Triggering with FlashCam

and a metric for assessing trigger homogeneity

Aaron Manalaysay
17 May 2011
CTA Consortium Meeting
Toulouse, France
MC/ELEC/TEL/FPI

Universität Zürich[UZH]

In collaboration with the FlashCam group:

ETH Eidgenössische Technische Hochschule Zürich Swiss Federal Institute of Technology Zurich

AGH

AIT

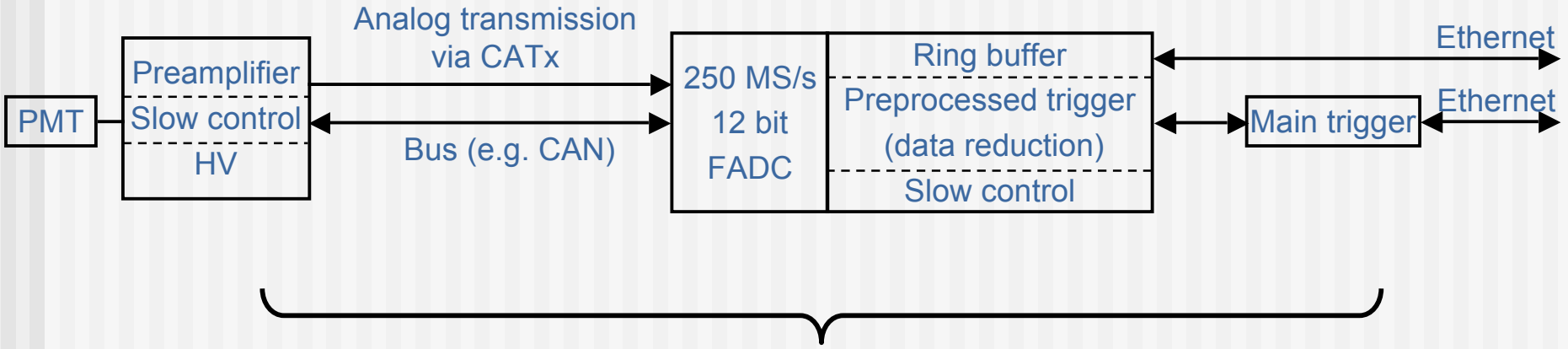
University of Leicester

cta cherenkov telescope array

Overview

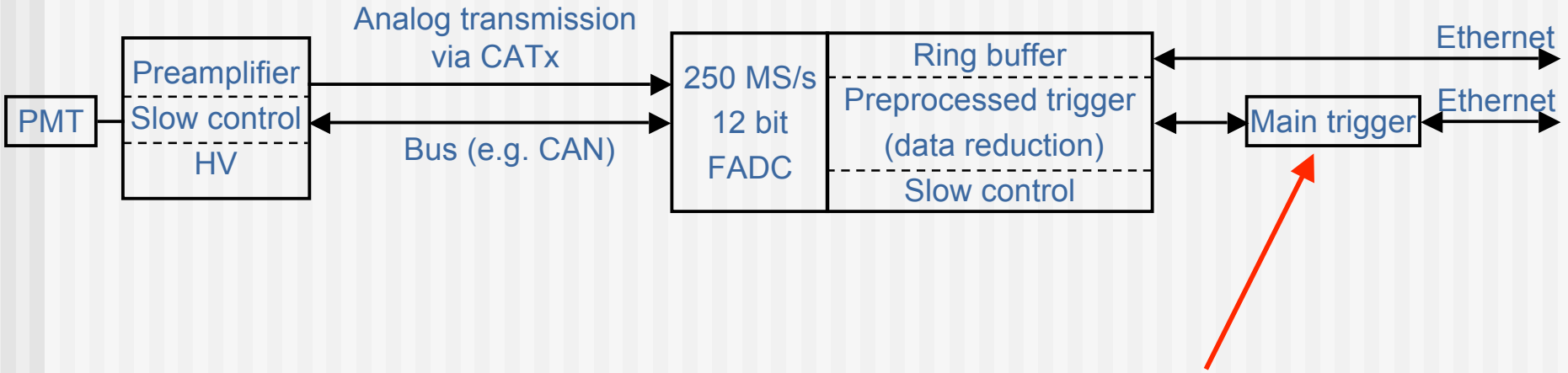
- FlashCam
- Trigger implementation
- Trigger simulation, trigger algorithms
- Trigger homogeneity: metric 1
- Trigger homogeneity: metric 2

FlashCam baseline topology



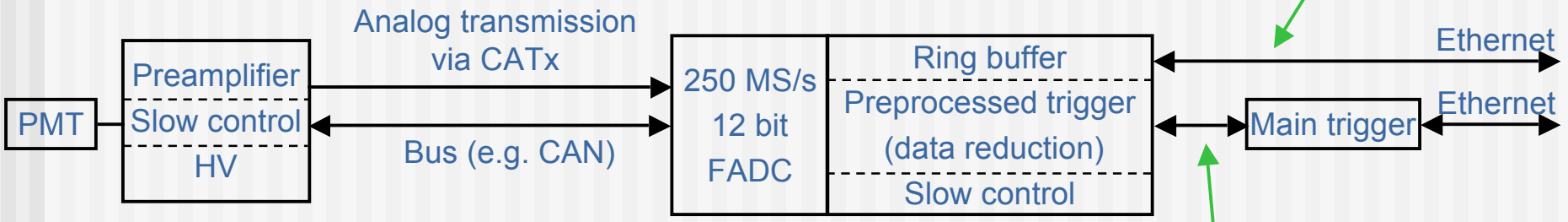
… many possible implementations of the technical details in this block diagram.

FlashCam baseline topology



FPGA-based trigger,
working on DIGITIZED data

FlashCam baseline topology



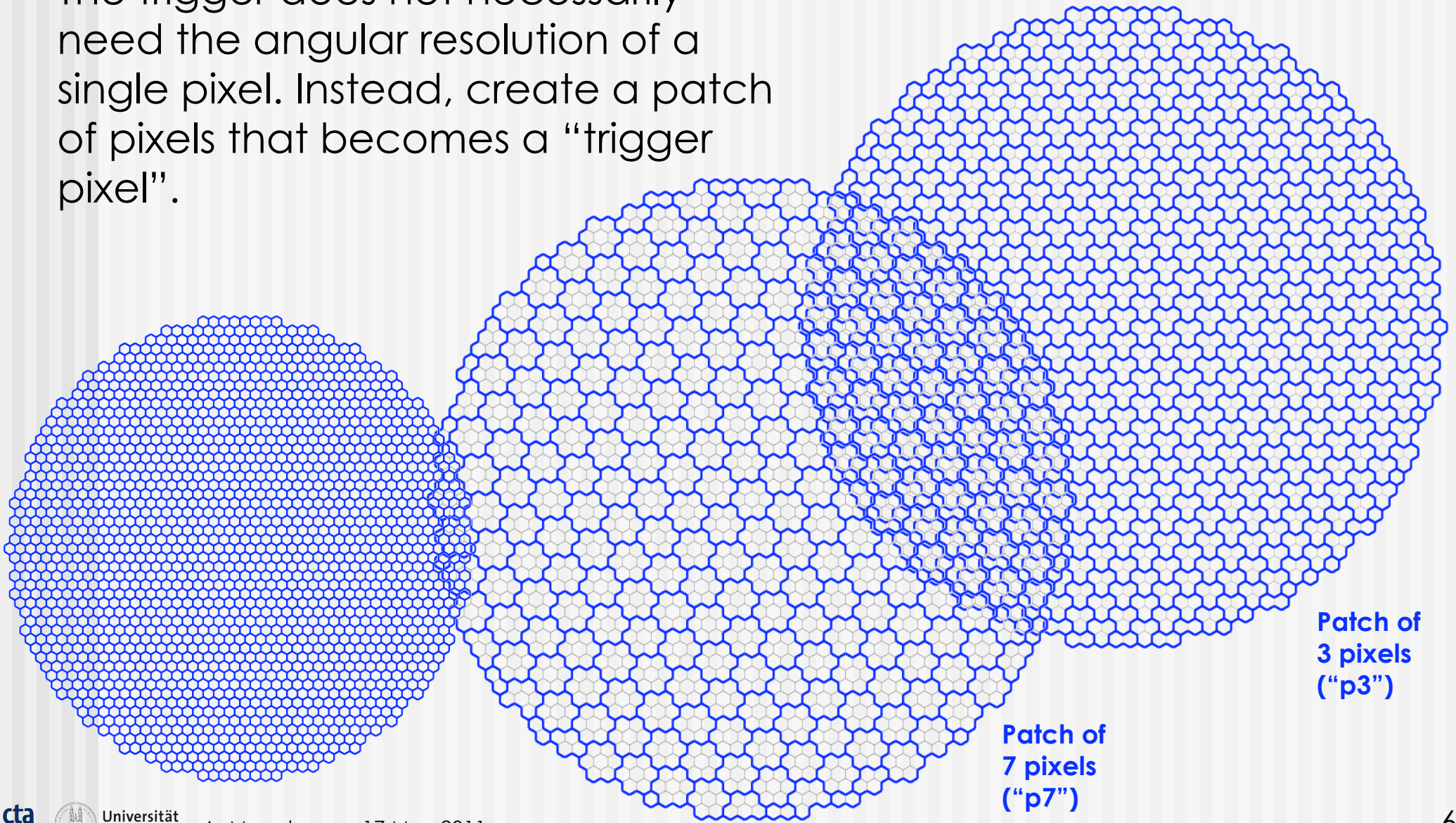
12-bit per pixel, only when triggered

… continuous data flow (don't want 12-bit per pixel continuous)

