# Status of Geant4 Simulation and validation in ATLAS Central Hadronic Calorimeter TileCal

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Physics Validation of LHC Simulation,

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# Outlook

- Introduction
- Calculation of Sampling Fraction from pions events
- Dead Material correction using Calibration Hit information
- Longitudinal Shower Profile for Pions
- Comparison between different G4 versions
- Conclusions and future work

# Introduction

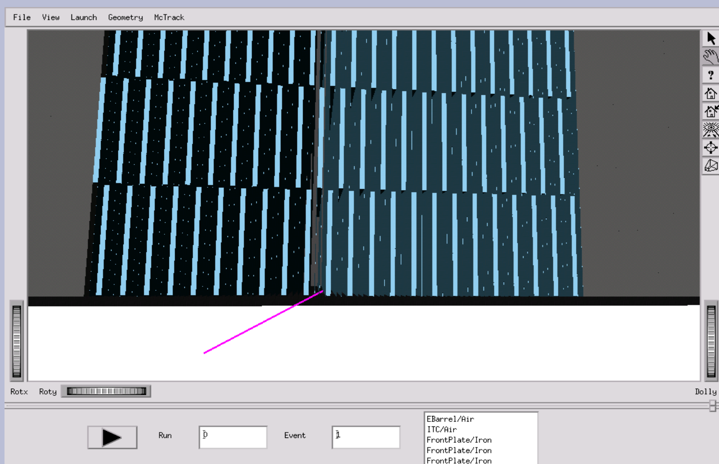
- TileCal had two different kind of test beams programs (with production modules) to compare data and MC:
  - standalone (or calibration) test beam 2000-2003
  - combined test beam (full ATLAS slice) 2004
- Two different versions of G4 used at the time
- Now we can simulate standalone TB in ATLAS official software framework (athena)
- We are starting now to compare data with simulation and different versions of simulation
- Many people involved, here some preliminary results obtained from different people

# Sampling Fraction calculation from pions data

# Sampling Fraction

- The e.m. sampling fraction is a fundamental parameter of the simulation in TileCal: $E_{cell}(e) = E_{vis}^{tiles}(e) * 1/sf$
- Energy in the cell is the input to next step of simulation (digitization), the output of digitization is very similar to real data
- At Test Beam real modules are calibrated using electrons beams, cells are inter-calibrated using a $^{137}Cs$ source
- A single constant pC/GeV is extracted from electrons data for each module exposed on beam
- This constant is an “avarage” over the response of all the module

