UNIVERSITY OF BIRMINGHAM | SCHOOL OF PHYSICS AND ASTRONOMY

Energy Resolution of DECAL in the FCC-hh

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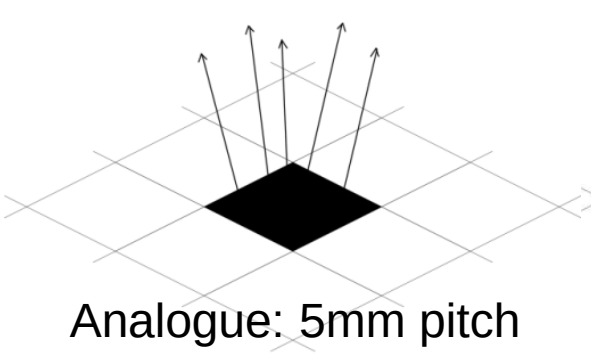
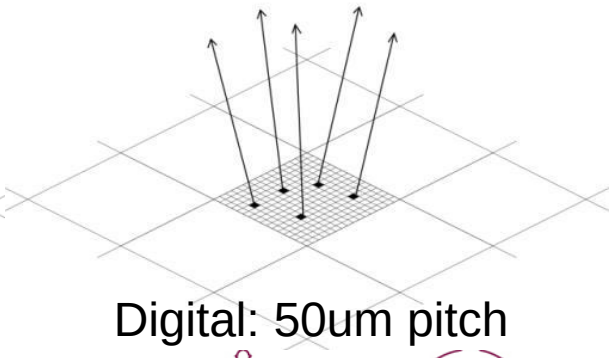
Digital Calorimetry: The Concept

- Dates back to c.2005 work within CALICE
- Make a pixelated calorimeter to count the number of particles in each sampling layer
- Ensure that the particles are small enough to avoid multiple particles passing through a single pixel to avoid undercounting and non-linear response in high particle density environments
- Digital variant of ILD ECAL would require 10^{12} channels, FCC-hh ECAL is similar



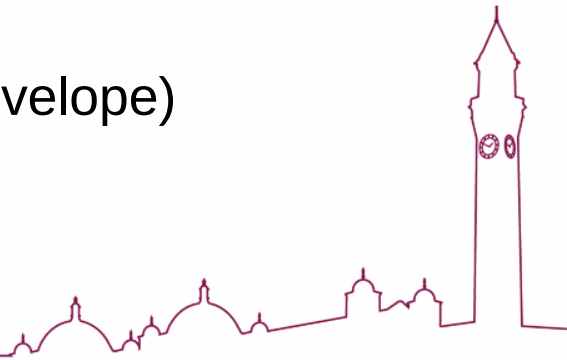
Analogue: 5mm pitch



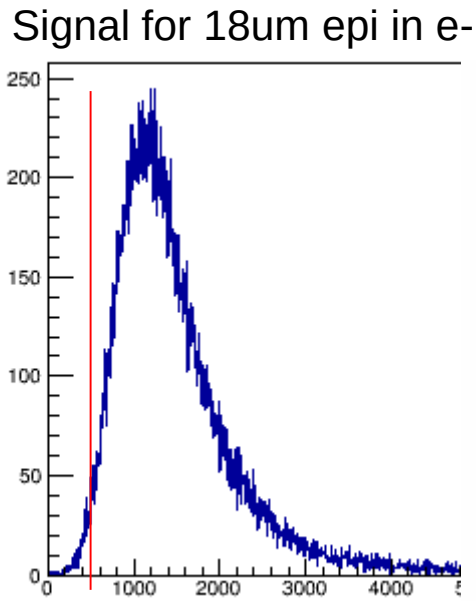
Digital: 50um pitch

DetFCChhECalDigital Geometry

- Modified ECAL barrel inner radius to 1700 mm
- Removed cryostat as not required for SiW calorimeter
- Access gap of 100mm so inner R = 18000 mm
- Modified geometry such that there are four repeated volumes per module
  - 25 um epitaxial (sensitive)
  - Silicon substrate
  - Tungsten
  - Air gap
- All configurable from xml files
- Currently ECAL is just 130mm deep (excluding envelope)



