Oak Ridge National Laboratory

CALICE AHCAL Simulation & Analysis

U.S. DEPARTMENT OF ENERGY

Validating HCAL Simulations

- I got my PhD in the CALICE AHCAL group on testbeam analysis…
  - Pro: I am intimately aware of the inner workings of the CALICE analyses
  - Con: I am five years out of business…
- Both ECCE and ATHENA forward HCAL sims seem to struggle in some way, can work together for a better understanding and validation of our shared “EIC Detector 1” design.
- Reproducing other published resolutions (both data and MC) is important to validate own simulation models
- Starting with ATHENA since Oleg’s slide caught my eye

CALICE AHCAL Simulation Setup

- QGSP_BERT_HP, FTFP_BERT_HP gave best results
  - Nowadays FTFP_BERT_HP is the standard?
- _HP: Precision neutron tracking (lower neutron energy threshold)
  - Found important for W-absorbers, exact hit timing distributions
  - Negligible in steel
- Enable Birk's Law!
  - Quenching of light yield for high ionization densities (mostly in organic scintillators)

Hadron Shower Simulations

- Fiducial Volume
  - ~1m^2 in AHCAL
- Timing
  - 150ns in AHCAL
- Threshold
  - 0.5MIP/cell (~400keV)
- Digitisation Effects
  - SiPM saturation model (negligible)