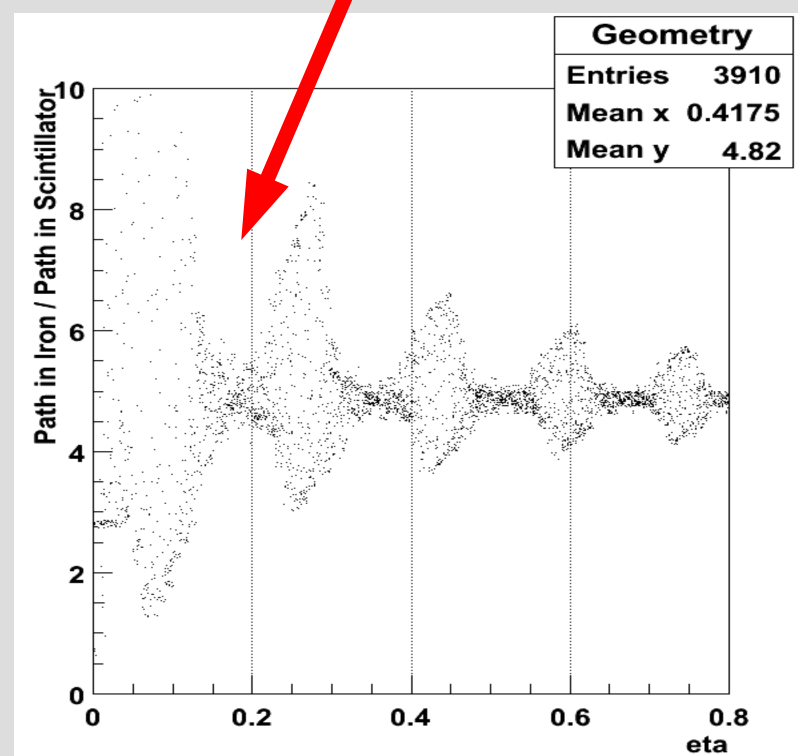
# Simulation Calibration



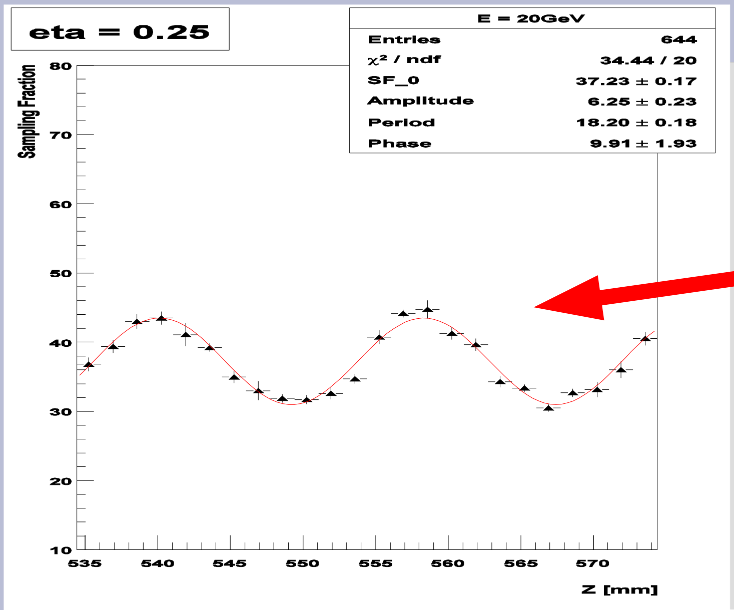

- Which constant assume for e.m. sampling fraction in simulation?

- The e.m. sampling fraction extracted from electrons simulation is sensitive to TileCal geometric structure

- The effect of noise, beam profile, reconstruction chain smears this effect in real data: visible at small angles with electrons and muons

