# Towards an ECAL $e^-$ analysis paper?

David Ward

- Would like to aim to progress from LCWS note to published paper(s). Envisage up to 4 papers:
  - 1. Hardware, calibration, technical performance (gain, noise, stability etc). Anne-Marie to coordinate.
  - 2-4. Electron response
- Schedule – drafts by the end of 2007???
- Basic topics much as in the LCWS note.
- Several problems to be addressed before we can be ready. Will mainly discuss these.
- Comments on systematics.

# Content of analysis papers?

C.Carloganu, DRW...
- Energy response
  - Linearity; uniformity (gap correction); angle dependence.
- Energy resolution
  - As a function of energy, angle, impact of gaps...

Valeria, George, Nige
- Shower longitudinal profile
- Shower transverse profile
  - Effective Molière radius

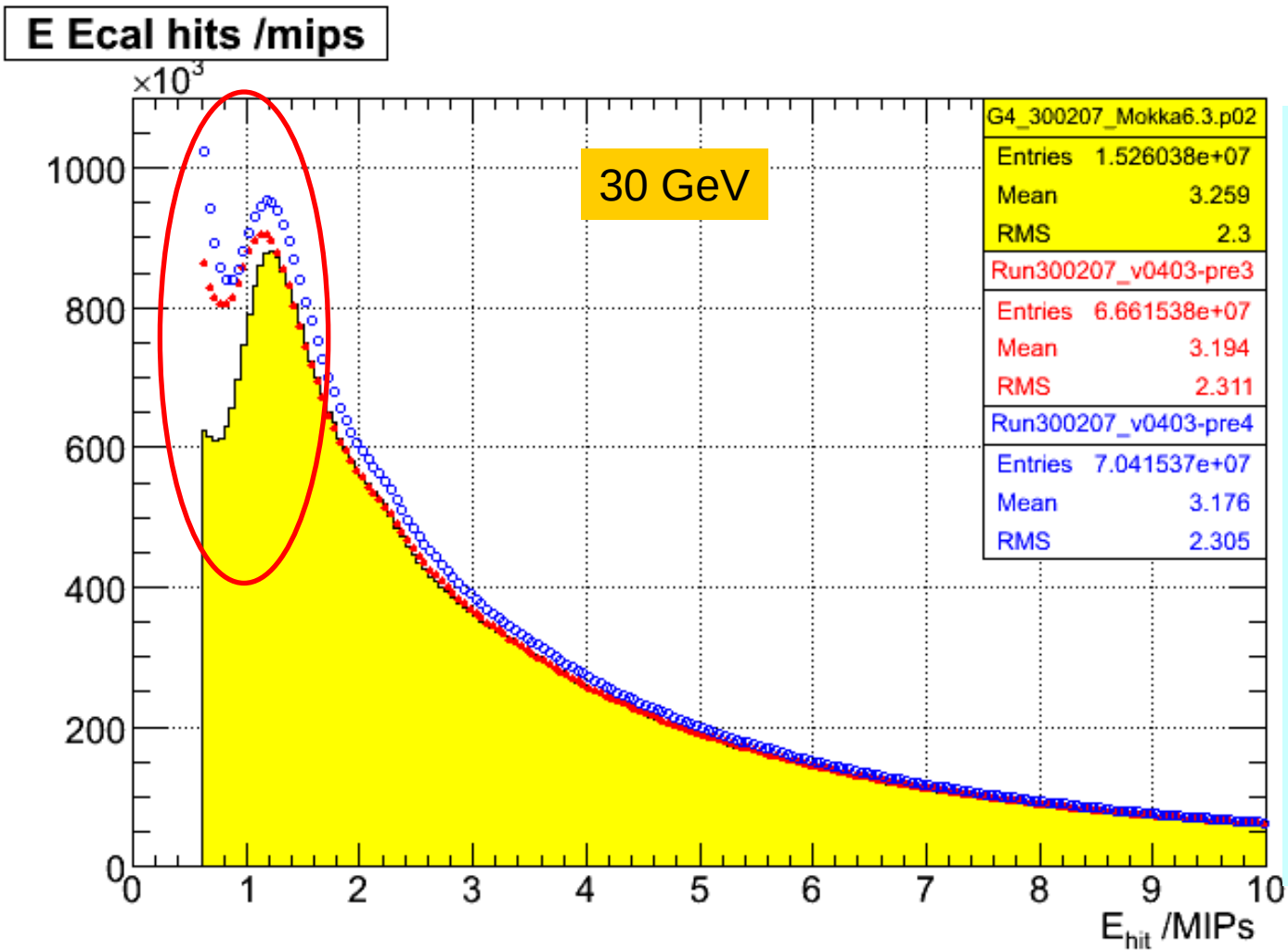
Paul, Hakan, Michele
- Position resolution
  - Using tracking
- Angular resolution
  - Using tracking

- 2-shower separation
  - Using double events/superimposed events
- All of the above compared with MC simulation.

# ECAL problem areas

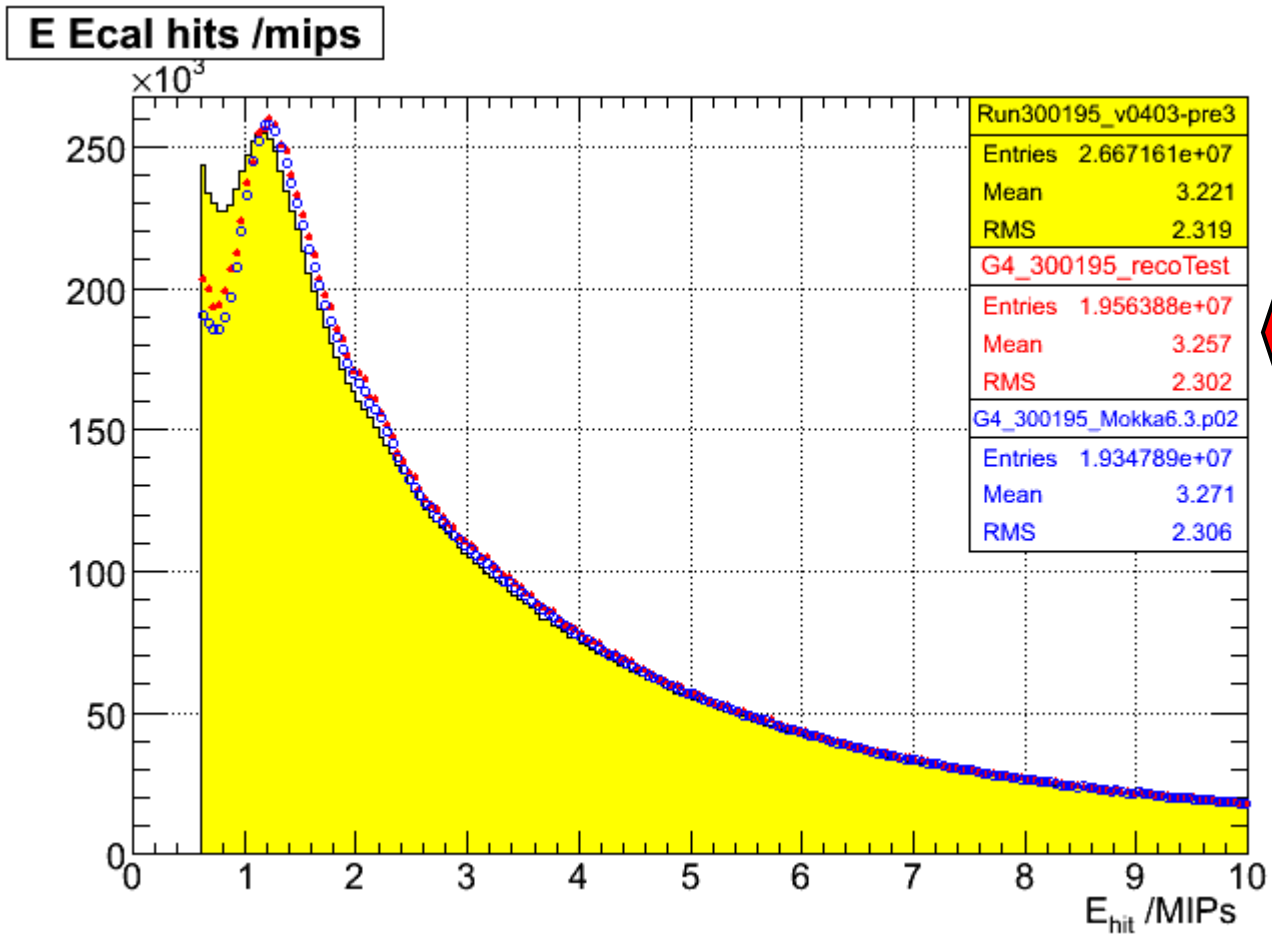
- There are several problematic areas, where we see discrepancies between data and Monte Carlo.
- Some at least may be partly interconnected.
  - Low pulse height hits
  - Number of hits.
  - Interwafer gaps (effect of guard rings etc)
  - Transverse shower shape ($\sim$ 10% higher in data)
  - Shower depth (understanding of beam line, upstream material?)
  - Mismatch of energy scale ($\sim$ 3%) between CERN and DESY

# Low energy hits




- Pre3 processing agrees with MC quite well down to 1.2 MIPs
- Pre4 processing (SIPS correction) gives extra hits; agrees less well with MC.
- Effect grows with increasing energy.
- Anne-Marie's MC digitization and reconstruction doesn't have any significant effect (next slide…).
- Similar in 2007 data; possibly a bit worse

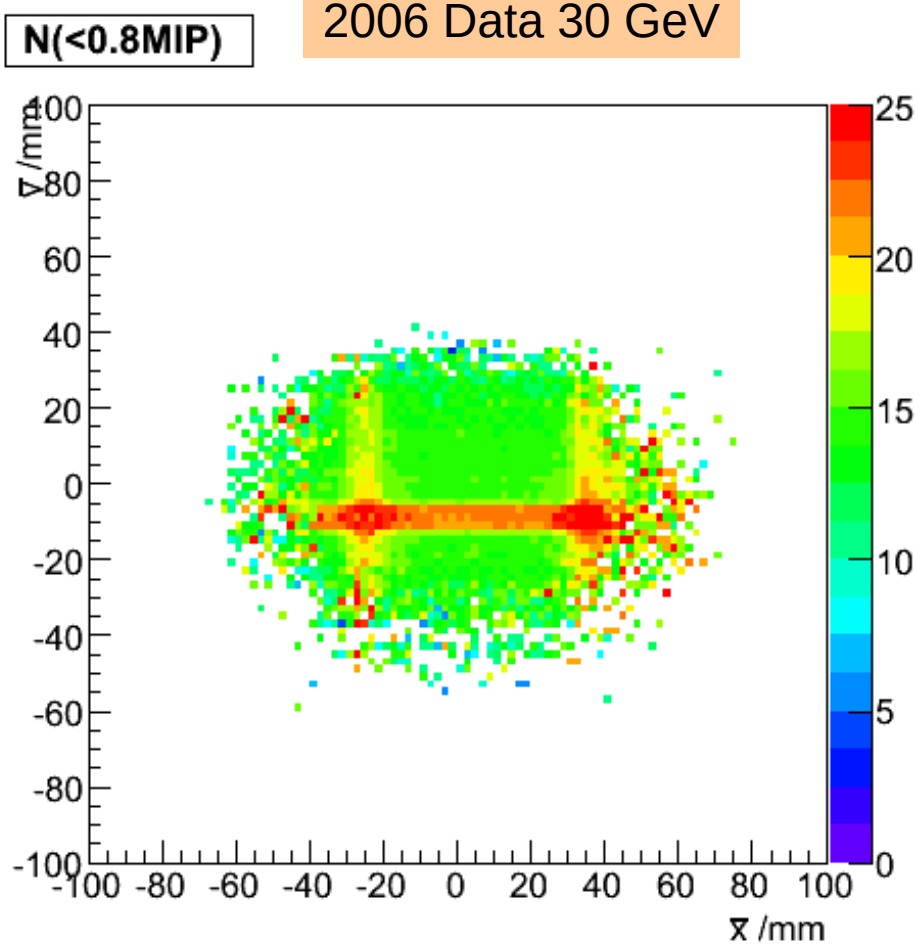
# Effect of MC digitization (45 GeV)



