Hadronic shower shapes in the Si-W ECAL

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Study of hadrons (pions, here) in the CALICE SiW ECAL

Why ?

- 2/3 of the hadrons interact in the ECAL ($\sim 1\lambda_I$): study of hadronic interactions
- high granularity: ECAL used as a tracker
- comparison between TestBeam data and Monte Carlo simulations to optimise physics lists

What ?

- data taken at FNAL in May and July 2008 + MC simulations
- picture of an interaction: procedure developped

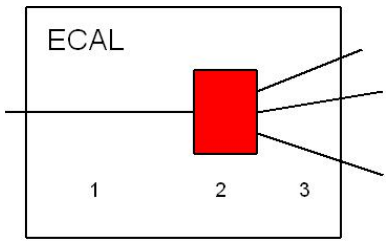
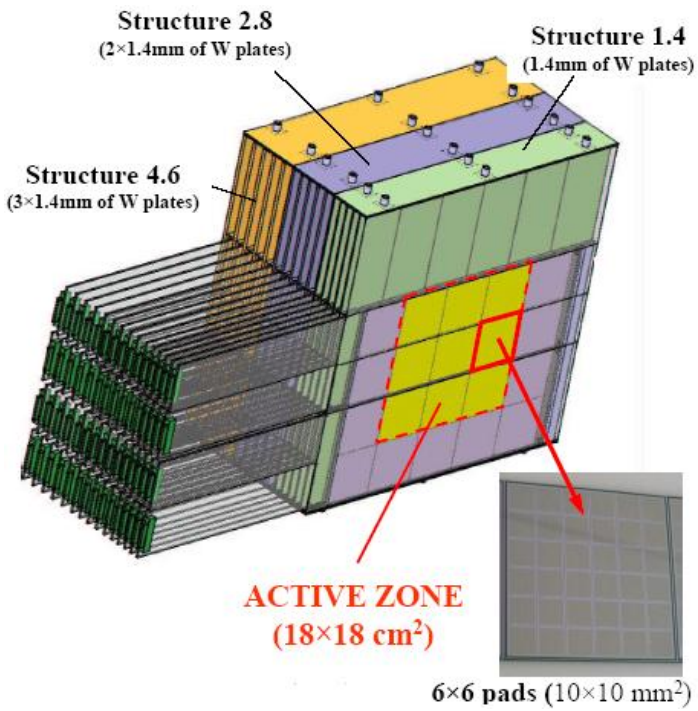


Figure: To define an hadronic interaction : first, find a MIP.

MipFinder finished for the ECAL & first layer of interaction almost always found

The SiW ECAL in 2008

Figure: Si-W ECAL prototype used at FNAL: 30 layers fully equipped



ECAL = sandwich of Si (detector) and W (absorber) layers

- $1 \times 1\ cm^2$ Si pixels 9720 channels
- 1 layer of $1.4mm = 0.4X_0$
- 3 different W depths: 3 stacks
- depth $= 24X_0 = 1\lambda_I$

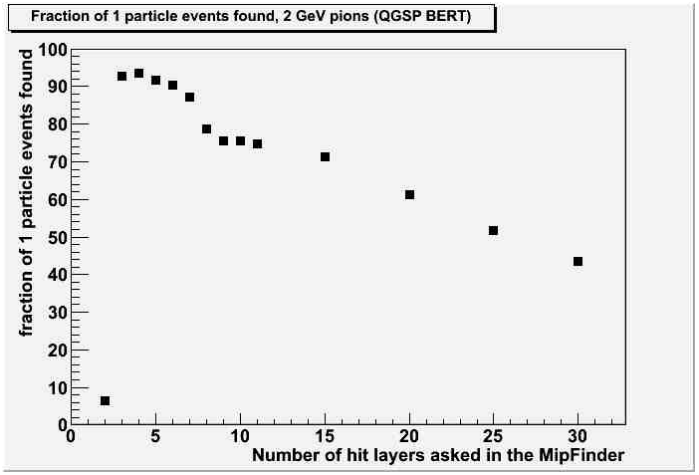
Finding the initial MIP - "True" efficiency

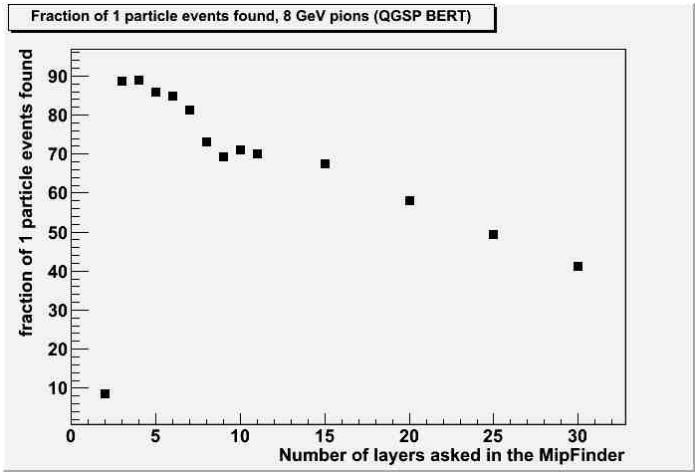
Soon available on the CALICE TWiki page

Before : "real" efficiency not taking into account non converging cases.

