# Few considerations on the design of the electromagnetic calorimeter

- About the barrel-end cap overlap region
- About the total thickness
- About the sampling and the resolution
- About the FE dynamics

largely borrowed from a presentation at the last EUDET meeting by JCB

These studies are based on a MOKKA simulation
of few versions of the LDC detector

The pad size relevant for most of the study is 5x5 $mm^2$

# About the barrel-end cap overlap region

In the study described in the LDC DOD, a problem in the collection of the energy is seen at the overlap between barrel and end-caps.

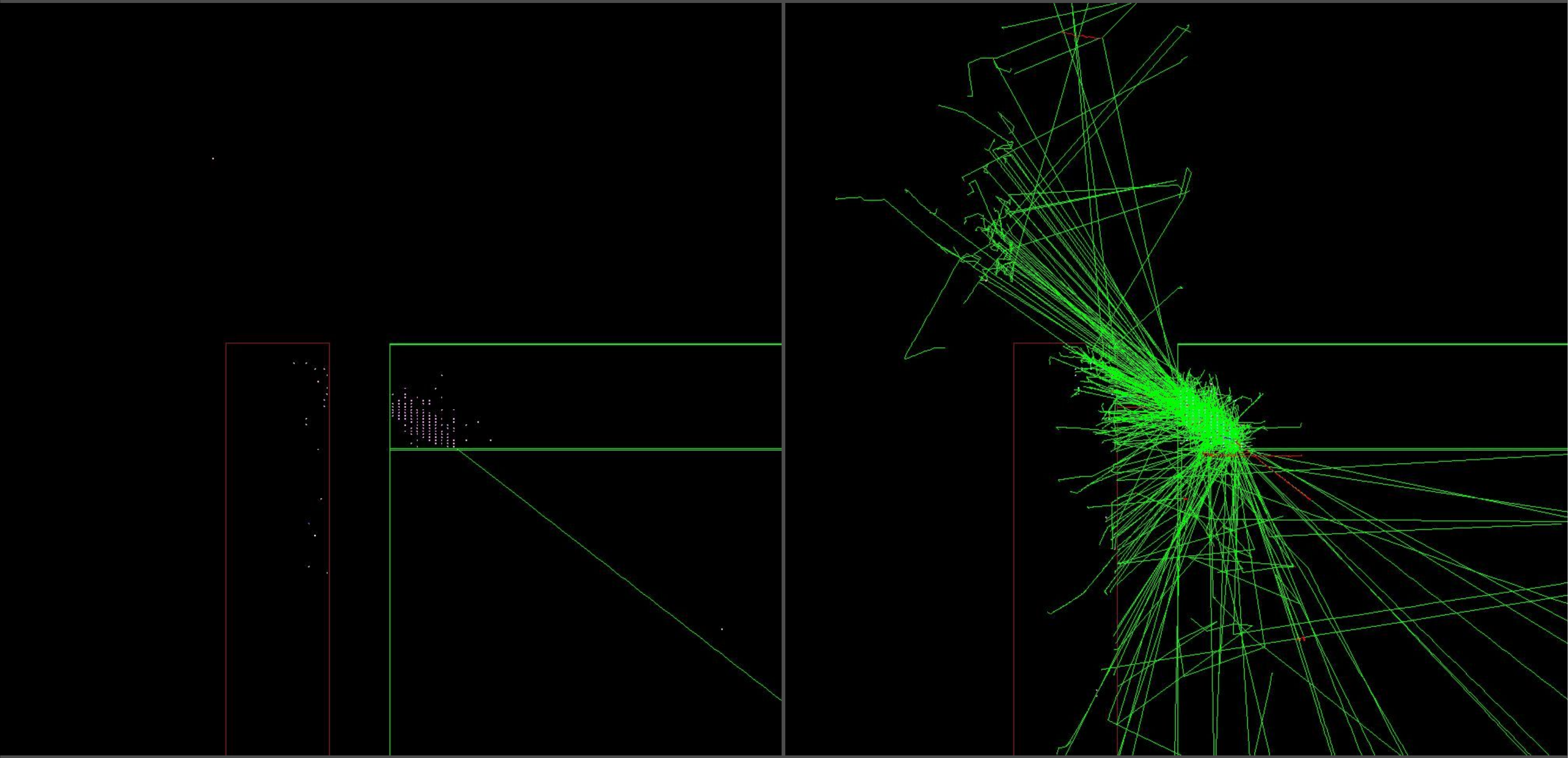
This points to a poor design of that region and is investigated in the following slides.

In the DOD description the distance between barrel and end-cap active regions is 10 cm and the end-cap outer radius is 3 cm larger than the barrel.
In the LDC01 model, if the distance is 10 cm, the end-cap outer radius is equal to that of the barrel.

For this study, an EC outer radius exceeding that of the barrel by 15cm has been used and 10 or 50 GeV photons have been simulated in the overlap region.

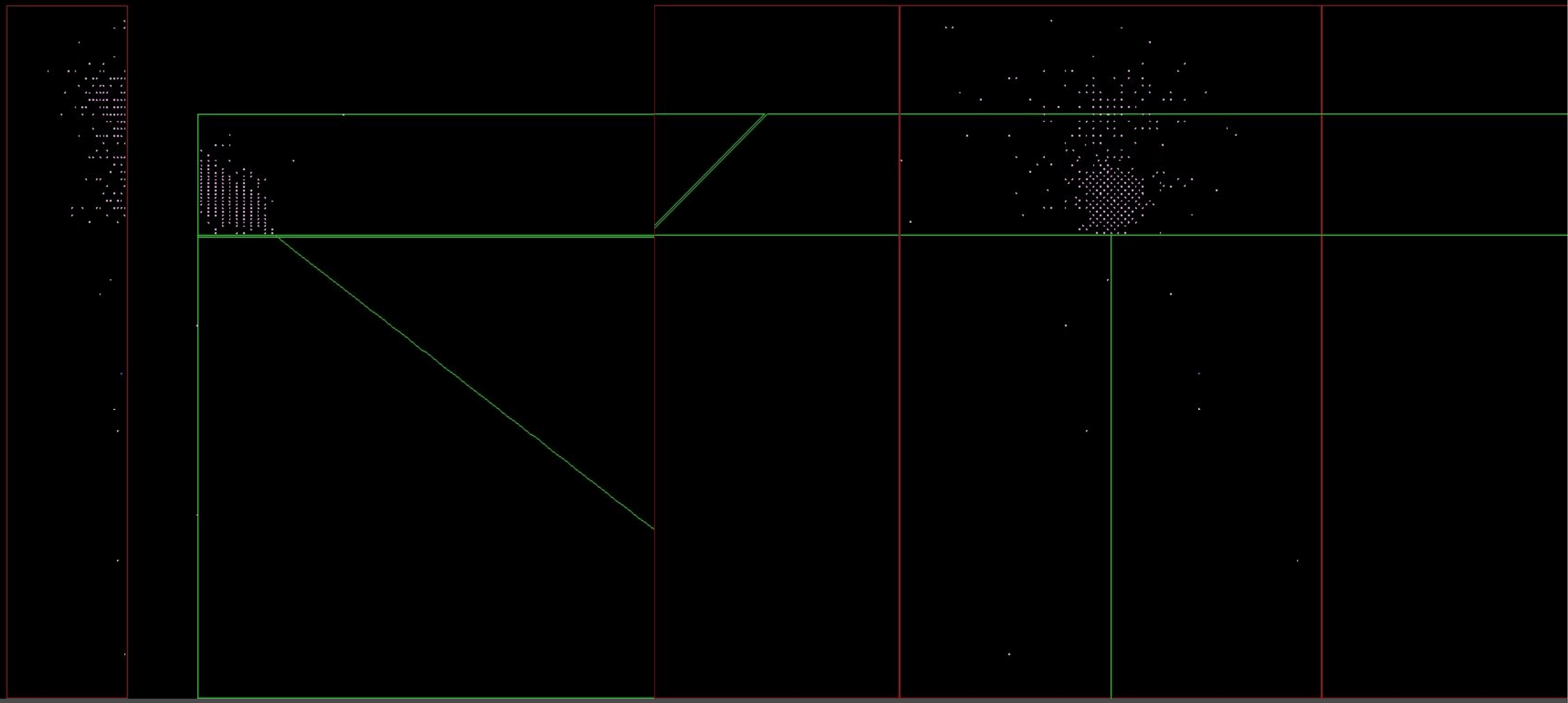
# 10 GeV gamma in LDC01

Hits on the left,
tracks on the right, the photon trajectories
dominate the picture showing how energy escapes.



