



DFG anr[®]
NUTRIG

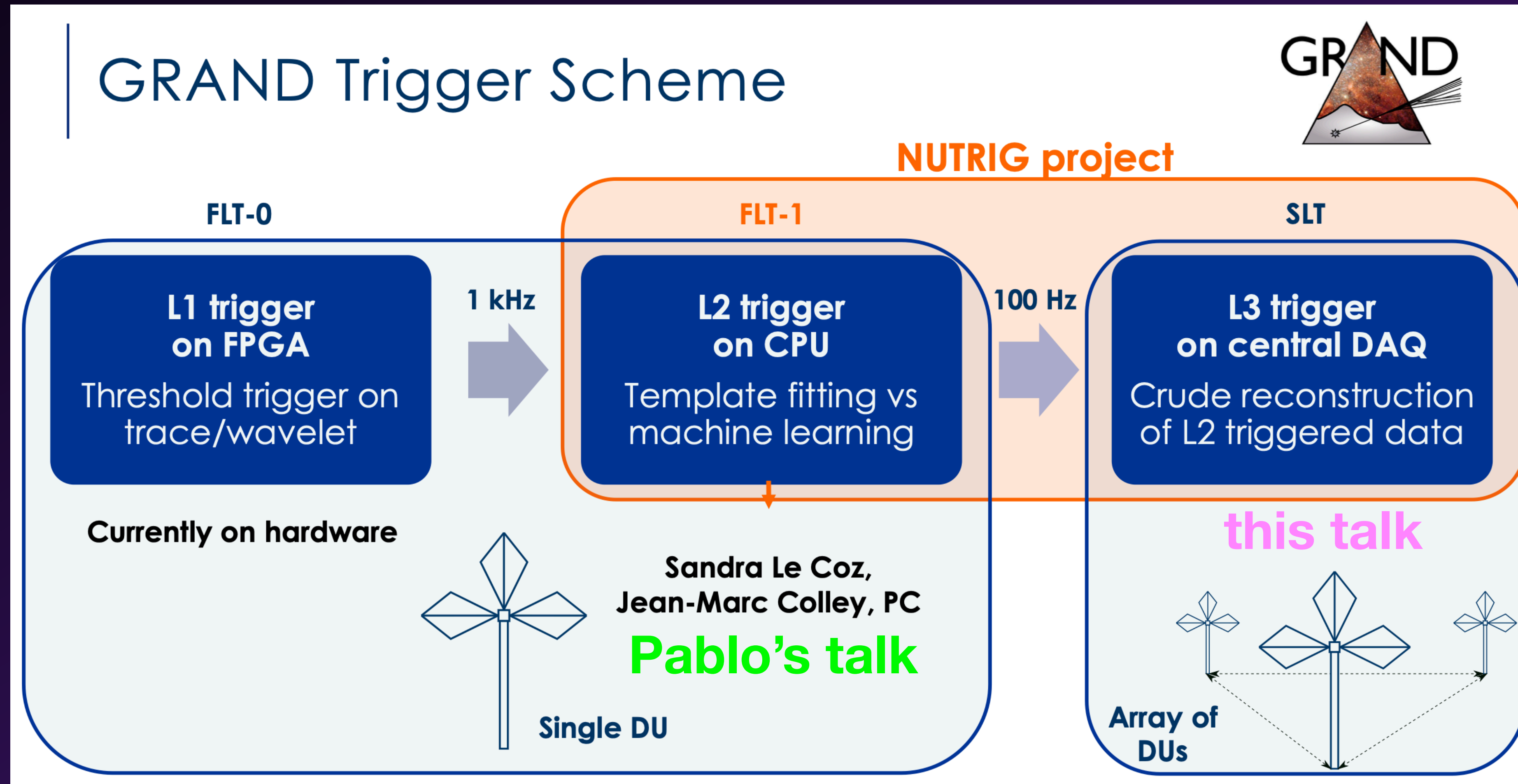
Next-Generation Triggering: A Novel Event-Level Approach

Jelena Köhler for the GRAND collaboration
Karlsruhe Institute of Technology

10th International Workshop on Acoustic and Radio EeV Neutrino Detection Activities (ARENA)