Now : "true" efficiency taking them into account. $\eta_\mu = 95.8\%$

Efficiency for 2 & 8 GeV pions vs. number of hit layers to count the particles (QGSP BERT).





Maximum distance between two clusters : 18 mm, 6 layers taken to avoid odd-even effects. Inefficiencies O(10%).

Applied to FNAL'08 data: pions

New run selection done : according to logbook "pions" with 10×10S trigger, Cherenkov trigger active : 14-24 July.
No 6 GeV after new selection. (Reconstruction problem)

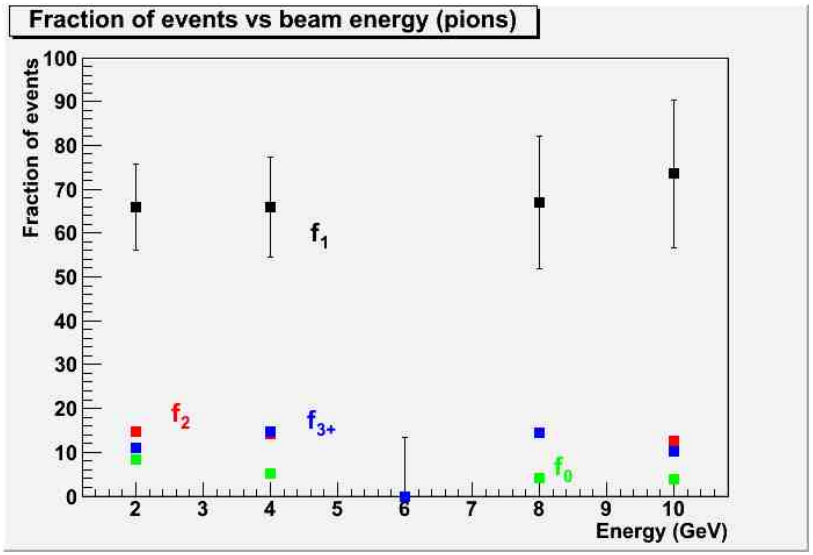


Figure: Fractions f_i of i entering particles vs momentum (TB data). Black: f_1, green: f_0, red: f_2, blue: f_{3+}. Inefficiencies extrapolated for f_1 from pion simulations, O(10%).

Interaction criteria : pions at low energy

1 $E^{layer}_{j,j+1,j+2} > E^{layer}_{cut}$, $E_{cut} = 5$ MIPs. Absolute value.

2 $(E^{layer}_{j} + E^{layer}_{j+1})/(E^{layer}_{j-2} + E^{layer}_{j-1}) > F_{j,cut}$,
$(E^{layer}_{j+1} + E^{layer}_{j+2})/(E^{layer}_{j-2} + E^{layer}_{j-1}) > F_{j+1,cut}$,
$(E^{layer}_{j+2} + E^{layer}_{j+3})/(E^{layer}_{j-2} + E^{layer}_{j-1}) > F_{j+2,cut}$
Layers taken 2 by 2 to reduce fluctuations
& 3 cuts because only 2 show isolated energy peaks.

3 criteria, called $\Phi^{F_{j,cut},F_{j+1,cut}}_{F_{j+2,cut}} = \Phi^{3,3}_{3}$ Relative increase.

Remark : Criteria $\Phi^{3,3}_{!3}$ to see energy "peaked" layers.

Efficiency of the cuts

The cuts are preferred to absolute value of 3 out of 4 layers > 10 MIPs (see David Ward & Takuma Goto) since energies, here, are smaller.
Efficiencies: $\eta_{2\ GeV} = 88\%$, $\eta_{8\ GeV} = 91\%$, O(7%) (eye-scanning over 200 events).
Major inefficiencies: punctual interaction $\Rightarrow$ no interaction seen (2 GeV), backscattering $\Rightarrow$ layer too small (8 GeV).

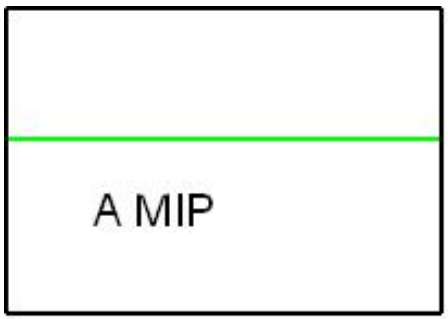
Fractions of interactions found : TB & MC

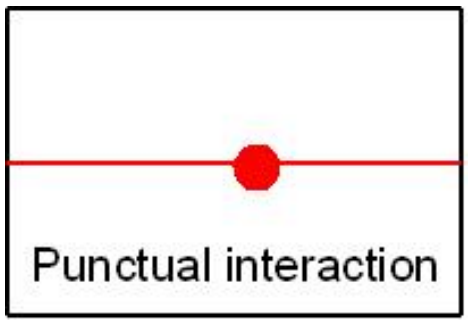
E (GeV)	2	4	8	10	2	8
P_{int}	49.4%	63.6%	67.3%	63.5%	40.2%	55.7%

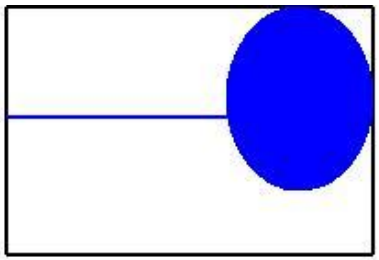
The expected $\sim 65\%$ are found. Energy dependence ? Inefficiency of the criteria O(10%).

