國立臺灣大學
National Taiwan University

Resistive Plate Chamber Digitization in a Hadronic Shower Environment

CALOR Conference - Daegu

Arnaud Steen

NTU

15-20 May 2016

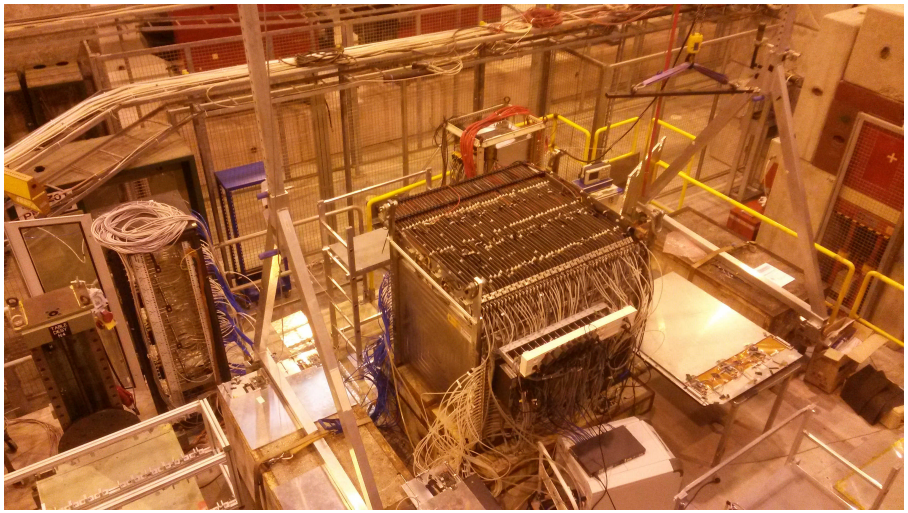
Outline

1. Introduction
2. SDHCAL simulation and digitization method
3. Digitizer results

CALICE SDHCAL technological prototype

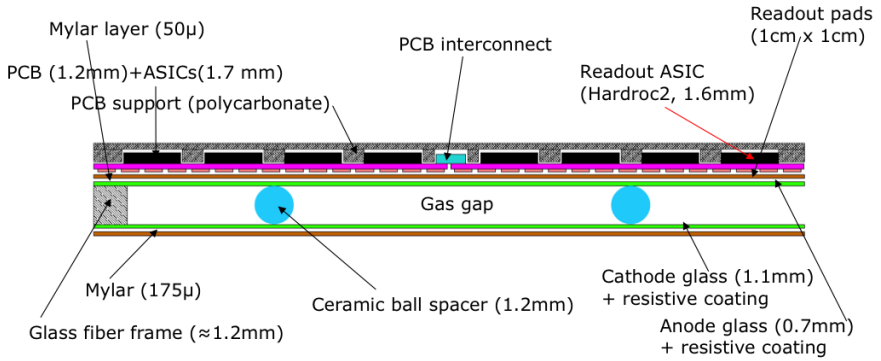
CALICE SDHCAL prototype

- Sampling calorimeter with 48 active layers (GRPC) separated by 2 cm thick steel plates
- Size : $1 \times 1 \times 1.3\ m^3$; total depth : $6\lambda_I$
- Readout : 442368 electronic channels ; semi-digital



Glass resistive plate chambers

- Glass electrodes separated by 1.2 mm gas gap
- Glass resistivity $\approx 10^{12}\,\Omega m$
- Gas mixture : 93 % TFE, 5 % CO_2, 2 % SF_6
- High voltage : $6.9\,kV \rightarrow$ avalanche mode
- Transverse segmentation : $1\,cm^2$
- Thresholds : 0.114, 5.0, 15.0 pC



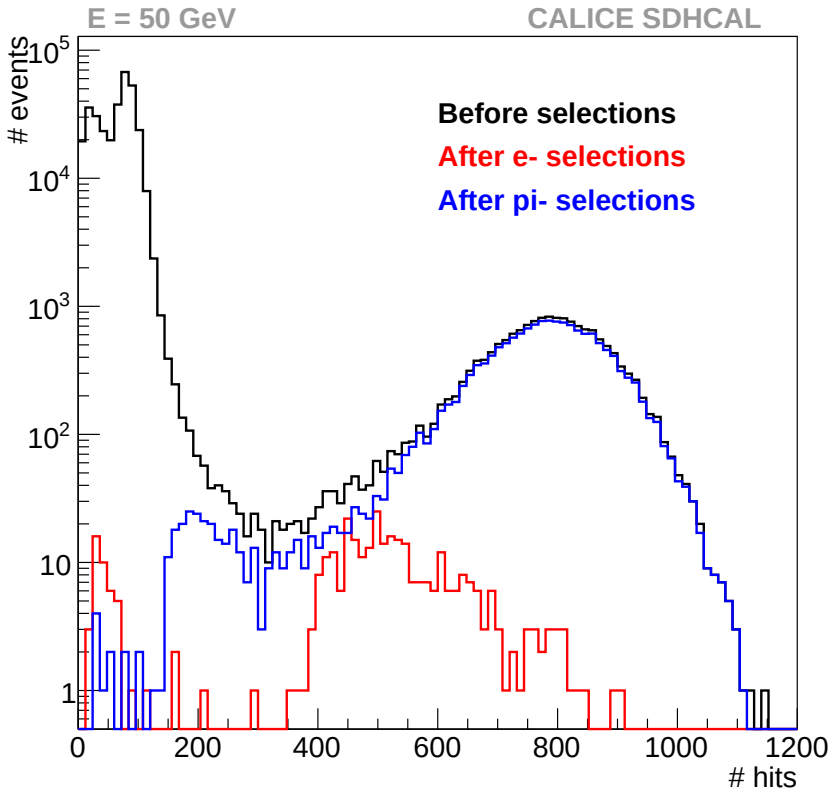
Beam test set-up

Data acquisition

- Triggerless $\rightarrow$ physical event reconstruction (time clustering method)
- No Cerenkov counter $\rightarrow$ proton, π, e^-, μ, (+ cosmics) in data samples $\rightarrow$ geometrical selection

Beam settings

- Large beam profile ($< 100 Hz/cm^2$)
- Need time calibation



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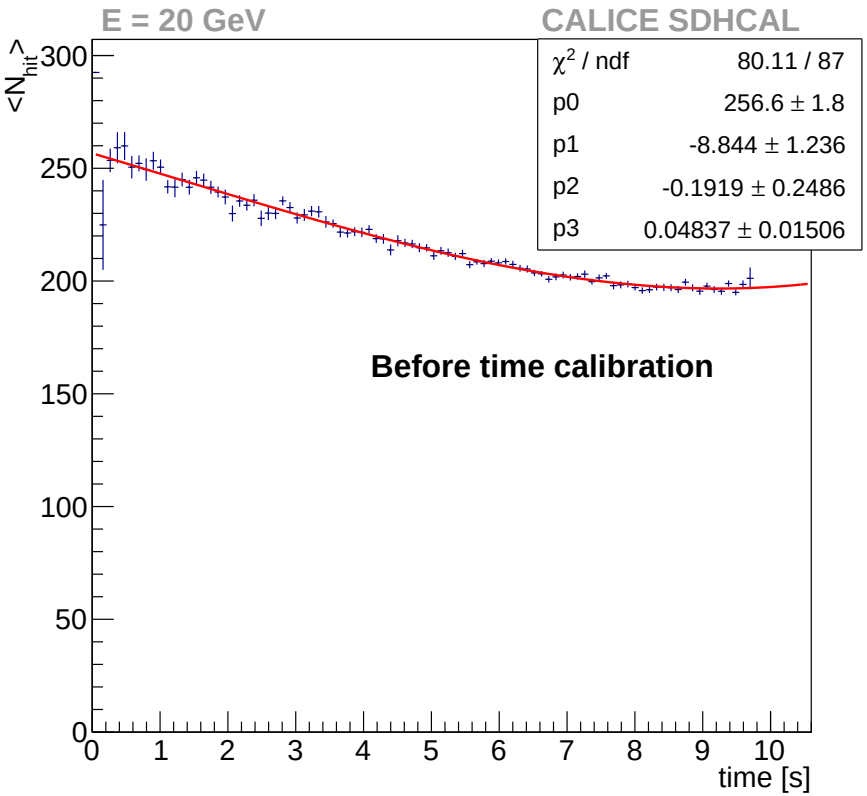


1 Introduction

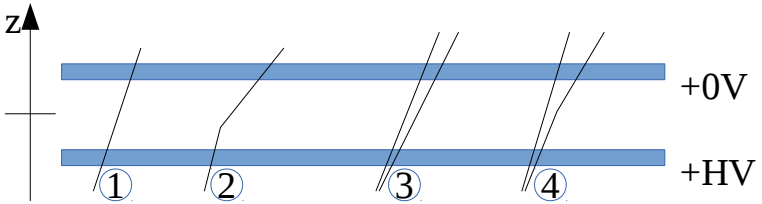
2 SDHCAL simulation and digitization method

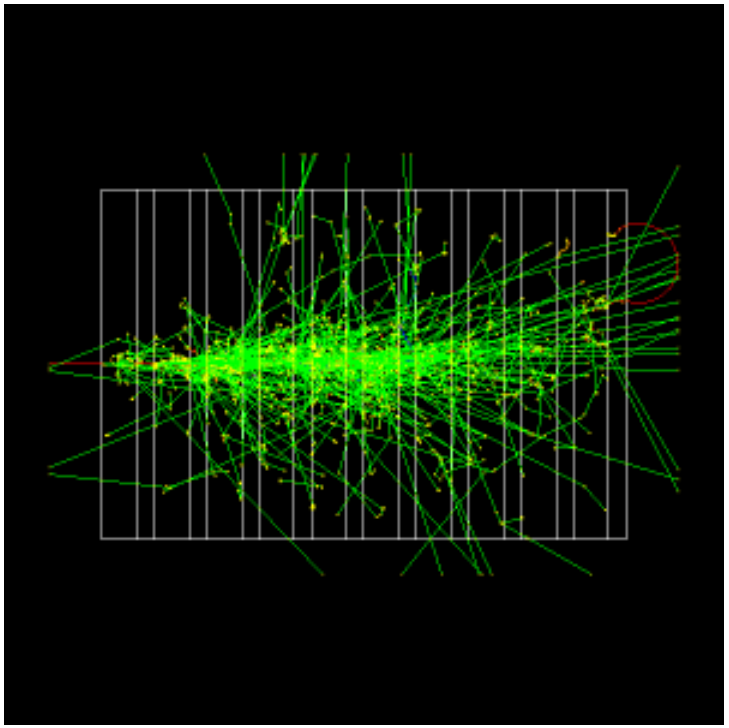
3 Digitizer results

Hadronic shower simulation

SDHCAL Simulation

- GEANT4 version 9.6
- SDHCAL geometry description : chemical composition ; density
- Particle propagation through steps :





Simulation output

- steps list inside RPC gas gaps
- deposited energy from these steps
- occurrence time of each step
- entrance and exit point positions of each step

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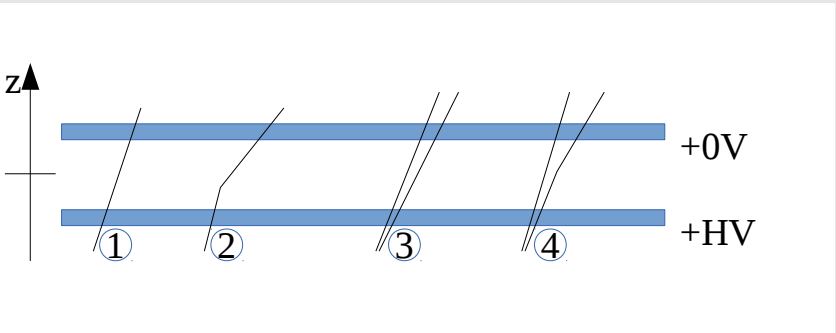

