A Brief Update on DECal Studies

Tony Price

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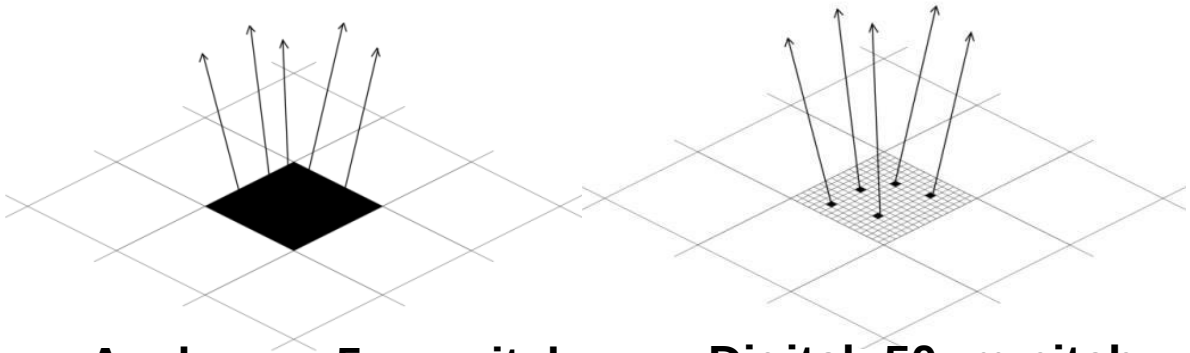
FCC-hh Detector Meeting

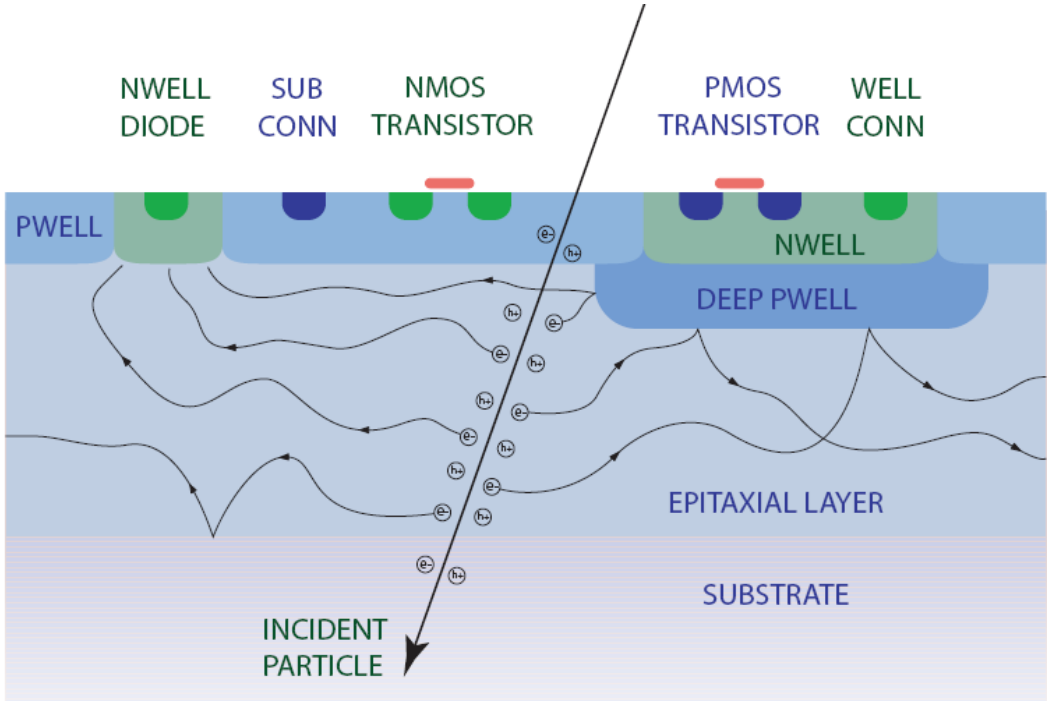
Digital Calorimetry: The Concept

- Dates back to c.2005 work within CALICE and ILCs
- Make a pixelated calorimeter to count the number of particles in each sampling layer
- Ensure that the pixels are small enough to avoid multiple particles passing through it to avoid undercounting and non-linear response in high particle density environments
- Proposed FCC-hh DECAL has a silicon area of ~6000m^2 .
- Would require 10^{12} pixels



