UNIVERSITÀ DEGLI STUDI DI
BARI "ALDO MORO"
DIPARTIMENTO INTERATENEO DI FISICA "MICHELANGELO MERLIN"

TESI DI LAUREA MAGISTRALE IN "PHYSICS"

Development of muon identification algorithms and atmospheric calibration for the Cherenkov Telescope Array

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Laureanda:
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Istituto Nazionale di Fisica Nucleare

cherenkov telescope array

Outline

1. **Muon identification on LST**
2. **Muon identification algorithms on ASTRI-CHEC**
3. **Muon identification parameters on LST-1 May data**
4. **Conclusions**

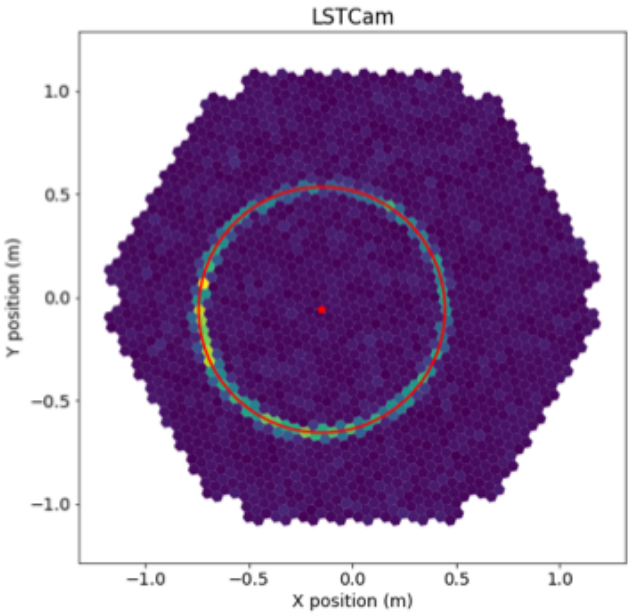
Muon identification algorithms on LST

- Currently used identification: *Chaudhuri – Kundu*
  - ➢ Analytical calculation (repeated 2-3 times)
  - ➢ Identification based on ring radius
  - ➢ slow processing rate (18.86 $\pm$ 7.56) Hz*

    *speed evaluated on a single image

Alternative algorithms:

- Taubin fit
  - ✓ fast
  - ✓ possibly more reliable than an analytical calculation
- Neural Network
  - ✓ fast
  - **x** lower efficiency wrt other methods
- Majority
  - very fast, good for tagging



Parameters for muon identification

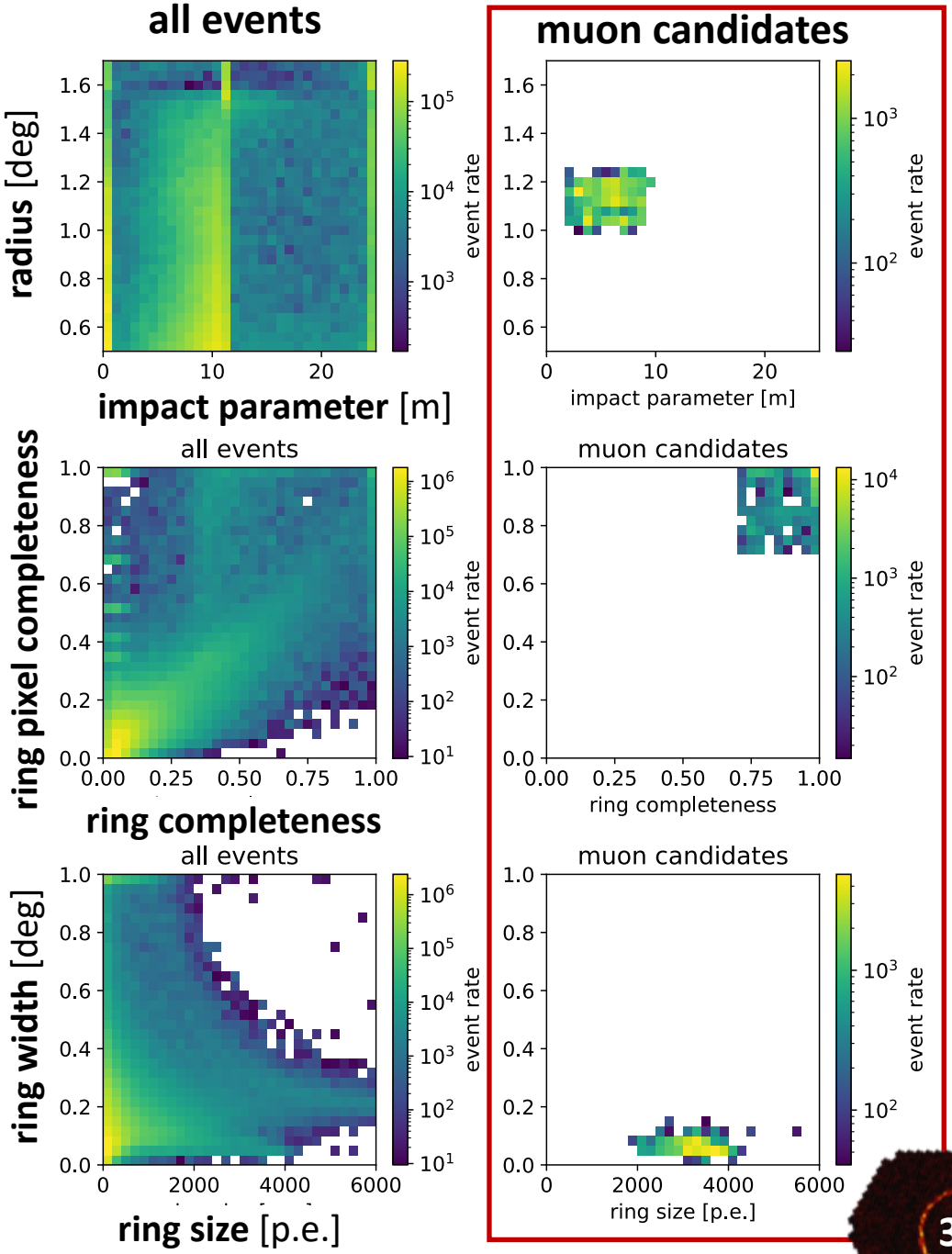
Parameters to identify muon signal and test algorithms (obtained with full analysis, except radius):

- Radius **$1.0\,° < r < 1.5\,°$**
- Impact parameter **$0.2\,R_{mir} < \rho < 0.9\,R_{mir}$**
- Ring (pixel) completeness **at least 0.7**
- Size outside ring **> 200 pe**

Additional parameters (no active cuts applied, but monitored):

- ring width
- ring size

Note: distributions are scaled to proton flux



muon signal with full analysis

Muon identification on LST: Taubin fit

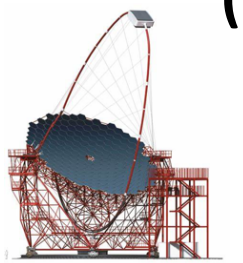
- circle fit to compute center and radius
- minimization of

$$\xi = \frac{\sum((x-x_c)^2+(y-y_c)^2-r^2)^2}{\sum((x-x_c)^2+(y-y_c)^2)}$$

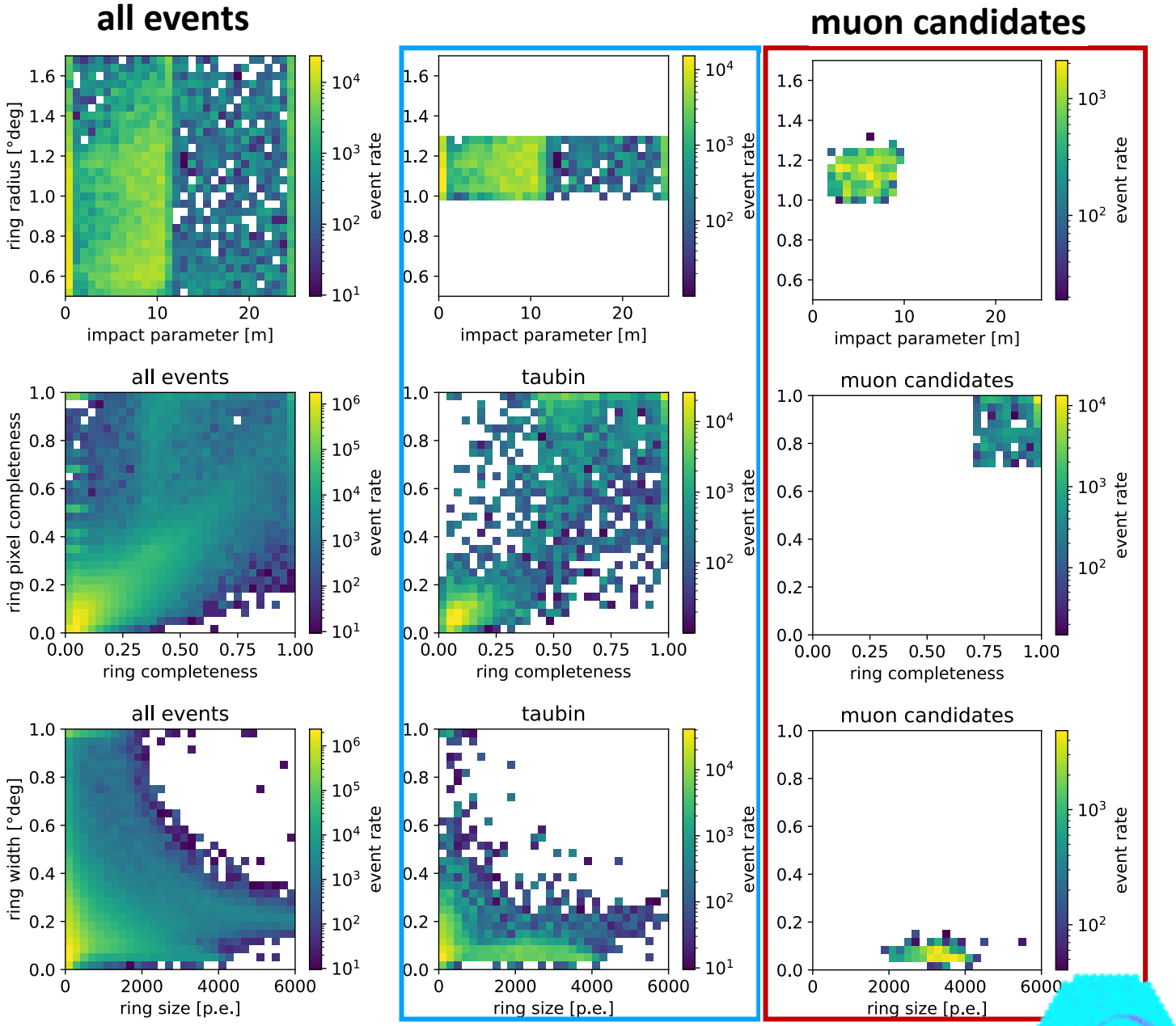
- cut on radius

1.0 ° < *r* < 1.5 °

- ➢ **efficiency > 90%**
- ➢ **processing rate (199.50 ± 30.20) Hz**



selected events with Taubin

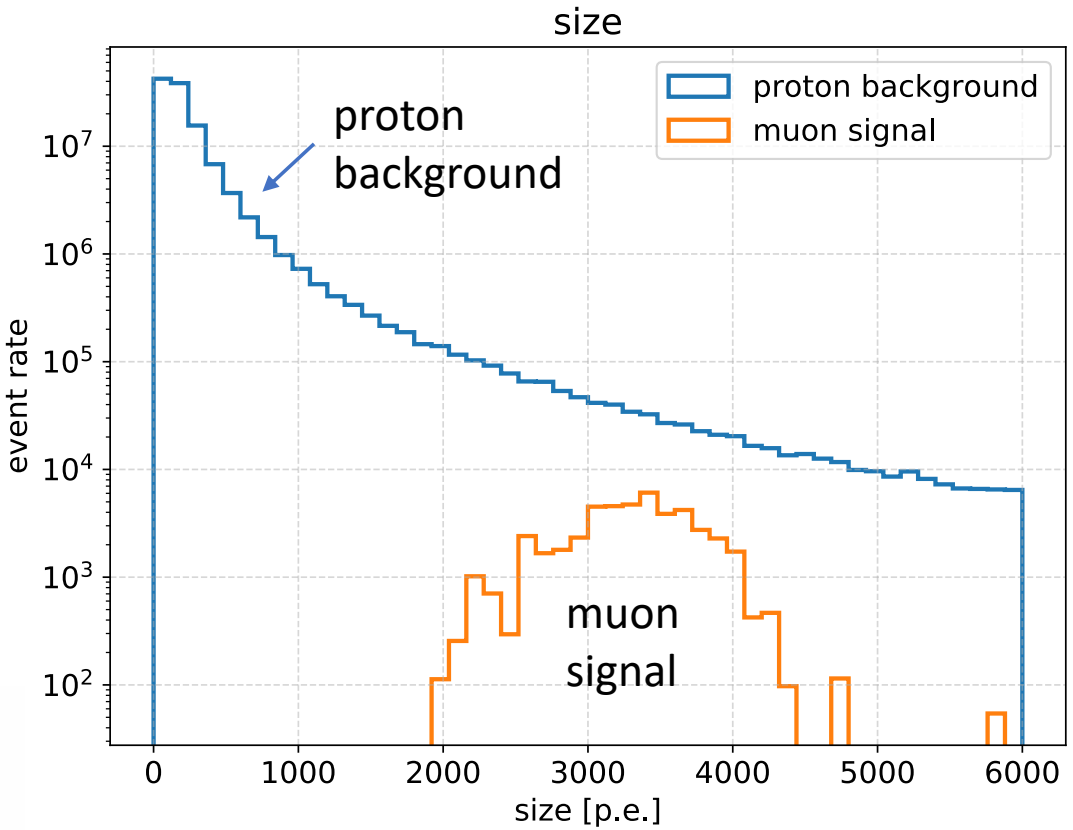


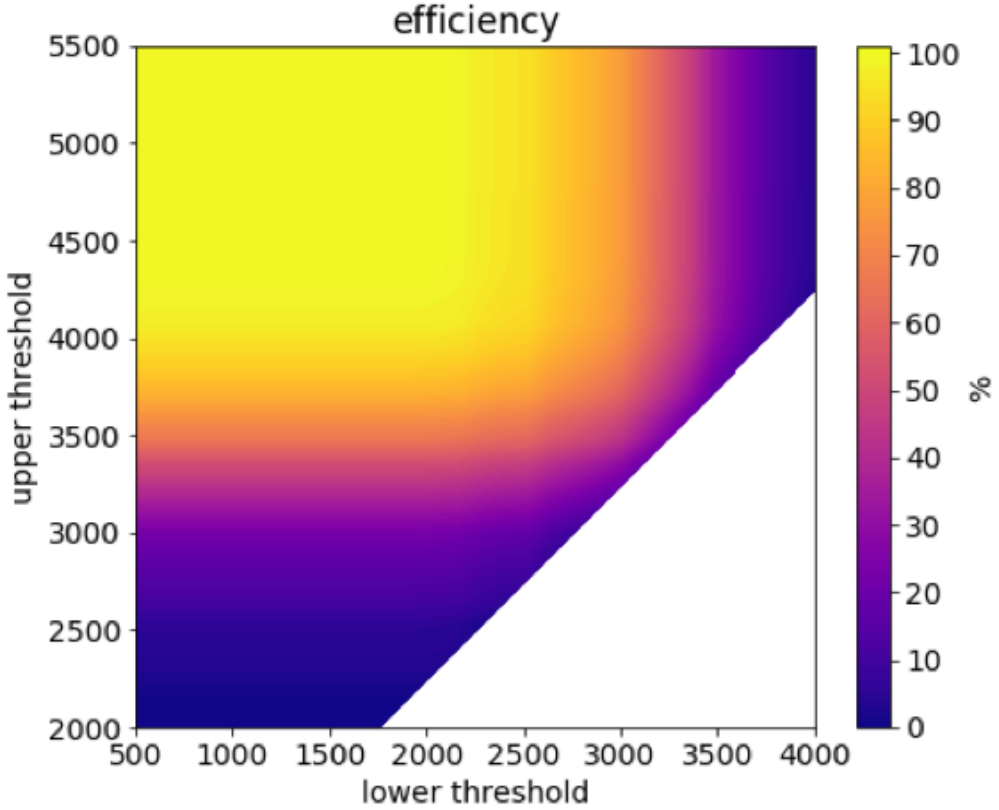
muon signal with full analysis

Muon identification on LST: Majority

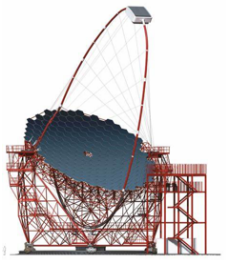
Comparison to a threshold of:

