Hadrons in the CALICE SiW Ecal

Naomi van der Kolk

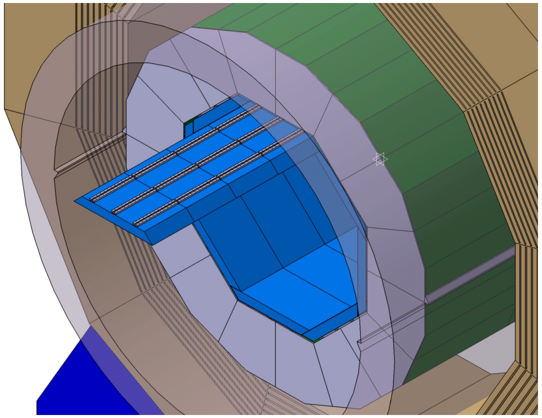
Summary of a CALICE internal publication* of the work of Philippe Doublet which will be published end of the year and which will be the starting point for more detailed research into the properties of hadronic showers

* Interactions of hadrons in the CALICE SiW ECAL prototype (CAN-025)

18 october 2012

ILC SiW Ecal

- The SiW Ecal is designed as a **Particle Flow** calorimeter.
- It should be able to reconstruct all individual particles in a jet.
- Especially it should be able to disentangle the showers of a neutral and charged particle in close proximity.
- To achieve this an extreme high granularity is needed.



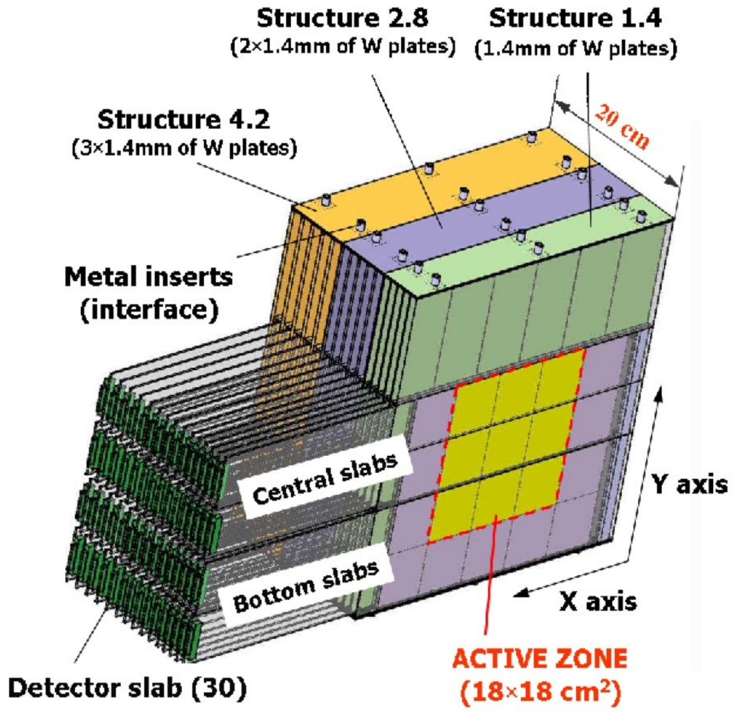
The SiW Ecal in the ILD Detector

- Tungsten as absorber material
  - Short radiation length, small Moliere radius
  - Narrow showers
  - Assures compact design

- Silicon as active material
  - Support compact design
  - Allows for pixelisation
  - Large signal/noise ratio

SiW Ecal Physics Prototype

- The aim of the prototype is to:
  - Establish the technology
  - Collect hadronic shower data with high granularity to validate existing MC models and to tune the reconstruction and clustering algorithms
  - Discover what can be seen/done with a high granularity Ecal



30 layer SiW sandwich structure
Active area 18 cm x 18 cm
3 sectors of 10 layers with different thickness of the tungsten
Silicon 1 cm x 1 cm pixels (pads)

