Update on hadronic interactions in the SiW ECAL (with FNAL'08 data)

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The SiW ECAL in 2008 to study hadronic interactions

- FNAL beam : e, μ, π from 1 to 60 GeV

For hadron analysis

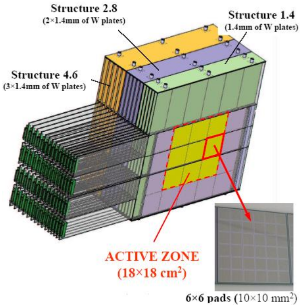
- depth $\sim 1\lambda_I$ i.e. 1/3 of the hadron interact
- 1 cm $\times$ 1 cm pixels $\Rightarrow$ tracking possibilities (AHCAL : 3 cm $\times$ 3 cm)

Goal: understand hadronic showers

Here: low energy hadrons : 2, 4, 6, 8 and 10 GeV available

- Fully equipped Si-W ECAL

Figure: 30 layers : 1 $cm \times 1$ cm Si pixels $\sim$ 10000 channels, 3 different W depths.



Understading the hadronic interactions with the ECAL

Work presented during the CALICE DESY meeting (03/30/09)

- Comparison between MC and TB data
- Clustering in the ECAL started

Today

- Using a MipFinder algorithm the count the number of entering particles
- Finding the starting point of the interaction

Data taken at FNAL in July 2008

- May: instabilities of the ECAL due to some electronic noise
- July: good and stable running period

N events (triggers)	p (GeV)
460 k (-v22,-v25)	2
820 k (-v24)	4
110 k (-v23,-v27,-v31)	6
540 k (-v27)	8
500 k (-v27)	10

ECAL data reconstructed by Hengne
No HCAL data available at the moment (pending and tedious)

Procedure to be developped

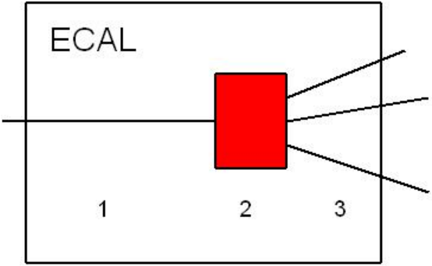


Figure: Clusterising scheme

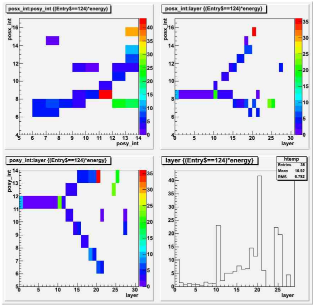


Figure: 3D projections of a 2 GeV pion interacting in the ECAL

1. Identify the MIP before the interaction layer
2. Investigate the interaction region
3. Find new MIPs after the interaction region

The MipFinder algorithm : Tools

MipFinder algorithm:

- Developped by Götz Gaycken at LLR, changes added
- Similar to the clusteriser but creates straight clusters
- Part of the CALICE software (calice reco : MipSelect.cc/.hh)
- Uses the "Box" (calice reco) and "Linear Regression" (calice userlib) classes

The "Box" class:

- One Box contains several CalorimeterHits
- Add(CalorimeterHit,Box) or Add(Box1,Box2)
- Allows to calculate the mean position, size and total energy contained in the box

The "Linear Regression" class:

- Can perform a linear regression with the positions of several CalorimeterHits

The MipFinder algorithm : Step-by-step

1. Create Boxes of nearby particles
   Conditions: CalorimeterHits must be reasonably aligned (θ_{cut}) and close enough
2. Perform a linear regression for each Box
3. Group nearby Boxes provided they are aligned (θ_{cut})
4. Redo the linear regression for each remaining Box
5. Create Clusters with the Boxes

Validation of the algorithm

Tested with samples of FNAL'08 TB data :
counting the number of particles entering the ECAL (5 first layers)
Condition : remove the Clusters with less than 2 hits.
Take 100 events (any kind of) and check visually if the algorithm is right (at 2, 4, 6, 8 and 10 GeV - $1/\sqrt{100} = 10\%$).

To do (better)

- Take muon MC samples and check the efficiency of the algorithm
  Then check the resolution of the algorithm by overlaying muon events.
- Check the results with Cristina's method : Hough transform (see talk of 03/30/09 at DESY)

Results

	2 GeV	4 GeV	6 GeV	8 GeV	10 GeV
Efficiency	97%	92%	85%	96%	84%
Purity	94%	97%	97%	96%	99%
Multiple particles	34%	28%	27%	26%	17%

Efficiency = Number of correctly selected 1 particle events / Total number of 1 particle events .
Purity = Number of correctly selected 1 particle events / Total number of selected 1 particle events .
Goal: Will help selecting good events for comparison with MC data.
Remark: Can be applied to the last layers to determine the number of outgoing MIPs. Inefficiencies: Backscattering, $E^{layer} = 0$!

