Validation: ATLAS Fast Chain and AtlFastSim3.

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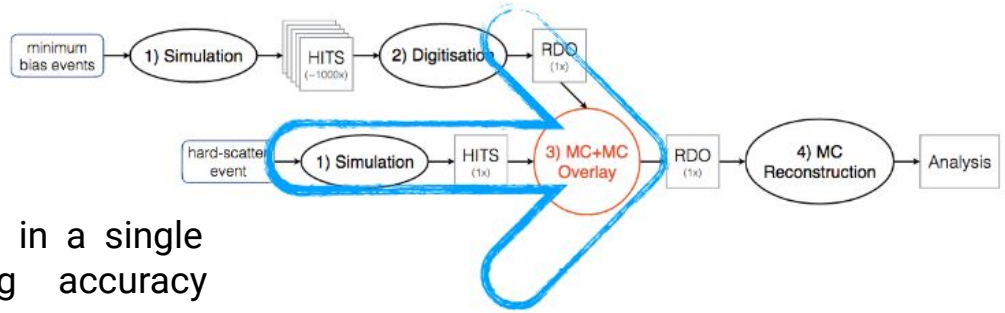
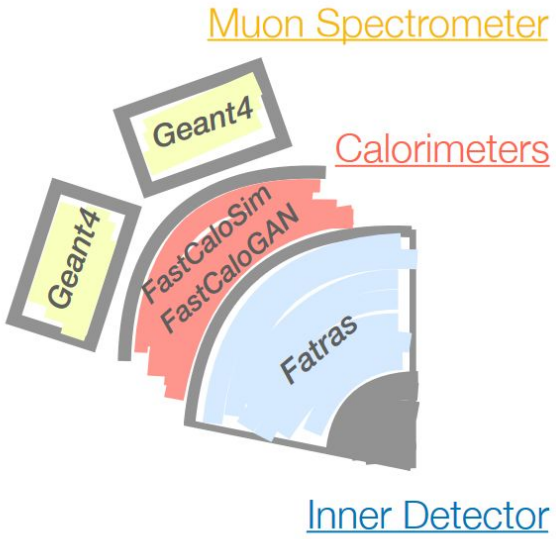
Introduction



FastChain: combine fast and full simulation tools in a single workflow to meet computing and modelling accuracy requirements for detector simulation.



- **FATRAS:** Fast Tracking algorithm with simplified detector geometry.
- **Fast Digitization:** Parametric simulation of the conversion of the energy deposited in into digital signals
- FastCalorSimV2: (FCSV2) Parametrized modelling.
- FastCaloGAN: (FCGAN) Generative Adversarial Network.

Figures from source

Validation

How is validation done?

➔ Classical based approaches. ML based approaches in development.

➔ Three stages:

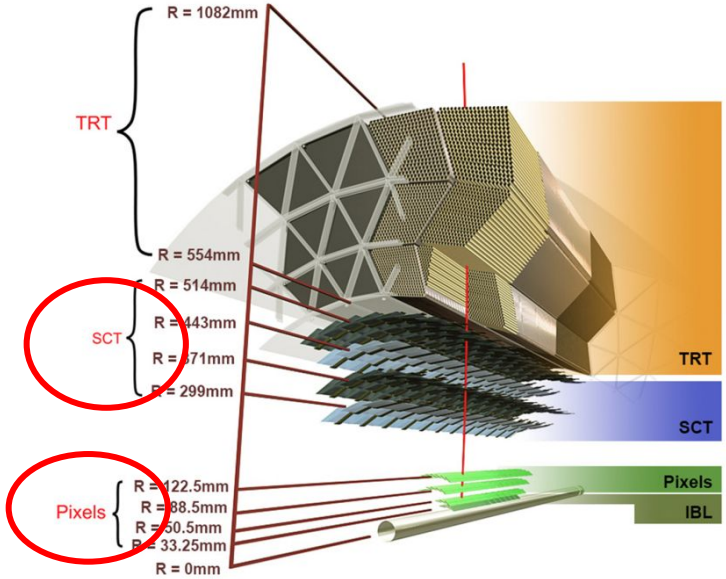
- **Single particle reconstruction**, smaller production of physics events.
- **Larger physics validation** campaigns across many physics channels.
- **Direct feedback** from analyses on areas of improvement.

