Preliminary study of muon selection with NectarCAM

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Outline

1. Assumptions
2. Data processing
3. Discussion

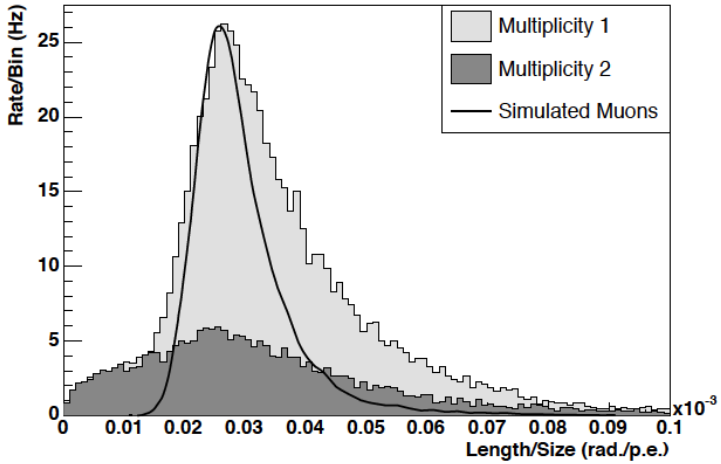
This talk reports work in progress and the content is thus VERY PRELIMINARY.

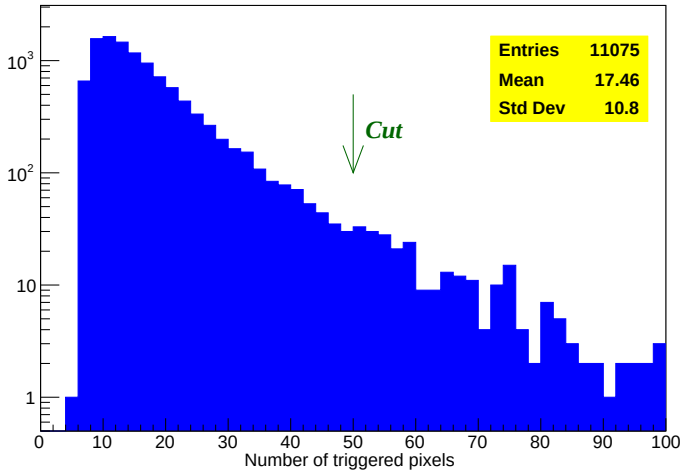
Assumptions for the study

- Selection can be made either at the trigger level (in the case of "digital trigger") or at the camera server level (preferred)
- Available at trigger level: list of hit pixels
- Available at camera server level: list of integrated charges and arrival times
- Study done with H.E.S.S. engineering data (level 2 trigger board of H.E.S.S. large telescope CT5)
- Available: map of trigged pixels

Cuts on event size

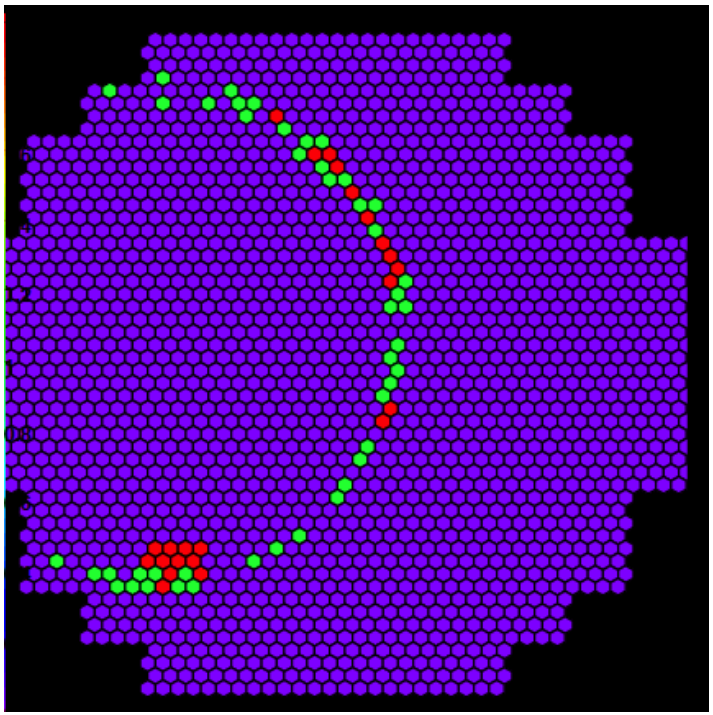
- Idea: ask for single telescope triggers with a large number of events
- H.E.S.S.1 single telescope data dominated by single muon events *S.Funk et al., Astropart. Phys. (2004)*
- Cuts:
  1. 4NN level 2 trigger cut to eliminate NSB
  2. event size $>$ 50 pixel
  3. Single telescope trigger
  4. List of pixels above a given charge available (true for both the trigger and camera server reconstruction)