- **size**: sum of p.e. of each pixel ⟶ double threshold on image size
- number of pixels above a given p.e. threshold (distributions are not separated)





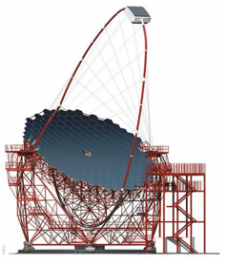
purity few % (plot in bkp)



Muon identification on LST: Majority

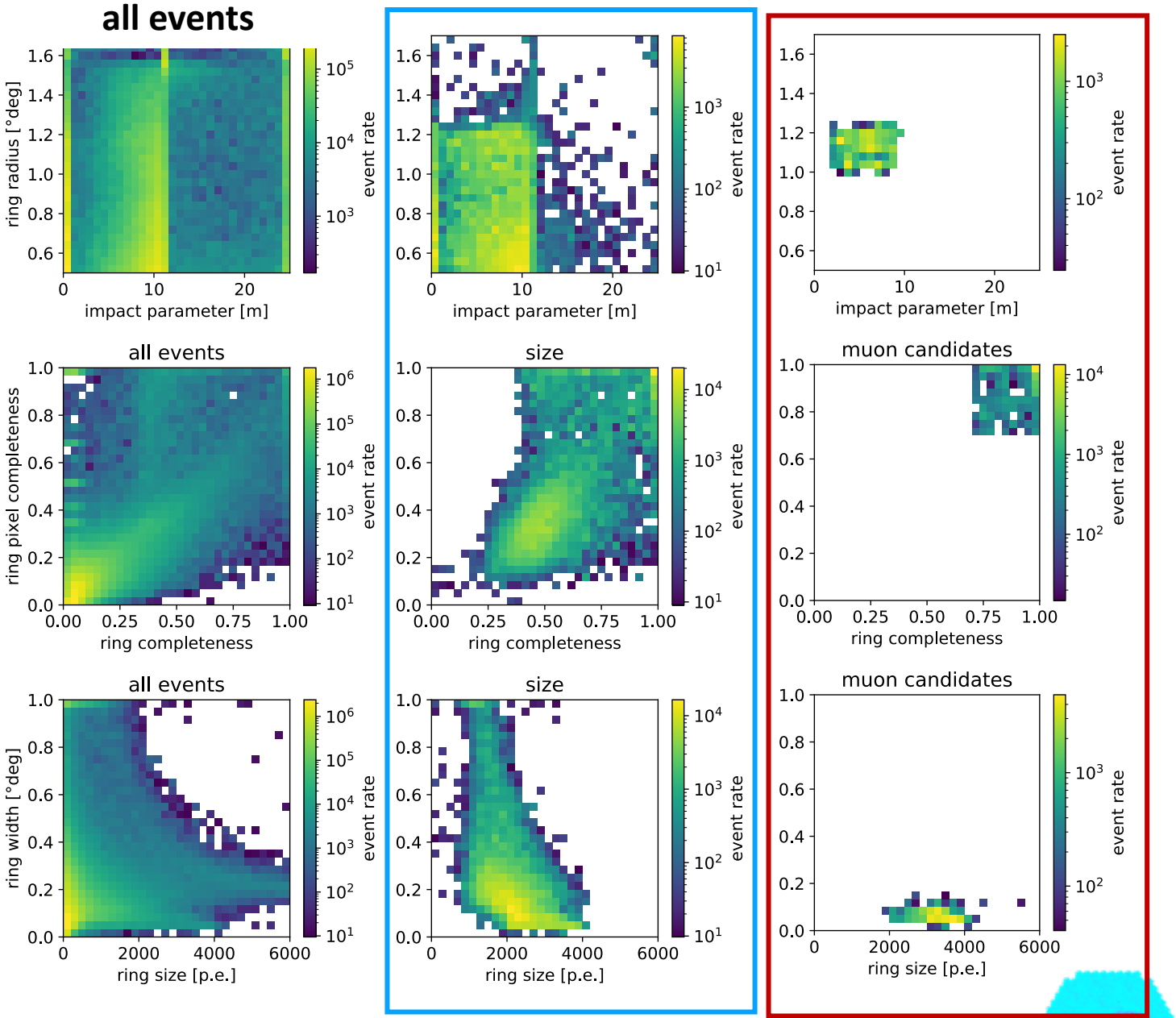
- **thresholds at 90% efficiency**
- **processing rate (157.15 ± 0.14) kHz**

- **Preselecting rings with Majority:**
  => full analysis computational time reduced by 1/2 !



selected events with Majority

muon candidates

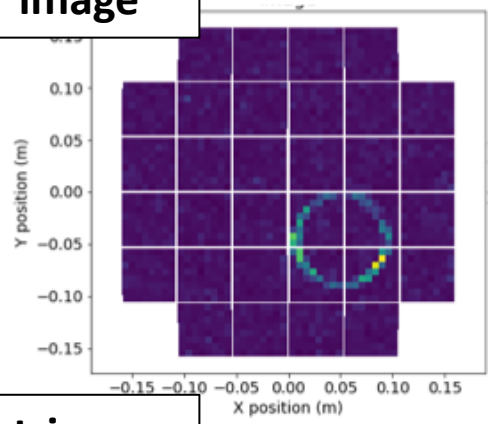


muon signal with full analysis

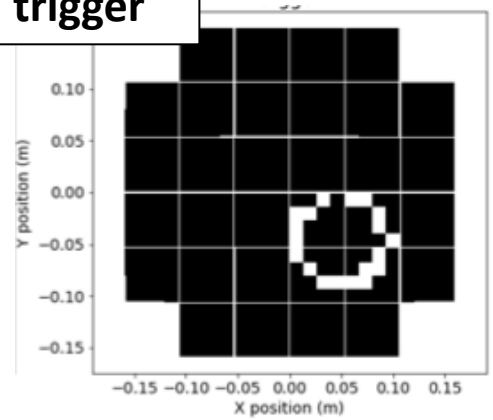
Muon identification on ASTRI-CHEC

Similar discussion as for LST
Trigger pattern readout possible –> **Muon trigger**

image



trigger

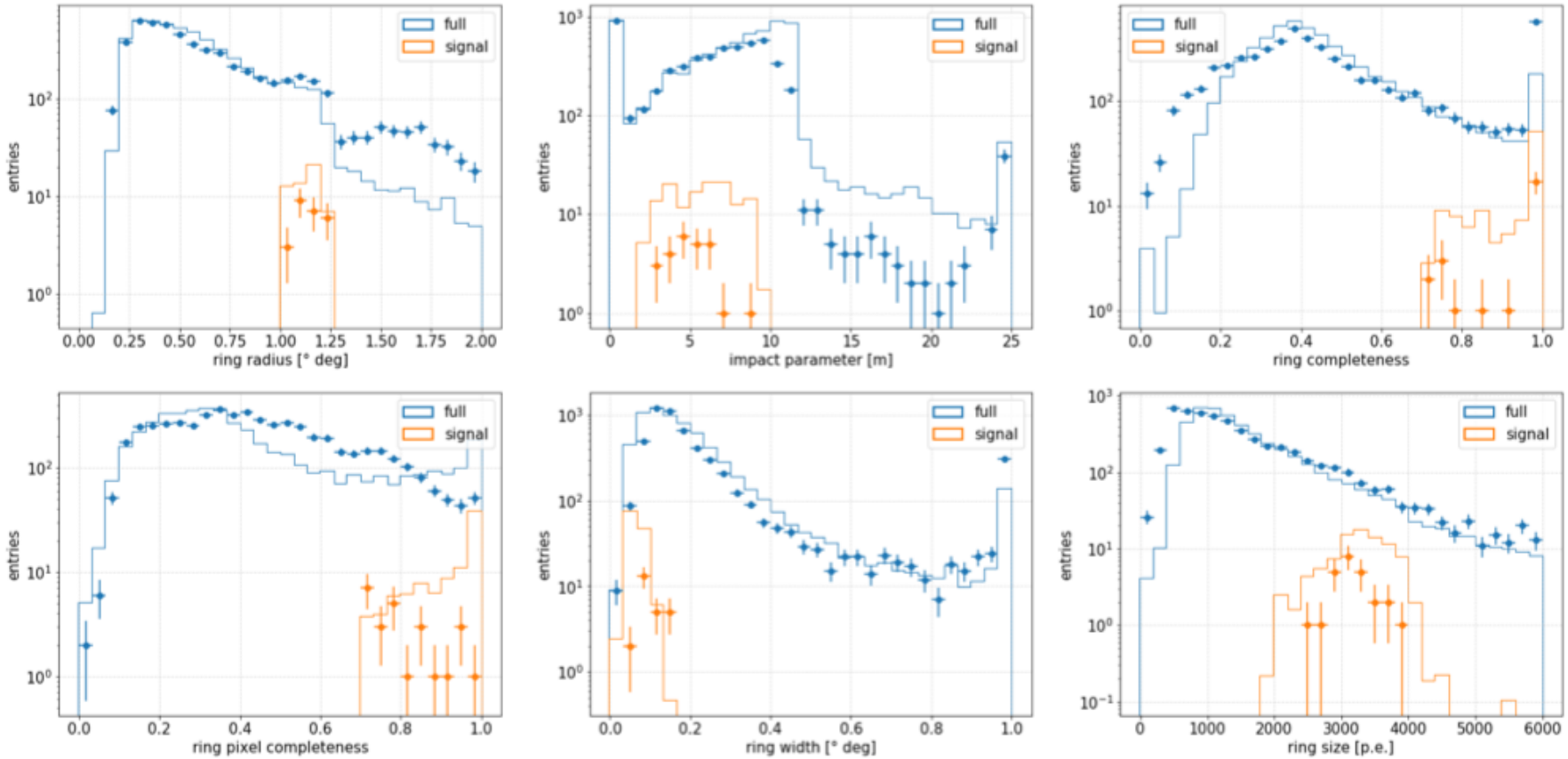


	efficiency	processing rate
• Taubin fit (both trigger and full image)	> 90 %	(74.80 ± 7.77) Hz
• Neural Network (only trigger image)	> 90 %	(1.31 ± 0.02) kHz
• Majority (only trigger image)	> 90 %	(60.18 ± 0.15) kHz

Expected camera trigger rate: 0.6 – 1 kHz & method is simple
hardware implementation possible!

