The SDHCAL Simulation

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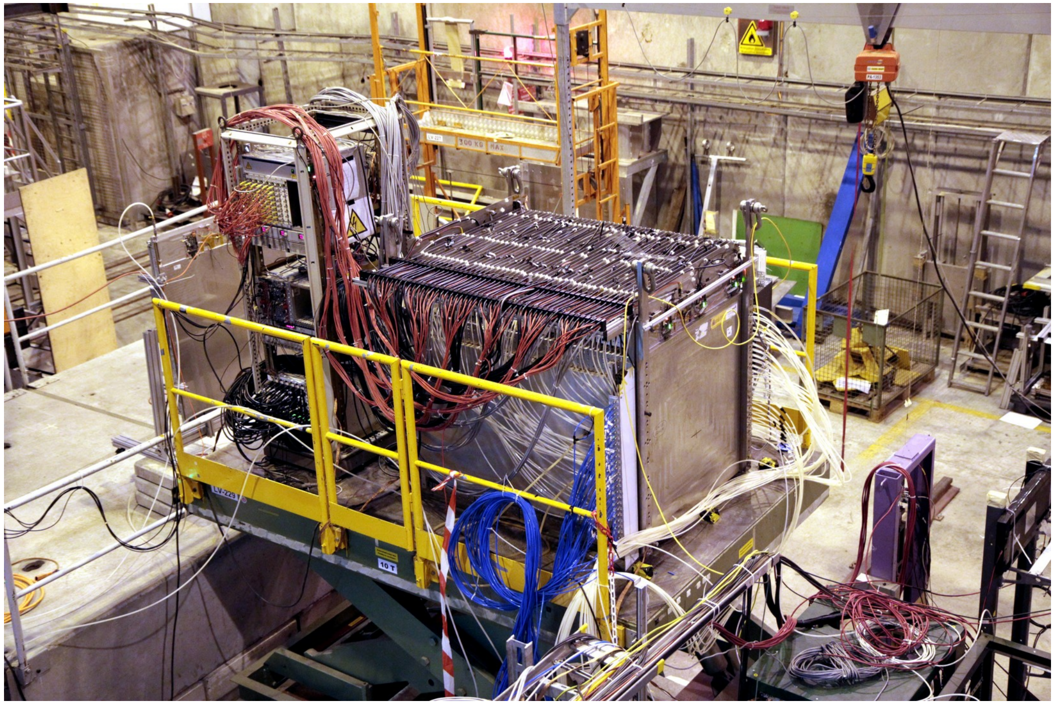
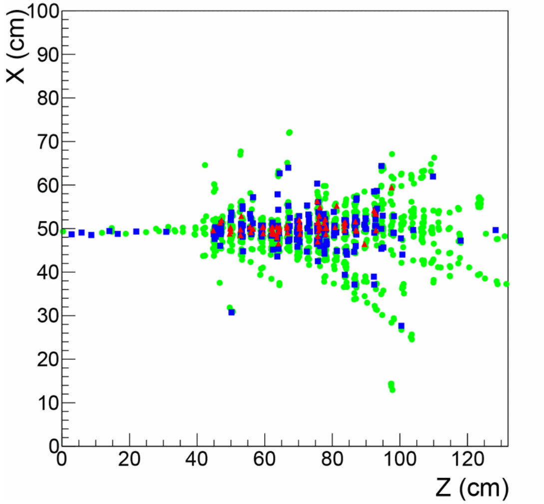
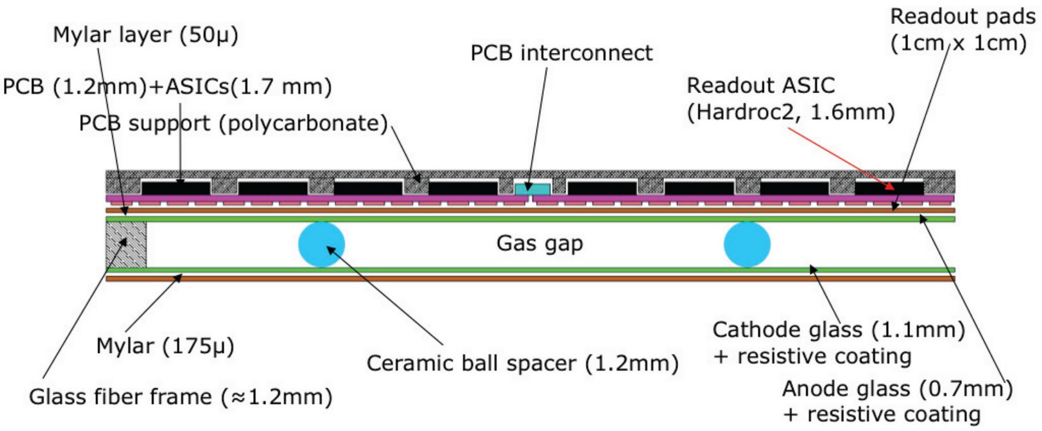
SDHCAL Prototype

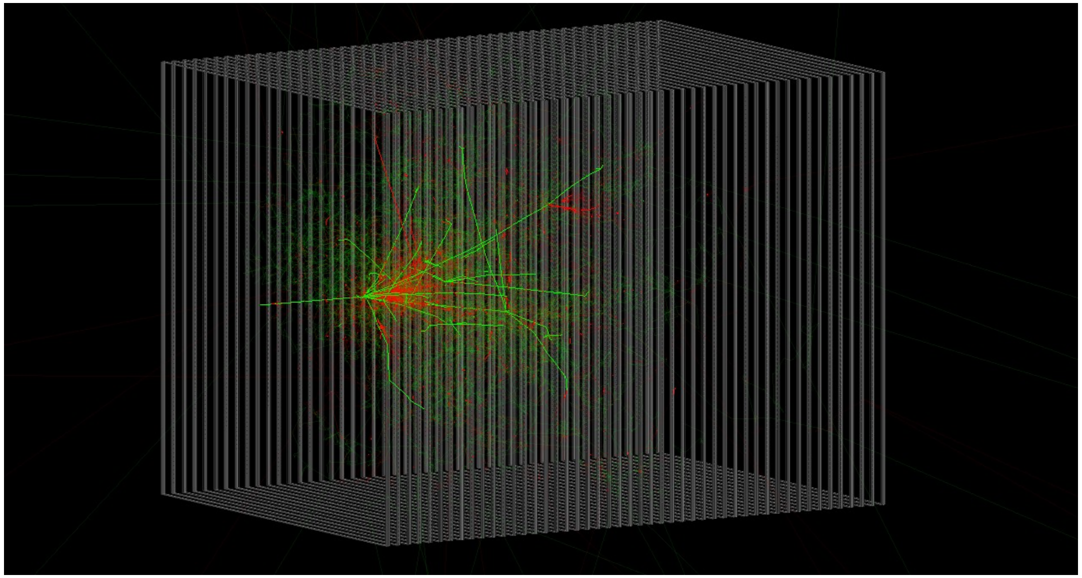
- Sampling calorimeter :
  - 48 GRPC sandwiched by 2cm of steel
- 1m x 1m x 1,3m
- 6 λ_I depth
- ~ 440000 1cm x 1cm readout pads
- 144 HARDROC2 per chamber
- 2 bit readout
  - Thresholds : 0,114pC, 5pC, 15pC



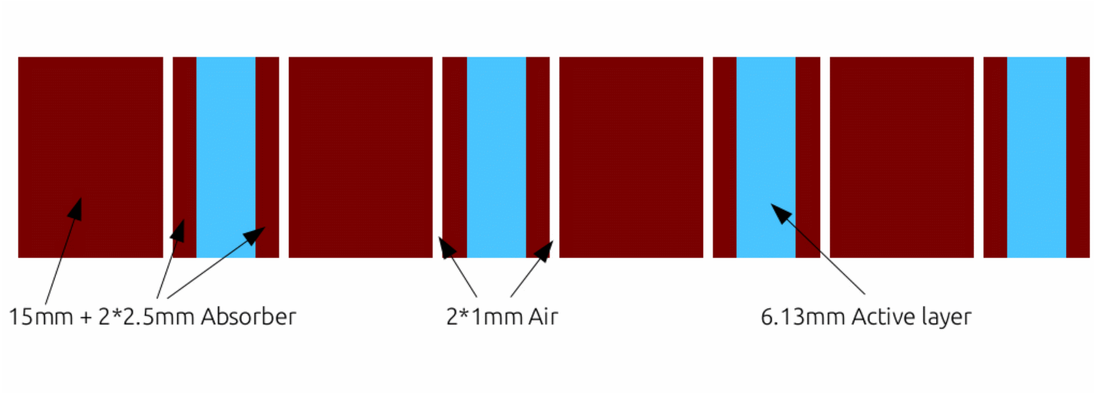


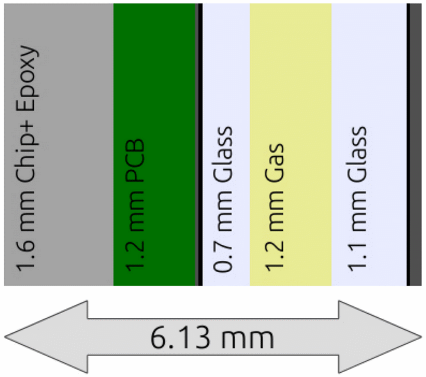


- Standalone GEANT4 program
- Detector geometry described as precisely as possible
- Outputs the list of steps for charged particles that crosses the gas gaps

