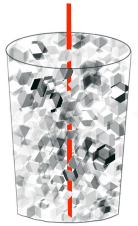

GRAiNITA status report

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IJCLab – CNRS Univ. Paris-Saclay

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GRAiNITA concept (2019)

Inspired by LiquidO technique for neutrino detector
(A. Cabrera et al. LiquidO Commun Phys 4, 273 (2021))

Typical sampling calorimeters:

$$\frac{\sigma_E}{E} \sim \frac{10\%-15\%}{\sqrt{E}}$$

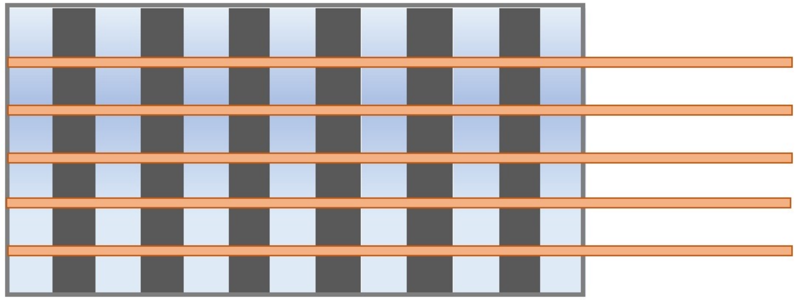
Crystal calorimeters :

$$\frac{\sigma_E}{E} \sim \frac{1\%-2\%}{\sqrt{E}}$$

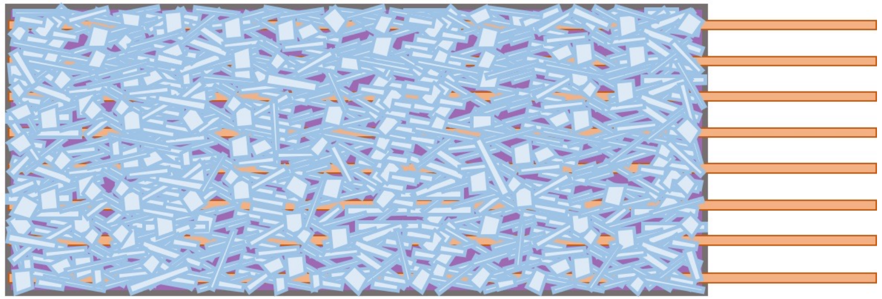
Requirements:

- fine sampling
- scintillation light locally contained

Shashlyk-type calorimeter



GRAiNITA



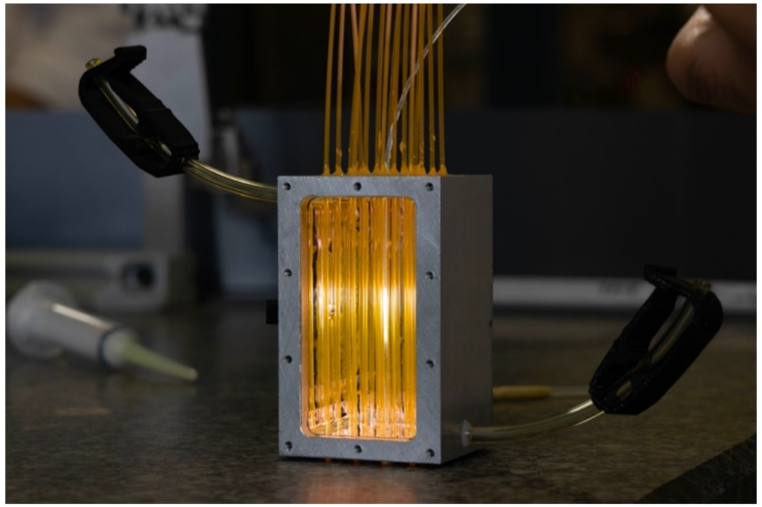
Where are we ?

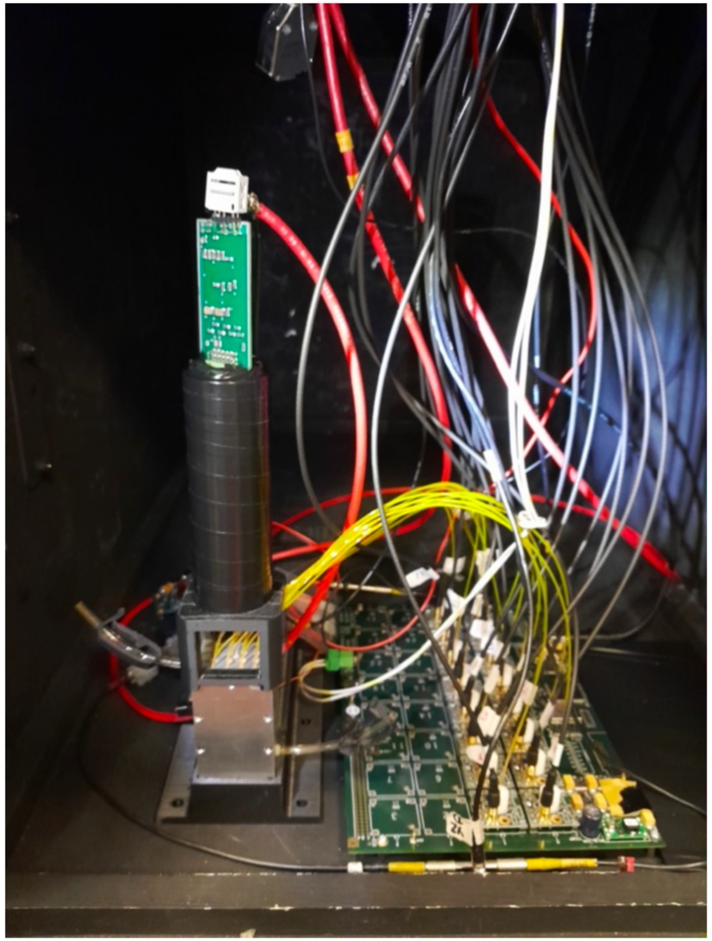
Small (2 x 2 x 5.5 cm^3) prototype filled with ZnWO4 grains + water or Heavy Liquid (EGL or LST_fastloat (d=2.8)) and 16 WLS fibers read out by SiPM and a Wave-Catcher

Depolished fiber in the center to allow for green light injection

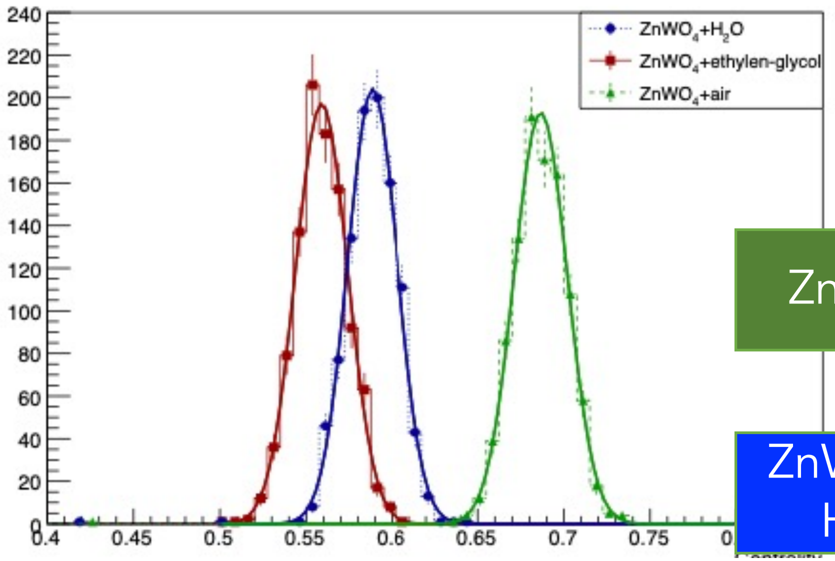
	$ZnWO_4$
Effective Z	61
Density (g/cm^3)	7.87
Refractive index	2.0 - 2.3
Light yield (photons/MeV)	~ 9000
Peak emission wavelength (nm)	480
Decay time (μs)	20
Radiation length (cm)	1.20
Molière radius (cm)	1.98

built in 2023





[JINST 19 P04008]

