A Level 2 Trigger for H.E.S.S. Phase 2

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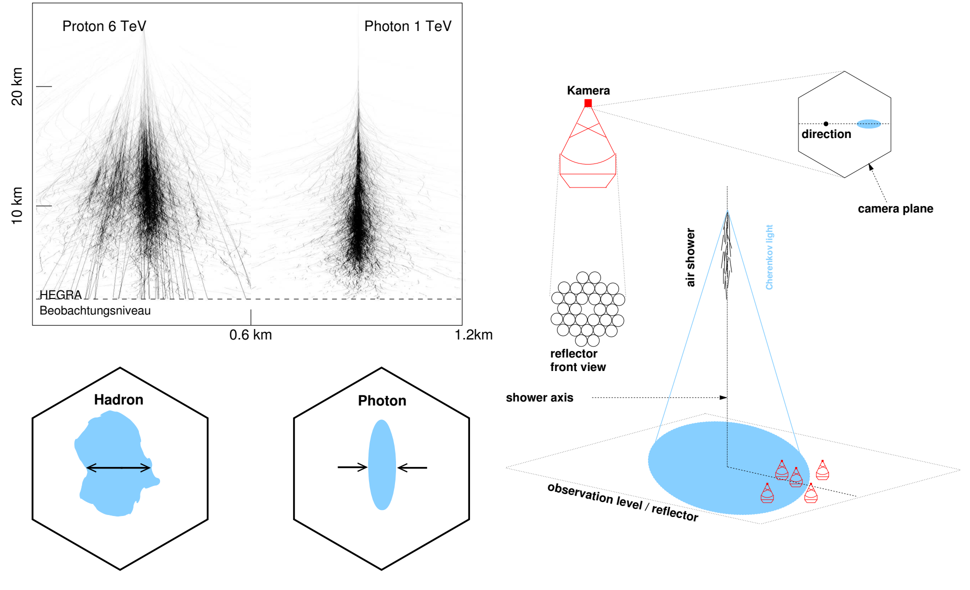
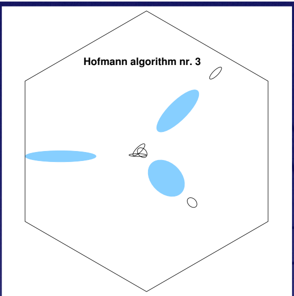
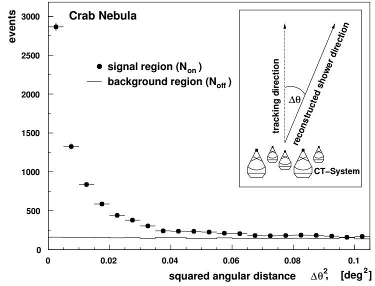
- From H.E.S.S. phase 1 to phase 2
- Performance: expectations
- Optimizing low energies: L2 trigger
  - Purpose & constraints
  - L2 Simulation: results

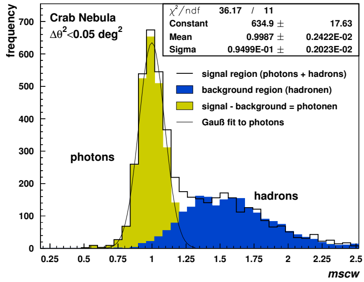
Observations with Cherenkov Telescopes



Stereoscopic Reconstruction







$\geq$ 2 images $\rightarrow$ superposition:

- ... in the camera $\rightarrow$ direction (θ)
- ... observation level
  $\rightarrow$ position d'impact ($core$)

Hadrons rejection:

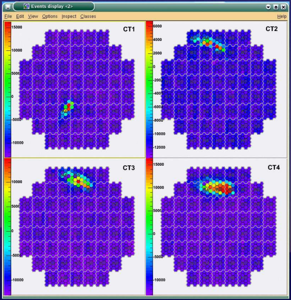
$core$ + amplitude + zenith angle

$\rightarrow$ $mean$ $scaled$ $width$ ($mscw$)

H.E.S.S. – Phase 1 Completed

First light telescope 1	:	June 2002
Two telescopes	:	February 2003
Stereoscopy	:	July 2003
Three telescopes	:	September 2003
Four telescopes	:	December 2003

←1.5 years→

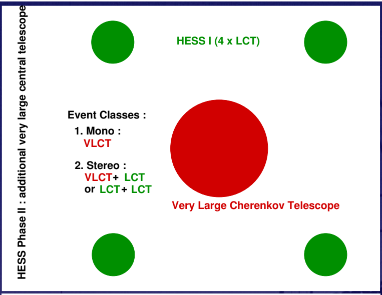


Phase 1 completed & fully operational !

