Upgrading the ATLAS Fast Calorimeter Simulation

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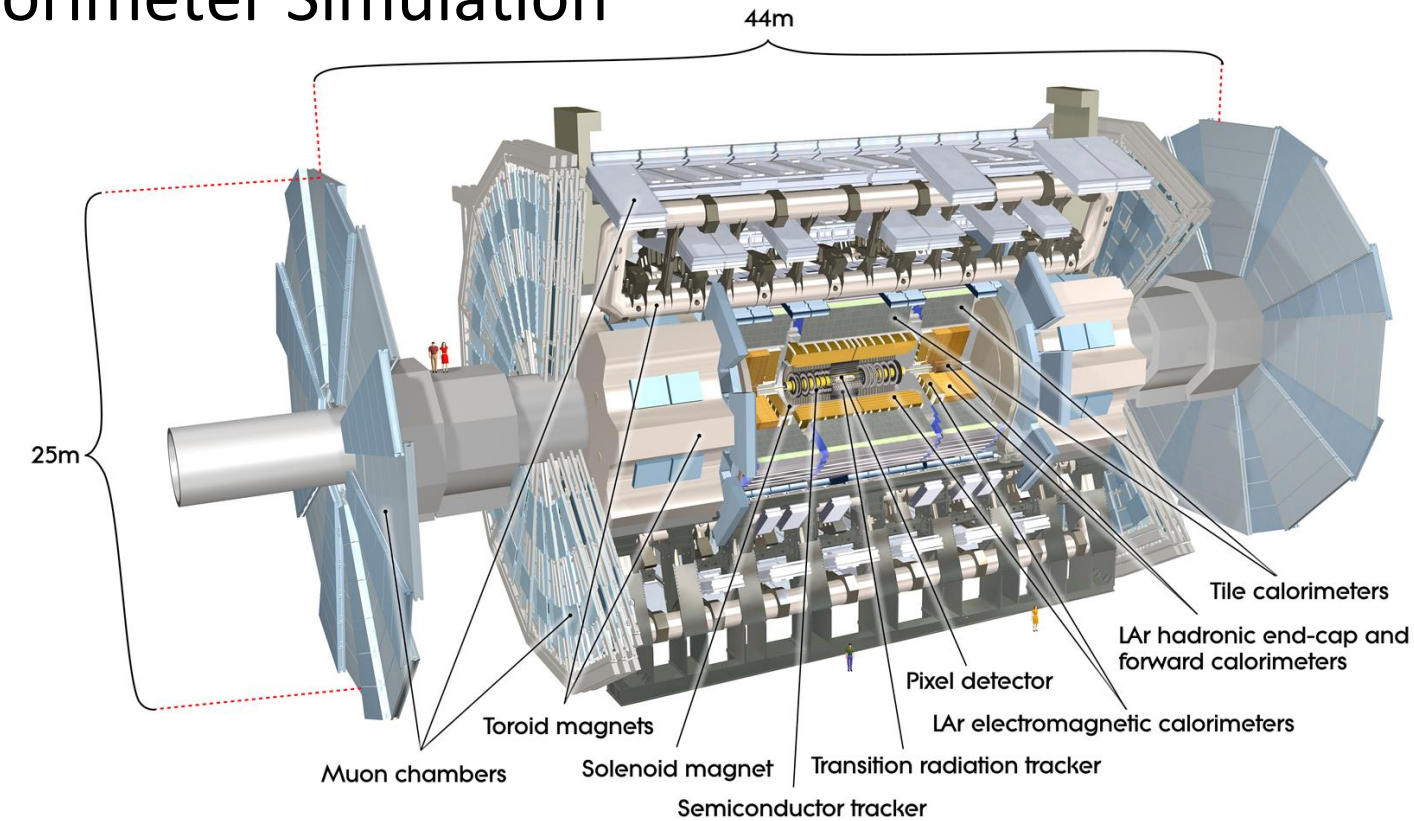
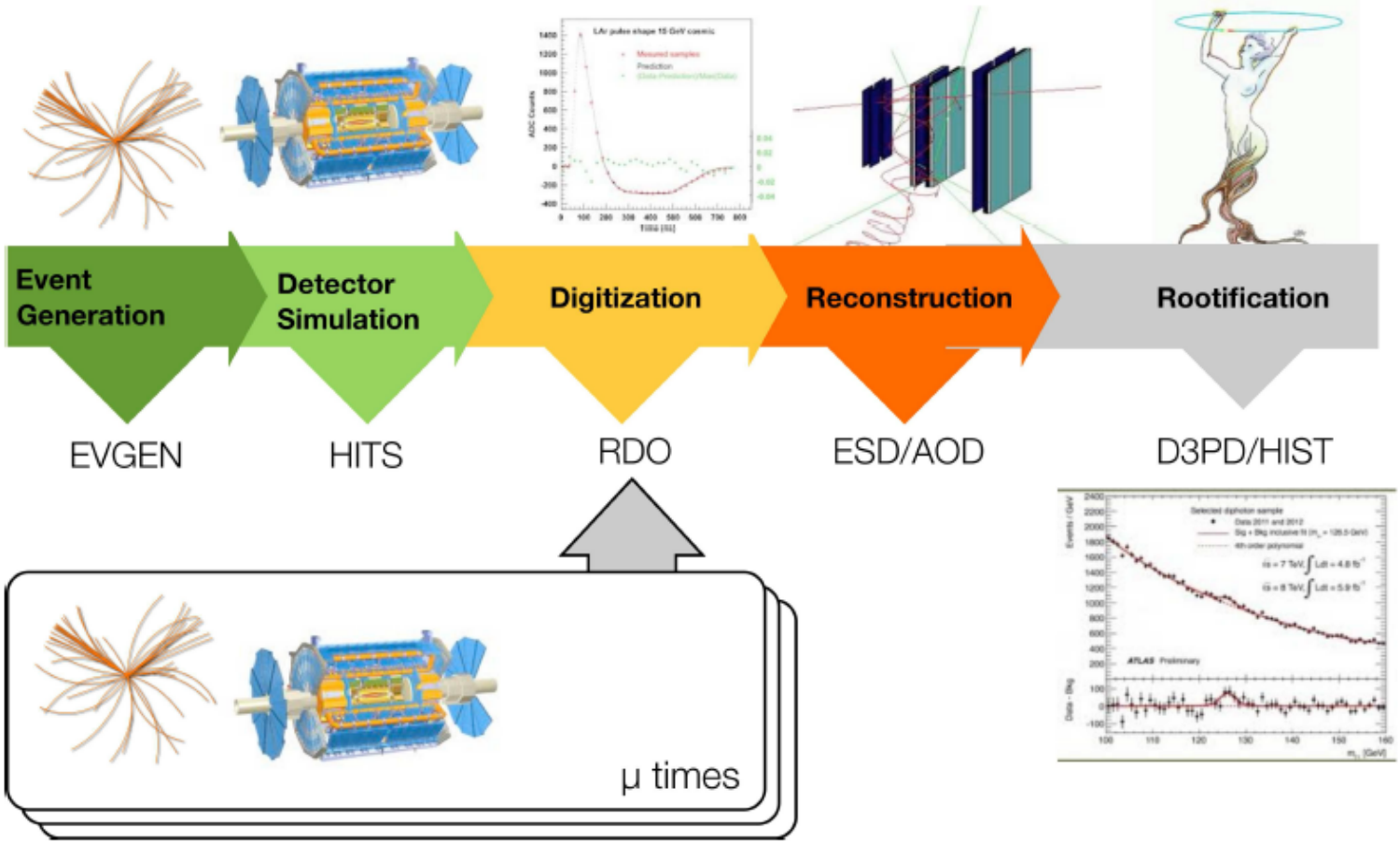
ACAT 2016, UTFSM, Valparaíso (Chile)
Jan 18-22, 2016

