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First – level trigger for the advanced SiPM camera

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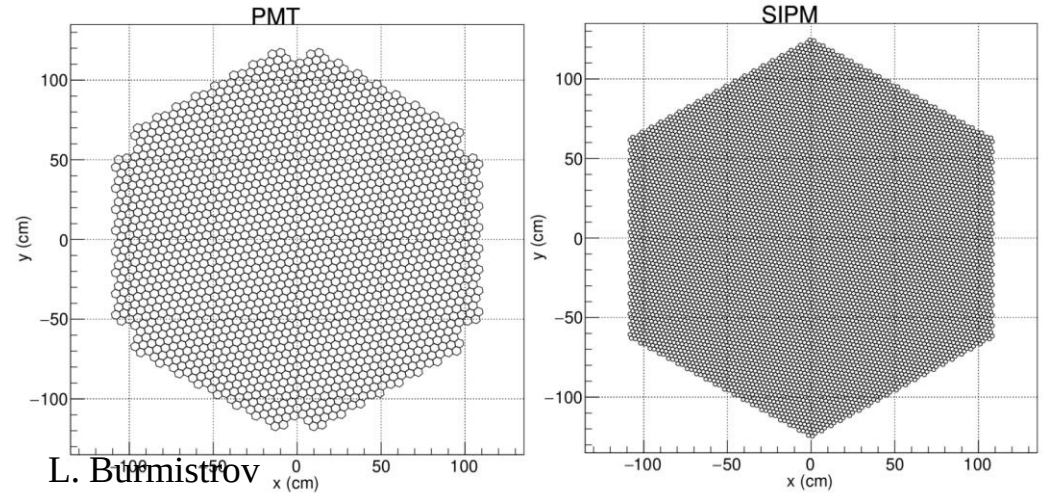
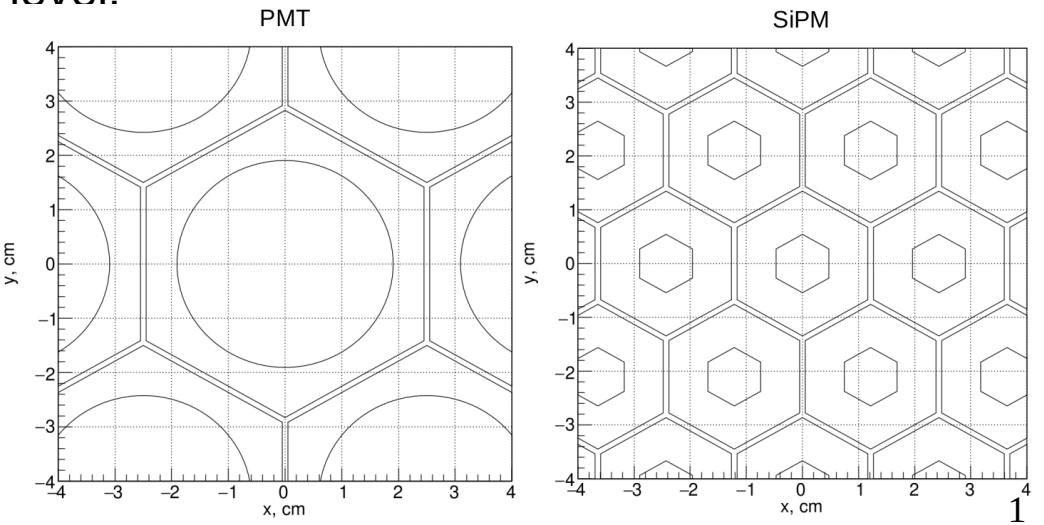
Outline

- Introduction and task reminder
- Hardware trigger
  Why digital sum is a good starting point to build the trigger ?
  And how one can lower its threshold while keeping same trigger rate ?
- Symmetry in the telescope images.
  Principal component analysis (PCA) as possible lightweight approach to for gamma/hadron separation on hardware level.





Introduction and task reminder

Gamma rates measured in ~Hz (Crab nebula : ~0.4 Hz measured with MAGIC (E>= 60 GeV))

Proton showers are fare dominant background.