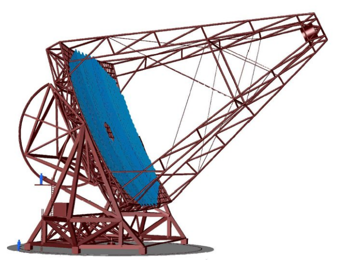
- 0.01 Crab in 25 h (20 deg zenith)
- $E_{thr} = 100$ GeV

Many physics results already shown/published

H.E.S.S. Phase 2 = H.E.S.S. 1 + Very Large Cherenkov Telescope



MAN Design: conventional alt-az mount



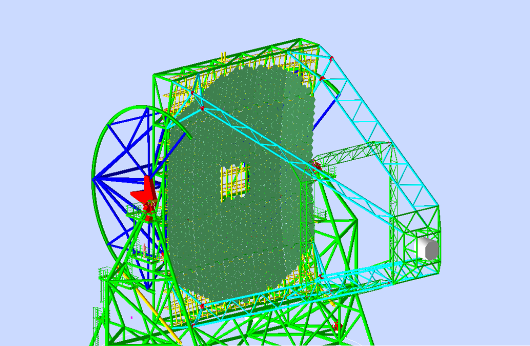
Very Large Cherenkov Telescope:

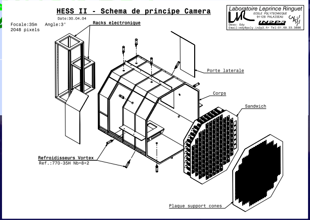
- Reflector : 28 m Ø ($\approx 600\,m^2$)
- Focal distance ≈ 36 m
- Camera: 2 m Ø (< 3 t)
- 2048 PMTs (0.07°/pixel)
- FoV : 3.17° Ø
- Trigger rate 2-20 kHz
- Faster analogue memories needed
- Optimize data flow: 2nd level trigger

From Phase 1 to Phase 2

reflector	13 m∅ / 107 m^2	$\longrightarrow$	28 m∅ / >600 m^2
	Davies-Cotton	$\longrightarrow$	Parabolic
	15 m f	$\longrightarrow$	35 m f
mirror facets	60 cm	$\longrightarrow$	90 cm
	circular	$\longrightarrow$	hexagonal
Camera	960 PMTs	$\longrightarrow$	2048 PMTs
	0.16deg / pixel	$\longrightarrow$	0.07deg / pix
	5 deg ∅	$\longrightarrow$	3.0 deg ∅

Telescope Mechanics





Huge telescope:

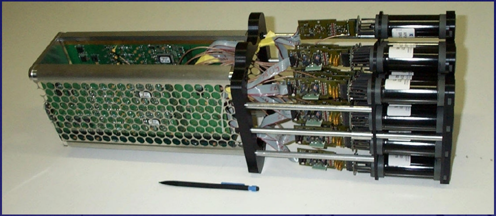
- Steel mount 500 t
- camera: $2\,\mathrm{m} \times 2.5\,\mathrm{m}$ ($<3\,\mathrm{t}$)

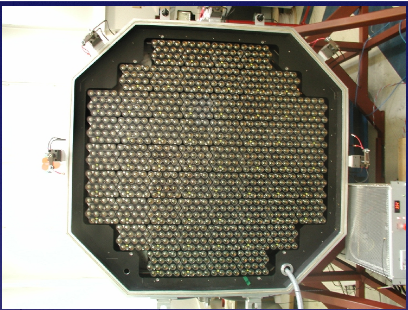
technical modifications/challenges

- improved Winston cones
- stronger drive units
- mirror facets / alignment
- camera: heat evacuation (cool dry air)

H.E.S.S. Camera electronics

modular concept, all inside camera





Phase 1 & 2

- large dynamic range, good linearity
- single photoelectron peak resolution
- GHz sampling
- signal storage in analogue memory
  $\longrightarrow$ trigger formation
  $\longrightarrow$ memory readout

