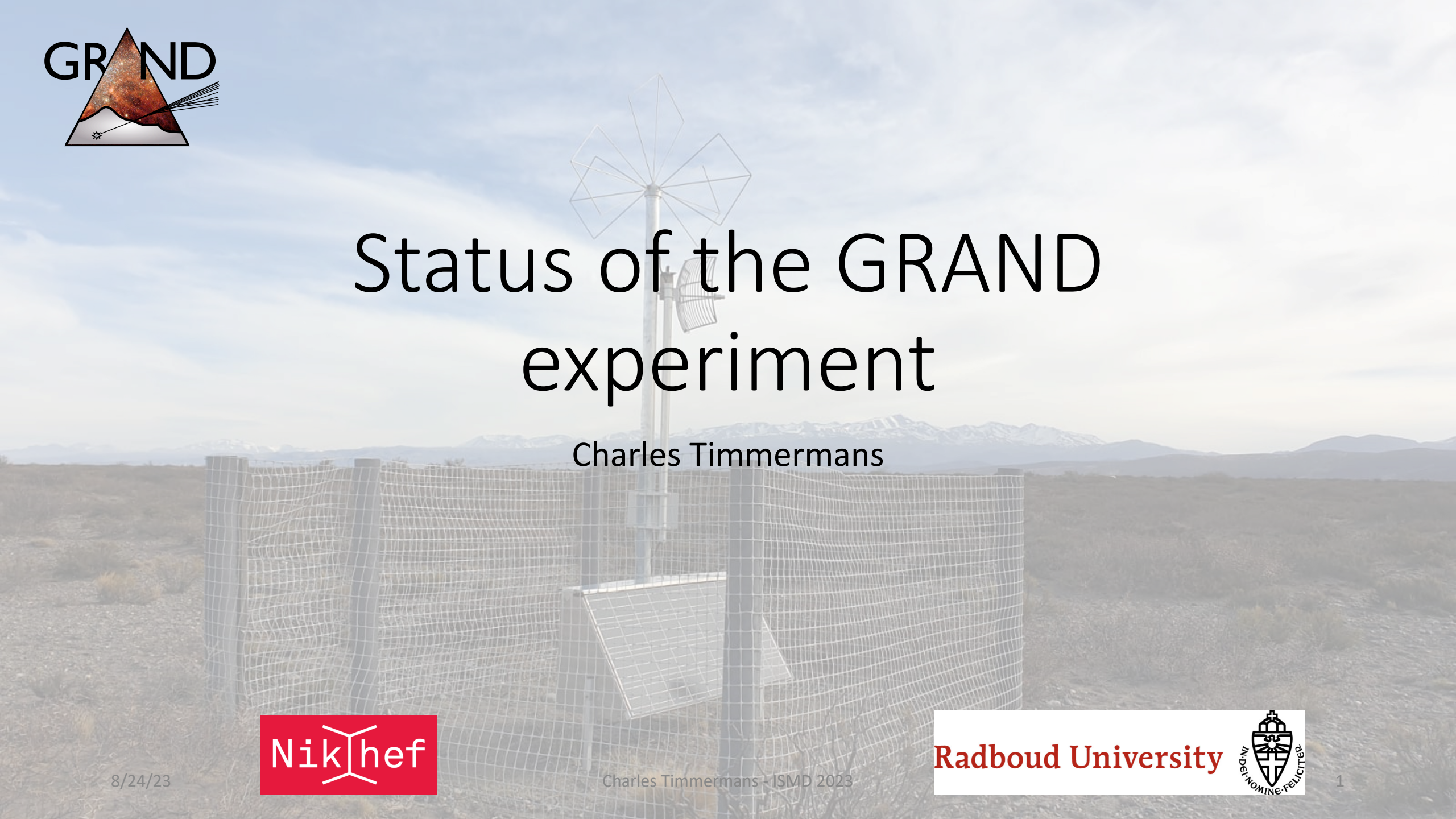
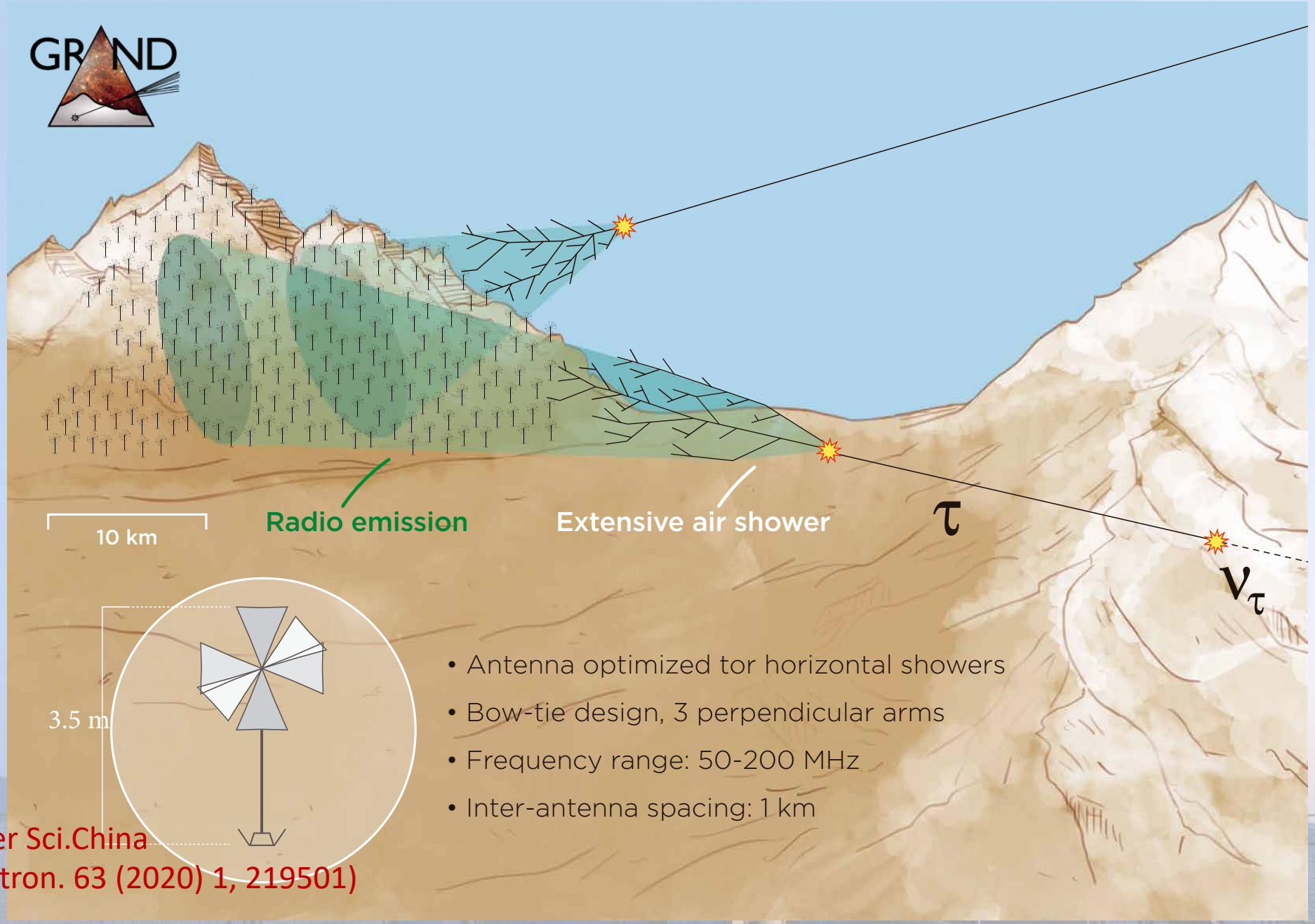