Current Validation :

- **FATRAS**: Single particle reconstruction.
- **Fast Digitization**: larger physics validation using many physics channels.
- **AtlFast3**: Stand-alone, larger physics validation, as well as inputs from analyses.

Fast Digitization: Algorithm

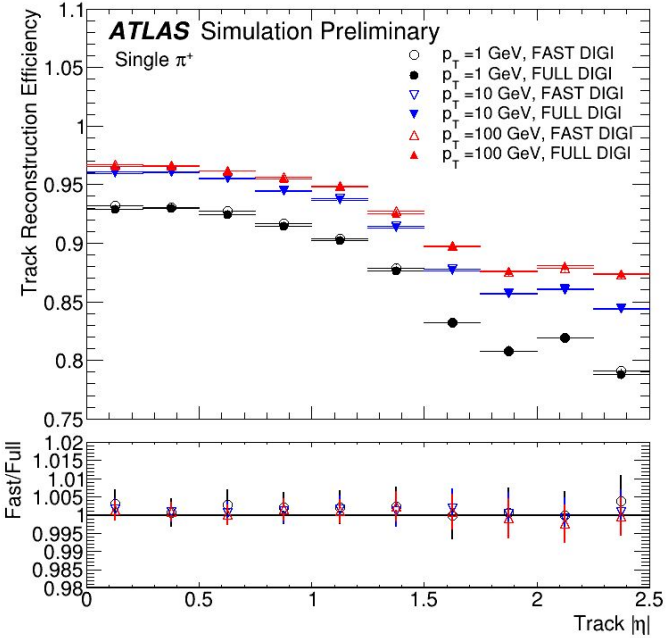
- Inner Detector silicon tracker components (for pile-up events).
- Inputs: Energy deposit locations
- Modules subdivided into cells (read-out elements)
- Reconstruct geometric trajectories for Module → split across the split cells.
- Signal strength ~ length of trajectory in the cell.
- Create clusters directly from track information ⇒ Saves CPU time!

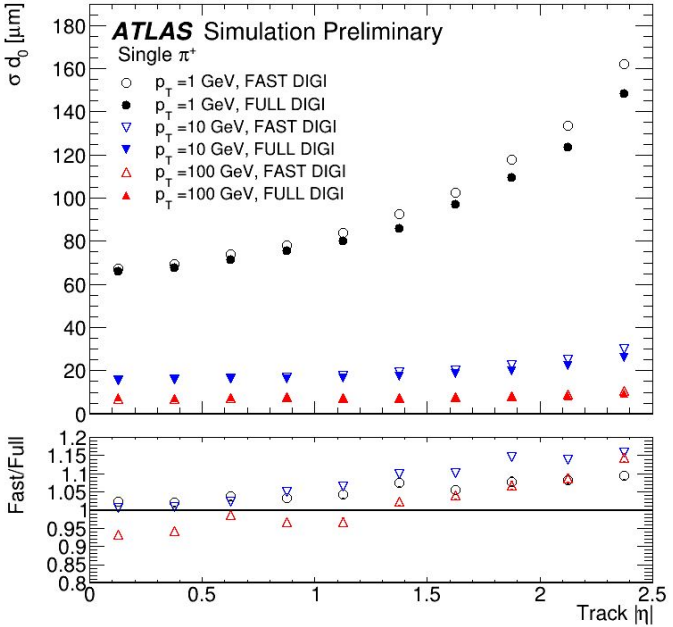


Figures from source

Fast Digitization: Performance and Validation

Looking at track/cluster level variables ~ Most relevant for Inner Detector.





Compare performance of single charged pions at different P_t
~ Tracking efficiency, Transverse Impact parameter resolution (σd_0).

