Simulation and Early LHC Data

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Standard Model with early LHC data workshop
31/03/2009

Issues Addressed

- What is simulation?
- Are particle interactions properly simulated?
- How can we use early data to improve simulation?
- Are the detector descriptions accurate?
- Overlaid events
  - Cosmics
  - Cavern background
  - Pileup events
- Fast Simulations

- Why am I mostly talking about Atlas?
  - Default unless CMS is explicitly stated

What is simulation?

Simulation is the means to take generated physics events and provide output as close as possible to the detector output during data-taking

Typically done in two stages (both using Geant4)

- simulate energy deposited from particle interactions with detector material
- simulate the detector response to deposited energy (digitization)

What is simulation?

Atlas Simulation Options

- Full Geant4 simulation
  - 1990s per ttbar event, full detail
  - ~80% of time spent simulating particles in calorimeter
  - ~75% of time spent simulating EM particles
- Fast Geant4
  - Frozen showers replace low energy EM particles in calorimeter
  - 757s per ttbar event
- Fast calorimeter simulation (Atlfast-2A)
  - Parameterised shower for each particle hitting the calorimeter face
  - 101s per ttbar event
- Fast calorimeter + inner detector simulation (Atlfast-2F)
  - Track hit distribution parameterised
  - 7.41s per ttbar event
- Fully parameterized fast simulation (**Atlfast-1**)
  - Particle kinematics modelled, most detector effects not modelled
  - 0.097s per ttbar event (includes reco)

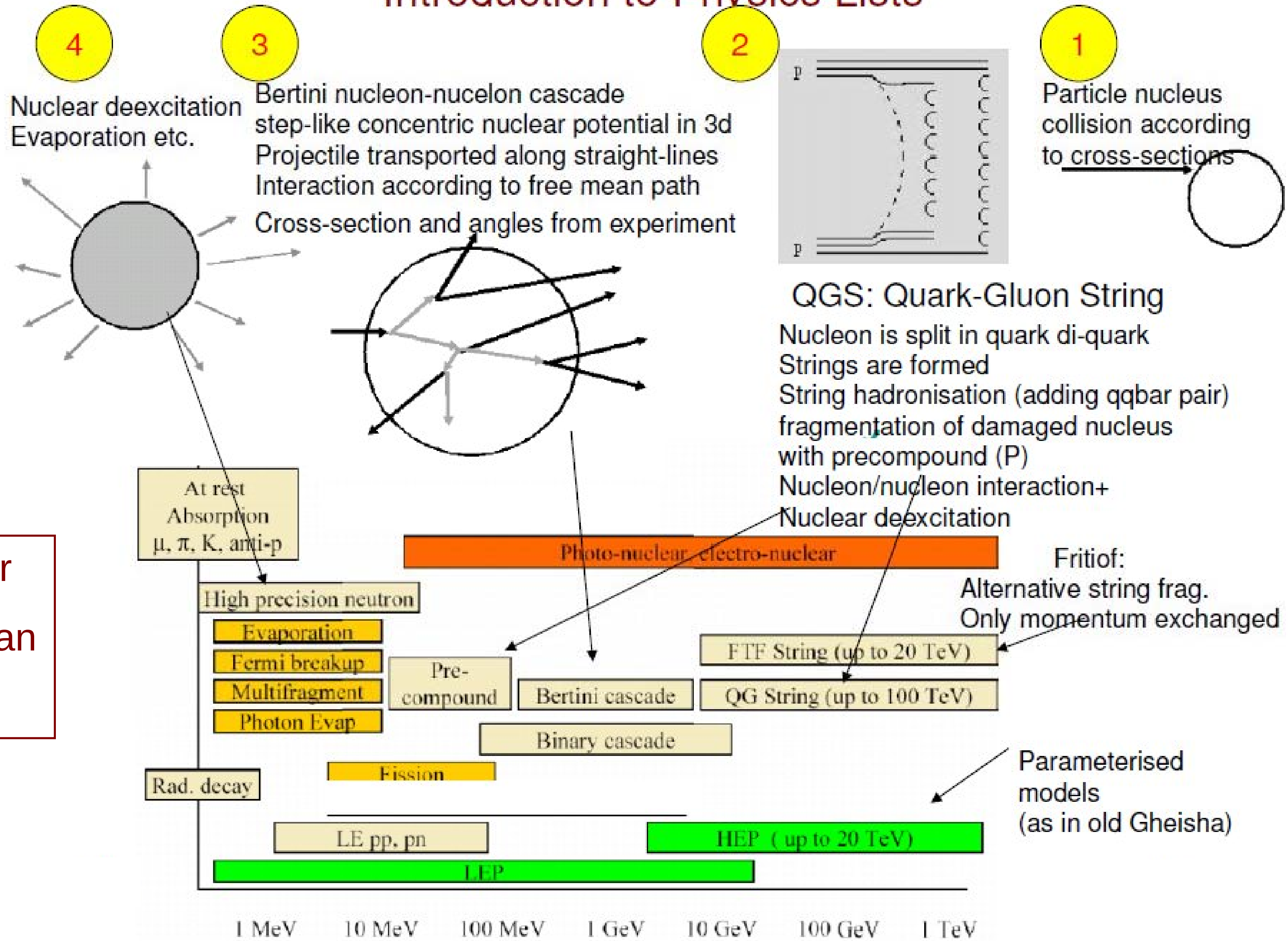
Timing measurements from upcoming publication "The ATLAS Monte Carlo Project"

