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Energy reconstruction of electrons and pions in the HGCAL beam test prototype using Graph Neural Networks

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Calorimetry at the High Luminosity-Large Hadron Collider faces two enormous challenges particularly in the forward direction: radiation tolerance and unprecedented in-time event pileup. To meet these challenges, the CMS experiment has decided to replace its current endcap calorimeters with a High Granularity Calorimeter (HGCAL), featuring a previously unrealized transverse and longitudinal segmentation, for both the electromagnetic and hadronic compartments. As part of the development of this calorimeter, a series of beam tests have been conducted using prototype segmented silicon detectors. In the beam test conducted at the CERN SPS in October 2018, the performance of a prototype calorimeter equipped with ≈12,000 channels of silicon sensors complemented with a CALICE AHCAL prototype, a scintillator-based sampling calorimeter, mimicking the proposed design of the HGCAL scintillator part was studied with beams of high-energy electrons, pions and muons with momenta ranging from 20 to 300 GeV/c.

The ultimate calorimetric performance of the HGCAL can potentially be realized using advanced deep-learning algorithms that exploit the detailed low-level hit information that effectively images the shower development in three spatial dimensions, while also measuring the corresponding energy deposition in the active elements. We have developed a novel machine-learning architecture based on dynamic graph neural networks using these low-level detector hits as input features and applied it to reconstruct the energy of electrons and pions with the HGCAL beam test prototype. The results show a very significant improvement in the relative energy resolution as compared to a simpler rules based reconstruction technique.

In this presentation we will cover this new machine-learning based reconstruction technique in detail and summarize the results obtained for both the energy response and resolution to electromagnetic and hadronic showers.

Author: Ms ALPANA, Alpana (Indian Institute of Science Education and Research (IN))

Presenter: Ms ALPANA, Alpana (Indian Institute of Science Education and Research (IN))

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