Different shapes to characterize

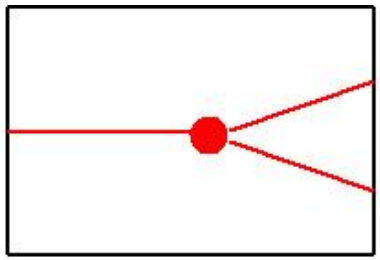
Final goal now : characterize those 4 kinds of interactions seen.







Interaction "fireball" shape



Interaction "fork" shape

Remark about peaked layers

Sometimes, some layers show a peak of energy : square events, punctual interaction...
Using the criteria $\Phi^{3,3}_{!3}$ tells if one layer is peaked.

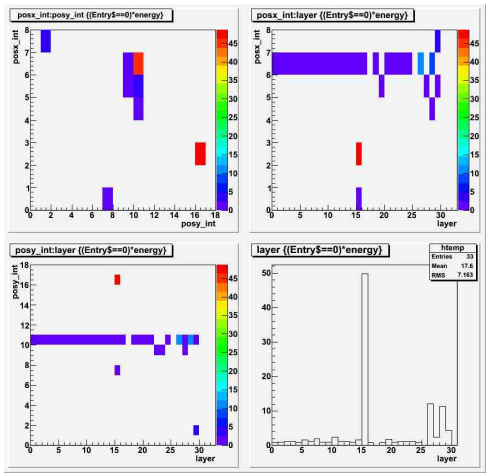


Figure: 2D profiles of a "peaked interaction" (simulated 2 GeV pion). Punctual interaction

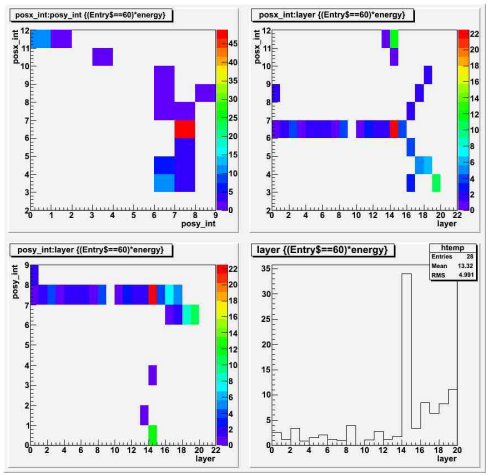


Figure: 2D profiles of a "peaked interaction" (simulated 2 GeV pion). Fork shape

2 kinds of interaction identified with this criteria, to be separated.

