

The Giant Radio Array for Neutrino Detection – the experimental status and plans

Lech Wiktor Piotrowski for the GRAND collaboration

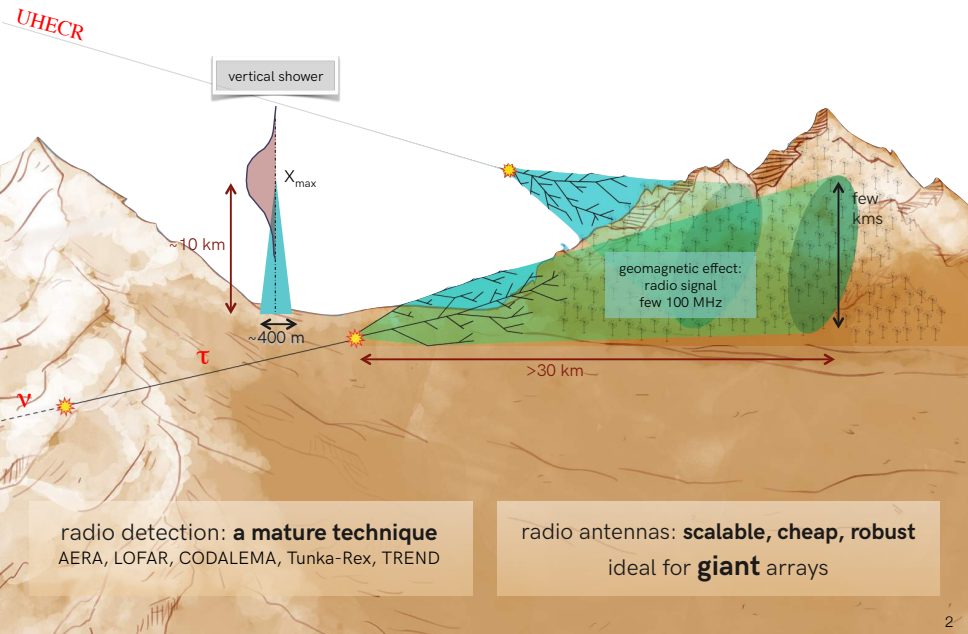
University of Warsaw

νT 2021, 01.X.2021

most slides by Kumiko Kotera @ ICRC2021



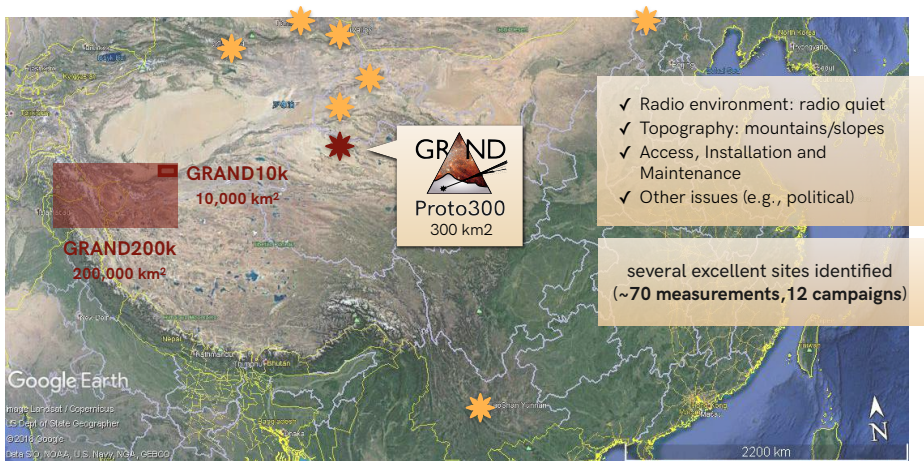
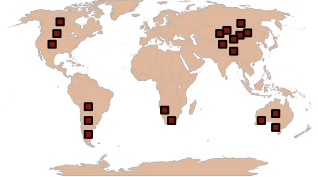
Radio detection of ultra-high-energy air-showers



The GRAND Concept

200'000 radio antennas over 200'000 km²
~20 sub-arrays of 10'000 antennas
over favorable sites in China and worldwide