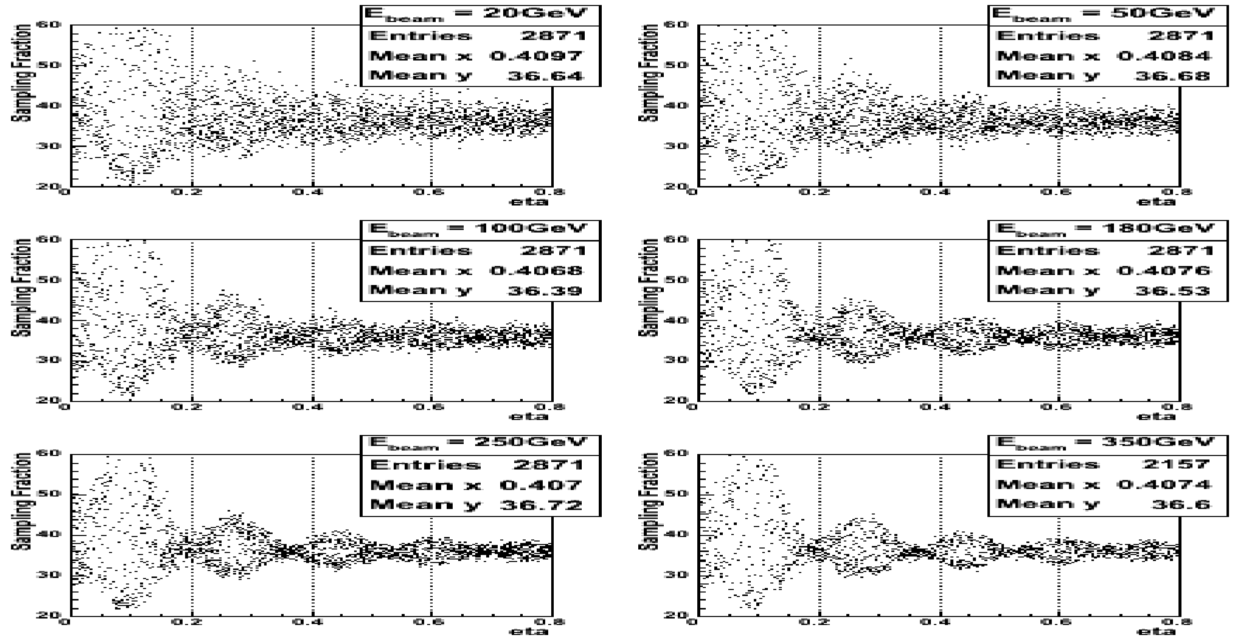


# Electromagnetic Sampling Fraction




Dependence on impact position (period ~18 mm): TileCal module structure

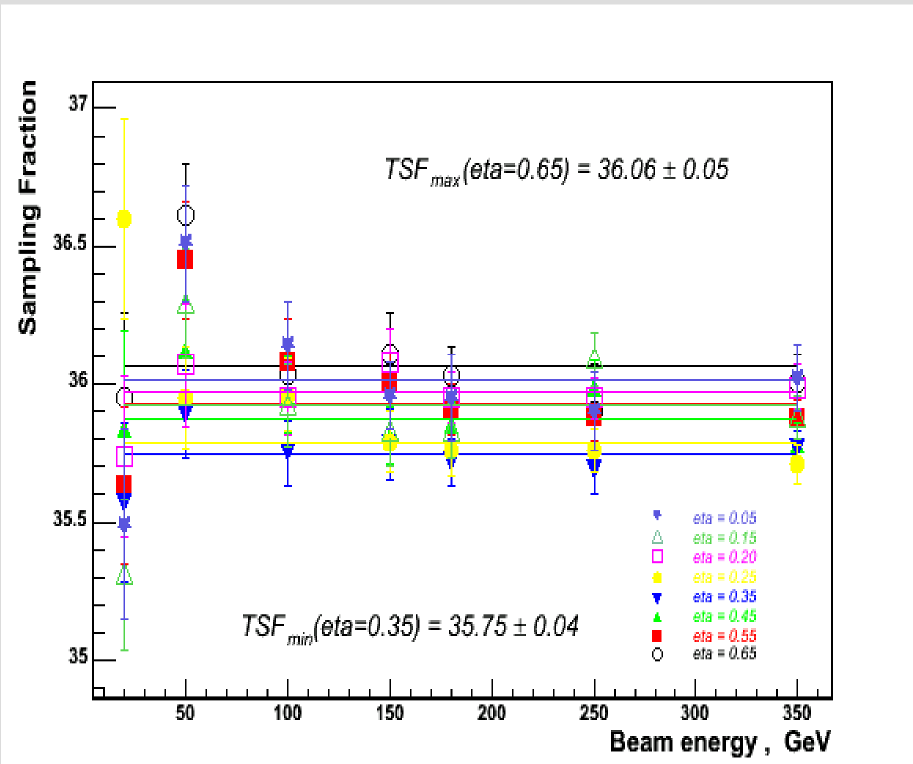
Dependence on beam position (eta) and beam energy: most energetic beams have bigger e.m. showers, the response is smeared on a bigger volume

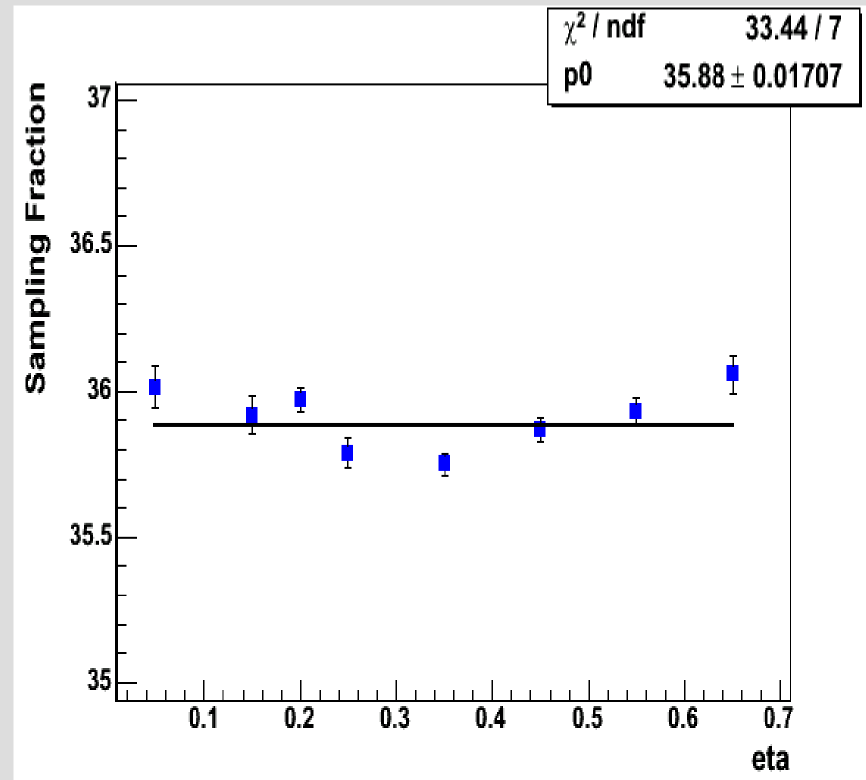


# Sampling fraction from pions using calibration hits

- ATLAS Geant4 simulation now contains information on energy deposit in material (active/passive) divided in:
  - $E_{em}$ (from e.m. process)
  - $E_{had}$ (from hadronic processes)
  - $E_{inv}$ (energy deposits not visible: i.e. nuclei breaks)
  - $E_{esc}$ (escaped energy: i.e. neutrinos, leakages)
- e: $E_{vis}=E_{em}$ → $E_{vis}^{sci}/E_{vis}^{tot}=E_{em}^{sci}/(E_{em}^{abs}+E_{em}^{sci})$
- π: $E_{vis}=E_{em}+E_{had}$ → $E_{vis}^{sci}/E_{vis}^{tot}=(E_{em}^{sci}+E_{had}^{sci})/(E_{em}^{abs}+E_{had}^{abs}+E_{em}^{sci}+E_{had}^{sci})$
- Pions shower are bigger: naturally smears TileCal geometry effects

