THE GIANT RADIO ARRAY FOR NEUTRINO DETECTION

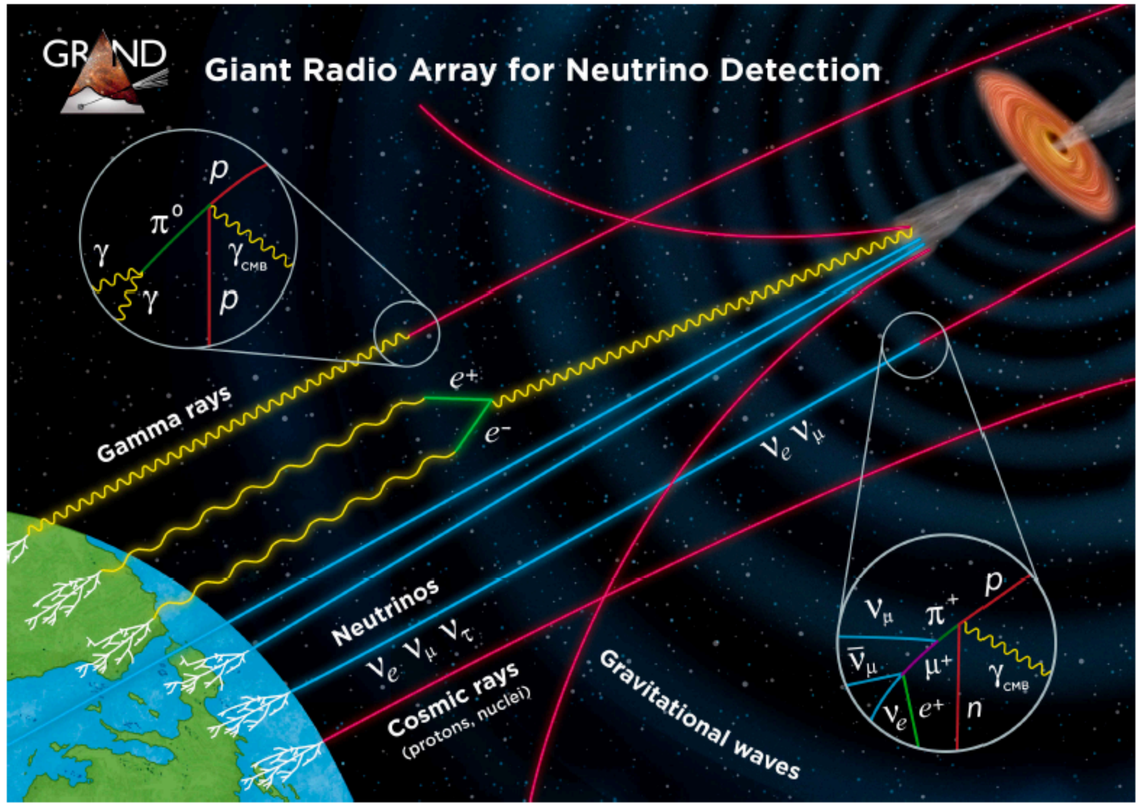
Status and Perspectives

Haoning He （贺昊宁）

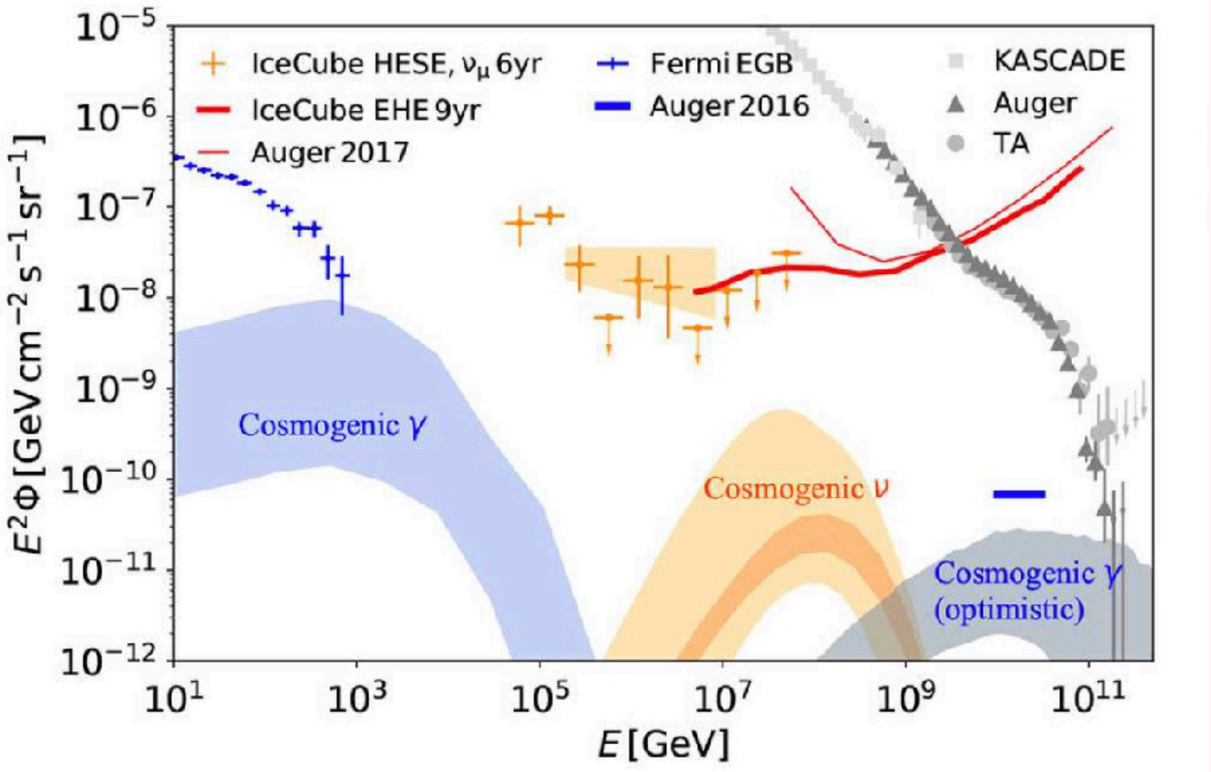
Purple Mountain observatory, Chinese Academy of Sciences

on behalf of the GRAND collaboration

Origins of Cosmic rays and Neutrinos



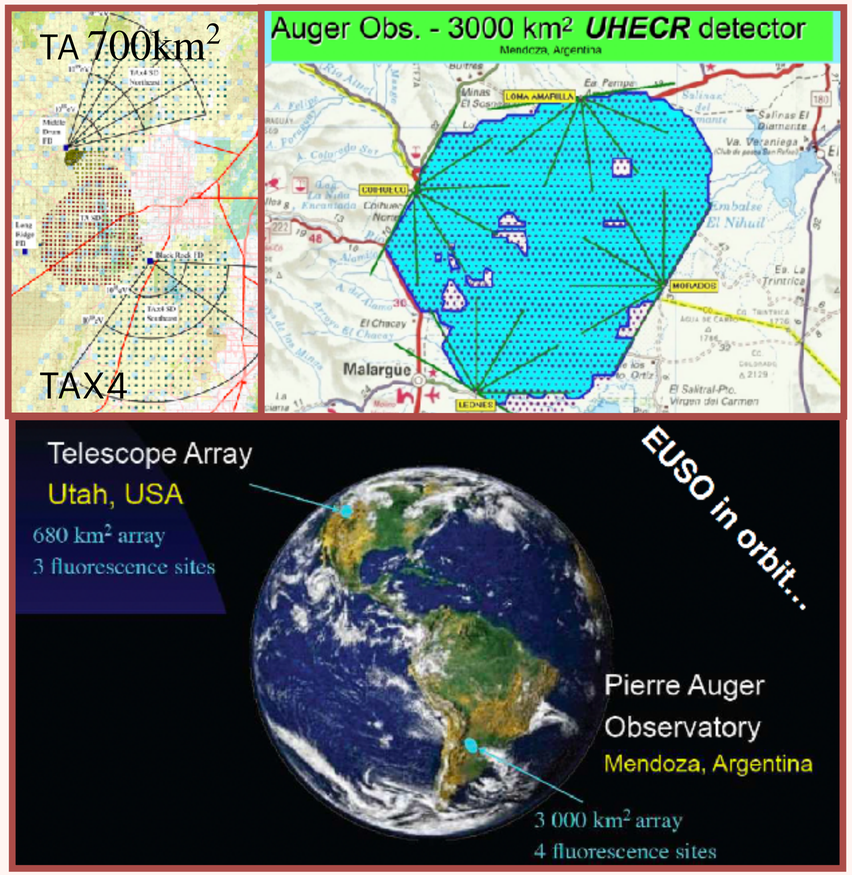
GRAND Collab., Sci. China Phys. Mech. Astron. 2020 [arXiv:1810.09994]



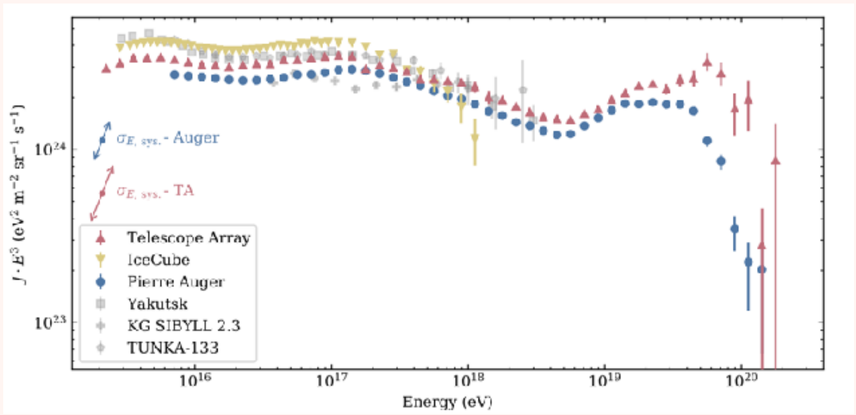
Alves Batista et al. (2019)

