The CALICE Si-W ECAL - physics prototype

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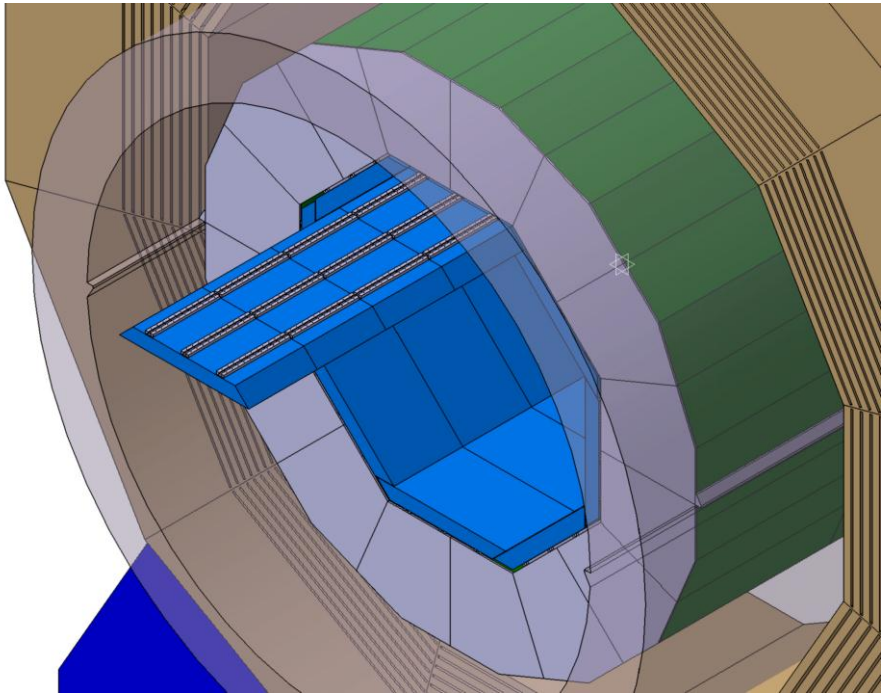
Introduction - SiW ECAL

- Basic requirements
  - ✓ Extreme high granularity
  - ✓ Compact and hermetic
- Basic choices
  - ✓ Tungsten as absorber material (X_0=3.5mm, R_M=9mm, λ_I=96mm)
    - →Narrow showers
    - →Assures compact design
  - ✓ Silicon as active material
    - →Allows for pixelisation
    - →Large signal/noise ratio

The SiW Ecal in the ILD Detector



→SiW ECAL is designed as particle flow calorimeter

The CALICE Collaboration

Calorimeter R&D for a future linear collider

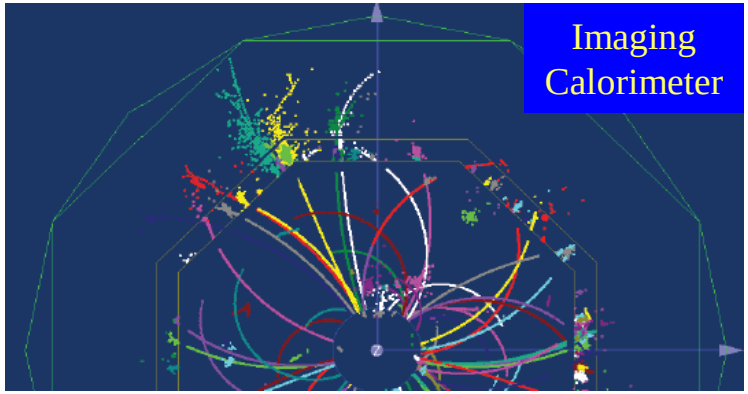
~330 physicists/engineers from 57 institutes
and 17 countries from 4 continents

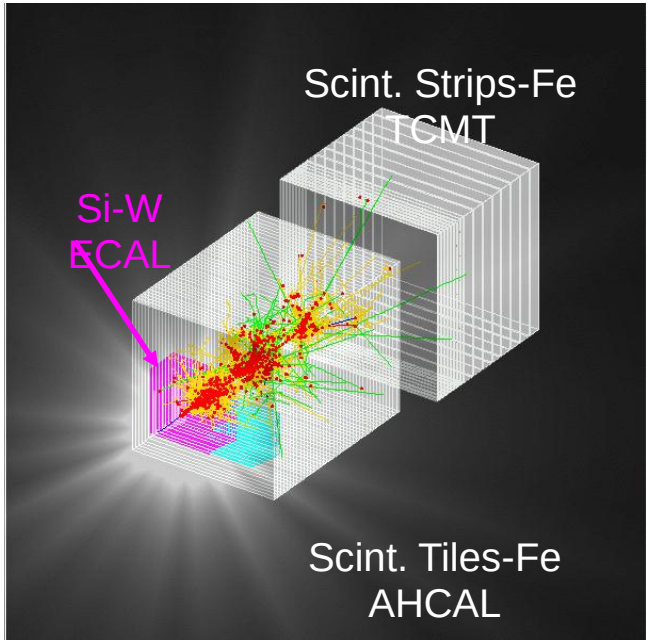
- Integrated R&D effort

- Benefit/Accelerate detector development due to *common* approach

The CALICE Mission

Final Goal:
A highly granular calorimeter optimized for the Particle Flow measurement of multi-jets final state at the International Linear Collider

