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Reconstructing Electrons and Photons in the CMS ECAL using Graph Neural Networks.

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One of the key sub-detectors of the CMS experiment, located at the CERN Large Hadron collider, is the electromagnetic calorimeter (ECAL). This homogeneous calorimeter is designed to detect electrons and photons with energies from as low as 500 MeV up to 1 TeV. The ECAL is a homogeneous calorimeter consisting of ˜76,000 scintillating crystals arranged around the collision point in an 8m long barrel that has a diameter of 3m and two endcaps, all within a 4T magnetic field. Electrons and photons are detected as showers that spread across many crystals due to the magnetic field and interactions with the detector material.

A multi-step procedure has been developed in order to reconstruct the energy of these particles from the energy deposits in the crystals of the ECAL. In the first step of this procedure a clustering algorithm is employed to gather the energies deposited around a "seed" crystal, which are above a certain threshold and subject to certain topological requirements to ensure that energy being clustered is not electronic noise and belongs to the showering electromagnetic particle. In the next step corrections are applied to this clustered energy in order to account for effects such as out of cluster energy deposits, energy losses upstream of the ECAL as well as in dead crystal and gaps in the ECAL, energy leakage, etc. In order to apply this correction a gradient boosted regression is trained using a detector simulation to correct the reconstructed energy of electrons and photons to their true energies. This regression uses several high level variables which describe the electromagnetic shower as its input features. This regression-based correction is crucial to ensure that electrons and photons are reconstructed with the correct energy scale and with an optimal resolution, and consquently is a key ingredient for several precision measurements, such as the masses of the Higgs and W bosons. This necessarily implies that any improved algorithm would result in gains in these flagship measurements in CMS.

We have recently developed an updated energy regression correction using graph neural networks which uses only low level information of the electromagnetic shower as input features. The algorithm we have developed already shows an improved energy reconstruction performance as compared to the current legacy algorithm and the same has also been validated in collision data. Efforts are now underway to extend it to other use cases, for example, discriminating prompt electrons and photons from jets which can fake them. In this report we will present this novel machine learning based algorithm and the results obtained with it, using both simulated and collision data from the CMS experiment.

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