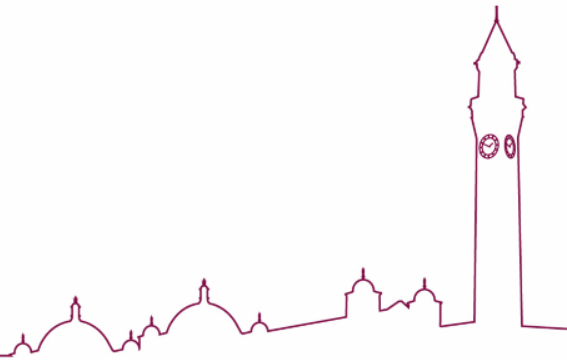
DetFCChhECalDigital Readout



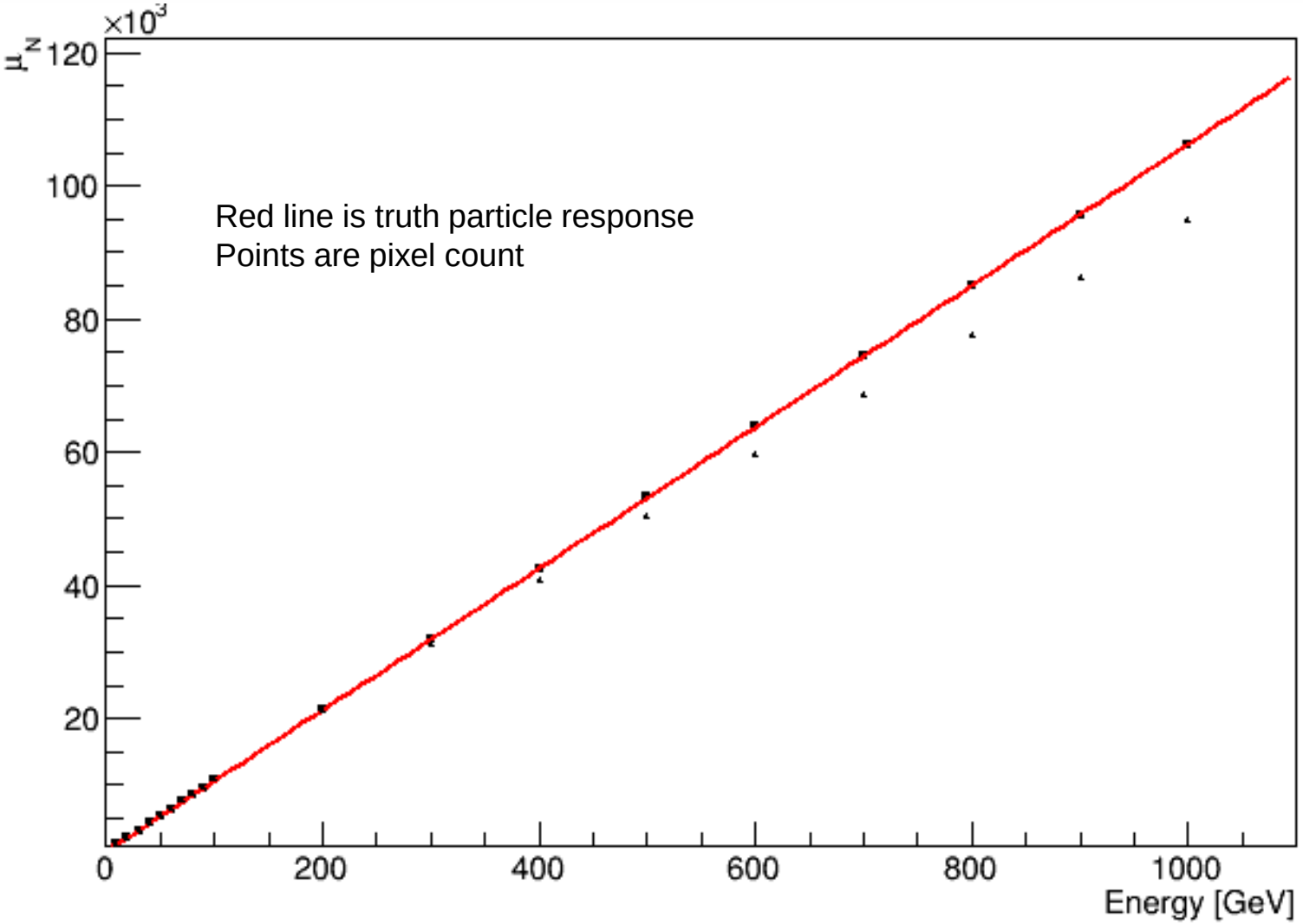
- Sum all the energy deposited in a cell
- Apply a threshold of 480 e- (6*noise of designed CMOS)
- Currently score
  - Number of pixels above threshold
  - Number of particle per pixel (for pile-up non linearity studies)
- Since the last meeting the hits remaining in the collection are stored in EDM format
- Thanks to Jana (and others on the SW team) I have replicated my simple python analysis to use EDM readout objects