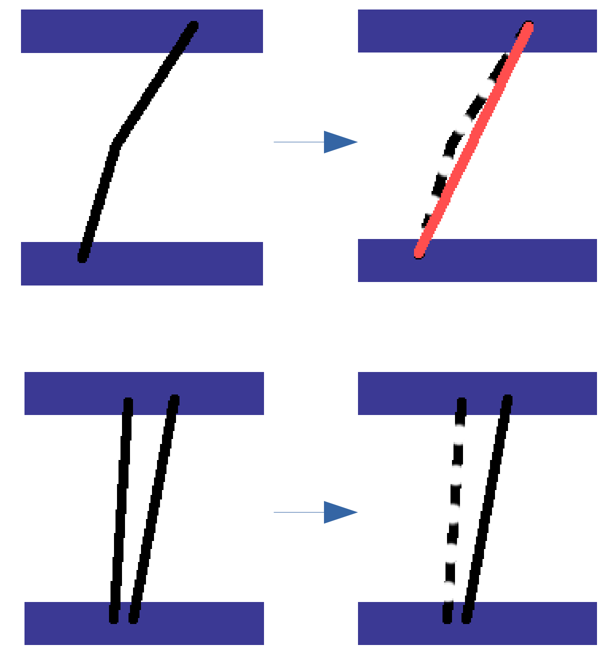


- To simulate the RPC response, a digitizer program is then applied



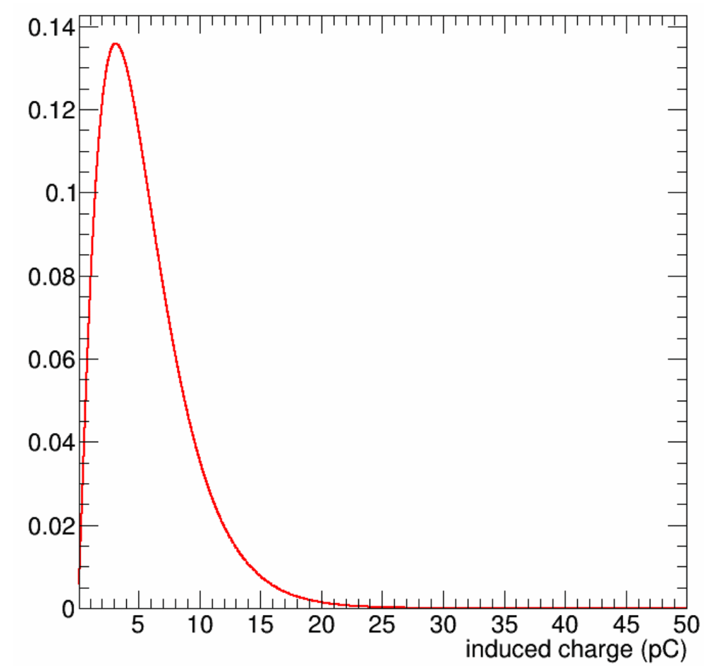


Digitization procedure



- Steps belonging to the same particle are linked together
- To reproduce the screening effect from close electronic avalanches, adjacent steps are removed if they are closer to a parameter $\mathbf{d}_{\mathbf{min}}$
- To reproduce the detection efficiency ε of the detector, the steps are randomly removed with a probability of 1 – **ε**
- For each remaining step, a charge q is randomly selected in the following distribution (parameters $\bar{\mathbf{q}}$ and **δ**) :

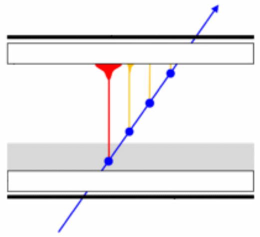
$$P(q;\bar{q},\delta) = \frac{1}{\Gamma\left(\frac{\bar{q}}{\delta}\right)\,\delta^{\frac{\bar{q}}{\delta}}}\; q^{\frac{\bar{q}}{\delta}-1}\; e^{-\frac{q}{\delta}}$$

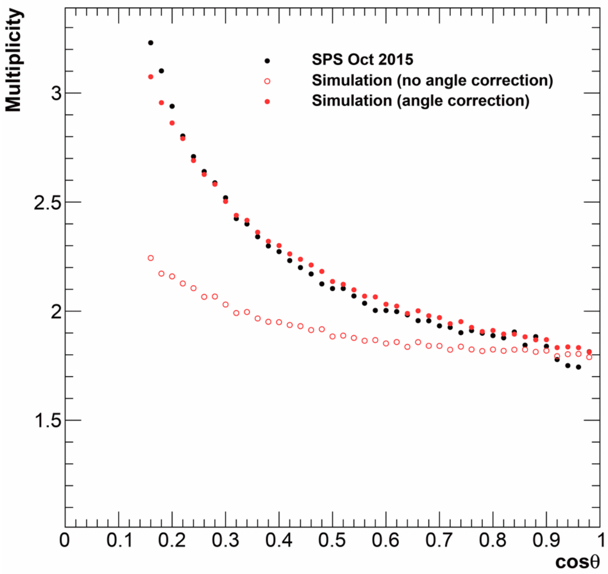


Digitization procedure

- This charge q is adjusted according to the step incidence angle (**k** parameter) :

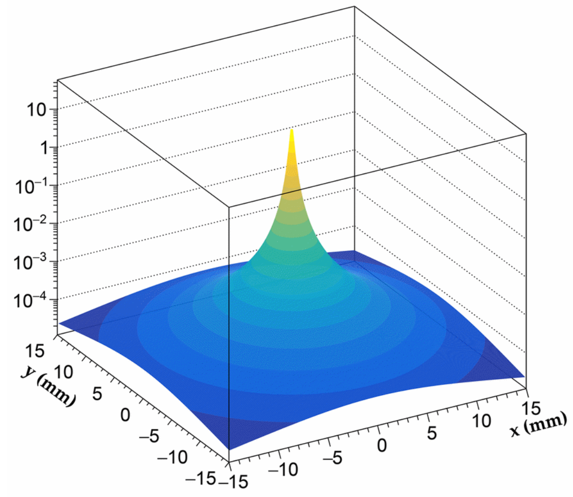
$$q_{corr} = \begin{cases} q \times \left(\frac{d}{d_{gap}}\right)^k & \text{if} \quad \frac{d}{d_{gap}} > 1 \\ q & \text{otherwise} \end{cases}$$