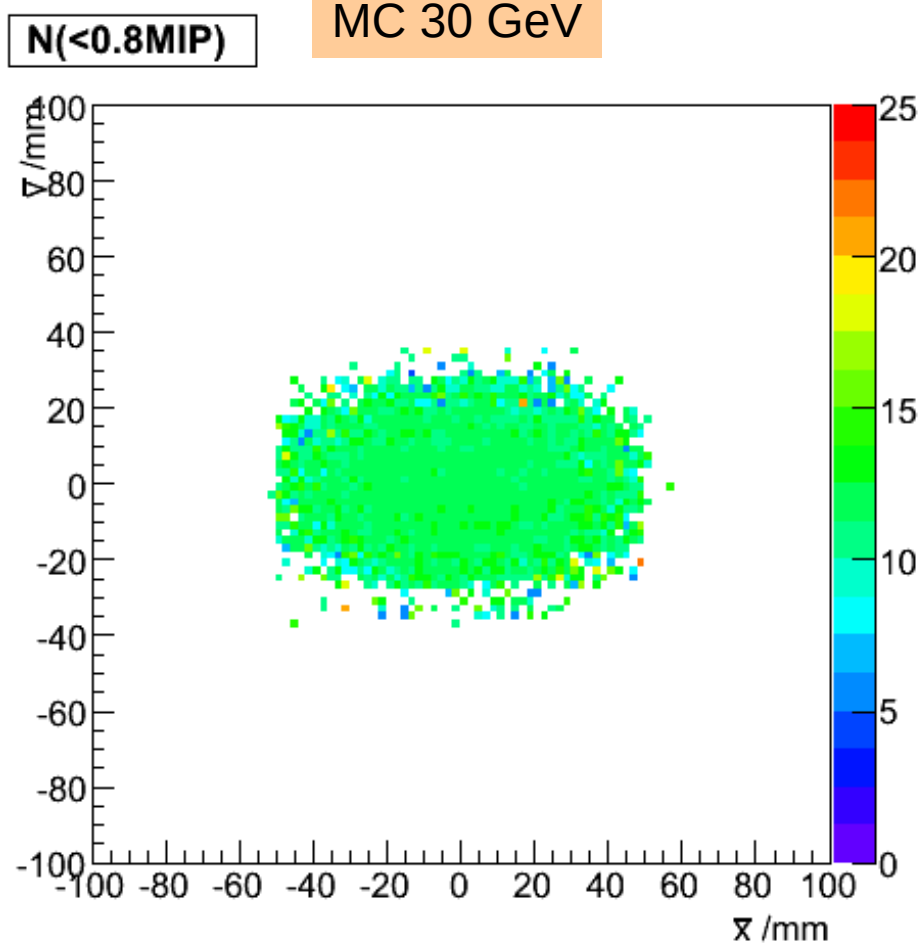

After MC digitization

# Correlated with shower position

2006 Data 30 GeV

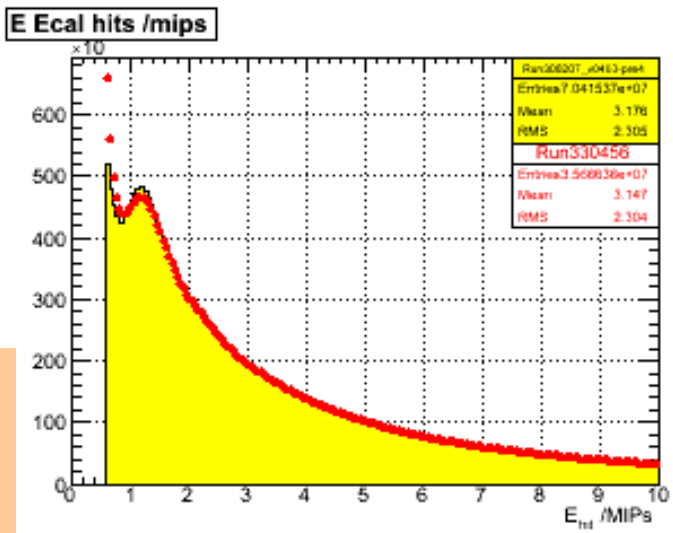


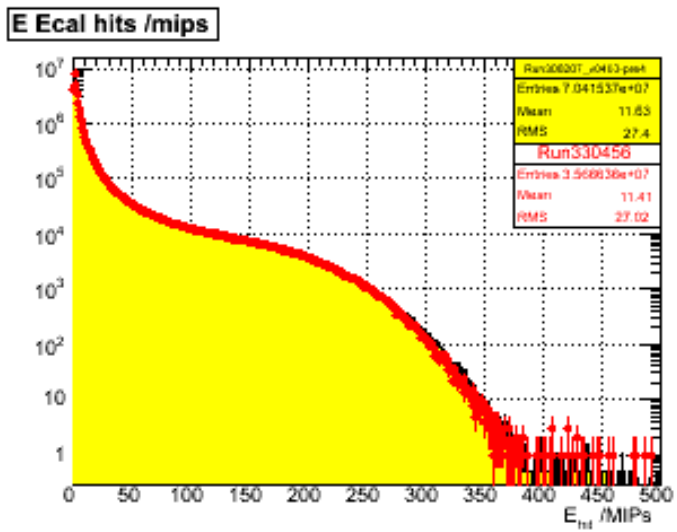

MC 30 GeV

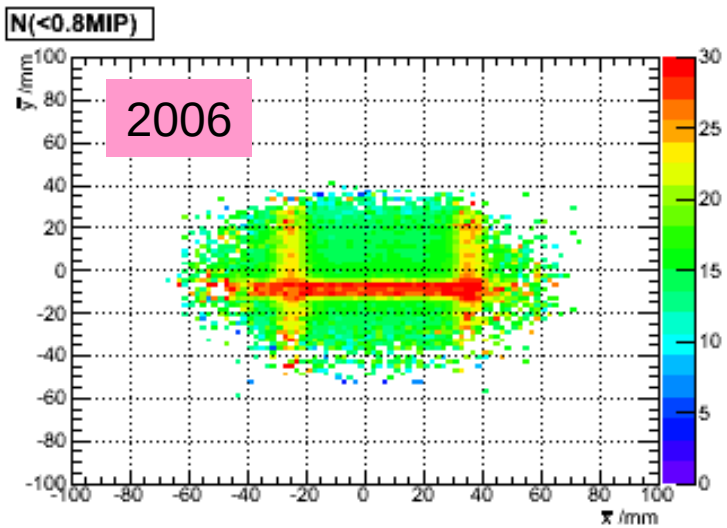


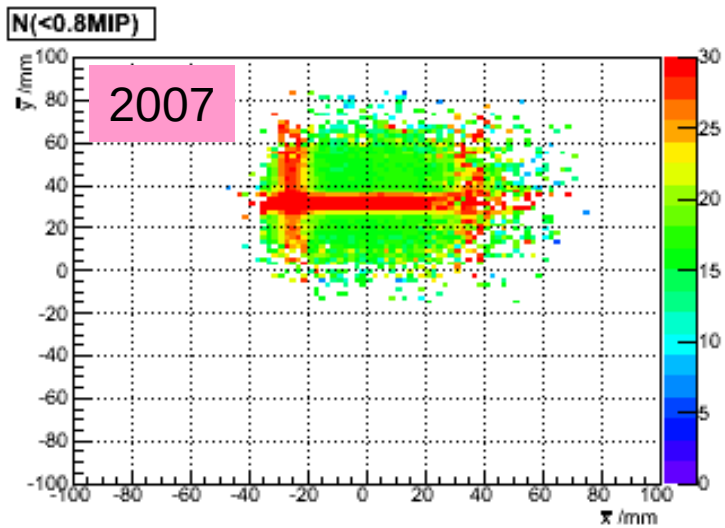
# 2006 *c.f.* 2007 – 30 GeV $e^-$

A little worse in 2007?

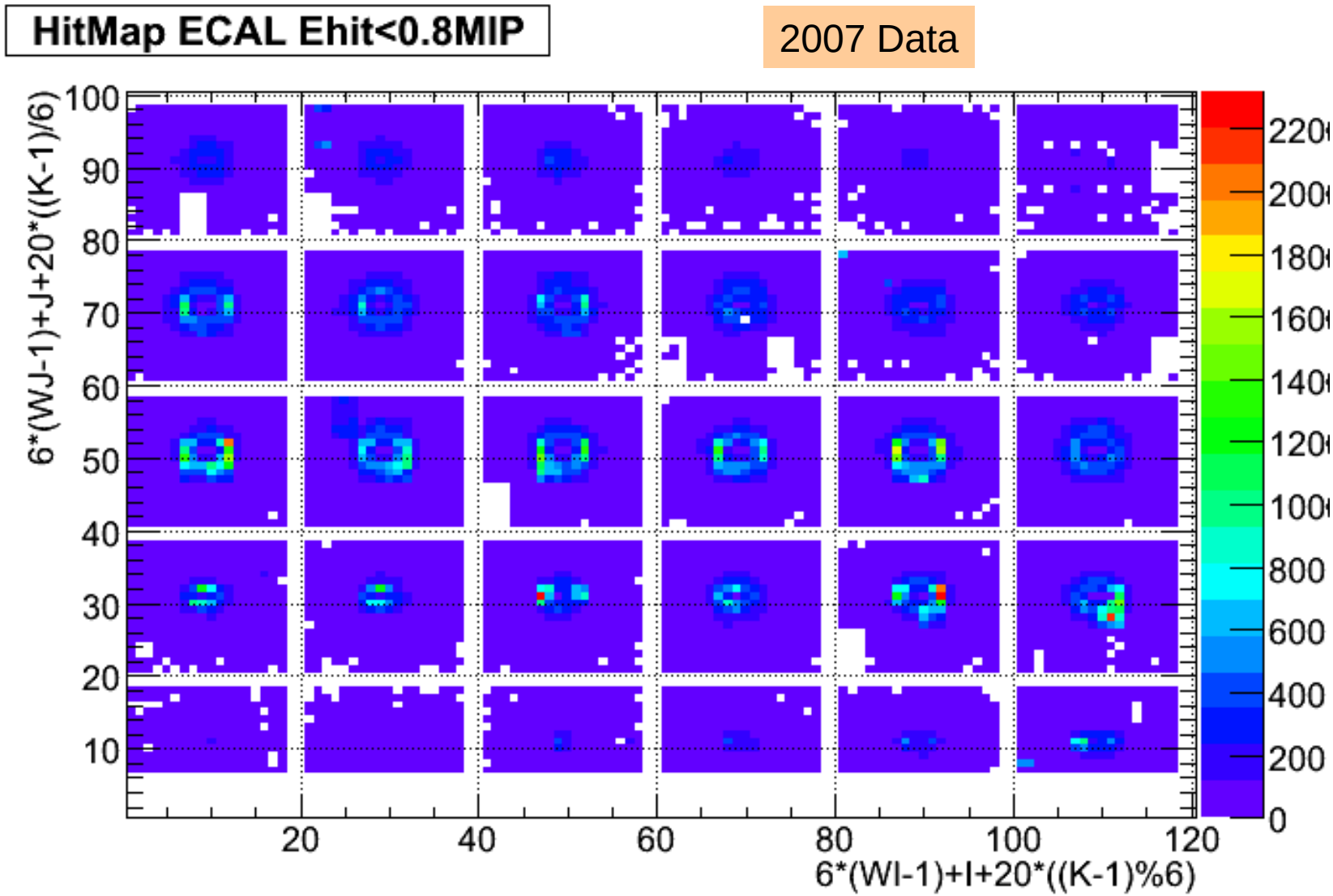


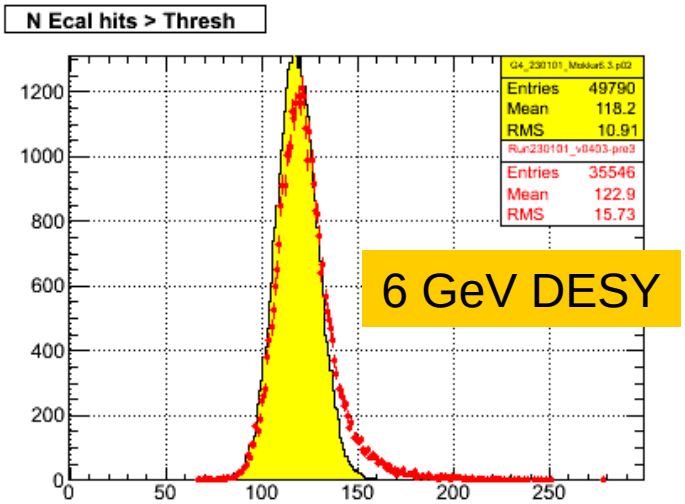



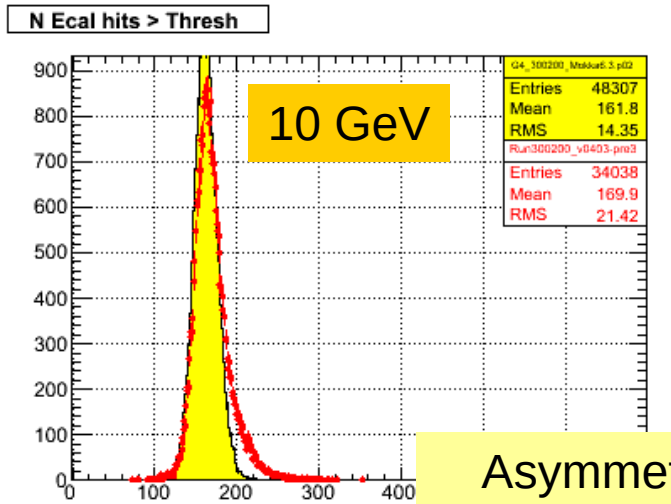



# HitMap of hits below 0.8 MIP

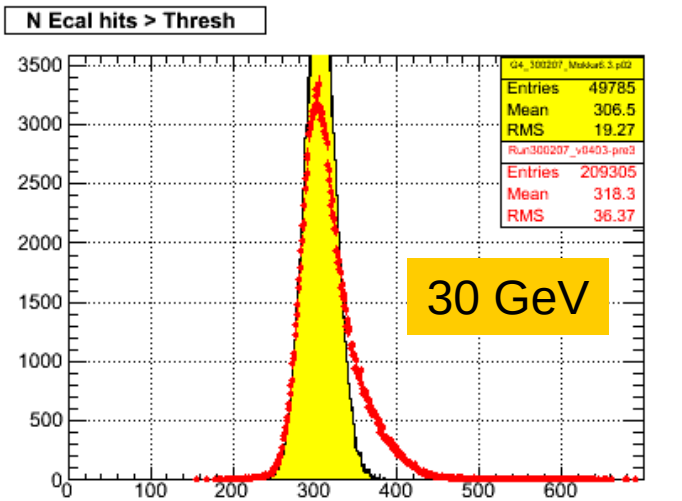


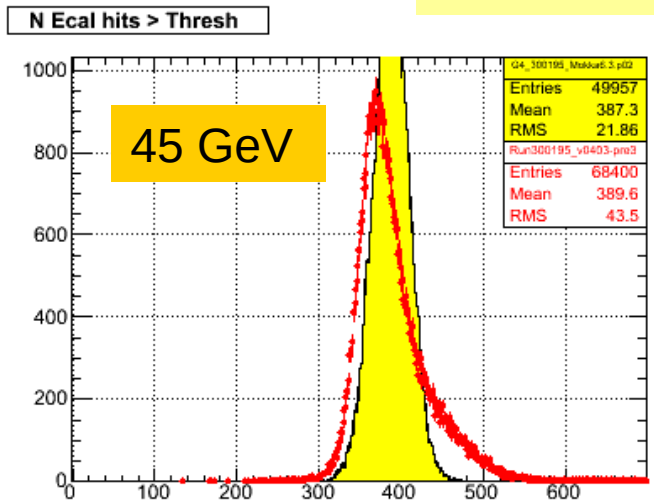
# Number of hits (above threshold)



