Hadron Calorimetry with 1-2 bits

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Introduction

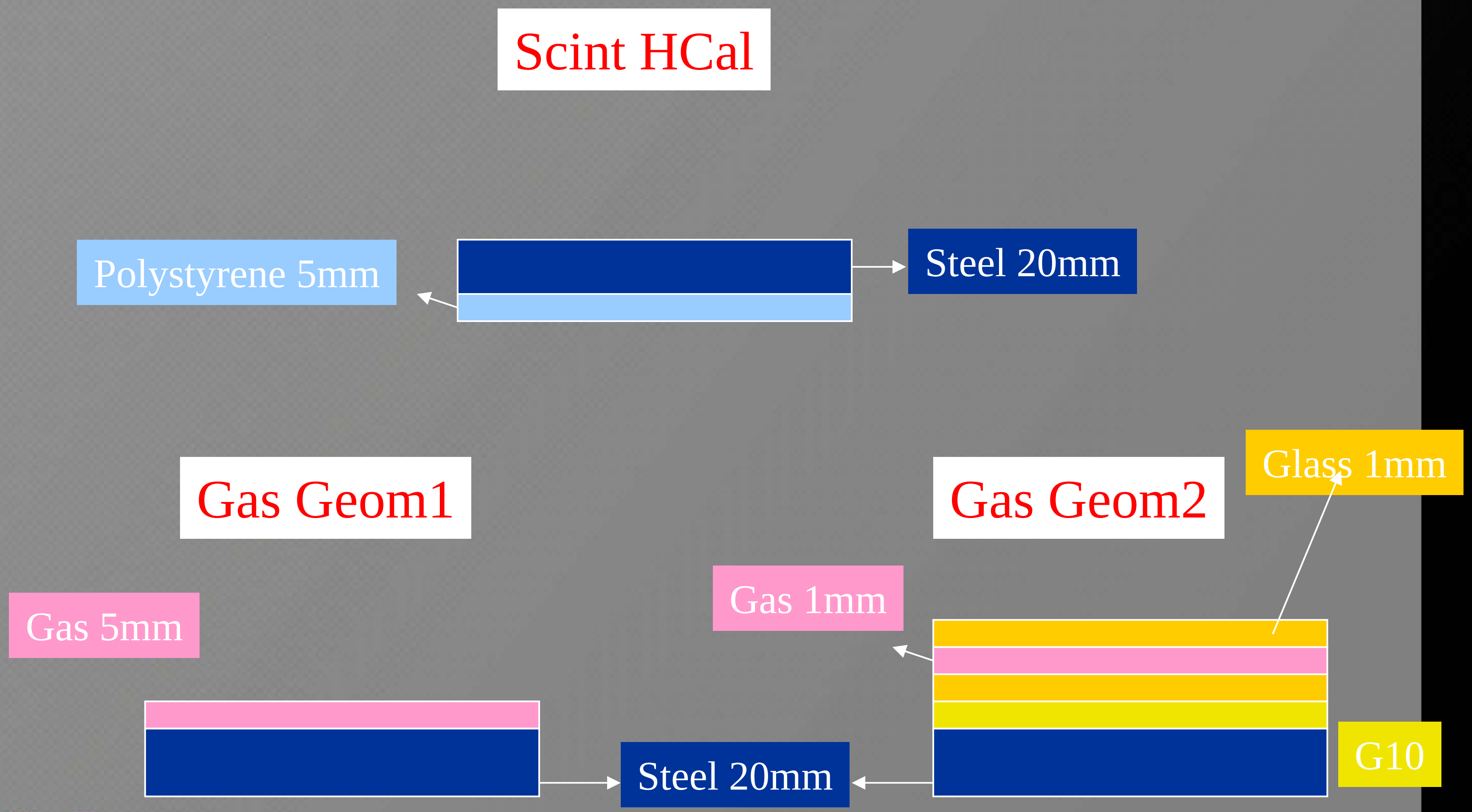
- We are basically talking about a calorimeter with a finite number of thresholds (1-3)
- Will look at gas and scintillator:

    energy resolution

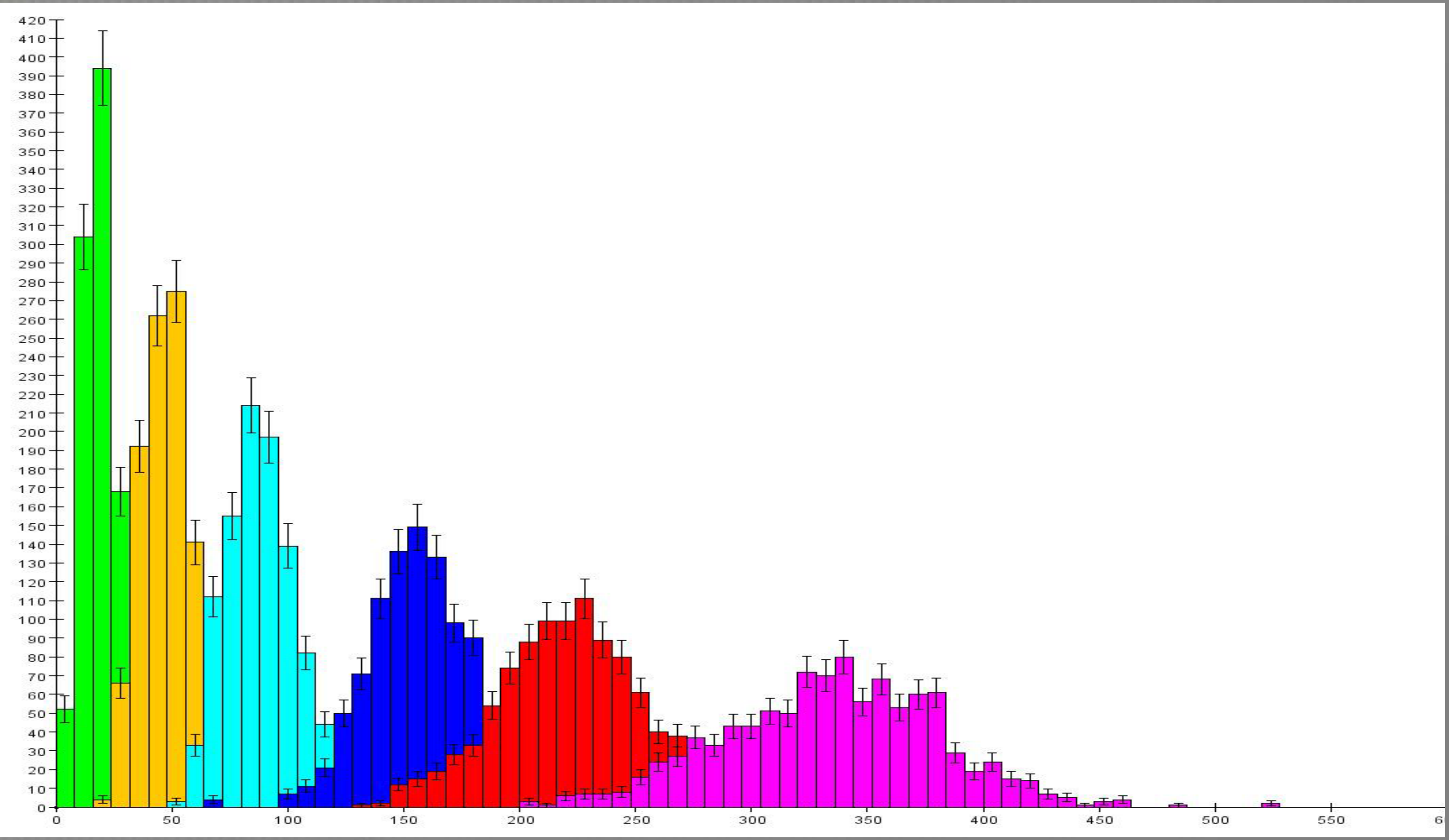
    shower widths

    clustering

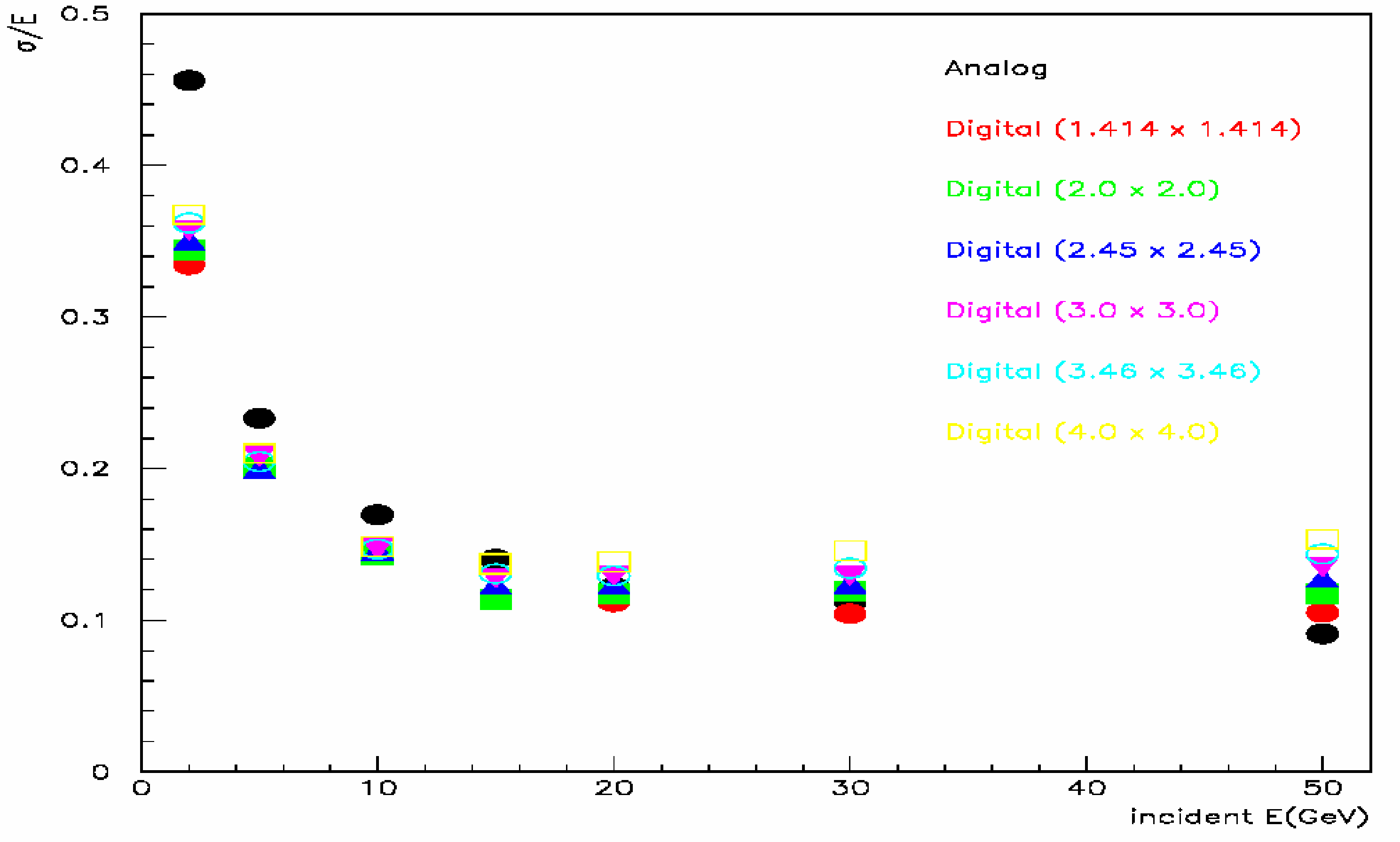
Geometries Considered



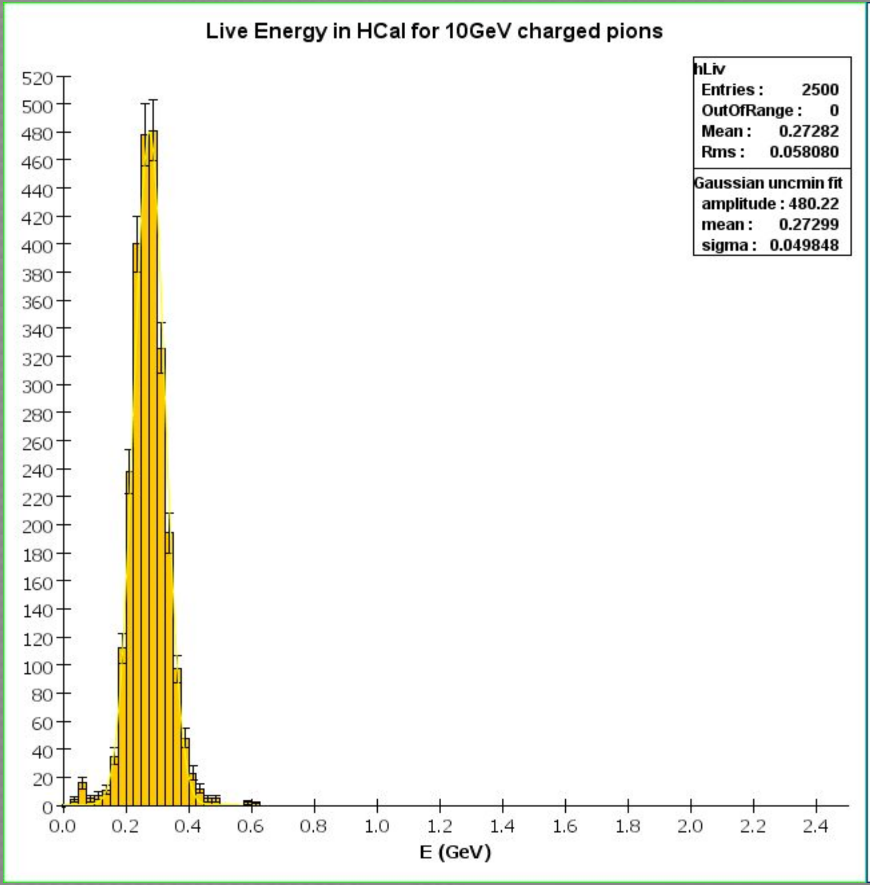
Ncells for hadrons

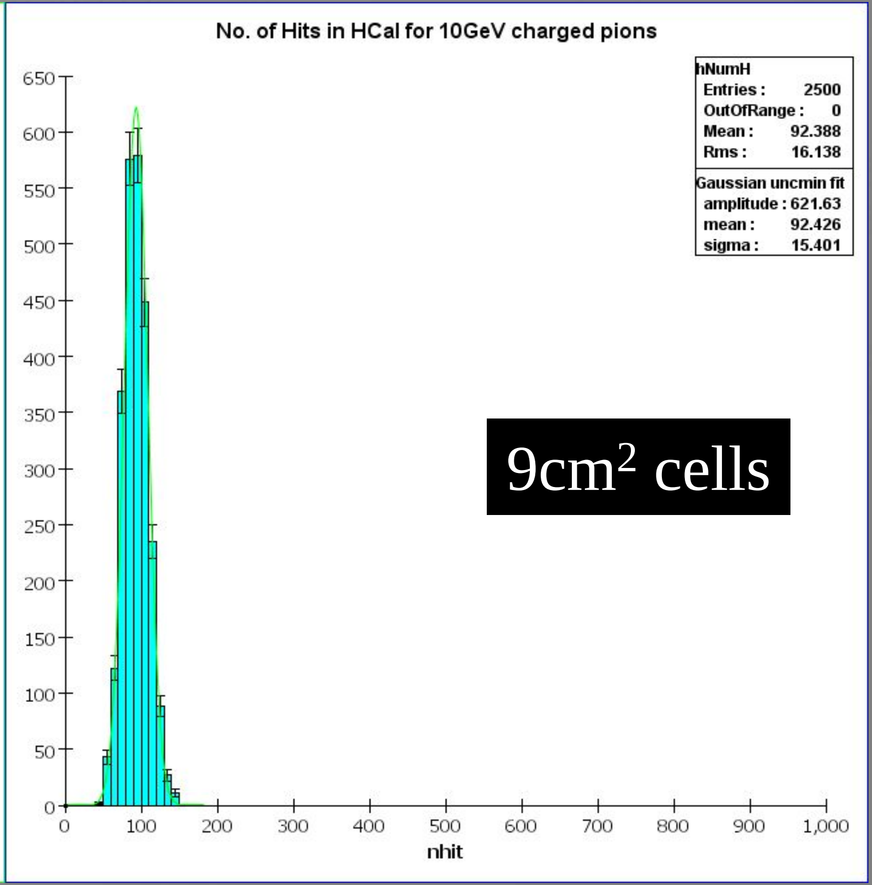


Single particle resolutions

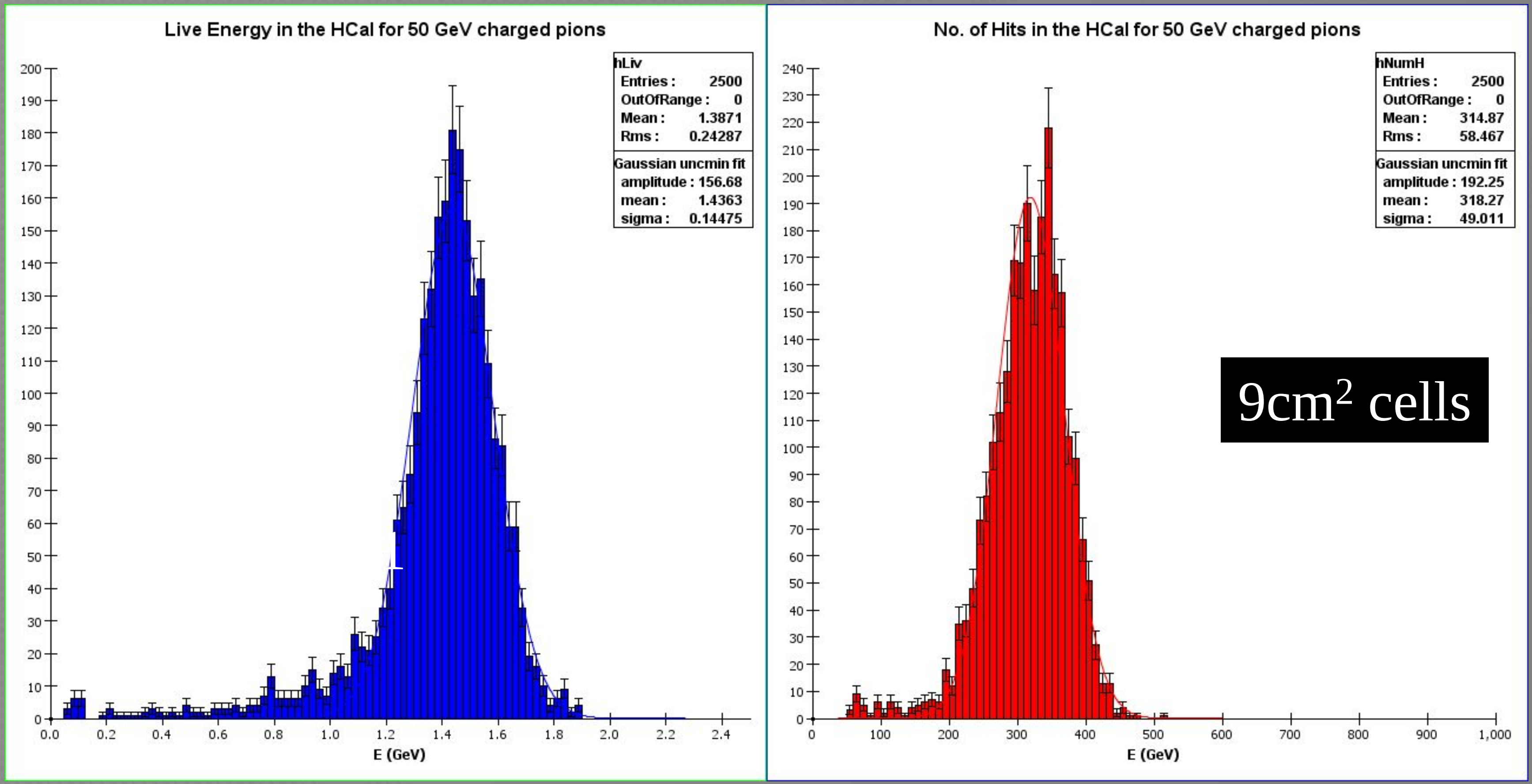


Single Particle Resolution (10GeV)

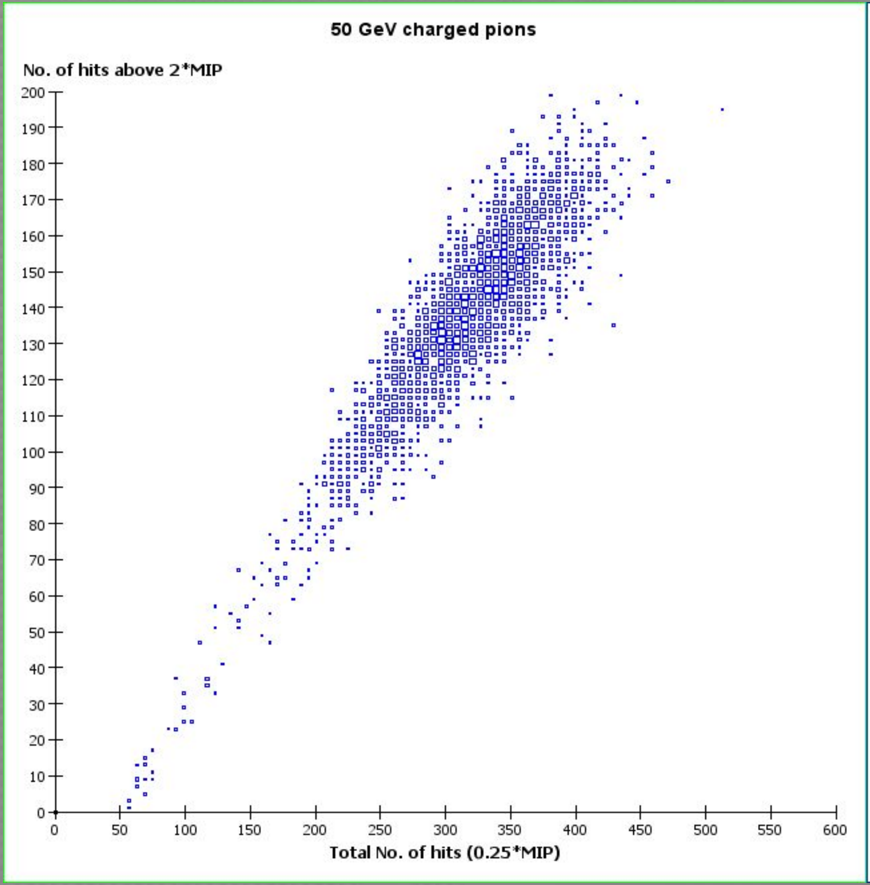


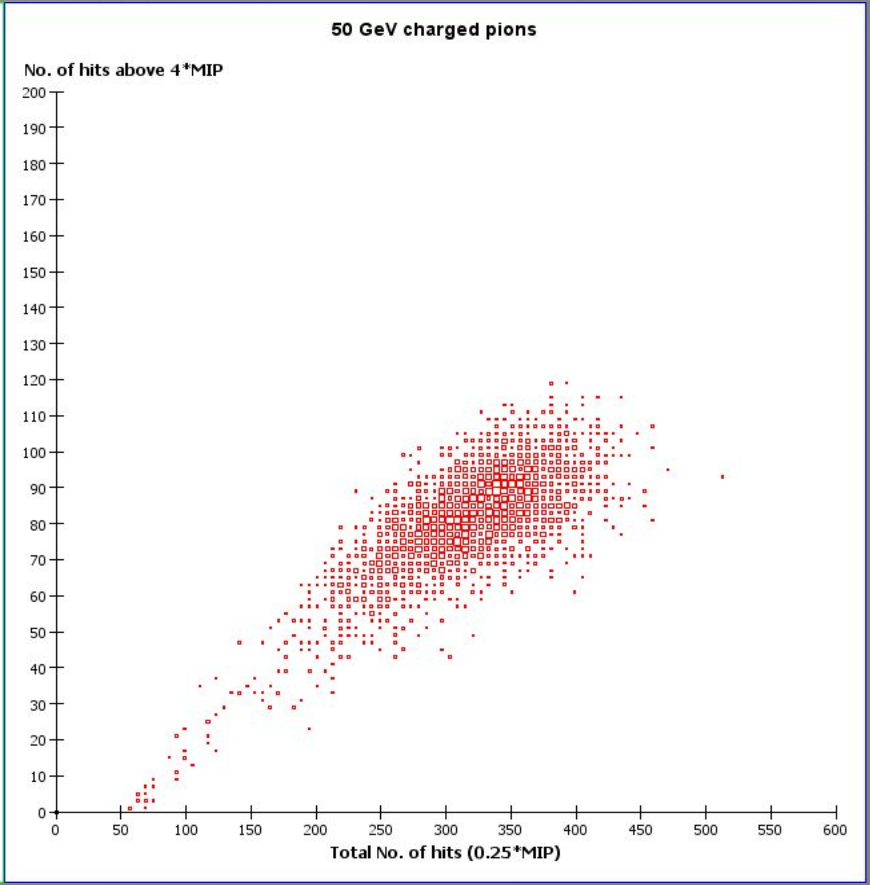


Single Particle Resolution (50GeV)