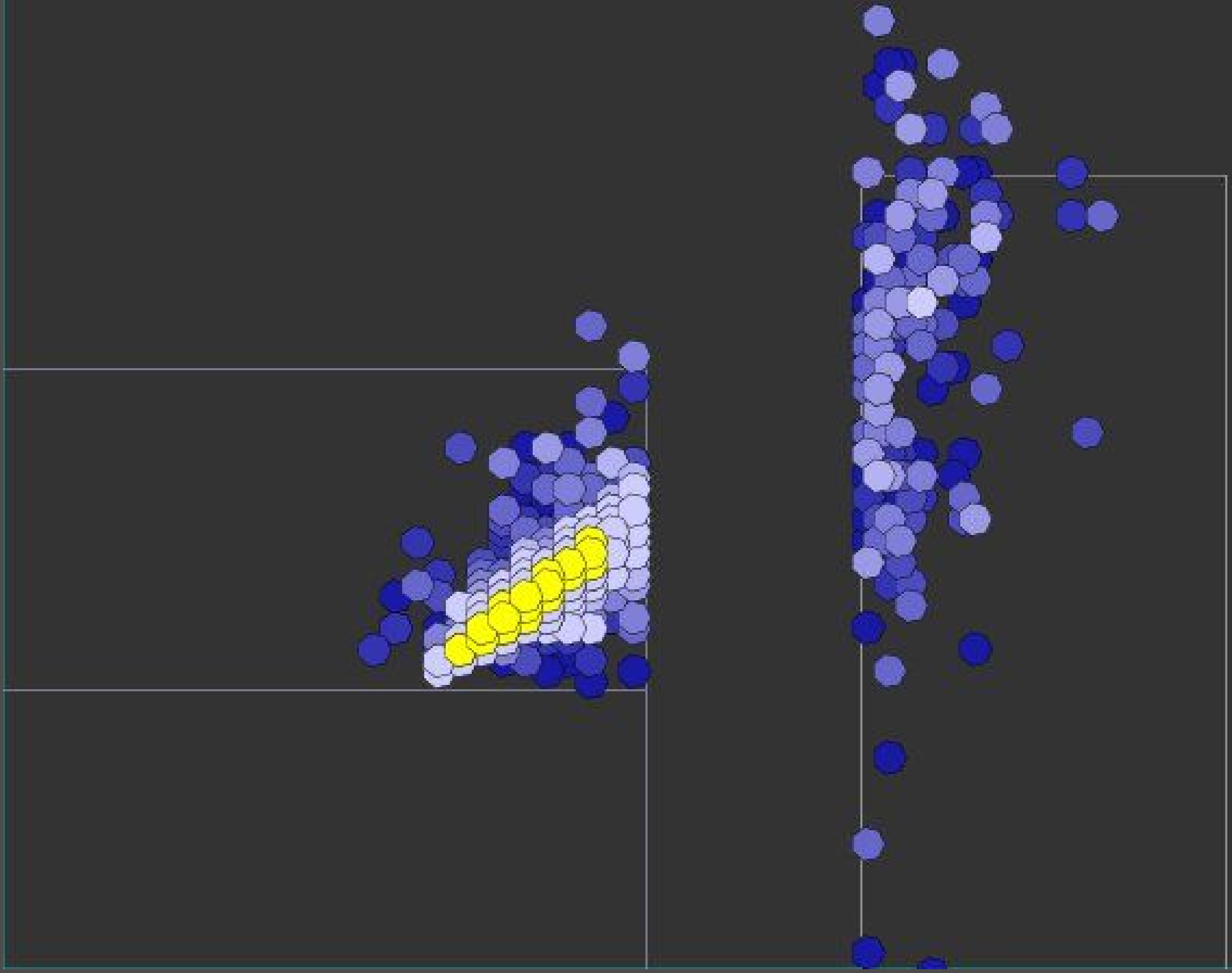
# 50 GeV 1685

Two components are clearly visible in the end cap



50 GeV photon

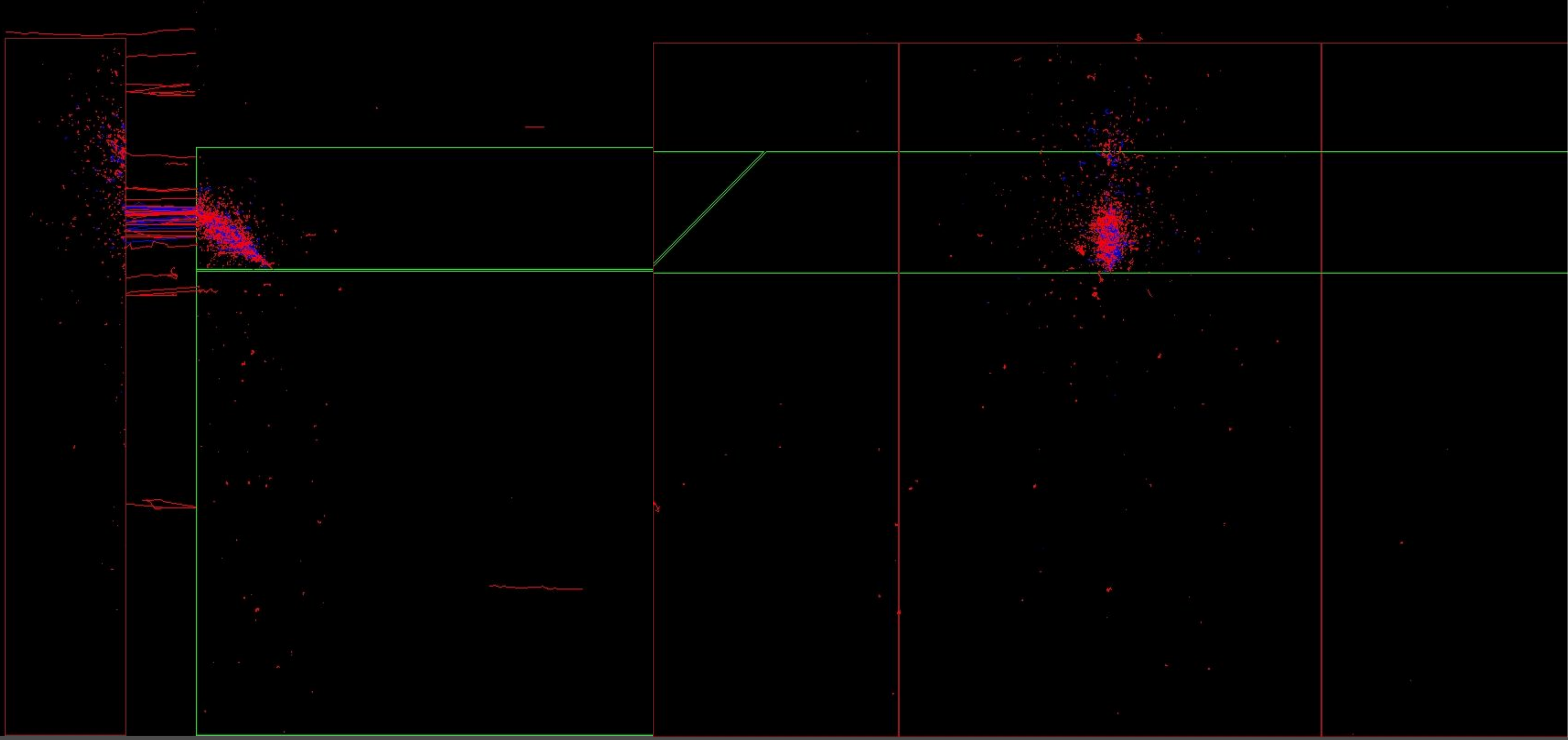
the end cap is drawn with a 184 cm radius

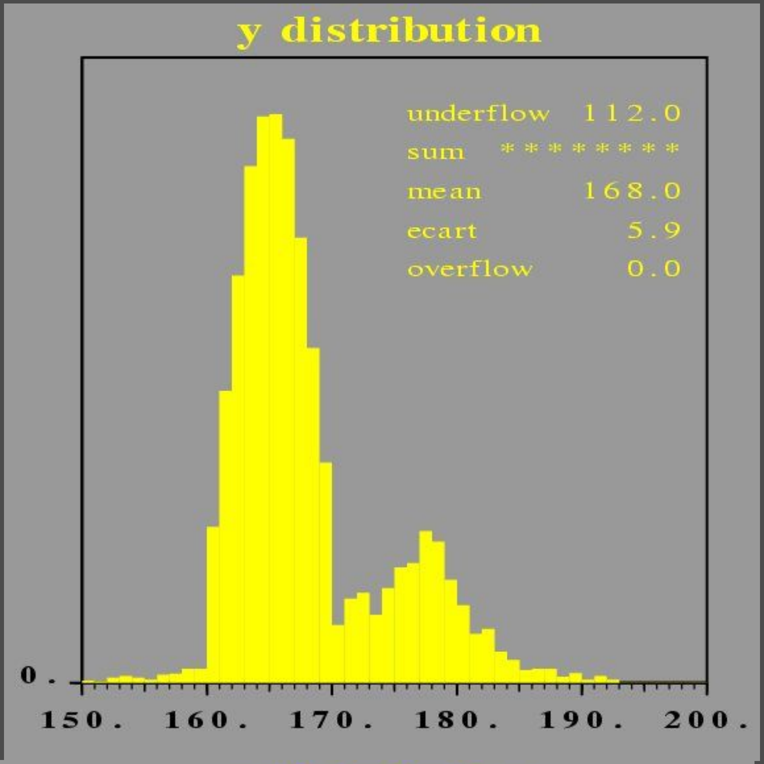


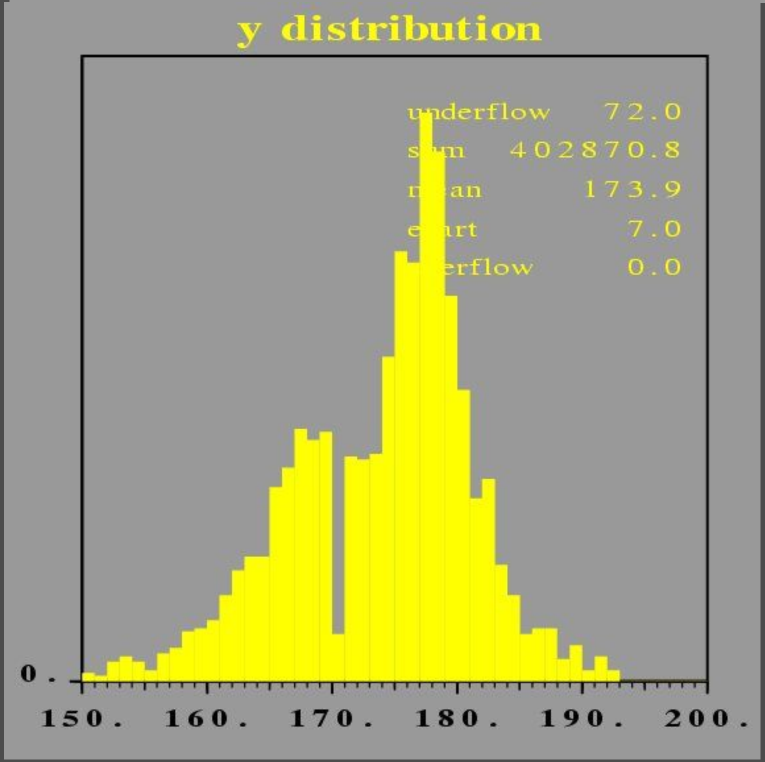
## 50 GeV 1685

To understand the origin of these two components
In red the electron trajectories, in blue positrons.

