AHCAL Digitisation

AHCAL ILD vs. Testbeam Simulation Models & Data

Oskar Hartbrich
CALICE Meeting
KEK, 20.04.2015

HELMHOLTZ ASSOCIATION

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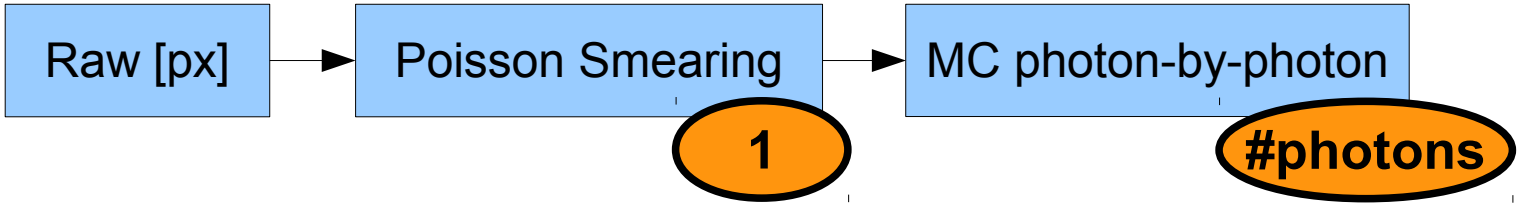
DESY

Outline

- Verification of SiPM digitisation models
- Additions to ILD calorimeter digitisation processor *ILDCaloDigi*
- Digitisation steps and their influence on spectra and resolutions
- Comparison of Resolutions from ILD simulations vs. prototype data
- Summary

SiPM Sensor Effects

- Finite number of pixels
  - Quantisation, drives resolution for low amplitudes
  - Saturation, drives resolution for very high amplitudes



- Photon-by-photon simulation model
  - For each photon: roll hit SiPM pixel, signal is no. of hit pixels
  - Simple, correct, but inefficient (n+1 random numbers)
  - Analytical resolution calculation (Stoykov et. al., arXiv: 0706.0746): Poisson term + saturation term

$$\mathrm{Res}^{Stoykov} = \frac{1}{\sqrt{m}} \sqrt{\frac{1}{\frac{a}{m}} + \left(\frac{1}{\frac{a}{m}} \sqrt{e^{\frac{a}{m}} - 1 - \frac{a}{m}} \right)^2} = \frac{\sqrt{m \left(e^{\frac{a}{m}} - 1 \right)}}{a}$$

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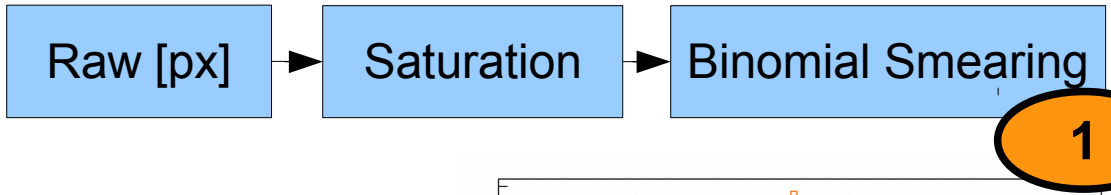
DESY

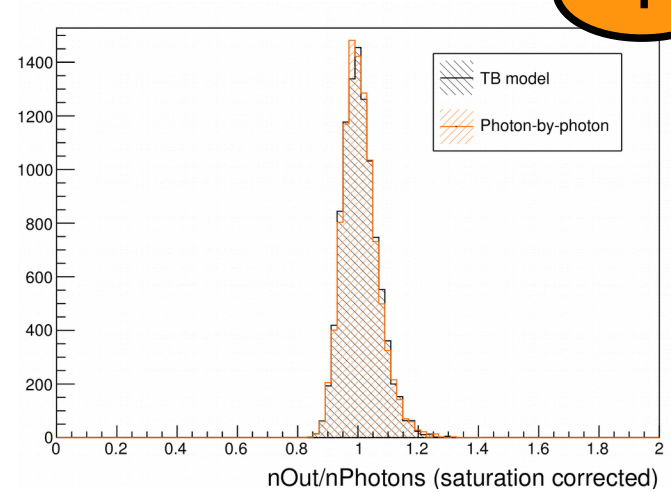
A Better SiPM Model

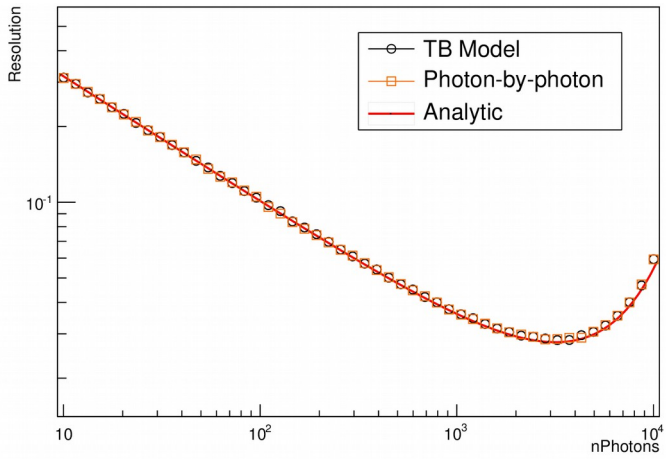
- Testbeam model
  - Less intuitive
  - Efficient (1 random number)
  - Was always used in AHCAL TB digitisation
- Analytical calculation

$$\mathrm{Res}^{TB} = \frac{\sqrt{m\left(e^{\frac{a}{m}} - 1\right)}}{a}$$

  - Identical to photon-by-photon model
  - Higher moments hard to access
- Shape in very good agreement
  - Analytic resolution matches simulations
- Models are identical
  - Use binomial (testbeam) model for all SiPM digitisation!