Status of the GRAND experiment

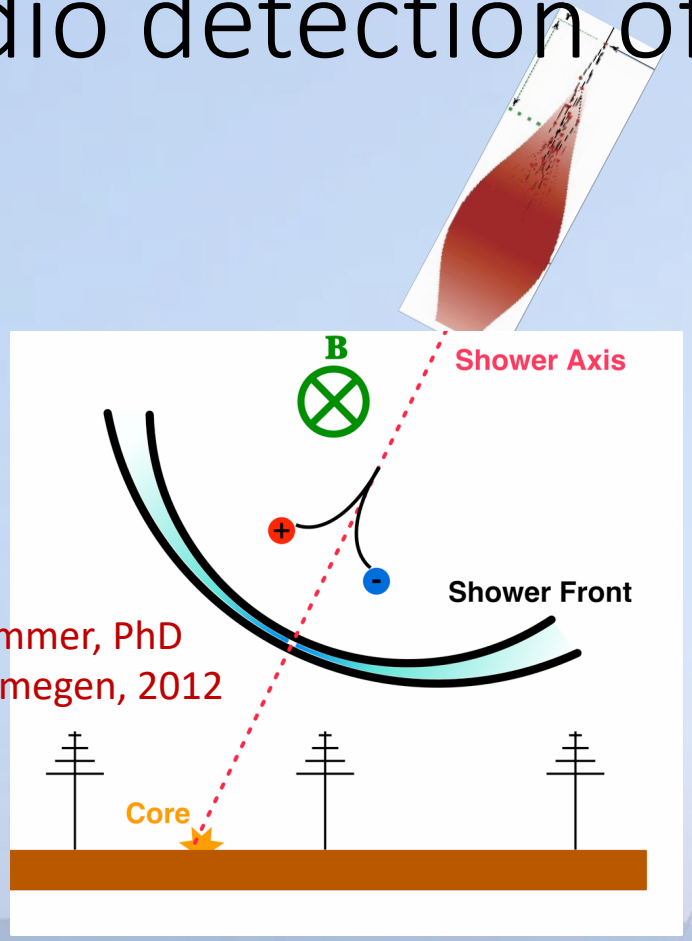
Charles Timmermans



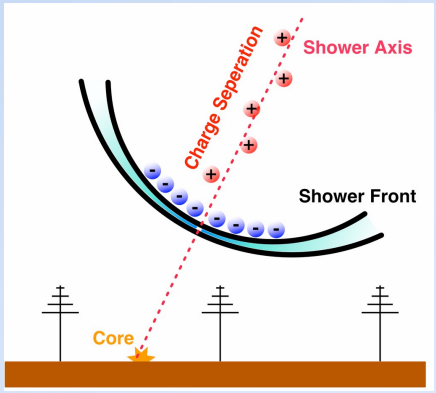
- Antenna optimized tor horizontal showers
- Bow-tie design, 3 perpendicular arms
- Frequency range: 50-200 MHz
- Inter-antenna spacing: 1 km

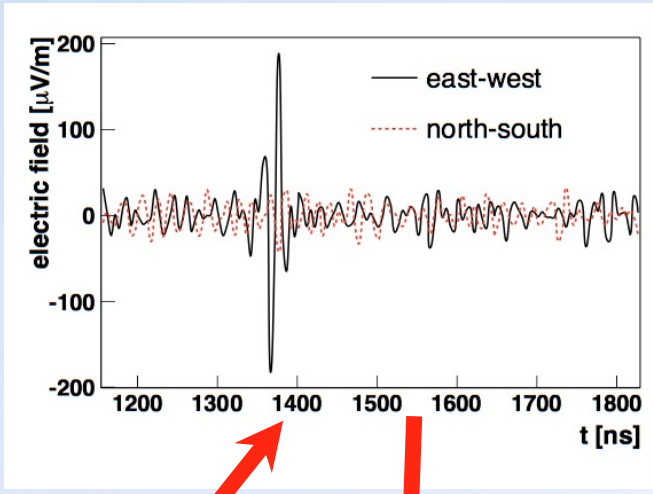
(Modified after Sci.China Phys.Mech.Astron. 63 (2020) 1, 219501)

Radio detection of air showers

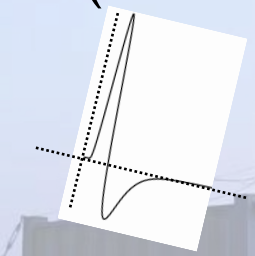


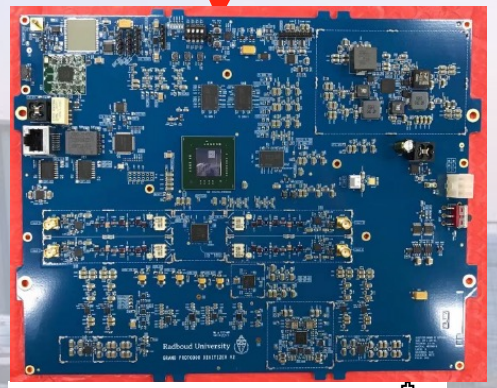
H. Schoorlemmer, PhD thesis U. Nijmegen, 2012





Short Pulse (~100ns)





