

# Current status and technical aspects of GRANDProto300

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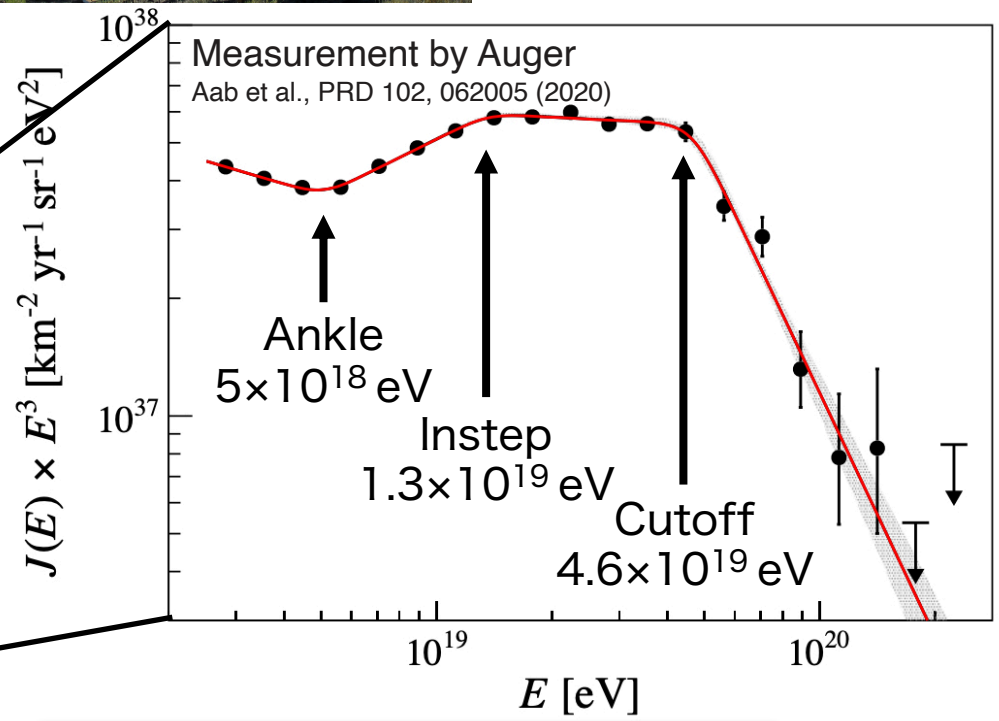
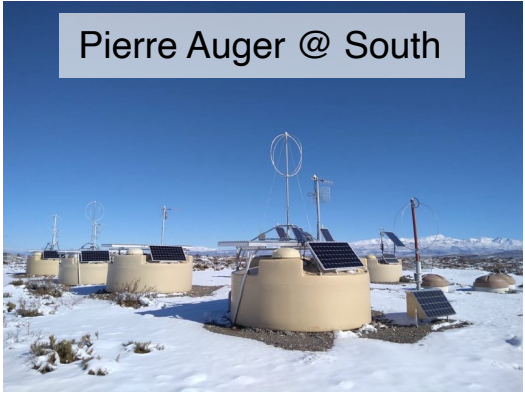
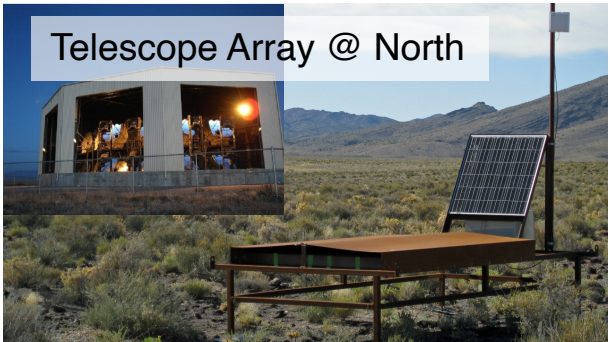
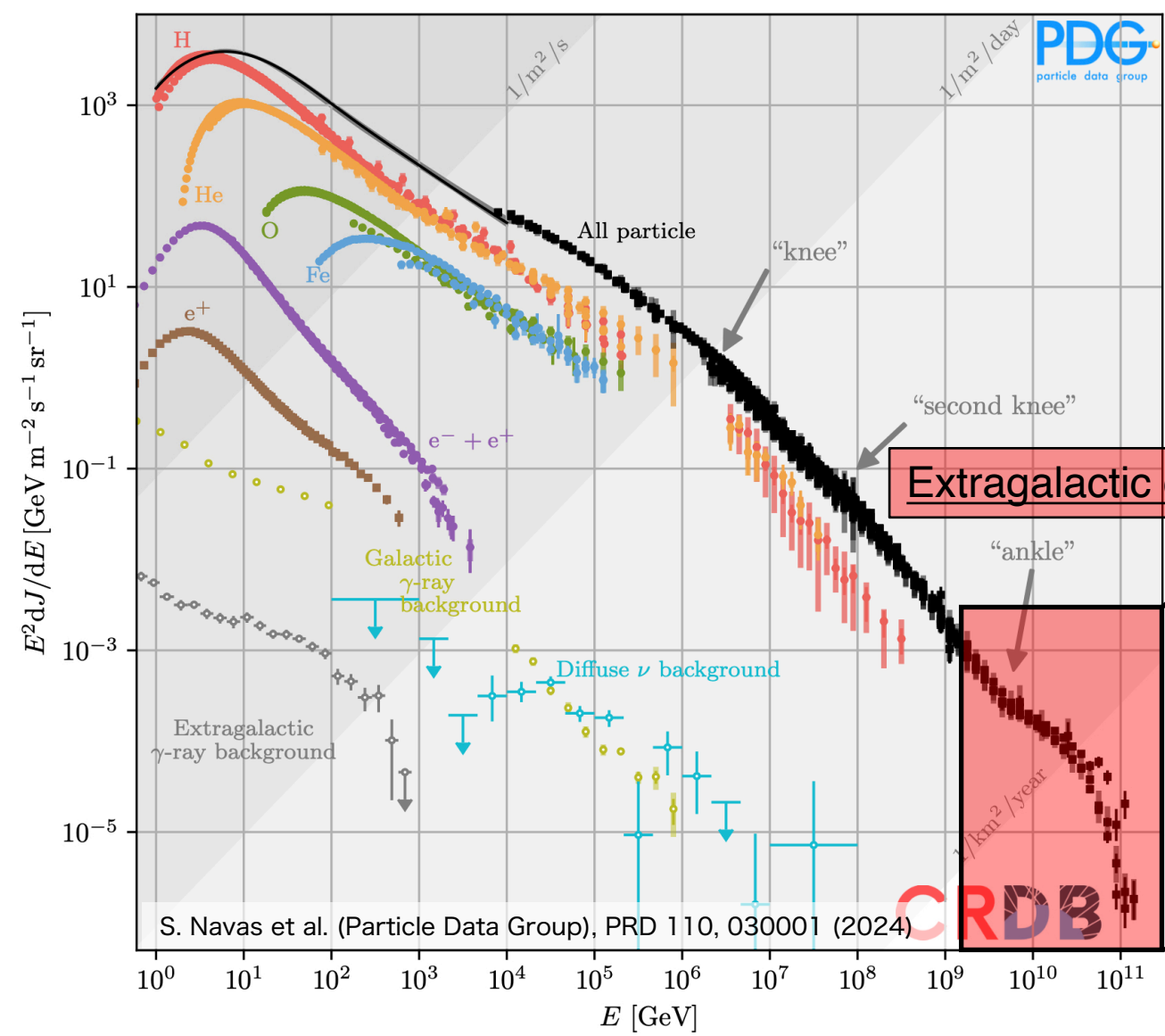




# Energy Spectrum of Ultra-High-Energy (UHE) Cosmic Rays

All particle CR energy spectrum (black)

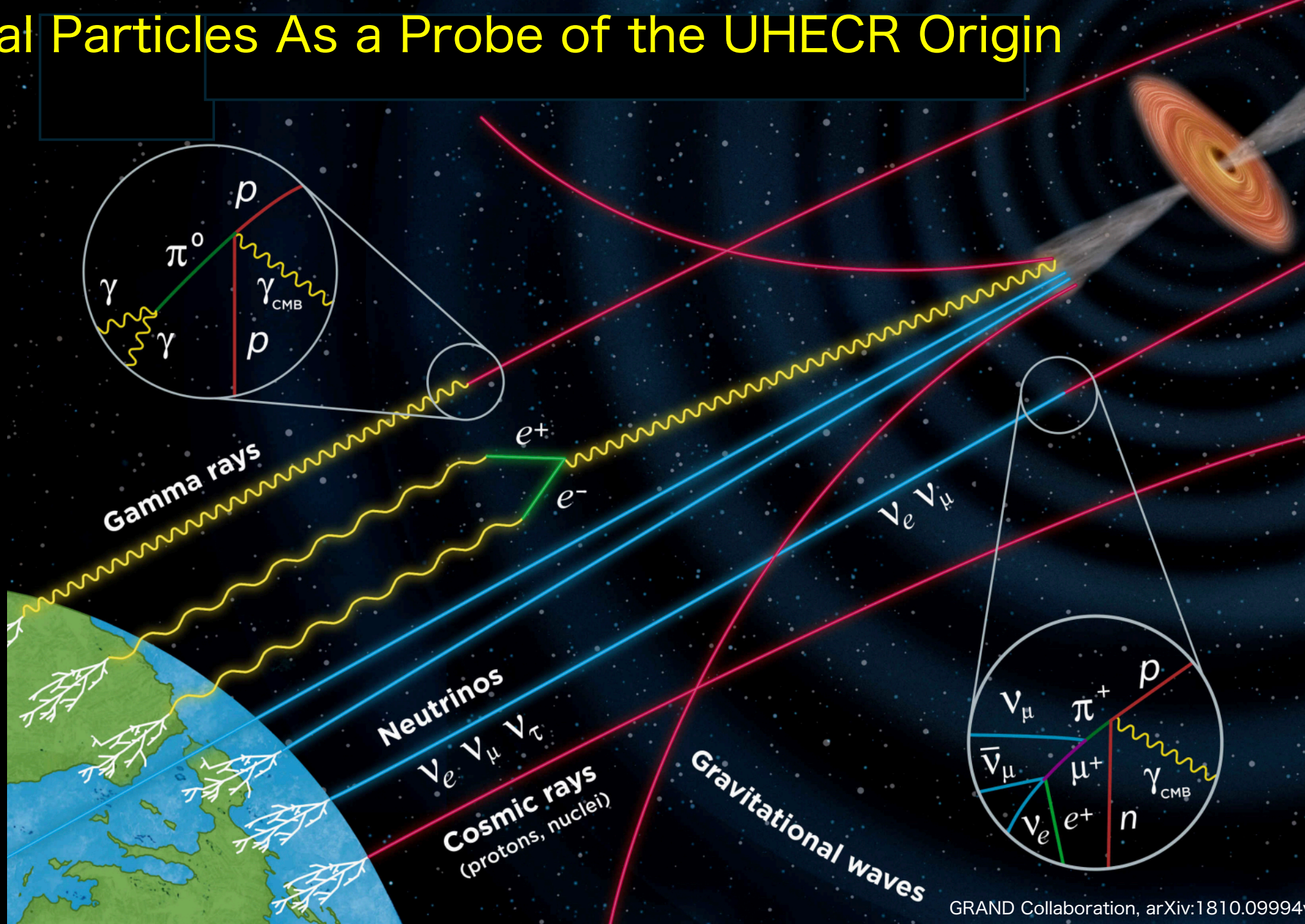
UHECR observatories



Origin of UHECRs?