Other kinds of events : MIP & fireball

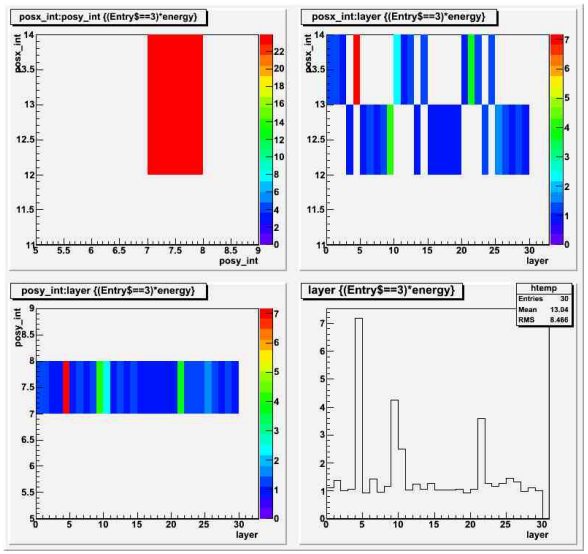


Figure: A MIP event : no interaction & no peak

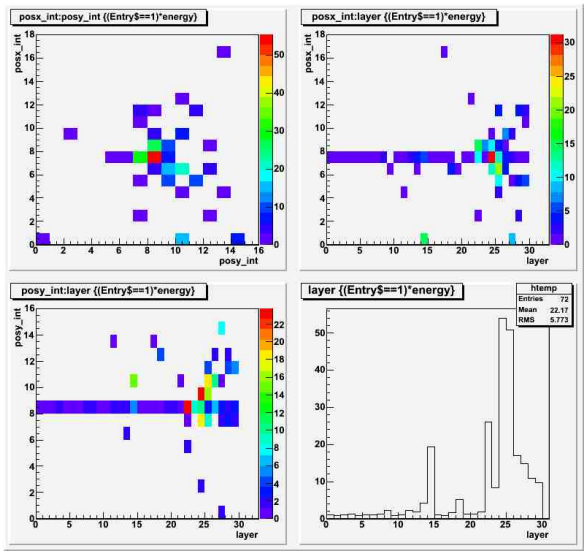
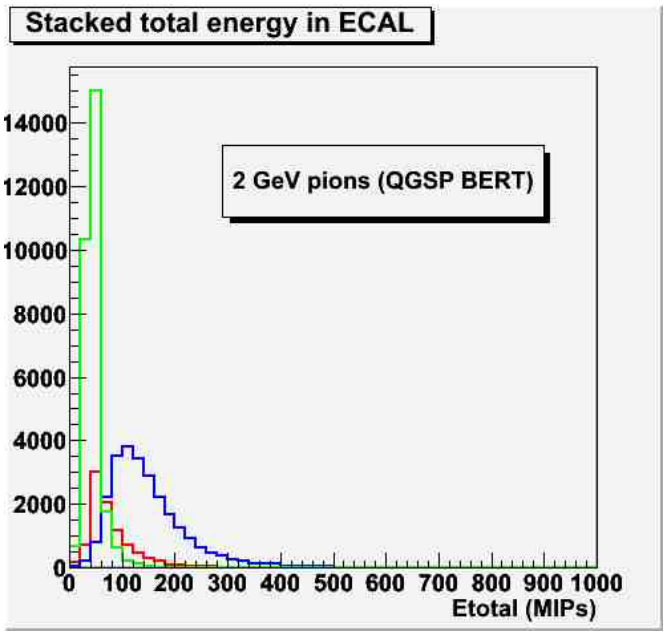
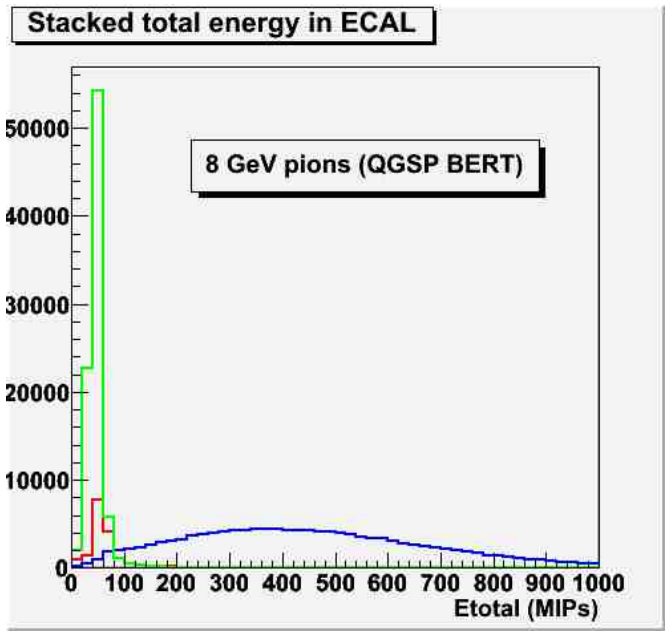


Figure: An interaction : fireball event

Events taken from 8 GeV simulations (QGSP BERT).