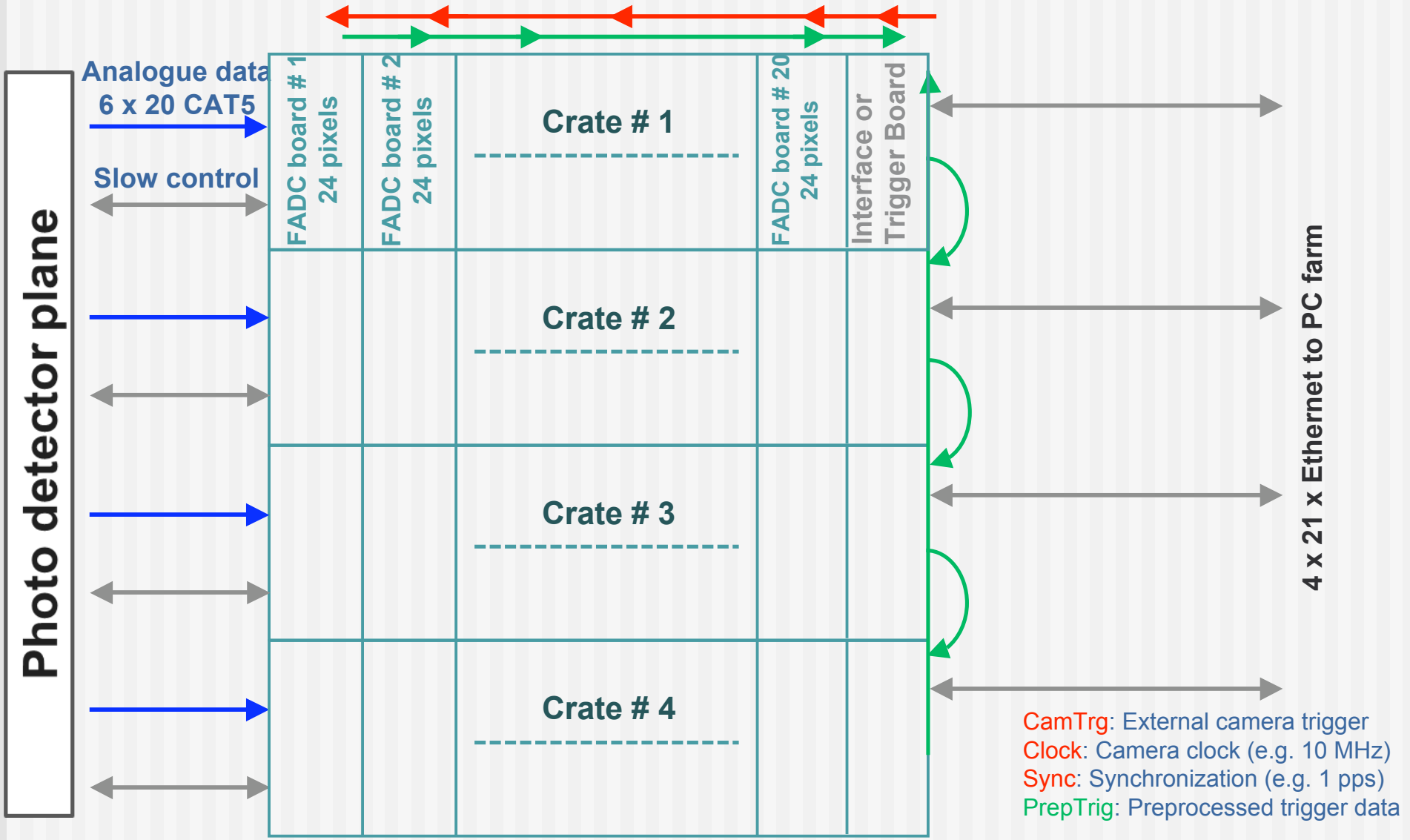
So the question becomes, how can we reduce the data going to the triggering system?

Data reduction for the trigger

The trigger does not necessarily need the angular resolution of a single pixel. Instead, create a patch of pixels that becomes a "trigger pixel".



Trigger hardware strategy



FlashCam Trigger Simulation

- MST-size telescope/camera, parabolic mirror (files generated by Konrad)
- Gaussian jitter (σ=1ns) applied to all PE emission times
- 100 MHz NSB
- SPE resolution of 0.42
- AP proportion of 2E-5, log slope of 3 (factor 3 reduction every 5 PE)
- Analog filtering: 6-pass 80 MHz RC filter
- Baseline noise: filtered RMS of ~0.1 PE
- 250 MS/s sampling; 1PE corresponds to 10 ADC bins

… then apply triggering algorithm…

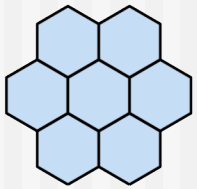
FlashCam Trigger Simulation

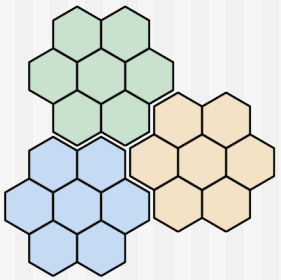
- MST-size telescope/camera, parabolic mirror (files generated by Konrad)
- Gaussian jitter (σ=1ns) applied to all PE emission times
- 100 MHz NSB
- SPE resolution of 0.42
- AP proportion of 2E-5, log slope of 3
- Analog filtering: 6-pass 80 MHz RC filter
- Baseline noise: filtered RMS of ~0.1 PE
- 250 MS/s sampling; 1PE corresponds to 10 ADC bins

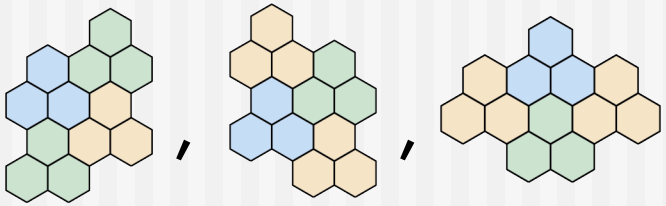
The following results are preliminary. (should I still show them? Why not, I have nothing to lose.. in Toulouse).

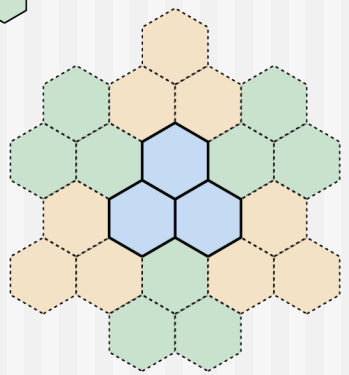
Trigger algorithms

- Digital Majority: ≥ 3 pixels above threshold
- P7-1 .....
- P7-3 ..... (all unique triplets)
- P3-4 ..... , , (all unique quadruplets)
- P3-7 ..... (all unique septuplets)



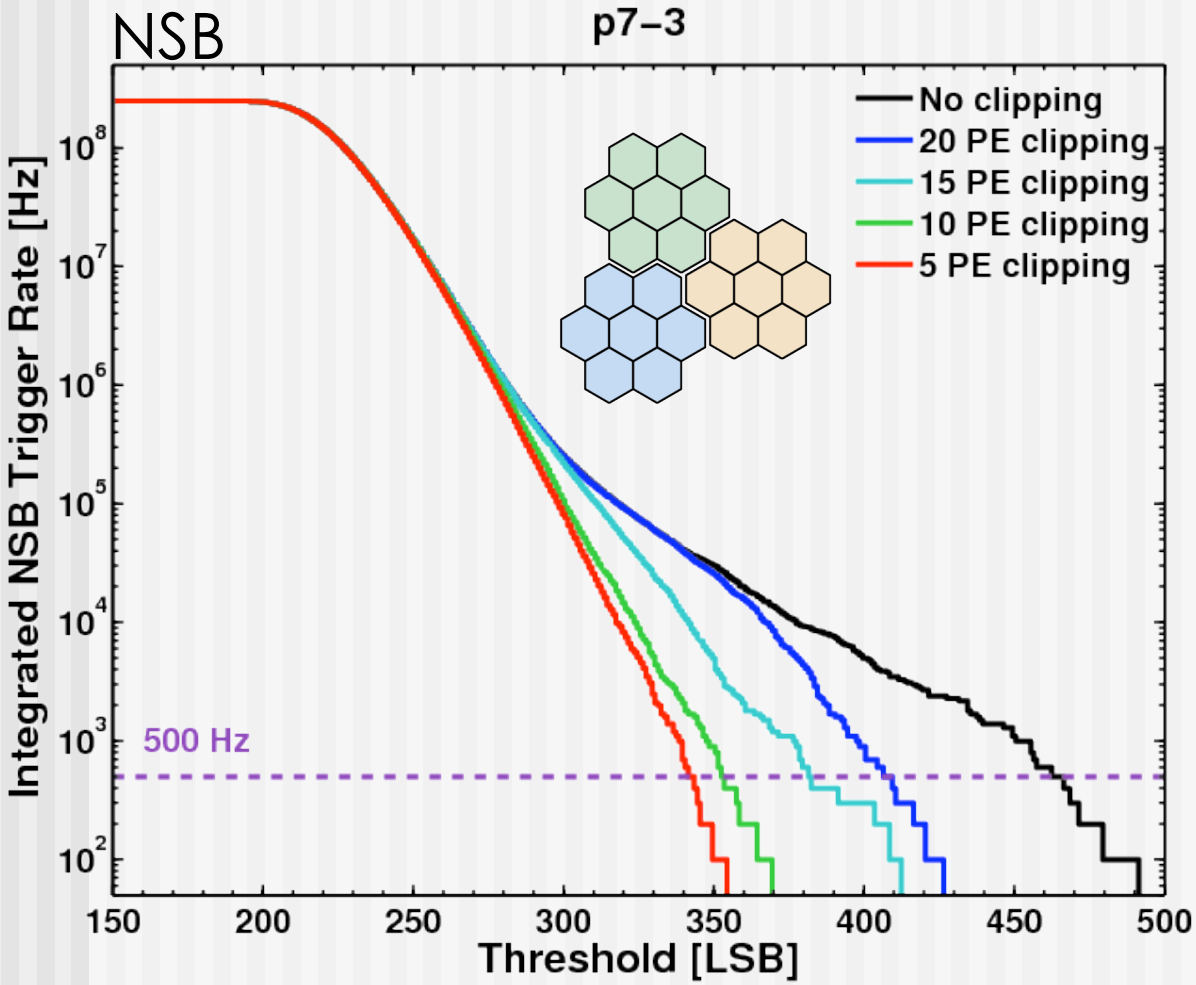






P[N]-[M] = "patches of N pixels, combining M such patches"