Introduction to Physics Lists

Margar

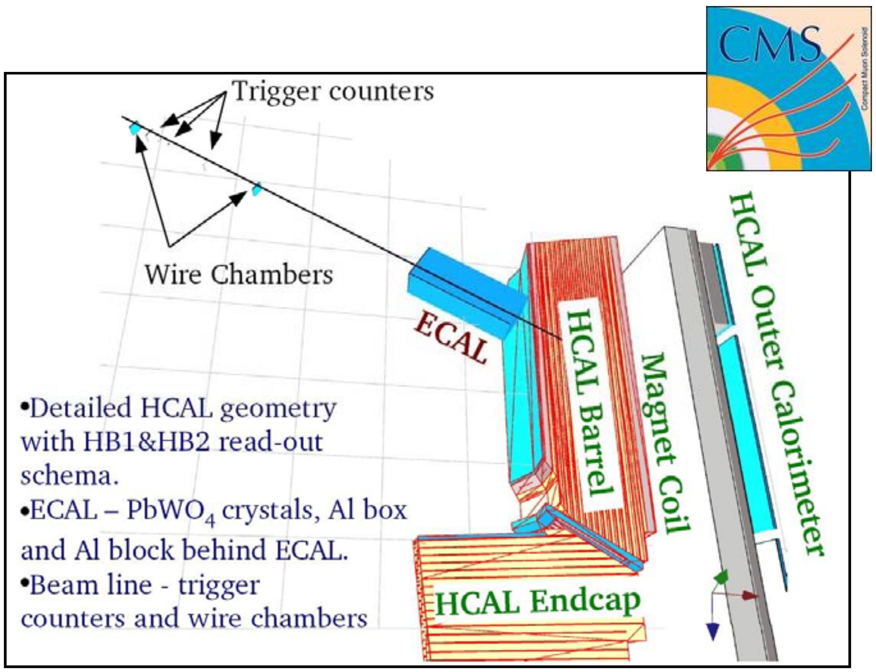
Simonyan

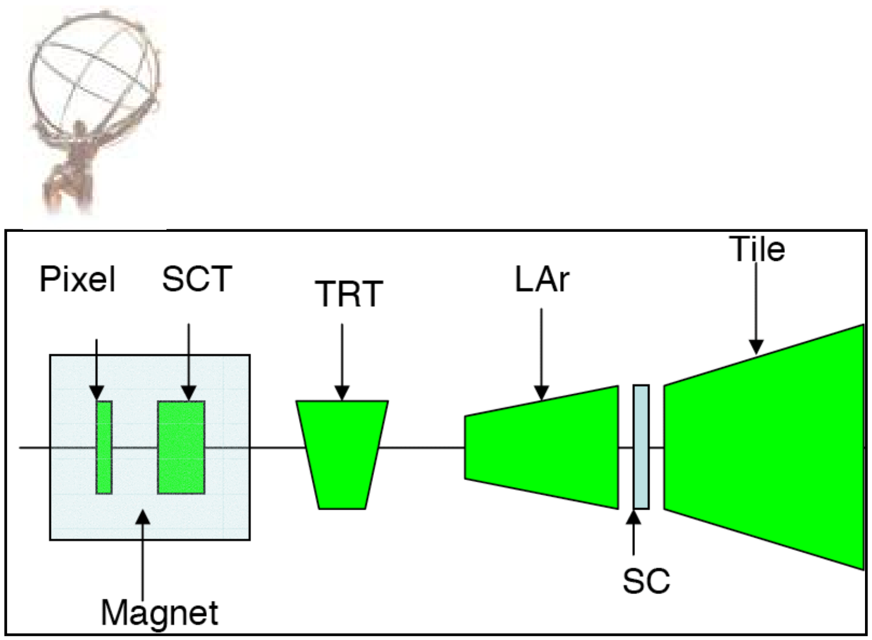
LAPP



How can we use early data to improve simulation?

- Early non-LHC data is already being used to tune simulation
  - 2004 and 2006 test beams
- This work will continue into LHC data-taking

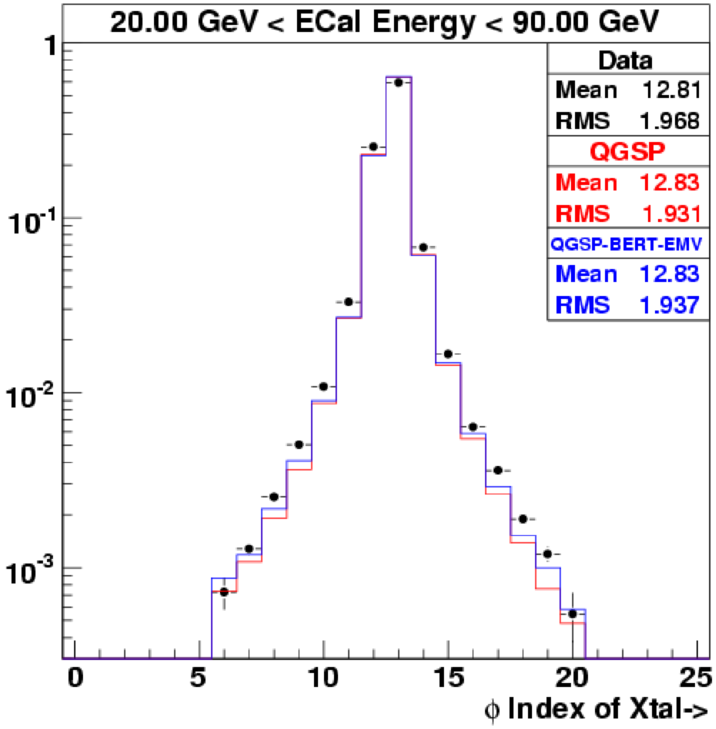


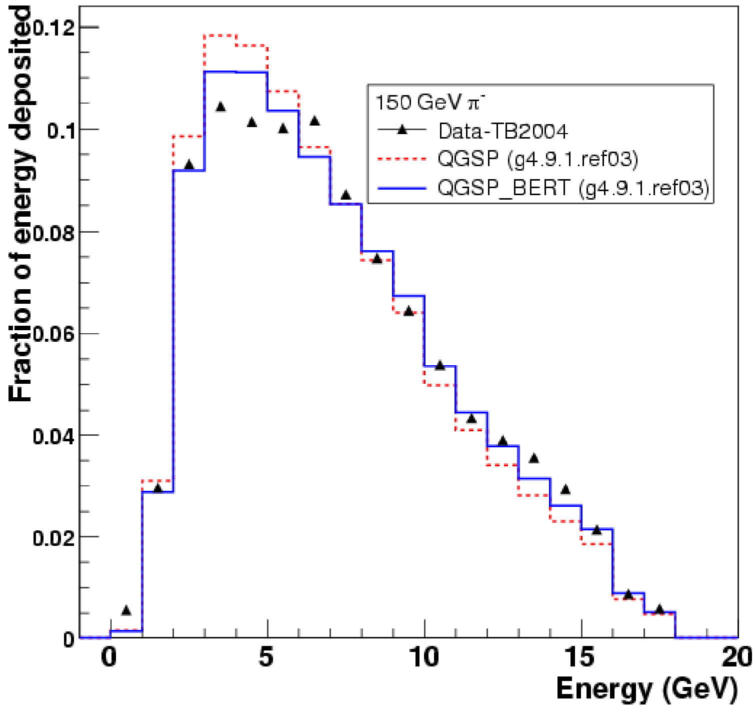


How can we use early data to improve simulation?