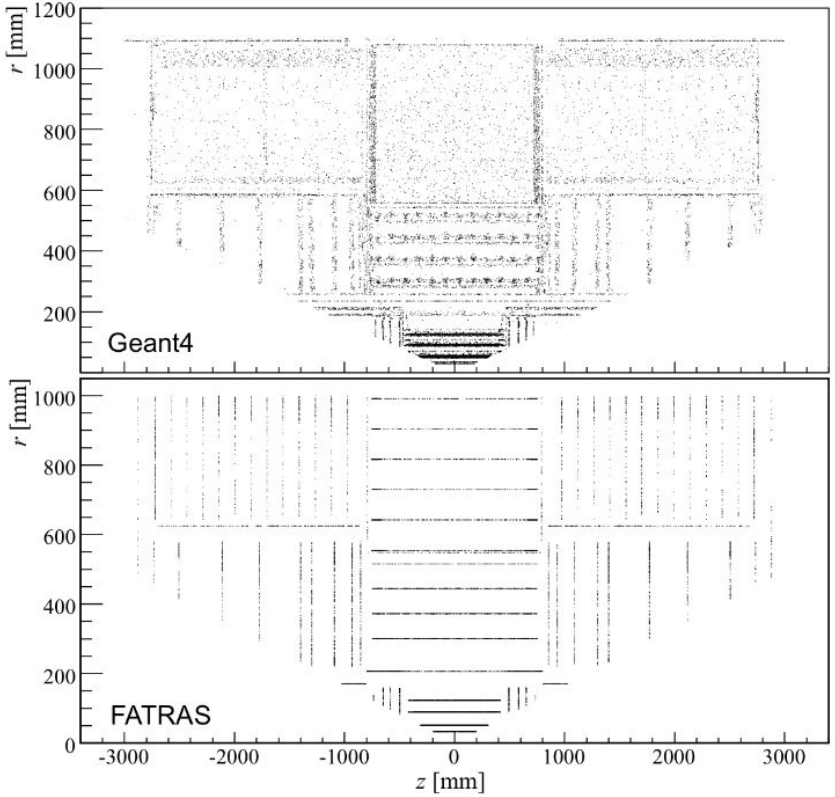
- Fast/Full digitization agreement in sub percent level for track efficiency!
- σd_0 agreement poor in forward region ~ $|\eta| > 1.5$.

Plots from source

Fast ATLAS Tracking Simulation (FATRAS): Algorithm

- *Simplify detector geometry.*
- Project inner detector material distribution onto thin layers.
- Particle interaction with layers ~ modelled by fast parametrization.
    - Radiative loss: Bethe-Heitler parametrisation of conversion probability, lepton energy sharing and angle.
    - Ionisation: Bethe-Bloch parametrisation.
    - Multiple Coulomb scattering: Gaussian Mixture models.

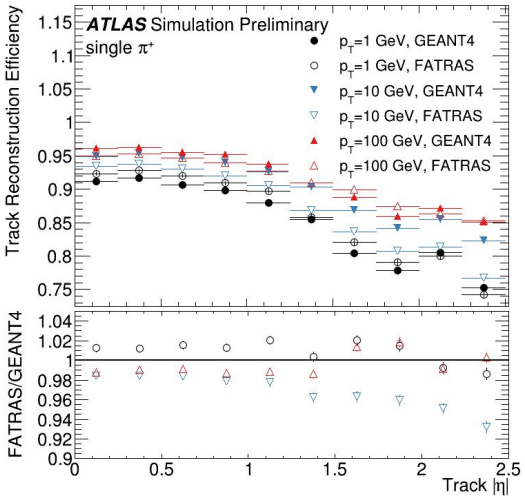
Nuclear Interactions: GEANT4.

