

# Search for cosmic rays in GRANDProto300

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- *For the GRAND Collaboration*  
Proceeding PoS(ICRC2025)314



# Giant Radio Array for Neutrino Detection

Cosmic ray

*Science News,  
Aug. 2025*

$\tau$

$\nu_\tau$

3 Prototypes

GRAND10k

GRAND200k

2023

2028

203X

**Cosmic Rays of  $10^{17-18}$  eV**

**Autonomous** radio detection  
of **very-inclined** air-showers

**- Discovery of EeV** for  
optimistic fluxes  
- 2 detectors of 5-10k antennas:  
GRAND North (China)  
GRAND-South (Argentina?)

**1st EeV detection and/or  
neutrino astronomy!**

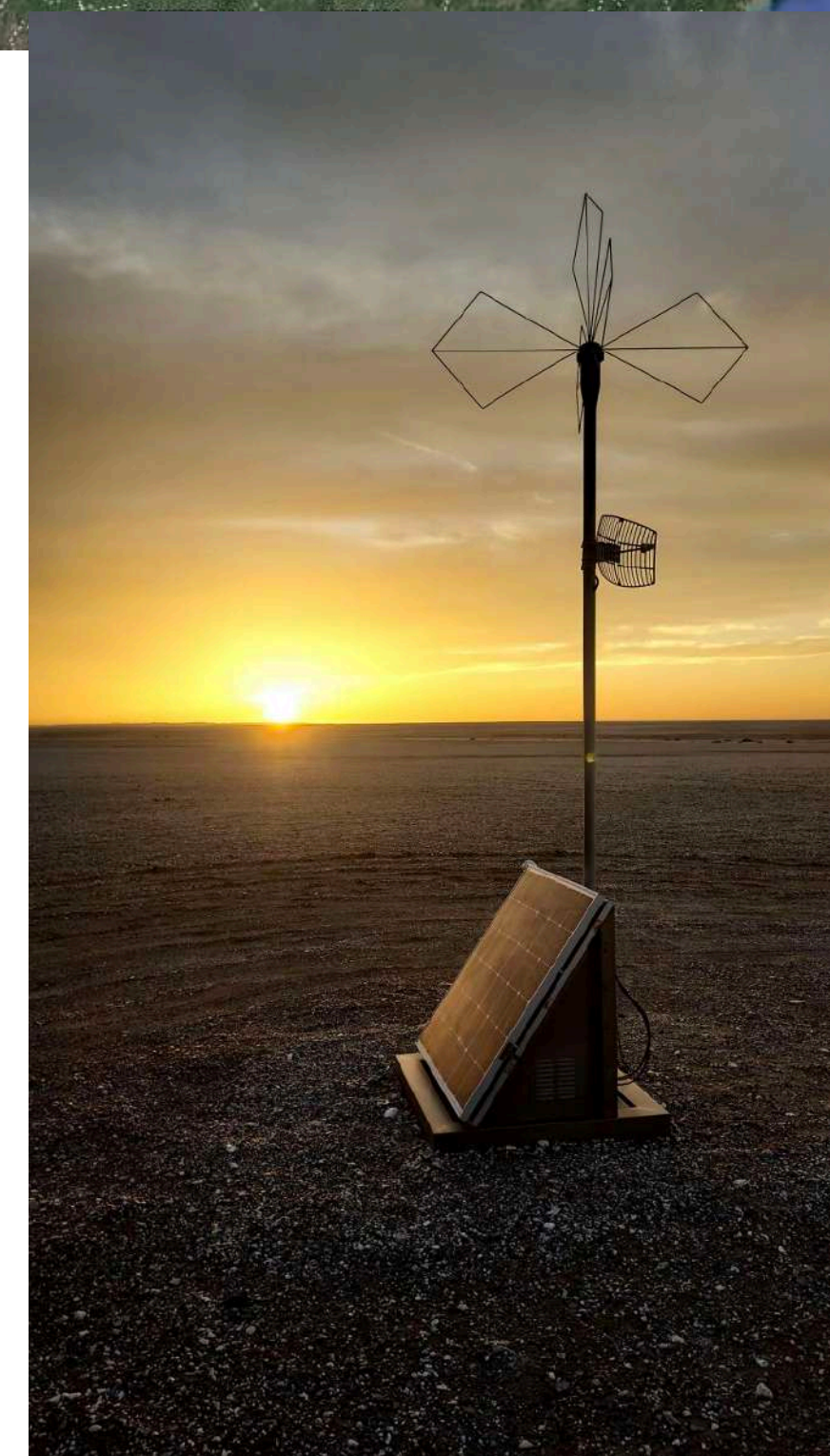
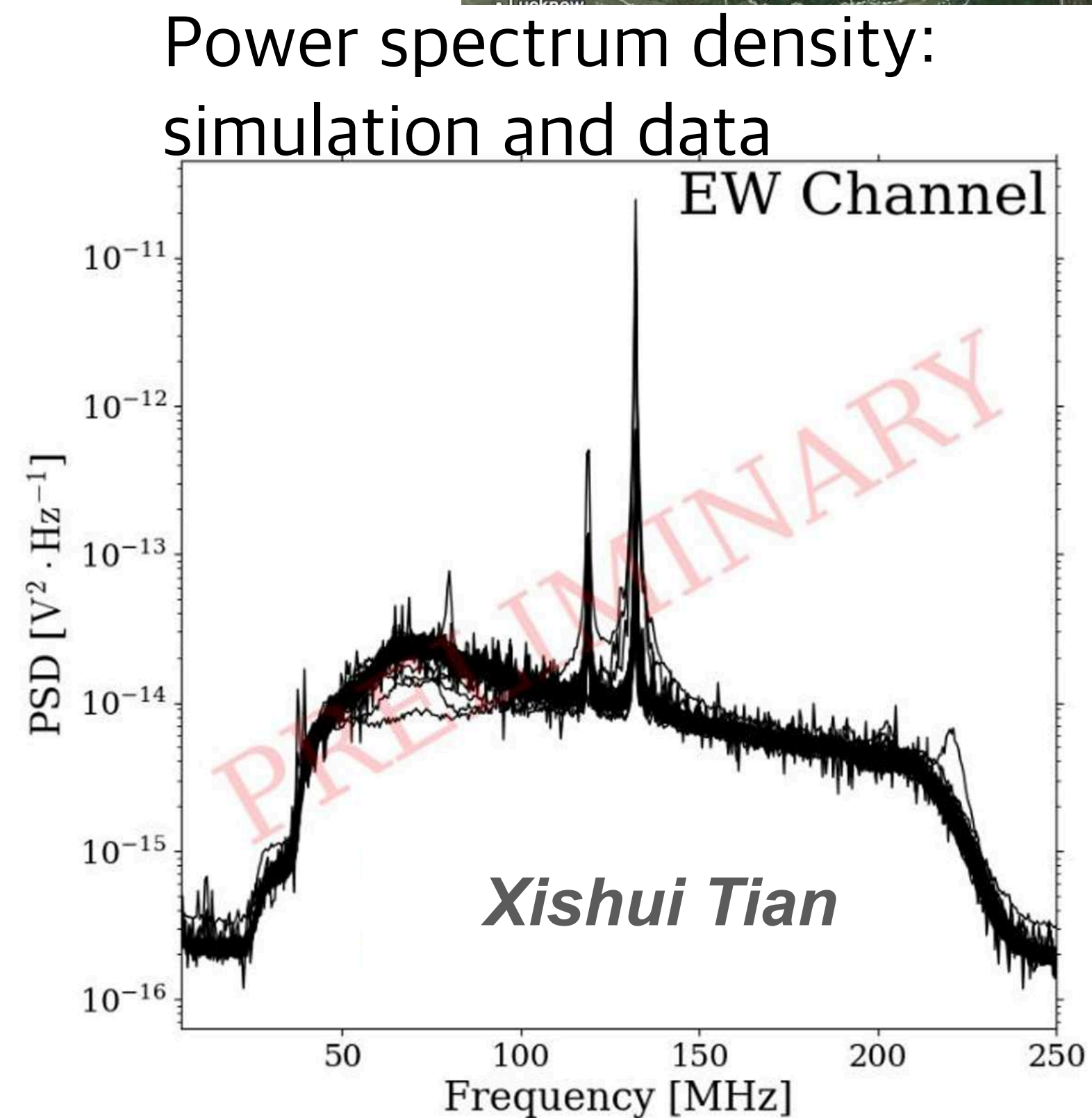
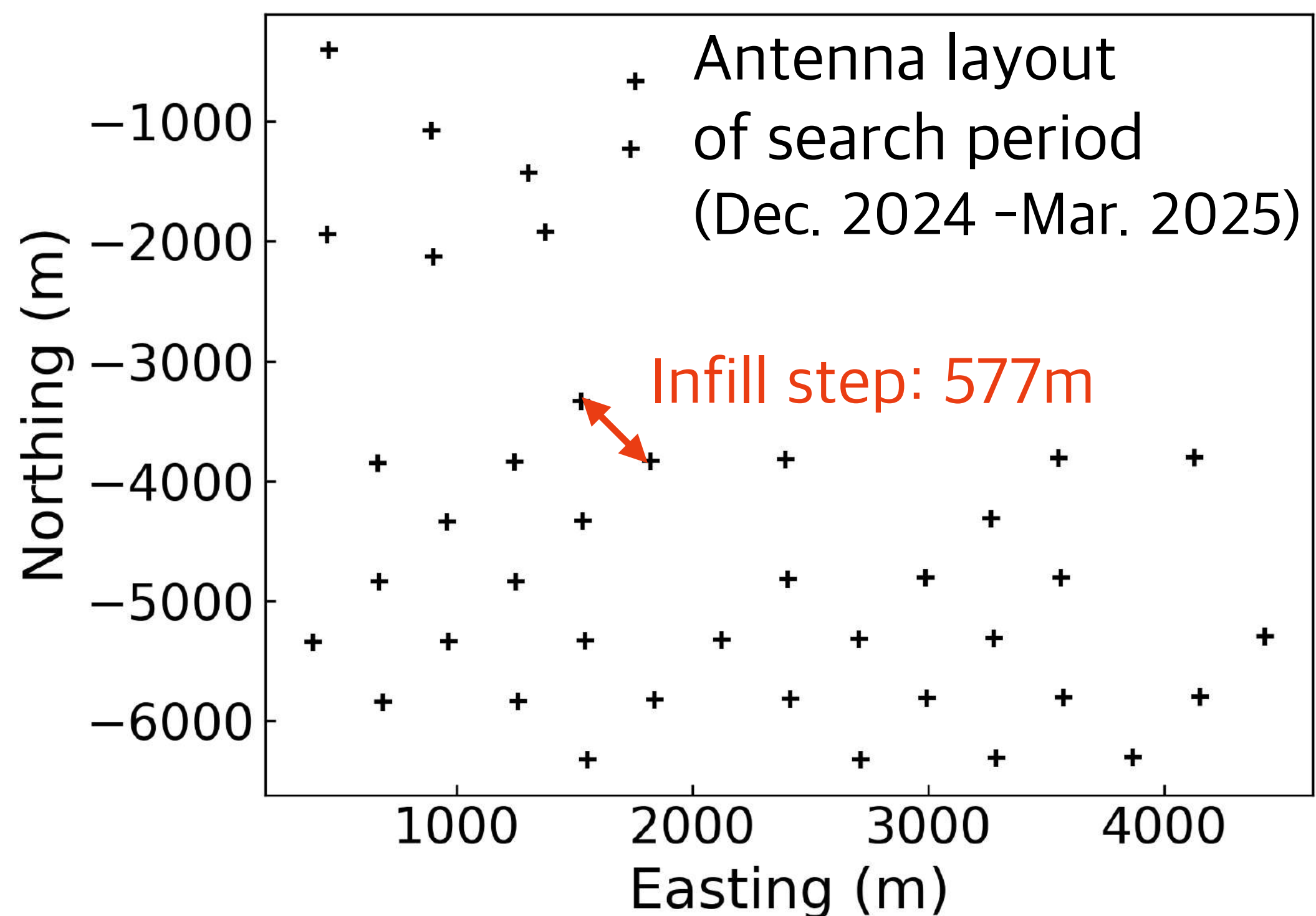
# GRANDProto300

Goal : validate the technique of **autonomous radio detection**, for very inclined cosmic rays, with energies of  $10^{17}$ – $10^{18.5}$  eV

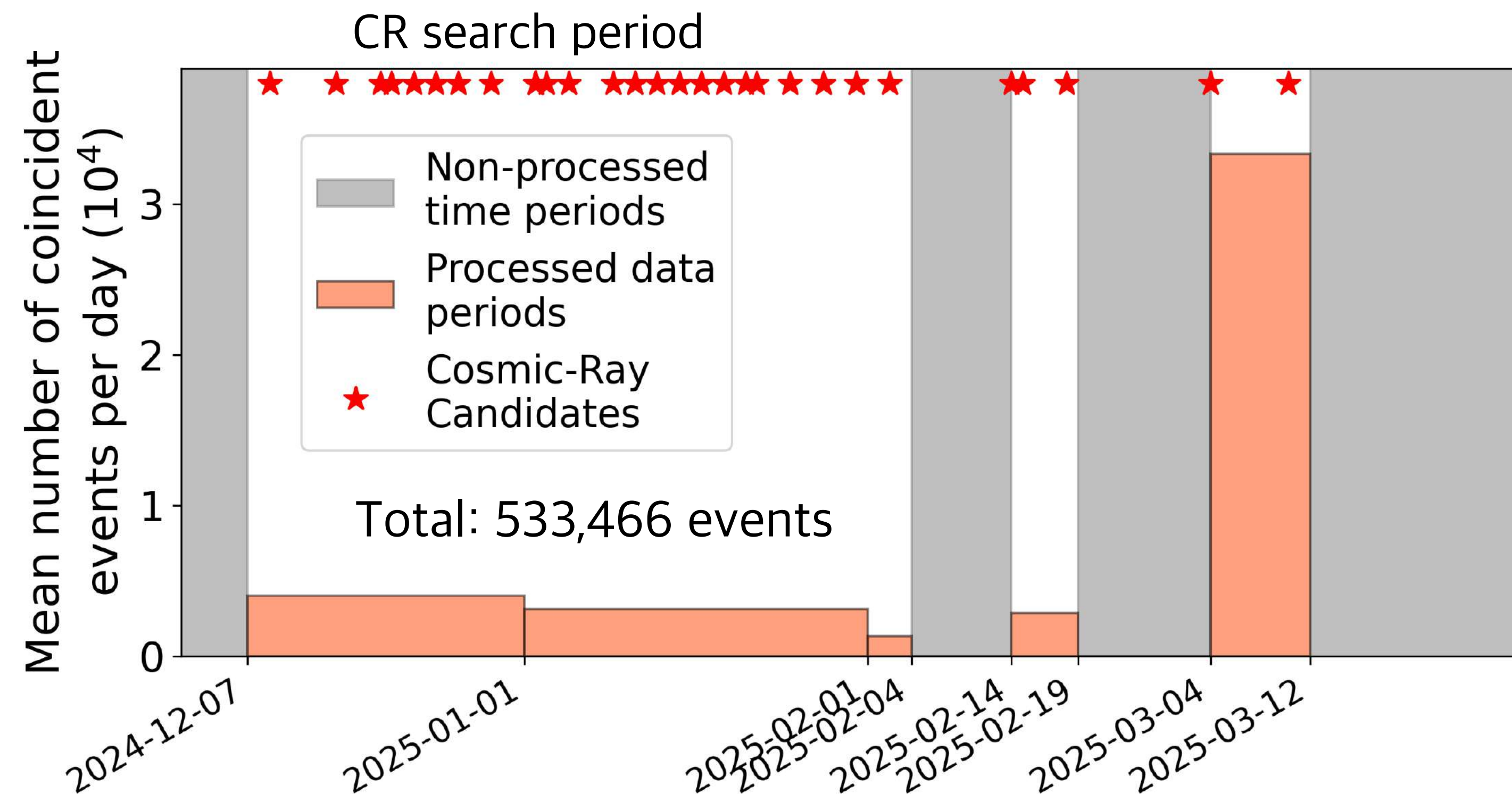
Stable run since Nov. 2024  
July 2025: 65 Detection Units (DUs)

