TB Data Analysis and Angular Resolution

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CALICE Collaboration Meeting,
Casablanca, Morocco

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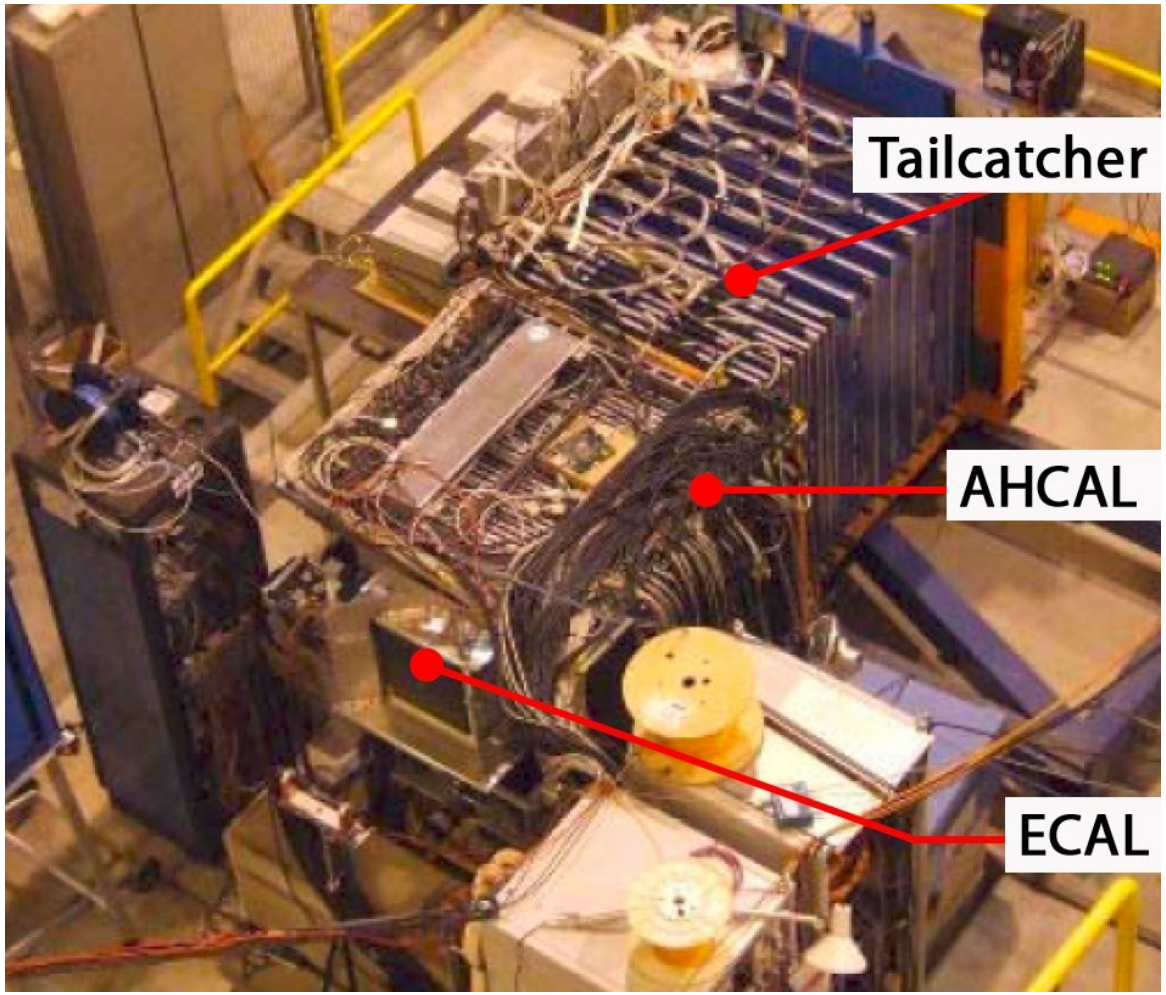
- A look at 2008 data sets
- **Events, calibration and bad channels**
- **Angular resolution studies**
- **Linearity, energy & track resolutions**
- A new tool to track particles

§ DAAD

Test Beam Data



2008 data analysed

No Čerenkov used (yet)

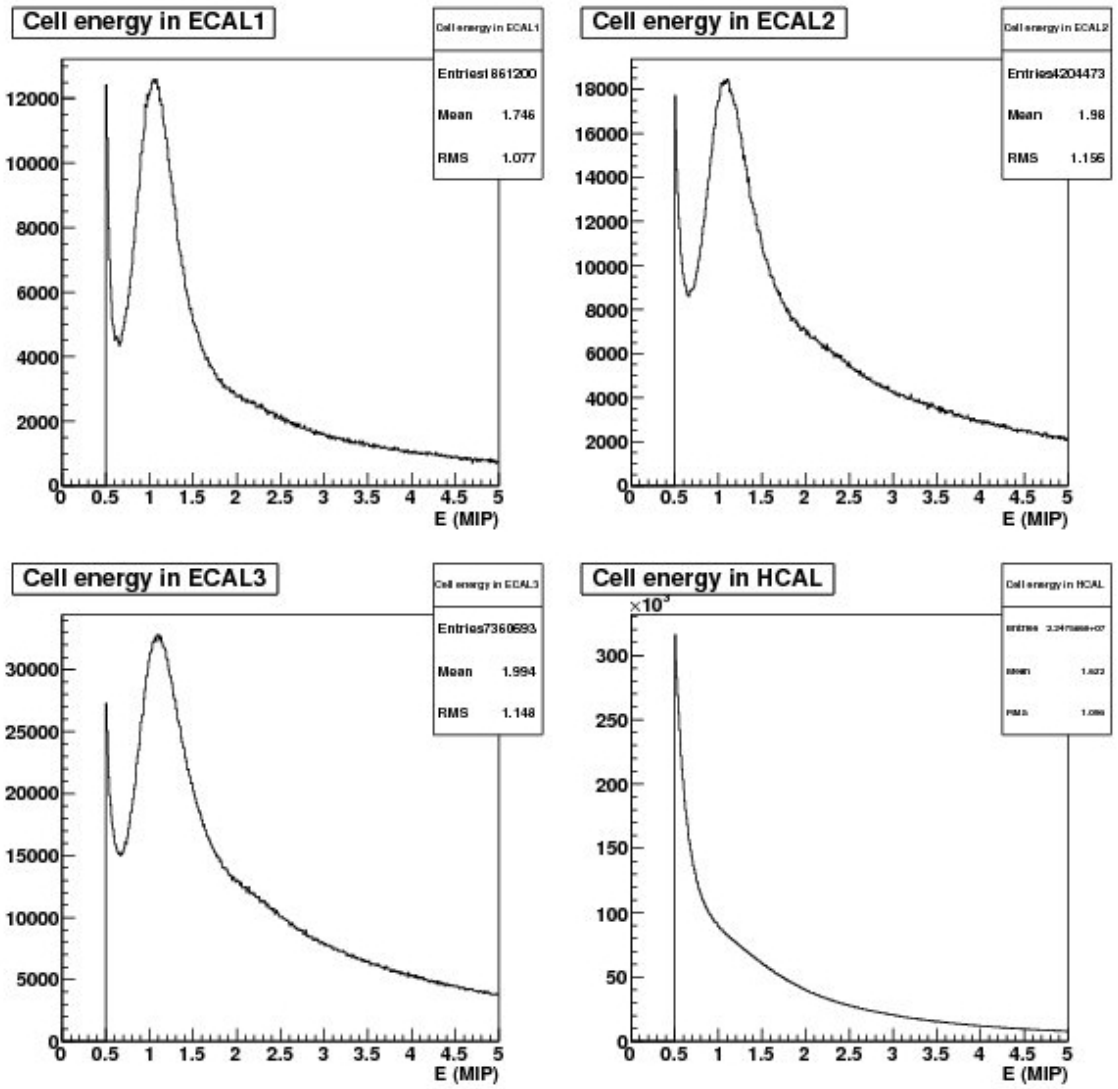
Data Sets:

- electrons 8 & 20 GeV
- muons 32 GeV
- pions 10 – 60 GeV
- angles from 0° to 30°

Calibration used is as in CALICE Analysis Note CAN-015

Noise and Data Handling

40 GeV data



Noise removal threshold cut at 0.7 mip in all ECAL modules ("cleaning").

Others:

Flashing channels: kept

Flashing layers: skipped

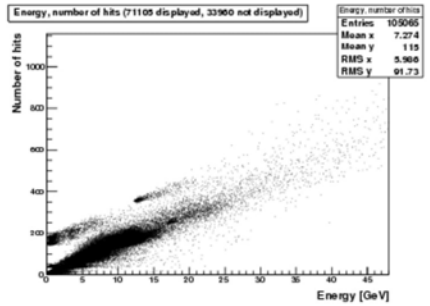
Missing Layers: skipped

First layer(s): no cut

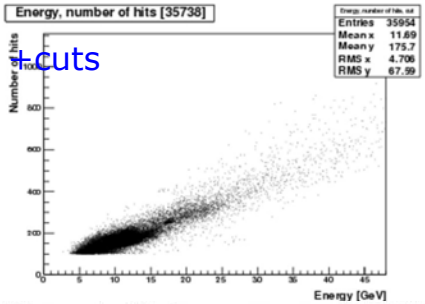
i.e. no energy correction done to compensate for those cases