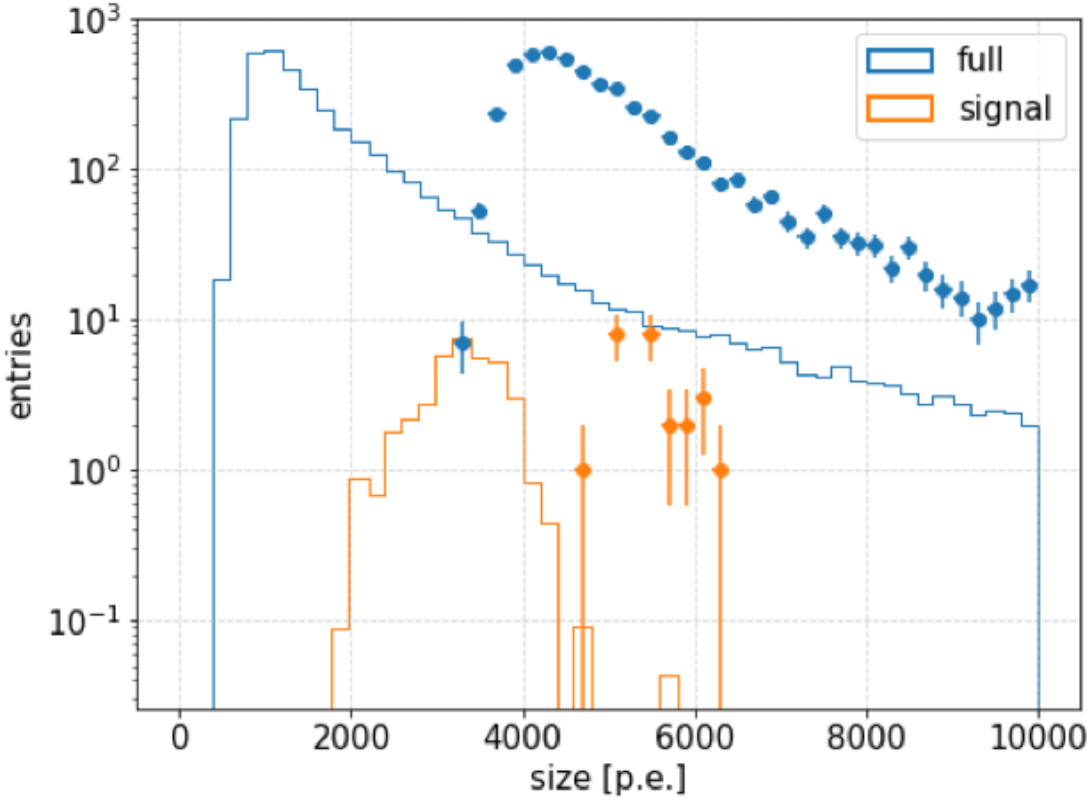
LST-1 data (preliminary): parameters

Run 442 **May** 2019



LST-1 data (preliminary): size

Run 442 **May** 2019

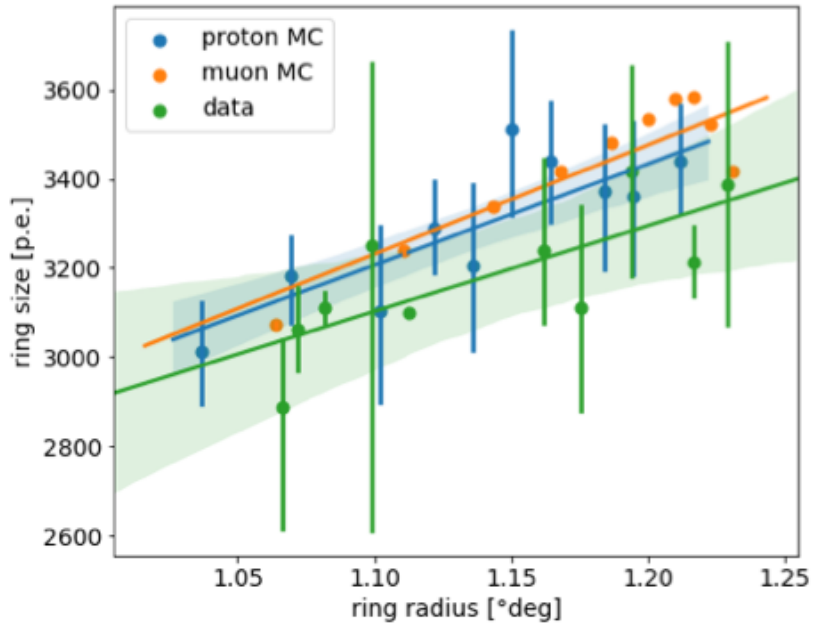


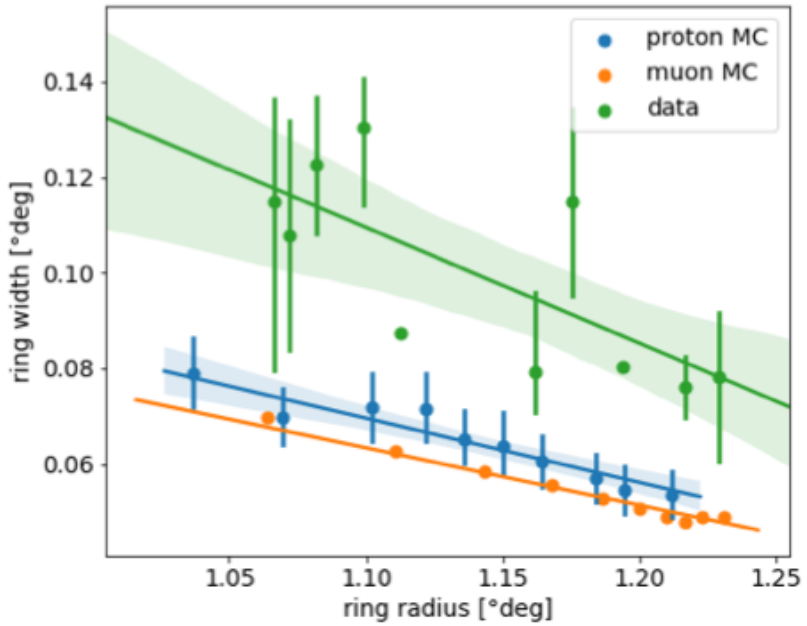
- probem with calibration
- different integration LocalPeakWindowSum instead of NeighborPeak...

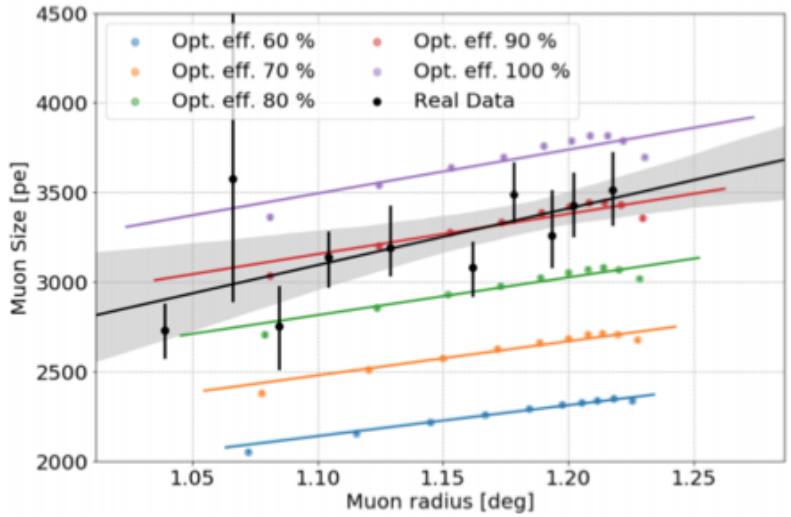
➢ Improve this when analyzing new runs

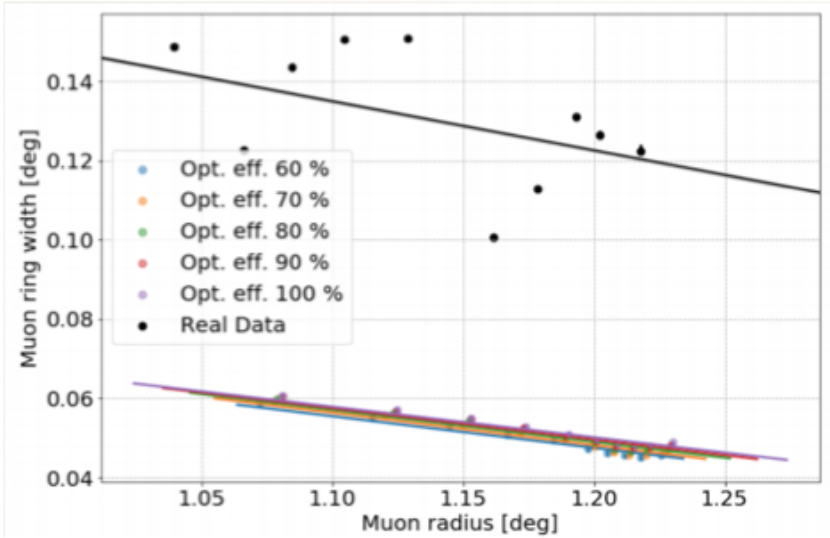
LST-1 data (preliminary): muon efficiency plots (for reference)

Run 442 **May** 2019









López-Coto
04/12/19
LST-Meeting
Marseilles

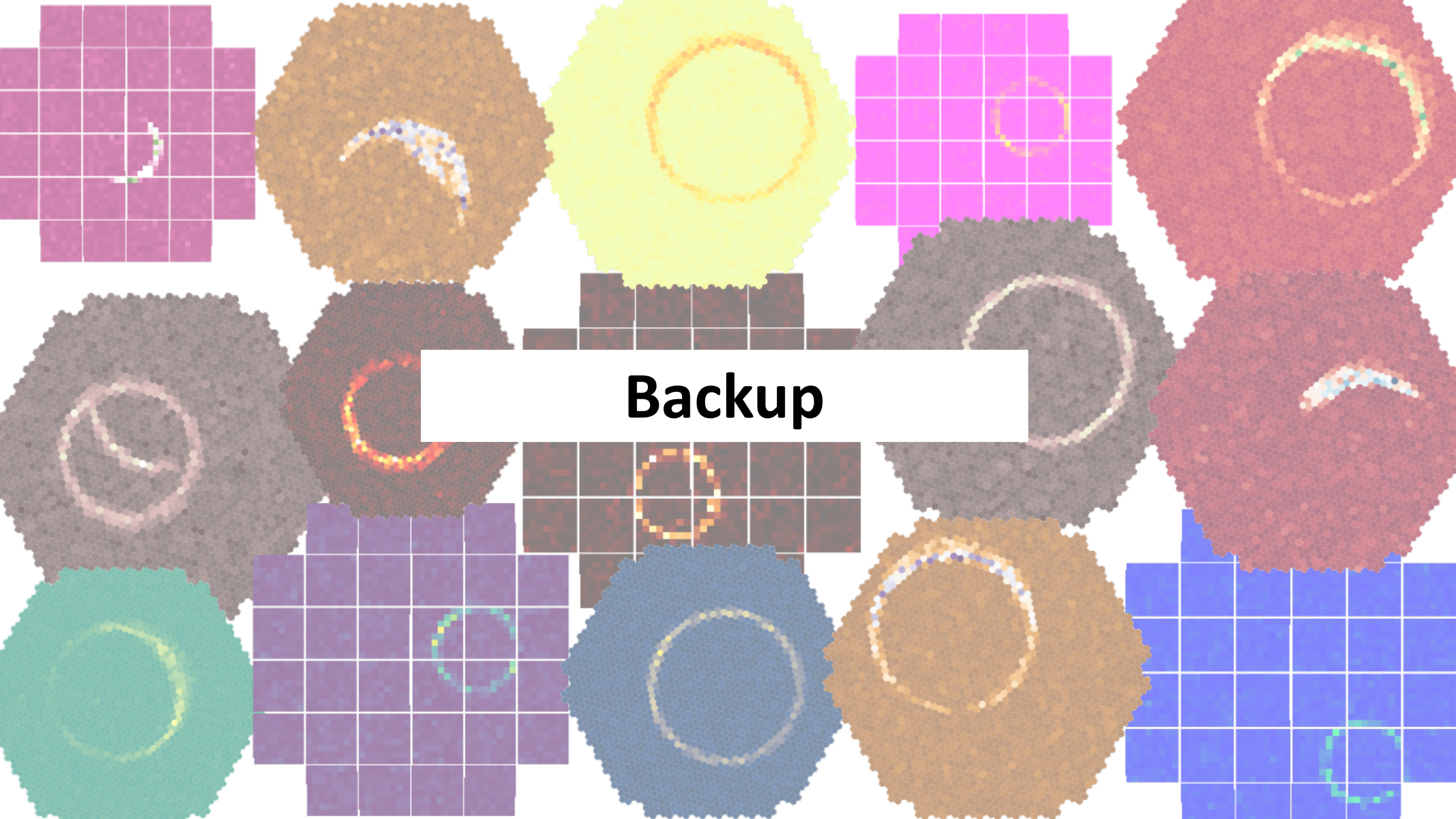
Conclusions

1. **The Taubin fit is a viable ring fit alternative (faster, reliable)**
2. **Majority is ideal for preselection: online (trigger) and offline**
3. **Possible optimized muon identification pipeline:**
    1. **preselection with Majority**
    2. **fit with Taubin**

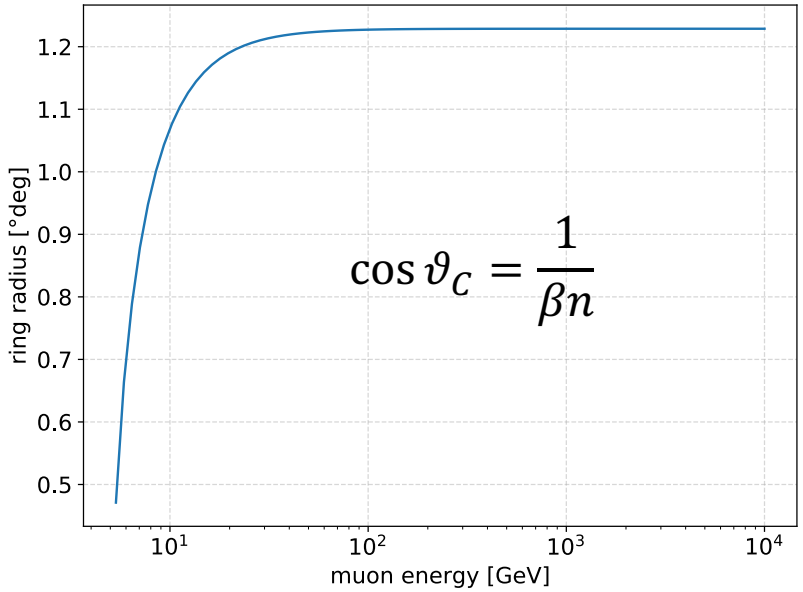
What’s next:

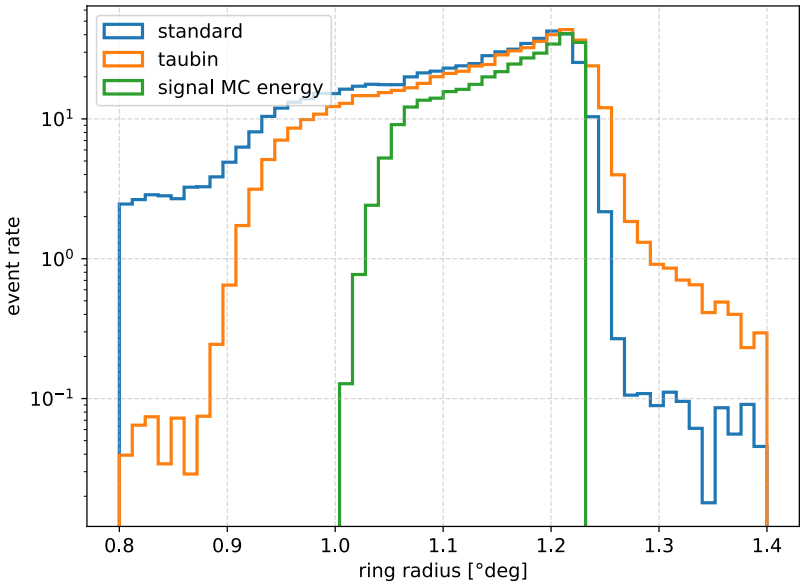
1. **Test on Crab campaign data**

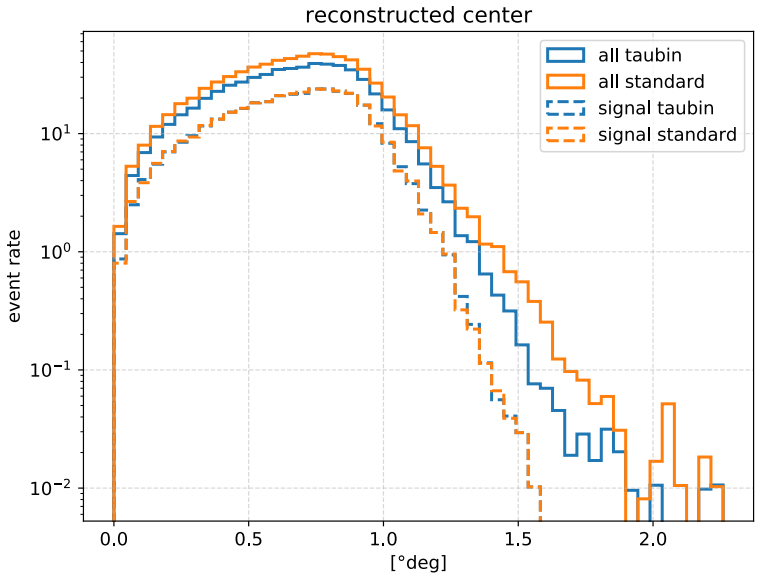

Thanks for your attention!
LST-1: run 442
event id 72370

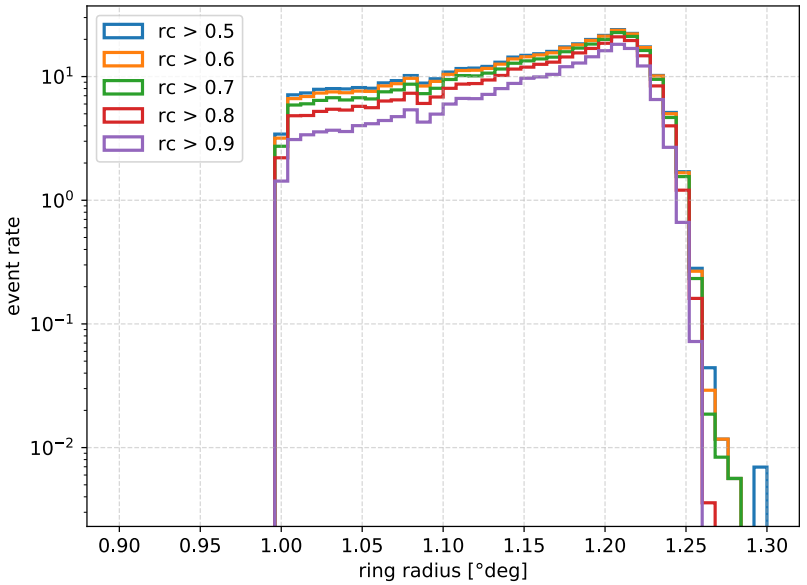

Backup

Radius LST


ring radius [°deg]
muon energy [GeV]
$\cos\vartheta_C = \frac{1}{\beta n}$

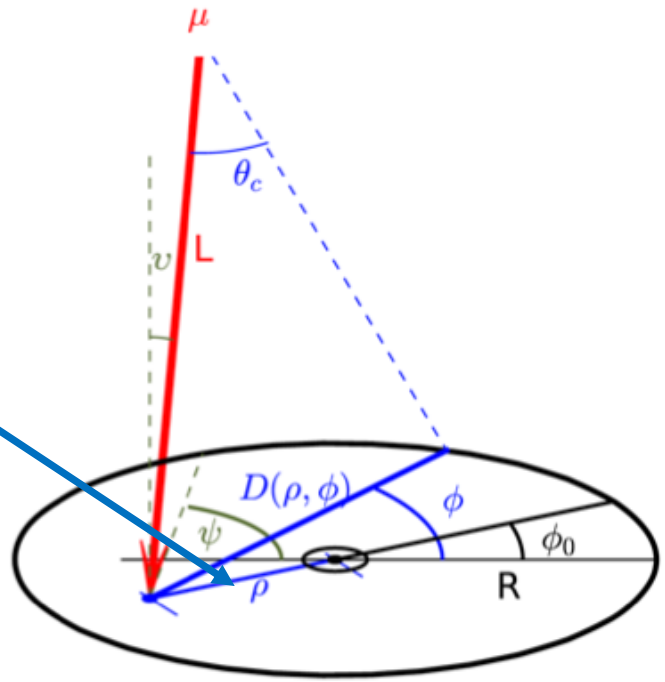

standard
taubin
signal MC energy
event rate
ring radius [°deg]

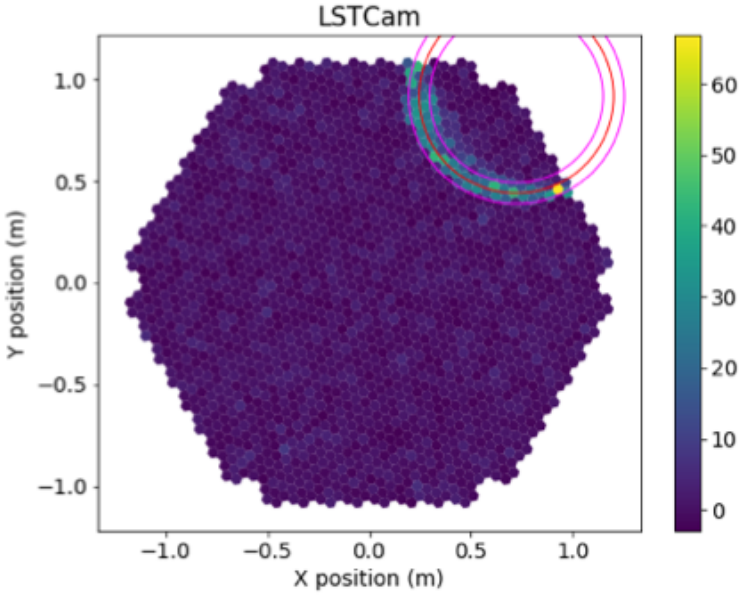

reconstructed center
all taubin
all standard
signal taubin
signal standard
event rate
[°deg]


rc > 0.5
rc > 0.6
rc > 0.7
rc > 0.8
rc > 0.9
event rate
ring radius [°deg]

