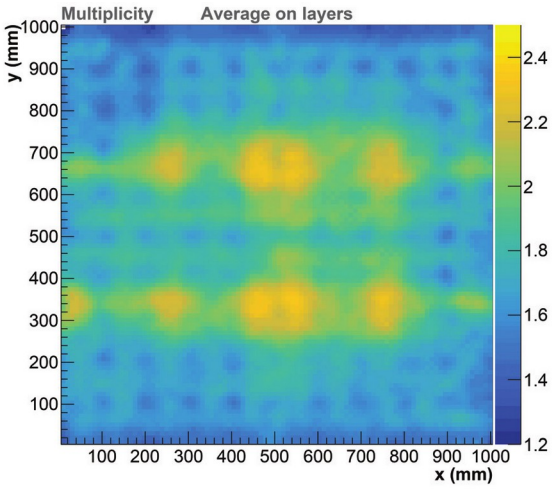
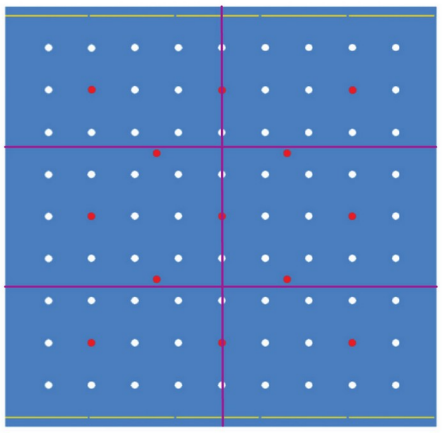
Calibration of SDHCAL using muons

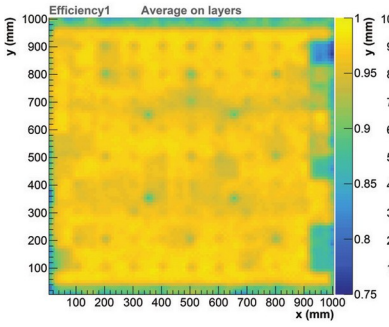
Guillaume Garillot
IP2I – CNRS – Université Lyon 1

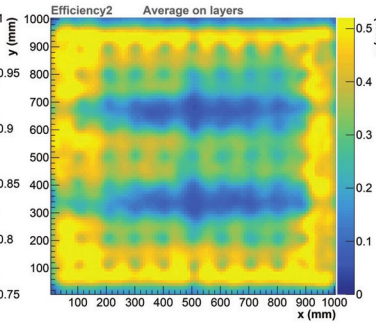
CALICE Collaboration Meeting
09/09/2021

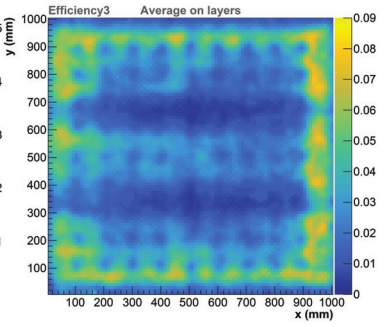
- Goal of the calibration :
  - Reduce the non-uniformities of the SDHCAL