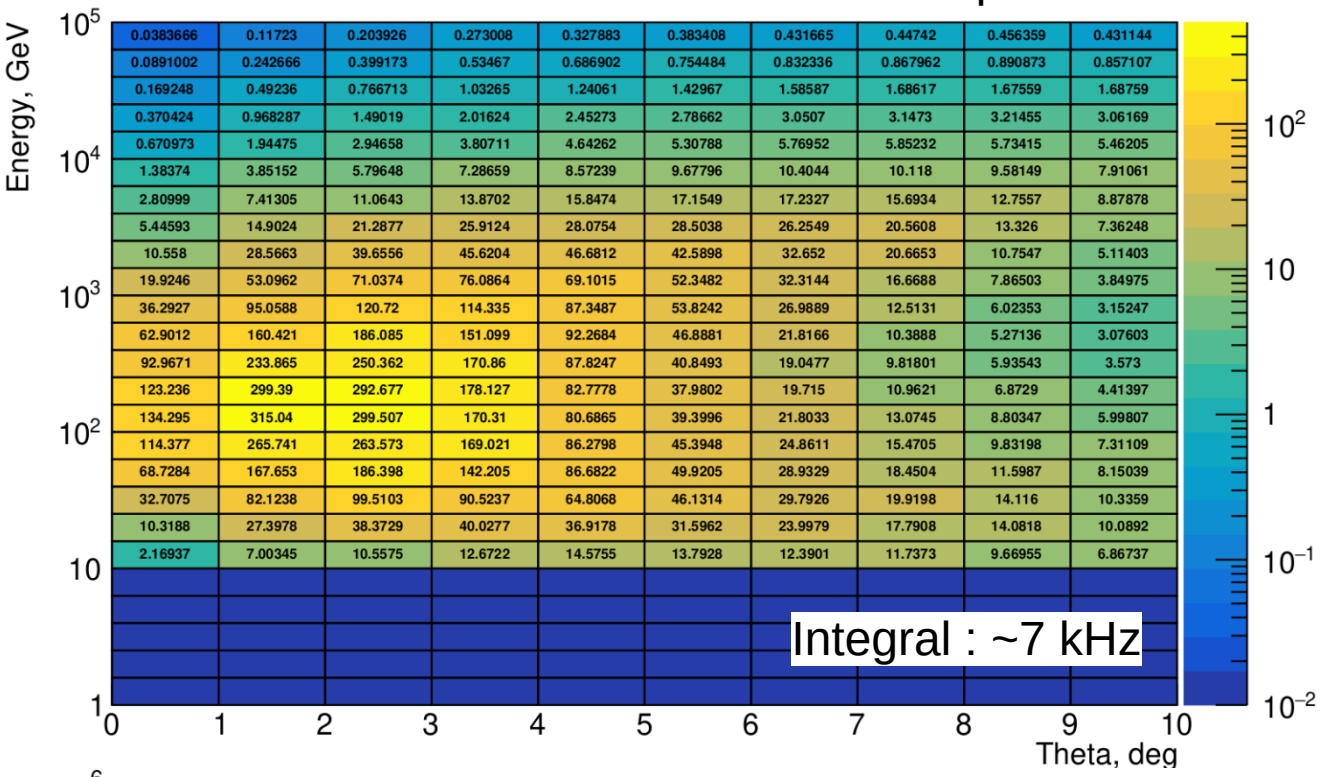
Theta : angle between particle direction and telescope optical axis.

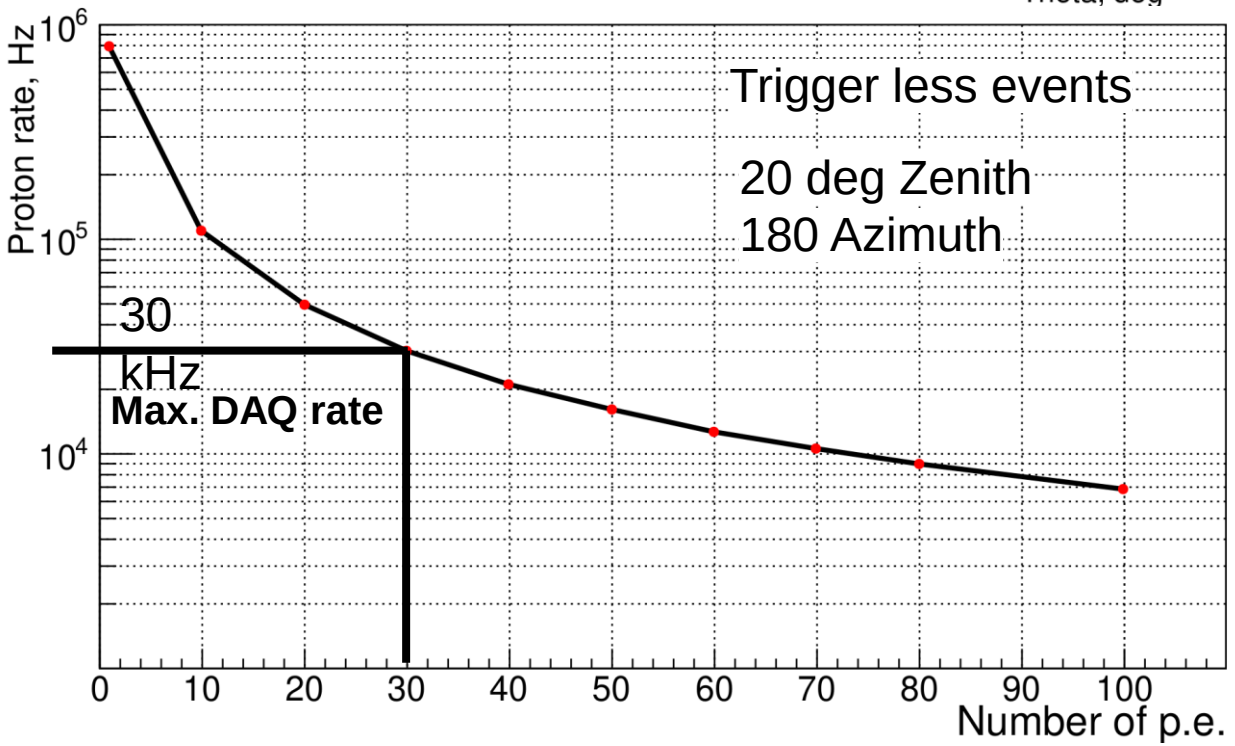
The DAQ can accept up to ~ 30 kHz. events.

We need to **efficiently trigger** on faint events with about **30 p.e.** in total only.

In case we can lower the threshold even more – one needs to implement gamma/hadron separation on hardware level.