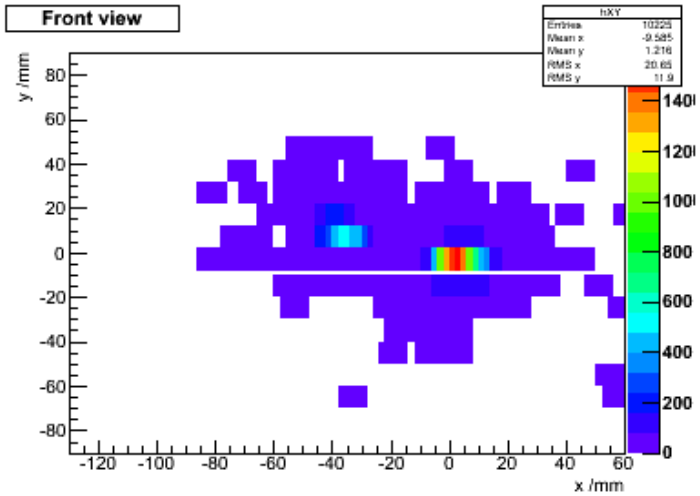



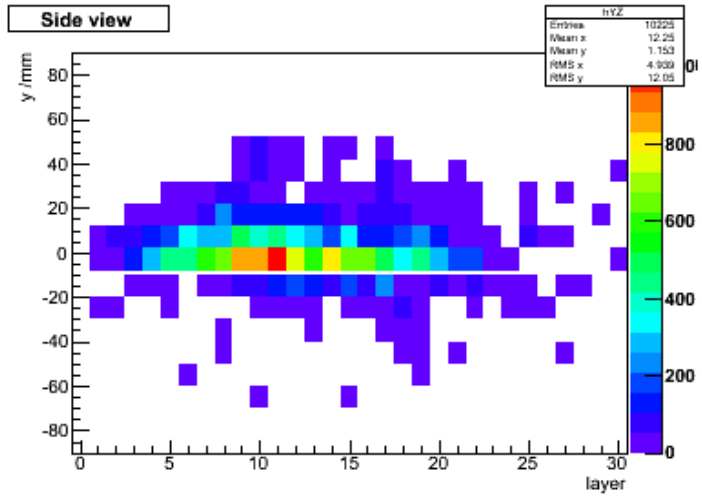

Asymmetric tail in data ∀ energies

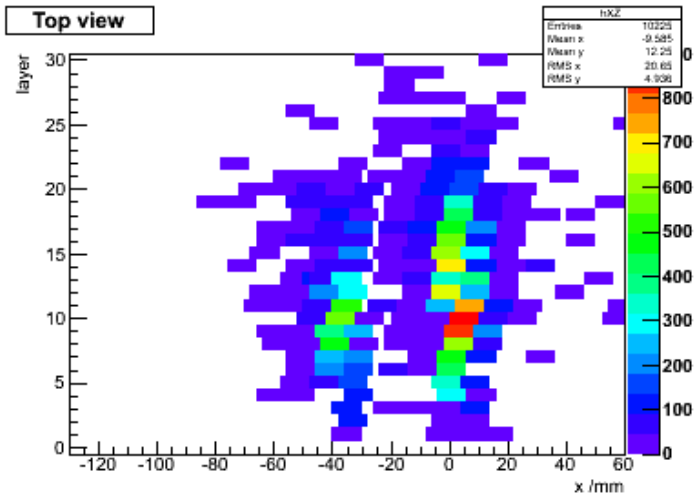


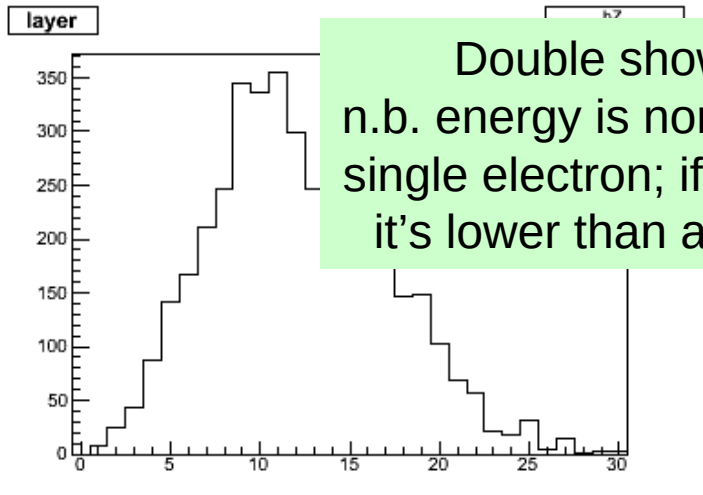



# Look at events in the high tail in data

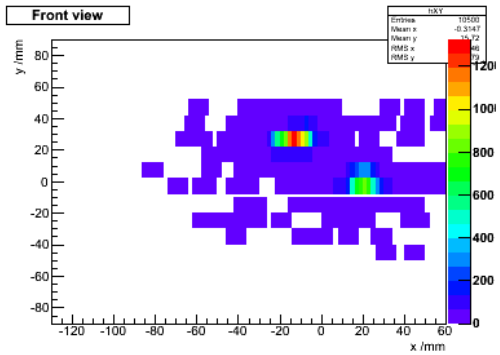


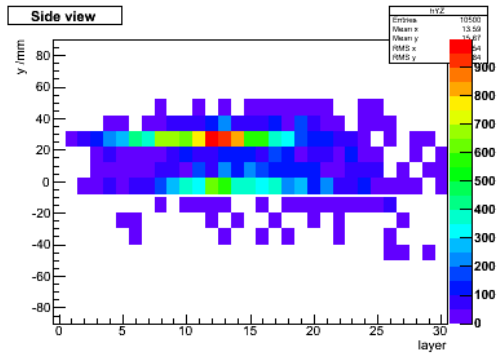



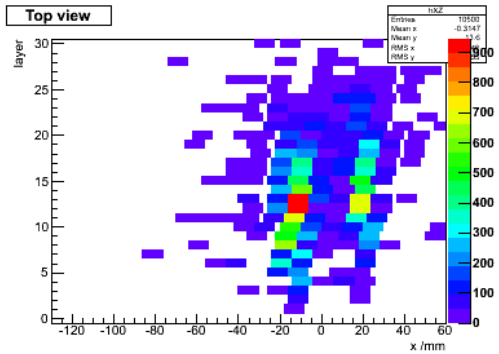



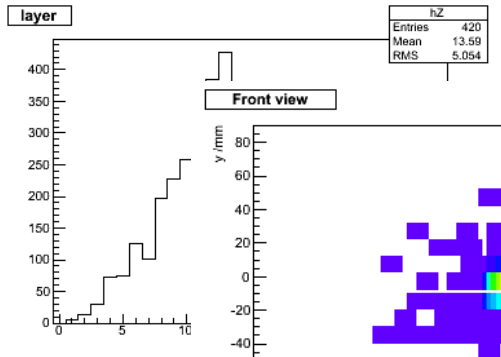



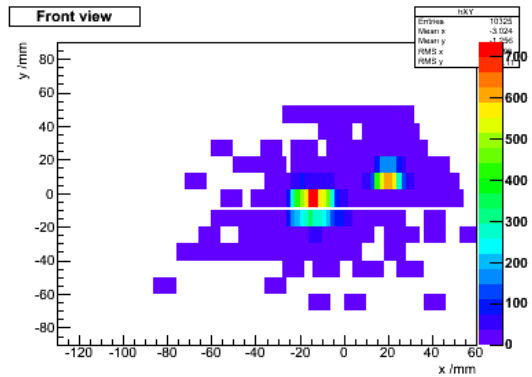

Double shower.
n.b. energy is normal for a single electron; if anything it's lower than average.

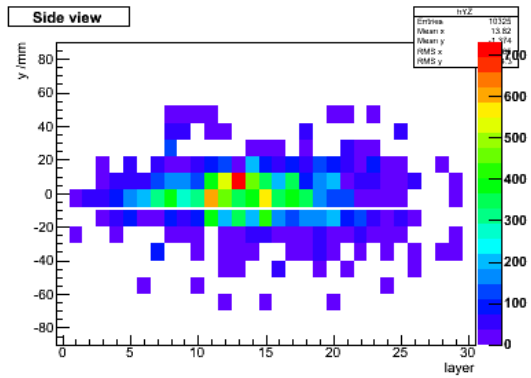


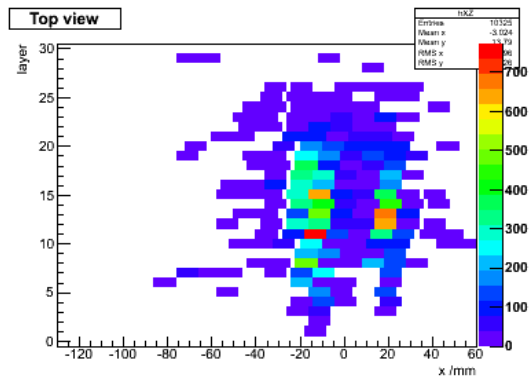



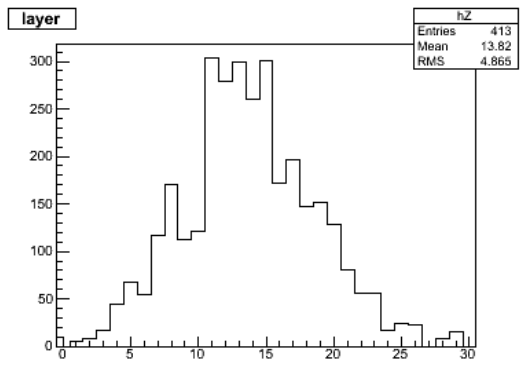



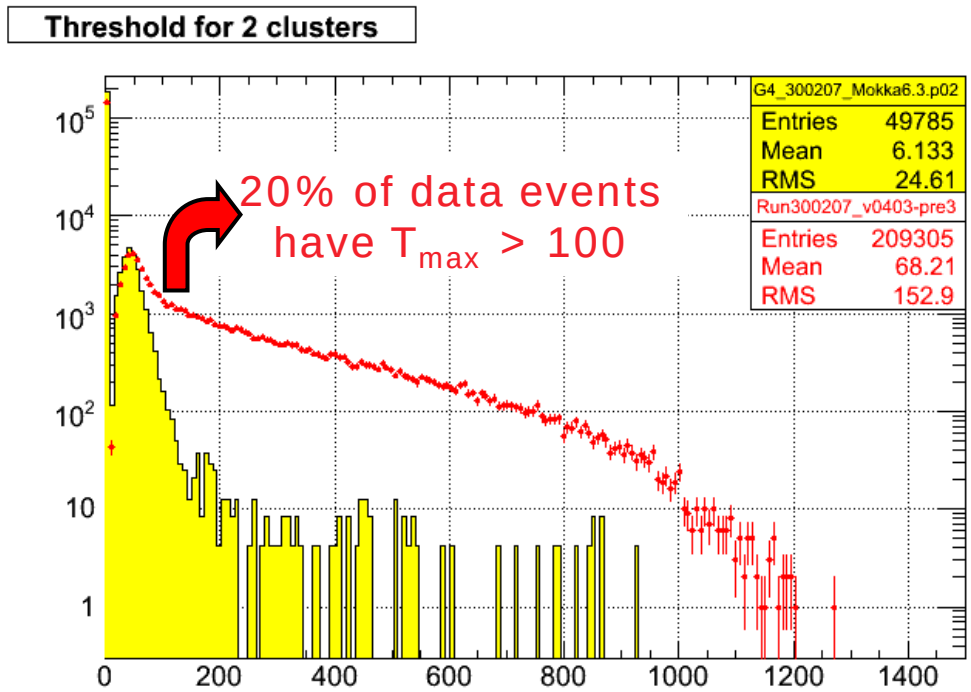




Such events are essentially not simulated at all in Mokka.
There is much still to understand about the beam!

