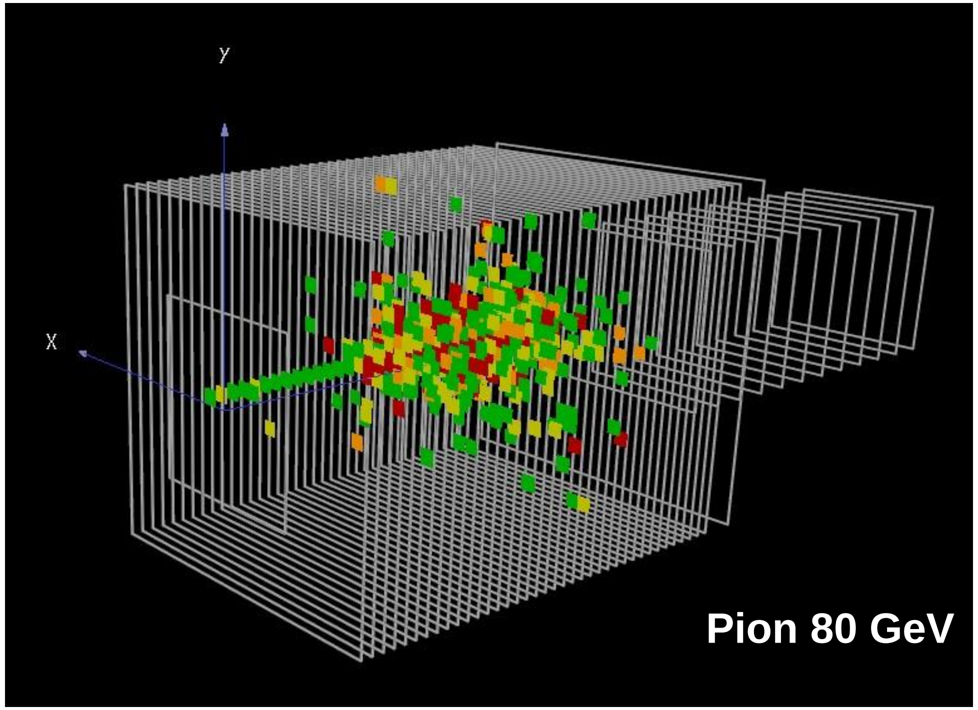
STATUS ON AHCAL PION ANALYSIS

Olin Pinto
CALICE Analysis Meeting
20th May 2020



HELMHOLTZ RESEARCH FOR GRAND CHALLENGES
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OUTLINE

Motivation

<u>Part I</u>

→ Response, linearity & resolution

<u>Part II</u>

→ Tile-gap study using MC

Summary and outlook

MOTIVATION

→ **Important parameters of a calorimeter:**

→ **Linearity** of the energy measurement

→ Precision of the energy measurement (**resolution**, ΔE / E) in general limited by fluctuations in the shower process

→ To achieve an improvement in the single particle energy resolution in the energy range from 10 GeV to 200 GeV the response to deposited hits/energy in the calorimeter for hadronic shower needs investigation

→ First pion results using AHCAL is presented in this talk (work in progress: numbers and figures shown in this presentation are not final)

Pion Data & Selection

Data used in this talk

→ Pions from **June 2018 CERN** test beam

→ **20k events are simulated using QGSP_BERT_HP** physics list from GEANT4 v10.03 for all available energies (10, 20, 30, 40, 60, 80, 120, 160 & 200) with a tile gap size of 0.7 mm

→ **Beam gun position** and the **smearing parameters** are obtained from the **mean and RMS** of the **centre of gravity distributions** in x and y from data and are used as an estimate for beam size

Selection

→ Performed **PID** selection including **shower start** between layer 1 to layer 6 to avoid leakage

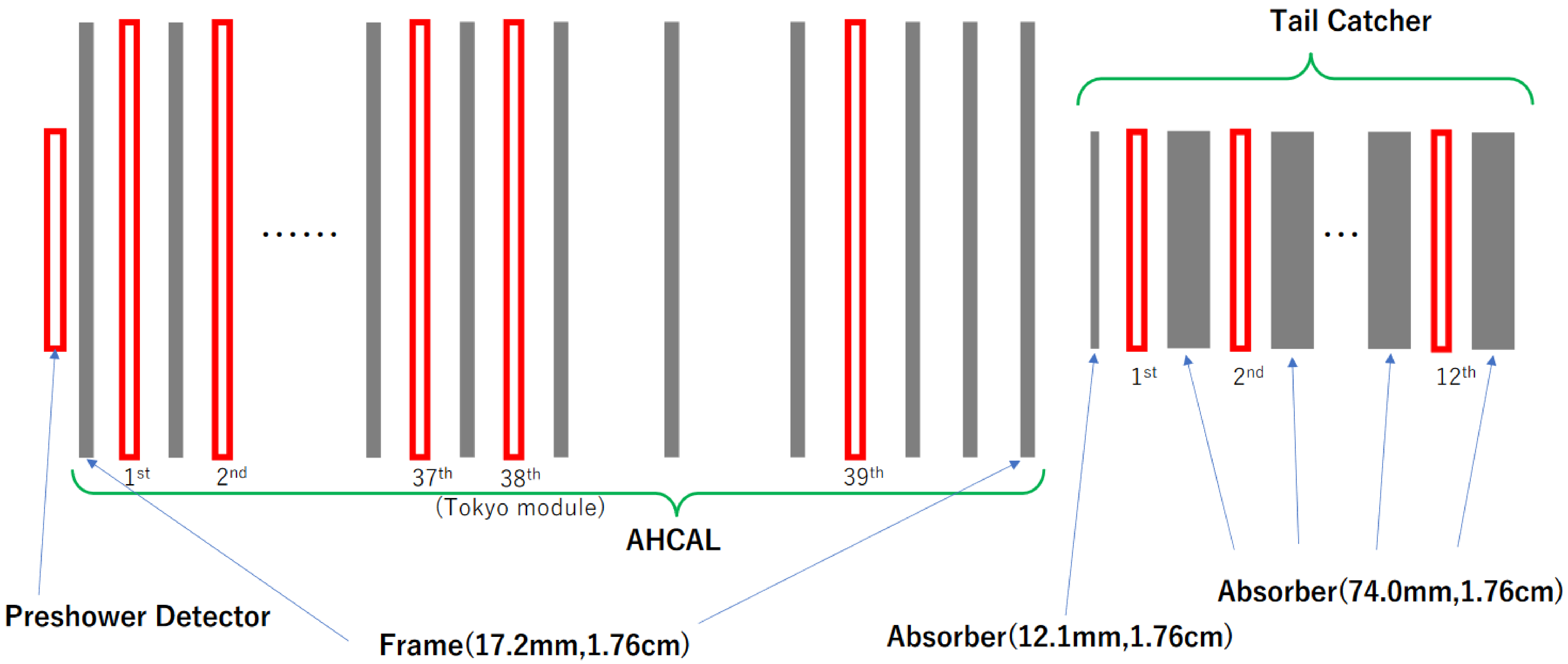
→ ~ 25 – 30 % events are selected (very low statistics are observed due to hard selection and low MC events)

