Pions in the SiW ECAL using FNAL 2008 data (CAN-025)

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Introduction

- Interactions of pions in the SiW ECAL
- Aim to use granularity and energy deposition to classify interactions
- And have a look at differences between models in physics lists

- CAN paper v2 submitted, now finalising answers to the questions of the EB

Data samples

- We study and compare interactions of pions (π^-) with E = 2, 4, 6, 8 and 10 GeV

- TB data were recorded at FNAL in 2008 and reconstructed (v0409)

- MC data are simulated + digitised for 5 physics lists : QGSP_BERT, FTFP_BERT, LHEP, QGS_BIC and QGSP_BIC (Geant4 9.2)

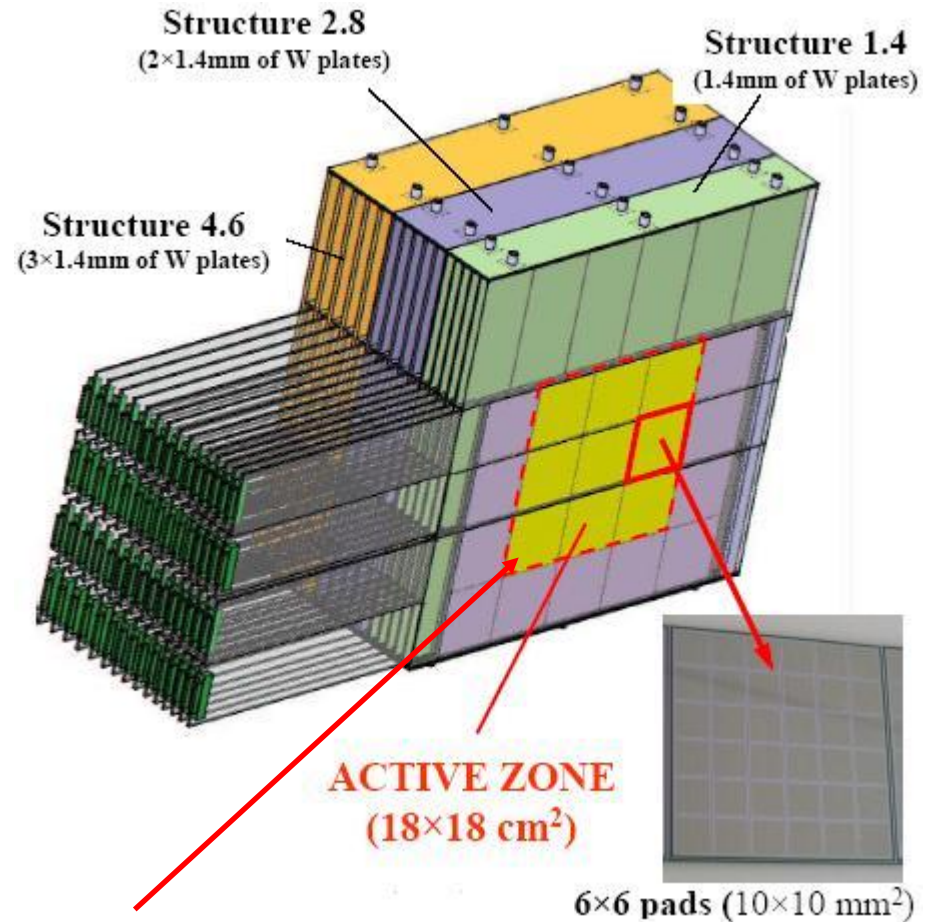- Calice soft v02-00 is used for both TB and MC data

Outline

- The SiW ECAL (in 2008)
- The test beam at FNAL (May & July 2008)
- MC simulations
- Finding the interaction point
- Classification and optimisation
- Observables
- Ongoing work
- Conclusions