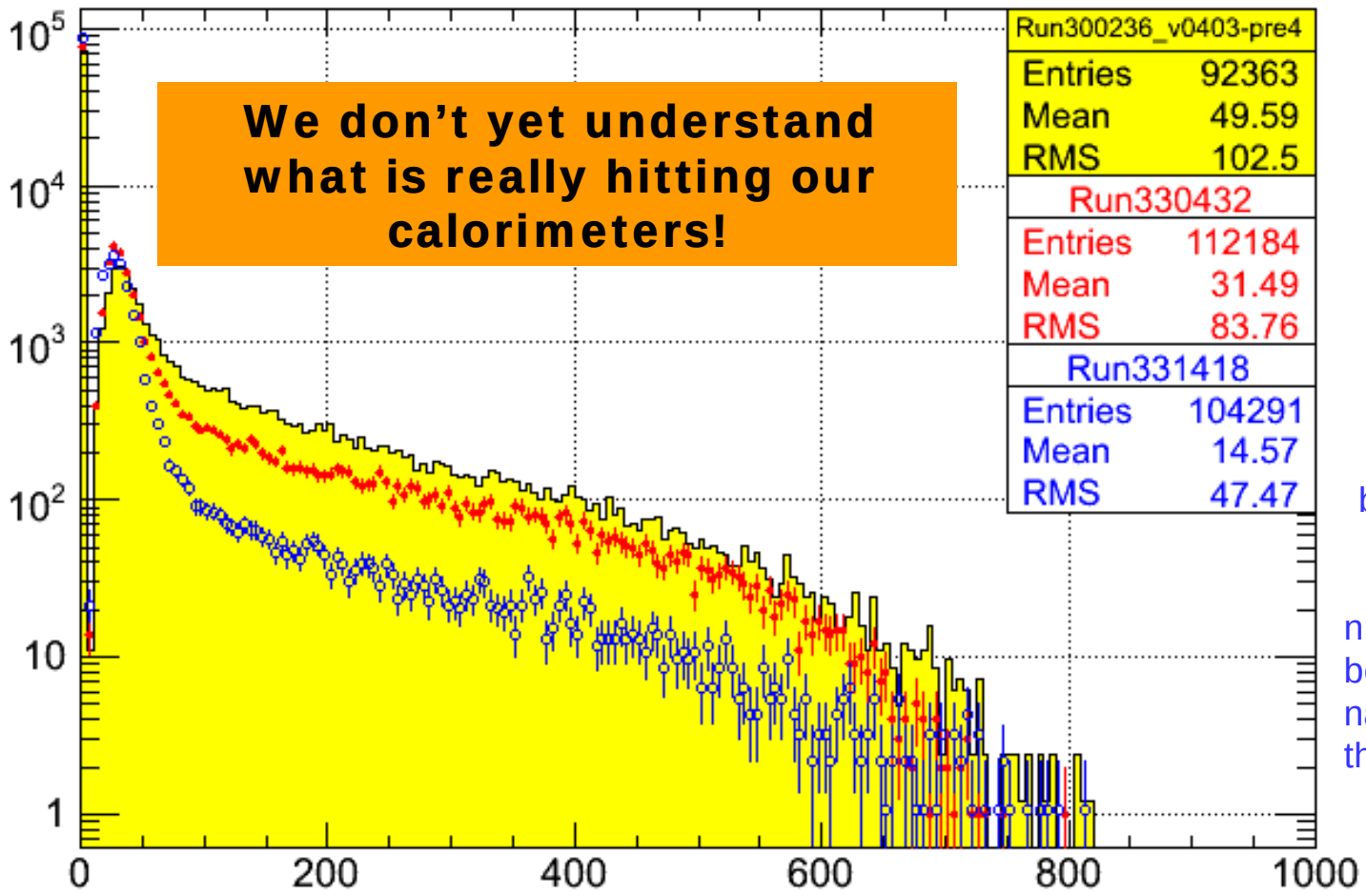
# Cut against double events

- Simple algorithm: form *x*-*y* projection of all 30 layers.
- Apply Threshold *T*
- Perform naïve nearest-neighbour clustering of cells above threshold.
- Find $T_{max}$ below which two or more clusters first appear.
- Dramatic difference between data and MC
- Cut $T_{max}$<100 to remove (most) double events.



# Compare with 2007 data (20 GeV)

**Threshold for 2 clusters**



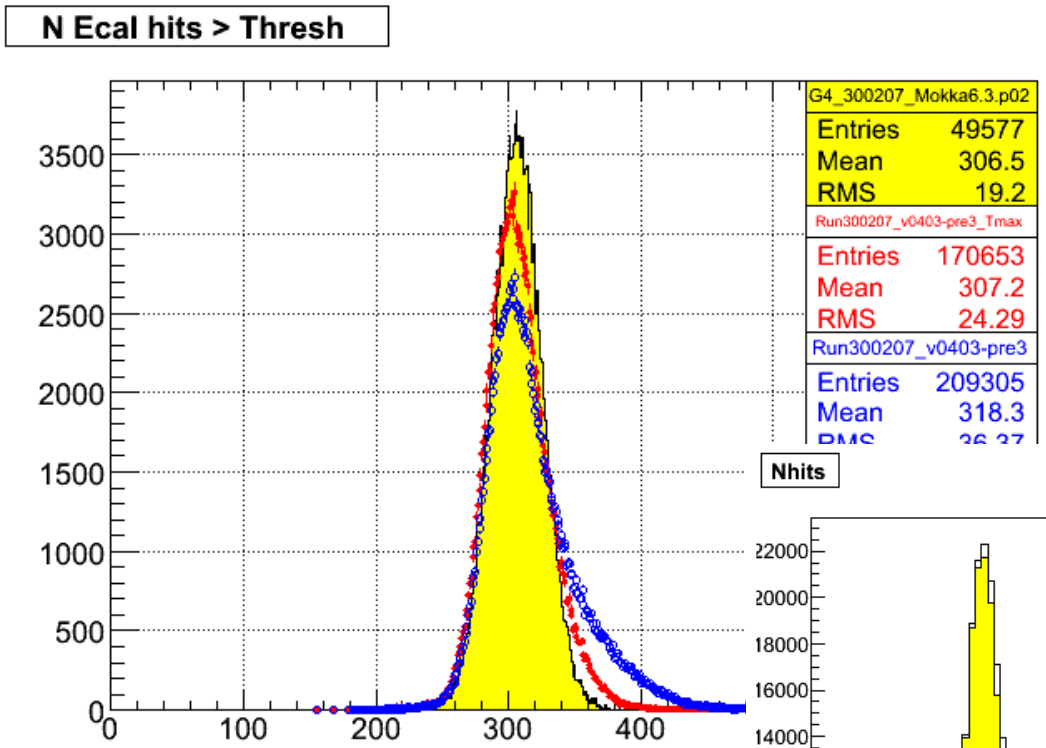

2006

2007 $e^-$
Better, but other runs worse

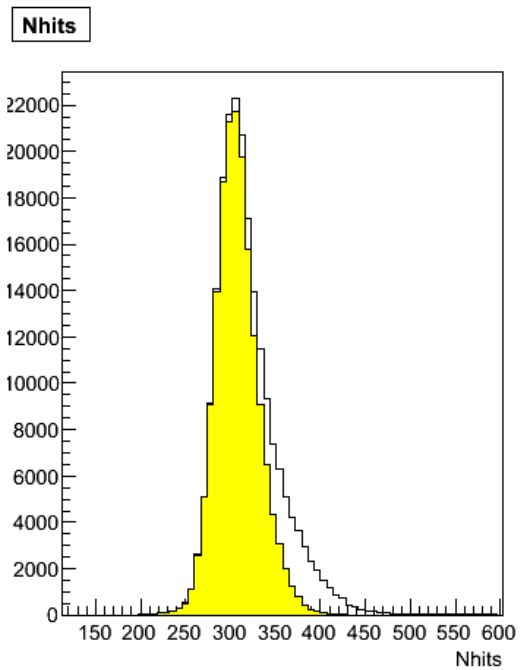
2007 $e^+$
Much better, but still worse than MC

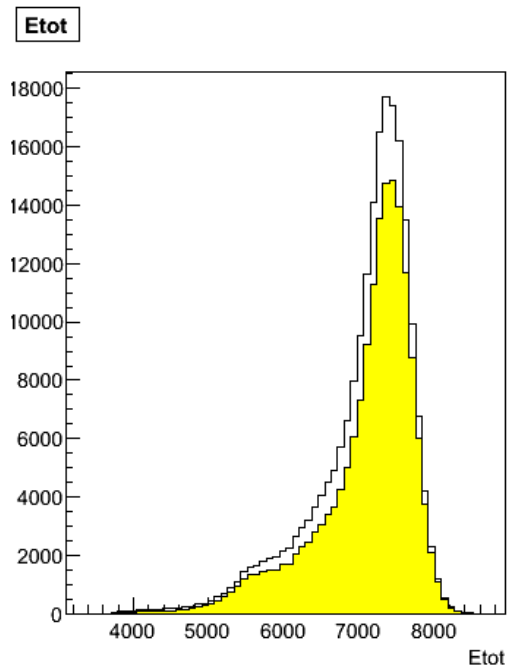
n.b. the $e^+$ beam is much narrower than the $e^-$ beam

# Effect of cut against double showers



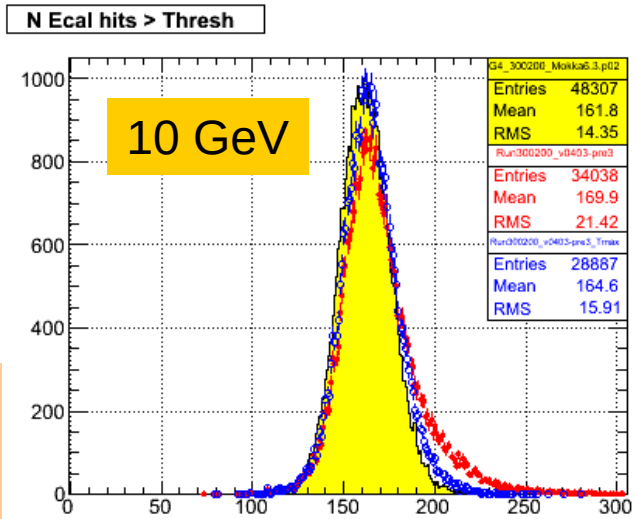

Helps with $N_{hits}$, but doesn't fully solve the problem. Little effect on $E_{tot}$.

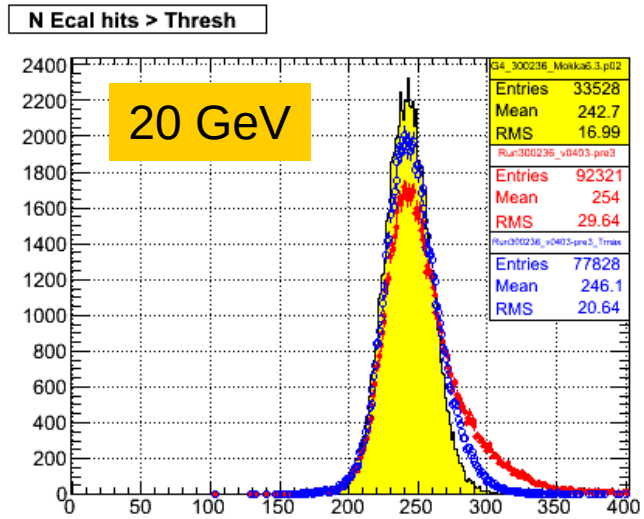


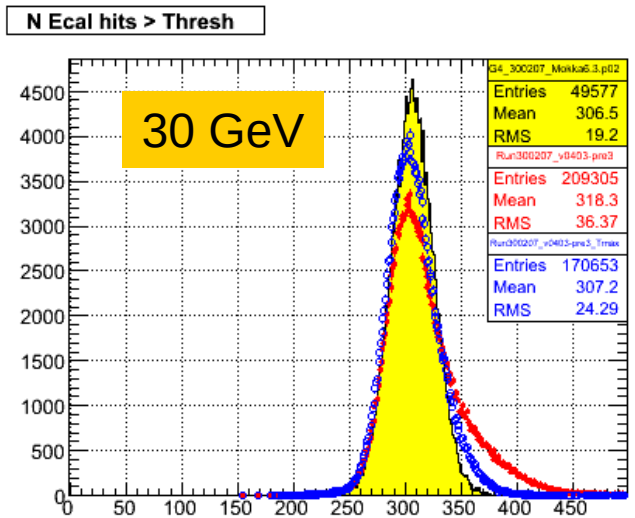



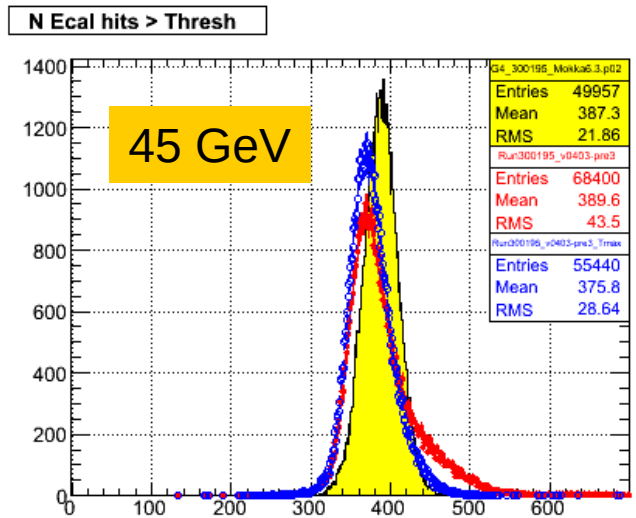
# Other energies?

