2-photon separation studies using CALICE SiW test beam data

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2-photon separation is central feature of highly granular ECALs

Important for

- Neutral pion identification and reconstruction
  - can give improvements in Jet Energy Resolution (c.f. G. Wilson et al)

- Tau lepton decay mode identification
  - use of tau as polarimeter in e.g. Higgs decay

Want to measure how well nearby photons can be resolved

- using real test beam data (SiW physics prototype),
  - and how well it is simulated

We have studied this by overlaying events collected by the SiW ECAL (physics prototype)

- at FNAL in 2011 (combined test beam with DHCAL from Jose et al)
- This analysis also serves to check this dataset

Compare performance different reconstruction algorithms

- PandoraPFA (M. Thompson et al)
- Garlic (Brient, Reinhard, DJ)

This is a status report; all is preliminary

Outline

Data quality checks
- Basic ECAL performance, data vs MC
- Event selection

Overlaying events

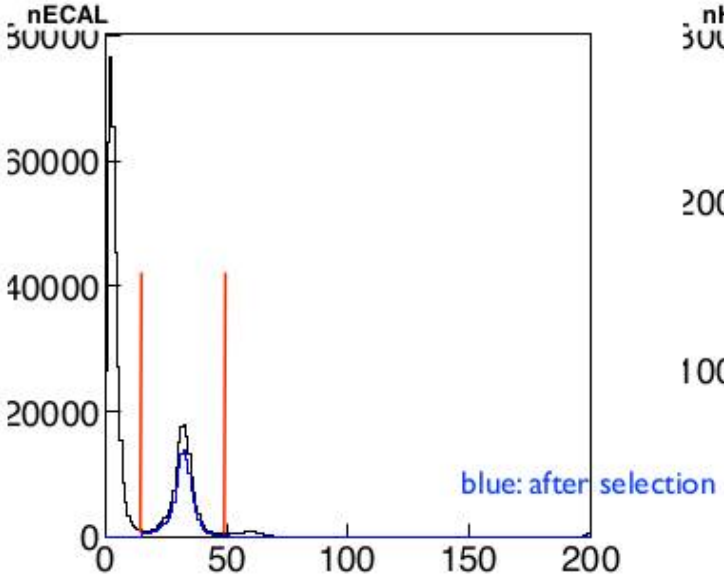
Reconstruction

Results

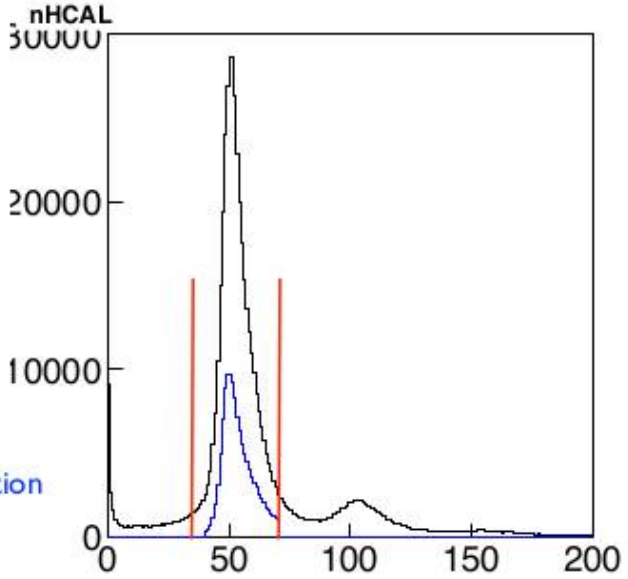
Calibration

"New" calibrations obtained from 2011 data uploaded to database
(Rouene, Poeschl)
1st task: check these calibrations in muon runs @ 32 GeV

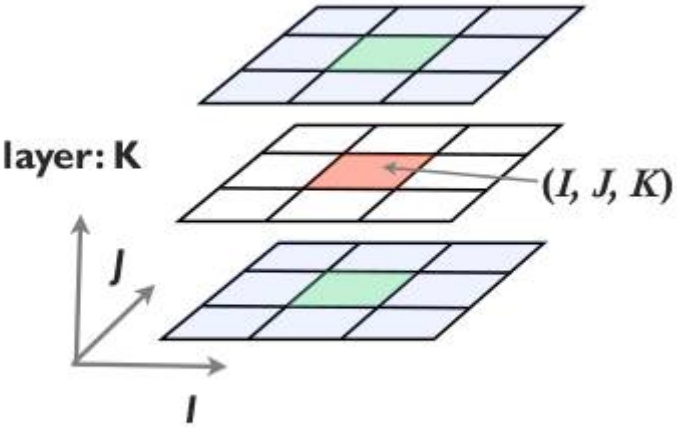
Simple event selection based on number of ECAL and DHCAL hits

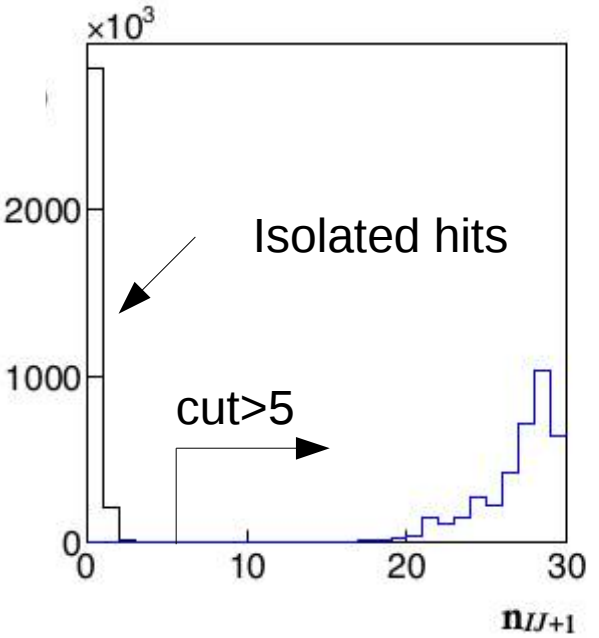


ECAL hits



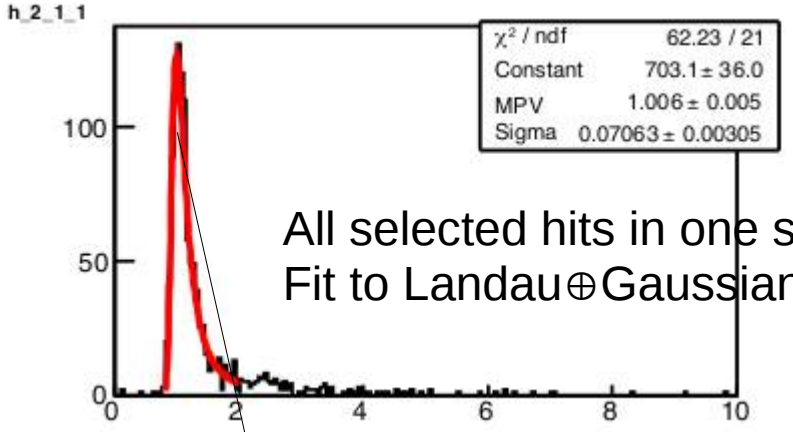
DHCAL hits





Look at energy of hits in these events which look like part of muon track

Statistics not enormous:
so look at sensor level (36 chan/sensor)

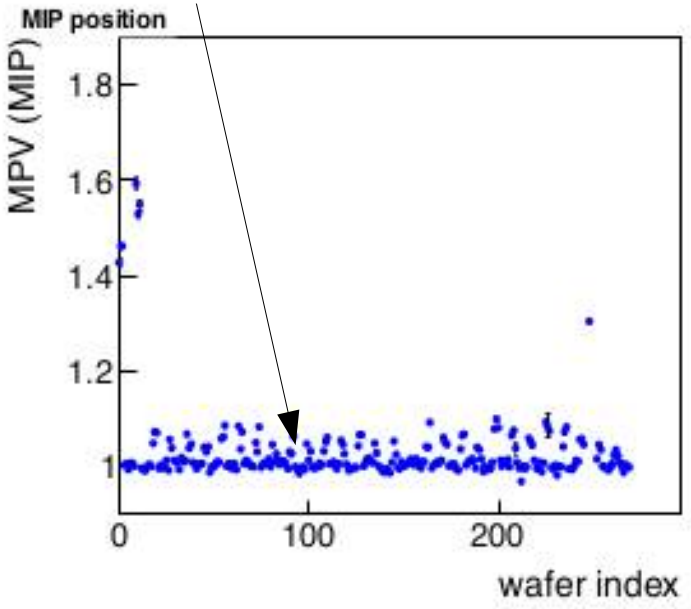


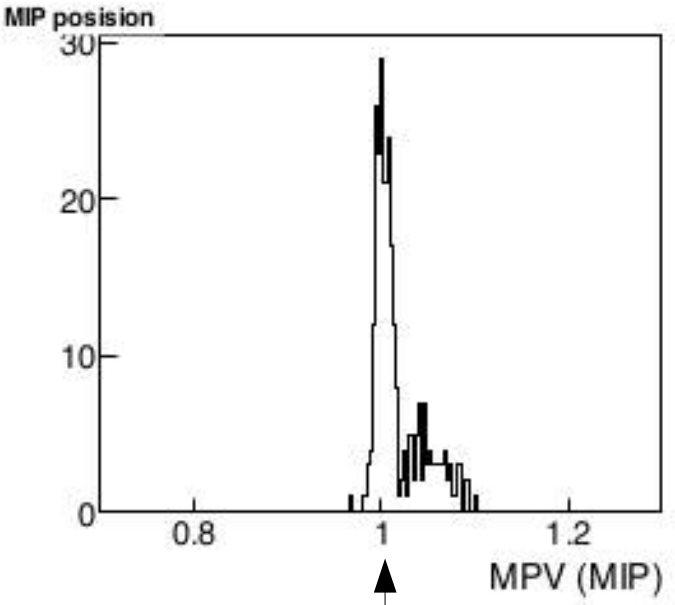
All selected hits in one sensor
Fit to Landau⊕Gaussian function

Hit energy (MIPs)

Original calibration

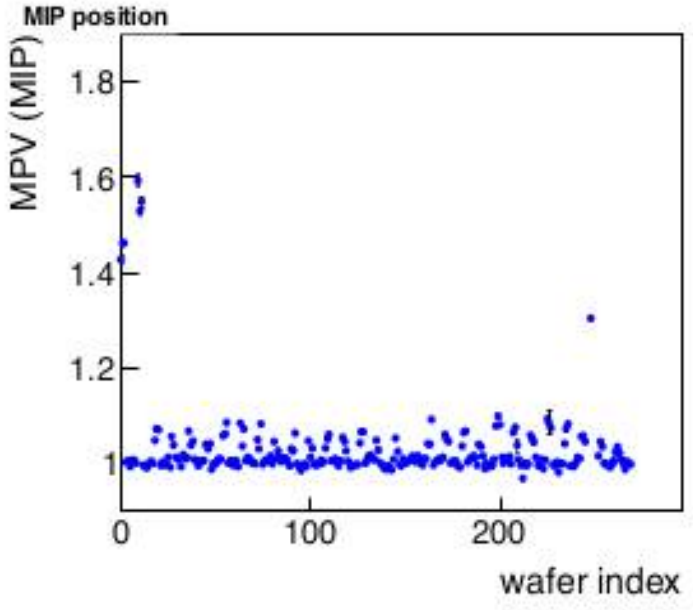
Measured peak position (MIPs)

