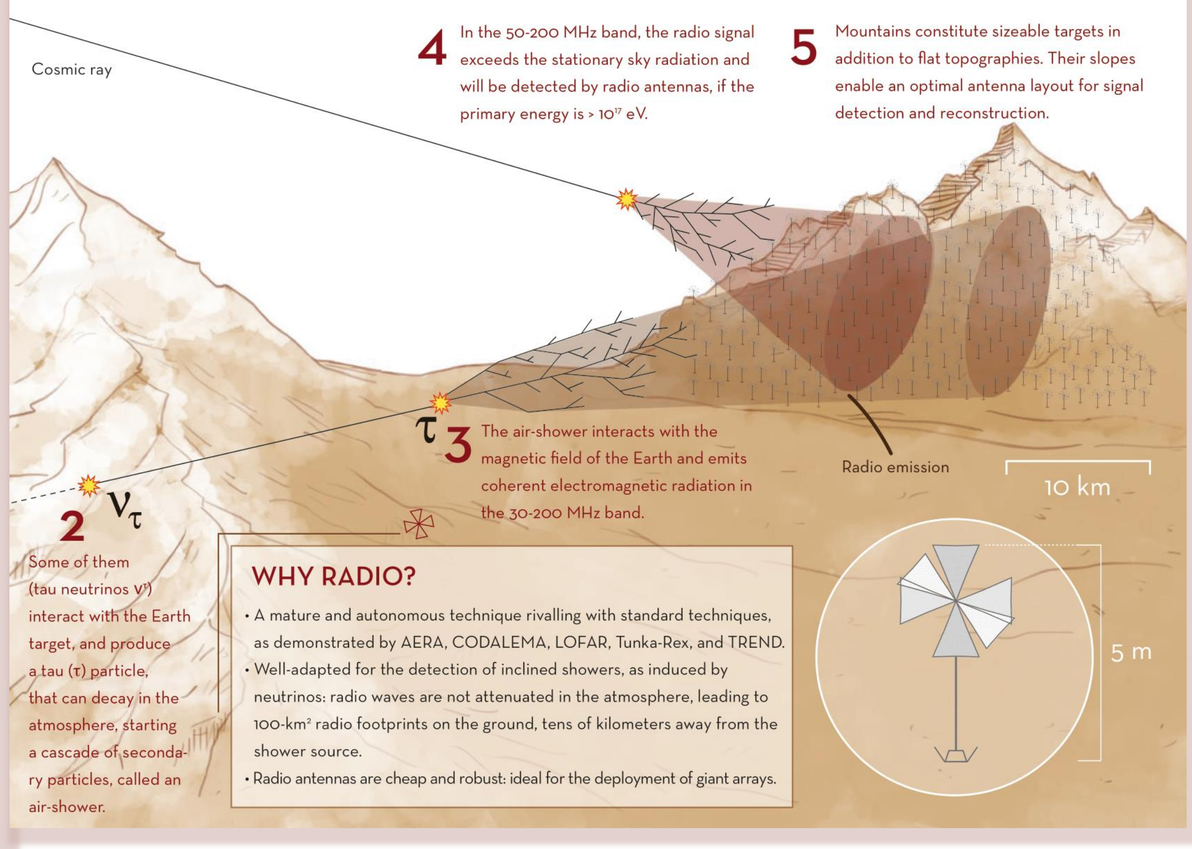
The Giant Radio Array for Neutrino Detection

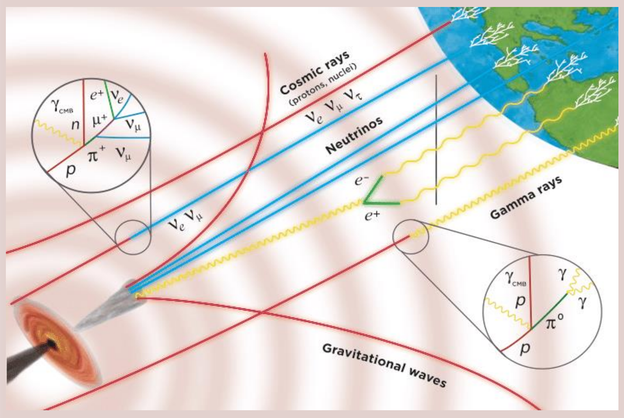
The Giant Radio Array for Neutrino Detection (GRAND) is a project dedicated to the radio detection of ultra-high energy cosmic rays, gamma rays and neutrinos. It aims at deploying 200 000 antennas in about 20 sub-arrays around the world, located in mountainous regions, with a combined area of 200 000 km².