Important slides for today's meeting topic
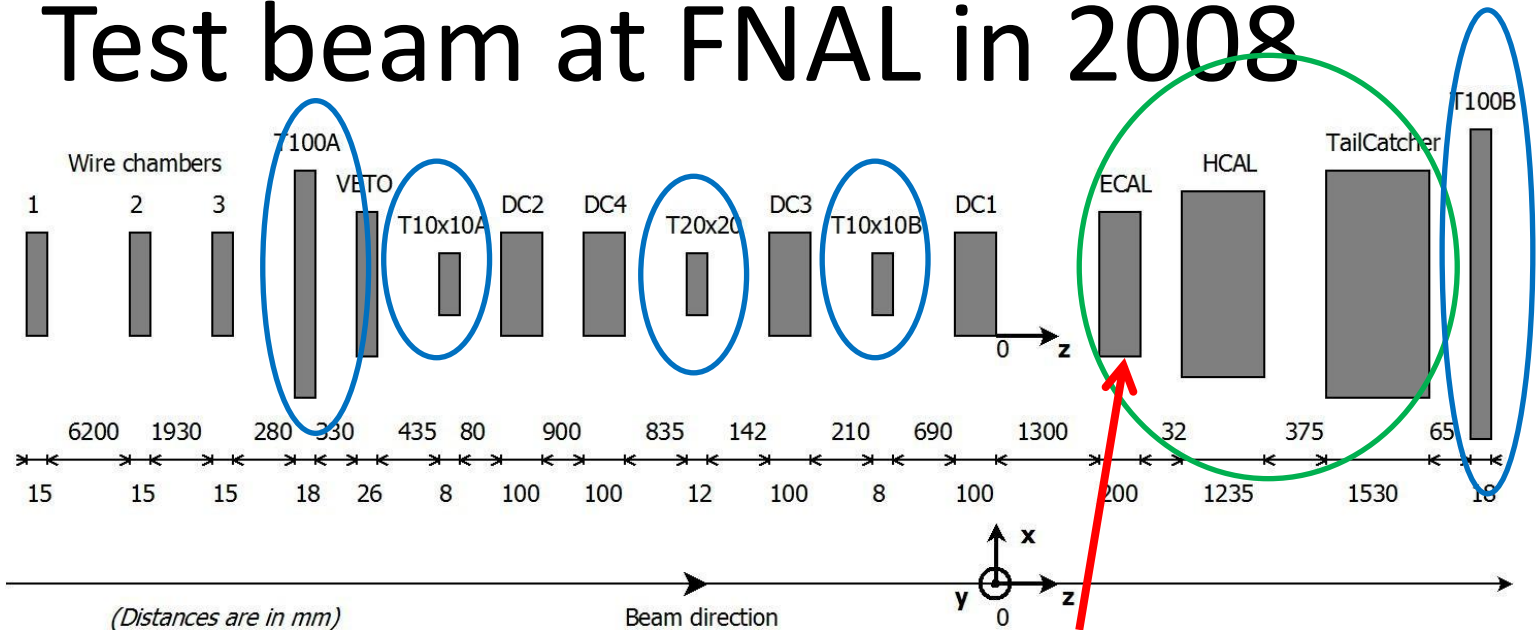
The SiW ECAL in 2008

- Fully equipped ECAL

- 3 x 3 wafers of 6 x 6 pads

- Sensors = Si pixels of 1 cm x 1 cm → tracking possibilities

- Absorber = W

- 30 layers in 3 different stacks :
  - 1.4 mm of W
  - 2.8 mm
  - 3.6 mm

- ≈ 24 X_0 ≈ 1 λ_I ≈ half of the hadrons interact inside the ECAL volume

Structure 2.8
(2×1.4mm of W plates)

Structure 1.4
(1.4mm of W plates)

Structure 4.6
(3×1.4mm of W plates)

ACTIVE ZONE
(18×18 cm^2)

6×6 pads (10×10 mm^2)

9 Si wafers

Picture of the fully equiped SiW ECAL

Test beam at FNAL in 2008

Beamline at FNAL

(Distances are in mm)   Beam direction

- 3 CALICE calorimeters installed : SiW ECAL, Analogue HCAL, TailCatcher (TCMT)

- Triggers : scintillators, Cherenkov counters

- Muon cuts added on the basis of simulated muons : < 0.6% remaining

- Ask for only one primary track found with the MipFinder

- Events left :

E (GeV)	2	4	6	8	10
N evts	212942	126222	73590	233820	454714

Monte Carlo simulations

- For comparisons, different physics lists were simulated in Geant4 9.2

- QGSP BERT is used as reference for optimisation

E (GeV)	2	4	6	8	10
QGSP BERT	BERT				BERT + LEP
QGS BIC	LEP (+ BIC for secondaries < 1.2 GeV)				
QGSP BIC	LEP				
LHEP	LEP				
FTFP BERT	BERT		FTFP		

Content of the physics lists for pions

A look at interactions of hadrons
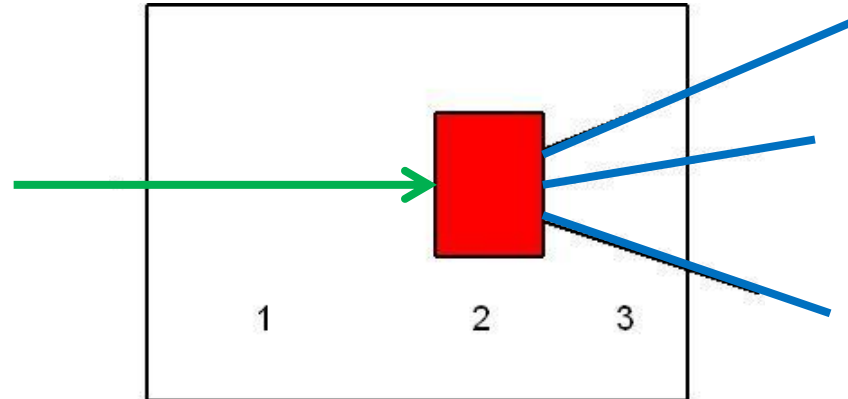

- Picture of a generic interaction in the calorimeters :
    1) A primary track enters the detector (« MipFinder »)
    2) The interaction occurs
    3) Secondaries emerge from the interaction zone