*O. Martineau*  
*PoS(ICRC2025)1114*  
*P. Ma*  
*PoS(ICRC2025)453*  
*J. Torres*  
*PoS(ICRC2025)1024*

*S. Kato*  
*PoS(ICRC2025)298*



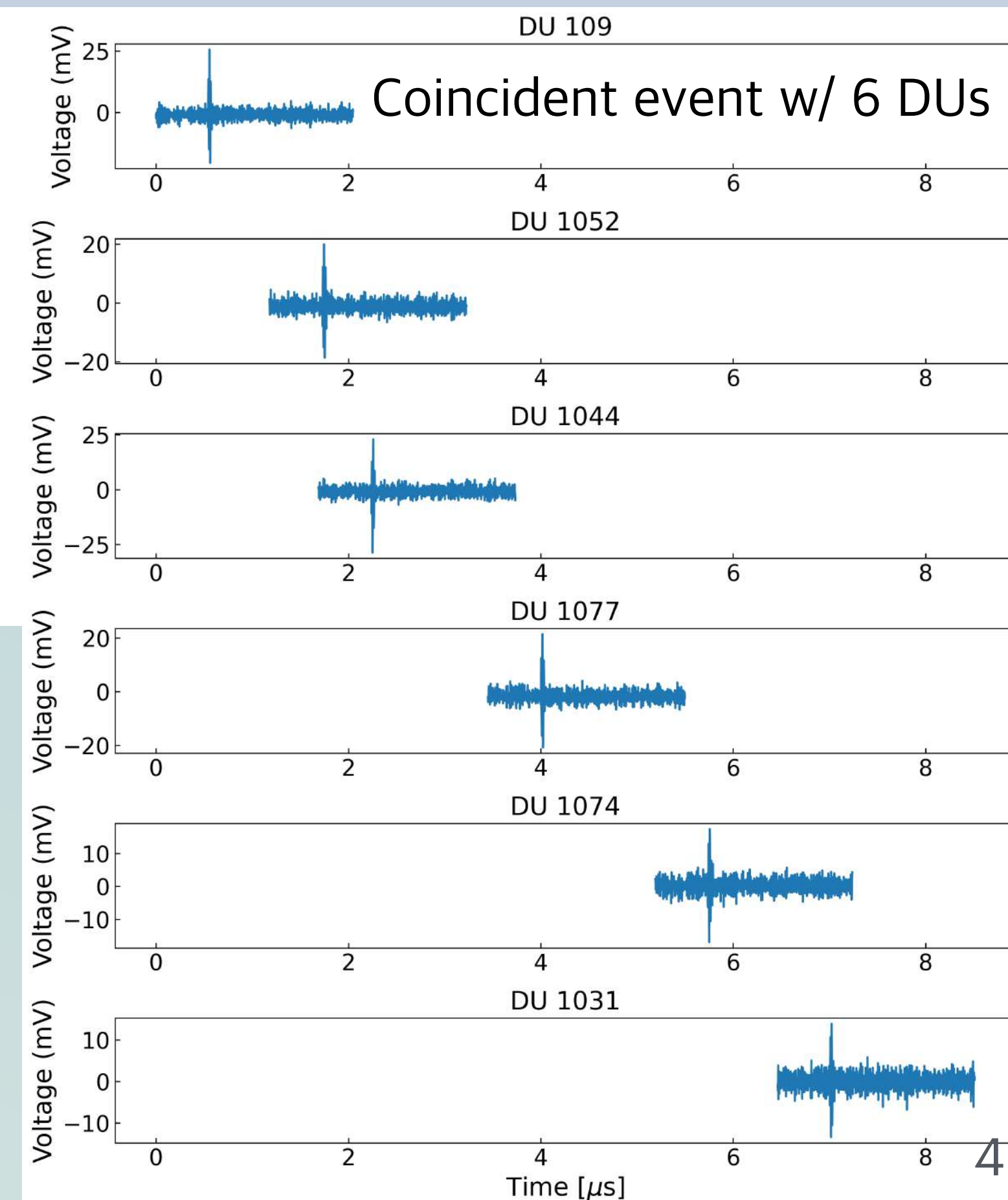
# GRANDProto300

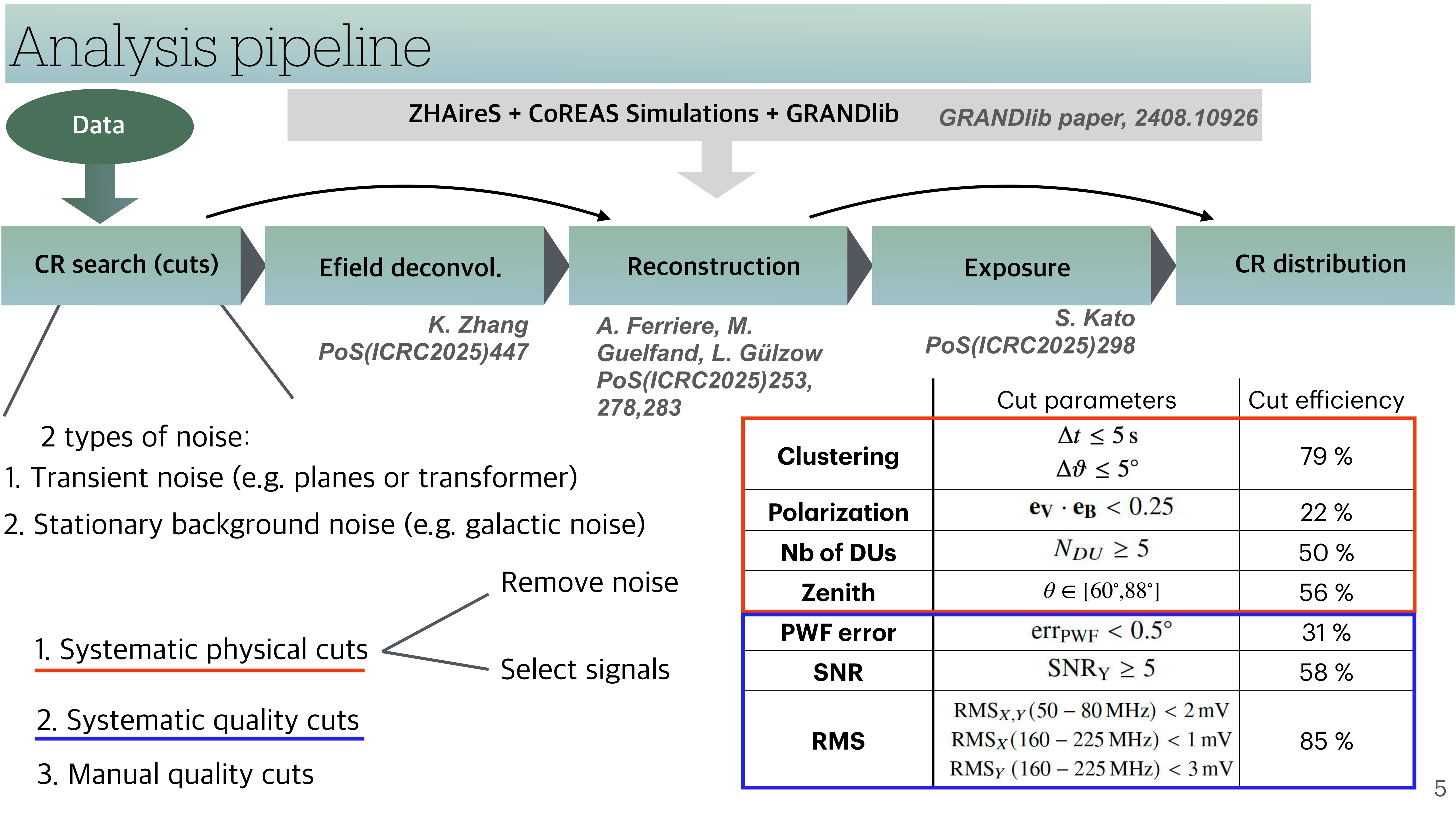


- Monitoring Data (MD): continuous recording
- Unit Data (UD): signal triggers one detection unit
- **Coincident Data (CD):**  
multiple ( $>4$ ) antennas triggered in  $10\ \mu\text{s}$

*P. Correa PoS(ICRC2025)229*  
*A. Benoit-Lévy PoS(ICRC2025)185*

Recording over 3 channels (X, Y, Z)  
Signal recording duration:  $2\ \mu\text{s}$   
Sampling frequency: 500 MHz  
Frequency range: 50-200 MHz  
ADC digitization  
2 trigger thresholds:  $5\sigma$  and  $3\sigma$ ,  $\sigma=\text{RMS}$  in ADC of each antenna





# Clustering

Arrival Direction reconstruction:

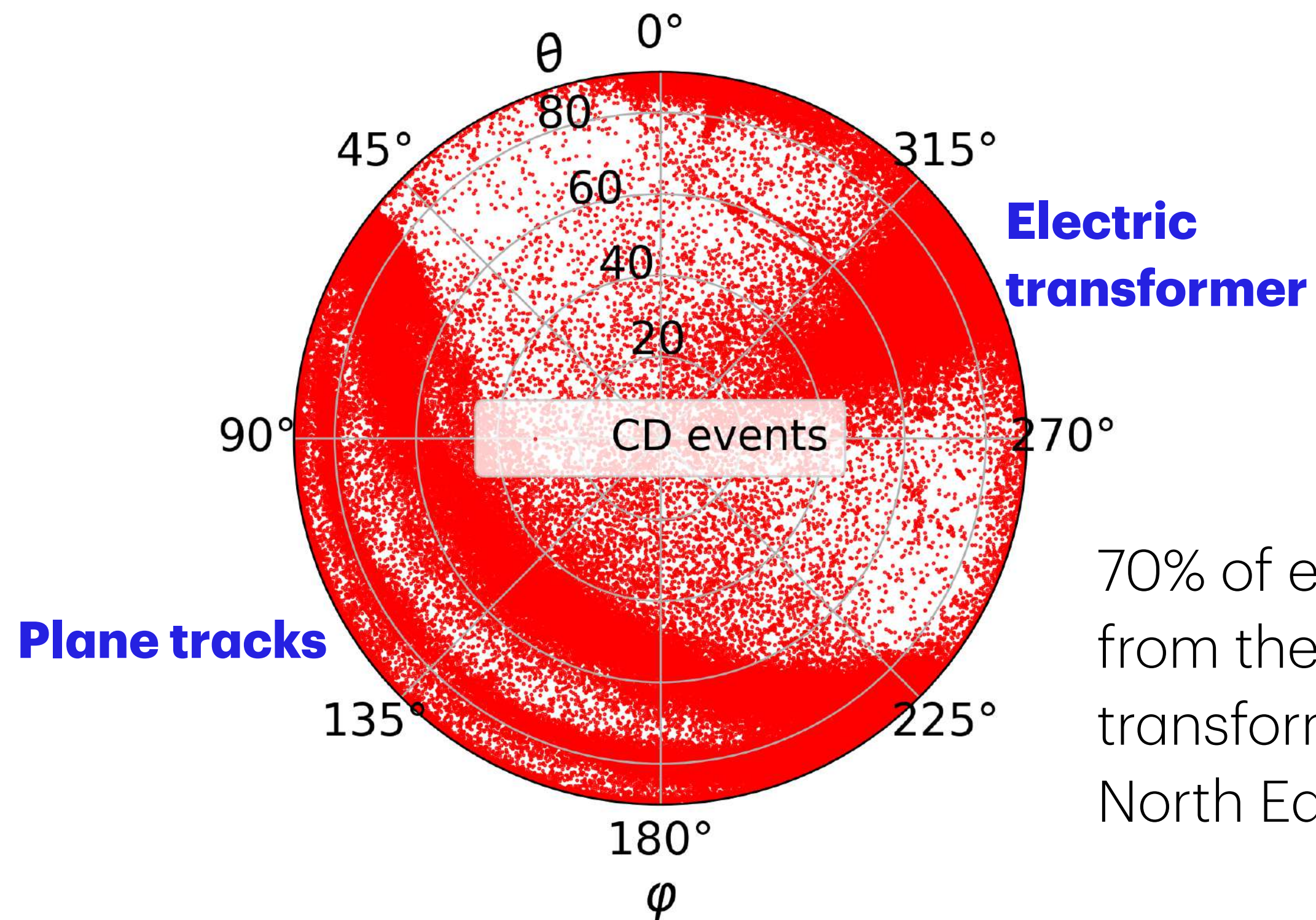
Plane Wave Fit **Ferriere et al. 2024**

Algorithm:

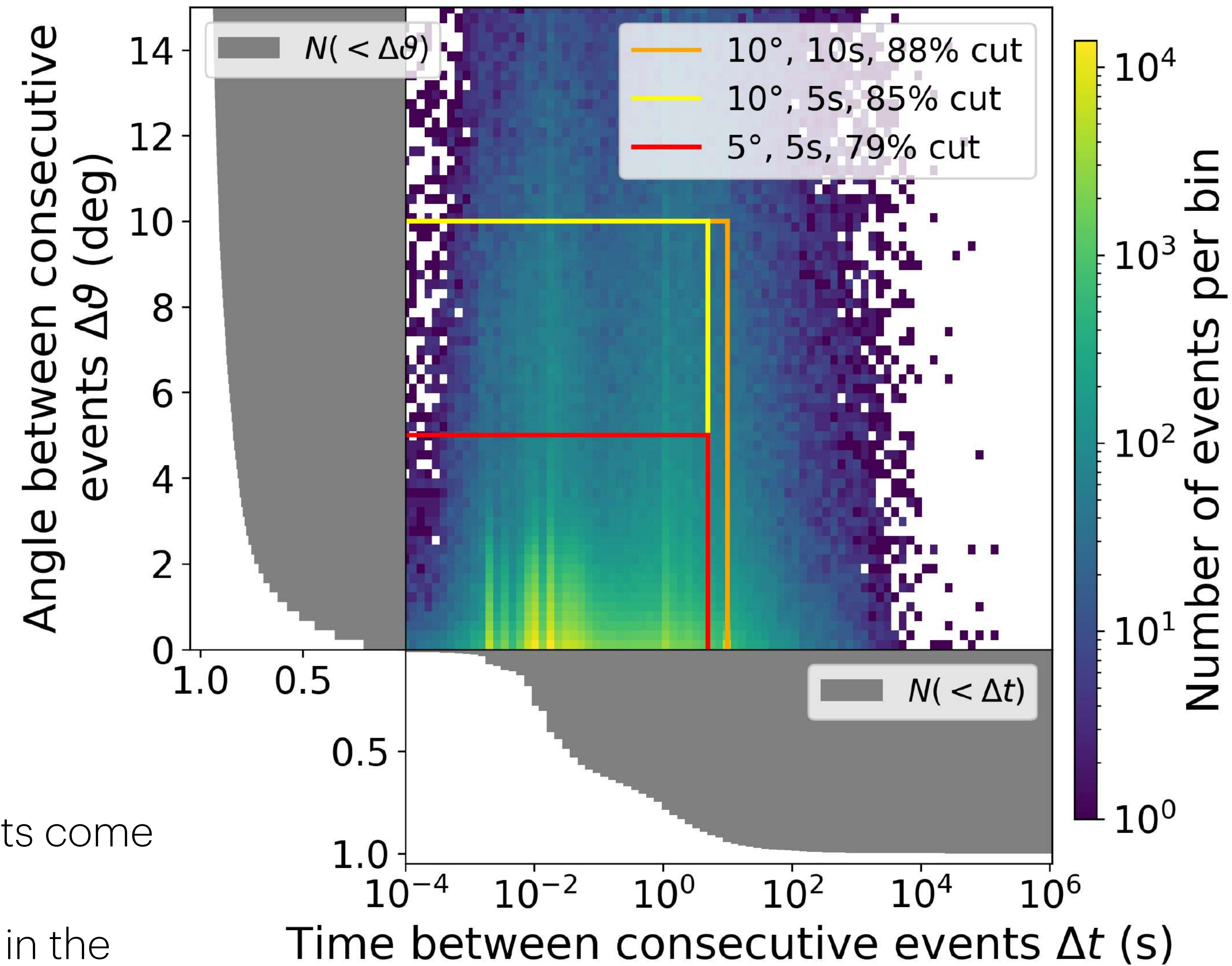
$\geq 2$  events  $\in [\theta - 5\text{deg}, \theta + 5\text{deg}]$

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

=> part of a cluster



70% of events come from the transformer in the North East



# Polarization

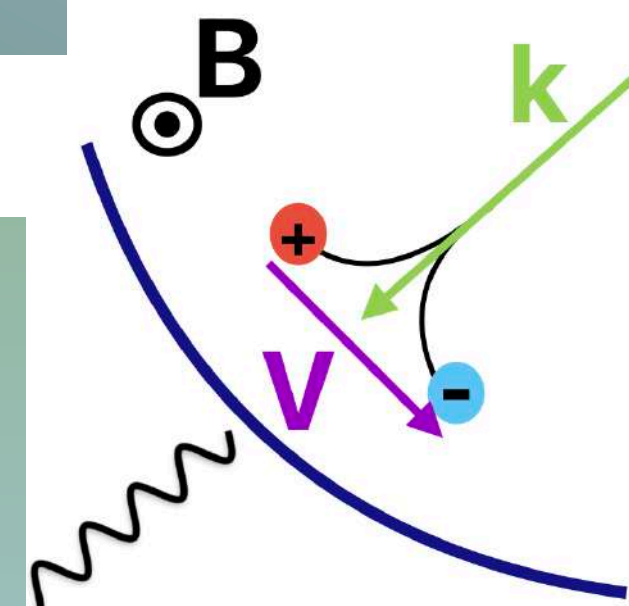
## Geomagnetic effect

Polarization estimator:

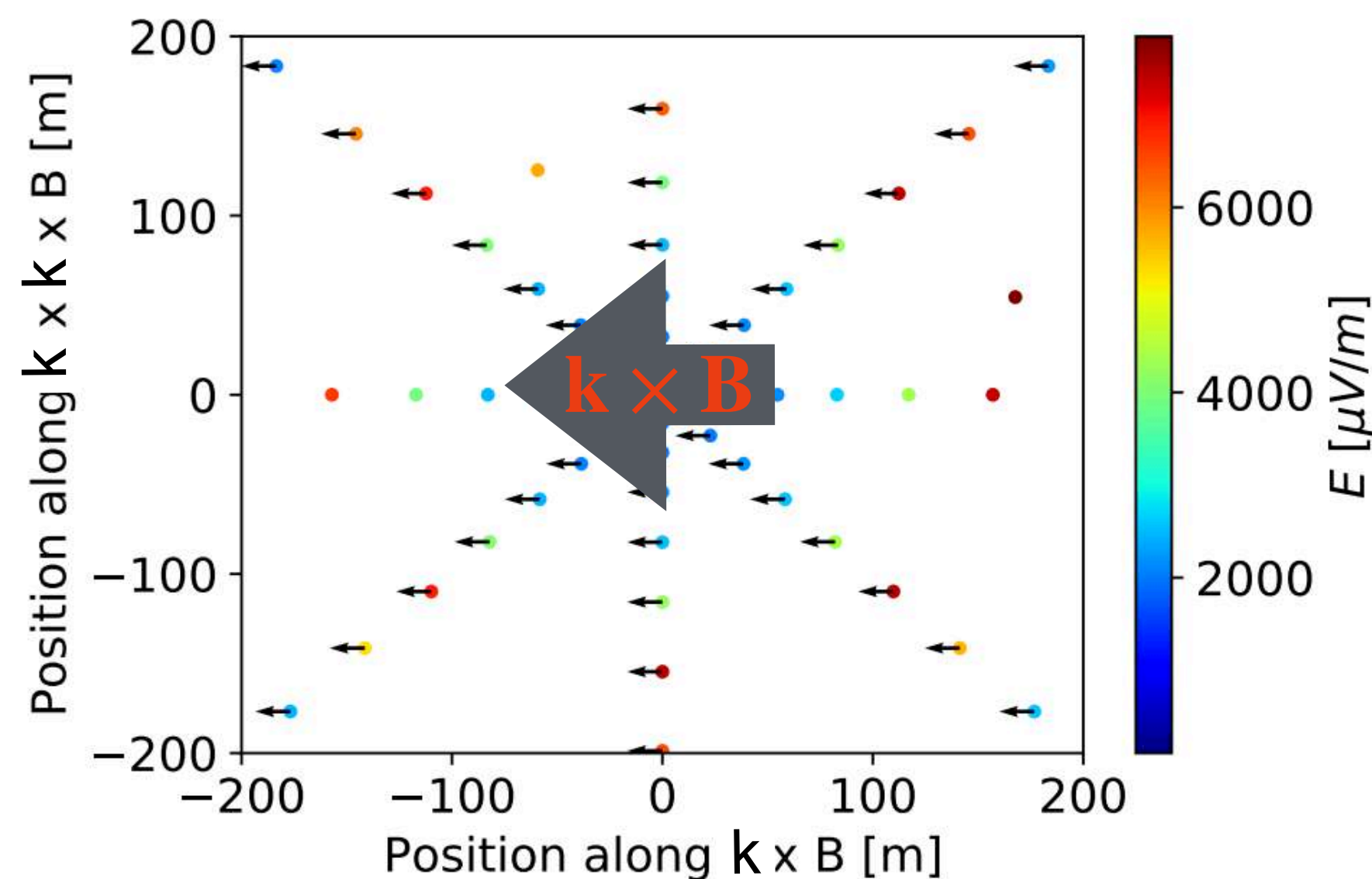
$$\mathbf{e}_V \cdot \mathbf{e}_B$$

For polarized events,

$$\mathbf{e}_V \cdot \mathbf{e}_B \sim 0$$

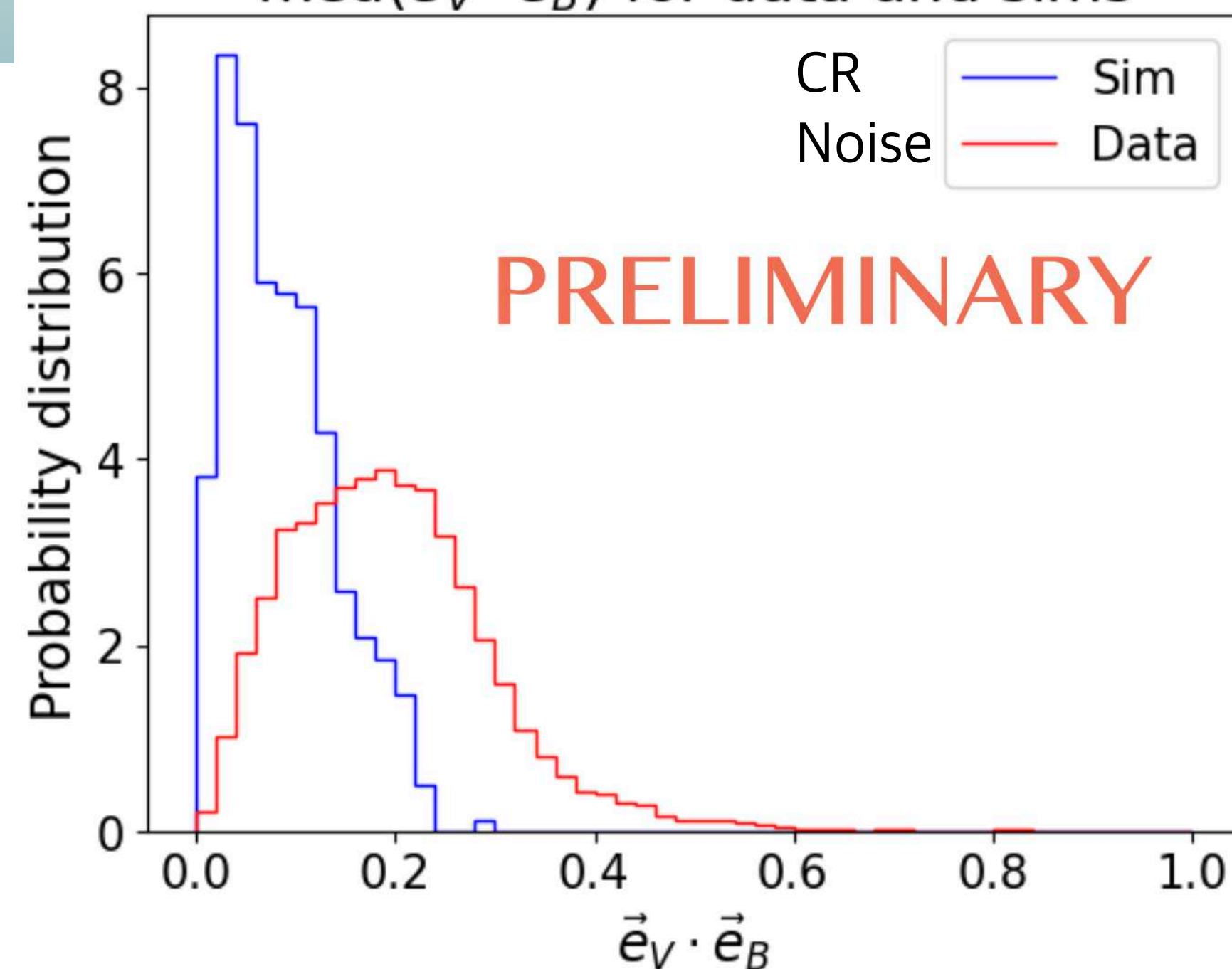


*Chiche et al. 2022*



E field amplitude and direction  
in the plane perpendicular to shower axis

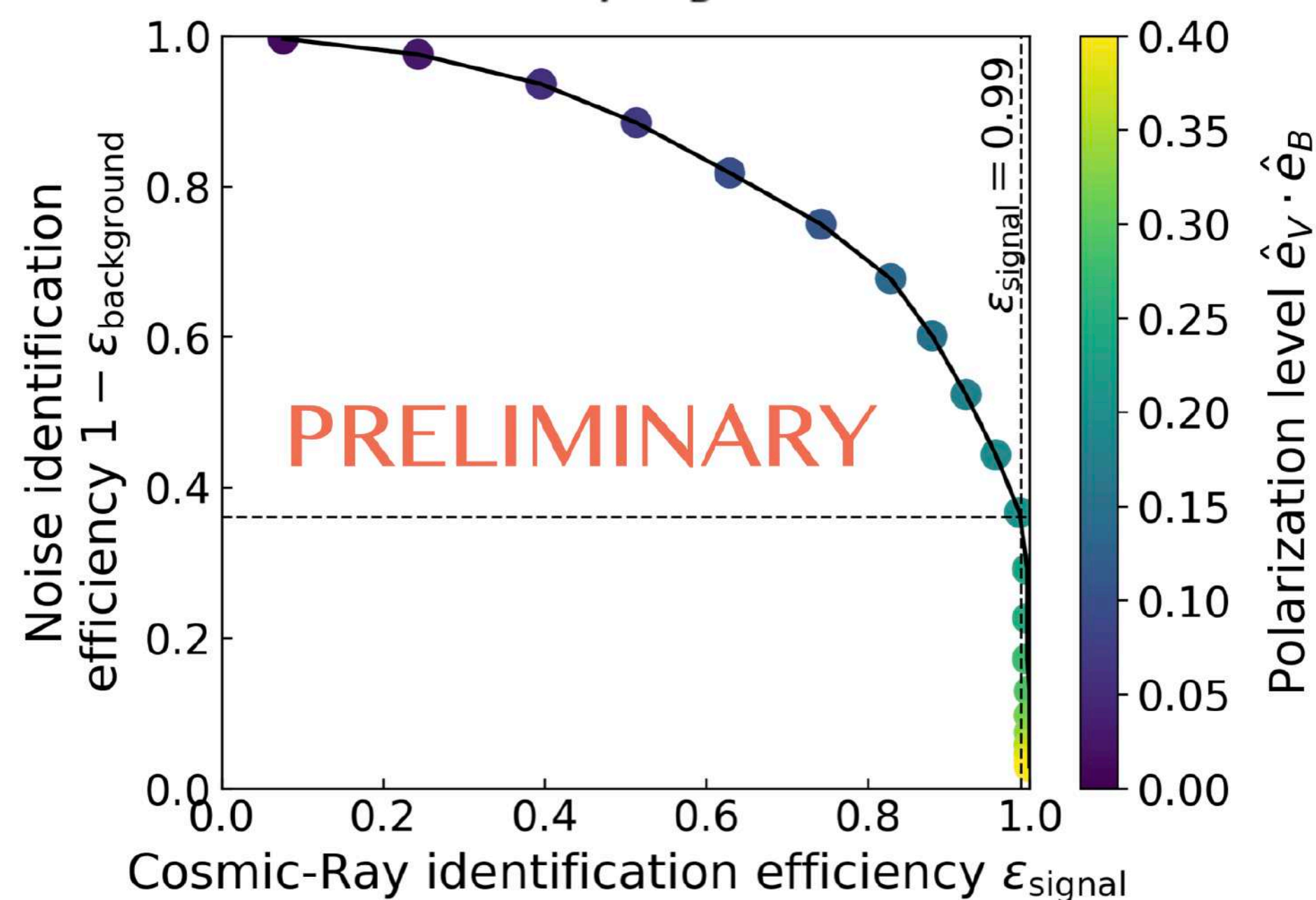
Normalized distribution of the values of  
 $\text{med}(\vec{e}_V \cdot \vec{e}_B)$  for data and sims