Proton rates with more then 100 p.e.



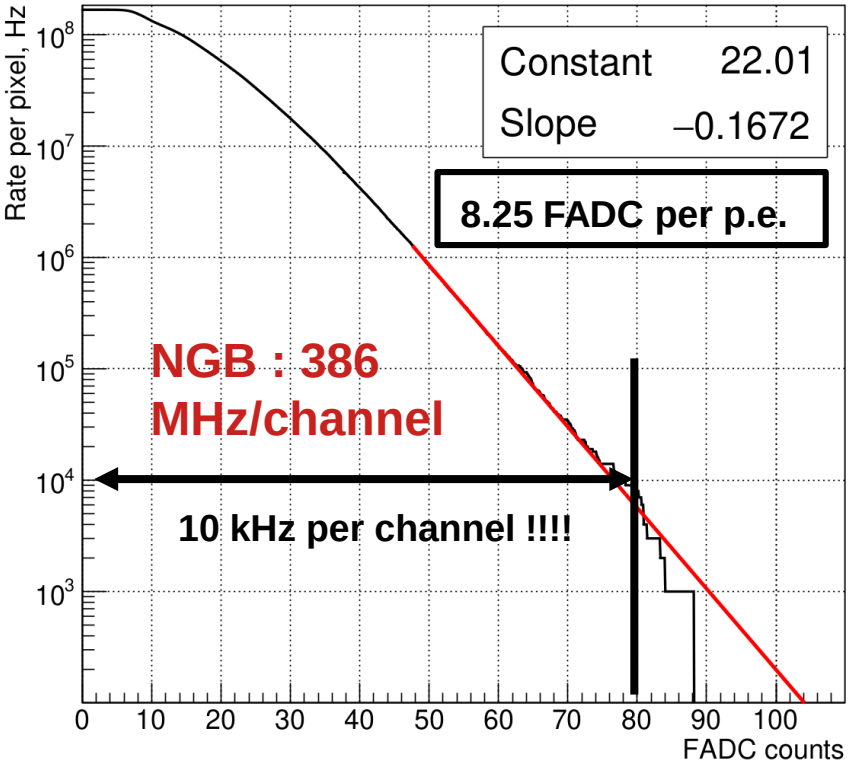


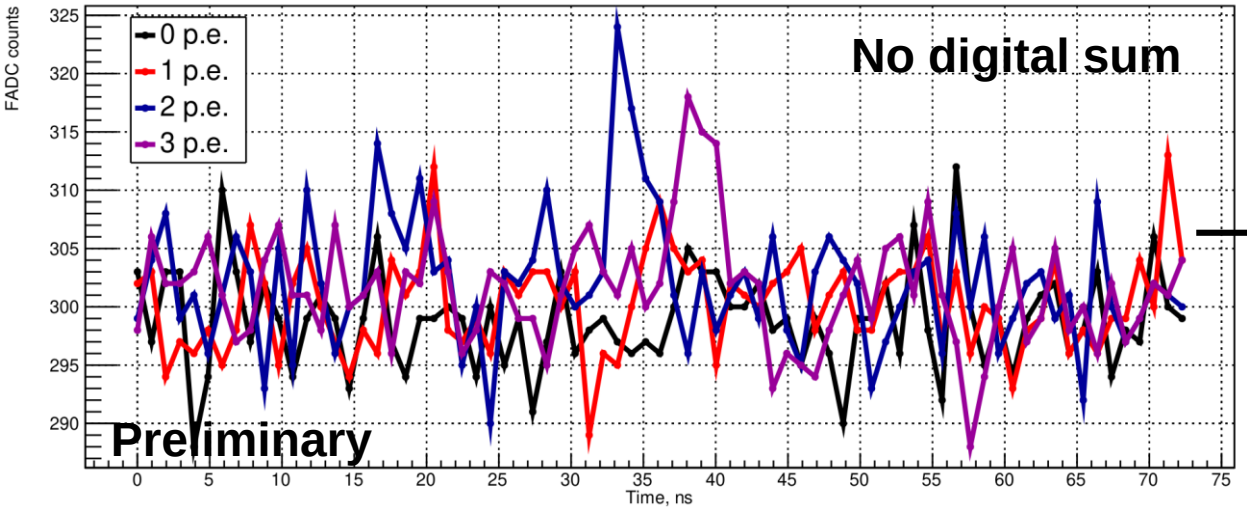
Why digital sum is a good starting point to build the trigger ?

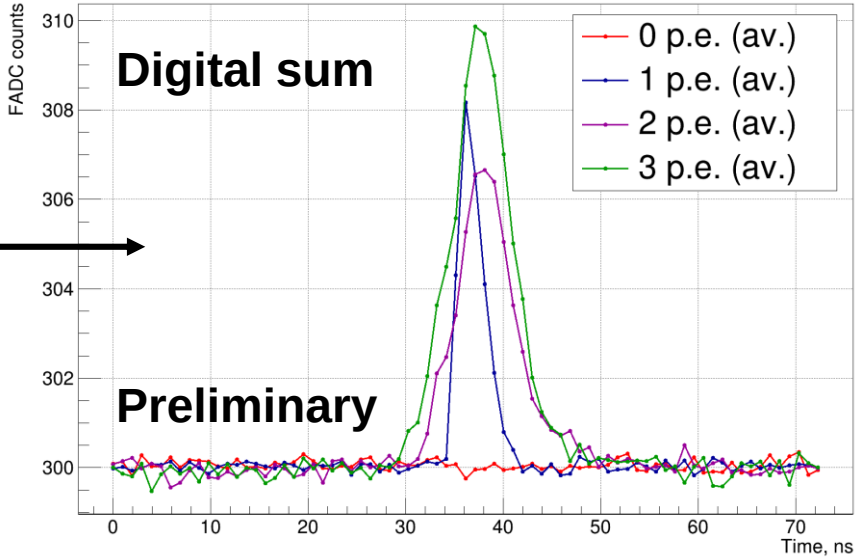
- Have better behavior than threshold applied to a single channel.
- Number of possible combinations for coincidence is very large number.

