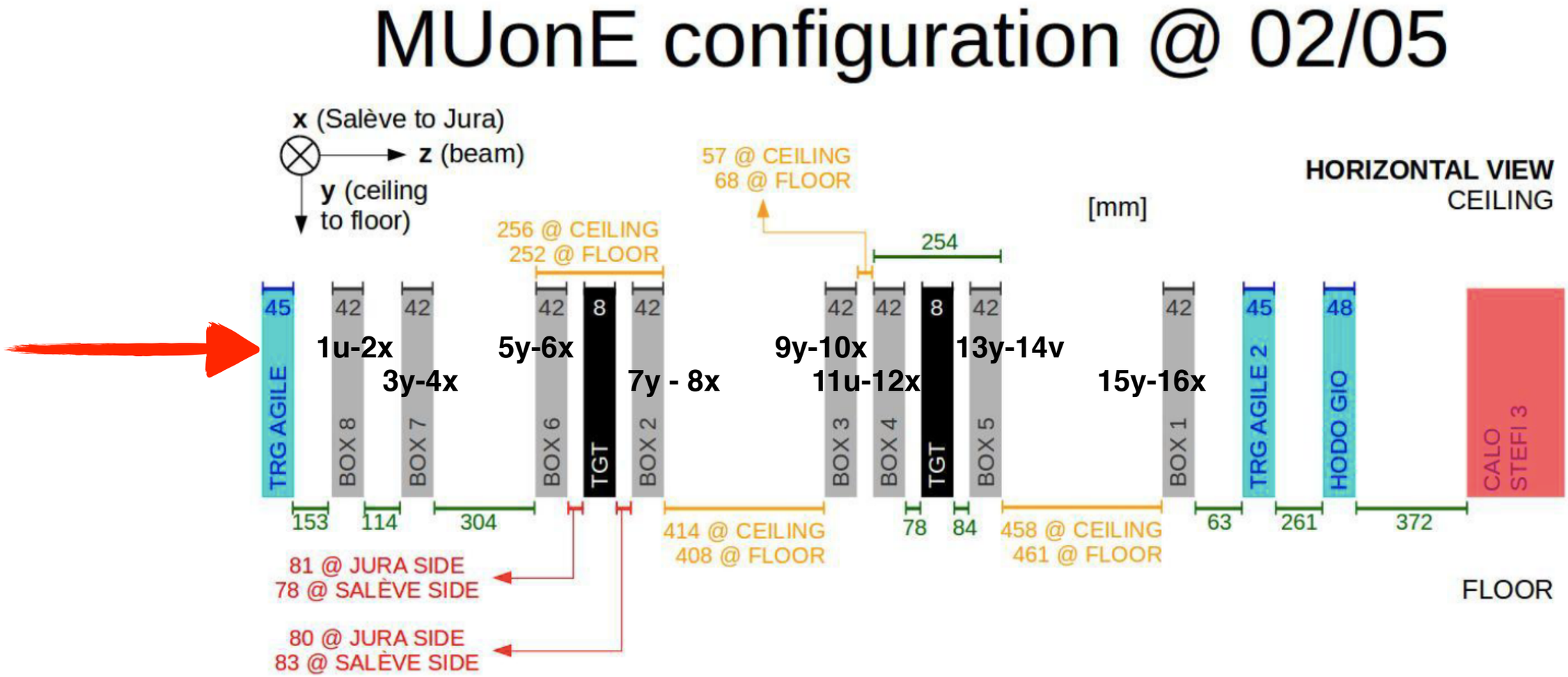
Test beam 2018 analysis: summary and updates

A. Principe

12/09/2018, Bologna meeting

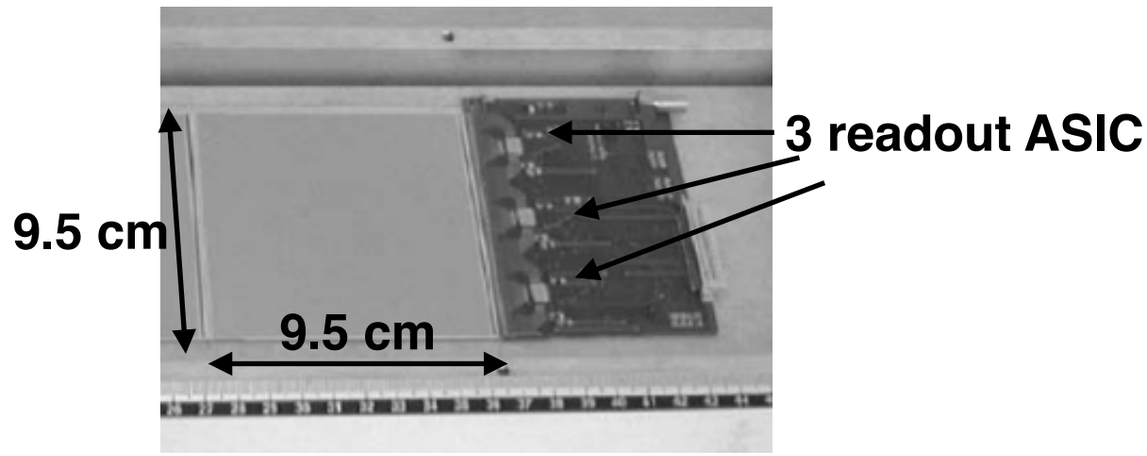
Apparatus setup



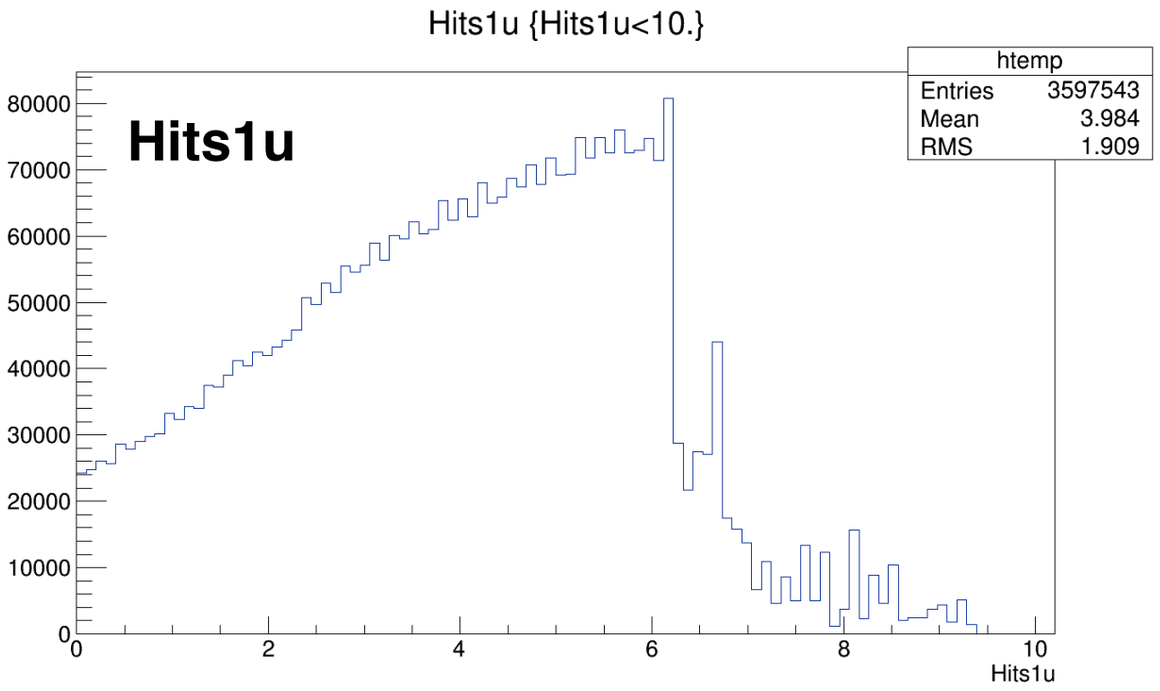
- Strip pitch: 242 um
- Nominal point resolution ~ 35-40 um

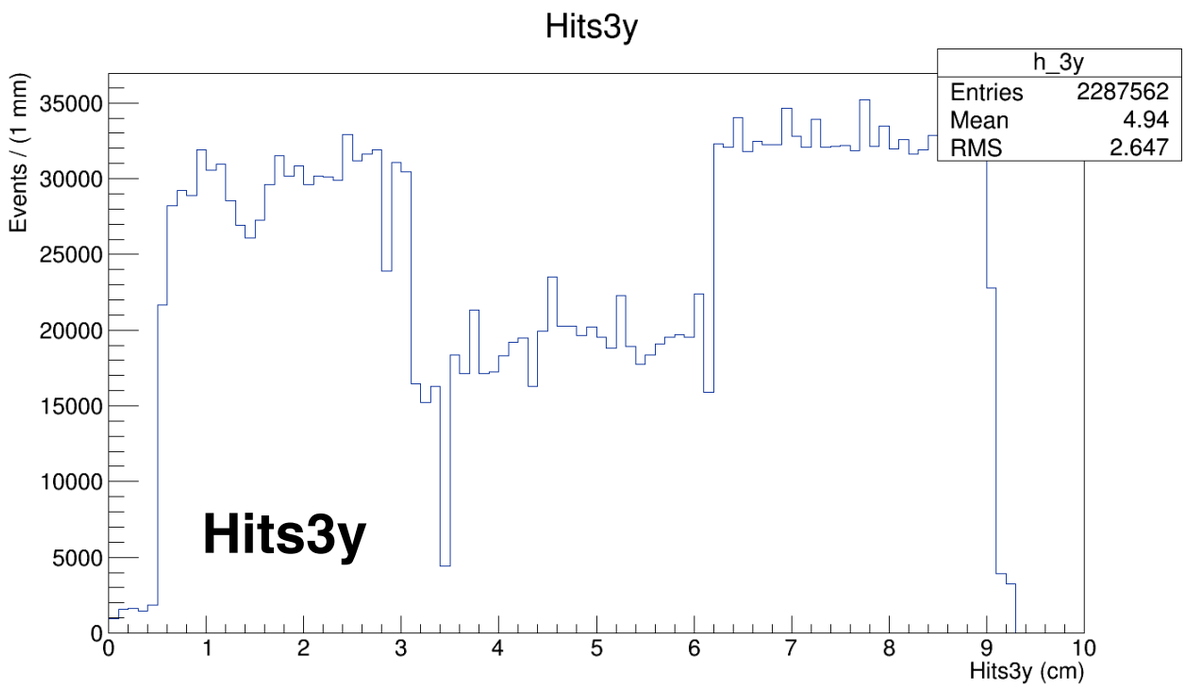
- **from 4/05: 3 upstream boxes**
- **from 27/06: no target 2**
- **from 20/08: new box 8 and 3**