Shower shape variables for simulations (1/4) - Total energy



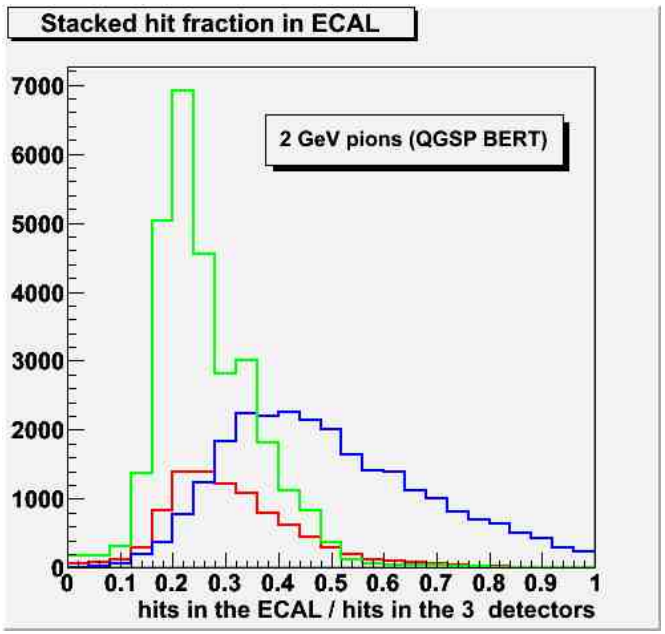


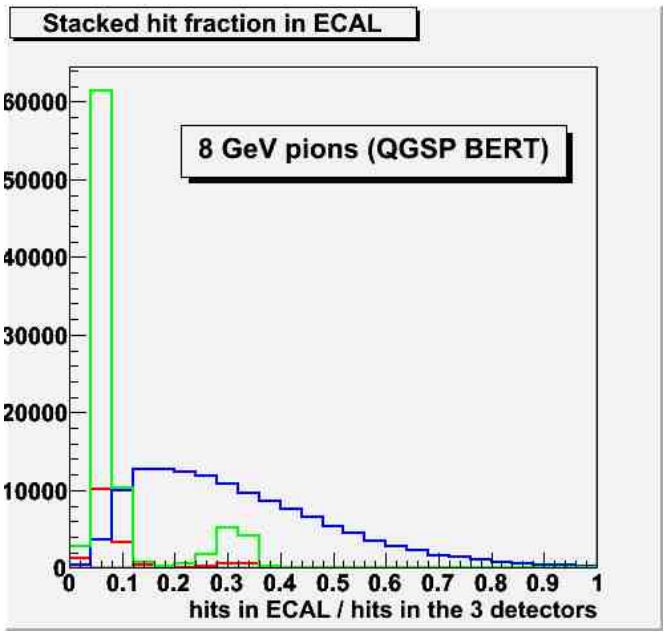
Mips (no interaction & no peak), peaks & no interaction, interaction.

Total energy deposited in the ECAL (only) in MIPs.

No cuts applied here. More to come next time...

Shower shape variables for simulations (2/4) - Hit fraction in ECAL



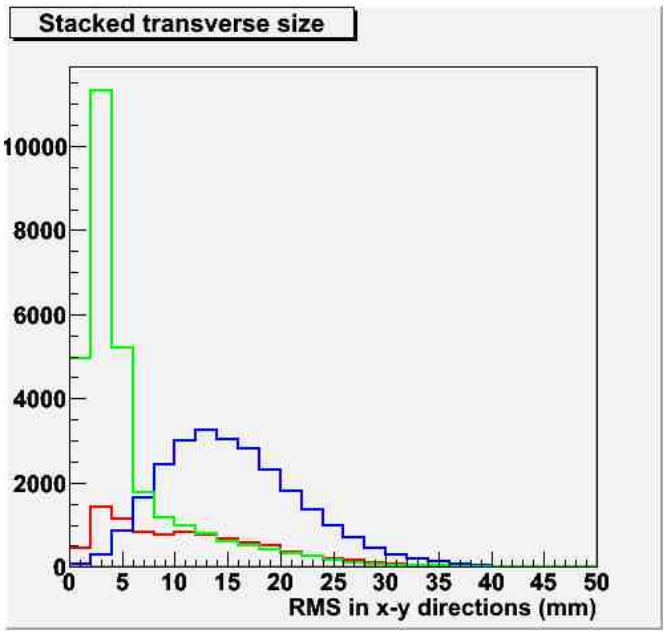


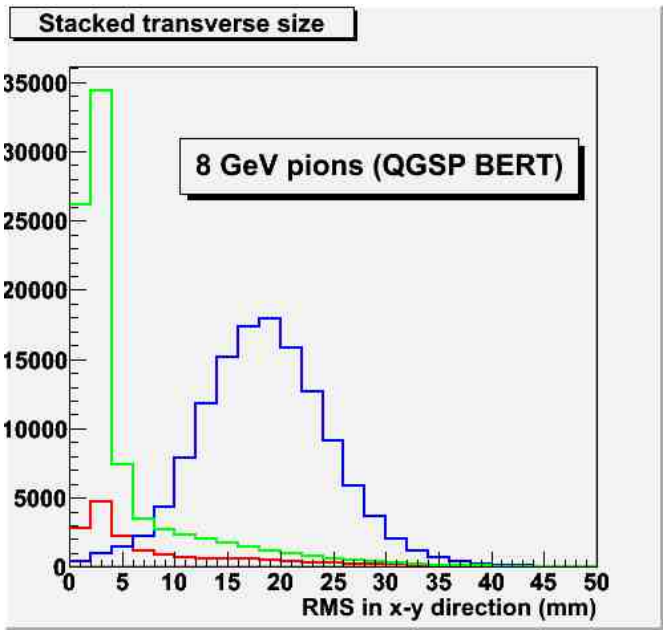
hit fraction = number of hits in the ECAL / number of hits in the ECAL+HCAL+TCMT

HCAL & TCMT information available (testing reco v0407). Cuts for pions more efficient. (Energies not now.)

Differencies seen : more hits at 2 GeV, TCMT effect seen at 8 GeV.