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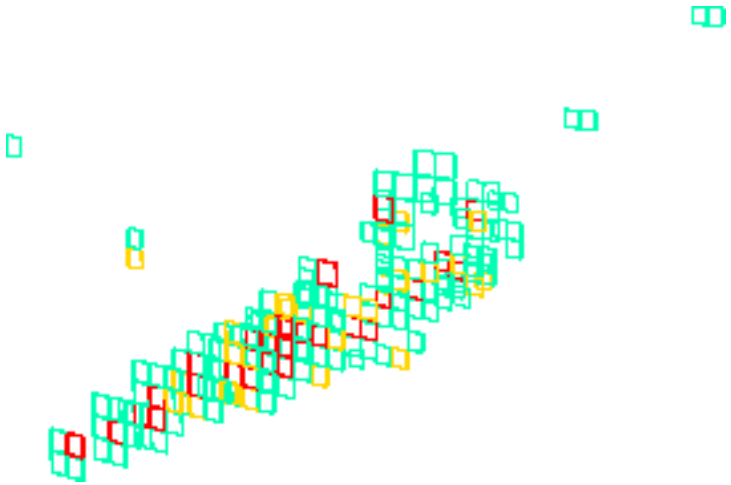
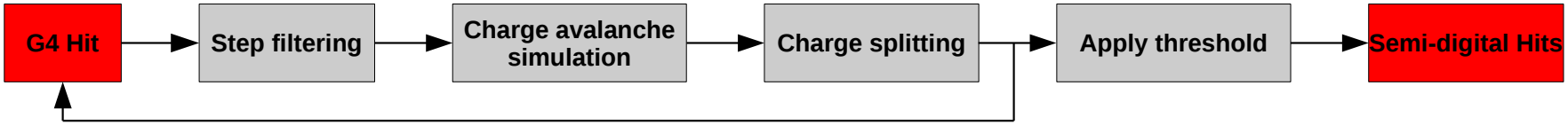


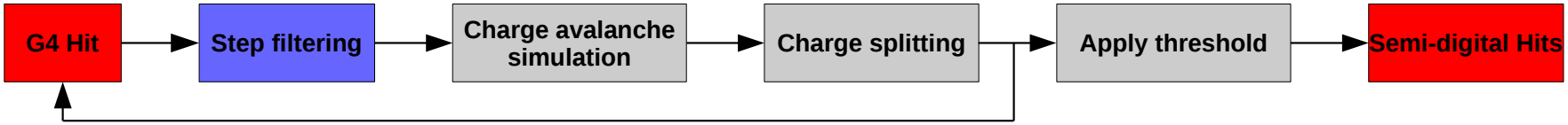
Digitizer goal

- Realistic simulation of the RPC response to charged particles
- RPC signal $\rightarrow$ induced charge
  GEANT4 $\rightarrow$ deposited energy by step
- Include multiplicity effect and detector efficiency
- Include charge screening

Digitizer method

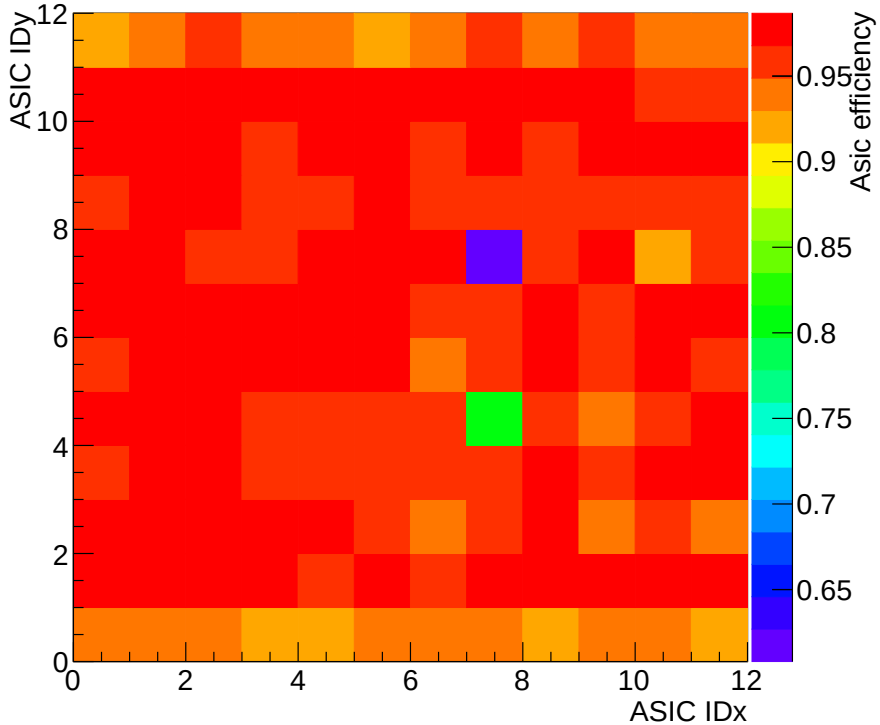


Digitizer method

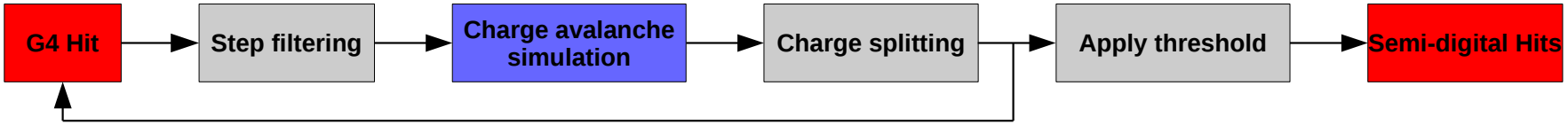


Step filtering

- Step occurrence time $< 1000\ ns$
- Step length $> 1\ \mu m$
- Efficiency map
- Charge screening (d_{cut} tuned with electromagnetic showers)



Digitizer method



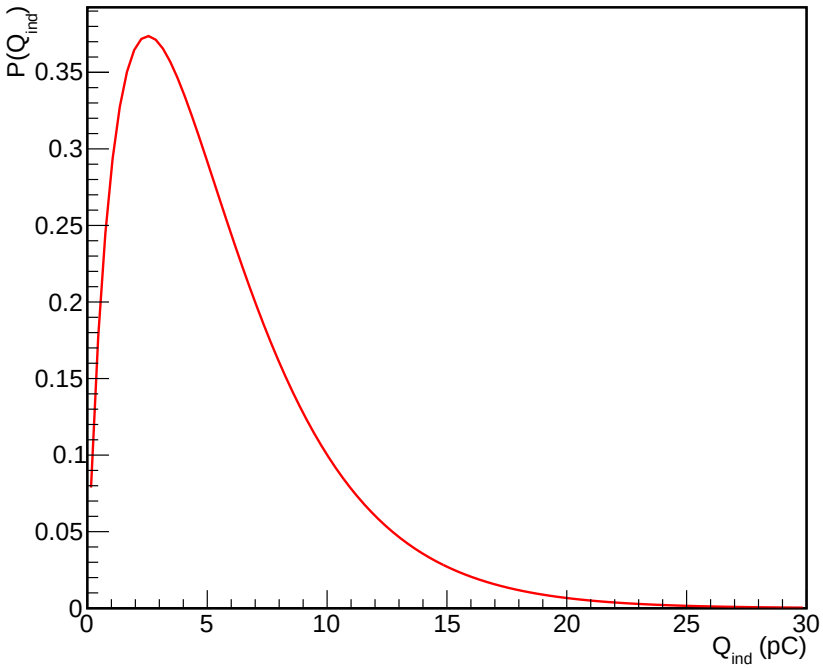
Charge avalanche simulation

- Charge randomly chosen in Polya distribution :

$$P(q) = \frac{1}{\Gamma(\delta+1)}\left(\frac{1+\delta}{\bar{q}}\right)^{\delta+1} q^{\delta} e^{[-\frac{q}{\bar{q}}(1+\delta)]}$$

- Length charge correction :

$$Q_{Corrected} = \begin{cases} Q_{ind}\left(\frac{d_s}{d_{gap}}\right)^{\kappa} & \text{if } \frac{d_s}{d_{gap}} > 1 \\ Q_{ind} & \text{otherwise} \end{cases}$$



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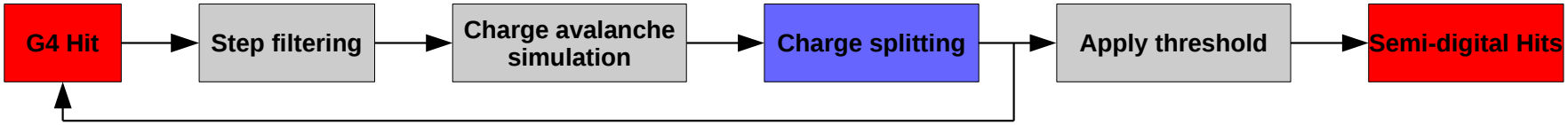
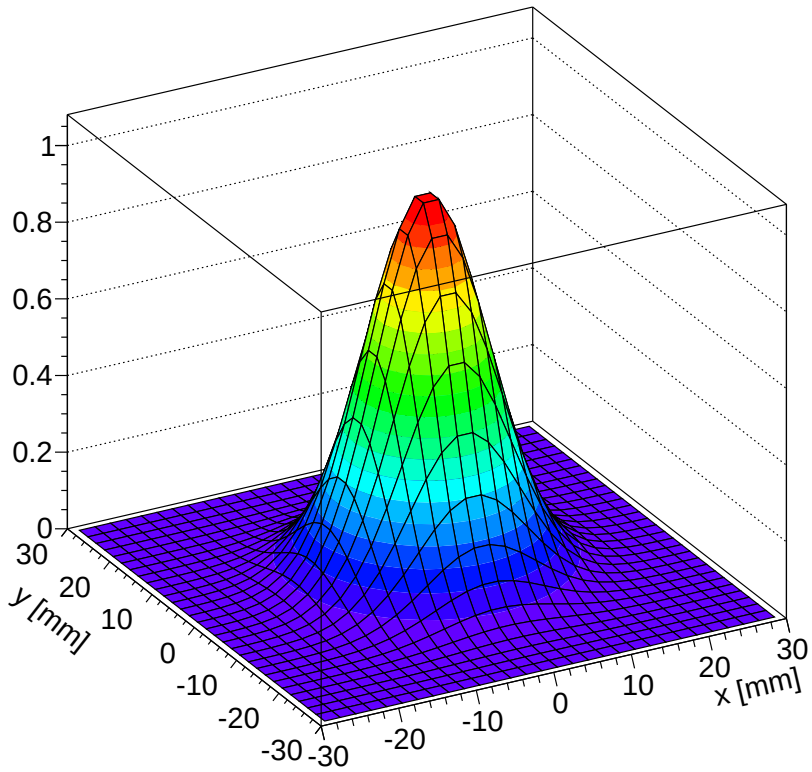


Charge spreading

$$R_i = \frac{\int_{a_i}^{b_i}\int_{c_i}^{d_i}\sum_{j=0}^{n}\alpha_j e^{\frac{(x_0-x)^2+(y_0-y)^2}{\sigma_j^2}}dxdy}{N}$$

- Charge in pad i incremented by $R_i Q_{corrected}$



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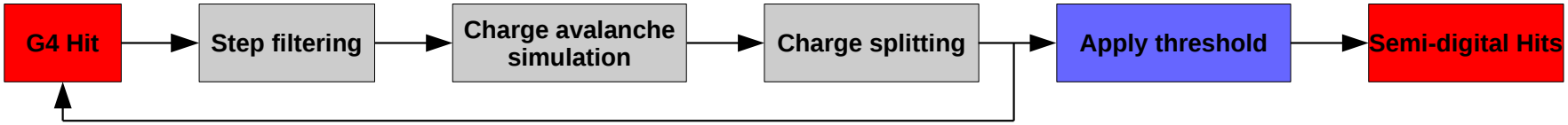
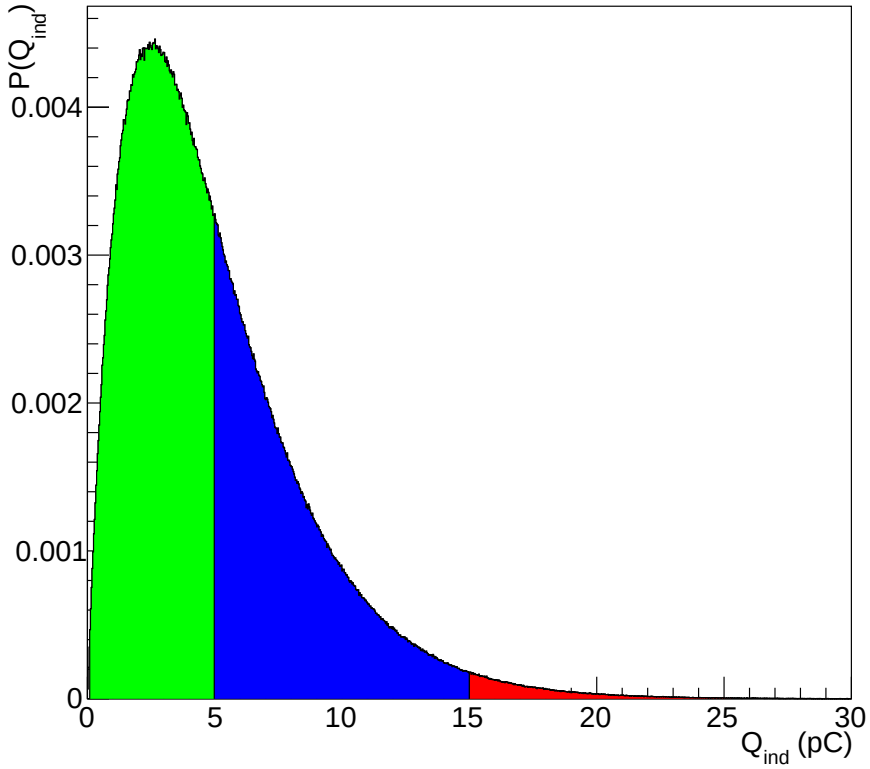