DETECTION PRINCIPLE

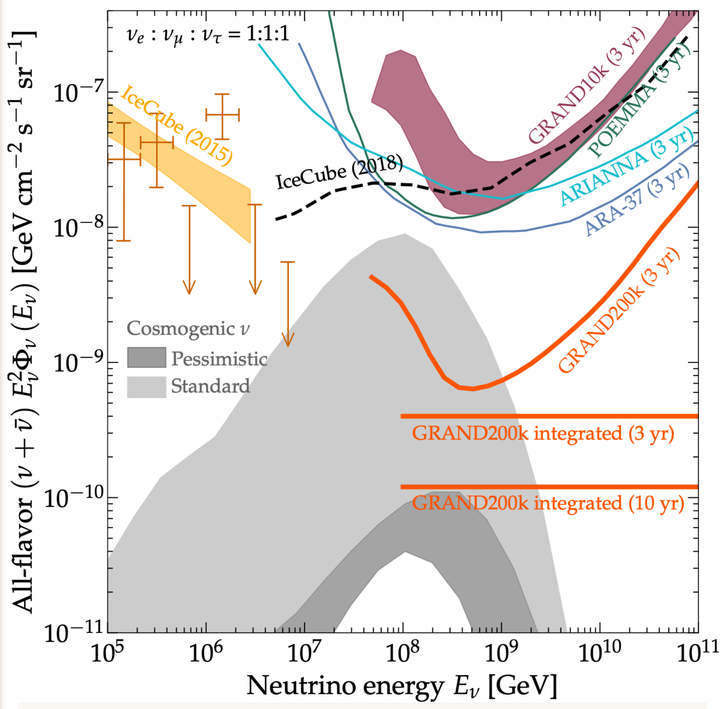


WHY RADIO?

- A mature and autonomous technique rivalling with standard techniques, as demonstrated by AERA, CODALEMA, LOFAR, Tunka-Rex, and TREND.
- Well-adapted for the detection of inclined showers, as induced by neutrinos: radio waves are not attenuated in the atmosphere, leading to 100-km² radio footprints on the ground, tens of kilometers away from the shower source.
- Radio antennas are cheap and robust: ideal for the deployment of giant arrays.



Sensitivity of GRAND and its first 10k hotspot, for 3 neutrino flavors, over 3 years:



Horizontal lines: 90% confidence level detection limit of GRAND for 3 and 10 years. Other project sensitivities for ARA, ARIANNA, POEMMA are shown for comparison with GRAND10k.
Yellow: IceCube astrophysicial flux. The gray band spans possible cosmogenic neutrino fluxes in the standard and most pessimistic scenarios*.

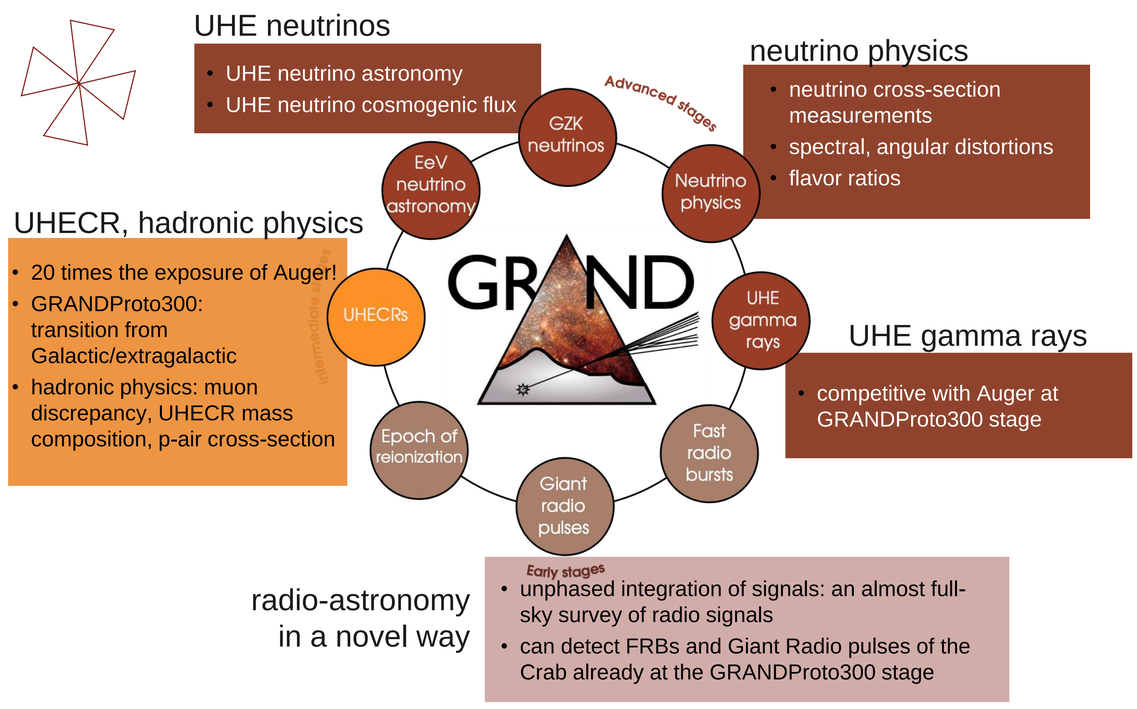
*R. Alves Batista, R. M. de Almeida, B. Lago, K. Kotera (JCAP), arXiv:1806.10879