Peak position vs. energy is still a issue

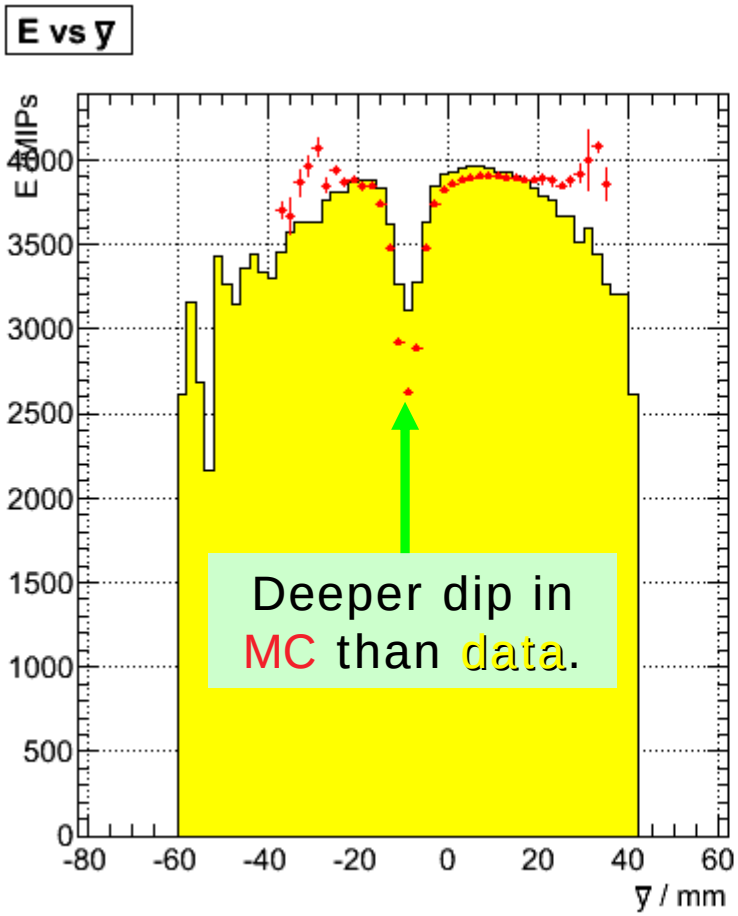


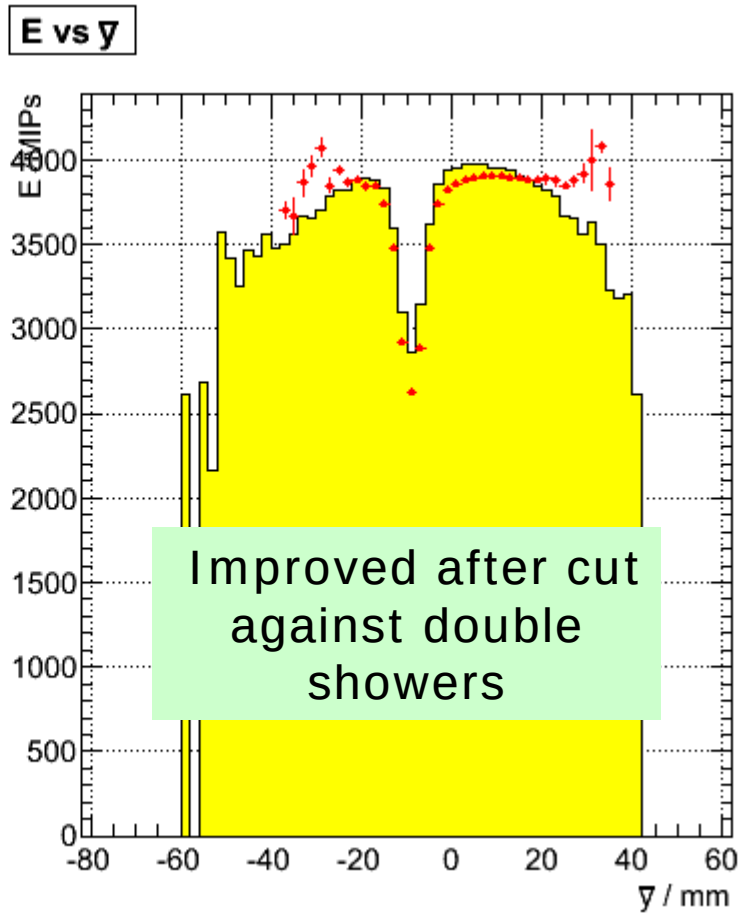



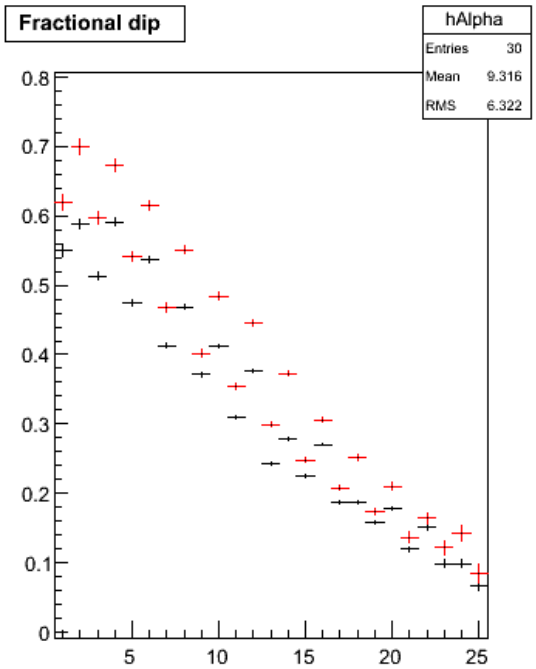
# Interwafer gaps; 30 GeV $e^-$

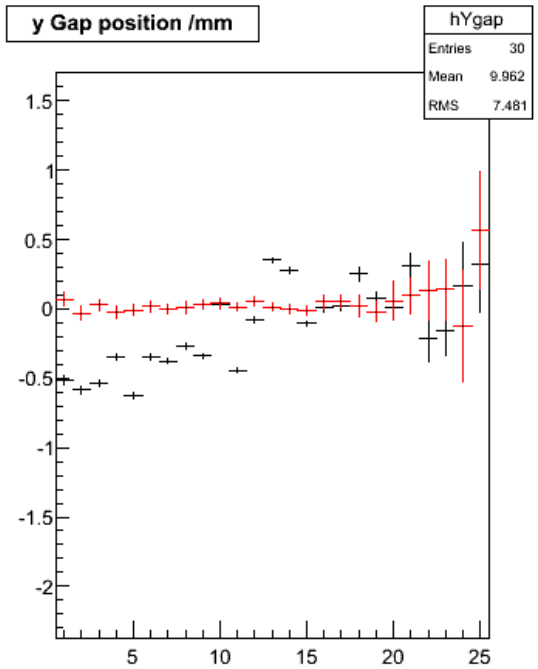


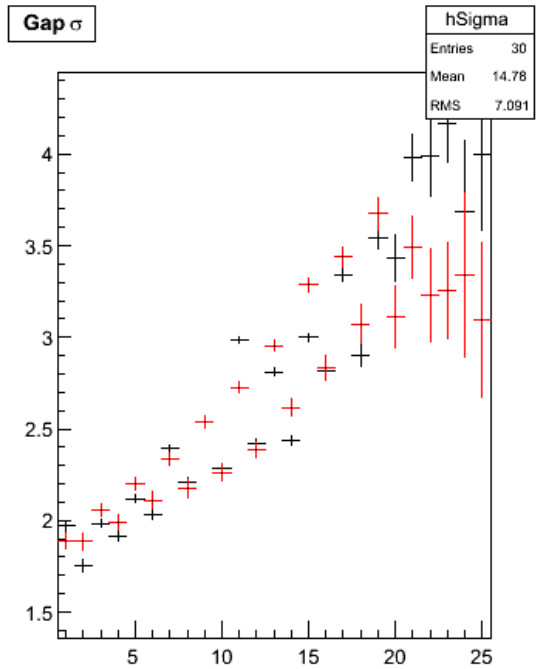



# Dip vs. Layer; 30 GeV $e^-$

Fit dip in energy vs y in each layer to a Gaussian.
Plot fractional depth of dip, position and $\sigma$, for data and MC



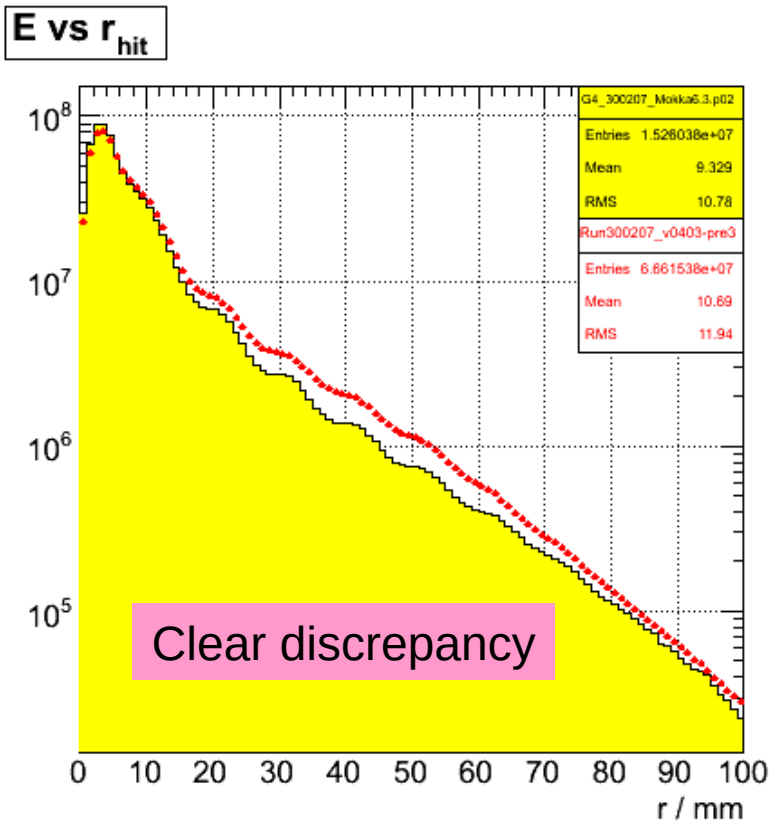



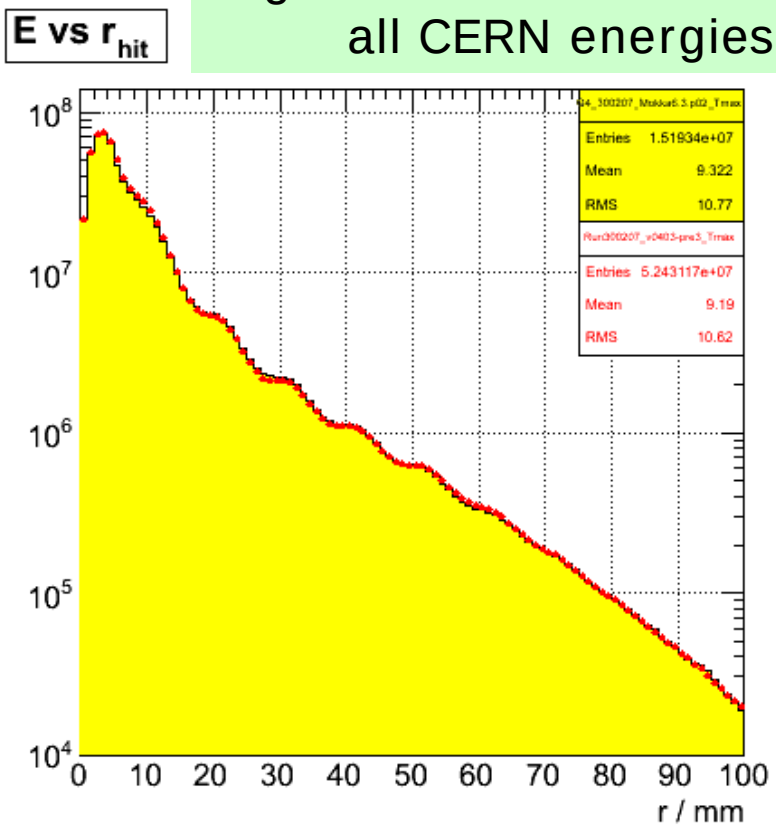

Dip in MC still slightly deeper than in data

Beam inclined in data? Alignment issues?