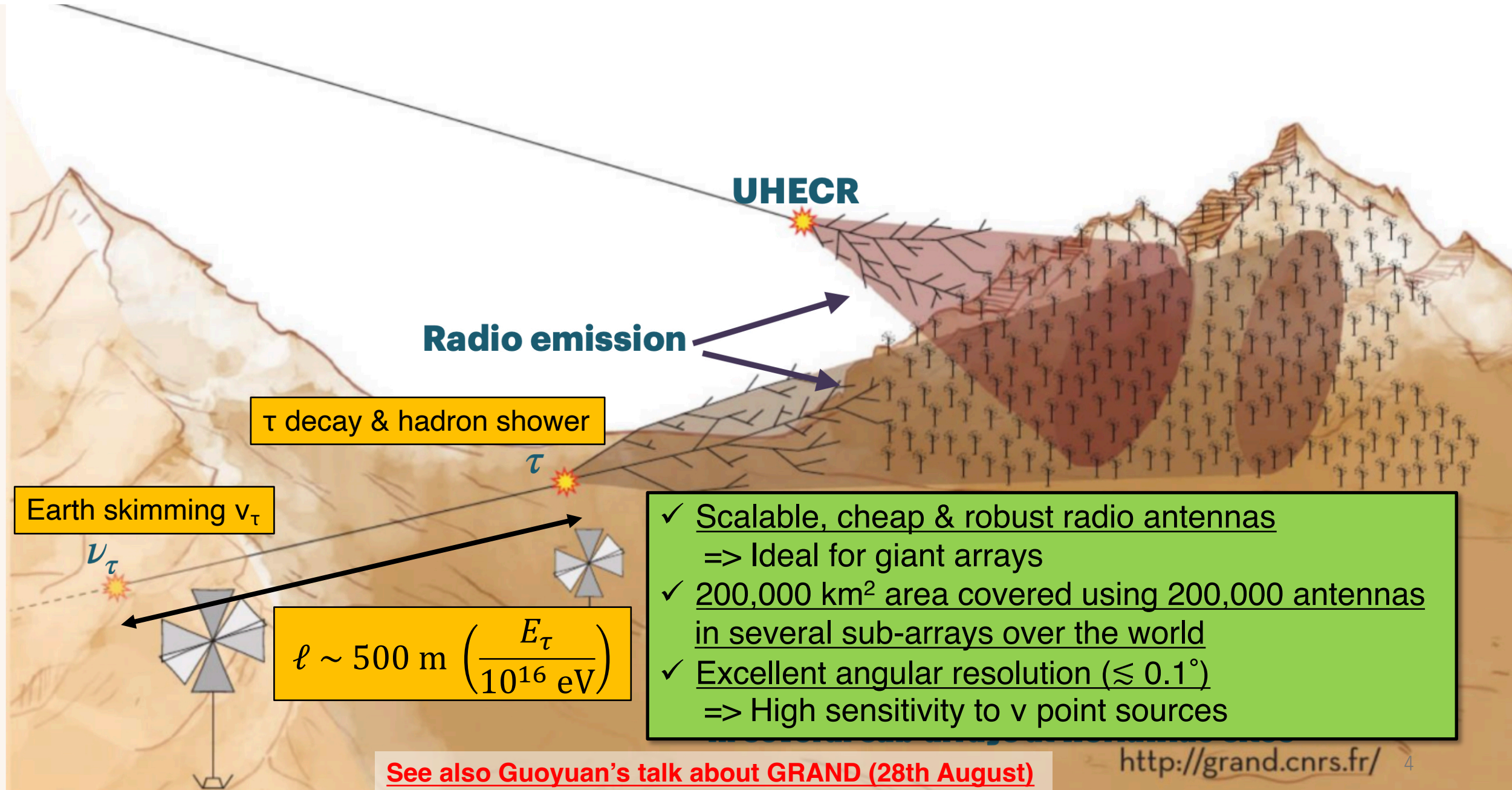


# Neutral Particles As a Probe of the UHECR Origin





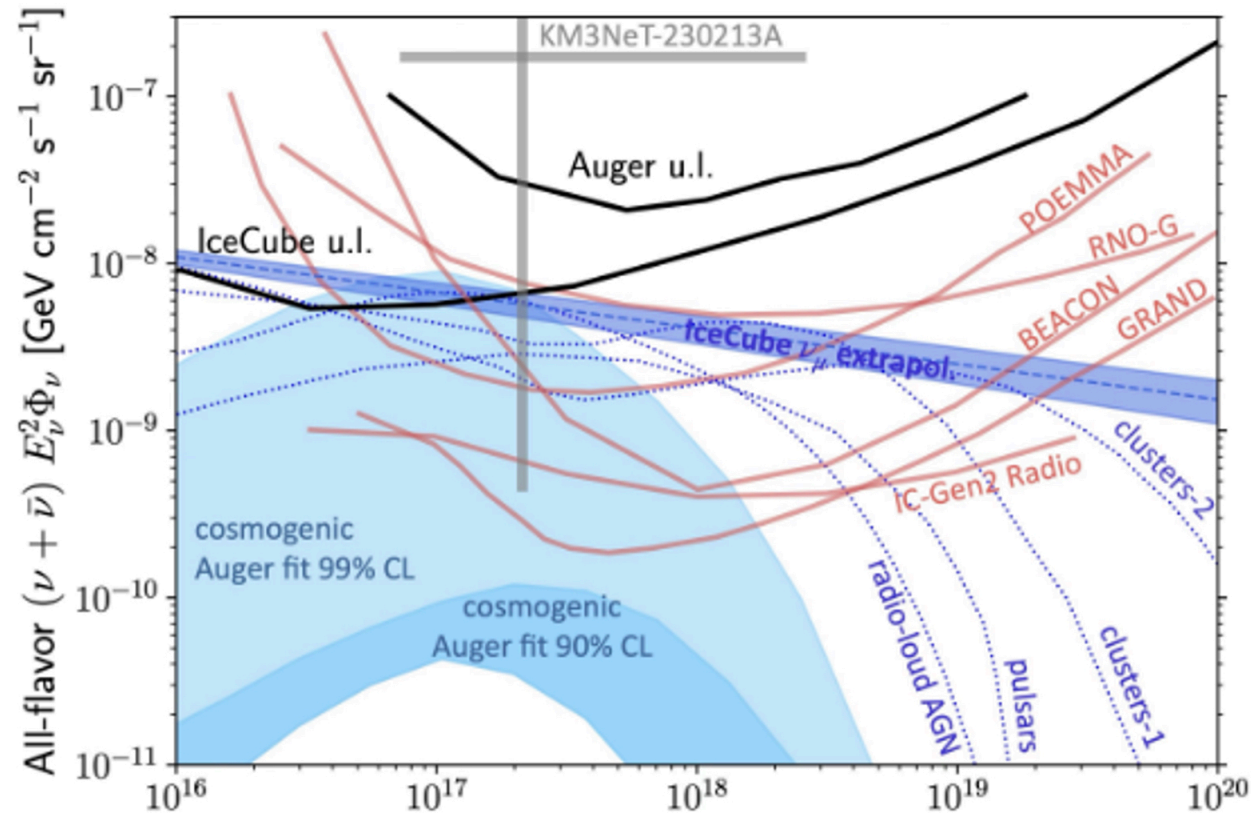
# Giant Radio Array for Neutrino Detection (GRAND)





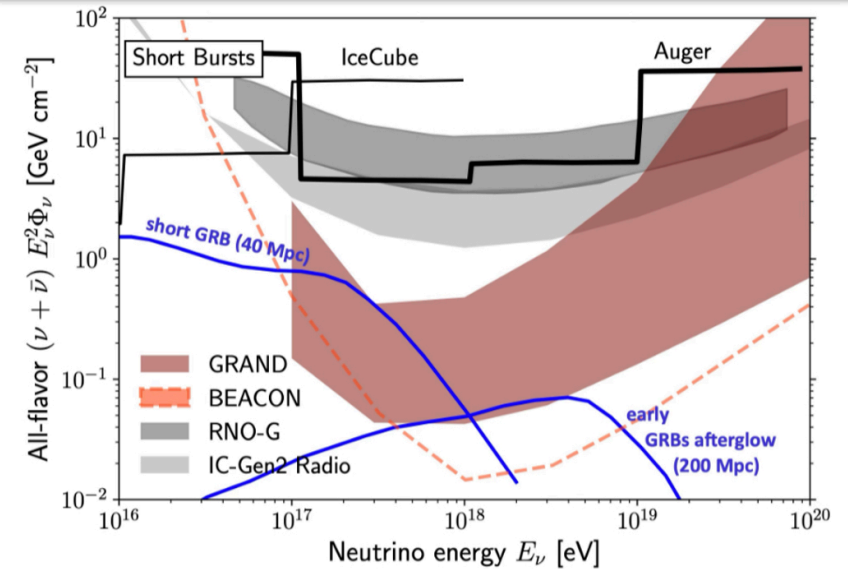
# GRAND Science Cases

## Sensitivity to diffuse neutrinos

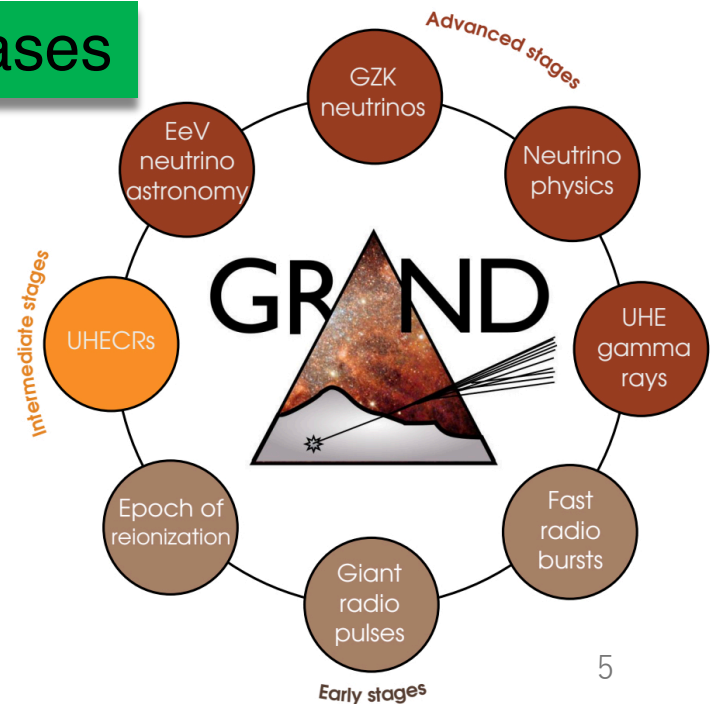


**$10^{-10}$  GeV/cm<sup>2</sup>/s/sr flux sensitivity in 10yr obs.**

## Sensitivity to transient neutrino sources



## Rich science cases





# The GRAND Collaboration

**119 members & 14 countries:** Argentina, Belgium, Brazil, China, Czech Republic, Denmark, France, Germany, Greece, Japan, Netherlands, Norway, Poland, USA

