MAPS simulation
Application of charge diffusion on Geant4 simulation and impact on the energy resolution

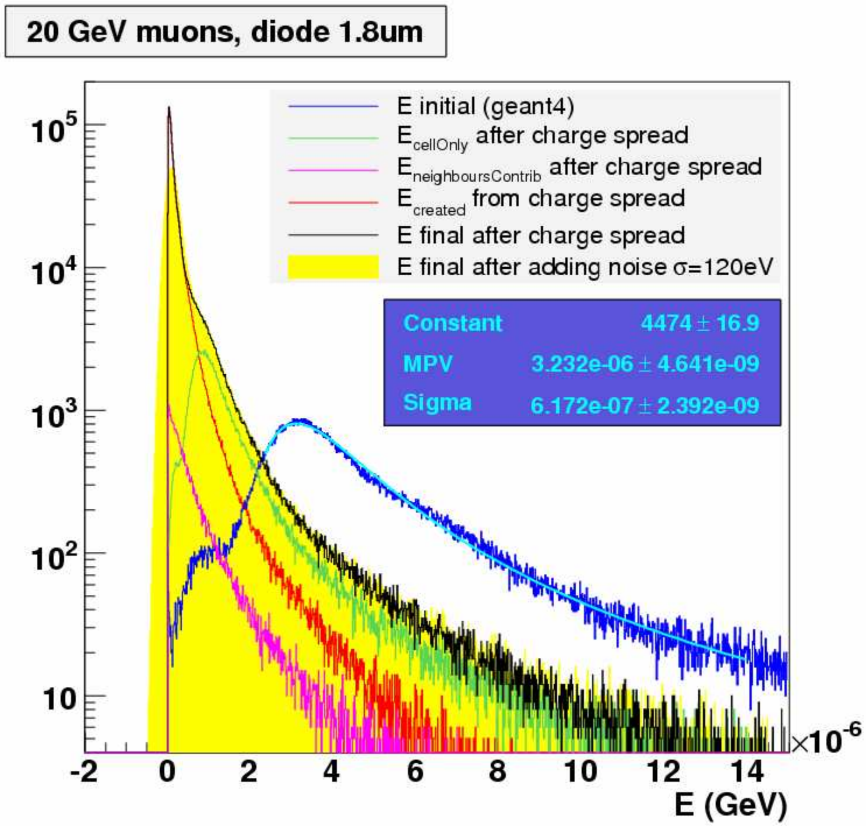
Study of different parameters

- with or without NWELL
- effect of the diode size
- input noise level
- input energy
- first tentative of "basic clustering"

Energy per hit

Muons 20 GeV
Simulated with Mokka-06-00
5000 events

Charge spread simulation :
with NWELL, diode size=1.8um,
Nb of generated electrons = 80 * total_detector_thickness in um
= 80 * 32 = 2560 e- for Giulio's simulation.
Geant4 effective Si thick considered = 15um.
Ł 1200 electrons. But the sum of the collected charge for 1.8um diodes goes beyond 1200 e- !!

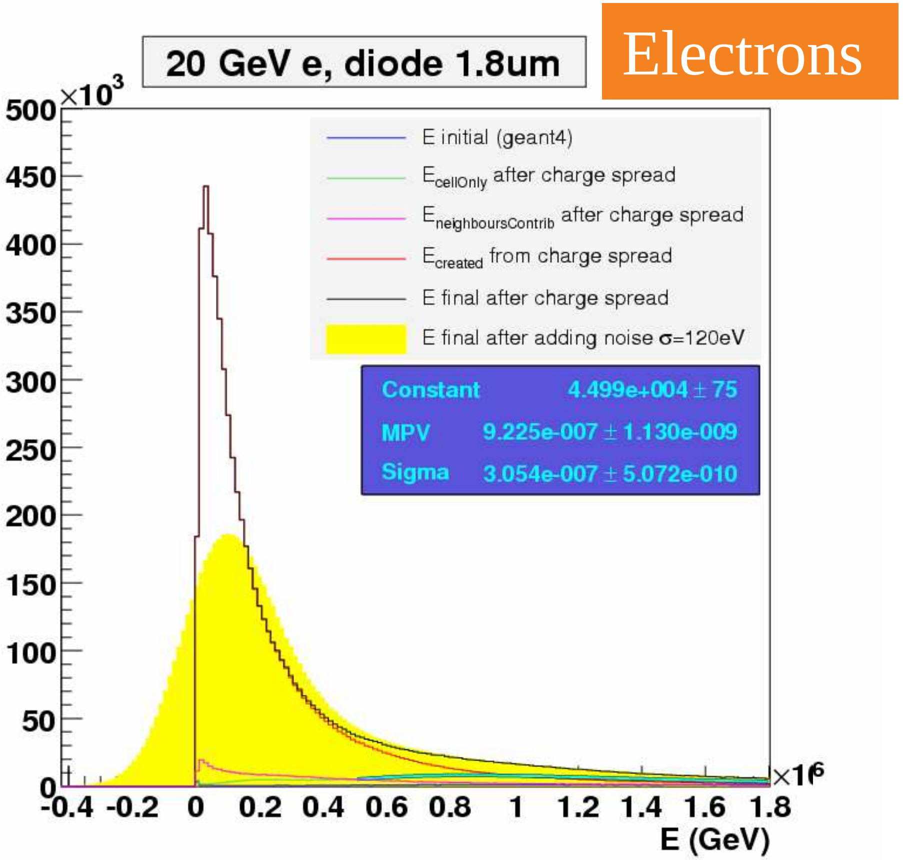


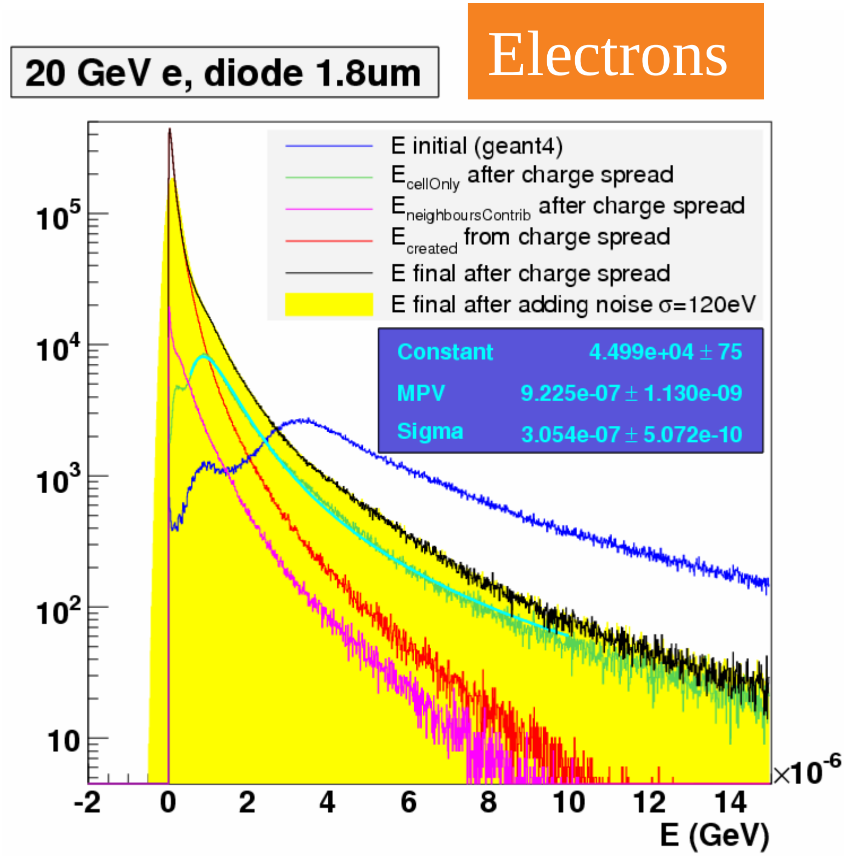
Ł Should simulate with 17um instead of 15 to be closer from the reality ! 17um = 12um thickness of epi layer + 5 um of substract where the charge created will not be recombined fast enough and so is falling into the epi.
Ł Finally, assumed 1300 electrons for the total number of electrons potentially collected.

