SDHCAL Linearity&Resolution Study

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* A part of this work was done thanks to the help of A. Petrukhin

GOALS

The aim of this analysis is to show that one can obtain the same results as those presented in the CALICE note CAN37 with “simple selections” as was asked by one of the referees.

In this work there is NO mention of:

→The fractal dimension method to eliminate the electrons

→The Principal Component method to determine the hadronic shower axes

→The Minimum Spanning Tree method to reconstruct the hadronic shower

There is only very simple selection and hopefully this can be understood by anybody.
There is still no correction on the data in this study.

The data to be presented in this work are those collected during the May (H2), September (H6) and November (H2) Runs

Pion Runs :

(E=80 GeV) : 714470, 715756, 716282, 716319
(E=70 GeV) : 714547, 715493, 715754, 716284, 716287, 716289, 716290
(E=60 GeV) : 715511, 715531, 715753, 716292, 716296, 716297, 716298
(E=50 GeV) : 714547, 714556, 715751, 715551, 716299, 716303, 716305
(E=40 GeV) : 714561, 715651, 715748, 716307
(E=30 GeV) : 714562, 715671, 715747, 716264, 716308
(E=25 GeV) : 715700, 715703
(E=20 GeV) : 714565, 715675, 716310, 716312, 716213,716215
(E=15 GeV) : 715699
(E=10 GeV) : 715692, 715693, 716321
(E=7.5GeV) : 715695
(E=5 GeV) : 715694, 715698

Electron Runs :

(E=10 GeV) : 715724, (E=20 GeV) : 715715, (E=40 GeV) : 715713,
(E=50 GeV) : 715716, (E=60 GeV) : 715721, (E=70 GeV) : 715723

Selection Variables:

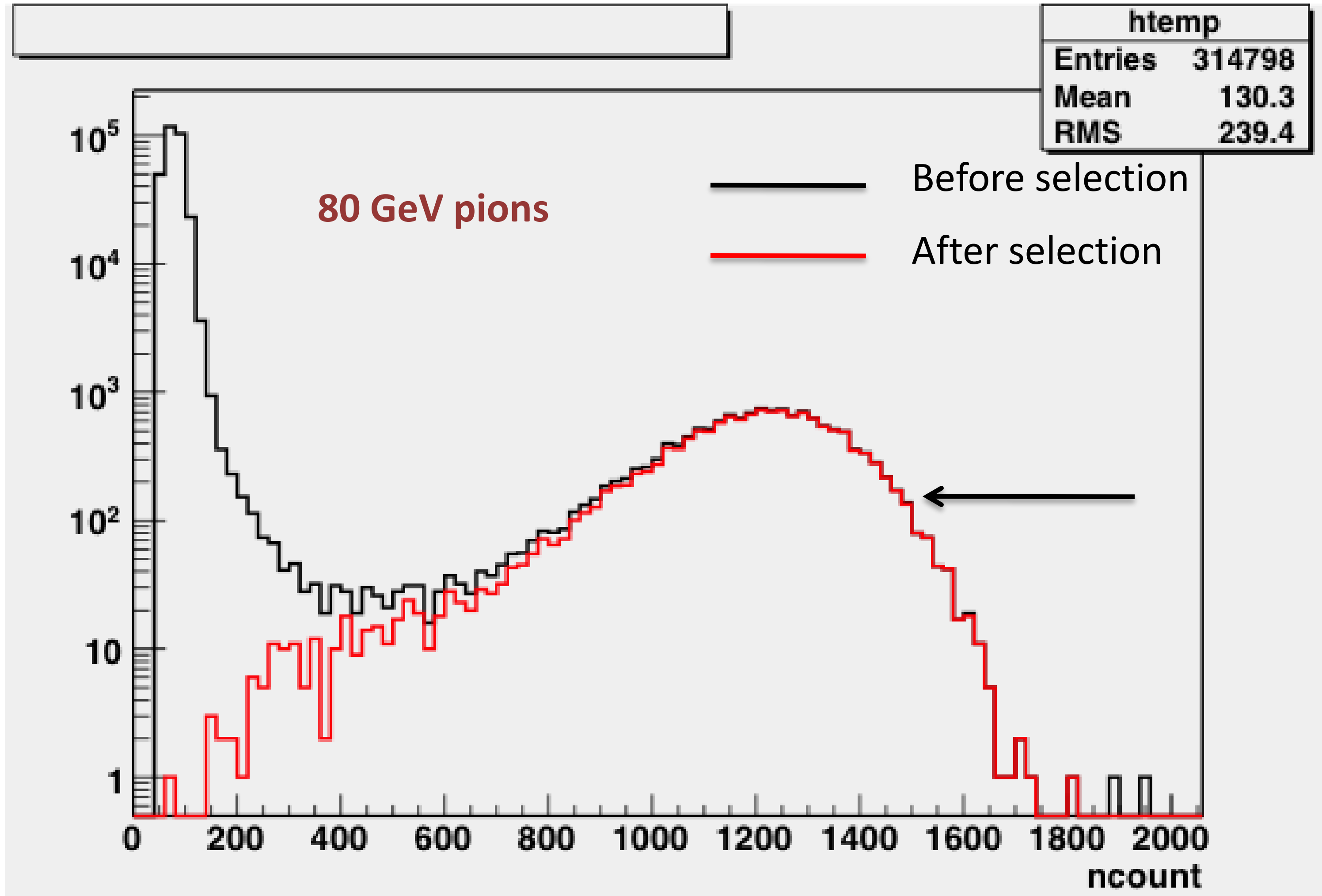
Ndeb : First layer with > 4 fired pads (hits) with the three following layers having >4 hits each.
Nedge : Total number of hits located in the 10 cm of the edges
Ncount : Total number of hits
Zcount : Total number of layers with at list one hit
Nlarg : Number of layers for which the hits dispersion in X or Y > 5 cm
Ndoub : is a Boolean = 1 if hits with at least 5 cm apart are found in the first five layers.
XGM, YGM coordinates of the x, y average values of all hits
Nhole : Number of layers with no hits with at least one layer with more than 4 hits in the three following layers.
Neut: is a Boolean ==1 if the total number of hits in the first five layers is less than 4 hits

The selection :

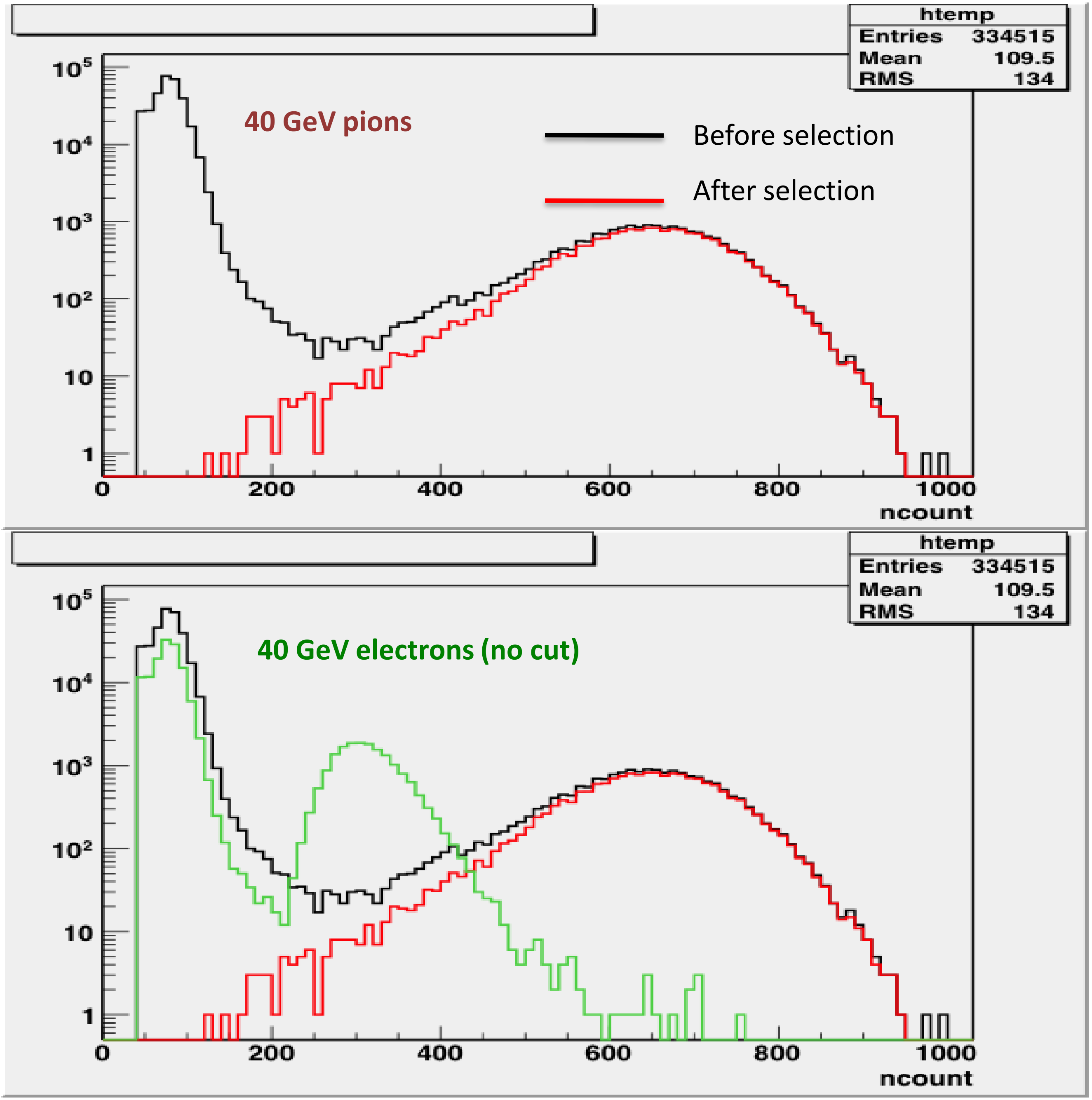
(Ndeb>4.or.Zcount>30) This to eliminate electron contamination
Ncount/Zcount>2 : To get rid of muons and cosmics
Nlarg/Zcount>.2 : To get rid of irradiative muons
Nedge/Ncount <.02 : To have laterally contained showers.
Neut = 0 : To get rid of neutrals and some cosmics as well