# Sampling fraction from pion events



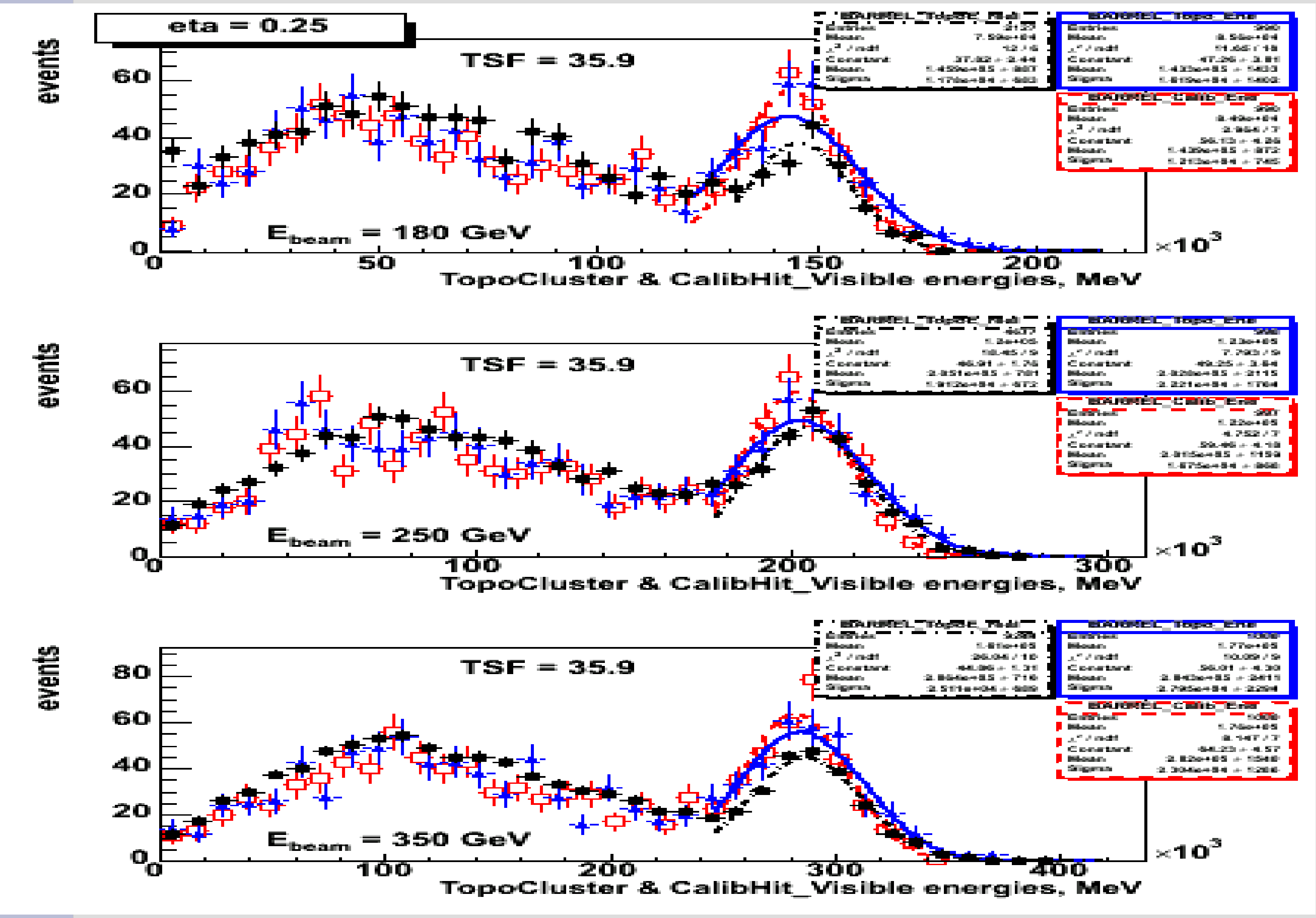




$TSF_{hadron} = 35.88 \pm 0.04$

$TSF_{electron} = 35.94 \pm 0.02$

Obtained on electrons after removing all the geometric effects

# Comparison with Real Data

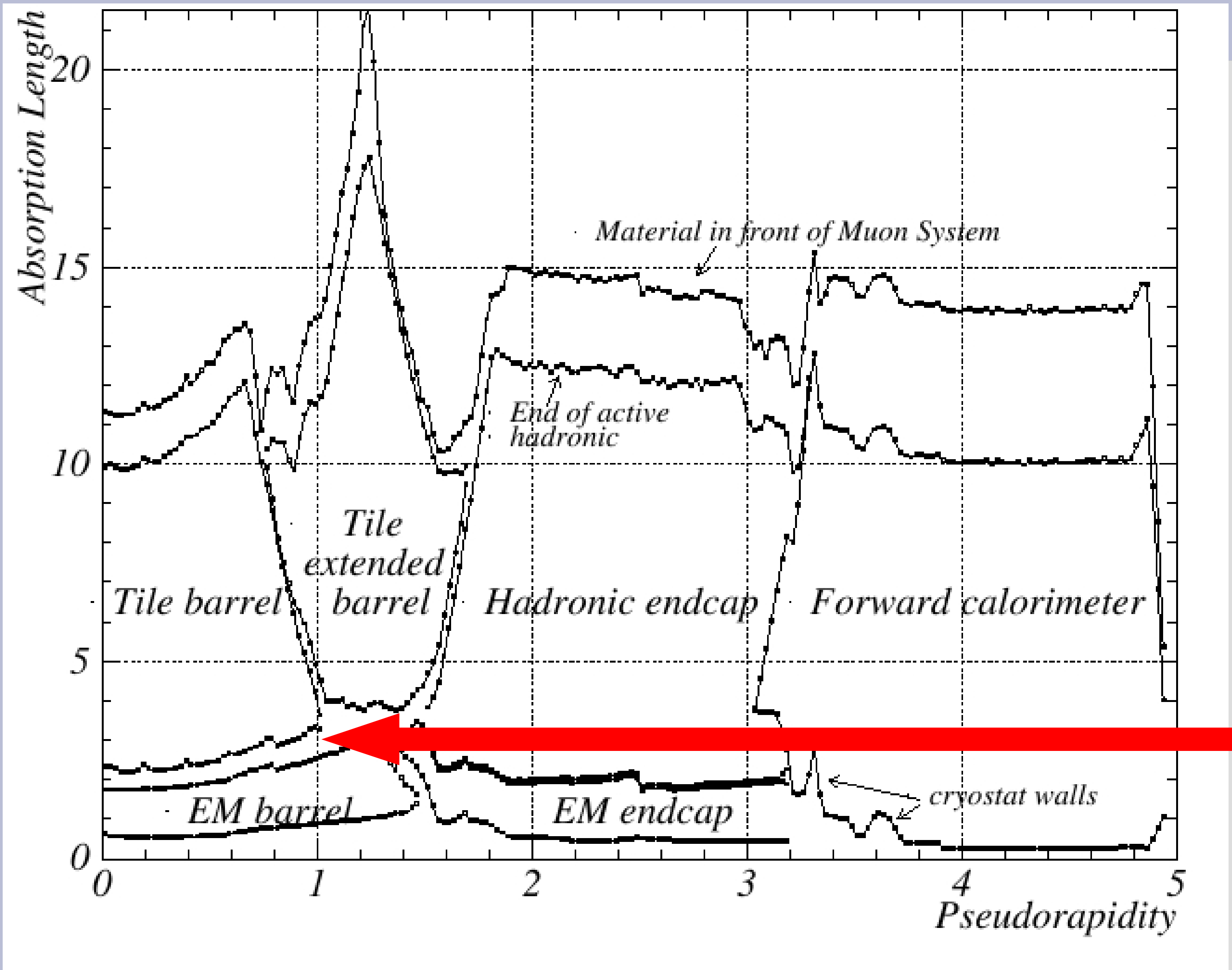



MC Truth
MC Reco
Real Data

MC Truth obrained from calibration hits (em+had) energy in active and passive material