Hits vs Energy for all datasets

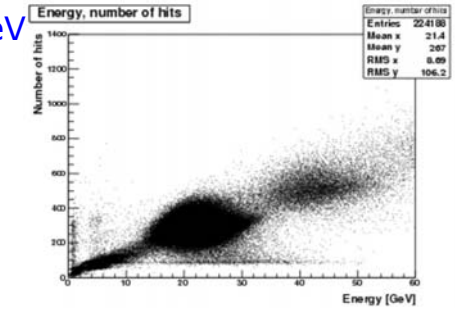
e, 8 GeV



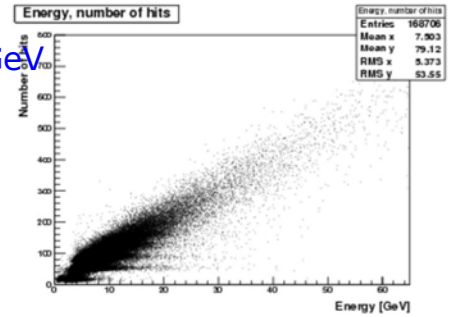
e, 8 GeV, +cuts



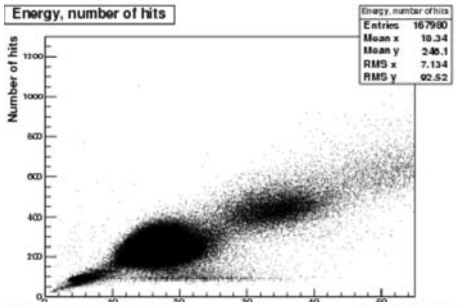
e, 20 GeV



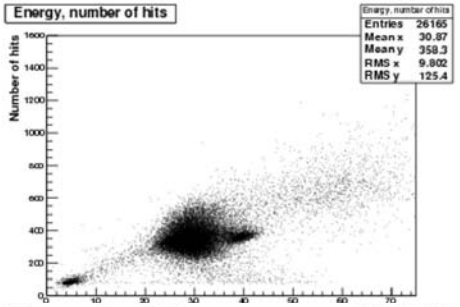
μ, 32 GeV



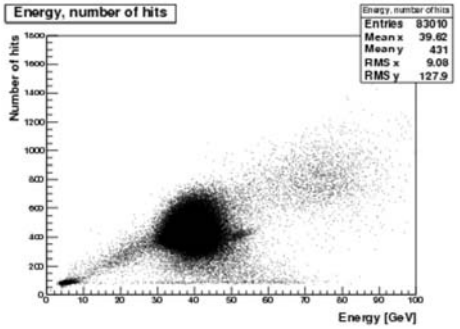
π, 15 GeV



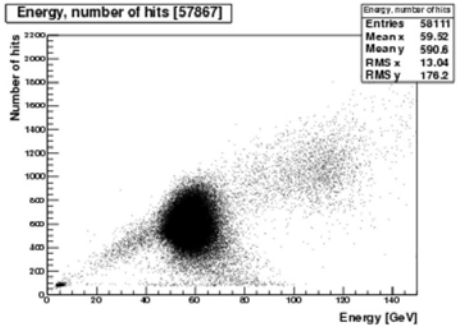
π, 30 GeV



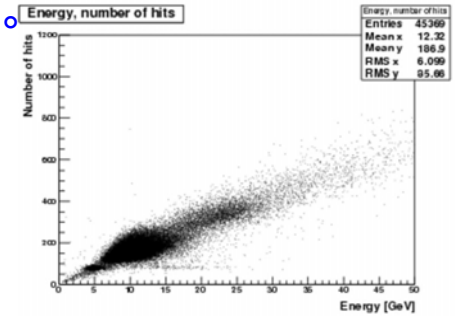
π, 40 GeV



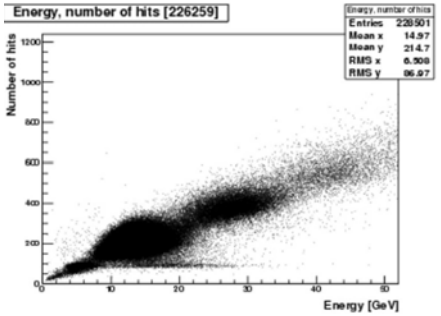
π, 60 GeV



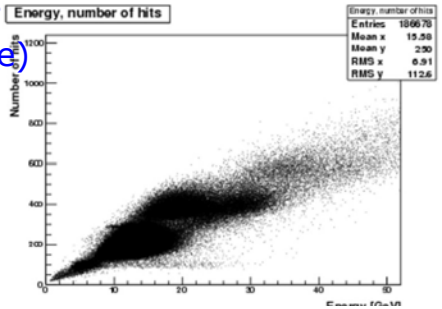
π, 10 GeV, 10°



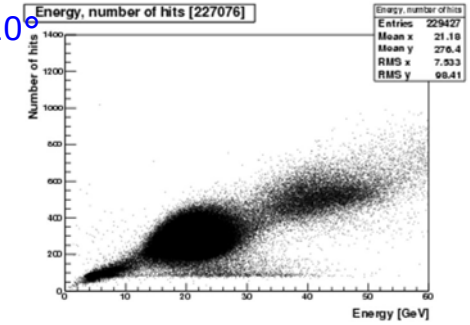
π, 12 GeV, 0°



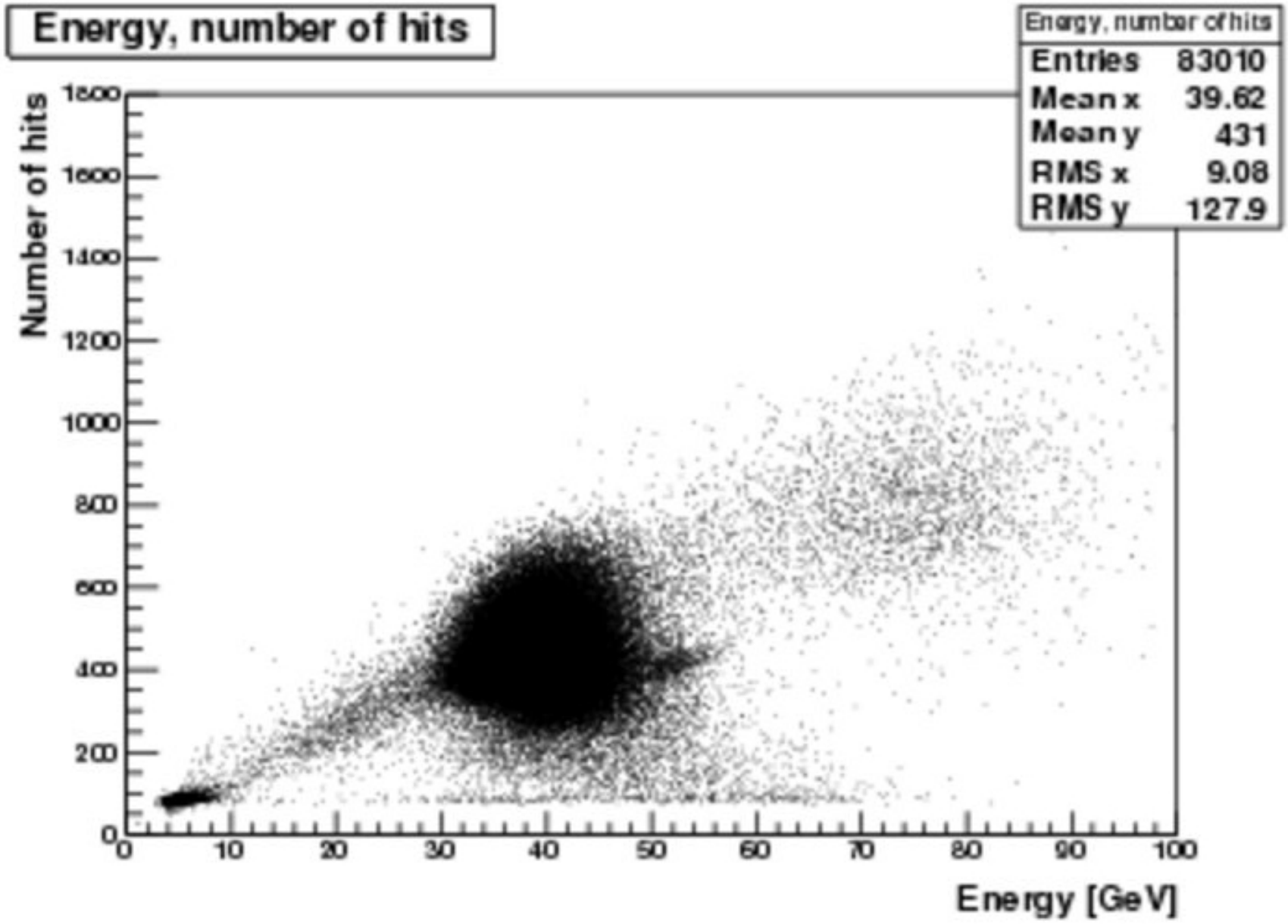
π, 12 GeV, 30°
(misfiring plane)