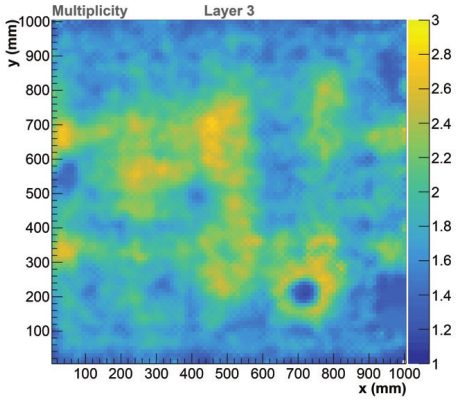


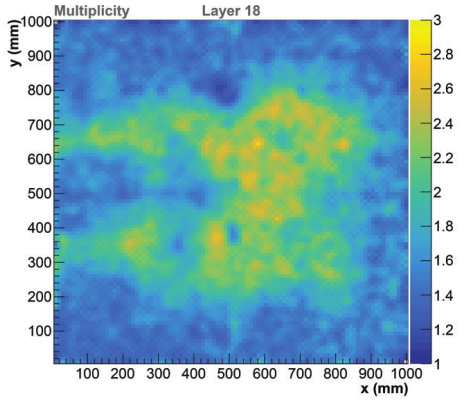


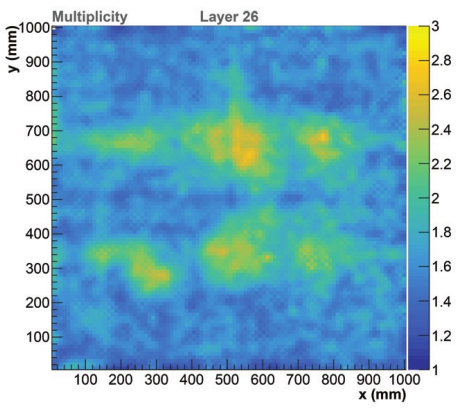


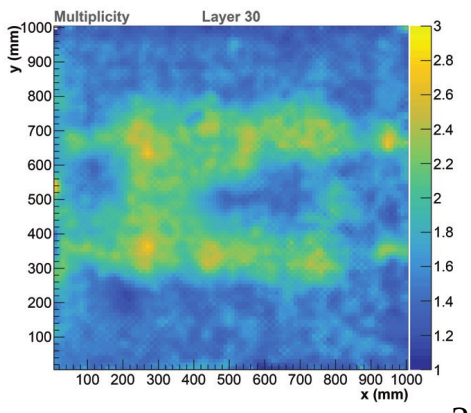




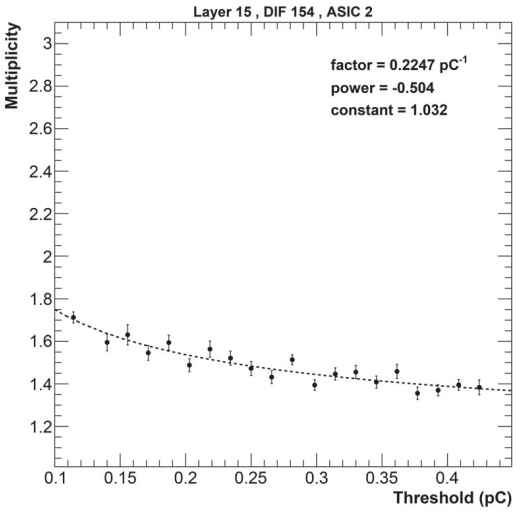


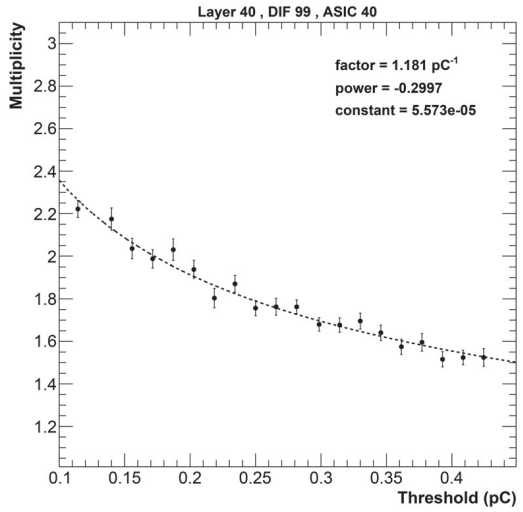


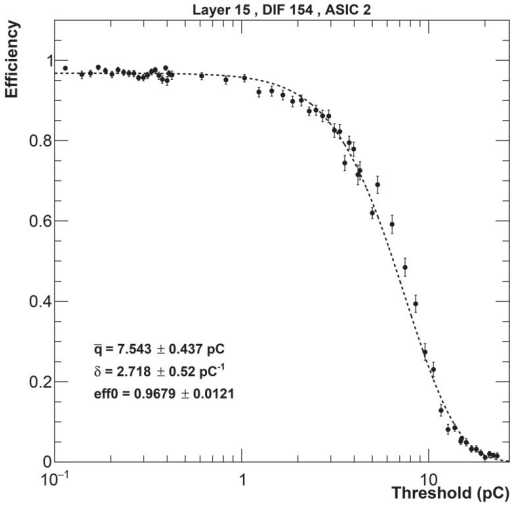


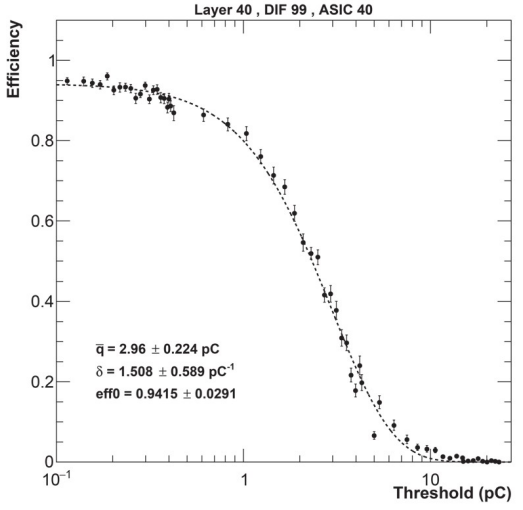


- Calibration procedure :
  - Using muons, perform a threshold scan for the three thresholds
  - Accumulate enough statistics to be able to compute multiplicities and efficiencies for each ASIC (at least ~300 tracks per ASIC), and for each threshold point
    - 1 ASIC = 8*8 pads
  - For each ASIC, fit the multiplicity vs threshold and efficiency vs threshold
  - Choose a target multiplicity and efficiency threshold 2 and threshold 3
  - Use the obtained fits to determine the corresponding thresholds to apply



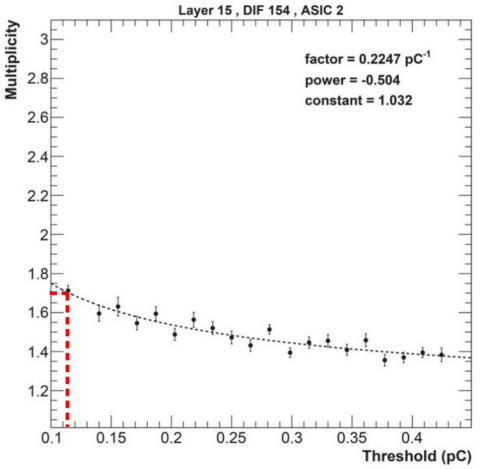


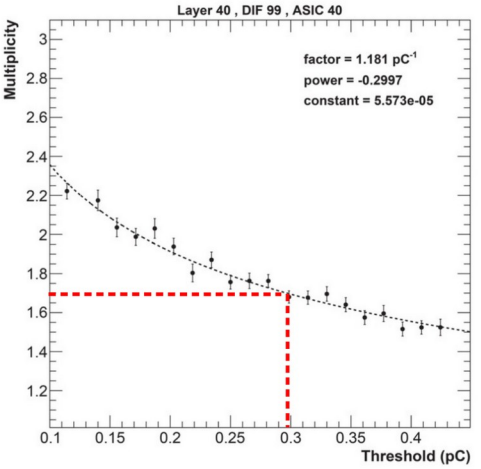




- **Multiplicity versus threshold :**
  (empirical formula)

$$\mu(t; f, p, c) = f \cdot t^p + c$$



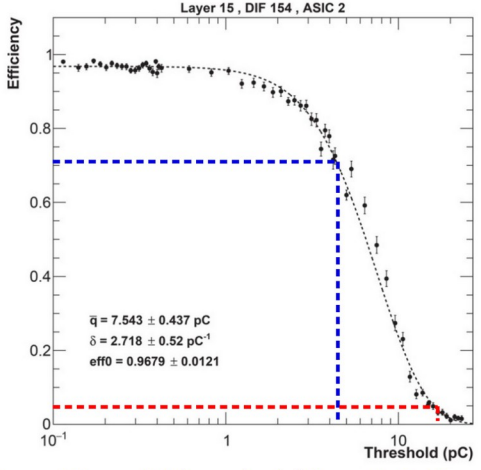


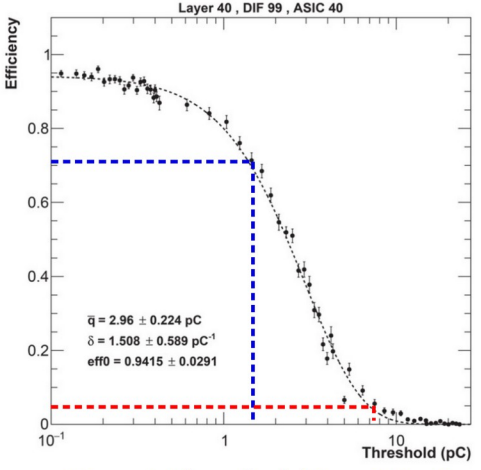
Example : for target multiplicity of 1,7 : Target threshold 1: 0,115pC Target threshold 1 : 0,3pC

- **Efficiency versus threshold :**

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

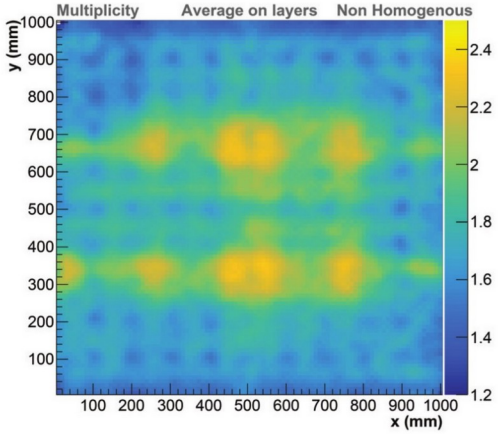
$$\epsilon(t; \bar{q}, \delta, \epsilon_0) = \epsilon_0 \cdot \left(1 - \int_0^t P(q; \bar{q}, \delta) dq\right)$$