Outline

- Simulation of the ATLAS Detector
- Integrated Simulation Framework
- Fast Calorimeter Simulation

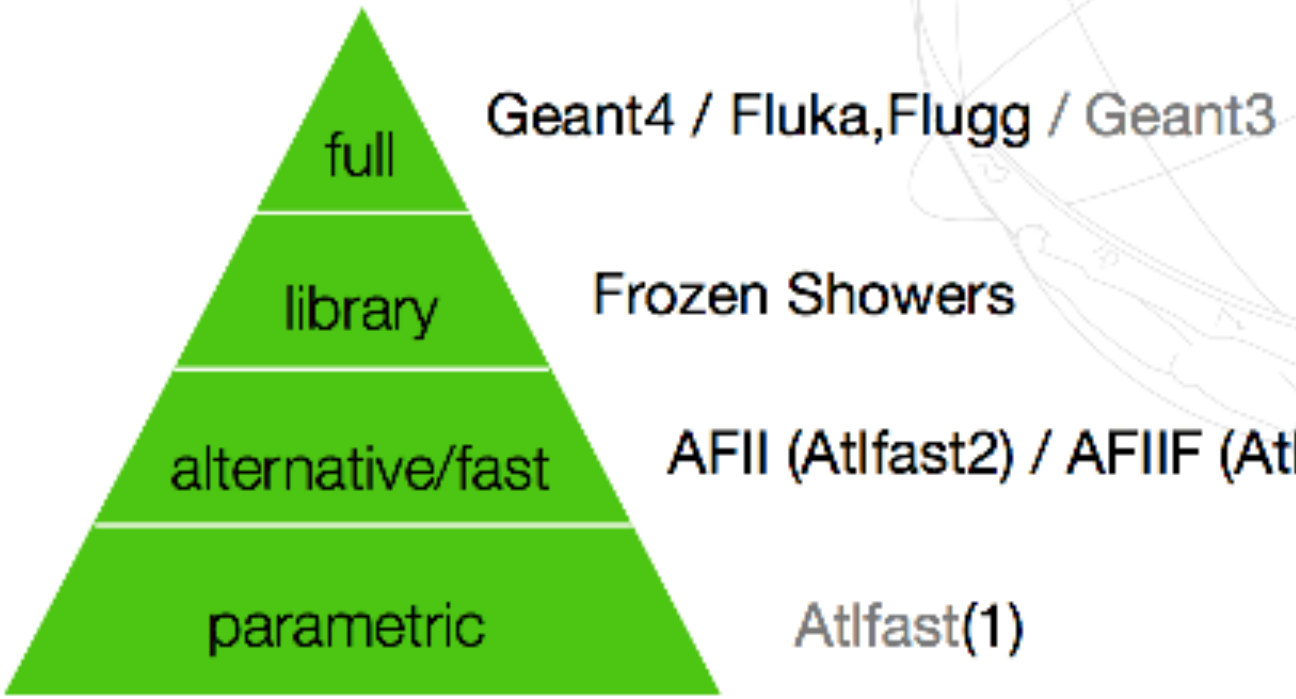


ATLAS Monte Carlo Production Chain



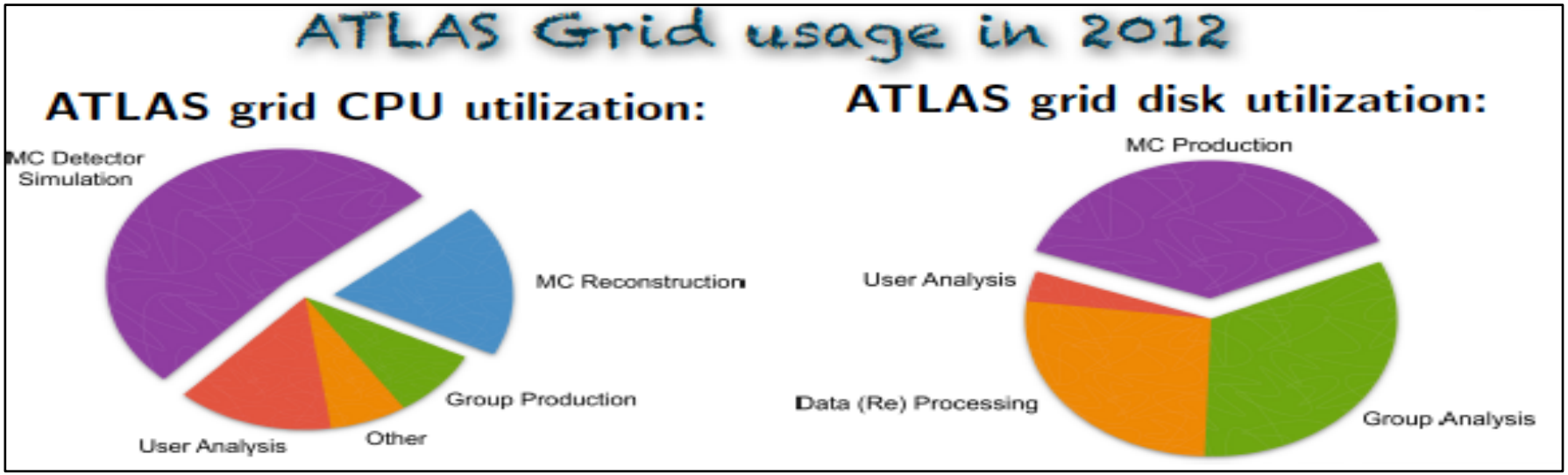
Detector Simulation Alternatives

Always a tradeoff between accuracy and speed



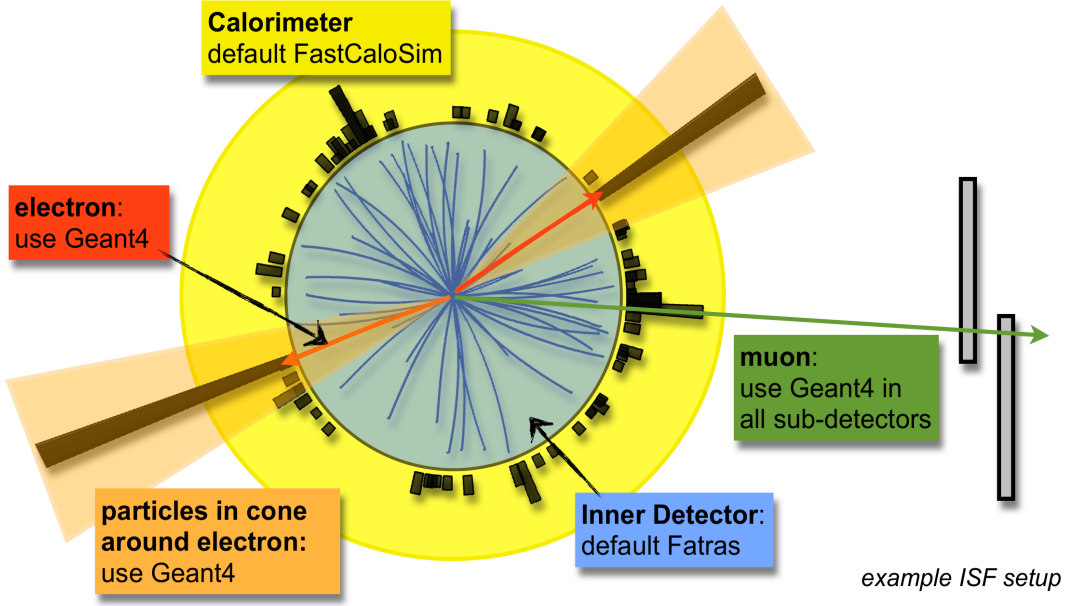
- What is the best choice?
- Can we optimize?