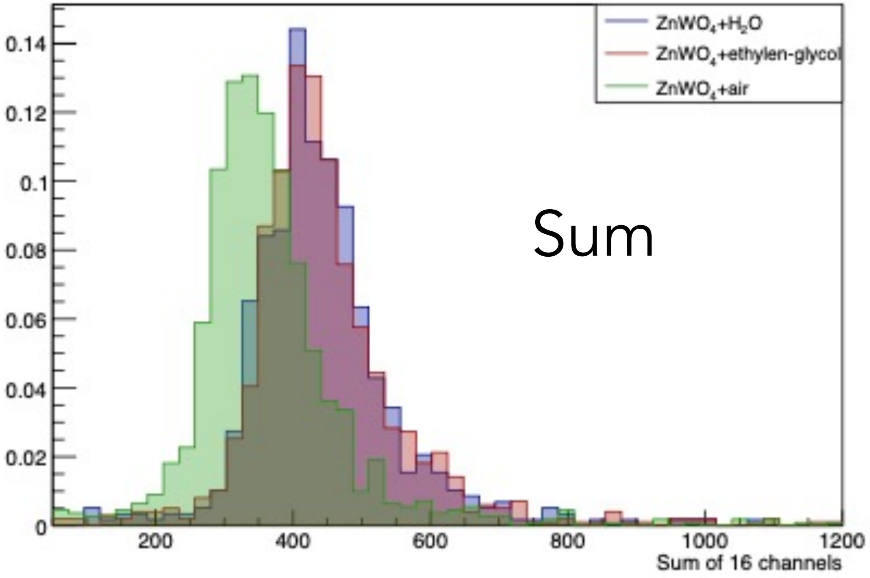


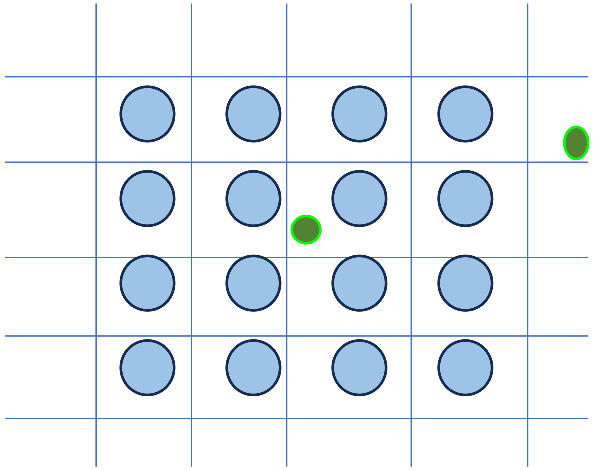
$ZnWO_4$

$ZnWO_4 + H_2O$

$ZnWO_4$ + EGL

$$\text{Centrality} = \frac{4\ central\ channels}{Sum}$$





Green light injection

1. **Light is confined**
2. **Most Probable value (fit by Landau) : ~400**

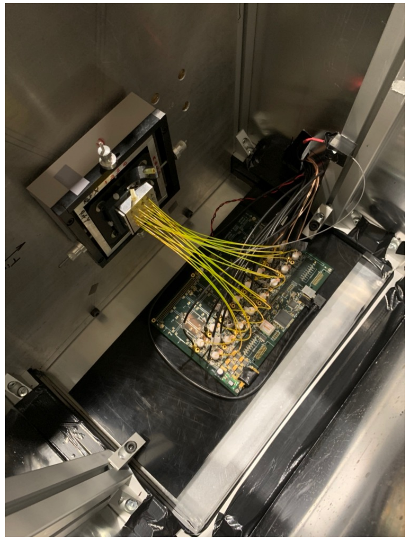
⇒ ~ 10 000 photo-electrons/GeV

⇒ opens the road to a a statistical fluctuation of $\frac{1\%}{\sqrt{E}}$ due to photon statistics

A test beam ?!

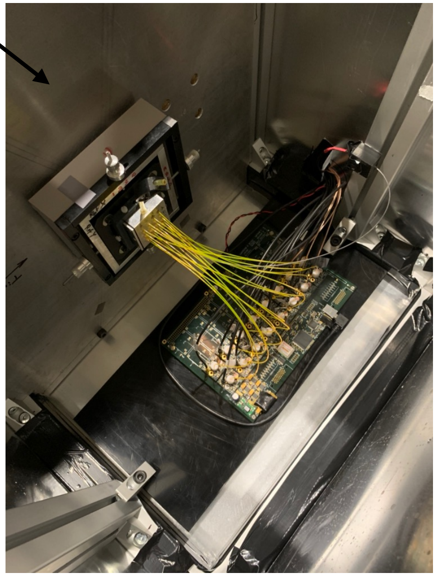
In March, we were informed of the possibility to be parasitic in a test beam for LHCb-U2 calorimeter tests in the H2 region in the CERN North Area

We decided to put our small prototype in a beam of muons and pions (about only ~5% of the pions are supposed to interact in our prototype).
It was a nice week-end



Many thanks to Yuri Guz
Loris Martinazzoli and Matteo Salomoni

We have recorded in ~ 48h ~million of muon and pion triggers in two configurations : $ZnWO_4$ grains immersed in water or in HL