Nikhef

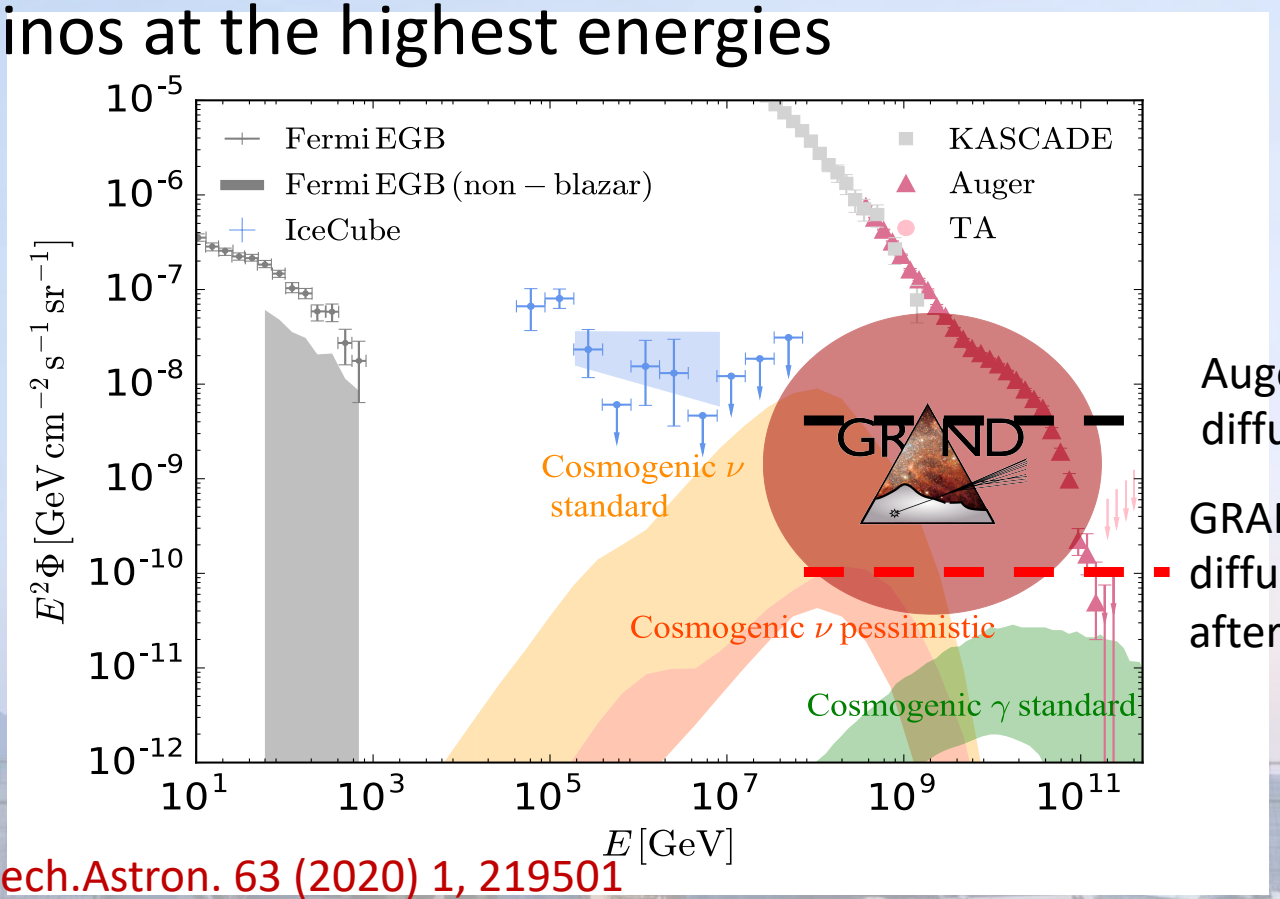
Radboud University

GRAND Fundamental Parameters

- Layout: 10-20 arrays with a combined area of 200,000 km^2
- 24/7 near 4 π sky coverage
- Angular Resolution <0.05 degrees (ArXiv 2107.03206)
- X_{MAX} resolution 20-40 g/cm^2. (ArXiv 2112.07542)
- Shower Energy resolution ~15% (Sci.China Phys.Mech.Astron. 63 (2020) 1, 219501)
- Neutrino sensitivity 10^{-10} GeV cm^{-2} s^{-1} sr^{-1} after ~ 10 years of running
- Fully efficient for UHECR and gamma rays above 10^{10} GeV for zenith angles beyond 65°

The Physics of GRAND

- GRAND is a multi-messenger experiment with the sensitivity to discover/detect neutrinos at the highest energies



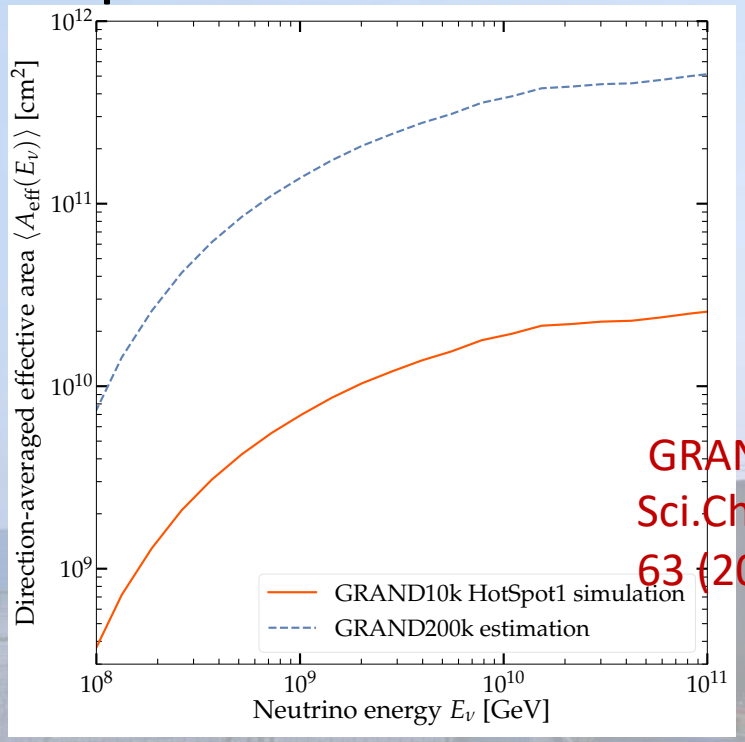
Auger 90% integrated diffuse neutrino limit

GRAND 90% integrated diffuse neutrino limit after 10 years running

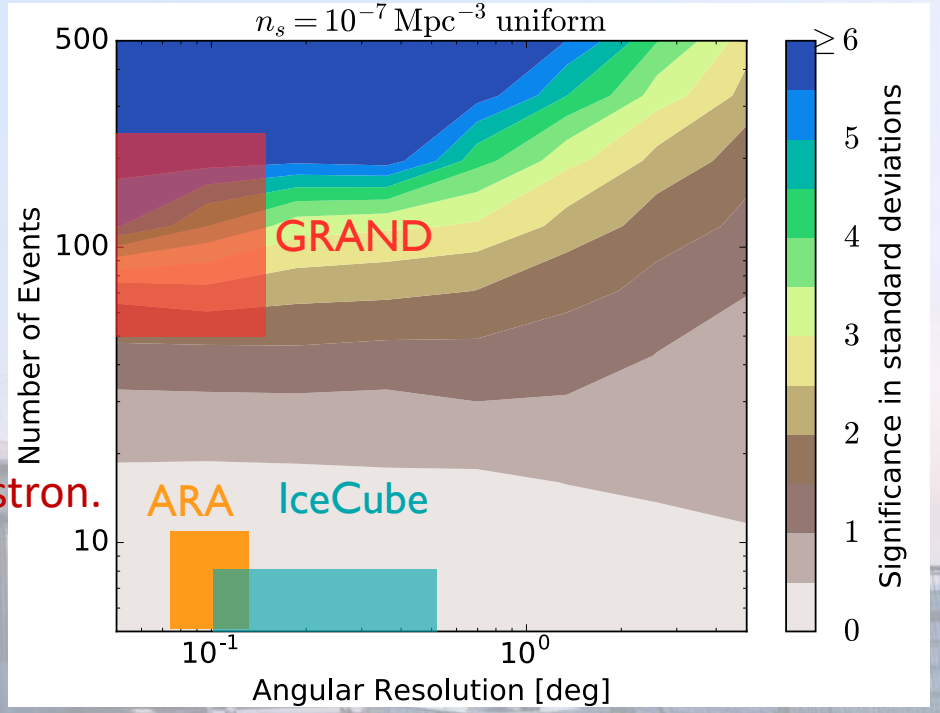
GRAND Collaboration, Sci.China Phys.Mech.Astron. 63 (2020) 1, 219501

The Physics of GRAND

- GRAND is a multi-messenger experiment with the sensitivity to discover/detect neutrinos at the highest energies
- GRAND will open the field of neutrino astronomy at the highest energies

