Status report on ECAL

Marco Incagli – INFN Pisa

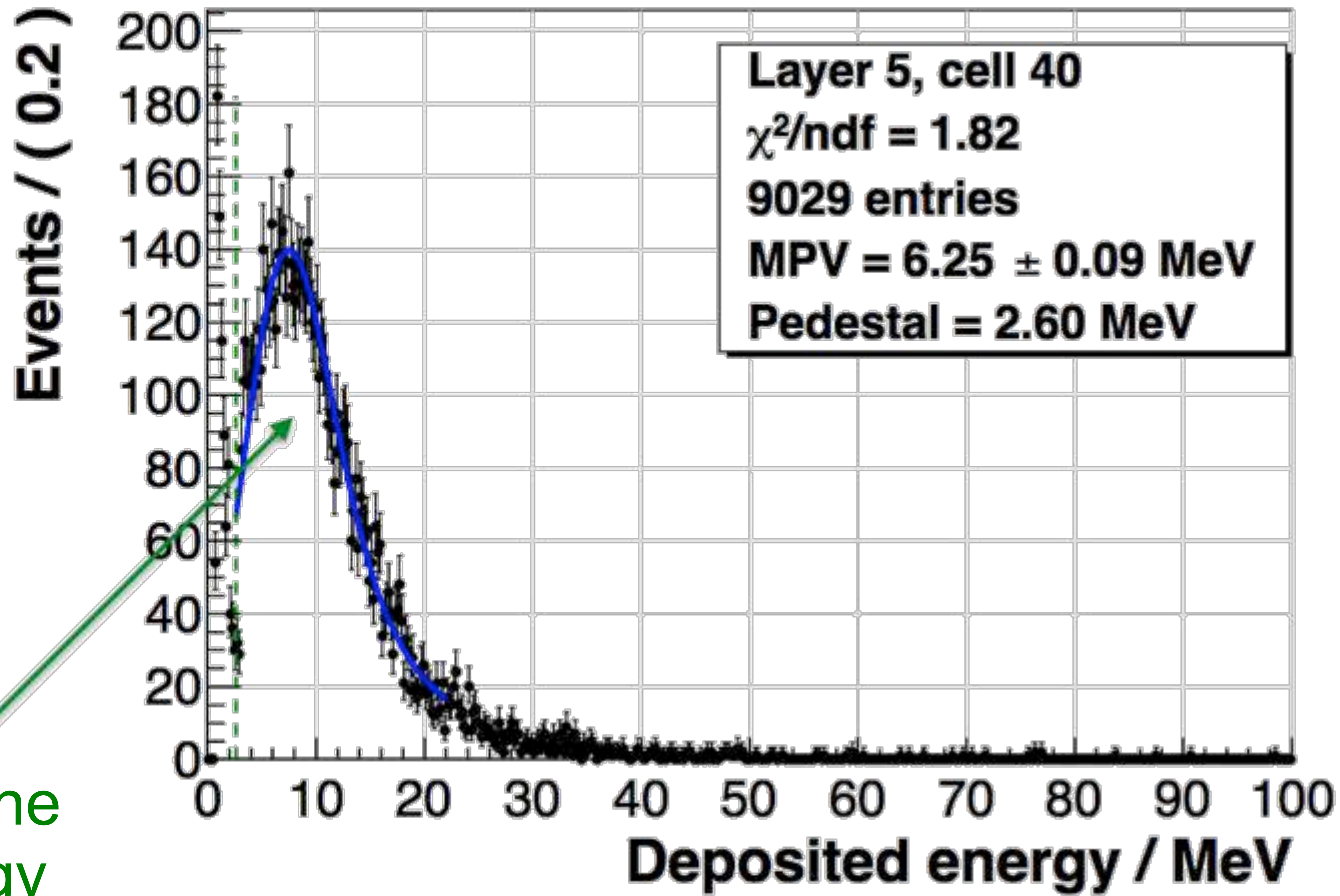
20 ott 2017 ECAL meeting

OUTLINE

- Review of ECAL equalization and calibration
  1. cell equalization
  2. anode correction
  3. dead cells/side leakage
  4. rear leakage / radiation length
  5. absolute energy scale
- Fiber saturation
- New reconstruction software
- Performance and comparison with old software

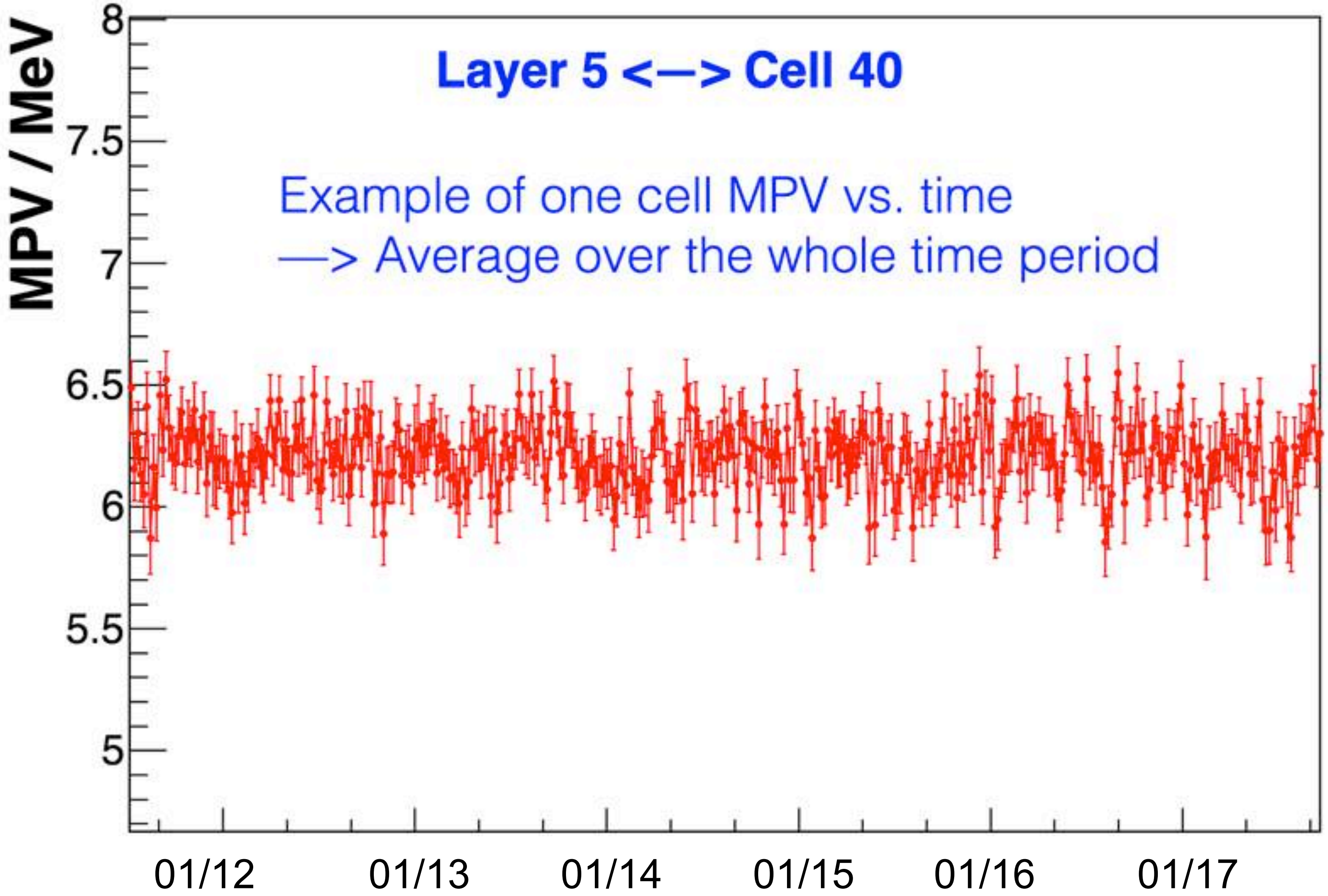
1. cell equalization with MIPs

MIP Energy Distribution

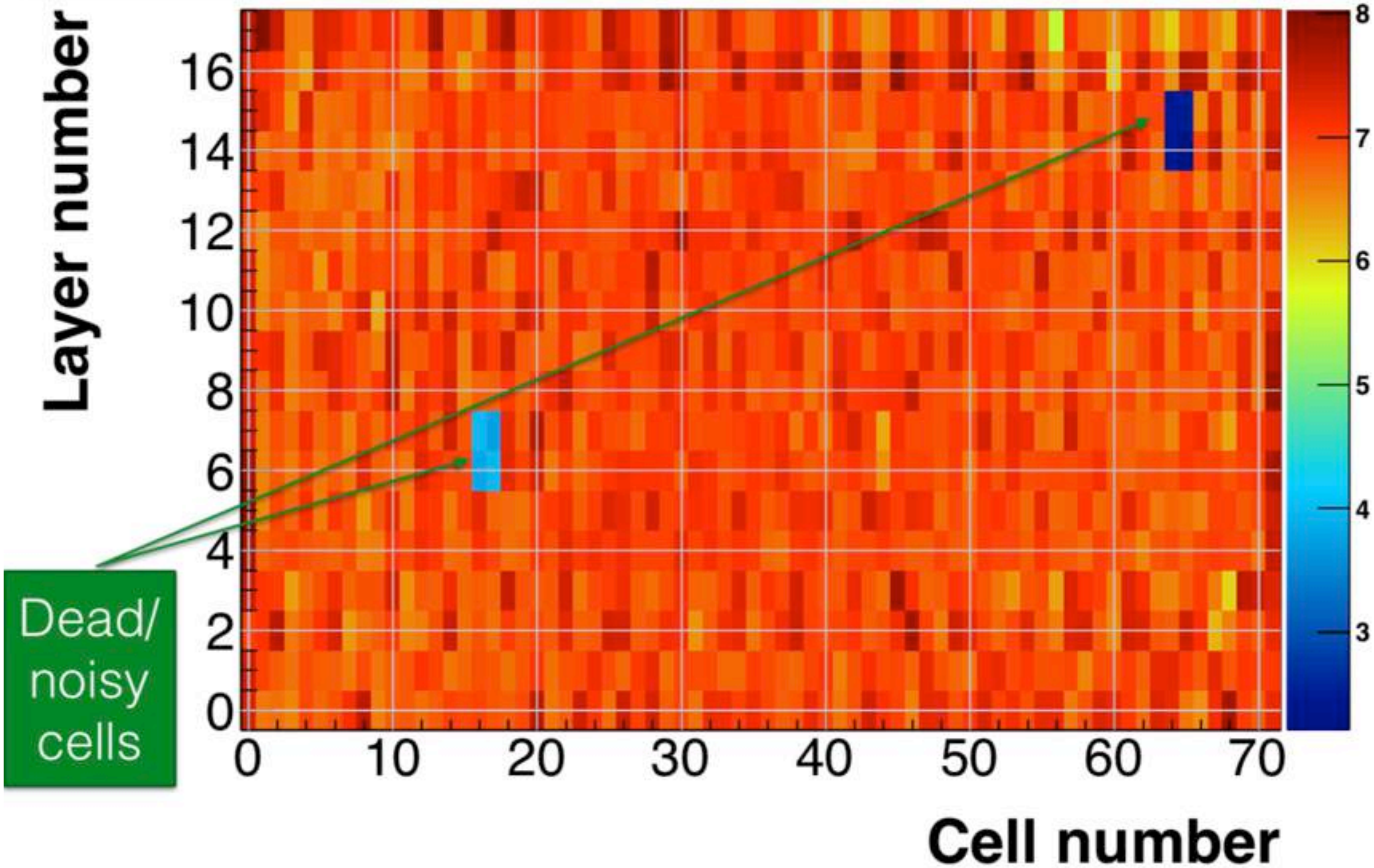


- Daily Fit of Landau-Gauss convolution to the proton deposited energy in each cell
- A dozen cells use Helium and are calibrate weekly

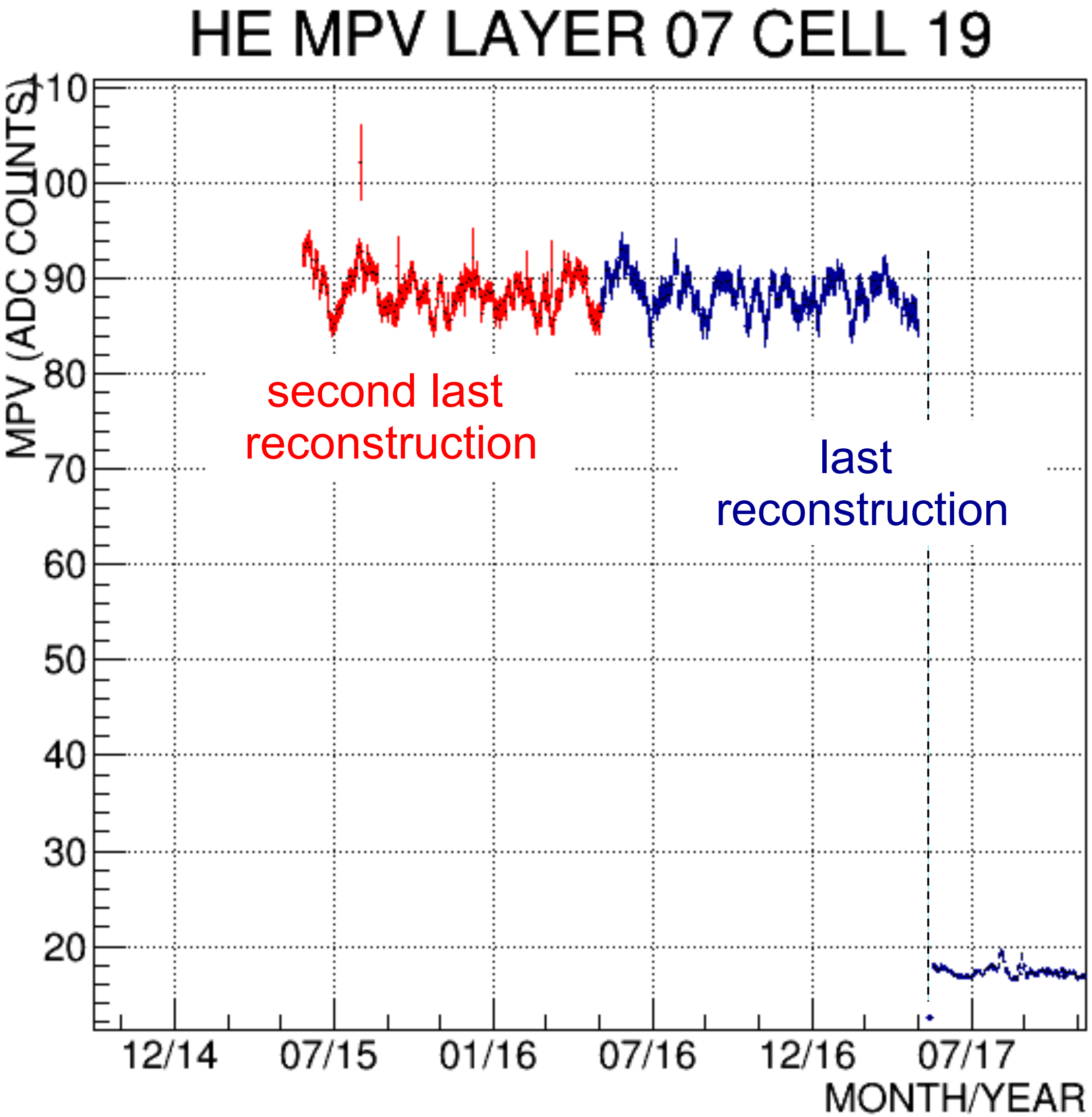
Long term stability



Daily equalization



—> All active cells are equalized!