Visual examples (1/2)

- 2D profiles of an event at 10 GeV in the SiW ECAL

- High energy deposition when the interaction starts

- Interaction layer confirmed by visual inspection

- Large number of secondaries created

- Equation to be satisfied:

$$E_i > \text{Ecut} \; , \; E_{i+1} > \text{Ecut} \; , \; E_{i+2} > \text{Ecut}$$
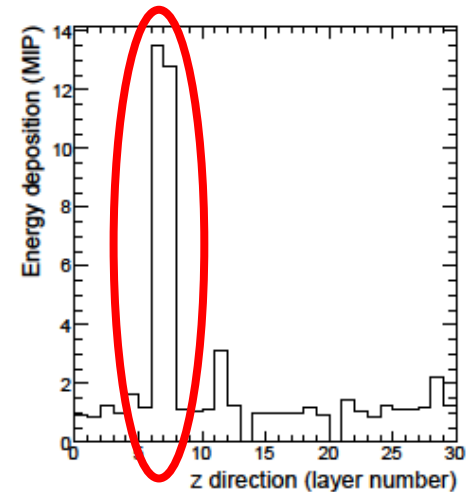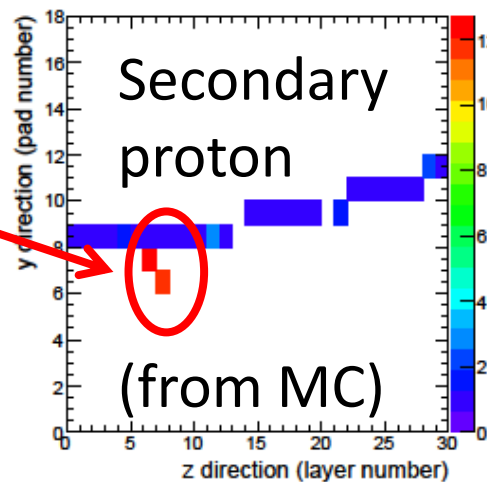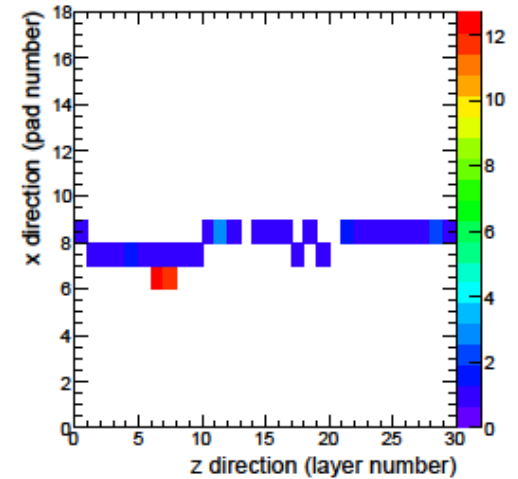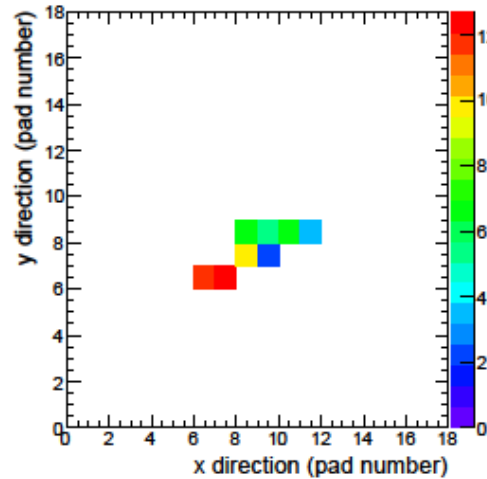