Current Knowledge on UHECRs

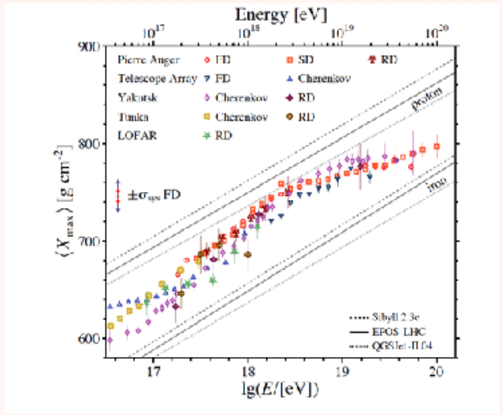
Current UHECR Observatories



Spectra

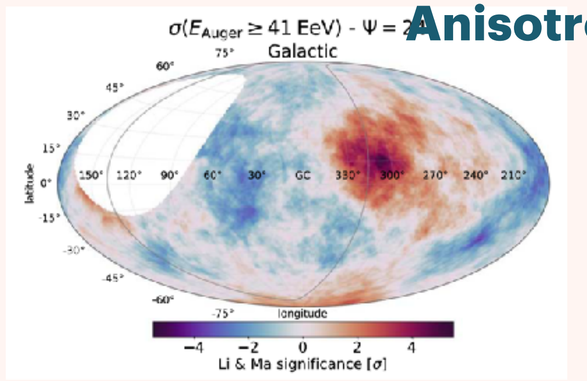


Composition

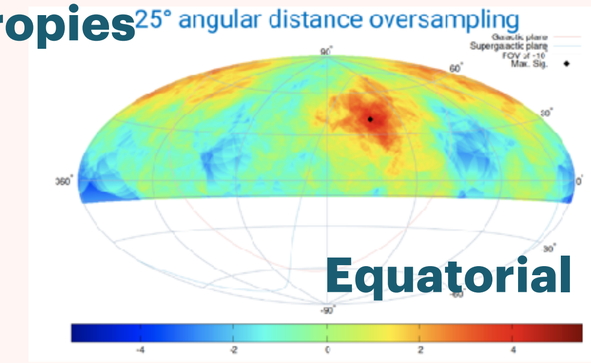


SNOWMASS review 2022, arXiv:2205.05845

Anisotropies



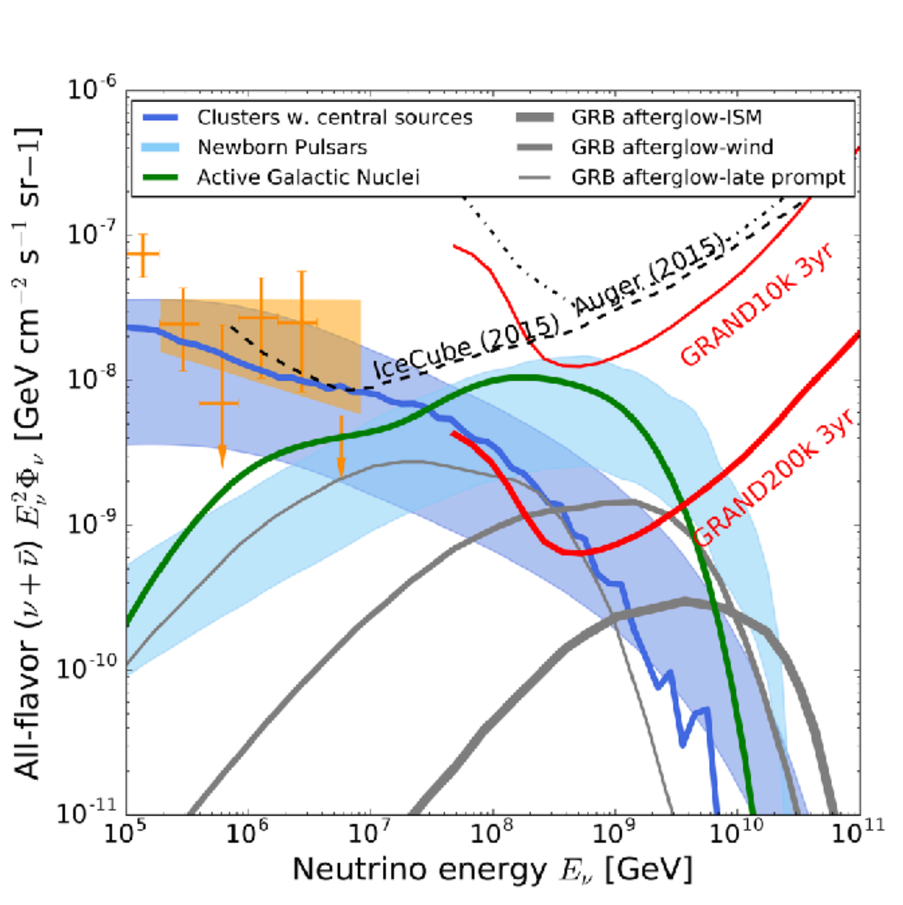
E>41 EeV (The PAO Collaboration, 2022)



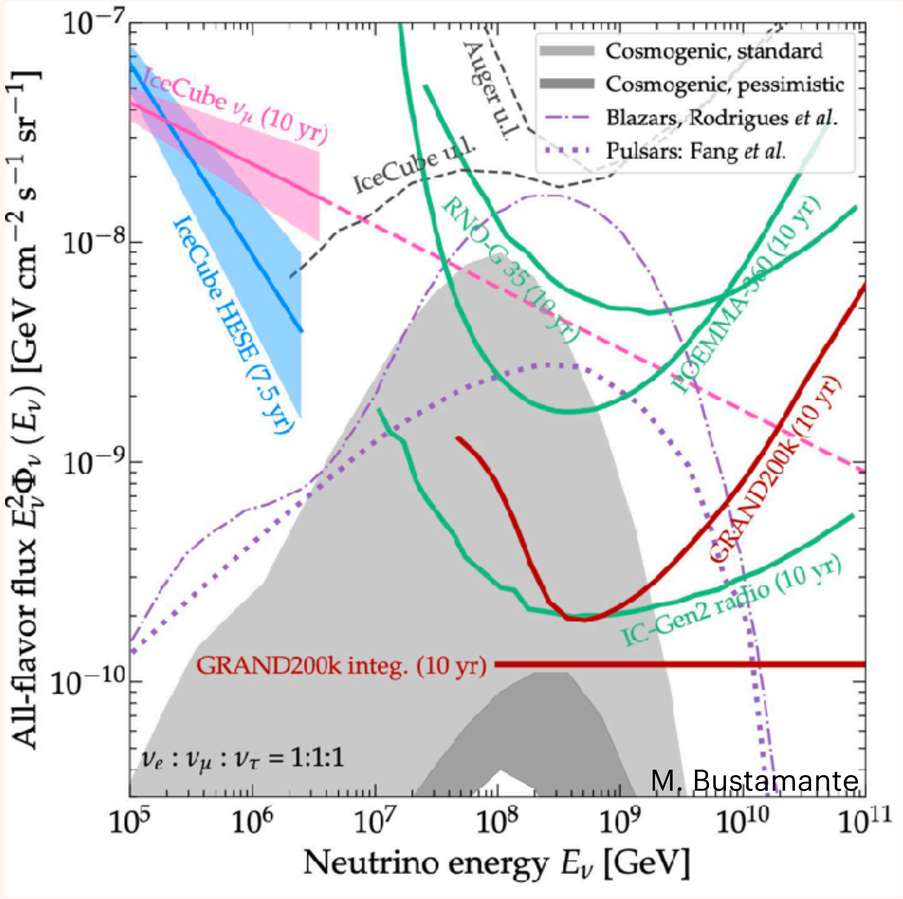
E>57 EeV (The TA Collaboration, 2024)