Science case

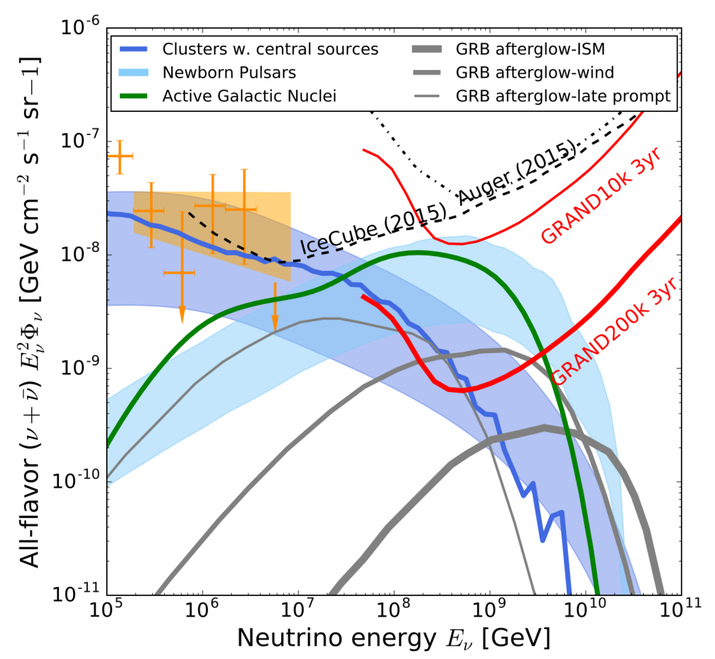
Why ultra-high energy neutrinos?

- **Because they exist:** Ultra-high energy neutrinos are bound to be produced by the interactions of ultra-high energy cosmic ray with the cosmic backgrounds, on their way from these sources to the Earth. Neutrinos should also be produced directly at the sources.

- **Because they are unique messengers:** Neutrinos are produced with 5% of their parent cosmic ray energy, and travel undeflected by cosmic magnetic fields. Neutrinos with energy >10^{17} eV can thus solve one of the most puzzling mysteries of our Universe: the origin of the ultra-high energy cosmic rays.



Predicted neutrino flux of diverse source candidates for astrophysical neutrinos:



For standard scenarios and a directional resolution of sub-degree, GRAND will enable to identify source classes and detect point sources with hundreds of events

GRAND Technical Challenges

Autonomous trigger on radio signals

- To be proven!
  TREND: ~32% efficiency (https://doi.org/10.1016/j.astropartphys.2011.01.002)
- Due to the ultra-dominant noise, efficient criteria for background rejection are required
- The aim is to perform an identification of signals at various trigger levels
- It will allow for an optimization of data collection

Reconstruction of primary particle parameters

- good performances for vertical air-showers
- no-man's land for inclined air-showers

Develop new "conventional" and machine learning methods

Challenges related to giant arrays

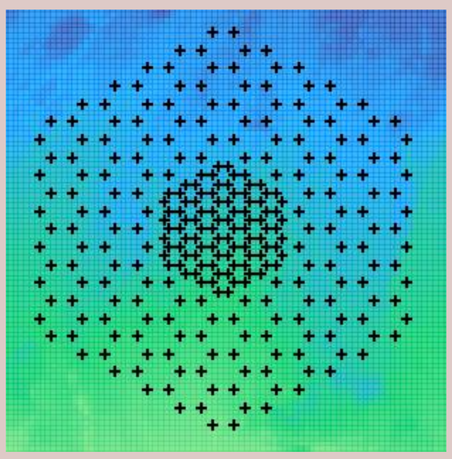
How to deploy and run 200,000 units over 200,000km²?
How much will it cost? Who will pay for it?