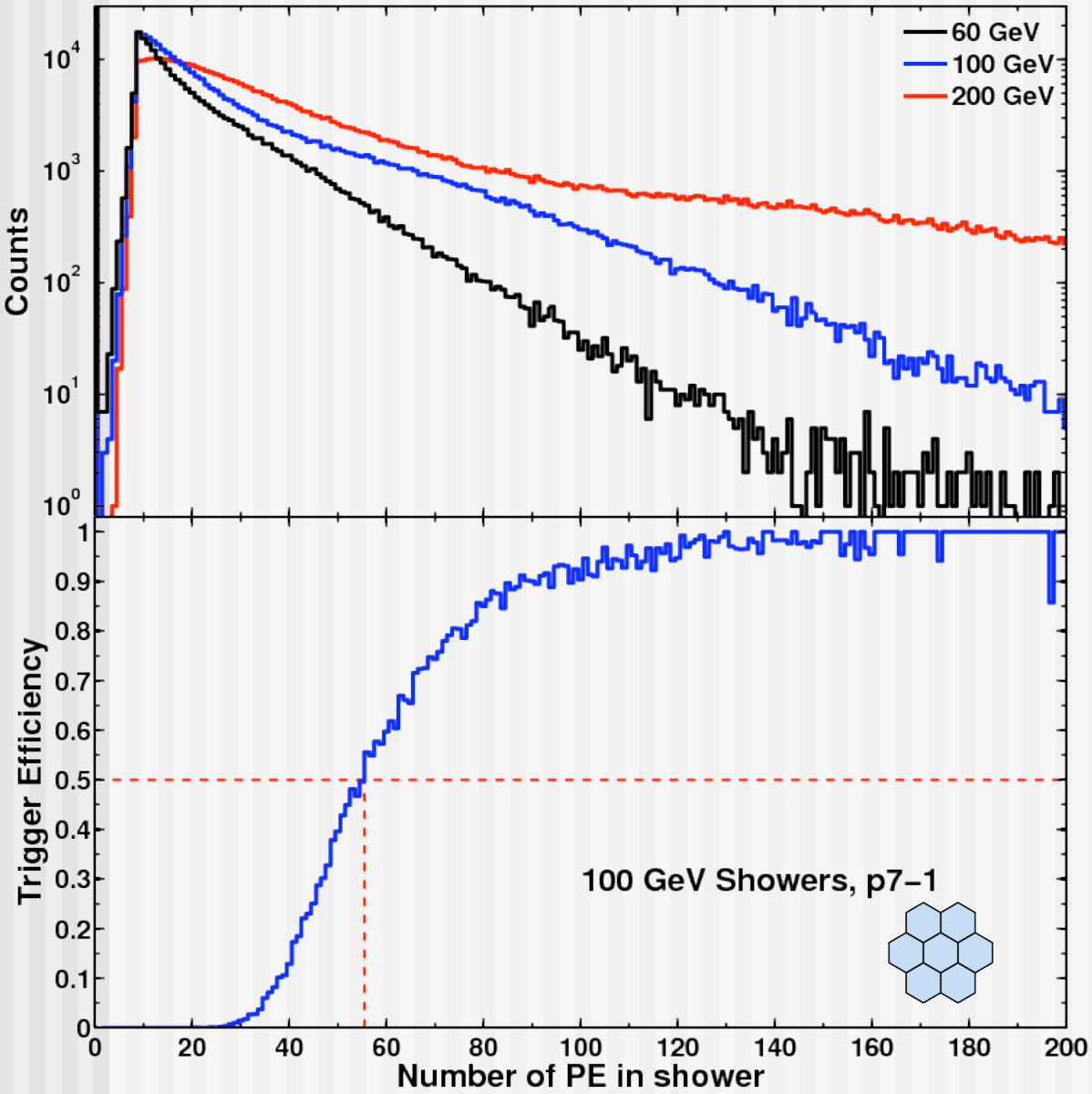
Afterpulsing, clipping, threshold



All algorithms are compared in a normalized way. This means, the threshold is adjusted so as to always give an NSB accidental rate of 500 Hz.

I am using a clipping level of 10 PE in all subsequent plots.

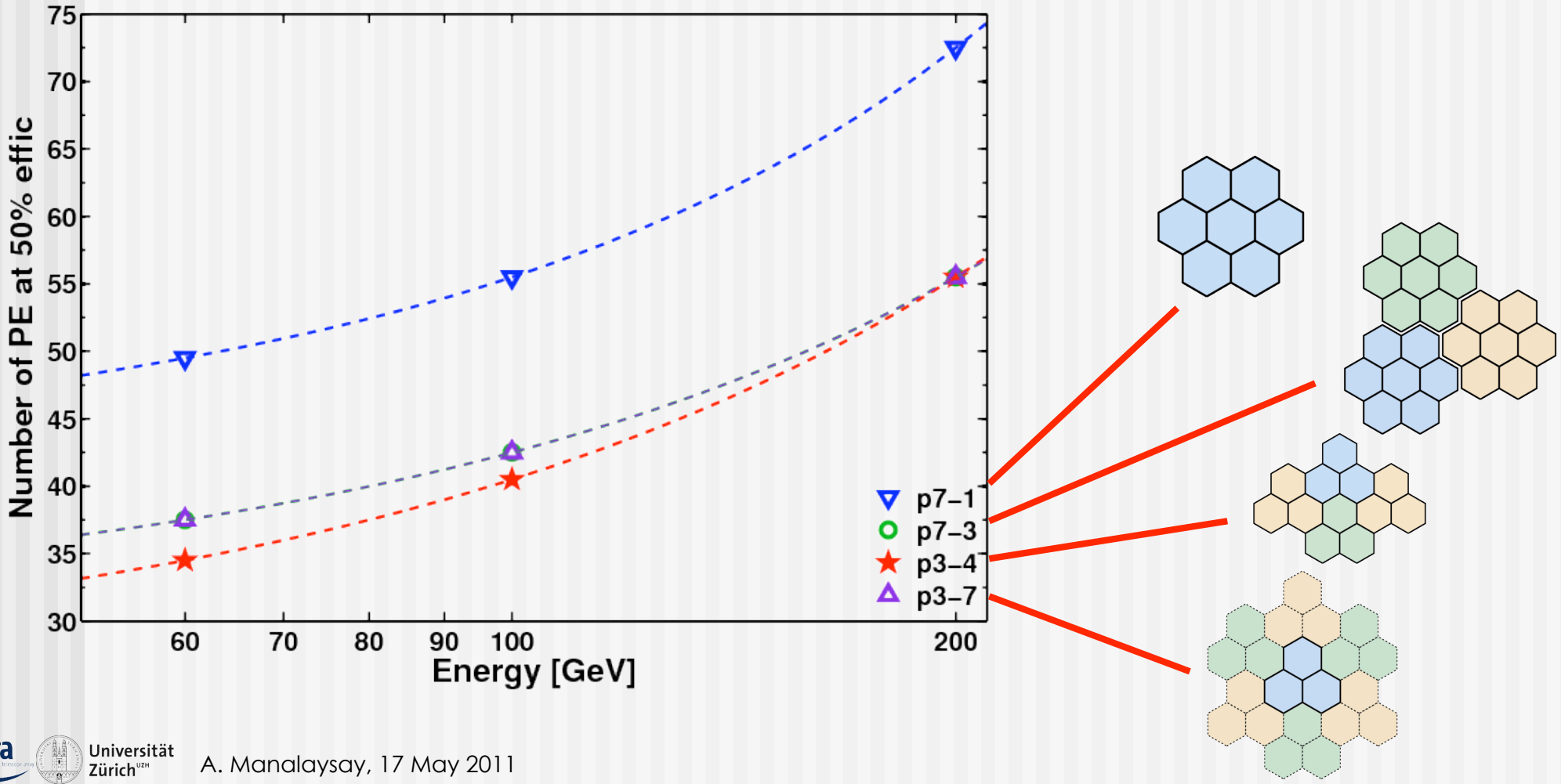
Threshold variation



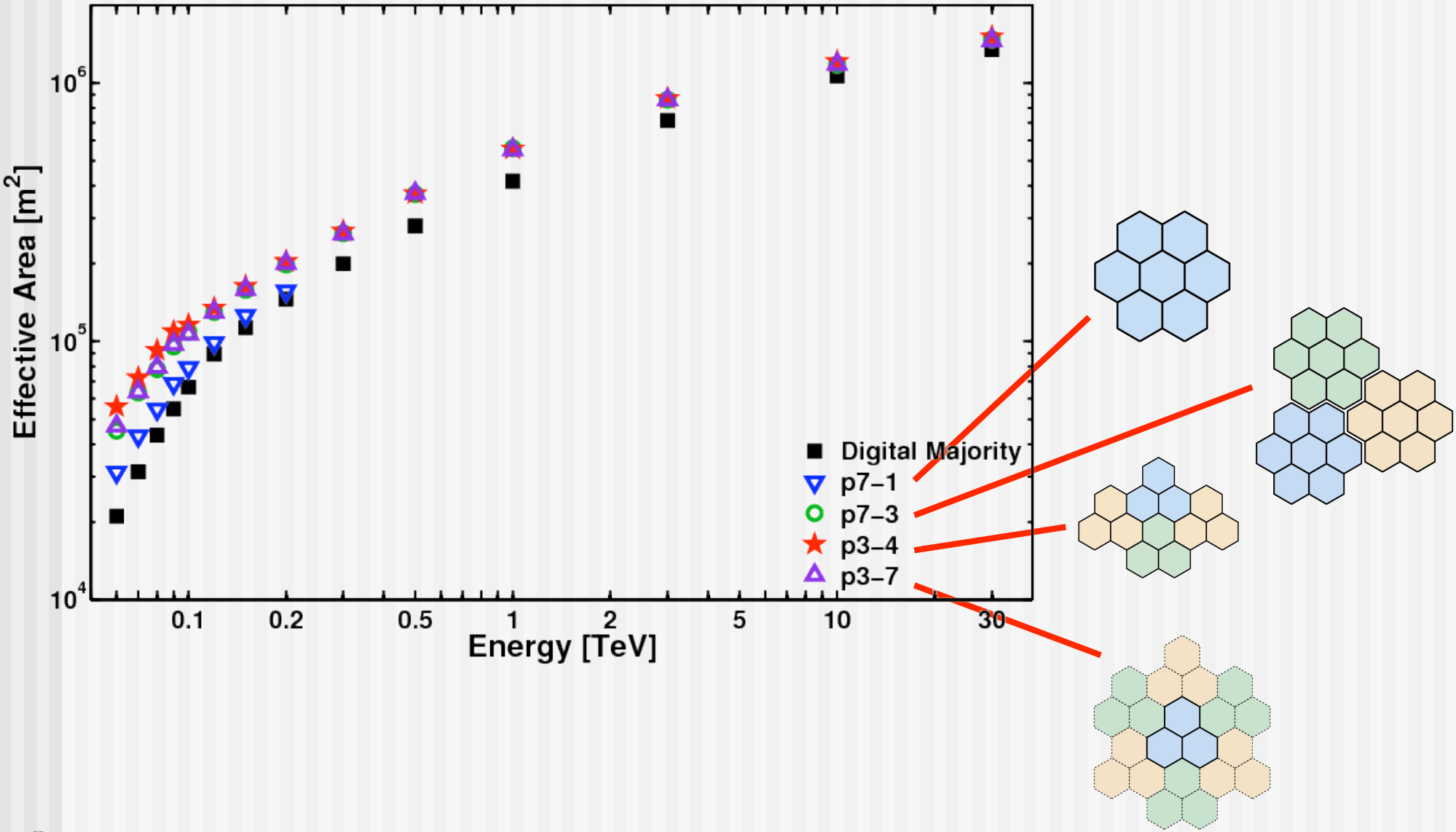
Simple to calculate the triggering efficiency as a function of number of PE. One performance parameter is the threshold for 50% trigger efficiency (shown here for one energy, one trigger algorithm).

Threshold variation

The threshold for 50% trigger efficiency, for four algorithms and three benchmark energies.

