The GRAND project
Status report

GRAND collaboration meeting

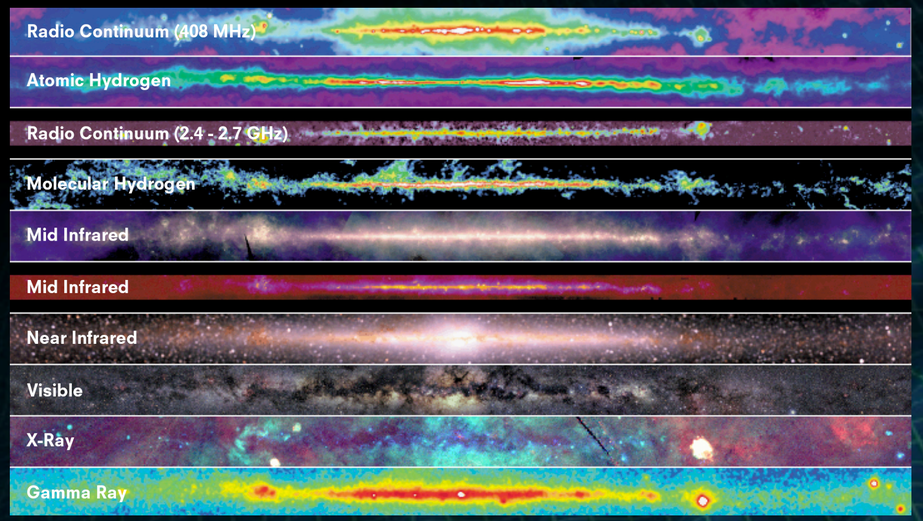
Warsaw University

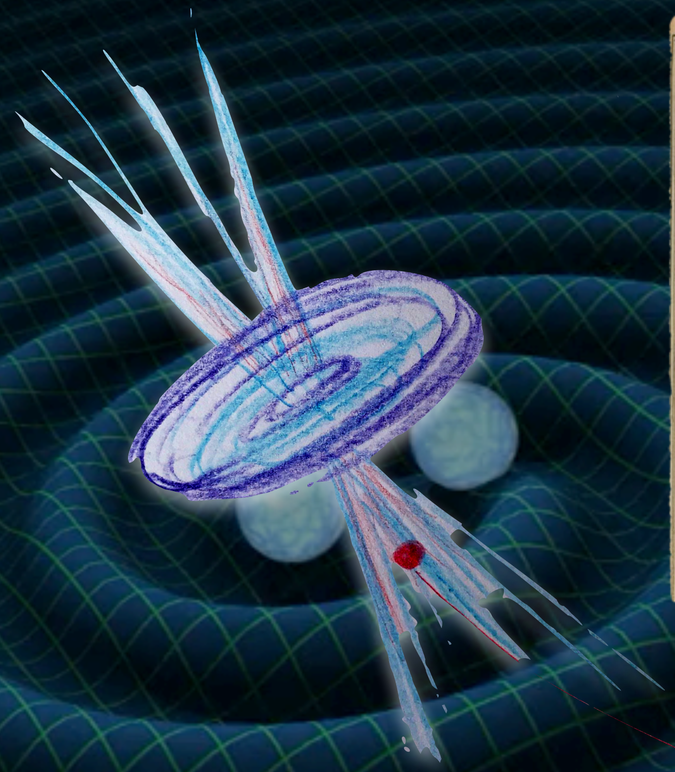
June 2nd, 2025

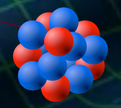
Kumiko Kotera, Olivier Martineau, XiangPing Wu