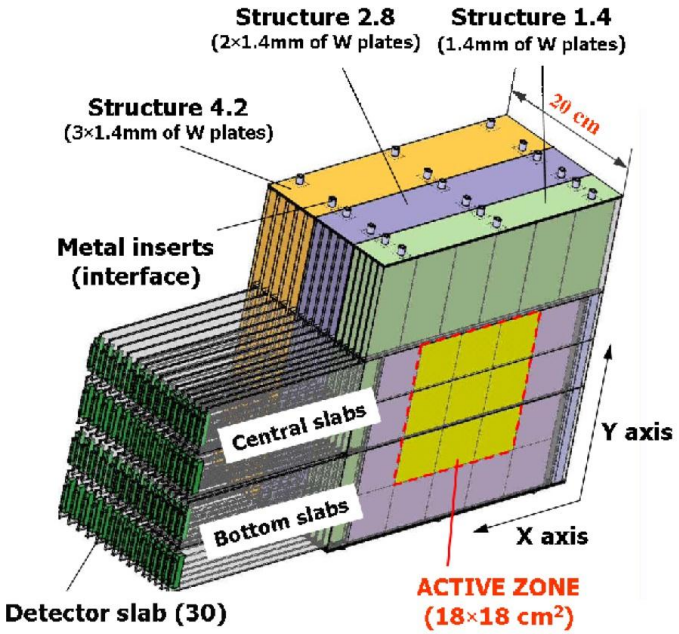


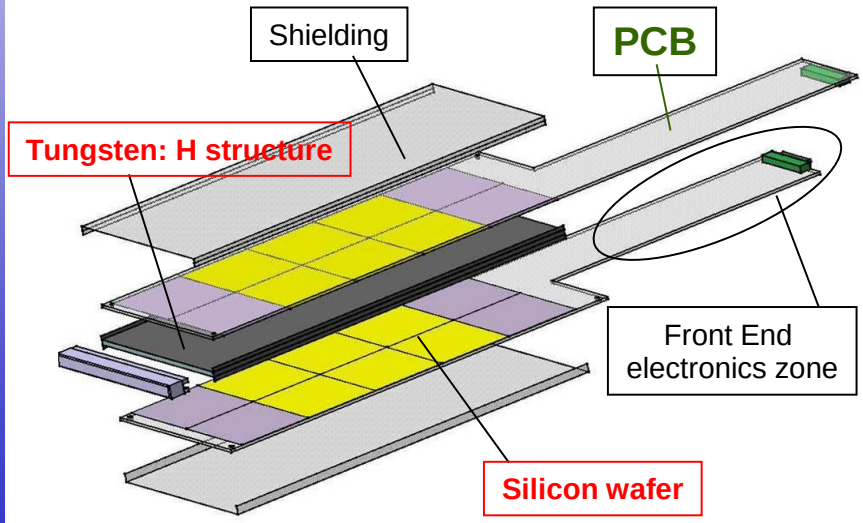


Intermediate task:
Build prototype calorimeters to

- Establish the technology
- Collect hadronic showers data with unprecedented granularity to
  - ✓ Tune clustering algorithms
  - ✓ Validate existing MC models

SiW ECAL Physics Prototype





Absorber layers

30 layers of tungsten:

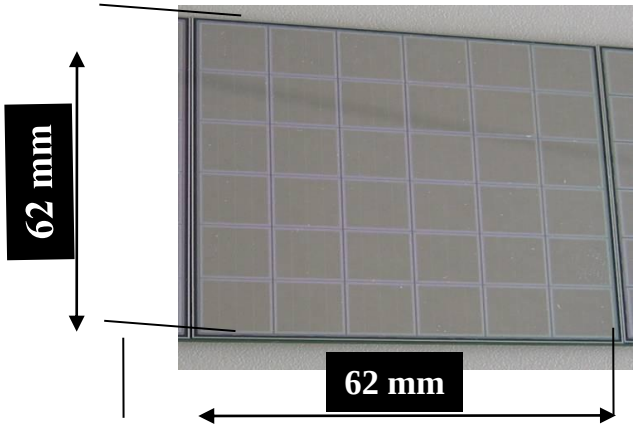
- 10 x 1.4 mm ($0.4X_0$)
- 10 x 2.4 mm ($0.8X_0$)
- 10 x 4.2 mm ($1.2X_0$)

→$24X_0$ in total, 1 λ_I

Active layers

Silicon Pad:

- 6x6 PIN diode matrix



Thickness:
525µm

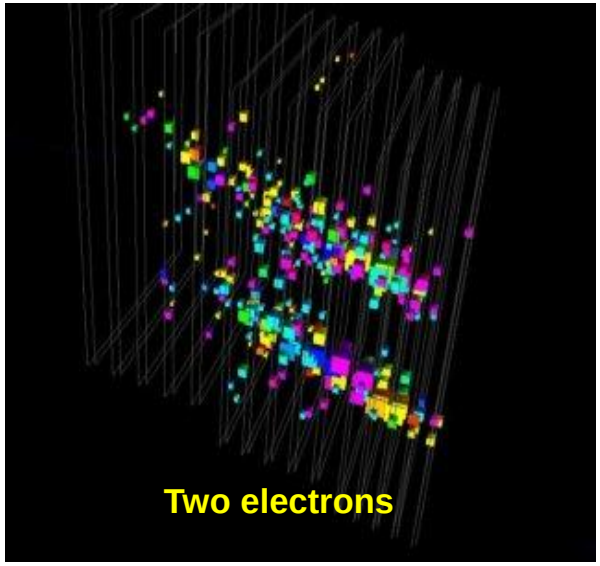
Total: 9720 Pixels/Channels

Test Beam w/ Phys. Proto.

- 2006, ECAL 2/3 equipped
  Low energy electrons (1-6 GeV at DESY), high energy elecrons (6-50 GeV at CERN)
- 2007, ECAL nearly completely equipped
  High energy pions (6-120 GeV at CERN), Tests of embedded electronics
- 2008 FNAL, ECAL completely equipped
  Pions at small energy

