Recent Results of the GRANDProto300

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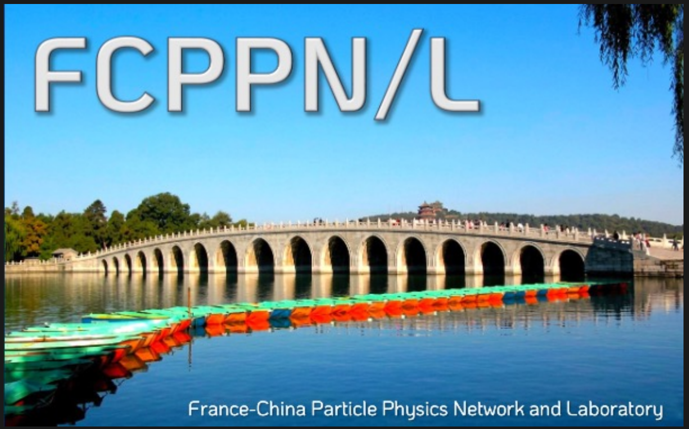
for the GRAND collaboration

17th workshop of FCPPN/L

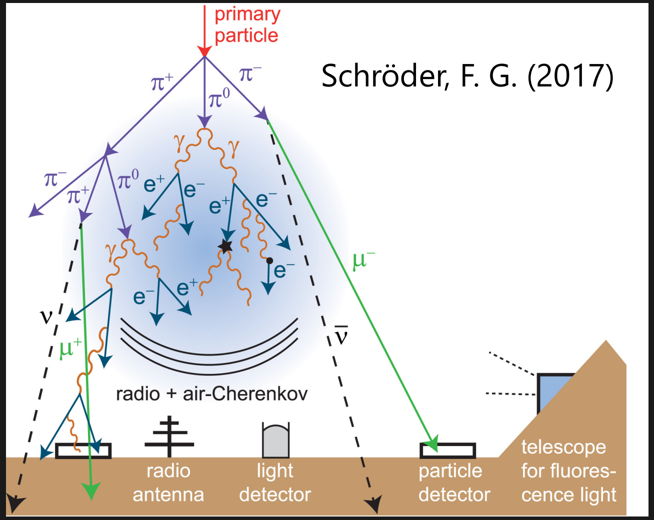
Lyon

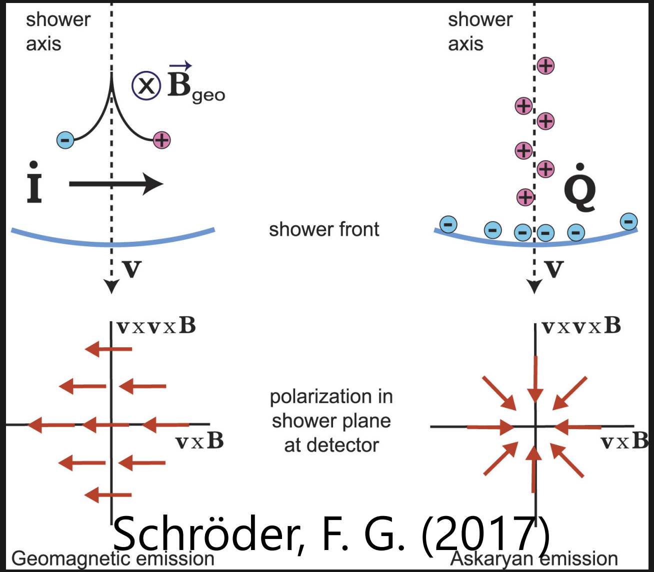
2026.07.02



Radio detection of air showers

1. Radio radiation mostly from geomagnetic effect: the deflection of charged particles in the geomagnetic field.
   → Frequency $\lesssim$ 100 MHz
2. Transparent atmosphere for radio waves.
3. Radio antennas: cheap, robust, scalable. Ideal for large arrays.





Schröder, F. G. (2017)

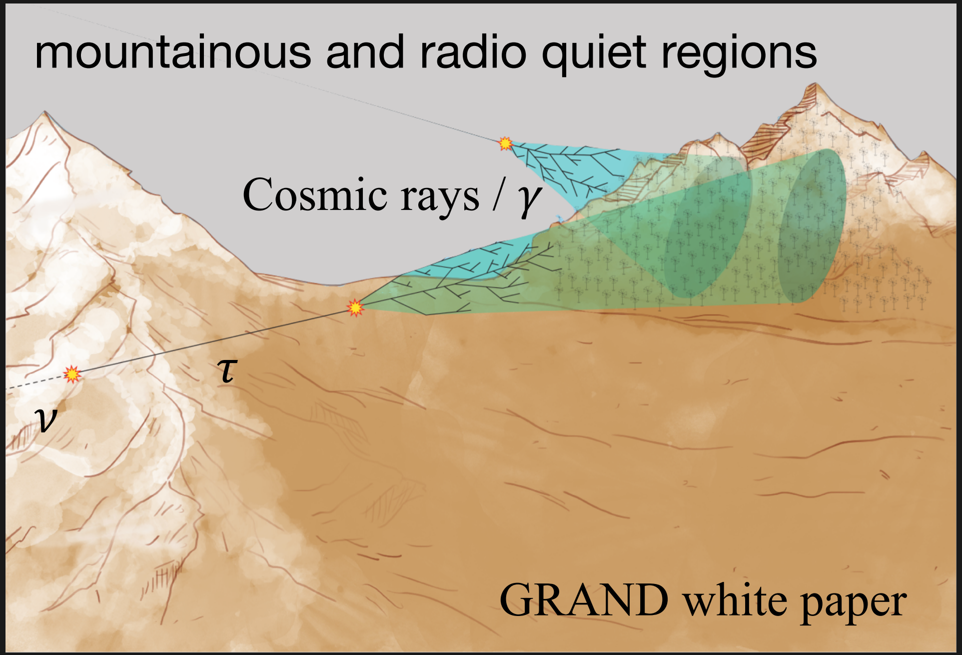
TREND (Tianshan Radio Experiment for Neutrino Detection)

- Date: 2008-2018, precedent of GRAND
- Proposed within the framework of FCPPL
- Co-located with the 21CMA detector, Tianshan mountains, Xinjiang, China
- 50 butterfly antennas, 150 m spacing, 1.5 km^2 in area
- Objective: autonomous radio detection of air showers.
- Success with 500+ CR found, but low efficiency (3%) and purity (80%). arXiv: 1810.03070

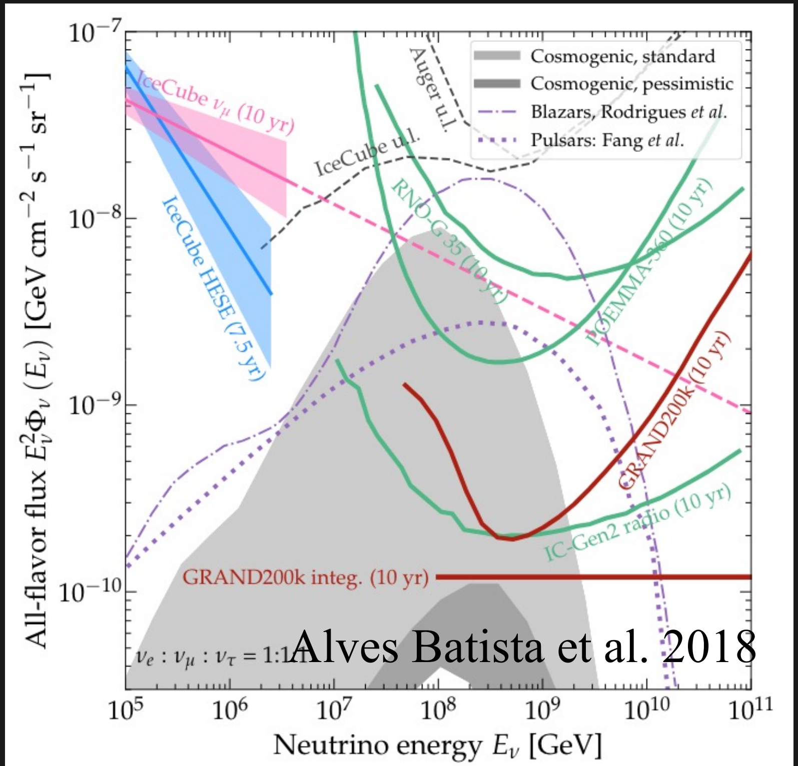
Le Coz+ ICRC2017

Giant Radio Array for Neutrino Detection

- Multi-messenger observatory of 20x10k radio antennas at different locations ~200k km^2
- Sensitivity~10^{-10}GeV$cm^{-2}s^{-1}sr^{-1}$, angular resolution ~0.1deg (GRAND white paper, Sci. China. Phys. Mech. Astron. 2020)
- >100 people involved from 47 institutes in 16 countries



