CALICE and GEANT4

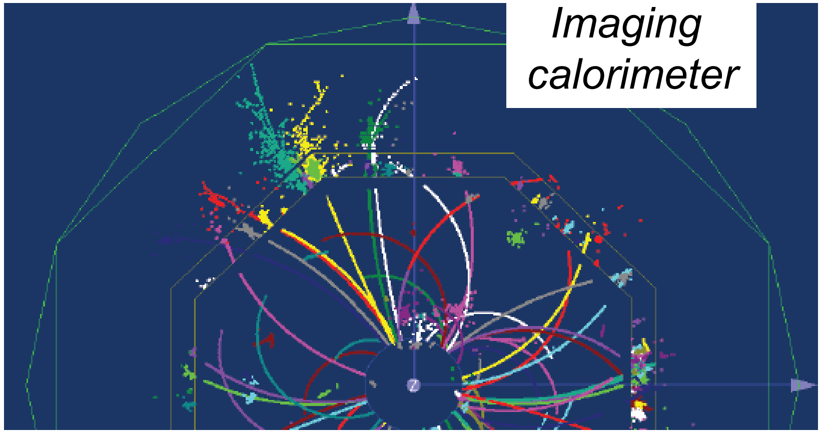
Erika Garutti

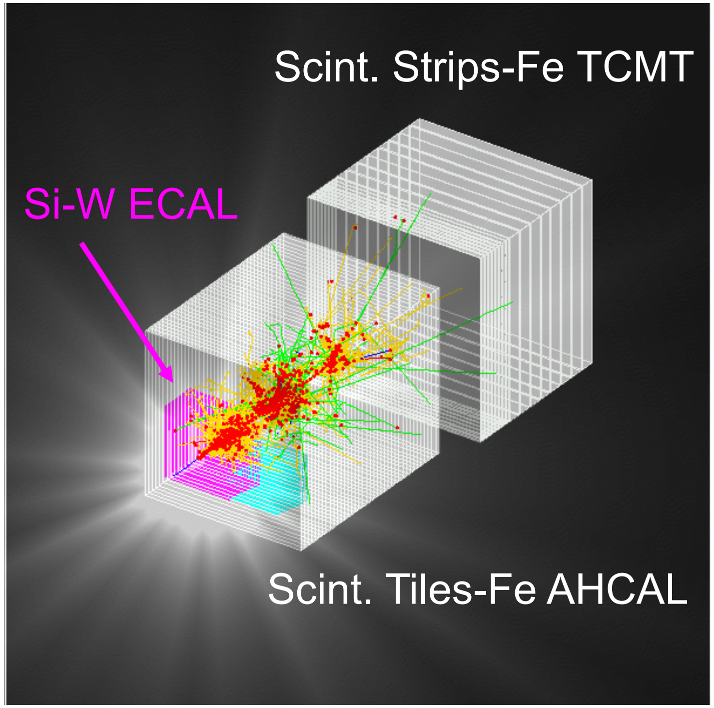
CALICE: from MC to reality

CAlorimeter for the LInear Collider Experiment

Final goal:

A high granularity calorimeter optimised for the Particle Flow measurement of multi-jets final state at the International Linear Collider

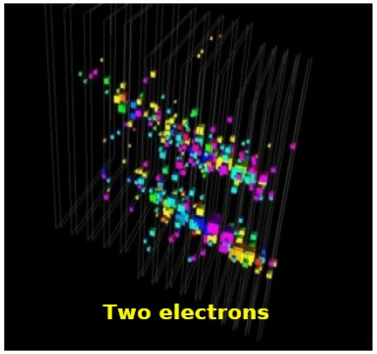


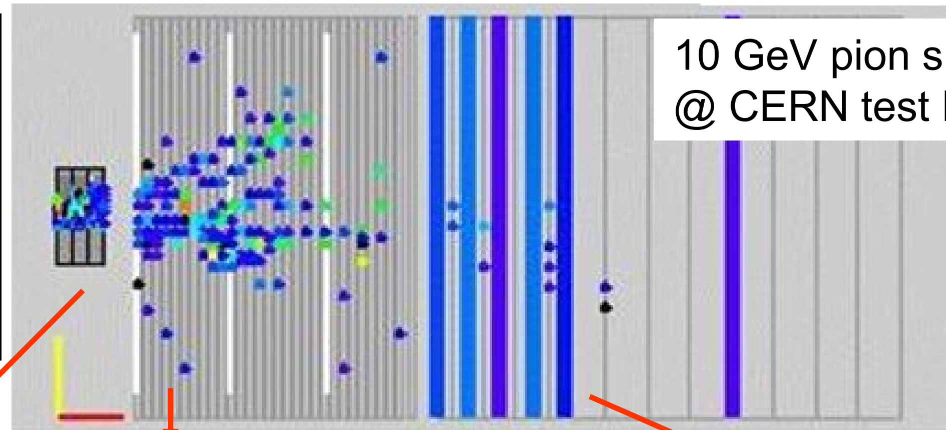


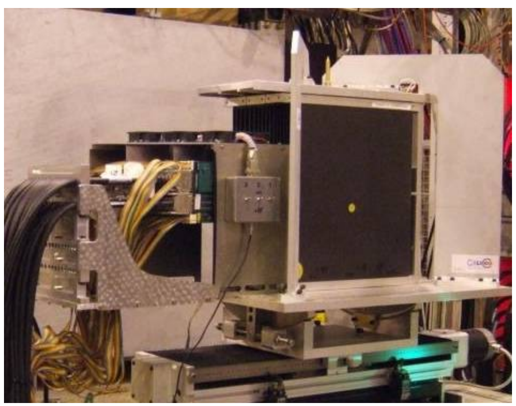
Intermediate task:

Build prototype calorimeters to
- Establish the technology
- Collect hadronic showers data with unprecedented granularity to
  - tune reconstruction algorithms
  - validate existing MC models

The test beam prototypes







Si-W Electromagnetic calor.
1x1cm² lateral segmentation
1 X_0 longitudinal segment.
~1λ total material

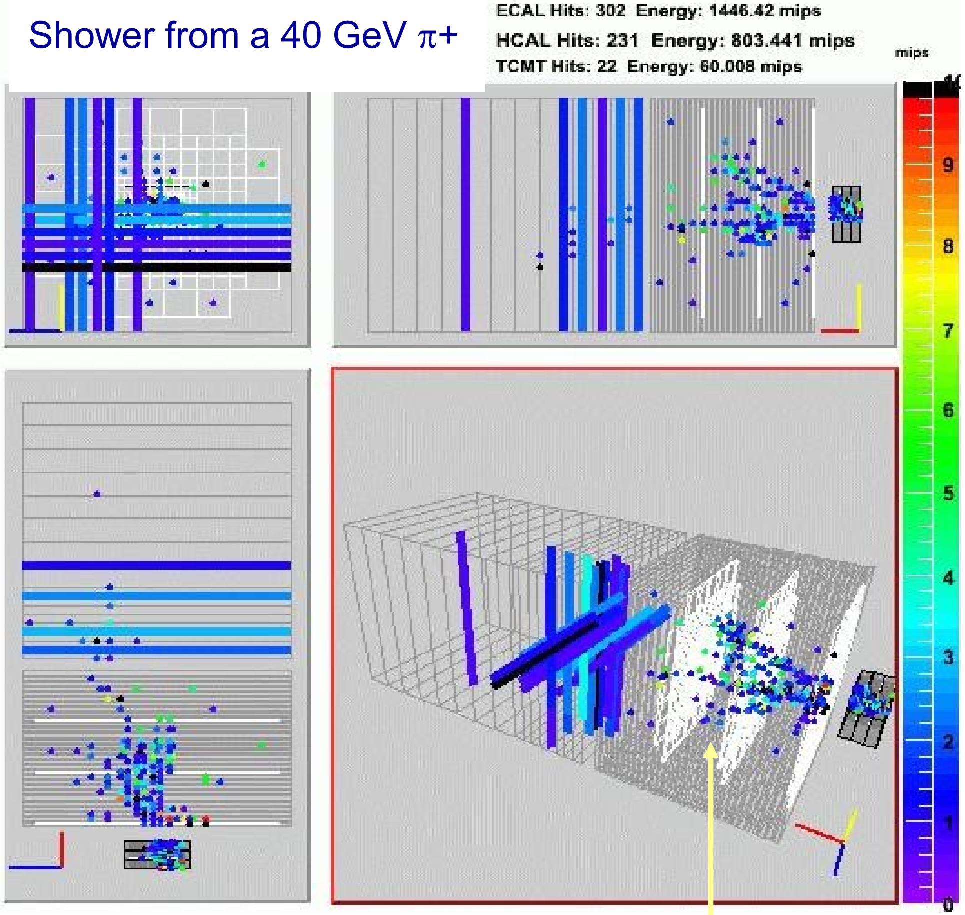
Scint. Tiles-Fe hadronic calor.
3x3cm² lateral segmentation
~0.1 λ/layer, 38 layers

Scint. Strips-Fe Tail Catcher
& Muon Tracker
5x100cm² strips
~5 λ in 16 layer

Event display

REAL DATA!