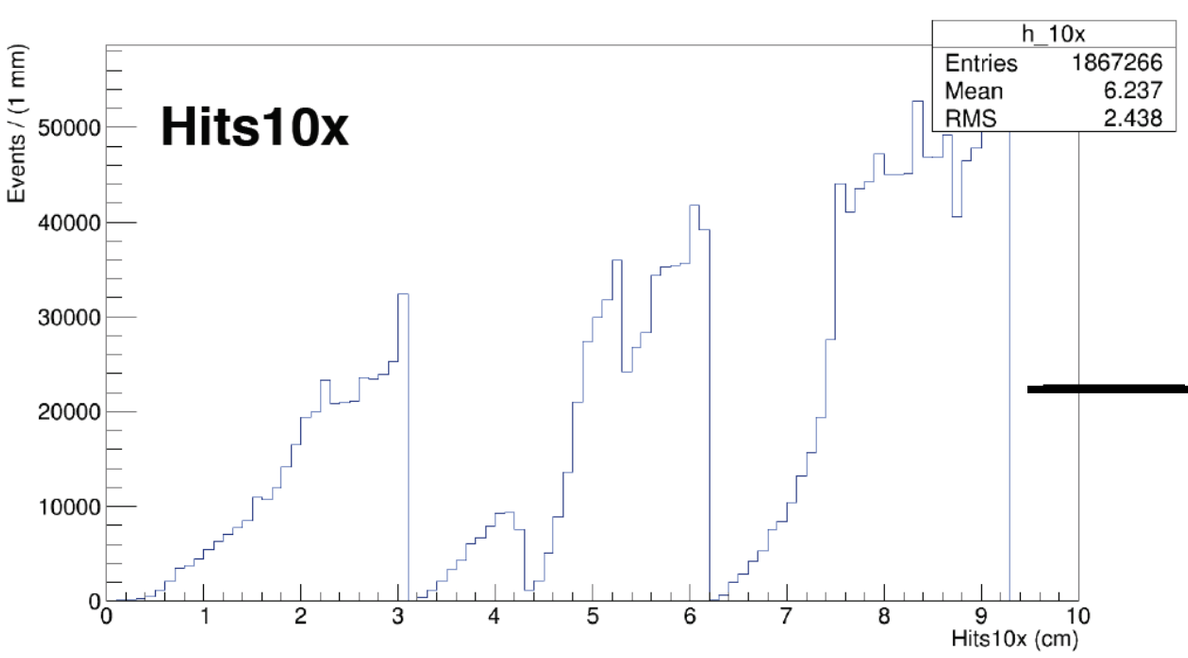
AGILE sensors



Layer problems: some examples

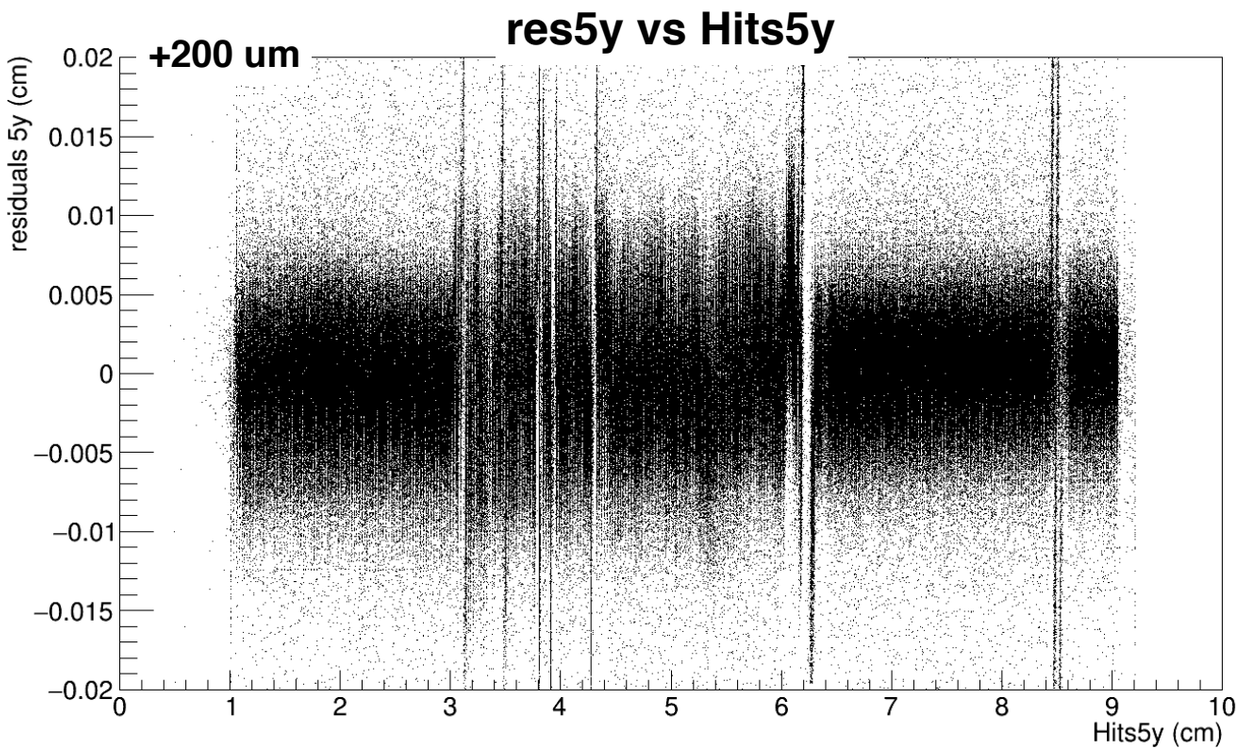


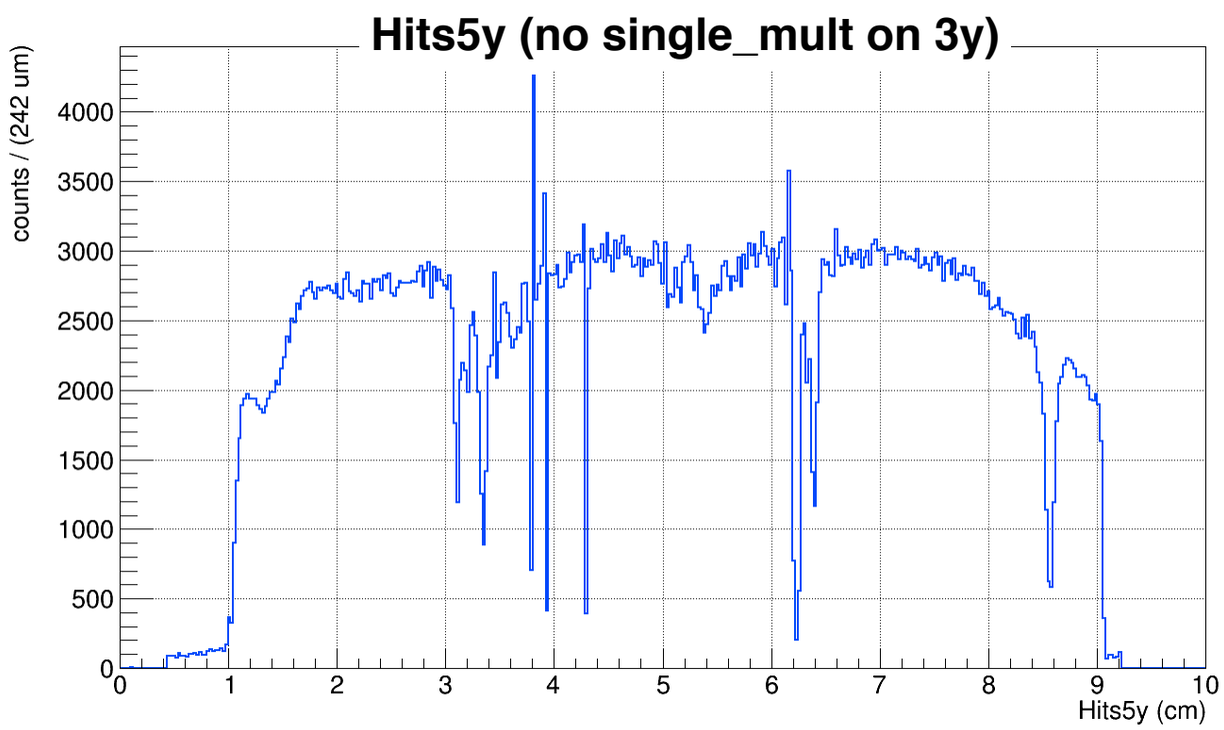


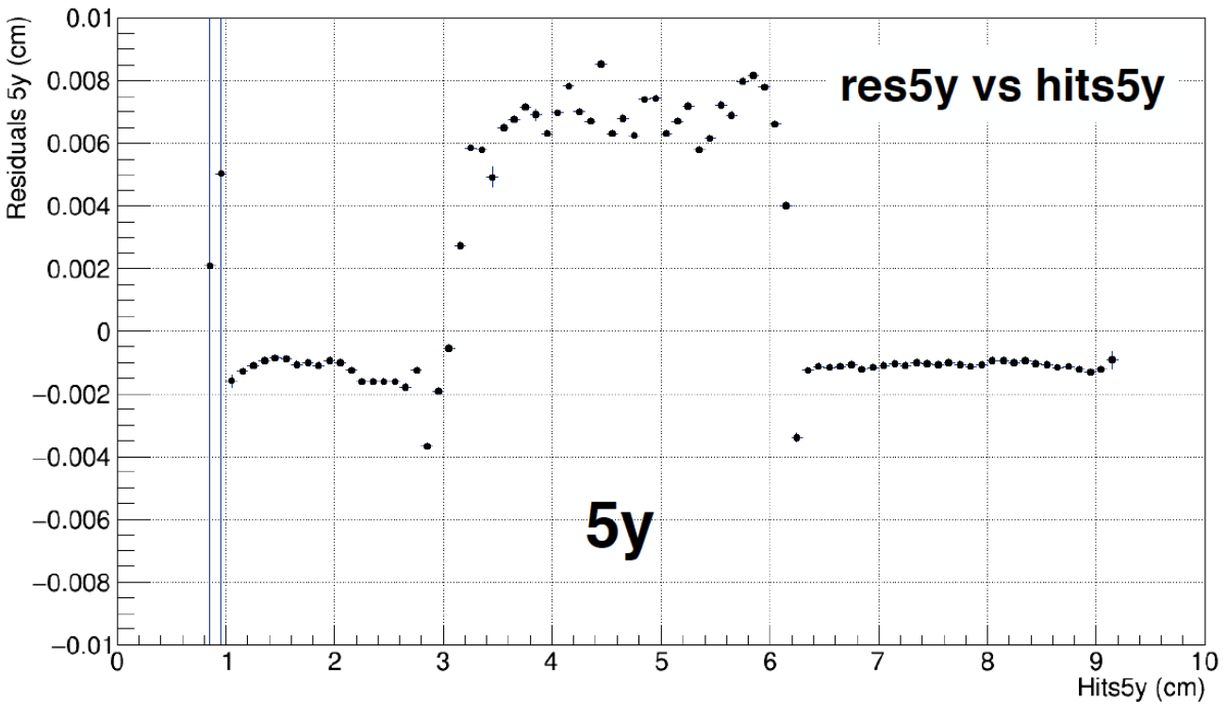


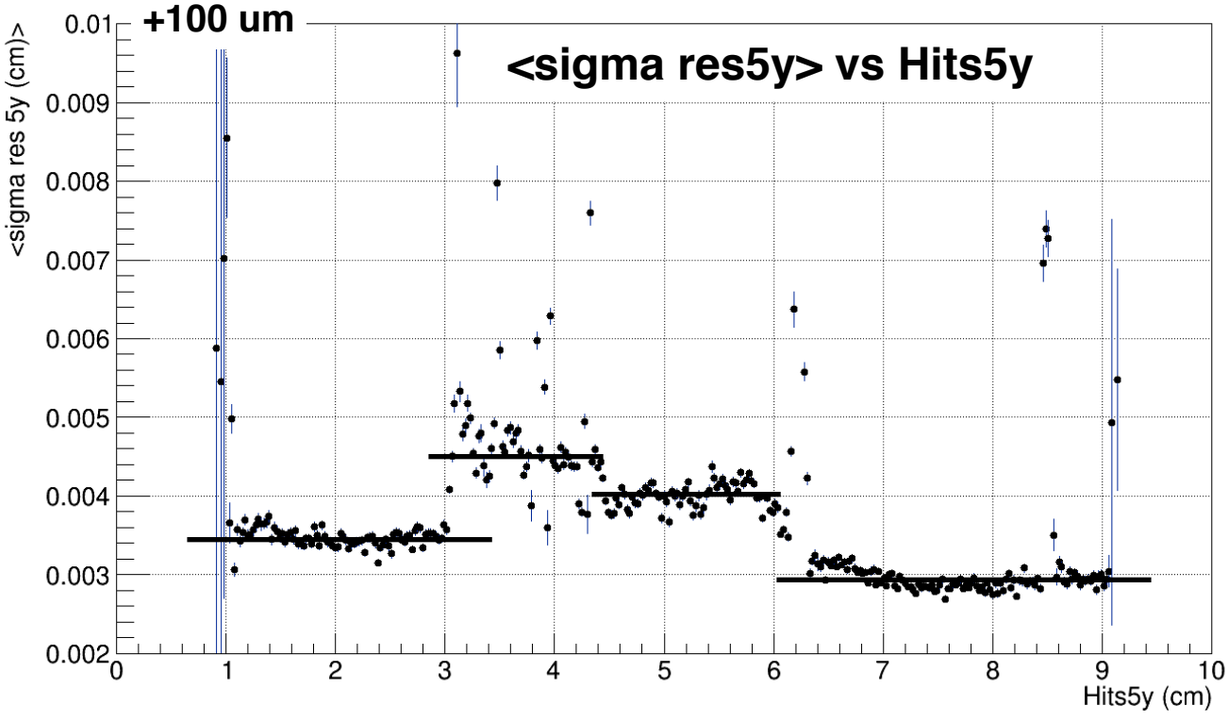
- Almost all layers show inefficiency problems: it's very clear the ASIC structure.
- In the next slides a quantitative efficiency analysis.
- We've correlated some of these problems with the high beam intensity relatively to the apparatus readout.
- Layers 1u and 10x have been changed at the end of August (test beam is running from May).
- In these slides new setup (new boxes) are not shown.