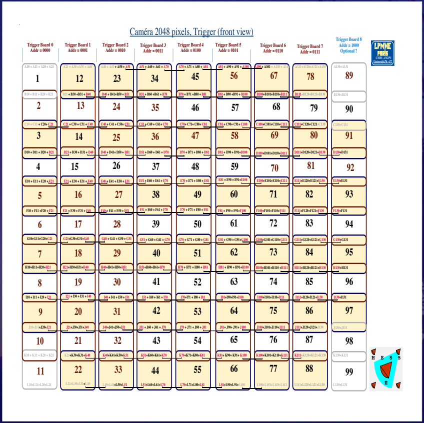
Improvements Phase 2

- 2-20 kHz trigger rate
  $\longrightarrow$ faster analogue memories
- acquisition rate limited ($\approx$ 3 kHz)
  $\longrightarrow$ Second Level trigger

The Camera Trigger (L1)

- A_{pix} amplitude threshold of PMs (photoelectrons)
- N_{pix} number threshold of PMs in one sector

L1 trigger: at least N_{pix} PMs with amplitude $>A_{pix}$ in one sector



LCT (Phase I)

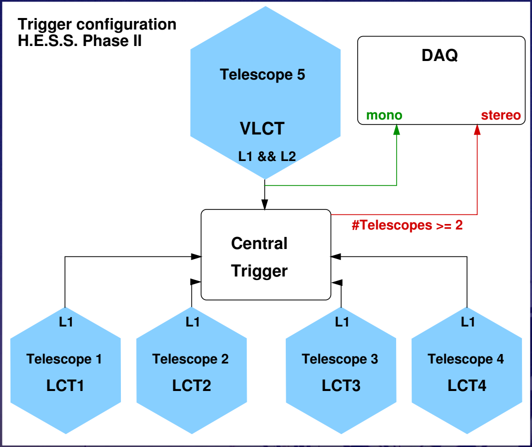
- 38 sectors (64 PMs)
- $N_{pix} = 4$, $A_{pix} = 3$
- trigger rate mono : $R < 2\,$kHz
- dead time : $T \approx 20\,\%$ (current ARS)
- trigger rate stereo : 350 Hz (total DAQ)

VLCT

- 96 sectors (64 PMs)
- new analog memories (SAM $\approx 2\mu$s)
- $T < 10\,\%$ @ $R < 50\,$kHz L1
- $T < 1\,\%$ @ $R = 3\,$kHz Data acquisition

Trigger configuration & Energy ranges

Zora

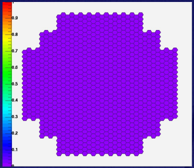


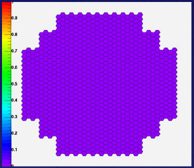
Ferdi Jade Cléa Jenny

each camera contains L1 trigger

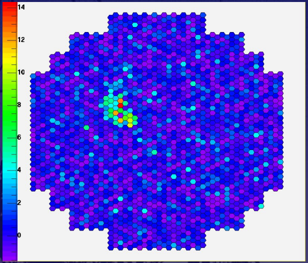
- $>$ 100 GeV
  - stereoscopy $\geq$2 LCT + VLCT
  - improved resolutions
  - improved sensitivity
- 50 GeV - 100 GeV
  - stereoscopy LCT + VLCT
  - «new» event class
- 10 GeV - 50 GeV
  - monoscopie VLCT
  - new event class