Why Fast Simulation



- Limited CPU resources, Limited disk space
- Grid CPU dominated by MC production
  - Precise detector simulation is CPU intensive
  - Production takes large fraction of disk space
  - Sensitivity limitation for physics analyses which need large MC statistics
- ~50% RunI MC was fast simulation
- Higher luminosity/pileup in RunII requires larger MC production

Integrated Simulation Framework (ISF)

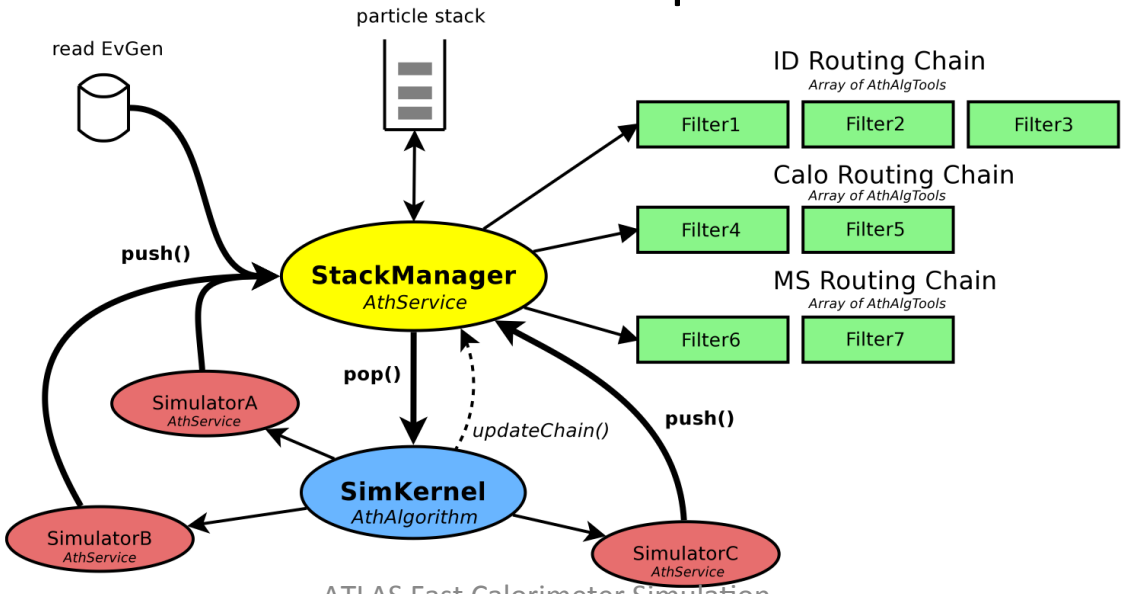


example ISF setup

- For most physics analyses, high precision is only needed for some particles/regions within each event
- ISF brings the possibility to mix different simulators
  - (Geant4/Fast tracking sim./Fast calorimeter sim.)
    - In different subdetectors
    - In the same subdetector – Geant4 for interesting objects, fast simulation for the rest of the event
  - CPU reduction factor: 10-100 depending on selected simulators

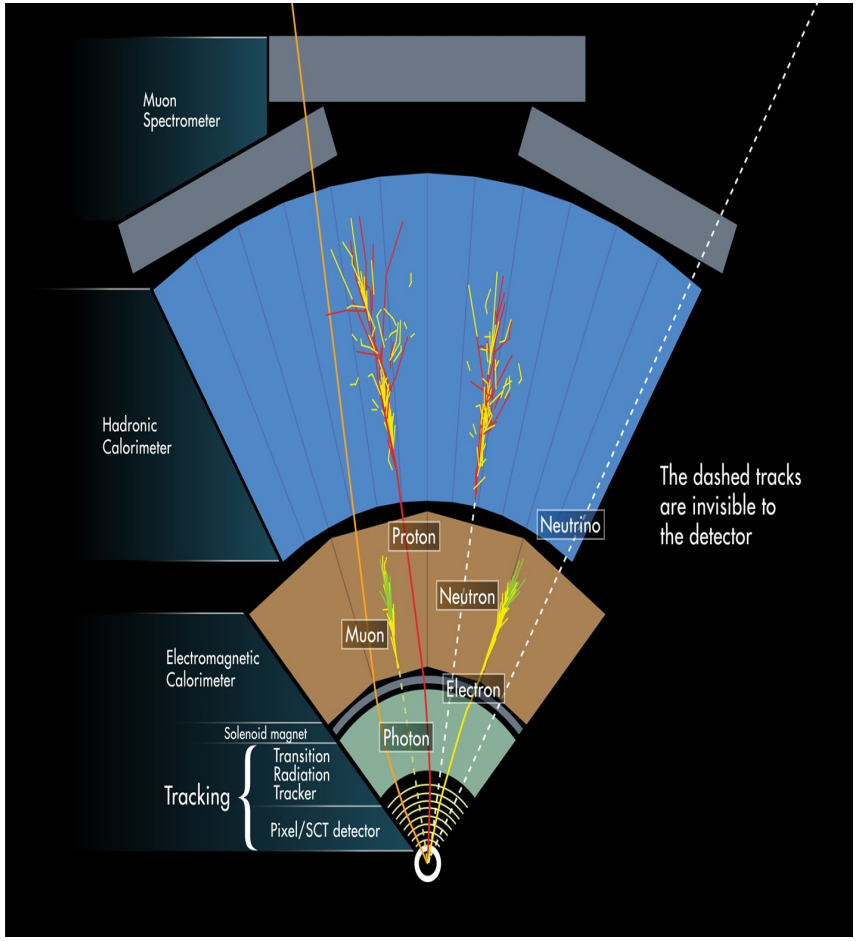
ISF Design

- ISF fully integrated in the ATLAS software framework (Gaudi Athena)
- SimKernel – responsible for sending particles to different simulators
- ParticleBroker – keeps particle lists and determines which simulator should be used for each particle



Standard ATLAS Simulator: Geant4

- Close collaboration with Geant4 team
- Stable, validated and precise simulation
- Currently using G4 v9.6
- Full description of the ATLAS detector
- High CPU consumption
  - Large number of G4 volumes
  - Mostly in (EM) calorimeters and for low energetic particles



