Improving realism of ILD ECAL simulation and digitisation

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Two options for the ECAL of ILD

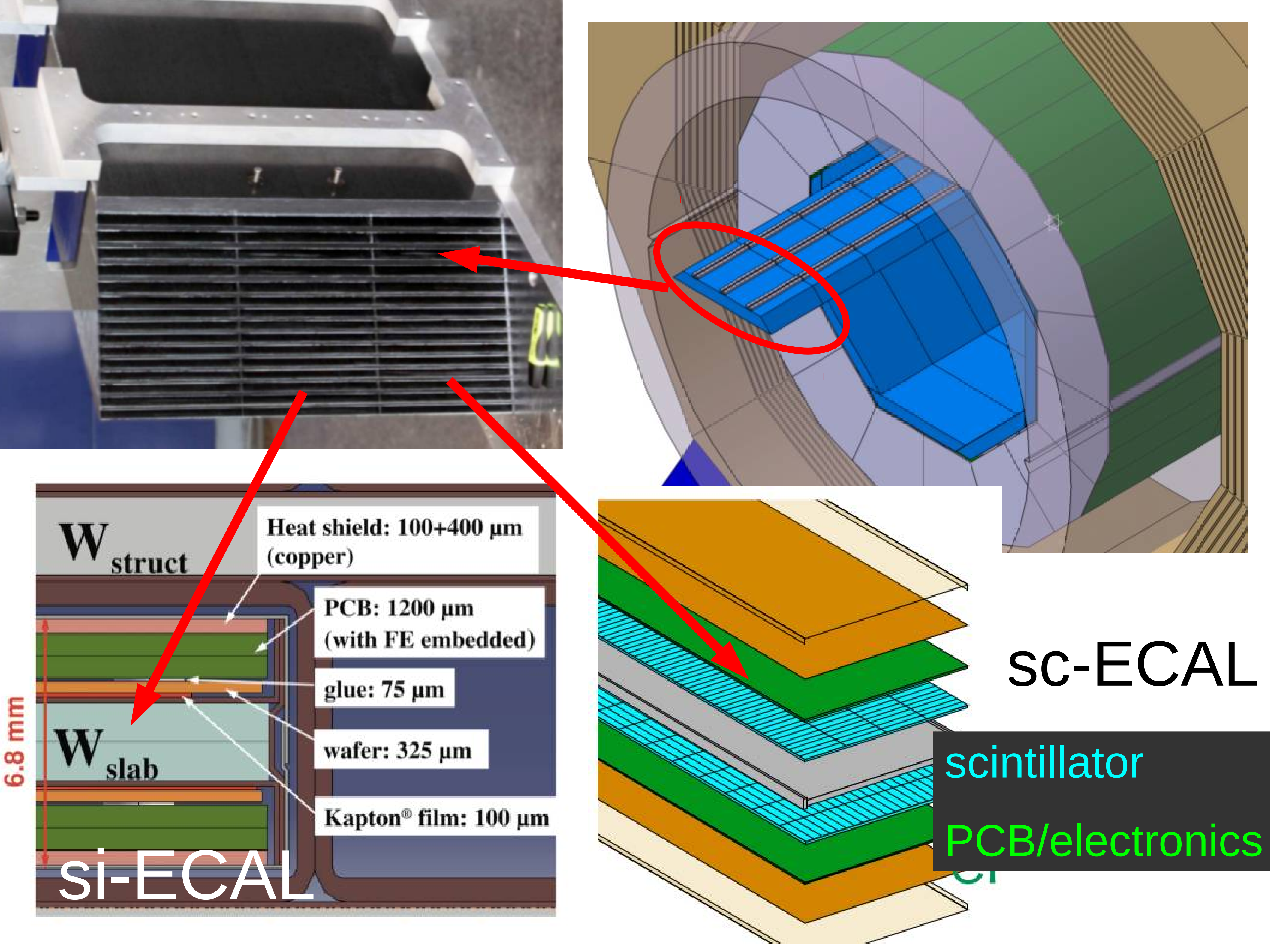
- silicon sensors
- scintillator strips + MPPC

~ same mechanical structure

We (ILD ECAL groups) have been discussing how to ensure that
different ECAL options are simulated with a
sufficient and **similar** level of realism

-> more confidence in
Predictions of performance
Comparisons between technologies

Idea of this talk is NOT to perform optimisation of # layers, technologies, radius, cell size, ...
but to ensure that these studies can be performed using
simulations with a good, and comparable, level of realism



W struct
Heat shield: 100+400 μm (copper)
PCB: 1200 μm (with FE embedded)
glue: 75 μm
W slab
wafer: 325 μm
Kapton® film: 100 μm
6.8 mm
si-ECAL
sc-ECAL
scintillator
PCB/electronics

Modeling of ECAL in ILD is quite realistic

Mechanical structures
Dead zones
Services

now is a good time to revisit some key parameters
comparing to reasonable extrapolation from today's prototypes

