

Test beam analysis of SiW ECAL physics prototype in 2011 FNAL

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Calice Meeting@Annecy
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Outline

Study of response of Calice SiW Physics Prototype to **positrons** (4eV~32GeV)

May 2011 @FNAL

- **Introduction**

- Physics prototype, Setup, Beam

- **ECAL performance study**

- Linearity, Energy resolution, gap correction

- **Pandora performance study with the TB data**

- Separation power of 2 overlapped clusters

SiW Physics Prototype

Sandwich calorimeter

Active layer

(pixel) 1cm×1cm

(pad) 6 × 6 pixels

(layer) 3 × 3 pads, (guard ring: 1mm)

(module) 30 layers

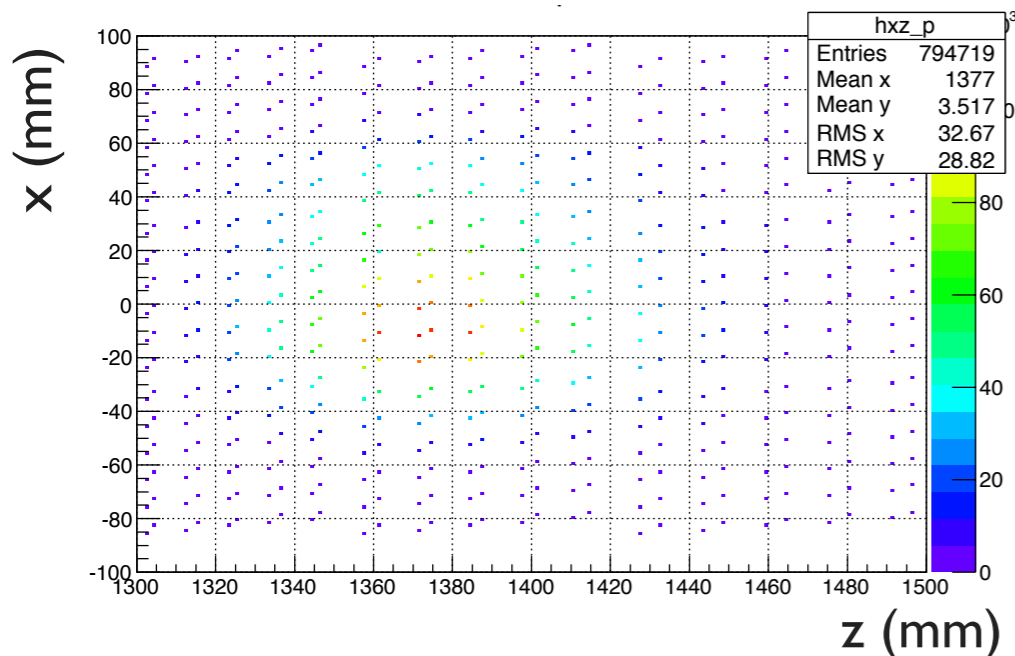
Absorber different thickness

0~9th layer: 1.4mm

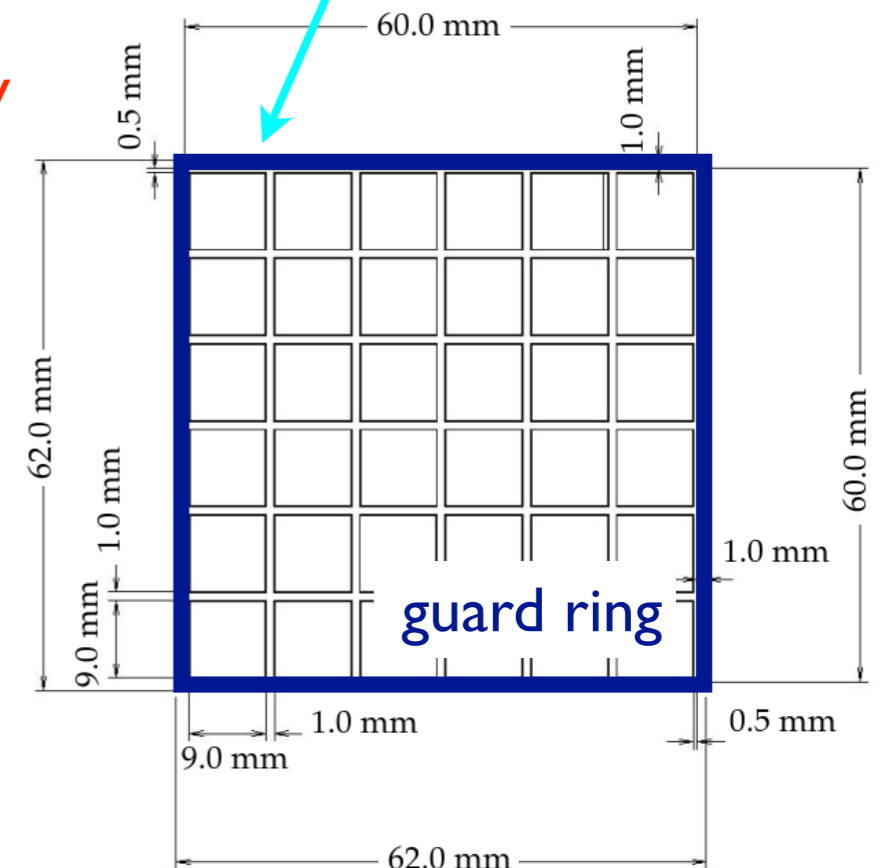
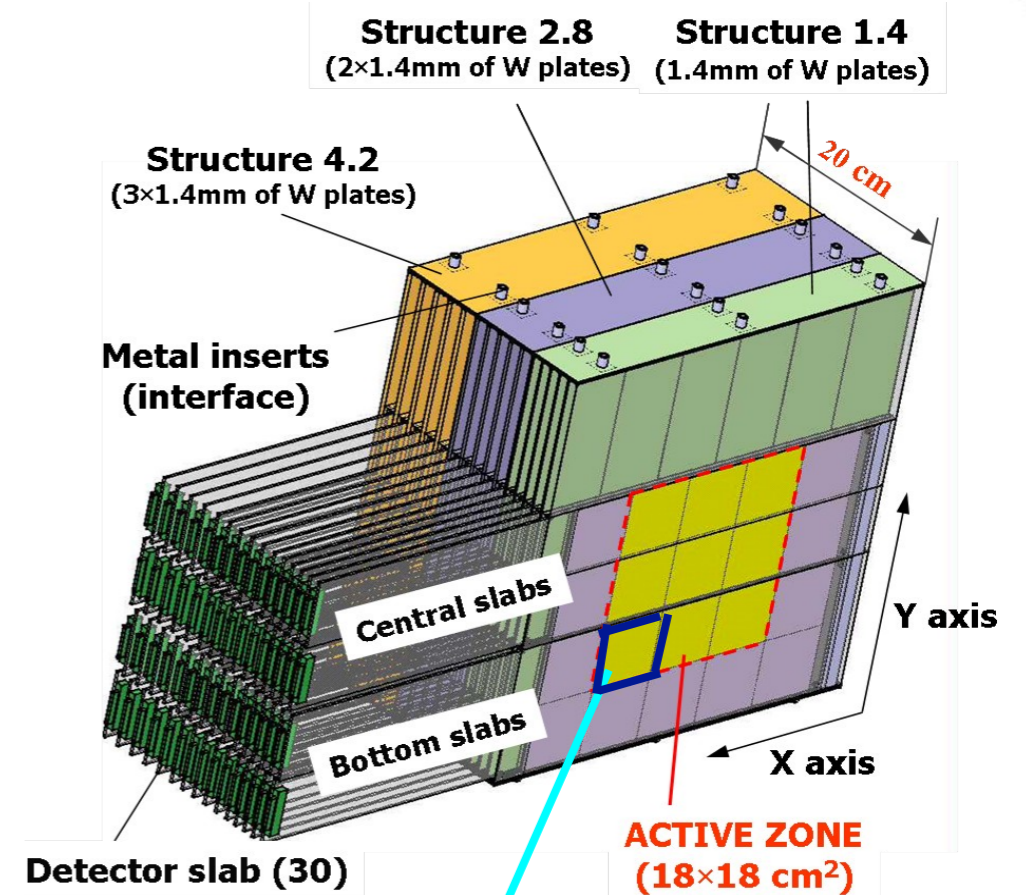
10~19th layer: 2.8mm

20~29: 4.2mm ⇒ Different weighting in calculate total energy

Staggered stacking in x direction



← center position of pixels



TB setup

Other detectors

Trigger cerencov (not used in this analysis) in the front
DHCAL behind

⇒ hit number information is available !

Beam

Pion dominant (Muon are available with a blocker)

Beam profile - flat along y direction

Momentum spread:

2.7 ± 0.3 % for 2-4GeV

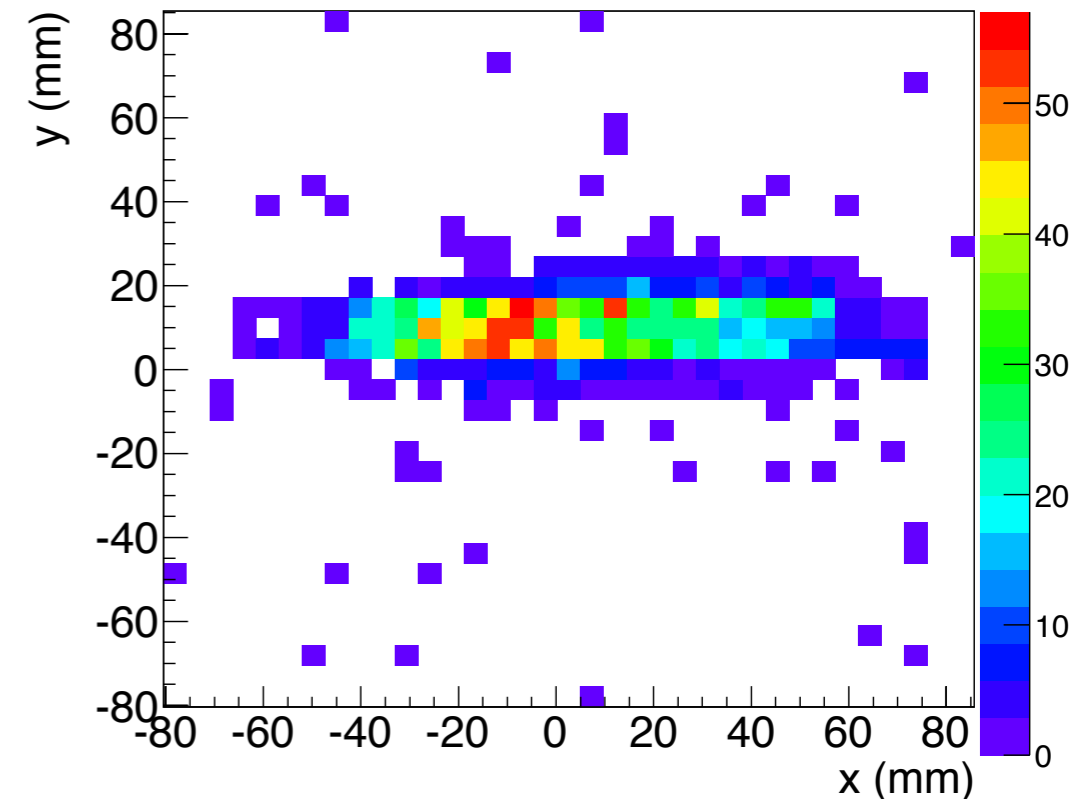
2.3 ± 0.3 % for 8-32GeV

Data selection

Based on MIP, noise rate

Runs with too small statistics are also discarded

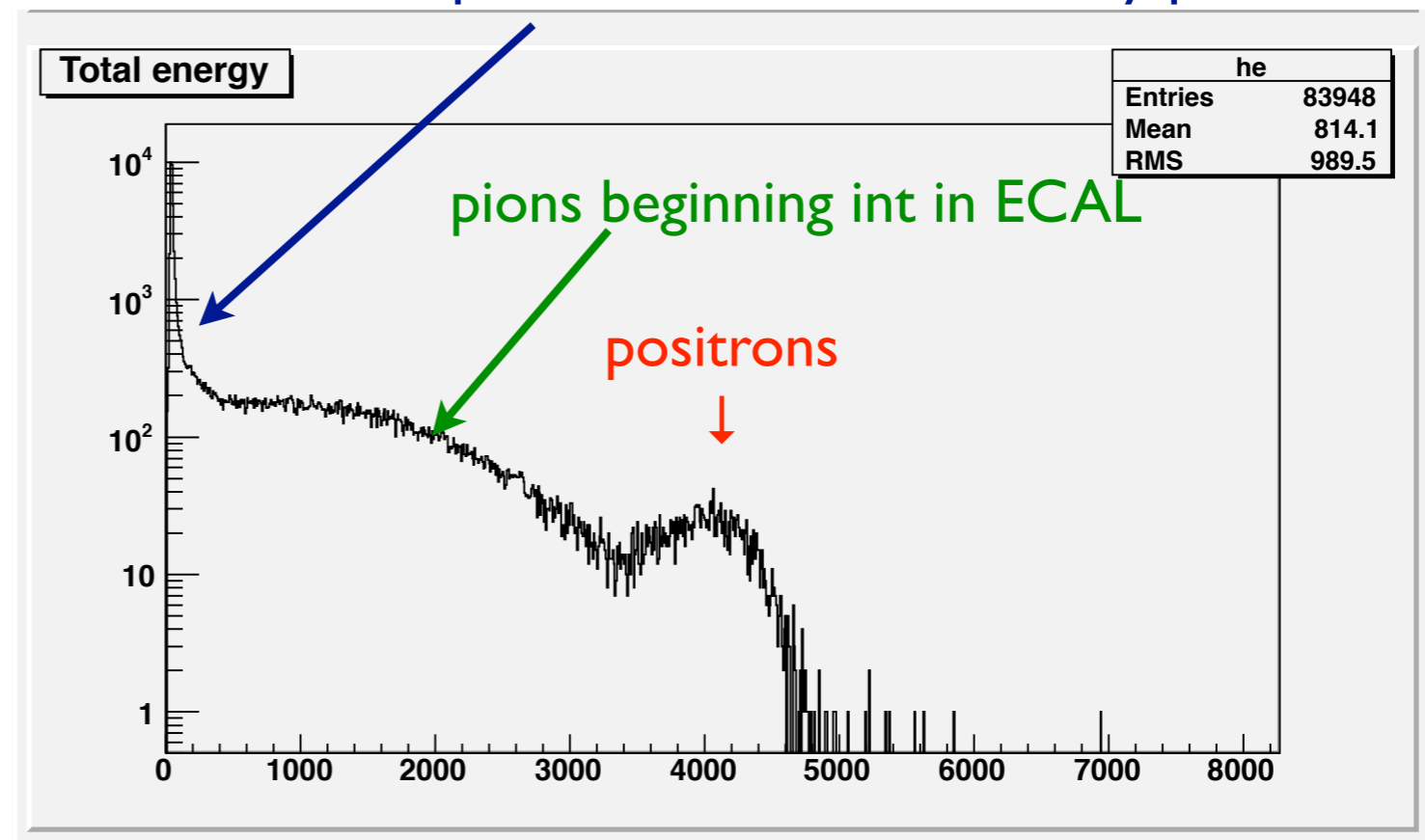
Beam profile



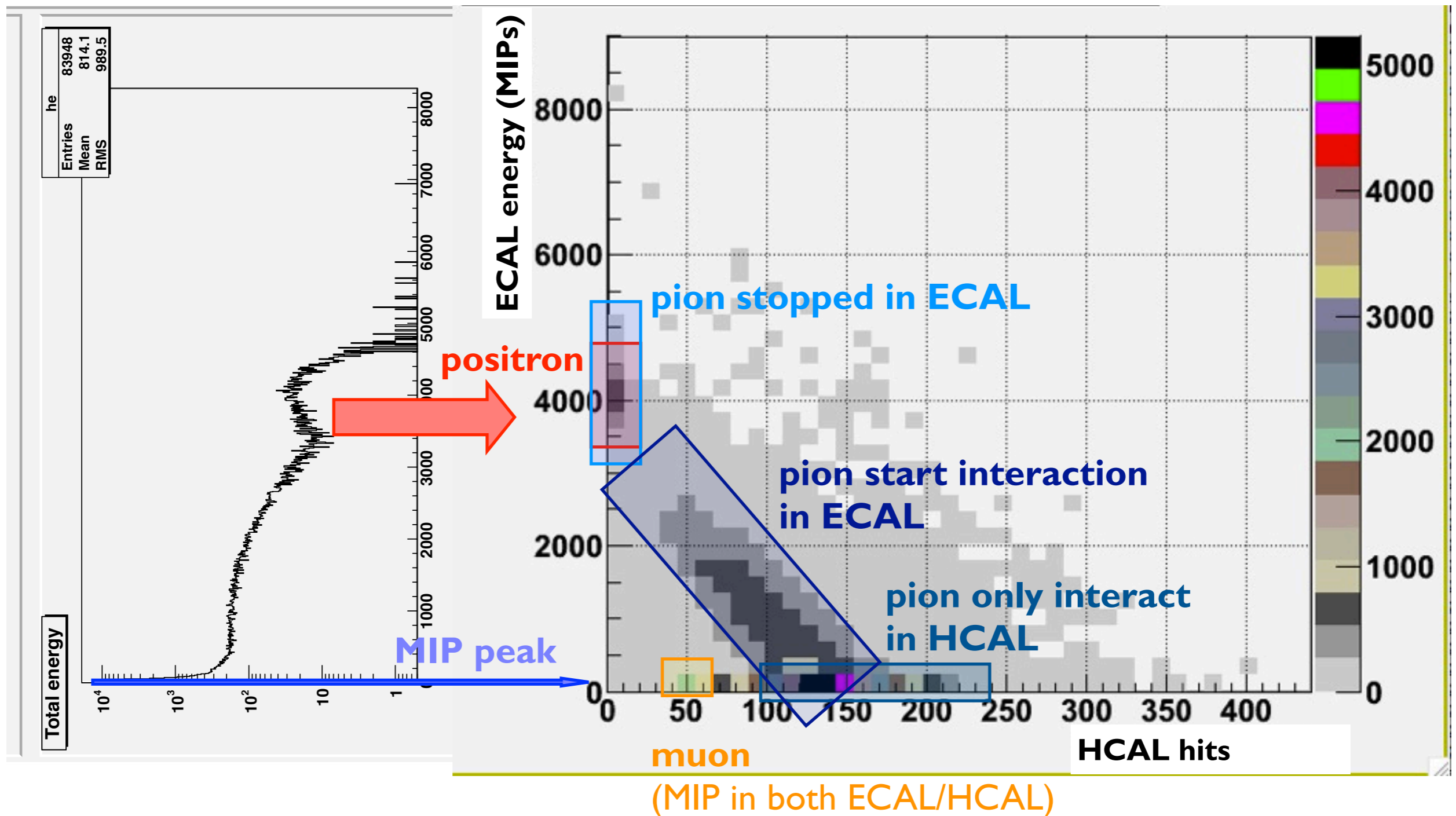
Looking for positrons out of the sea of pions...

