DHCAL Response to Positrons and Pions

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Prelude

- **The large Digital Hadron Calorimeter (DHCAL) prototype was built:**
  - The active medium is Resistive Plate Chambers (RPCs).
  - Sampling calorimeter with 52 layers (38 layers DHCAL, 14 layers tail catcher - TCMT).
  - Each layer has 96 x 96 readout channels (pads) of size 1 cm x 1 cm.
  - Total number of readout channels is ~480K in ~2 m^3.
  - Readout is digital: A pad registers a “1” (hit) if the signal it measures exceeds a predefined threshold, “0” otherwise.
- **The DHCAL was tested (is being tested):**
  - At FNAL in October 2010, January 2011, April 2011 (with SiW ECAL) and May 2011 - (currently in the beamline).
  - With a broad-band muon beam, pion and positron beams of various momenta between 2-60 GeV/c and the primary proton beam at 120 GeV/c.

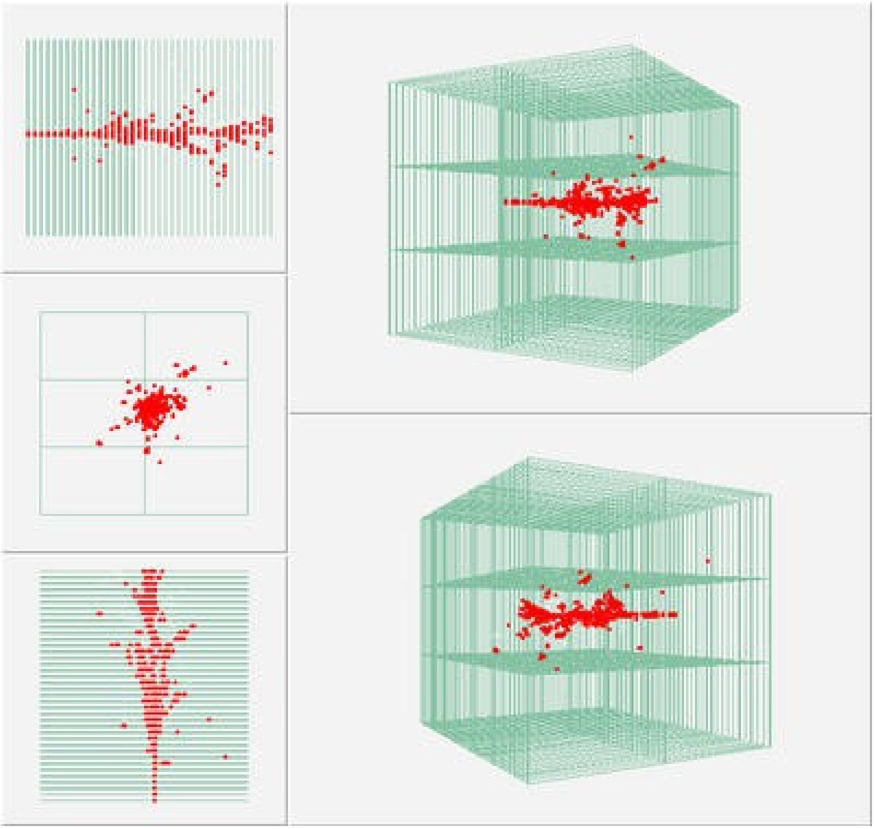
Scope

- Promptly investigate the calorimetric properties of the DHCAL with preliminary methods. Calorimeter response not yet calibrated, assuming uniform layer to layer response.

- Initiate the development of DHCAL-specific algorithms in calorimetry.

- Validation of the DHCAL concept.

A 16 GeV/c pion event



Analysis Strategy - I

Event selection

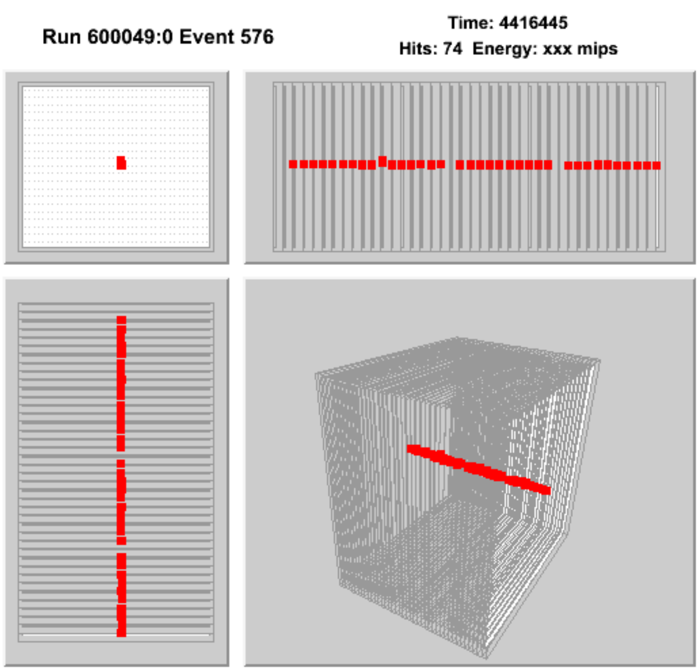
Cluster hits in each layer using closest-neighbor clustering (1 common side)

1) Exactly 1 cluster in layer 1 (← rejects multi-particle events)
2) Not more than 4 hits in layer 1 (← rejects upstream interactions)
3) At least 3 layers with hits (← rejects spurious triggers, cosmic rays)
4) No hits within 2 cm to layer edges (← improves lateral containment of showers)

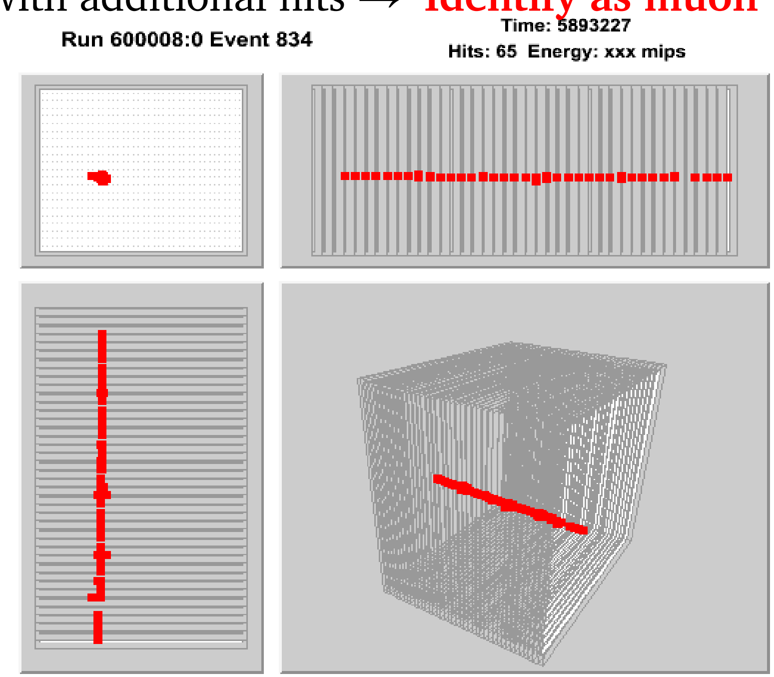
Identify muon tracks

1) Count layers with at least 1 hit = N_{active}
2) Draw line from cluster in layer 1 with last cluster in stack
3) Count clusters in intermediate layers and within 2 cm of line = N_{match}
4) Identify layers with additional hits within a cylinder with 1.5 cm < R < 25 cm around line

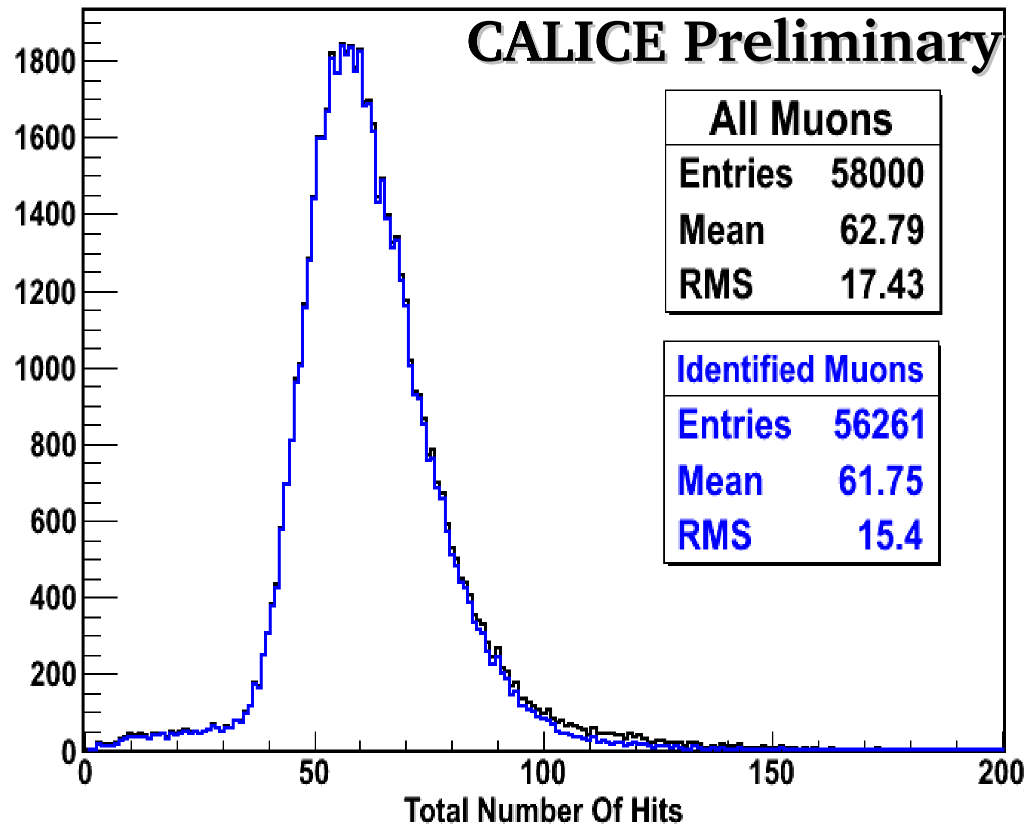
If $N_{match} = N_{active}$ → **Identify as muon**



If $N_{match} > 0.8\, N_{active}$ and no 2 consecutive layers with additional hits → **Identify as muon**