Thresholds

- Threhsolds 2 and 3 tuned with muon data to reproduce efficiency related to threshold 2 and 3



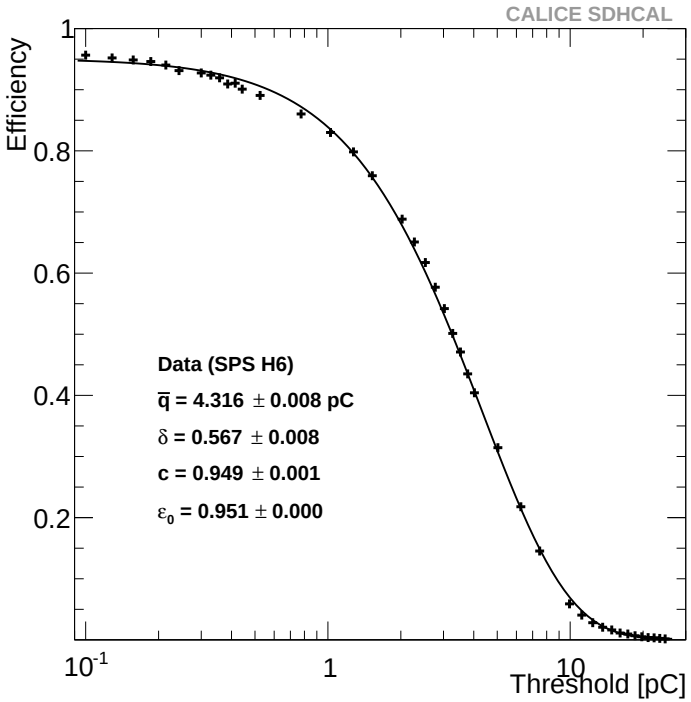
Digitizer parametrisation : threshold scan

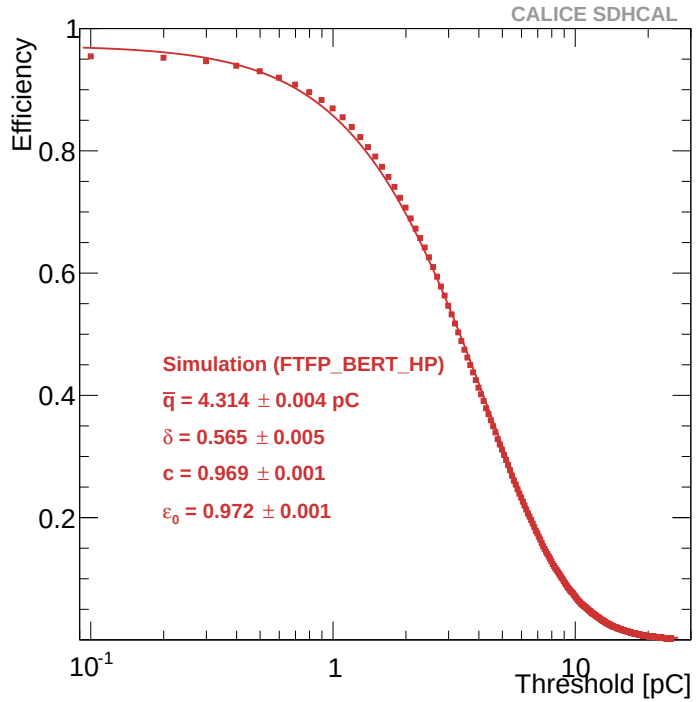
Threshold scan method :

- $\sim$ 20 dedicated muon runs
- Threshold variation in few chambers
- Efficiency reconstructed with tracks from other layers
- Fit the curve to extract $\bar{q}$ and δ parameters

$$\epsilon(q) = \epsilon_0 - c \int_0^q P(q')dq'$$

Polya parameter	Digitizer input value
$\bar{q}$	4.58 pC
δ	1.12





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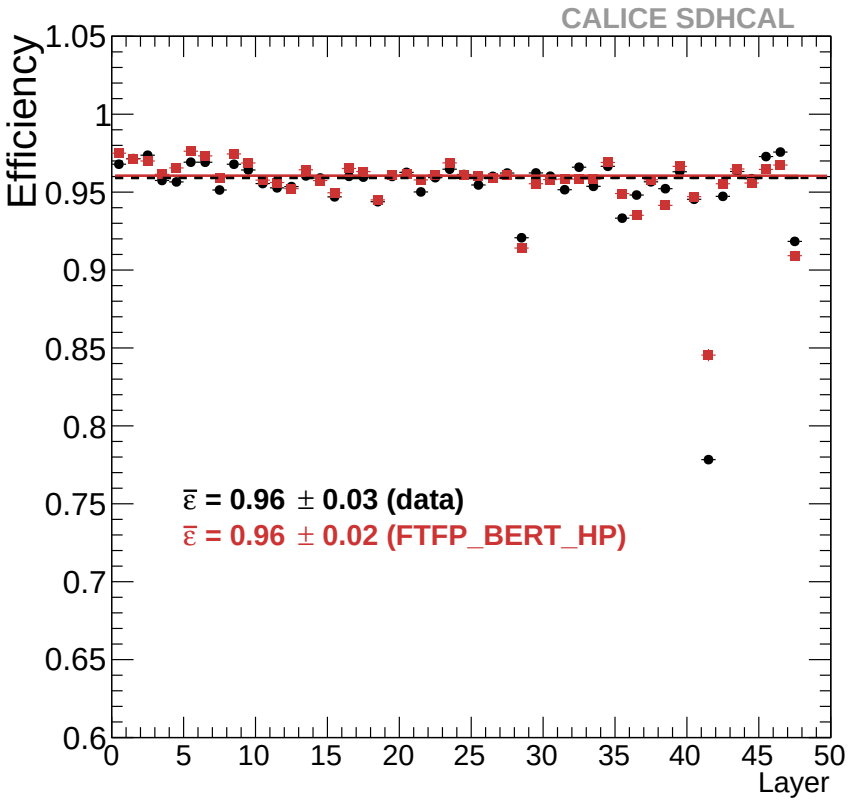