Event Display – Simulation

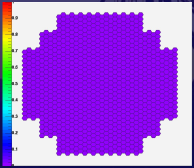


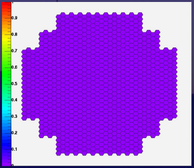


10 GeV γ-ray shower



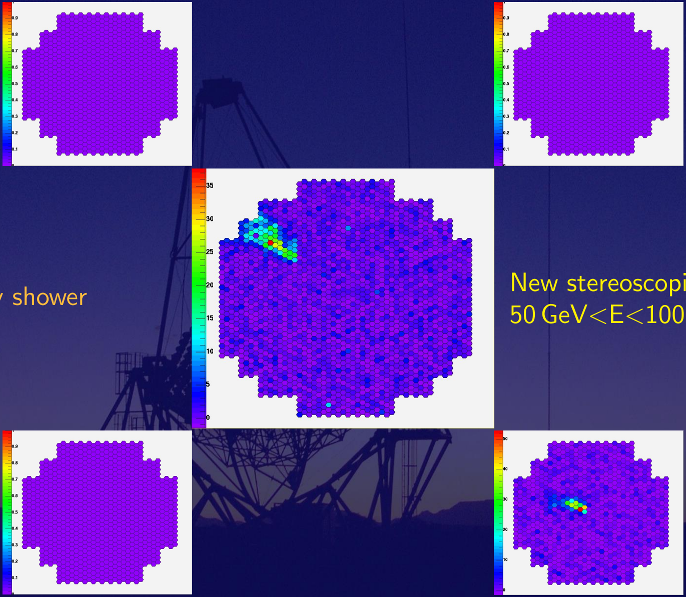
Monoscopic event class
10 GeV$<$E$<$50 GeV