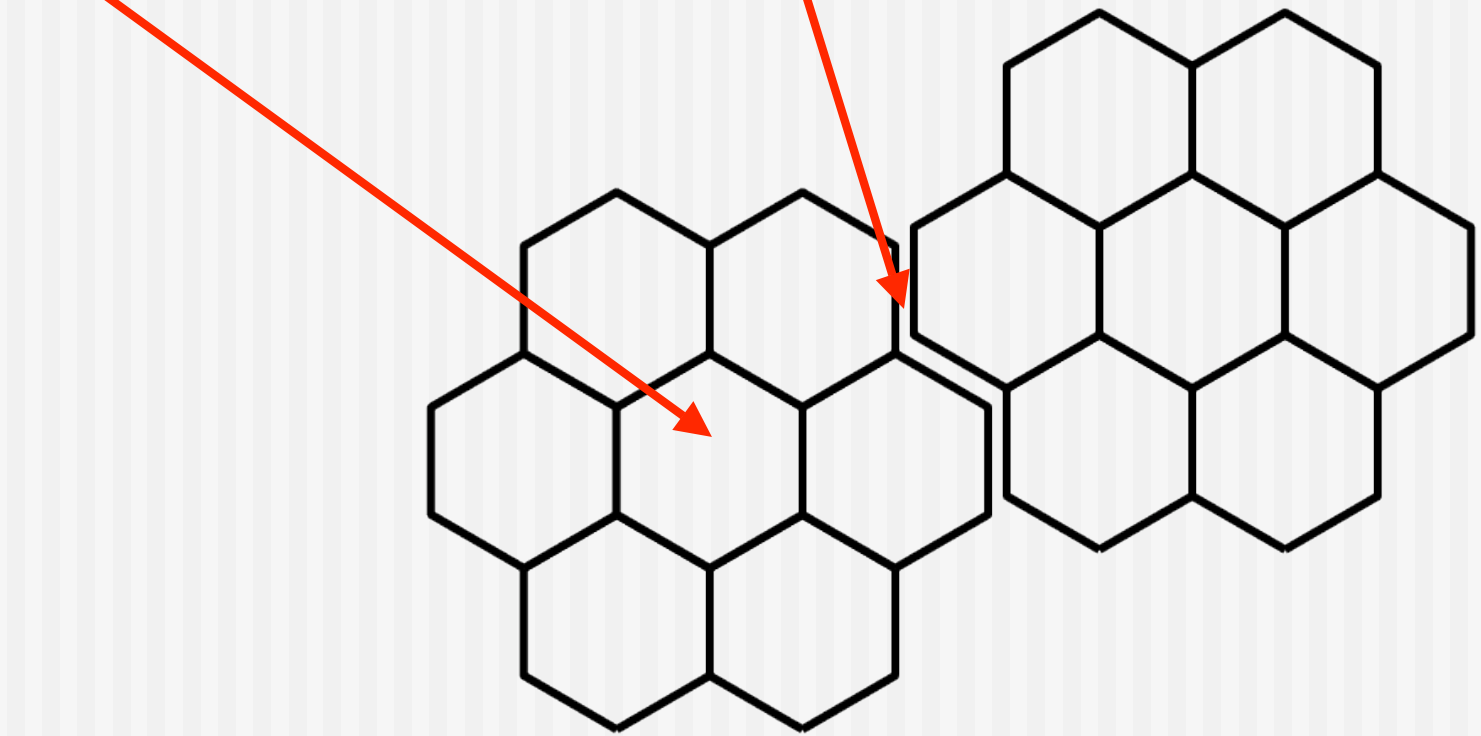


Effective areas



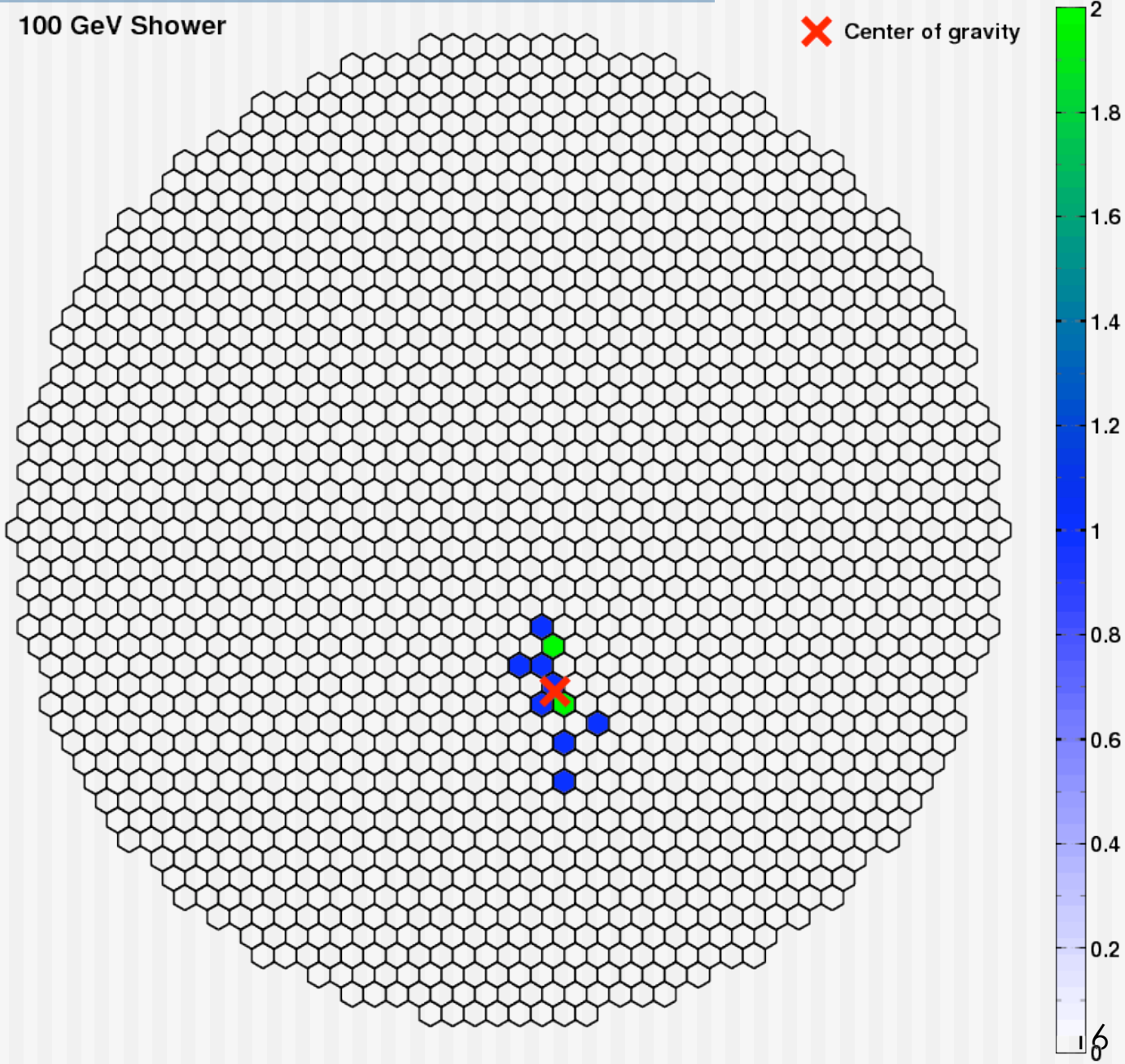
Homogeneity of the trigger

The homogeneity problem: The efficiency for detection here and here should be ~equal



Homogeneity of the trigger

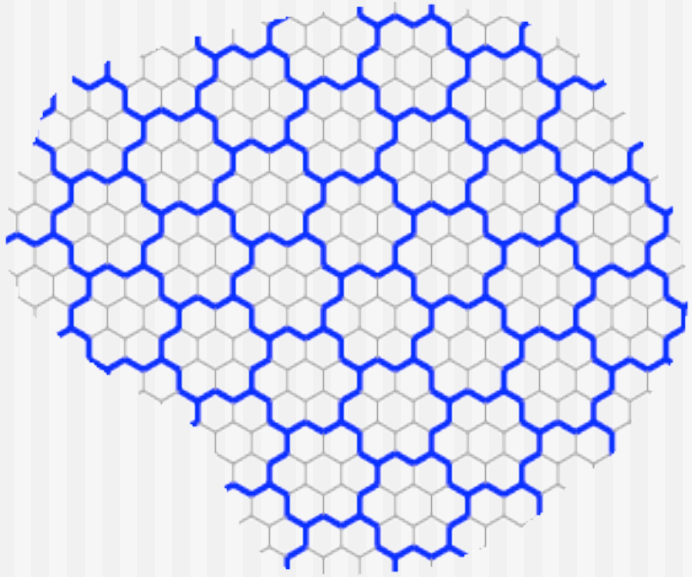
Quantify the shower position as the Center Of Gravity (C.O.G.) of the raw PEs.