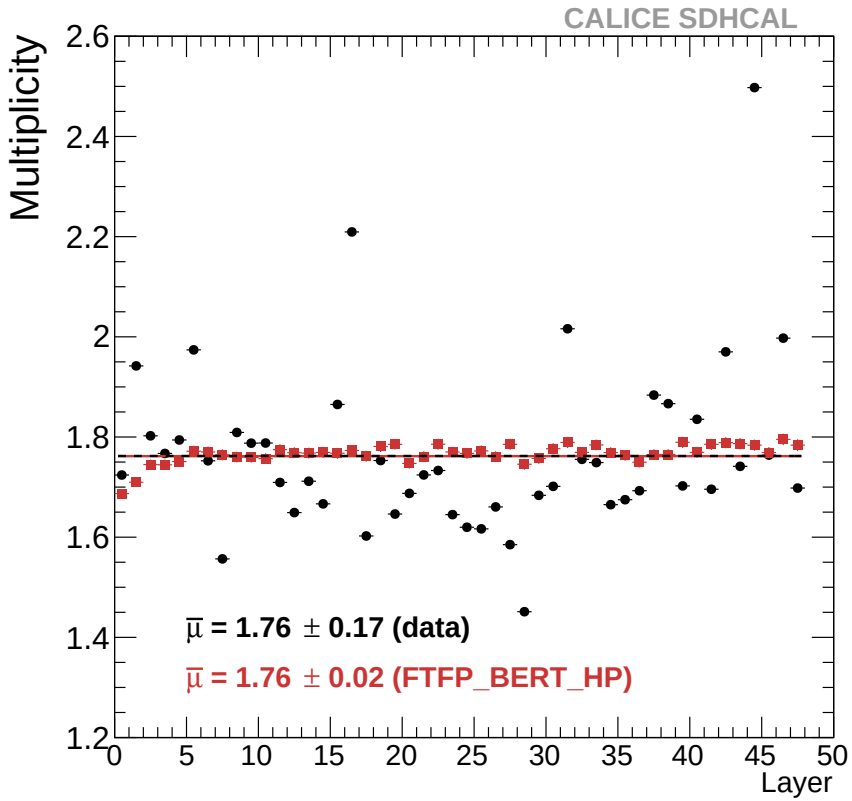

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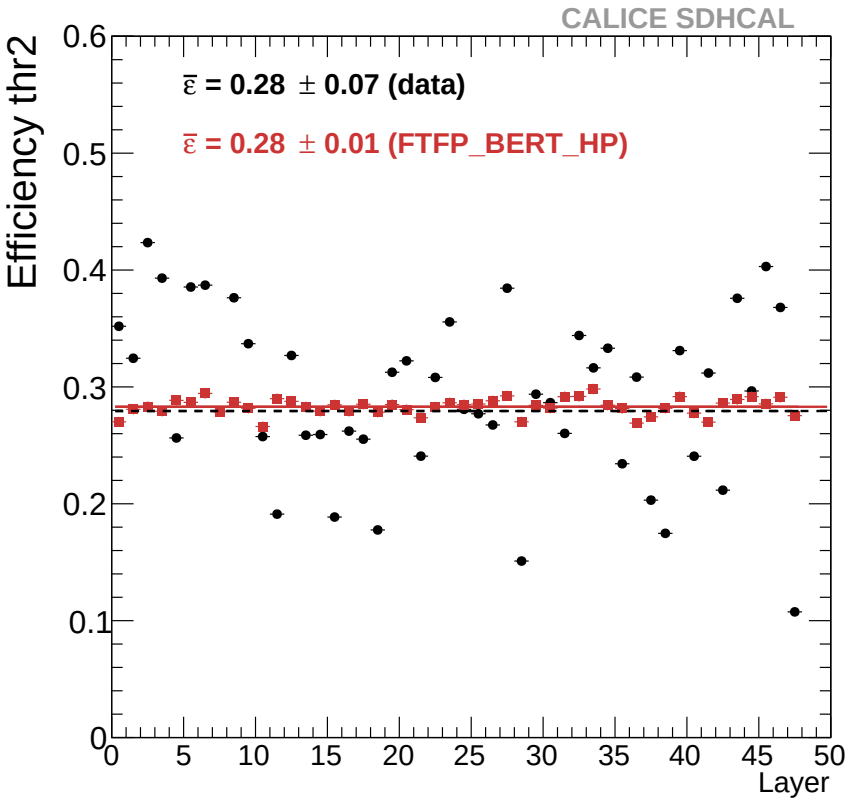
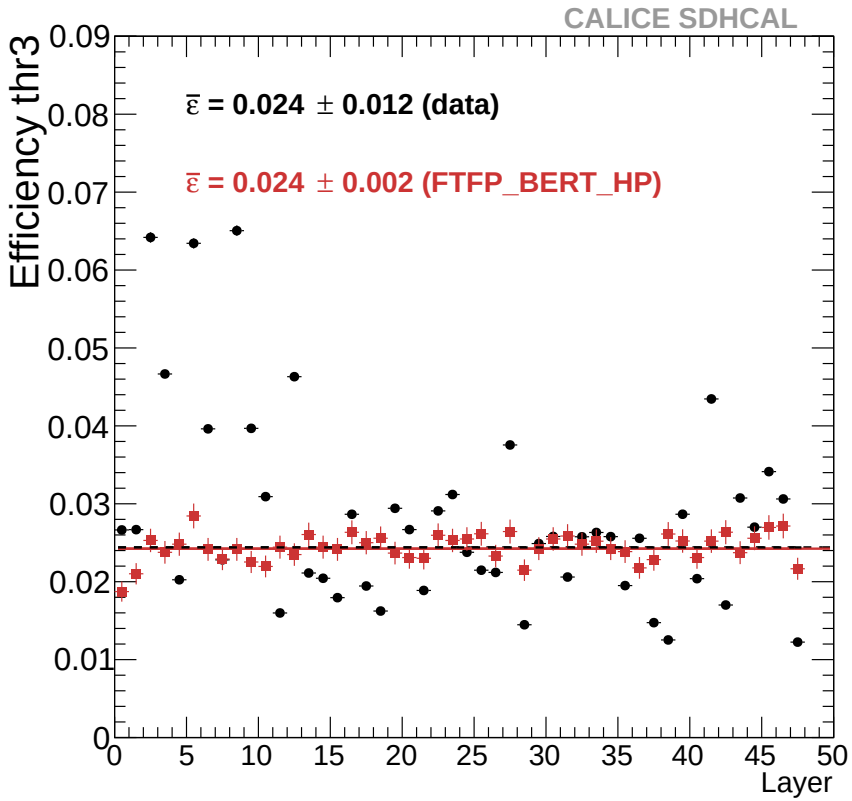
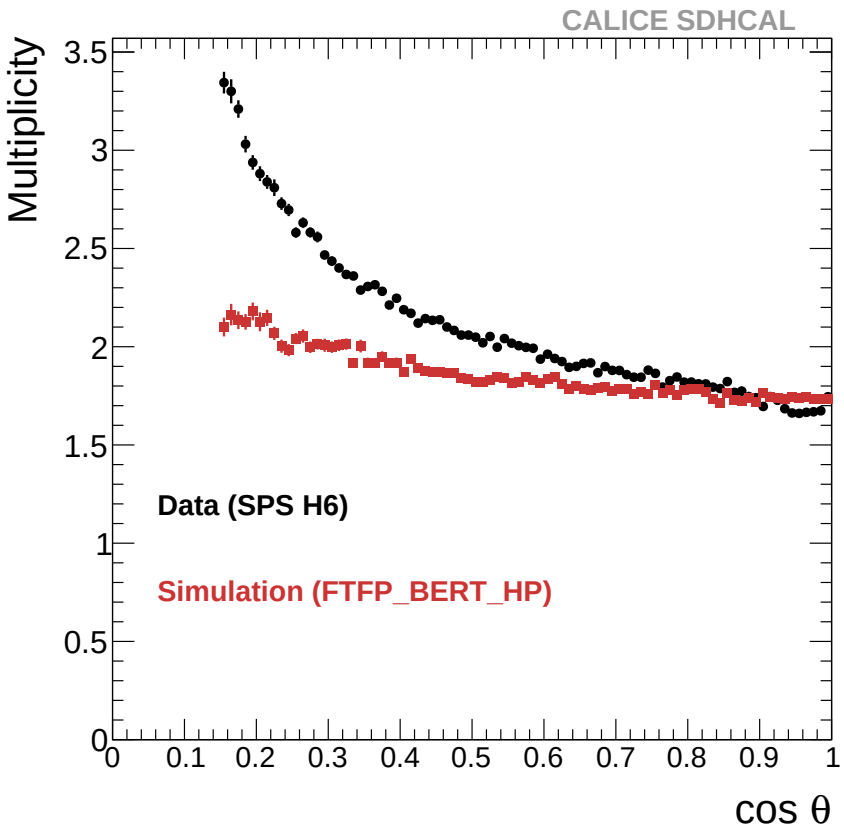


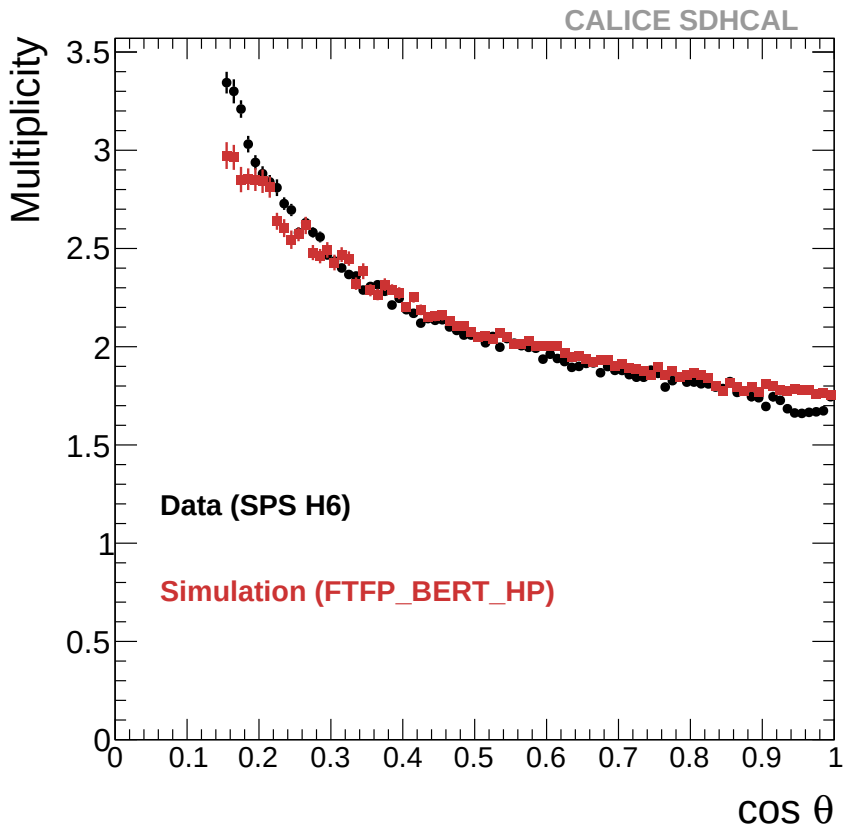


Digitizer parametrisation

Before length correction



After length correction



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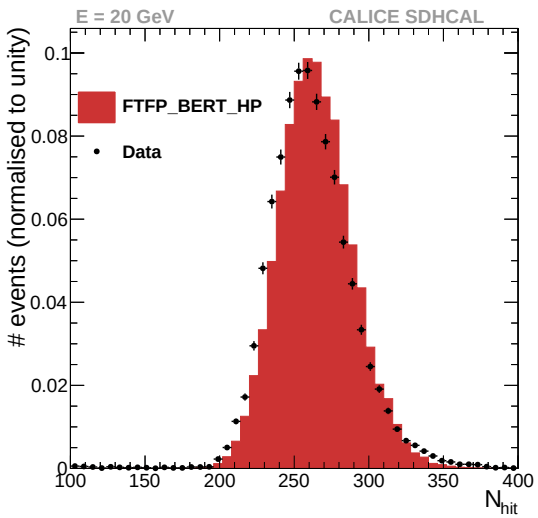
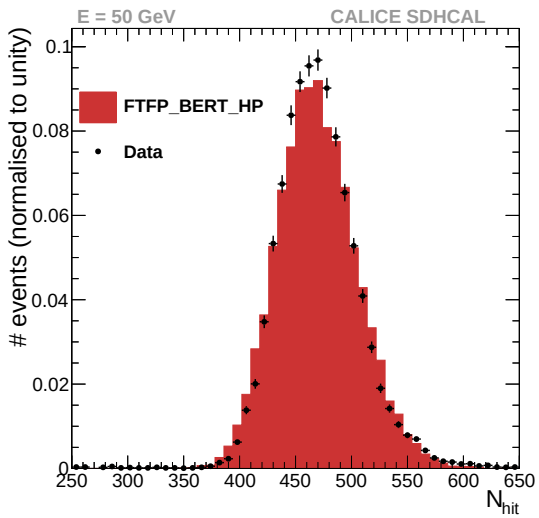
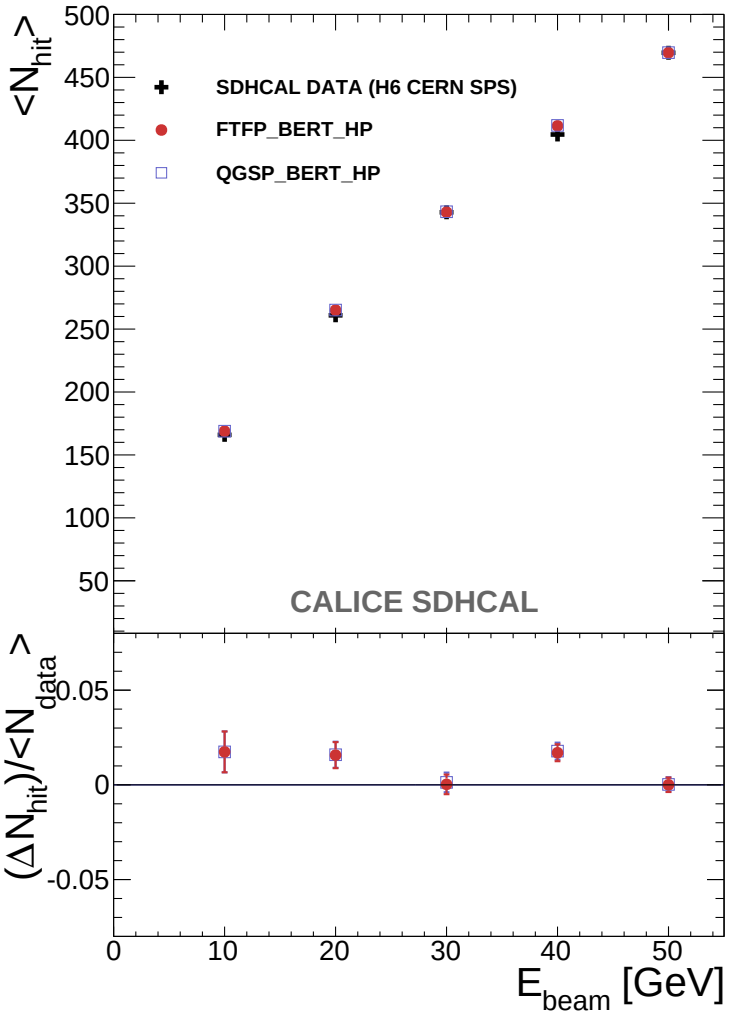
Validation with electromagnetic showers