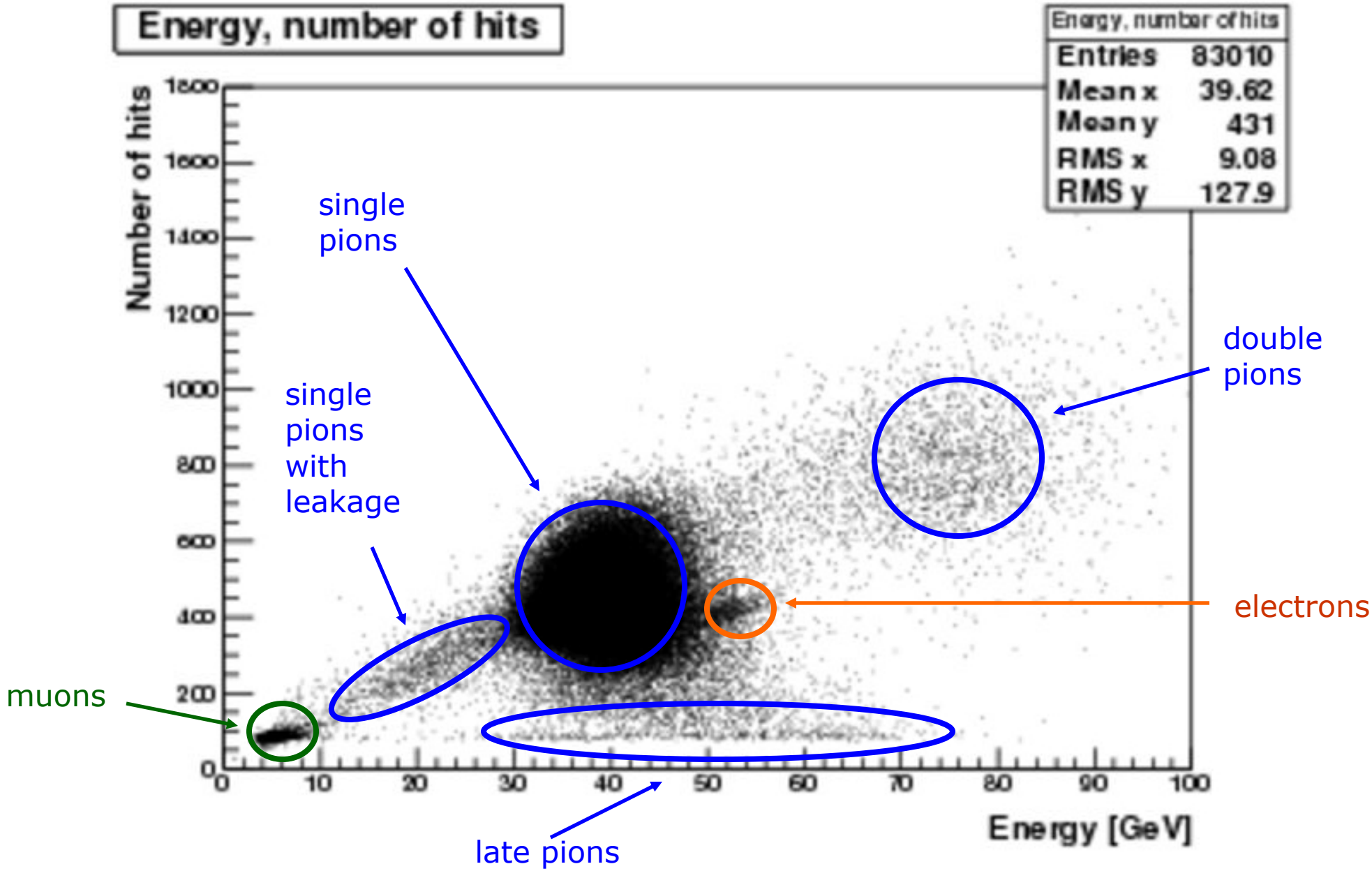
π, 20 GeV, 20°



Hits vs Energy - 40 GeV π



Hits vs Energy - 40 GeV π



Event Display - 40 GeV π

Pi40

Beam type: Pion40GeV

Eventnumber: 1128

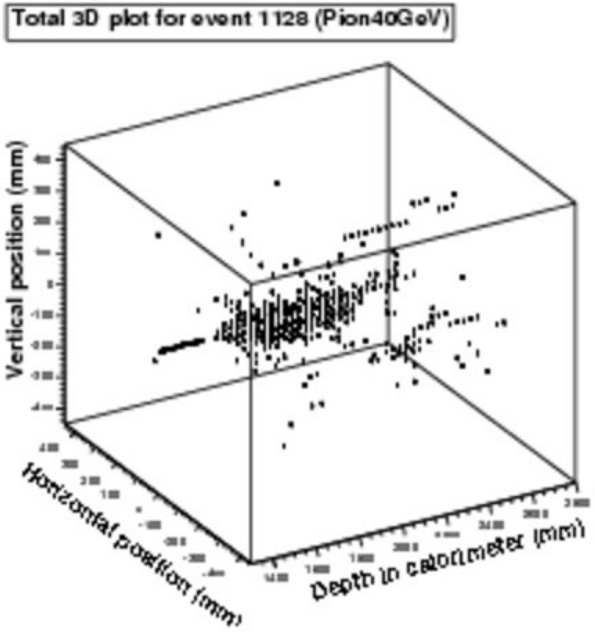
Entrynumber: 1

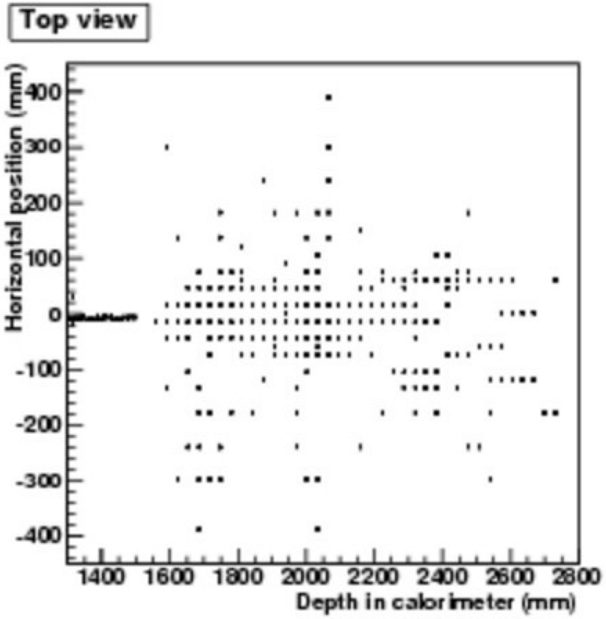
Total energy: 42.06 GeV

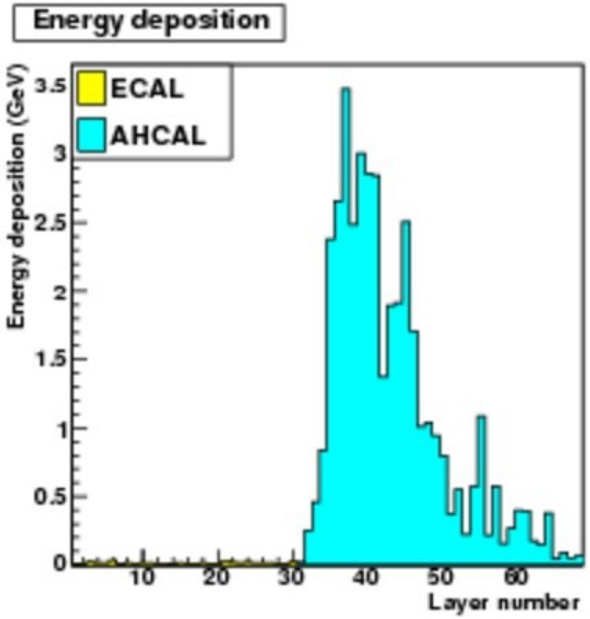
Energy deposition in ECAL: 0.42 GeV

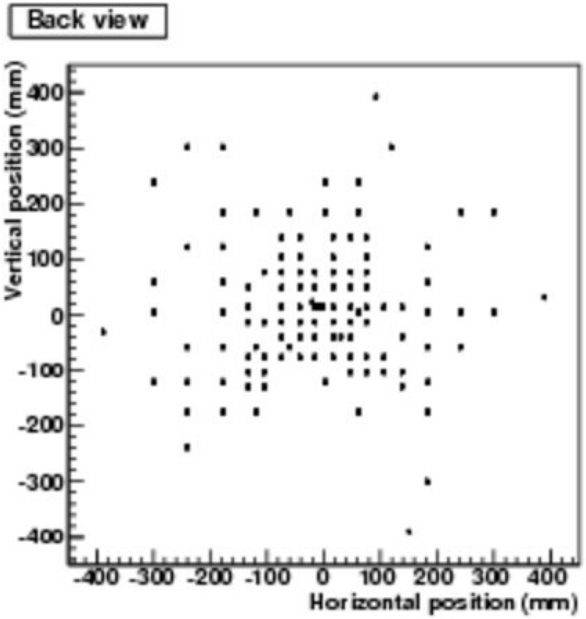
Energy deposition in AHCAL: 40.25 GeV

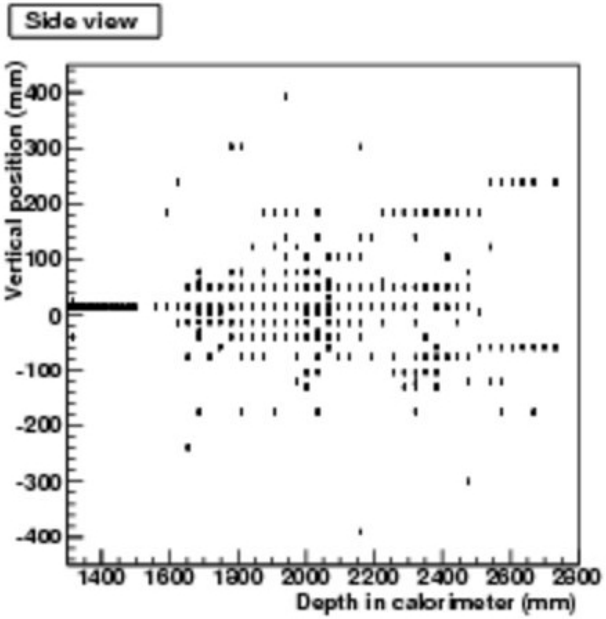
Energy deposition in TCMT: 1.40 GeV











Event: 1 pion + 1 electron

Pi30

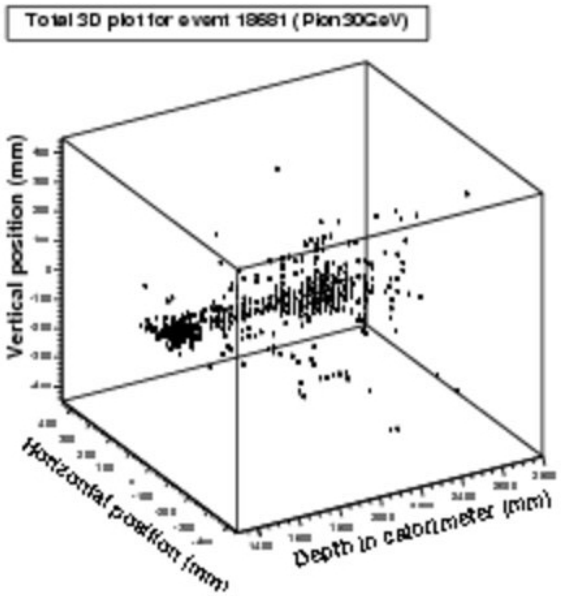
Beam type: Pion30GeV

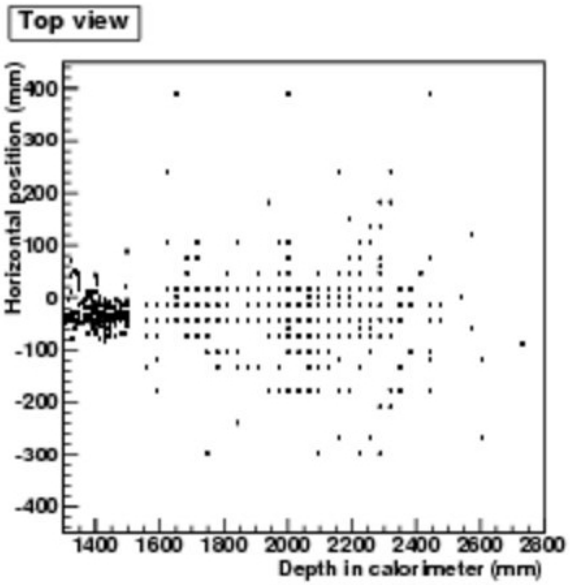
Event 18681

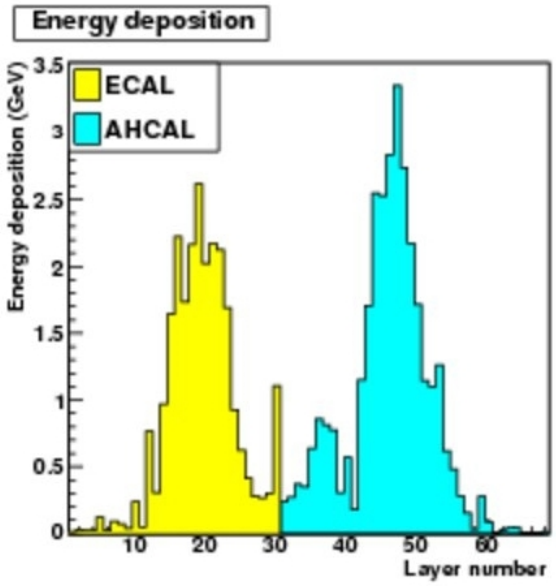
Energy deposition in ECAL: 25.08 GeV

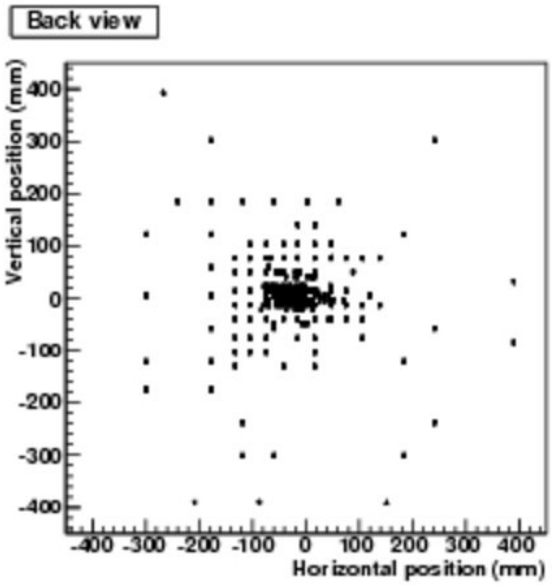
Energy deposition in AHCAL: 31.72 GeV

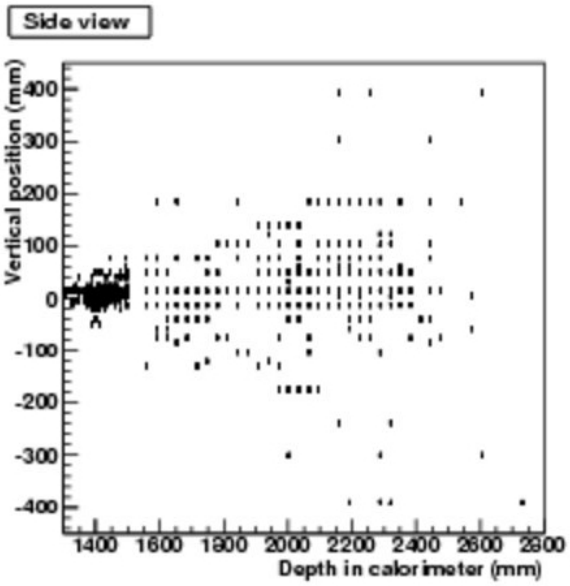
Energy deposition in TCMT: 0.36 GeV











Event: 1 pion + 1 muon

Pi12

Beam type: Pion12GeV

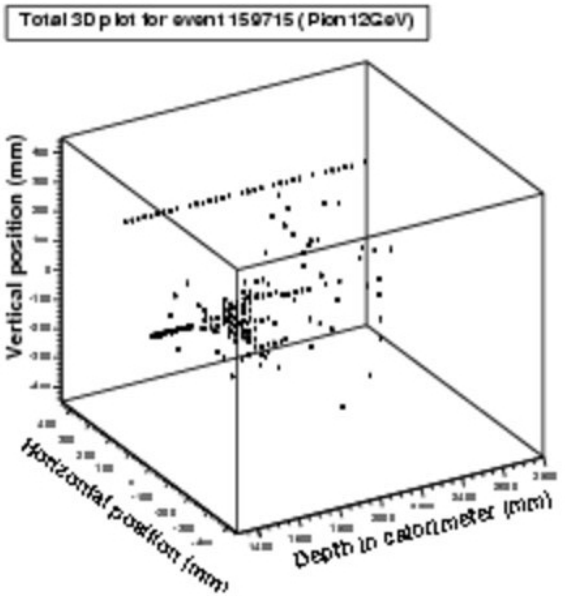
Event 159715

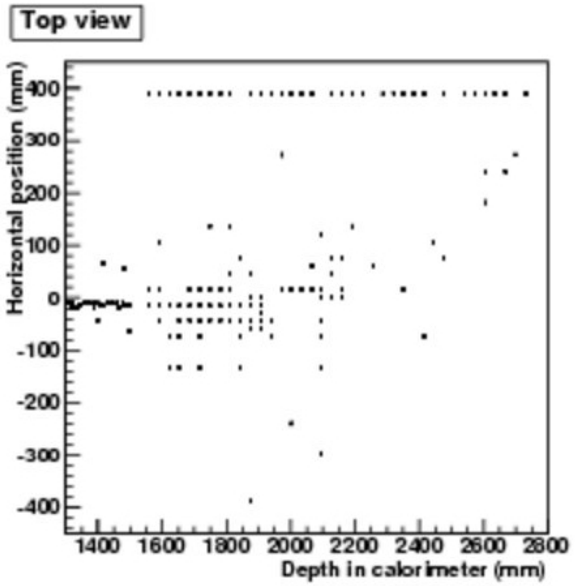
Total energy: 15.00 GeV

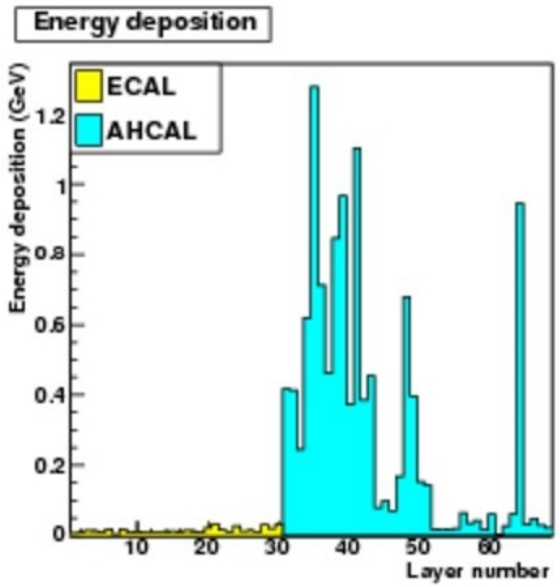
Energy deposition in ECAL: 0.43 GeV

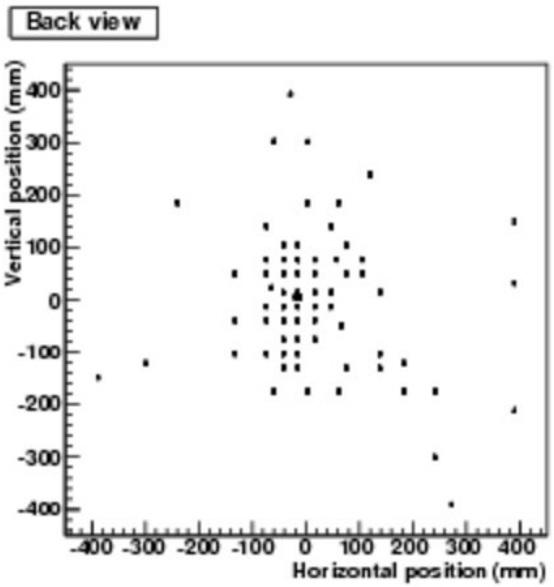