Ecut
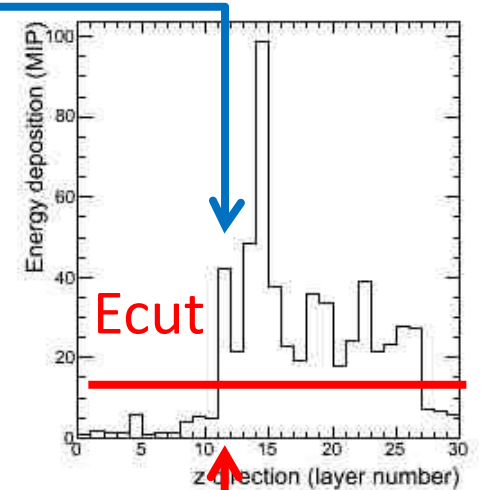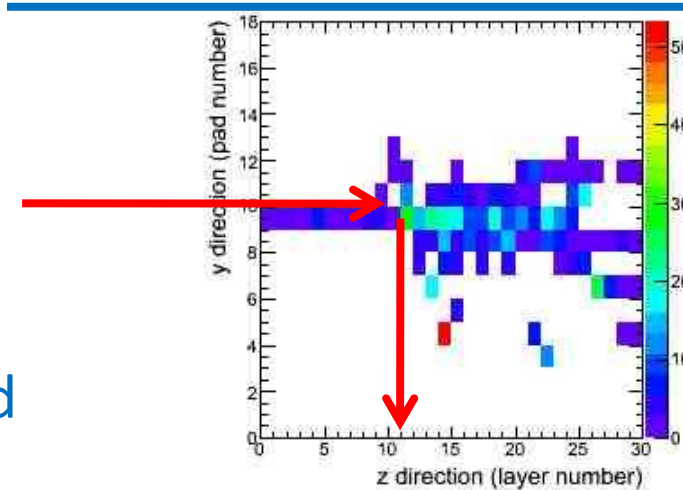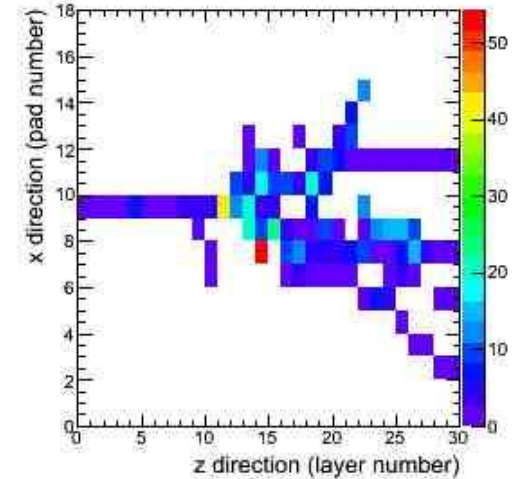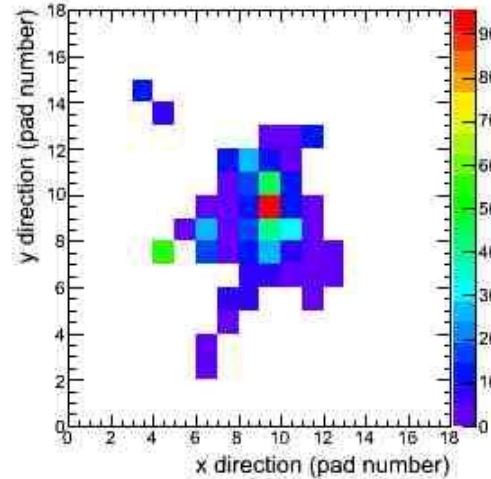
TB data event at 10 GeV

Visual examples (2/2)

- Previous example not always valid, especially at low energies

- Sometimes, slow increase in energy

- Here, local energy deposition

- Quantified by the relative increase in energy:

Secondary proton

(from MC)

MC event at 2 GeV

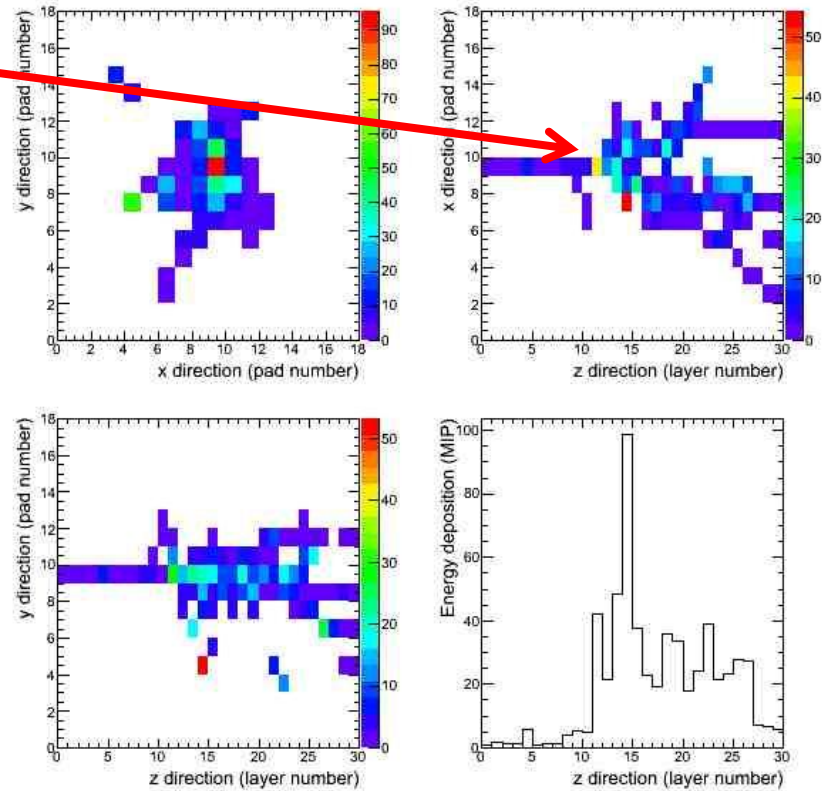$$\frac{E_i + E_{i+1}}{E_{i-1} + E_{i-2}} > \text{Fcut} \text{ and } \frac{E_{i+1} + E_{i+2}}{E_{i-1} + E_{i-2}} > \text{Fcut}$$