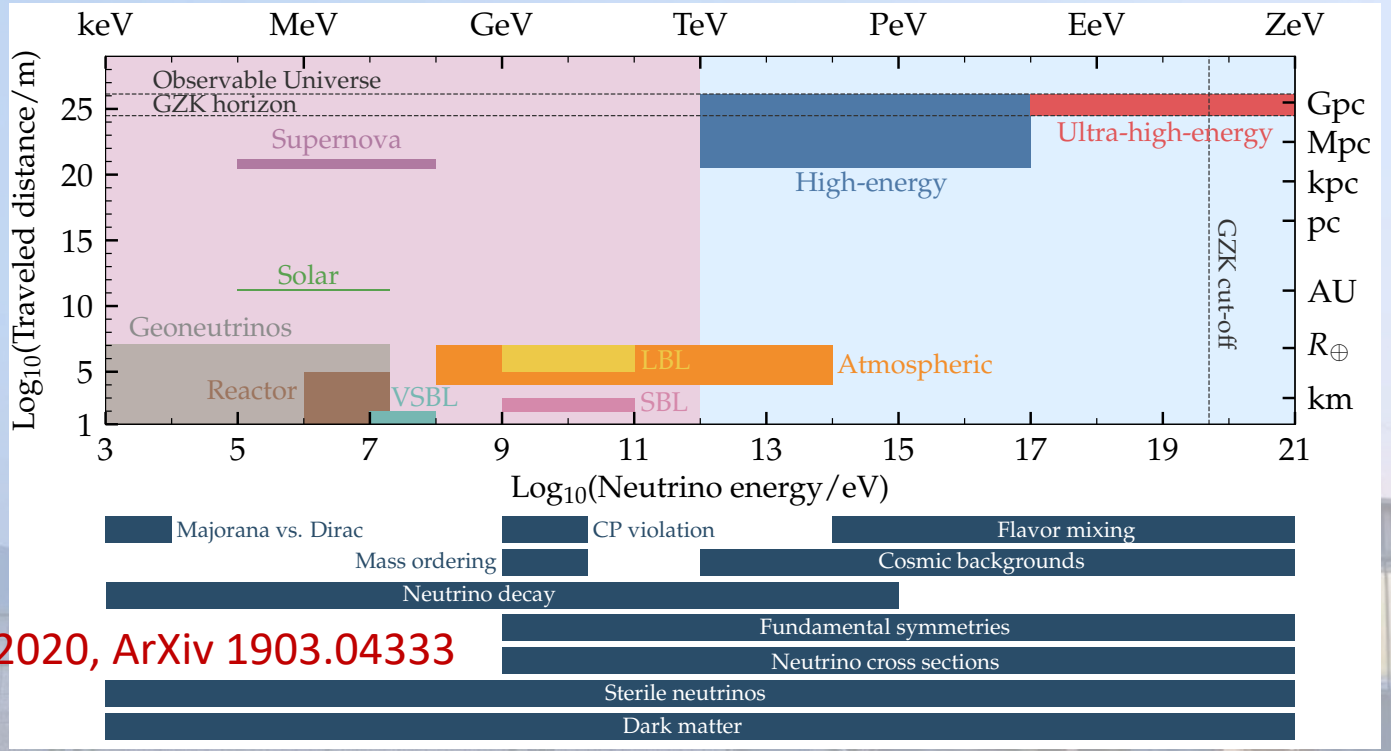


GRAND Collaboration, Sci.China Phys.Mech.Astron. 63 (2020) 1, 219501

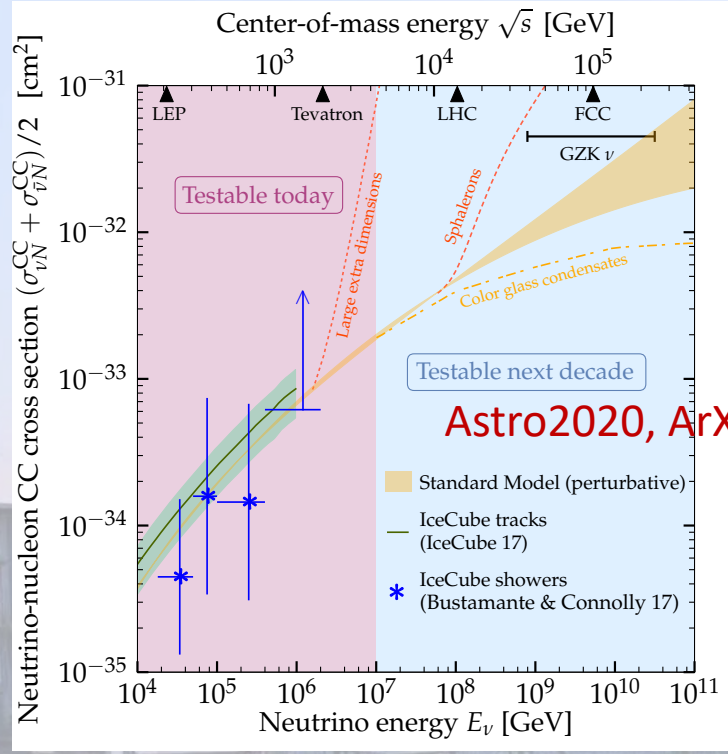


The Physics of GRAND

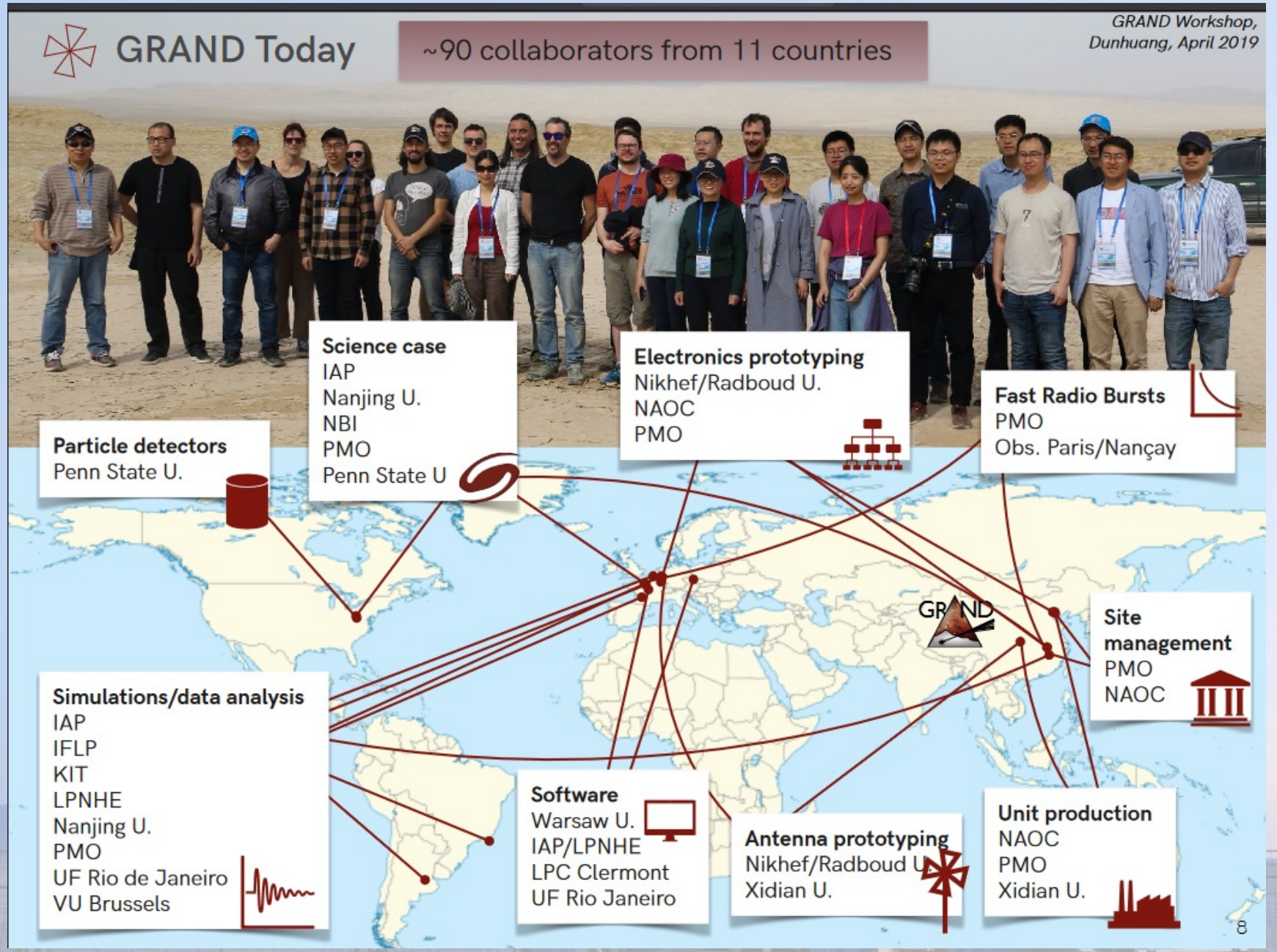
- GRAND is a multi-messenger experiment with the sensitivity to discover/detect neutrinos at the highest energies
- GRAND will open the field of neutrino astronomy at the highest energies
- **GRAND will measure fundamental properties of UHE interactions**