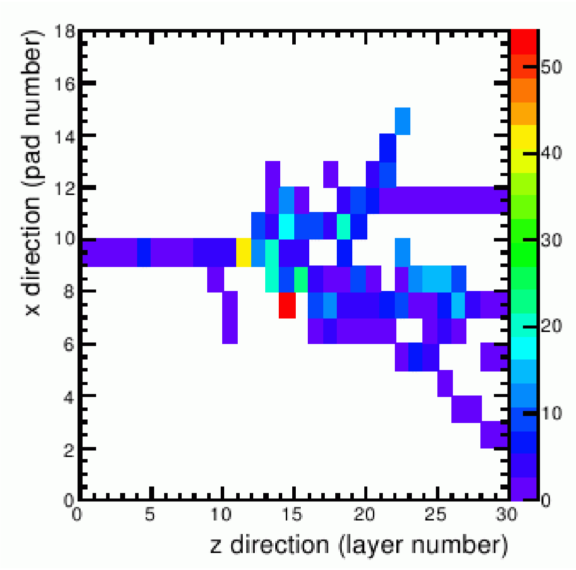
Total 24 X_0 and 1 λ_I

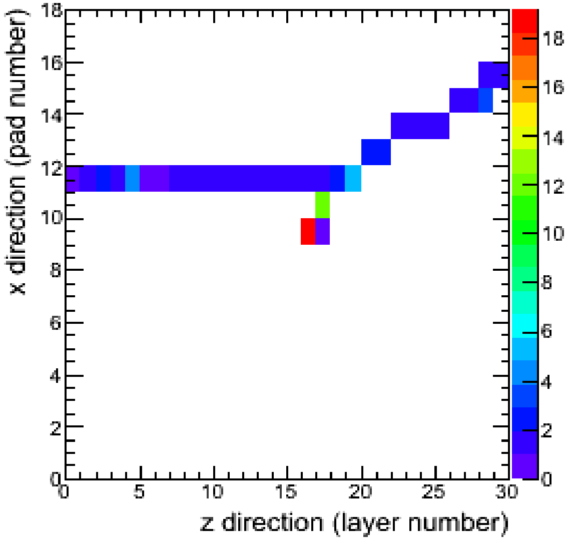
FNAL 2008 test beam

- The prototype has been subjected to a pion test beam at Fermilab in a setup together with the HCAL and a Tailcatcher.
- The π^- beam energy was 2, 4, 6, 8, 10 GeV
- This test complements another CALICE study at higher beam energies (ArXiv:1004.4996)
- Data is selected with the following criteria:
  - At least 25 hits (of 30)
  - Shower in central area
  - At least 0.6 MIP/hit
  - Isolated hits are removed
  - Pions are selected with Cherenkov counters and muons are rejected based on their hit distribution in Ecal, HCAL and tailcatcher

Interactions in the Ecal

- Hadrons traversing the Ecal will either pass as an ionising particle or create secondaries in an interaction (start of a hadronic shower).
- Identify the interaction layer:



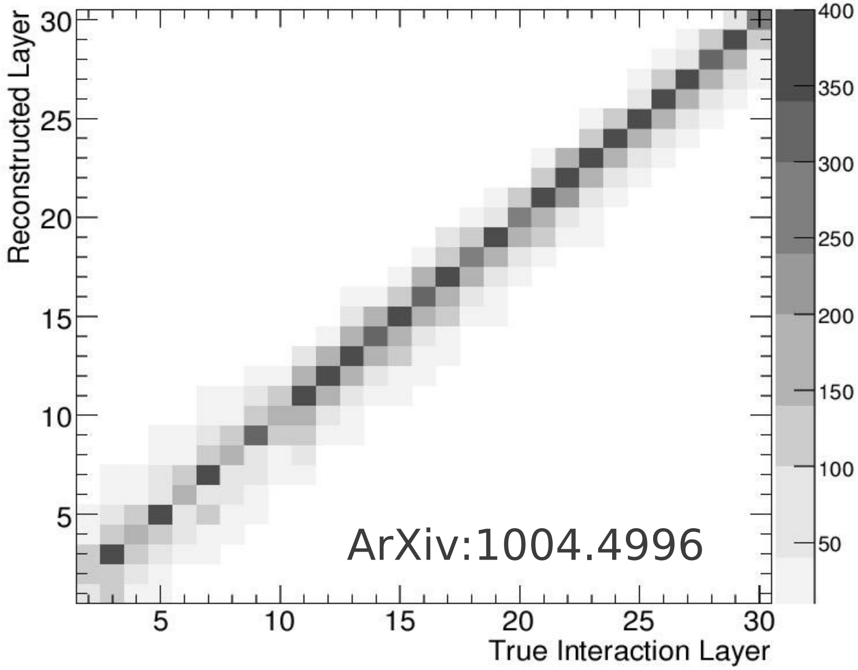


At high energy: absolute increase of energy in consecutive layers

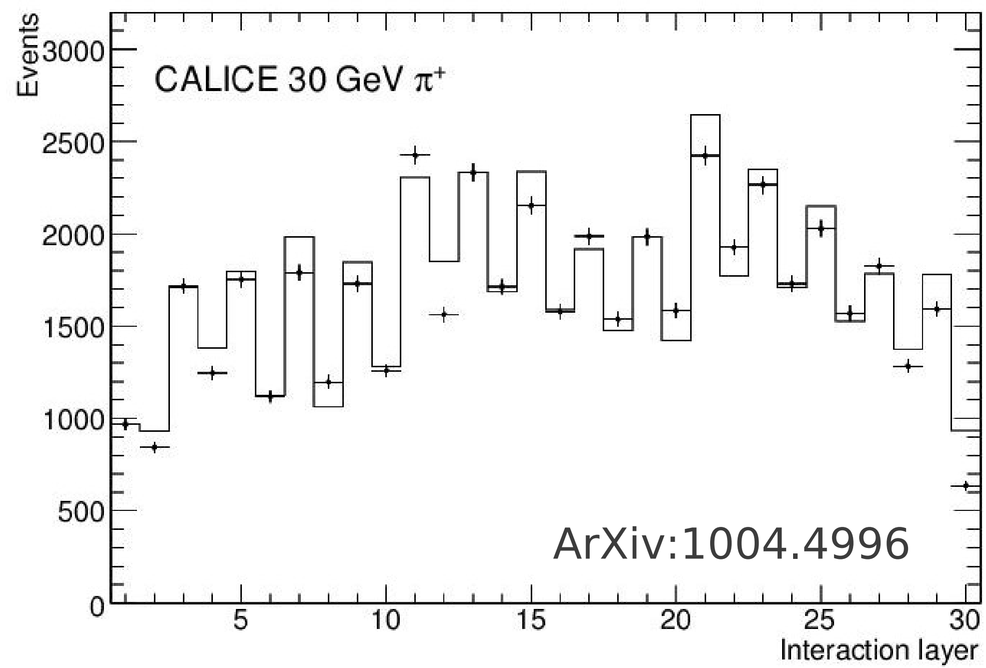
At small energy: relative increase of energy in consecutive layers

Interaction layer

Correlation:
True interaction <-> Found interaction



Distribution of found interaction layers



Determination precise to two layers
(Overall Layer thickness ~7mm max.)

Good agreement between data and simulation (G4, here QGSP_BERT)

The high granularity allows for resolving the interaction layer with high resolution