Fully digital readout allow us to build almost any trigger schemes including hybrid.

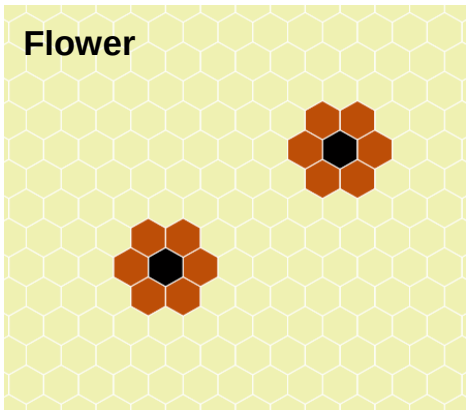
- While the digital sum requires little computational power. While reducing random noise and amplifying the signal.
- To show how the digital sum work, we calculate the sum taking into account true time of the photon.

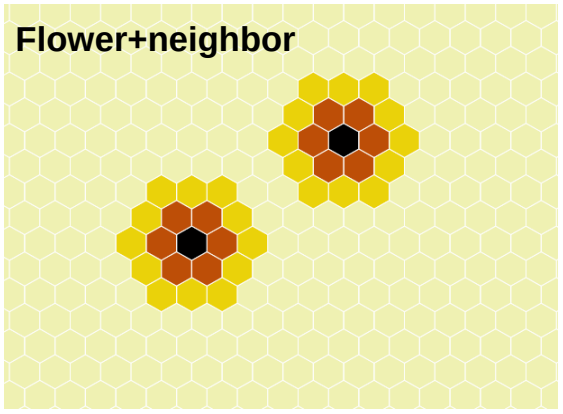


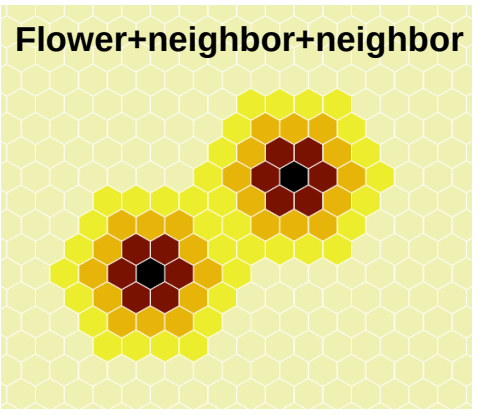


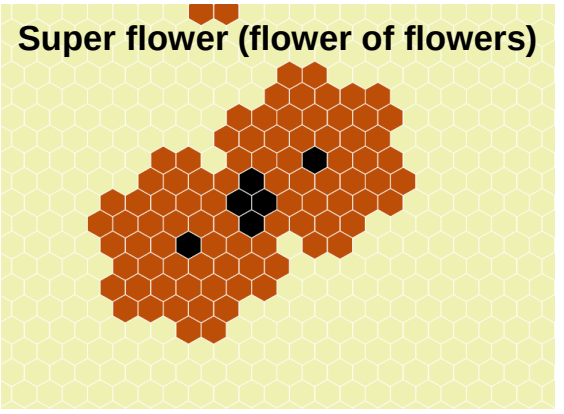


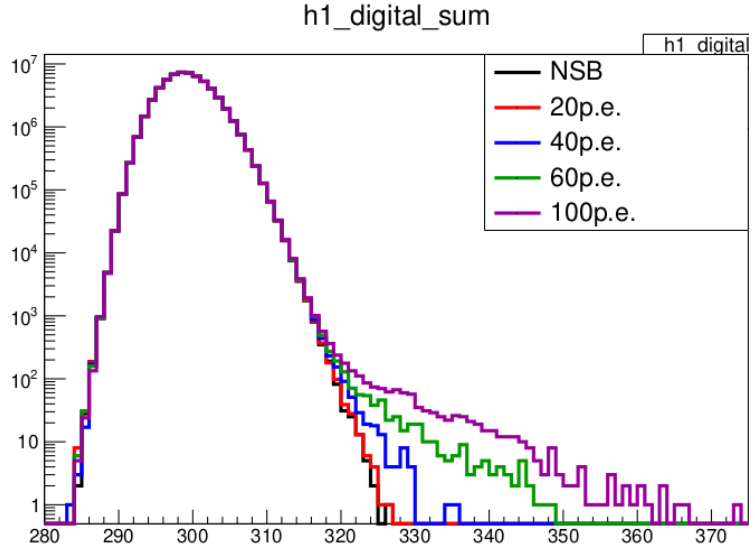
Spacial and temporal parameters can be tuned to get better performance