GRAND white paper

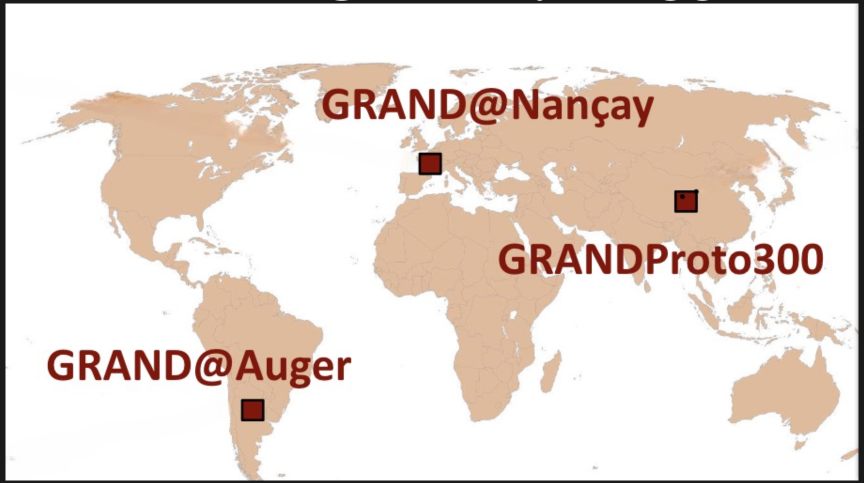


Alves Batista et al. 2018

GRAND prototypes

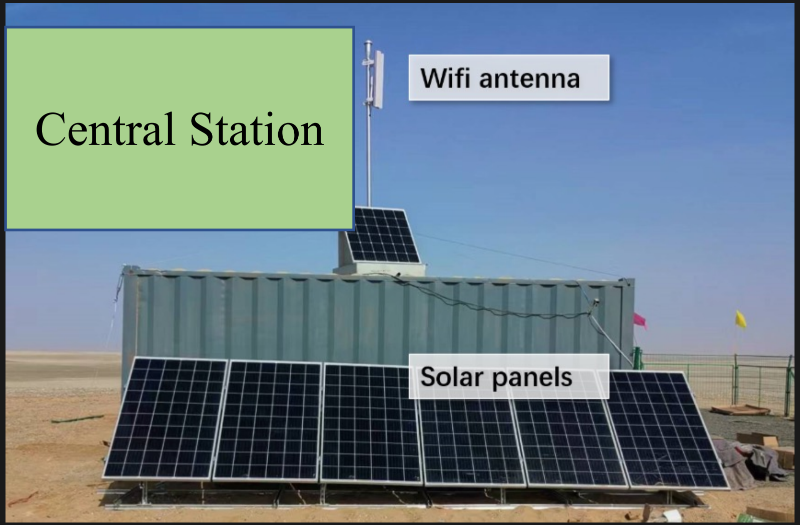
Arrays

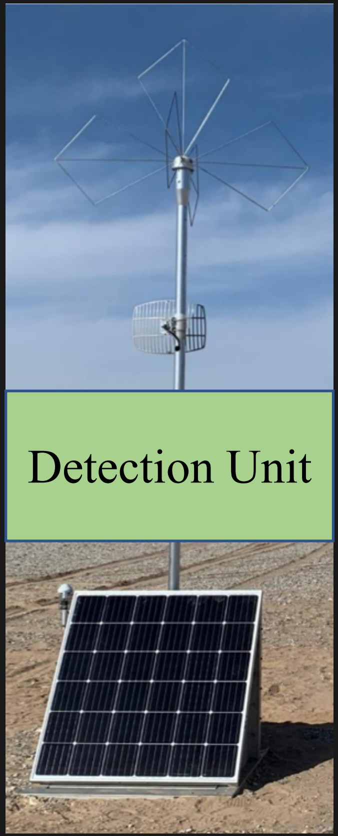
- GP300: Dunhuang, China
- GRAND@Auger: cross check with the Auger particle detectors.
- GRAND@Nançay: trigger test



Detection unit

- Butterfly-shaped antenna
- Powered by solar panel
- Communication via Wi-Fi
- Working frequency: 50-200 MHz

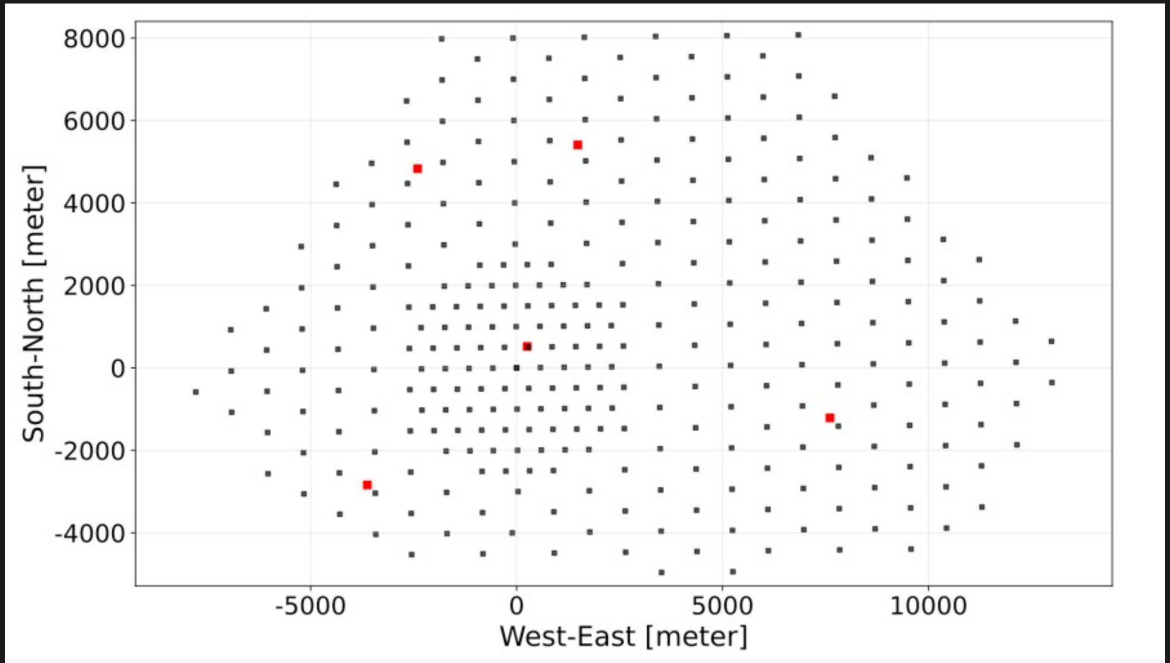


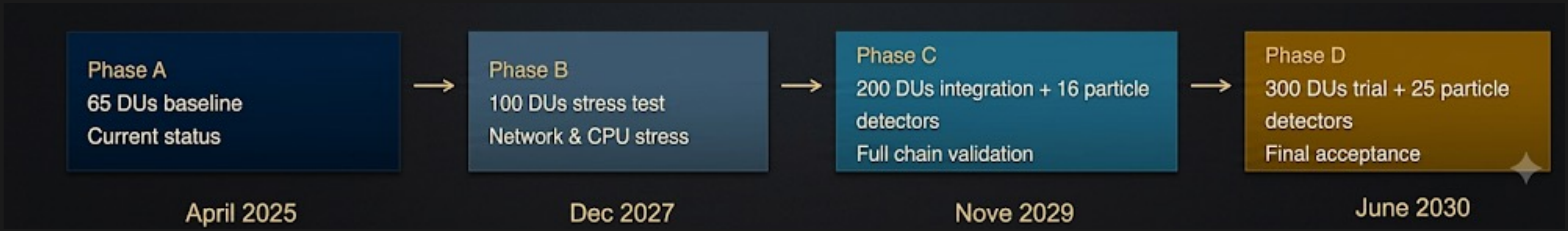


GP300

- Located in the Gobi dessert, China
- 300 antennas (+ 25 particle detectors) to cover an area of 13km × 15km
- Deployment secured by the local government and Chinese funding