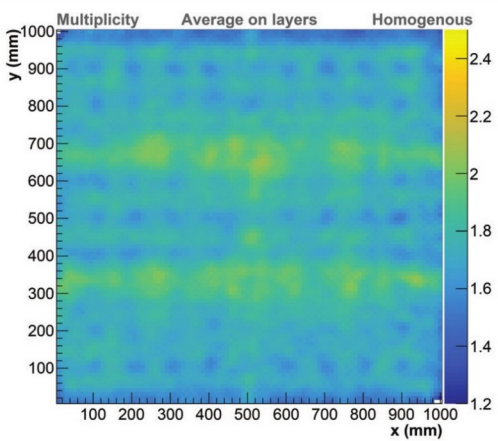


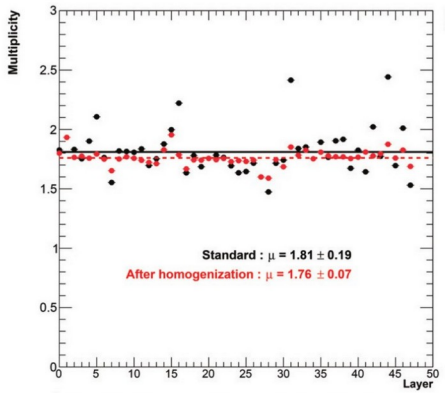


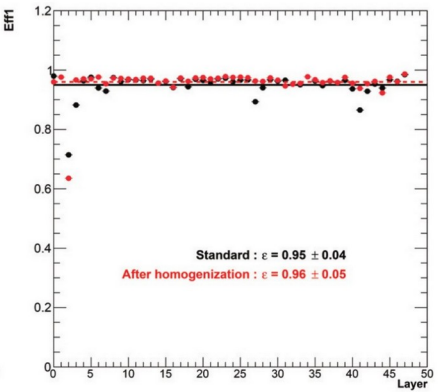
Example : for target efficiency threshold 2 of 70% : Target threshold 2 : ~4,5pC Target threshold 2 : ~1,5pC
Example : for target efficiency threshold 3 of 3,5% : Target threshold 3 : ~15pC Target threshold 3 : ~7,5pC

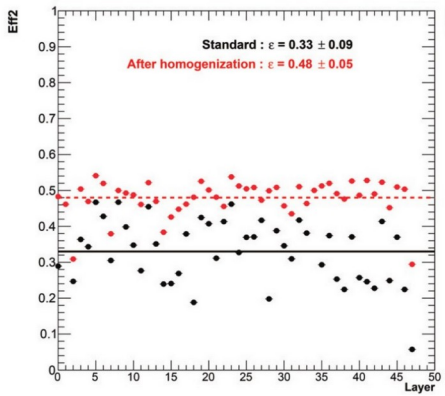
- October 2015 TB results :

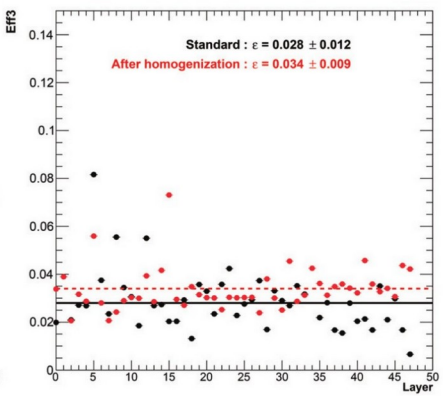






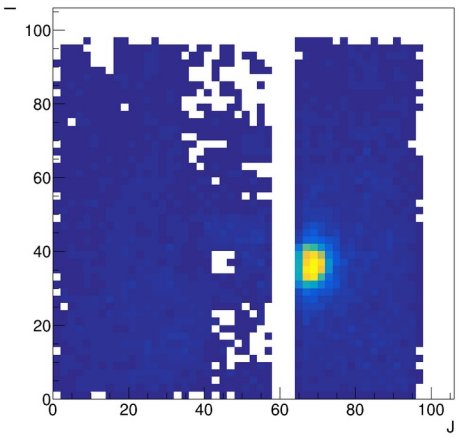


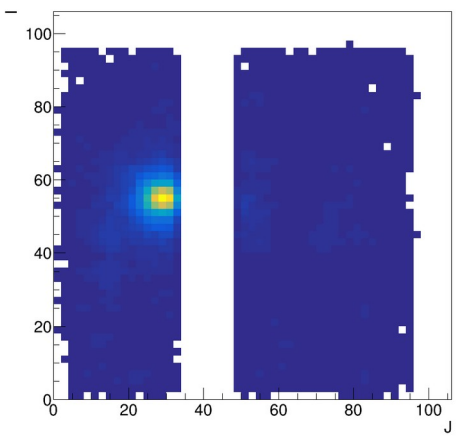




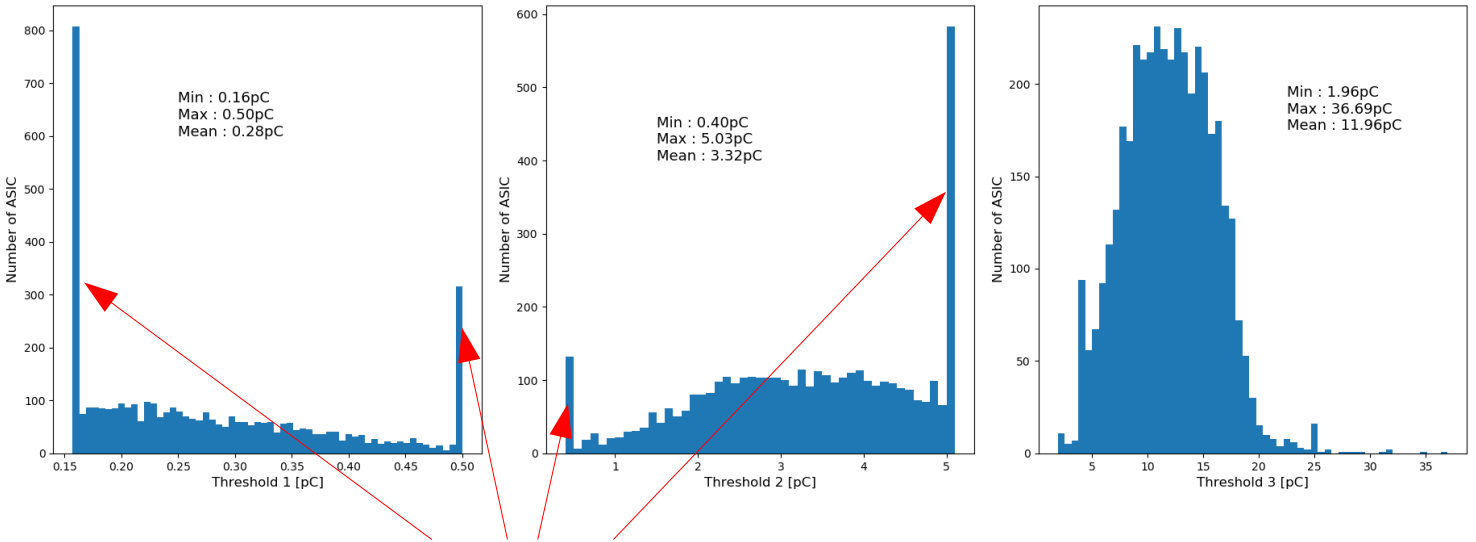
- September 2018 Test Beam :

- Combined test beam with ECAL in front
- Only 37 layers were present in the SDHCAL, among which :
  - 3 layers were off during the calibration phase
  - 2 layers had faulty electronics
  - 1 layer was badly calibrated (human mistake - by me)
  - → these 6 layers are not taken into account in the following results
- The muon scan was performed with 6.9 kV, but due to a lot of noise, the hadron runs were performed with 6.7 kV
- The first threshold was limited to 0.16 pC, instead of 0.114 pC usually