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DESY

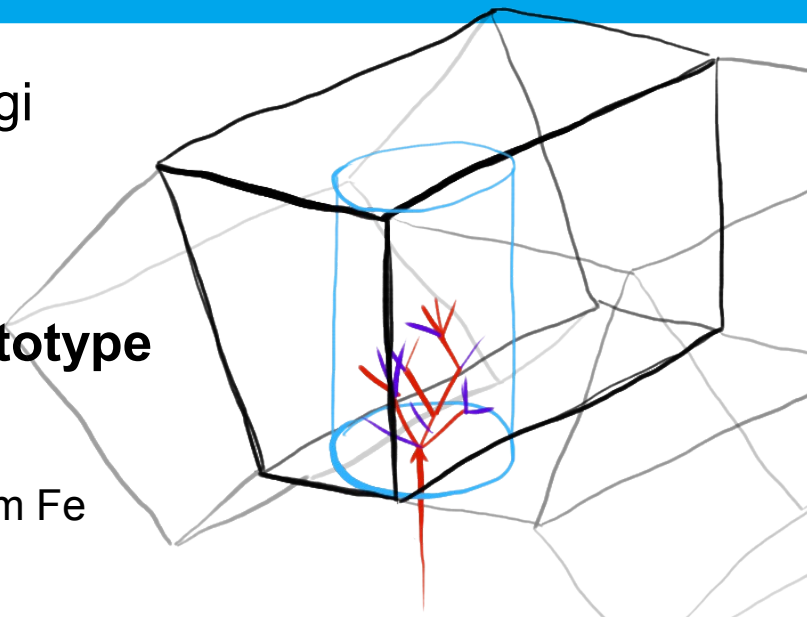
ILDCaloDigi

- New features in ILDCaloDigi Processor (Daniel Jeans, OH)
- Sensor modelling (SiPM & Silicon)
  - Binomial SiPM model, SiPM pixel charge non-uniformity
  - Electronics noise (rudimentary)
- Timing cut
  - New default parameter: `SimpleTimingCut = true`. Simple box timing cut. Previous implementation has possible unintentional effects
  - Caveat: `/Mokka/init/lcioDetailedShowerMode true` mandatory!
- Calorimeter imperfections
  - Dead channel fraction (random per event, fixed per run)
  - Scintillator strip response non-uniformities
  - Miscalibrations (response, saturation scale, … correlated and uncorrelated)
- Available in SVN: marlin_reco_trunk.
  - Includes documentation

Digitisation Steps

- Setup: ILD HCAL standalone + ILDCaloDigi
  - Both ILD and AHCAL prototype sampling
  - Particle gun similar to testbeam setups
- Parameters:

	ILD	Prototype
Scintillator	3mm	5mm
Absorber	20mm Fe	21mm Fe
Layers	48	64
MIP2GeV:	489.6keV/MIP	817.0keV/MIP
Fiducial cut:	yes	yes
Timing:	-10..150ns	-10..150ns
Threshold:	0.5MIP	0.5MIP
Lightyield:	15px/MIP	13.7px/MIP
SiPM NPixel:	2000px	1156px
Electronic Noise:	0.3px	0.3px
Pixel non-uniformity:	10%	10%