Multi-messenger astronomy : understanding the Violent Universe

light







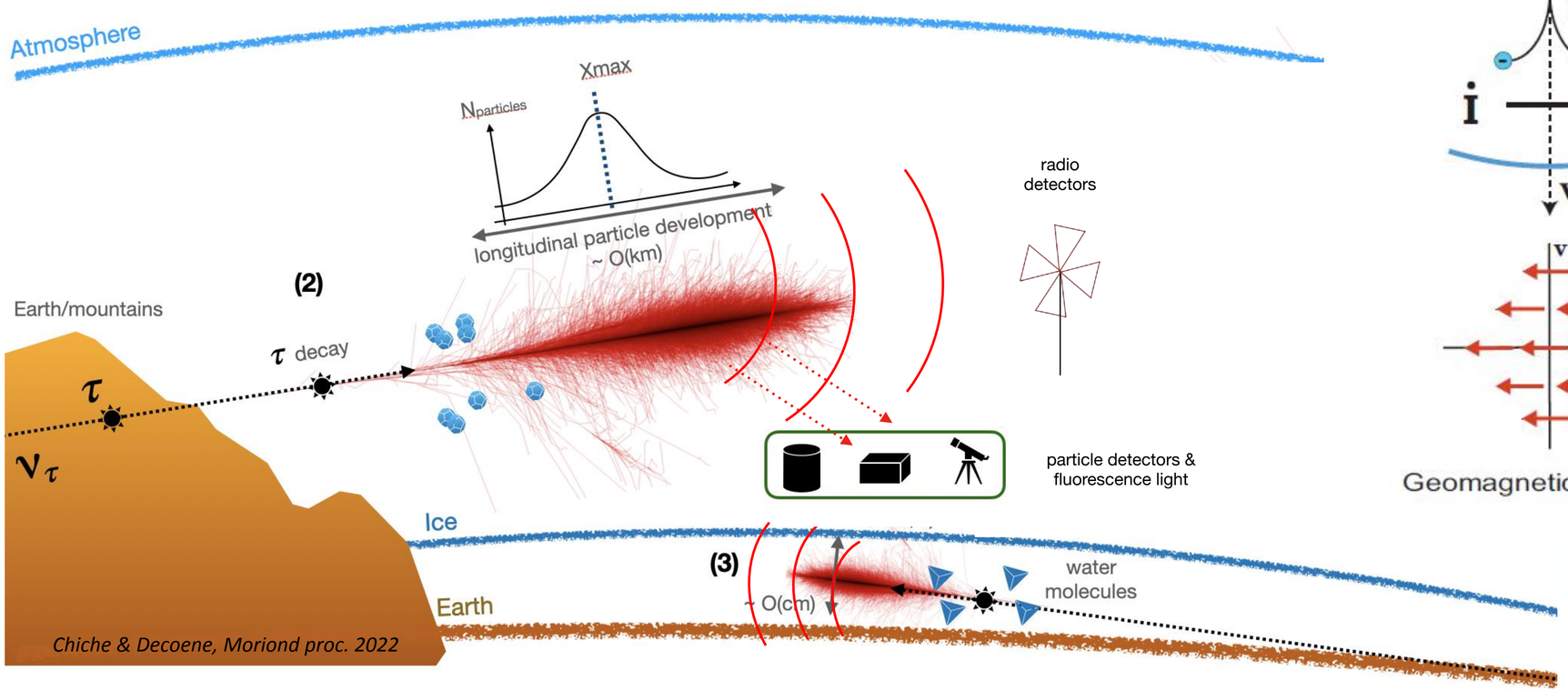
cosmic rays

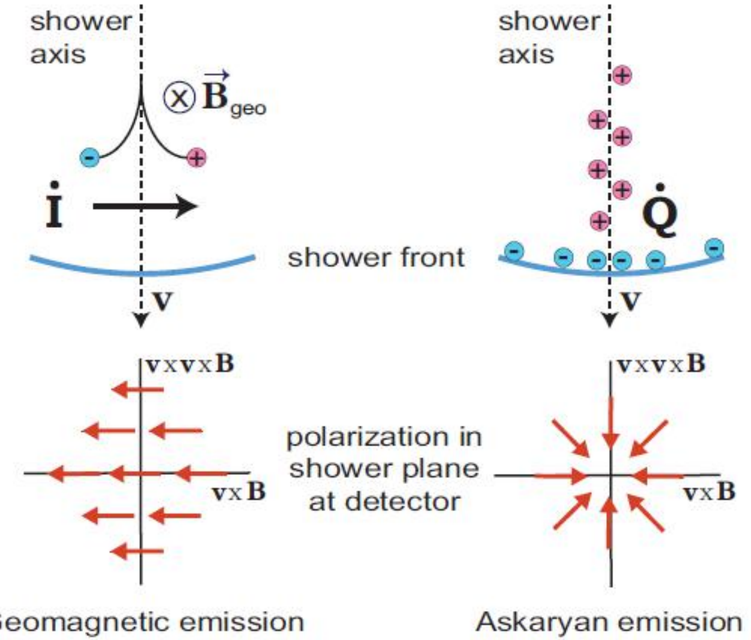
gravitational waves

ν

neutrinos

Radio detection as a cost-effective technique





- Radio antennas: cheap, robust, scalable
- 100% duty cycle
- benchmarked technique
  in-ice & in-air for specific configurations

Performances	instantaneous sensitivity	daily aver. sensitivity	iFoV	dFoV	angular resolution
in-ice	+ wide & shallow	++	**+++** wide & shallow	++ no gain by Earth rotation if South Pole	+ reconstruction of polarization difficult
in-air	**+++** deep & narrow	++ equivalent as experiments tuned to diffuse flux	+ deep & narrow	**+++**	**+++** large footprints

Challenges of radio-detection

A good radio detector?

by Abby Vieregg
GRAND-BEACON Workshop
PSU, Jan. 2024

- antenna collecting area (number & gain of antennas)
- trigger threshold (reducing system noise, smart triggering and noise rejection)
- collecting enough information so that events can be separated from background in analysis

Deployment over large/challenging areas

- quiet site identification + geopolitics
- logistical challenges

Complexity & efficiency trade-off

- Number of channels
- Phasing or not
- Low noise system
- Robust for desert/ice environments & temperature fluctuations
- Simple deployment for large numbers

Reconstruction of shower parameters

- Different physics, asymmetries, ground reflections… for very inclined air-showers, in-ice propagation
- New reconstruction methods to develop & test

RFI discrimination & autonomous triggering on radio signals

- Ultra-dominant noise: ideal quiet sites
- New electronics necessary: high sampling rate & autonomous triggering
- Identification of signals & denoising methods
- Previous successful efforts in other contexts: ANITA, TREND

Data volume & transfer: low-rate, low-power

- Huge data volume (currently on GRAND prototype ~10 kBy/trigger)
- Online treatment to reduce stored information (trigger time, amplitude, polar…)