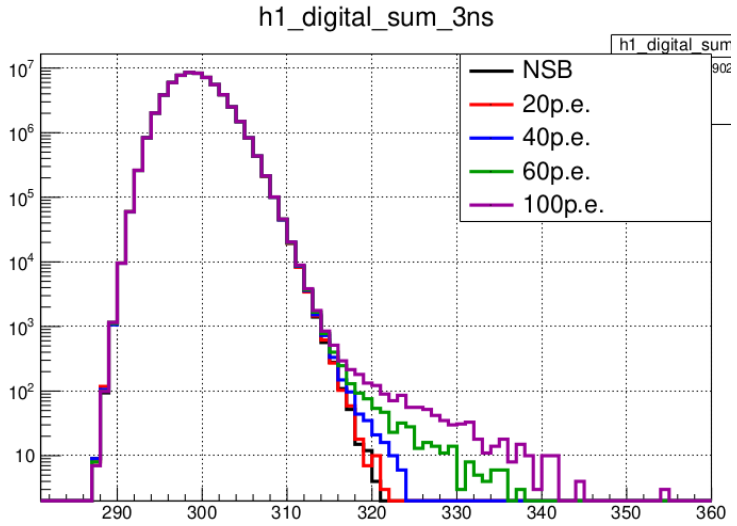


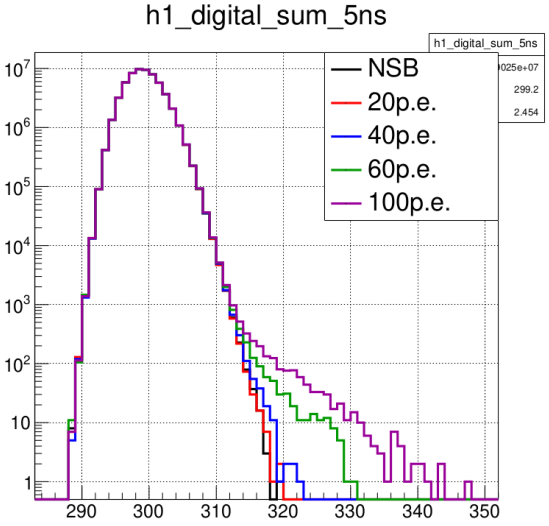








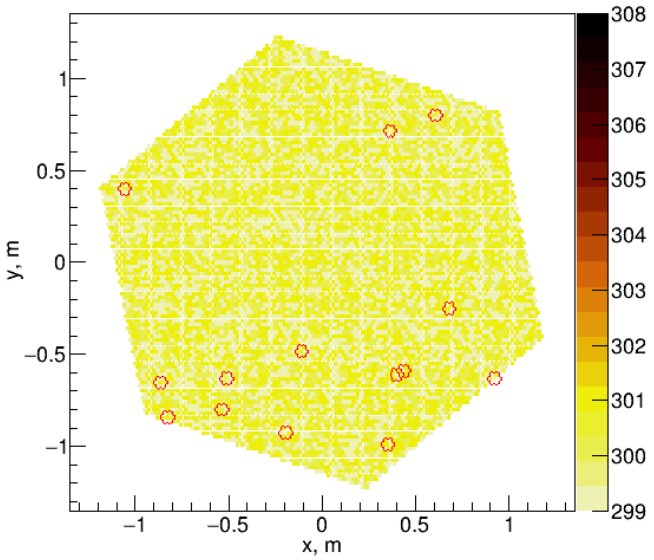




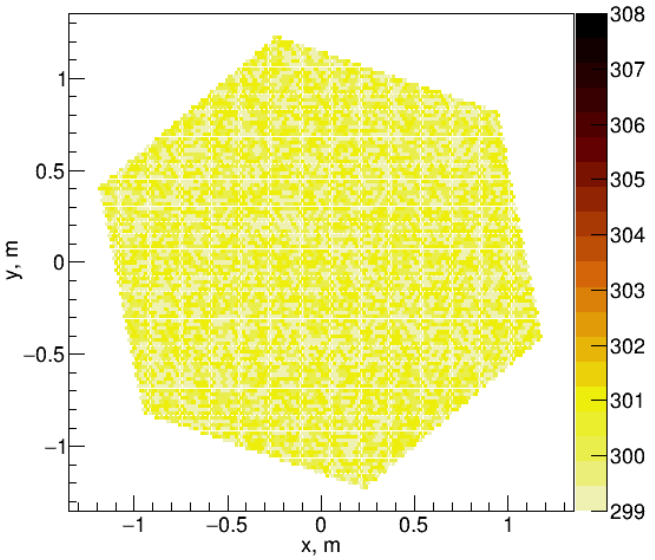
The digital sum can be used as initialization stage for clustering algorithms.