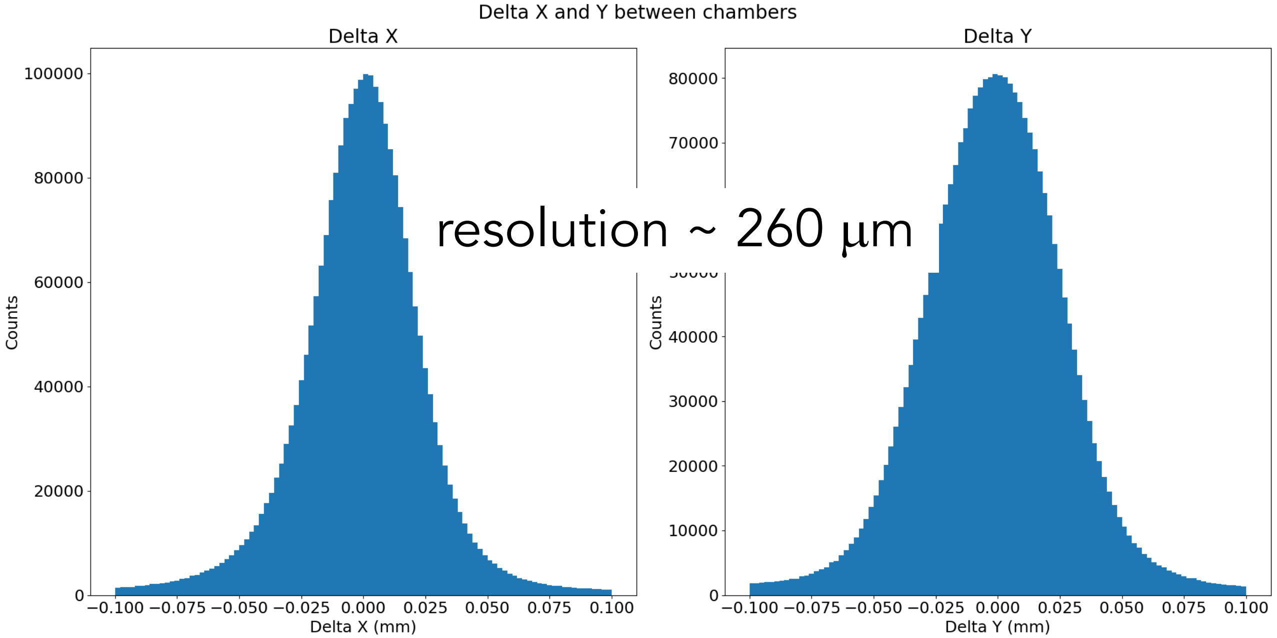
GRAiNITA

- triggered by the drift chamber + scintillators
- read-out by a 16-channels wave catcher adapted to count the number of photo-electrons in a 25 μs window

Millions of triggers

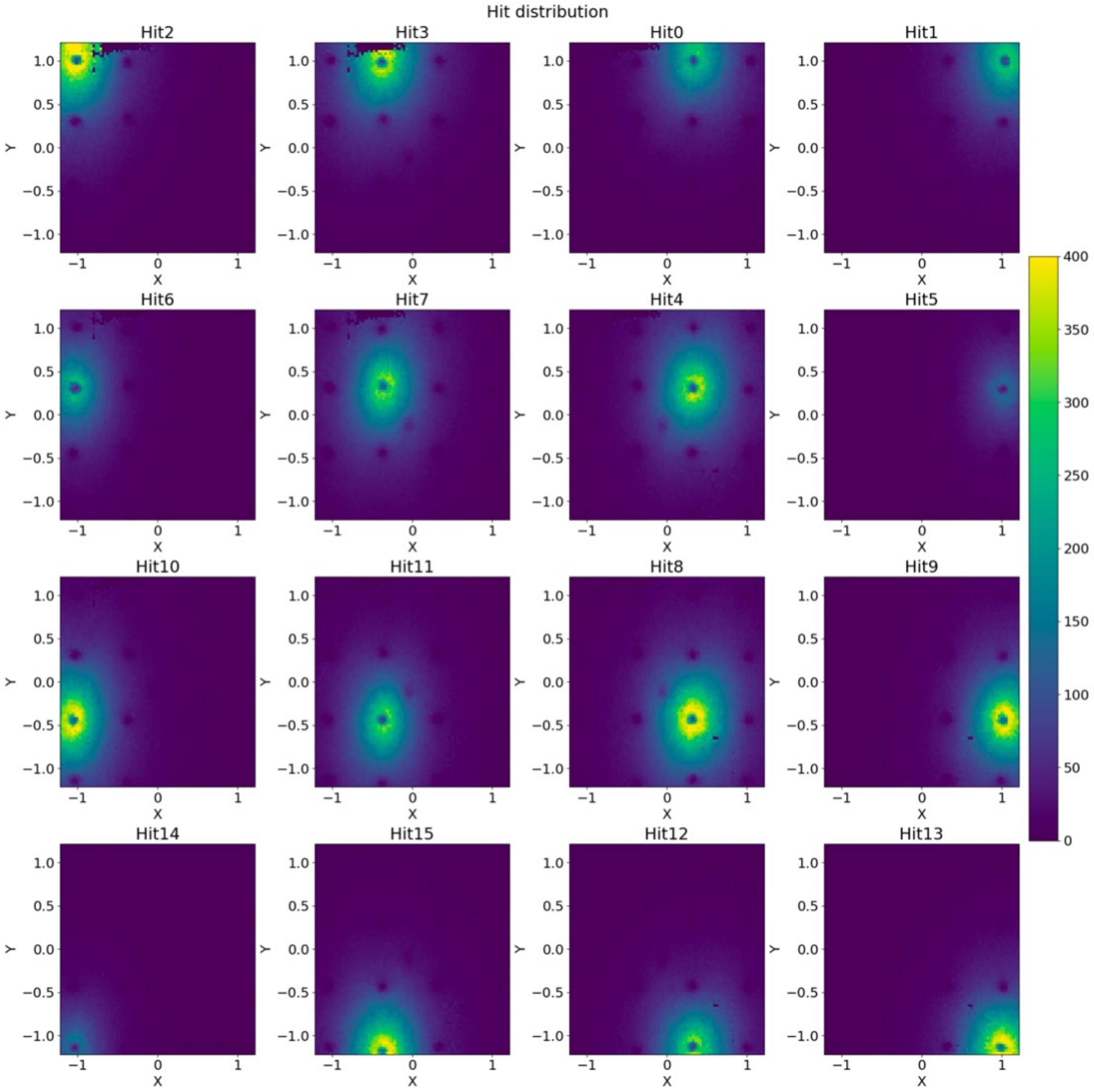
~ 0.2 million of high-quality muons passing through GRAiNITA

