Proposal for more realistic ILD ECAL simulations

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+ many others

At present, ILD ECAL simulation models have a number of
"aggressive" and/or "historical" parameters
probably unfeasible if we write TDR in a few years.

The digitisation of ECAL hits is very simplistic
reject hits with an energy < 0.5 MIP

To make more reliable estimates of performance,
and fairer comparisons between different options,

silicon & scintillator ECAL groups have agreed to
define more realistic simulation/digitisation procedures,
and then to recommend them for use in ILD simulation/reconstruction

Aim is to ensure reasonable technical realism of simulation models
guided by experience of “technological prototypes”

not to optimise the large-scale parameters (radius, # layers, ...)
for performance or cost

these realistic simulations should later be used to
perform such large-scale optimisations

Recommended changes to Mokka simulation parameters

thickness of PCB+components (“Ecal_Slab_(Sc_)PCB_thickness”)

DBD:	0.8 mm
“realistic” Sc-ECAL:	1.6 mm
“realistic” Si-ECAL (integrated ASIC):	1.2 mm
“realistic” Si-ECAL (packaged ASIC):	2.8 mm

(“realistic” means “only-slightly-better-than-today”)

This change can have, for example,
an effect on the ECAL's effective Moliere radius

Silicon thickness: reduce from 0.5 mm to 0.32 mm (most cost-effective thickness for HPK)
reduces sampling ratio
Sensor guard ring width kept at 0.5 mm (insensitive area)

Scintillator thickness: reduce from 2 mm to 1 mm (current design from Shinshu group)
reduces sampling ratio
Reflector foil thickness kept at 0.057 mm

These changes give ECALs much closer to today's prototypes/designs

<u>Virtual cells</u> 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

Digitisation

In DBD used energy deposit in silicon / scintillator, without additional effects

Proposal:

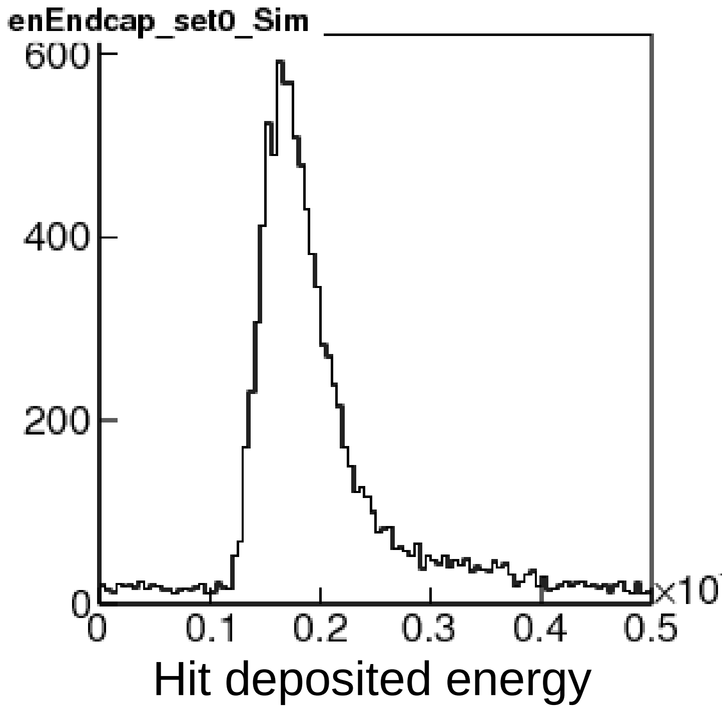
Implement (relatively simple but) more realistic digitisation
parameterised models

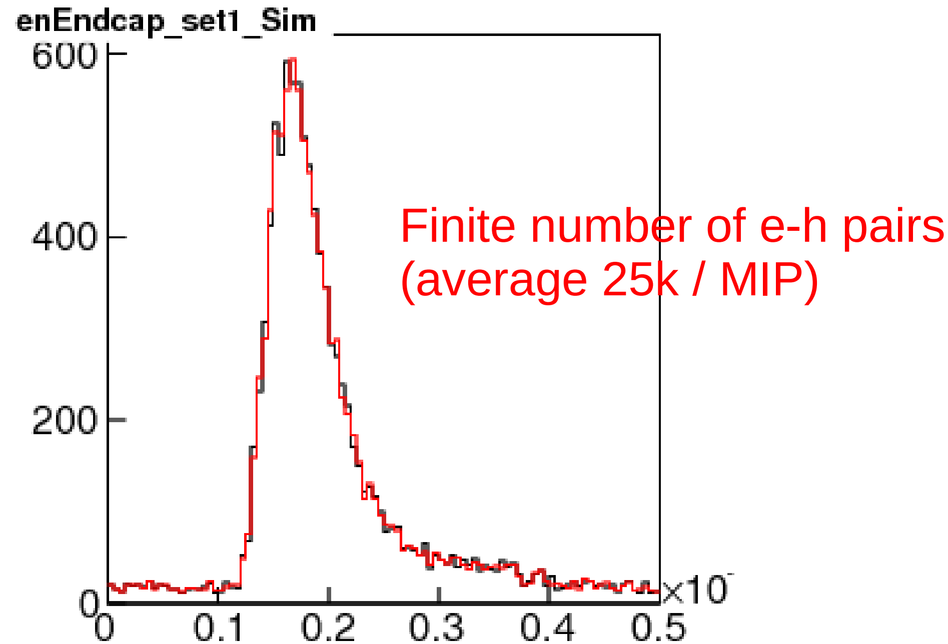
Silicon
- fluctuation in # electron-hole pairs
- uncorrelated electronics noise

