Hadron analysis using 2008 data

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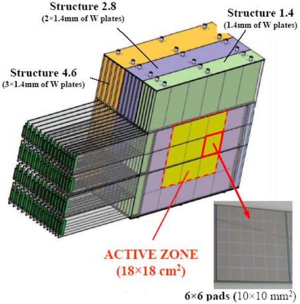
- Highly segmented Si-W ECAL
- Testbeams at FNAL during May and July 2008
- Available particles at FNAL : $e^{\pm}$, $\pi^{\pm}$, $\mu^{\pm}$
- This study: π from 1 GeV to 10 GeV

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
- 3 different W depths
- depth $= 24X_0 = 1\lambda_I$

Why are we interested in low energy hadrons in the ECAL ?

Remark: 1/3 of the hadrons interact in the ECAL

- Need to validate Geant4 physics lists
  $\Rightarrow$ higher precision for hadronic cross-sections
- Better segmentation than the HCAL used during testbeam ($3 \times 3cm^2$)
  $\Rightarrow$ tracking possibilities inside the hadronic shower
- Physics studies for the ILC
  for instance $e^+e^- \longrightarrow t\bar{t} \longrightarrow$ hadrons ($\sqrt{s} = 500$ GeV)

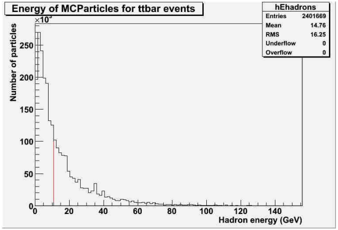
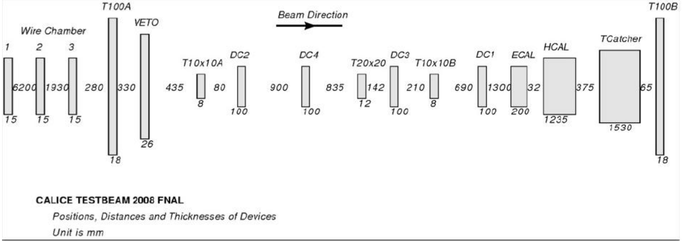


Figure: Hadrons energies for $e^+e^- \longrightarrow t\bar{t}$ (generator level)

54% hadrons have E < 10 GeV
$\Rightarrow$ requires a very good knowledge of low energy hadrons and their interactions

Setup at FNAL

Figure: Up: Photo of the detector: ECAL in front, then HCAL and the Tail catcher in the back. Down: Sketch of the beamline (Hengne Li, Alex Kaplan)



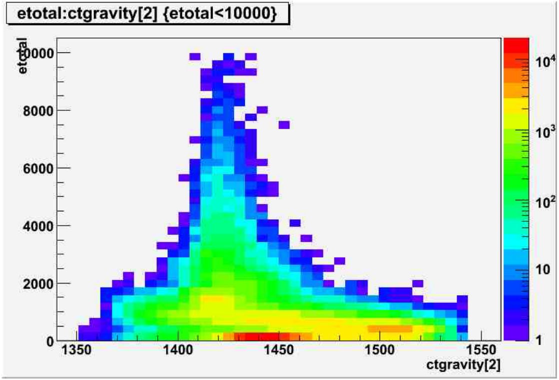
Summary of data taken with pions (π^-) in July 2008

Number of events recorded	Momentum (GeV)
460 k	2
820 k	4
110 k	6
540 k	8
500 k	10
at 30°	
310 k	4
220 k	8

A lot of statistics is available and will be checked and processed.
For today, the work only contains 230k events from 10 GeV pions.

An overview of a 10 GeV run

Figure: 2D histogram of the run (500642) showing the total energy deposited in the ECAL versus the center of gravity of the shower. One can identify electrons, pions and MIP particles



How to select pions ?

$\longrightarrow$ Use triggers, especially a Cherenkov counter.