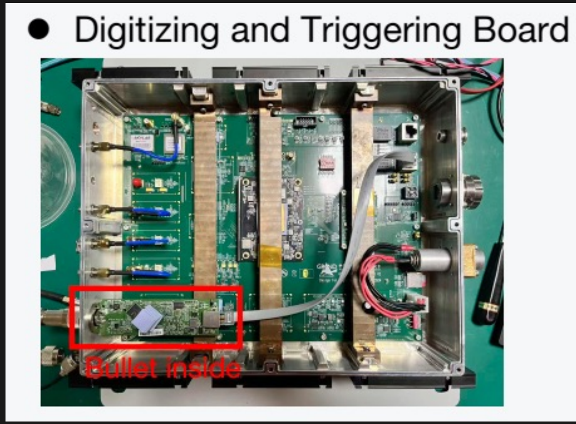
GP300 layout: infill + sparse array

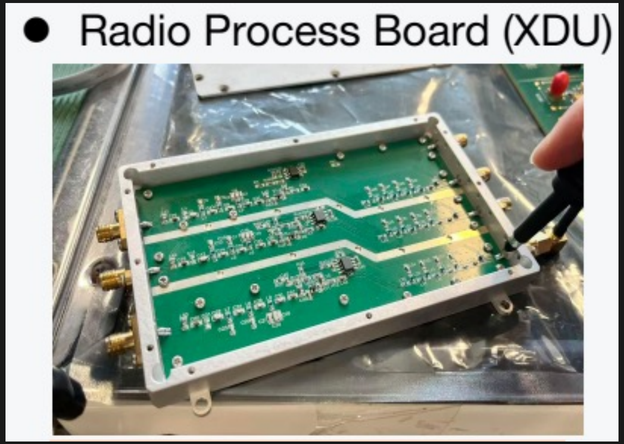


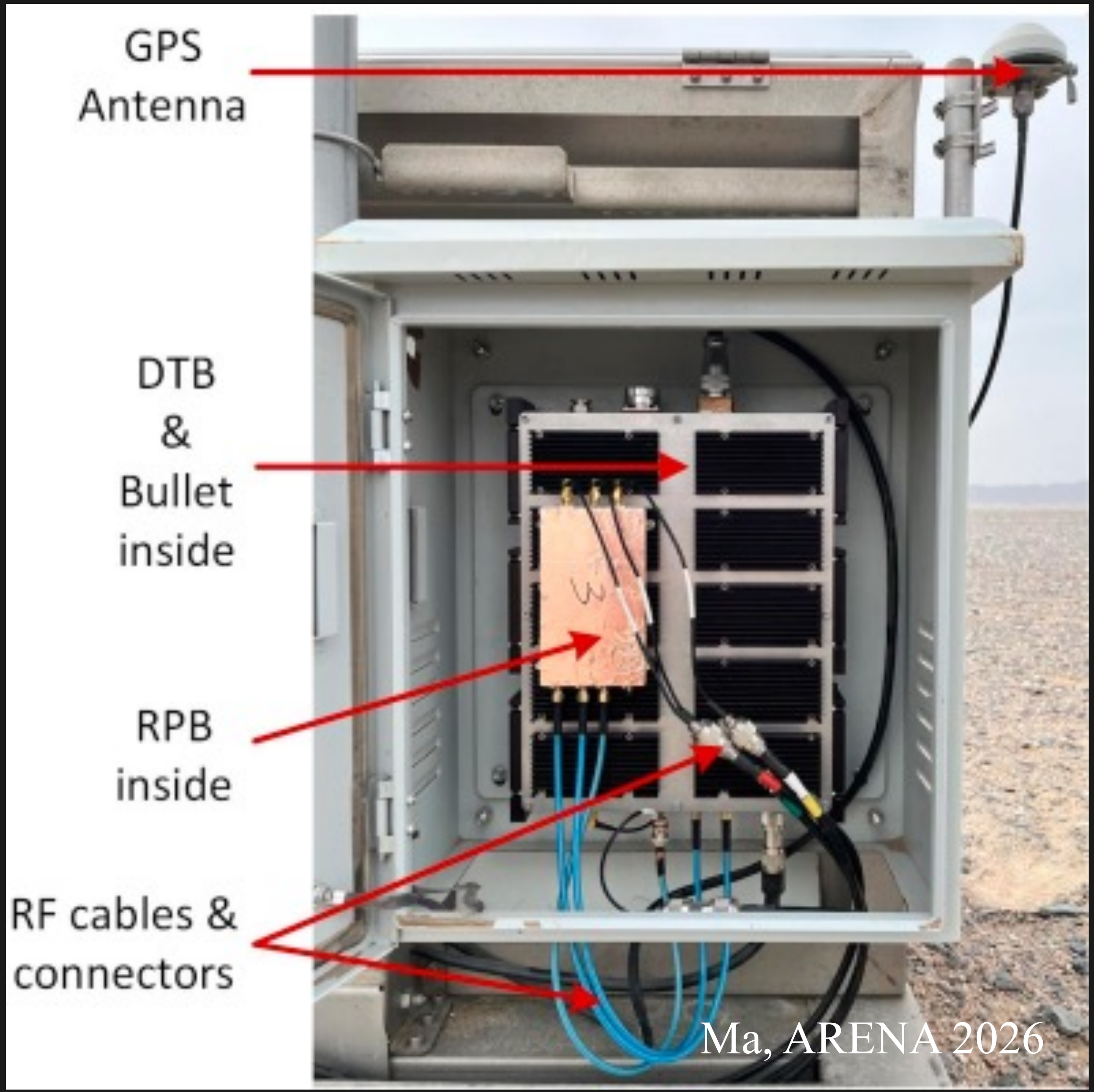


Hardware

- The next prototype: new antenna, LNA, FEB
  - Radio process board (RPB)
  - Digitizing and triggering board (DTB)
- Still under active development!







Detector Calibration

GNSS time: offset and resolution

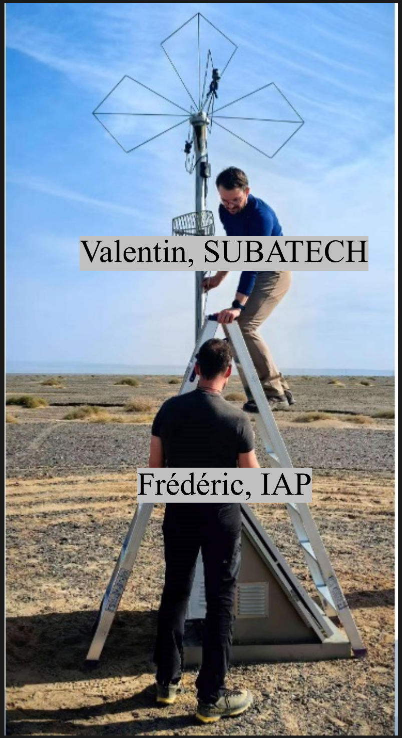
Radio frequency chain: noise and gain

GNSS time calibration

Reconstruction precision of the source position $\sim\mathcal{O}(1\ \mathrm{m})$

Position

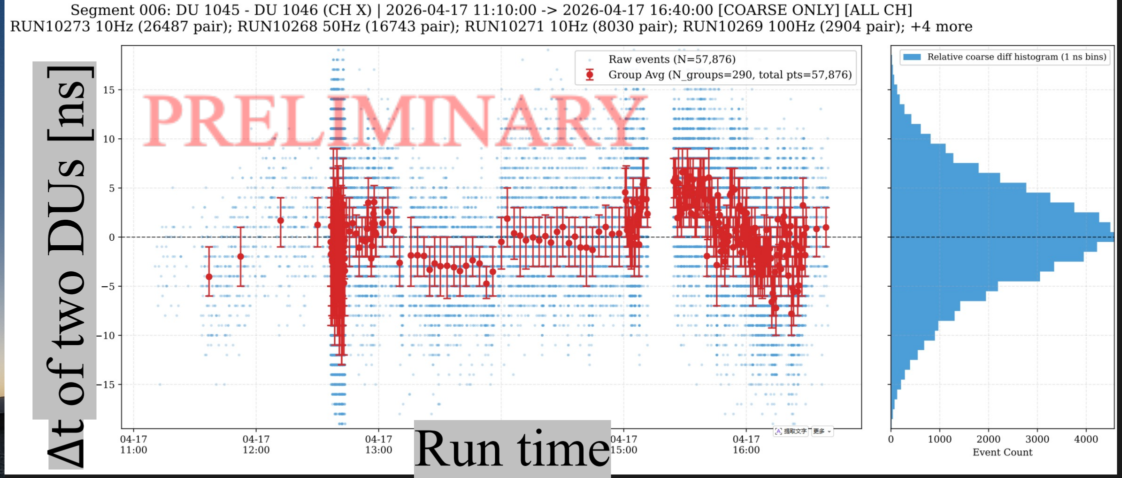
Independent RTK measurements to reach **~cm** positioning in horizontal directions.



Time

Use beacon-generated pulse to trigger the array.

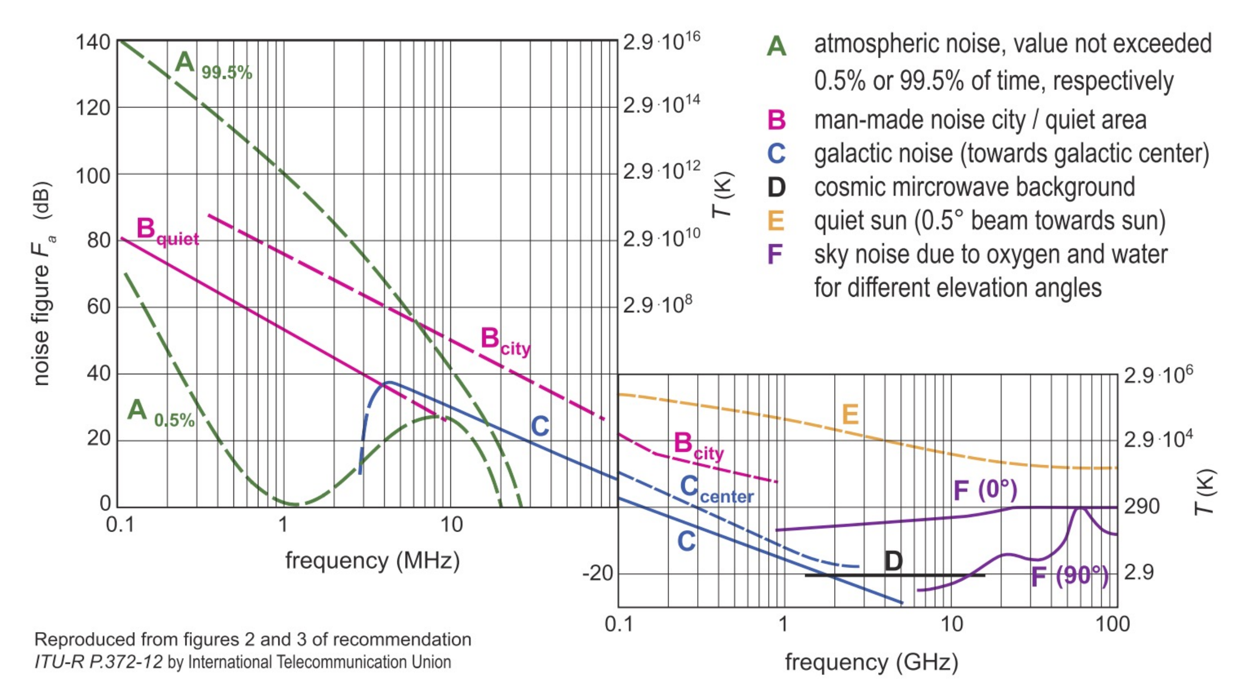
- to calibrate the offsets among the GNSS chips (~10ns, time-varying)
- to estimate the timing resolution within minute timescale (<5ns)