Digitisation of ECAL hits is rather (too) simplistic

Energy deposit in scintillator / silicon
Reject hits with energy < 0.5 MIP

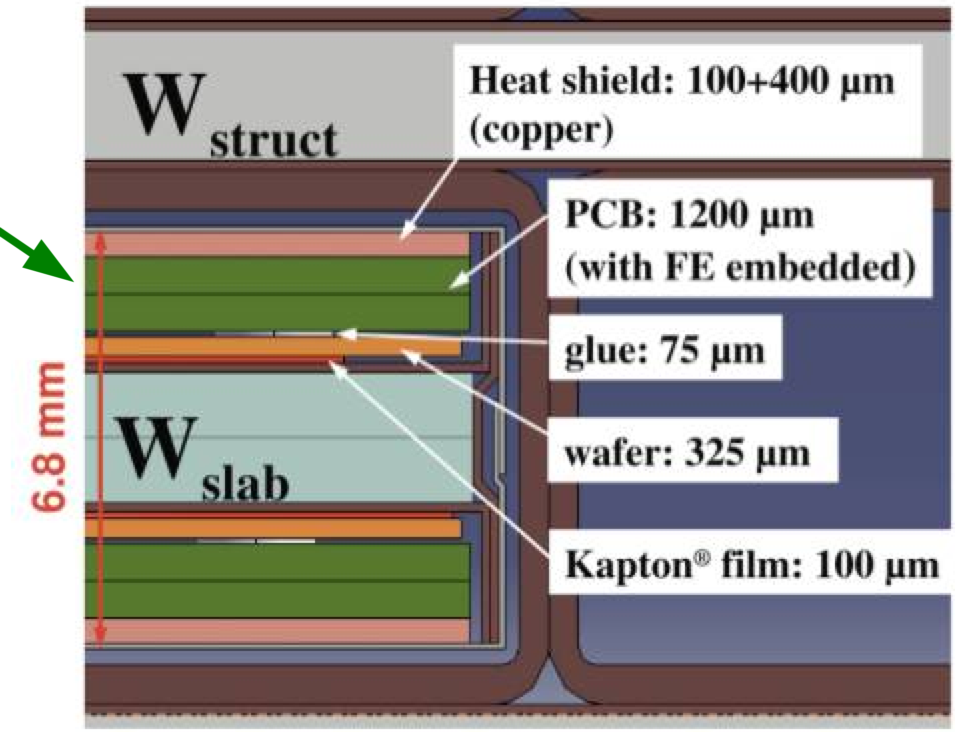
Simulation: Mokka parameters

In DBD simulation, this PCB is taken to be 0.8mm thick

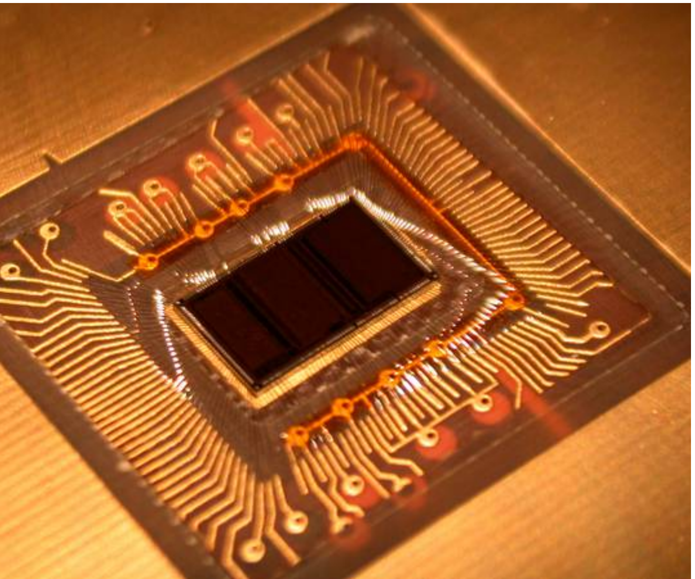
We now recognise that this is technically very challenging

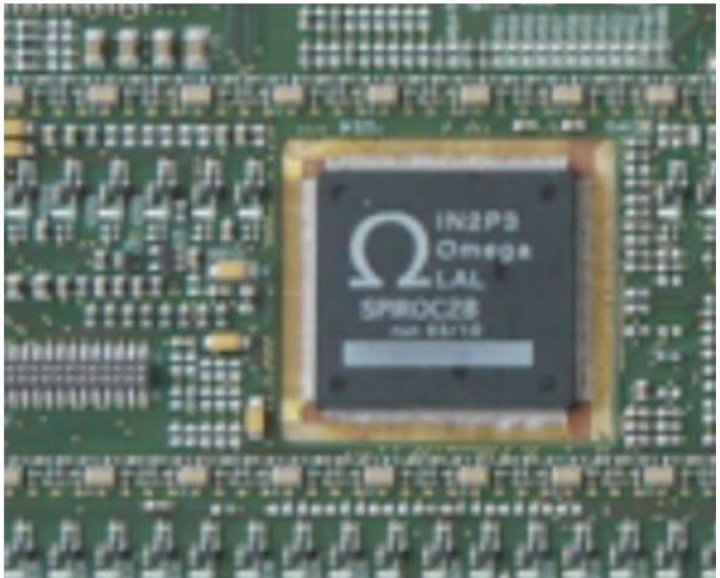
Based on today's technologies, and depending on who you talk to, we expect that PCB will be in the range
~ 1.2 -> 2.8 mm thick
(we may be able to agree on a single thickness for general ILD simulations)