18 Member & Associate Institutes represented at the Board

- China University of Geoscience, Wuhan, China
- Hellenic Open University, Greece
- Institut d'astrophysique de Paris, France
- Institute of Physics of the Czech Academy of Sciences, Prague, Czech Republic
- Inter-University Institute for High Energy at Vrije Universiteit Brussels, Belgium
- Karlsruhe Institute of Technology, Germany
- LPNHE, Paris, France
- Laboratoire Univers et Particules de Montpellier, France
- Nanjing University, China
- National Astronomical Observatories, Beijing, China
- Pennsylvania State University, State College, USA
- Purple Mountain Observatory, Nanjing, China
- Radboud University, Nijmegen, The Netherlands
- San Francisco State University, USA
- University of Warsaw, Poland
- Universidade Federal do Rio de Janeiro, Brasil
- Universidade de Santiago de Compostela, Spain
- Xidian University, Xi'An, China



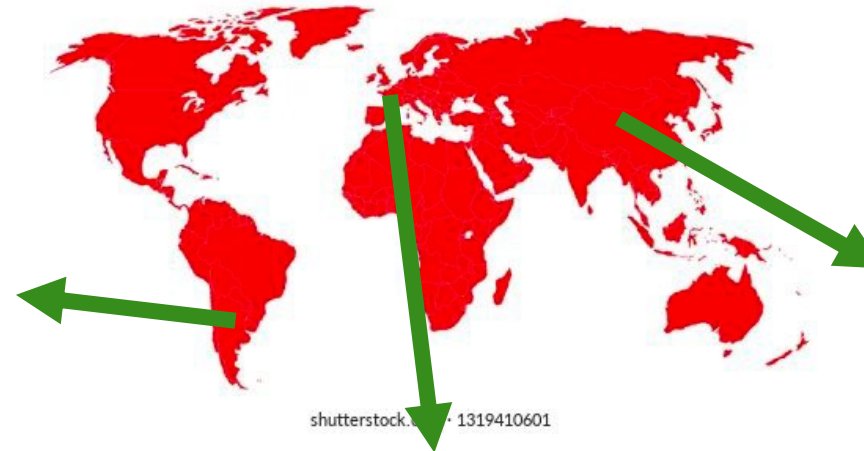


# GRANDProto300: One of the GRAND Prototypes

Adapted from a slide of H. He in TMEX2025

## GRAND @ Auger

Cross-calibration w/ Auger  
Cosmic-ray event search

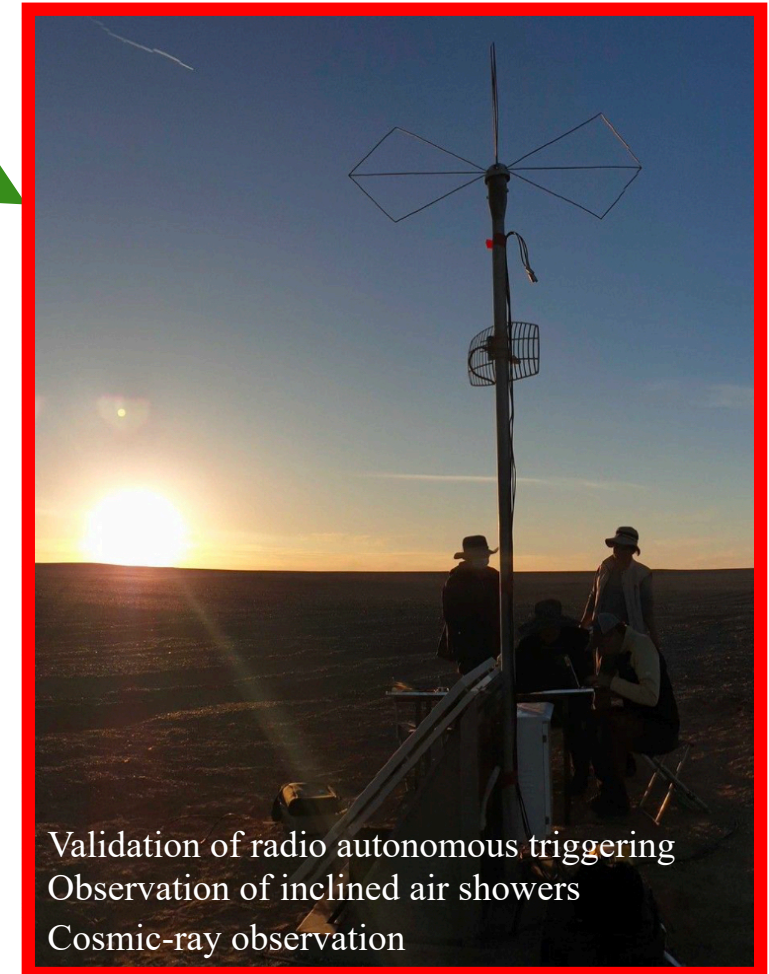


## GRAND @ Nançay

Trigger testbench



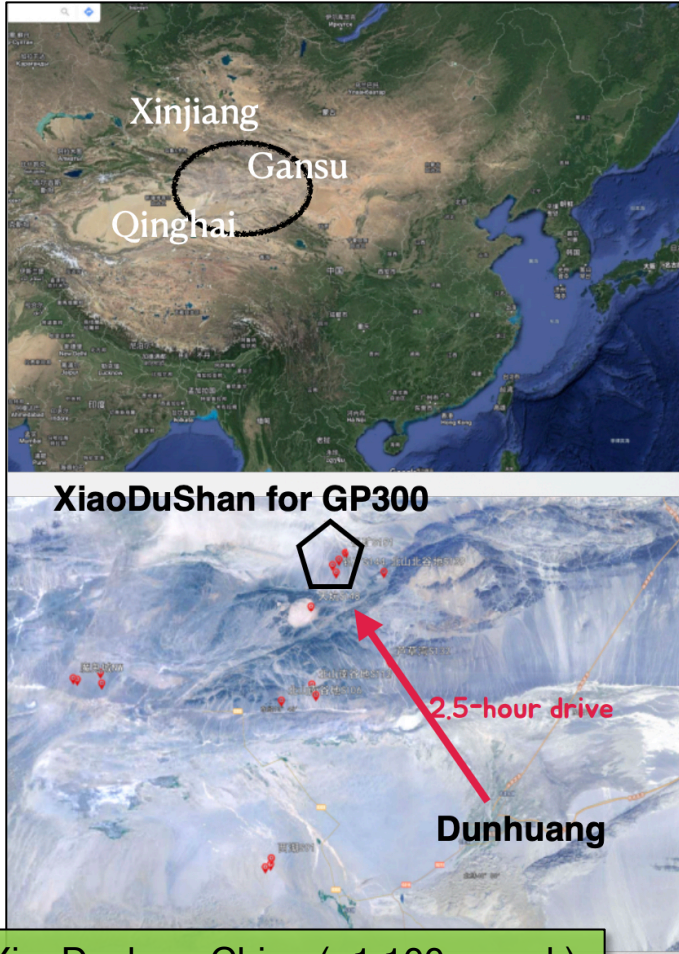
## GRANDProto300



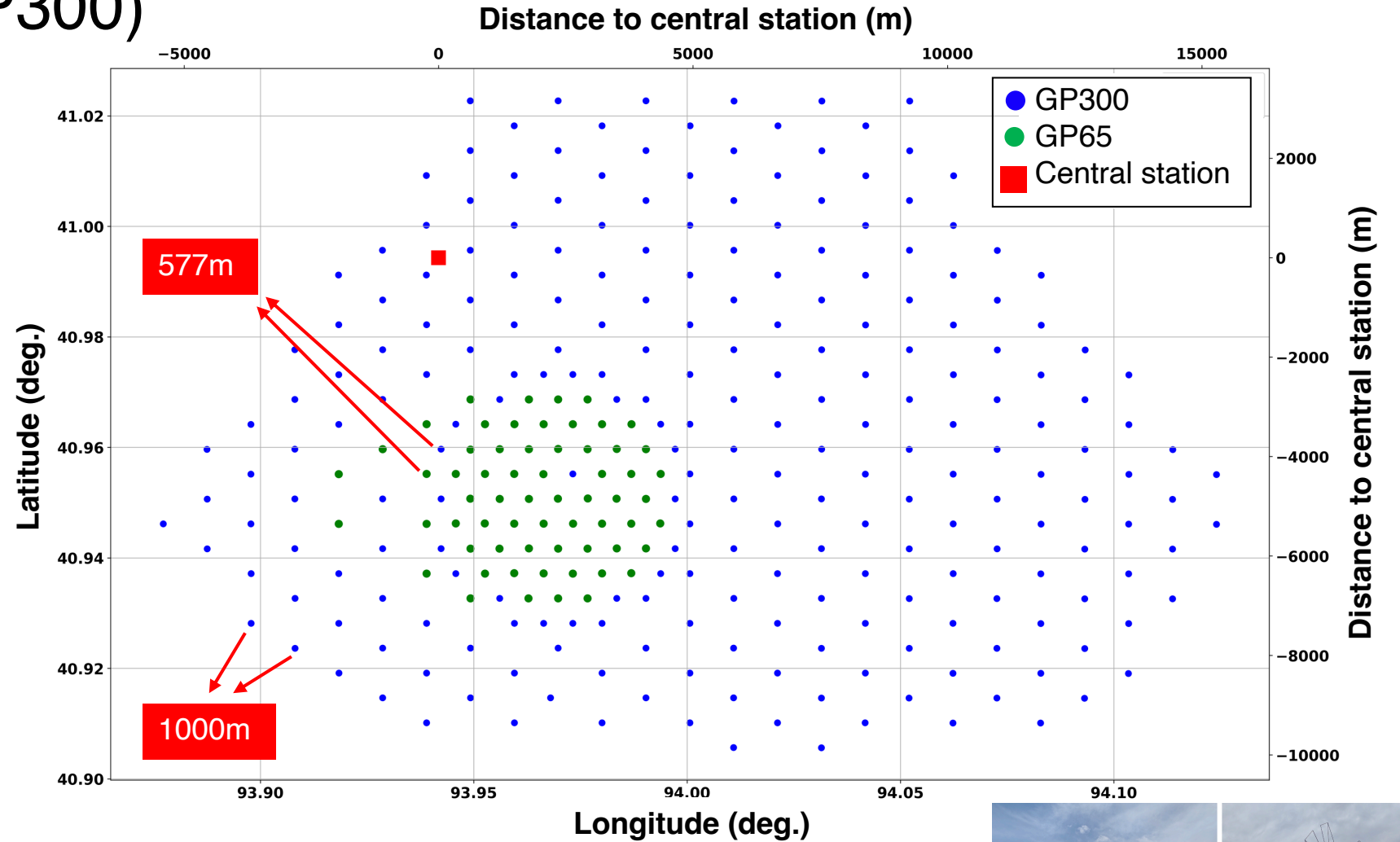
Validation of radio autonomous triggering  
Observation of inclined air showers  
Cosmic-ray observation