UHE neutrinos

Neutrinos from Sources

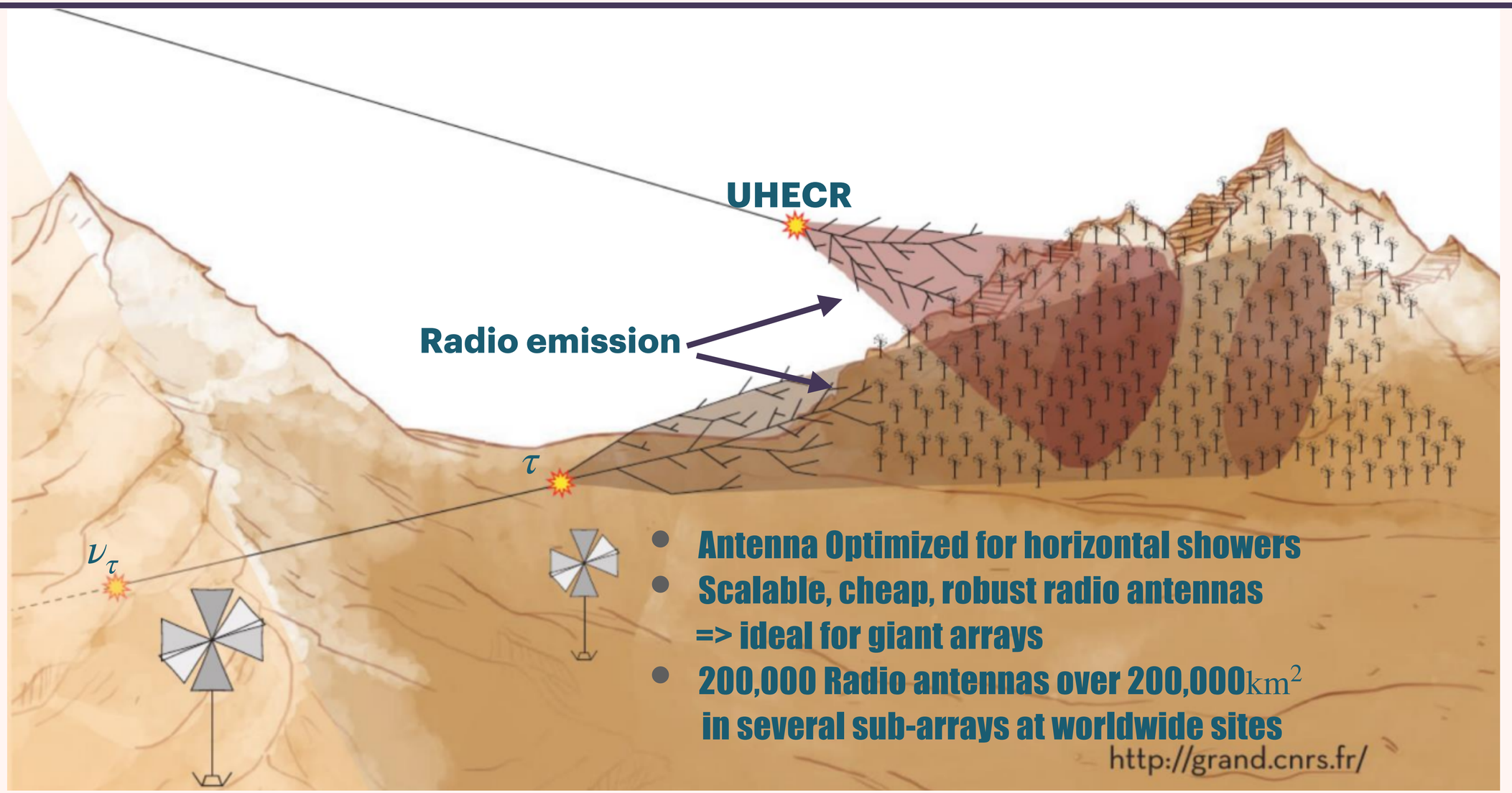


Cosmogenic Neutrinos

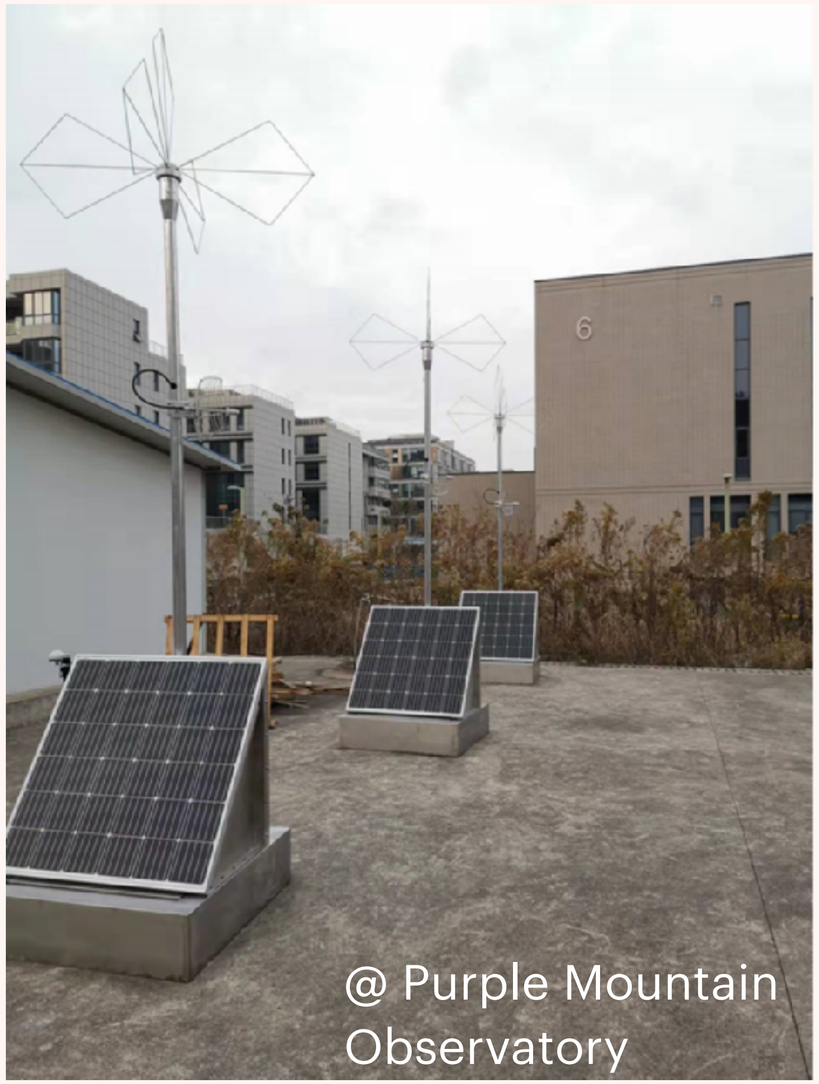


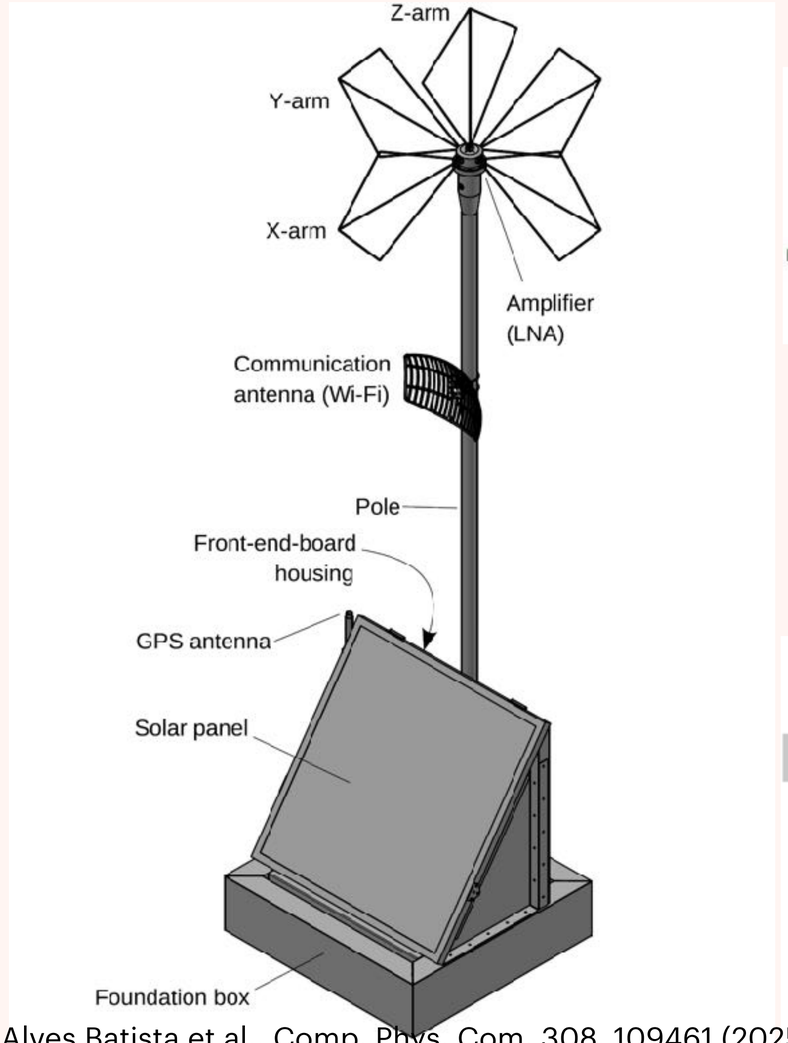
GRAND Collab., Sci. China Phys. Mech. Astron. 2020 [arXiv:1810.09994]

GRAND Concept



GRAND Detection Unit

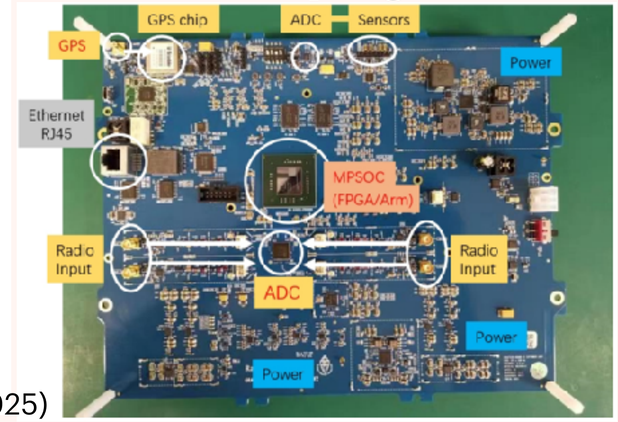




Alves Batista et al., Comp. Phys. Com. 308, 109461 (2025)

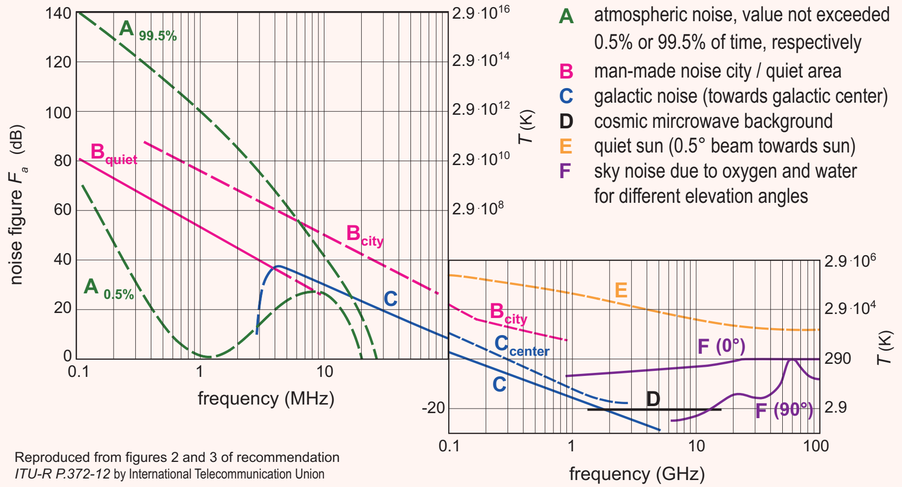
Nut and Low Noise Amplifier (LNA)

Front-End Board (FEB):
30-230MHz analog filtering
a high pass with cut off at 43MHz was added to kill the short wave
500 MSPS sampling



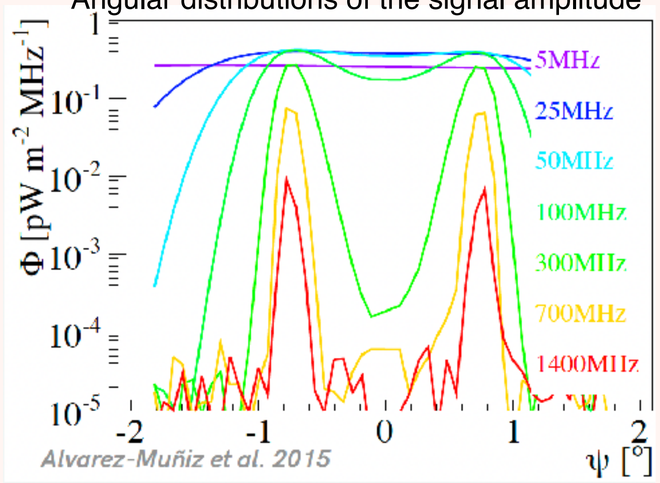
Radio Signals at Our Detectors

- Frequency range : ~50-200 MHz
- Transient pulses, duration: <~ 100ns
- Amplitude of detectable signals at unit level:
  > 3-5 σ above stationary Galactic background
- Amplitude scales linearly with particle energy
- Target detection energy threshold with 5 units: $10^{16.5}$ eV