Details of the different contribution to the energy before applying threshold

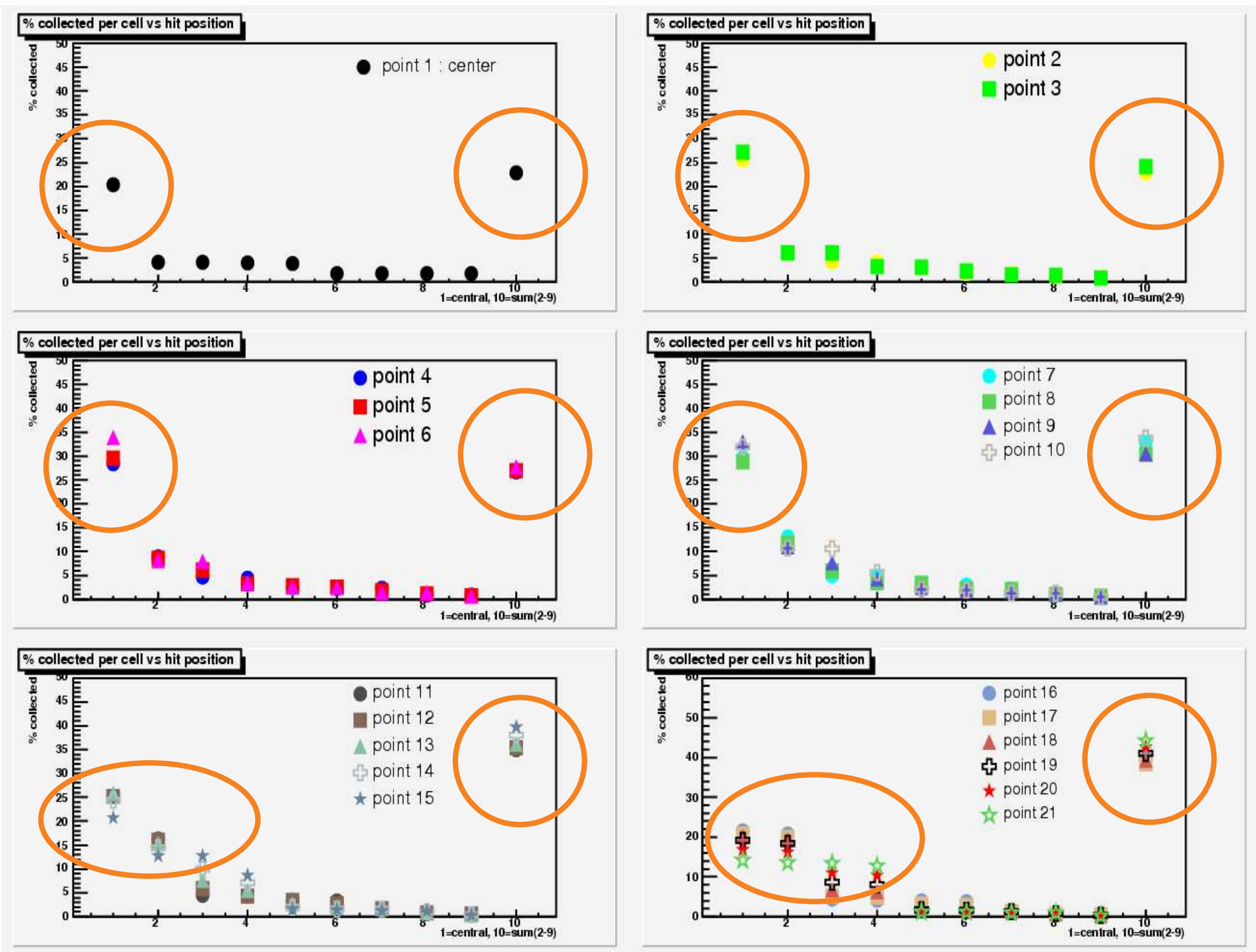
When applying charge spread, the energy of each hit is coming from :
- initial geant4 energy*% in the cell, + % of possible neighbours leak = green+pink curves
- just % of neighbour(s), creating a new hit : red curve

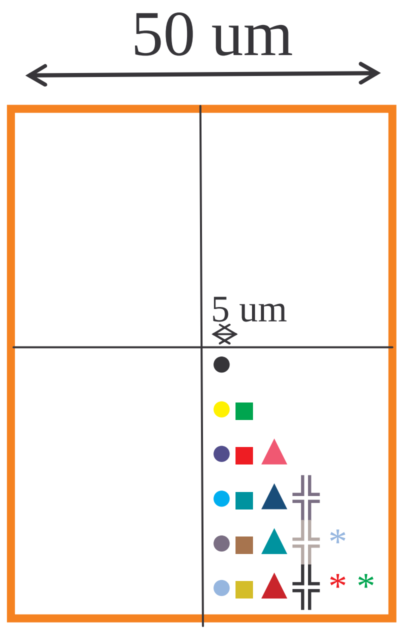
The total (not sum of histos!! Per hit) is in black, and in yellow after a noise adding of 120 electrons.



