Analysis of pion showers in the SiW ECAL with 2008 FNAL data

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Overview

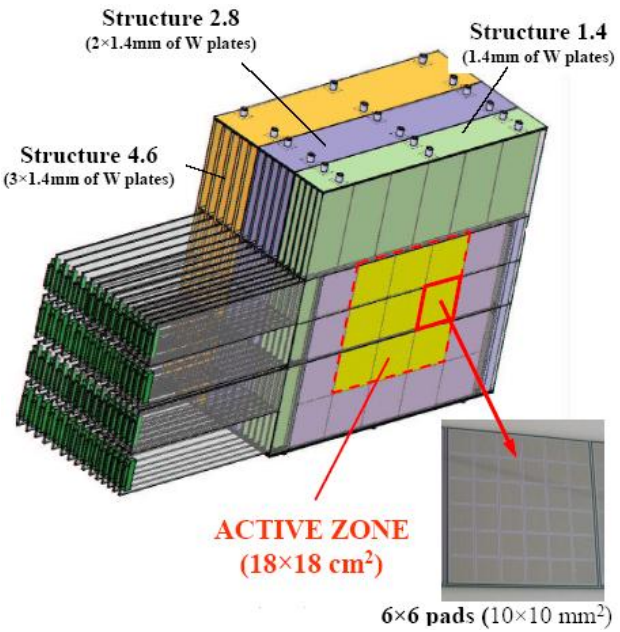
Setup of the SiW ECAL in 2008

- FNAL beam: e, μ, π from 1 to 66 GeV
- Beamline: scintillator counters, Cherenkov counters and tracking chambers.

For hadron analysis

- depth $\sim 1\lambda_I \Rightarrow$ 1/2 of the hadrons interact
- 1 cm $\times$ 1 cm pixels $\Rightarrow$ tracking possibilities (AHCAL: 3 cm $\times$ 3 cm)

Figure: Fully equipped Si-W ECAL. 9 Si wafers divided in 6 $\times$ 6 pads: 9720 channels and 30 layers with 3 different W depths.

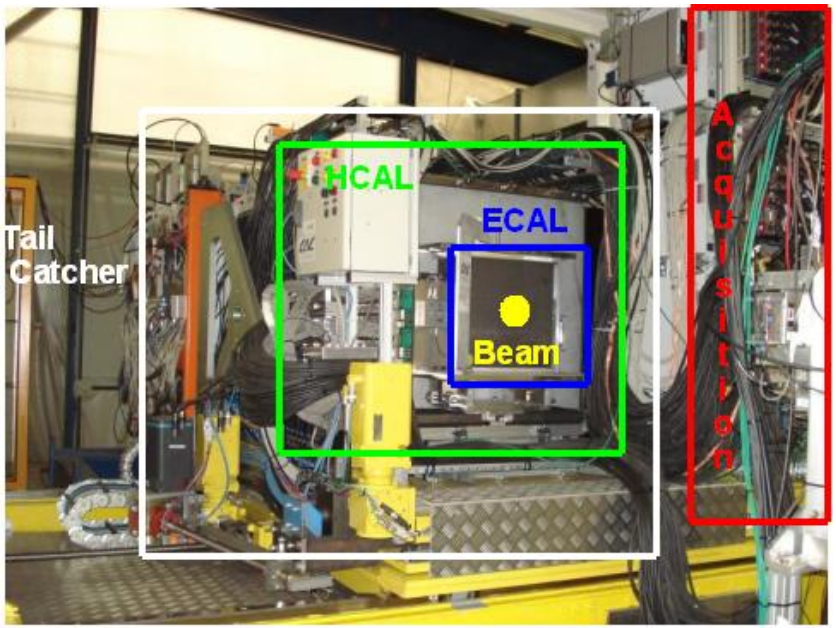


Goal: understand hadronic interactions and hadronic showers
Here: low energy hadrons i.e. from 2 to 10 GeV

Testbeams at FNAL in May and July 2008

- May: instabilities of the ECAL due to some electronic noise
- July: good and stable running period (despite some failures due to temperature)

Figure: Installation at FNAL with ECAL, AHCAL, TailCatcher.



N events	N runs	P_{π^-} (GeV)
210 k	16	2
407 k	5	4
114 k	1	6
551 k	4	8
768 k	6	10

Simulations available

Official simulations + digitisation prepared by Lars Weuste:
100k events for:

- 2, 4, 6, 8 and 10 GeV
- QGSP BERT, FTFP BERT, QGSP FTFP BERT and LHEP

Learnt too late : QGSP FTFP BERT almost identical to LHEP due to technical reasons... (see later on)

Inofficial simulations for faster response in the analysis at LAL done by Michele Faucci Giannelli.

Cuts used for event selection

Reconstructed (TB) events: Beam trigger and Cherenkov active.
Both reconstructed (TB) and simulated (MC) events: center of gravity of the hits inside the central wafer:

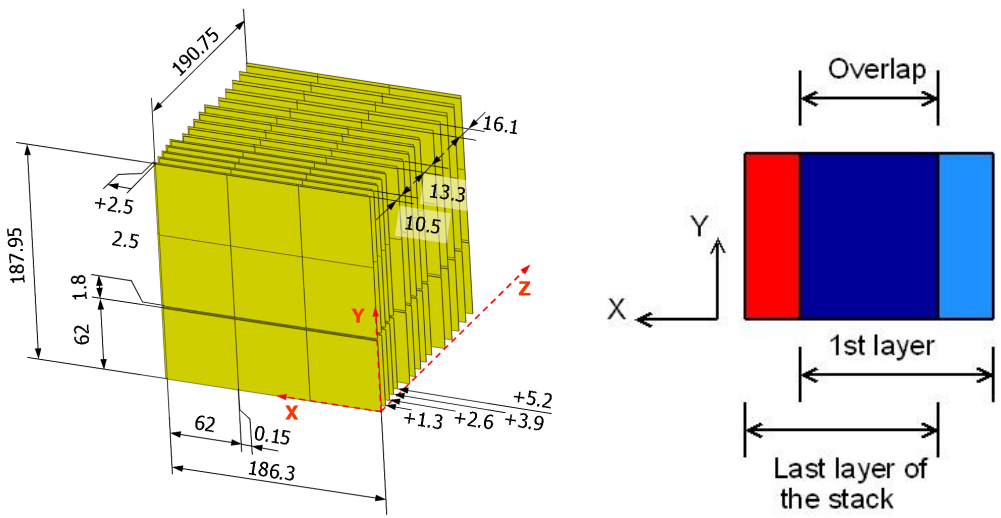
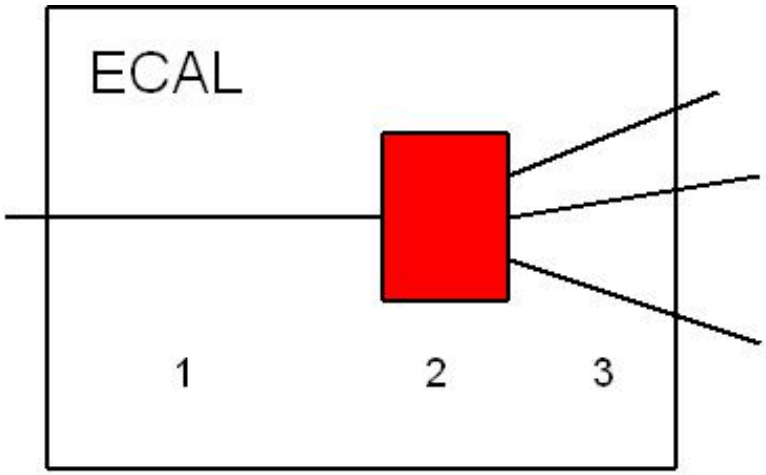


Figure: Picture of the ECAL layers' showing the staggering and drawing of the cut used

Used: $-22\,mm < x_{grav} < 30\,mm$; $-30\,mm < y_{grav} < 30\,mm$.
Then all the analysis chain is exactly the same.

Procedure developped

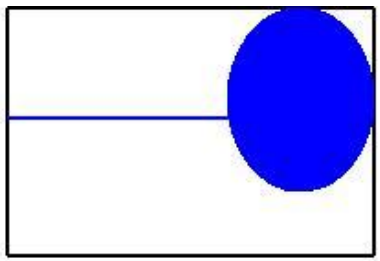
Proposed ∼1 year ago.



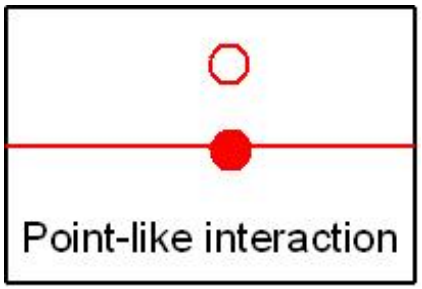
1. Find the MIP entering the ECAL ⇒ high granularity
2. Find the interaction region ⇒ energy deposition and longitudinal segmentation
3. Describe the shower structure (will require everything)

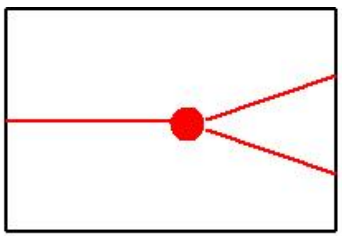
Different shapes to characterise

Final goal: characterise those 4 kinds of interactions seen.



Interaction "fireball" shape



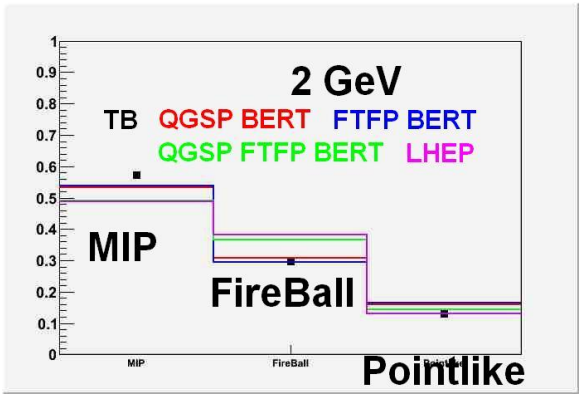


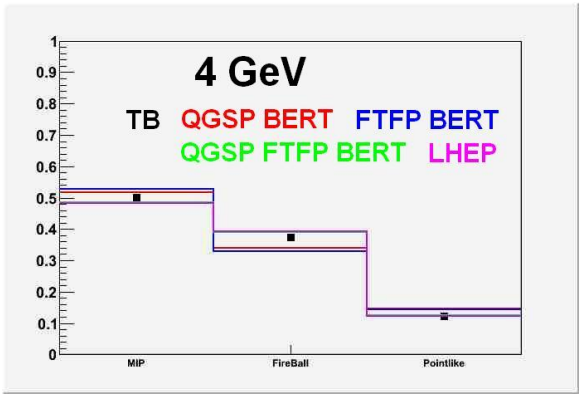
Interaction "fork" shape

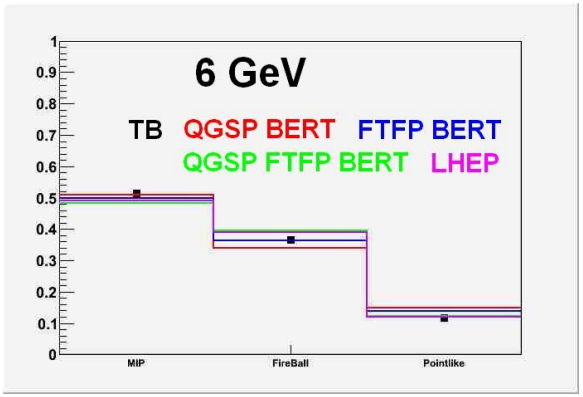
"Usual" types of interaction.