No cut on the leakage or on the hadronic shower starting point

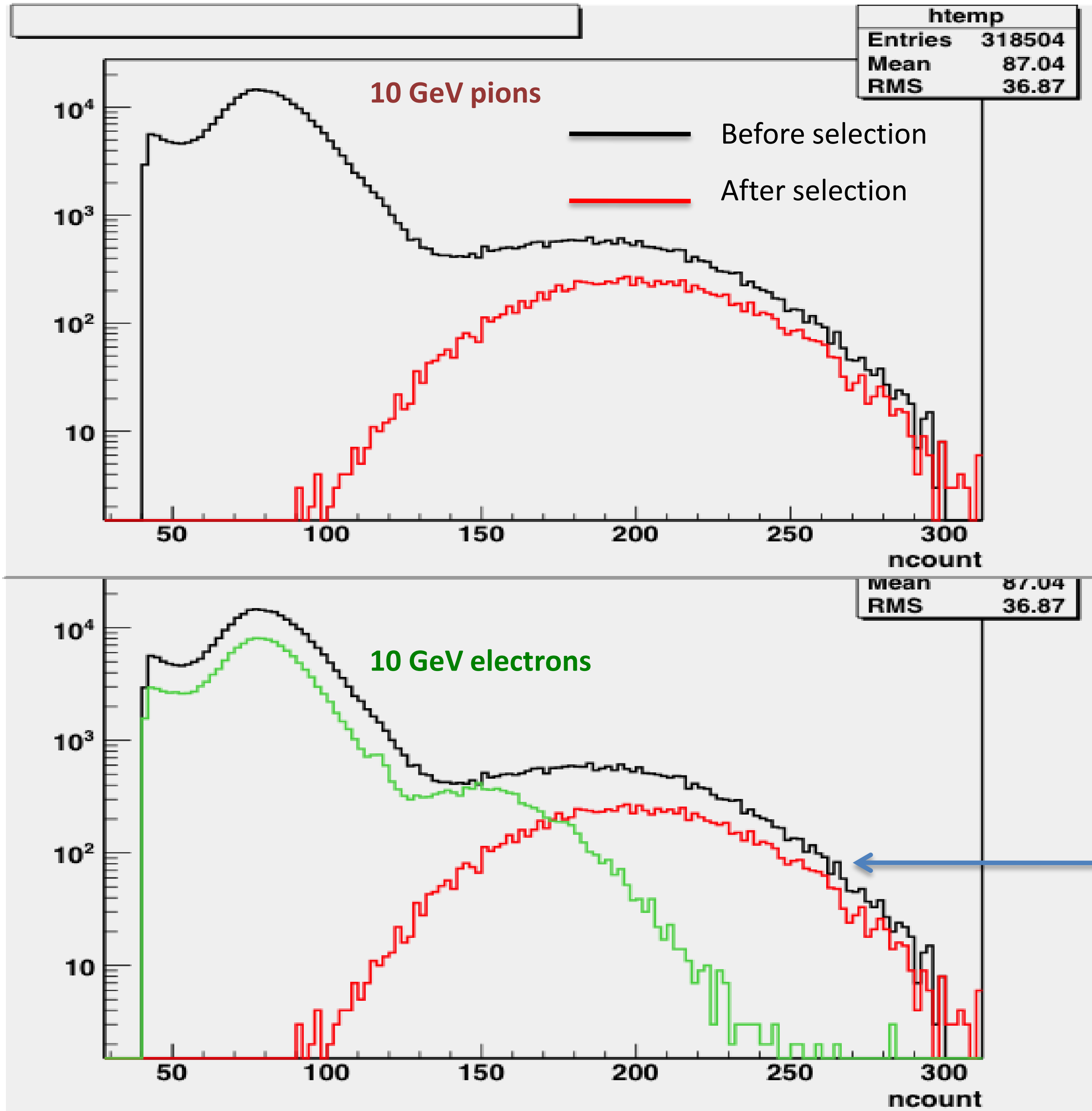
The selection should not impact the hadronic shower resolution



The selection should not impact the hadronic shower resolution

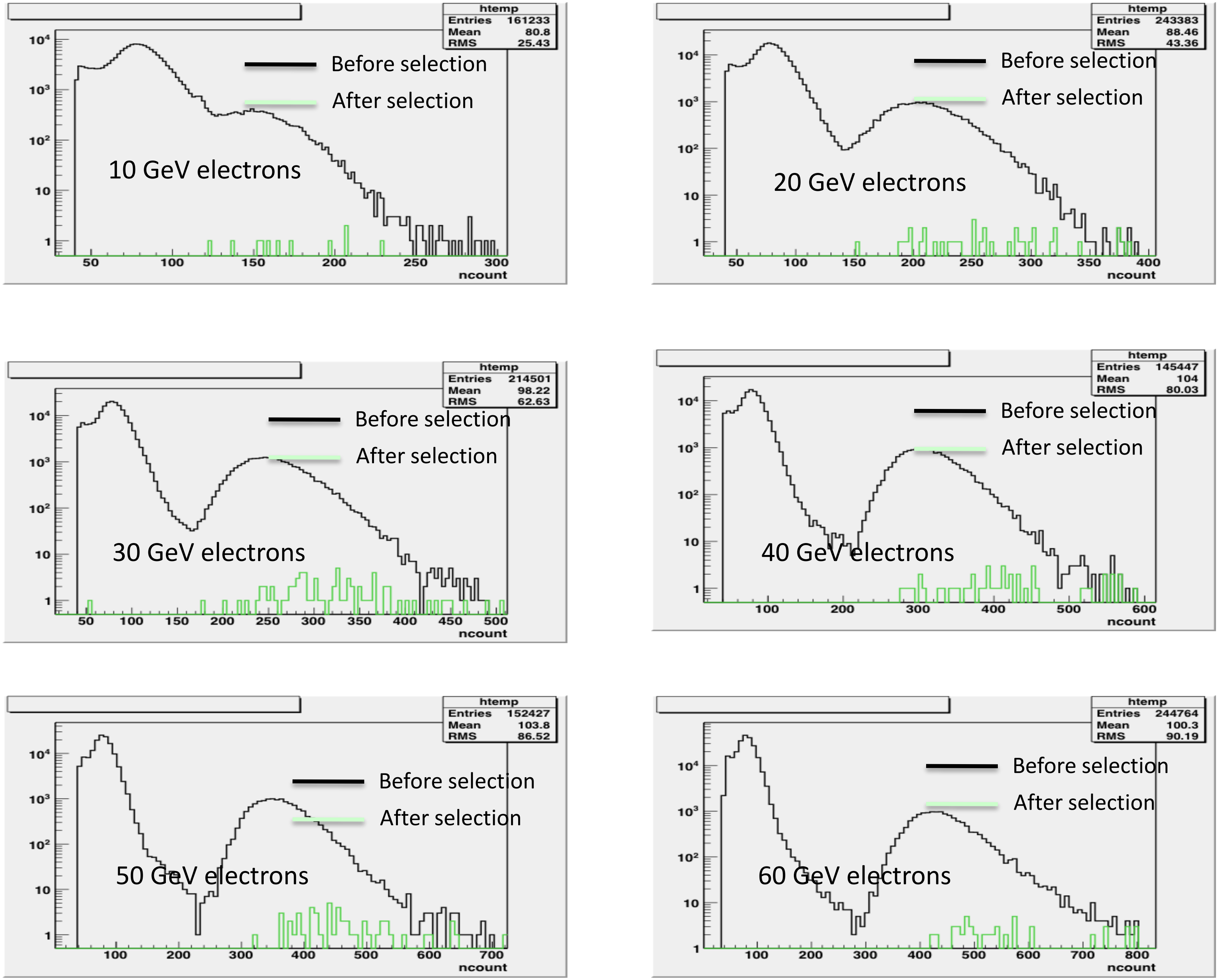


The selection should not impact the hadronic shower resolution



Reduction effect due to Ndeb> 4. This does not affect resolution

The selection “eliminates” the electron contamination



Energy estimation :

The thresholds weight evolution with the total number of hits obtained by minimizing a χ^2

