Analysis of 2012 and 2014 Beamtests

January 22, 2015

1 Event selection

2 Time analysis

3 Seed Analysis

3.1 Hits tagging

Hits are separated in 3 categories:

- ISOLATED= The hit has no neighbours in a 6 cm radius sphere
- EDGE = The hit belongs to a track segment in a 6 cm radius sphere
- CORE= all other hits

Each hit defines a neighbouring sphere of 6 cm and a principal component anlysis is done on all neighbours. The ratio w of the 2 principal axis is then used to tag the hit.

- w=0 $\rightarrow$ less than 3 neighbours, the hit is ISOLATED
- w $<$ 0.3 $\rightarrow$ the second axis is small, most probably hits are aligned along the first axis, the hit is an EDGE one.
- w $>$ 0.3 , the hit is in the CORE of the shower.

The figure 1 shows the distribution of w for all the hits of a 60 GeV pion run. The 3 categories clearly exhibits. On figure 2 the same ratio is shown for preselected muon candidates and preselected pions interaction in the same run.

3.2 MIP tagging

Once hits are sorted in those three categories. Clusters are built plane by plane by adding hits in plane distant from less than 4 cm to an existing cluster. Two collections are built. “Interaction” clusters are built from CORE hits and “real” clusters from the other hits. Finally “Interaction” clusters of less than 5 hits are

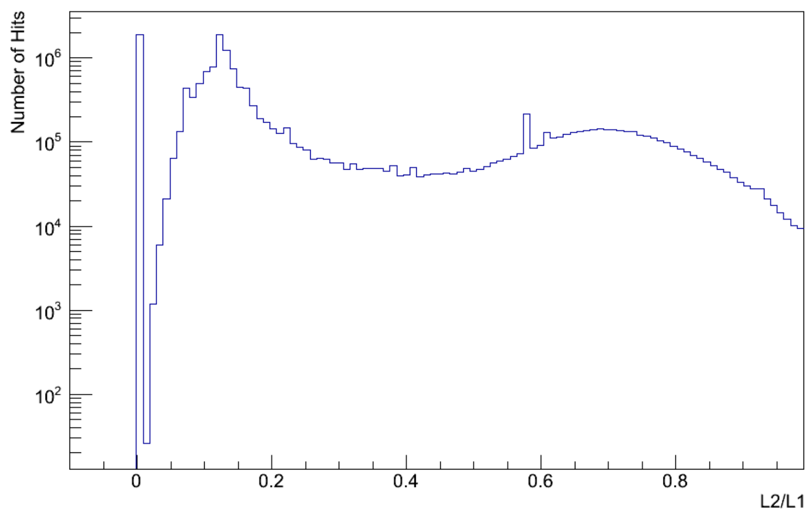

Figure 1: Ratio of L2/L1 derived from PCA of neighbours hits

moved in the “real” collection and in paralell “real” clusters of more than 5 hits are moved in the “interaction” one.

The “real” collection is then used to reconstructed track segments according to this algorithm:

- Once again a principal component anlysis is used for all clusters to find main direction in a 15 cm sphere around each point
- Each point is associated to existing tracks according to:
  - if the track has at least 2 hits, the error of the extrapolation is taken and the point is added if
    - It is not the track path
    - it is less than 3 planes away from the end of the track
    - it is less than 5 sigma from the extrapolation
  - if the track has only one hit
    - the track hit is one plane before
    - the principal axis of the cluster is used to build track parameter and point is added if it is less than 6 cm from the extrapolation
- If no association is found, a new single hit track is created with track parameters deduced from the principal component analysis of its neighbouring.