Conditions to find the interaction

Previous condition: $E^{layer}_{j,j+1,j+2} > E_{cut} = 10$ MIPs.
Doesn't work on several events:

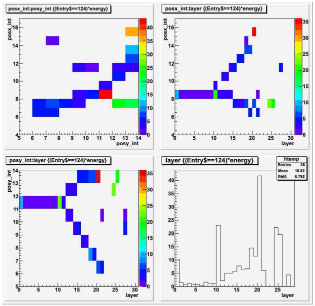


Figure: 3D projections of a 2 GeV pion interacting in the ECAL

$\Rightarrow$ relative increase of energy

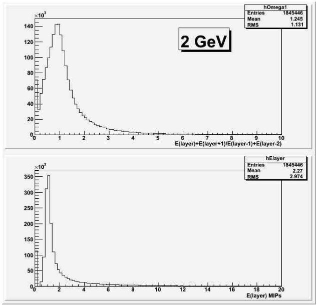


Figure: Histograms at 2GeV of the fraction $frac = \frac{E^{layer}_{j} + E^{layer}_{j+1}}{E^{layer}_{j-1} + E^{layer}_{j-2}}$ (top) and E^{layer} (bottom)

Add a second condition

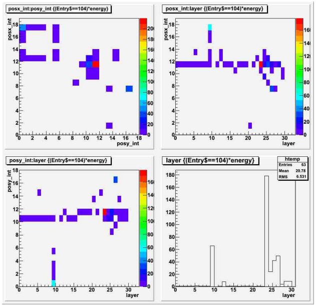


Figure: Square event : noisy event that should not lead to the detection of an interaction layer 9 but 23

$$frac = \frac{E_j^{layer} + E_{j+1}^{layer}}{E_{j-1}^{layer} + E_{j-2}^{layer}} > 3$$

AND

$$frac' = \frac{E_{j+1}^{layer} + E_{j+2}^{layer}}{E_{j-1}^{layer} + E_{j-2}^{layer}} > 3$$

$\Rightarrow$ Condition $\Phi_{frac'}^{frac}$, (Φ_3^3 here) Then take the smallest value of j for the interaction layer.

- The combination of the two conditions allows for the identification of noisy layers.

E_{cut} distributions at 2 GeV and 10 GeV

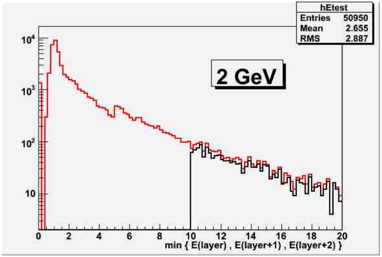


Figure: Black : with $E_{cut} = 10$ MIPs, Red : with $E_{cut} = 5$ OR Φ_3^3

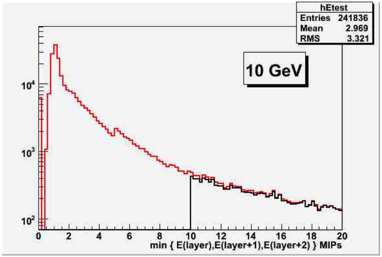


Figure: Black : with $E_{cut} = 10$ MIPs, Red : with $E_{cut} = 5$ OR Φ_3^3

Interest for these conditions

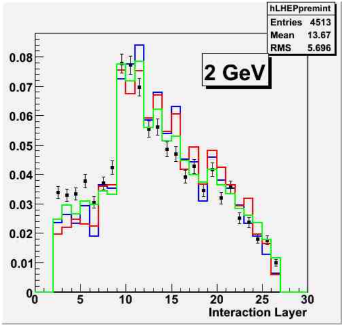
Using the two conditions improves the efficiency to find the first interaction.

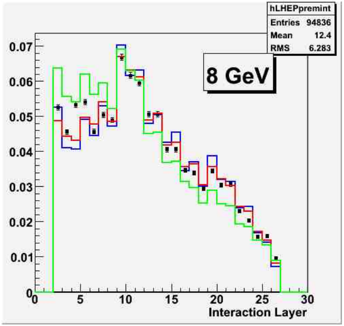
with	2 GeV	4 GeV	6 GeV	8 GeV	10 GeV
$E_{cut} = 10$	11%	25%	52%	38%	36%
$E_{cut} = 5$	19%	31%	55%	41%	39%
$E_{cut} = 10$ OR Φ_3^3	41%	47%	59%	54%	53%
$E_{cut} = 5$ OR Φ_3^3	41%	47%	59%	55%	53%

Lowering the energy condition from 10 to 5 MIPs does not change a lot but adding the new condition improves a lot the efficiency.

Results : interaction layer with MC data

Tests performed on interacting pions only (selected with Cherenkov bits AND $N_{hits} > 40$ AND $E_{10\ layers}/E_{total} < 0.2$)





Histograms : TB, LHEP, LCPhys, QGSP BERT

	2 GeV	4 GeV	6 GeV	8 GeV	10 GeV
Efficiency	90%	70%	60%	70%	90%

Conclusion and Outlook

- Good purity of the MipFinder for entering particles and efficiency good enough with the statistics we have to use it and select good pion candidates
- Conditions to find the starting point of the interaction to be defined

To do:

- Find the end of the interaction region and define a cluster inside
- Count the number of outgoing particles
- Use MC data and overlayed events to check the MipFinder's resolution, do Hough transform
- Reconstruct AHCAL data, check the efficiency of the Cherenkov counters

Thank you for your attention, any comments are welcome.