Astro2020, ArXiv 1903.04333



Astro2020, ArXiv 1903.04


GRAND Today
~90 collaborators from 11 countries
GRAND Workshop,
Dunhuang, April 2019
Science case
IAP
Nanjing U.
NBI
PMO
Penn State U
Electronics prototyping
Nikhef/Radboud U.
NAOC
PMO
Fast Radio Bursts
PMO
Obs. Paris/Nançay
Particle detectors
Penn State U.
Site management
PMO
NAOC
Simulations/data analysis
IAP
IFLP
KIT
LPNHE
Nanjing U.
PMO
UF Rio de Janeiro
VU Brussels
Software
Warsaw U.
IAP/LPNHE
LPC Clermont
UF Rio Janeiro
Antenna prototyping
Nikhef/Radboud U.
Xidian U.
Unit production
NAOC
PMO
Xidian U.
8

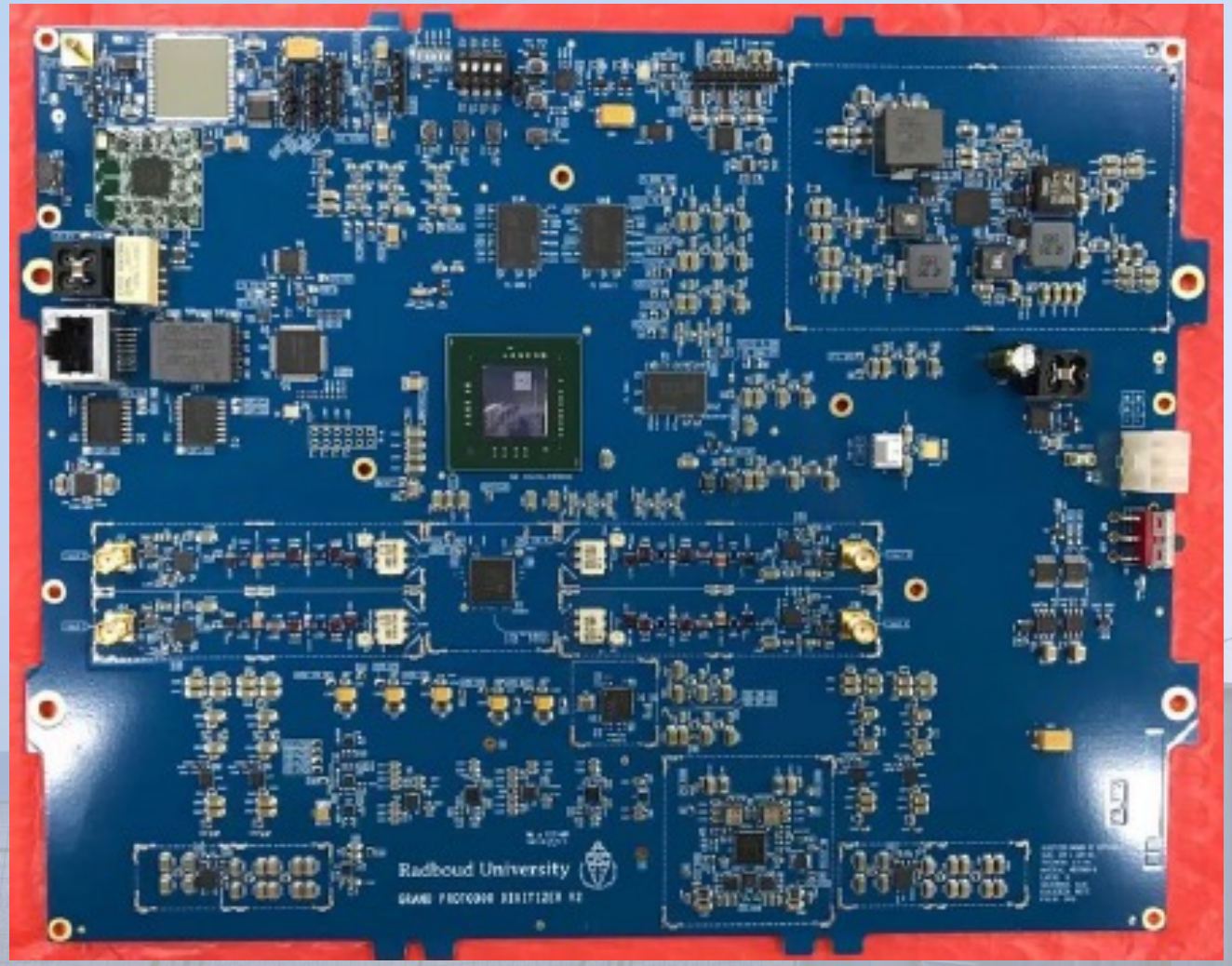
A staged approach with self-standing pathfinders

	Prototype stage	GRAND10k	GRAND200k
	2021	2028	203X
Goals	autonomous radio detection of very inclined air-showers cosmic rays $10^{16.5\text{-}18}$ eV •Galactic/extragalactic transition •gamma rays •muon problem •radio transients	Two GRAND 10K arrays • discovery of EeV neutrinos for optimistic fluxes • radio transients (FRBs!) • one in each hemisphere	sensitive all-sky detector 1st EeV neutrino detection and neutrino astronomy!
Setup	•GRAND@Nançay: 4 antennas for trigger testing • GRAND@Auger: 10 antennas for cross-calibration • GRANDProto300: 300 antennas over 200 km2	•10,000 radio antennas over 10,000 km^2 on each site	• 200,000 antennas over 200,000 km^2 • 20 sub-arrays of 10k antennas • on different continents
Budget	2 M€ 100 antennas produced funded by China + ANR PRCI NUTRIG (France) + Radboud University	13 M€ host country 1500€/unit	300M€ in total 500€/unit to be divided among participating countries