$\chi^2 = (E_{beam}-E_{rec})^2/E_{beam}$

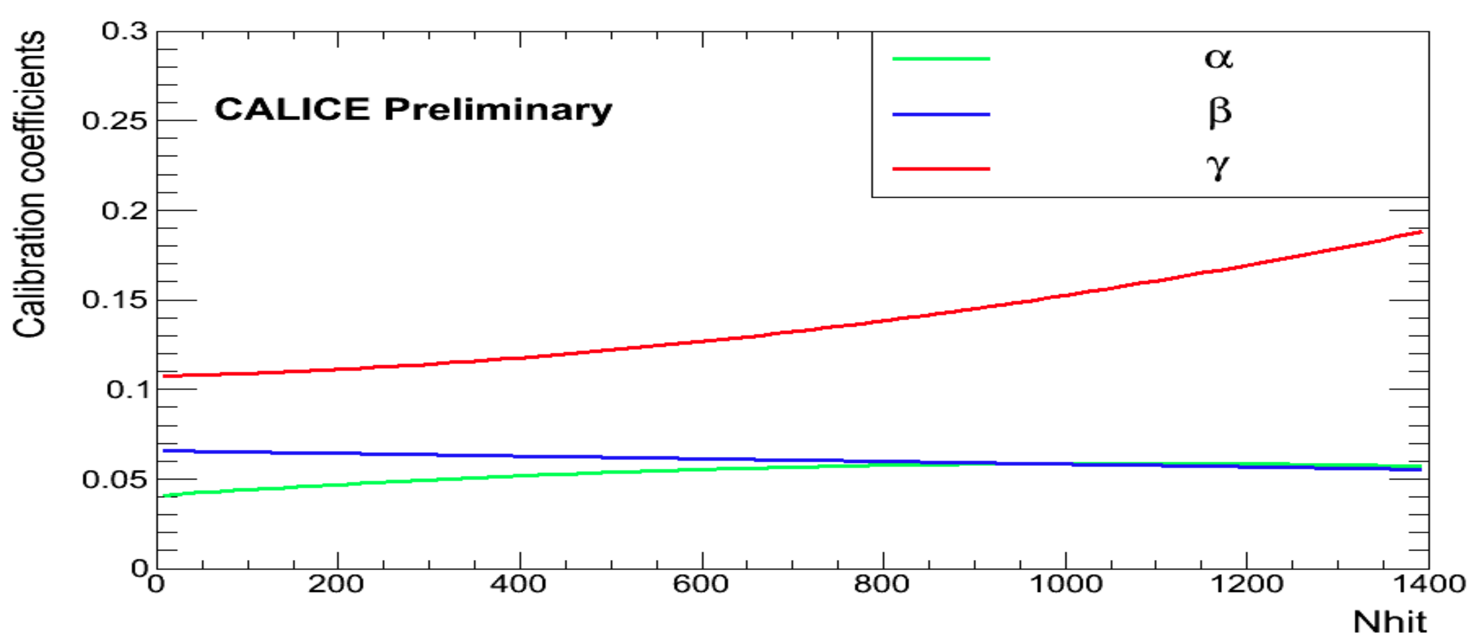
$E_{rec} = \alpha(N_{tot})\, N_1 + \beta(N_{tot})\, N_2 + \gamma(N_{tot})\, N_3$

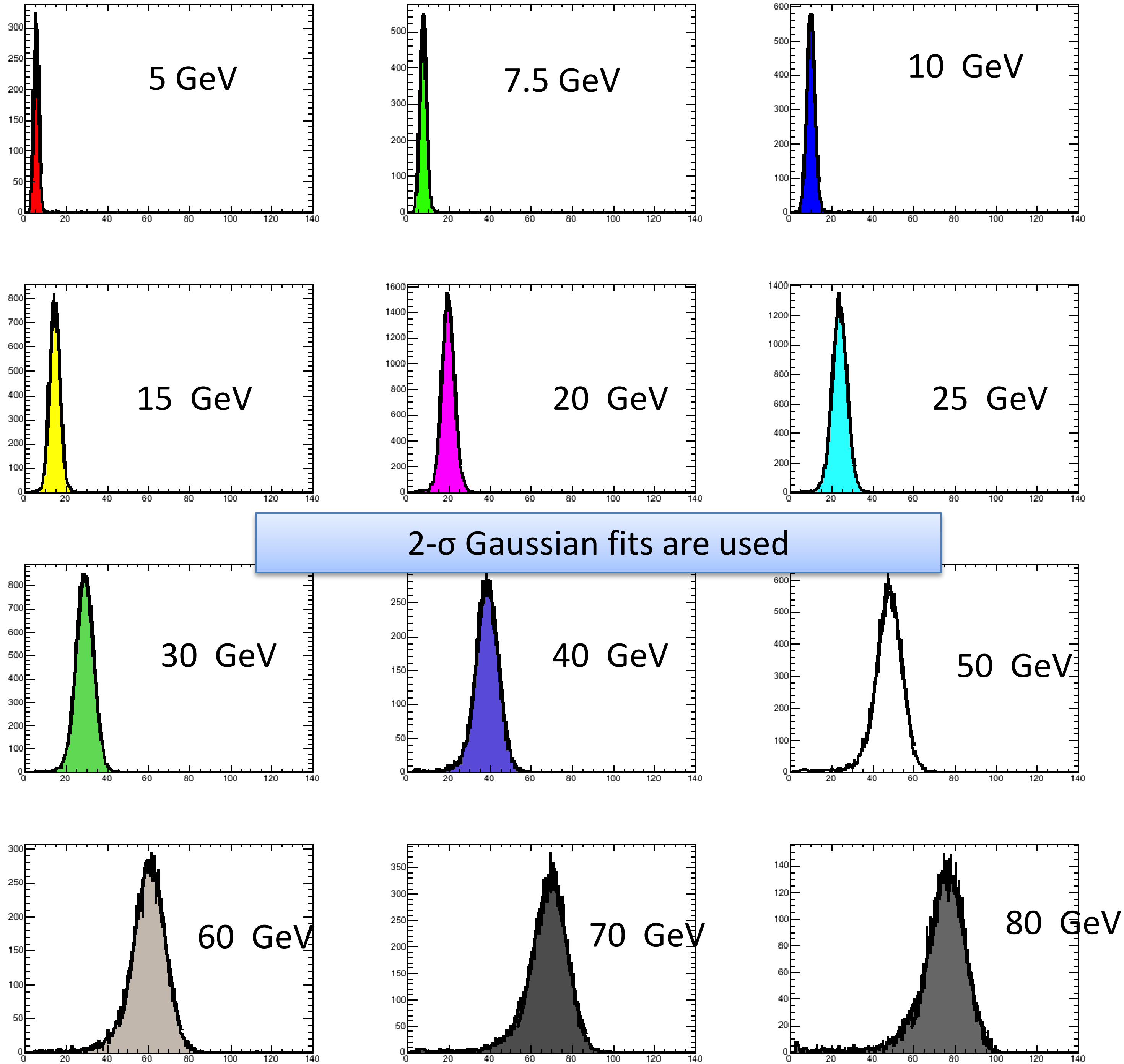
N_1,N_2 and N_3 : exclusive number of hits associated to first, second and third threshold.

α, β, γ are quadratic functions of the total number of hits (N_{tot})

For instance $\alpha = \alpha_0 + \alpha_1 N_{tot} + \alpha_2 N^2_{tot}$

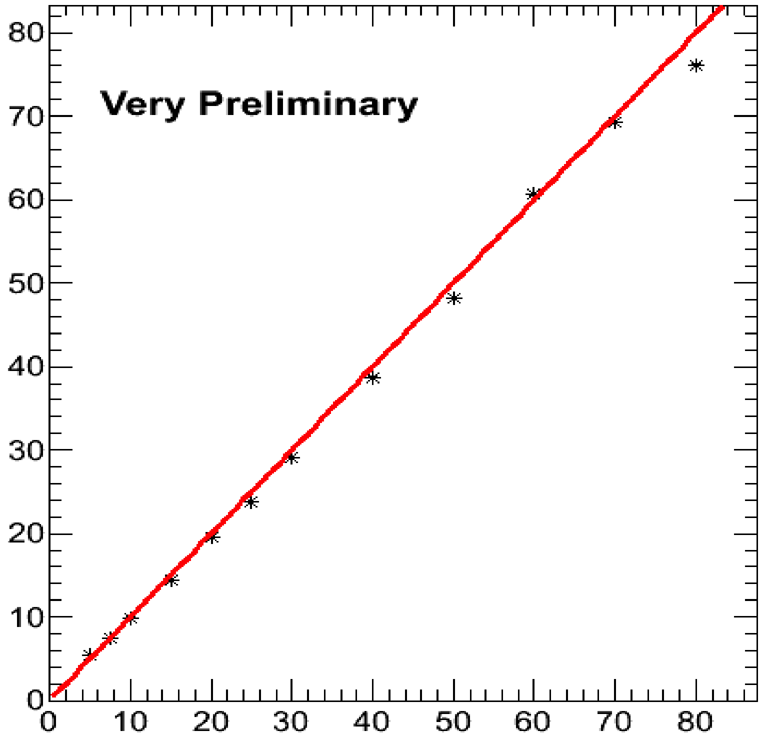
Events of September runs corresponding to energies : **5, 10, 30 , 60** and **80** GeV were used to fit the 9 parameters. This represents more than 50 k events.