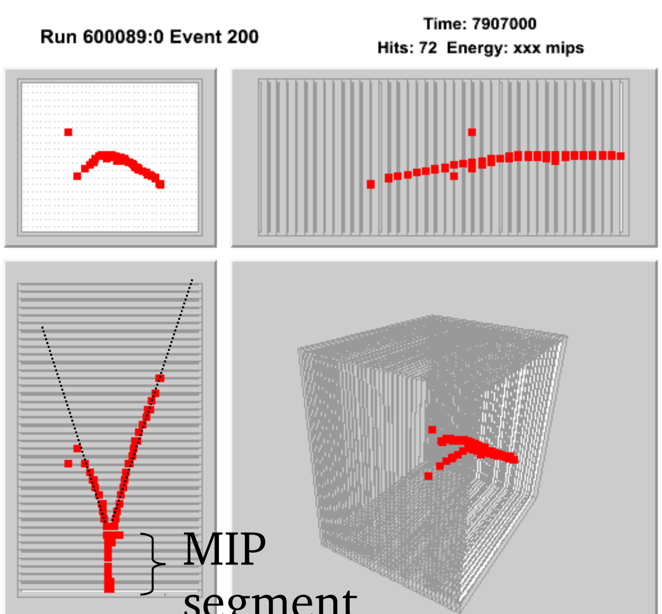
Analysis Strategy - II



Test muon ID

Muon Run
Efficiency ~ 97%
Remaining 3% not included in pion/positron sample, due to longitudinal containment cut

4 GeV/c pion event



Pion ID

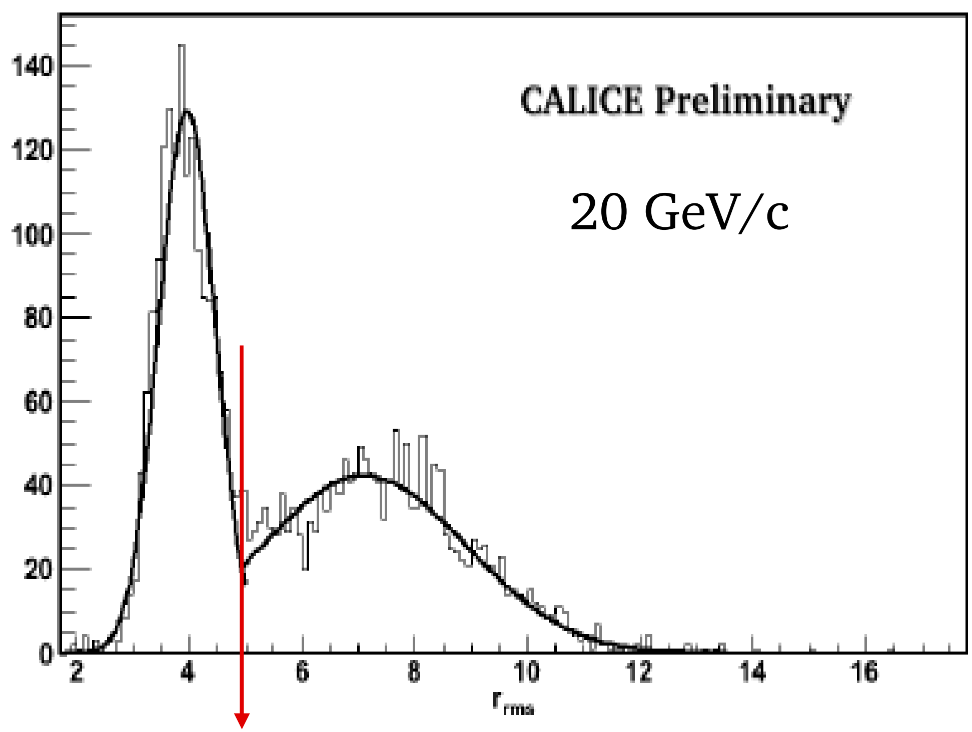
(Easy at high momenta, tough < 8 GeV/c)
Identify MIP segment starting from layer 1 following the muon id
Identify the clusters in the forward layers and
draw line to last MIP cluster (not compatible with the beam direction)
If at least 4 intermediate clusters → **pion**
If 2 track segments found with at least 3 layers and angle > 20^0 → **pion**

Analysis Strategy - III

Pion And Positron ID:

- For the events not already classified, $r_{rms} = \sqrt{\frac{\sum r_i^2}{N_{Hits}}}$ variable is defined,

where r_i is the distance of each hit to the x-y center of all the hits in the corresponding layer and N_{Hits} is the total number of hits.



If $r_{rms} > 5$ cm → **Identify as pion** (this adds 4% of pions)

If $r_{rms} < 5$ cm → **Identify as positron** (this is the only positron selection)

Topological Particle ID - Summary

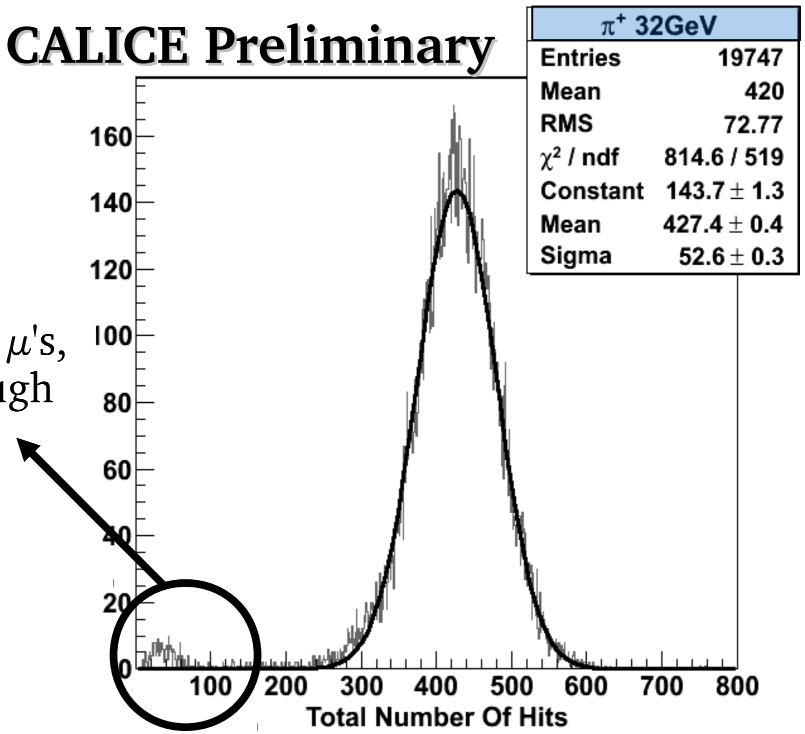
Muons: All active layers have aligned clusters with no more than two consecutive layers with non-isolated clusters.

Pions: At least one track segment in the interaction region that spans at least four layers and is not compatible with the beam direction. If such a track segment is not found, at least one pair of track segments that span three layers with at least 20° angle in between. $r_{rms} > 5$ cm.

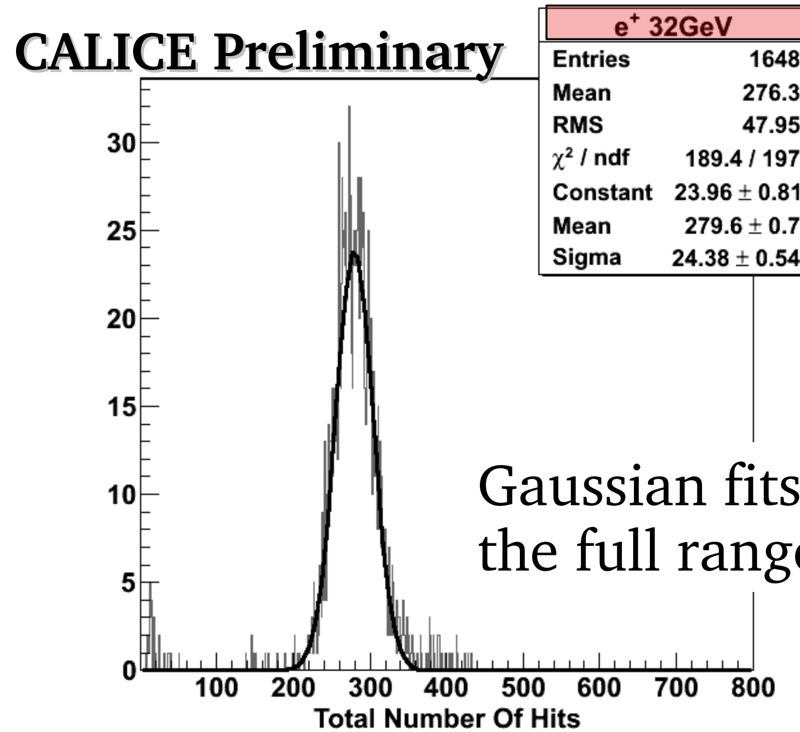
Positrons: $r_{rms} < 5$ cm.

This is a preliminary particle ID method to provide a first look at the data. More refined methods are being developed.