Energy deposition in AHCAL: 11.53 GeV

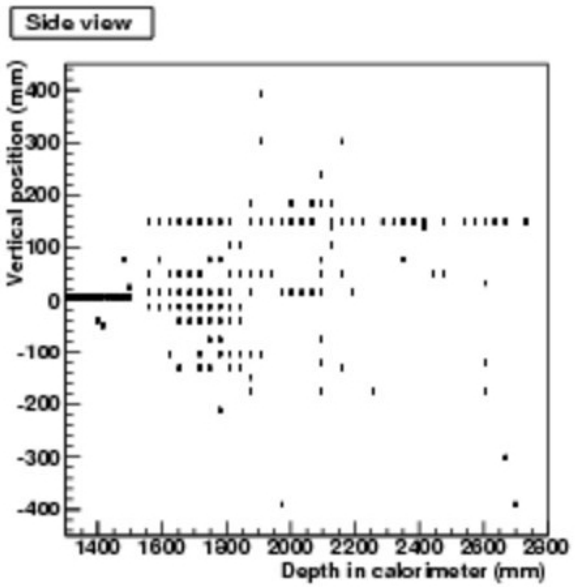
Energy deposition in TCMT: 3.04 GeV











Muons

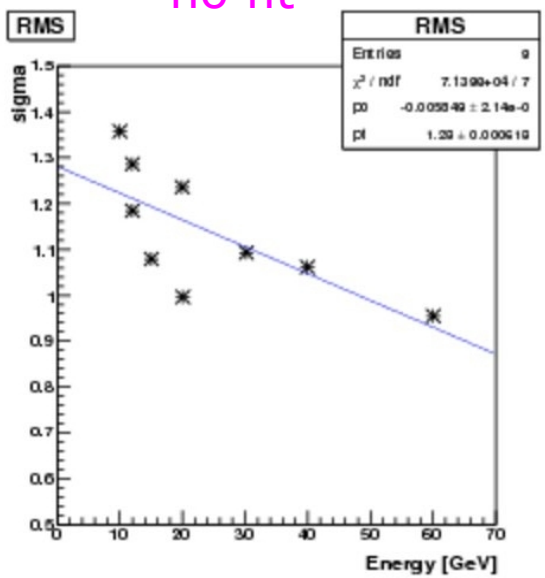
Signal widths

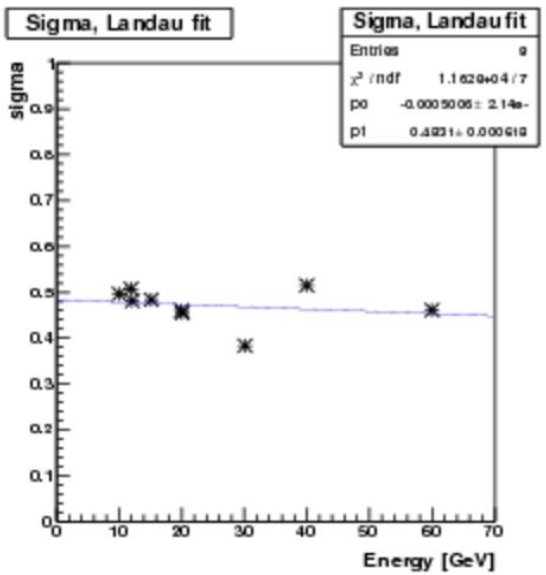
Signal means

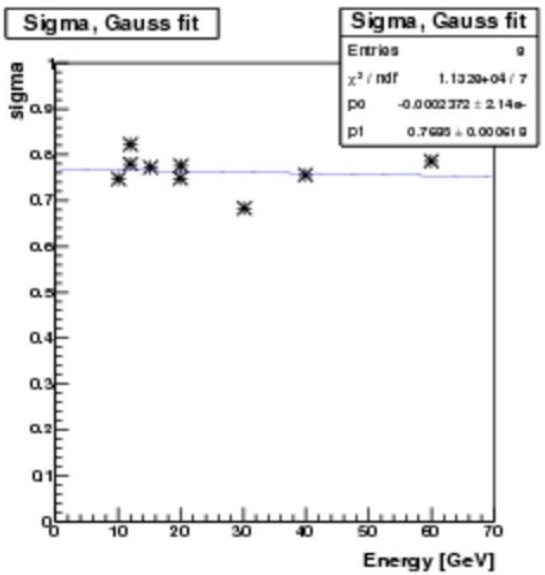
no fit

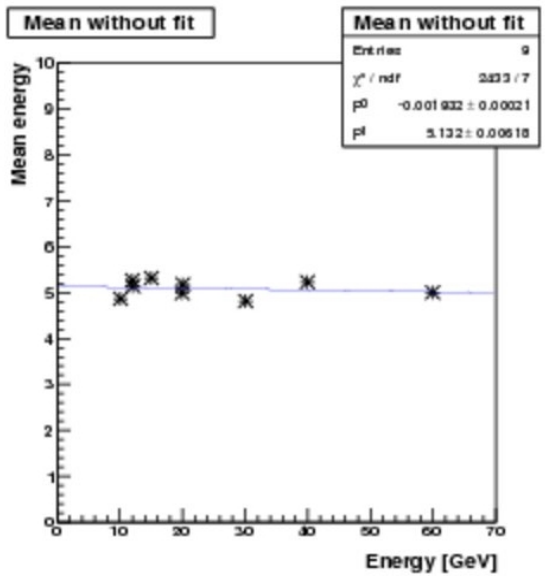
Landau fit

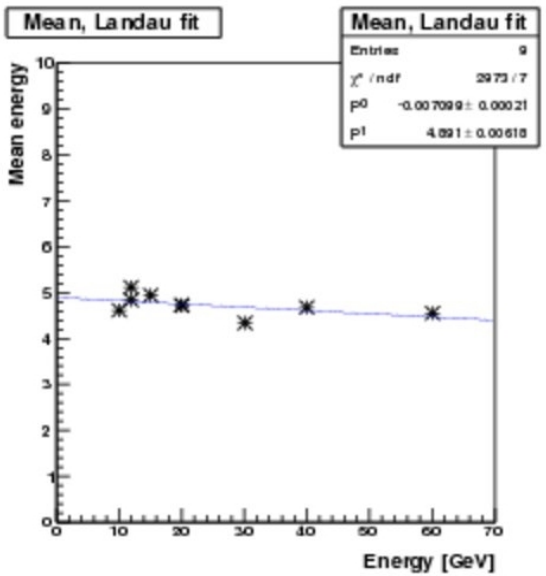
Gauss fit

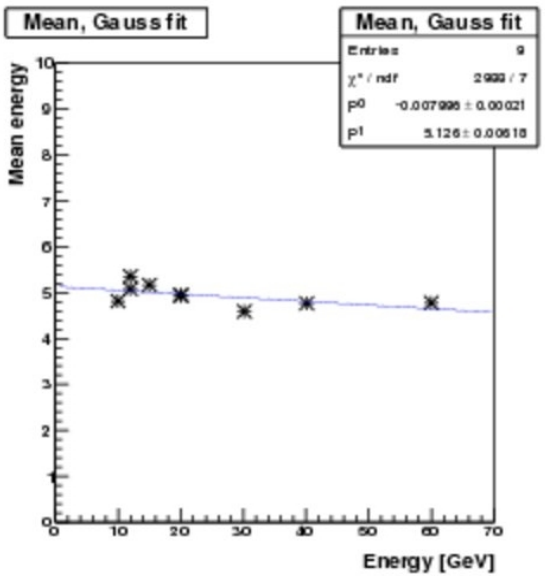










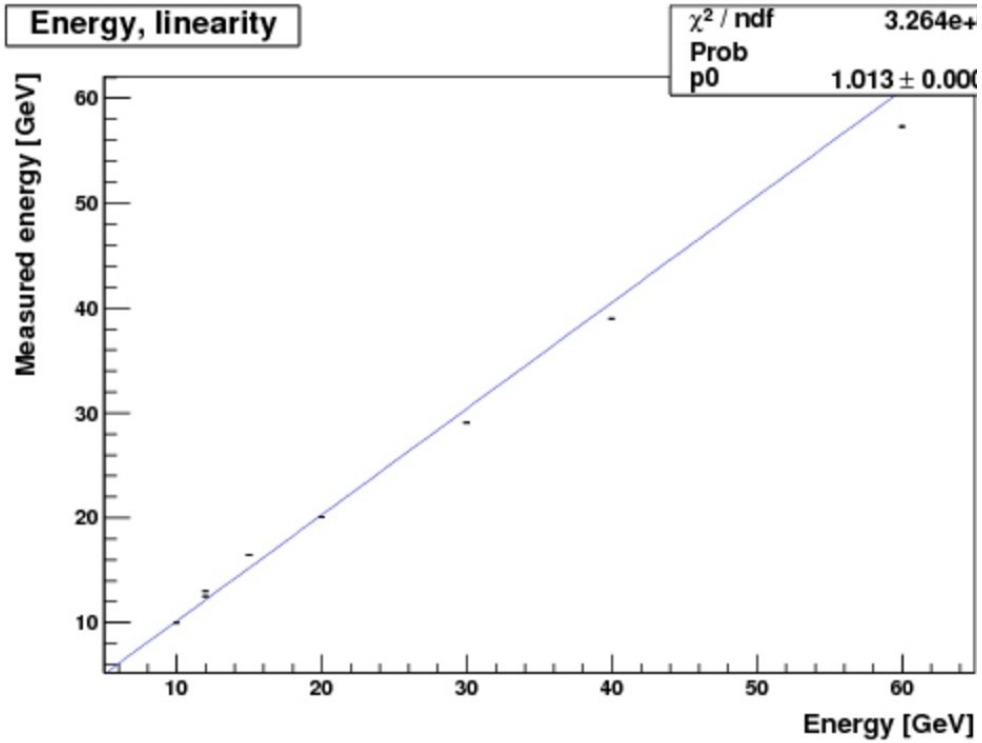


Results ~ independent of muon energy

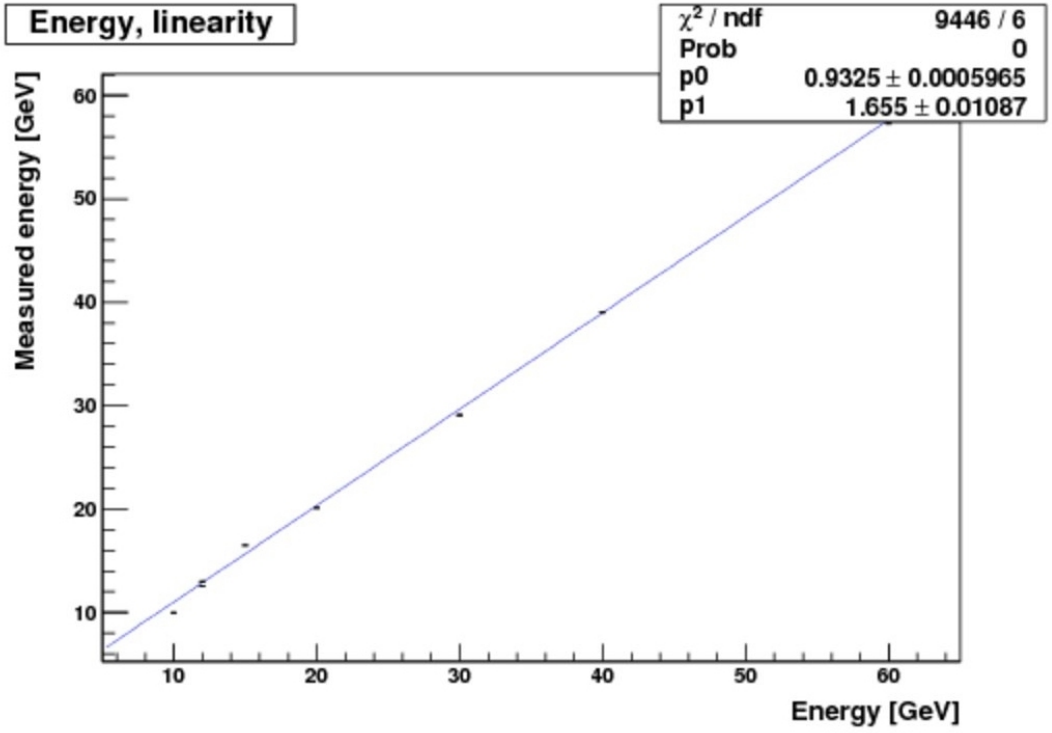
Linearity

For single pions

Only slope



Slope + Constant

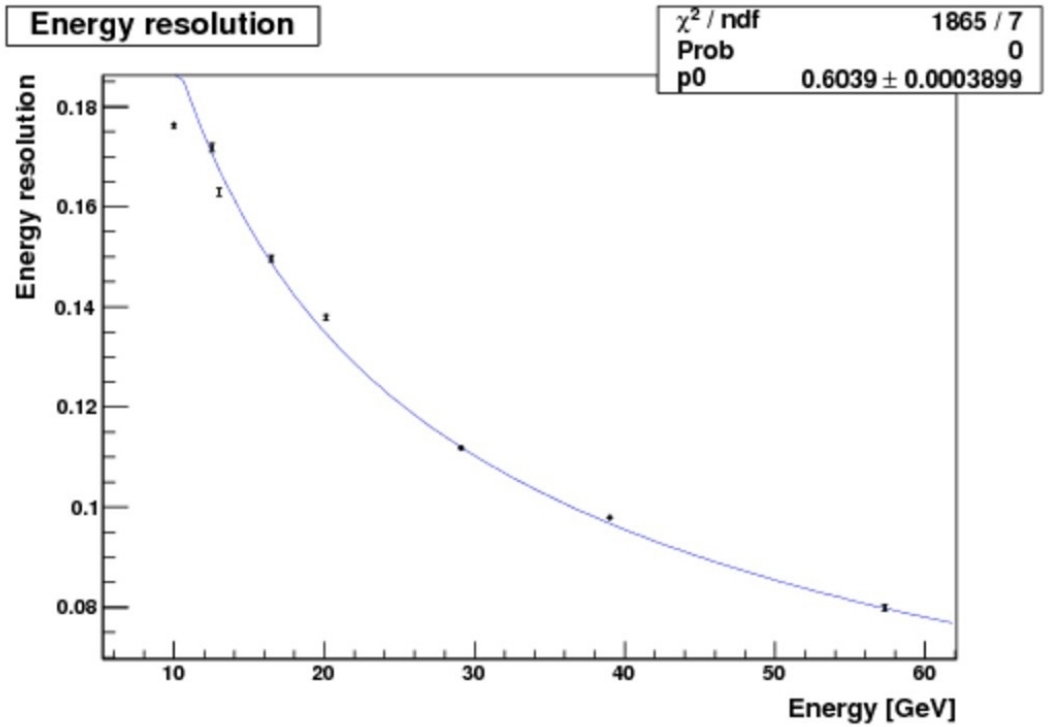


Very preliminary plot: disregard errors

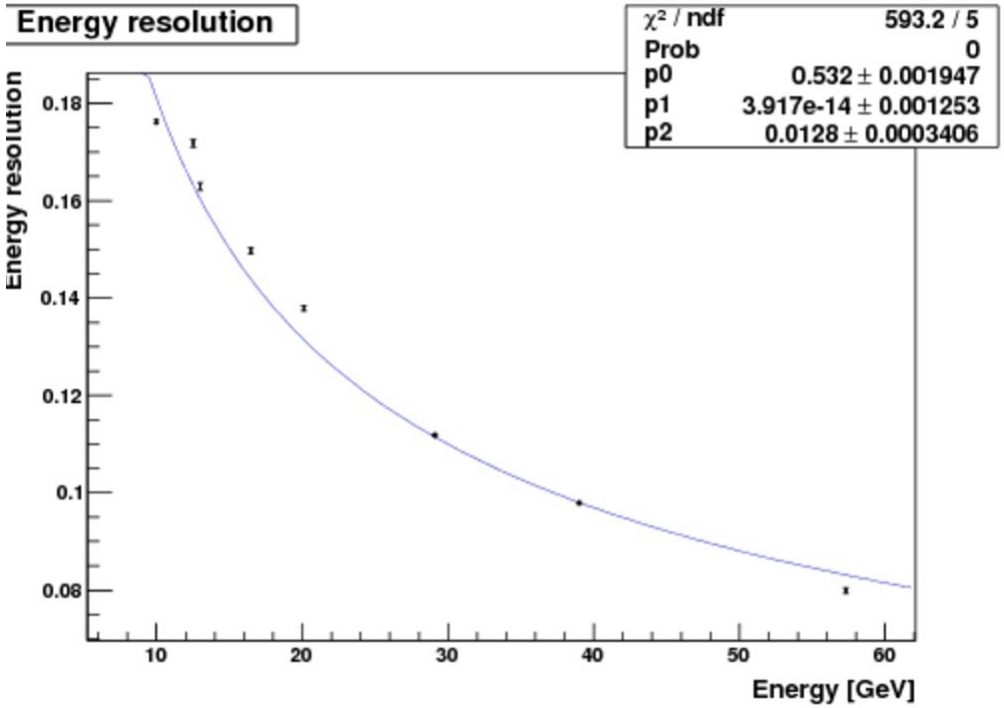
Energy Resolution

For single pions

Stochastic term only



All terms



$$\frac{\sigma_E}{E} = \frac{p_0}{\sqrt{E}} \oplus \frac{p_1}{E} \oplus p_2$$

Very preliminary plot: disregard errors.

Results similar to other CALICE analyses.

Angular Resolution

Dynamic angular resolution algorithm:

1. Treat a shower as a cloud of point masses.
2. Determine the best ("**dynamic**") method of analysis:
   - If a mip track can be identified (≥5 layers), restrict points used to the track.