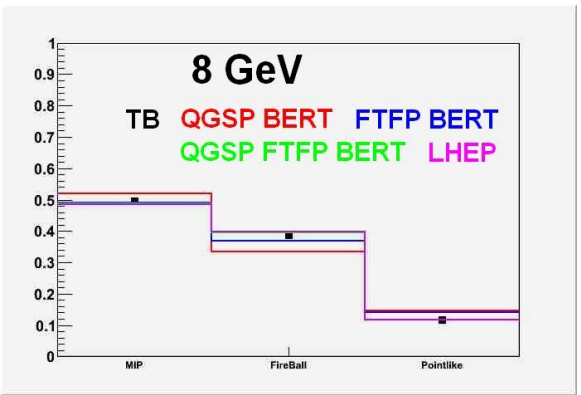
Not yet distinguished (to do) - both called "pointlike" here.

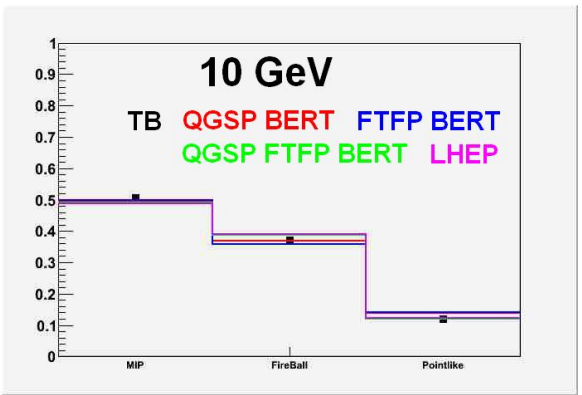
Fraction of events from 2 to 10 GeV











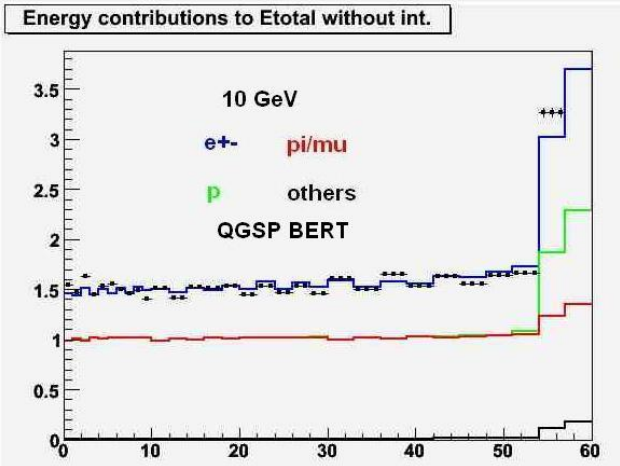
Good agreement data - MC for all lists.
Small discrepancies for MIPs (shown 2 slides later).
Small statistics for pointlike events (10%).

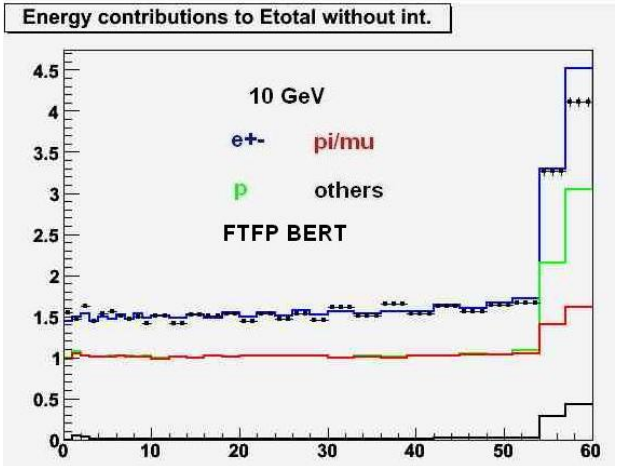
Longitudinal profile decomposition

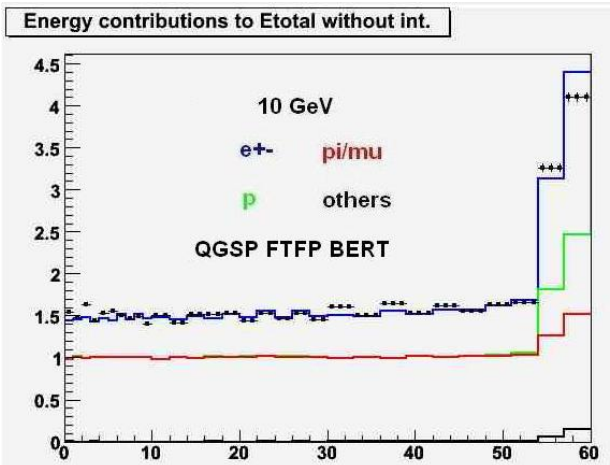
The ECAL is divided "à la David": 60 equal layers (stacks 2 and 3 are divided in 2 and 3).
Pions events are subdivided in MIPs, pointlike and FireBall events.
The layer of interaction (IL) must satisfy: $5 < IL < 20$. (Algorithm to find the interaction discussed later.)

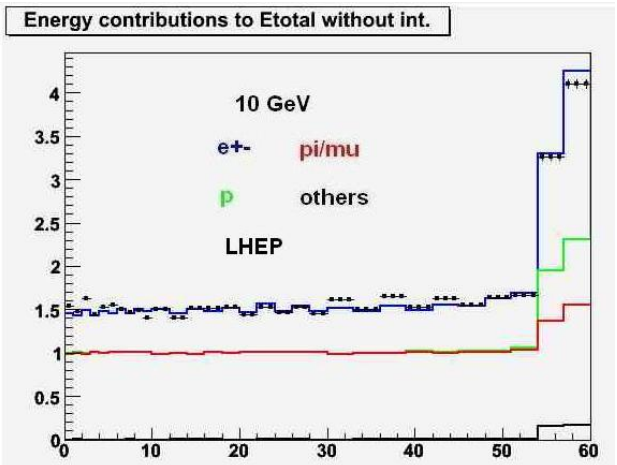
Principle: pile up MC contributions (electrons, protons, pions, others) and compare with data.
Normalisation by the number of events.