Experimental setup

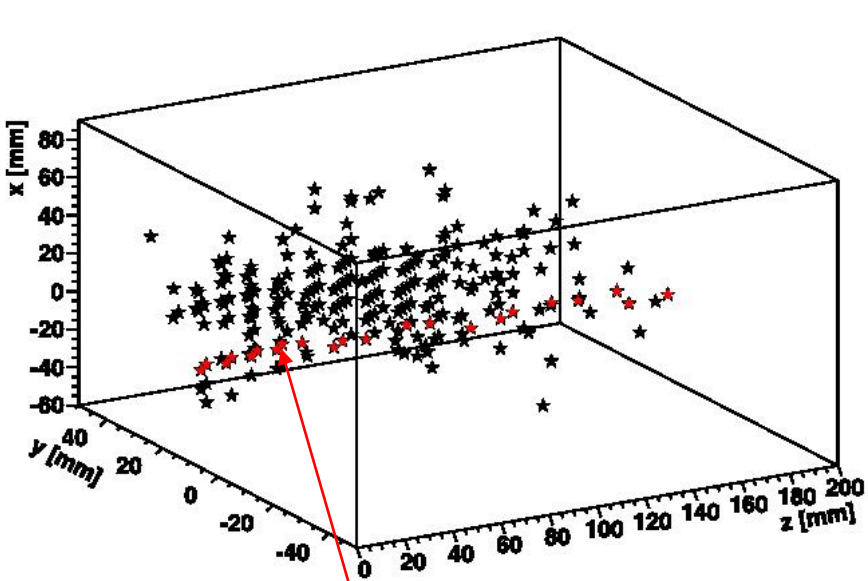
Zoom into ECAL

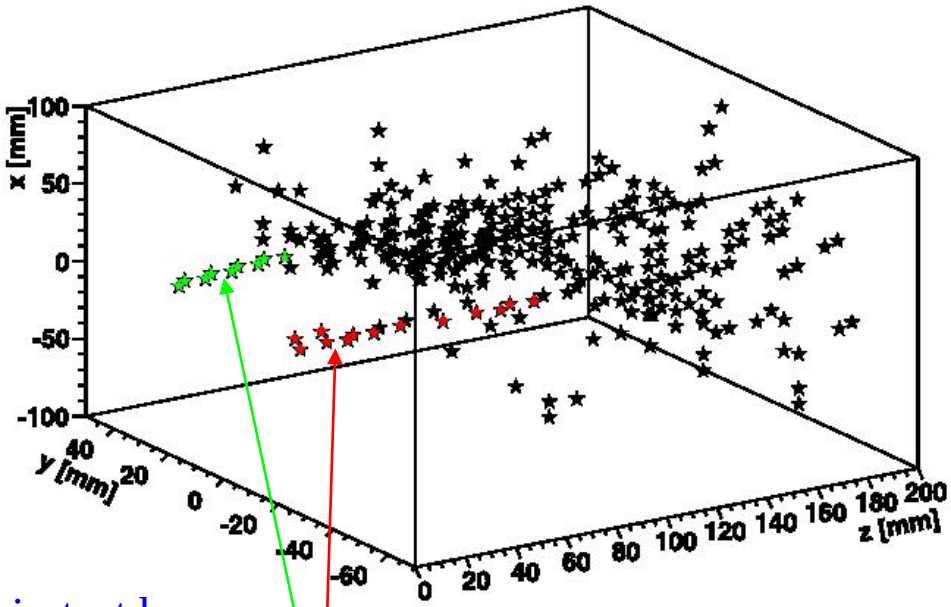


Particle distance = 5 cm
→No confusion!!

Particle Separation

High granularity allows for application of advanced imaging processing techniques
e.g. Hough transformation