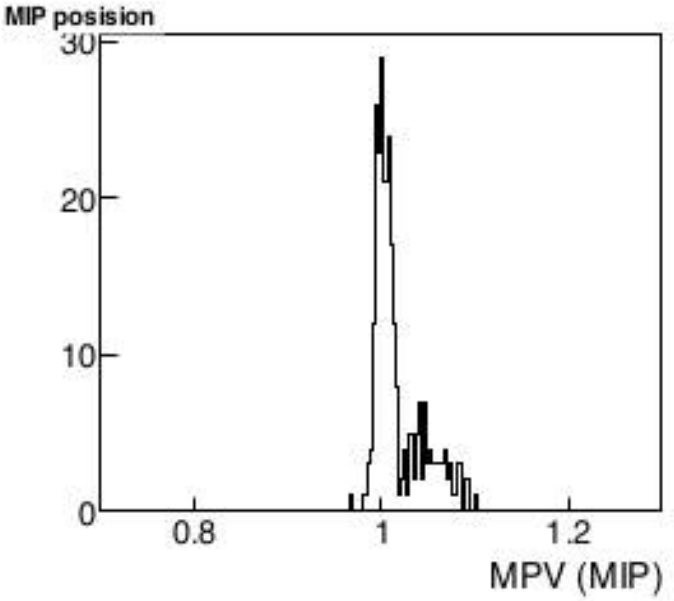




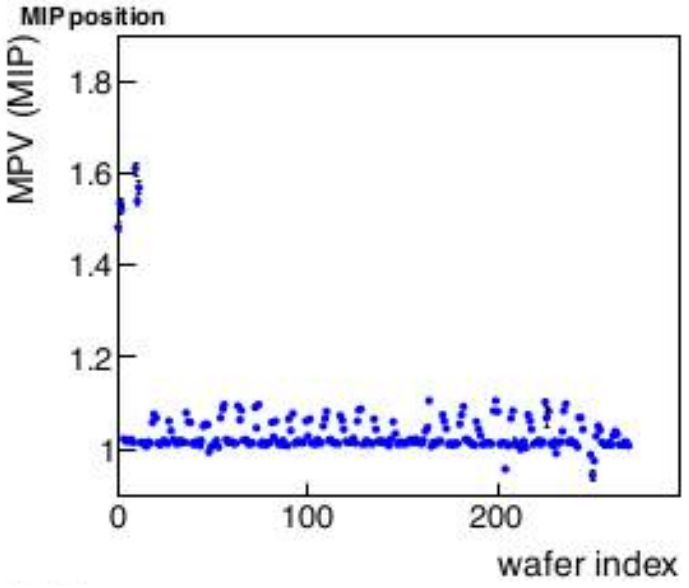
Should ideally be delta function @ 1.0

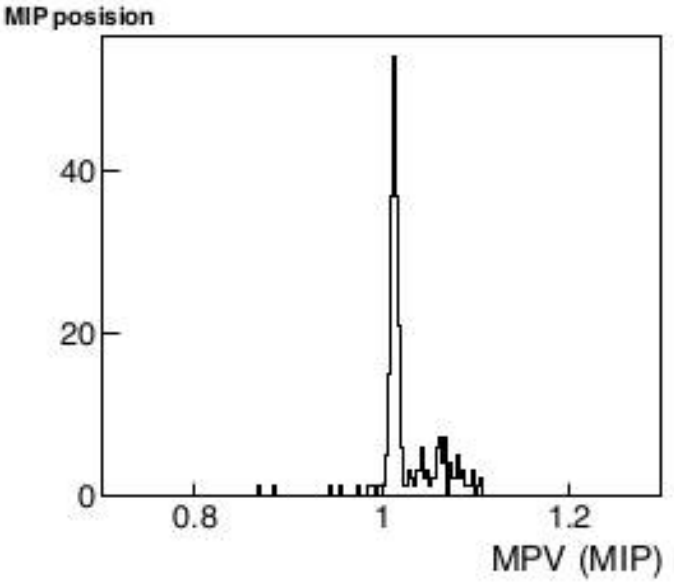
Original calibration





“new” calibrations

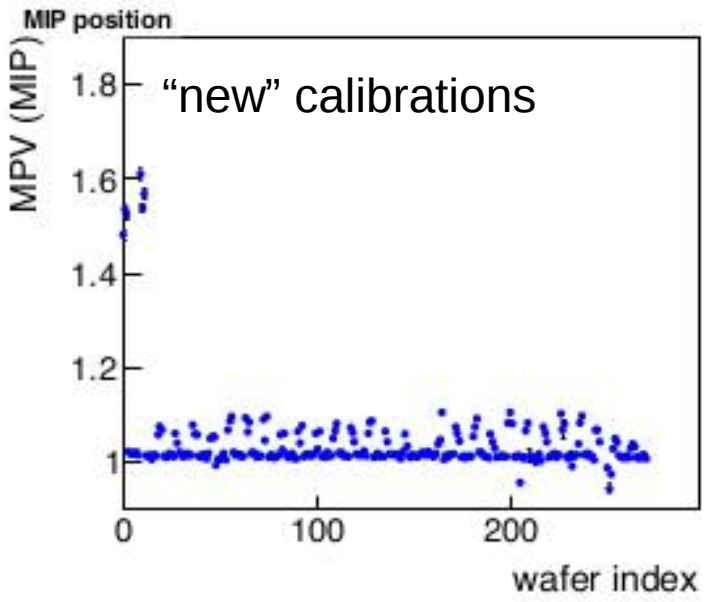


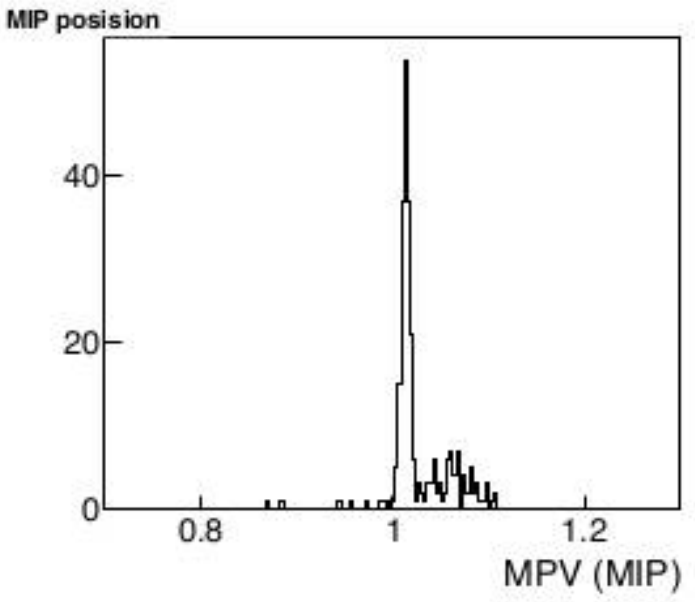


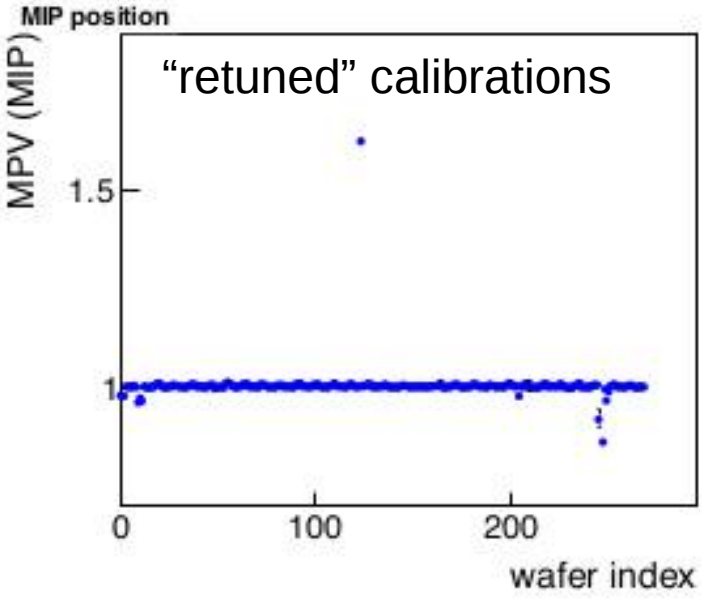
Measured peak position (MIPs)

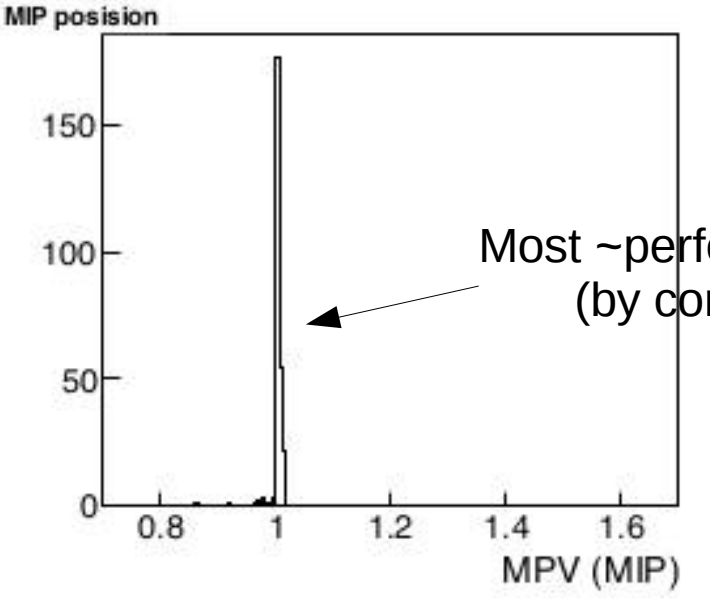
New calibrations look better than new ones, but still not great