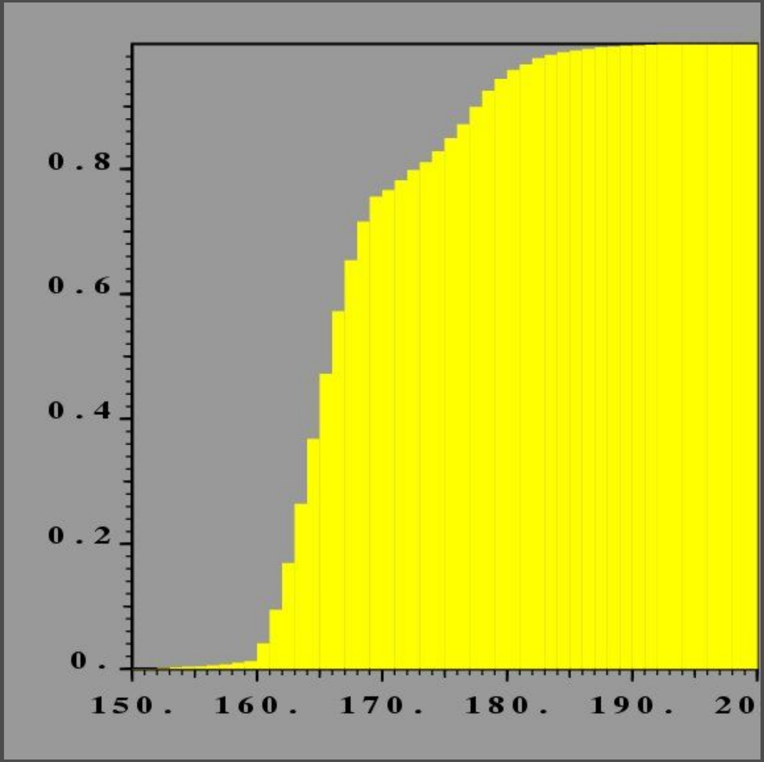
We see that one component is due to the shower photons
the other to the shower electrons captured by the magnetic field







Distribution in y (radius) of the energy collected
On the top for barrel and end-cap together
On the bottom for the end cap only, one can see the photon and the electron components



statistics on 50 GeV photons leaving the barrel at mid-height we collect 96% of the energy with an end-cap at 180 cm, 99% at 185

# Conclusions

When crossing from barrel to end-cap
the showers open exhibiting two components
- one corresponds to the photonic part of the shower,
  it blows out in the incoming direction
- a second corresponds to the charged part of the shower
  it follows the strong magnetic field

Actions:
- make the gap as small as possible (go to 5cm?)
- extend the end-cap to barrel + 7 or 8 cm i.e. 184 or 185
- care in the reconstruction of the induced shower position bias

## About the total thickness

The tungsten thickness of the ECAL considered for LDC is now 20 x 2.1 mm + 9 x 4.2 mm = 23 $X^0$

Is it enough?

too much ?

What about the leakage at high energies

does it hamper the linearity

the resolution?

The leakage induces a non linearity at high energy

Trivial solution: define the law and rescale

but possibility of non additivity

limited by the excellent separation

we did not consider the Hcal help

induces also a constant term in the resolution

non trivial solution:

- use for parameter the depth of the shower event by event

it cures the linearity, the non additivity and the resolution!

after such a correction the constant term is at the level of few ‰

This is true for 24 X0

how much can we reduce it?

# Defining the sampling

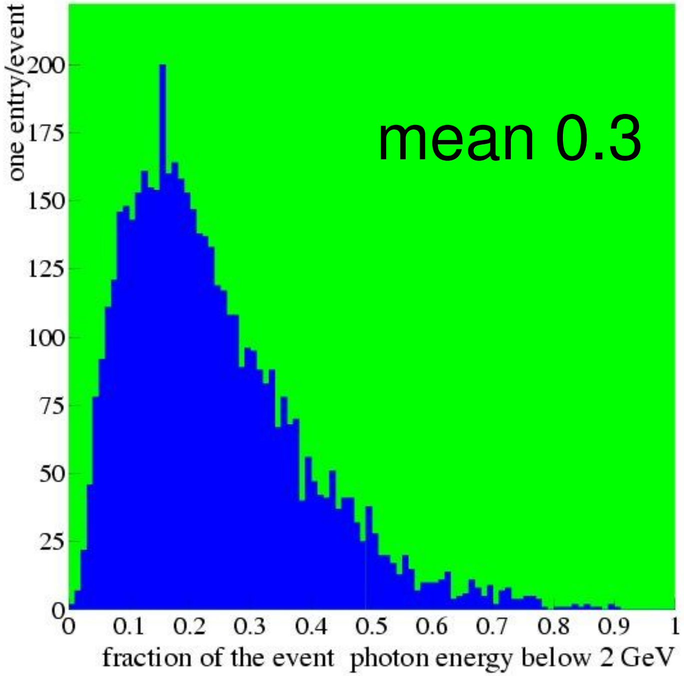
## a question of resolution

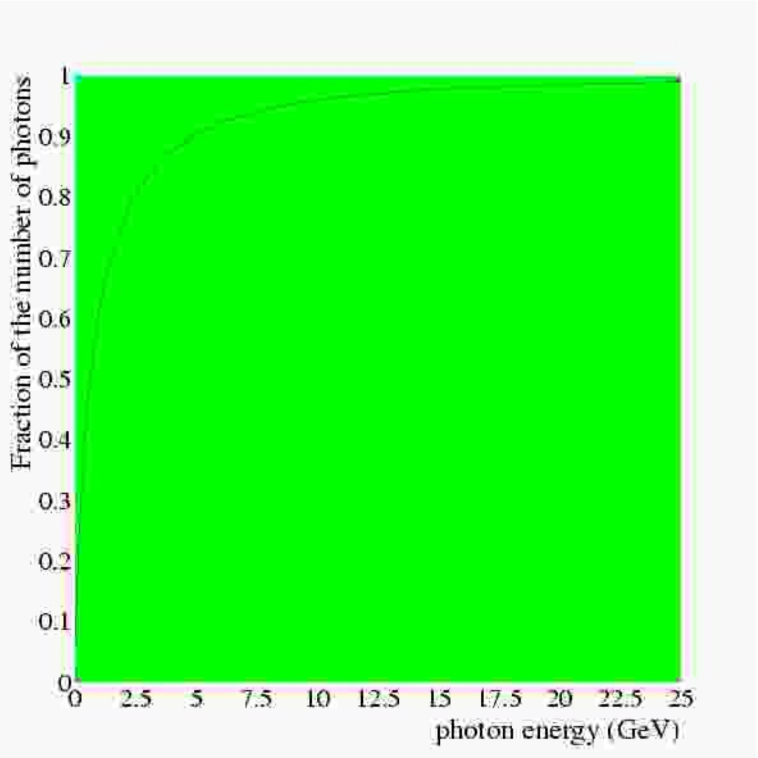
Nota bene: When using different samplings in depth
the resolution can not behave in $\alpha/\sqrt{E}$

A large fraction of the photon energy comes
from low energy photons < 2 GeV

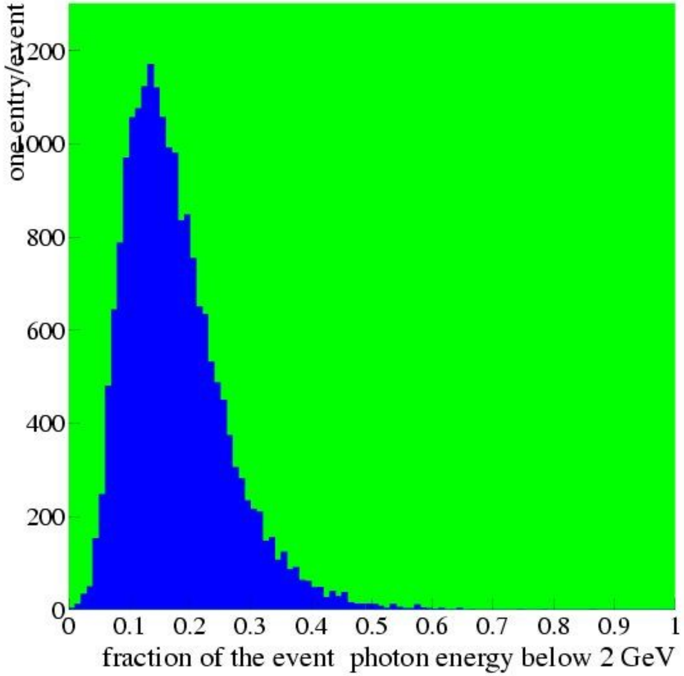
Improve the event resolution by
- using thinner sampling in the first part
- improving the algorithm

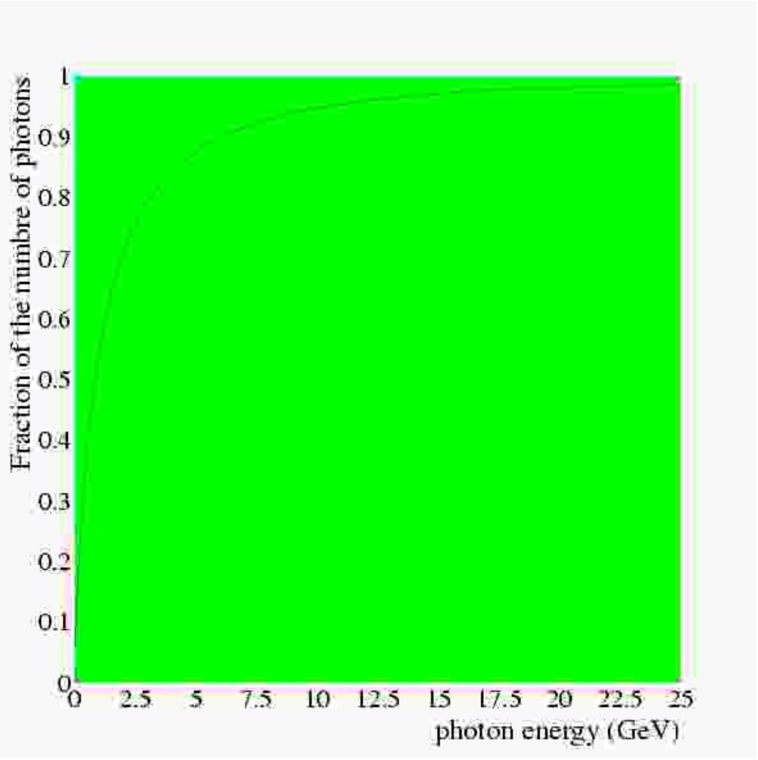
ννWW


mean 0.3



ZH





- MOKKA LDC with 1, 2 or 3 different tungsten thicknesses
  - 30 x 2.8 mm,
  - 20 x 2.1 + 10 x 4.2mm,
  - 10 x 1.4 + 10 x 2.8 + 10 4.2 mm

