure large signals, nonlinearity between the TOT and energy and the reliability of energy measurement in the intermediate dynamic range where it is converted from ADC to TOT need to be carefully studied.

A pad layer of the prototype consists of 72 cells. When the TOT values of all cells in the eighth layer, which is one of the shower maximum layers, were summed up for a 150-GeV beam energy, two peaks were observed. One was the case when all TOT values were zero. The other was a Gaussian peak around a non-zero value.

In the electron beam, a finite fraction of the hadron background exists. We assumed the former comes from the hadron background and the latter comes from the electron. This assumption is reasonable because the maximum energy deposit of a cell in the eighth layer by the electron was predicted by simulation to be larger than a level of 200 MIP, which is sufficient to fire the TOT even though the electron hits the edge of a cell. Therefore, events where at least one cell has non-zero TOT value in the eighth layer were selected to enhance the electron event. Mean of TOT sum, ⟨TOT sum⟩, was calculated for all pad layers to estimate the detector performance from the longitudinal shower profile.

Figure 1 shows the longitudinal shower profiles of the FoCal-E pad prototype with four different beam energies. As the beam energy increases, not only does the ⟨TOT sum⟩ increase but also the shower max layers move backward.

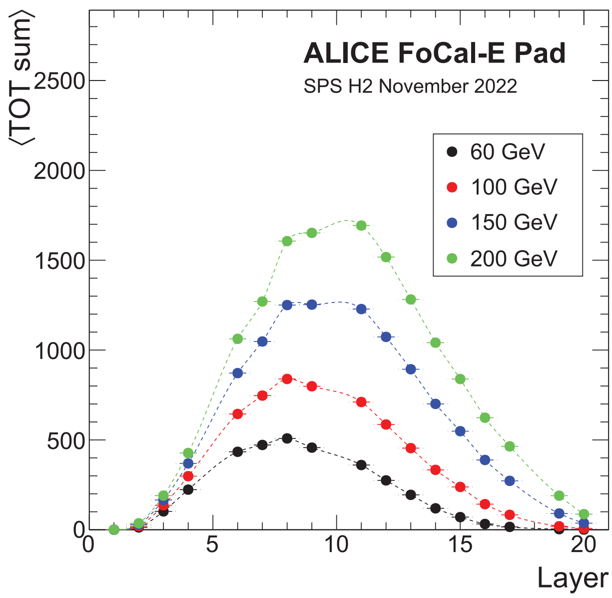

Fig. 1. Longitudinal shower profiles of the FoCal-E pad prototype, which shows the ⟨TOT sum⟩ with four different beam energies over the layers. Layer 5 and 10 are the pixel layers. Layer 18 is not shown due to a gain problem.

The FoCal-E pad prototype showed a reasonable performance even though the analysis cut condition was simple. However, the estimated energy resolution was 1.5 times worse than that expected by simulation. We are now processing the quality assurance (QA) for each run. After QA, more strict conditions will be applied to separate the electron from the hadron background. Calibration parameters will also be provided to combine the TOT and ADC and also to reduce the TOT nonlinearity. Taking these factors into account, precise detector performances will be studied.

References
1) ALICE Collaboration, CERN-LHCC-2020-009 (2020).
2) CMS Collaboration, CERN-LHCC-2017-023 (2017).

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