**Sim:** 407 ZHAiReS simulations  
(with data background noise)

Polarity calibration preliminary  
Post-calibration: fold polarity  
to favor signals with  
ill-reconstructed polarity  
(conservative approach  
to keep CR events)

**Data:** 35 167 data events  
(Noise events maximized in  
batch)



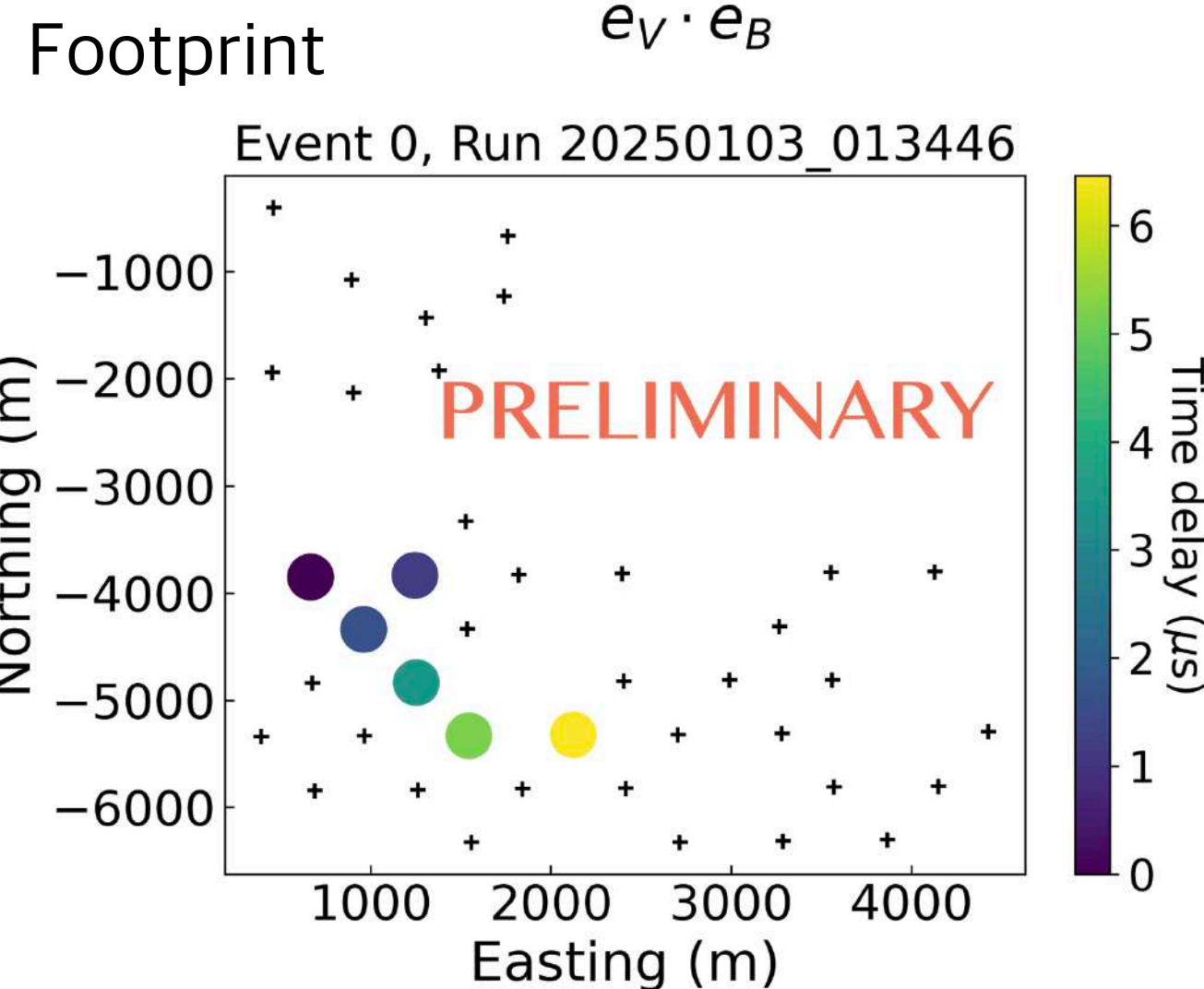
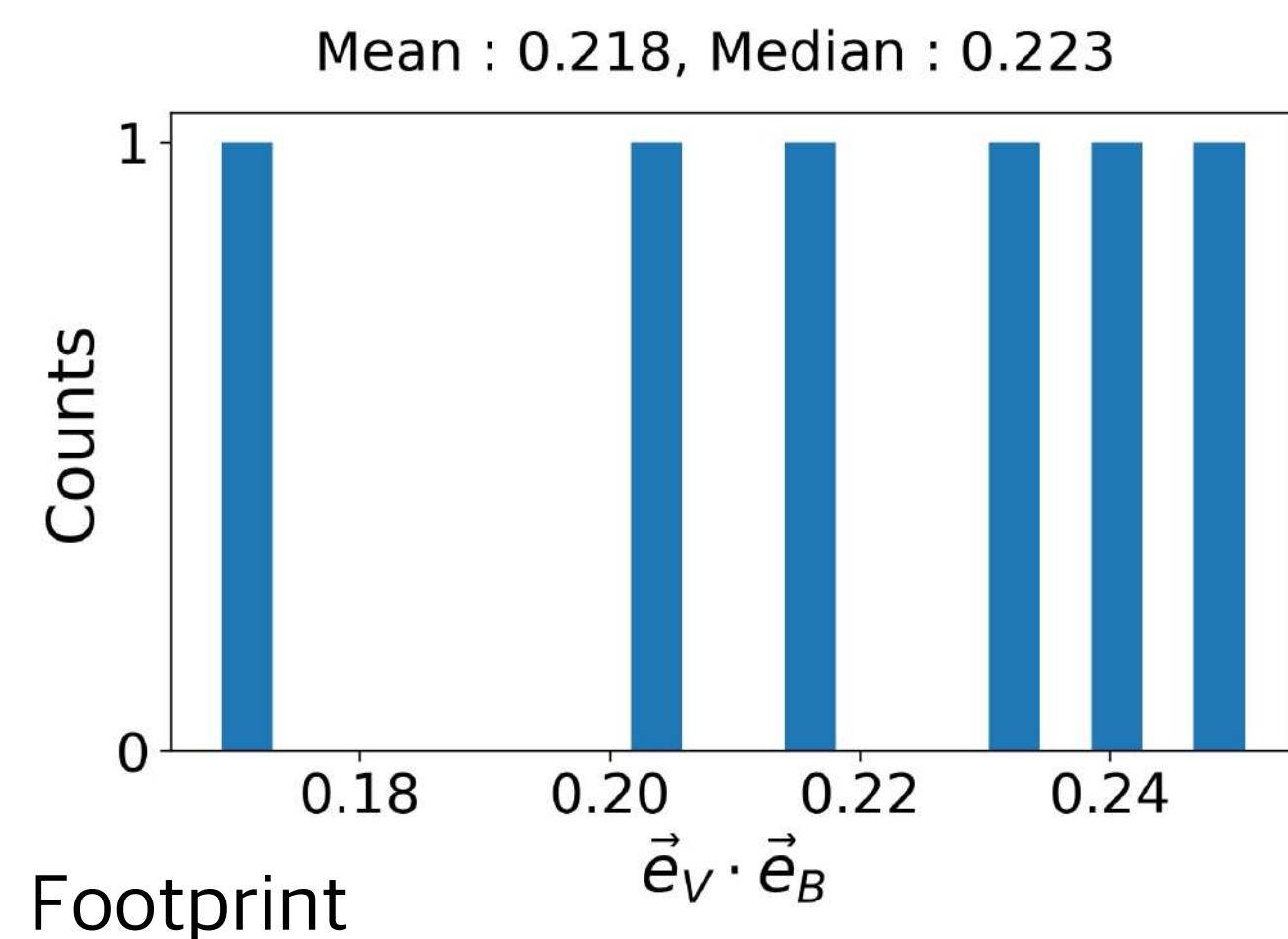
Noise and signal  
identification efficiency  
depending of polarization level

# Manual cuts

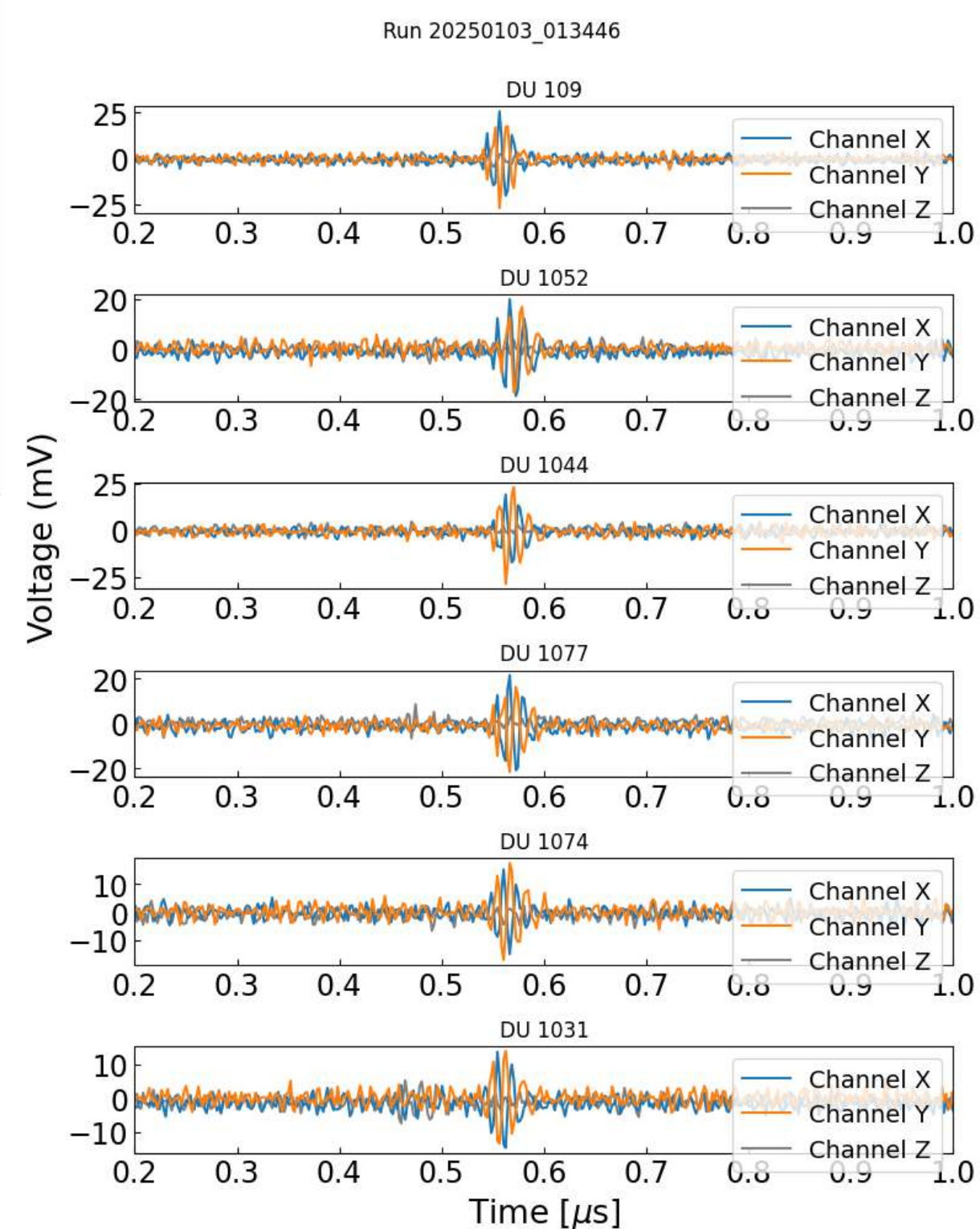
Traces: low frequencies and short signal pulse  
Footprint: DUs triggered in ellipse-shaped configuration