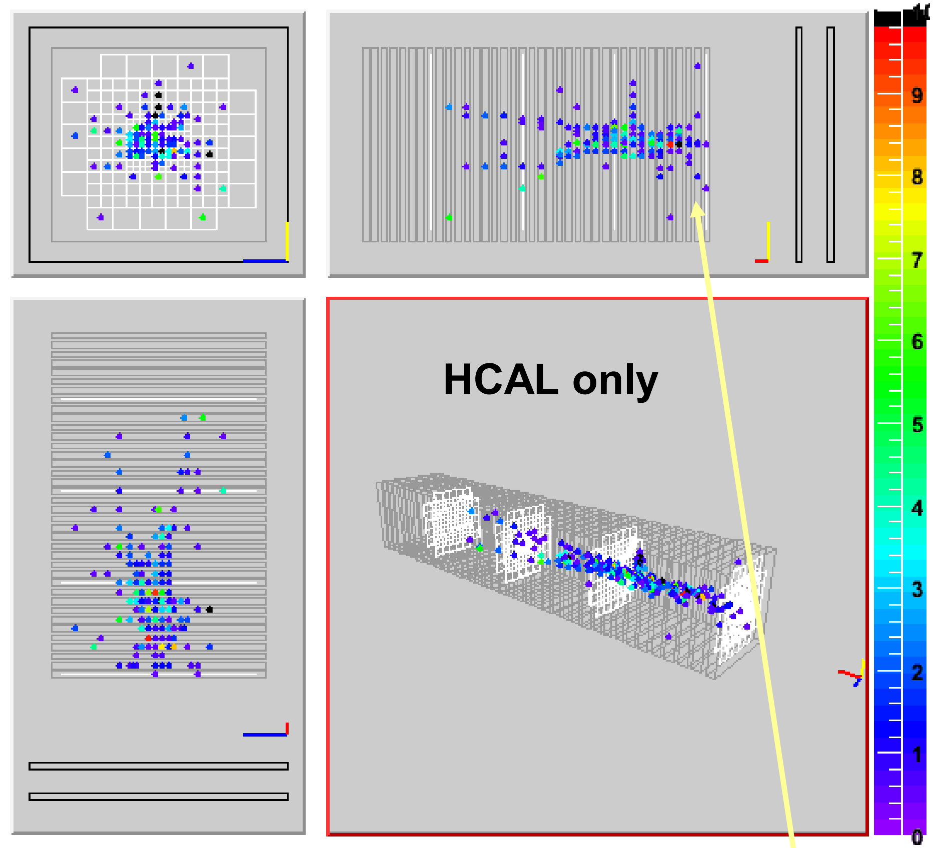
Shower from a 40 GeV π+



20 GeV π+

Time: 05:39:16:985:771 Thu Oct 19 2006

Hits: 243 Energy: 727.372 mips



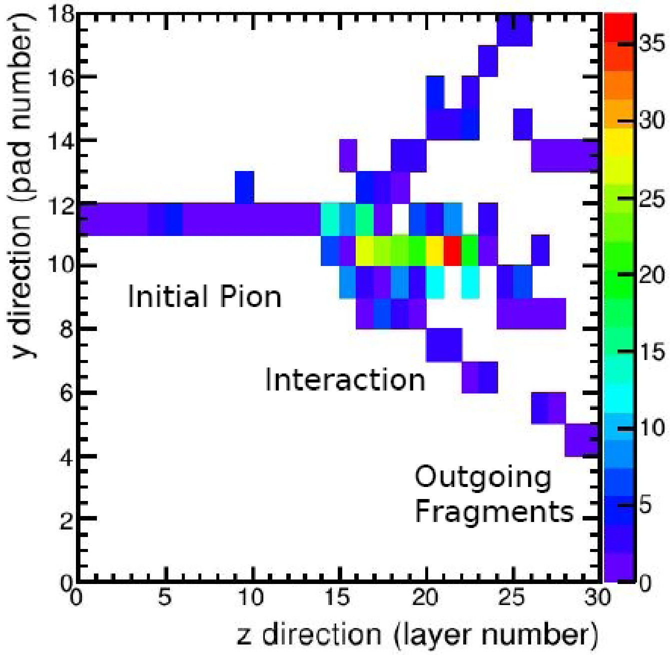
Clear structure visible in hadronic shower

Back-scattered particle

ECAL event display

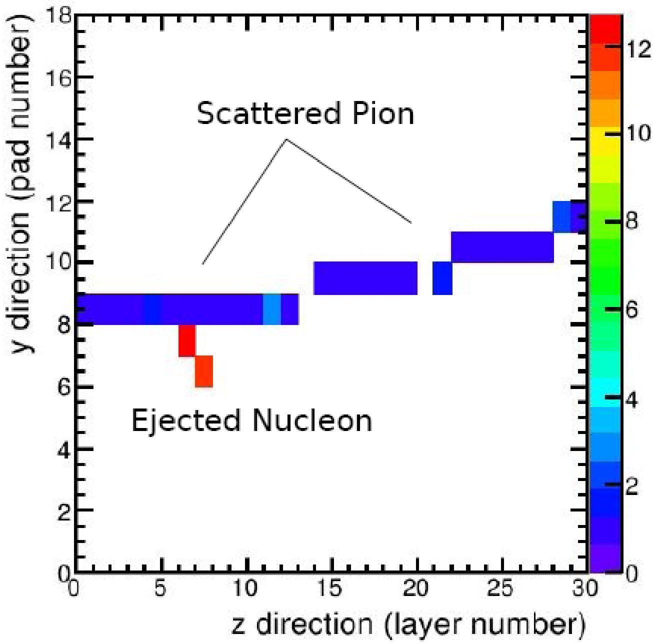
ECAL (Si/W)