# GRANDProto300 (GP300)

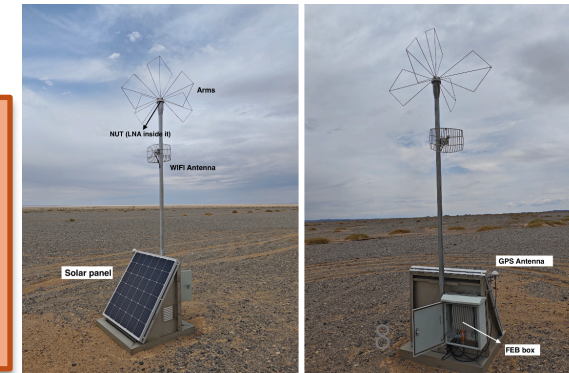


XiaoDushan, China (~1,100m a.s.l.)  
Longitude: 94° E  
Latitude: 40.96° N



## **Motivation:**

- ✓ Validation of radio autonomous triggering
- ✓ Observation of inclined air showers
- ✓ Cosmic-ray observation @  $10^{16.5} \text{ eV} < E < 10^{18} \text{ eV}$

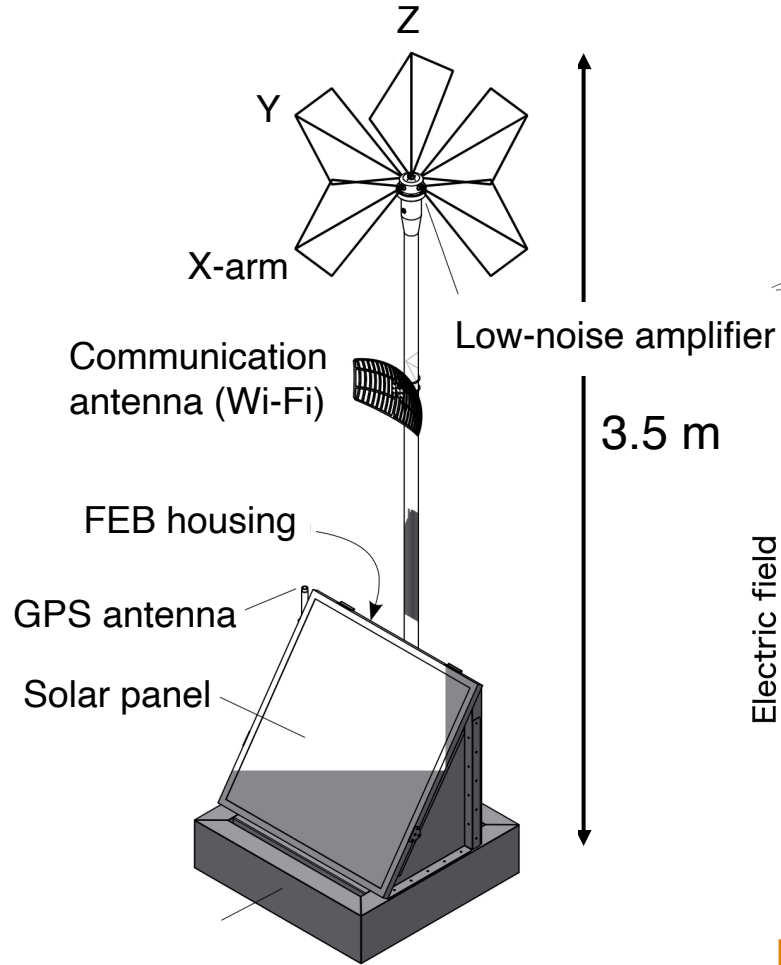




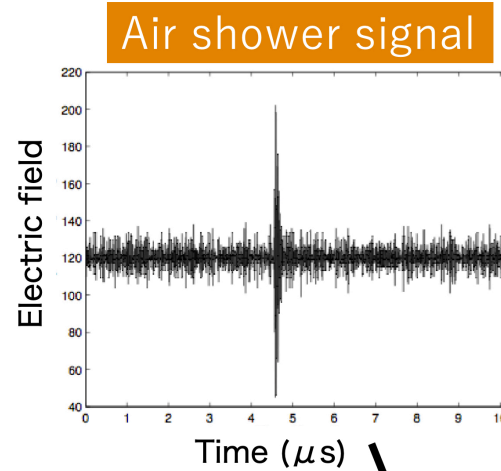
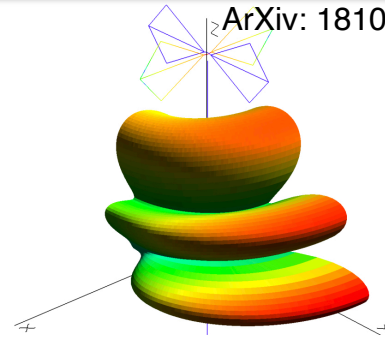
# Design of GP300

Gain of X-arm @ 100MHz

ArXiv: 1810.09994



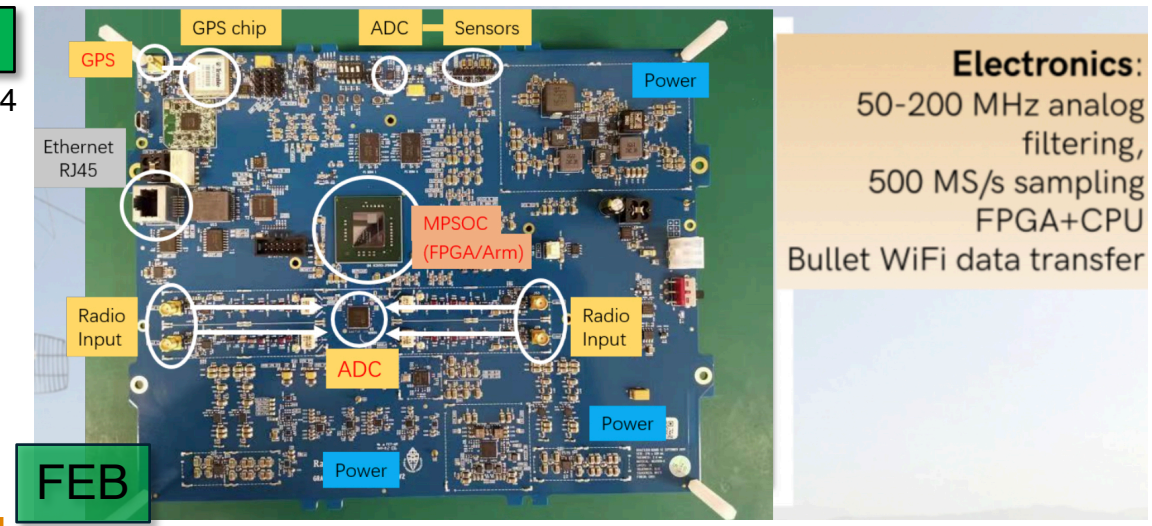
**Wi-Fi (@ 5GHz band)**  
150 Mbps bandwidth  
=> Tens of Hz trigger rate  
(for event size of 8kB/DU)