Analogue: 5mm pitch **Digital: 50um pitch**

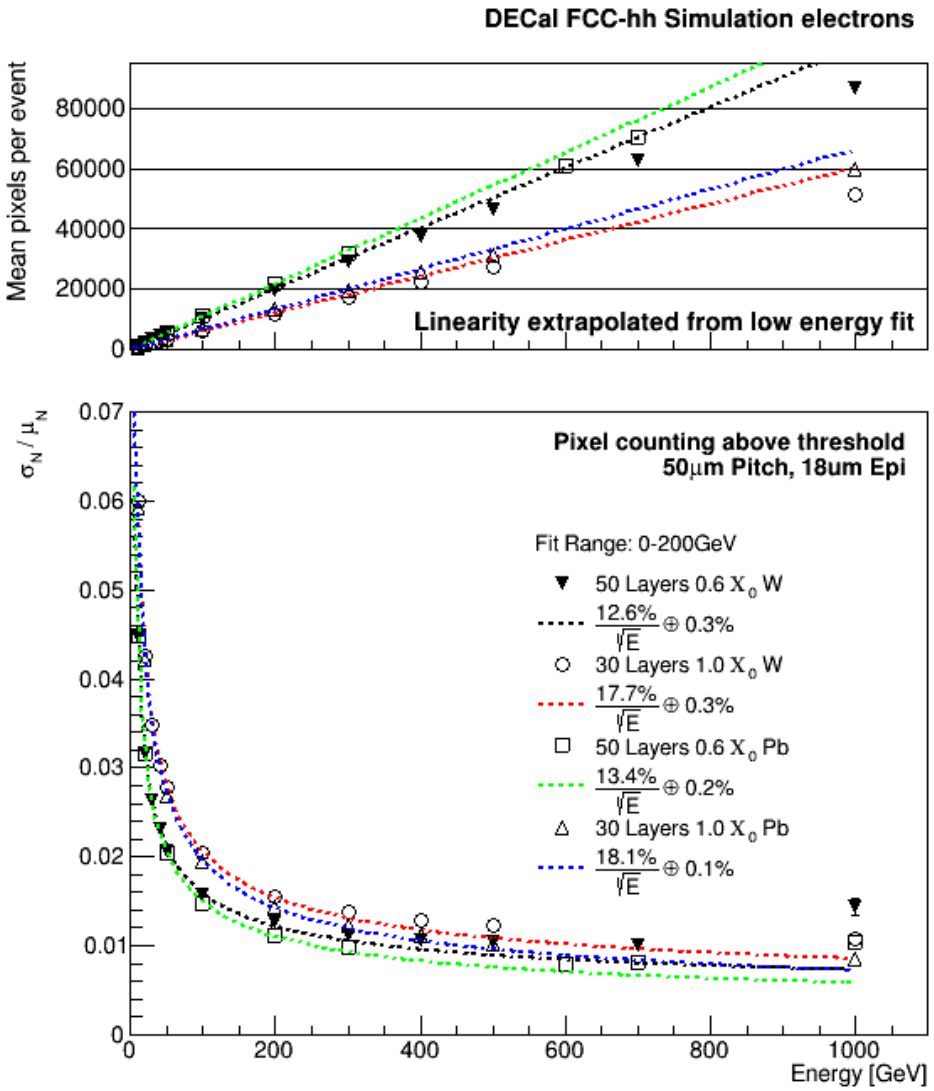
CMOS MAPS



- Can achieve the ultra high granularity with the use of CMOS Monolithic Active Pixel Sensors
- Thin sensitive region, usually 12-25um
- Low noise
- Low cost (compared to hybrids)
- Readout on the sensor so no need for separate chip
- Developments in HV/HR CMOS to deplete the sensor improve charge collection speed and radiation hardness

