Polarisation cut performances

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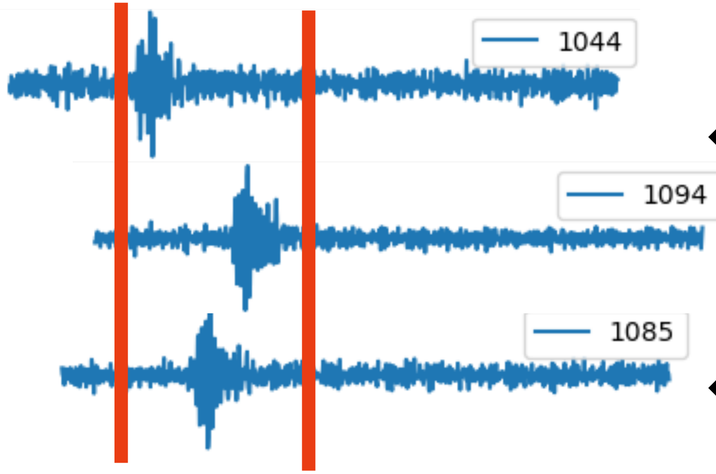
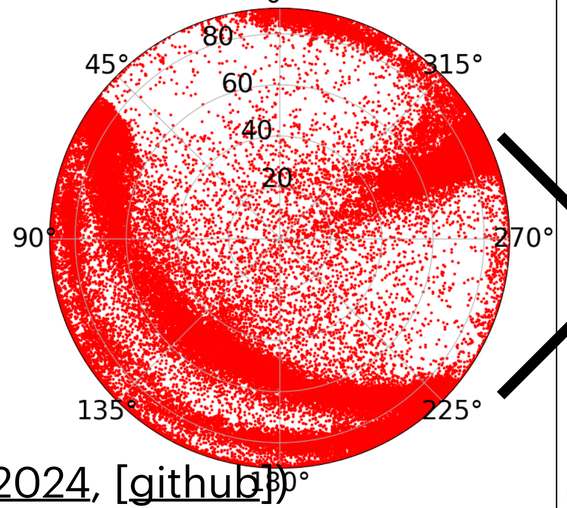
Pipeline overview

Getting CD events



Plane Wave Front reconstruction

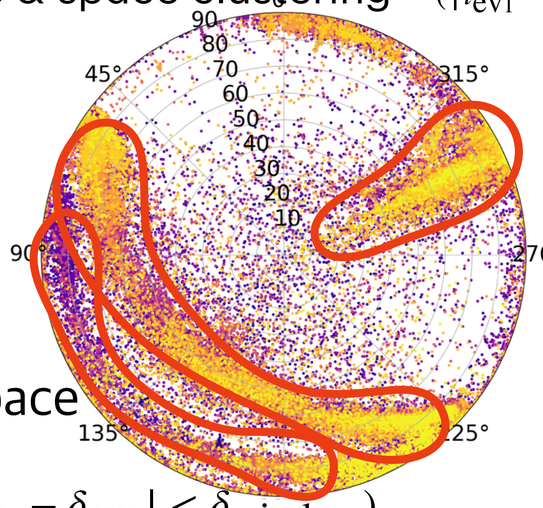
Result in
θ and φ



(Ferriere et al. 2024, [github])

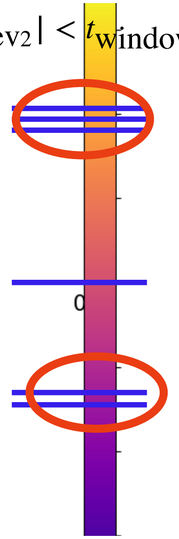
Time & space clustering

$(|t_{ev1} - t_{ev2}| < t_{window})$



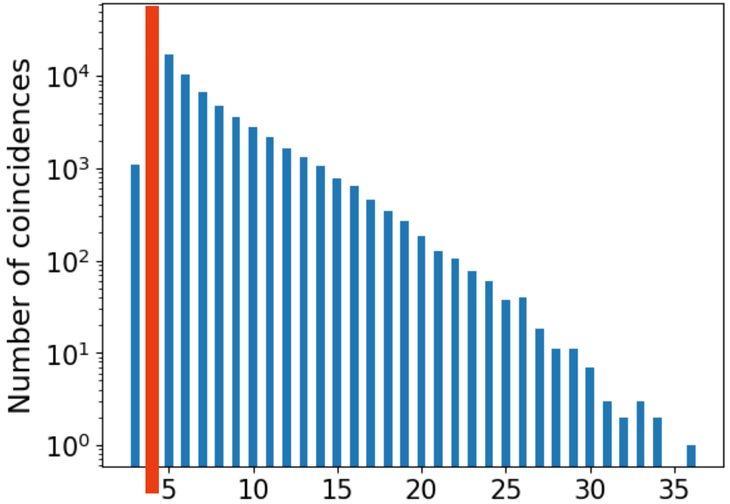
Space

$(|\delta_{ev1} - \delta_{ev2}| < \delta_{window})$



Time

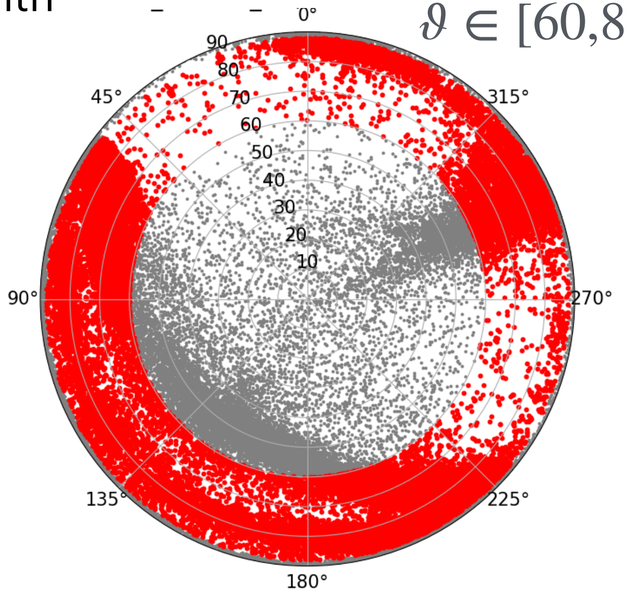
Number of antennas



Footprint too small

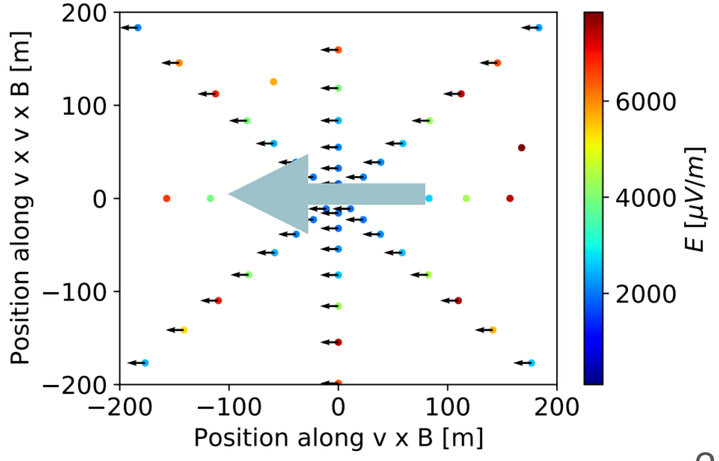
Zenith

$\vartheta \in [60,88]$deg



Polarisation

Polar $\perp \vec{B}_{geo}$

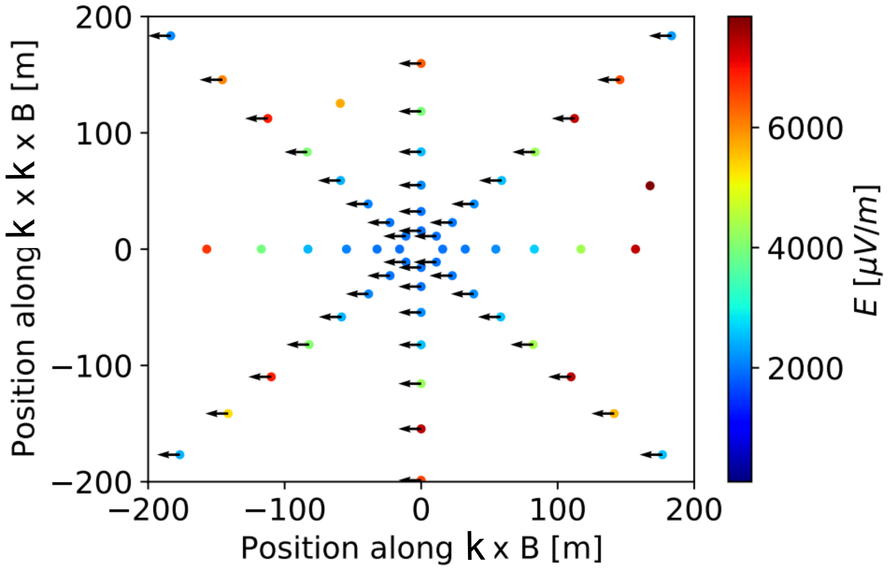


(Chiche et al. 2022)

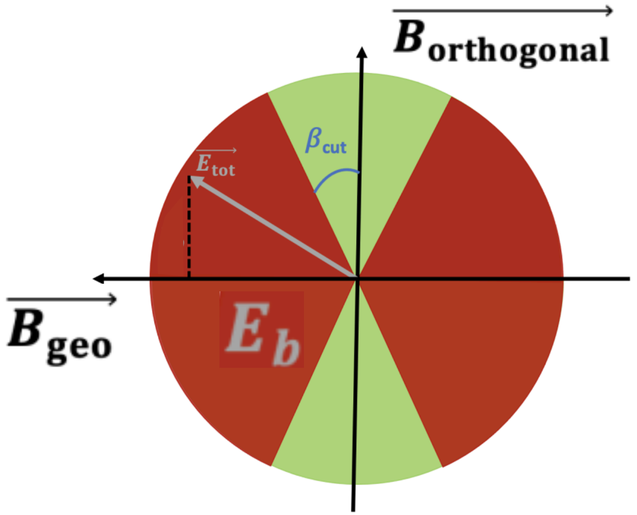
Polarisation distribution expected for CRs

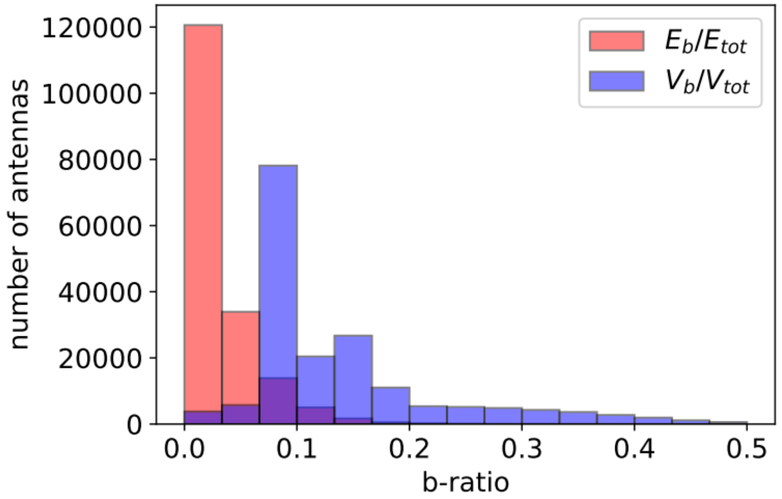
E-field amplitude and direction of the geomagnetic emission