Noise  
Galactic  
Anthropogenic

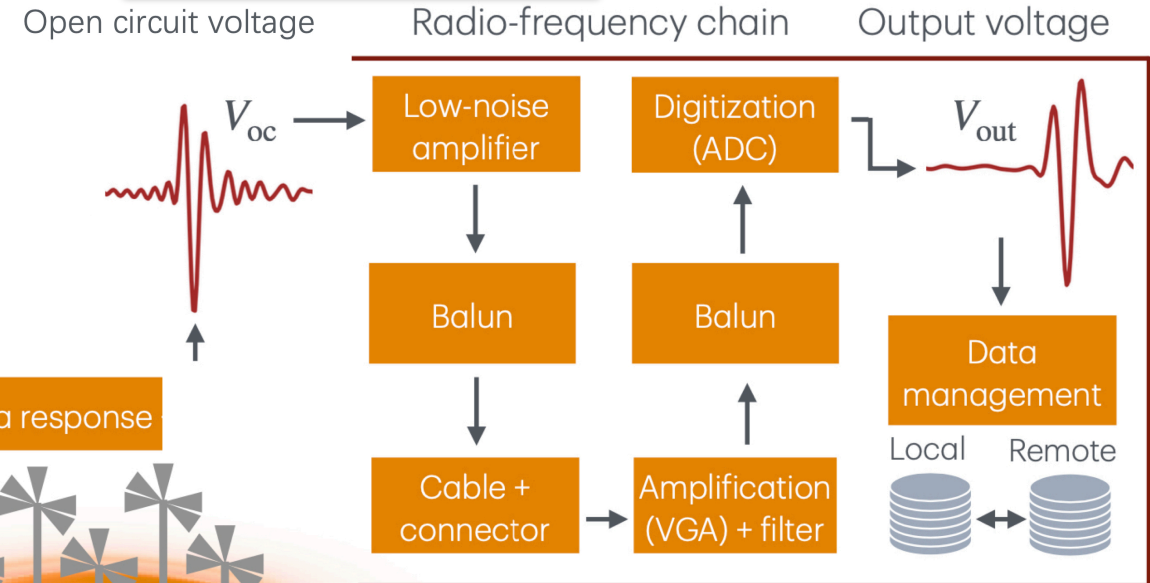


Antenna response



**Electronics:**  
50-200 MHz analog  
filtering,  
500 MS/s sampling  
FPGA+CPU  
Bullet WiFi data transfer

## Signal processing



# Current Status: GP65

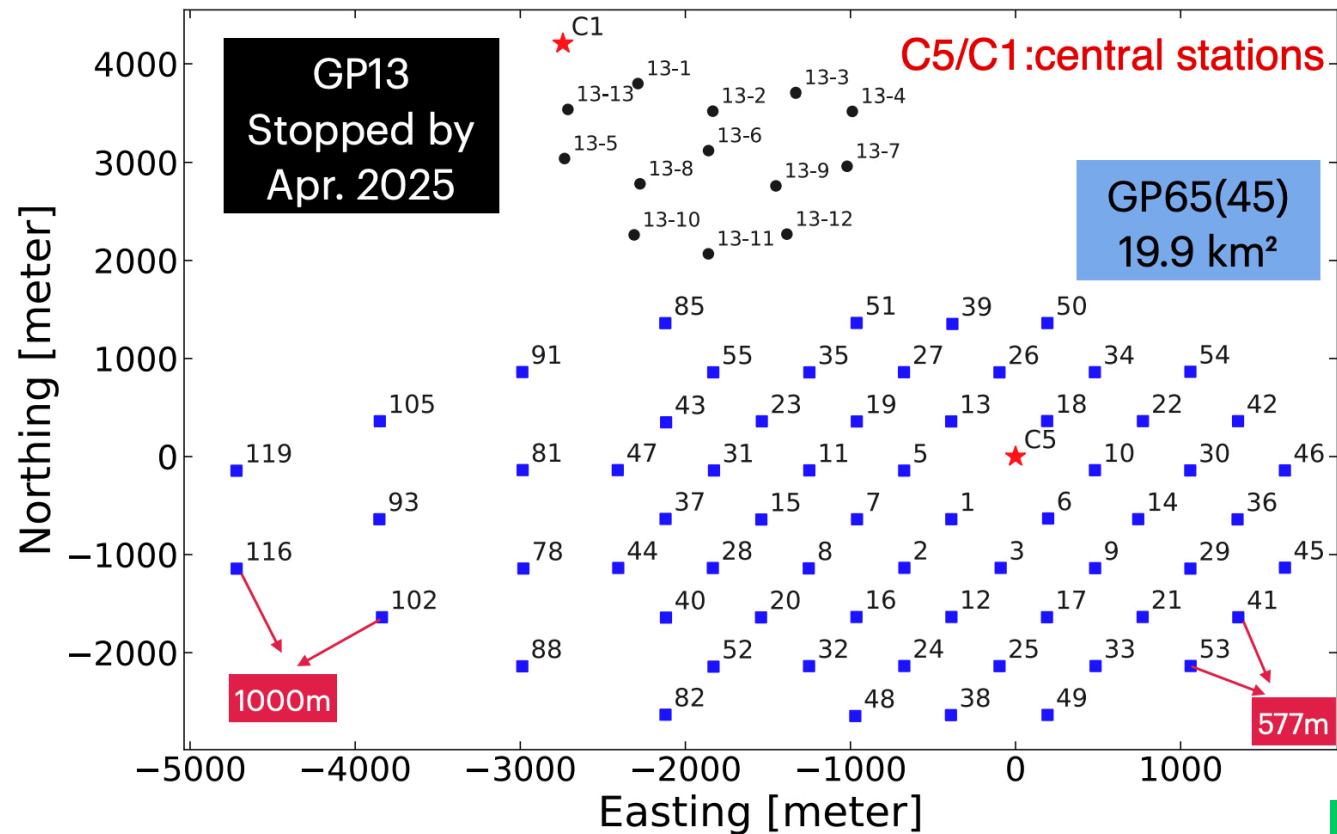
Site: Gobi desert



DAQ room (& living quarters)



GP13 (Mar. 2023) -> GP45 (Sep. 2024) -> GP65 (Apr. 2025)



Adopted from a slide of P. Ma in ICRC2025

## RFI suppression

- Noise shielding was main task in past two years.
  - Charge controller, AM band, satellite and planes ranging from 118MHz to 140MHz. FEB power supply, Ethernet and sensor cables.
  - One strong RFI source above 150MHz, transformer station ~13 kilometers far away.

## Thermal issue

- Improved FEB box cooling by diffusion through copper dissipators.
- Better ventilation of DU base to ensure reasonable temperature for battery
- Modified LNA configuration for temperature independent gain.

*Stable data-taking is ongoing!*

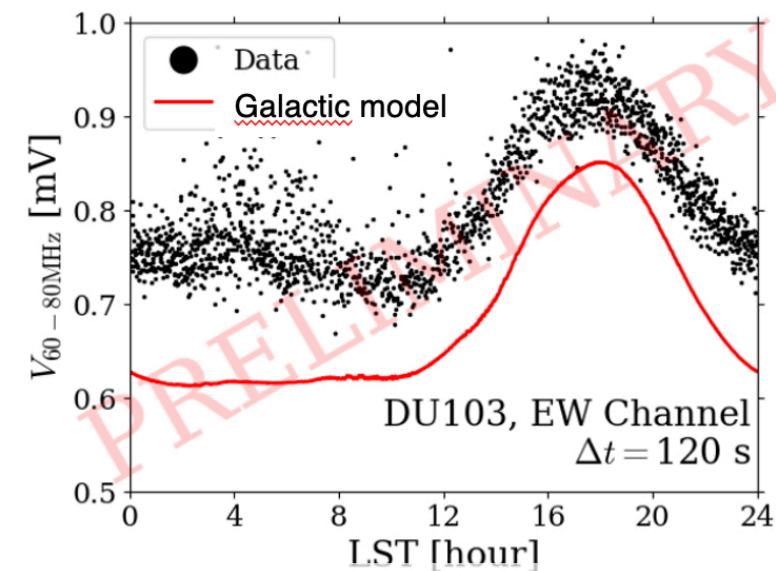




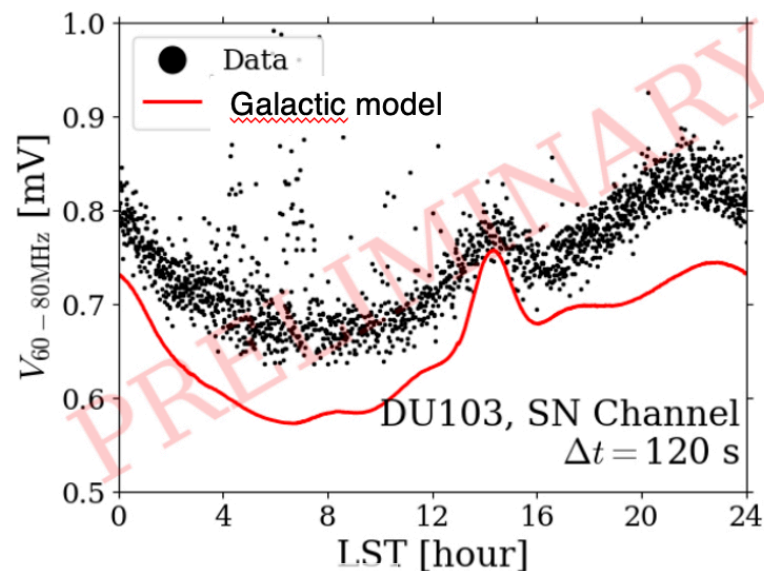
# Detector Calibration

65 DUs up and running  
Clean environment, stable, homogenous & well-modeled response  
Galactic transit observed  
(Relative) timing resolution < 5ns from the calibration using a beacon

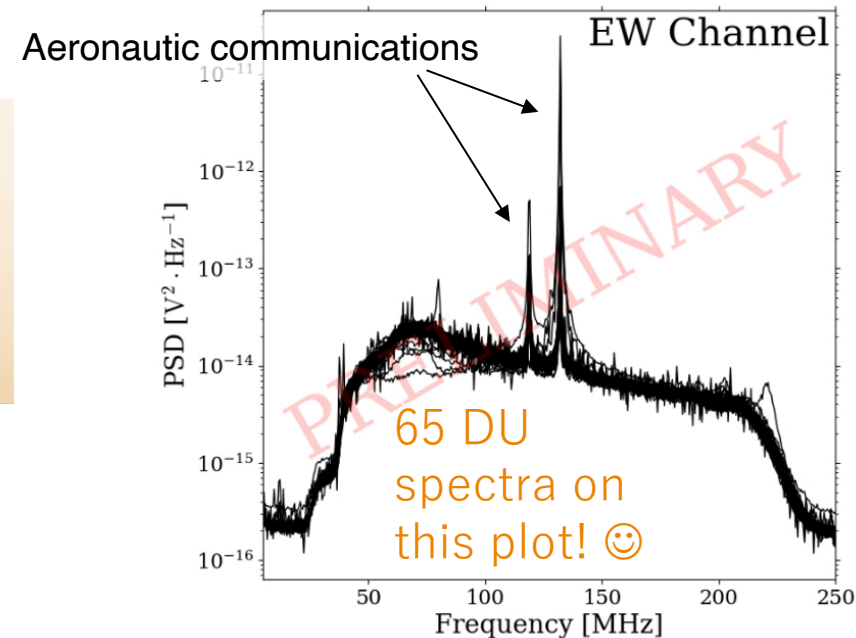
Noise RMS along LST  
(using unbiased data samples)



Offset b/w data & model: electronics noise component

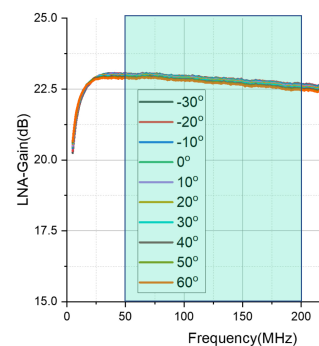


Noise spectrum  
(using unbiased data samples)