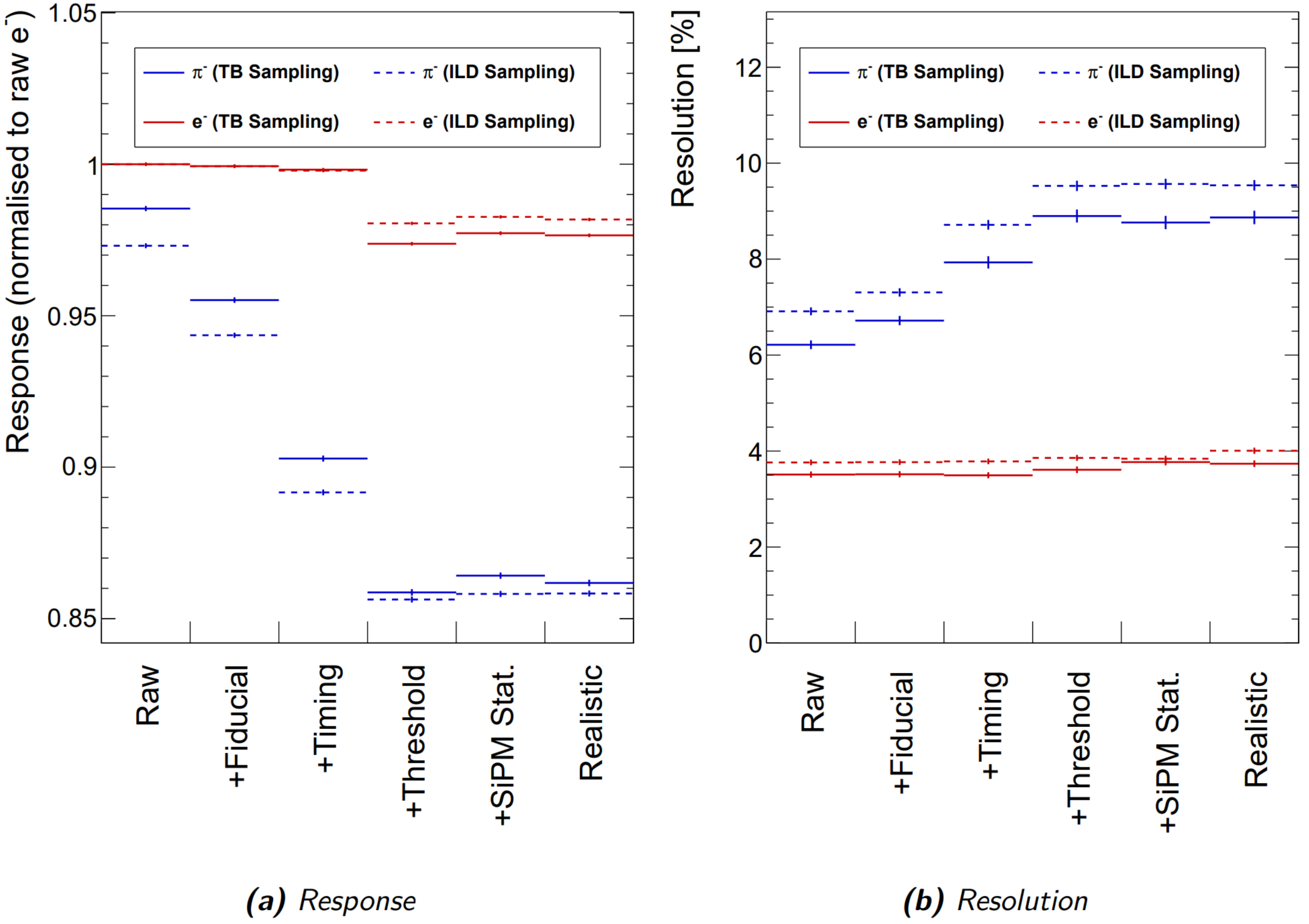