To be implemented as a systematic cut

## Polarization **Cosmic-ray Candidate event**

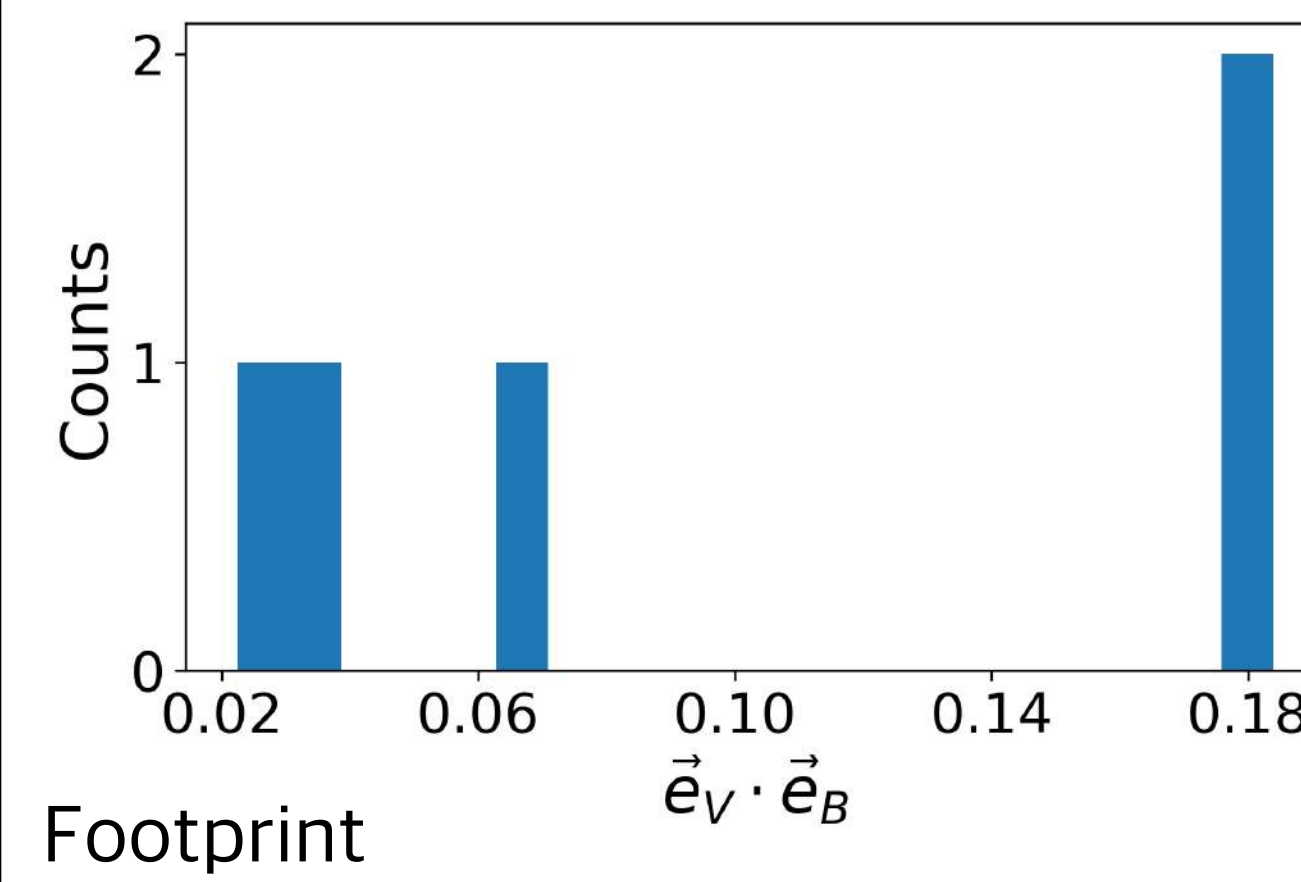


### Traces of triggered DUs

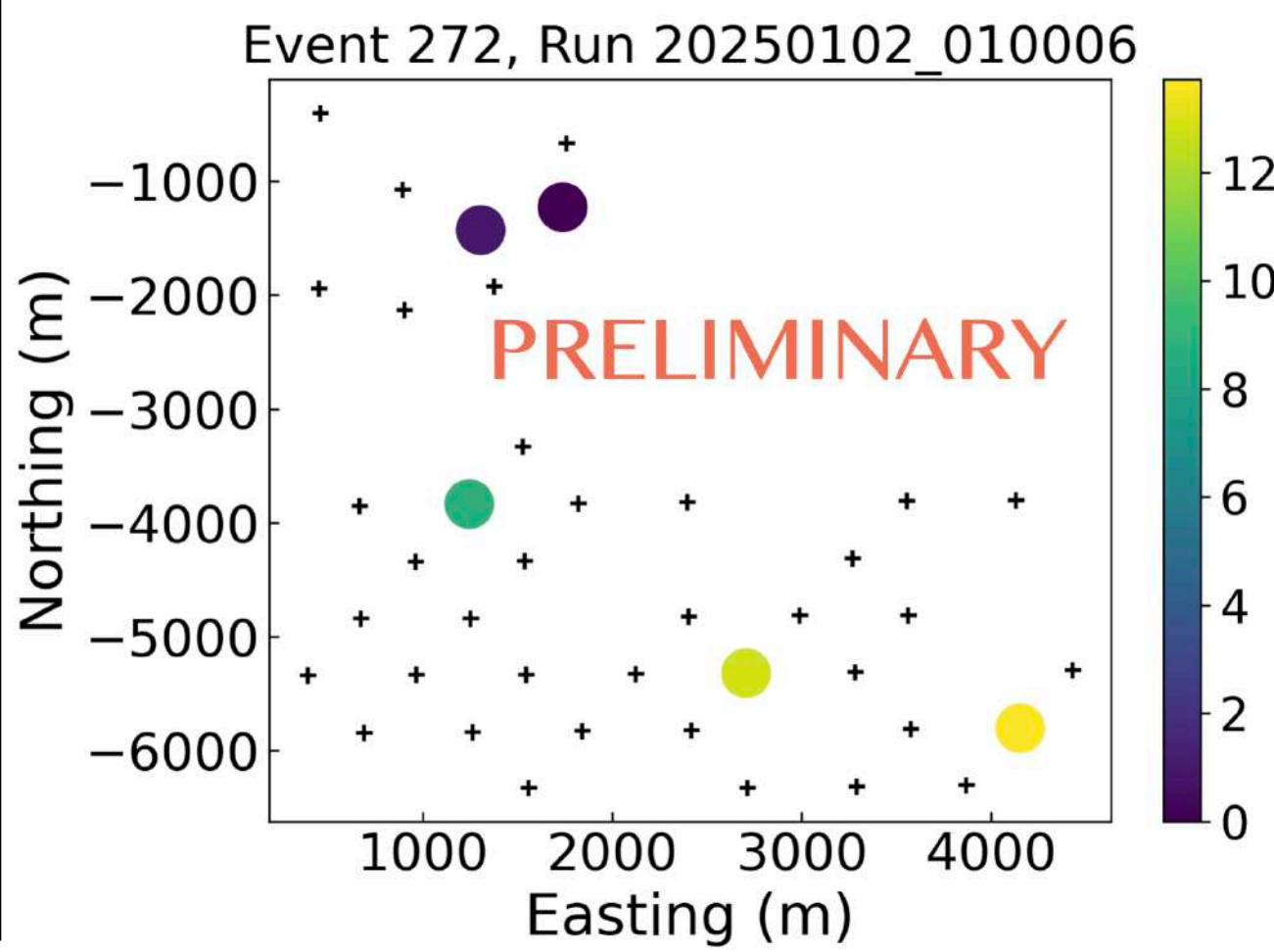


## Polarization

Mean : 0.099, Median : 0.069

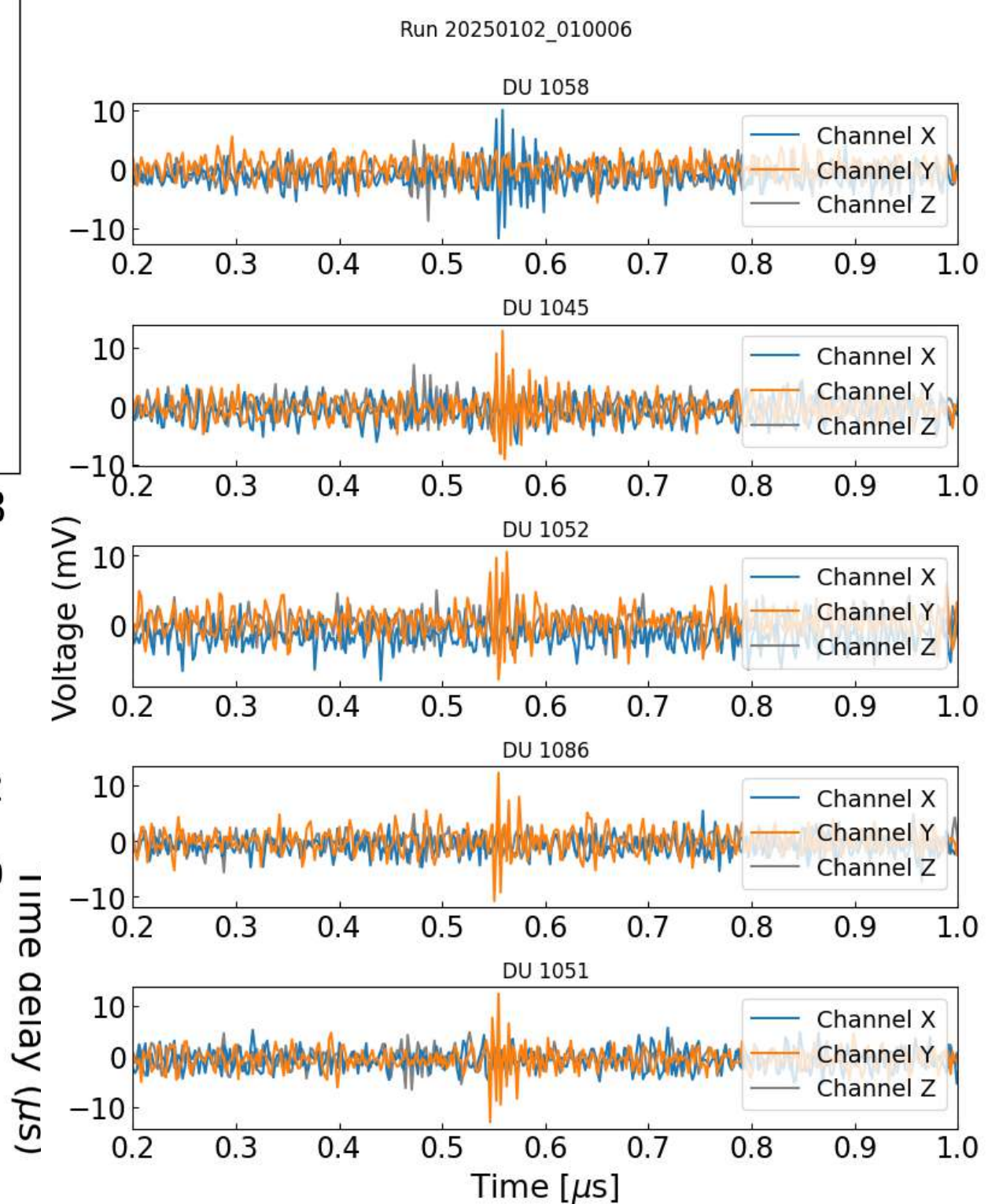


## Footprint



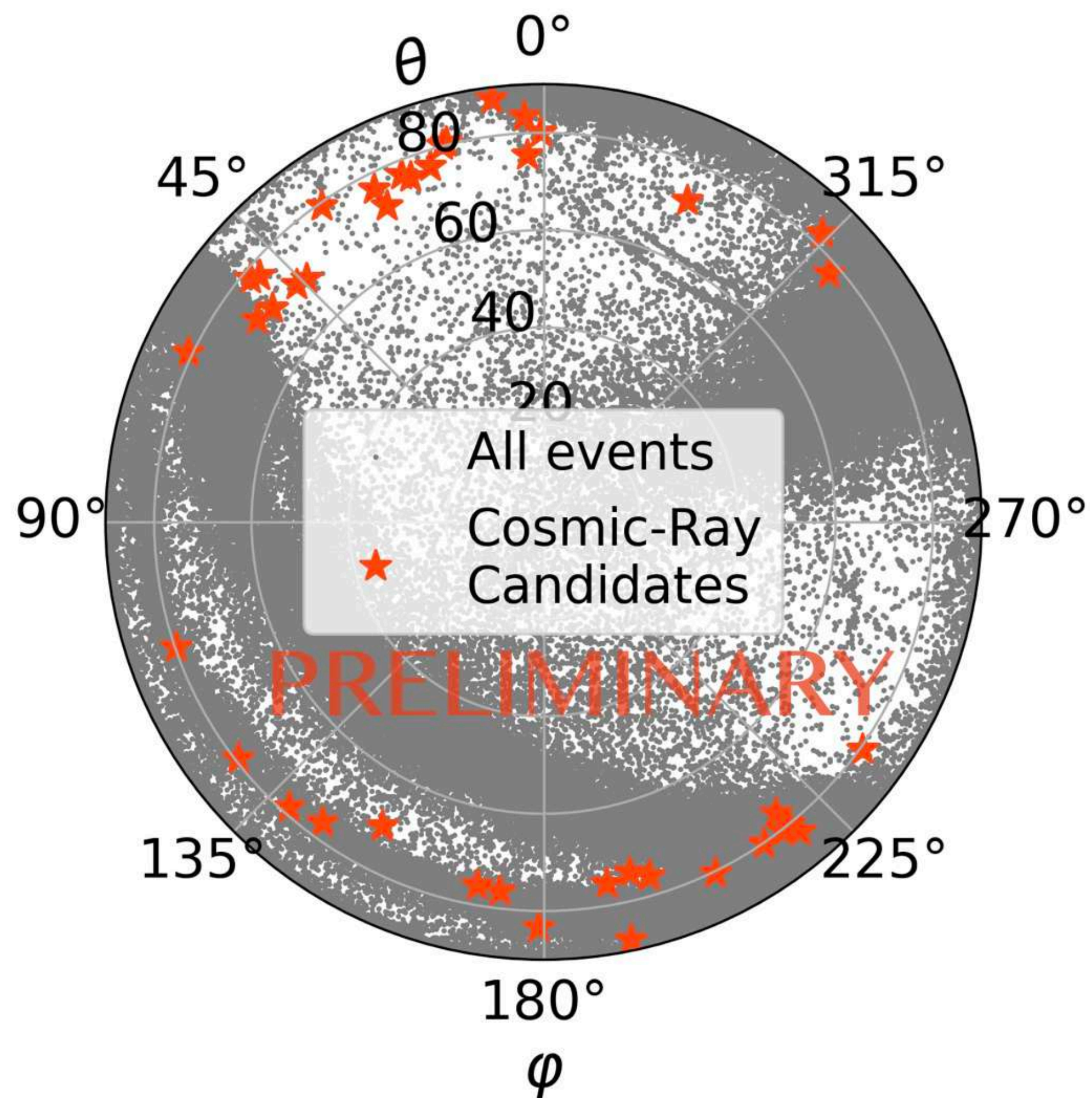
## **Noise event**

### Traces of triggered DUs



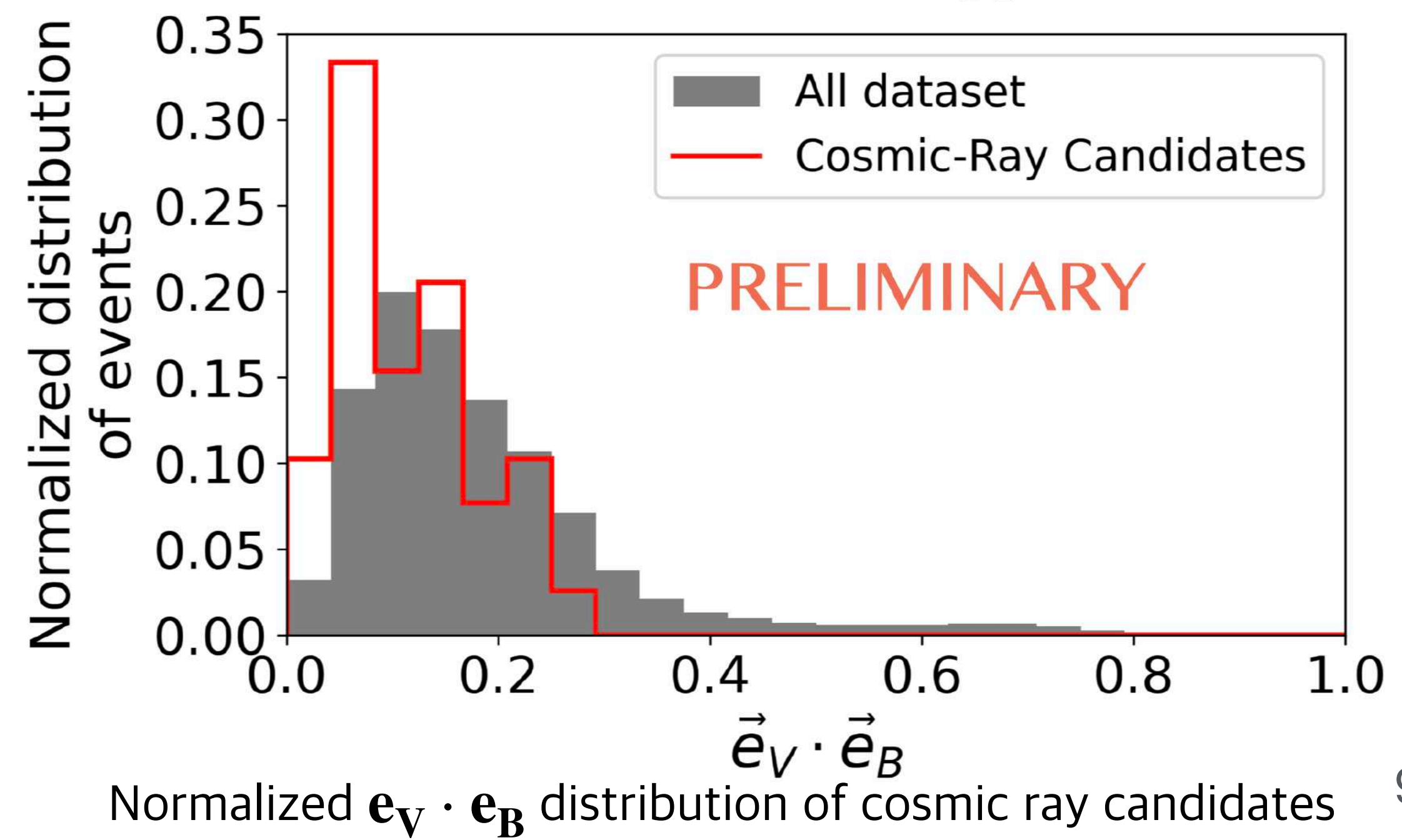
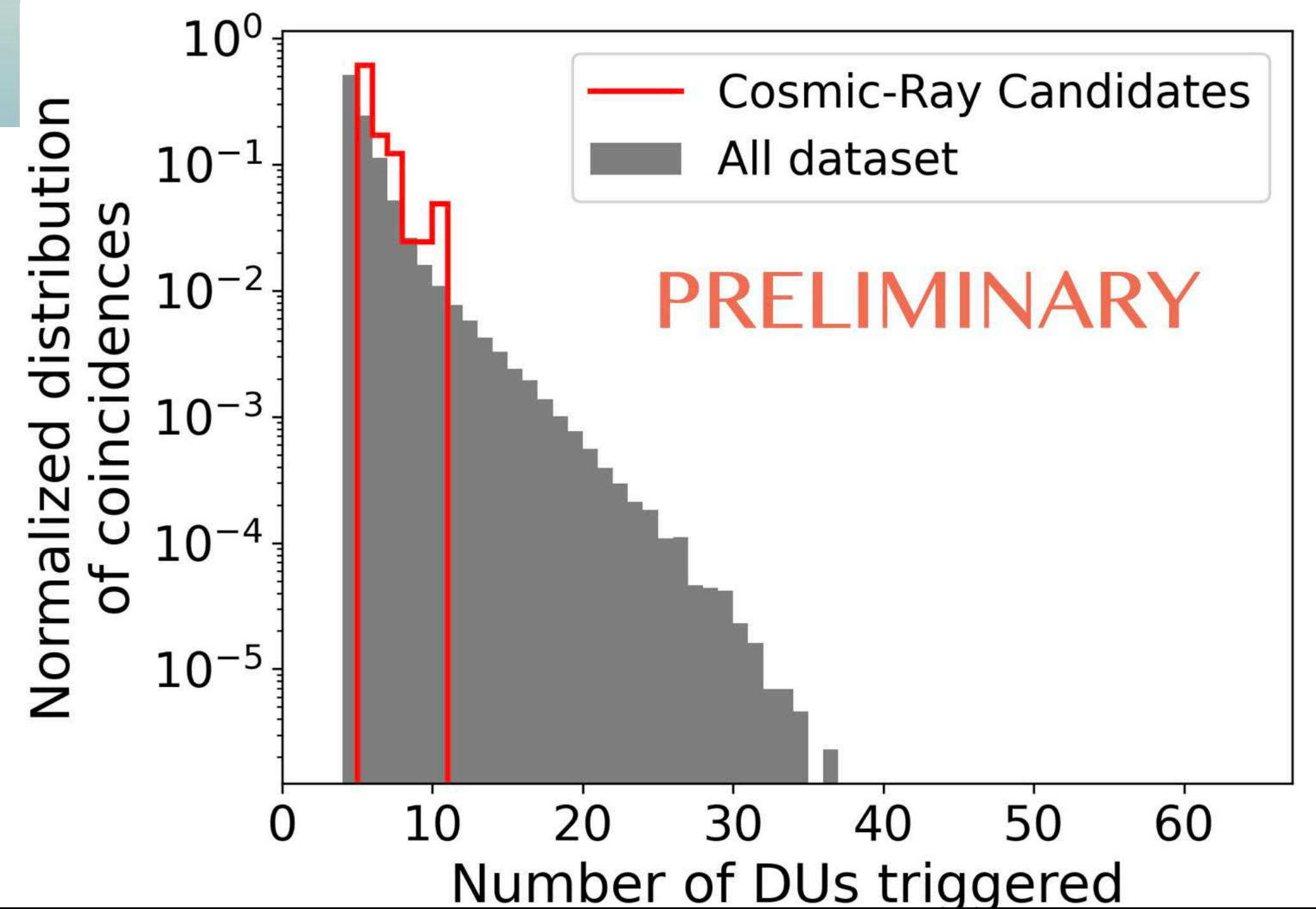
# Cosmic-Ray candidates

Result: 41 cosmic ray candidates with consistent physical signatures