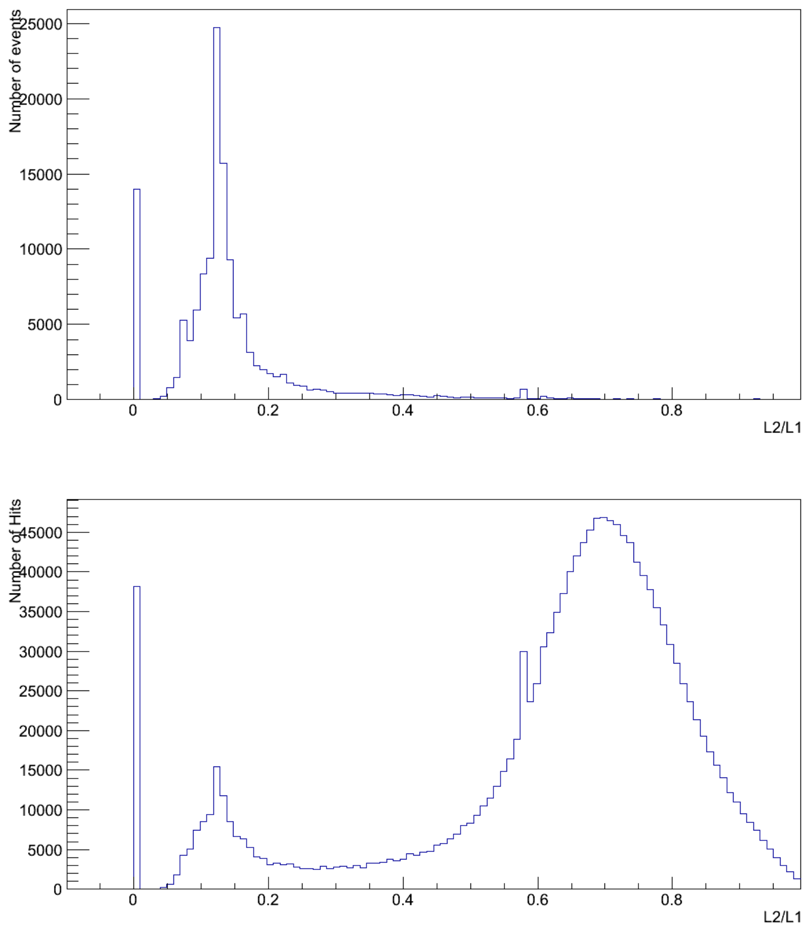

Figure 2: Ratio of L2/L1 for preselected muon tracks (top) and preselected showers (bottom)

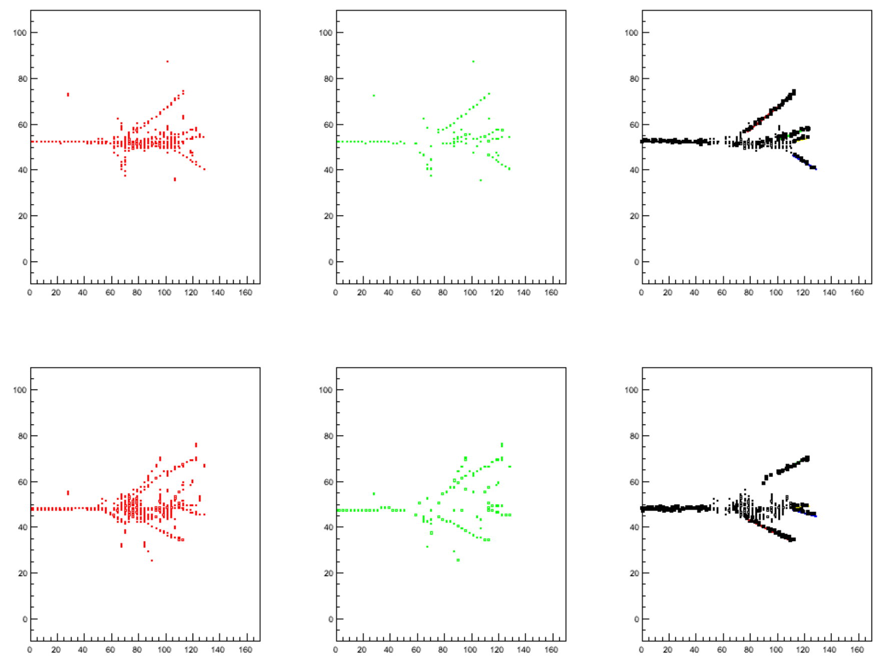

Figure 3: 60 GeV Pion interaction display. The left (red) column shows the hits position in (Z,X) and (Z,Y) projection. The midle (green) column shows the "real" collection of clusters projection. Finally on the right, track segments, MIP hits (black) and 3D clusters of CORE hits are shown

The algorithm is run handling hits from the beam entry to the end of the calorimeter. At the end , a last pass is done trying to associate single hit tracks and previously unselected hits to valid segments. Finally all hits belonging to a cluster associated to a track segment are tagged MIP. The figure 3 shows the result of the different steps of the algorithm.