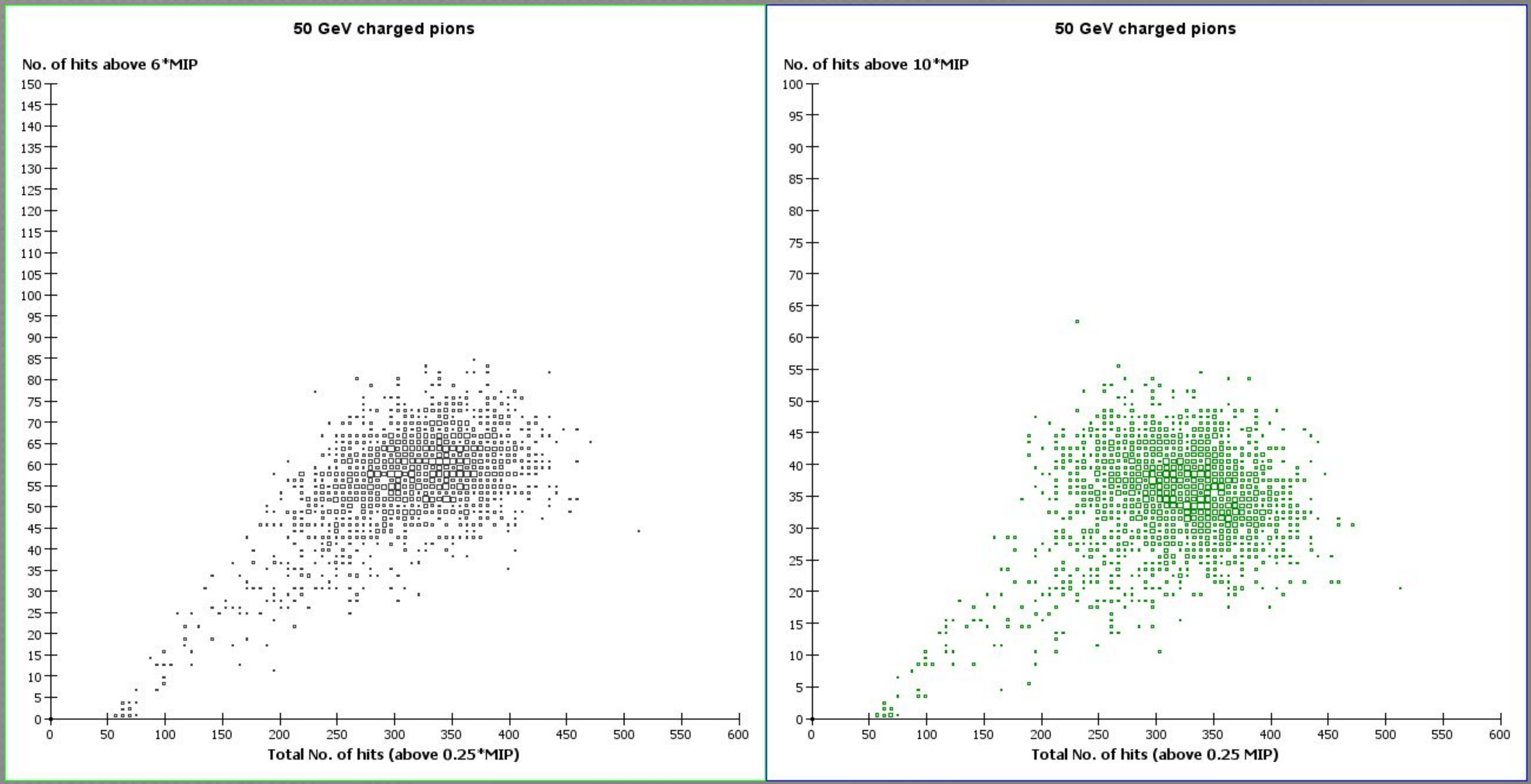


Nhit correlations

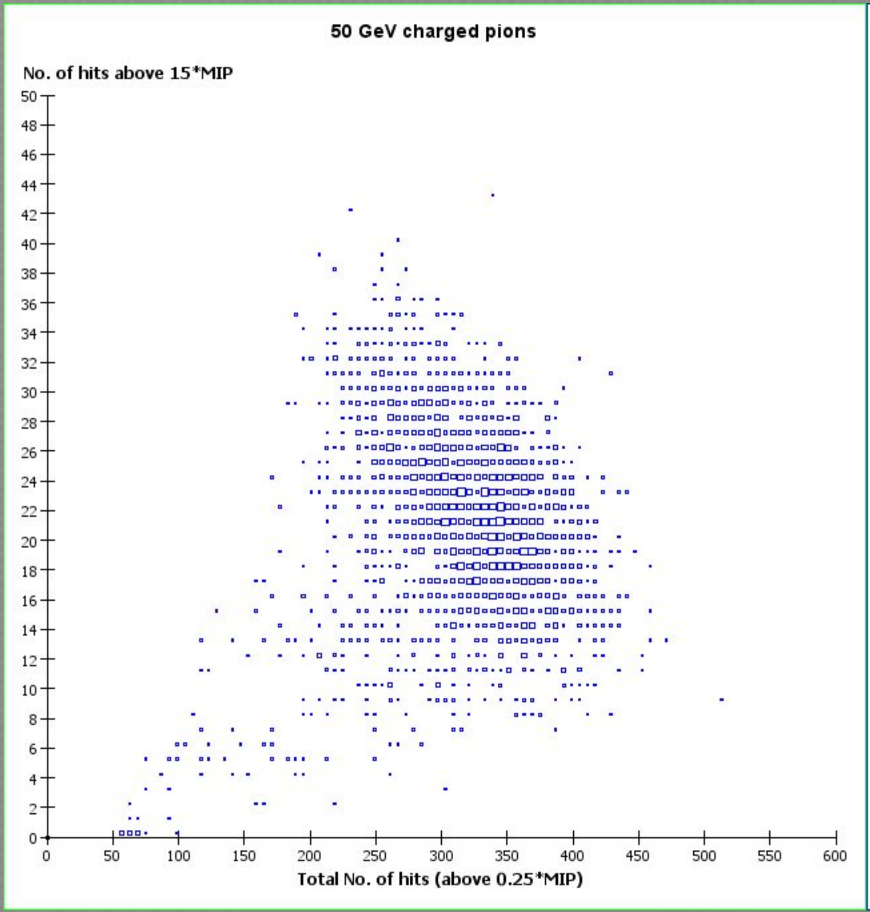


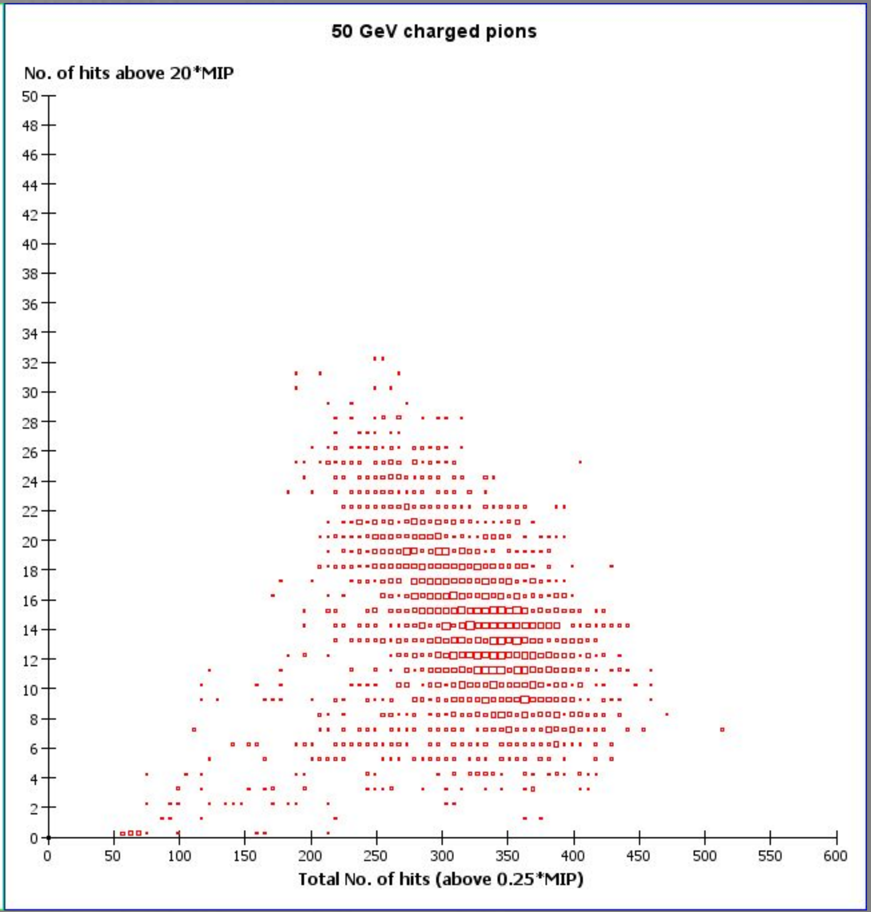


Nhit correlations

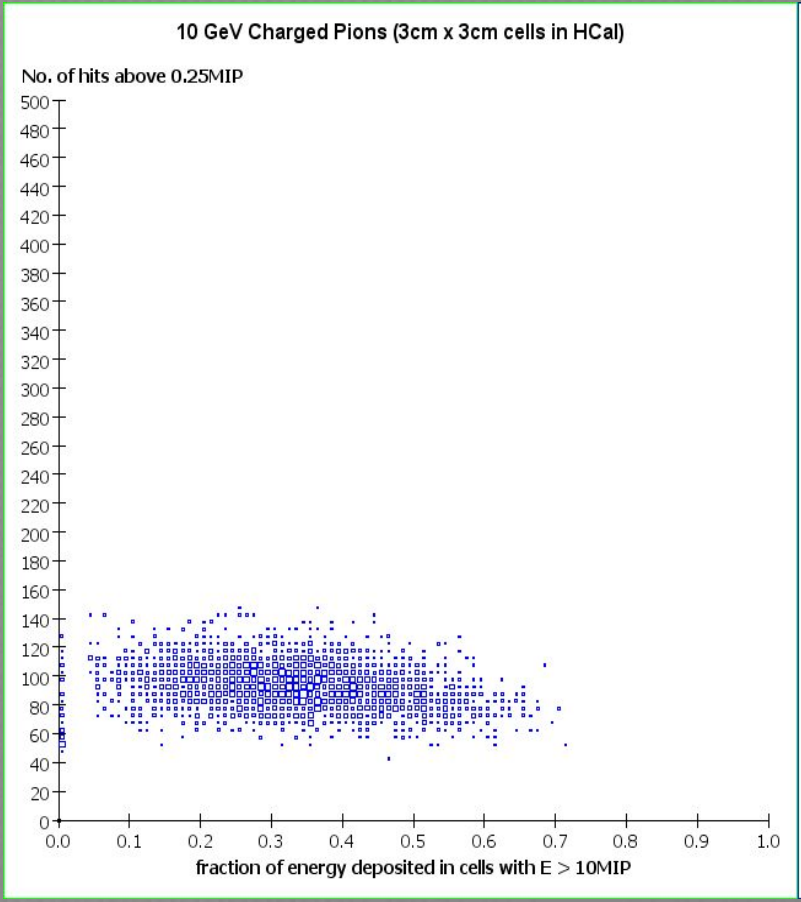


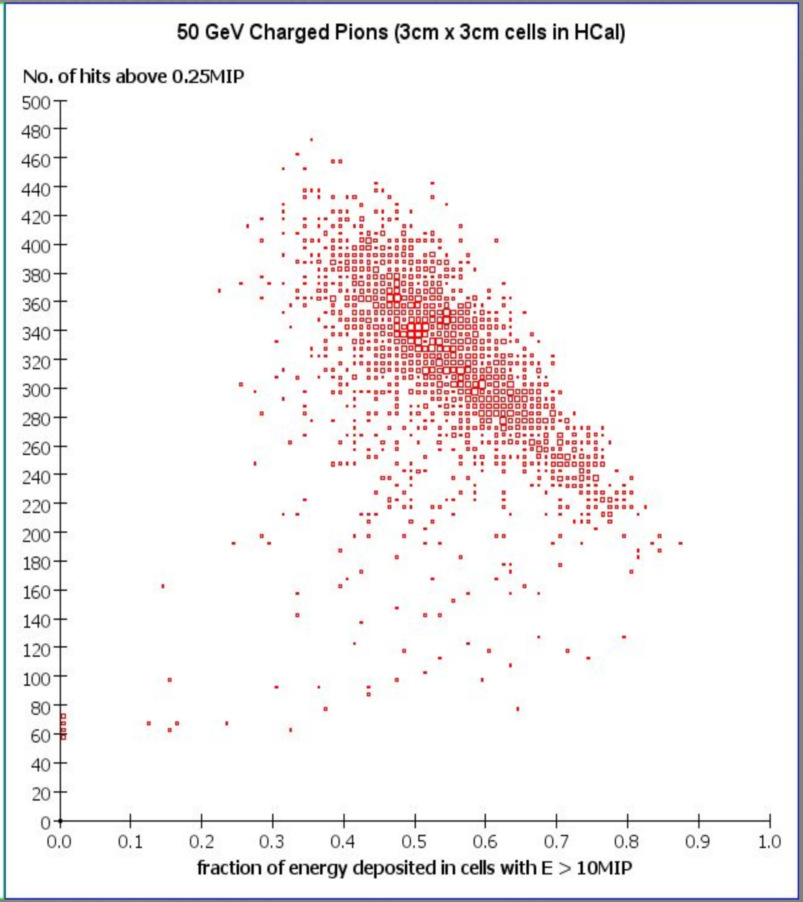
Nhit correlations





Alternatively..

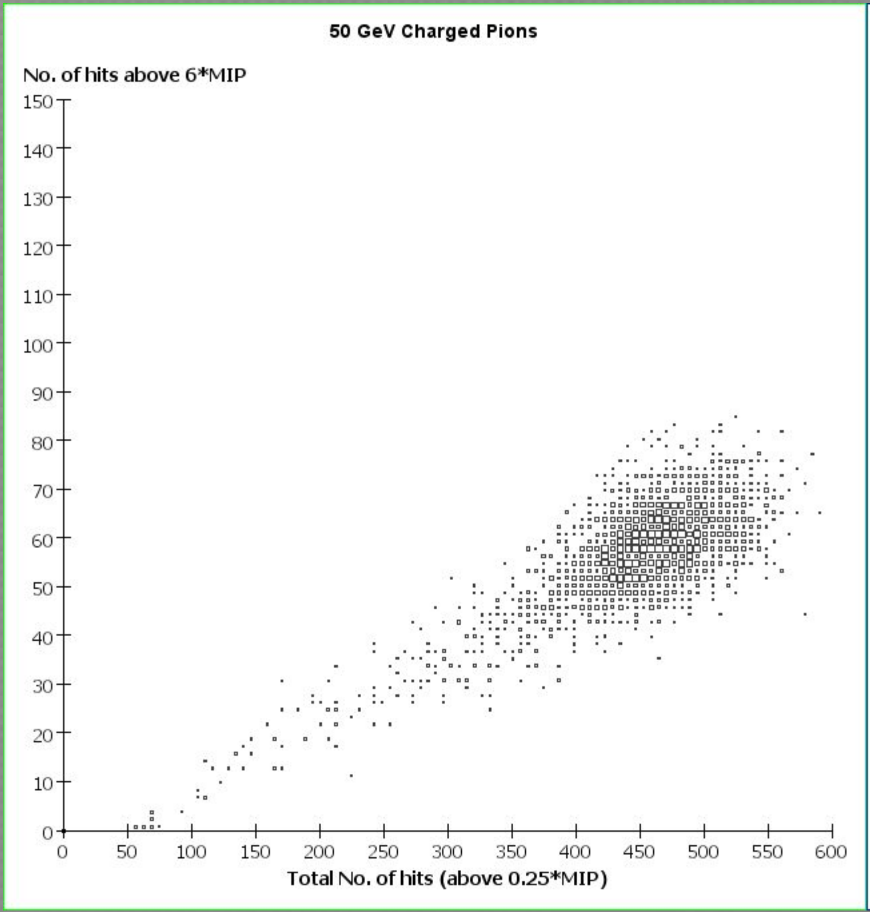


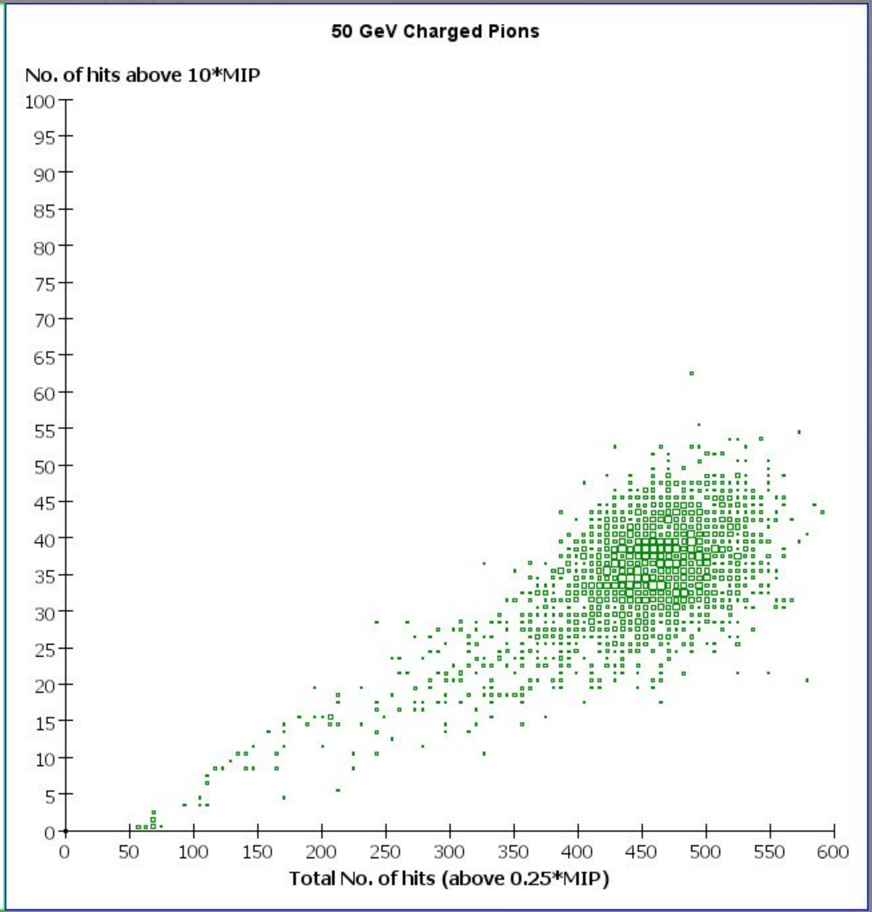


Compensation

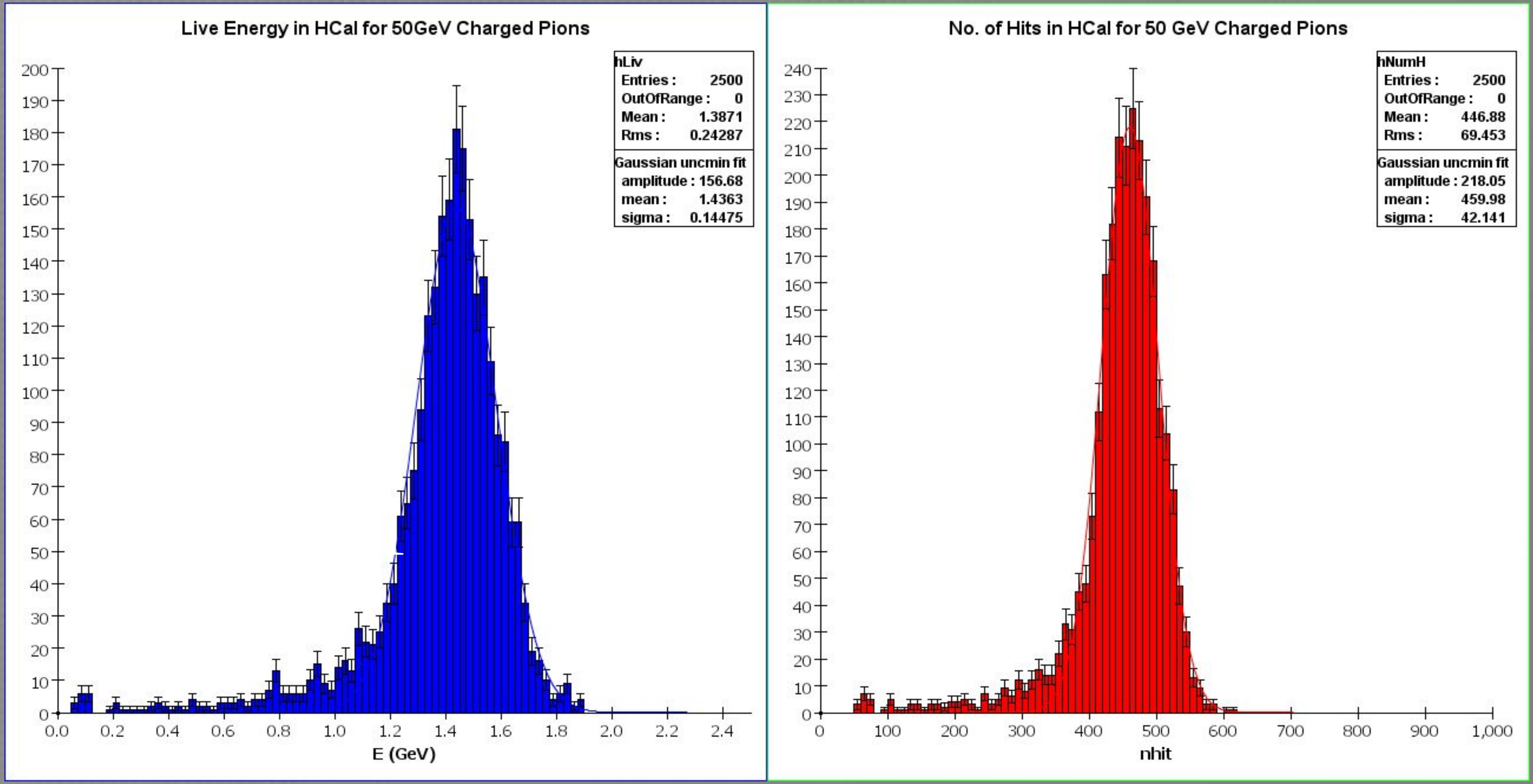
- So in a sense counting has its own version of the compensation problem in scintillators
- With multiple threshold this can be overcome by weighting cells differently (according to the threshold they passed)
- In MC 3 thresholds seem to be adequate