- CMS results - lateral and longitudinal profile of pion shower
  - Shows good agreement

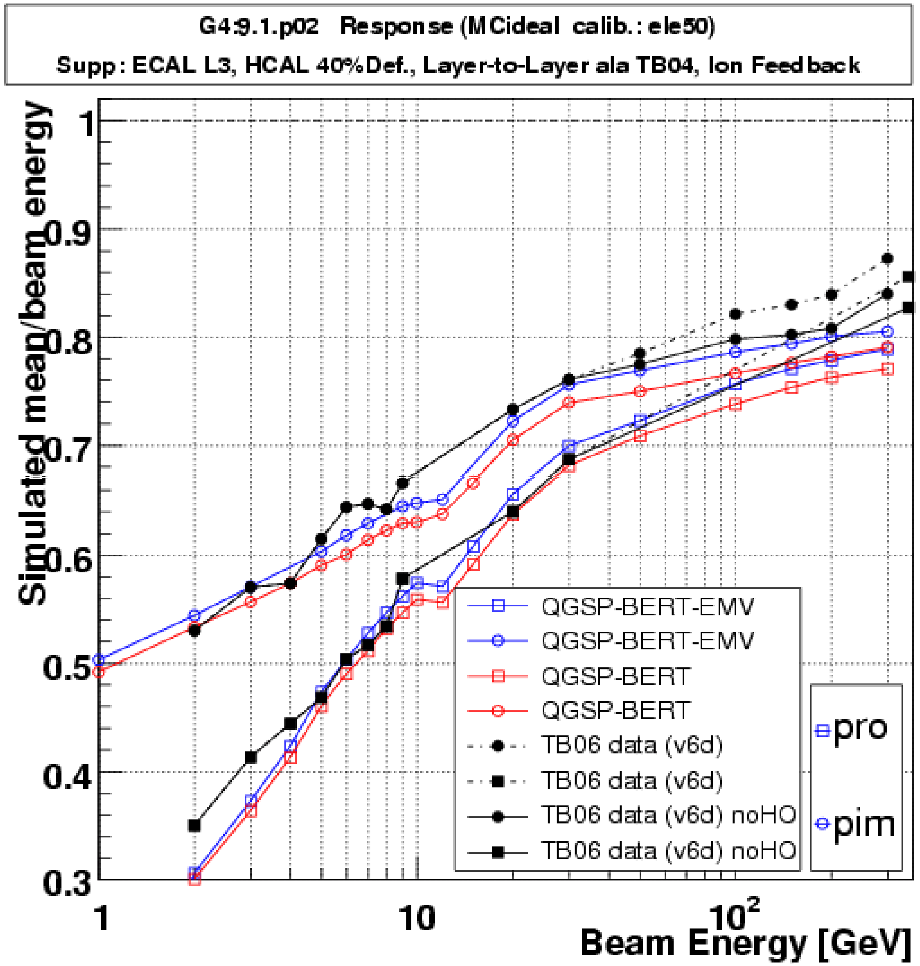
CMS HCAL group





How can we use early data to improve simulation?

- Normalized ECAL+HCAL response as a function of pion beam energy.



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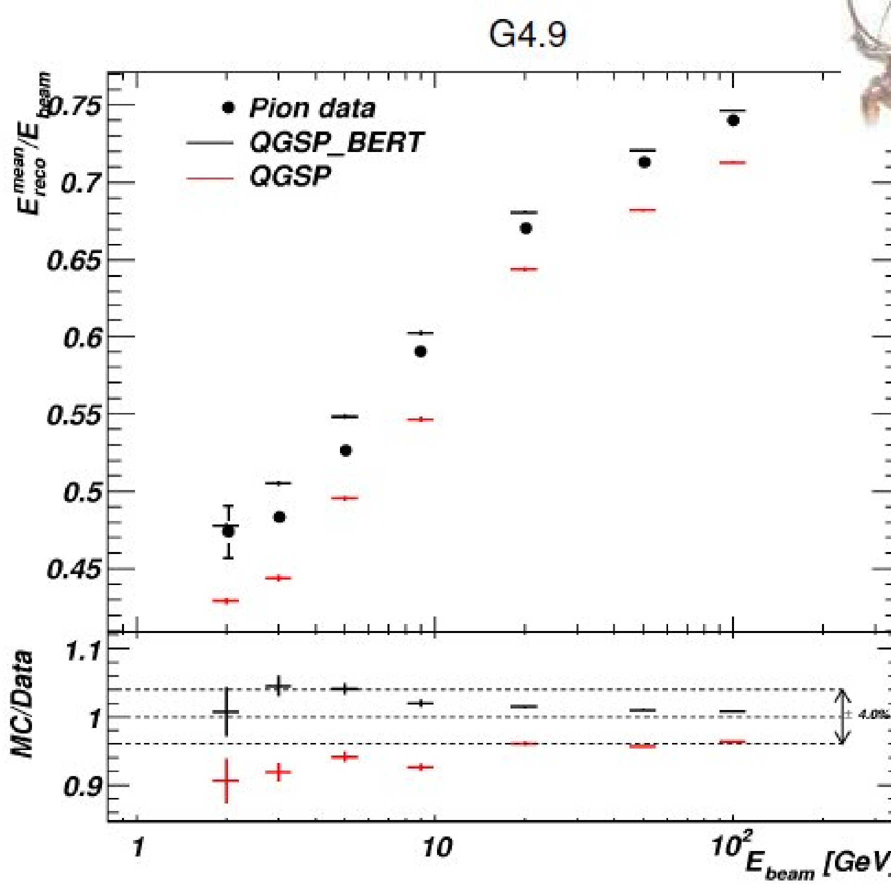
How can we use early data to improve simulation?