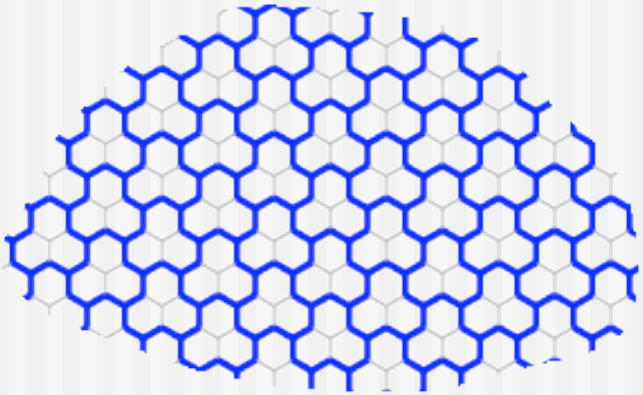


Homogeneity of the trigger

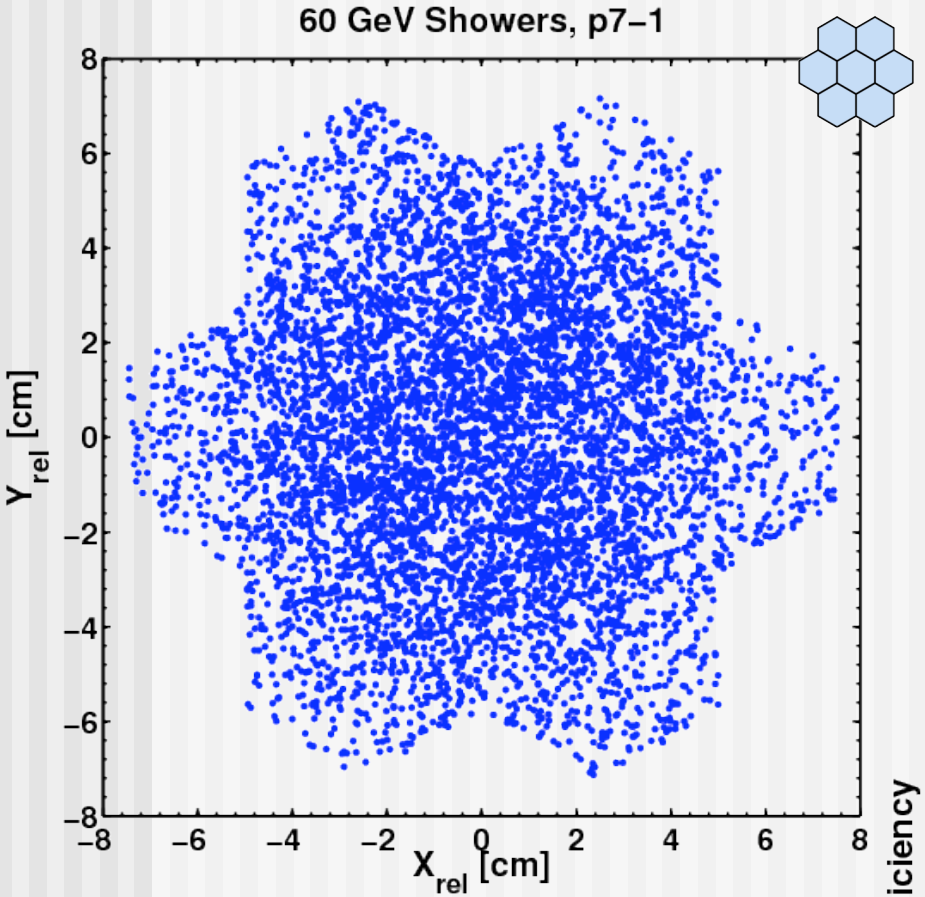
For all cases, the basic repeated unit is the patch. So if there is any inhomogeneity, it should repeat in the same patter with which the patch is repeated, *regardless of how those patches are grouped*.

This symmetry allows me to stack all patches for a given trigger algorithm, and represent the whole camera as a single patch.



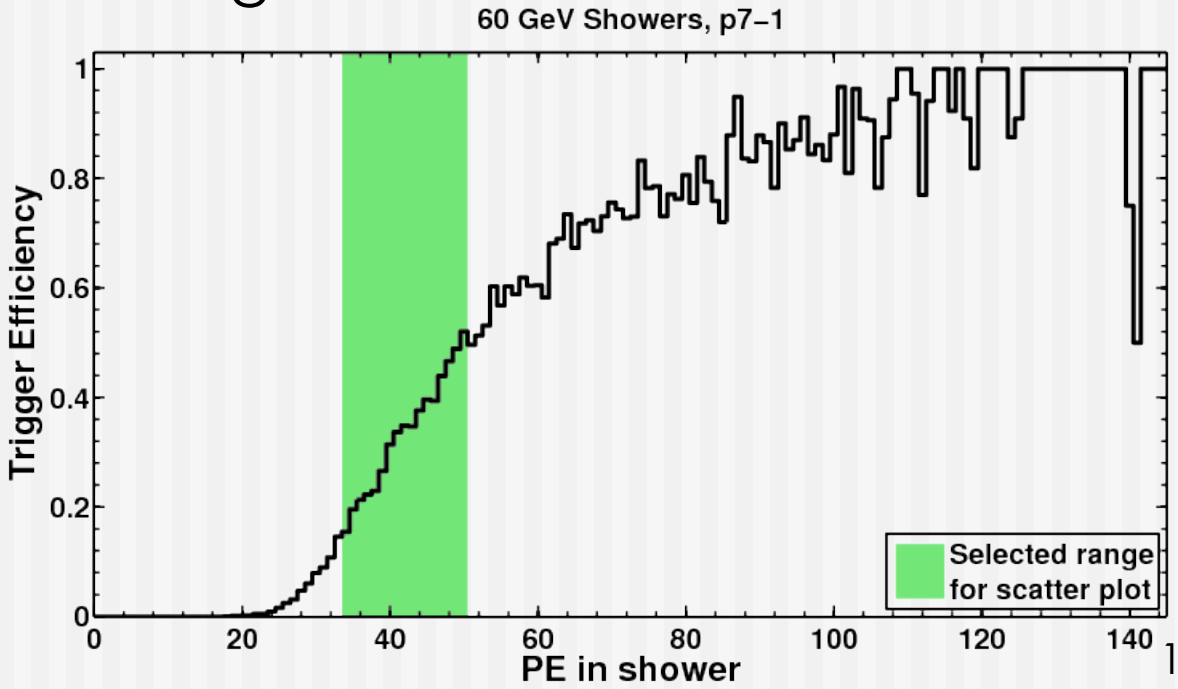


Homogeneity of the trigger

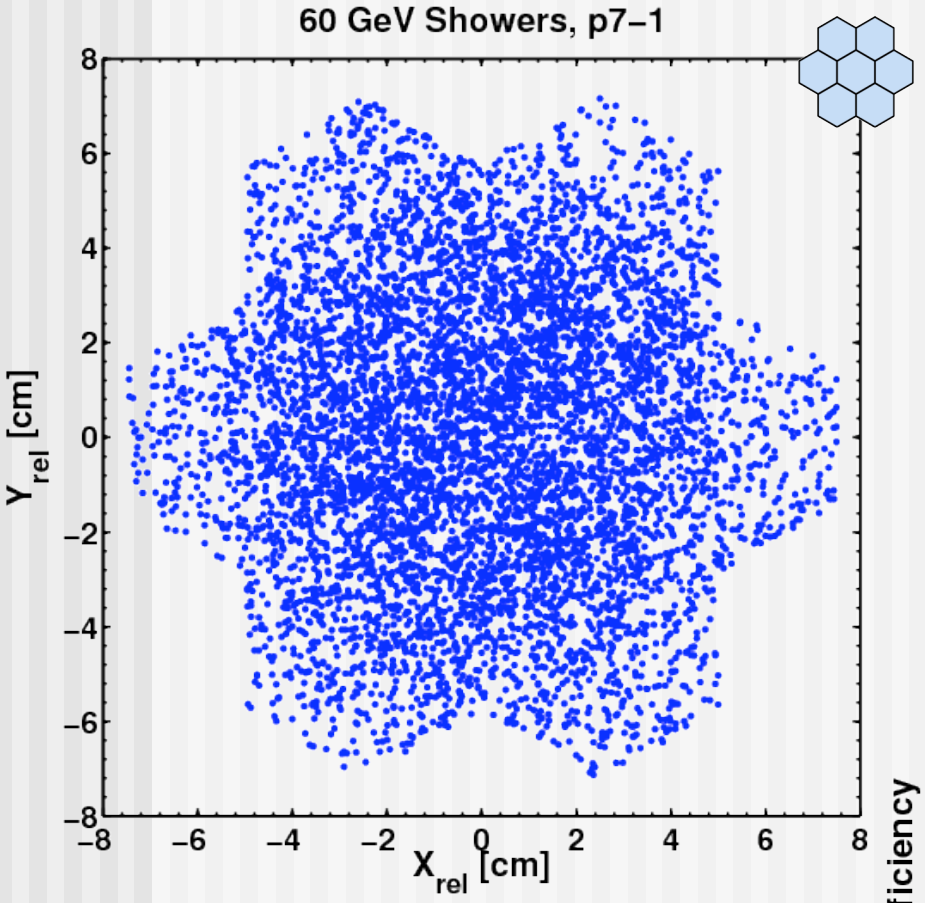


(p7-1 has no overlapping patches, so is expected to have the worst homogeneity)

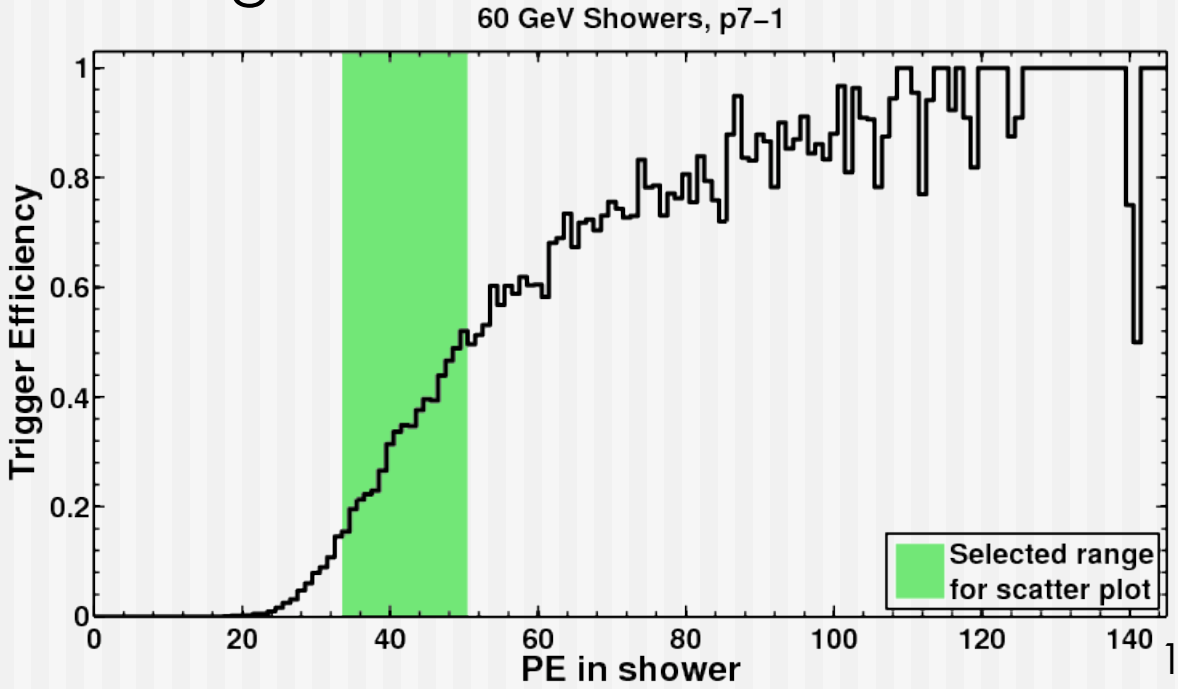
Scatter plot shows the C.O.G. of only those showers that trigger, taken from the green band below. As expected, the density of points in the center is higher than at the edges.



Homogeneity of the trigger



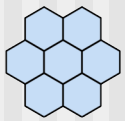
Scatter plot shows the C.O.G. of only those showers that trigger, taken from the green band below. As expected, the density of points in the center is higher than at the edges.