Increasing thickness affects effective Moliere radius



(depends on the ASIC packaging and flatness requirement)





Other important parameters:

Silicon thickness should be reduced
500 -> 320 microns (preferred thickness for Hamamatsu)

Width of dead zone at edge of sensor (guard ring)
maintained at 0.5 mm

Scintillator thickness reduced
2 -> 1 mm (current ScECAL design)

Dead zone at surface of strip (reflector film)
maintained at ~60 microns

Digitisation

Until now:

Hit energy = energy deposited in cell
0.5 MIP threshold is applied to each cell

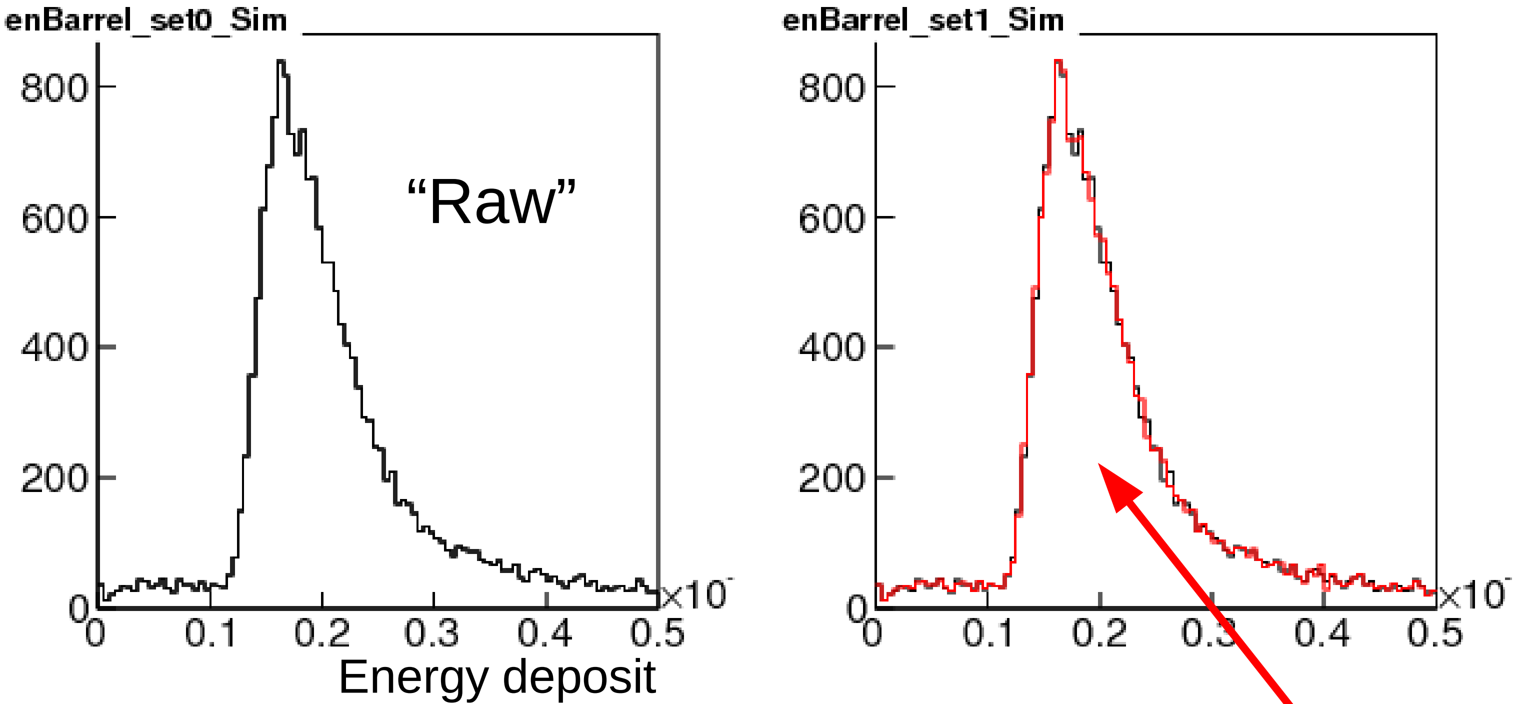
I have been developing framework to apply more realistic digitisation,