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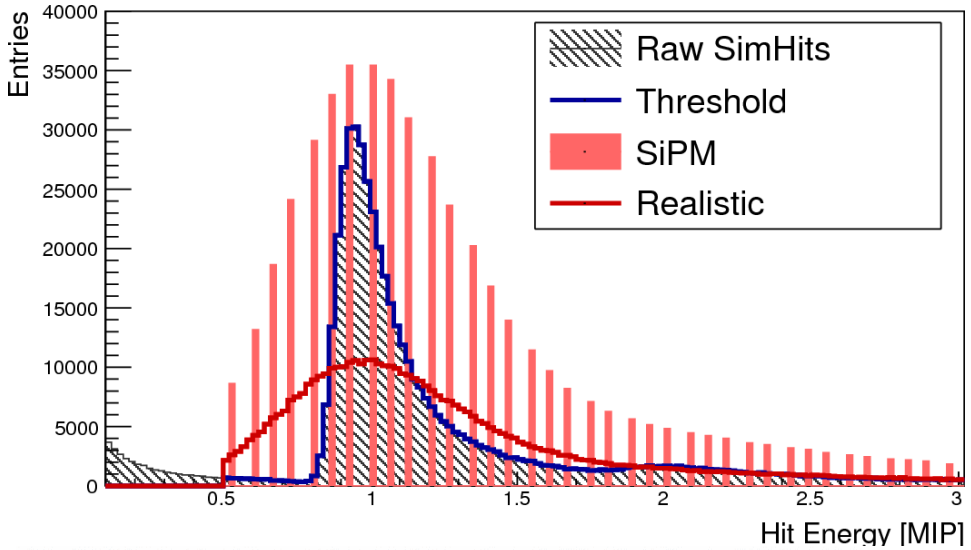
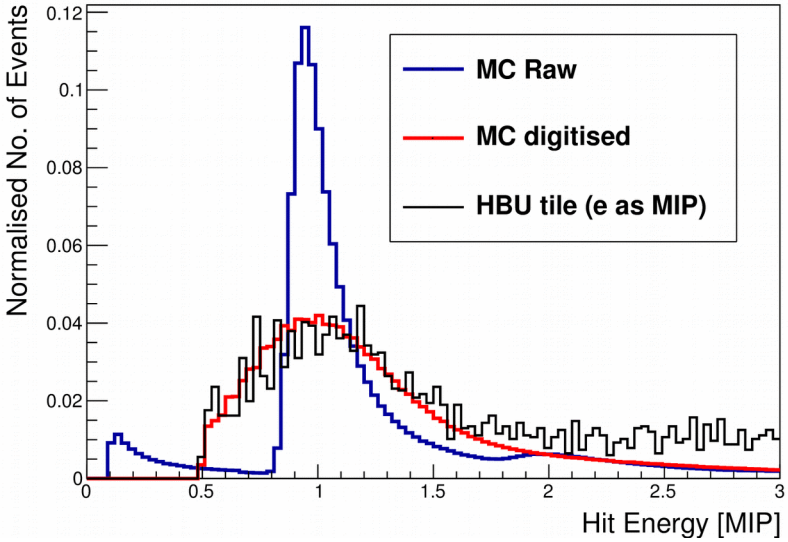
MIPs

- Notable effect of SiPM modelling on MIP spectrum
  - Electronics noise smears out quantisation
- Good agreement in MIPs for every prototype
  - Including 3mm ILD-like tiles from 2nd AHCAL prototype





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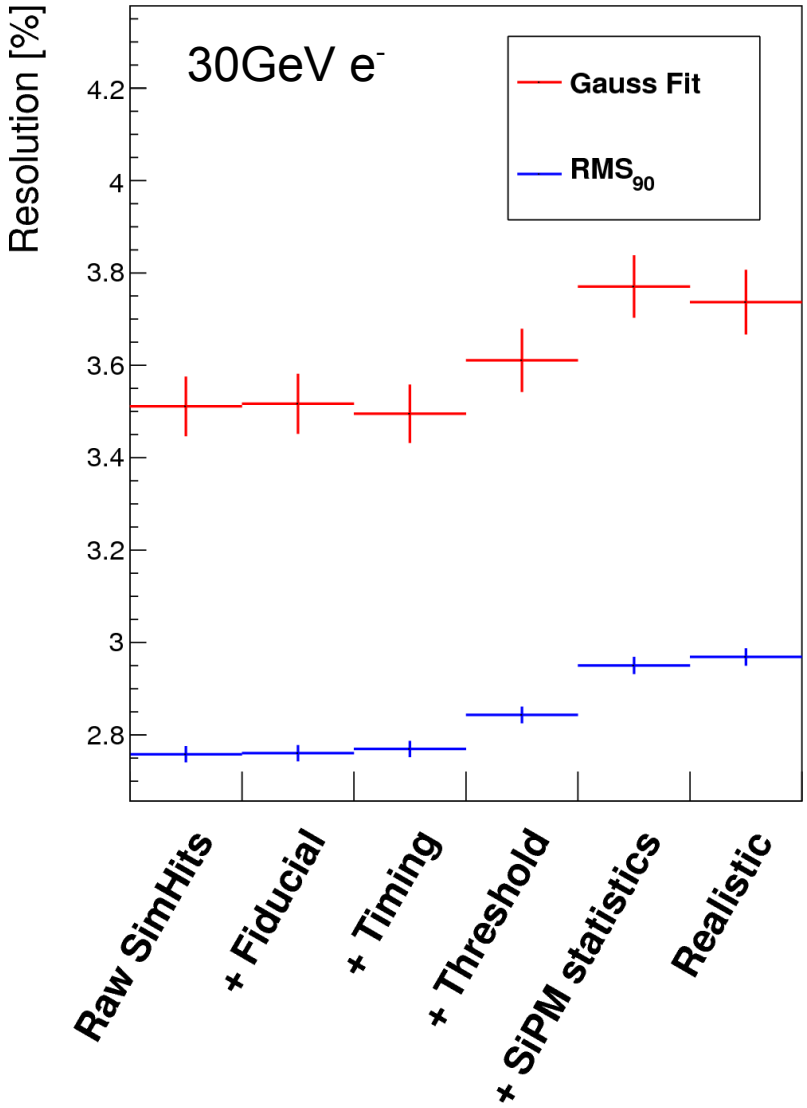
DESY

Resolution Breakdown Electrons

- 30 GeV electrons
- ~10% impact on resolution
  - No effect from fiducial cut, timing
  - 5% effect from threshold
  - 5% from SiPM (saturation)
  - Small effect from noise (affects fully saturated cells)
- Small influence from SiPM effects
  - Smaller for lower energy electrons
  - High energy electrons very rare in AHCAL