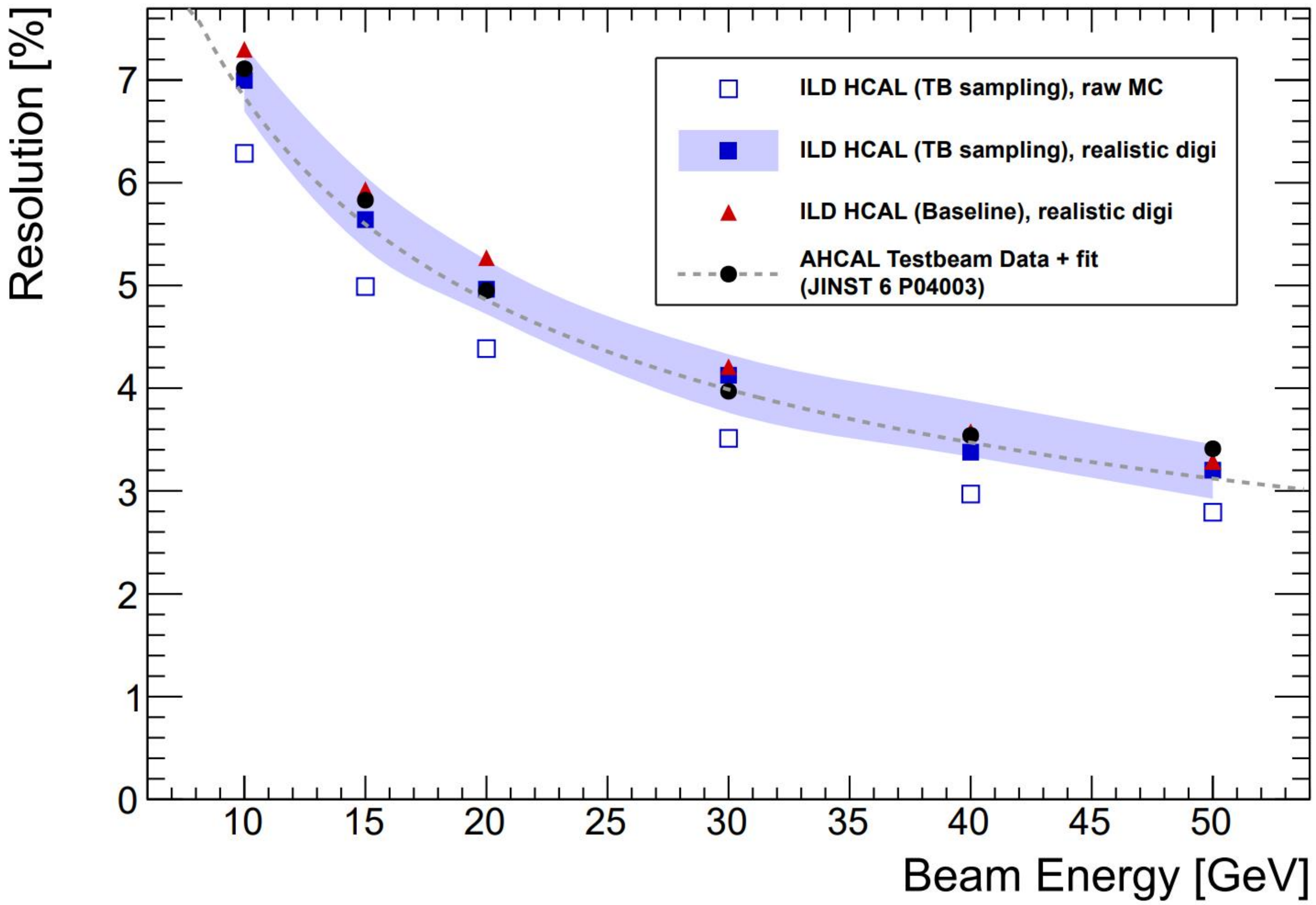