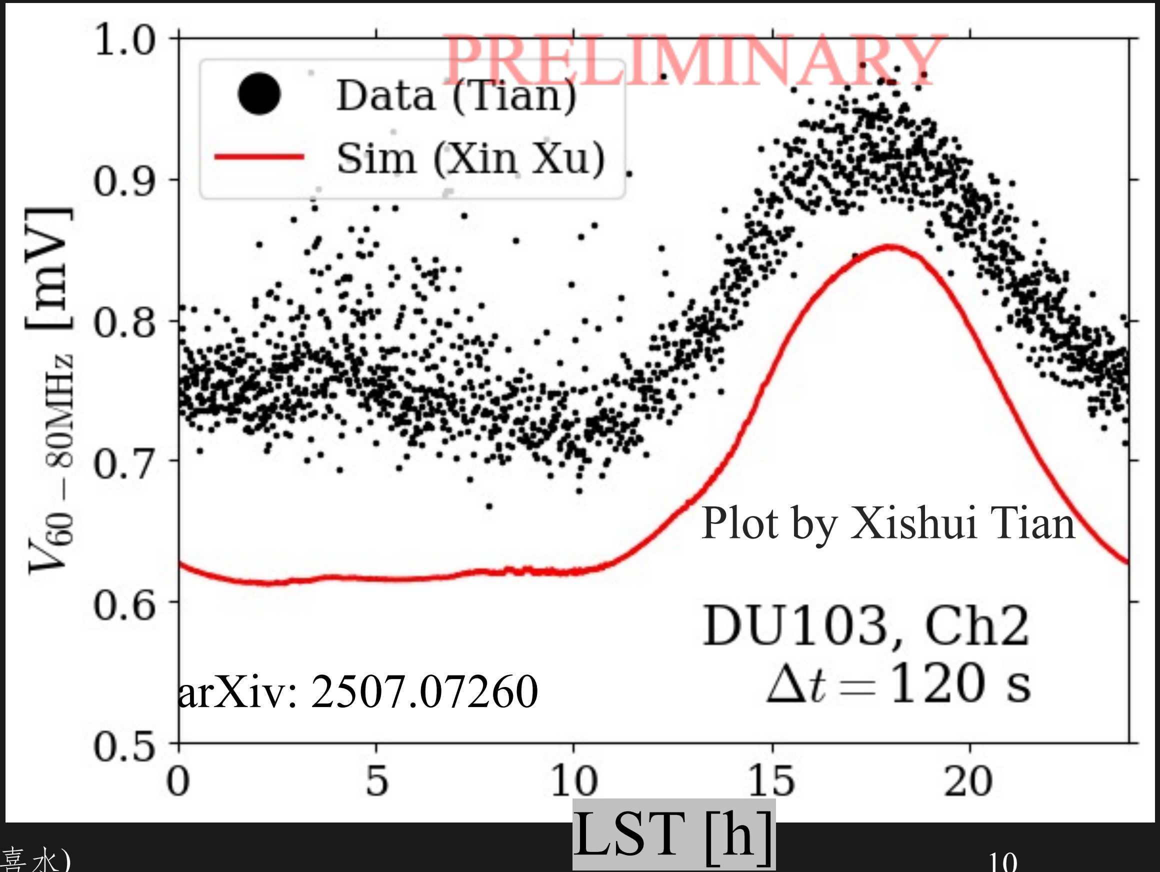
Plot by Yanbo Wang

Antenna response calibration

- Use the Galactic radio background as the calibration source



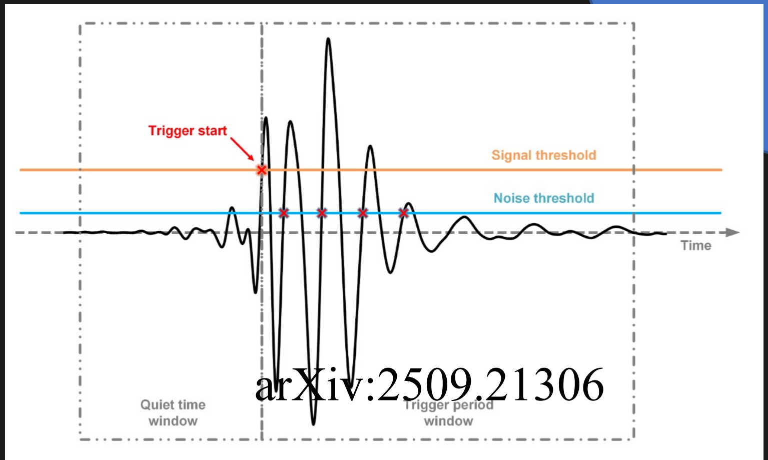
Reproduced from figures 2 and 3 of recommendation *ITU-R P.372-12* by International Telecommunication Union



Multilevel trigger

- Three levels of trigger: FPGA → Arm CPU → Central station

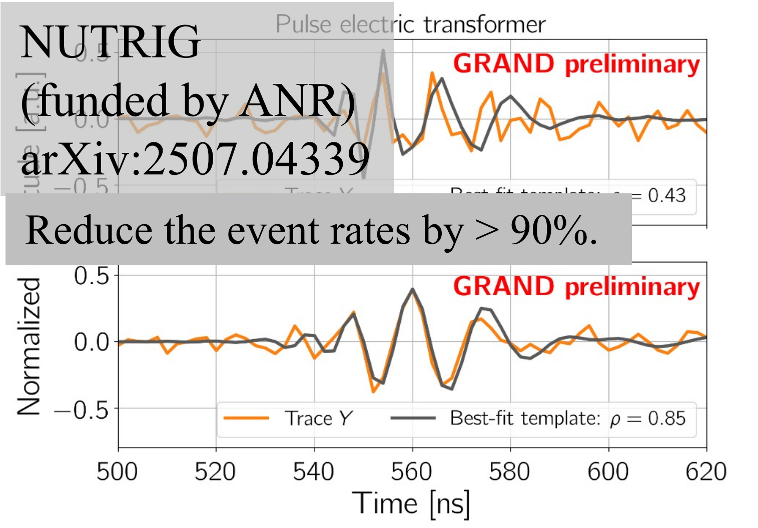
Antenna output → Detection unit: FPGA (L1) → CPU (L2) → Triggered Event → Central Station L3



arXiv:2509.21306

Plot by Xing Xu

NUTRIG
(funded by ANR)
arXiv:2507.04339



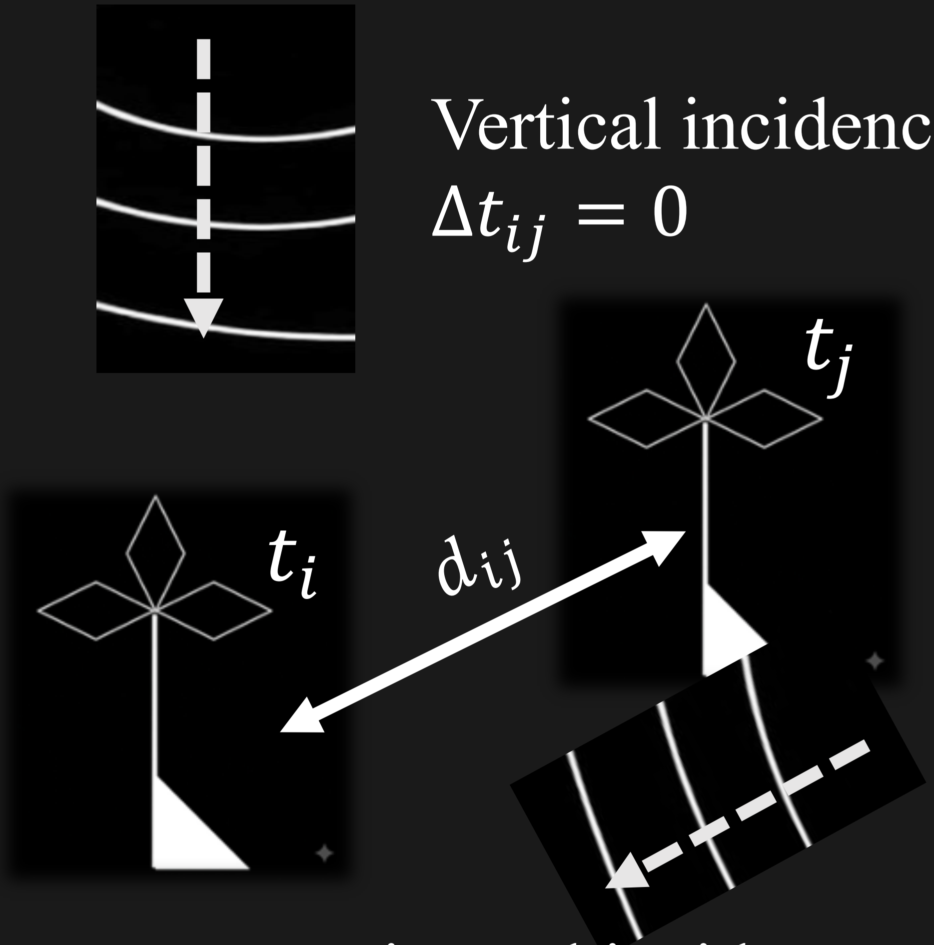
Reduce the event rates by > 90%.