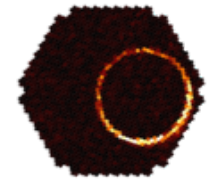
Parameters for muon identification

- Radius
- **Impact parameter ρ**
- Ring completeness
- Size outside the ring

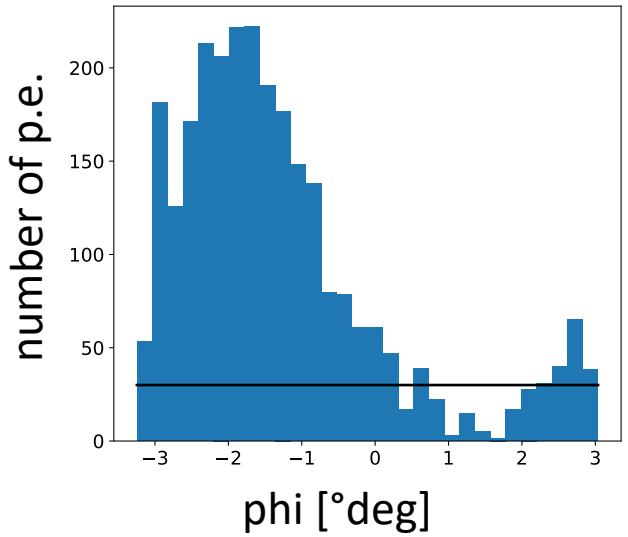


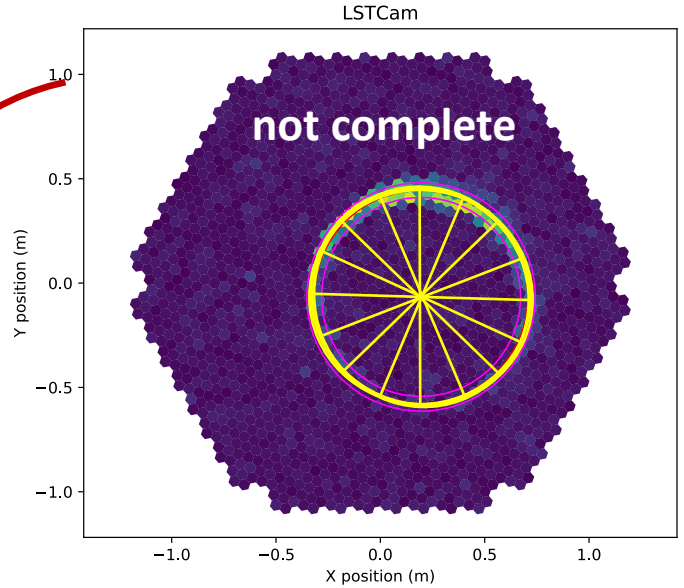


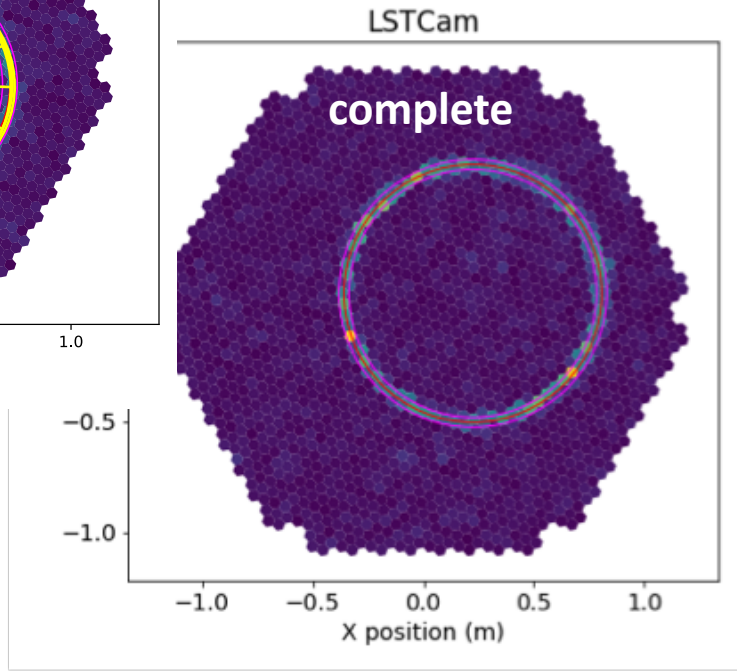
0.2 R < ρ < 0.9 R



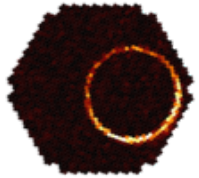
Ring completeness





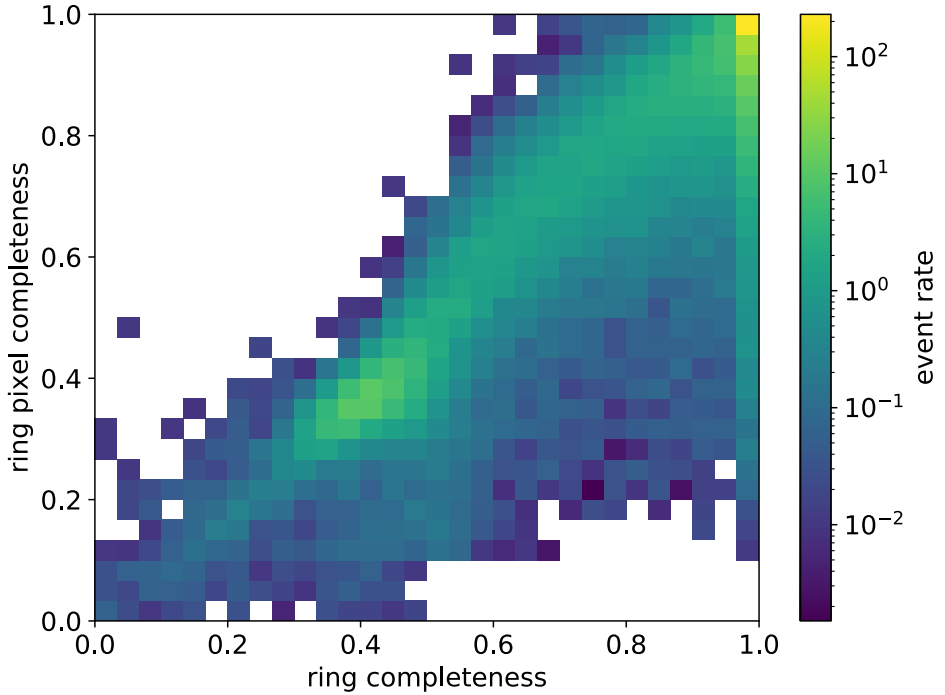


at least 0.7

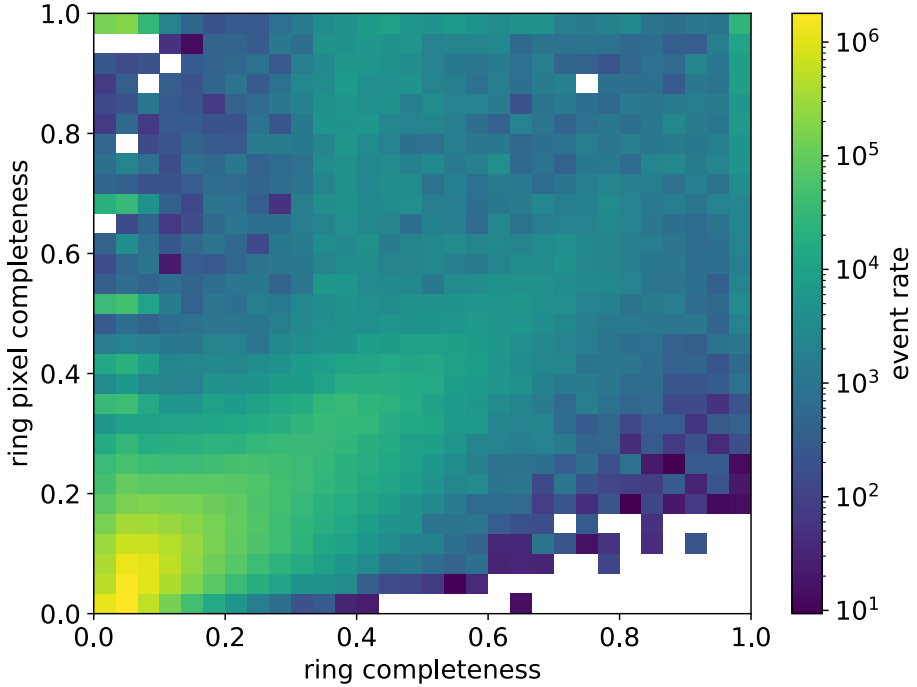


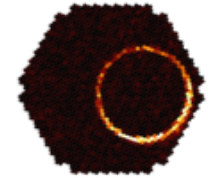
Ring completeness

Muon MC

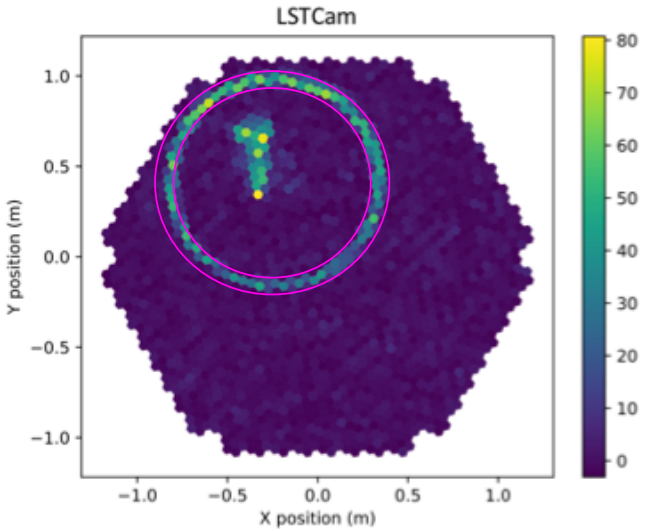


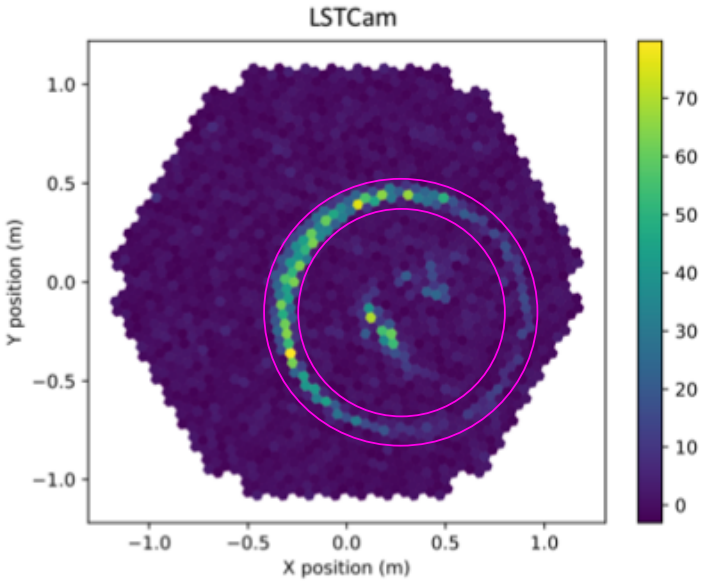
Proton MC



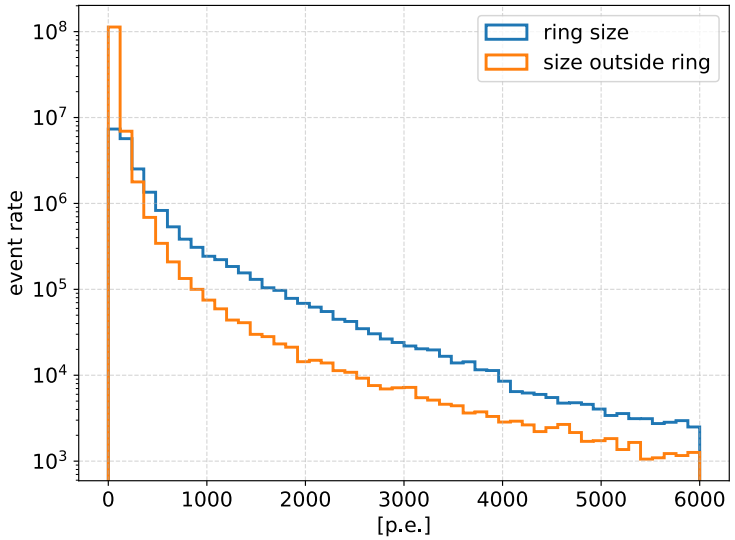


Size outside ring



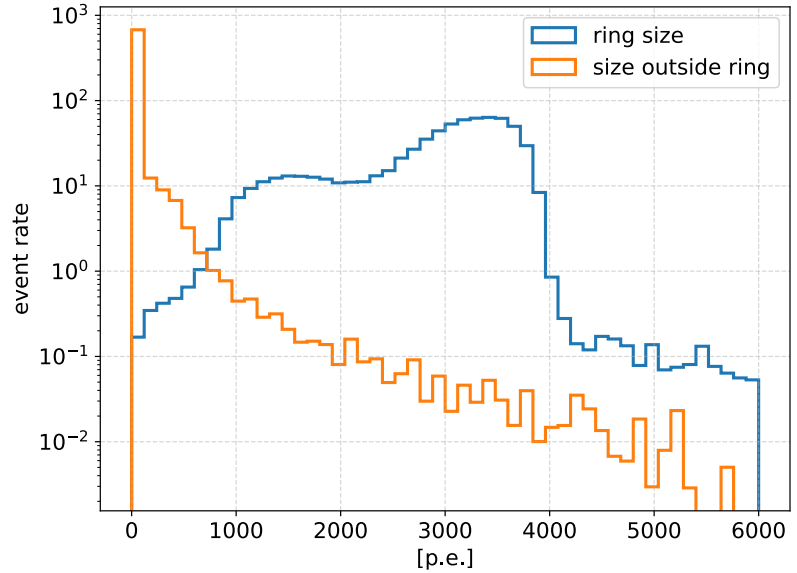


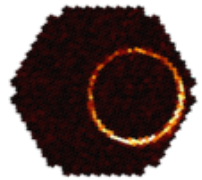
proton MC



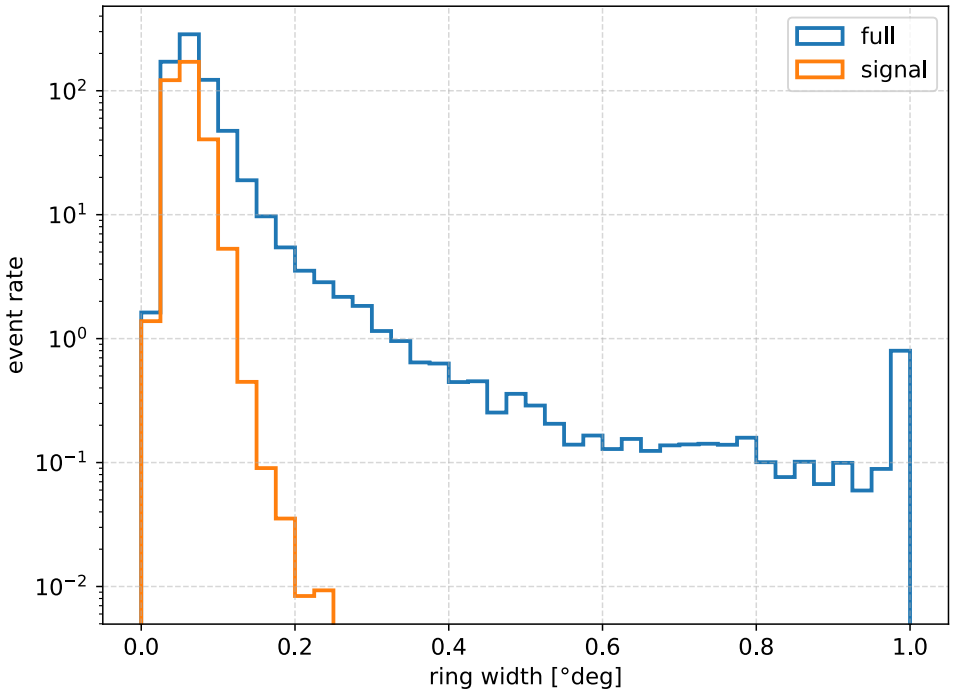
size outside < 200 p.e.

muon MC

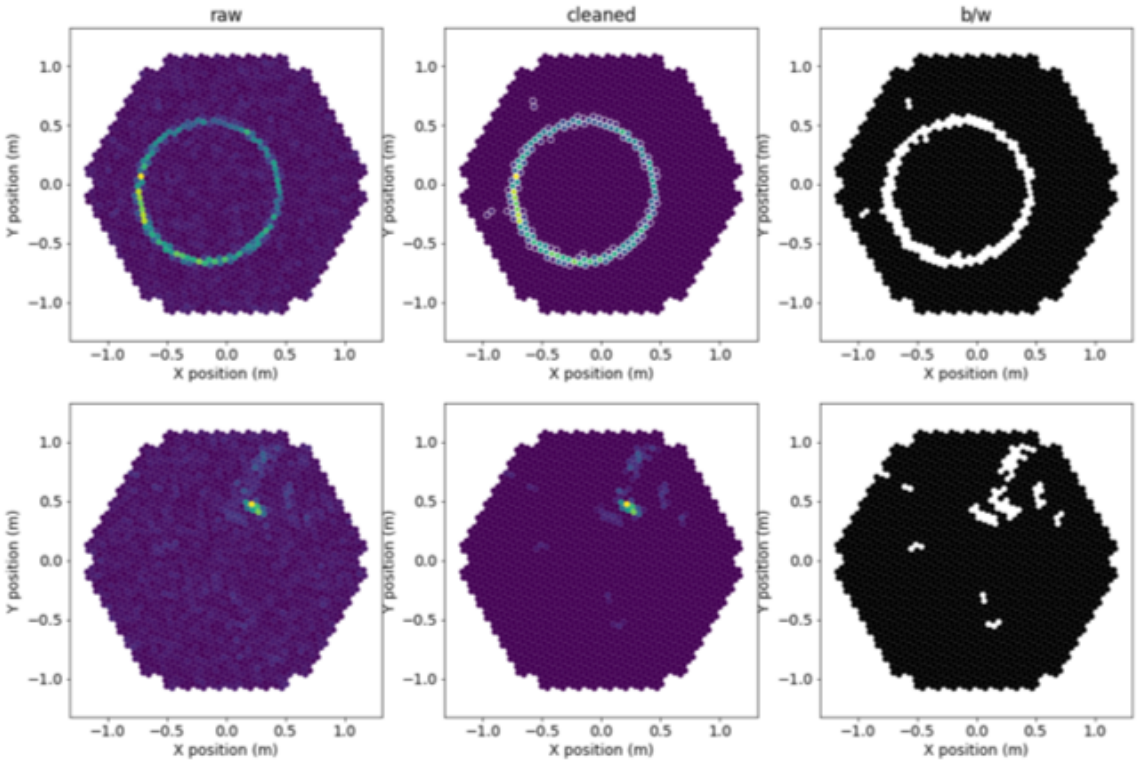




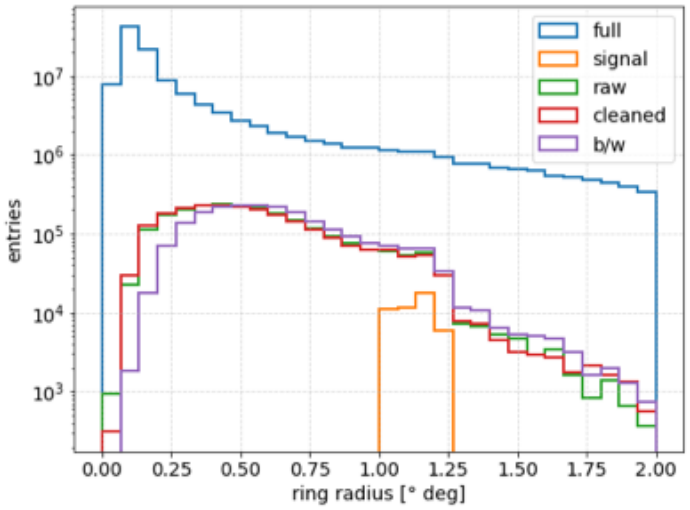
Ring width

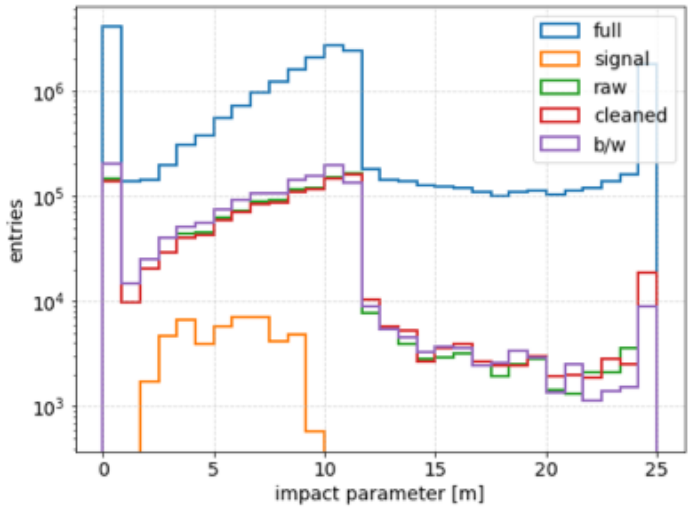

full
signal
event rate
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
0.0
0.2
0.4
0.6
0.8
1.0
ring width [°deg]