   - If early shower but $E_{ECAL} > 0.9 \cdot E_{total}$, restrict points used to ECAL only.
   - Otherwise, both ECAL and HCAL informations are used.
3. Disregard any point that fails any other cut specified.
4. Calculate the center of mass of the cloud of point masses
5. Compute the inertial tensor of the cloud relative to the center of mass:

$$\mathrm{I} = \sum_{i=1}^{n} E_i \begin{pmatrix} \Delta y_i^2 + \Delta z_i^2 & -\Delta x_i \Delta y_i & -\Delta x_i \Delta z_i \\ -\Delta x_i \Delta y_i & \Delta x_i^2 + \Delta z_i^2 & -\Delta y_i \Delta z_i \\ -\Delta x_i \Delta z_i & -\Delta y_i \Delta z_i & \Delta x_i^2 + \Delta y_i^2 \end{pmatrix}$$

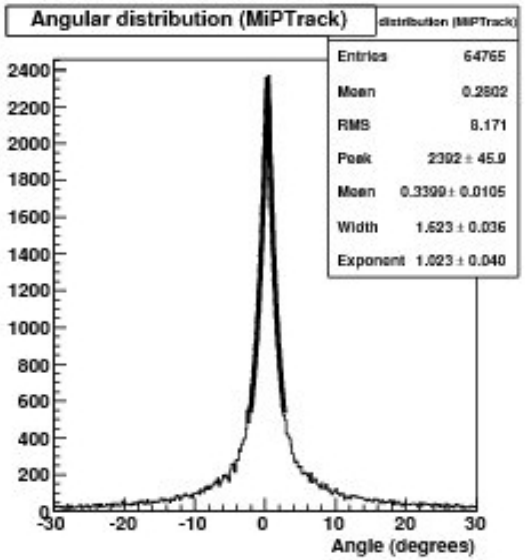
6. Find eigenvectors of the tensors. The one corresponding to the smallest eigenvalue is the main axis of the shower.
7. Take the angle of incidence from the entries of the chosen eigenvector.

$$\Theta = \frac{180^\circ}{\pi} \arctan\left(\frac{x}{z}\right)$$

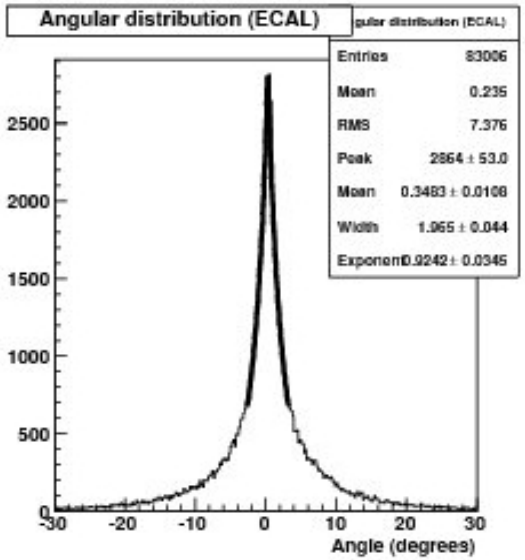
Angular Resolution

40 GeV

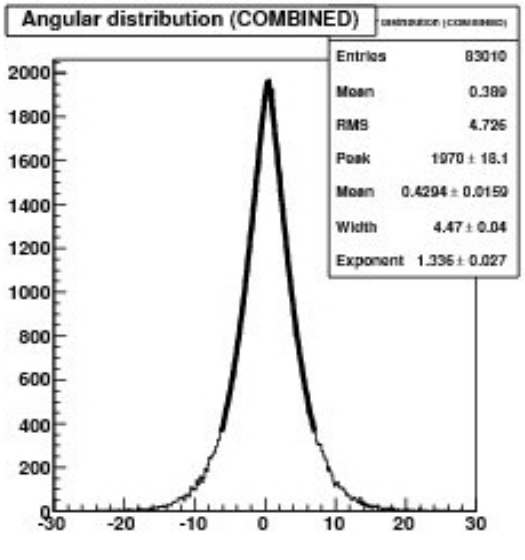
mip

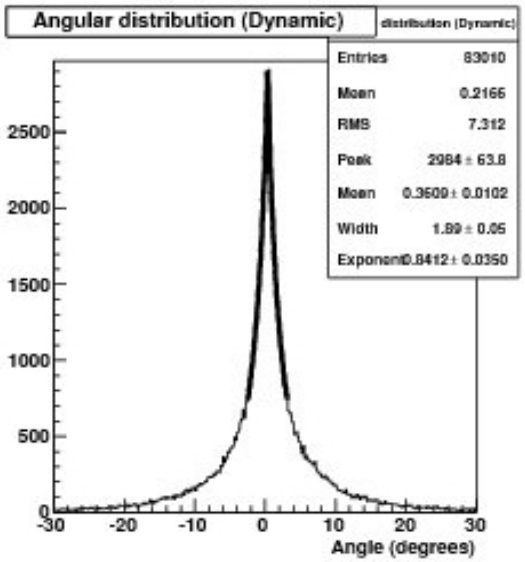


ECAL

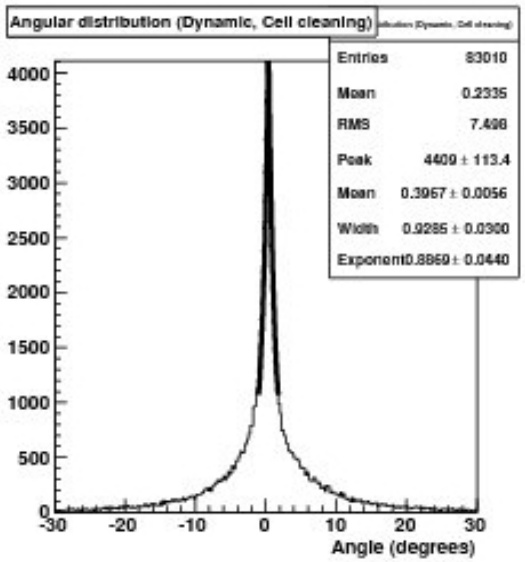


ECAL+HCAL

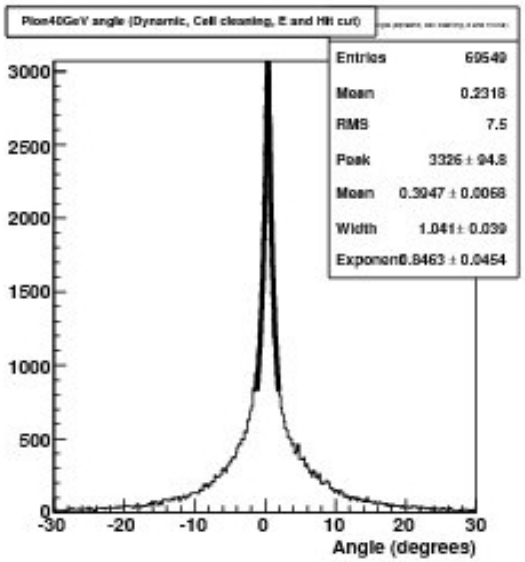




dynamic



dynamic+cleaning



dynamic+cuts(energy&hits)