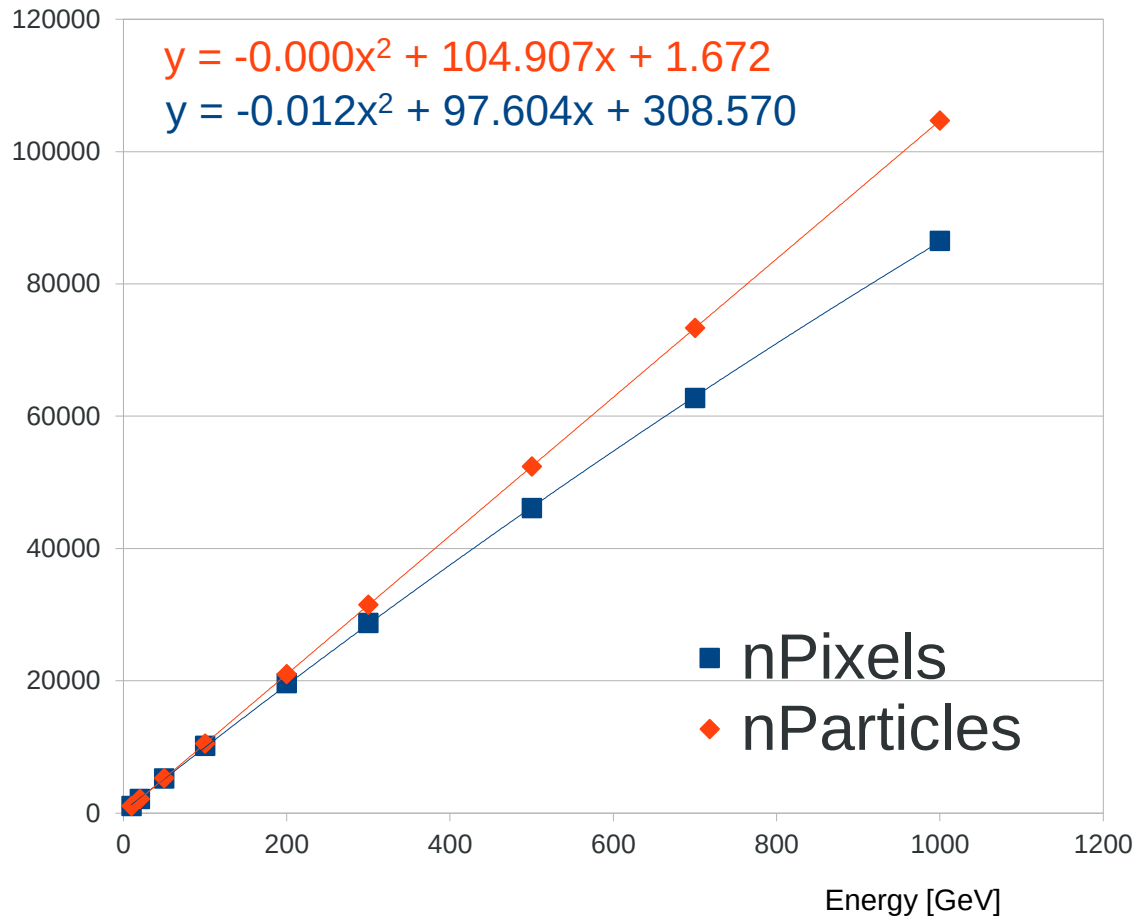
Summary from FCC Week

- Detector Configuration
  - 30 layers of 1.0χ_0 W
  - 30 layers of 1.0χ_0 Pb
  - 50 layers of 0.6χ_0 W
  - 50 layers of 0.6χ_0 Pb
- Increased number of layers (sampling fraction) improves resolution for both materials
- Material choice has minimal effect on energy resolution
- **Pb improves linearity and 50 layers achieves energy resolution of 13%/√E (but thicker)**



Compensating non linearity

- Studies using 50 layers, 2.1mm W, 18um epi layer
- Modified SD to extract the number of incident particles to a layer not just the steps.
- DD4HEP::Simulation::Geant4CalorimeterHit loses a lot of information compared to G4Hit
- Linear response of particles vs energy
- Non linear response of pixels vs energy due to multiple particles through each pixel



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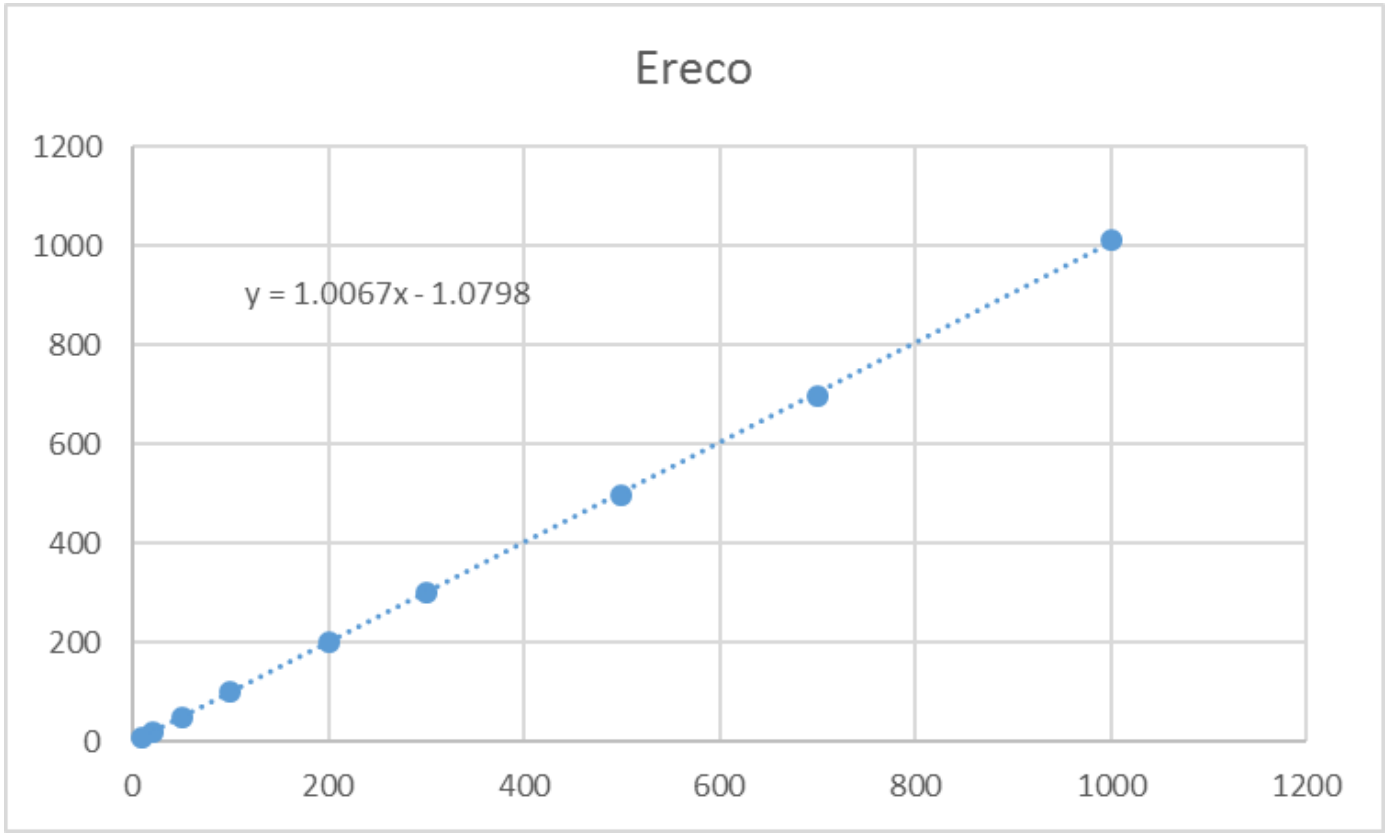