Selecting pions with the FNAL Cherenkov 1/2

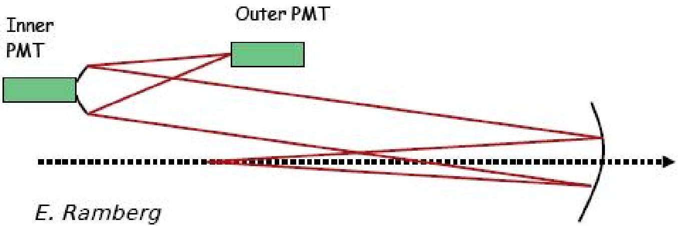


Figure: Scheme of the differential Cherenkov counter used to select particles

4 cases if pressure was well adjusted and the PMs were perfect

C1	C2	Comment
0	0	2 PMs missed i.e. smallest θ
1	0	First PM touched only i.e. larger θ
1	1	Both PMs touched i.e. largest θ
0	1	Not physical

Selecting pions with the FNAL Cherenkov 2/2

$$\cos(\theta) = \frac{1}{\beta n}$$

Set the pressure ($\Rightarrow$ n) so that each particle may be distinguished (known by calibration)

For given $\vec{p}$ and n : $\beta_\pi < \beta_\mu < \beta_e \Rightarrow \theta_\pi < \theta_\mu < \theta_e$

- Large dependence on pressure
- $\mu - \pi$ contamination
- Problems in some runs : C1 && !C2 is true ! O(1%)

Figure: Table of Cherenkov 1 and 2 signals, run 500642

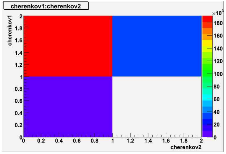
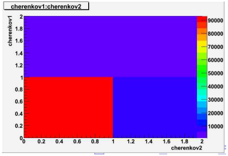


Figure: Table of Cherenkov 1 and 2 signals, run 500780 (4 GeV π^-)



First cuts

Cuts used : 2 Cherenkov bits and the total number of hits>50 .

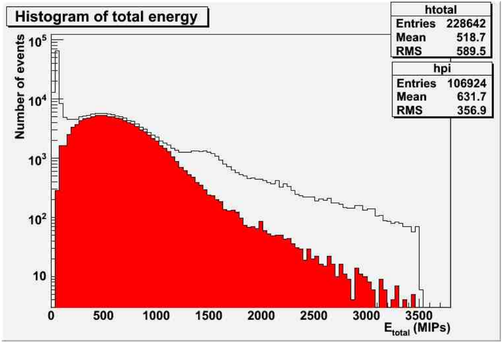


Figure: Total energy in the ECAL without selection (black) and with selection (red). MIP and electron peaks have been removed.

Detailed investigation of hadronic response - Detect first interaction

3D view of a 10 GeV event

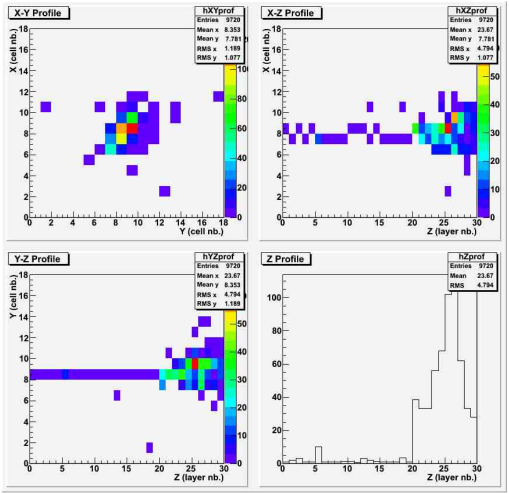


Figure: Projections in the XY / XZ / YZ planes and Z profile of the event. Energies are in MIP.

Starting from the first interaction layer

Condition: $E_{min}^{layer} = 10$ MIPs for 3 consecutive layers

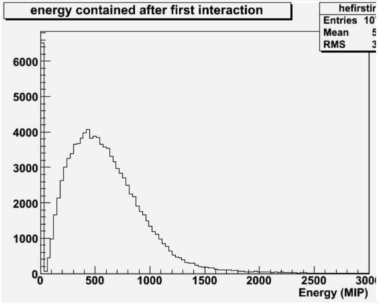


Figure: Histogram of the total deposited energy after the interaction

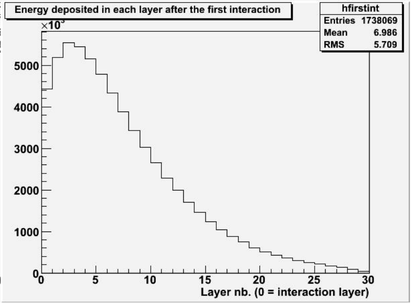


Figure: Deposited energy after the layer of interaction

Summary and outlook

- Analysis of the 2008 testbeams at FNAL have started
- Some unefficiencies of the Cherenkov counters have been seen O(1%)
- The understanding of the hadronic interaction at low energy has started

- Next steps :
  - use different energies (go below 10 GeV)
  - improve 1st interaction layer algorithm (see with Takuma Goto & David Ward)
  - compare with Monte Carlo simulations