Electromagnetic showers

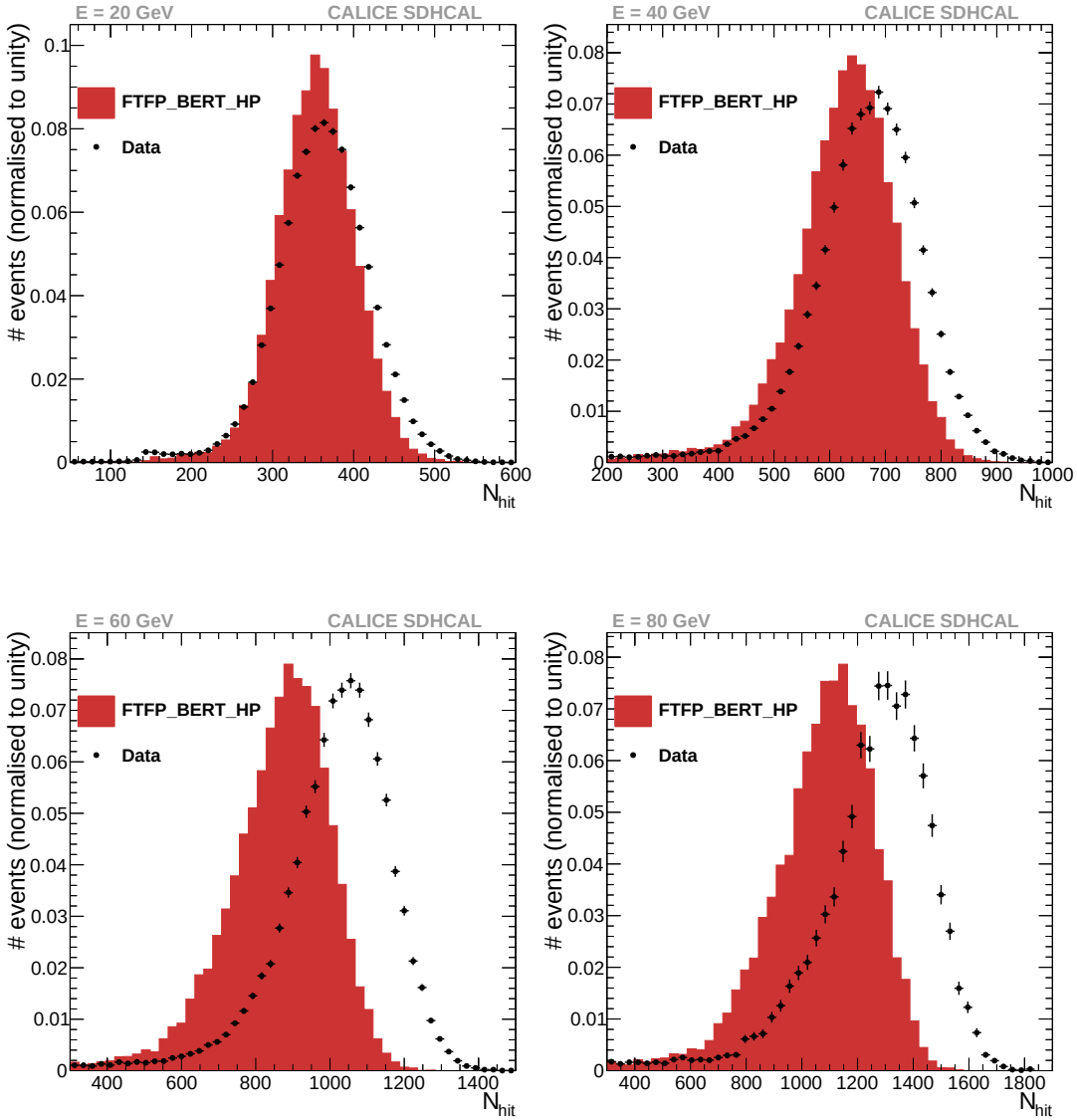
- Digitizer parameter tuned with EM showers (d_{cut})
- EM shower selection :
  $N_{tracks} = 0$ & $P_{start<5}$ & $N_{layers} < 30$
- Selection efficiency $\geq 98\,\%$
- Relative deviation $< 3\%$

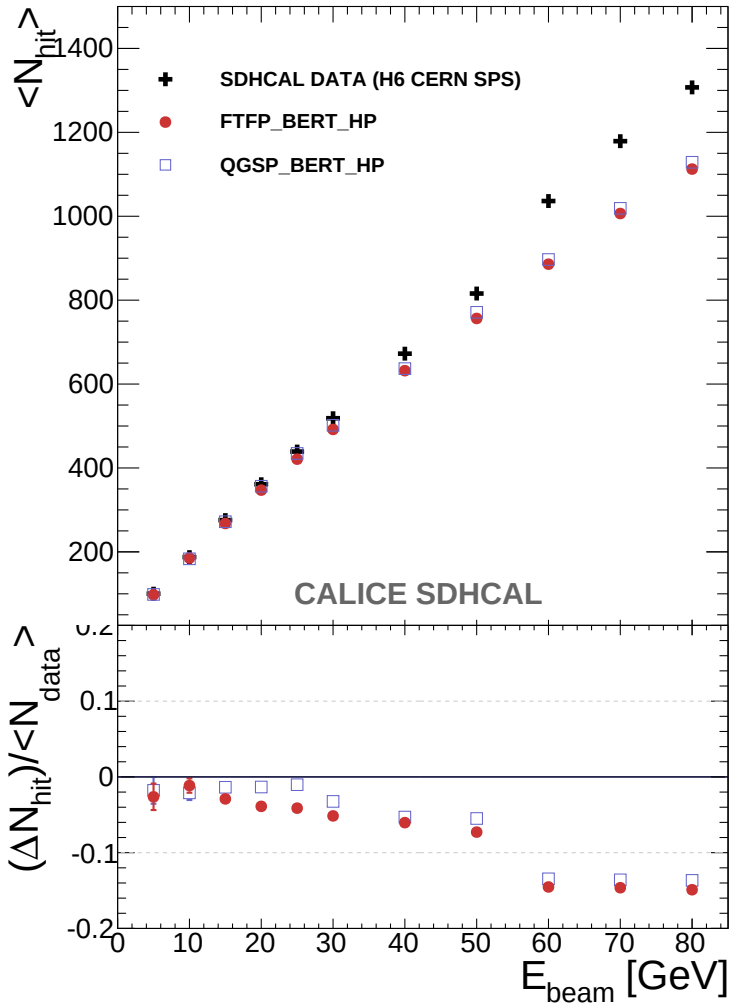






Comparison with hadronic shower data





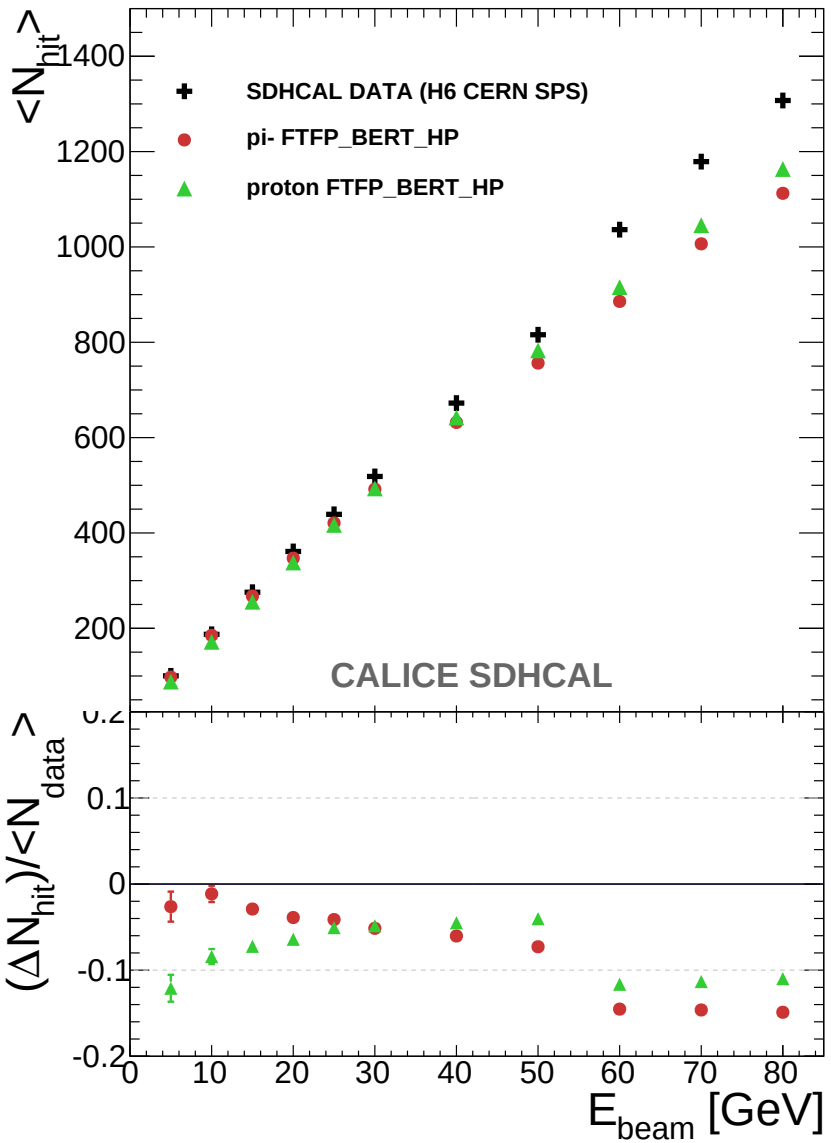
Comparison with hadronic shower data

H6 proton contamination

- E. Abat et al., *Study of energy response and resolution of the ATLAS barrel calorimeter to hadrons of energies from 20 to 350 GeV*

Beam energy	Fraction of protons
50	0.45 ± 0.12
100	0.61 ± 0.06

- Pion interaction length in steel : $\lambda_I^{\pi} \simeq 20.4$ cm
- Proton interaction length in steel : $\lambda_I^{p} \simeq 16.8$ cm



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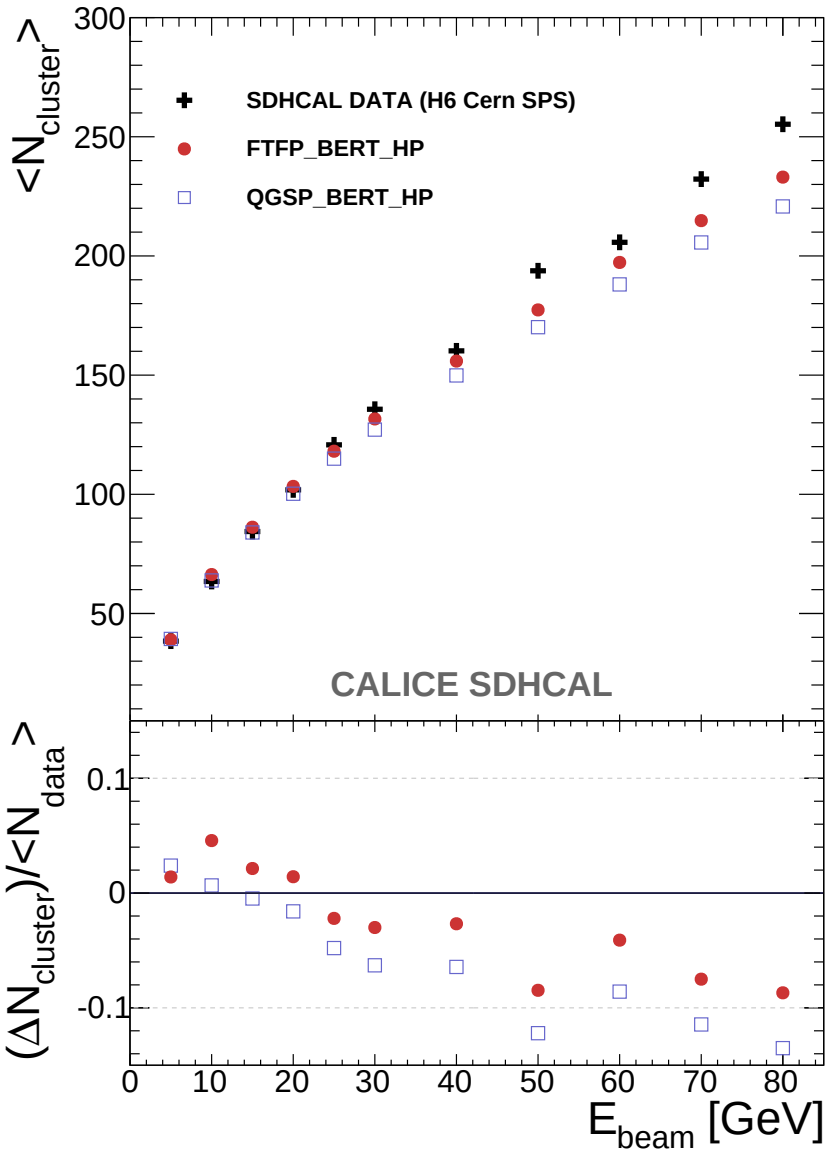
2D clusters

- More independent from digitizer parametrization
- Hits are gathered into a cluster if they share an edge

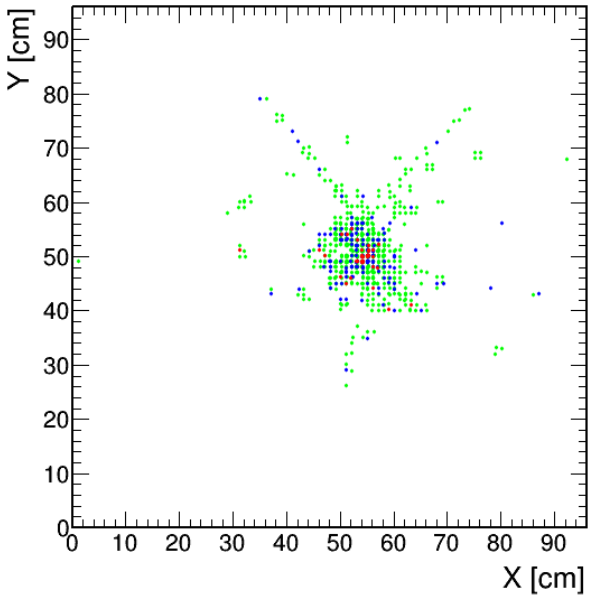


Radial shower profiles

Radial profile

- Hits counted in 1 *cm* width rings around shower axis
- Mean radial profile :

$$< R >= \frac{1}{N_{event}} \sum_{i=0}^{N_{event}} \sum_{r=0}^{R_{max}} r \frac{N_{r,i}}{N_{tot,i}}$$