Positron Event selection

MIP peak of muons / some lucky pions



Energy deposit in ECAL vs Hits in HCAL



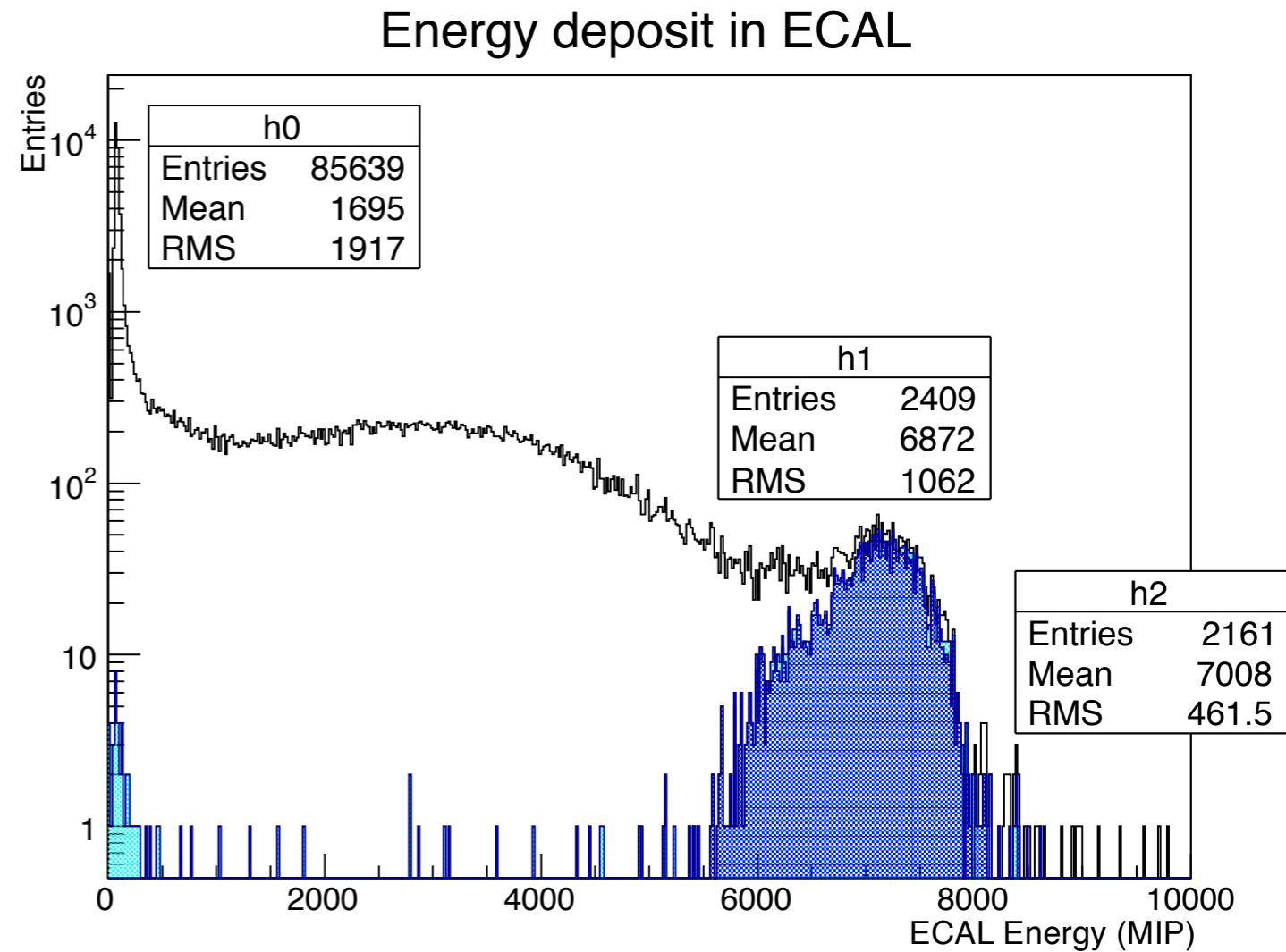
pion stopped (fully interacting) in ECAL \Rightarrow Large part of energy is likely to be taken by π_0 component. (Anyway EM)

Event selection

- # HCAL hits < 5
- # ECAL hits > 10

After MIP-GeV calibration

- $0.6 * E_{\text{beam}} < E_{\text{ECAL}} < 1.4 * E_{\text{beam}}$



Additional selection

- Moliere radius < 30mm (cut noise / multi-shower events)
(definition) 90% coverage of hit energy around the barycenter
If true positron, Moliere radius ~20mm
- Removed events with an entire wafer firing (noise)

ECAL Performance

- Linearity
- Energy resolution

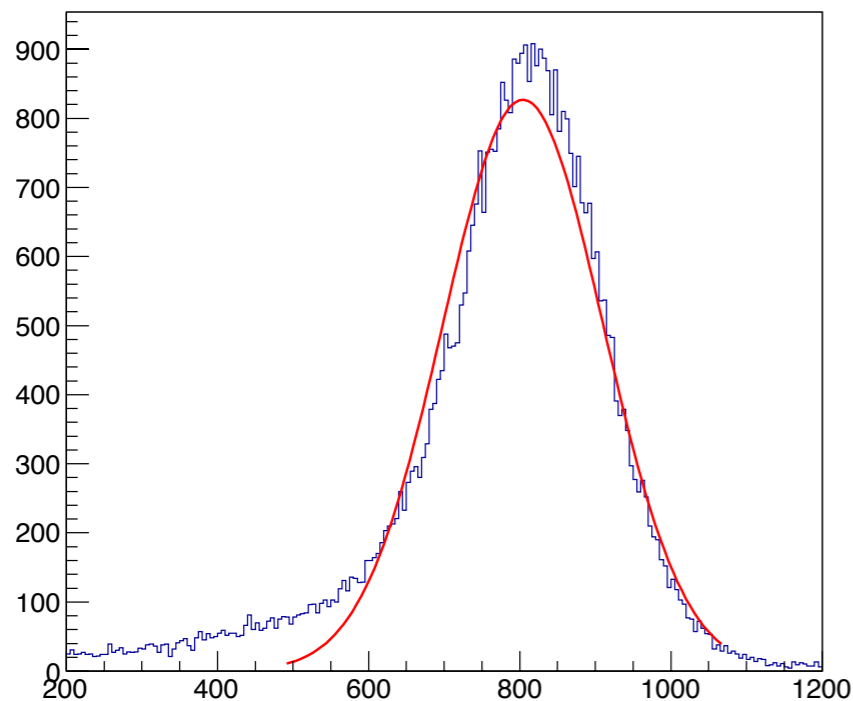
Fit the energy distribution of the selected sample

Fitting range:

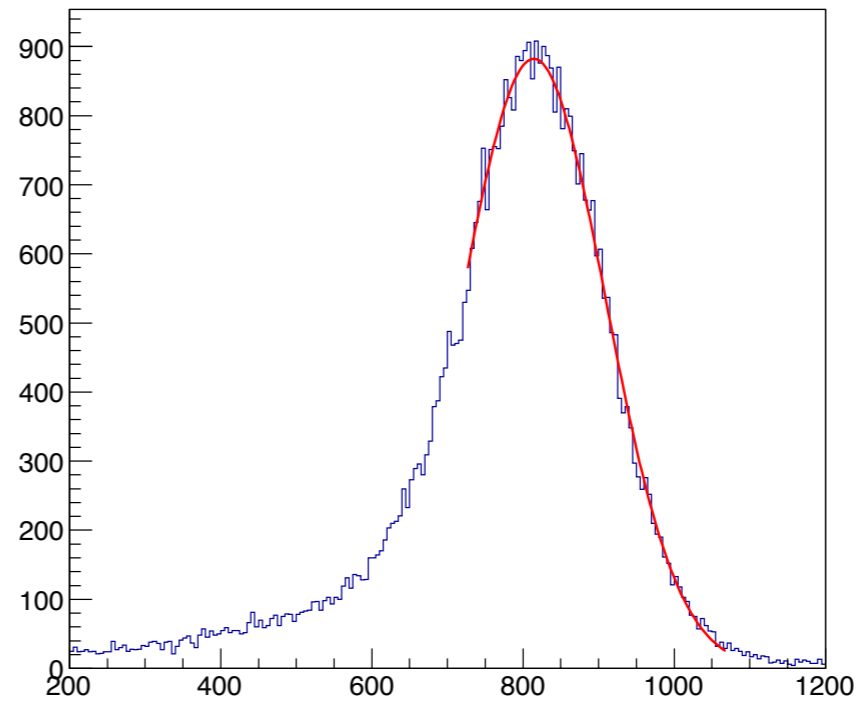
[mean - 2σ + $1.5*|skewness|*\sigma$, mean + 2σ]

Lessen the influence of negative tail

[mean- 2σ , mean+ 2σ]

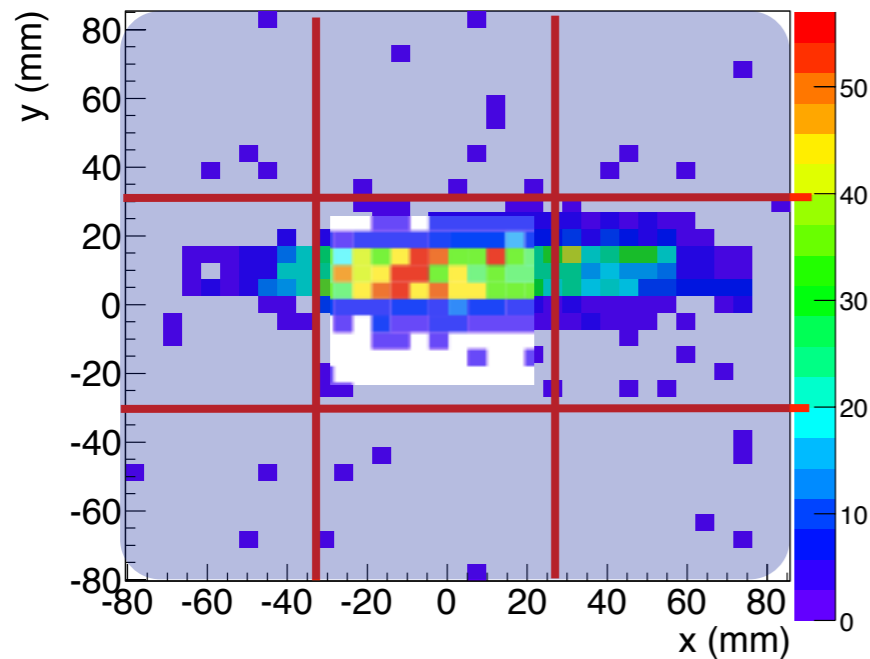


[mean - 2σ + $1.5*|skewness|*\sigma$, mean + 2σ]



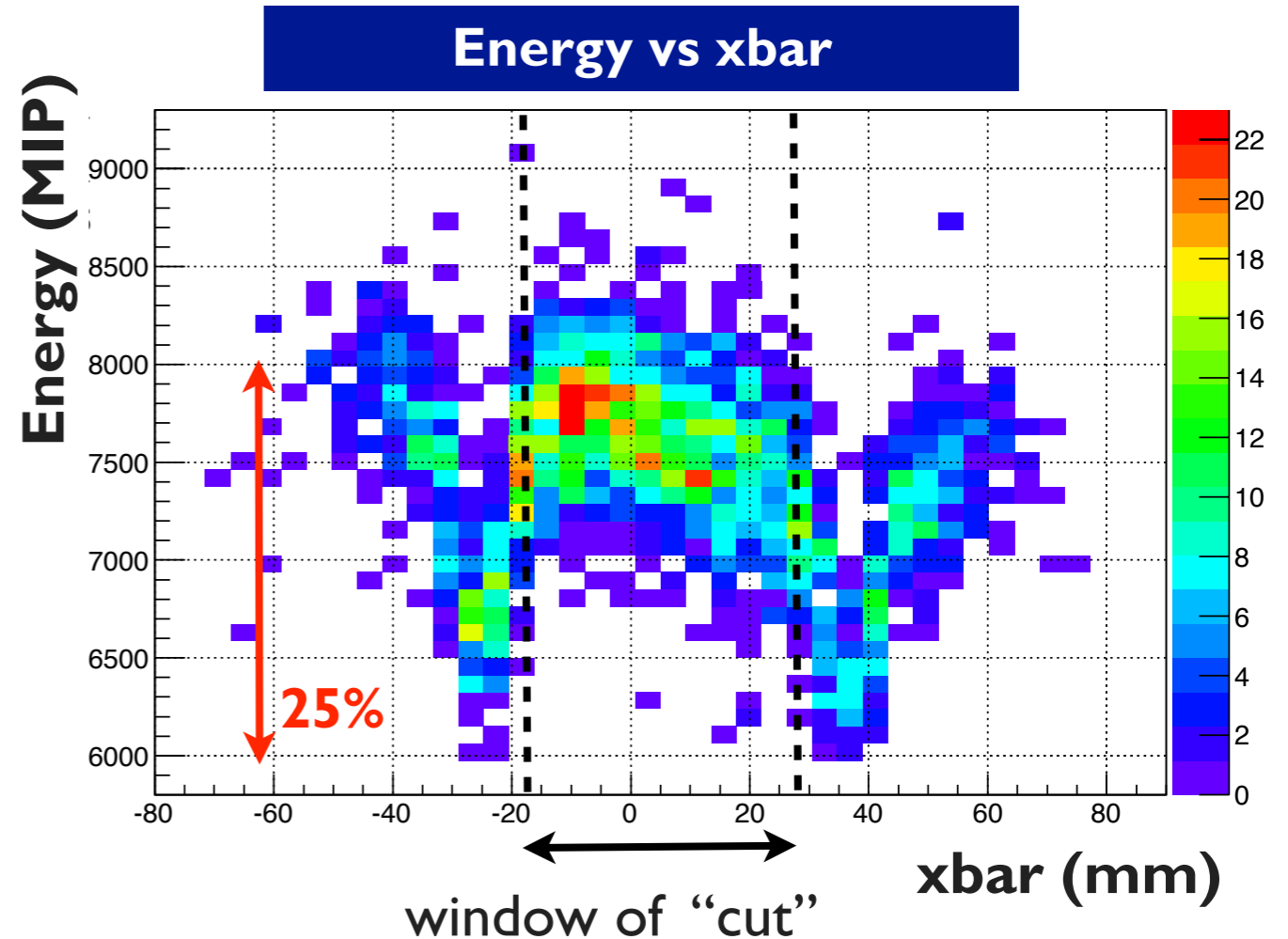
Gap events treatment

① Cut



$$-18\text{mm} < \bar{x} < 28\text{mm}$$

$$-25\text{mm} < \bar{y} < 25\text{mm}$$



barycenter

$$(\bar{x}, \bar{y}) = \left(\frac{\sum_i E_i x_i}{\sum_i E_i}, \frac{\sum_i E_i y_i}{\sum_i E_i} \right)$$