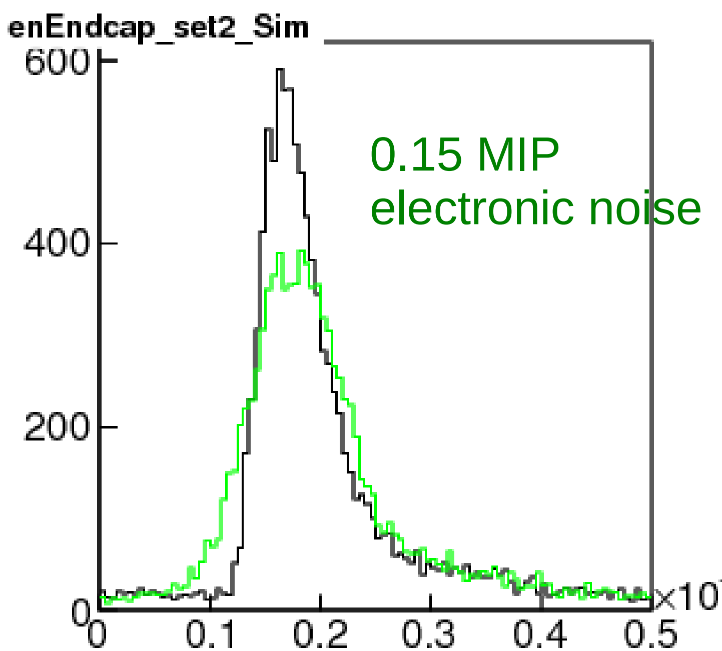
Scintillator
- scintillator non-uniformity
- photo-electron statistics
- MPPC response
- uncorrelated electronics noise

For both, implement ability to
turn off random channels
random miscalibration

In the next few slides, I show what effect this digitisation procedure has
on hit energies in single 10 GeV muon events
using some maybe reasonable (not recommended) parameters







<u>silicon-ECAL</u>

ECAL hits in 10 GeV muon events

Sc-ECAL

Convert energy to expected # p-e
Smear #p-e using Poisson statistics

Apply saturation and statistics of MPPC:
 See arXiv:0706.0746 for details

Unfold average MPPC saturation response

Allow for random (Gaussian) fluctuations in
 Energy -> #pe conversion
 MPPC per-pixel charge
 Knowledge of MPPC pixel number

This is parametrised model of scintillator MPPC response
 I can guess some reasonable parameters,
 but I think they should be chosen by ScECAL group

“representative” (not “official”, not “recommended”) set of parameters:

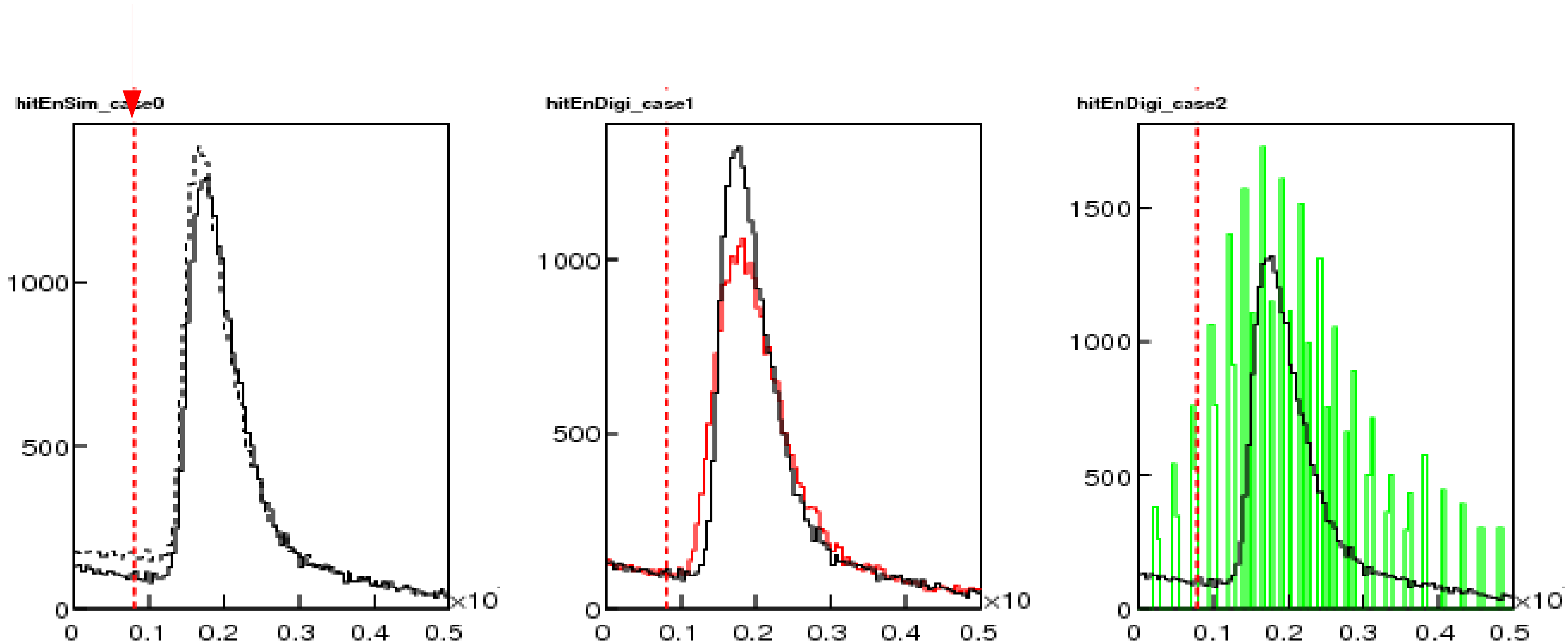
- Absorption length along strip: 100mm
- 7 photo-electrons / MIP
- 5000 MPPC pixels
- 5% spread in single pixel response
- 0.2 MIP electronics noise
- 5% uncertainty of effective pixel number