MIP-like events with 4 different physics lists - 10 GeV

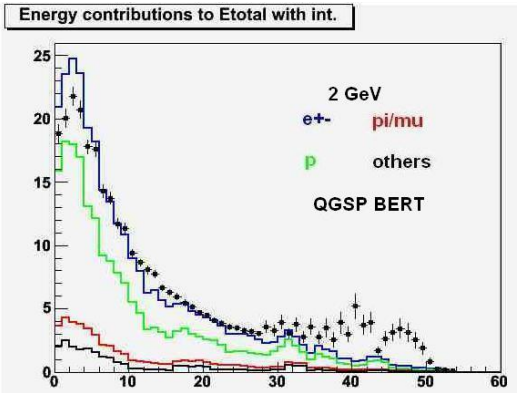


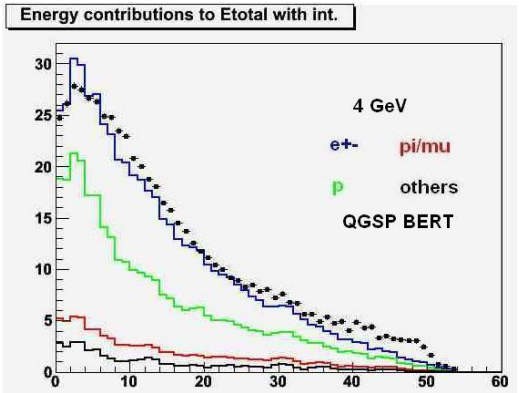


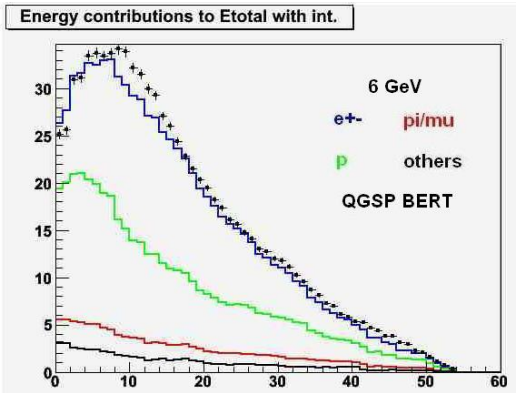


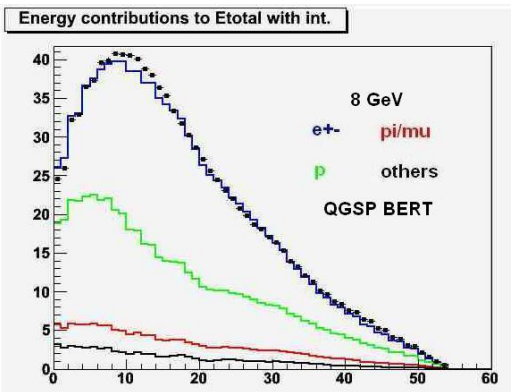


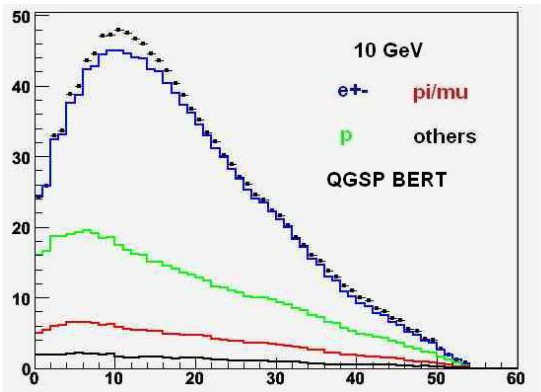
From 2 to 10 GeV with QGSP BERT, fireball events