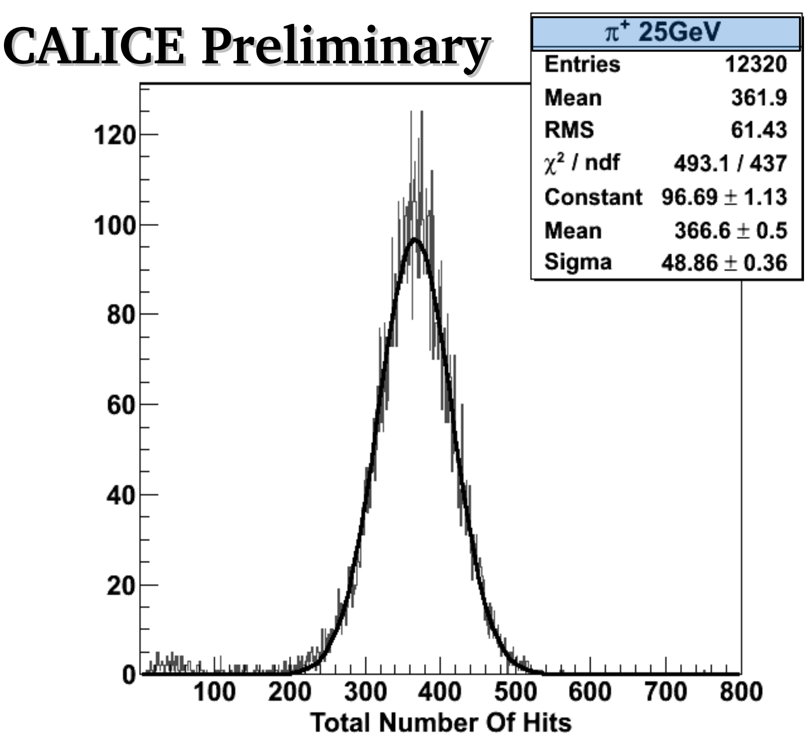
Particle ID Results in Oct '10 Data

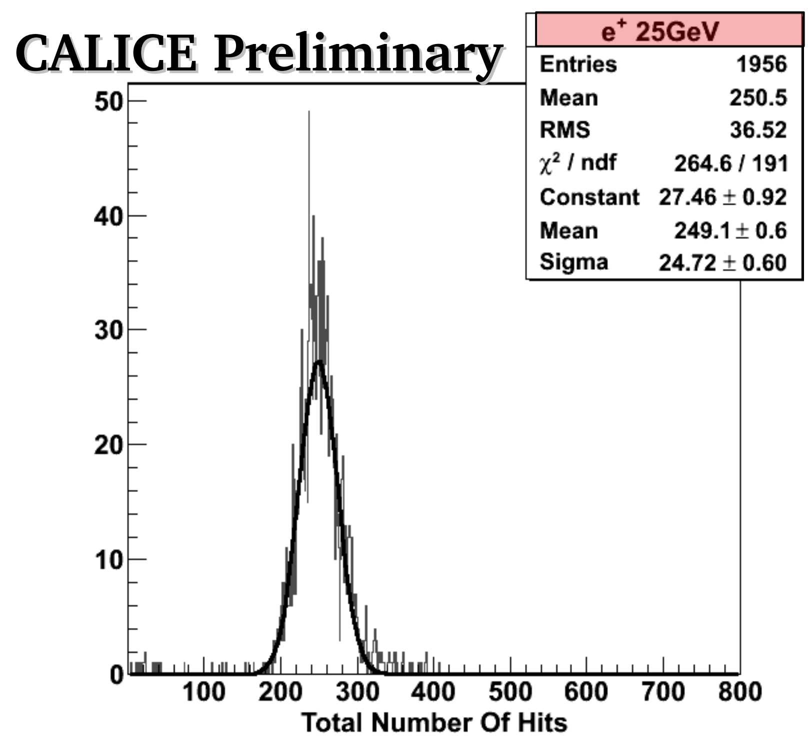


Unidentified μ's, punch through

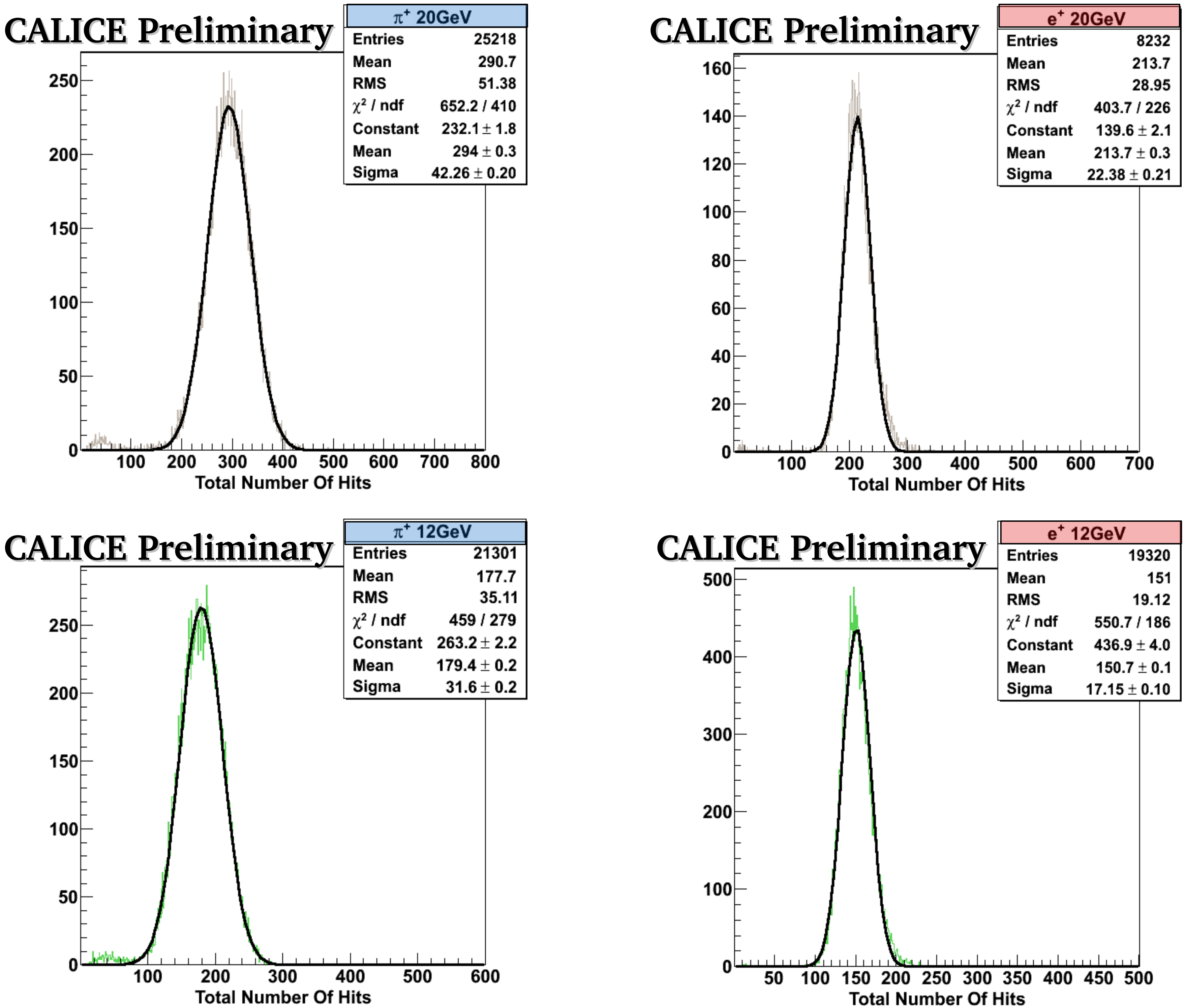


Gaussian fits for the full range

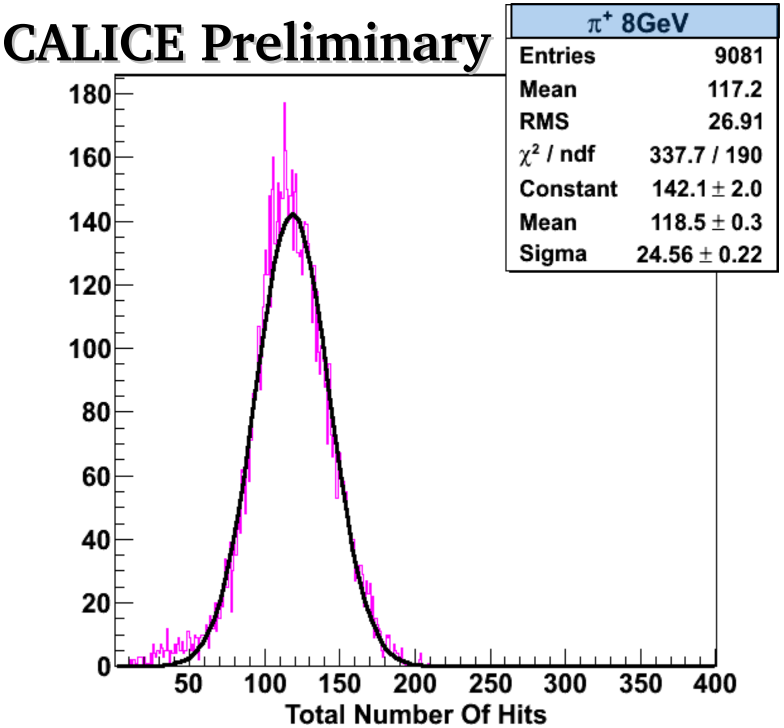


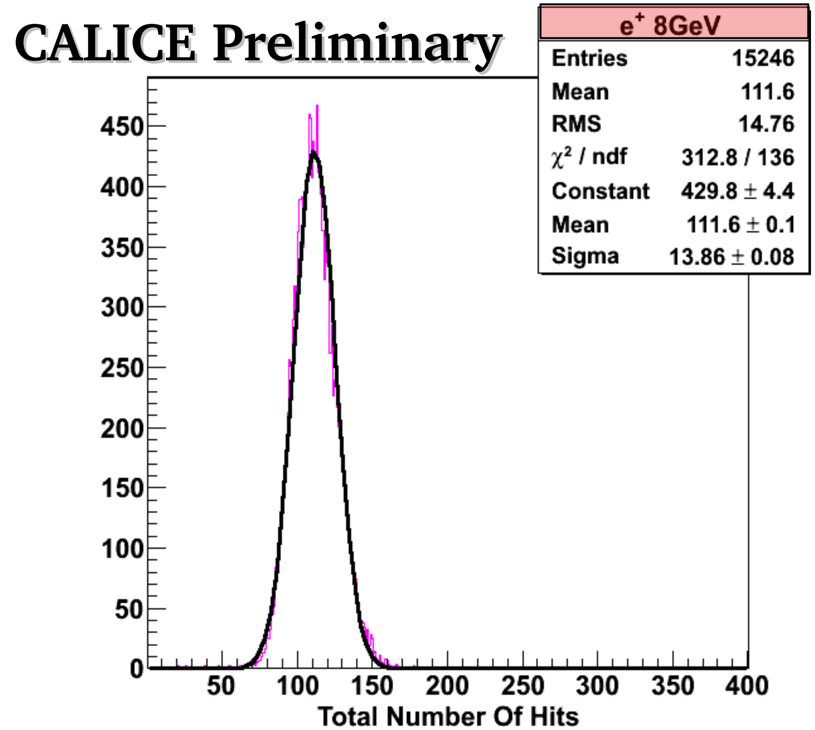


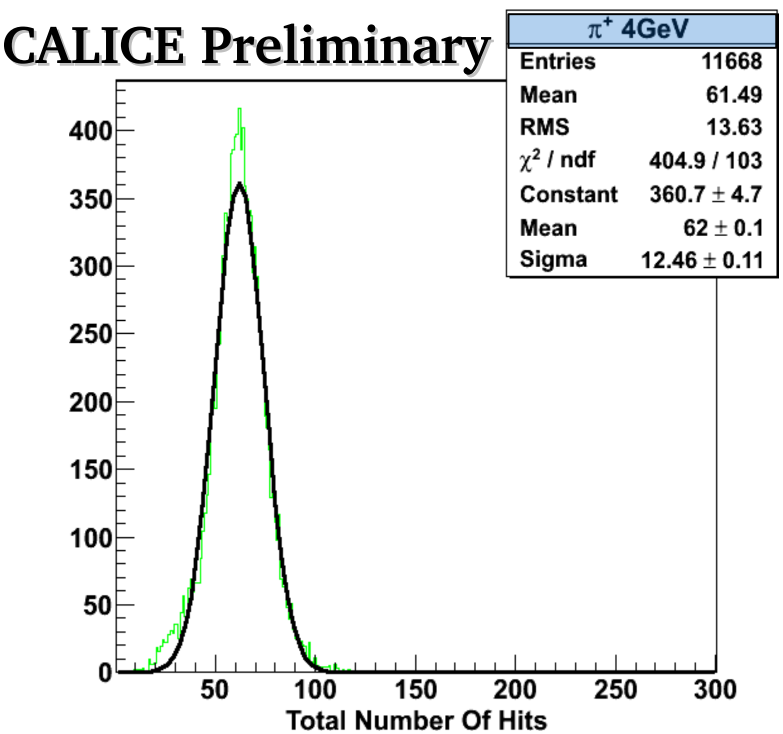
Particle ID Results in Oct '10 Data