→ Reconstructed energy involves **tail catcher (TC)** to account for leakage

→ Simple weights are applied to TC based on absorber ratio

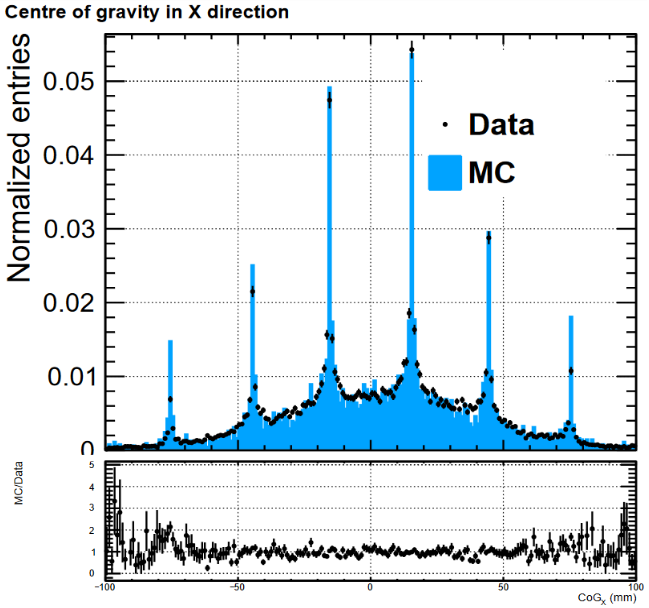
AHCAL + Tail Catcher setup

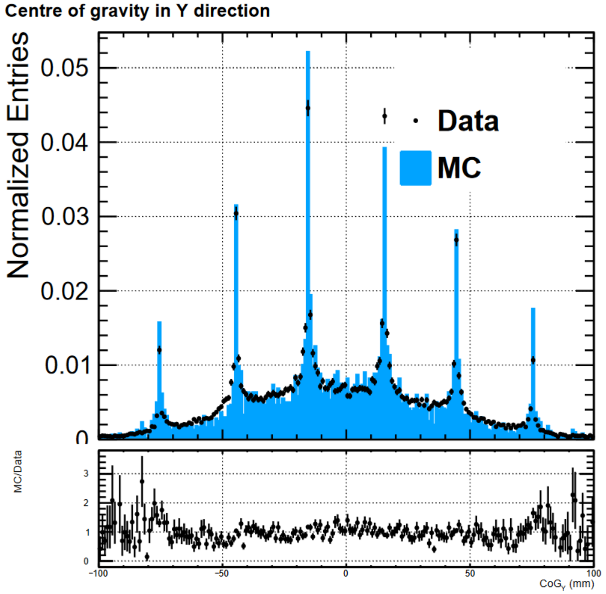
CERN 2018



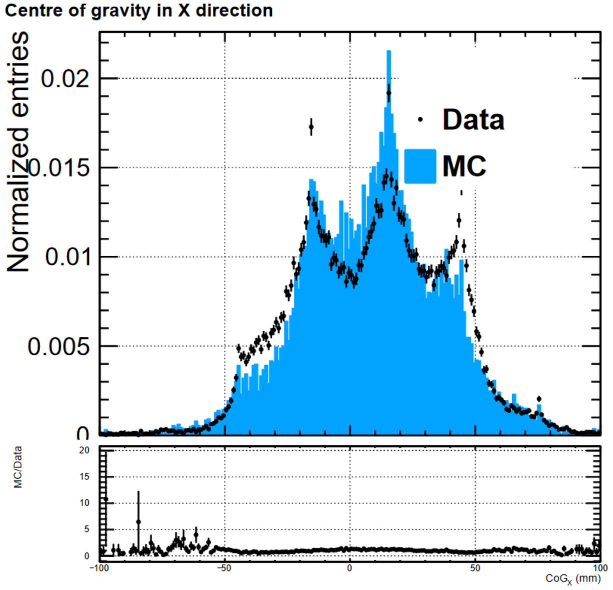
Beam profile

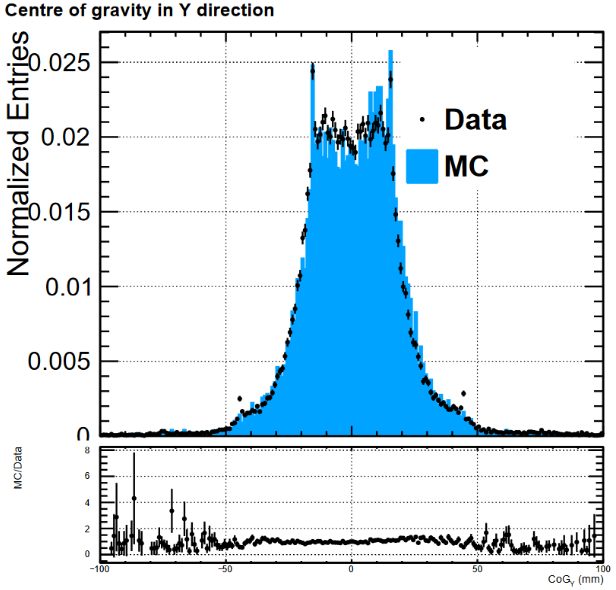
10 GeV



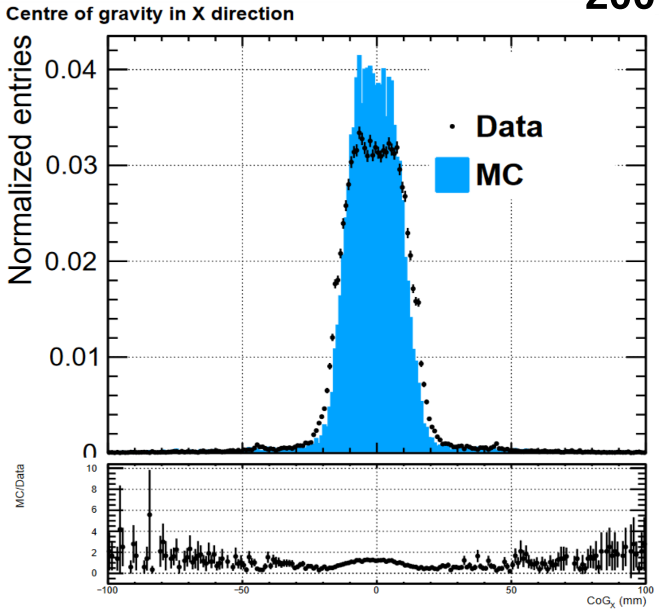


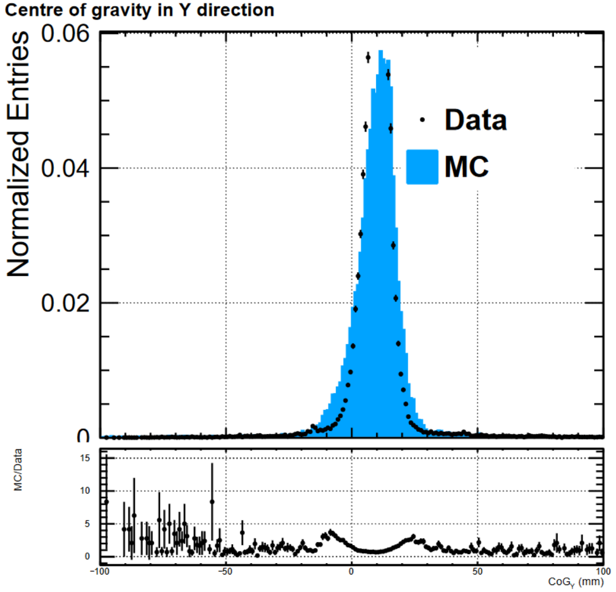
80 GeV





200 GeV





The centre of gravity is calculated as the following:

$$\mathrm{CoG_x\,(mm)} = \frac{\sum_i E_i\, x_i}{\sum_i E_i} \quad \mathrm{CoG_y(mm)} = \frac{\sum_i E_i\, y_i}{\sum_i E_i}$$

→ Beam profiles are tuned so that same channels of the detector are hit both in data and simulation
  → No bias in data and simulation

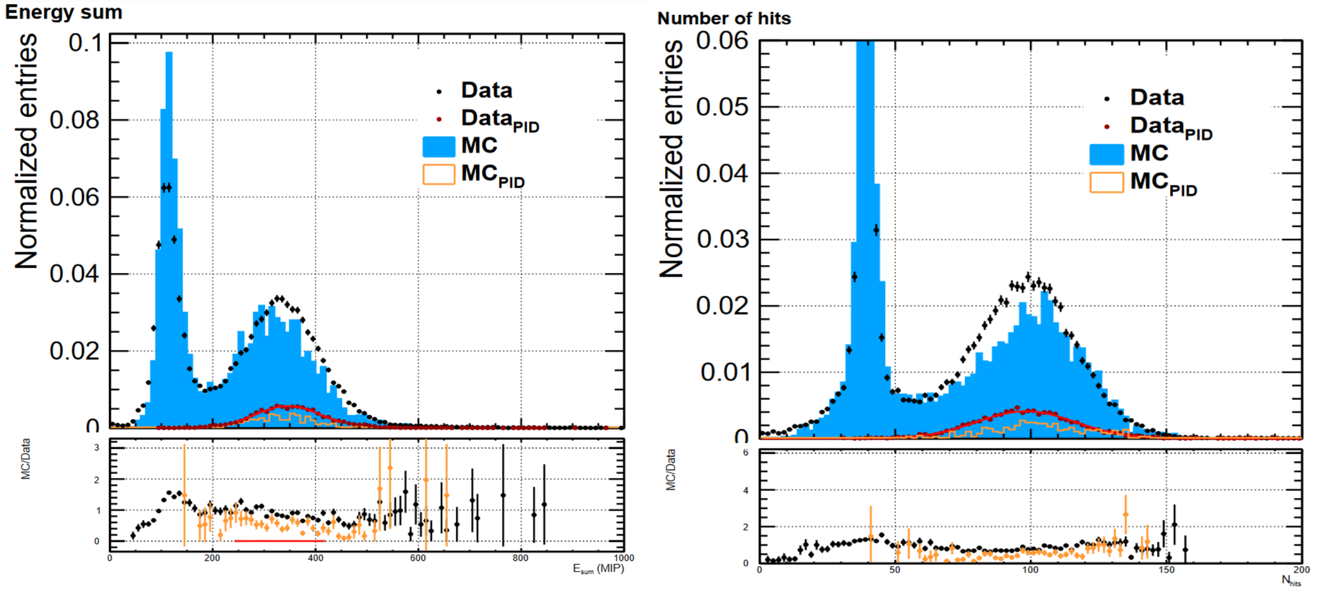
→ Beam profiles for June 2018 data are well tuned for all the available particle energy

Standard variables

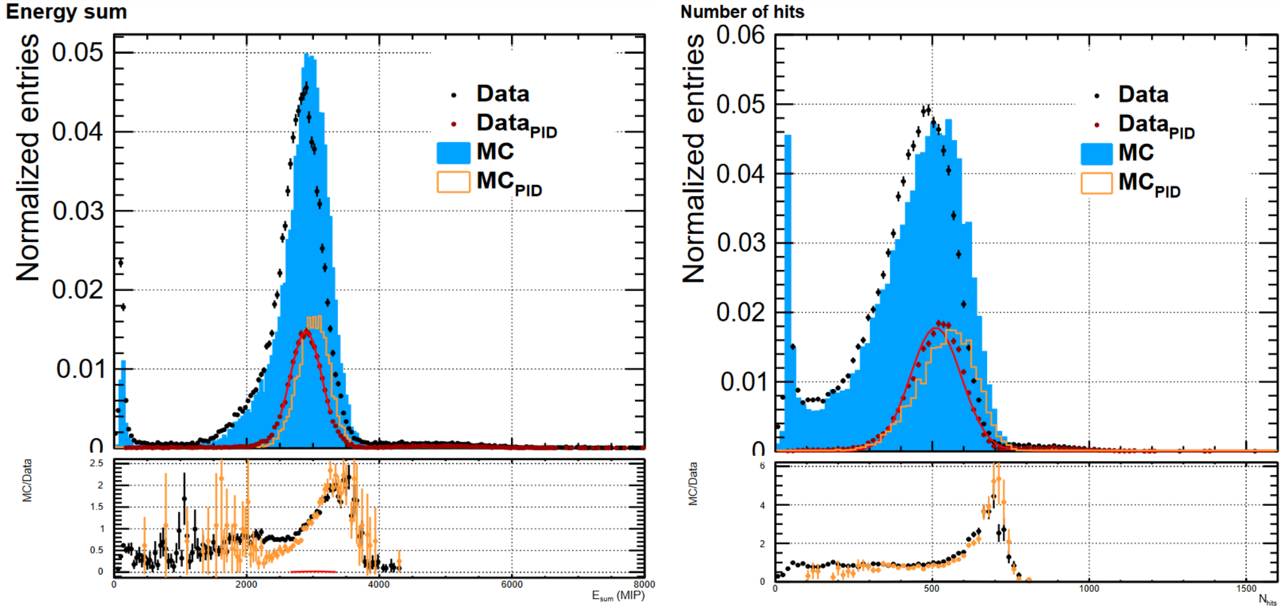
Energy sum and number of hits

→ The number of hits in MC are higher compared to data
→ The red line indicated the result of performing gaussian fits