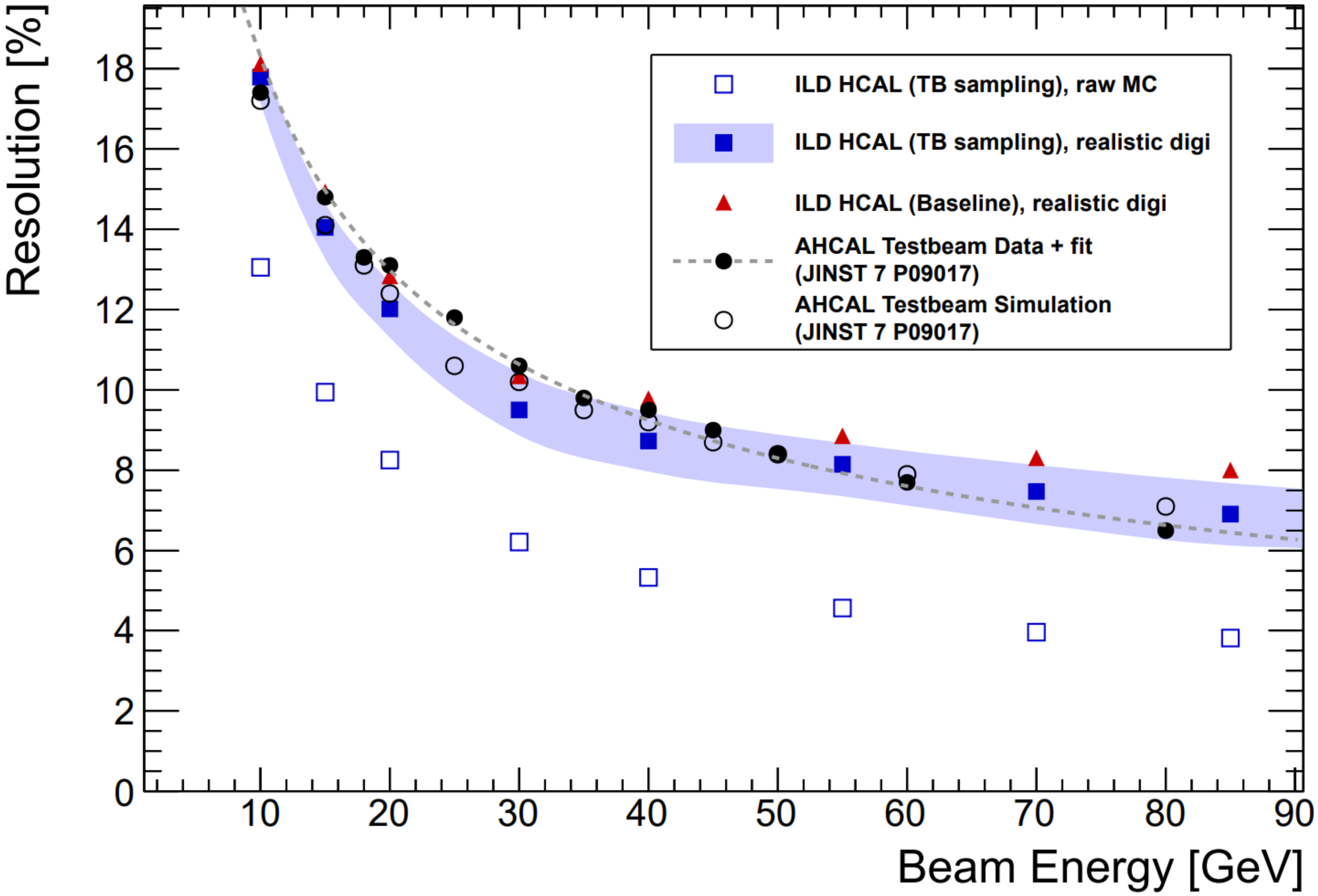