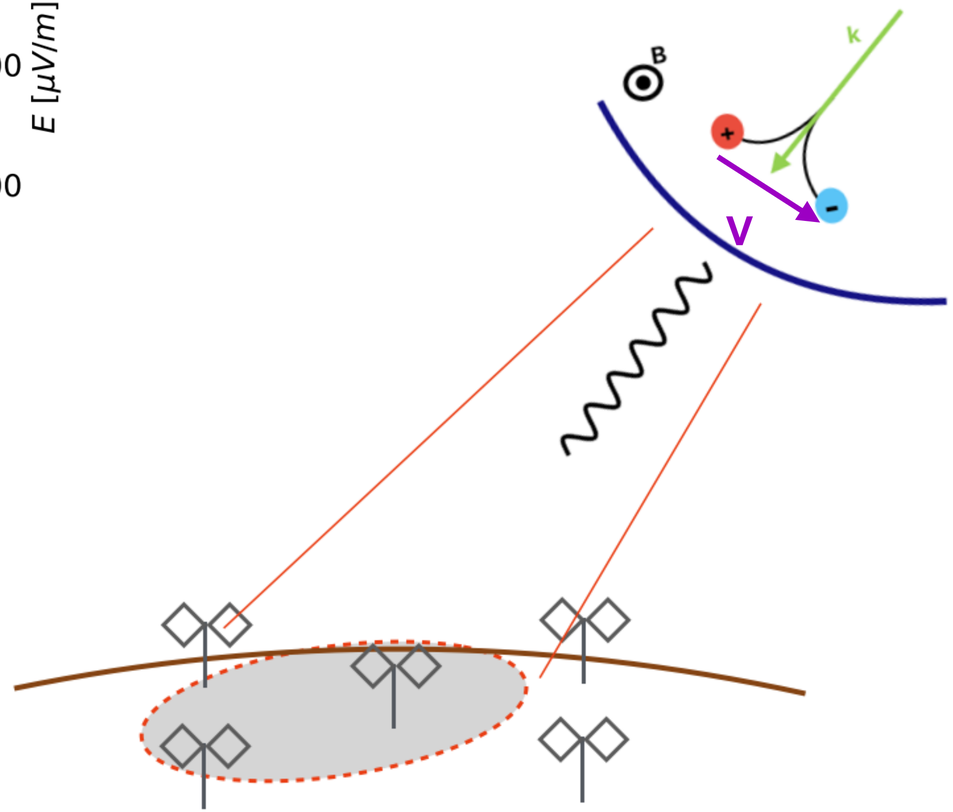
Geomagnetic effect



Chiche et al., 2022





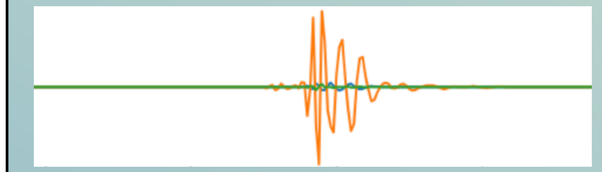


Subsample of DC2 simulations (released early April)

3 types : NJ, AN, “plain”; 1000 simulated CRs

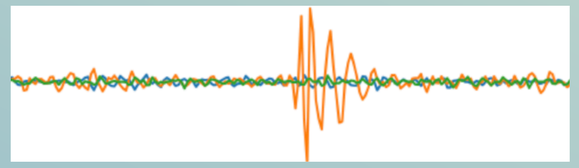
Noiseless, no jitter

NJ



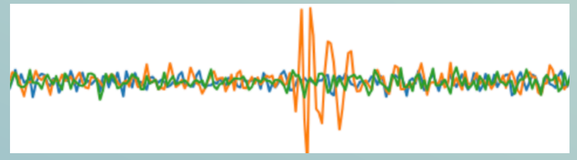
Simulated noise

“plain”



Experimental noise

AN



Problem: traces selected according to proximity to the shower axis, but do not pass T1 & T2

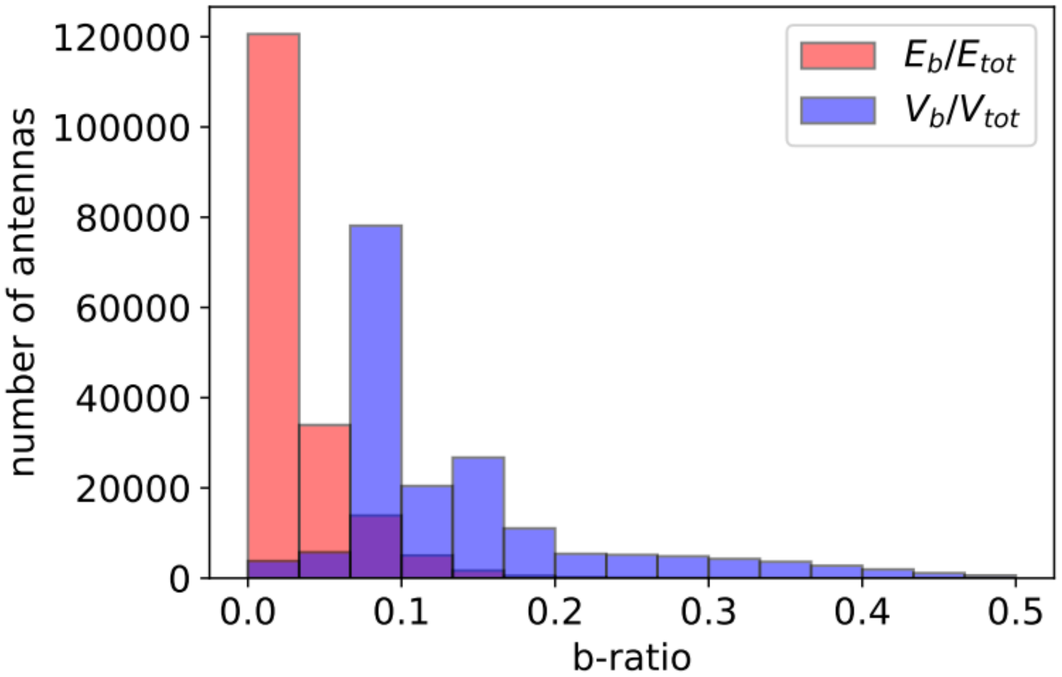
After T1 + T2 trigger --> 407 events left (with >= 1 antennas)

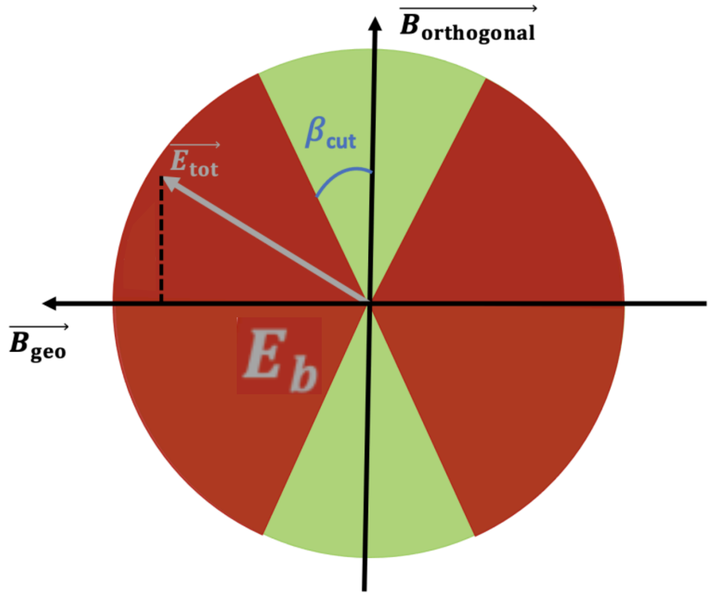
Statistical performances computed on AN sims

Strategy behind the polarisation cut

E field polarised at antennas ($\perp \overrightarrow{B}_{geo}$)

$$E_b = \overrightarrow{E} \cdot \overrightarrow{B}_{geo} \simeq 0$$ (Red)

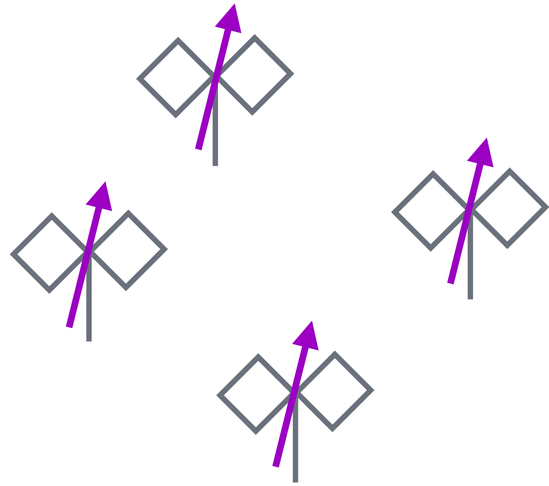




Strategy: measure E_b for all antennas of an event, and keep the median

No access to E => measure on voltage V (blue distribution)

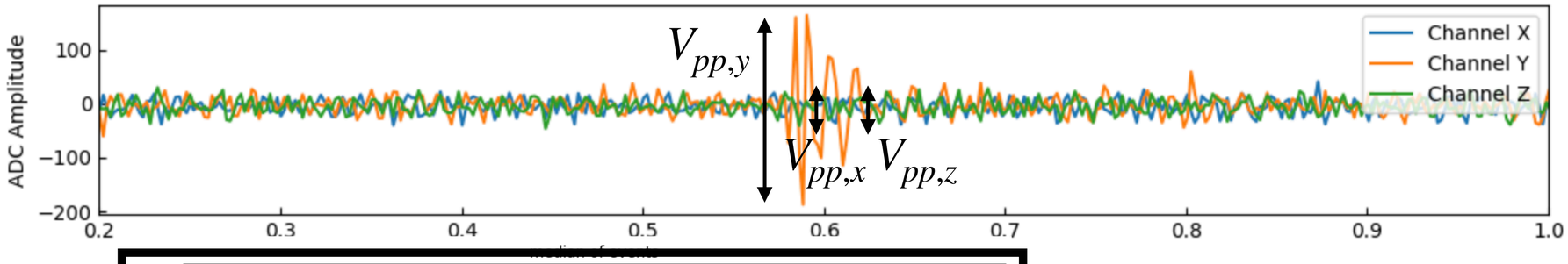
How to construct the $\overrightarrow{V}$ vector?