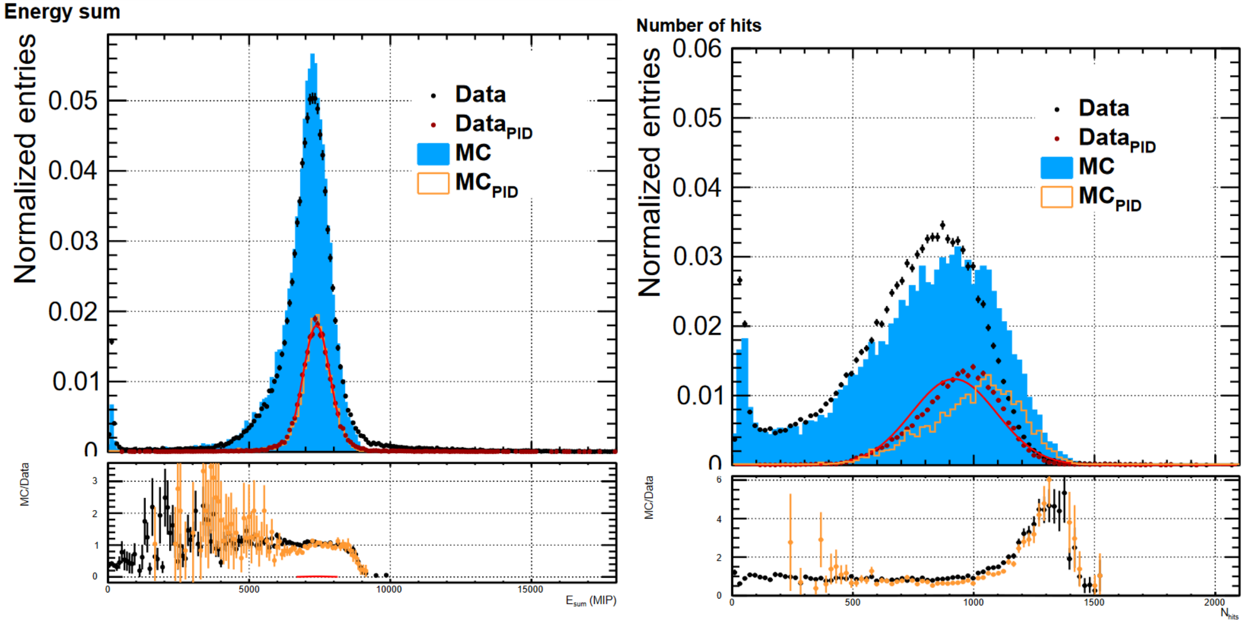
10 GeV



80 GeV



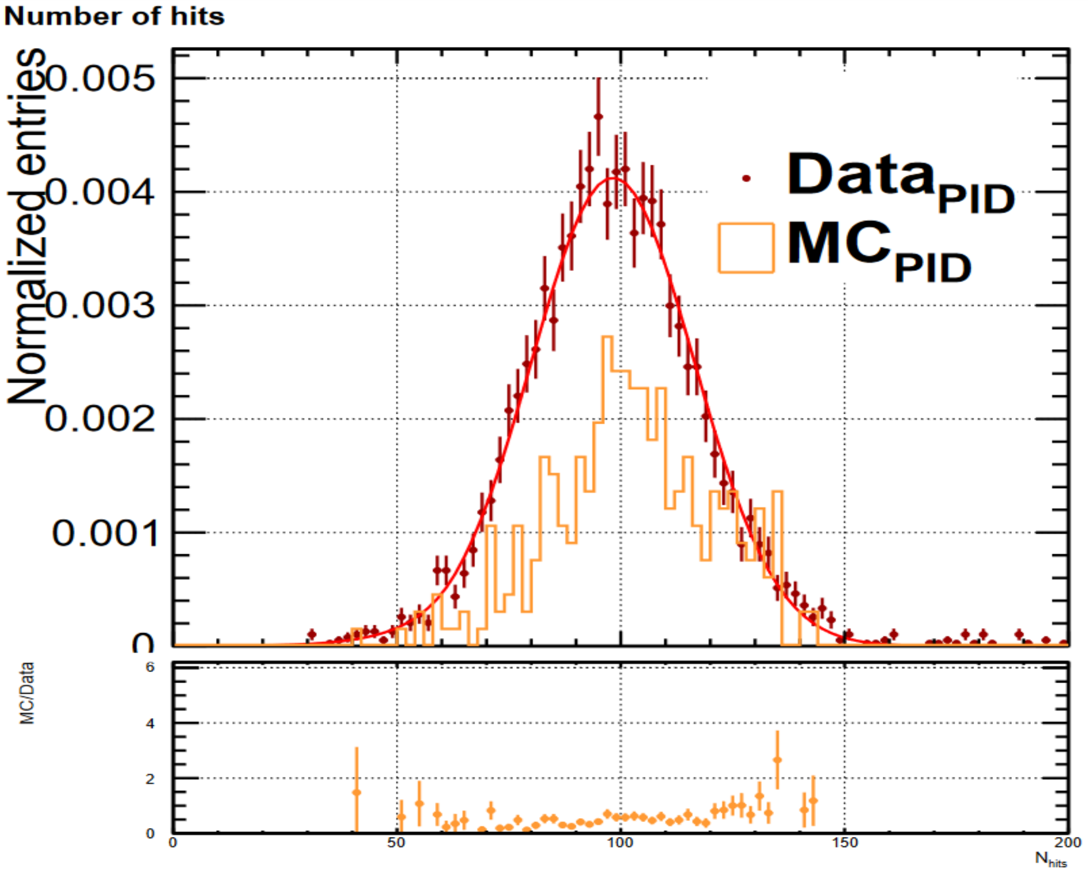
200 GeV

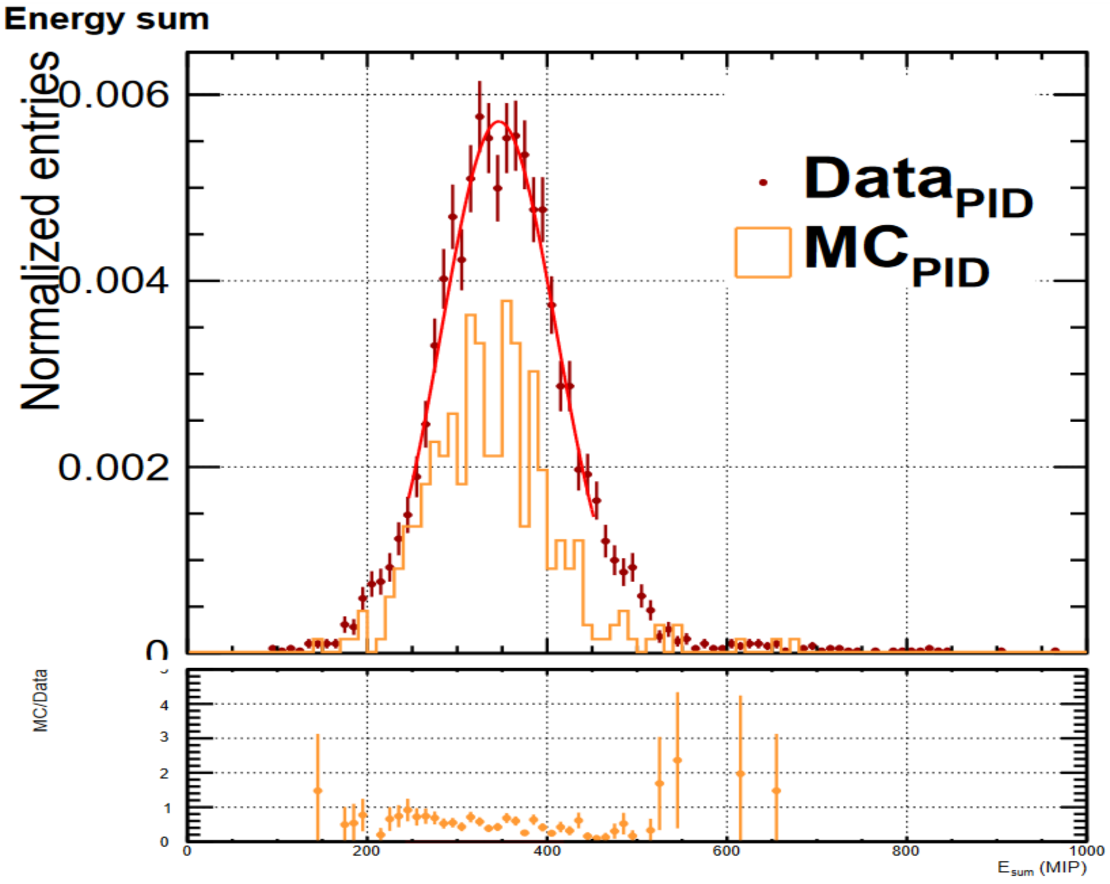


10 GeV

Selected Pions

For both data as well as MC, hit distributions are fitted with the function: Gaussian with 2 exponential tails and energy distributions are fitted with the Gaussian mean +- 1.5 sigma