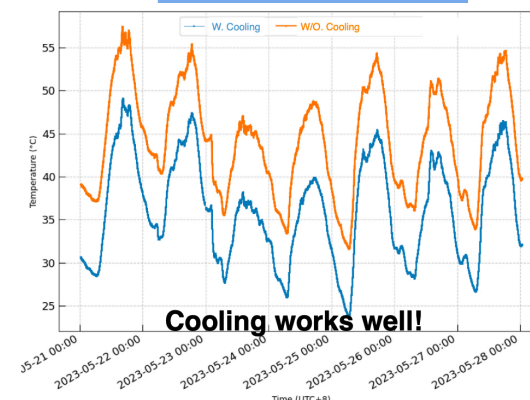


Stability of detector component

Temperature dependence of LNA's gain

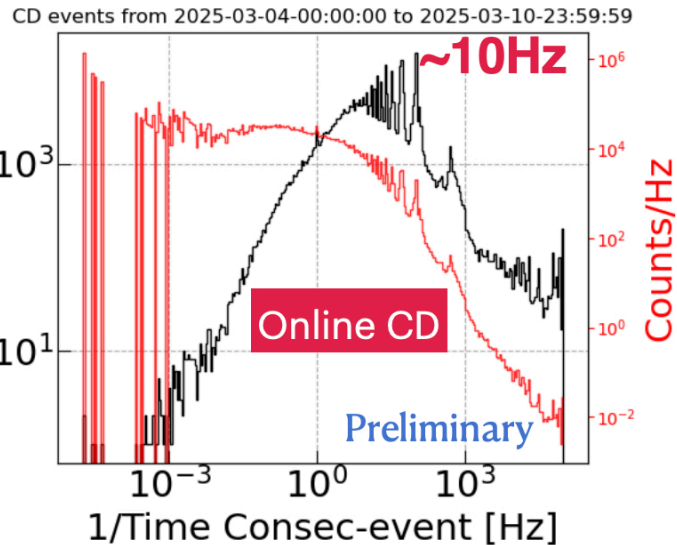
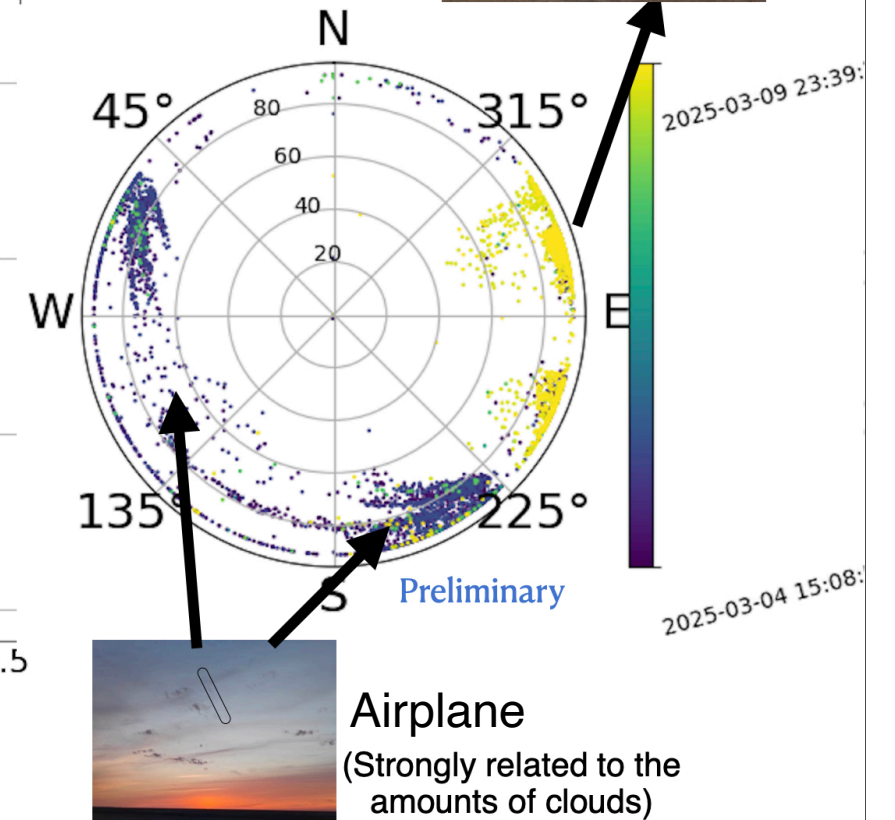
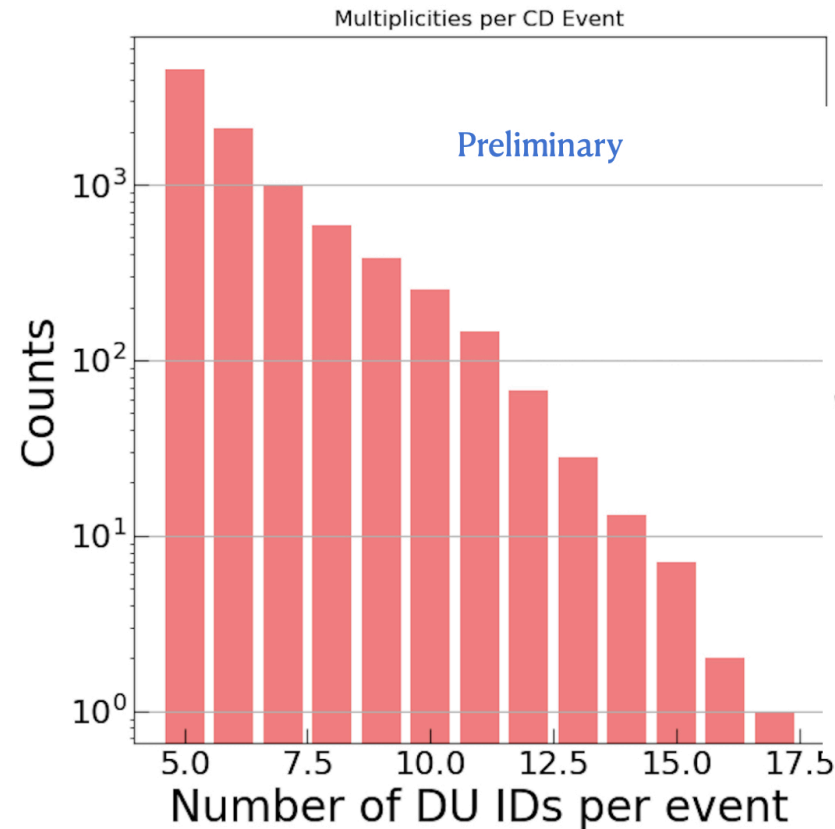


Temperature inside FEB box



# Coincidence Data

Transformer station



**Most of events are from RFI, including airplane tracks and a nearby transformer station**





# GRANDProto300: First Cosmic-Ray Candidates

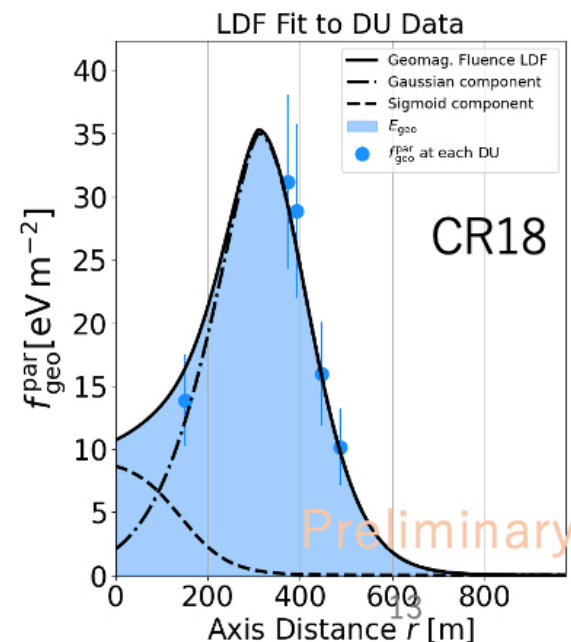
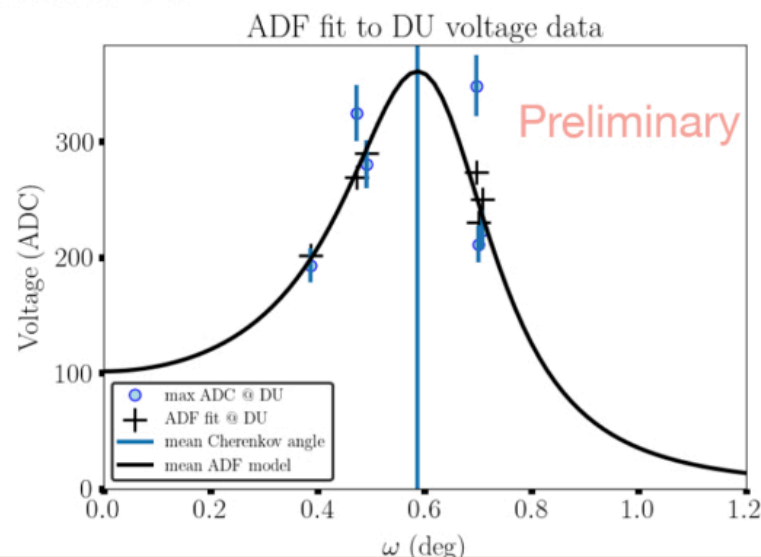
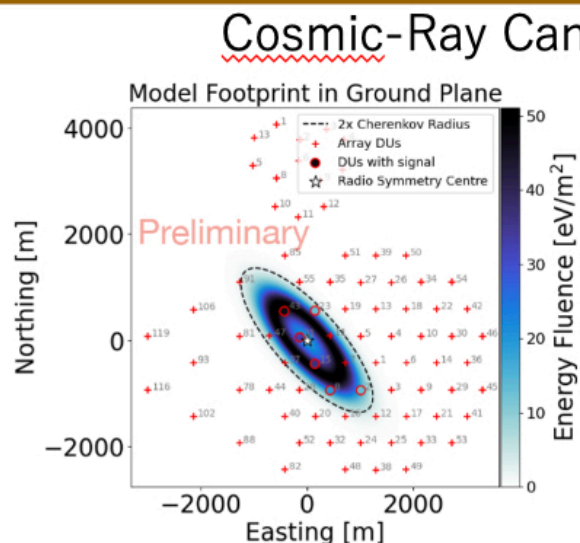
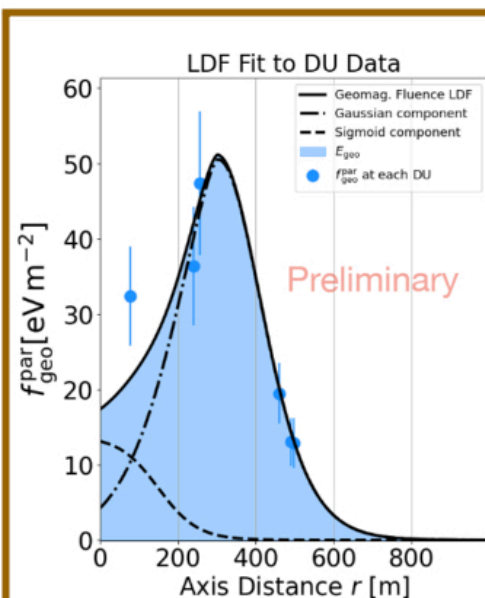
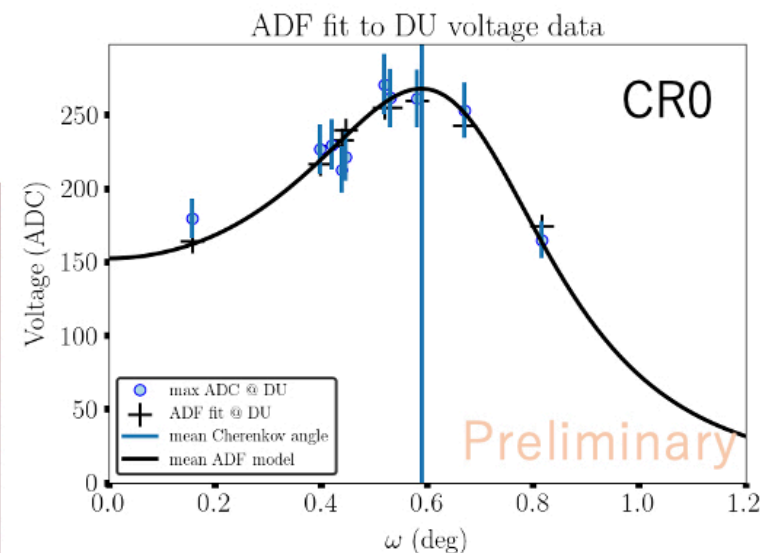
Adapted from a slide of O. Martineau in ICRC2025