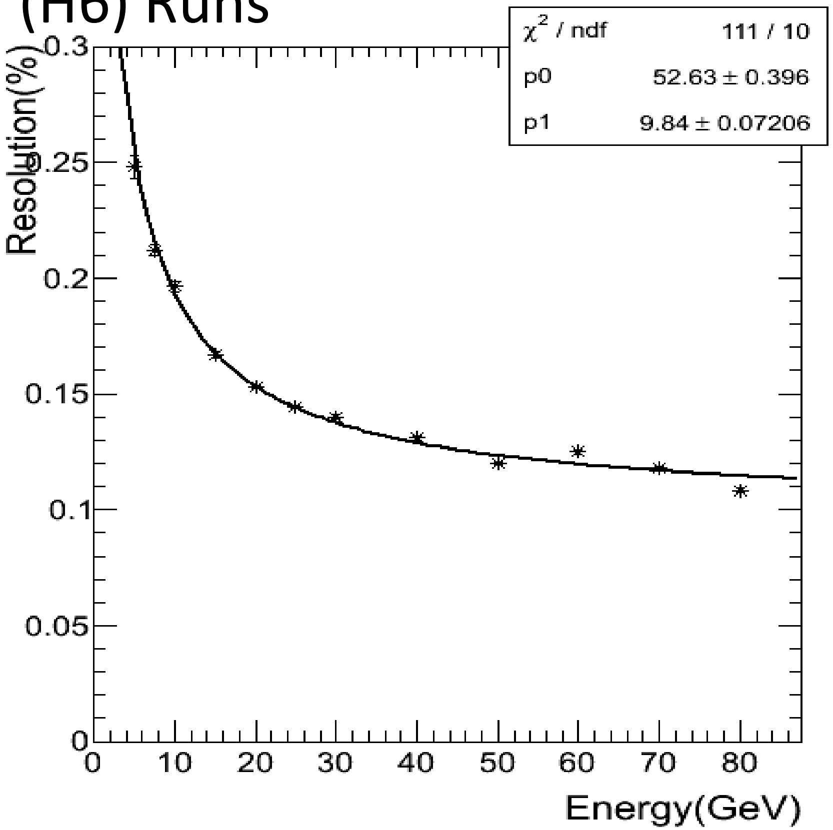




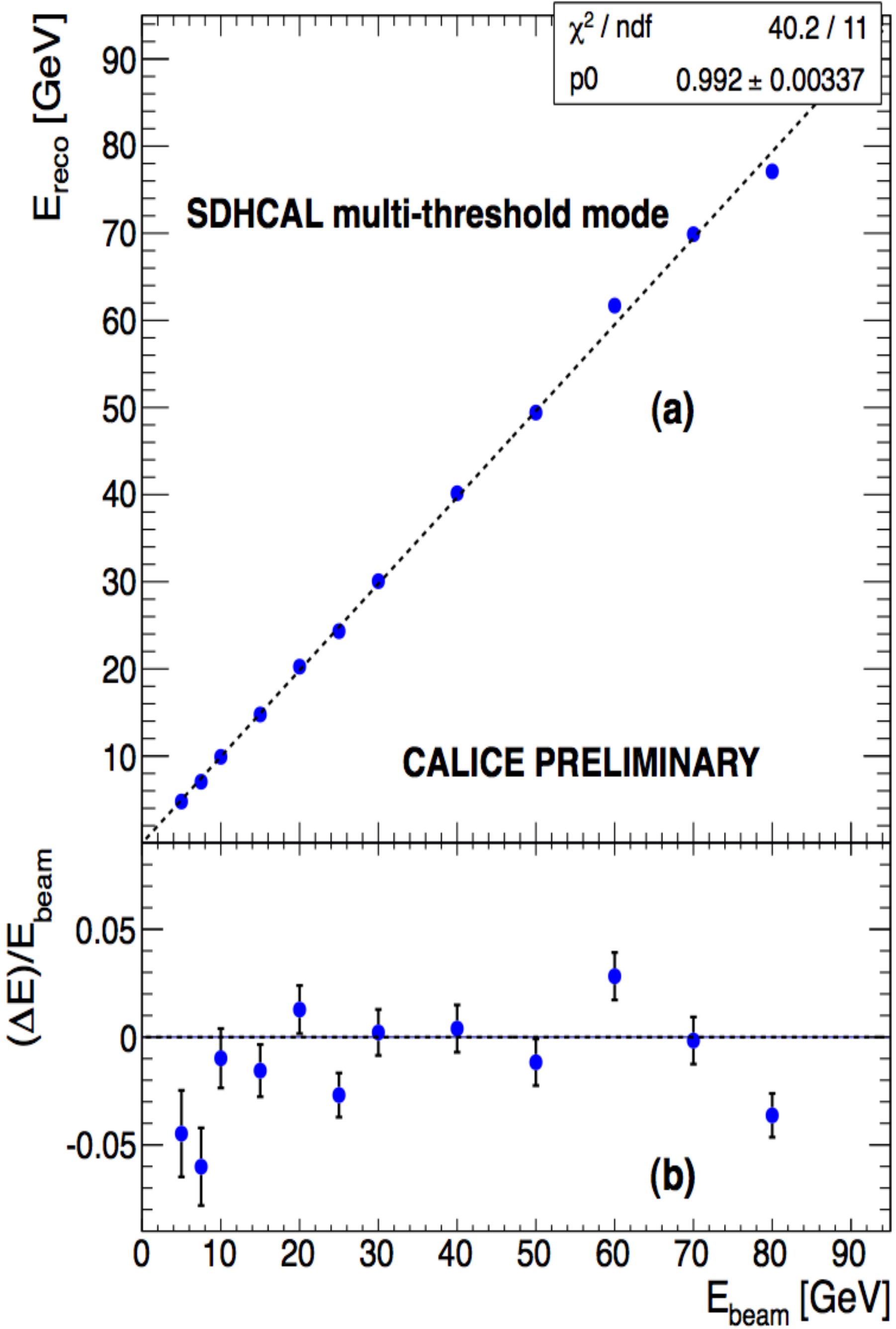
2-σ Gaussian fits are used

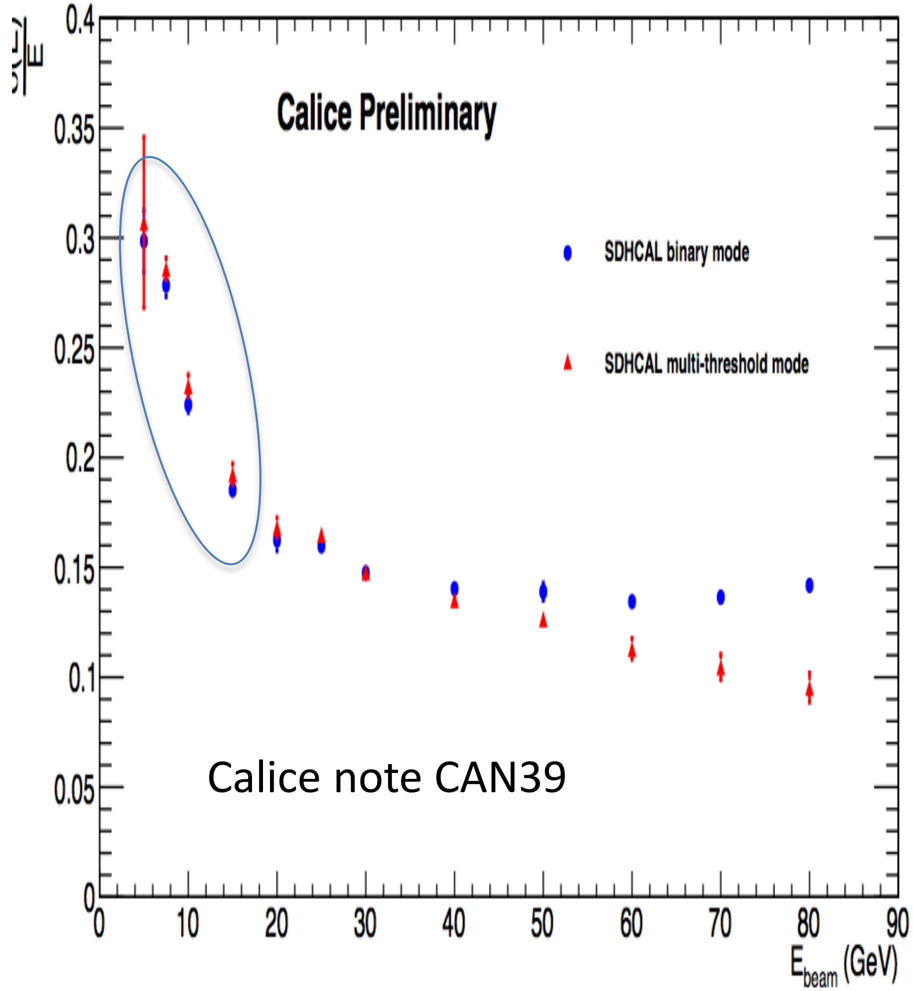
September (H6) Runs





E(GeV)	5	7.5	10	15	20	25	30	40	50	60	70	80
ΔE/E	0.077	0.012	0.008	0.037	0.021	0.047	0.031	0.032	0.035	0.010	0.010	0.048
σ/E	0.248	0.212	0.196	0.167	0.153	0.144	0.140	0.131	0.119	0.125	0.118	0.108