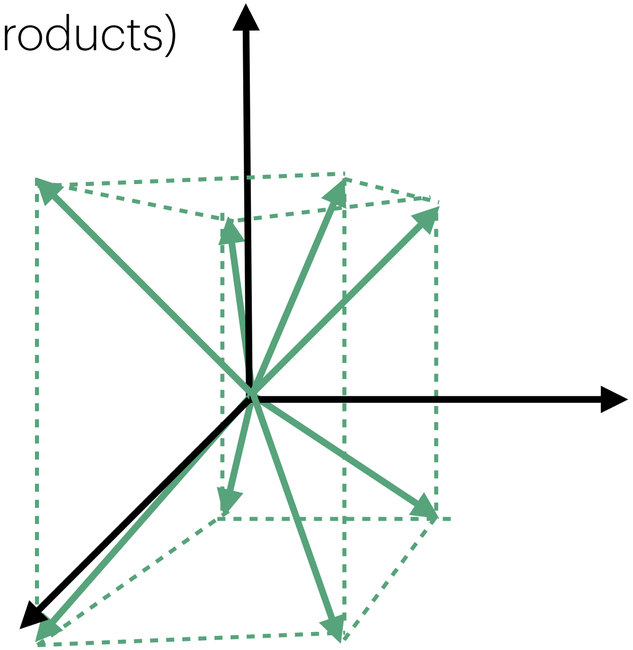
→ : polarisation at each antenna

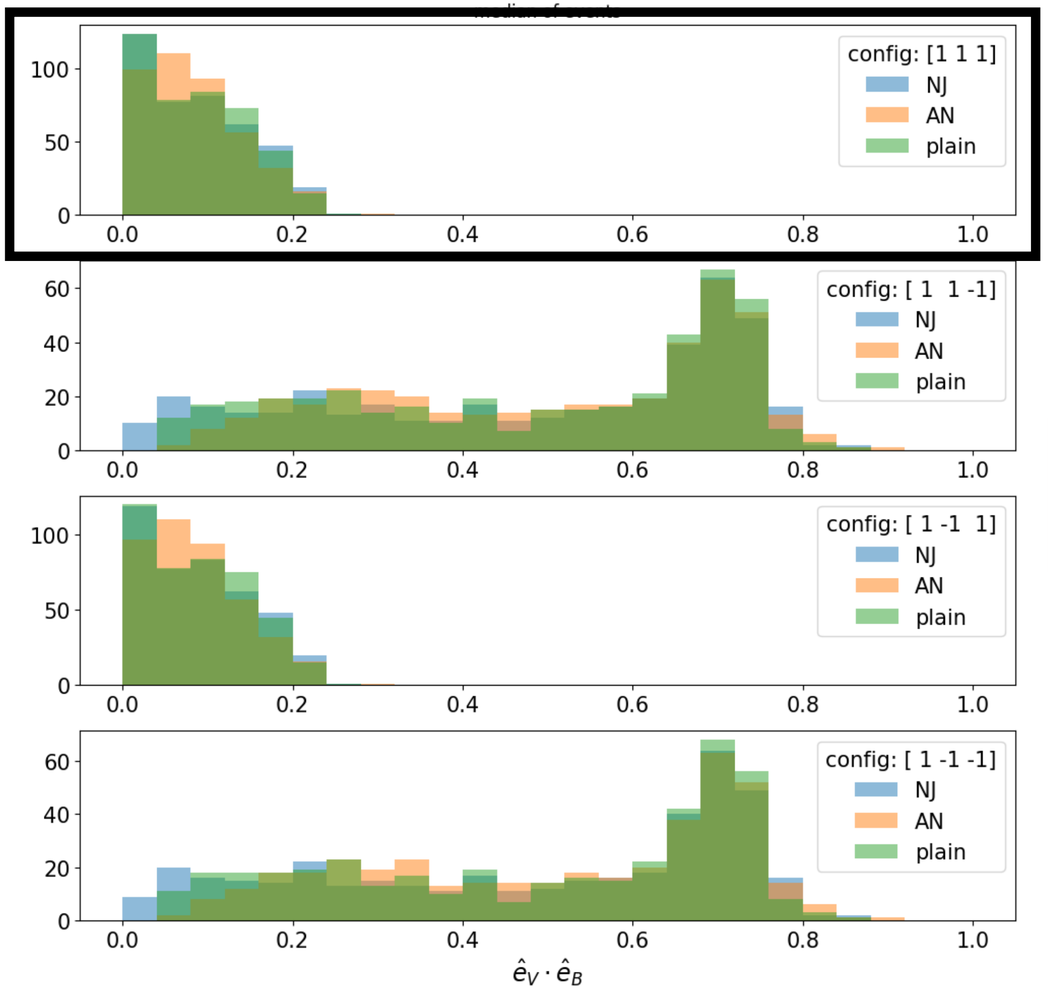
Building a voltage vector with traces

Technique: build a vector $\vec{V}$ with the trace



Orientation: 8 possibilities, but really 4 (looking at scalar products)





$$\vec{V} = \left(V_{pp,x}, V_{pp,y}, V_{pp,z}\right)$$

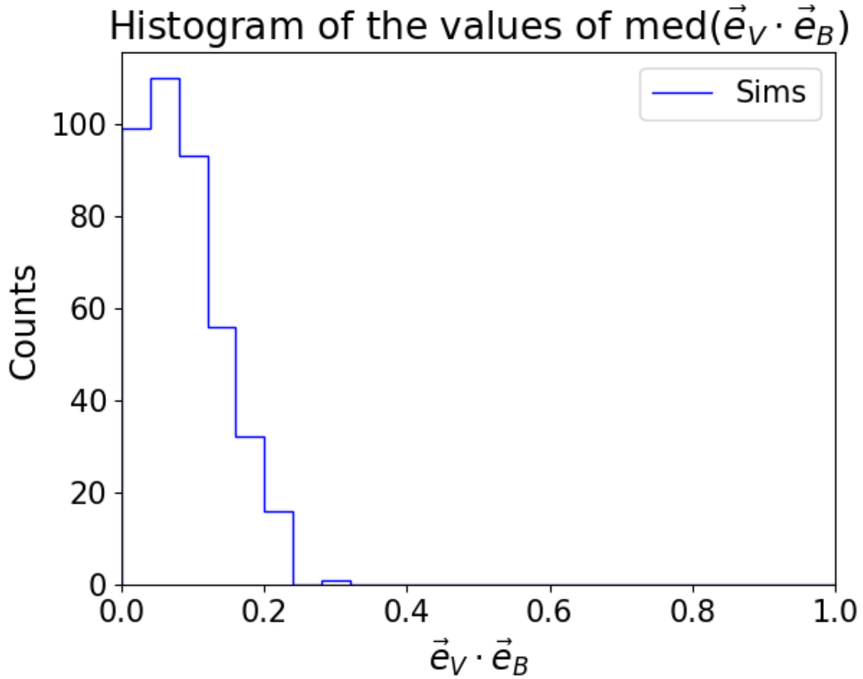
Polarisation cut estimate

What do we want for the cut? → Conservative. Maximize the nb of CR candidates, minimize wrong cuts

Prioritize efficiency over purity

Set a maximum acceptable for $\vec{e}_V \cdot \vec{e}_B$

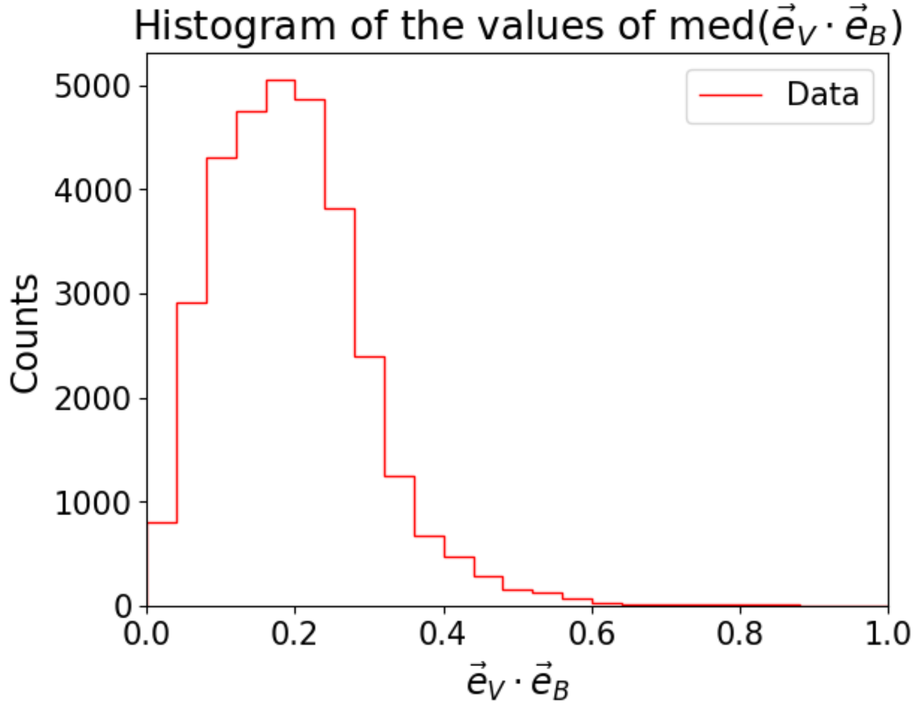
All simulations: 407 events (with ≥ 1 antenna through T1 + T2)



To compare: data sample, noise-like events

32k events, direction of the mine and planes (9 days data)

Hypothesis: low CR proportion



Best polarisation cut parameter estimate

Build normalized polarisation distribution in each case

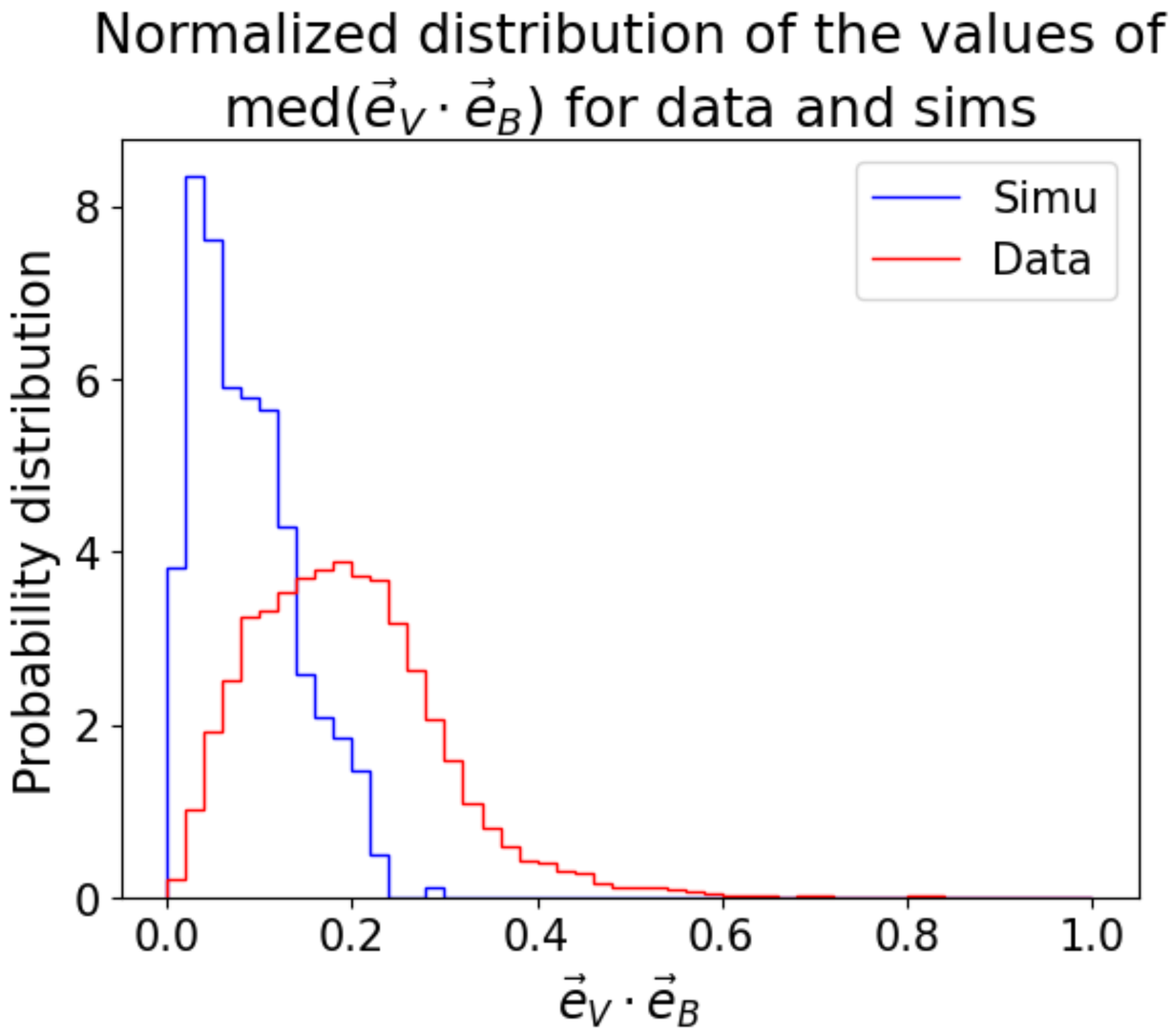
For event A:

Blue: $\mathbb{P}_{(A=\mathsf{CR})}(\vec{e}_V \cdot \vec{e}_B = x)$

Red: $\mathbb{P}_{(A=\overline{\mathsf{CR}})}(\vec{e}_V \cdot \vec{e}_B = x)$

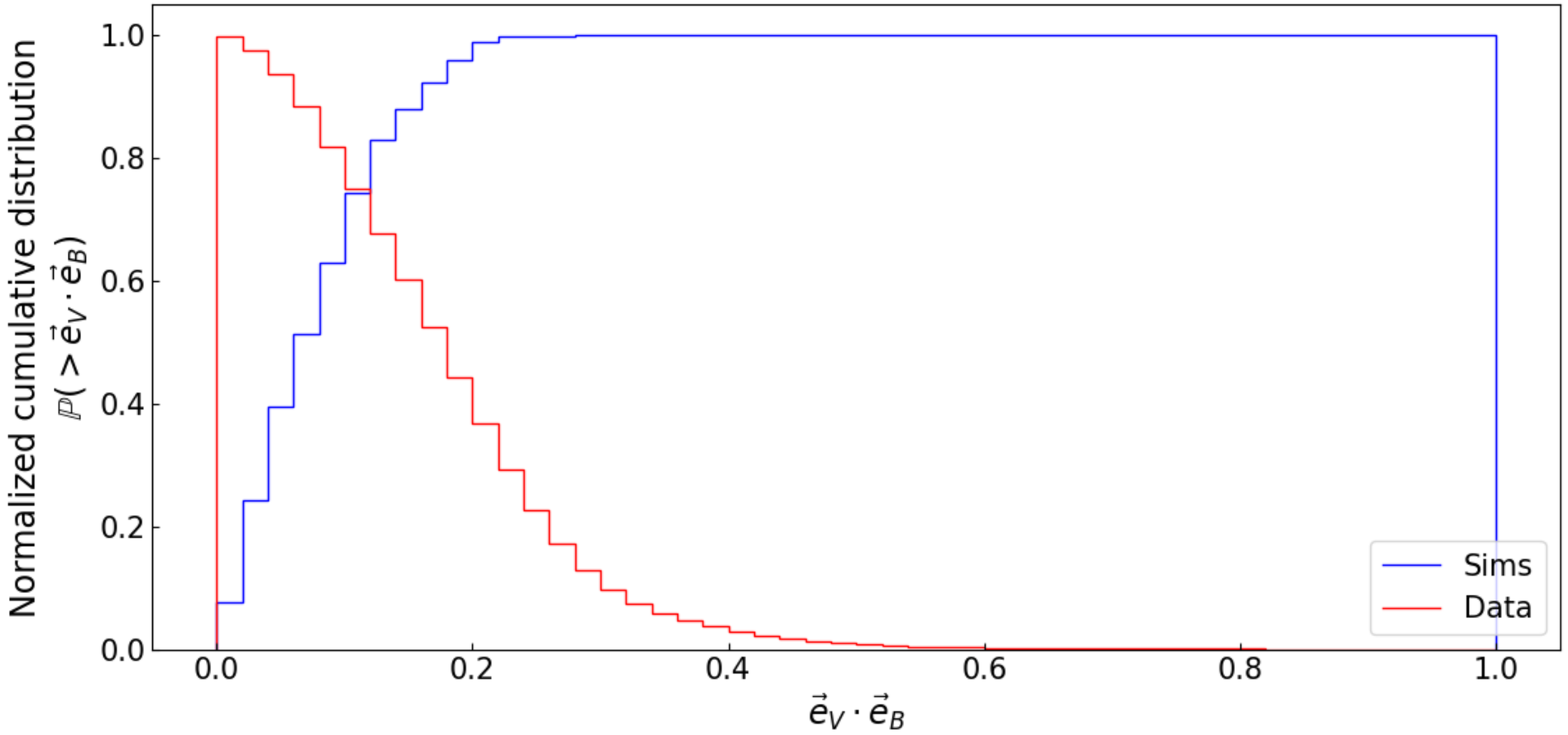
=> find the max value of $\vec{e}_V \cdot \vec{e}_B$ s.t. maximize efficiency

Set a threshold of 95% CR after cut



Best polarisation cut parameter estimate

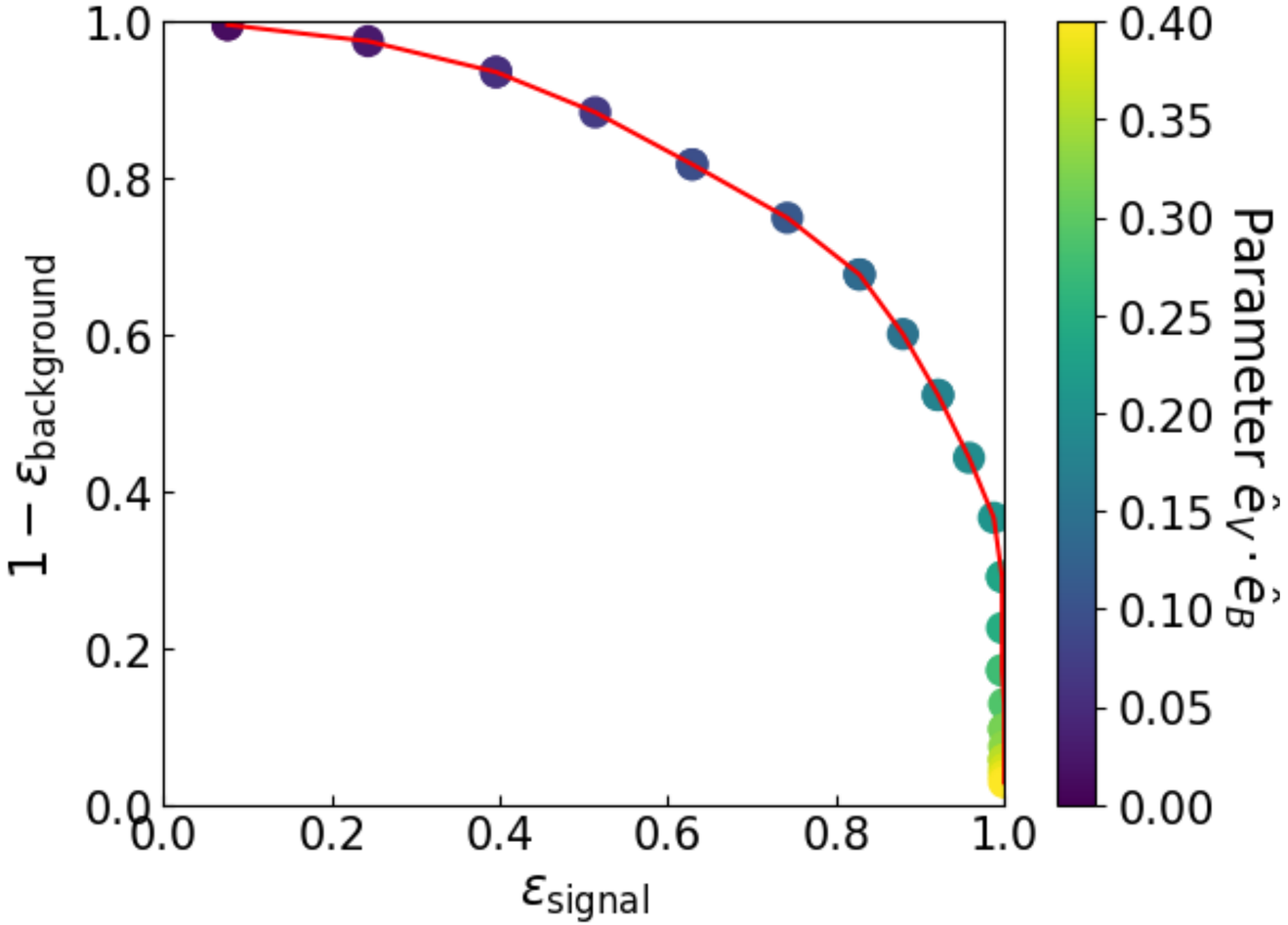
Cumulative sum of simulations (ie signal, or CR) and inverse CUMSUM of data (1-CUMSUM)



Blue: fraction of signal accumulated polarisation value: **ε_signal**

Red: fraction of background events excluded up to a polarisation value: **1-ε_bg**

