Study of hadrons in the SiW ECAL

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

Why ?

- 1/3 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

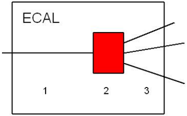
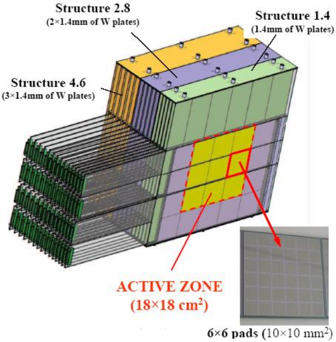


Figure: The three steps in defining an hadronic interaction

Today ? MipFinder finished & 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 ~ 10000 channels
- 1 layer of $1.4mm = 0.4X_0$
- 3 different W depths: 3 stacks
- depth $= 24X_0 = 1\lambda_I$

The MipFinder in a nutshell

Algorithm based on MipSelect.cc/hh developped by Götz Gaycken.
Criteria to create or merge clusters:

- distance D_{max} between hits and/or straight clusters
- angle θ_{cut} between straight clusters
  did not exist in MipSelect and avoids problems like backscattering

LayerMin $\leq$ Mip Searching $\leq$ LayerMax. *If* layers not hit, *then* add others $\Rightarrow$ constant number of layers.

a MIP = a cluster with $N_{hits} \geq 3$.

Efficiency using simulated samples of muons - D_{max}

Efficiency to find one single particle: η_1

η_1 = nb of 1 particle events / nb of total events, as given by the MipFinder.

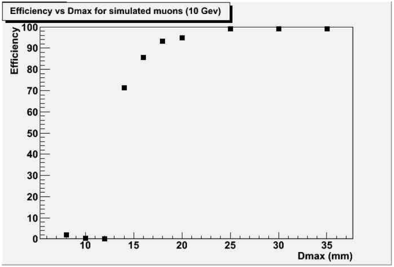
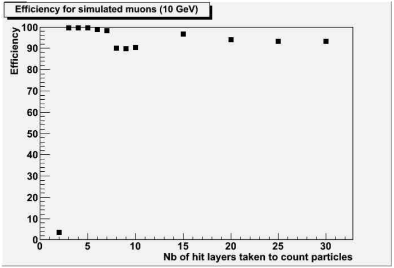


Figure: η_1 vs. D_{max} the criteria of the maximum distance between a cluster and a hit/cluster.

$D_{max} = 18$ mm chosen: good compromise between cellsize and efficiency. *Remark:* T_{cut} previously presented, now obsolete.

Efficiency vs. number of hit layers to count the entering particles for muons

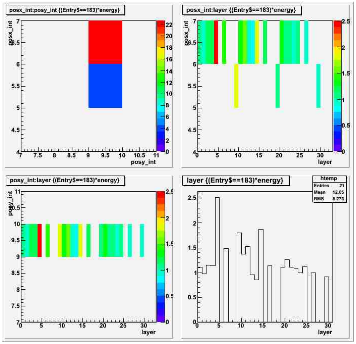
Figure: Efficiency for 10 GeV muons vs number of hit layers taken into account (QGSC).



Principal reason for inefficiencies next slide... = 0.4% inefficiencies with simulated muons.

"Plateau" for 8, 9 and 10 layers to be removed...

Inefficiencies



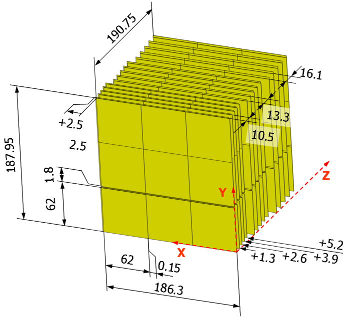


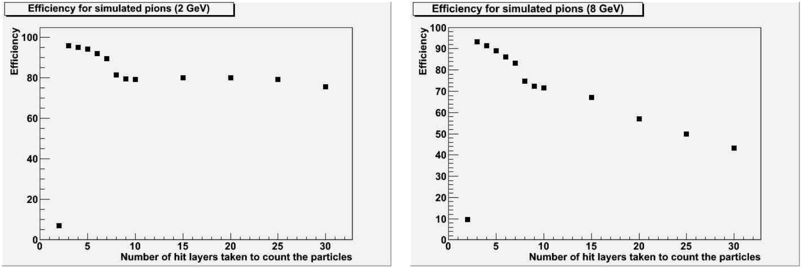
Figure: Energy deposition in the ECAL for a 10 GeV simulated muon. The staggering of each stack can be seen.