# Dead Material Correction from MC calculations

# Material Budget in ATLAS



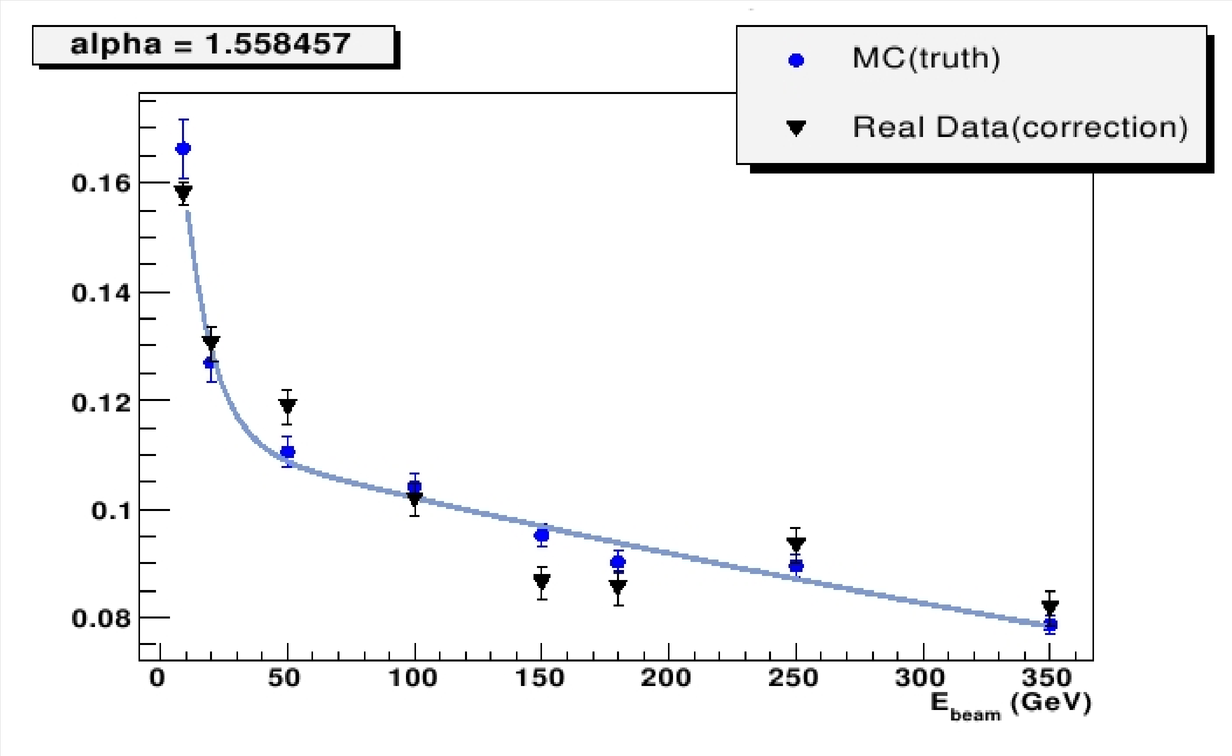

LAr Cryostat, services

# Cryostat correction to data

- We can use a parametrization to recover energy deposited in crack between LAr and TileCal ($|\eta|<0.7$) $E=C*\sqrt{Elar3*Etile1}$
- Elar3: energy in last sample of LAr
- Etile1: energy in first sample of TileCal
- C must be extracted from MC (using Calibration Hits)

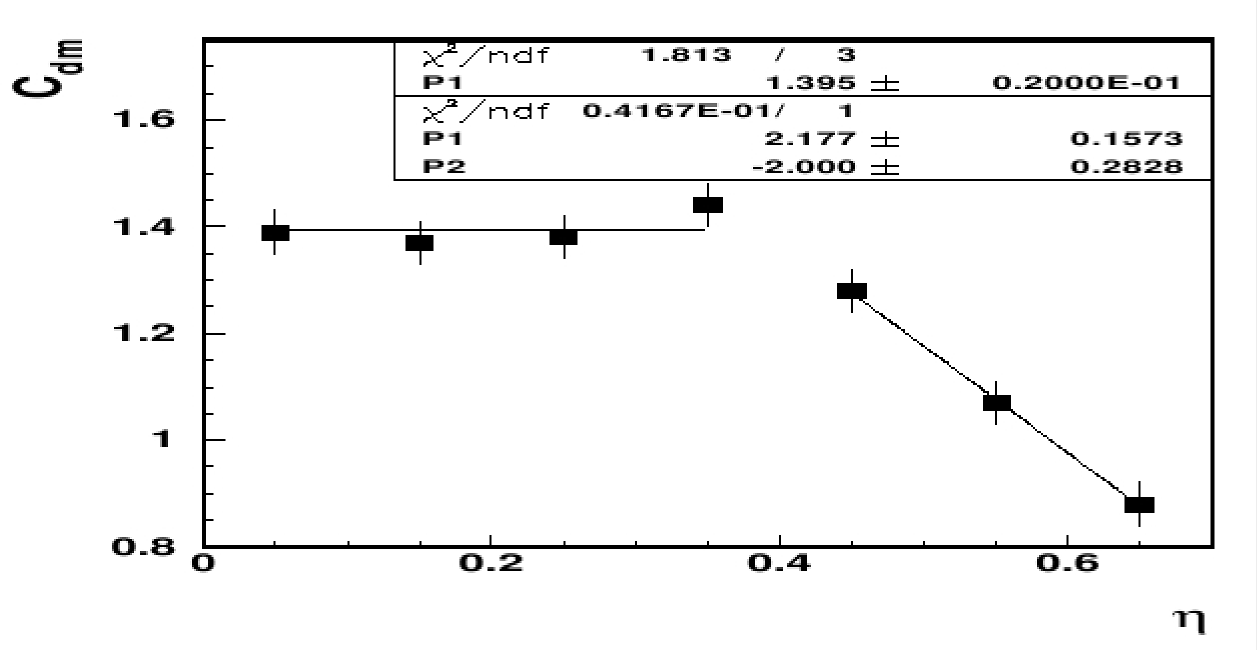
# Energy in Cryostat

- Good agreement between MC truth (energy in dead material from calibration hits) and cryostat correction calculated from real data



# Normalization Constant

- Normalization Constant C is obtained normalizing correction from data to the MC truth. C depends on eta