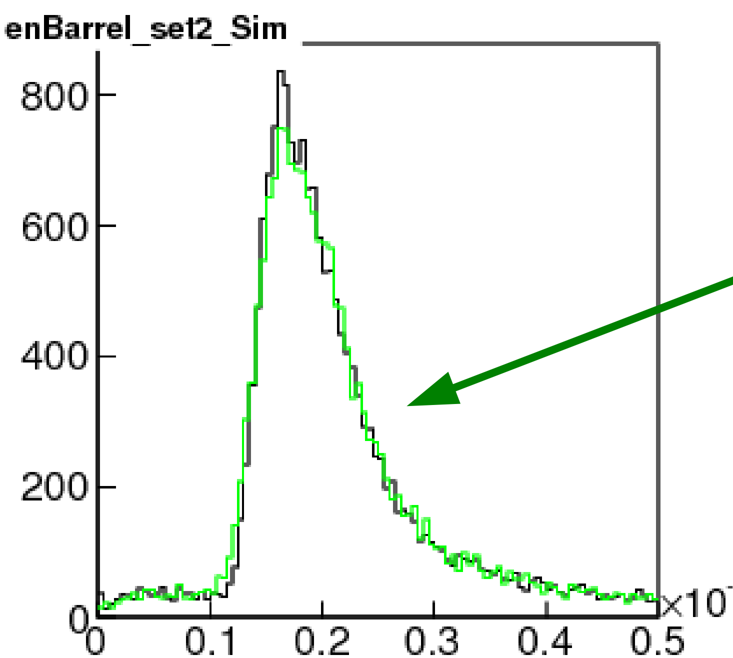
intrinsic detector characteristics
(uncorrelated) electronics noise
dynamic range of electronics

In the next few slides I show the effect of
taking these factors into account

The parameters I have used are close to my “best guess”,
but are not agreed among us, and are therefore “illustrative”

10 GeV muons: energy of hits in si-ECAL barrel





Take account of:

- finite # of e-h pairs in silicon
- electronics noise (1/15)*MIP

Rather small effects:

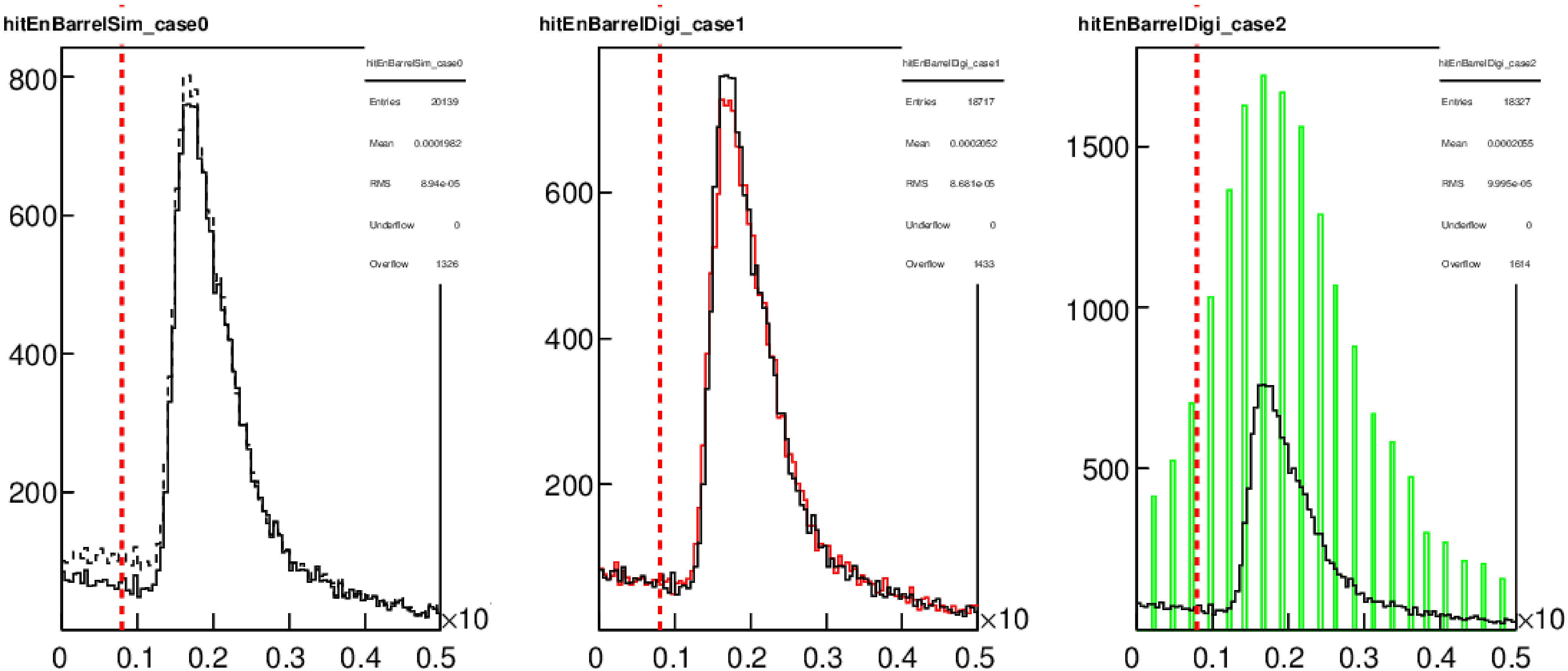
OK to ignore

Scintillator + SiPM/MPPC modeling

Naive model:

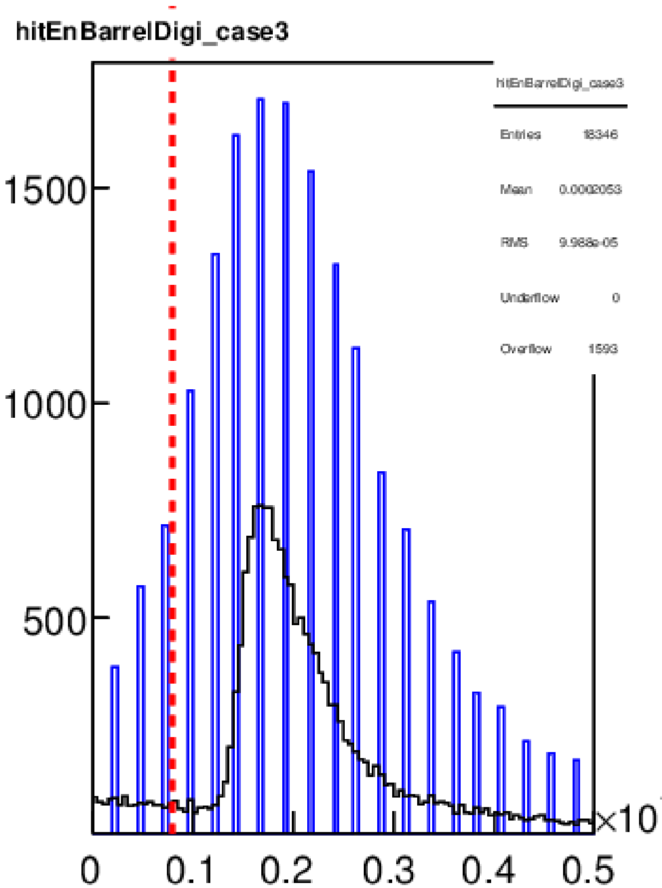
- Non-uniformity of response along scintillator strip
  - Simplified exponential dependence
- Finite number of photo-electrons created in MPPC
  - Causes additional fluctuations at low signal levels
- Finite number of pixels in MPPC
  - Causes saturation at high signal levels