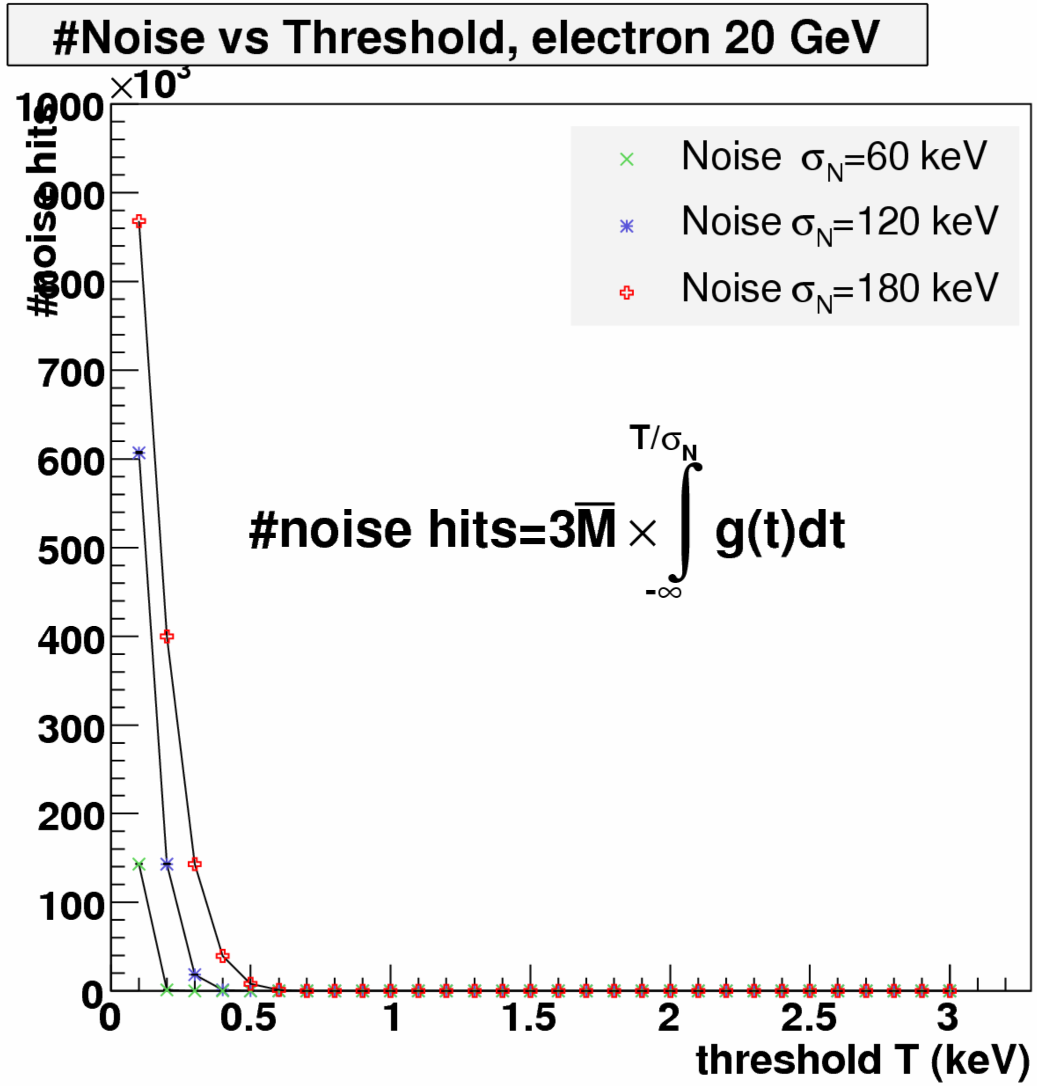


Importance of the charge spread





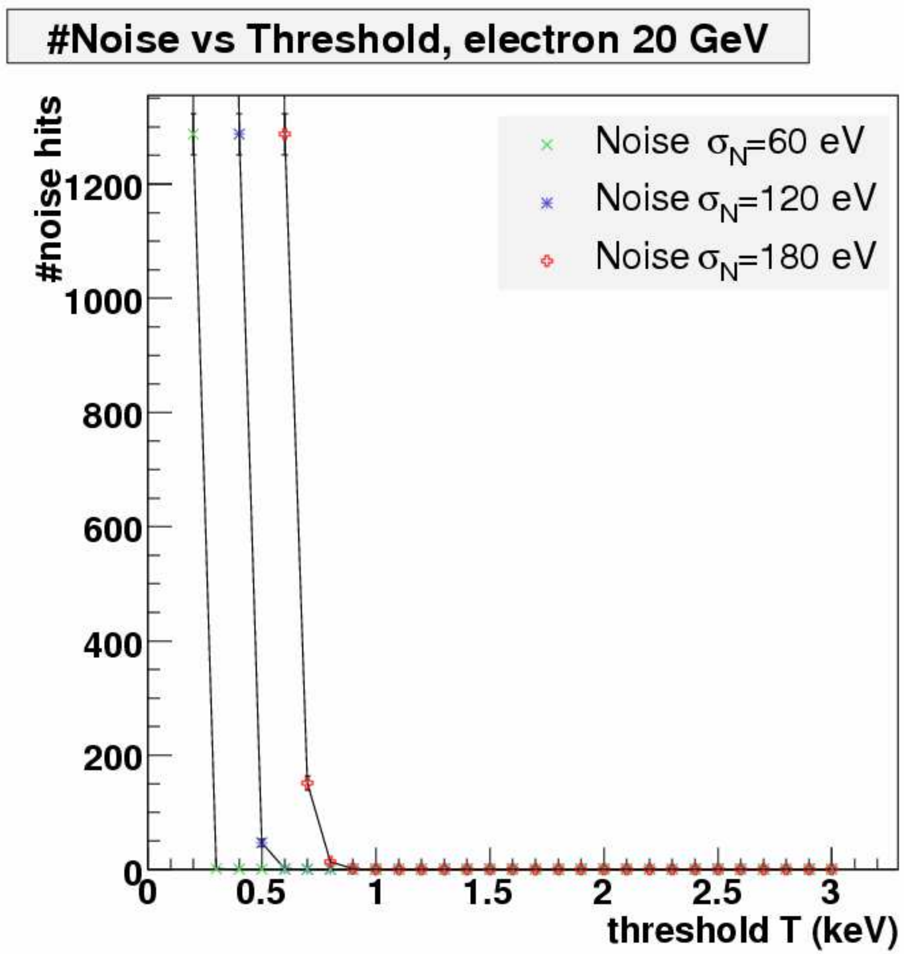
Adding of Noise only hits, depending on threshold



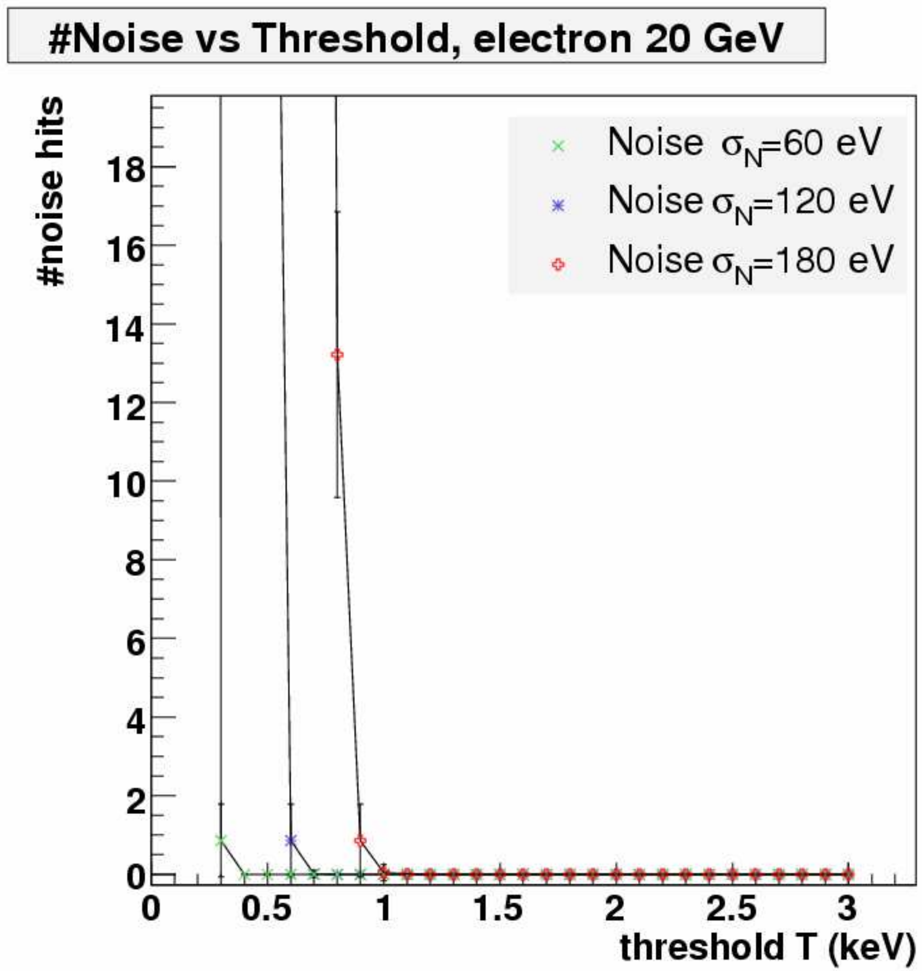
For a threshold > 600 eV (= 5σ for the expected noise level) : noise only hits are effectively "0" per cone around the shower.