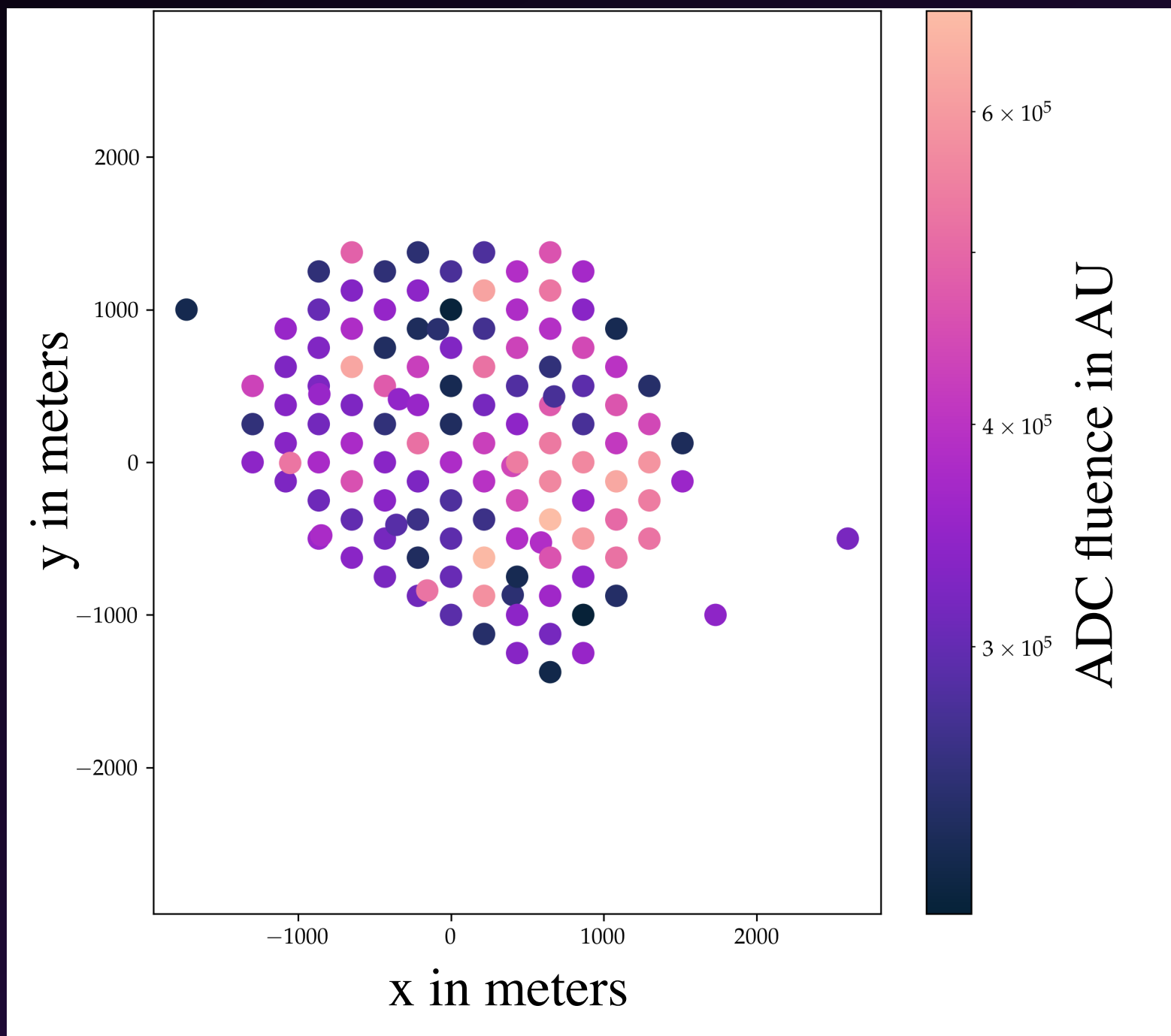
The GRAND Challenge

Autonomous Triggering

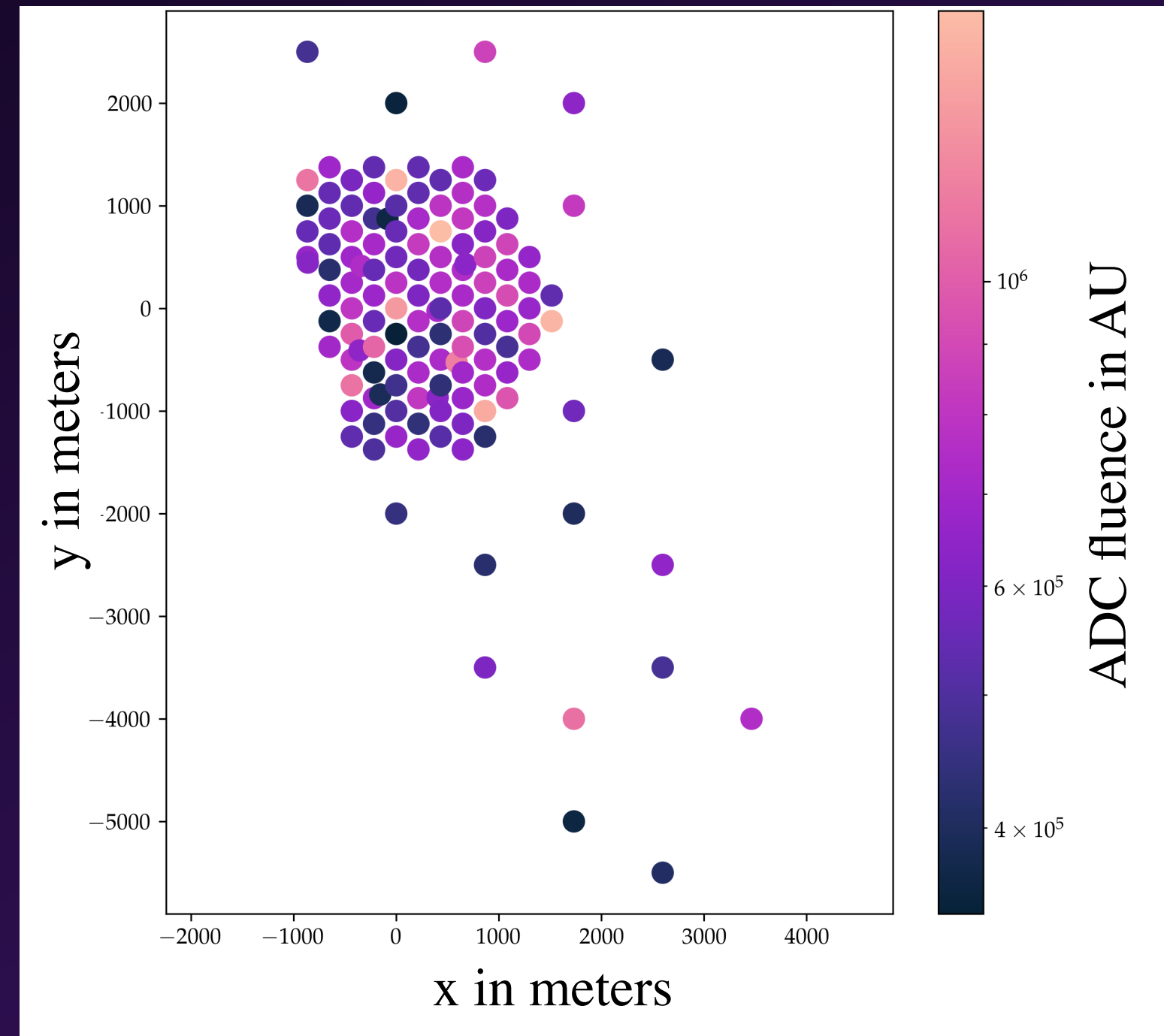


Event Level Trigger Method

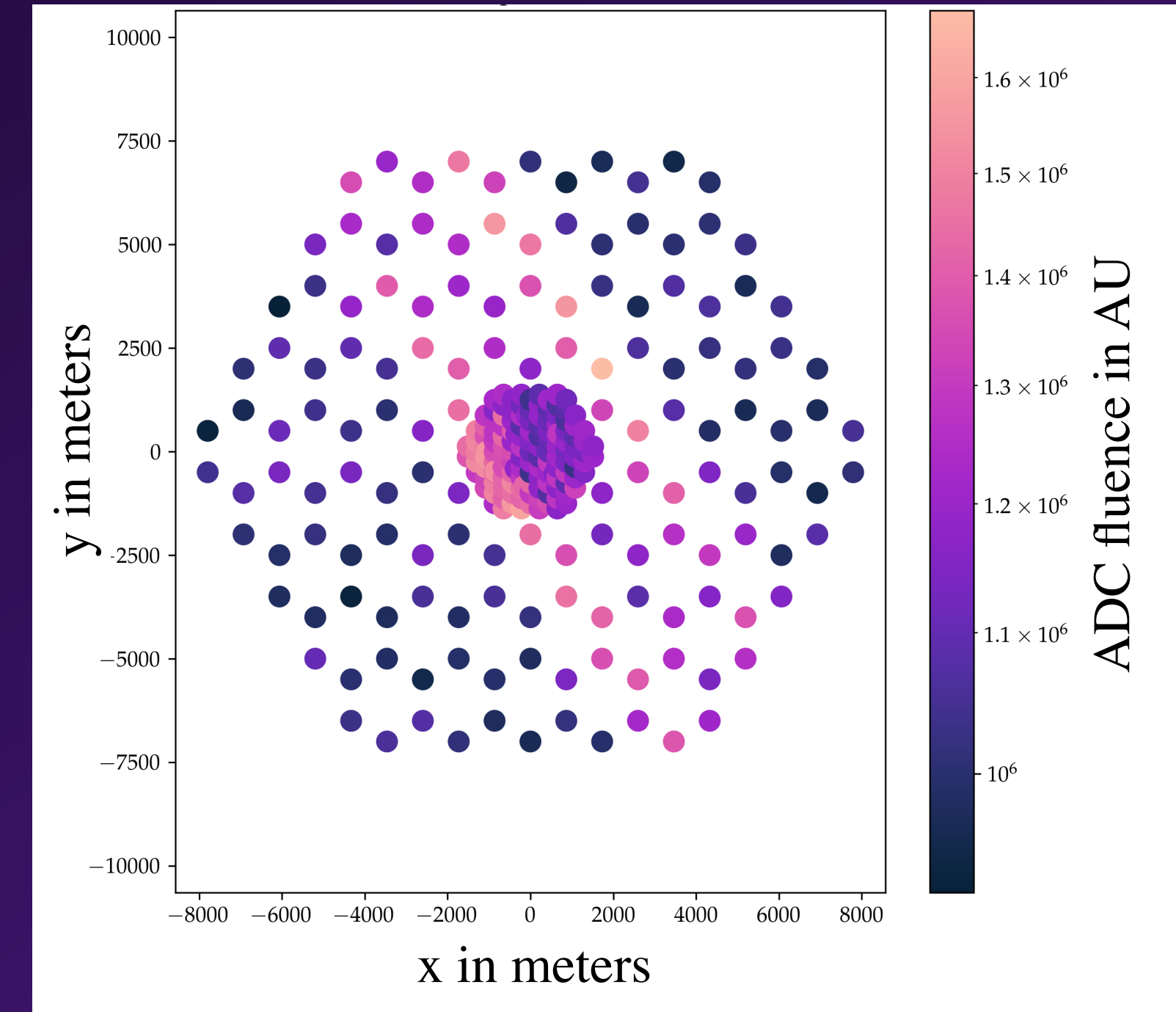
Improve and/or validate event classification using 2 methods



$$\theta = 64^\circ$$



$$\theta = 69^\circ$$

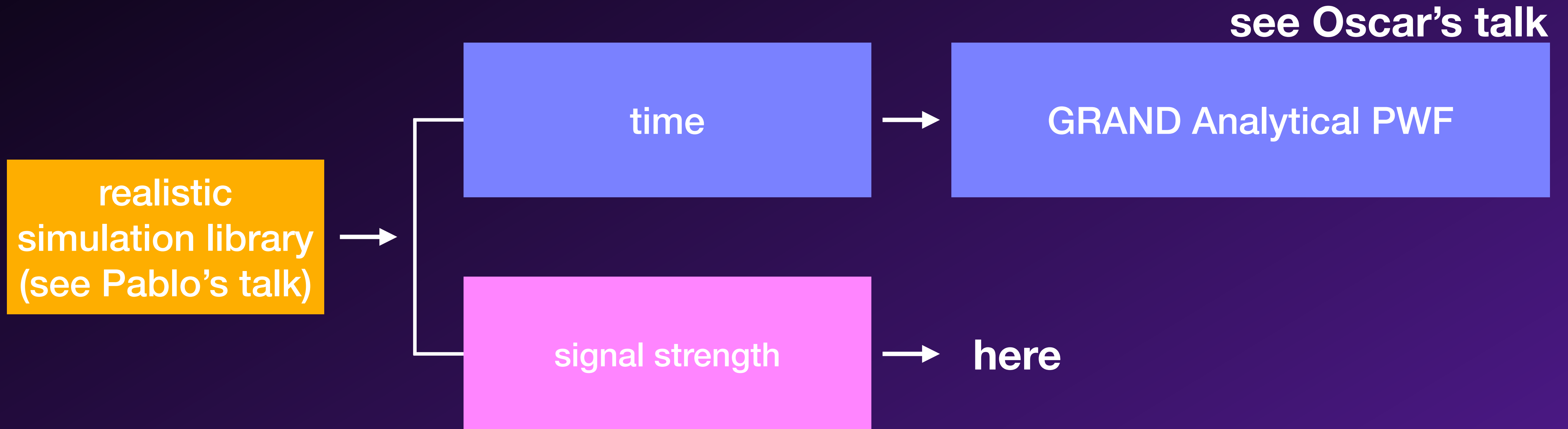


$$\theta = 86^\circ$$

“ADC fluence” in ground plane \rightarrow 1 pixel = 1 antenna

Event Level Trigger Method

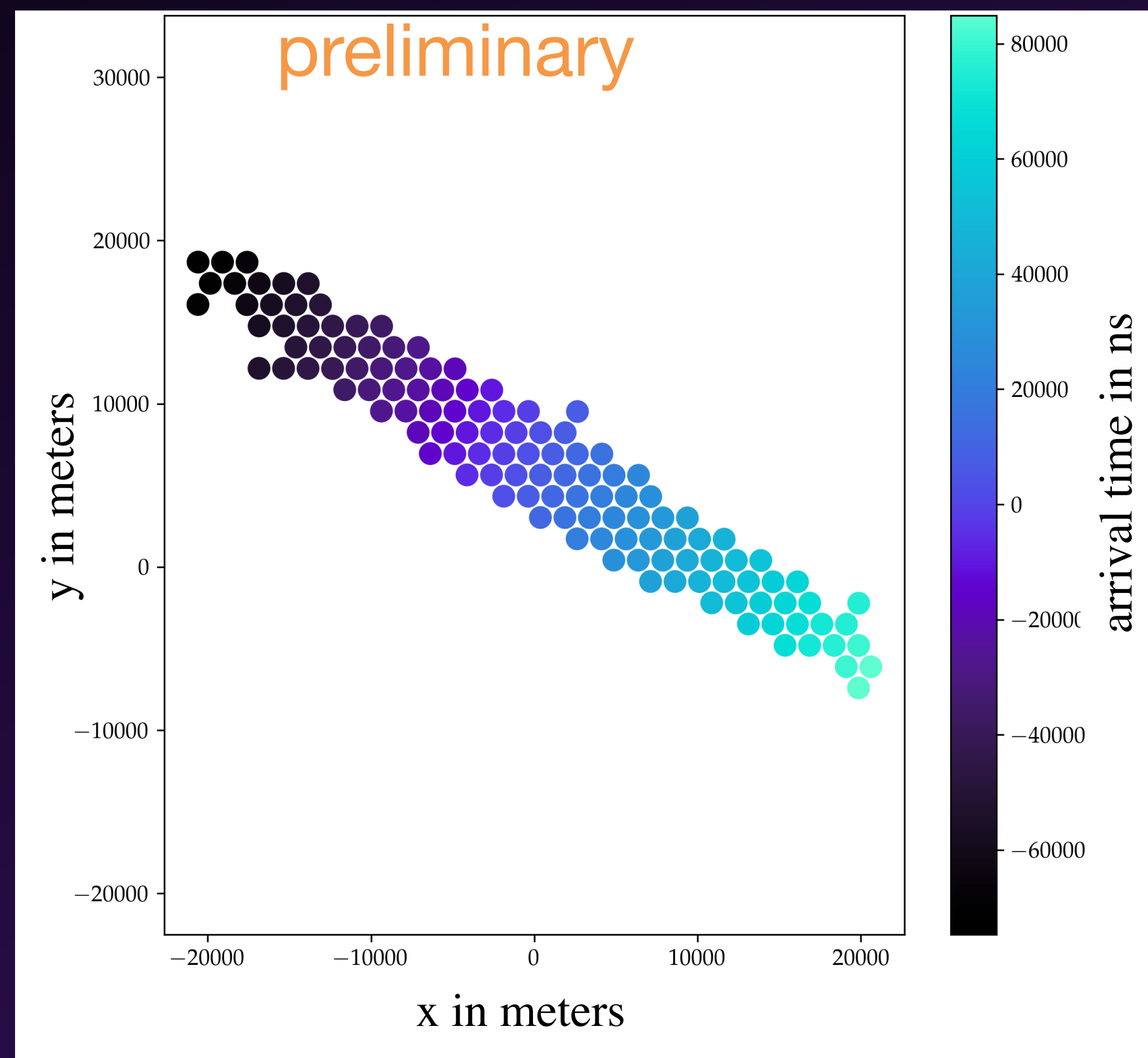
Improve and/or validate event classification using 2 methods



Method 1

Reconstruction of Trigger Parameters with timing

★ signal arrival times \rightarrow Plane Wave Fit $\rightarrow \theta_{reco}, \varphi_{reco}$