~ 3.8 millions of high-quality pions passing through GRAiNITA



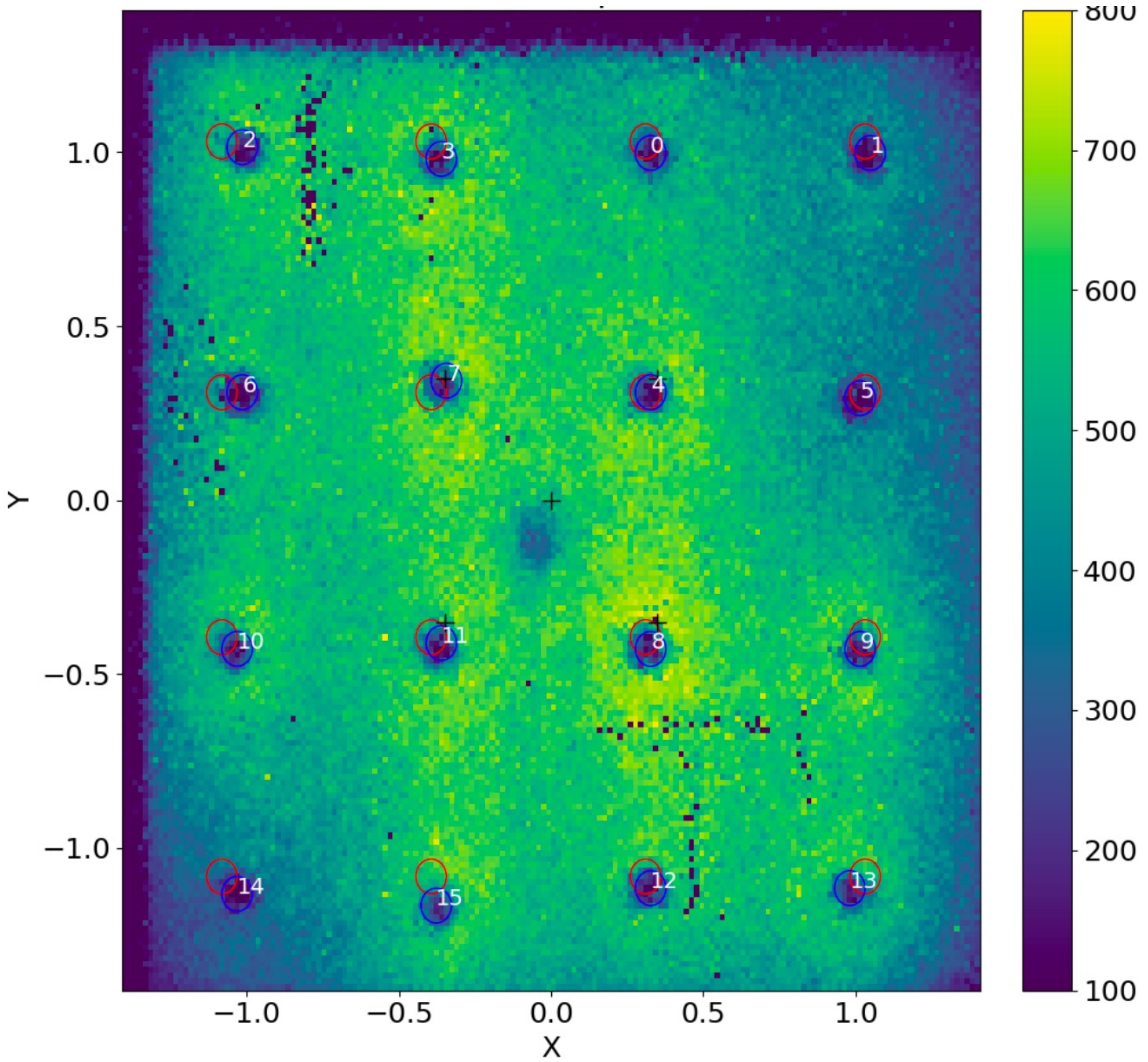
resolution ~ 260 μm

(x,y) map for all tracks weighted by the response from each fiber

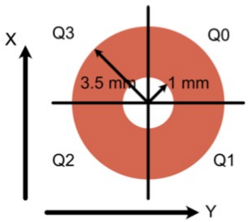


Confirmation of the light confinement

(x,y) map for all tracks weighted by the global answer from the prototype



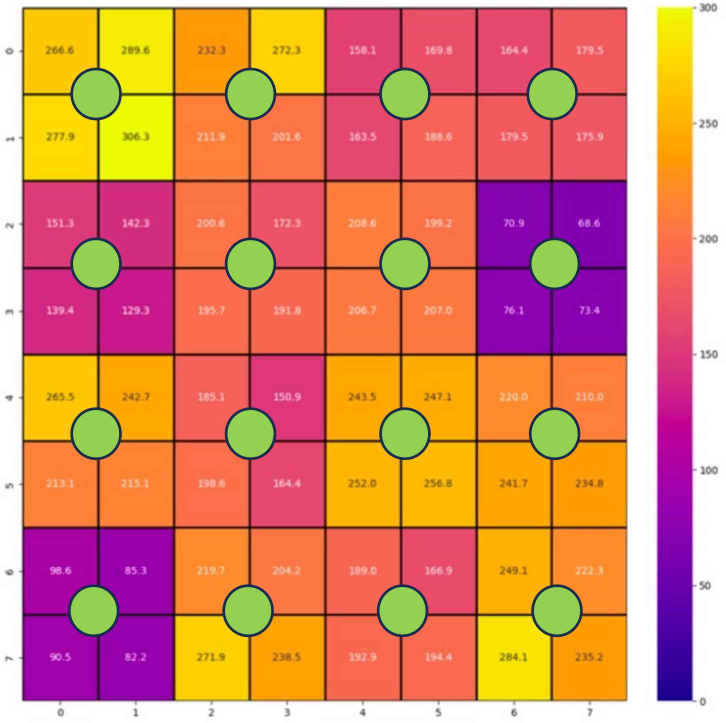
Uniformisation of the fiber response



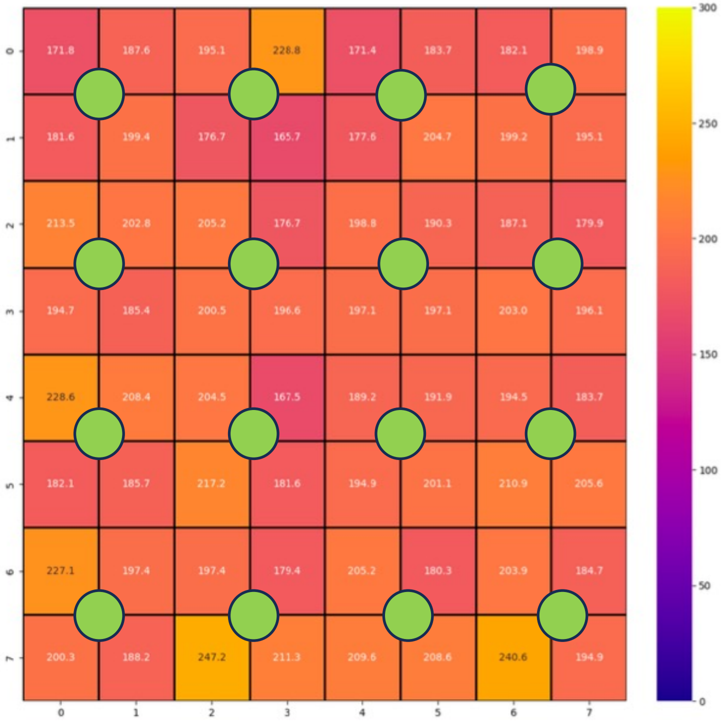
For each fiber:

- plot the fiber response (avoiding edge effect) and fit with Landau⊗Gaussian → MPV
- compute the average of the MPV (<MPV>).
- → 16 coefficients (one per fiber)