Complex and Impressive



Inelastic Reaction in SiW Ecal

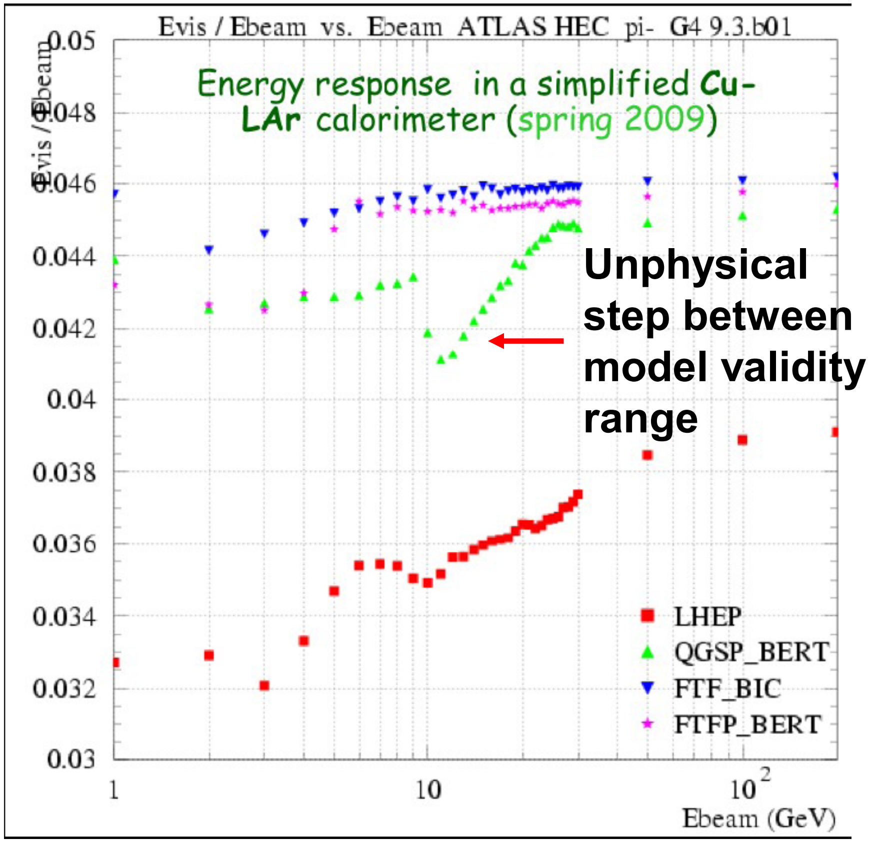
Simple but Nice

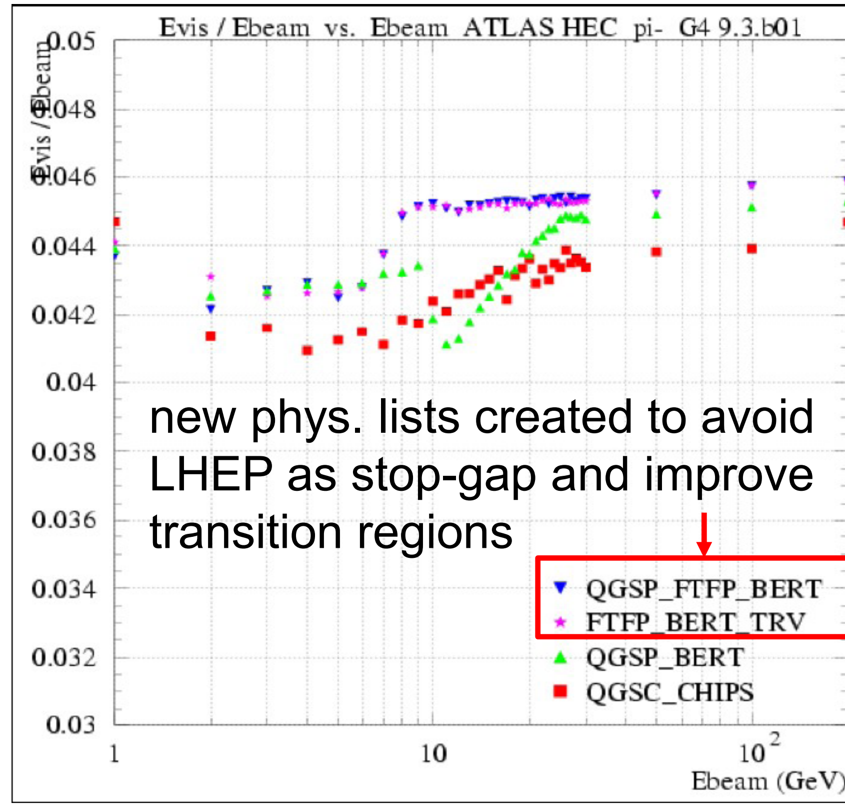


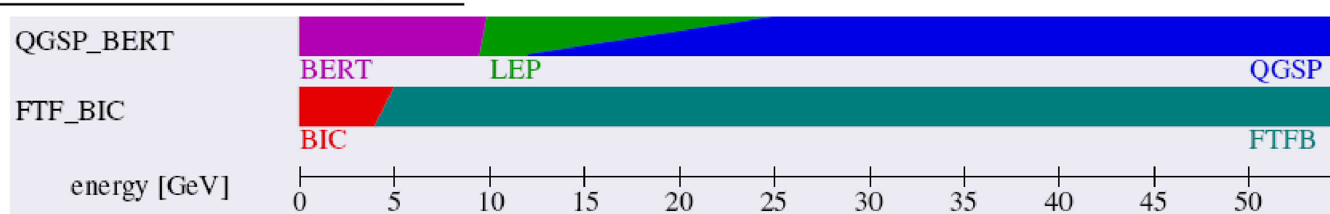
Nucleon Ejection in SiW Ecal

High granularity permits detailed view into hadronic shower

G4 discontinuity in hadronic models







Introduction (CHIPS Phys. List status)

- The CHIPS physics list is an experimental physics list, which simulates (** in all physics lists, * in many other physics lists):
  - all inelastic hadron-nuclear reactions (all particles, all energies)
  - photo/lepto-nuclear reactions**(including neutrino-nuclear reactions)
  - elastic hadron-nuclear reactions (all particles, all energies)*
  - stopping for all negative hadrons** + μ^- and τ^- leptons
  - synchrotron radiation (all particles, not only for e^-/e^+) important for γ-nuclear

Important open issue:

- The low energy (LE) neutron cross-sections are not implemented because the low energy inelastic nA cross-sections can not be implemented in the open code toolkit ($\rightarrow$ callorimeter response overestimation).

➔ Expected too high reconstructed energy

Mikhail Kosov

Important issues for calorimeter simulation

- Production of γ's in hadron EM decays of π^0,η, $\eta^{/}$, ω, Σ^0 etc., switching distributed hadronic energy to short range electromagnetic cascades
  - usually a source of γ's are π^0's; in CHIPS + direct γ's & massive mesons (η, ω)
  - π^0+γ+η energy is better for the short range deposition estimate than just π^0's energy.

➔ f_{EM} should be more accurate then in other models

- The quasi-elastic and diffraction parts of the inelastic cross-sections
  - In CHIPS both problems are solved in the first order, and can be improved.
  - Quasi-elastic & diffraction are very important for the longitudinal shower shape
    - Both quasi-elastic and diffraction effectively reducing the real inelastic cross-section
    - That is why sometimes an artificial reduction of the inelastic cross-section to the "production" cross-section level helps to improve simulation results.

➔Expected too long shower (as opposed to other lists which predict Too short showers since they don't include diffraction)

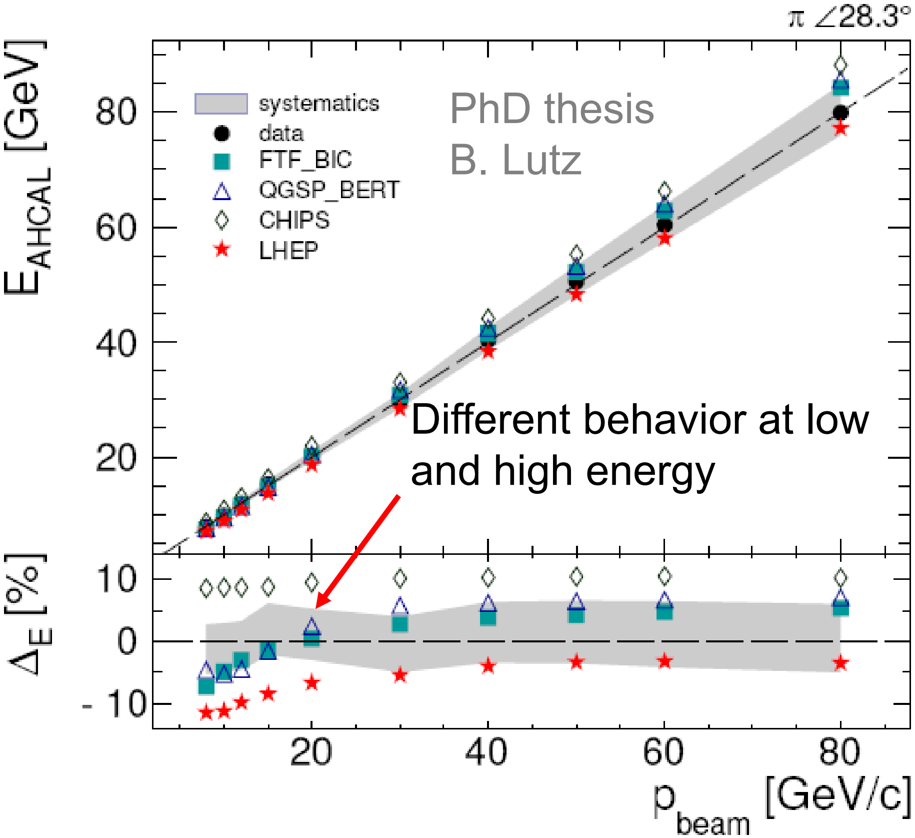
Additional recommendation emerged during discussion with G4 team
➔Check the multiplicity of particles after the first interaction
!!! Possible on very highly segmented calorimeters

Mikhail Kosov

Total visible energy

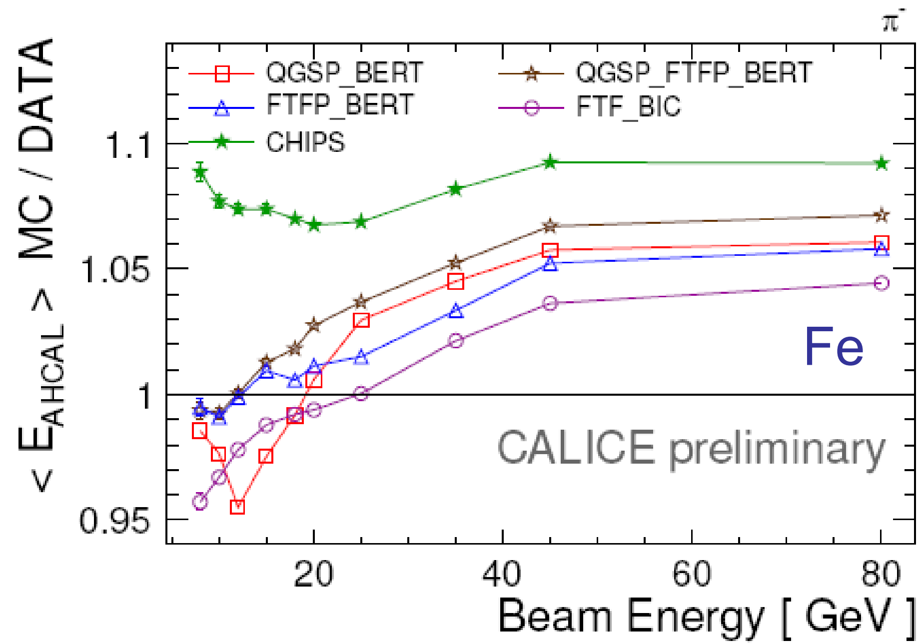
Geant 4.9.3 final version (12/2009)