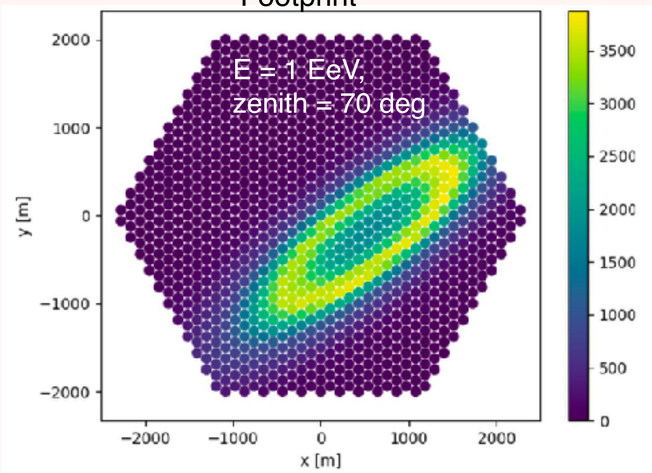


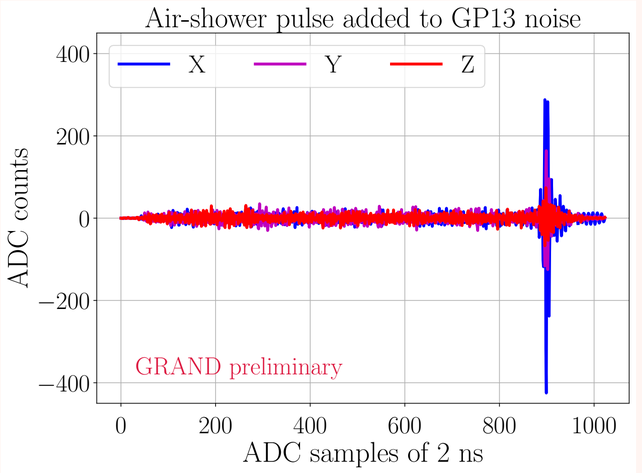
GRAND Collab., Sci. China Phys. Mech. Astron. 2020 [arXiv:1810.09994]

Angular distributions of the signal amplitude



Footprint





Pablo Correa

A Staged Approach with Self-Standing Pathfinders

	Prototyping	GRAND10k North/South	GRAND200k
	2023	2028	203X
Goals	**autonomous** radio detection of **very inclined** air-showers **cosmic rays $10^{16.5\text{-}18}$ eV** • Galactic/extragalactic transition • muon problem • radio transients	**1st GRAND sub-arrays** • **discovery of EeV neutrinos** for optimistic fluxes • radio transients (FRBs!)	sensitive **all-sky** detector **1st EeV neutrino detection and/or neutrino astronomy!**
Setup	• **GRAND@Nançay**: 4 antennas for trigger testing • **GRAND@Auger**: 10 antennas for cross-calibration • **GRANDProto300**: 300 HorizonAntennas over 200 km²	• 10,000 radio antennas over 10,000 km²	• 200,000 antennas over 200,000 km² • 20 sub-arrays of 10k antennas • on different continents
Budget	**2 M€** 100 antennas produced funded by China + Radboud University + ANR-DFG PRCI NUTRIG (France-Germany) + CNRS INSU (IAP, MITI)	**13 M€** 1500€/unit	**300M€** in total 500€/unit to be divided between participating countries

GRAND Challenges :

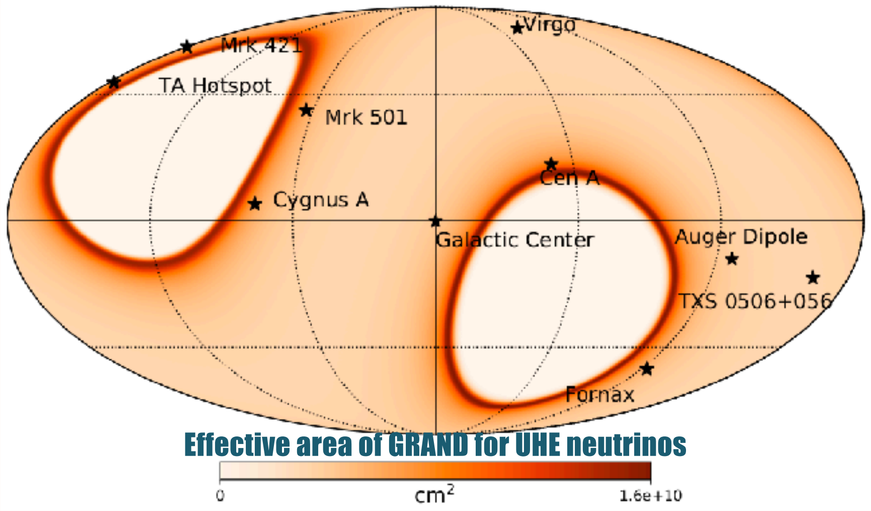
- **scalable, robust detection units**
- **Autonomous triggering**
- **Reconstruction of inclined events**
- **Data volume and transfer**

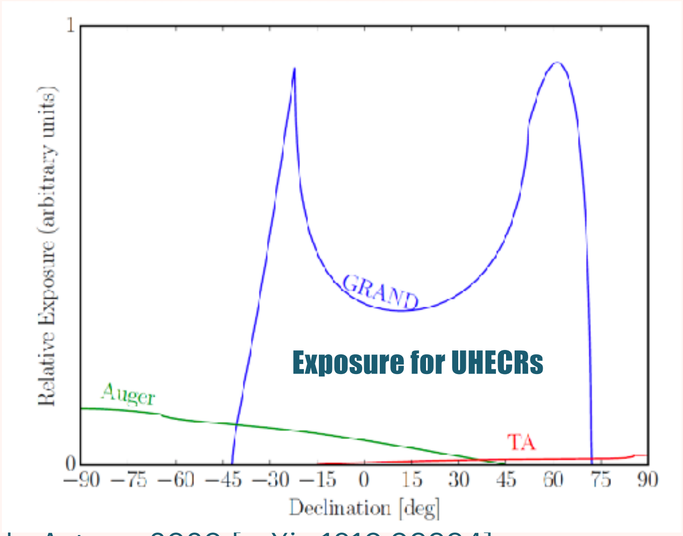
  Huge data volume (10kBy/trigger)
  GP300 (nominal) rate:
  L1 trigger: 1 kHz
  L2 trigger: 10 Hz

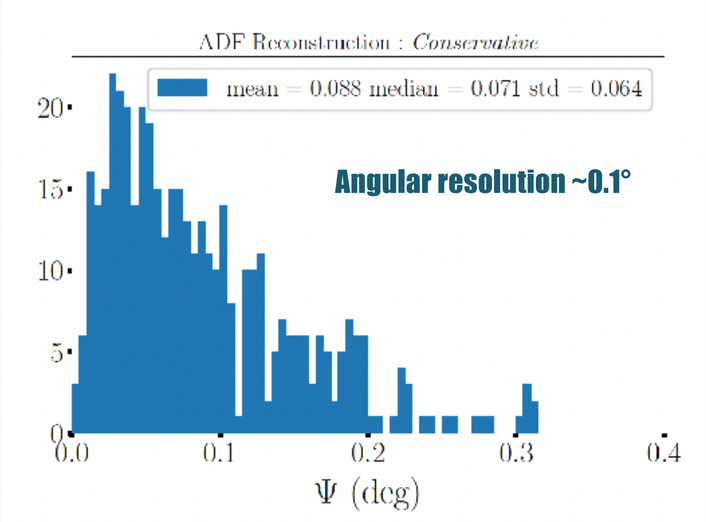
Expected Performances

- Wide filed of view
- Large effective area
- Angular resolution ~0.1°
- Excellent sensitivity

Diff. sens. lim. in GeV cm^{-2} s^{-1} sr^{-1}	iFoV in sky %	dFoV in sky %	ang. res.	2021 2025 >2030
4.2×10^{-8} in 30 d	6	19	<2.8°	PUEO
3.6×10^{-9} (2030)	35	20	5°	ARA
1×10^{-8} in 5 yr	30	35	2°×10°	RNO-G
8×10^{-9} in 5 yr	50	>50	2.9−3.8°	ARIANNA-200
3×10^{-10} in 5 yr	50	>50	?	RET-N
4×10^{-10} in 5 yr	43	43	2°×10°	IceCube-Gen2 Radio
1.2×10^{-8} in 5 yr	6	19.5	0.3°−1°	BEACON
1×10^{-8} in 5 yr	6	80	0.1°	**GRAND10k**
4×10^{-10} in 5 yr	45	100	0.1°	**GRAND**
[1.5×10^{-8} (2019)]	30	92.8	<1°	Auger
?	27	62	1°	TAMBO
7×10^{-8} in 5 yr	0.6	18−36	0.4°	POEMMA Cerenkov
1×10^{-10} in 5 yr	6	62	<1°	Trinity





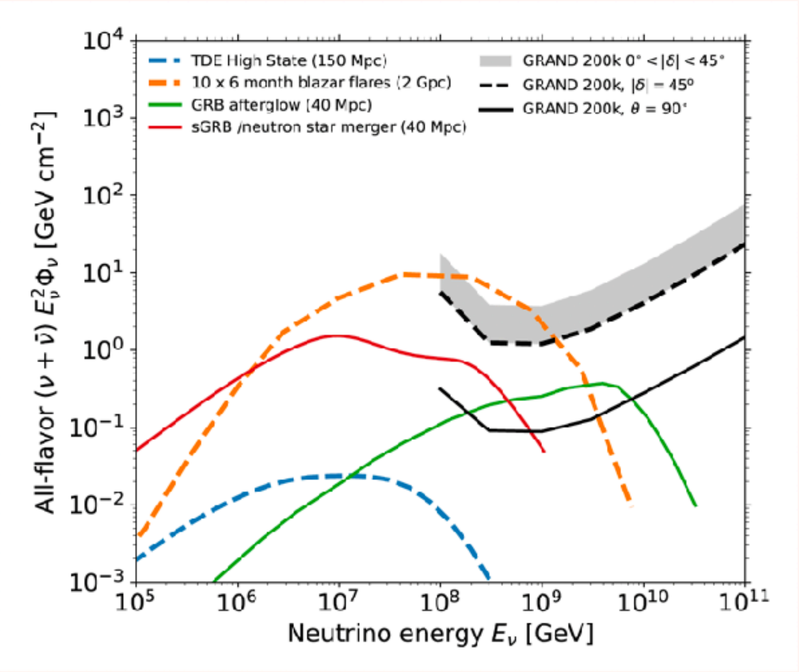


GRAND Collab., Sci. China Phys. Mech. Astron. 2020 [arXiv:1810.09994]