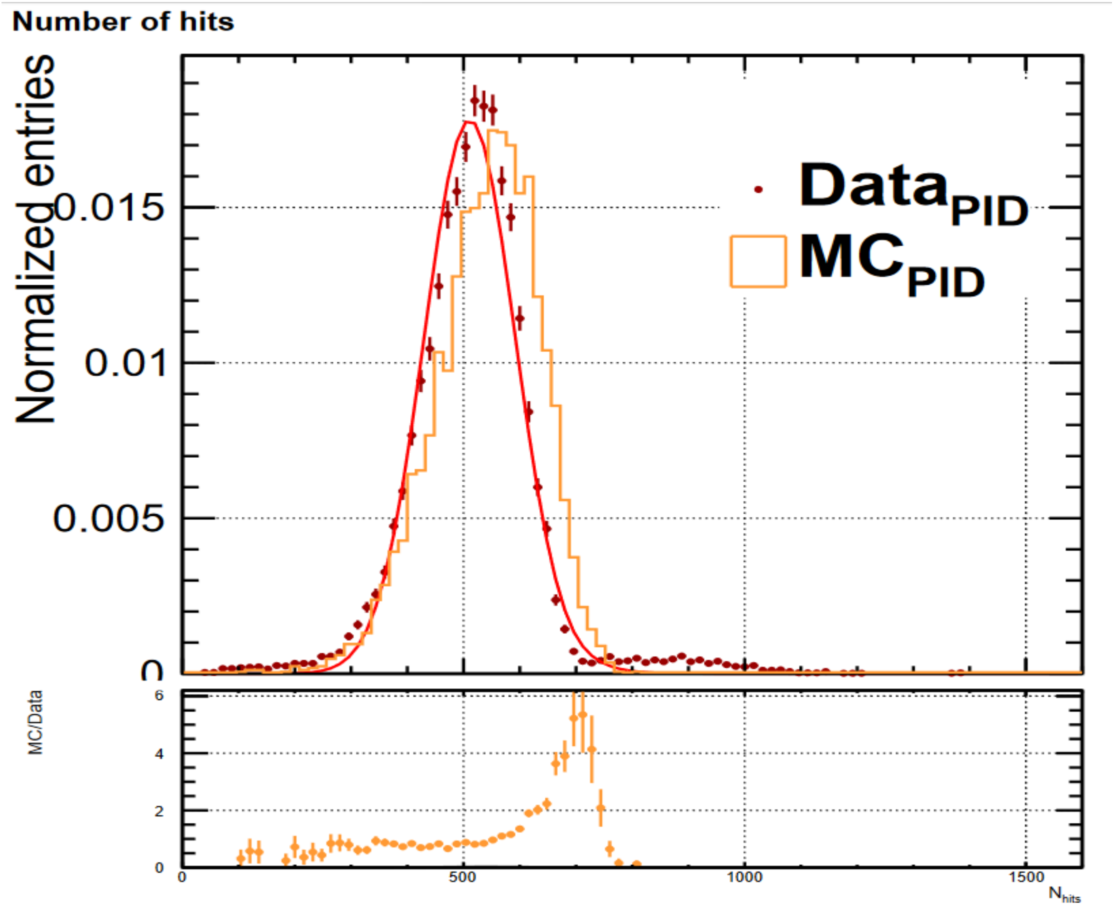


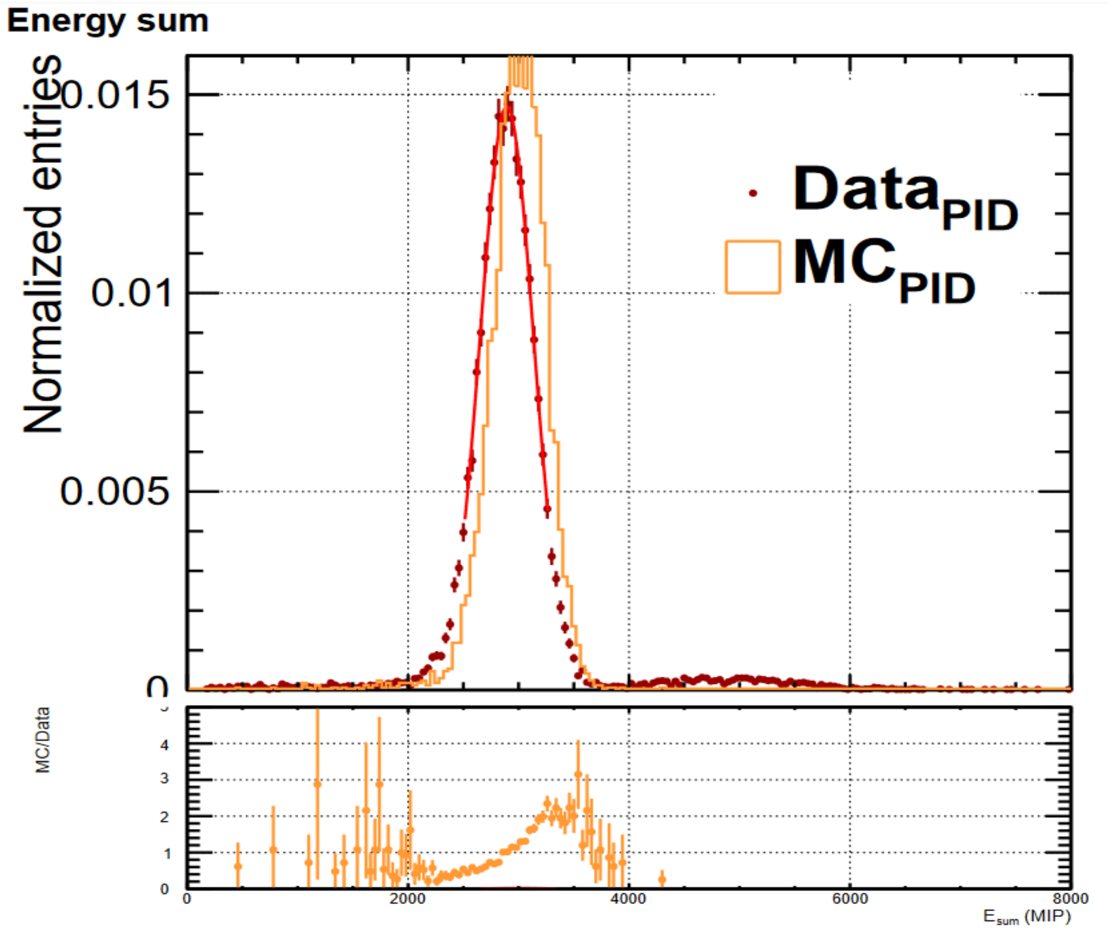


80 GeV

Selected Pions

For both data as well as MC, hit distributions are fitted with the function: Gaussian with 2 exponential tails and energy distributions are fitted with the Gaussian mean +- 1.5 sigma

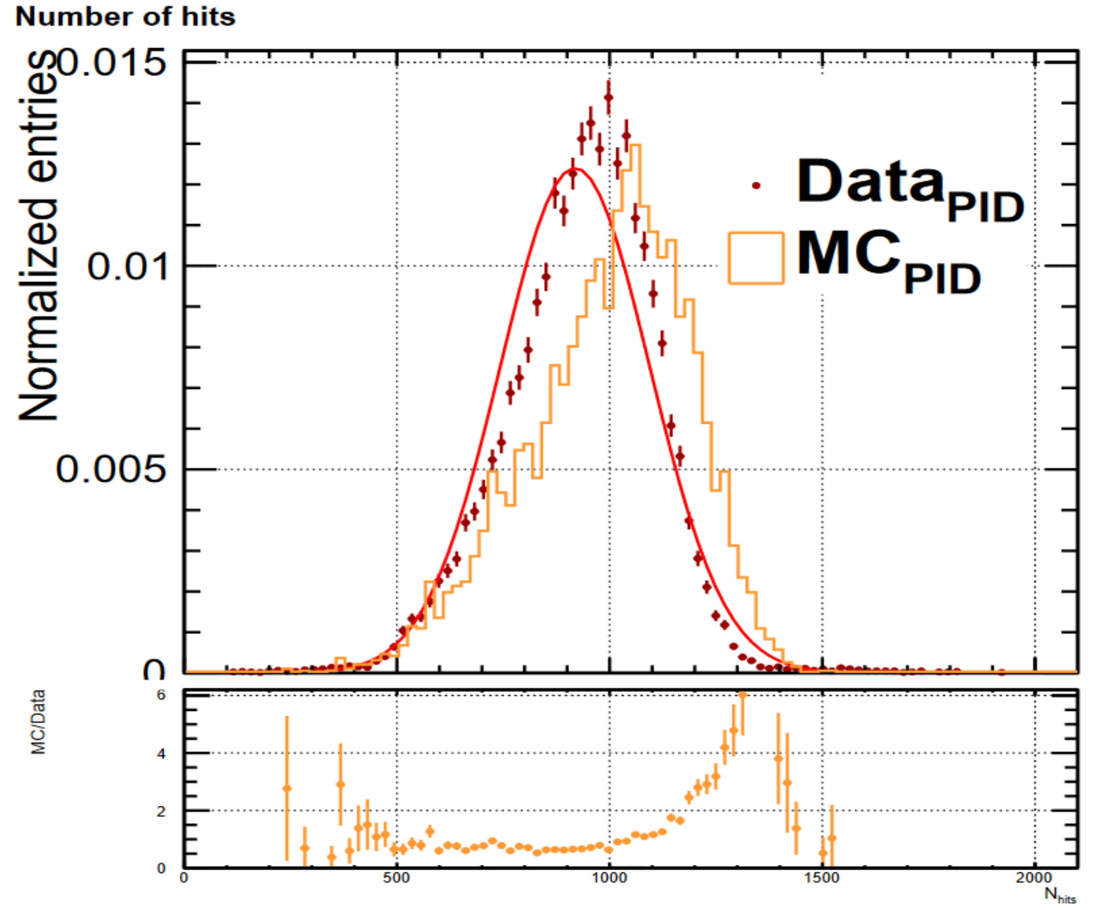


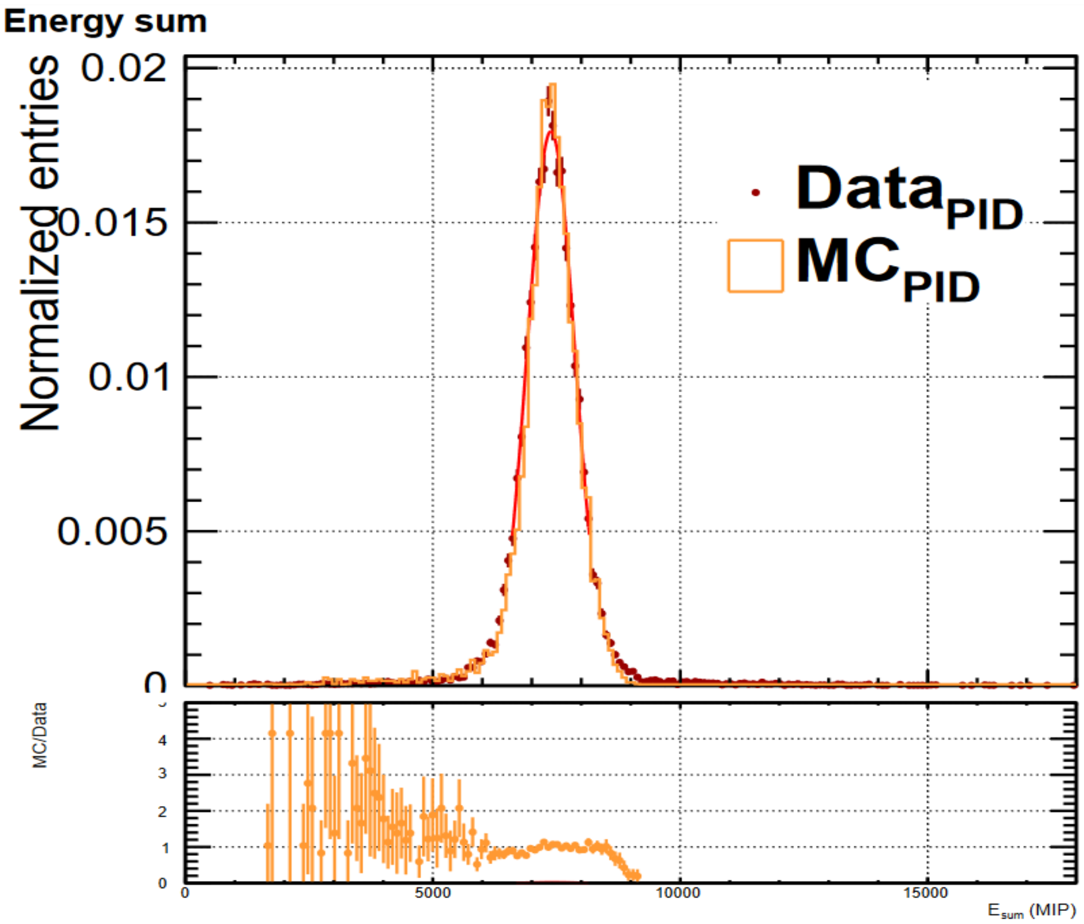


200 GeV

Selected Pions

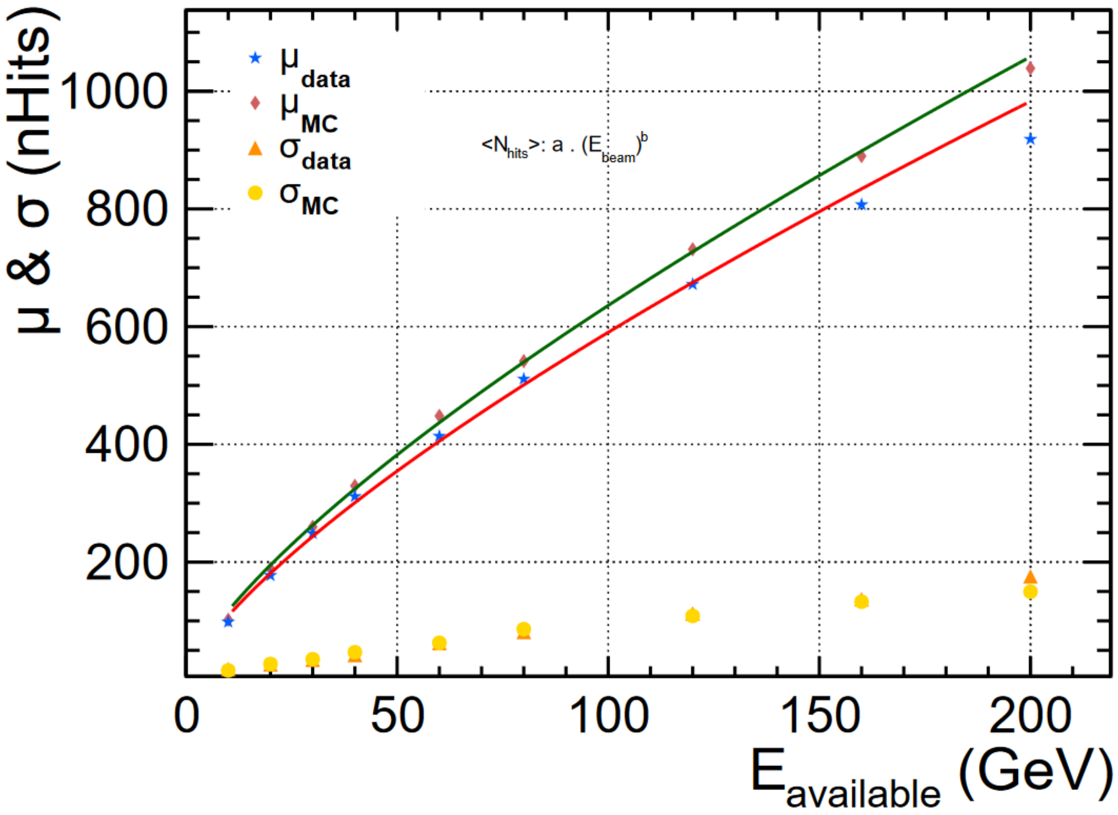
For both data as well as MC, hit distributions are fitted with the function: Gaussian with 2 exponential tails and energy distributions are fitted with the Gaussian mean +- 1.5 sigma