Difference to <MPV>

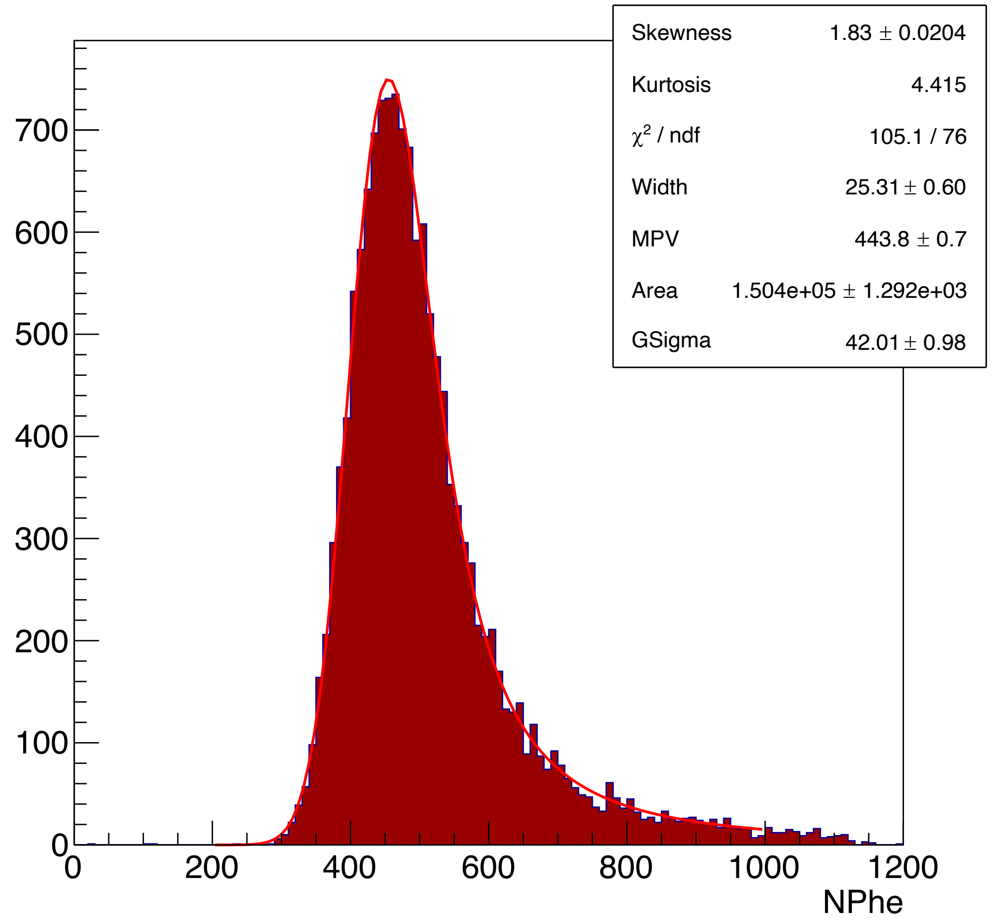


Before



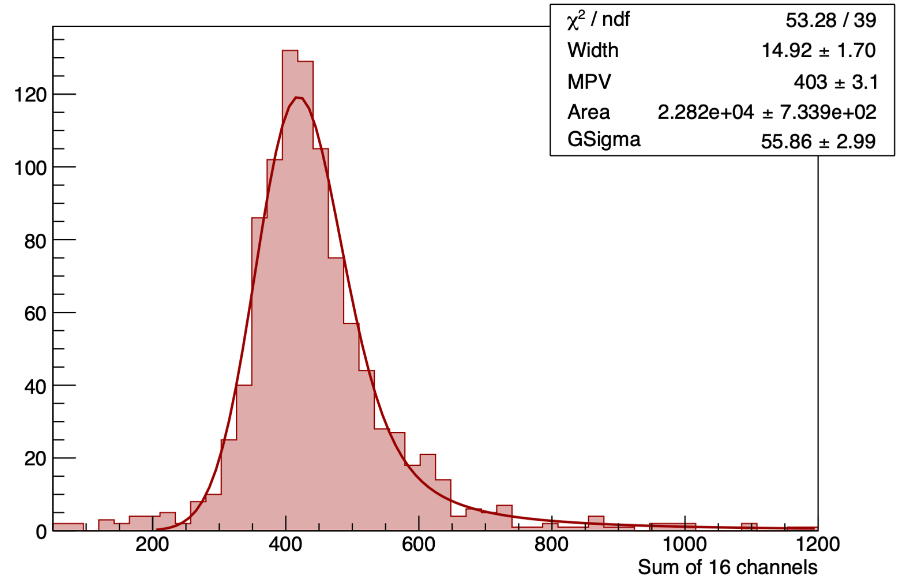
After

Muon/HL 444+/- 1



403+/- 3

JINST 19 P04008



confirmation of the possibility to have a statistical fluctuation of 1% /√E due to photon statistics

Towards the uniformity study

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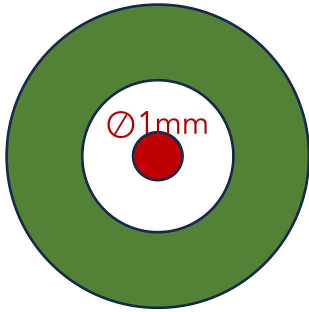
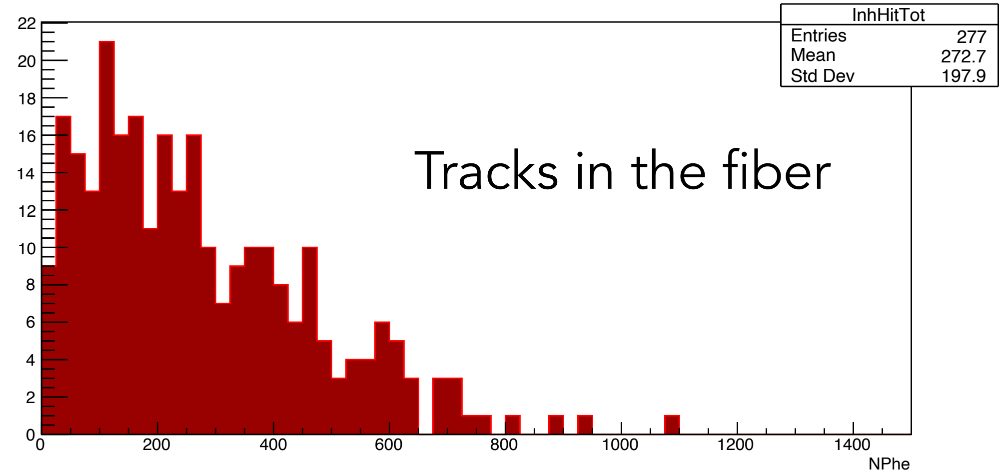
How does the signal evolves around a fiber ?