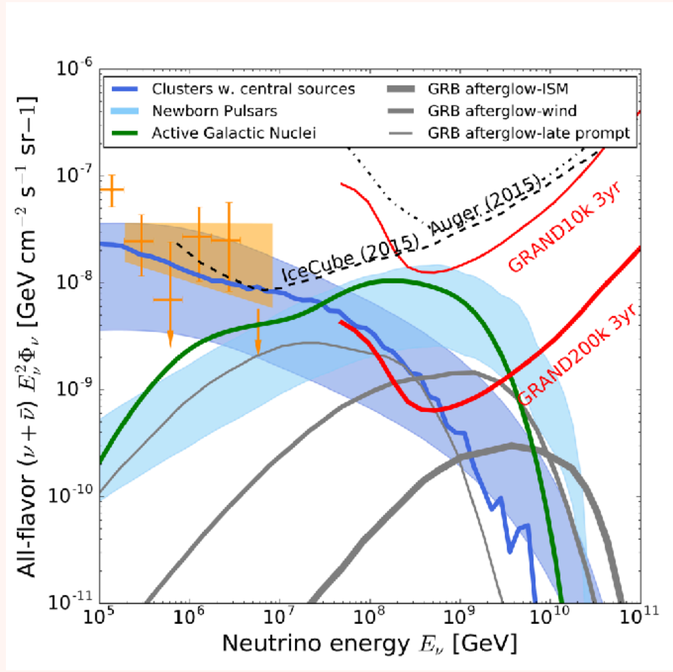
Decoene et al., 2022

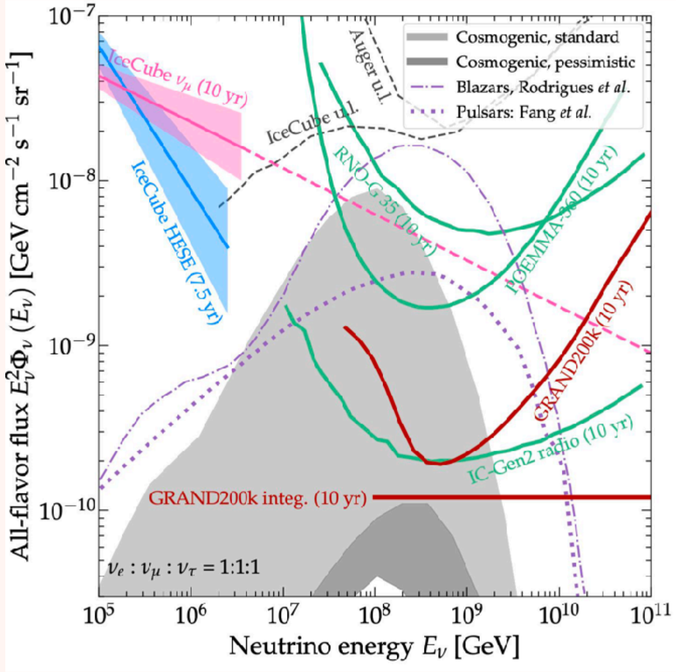
Excellent Sensitivities for UHE neutrinos

Fluence sensitivity



Diffuse sensitivity

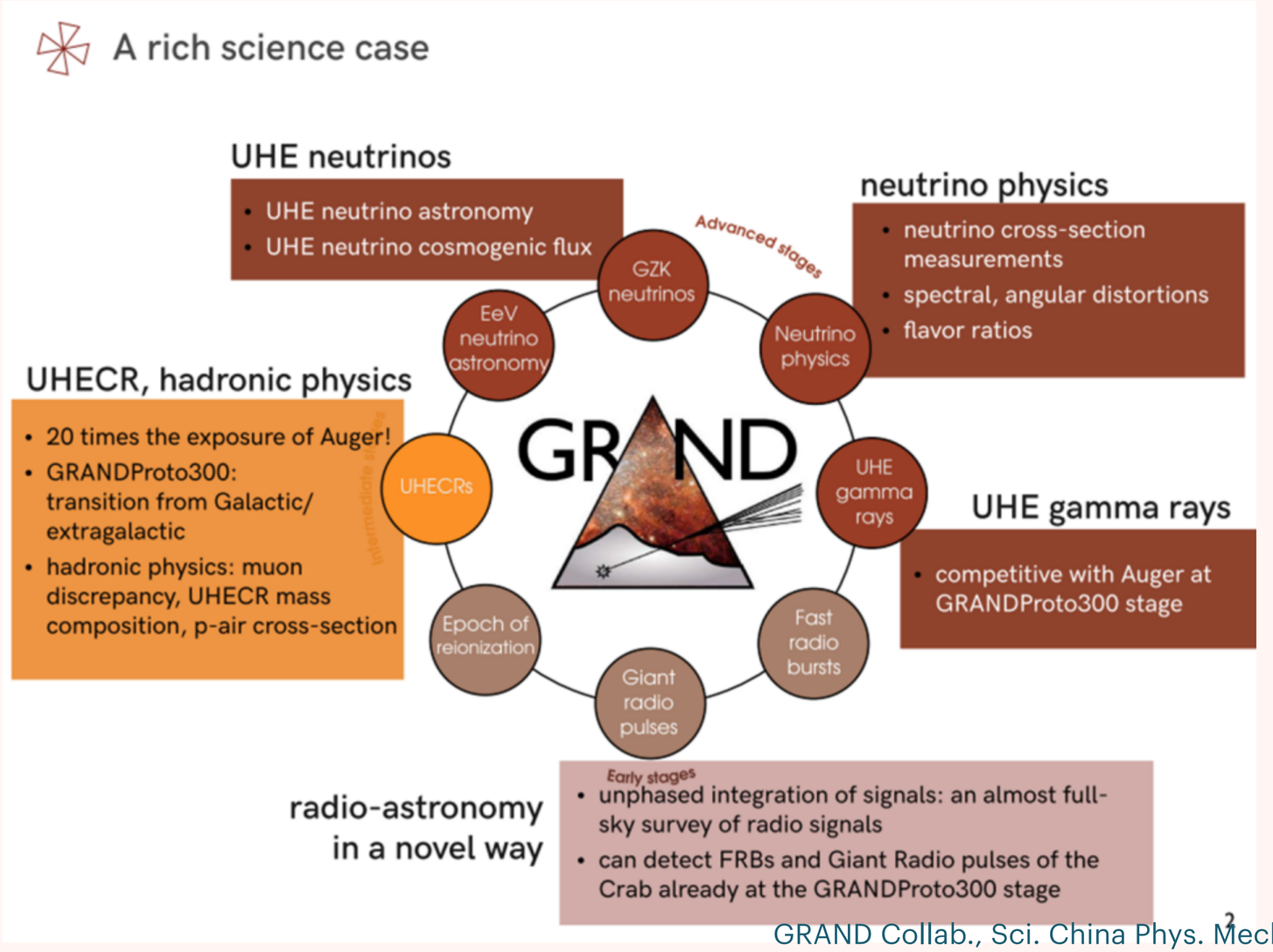




GRAND Collab., Sci. China Phys. Mech. Astron. 2020 [arXiv:1810.09994]

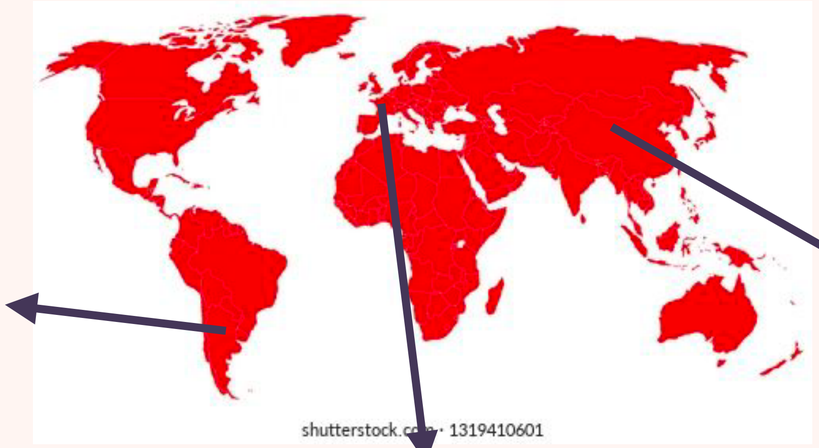
M. Bustamante

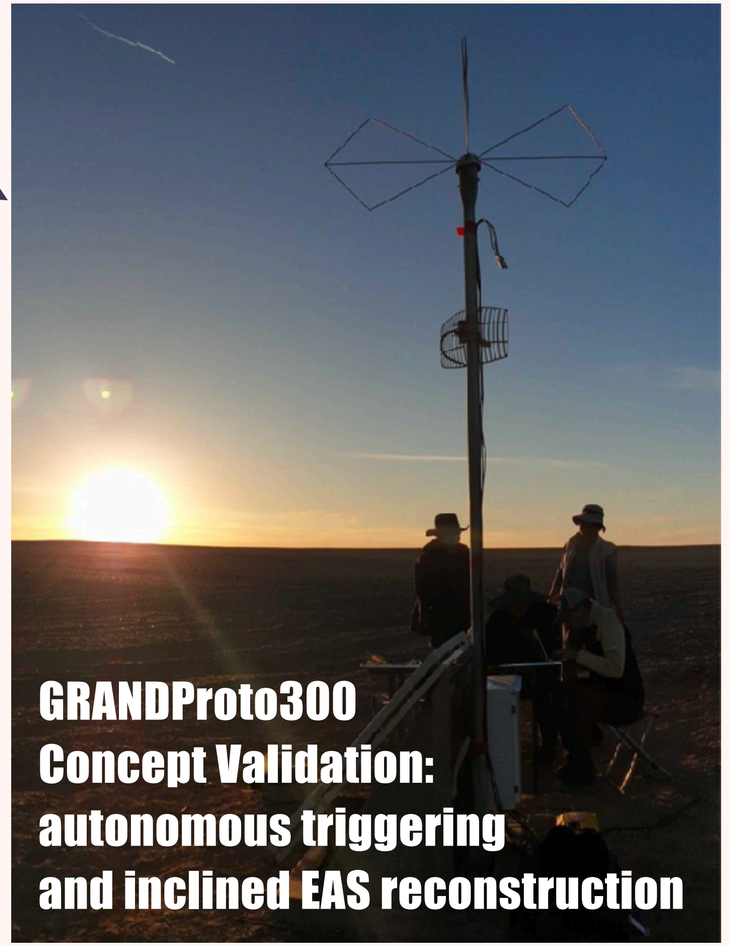
GRAND Science Case



GRAND Collab., Sci. China Phys. Mech. Astron. 2020 [arXiv:1810.09994]