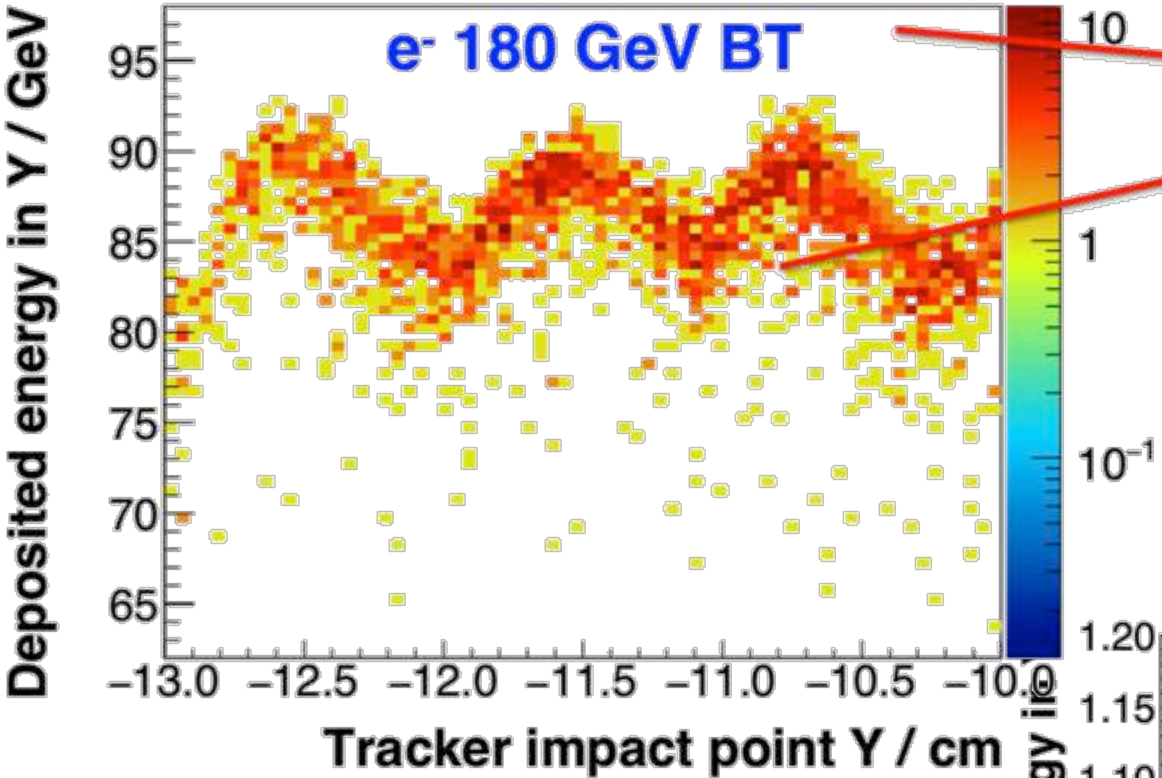


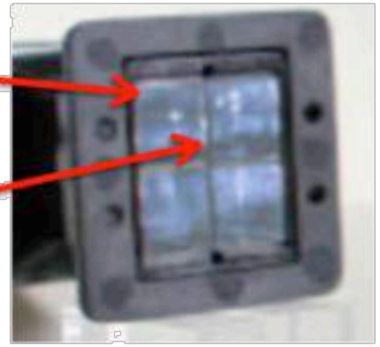
next reconstruction (mail from Choutko few days ago)

- Daily fitting still responsability of Pisa
- 2 PMTs with lower gain since July 2017
- Now equalized with Helium

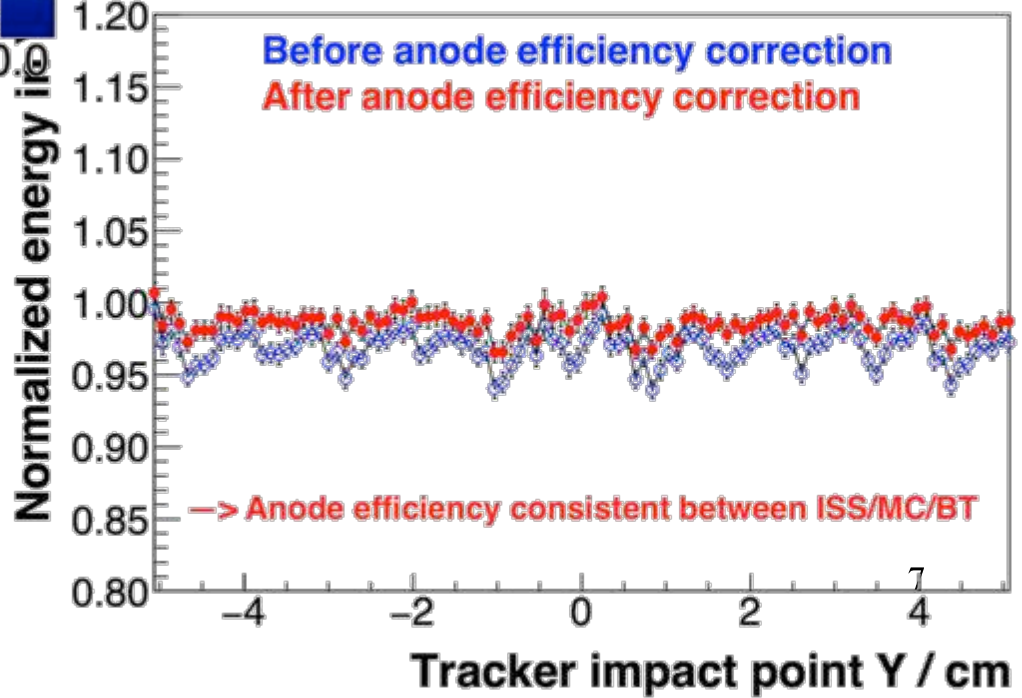
2. anode correction

Anode efficiency is non-uniform, decreases at cell borders.



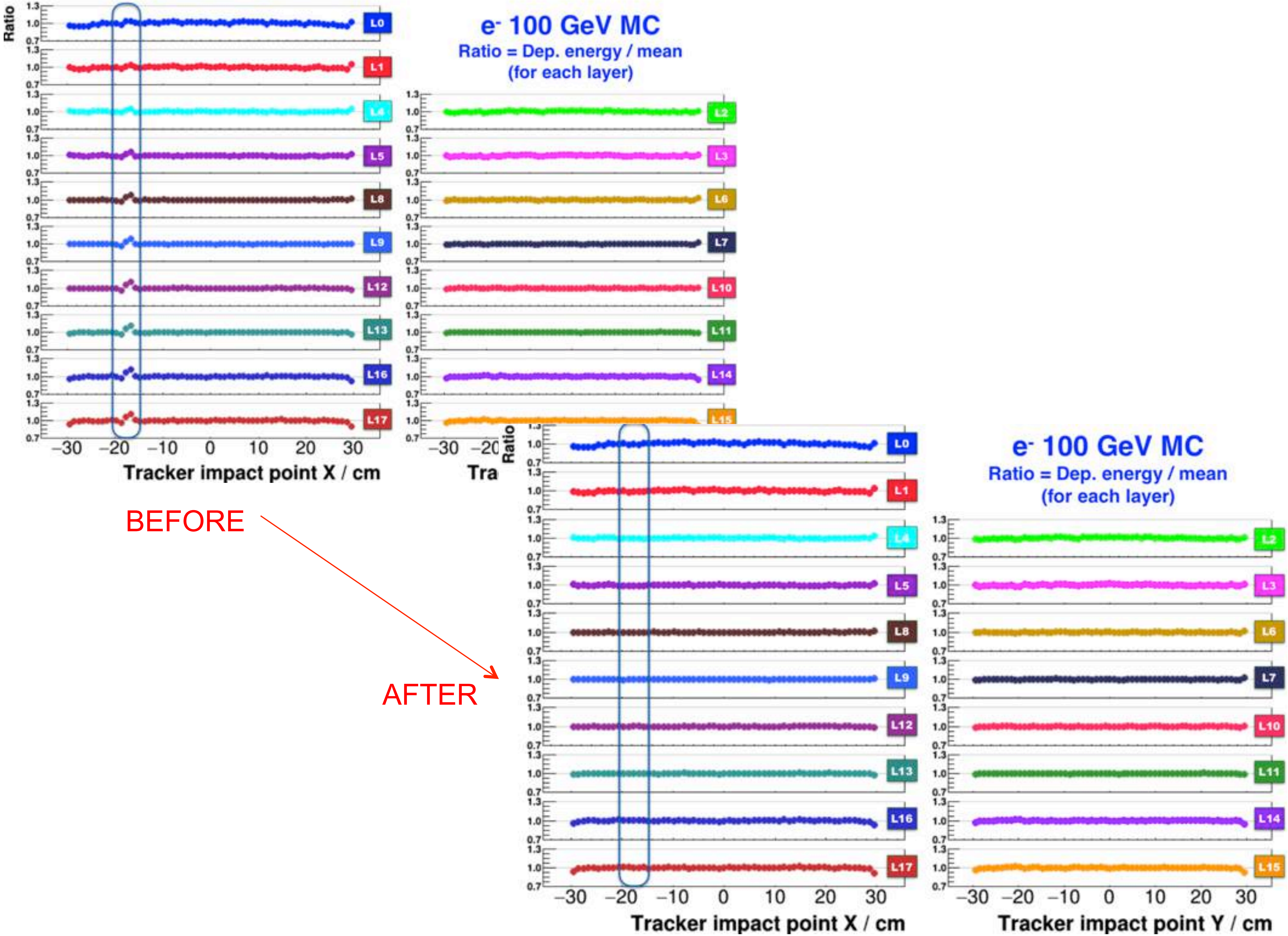


- correction tuned on TB data
- based on S13 ratio (energy deposited in highest cell over energy in highest + two adjacent cells)

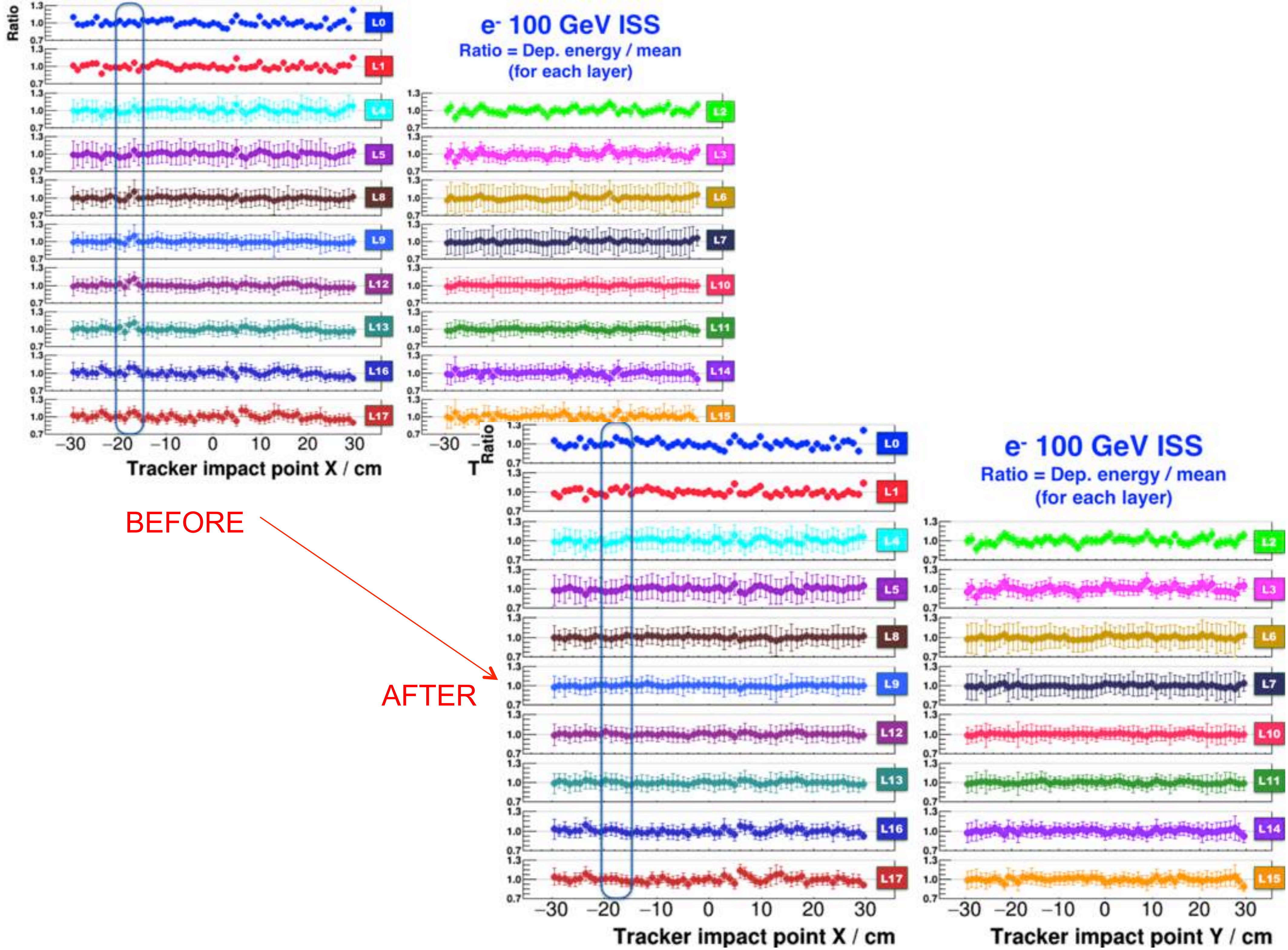


3. dead cell/lateral leakage

- In pass6 5 dead cells were not masked leading to wrong result in energy reconstruction and in ep rejection
- ~4% of the tracks went through these cells → ~10% deviation
- ZuahoLi developed a correction applied in pass7
- The same software also corrects for side leakage