After semi-digital treatment

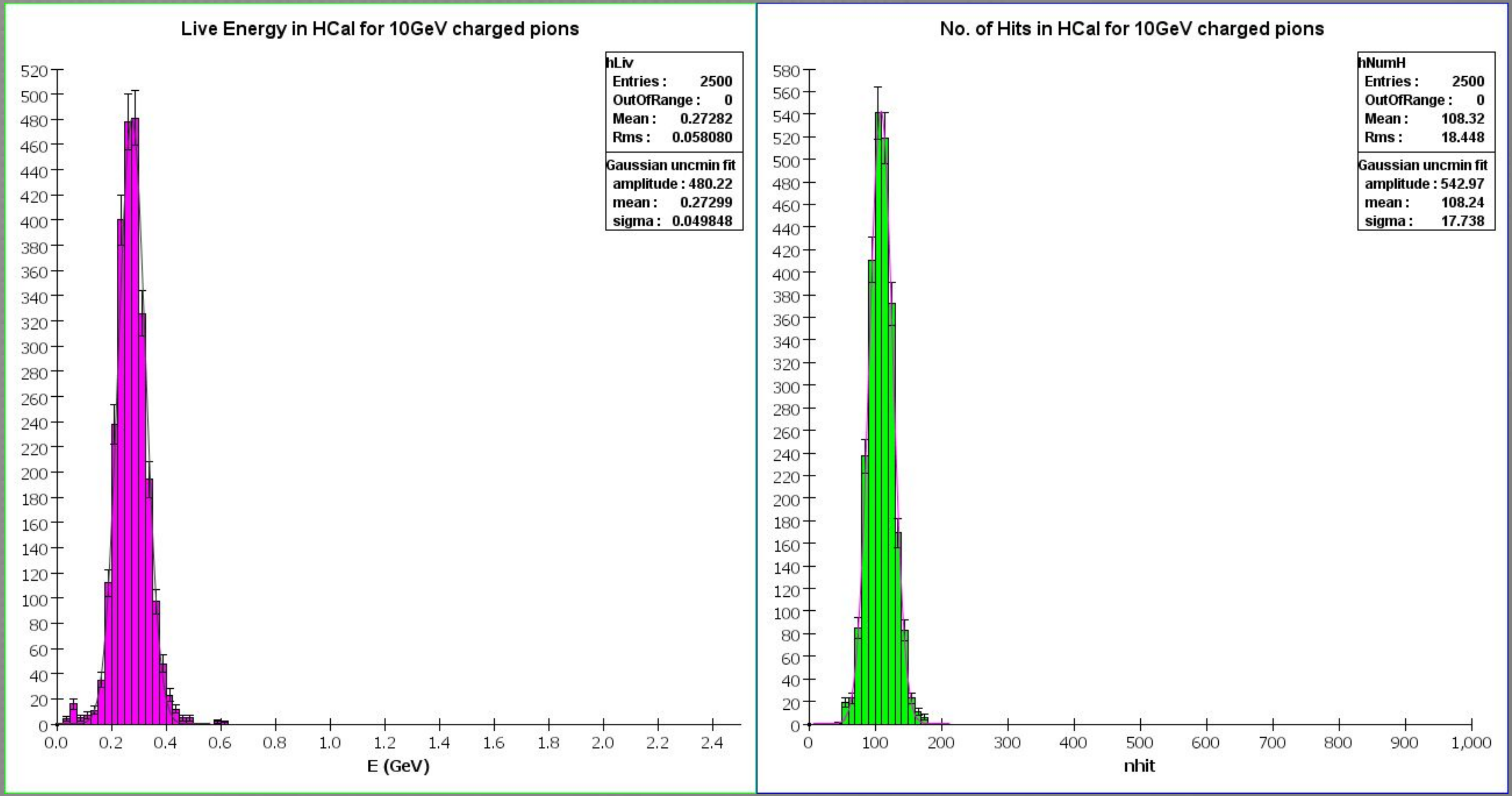




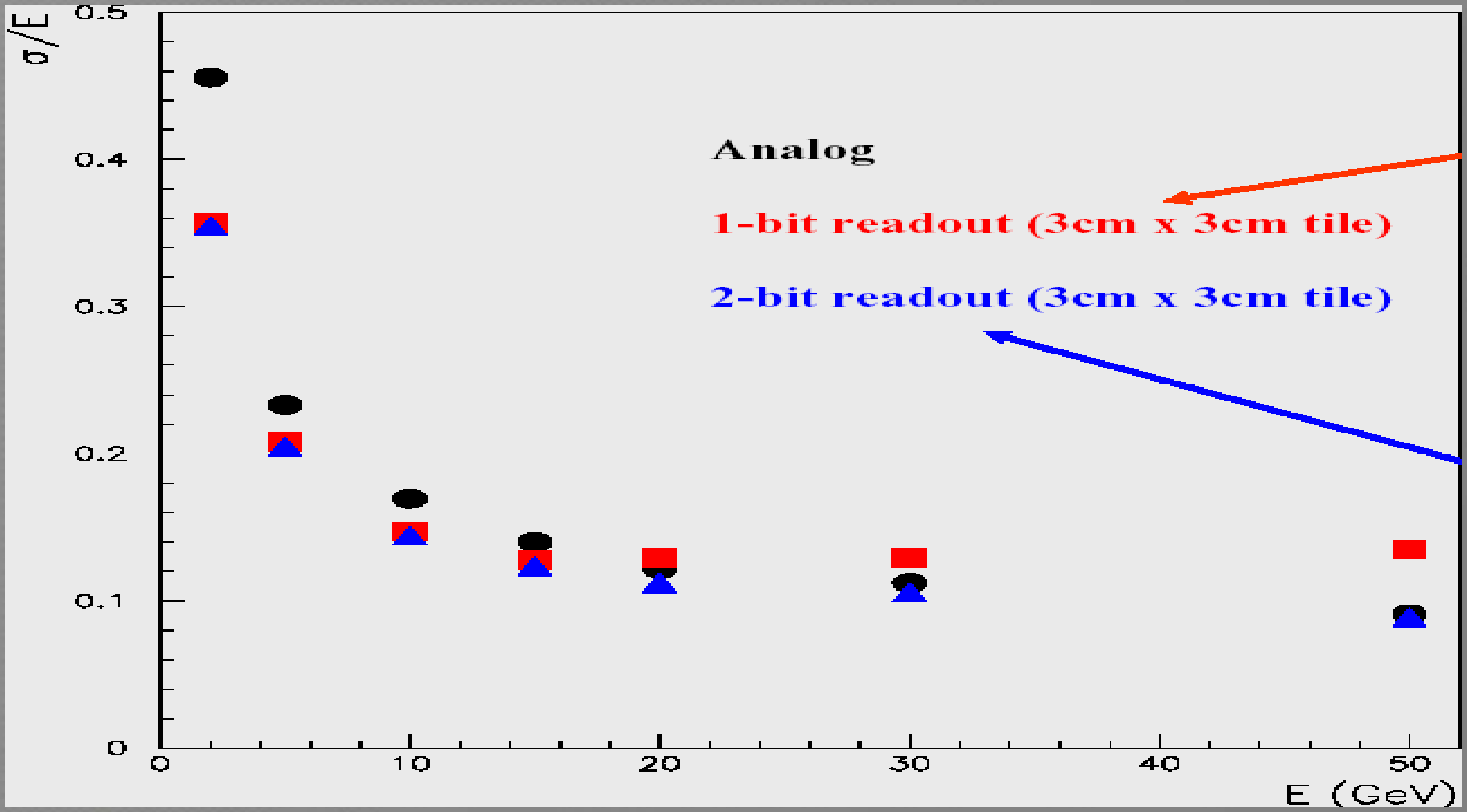
Single Particle Resolution (50 GeV)



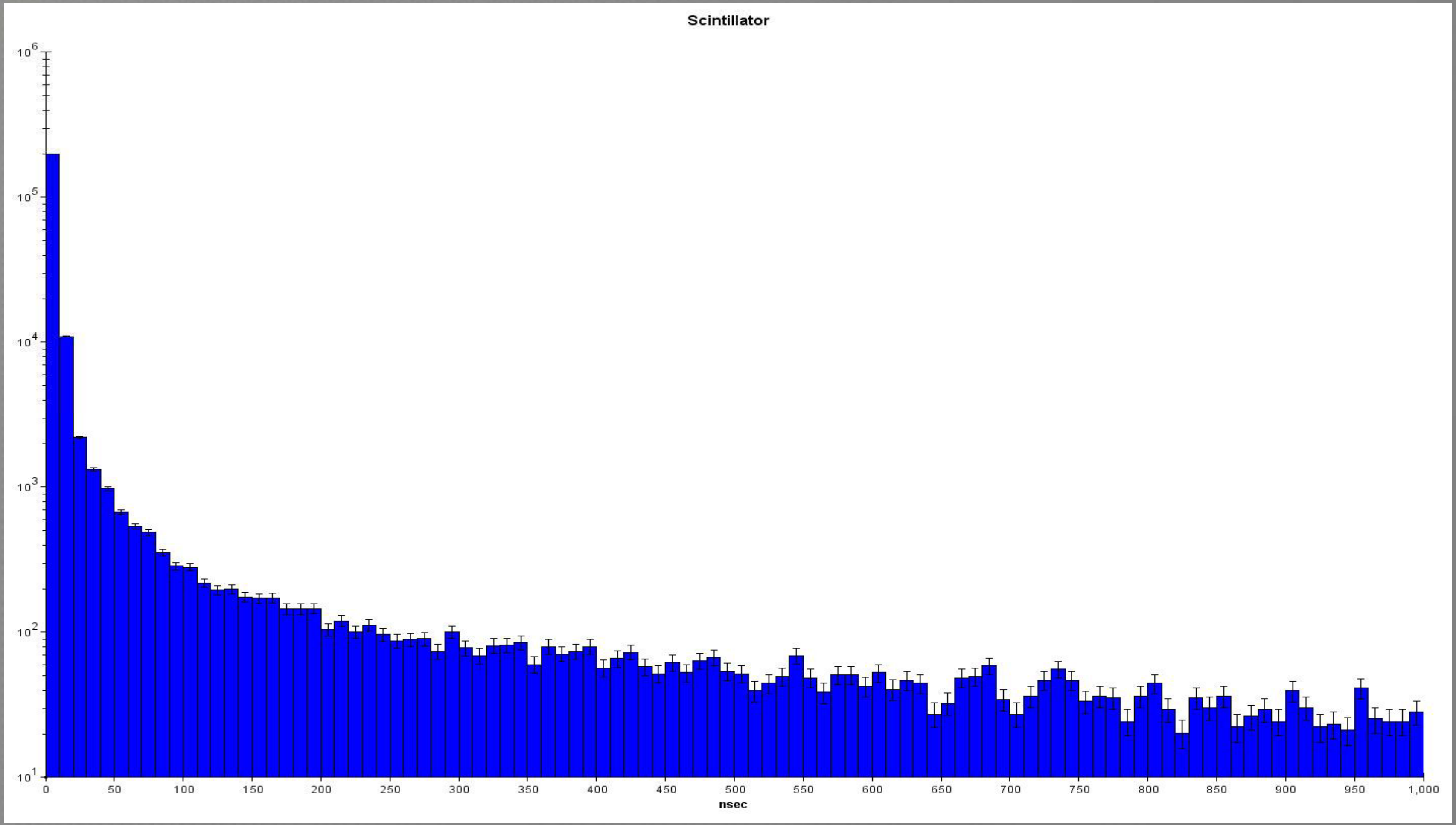
Similar treatment to 10 GeV....



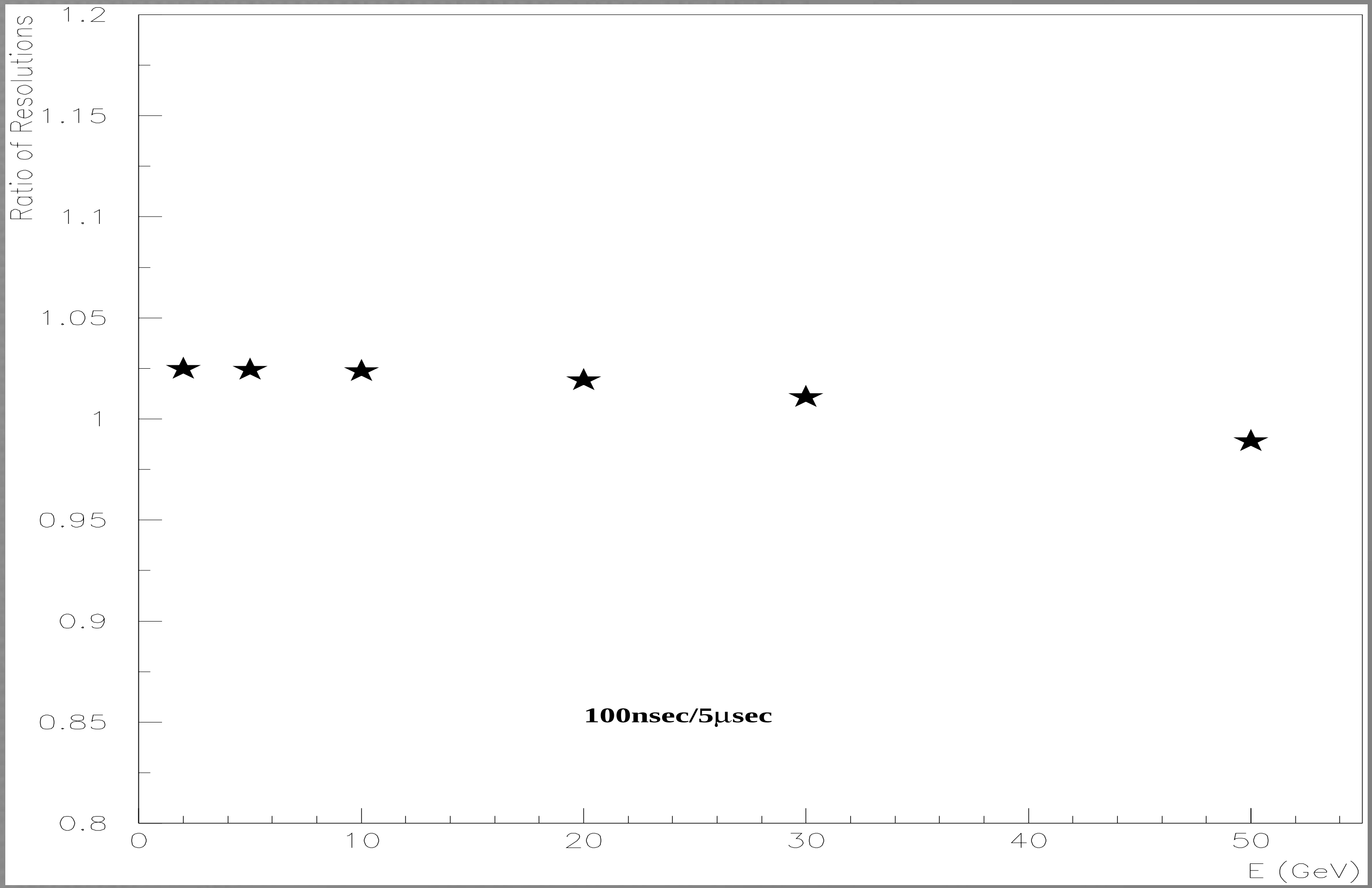
Single particle resolutions



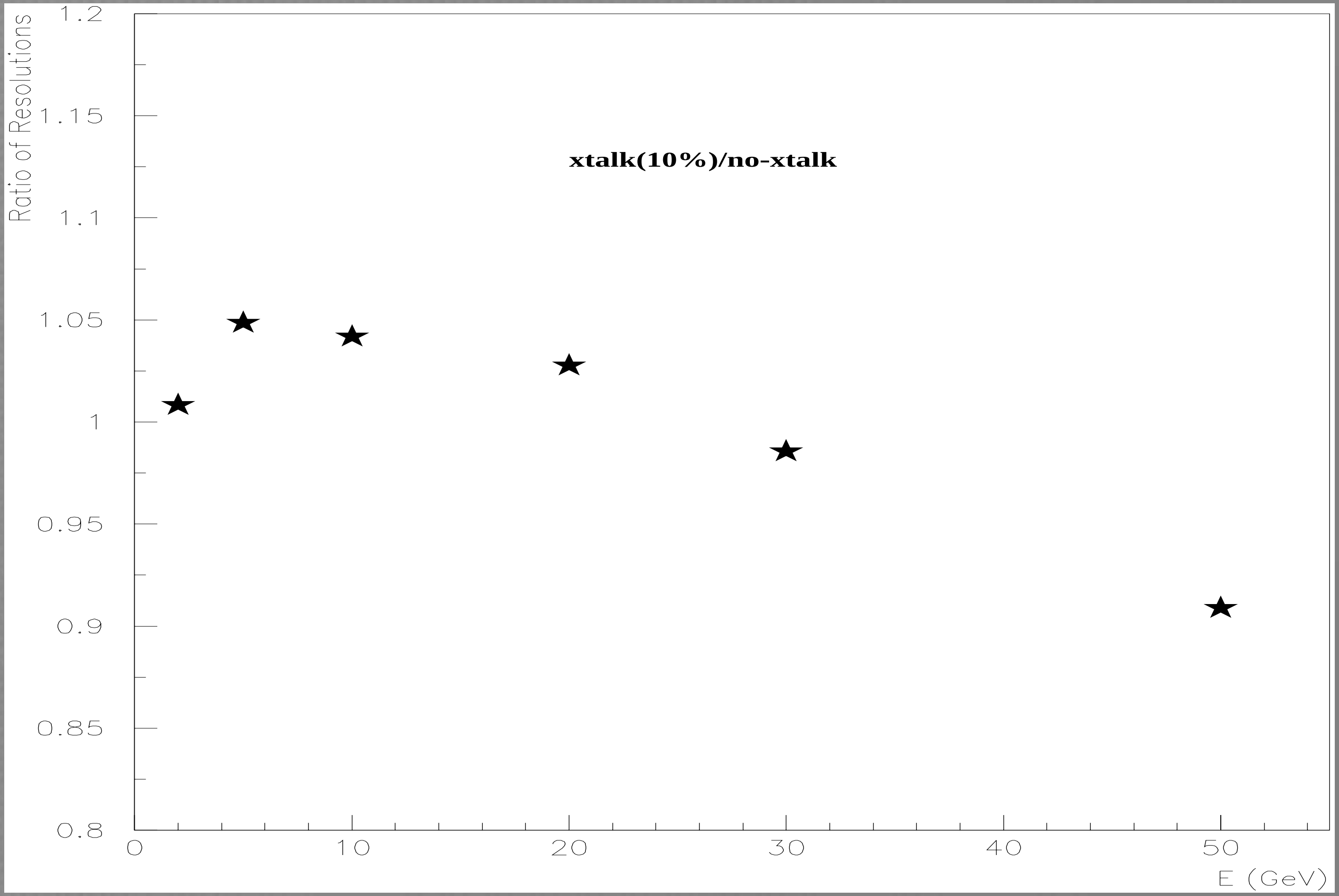
ToF


Scintillator
10^6
10^5
10^4
10^3
10^2
10^1
0 50 100 150 200 250 300 350 400 450 500 550 600 650 700 750 800 850 900 950 1,000
nsec