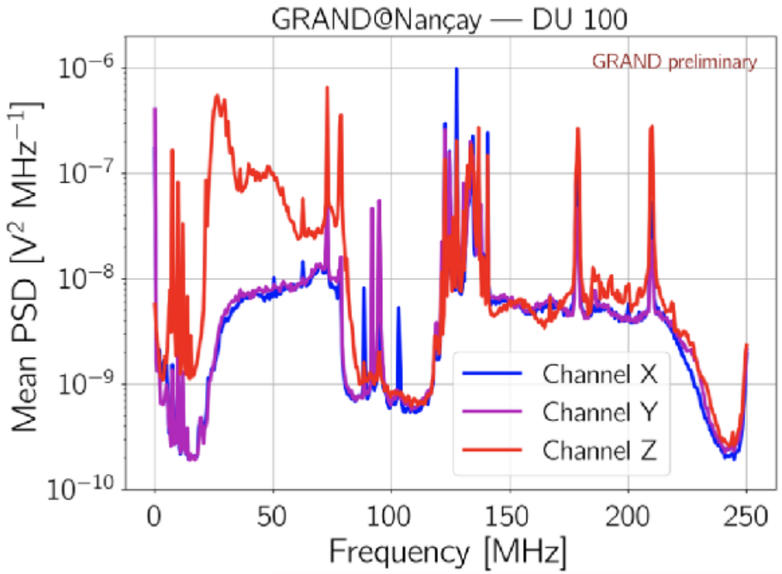
Three Prototypes

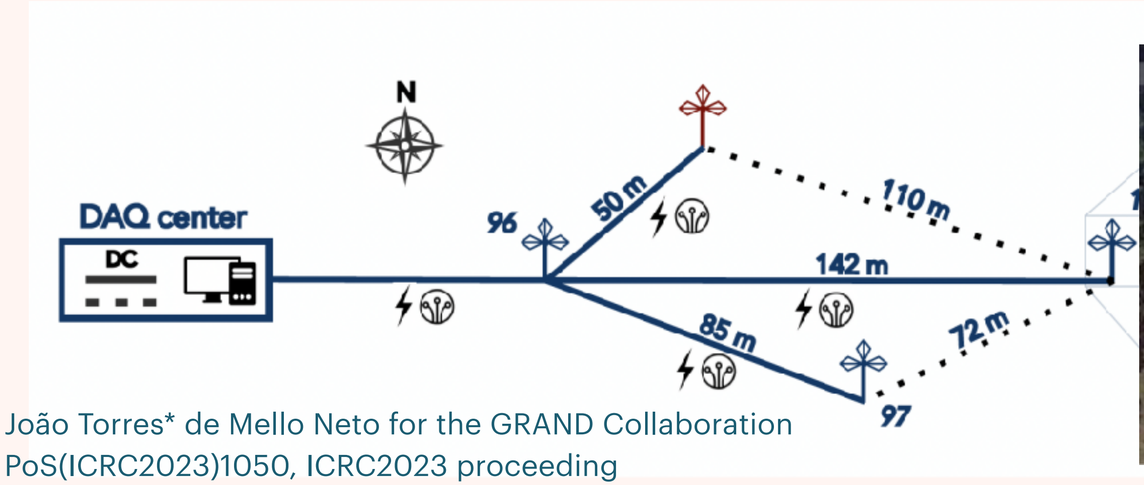


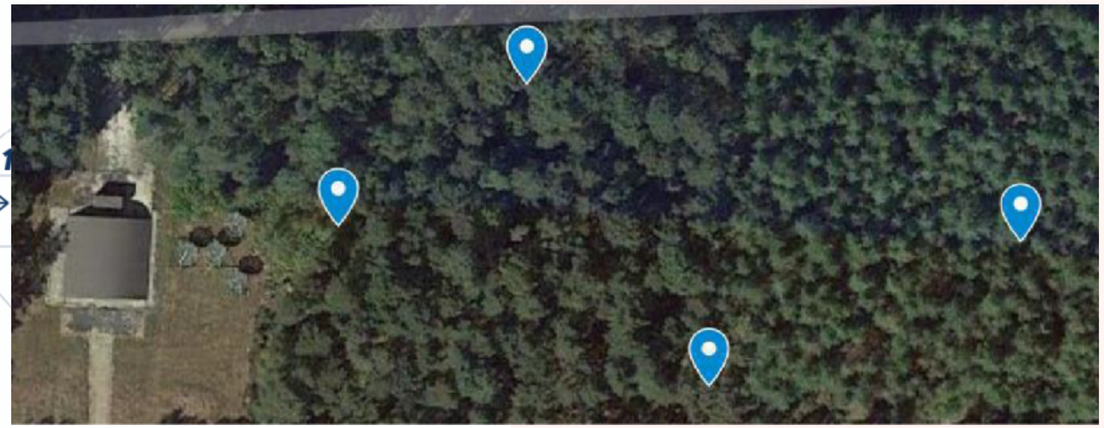


GRAND@ Nançay

- Hosted at the Nançay Radio Observatory, France
- Antennas were shipped from China and the rest of the equipment was funded by the ANR-DFG grant between Paris (LPNHE and IAP) and Karlsruhe (KIT)
- Setup: 4 DUs have been deployed
- Test bench for triggering and hardware

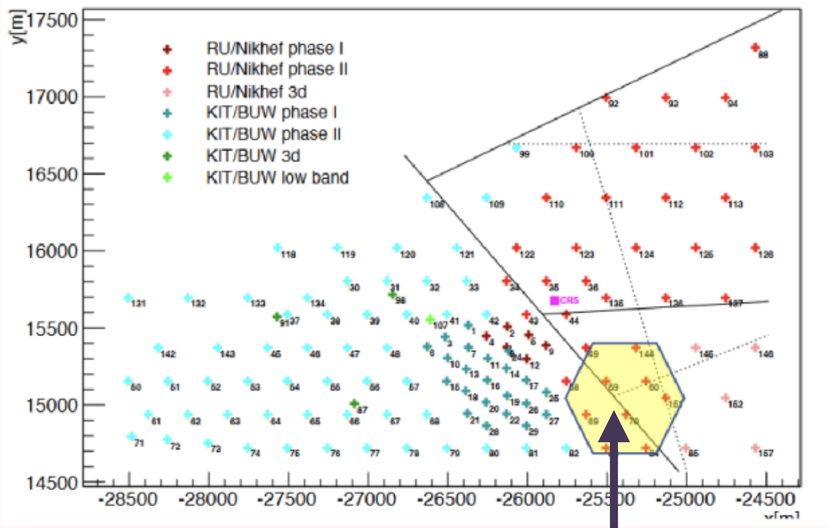




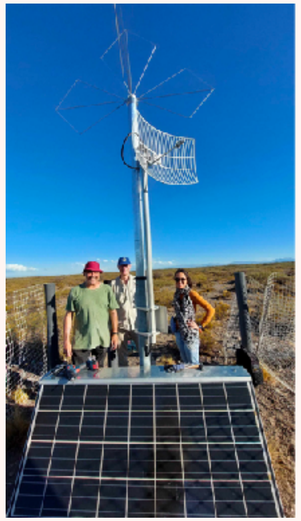


João Torres* de Mello Neto for the GRAND Collaboration
PoS(ICRC2023)1050, ICRC2023 proceeding

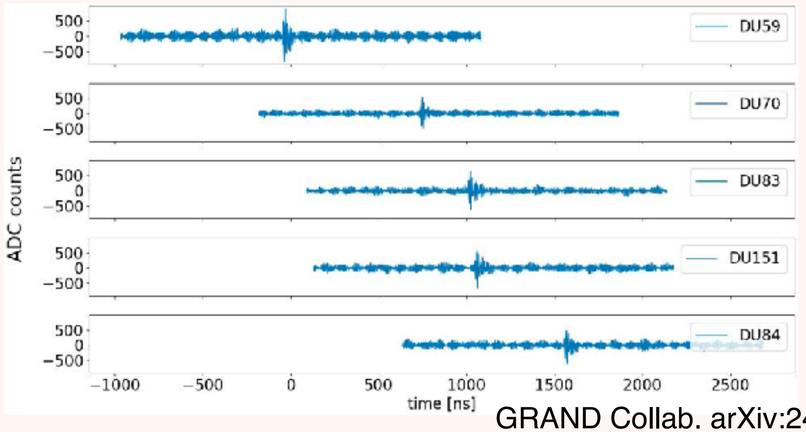
GRAND@Auger



GRAND@Auger

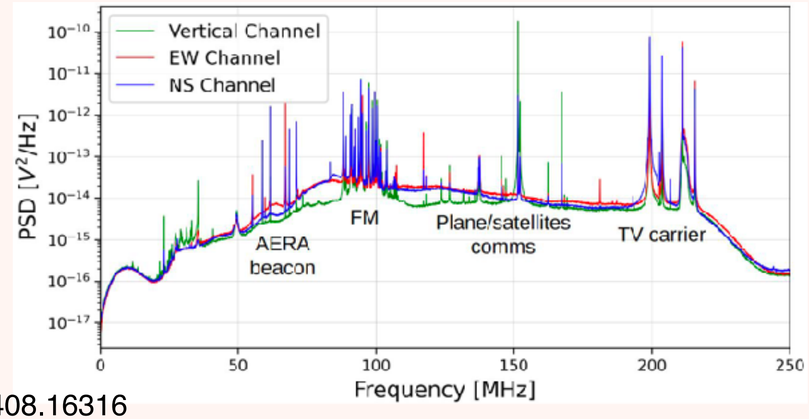


- 10 antennas deployed
- Auger mechanical structure + infrastructure
- Cross-calibration with Auger detectors
- Hardware tests, Firmware tests
- Online coincidence search at central DAQ (L3 triggering)
- 1 event/day expected
- 14 reconstructed events
- Galactic calibration on-going