Arrival direction of cosmic ray candidates

Normalized number of antennas for cosmic ray candidates

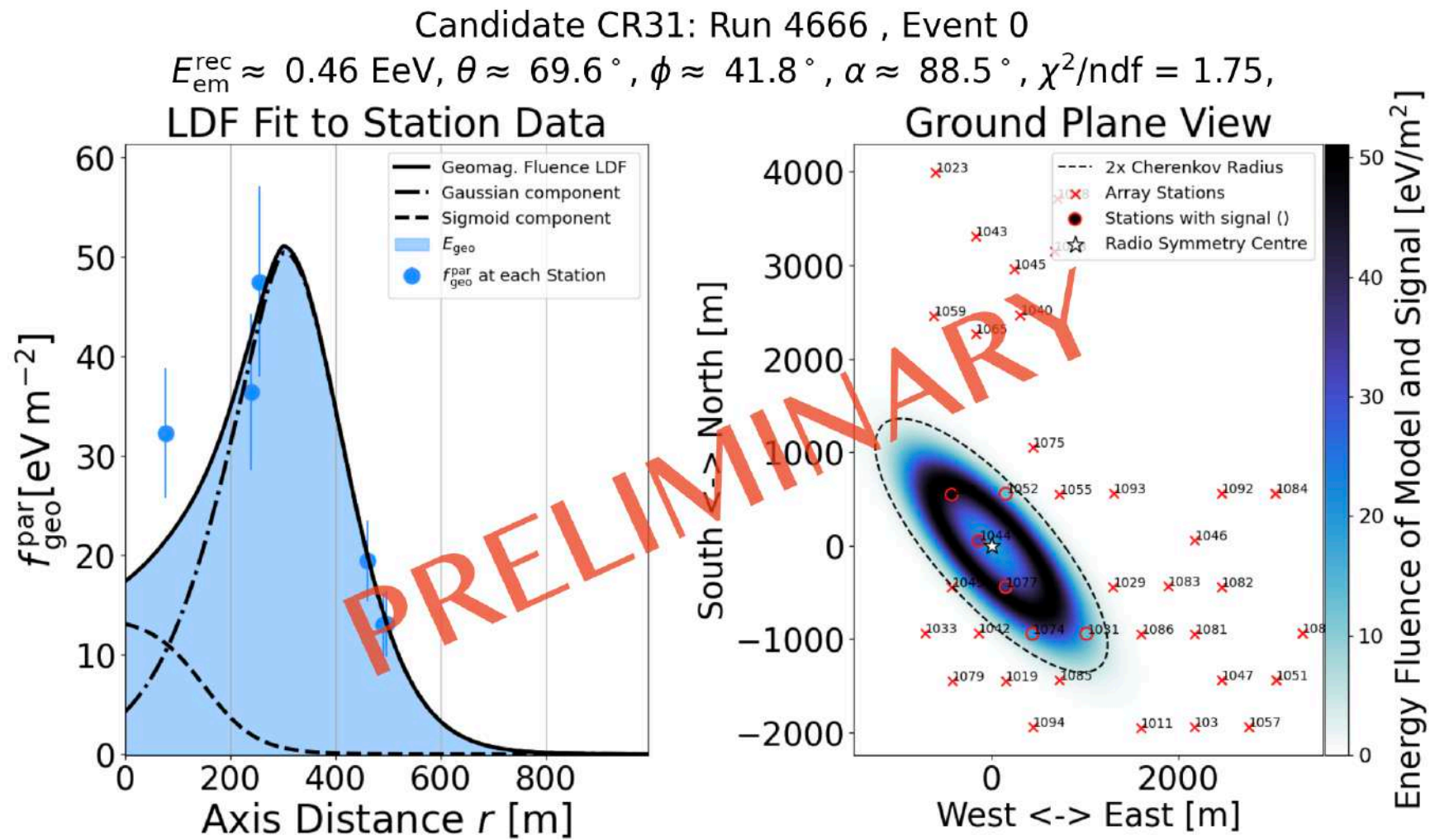


# Reconstruction as a quality cut

3 orthogonal reconstruction methods applied to cosmic-ray candidates

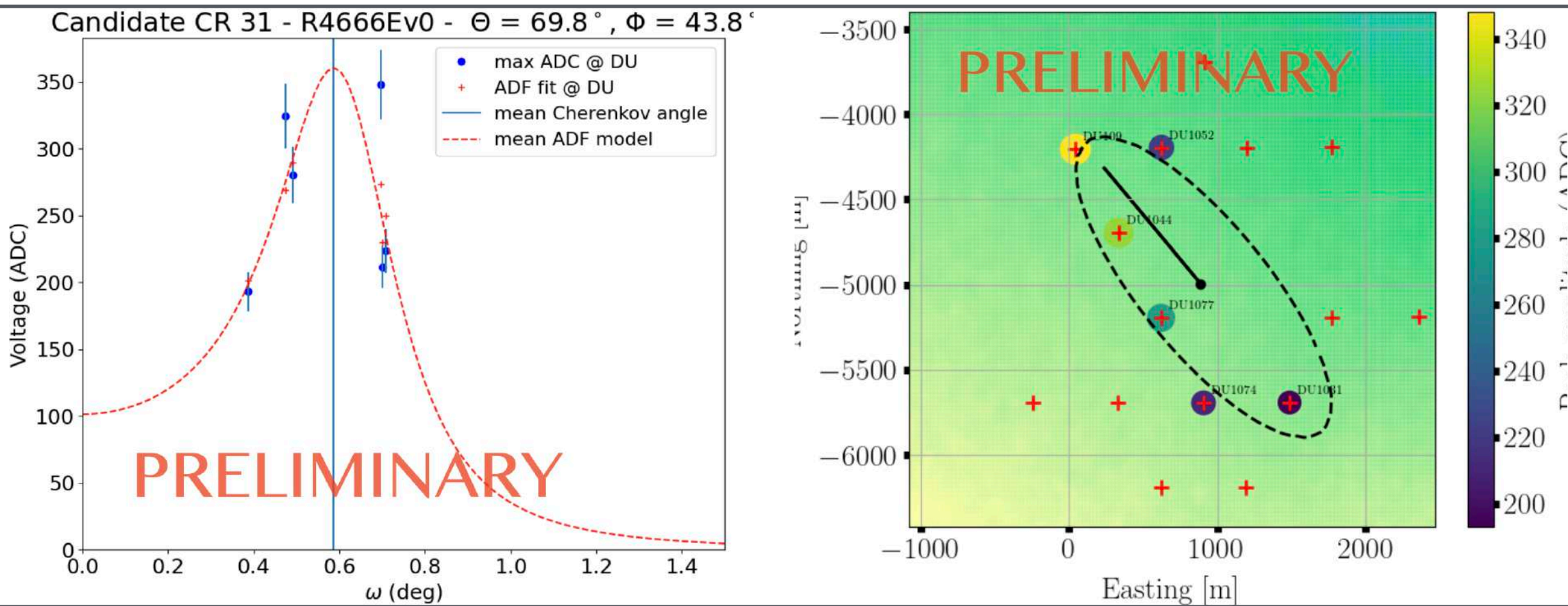
Electric field deconvolution + Lateral Distribution Fit (LDF)

K. Zhang  
PoS(ICRC2025)447  
L. Gülzow  
PoS(ICRC2025)283



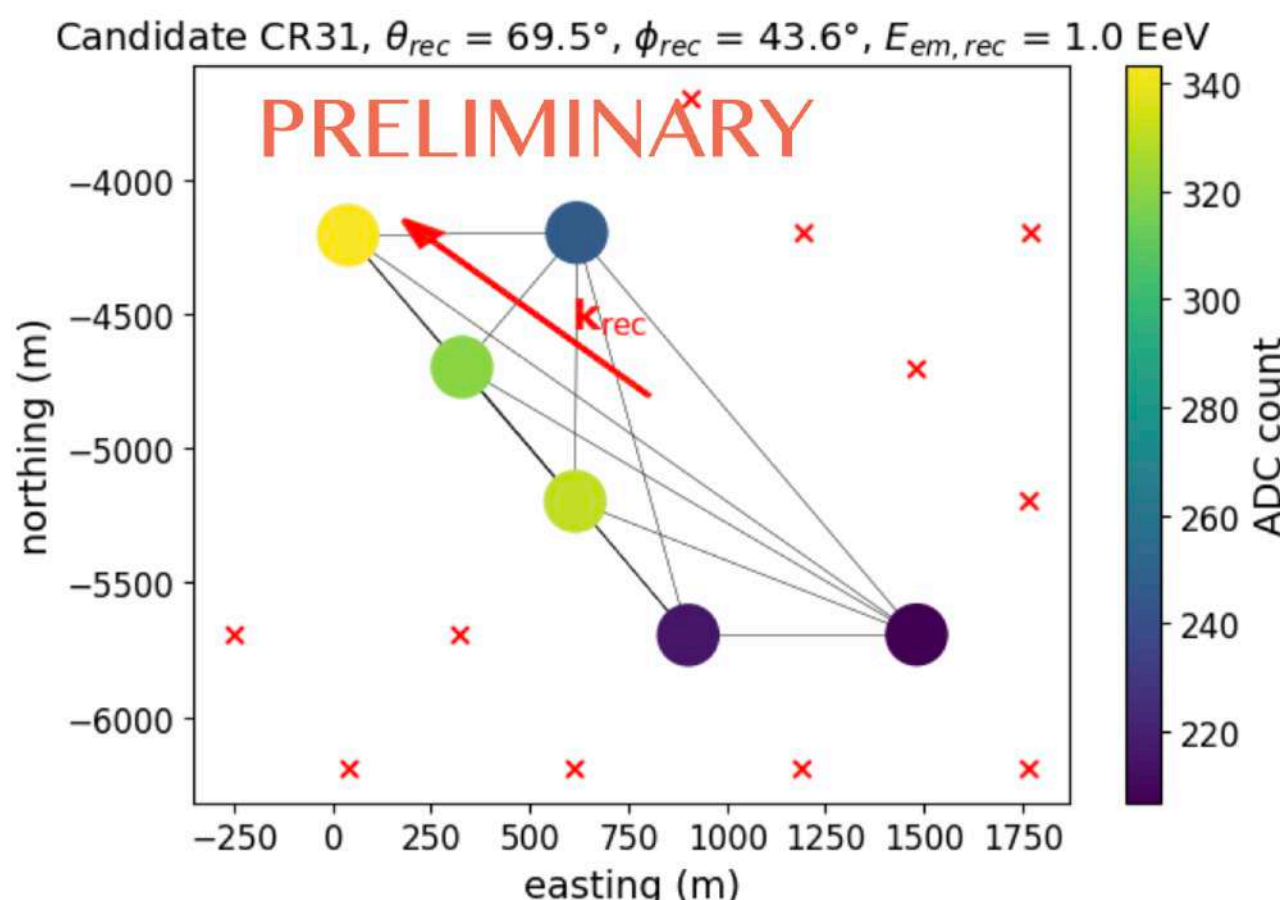
Angular Distribution Function (ADF)