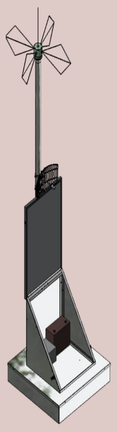
Need for an experimental setup to test and optimize GRAND Proto300

go for INDUSTRIAL approach!
- low failure rates
- Antennas will be deployed on electric poles like structures
Answers to be studied at later stages

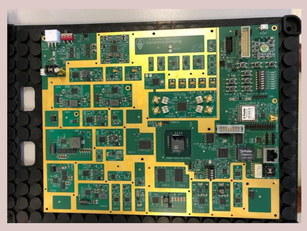
GRANDProto300

Antenna set-up:
Simulated design of an antenna.
Entering production phase.





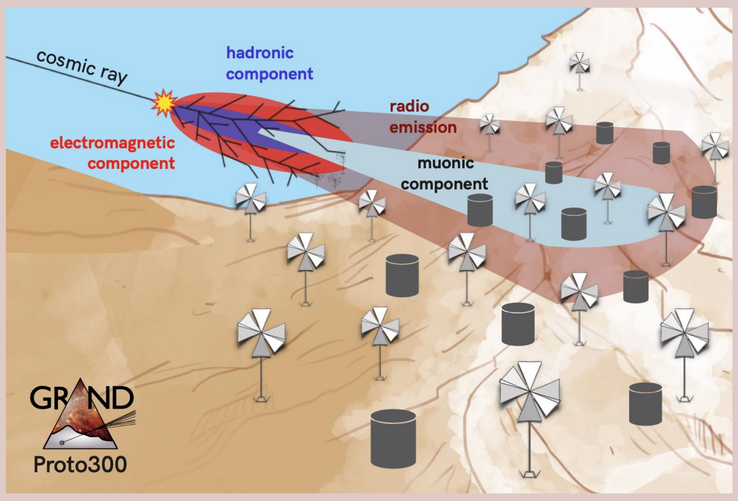
Electronics:
50-200MHz analog filtering,
500MSPS sampling
FPGA+CPU
Bullet WiFi data transfert



Preliminary layout of 300 antennas over 200km²:
1km step size with denser infiil
➔ Energy range for cosmic rays= $10^{16.5}$-10^{18}eV

Science case: Independent detection of the particle content and of the electromagnetic emission:

- Allow for a study of the muon content in air showers
- Efficient discrimination between gamma and cosmic-ray induced air-showers



GRAND 10K

GOALS
- First GRAND sub-array, **sensitivity comparable to ARA/ ARIANNA on similar time scale,** allowing potential 1st discovery of cosmogenic neutrinos
- Efficient communication and power supply between autonomous units spread over 10 000 km²

SETUP
- Data acquisition system with discrete elements, but mature design for trigger, data transfer, consumption

BUDGET & STAGE
- 1500€ per detection unit

2020 — 2025 — 2035

GRAND PROTO300

GOALS
- Standalone radio detection of **inclined showers** (zenith angle >65°) induced by high energy cosmic rays (>$10^{16.5}$ eV)
- Probing the transition between Galactic to extra-galactic cosmic rays at energy ~10^{18} eV, with detailed composition measurements
- Understanding the physics of air-showers in the $10^{16.5}$-10^{18} eV energy range with independent measurements of their electromagnetic and muon contents

SETUP
- 300 Horizon Antennas over 200 km²
- Fast data acquisition system
- Solar panels (24/7) + WiFi data transfer
- Array of surface muon detectors

BUDGET & STAGE
- 1.3 M€ for radio only, funded by Chinese Institutes

GRAND 200K

GOALS
- **Discover neutrinos of 10^{18} eV and neutrino astronomy**
- Selection of optimal sites (mountainous, accessible, radio-quiet) worldwide for deployment of 10 000 km² hotspots

SETUP
- 200 000 antennas over 200 000 km²
- ~20 x 10 000 km² hotspots worldwide

BUDGET & STAGE
Industrial scale allows to cut costs down: 500€ per unit (150M€ in total)

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