30-layer ScECAL with 1mm thick scintillator strips (45x5 mm^2), segmented into 9 “virtual” cells

Mokka sums energy deposited in each virtual cell
Combined in the digitisation stage,
with different weights to
fake ~exponential response

ScECAL hit energies in uniformly distributed 10 GeV muon events

0.5MIP threshold

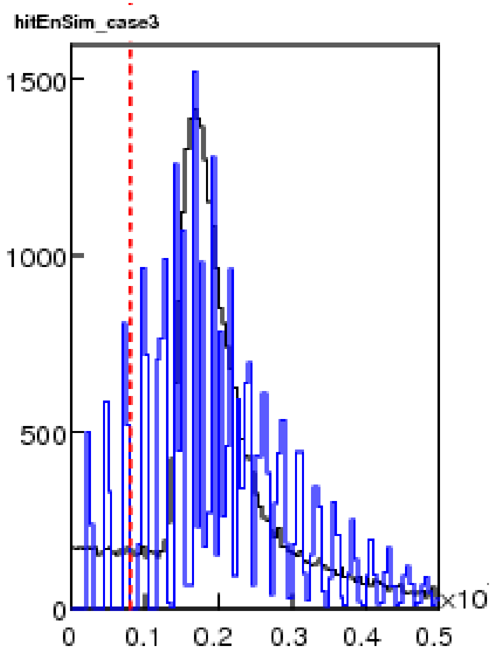


Deposited hit energy
(before calibration to EM)

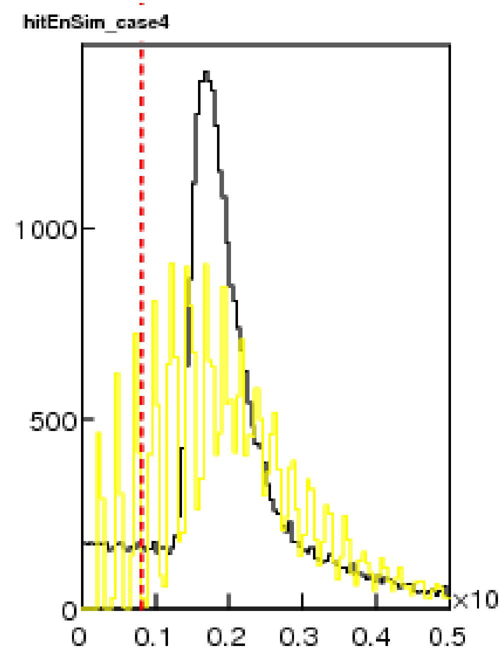
dashed: virtual cells
continuous: combined cells

100mm absorption length along strip

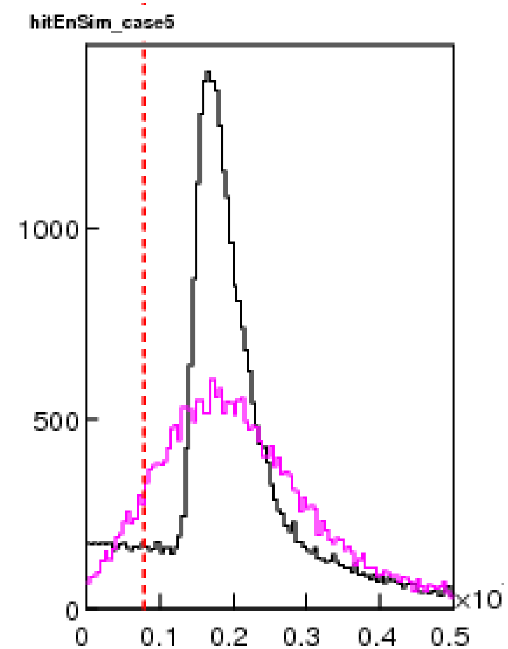
+ 7 p-e / MIP
(Poisson smear)