Layer problems: plane 5y



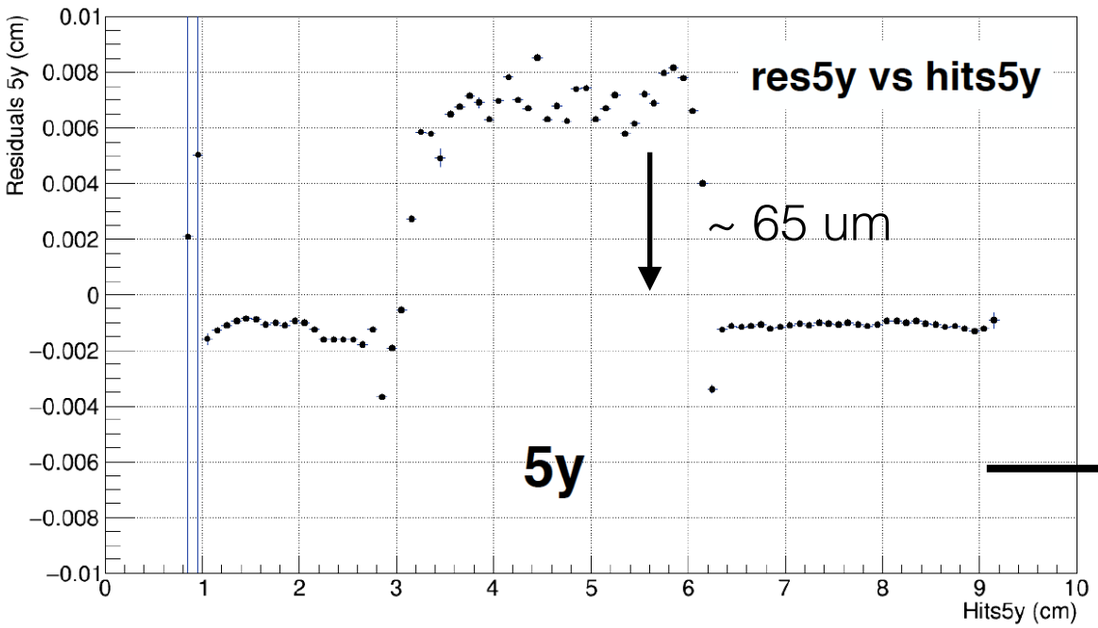


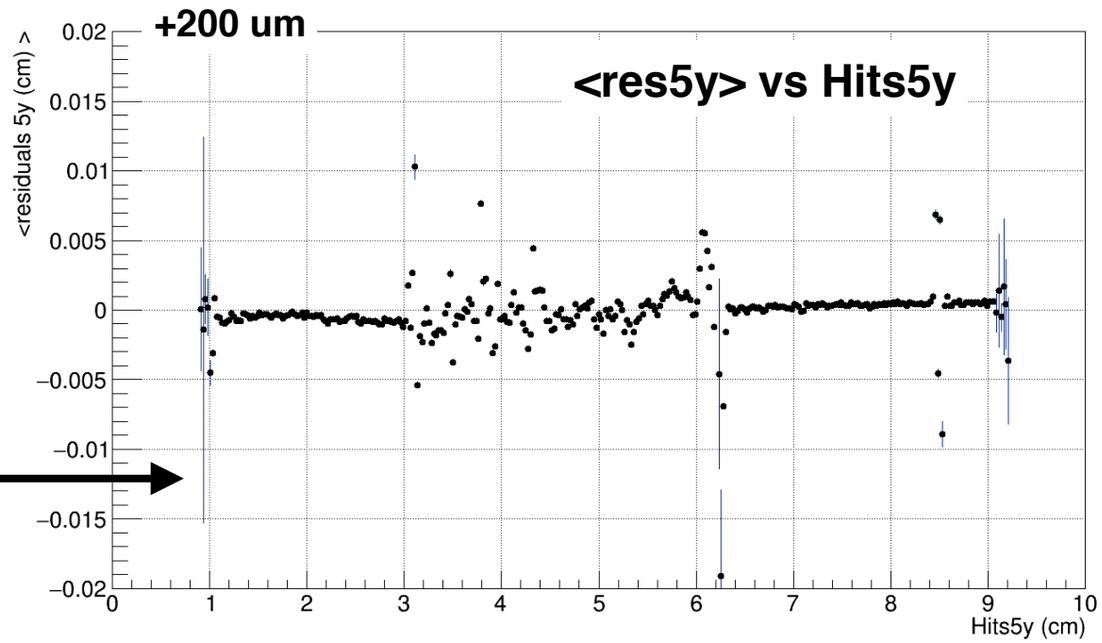




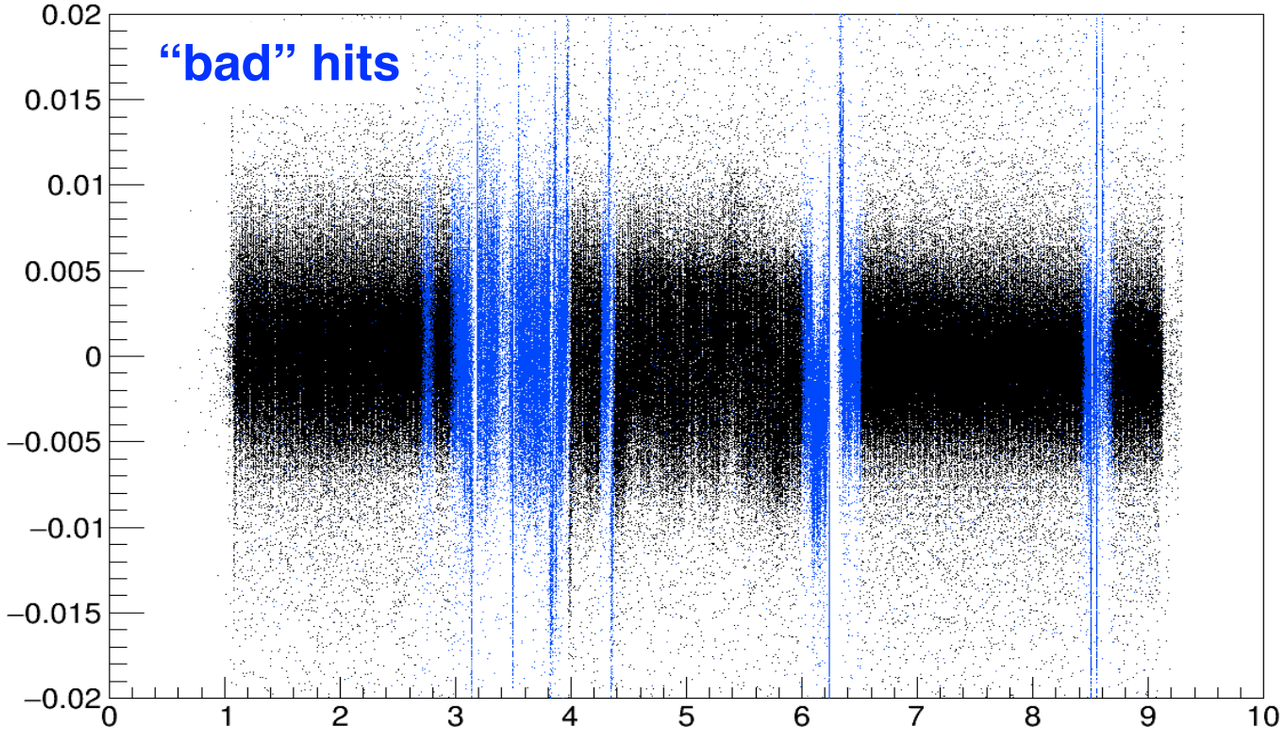
- Situation of 5y trackers (upstream) **pre-correction**: noisy behavior and shift of central ASIC. Also the resolution at the center is significantly different (sigmas plot).
- As other planes, many dead strips which induce a bad reco of nearest strips.

Layer problems: some solutions



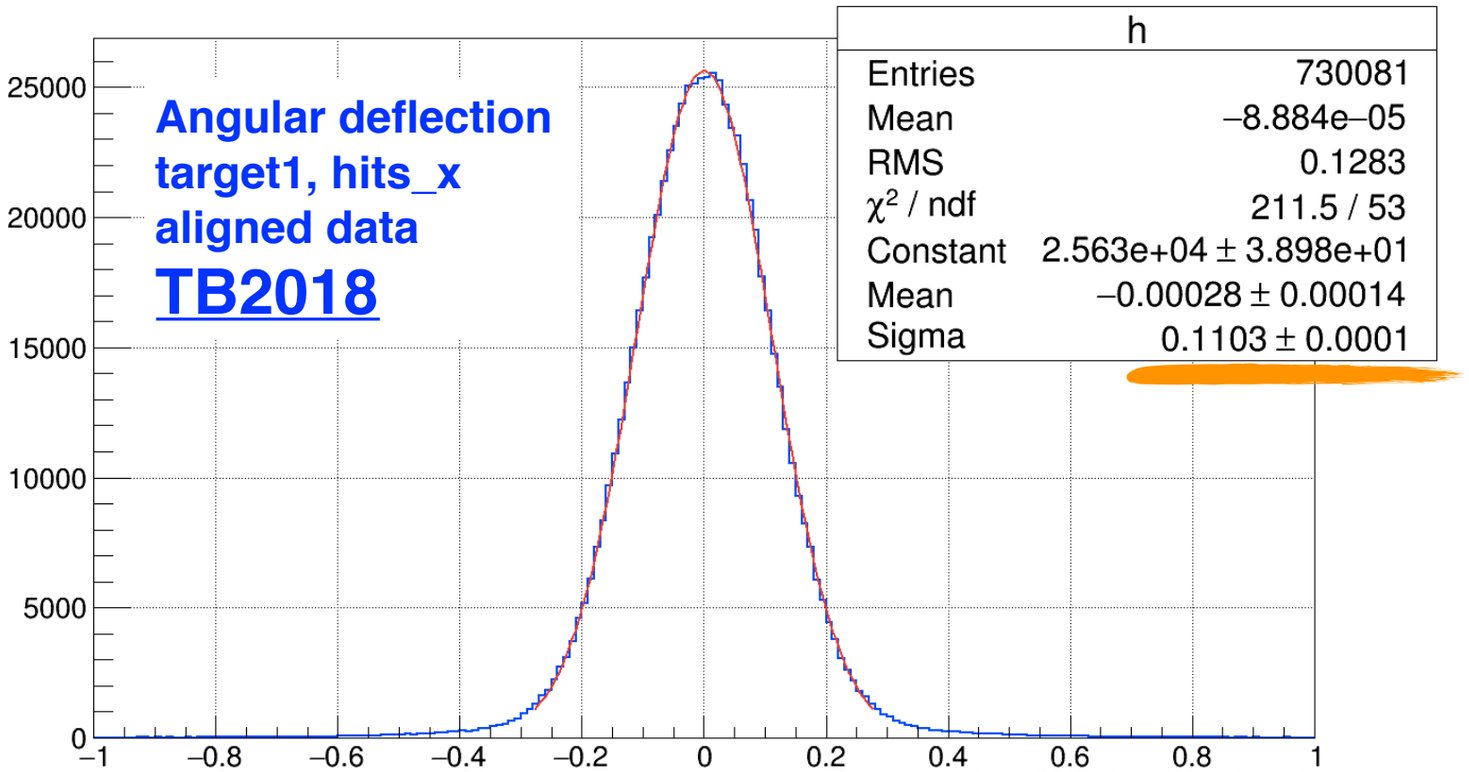


res7y:Hits7y

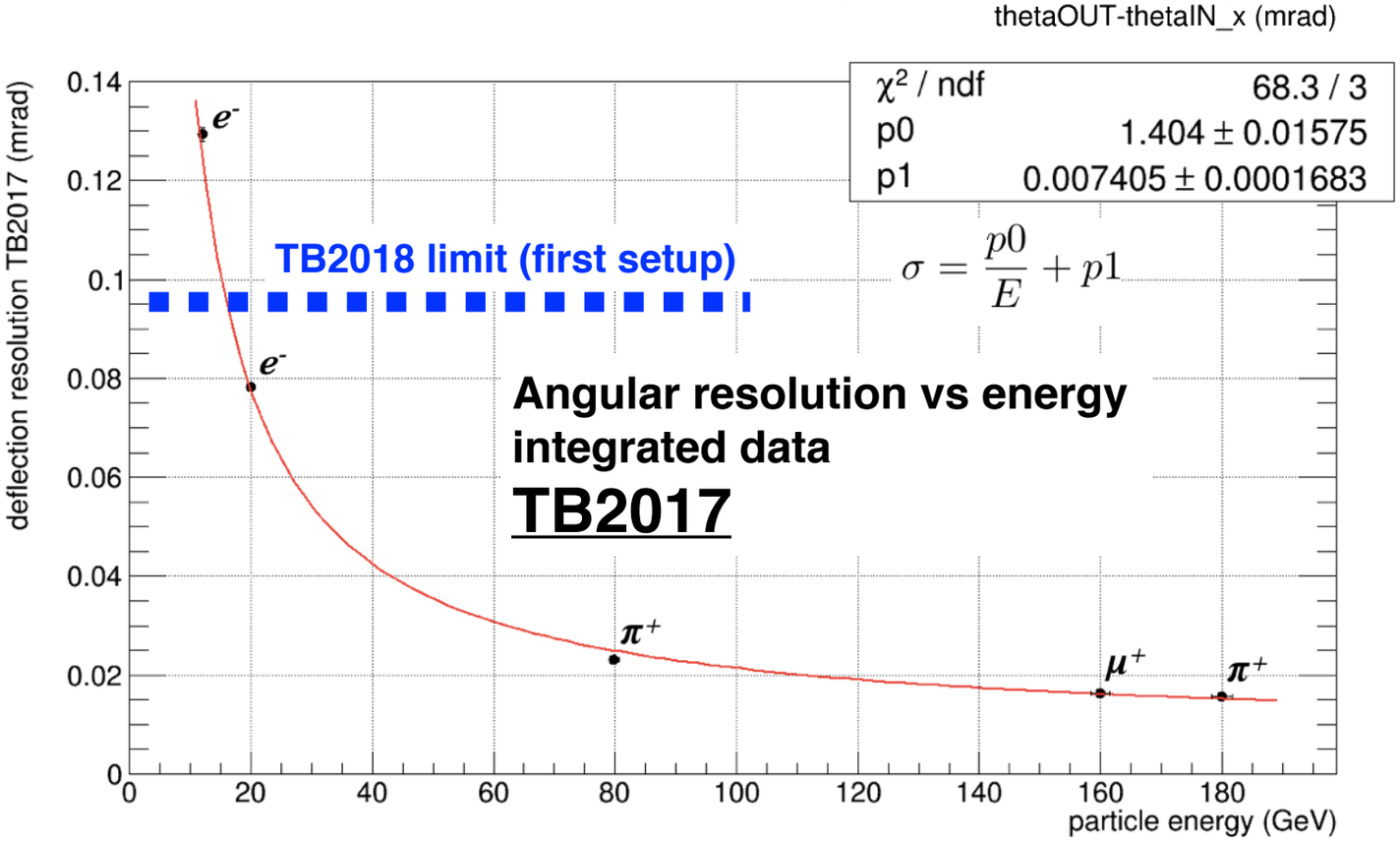


- Systematic readout shifts of layer 5y (~ 65 um) and 3y (~ 21 um) were corrected in analysis.
- Dead strips and nearest strips were masked, layer per layer.

Resolution comparison: test beam 2017 / 2018



- For **~ 187 GeV** muon (sigma Highland MS):
  - 8 mm graphite **~ 0.012 mrad**
  - 4-5 Si layer of 410 um **~ 0.009 mrad**
  - sum in quadrature **~ 0.015 mrad** (not so different from pion data TB2017).
- Why sigma is now > 0.10 mrad? Because the intrinsic resolution of apparatus 2018 (pitch 242 um with floating strip, medium downstream arm ~ 50 cm) is:
  - 35 um * sqrt(2) / 50 cm **~ 0.10 mrad**



- With our previous dedicated apparatus to multiple scattering measure, we were able to see MSC of pions and muons over 150 GeV.
- Now, the second setup (**without target2**) should be able to achieve ~0.040-0.045 mrad of point resolution: we might see this difference on analysis of both data sets (next slides)

Efficiencies analysis: hit / event

Layer	$\sigma_{residual}$
1y	49 μm
2x	38 μm
3y	43 μm
4x	40 μm
5y	31 μm
6x	32 μm
7y	26 μm
8x	25 μm
9y	28 μm
10x	40 μm
11y	39 μm
12x	25 μm
13y	31 μm
14x	41 μm
15y	45 μm
16x	48 μm

Layer resolution

Cutted hits % (with mask)	
1y	~34%
2x	~13%
3y	~6%
4x	~3%
5y	~19%
6x	~10%
7y	~7%
8x	~5%
9y	~4%
10x	~65%
11y	~1%
12x	~1%
13y	~8%
14x	~1%
15y	~5%
16x	~16%

% bad hits

$$\epsilon_{3.28\sigma}$$
$$\chi^2_x + \chi^2_y < 26$$

(only chi2, no mask)

1y	**94.6%**
2x	**95.1%**
3y	**73.9%**
4x	**76.8%**
5y	**98.6%**
6x	**98.8%**
7y	**96.1%**
8x	**96.7%**
9y	**59.9%**
10x	**59.2%**
11y	**98.2%**
12x	**98.4%**
13y	**94.8%**
14x	**94.3%**
15y	**82.1%**
16x	**83.4%**

Hit eff

Event efficiencies downstream planes

7y	**67.5%**
8x	**54.4%**
9y	**78.2%**
10x	**25.0%**
11u	**81.3%**
12x	**88.6%**
13y	**83.8%**
14v	**79.5%**
15y	**80.6%**
16x	**85.2%**