Prototype setup in Argentina and China

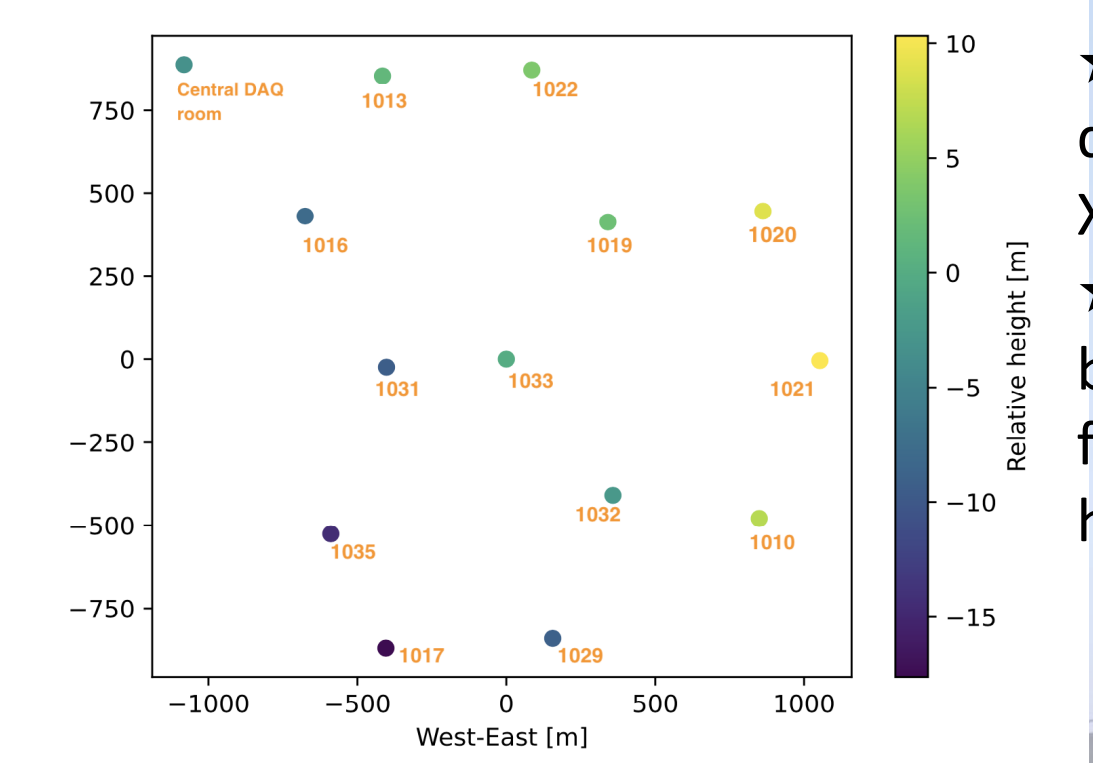
Sensor antenna, 3 polarizations
Pole 3.5 m high
Communication antenna
GPS antenna
Inside box: battery, electronics
Solar panel
Optimized for horizontal showers

Prototype Electronics



- 30-230 MHz analog filter
- 500 MSPS ADC
- Powerful FPGA/CPU for flexible digital options in filtering and triggering
- Ethernet output allows for several options for (wireless) data transfer
- Data Transfer:
  - Ubiquity AIRMAX® system in China and Auger
  - Data Transfer through fiber in Nançay

GP13: Prototype in the Northern Hemisphere

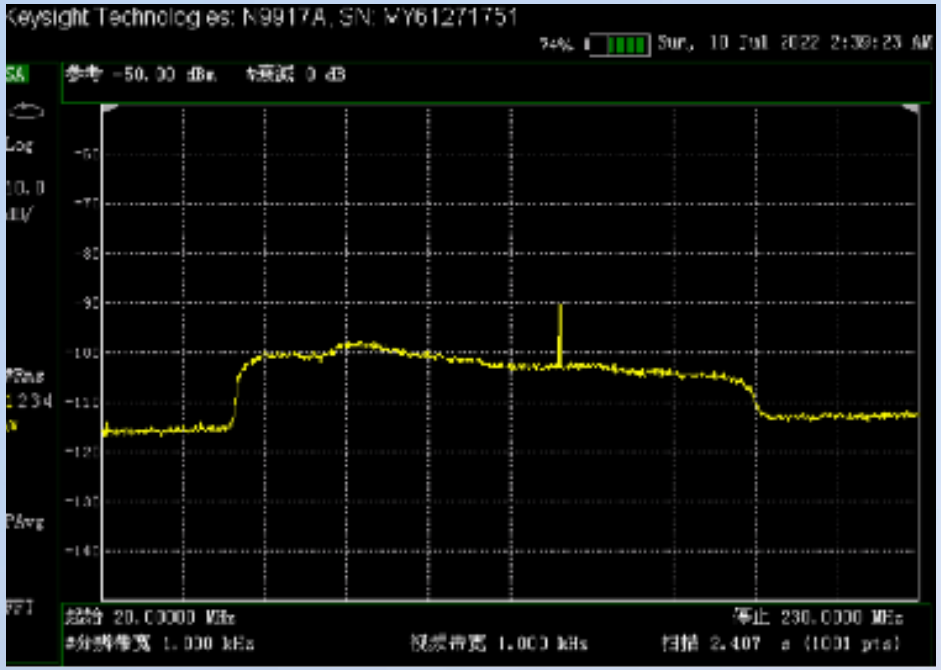


GRAND Collaboration, ICRC2023

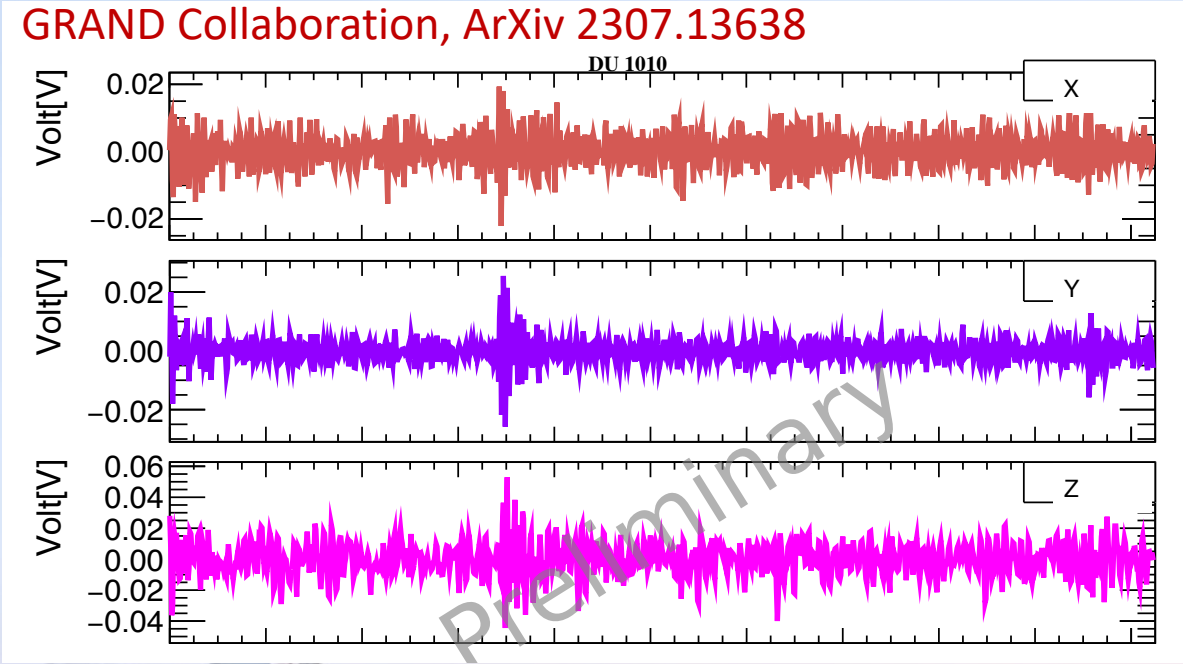
★ 13 antennas (+1 reference antenna) deployed in Dunhuang, Gansu, China by Xidian U. & Purple Mountain Observatory