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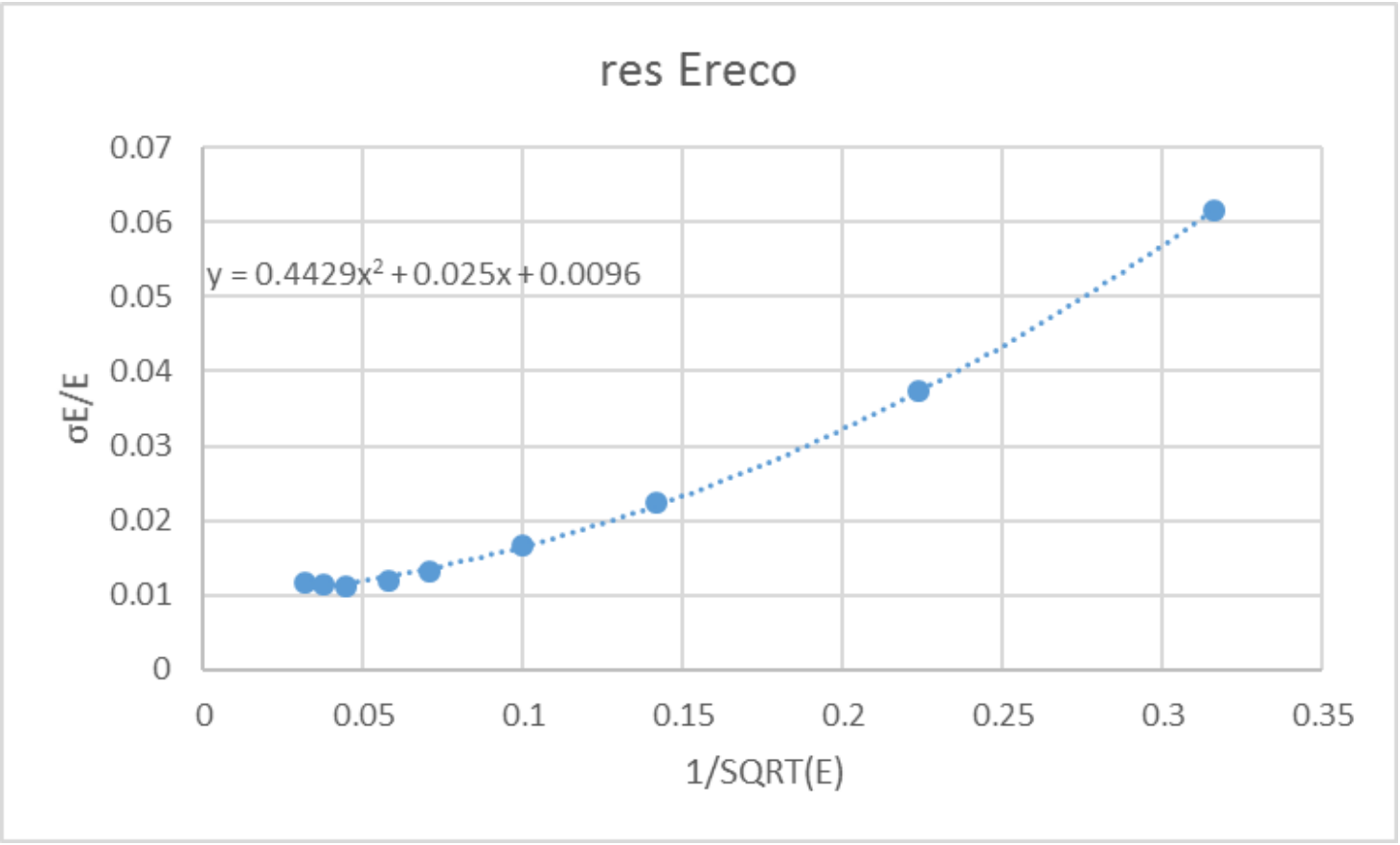
- Can see that the mean energy response behaves quite nicely