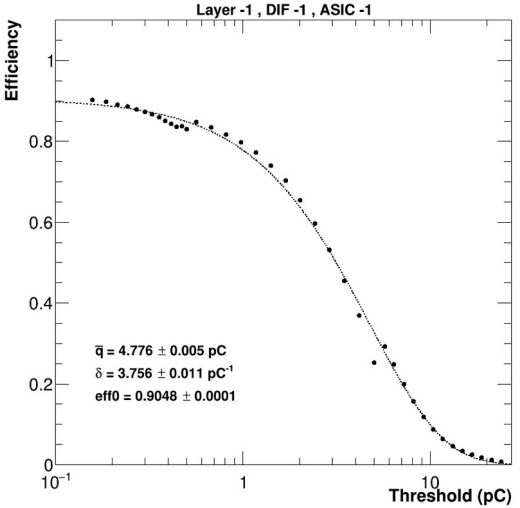


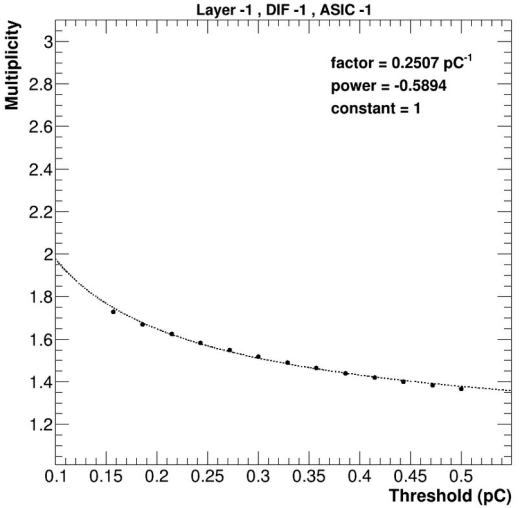


- Thresholds after calibration :



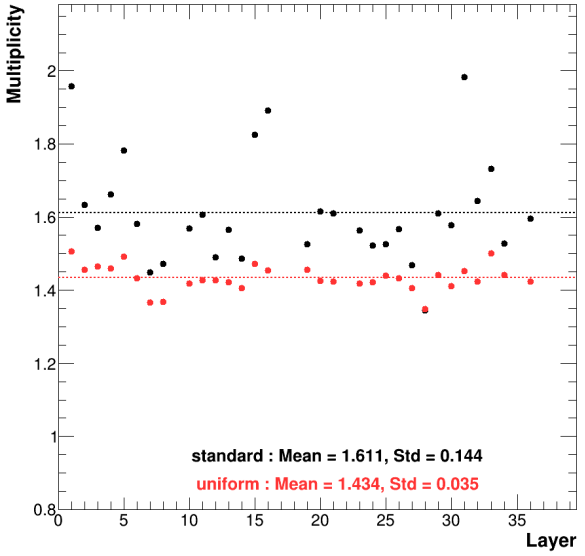
Electronics limitation

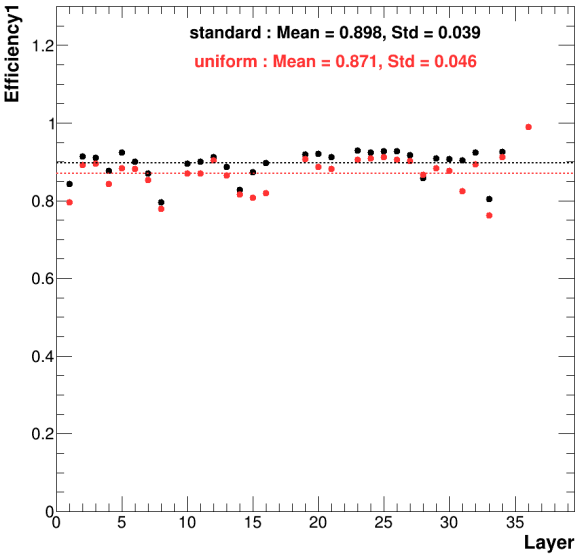


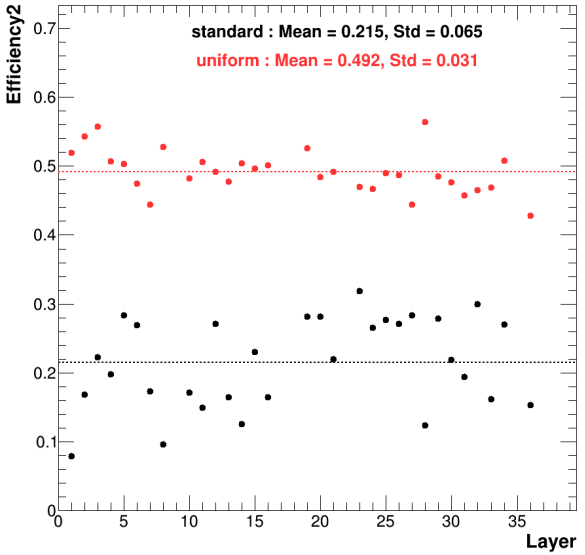


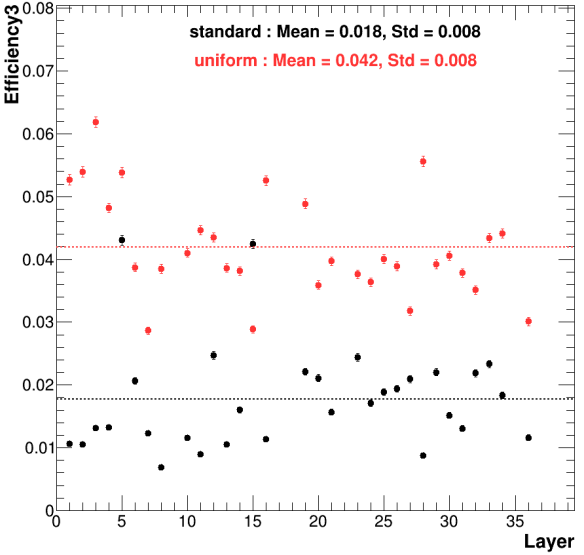
- SDHCAL standard thresholds : {0.16, 5, 15} pC

- Deviations of the multiplicity are greatly reduced, at the cost of a small increase of deviations for the efficiency of the first threshold
- Deviations of the second threshold efficiency reduced, but the third threshold is too hard to calibrate