- Pion response
- Bertini cascade model increases the response.
- QGPS_BERT shows the
- best overall performance for the response (within 4%).



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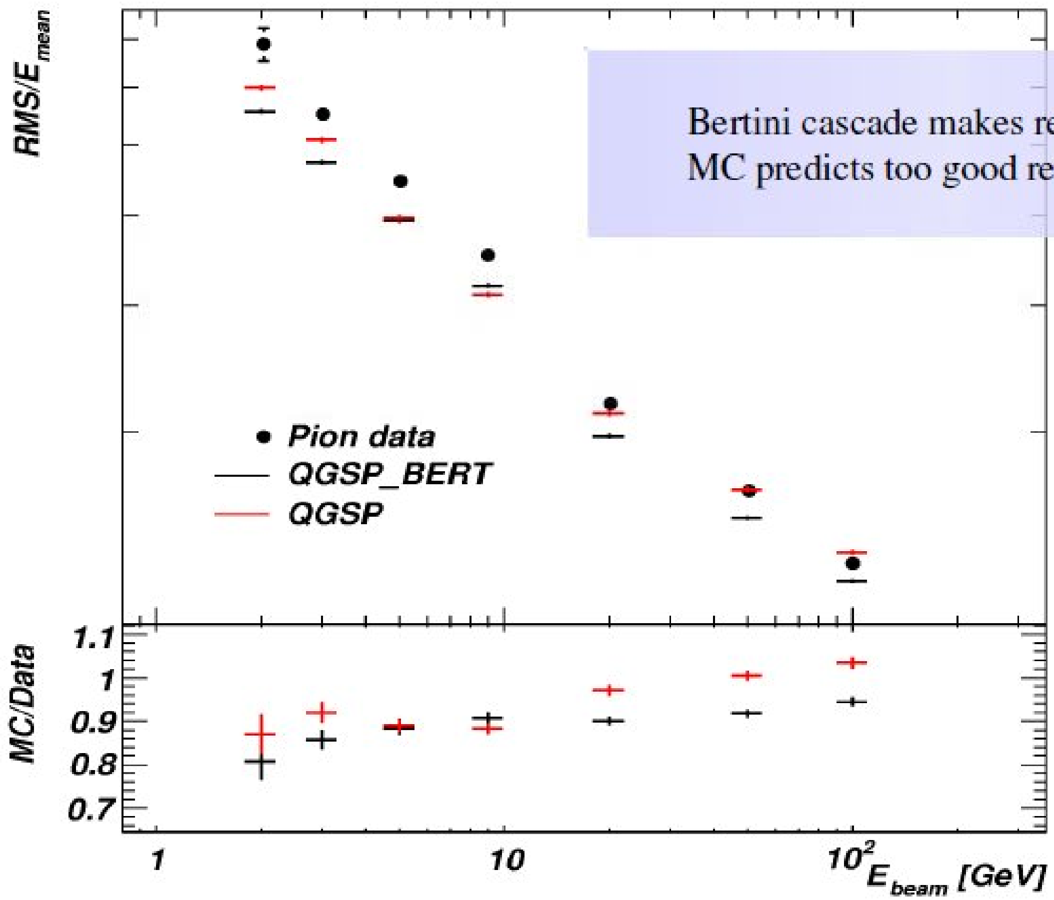
How can we use early data to improve simulation?

- Pion resolution

G4.9



Bertini cascade makes resolution better
MC predicts too good resolution -5 ÷ -10%

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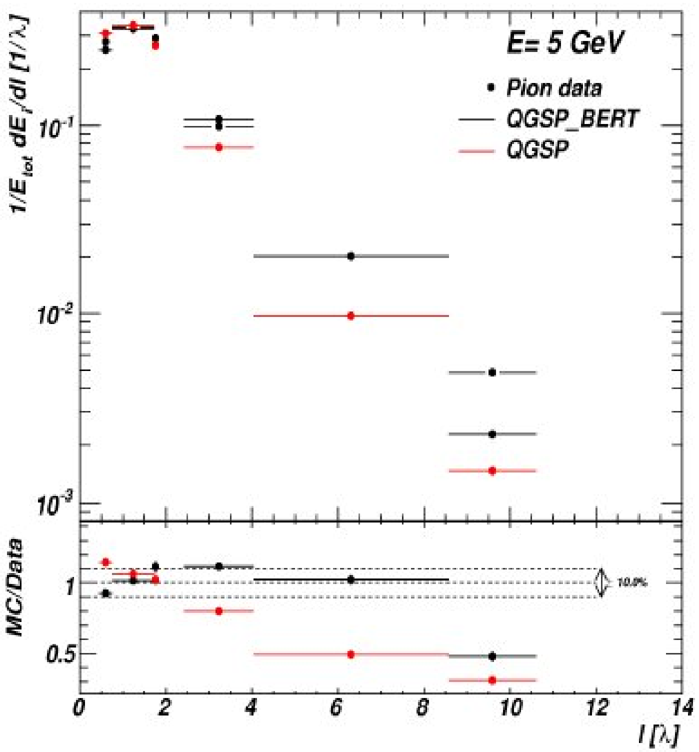
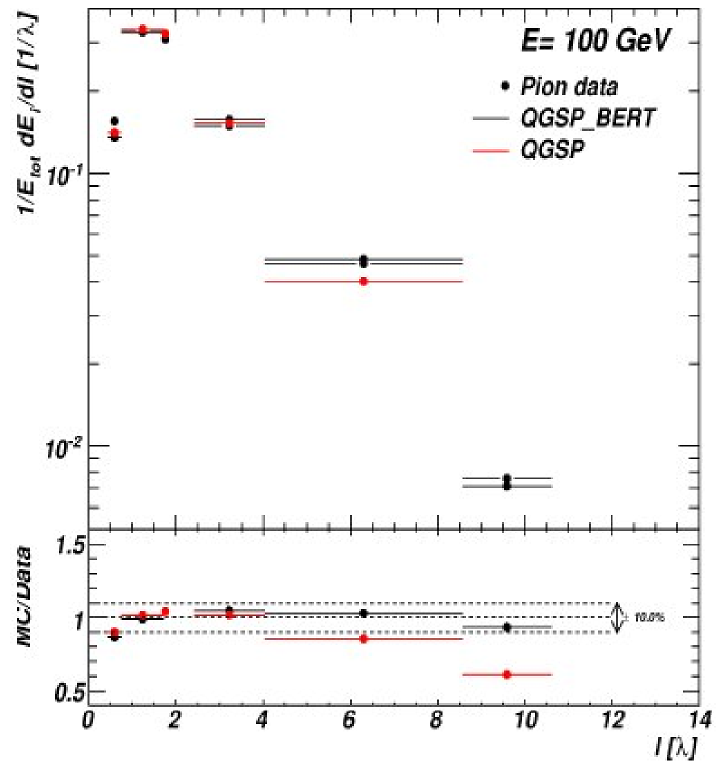
How can we use early data to improve simulation?