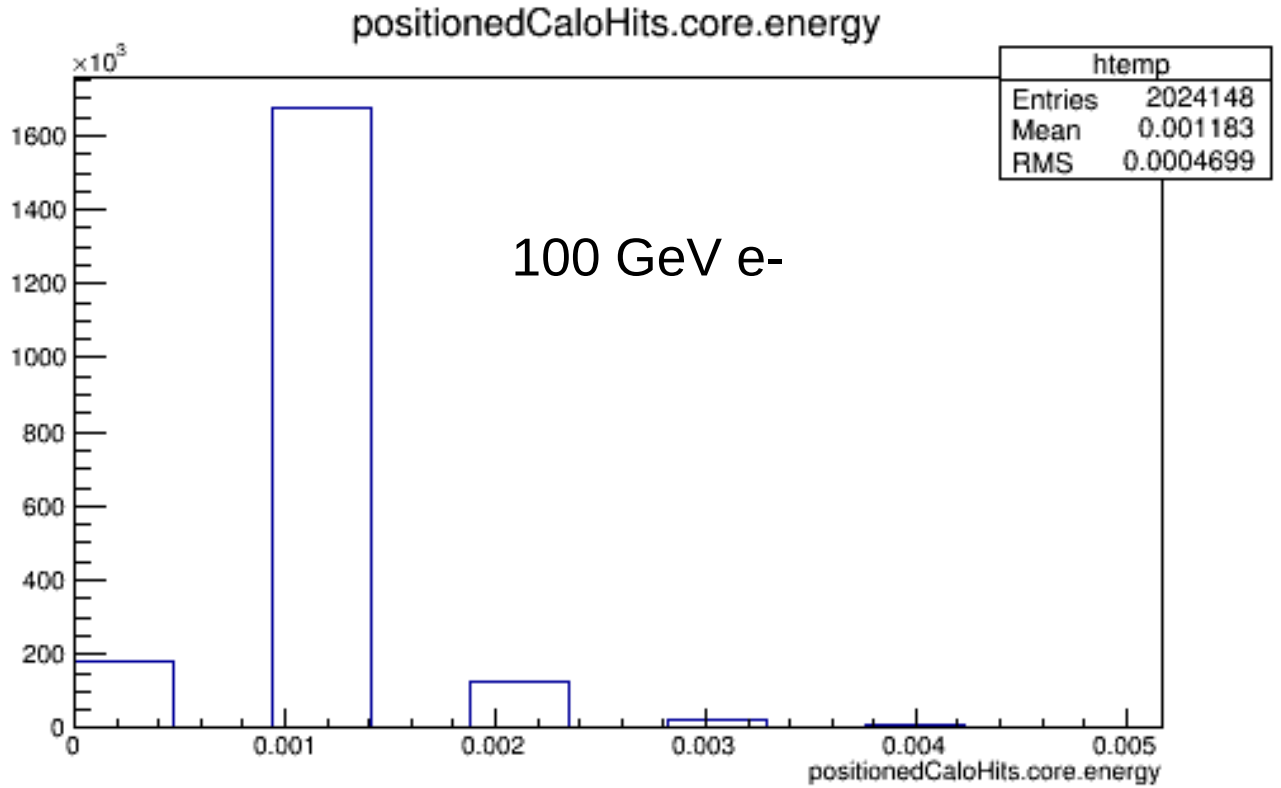
Compensating non linearity



- First, we take the second order polynomial to calibrate the energy
- Can see that the mean energy response behaves quite nicely
- However, when we plot the resolution vs 1/SQRT(E) we would expect linear response
- As correcting with non linear function the Gaussian spread increases at higher energies, and reduces σE/E
- Dominant term now 44%/E (not √E!)

Where are the particles going?