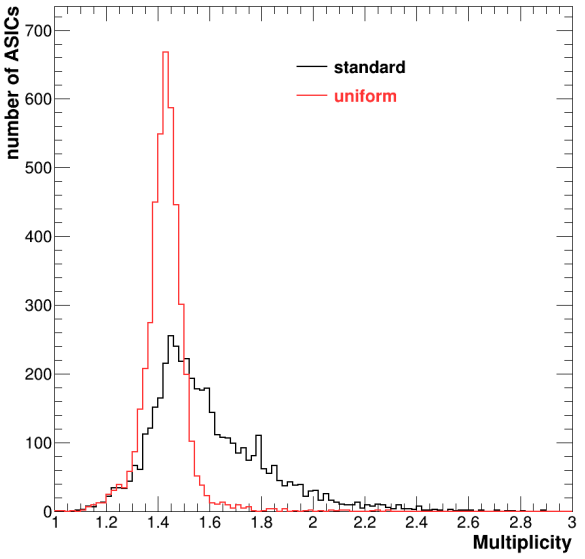


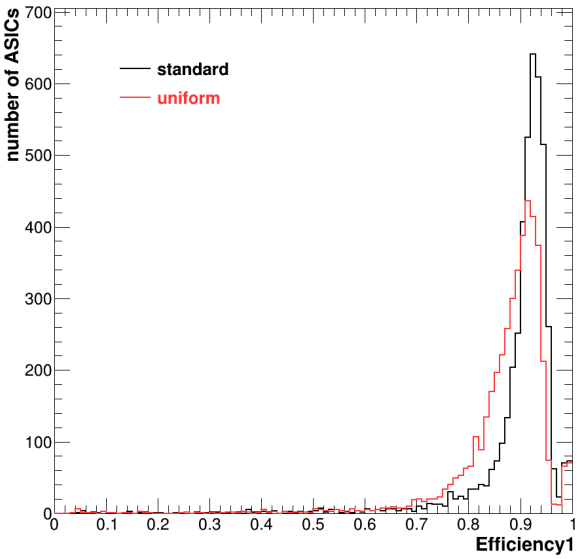


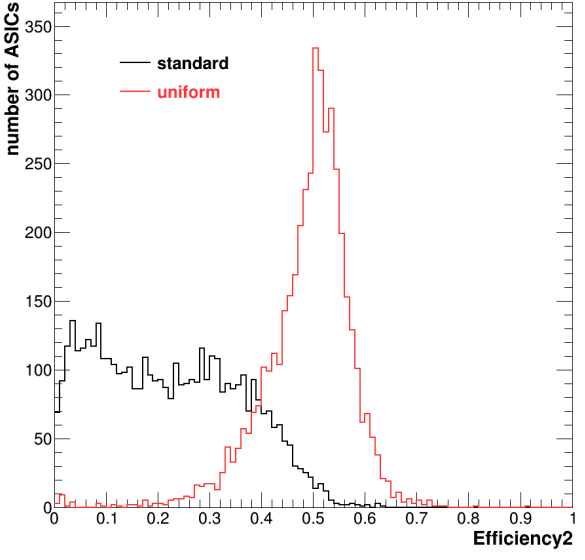


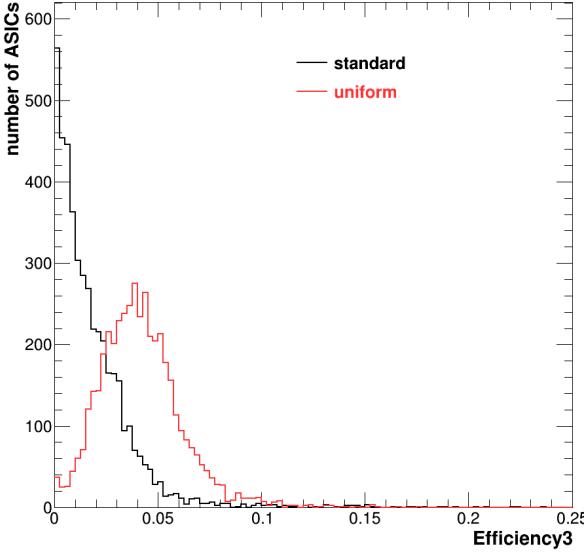


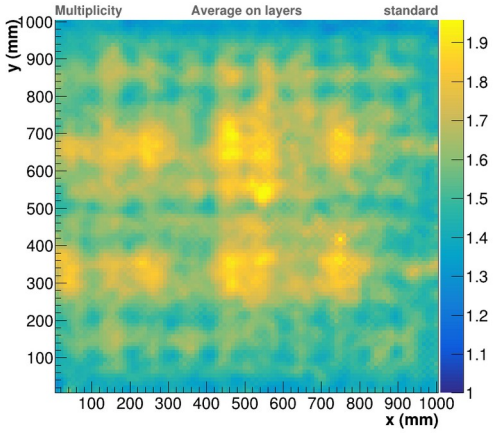
- Deviations of the multiplicity are greatly reduced, at the cost of a small increase of deviations for the efficiency of the first threshold
- Deviations of the second threshold efficiency reduced, but the third threshold is too hard to calibrate

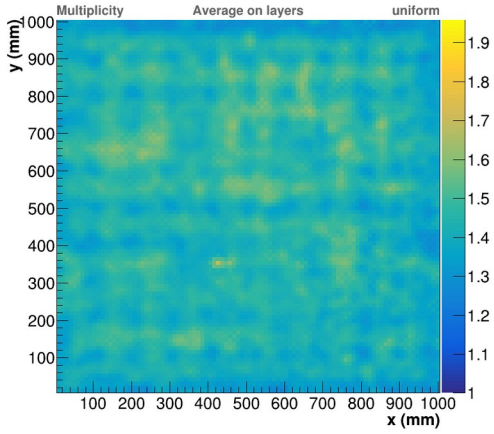


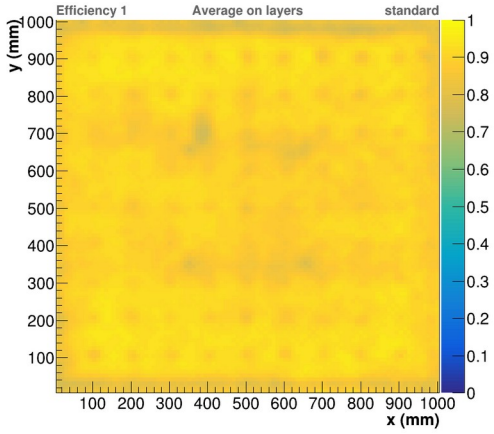


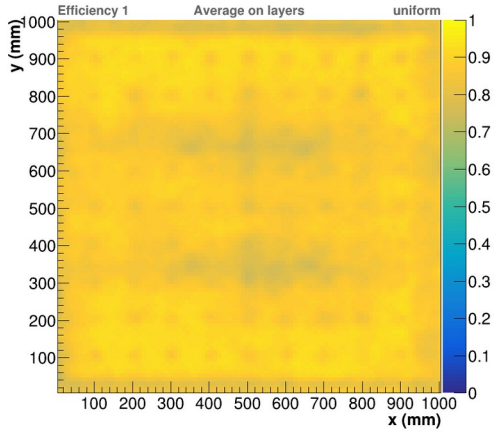


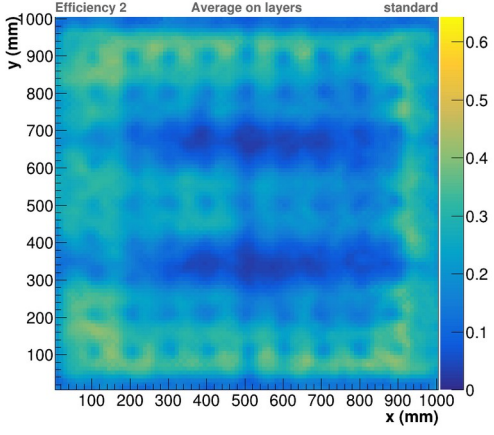


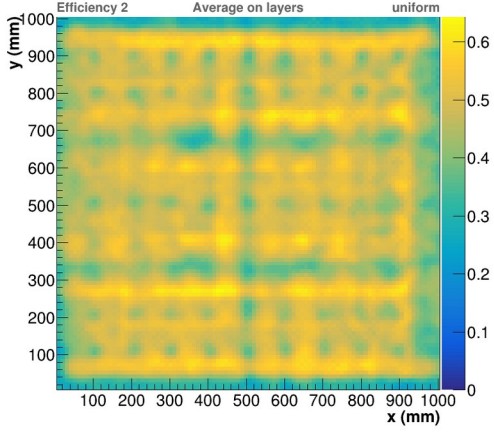

Multiplicity
Average on layers
standard
y (mm)
x (mm)