10 GeV muons: hits in sc-ECAL barrel

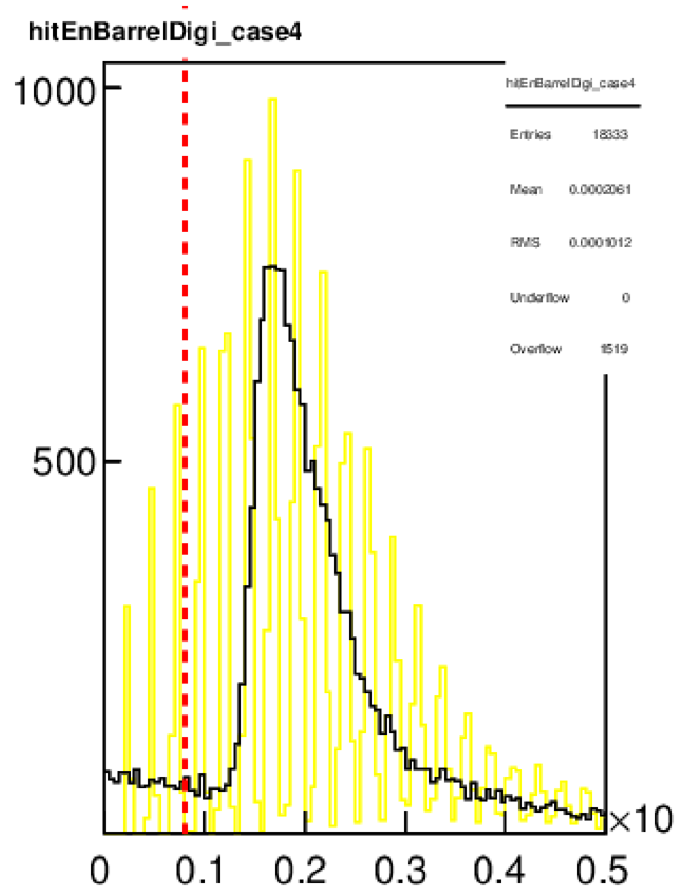


energy deposit | strip non-uniformity | finite # photo-electrons

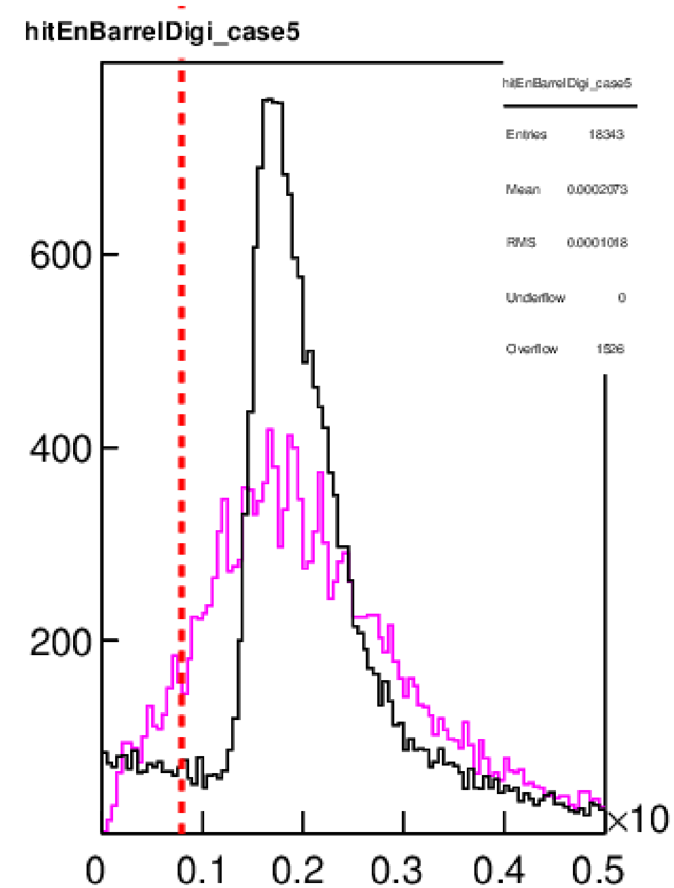
10 GeV muons: hits in sc-ECAL barrel



finite # pixels



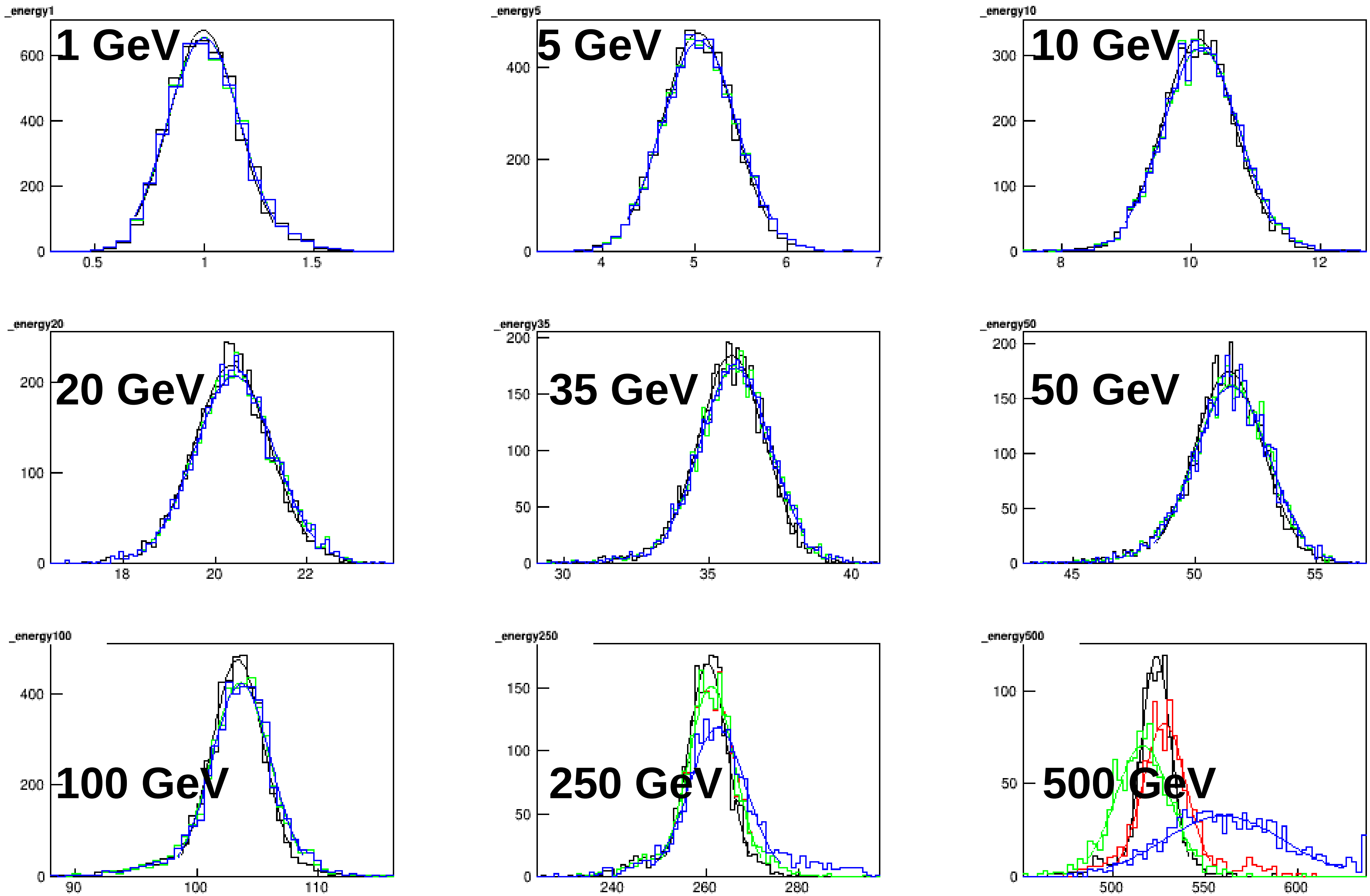
pixel-to-pixel nonuniformity



electronics noise

Low energy hits (~ 1 MIP) significantly smeared
some loss of efficiency @ 0.5 MIP threshold

Single (unconverted) photons in ScECAL: sum of PFO energies



“raw”; realistic: 10k pixel , 10k pixel + electronics dynamic range , 5k pixel

Effects become visible ~ 100 GeV

Discussions in progress on whether
simple MPPC model is sufficient
or if measured performance should be used

Such a simple model does not accurately describe
additional effects (cross-talk, after-pulsing, pixel recovery)

Will try to measure of average MPPC response and its fluctuations
If this is not feasible on a short timescale,
may use the simplistic model in the interim

Summary

Improvements to realism of simulation and digitisation
give simulation models closer to today's prototypes

More realistic digitisation of
- silicon: has rather small effects
- sintillator: introduces some effects, especially for small or large signals.