We therefore apply a re-calibration procedure on a sensor-by-sensor level



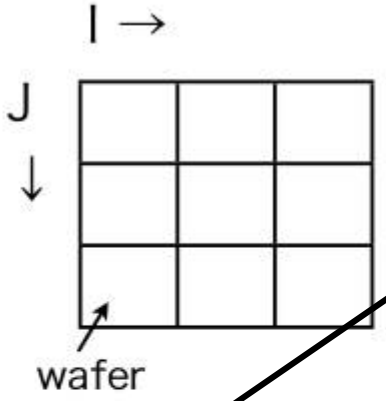


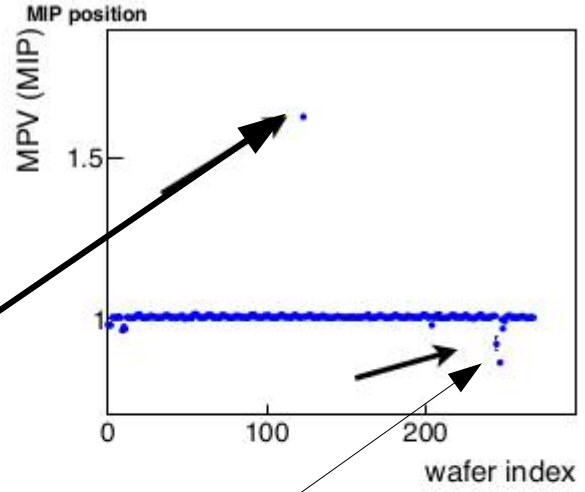


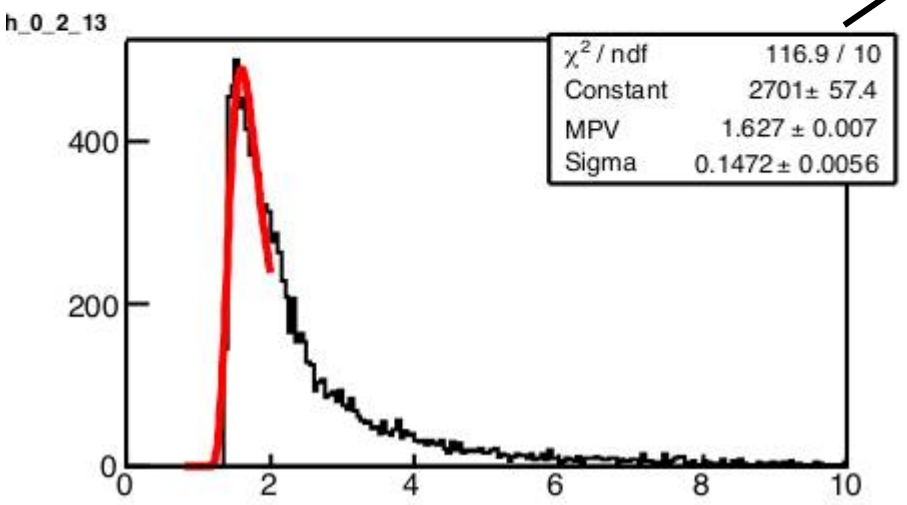


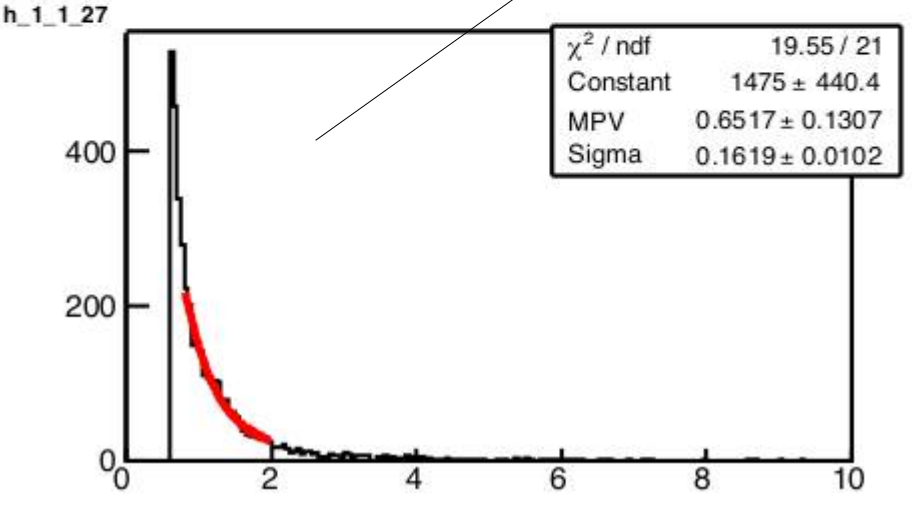
Bad wafers

- **Bad**
  - layer13, (I,J) = (0,2)
  - layer27









A few wafers do not show a good MIP peak;
Noisy, dead, too high threshold when writing Icio file?

Summary on calibrations:

need to understand differences between standard calibrations and Chen's procedure

positron events

Performance analysis w/ the new calib.

Subtracting 2.5% expected beam mom spread

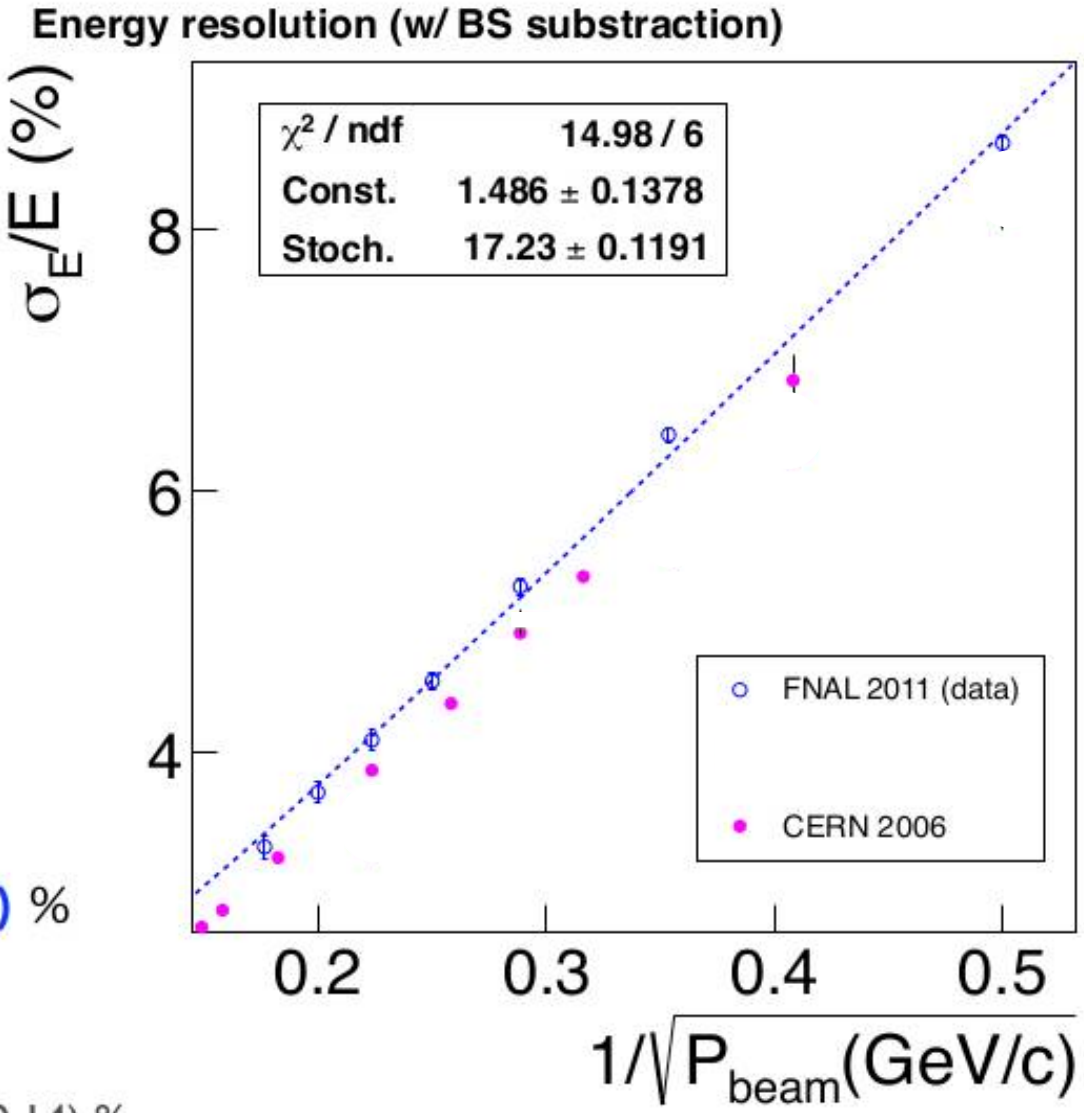
- **Cut**

Reconstructed shower center

- $x \in [-15,25]$
- $y \in [-20,20]$

Not too close to interwafer gap

- Reconstructed shower radius $< 40mm$
- reject events with identified ECA L noise
- reject ECAL "square" events
- # DHCAL hits < 5



$\sigma/E = (1.49\pm0.14) + (17.2\pm0.12)\ \%$

const. stoch..

(w/ old calib.) $\sigma/E = (1.58\pm0.14) + (17.7\pm0.14)\ \%$

New re-calibration slightly improves resolution;
still worse than the performance measured in 2006 data

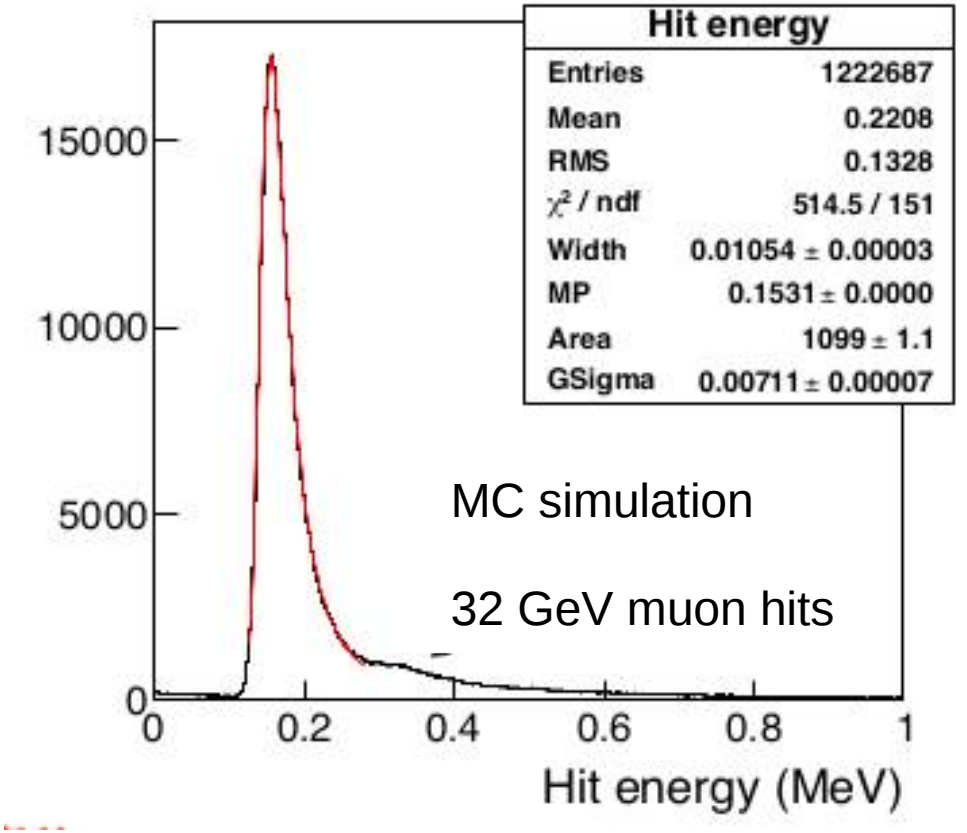
MC simulation

Use usual SiW Mokka driver
    no description of beamline instrumentation or DHCAL

Use measured beam profile

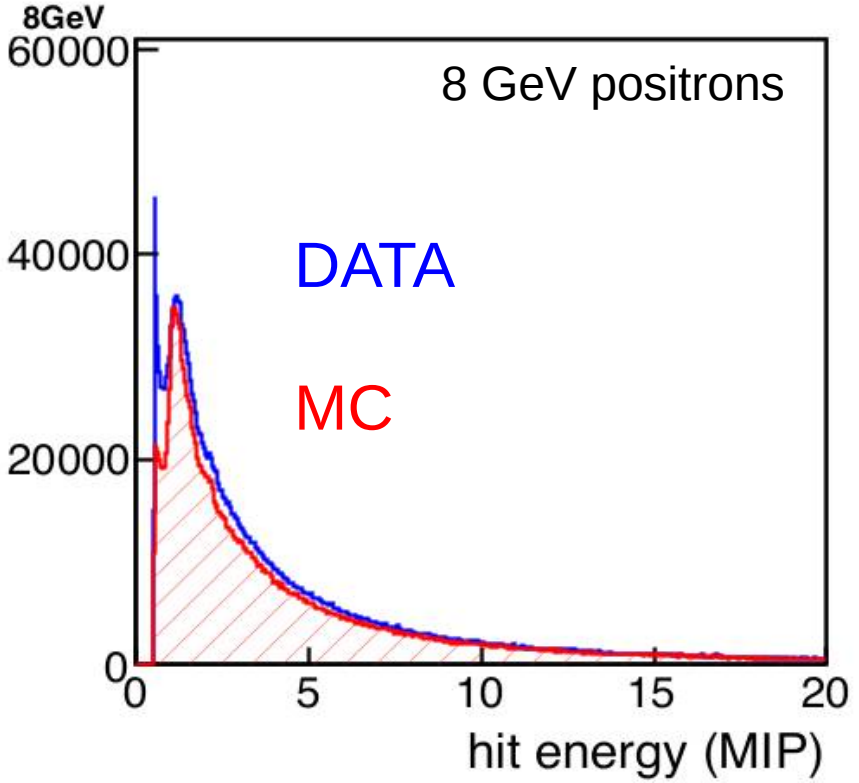
2.5% momentum spread assumed at all beam energies