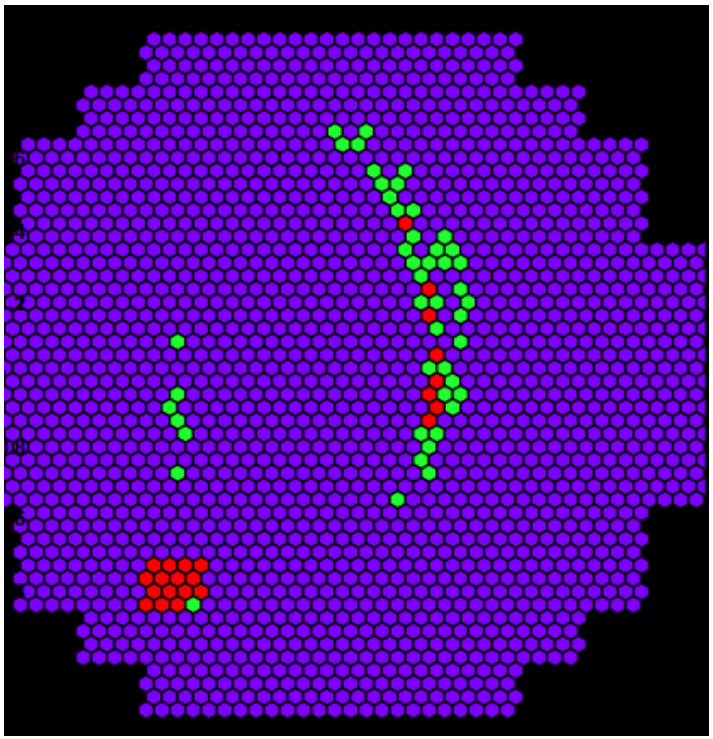


A few events

The size cut (original idea from Michael Punch) actually selects events with a large proportion of muon rings.