CHIPS: no transition region, only available from version 4.9.3.p01



Different behavior at low and high energy

string+cascade within errors — only CHIPS flat like data

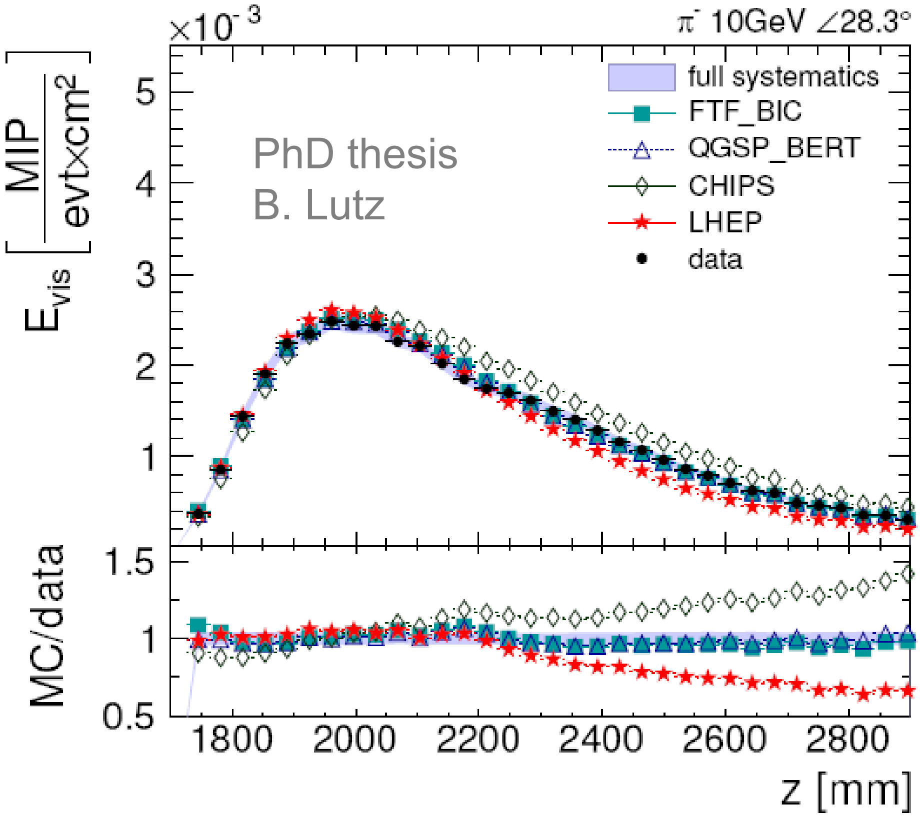


shower almost contained in AHCAL

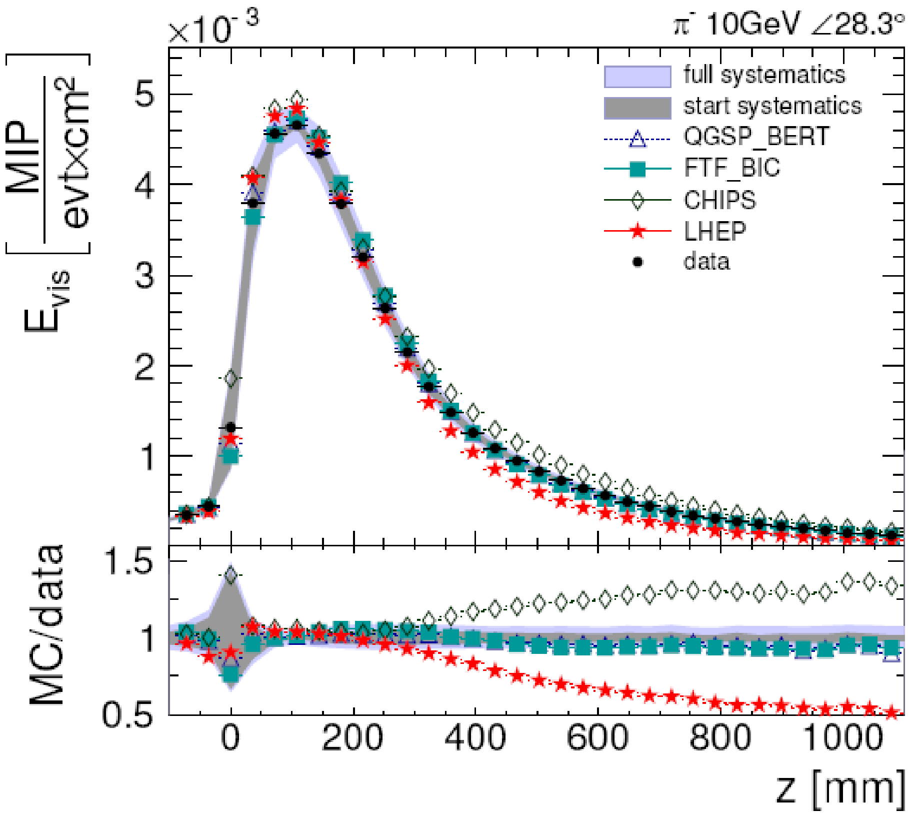
🡐As expected CHIPS over estimates reconstructed E but no E-dependent transition region

AHCAL longitudinal shower profile

from calorimeter front face



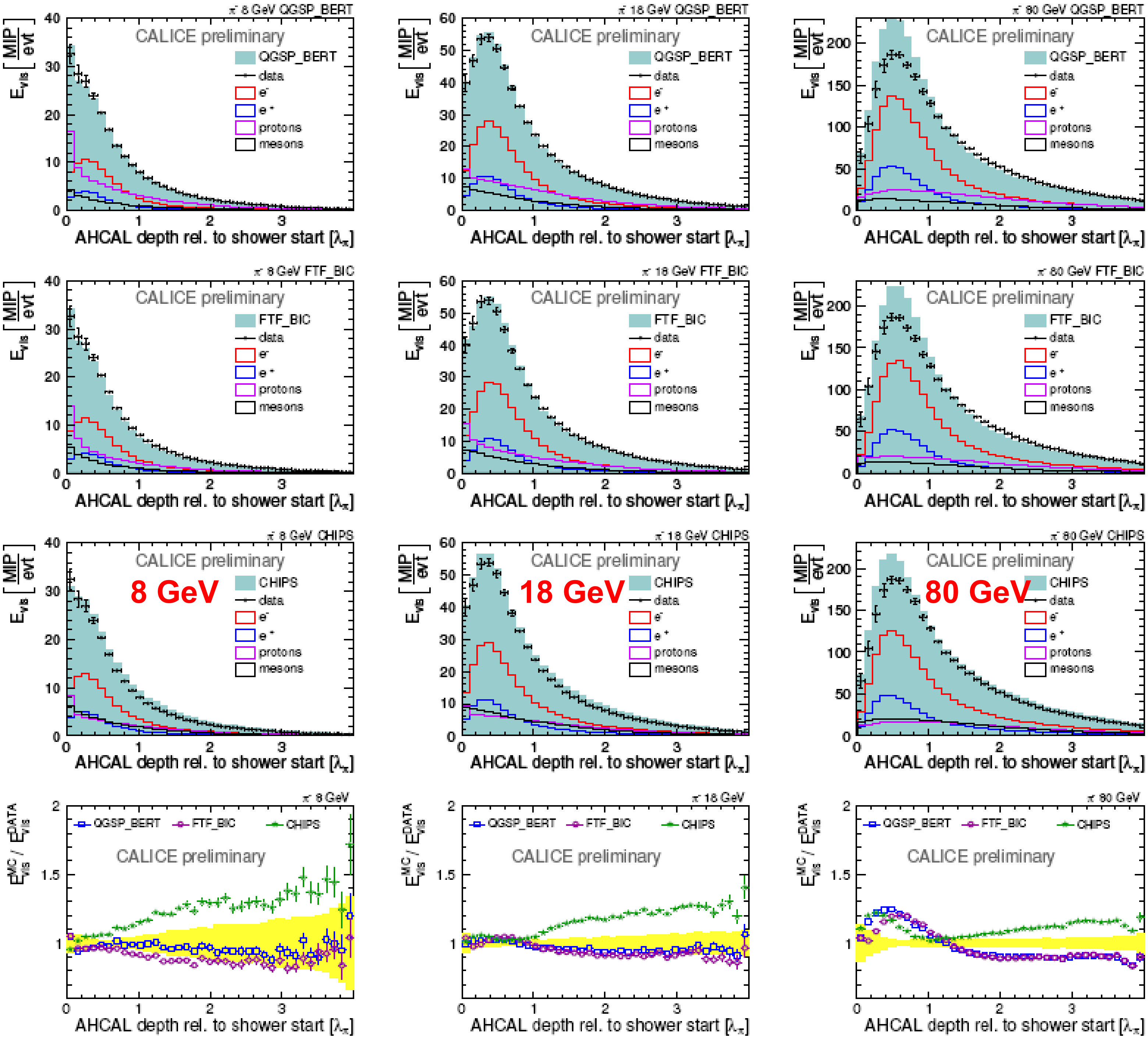
from shower starting point



cascade models good — CHIPS/LHEP wrong tails

increased sensitivity with profile from starting point

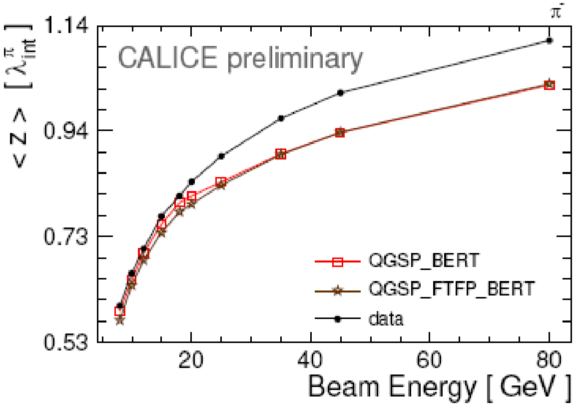
As expected from (un-tuned) diffractive processes CHIPS too long shower