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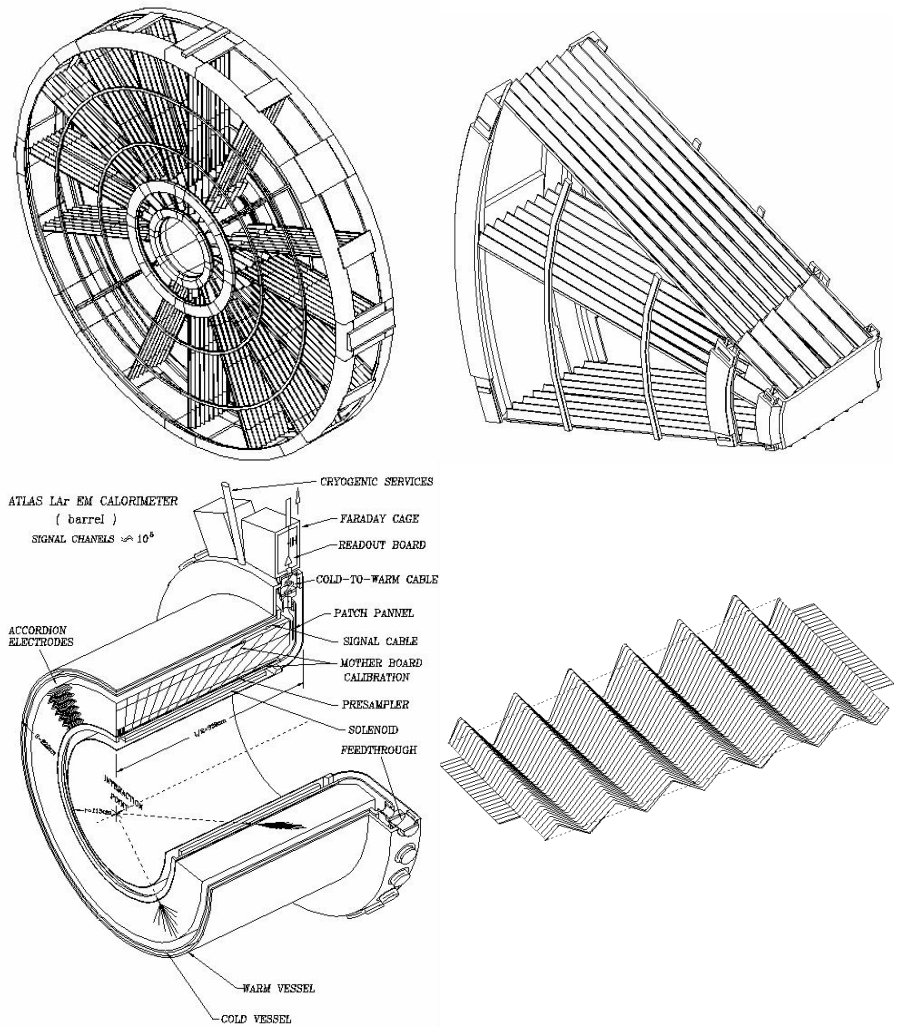
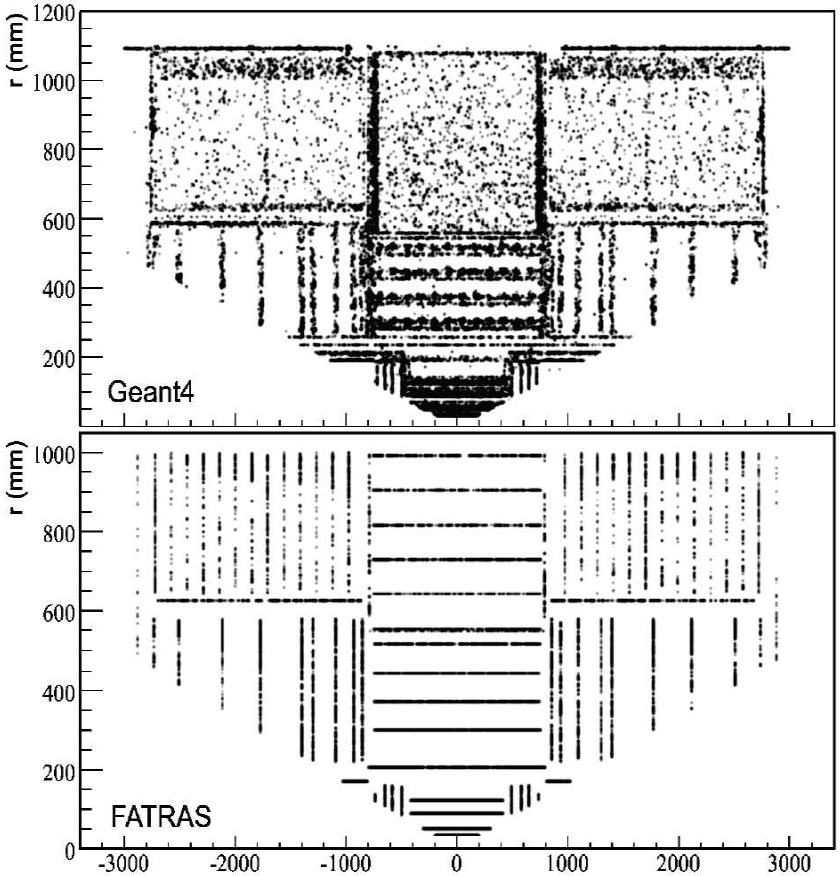
ATLAS LAr calorimeter



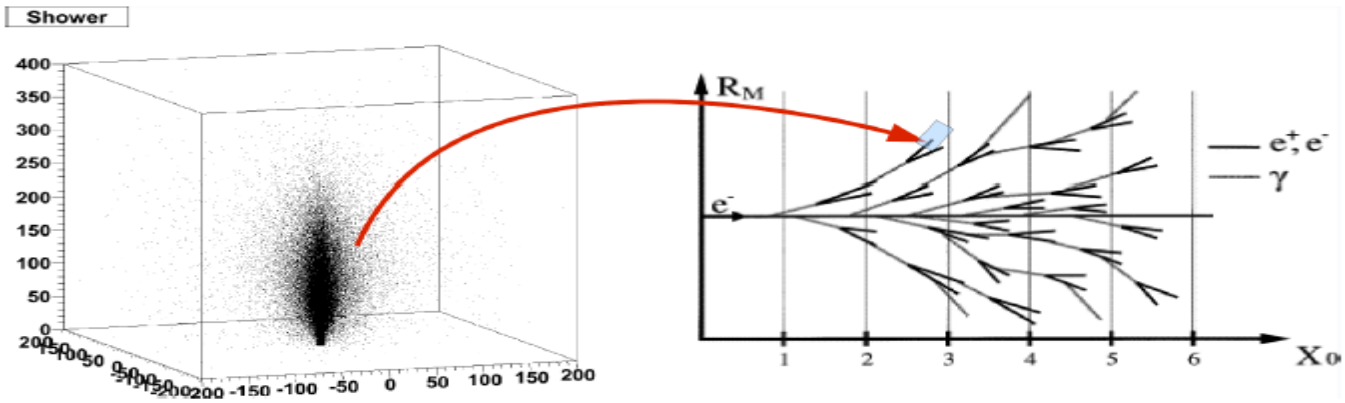
FATRAS

- Fast ATLAS Tracking Simulation (inner detector and muon spectrometer)
- Simplified detector geometry and simplified interaction processes