Selection pipeline for cosmic rays applied over 12/24 – 03/25 GP300 data

➔ 41 candidates

3 independent methods for amplitude analysis:

- Reconstructed Efield from antenna response deconv.
  - + Lateral Distribution Function on Efield
  - Angular Distribution Function on Voltage
  - Graph Neural Network on Voltage
- ➔ “CR-like” amplitude profiles (Cherenkov enhancement)

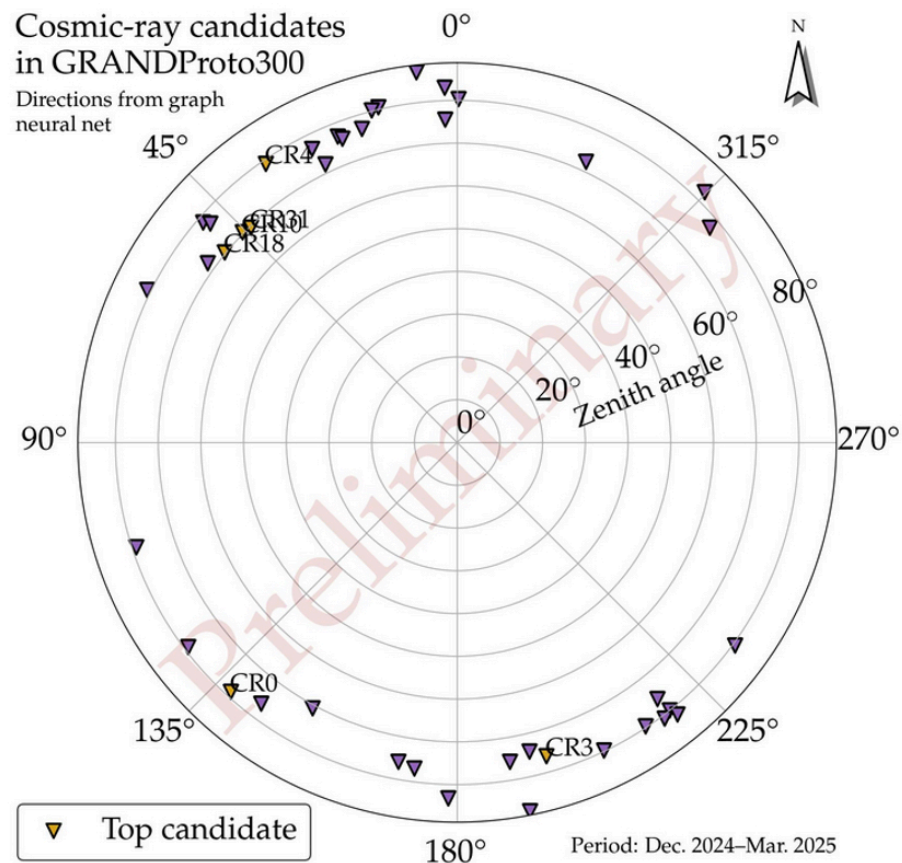




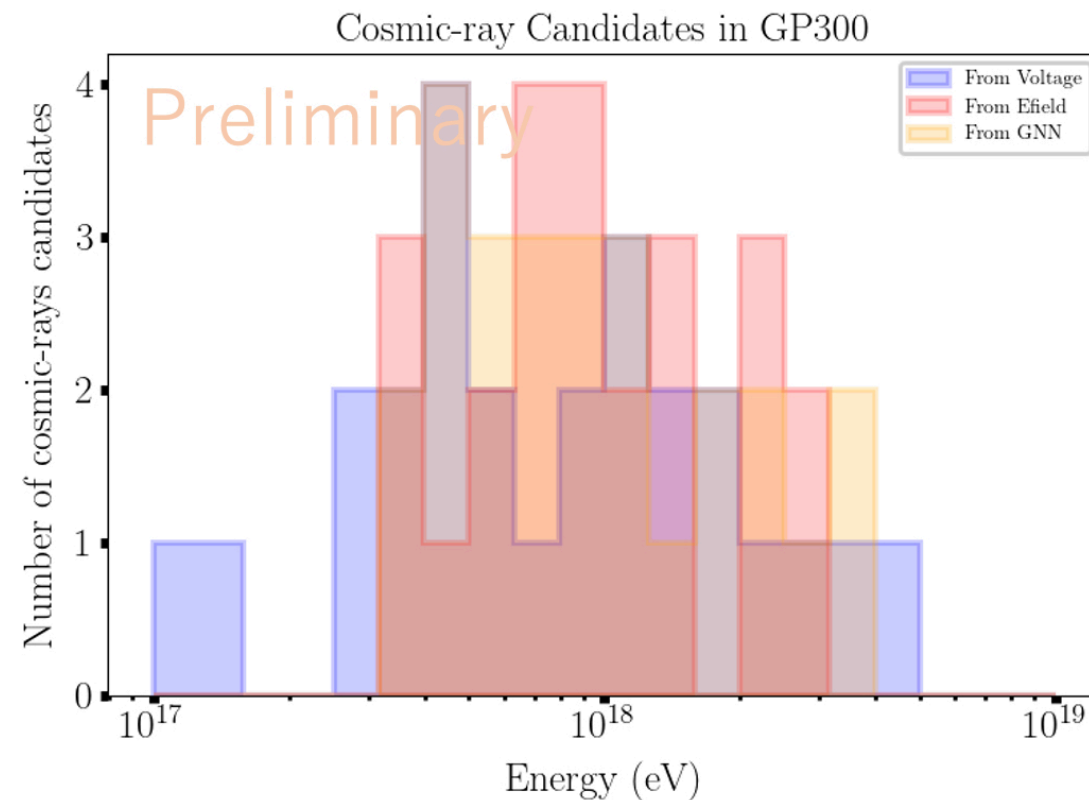
# First Search for Cosmic-Ray Candidates

Slide from O. Martineau in ICRC2025

Direction of arrival consistent among 3 methods

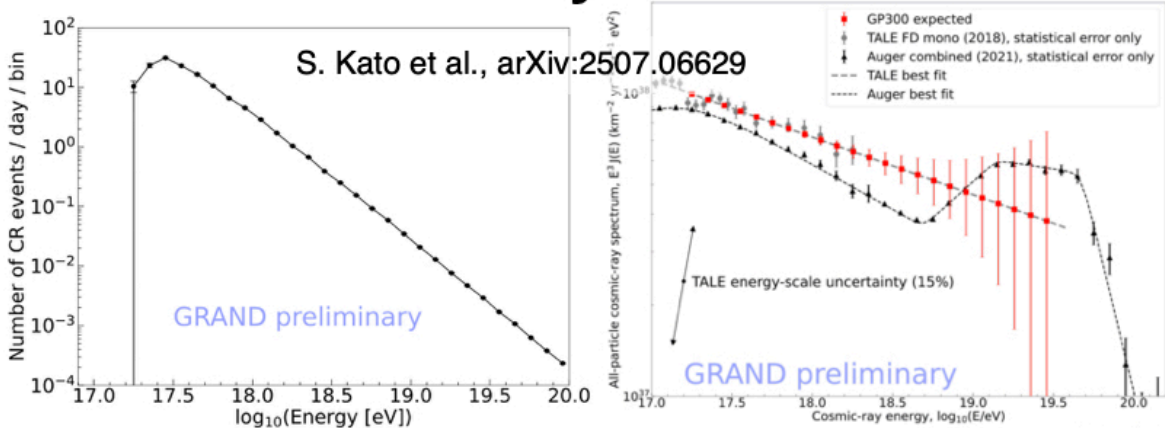


- Energy spectrum for 26 candidates with
- ✓ Reconstructed Efield for 5+ DUs
  - ✓ LDF error  $< 10^{20}$  eV
  - ✓ ADF  $\chi^2 / \text{ndf} < 25$  (see PoS278)



Disclaimer: **GP300 now in commissioning phase.** Only validating HW, DAQ and reconstruction for now.  
Efficiency and purity not known yet for CR detection process → no physics (yet)!