+ finite pixel number (5000)



+ 5% spread in single pixel response

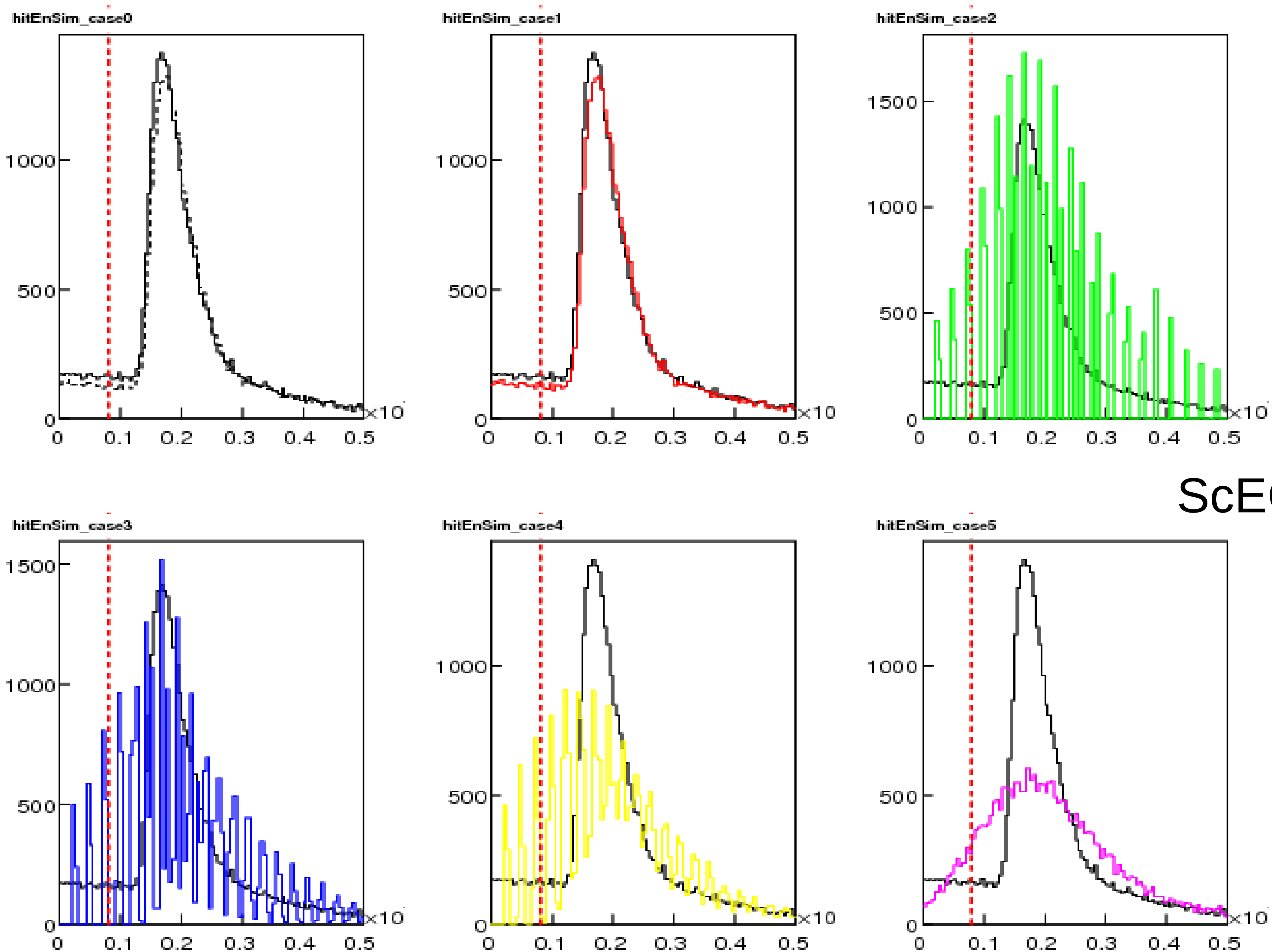


+ 0.2 MIP electronics noise, 5% uncertainty in eff. # pixels

ScECAL

Cells -> strips | absorption along strip | finite p-e

ScECAL



Finite #pix | spread in pixel resp | elec noise, npix uncert

Summary

ECAL groups aim to see more realisitic simulation and digitisation
used for ILD optimisation, including comparison of technologies

We have:
(more-or-less) agreed on ILD simulation guidelines for “realistic ECALs”
Recommend values for some parameters of Mokka ECAL driver