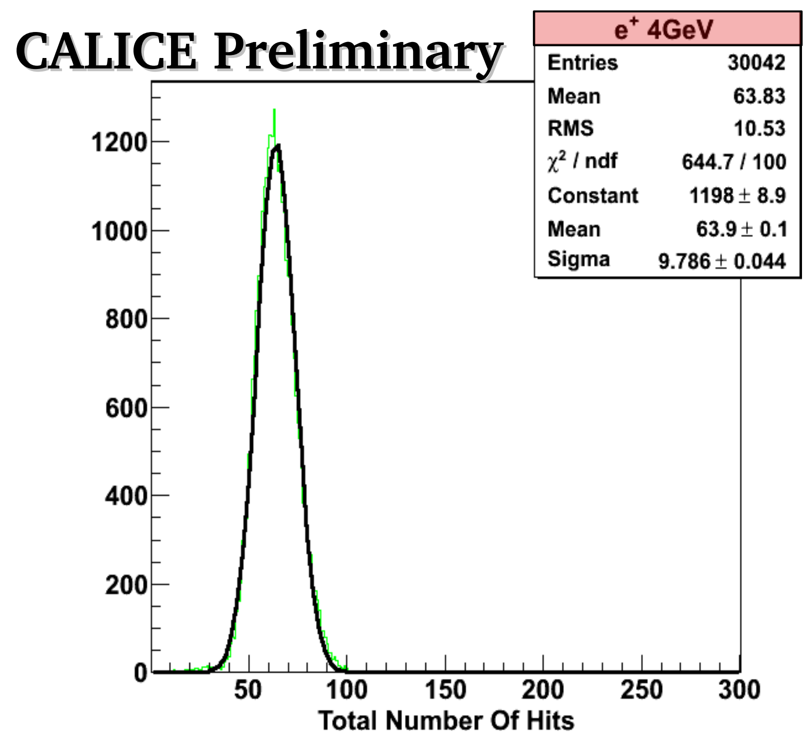


Particle ID Results in Oct '10 Data

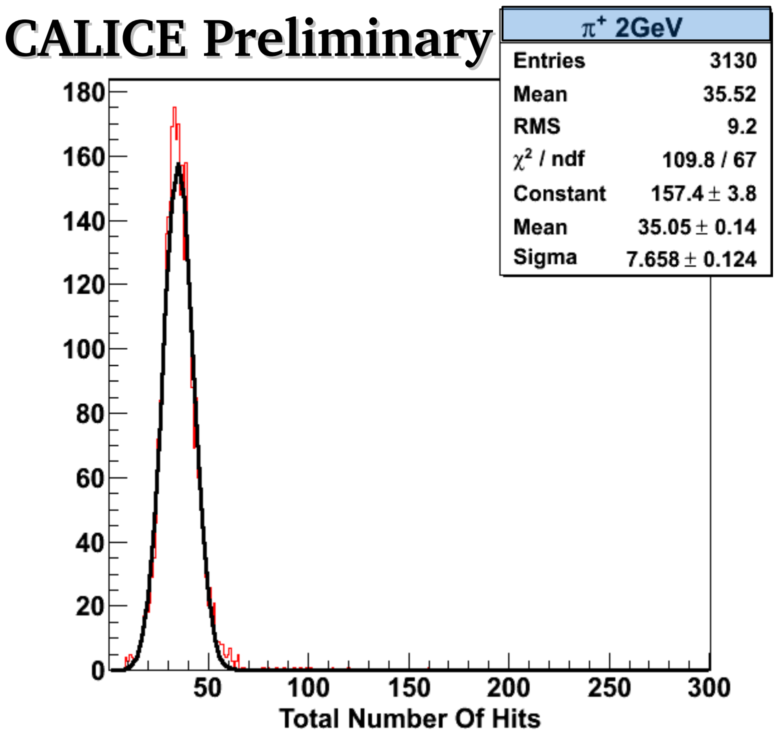


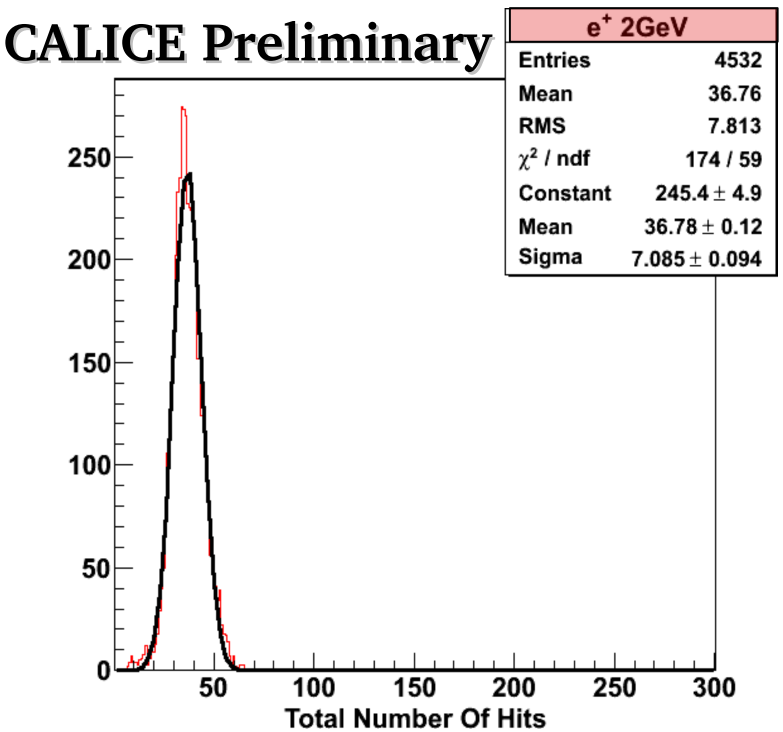






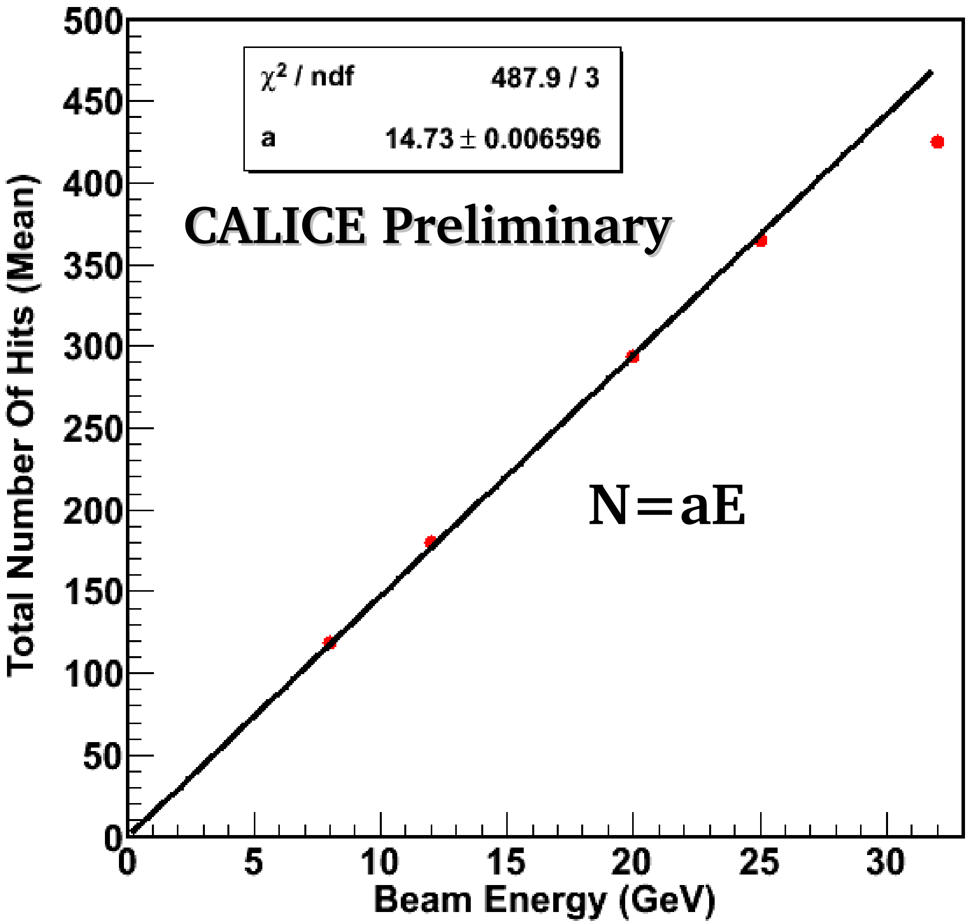
Particle ID Results in Oct '10 Data

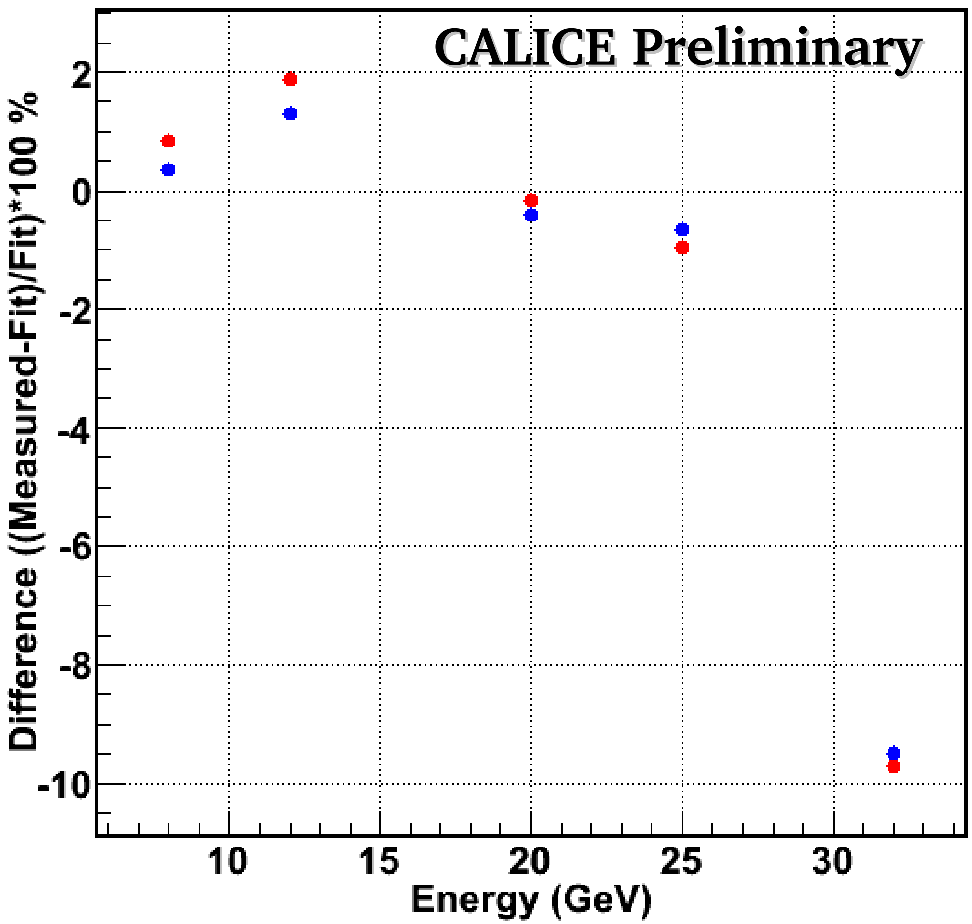




For < 8 GeV/c, the calorimeter is close to compensating. At these momenta, the pion selection is overwhelmed with