Digital sum and clustering algorithms

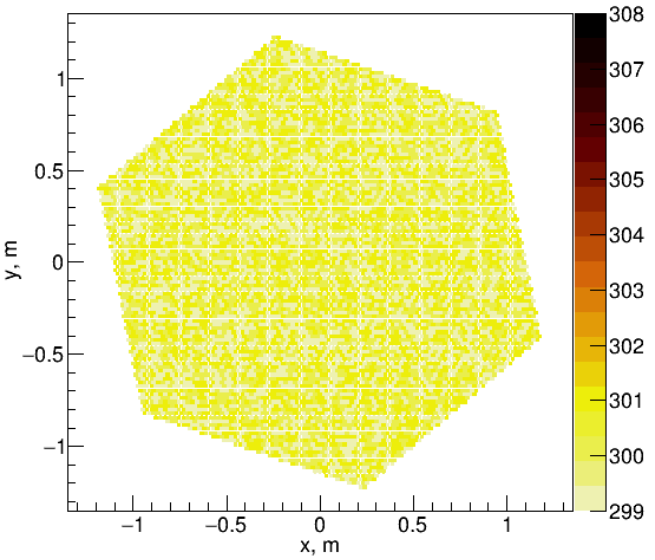
Sum only

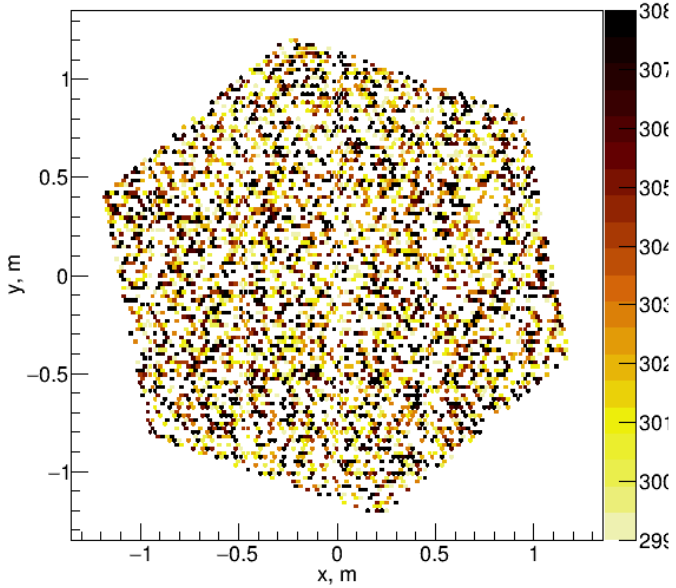


Sum+spatial clustering



Sum+spatial+temporal clustering

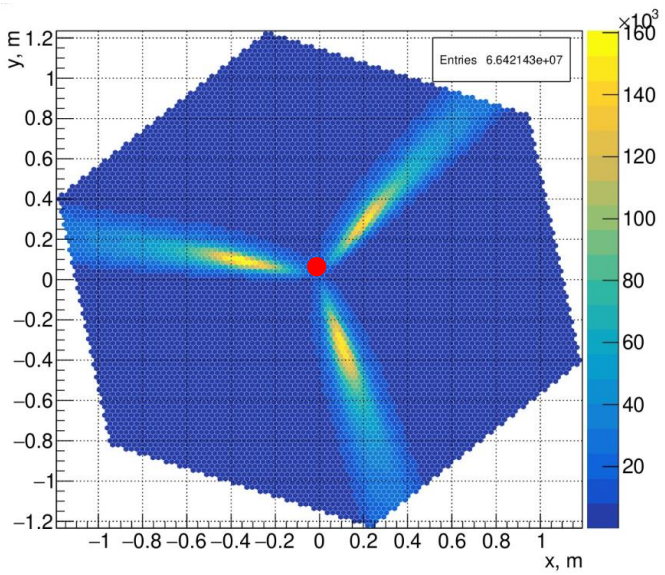




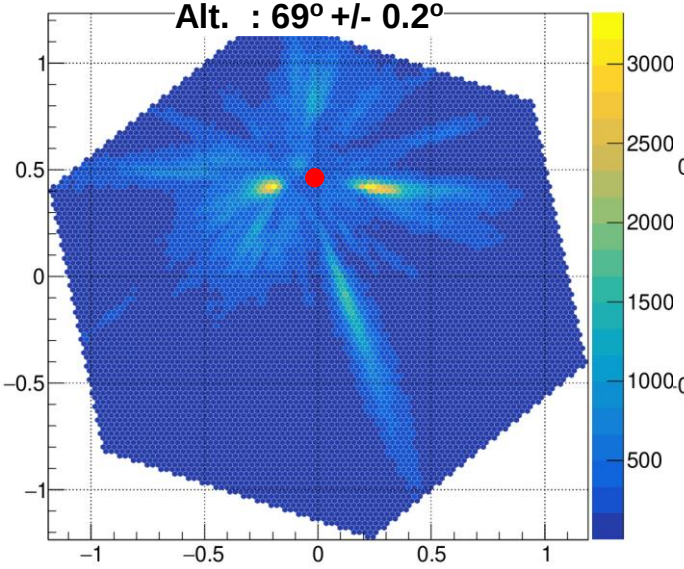
wf_time : 0 ns
gamma
event_id : 23801
energy : 15 GeV
xcore : -51 m
ycore : -203 m
ev_time : -71 ns
nphotons : 146
n_pe : 42
n_pixels : 25
azimuth : 1800/10 deg
altitude : 699/10 deg
h_first_int : 23186 km
hmax : 11727 km

Symmetry in the telescope images : x-y shift[1] + rotation.