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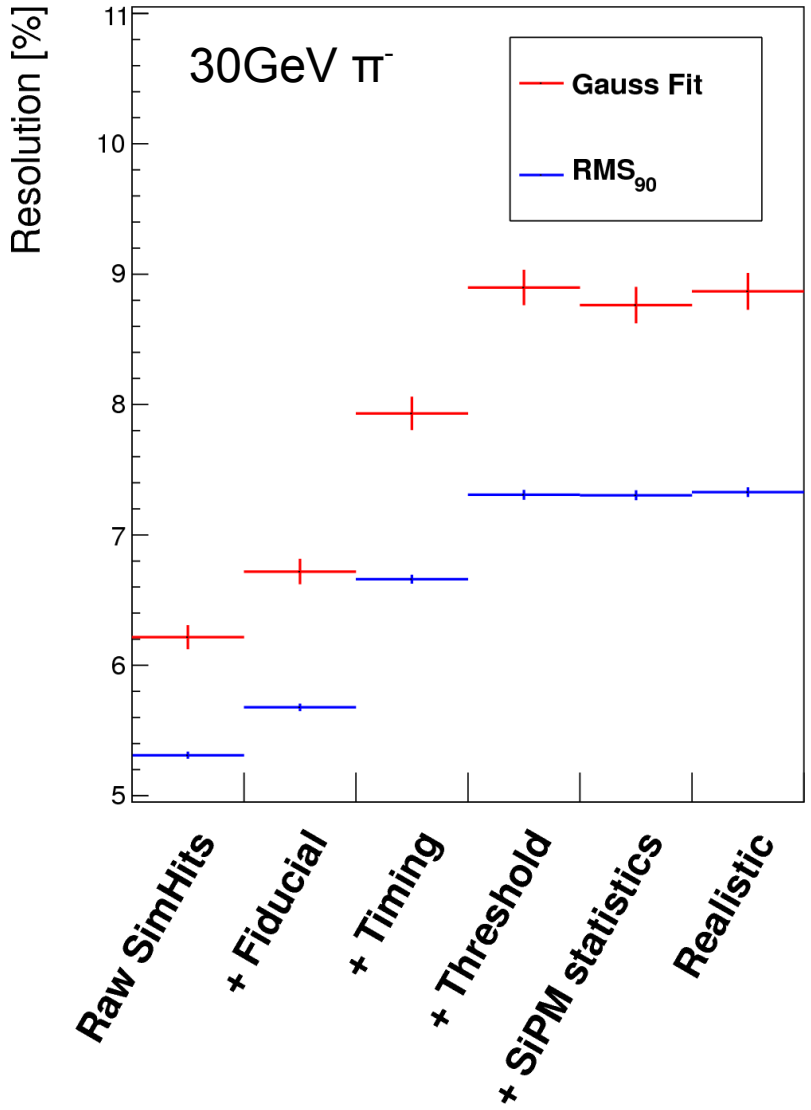
DESY

Resolution Breakdown Pions

- 30 GeV pions
- ~40% influence on resolution
- Important effects: Fiducial cut, timing, threshold
  - Have been implemented in ILD simulations since long time
- Hadron resolution not influenced by SiPM effects



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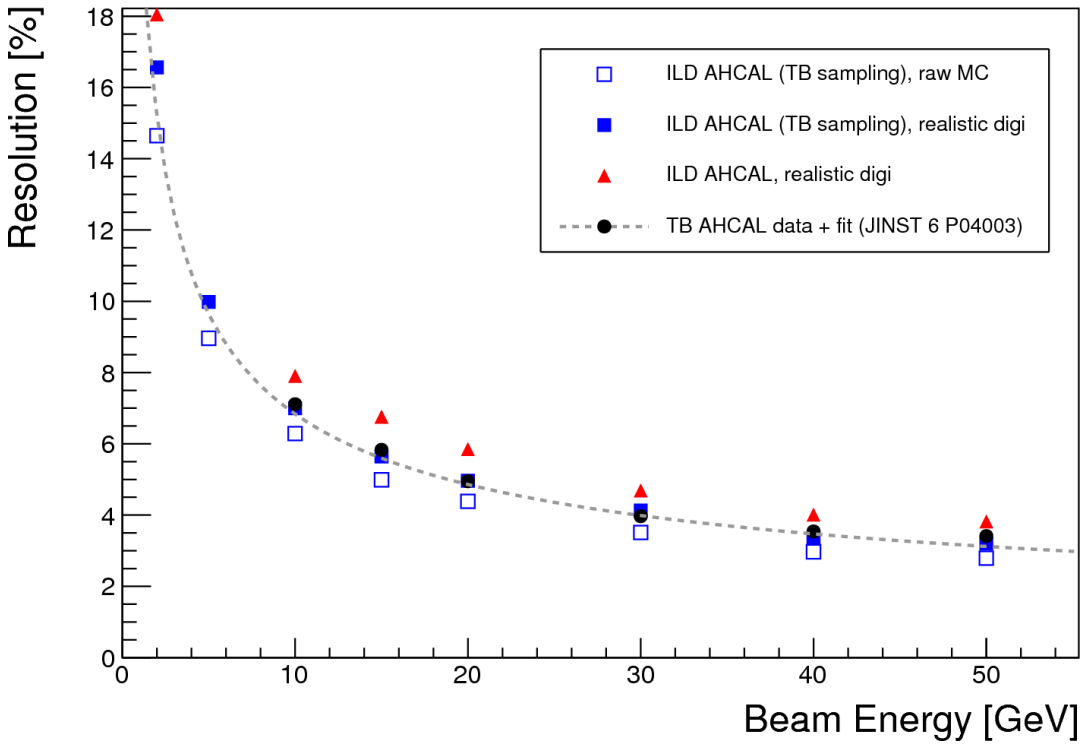
DESY

