Test of n-type silicon pad array detector at PS CERN

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Introduction

This work reports the testing of an n-type silicon pad array detector at Proton Synchrotron (PS), CERN. This detector is intended for the Forward Calorimeter (FoCal), which is an upgrade of the ALICE detector for data taking in Run 4 (2029-2034) [1]. FoCal is designed to study the unexplored gluon saturation effects in the low-x regime ($\sim 10^{-5} - 10^{-6}$) by measuring direct photons, neutral hadrons, vector mesons, and jets. It is made up of a hadronic and an electromagnetic calorimeter. The electromagnetic part is a segmented sampling calorimeter made of alternating tungsten absorbers with silicon detectors.

The tested prototype is an 8×9 n-type silicon pad array (single pad size 1×1 cm^2) fabricated for the first time in India on a 6-in silicon wafer [2] and read out using HGCROCv2 chip [3]. The detector performance was evaluated with 10 GeV pion beams and 1-5 GeV electron beams, focusing on measuring the Minimum Ionizing Particle (MIP) response for pions and the shower profiles for electrons.

Test beam setup

A dedicated test setup was commissioned at the T9 area of the PS facility at CERN to evaluate the performance of the silicon pad array detector as shown in Fig. 1. The detector assembly consists of a silicon pad array mounted on a printed circuit board (PCB) that hosts the HGCROCv2 chip, connected to the DAQ board via a dedicated interface PCB. A source meter supplies reverse bias voltage to the detector, which operates in full depletion mode. An aluminium structure placed in front of the detector assembly holds 3.5 mm-thick (~ 1 radiation length, X_0) tungsten (W) absorber plates. The structure allows the modular adjustments of W plates to study electromagnetic showers at various depths.

The trigger is generated using four plastic scintillators in which two large scintillators cover the detector's acceptance area, while two smaller ones, arranged in a cross pattern, ensure beam incidence on a single pad. The trigger is sent to the discriminator and converted to TTL signals compatible with the

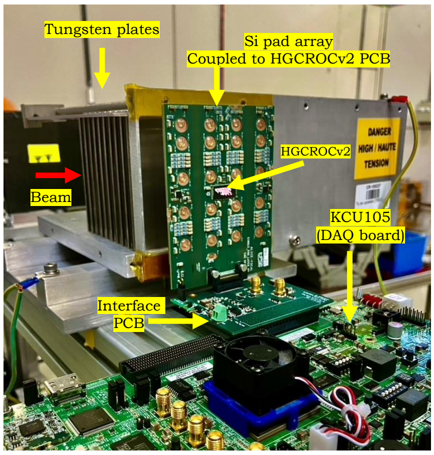

FIG. 1: Test setup at PS, CERN showing detector assembly and the aluminium mechanical structure holding tungsten absorber plates.

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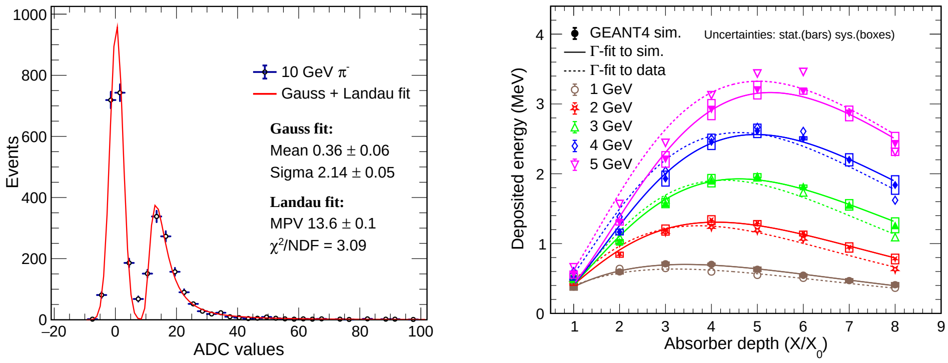

FIG. 2: (Left) Pion MIP distribution fitted with combined Gaussian and Landau functions. (Right) Longitudinal shower profile of electron with energy from 1-5 GeV.

DAQ board, which transmits data to a computer for analysis.

This test beam setup was replicated in Geant4 simulations, incorporating identical detector materials and configurations.

Results and discussion

The pion energy loss distribution in units of ADC values is shown in Fig. 2 (left). The mean value of the Gaussian fit to the pedestal is subtracted from the distribution so that the pedestal peaks around 0 ADC value. The distribution is fitted with a combination of Gaussian (for the pedestal) and Landau (for the MIP) functions. A clear separation between the pedestal and MIP is observed with a S/N ratio of about 5.8.

Electrons with energies in the GeV range lose energy via radiation losses (bremsstrahlung and pair production), initiating an electromagnetic shower. The energy deposited by the shower at various absorber depths, known as the longitudinal shower profile, is analyzed by varying the number of tungsten plates. The shower profile is fitted with a Gamma distribution and also compared with Geant4 simulations as shown in Fig. 2 (right). The deposited energy increases with absorber depth, reflecting the generation of secondary particles within the shower. It peaks at the shower maximum and then decreases as low-energy particles are absorbed. The data and simulations are in agreement with each other, with a mean relative difference of less than 9% between the two.

Outlook

The next step in this experiment is the preparation of a full-scale prototype with 20 Si-W detector layers to study the energy resolution of the sampling calorimeter. The same will be tested with electrons and pions at the PS and SPS test beam areas at CERN.

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