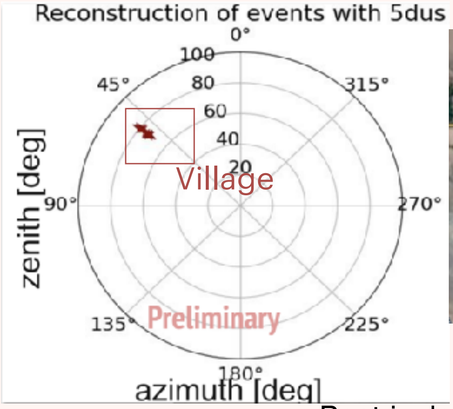


GRAND Collab. arXiv:2408.16316

Power Spectrum Density



Reconstruction

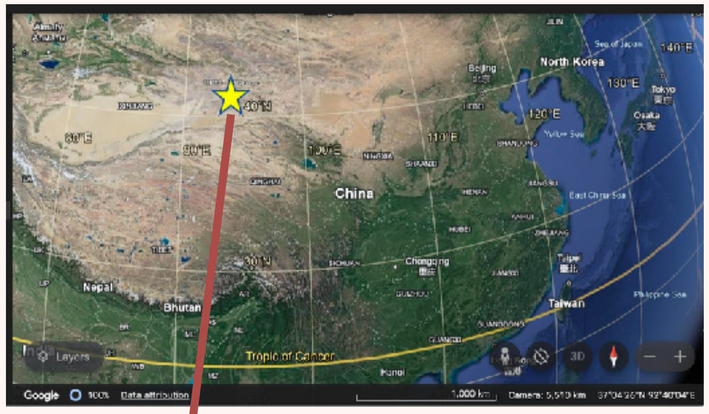


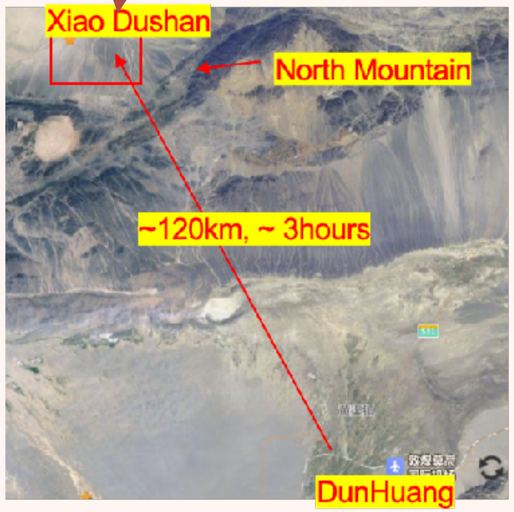
GRAND@Auger

Beatriz de Errico

GRANDProto300

Location: Xiao Dushan, Gansu, China





The deployment site has been officially approved in 2024 !

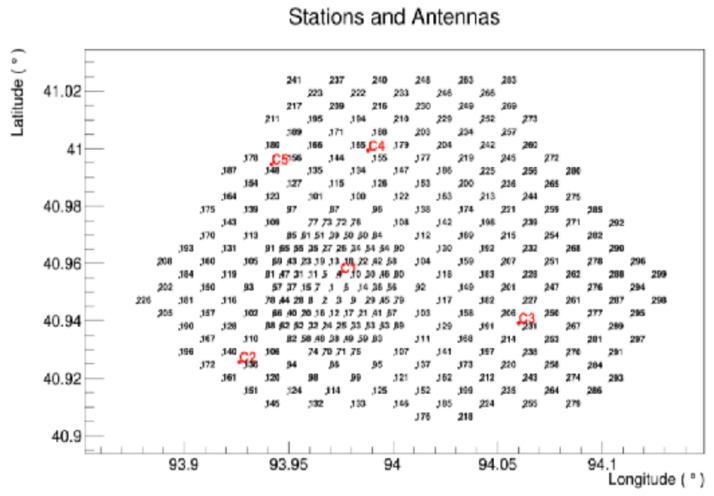
敦煌市自然资源局文件

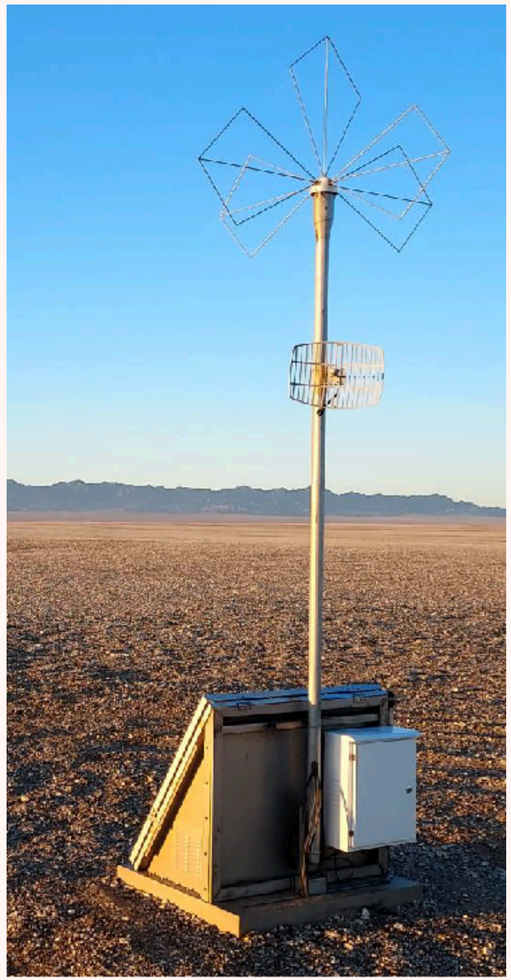
敦自然资发〔2024〕23号

敦煌市自然资源局
关于大型中微子射电观测站二期子阵项目用地
准予备案的通知

Layout of final GP300 array

Sparse array (1km step) with denser infill (577 m) ~100 events/day





GP300 Site

Ma Pengxiong

Animals

Mongolian Gazelle (Procapra gutturosa)

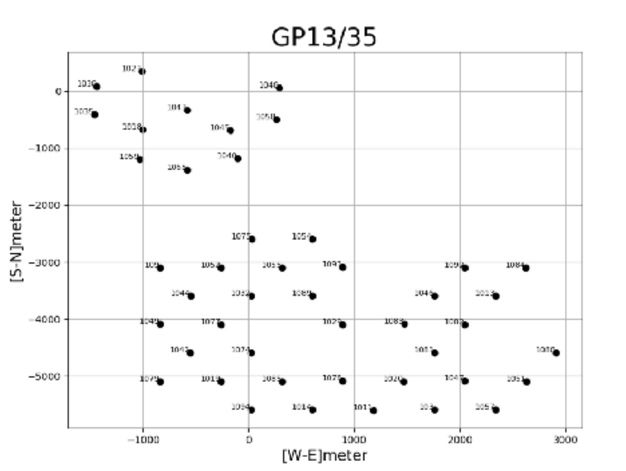
Construction on GP300

Ma Pengxiong

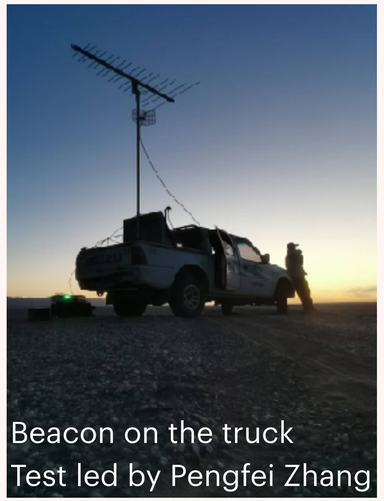
Work-life Balance @ GP300

Ma Pengxiong

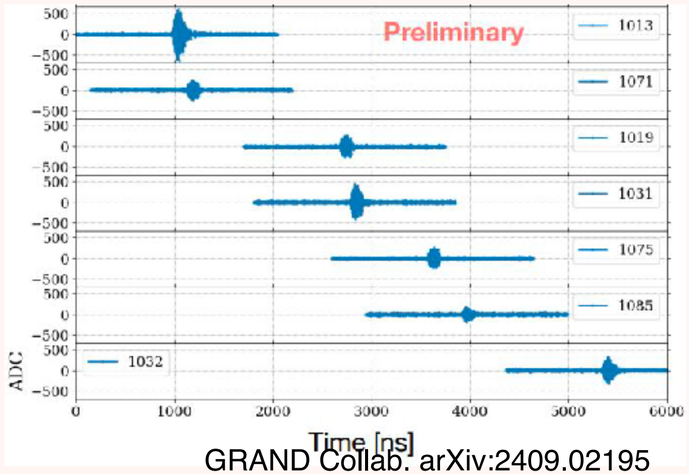
GP300 in the Commissioning Stage



- A pathfinder for the GRAND experiment: autonomous triggering & inclined air showers reconstruction test
- 48 antennas+43 FEB+ a new center station have been deployed
- Hardware and firmware test
- Offline trigger analysis