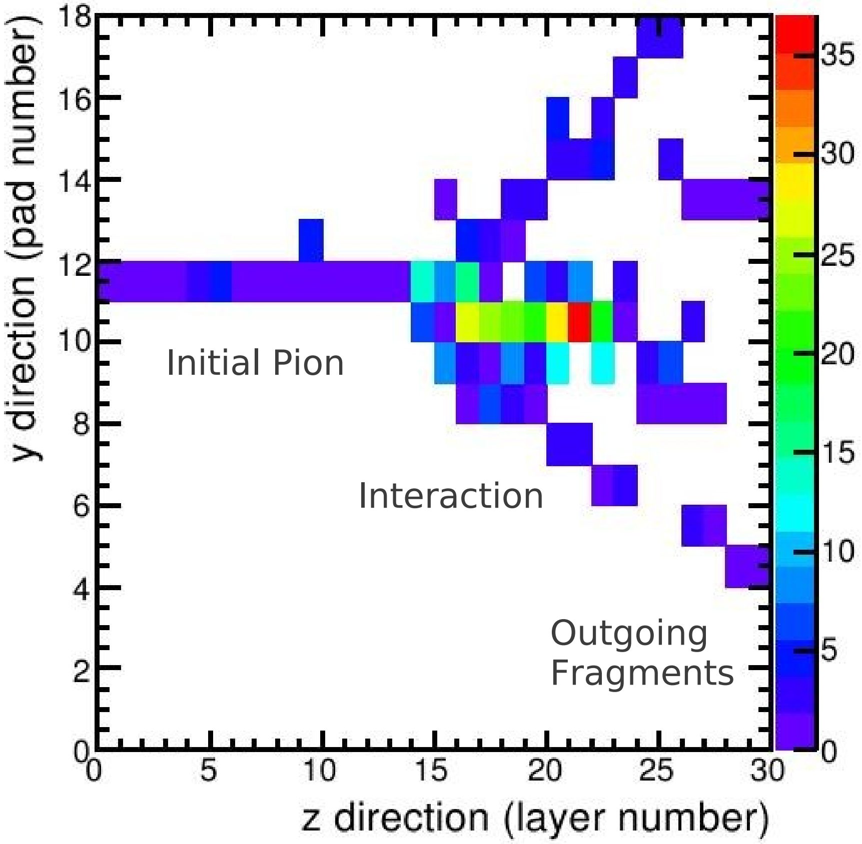
Efficiency: 10 GeV 84%
Efficieny: 2 GeV 63% (compared to 25% with only absolute energy increase cut)

Classification of interactions

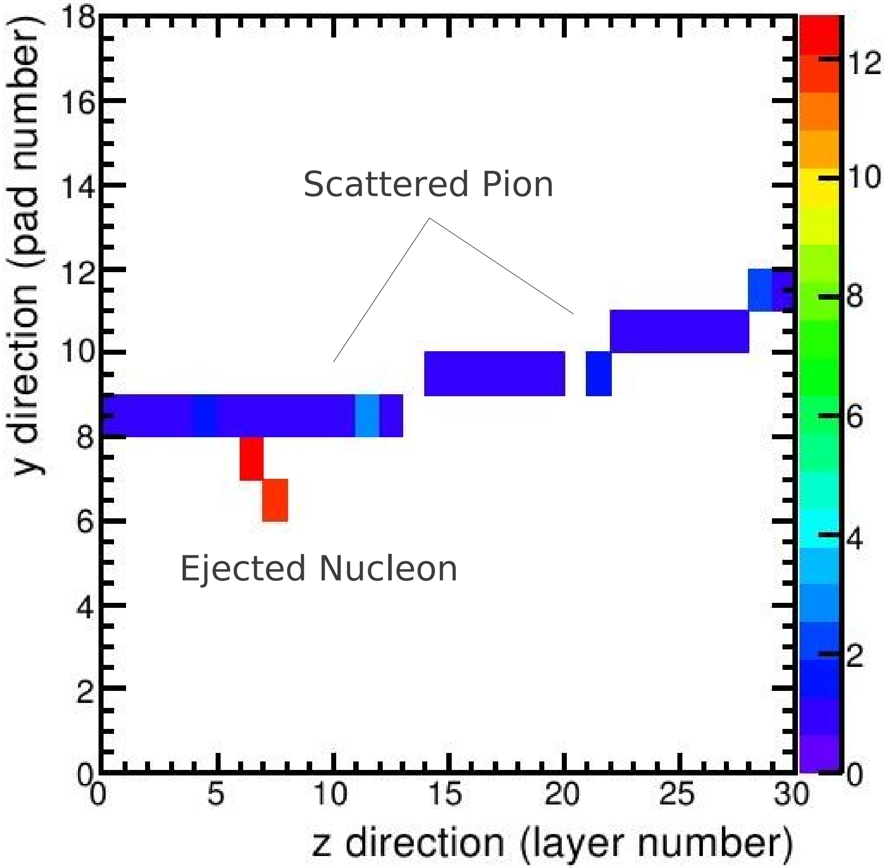
- 4 different types based on topology
  - Inelastic interactions
    - Fireball — Absolute increase in energy and long range relative increase.
    - Pointlike — short range relative increase.
  - Non-interacting
    - Elastic scattering — Lateral distance between ingoing and outgoing track (2 pixels)
    - MIP — ---