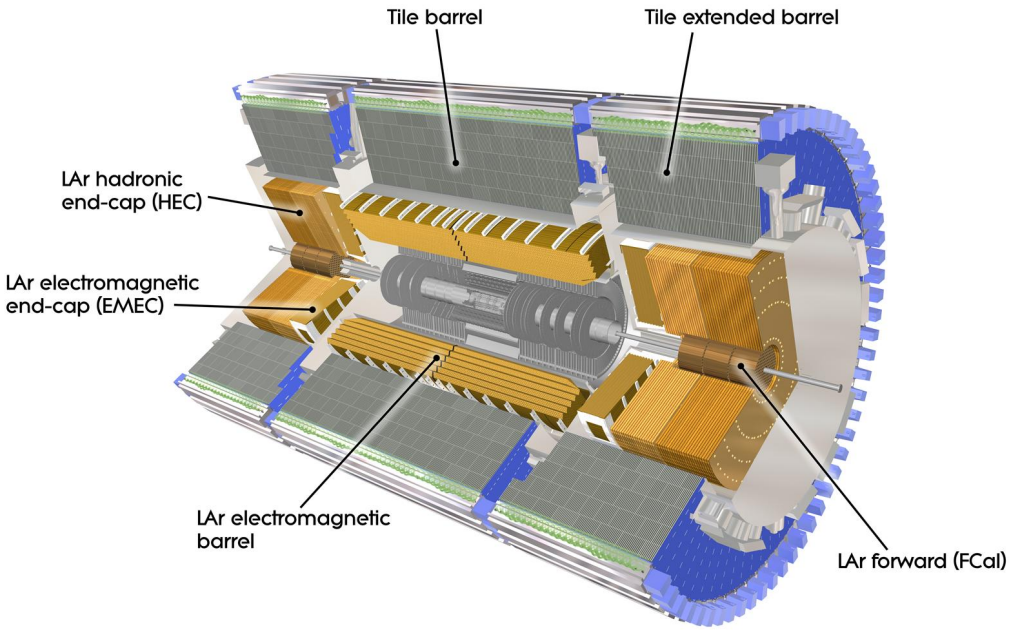
Frozen Showers

- Many high energetic particles in the forward direction
- Replace low energetic particles in the shower with pre-simulated EM showers (1 GeV electron and similar)
- Used by default in the full simulation in forward calorimeters



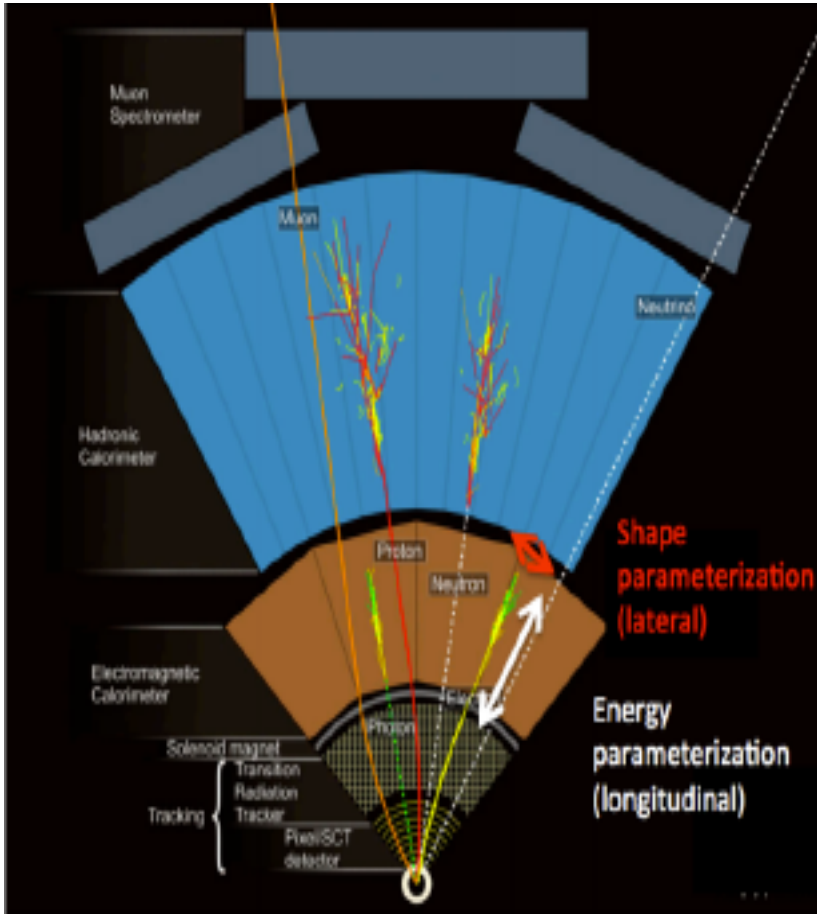
FastCaloSim - Calorimeter Simulation

- Parameterization of calorimeter response based on Geant4 full simulation
- Tuned to data
- Used as an alternative to the full simulation, requires dedicated calibration



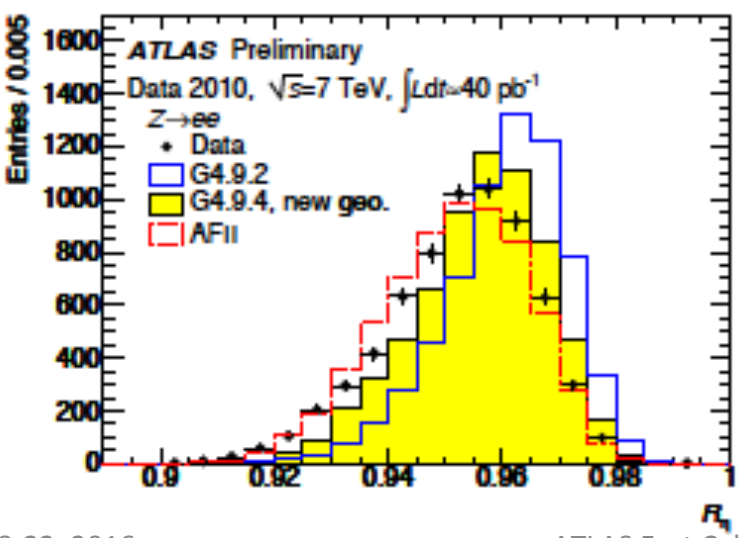
FastCaloSim

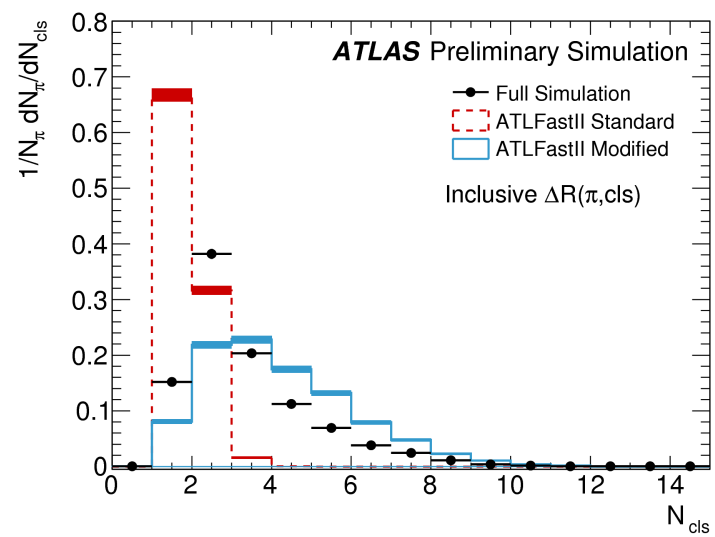
- Energy and shape parametrization for single particles (e, γ, π) (E-η grid)
- Priority order
  - Correct simulation of the total energy
  - Correct simulation of the longitudinal shower depth
  - Correct simulation of energy fractions in each calorimeter layer
  - Correct simulation of correlation of energy fractions in each calorimeter layer
  - Correct description of the lateral energy distributions (shower shapes)



Current FastCaloSim Performance and Limitations

- Lateral shower shapes could be tuned to data to improve agreement
- Hadronic objects not well described due to average shower shape simulation
- Prototype of random fluctuation model tested