- Pion longitudinal shower profile
- QGPS_BERT describes data within ±10%

G4.9





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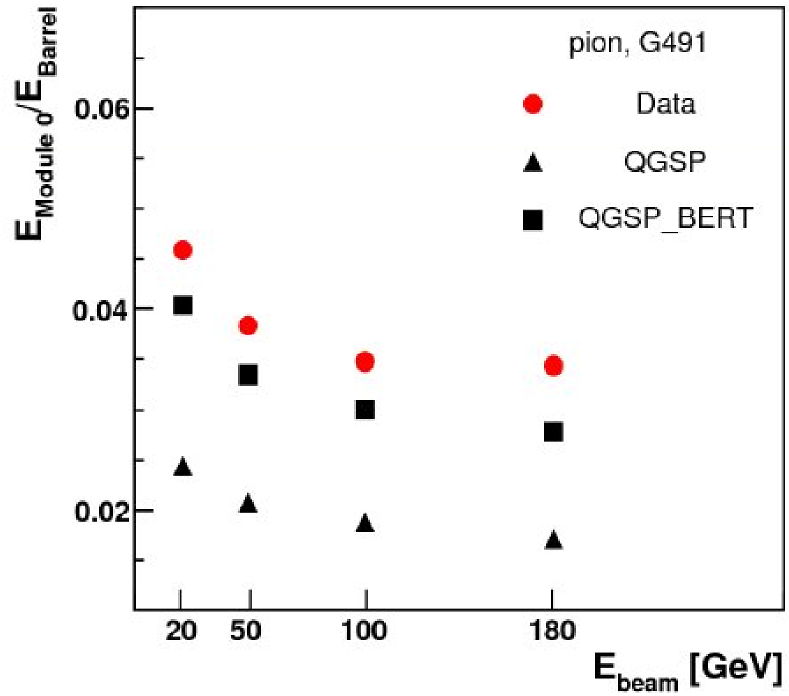
How can we use early data to improve simulation?

- Pion lateral spread in tile calorimeter
- Bertini cascade makes shower wider, which is in better agreement with data but data are still a bit wider.



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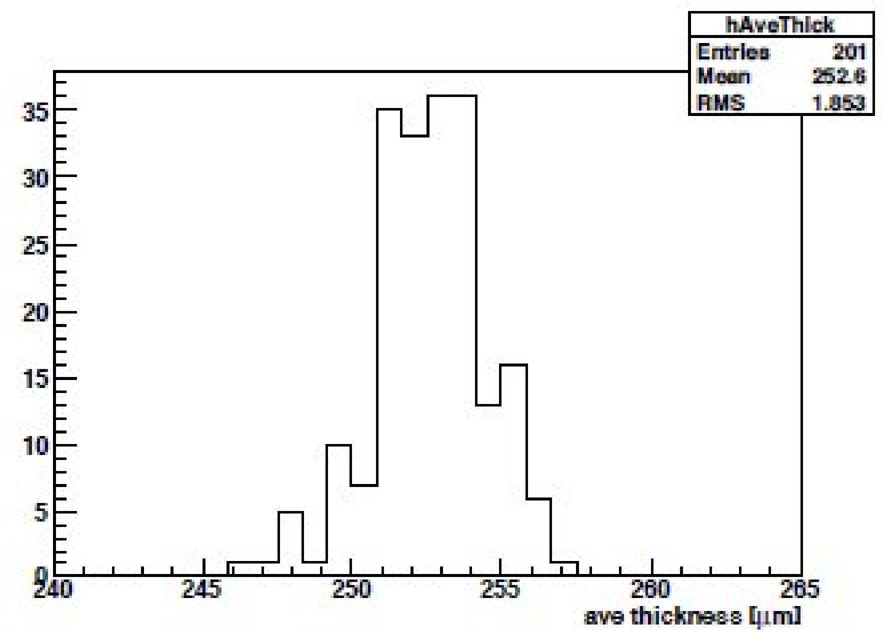
How can we use early data to improve simulation?

- ATLAS and CMS have both taken the decision to use QGSP_BERT as default physics lists for simulation of first collision data.
  - Great for consistency!
- 10 TeV data-taking will
  - tell us about more specific detector problems
  - allow better calibration using resonances, eg.. Drell-Yan Z($\rightarrow$ee, $\mu\mu$) for ECAL calibration / Muon system alignment
- Possible further improvements
  - Fritiof model testing, may improve on QGSP..
  - Birk's Law
    - saturation of response in LAr for particles with large dE/dx

Are the detector descriptions accurate?