Angular Resolution

Angle	Nominal Angle	mip	ECAL	ECAL +HCAL	Dynamic	.. -noise	.. .. +cuts
60 GeV π	0	0.33	0.27	0.45	0.26	0.41	0.42
40 GeV π	0	0.34	0.35	0.43	0.36	0.40	0.39
30 GeV π	0	0.04	0.12	0.49	0.09	0.35	0.35
20 GeV π	20	19.00	19.26	20.71	19.24	19.06	19.03
12 GeV π	0	0.27	0.27	0.41	0.25	0.39	0.26
12 GeV π	30	28.76	29.89	30.14	29.05	28.67	28.64
10 GeV π	10	9.18	9.37	12.42	9.29	9.15	9.10
20 GeV e	0	0.32	0.34	0.47	0.32	0.41	0.33

all values in degrees

within ~1° of nominal

nominal angle precision not known

Width	Nominal Angle	mip	ECAL	ECAL +HCAL	Dynamic	.. -noise	.. .. +cuts
60 GeV π	0	1.84	2.45	3.77	2.40	0.99	0.93
40 GeV π	0	1.62	1.97	4.47	1.89	0.93	1.04
30 GeV π	0	2.20	2.37	4.42	2.43	1.24	1.19
20 GeV π	20	1.56	1.91	4.89	2.15	1.44	1.29
12 GeV π	0	1.62	1.93	6.22	1.94	0.98	1.92
12 GeV π	30	1.85	4.82	5.99	2.31	1.51	1.43
10 GeV π	10	2.63	3.02	6.98	3.09	1.37	2.34
20 GeV e	0	1.72	1.87	4.73	1.94	1.06	1.93

mip more precise

noise removal ("cleaning") essential

other cuts still only preliminary

position resolution a corollary of this

Two-Track Resolution

Make use of the large number of two-particle events, e.g. here 1 pion + 1 electron

Pi60

Beam type: Pion60GeV

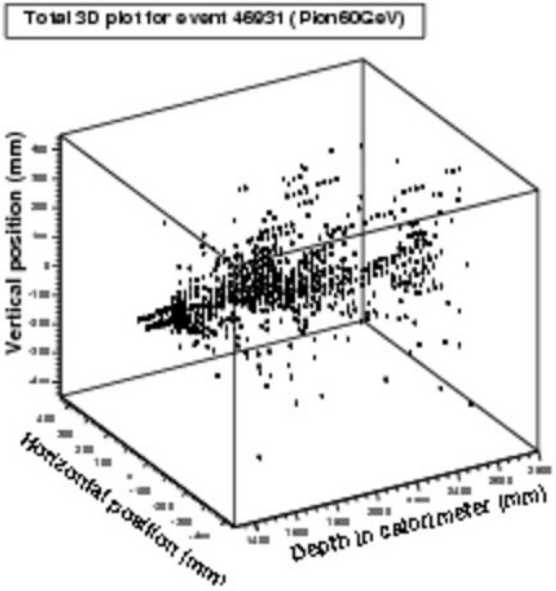
Event 46931

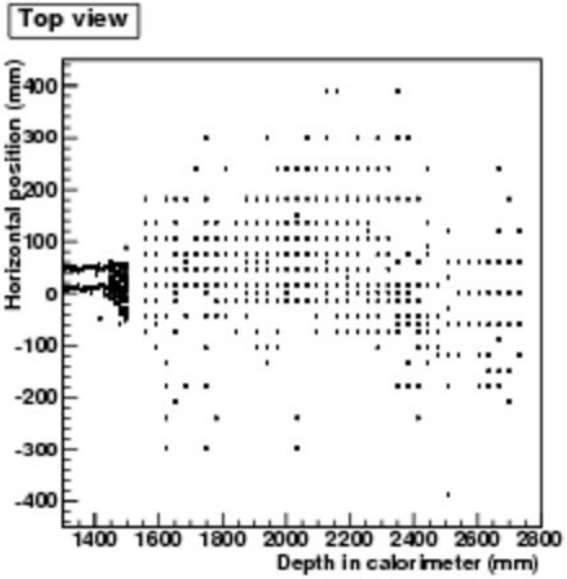
Total energy: 124.14 GeV

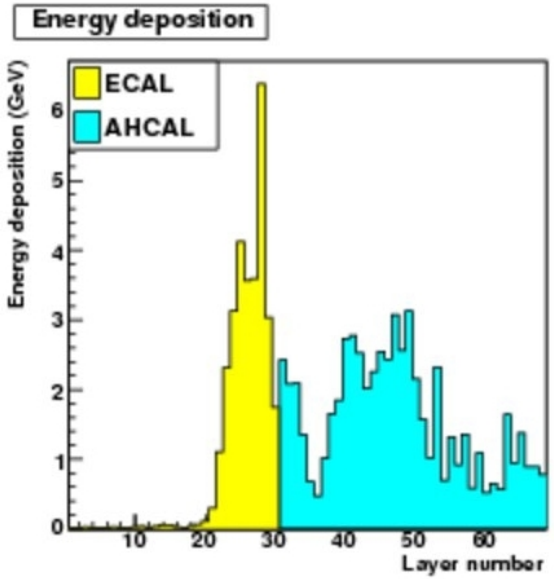
Energy deposition in ECAL: 29.96 GeV

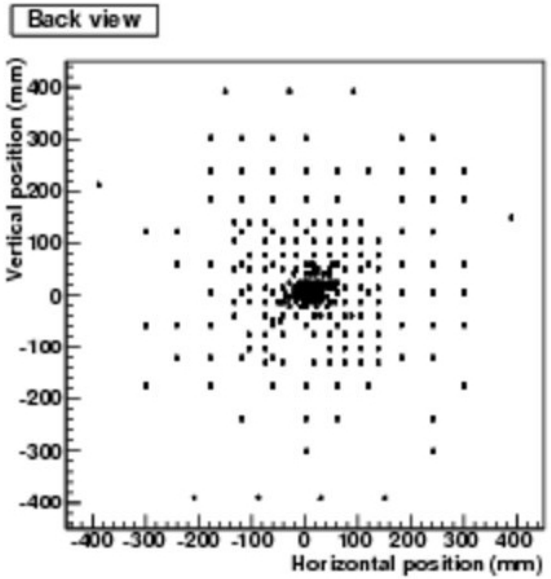
Energy deposition in AHCAL: 60.98 GeV

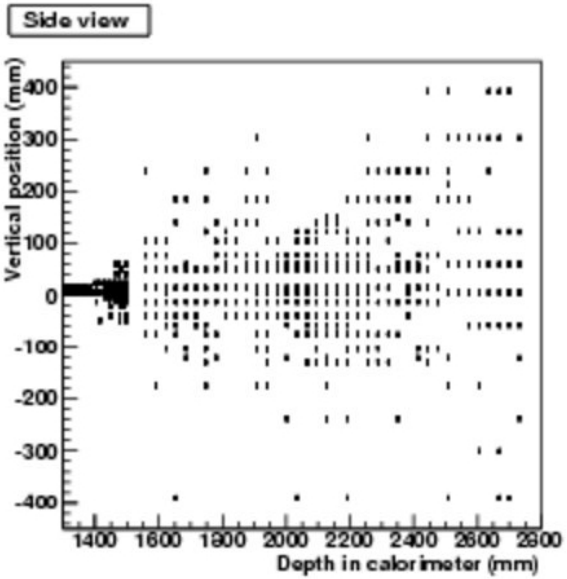
Energy deposition in TCMT: 33.20 GeV









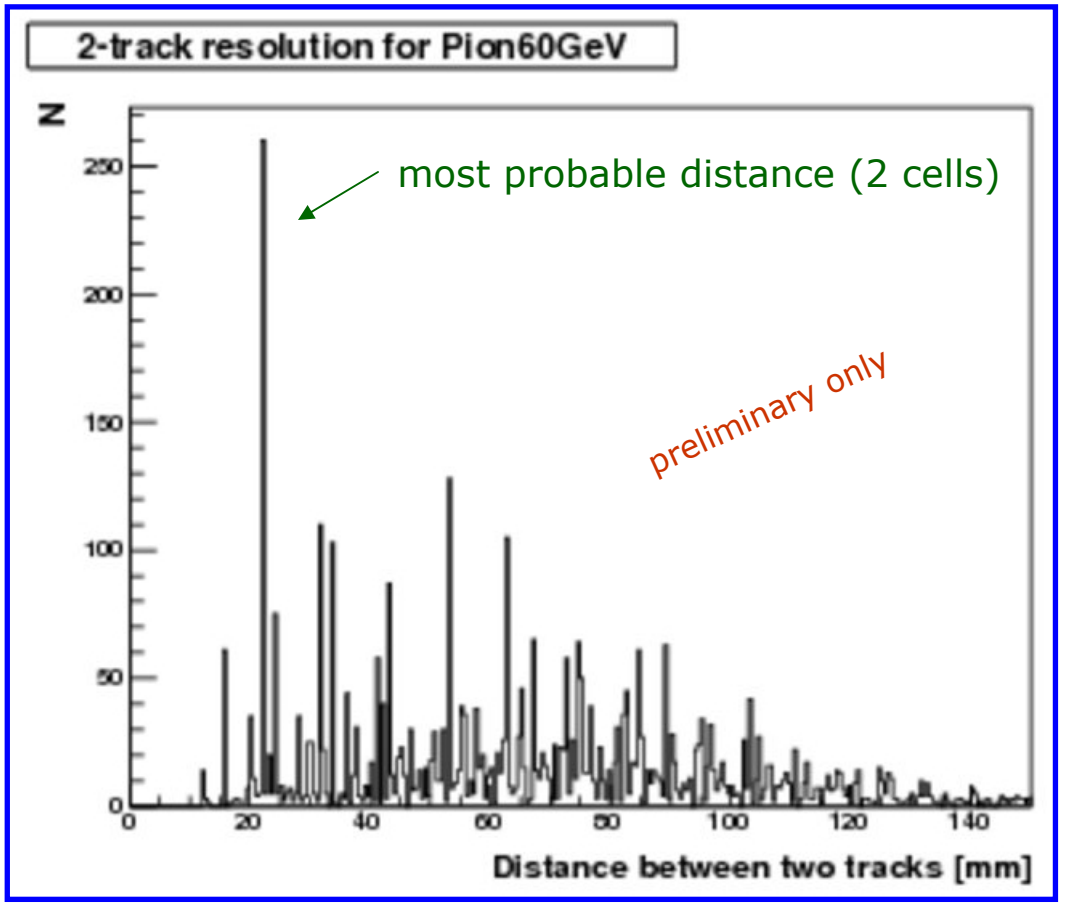


Two-Track Resolution

For any one event in ECAL:

1. find the hits in the first layer and construct the islands (i.e. having no adjacent hits over threshold of 0.7 mip's)
2. search next layer for hits close to previous layer's islands
3. contruct the islands
4. either continue loop to 2) or stop if:
   - too many hits in the next layer (shower starts)
   - no compatible islands for two consecutive layers
   - the end of ECAL is reached
   - calculate distance between tracks if >5 layers

d > 12 mm



New TSE Tool

TSE = "Track Sniffer Evaluator" (whatever)

Merging of the angular resolution and the two-track algorithms to sniff out charged particles by their tracks:

1. find their number, and
2. for each track:
   - length of minimum of ionization in layers
   - numbers of hits per section/module
   - energy deposition per section/module
   - angles
   - distance(s) from other tracks
   - estimate energy deposition ratios, shower sizes, ..
   - determine particle ID probability (see backup slides)