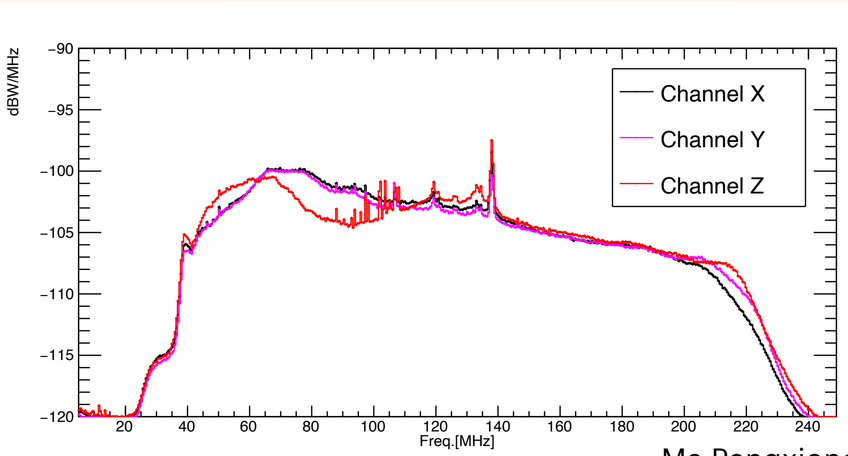

Beacon on the truck
Test led by Pengfei Zhang

Triggered events



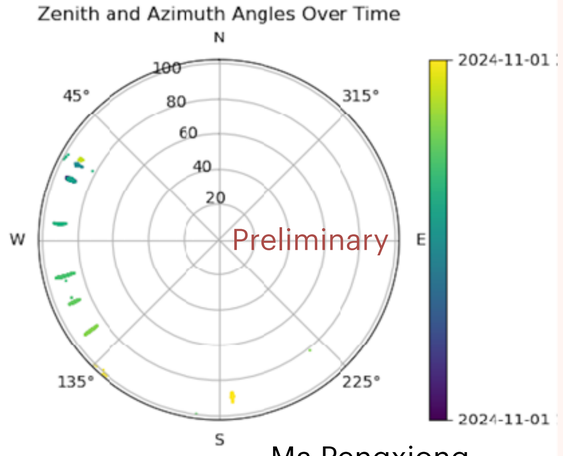
GRAND Collab. arXiv:2409.02195

Power Spectrum Density



Ma Pengxiong

Reconstruction of Events



Ma Pengxiong

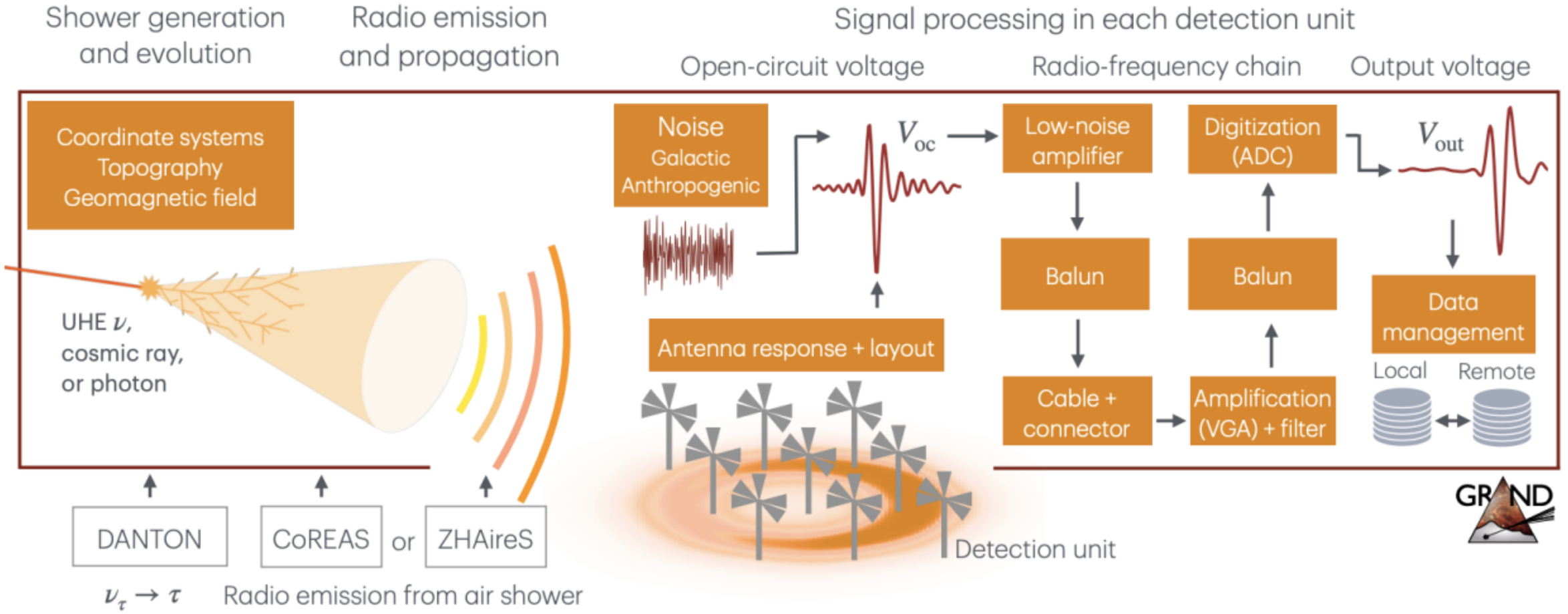
GP300's Next Stage Deployment

More antennas to be deployed

Check Sei Kato's talk tomorrow for more details on GP300

Photo by Ma Pengxiong

Software Pipeline: GRANDlib



https://github.com/grand-mother/grand arXiv:2408.10926v2

Summary

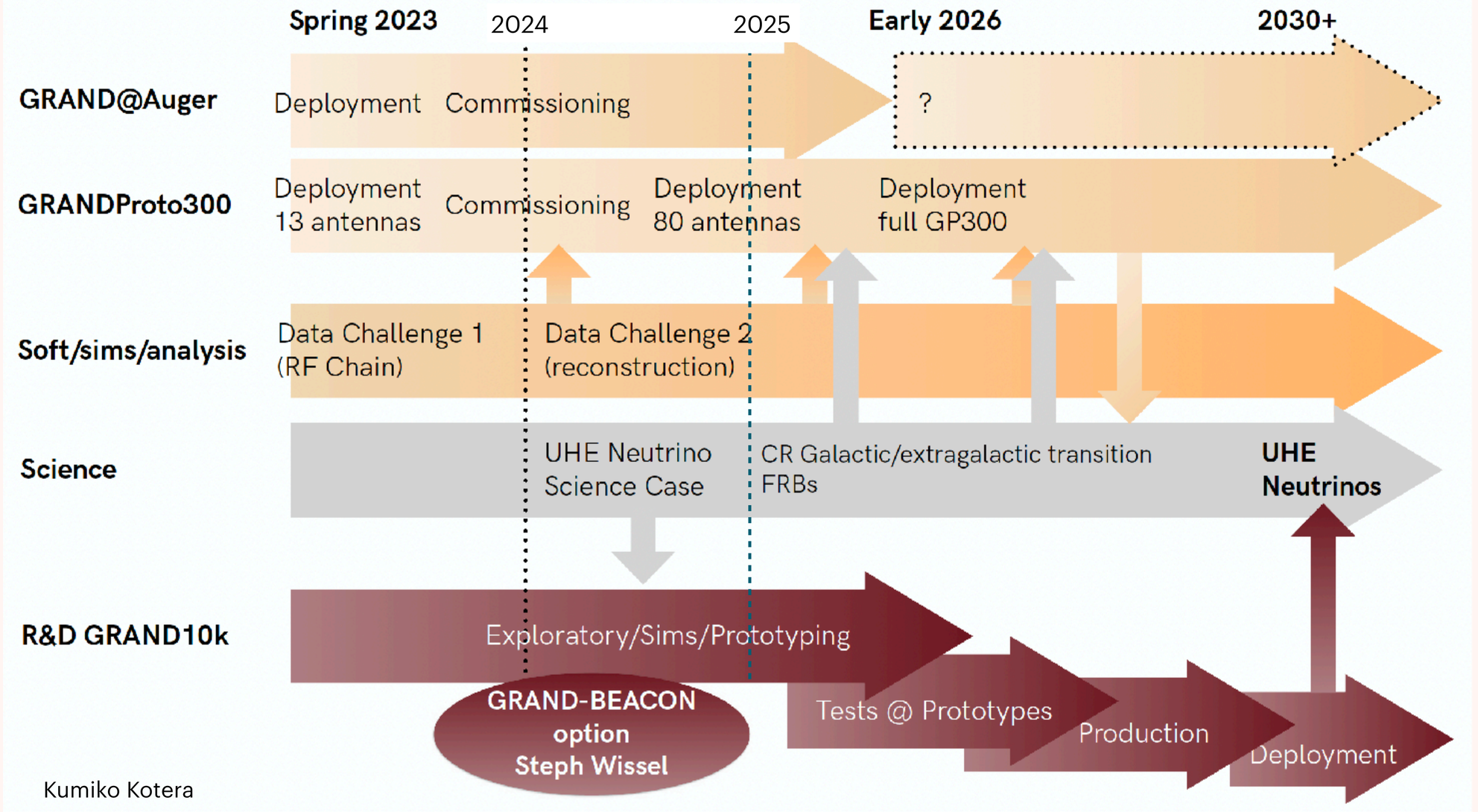
GRAND key features:

- Modular design using relatively inexpensive antennas
- One of the largest UHE neutrino observatories: excellent sensitivity, large FoV, 0.1 degree angular resolution
- Rich Science case: UHE neutrinos; UHE Cosmic rays; UHE gamma rays; Radio Astronomy

Prototype Stage:

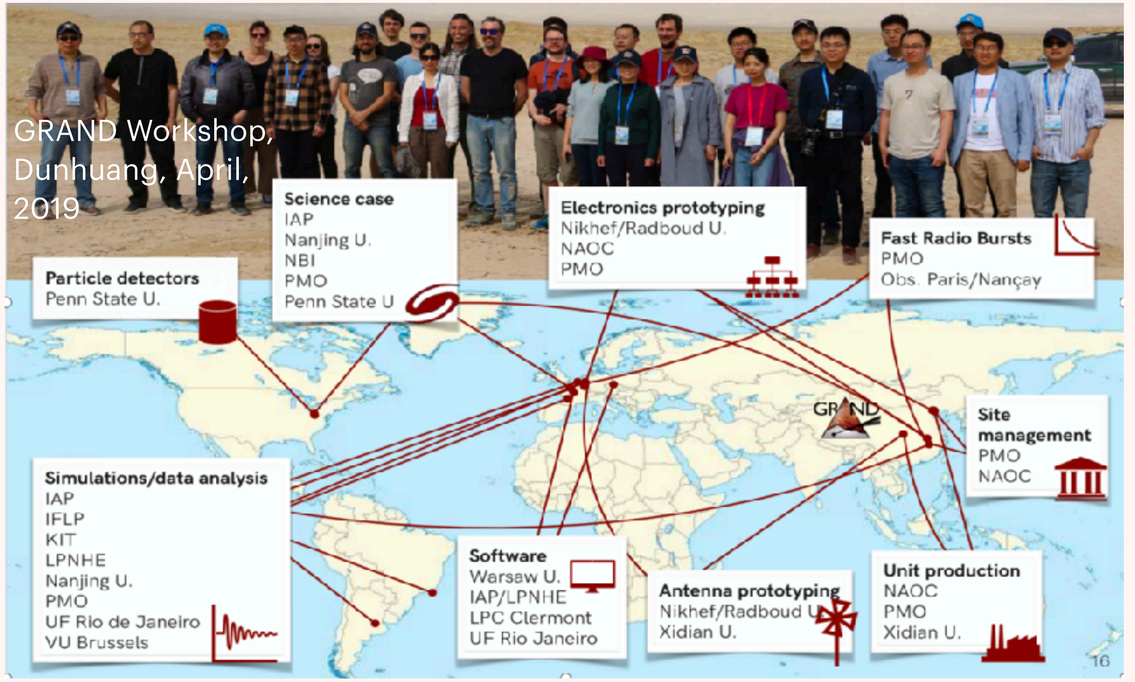
- 3 Prototypes: GRAND@Nançay, GRAND@Auger, GRANDProto300
- Official approval for 200-km^2 GP300 site in Gansu, China
- 48 antennas were deployed by the end of 2024 at GP300
- Software pipeline GRANDlib (arXiv:2408.10926v2)
- The search for cosmic ray air showers is ongoing

Ideal Timeline



Kumiko Kotera

GRAND Collaboration



120 members, 45 institutions,14 countries

Argentina, Belgium, Brazil, China, Czech Republic, Denmark, France, Germany, Greece, Japan, Netherlands, Norway, Poland, USA

Stay Tuned! Thank you !