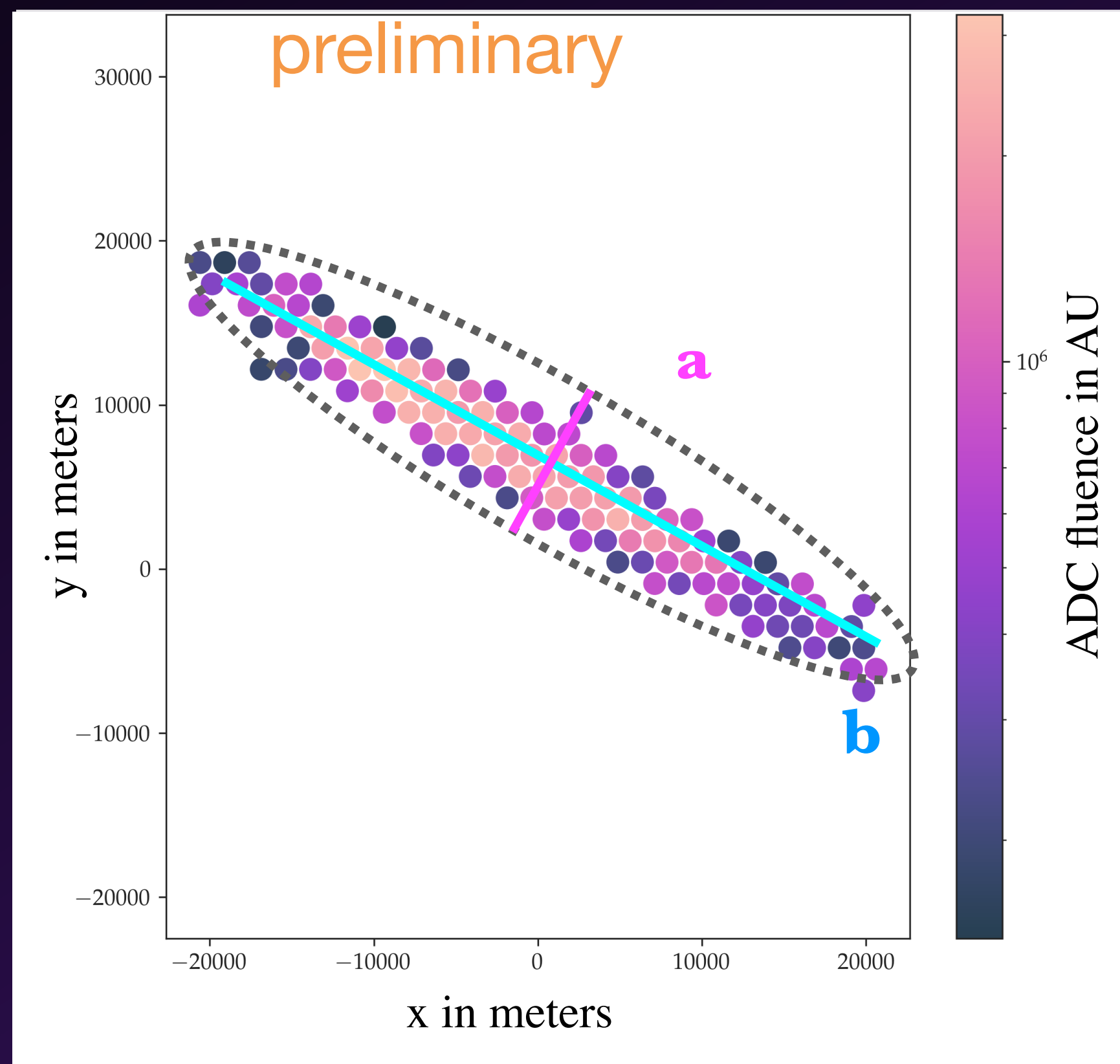


- ★ approximates curved wavefront with a flat plane
- ★ orientation of best-fit plane determines zenith and azimuth

Method 2

Reconstruction of Trigger Parameters with signal strength

★ measured signal strength \rightarrow a & b $\rightarrow \theta_{fit}, \varphi_{fit}$

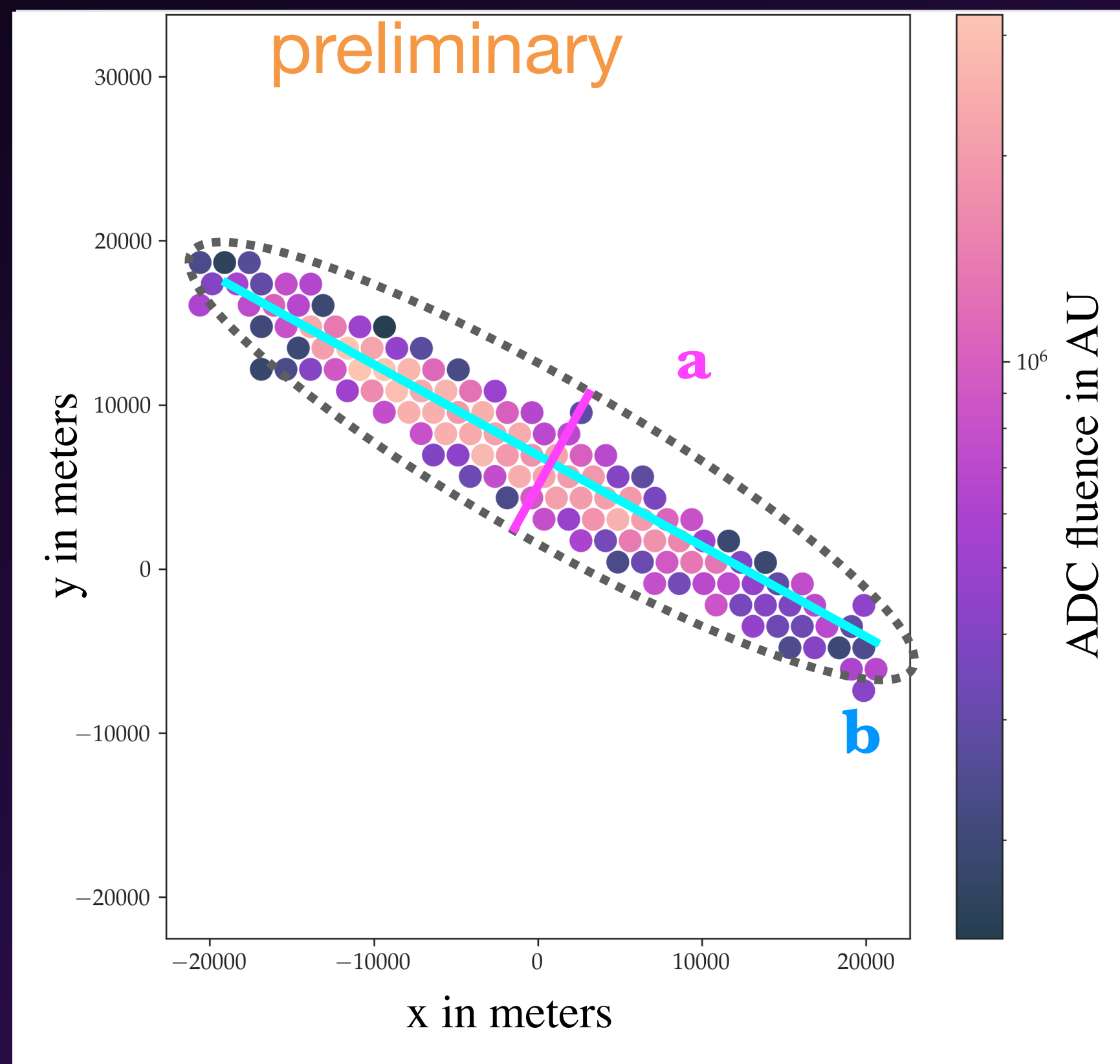


- ★ θ_{fit} : from **eccentricity** of ellipse
 \rightarrow based on conic section model of air shower
- ★ φ_{fit} : from **orientation** of ellipse
 \rightarrow introduces 180° ambiguity

Method 2

Reconstruction of Trigger Parameters with signal strength

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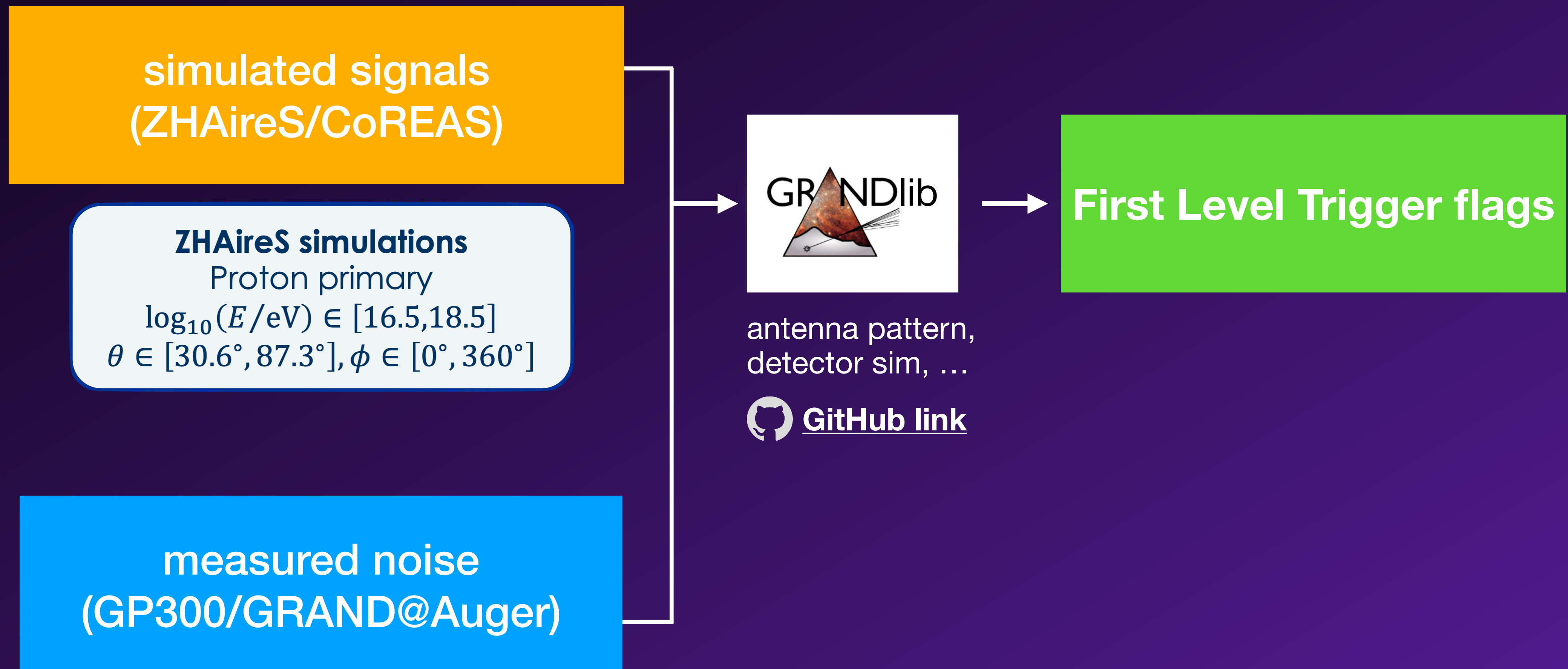
compare to timing method
 \Rightarrow if the values match, trigger

Simulation Analysis



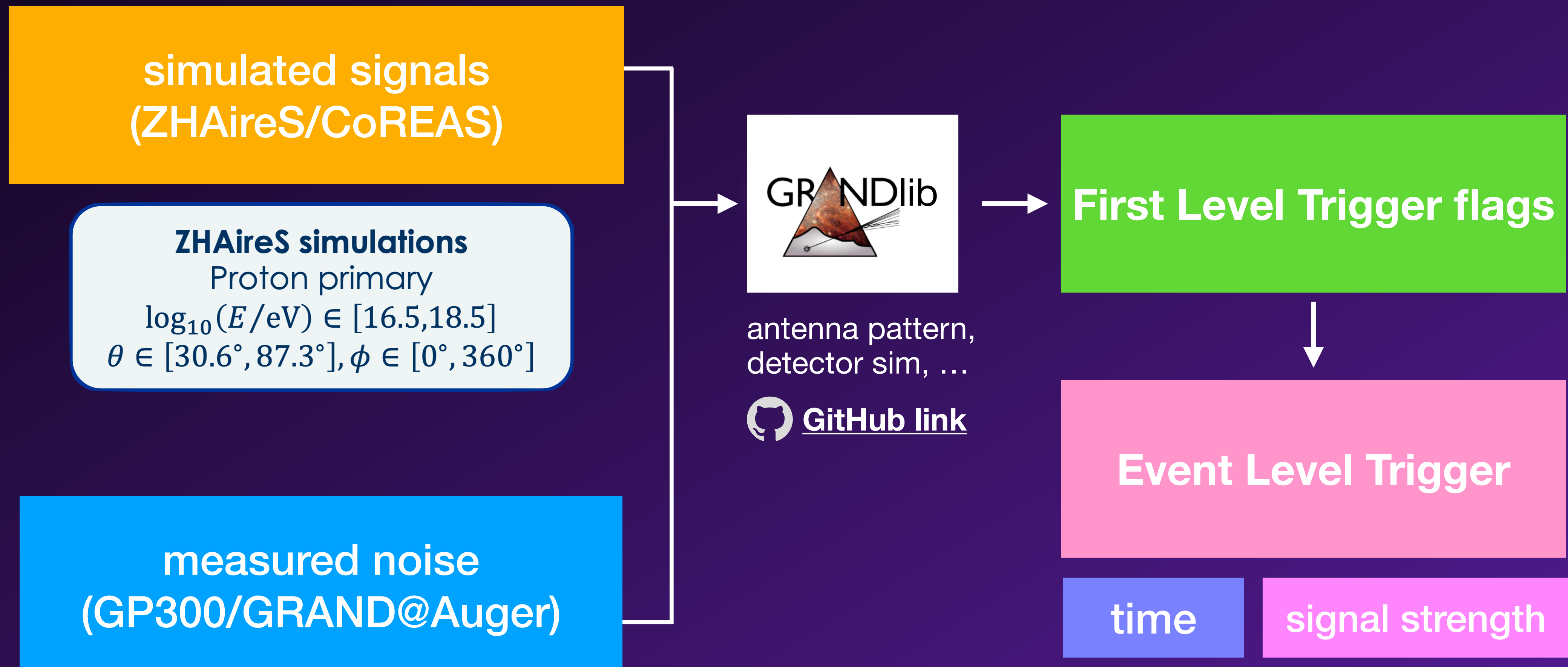
Realistic Simulated Signal With Measured Noise

based on GRAND's Data Challenge 2 (realistic simulation library) - **Oscar's talk**
+ more sophisticated noise selection - **Pablo's talk**