Simple digitisation:
    Convert to MIP units
    Remove hits < 0.5 MIP
    Remove hits in “dead” sensors



All selected positron data events compared to positron MC

Hit energies

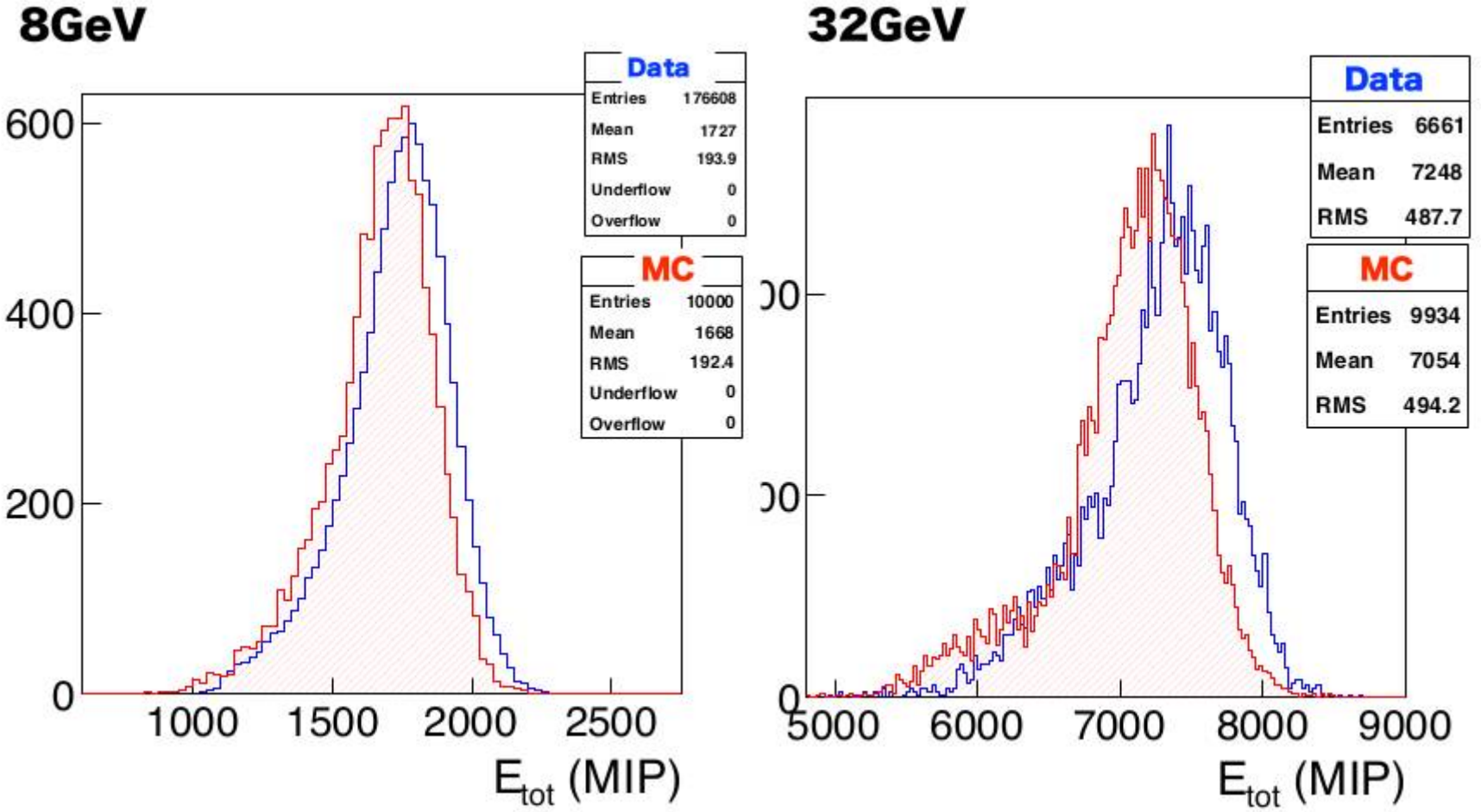


Excess of low-energy hits in data

Electronics noise? Physics?
Needs further investigation

All selected positron data events compared to positron MC

Total energy



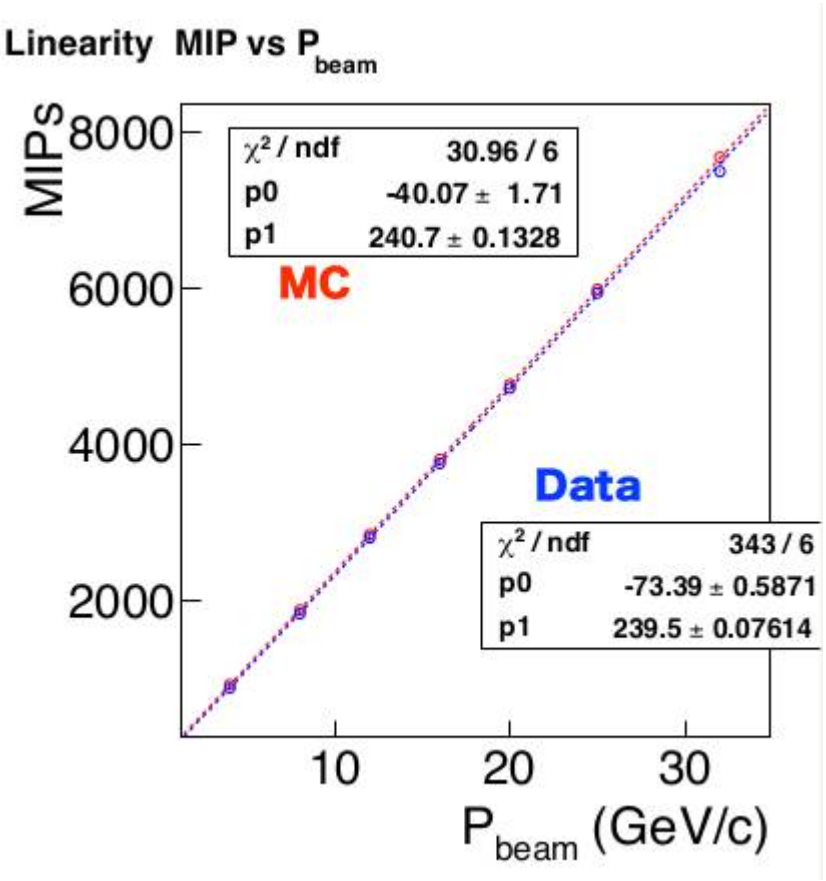
See some discrepancy on energy scale of MIP level

Shape pretty well described

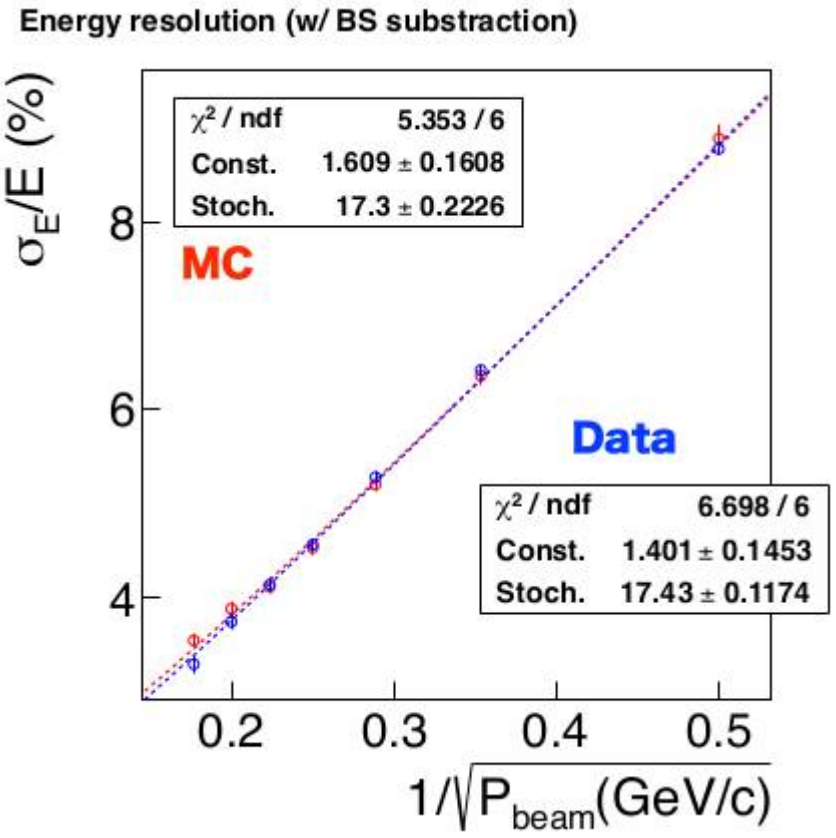
- interwafer gaps

positron-like events not too close to inter-wafer gaps

Fit energy spectra



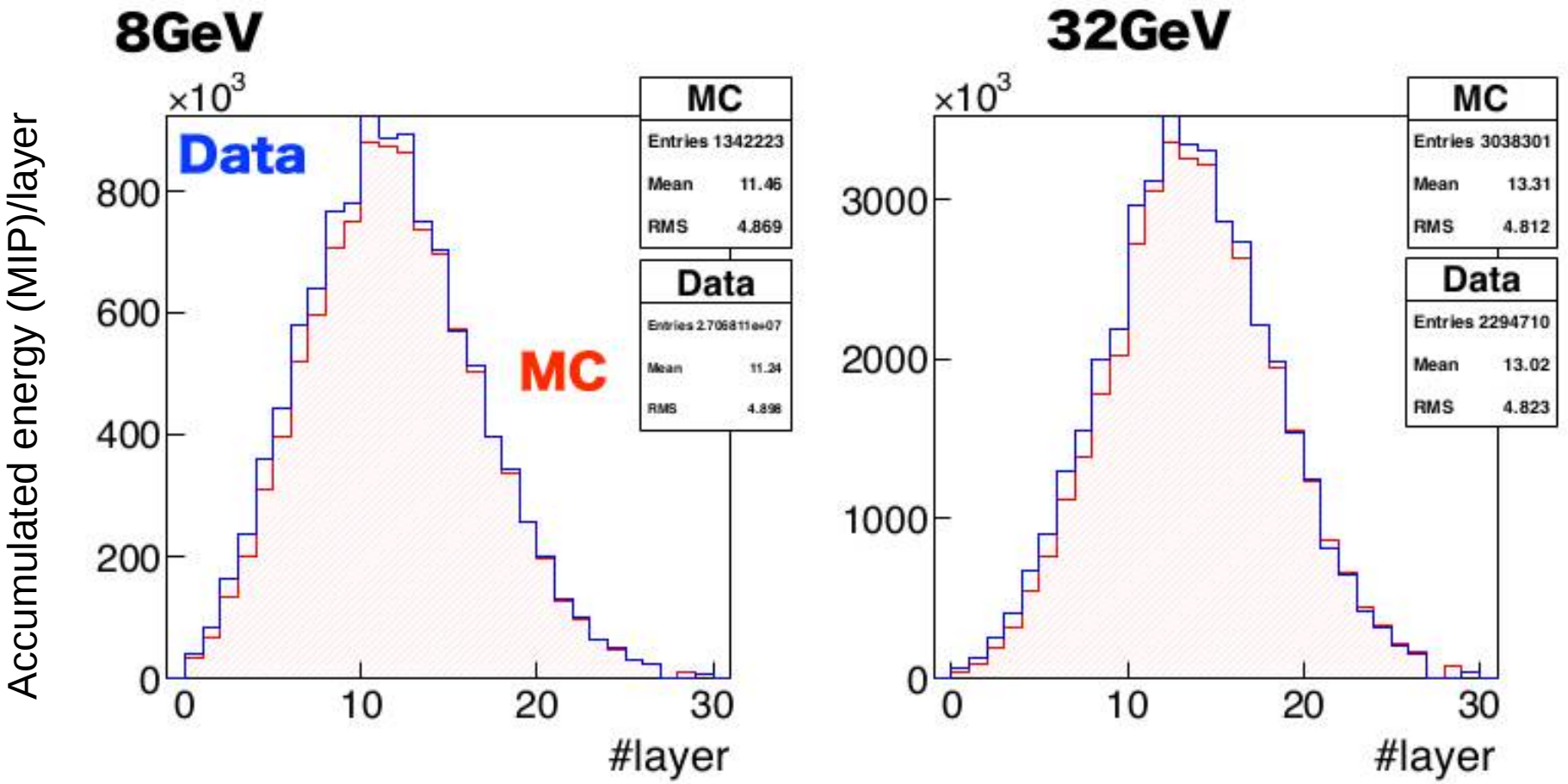
Subtract 2.5% beam mom. spread



Quite good description of average energy response and resolution

How about shower profiles?