Interaction types

Fireball
Inelastic reaction in SiW Ecal



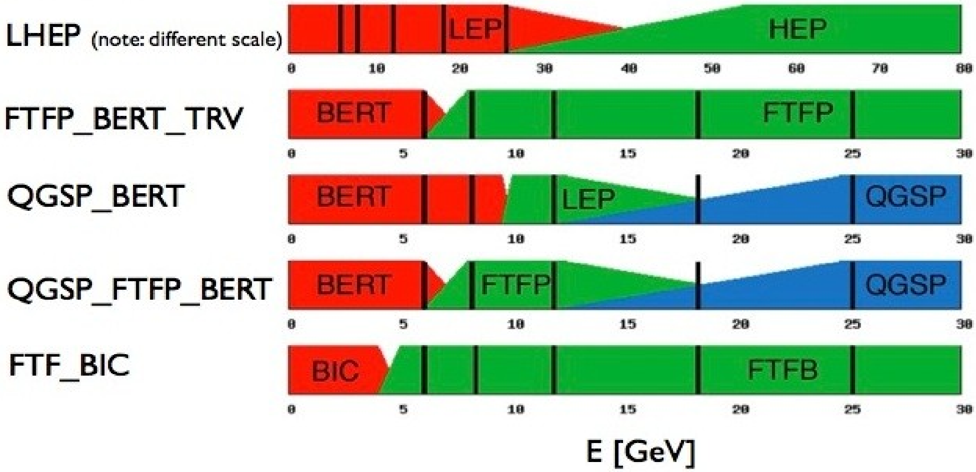
Pointlike
Short truncated showers



High granularity permits detailed view into the start of the hadronic shower

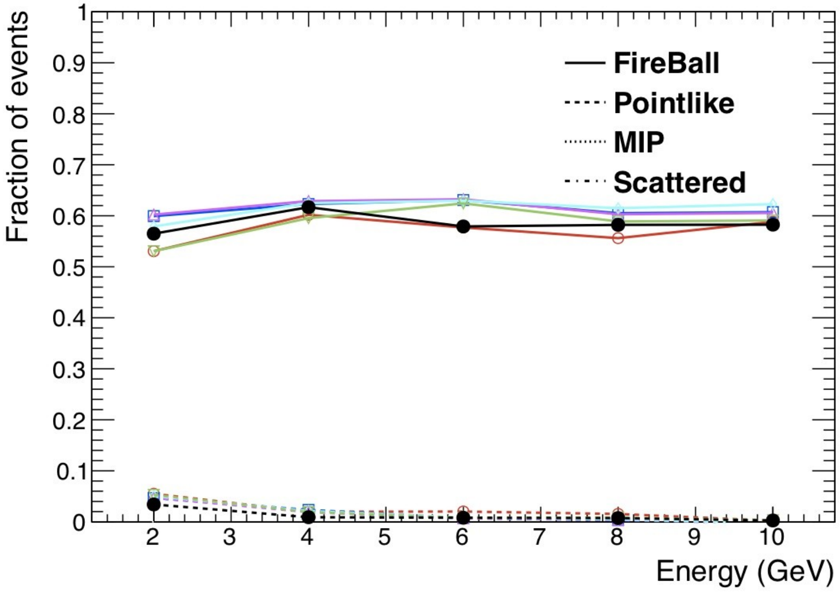
Compare data to MC models

- In GEANT 4 several models for hadronic interactions are available
- Compare shower properties of the different event classes to these models
  - Event rate
  - Shower radius
  - Longitudinal shower profile