ToF dependence

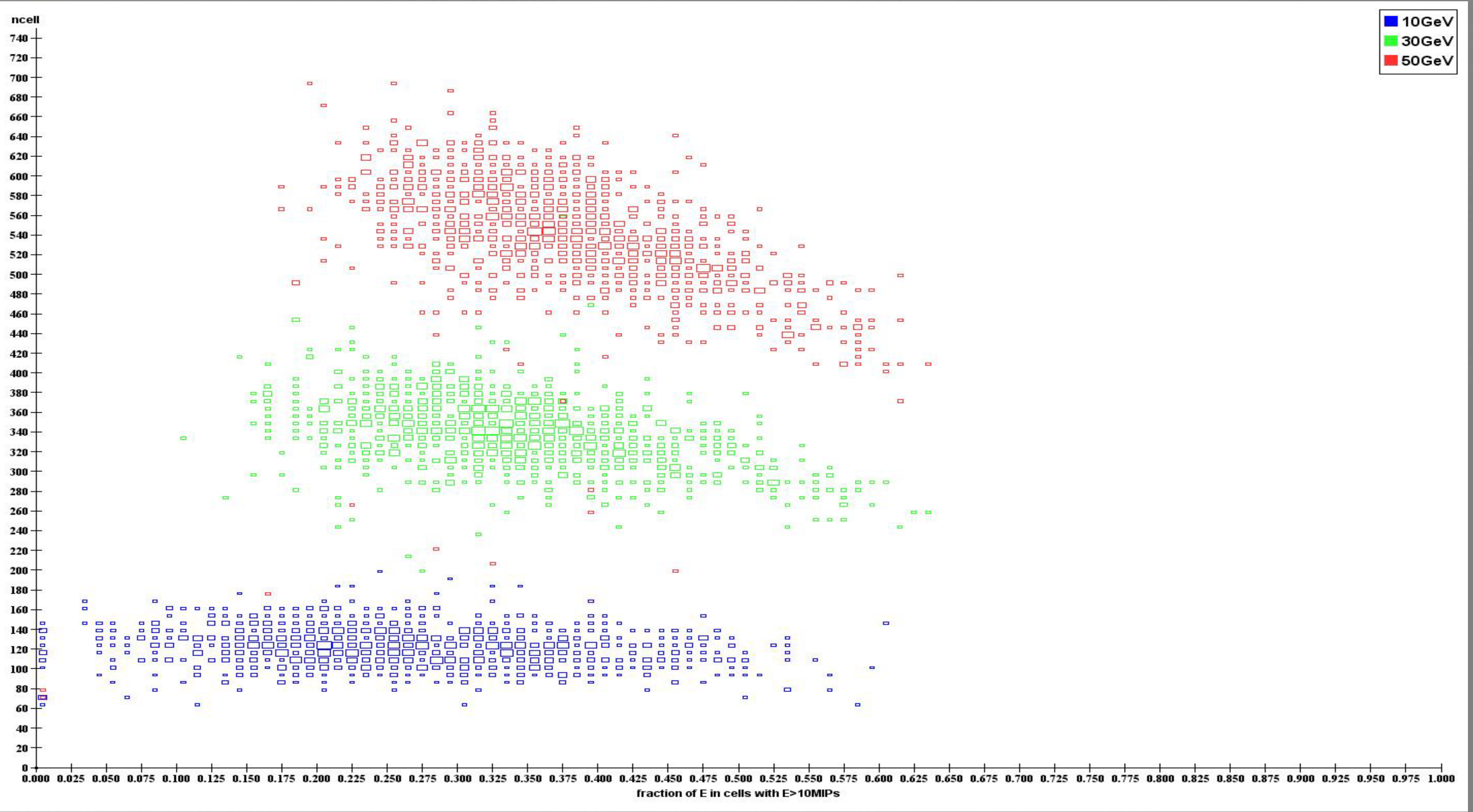


X-talk

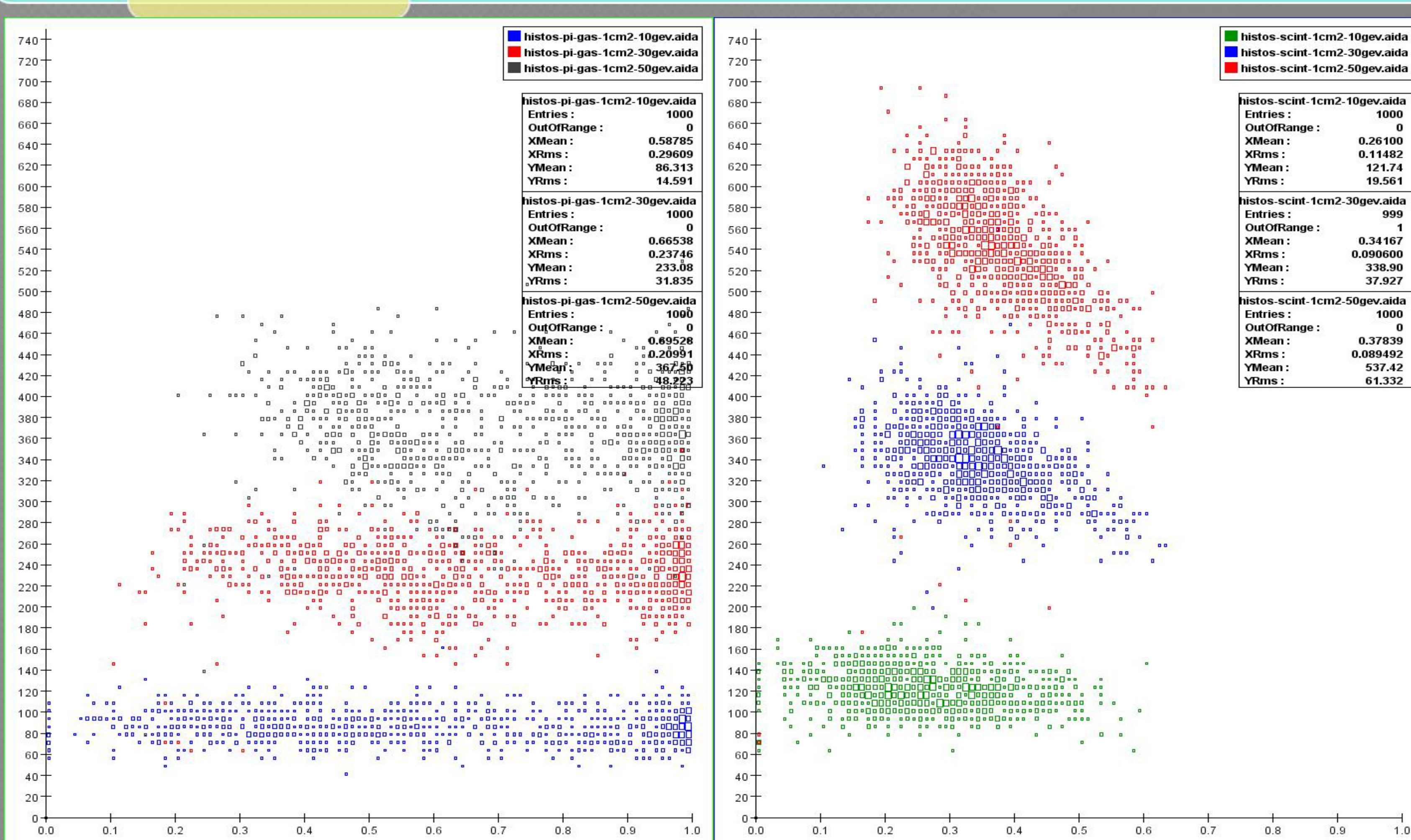


xtalk(10%)/no-xtalk
Ratio of Resolutions
1.2
1.15
1.1
1.05
1
0.95
0.9
0.85
0.8
0
10
20
30
40
50
E (GeV)

1cm x 1cm scintillator

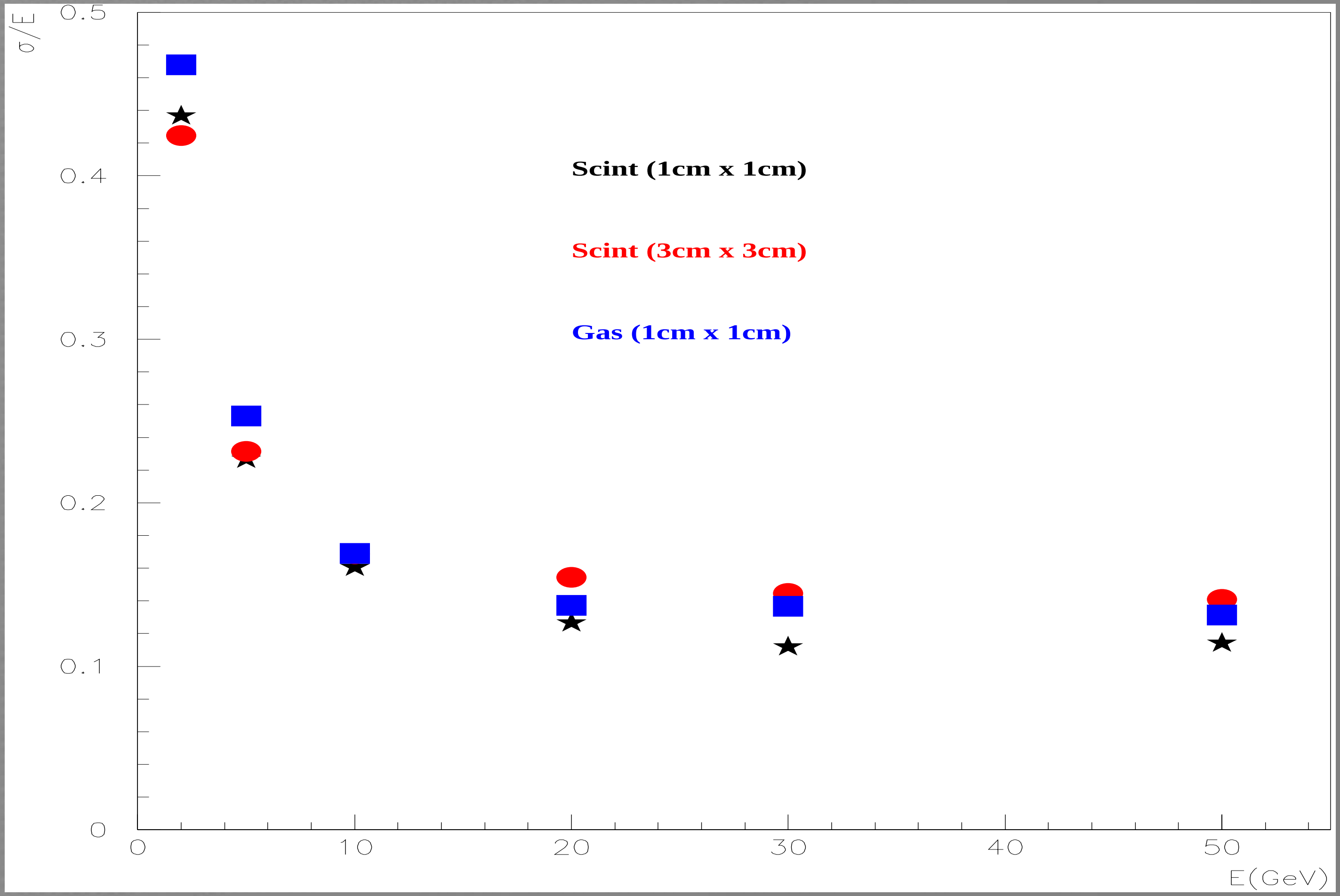


Gas vs. scintillator



Single particle resolutions

Multiple thresholds not used



Non-linearity

- Note that the nhit/GeV does not remain constant
- This will introduce additional pressure on the constant term
- For scintillator the non-linearity can be effectively removed by ‘semi-digital’ treatment

“Density”

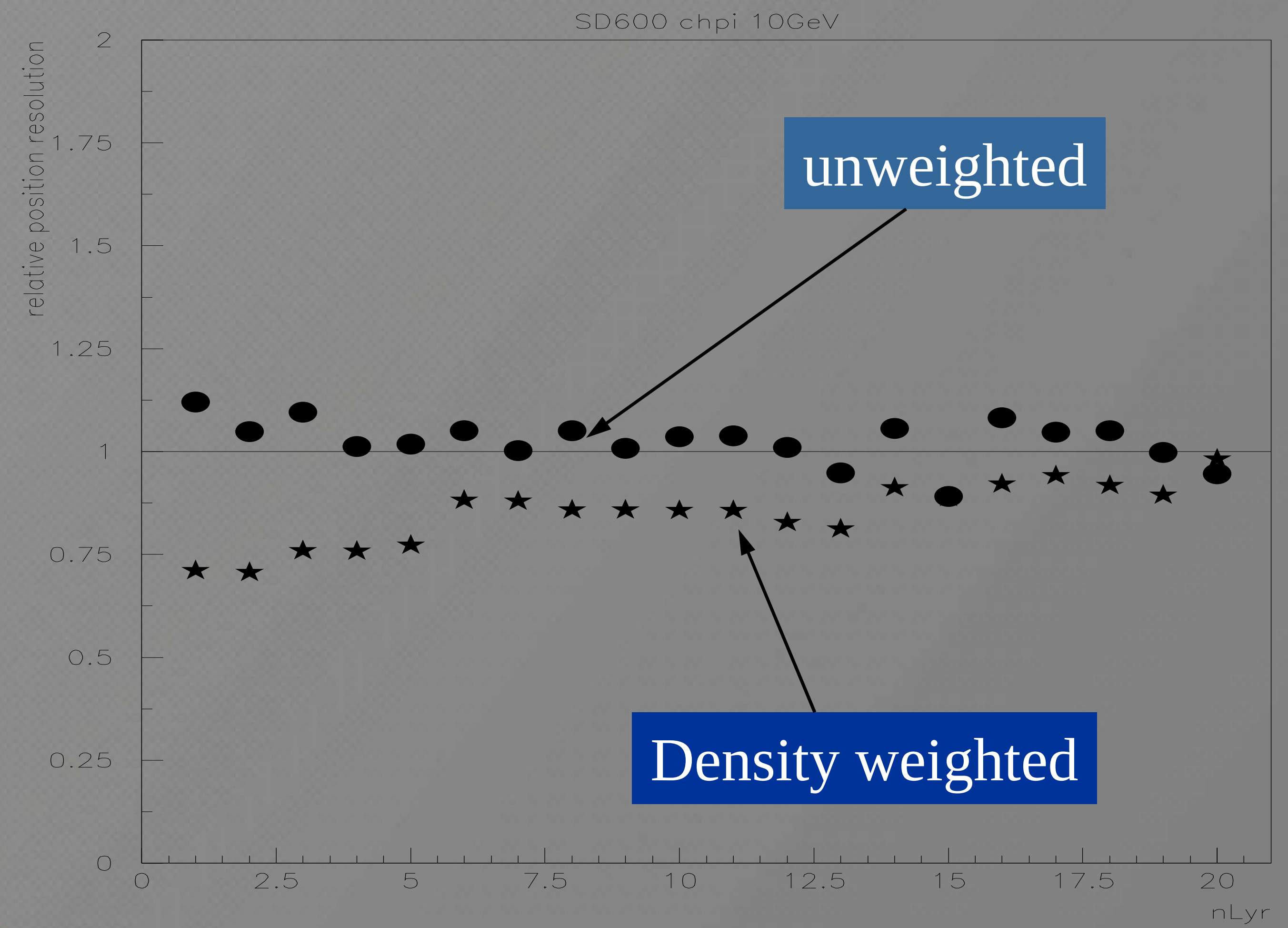
- Need a hierarchy in the absence of an energy measurement
- Clumpiness of the surrounding
- A simple-minded realization of this used here:

$d_i = \Sigma (1/dR_{ij})$ where dR_{ij} is the angular distance between cell ‘i’ and cell ‘j’

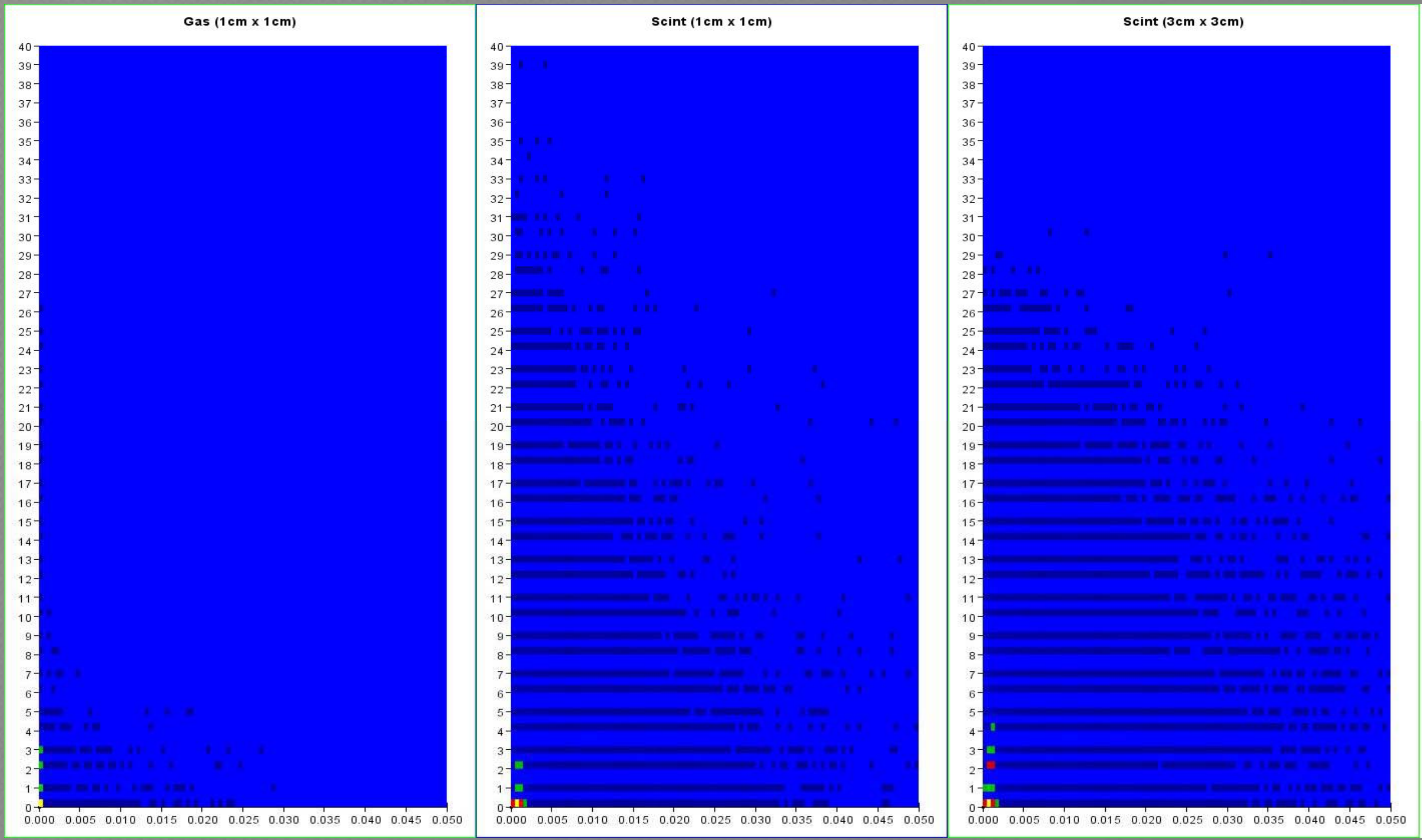
10 GeV $\pi^{\pm}$

Thanks Ben

Measured relative to the energy weighted resolutions



Density vs. E



Gas (1cm x 1cm)
Scint (1cm x 1cm)
Scint (3cm x 3cm)
0.000 0.005 0.010 0.015 0.020 0.025 0.030 0.035 0.040 0.045 0.050
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40