- Example: pixel sensor thickness
- Amount of charge deposited depends on the amount of silicon traversed
  - Assumed 250 μm in simulation
  - Thickness as measured in the lab shown
- Eventually, with higher track statistics, one could try relating the MPV per module back to the data to determine corrections



Heather Gray, CIT, Columbia University

Overlaid Events

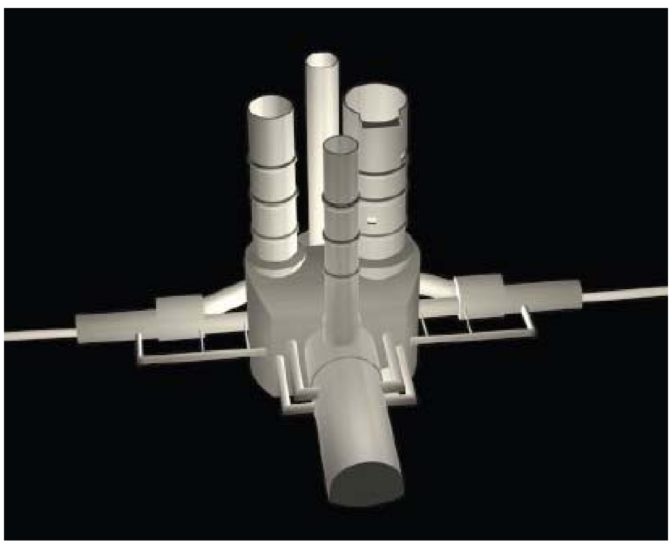
- It is possible to "overlay" events at the digitization stage
  - add hits from additional events into simulated physics events

Cosmics

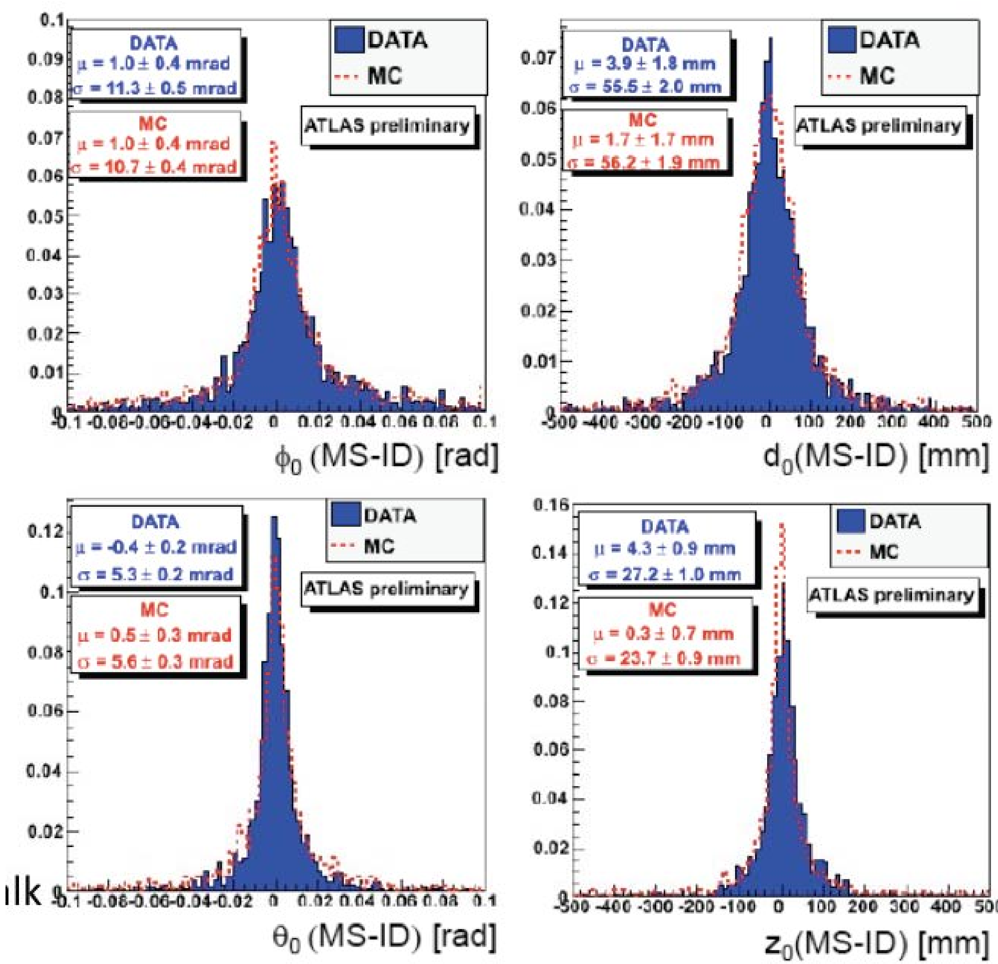
- For correct angular and energy dependence of the simulated cosmics, need to simulate propagation through the rock above ATLAS (because of the large effect of the shafts)
- Also need to simulate over a large area on the ground above ATLAS
  - This means that most generated cosmic rays completely miss the detector and are not useful
  - These are filtered to improve performance

Overlaid Events - Cosmics

- Model cavern in Geant
- Reasonable comparison between MC and data



María Moreno Llácer (IFIC-Valencia)