- Simulate the low energy 0.2 , 0.5 , 2 , 5 , 10 GeV

- Shoot at about 40 degrees

- Use the deposited energy, but also the counting
  to estimate a best possible energy resolution

# Method

## Once the showers clustered

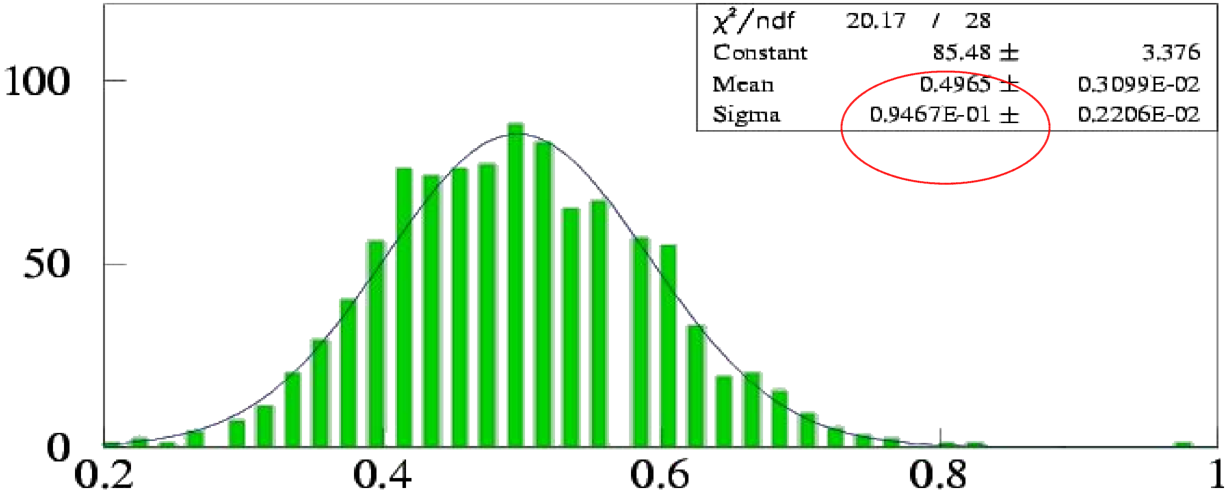
- Measure the dependence of the hit multiplicity with energy
- Fit a smooth function Emul(Etrue)
- Estimate energy from hit multiplicity via the function Emul(deposited energy)
- For each simulated energy, do a fit to establish the best measurement as a linear combination of Emul(Edepot) and Edepot imposing linearity (F)
- Fit F as a function of the true energy F(Etrue)
- Use Edepot to have F(Edepot) , and use it in Ebest

**Ebest = F(Edepot) x Emul(Edepot) + (1-F(Edepot)) x Edepot**

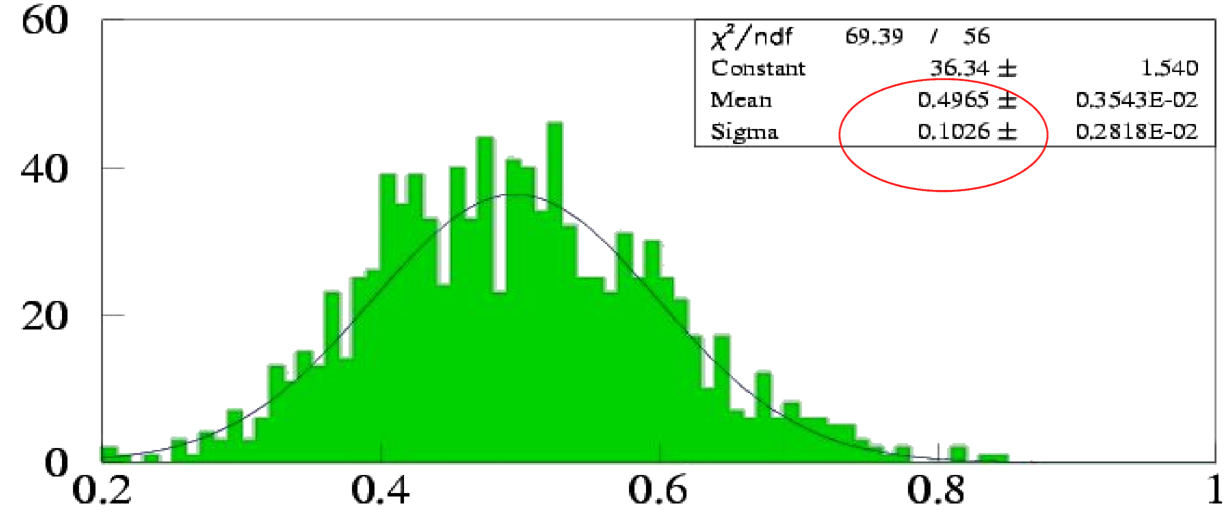
A fit procedure has been used to estimate the relative weight of the stacks.
It provides the expected result, proportional to the tungsten thickness