Event Display – Simulation

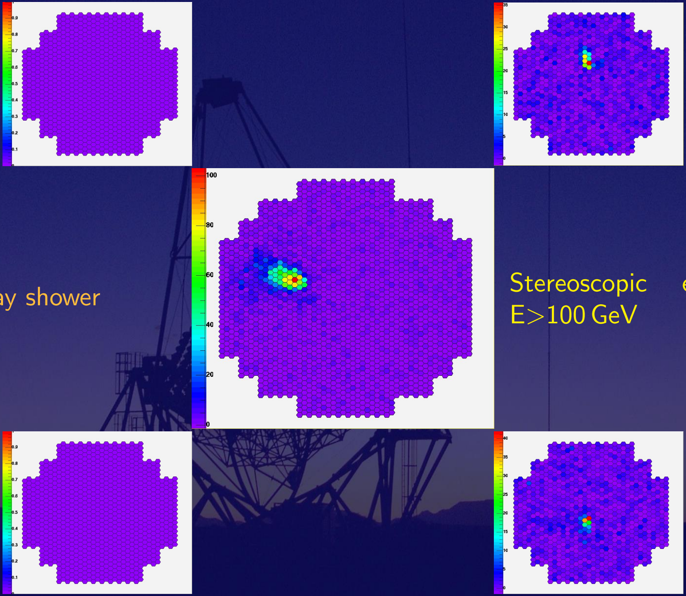
70 GeV γ-ray shower



New stereoscopic event class
50 GeV$<$E$<$100 GeV

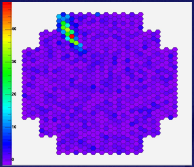
Event Display – Simulation

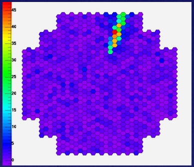
100 GeV γ-ray shower



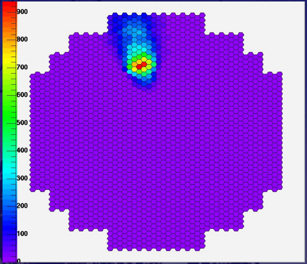
Stereoscopic event class E>100 GeV

Event Display – Simulation

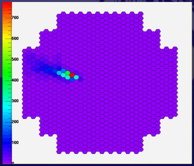


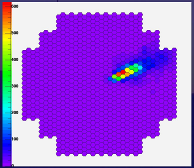


1 TeV γ-ray shower



Stereoscopic event class E>100 GeV

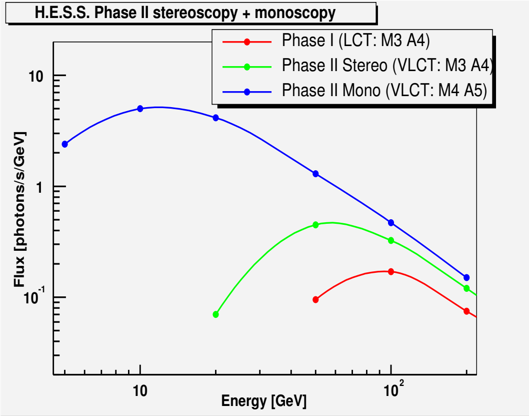




●*First* ●*Prev* ●*Next* ●*Last* ●*Go Back* ●*Full Screen* ●*Close* ●*Quit*

Simulation of H.E.S.S. Phase 2 on trigger level

Parallel operation in monoscopic & stereoscopic mode



- stereoscopy phase 1
- hyprid stereoscopy phase 2
- monoscopy phase 2

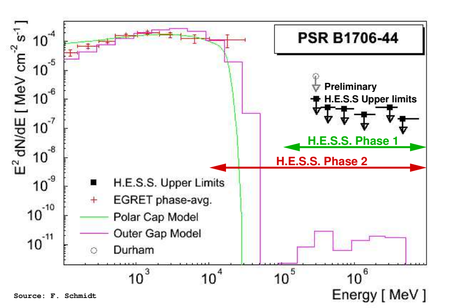
- $E_{thres} \approx$ 20 GeV
- # events γ $\times$ 25 (peak)
- trigger rate : 2.5 kHz
- dead time $< 1\,\%$

Further imrovement: lower energy threshold & better low-energy efficiency

$\Downarrow$

Lower PM thresholds $\Leftrightarrow$ Level 2 Trigger

Purpose of L2: optimize lowest energies / reduce trigger rate



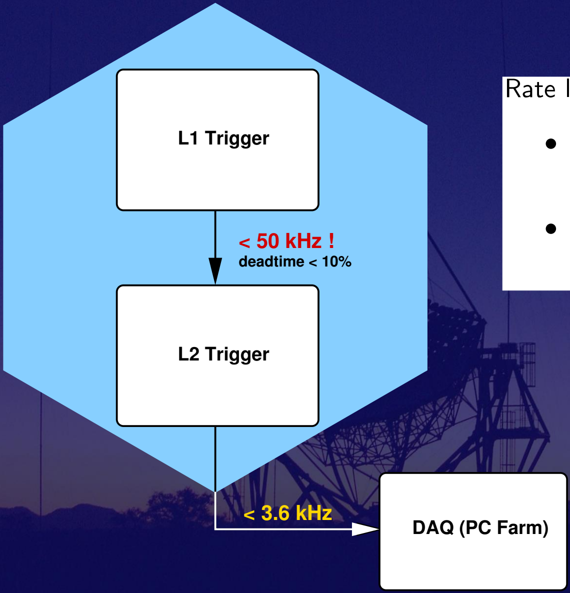
- Pulsars (low energy cutoff)
- Microquasars
- AGN at high z
- unidentified sources (EGRET & H.E.S.S.)

loosen L1 conditions (lower thresholds)

⟶ Lower energy threshold
⟶ More low energy events
⟶ Higher γ sensitivity
⟶ Higher trigger rate
- Night Sky Background
- Hadronic showers

L2 : reject Night Sky Background & Hadrons & Muons

Constraints on trigger rates



Rate limits:

- L1 : $<$50 kHz
  dead time $<$10 %
- L2 : $<$O(4 kHz)
  data flow

Available information at trigger level

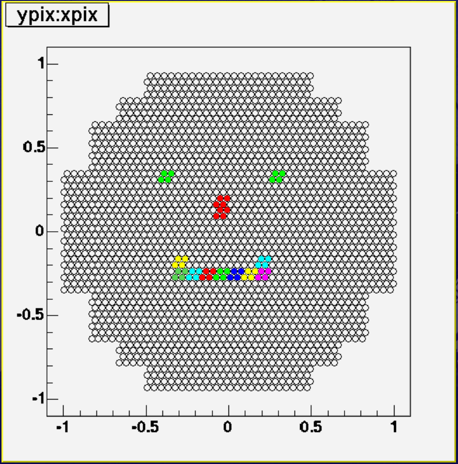
Trigger level image:

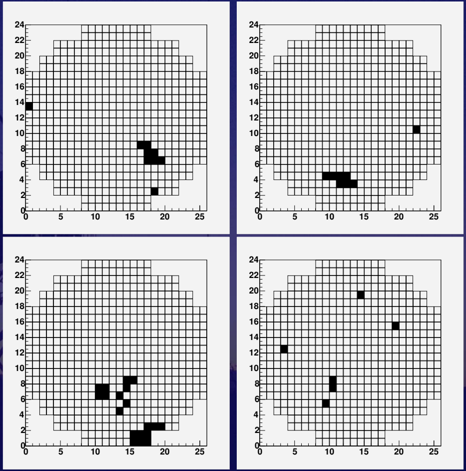
- information unit: *bloc*
- 1 *bloc* = 4 PMs
- 1 *active* bloc = 2 PMs triggered

binary information!