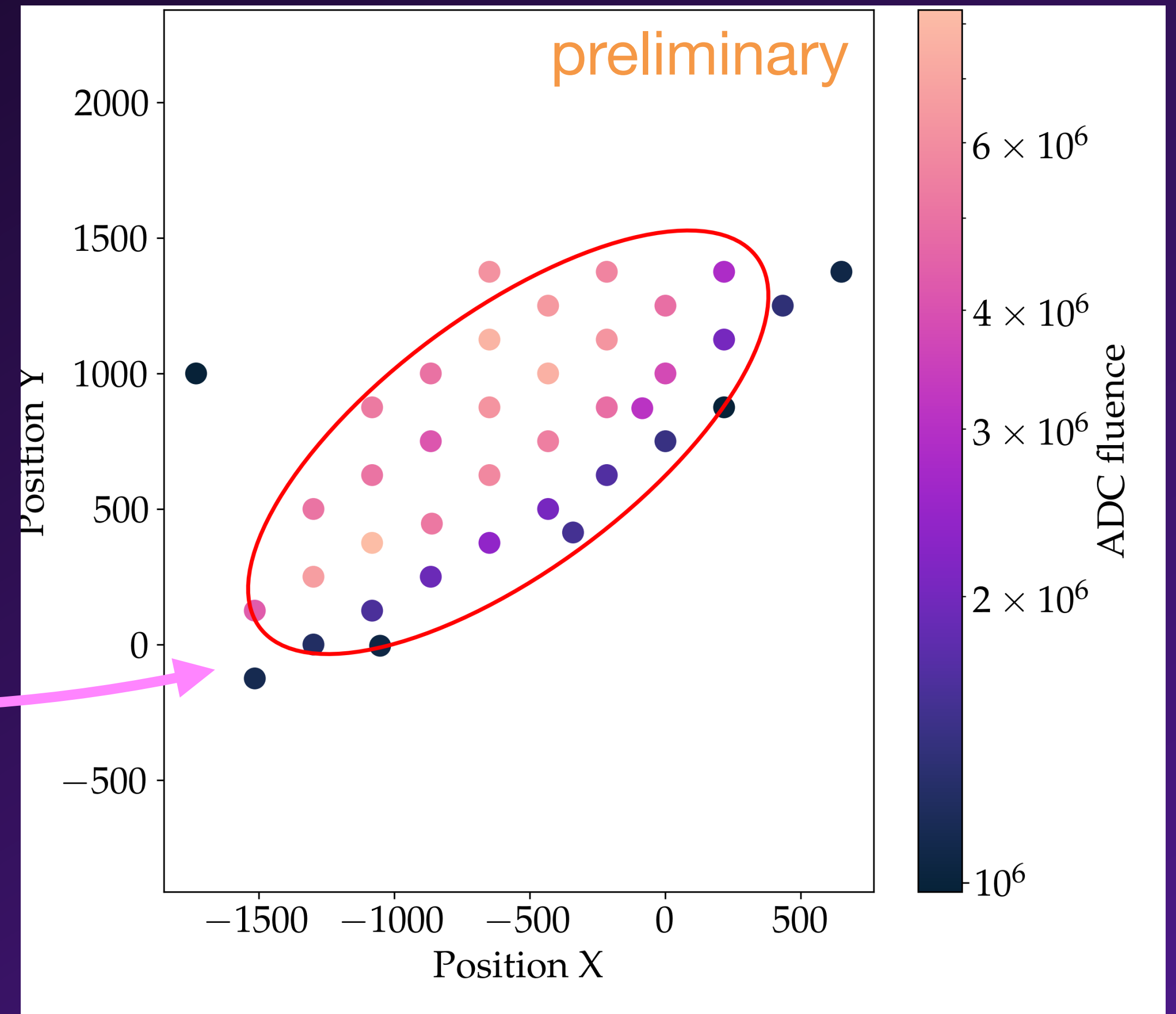
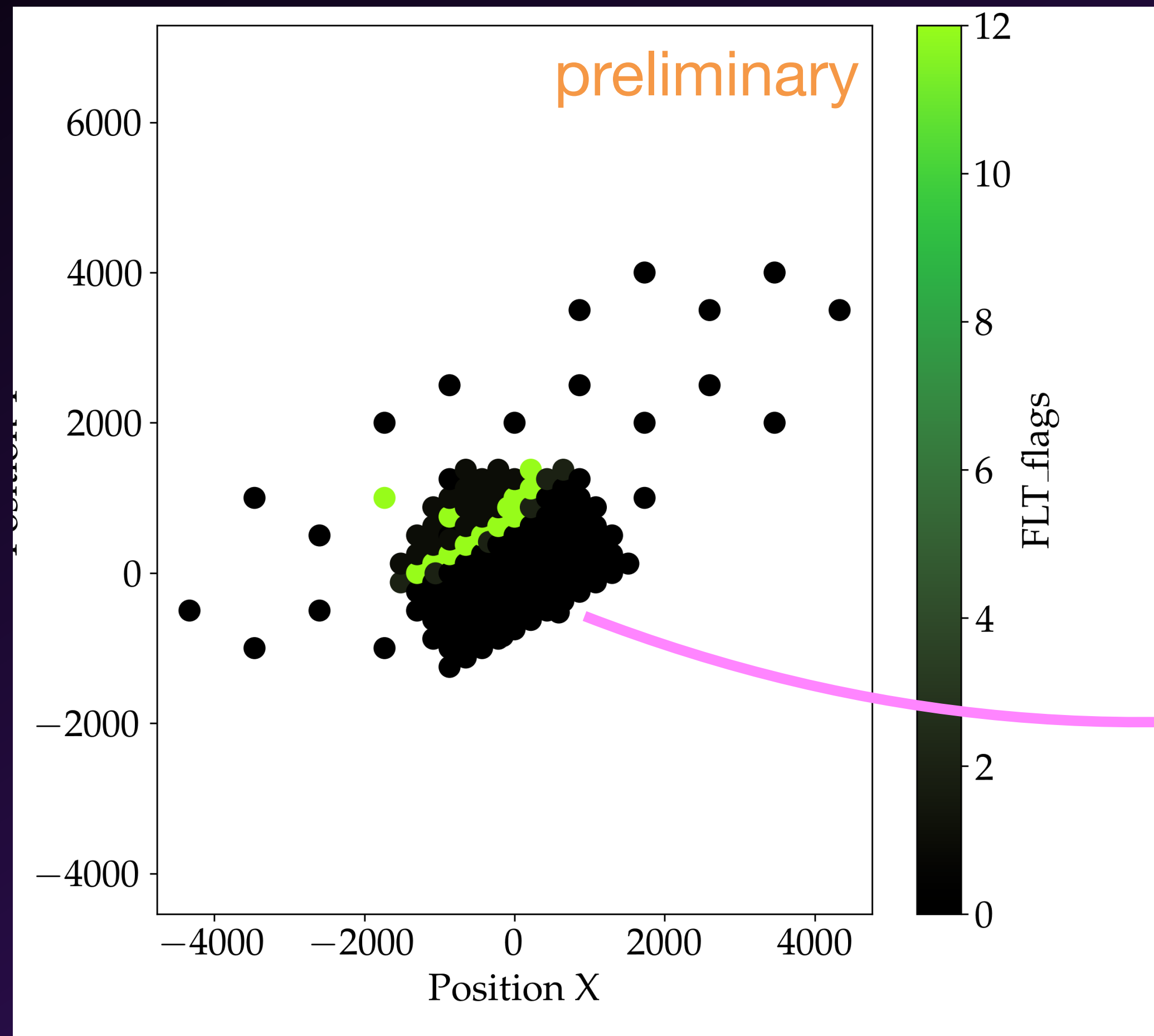
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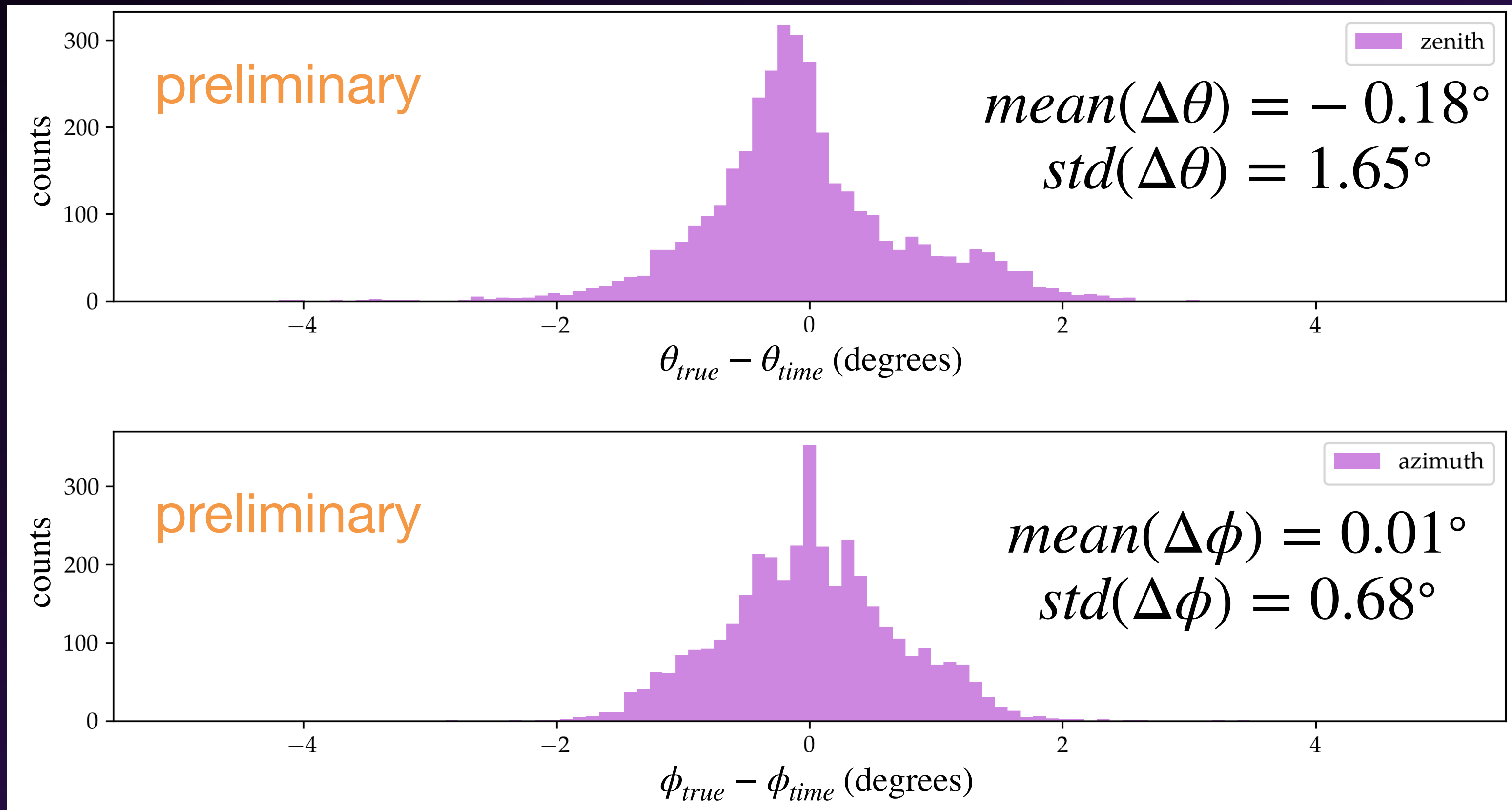
Simulated Signal + Measured Noise