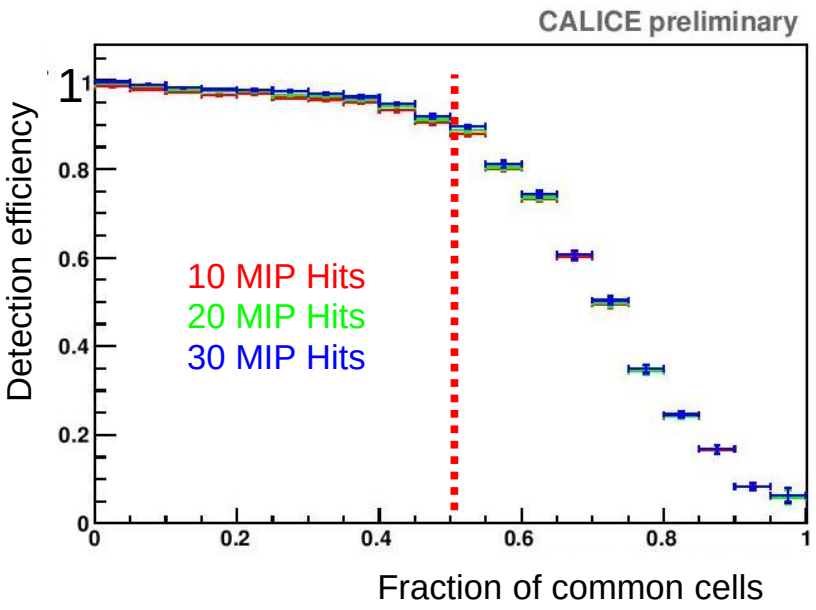


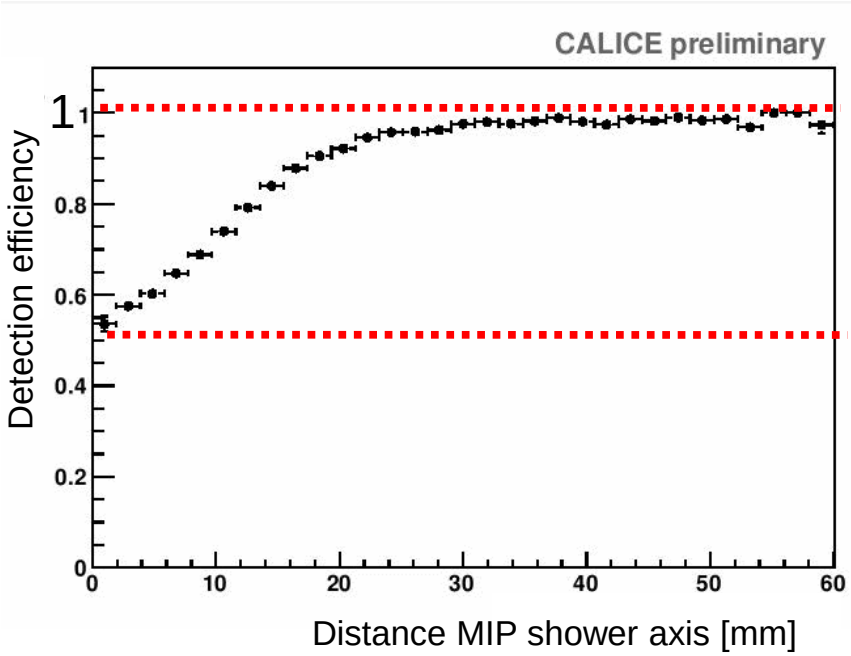
Events recorded in test beam

Secondary muon within electron shower

Two pions entering the SiW Ecal

Efficiency of Particle Separation



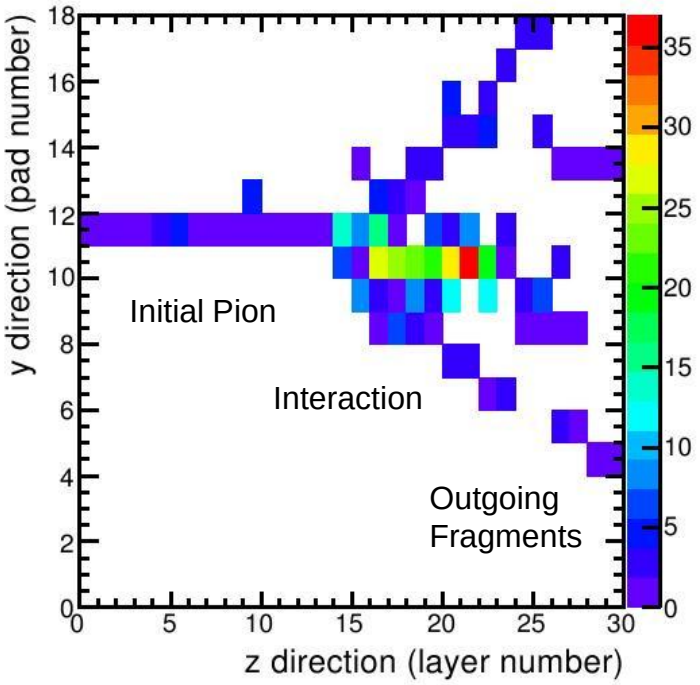


Efficiency ~ 100% for up to 50% shared hits

Full separation for distances > 2.5cm

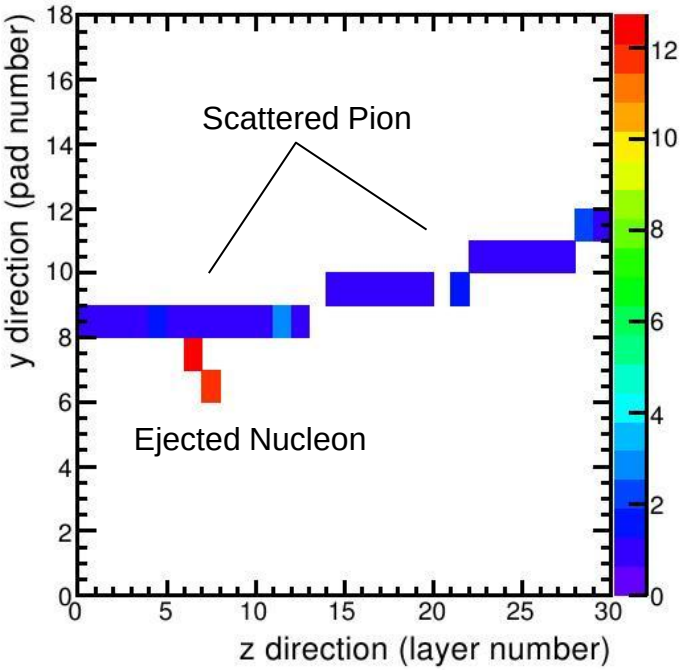
Hadronic Showers in the SiW ECAL

Easy at high energies



Inelastic reaction in SiW ECAL
→FireBall event

Simple but nice

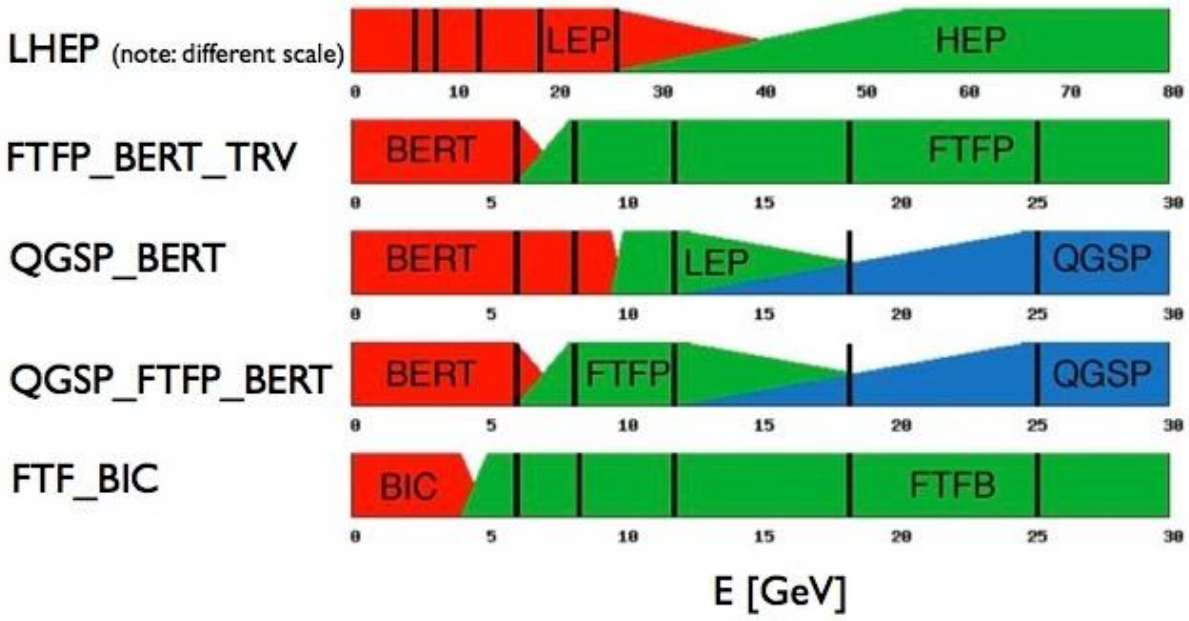


Short truncated showers
→pointlike event

High granularity permits detailed view into hadronic shower

Hadronic models in Geant4

Variety of models available to describe hadronic showers

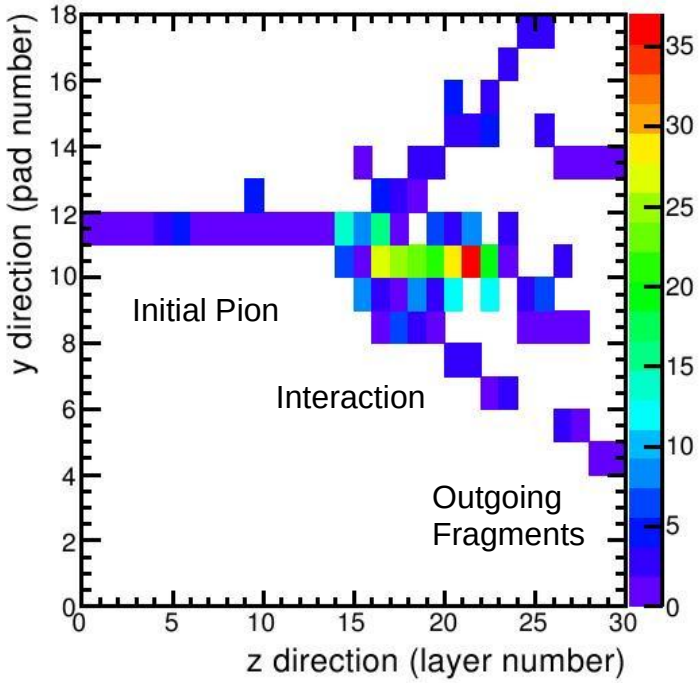


Discriminative power by high granularity !?