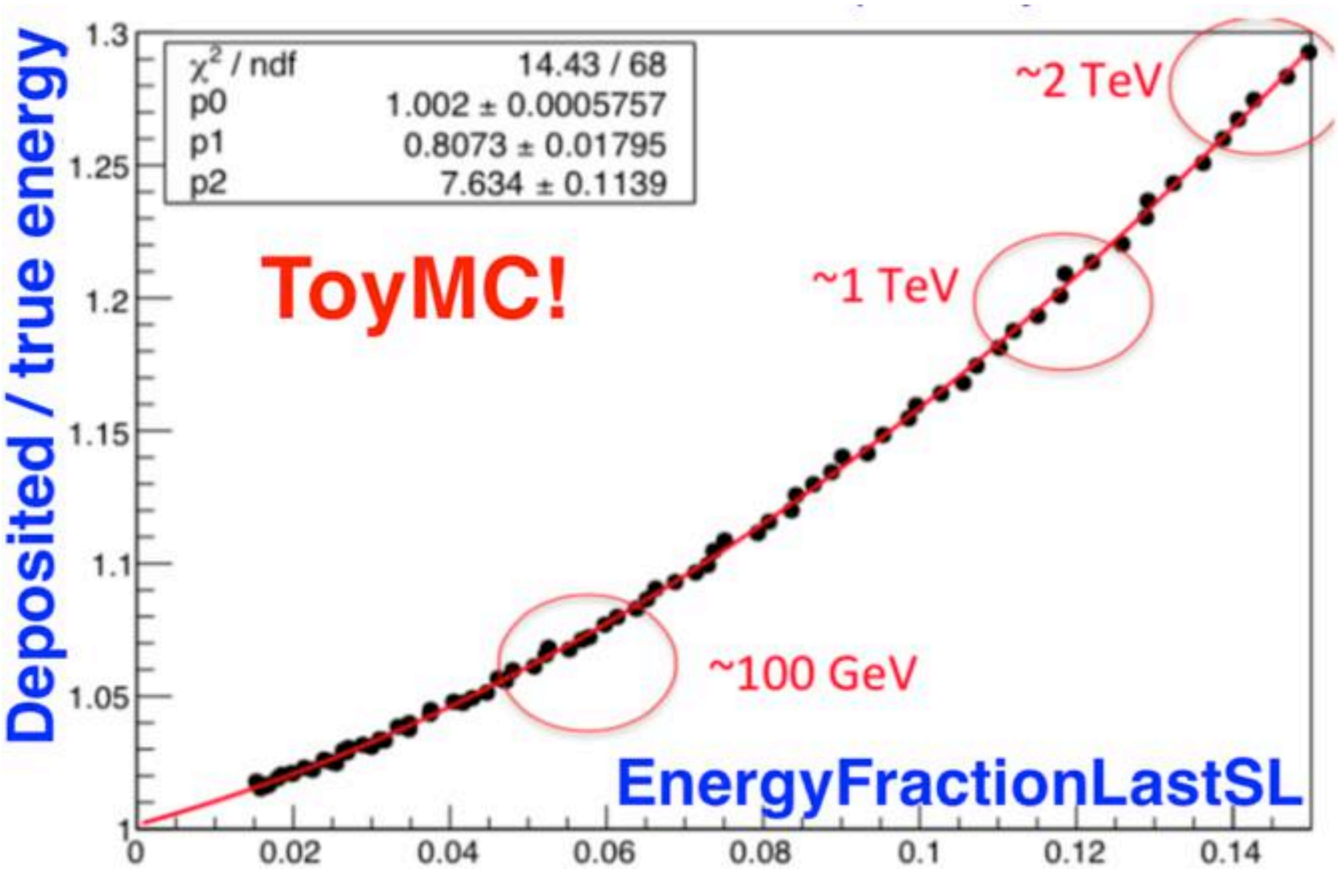


e- 100 GeV MC
Ratio = Dep. energy / mean
(for each layer)
Ratio
L0
L1
L2
L3
L4
L5
L6
L7
L8
L9
L10
L11
L12
L13
L14
L15
L16
L17
Tracker impact point X / cm
BEFORE
AFTER
e- 100 GeV MC
Ratio = Dep. energy / mean
(for each layer)
Tracker impact point X / cm
Tracker impact point Y / cm


e- 100 GeV ISS
Ratio = Dep. energy / mean
(for each layer)
Ratio
L0 L1 L4 L5 L8 L9 L12 L13 L16 L17
L2 L3 L6 L7 L10 L11 L14 L15
Tracker impact point X / cm
Tracker impact point Y / cm
BEFORE
AFTER

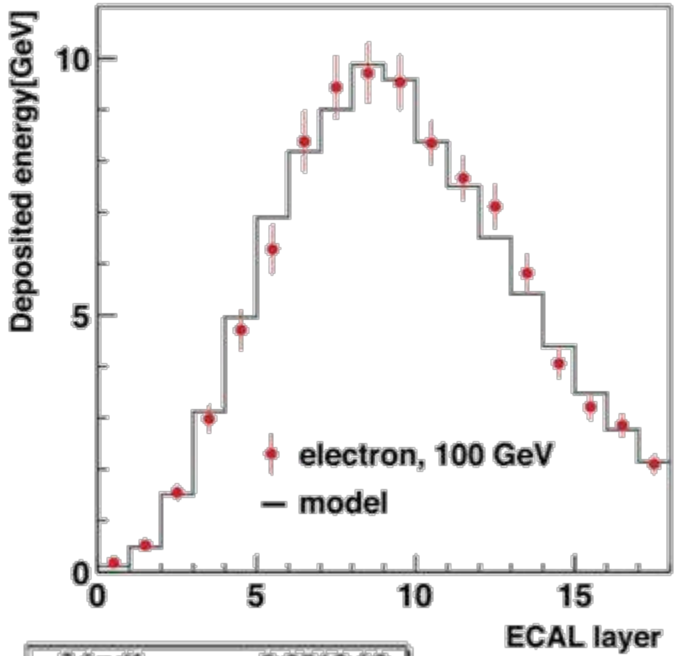
4. rear leakage

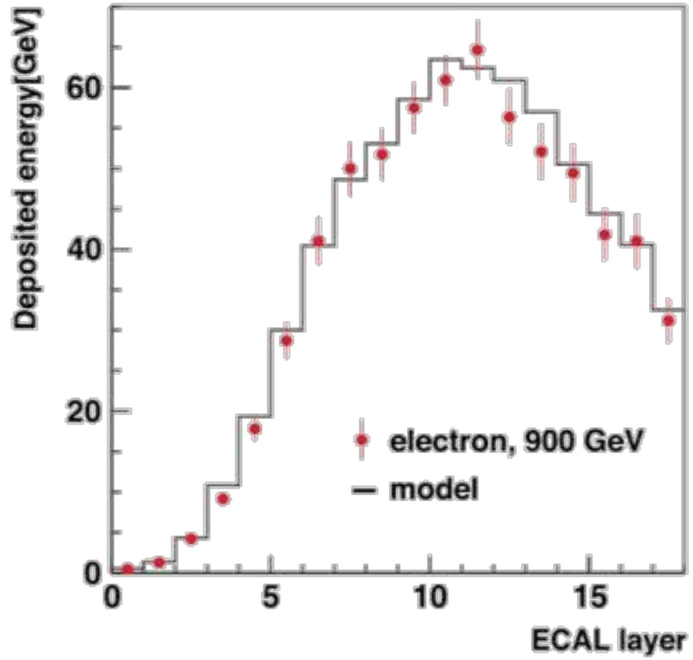
- The rear leakage is corrected based on the fractional energy deposited in last two layers (~last two X0)

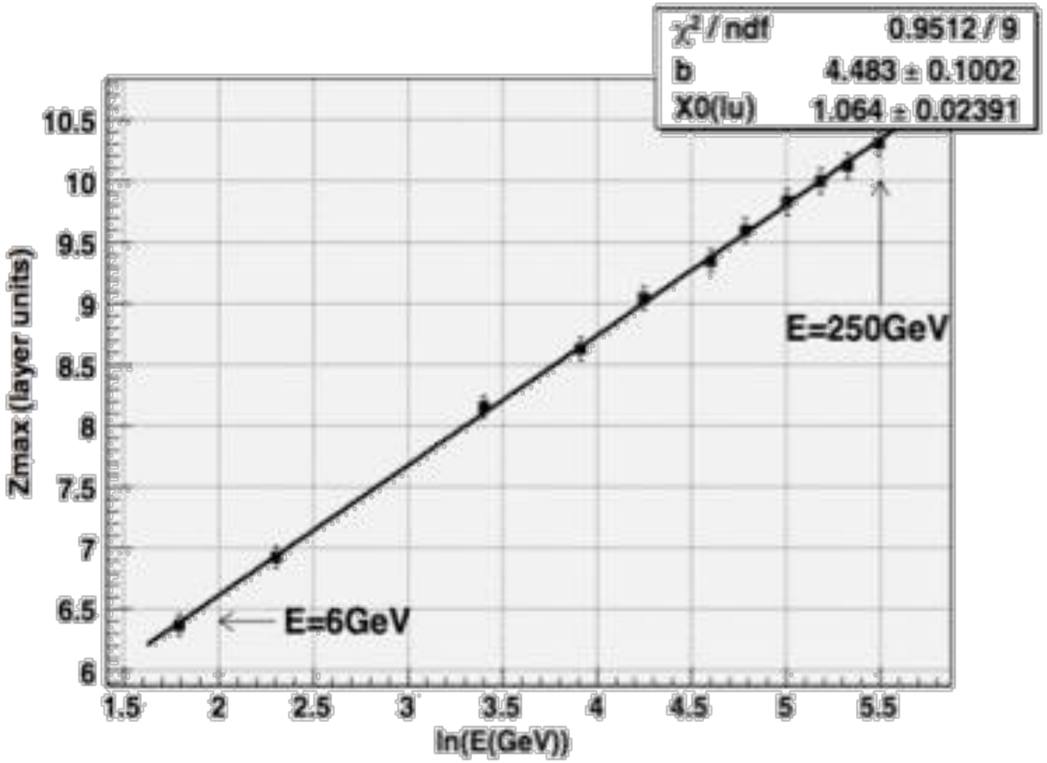


4. rear leakage and Radiation Length

- Shower longitudinal development for electrons/positrons with different energies







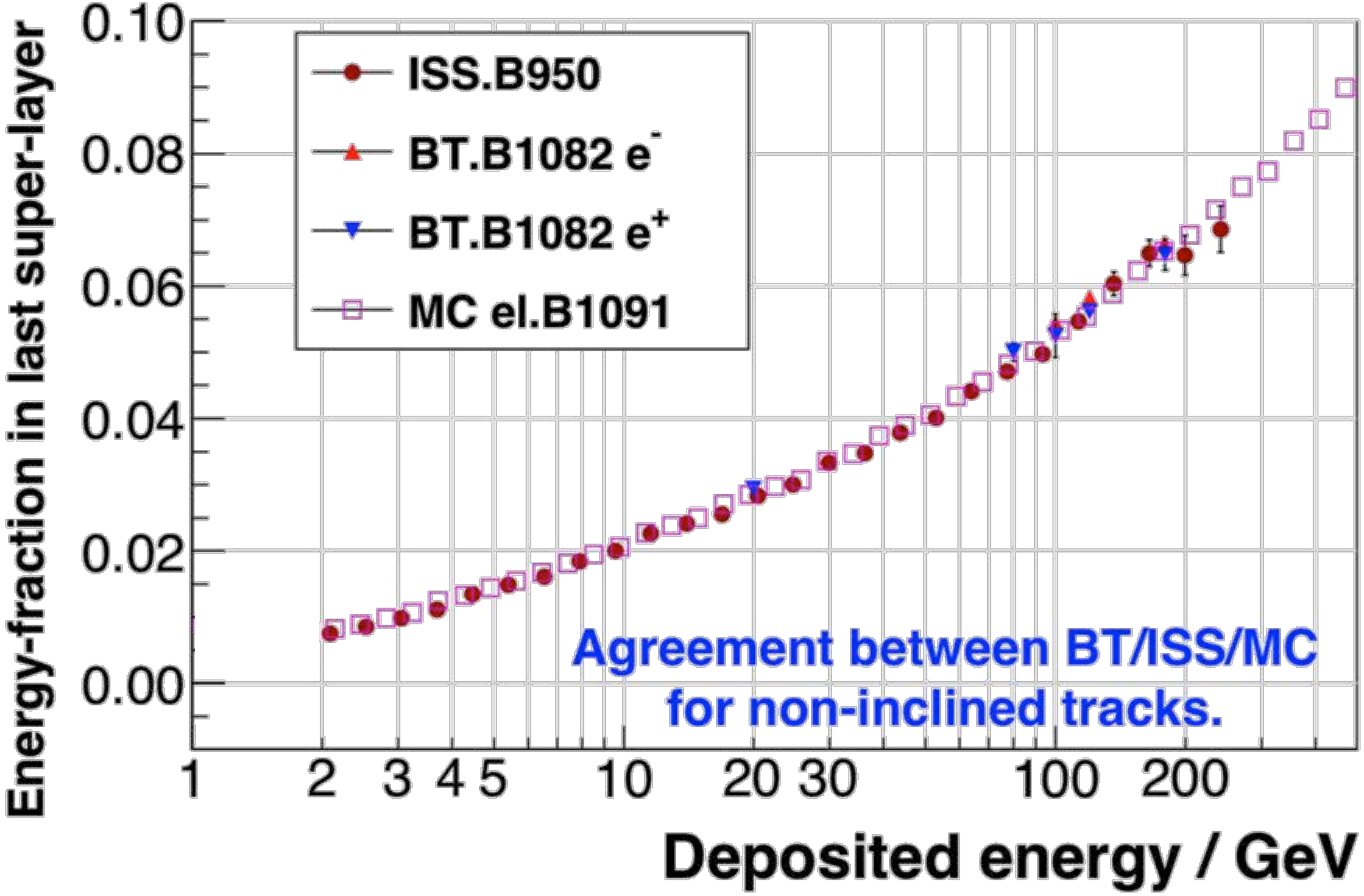
Longitudinal shape parametrized by Rossi function.

X_0 = 0.98 ± 0.02 cm

Total thickness ~ 17 X_0

Energy containment:
~ 80% for 900GeV electrons.

4. rear leakage



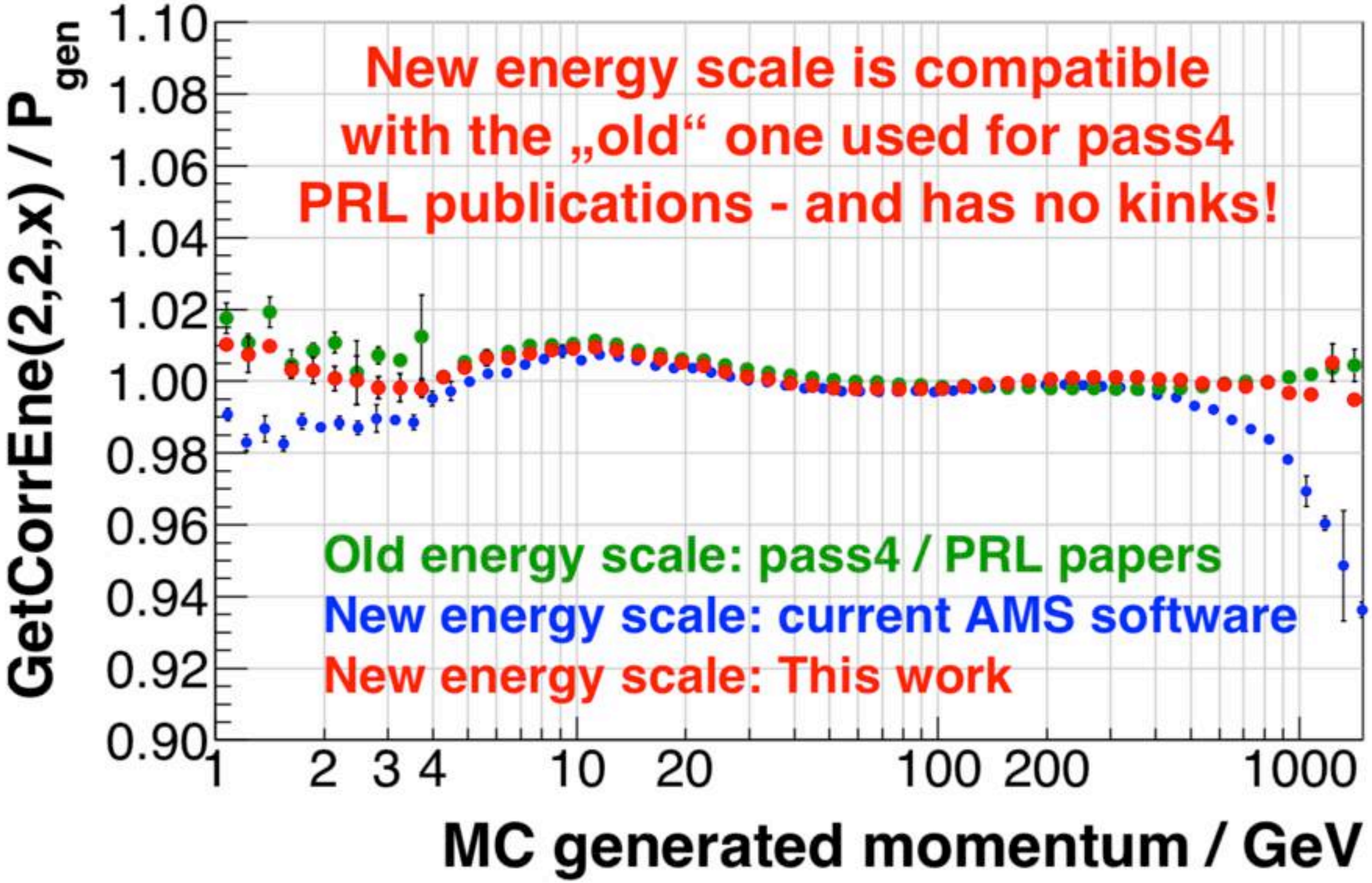
5. absolute energy scale

- enegy scale determined at test beam 2010, after correcting for top-of-the-instrument and rear-leakage, in the energy range 20-250 GeV
- the quadratic form used to correct test beam has been extended to higher and lower energies with MC