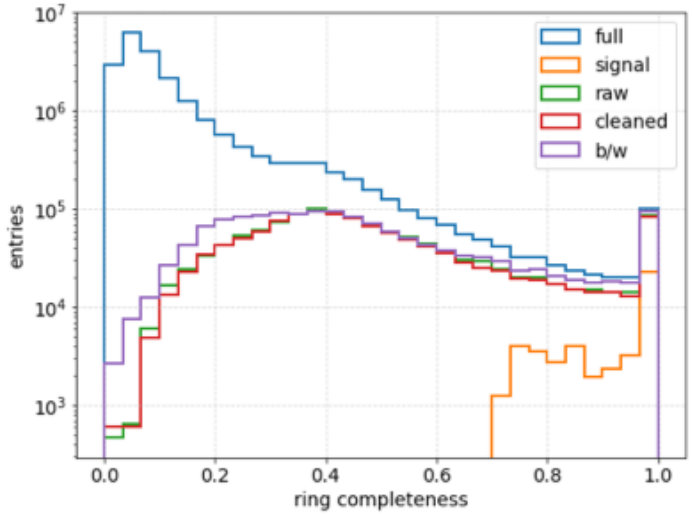
Neural network input

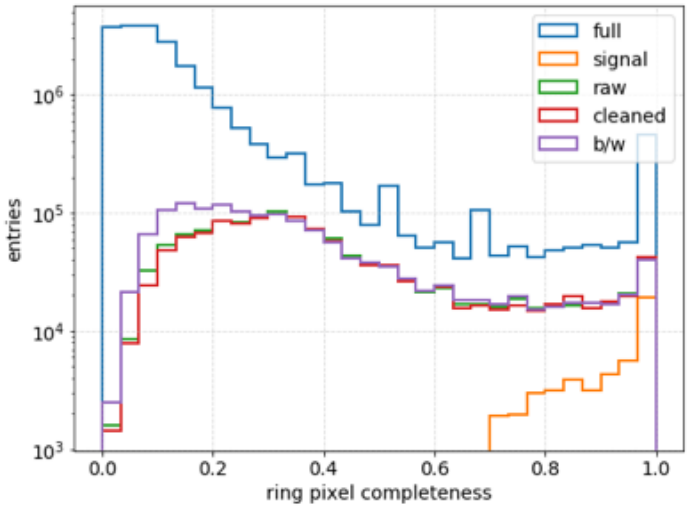


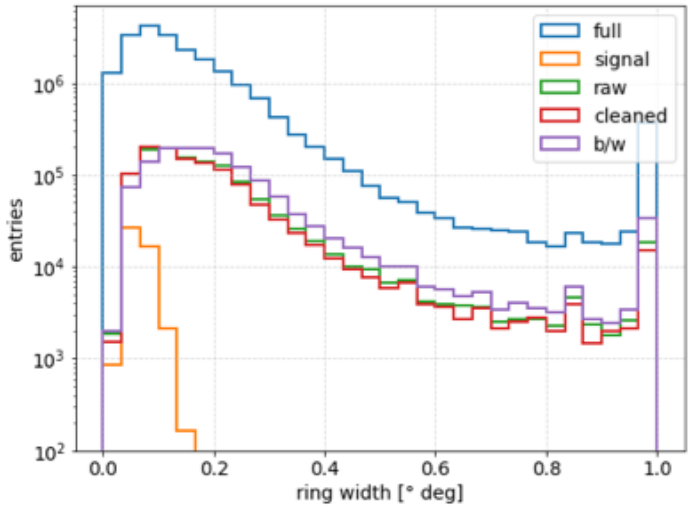
Neural Network on parameters

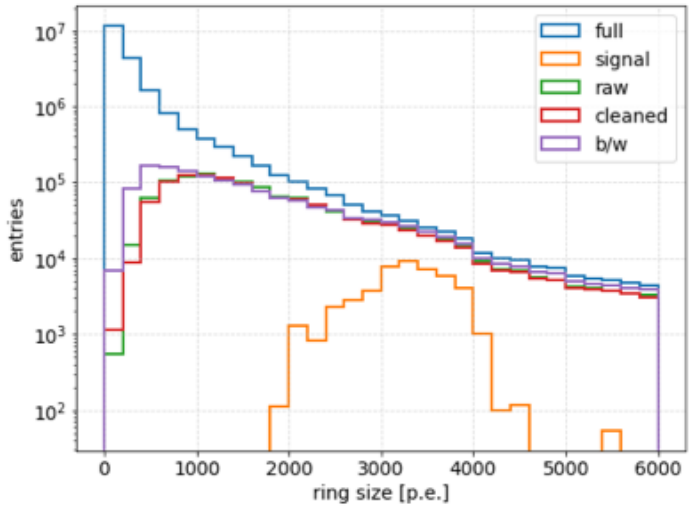




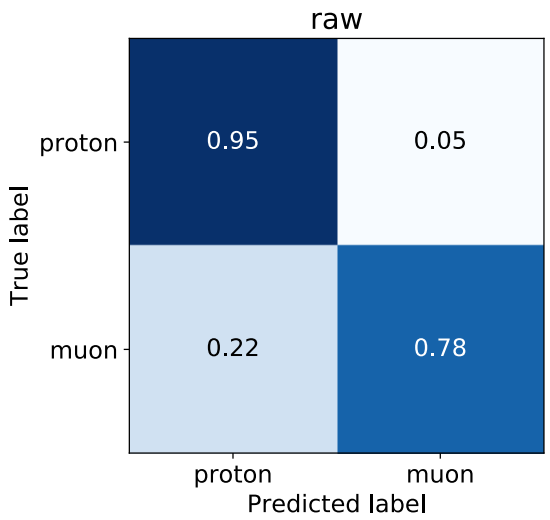


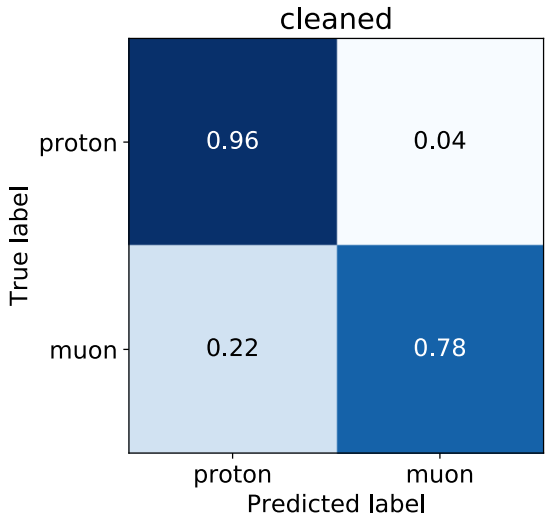


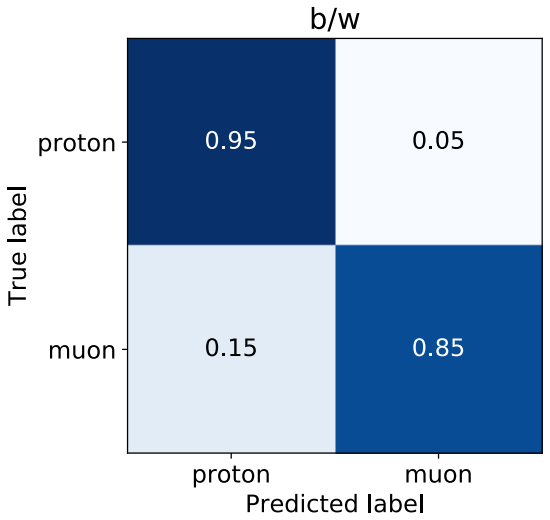




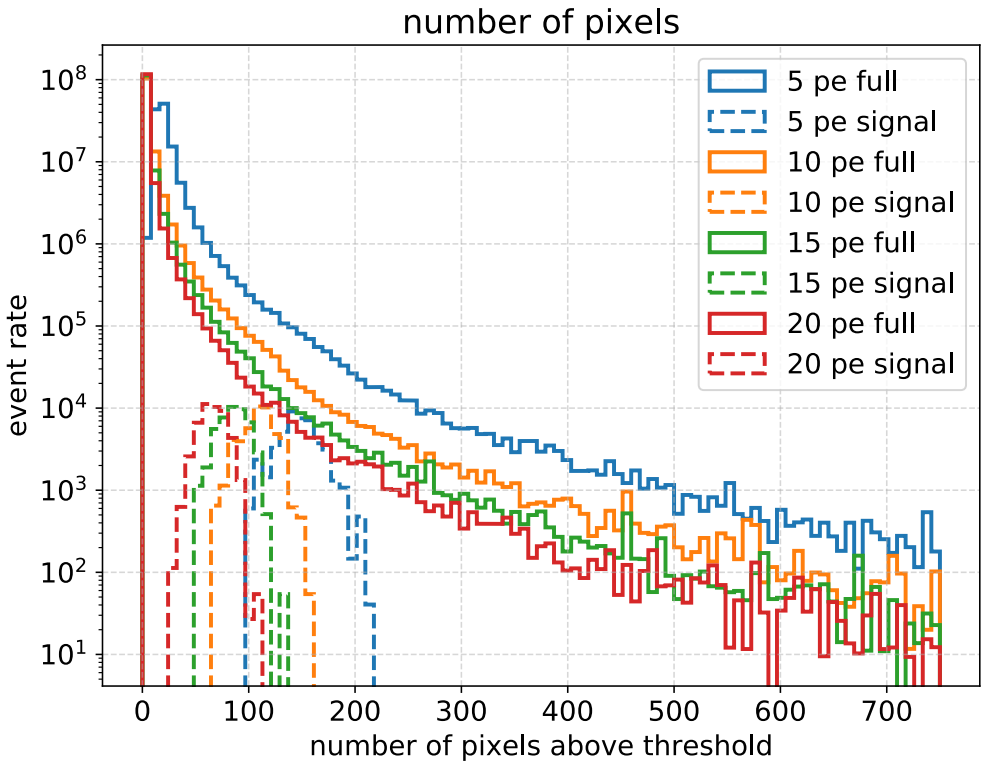
Neural Network results