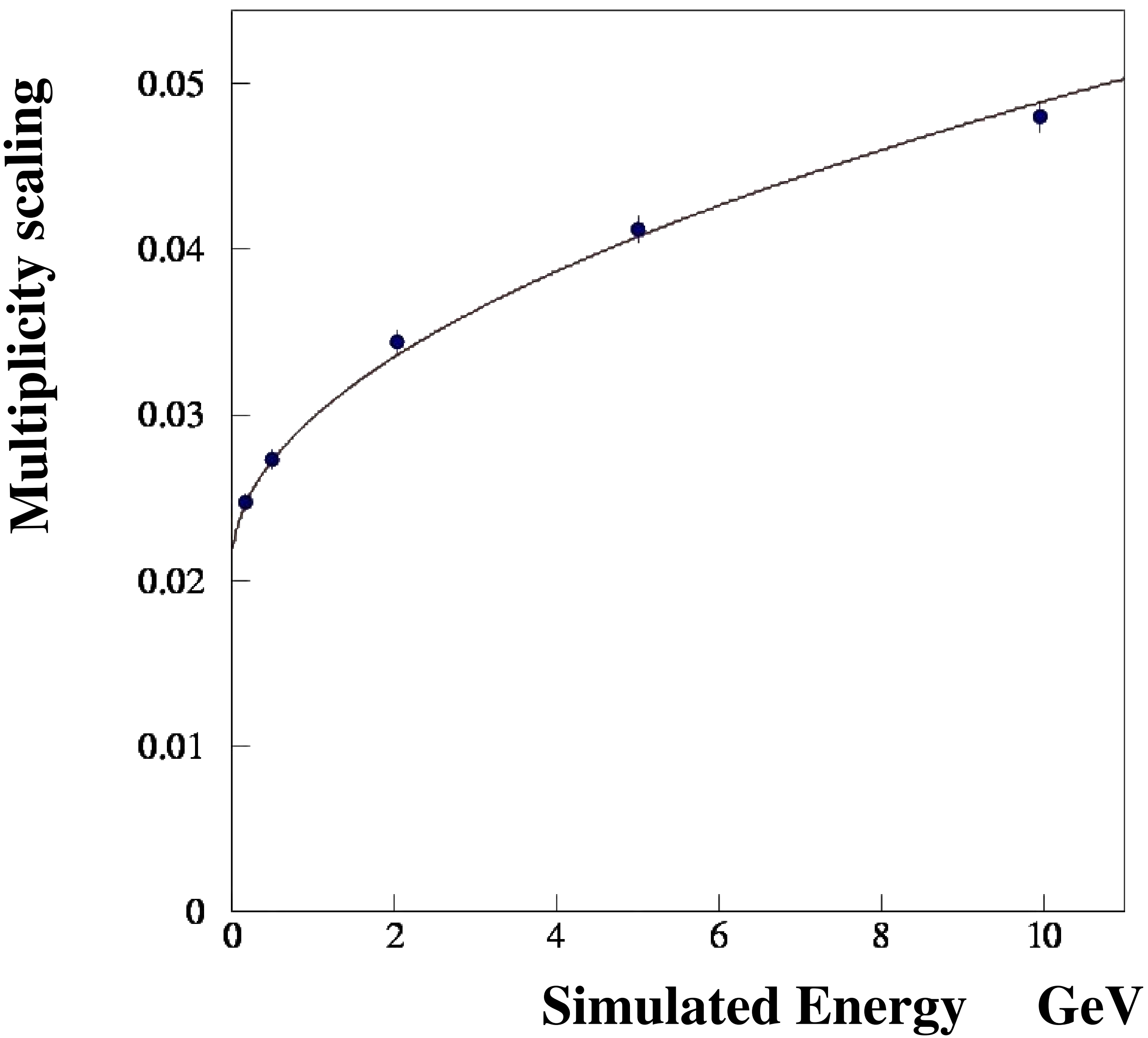
# 2w , 500 MeV

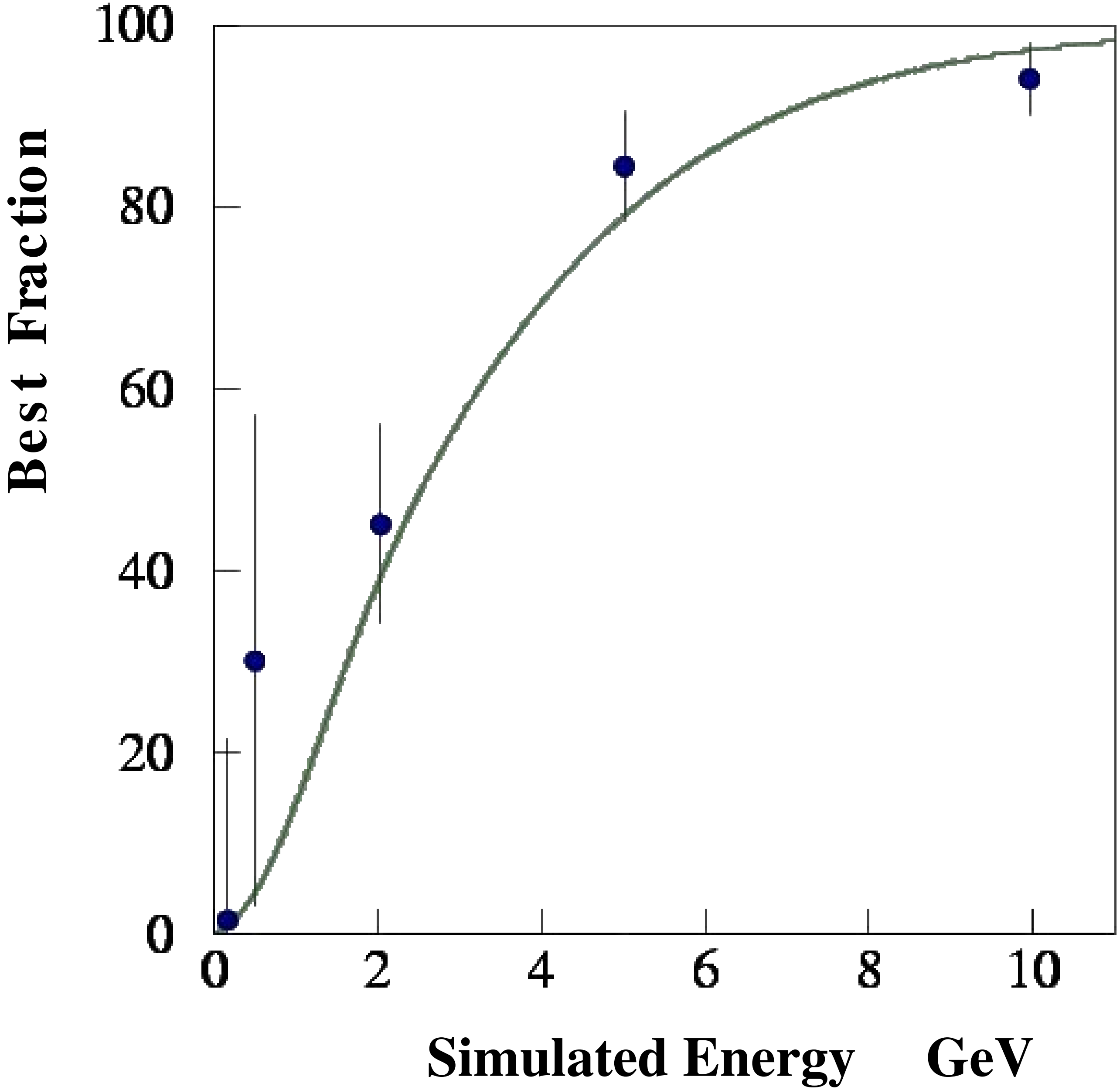
Knowing
the true energy

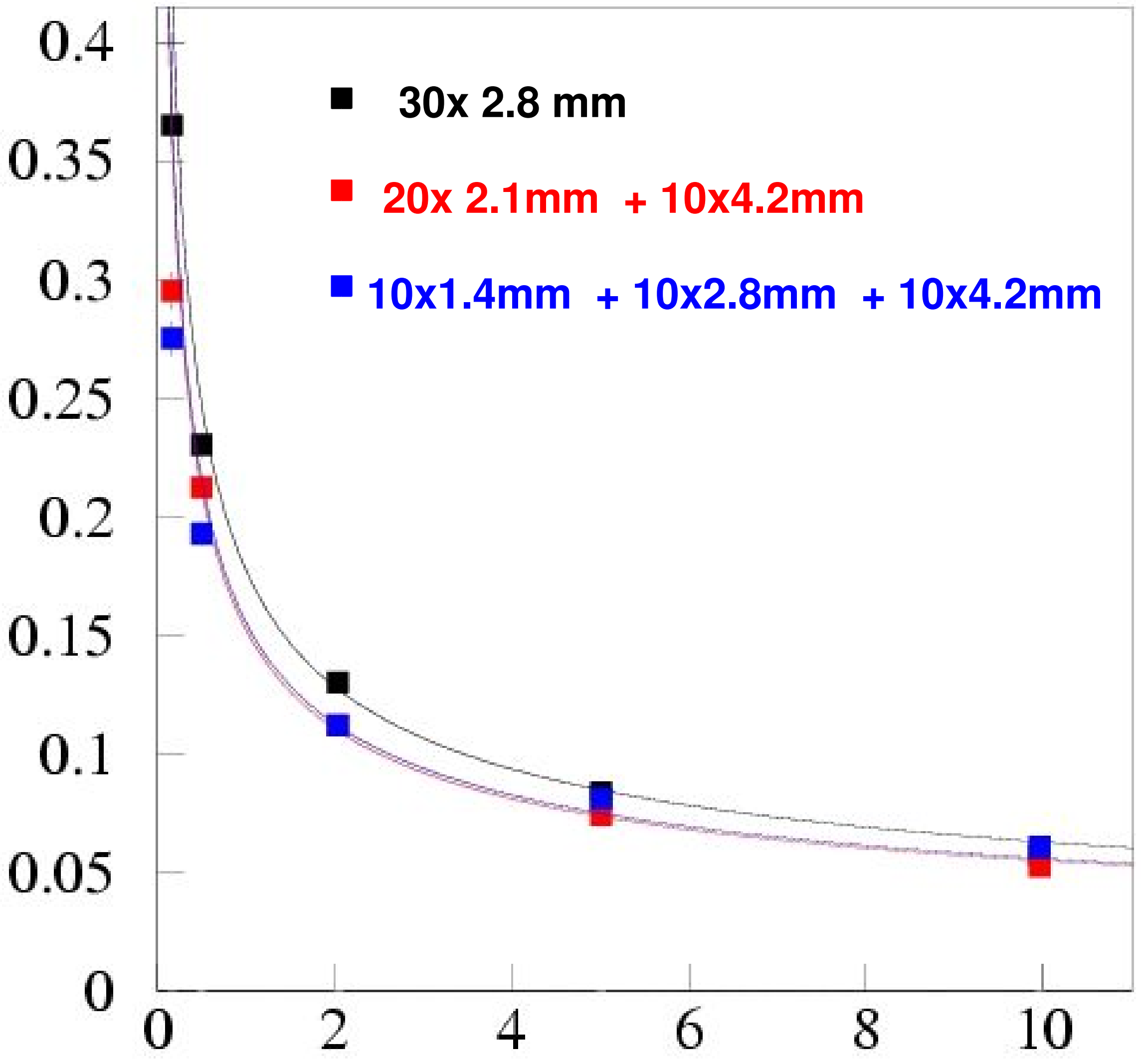


With parametrisation
and using the deposited
energy




Multiplicity scaling
0.05
0.04
0.03
0.02
0.01
0
0
2
4
6
8
10
Simulated Energy GeV


100
80
60
40
20
0
0
2
4
6
8
10
Best Fraction
Simulated Energy GeV


0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
2
4
6
8
10
■ 30x 2.8 mm
■ 20x 2.1mm + 10x4.2mm
■ 10x1.4mm + 10x2.8mm + 10x4.2mm

|  | 30 x **2.8 mm** | 20x **2.1mm** ⊕<br>10x **4.2mm** | 10x **1.4mm** ⊕<br>10x **2.8mm** ⊕<br>10x **4.2mm** |
|---|---|---|---|
| Fit **2-10 GeV** standard | $\frac{17.6}{\sqrt{E}} + 0.4\%$ | $\frac{14.3}{\sqrt{E}} + 0.9\%$ | $\frac{12.2}{\sqrt{E}} + 2.5\%$ |
| Fit **2-10 GeV** fixed cst term | $\frac{16.7}{\sqrt{E}} + 1.0\%$ | $\frac{14.2}{\sqrt{E}} + 1.0\%$ | $\frac{14.5}{\sqrt{E}} + 1.0\%$ |
| Fit **0.2–0.5 GeV** | $\frac{16.4}{\sqrt{E}} + 0.0\%$ | $\frac{10.1}{\sqrt{E}} + 6.6\%$ | $\frac{10.2}{\sqrt{E}} + 4.9\%$ |
| Fit **0.2–0.5 GeV** cst term at 0.05 | Very BAD $^{2}$ | $\frac{11.1}{\sqrt{E}} + 5.0\%$ | $\frac{10.1}{\sqrt{E}} + 5.0\%$ |

# Local conclusion

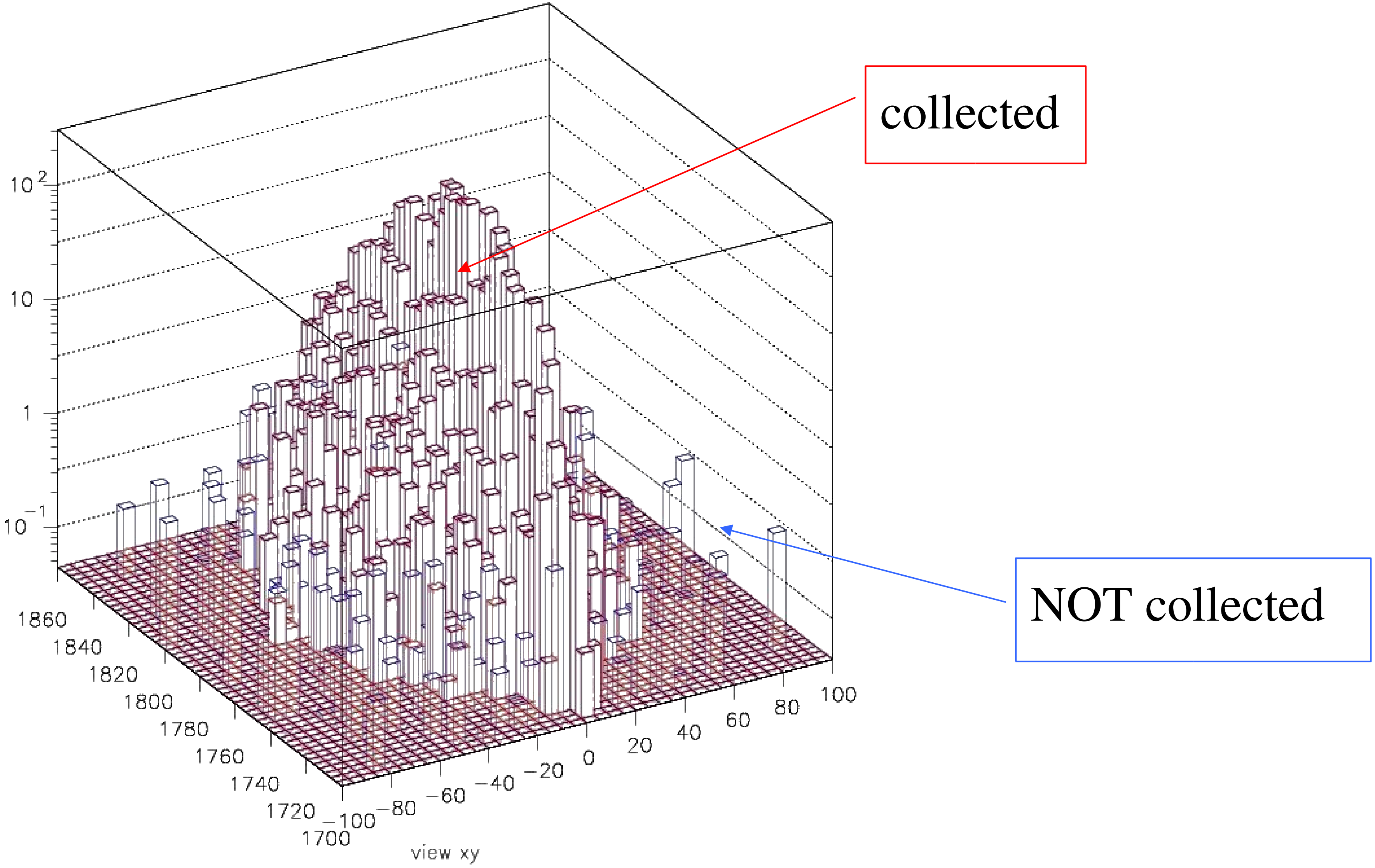
- Using the counting provides at low energy a large (20%) improvement
- 2 thicknesses of tungsten seems a good choice
  it induces also a rather flat dependence of resolution with angle
- The repartition: it could be different but not much from 20 + 10
- For the EUDET module go to 20 x 2.1 + 9 x 4.2