Figure 5.3.: *Response and resolution of 30 GeV electrons and pions for different steps in the digitisation as explained in Table 5.1, for both the ILD baseline model and the ILD testbeam model (TB).*

Resolution Impact - Electrons



Resolution Impact - Pions



CALICE AHCAL Geometry/Materials

- 1.74cm steel absorber, 2*0.2cm cassette material, 0.5cm scintillator per layer
  - Rest likely negligible
- For constant term/high energy points: need to include tail catcher

material	ρ [g/cm^3]	λ_π [cm]	λ_π/ρ [g/cm^2]	λ_n [cm]	λ_n/ρ [g/cm^2]	X_0 [cm]	X_0/ρ [g/cm^2]	R_M [cm]	f [%]
Fe	7.87	20.4	160.8	16.8	132.1	1.76	13.8	1.72	98.34
Mn	7.44	21.5	160.2	17.7	131.4	1.97	14.6	1.85	1.4
C	2.27	52.0	117.8	37.9	85.8	18.9	42.7	4.89	0.17
S	2.0	70.9	141.7	56.2	112.4	9.75	19.5	5.77	0.045
P	2.2	64.0	140.7	50.6	111.4	9.64	21.2	5.39	0.045
steel	7.86	20.5	160.8	16.8	132.1	1.76	13.9	1.72	100
tile	1.06	107.2	113.7	77.1	81.7	41.3	43.8	9.41	100
Si	2.33	59.1	137.7	46.5	108.4	9.37	40.2	4.94	18.1
O		106.8	121.9	79.0	90.2	30.01	34.2	9.52	40.6
C	2.27	52.0	117.8	37.9	85.8	18.9	42.7	4.89	27.8
H		1134	80.3	734.6	52.0	890.4	63.0	67.92	6.8
Br	3.1	56.6	175.5	47.5	147.2	3.68	11.4	4.52	6.7
FR4	1.7	71.4	121.4	52.6	89.45	17.5	29.8	6.06	100
3M foil	1.06	107.2	113.7	77.1	81.7	41.3	43.8	9.41	100
PVC	1.3	98.9	128.5	74.6	97.0	19.6	25.5	8.34	87.2
polystyr.	1.06	107.2	113.7	77.1	81.7	41.3	43.8	9.41	11.9
Cable	1.35	93.7	126.5	70.2	94.8	19.9	26.9	7.95	100
air		101k	122	74.8k	90.1	30.4k	36.6	7.3k	0.9

Table 1. Composition and properties of the absorber (cassette) plates and materials used in a cassette of one AHCAL layer [14], where ρ, R_M and f respectively denote the density, Molière radius and fraction of components in composite materials (steel, PCB boards and cables) while other quantities are defined in the text.

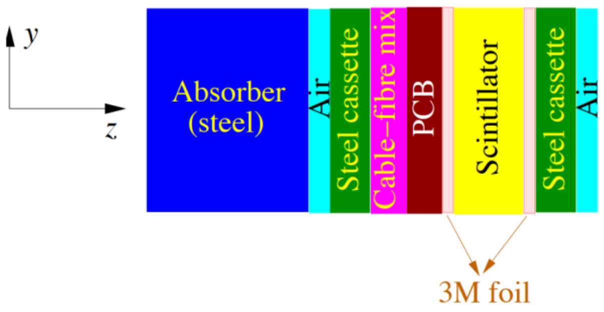
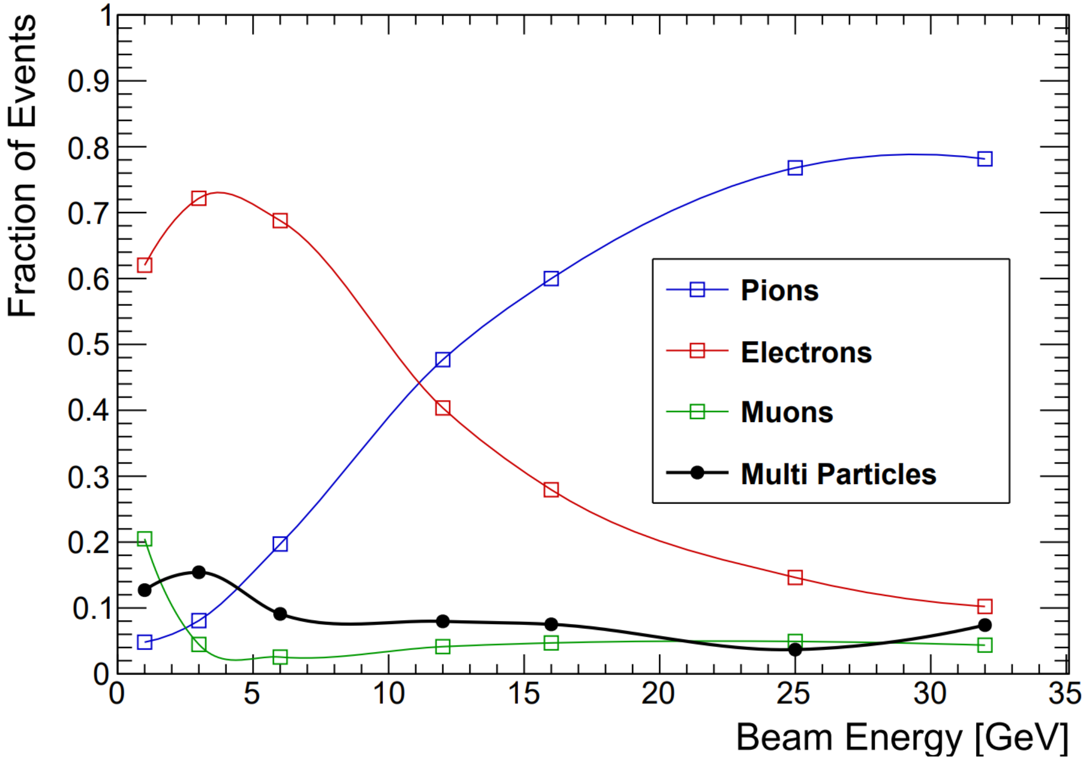