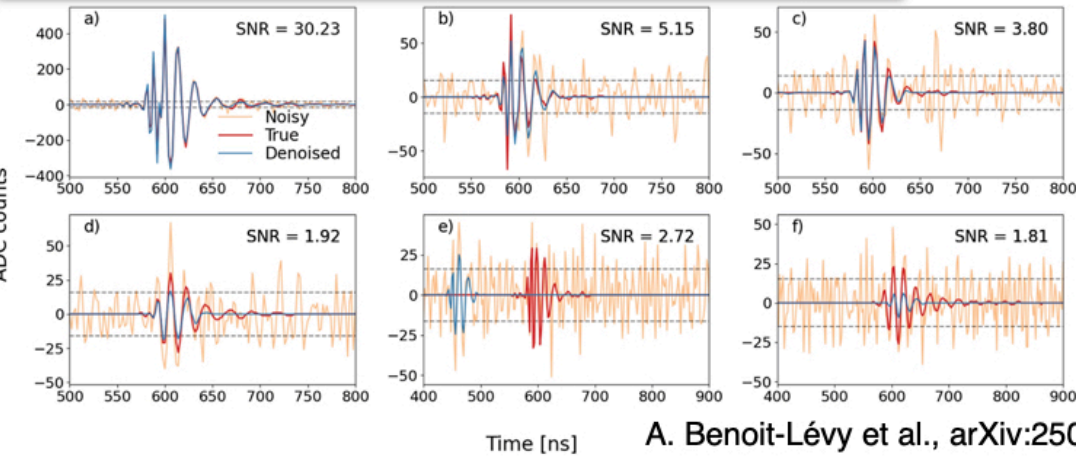
# Simulation Study of GP300



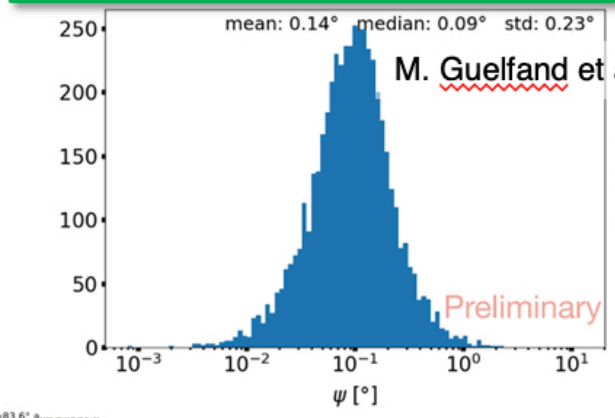
CR event rate estimate  
tens of events / day

Prediction of CR spectral measurement  
 $10^{17} \text{ eV} \lesssim E \lesssim 10^{19.5} \text{ eV}$  in 1yr

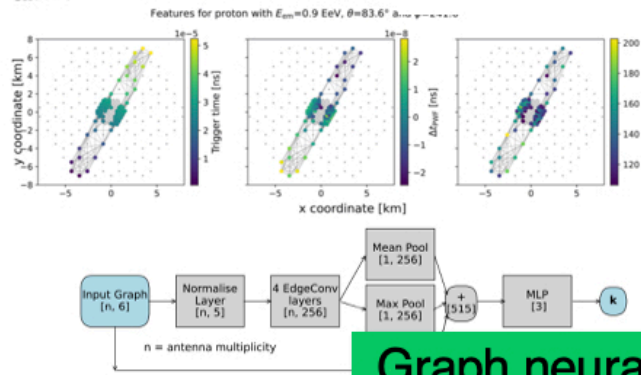
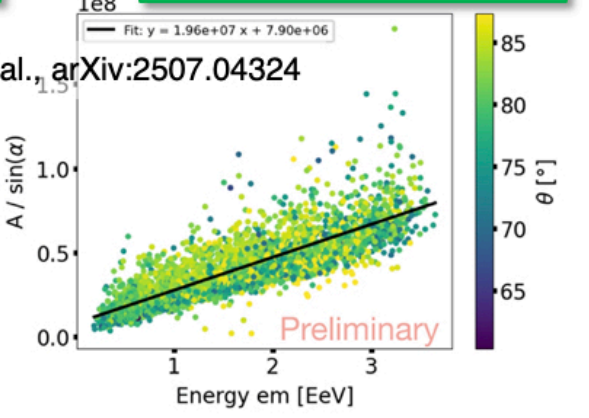
Denoising of the signal trace  
Successful denoising > 95% @ SNR > 4



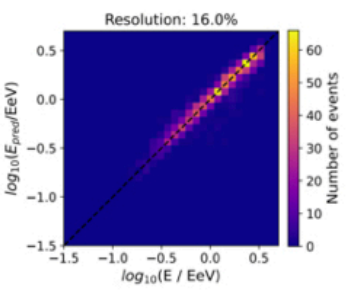
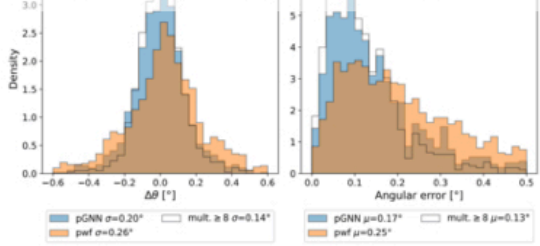
Angular resolution  $\sim 0.1^\circ$



Energy estimation

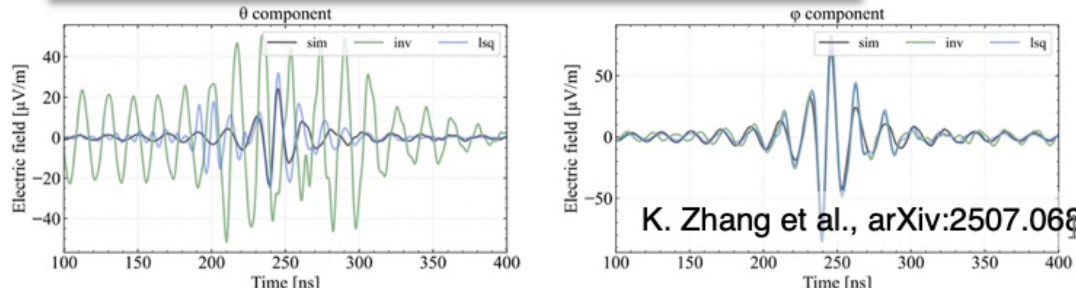


A. Ferrière et al., arXiv:2507.07541



Graph neural network for energy & direction estimation  
Energy resolution  $\sim 15\%$

E-field reconstruction from voltage  
Accuracy of  $\lesssim 5\%$  for the amplitude







# Next Steps for GP300

Coming months:

- ✓ Optimize HW, DAQ & CR selection procedures
- ➔ start Physics run @ GP300 with nominal rate of several 10s CRs/day
- ✓ Build energy spectrum, arrival direction distribution, nature of primary
- ✓ Extend analysis to horizontal events ( $\theta > 85^\circ$ )
- ➔ Validate detection principle of GRAND
- ➔ Do CR physics around the Galactic-Extragalactic transition ( $10^{16.5} \text{ eV} < E < 10^{18} \text{ eV}$ )

In 1-3 years

- ✓ Complete GP300
- ✓ Increase statistics, refine methods and analysis (horizontal events)
- ✓ Test GRAND10k design with improved HW & trigger/DAQ

Later:

Deploy GRAND10k on 2 sites in 2 hemispheres and **start neutrino search**





# Summary

GRAND: Next-generation sensitive astrophysical UHE  $\nu$  detector ( $> 10^{17}$  eV)

Rich science cases are also covered

**GRANDProto300**: one of the GRAND prototypes

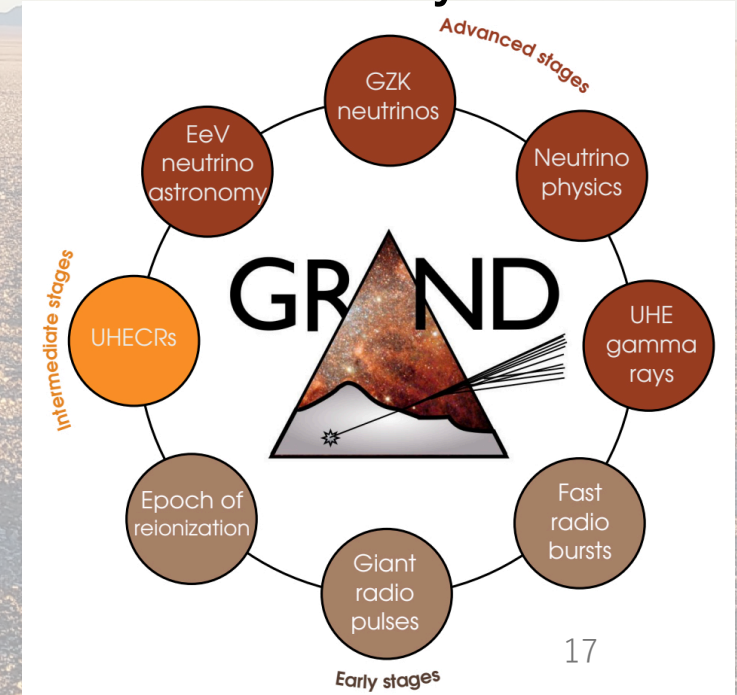
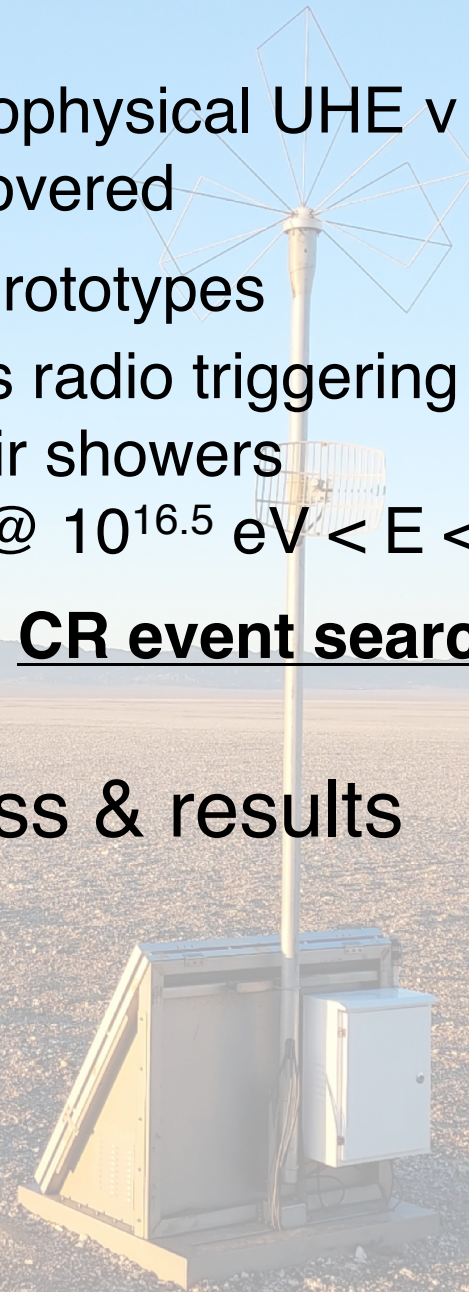
Motivation: Validation of autonomous radio triggering technique

Observation of inclined air showers

Cosmic-ray observation @  $10^{16.5}$  eV  $< E < 10^{18}$  eV

ONGOING!: Data taking, calibration, **CR event search**, simulation study

Stay tuned for upcoming progress & results





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# Thank you for your attention!