4 runs only T1
2x-3y-4x-5y-6x (m==1)
11111 T: 18.4e+06 incoming muons

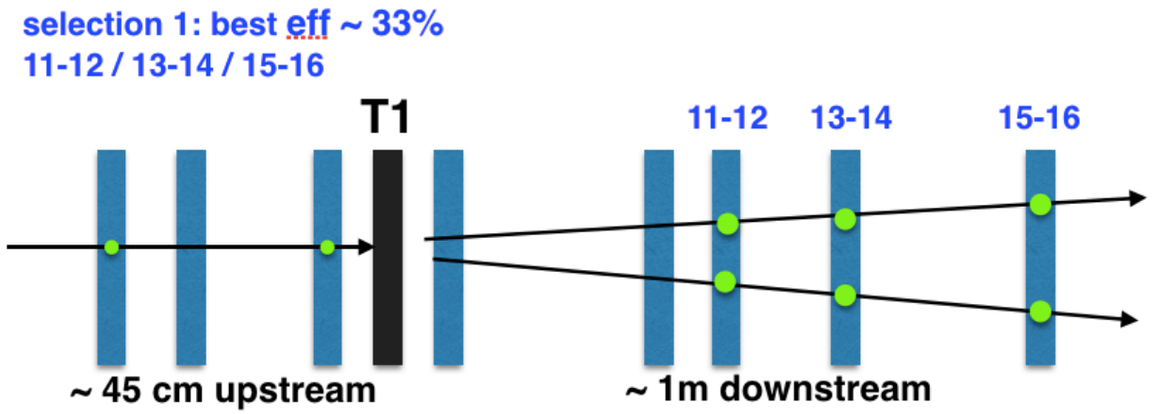
- Taking in coincidence 3 best layers per view: (11u-12x-13y-14v-15y-16x)

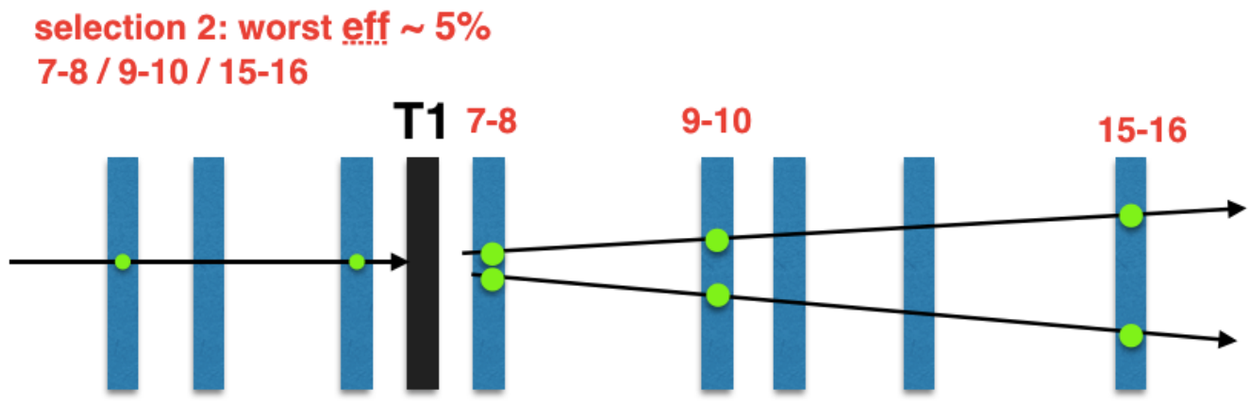
0.81*0.89*0.84*0.80*0.81*0.85 ~ 33%
(best event eff)

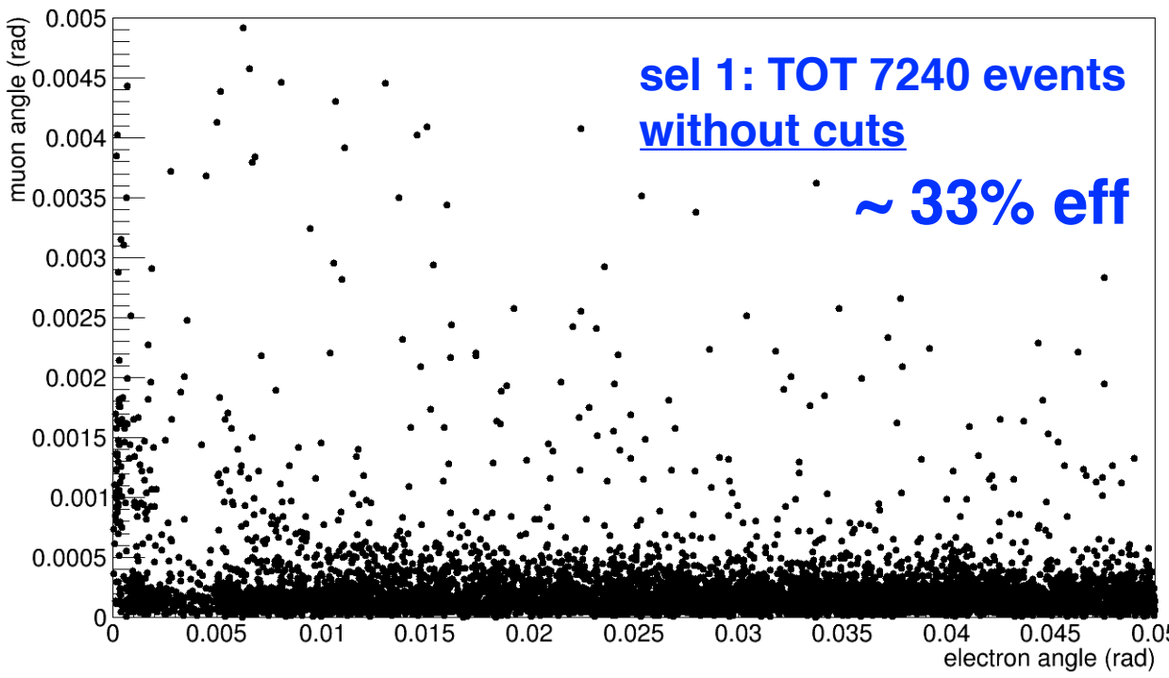
- With the worst: (7y-8x-9y-10x-15y-16x)

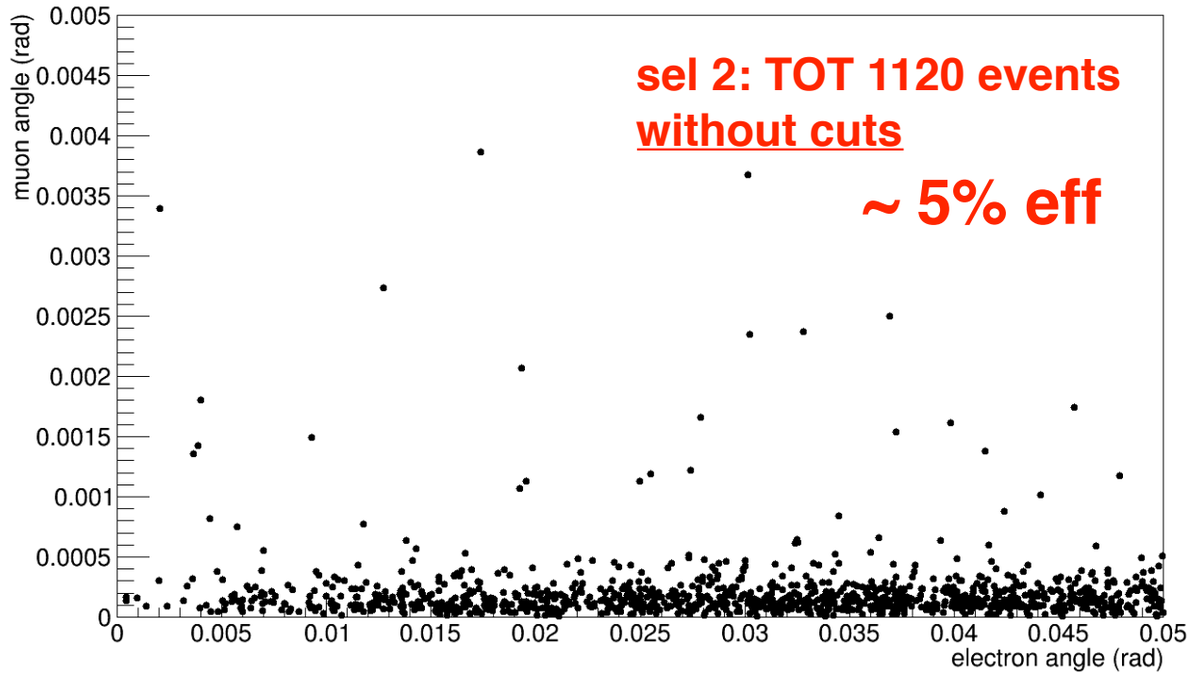
0.68*0.54*0.78*0.25*0.81*0.85 ~ 5%
(worst event eff)

Data sets of different event efficiency: plot θ_mu θ_e





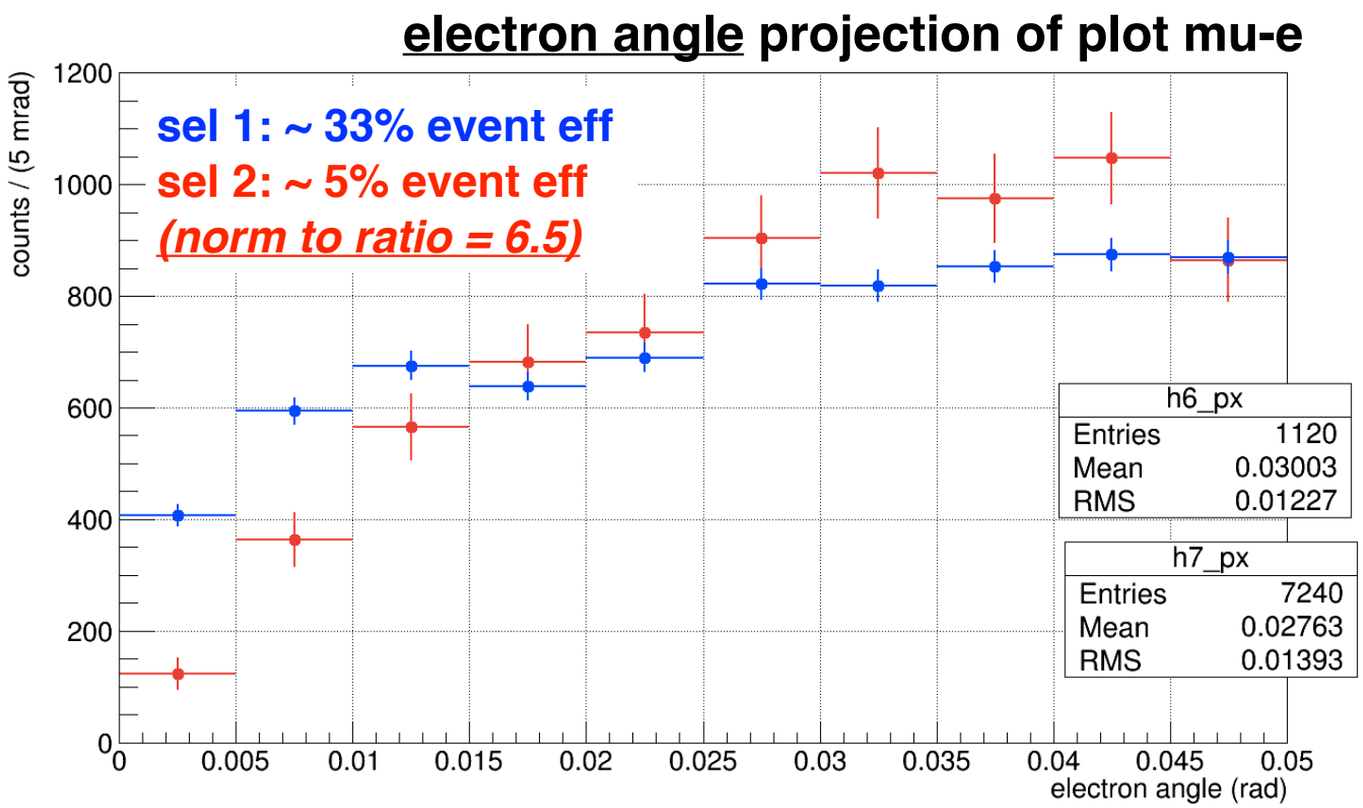




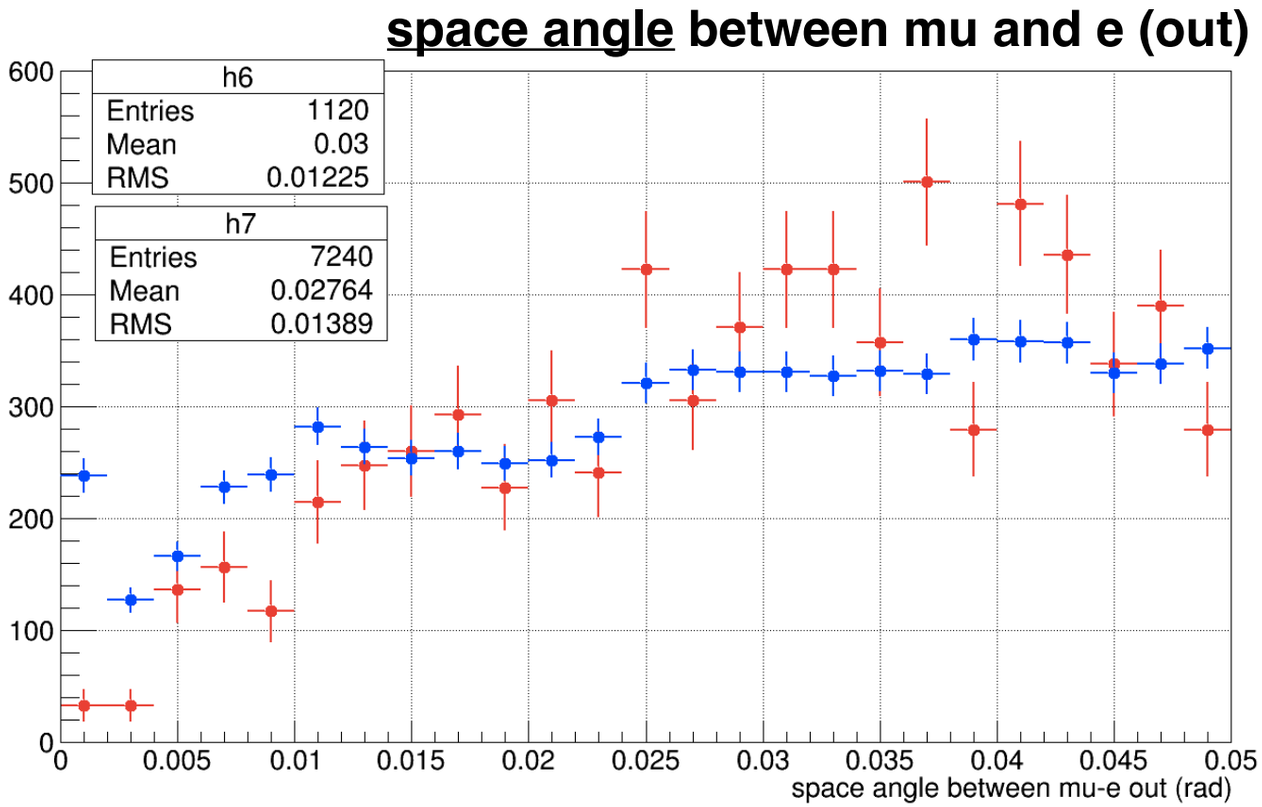
- Tot counts ratio [0, 50] mrad: **7240 / 1120 = 6.5 ± 0.3**
- Efficiency event ratio: **33% / 5% = 6.6**

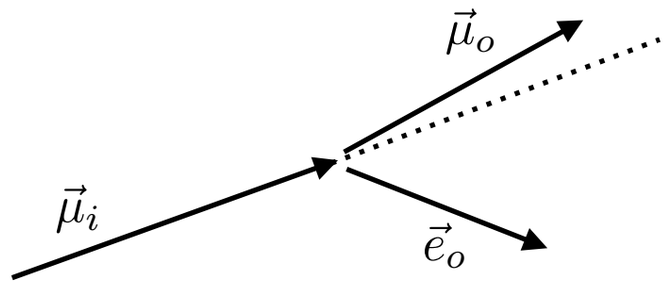
- Same 18.4e+06 incoming muons and same analysis: we can read this agreement as a relative goodness of estimated event efficiencies.