Calculation based on 3M pixels ~ 1.5*1.5 cm towers.

zooms



#Noise vs Threshold, electron 20 GeV
#noise hits
threshold T (keV)
Noise σN=60 eV
Noise σN=120 eV
Noise σN=180 eV



#Noise vs Threshold, electron 20 GeV
#noise hits
threshold T (keV)
Noise σN=60 eV
Noise σN=120 eV
Noise σN=180 eV

Extracting the energy resolution

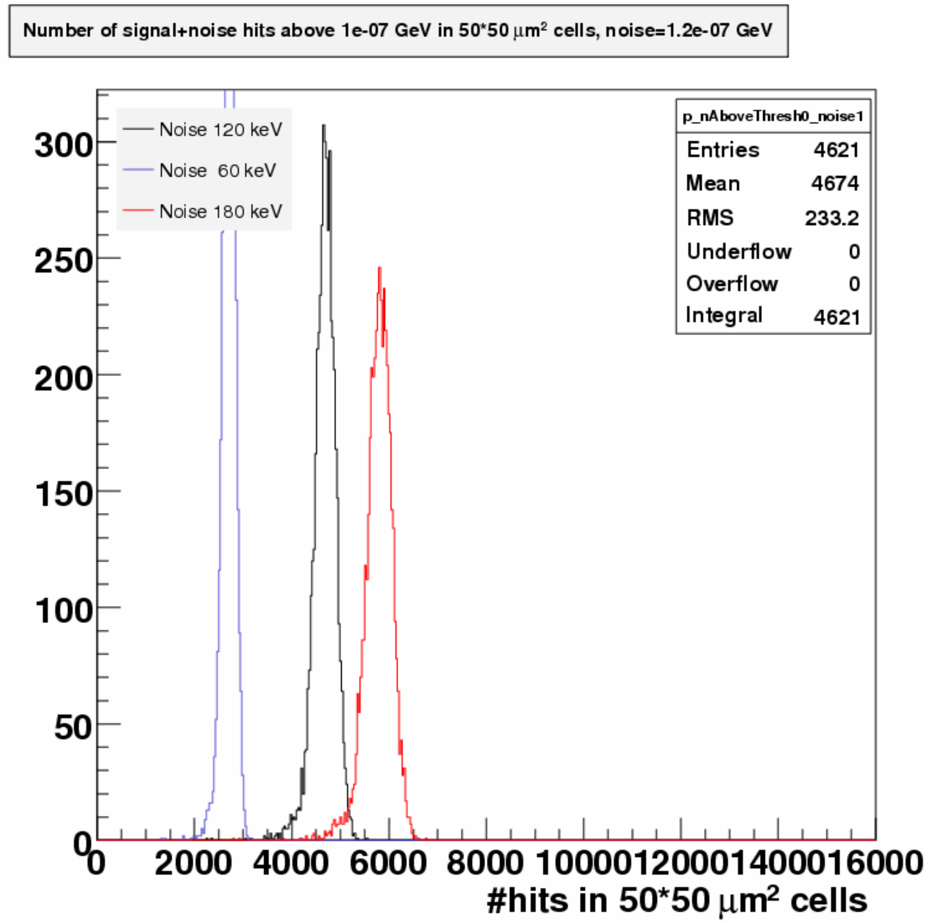
Assumption : the total energy is proportional to the number of hits after threshold, per threshold :