- For every pixel which fires in an event we found the number of particles incident upon it
- Can we use this information to calibrate out?
- As incident particle energy increases so does the number of pixels with multiple particles



X-axis needs x1000 due to internal workings of FCCSW

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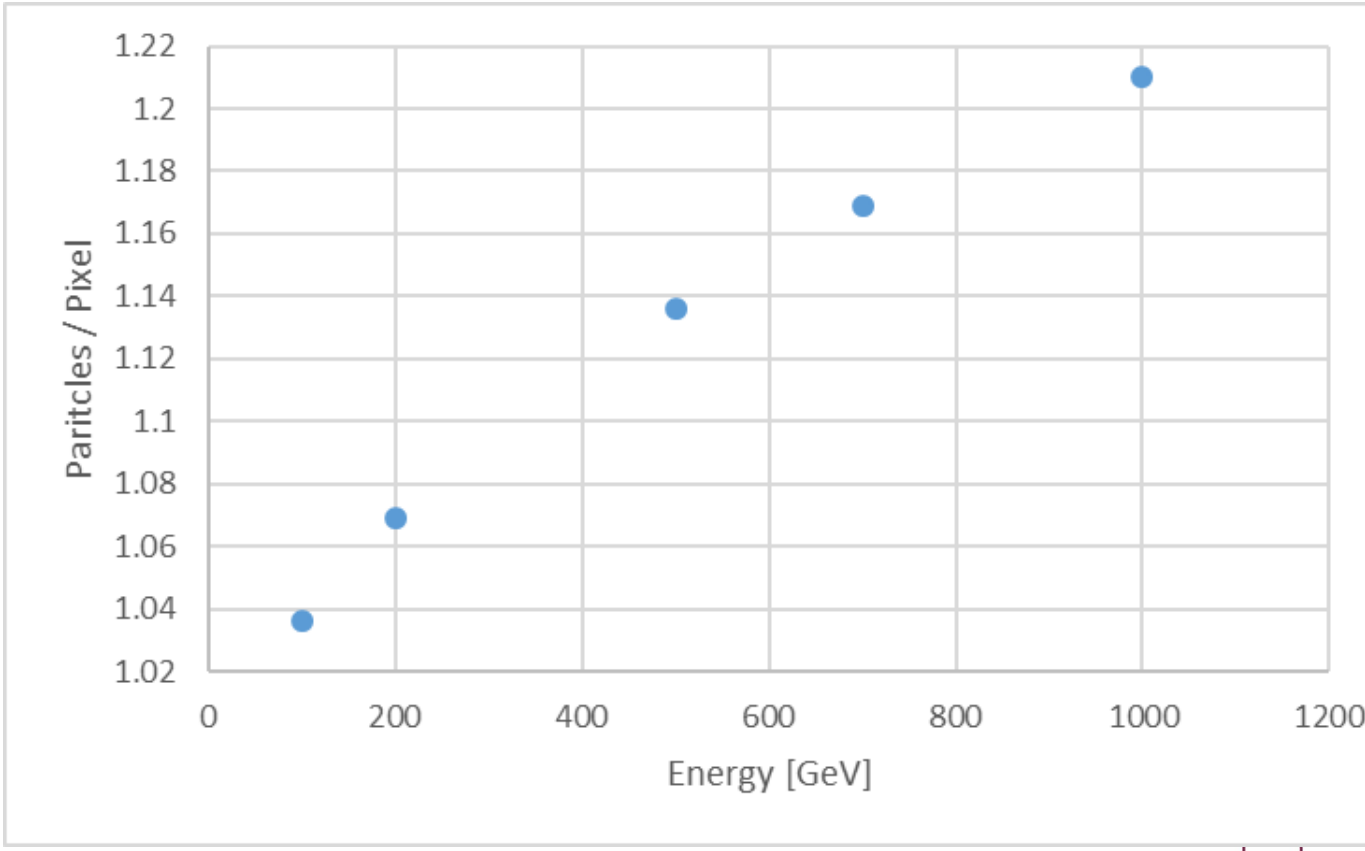