Time coincidence
Correlation score
Causality cut
Rejection of space clustering

Plot by Pablo Correa

Causality cut to reduce random coincidence

- For incident EM waves:
  - Vertical: $\Delta t = 0$
  - Horizontal: $\Delta t = d/c$
- Noise triggers randomly, likely violating the causality condition $\Delta t < d/c$.
- Reduce the event rate by >90%

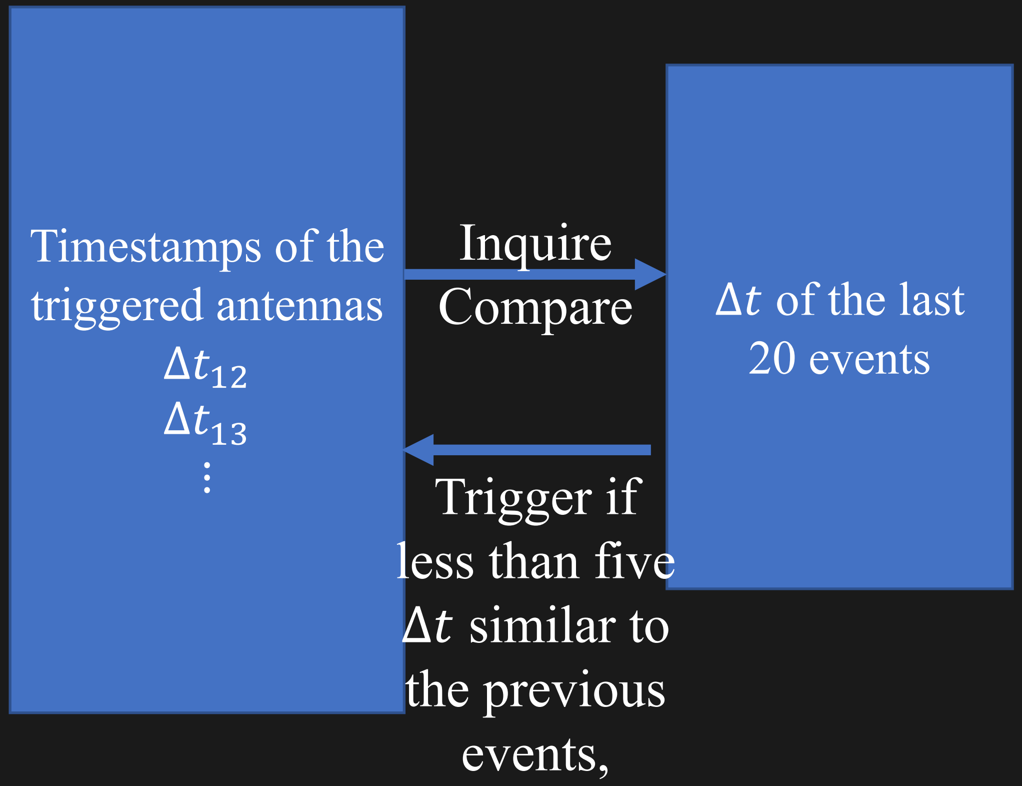


Vertical incidence, $\Delta t_{ij} = 0$

Horizontal incidence, $\Delta t_{ij} = d_{ij}/c$

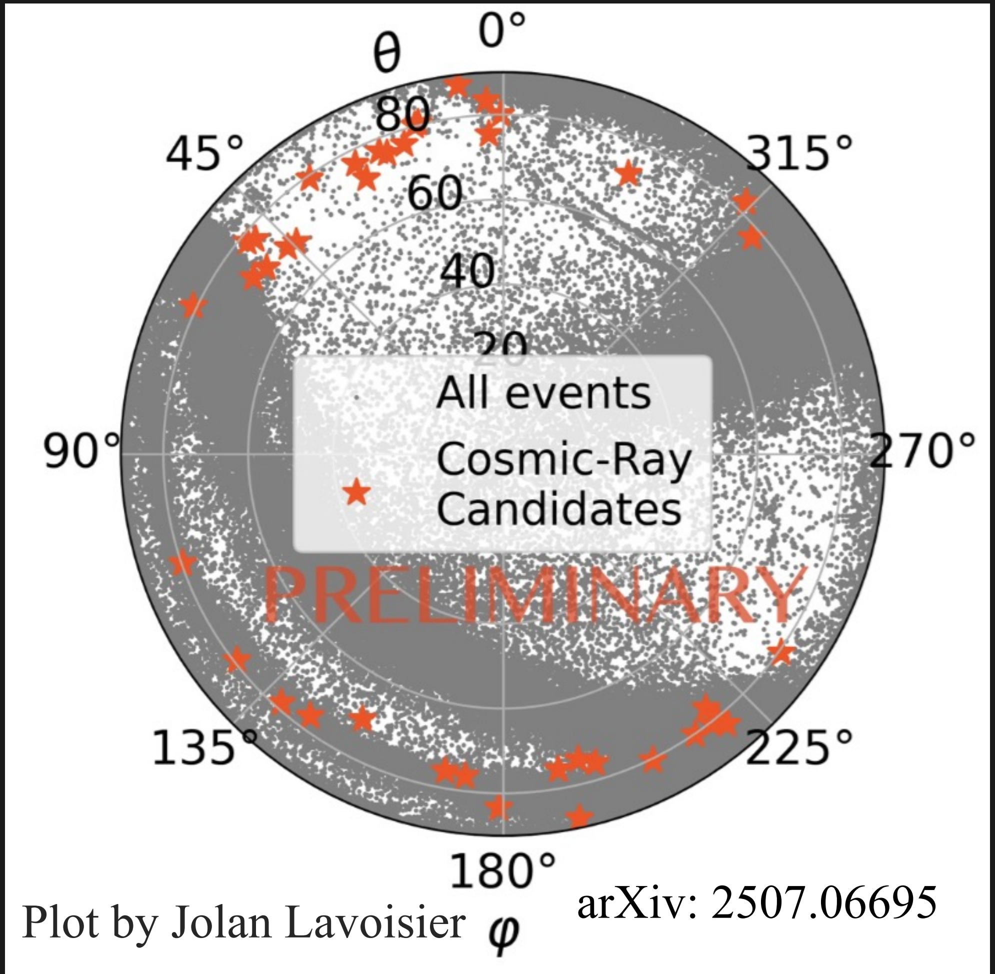
Cuts to exclude clustered events

- The background events are **bursty in time.**
- The background events are **clustered in space**.
- Discard the event if the Δt among antennas are the same as the previous events.
- Reduce the event rate by ~95% during noisy period.



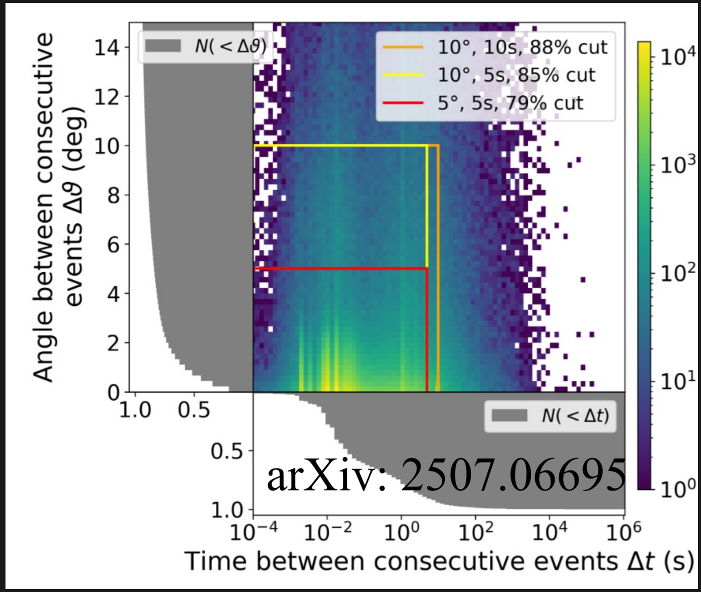
Searching for CRs in GP300 data

- 533k events → 41 CR candidates after the cut (out of 73-day data)



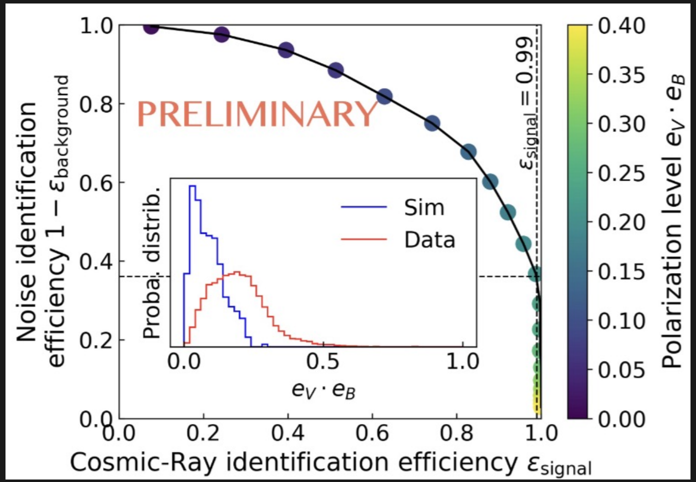
CR cuts of GP300

Clustering cut
To reject the bursty sources
Veto window for events close in time and space



Cut efficiency: 79%

Polarization cut
To reject non-shower events
The EAS has a strong $\vec{v}\times\vec{B}$ polarization ($e_V \cdot e_B \approx 0$)