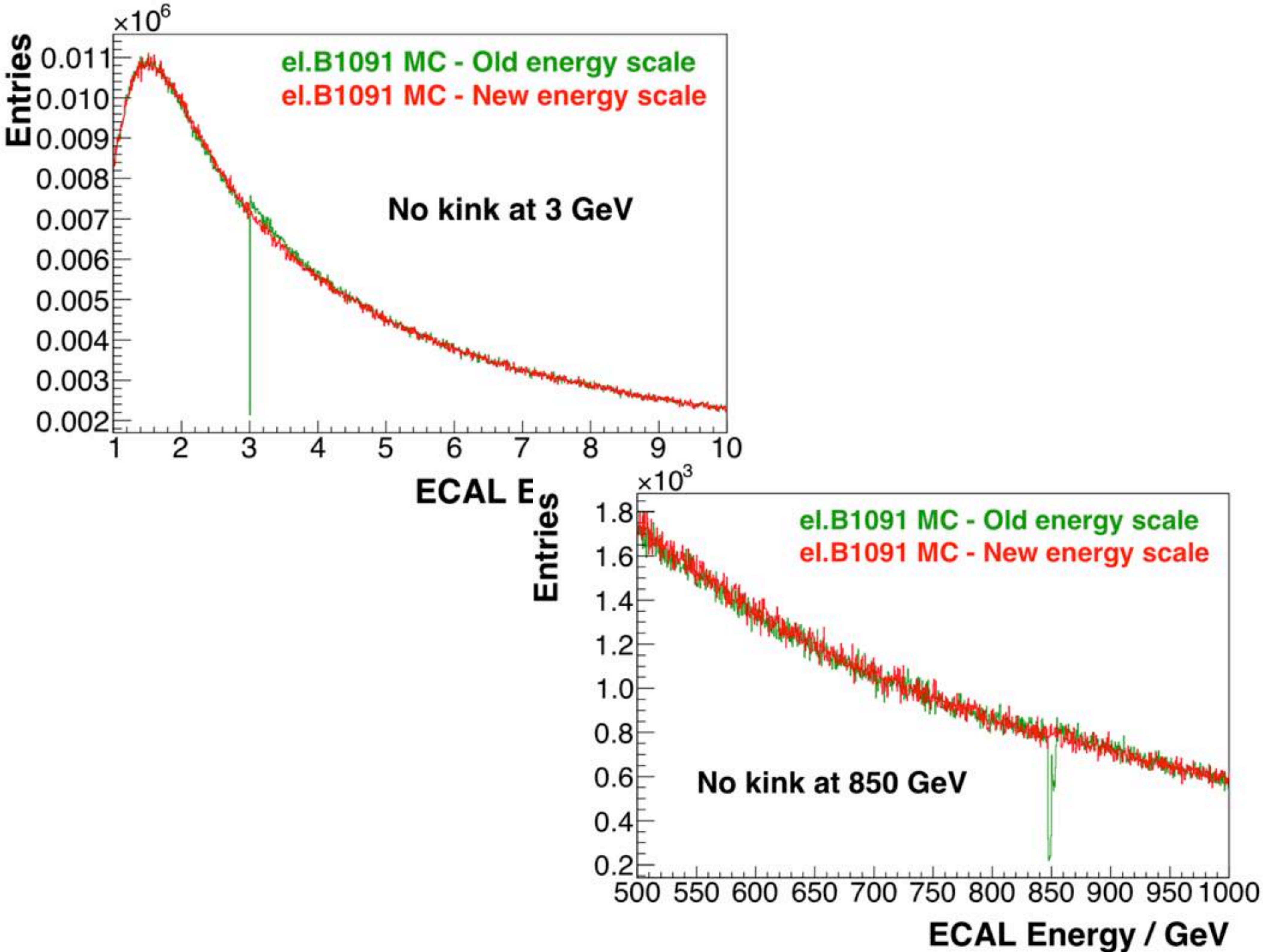
$$E_{\mathrm{true}} = E_{\mathrm{dep}}(\underbrace{\alpha(E_1)}_{= f_{\mathrm{corr}}(x)} + \beta(E_1) f_{L2} + \gamma(E_1) f_{L2}^2)$$

$$f_{\mathrm{corr}}(x) = \begin{cases} 1/(p_0 + \frac{p_1}{x} + \frac{p_2}{x^2} + p_3 x^{p_4}) & x \leq x_{\mathrm{low}} \\ 1/(p_5 + p_6 x + p_7 x^2 + p_8 x^3 + \underline{p_9 x^4})_{\text{New}} & \end{cases}$$

GetCorrectedEnergy(2,2,X) (X=0 PASS4, X=1 PASS6>)

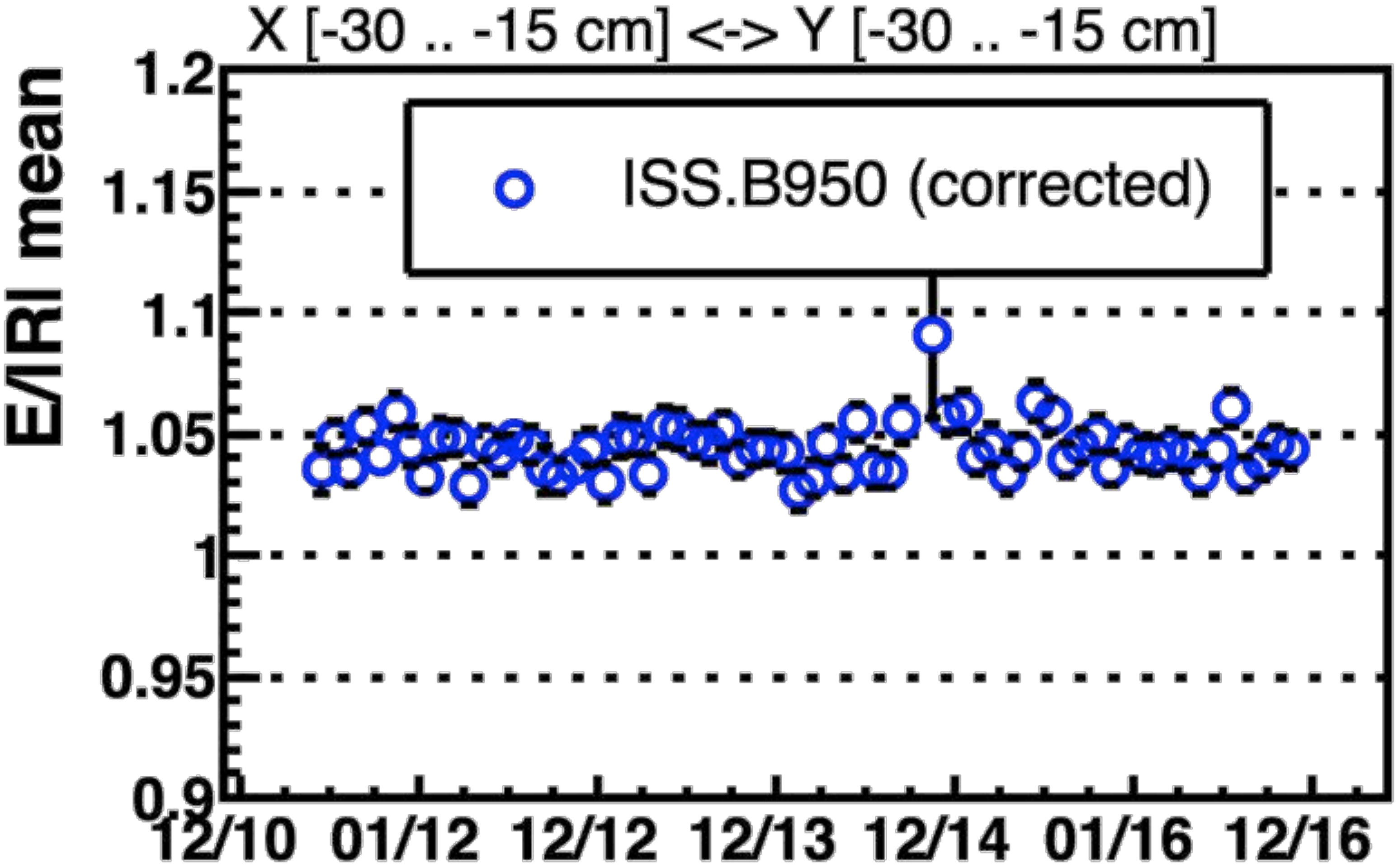


- GetCorrectedEnergy(2,2,0)
- GetCorrectedEnergy(2,2,1)
- ElectronEnergy2017()


×10^6
Entries
0.011
0.010
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
el.B1091 MC - Old energy scale
el.B1091 MC - New energy scale
No kink at 3 GeV
1
2
3
4
5
6
7
8
9
10
ECAL E
×10^3
Entries
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
el.B1091 MC - Old energy scale
el.B1091 MC - New energy scale
No kink at 850 GeV
500
550
600
650
700
750
800
850
900
950
1000
ECAL Energy / GeV

Stability of energy calibration vs time

- Energy calibration monitored with E/p ratio



Plot done by Niko; similar results found by Maura and Marta

The saturation effect
and
the 3D reconstruction

November 2016

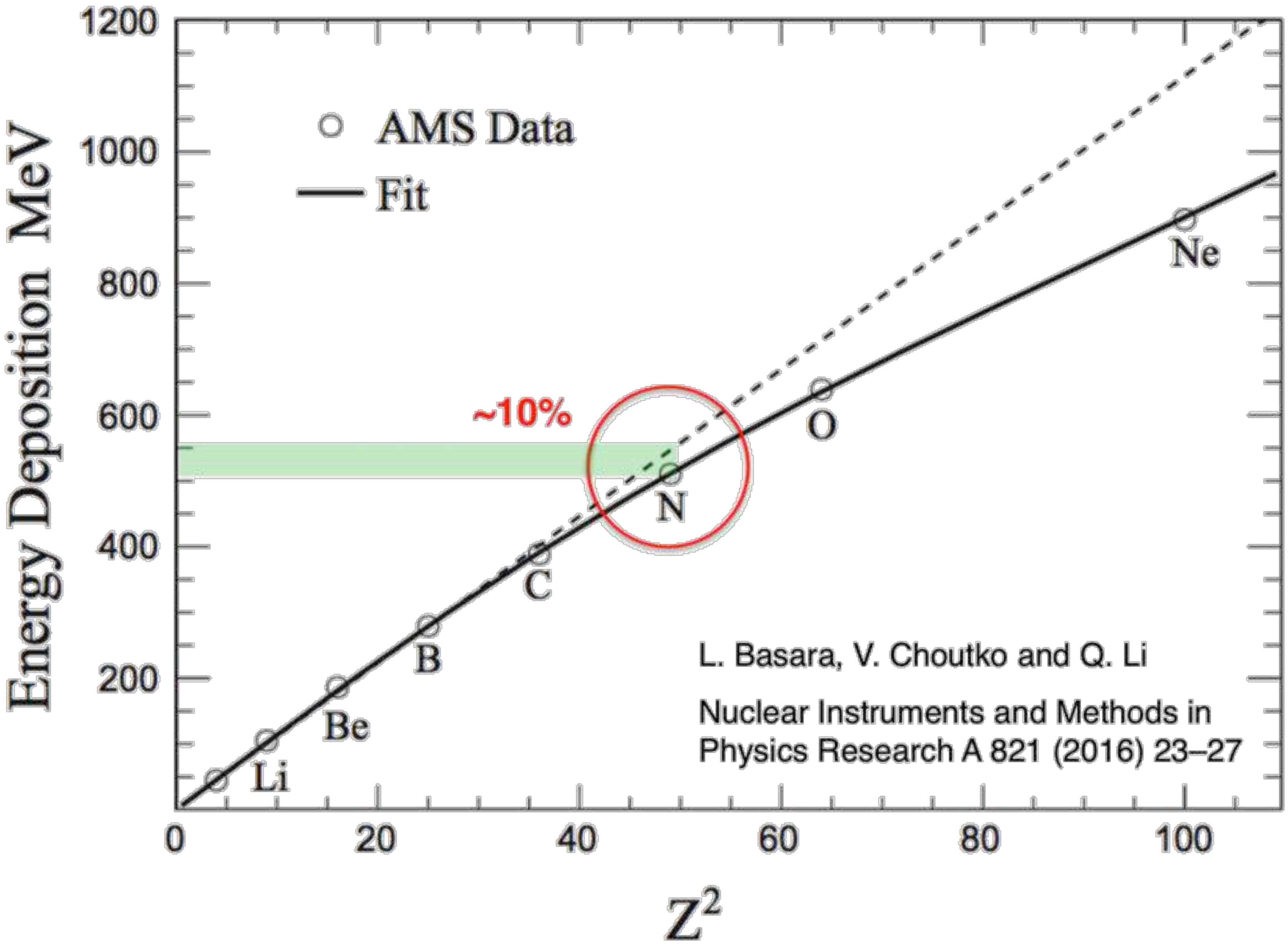
MIT group

The saturation effect

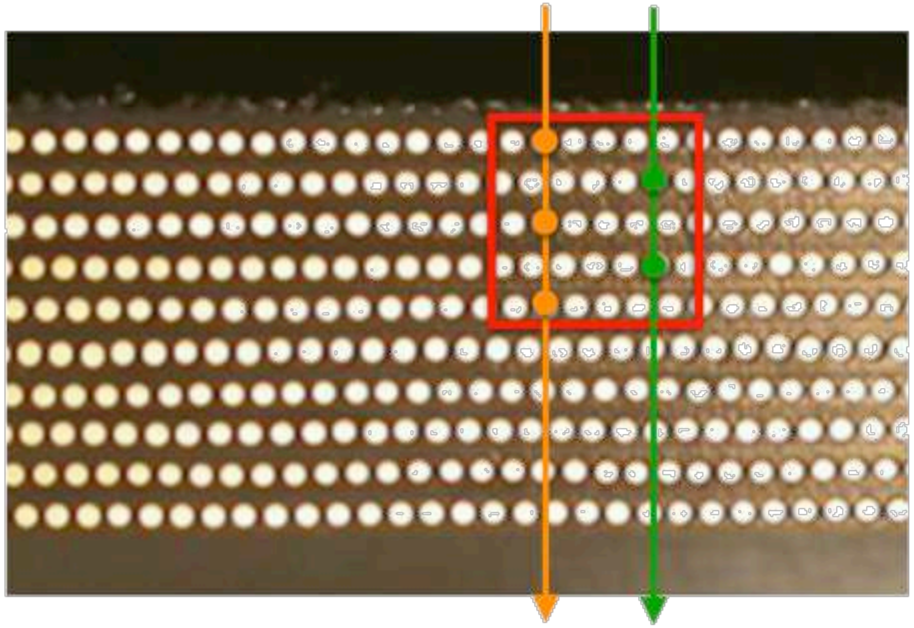
- In November 2016, and following months, the MIT group shows an effect which is compatible with fiber saturation in em showers core

Birks law observed by nuclei ionization

The saturation effects is sizable at 550 MeV/cell



Connection between Nuclei dE/dx and electromagnetic shower

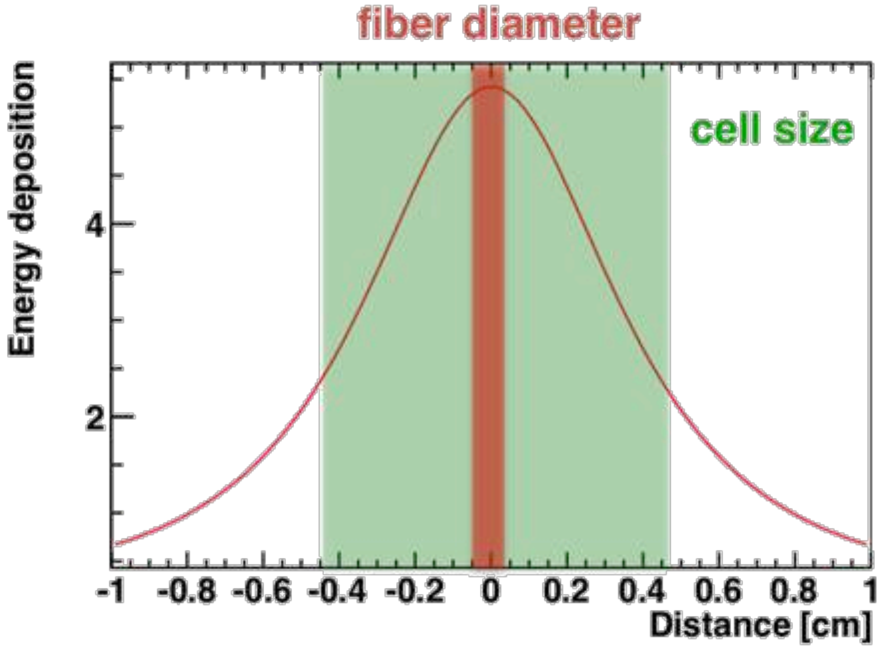


The number of fibers passed by the nuclei depends on the impact position and incident angle.