A nice muon ring



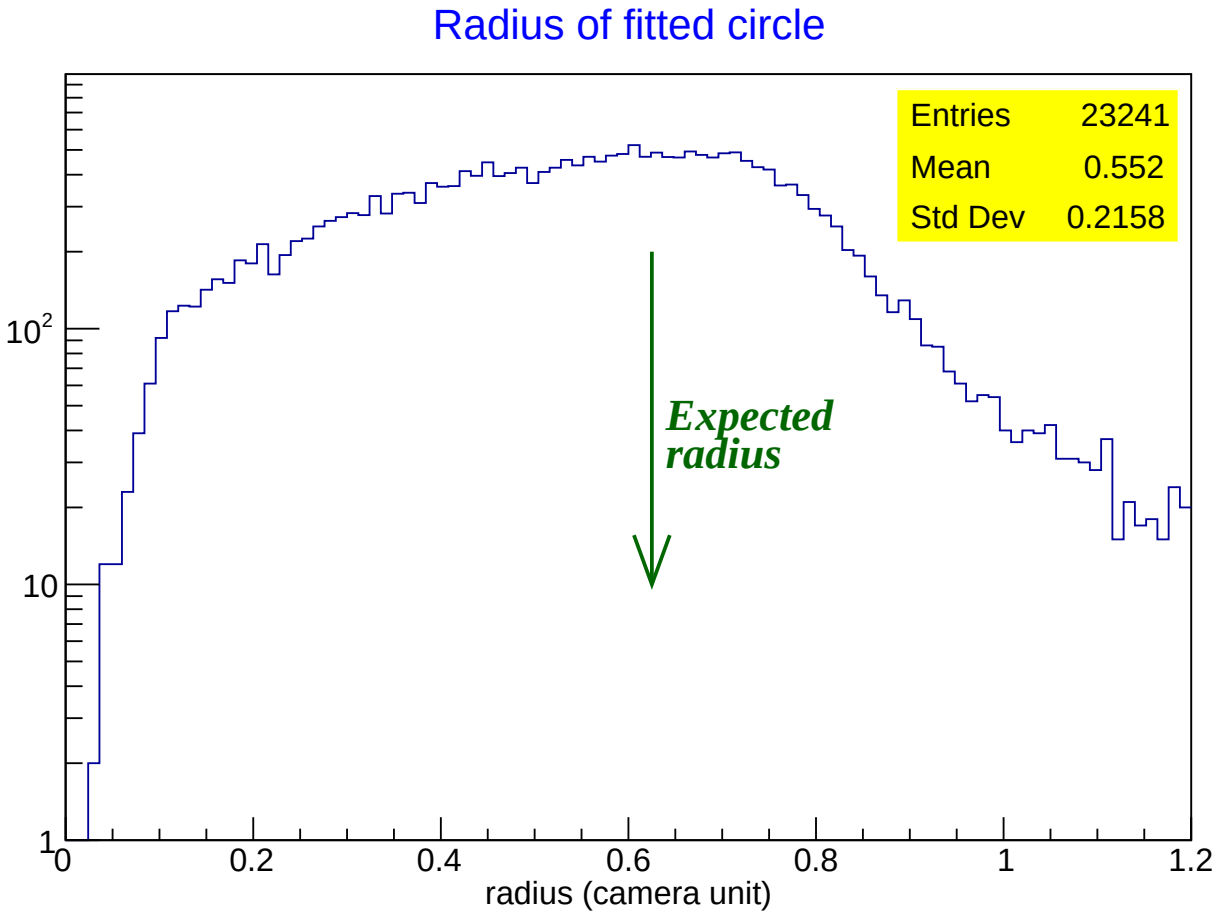
Another, not so nice

Improving over the size cut

- The muon selection can be improved with shape recognition (e.g. Hough transform) or a circle fit (e.g. Kasa method).
- The selection should not be CPU intensive
- Analytical values of the radius and center positions provided by a variant of Kasa's method: the modified least square method (Umbach & Jones, 2000)
- Radius and center positions obtained by statistical moments (up to order 3) of the list of hit pixels.
- Formula valid only if $\delta = AC - B^2 \neq 0$ with $A = n(n-1)\sigma_x^2$, $C = n(n-1)\sigma_y^2$, $B = n(n-1)\sigma_{xy}$.
- $\delta = 0$ for "line-like shapes" (e.g. Hillas ellipses).