Best polarisation cut parameter estimate

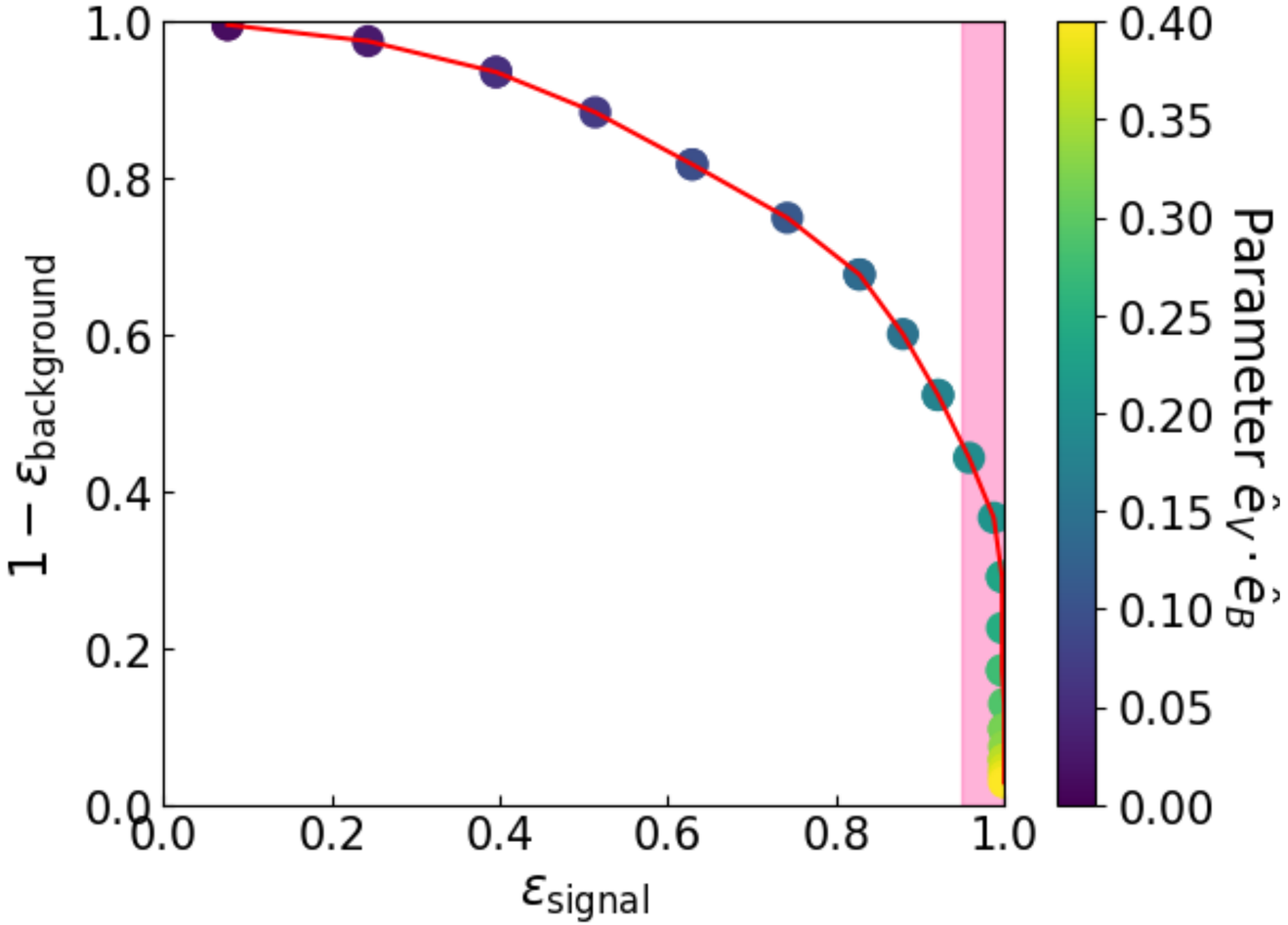


We need to chose which maximisation to prioritize

Here: we want the fraction of signal accumulated to a polarisation value (ε_{signal}) to be maximized

max(eV.eB)	ε_signal	1-ε_bg
0.193	0.958	0.44327836
0.207	0.987	0.36669165
0.220	0.9975	0.29129185

Best polarisation cut parameter estimate



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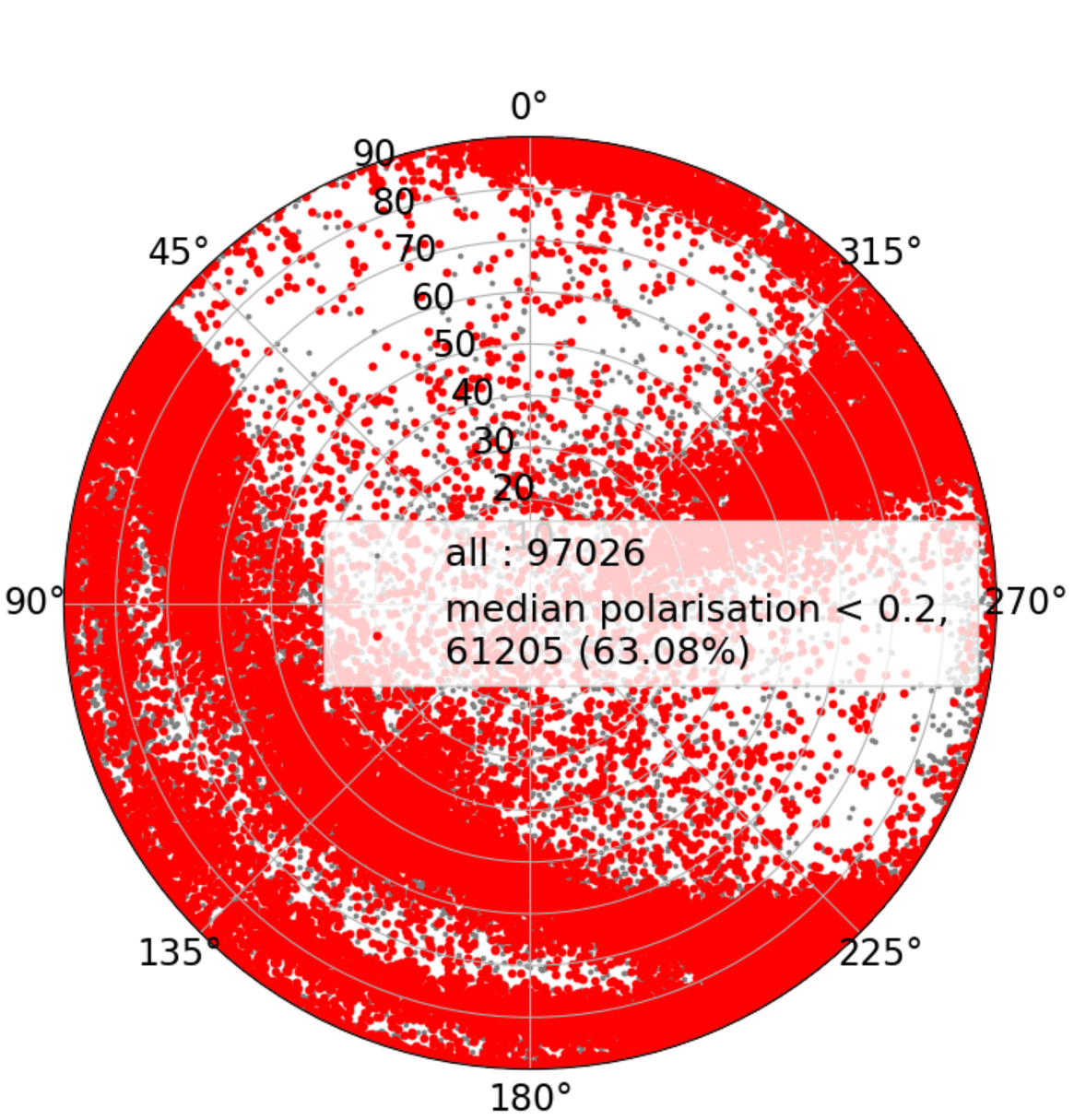
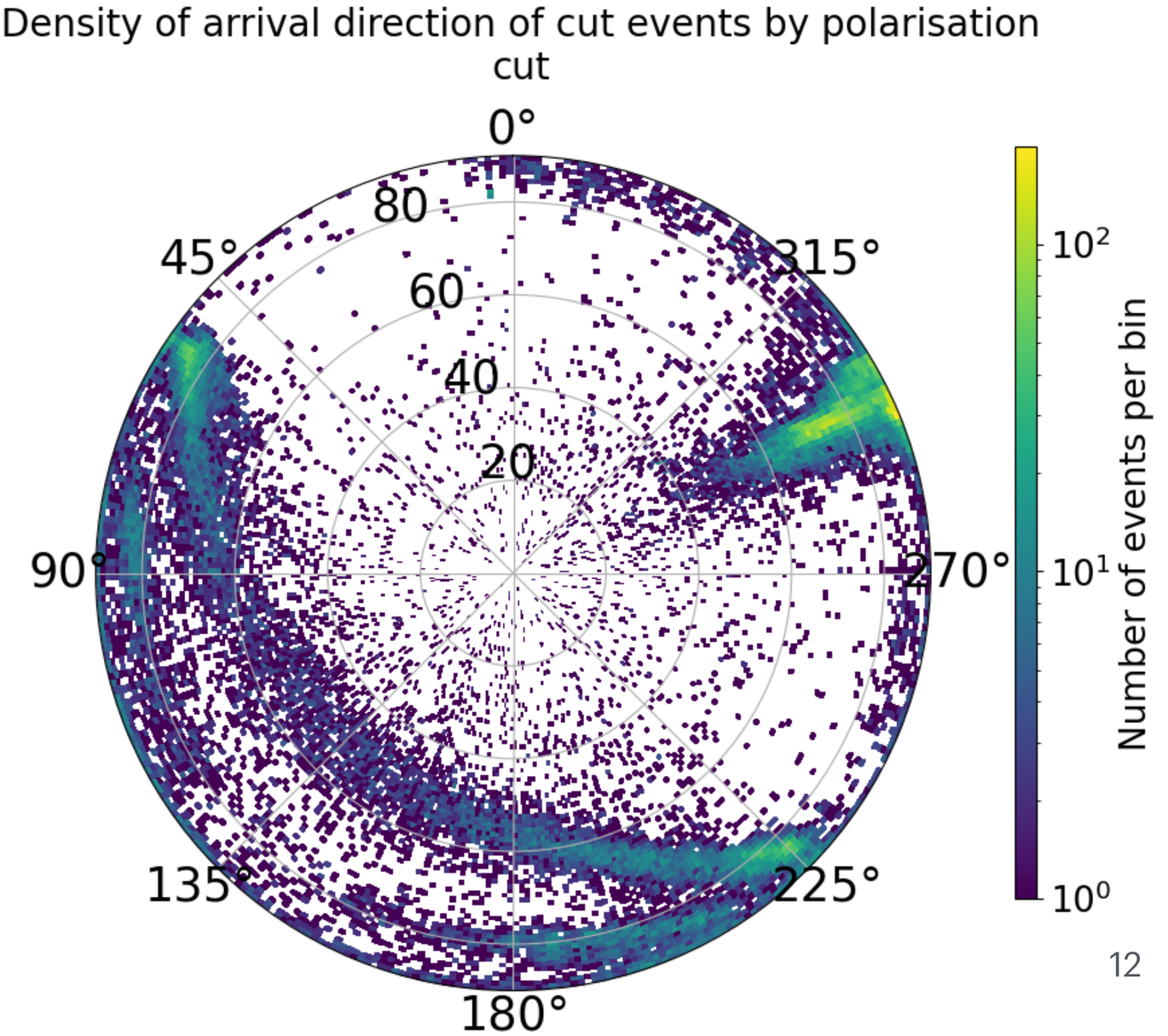
Result on month of January





Clustering cut

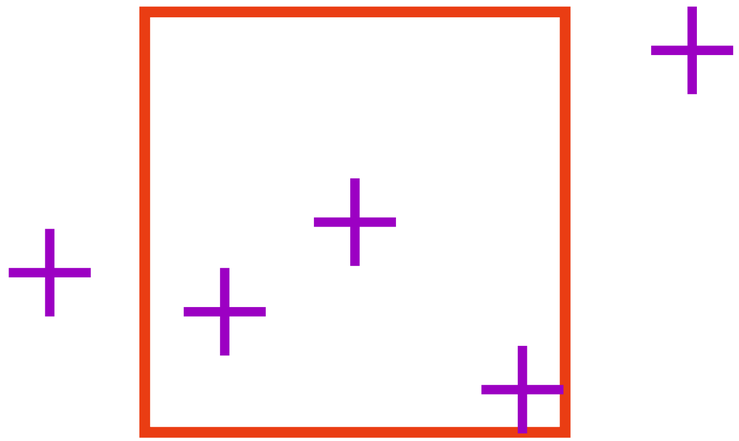
Objective: getting rid of events coming in waves