positrons. We are not able to provide an unbiased sample of pions.

DHCAL Response To Hadrons (Oct '10 Data – Pion ID)

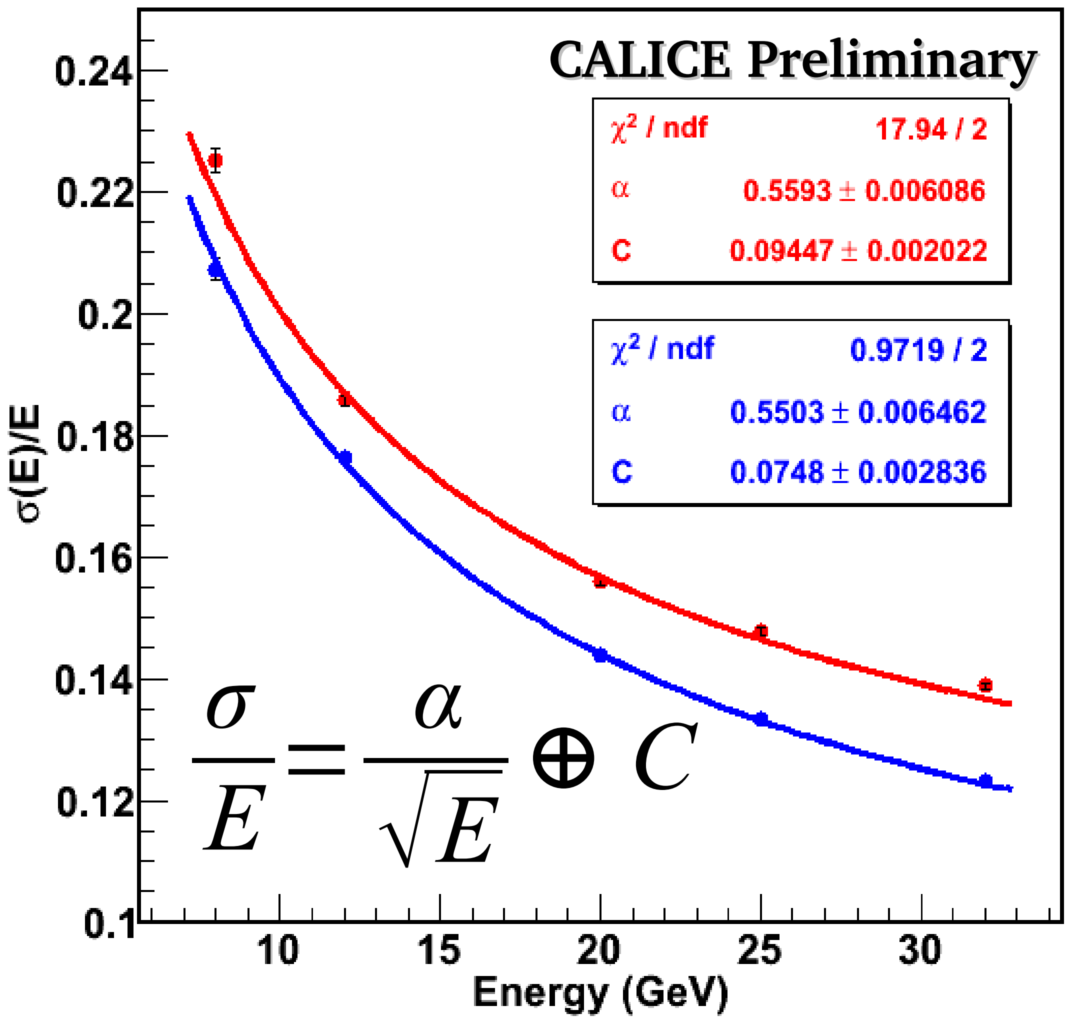


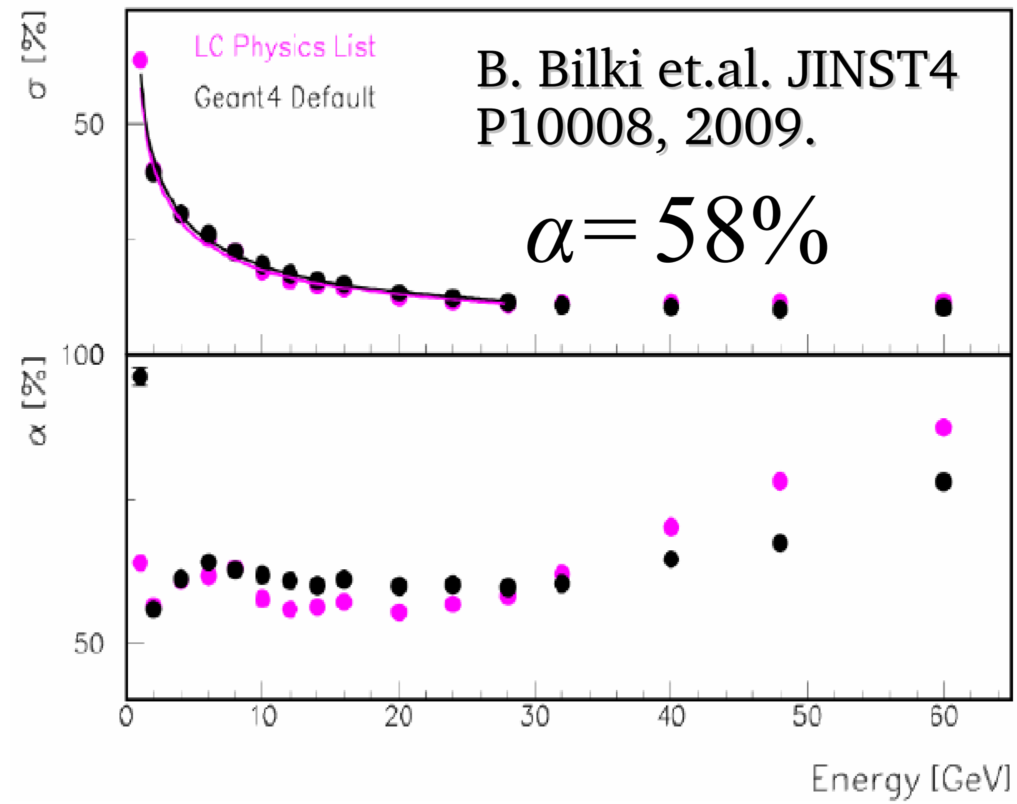


32 GeV data point is not included in the fit (saturation effects become visible).

Standard pion selection
+ No hits in last two layers

DHCAL Response To Hadrons (Oct '10 Data – Pion ID)