Developed (idealised) parameterisation of ECAL response
for silicon and scintillator technologies

Recommended parameter values still need to be agreed using input from test beam results

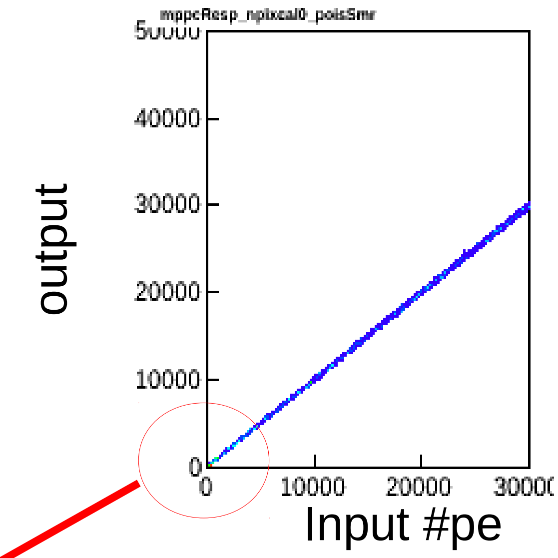
Discussing with AHCAL group:
hopefully agree on common parametric model for scintillator
(of course parameters will be different)

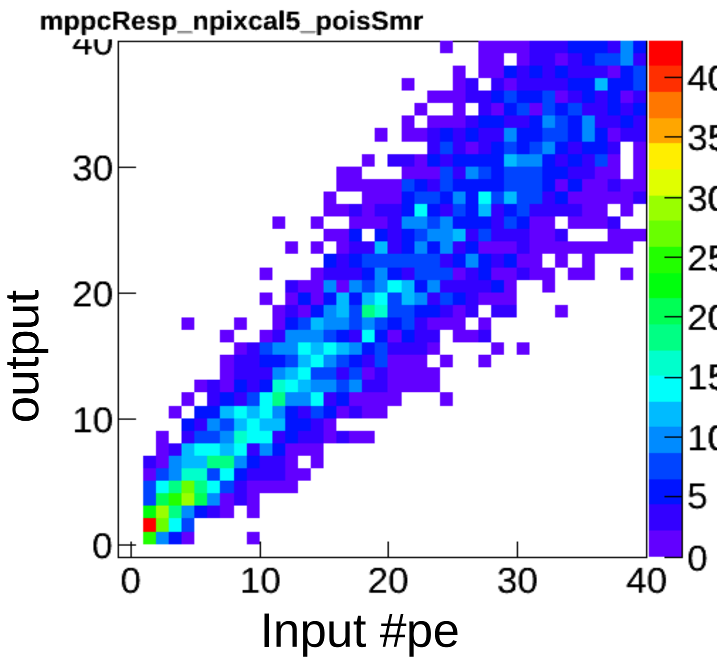
Implemented into (still private) version of ILDCaloDigi processor
I hope we can soon converge to an “official” procedure

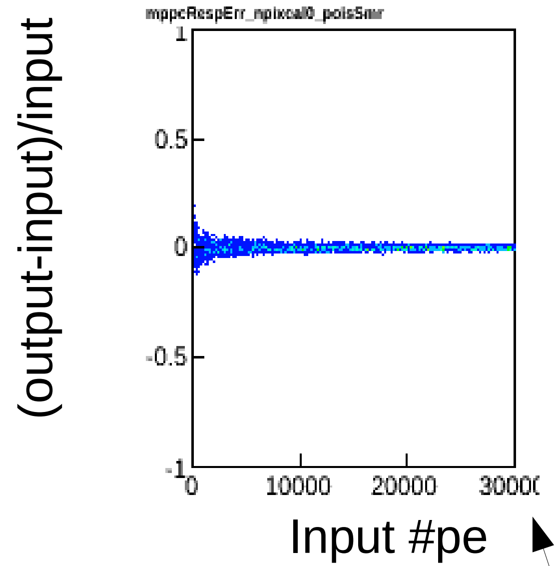
Backup slides

Convert energy deposit to mean
photoelectrons
(e.g. 7 pe / MIP)

Smear this #pe according to
Poisson distribution







ALL PLOTS ASSUME 10K PIXELS

Very wide range tested!!!!