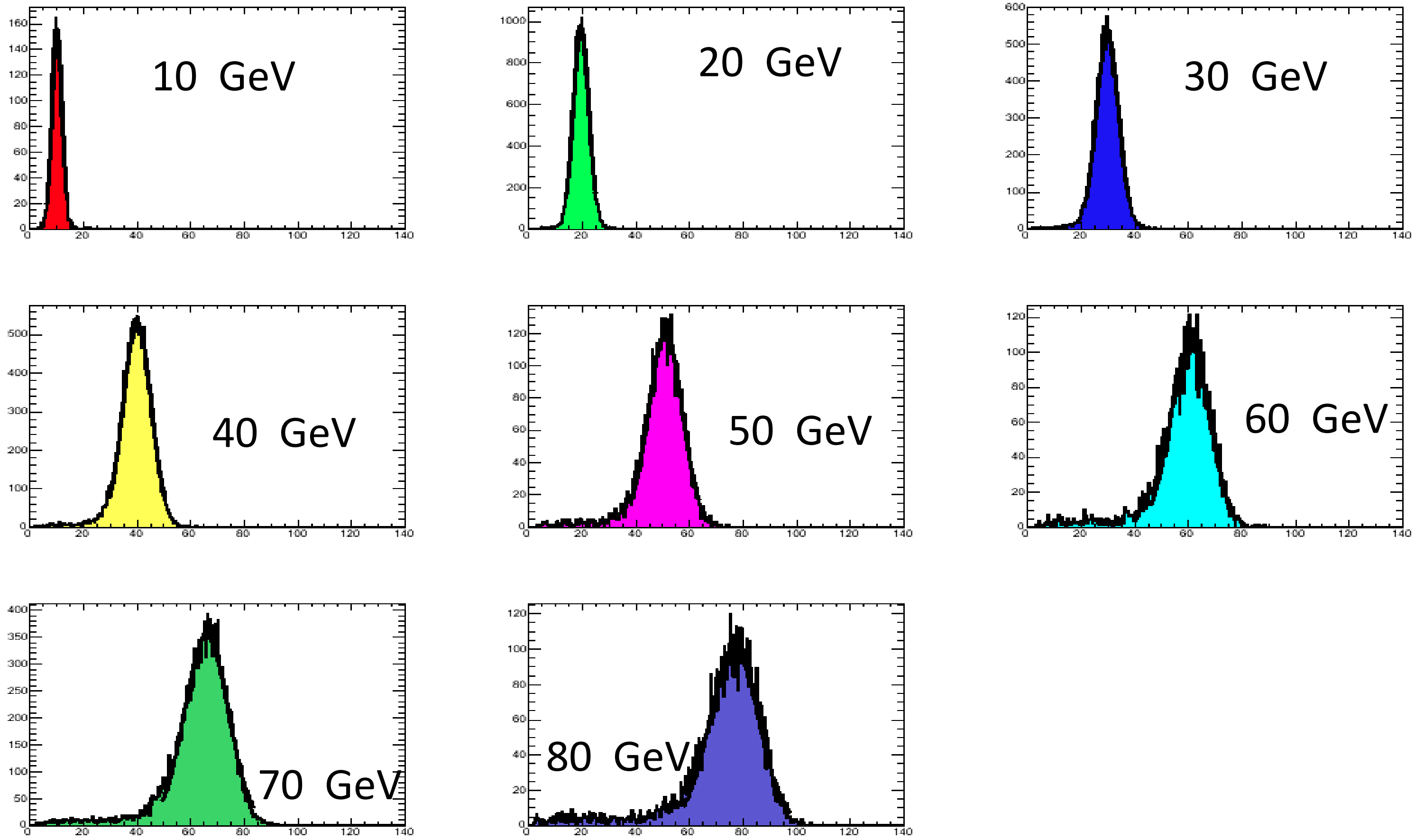




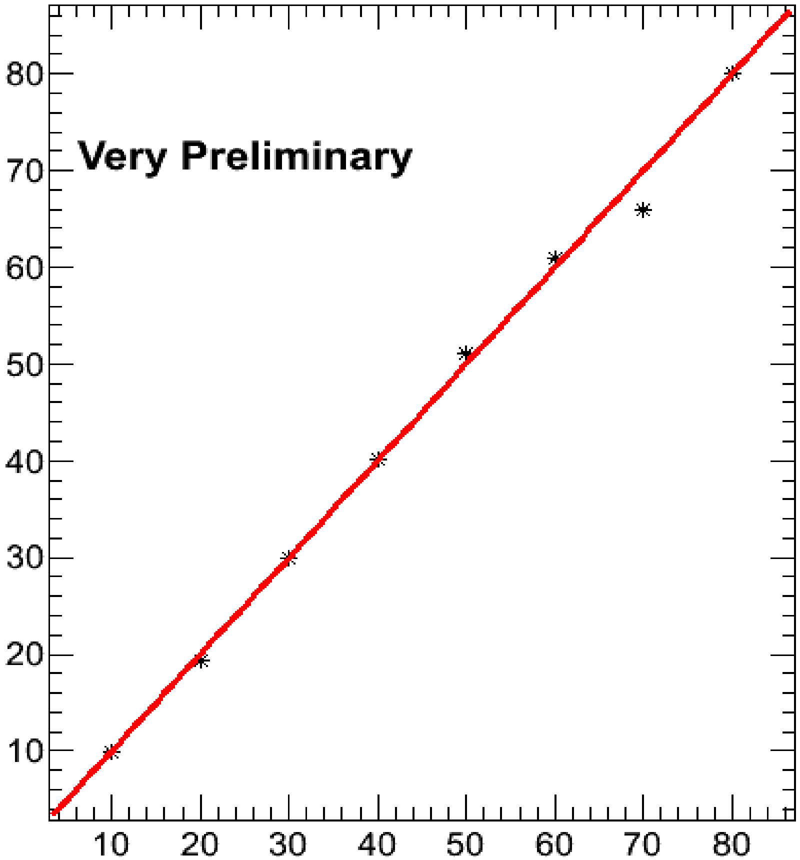
Calice note CAN39

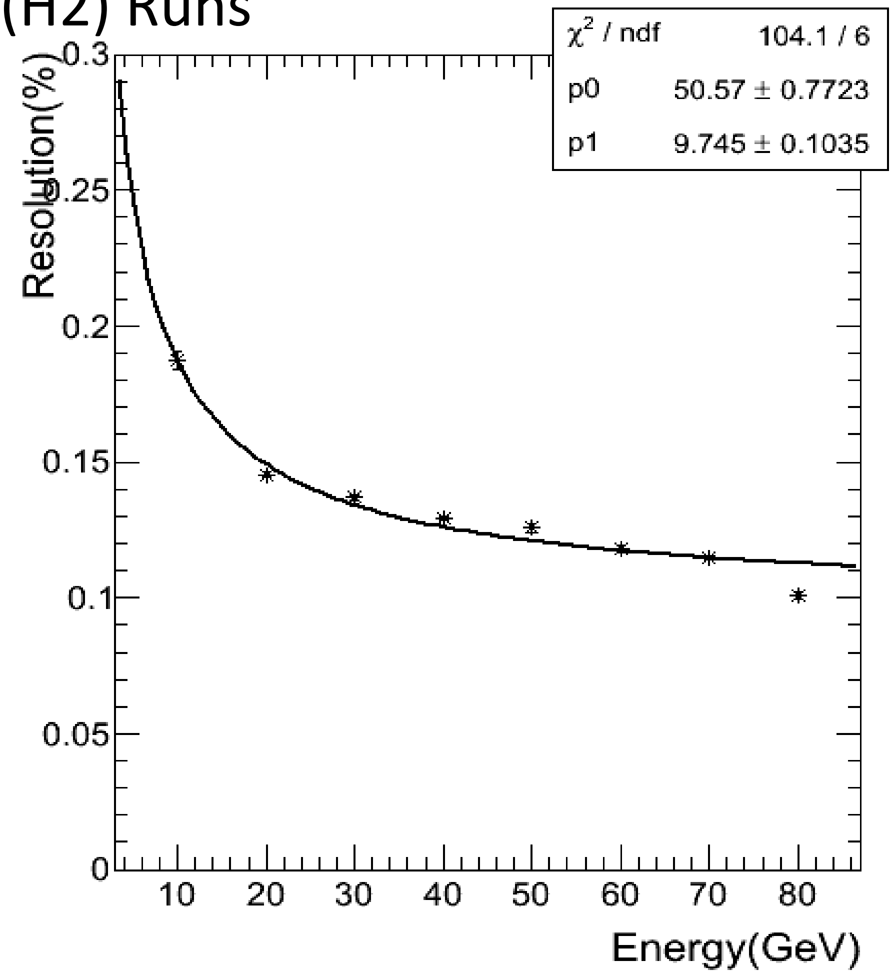
The resolution at low energy was improved :
electron contamination reduced.

Applying the same cuts and using the same calibration parameters as for the September Runs (H6) on the the November Runs (H2)