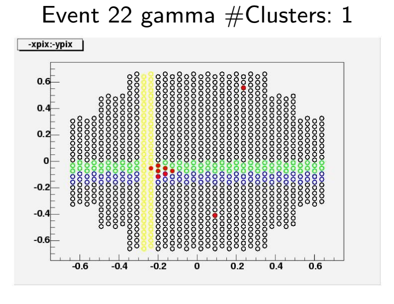
images based on blocks:

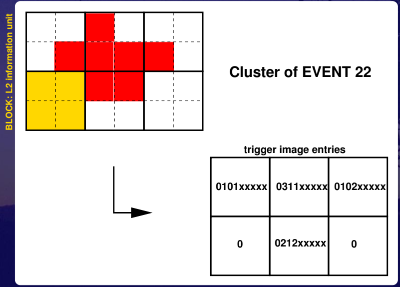
γ, μ, proton, Night sky background





Clustering Condition





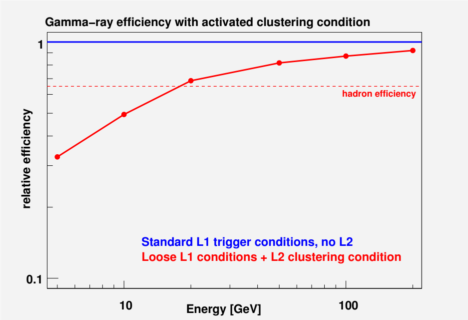
1. **L1: Lower PMT amplitude threshold**
   5 ph.e. ⟶ 3 ph.e. ⟶ L1 trigger rate: 5 kHz
2. **L2 = Reject events with 0 clusters**
   ⟶ L1 + L2 trigger rate: 3.3 kHz

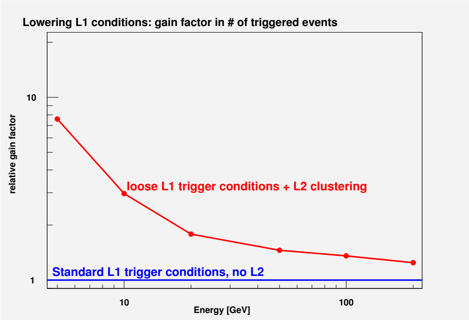
– low energies: rejection of gammas
+ very good rejection of NSB
+ rejection of hadrons
+ rejected gammas unclustered = bad
  better reconstruction of remaining γs

next step: more information, e.g. amplitude

L2 clustering: loss & gain in performance (γ)

- loss : γ efficiency of L2 clustering condition
- gains : # of triggered events due to lower threshold



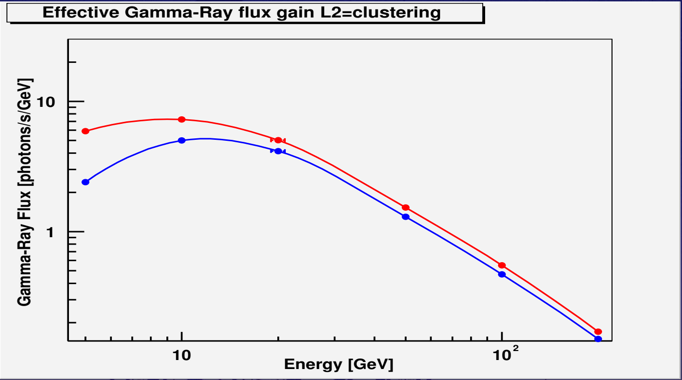


Total gain positive ?