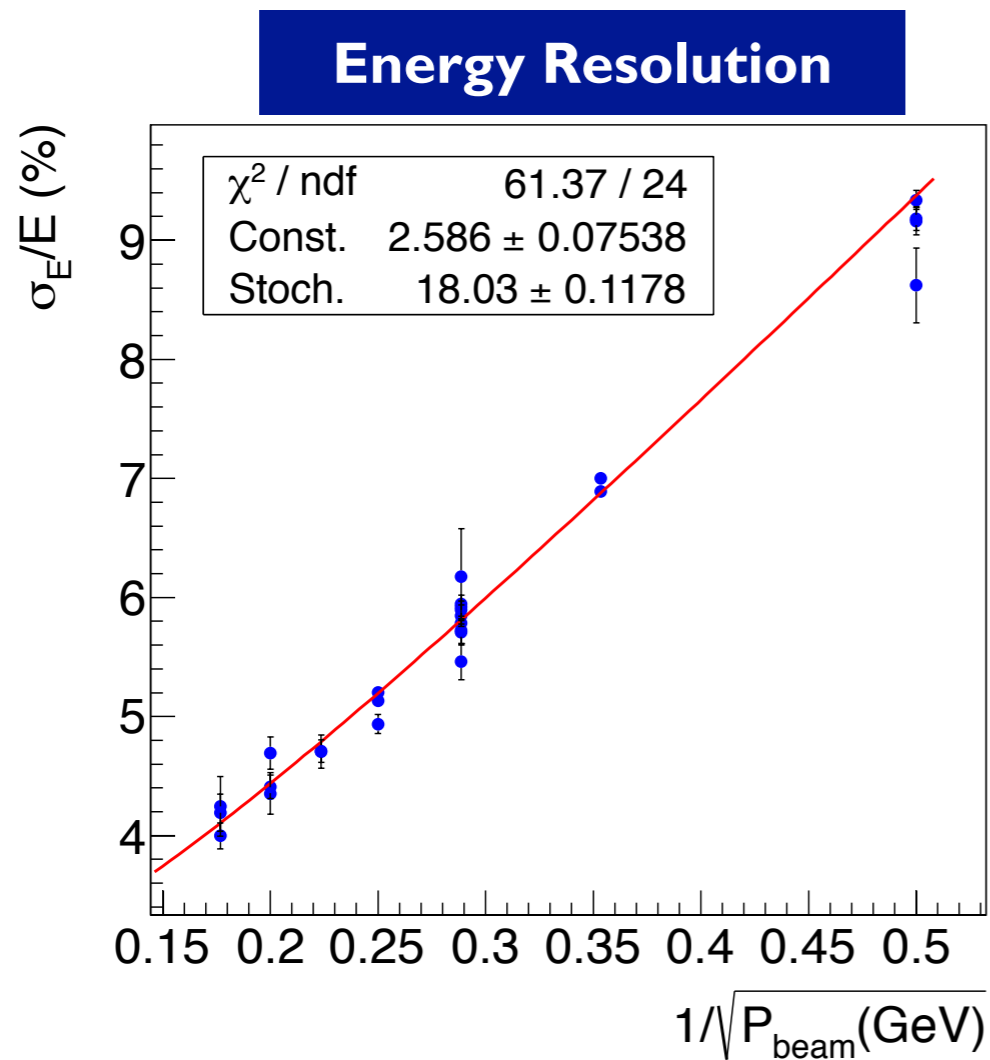
E_i : hit energy

x_i, y_i : x/y position of hit i

② Correction → Cut

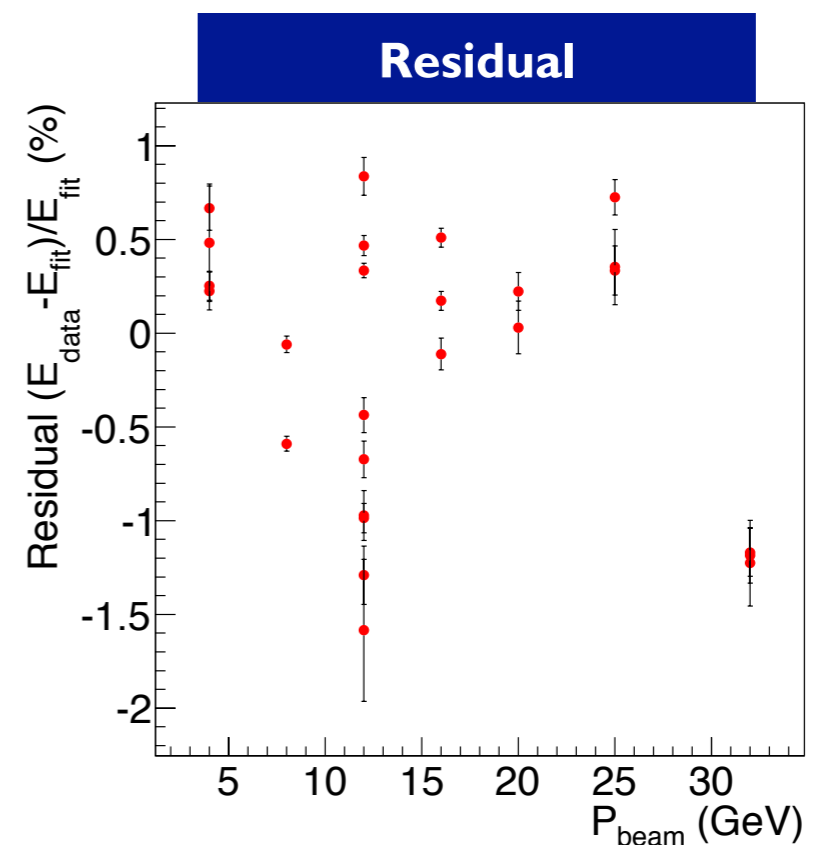
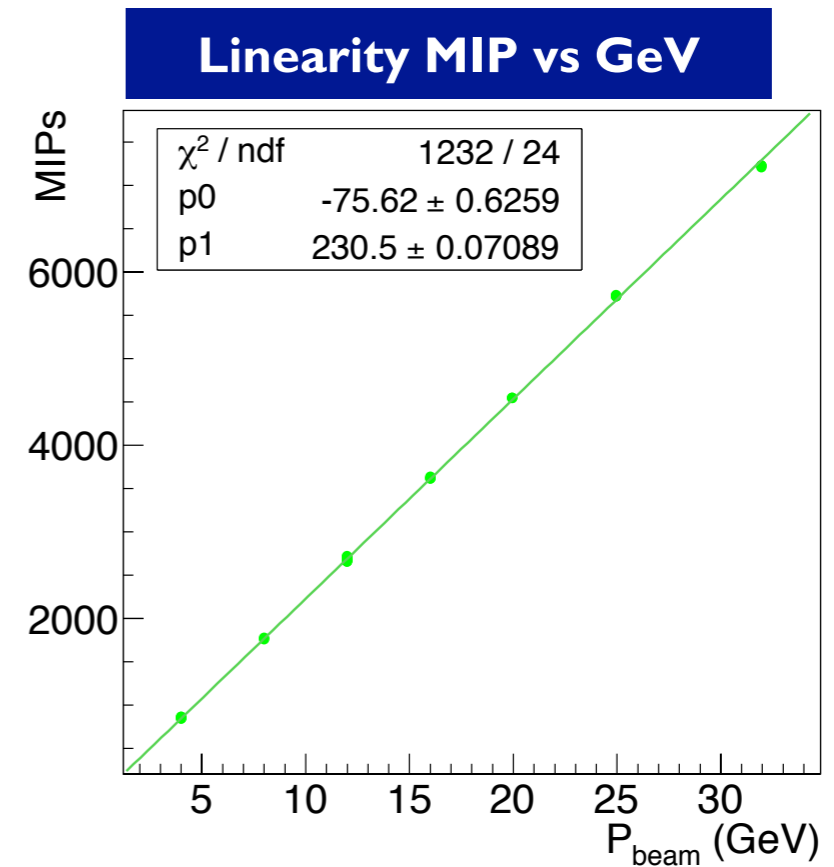
- Area based correction
- Fitting correction

Resolution / Linearity (Cut)



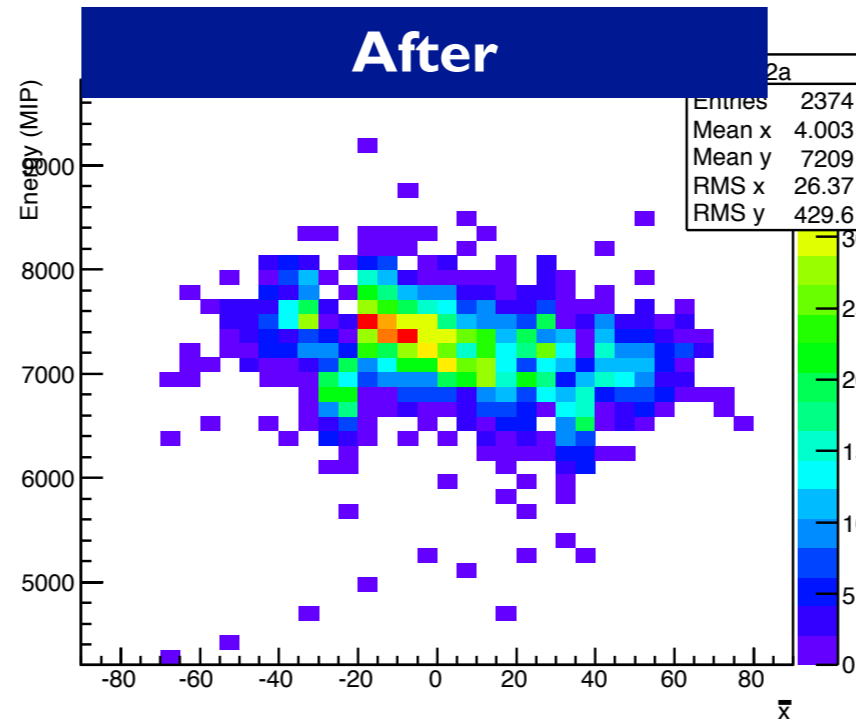
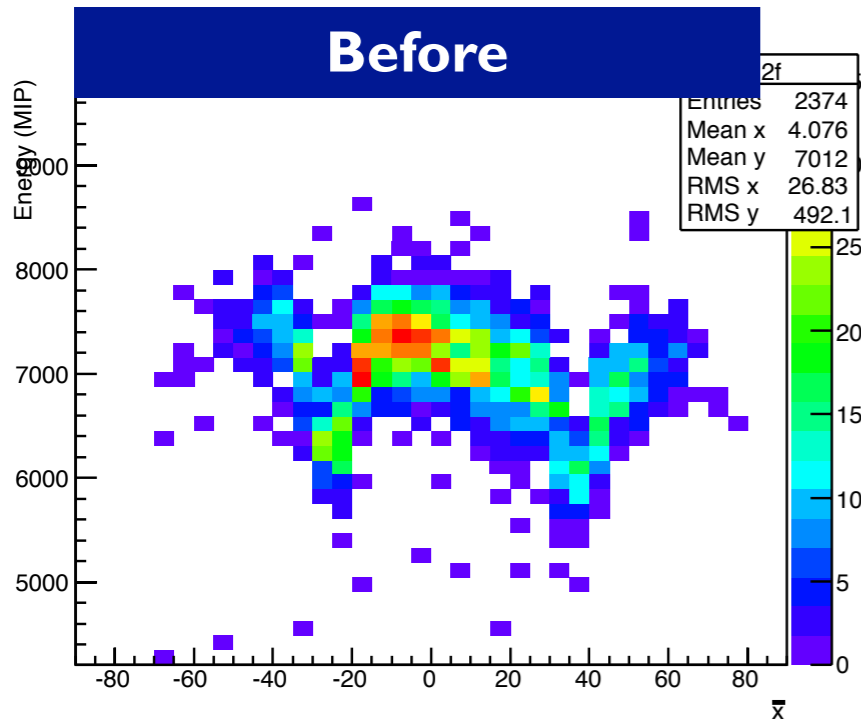
■ Non-linearity:
within +1.0% -1.5%

■ Resolution
(Const.) 2.59%
(Stoch.) 18.0%



Area based correction

$$E'_{\text{gaphit}} = E_{\text{gaphit}} \times \frac{2.15\text{mm}/2}{10\text{mm}}$$

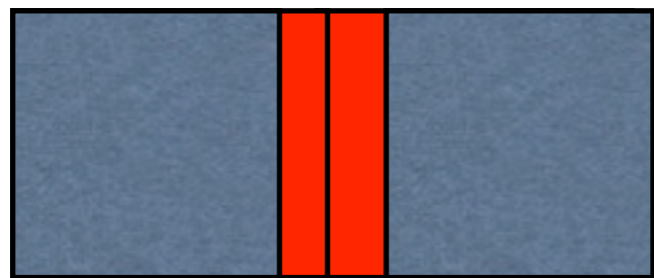


If the adjacent two cells over the gaps both get hits

→ multiply a factor defined by the dead area

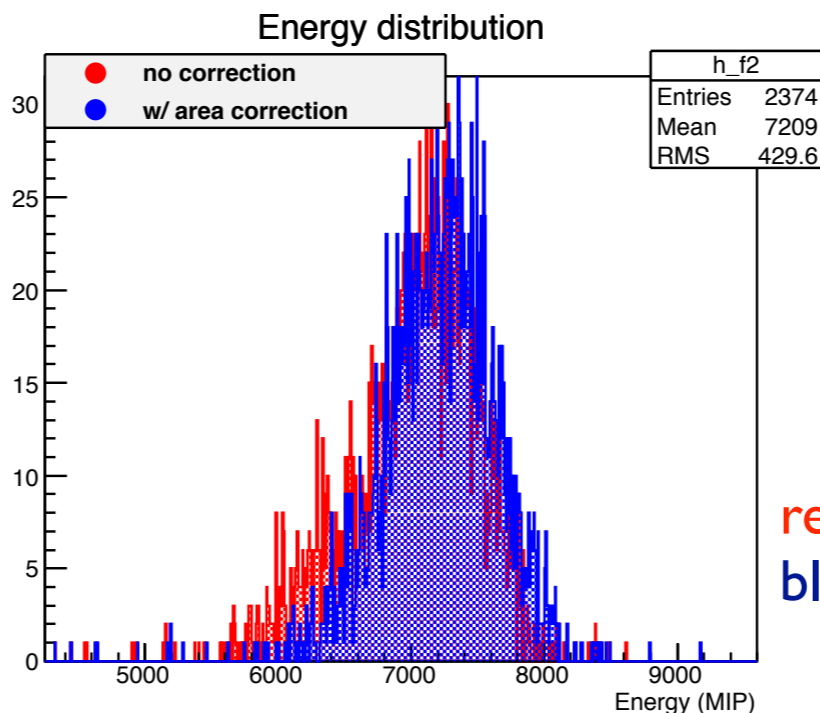
The “tail” events are much improved

Gap: 2.15mm



pix: 10mm

pix: 10mm

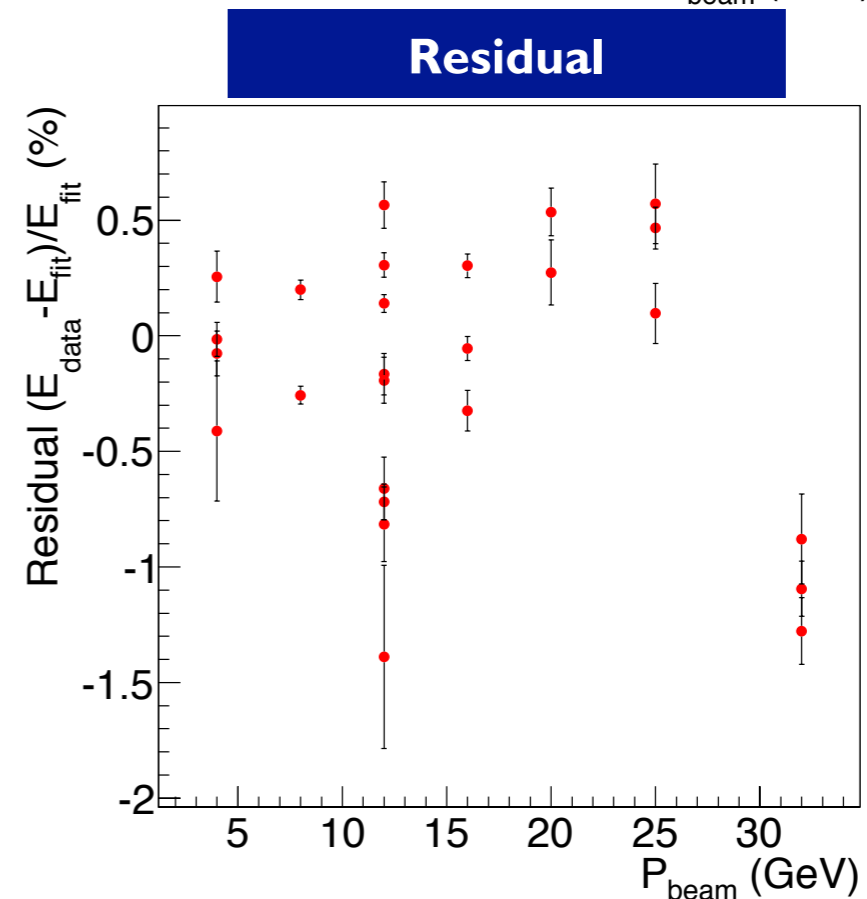
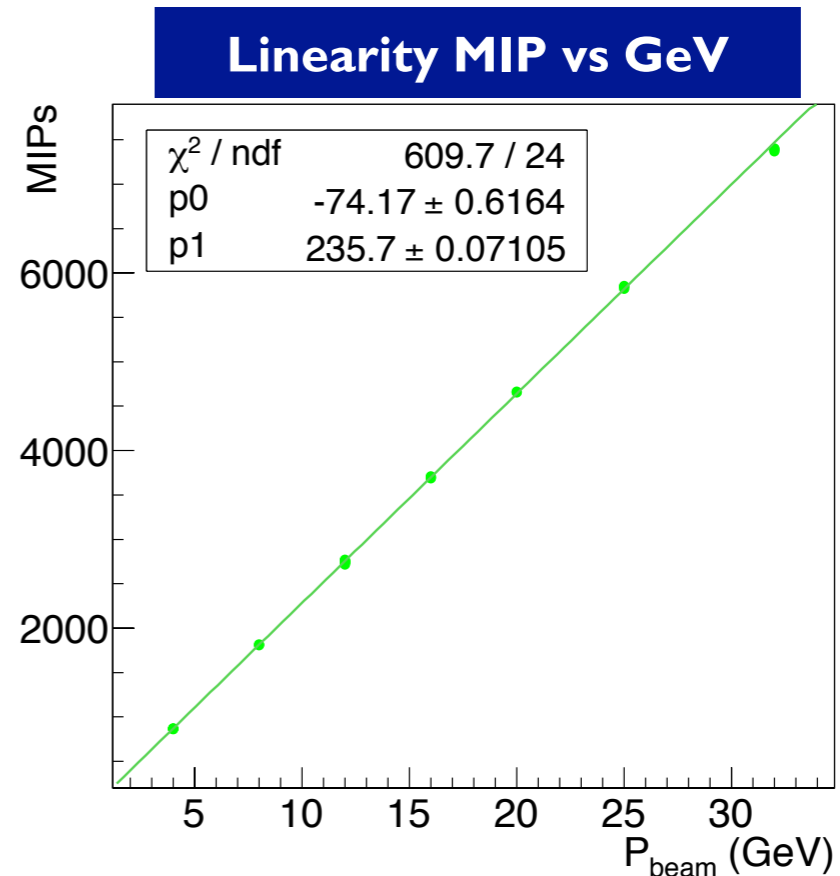
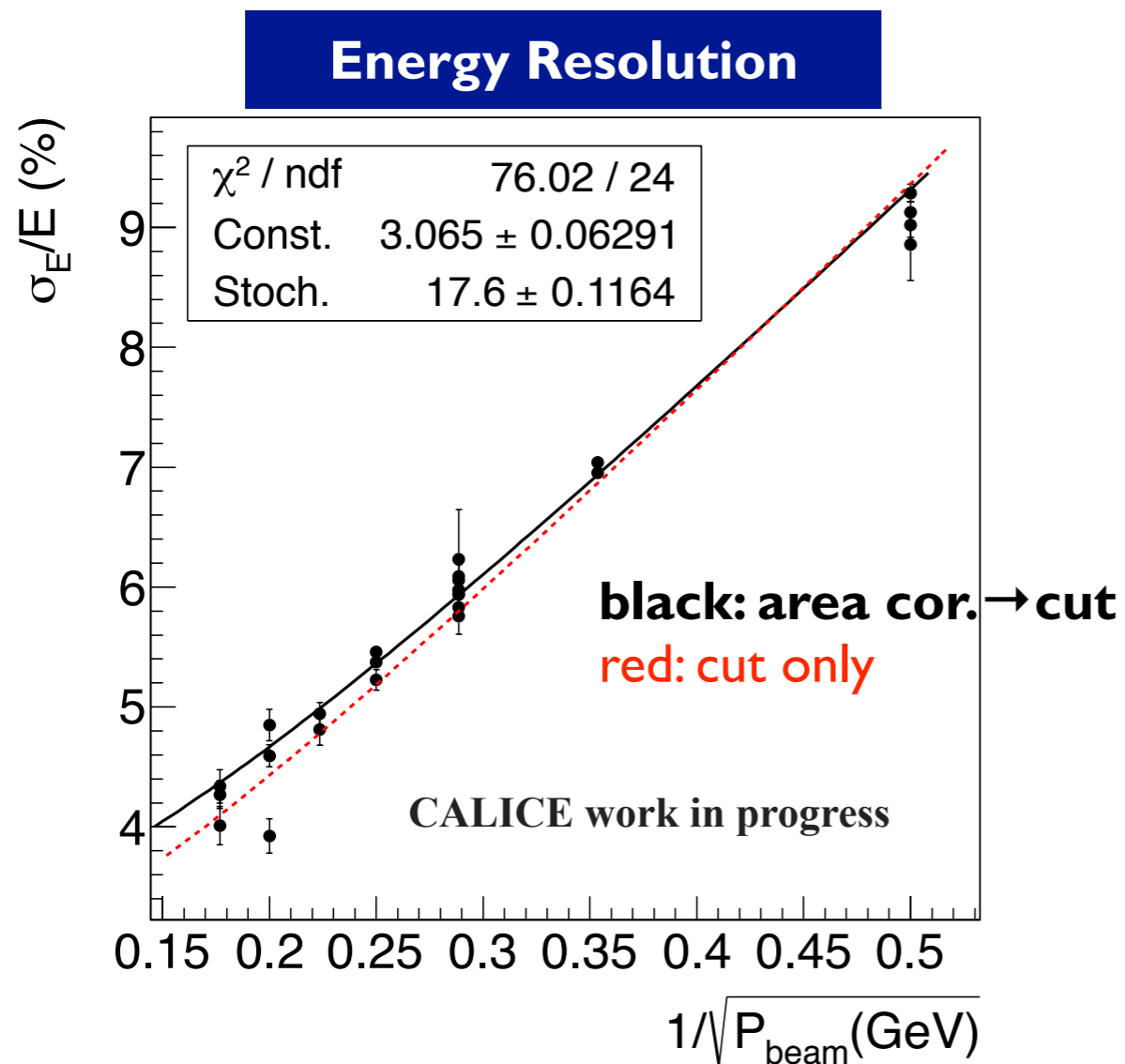