Response & Linearity

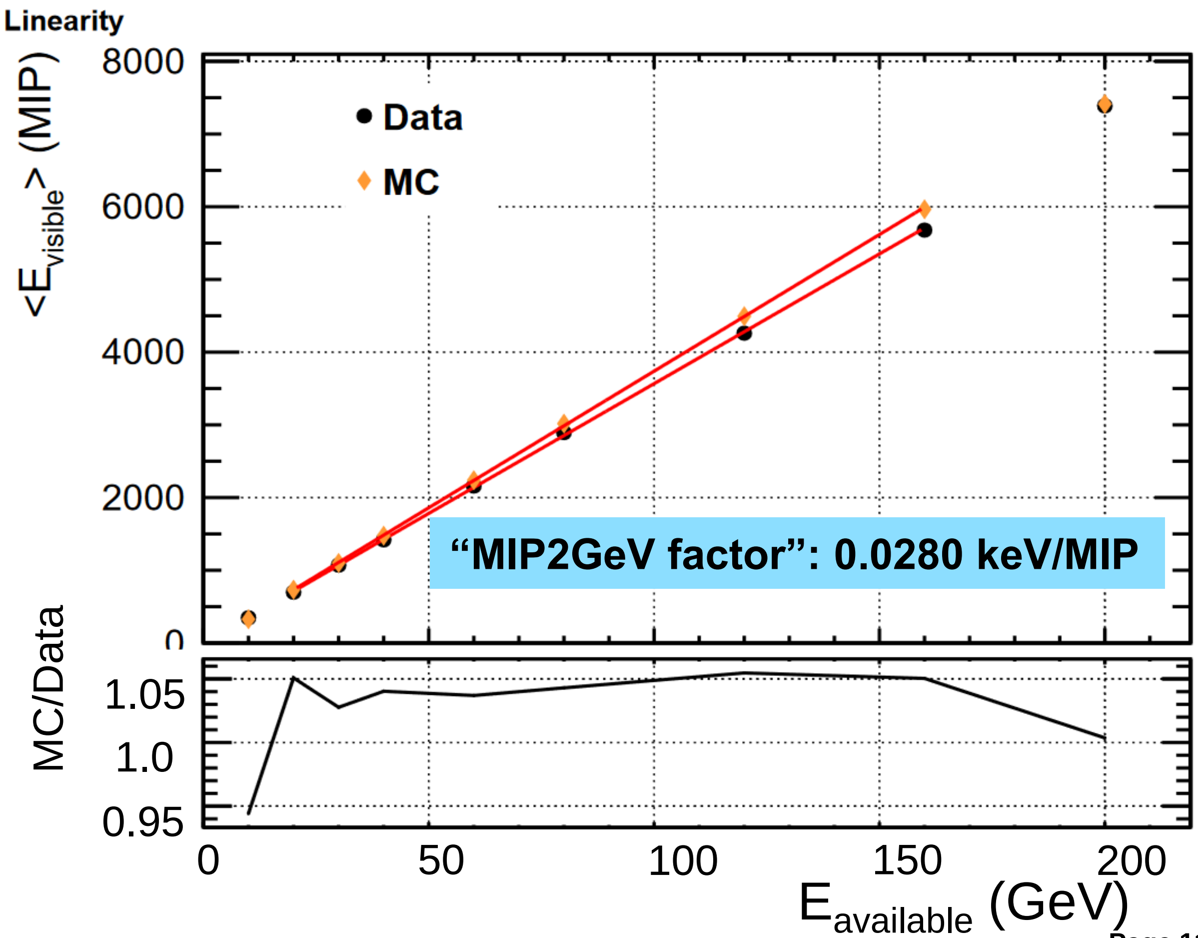
→ Mean & RMS of nHits distribution is extracted using the fit function: Gaussian with 2 exponential tails



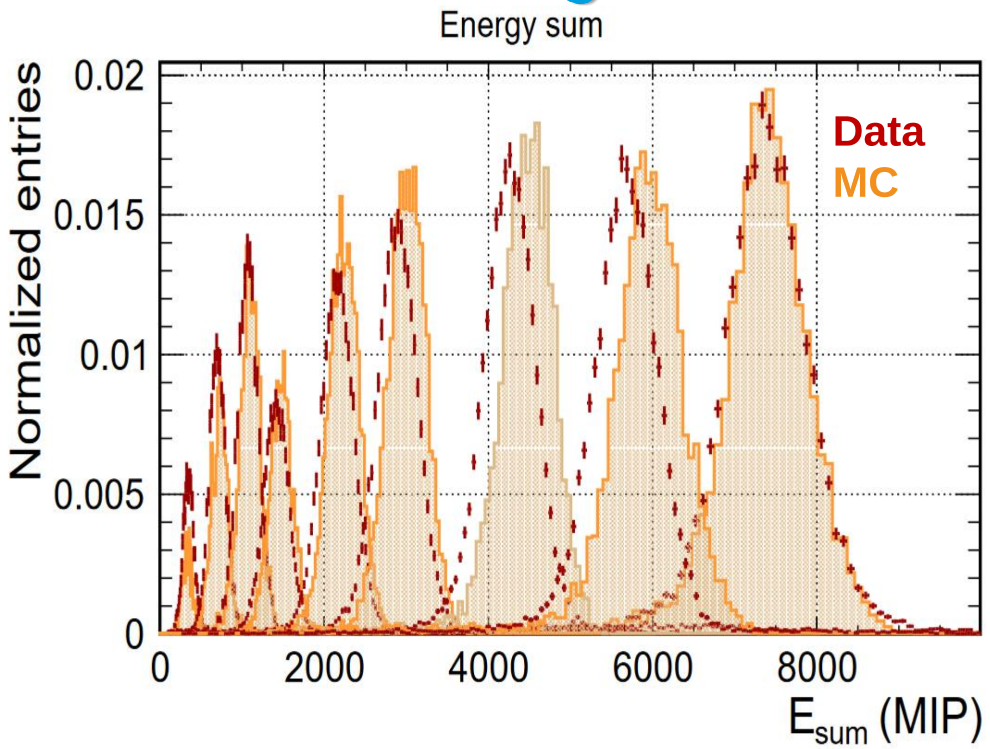
Mean and RMS of the energy distribution are extracted using mean +- 1.5 sigma to get rid of statistical fluctuations in the tails

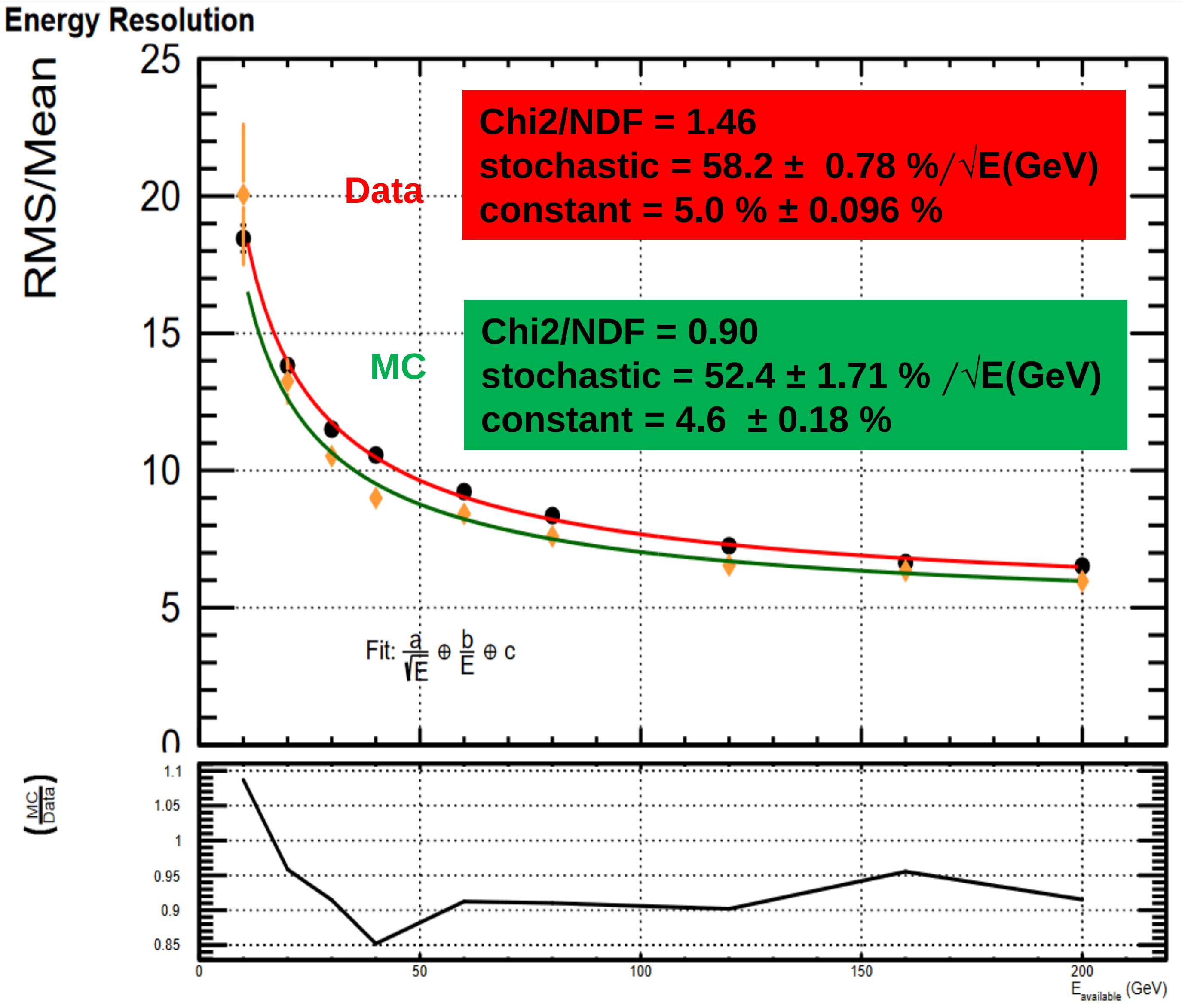
→ Reconstructed energy(MIP) is fitted within the energy range [20,160]

→ Linearity looks reasonable for both data and MC (within ~5%)



Relative energy Resolution





→ The functional form is employed to fit the relative energy resolution which consist of: Stochastic term, noise term & constant term

→ The noise term is fixed to zero as the detector has very low noise level

→ ~ 8 to 10 % difference between Data & MC

→ The errors are extracted from fit and added in quadrature

PART II

Tile-gap study

AHCAL tile

Nominal values

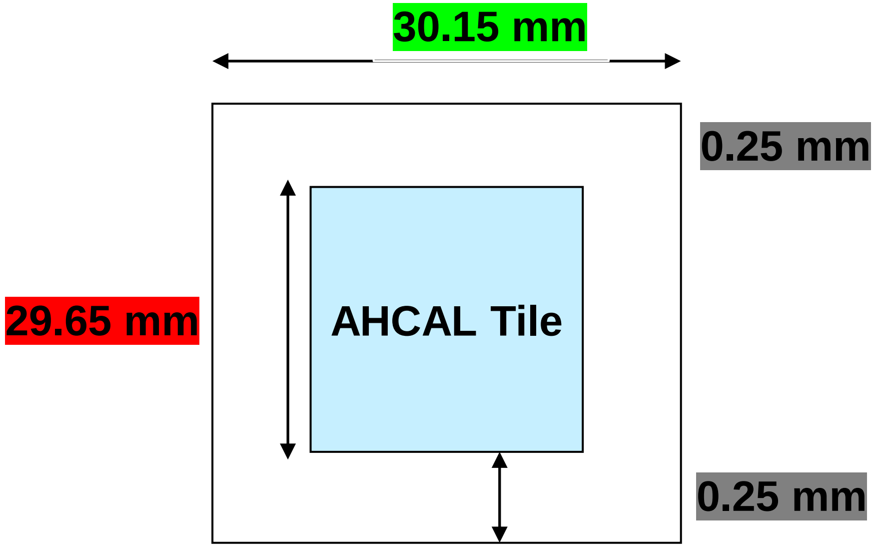
Tile pitch = 30.15 mm

Tile size = 29.65 mm

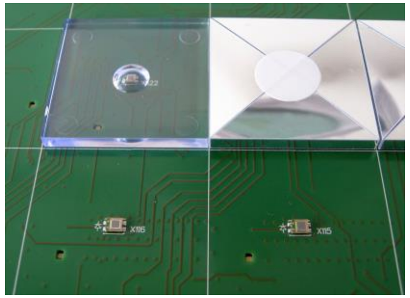
Dead-space = 0.5 mm

→ What are the actual tile sizes?