L2 clustering: Total positive gain

gain after lowering PM thresholds + L2 activation

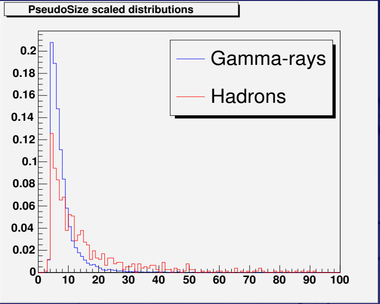
$$\text{flux} = \text{flux}_0 \times \text{efficiency} \times \text{gain} \times (1 - \text{dead time})$$

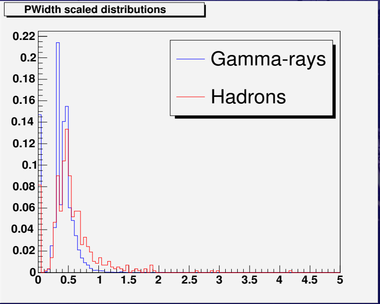


Standard L1 trigger conditions, no L2

Lower PM thresholds + L2

Other simple criteria





Reject high image amplitudes: small effect

- reject high energies
- keep low energies

⟶ possible for steep source spectra (Pulsars)

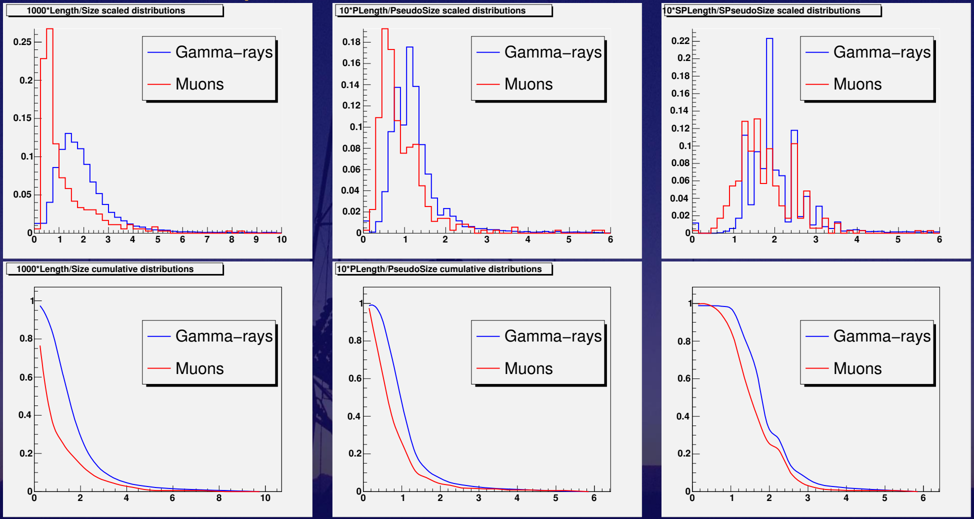
⟶ bad idea for hard spectra

Second moment analysis (Hillas)
loose analysis cuts on trigger level
(width, length, distance, length/size, etc.)

Σ of individual cuts, potential O(50 %)

LoverS - Muons

Offline intensity | PseudoSize | SPseudoSize

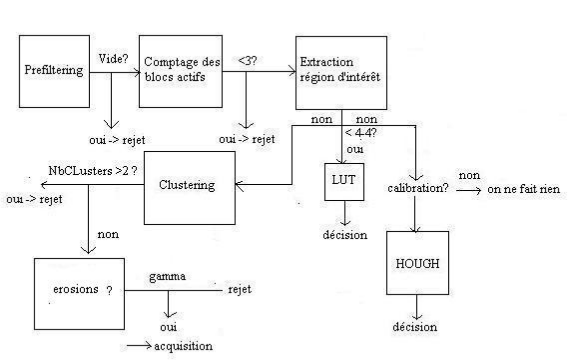


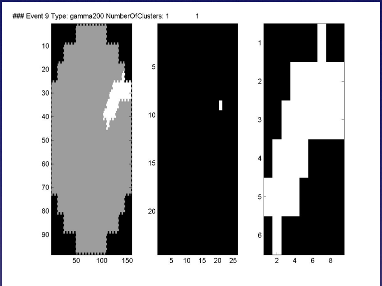
finer amplitude information is usefull

Complex algorithms

currently under study : Neural networks, Hough transform (μ-ring tagging)

neural network architecture





extracting small zones of interest
Cascade of criteria from most simple to complex

Summary

- **L2: Optimize data flow**
  - Low energy threshold
  - Low acquisition rate

- **Simple criteria show positive results**
  - Clustering
  - Hillas analysis

- **Complex criteria under study**
  - Neural networks
  - Hough transform