★ exceptionally low levels of radio background noise across a wide frequency range, ranging from MHz to hundreds of MHz

GP13: First Data



GRAND Collaboration, ICRC2023

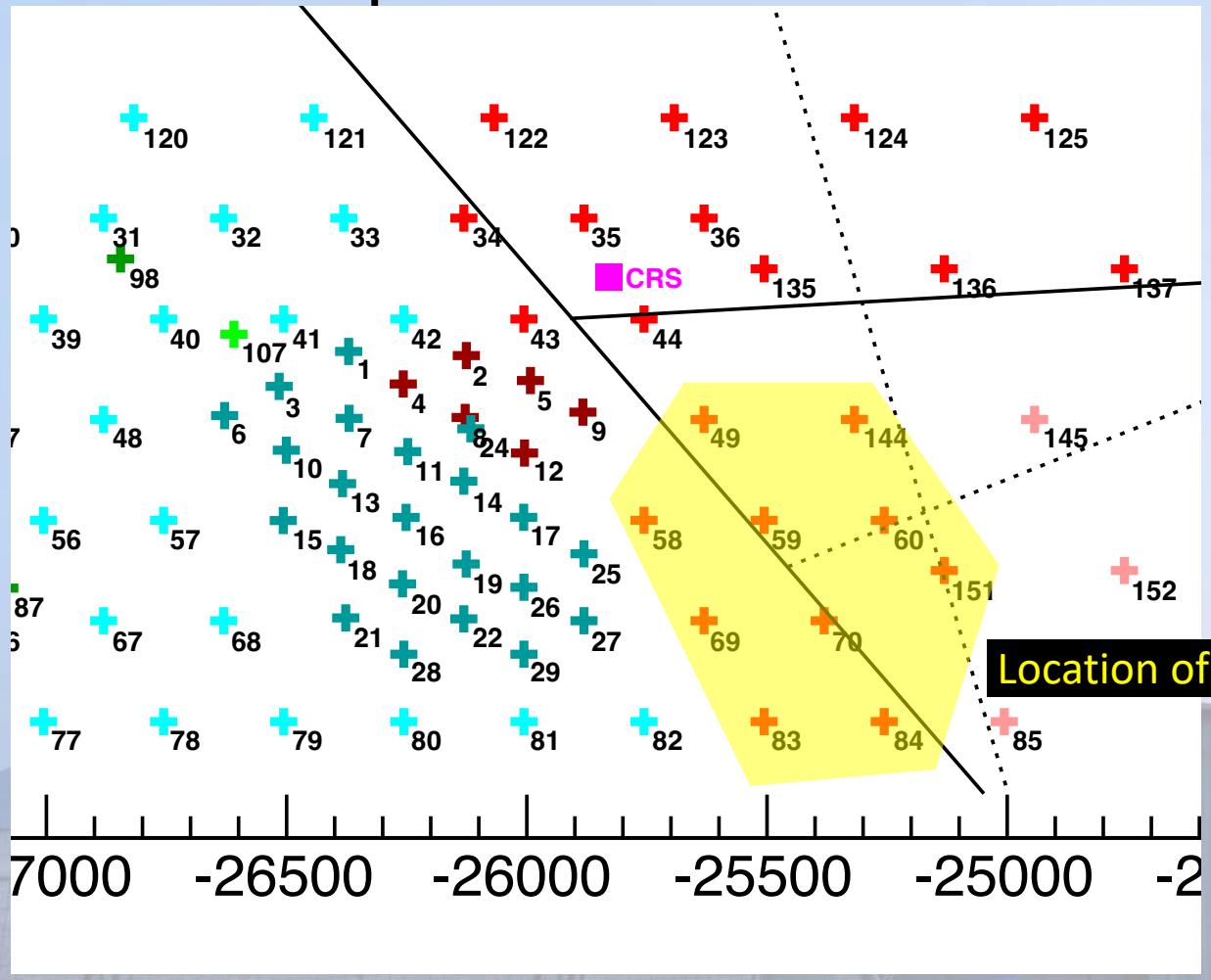


Background verified with spectrum analyzer

Status: Validating current setup

Next step: Deployment of 70 additional antennas

GRAND@Auger: Prototype in the Southern Hemisphere

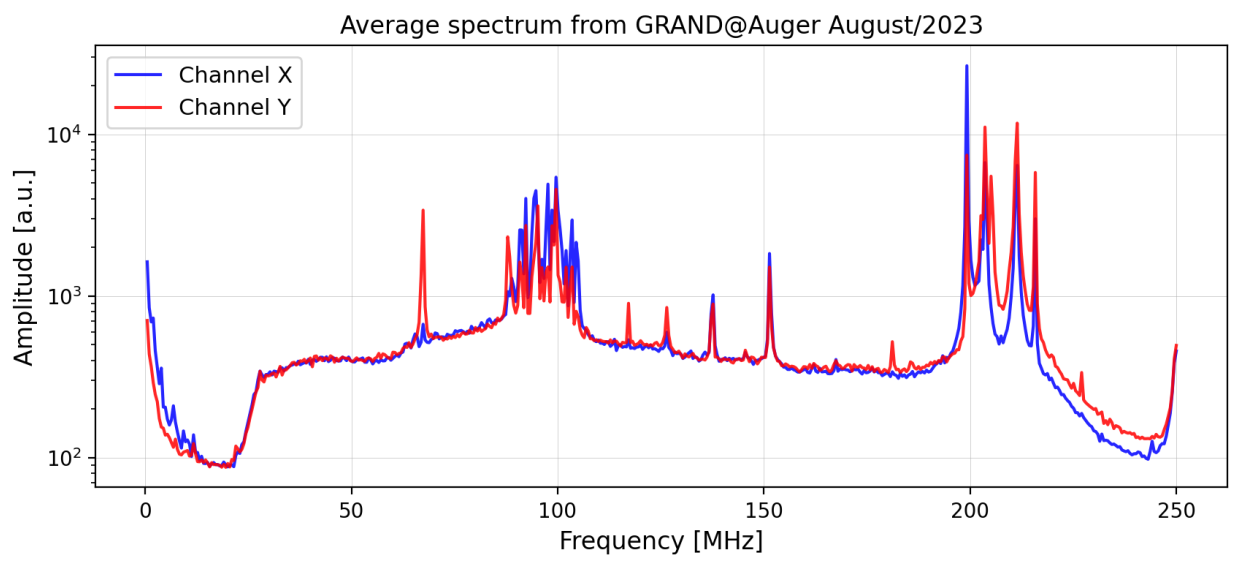


Re-use part of the AERA array in the Auger experiment

10 stations fully deployed in August 2023

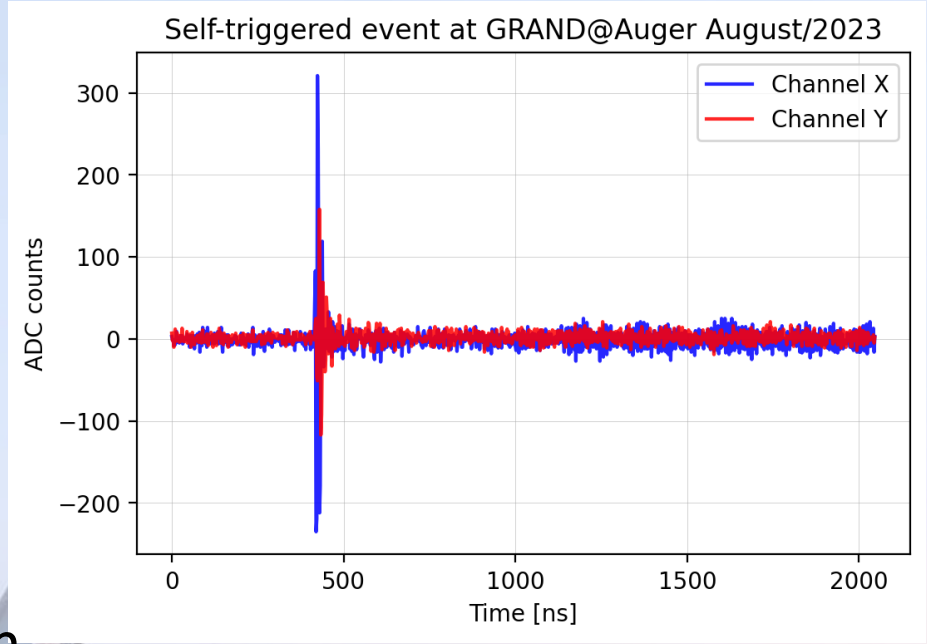
First data now being analyzed

GRAND@Auger Data



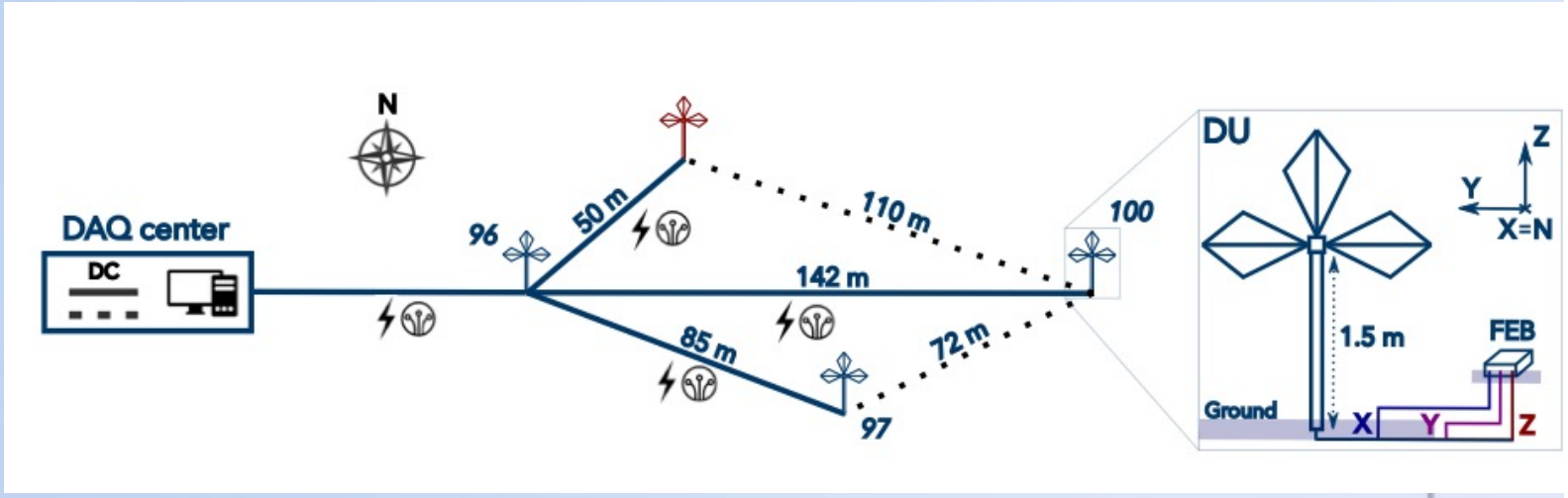
Averaged Frequency spectrum of a single station