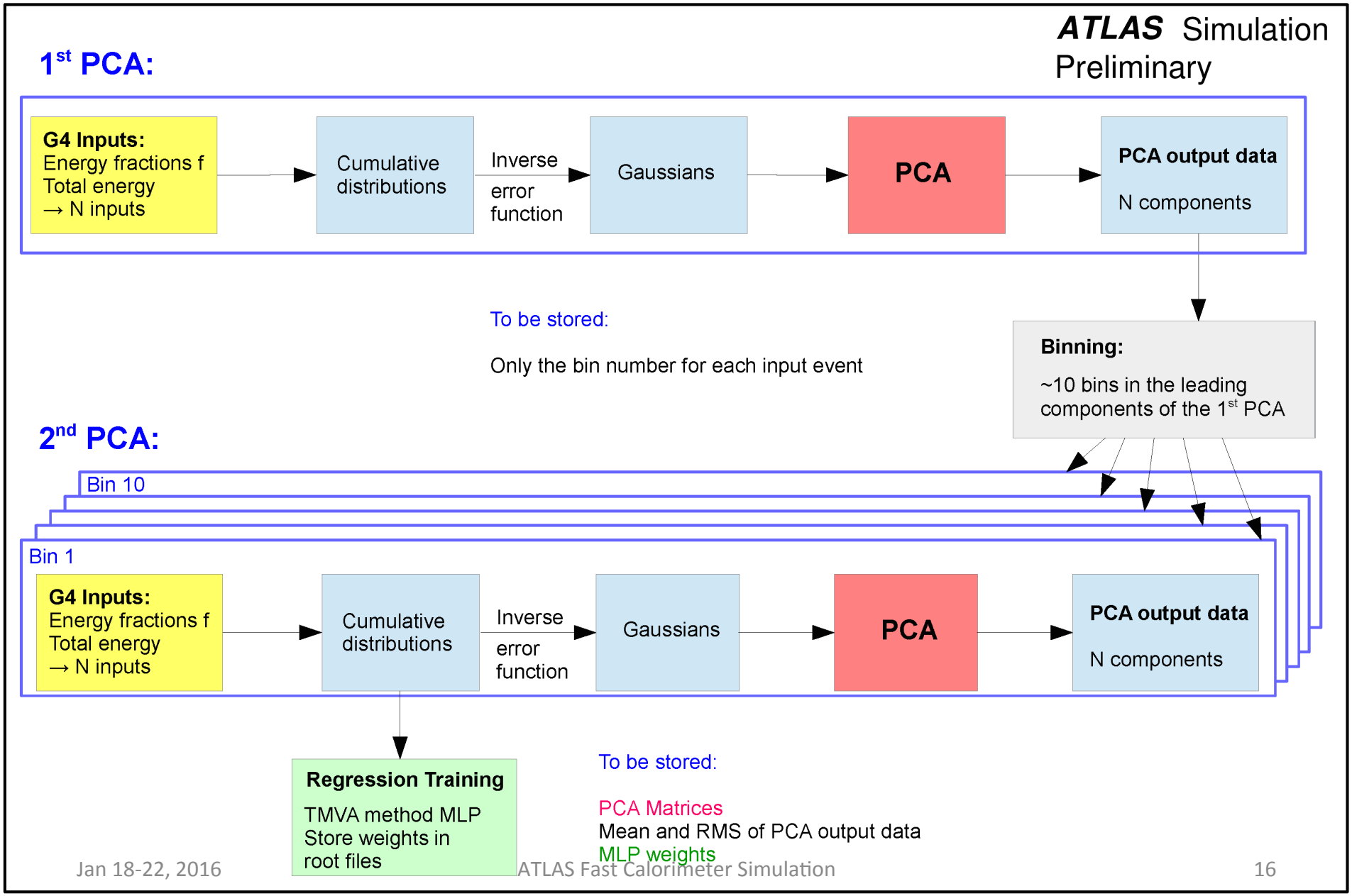




New Parameterization

- Re-simulate single particles (e, γ, π) on a fine energy and η grid (approx 15x100 points)
  - Using full Geant4 simulation, current ATLAS geometry
  - Save detailed spatial information (x,y,z,t,E) of the developed shower
- Re-derive the energy parameterization (longitudinal) and shower shape (lateral)
  - Reduce the amount of information to a compact form
  - Use TMVA Regression to approximate histograms