~7k events



Method 1: Timing

~7k events



★ Plane Wave Fit

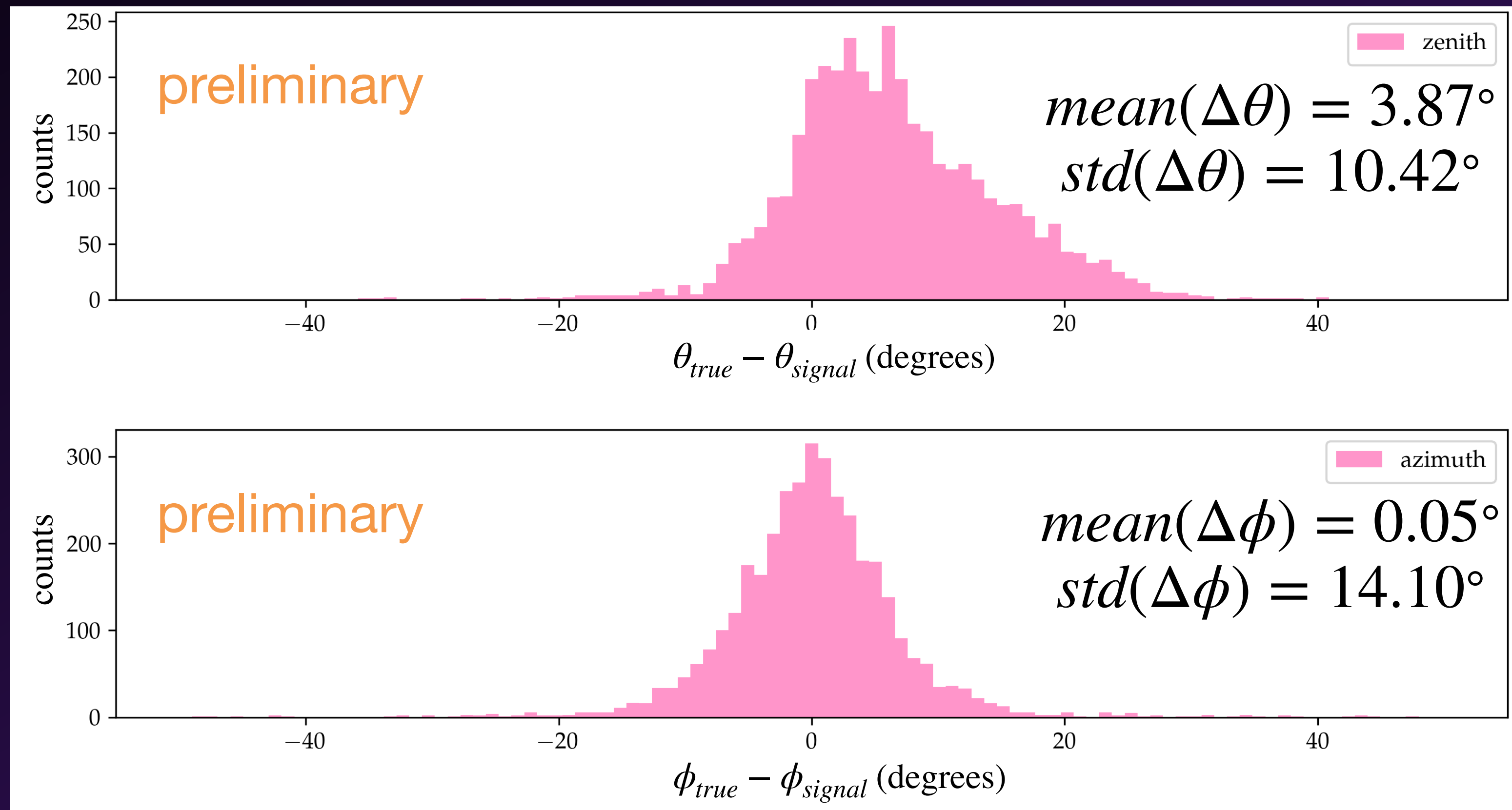
★ sophisticated analytical method including errors

★ **sub degree resolution**



Method 2: Signal Strength \Rightarrow completely independent of PWF

~7k events



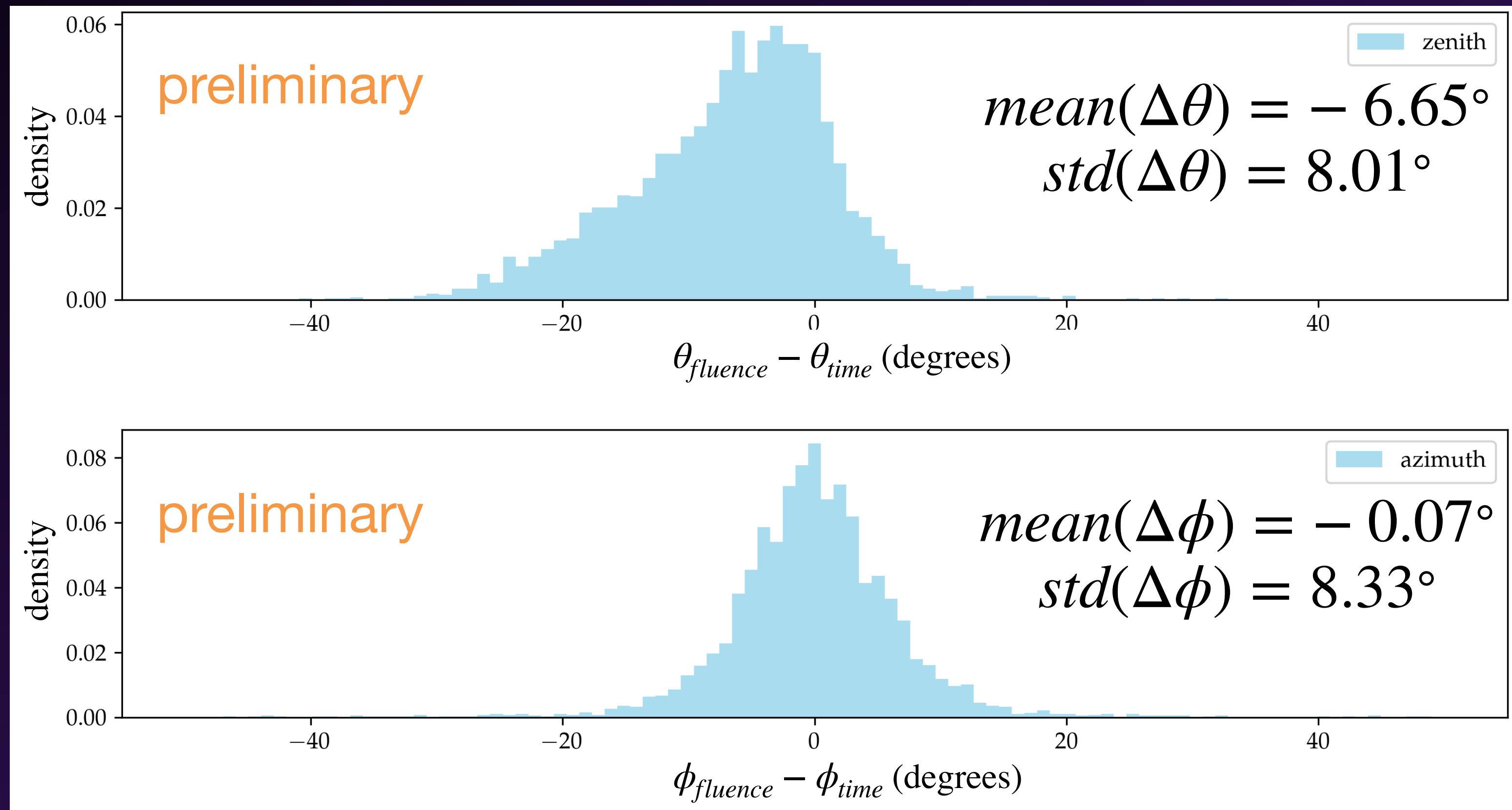
biased towards larger angles
 \rightarrow could be due to border effects

\Rightarrow investigate this method further !

180° ambiguity excluded

Comparing the Methods

~7k events



bias most likely from signal strength method

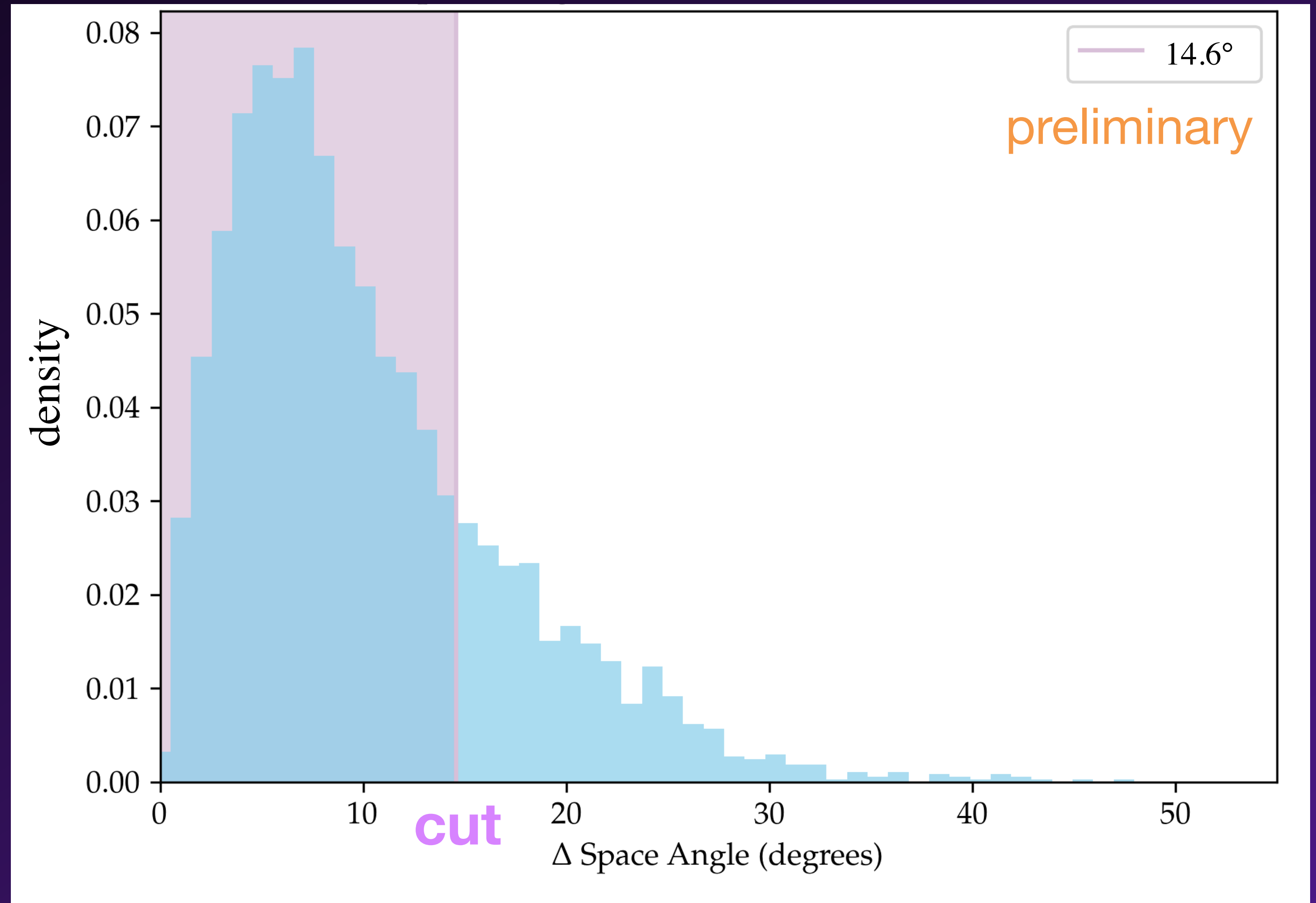
**combination of both methods
⇒ powerful discrimination of background**