Mean MPPC saturation

MPPC statistics

MPPC saturation also induces statistical fluctuations

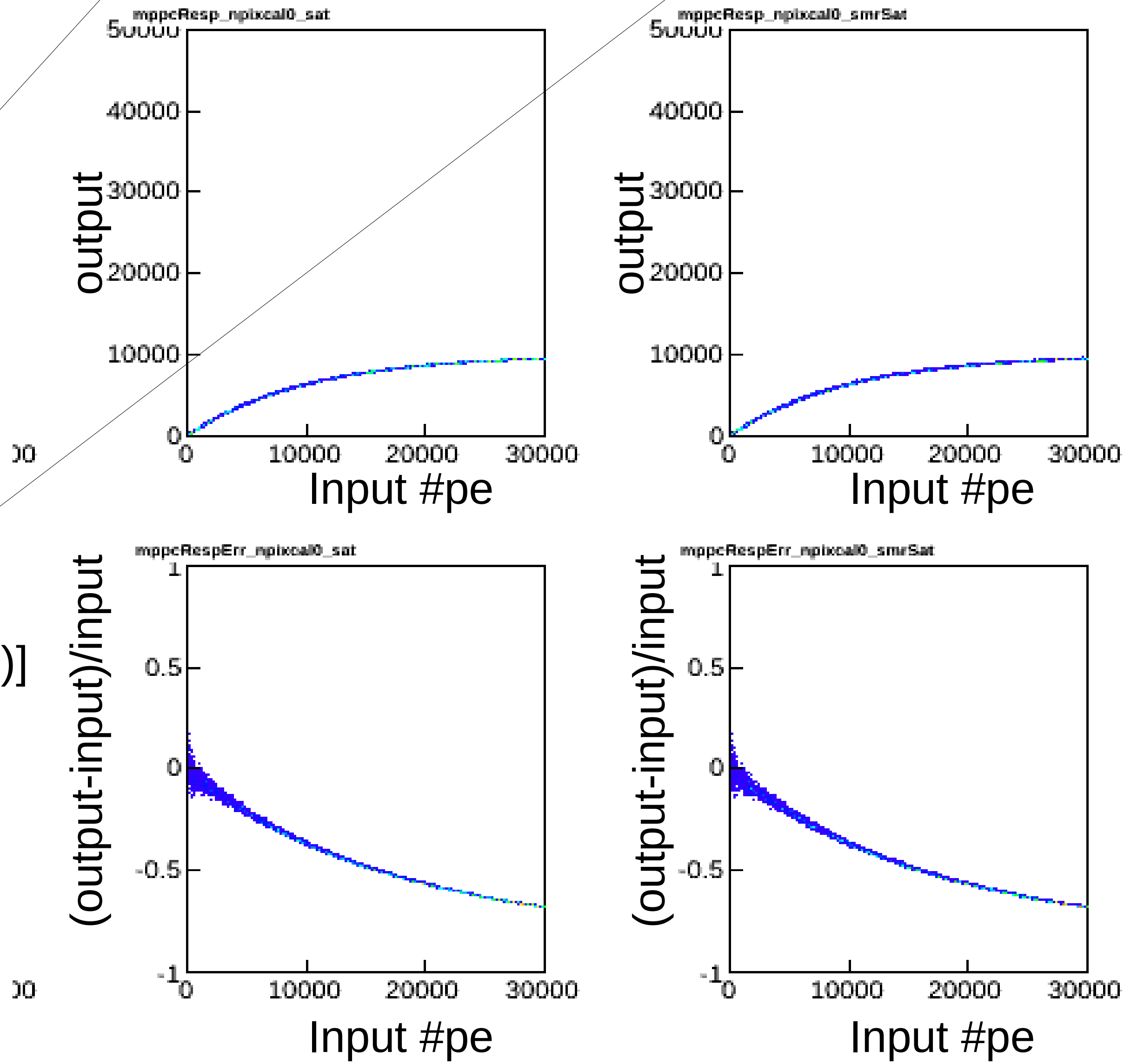
arXiv:0706.0746 [physics.ins-det]

Total # pixels: m
p-e: n
Hit # pixels: N

Approx normal distribution, with

$\langle N \rangle = m(1-\exp(-n/m))$
(we know this formula)