Under development

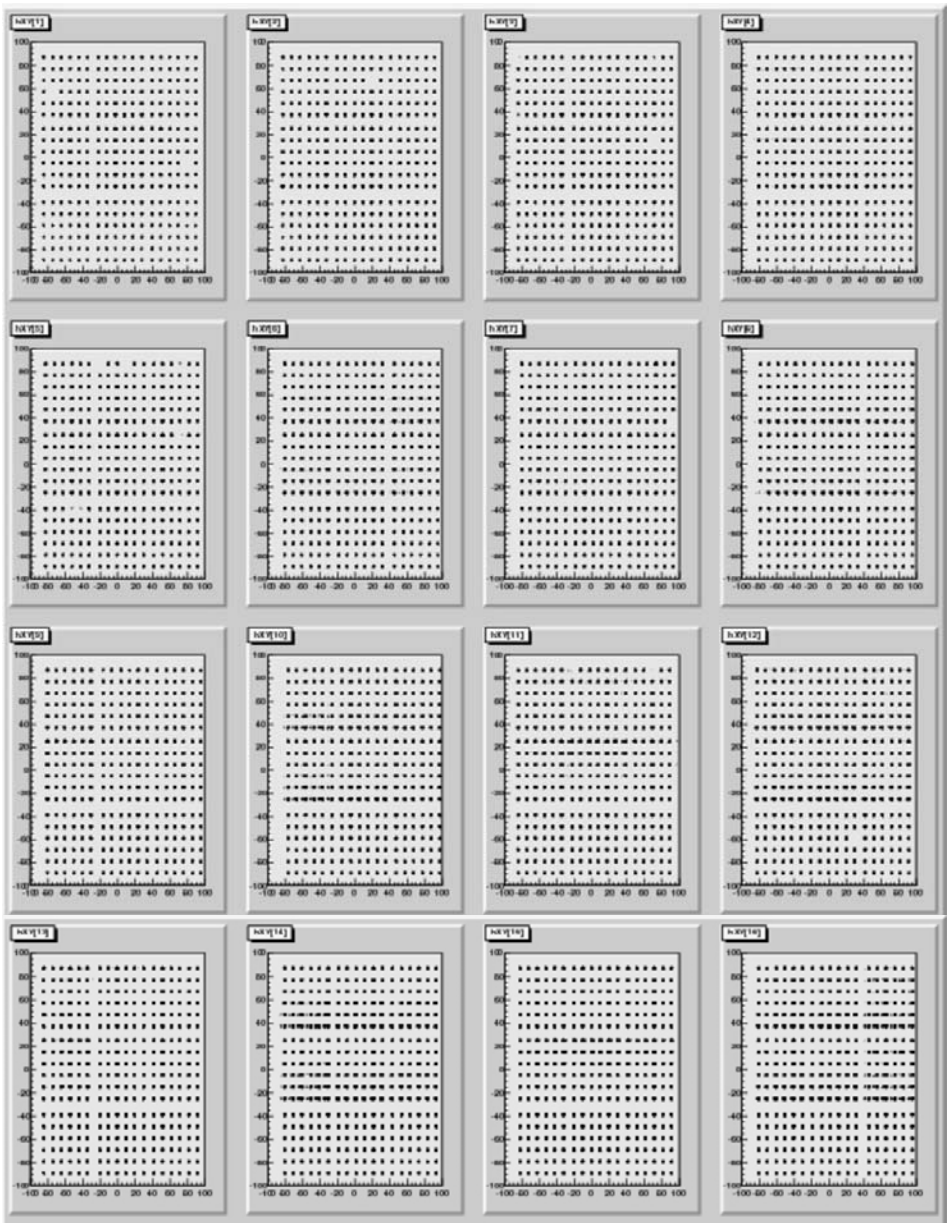
Outlook

1. Test beam data analysis proceeding at McGill in a small group
2. Usefull insights into data quality and characteristics
3. Rough consistency estimates on linearity and energy resolution
4. First results on angular resolution and 2-track separation
5. Second iteration of analysis results soon
6. A new analysis tracking tool is being developed