M. Guelfand  
PoS(ICRC2025)278



Graph Neural Network (GNN)

A. Ferriere  
PoS(ICRC2025)253



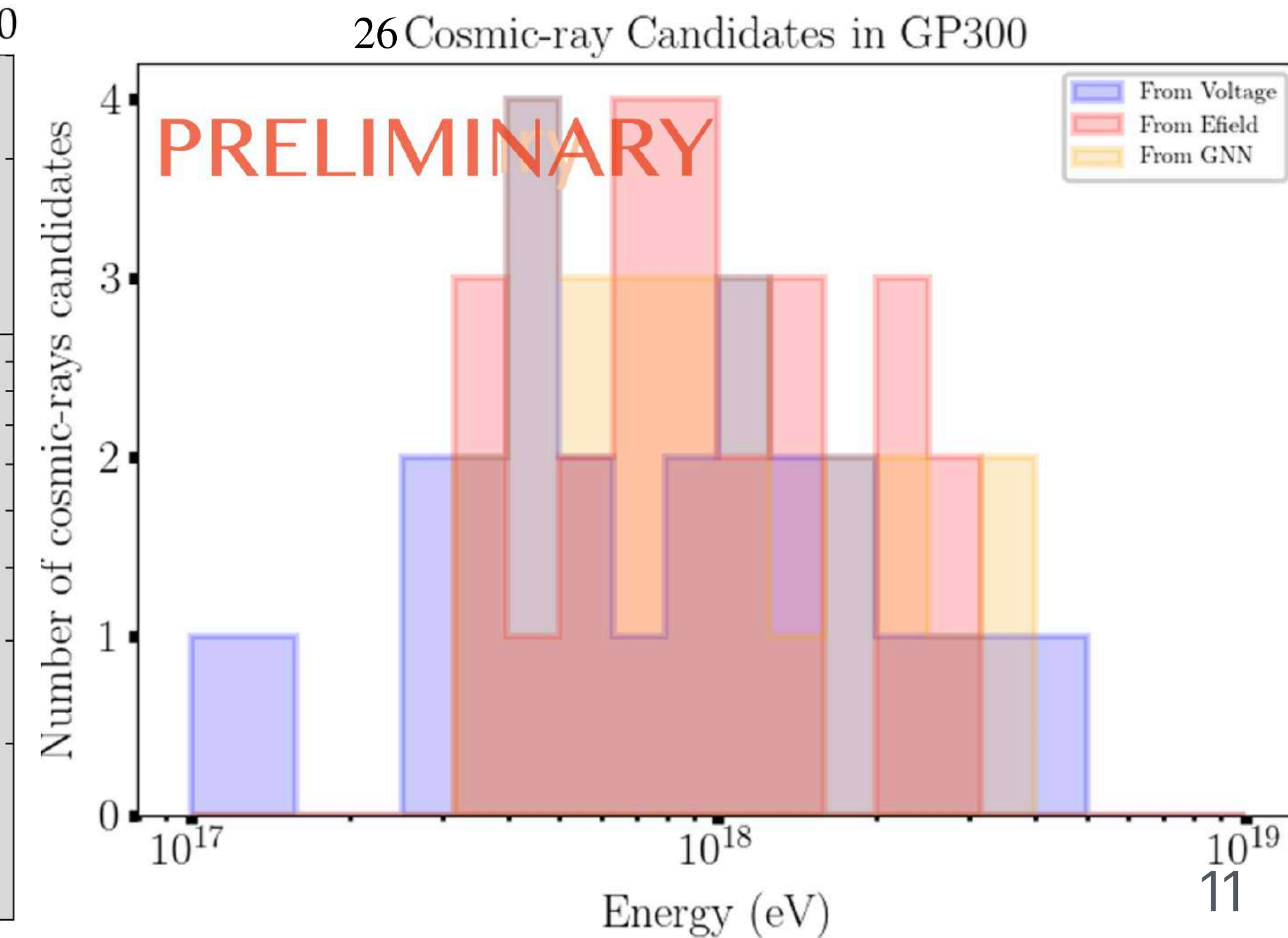
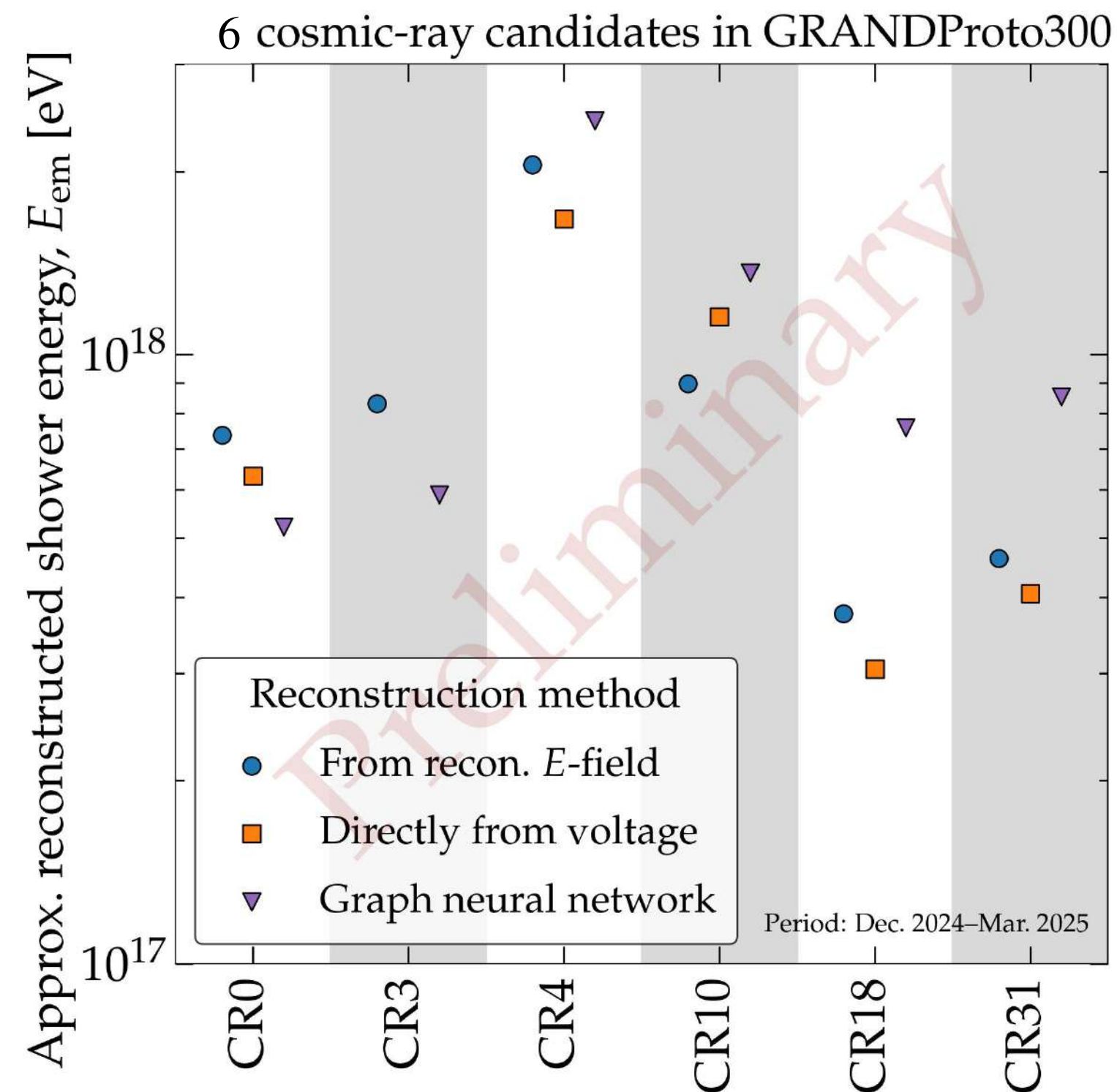
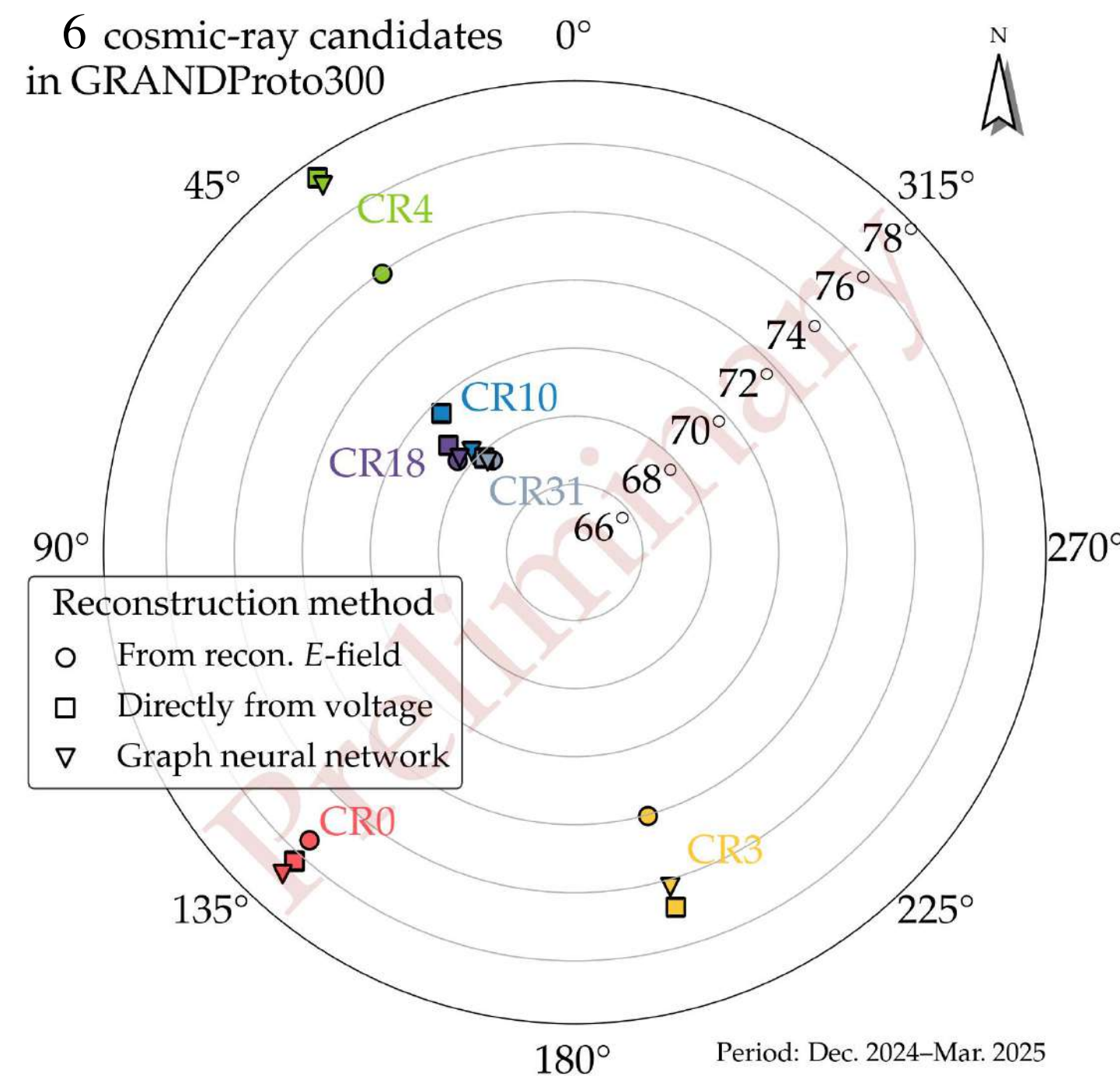
# 26 Reconstructed events

- 3 reconstruction methods provide consistent CR energy and arrival directions
- 26/41 well-reconstructed cosmic-ray candidates found over the analyzed period

Well-reconstructed:

- $\geq 5$  DUs with reconstructed E field
- reconstructed energy  $< 10^{20}$  eV
- ADF-associated  $\chi^2 < 25$

Caution: Preliminary search:  
Do not interpret distributions yet  
(numerous biases: quality of events,  
particular attention towards the North)



# Perspective



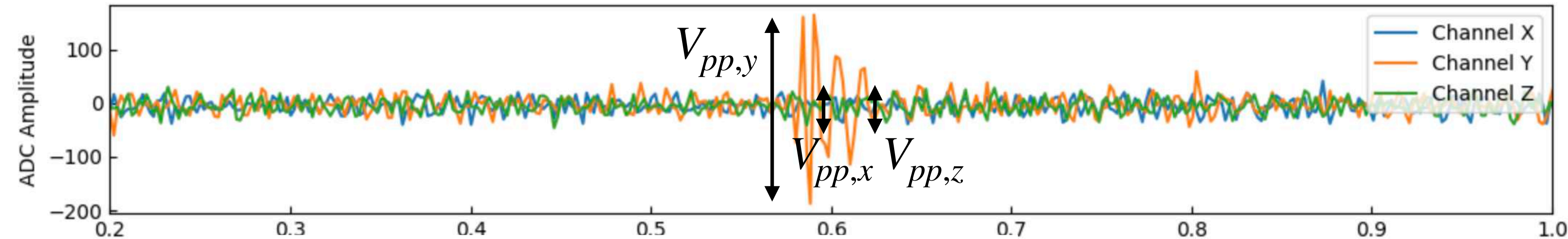
- Preliminary Cosmic-ray search conducted over 75 days of stable data taking with 36 antennas
- Simulations including RF chain and data match. We understand our environment & our setup.
- 26 Cosmic-Ray Candidates with energy  $\sim 2 \times 10^{17}$ - $3 \times 10^{18}$  eV have been detected in a preliminary search in the GP300 data.
- Reconstruction methods are consistent with each other and with physical expectations (energy and arrival direction). They provide additional reliability to the CR candidates.
- Need to optimize data taking, trigger, and CR identification pipeline. Then we will compute our efficiency and deliver a spectrum
- Currently: 65 antennas taking data stably. GP300 to be completed in 2026.
- Stay tuned for more cosmic ray events and science!