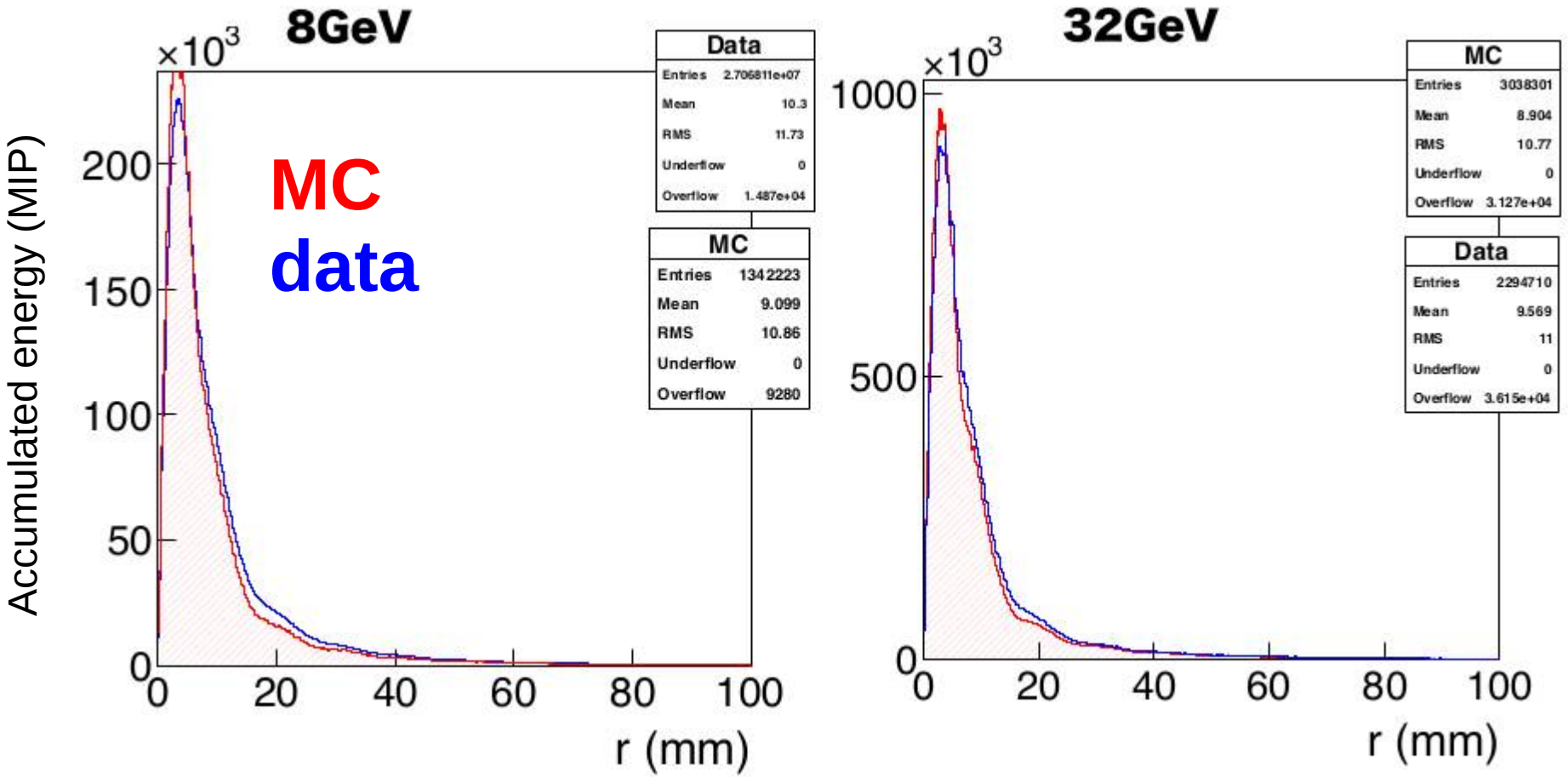
Longitudinal:



consistently a little earlier in the data

Transverse

Hit distance from shower barycentre
(important for 2-particle separation)



Pretty good: but MC looks a little sharper

Summary on data-MC comparison

I would say reasonable agreement; some things to look at more closely
OK to continue to 2-particle studies

Overlap studies

Select electron-like events
(simple attempt to reject data events with large preshowering)

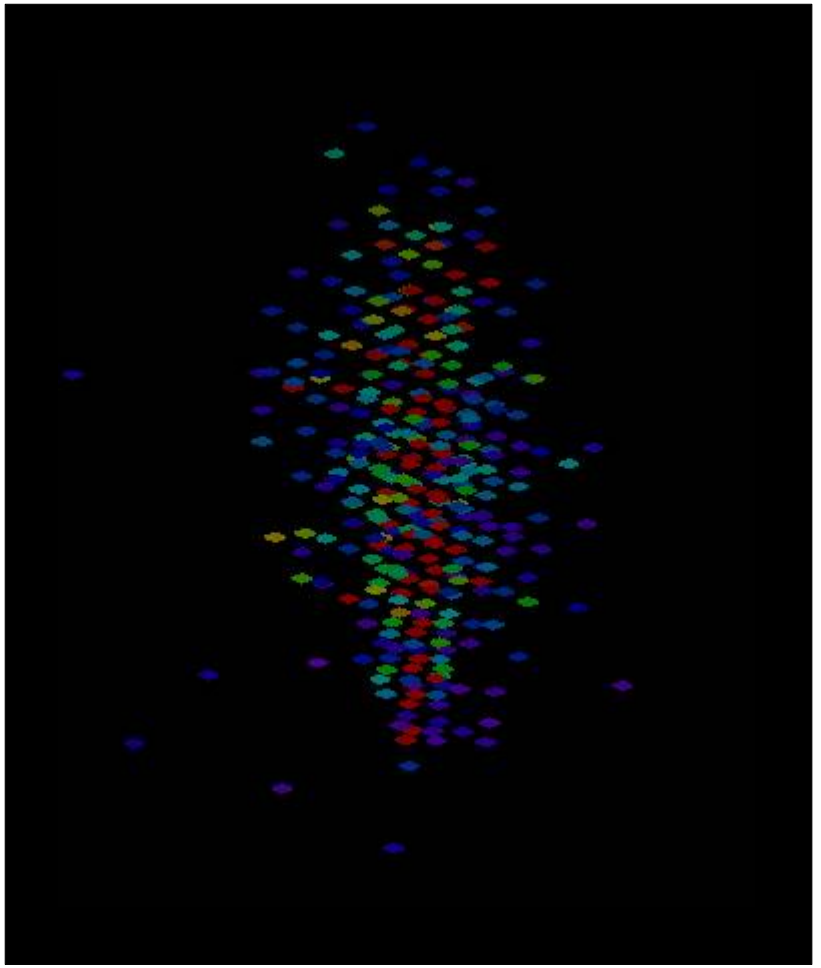
Map CALICE data & MC events into ILD barrel

Treat as photons (i.e. no tracks)

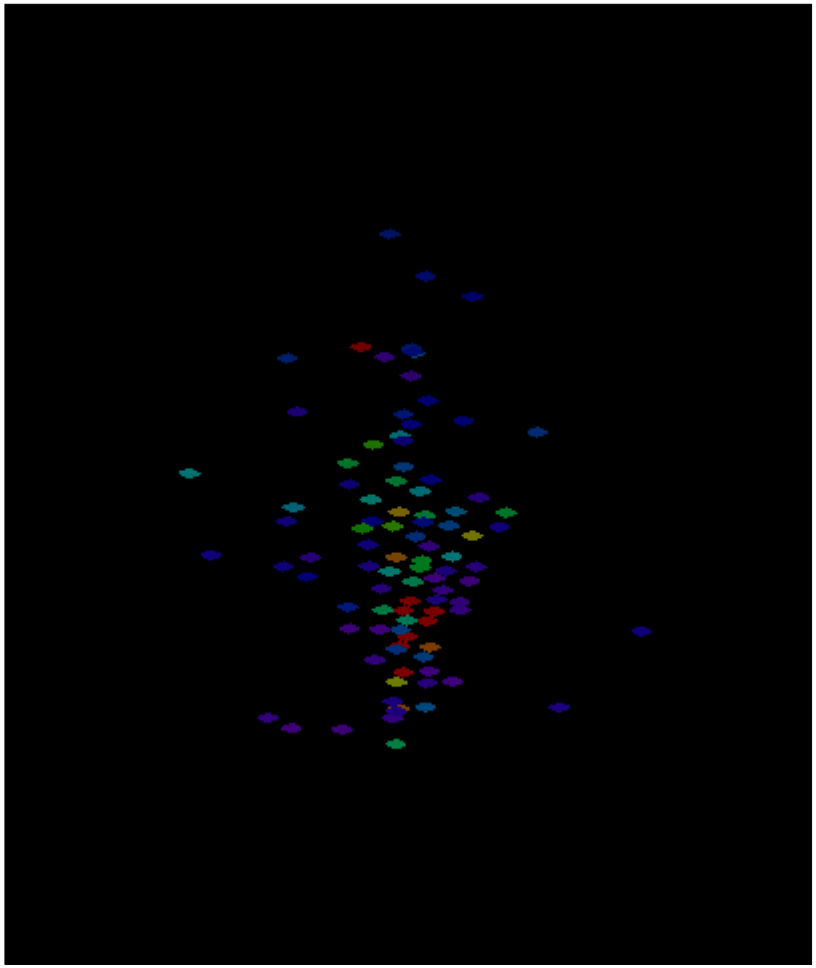
Apply PandoraPFA and Garlic algorithms on resulting events