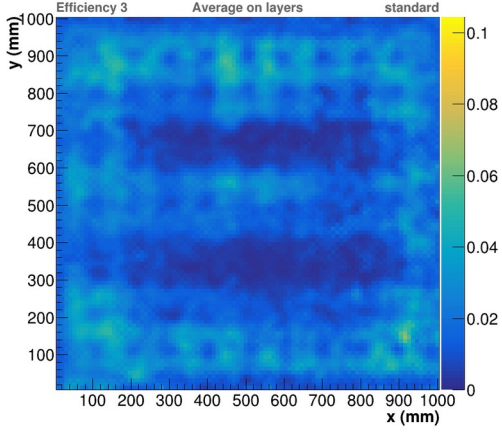

Multiplicity
Average on layers
uniform
y (mm)
x (mm)

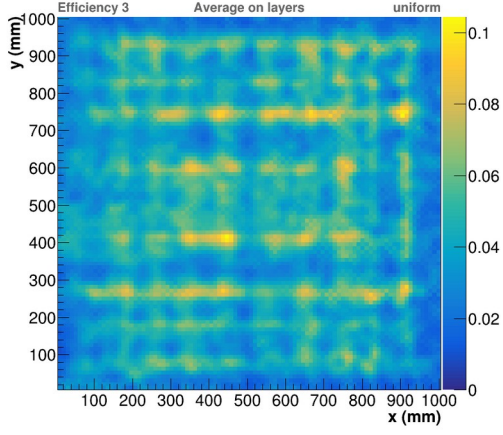

Efficiency 1
Average on layers
standard
y (mm)
x (mm)


Efficiency 1
Average on layers
uniform
y (mm)
x (mm)

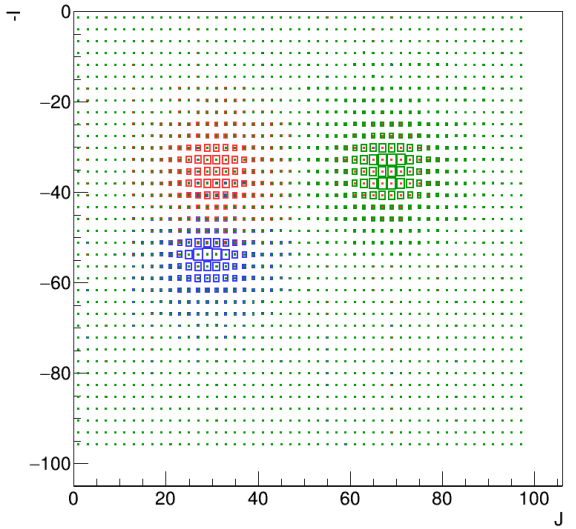

Efficiency 2
Average on layers
standard
y (mm)
x (mm)


Efficiency 2
Average on layers
uniform
y (mm)
x (mm)

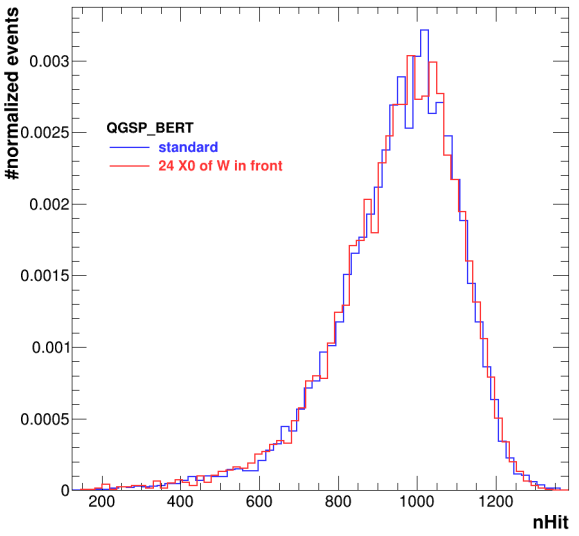

Efficiency 3
Average on layers
standard
y (mm)
x (mm)

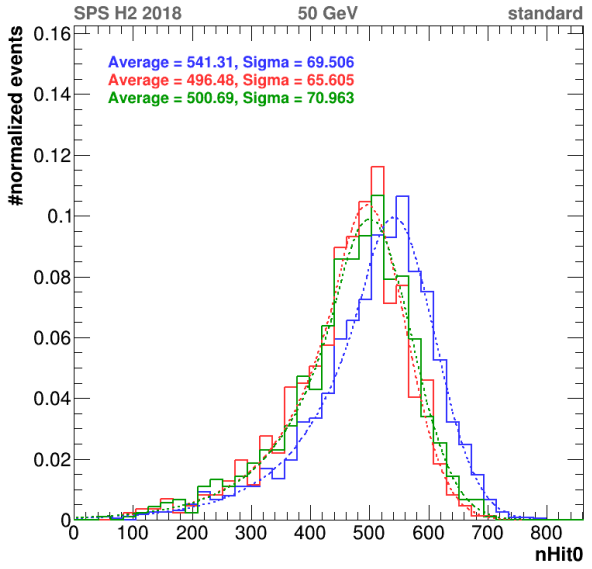

Efficiency 3
Average on layers
uniform
y (mm)
x (mm)

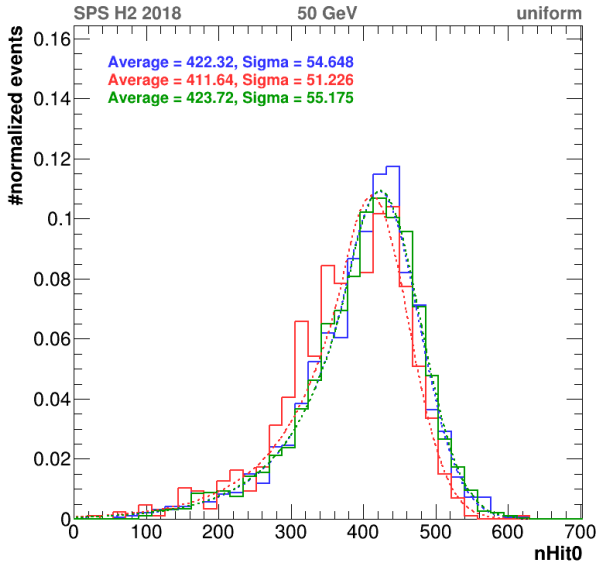
- Hadron runs :
  - 2 energies : 50 GeV and 70 GeV
  - 3 spots :
    - ECAL in front of spot 1 and spot 2