Shower shape variables for simulations (3/4) - Transverse size

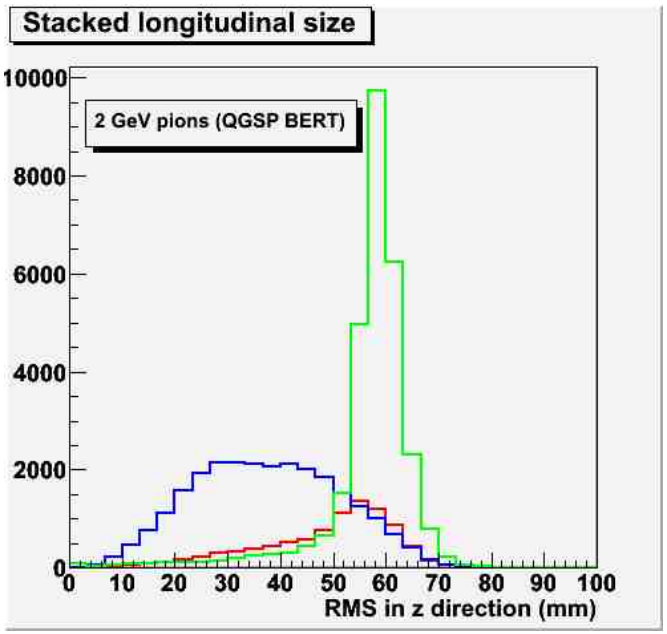


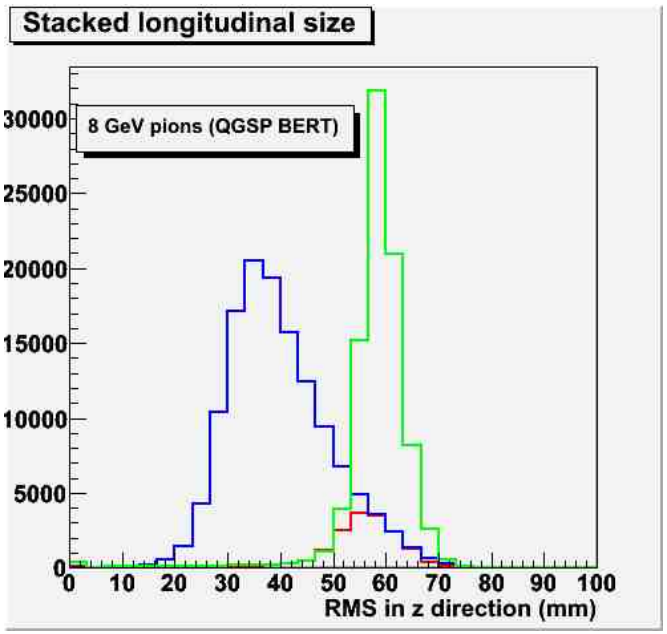


Transverse size calculated for all hits in the ECAL (energy weighted).

$$\sigma^2_{trans} = \sum_{hits} E_i * (x^2 + y^2)/E_{total} - (\sum_{hits} E_i * \sqrt{(x^2 + y^2)}/E_{total})^2$$

Shower shape variables for simulations (4/4) - Longitudinal size





$$\sigma^2_{long} = \sum_{hits} E_i * (z^2)/E_{total} - (\sum_{hits} E_i * z/E_{total})^2$$

All hits taken into account. Next time : remove the Mip part of the interaction and recalcuate the sizes.

Expected better separation of MIPs and interacting pions.

Shower shape variables : MC vs TB at 2 GeV (1/2)