※ barycenter itself also change by the correction

red: no correction

black: after area-based correction

Result with **area-based correction**



- Non-linearity:
within +0.5% -1.5%
- Resolution
(Const.) **3.07%** (2.59%)
(Stoch.) **17.6%** (18.3%)

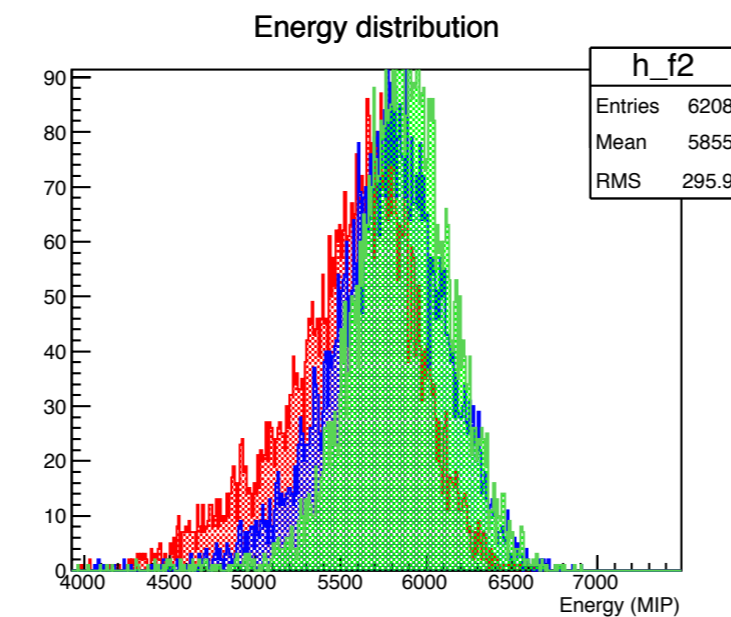
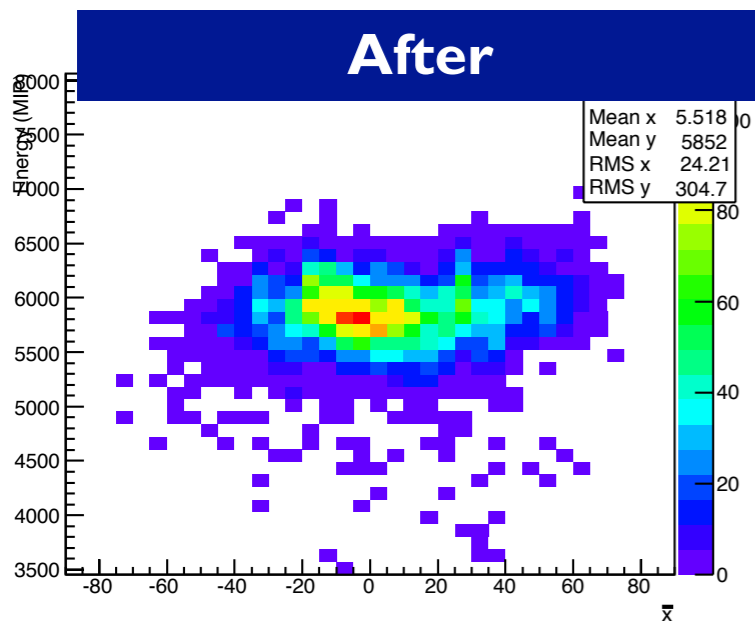
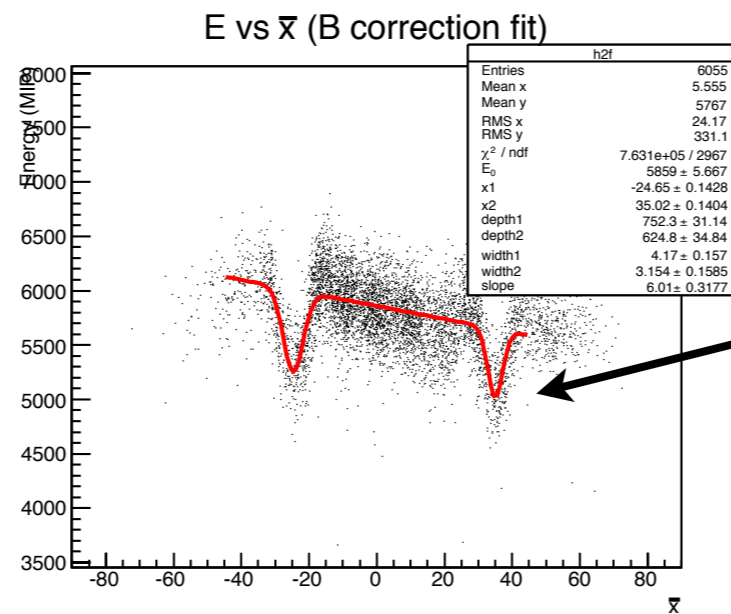
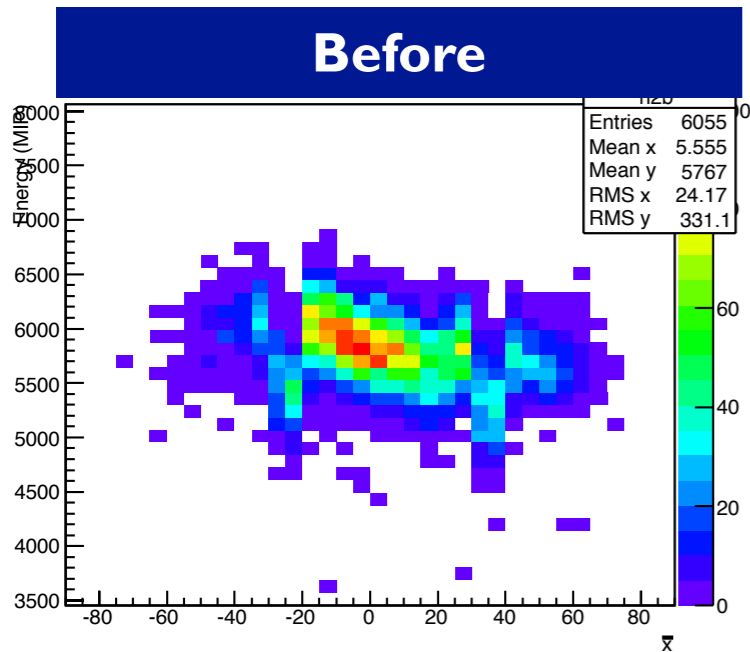
+Fitting correction

Correction function

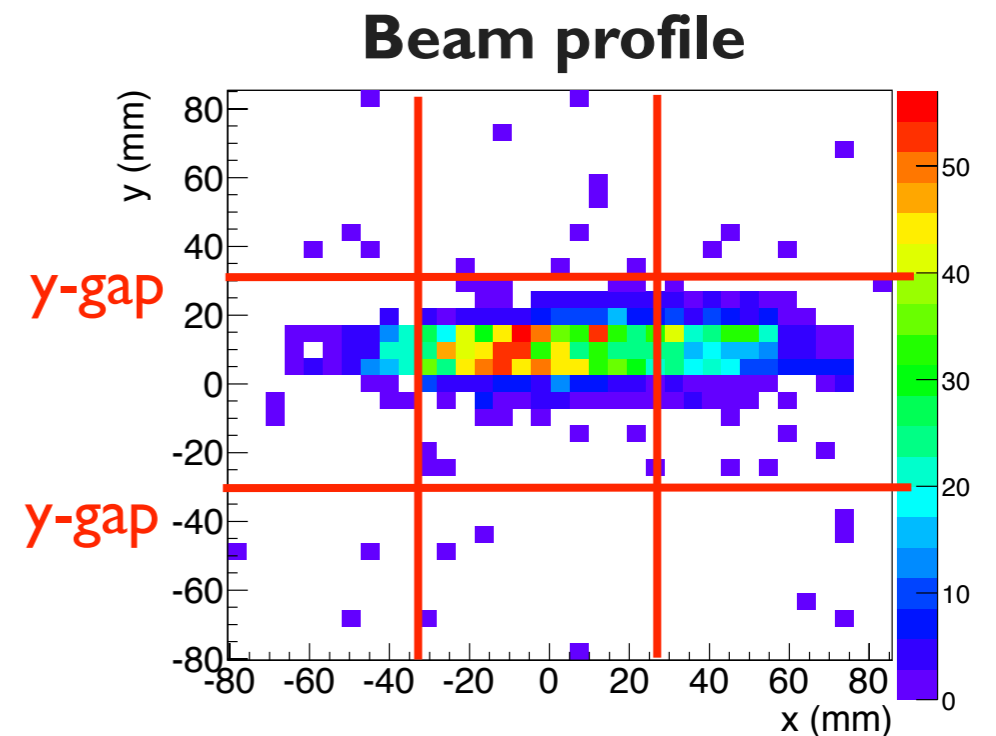
$$E = p_0 + p_1 * \bar{x} + 2 \text{ gaussian}$$

※ The slope seems to due to the beam spread

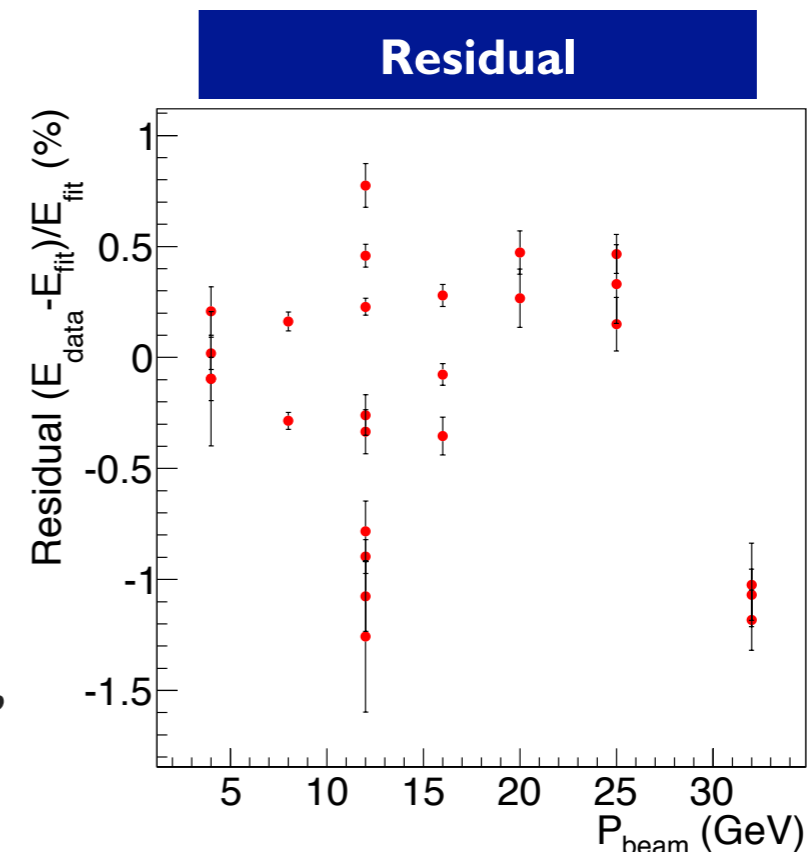
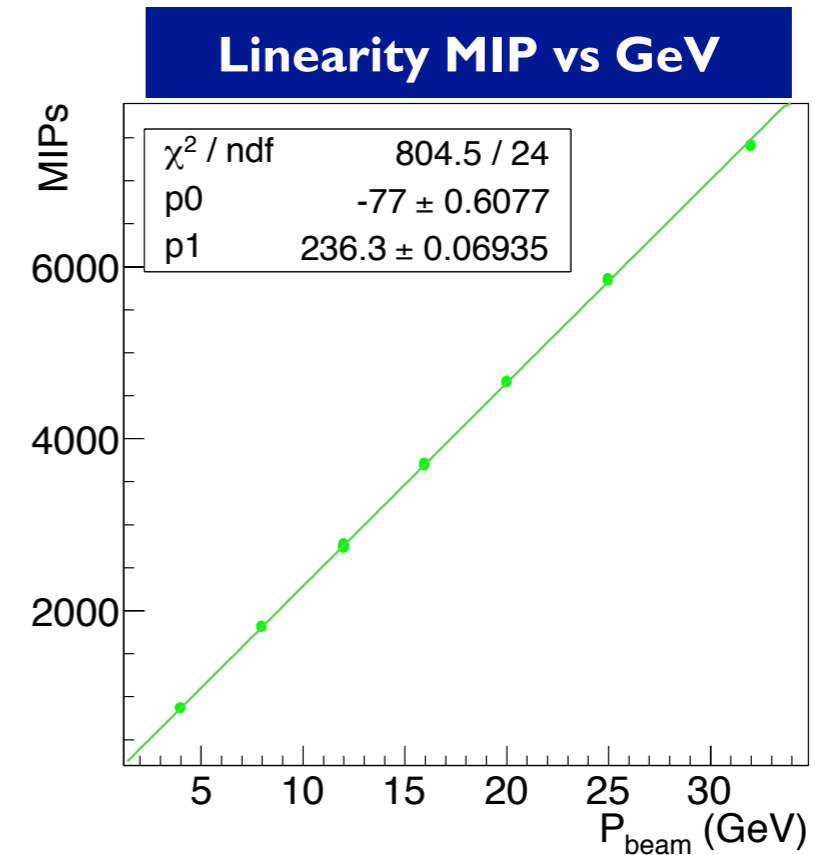
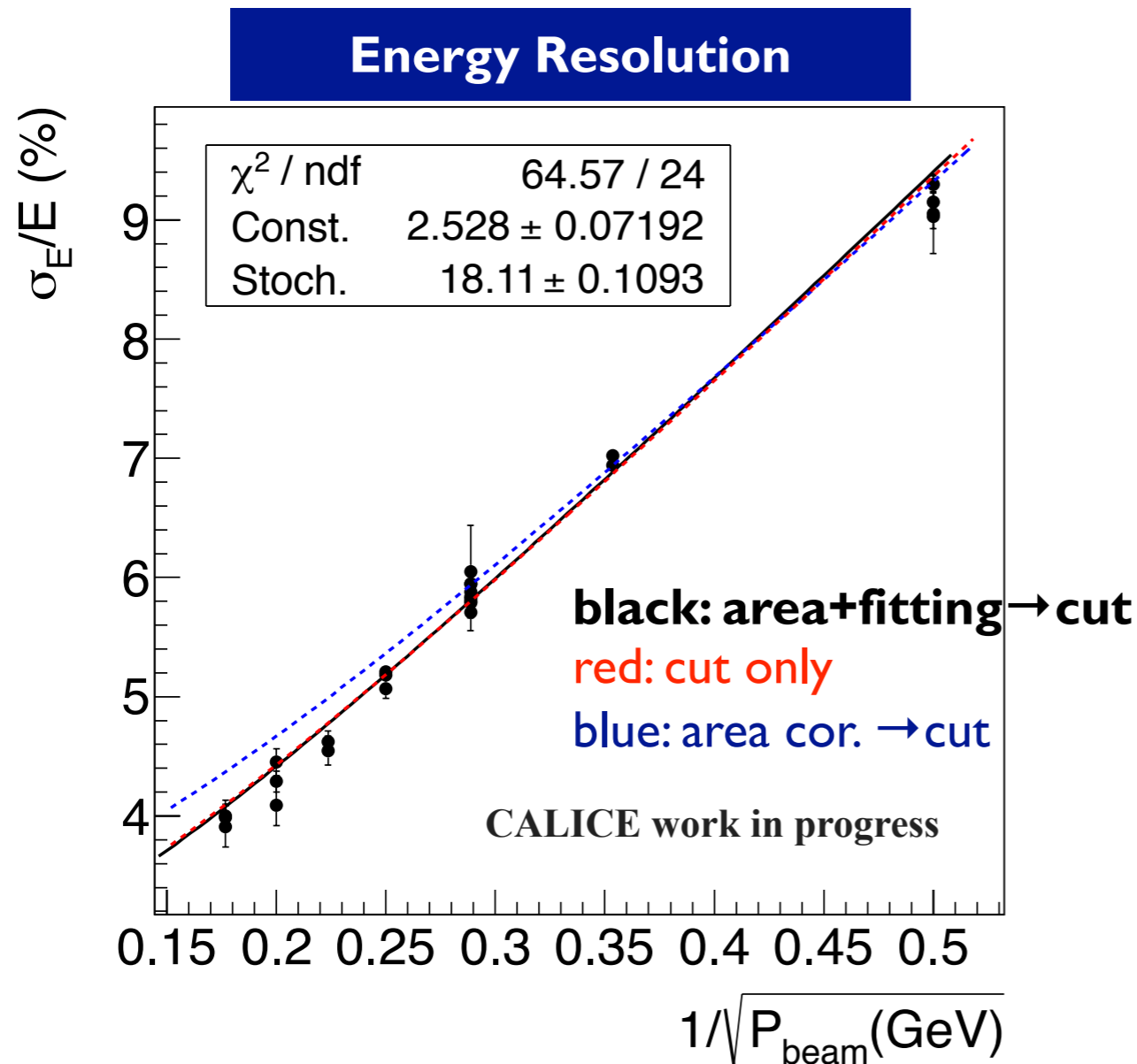
※ Influence by y-gaps can be ignored



red: no correction
blue: area-based only
green: area+fitting



Result with **area+fitting correction**



- Non-linearity: within $\pm 1.0\%$
- Resolution
 - (Const.) $3.09\% \rightarrow 2.53\%$ (cut: 2.59%)
 - (Stoch.) $17.6\% \rightarrow 18.1\%$ (18.0%)
- No significant improvement compared with “cut”
- Simply use the “cut only” for later analysis