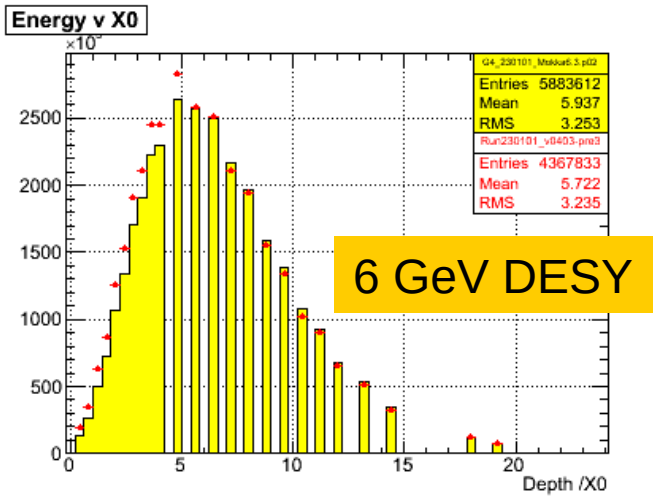
# Radial energy distribution

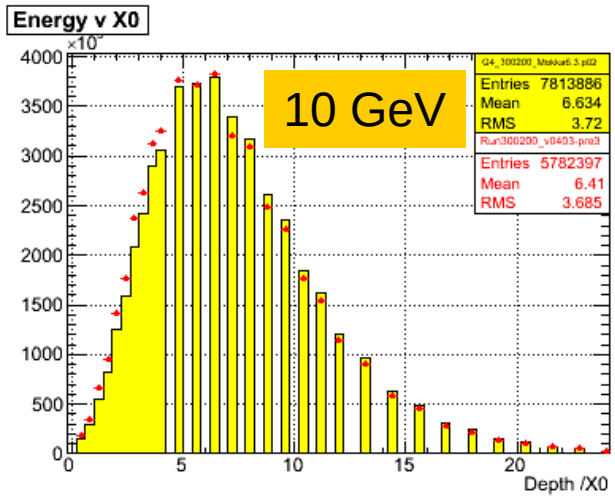
Greatly improved by cut against double showers; at all CERN energies

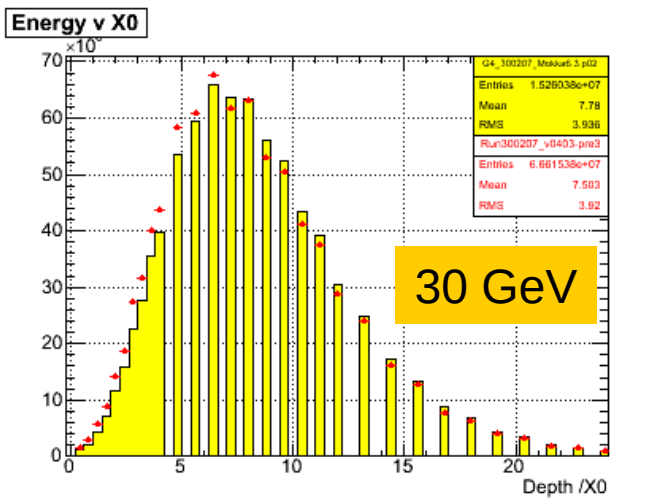


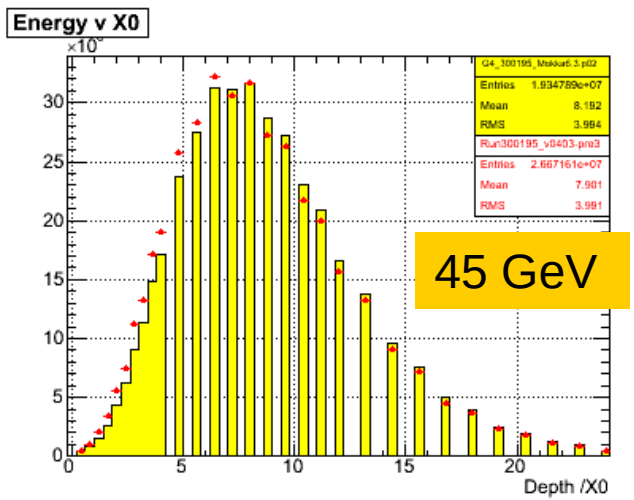



# Shower depth



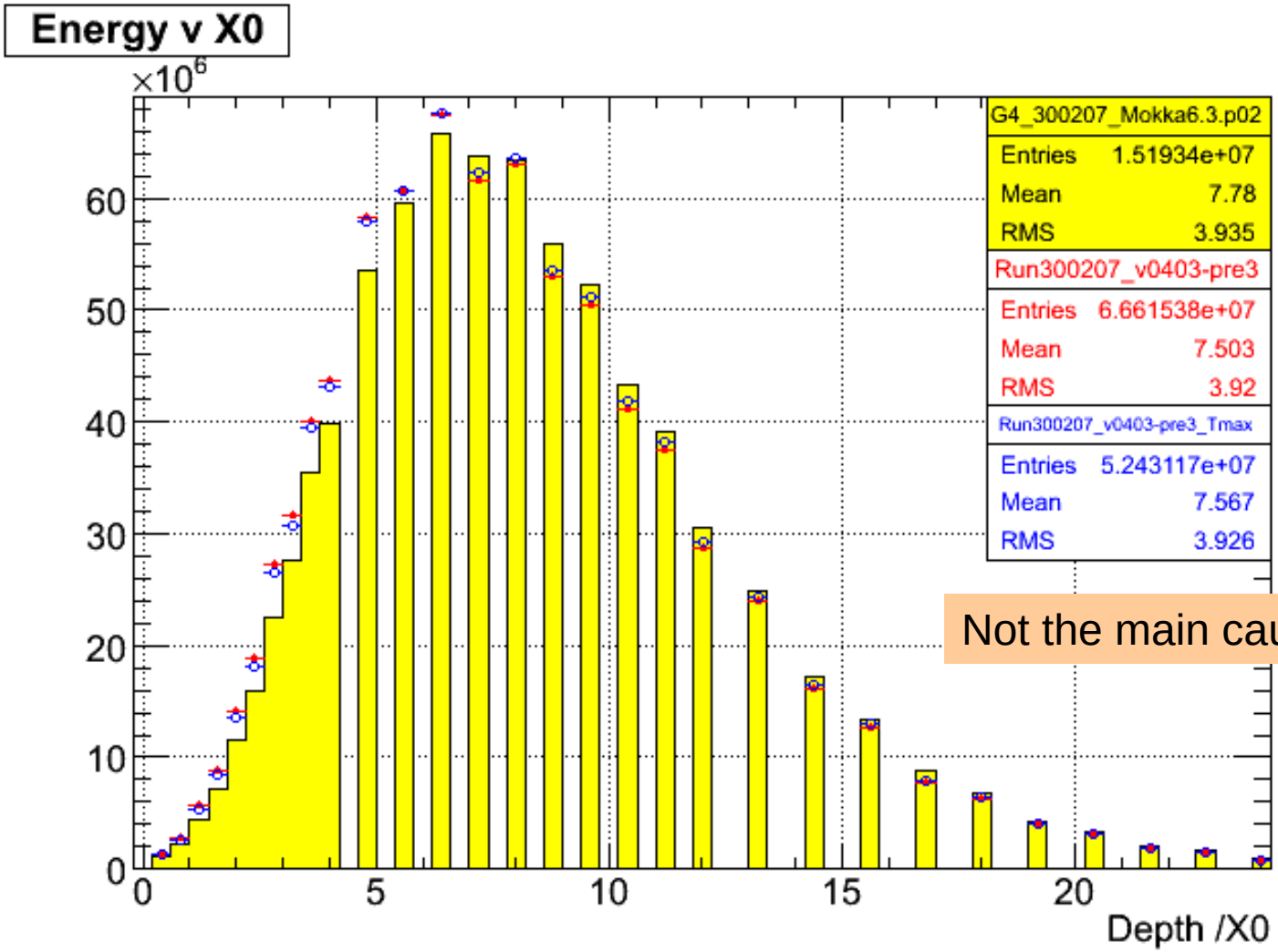




- Shower depth consistently » 0.2-0.3 $X_0$ deeper in MC than data.
- R.M.S. seems quite well modelled.
- Suggests problem with modelling the beam line rather than the material of ECAL?

# Shower depth – effect of double shower cut



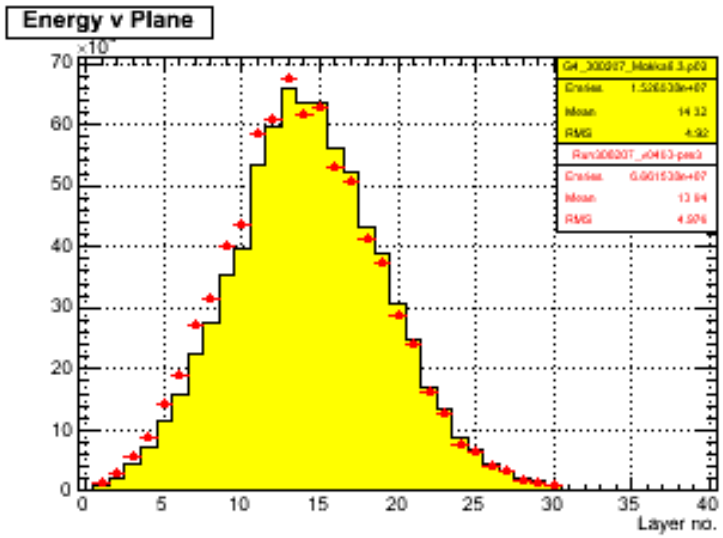

MC 7.78

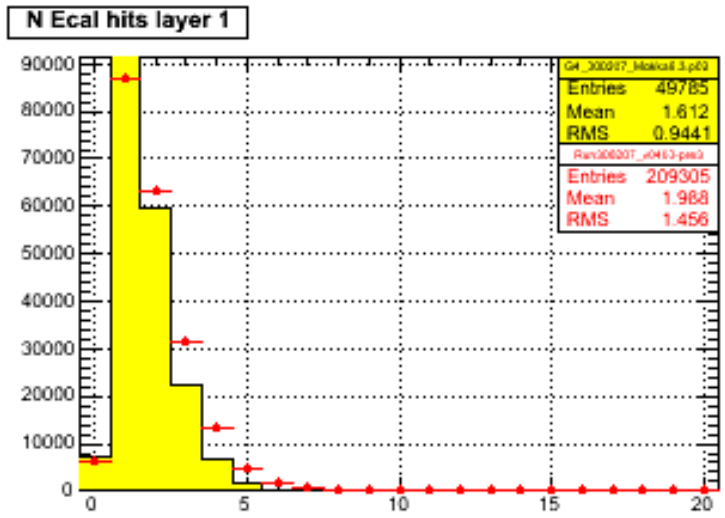
Data 7.50

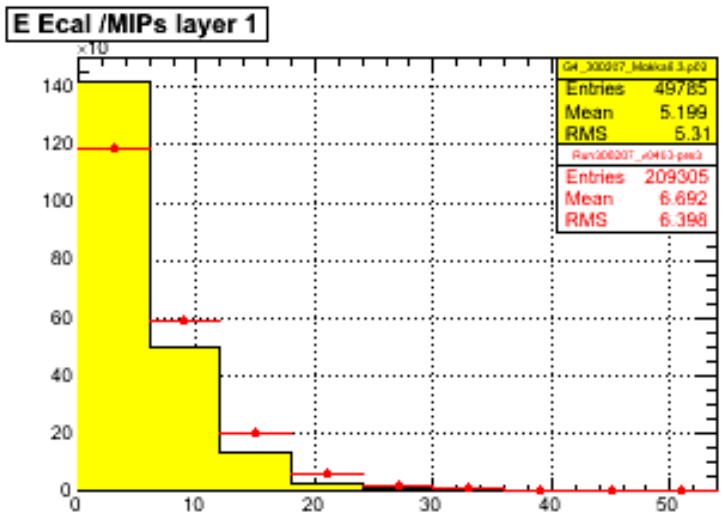
After $T_{max}$ cut 7.57

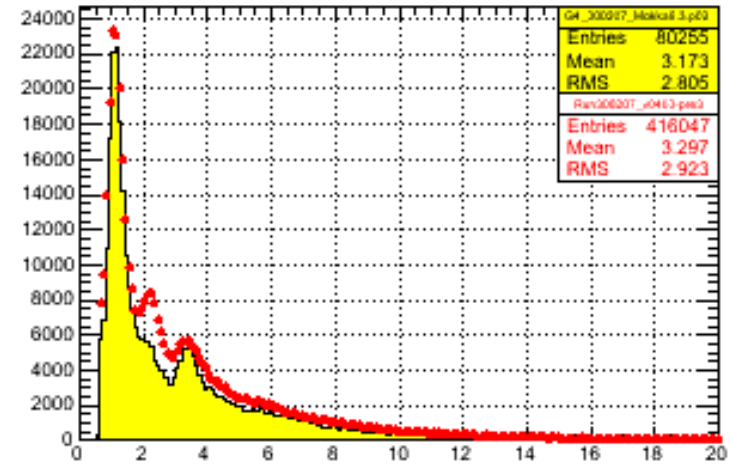
Not the main cause of the problem.