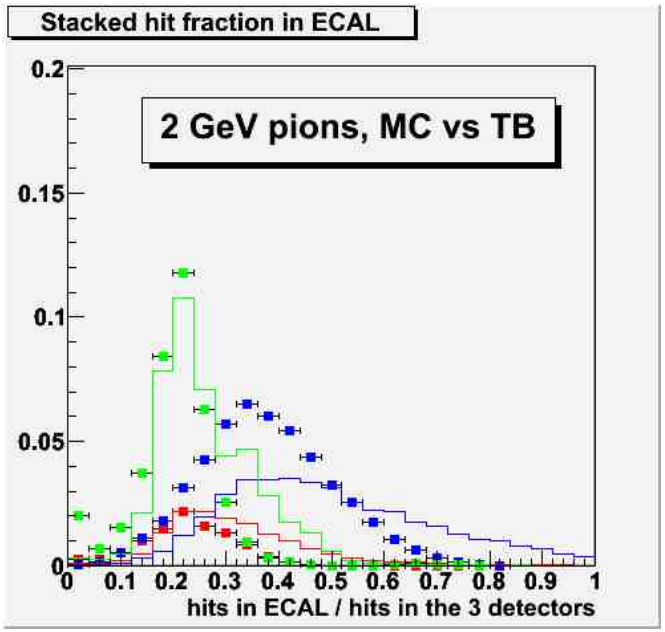


Figure: Hit fraction in the ECAL - 2 GeV

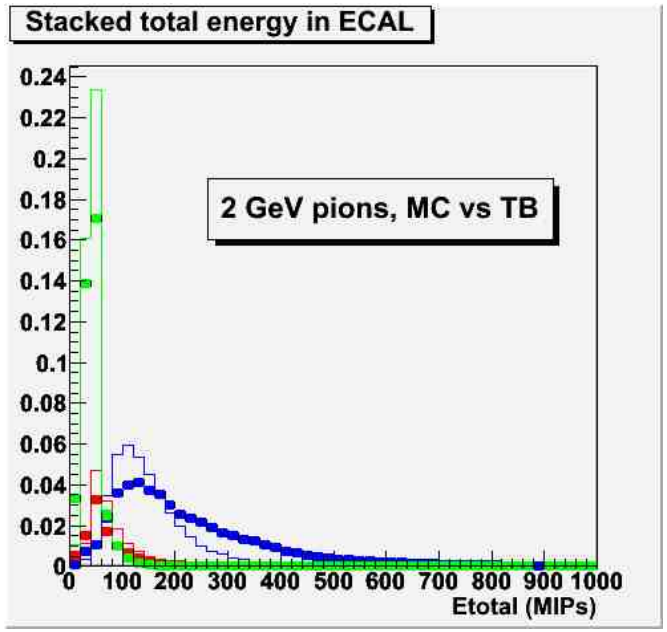


Figure: Total energy in the ECAL - 2 GeV

Effects not yet fully understood. Real difference reality - physcics list, or TB effect ?

More hits in ECAL for MC but larger energy distribution in TB...

Shower shape variables : MC vs TB at 2 GeV (2/2)

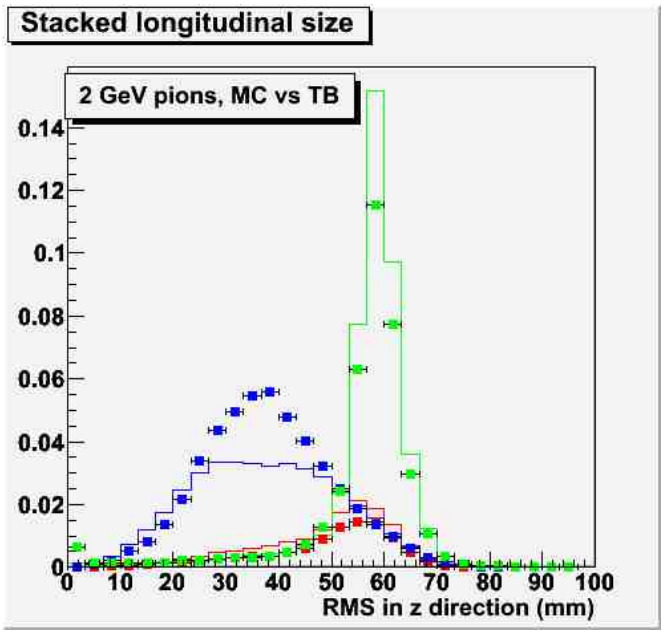


Figure: Longitudinal size in the ECAL - 2 GeV

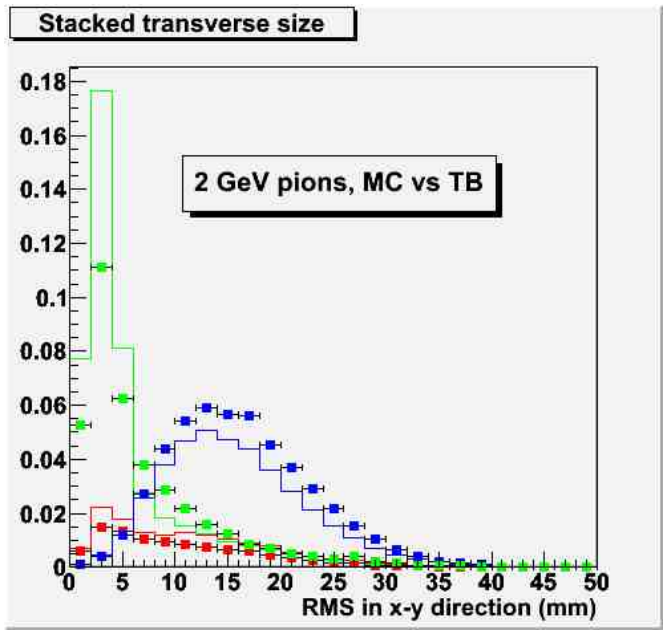


Figure: Transverse size in the ECAL - 2 GeV

"Plateau" in longitudinal size distribution for interacting particles in MC at 2 GeV ?

Shower shape variables : MC vs TB at 8 GeV (1/2)