Width Definition

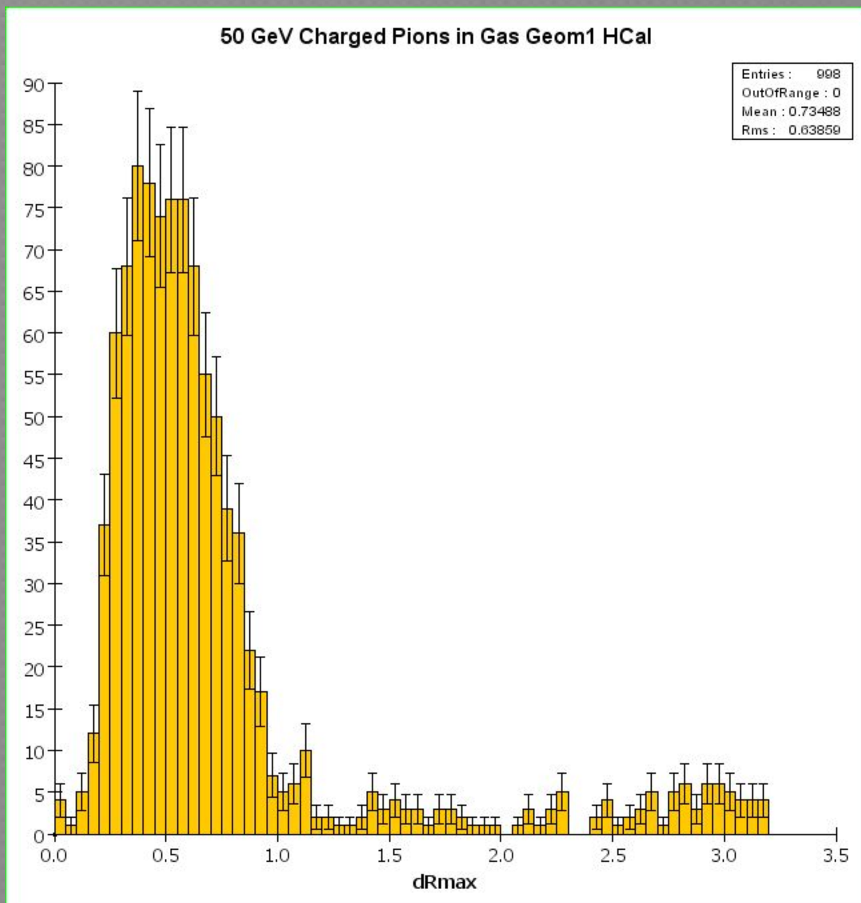
- Find centroid $\{w_i x_i / \Sigma w_i\}$
- 'width' = sqrt($w_i dR^2_i / w_i$)
- Three w_i were used:

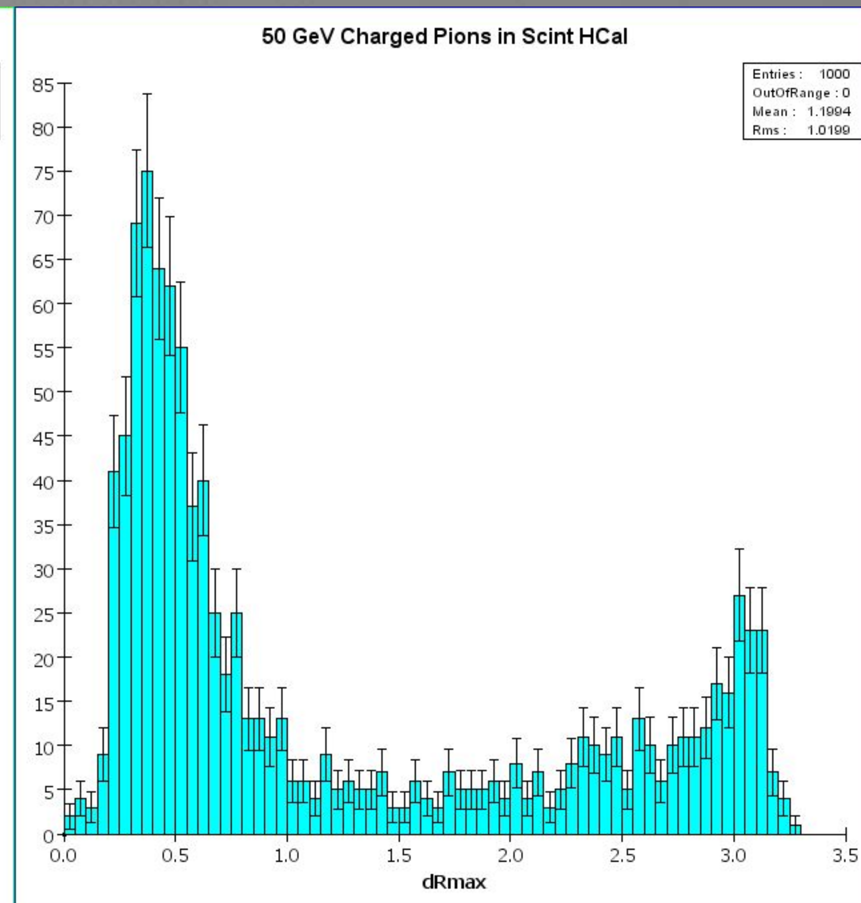
  Unweighted (=1)

  E weighted (=cell energy)

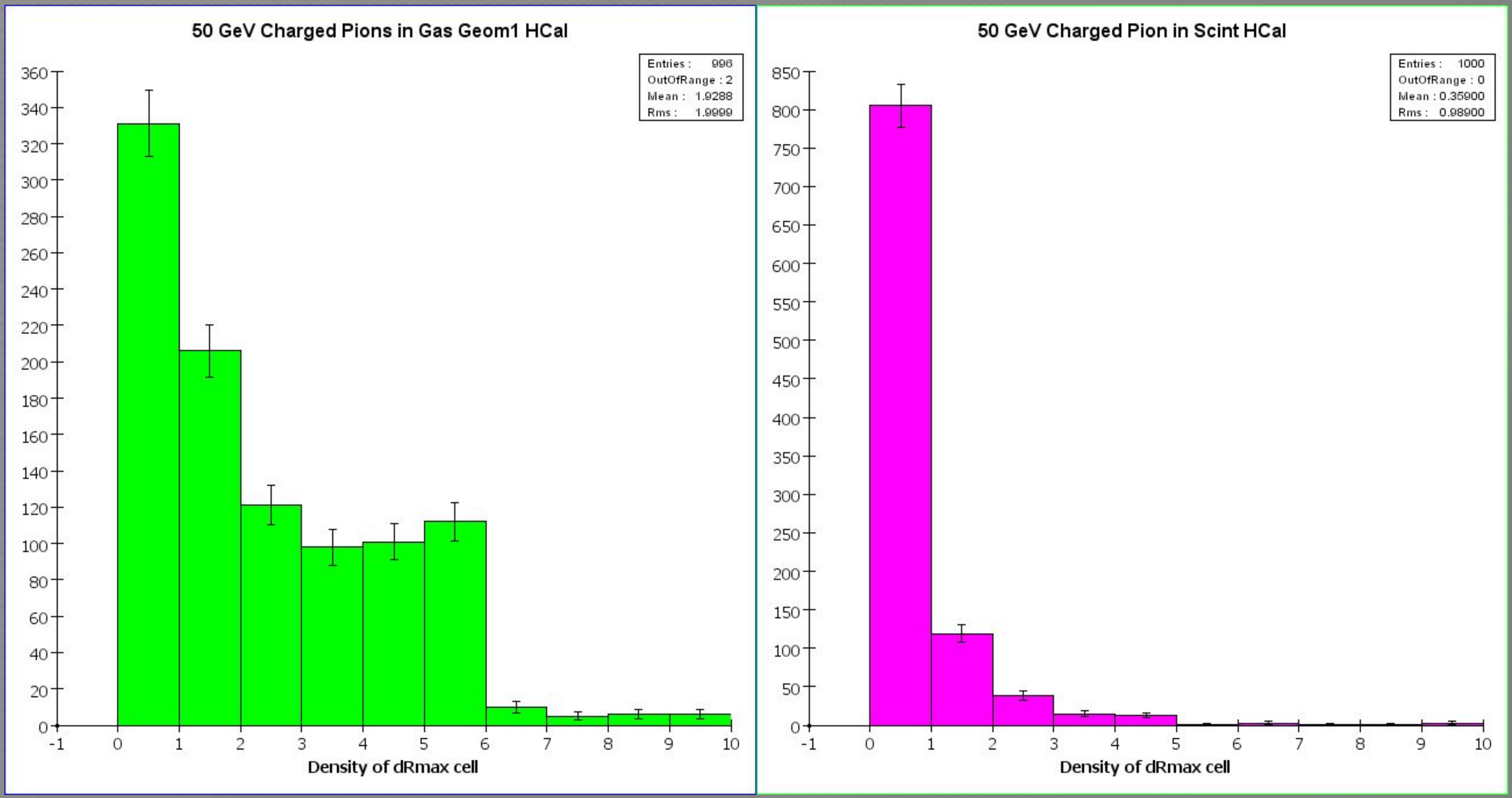
  'Density' weighted (nearest neighbor occupancy in 5x5 window in lyrs n-1,n,n+1)