Example: 2 test beam events

1x1 cm^2 cells
colour=energy

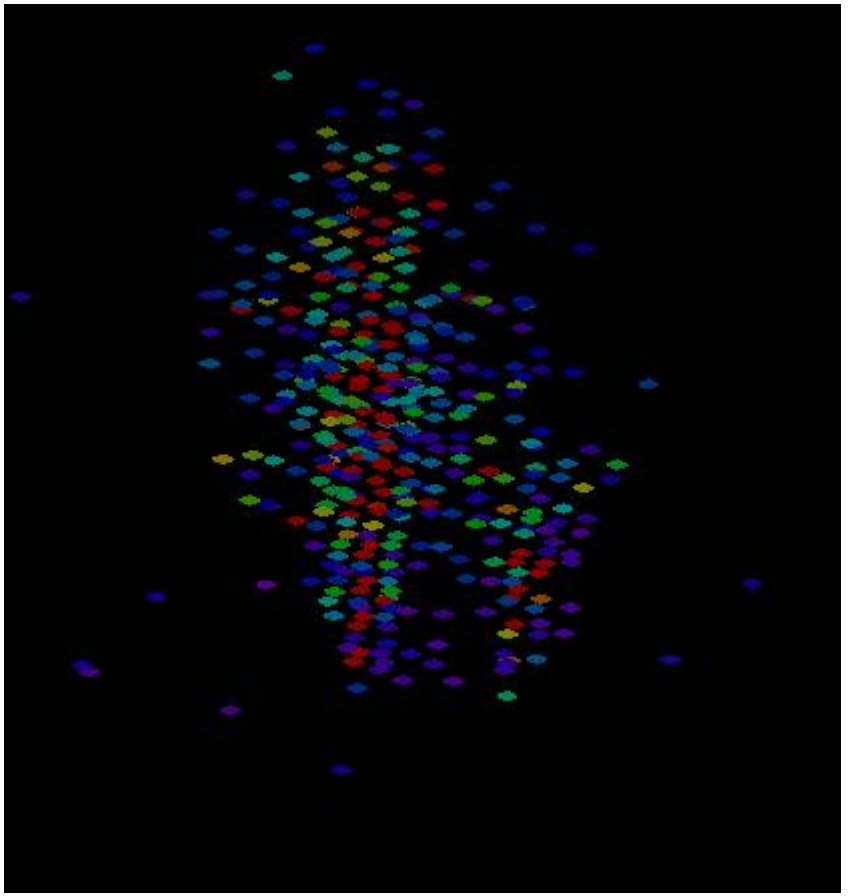


32 GeV e+
(data)



4 GeV e+
(data)

Combined event



(If a cell is hit in both events, energies summed)

Then apply reconstruction algorithms

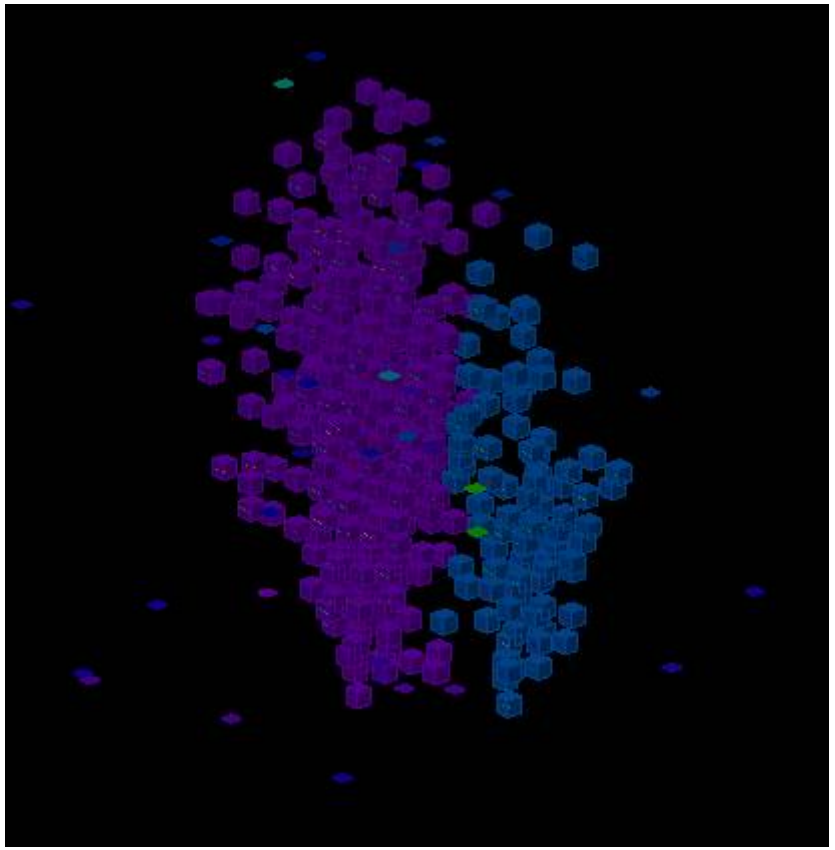
PandoraPFA:

- General purpose PFA reconstruction
- Same version as used in DBD analyses

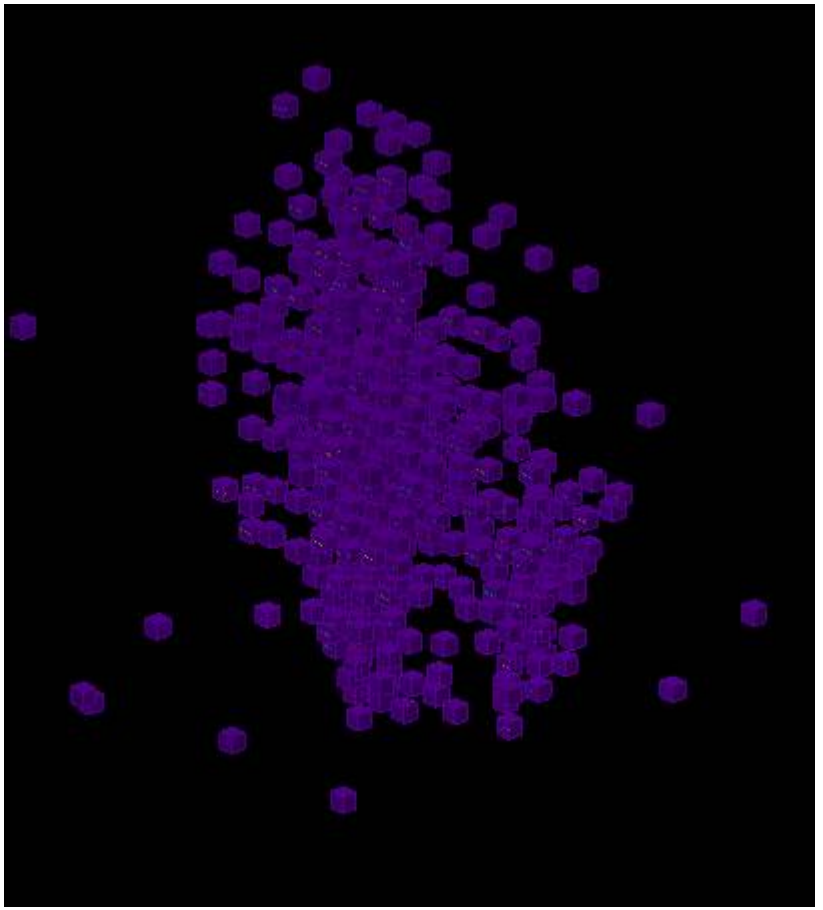
GARLIC:

- Specialised photon reconstruction

GARLIC clusters



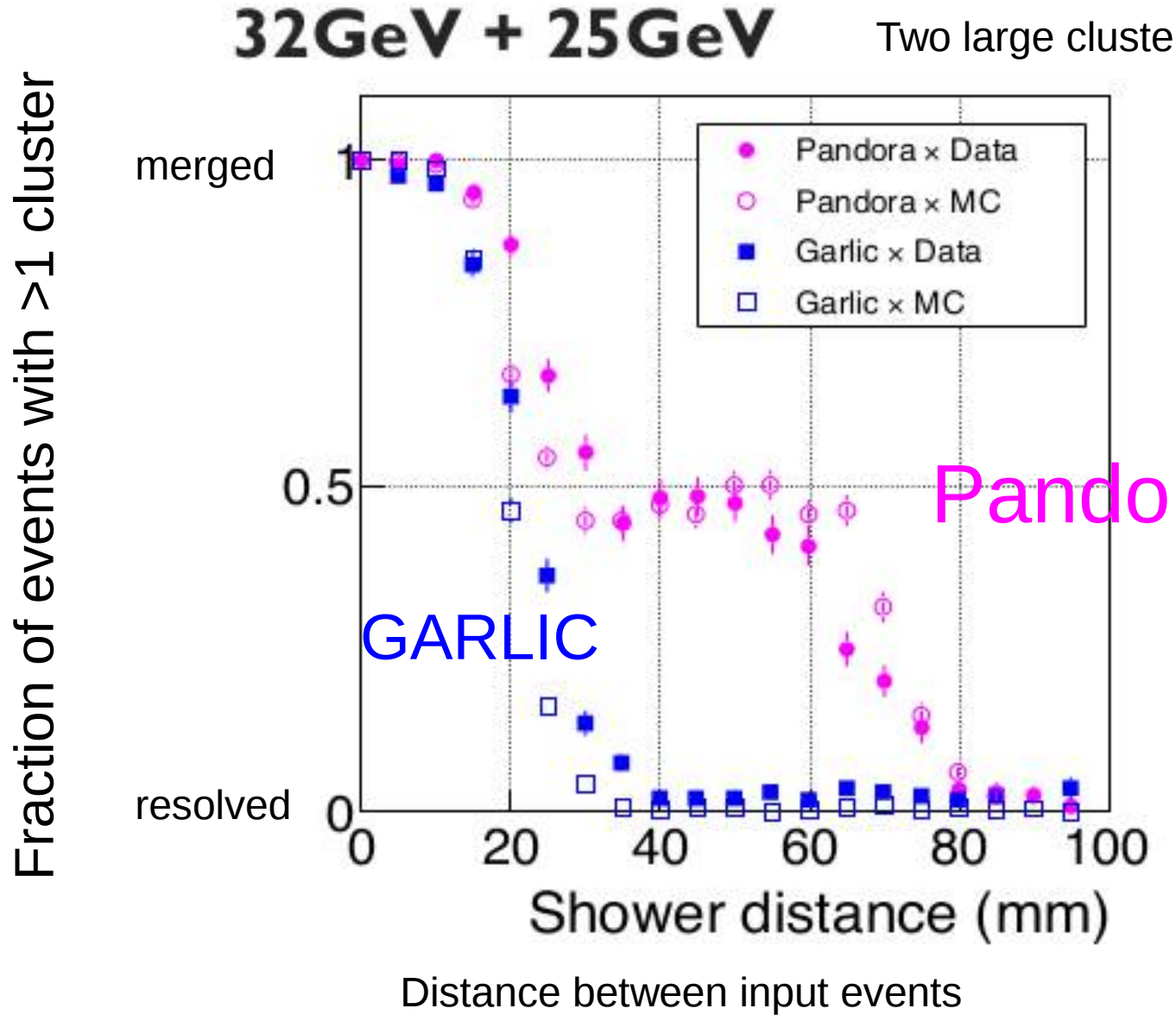
Pandora photon clusters



In this case, GARLIC successfully separated the clusters, Pandora did not

Example overlaying 32 GeV and 25 GeV events

Measure how often >1 (large energy) clusters are reconstructed



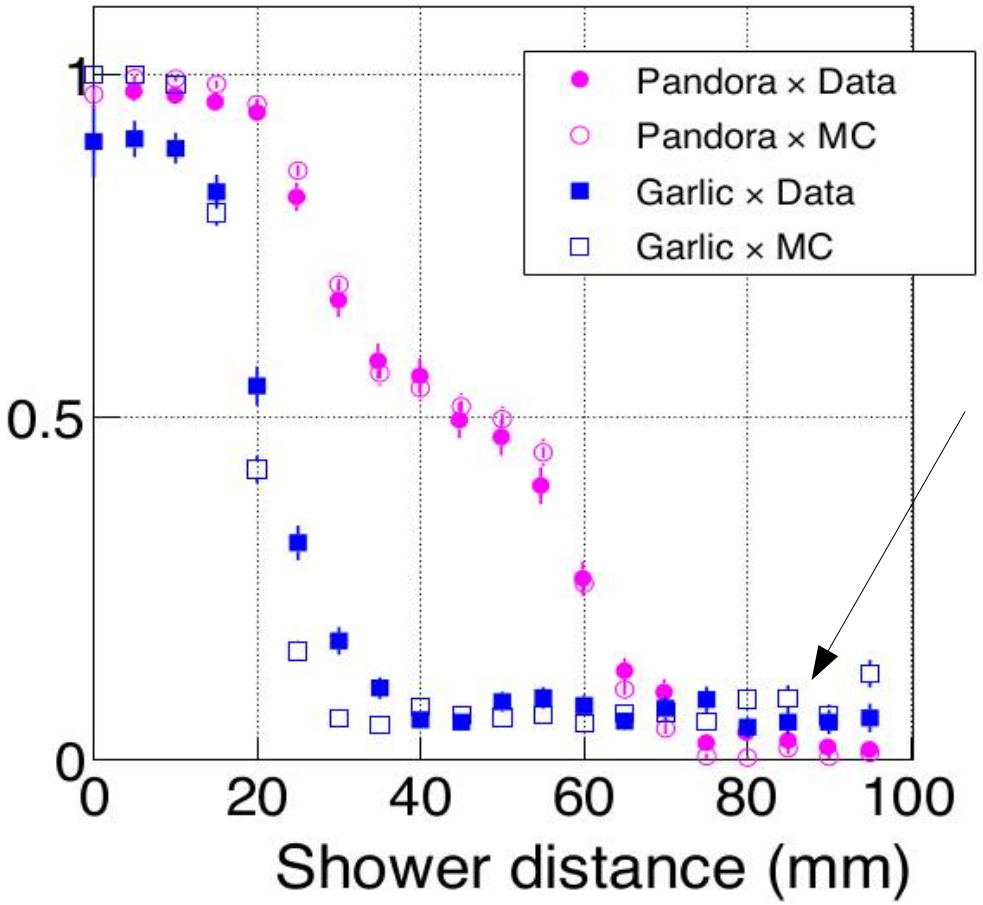
GARLIC well behaved, separates 50% @ ~20mm