$E = f. \#pix$

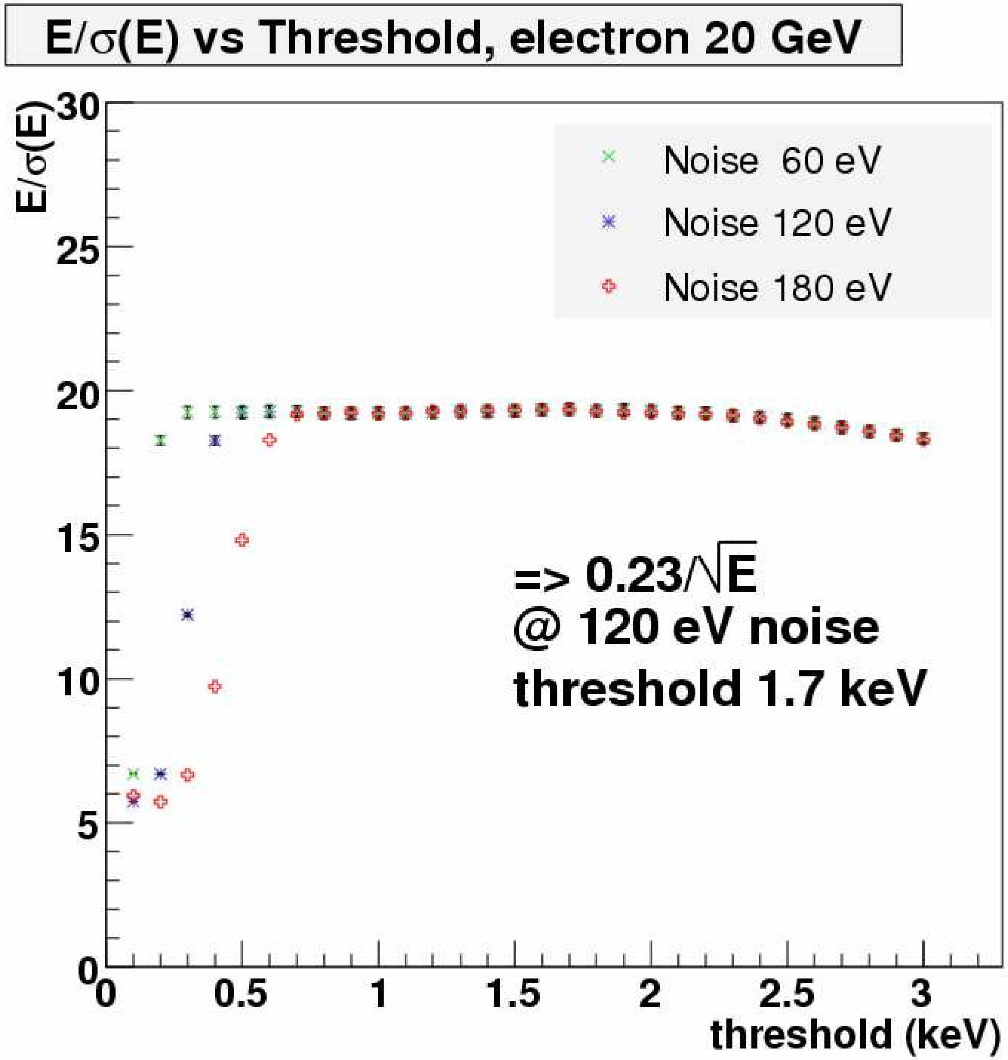
And so $\sigma_E = f. \sigma_{\#pix}$

Finally, $E/ \sigma_E = \#pix / \sigma_{\#pix}$

- Get the mean and RMS of the number of hits after threshold, per threshold value.
- scan : between 100 eV and 3 keV.



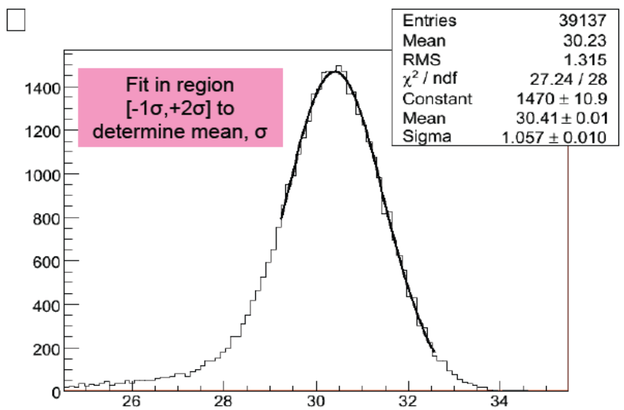
The "ideal" result : without charge spread.



The "official" value for the standard ECAL is 0.15, the objective is 0.12.

But here : no Gaussian fit, so conservative.

Ł Comparison with Calice : seems in reasonable agreement !