Classification

- High energy deposition
  → « FireBall »

- Increase continues + veto for backscattering
  → « FireBall »

$$\frac{E_{i+2} + E_{i+3}}{E_{i-1} + E_{i-2}} > \text{Fcut} \quad + \quad \frac{E_{\text{around},i}}{E_i} > 0.5$$

Works here and meant for small energies

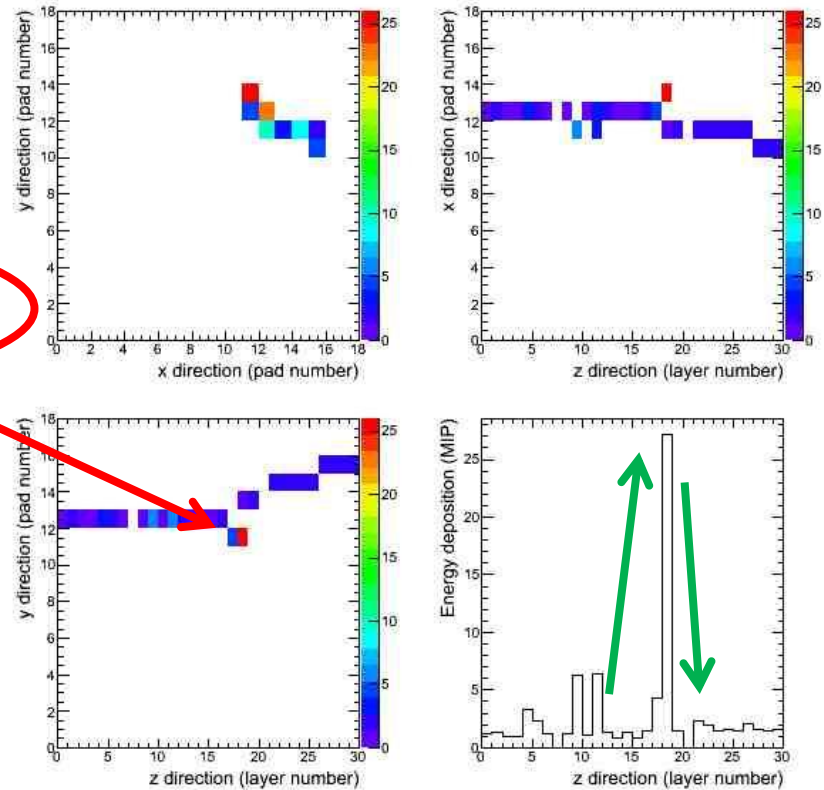Event view of the
« FireBall » type at 10 GeV

Classification

- High energy deposition → « FireBall »

- Increase continues + veto for backscattering → « FireBall »

- Local increase → « Pointlike »