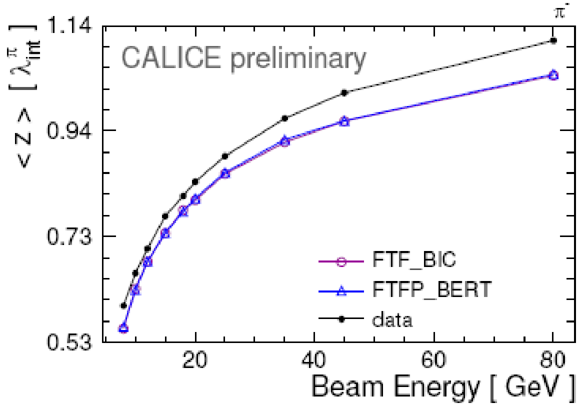


QGSP_BERT

FTF_BIC

CHIPS

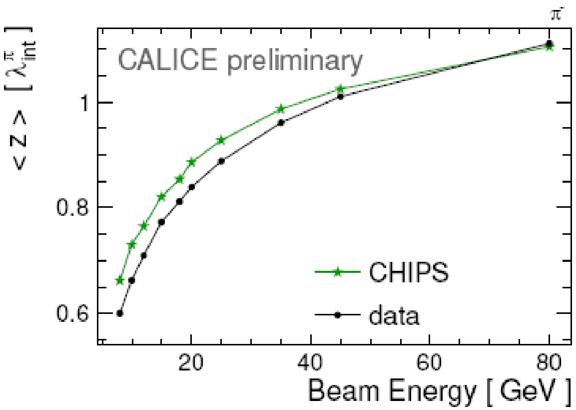


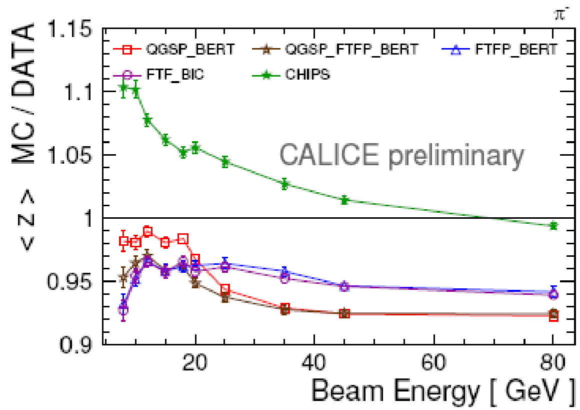


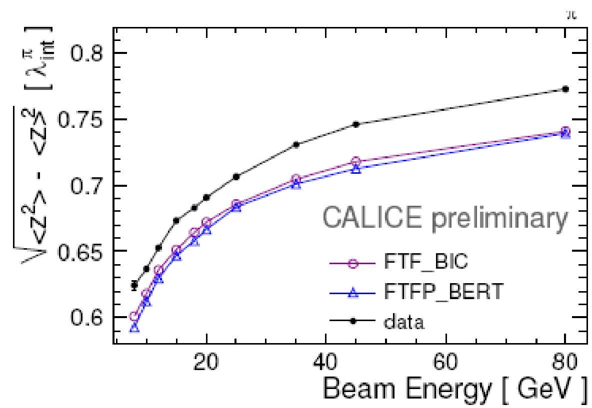
← center of gravity in longitudinal direction

All models ~ 5% too short showers apart from CHIPS

FTF models perform better than QGS ones



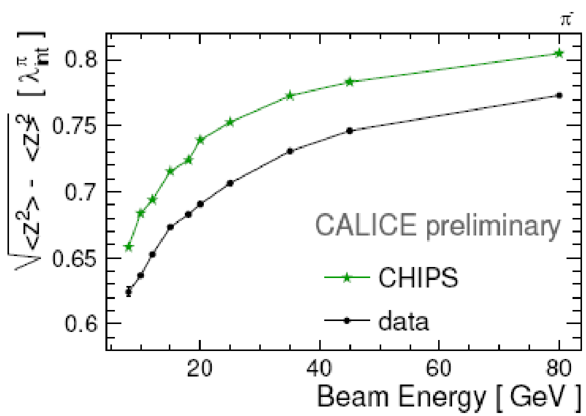


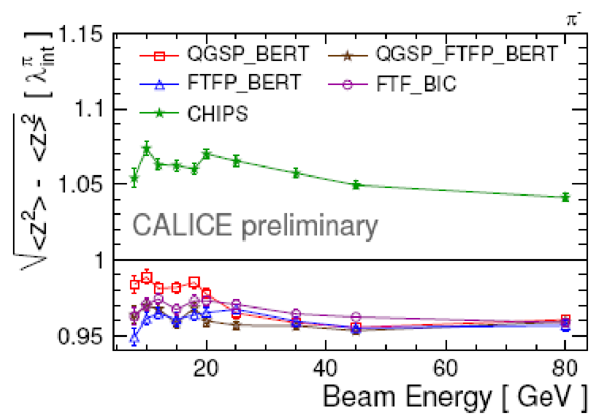


AHCAL (Scint./Fe)

RMS of longitudinal → shower distribution

CHIPS ~6% too broad showers, while other models are ~3% too compact



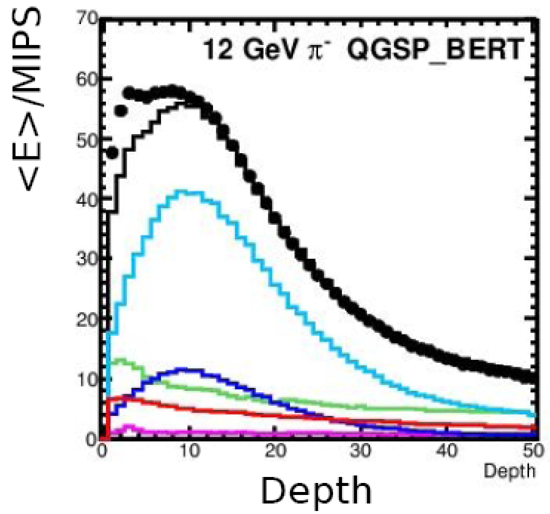


ECAL longitudinal shower profile

Longitudinal Energy Profiles

Sensitivity to different shower components

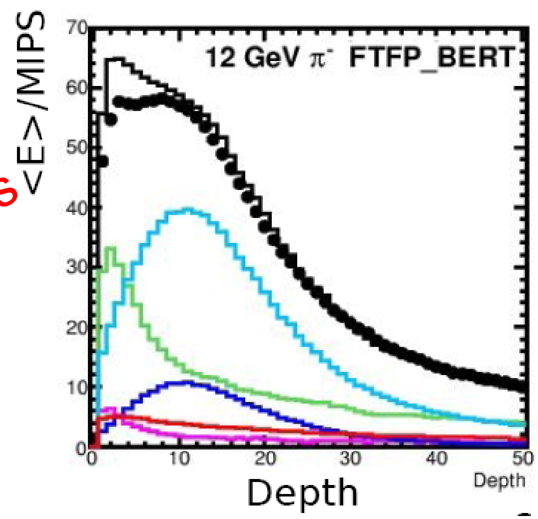
Too few protons



Shower Components:

- electrons/positrons
  knock-on, ionisation, etc.
- protons
  from nuclear fragmentation
- mesons
- others
- sum

Too many protons

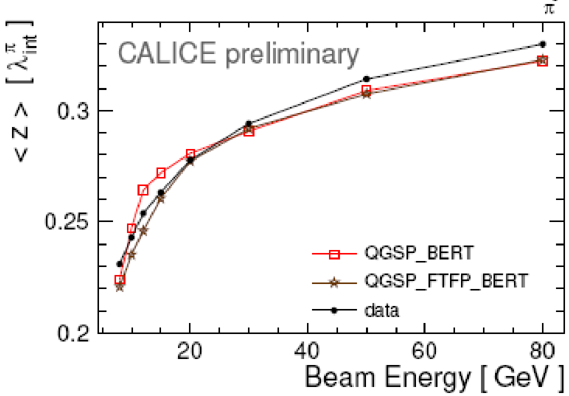


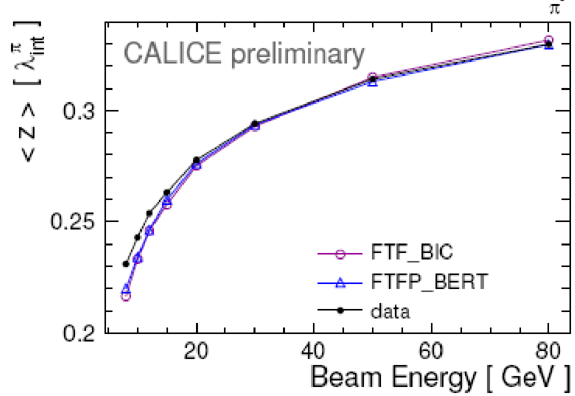
Significant Difference between Models

- Particularly for short range component (protons)