Pandora has more “interesting” behaviour

Both quite well described in MC: simulation generally a little better

32GeV + 4GeV

Large + small cluster

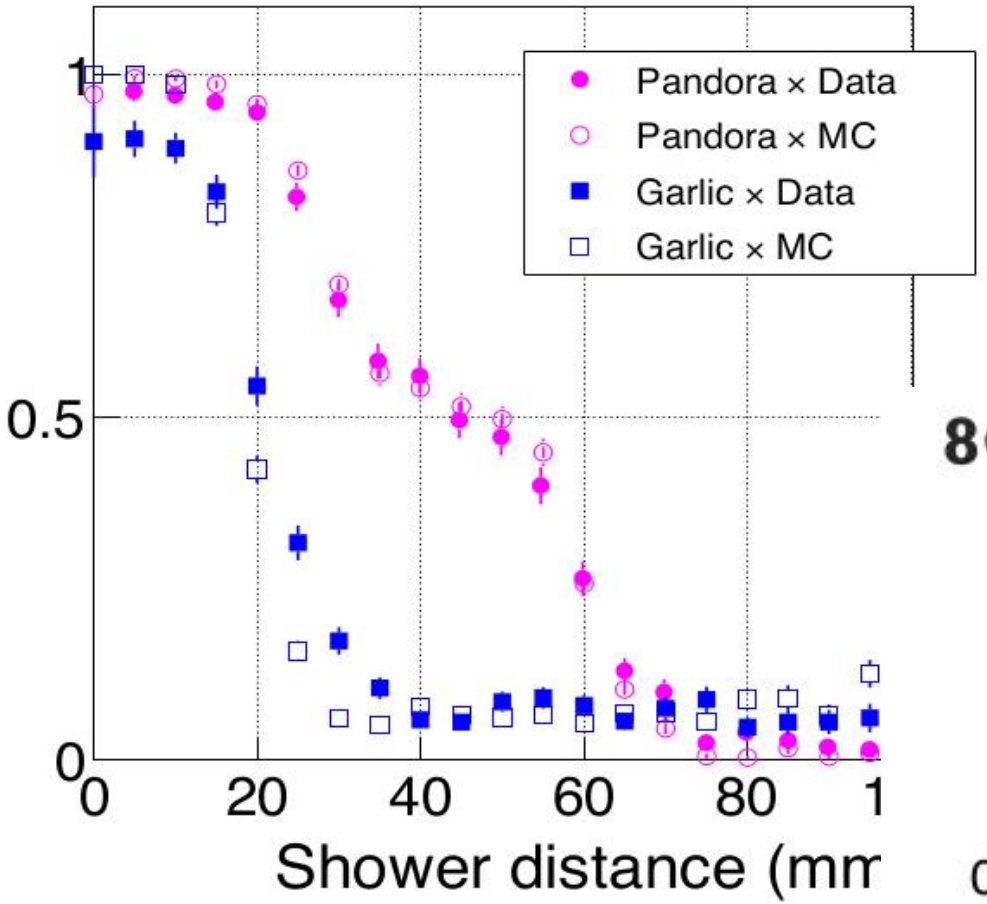


Even @ large separation,
GARLIC shows in-efficiency:

Traced to use of wrong parameter:
understood, will soon be fixed
Reduces eff. for late showering,
low energy photons

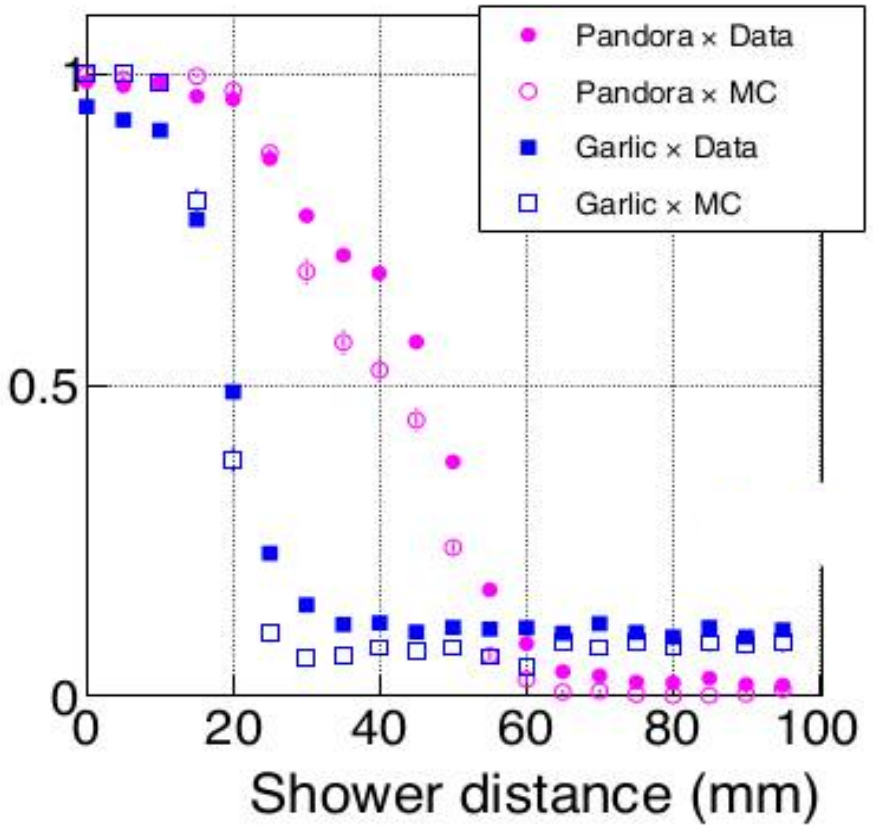
32GeV + 4GeV

Large + small cluster



8GeV + 4GeV

Two smaller clusters



GARLIC performance quite energy-independent

Pandora is less so

Summary

A few features to understand in 2011 data

Revisit calibrations?

Some differences to understand in data-MC
- MIP energy scale
- Low energy hits
- Shower shapes

Overlaying of testbeam positron events

Quite well described in simulation

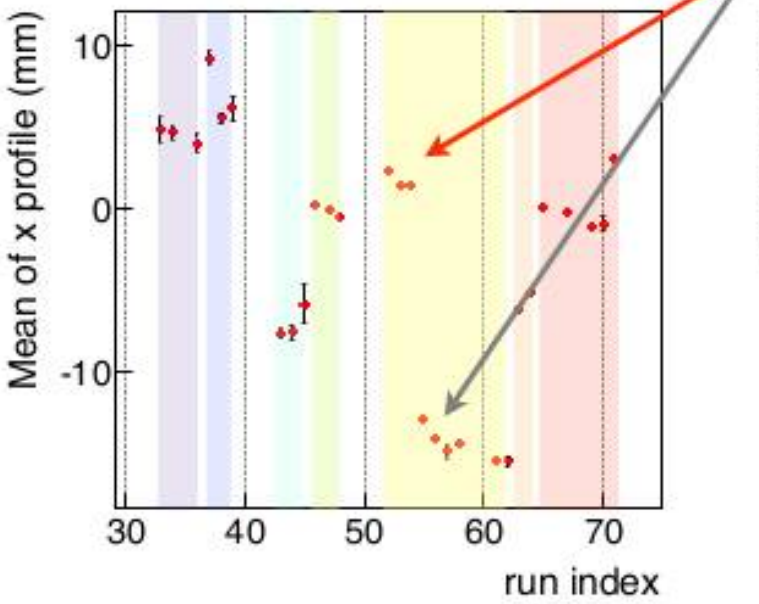
GARLIC provides good separation: 50% ~20mm (~Moliere radius)
- need to repeat using corrected parameters

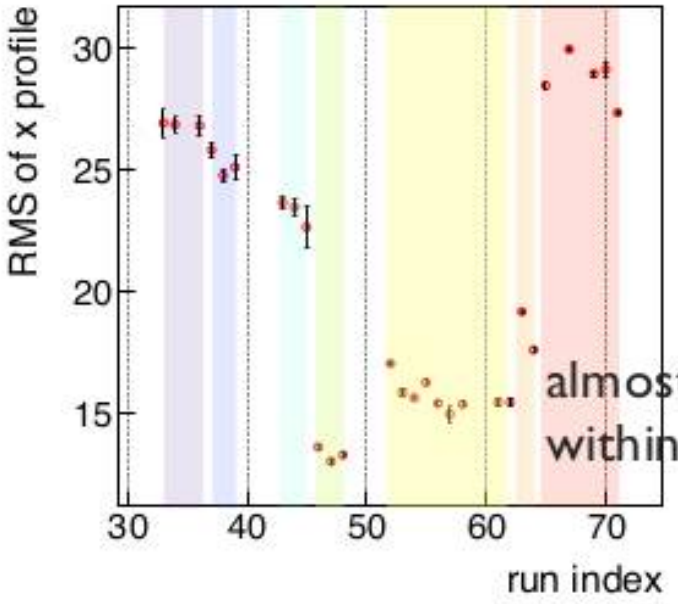
Pandora less good: 50% @ ~40mm

backups

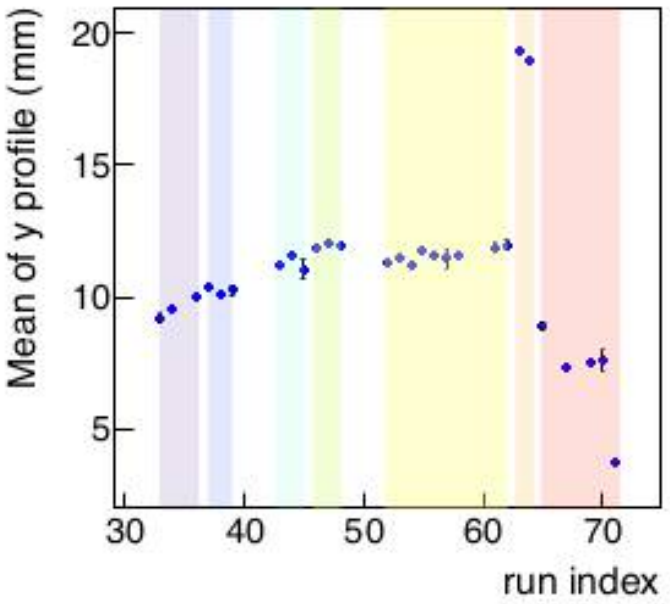
Beam spread

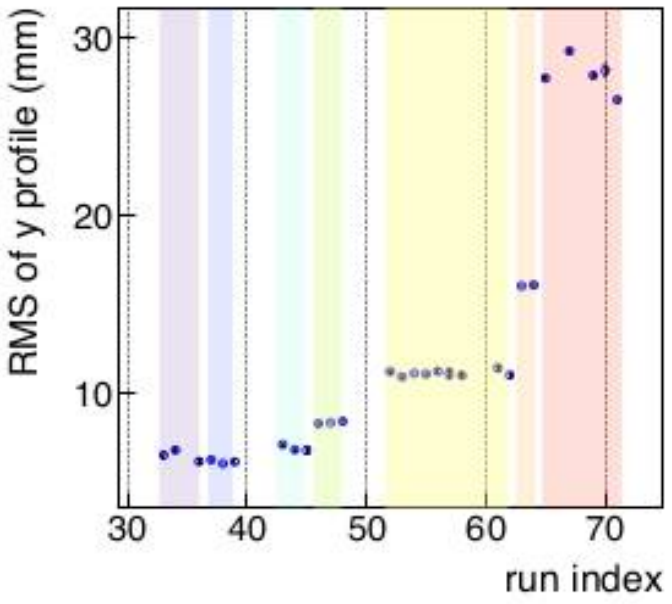
some inconsistency → use only the earlier 3 runs for 12 GeV sample