From D. Ward, Calice-software 23/11/2006

Ł $\sqrt{30}$ / (30.23/1.315) = 0.23

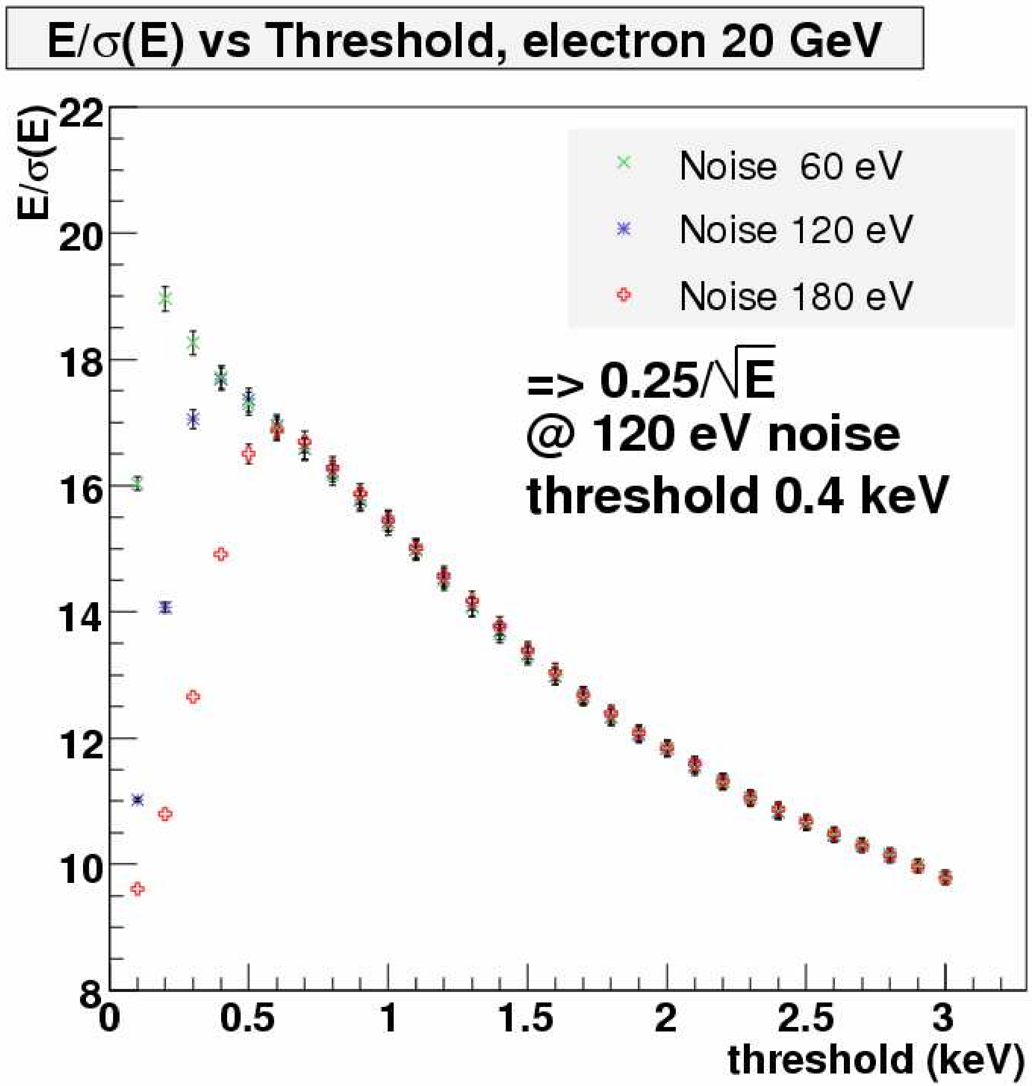
Ł $\sqrt{30}$ / (30.41/1.057) = 0.19

After charge spread for 1.8 um diodes

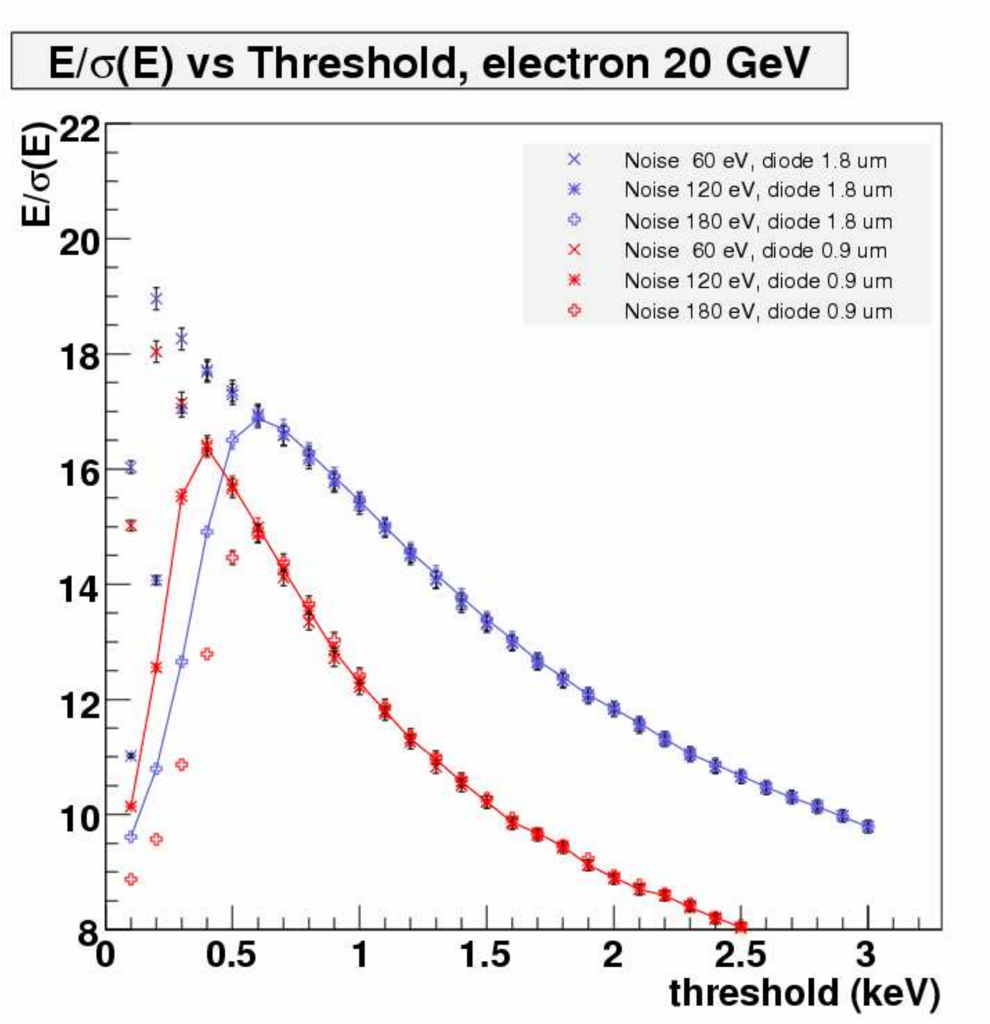
The noise level is assumed to be ~40 electrons to be conservative.
Conversion factor : 1 e- = 3 eV
Ł 120 eV will be the basic level considered here.

Study if 60 or 180 eV instead :
Ł Below 400 eV , the influence is due to the increased number of noise only hits.
Ł After 600 eV, no more noticeable impact.

Ł this seems to not be a critical parameter in terms of energy resolution !!!



Influence of the diode size



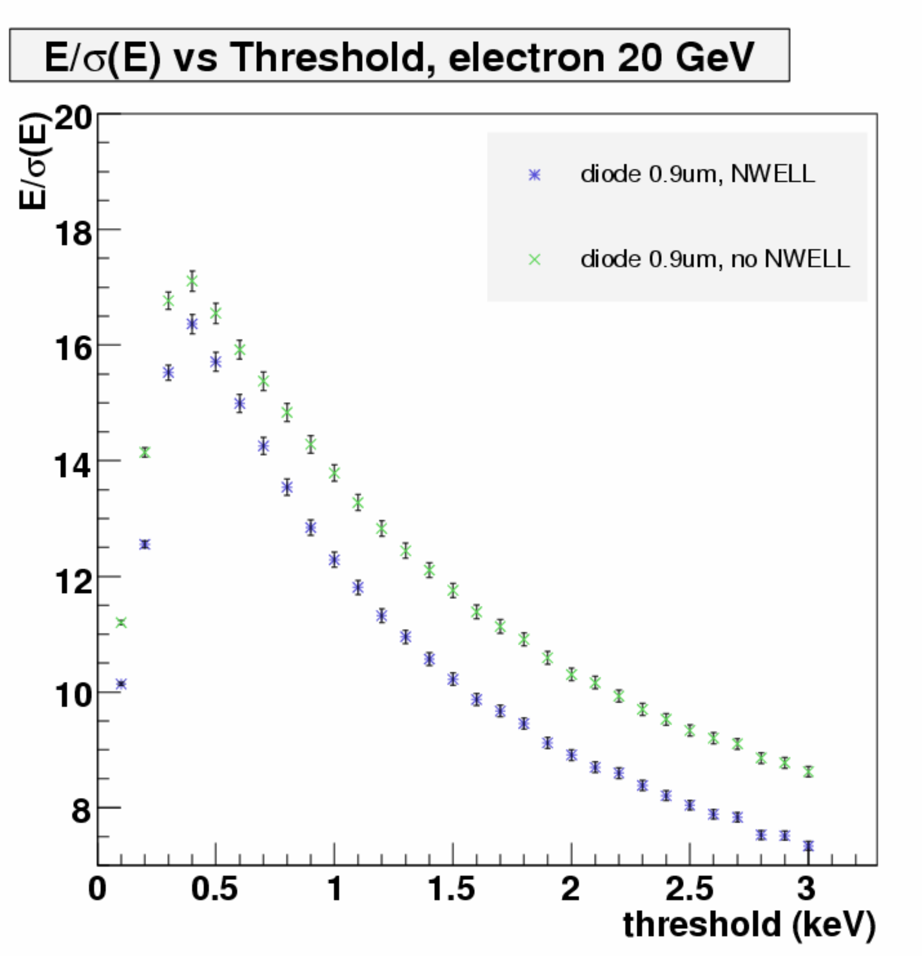
Ł Let's assume : bigger diode size = bigger noise.

Ł So compare : 0.9 um with 120 eV noise, and 1.8 um with 180 eV noise

Ł What we already know : bigger diodes is better above 500 eV threshold !