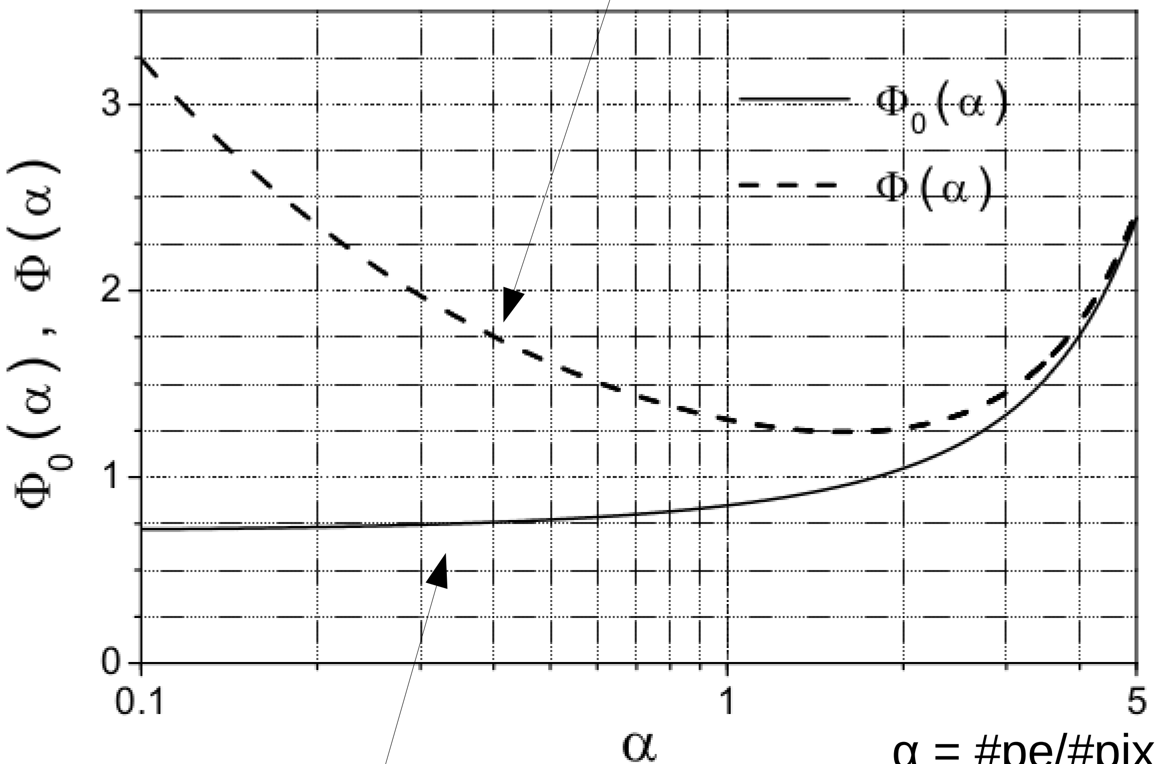
$\mathrm{var}(N)=m\cdot\exp(-n/m)\cdot[1-(1+n/m)\cdot\exp(-n/m)]$
(I didn't know this one...)



From arXiv:0706.0746 [physics.ins-det]