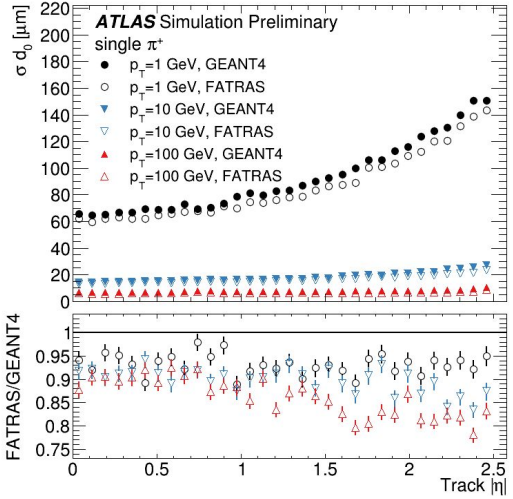


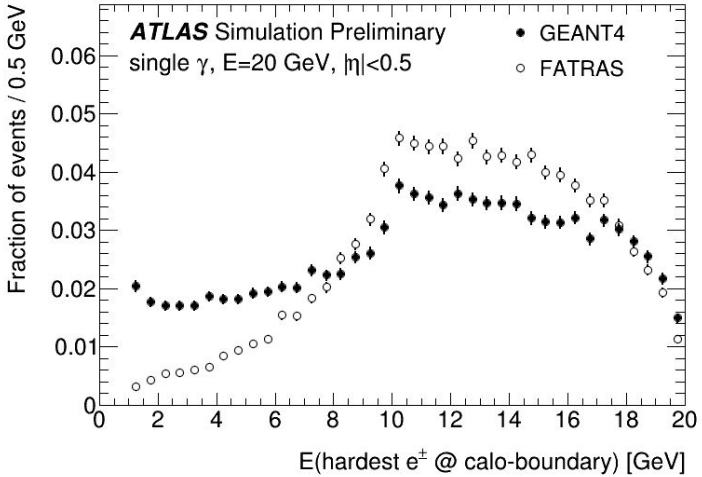
Visualization of the simplified geometry used by the standard ATLAS track reconstruction and FATRAS, derived from photon conversion vertices. (ref.)

FATRAS: Performance and Validation

Looking at track/cluster level variables ~ Most relevant for Inner Detector.







Track efficiency and Transverse impact parameter resolution for single pions for different P_t

- Efficiency: 10 GeV pions ~ largest discrepancy.
- Resolution: ~ 5 - 15 % better resolution compared to GEANT4.

Validate photon conversion : Energy distribution of the highest energy electron at tracker-calorimeter boundary.

Plots from source

FastCaloSim and FastCaloGAN: Validation

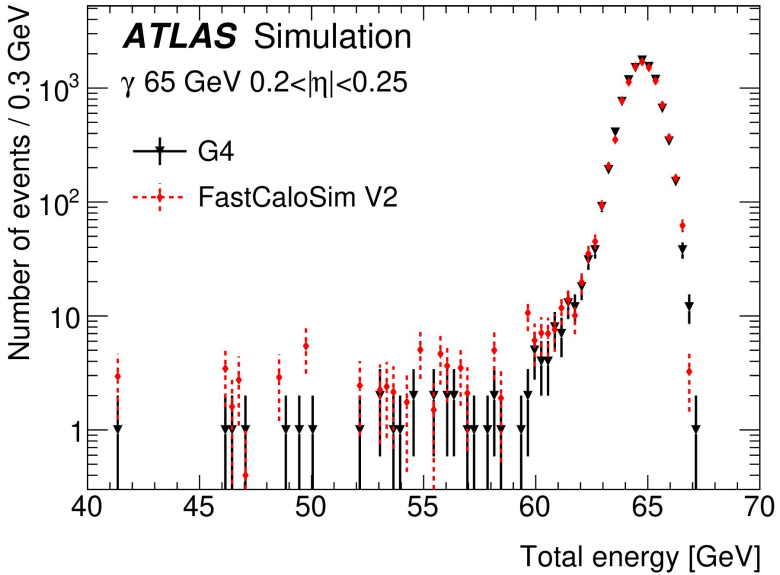
Stages:

- **Single Particle Reconstruction:**
  - Standalone (outside of ATHENA used for ATLAS sample production)
    - Validate against G4 total energy, energy fractions, lateral shower shapes. (FCSV2)
    - Validate Total Energy. Energy fractions for a given voxelisation. (FCGAN)
  - Within ATHENA (simulation, digitisation, reconstruction) ~ reproduce cluster level variables.

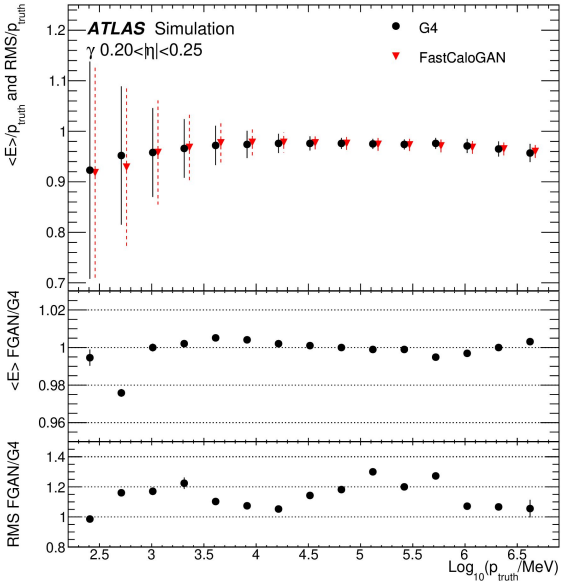
- **Multiparticle physics samples for validation campaigns.**
- **Direct feedback from physics analyses**

Fast Simulation AtlFast3 (AF3): Validation of components

AF3 = combine Fast Calo Sim, Fast Calo GAN and GEANT4 flexibly.