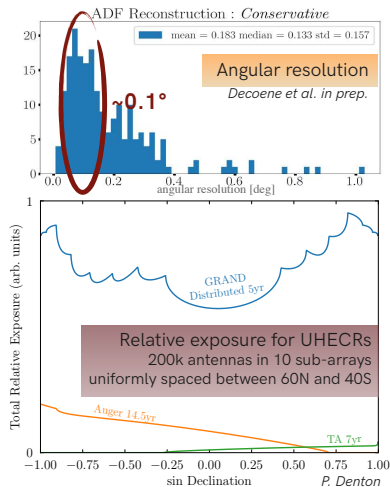
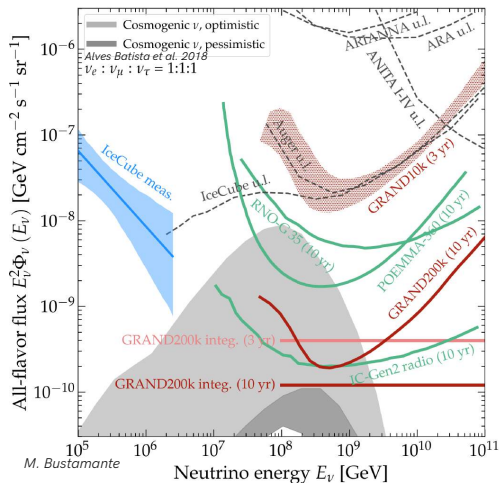
example of sub-array locations





Simulated performances

GRAND Science & Design, GRAND Coll.
Science China, arXiv:1810.09994



- **GRAND full sensitivity to neutrinos** ($E > 10^{17}$ eV) $\sim 4 \times 10^{-10}$ $\text{GeV cm}^{-2} \text{s}^{-1} \text{sr}^{-1}$
- **Angular resolution** $\sim 0.1^\circ$ for GP300 & GRAND
- **Energy resolution** $< 10\%$ for GP300 & GRAND
- **X_{max} resolution** < 40 g/cm² achievable for $E > 10^{19}$ eV for GRAND

V. Decoene PhD 2020

B. Lago & Rio GRAND team

C. Guépin PhD 2019

GRANDProto300: a self-standing pathfinder

Autonomous detection of **very inclined cosmic rays** $E=10^{16.5}-10^{18}$ eV

reconstructing spectrum, arrival direction & composition

validation via comparison to known results

test bench for further GRAND stages

Proficient physics instrument if complemented by **particle detector array**

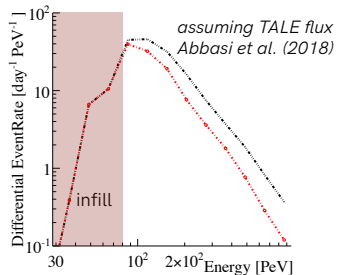
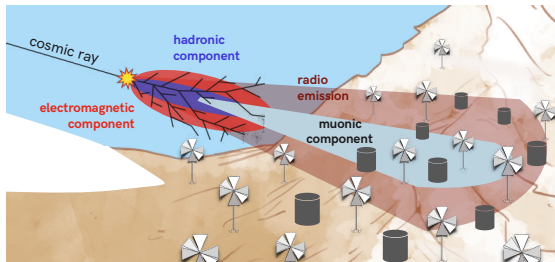
Galactic/extragalactic transition

hadronic physics (muon content in EAS)

UHE gamma-rays

Fast Radio Bursts

+ to check radio calibration
at 30-200 MHz, pulse-shape
analyses, Cherenkov-cone analyses



GRANDProto300: hardware setup and status

HorizonAntenna,
successfully tested in the
field (Aug., Dec. 2018)

Antenna set-up:
antenna simulations, nut
design, unit design.

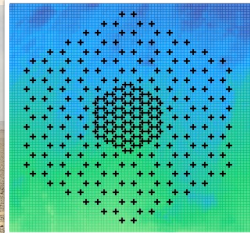
Status:

First 100 antennas:

- Mechanics ready
- Electronics ready and tested

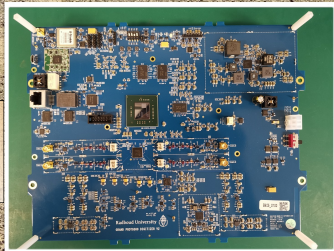
Waiting for
deployment!