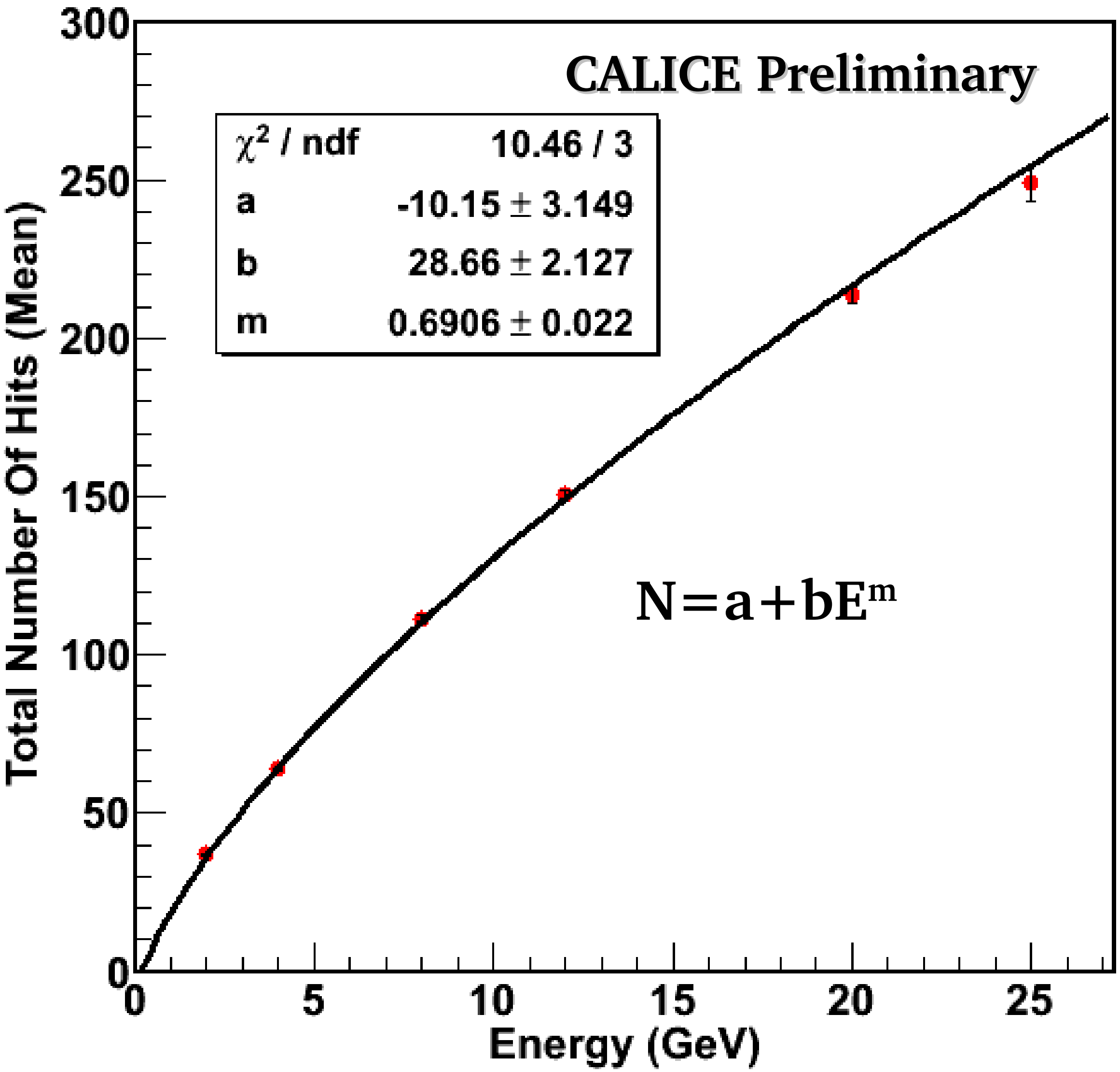
32 GeV data point is not included in the fit.

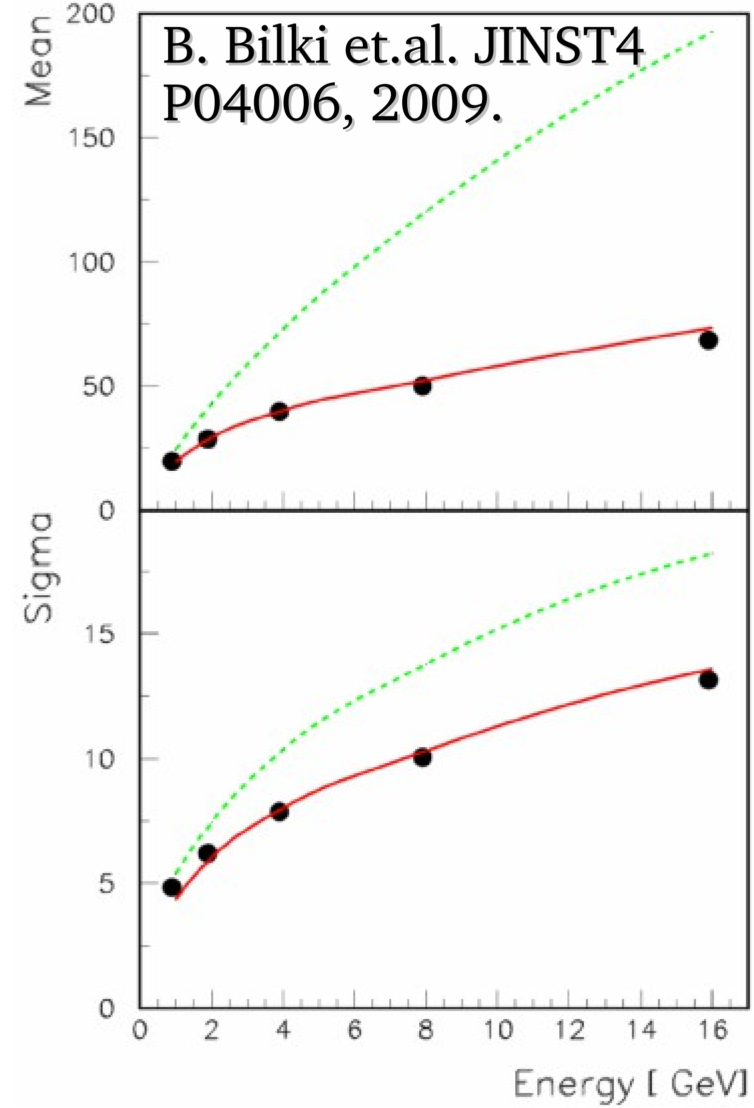
MC predictions for a large-size DHCAL based on the small-size prototype results.

Standard pion selection

+ No hits in last two layers

DHCAL Response To Positrons (Oct '10 Data – Positron ID)

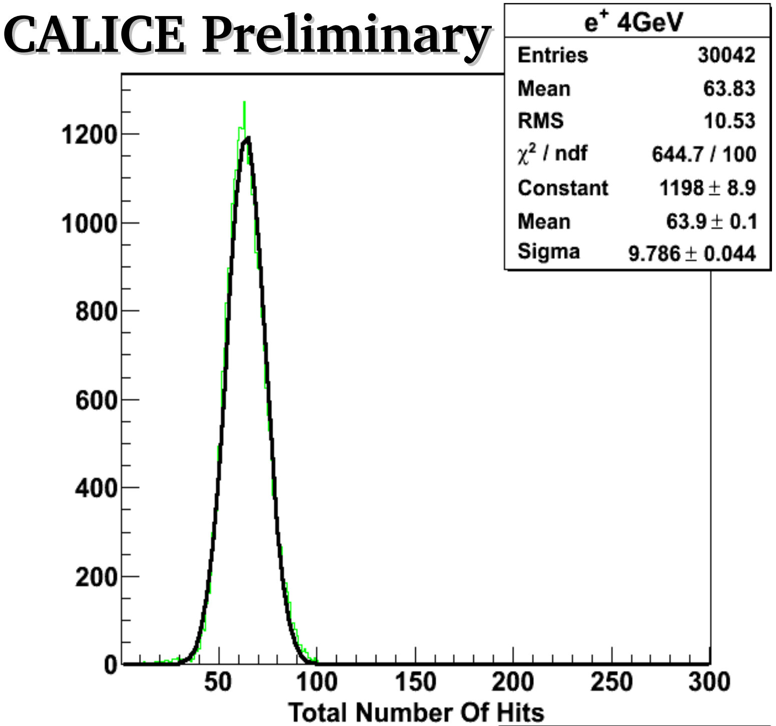


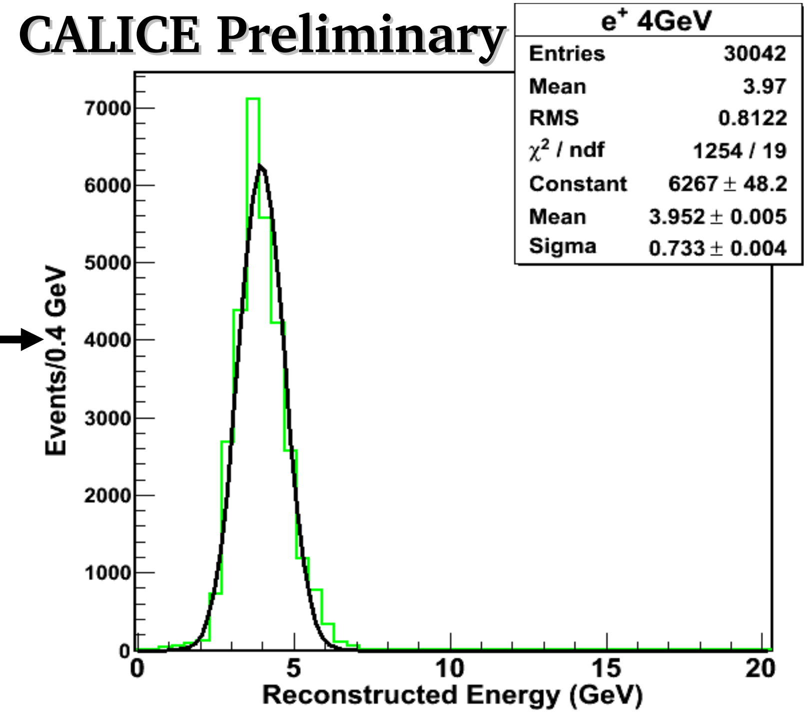


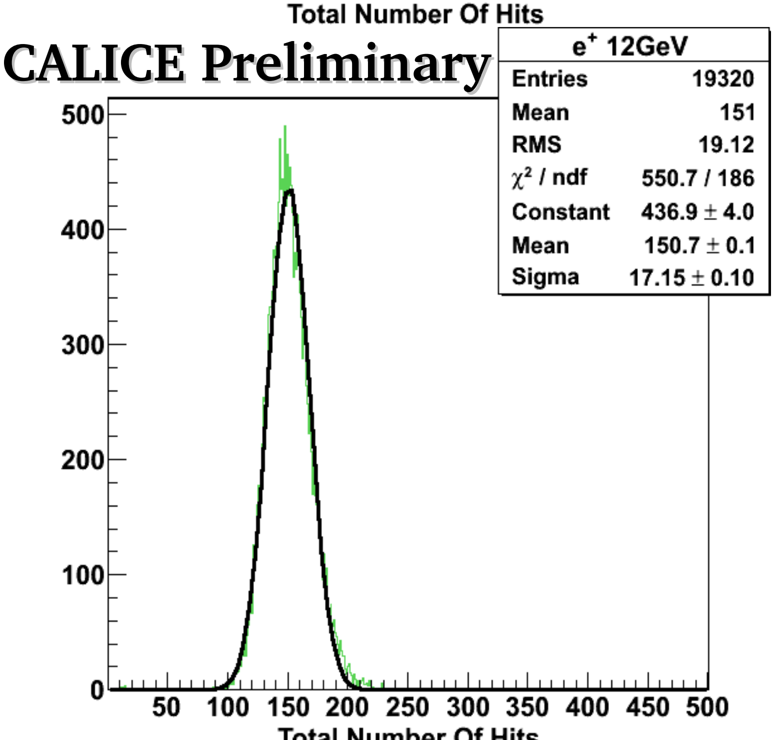
⇨ Reconstruct the positron energies using this fit function on an event by event basis.