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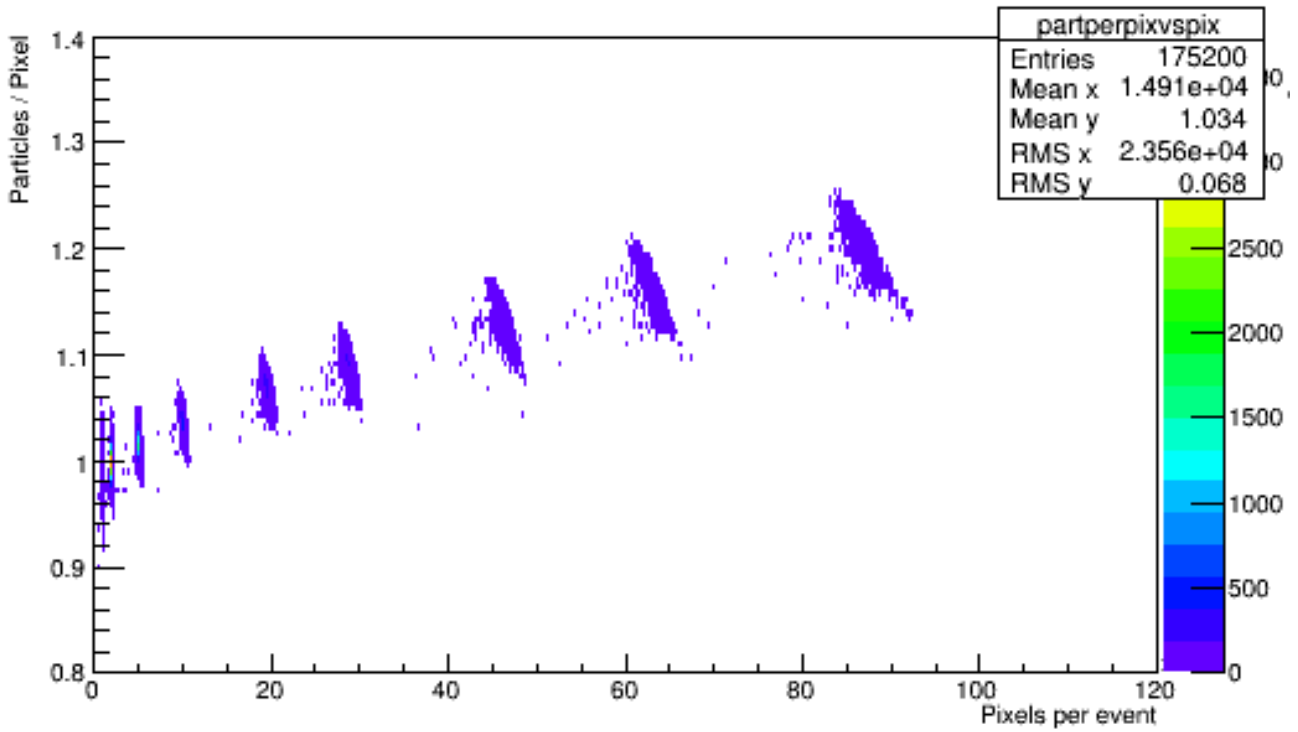
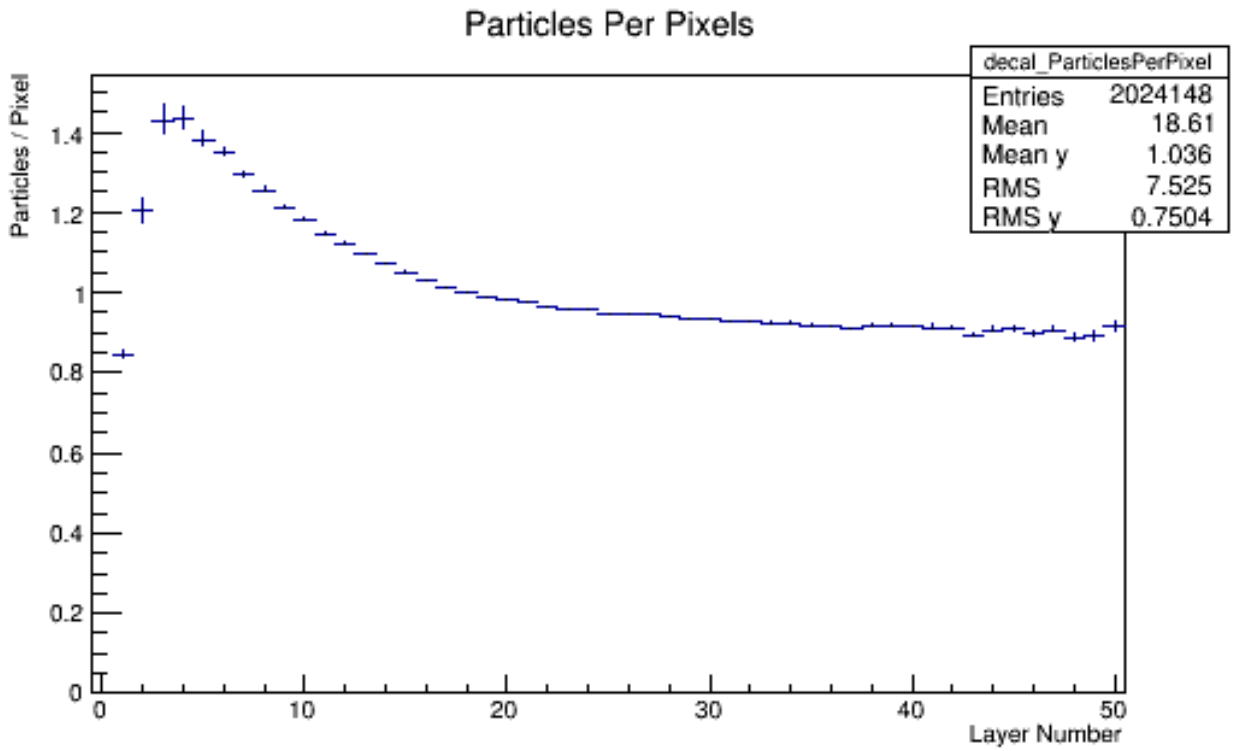
- Scatter of pixels in event vs particles / pixel reinforces the previous point