Data sets of different event efficiency: angle projections



- The angle projection show us a counting depression, in particular for the selection of worst case: MC studied are necessary for comparison.





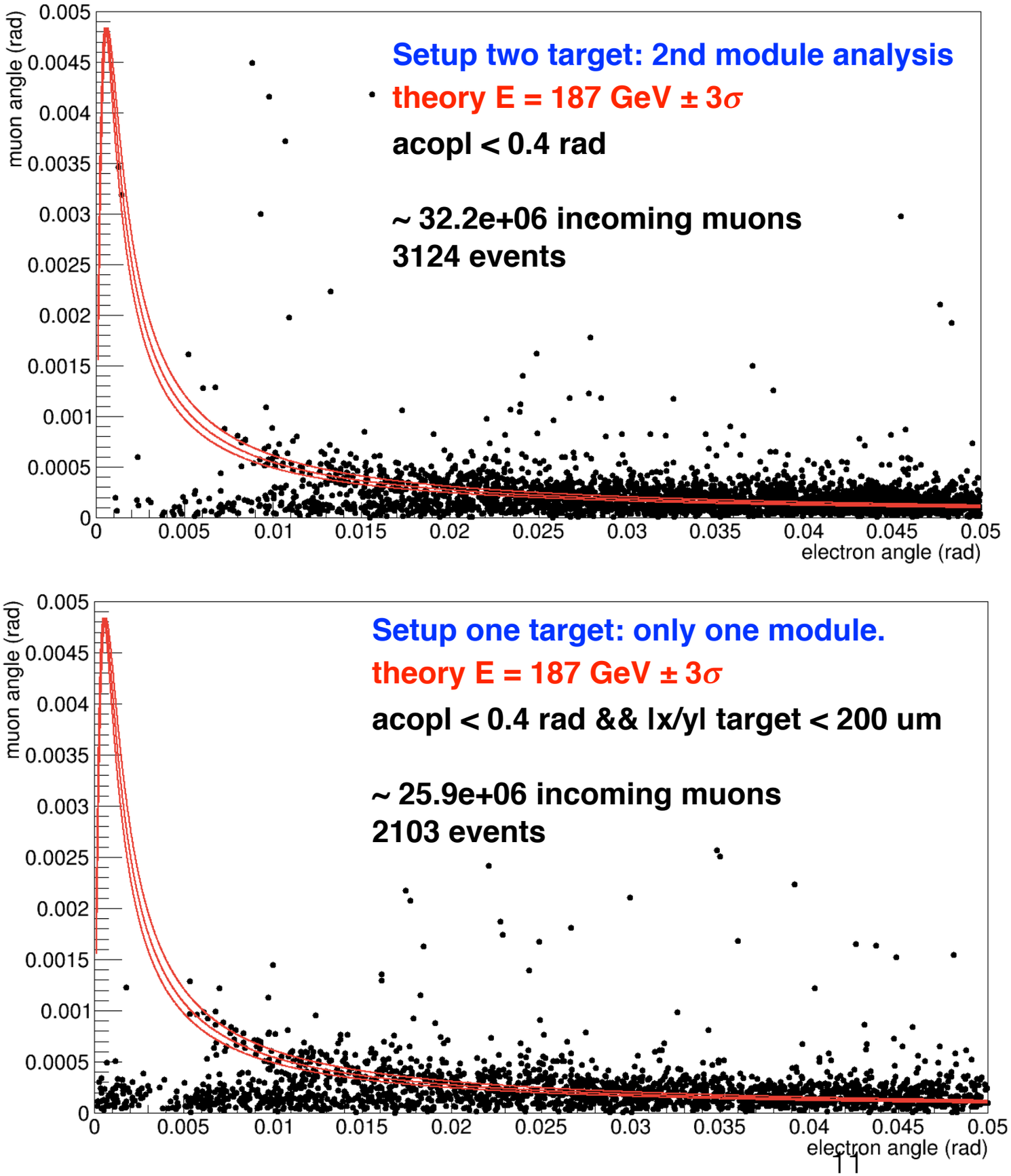
- Also the distribution of angle between muon and electron shows the same behavior: need of MC confirmation.

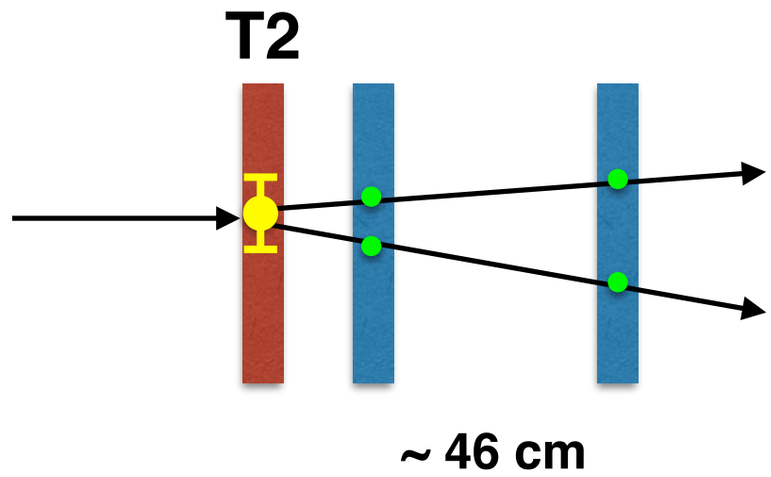
Correlation plots: selection variables

- Elasticity (not yet implemented)
- Acoplanarity: different definitions under study
- Track chi2 of secondaries
- Target constraint
- Energy (for calo details see Mattia's slides).

(other details in the backup slides)

Correlation plot θ_μ θ_e: tracker analysis (no calo)



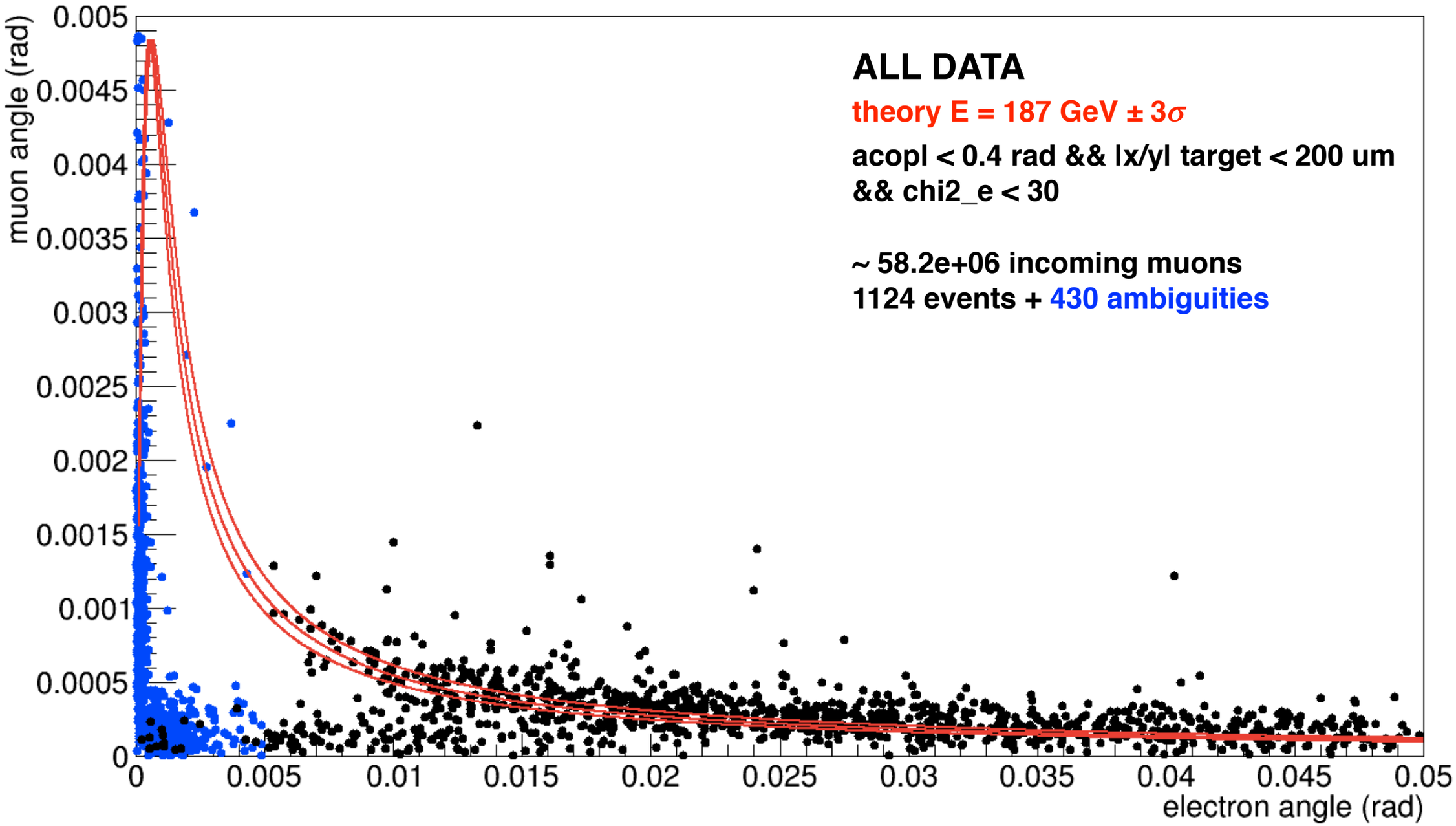


- Here, an analysis **without** calorimeter correlation.

- In the **second module**, after second target, there are only two stations: I created a chi2 with a third “fake” point on target of error of 70 um (from distribution of muon residuals at target). This vertex constraint cleans up pair background, in particular at low angles.

- With setup with only **one target**, interactions happen in T1: there is a better downstream resolution (~ 1 m).

Correlation plot θ_μ θ_e: tracker analysis (no calo)



ALL DATA

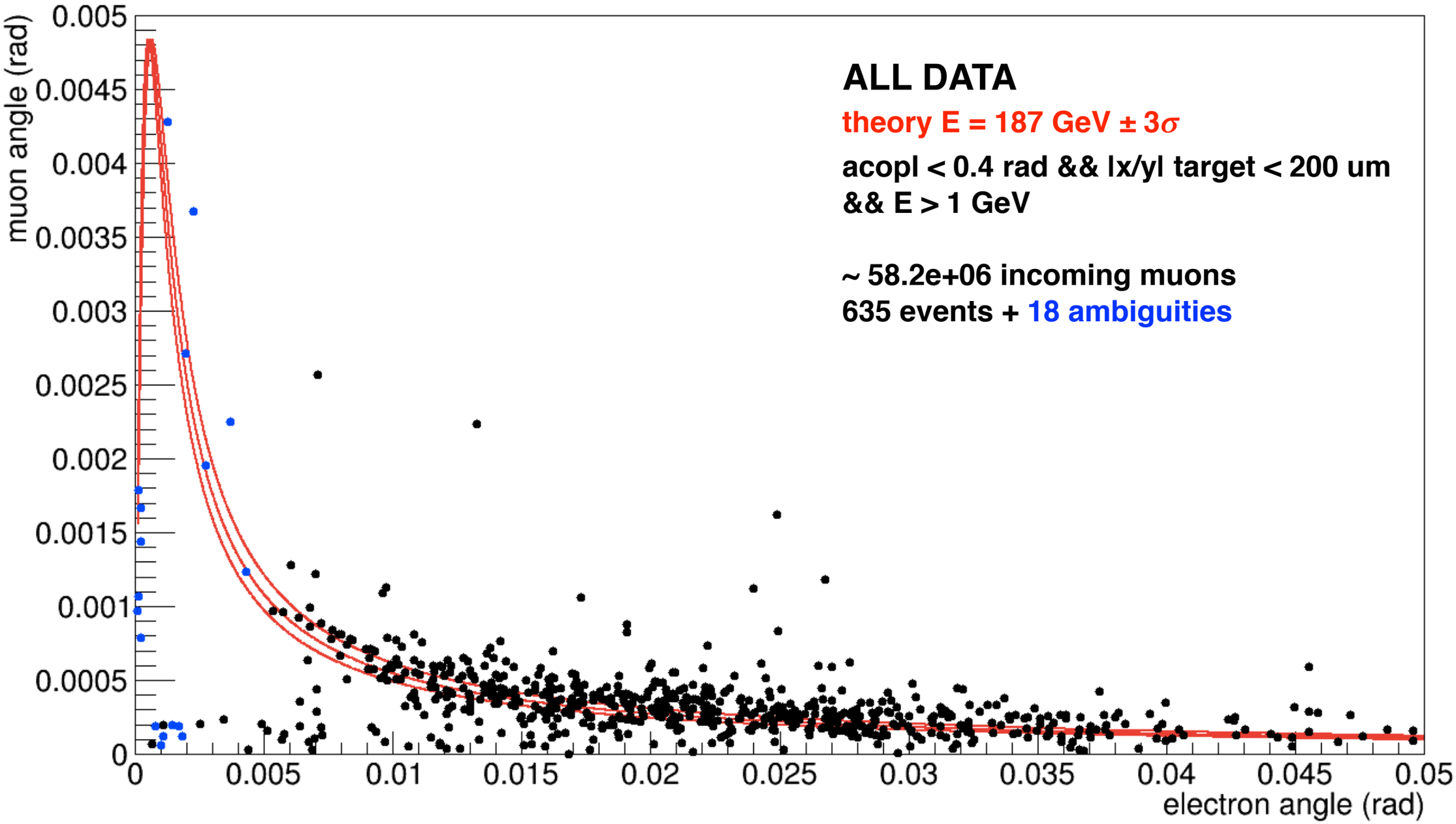
theory E = 187 GeV ± 3σ

acopl < 0.4 rad && |x/y| target < 200 um && chi2_e < 30

~ 58.2e+06 incoming muons
1124 events + 430 ambiguities

- Here also a chi2 cut for electrons which seems to clean up background after 20 mrad.
- Blue points are ambiguities: pattern reco algorithm is not able to discriminate mu / e; both have good chi2 and roughly same angles. Calorimeter could help in this case to identify electrons.