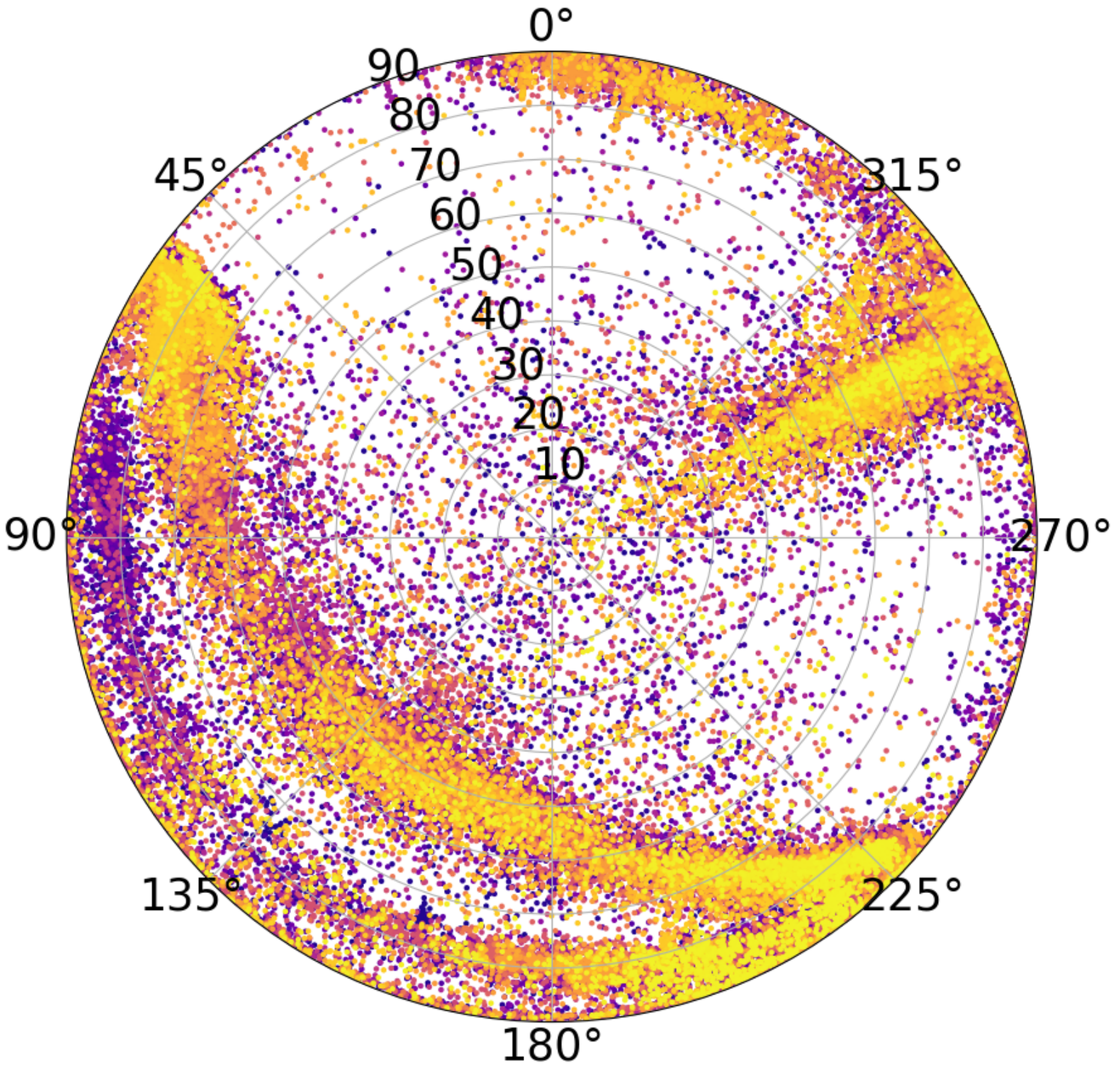
Algorithm:

$\geq$2 events $\in [\vartheta - 5\text{deg}, \vartheta + 5\text{deg}]$

$\in [t - 5\text{s}, \text{t} + 5\text{s}]$

=> part of a cluster





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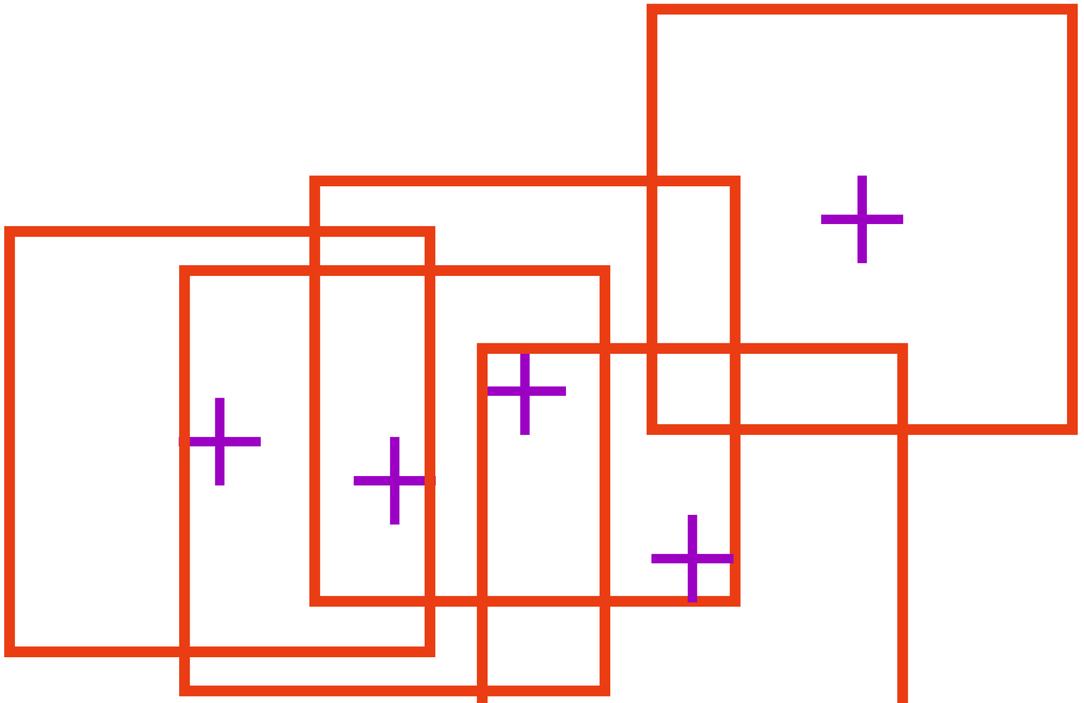
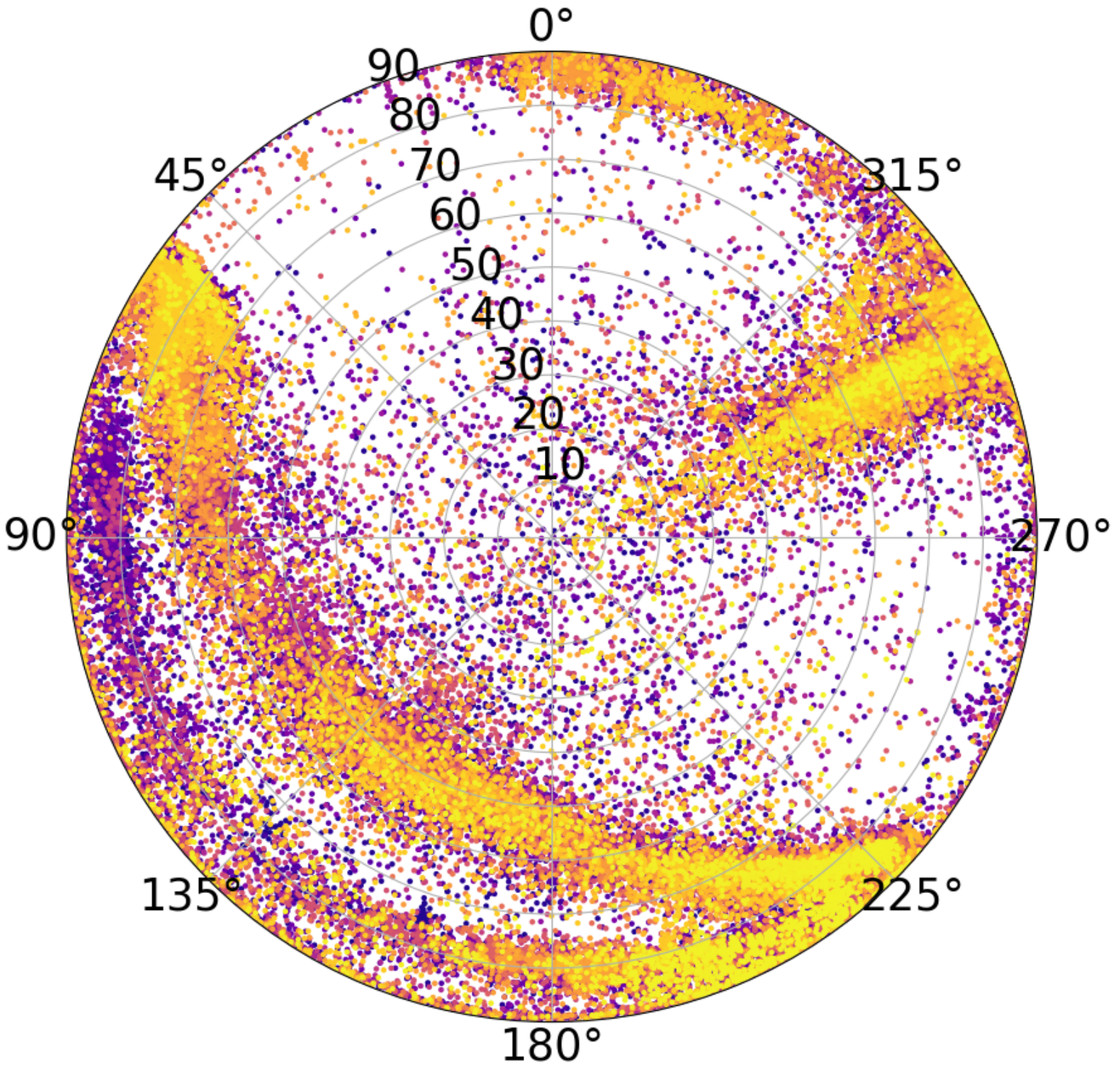
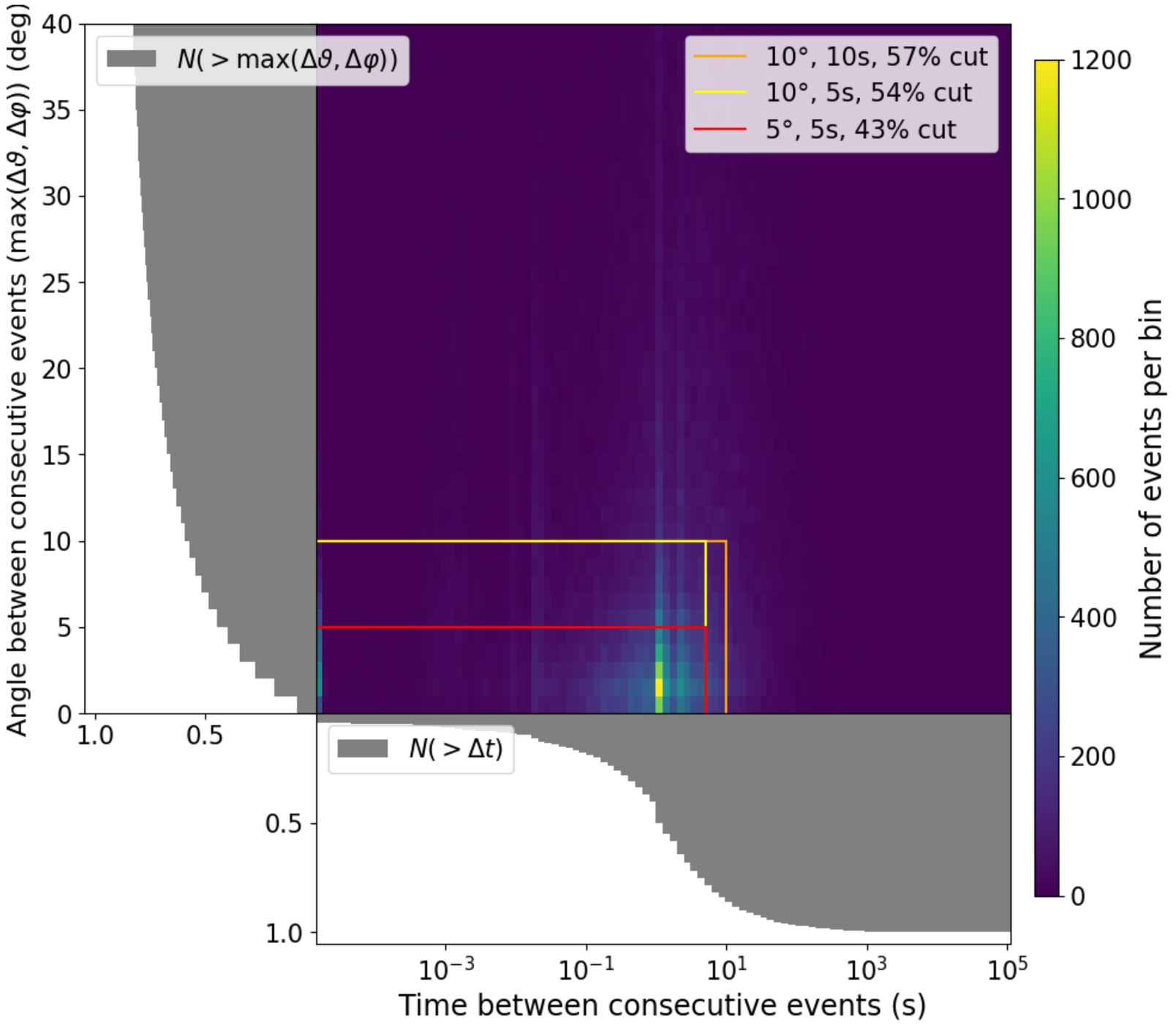