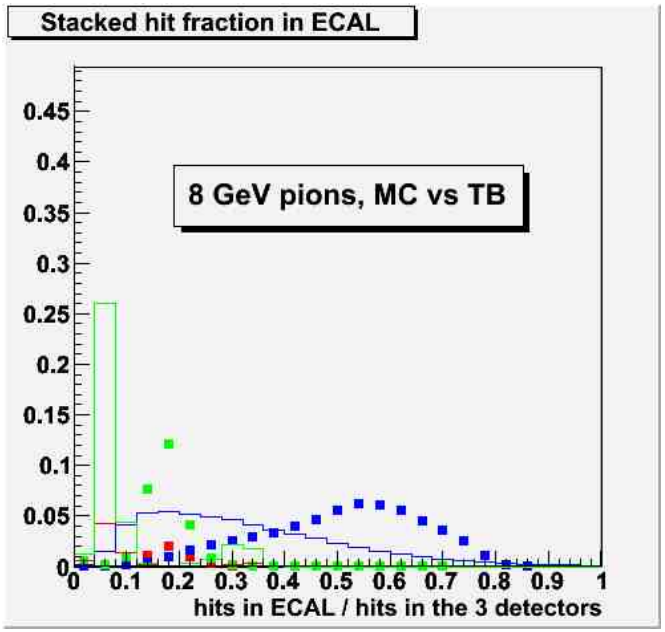


Figure: Hit fraction in the ECAL - 8 GeV

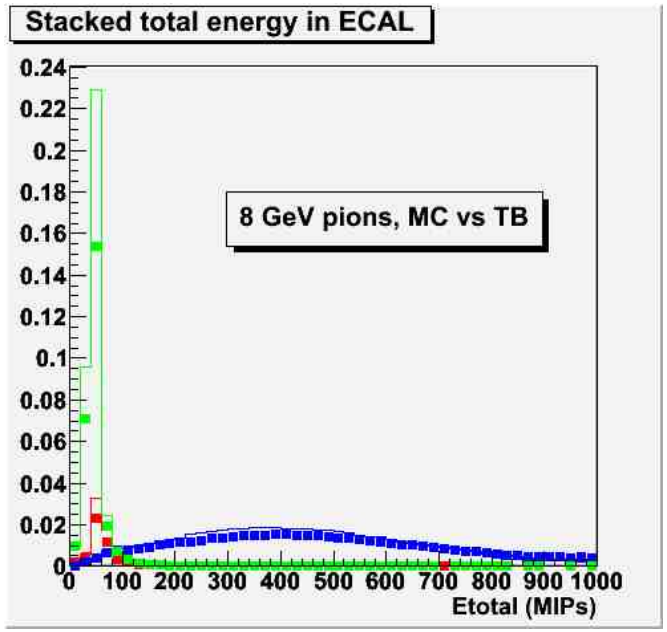


Figure: Total energy in the ECAL - 8 GeV

Hit fraction completely different. Factor ~ 2 in the disctribution...
But total energy in ECAL very well described.

Shower shape variables : MC vs TB at 8 GeV (2/2)

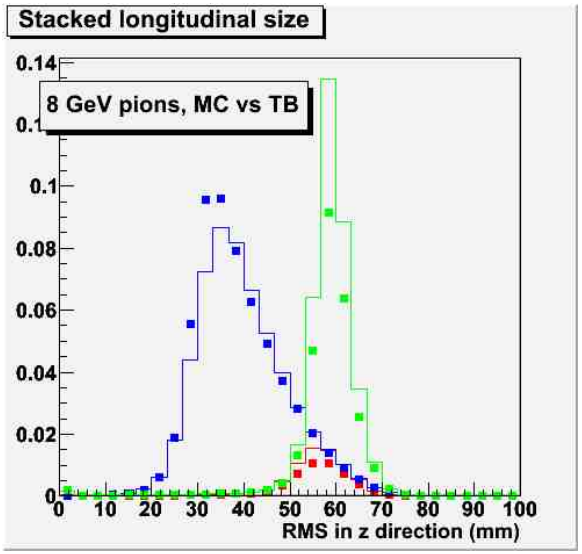


Figure: Longitudinal size in the ECAL - 8 GeV

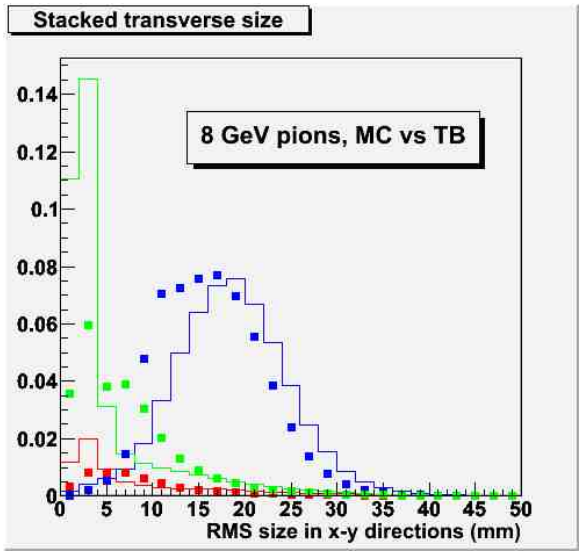


Figure: Transverse size in the ECAL - 8 GeV

Discrepancies in small transverse sizes : maybe some electrons selected in the runs.

Conclusion and Outlook

MipFinder:

- MipFinder finished: will be released in CALICE software
- Very good efficiency
- First step to study hadronic showers done

First layer of interaction:

- Criteria show good efficiencies
- 3 kinds of "interactions" defined.

First steps towards a basic PFA & a full study of hadronic showers.

Next steps:

- Better understanding of differencies in the distributions
- Go to 4 kinds of interactions
- Remove the MIP part of the interacting particles
- Go deeper in combined analysis (use energy, ...)

Thank you for your attention, any comments are welcome.