Combine runs / comparison with other TBs

Subtract the contribution from beam spread

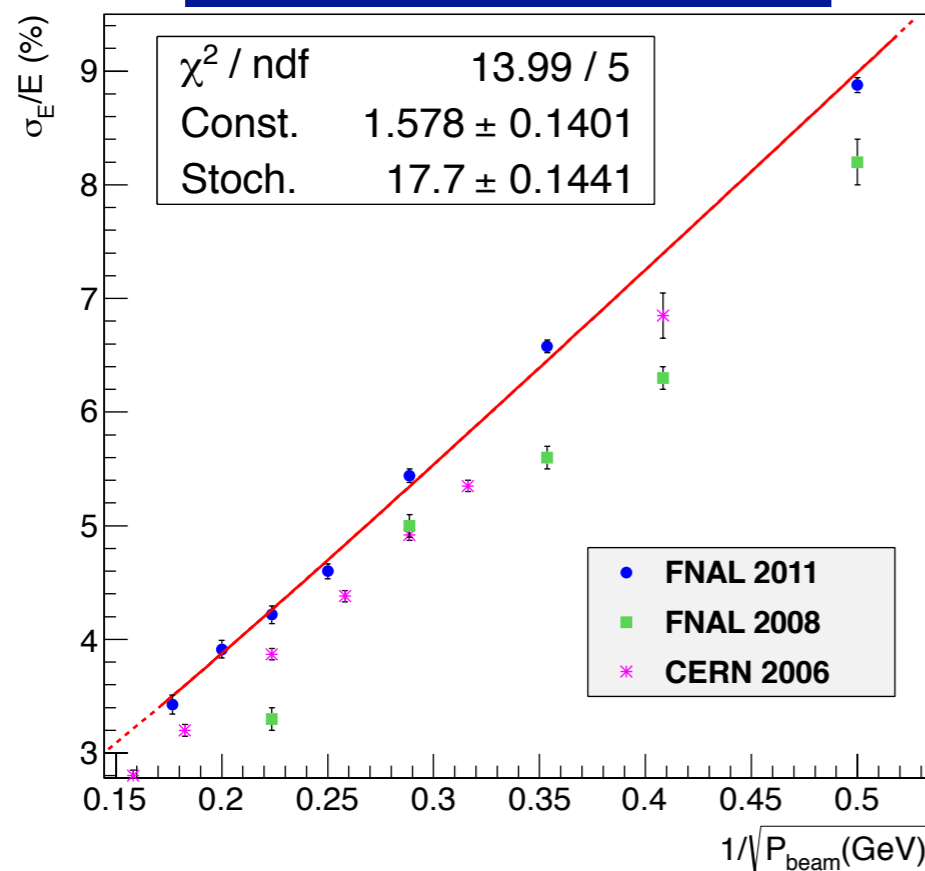
$$\frac{\sigma}{E} = \sqrt{\left(\frac{\sigma_{\text{meas}}}{E}\right)^2 + \left(\frac{\sigma_{\text{meas}}}{P_{\text{beam}}}\right)^2}$$

σ/P_{beam} :

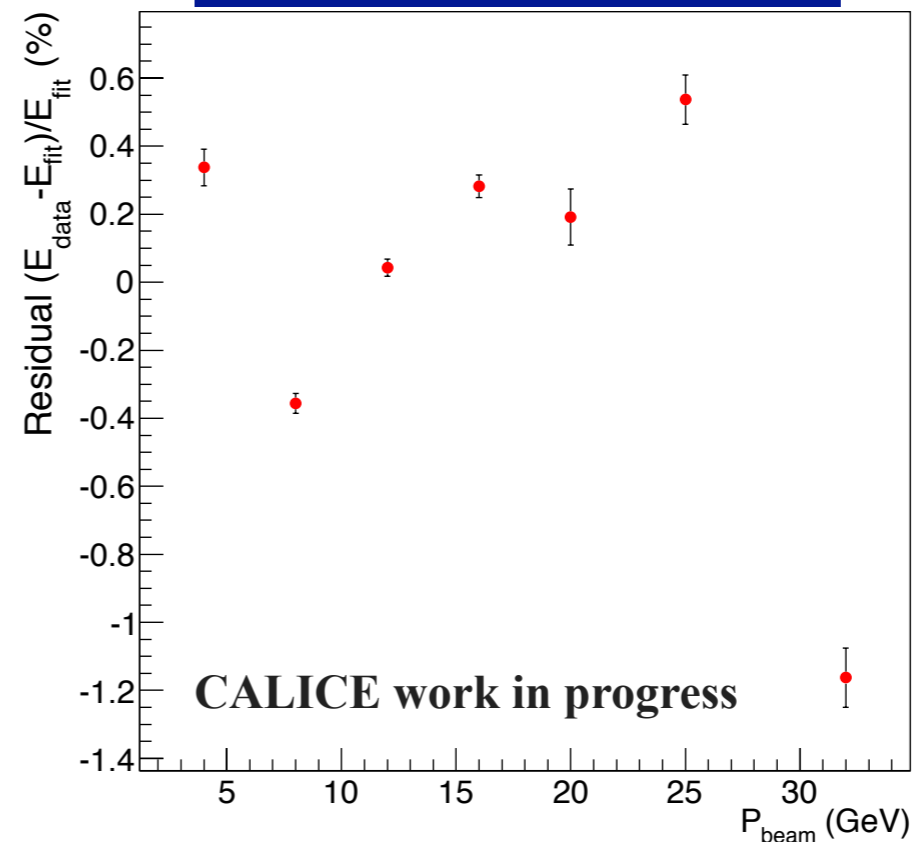
2.7 ± 0.3 % for 2-4 GeV

2.3 ± 0.3 % for 8-32 GeV

Energy Resolution



Residual



- Non-linearity: $\sim 1\%$ ($\sim 0.6\%$ if 32 GeV is excluded)
- Resolution
 1.58 ± 0.14 (const.) + 17.7 ± 0.14 (Stoch.) (%)

Resolution looks a bit high. Need more investigation

Pandora performance study with the TB data

- Study the **separation power** of Pandora
number of PFOs, PFO energy vs shower distance

【Motivation】 Separation of 2 close photons is important for tau ID / π_0 reco.

- **Map TB events (Calice prototype) onto the ILD model**

z axis (@CALICE) \rightarrow y axis (@ILD)

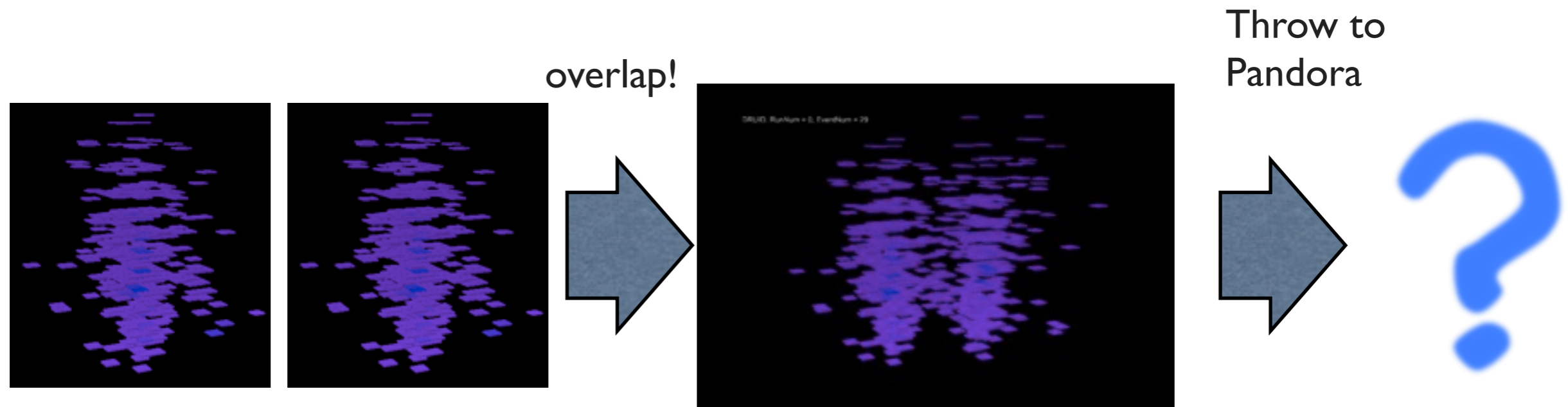
Tune cell size 5mm \rightarrow 10mm

Shower tilt is not considered at this moment

- **Overlap 2 event from 2 different runs**

Overlapped cells \rightarrow summed energy

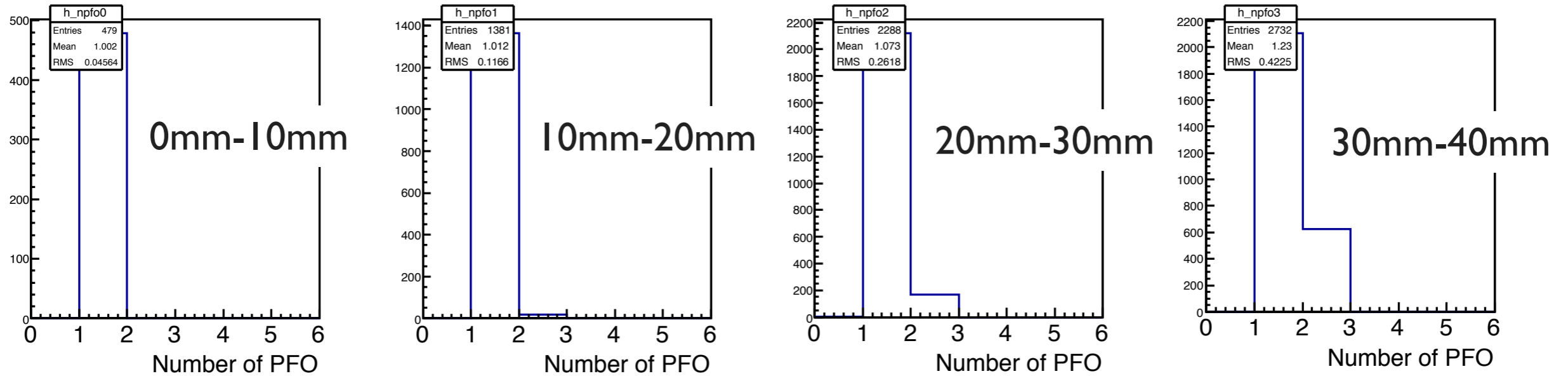
No track \rightarrow disguise as photon clusters



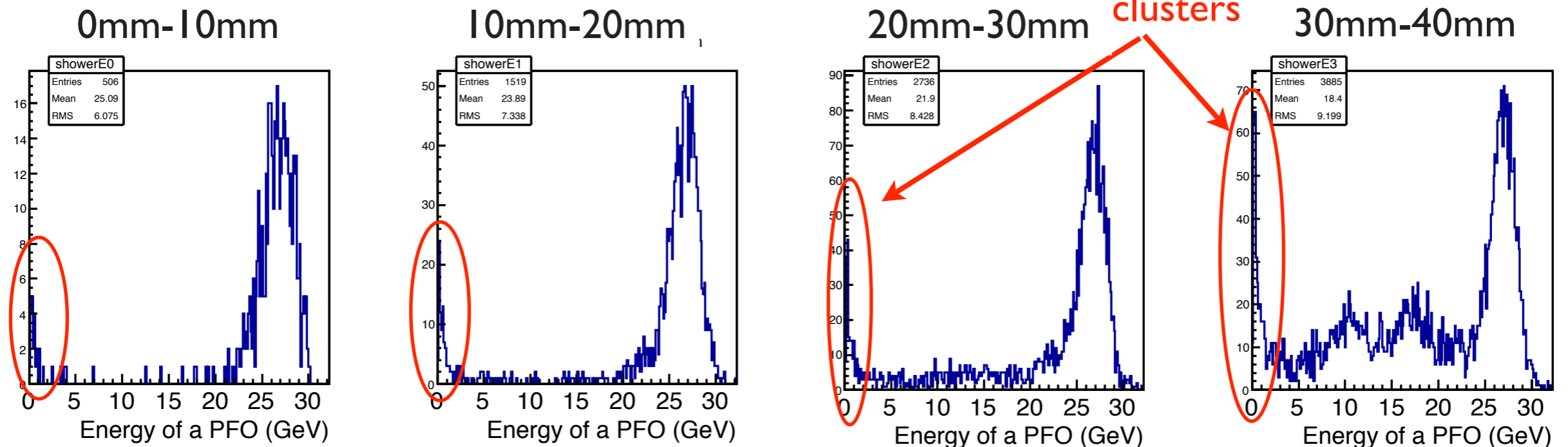
Overlap study (16GeV+12GeV)

- **Event selection**
Cuts applied in the ECAL analysis

■ Number of PFOs vs shower distance (mm)



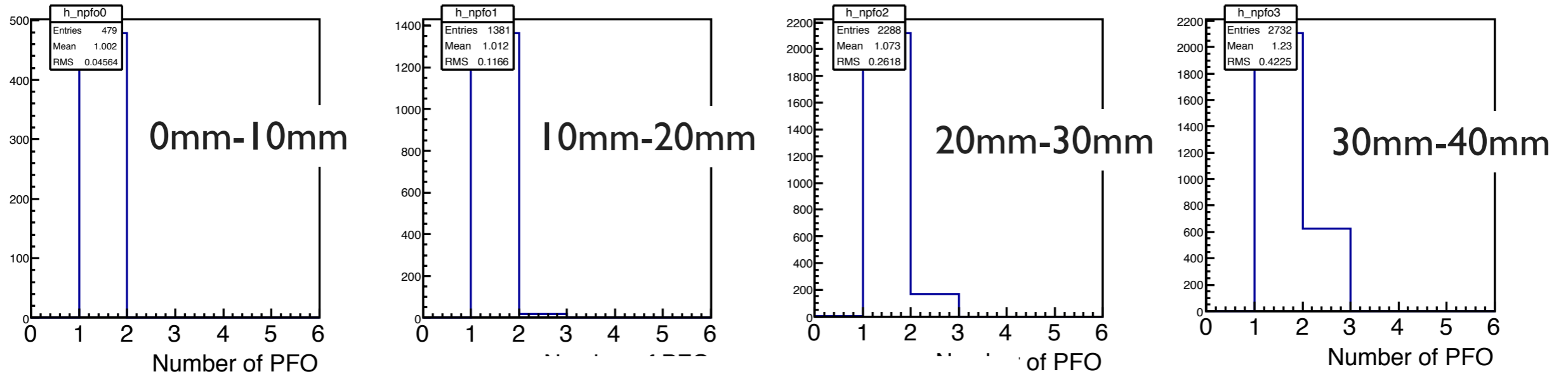
■ Energy of one PFOs



Overlap study (16GeV+12GeV)

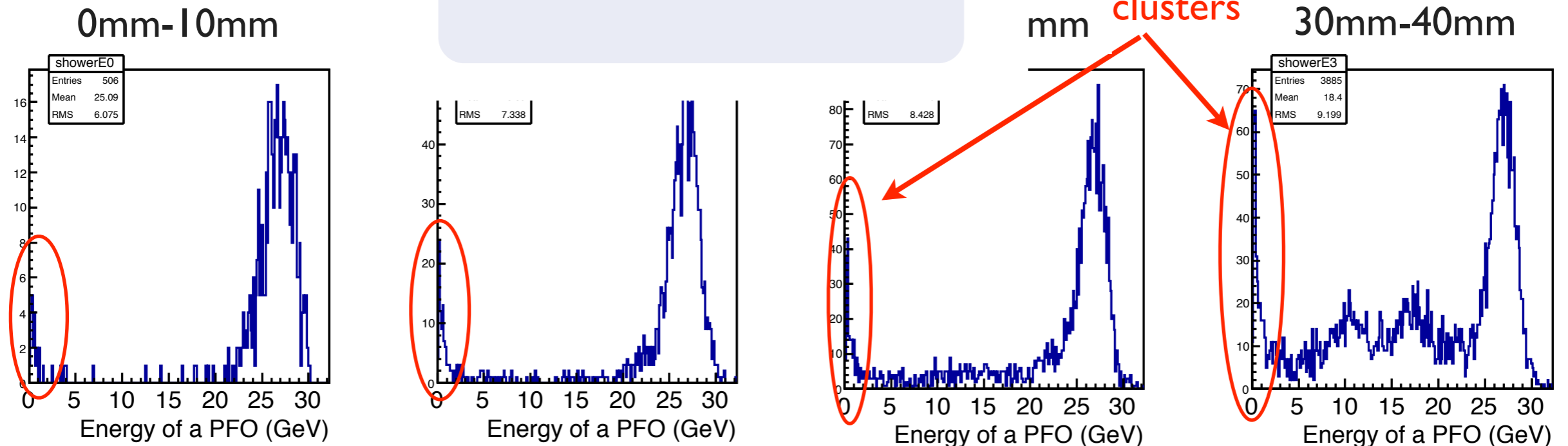
- **Event selection**
Cuts applied in the ECAL analysis
&& $E > 0.5 * (E_{\text{beam},1} + E_{\text{beam},2})$

■ Number of PFOs vs shower distance (mm)