Layout: 300 antennas, 200 km²,
1 km step size with denser infill
Erange = $10^{16.5}$ - 10^{18} eV



Electronics:

50-200 MHz analog filtering,
500 MSPS sampling
FPGA+CPU
Bullet WiFi data transfer



Software

Data format:

- *Idea*: raw/sim → HDF5 ROOT TTrees
- *Status*: ready for ZHAireS, in preparation for raw and CoREAS

Data analysis:

- *Idea*: ~~astropy~~-based GRANDlib - Python + C(++) speedups/alternatives
- *Status*:
 - Preliminary energy reconstruction with GRANDlib and CoREAS working
 - Finished writing the topography module
 - GRANDlib restructuring in progress

Other

Carbon footprint:

- Estimated in 10.1016/j.astropartphys.2021.102587
- GRAND Green Policy under final stages of construction

Simulations

ZHAireS:

- Migration to ZHAireS 1.0.30a on Aires 19.04.06 soon
- For big studies, interpolation used (*M. Tueros and A. Zilles 2021 JINST 16 P02031*)
- ZHAireS 1.1 in progress → more accurate description of the atmosphere using GDAS

CORSIKA7/CoREAS:

- Generated big library of inclined showers
 - Up-going showers handling in progress (*Chao Zhang et al., PoS(ICRC2021)248*)

Radio-morphing:

- (*A. Zilles et al., 10.1016/j.astropartphys.2019.06.001*)
- Good agreement with microscopic simulations
 - New scaling laws and new interpolation → better accuracy of the peak time and amplitude of the interpolated pulse (*Chiche et al., PoS(ICRC2021)194*)

MGMR3D:

- (*O. Scholten et al., Phys. Rev. D 97, 023005*)
- Adaptation from LOFAR to GRAND in progress

A staged approach with self-standing pathfinders

	GRANDProto300	GRAND10k	GRAND200k
	2021	2025	203X
Goals	autonomous radio detection of very inclined air-showers cosmic rays $10^{16.5-18}$ eV - Galactic/extragalactic transition - muon problem - radio transients	1st GRAND sub-array discovery of EeV neutrinos for optimistic fluxes - radio transients (FRBs!)	sensitive all-sky detector 1st EeV neutrino detection and/or neutrino astronomy!
Setup	300 HorizonAntennas over 200 km² - Particle detectors (a la HAWC/Auger) - Qinhai Province, China	10,000 radio antennas over 10,000 km² - in China	200,000 antennas over 200,000 km² 20 sub-arrays of 10k antennas - on different continents
Budget	2 M€ 100 antennas already paid (China)	13 M€ 1500€/unit confident for large contribution from China	300M€ in total 500€/unit to be divided between participating countries



A rich science case

UHE neutrinos

- UHE neutrino astronomy
- UHE neutrino cosmogenic flux

neutrino physics

- neutrino cross-section measurements
- spectral, angular distortions
- flavor ratios

UHECR, hadronic physics

- 20-80 times the exposure of Auger!
- GRANDProto300: transition from Galactic/extragalactic
- hadronic physics: muon discrepancy, UHECR mass composition, p-air cross-section

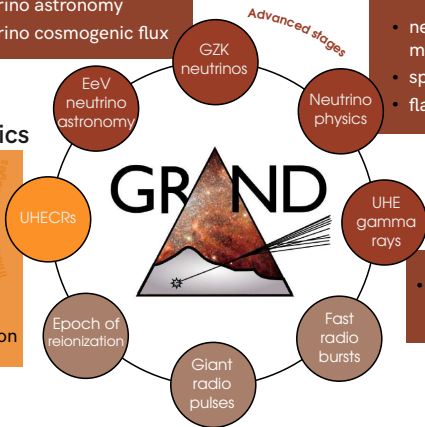
UHE gamma rays

- competitive with Auger at GRANDProto300 stage

radio-astronomy in a novel way

Early stages

- unphased integration of signals: an almost full-sky survey of radio signals
- can detect FRBs and Giant Radio pulses of the Crab already at the GRANDProto300 stage





Particle detectors
Penn State U.

Science case
IAP
Nanjing U.
NBI
PMO
Penn State U.

Electronics prototyping
Nikhef/Radboud U.
NAOC
PMO

Fast Radio Bursts
PMO
Obs. Paris/Nançay

Simulations/data analysis
IAP
KIT
LPNHE
Nanjing U.
PMO
UF Rio de Janeiro
VU Brussels
Univ. of Warsaw

Software
Univ. of Warsaw
IAP/LPNHE
LPC Clermont
UF Rio Janeiro

Antenna prototyping
Nikhef/Radboud U.
Xidian U.

Site management
PMO
NAOC

Unit production
NAOC
PMO
Xidian U.