Resolution Electrons

- ILD simulation very similar to published results
  - Dependence on dead channel fraction (+ exact positions of dead channels)
  - Strong resolution dependence on dead channel fraction >5%
- Small effect of digitisation
  - Mostly threshold
- ILD sampling:
  Slightly worse resolution



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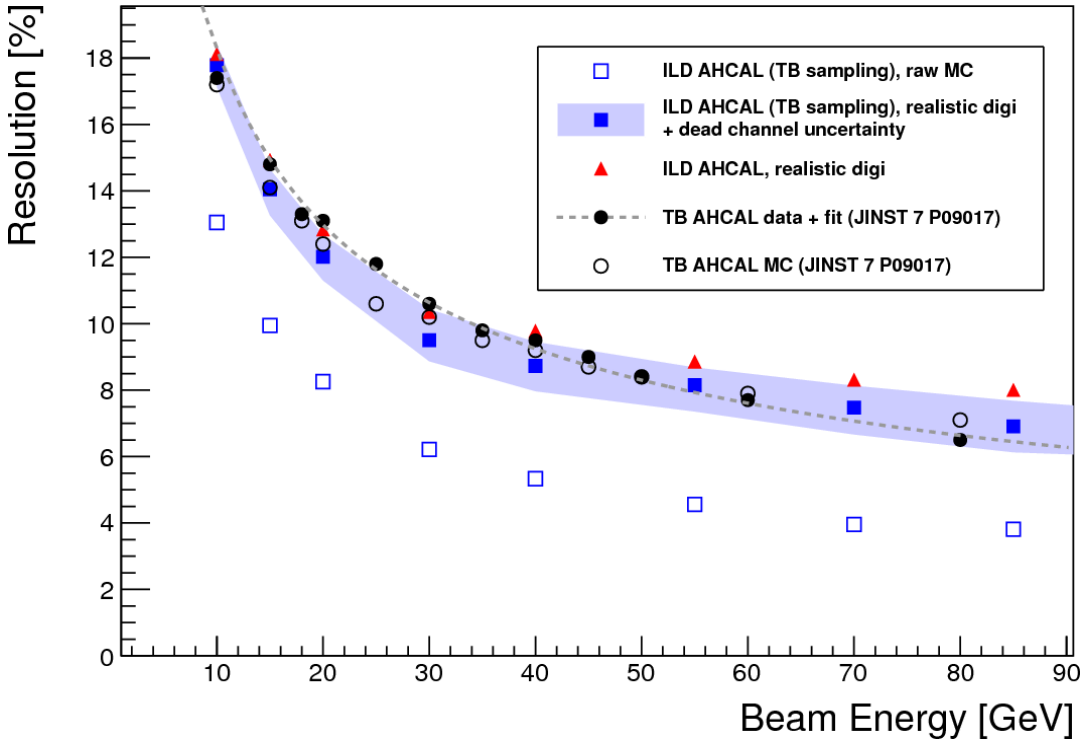
DESY

Resolution Pions

- ILD simulation very similar to published results
  - Simplified geometry, missing channelwise calibration etc.
  - Dependence on dead channel fraction (5-7% in prototype)
- Large effect of digitisation on resolution
  - Fiducial cut (clustering), timing, threshold.
  - SiPM effects negligible
- ILD sampling: worse for higher energies
  - Less layers → leakage



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DESY

Summary

- Validated “Testbeam model” as fast and correct SiPM modelling
  - Implemented in updated ILDCaloDigi + other new features
- SiPM effects on AHCAL single particle energy resolution are small
  - Visible for electrons >20GeV (rare in HCAL)
  - Irrelevant for hadrons (driven by clustering, timing, threshold)

  → All relevant effects have been included since LOI
- Can reproduce published AHCAL results in ILD model
  - From MIP-spectra to hadron resolutions
  - Using prototype-like sampling & reasonable dead channel fractions
- ILD sampling: Slighty worse resolutions
  - Expected from lower sampling fraction

Summary

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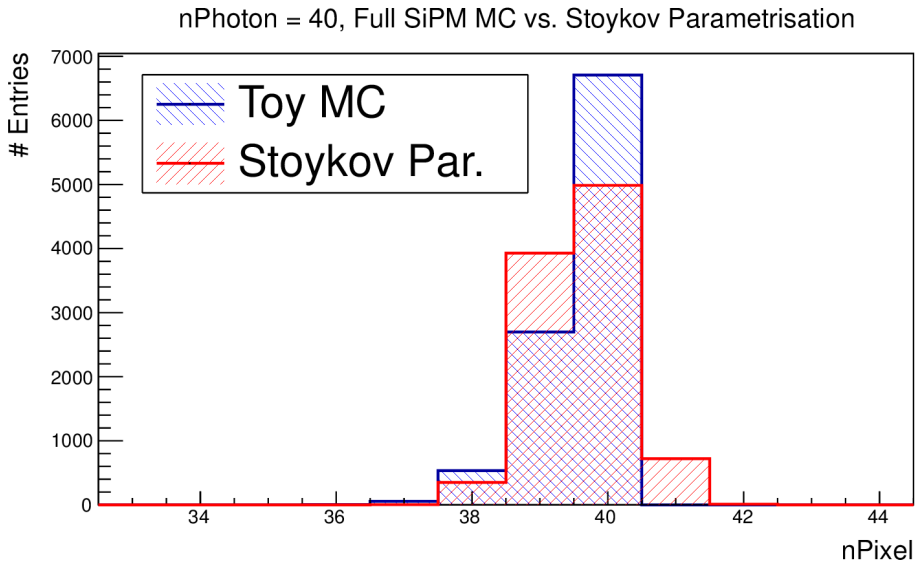
Very special thanks to Daniel and all of Uni Tokyo Komamiya group for weeks of hospitality and collaboration