I have implemented these effects in a (private) version of ILDCaloDigi processor

Next steps

Reach agreement among ECAL groups on “reasonable” parameters

based on experience of CALICE prototypes

release new digitisation code and recommended parameters to ILD

Continue discussion with AHCAL group

In ~mid-term, possibility for common scintillator/SiPM treatment backup

- energy deposit in scintillator E

Landau fluctuation (MPV for min. ion. part = E_mip)
dealt with by Geant4

- conversion to photons

assume (average # photons)/(MIP energy) = n
Fluctuate by **Poisson** statistics

n_gamma = (E/E_mip)*n
d(n_gamma)/n_gamma = 1/sqrt(n_gamma)

- creation of p.e.

Assume each photon has a fixed probability p of creating a p.e.
Fluctuate by **binomial** statistics

n_pe = p*n_gamma
d(n_pe)/n_pe = sqrt(n_gamma * p * (1-p)) ⊕ d(n_gamma)/n_gamma

- firing of pixels

Fluctuate to take account of possibility of >1 p.e. / pixel
Depends on #pixels in device m ; let a = n_pe/m

n_firedpixel = n_pe * (1 – exp (- a))
d(n_firedpixel)/n_firedpixel =
sqrt(m exp (- a) (1 – (1+a) e(-a))) ⊕ d(n_pe)/n_pe

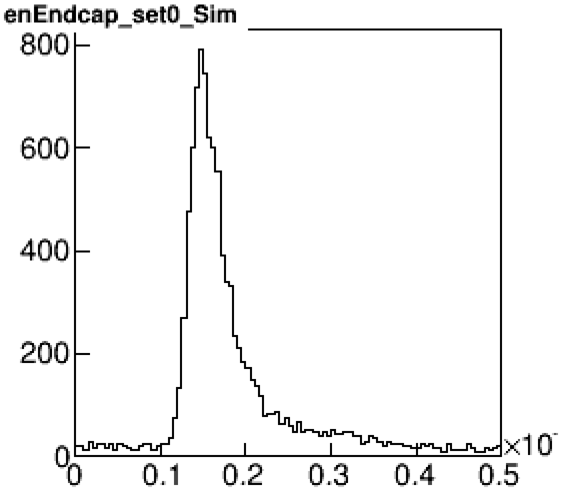
Virtual cells along Sc strip ("Ecal_Sc_number_of_virtual_cells"): 9

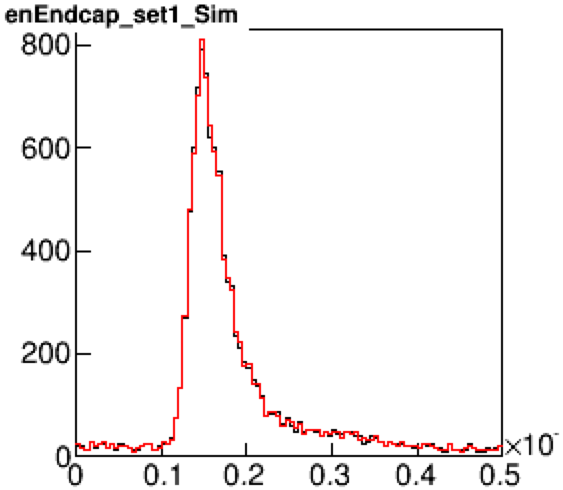
allows implementation of non-uniformity along strip

Mokka sums energy deposited in each virtual cell
re-combined in the digitisation stage,
with (optionally) different weights to
approximate exponential response

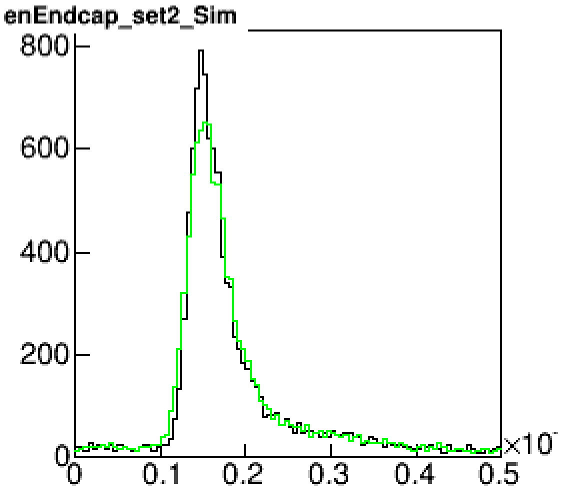
Parameters I used for plots.
Not “official” or “recommended” parameters

Silicon:	25k e-h pairs / MIP electronics noise = 7% of MIP
Scintillator:	7 p.e. / MIP 10k pixels electronics noise = 5% of MIP absorption length along strip = 200 mm variation in number of pixels = 5% variation in single pixel signal = 5%