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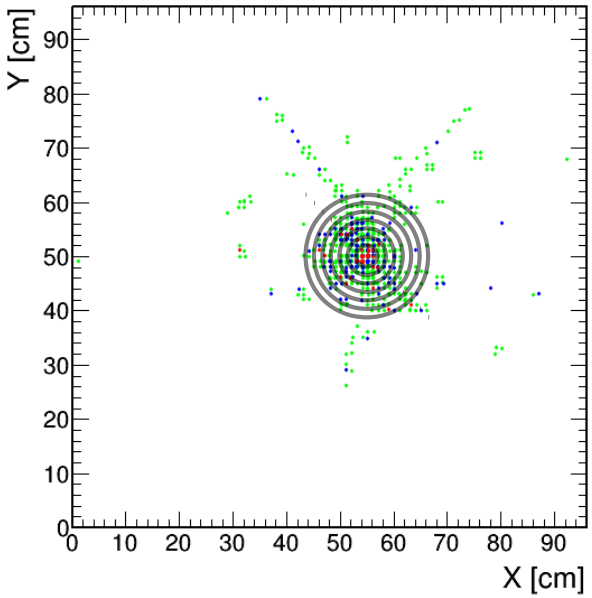

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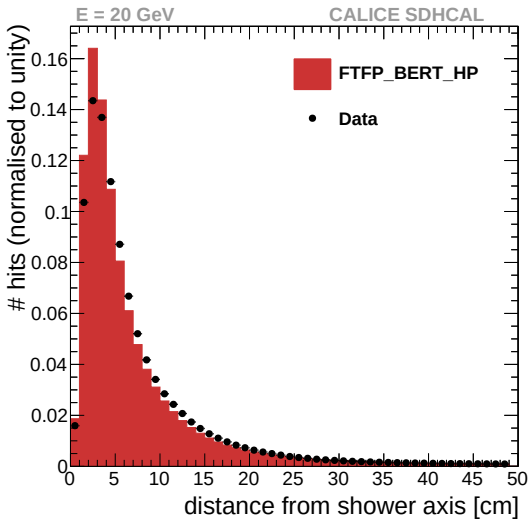
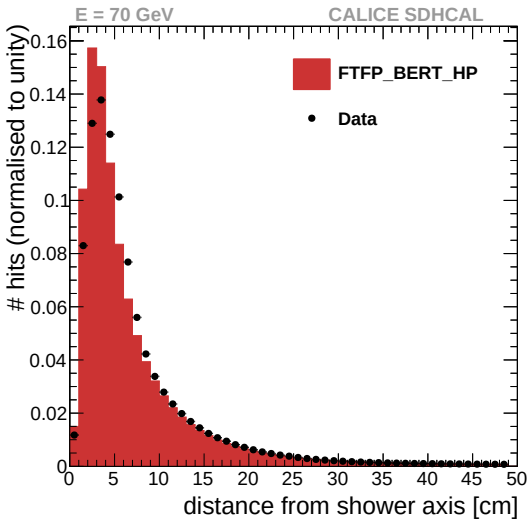
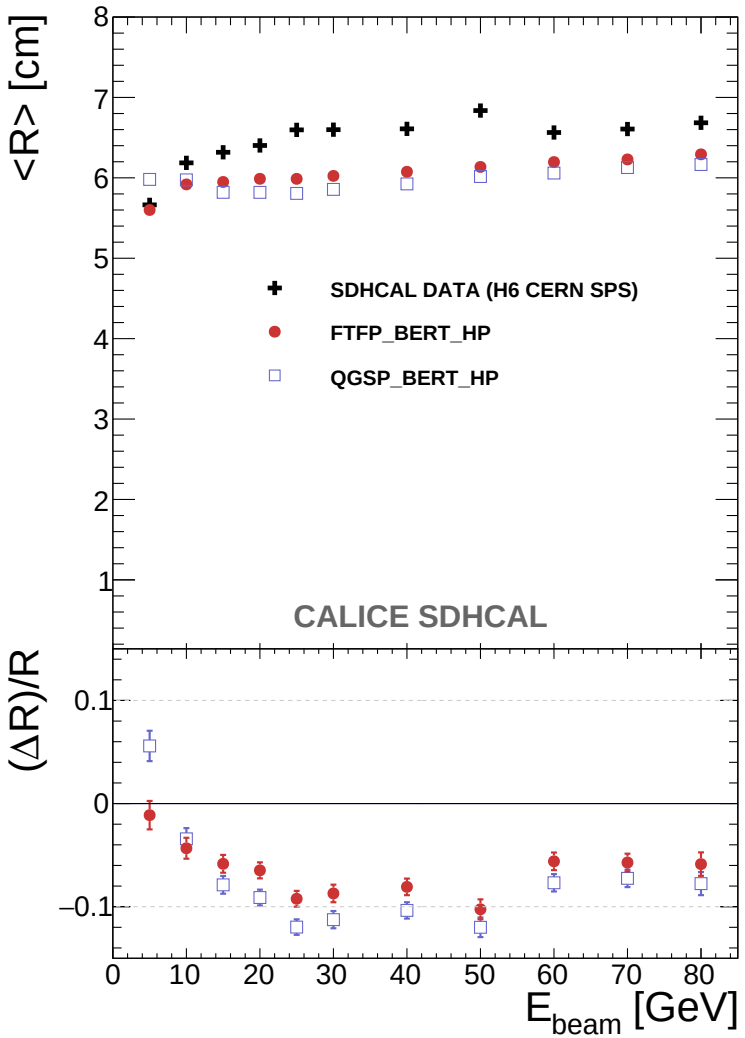






Conclusion

Simulation and digitization

- Digitizer parameters extracted from muon and electromagnetic shower data :
  - Polya parameters extracted from threshold scan
  - Efficiency and multiplicity well reproduced
  - Step length correction improve multiplicity behaviour with angles
  - Threshold values (2 and 3) set to reproduced the efficiency for high thresholds
  - d_{cut} tuned to reproduced electromagnetic shower response

Comparison with data

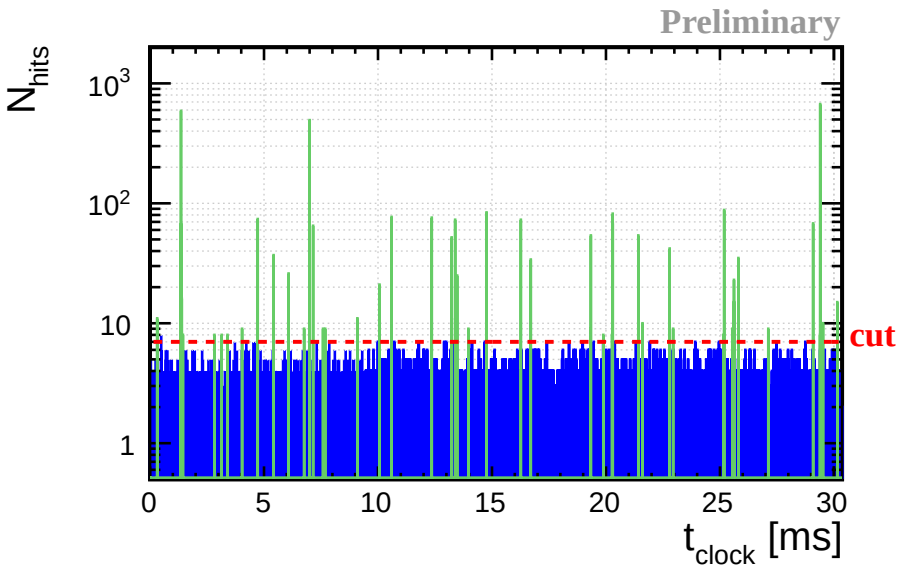
- Discrepancies about hadronic shower response between data and simulation appear at high energies
- Discrepancies still present in number of reconstructed clusters
- Simulation models seem to underestimate the radial extent of hadronic showers

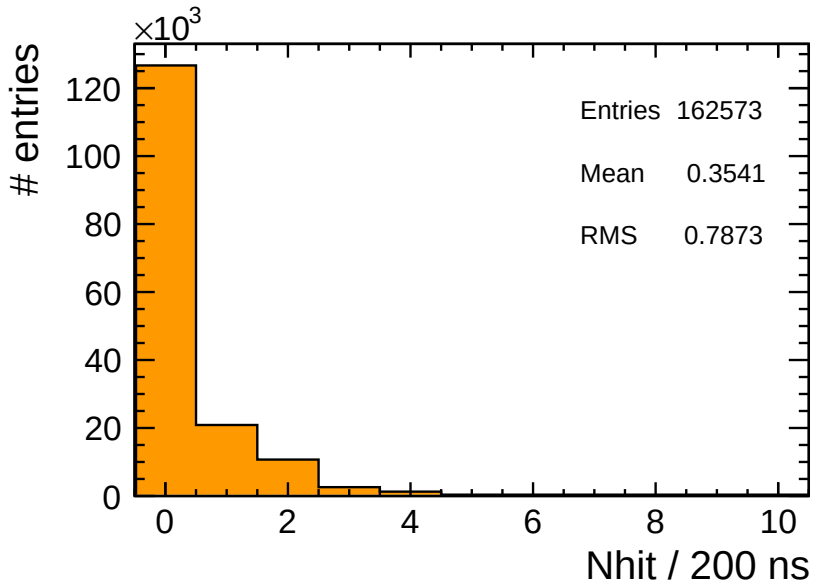
Back-Up

Physical event reconstruction

Physical event reconstruction

- Hits recorded using 200 *ns* internal clock
- Seed t_0 if $N_{hit}(t_0) > 7 +$ local maximum
- Aggregate hits | $t = t_0 \pm 2 \times 200\,ns$
- Noise estimation within rejected hits