→ Have an influence on the measurements?

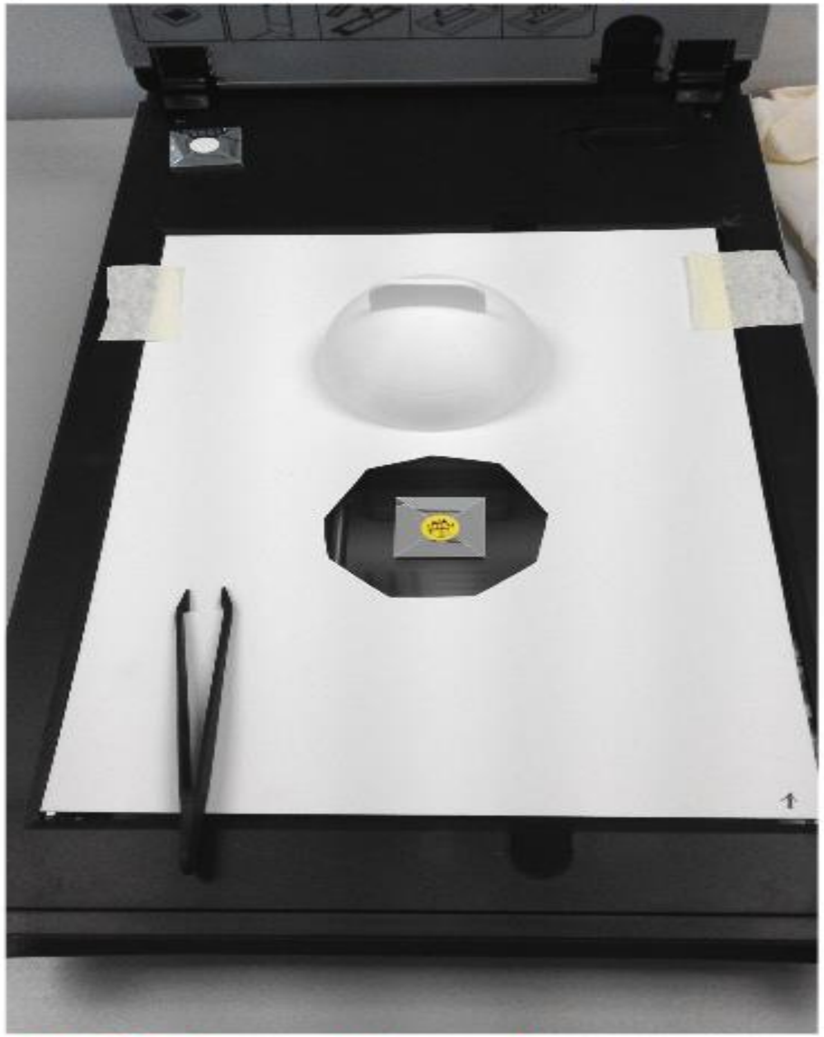


Not to scale

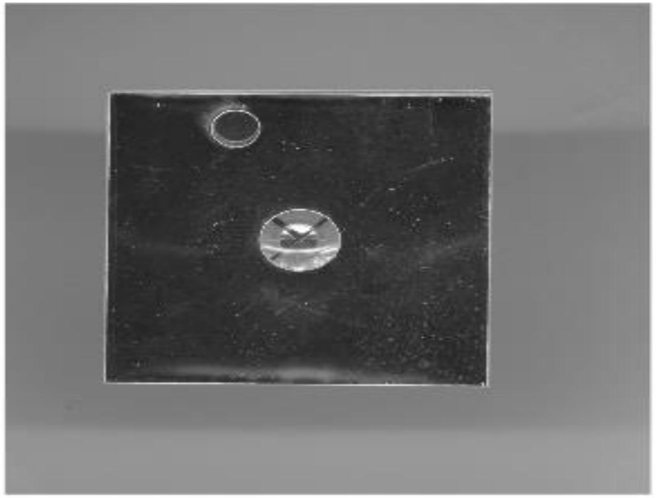


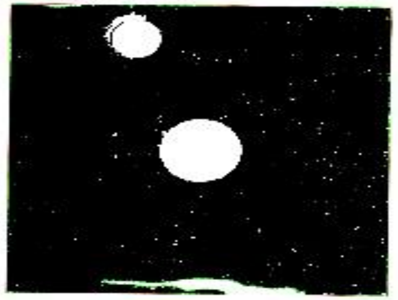
Quality Control – From each 50-tile-box: One Scan

- Squeezing with caliper is not allowed

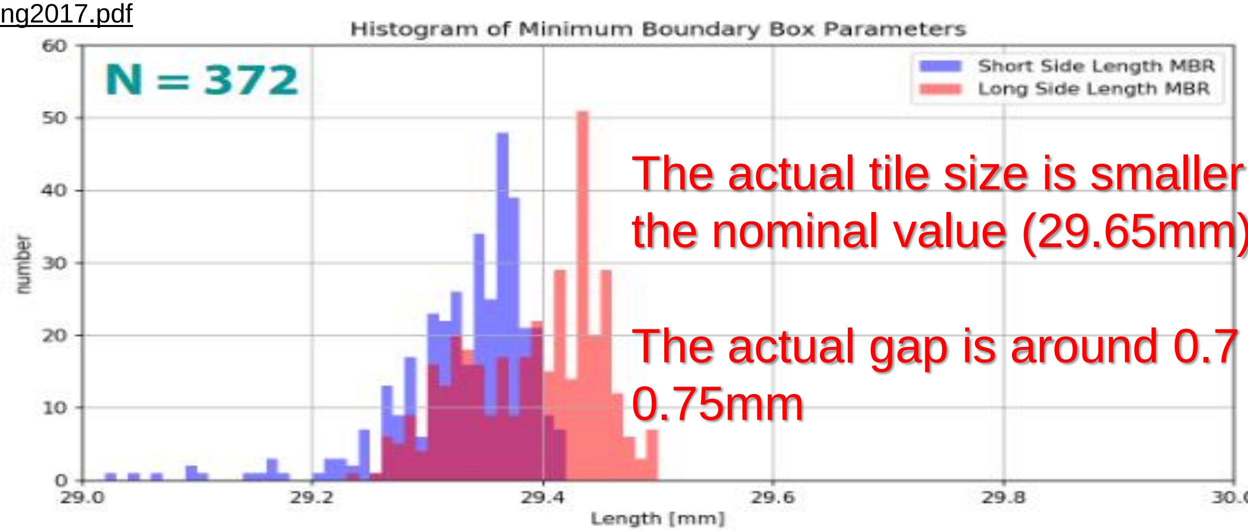


Half integrating sphere





https://agenda.linearcollider.org/event/7807/contributions/40519/attachments/32551/49482/TileWrapping-CollMeeting2017.pdf



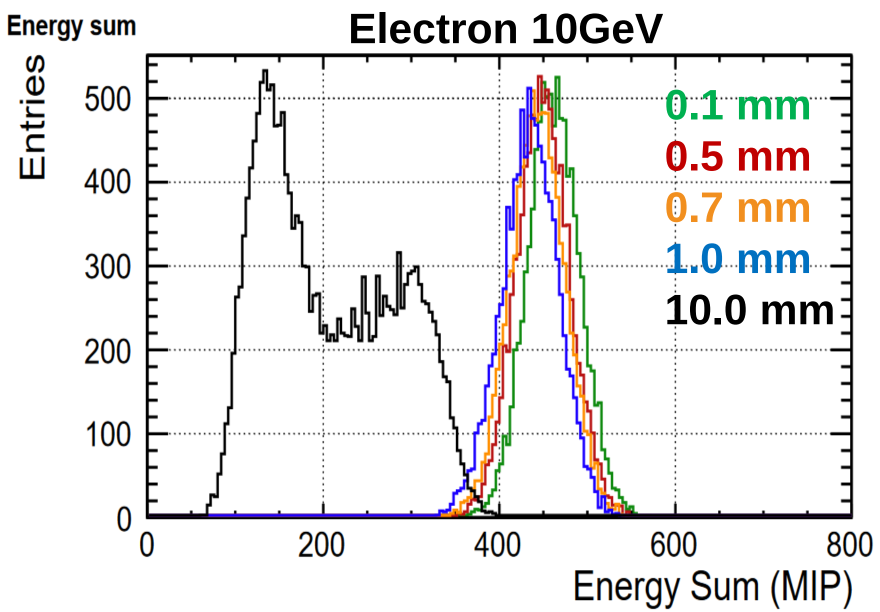
The actual tile size is smaller than the nominal value (29.65mm)