**Science**

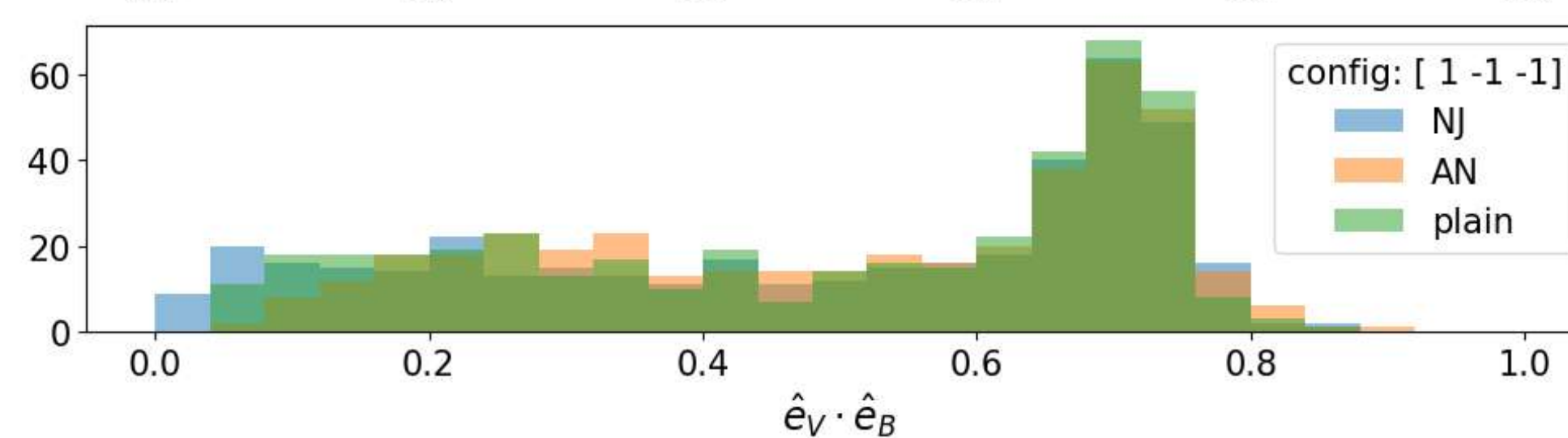
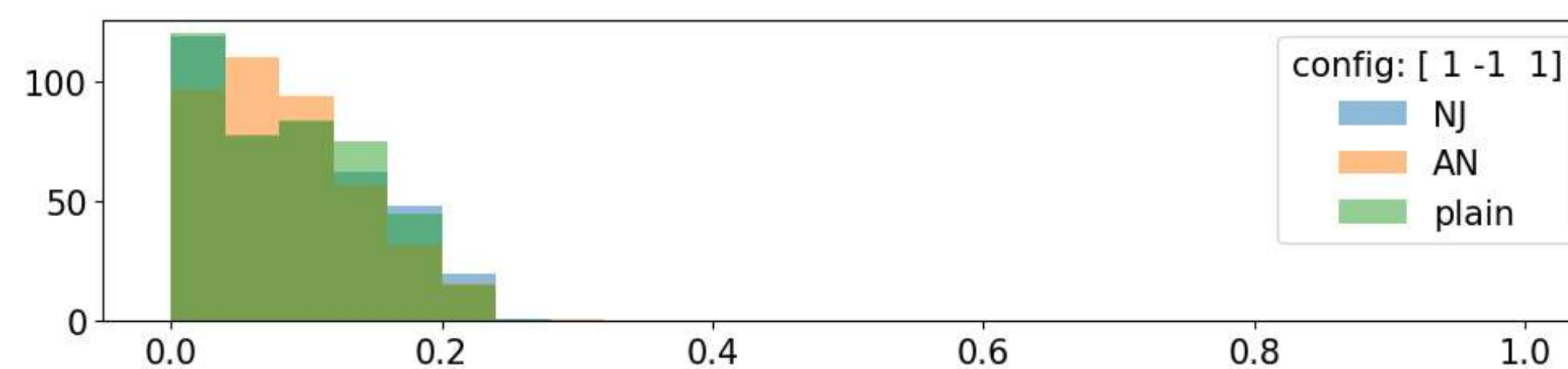
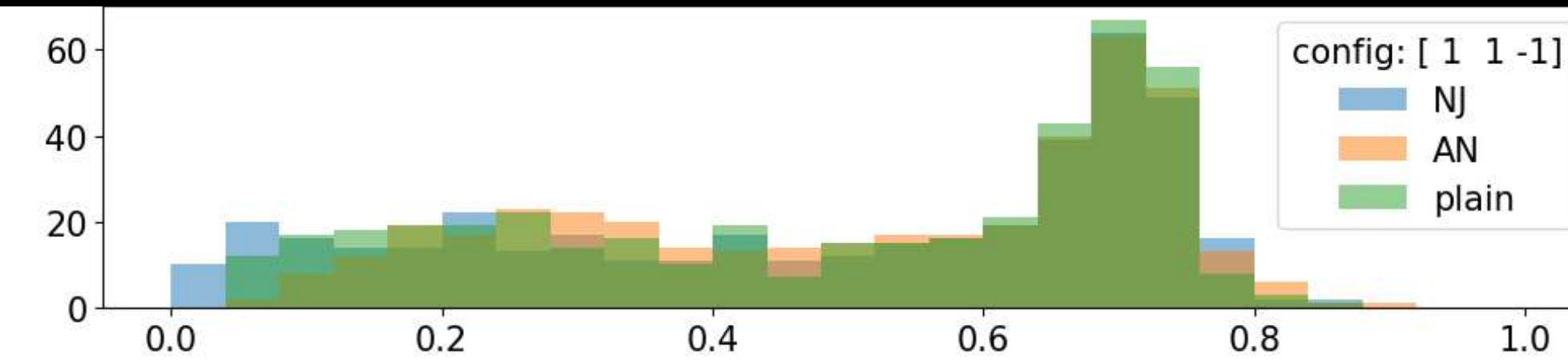
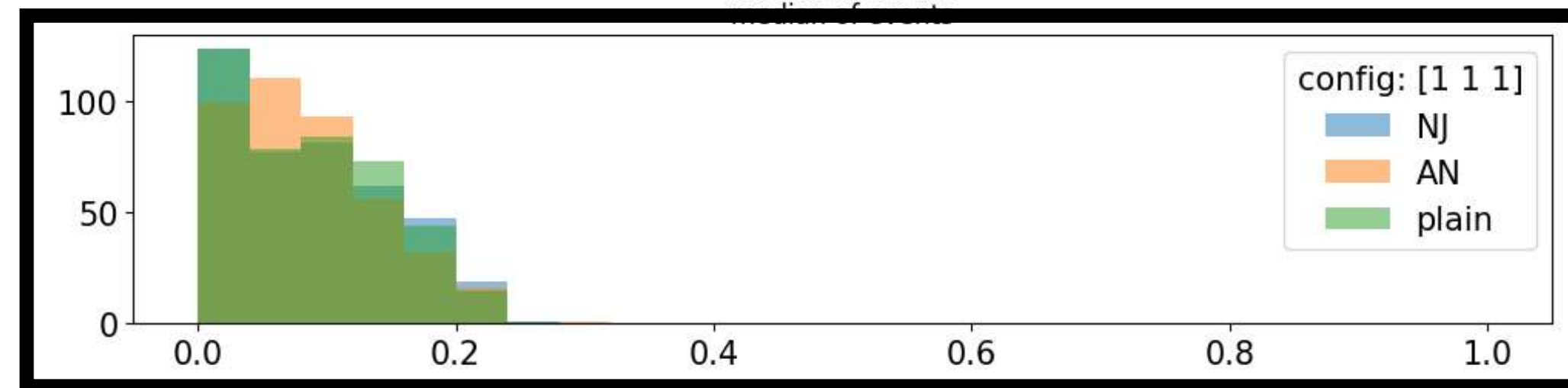
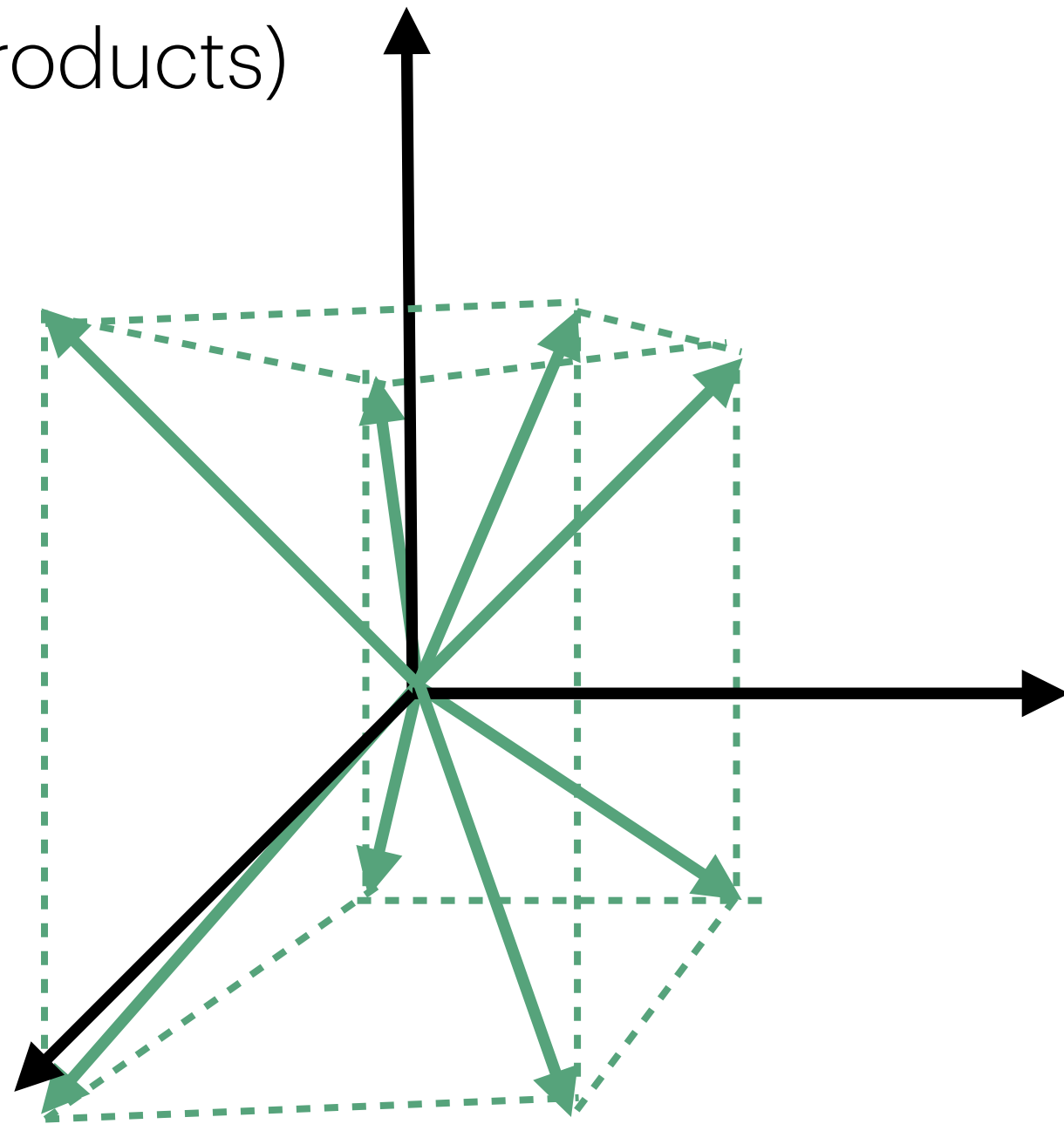
**Science News,** 12  
**Aug. 2025**

# Backup slides

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



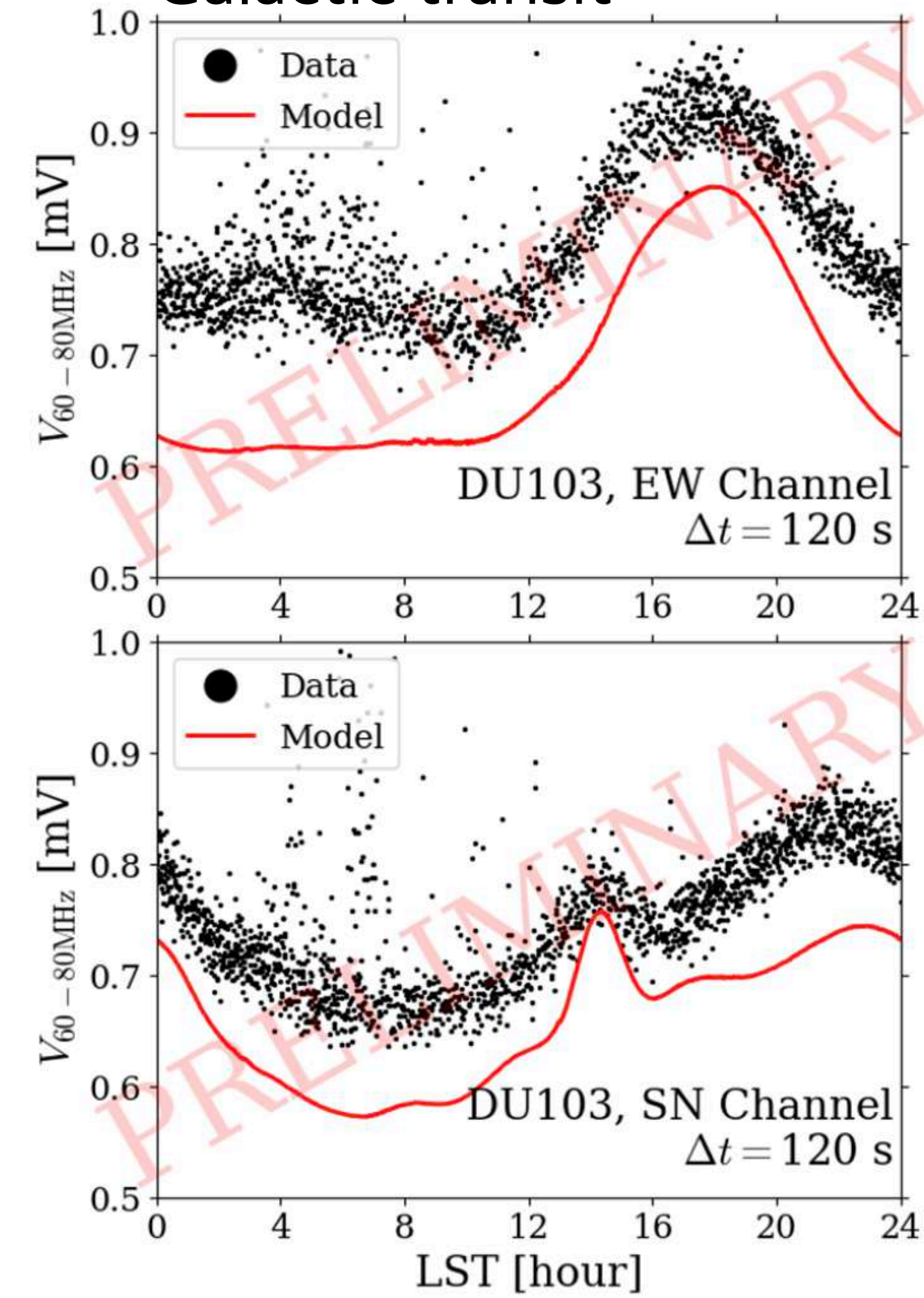
Orientation: 8 possibilities, but really 4 (looking at scalar products)



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

# Backup slides

## Galactic transit



## Trigger algorithm