Backup

Saturation Smearing

- Finite no. of pixels: Chance to hit same pixel twice
  - Saturation
  - Reponse widening
- Reponse widening: “Stoykov Parametrisation”
  - RMS as function of amplitude
  - Shape unknown → Gaussian
  - Need to apply saturation separately
- Toy MC
  - Roll dice for each incoming photon
  - Only count first photon per pixel
  - Solves saturation and response



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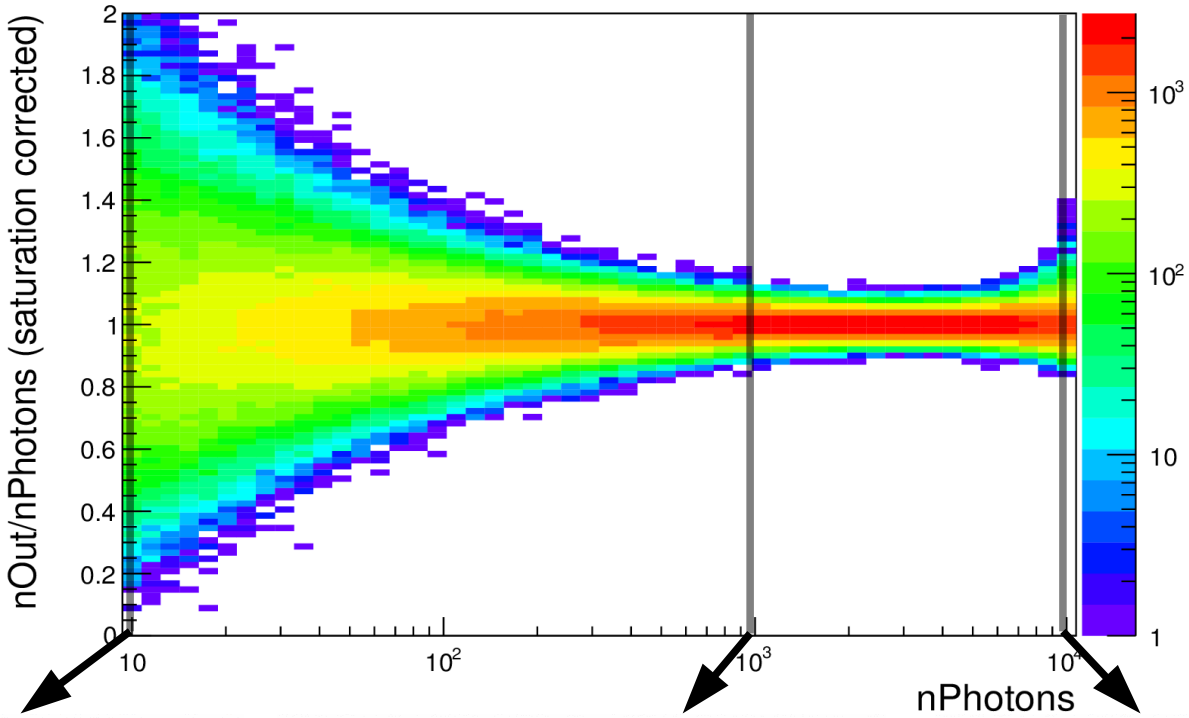
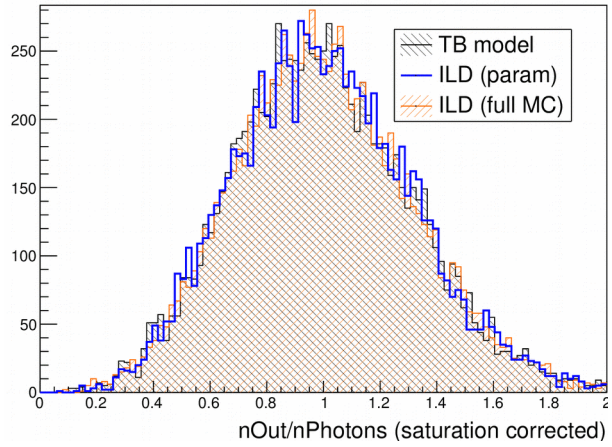
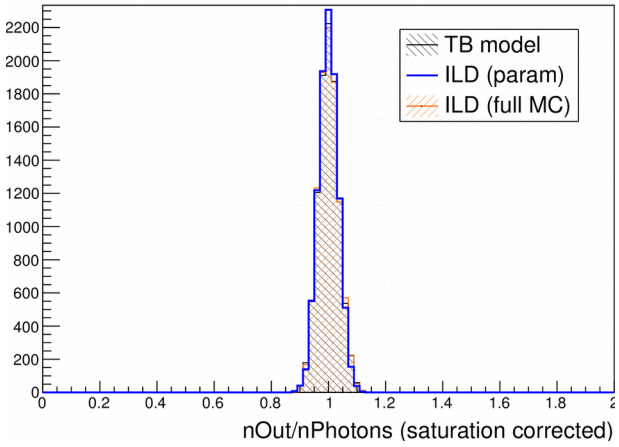
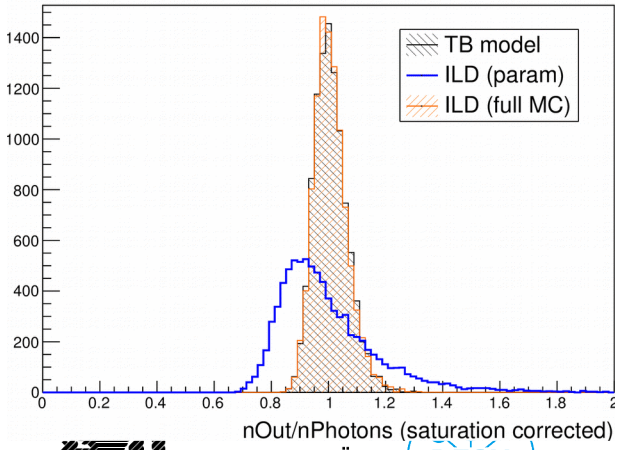
Transfer Function Slices