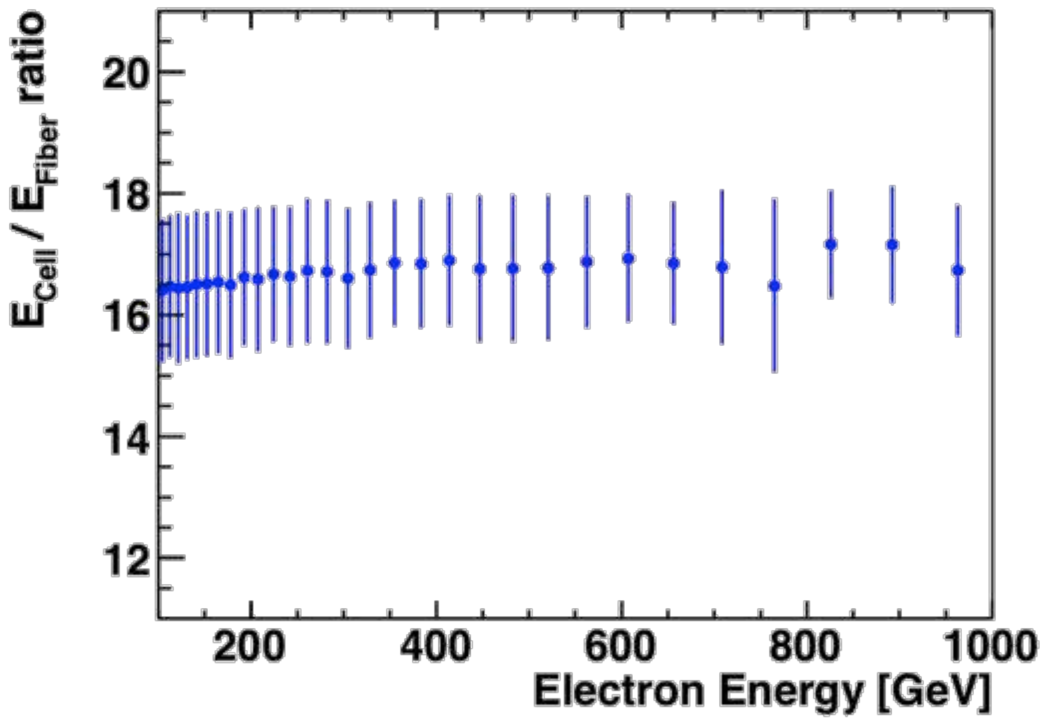
~3 fibers on average for nuclei

The saturation is ~10% at 0.18 GeV / Fiber for the ionization energy loss

Connection between Nuclei dE/dx and electromagnetic shower



Lateral shape near the shower maximum



All 35 fibers of the cell are illuminated by the shower

The peak fiber shares ~1/17 of the energy in the maximum cell.

Because the shower is more spread along the fiber than the ionization, the saturation should happen at higher energy deposition than the ionization, by a factor of *N* (5 to 10)

The saturation is expected to be ~10% for ~20 GeV/Cell

The saturation effect

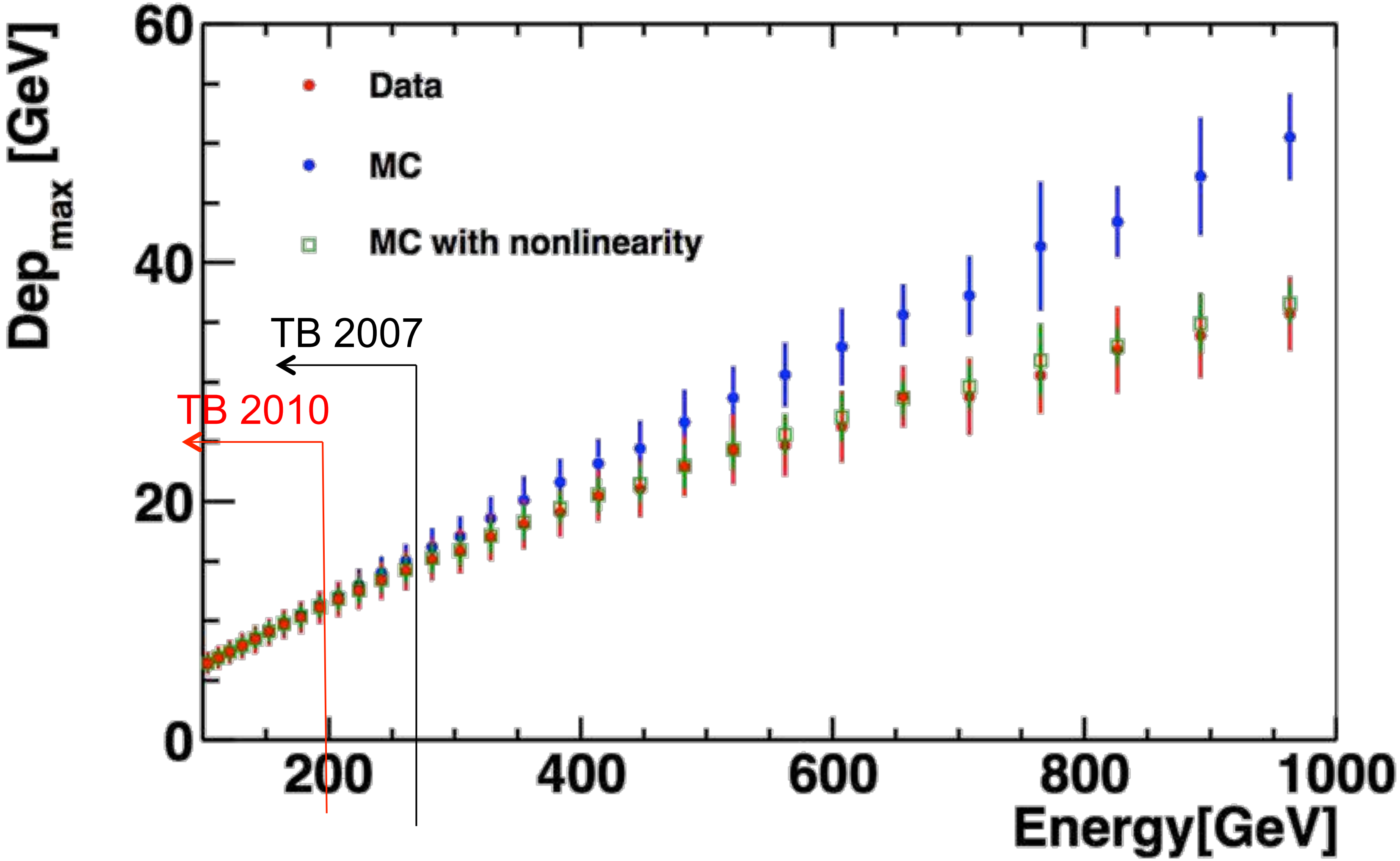
- This effect is not expected in fiber based calorimeters
- Comment from Wigmans:

I have a hard time imagining how such effects [=nuclear ionization] could play a role in em showers, which deposit almost all their energy through minimum ionizing particles. When a mip crosses a 1 mm fiber, it deposits typically of the order of 0.2 MeV. This means that more than 1000 shower particles would have to cross the fiber AT THE SAME SPOT in order to get a 200 MeV energy deposit, comparable to the dE/dx values typical for a few-MeV recoil proton. I don't think that that these conditions would occur for TeV showers in your ECAL.

- The effect that it's not expected does not mean that it's not there!

Saturation effect

- Saturation effect when the energy deposited in a single cell is larger than ~20 GeV
- Dep_{max} = maximum energy deposited in cell



The 3D reconstruction

- The MIT group started the project of the 3D shower reconstruction in ~2012
- The method is based on a very accurate parametrization of the shower development based on standard formulas, and relying heavily on MC
- The breakthrough was the inclusion in MC of the saturation effect
- Note that EnergyE(,A,C) use MC to extrapolate the rear leakage correction to high energies, thus saturation is a 2nd order effect
- BUT MC can be used efficiently for ep separation at high energies → BDT or other classifiers

Nuclear Inst. and Methods in Physics Research, A 869 (2017) 110–117

Contents lists available at ScienceDirect

Nuclear Inst. and Methods in Physics Research, A

journal homepage: www.elsevier.com/locate/nima

Precision measurement of 0.5 GeV–3 TeV electrons and positrons using the AMS Electromagnetic Calorimeter

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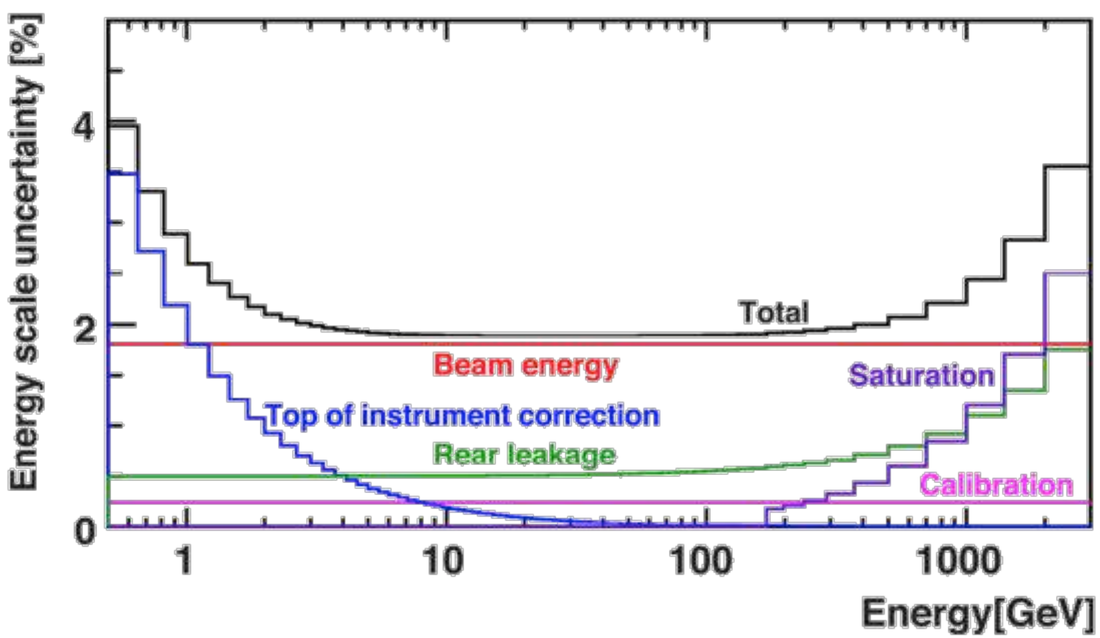
[a] Massachusetts Institute of Technology (MIT), Cambridge, MA 02139, USA

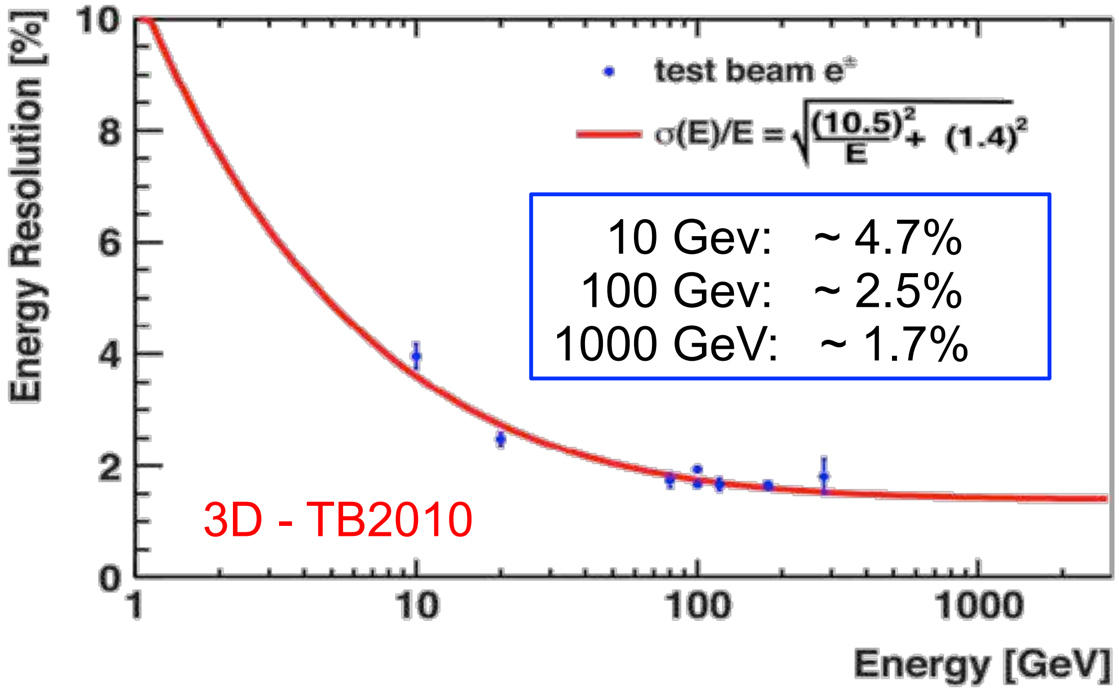
[b] Institute of High Energy Physics (IHEP), Chinese Academy of Sciences, Beijing 100039, China