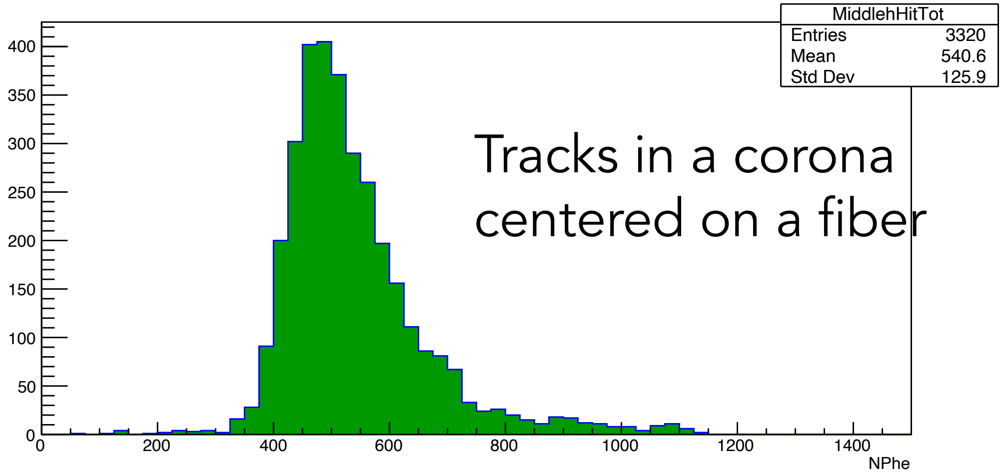
1.5<R<3.5 mm

R<.5 mm

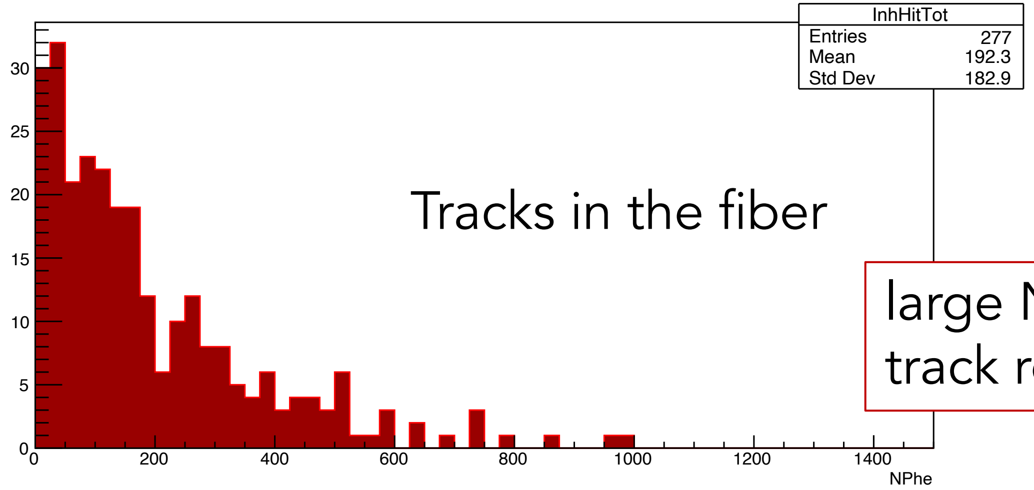


Fiber7

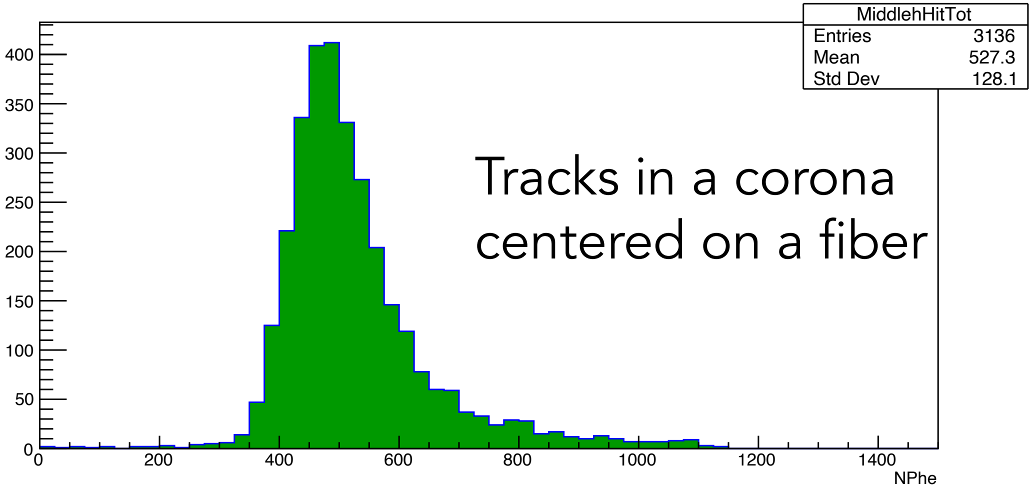




Fiber4



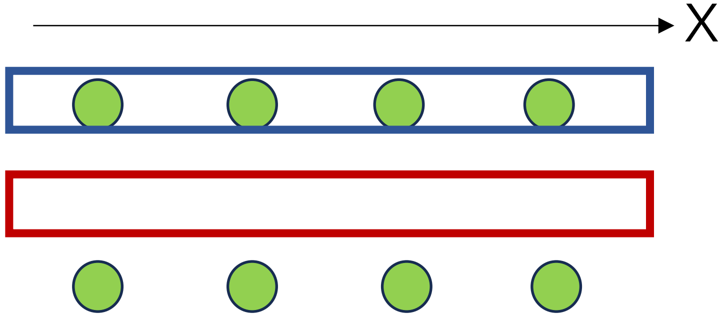
large NPhe values : track resolution

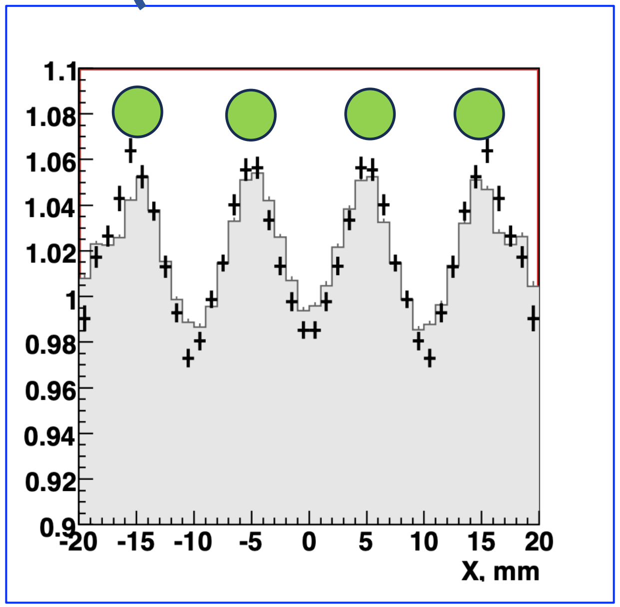


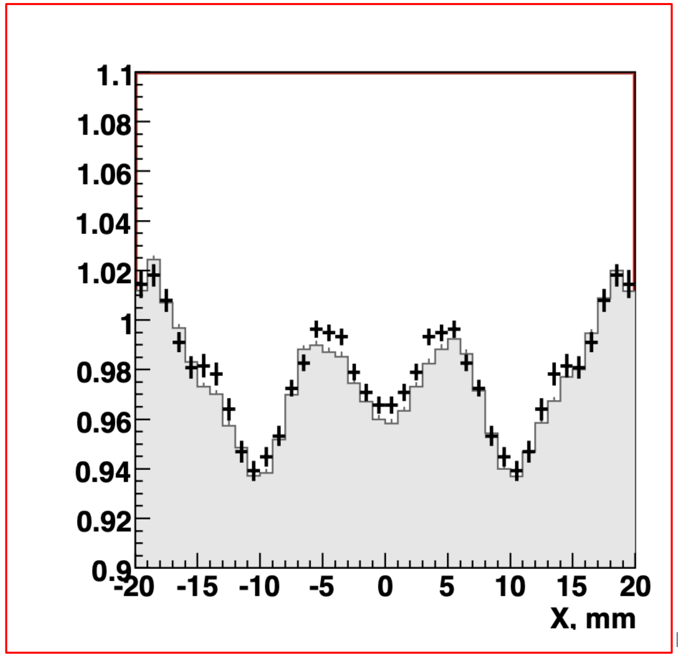
Principle of the method (LHCb calorimeter)

[Beam Test Results of the LHCb Electromagnetic Calorimeter]