Samples

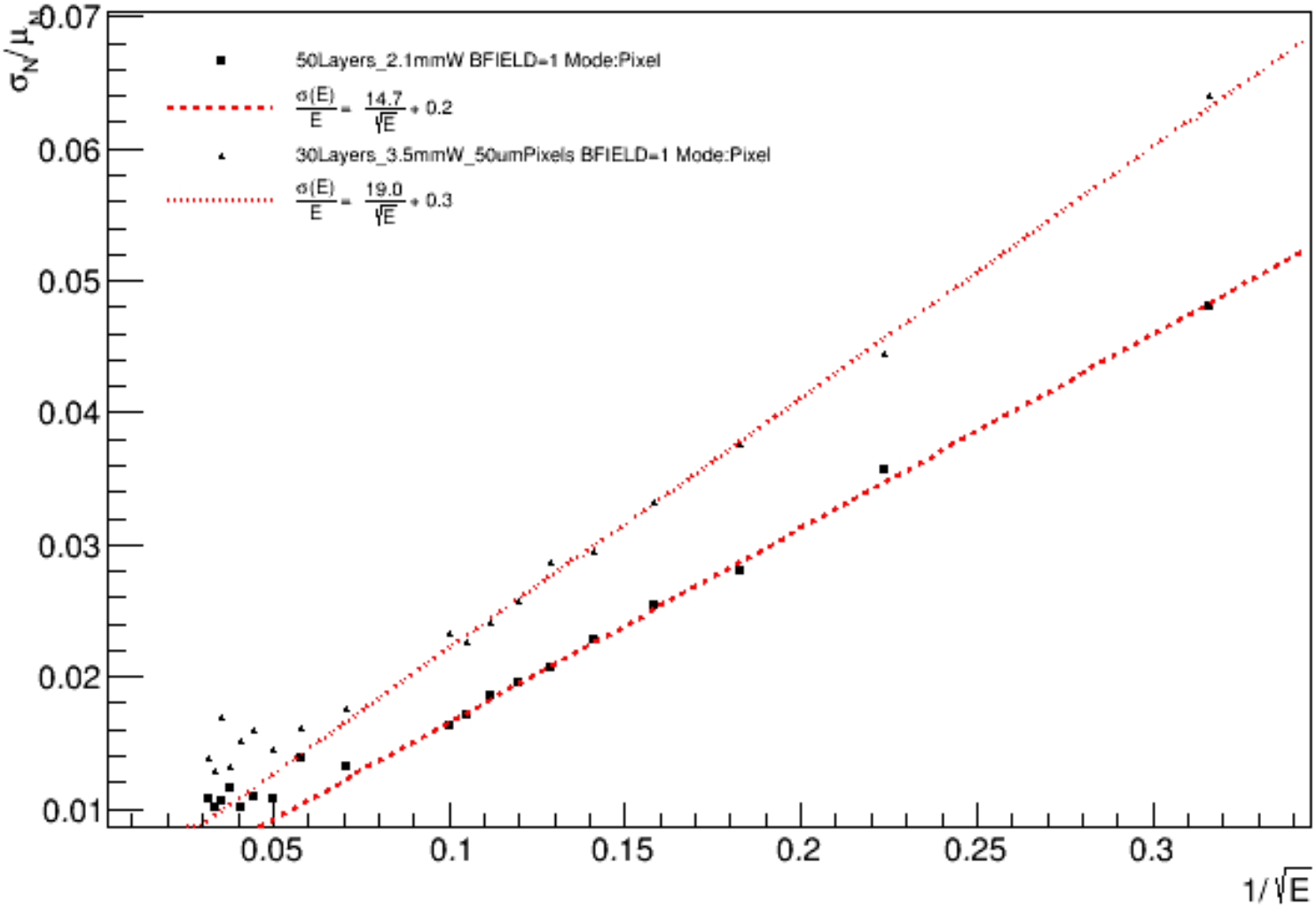
- Single electron samples of energy 10-1000 GeV
- Barrel restricted to +/- 1m in Z due to limitations in number of cellIDs (need to optimise what I am doing)
- Uniform in theta
- Restricted to eta < 0.1
- All ECAL has 30 radiation lengths of W. Assuming for now the Si does not contribute