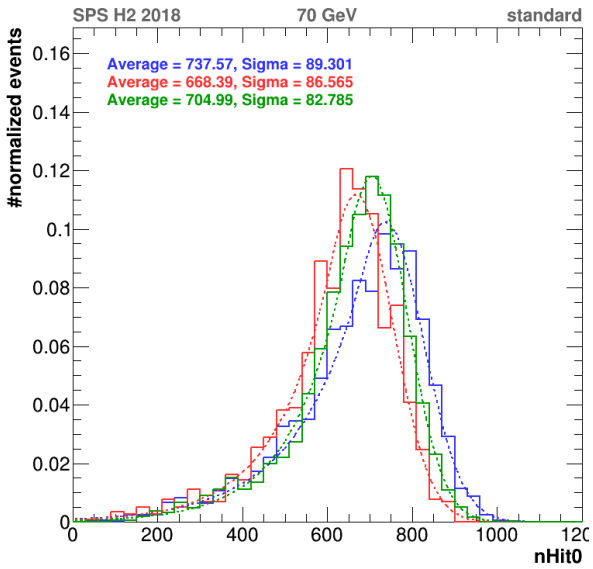


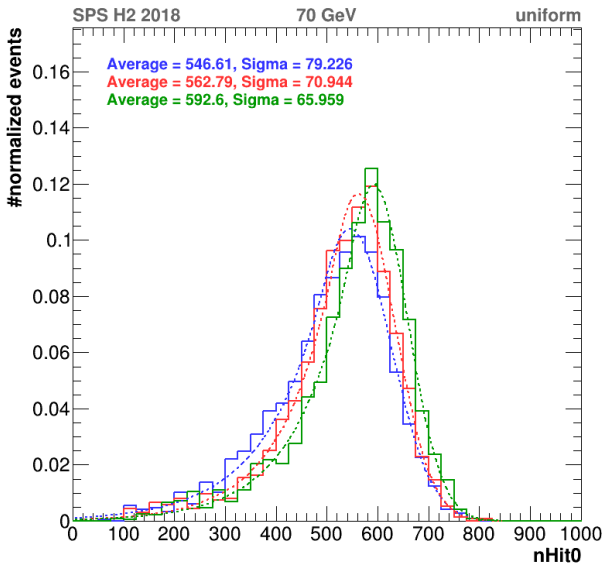
- To remove hadrons which interacted in the tungsten in front of the SDHCAL, an additional cut was applied :
  - The 3 first layers must have less than 5 hits each
- This cut was checked in Geant4 SDHCAL simulation









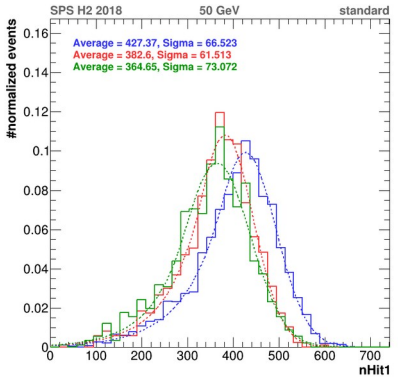


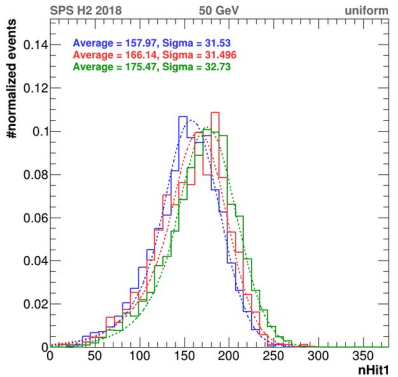
- GaussExp fits

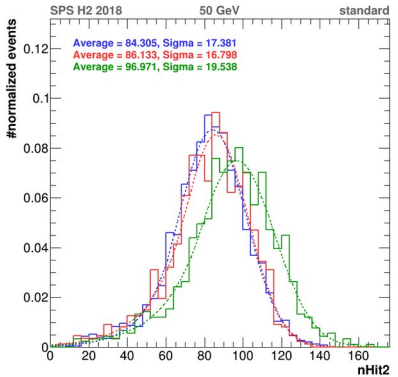
$$f(x;\bar{x},\sigma,k) = e^{-\frac{1}{2}\left(\frac{x-\bar{x}}{\sigma}\right)^2}, \quad \text{for} \quad \frac{x-\bar{x}}{\sigma} \geq -k$$
$$= e^{\frac{k^2}{2}+k\left(\frac{x-\bar{x}}{\sigma}\right)}, \quad \text{for} \quad \frac{x-\bar{x}}{\sigma} < -k$$

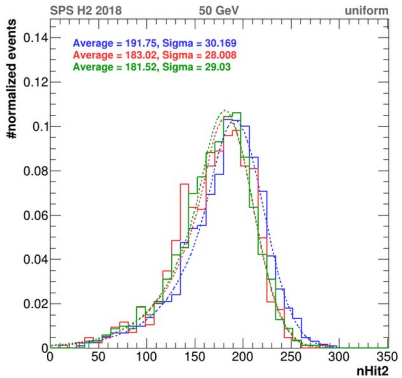
- nHit 50 GeV :
- Standard : (spot2-spot1)/spot1 = -8.28 %
  (spot3-spot1)/spot1 = -7.50 %
- Uniform : (spot2-spot1)/spot1 = -2.53 %
  (spot3-spot1)/spot1 = 0.33 %

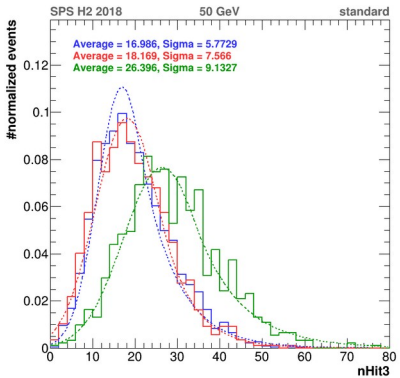
- nHit 70 GeV :
- Standard : (spot2-spot1)/spot1 = -9.38 %
  (spot3-spot1)/spot1 = -4.42 %
- Uniform : (spot2-spot1)/spot1 = 2.96 %
  (spot3-spot1)/spot1 = 8.41 %

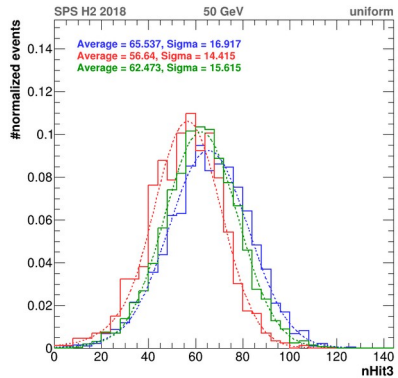








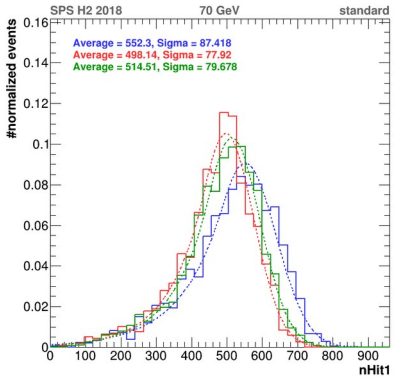


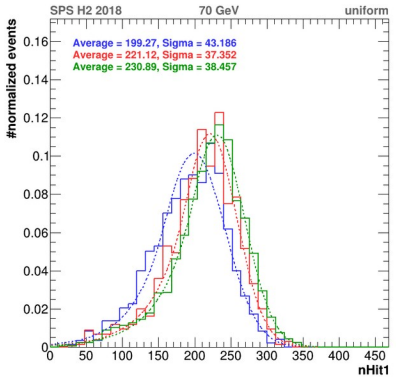


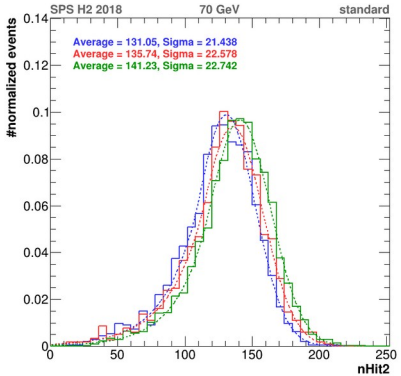
- nHit1 50 GeV :
- Standard : (spot2-spot1)/spot1 = -10.48 %
  (spot3-spot1)/spot1 = -14.68 %
- Uniform : (spot2-spot1)/spot1 = 5.17 %
  (spot3-spot1)/spot1 = 11.08 %