Correlation plot θ_μ θ_e: calo analysis, E > 1 GeV



ALL DATA

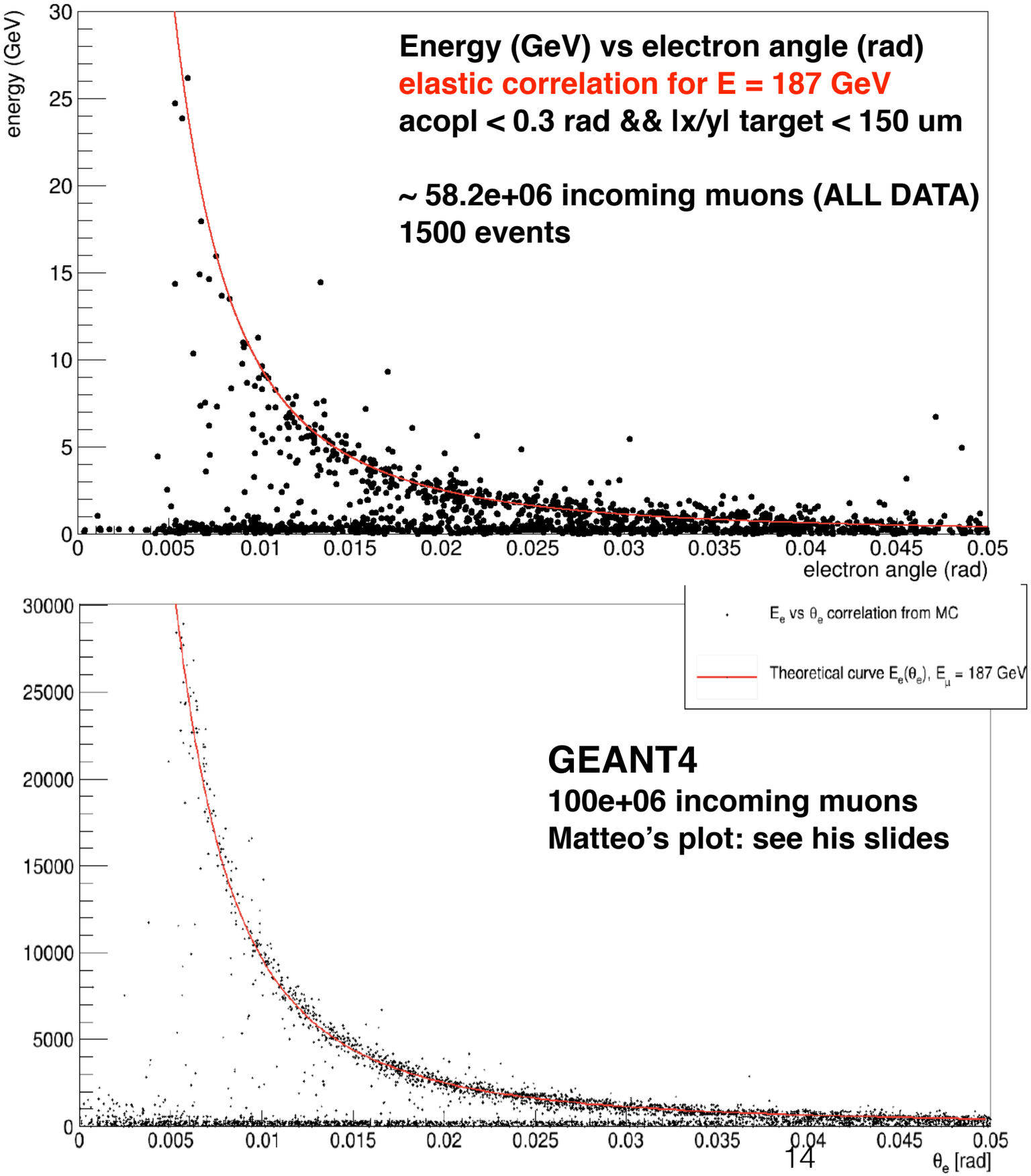
theory E = 187 GeV ± 3σ

acopl < 0.4 rad && lx/yl target < 200 um && E > 1 GeV

~ 58.2e+06 incoming muons
635 events + 18 ambiguities

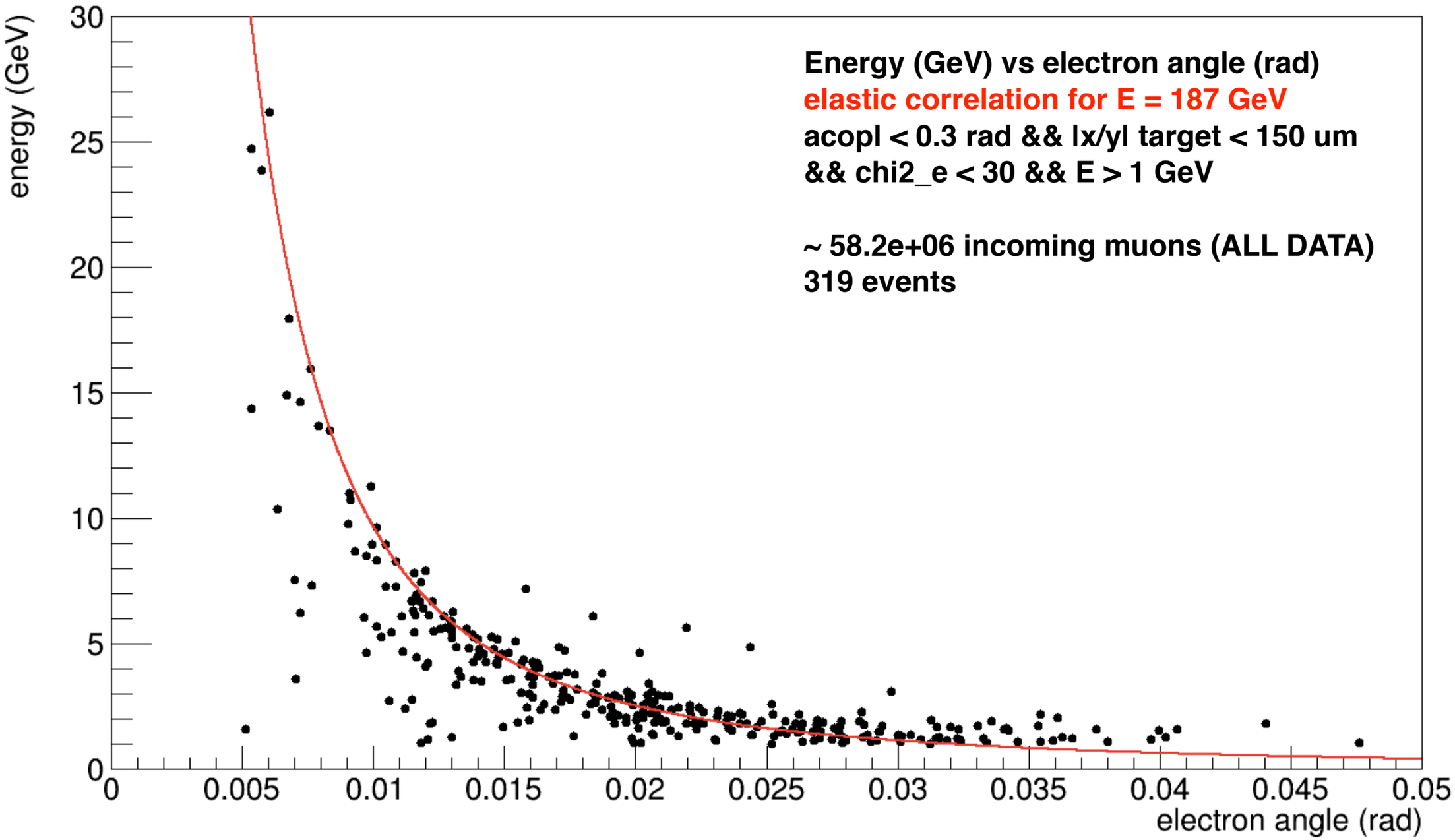
- Here a correlation with calo signal: energy cut of 1 GeV.
- Some blue points on the curve (ambiguity) could be recover to analyze energy deposition of the two tracks.

Correlation plot E_e θ_e (preliminary)



- Clear elastic correlation.
- There are a lot of events under the curve in data and also in Geant.
- Obviously cuts need quantitative MC studies on cut efficiency.

Correlation plot E_e θ_e: energy cut E > 1 GeV



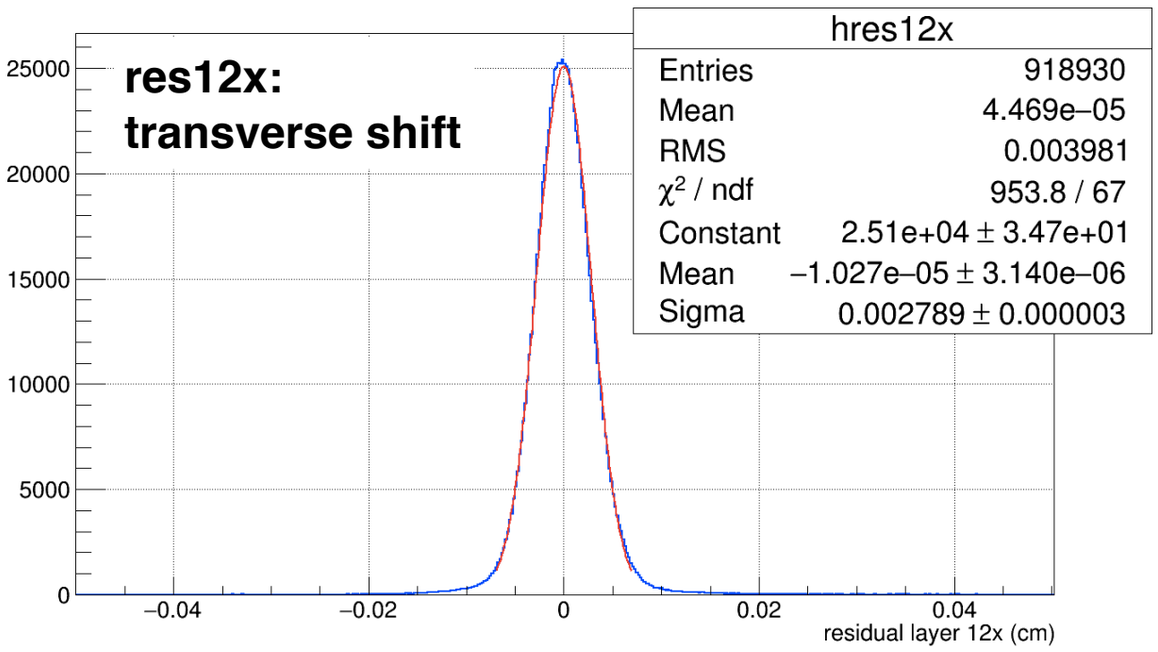
- Here also a chi2 and energy cut: E > 1 GeV. Events around the elastic curve in the previous plots θ_μ θ_e, at large electron angle, are surely “elastic events”.
- Calorimeter calibration to check.