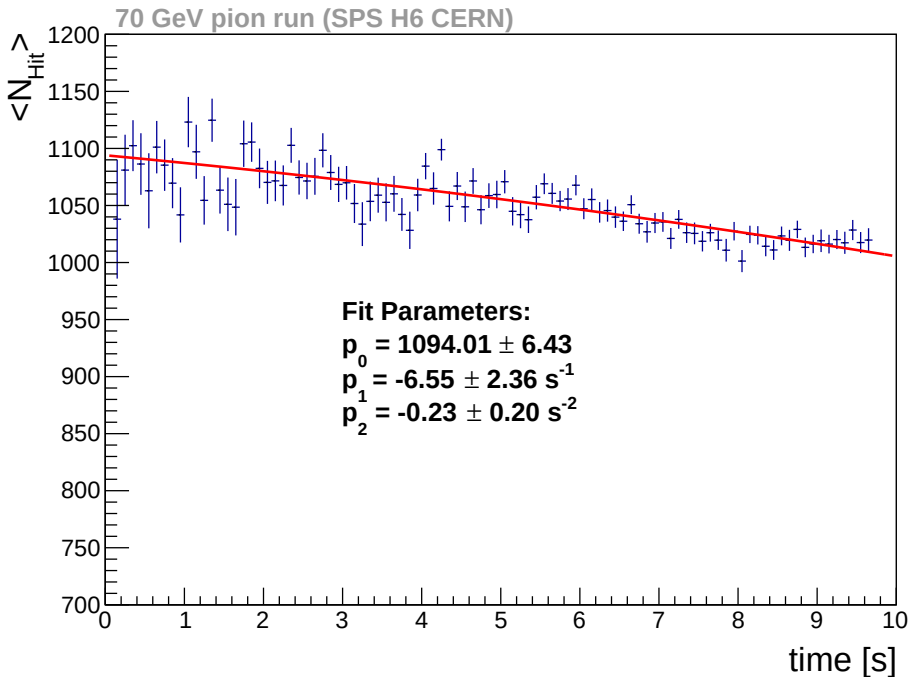


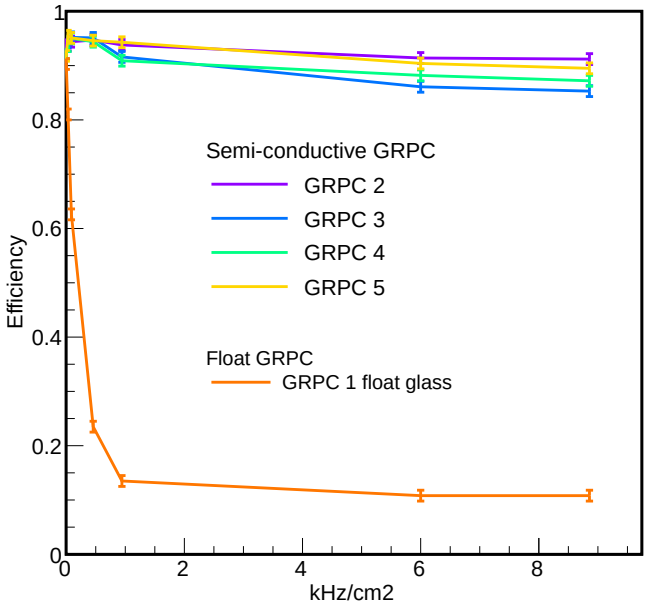
SDHCAL Time calibration

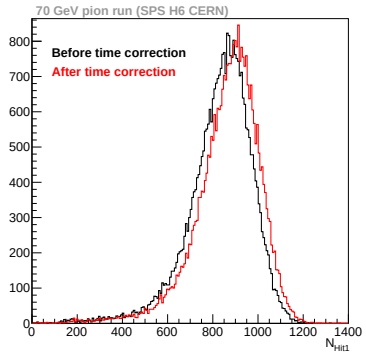
Time calibration

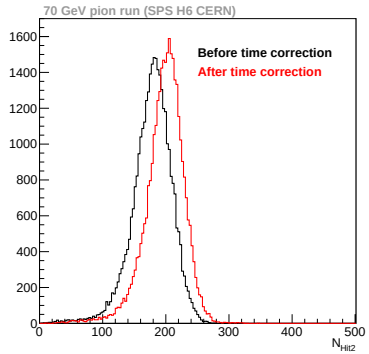
- Glass resistivity $\approx 10^{12} \Omega m$
- Highest particle rate detection : 100 $Hz.cm^{-2}$
- 1 calibration per run for each threshold :

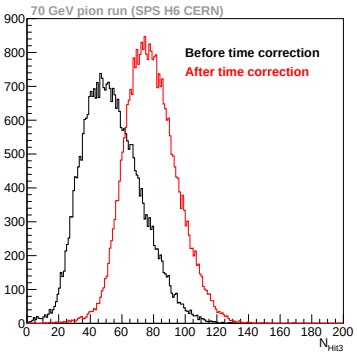
$$N_{corr,i} = N_i - \sum_{j=0}^{d} p_{j,i} t^j$$











Hadronic shower identification

Topological selection

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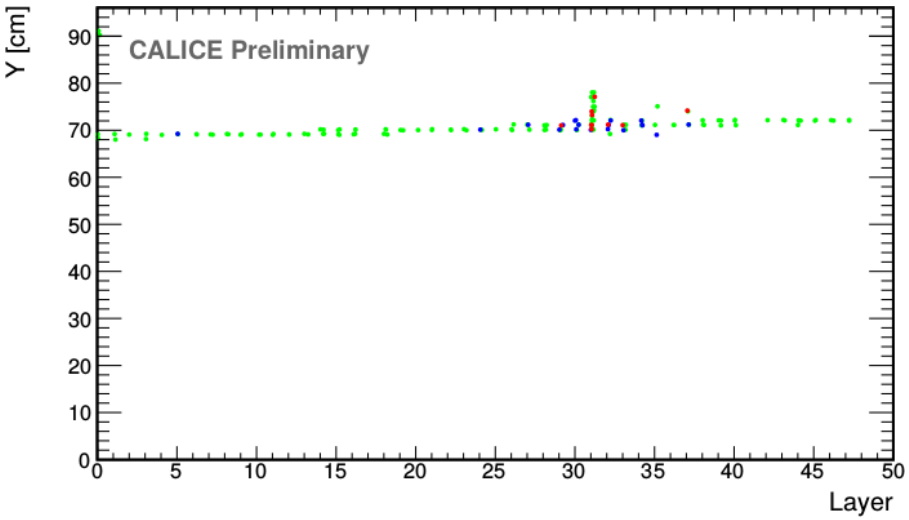
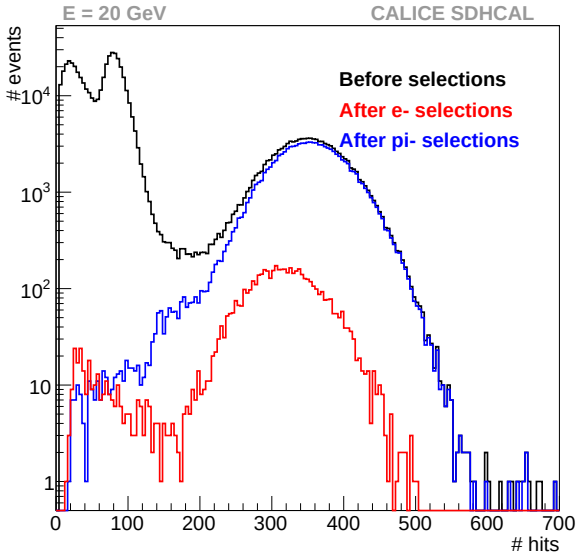
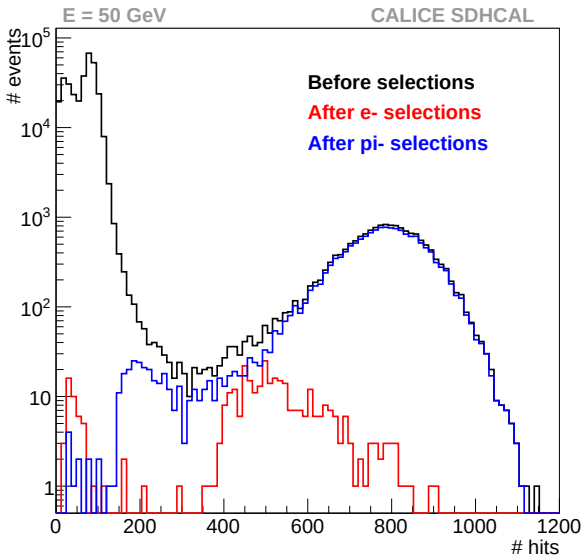
- Electromagnetic showers rejection (compact shower)
- Proton contamination on H6







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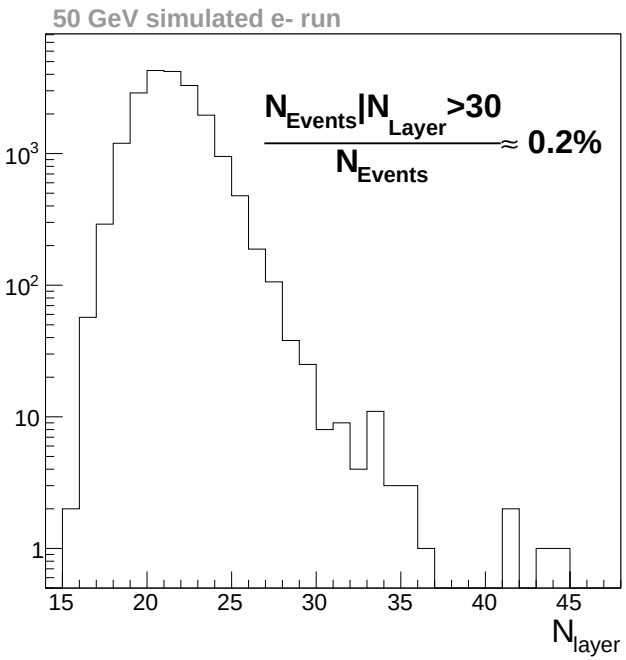
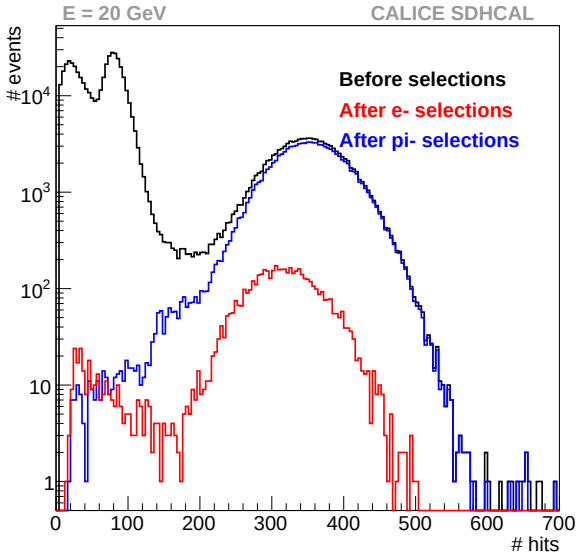
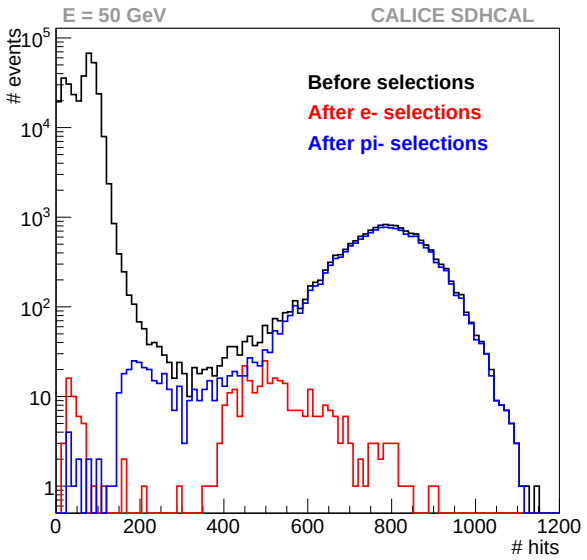
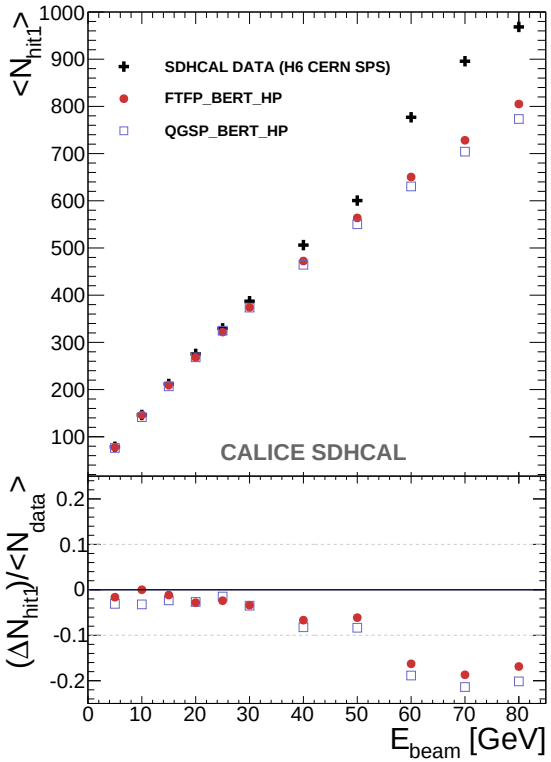
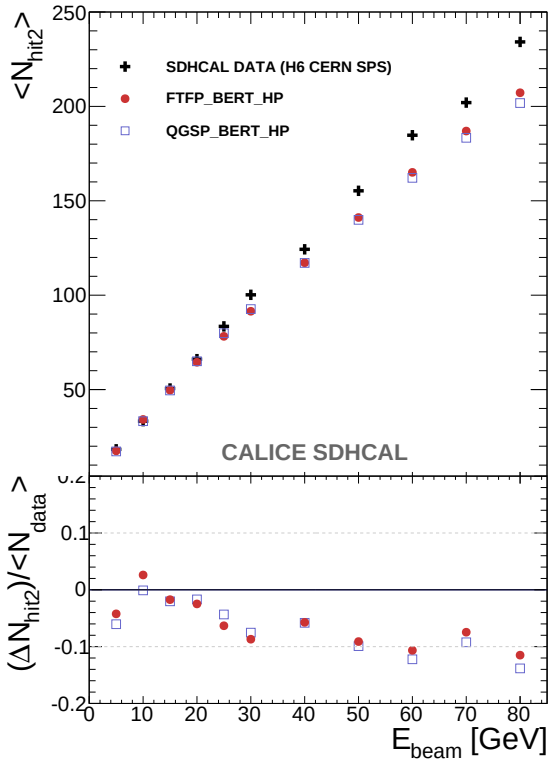