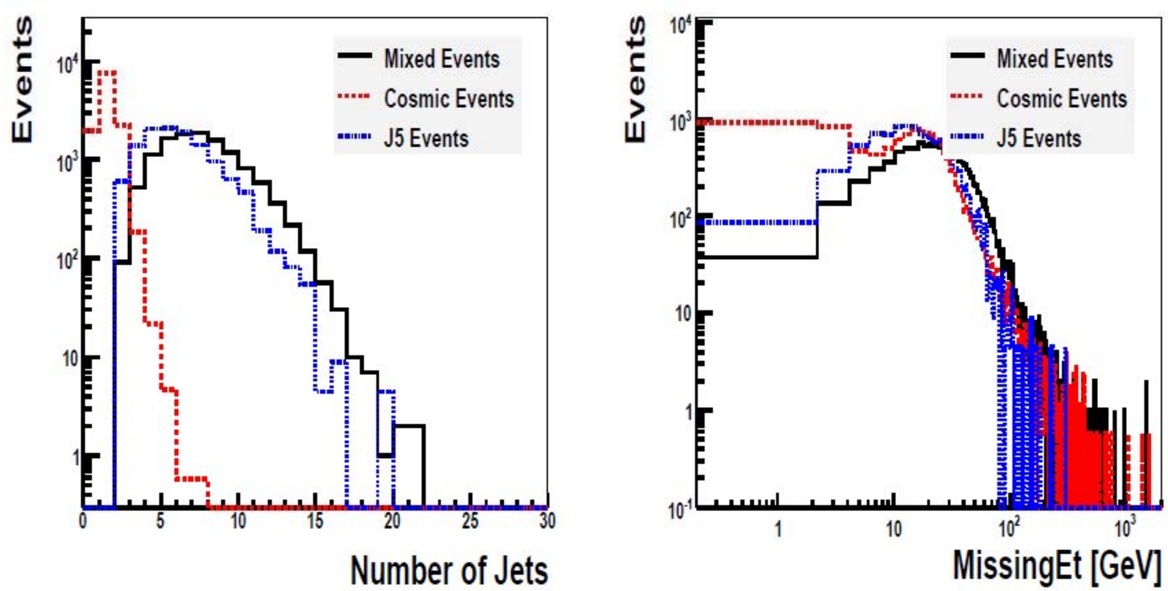
Overlaid Events - Cavern Background

- Neutrons fly around the ATLAS cavern for a few seconds until they are thermalised, thus producing a kind of permanent neutron-photon "bath" resulting in a steady rate of Compton electron and spallation protons, which are observed in the muon system.
- Simulation
  - parellel geometries in G4.9.1 allow the G4 implementation of pileup events
  - done by adding "scoring volumes" to typical physics event
  - records and removes neutrons and photons
  - can be used as cavern background events
  - so far, GEANT3/GCALOR used for these events (inconsistent)
  - will allow for far higher-statistics cavern background samples than we have so far
  - considerable testing and validation still needed

Overlaid Events - Pileup

- Currently overlaying events in order to simulate pileup
- Study shown here overlays MC (minimum bias) and MC (cosmics)
- These mixed events (black) are compared with data cosmics (red) and MC dijets (blue)

Yingchun Zhu, Wisconsin



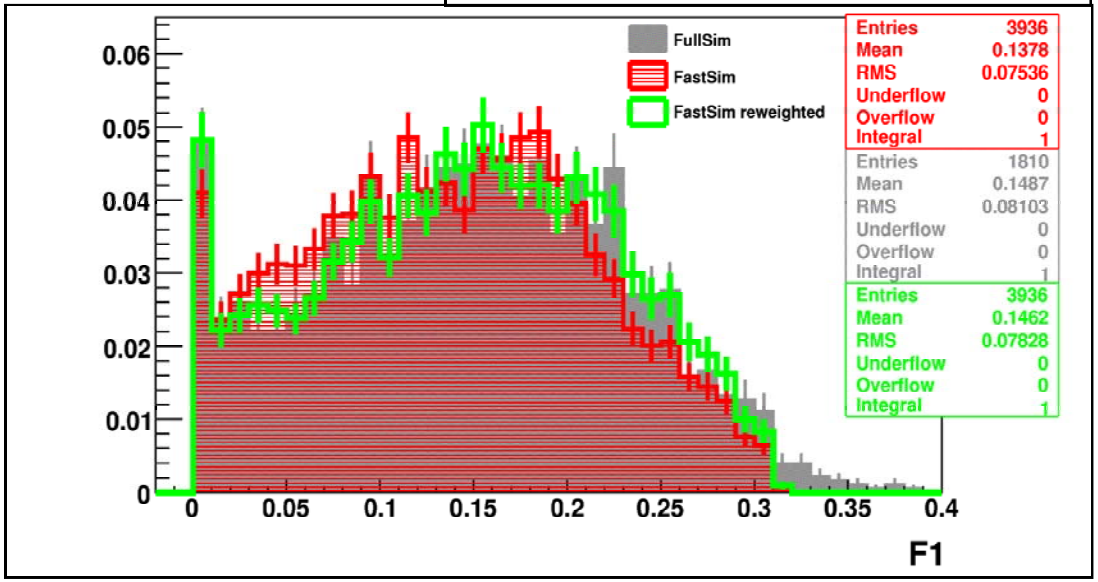
Pileup and Cavern Background

- Important to obtain samples of pileup + cavern background events in early LHC data because
  - we can use these to tune our simulations
  - we can overlay these directly on top of simulated hard events for better realism