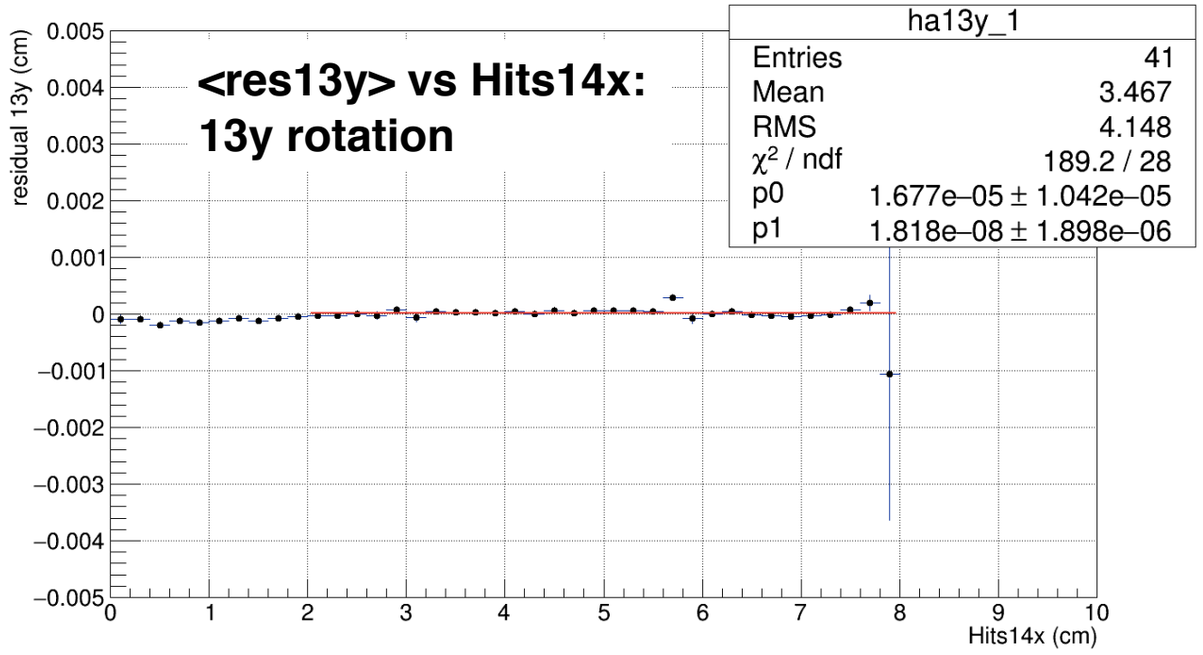
Conclusions

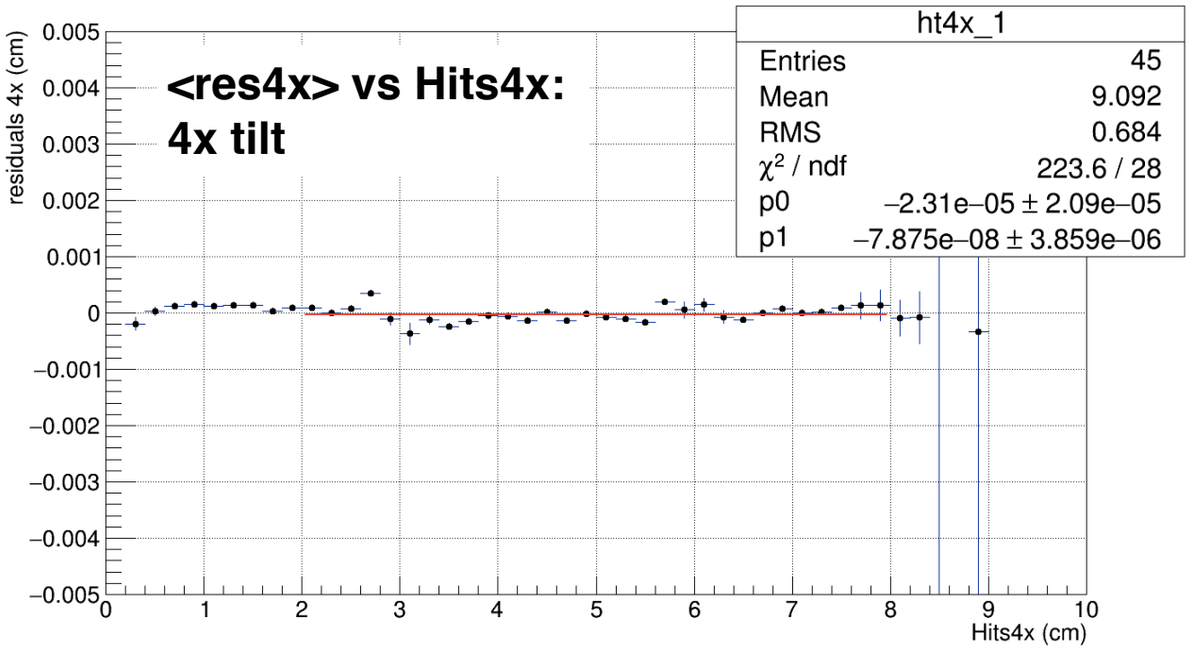
- Main analysis update: efficiency analysis and latest correlation plots.
- To do: analyze last setup data with new boxes and study more deeply selection variables, acoplanarity in particular.
- MC is needed to check cut efficiencies and possibly to extract some quantitative conclusion.
- Also it could be important to confirm efficiency analysis and the lack of events that worried us so much.

Backup slides

Trackers alignment: some examples

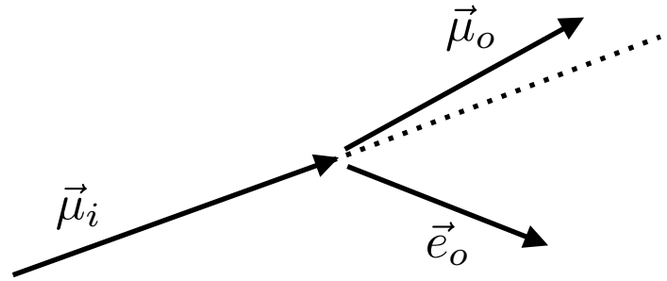




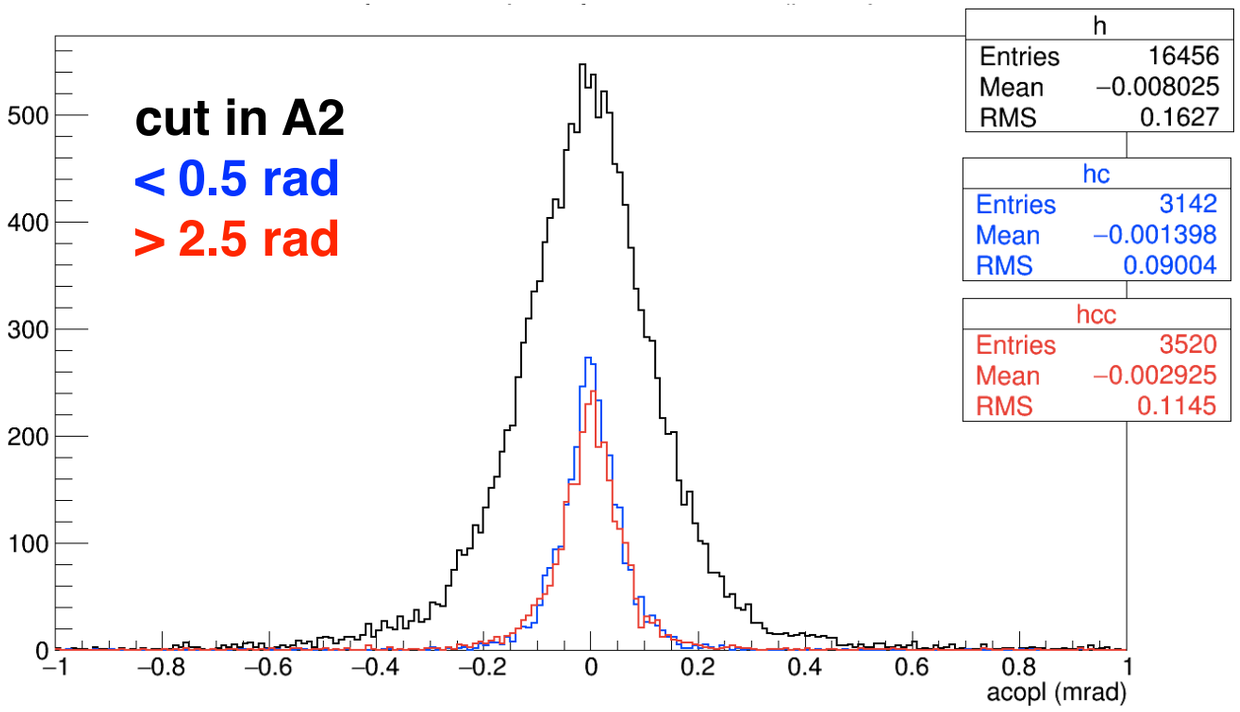


- Alignment has been achieved with residuals analysis, taking reference planes.
- Residual means (transversal shifts) are within 1 um.
- Correlation res vs hits (rotations along z axis) are within ~ 0.01 mrad.
- Also layer tilts was taken in account, analyzed with correlation res vs hits on the same view.

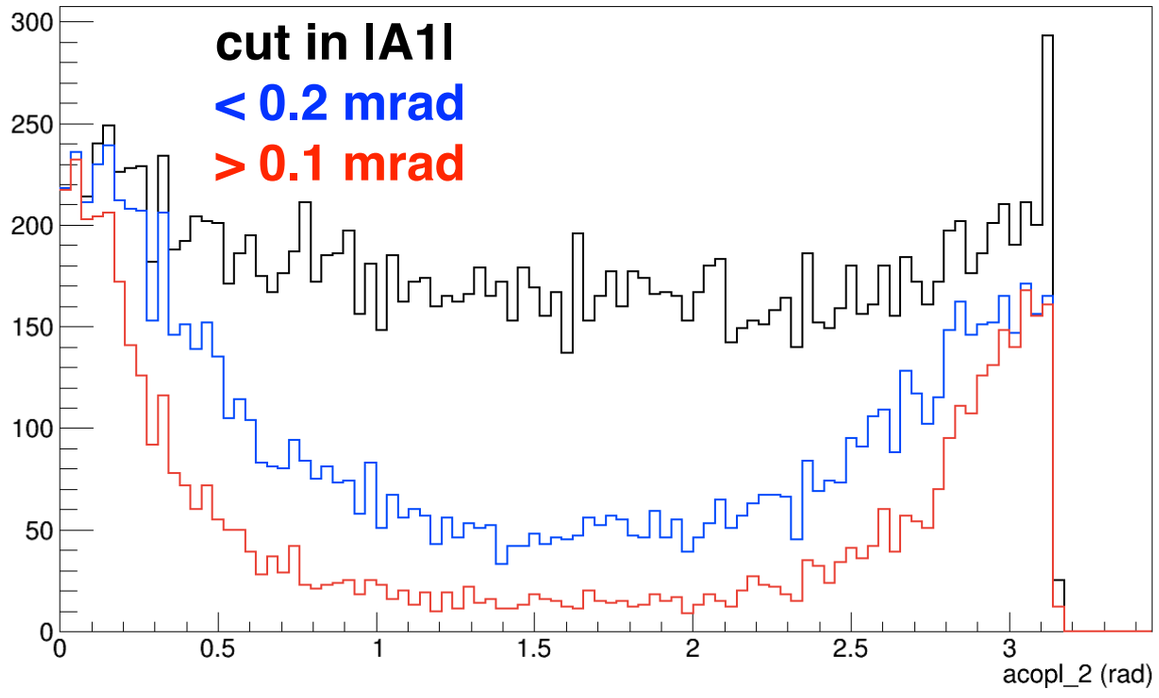
Selection variables: acoplanarity



A1 $$A = \frac{\pi}{2} - \arccos\left(\frac{\vec{\mu}_i \cdot (\vec{\mu}_o \times \vec{e}_o)}{|\vec{\mu}_i||\vec{\mu}_o \times \vec{e}_o|}\right)$$

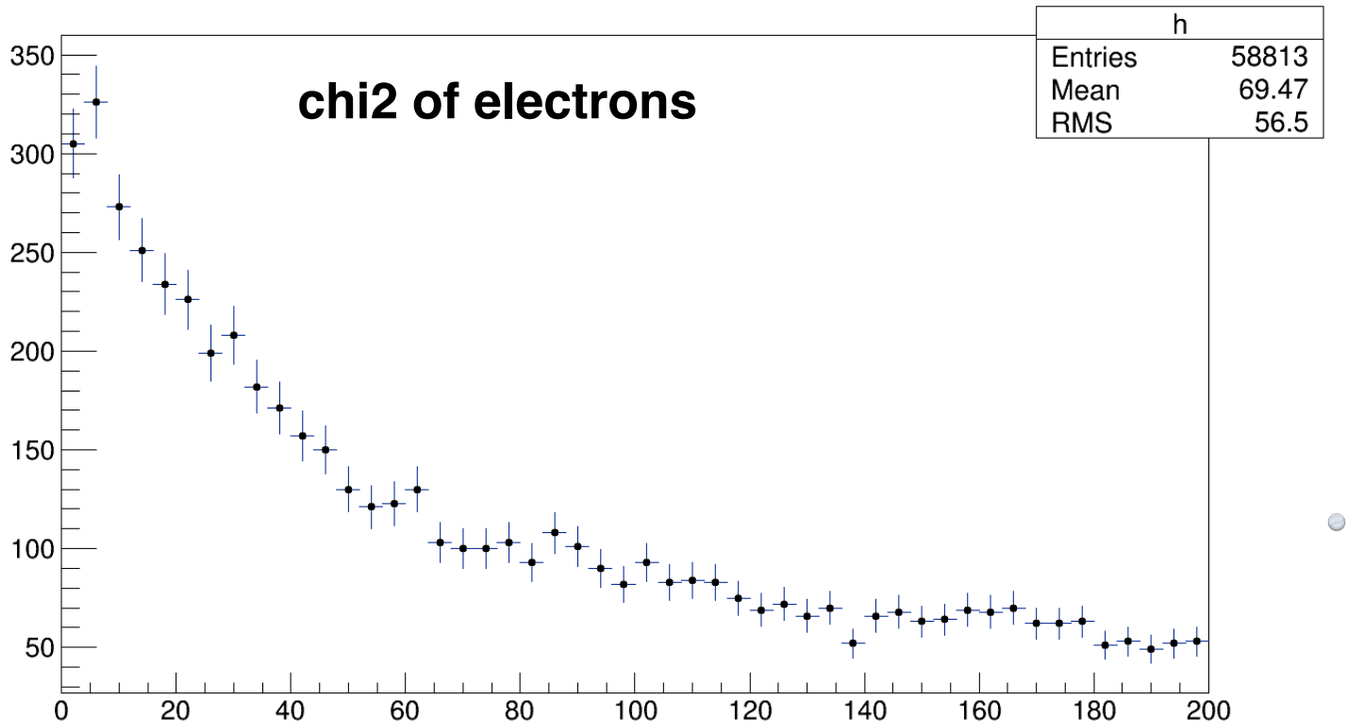


A2 $$A = \pi - \arccos\left(\frac{(\vec{\mu}_i \times \vec{\mu}_o) \cdot (\vec{\mu}_i \times \vec{e}_o)}{|\vec{\mu}_i \times \vec{\mu}_o||\vec{\mu}_i \times \vec{e}_o|}\right)$$