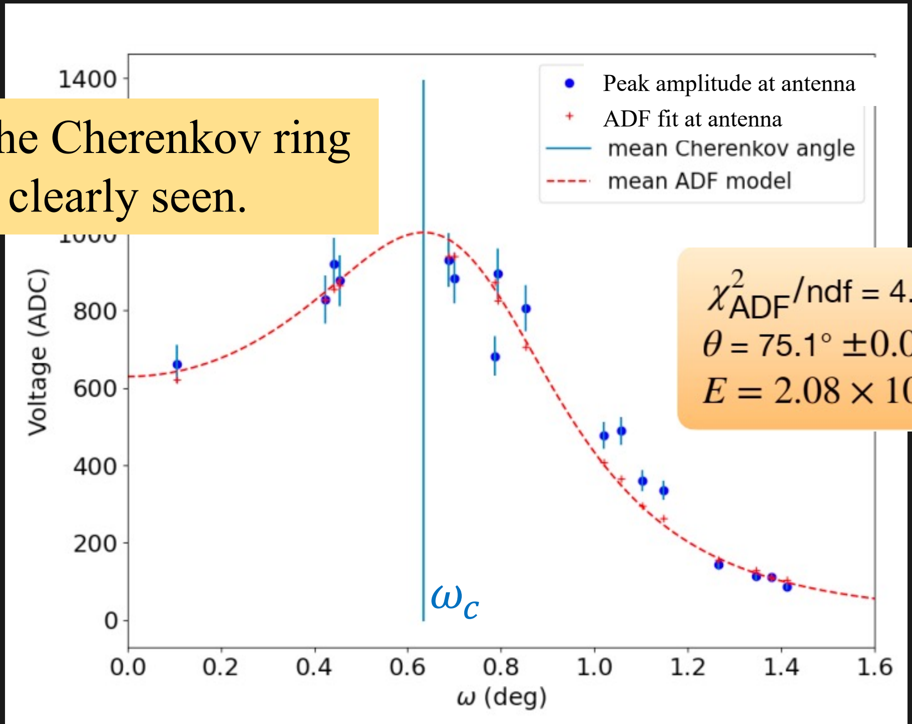
Cut efficiency: 22%

Quality cuts
Minimum multiplicity
Reconstruction quality
Zenith angle
SNR
RMS

Plots by Jolan Lavoisier

An example of CR event with GP300

- Angular distribution function



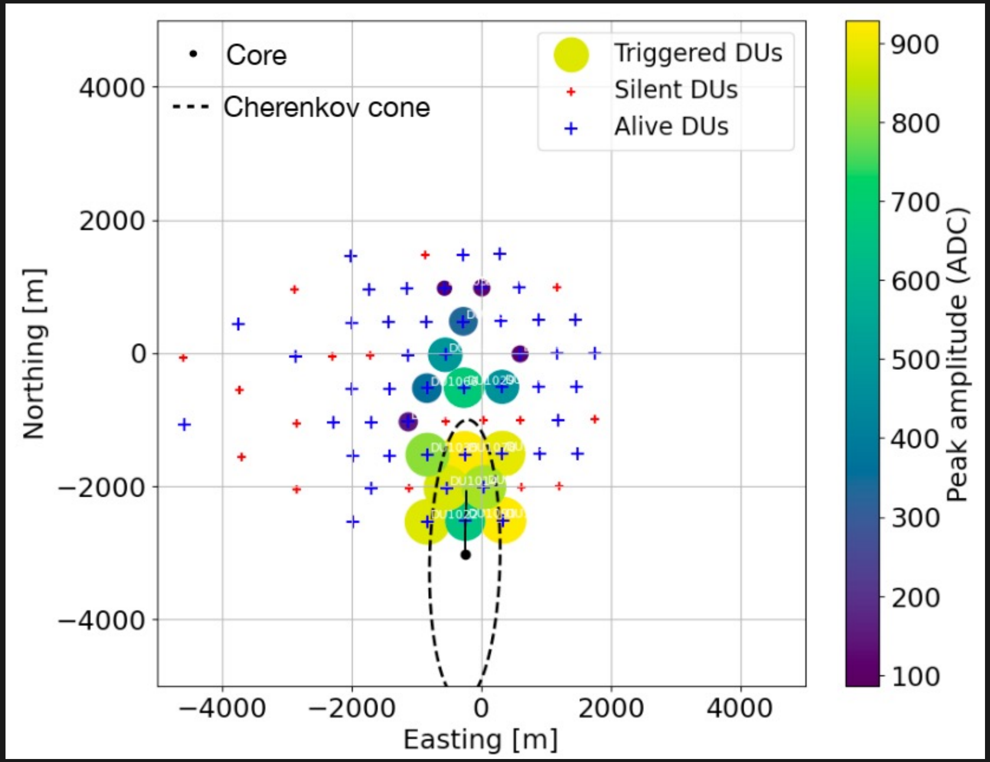
The Cherenkov ring is clearly seen.

χ^2_{ADF}/ndf = 4.73

$\theta = 75.1^\circ \pm 0.03^\circ$, $\phi = 358.7^\circ \pm 0.02^\circ$

$E = 2.08 \times 10^{18}$ eV

- Footprint



Plots by Marion Guelfand

Summary

References:
Website: http://grand-observatory.org
GRAND Whitepaper: https://arxiv.org/abs/1810.09994
GRAND ICRC2025: https://arxiv.org/html/2507.09585/
GRANDlib: https://arxiv.org/abs/2408.10926
https://github.com/grand-mother

1. 200+ cosmic rays have been detected at GP300 via self radio trigger.
2. GP300, expected to be completed in 2030, will continue to measure CRs of 100 PeV – 1 EeV.
3. GRAND is to detect UHE neutrinos in the next decade.

Working on the first UHECR spectrum with GP300!

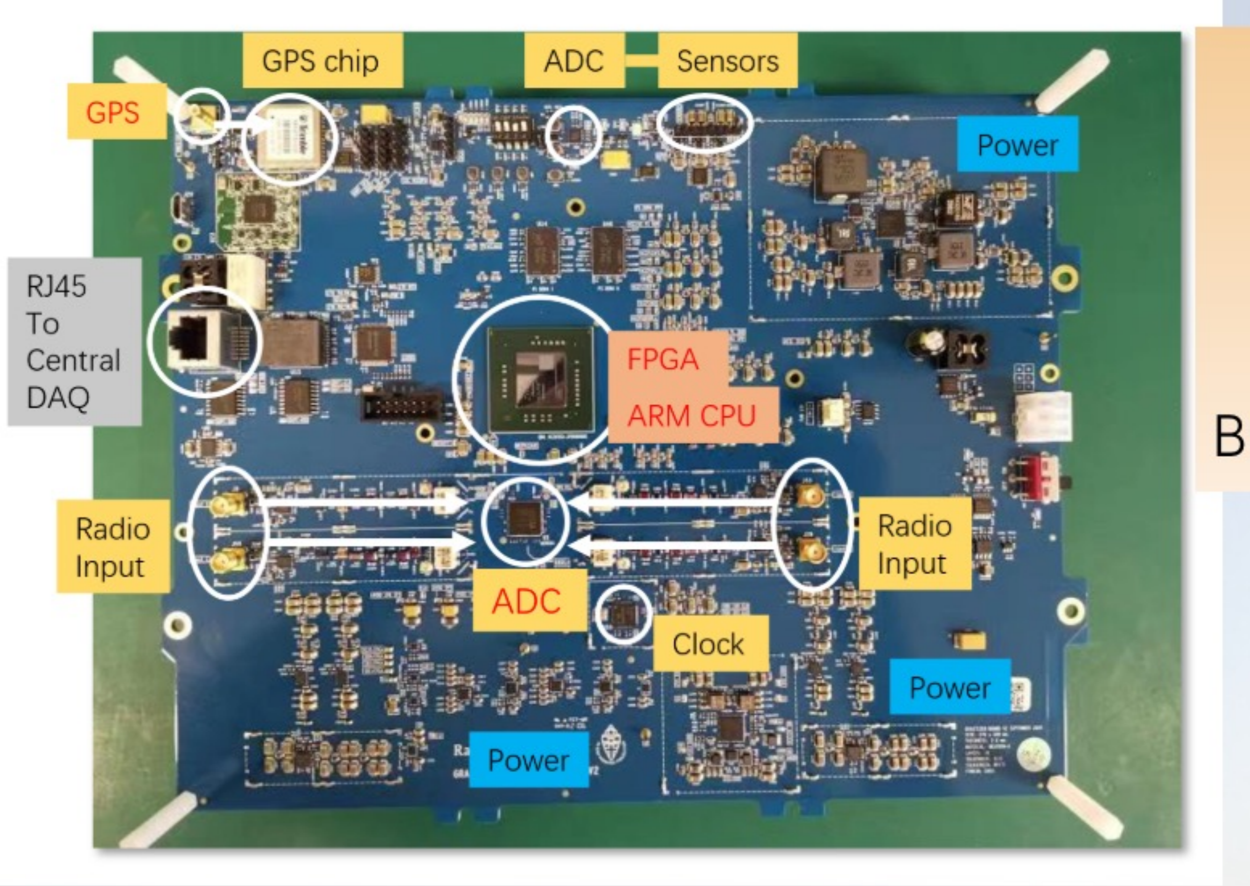
GRAND Collaboration Meeting @Dunhuang, May 2026

A small AD about MT3C

(三分钟通俗易懂说论文)

- Any student who benefits from the Sino-French collaboration (i.e., **everyone in this meeting!**)
- Use three minutes to introduce your PhD work.
- The prize is a one-week trip sponsored by CAMPUS FRANCE (+ RMB)