Scan in two regions



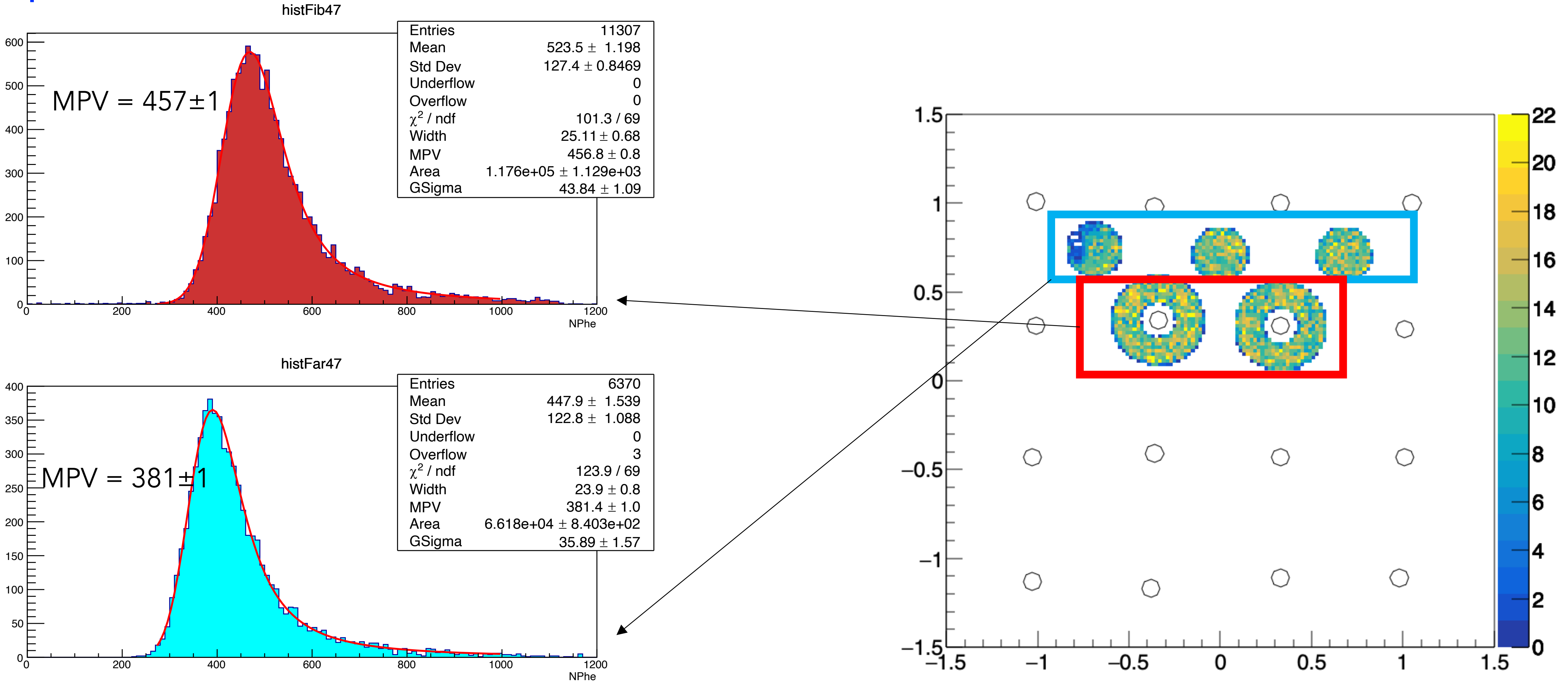




Grey = simulation

~0.8% constant term for LHCb calorimeter

A preliminary look



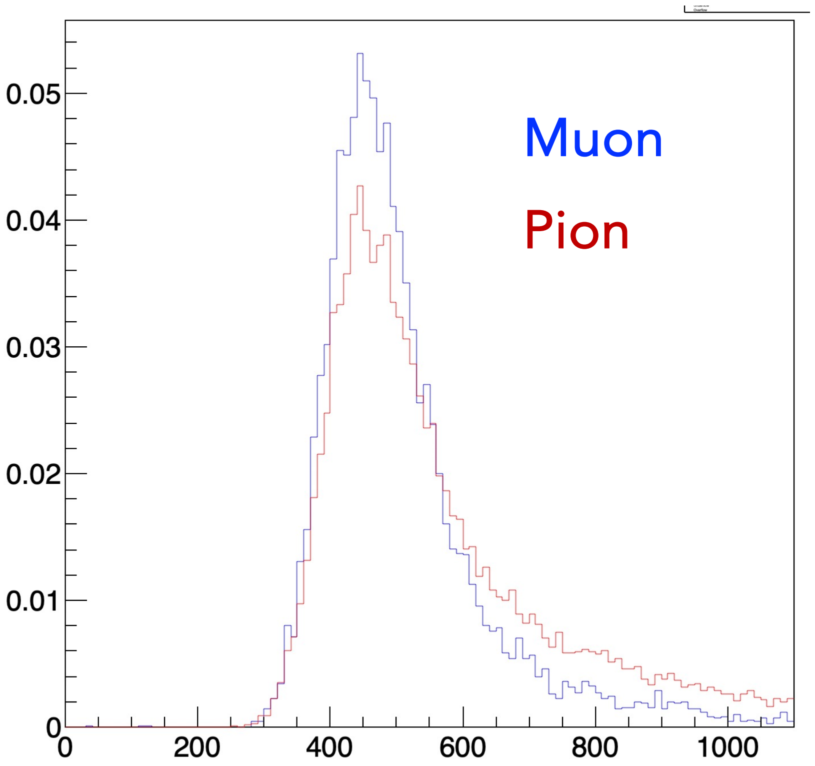
~±9% variation

Simplified simulation(*) indicates that $\frac{\sigma_E}{E} \sim 1\%$ should be at reach

(*) $1 + 0.07\cos\left(\frac{2\pi X}{7\ mm}\right) + 0.07\cos\left(\frac{2\pi Y}{7\ mm}\right)$

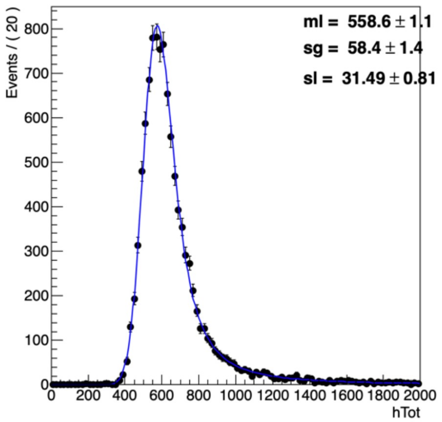
Towards the use of the π beam data

About 5% of the π interact in the prototype
π beam has higher-stat but is more less pure