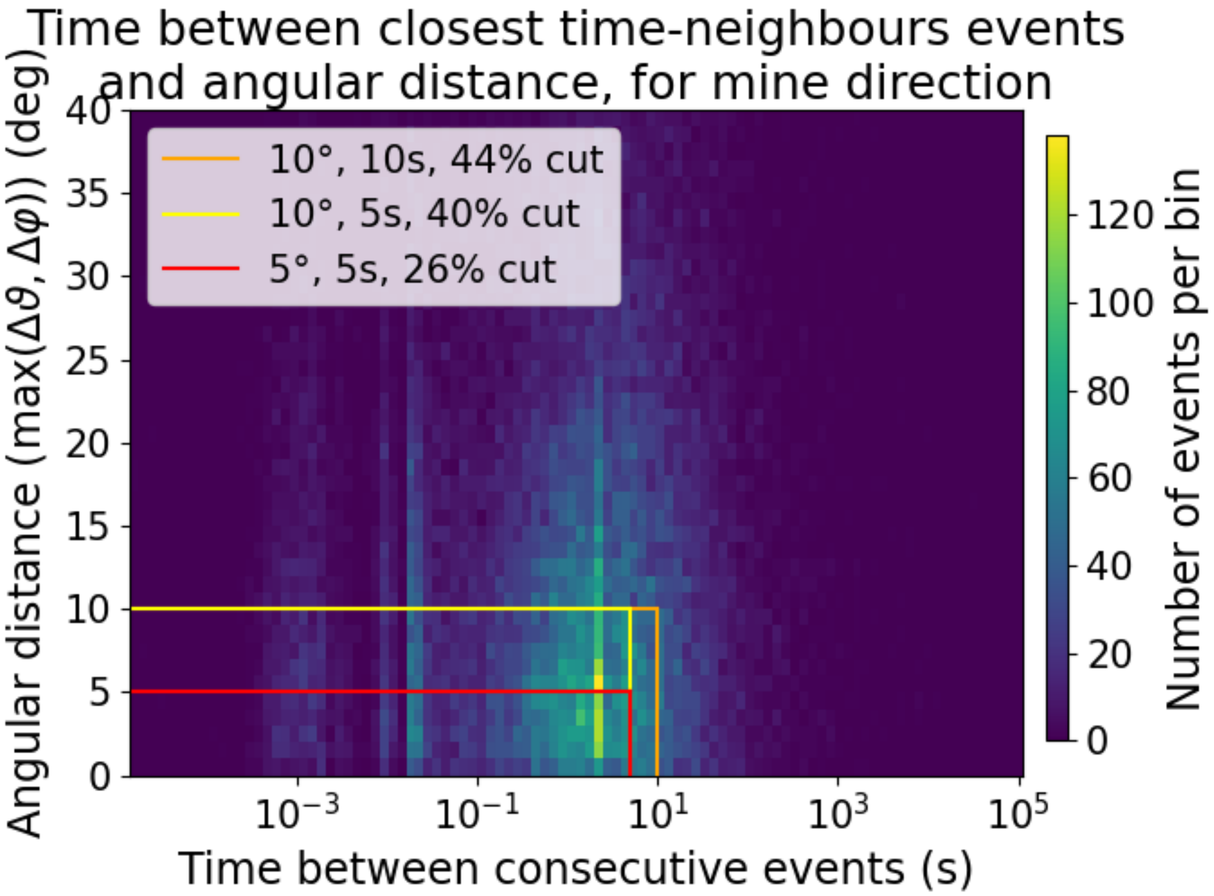
Plot:

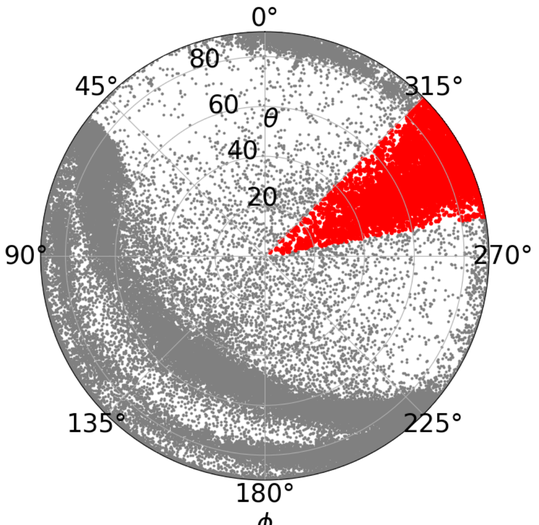
2d histogram of angular and time distances of consecutive events

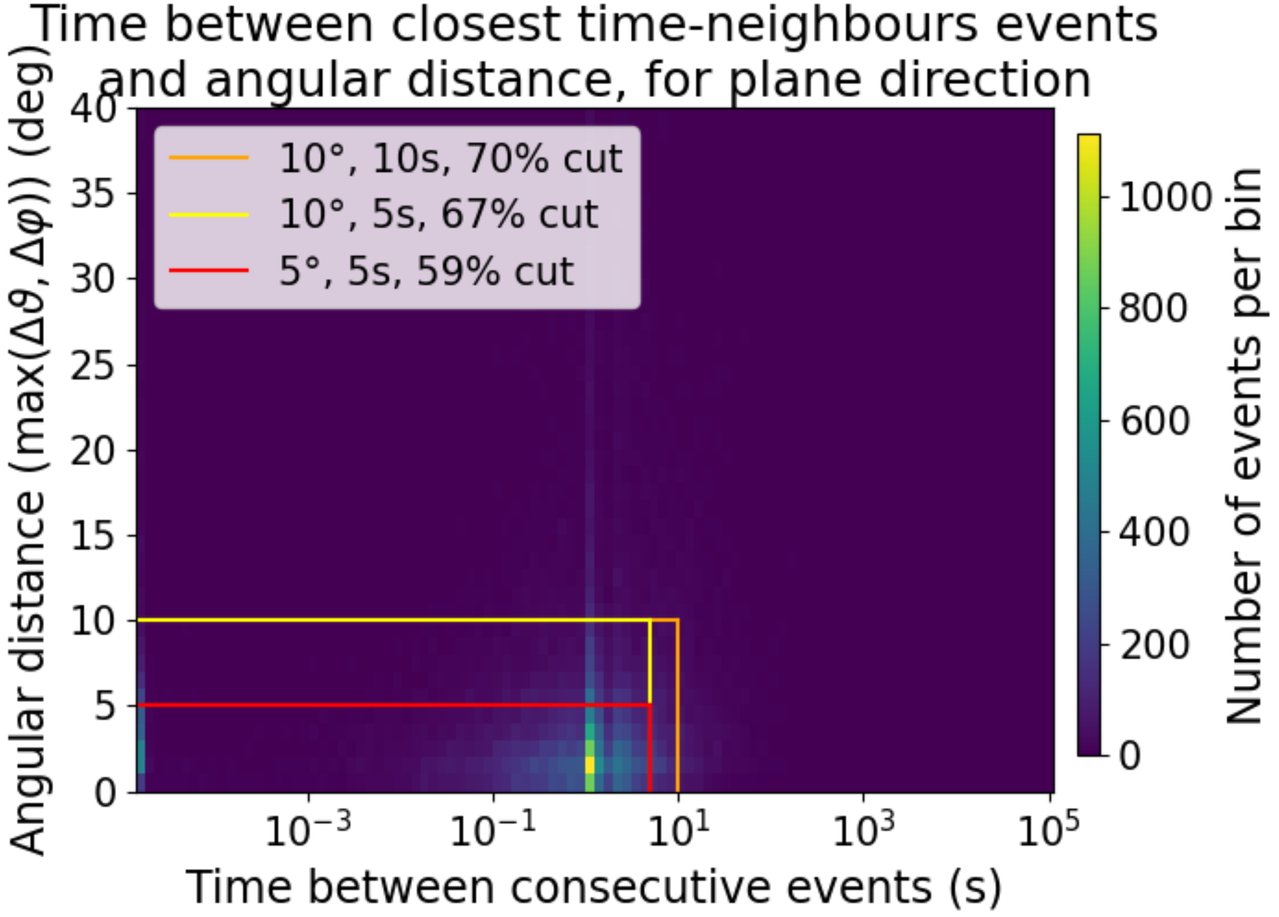
$$\Delta\vartheta < 5 \wedge \Delta\varphi < 5$$
$$\Leftrightarrow$$
$$\max(\Delta\vartheta, \Delta\varphi) < 5$$