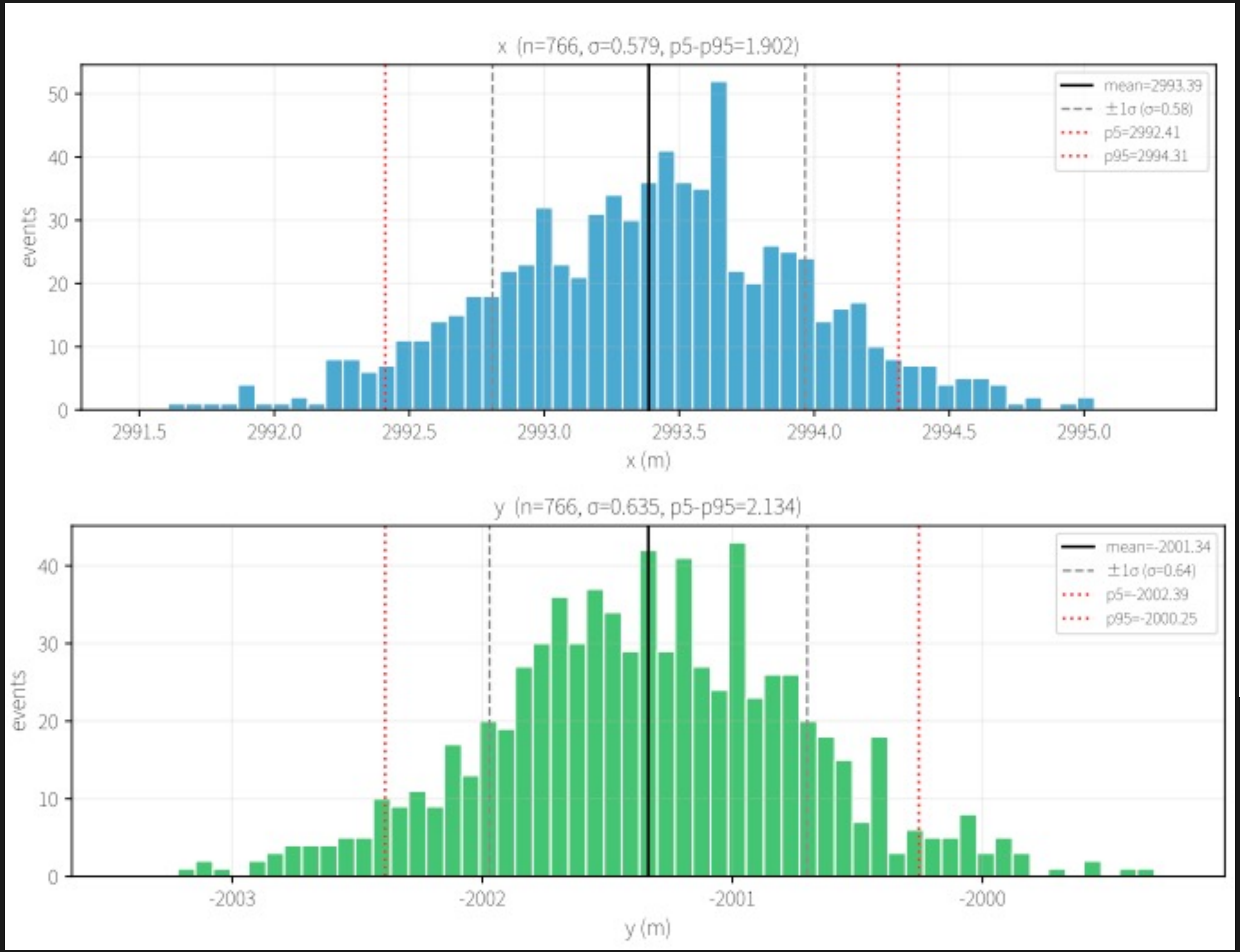
Frontend Electronic Board of GRANDProto

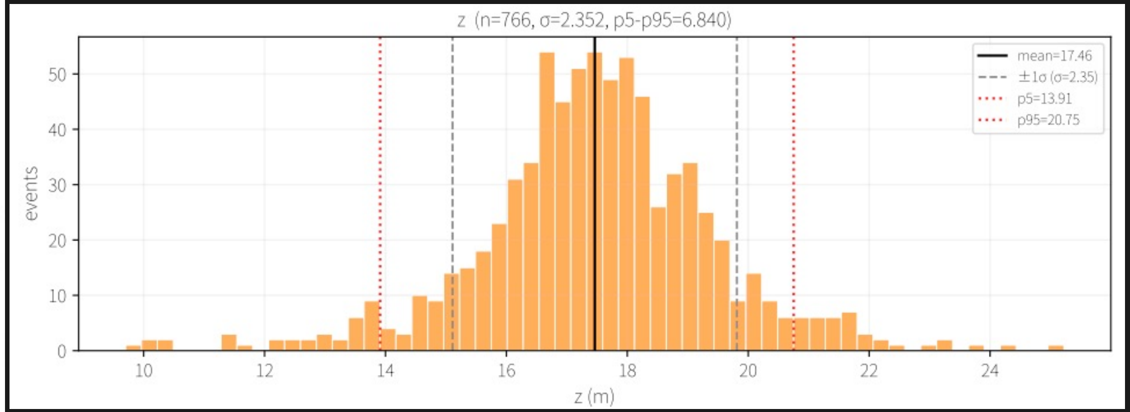


Electronics:
50-200 MHz analog filtering,
500 MS/s sampling
FPGA+CPU
Bullet WiFi data transfer