NB: using the shower start or mean depth does not really improve resolution

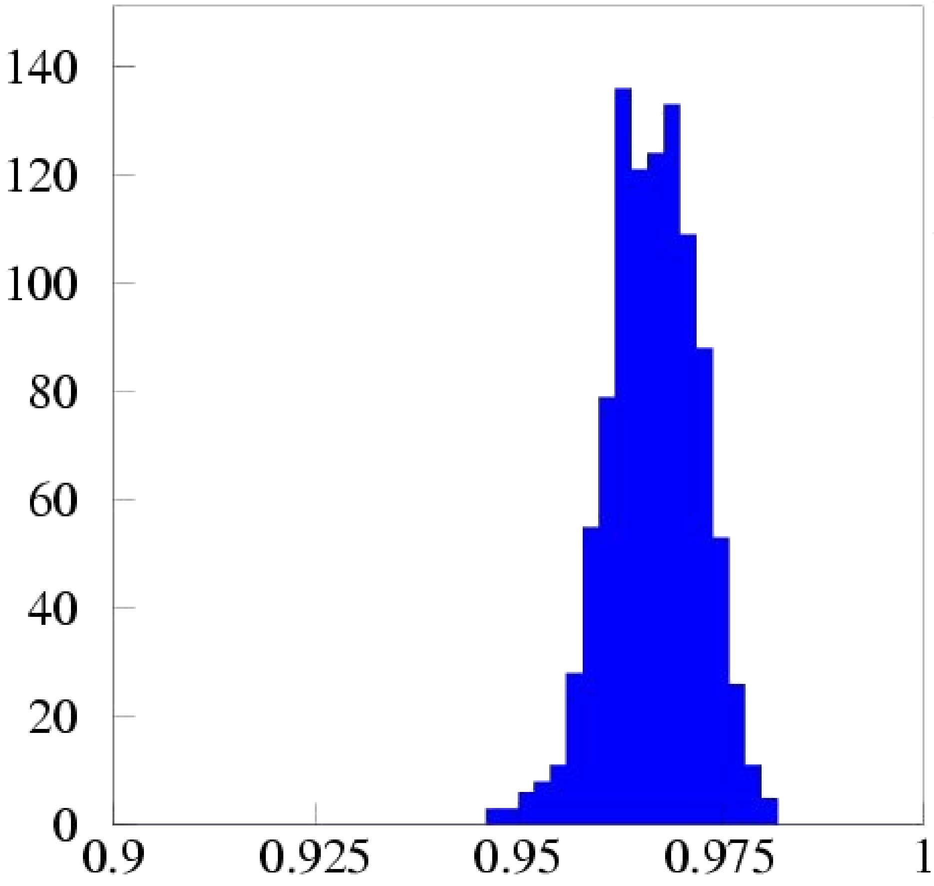
# About the front-end dynamics

- MOKKA LDC
- Simulate high energy electrons 50,100,200,500 GeV
- Shoot at about 45 and 90 degrees at the centre of a pad
  - Clustering
  - Resolution
  - Saturation of the signal