A. Dotti (G4 Collaboration): “Rough granularity of LHC calorimeters limits possibilities”, “CALICE is the perfect tool”

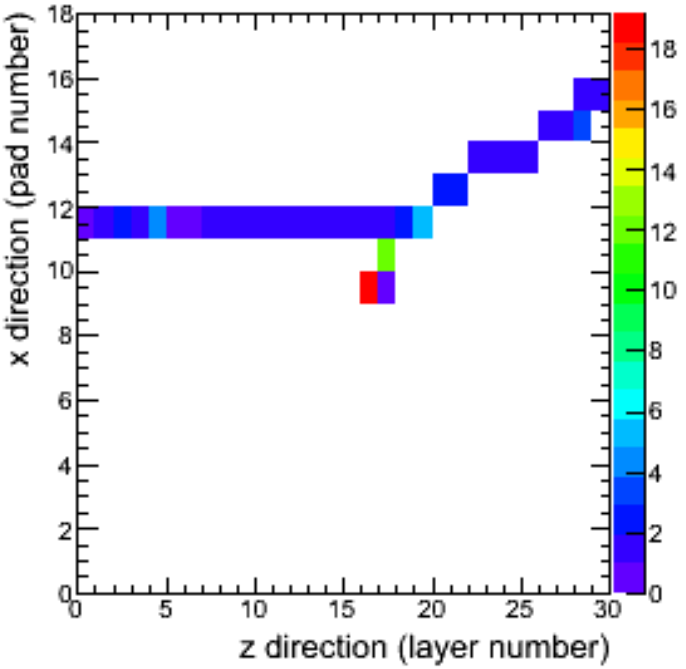
Finding the interaction point

Complex and impressive



Check for absolute increase of energy in consecutive layers

Difficult at small energies



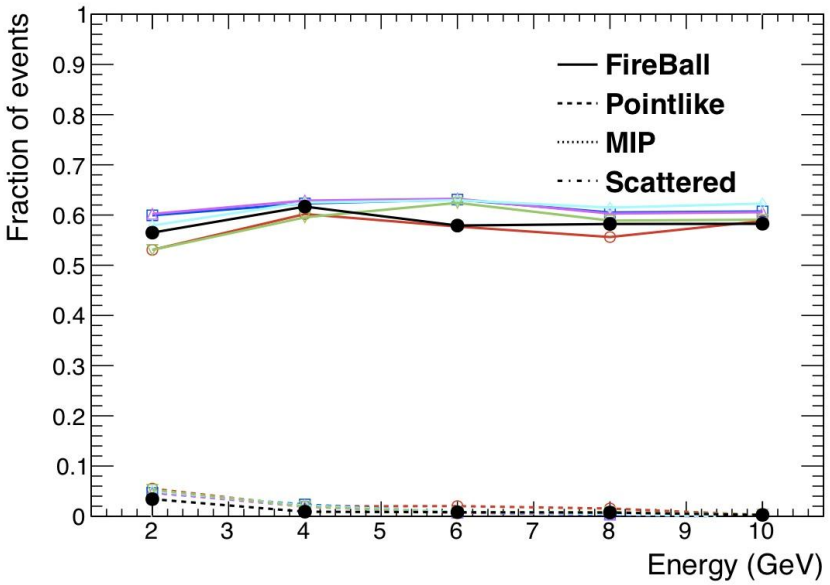
Check for relative increase of energy in consecutive layers