2024 2026 2030+

RADIO DETECTION OF UHE NEUTRINOS

BALLOON

IN-AIR

IN-ICE

POEMMA

planned launch

PUEO

self-triggered

phased

pathfinders in commissioning

BEACON

PIERRE AUGER OBSERVATORY

GRAND

Proto300

HERON

RNO-G

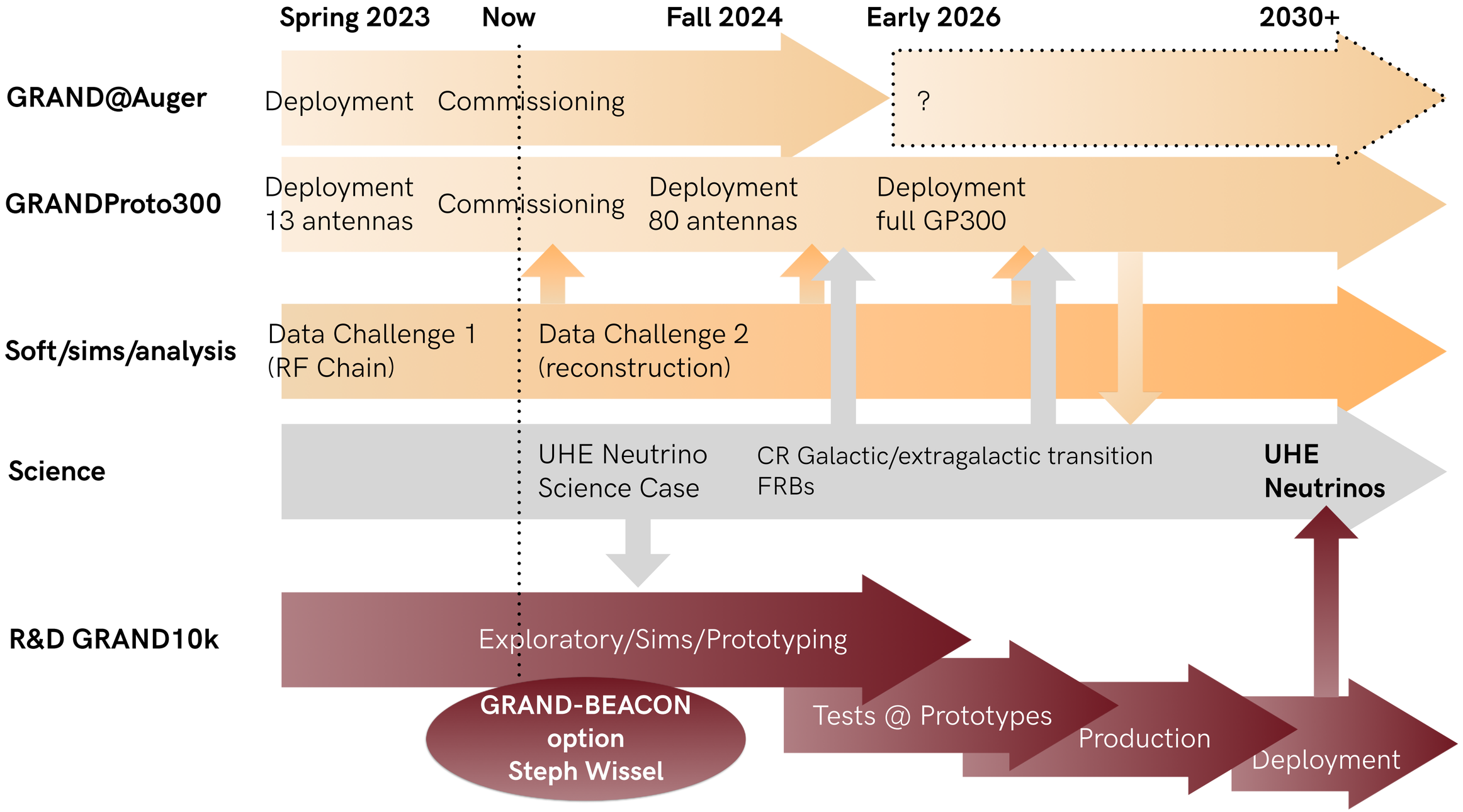
Radio Neutrino Observatory - Greenland

RET

ICECUBE GEN2

Ideal Timeline

Nanjing Coll. Meeting 2024



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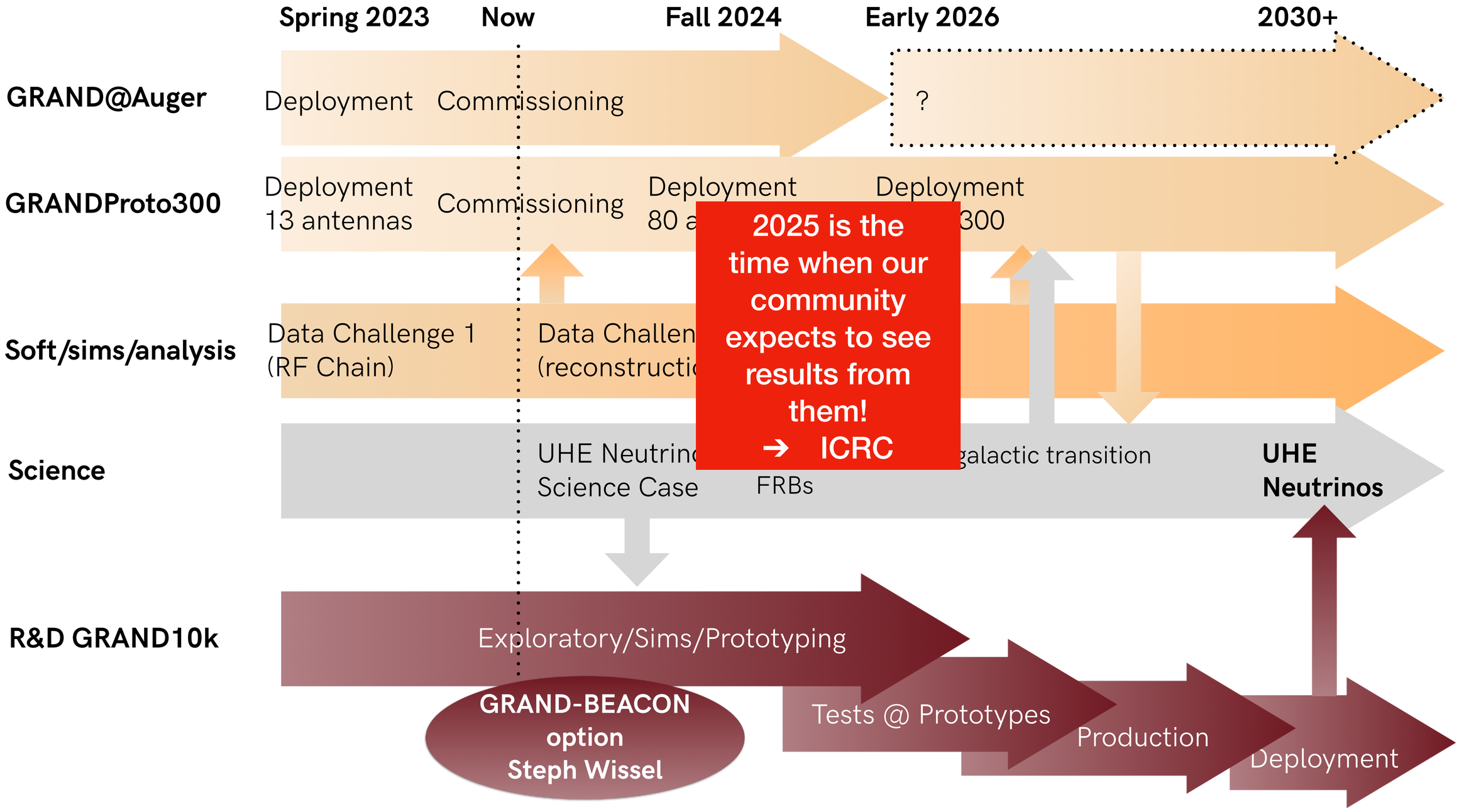

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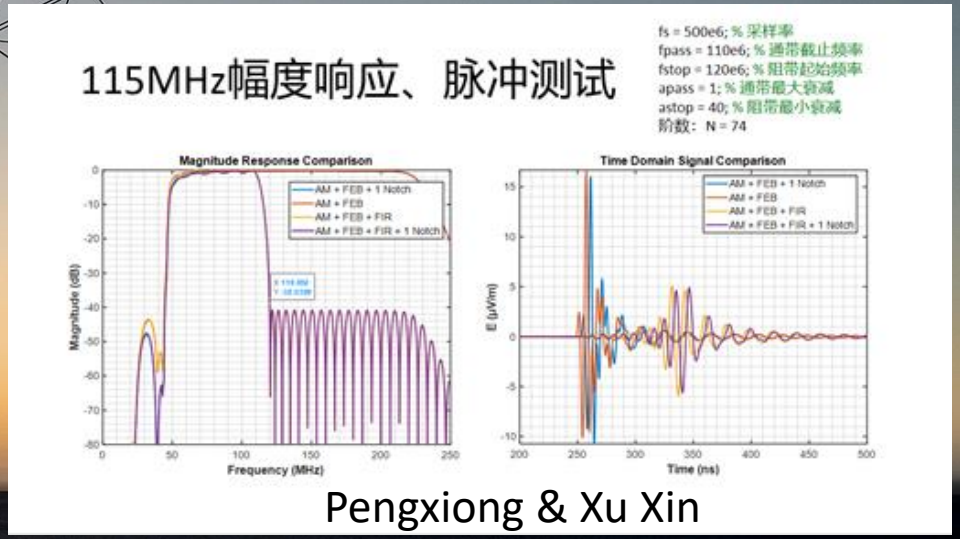