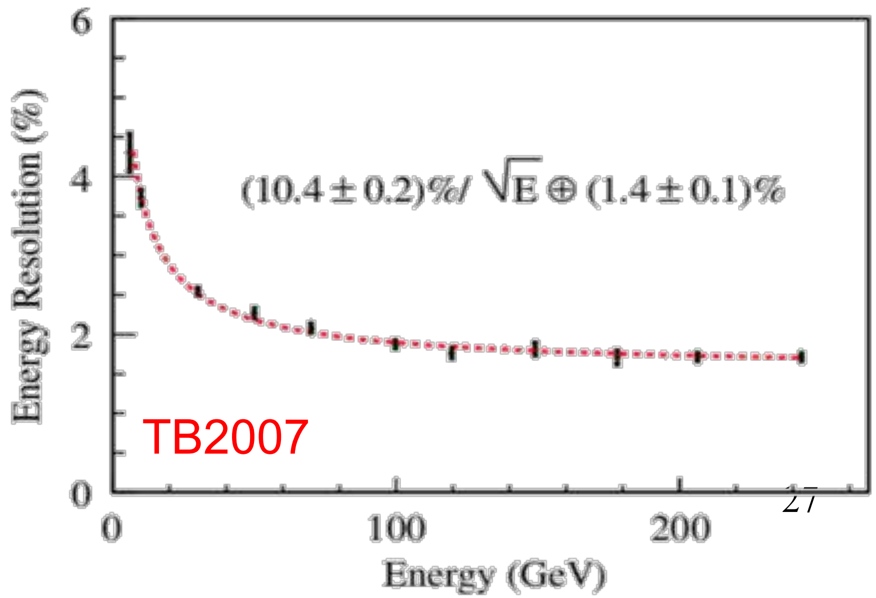
- In the next slides the resolution of the new method is reported and compared with the one of the "classic" one

Energy Scale and Resolution



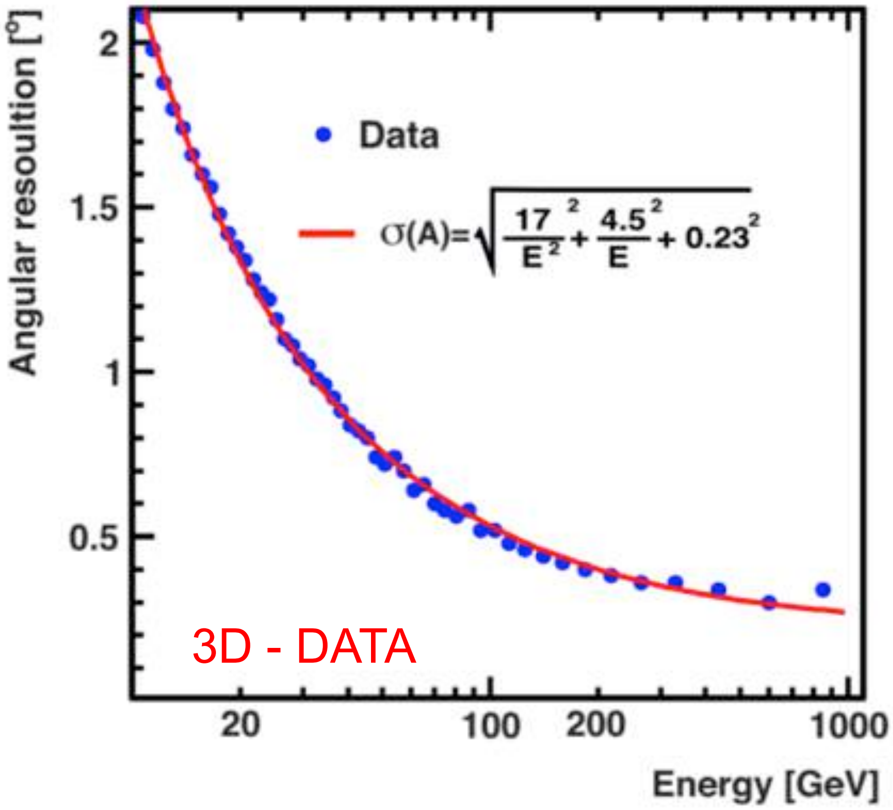
- The energy scale uncertainty is dominated, for most of the spectrum, by the *transfer of the Test Beam energy scale to orbit using the E/p (energy/ momentum) ratio*
- At high energies, the *rear leakage* and the *effects due to signal saturation* become dominant

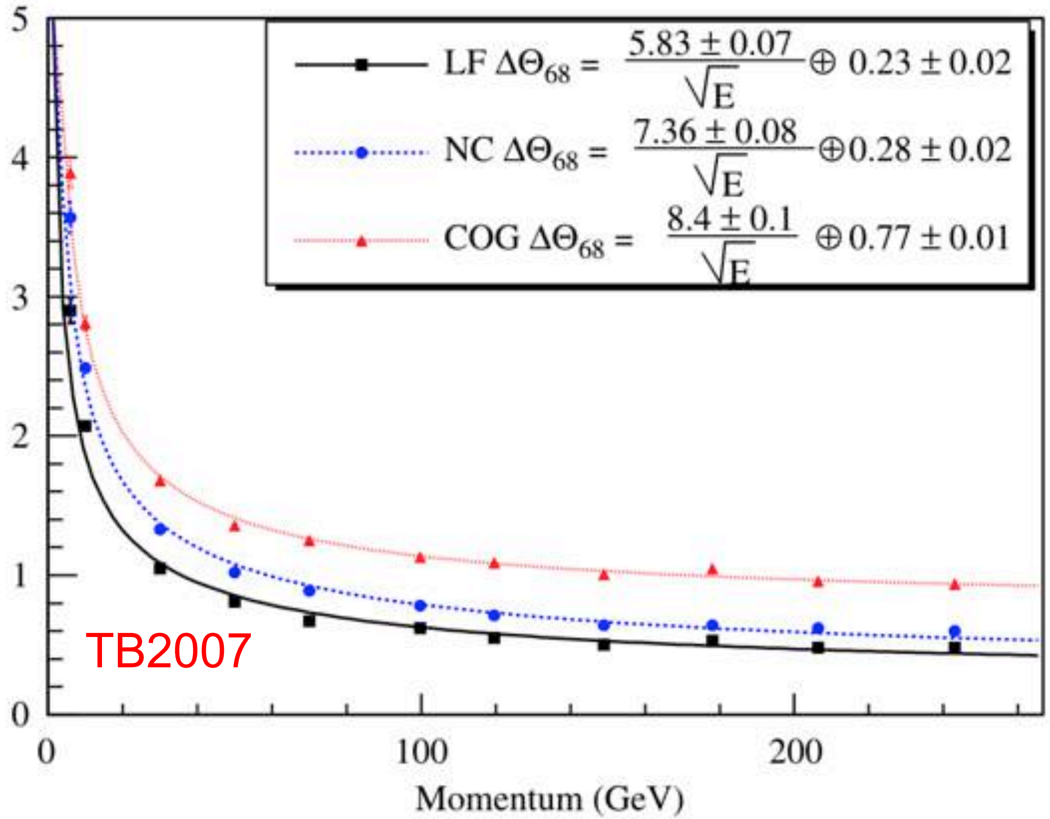




Position and angular resolution

- By comparing with tracker tracks, it is possible to measure the ECAL resolution in position and angle:



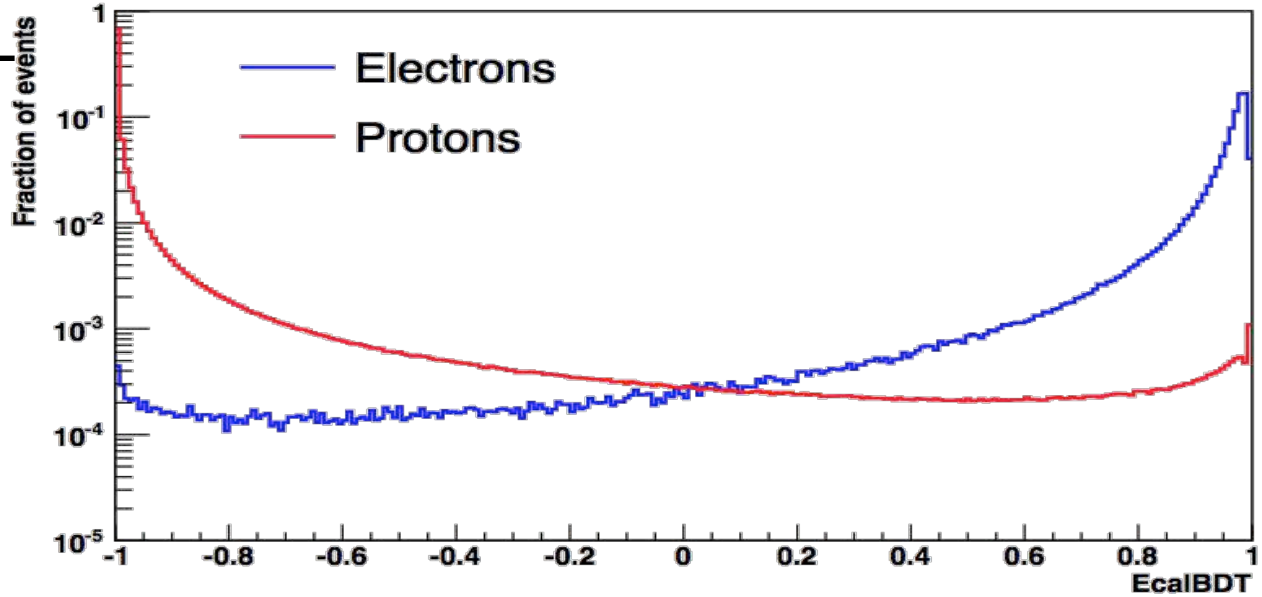


- Note that for ***E>100 GeV*** the shower axis angular resolution is dominated by the constant term: ***$\Delta\theta$ = 0.23º = 13 mrad***

Proton rejection

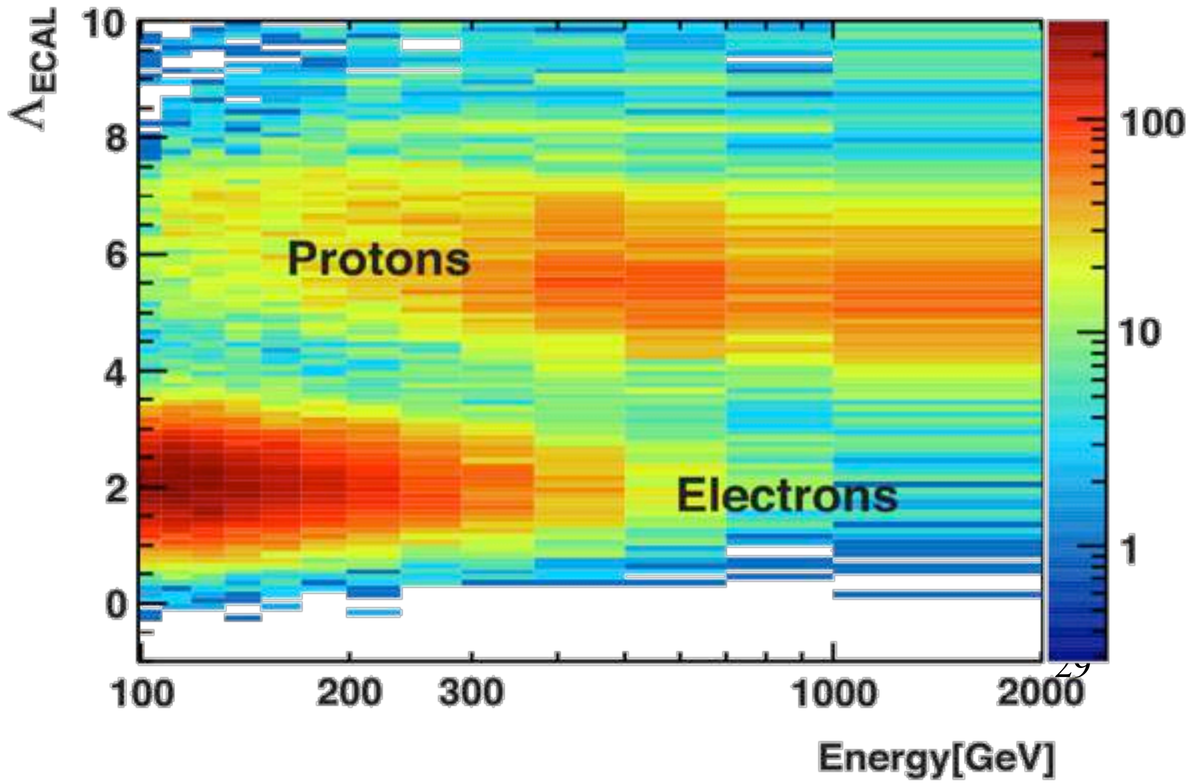
"classic" reconstruction: BDT

- Boosted Decision Tree (BDT) with electrons and protons selected using TRD, Tracker, very loose E/P cuts
- No MC used