Looking forward to test 3.2 um ☺

Influence of the central NWELL

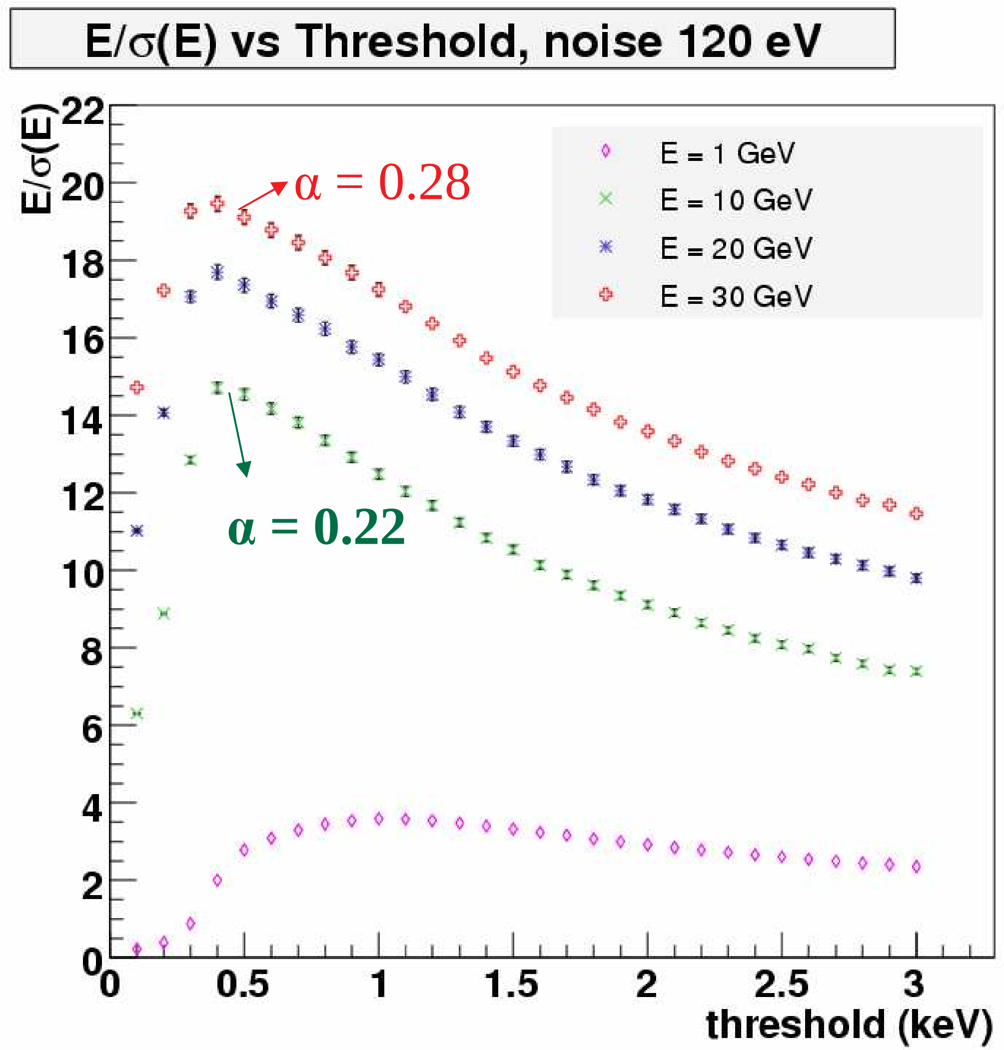


Tested only with 0.9 um diodes.

Ł The NWELL will systematically take 50% everywhere, but without NWELL the charge spreads further than the closest neighbours, so is here considered as lost....

Ł Need to confirm the influence with 3.2 um diodes !

Influence of the incoming energy

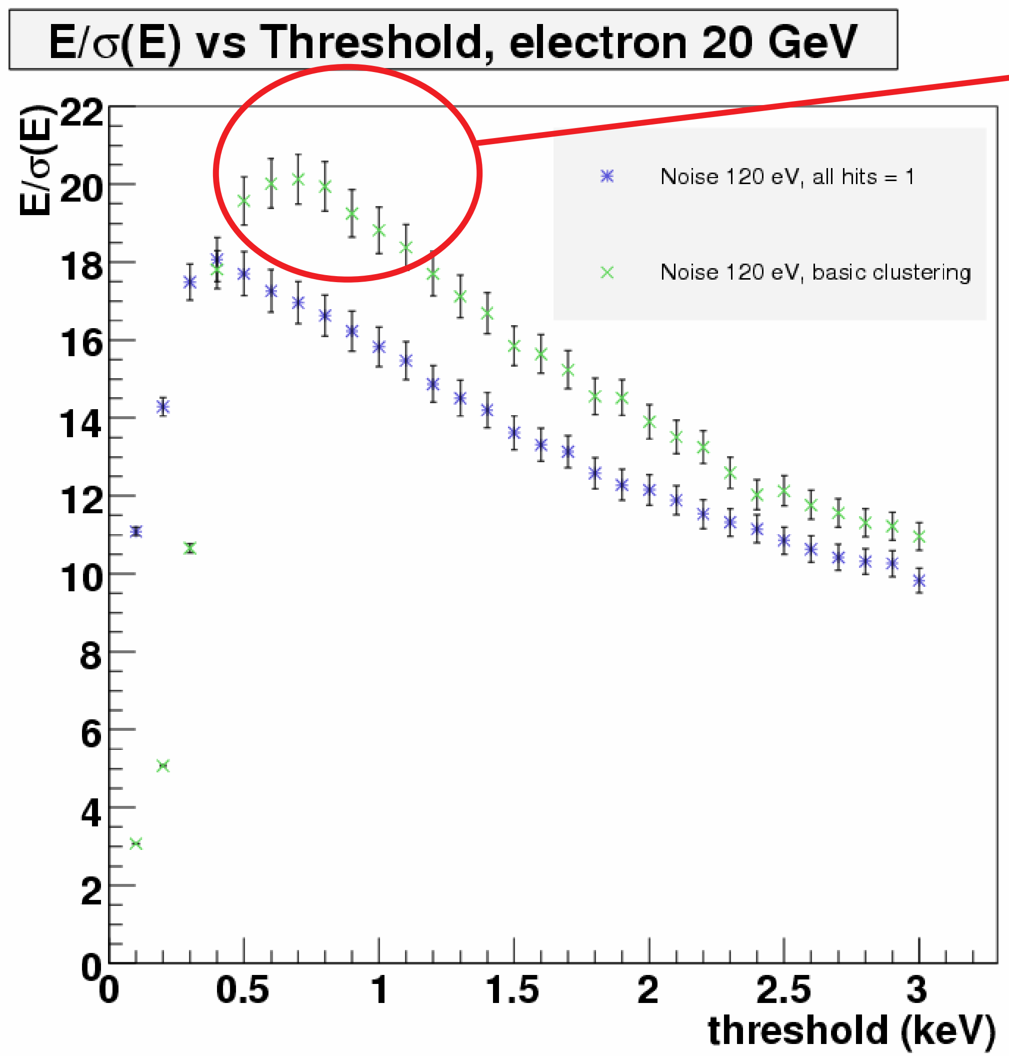


At 20 GeV Ł α = 0.25

à Would expect
E/σE ~ 22 @ 30 GeV,
12.6 @ 10 GeV,
4 @ 1 GeV

Consistent @ +/- 10 % ...