Distance to Farthest Cell

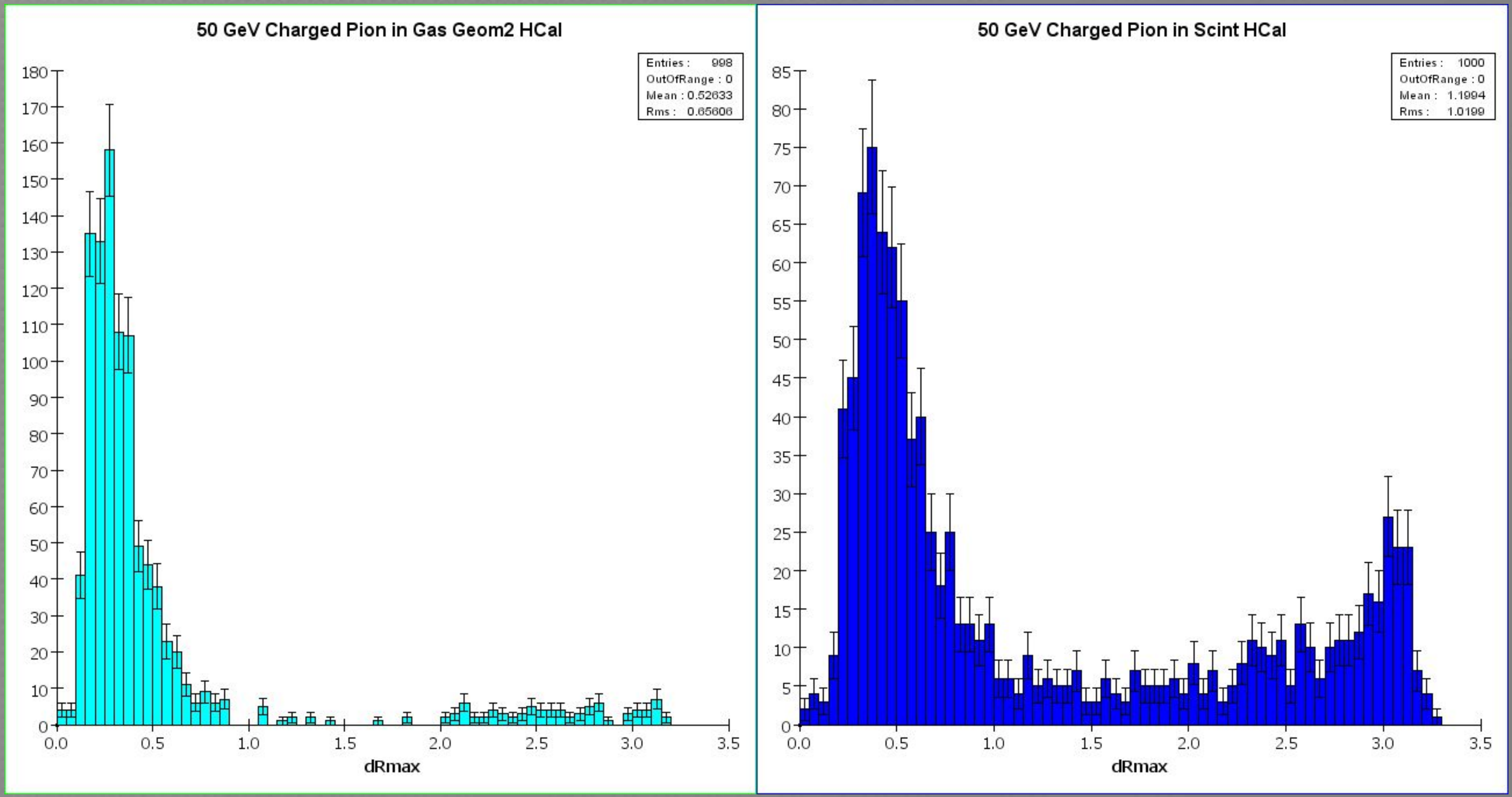




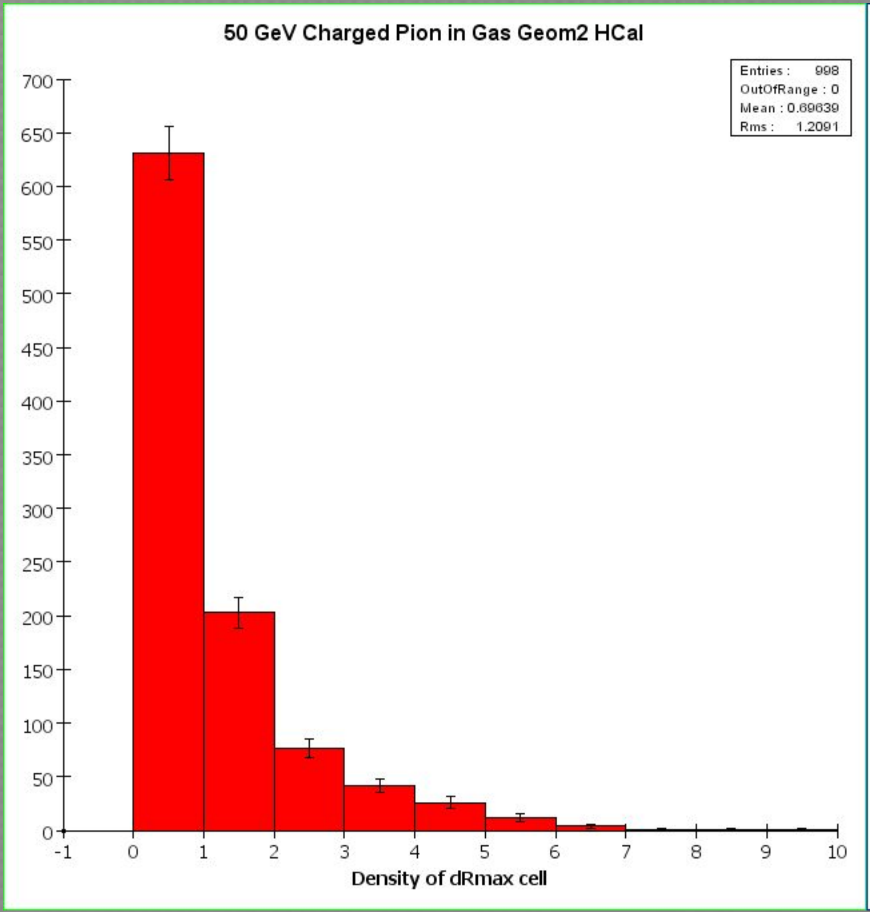
Density of Farthest Cell

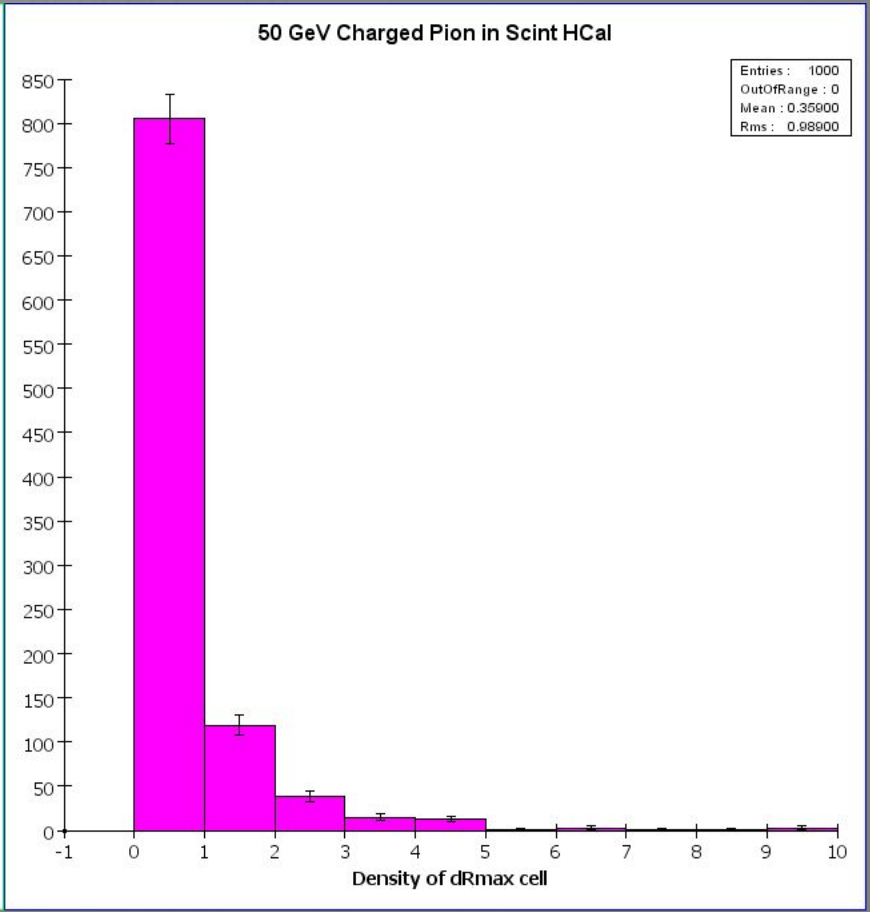


Distance to Farthest Cell

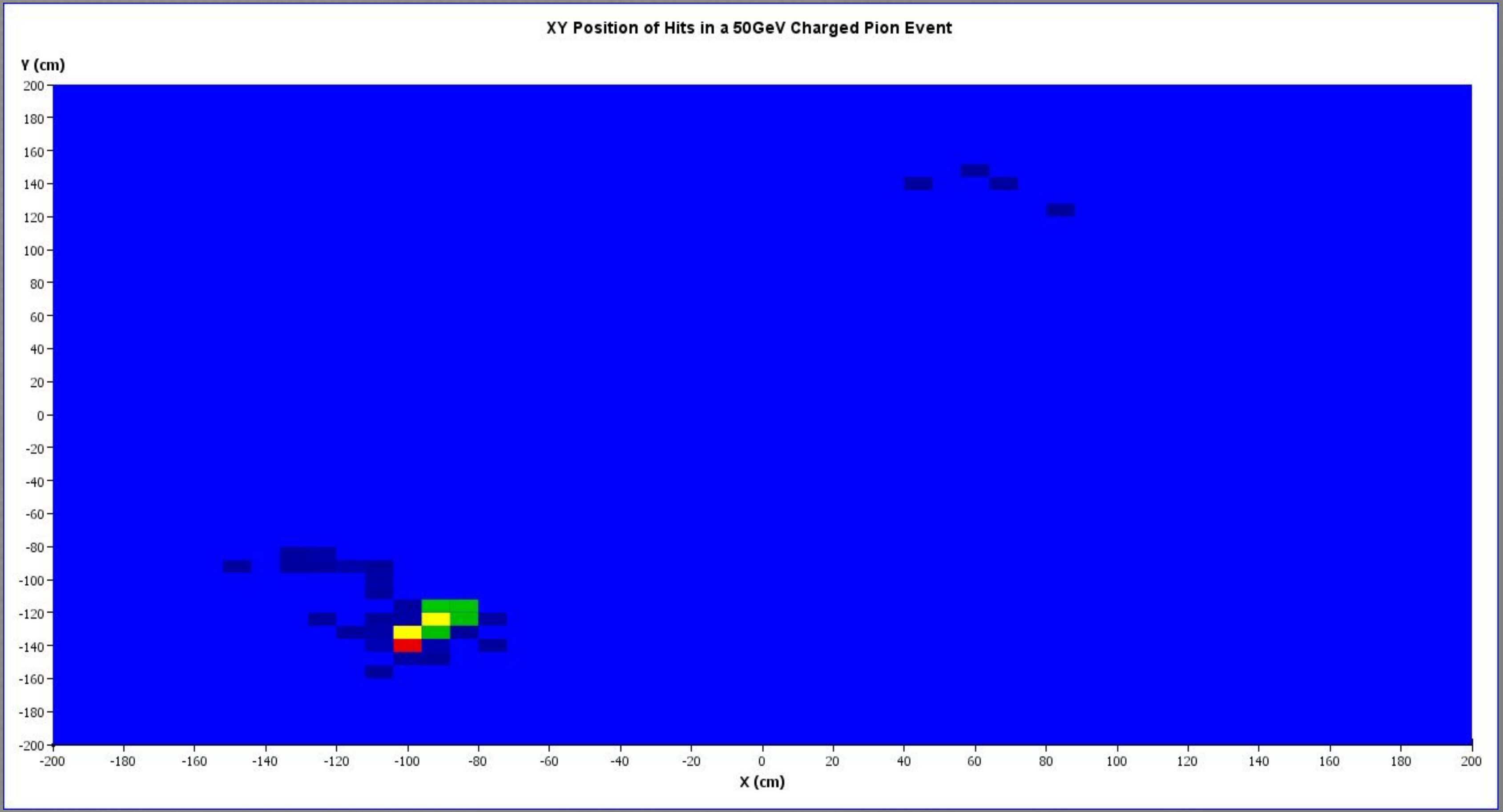


Density of Farthest Cell

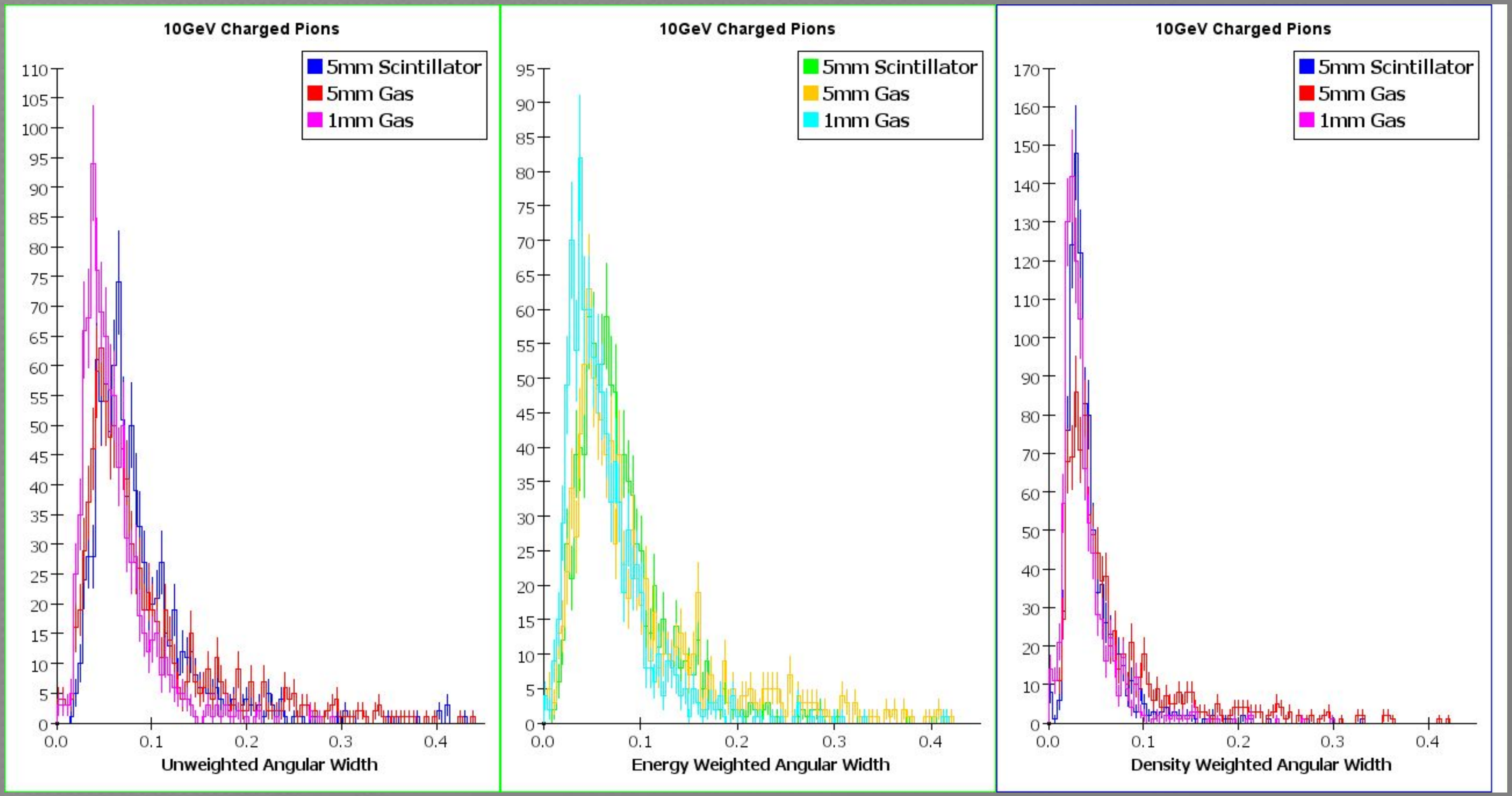




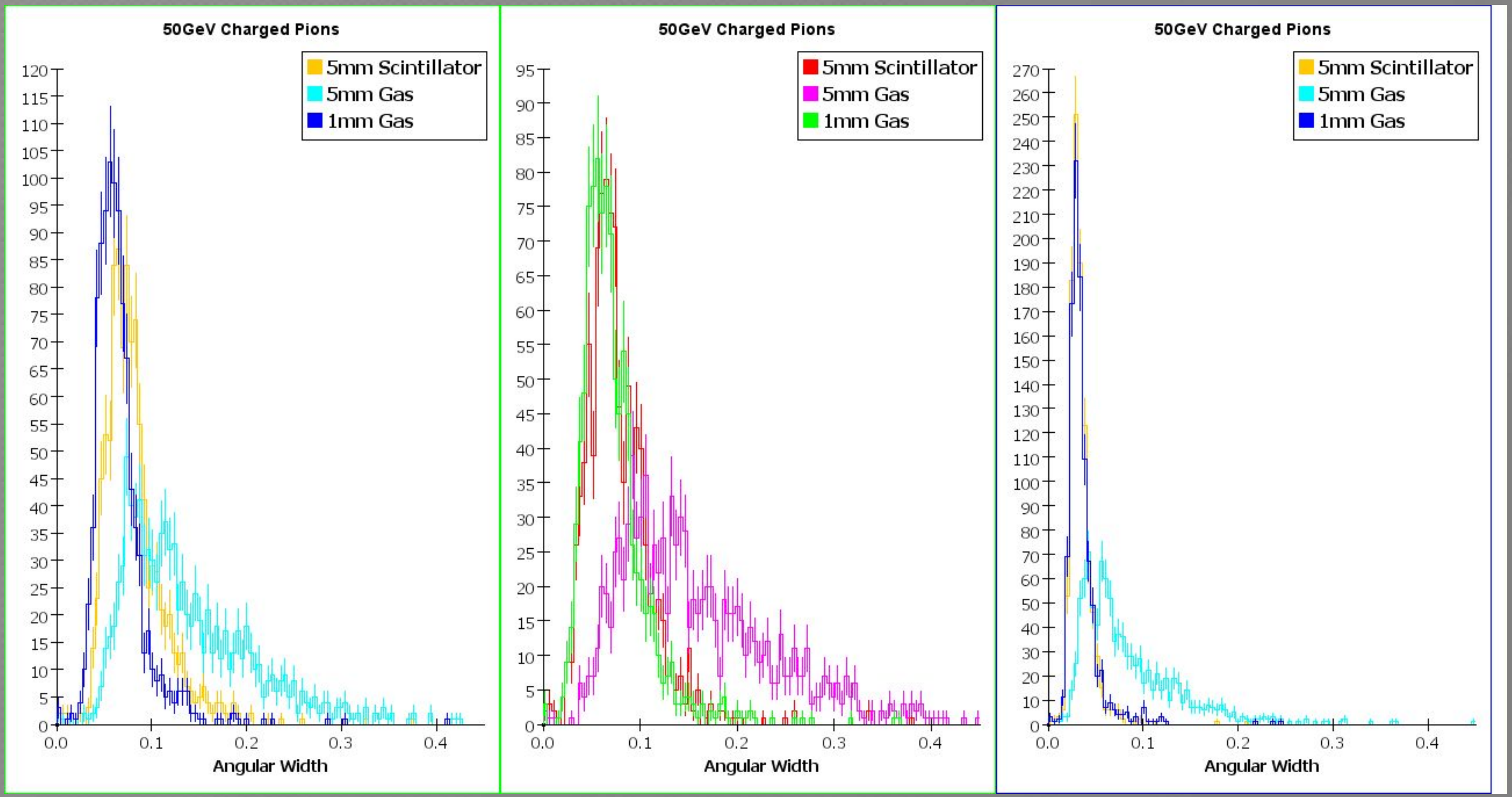
Backscatter



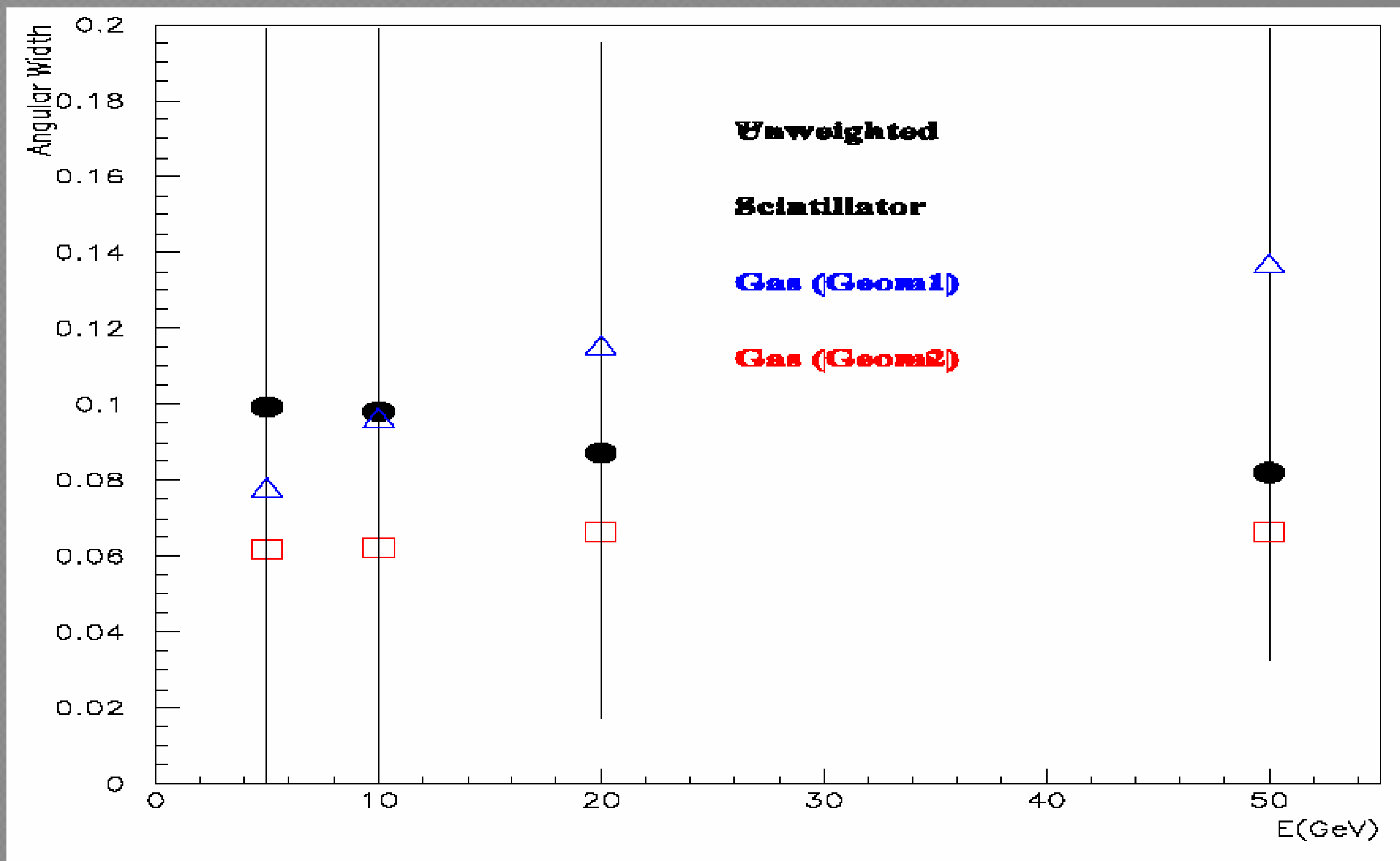
Shower Width for 10GeV $\pi^{\pm}$



Shower Width for 50GeV $\pi^{\pm}$

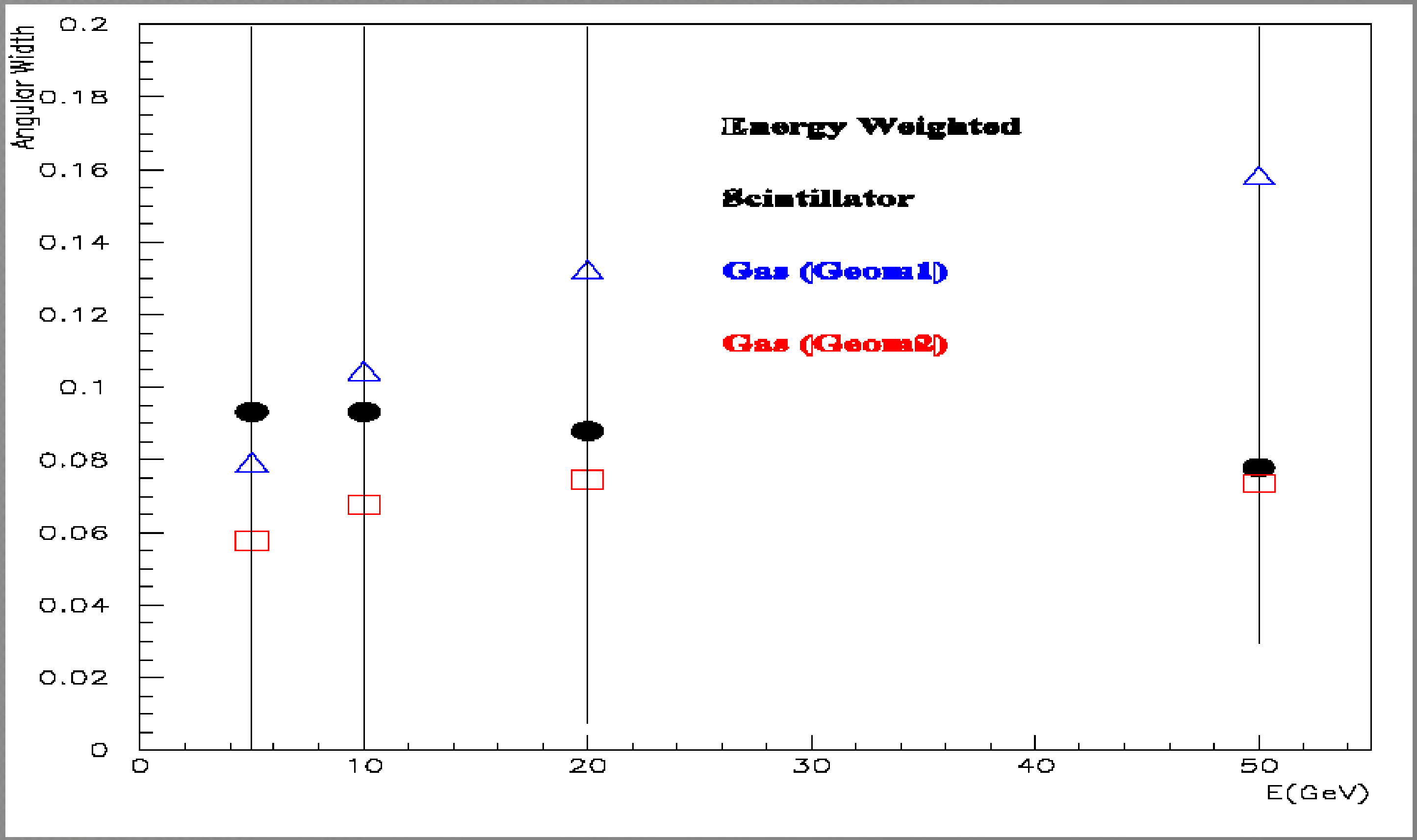


$\pi^{\pm}$ Angular Width

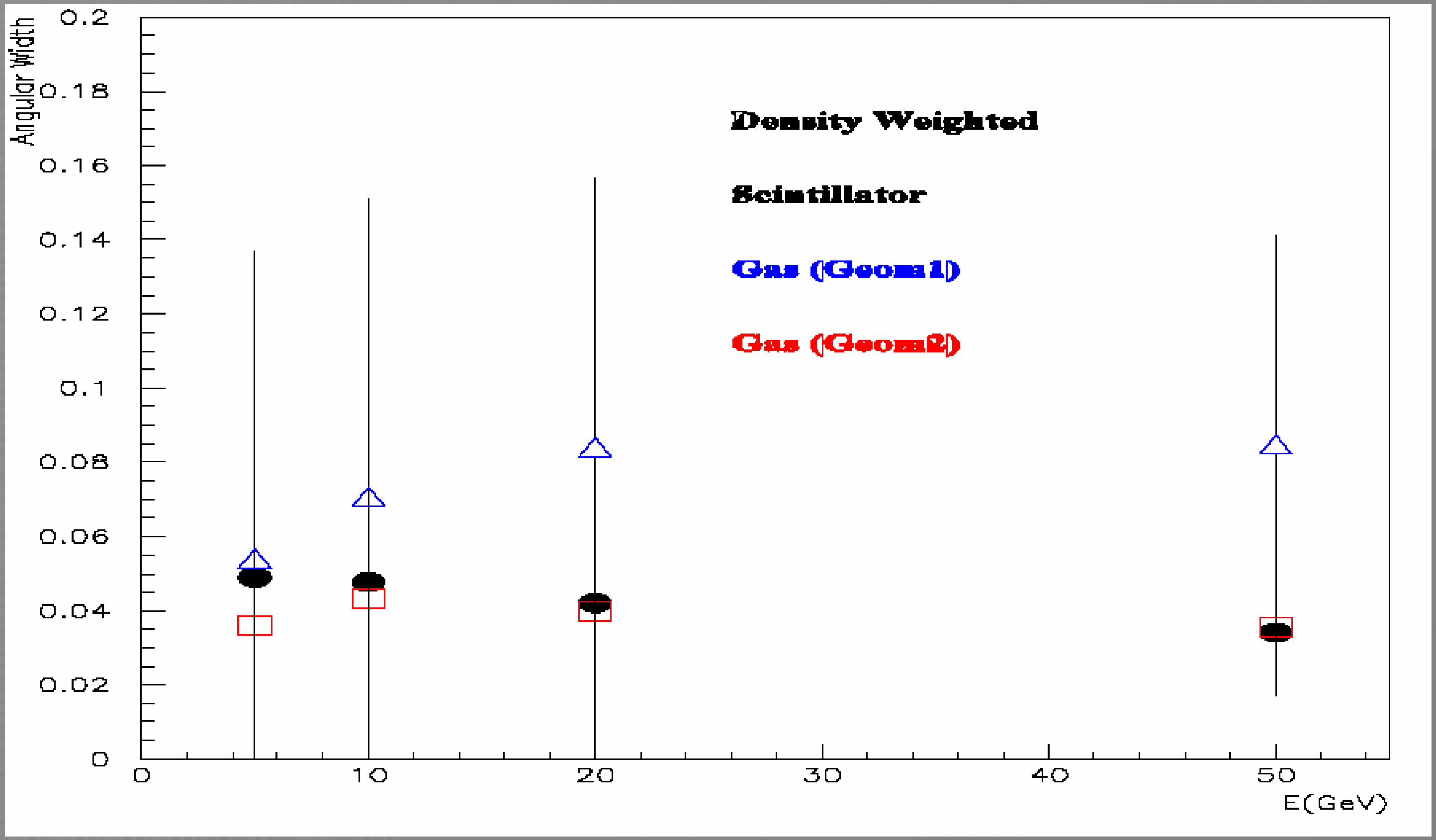


rms shown as error

$\pi^{\pm}$ Angular Width



$\pi^{\pm}$ Angular Width



Comments

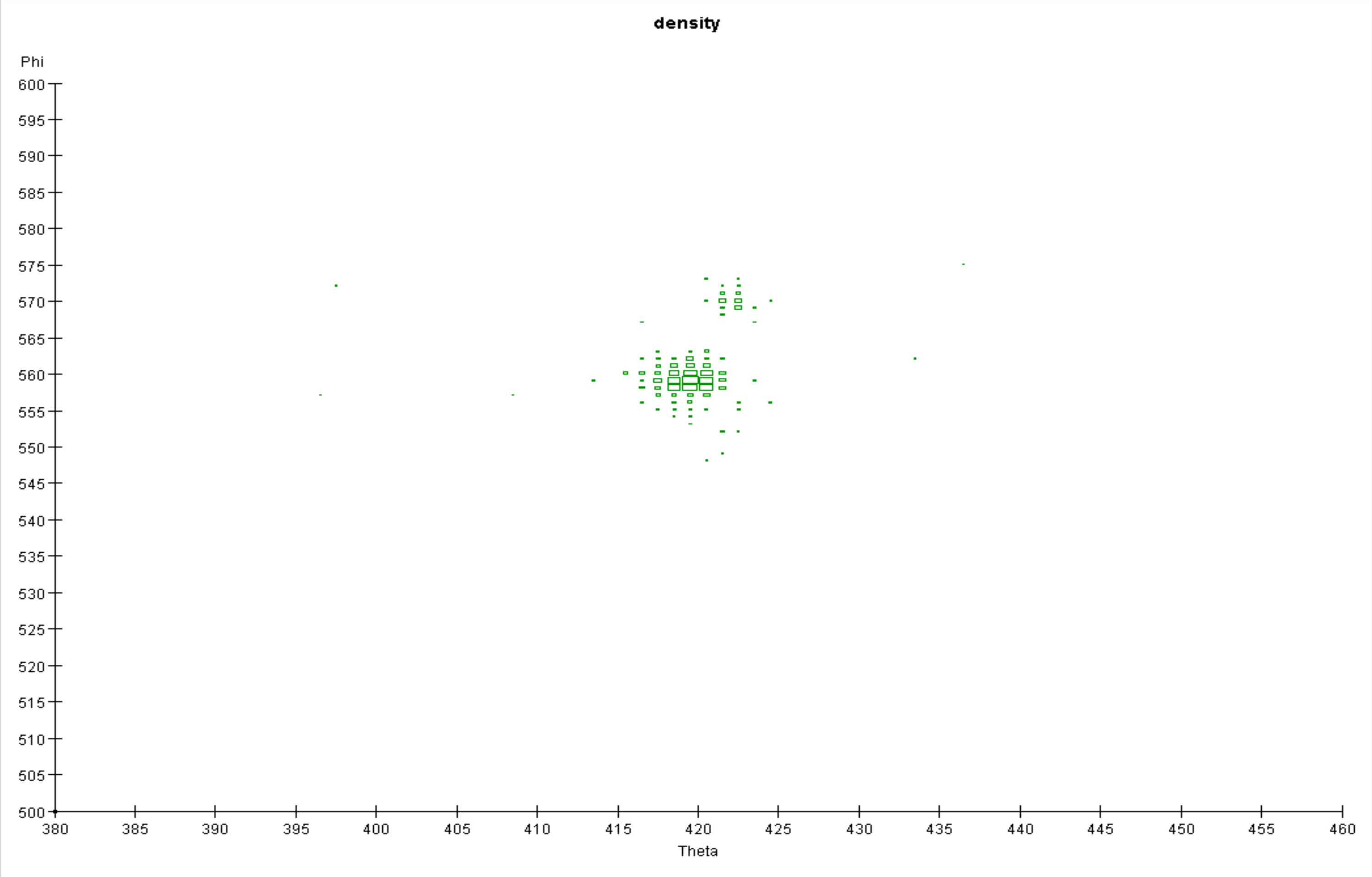
- Previous slides indicate that shower separation may not suffer at all