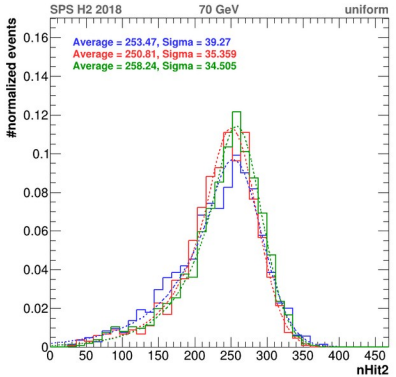
- nHit2 50 GeV :
- Standard : (spot2-spot1)/spot1 = 2.17 %
  (spot3-spot1)/spot1 = 15.02 %
- Uniform : (spot2-spot1)/spot1 = -4.56 %
  (spot3-spot1)/spot1 = -5.34 %

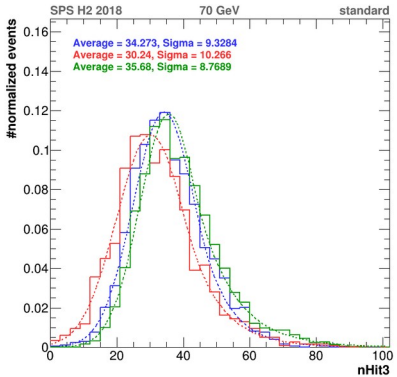
- nHit3 50 GeV :
- Standard : (spot2-spot1)/spot1 = 6.96 %
  (spot3-spot1)/spot1 = 55.40 %
- Uniform : (spot2-spot1)/spot1 = -13.58 %
  (spot3-spot1)/spot1 = -4.67 %

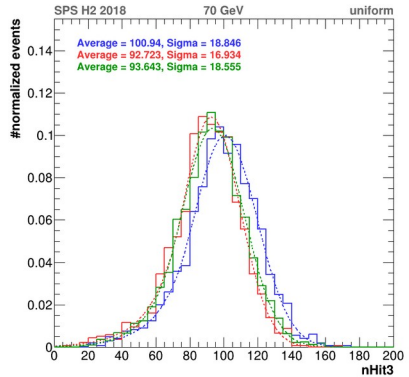










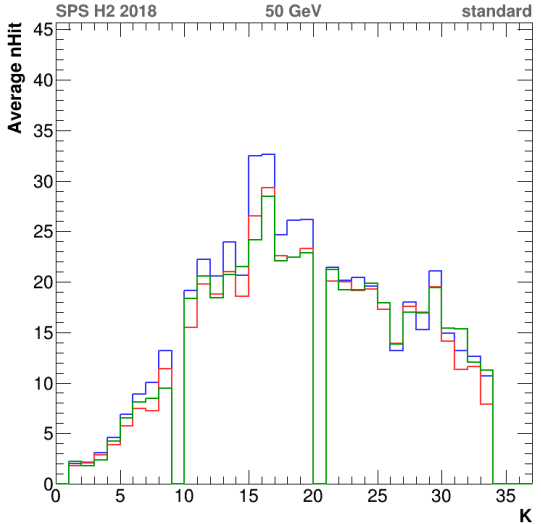


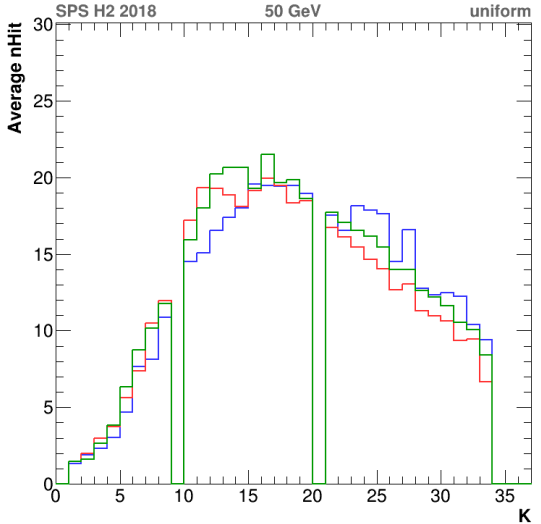
- nHit1 70 GeV :
- Standard : (spot2-spot1)/spot1 = -9.81 %
  (spot3-spot1)/spot1 = -6.84 %
- Uniform : (spot2-spot1)/spot1 = 10.97 %
  (spot3-spot1)/spot1 = 15.87 %

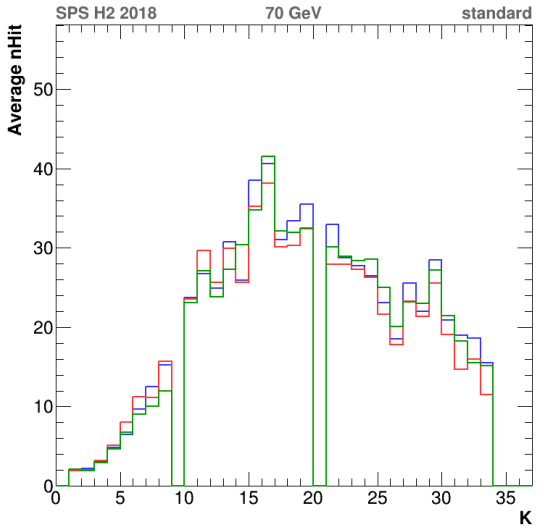
- nHit2 70 GeV :
- Standard : (spot2-spot1)/spot1 = 3.58 %
  (spot3-spot1)/spot1 = 7.77 %
- Uniform : (spot2-spot1)/spot1 = -1.05 %
  (spot3-spot1)/spot1 = 1.88 %

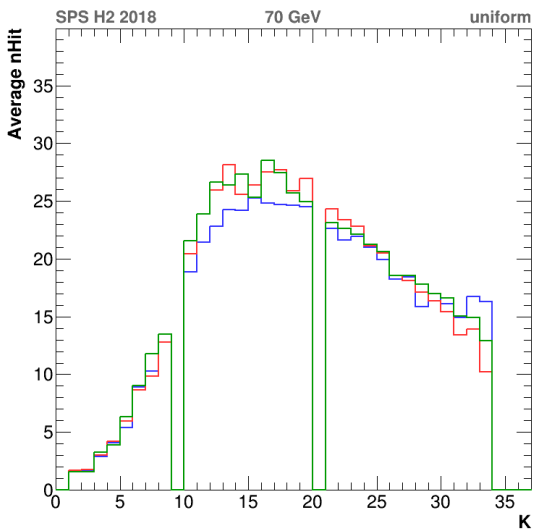
- nHit3 70 GeV :
- Standard : (spot2-spot1)/spot1 = -11.77 %
  (spot3-spot1)/spot1 = 4.10 %
- Uniform : (spot2-spot1)/spot1 = -8.14 %
  (spot3-spot1)/spot1 = -7.23 %

- Longitudinal profiles









- Summary :
  - Calibration of the SDHCAL using muons was tested :
    - Reduction of non-uniformities for first and second threshold seen for muons
    - Third threshold difficult to adjust

  - The effect of the calibration on hadronic showers is not very clear, but test conditions were harsh :
    - Lots of missing layers, lot of noise, very low statistics…
    - Different voltage applied between calibration and application