Granularity of SiW Ecal allows (some) disentangling of components

Further studies for shower decomposition are ongoing

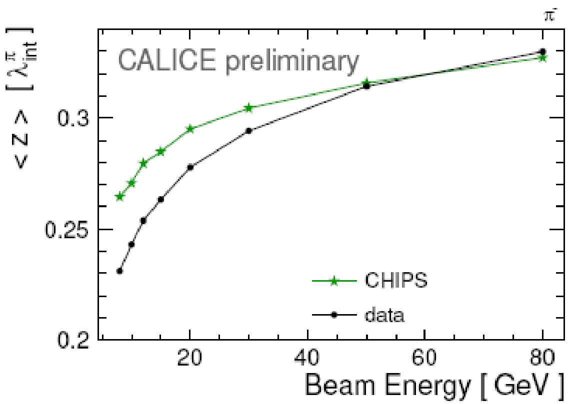


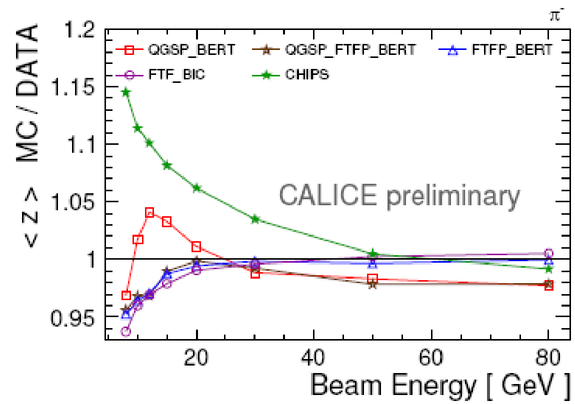


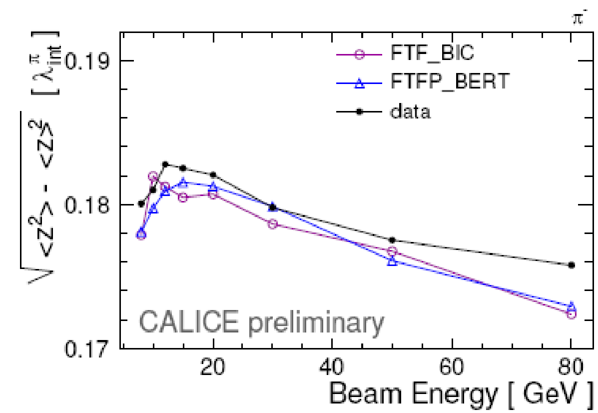
← center of gravity in longitudinal direction

<u>Larger disagreement at low energy</u>

All models ~ 5% too short showers apart from CHIPS (>10% too long)



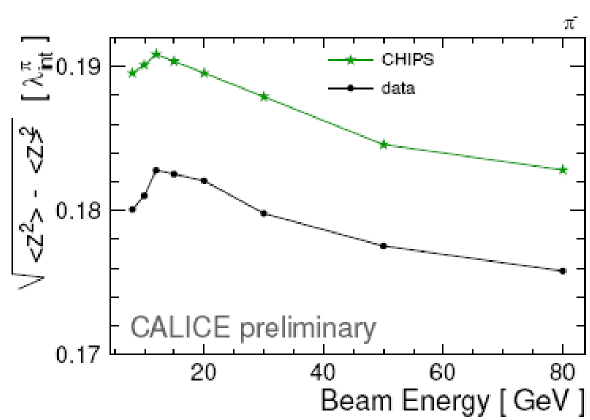


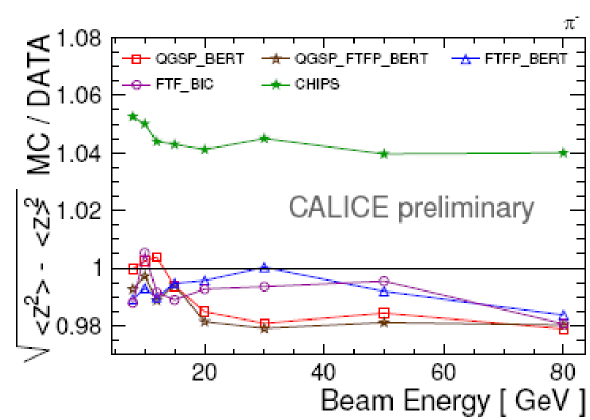


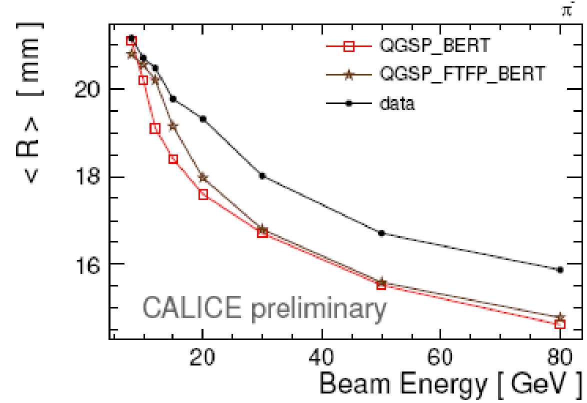
ECAL (Si/W)

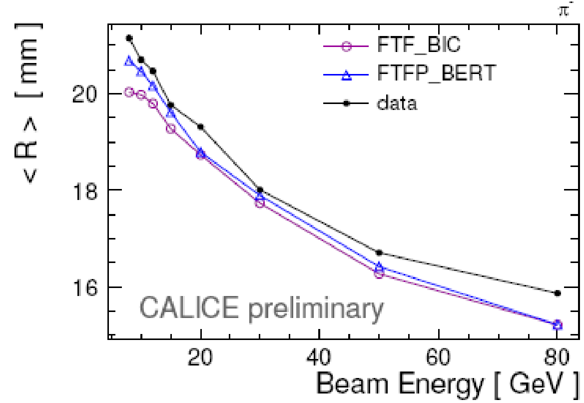
RMS of longitudinal shower distribution →

CHIPS ~5% too broad showers, while other models are up to 2% more compact



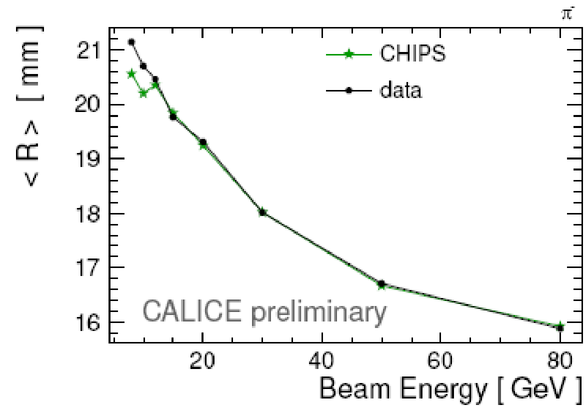


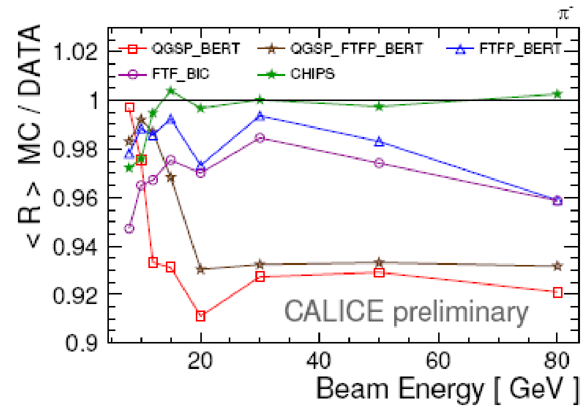


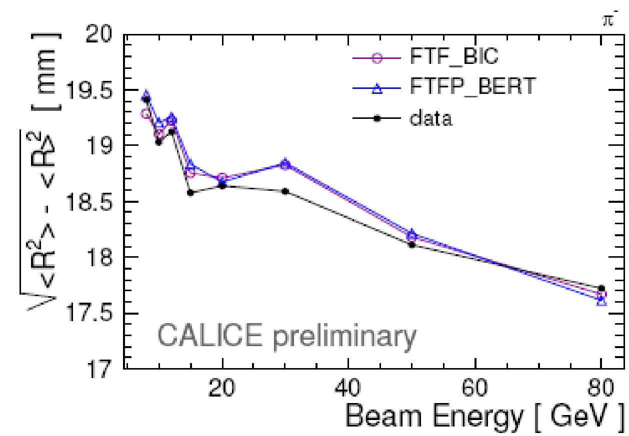


← mean shower radius in lateral direction

CHIPS and FTF models agree with data at 2-3% level, QGS models large E dependence

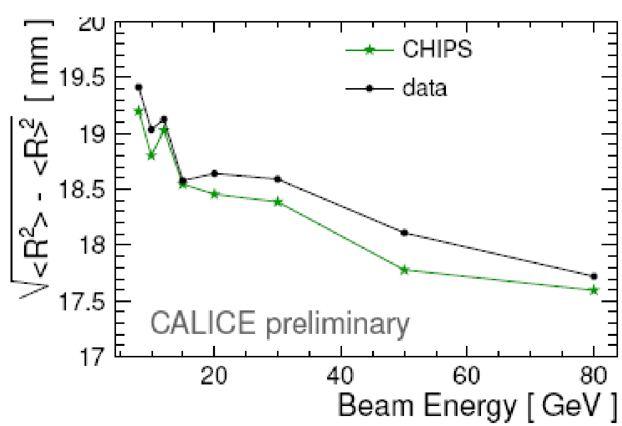


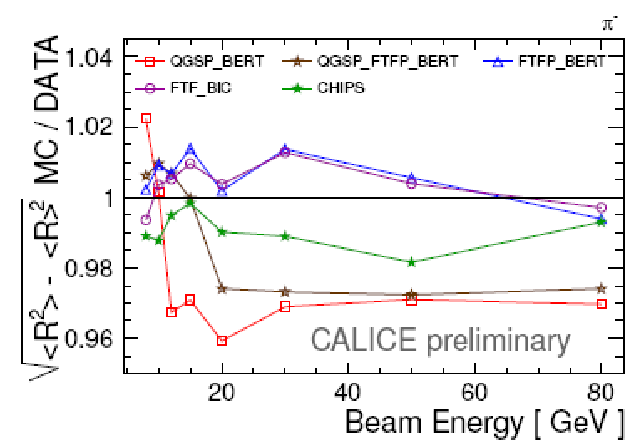




RMS of lateral → shower distribution

ECAL (Si/W)