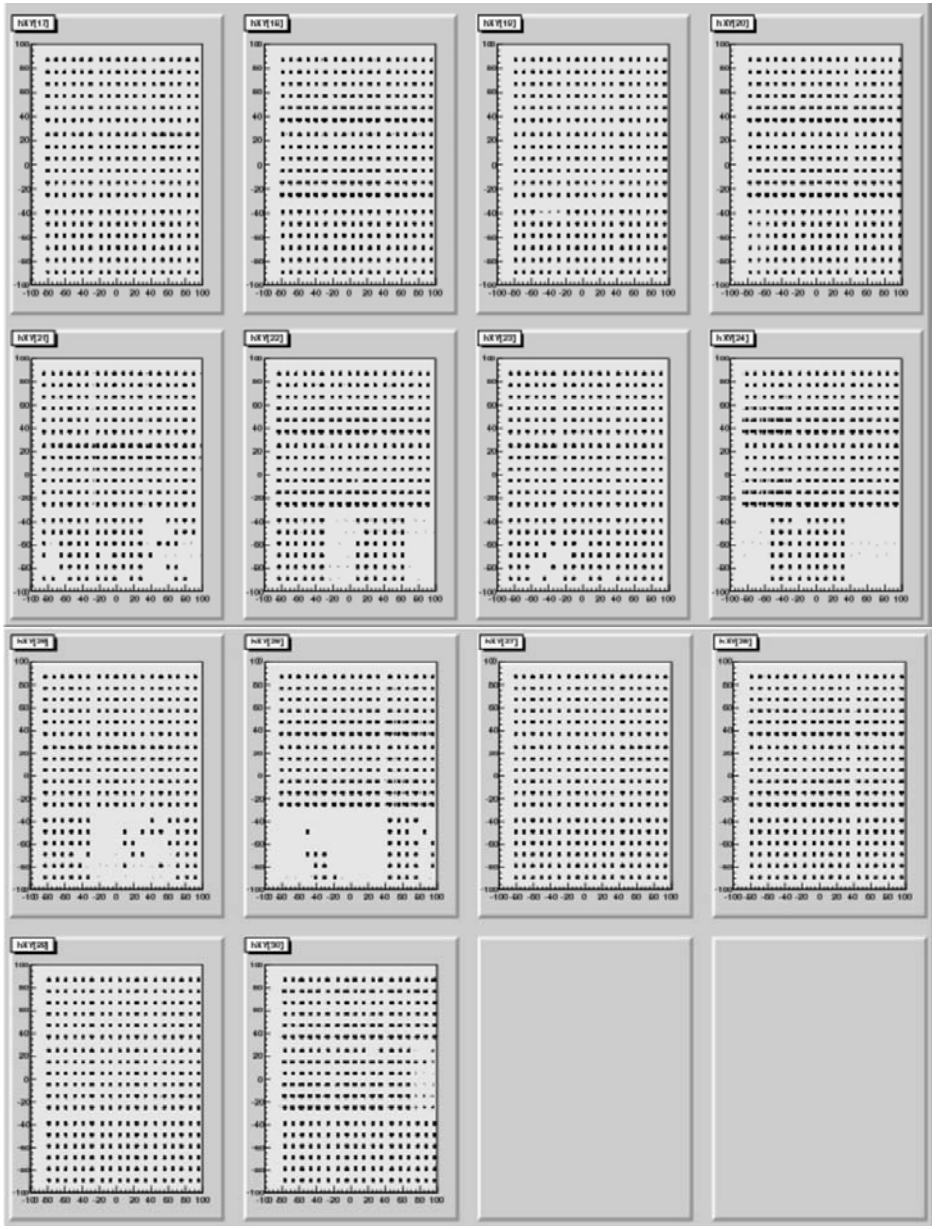
Backup Slides

ECAL Layers - 40 GeV π

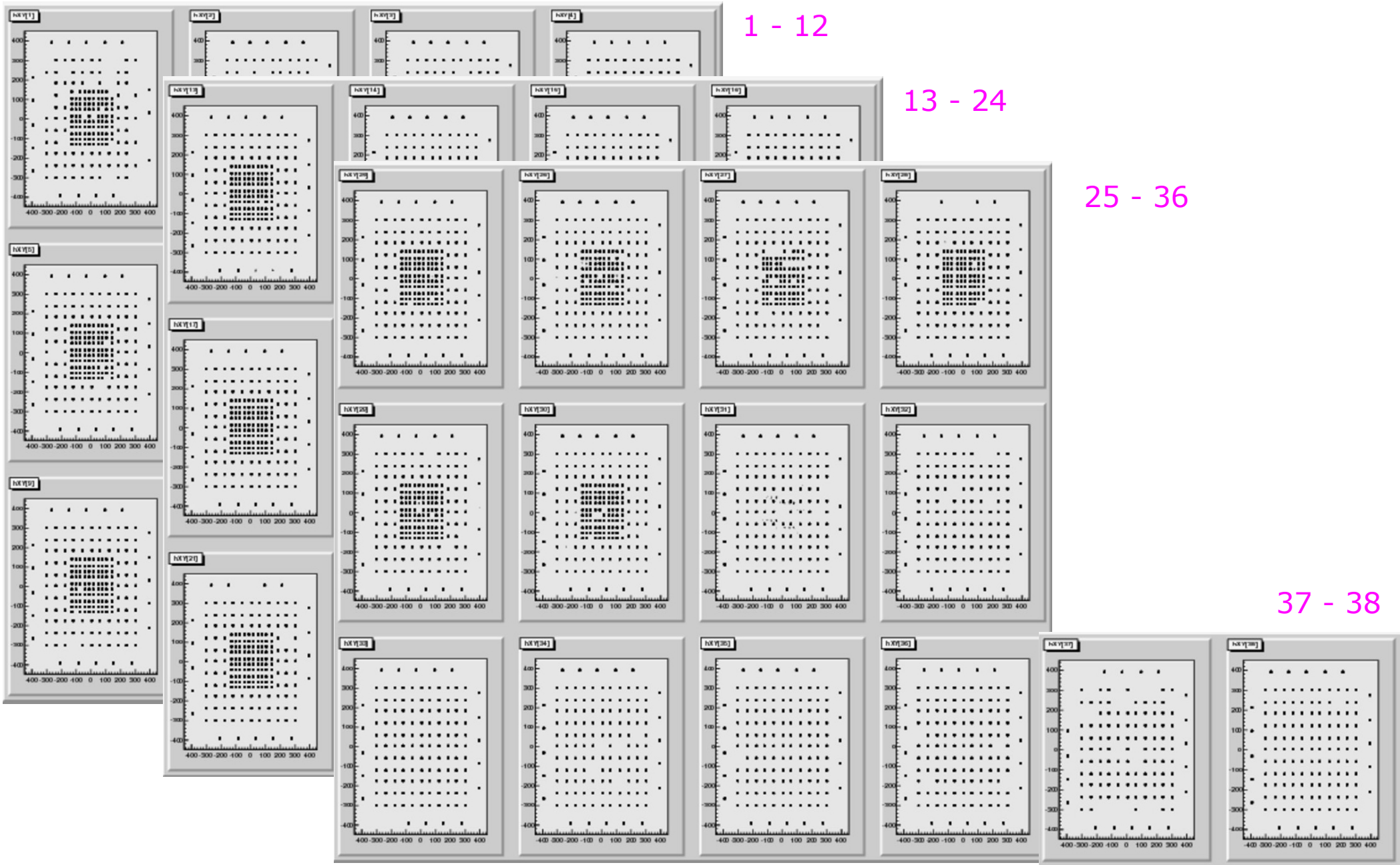
1 - 16



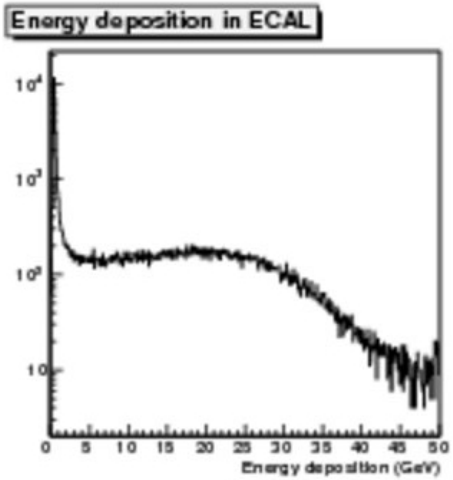
17 - 30

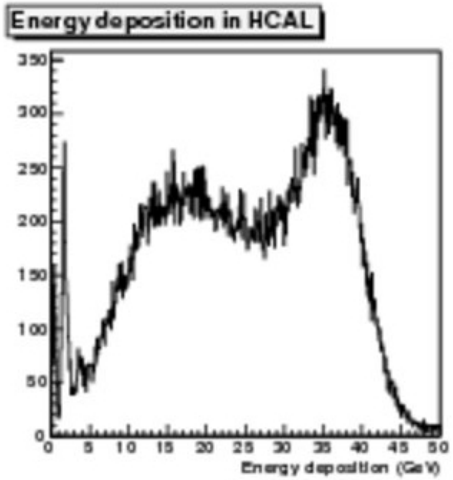


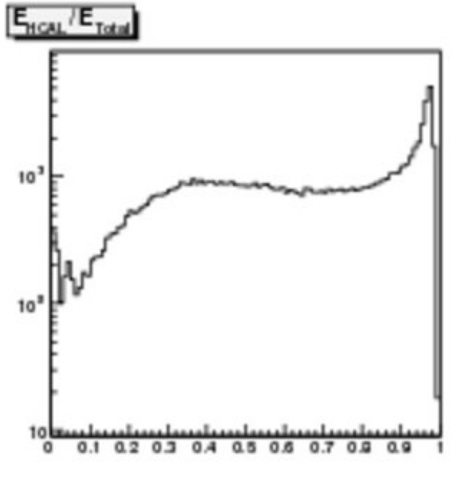
HCAL Layers - 40 GeV π

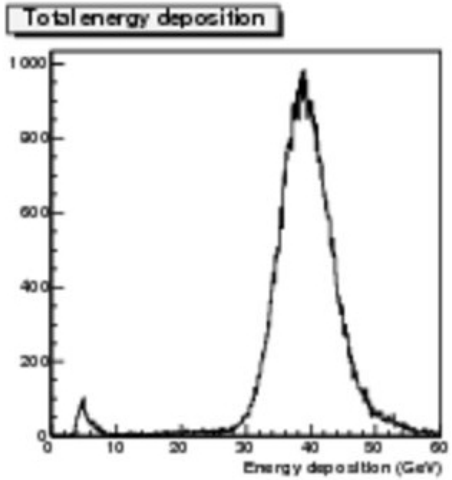


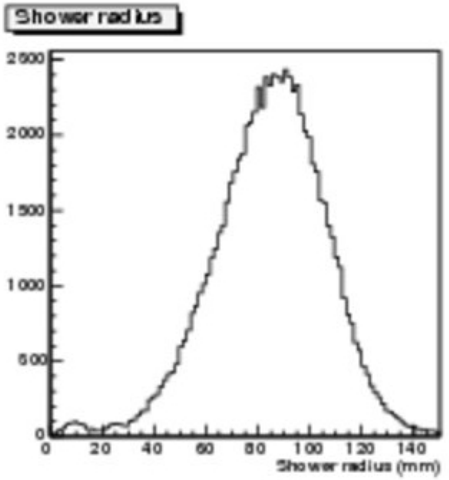
Distributions - 40 GeV π

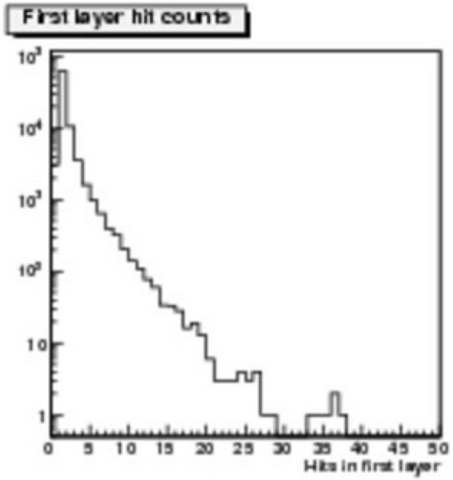


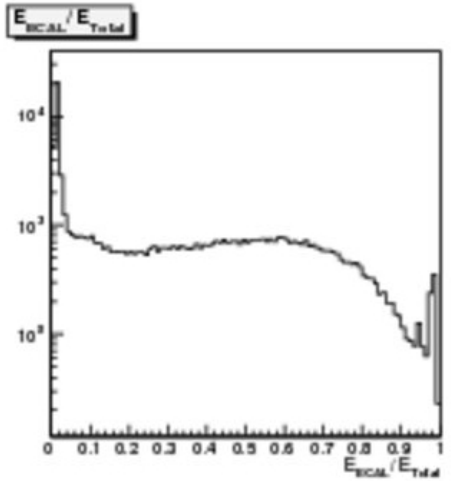


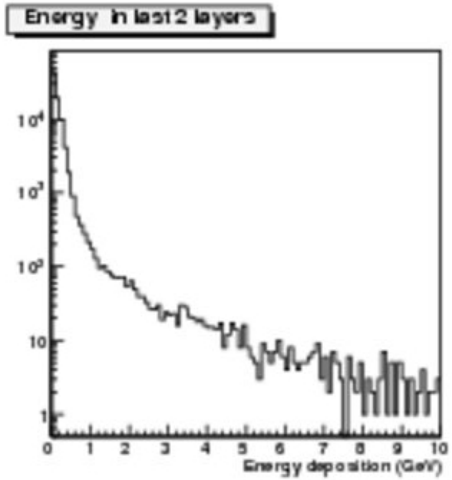




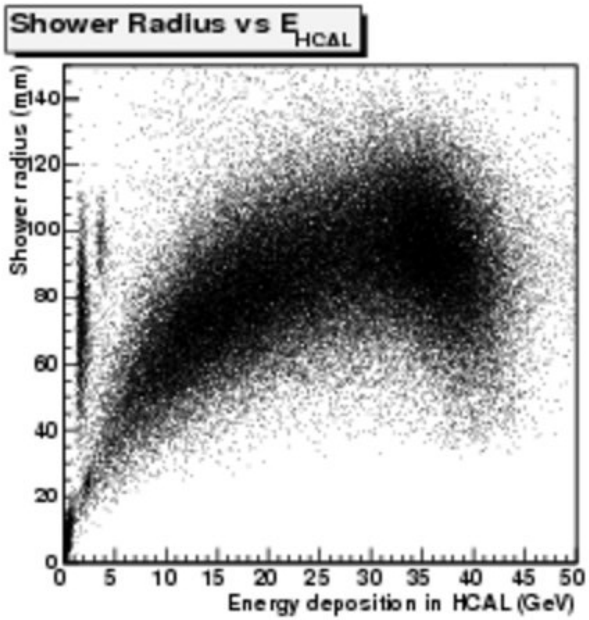


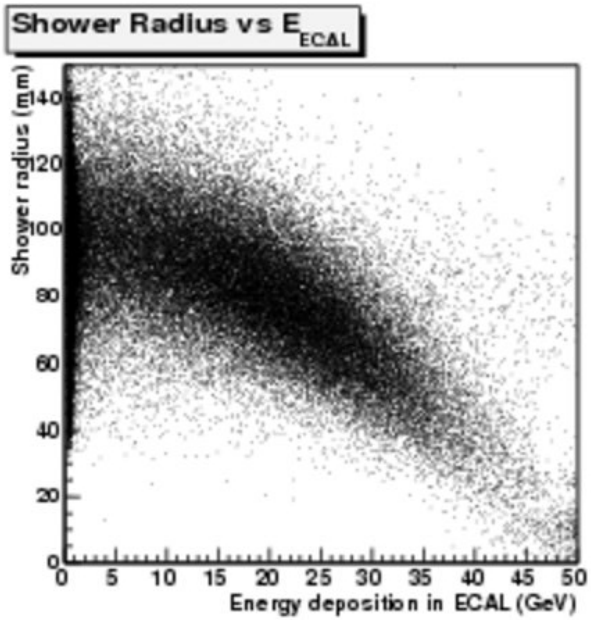


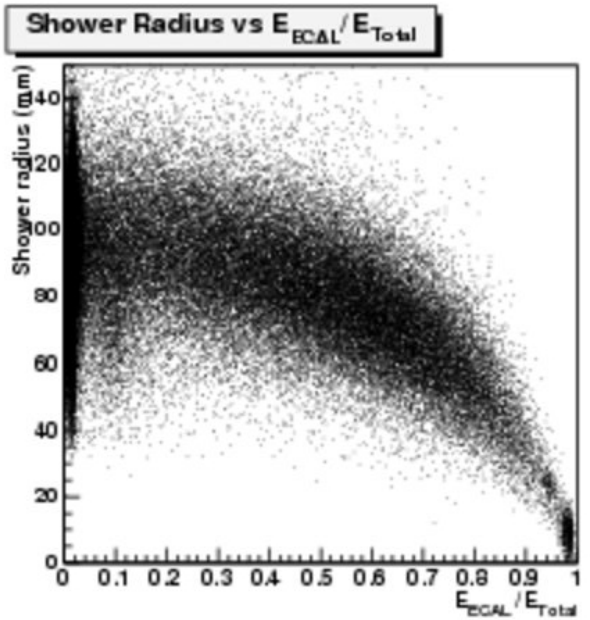


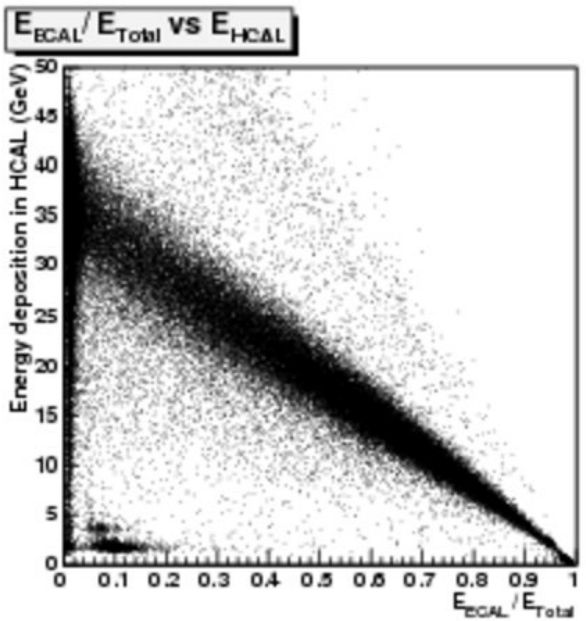


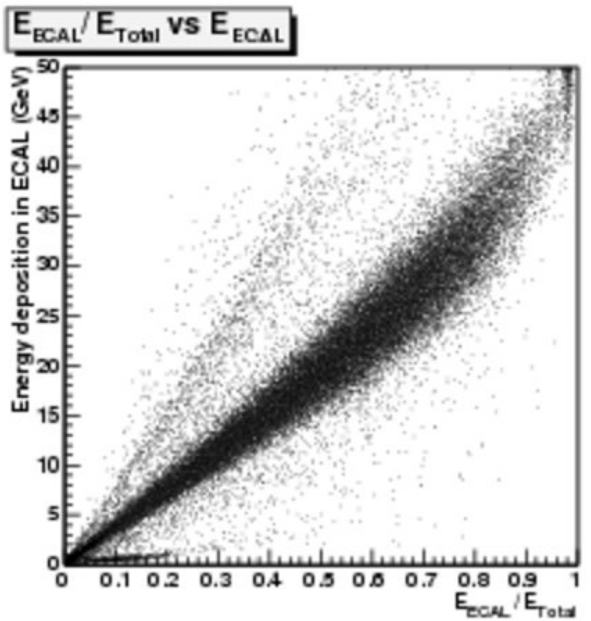
Correlations - 40 GeV π

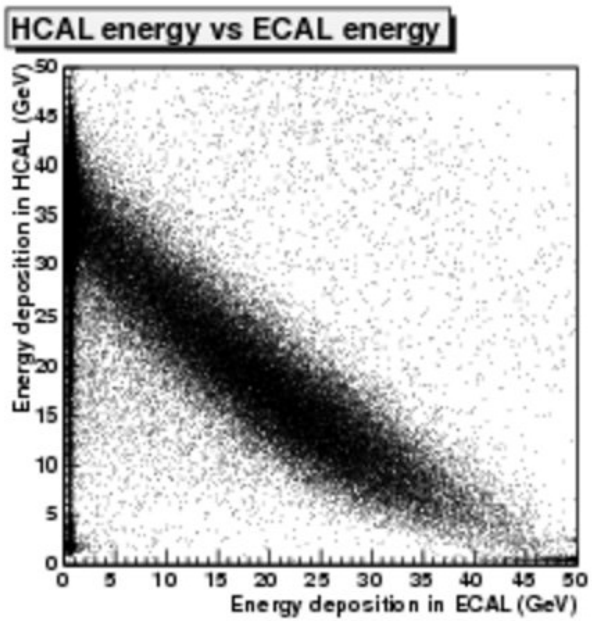












Event Display

Pi12_30

Beam type: Pion12GeV_30

Event 48134

Energy deposition in ECAL: 31.13 GeV

Energy deposition in AHCAL: 1.91 GeV