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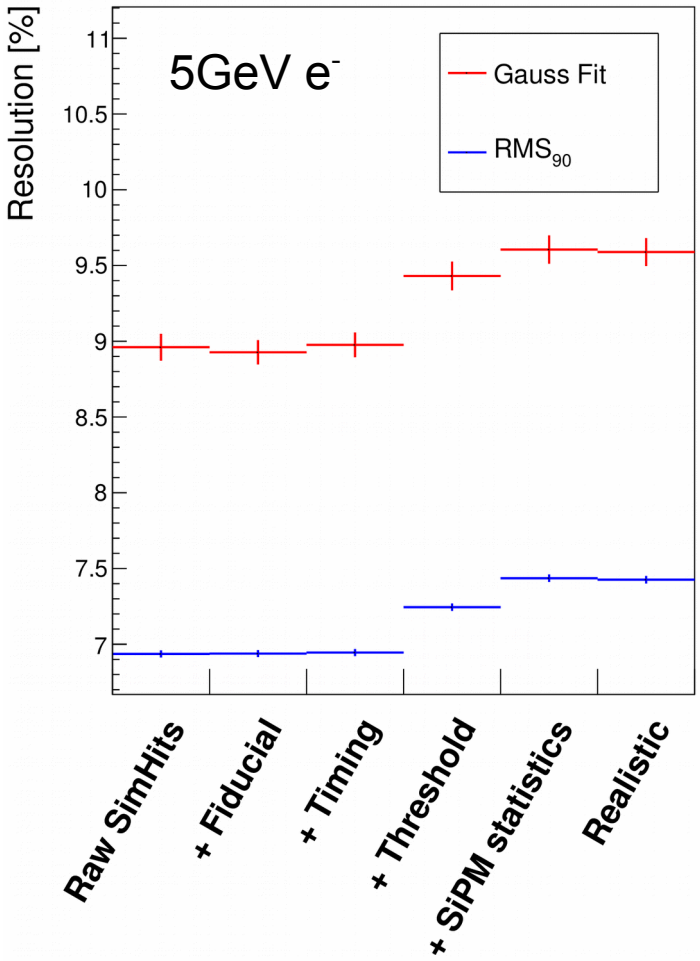
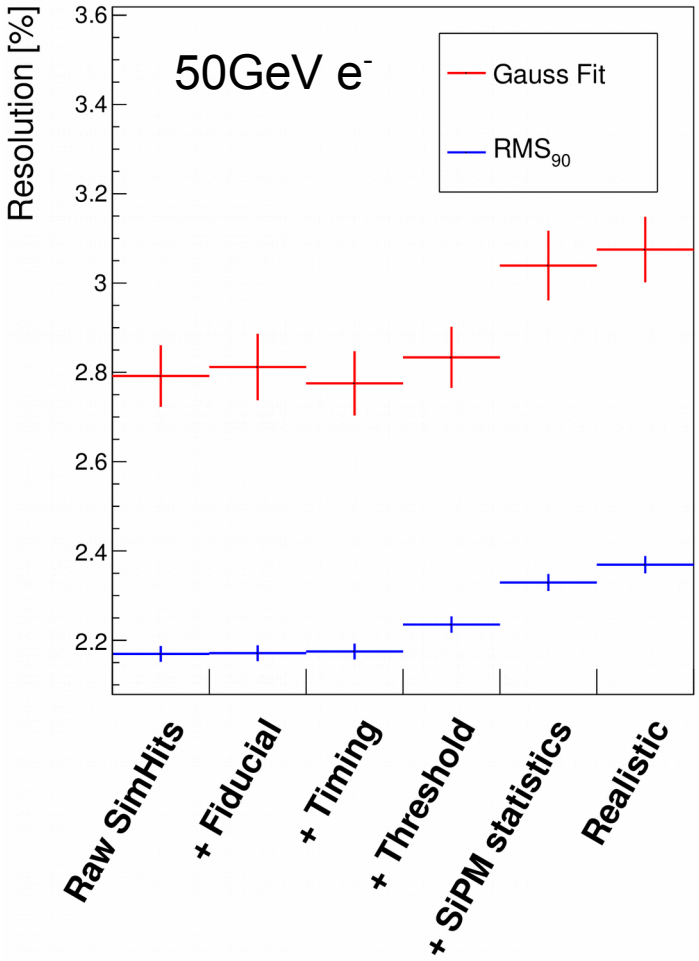
Digitisation Resolution Breakdown Electrons