Energy Parametrization Method



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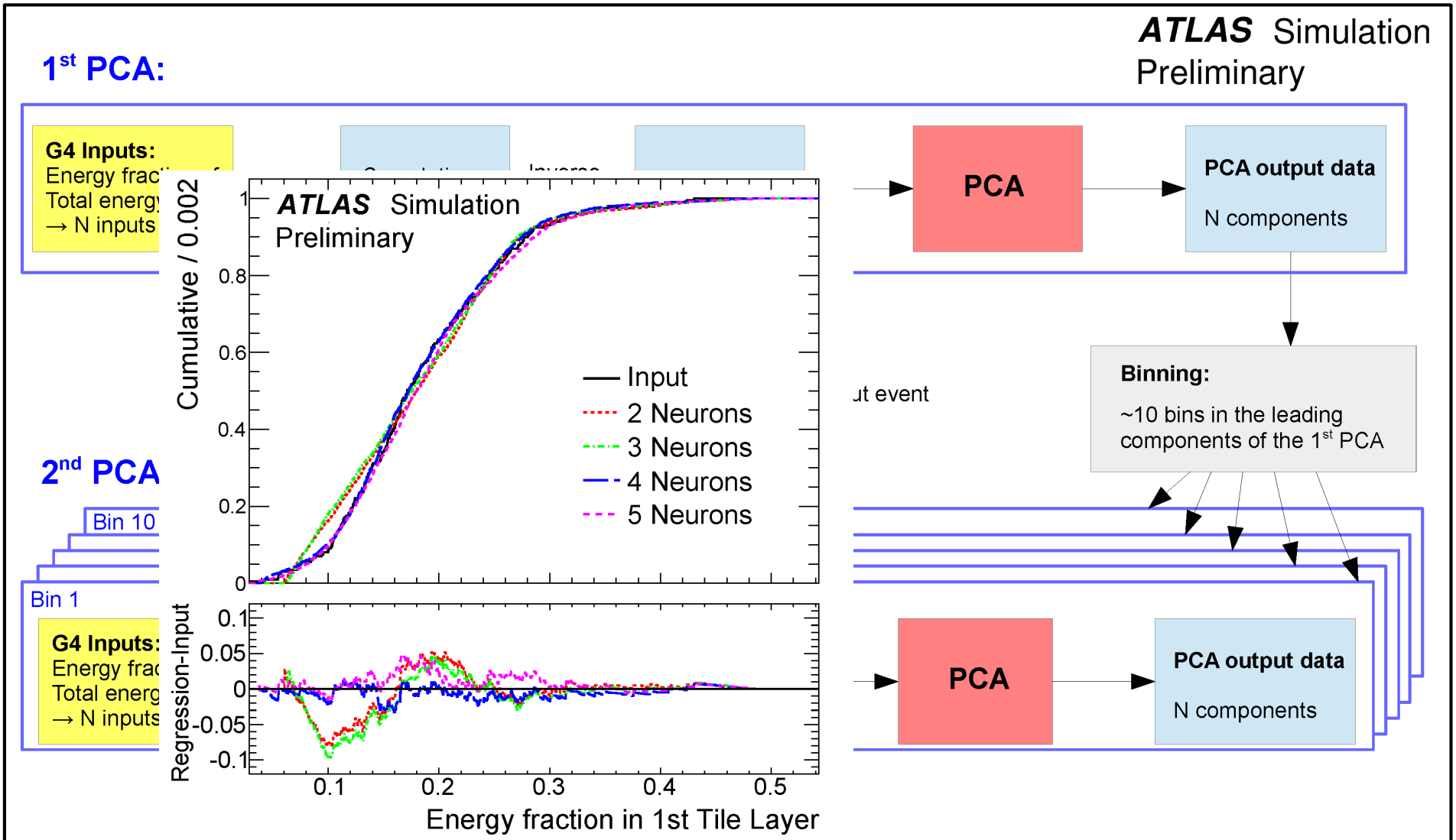
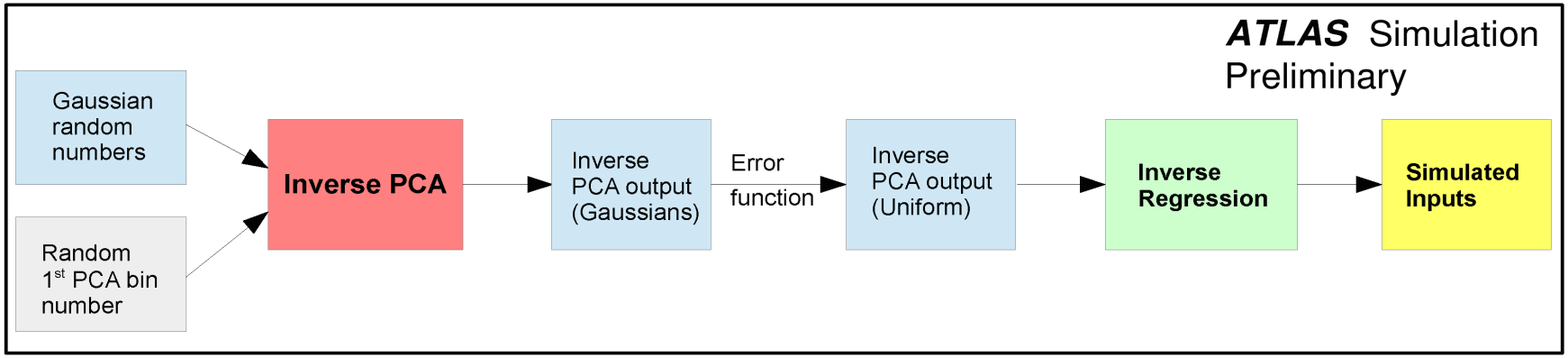
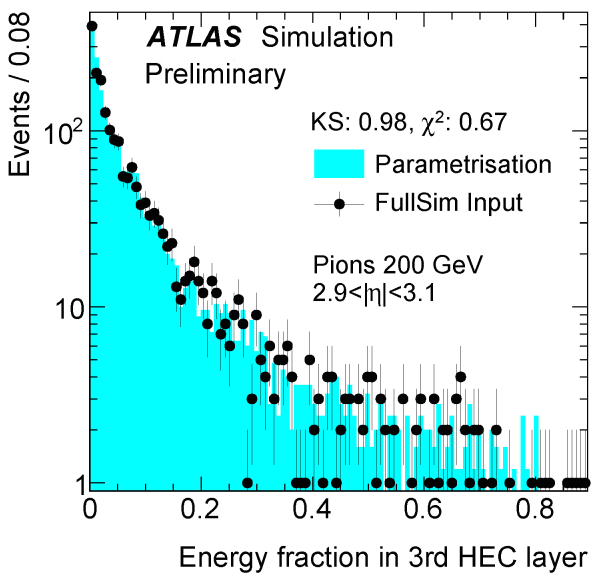
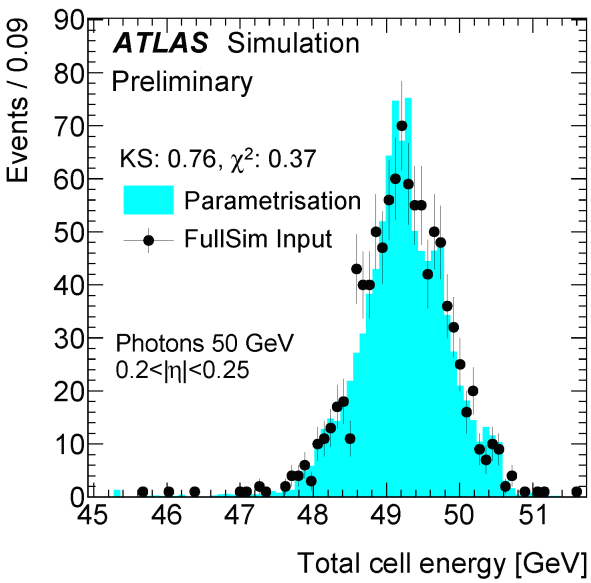


Toy Simulation

From random numbers and stored weights and PCA matrix

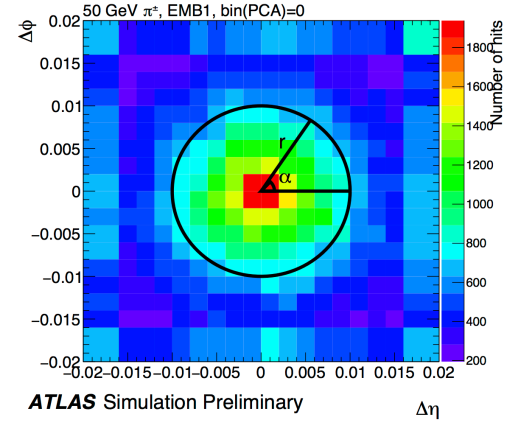


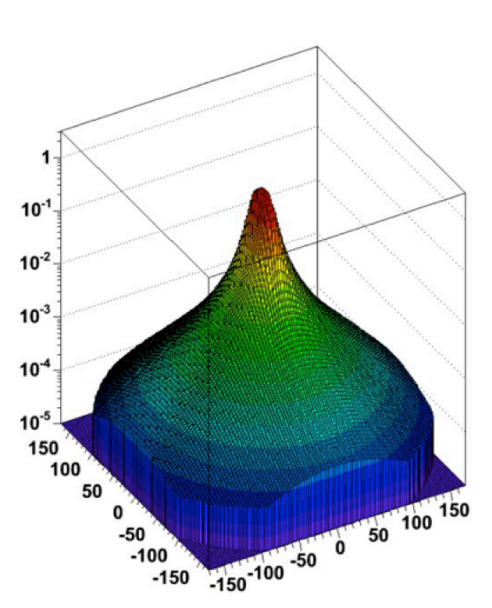


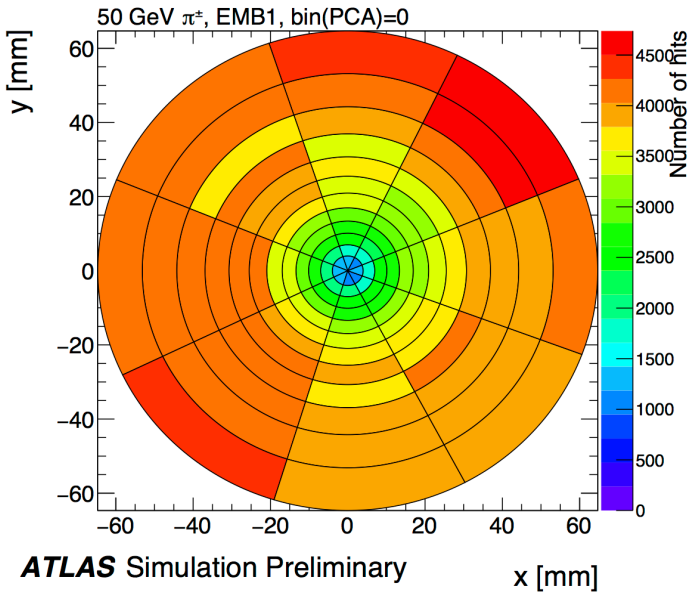


(Lateral) Shower Shape

- Get average shower shape per layer and per PCA bin
- Optimal binning derived iteratively