Figure 3. Schematic cross section of a cassette (not to scale).

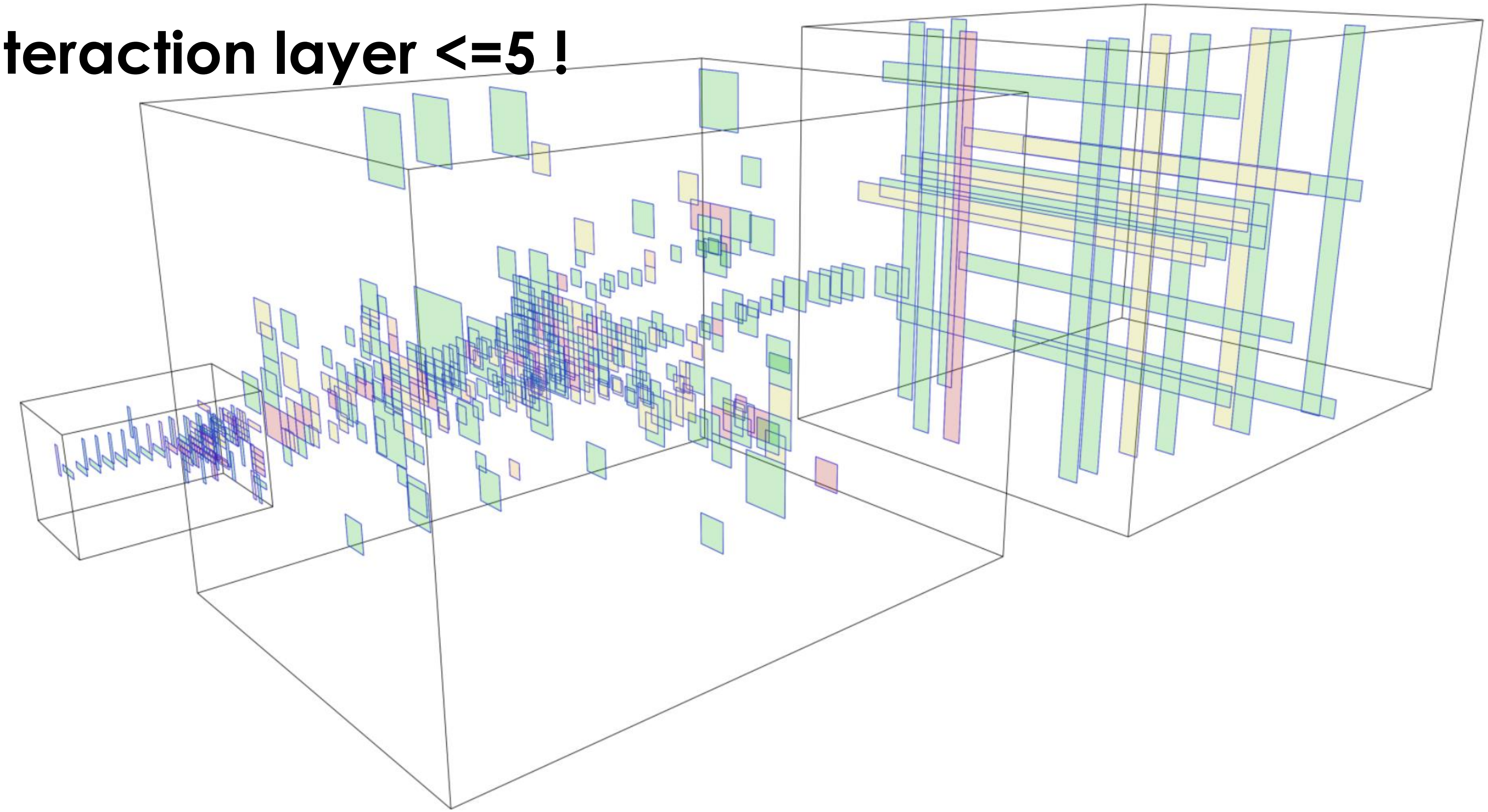
AHCAL Event Selection

- Some experimental constraints
  - E.g. Beam contamination rejection
- Some fundamental choices
  - Always debatable!
- AHCAL analysis:
  First hard interaction layer <=5 !