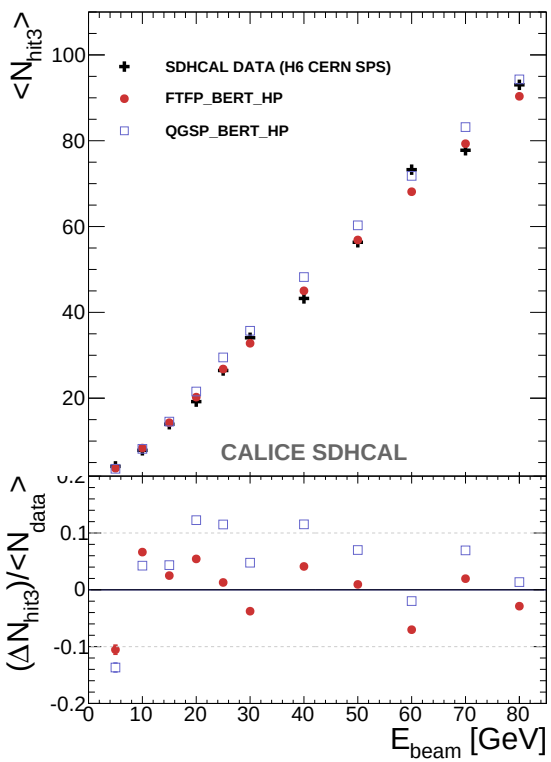




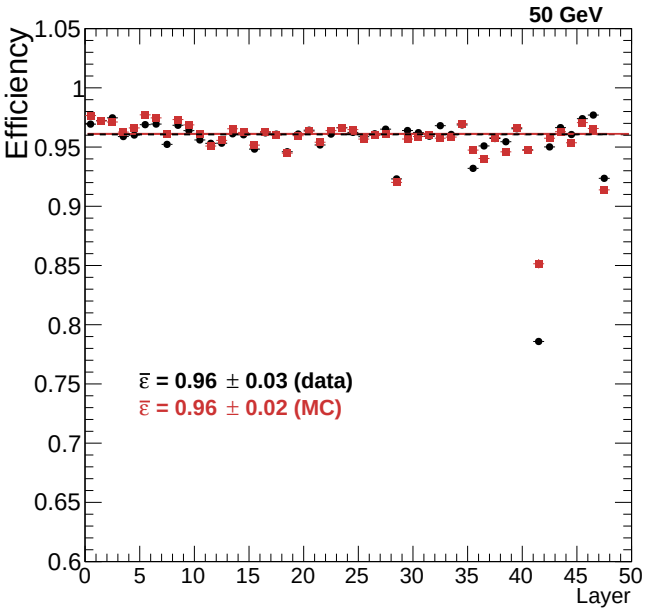
Number of hits per threshold

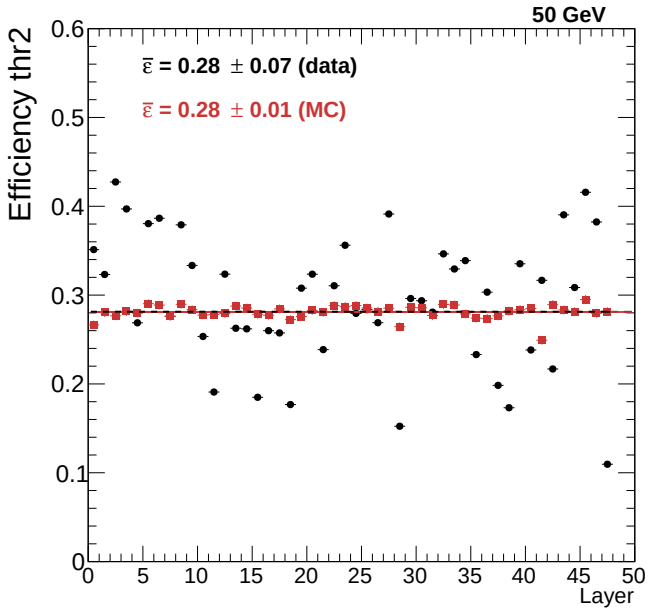


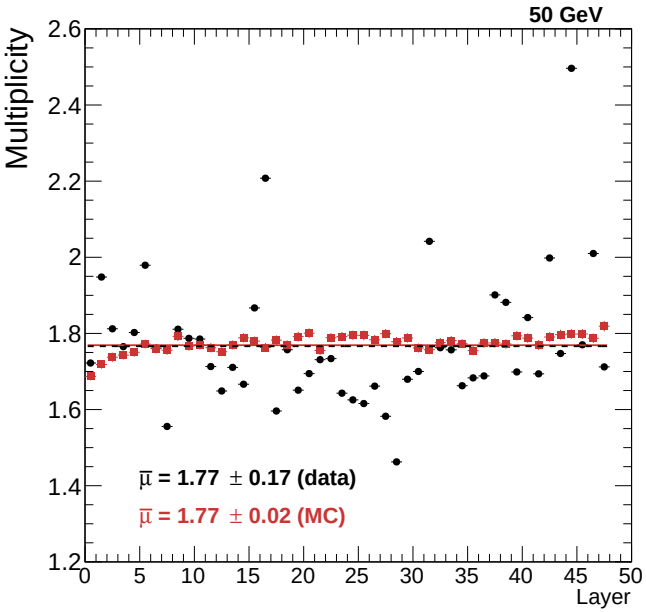


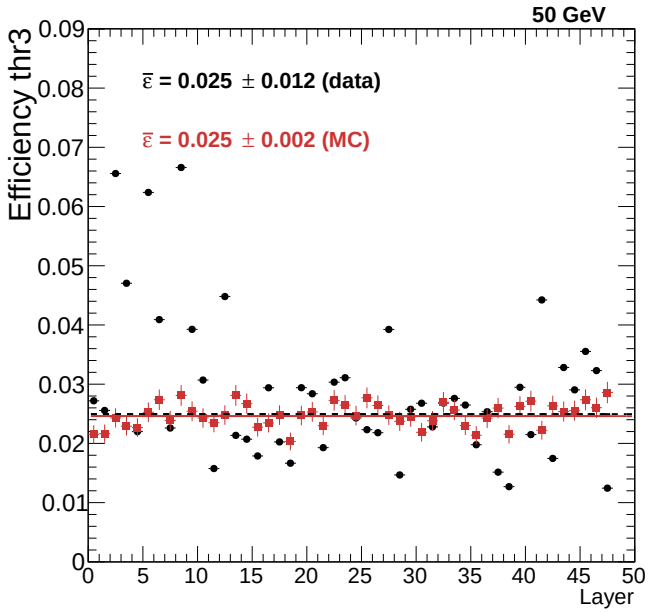
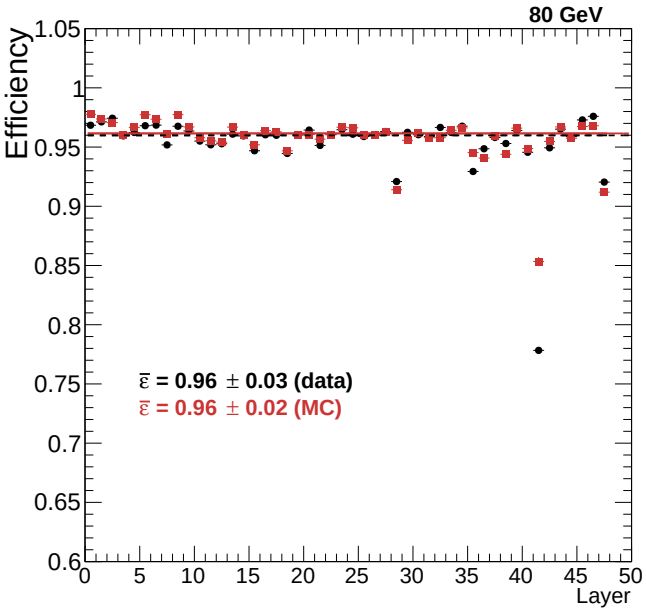
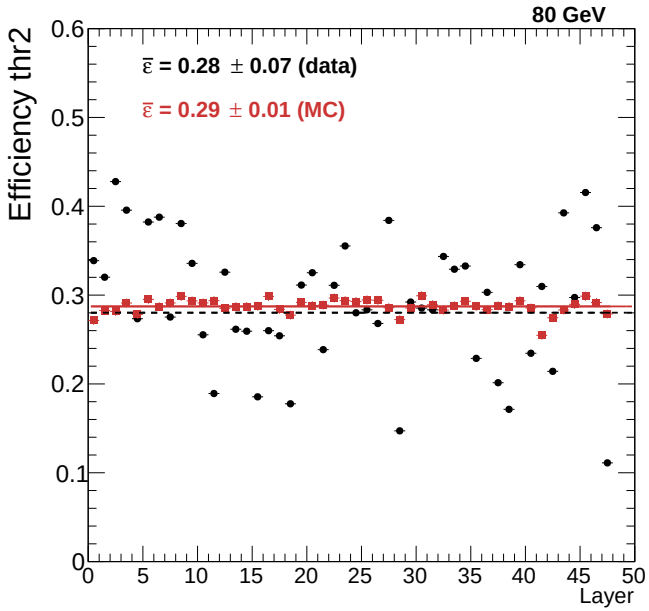
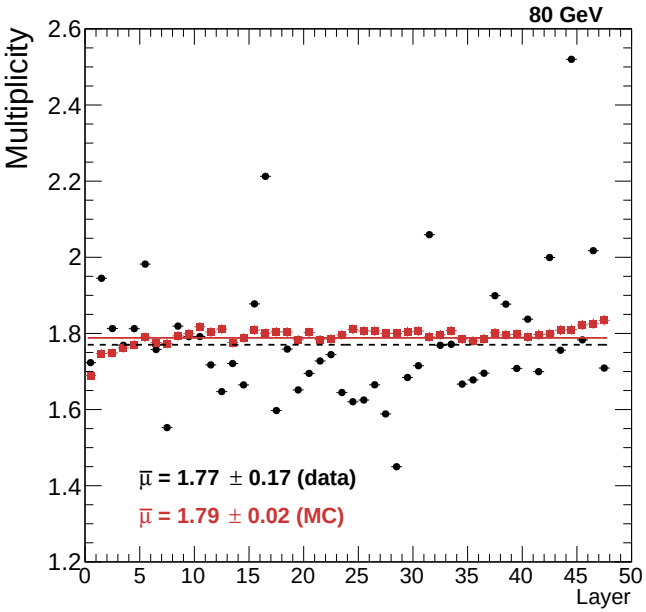
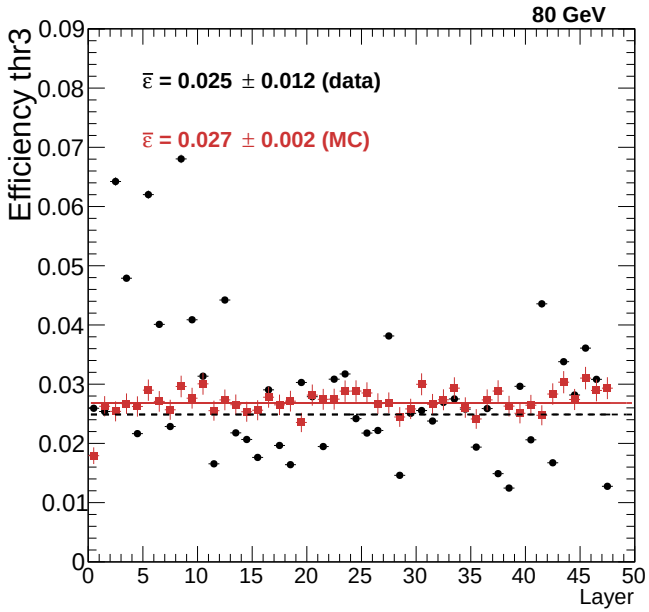


Digitizer parametrisation









Digitizer parametrisation