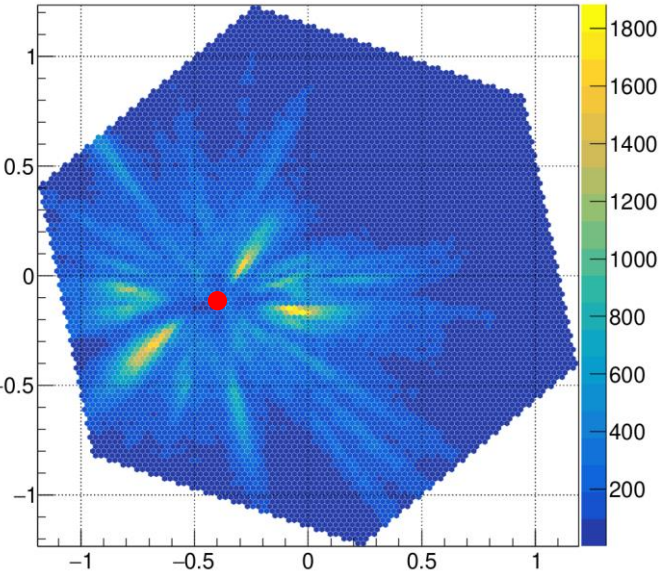
Core location with respect to optical axis : [0,10º], [125, 135], [245, 255]



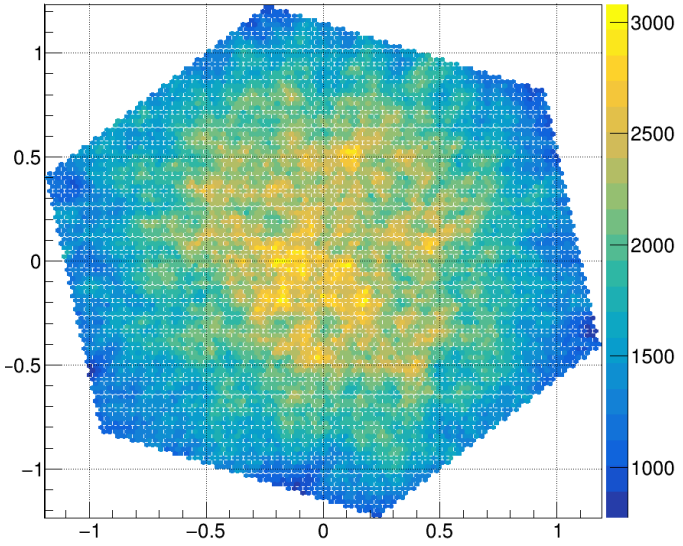
Azi. : 180º +/- 0.2º
Alt. : 69º +/- 0.2º



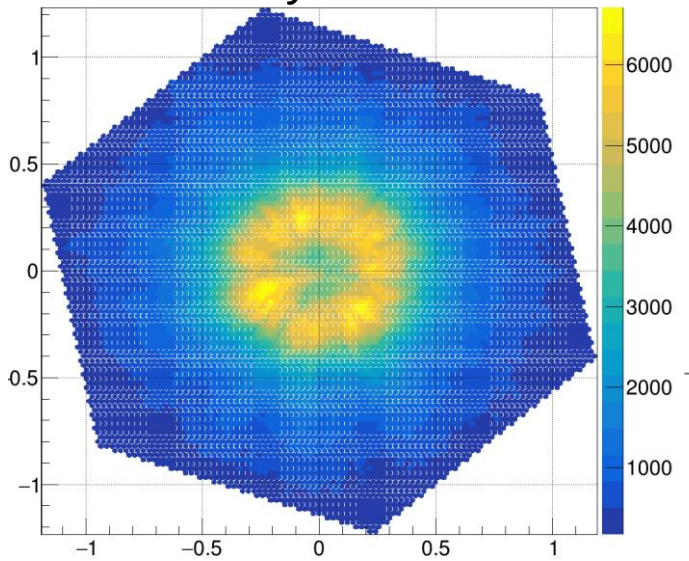
Azi. : 177.5º +/- 0.2º
Alt. : 70º +/- 0.2º