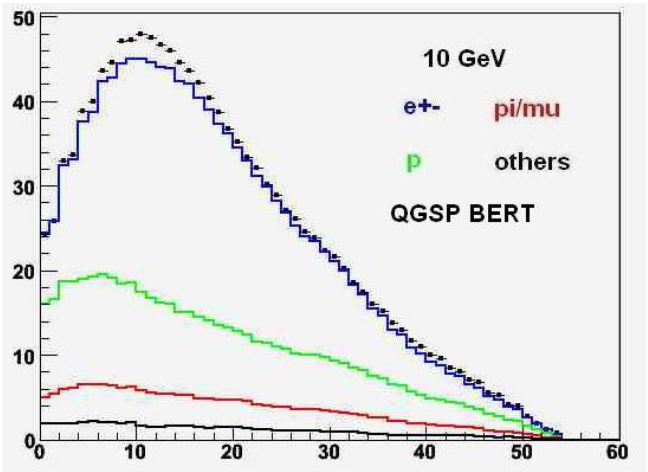


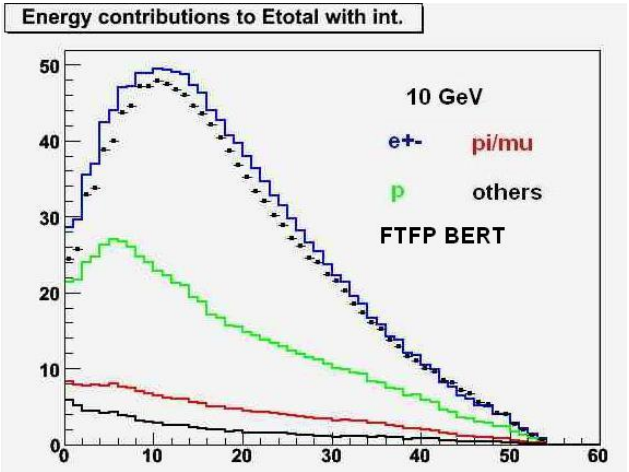


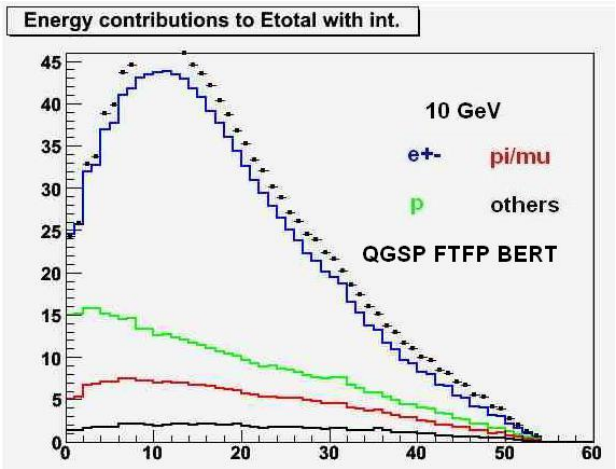


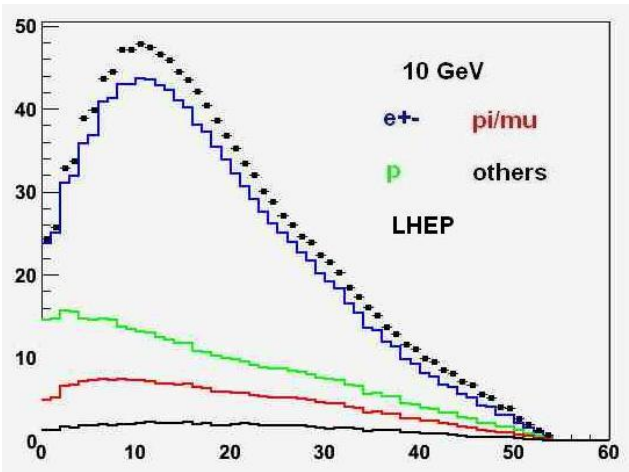
Evolution of the longitudinal profile with the energy.
A bump is seen for TB data at 2 GeV due to a noisy layer. Problem identified, some runs will be removed.