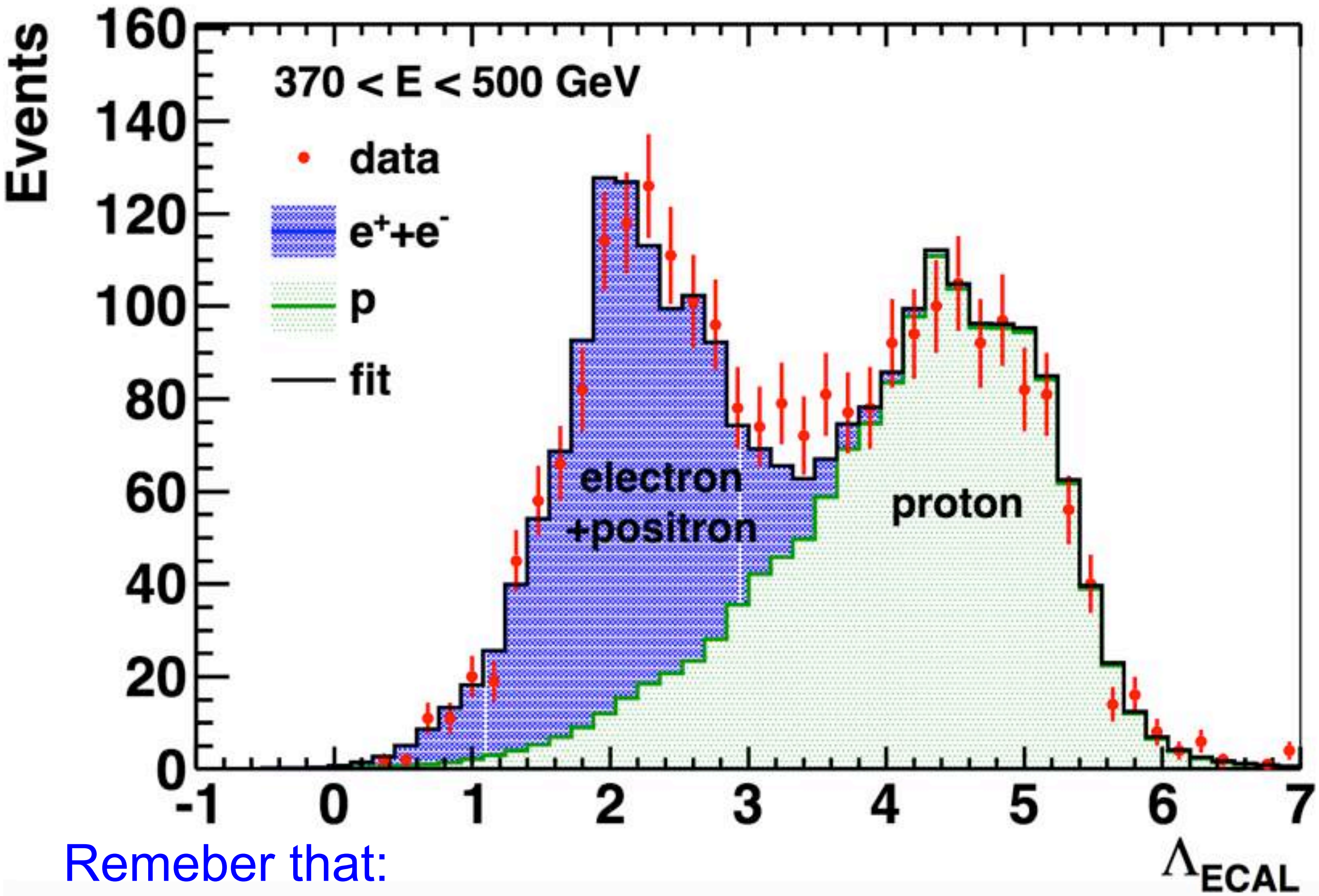


3D shower reconstruction

- New estimator based on 3D shower reconstruction
- MC used to build it



electron proton separation @ 450 GeV

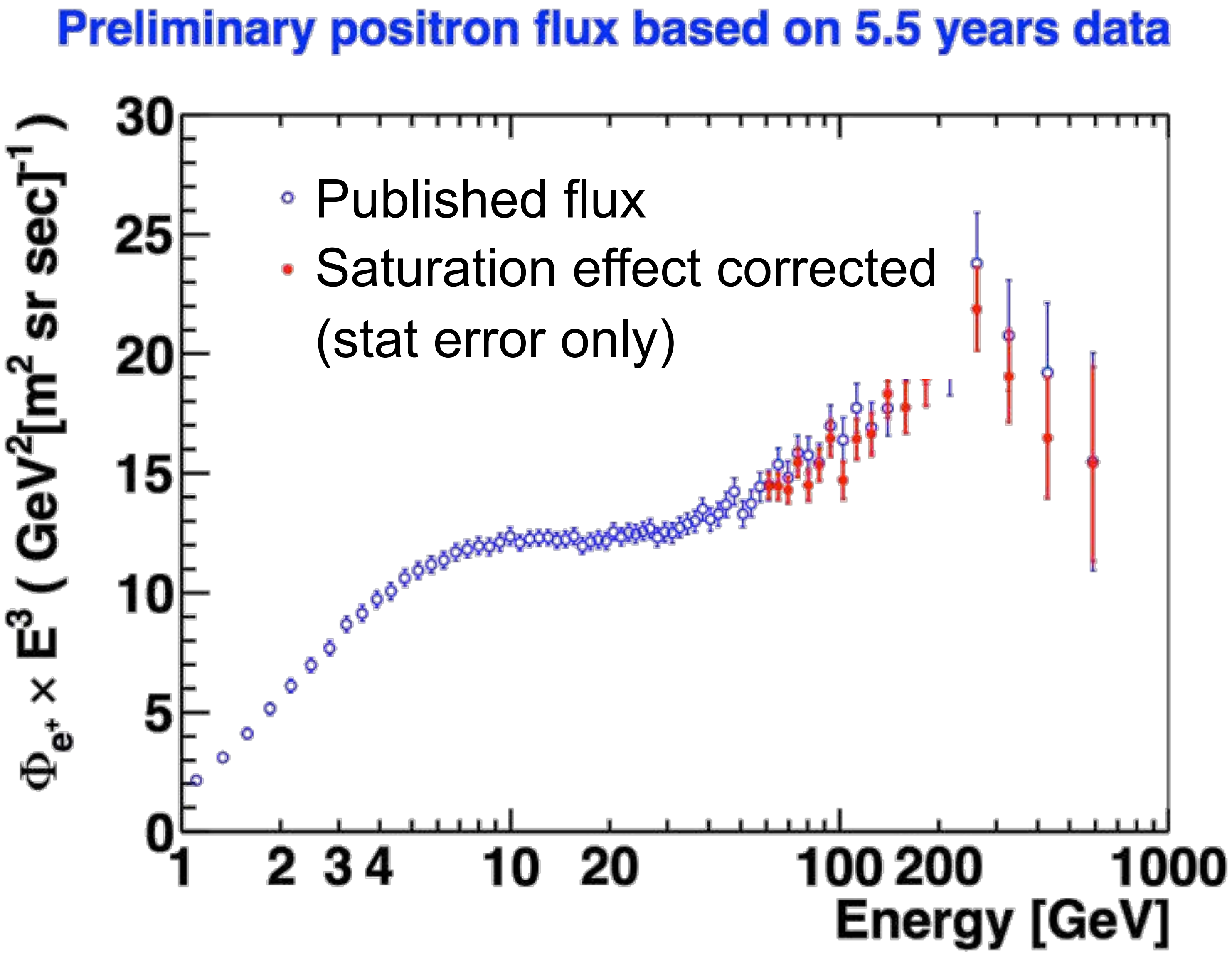


Remeber that:

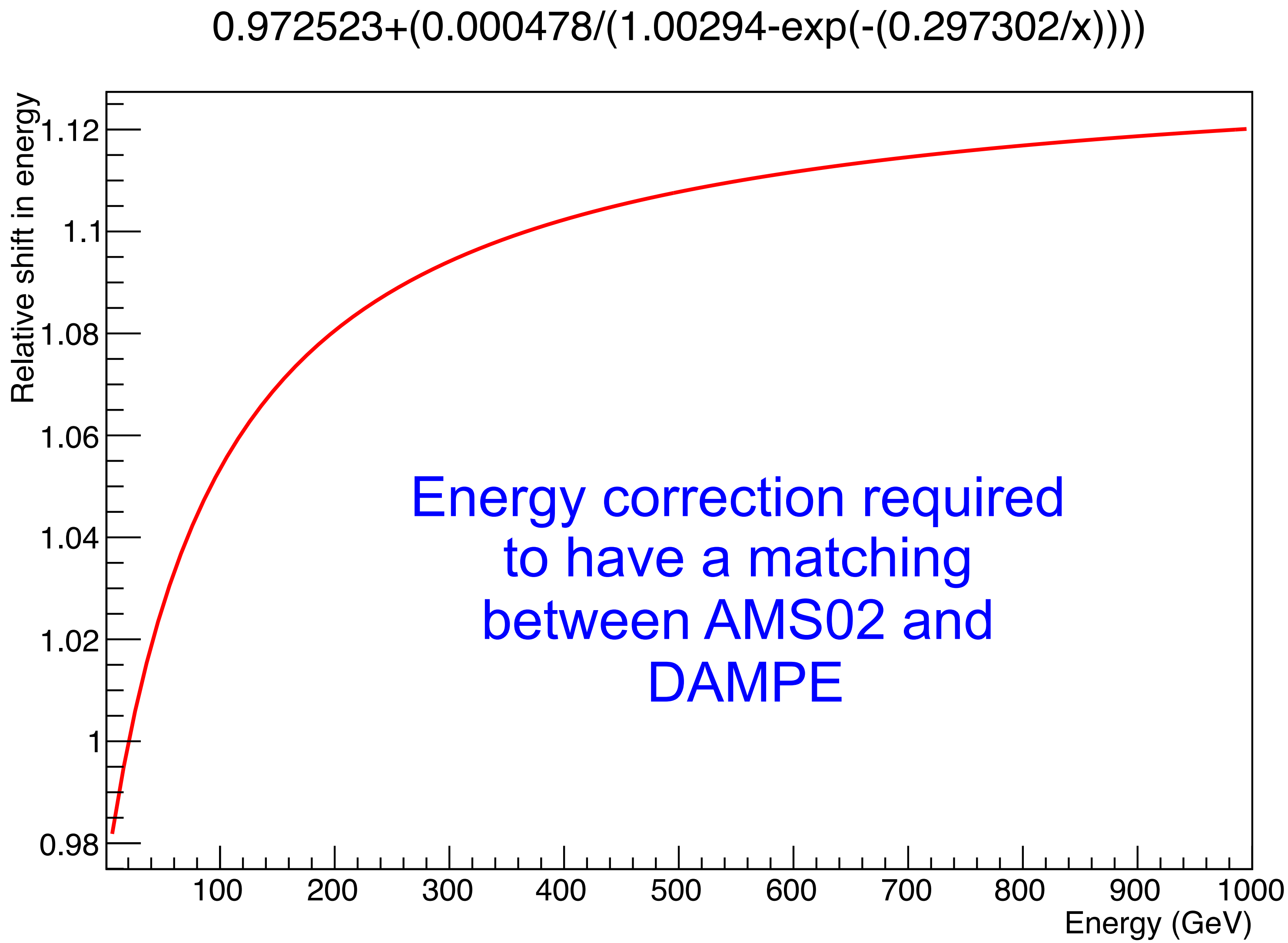
- at 500GeV the electron-proton ratio is ~10^{-3}
- protons in the plot above have 500-1000 GeV momentum

Saturation: effect on flux

- Thanks to ECAL granularity, the number of satured cells is few units at 1 TeV and the energy flux is almost unaffected



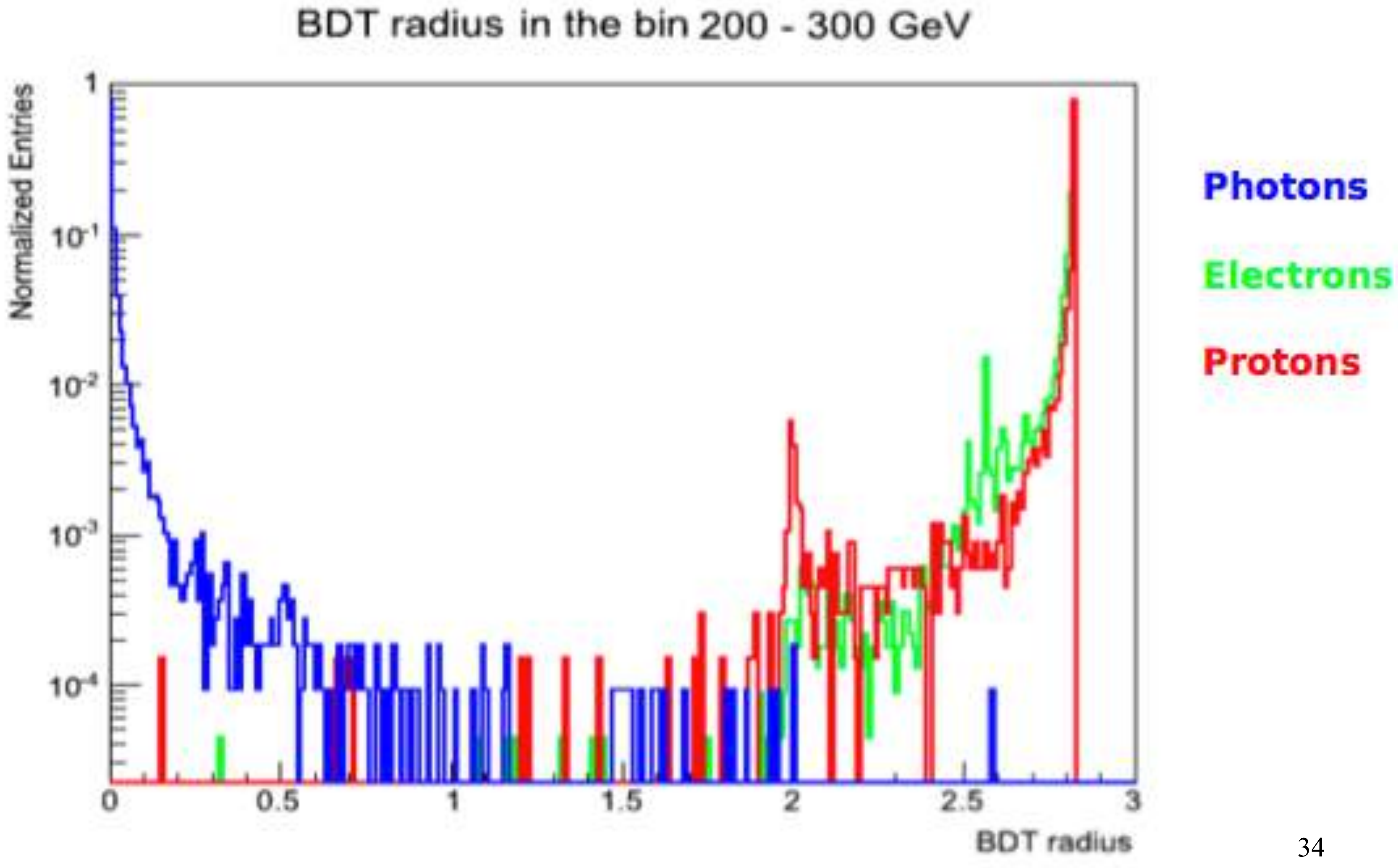
- Can this explain the difference with DAMPE?
- Doesn't seem to be the case