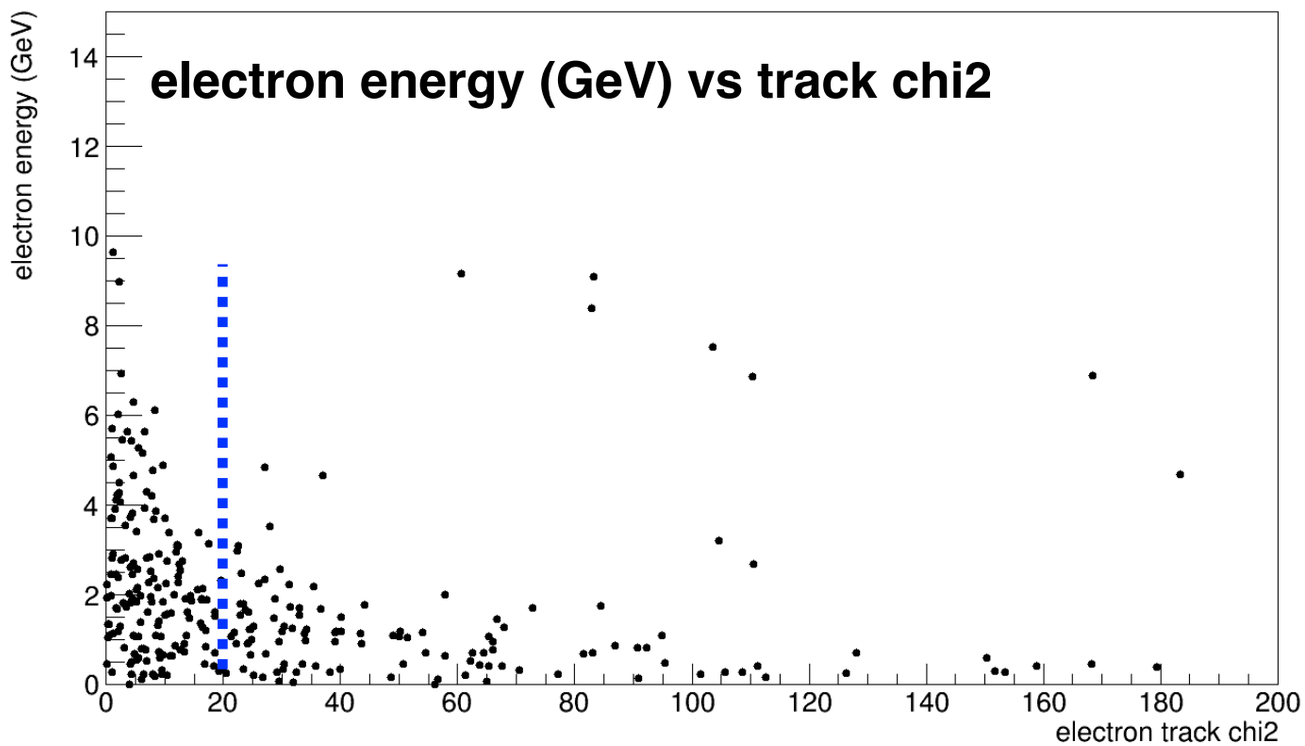


- A1 = 0 (coplanarity); A2 = 0, pi (coplanarity) and only A2 = 0 for back-to-back particles.
- Second definition of acoplanarity requires to cut at high angle values ~ 0.3 - 0.4 rad, however its action seems good and stronger than the first one.
- These variables needs further work and also in this case MC will fundamental to study cut efficiency.

Selection variables: track chi2

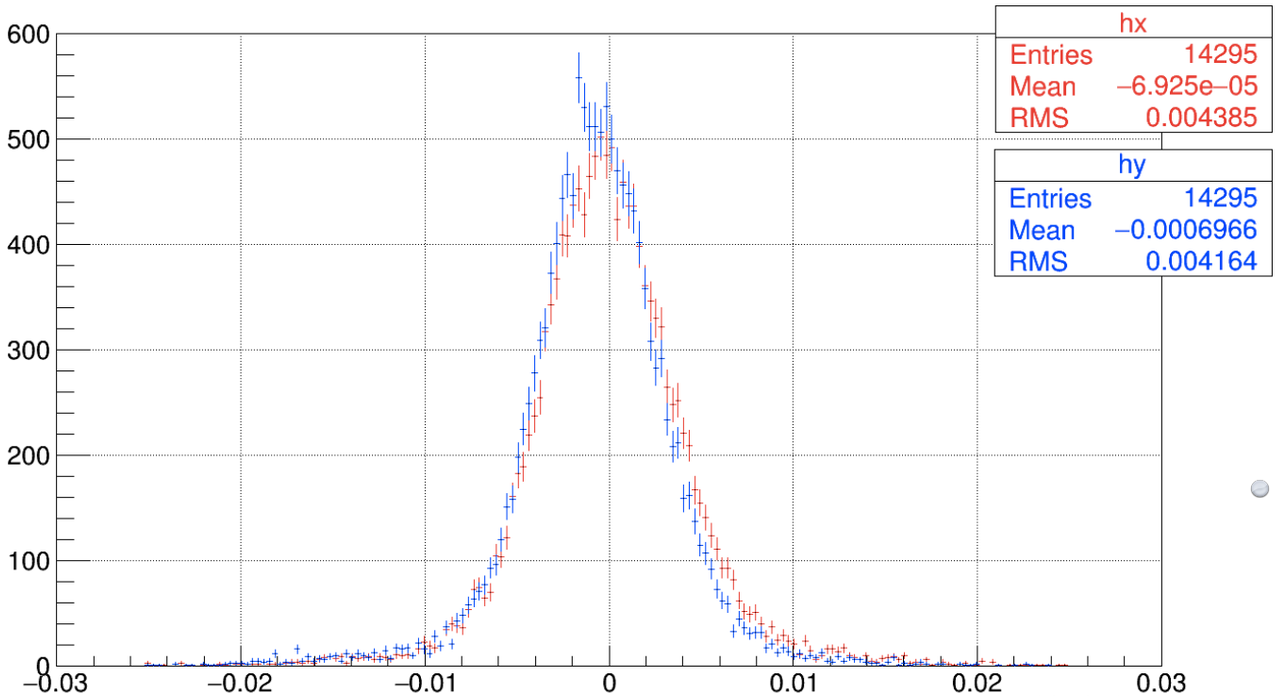


- Chi2 distribution of secondaries looks like roughly regular, considering that tracking errors for electrons are underestimated.



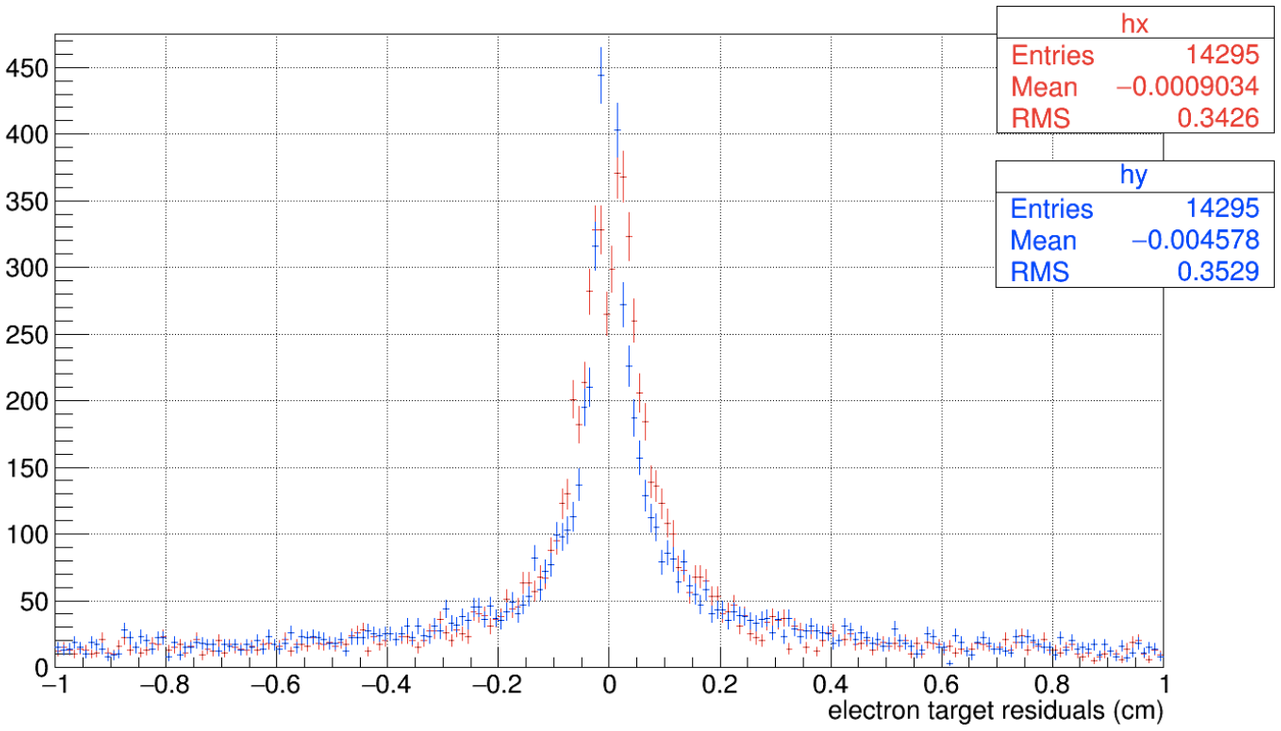
- Old discussion: there is a correlation between energy and track chi2, on average energetic particles have better chi2.
- However an hypothetical **chi2 cut** to select energy seems not too sharp.

Selection variables: target constraint

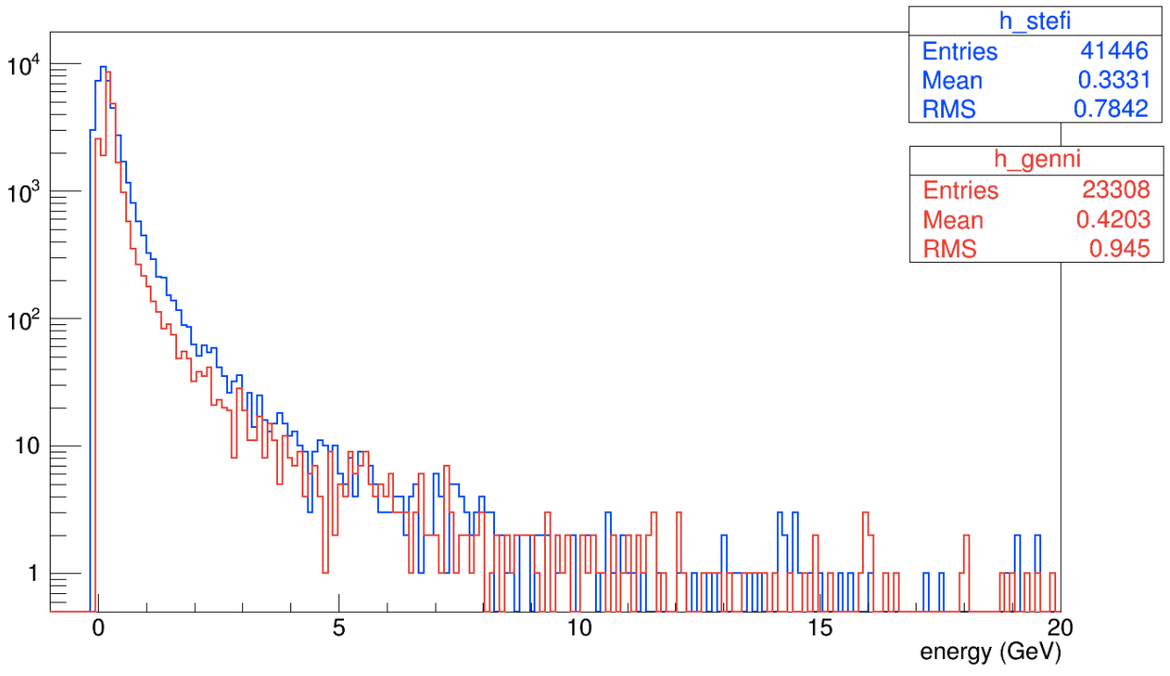


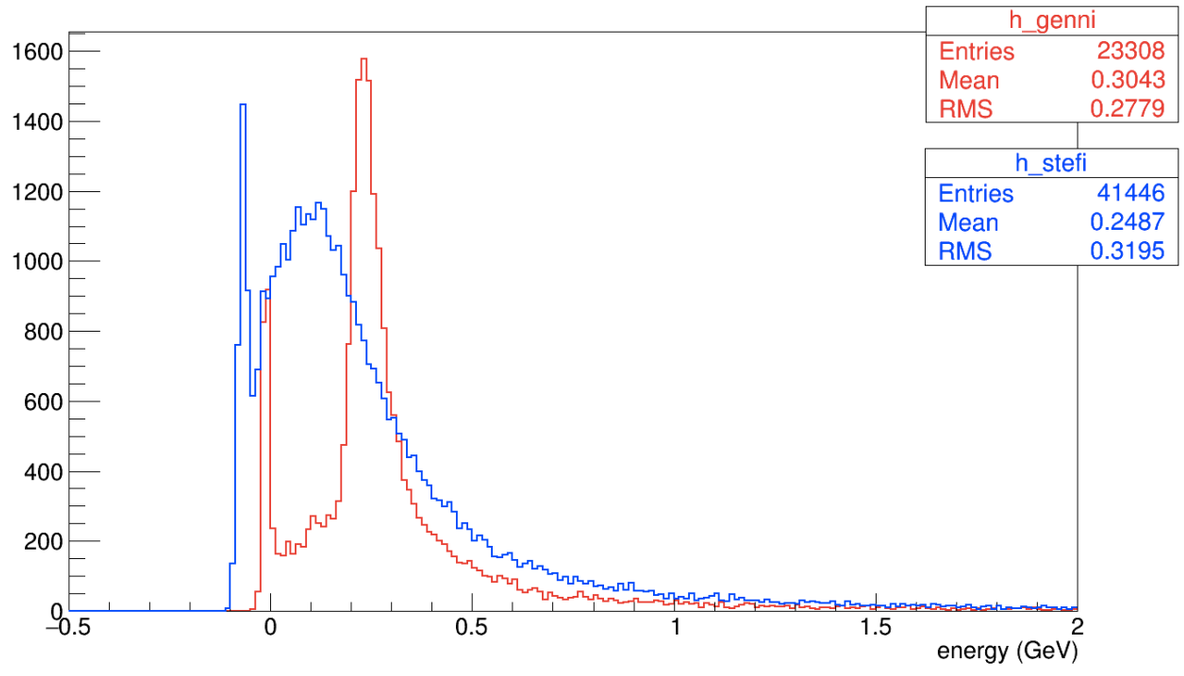
- **Residuals** between extrapolation of income muon tracks and the one of output tracks of eletrons and muons.

- For muons, the sigmas are ~ 70 um.
- For electron ~ 450 um with long tails probably due to multiple scattering on silicon planes.
- For both the fit gaus means are within ~ few microns.
- This variable seems very useful because it looks like well defined and with a clear physical meaning: constraint of interaction vertex.



Selection variables: energy (preliminary)





Calorimeter analysis: tracks at calo position