Energy depositions in different calorimeter depths

ECAL (Si/W)

Layer 1-3:

Nuclear breakup

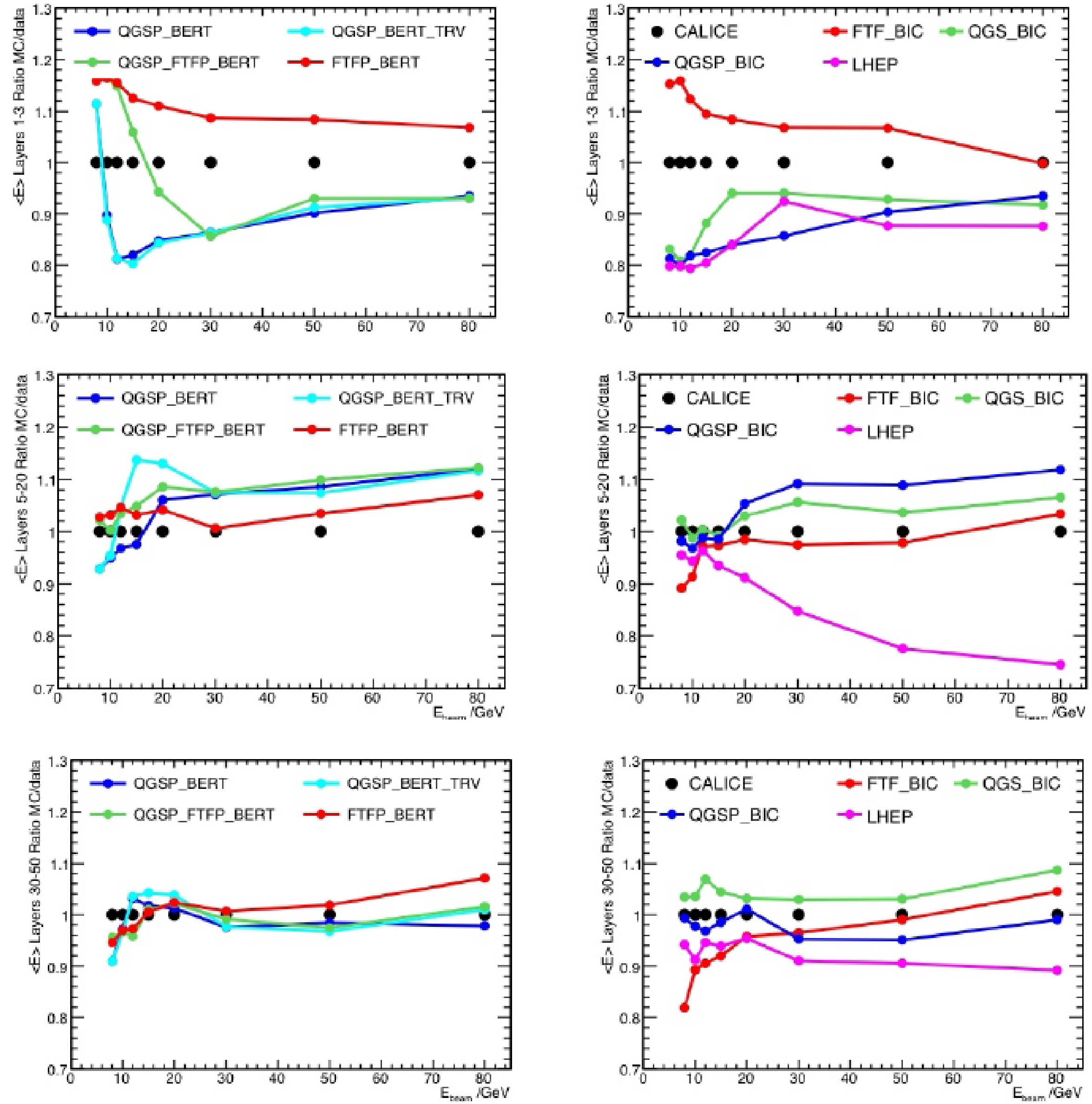
Layer 5-20:

elm. component

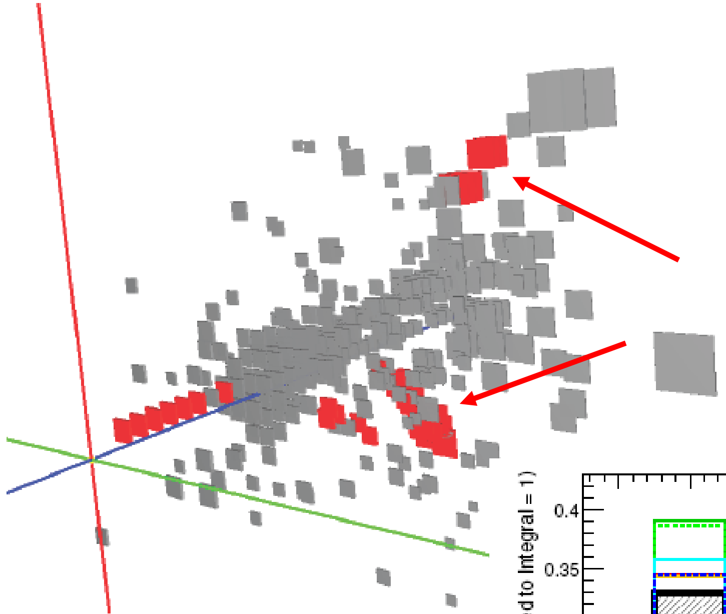
try to access a variable proportional to “f_{EM}”

Layer 30-50:

Shower hadrons



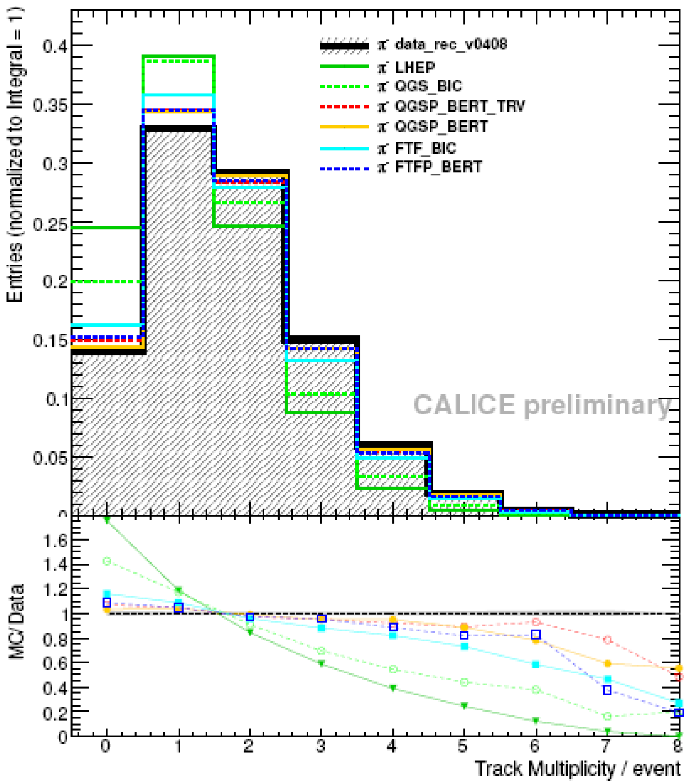
AHCAL Track multiplicity

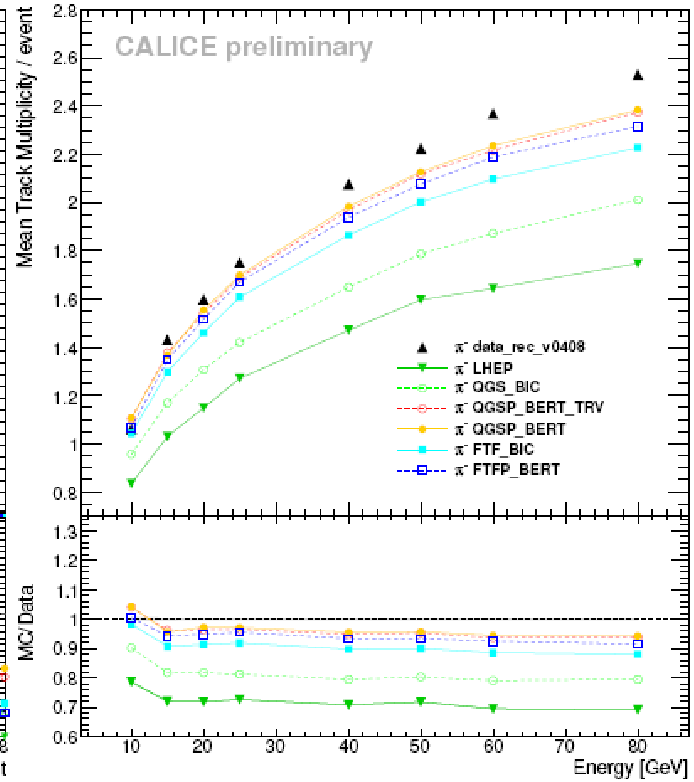


(a) Typical shower in the hadroni

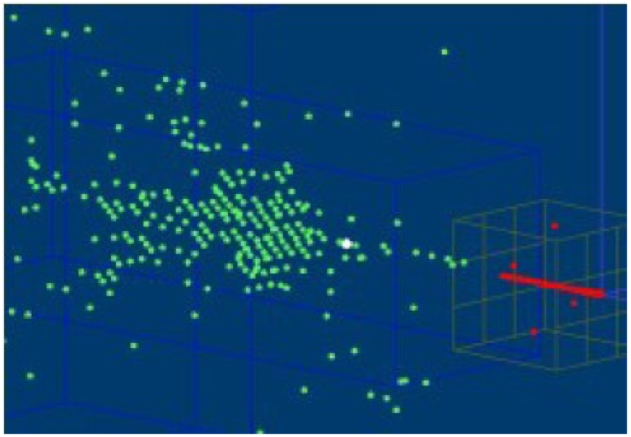
Count number of track segments in AHCAL hadronic shower