Fireball events with 4 different physics lists - 10 GeV

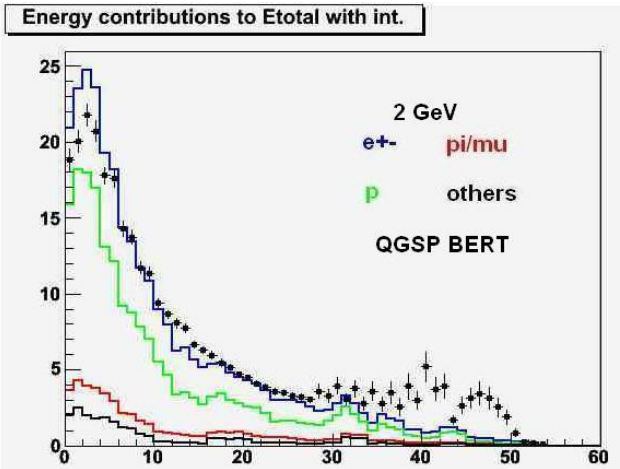


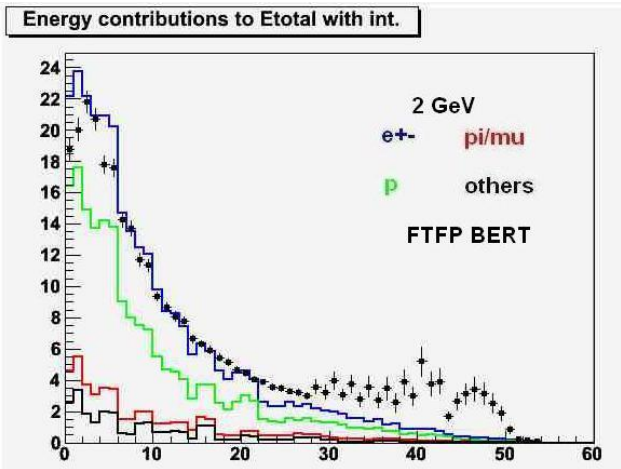


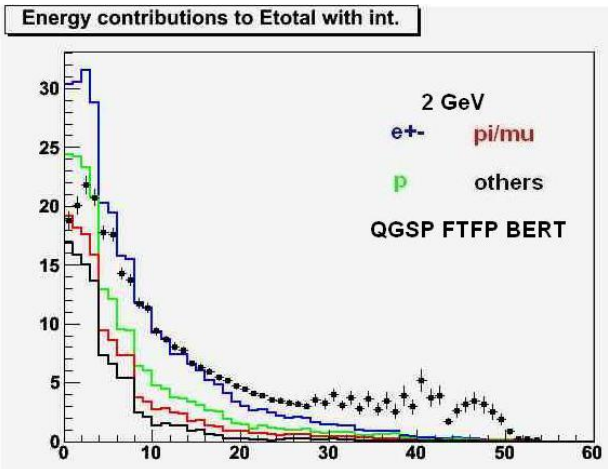


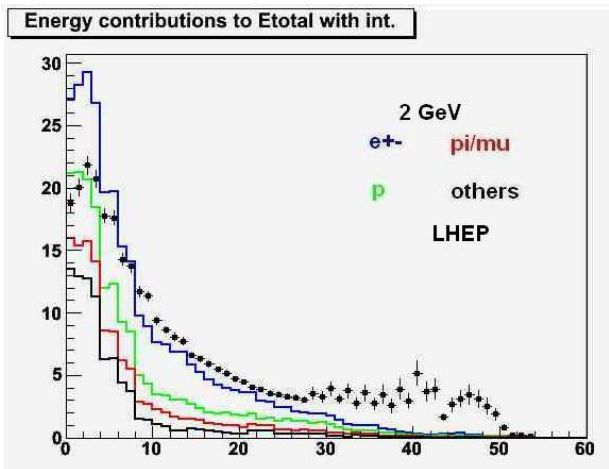


Fireball events with 4 different physics lists - 2 GeV

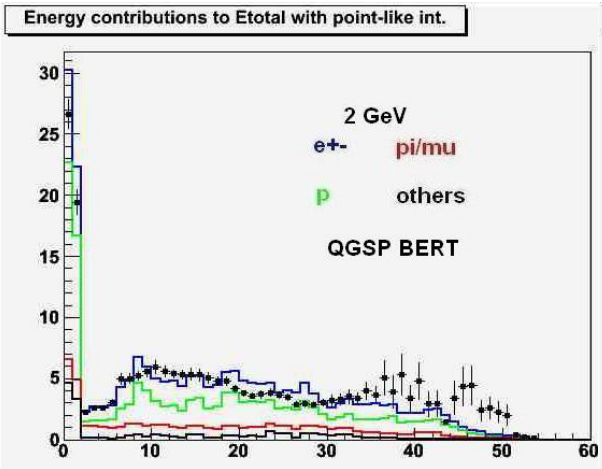


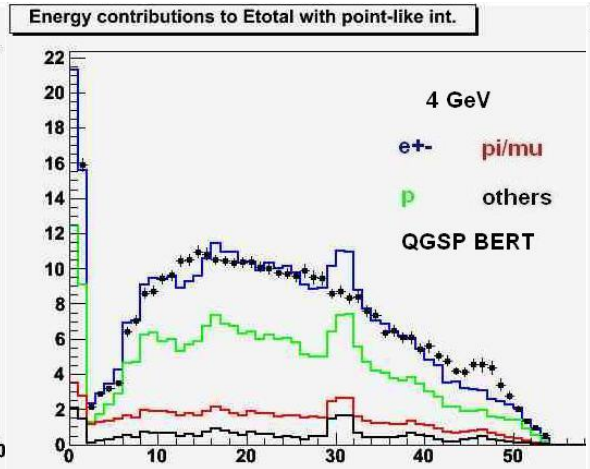


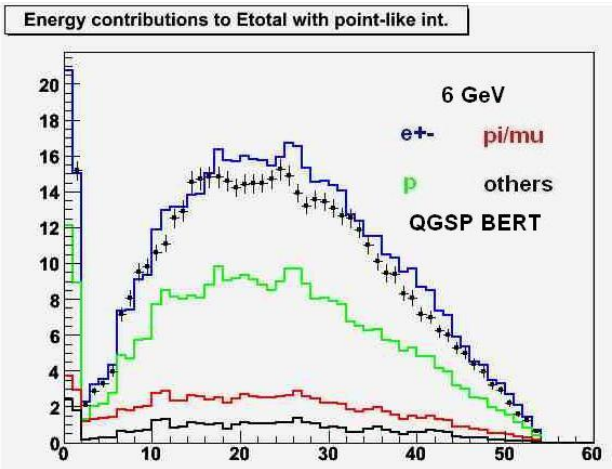


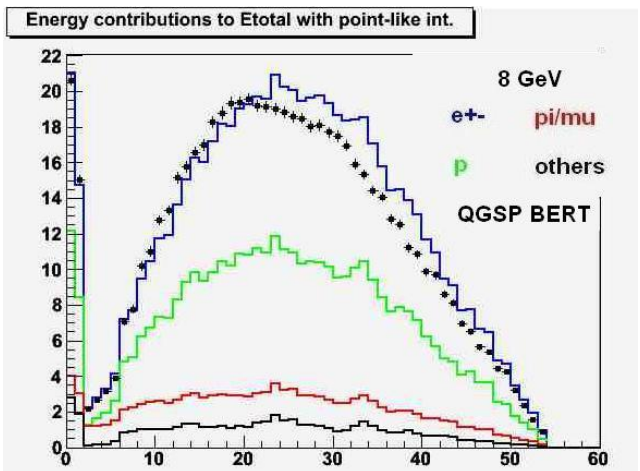


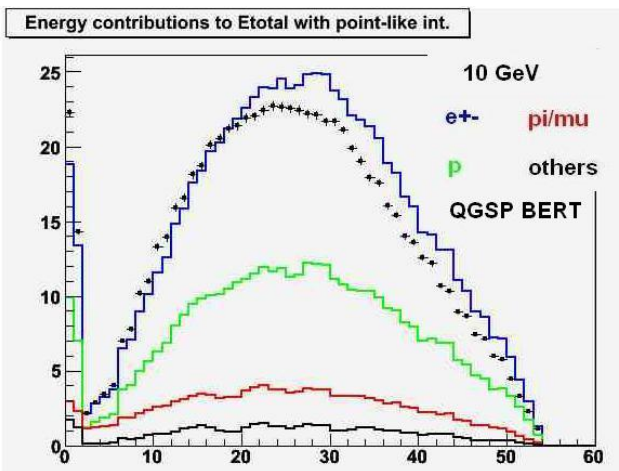
From 2 to 10 GeV with QGSP BERT, pointlike events