Usage: online triggering

Delta Space angle

angular difference
between true and
reconstructed arrival
directions

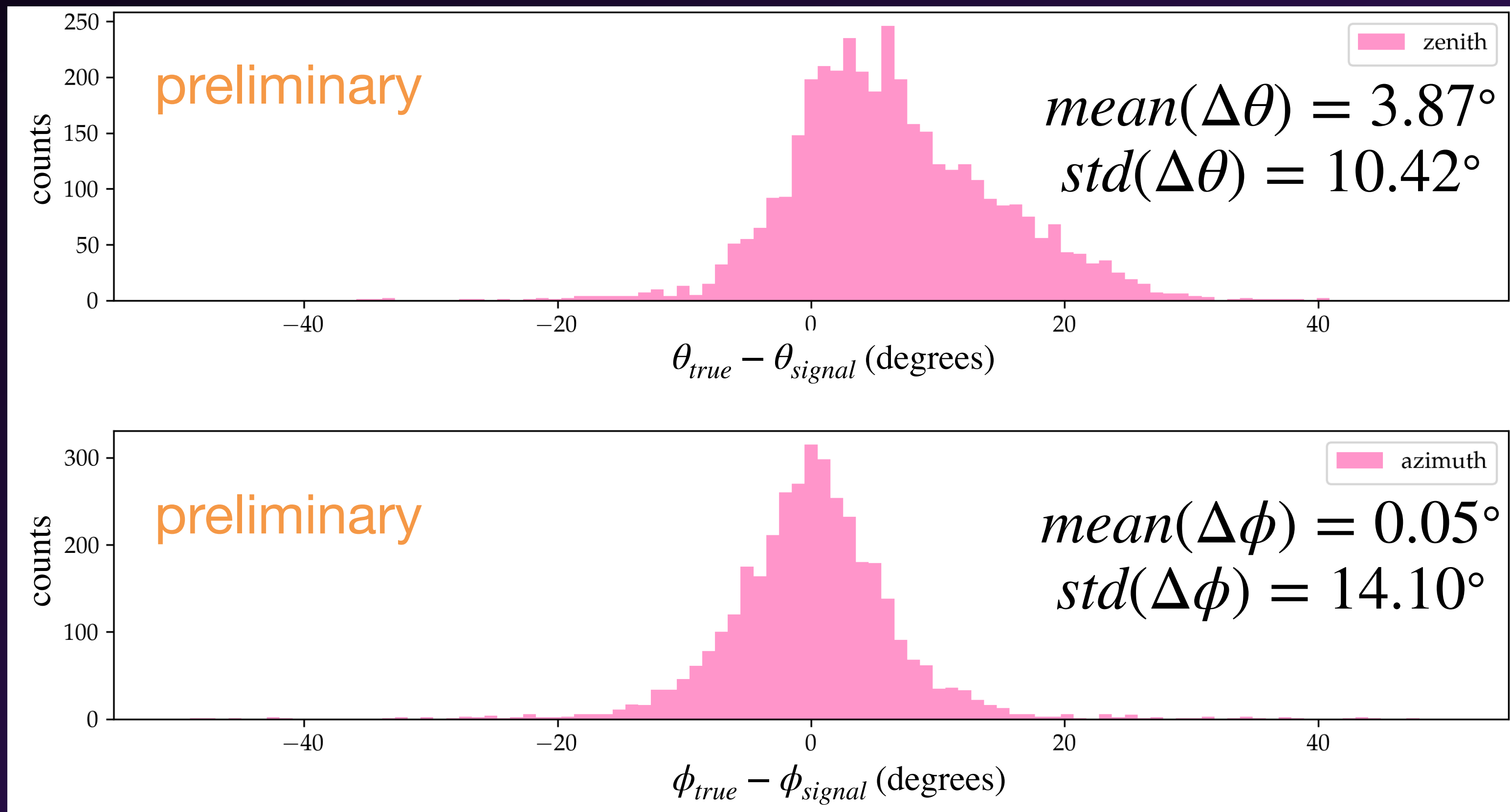
→ 3rd quantile at 14.6°
(to be improved)



Outlook



Next Steps in Signal Strength Analysis

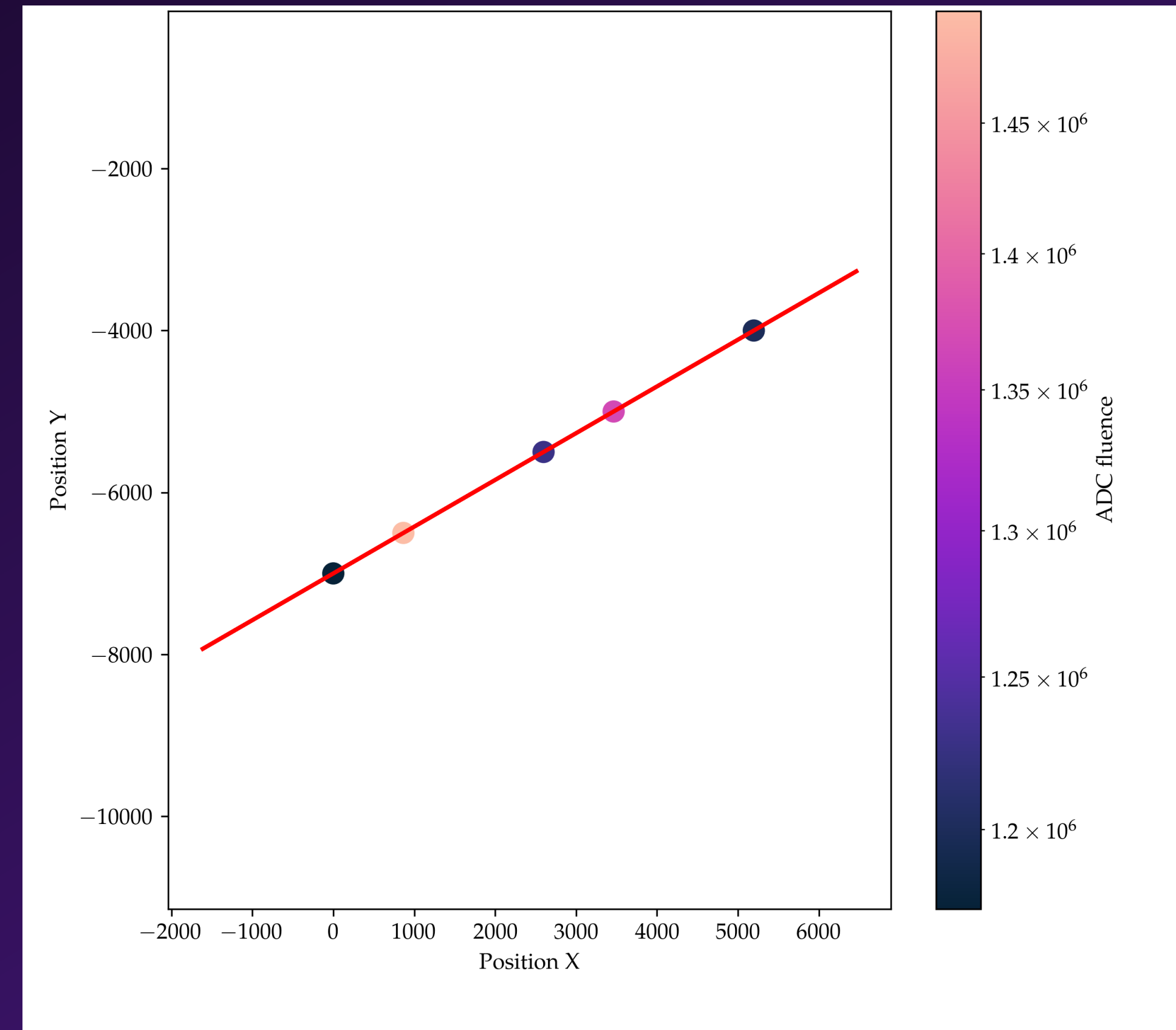
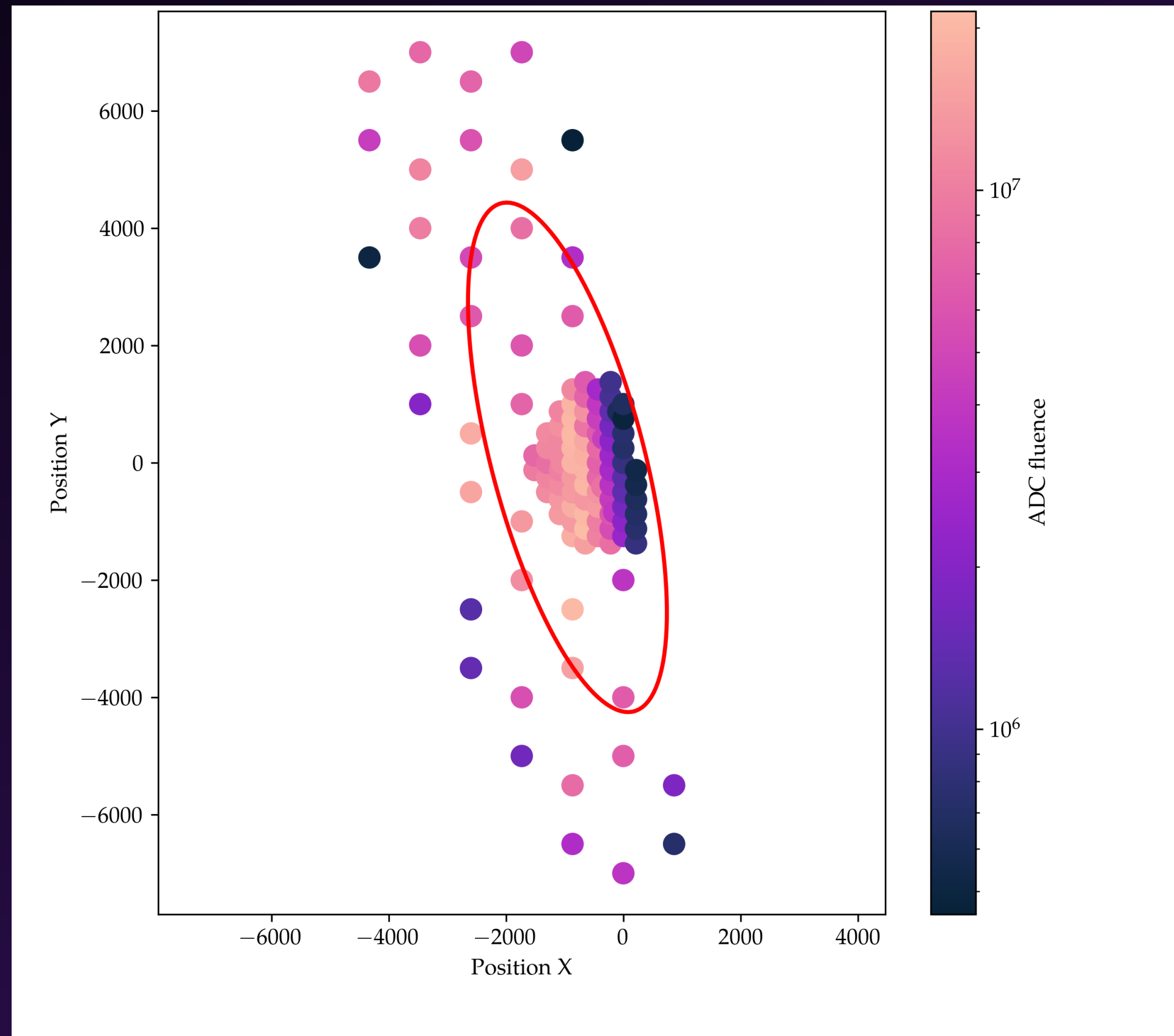


⇒ investigate this method further

or find alternatives!