# Hits in Layer 1 only (30 GeV $e^-$)

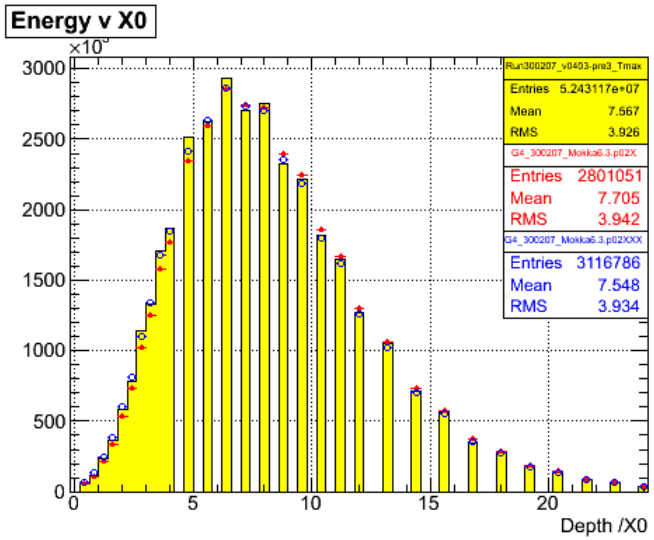


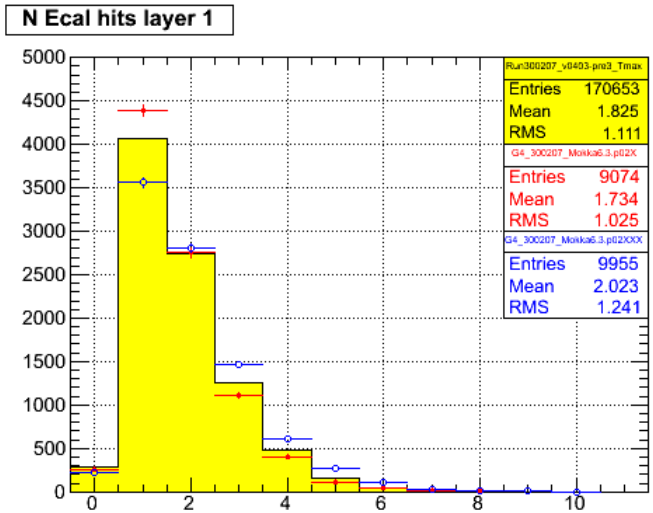



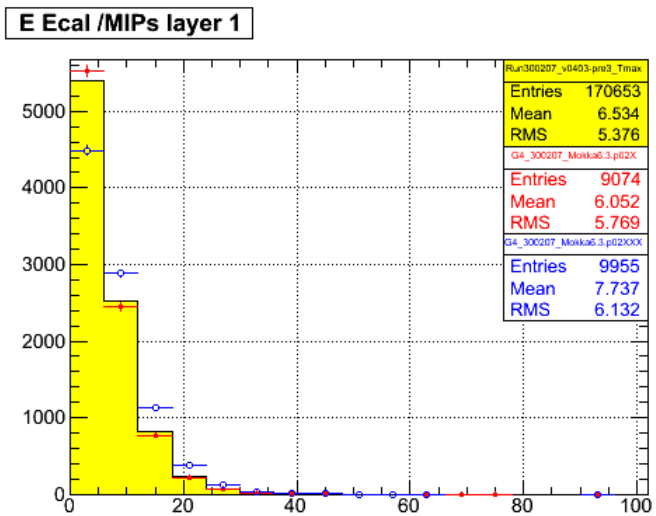



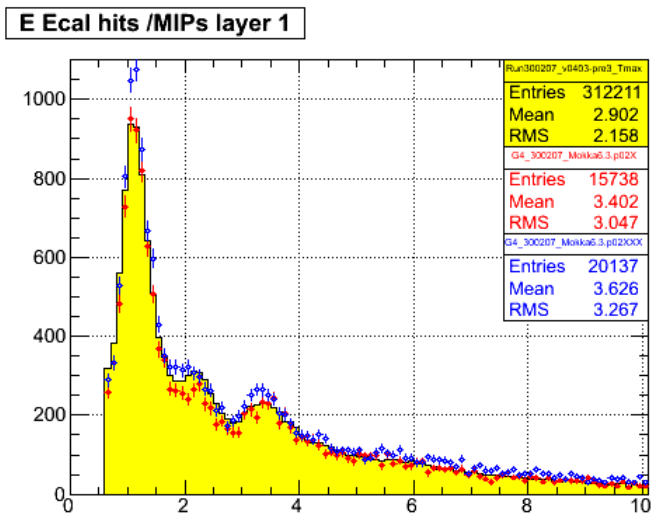



# Increase material in beam



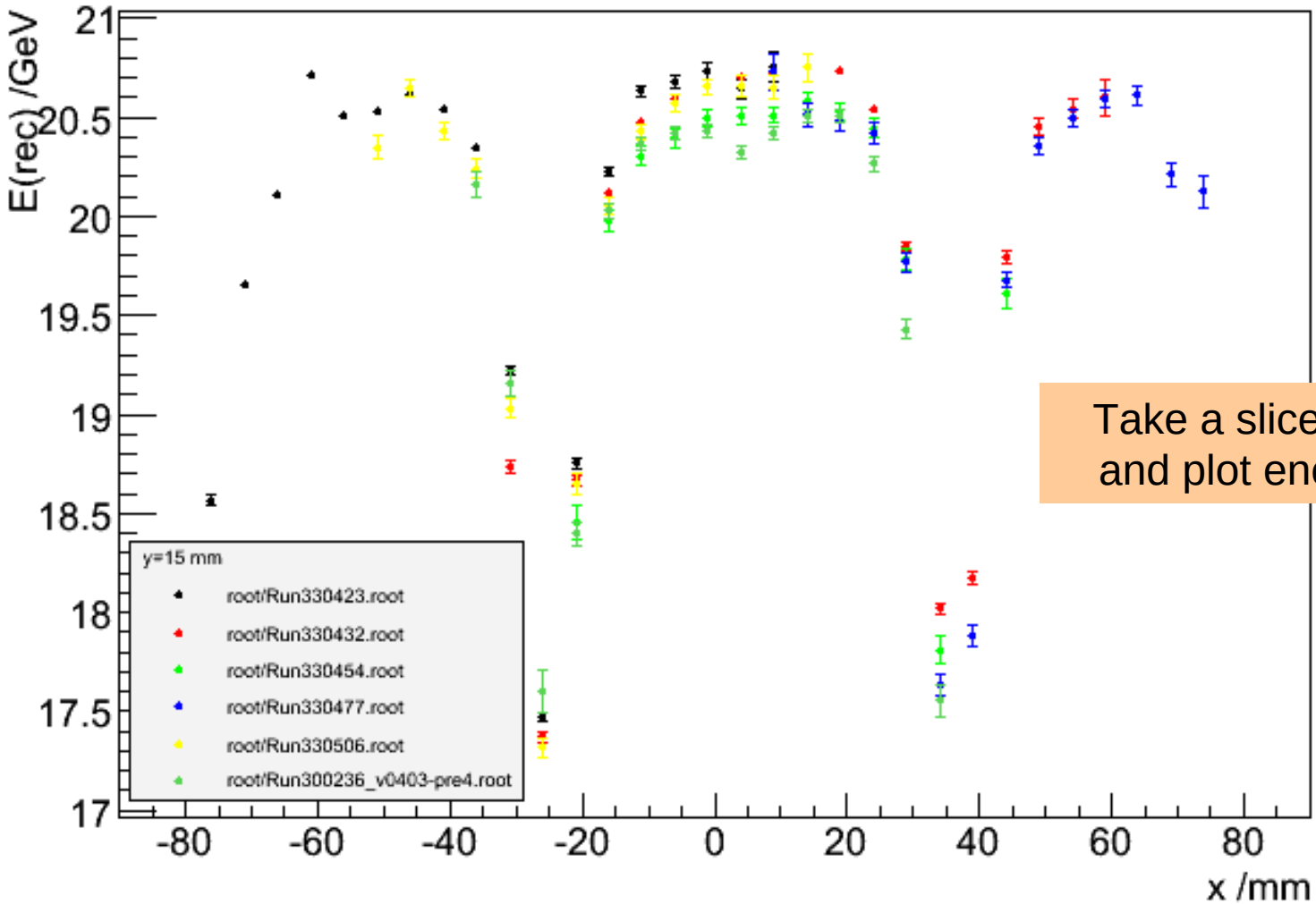



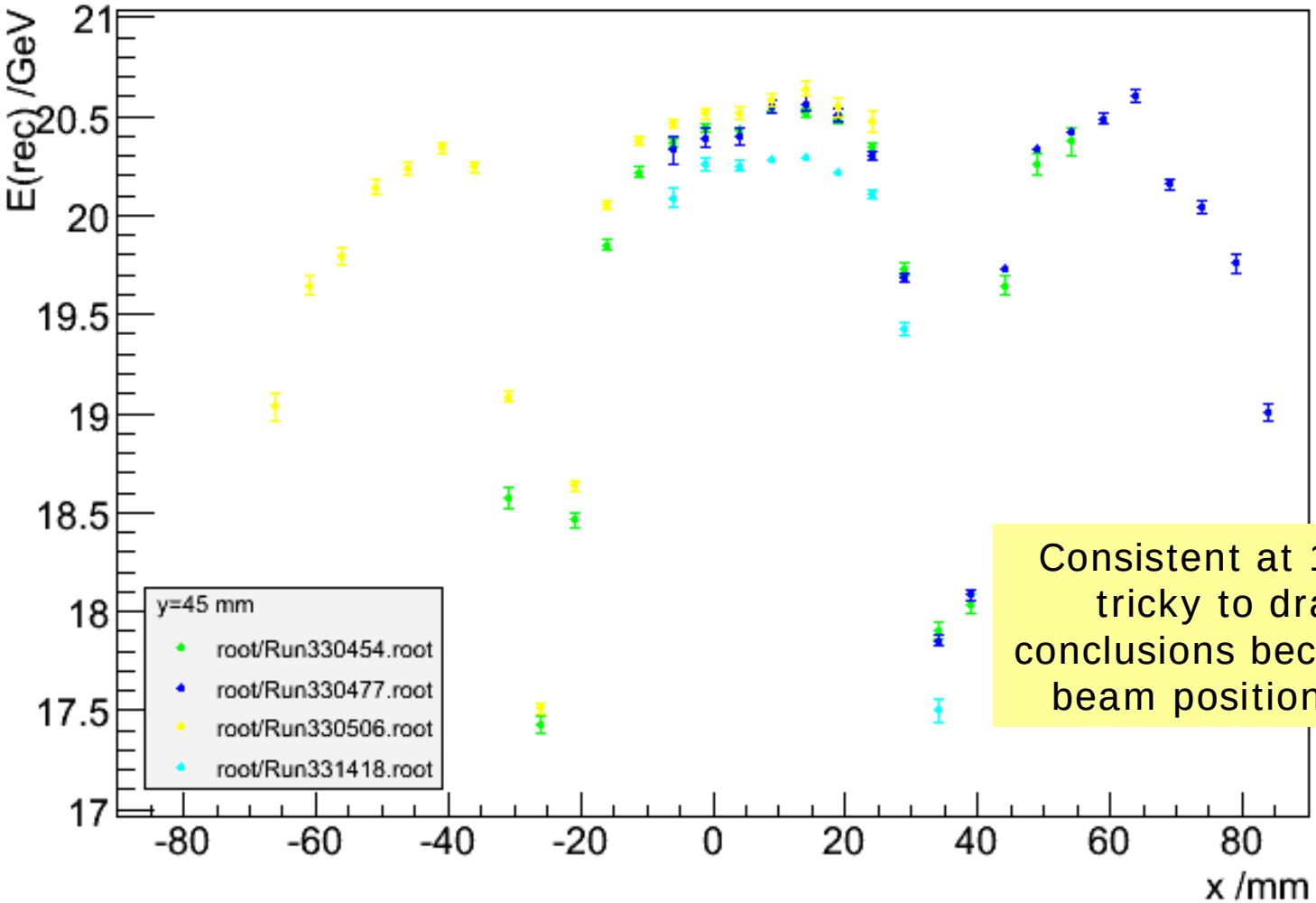

- Try increasing material in beam by 10% or 20% $X_0$
- Technically done by doubling or trebling thickness of scintillators.
- Obviously too crude, but suggests ~ 10-20% $X_0$ upstream material would be needed.
- Seems improbably much?
- Emphasises the need to understand the beam better.

# Uniformity across detector in 2007 data



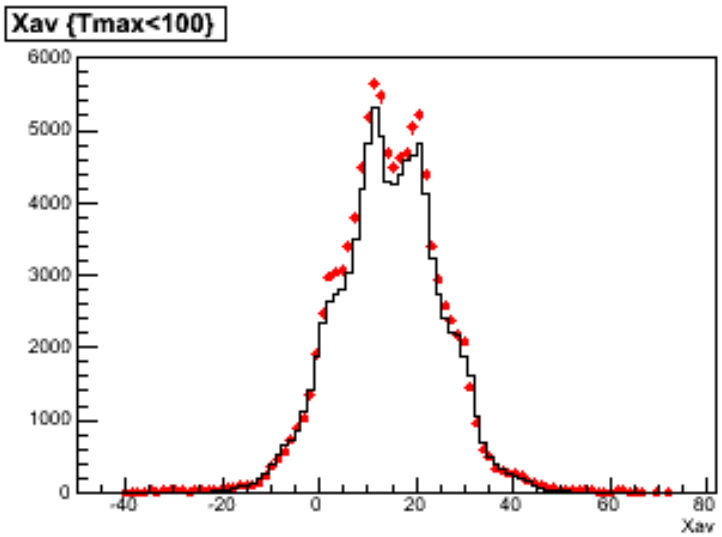

Take a slice 10<y<20 and plot energy vs x.