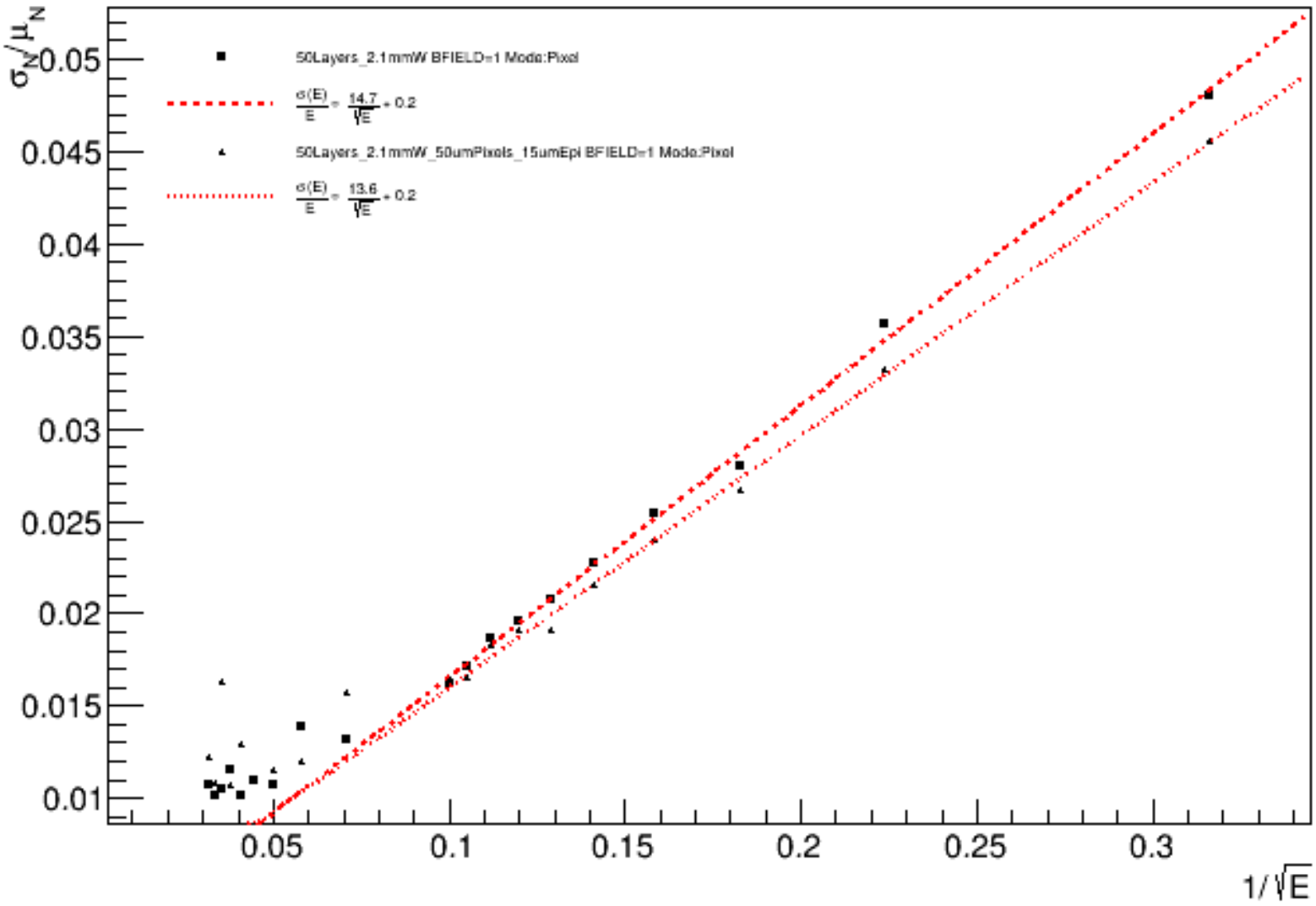
Linearity


×10³
μ_N
120
100
80
60
40
20
0
200
400
600
800
1000
Energy [GeV]
Red line is truth particle response
Points are pixel count