■ Energy of one PFOs

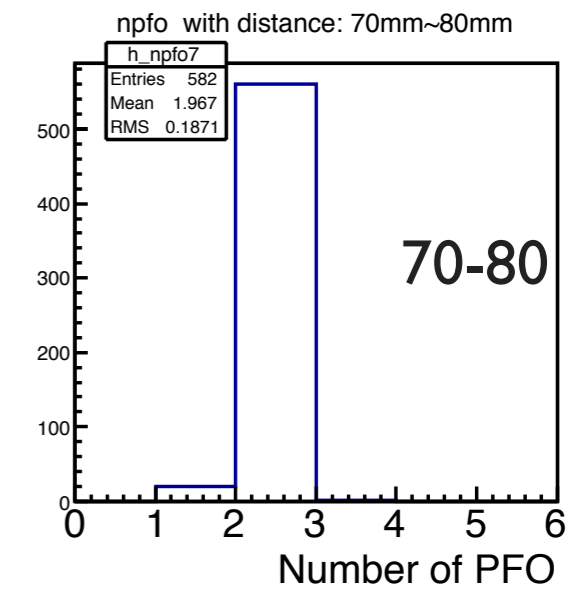
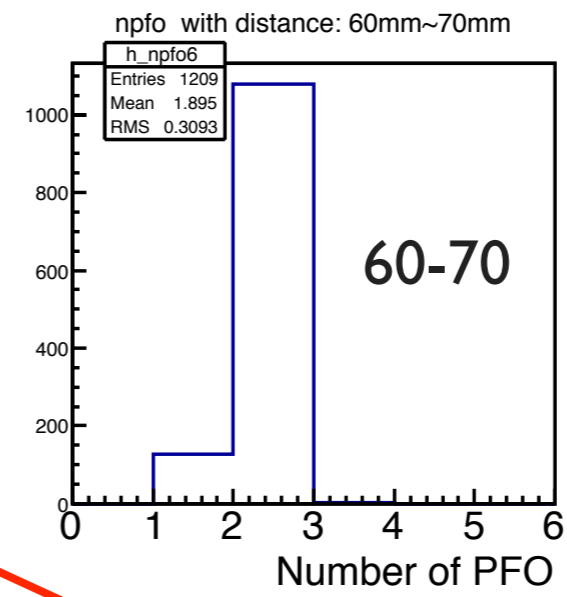
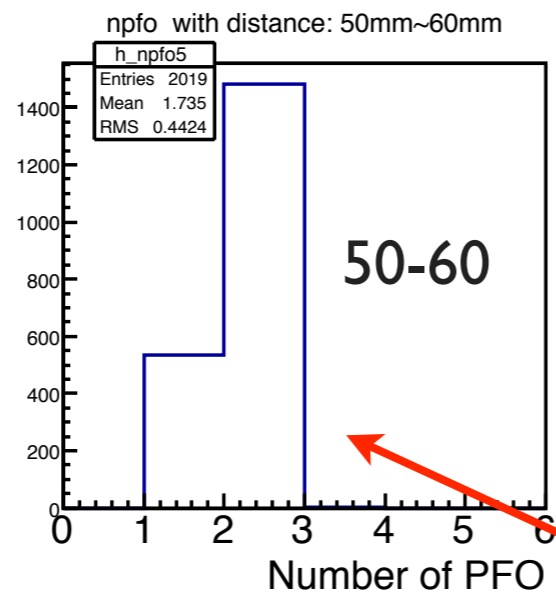
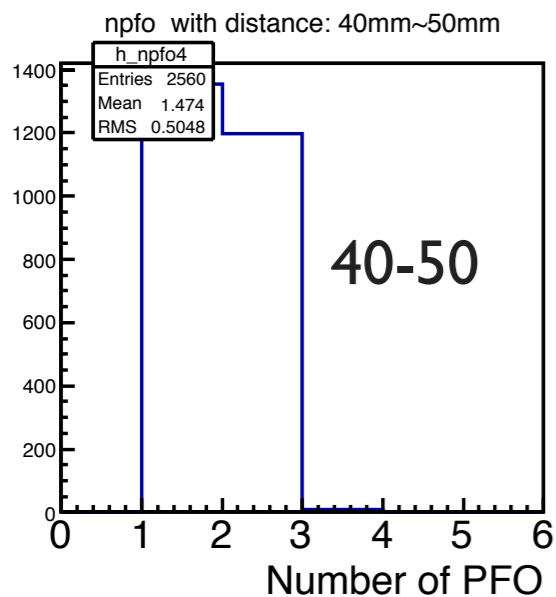
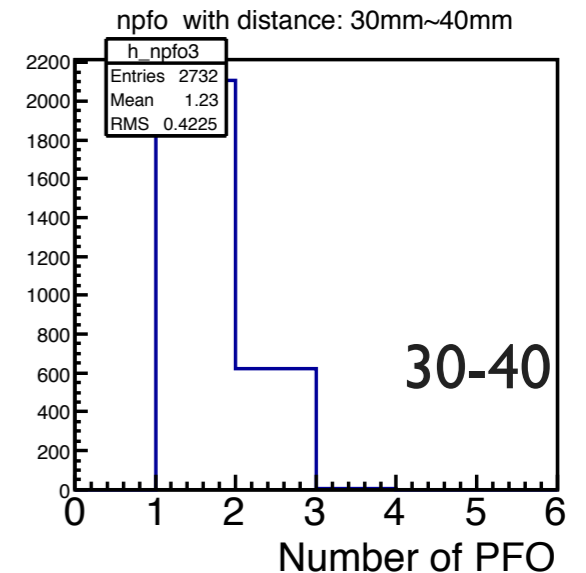
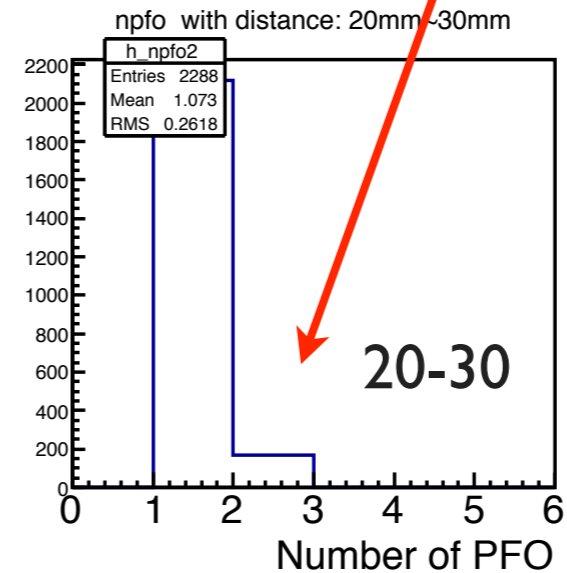
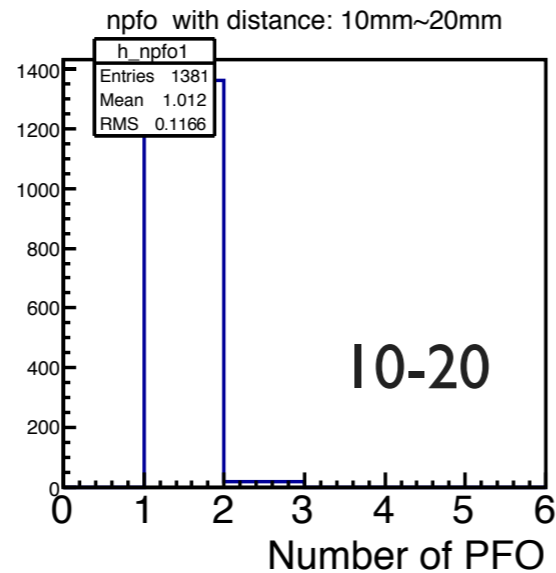
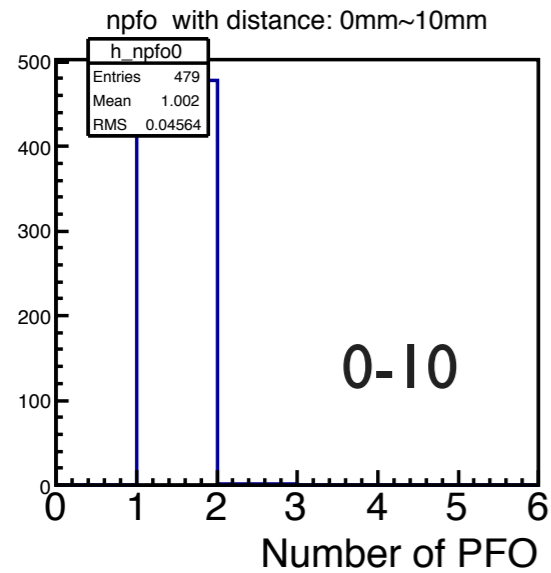
- **PFO selection**
 $E_{\text{PFO}} > 0.3 * E_{\text{beam}}$



Overlap study (16GeV+12GeV)

■ Number of PFOs vs shower distance (after selection)

come to be separated
(20mm~30mm)



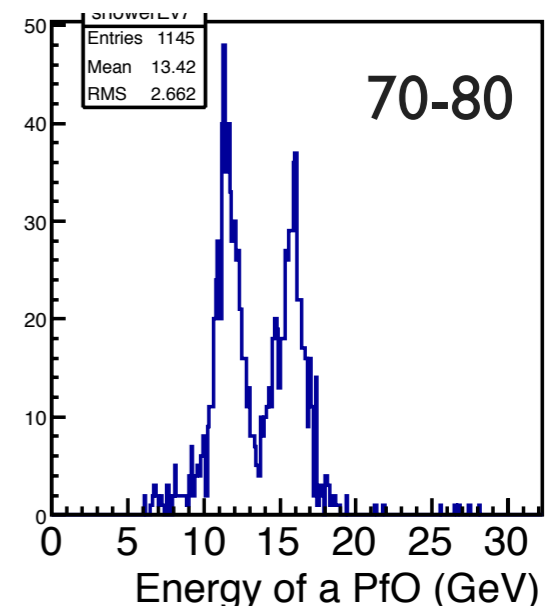
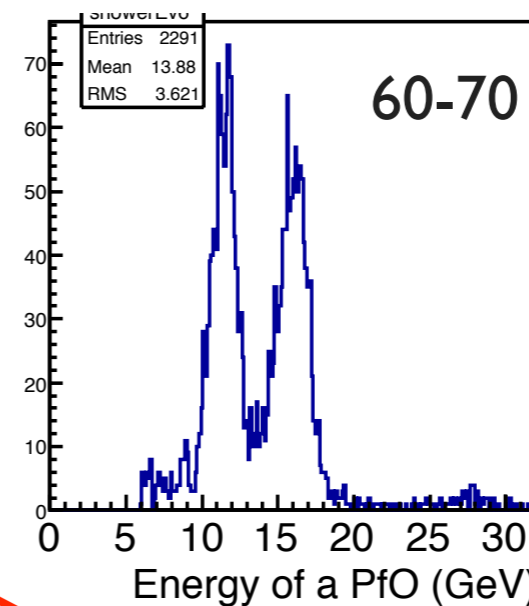
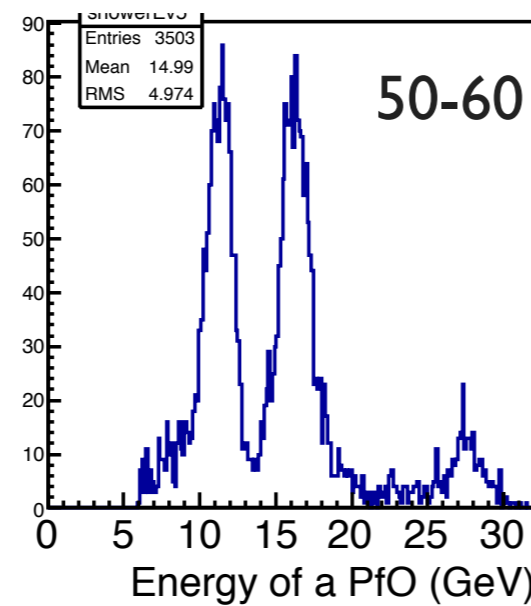
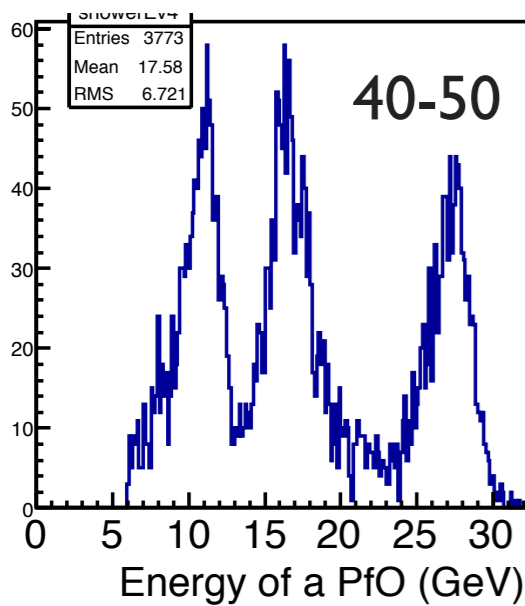
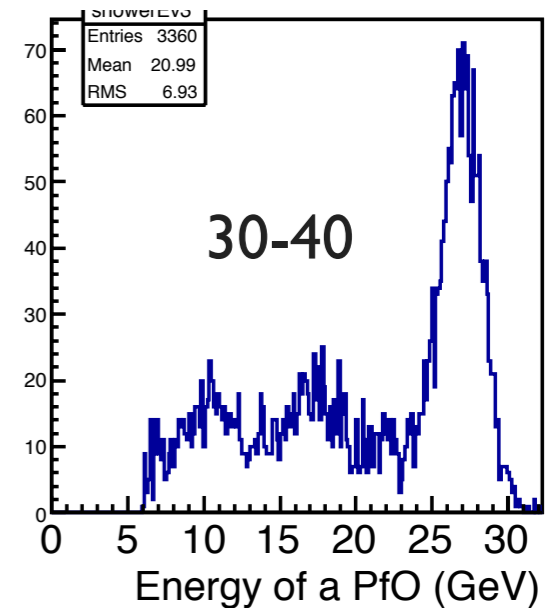
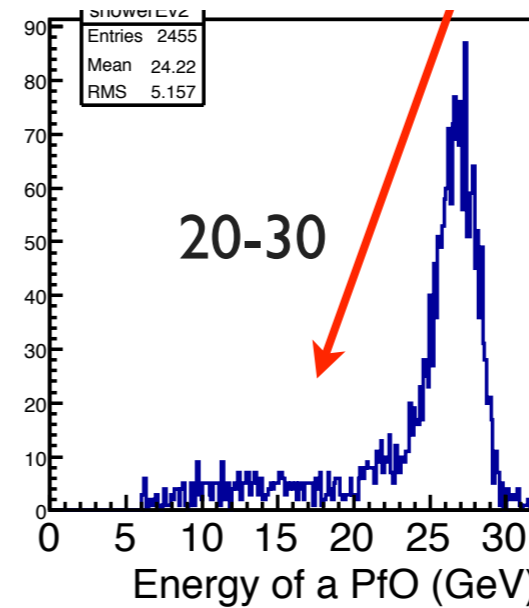
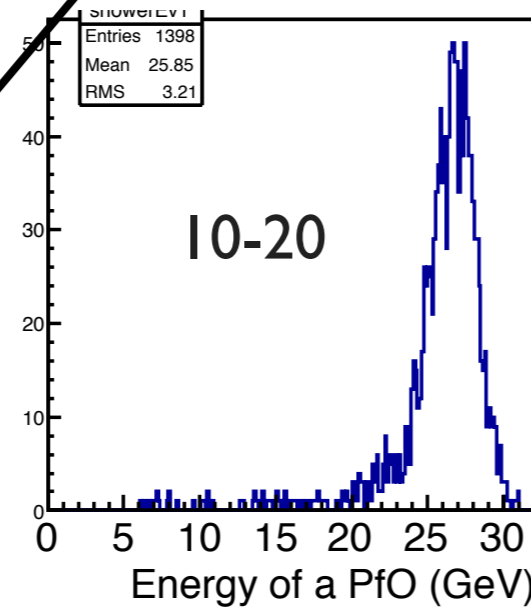
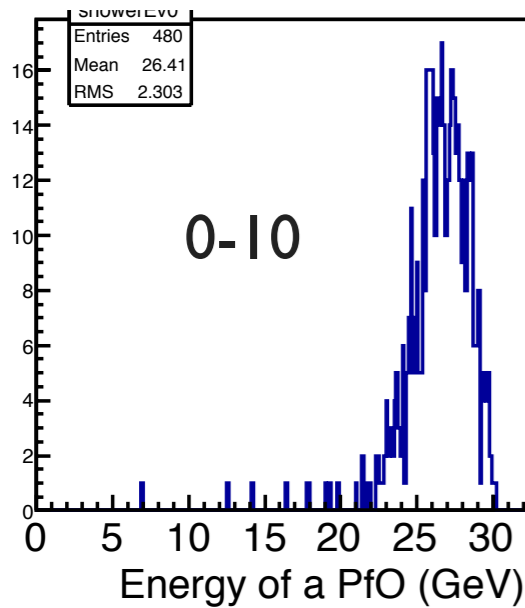
Almost resolved (50~60mm)

Overlap study (16GeV+12GeV)

■ Energy of one PFOs

45GeV (two showers are ID as one cluster)

come to be separated (20mm ~ 30mm)

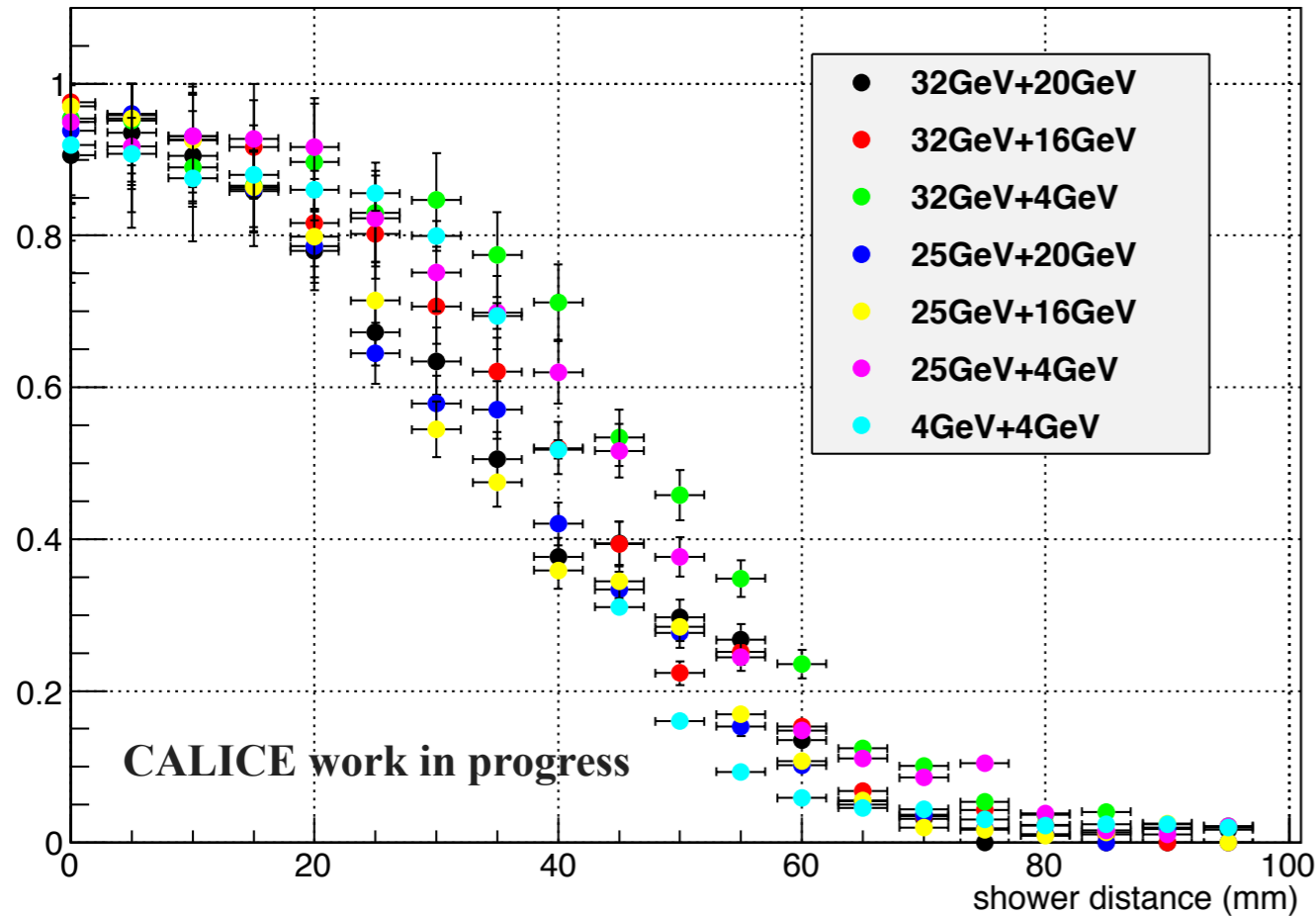


※ Moliere raduis ~20mm

Almost resolved (50mm ~ 60mm)