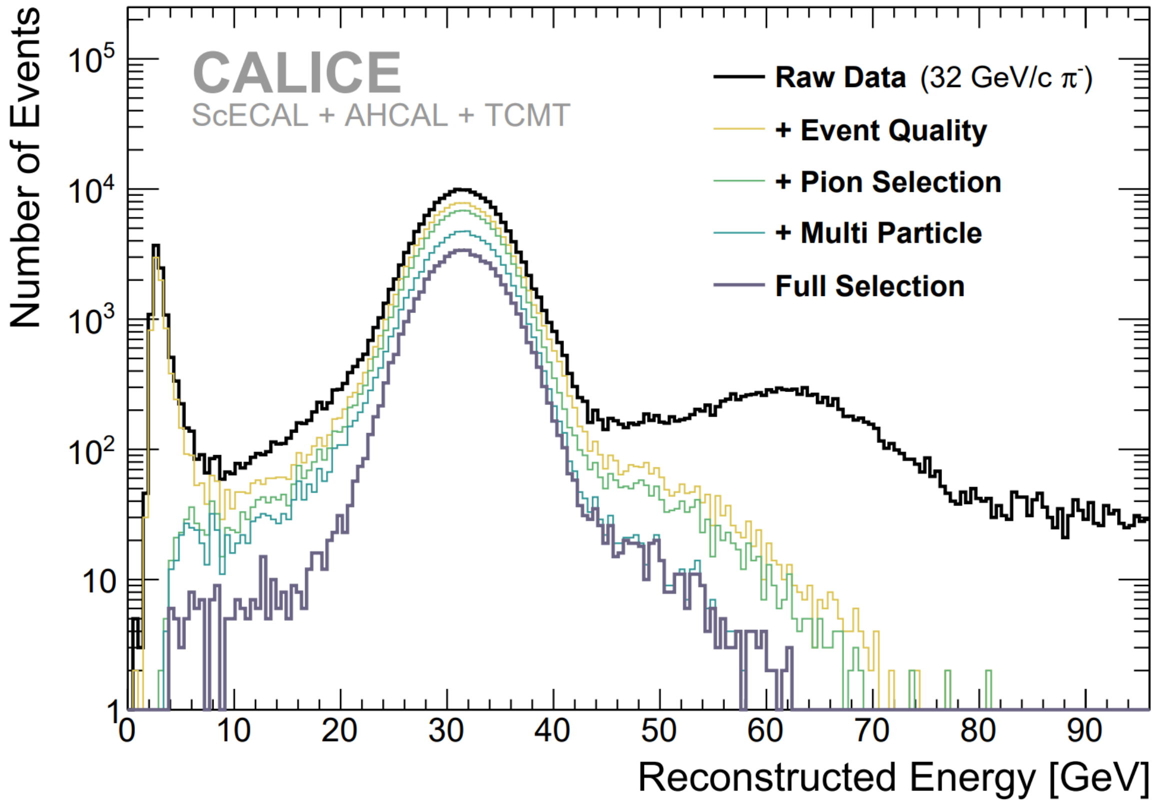
AHCAL Event Selection

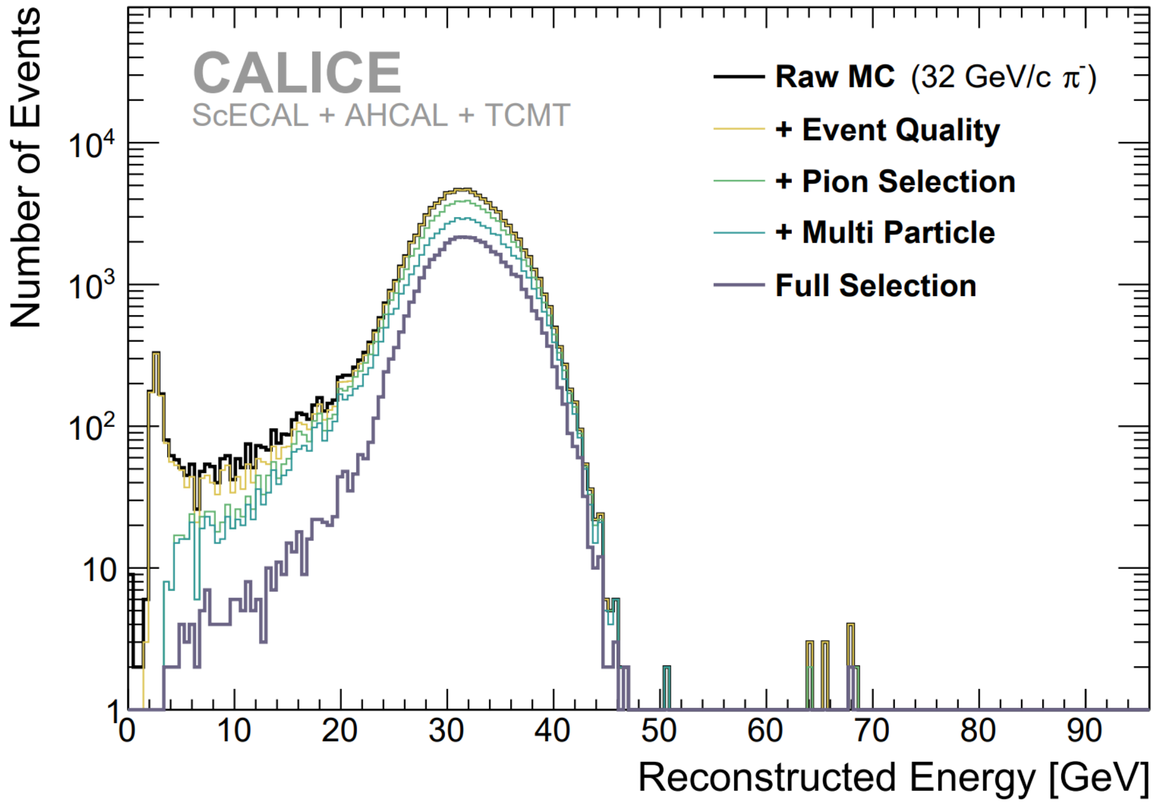
- **First hard interaction layer <=5 !**



AHCALEvent Selection

- **First hard interaction layer <=5 !**





“Resolution”

- Every hadron shower spectrum will have some tails
  - Some understood, some not so understood
- How to fit/extract resolution is not straightforward
  - CALICE paper #1: Gaussian within +-2 std. dev.
  - CALICE paper #2: Novosibirsk fit, MC integration of std. dev.
  - Some other CALICE paper: “RMS90”

References

- Construction and commissioning of the CALICE analog hadron calorimeter prototype
  – https://iopscience.iop.org/article/10.1088/1748-0221/5/05/P05004
- Hadronic energy resolution of a highly granular scintillator-steel hadron calorimeter using software compensation techniques
  – https://iopscience.iop.org/article/10.1088/1748-0221/7/09/P09017
- Hadronic energy resolution of a combined high granularity scintillator calorimeter system
  – https://iopscience.iop.org/article/10.1088/1748-0221/13/12/P12022
- Scintillator Calorimeters for a Future Linear Collider Experiment
  – https://cds.cern.ch/record/2637264?ln=en