Designed by Radboud University
Produced by PMO & NAOC

Spherical wave fitting of beacon position

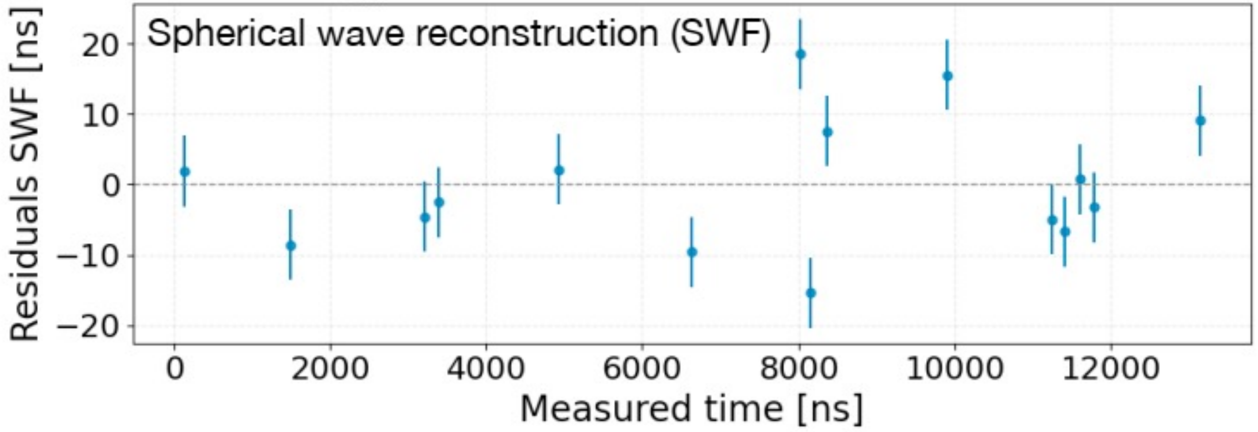


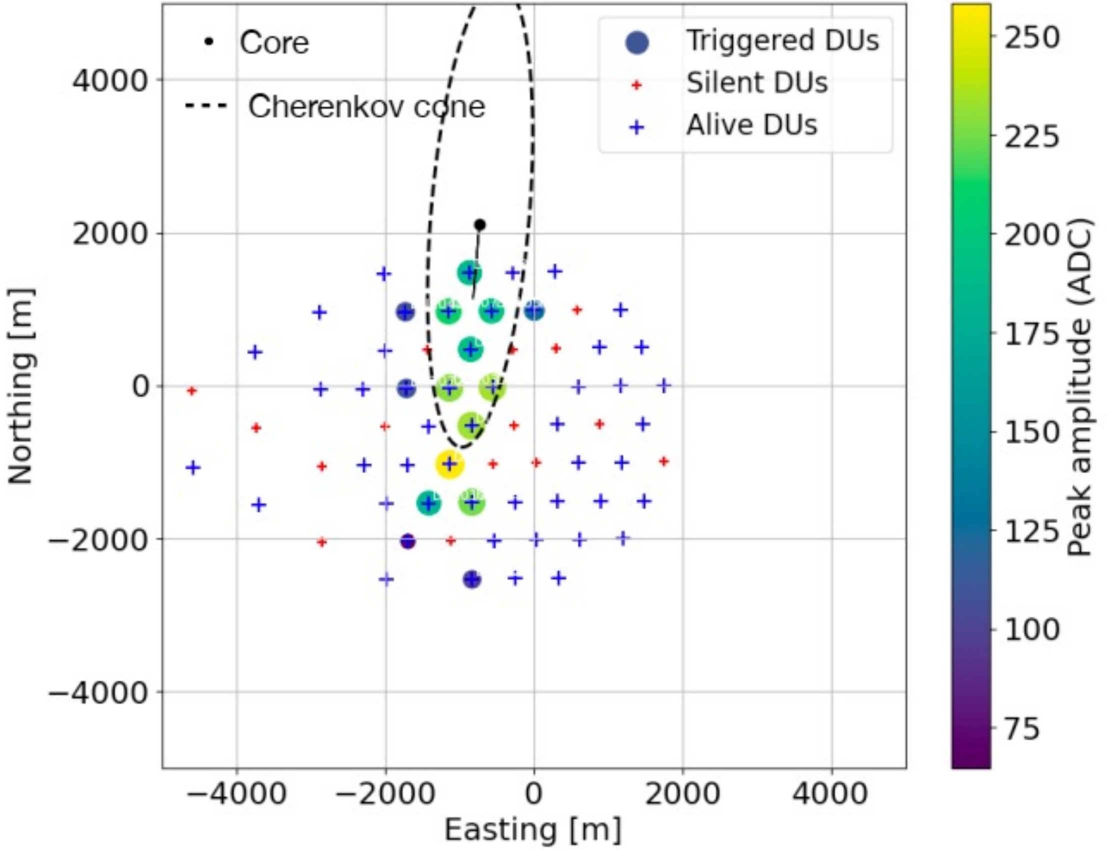


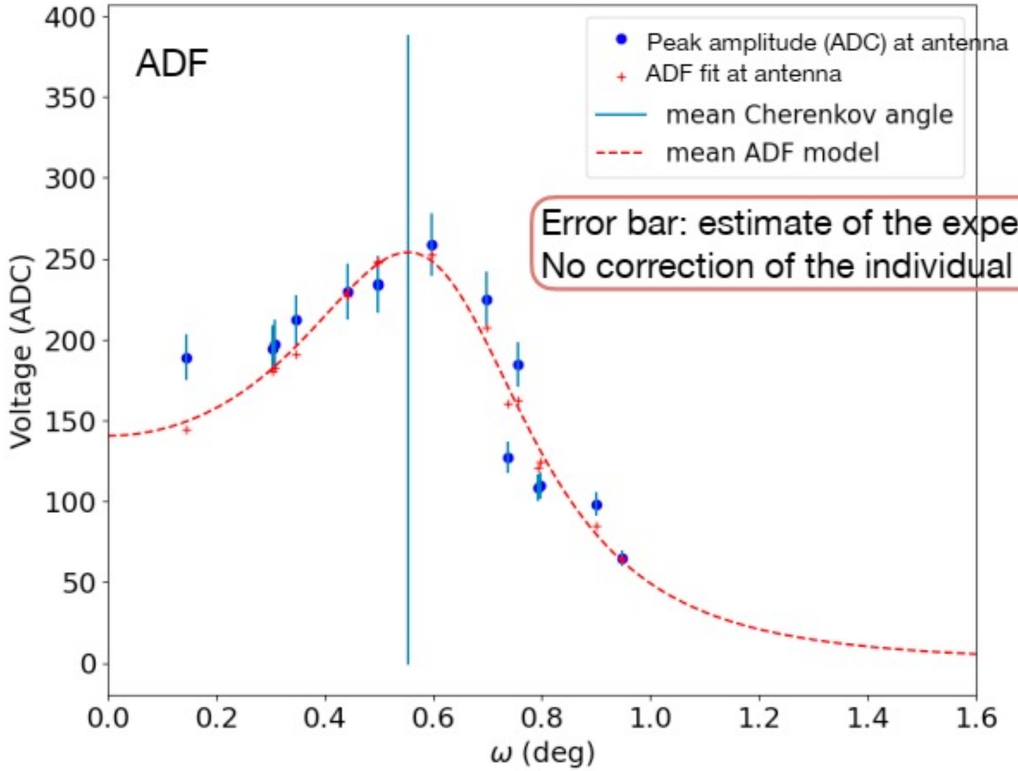
Plots by Yanbo Wang

Example of cosmic-ray candidates

$\chi^2_{\rm swf}/{\rm ndf} = 4.33 \quad ||X_{\rm source} - X_{\rm core}|| = 68.4\,{\rm km}$







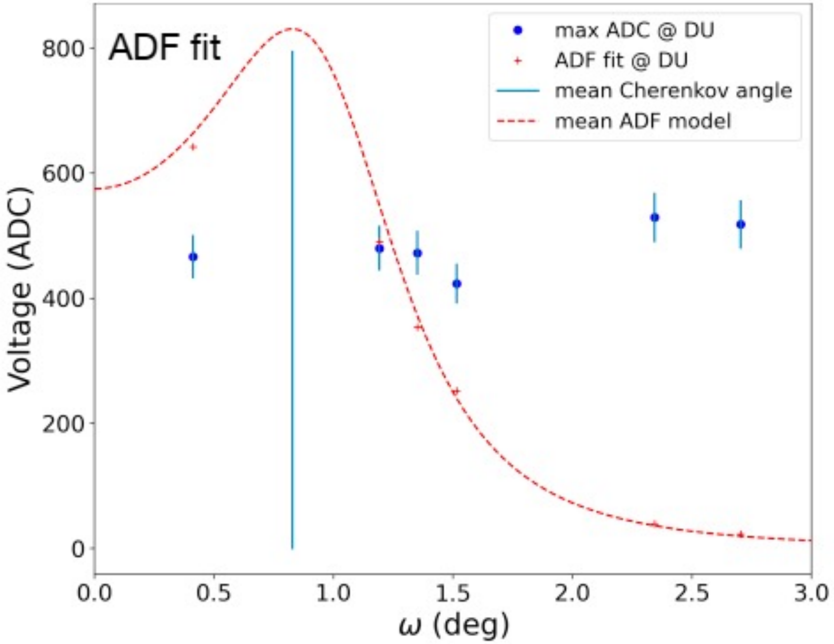
Error bar: estimate of the expected error: 7.5%
No correction of the individual antenna response yet

$\chi^2_{\rm ADF}/{\rm ndf} = 3.59$
$\theta = 77.5^\circ \pm 0.03^\circ$, $\phi = 175.1^\circ \pm 0.01^\circ$
$E = 7.42 \times 10^{17}$ eV

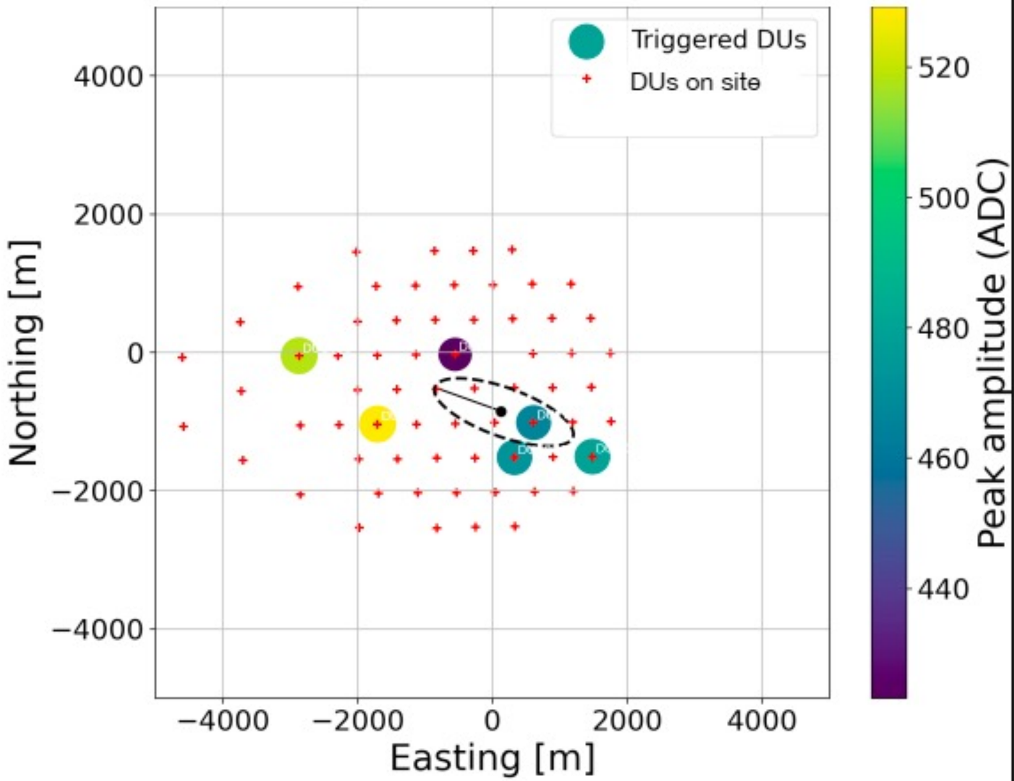
Slide from Guelfand+
Rencontres de Moriond 2026

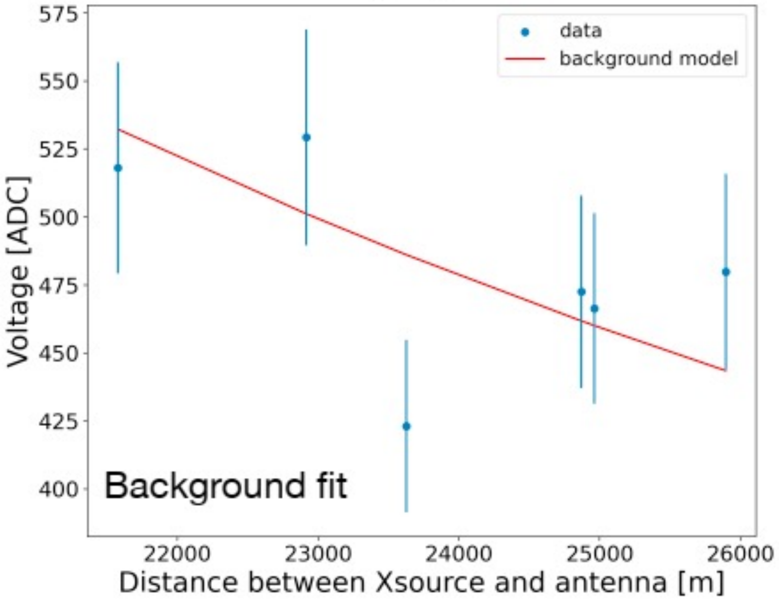
Amplitude profile:
Expected enhancement at reconstructed
Cherenkov angle ω_c position: cosmic ray signature
15 triggered antennas close to ω_c

Candidate not passing ADF selection criteria



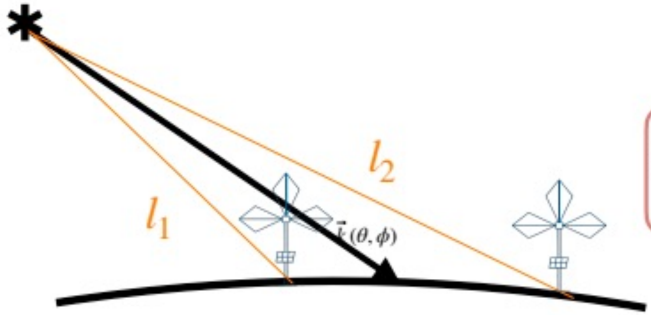
$\chi^2_{\text{ADF}}/\text{ndf} = 190.25$
$\theta = 71.0°, \phi = 70.7°$
$E = 1.02 \times 10^{18}$ eV





$\chi^2_{\text{background}}/\text{ndf} = 1.14$

Background source
at X_{source} (from SWF)



Background model: assumes isotropic emission from X_{source}: $A = \kappa/l$

Free parameter

Amplitudes very similar along all antennas
Tagged as background event