- Those charges are spread on the 1cm x 1cm pads, using the following spread function (**d** parameter) :

$$Q(x,y) = \frac{d}{\left[(x-x_0)^2 + (y-y_0)^2 + d^2\right]^{3/2}}$$

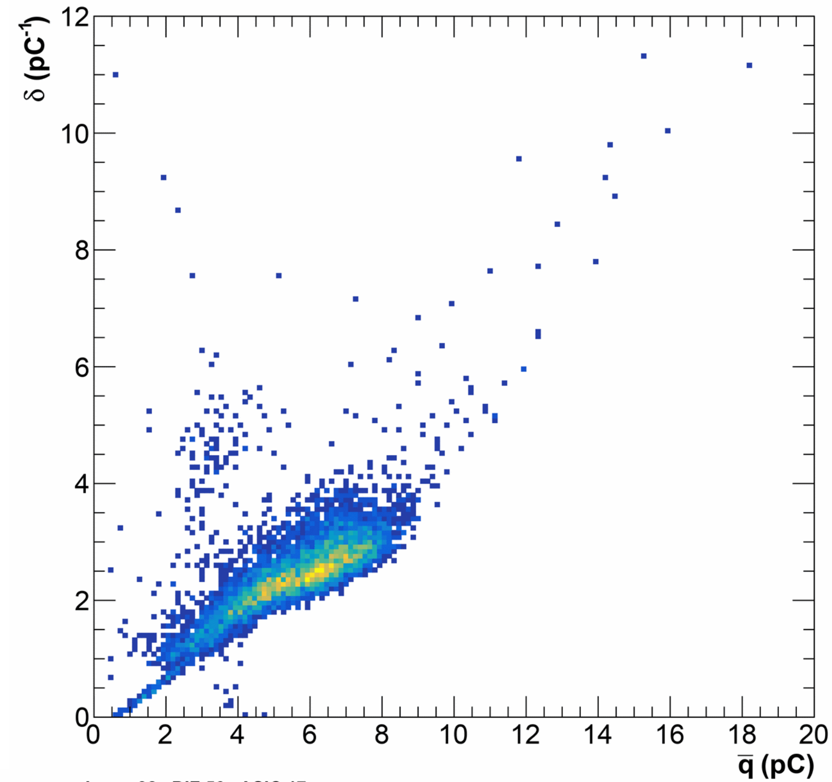


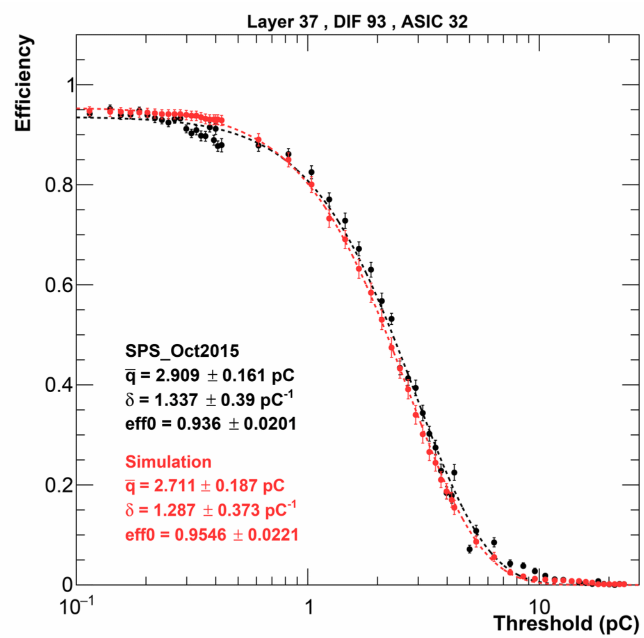
- The three readout thresholds $\mathbf{s_1}$, $\mathbf{s_2}$, $\mathbf{s_3}$ are finally applied

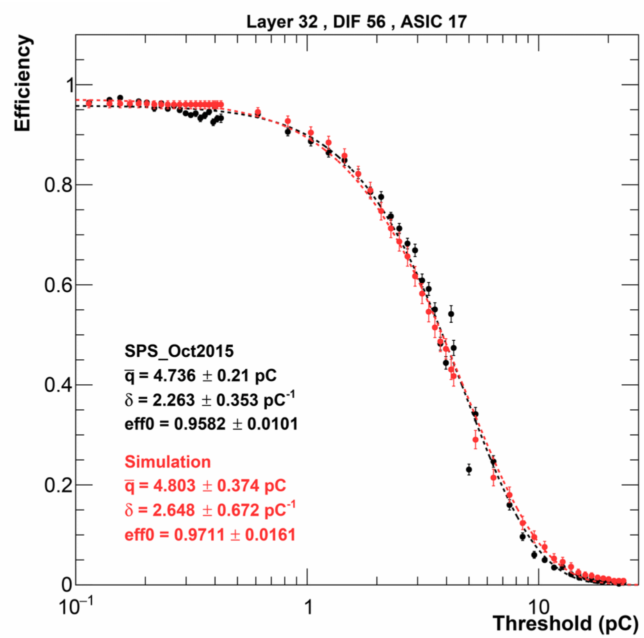
Digitizer tuning

- The parameters **ε**, $\bar{\mathbf{q}}$, **δ** and **d** are adjusted for each ASIC (8x8 readout pads)

$$\epsilon(t;\bar{q},\delta,\epsilon_0) = \epsilon_0 \cdot \left(1 - \int_0^t P(q;\bar{q},\delta)dq\right)$$