Overlap study (various combination)

Probability to have only 1 PFO in the end

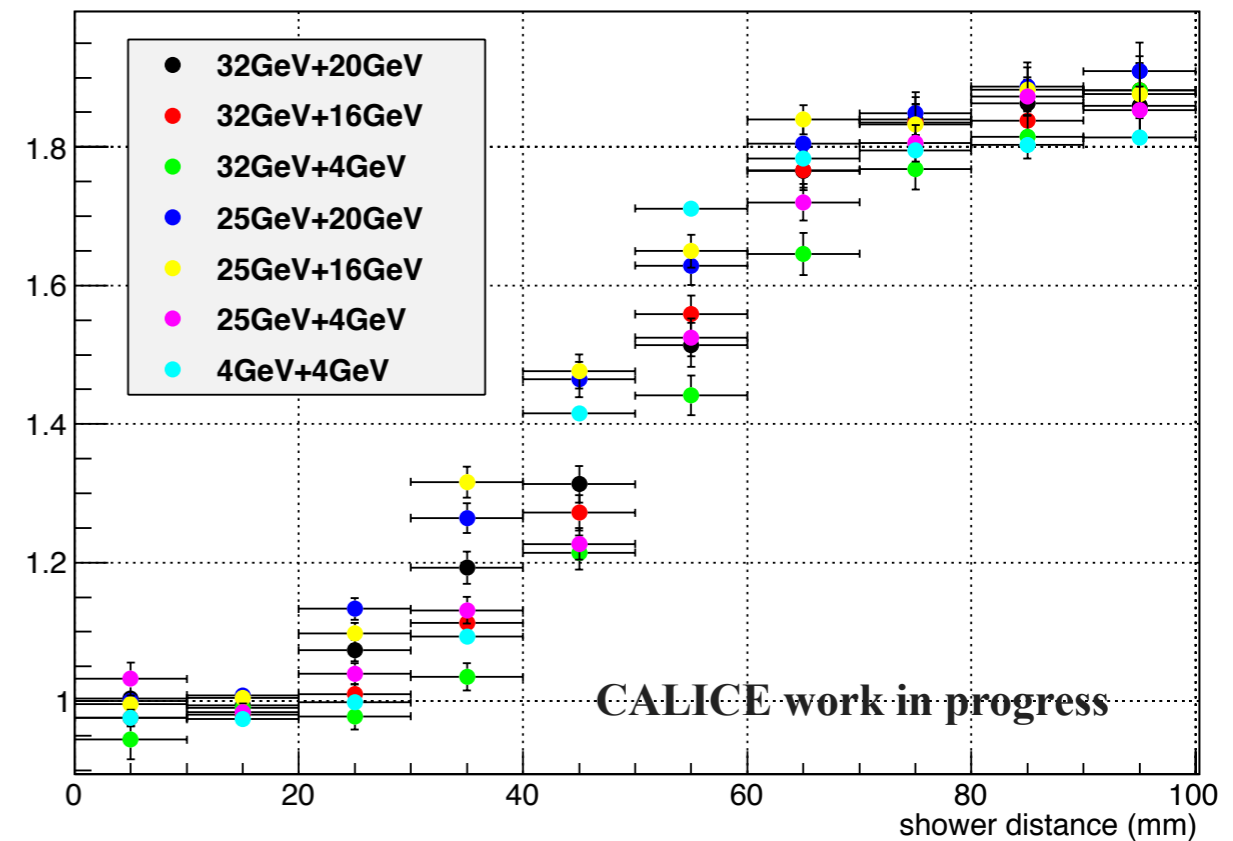


Critical points are around 30mm~50mm

Pandora seems to prefer to attach small cluster to larger one

Need cross check with MC

Average number of PFA we have in the end



Summary and Outlook

- **Test beam of SiW Physics prototype in FNAL 2011 is analyzed**

- **Performance**

Non-linearity: +0.6% - 1.2%

Energy resolution:

$$\sigma/E = 1.58 \pm 0.1 \text{ (const.)} + 17.7 \pm 0.1 \text{ (Stoch.) (\%)}$$

- **Pandora performance study with the TB data**

In TB data, SiW ECAL + pandora can separate EM showers @ ~50mm

Simulation study for comparison is planned

Further investigation on if separation can be improved is ongoing

Backup

MIP check

Run removed

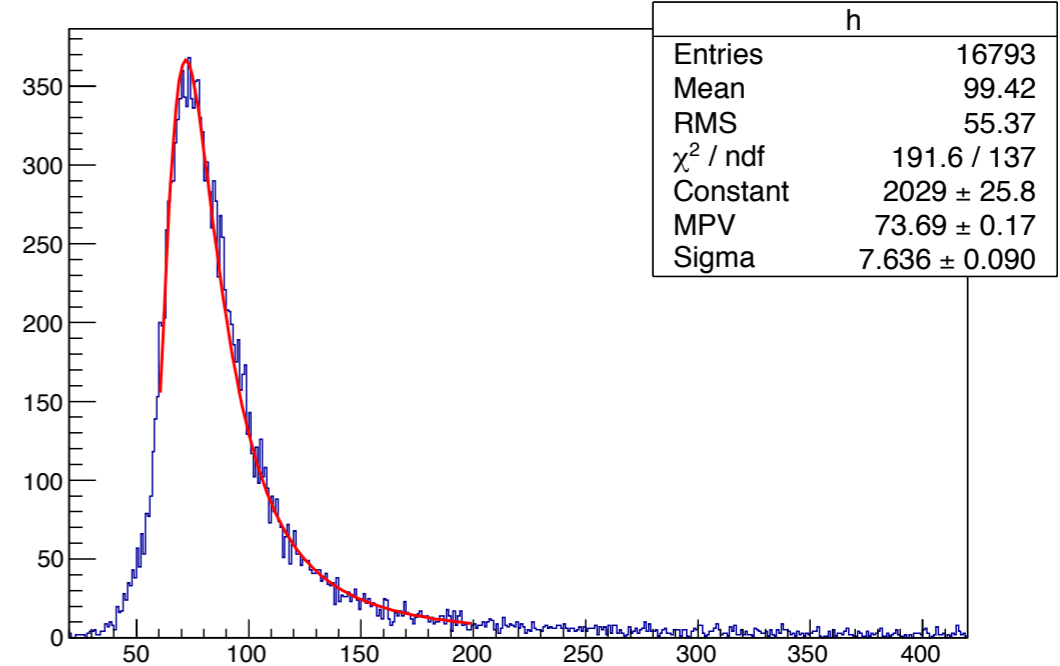
22, 23, 24, 27, 28, 51, 59, 60: Too little statistic

71: Strange in every aspect

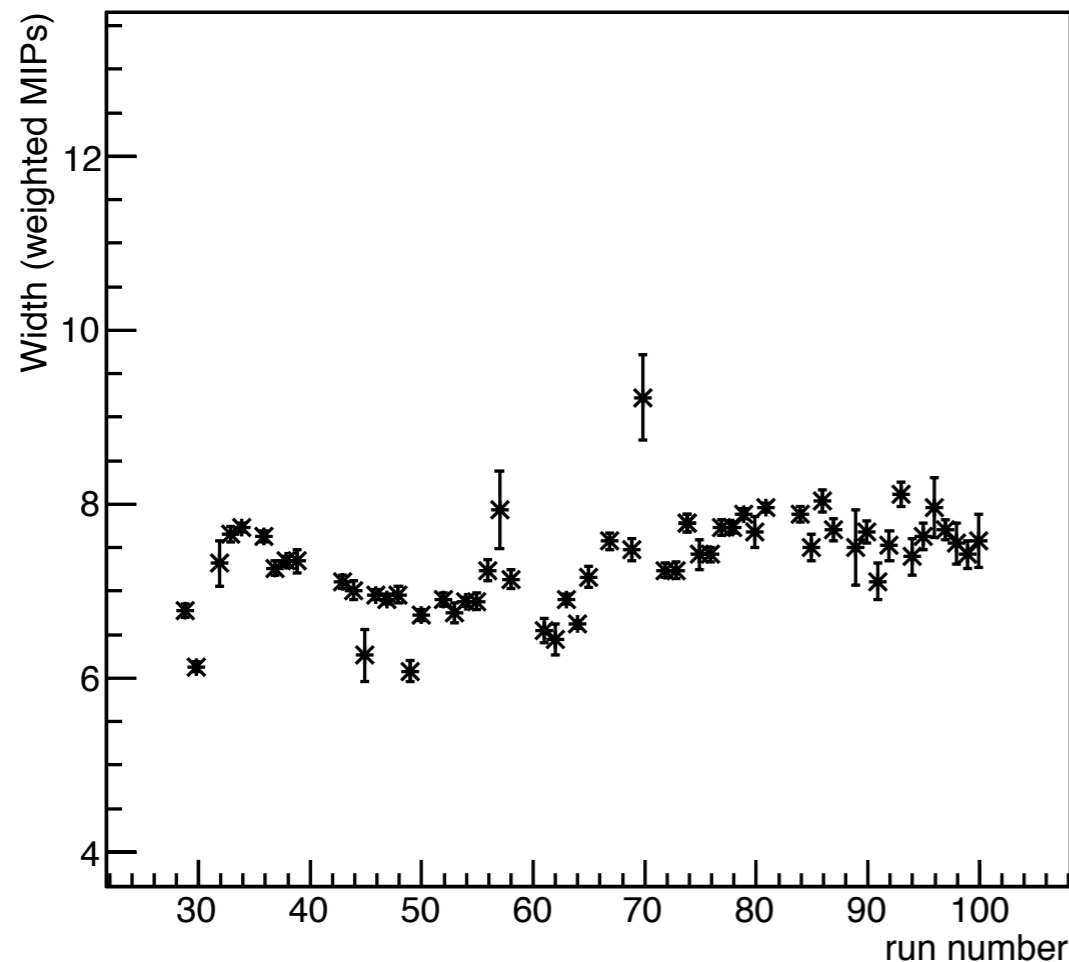
Fit with only Landau

(G-convoluted sometimes explode)

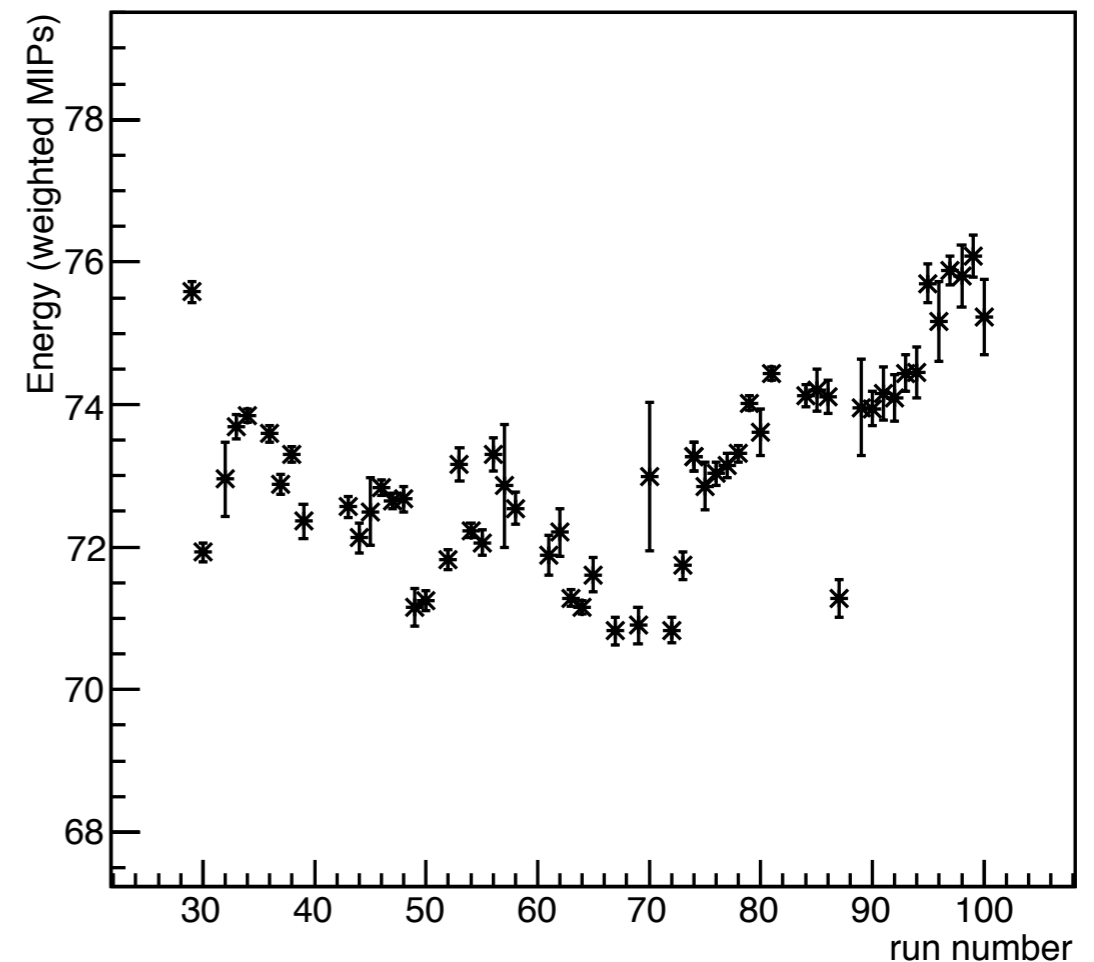
Energy deposit630033



Width of MIP energy deposit distribution



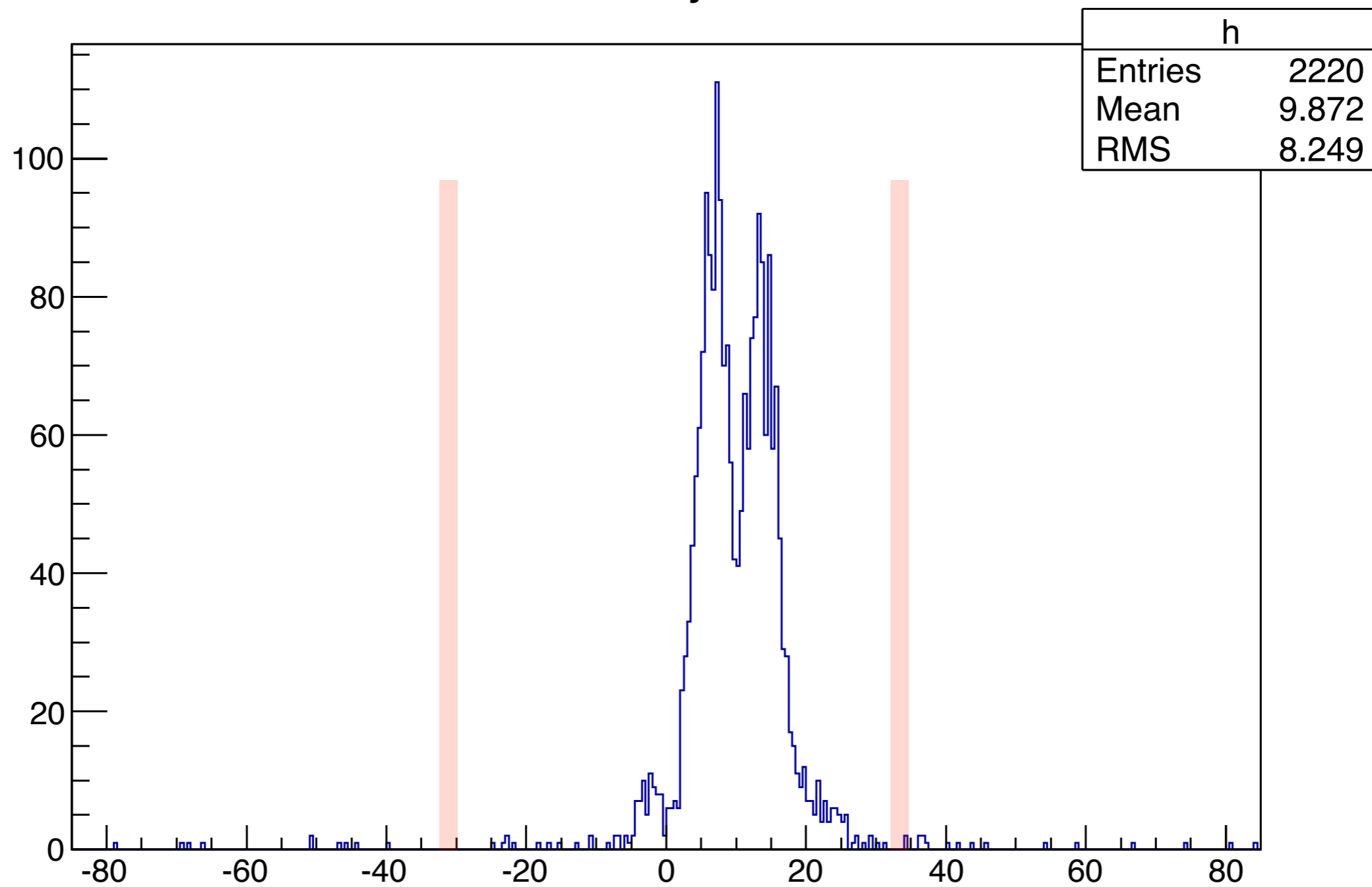
MPV of MIP energy deposit distribution



More or less consistent
(better than before)