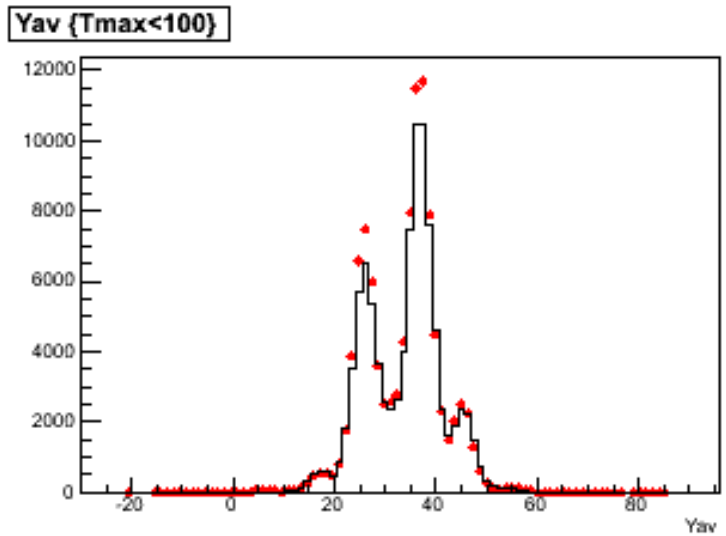
# Another slice (40<y<50)

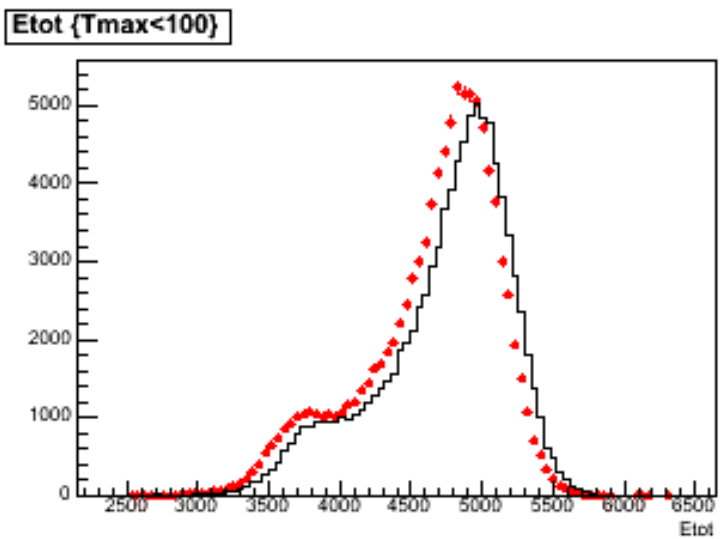


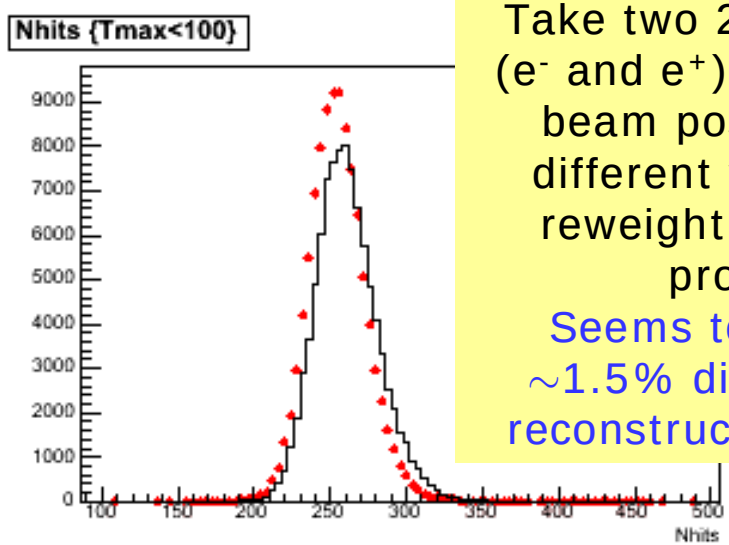

Consistent at 1-2% level, but tricky to draw definitive conclusions because of different beam positions and profiles.

# Reweight two 20 GeV runs to same beam profile



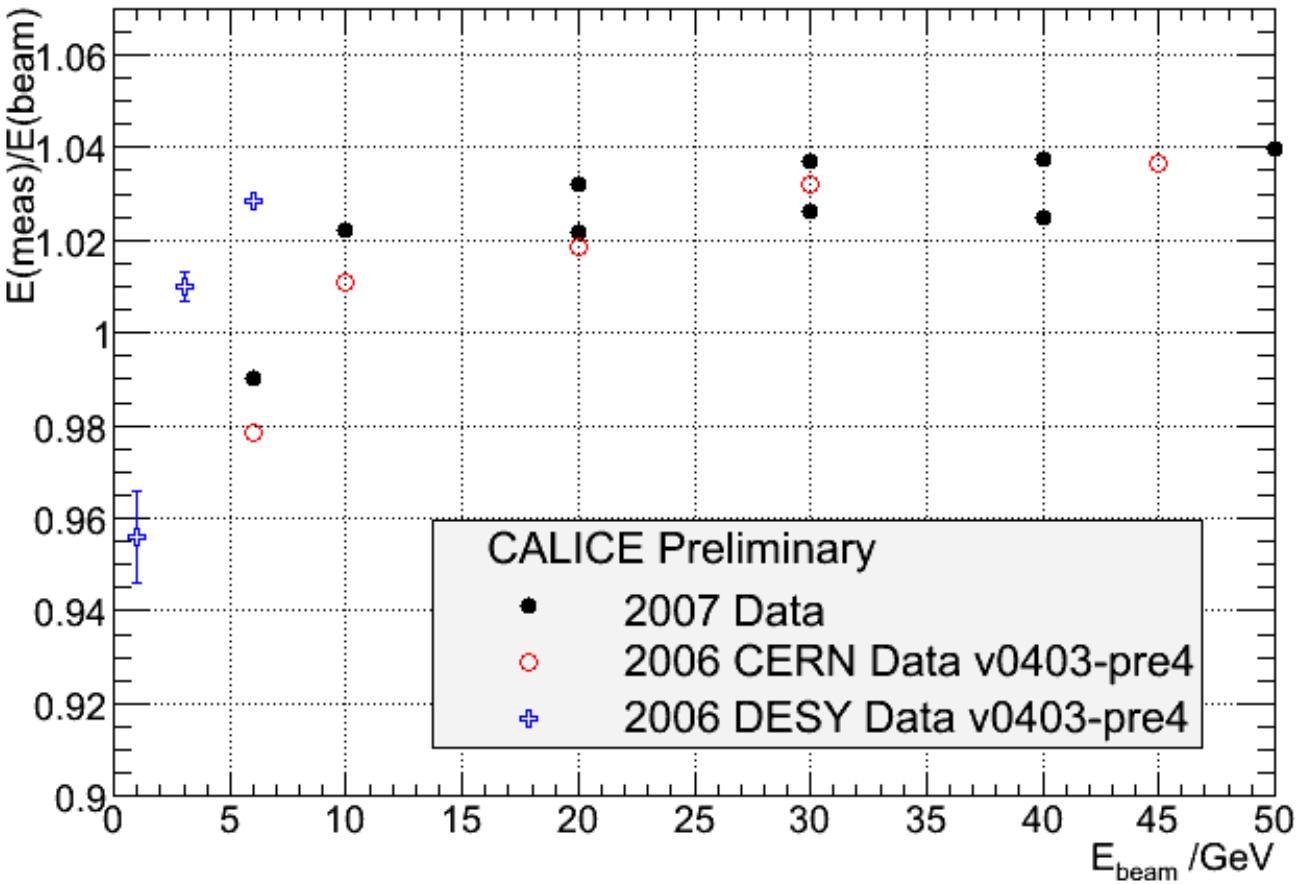



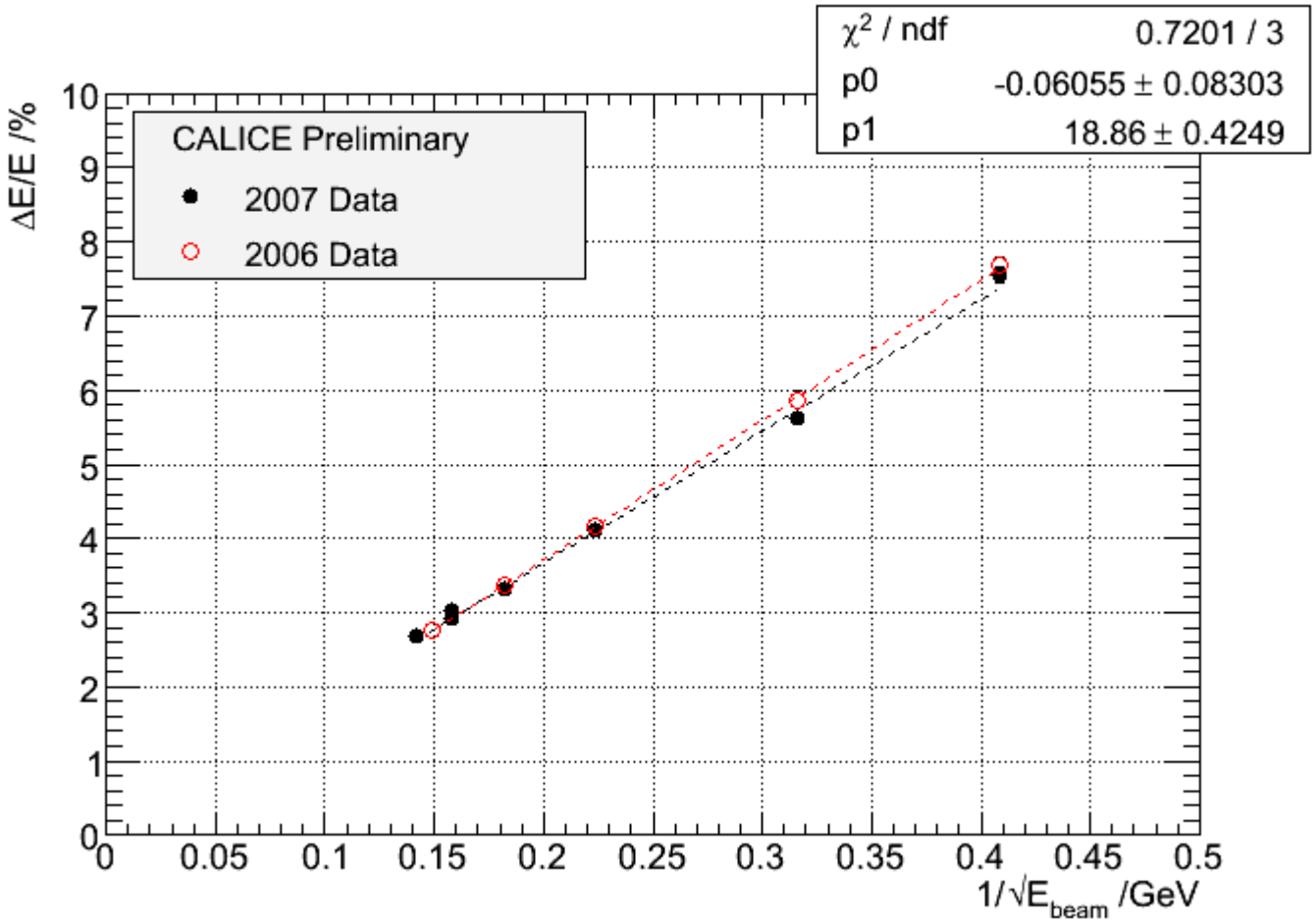

Take two 20 GeV runs ($e^-$ and $e^+$) with similar beam position, but different width, and reweight to ~same profile.

Seems to be clear ~1.5% difference in reconstructed energy.

# Linearity 2006 *c.f.* 2007



# Resolution 2006 *c.f.* 2007



# Thoughts on systematic errors

- A major deficiency in what we've presented so far.
- Think what we might need to do, and whether software framework is adequate at present. Comments welcome.
  - Vary threshold cut.
    - Is the signal/noise cut in data reconstruction adequate?
  - Vary calibration constants within their statistical errors.
    - Reprocess using database? Or just smear? Or simulate using MC?
  - Vary alignment
  - Vary cuts for selecting good $e^{\pm}$ events.
  - Compare runs at same nominal energy.
  - Vary fit procedure/range for extracting response/resolution
  - Different inter-wafer gap corrections?
  - Intrinsic beam energy uncertainty (0.5%$\oplus$150 MeV/$p$) and spread (typically 0.5%).
- I think most of these could be done (or approximated well enough) using the existing reconstructed files.
- ...

# ...Continued...

- Would be good to add to the reconstructed files info about the beam (energy (nominal or “true”?), spread, position, angle, magnet currents?).
- Needs for the Monte Carlo?
  - Correct calorimeter geometry.
    - Including misalignments?
  - Dead cells (especially for 2007)
  - Signal-related crosstalk/pedestal shift, if we can understand the effect well enough.
  - More realistic simulation of the beam.
    - Spread of energy/position/angle; correlations between these.
    - Upstream material and showering.
    - Do we need a full beam line simulation?

# Summary

- Do we go for publication of 2006 data soon, or wait till we understand 2007 data?
- Should we split up topics into smaller papers?
- Do we combine the DESY and CERN data?
- Big questions to resolve:
  - Understand/simulate the beam more correctly
  - Treatment of energy loss in inter-wafer gaps, in a way that is angle-independent.
  - Characterise/correct/simulate “square events” and other coherent signal-related effects, e.g. SIPS.
- Think realistically about systematics. We are not making precision SM measurements, but we do have to assess the reliability of anything we measure.