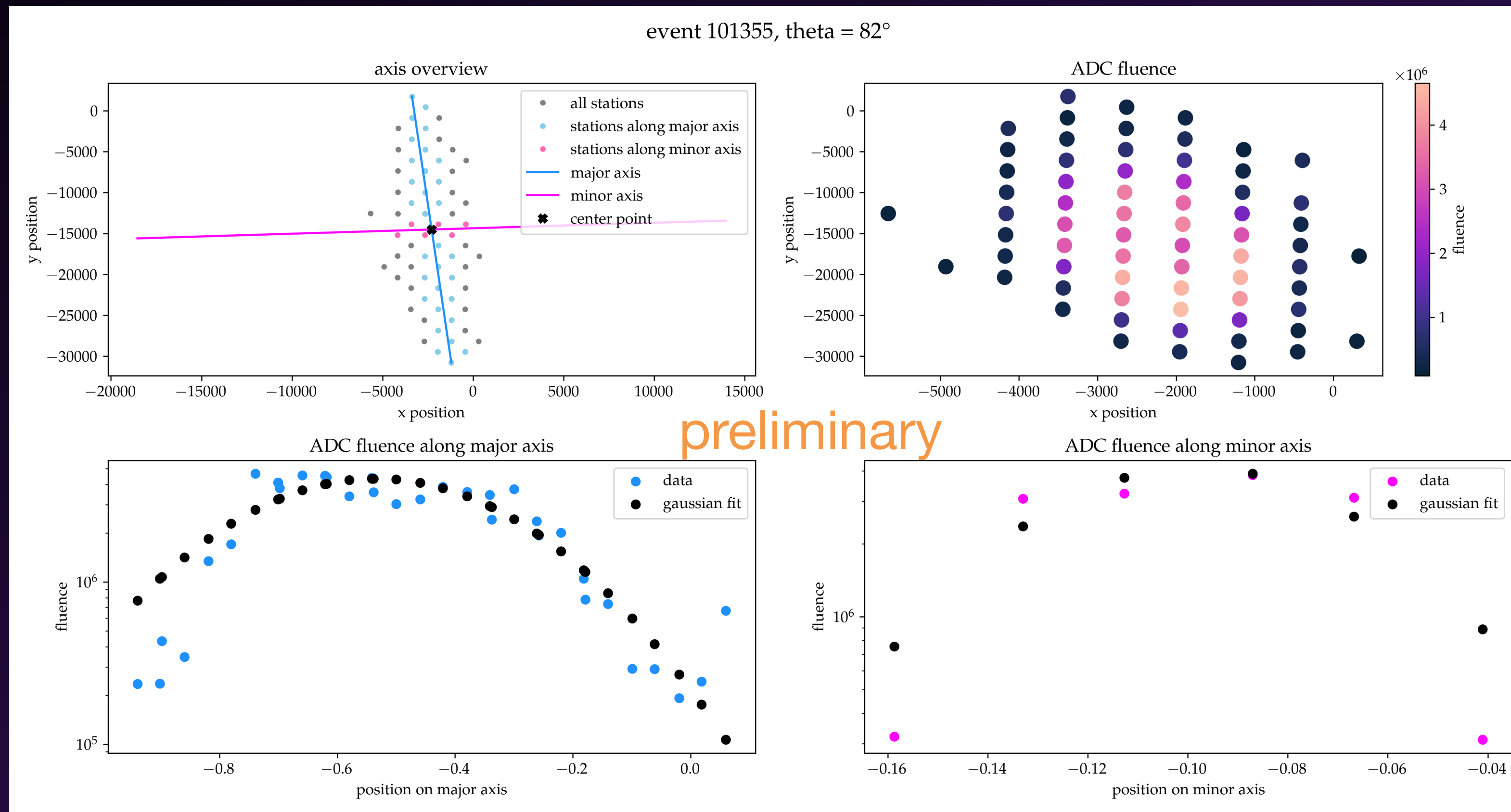
Next Steps in Signal Strength Analysis

Further Investigation → fix bugs



Next Steps in Signal Strength Analysis

Further Investigation → more options



★ size of footprint

★ distribution of signal strength

Alternative to Signal Strength Analysis

Polarization Analysis based on work by Simon Chiche

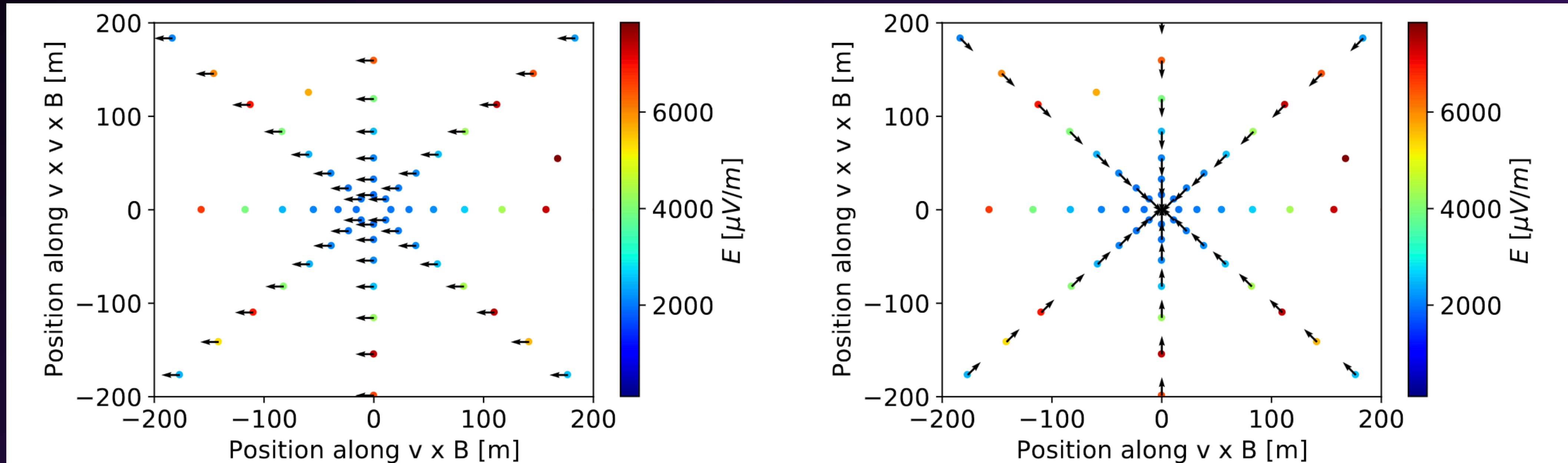
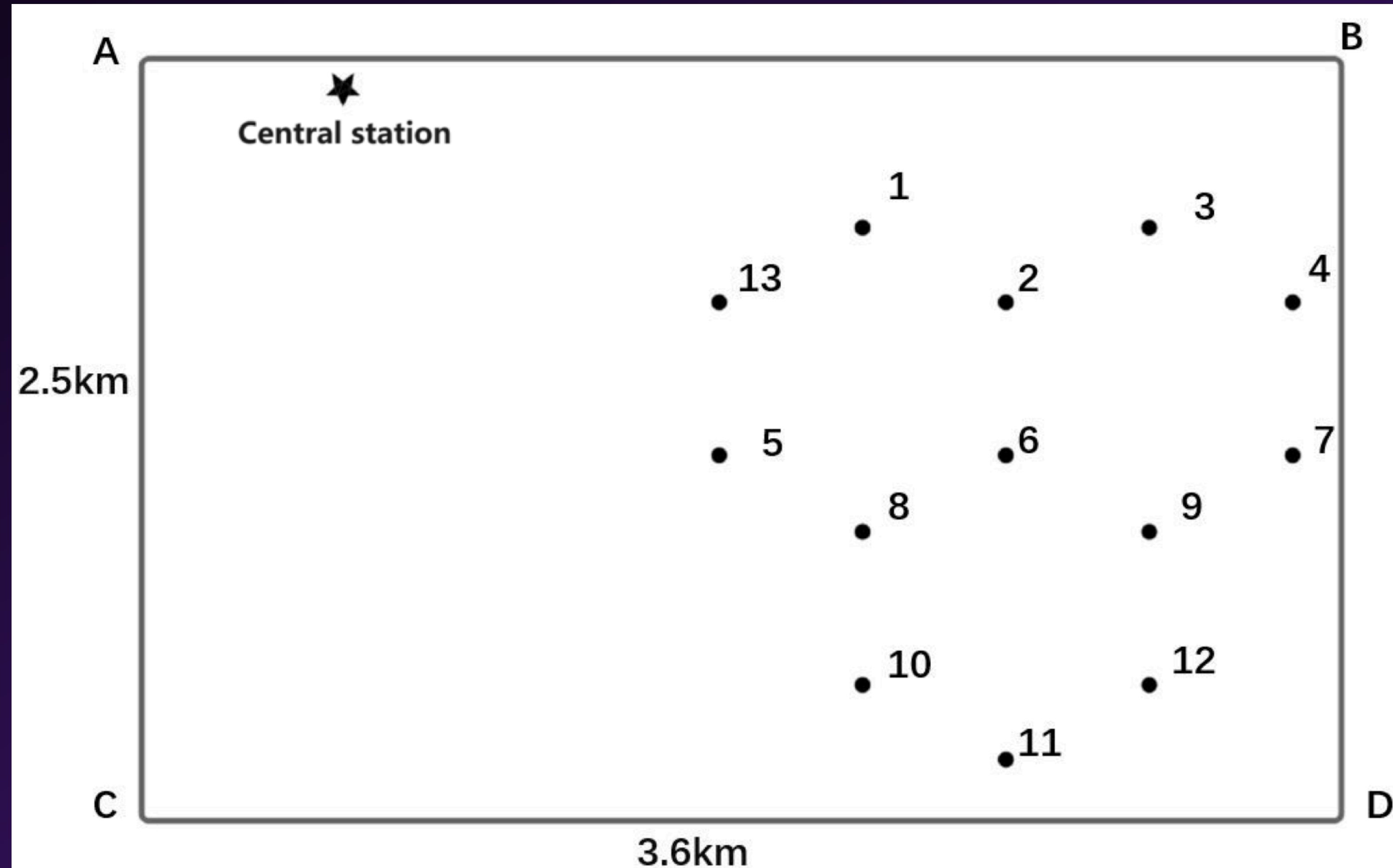


Figure 1: Total (geomagnetic + charge excess) electric field amplitude (color scale) and direction (arrows) of the geomagnetic (*left*) and charge excess (*right*) emissions, for a shower with primary particle energy $E = 0.68 \text{ EeV}$ and zenith angle $\theta = 53^\circ$, represented in the plane perpendicular to the shower axis ($\mathbf{e}_{\mathbf{v} \times \mathbf{B}}$, $\mathbf{e}_{\mathbf{v} \times (\mathbf{v} \times \mathbf{B})}$). A small number of antennas is also generated outside of the star-shape pattern in our simulations, for cross checks.

