Upgrading ATLAS Fast Calorimeter Simulation

Introduction

The ATLAS experiment uses simulated events that reproduce the detector response. Particle interactions with a detailed description of the detector geometry is handled using the Geant4 package (full simulation). Up to 90% of full simulation time is spent in the ATLAS calorimeters [1]. With increasing luminosity at the Large Hadron Collider, a simplified fast simulation is needed that describes collision data adequately enough for physics analyses. Fast Calorimeter Simulation (FastCaloSim) was developed to provide a parametrised response of the ATLAS calorimeter, decreasing simulation time by an order of magnitude when run with Geant4 to simulate the tracking detector and muon system in a mode known as ATLFASTII [2]. An improved version of FastCaloSim is currently in development in order to improve on the previous iteration, described here.

Current Fast Calorimeter Simulation

Current FastCaloSim reduces simulation time by making the following simplifications:

- Calorimeter cells modelled as cuboids
- >10⁶ Geant4 simulated single particle events
- Use $e$, $γ$ for EM interactions, and $π$ for hadronic
- Energy parametrised longitudinally (deposition) and laterally (shape)

ATLAS Calorimeter

Electromagnetic (EM) Calorimeter
- Liquid argon (LAr) and lead absorber (barrel: $|η|<1.475$, end caps $1.375<|η|<3.2$).
- Accordion shaped sampling electrodes.

Forward Calorimeter
- LAr with copper & tungsten absorber ($|η|<4.9$).

Hadronic Calorimeter
- Barrels: steel absorber and plastic scintillating tiles (main: $|η|<0.8$, extended $0.8<|η|<1.7$).
- End-caps: LAr and copper absorber ($1.5<|η|<3.2$).

FastCaloSim Upgrade

Current FastCaloSim does not describe shower sub-clusters, preventing use in analyses with jet substructure. Upgrading FastCaloSim includes the following improvements:

- Correlated inputs of energy deposition are decorrelated with principal component analysis. Multivariate regression is performed on energy distributions to reduce storage.
- Shower shape is parametrised in radius and angle about the shower centre and used as 2D probability densities. Simulating energy deposit positions using these introduces fluctuations that lead to localised shower sub-clusters.
- Corrections in the cell assignment of energy deposits to take accordion shape of LAr into consideration.
- Added exact geometry of forward calorimeter.

Schematic of the ATLAS calorimeter system [3].

Validation

- First upgraded FastCaloSim prototype for single particles is under validation.
- Comparisons are made to full Geant4 and to current FastCaloSim (ATLFASTII).

Event display of pion (left), electron (middle), and photon (right) with new FastCaloSim.

Photon Energy in EMB3

Total energy deposited by photons using the energy parametrisation, compared to full simulation input [1].

Effect of number of hits simulated on lateral shower shape [4].

References