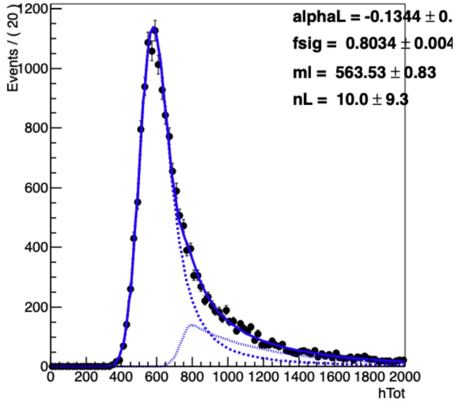


Use the tracks close to a fiber (here Fiber8) for the modelling of the response

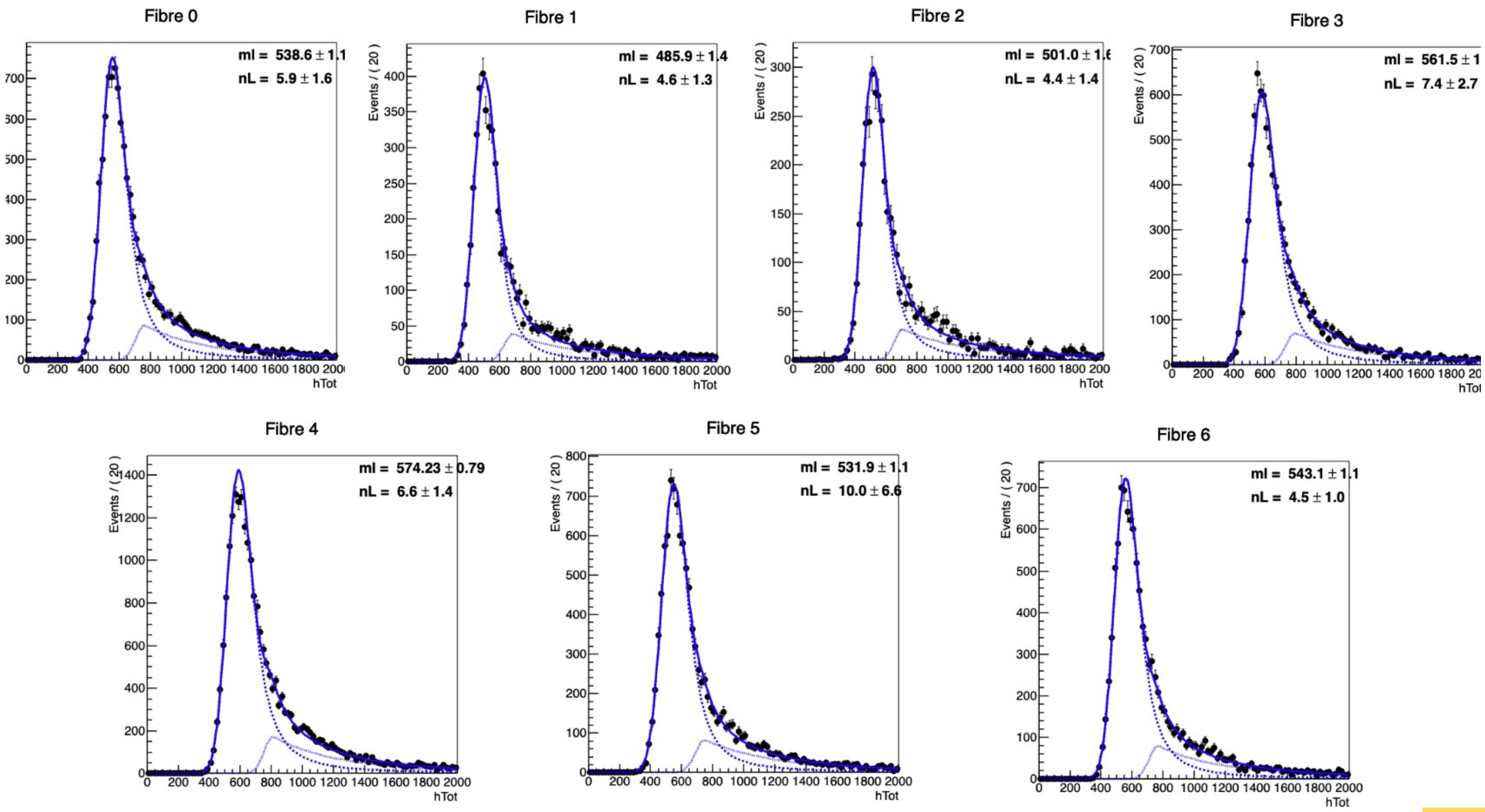
Muon Fit:
Landau⊗Gaussian



Pion fit :
Landau⊗Gaussian (parameters from Muon, but MPV) + Asym-CB (mean and sigma related to Landau ⊗Gaussian)



Is this shape universal enough ?

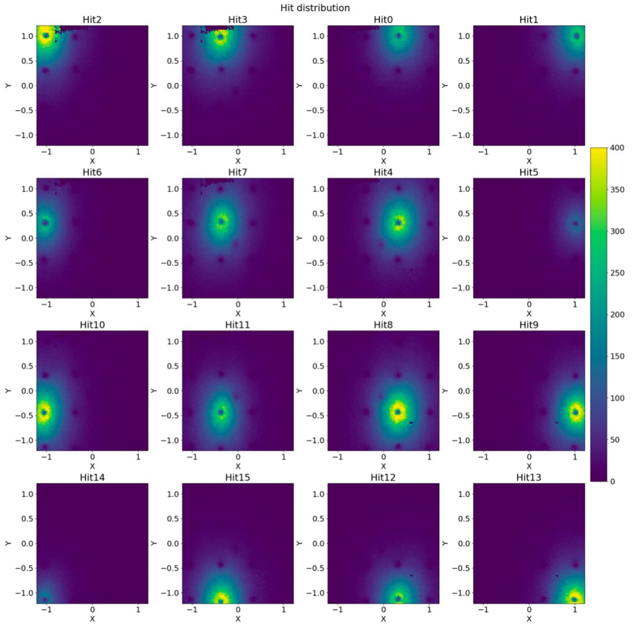


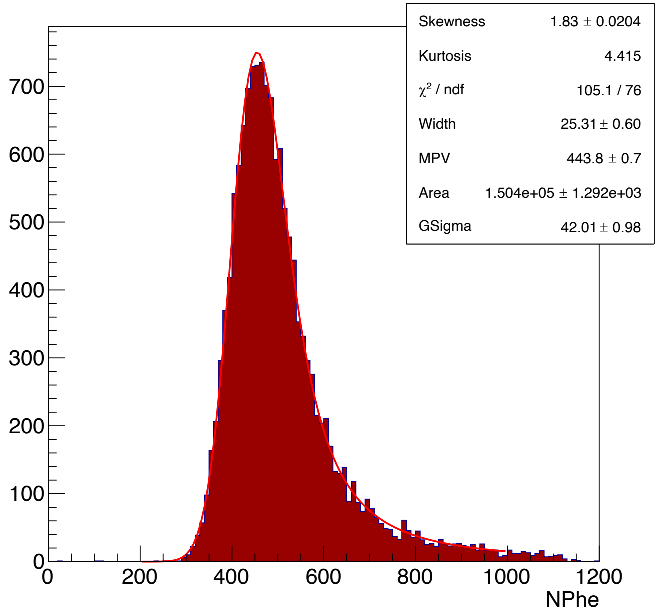
'Blind' application to the 15 other fibers

seems promising !

Conclusion

- Confirmation of the NPhe ~ 10k/GeV : statistical fluctuation of $\frac{1\%}{\sqrt{E}}$ at reach
- Next question : constant term due to non-uniformity
  - If the track is more than 0.5 mm away from the limit of the fiber, the variations are small
  - A priori enough data for a first study of the uniformity, preliminary results are encouraging
  - Limitations due to the prototype size





Stay tuned !