<https://arxiv.org/pdf/2202.06846>

Noise Set Analysis

currently only measurements from GP13 → too small



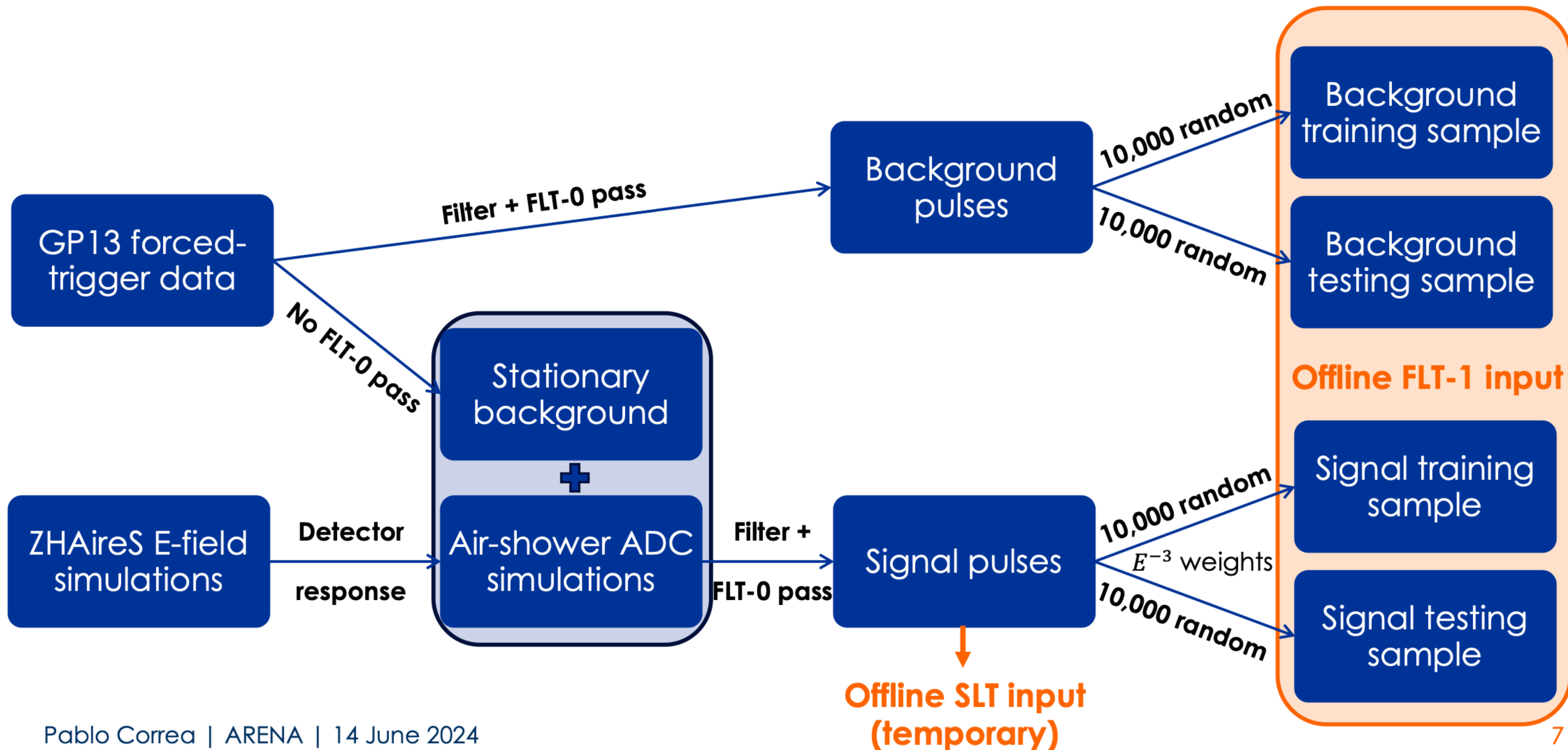
Summary

- ★ **trigger radio autonomously** by cross-validation of two methods
- ★ developed for GRAND, but **generally applicable** to any large-scale radio array

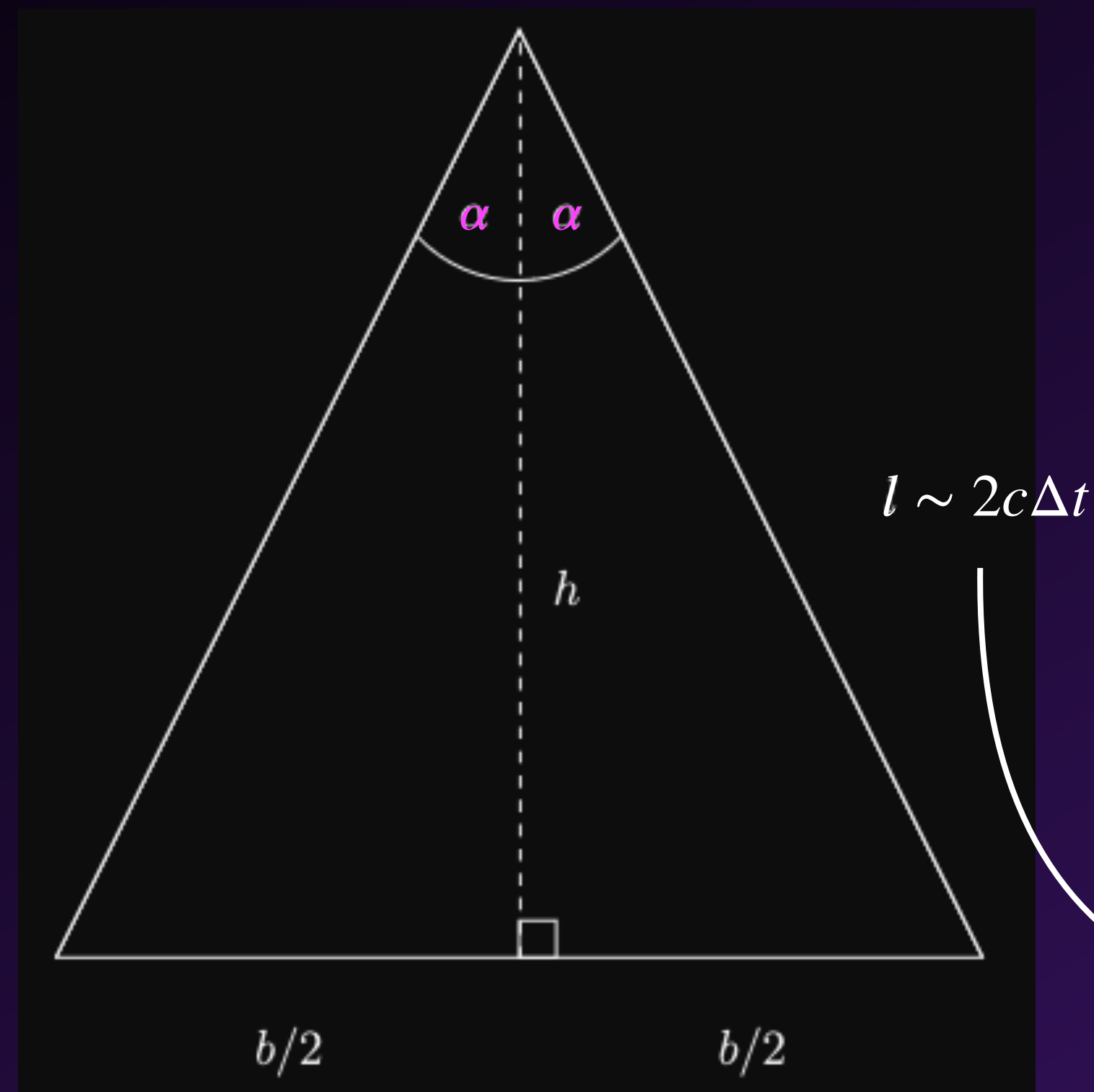


Backup

Offline FLT-1 Database Construction



Zenith Calculation

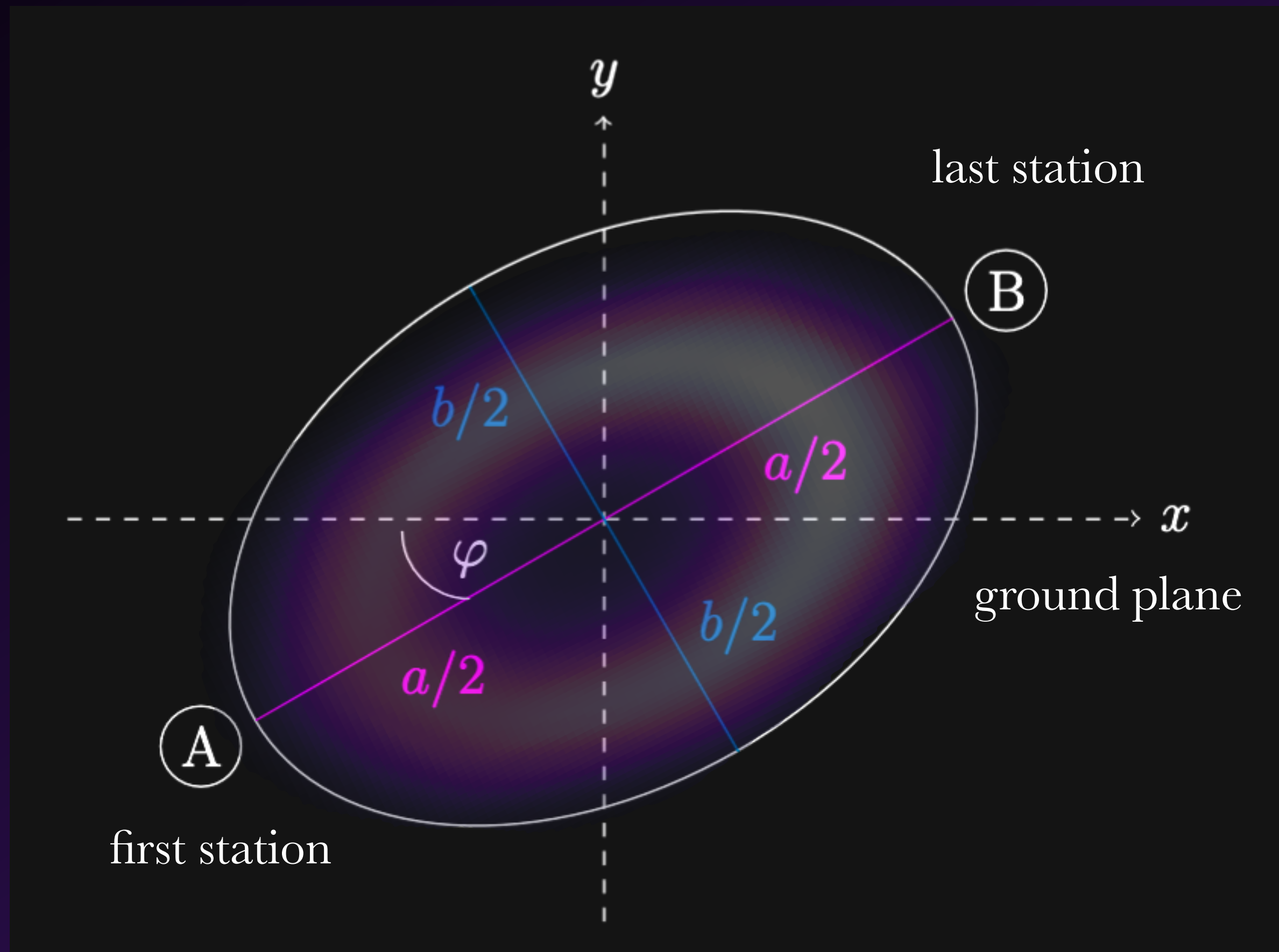


$$\varepsilon = \frac{\sin \theta}{\sin \alpha} = \frac{\sqrt{a^2 - b^2}}{a}$$

with $\alpha = \arccos \frac{b}{l} \approx \arccos \frac{b}{2c\Delta t}$:

$$\sin \theta = \frac{\sqrt{a^2 - b^2}}{a} \cdot 1$$

Azimuth Calculation



$$\tan \varphi = \frac{dy}{dx}$$