gaps: $y=\pm 30\text{mm}$
width: 2.15mm

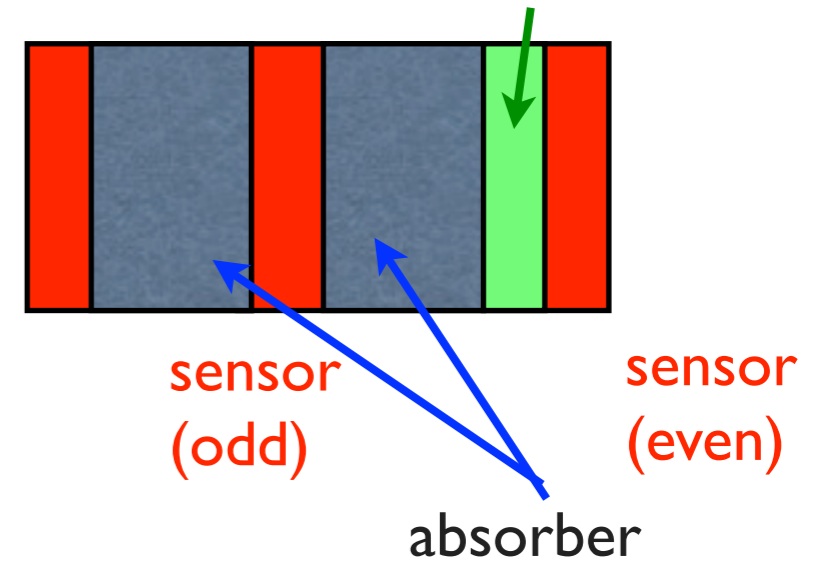
BCy



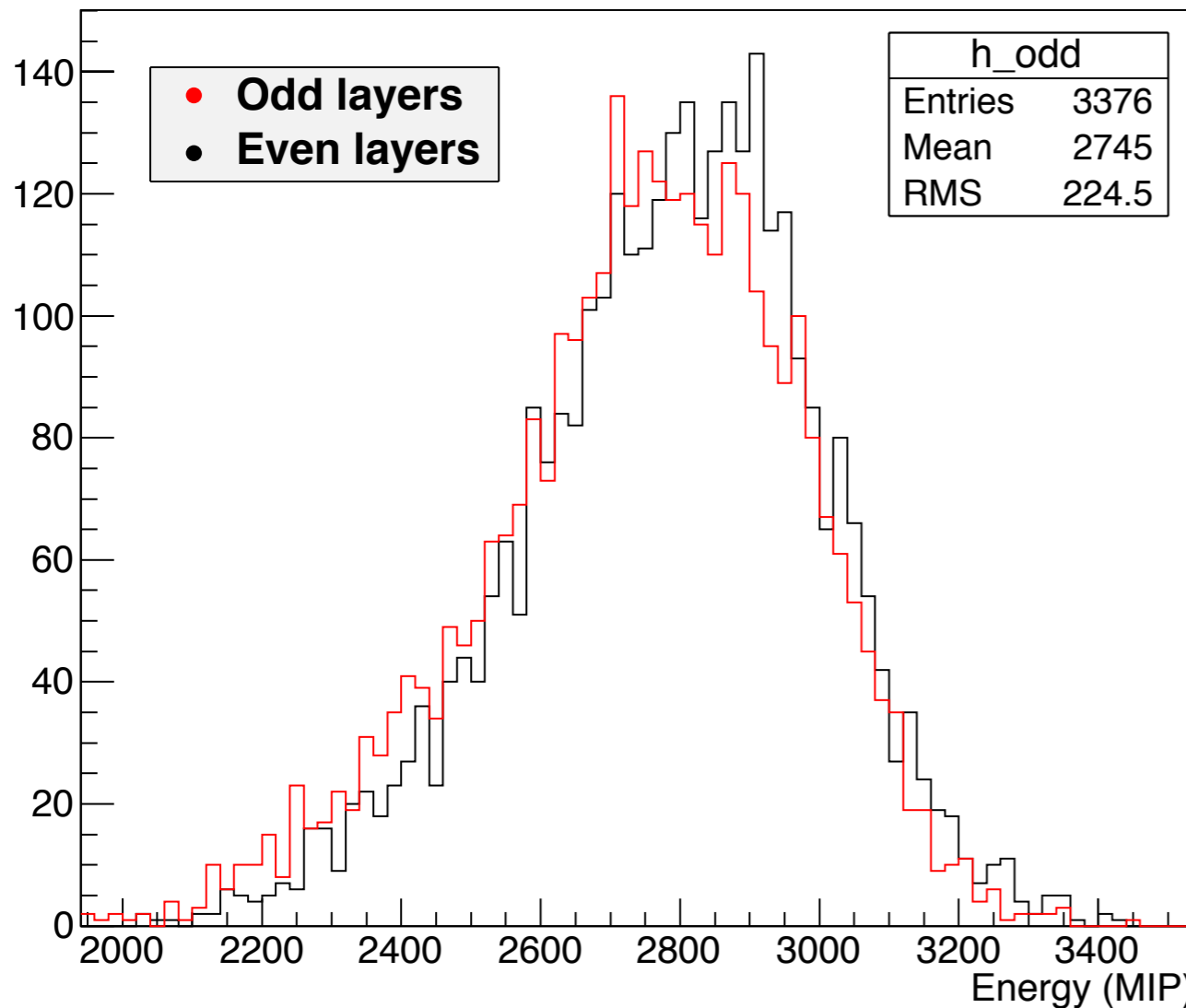
Odd / even layers correction

- The sampling ration is different in odd / even layers
Even layers always have more matter before

PCB / supporting structure

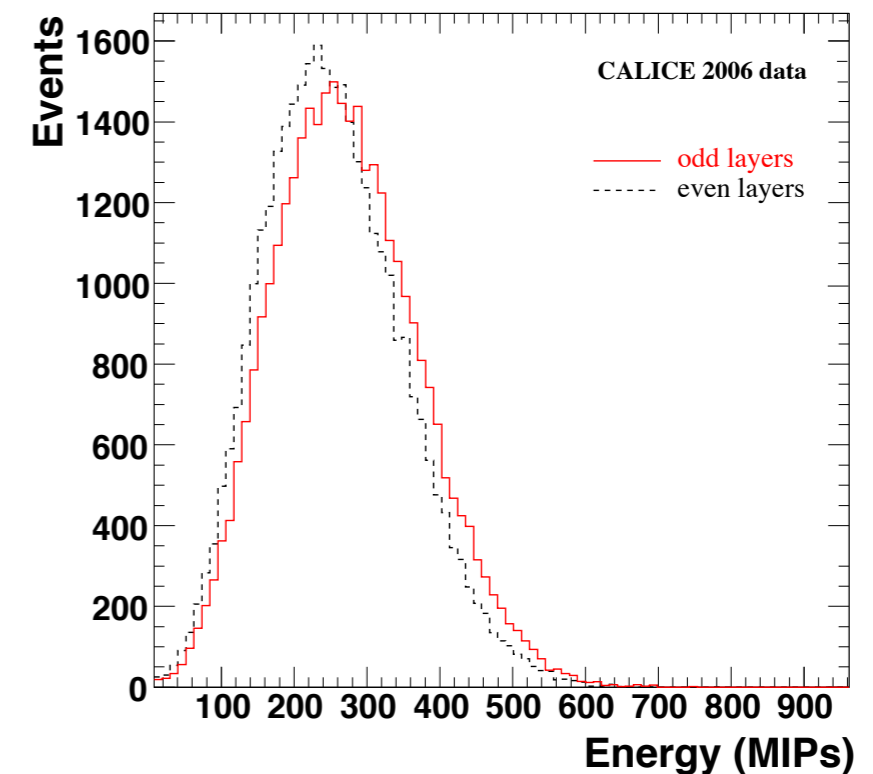


Energy deposit in odd layer run:630037

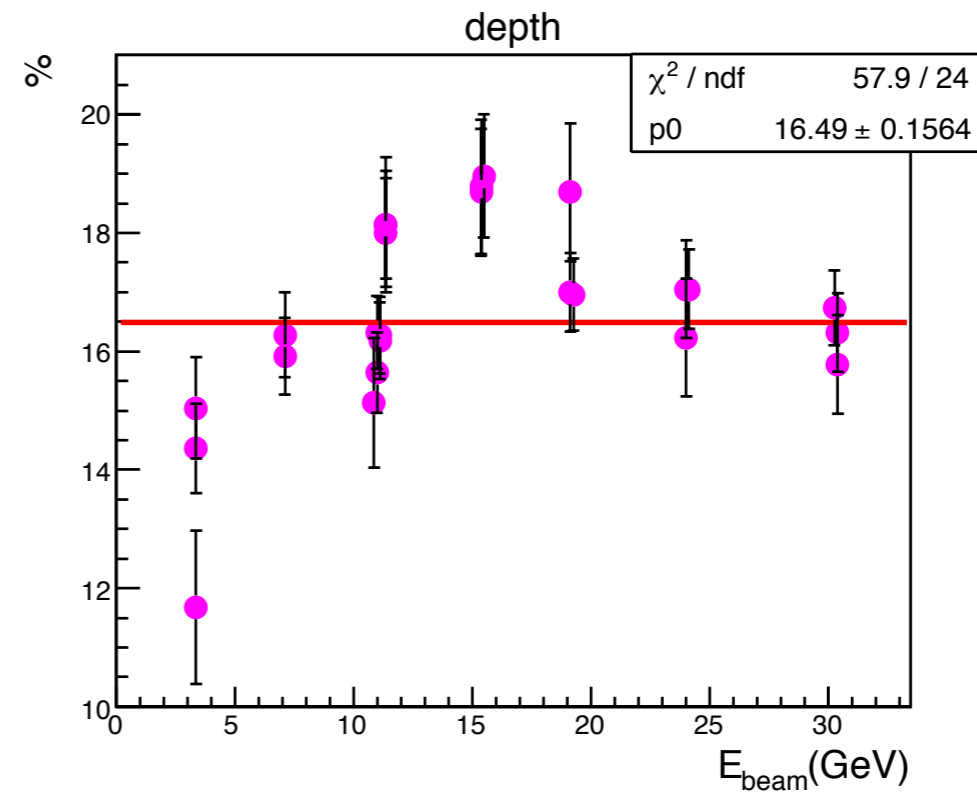
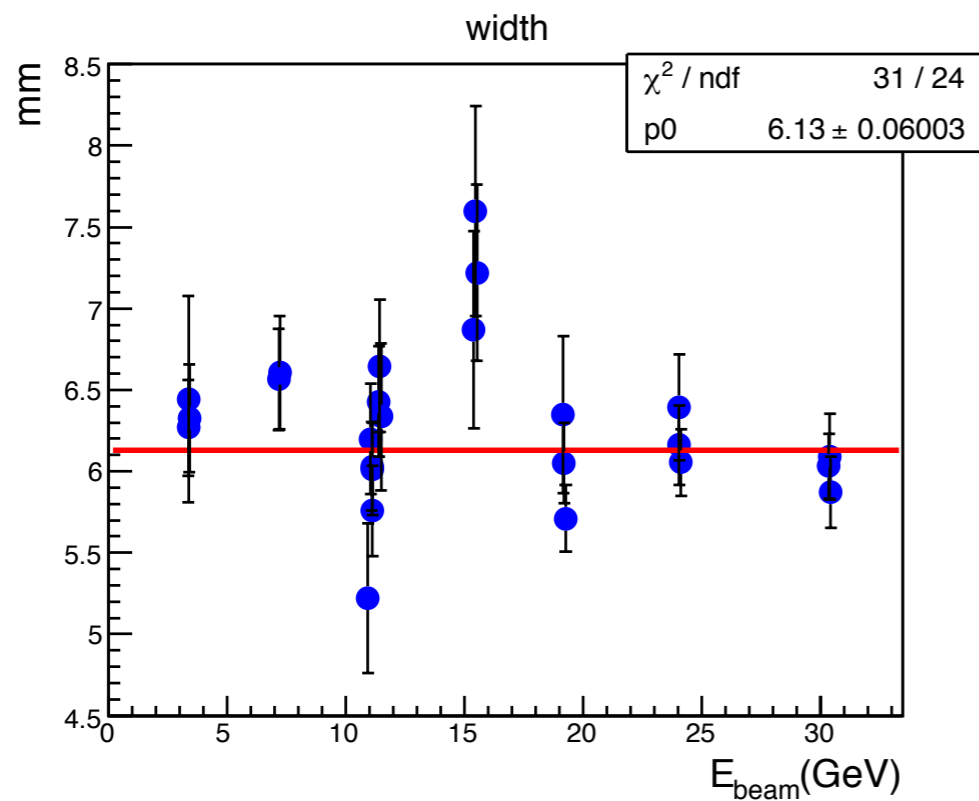
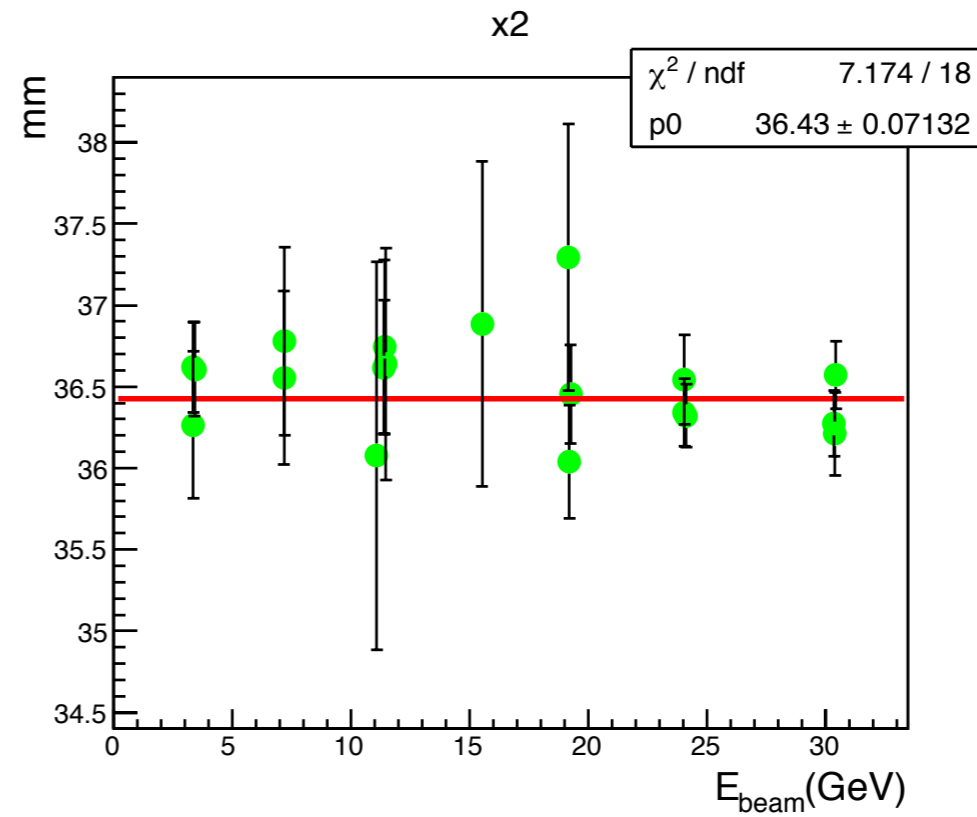
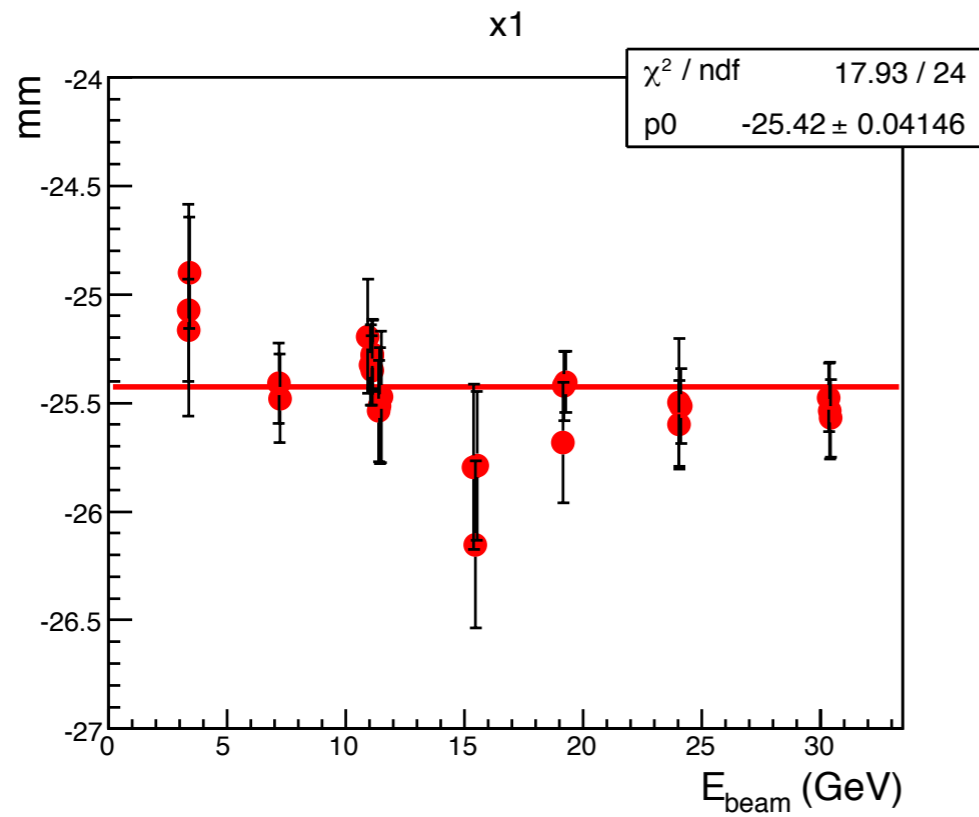


(CERN 2006)

notation of “odd/even” is opposite?
first lay -> layer 0 -> even?



Fit gap position/width (no correction)



Fit gap position/width (w/ area-based cor.)

