Abstract:
New technologies have enabled the development of granular calorimeters with millions of channels. The signal of the ultra-sampled shower produced by these devices is thought to provide greater discriminating power to event reconstruction. Combining sub-nanosecond digitization with small area photosensors in a fiber calorimeter, we propose an enhancement to the traditional dual readout design that provides benefits of both high-granularity and multi-readout [1,2]. We show that by applying machine learning techniques, namely Convolutional Neural Networks (CNN), and Graph Neural Networks (GNN) to both a highly granular and proposed fiber calorimeters. We see, for instance, in the simple high granularity setup, the CNN improves reconstructed energy resolution. These results indicate the spatial distribution of energy deposition within the sensitive elements is both identifiable (able to be learned) and representative of underlying physical processes.

CNN for Energy Reconstruction:
- CNN is well suited at image classification:
  - Raw images are used
  - Higher level features extracted using sequential convolutional operations
  - Regression performed

Simulation Setup (Calorimeter):
- Copper/Silicon sampling calorimeter is simulated with GEANT4
- Alternating Cu 17 mm (absorber). Si 3 mm (active) layers, with total size of 1.0×1.0×1.5m³
- Readout granularity is 2×2×2cm³
- Signal is integrated over 5ns with correction for the longitudinal propagation time

Traditional reconstruction techniques:
- Simple energy sum over all channels in the volume and reconstruction with correction for the fluctuations in the Electromagnetic (EM) fraction [1].

Energy reconstruction with the CNN

Single Hadrons:
- The CNN closely resembles with the raw calorimeter, with minimal degradation in the energy resolution. Sum over all channels (green) and CNN regression (red). CNN has been trained on pions.

Electrons:
- The CNN performance with electrons and its comparison with simple energy sum is illustrated here. The horizontal axis indicates the assumed timing precision for the GNN technique.

Multi-particles (Jets):
- The energy resolution (σ/E) for 30 GeV (black) and 100 GeV (red) pions: simple energy sum (Esum), EM-corrected energy sum (EMcorr), CNN and GNN reconstruction techniques. The horizontal axis indicates the assumed timing precision for the GNN technique.

Summary:
- CNN can extract topological information from shower and do a better reconstruction than traditional techniques.
- GNN provided convolutional capabilities similar to CNN, which is able to handle irregular detector geometry, and a larger set of properties per spatial cell (multi-readout energy and timing measurements).

References:
2. CERN-LHCC-2017-013 / CMS-TDR-017