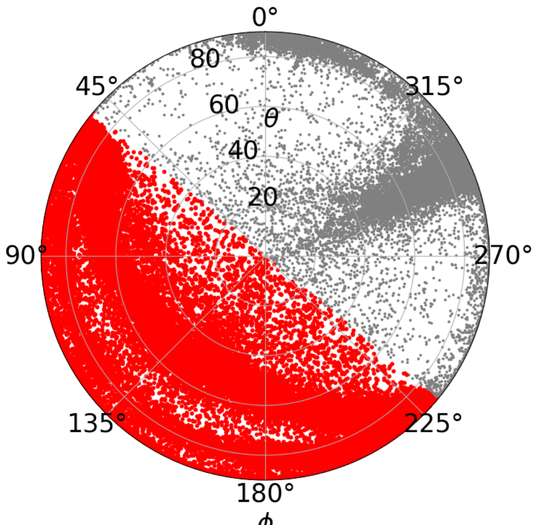
January data

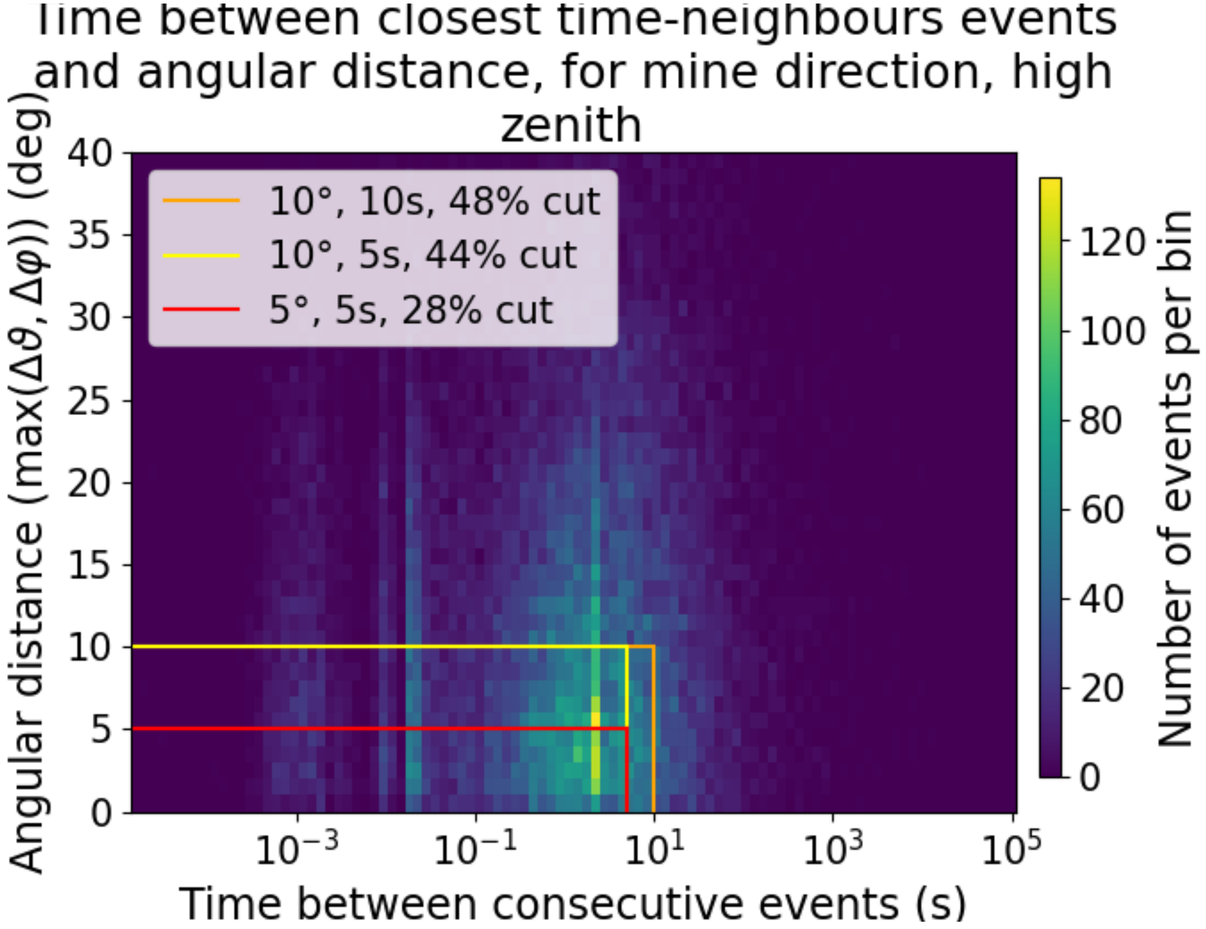
3 sets of parameters tested

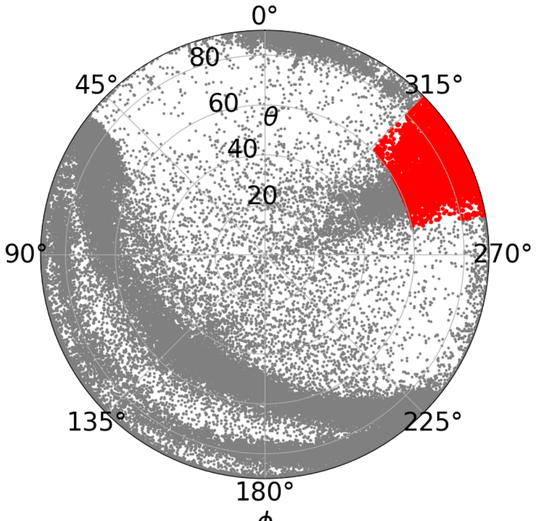

Time between closest time-neighbours events and angular distance, for mine direction
10°, 10s, 44% cut
10°, 5s, 40% cut
5°, 5s, 26% cut
Angular distance (max(Δθ, Δφ)) (deg)
Time between consecutive events (s)
Number of events per bin

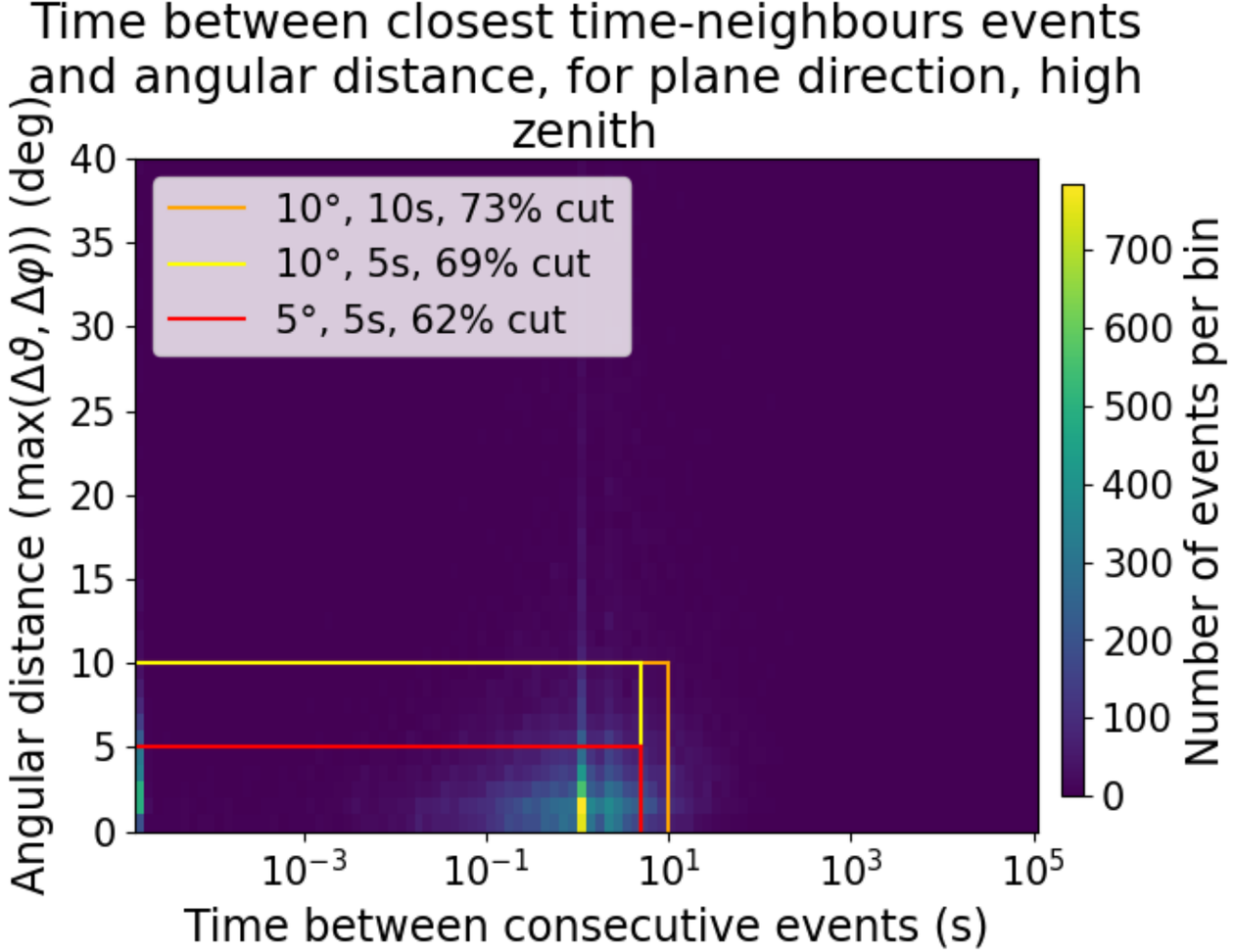

θ
φ

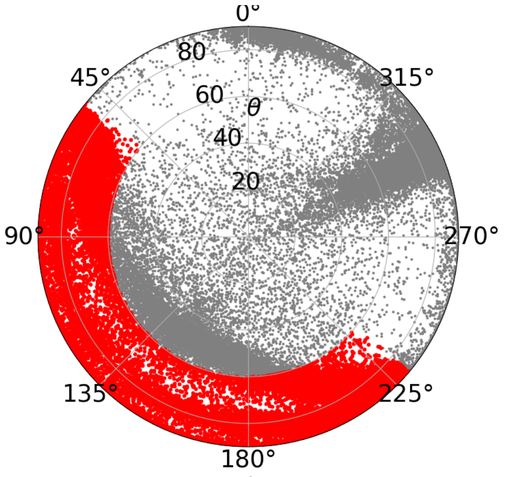

Time between closest time-neighbours events and angular distance, for plane direction
10°, 10s, 70% cut
10°, 5s, 67% cut
5°, 5s, 59% cut
Angular distance (max(Δθ, Δφ)) (deg)
Time between consecutive events (s)
Number of events per bin


θ
φ


Time between closest time-neighbours events and angular distance, for mine direction, high zenith
10°, 10s, 48% cut
10°, 5s, 44% cut
5°, 5s, 28% cut
Angular distance (max(Δθ, Δφ)) (deg)
Time between consecutive events (s)
Number of events per bin


0°
45°
315°
90°
270°
135°
225°
180°
θ
φ


Time between closest time-neighbours events and angular distance, for plane direction, high zenith
10°, 10s, 73% cut
10°, 5s, 69% cut
5°, 5s, 62% cut
Angular distance (max(Δθ, Δφ)) (deg)
Time between consecutive events (s)
Number of events per bin


0°
45°
315°
90°
270°
135°
225°
180°
θ

Summary

- ✦ Enhanced polarisation cut:
  - ❖ Cuts 30-40% data with a consistent cut
  - ❖ Apply study to late-May simulations
- ✦ Clustering cut:
  - ❖ Parameters could be changed, but for now prioritize conservative approach
  - ❖ Noise clustering identification using ML
- ✦ Other physical cuts to explore:
  - ❖ Footprint
  - ❖ Timing