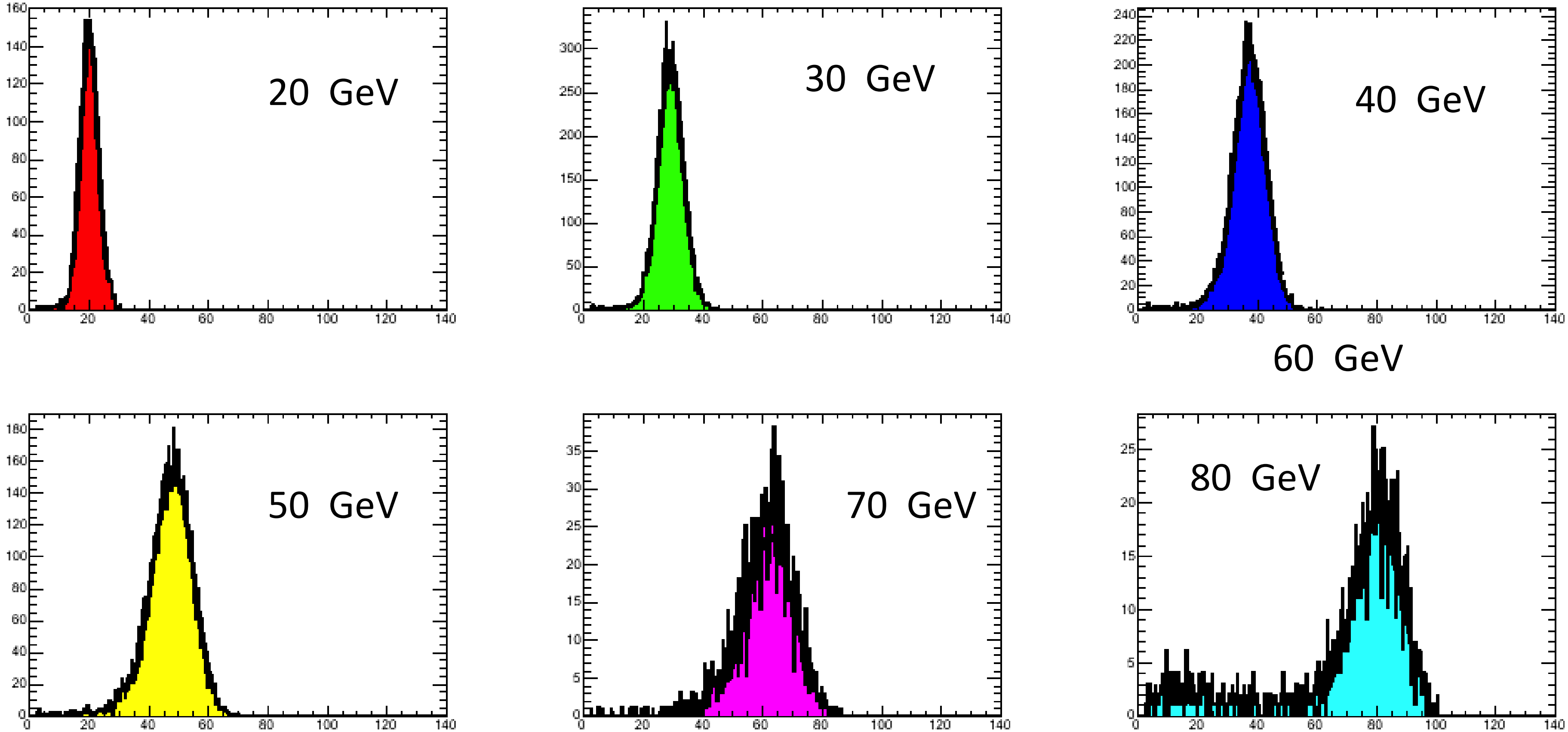
November (H2) Runs



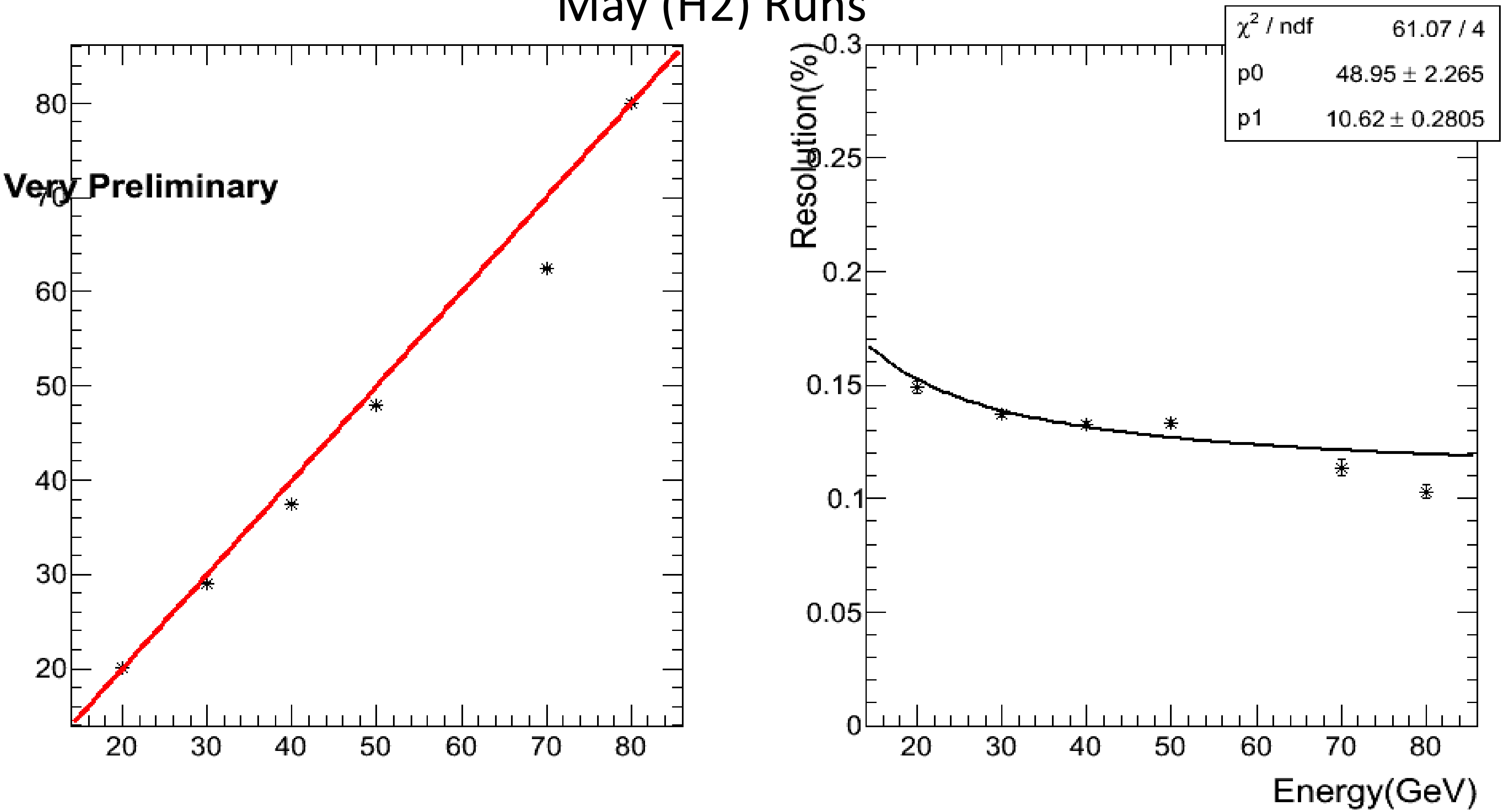


E(GeV)	10	20	30	40	50	60	70	80
ΔE/E	0.001	0.028	0.002	0.004	0.023	0.015	0.057	0.033
σ/E	0.187	0.145	0.137	0.129	0.125	0.118	0.114	0.100

Applying the same cuts and using the same calibration parameters as for the September Runs (H6) on the the May Runs (H2)



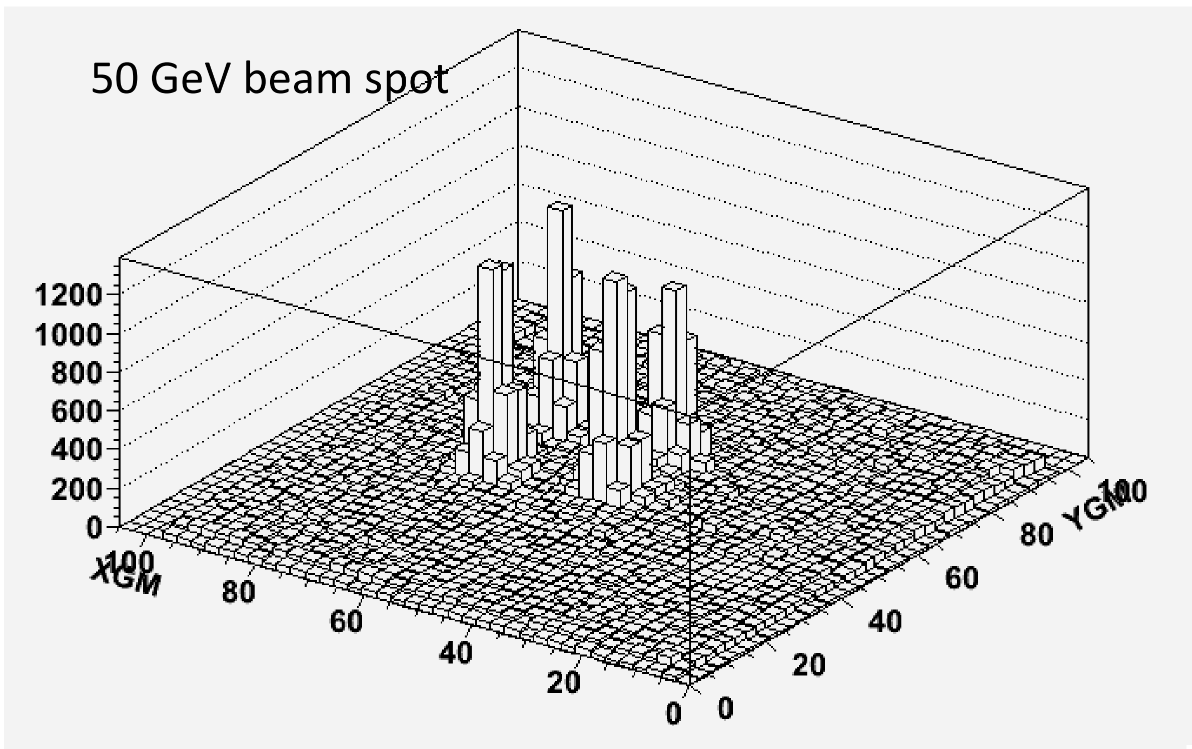
May (H2) Runs



E(GeV)	10	20	30	40	50	60	70	80
ΔE/E		0.001	0.03	0.062	0.04		0.11	0.001
σ/E		0.149	0.137	0.132	0.133		0.114	0.100

The small deviation of May data with respect to that of September and November could be explained by the fact that in May the beam was shot in different zones of the detector.