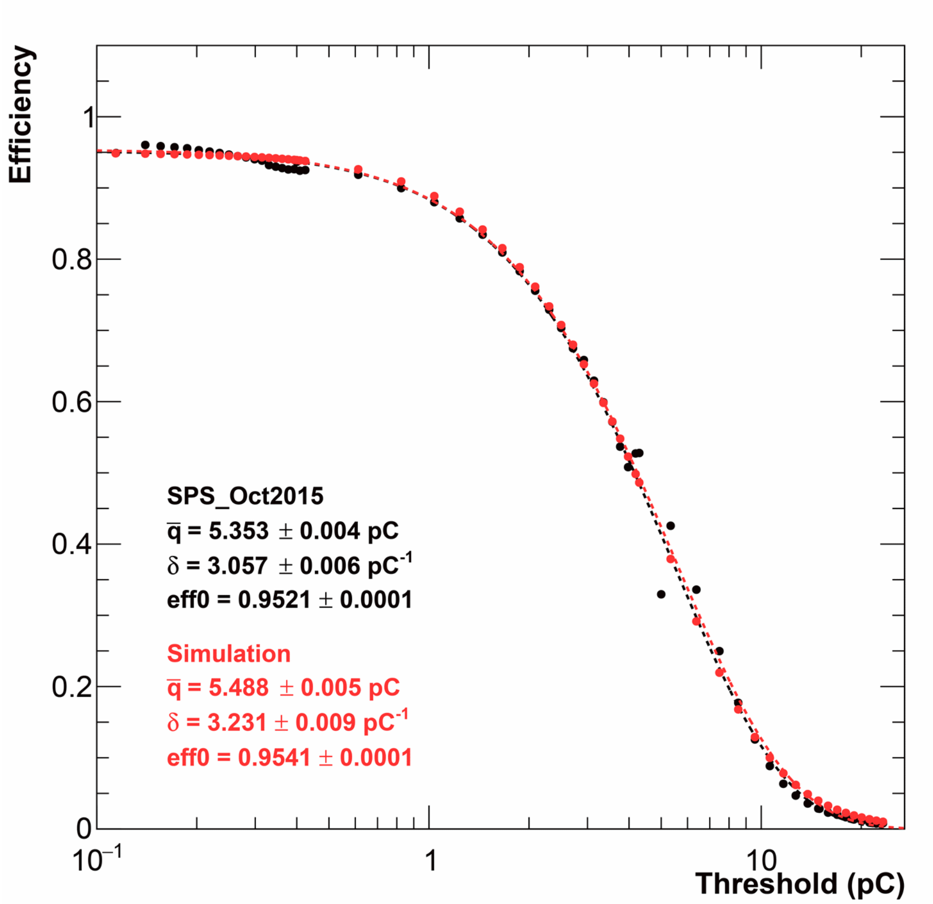






Digitizer tuning

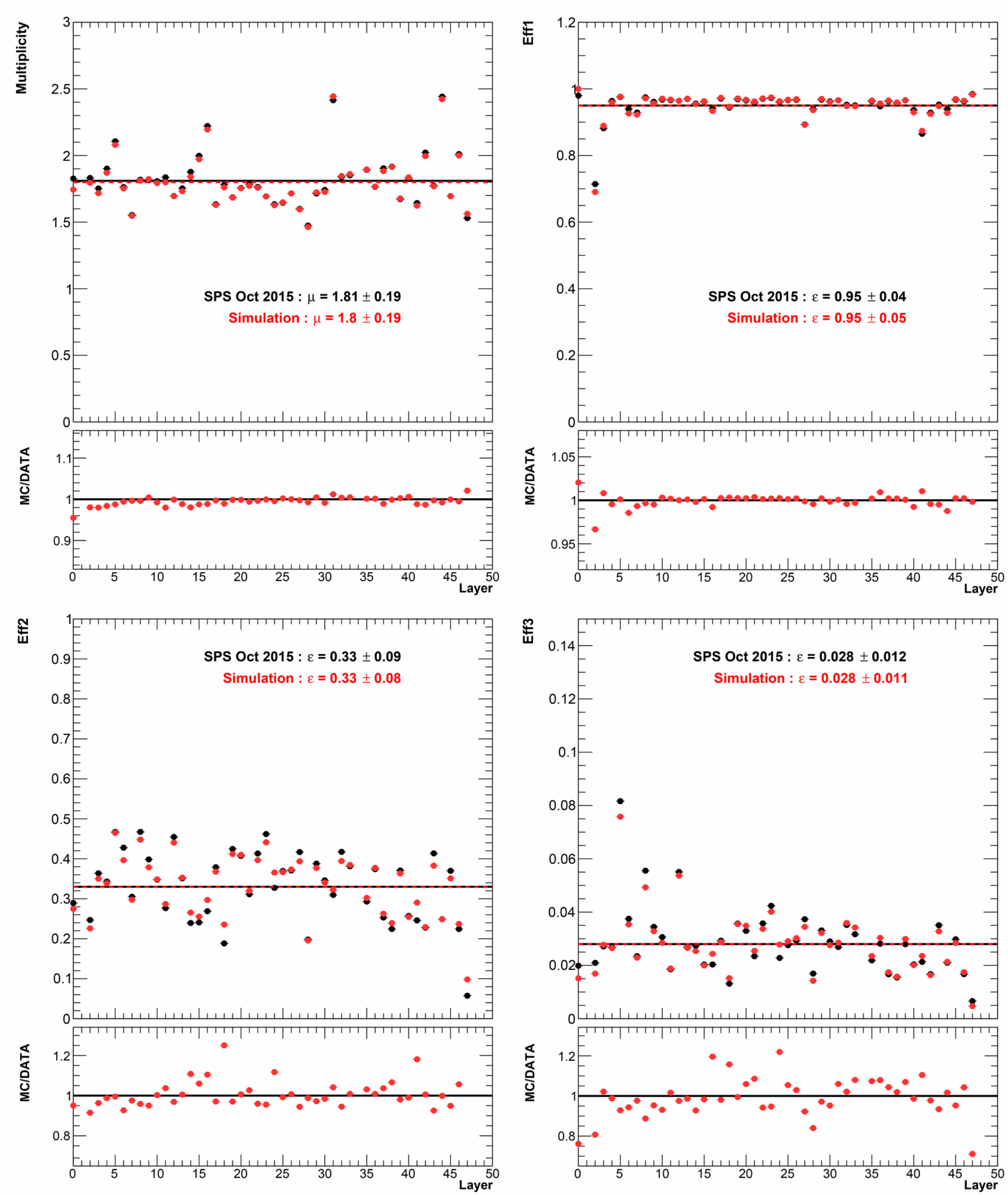
Parameter	Tuned to reproduce
$0 < \boldsymbol{\varepsilon} < 1$ $\mathbf{s_1}$ = 0,114 pC $\mathbf{s_2}$ = 6,12 pC $\mathbf{s_3}$ = 16,83 pC	Detection efficiency
0,2 pC < $\bar{\mathbf{q}}$ < 14 pC 0,2 pC^{-1} < $\boldsymbol{\delta}$ < 6 pC^{-1} **k** = 0,65	Induced charge
$\mathbf{d}_{min}$ = 0,5 mm	Number of hits for electromagnetic showers
0,05 mm < **d** < 1,3 mm	Multiplicity