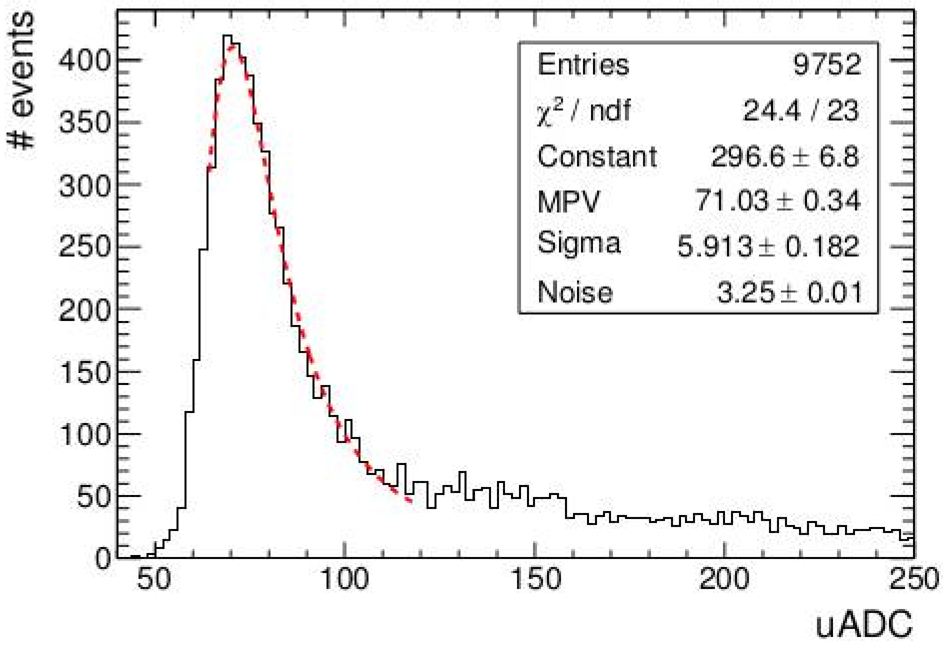




10 gev muon simulation
(corrected for path length in silicon)



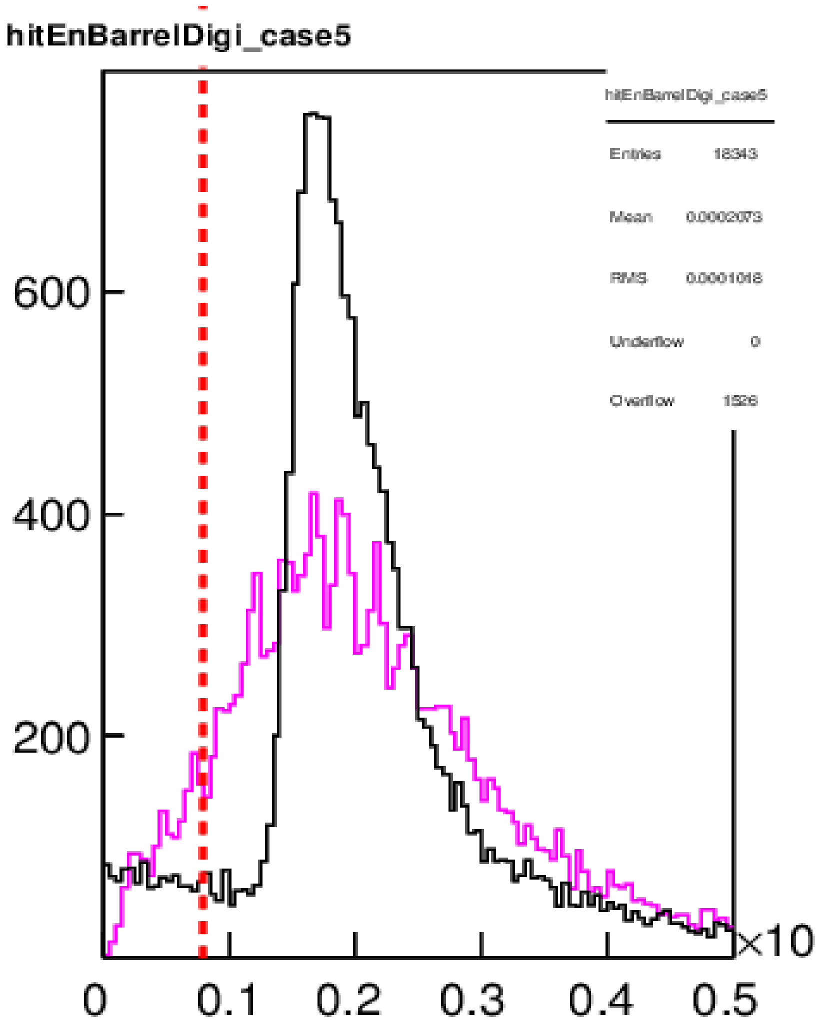
3 GeV electrons (testbeam data),
normal incidence



SiECAL:

ILD simulation vs. Test beam data

10 gev muon simulation
(barrel)



Test beam (normal incidence)
(electrons ~3 GeV)