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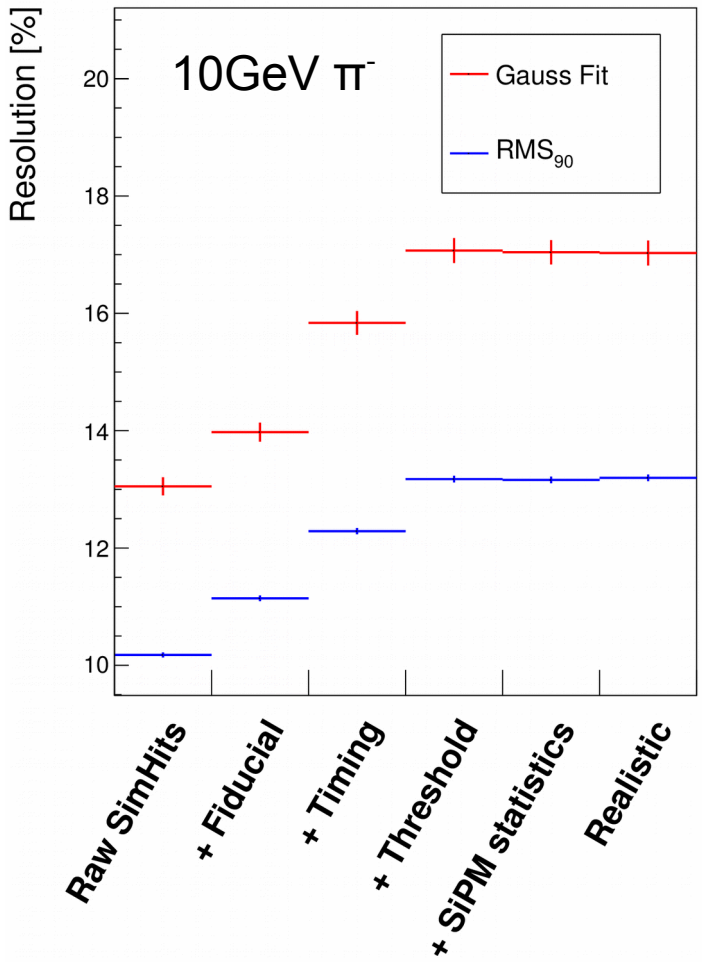

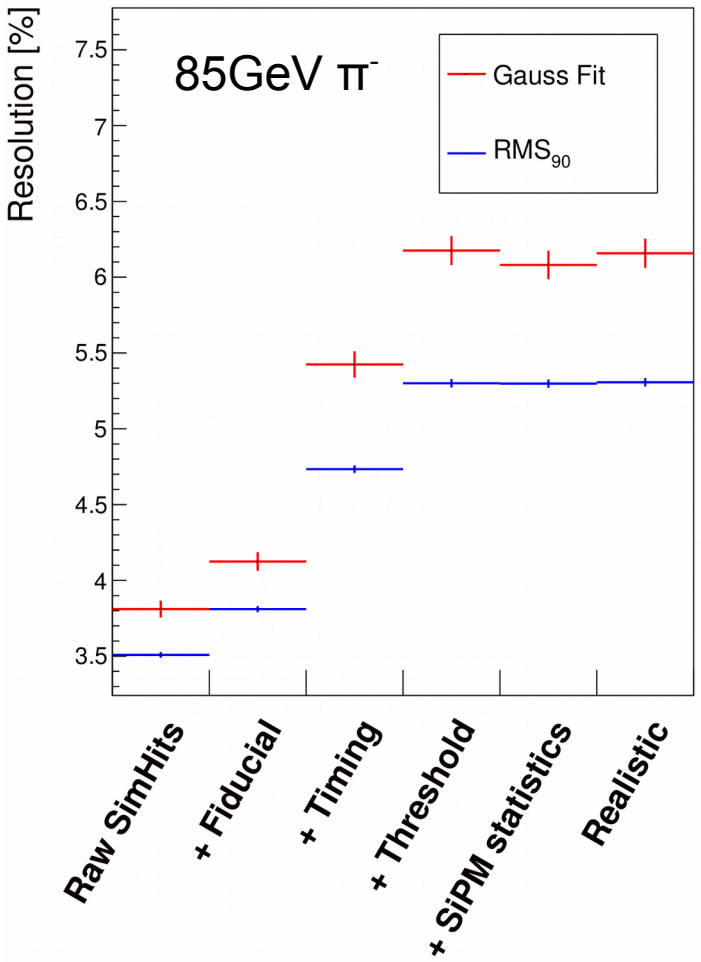

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