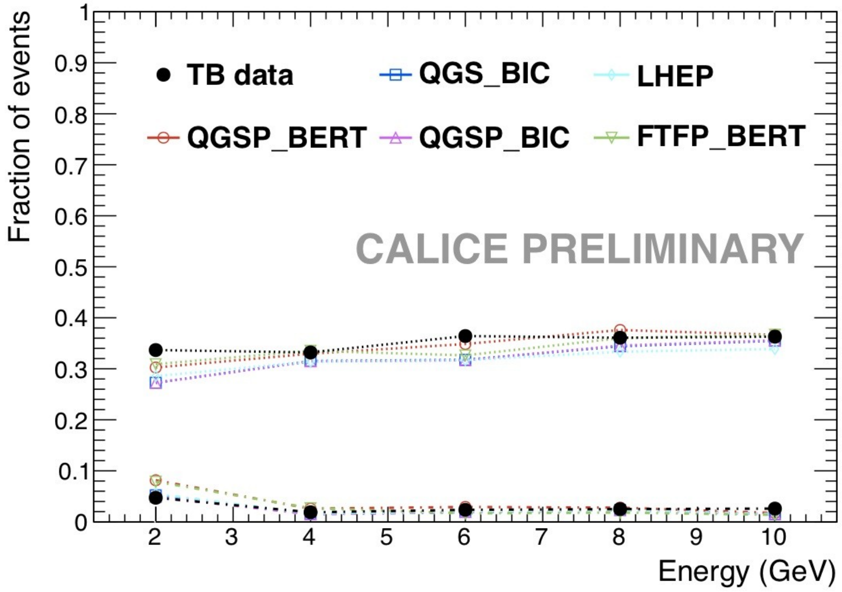


Event rates

Events with found hadronic interaction



Events w/o found hadronic interaction

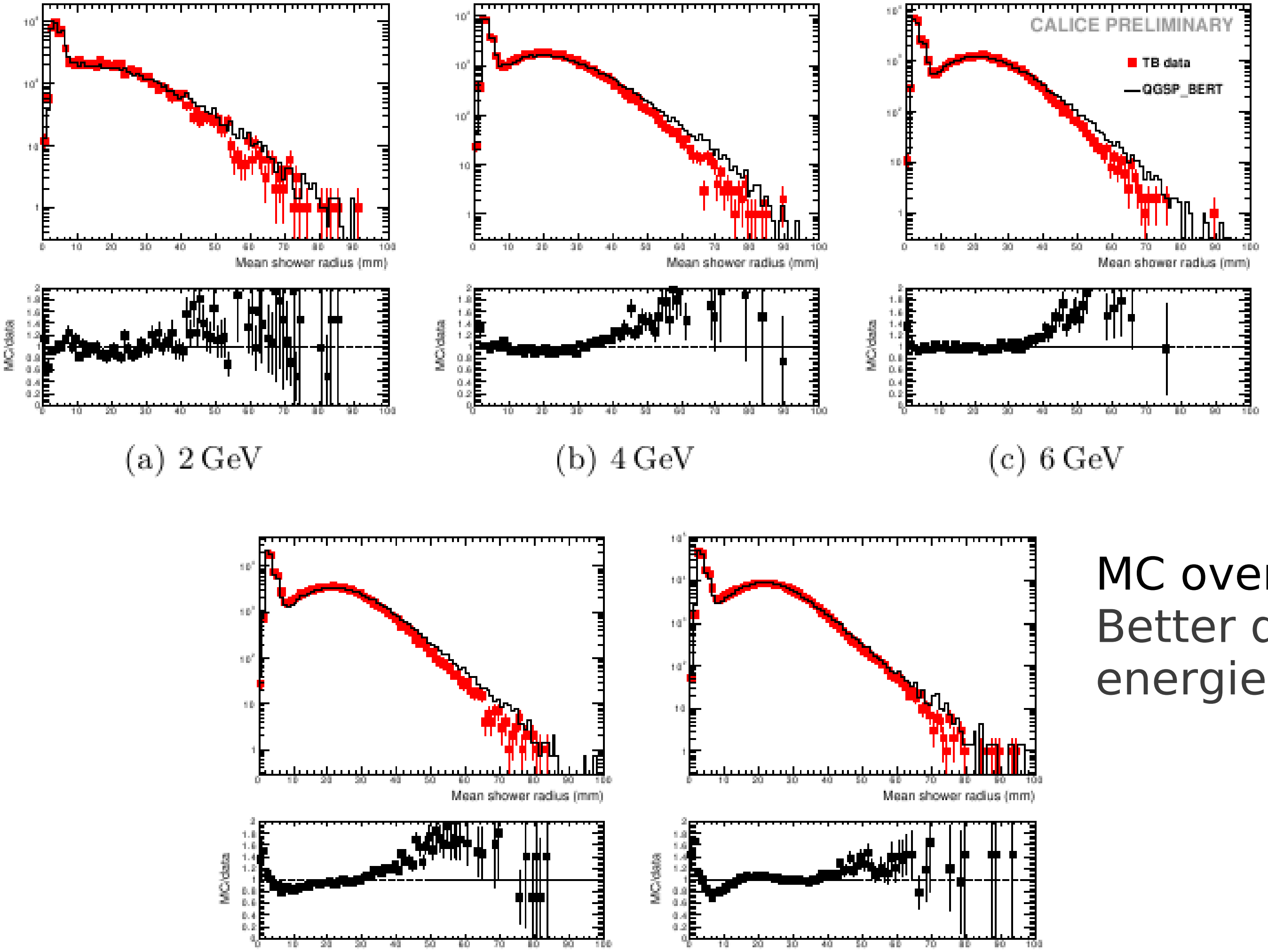


Cross sections of underlying scattering processes well modelled by GEANT4

Decomposition of interactions demonstrates sensitivity to details of interactions

Shower radius

The shower radius affects the overlap of showers and is therefore important for Particle Flow Algorithms