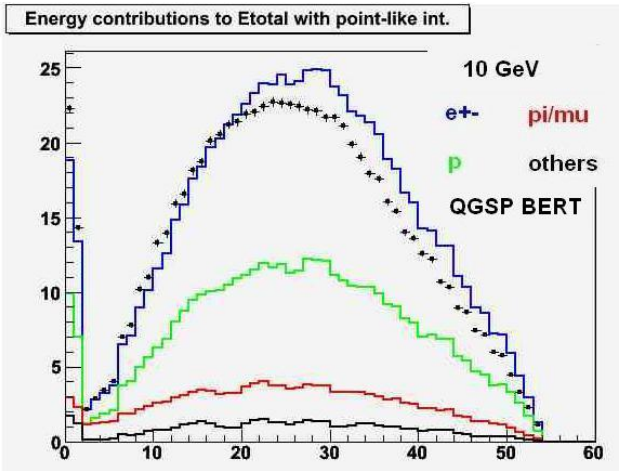


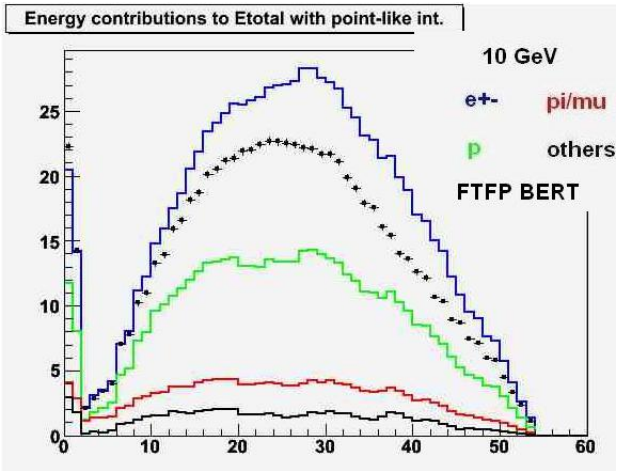


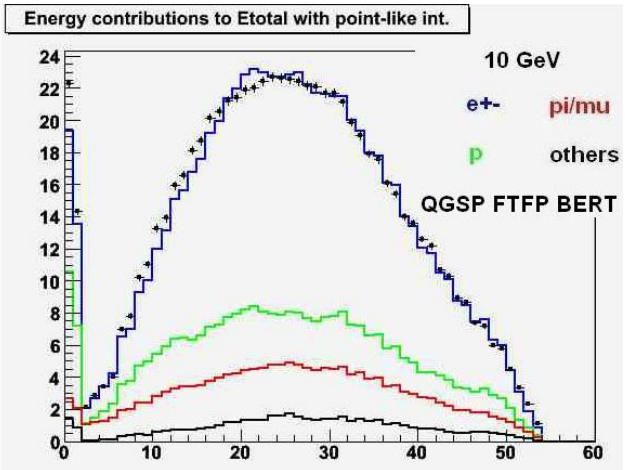


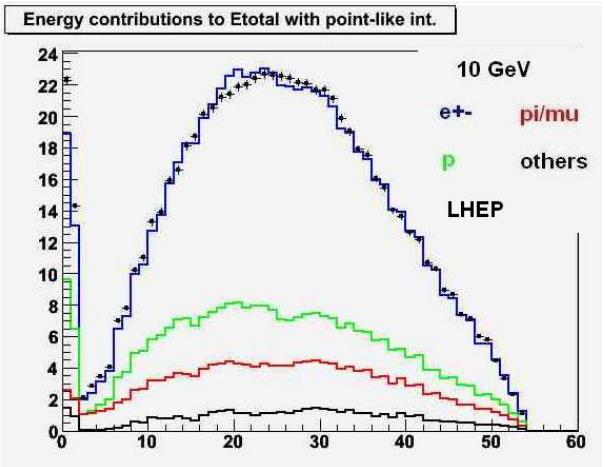


Pointlike events with 4 different physics lists - 10 GeV









Finding the first interaction

The algorithm now developped to find the first interaction does not give sufficiently good results. Low energy interactions' are difficult to understand easily.

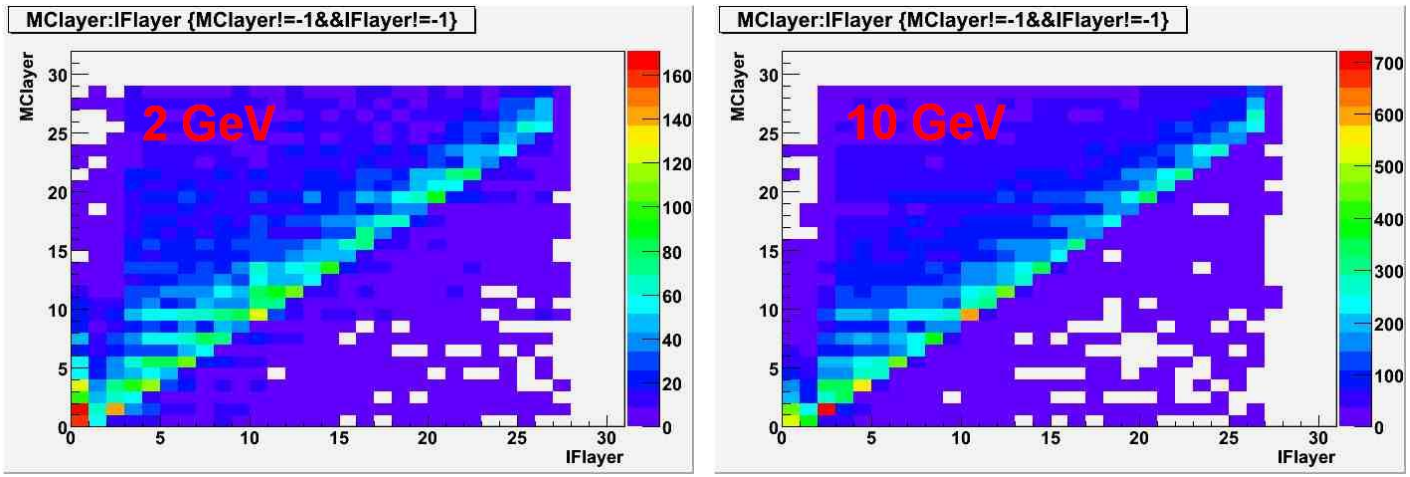


Figure: Interaction layer : MC (vertical) vs Algorithm (horizontal)

Layer found very often too small because of particles going backward after the interaction.