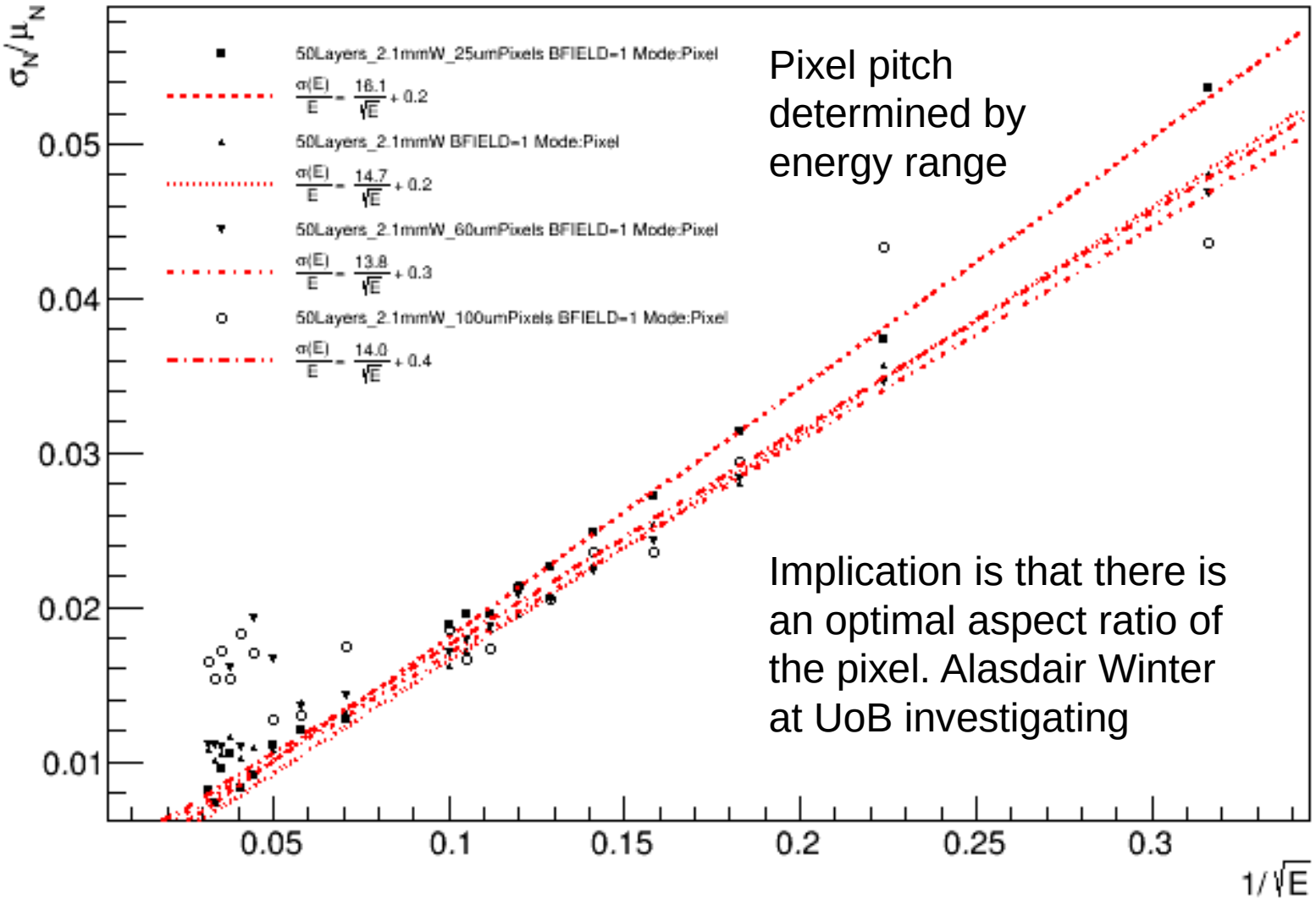
Impact of Sampling Fraction



Impact of Epitaxial thickness



Impact of Pixel Pitch

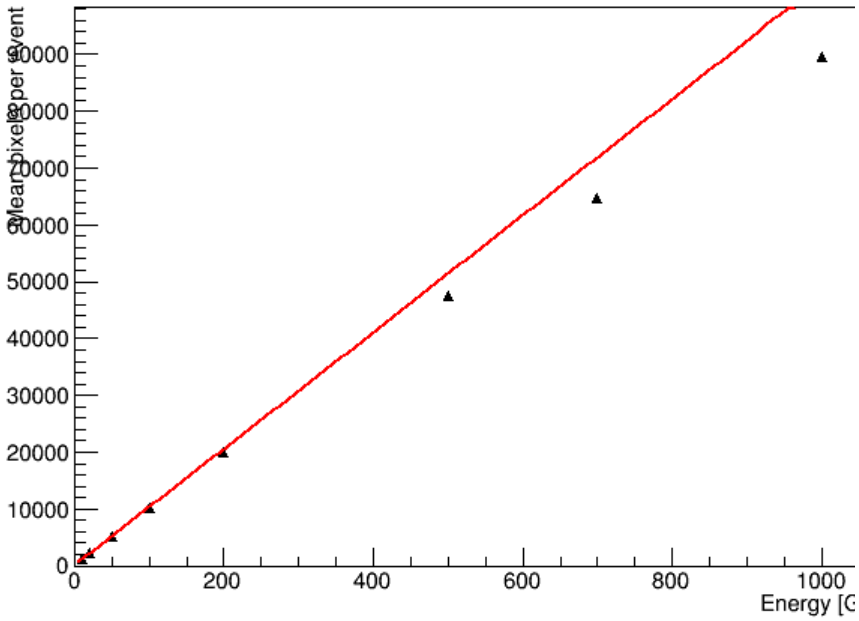


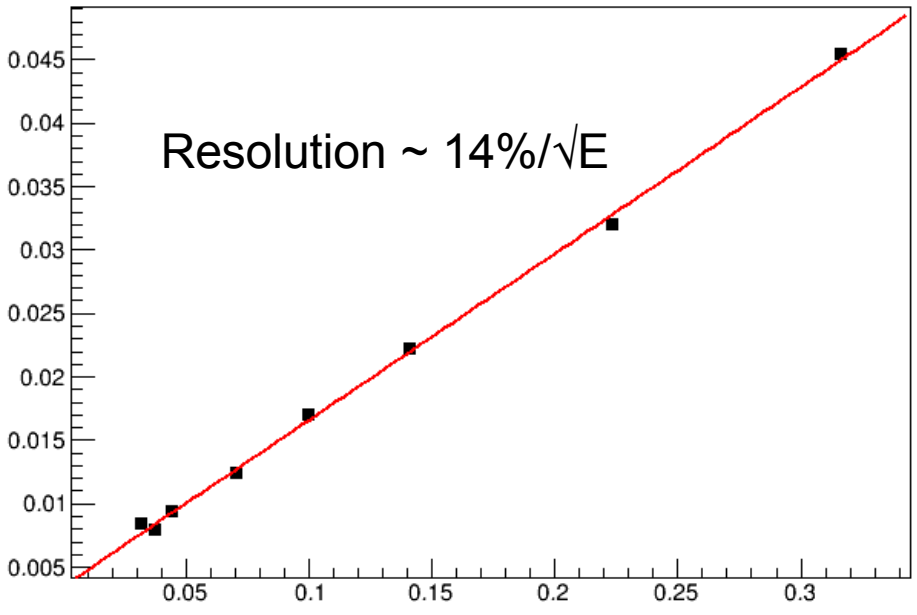
Pixel pitch determined by energy range

Implication is that there is an optimal aspect ratio of the pixel. Alasdair Winter at UoB investigating

EDM Analysis

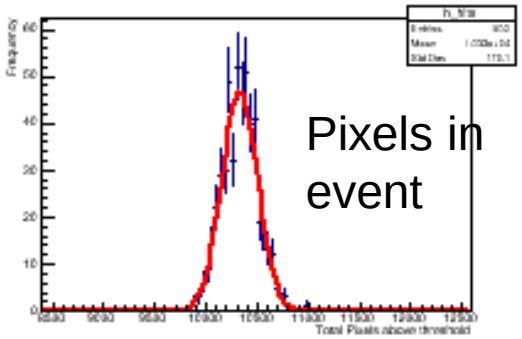
- Up to now all plots have been made by just printing number of pixels to terminal and analysing log files with python
- Now, I have readout using EDM which I can analyse
- This will allow us to look into other properties of the shower to investigate whether we can improve performance at higher energies