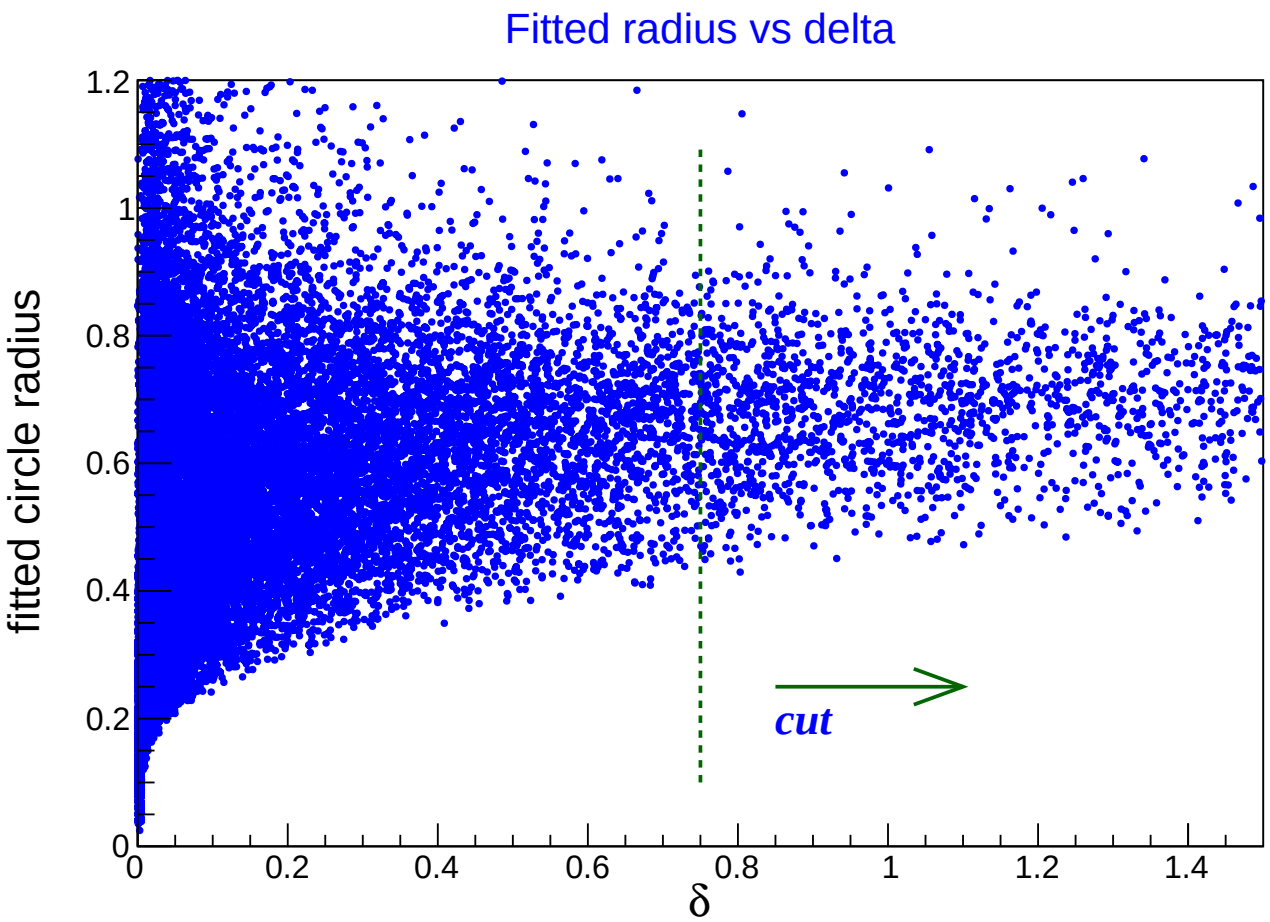
Results from the circle fit

Events selected by the size cut give a wide range of fitted radius.
The expected radius (in camera units) is $R = 0.62$.