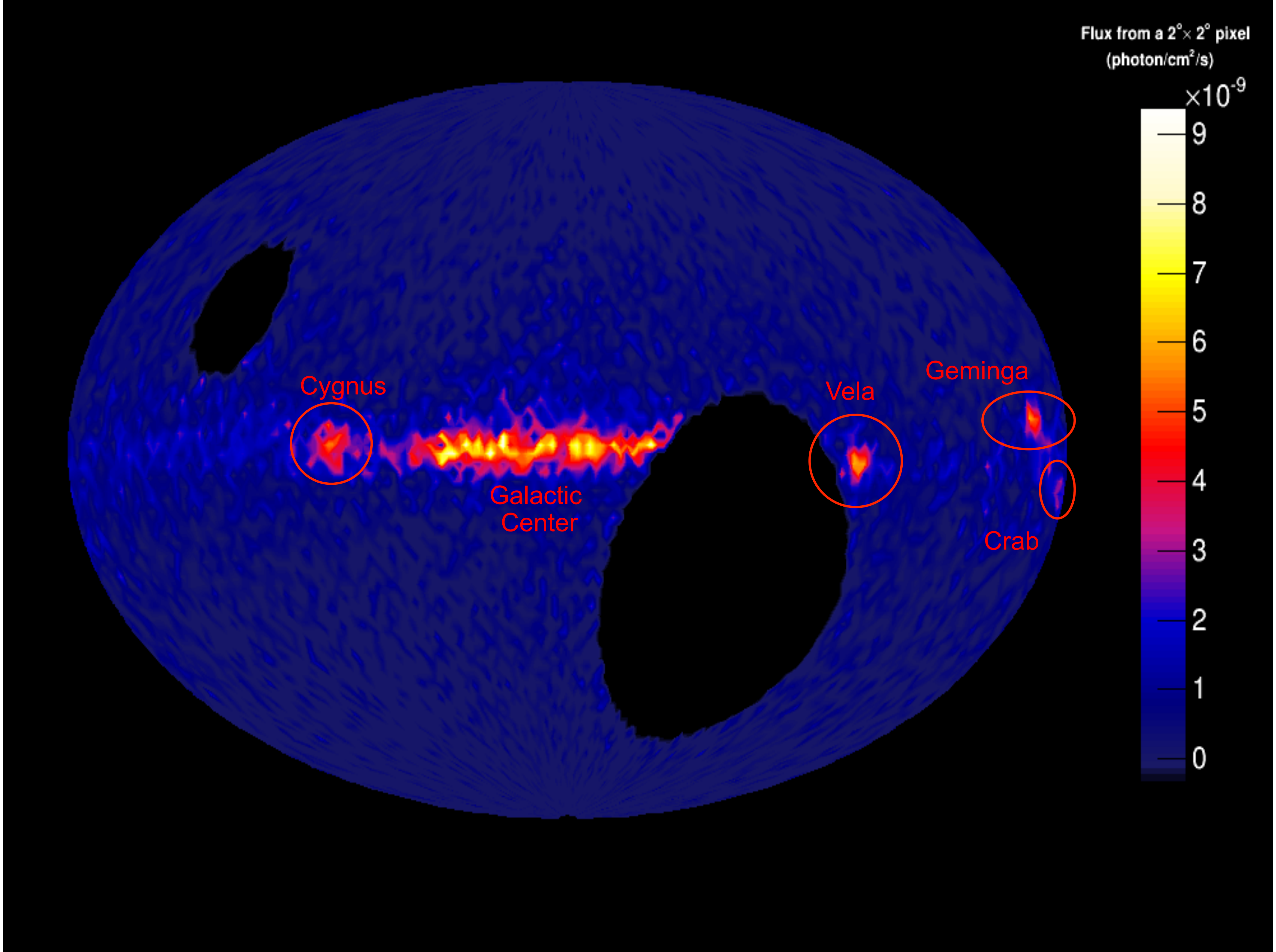


Photon physics in AMS using ECAL

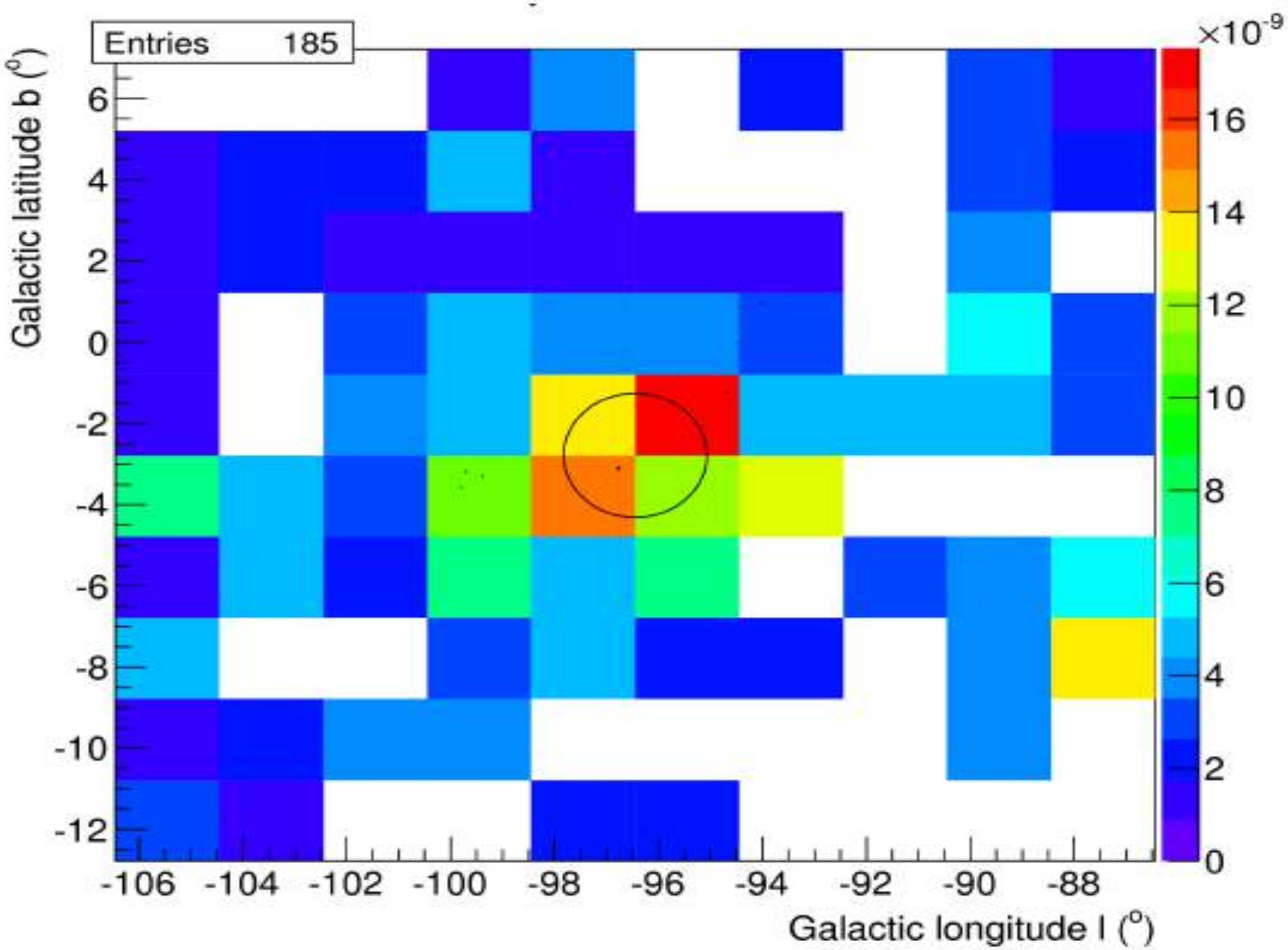
- Material above Ecal: 0.6 X0 → ~63% of the photons reach ECAL without interactions
- The ECAL Gamma Trigger efficiency is ~100% at E>5GeV
- Two new BTDs, one separating photons from protons and one photons from electrons, are built which include the presence of hits in the detectors above ECAL
- *"BDT radius"* = combination of the two BDTs

Photon identification




Flux from a 2°× 2° pixel
(photon/cm²/s)
×10⁻⁹
9
8
7
6
5
4
3
2
1
0
Cygnus
Galactic
Center
Vela
Geminga
Crab

Pointing Accurancy: Vela [3,10] GeV



DIFFERENCE FROMFERMI LAT2YEARS CATALOG

$\Delta l = -0.4 \pm 0.5$

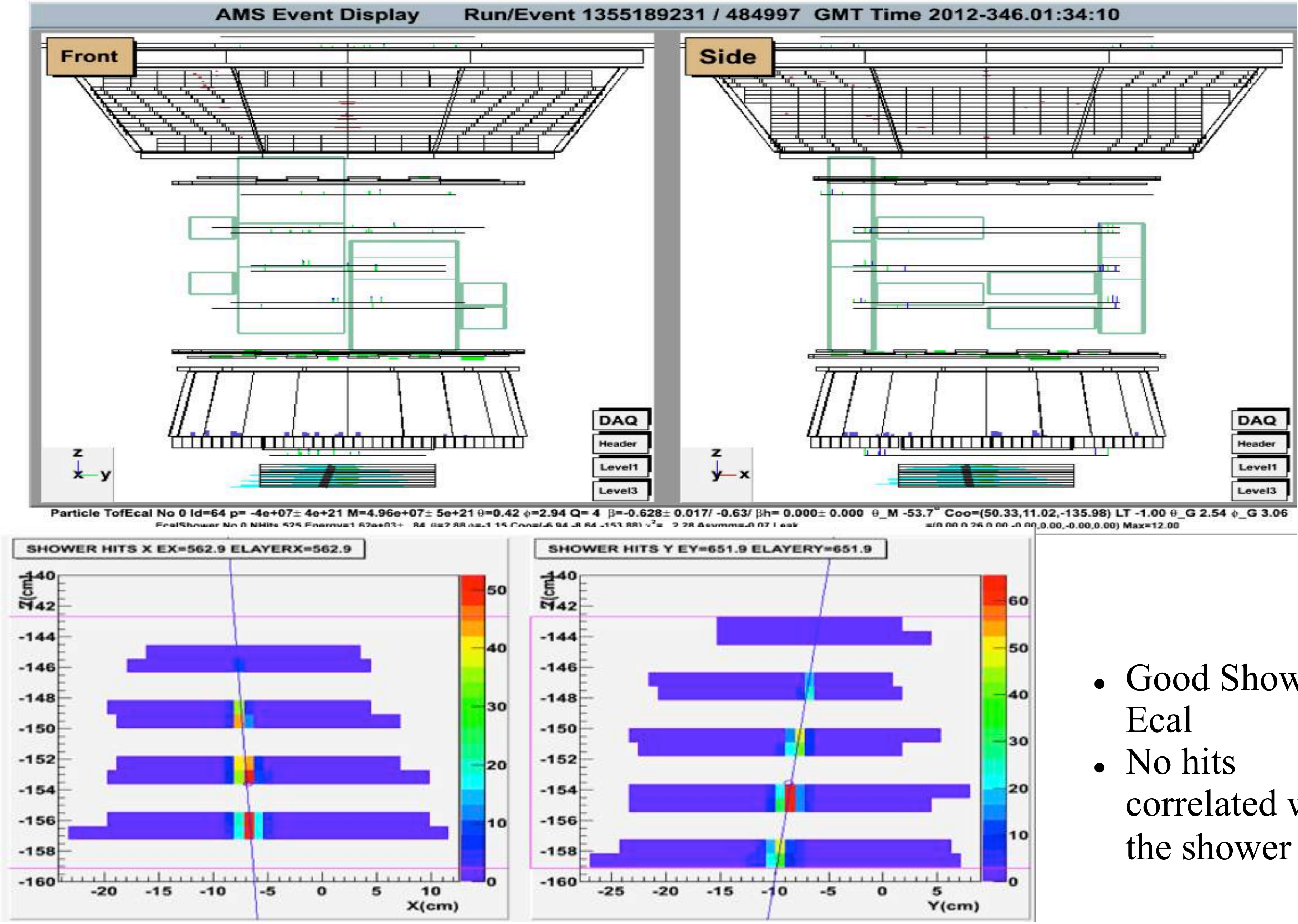
$\Delta b = -0.3 \pm 0.3$

$\sigma(l) = 3.0 \pm 0.7$

$\sigma(b) = 1.9 \pm 0.3$

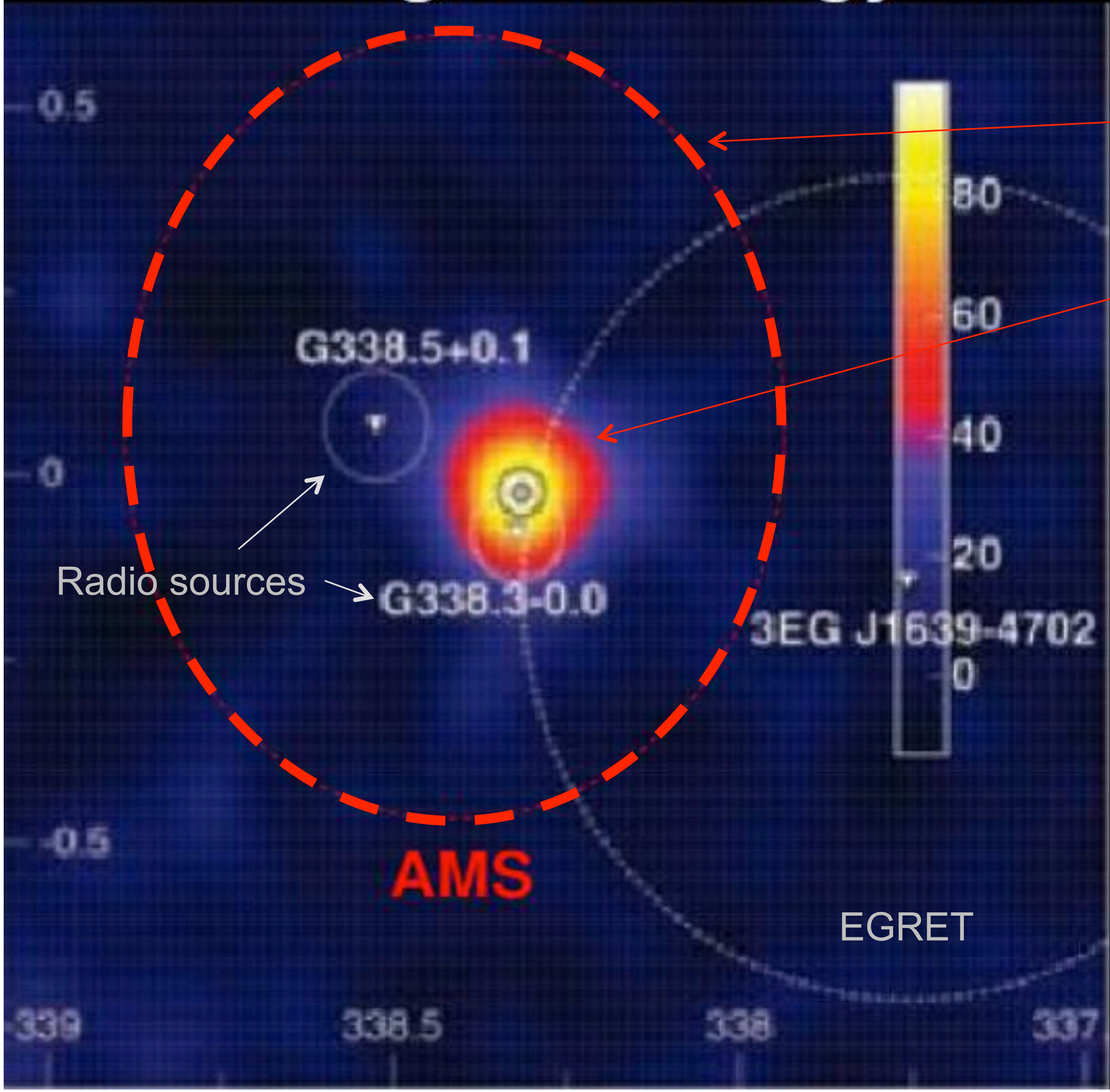
$\Delta\Theta \sim 3.5^{o}$ as expected (included error of position and orientation of AMS)

A 1.7 TeV photon?!?



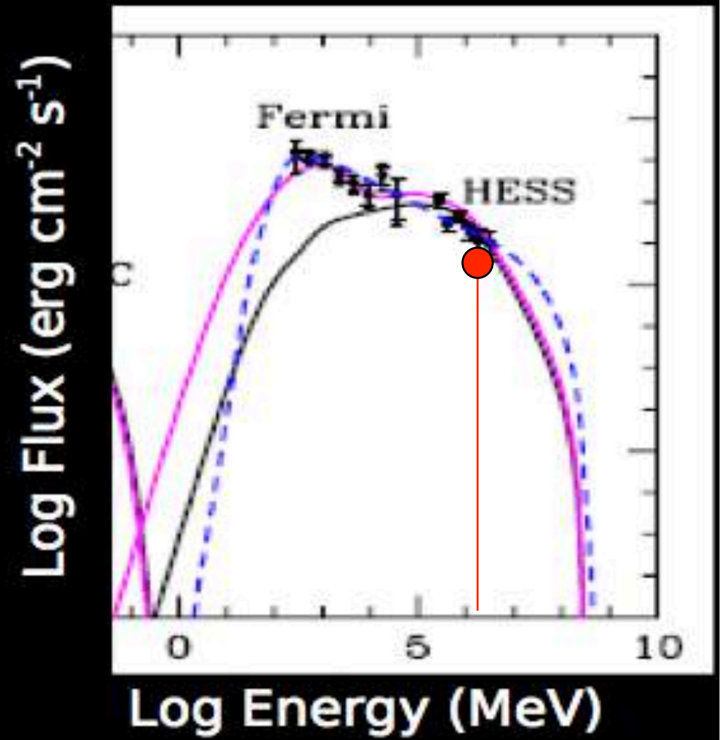
- Good Shower in Ecal
- No hits correlated with the shower axis

The highest energy AMS ECAL photon



AMS: l=338.4° ± 0.5°
b= 0.05° ± 0.5°

HESS J1640-465:
l=338.316° ± 0.007°
b= -0.021° ± 0.007°



Conclusions

- ECAL low level reconstruction stable (MIPs, attenuation length, HGLG ratio, ...)
- 3D reconstruction developed by MIT
- results are compatible with "classic" reconstruction in test beam energy interval
- main improvement: saturation effect included in MC, which allows to extend corrections to 1TeV and above