Fast Calo Sim. V2

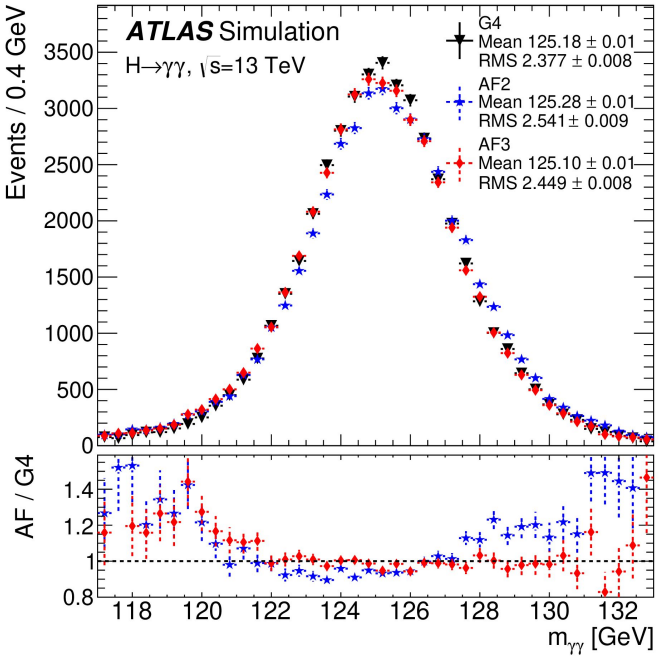


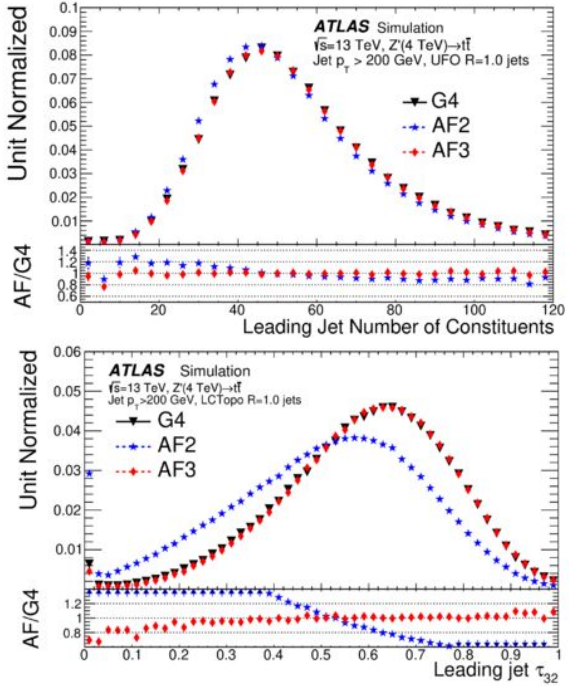
Fast Calo GAN

Stand-alone validation:

- Total energy for a photon in calorimeter: FCSV2 in good agreement with GEANT4.
- Sum of energy in all voxels normalised to true momentum: FCGAN in good agreement with GEANT4.

AtlFast3 (AF3): Validation





Validation: Feedback from physics analyses~

- di-photon mass reconstruction ~ Excellent agreement with G4
- Improvement in Jet variable modelling: # constituents, substructure variable agreement within a few percent.

Summary:

3 stages of validation in ATLAS:

- Single Particle
- Larger Physics production
- Direct feedback from analyses.

Production readiness

Example low-level variables used:

- FATRAS : Track level properties, Validation of photon conversion
- Fast Digitisation: Cluster level properties.
- AtlFast3: Total energy, Energy fractions,...

Example high-level variables used:

- AtlFast3: Higgs → ɣɣ mass spectra, jet level variables,...