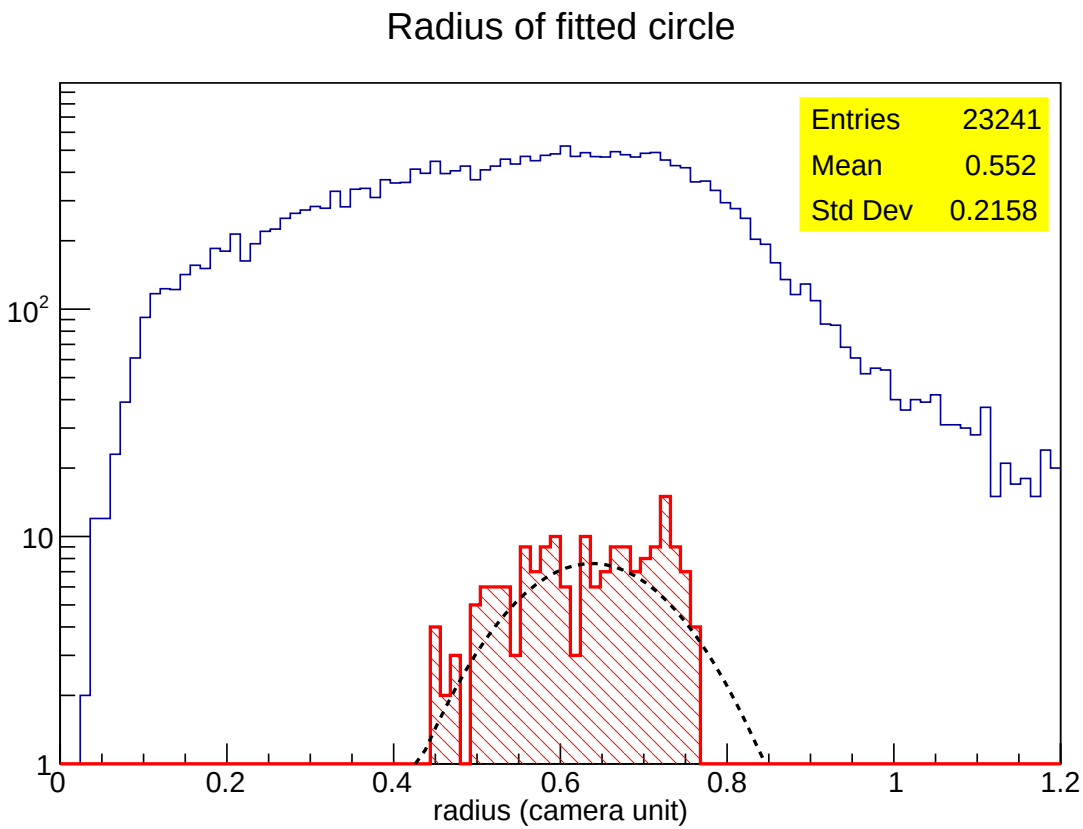


The δ cut

- Based on statistical sums $\rightarrow$ easy to implement online
- Radius distribution insensitive to δ cut value when δ large

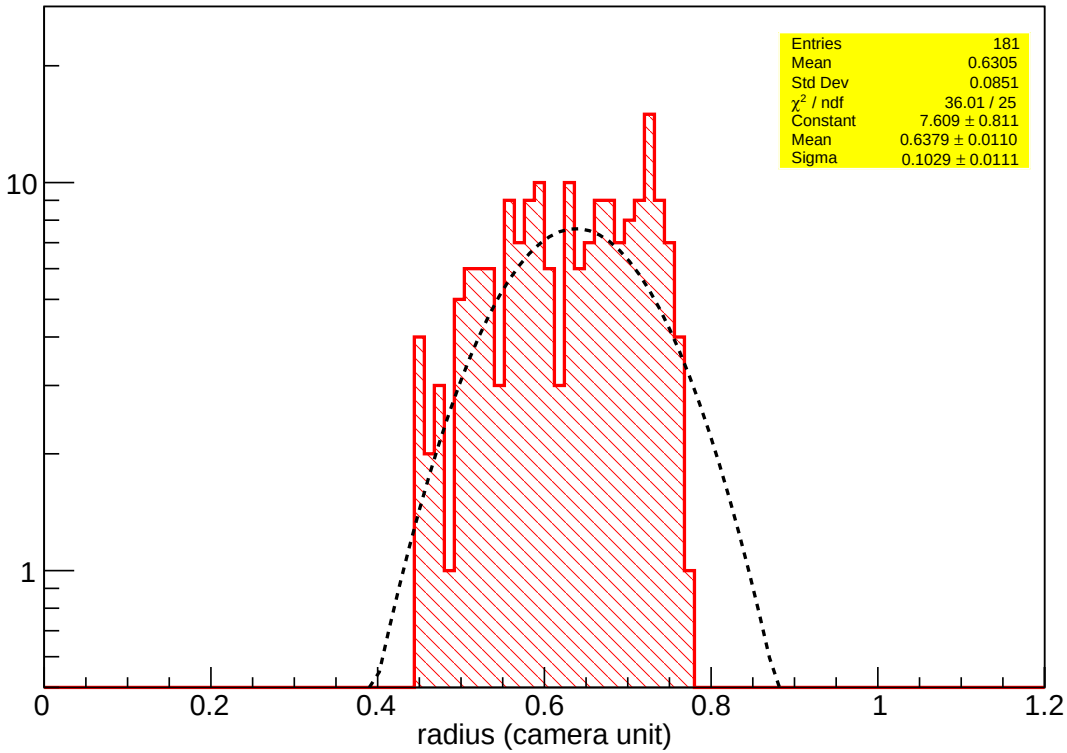


Muon selection



- After applying the δ cut, the signal is cleaner and centered on the expected value (R=0.62).
- $\sim$ 0.8 % of the data are selected.

Muon selection (continued)



- Assuming 5 kHz of cosmic data, the rate of selected muon rings $\sim$ 40 Hz.
- Fast selection: O(10 $N_{hitpixels}$) operations required (Chernov 2010)

Conclusion

- Muon selection with NectarCAM was studied with H.E.S.S. engineering data.
- The preliminary conclusion is that a clean sample of muon rings can be obtained by applying 2 simple cuts to single telescope events. The rate is a few tens of Hz.
- The list of hit pixels can be obtained either at the trigger level or by applying a threshold to charge (calculated in the front end board FPGA).
- The selection is fast $O(N_{hitpixels})$ operations required. It could be implemented either at the trigger or camera server level.