Where are the particles going

- What if we look for a scale factor to use in each layer?
- Greater particles / pixel in earlier layers due to early showers being very tightly packed
- In earlier layers there are less particles so the effect of multiple particles / pixel is small
- Higher energies, the value in deeper layers becomes very important and we can see the it stays >> 1
- Cannot simply apply a factor in each layer as not linear



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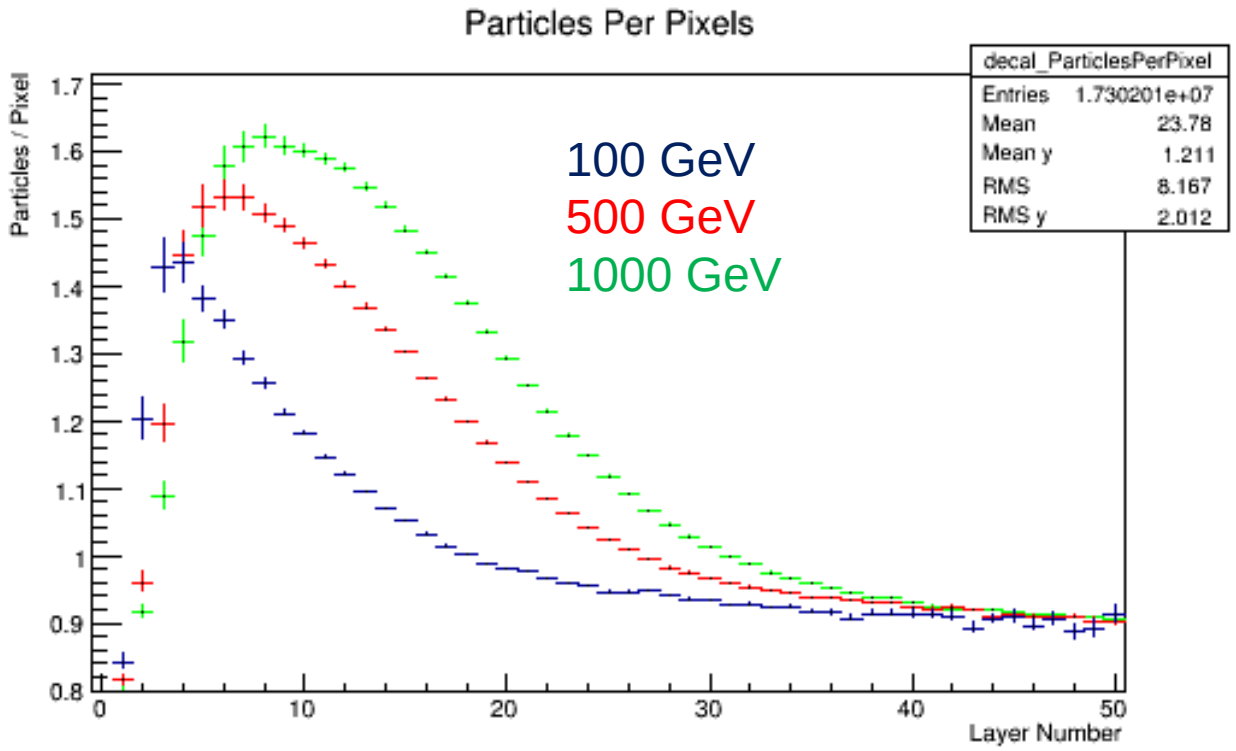

MVA Approach

- It appears that using a single variable is not very feasible to correct the non-linear response at high energies.
- ATLAS and CMS use MVA approaches to improve energy resolution in their ECALs
- Kostas Nikolopolous (UoB) is implementing a BDT which incorporates multiple variables for DECAL response
- Replace log likelihood ratio with a generic function relating to energy resolution to minimise
- https://indico.cern.ch/event/472938/contributions/1150753/attachments/1275329/1891843/calorRegressionMay19-2016.pdf ← CMS talk on the topic
- Work is still in very preliminary stages but incorporates many of the parameters suggested at FCC Week. Hoping to present more next month.

SiW Analogue

- Working with Clement et al to use the implementation of the DECAL to simulation analogue response
- Is possible by making the epi layer 300um (to match ILD SiW) and substrate 0um (to remove it)
- DigitalECalSD sums all deposits in a pixel and then applies a threshold. This method works too for Analogue
- Boolean in the class to pass either number of particles in a pixel or total energy deposited added.
- I will try to push my code to github soon for people to use
- **Initial results suggest ~16%/√E (very similar to ILD results)**
- Clement also suggested moving towards the octagonal shape used by ILD in their new DD4HEP implementation. Potential of new PhD student in Birmingham to work on this for a short while