The track segments can also be used to dicriminate muons and elctrons from hadrons, using the ration of the total track length over the total number of hits. The figure 4 shows this ratio. The peak at zero corresponds to electron with no MIP exiting from the shower. The 1.4 peak is due to muons with a hit multiplicity ~ 1.6 and finally hadron showers have a low ratio up to 0.7. Events are tagged:

- ELECTRON if R<1E-4
- MUON if R> 0.75

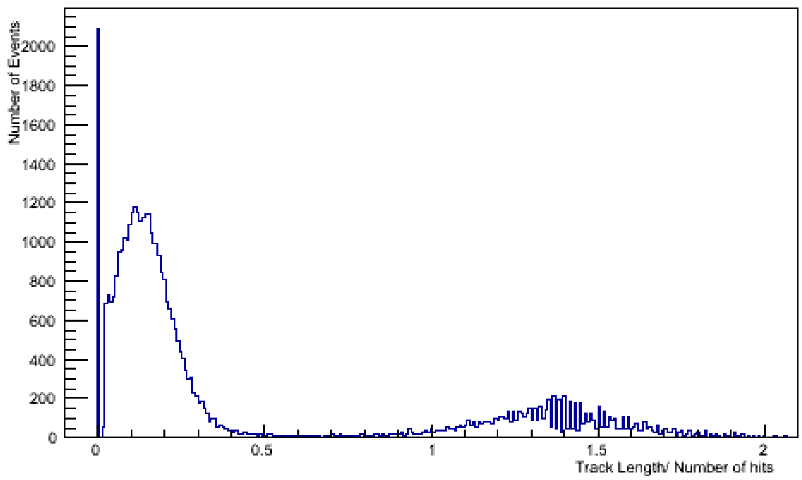

Figure 4: Ratio of total tracks length over the total number of hits per event in a 60 Gev Pion run

4 Shower Analysis

4.1 Shower building and selection

Hits are grouped per plane. A loop on all planes starting from beam entry is run. An unassociated hit is the seed of a new "shower". A hit is associated to a shower if the distance of the hit to one hit of an exiting shower is

$$D_{i,j} = 2 \times (|I_i - I_j| + |J_i - J_j|) + |plane_i - plane_j| < 15$$

A second pass is done once all hits are associated, merging showers when at least one of the first one hits is less than 20 distant from the second one.

Only showers with more than 4 planes are kept adn a principal analysis is run rejecting "muons" , ie, showers where $\sqrt{\frac{l0+l1}{l2}} < 0.01$

Events with more than one shower found are rejected for the energy and resolution analysis.

This method is efficient to build the showers topology but rejected isolated hits or clusters (up to 10 % of loss). In the following analysis all hits in the calorimeter are considered and not only those included in the single selected one.

4.2 Shower selection

A final selection is done to remove interaction prior to the calorimeter

$$|x_{shower} - 50| < 15\ cm, \quad |y_{shower} - 45| < 15\ cm$$

Electron are rejected asking:

$$N_{MIP} \neq 0 \;\&\; Length(tracks) > 30\ cm$$

Residuals muons are cut with

$$\frac{N_{MIP}}{N_{hits}} < 0.5 \;\&\; \frac{Length(tracks)}{N_{hits}} < 0.5$$

Finally to minimize leakage , the first interaction plane is bellow 10, more than 5 interaction plane are required and more than 50 % of the shower hitted planes should see an interaction (An interaction plane is defined as a plane where more than 5 hits are seen and the hits dispersion is bigger than 1.5 cm).

4.3 Energy calibration

The shower energy is fitted to the following function:

$$\begin{aligned} E_{rec} = C \times (Track_{length} \times (\alpha_{MIP} + \beta_{MIP} \times N_{hit}) \\ + N_0 \times (\alpha_0 + \beta_0 \times N_{hit}) \\ + N_1 \times (\alpha_1 + \beta_1 \times N_{hit} + \gamma_1 \times N_{hit}^2) \\ + N_2 \times (\alpha_2 + \beta_2 \times N_{hit} + \gamma_2 \times N_{hit}^2) \end{aligned} \tag{1}$$

where $N_{0..2}$ is the number of hits for each threshold excluding the ones tagged MIP. Track length or number of MIP hits leads to the same energy resolution. December 2014 pions runs at 20,50 and 80 GeV are used and the Fit converged to:

$$\begin{aligned} C &= 6.864E-02 \pm 5.334E-04 \\ \alpha_{MIP} &= 9.041E-02 \pm 3.000E-02 \\ \beta_{MIP} &= -1.508E-04 \pm 3.128E-05 \\ \alpha_0 &= 7.816E-01 \pm 8.481E-03 \\ \beta_0 &= 4.292E-07 \pm 7.603E-06 \\ \alpha_1 &= 7.704E-01 \pm 3.123E-02 \\ \beta_1 &= -3.201E-04 \pm 3.247E-05 \\ \gamma_1 &= 3.643E-07 \pm 2.131E-08 \\ \alpha_2 &= 1.407E-01 \pm 8.861E-02 \\ \beta_2 &= 8.234E-03 \pm 1.039E-04 \\ \gamma_2 &= -4.792E-06 \pm 6.950E-08 \end{aligned} \tag{2}$$