Example of a self-triggered radio event

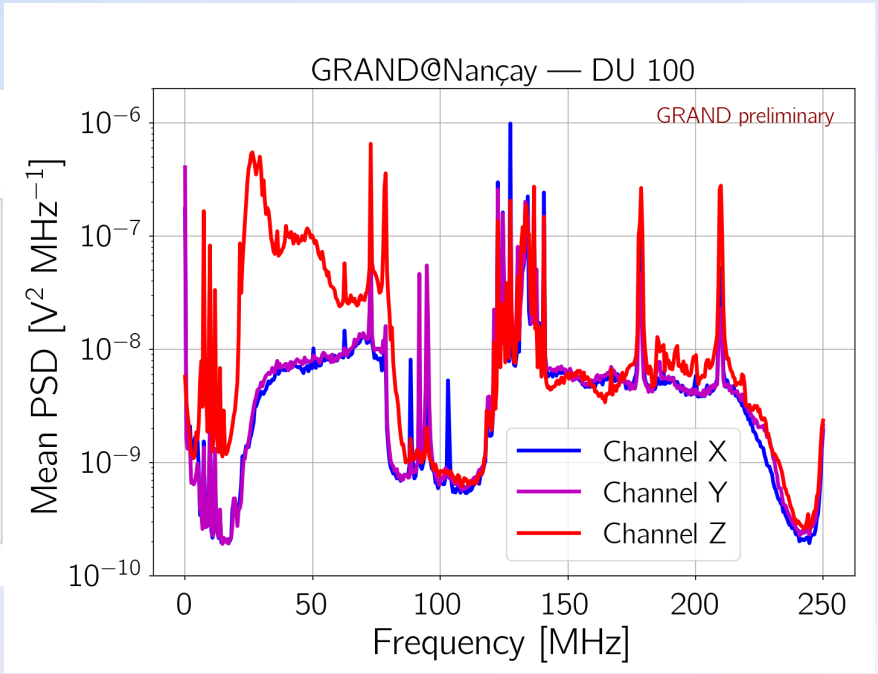


Next steps: Commissioning of setup and calibrate the detector
Compare common events to well known Auger detector

GRAND@Nançay – European test facility



GRAND Collaboration, ICRC2023



Setup at the Nançay observatory in order to test equipment and new ideas in design, triggering and acquisition

Conclusion

- GRAND is a distributed next generation multi-messenger experiment with emphasis on neutrino (Astro) physics
- GRAND development proceeds in stages in both the Northern and the Southern Hemispheres
- First prototypes are taking data and first data looks very promising
- A test setup in Nançay enables swift testing of new designs and ideas