The GRAND prototypes: GRANDProto300

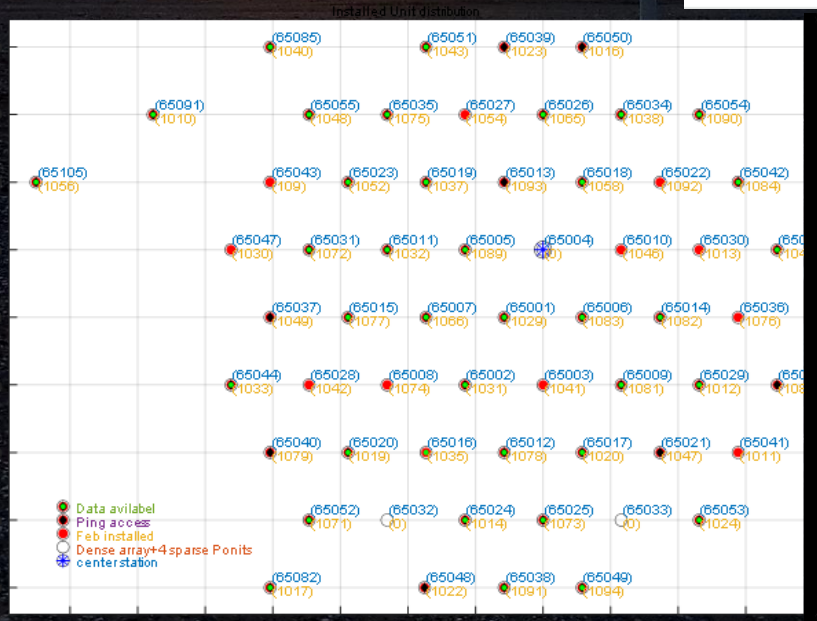
- GRANDProto13 deployed Feb 2023 – dismantled April 2025
- GRANDProto80 deployment started Sep 2024. 60 DUs today.
- Over past 3 years, tremendous effort on deployment and commissioning to fix issues and understand our detector (XiDian & PMO)
  - Thermal heating
  - Self-made noise
  - Triggers T1 and T3
  - DAQ
  - Data transfer / management
  - Stability (temperature / ressource
  - Time and amplitude calibration
  - Environment study (planes, mine)
- … Yet not fully satisfying:

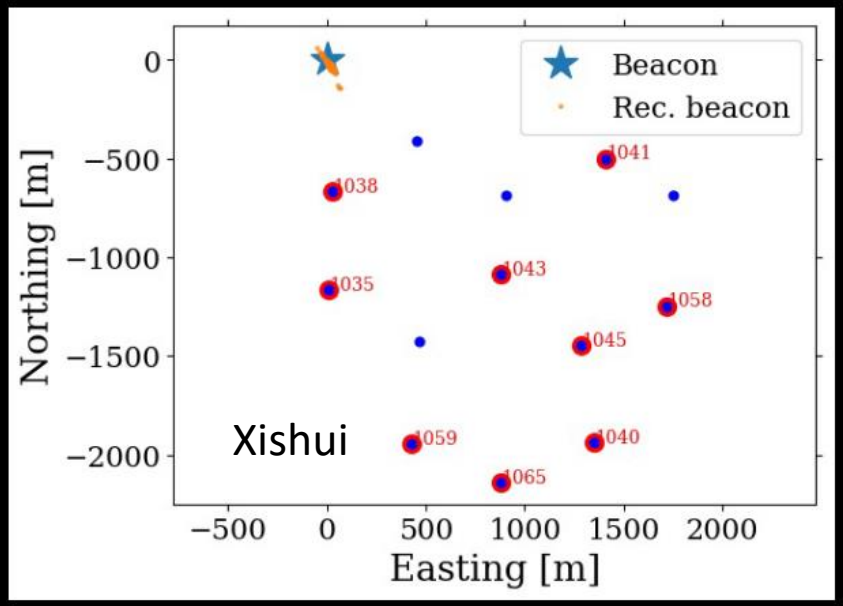
today only ~5 antennas running!

➔ **GP300 status, Monday pm,**
➔ **GP300 operation + trigger Wednesday pm**
➔ **GP300 calib Thursday pm**