Those calibration constants are then used to calibrated any selected shower. The energy distribution is then fitted with a Crystal ball parametrisation as shown on figure 5

Eventually we obtain th linearity and the associated resolution seen on figure 6 and table 1

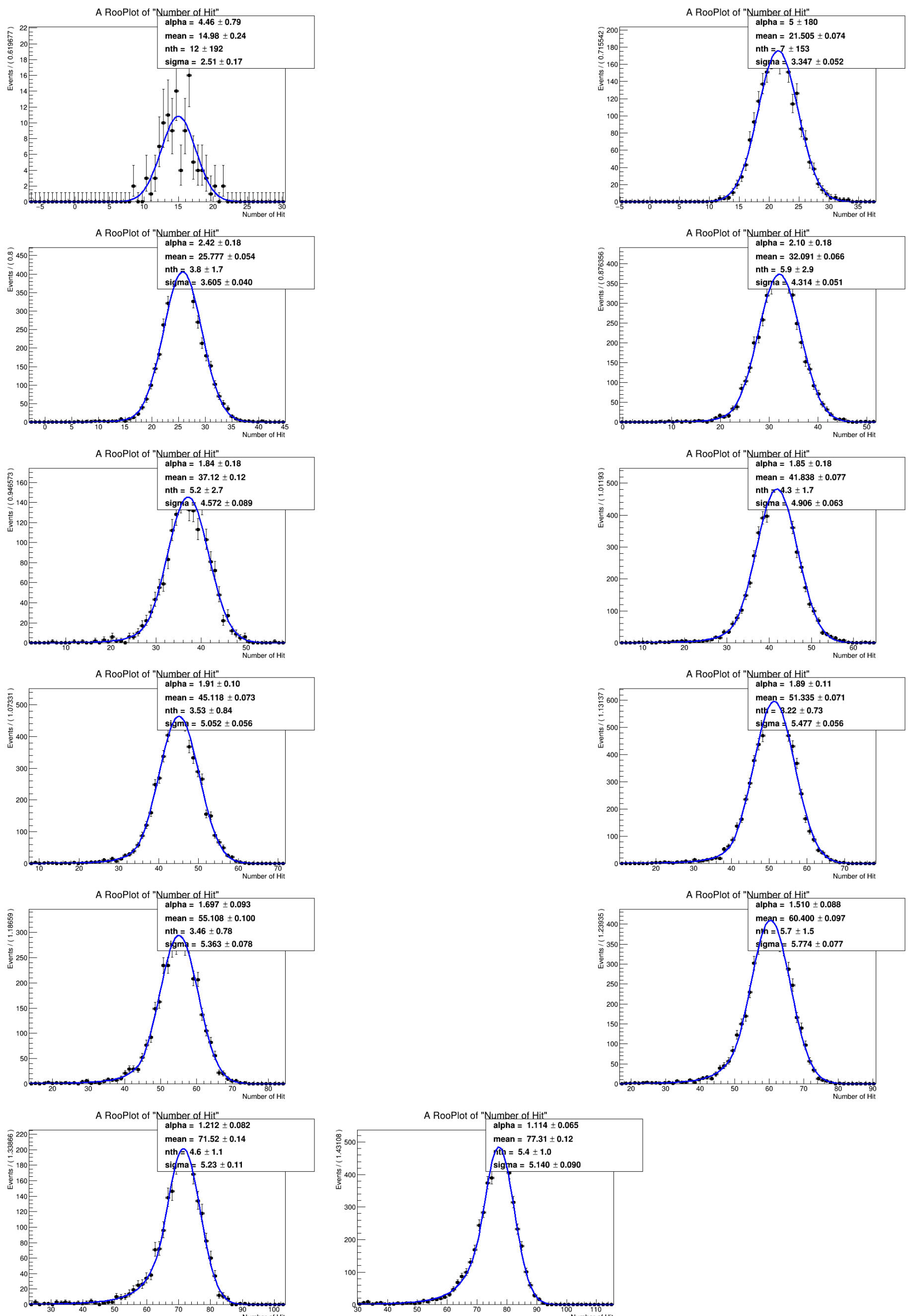

Figure 5: Crystal ball fit of the hit distribution for pions from 15 to 80 GeV

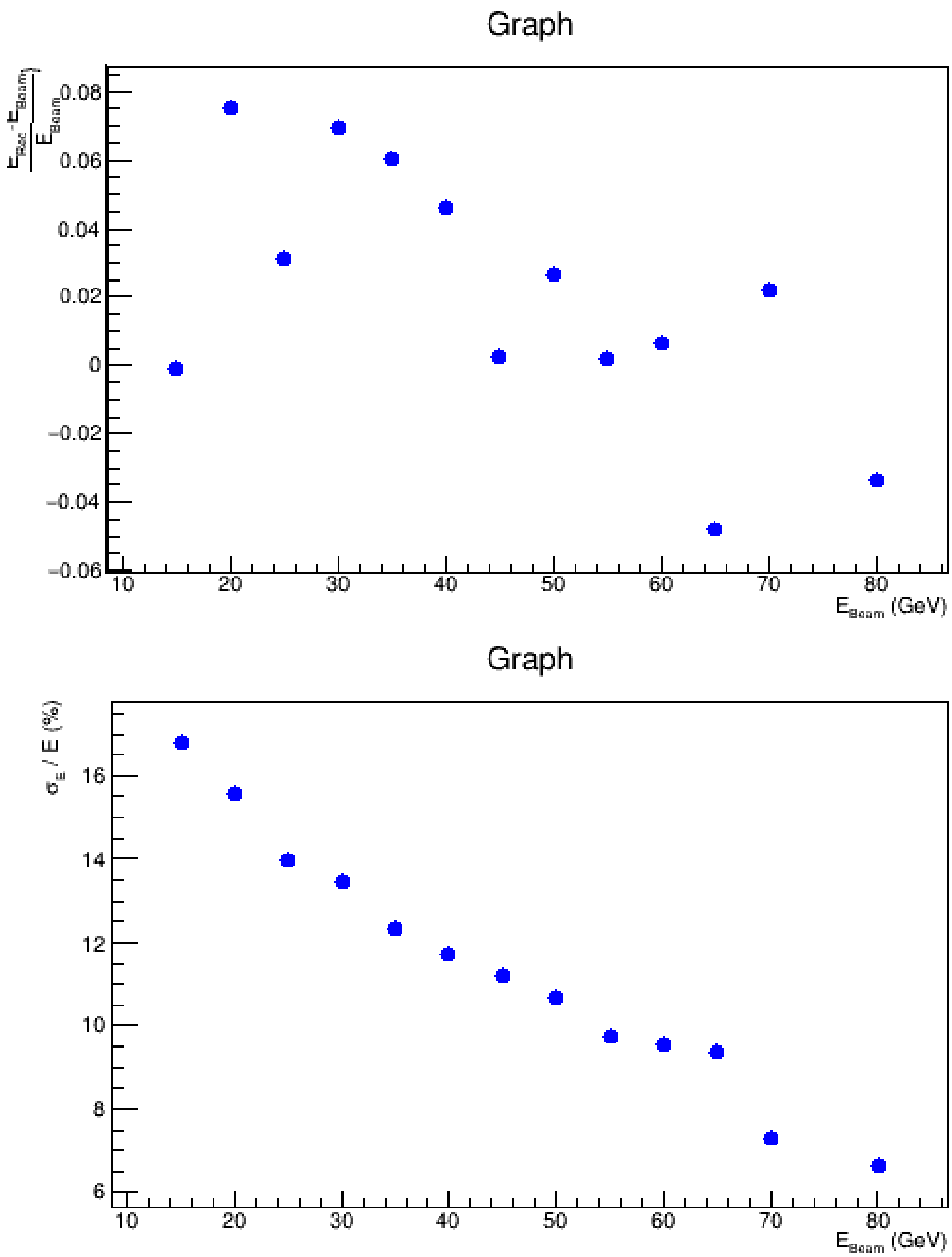

Figure 6: Linearity and energy resolkution achieved in December 2014

E	E rec	dE	Linearity	Resolution
15.00	14.98	2.51	-0.10	16.77
20.00	21.51	3.35	7.53	15.56
25.00	25.78	3.61	3.11	13.99
30.00	32.09	4.31	6.97	13.44
35.00	37.12	4.57	6.06	12.32
40.00	41.84	4.91	4.59	11.73
45.00	45.12	5.05	0.26	11.20
50.00	51.34	5.48	2.67	10.67
55.00	55.11	5.36	0.20	9.73
60.00	60.40	5.77	0.67	9.56
65.00	61.88	5.78	-4.79	9.34
70.00	71.52	5.23	2.17	7.31
80.00	77.31	5.14	-3.36	6.65

Table 1: Linearity and energy resolkution achieved in December 2014