Efficiency: 84% for 10 GeV and 64% for 2 GeV

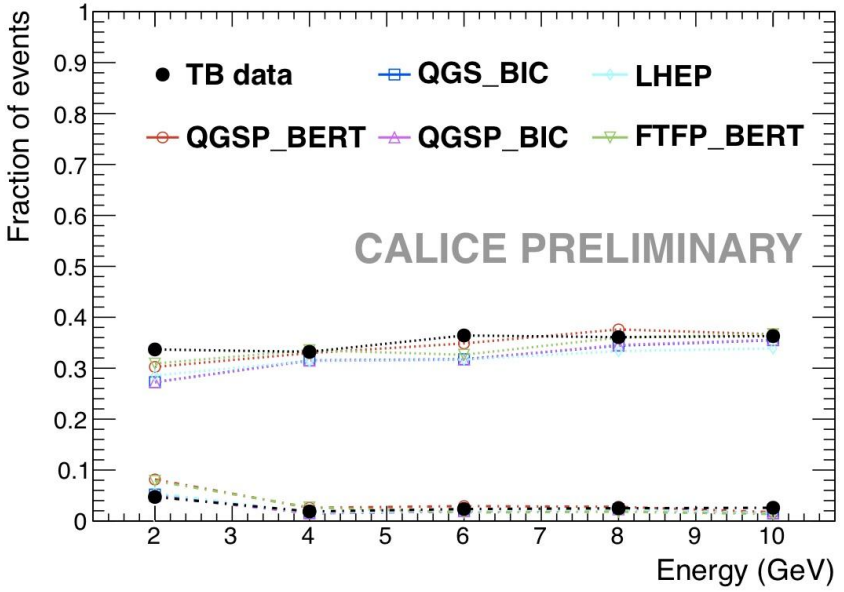
Event Types and Rates

Explore and understand of what we can “see” with the SiW ECAL

Events with found hadronic interaction

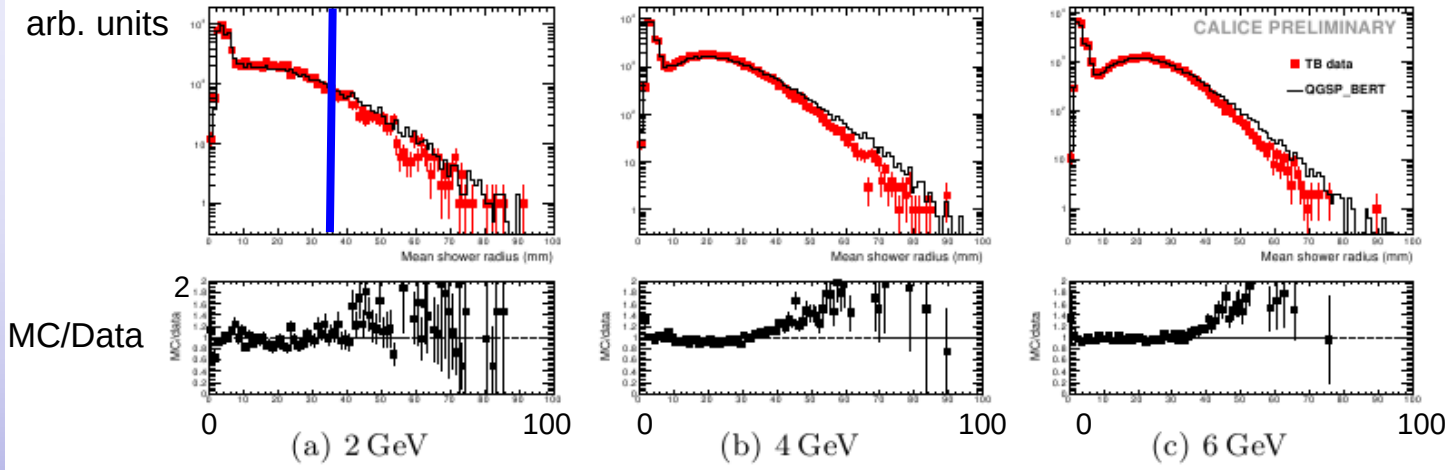


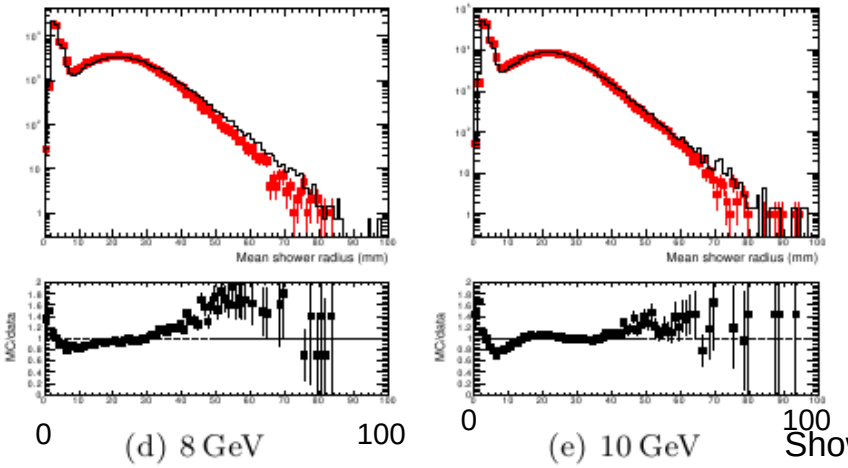
Events w/o found hadronic interaction



Cross section of underlying scattering processes well modeled by GEANT4
Decomposition of interactions demonstrate sensitivity to details of interactions

Transverse Profiles (low energies)





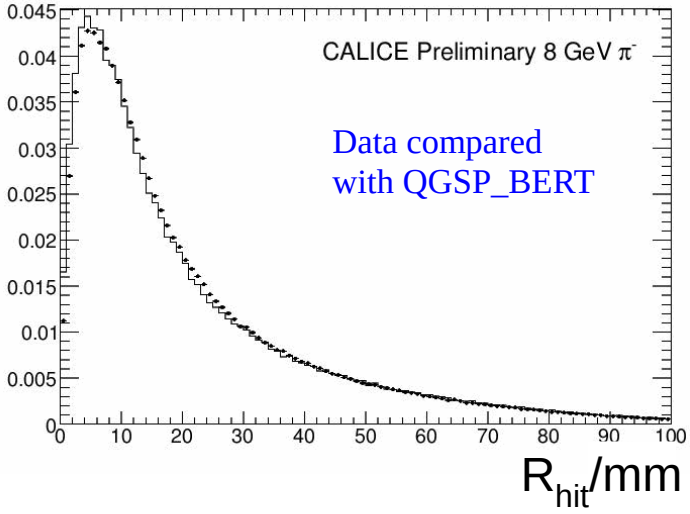
- 2-10 GeV
- QGSP_BERT

- MC overshoots data for large radii at all energies
- Relatively better description at higher energies

Shower width/mm

Transverse Profiles(High energies)

Transverse profiles



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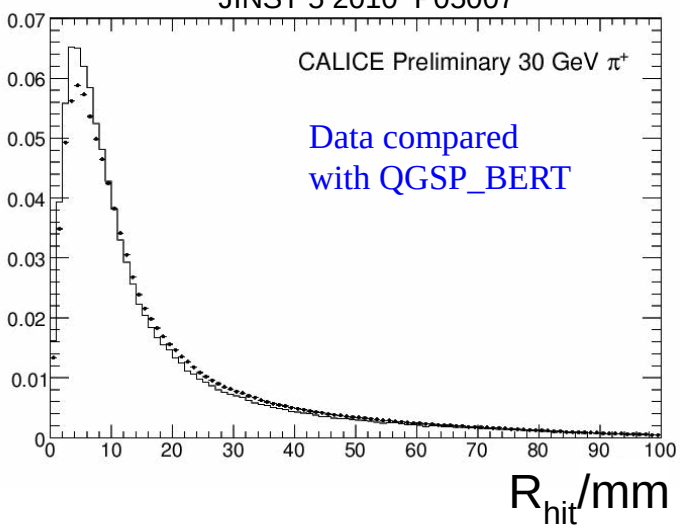
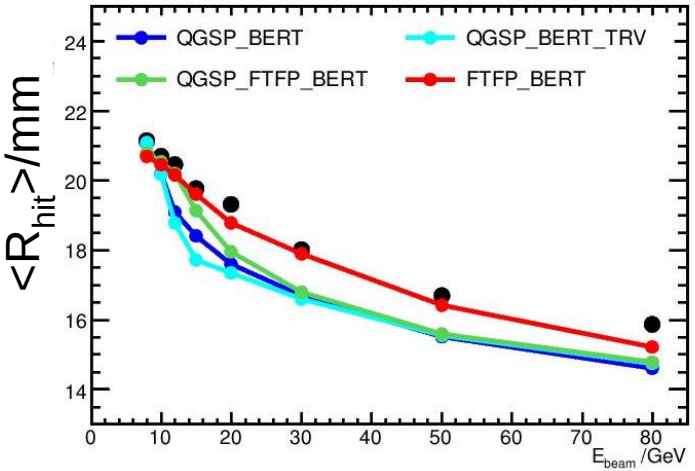
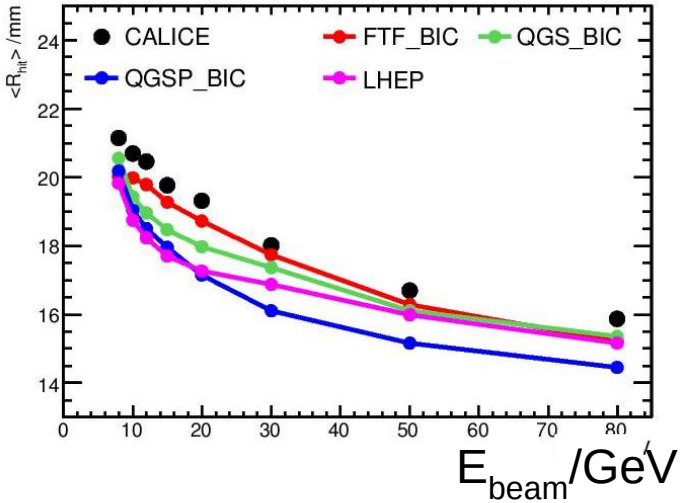