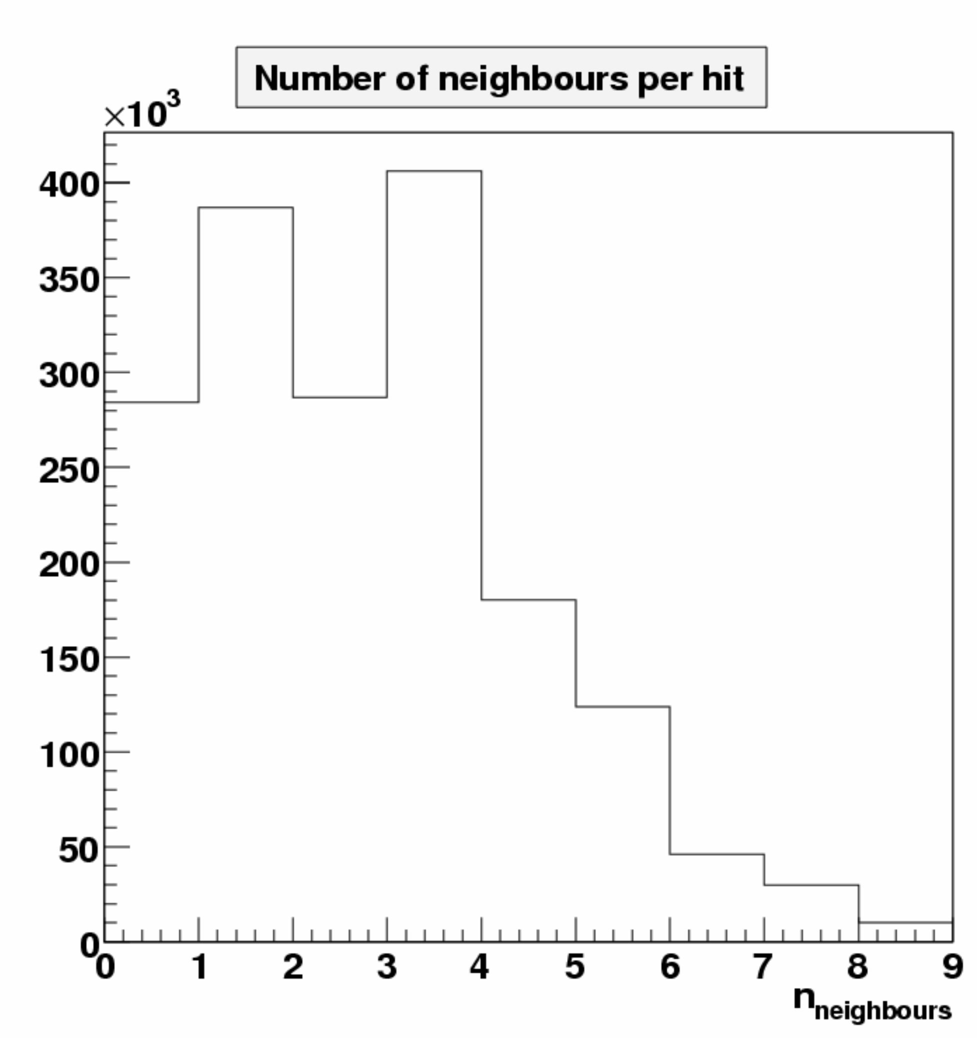
Influence of a basic clustering



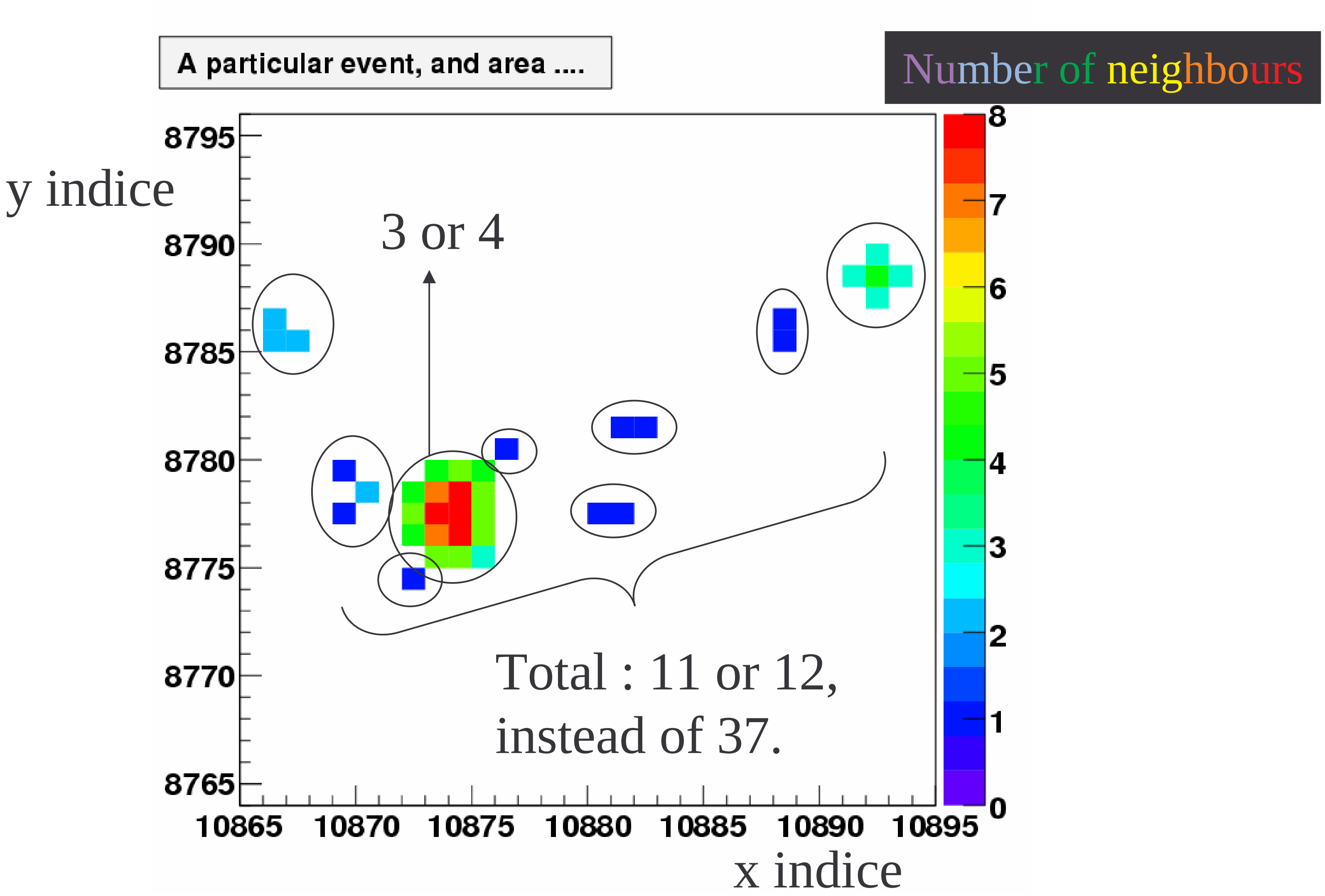
Close to the “ideal” case !

“clustering” = just counting one hit and its closest neighbours that passed the threshold as “1 hit” only.
Hits classified by number of neighbours, and removed from the list when already taken care of...
Only other case taken care of : if the hit has 8 closest neighbours (= the max possible), and one of the closest neighbours has also 8 neighbours Ł count 2.

Number of neighbours after 600 eV (= 5 σ) threshold for example...



Example...


A particular event, and area ....
Number of neighbours
y indice
x indice
3 or 4
Total : 11 or 12,
instead of 37.
8795
8790
8785
8780
8775
8770
8765
10865
10870
10875
10880
10885
10890
10895
0
1
2
3
4
5
6
7
8

To do list

- Include the dead area
- Better scan in energy
- further study of clustering neighbours hits, at higher energy also....

- Simulate full physics events ... and optimise the code for a big number of hits.