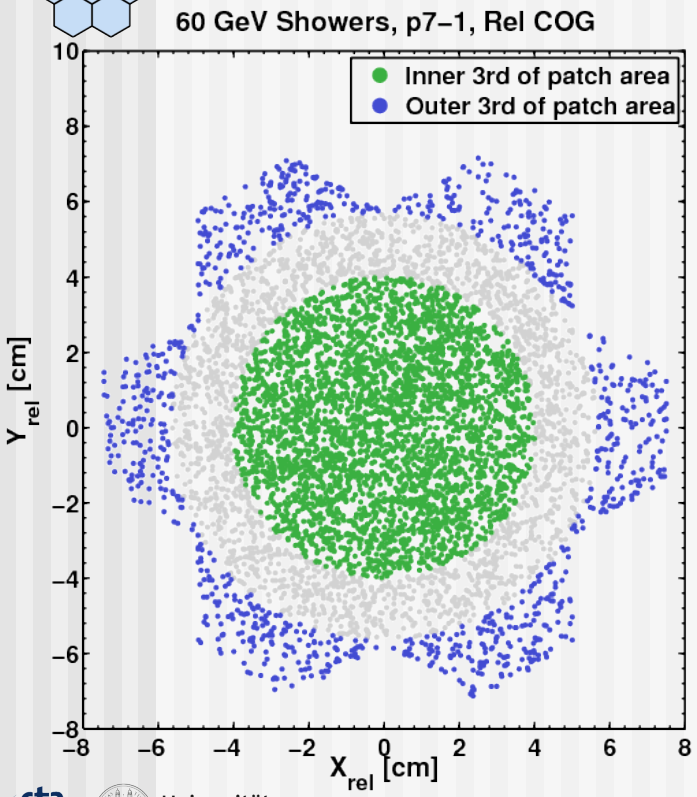


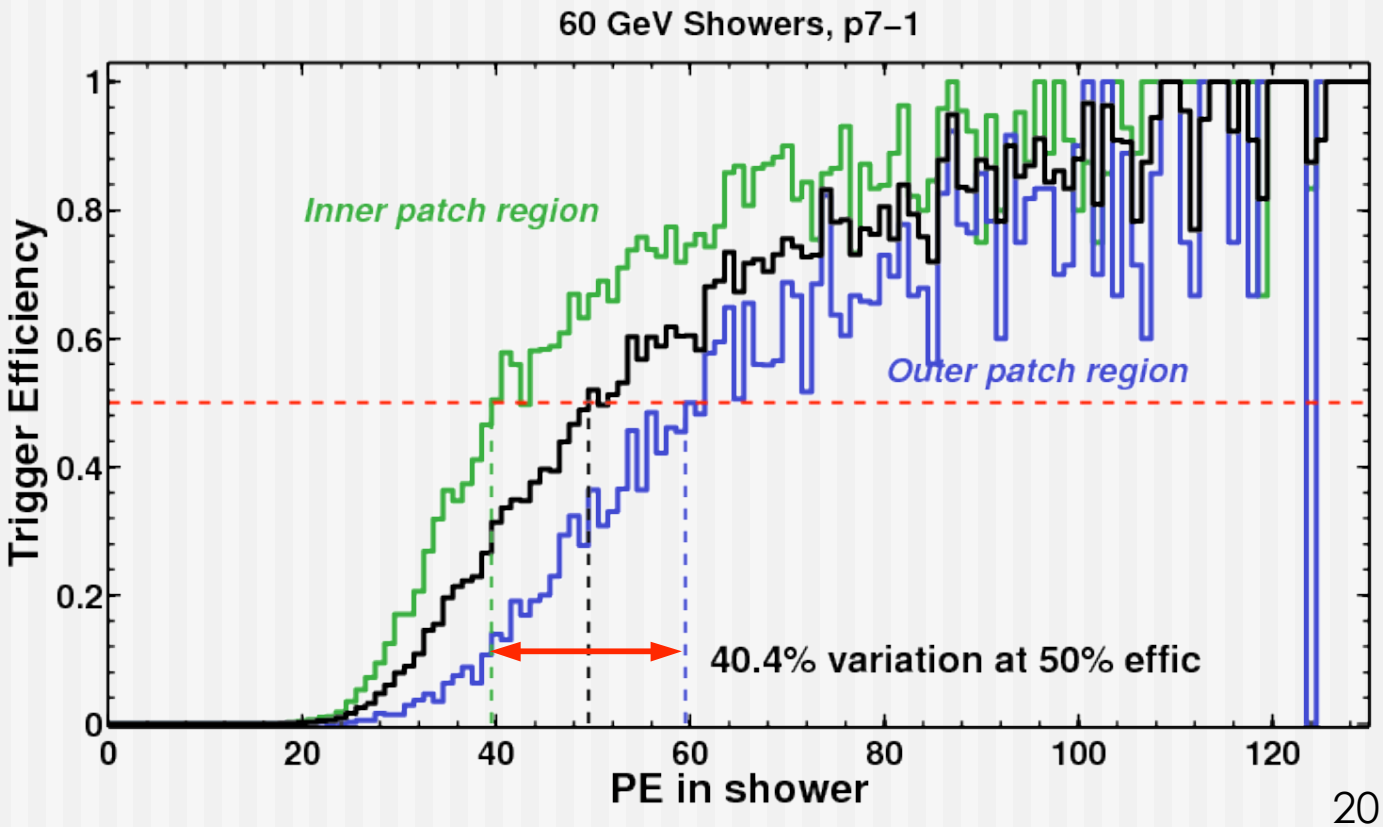
… but how to quantify this in a way that facilitates a solid comparison between algorithms?

Homogeneity: threshold variation

One idea: break up the patch into three regions of equal area, compare the trigger roll-off of the inner region with that of the outer region. Use the relative variation at 50% detection efficiency.