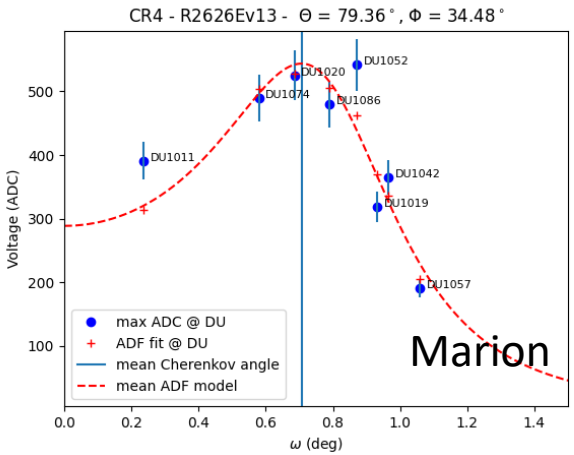


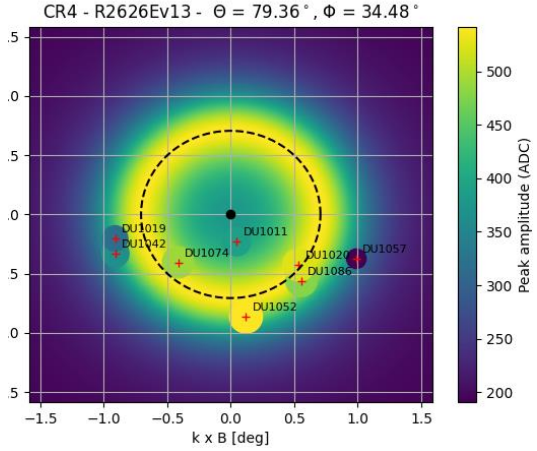
Pengxiong & Xu Xin



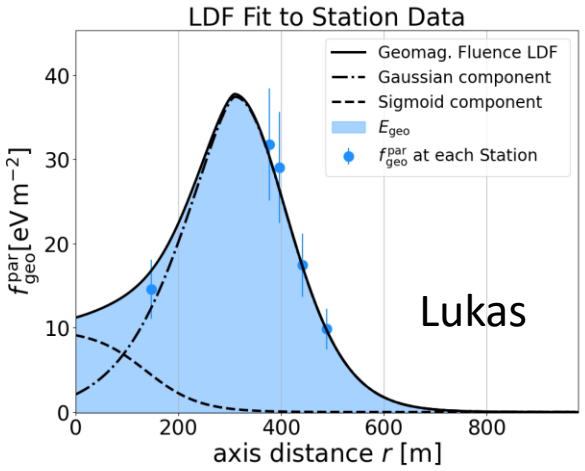


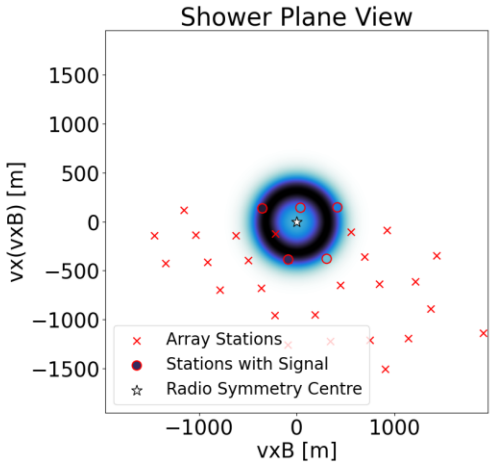
GRANDProto300 cosmic ray candidates





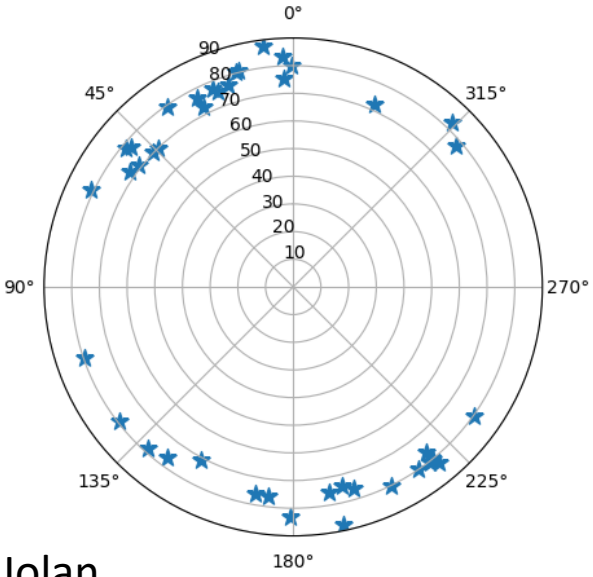
(Run 6222 , Event 1): $E_{em}^{rec} = 0.37 \pm 0.02$ EeV, $d_{max}^{fit} = 31 \pm 13$ km
$\theta = 70.4°$, $\phi = 52.4°$, $\alpha = 91.3°$

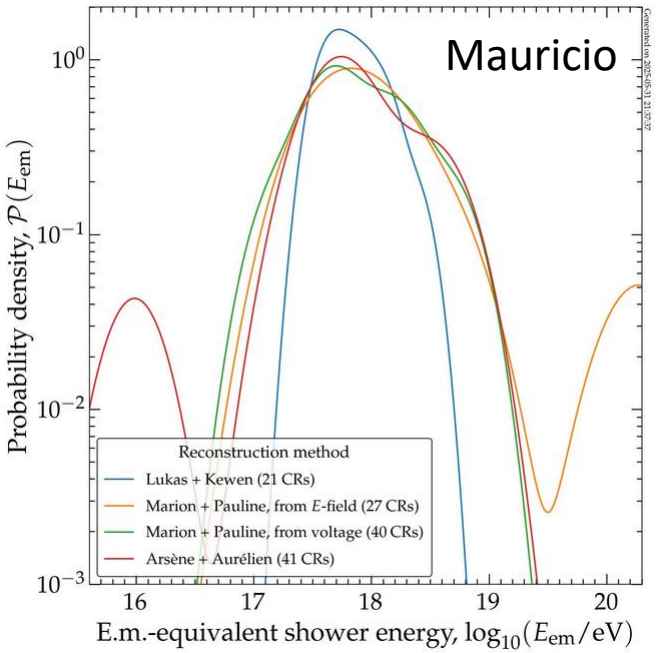




➔ **Analysis + CNN Tuesday**
➔ **CR analysis pipeline Thurdsay pm**

Very active working group #cr_search (coordinator Mauricio):
41 candidate selected, ~30 with succesfull reconstruction. Coherent distribution for direction and energy.