Results

multiplicity

1^{st} threshold efficiency



2^{nd} threshold efficiency

3^{rd} threshold efficiency

Results

multiplicity

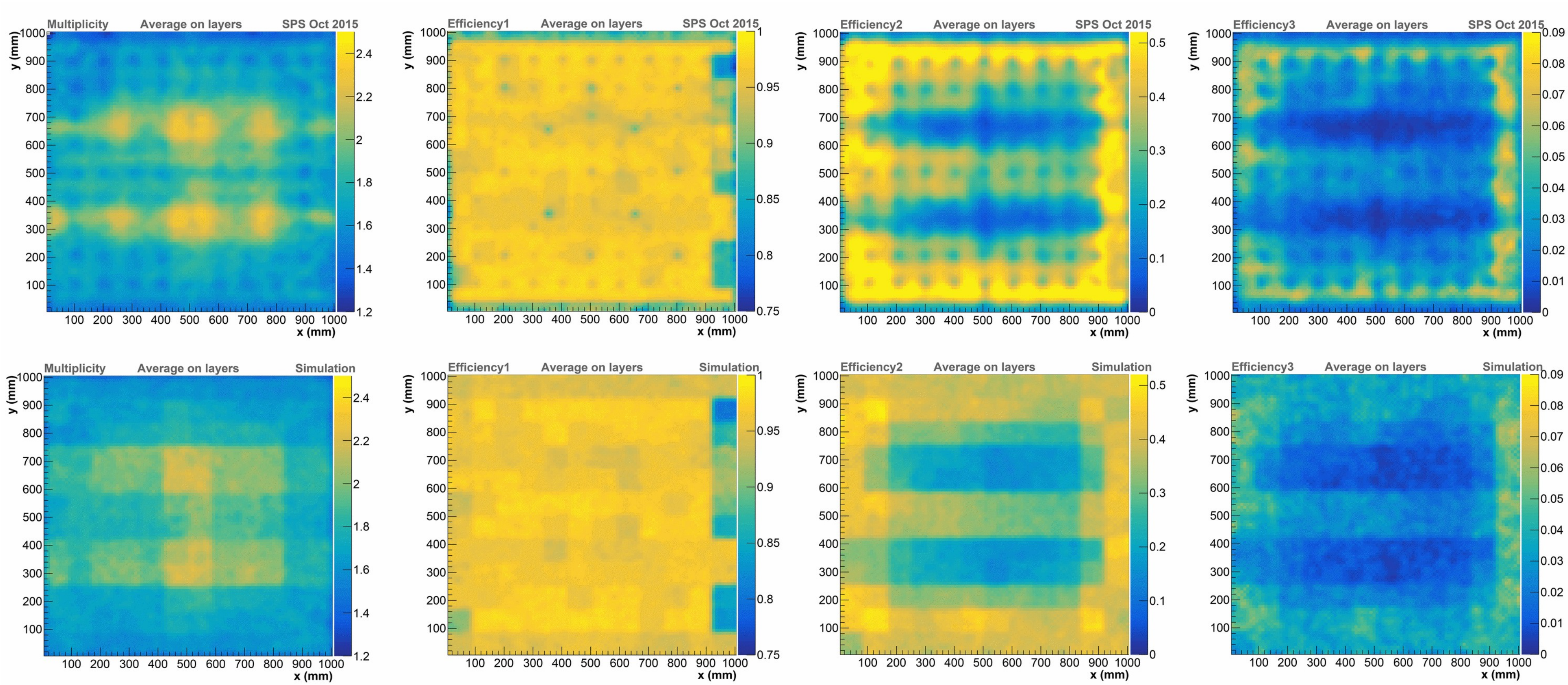
1^{st} threshold efficiency

2^{nd} threshold efficiency

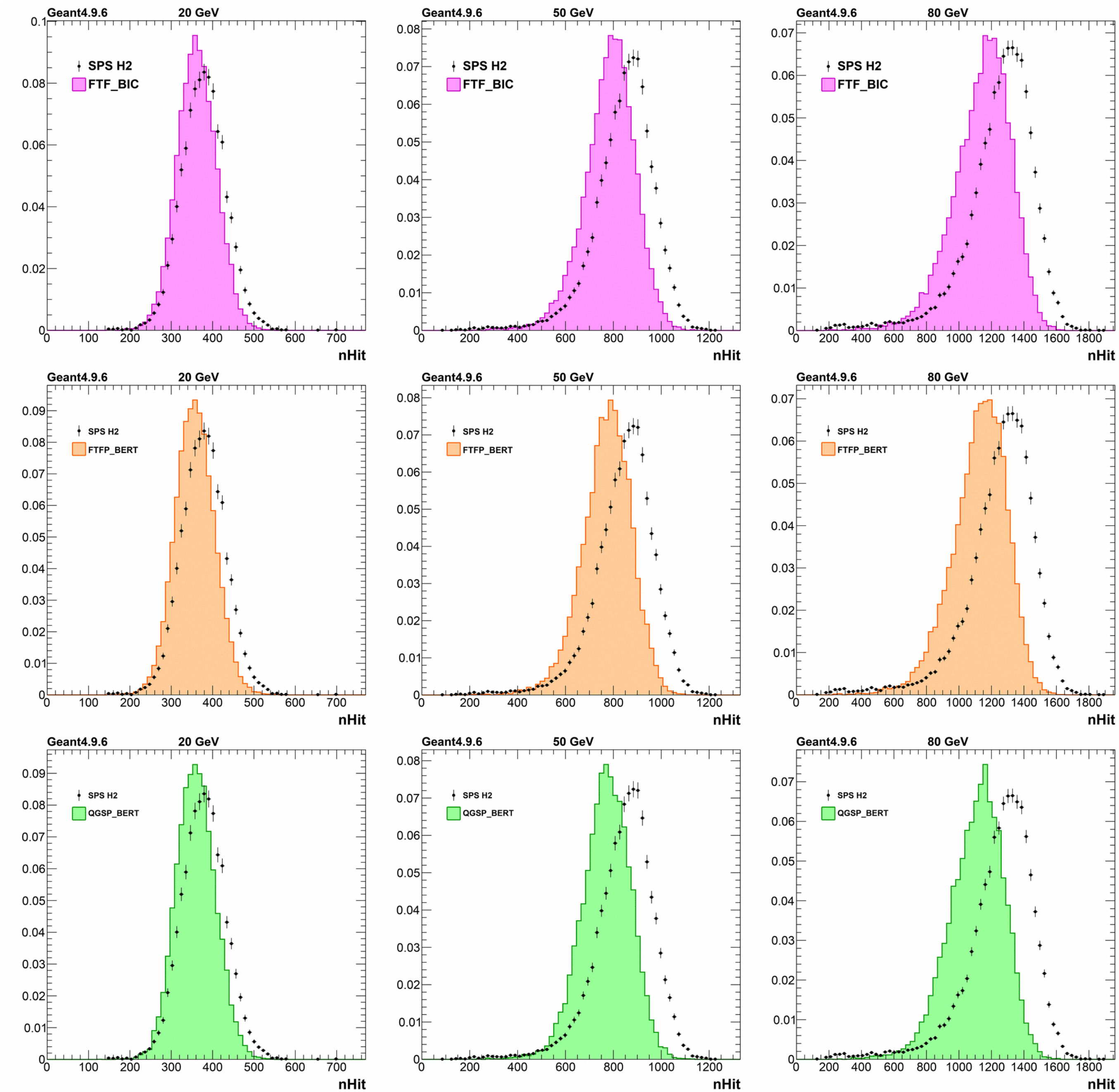
3^{rd} threshold efficiency

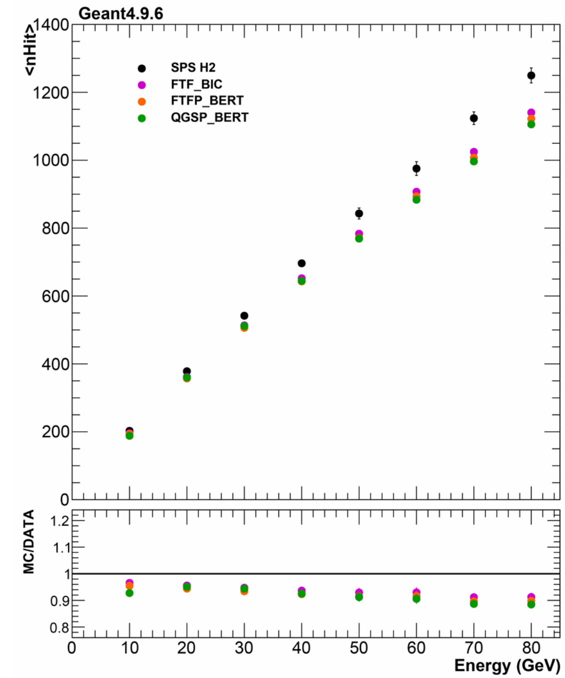
DATA

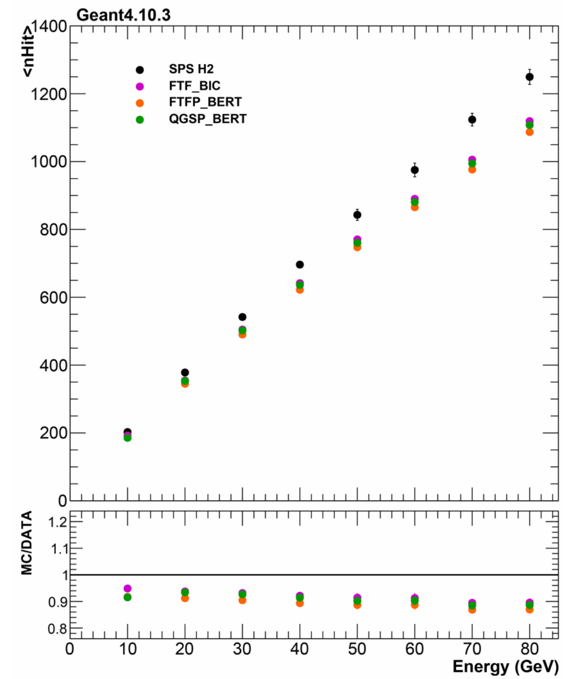
Simulation



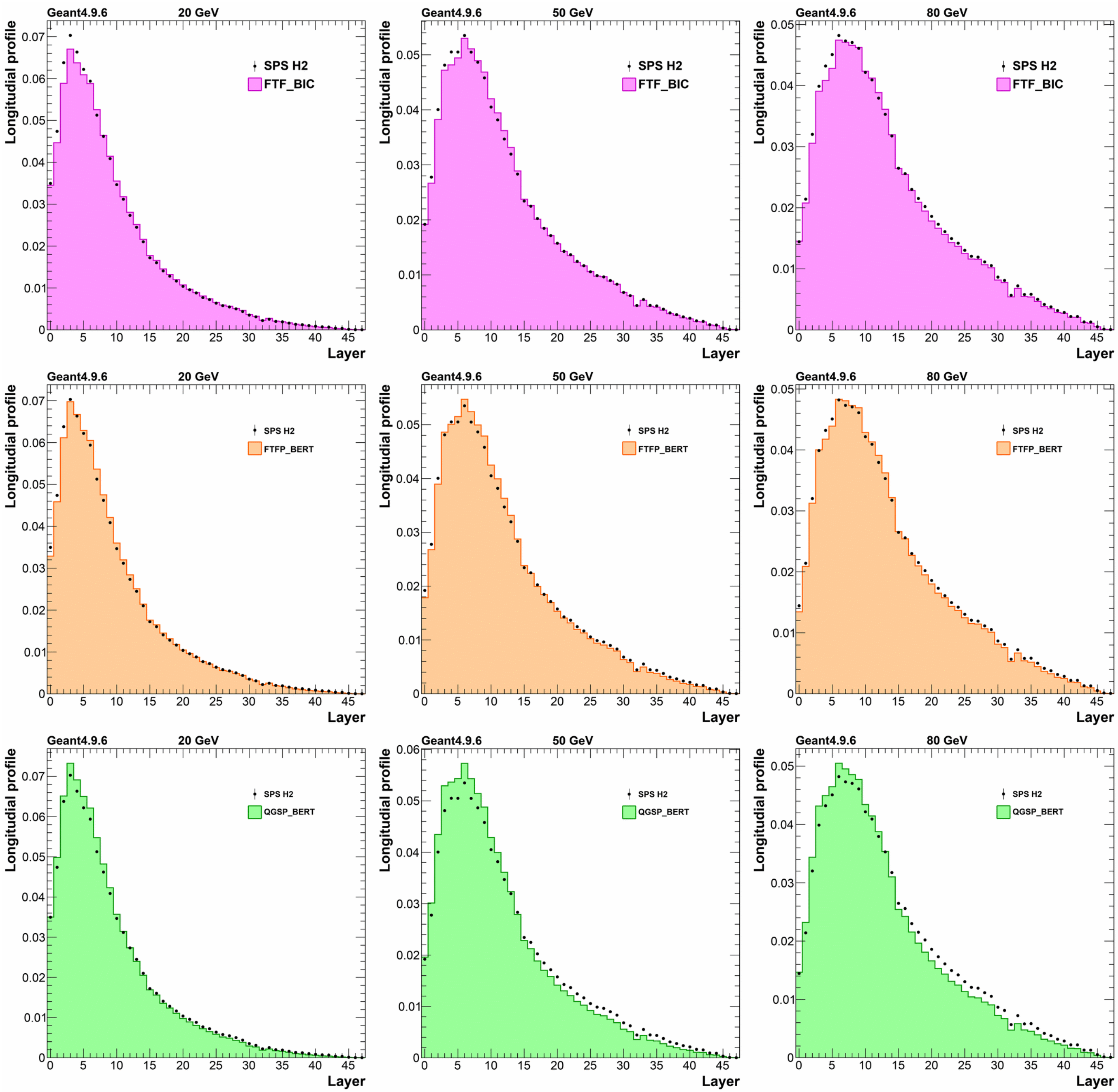
Hadronic showers - Number of hits

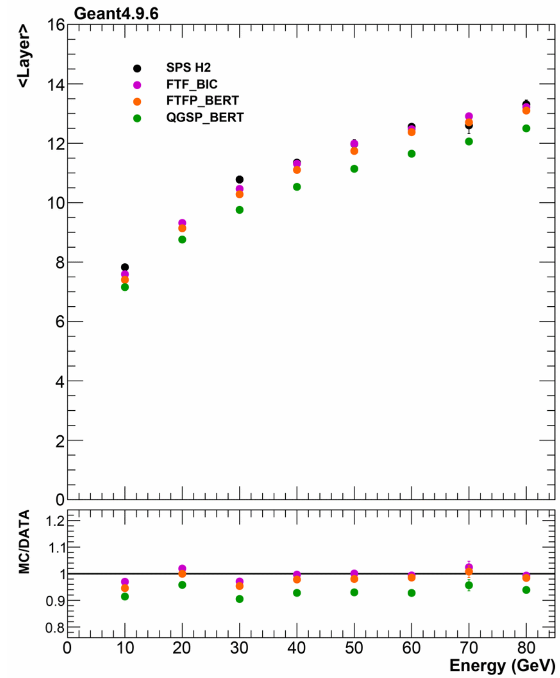


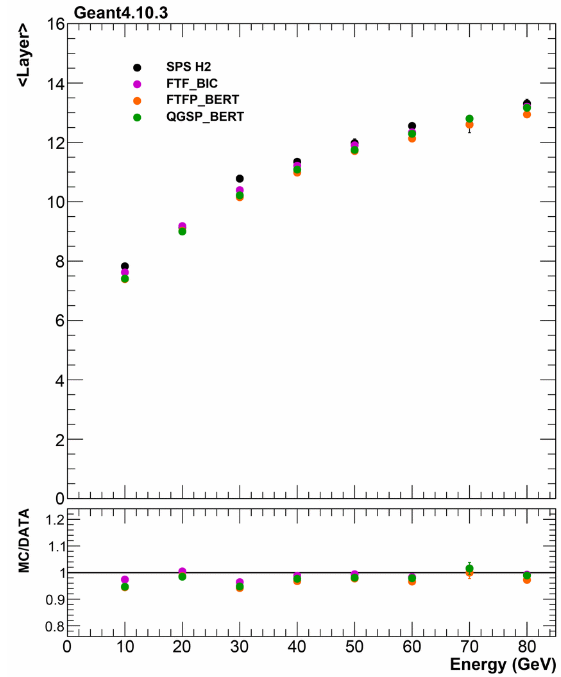