(a) 2 GeV (b) 4 GeV (c) 6 GeV (d) 8 GeV (e) 10 GeV

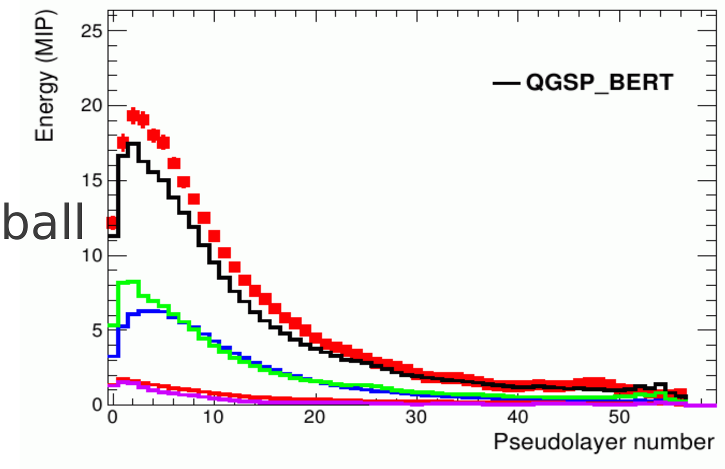
MC overshoots data for large radii

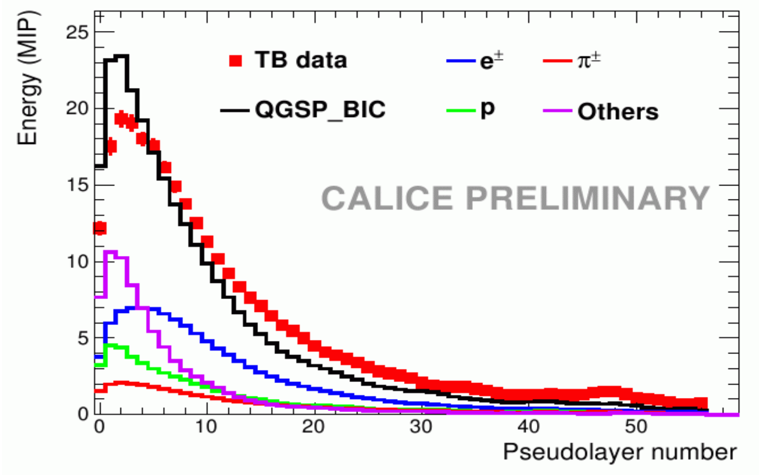
Better description at higher energies

Longitudinal profile

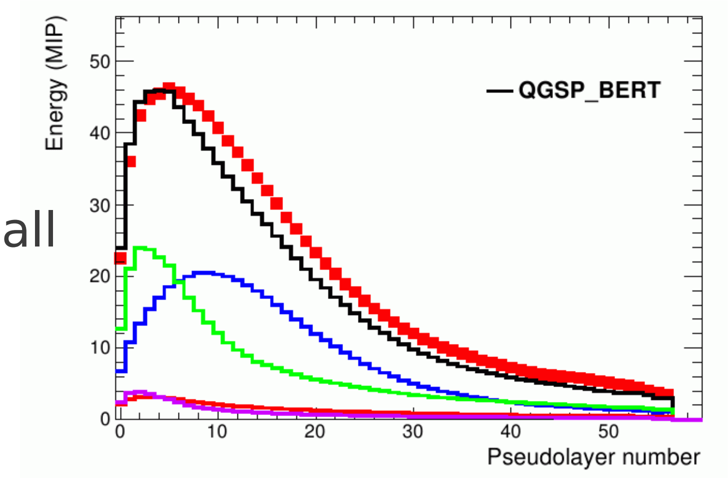
MC does not offer a satisfactory description

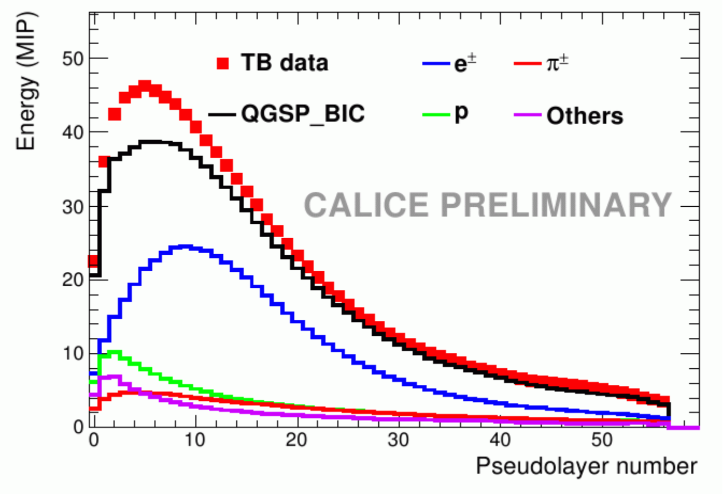
2GeV Fireball





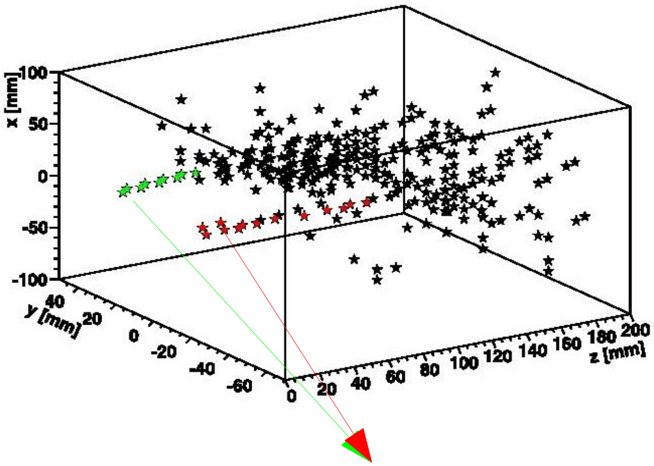
8GeV Fireball





Conclusion & outlook

- With highly granular Ecal detailed studies of hadronic showers are possible
- As well as comparisons to MC models which will lead to increased understanding of hadronic showers
- Particle Flow Algorithms can be improved
  - Improve shower reconstruction using advanced pattern recognition algorithms
  - If individual showers are well known two overlapping showers can be disentangled



Two pions entering the SiW Ecal