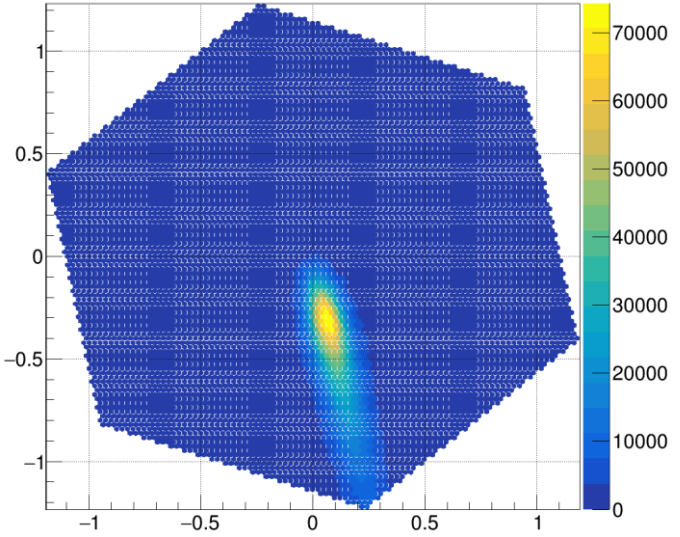
Diffused gamma



x-y shift



x-y shift and rotation

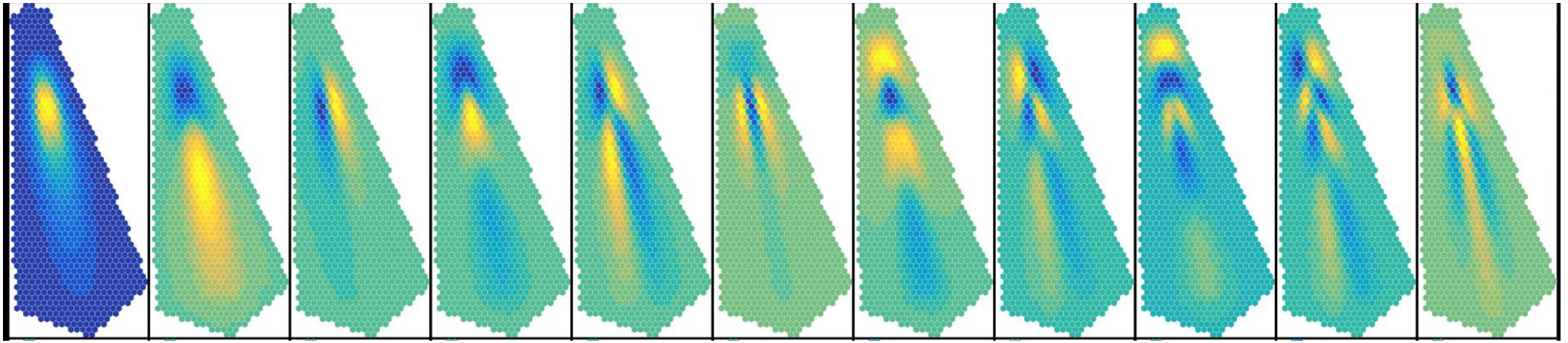


We use mc – information to obtain the simplest representation of the shower to get the PCA.

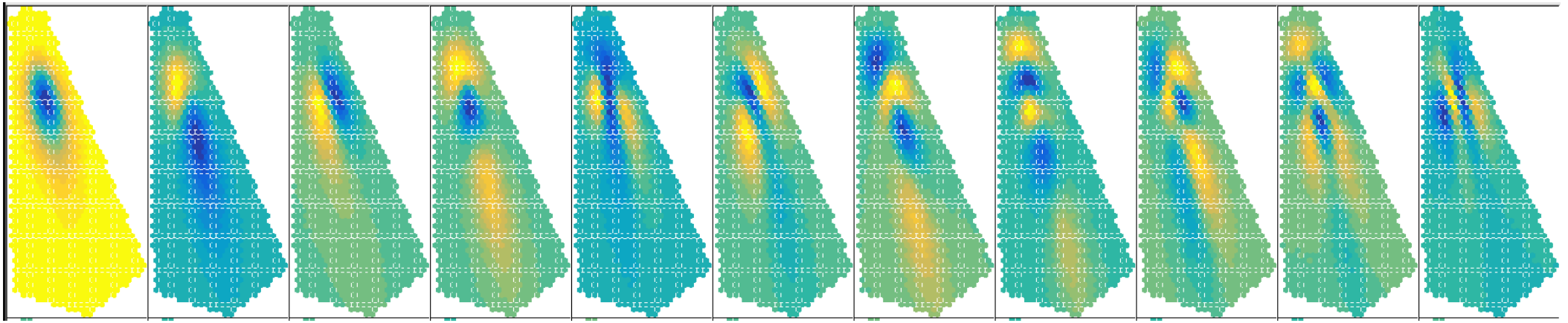
1) The LST parabolic mirror is flipping the image on the camera.

First 11 eigenvectors (PCA)

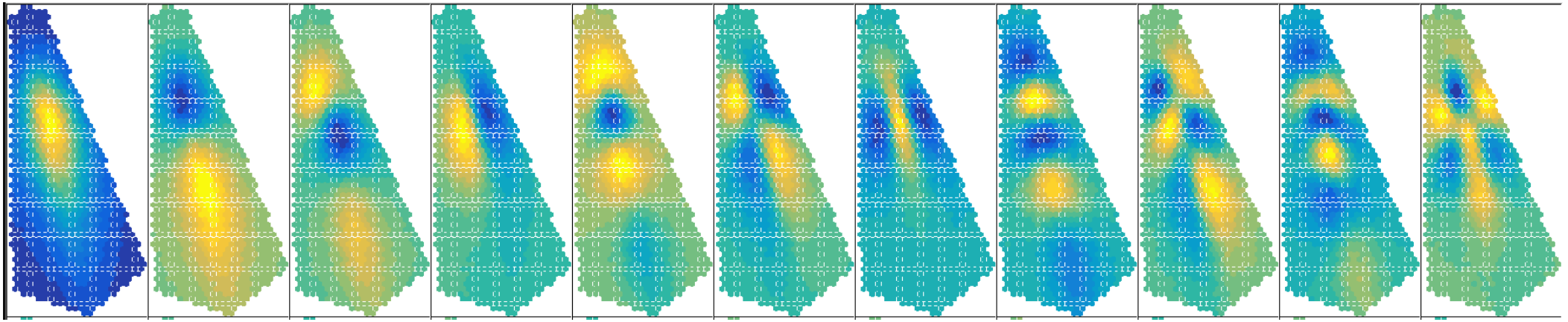
Gamma



Gamma diffuse



Protons



Conclusion and future plans

- Fully digital readout opens unique freedom of choice for trigger architecture.

- Work is in progress.
  - Scan the phase space to optimize digital sum.
  - Implement efficient clustering (spatial and temporal).
  - Optimize the L1 board shape (topology), and estimate effect on the trigger.
  - Test the PCA and other ML (lightweight) technics for gamma/hadron separation at early stages (hardware level).