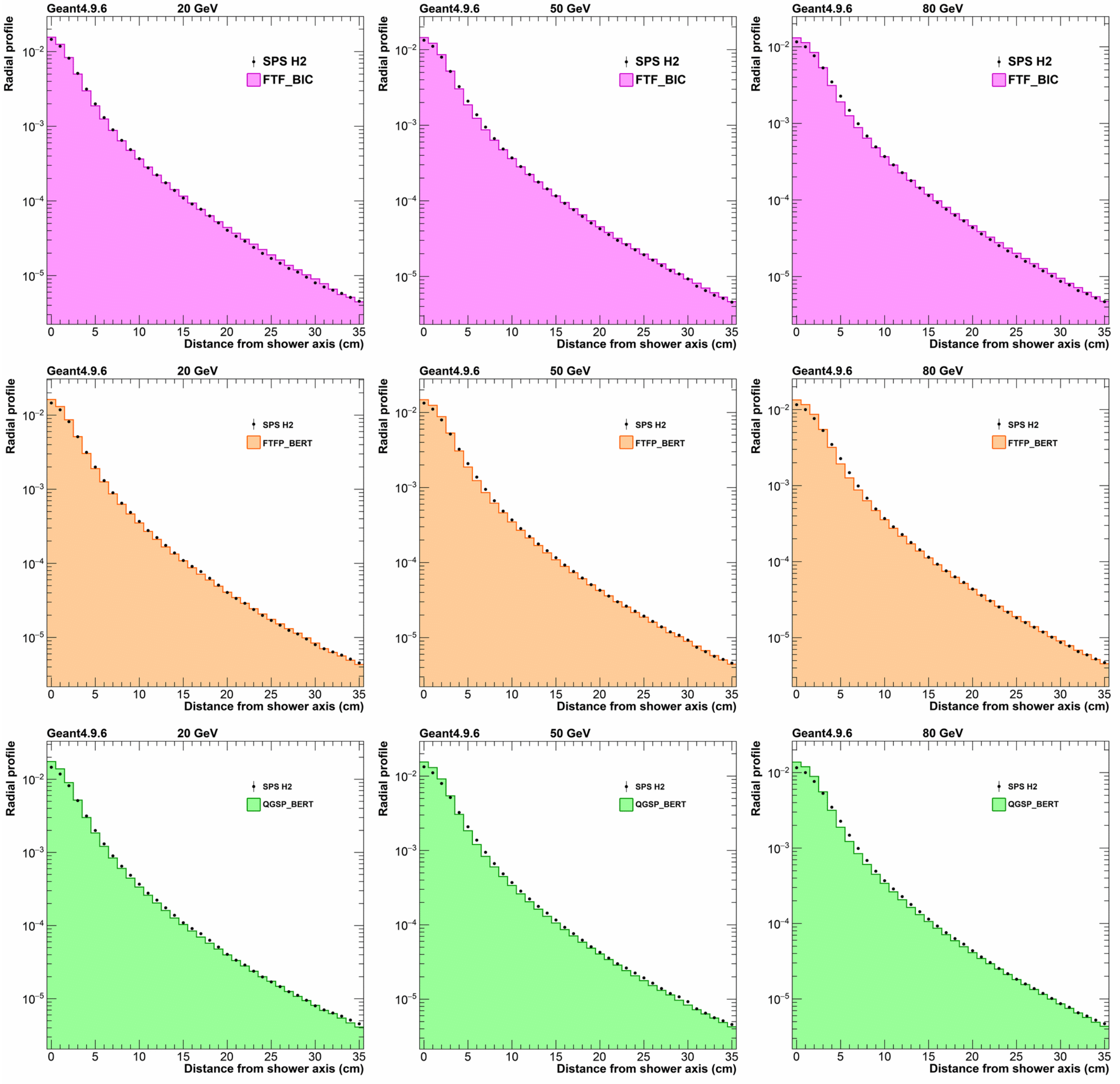
Hadronic showers - Longitudinal profile

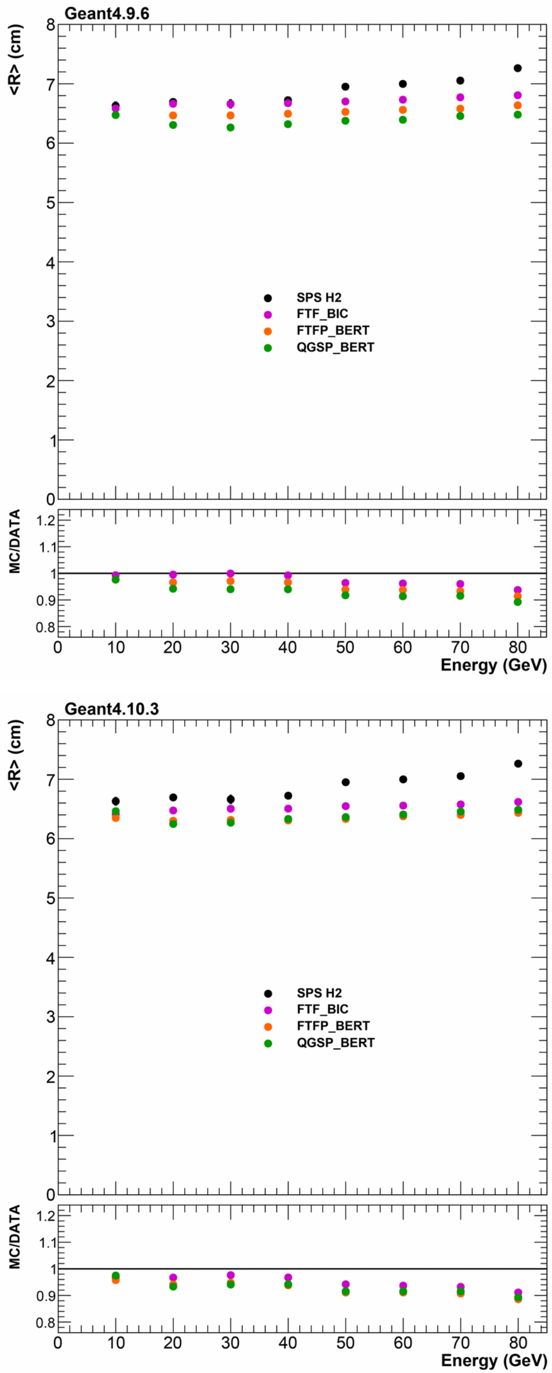




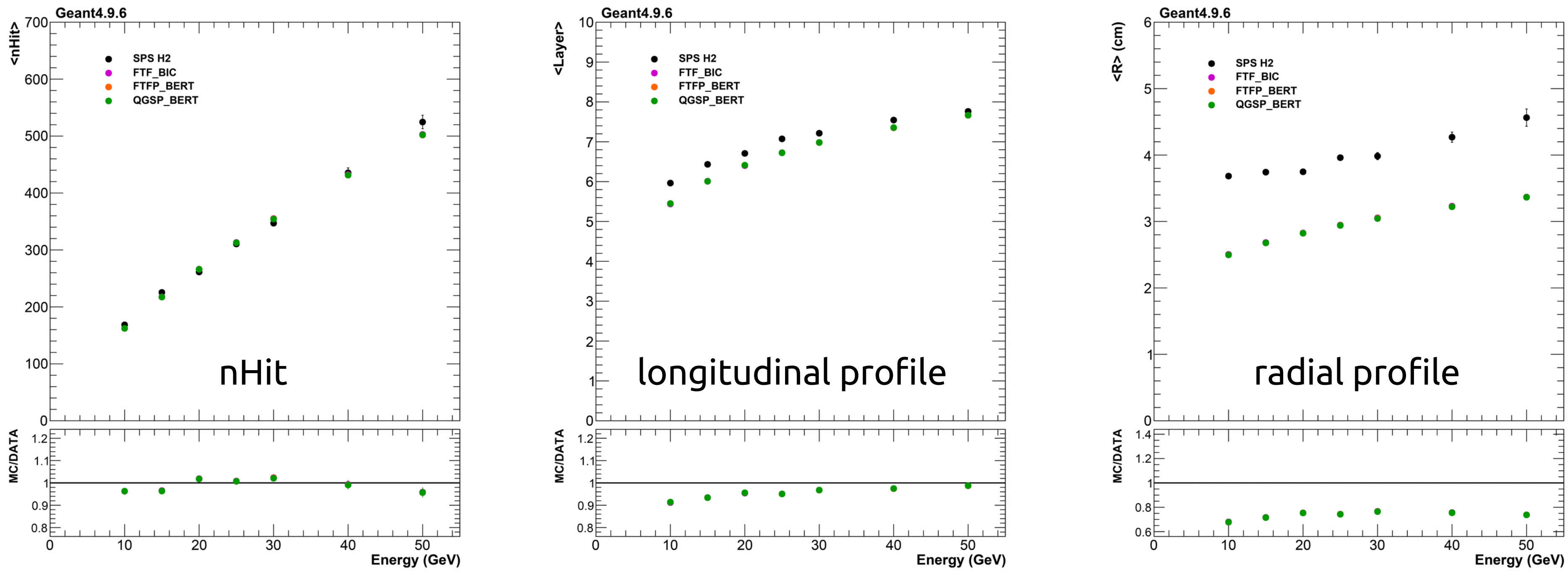


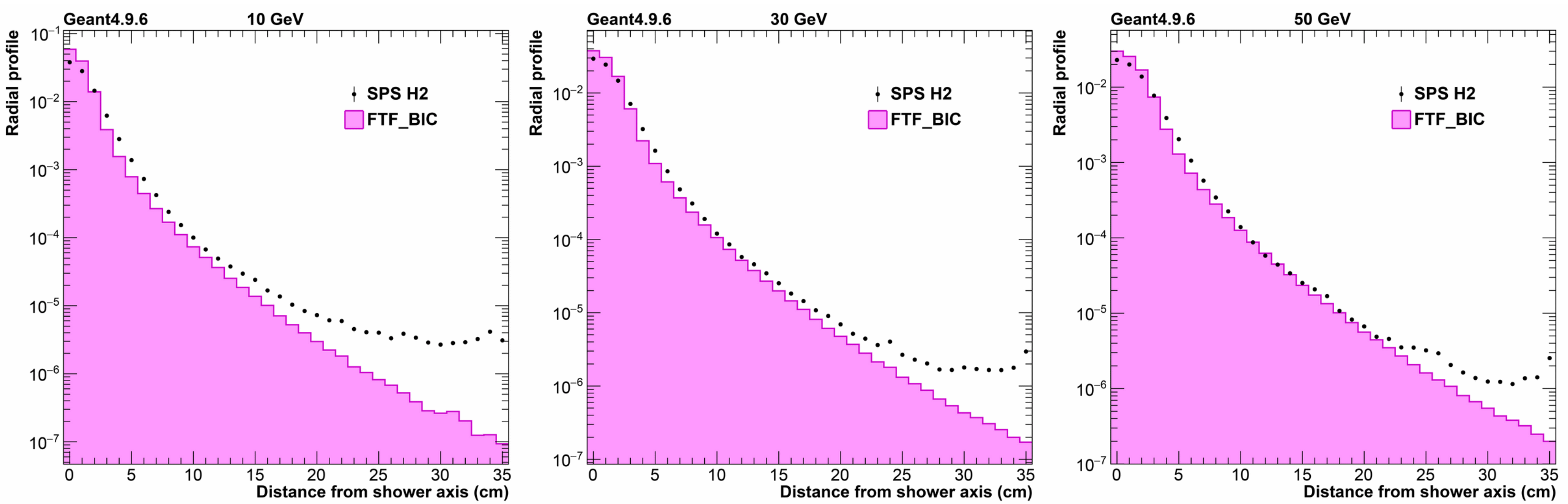
Hadronic showers - Radial profile





Electromagnetic showers

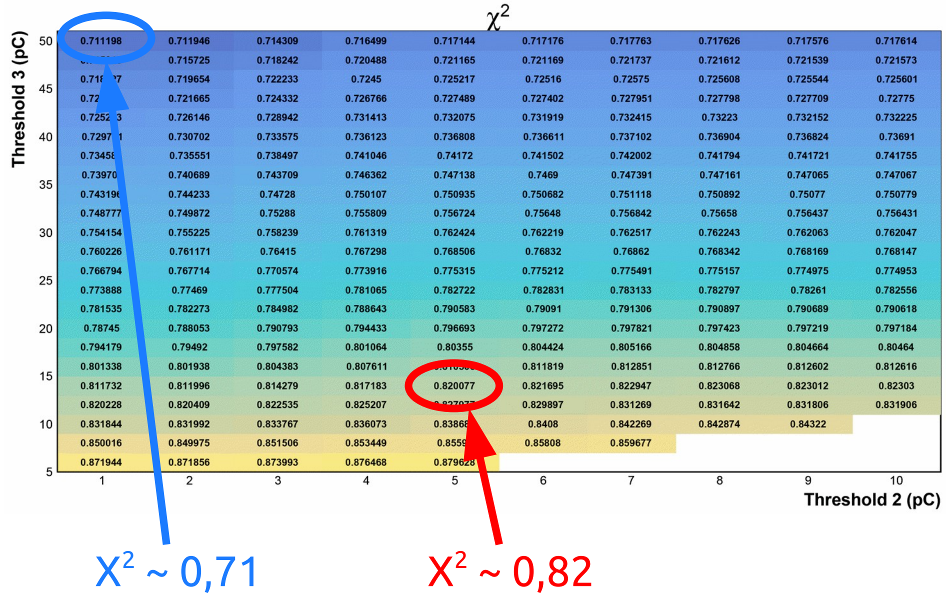




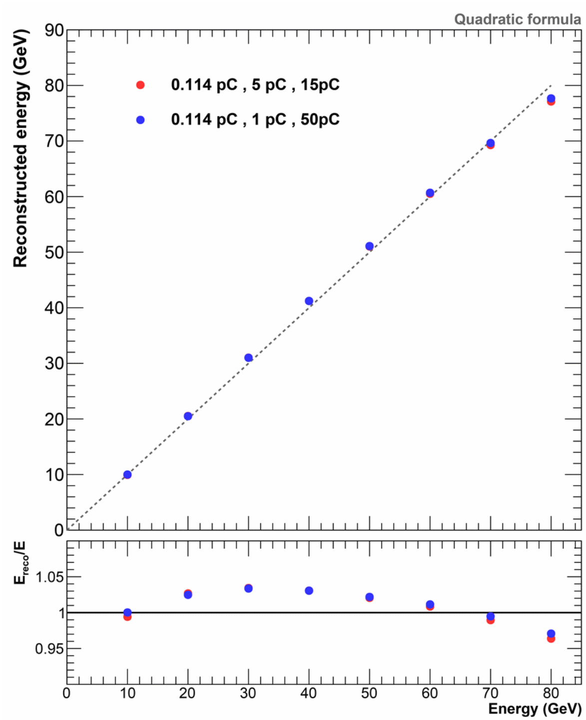
Readout threshold variation

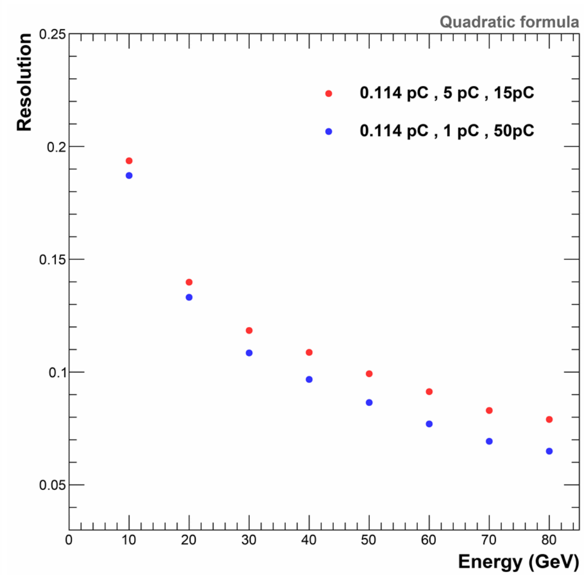
$$E_{reco} = \alpha(N_{hit}) \cdot N_{hit1} + \beta(N_{hit}) \cdot N_{hit2} + \gamma(N_{hit}) \cdot N_{hit3}$$