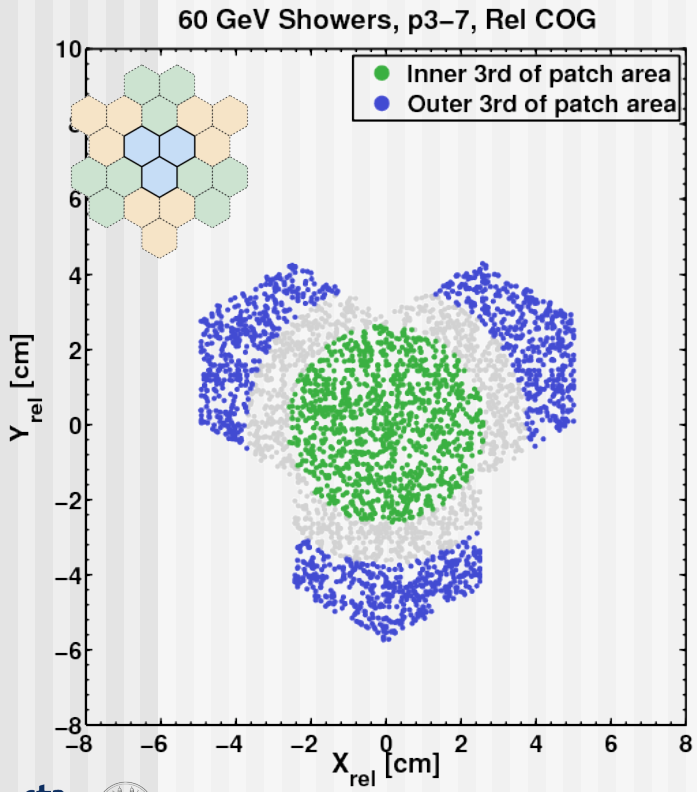


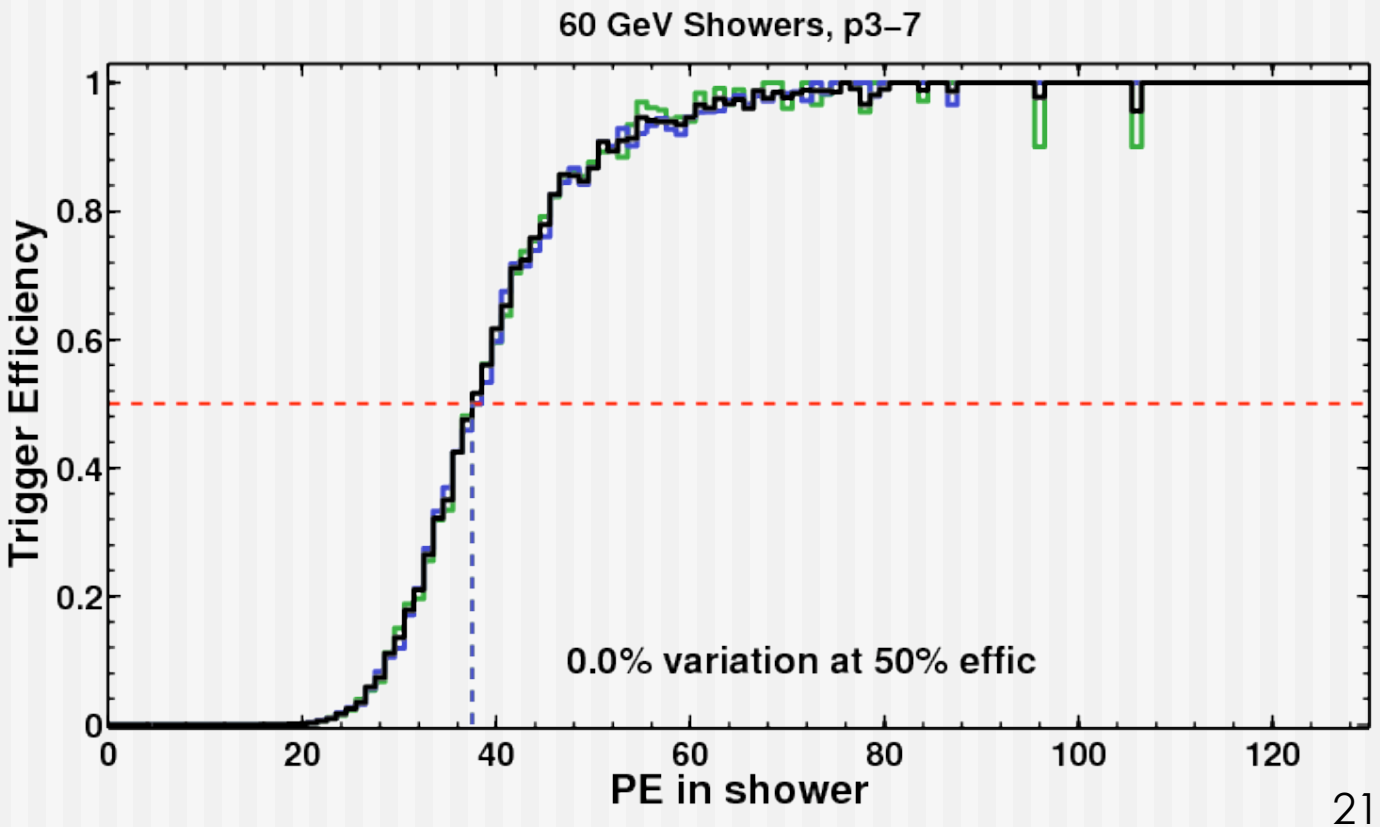




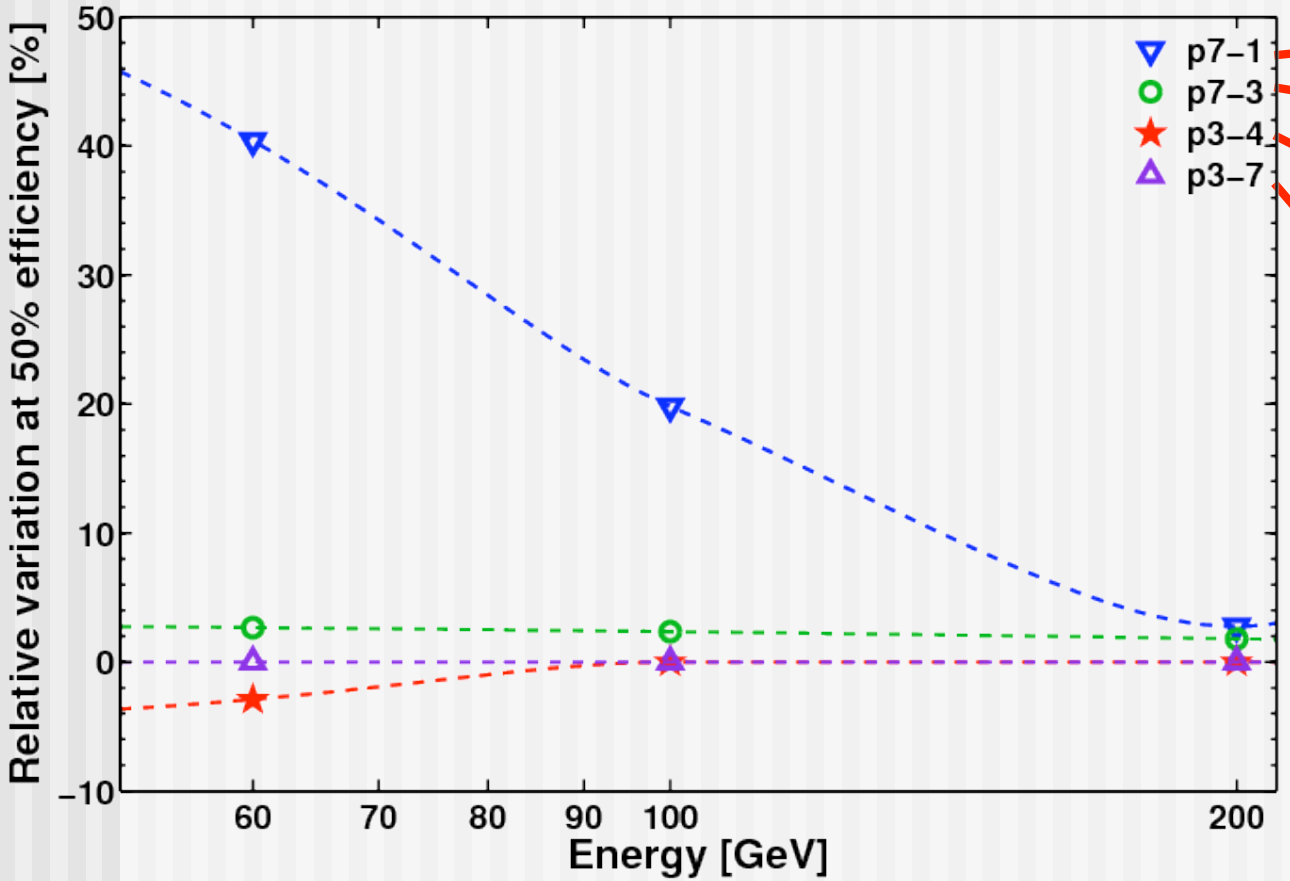
Homogeneity: threshold variation

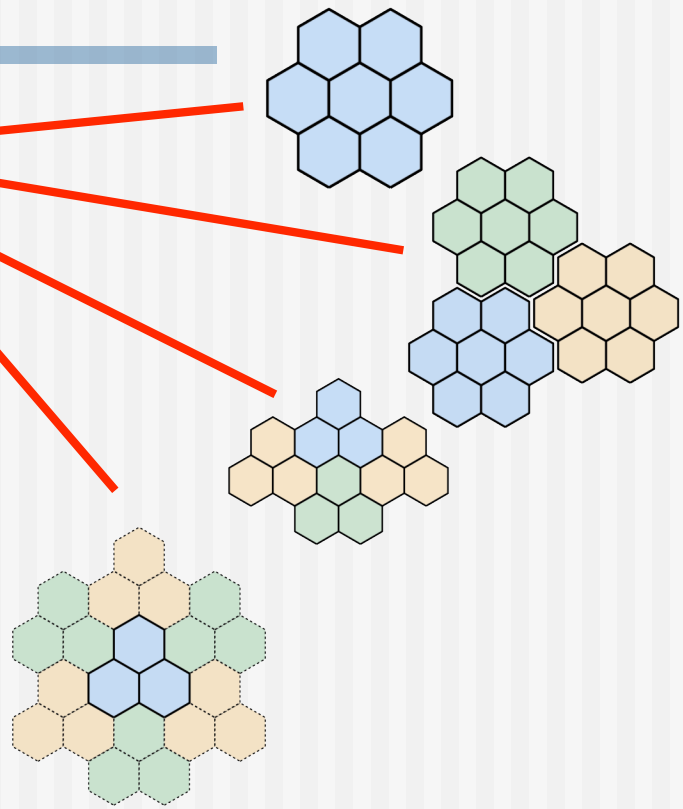
One idea: break up the patch into three regions of equal area, compare the trigger roll-off of the inner region with that of the outer region. Use the relative variation at 50% detection efficiency.





Homogeneity: threshold variation



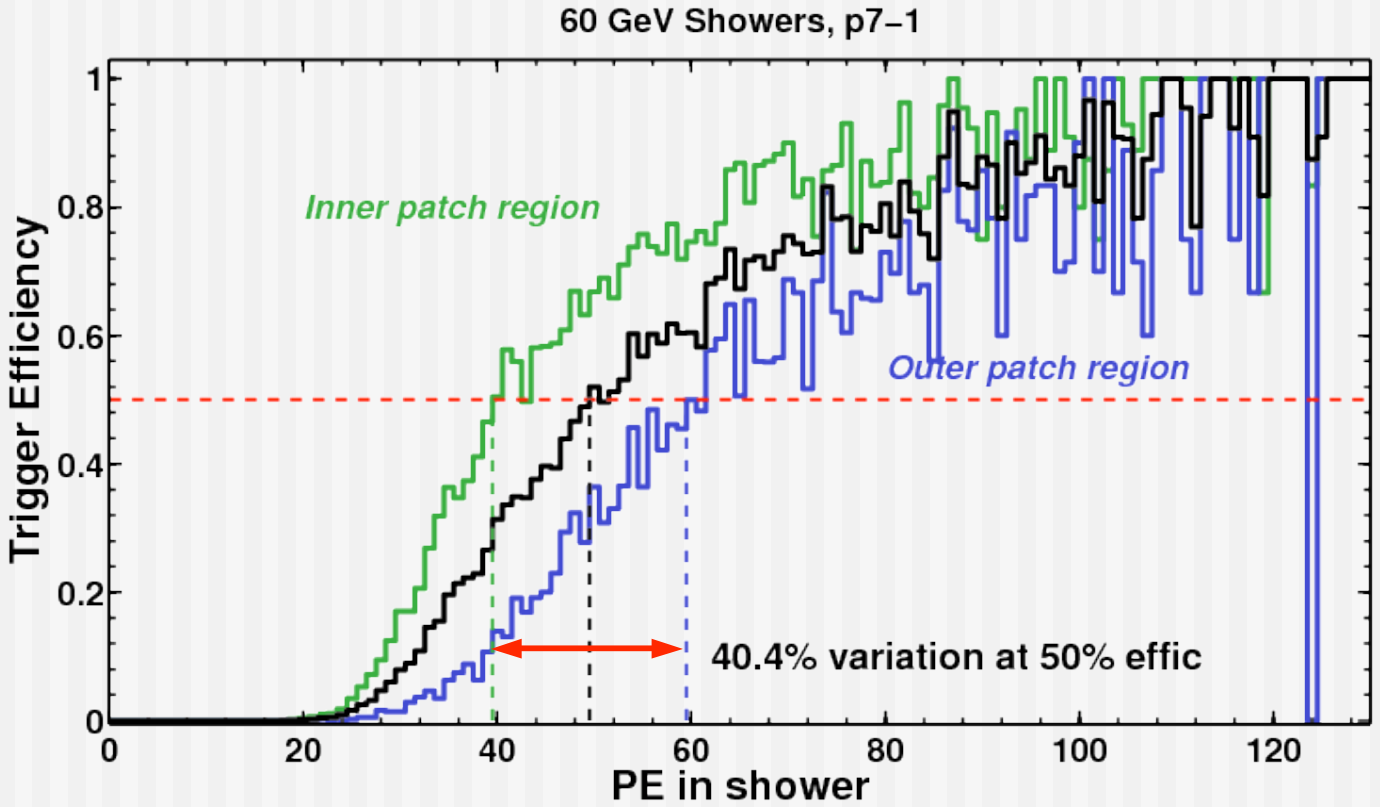


What is good enough? Well, equalization of PMT/amp gains will likely not be better than ~few% level, so the homogeneity needs to be at least below this level (but not necessarily an order of magnitude lower…)

Homogeneity: threshold variation

This metric could perhaps be improved in two ways:

- Arbitrary choice of trigger efficiency to measure the variation.
- Only quantifies this variation at a single spot.