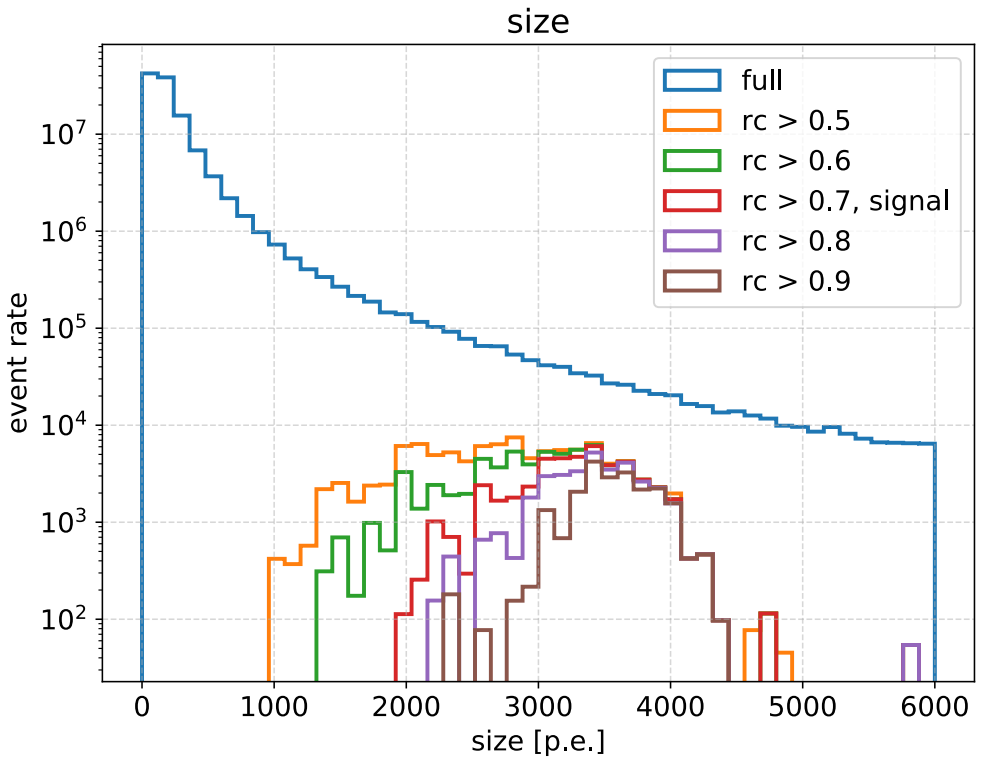




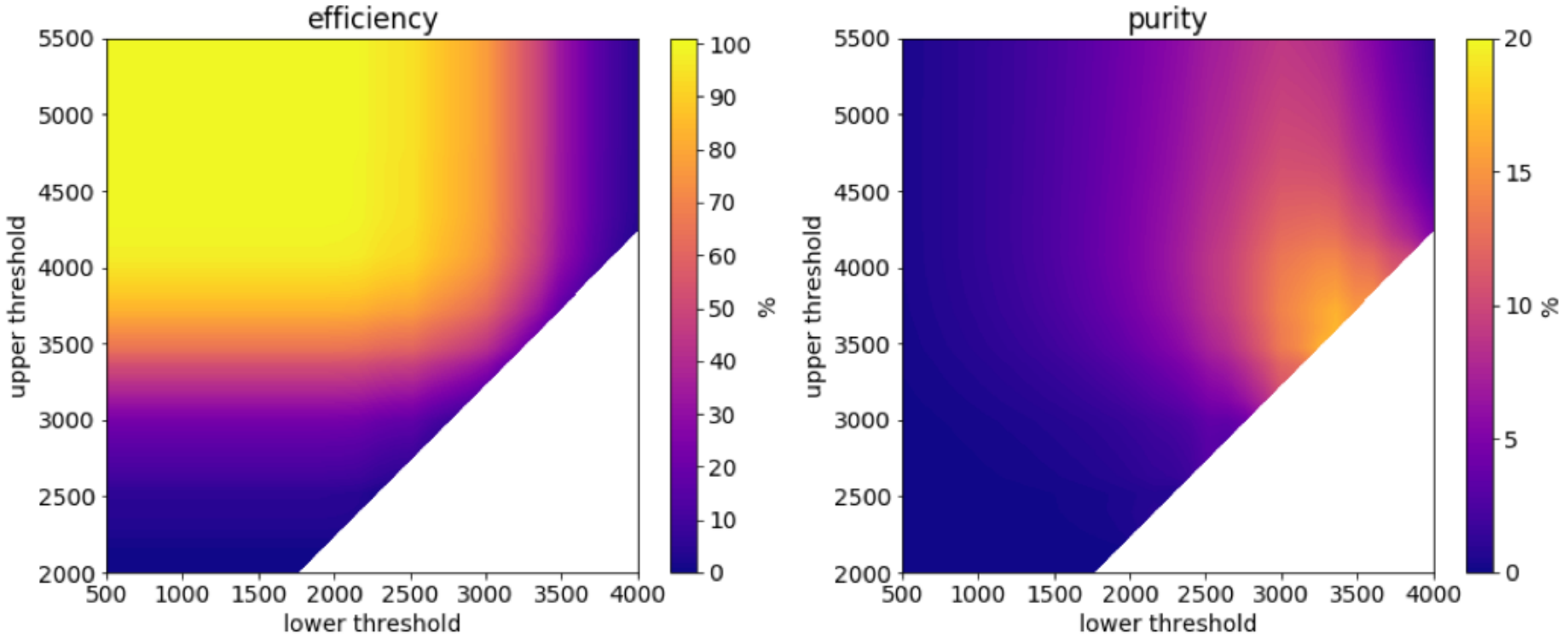


Size and pixel above threshold LST

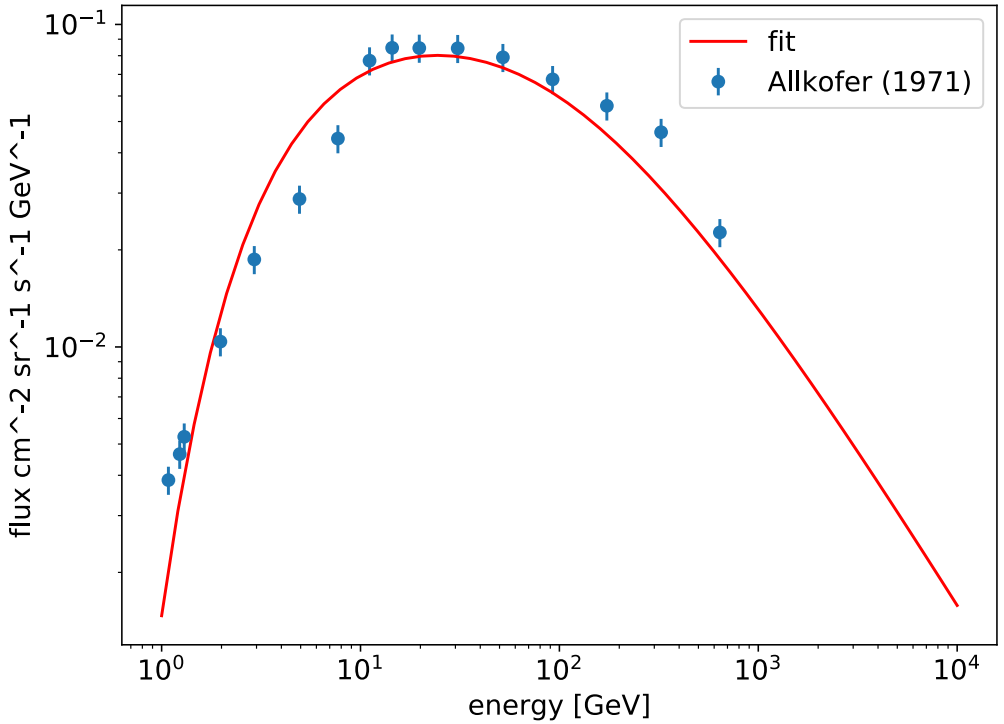




Efficiency and purity of Majority

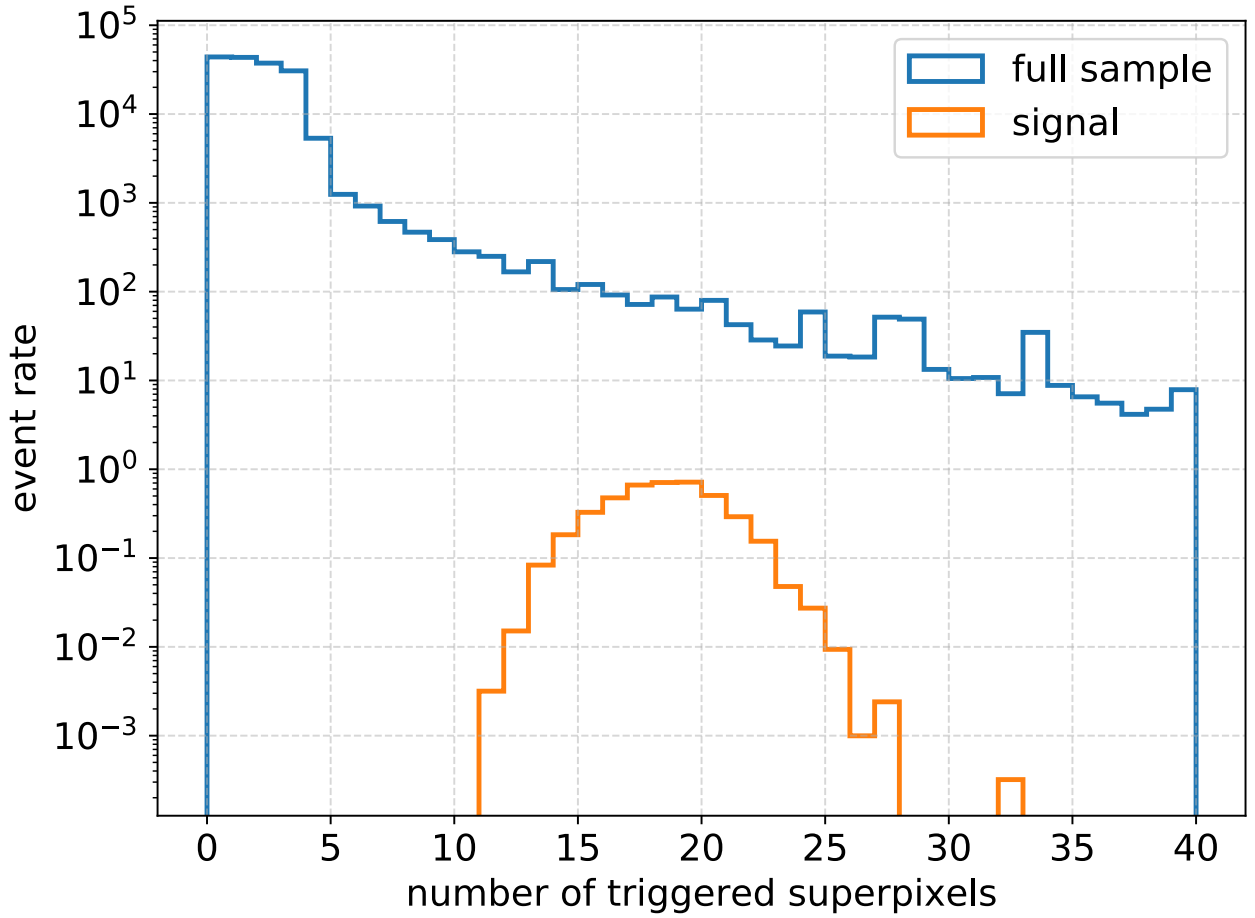


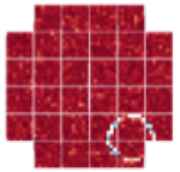
Muon flux and scaling



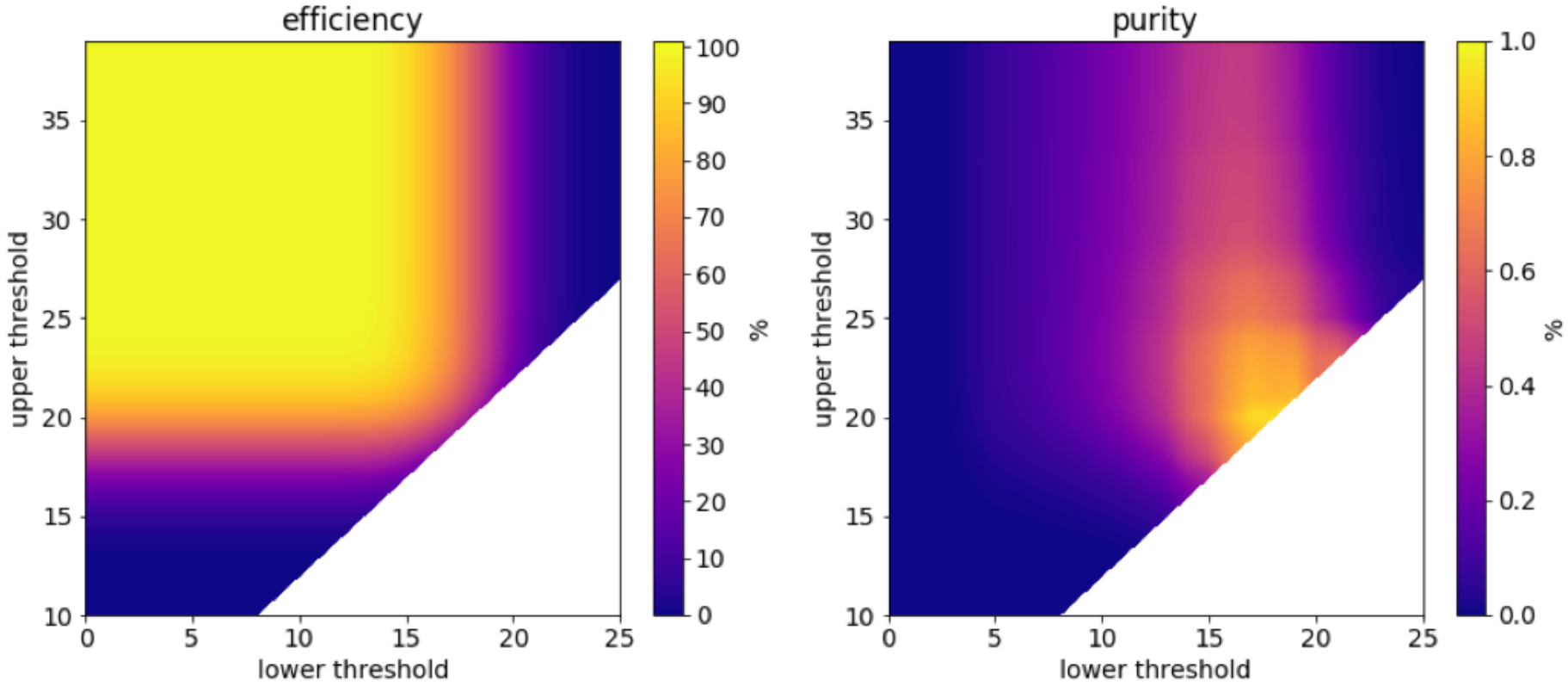
$$w(E) = \frac{dN_{real}/dE}{dN_{sim}/dE} \cdot A\Omega$$