Fast Simulations

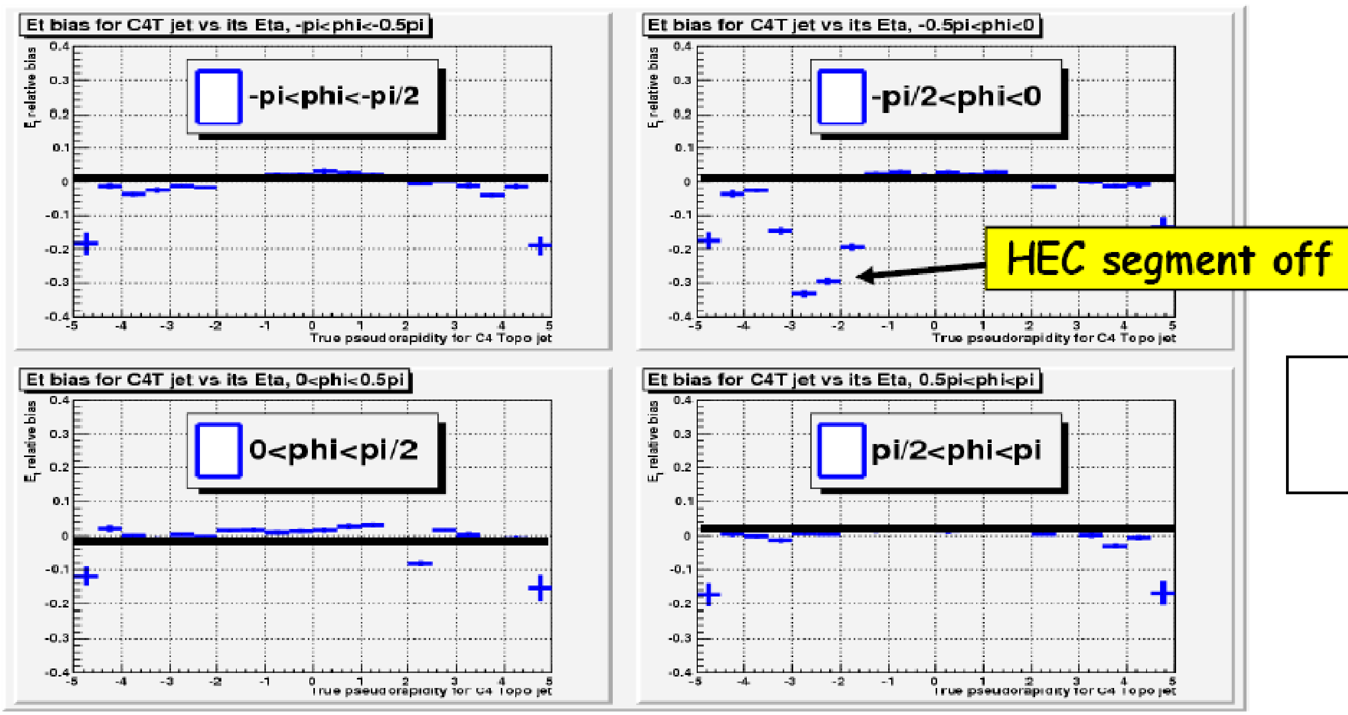
- Fast Calorimeter Simulation is at the heart of Atlfast-2
- Tuning
  - Reweighting of shower parameterisation based on comparison with full-sim for now
  - Proof of principle for tuning in data

Evelyn Schmidt, Freiburg



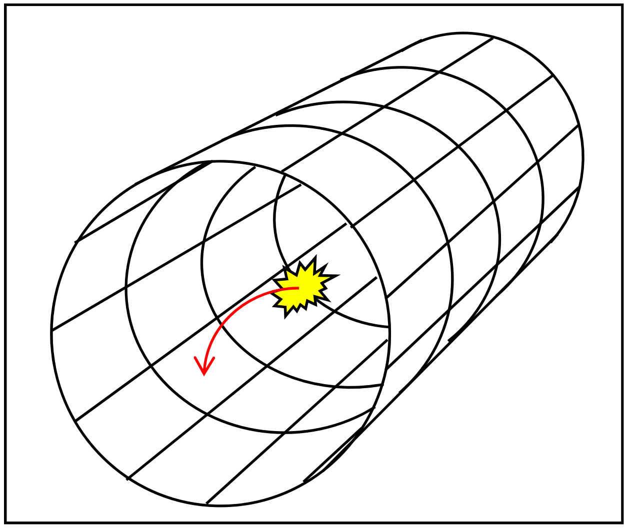
Fast Simulations

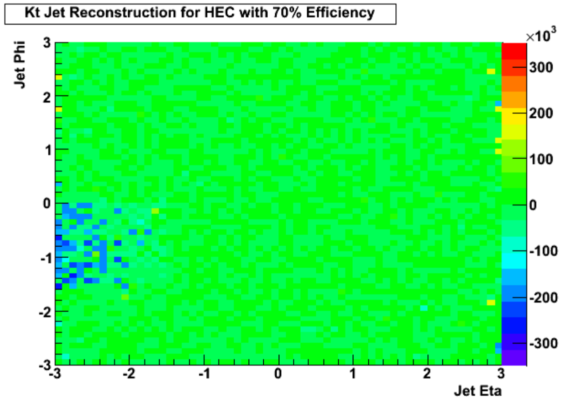
- Hadronic Endcap sector problem (electronic readout) modelled in Atlfast-1
- E_T bias = $(E_T(\text{reco}) - E_T(\text{truth}))/E_T(\text{truth})$

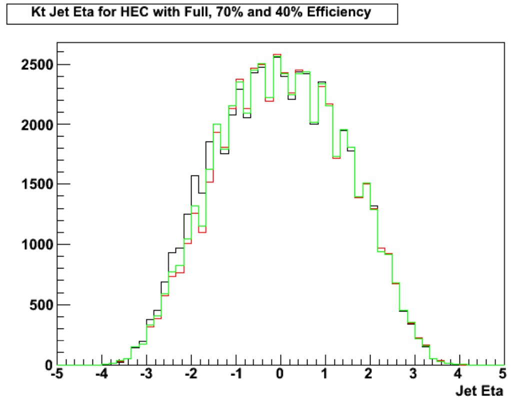


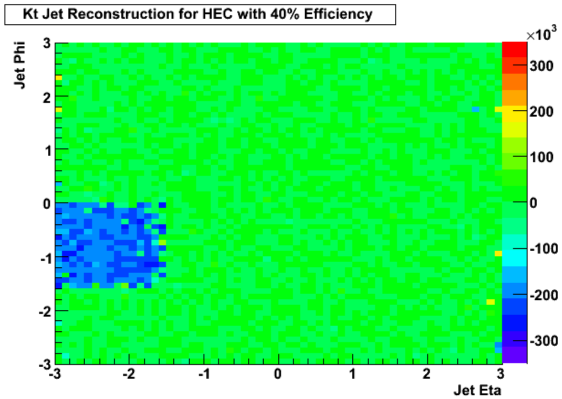
Effect in full simulation

Fast Simulations









- Crude granularity in Atlfast-1 calorimeter
  - $\eta \times \phi = 0.1 \times 0.1$ in central region, no sample layers

Sarah Baker, Alex Richards and SD, UCL

Many thanks to

Margar Simonyan, Tancredi Carli, Adele Rimoldi, Zach Marshall, Andrea Dell Acqua, CMS HCAL group, Heather Gray, Jamie Boyd, María Moreno Llácer, Yingchun Zhu, Evelyn Schmidt, Sarah Baker, Alex Richards.