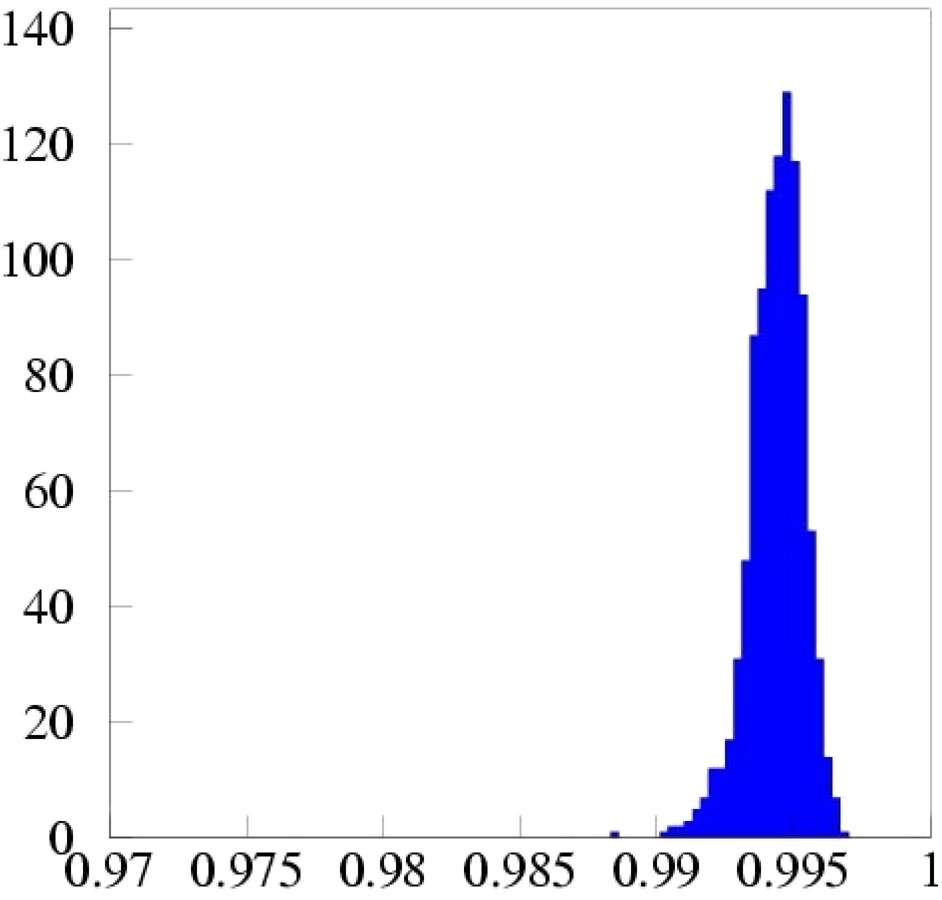
# Clustering at 500 GeV



# Clustering at 500 GeV

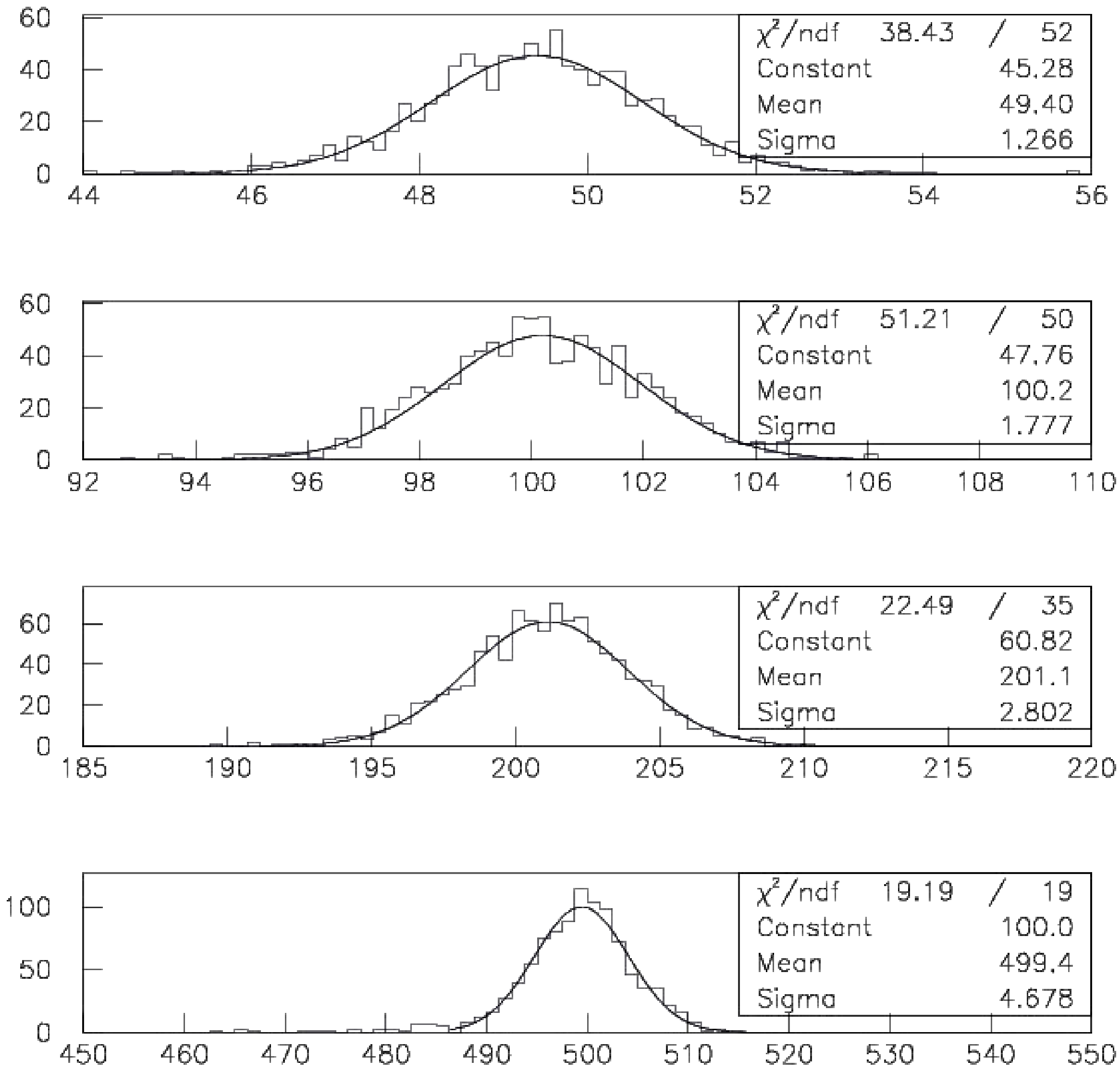


**Fraction of pads collected**



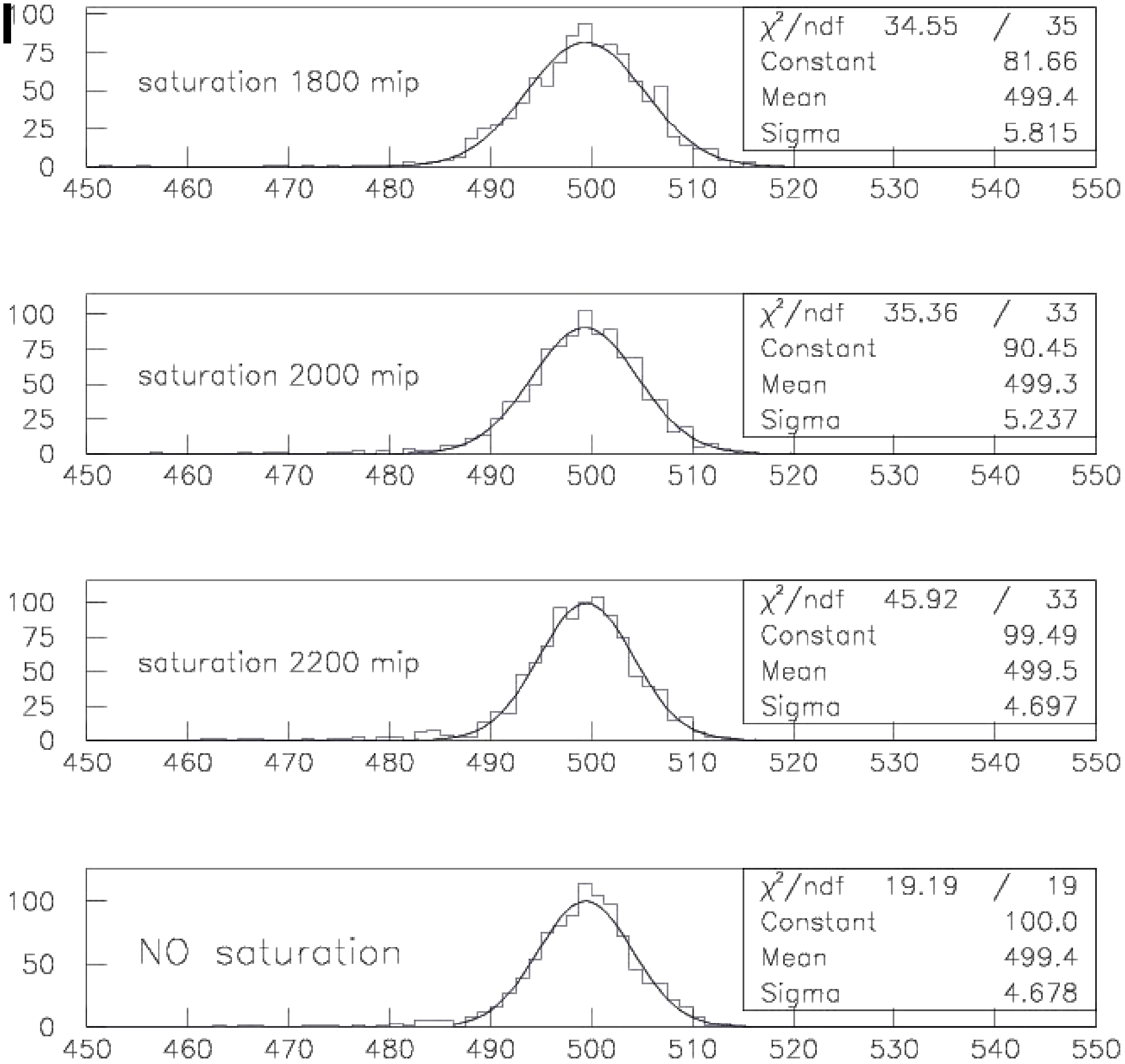
**Fraction of energy collected**

- Use deposited energy
- Correct for leakage using the average depth calculated shower per shower



## Saturate the signal

**Only electrons at 500 GeV are concerned**



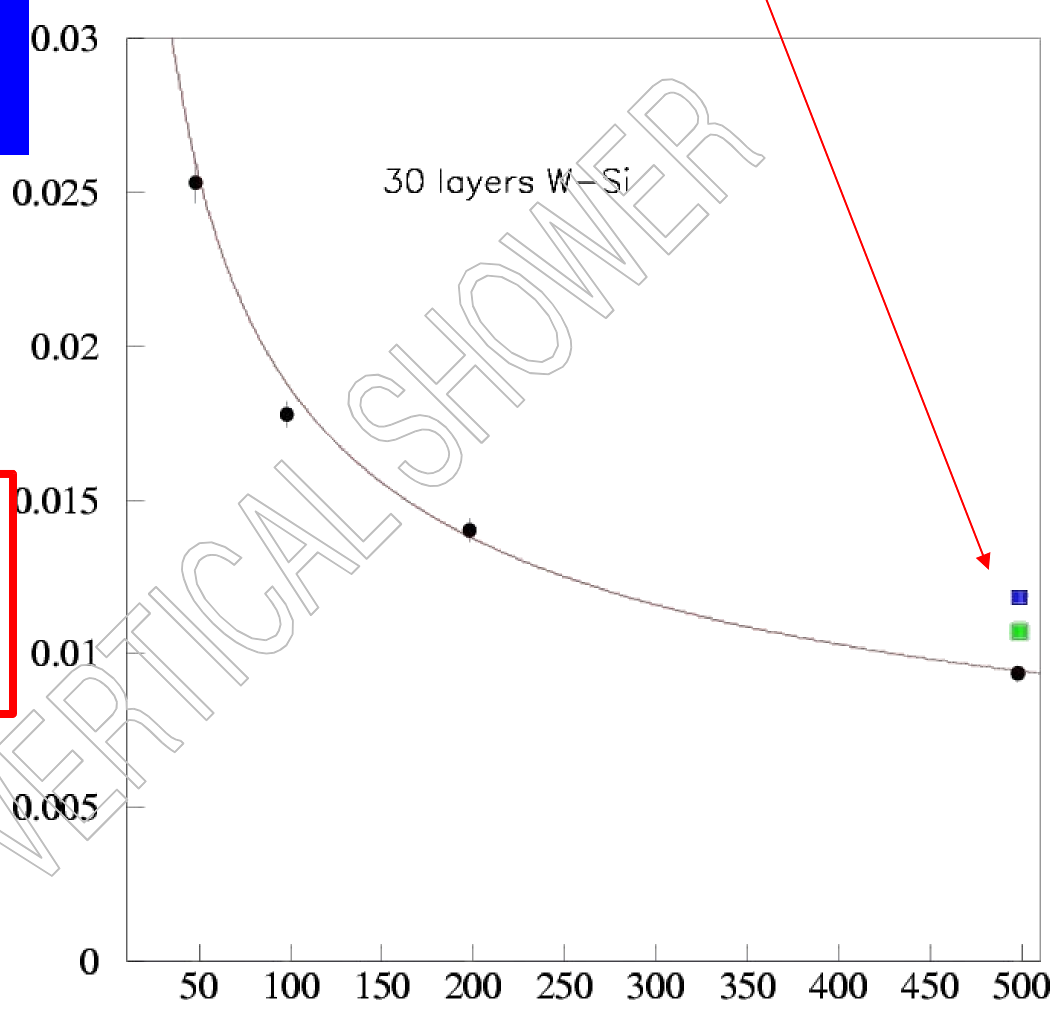
- **Stochastics term about 16.6% at 90 degrees**
- **the constant term related to leakage is very small**
- **the effect of the saturation could be very important !!!**

$$\frac{E}{E} = \frac{0.166}{\sqrt{E}} + 0.002$$

*WARNING VERTICAL shoot*

Only the part related to the leakage

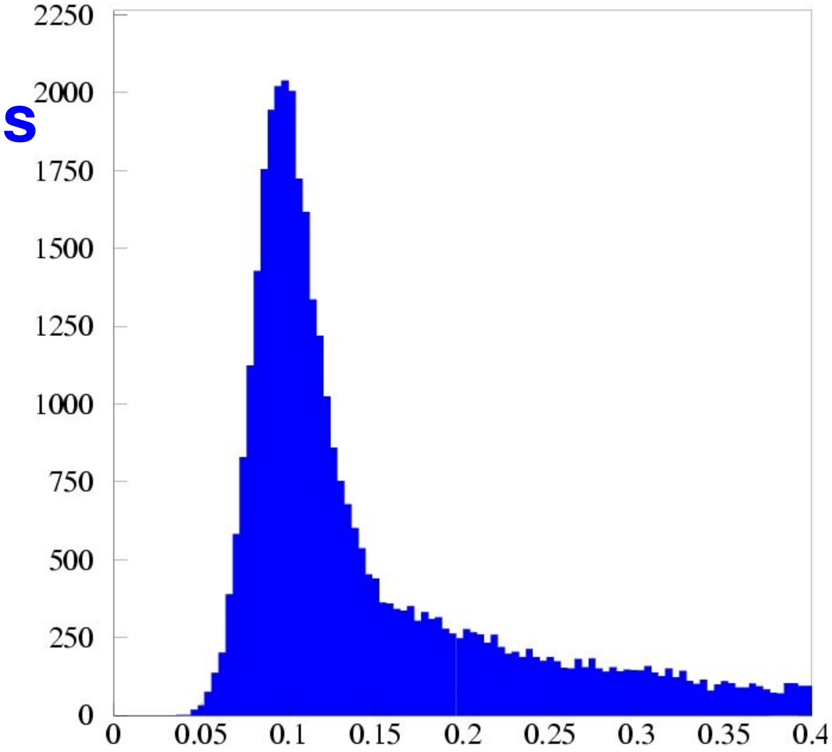
Max at 2500,
saturate@2000,
saturate@1800