Trigger size ASTRI-CHEC

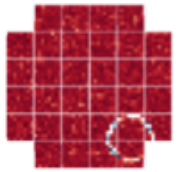


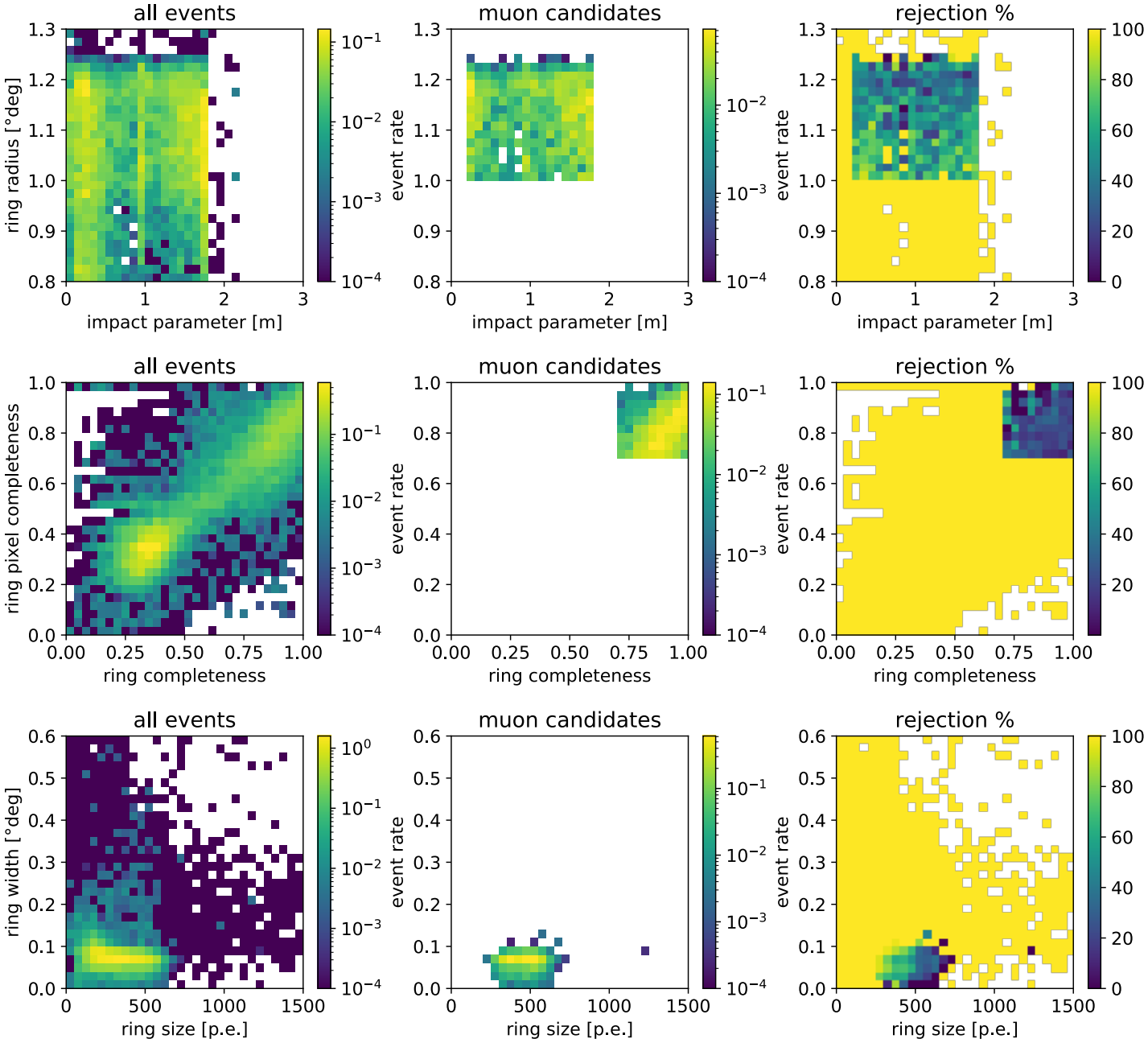


Majority ASTRI – CHEC

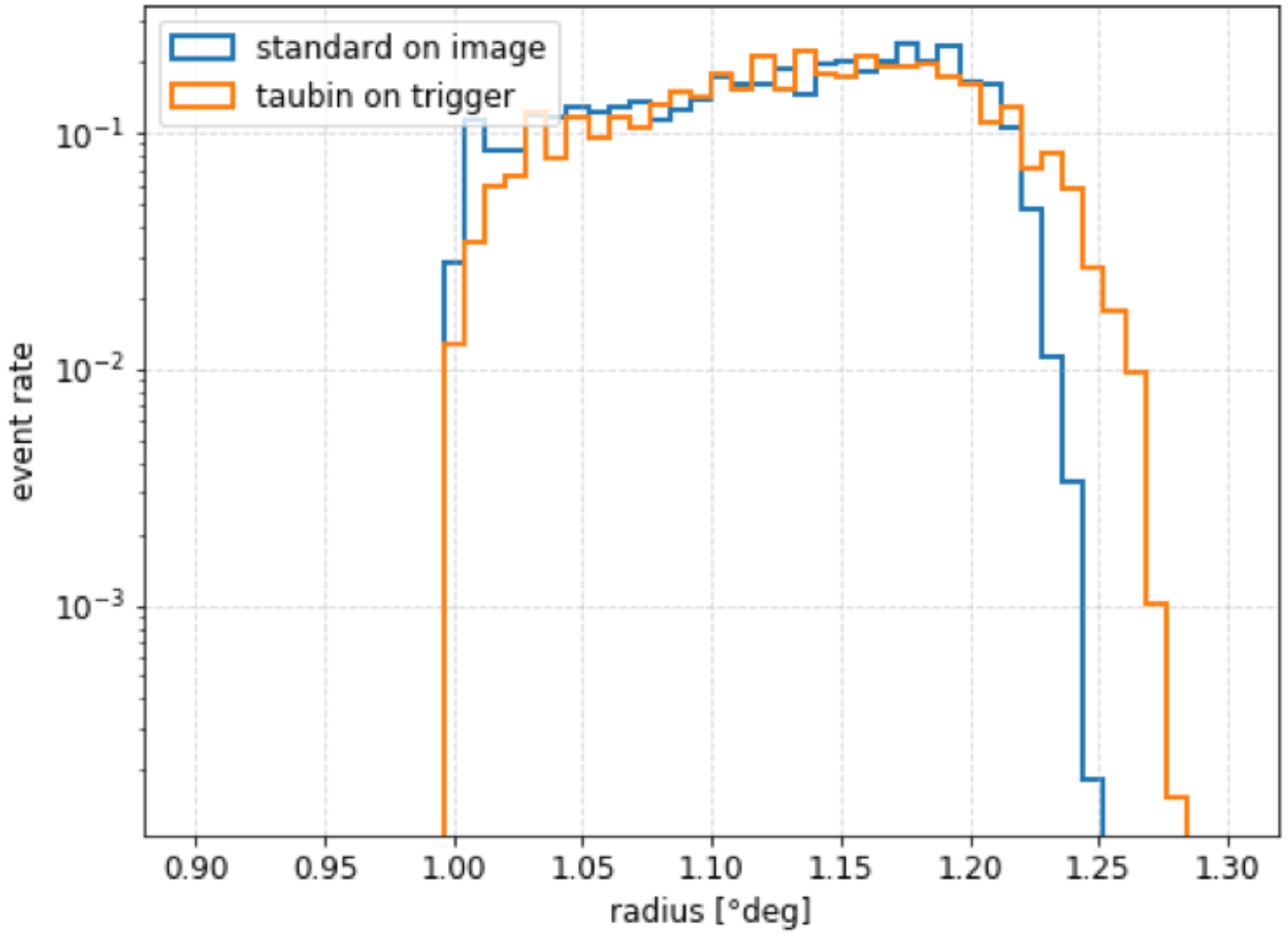


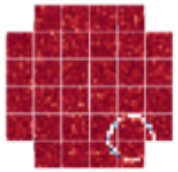
MC sample
ASTRI – CHEC



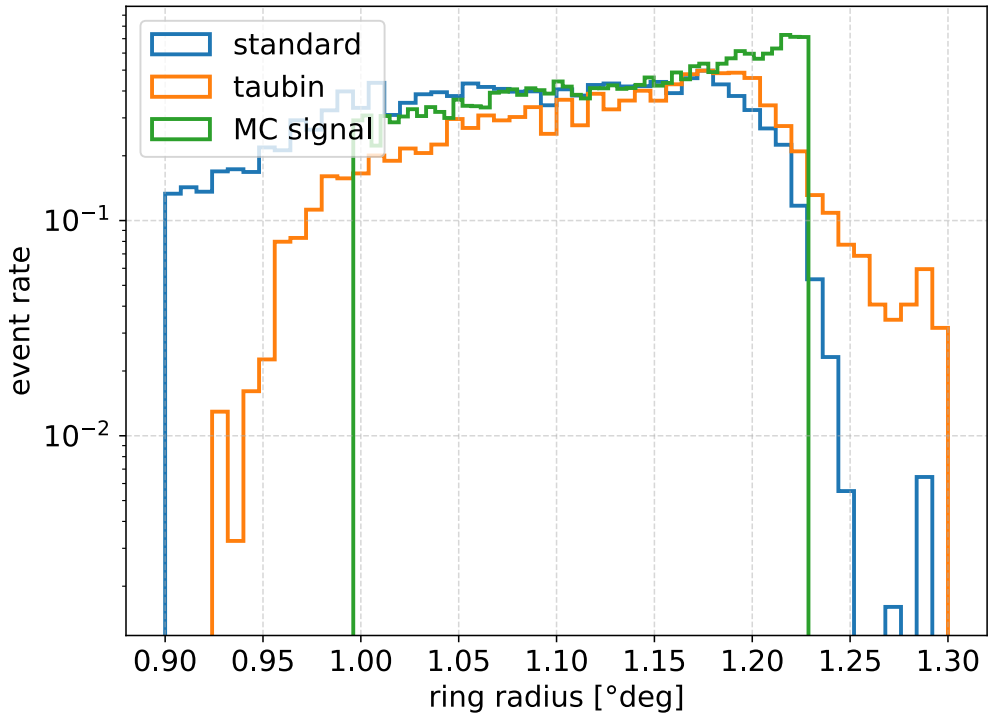


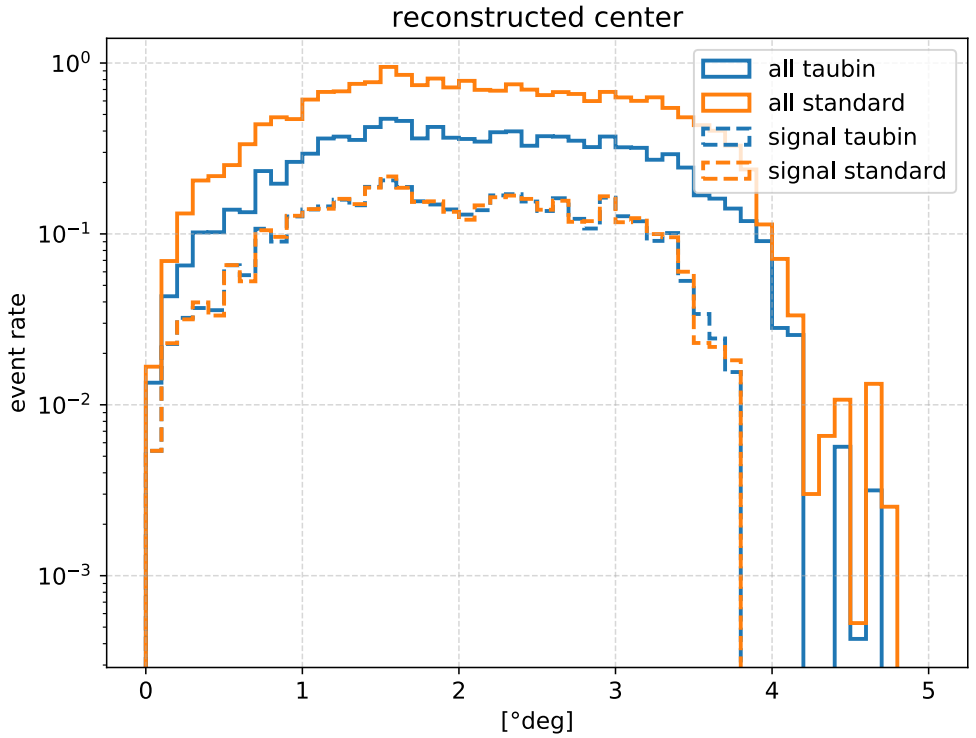
ASTRI – CHEC

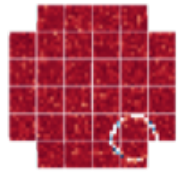

standard on image
taubin on trigger
event rate
10^{-1}
10^{-2}
10^{-3}
0.90
0.95
1.00
1.05
1.10
1.15
1.20
1.25
1.30
radius [°deg]



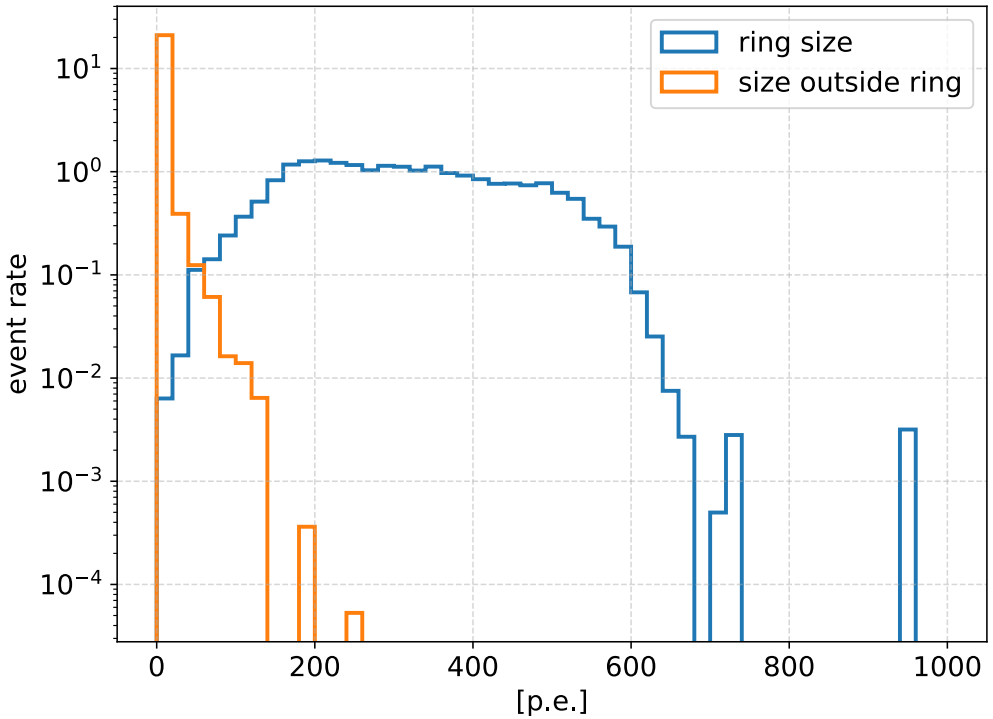
radius and center

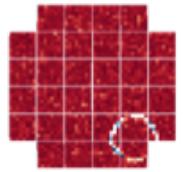




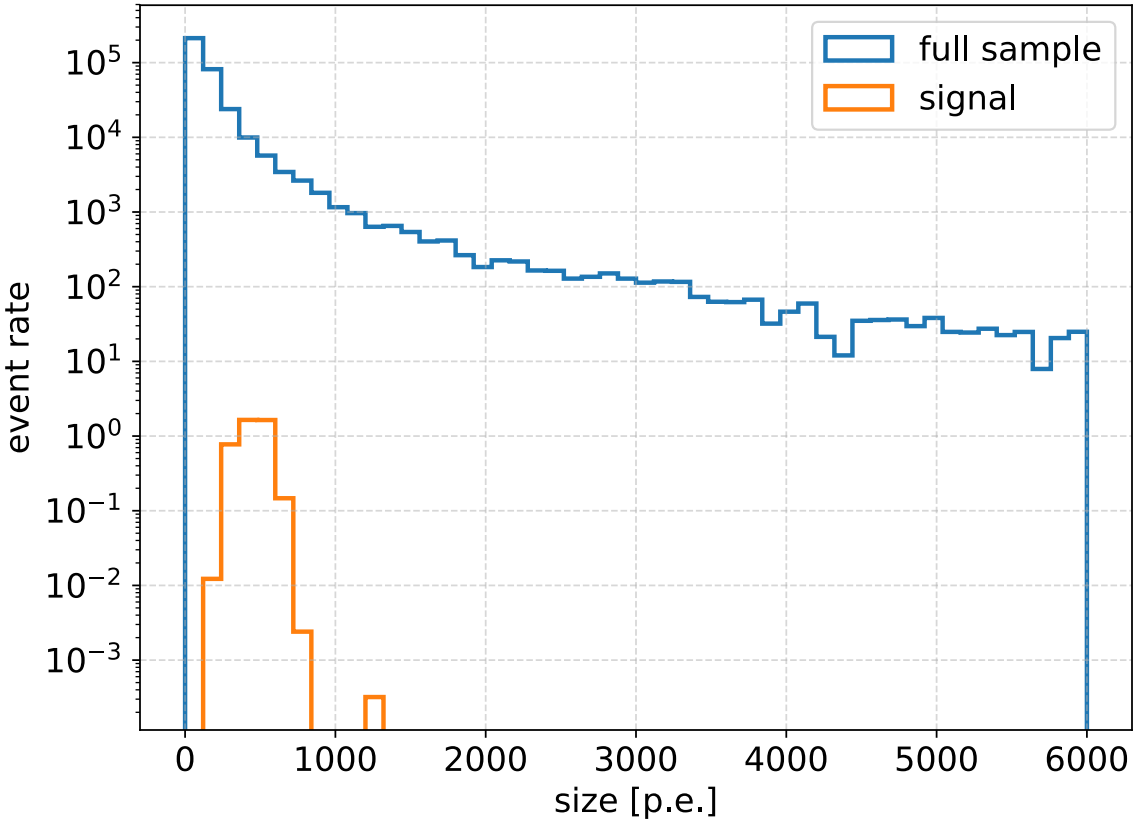


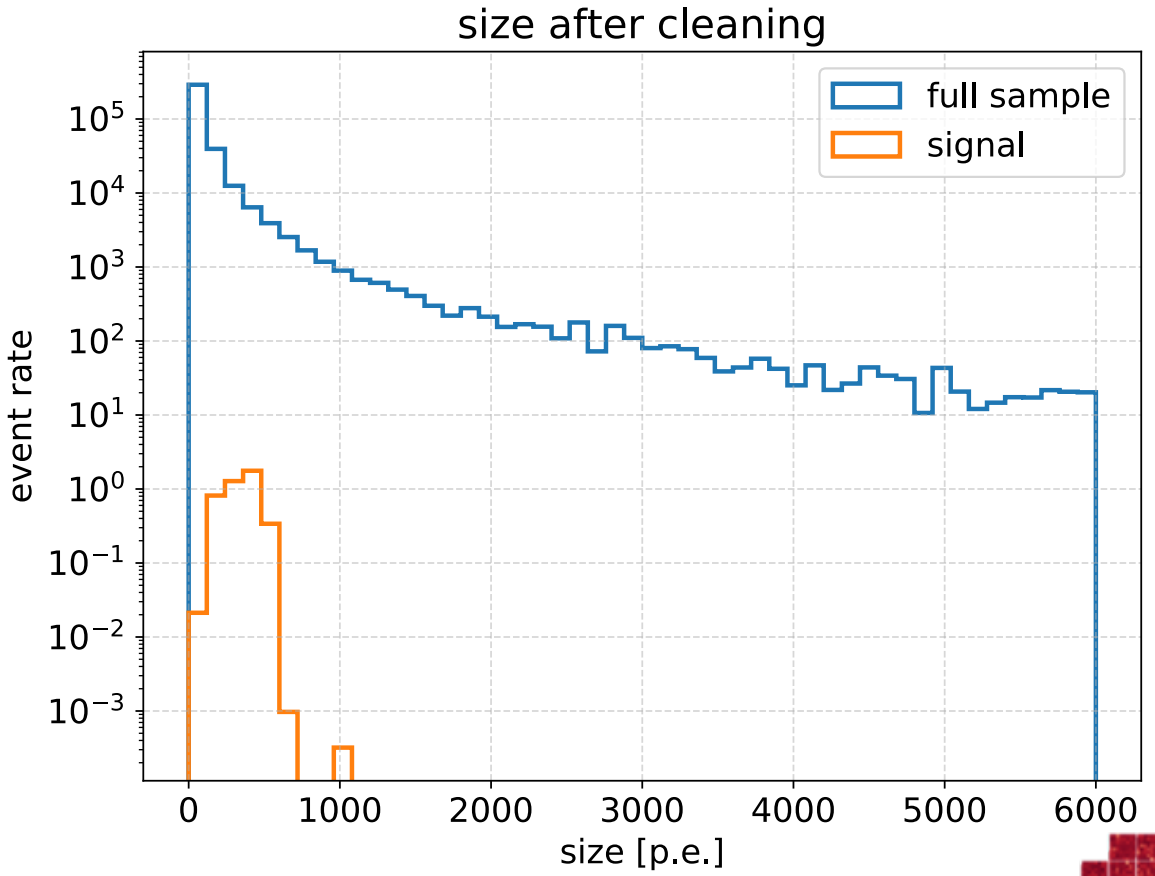
Size and size outside

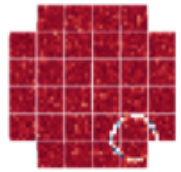




Size before and after cleaning







Neural Network ASTRI – CHEC