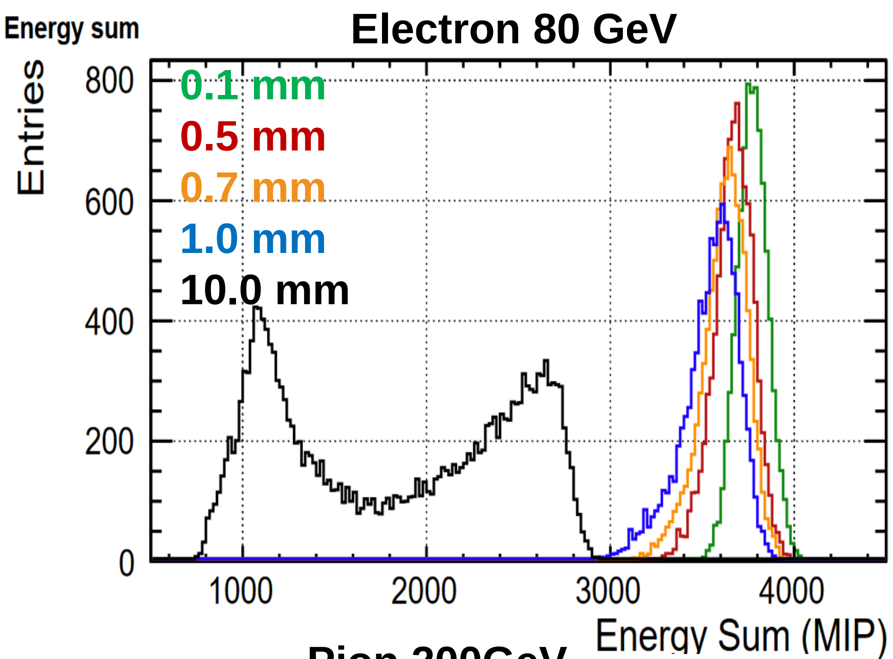
The actual gap is around 0.7 to 0.75mm

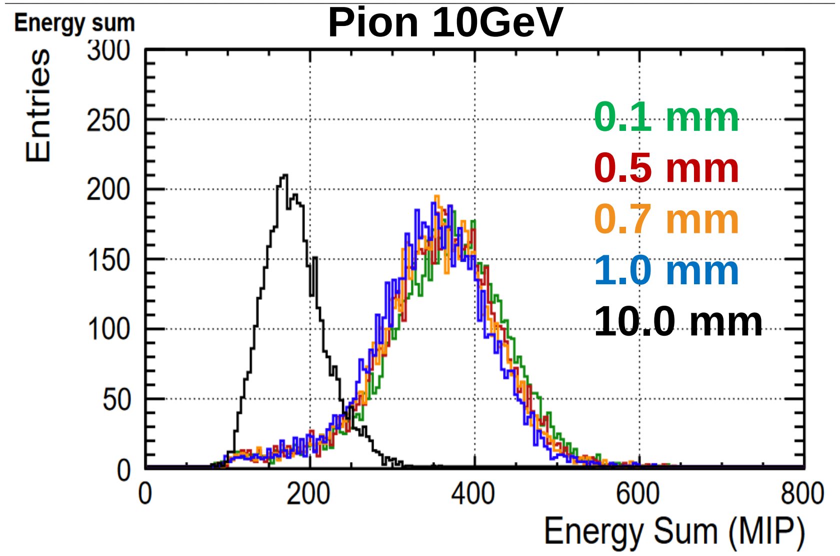
Energy sum distributions

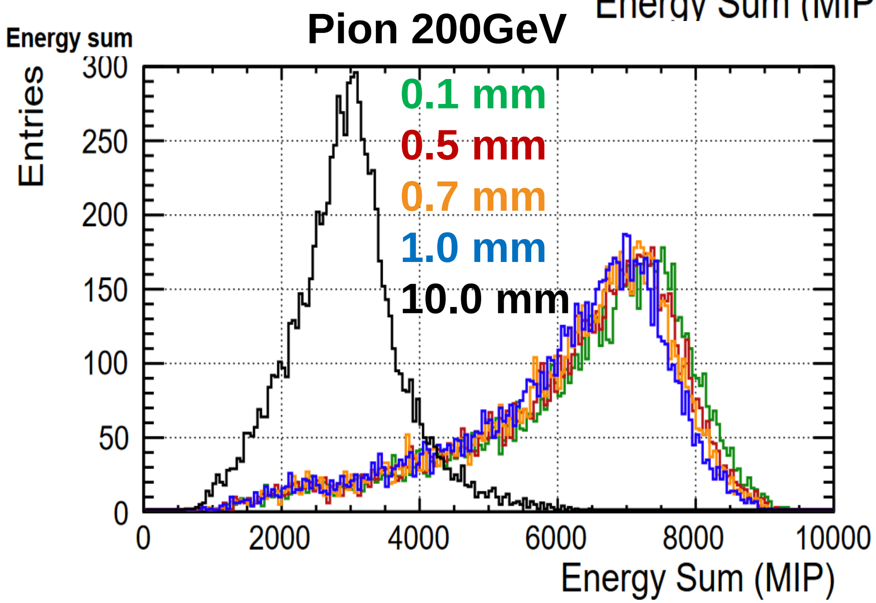
→ Effect of larger tile-gap on energy sum prominent in case of electrons compared to pions

→ The distribution are fitted with gaussian mean +- 2. sigma to extract the mean and width









Fit function used

The nominal tile size, $F_0 = (30.15\ \text{mm})^2$

$F(gap) = (30.15\ \text{mm} - gap)^2$

Visible energy (E_{vis}) ≈ Number of incident particles (N)

$E_{vis}(gap)/E_0 = F(gap)/F_0$

$$\boxed{E_{vis}\,(gap) = E_0\,(1 - gap/30.15)^2 \longrightarrow a\,.\,(1 - x/30.15)^2}$$

Relative resolution, $\sigma_{vis}/E_{vis} \approx 1/\sqrt{E}$

$$\frac{\sigma_{vis}}{E_{vis}}(gap) = \sigma_0/E_0\,\left(\frac{1/\sqrt{E_{vis}}}{1/\sqrt{E_0}}\right) \qquad \frac{\sigma_{vis}}{E_{vis}}(gap) = \sigma_0/E_0\,\left(\frac{\sqrt{E_0}}{\sqrt{E_{vis}}}\right)$$

$$\boxed{\frac{\sigma_{vis}}{E_{vis}}(gap) = \sigma_0/E_0\,\left(\frac{30.15}{30.15 - gap}\right) \longrightarrow a\,/\,(30.15 - x.b)}$$

"b" should be 1 in the purely geometrical case

<E_Sum> Vs. Dead-space

$a \, . \, (1 - x/30.15)^2$

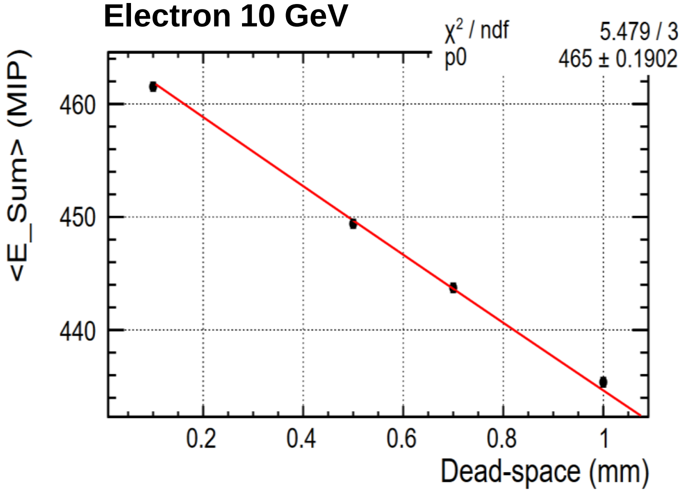
Resolution Vs. Dead-space

$a \, / \, (30.15 - x.b)$

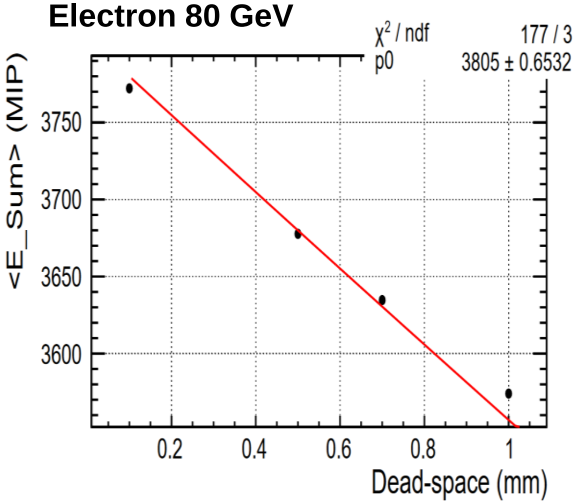
→ Both electrons and pions show a reduced energy sum with an increase in gap size (which agrees reasonably well with the assumption that this is purely a geometrical effect) and the effect on resolution for pions is small