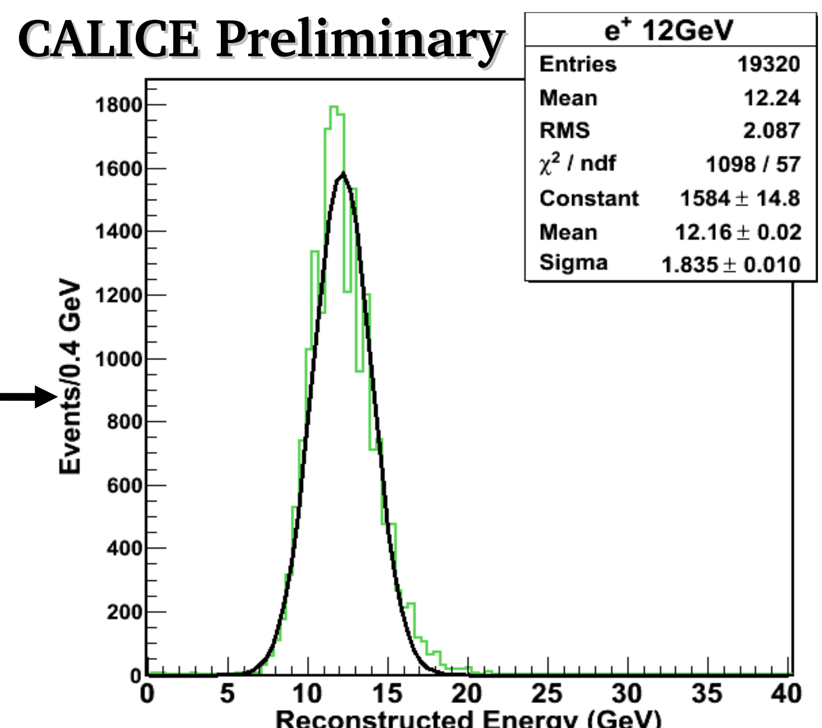
Data (points) and MC (red line) for the small-size prototype and the MC predictions for a large-size DHCAL (green, dashed line).

DHCAL Response To Positrons (Oct '10 Data – Positron ID)

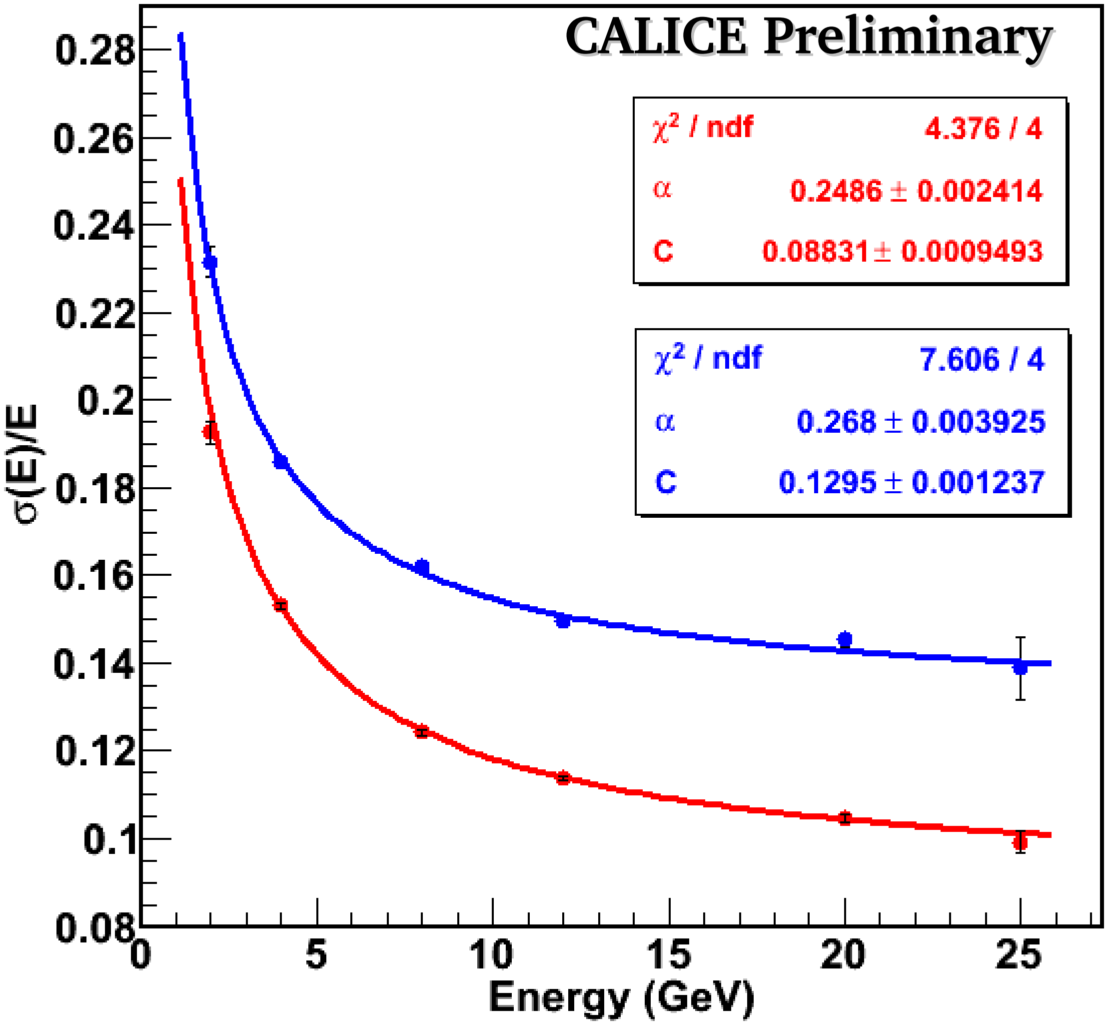








DHCAL Response To Positrons (Oct '10 Data – Positron ID)



$$\frac{\sigma}{E} = \frac{\alpha}{\sqrt{E}} \oplus C$$

Uncorrected for non-linearity

Corrected for non-linearity

Summary

- With the ongoing successful test beam campaigns, the digital hadron calorimeter concept is being validated under extensive physics and technical tests. Here, we present a first look analysis on the October 2010 secondary beam data to obtain the digital hadron calorimeter properties. More sophisticated analyses will be forthcoming in the near future.

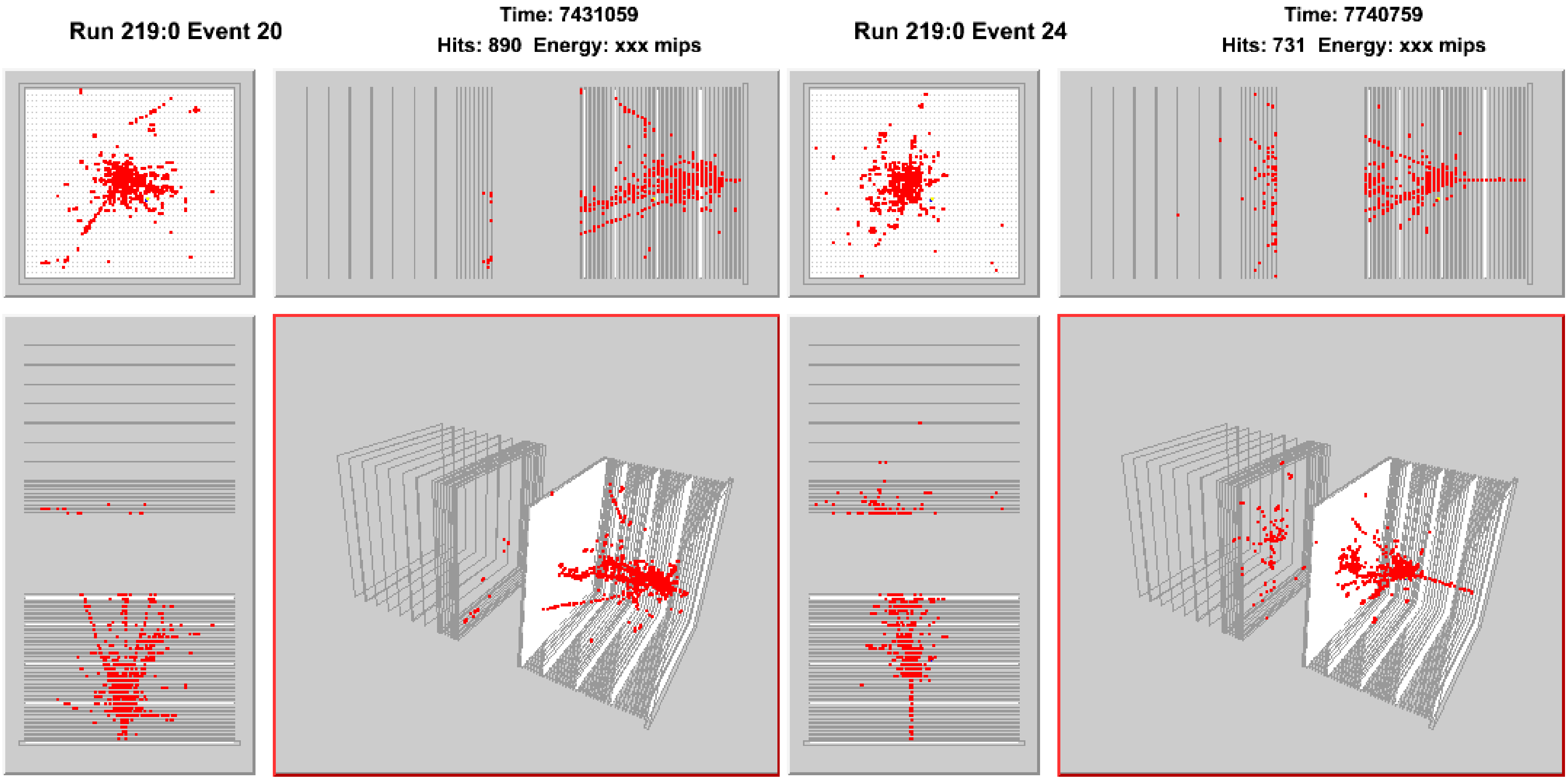
- With the present algorithms, a hadronic energy resolution of $\frac{\sigma}{E} = \frac{55\%}{\sqrt{E}} \oplus 7.5\%$

and an electromagnetic energy resolution between 24% and 14% in the energy range of 2 – 25 GeV are obtained.