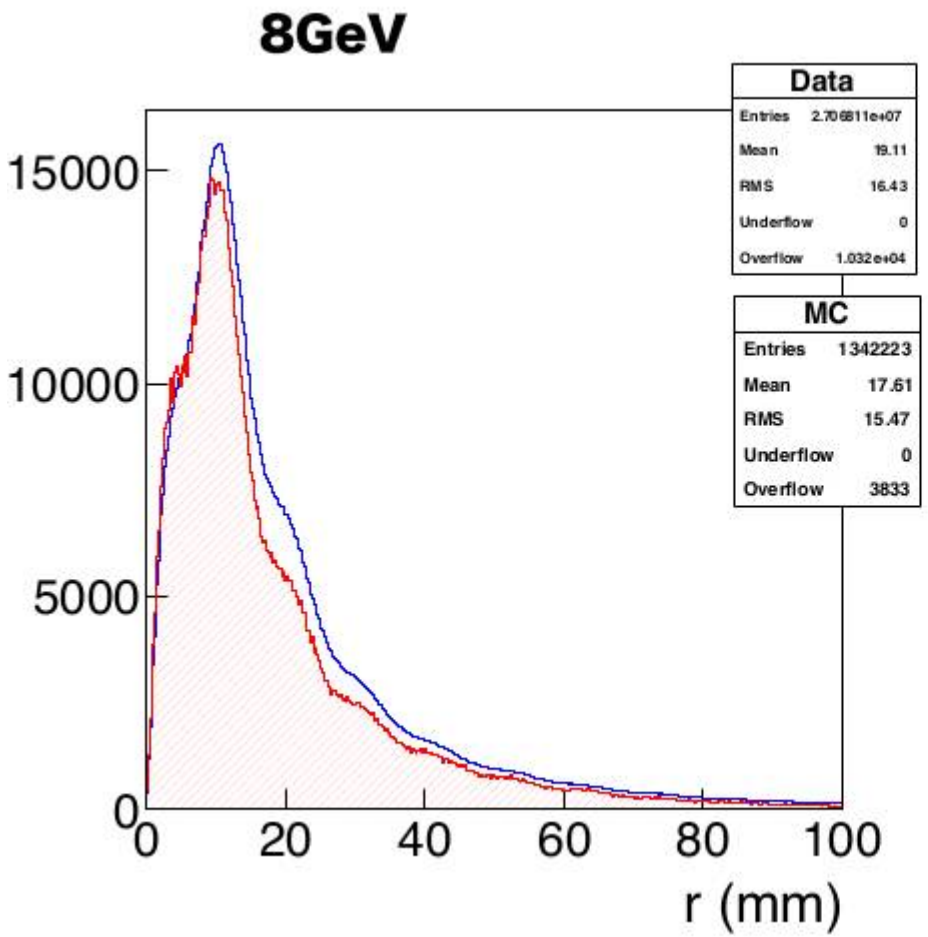
almost consistent within the same energy

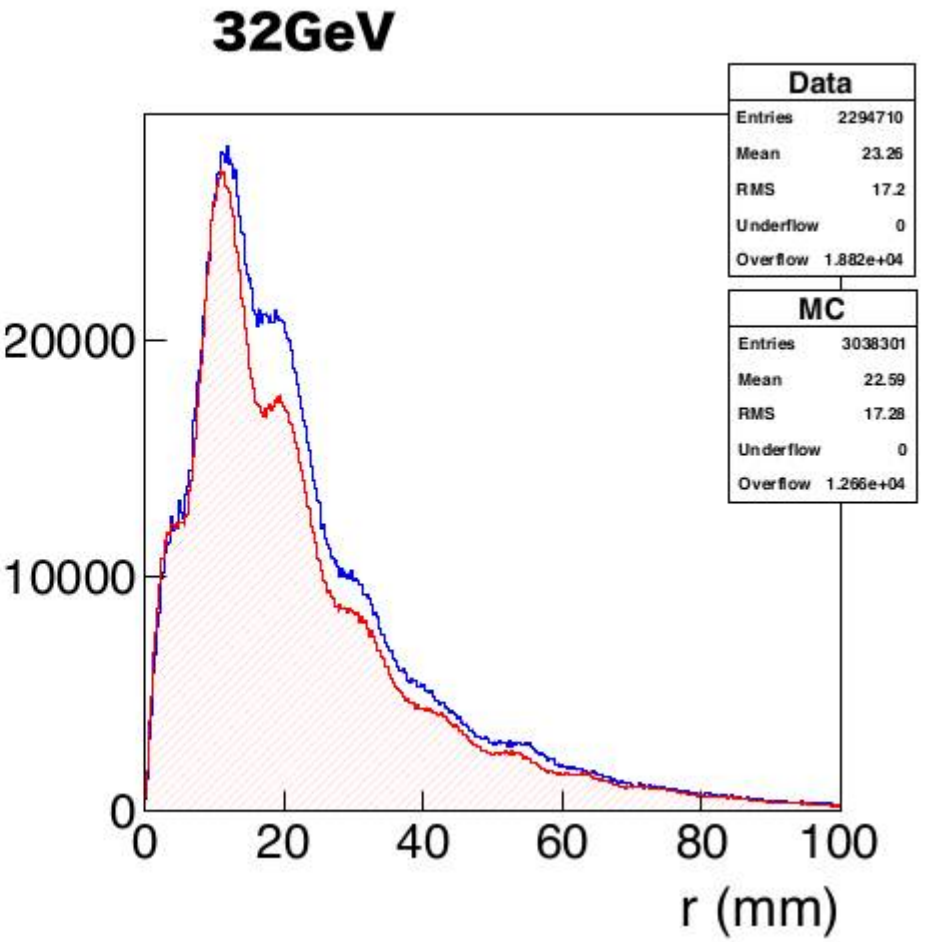




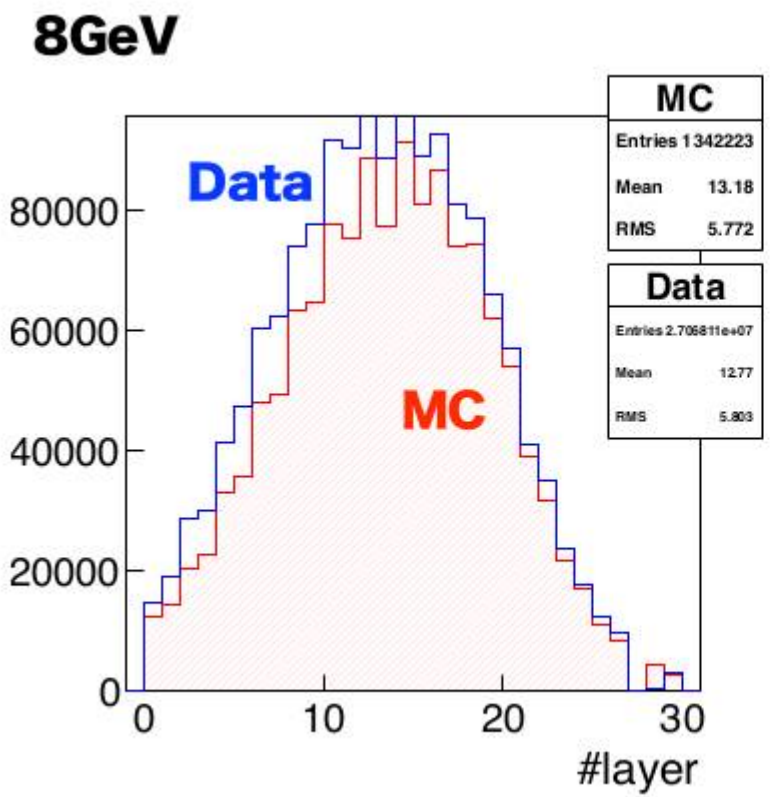
- 4GeV
- 8GeV
- 12GeV
- 16GeV
- 20GeV
- 25GeV
- 32GeV

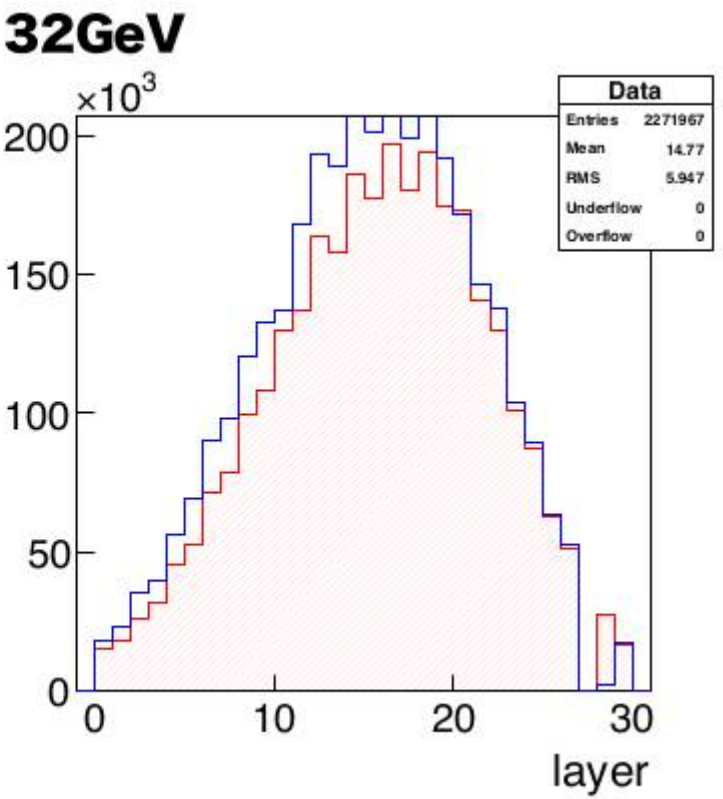
Transverse profile: # hits





longitudinal profile: # hits





GARLIC
Gamma Reconstruction at a Linear Collider

JINST 7 P06003

Photon identification in hadronic jets
in a highly segmented calorimeter

Algorithm outline

Track veto
Remove hits close to track extrapolations

Seed finding
Identify cluster seeds in first part of ECAL

Core building
Build dense core of EM shower

Final clustering
Add nearby hits: “halo” around the core

Neural Network identification
Decide if cluster is photon-like