$$\frac{E_{i+2} + E_{i+3}}{E_{i-1} + E_{i-2}} < Fcut$$

- Remark : delta rays are naturally included in « Pointlike » but contribute less than 4%
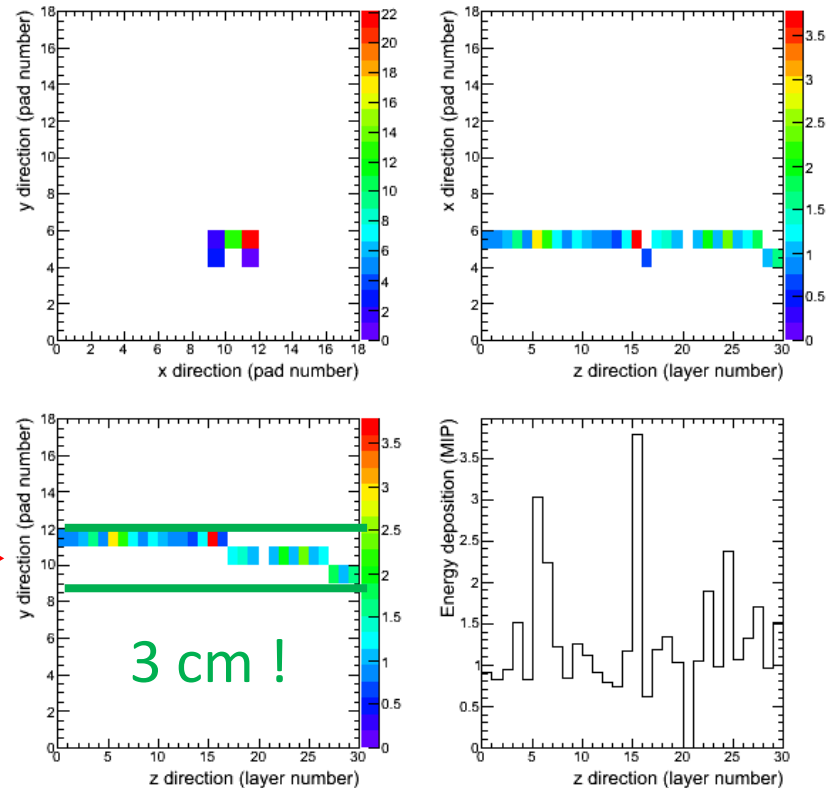
Real TB data event at 2 GeV

Event view of the « Pointlike » type at 2 GeV

Classification

- High energy deposition → « FireBall »

- Increase continues + veto for backscattering → « FireBall »

- Local increase → « Pointlike »

- Others = non interacting
  - « MIP »
  - « Scattered »

- Remark : delta rays are naturally included in « Pointlike » but contribute less than 4%

Real TB data event at 2 GeV

3 cm !

Event view of the « Scattered » type at 2 GeV

Optimisation

- Cuts need to be optimised (not discussed today, see my talk at [CASABLANCA](#))

- After optimisation →

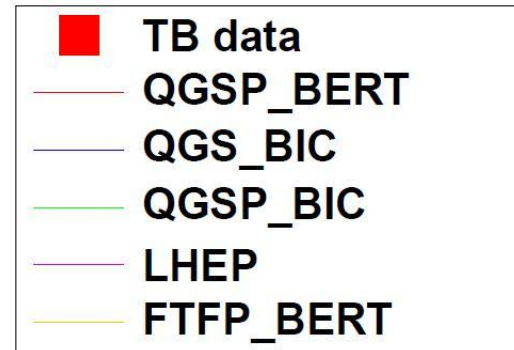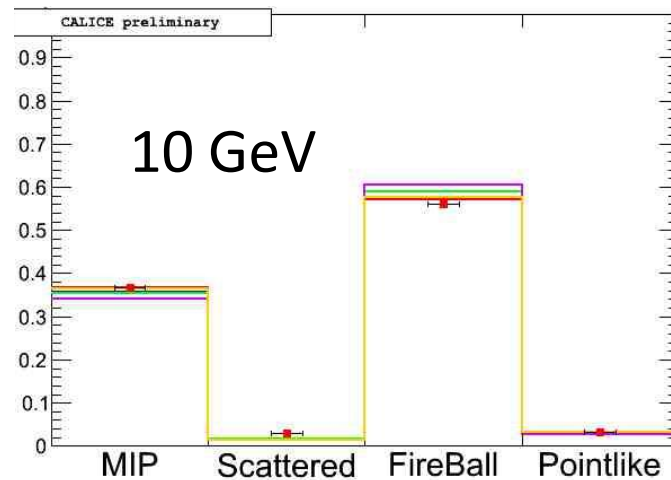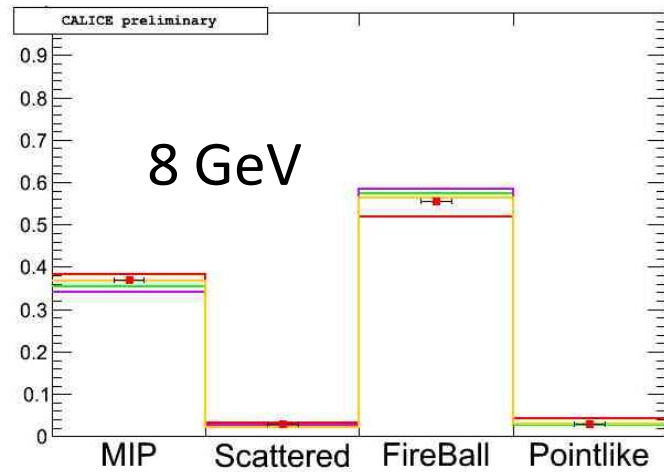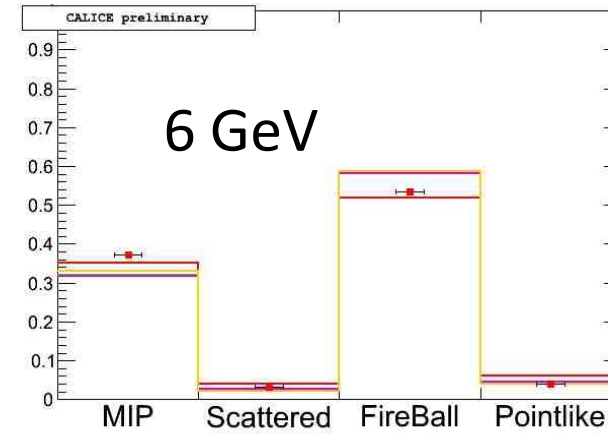- Choice was made to merge all Fcut to one single value for simplicity