$$\chi^2 = \sum_{i=1}^{N} \frac{\left(E^i_{reco} - E^i_{beam}\right)^2}{\sigma_i^2} \qquad \sigma_i = \sqrt{E^i_{beam}}$$



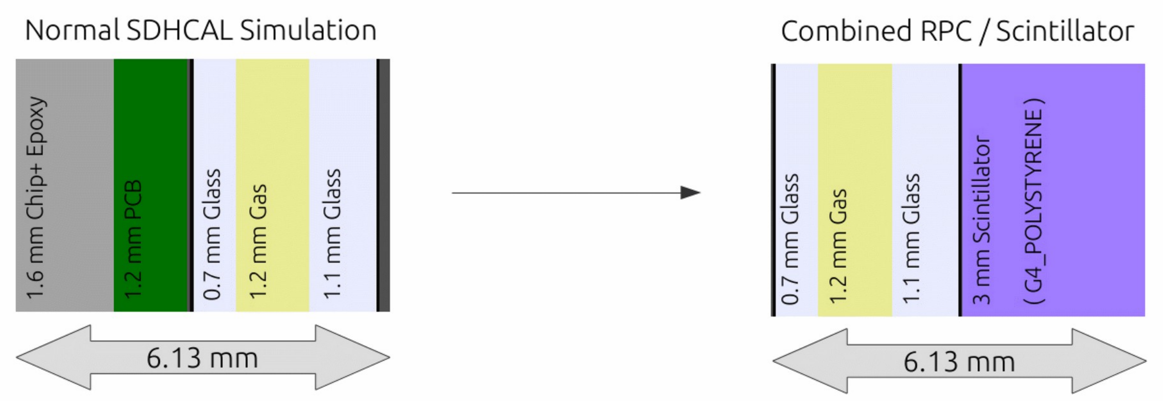
- HARDROC2 chips :
  - maximum 3rd threshold : 15pC
- HARDROC3 chips :
  - maximum 3rd threshold : 50pC
- Threshold scan for reconstructed energy, the X^2 is used as an estimator to find the optimal thresholds
  - 2nd threshold : 1pC
  - 3rd threshold : 50pC
- 20 % Relative improvement at 80 GeV

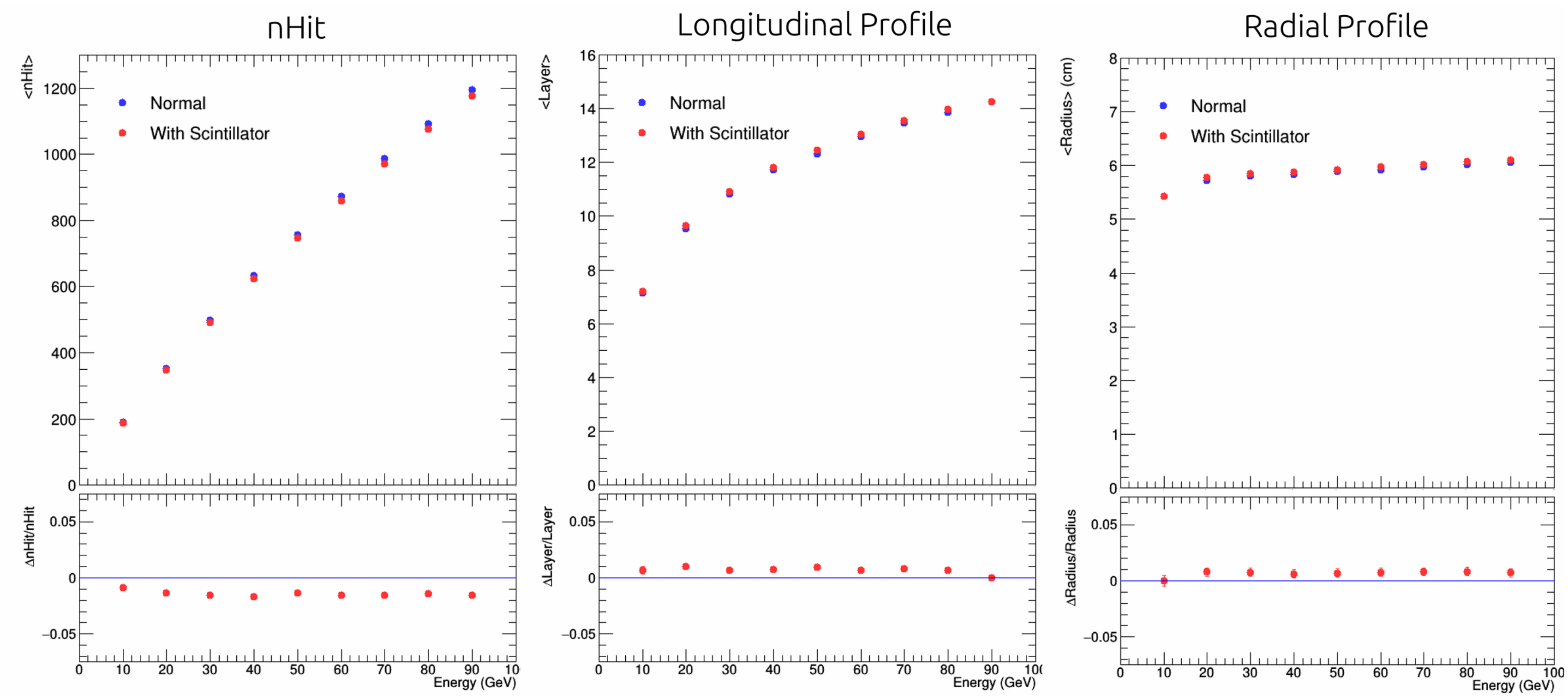




ILD hybrid simulation

- The ILD model uses an hybrid RPC/Scintillator model to simulate both SDHCAL and AHCAL simultaneously
- No significant difference compared to pure SDHCAL model (~1% deviation)





Summary

- The SDHCAL simulation is tuned to reproduce the non-uniformities of the SDHCAL prototype
- Variations of detection efficiencies and multiplicities are well-reproduced
- Disagreements for electromagnetic and hadronic radial profiles
- Usage of HARDROC3 chips could improve the energy resolution
- Hybrid model used in ILD compatible with standalone SDHCAL simulation