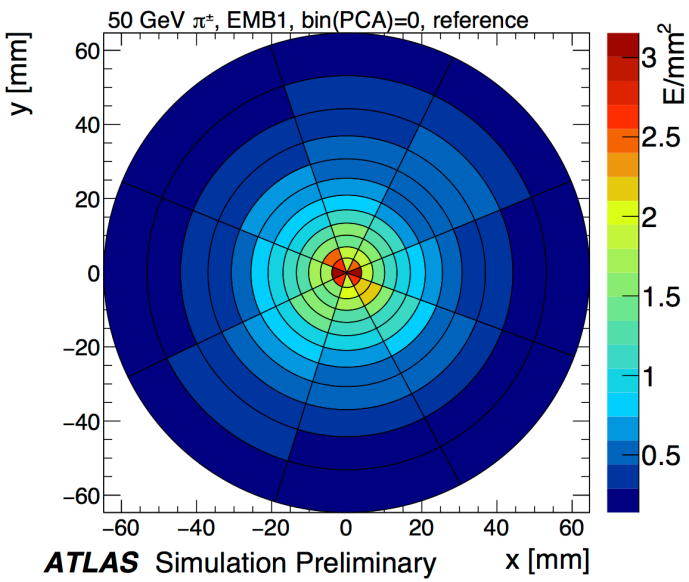


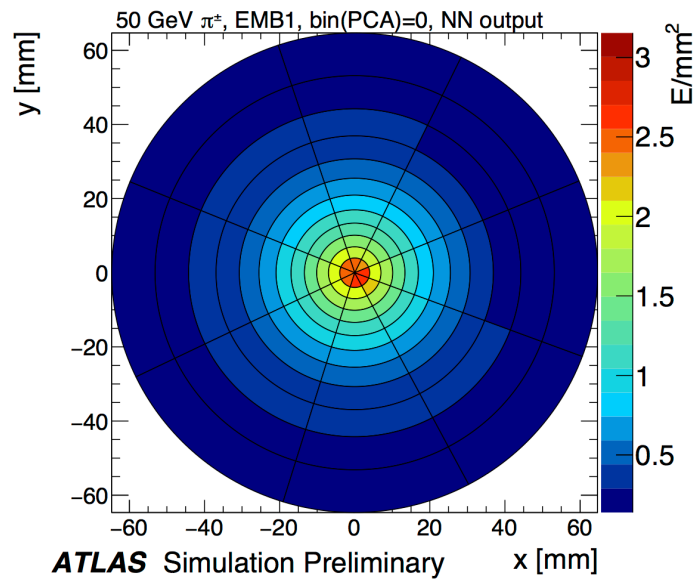




Shower Shape

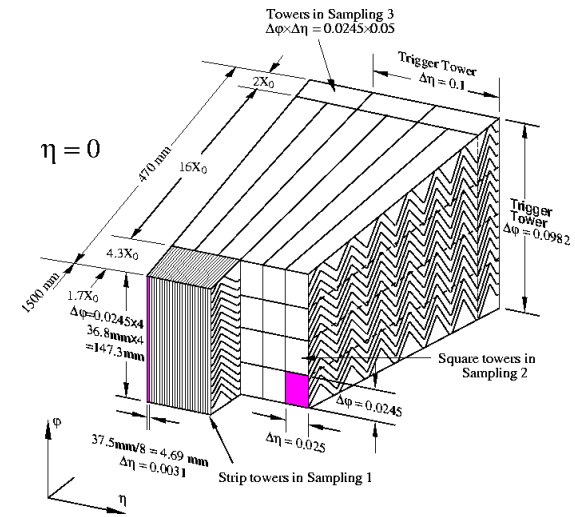
- The binned energy fractions are fit with a Neural Network
- Store TMVA weights instead of histograms



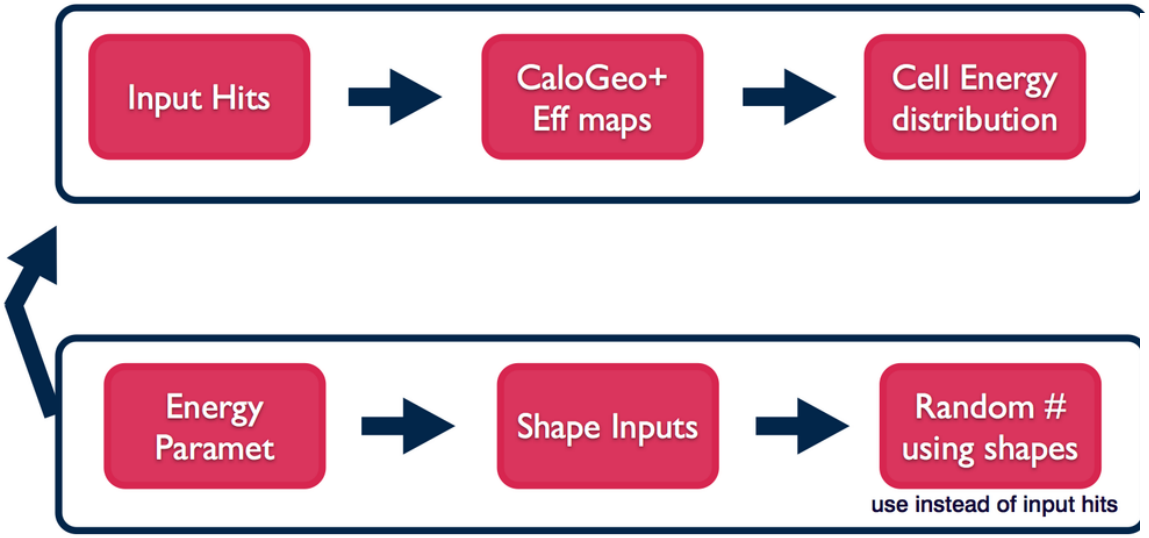


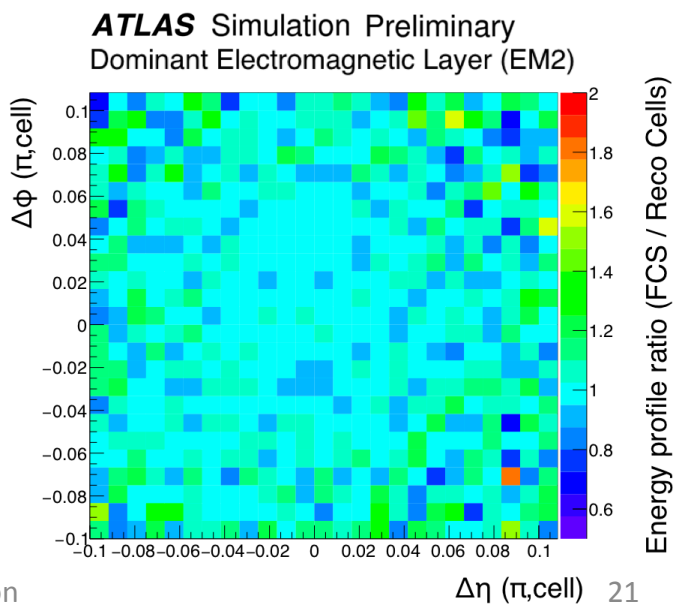
Towards a Prototype

- Work on going on a prototype to implement the particle simulation



Closure Test





Check for agreement on cell level

Summary

- (Fast) calorimeter simulation essential for ATLAS physics program
- ATLAS implemented Integrated Simulation Framework for greater simulation flexibility
- FastCaloSim – fast parameterized calorimeter update in development