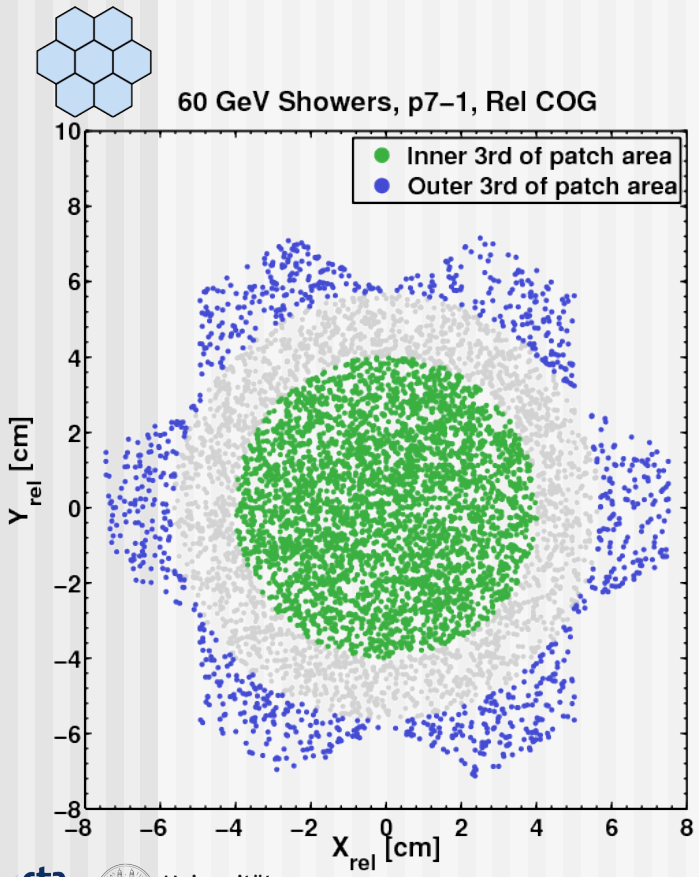


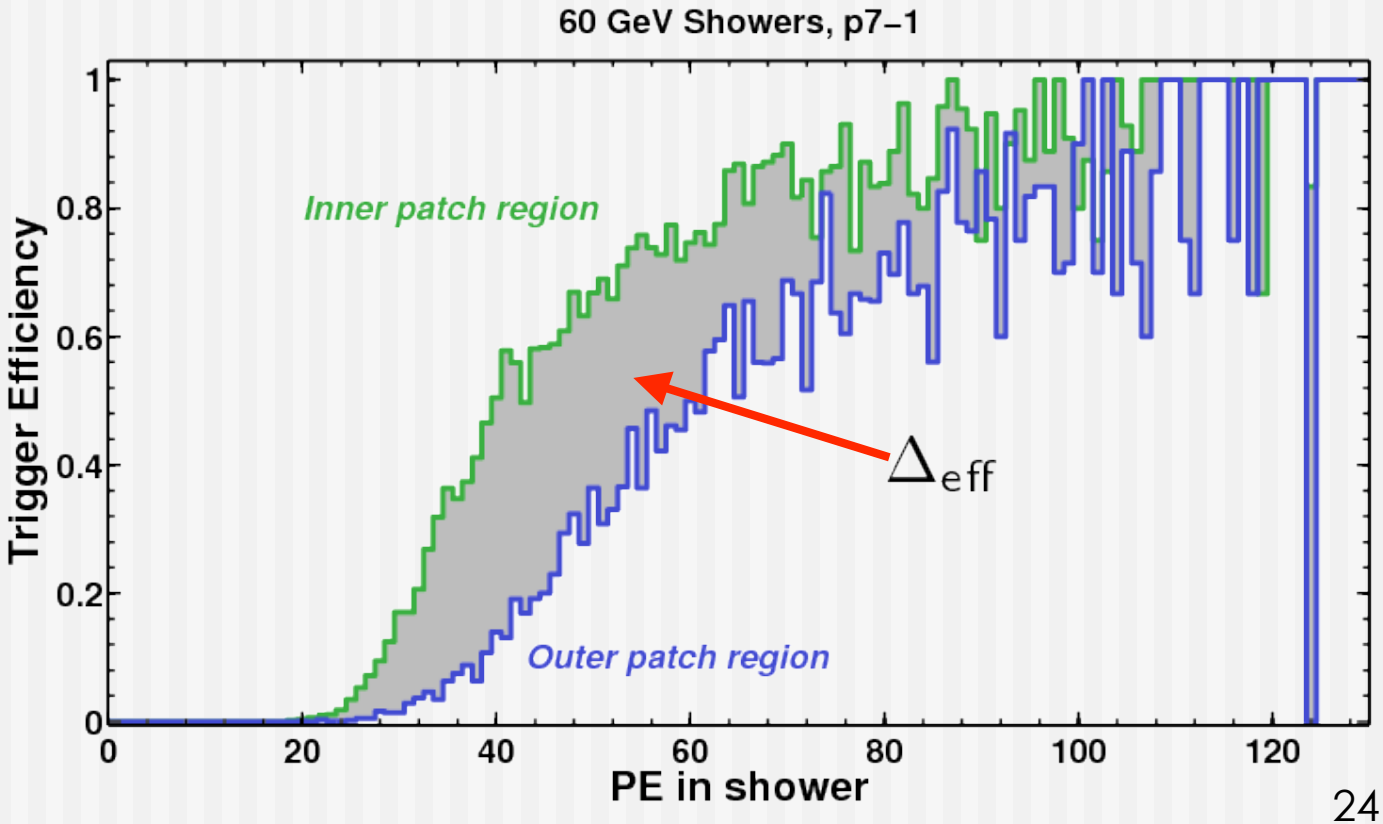
Homogeneity: roll-off variation

Another idea: again break up the patch into three regions of equal area, compare the trigger roll-off of the inner region with that of the outer region. I call the area between the two roll-off curves Δ_{eff}.

$$\Delta_{\text{eff}}^{(i)} = (\varepsilon_{\text{inner}}^{(i)} - \varepsilon_{\text{outer}}^{(i)})\Delta\text{PE}$$

$$\Delta_{\text{eff}} = \sqrt{\sum_i \left(\Delta_{\text{eff}}^{(i)}/\sigma_i\right)^2}$$

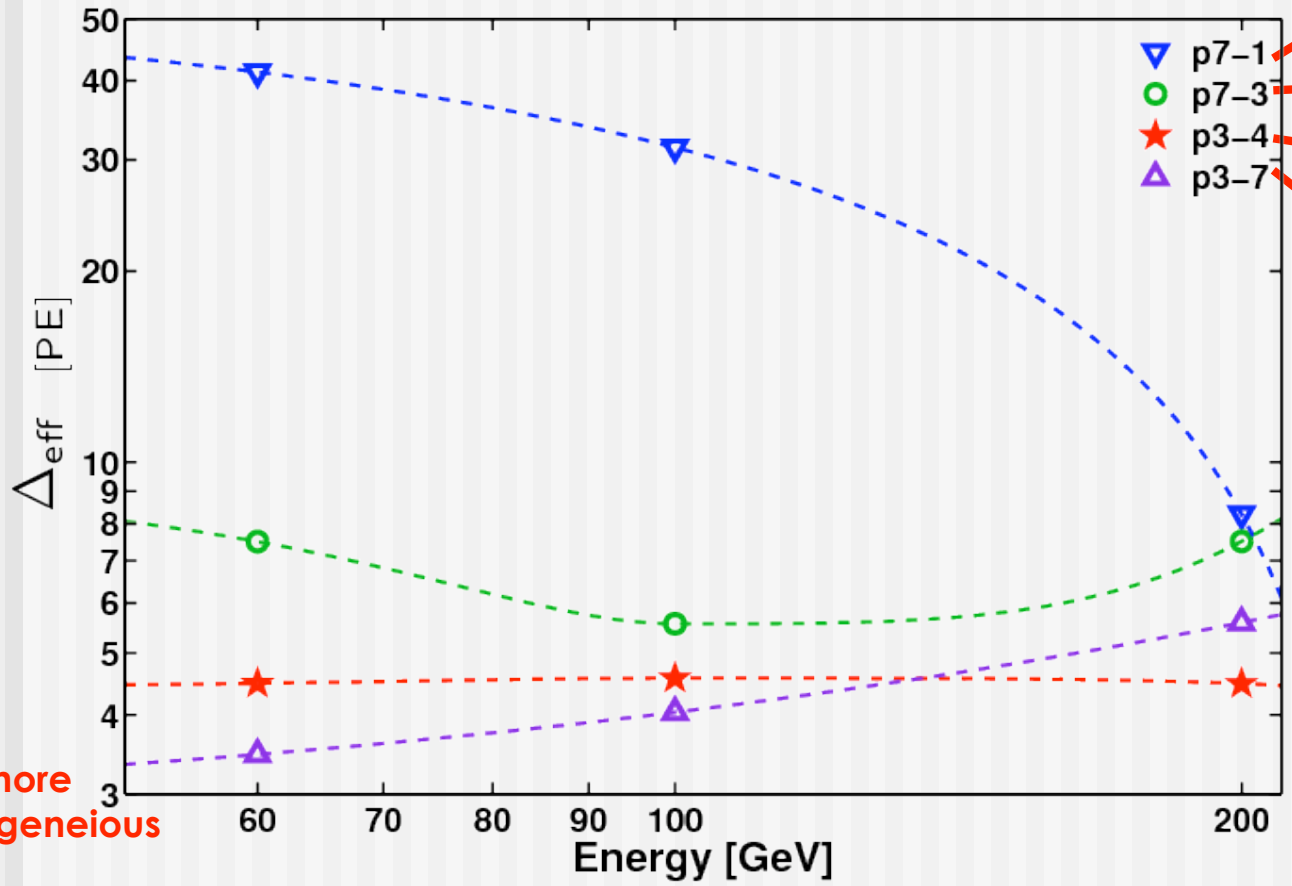


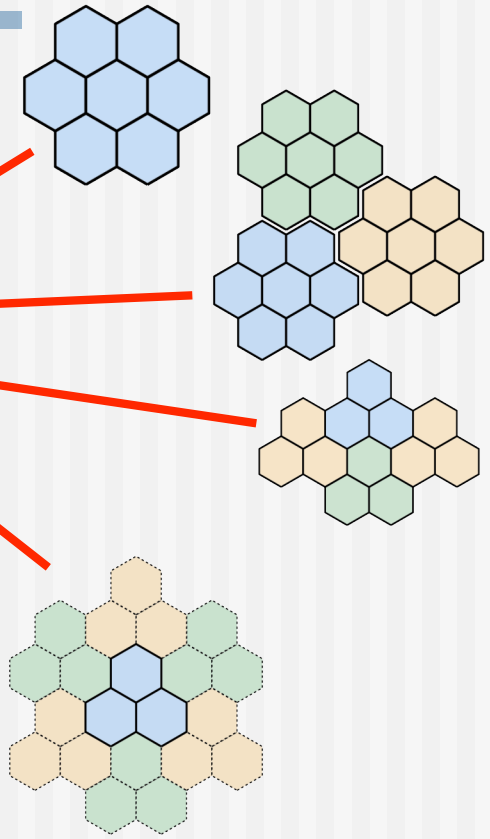


Homogeneity: roll-off variation

Less homogeneious

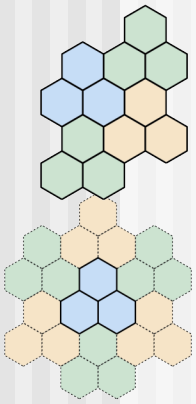
more homogeneious





Summary and next steps

- FlashCam trigger is modular, and *versatile*.
- Considering two pixel-grouping schemes: 3 pixels or 7 pixels, with many possible triggering algorithms.



- P3-4 shows best effective area
- P3-7 shows best homogeneity
- Next: investigate higher NSB, higher AP rates.
- What amplitude resolution does the trigger need? (12-bit? 4-bit?)

Thanks for your attention!