Why does it fail ? Some examples

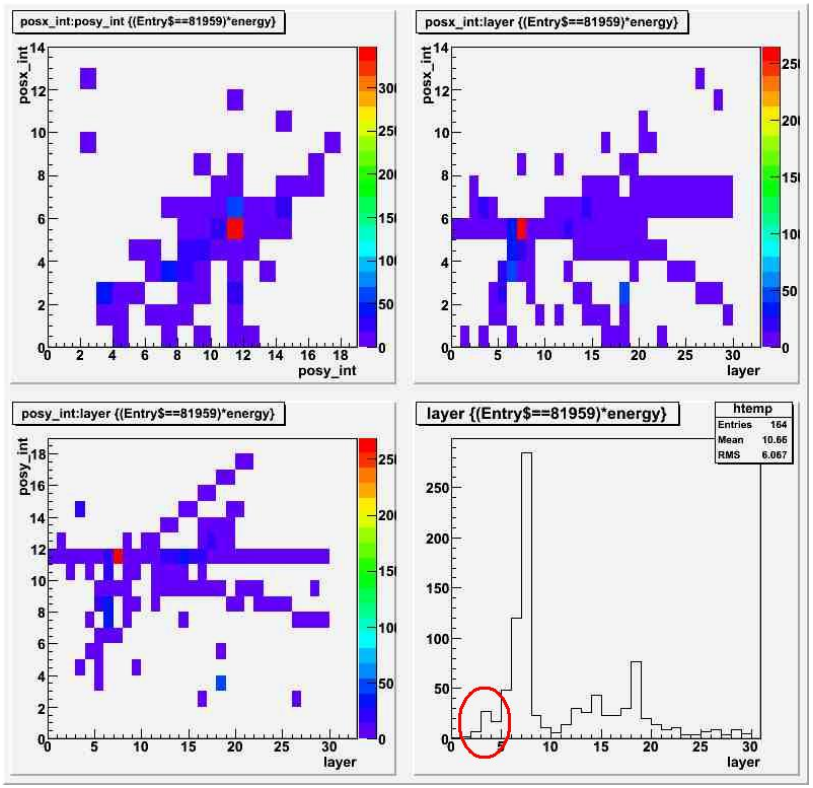


Figure: Event where the algorithm is too sensitive to small activity.

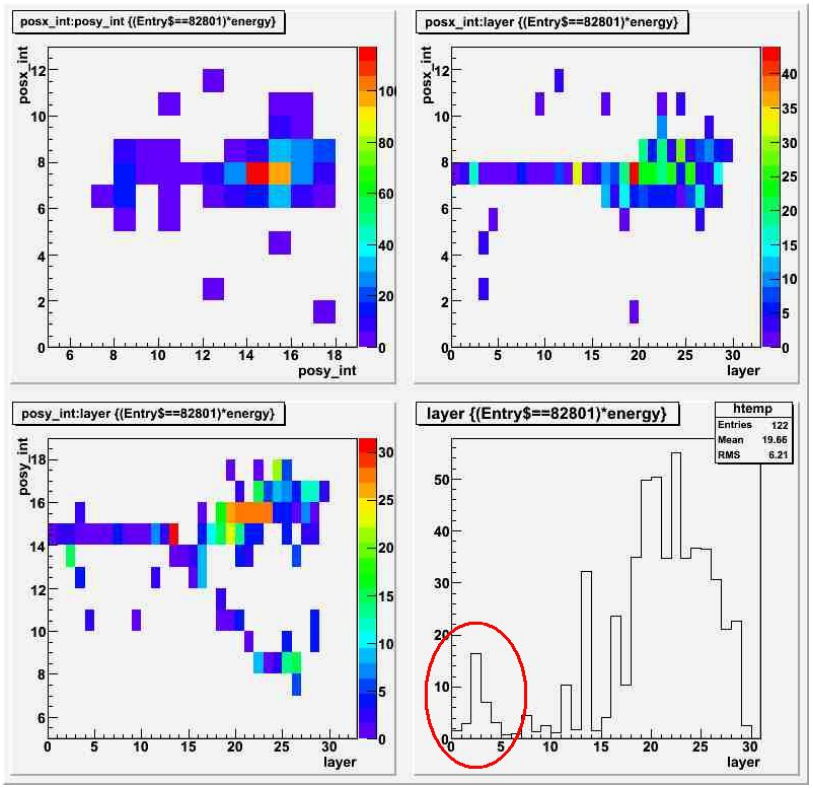
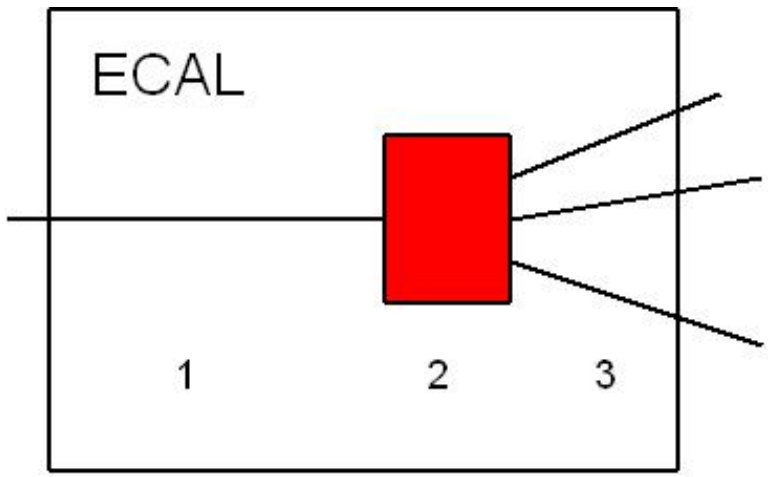


Figure: Again some activity leads to a smaller interaction layer found. Nice event anyway with a cluster and a track.

Improvements ?

Further exploitation of high granularity

Going back to the procedure developped to study hadronic interactions, steps 1 and 2 must be combined.



1. Follow the MIP-like track until fireball interaction
2. If not, look for other kinds of interaction

Summary and Outlook

- Different hadronic shower topologies compared between TB data and MC $\Rightarrow$ Reveals the large potential to understand details of hadronic showers
- Improvement of the algorithm to find the interaction layer $\Rightarrow$ Exploit more and more the high granularity
- Beyond: further classification of hadronic interactions (with traces, density, extension,...)

General prospects of study

1. Deep understanding of the hadronic showers
2. In-situ MIP calibration with the MIP-finder
3. Challenge to develop a PFA

Aim for a note around Easter and CALOR2010.

Thank you for your attention, any comments are welcome.