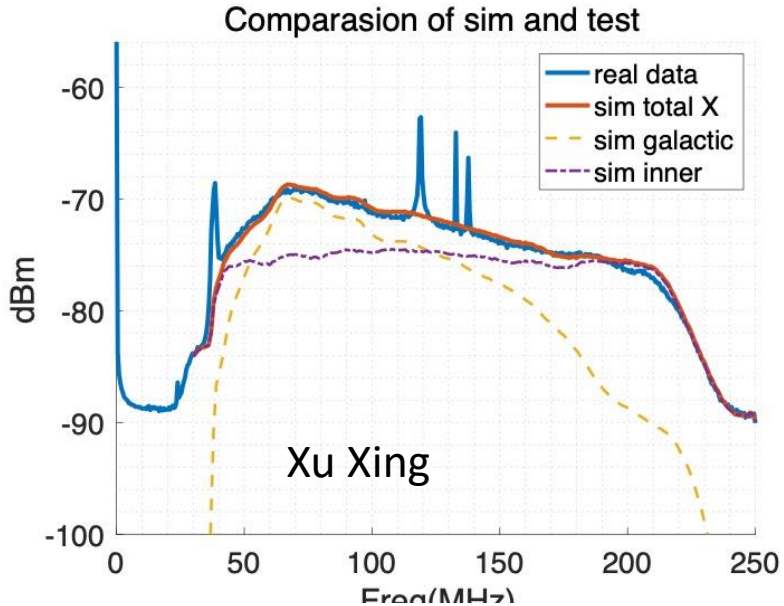
GRAND sims and soft

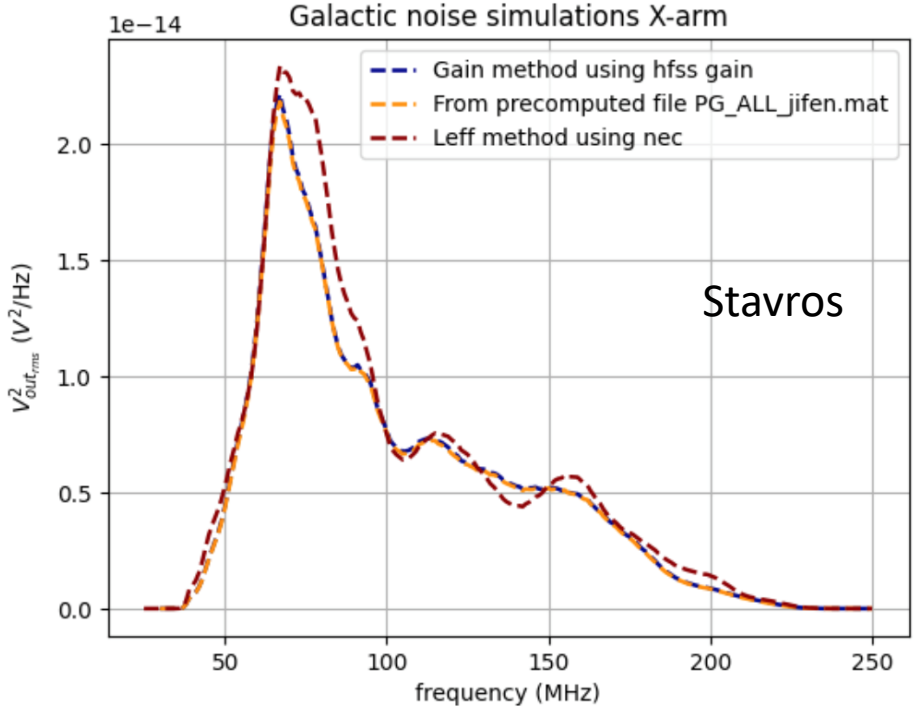
- Long term effort by **very few individuals** (in particular: Matias, Lech, Ramesh) to provide proper tools for data analysis
  - GRANDlib
    - Topography management
    - Referential management
    - Data handling
    - Antenna response + RF chain model
  - DC2: 3 years of effort to provide realistic simulations of the GRAND detectors

- Work still needed, in particular for better documentation, ease of access (eg Docker/conda/Mac…) and checking validity!