E (GeV)	Ecut	Fcut
2	3	4 → 6
4	8	5.5 → 6
6	10	6.5 → 6
8	13	7 → 6
10	10	6 → 6

Efficiencies after optimisation

- The efficiency to find the true interaction layer within ±1 and 2 layers is the result of the optimisation.

- It is compared with another method.

E (GeV)	η (±1)	η (±2)	η (3-4, ±2)
2	56 %	67 %	28 %
4	60 %	73 %	61 %
6	62 %	76 %	69 %
8	64 %	78 %	71 %
10	72 %	84 %	76 %

Rates of interactions

2 GeV

4 GeV

6 GeV

8 GeV

10 GeV

TB data
QGSP_BERT
QGS_BIC
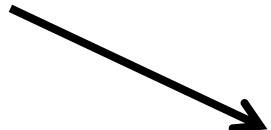**QGSP_BIC**
LHEP
FTFP_BERT
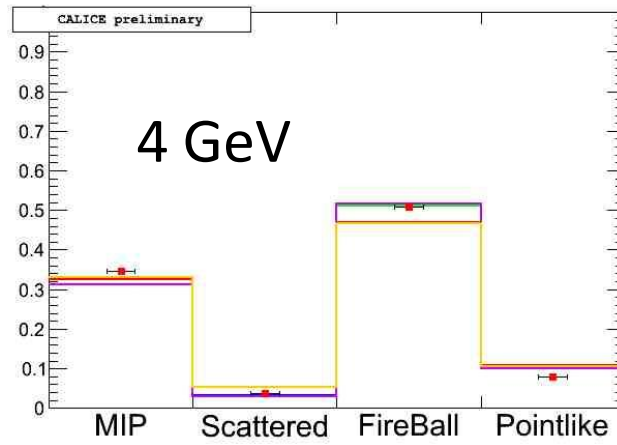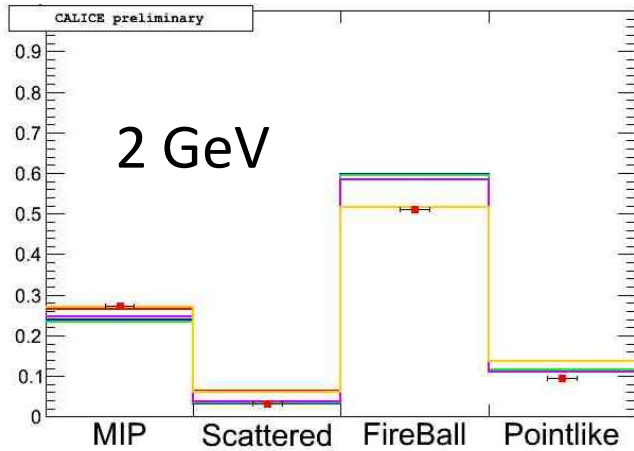
Interaction rates similar between physics lists