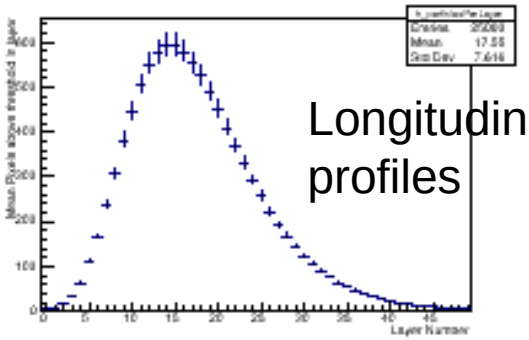


Parameters under investigation

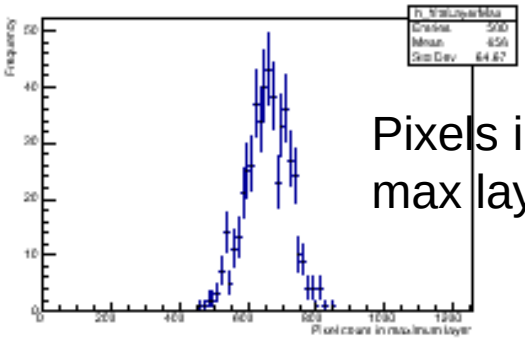
100 GeV



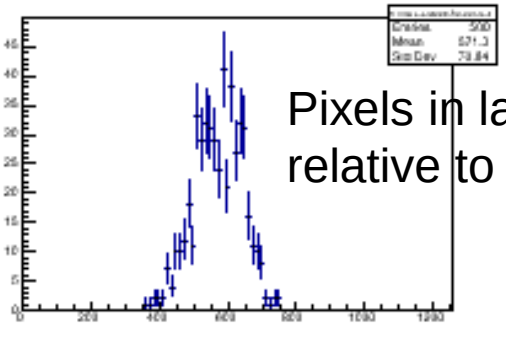
Pixels in event



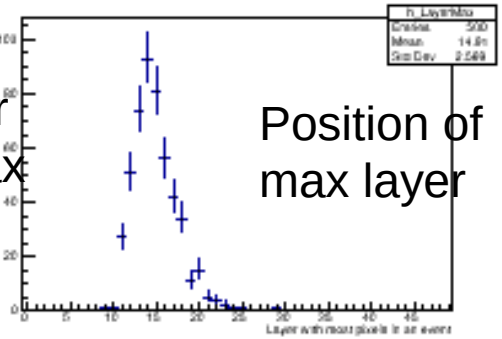
Longitudinal profiles



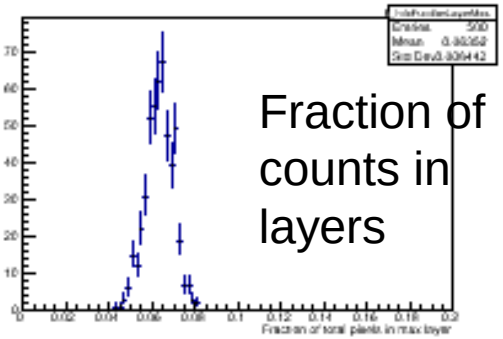
Pixels in max layer



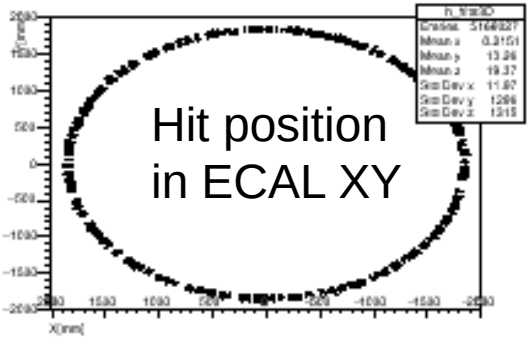
Pixels in layer relative to max



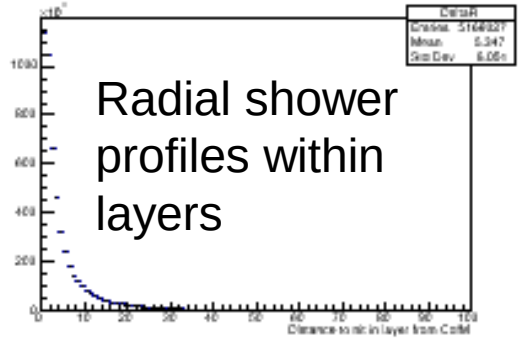
Position of max layer



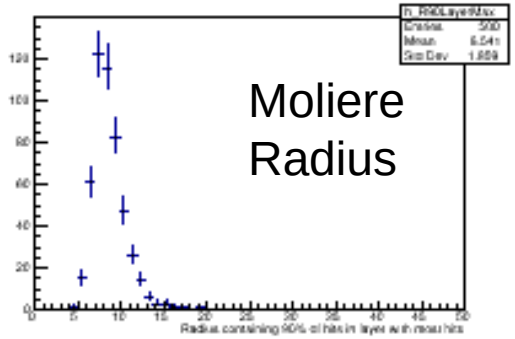
Fraction of counts in layers



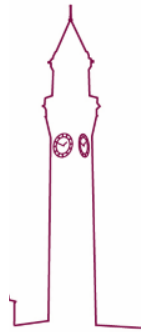
Hit position in ECAL XY



Radial shower profiles within layers

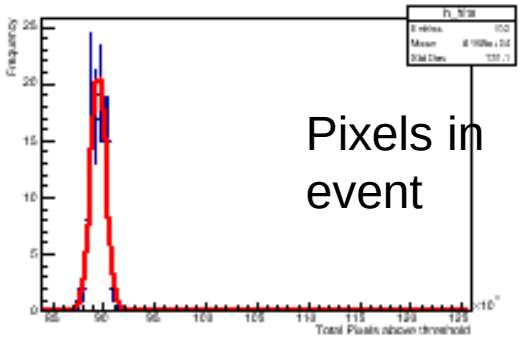


Moliere Radius

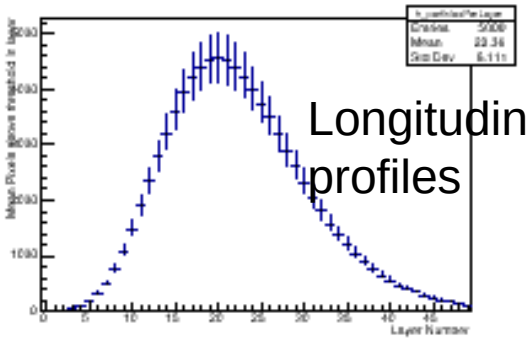


Parameters under investigation

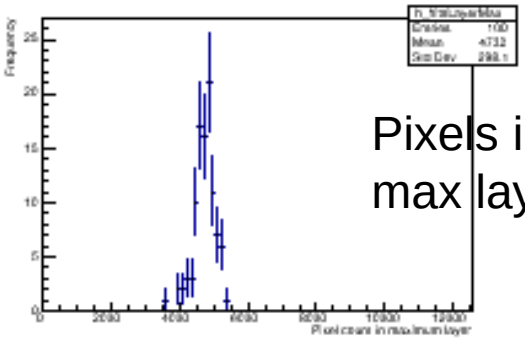
1000 GeV



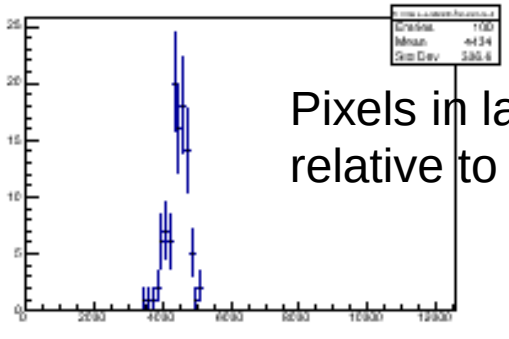
Pixels in event



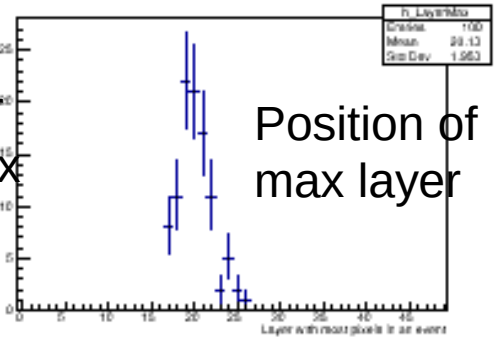
Longitudinal profiles



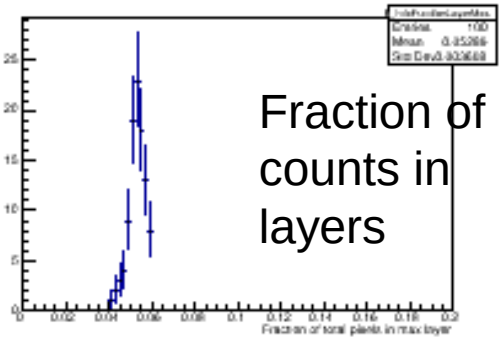
Pixels in max layer



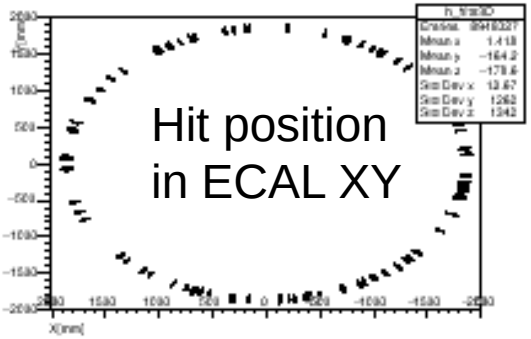
Pixels in layer relative to max



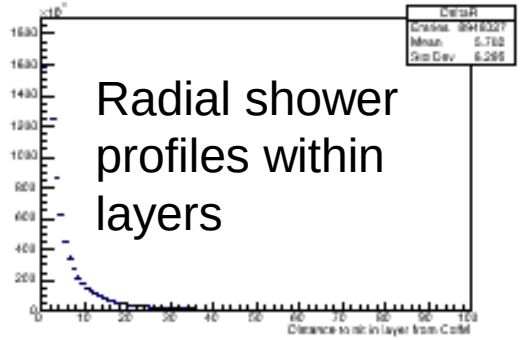
Position of max layer



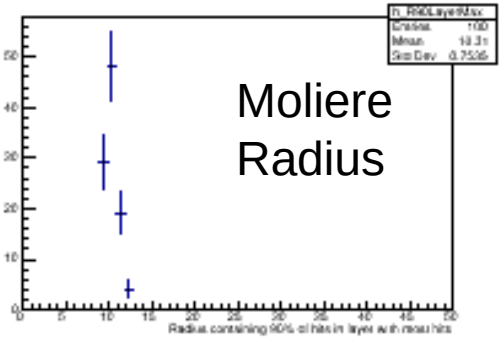