This deviation is a kind of heterogeneity measurement of our detector in the absence of any correction.



Correction of this by using the in-between beam muons and the tracks within the hadronic shower (Hough-Transform) is an ongoing work

Energy resolution beyond counting : Hough-Transform

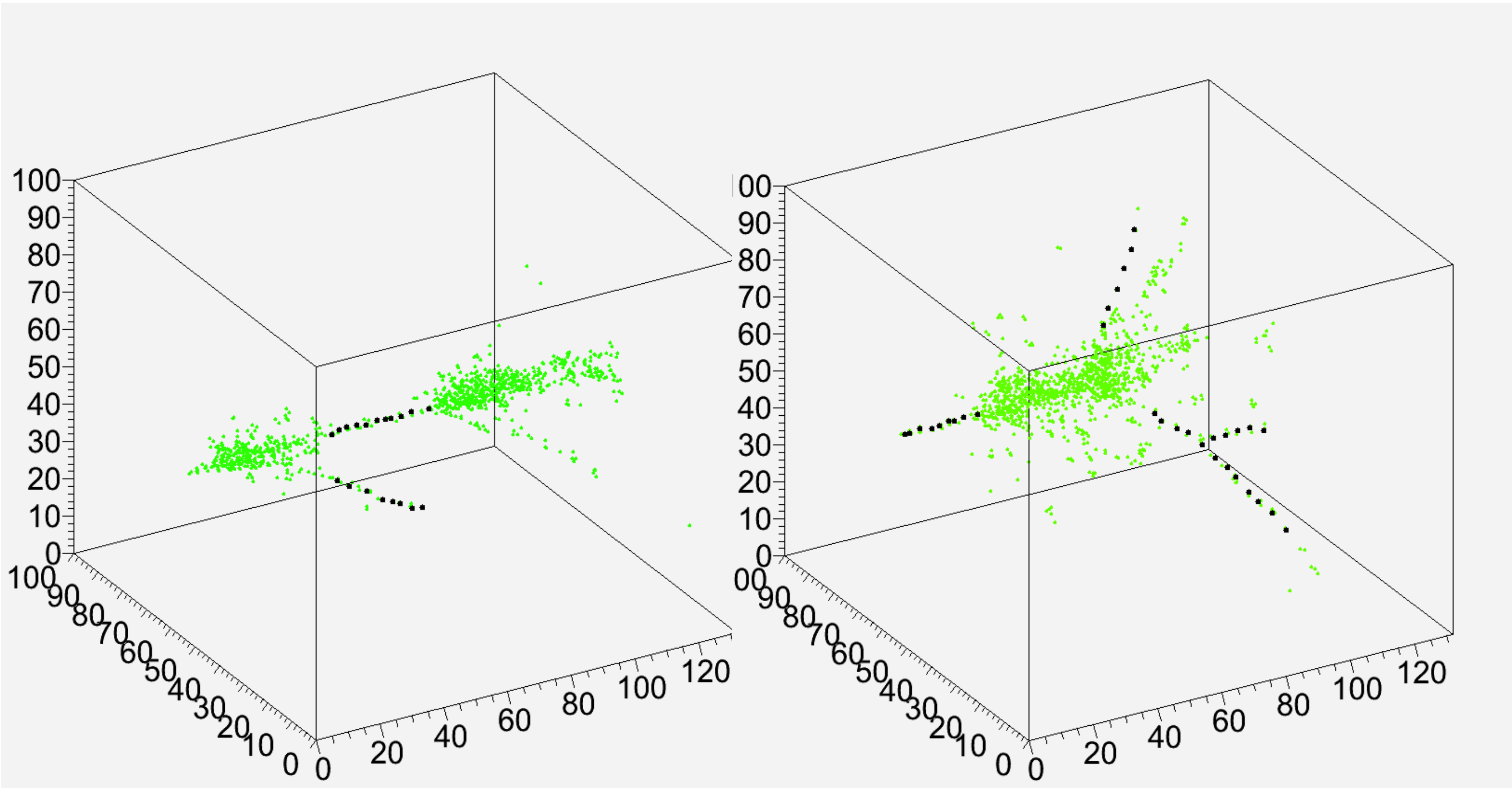
Tracks found using Hough Transform method can be used to calibrate the detector in situ. They can also help to better understand the hadronic shower structure and improve on the energy/linearity resolution.

This comes from the fact that hits belonging to tracks/mips should not be treated in the same way as those of the hadronic shower core for instance

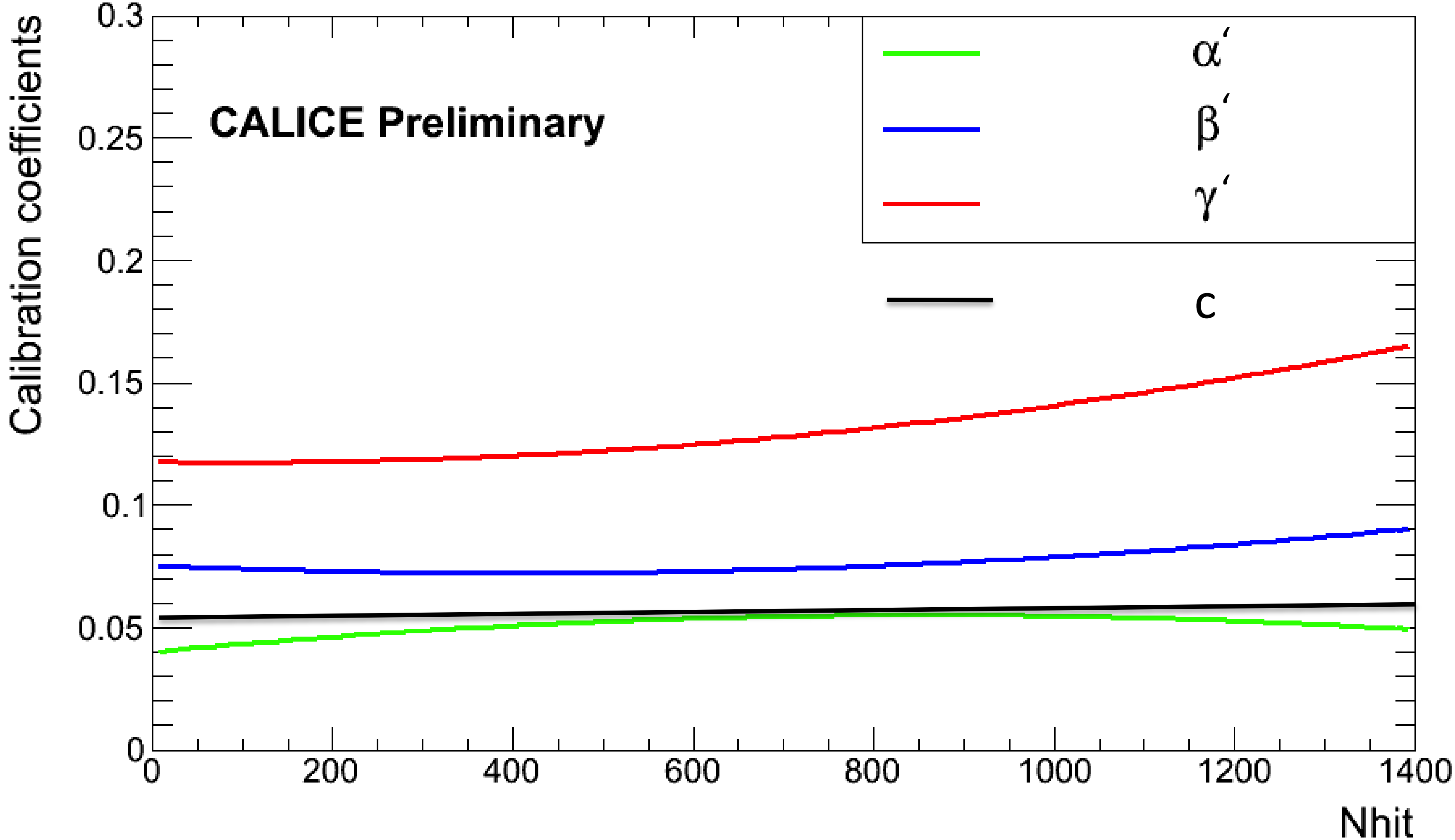
$E_{rec} = \alpha'(N_{tot})\, N'_1 + \beta'(N_{tot})\, N'_2 + \gamma'(N_{tot})\, N'_3 + C\, N_{HT}$

Where N_{HT} are the number of hits associated to HT tracks.
N'_1,N'_2 and N'_3 : exclusive number of hits associated to first, second and third threshold after subtracting the N_{HT}