$C_{dm}=1.4\pm0.2$

$|\eta|<0.35$

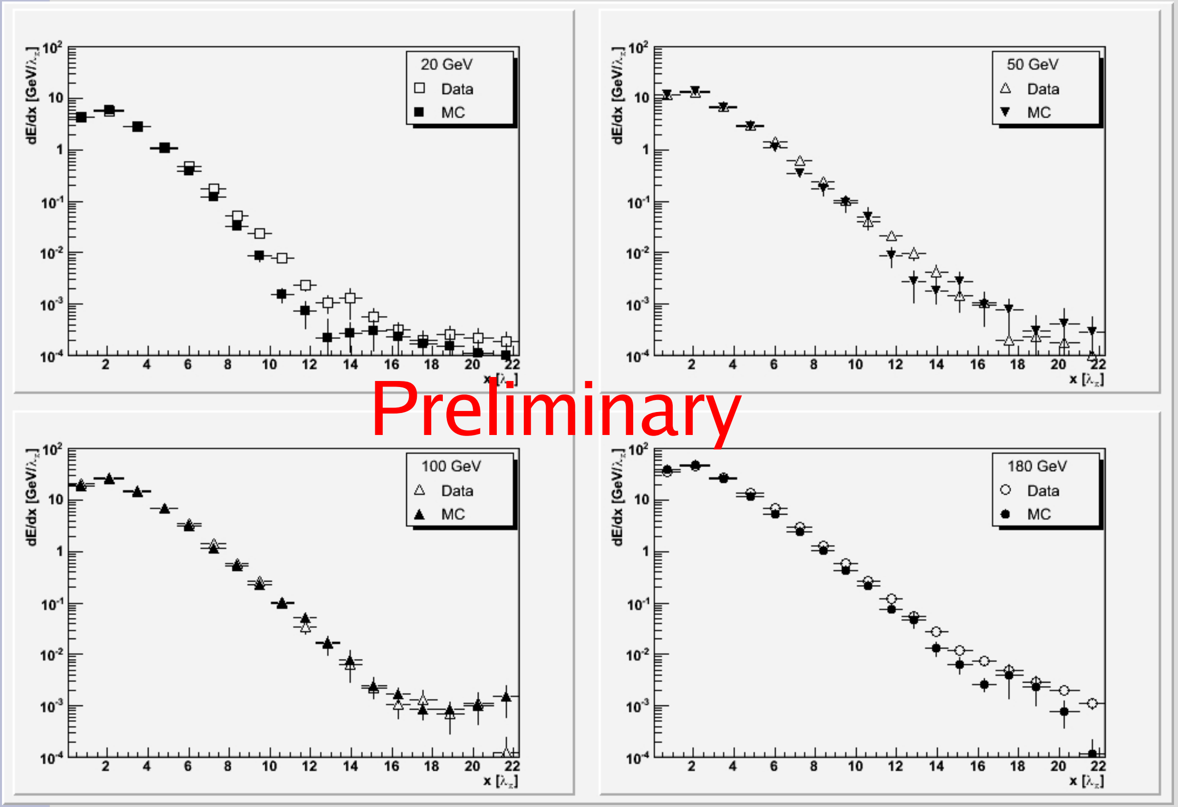
$C_{dm}=(2.2\pm0.2)-(2.0\pm0.3)\eta$

$|\eta|>0.35$

# Longitudinal Shower Profile

# Comparison Data/G4: TileCal standalone simulation

- Now standalone TileCal TB simulation is available in Athena framework with Geant4 version



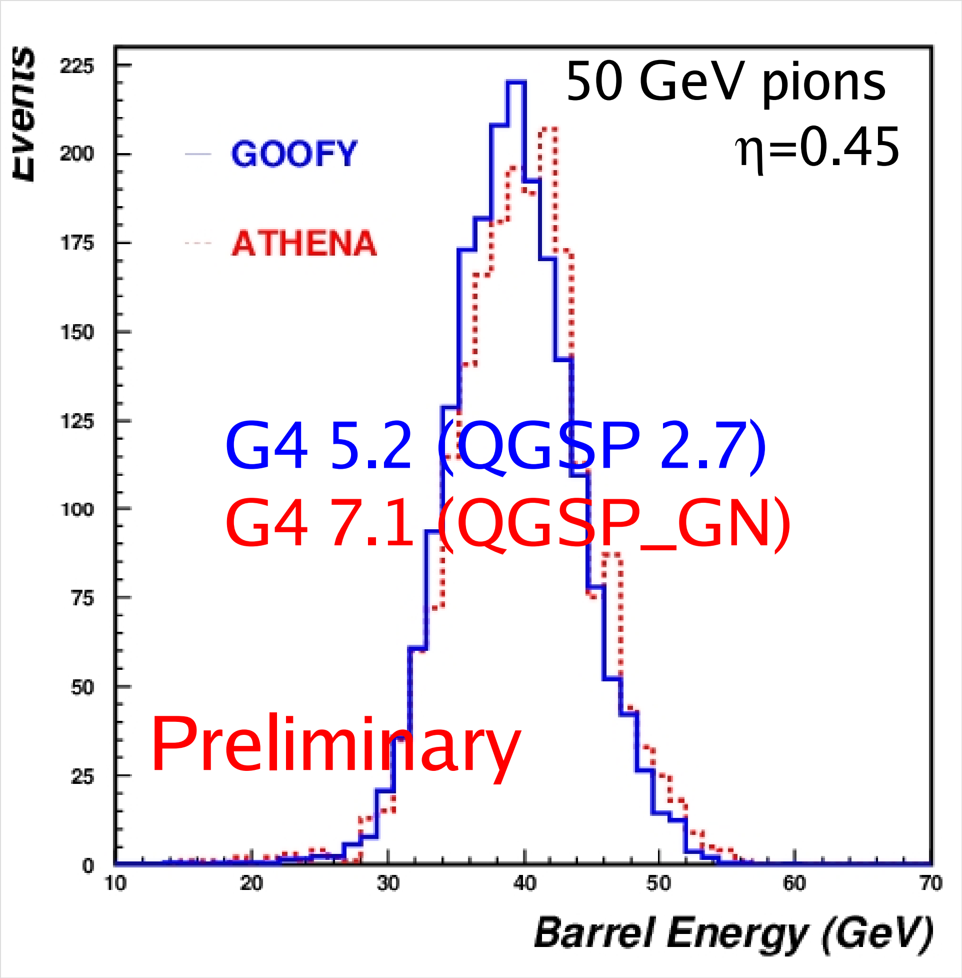

- Pion beam impinging at 90° degrees on TileCal (used for calibration during TB runs)
- Full simulation/reconstruction of MC data (sim→digi→reco)