- There is no clear cut case either way at the moment; detailed studies of assessing impact needed
- Going to look at cluster separability next
- Need to evaluate this in the global context of calorimeter performance

Clustering

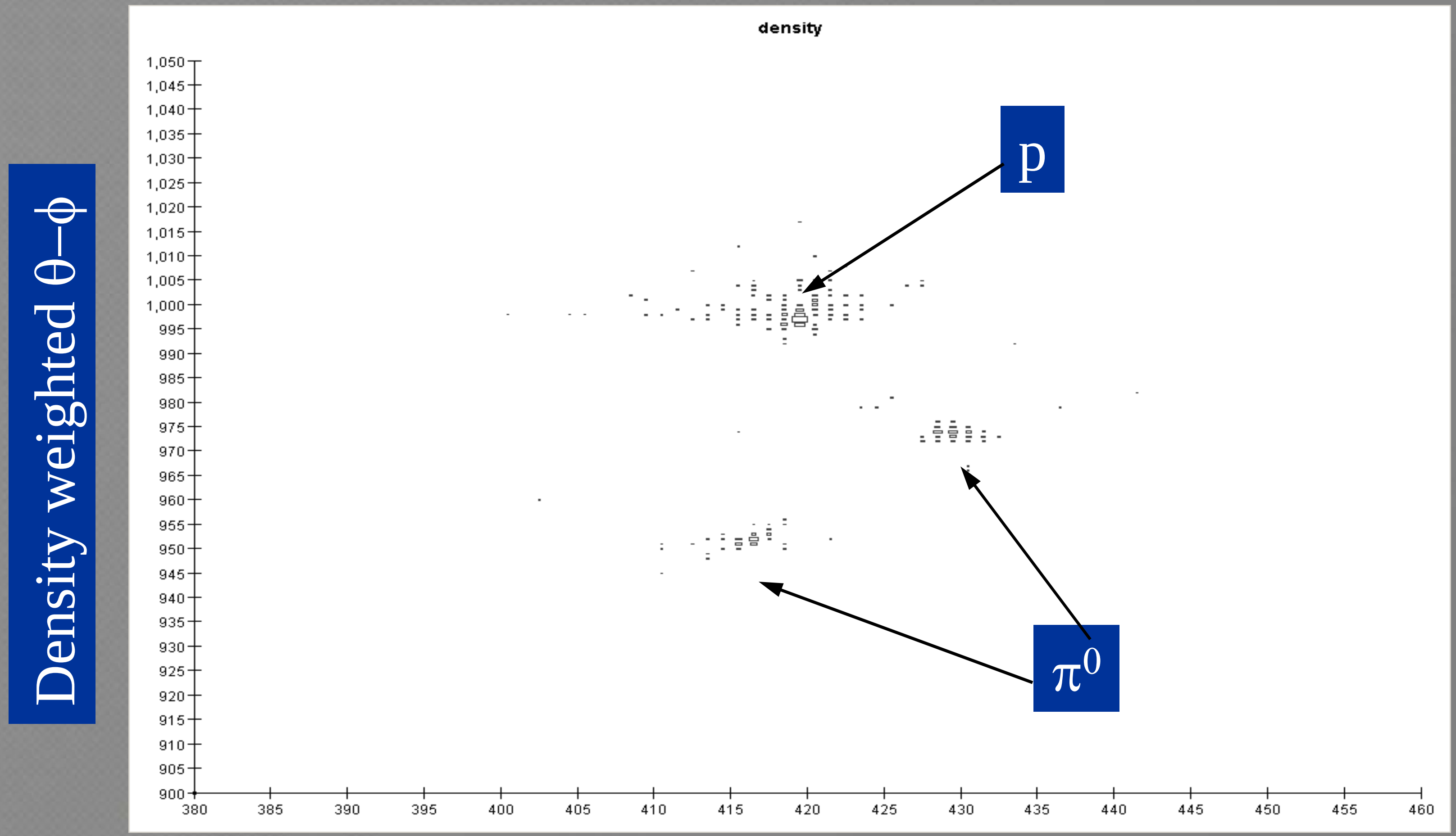
- Local 'density' maxima based clustering seems to work
- Alternative to track initiated clustering
- Can be used in the ECal and HCal
- Full PFlow implementation has shown encouraging results

10 GeV π^0

Density weighted $\theta-\phi$



$\Sigma^+ \rightarrow p\pi^0$



Summary

- Large phase space in the nbit-segmentation plane for hadron calorimetry. Is there an optimum? The answer may be medium dependent.
- Scintillator and Gas ‘digital’ calorimeters behave differently
- Needs verification in data
- More studies underway