p.e. statistics + MPPC statistics

#pix resolution
~ Φ/√#pix

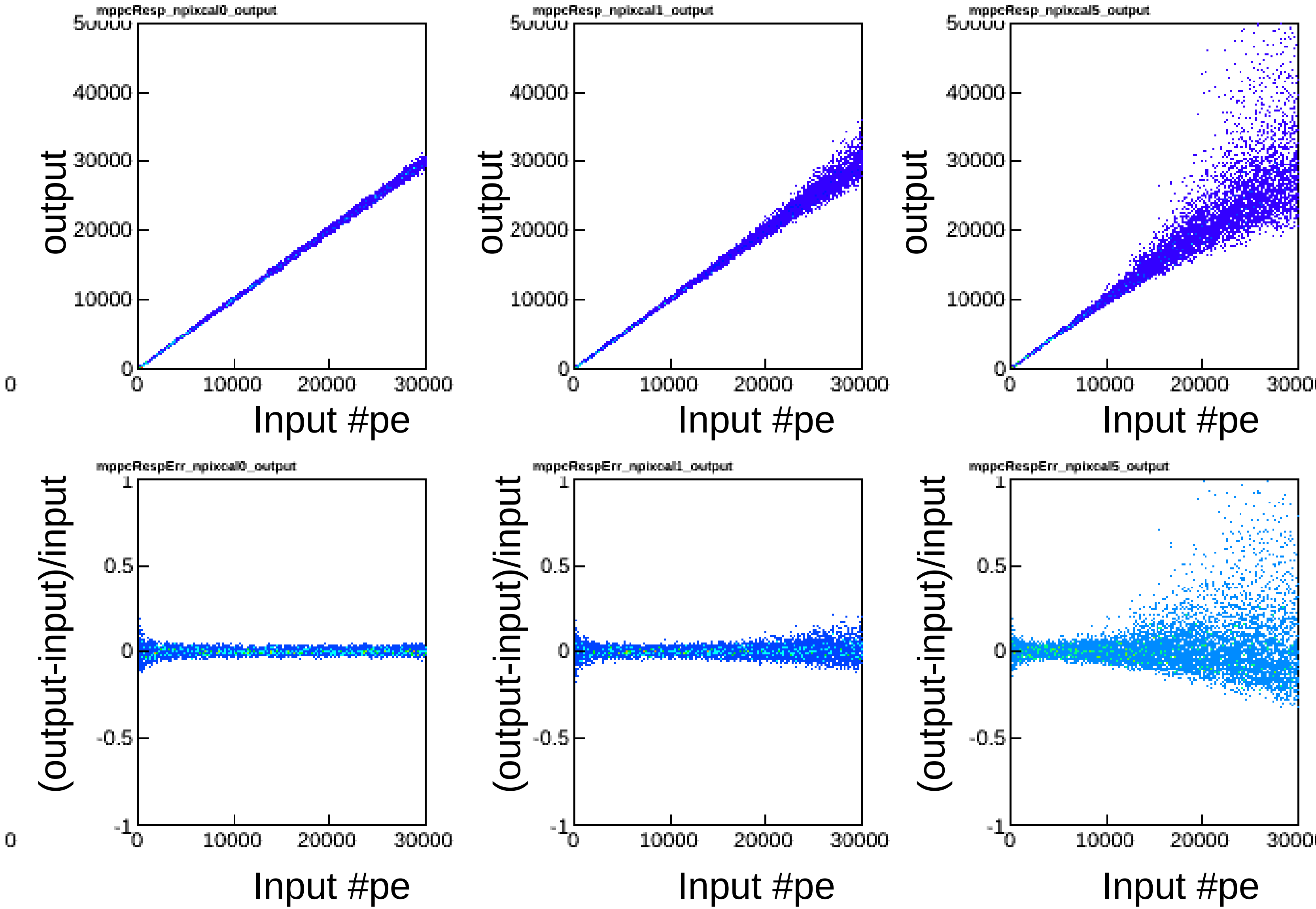


α = #pe/#pix

MPPC statistics
(fluctuation in m when putting n balls into m baskets
n p.es into m pixels)

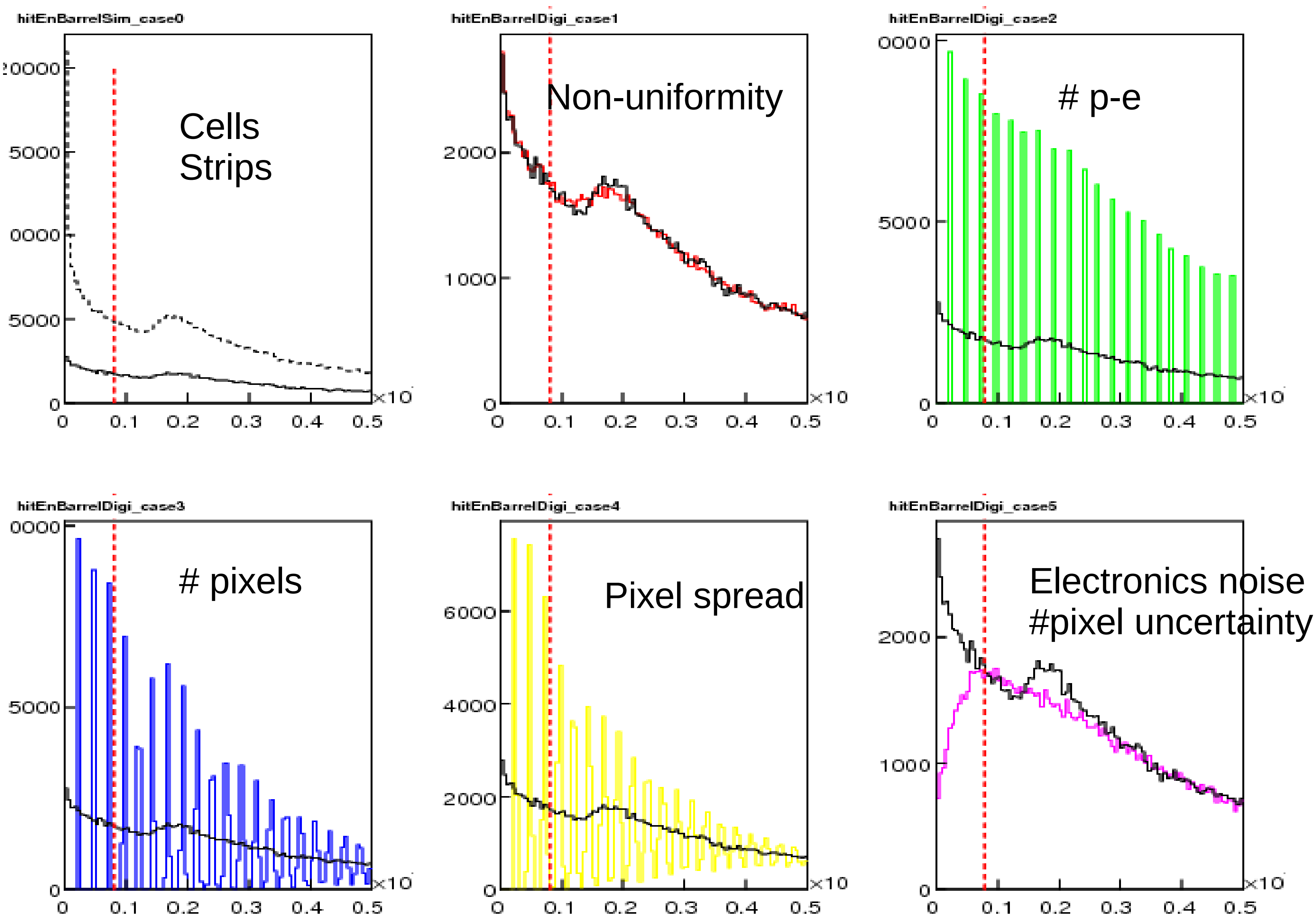
Now unfold the saturation effect,
assuming some (Gaussian) uncertainty on knowledge of total # pixels

0% uncertainty | 1% uncertainty | 5% uncertainty



100 GeV photons

Hit energies in barrel



100 GeV photons