AHCAL (Scint./Fe)



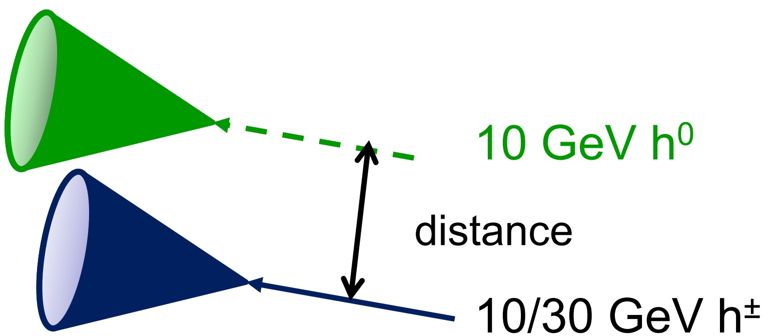


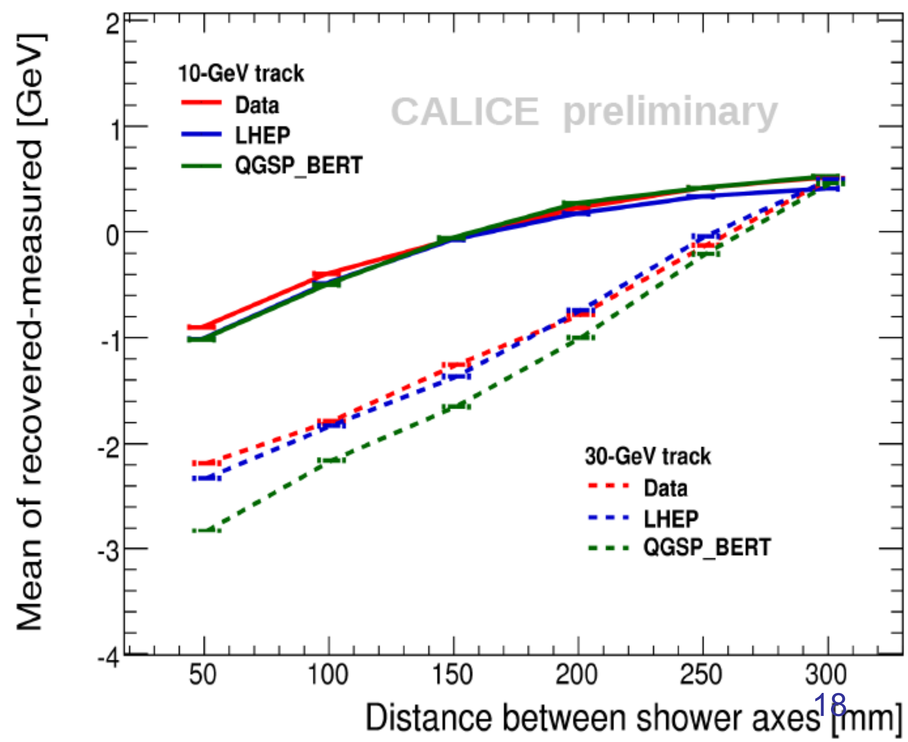
Pflow studies with CALICE data



Use CALICE hadronic showers with a track in ECAL
Overlay two events with same or different E
Remove incoming track from one event (neutral-had)

Apply PandoraPFA to find clusters
Compare cluster energy with calo-true energy for the reconstructed neutron

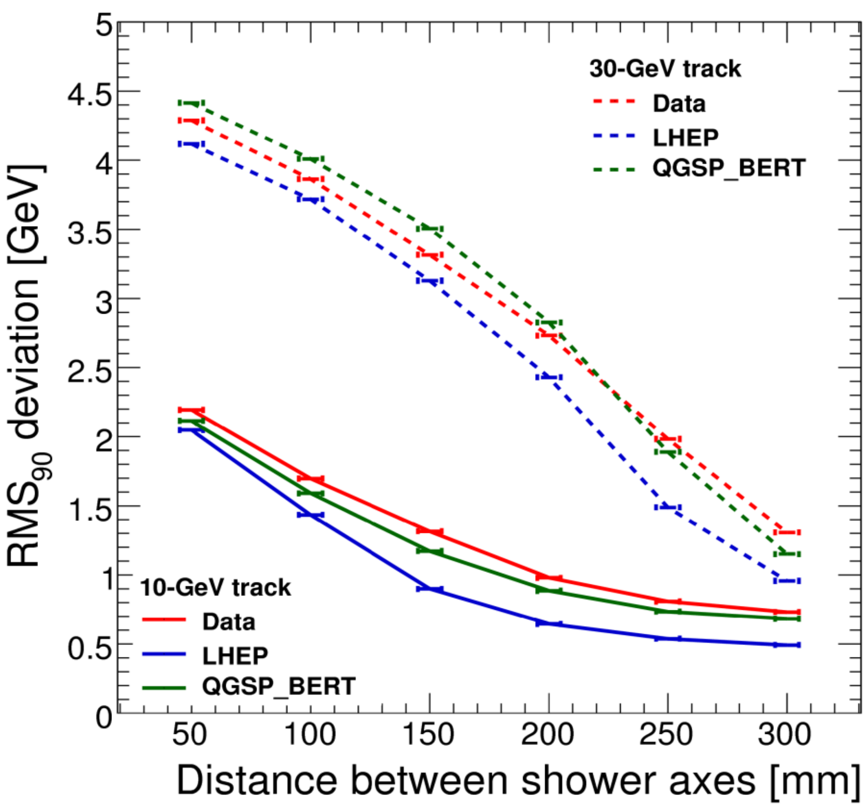


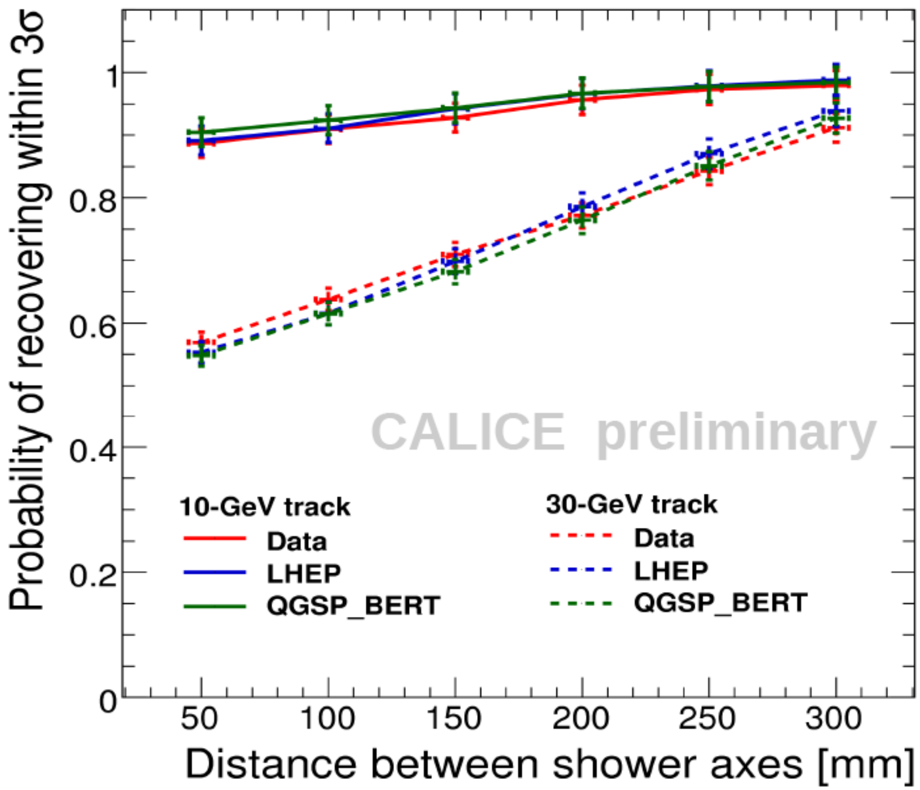


- No hidden imperfections in the real data which could deteriorate the PFA performance were found
- The PandoraPFA performance for the real data is as god as for MC simulation

Pflow studies with CALICE data

Deviation between *cluster* energy and energy *measured* in the calorimeter for the “neutral” 10 GeV hadron





Probability to recover the 10 GeV neutral hadron energy within 3 σ from its real energy

Conclusions

- High granularity of CALICE offers unprecedented possibilities to investigate hadronic showers
- Active collaboration between CALICE and G4 in hadronic shower model studies
- First preliminary results demonstrate the discrimination power of highly granular calorimeters
- First test of PandoraPFA on data were performed.

G4 9.2 vs 9.3.1

improvement in BERT linearity, BIC linearity worse
significant improved FTF transverse physics