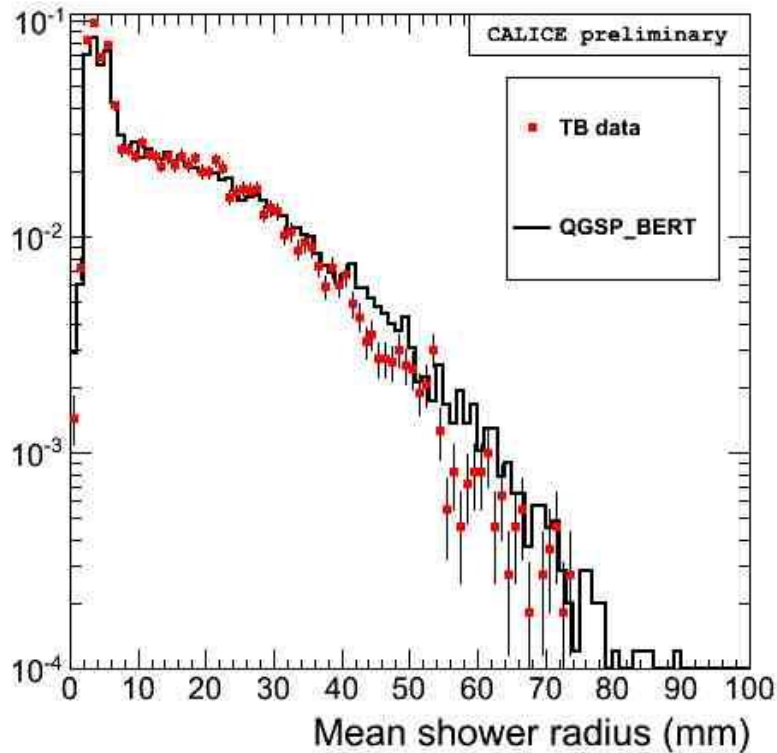Small systematics with Ecut and Fcut in ±1

Observables

- The following results are still under discussion with the EB

- We compare TB data and MC using
  - Rates of interactions (previous slide)
  - Mean shower radius (rms of transverse profile)
  - Longitudinal profile
    (as defined in the CALICE
    pions in the SiW ECAL paper)

$$<r>_{\mathrm{E}} = \sqrt{\sigma_{\mathrm{E,x}}^2 + \sigma_{\mathrm{E,y}}^2}$$

$$\sigma_{\mathrm{E,x}}^2 = \frac{\sum\limits_{\mathrm{hits}} x_{\mathrm{hit}}^2 E_{\mathrm{hit}}}{\sum\limits_{\mathrm{hits}} E_{\mathrm{hit}}} - \left(\frac{\sum\limits_{\mathrm{hits}} x_{\mathrm{hit}} E_{\mathrm{hit}}}{\sum\limits_{\mathrm{hits}} E_{\mathrm{hit}}} \right)^2$$

Examples

Mean shower profile (log)   **Longitudinale profile**
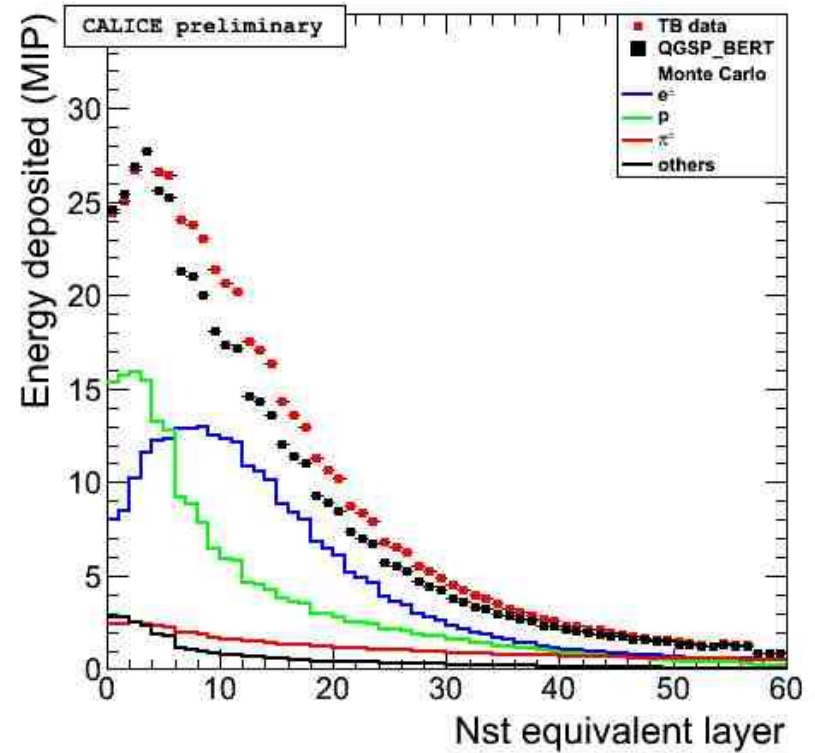
Example of data vs QGSP_BERT simulation at 2 GeV

Ongoing

- Agreement with hadrons in SiW ECAL paper
- Redoing style of the figures
- Text improvement on comparison data – MC
- Quantitative check of systematics of optimisation with physics lists
- Write a new version of the note

Conclusions

- Interactions of hadrons in the SiW ECAL at energies from 2 GeV to 10 GeV are found and classified into 4 kinds, using energy deposition and high granularity

- Efficiencies to reconstruct the interaction layer within ± 2 layers are > 67 %

- Still answering to the EB (good progress)

- Hope for a validation before the end of the year