Shower radius



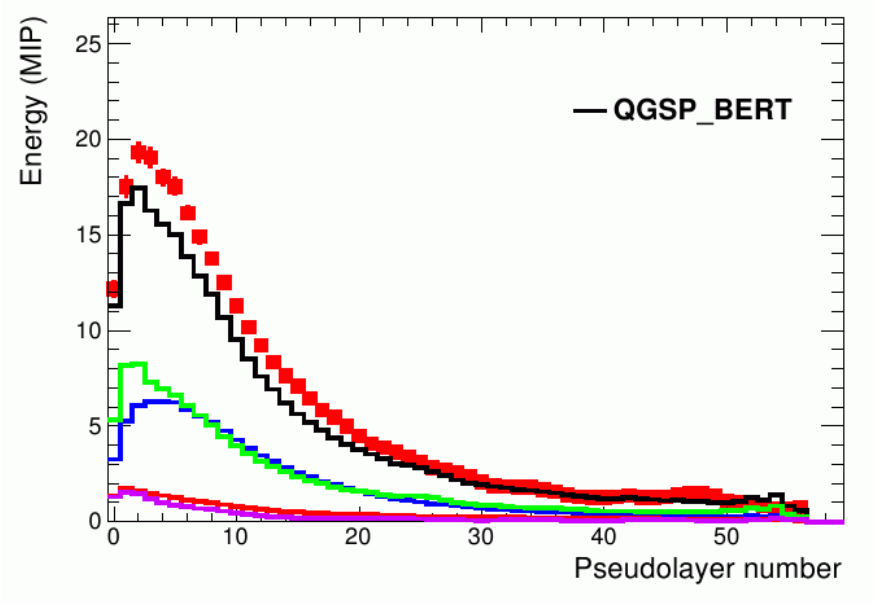


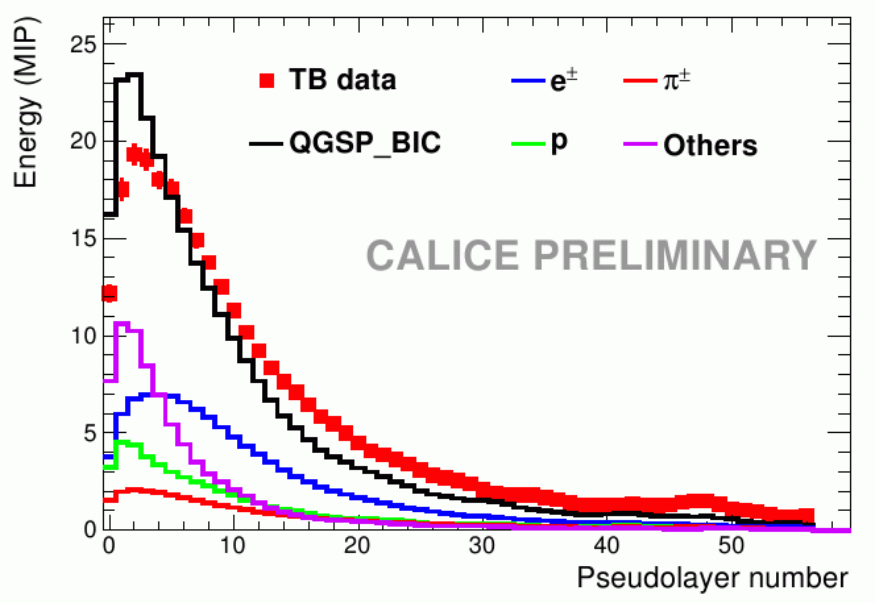
Small energy OK for "BERT" models

Towards high energy : Underestimation of content in SiW ECAL

Longitudinal Profiles

Pi @ 2GeV Inelastic reactions



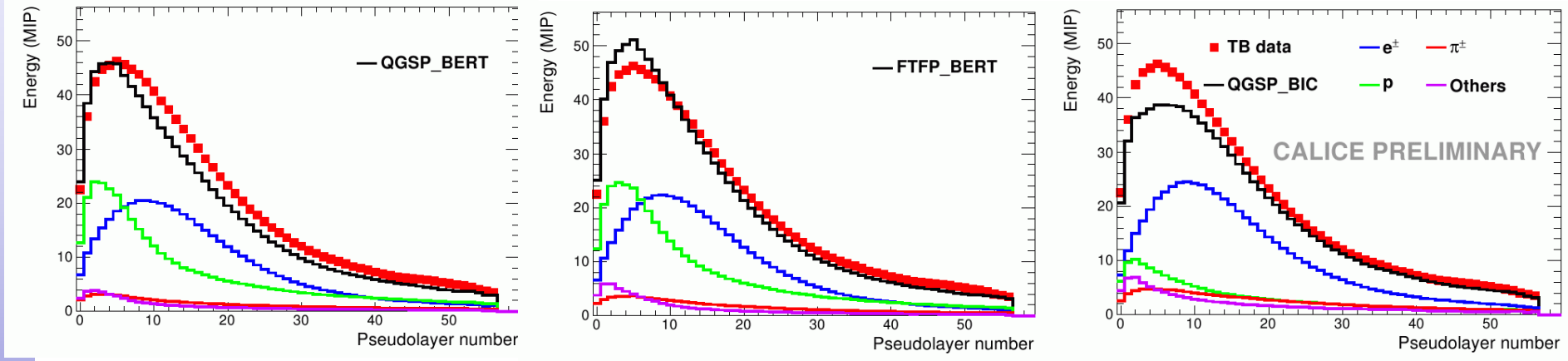


- ✓ BERT gets tails about right
- ✓ Models have different approaches for shower composition

→No satisfactory description of longitudinal shower profile

Longitudinal Profiles

Pi @ 8GeV Inelastic reactions



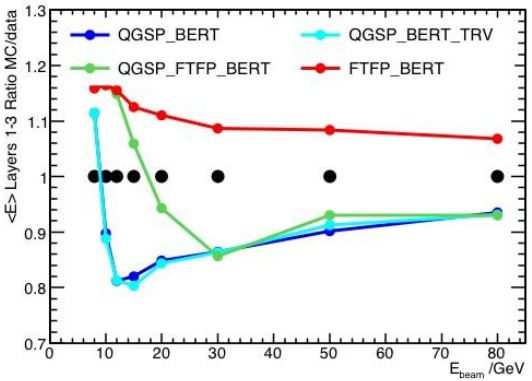
- ✓ Again tails about right
- ✓ Models have different approaches for shower composition

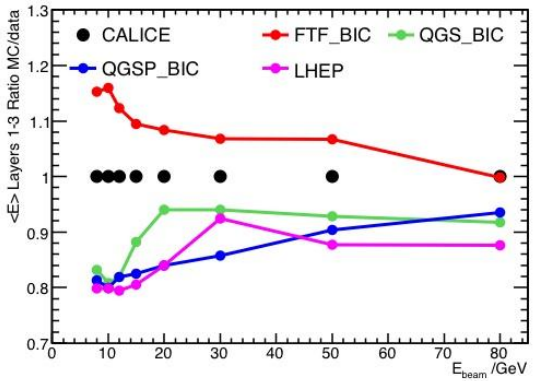
→No satisfactory description of longitudinal shower profile

Energy Deposition in different ECAL Depths

Layer 1-3:

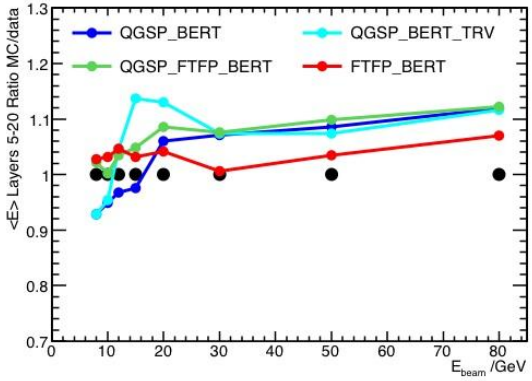
Nuclear breakup

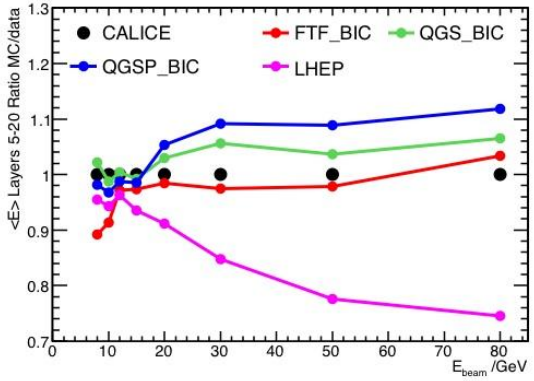




Layer 5-20:

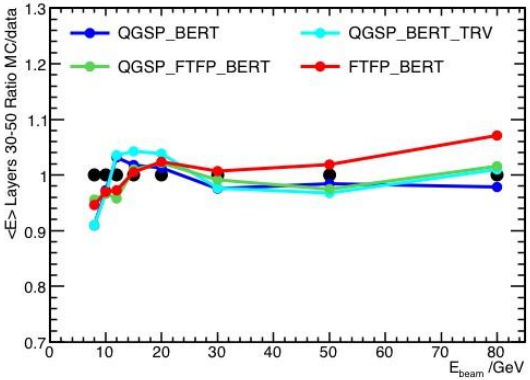
elm. component

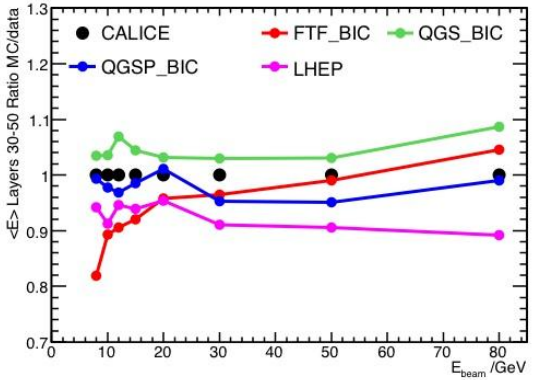




Layer 30-50:

Shower hadrons

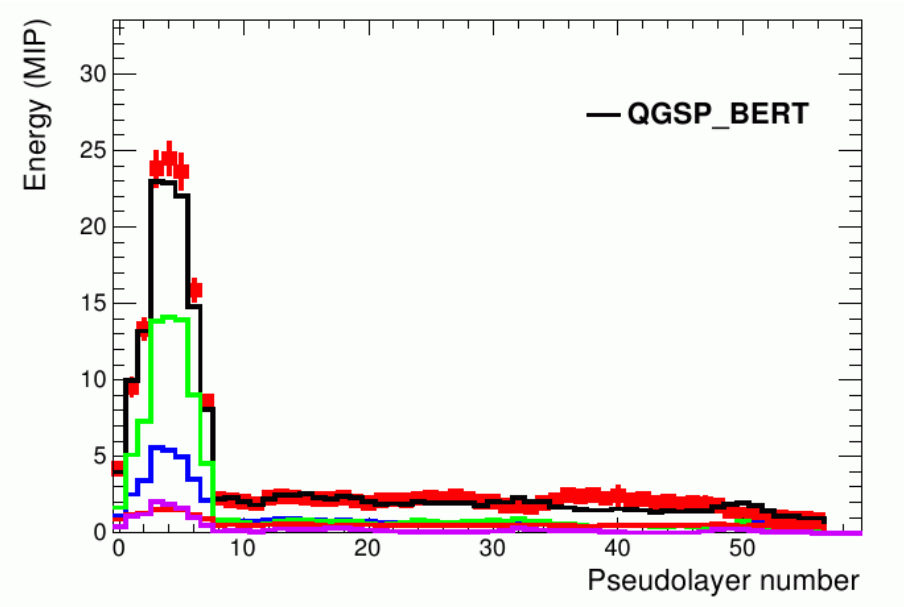


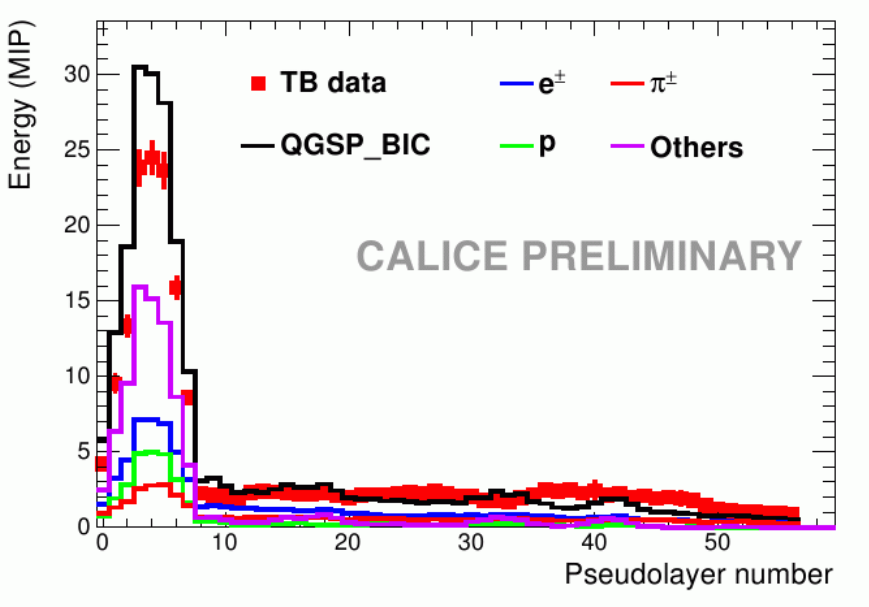


Details of Pointlike Events

Recognition of these events is result of large granularity

Pi @ 2GeV





→Pointlike events are relatively well modeled by QGSP_BERT

Summary

- Successful R&D for a highly granular electromagnetic calorimeter
- Detector concept is built on Particle Flow

✓ Physics Prototype (2005-2011)
- Energy resolution ~17%/√E
- Signal to Noise Ratio ~8/1
- Stable calibration

- Capacity of separating particles impressively demonstrated by test beam analysis
- Unprecedented realistic views into hadronic showers thanks to high granularity

✓ Technological Prototype(2010-…)
→Next talk by Roman