2 layers not hit and different x between the two pixels.

But avoids having a too large D_{max} (not a straight cluster anymore).

Efficiency vs. number of hit layers to count the entering particles for pions

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



First layers: backscattering, early interactions or preshowering

Last layers: interaction very likely (1/3) ⇒ 2-8 GeV difference

Results are similar between the three physics lists LHEP, LCPhys and QGSP BERT, when done with 5 layers: optimum.

Applied to FNAL'08 TB data: muons

Estimation of the quality of the beam: use the MipFinder to count the particles entering the ECAL. The uncertainty is given by the inefficiency obtained for simulated samples.
Real data: $\eta_i \Rightarrow f_i$, fraction of events with i particles.

For muons at 32 GeV:
$f_0 = 9.8\%$, $f_1 = 84.8\%$, $f_{2+} = 5.4\%$, $\pm 0.4\%$ from simulations.

Can be done with the CERN data to compare the beams' qualities.

Applied to FNAL'08 data: pions

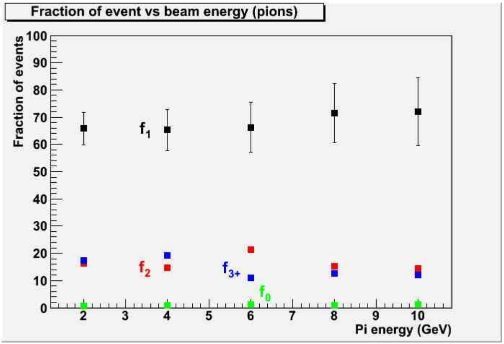


Figure: Fractions f_i of i entering particles vs momentum (TB data). Black: f_1, green: f_0, red: f_2, blue: f_{3+}. Inefficiencies extrapolated for f_1 from pion simulations, O(10%).

Need to revise my runs' selection : maybe some runs are *mixed*.

Second task : find the interaction layer

Interaction criteria:

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.

Efficiencies: $\eta_{2\ GeV} = 85\%$, $\eta_{8\ GeV} = 85\%$, O(10%) (eye-scanning over 100 events).

Major inefficiencies: punctual interaction ⇒ nothing reported (2 GeV), backscattering ⇒ layer reported too small (8 GeV).

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.

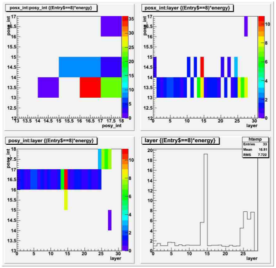


Figure: 2D profiles of a "punctual interaction" (simulated 2 GeV pion). Not the start of the shower

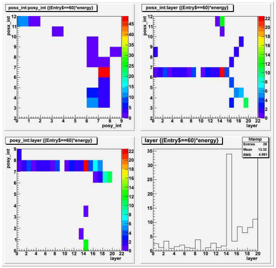
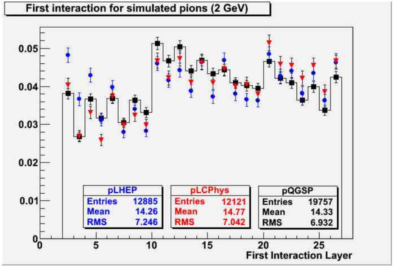
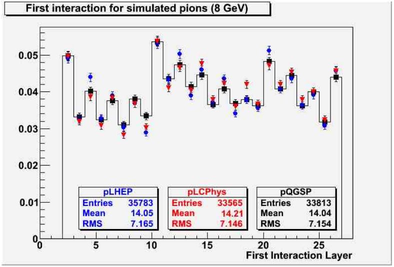


Figure: 2D profiles of a "punctual interaction" (simulated 2 GeV pion). Real interaction.

First interaction layer: comparison between physics lists

Figure: First layer of interaction for 2 GeV simulated pions.
Black: QGSP BERT, red: LCPhys, blue: LHEP.
Normalized by the number of events + statistical errors.





The physics lists agree reasonably well.
Small discrepancies at 2 GeV : physics lists not optimized at low energies. Now, apply it to the data.

Conclusion and Outlook

MipFinder:

- MipFinder finished: will be released in CALICE software
- Very good efficiency
- First step to study hadronic showers done
- Can also be used to calibrate *faster* the ECAL

First layer of interaction:

- Criteria show good efficiencies
- Revise my FNAL run selection and apply it
- Compare results with MC data

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

Next steps:

- Describe the interaction region with various shapes + number of outgoing particles
- Hough transform...

Thank you for your attention, any comments are welcome.