Fraction of counts in layers



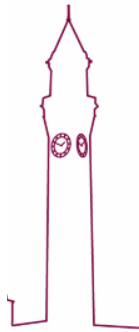
Hit position in ECAL XY



Radial shower profiles within layers

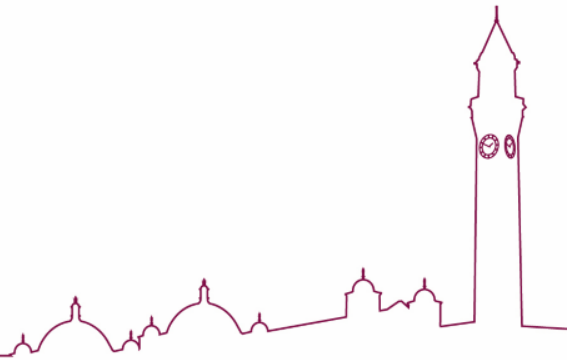


Moliere Radius



Prototype Sensor

- As part of current grant we are also developing a reconfigurable CMOS MAPS for use in DECAL
- Counting will happen by column then row readout
- Lends itself to a readout mode with column readout as a strip
  - Could be used in the outer tracking layers?
- Results from these simulations are influencing design choices



Conclusions

- Simulation still underdevelopment but progressing well
- Single particle resolution ~14% achievable for 50 layers (2.1mm W), 19% for 30 layers (3.5mm W)
- An ECAL of just 130mm would allow smaller detector overall
- Aspect ratio of pixel will have an impact so investigating
- Readout and analysis with EDM now possible and simulation more flexible
- Investigating ways to improve performance at higher energy
- Possibility of SiW pre-shower (before cryostat) with LAr ECAL?
- Evaluating the impact of pile-up under discussion with Joshcka and Valentin
- Results from FCCSW used to impact design choices of prototype sensor