➔ **use it and give feedback!**

➔ **Software and sims + hands-on Thursday am**

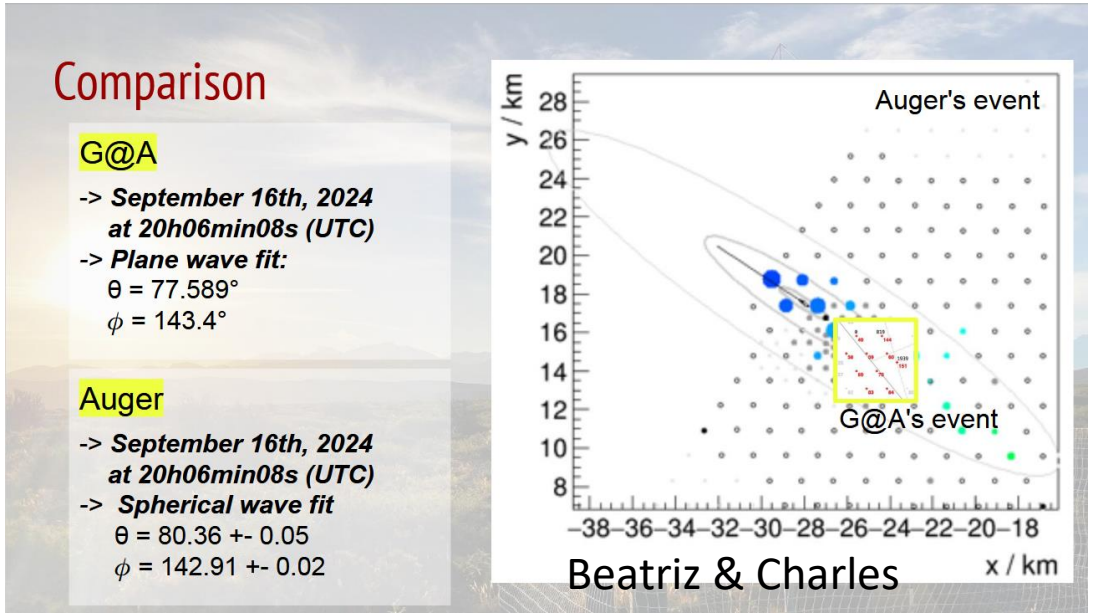


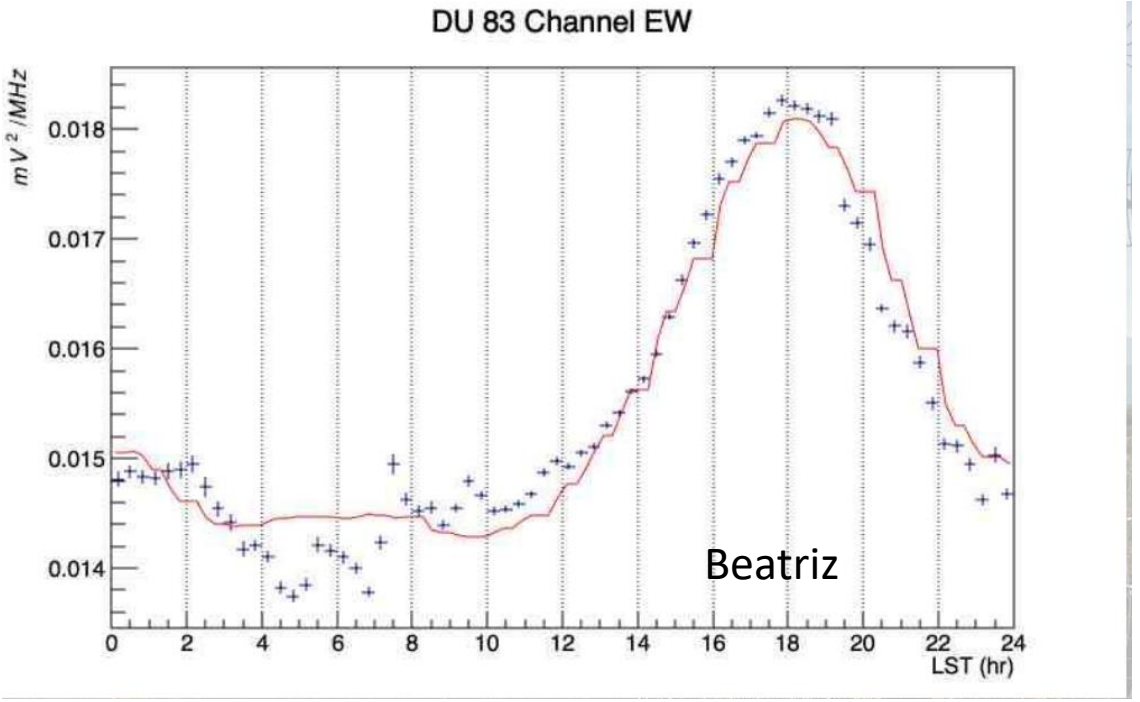


The GRAND prototypes: GRAND@Auger

- 10 DUs deployed in 3 trips between Nov 2022 and Nov 2023 (Charles, Beatriz and Juan-Pablo)
- Stability issues:
  - Power supply
  - Heating
  - Lack of time on site

  ➔ Limited time with 4+ DUs running together
- Yet galactic fluctuation visible & one candidate indentified in coinc with Auger



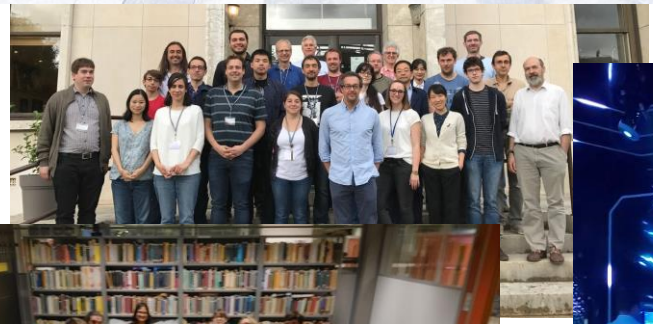


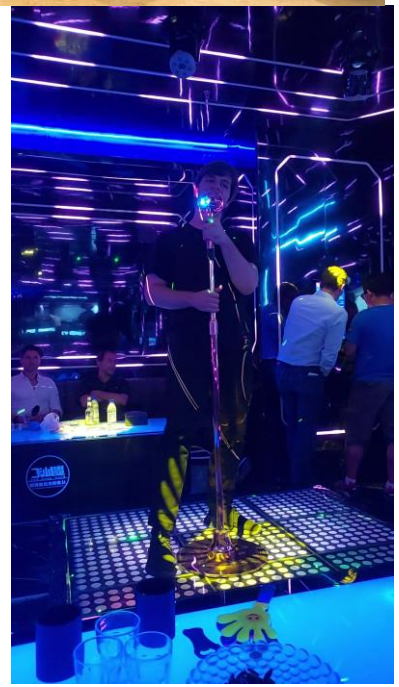
What's next?

- GP80
  - Reach stable operation on GP80 within weeks
  - Improve detection efficiency (Trigger? Data transfer?)
  - Detect hundreds of CRs/day ➔ Science session Monday pm
  - Validate GRAND detection principle & perform CR (+ gamma?) study
- G@A ?
- GP300 extension / GRAND10k ➔ R&D session Wednesday pm
- … GRAND200k ➔ Science session Monday pm
- Funding: ➔ Collab life session Wednesday am
  - running costs to be implemented on GP300 in 2025
  - Application for funding for GP300 completion/G10k R&D phase

The collaboration meeting: a key moment in collaboration life

- LPNHE Feb 2015
- IAP May 2017
- Nijmegen Feb 2018
- DunHuang April 2019
- Karlsruhe Feb 2020
- LPNHE Dec 2021
- Nijmegen Jan 2023
- Nanjing May 2024
- Warsaw June 2025
- … Many more to come ☺ !





GRAND collaboration life

- We built collaboration tools up to 2024: MoU, forums, digital tools (Wiki / Forge / Mattermost, box)
- **Yet these can surely be improved! GRAND is YOUR collaboration (and we are only the spokespersons, not the PIs). Speak up!**
- We work in an environment which can be challenging: pressure for results, publications, funding, recognition,… cultural differences, communication issues...

➔ **We have to work at maintaining a collaborative, open spirit where people & work blossom**

➔ Collab life session Wednesday am

Enjoy your week in Warsaw and many thanks to the LOC!!!