→ **Dead-space 0.7 mm has been used in the pion analysis**

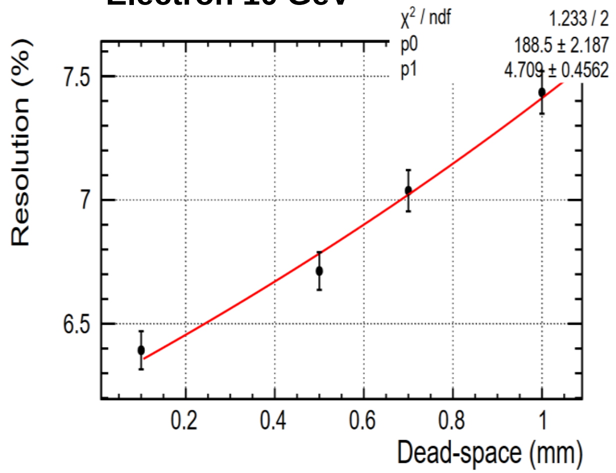
Electron 10 GeV



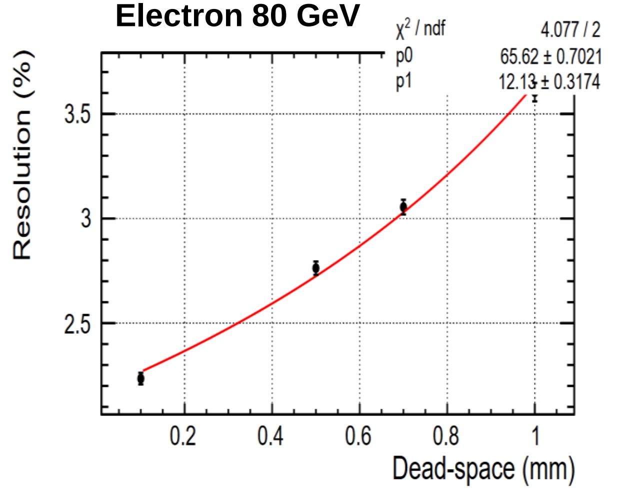
Electron 80 GeV



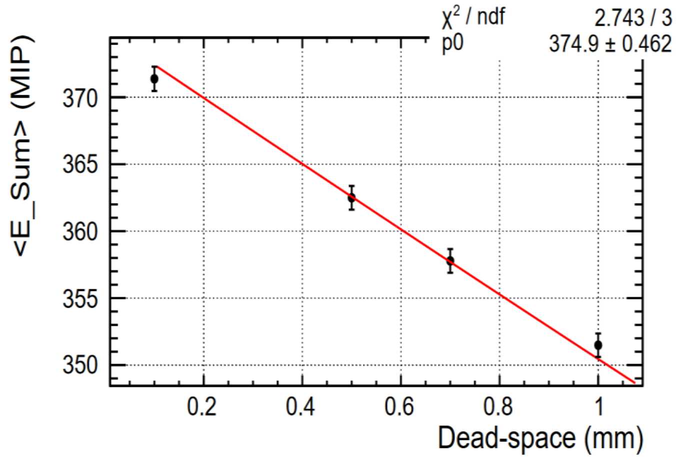
Electron 10 GeV



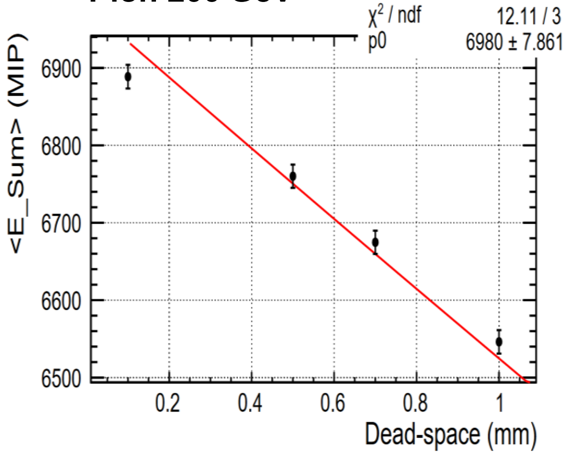
Electron 80 GeV



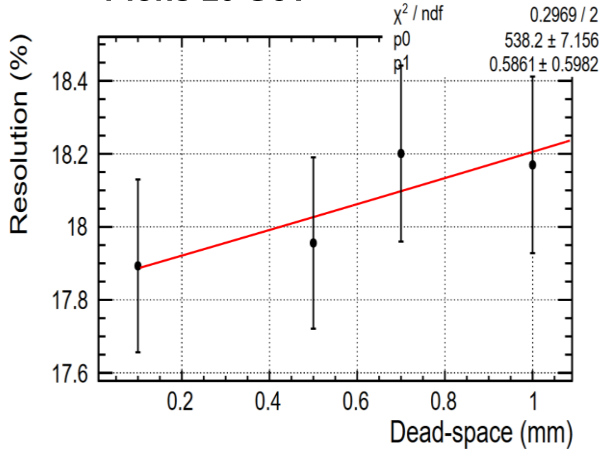
Pion 10 GeV



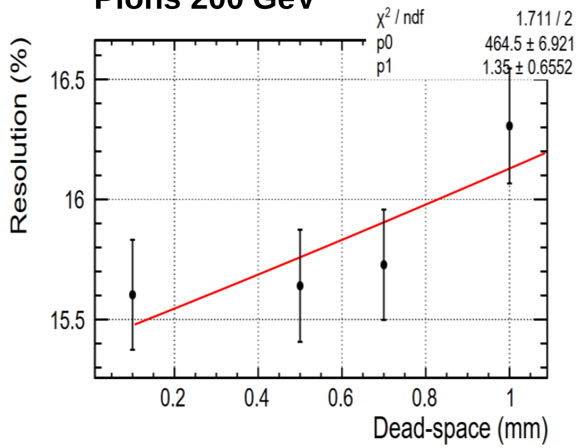
Pion 200 GeV



Pions 10 GeV



Pions 200 GeV



Summary

→ The AHCAL response, linearity and resolution are measured and are in reasonable agreement between data and simulation

→ Large MC production is under process

→ Tile-gap of 0.7 mm is used in simulation

& Outlook

→ Systematics to be done

→ Improvement in single particle energy resolution

→ Look deep into the shower shapes to understand the different components of the hadronic shower

→ More detailed studies comparing different physics models provided by the GEANT4

THANK YOU

SPARES

Beam Profile

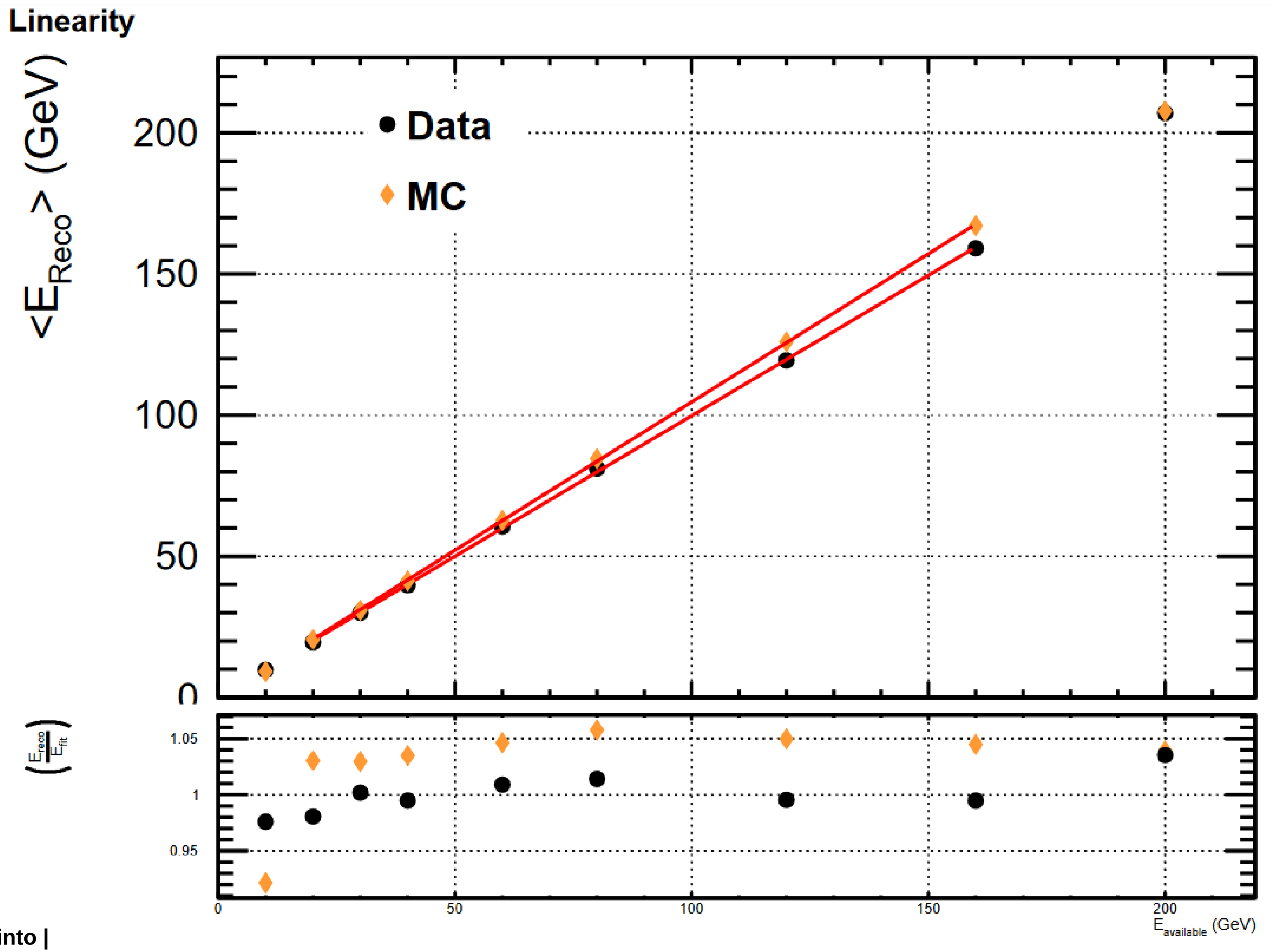
Tuned for 20K MC events

DATA
MC

Energy (GeV)	Run number	CoG mean X (mm)		CoG mean Y (mm)		CoG RMS X (mm)		CoG RMS Y (mm)	
10	61265	4.28	4.02	-1.84	-2.16	35.8	35.05	38.33	37.1
20	61272	5.7	6.05	-5.76	-4.65	32.03	30.33	30.24	29.27
30	61378	-115.21	-115.06	-19.07	-18.42	31.98	30.31	26.2	26.11
40	61275	9.23	9.06	7.43	6.91	30.98	29.77	25.35	24.28
60	61262	9.32	9.39	-7.67	-7.72	31.24	28.61	21.47	19.98
80	61279	8.79	8.6	0.64	0.82	30.37	28.35	20.58	19.38
120	61233	8.13	8.11	1.51	0.44	14.96	13.81	12.97	12.81
160	61287	5.63	5.35	1.87	2.19	14.42	14.16	12.43	12.80
200	61201	-0.28	-0.78	10.03	9.41	14.42	13.77	11.59	13.99

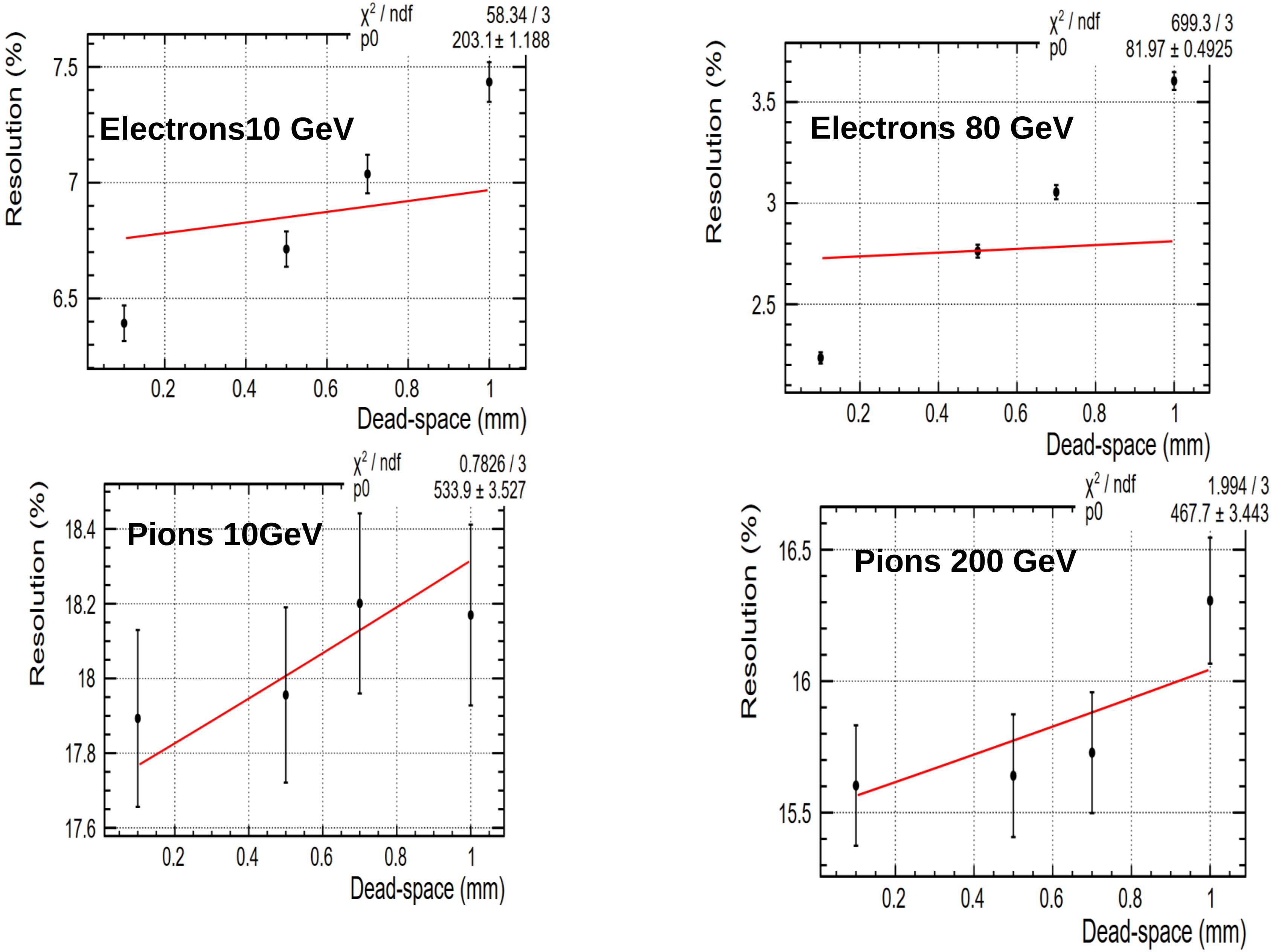
The Z coordinate of the beam was always set to -50000 mm

Reconstructed Energy in GeV



Resolution Vs. Dead-space

a / (30.15 – x)



Electron energy resolution