- Further methods are being developed to obtain unbiased samples of pure beam particles and to obtain the DHCAL response not only as an energy measuring calorimeter, but also as a unique source of information of detailed hadronic interactions with unprecedented spatial resolution.

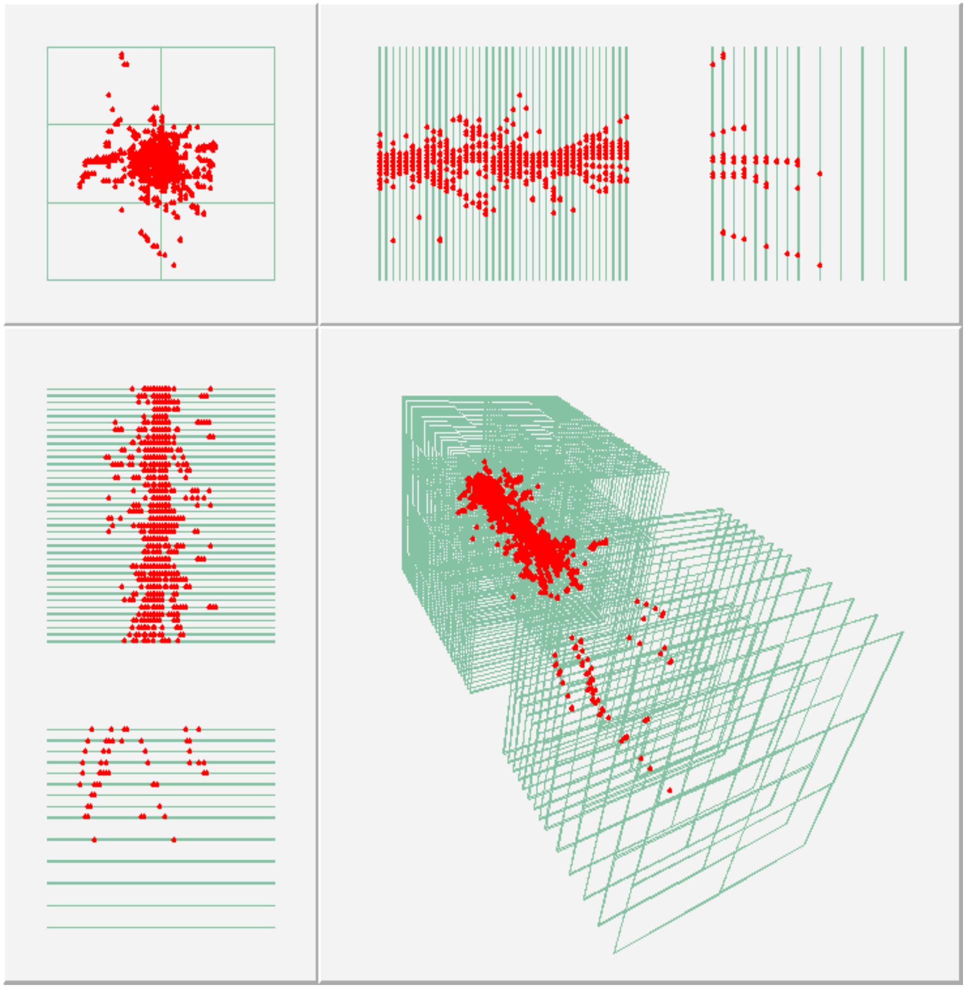
Epilogue

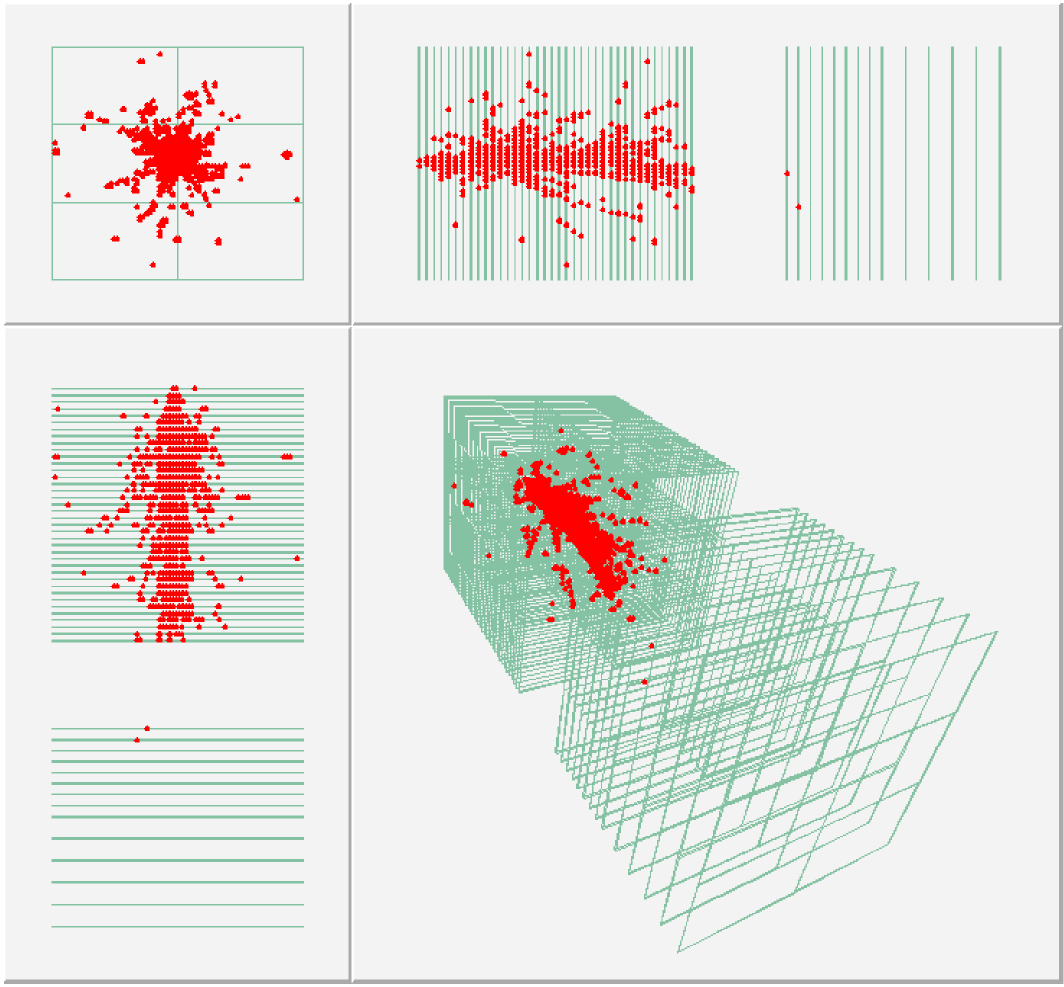
60 GeV/c pions in DHCAL



Epilogue

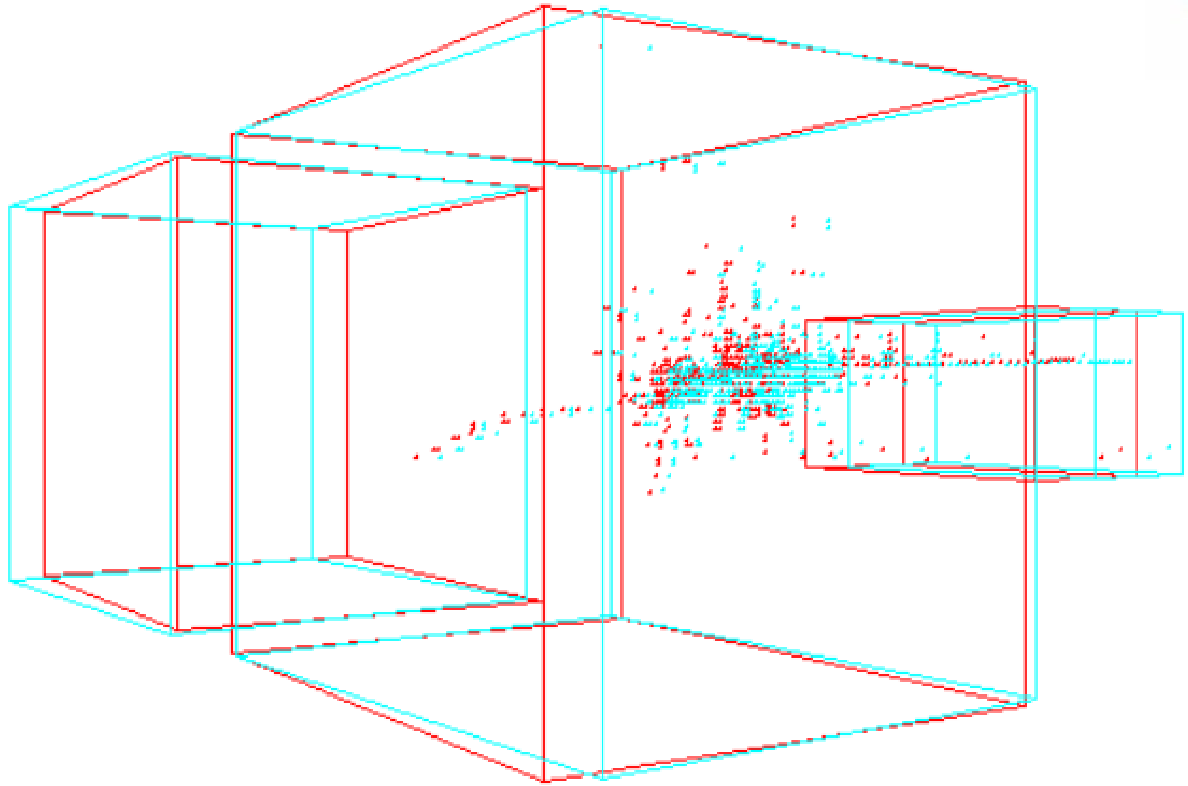
120 GeV/c protons in DHCAL





Epilogue

Combined System (SiW ECAL+DHCAL) in 3D



http://polywww.in2p3.fr/~jeans/autoDisplays_stereo/show.html