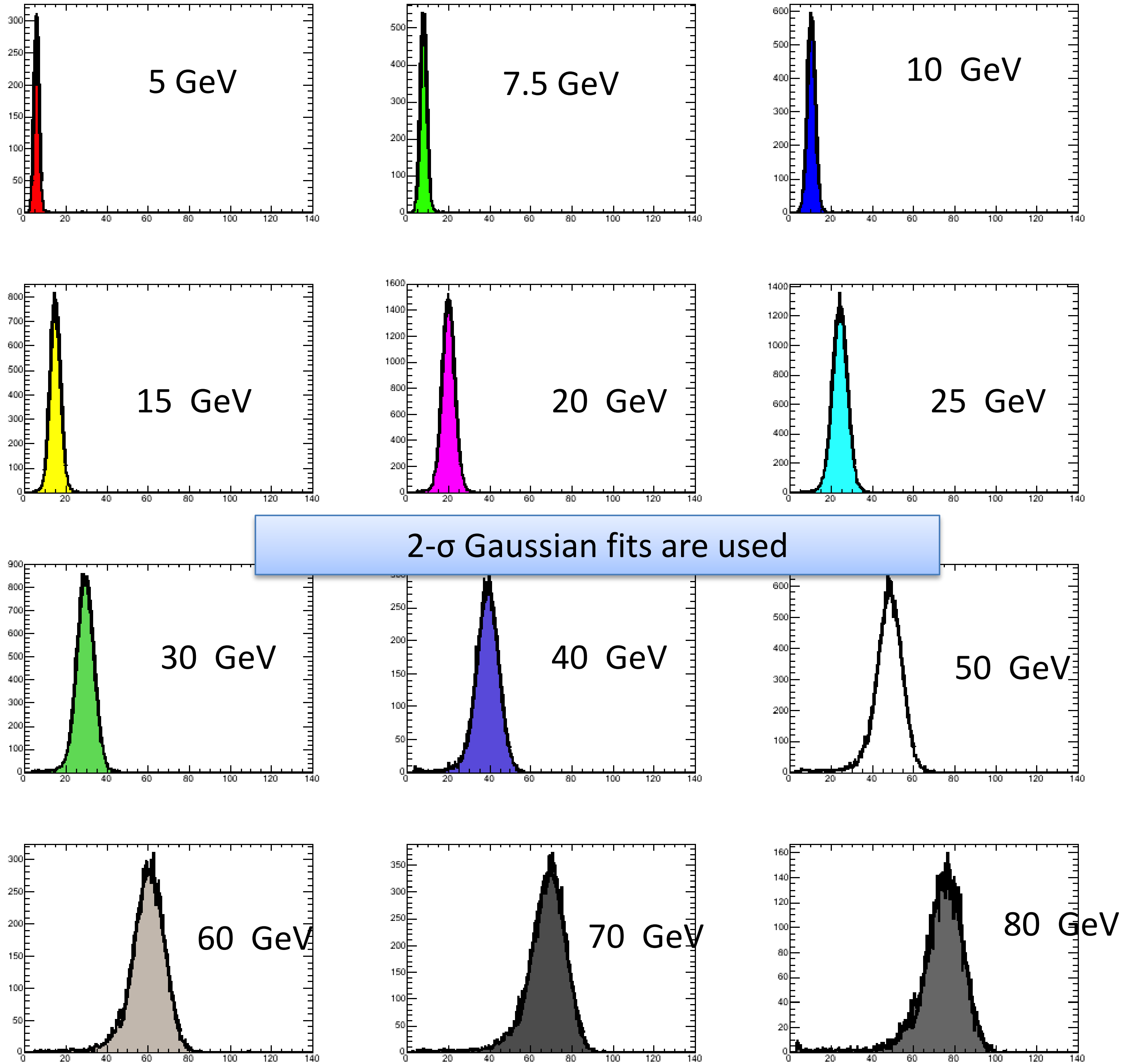
C is a constant. C, α', β' and γ' are determined in the same way as in the standard case using part of the September data.



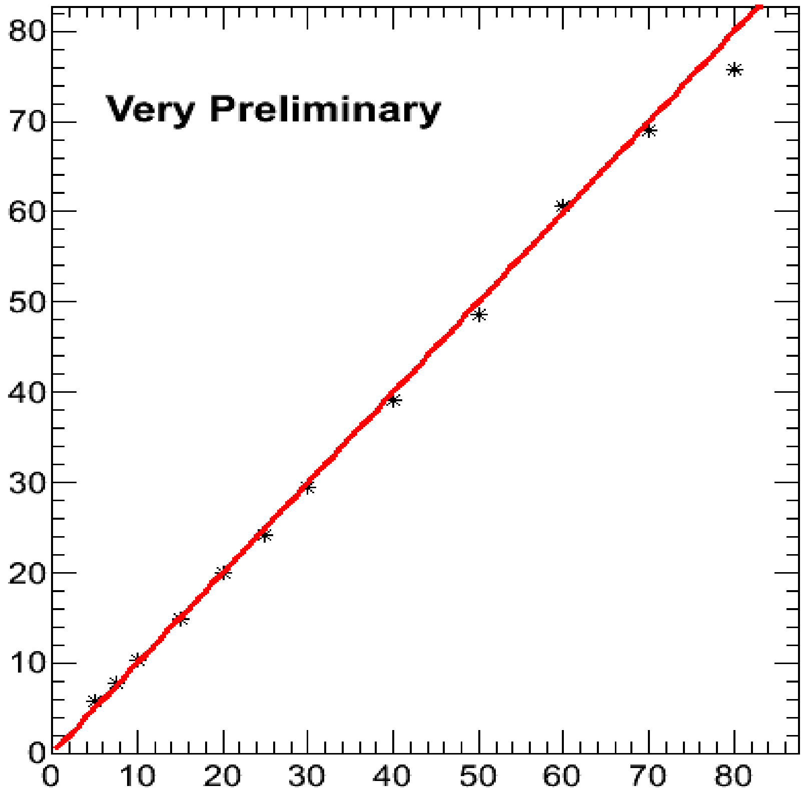
In black clusters selected by the HT method

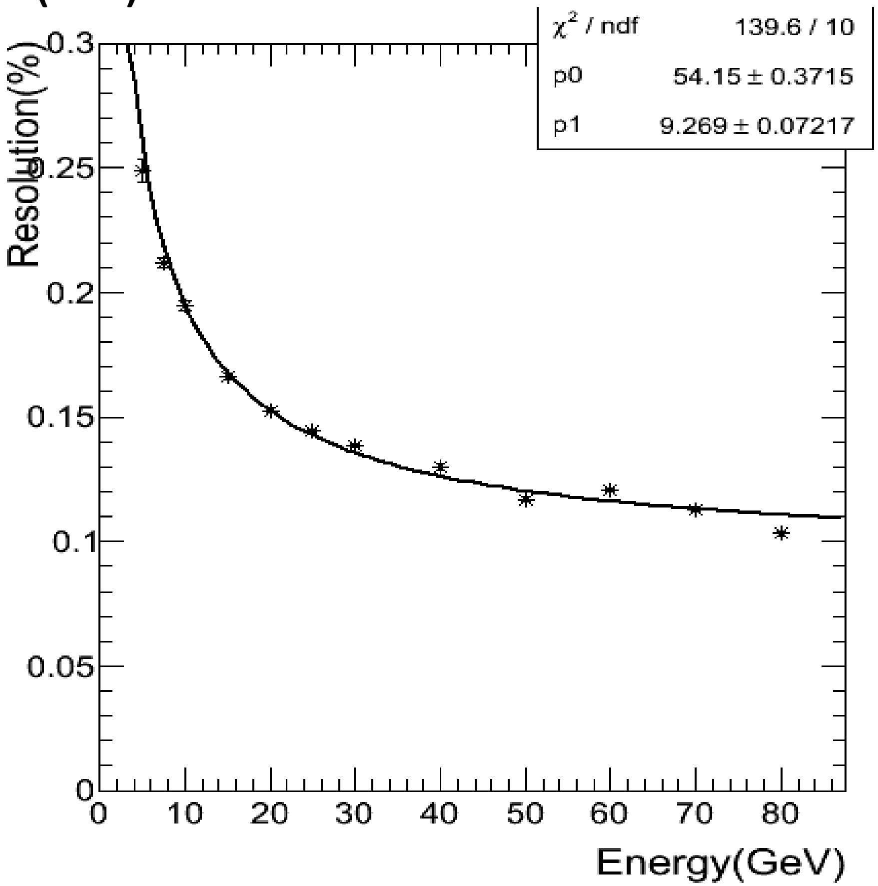


CALICE Preliminary
Calibration coefficients
Nhit
α´
β´
γ´
c
0
0.05
0.1
0.15
0.2
0.25
0.3
0
200
400
600
800
1000
1200
1400


5 GeV
7.5 GeV
10 GeV
15 GeV
20 GeV
25 GeV
2-σ Gaussian fits are used
30 GeV
40 GeV
50 GeV
60 GeV
70 GeV
80 GeV

September (H6) Runs





Small improvement on the energy resolution for free

E(GeV)	5	7.5	10	15	20	25	30	40	50	60	70	80
ΔE/E	0.14	0.039	0.031	0.011	0.002	0.03	0.017	0.022	0.028	0.011	0.013	0.054
σ/E	0.249	0.212	0.195	0.166	0.152	0.144	0.138	0.129	0.117	0.120	0.113	0.103

Energy resolution beyond counting : Perspectives

More work is still needed to better calibrate our data so counting method could be improved. The improvement will be however limited.

The calibration constants (.C, α', β' and γ') in our case don't take care of the shower starting point, the leakage and other topological elements in appropriate way.

As we proposed few years ago Neural Network technique could provide a good tool to deal with this and achieve better energy resolution.

Conclusion

In this work, we showed that the results presented in our note CAN39 are robust. Improvement at low energy is possible by reducing the electron contamination.

We validated our method of energy calibration by applying it to data taken in different scenarios (different energies and different beams..)

No tail catcher, no Cerenkov and no gain correction were used in this work and calibration is still not included.

Calibration using in-between beam muons is ongoing.

In the near future we intend to use the MM information (used as a tail catcher in the November Runs of SDHCAL-GRPC

We intend to use the NN techniques with the hope to improve on the energy resolution.