# Geant4 validation: Athena framework Vs GOOFY application

# TileCal stand alone simulation

- In the past we had a stand alone application (FADS/GOOFY) to simulate TileCal stand alone testbeam based on Geant4 5.2 (here results with QGSP 2.7)
- standalone simulation is now available in ATLAS offline framework (Athena) with Geant4 7.1 (here results with associated QGSP_GN)
- We want to cross check results between two versions of G4 (possible since now we have the standalone simulation in Athena framework)

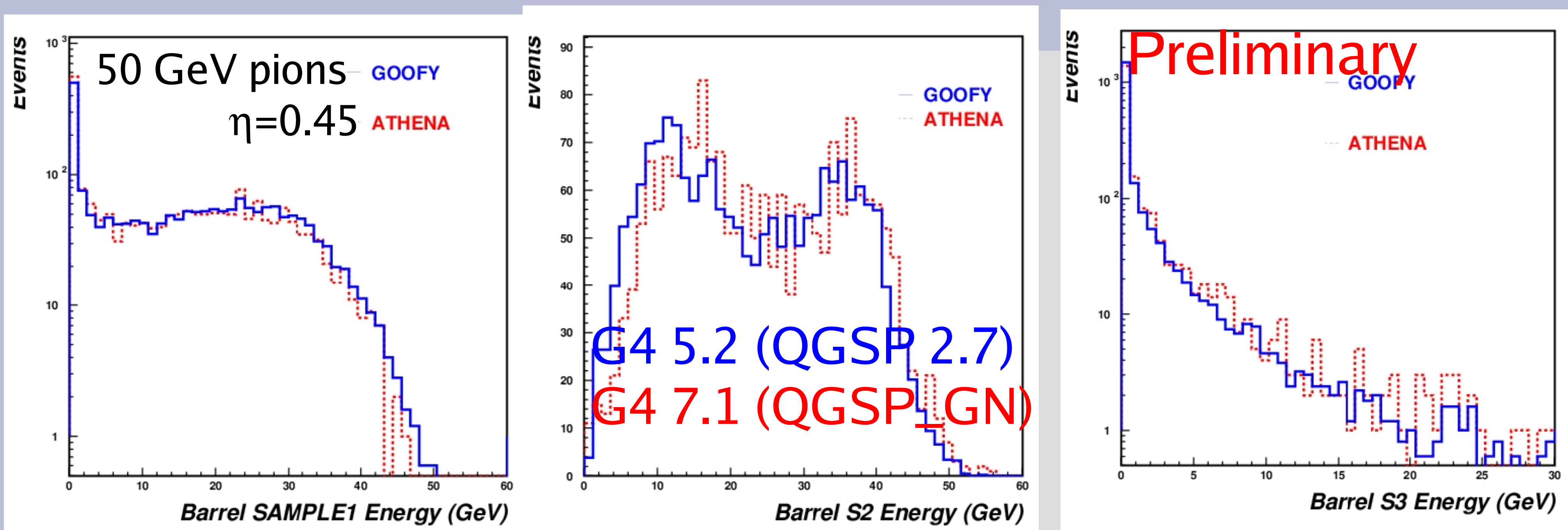
# Total Energy Deposit




- Comparison of different versions of G4
- We have shown results for standalone simulation in:

  CERN-LCGAPP-2004-10
- We want to disentangle digitization/reconstruction effects from simulation ones: direct registration of G4 hits in active material
- Applied the same calibration constant to both

# Energy in Samples




- Small differences in the two version of the simulation, we have to compare to data to really judge if this is an improvement

# Conclusions

- We are starting now to work on many different topics
- We started the systematic study of different aspects of simulation validation
- Some preliminary results show agreement between data and G4
- We need to better understand energy reconstruction on both data and simulation side to give a detailed feedback on hadronic simulation in G4
- Expected many new results in the near future

# Not touched here

- Many other aspects of detector simulation have not been discussed here (not strictly related to physics validation)
  - Real detector simulation (breaking of ideal detectors symmetries)
  - Energy cluster classification using calibration hits
  - ...
- Combined simulation with other sub-detectors and comparison with CTB data (already shown some preliminary results in the past)

# Results obtained from:

- sampling fraction: G.D Khoriauli, A. Khukhunasihvili, Y. Budagov, J. Khubua, Y.A. Kulchitsky
- dead material correction: Y.A. Kulchitsky, P.V. Tsiareshka, G.D. Khoriauli, V.B. Vinogradov
- longitudinal shower profile: M. Simonyan
- Athena/Goofy comparison: A. Lupi, A. Dotti
- Support: A. Solodkov, M. Gallas