# Which dynamics

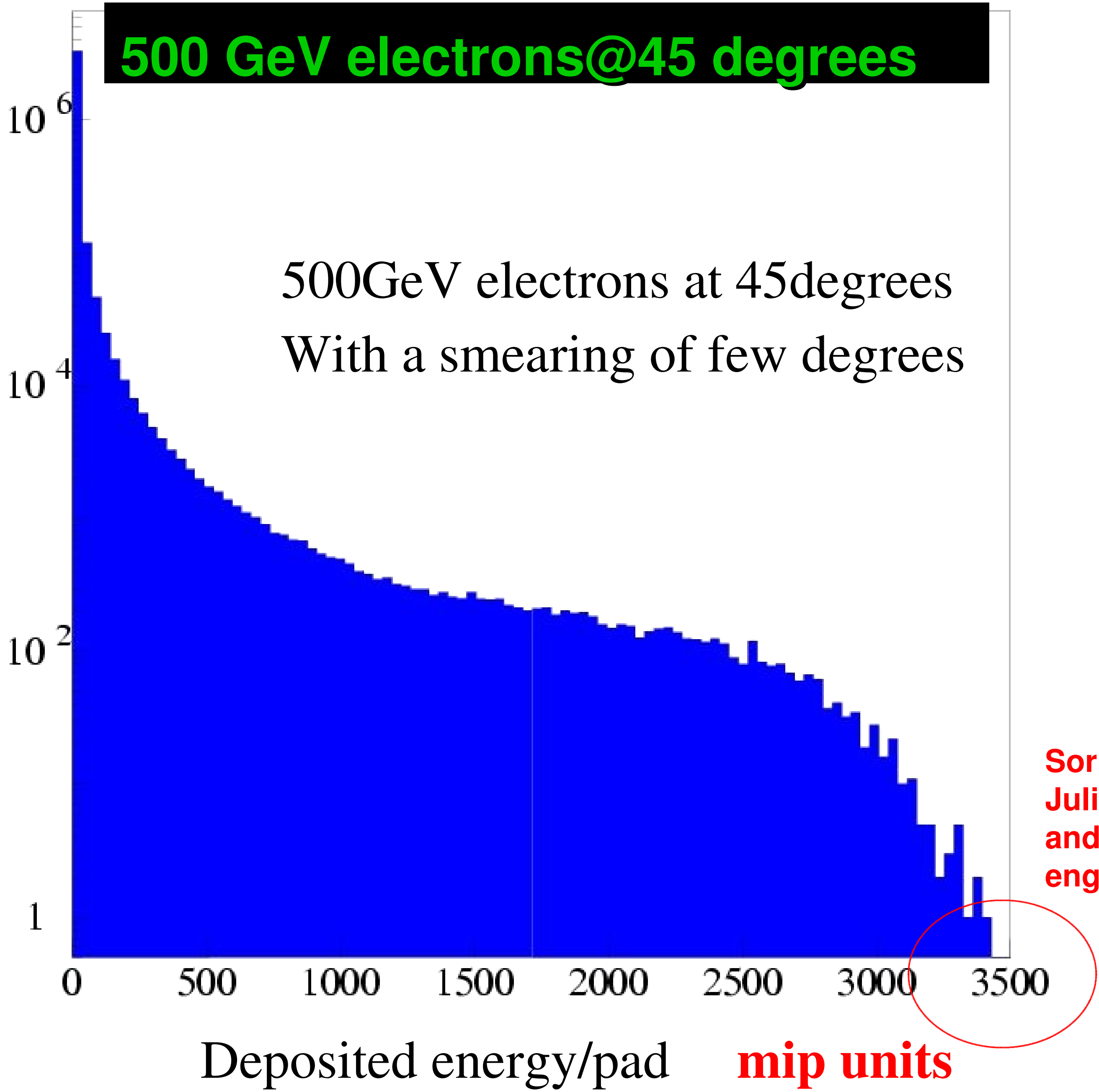
**Start from vertical muons**

Vertical muons define the “mip”



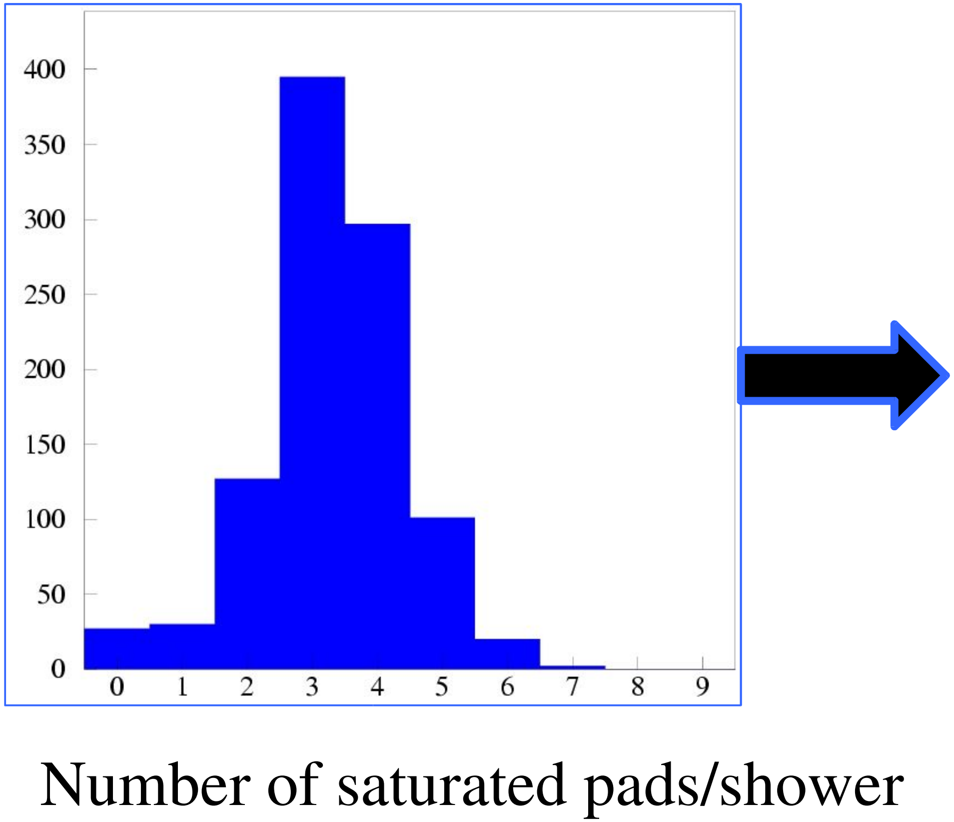
Deposited energy/pad KeV

# 500 GeV electrons@45 degrees

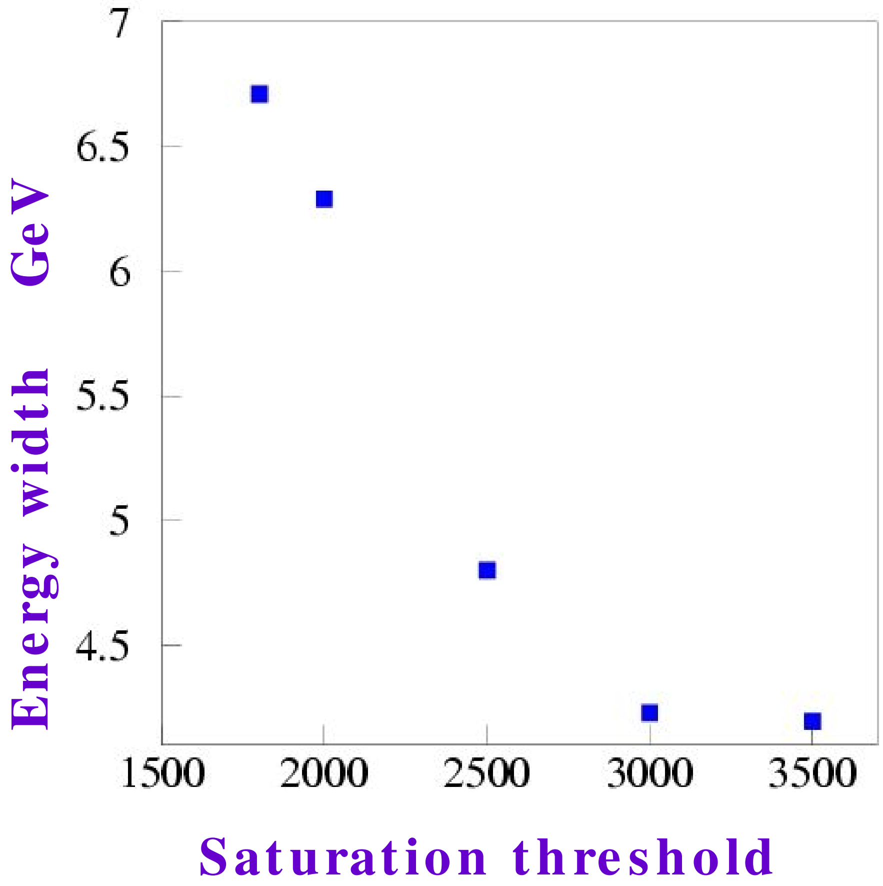


Sorry for
Julien and Christophe
and all electronics
engineers

# 500 GeV electrons@45 degrees



**Saturation@2000 mips**



- The energy resolution is STRONGLY dependent on the saturation, even if the number of saturated pads is **small**

The dynamics is weakly dependent on the pad size

by going from 5x5 to 3x3 gain about 1.5

by going from 5x5 to 1x1 $mm^2$ gain less than 3

We begin to know what we want to build and how
but still a lot to understand on the information provided
by these very granular calorimeters.

Henri Videau