GRAND: Giant Radio Array for Neutrino Detection

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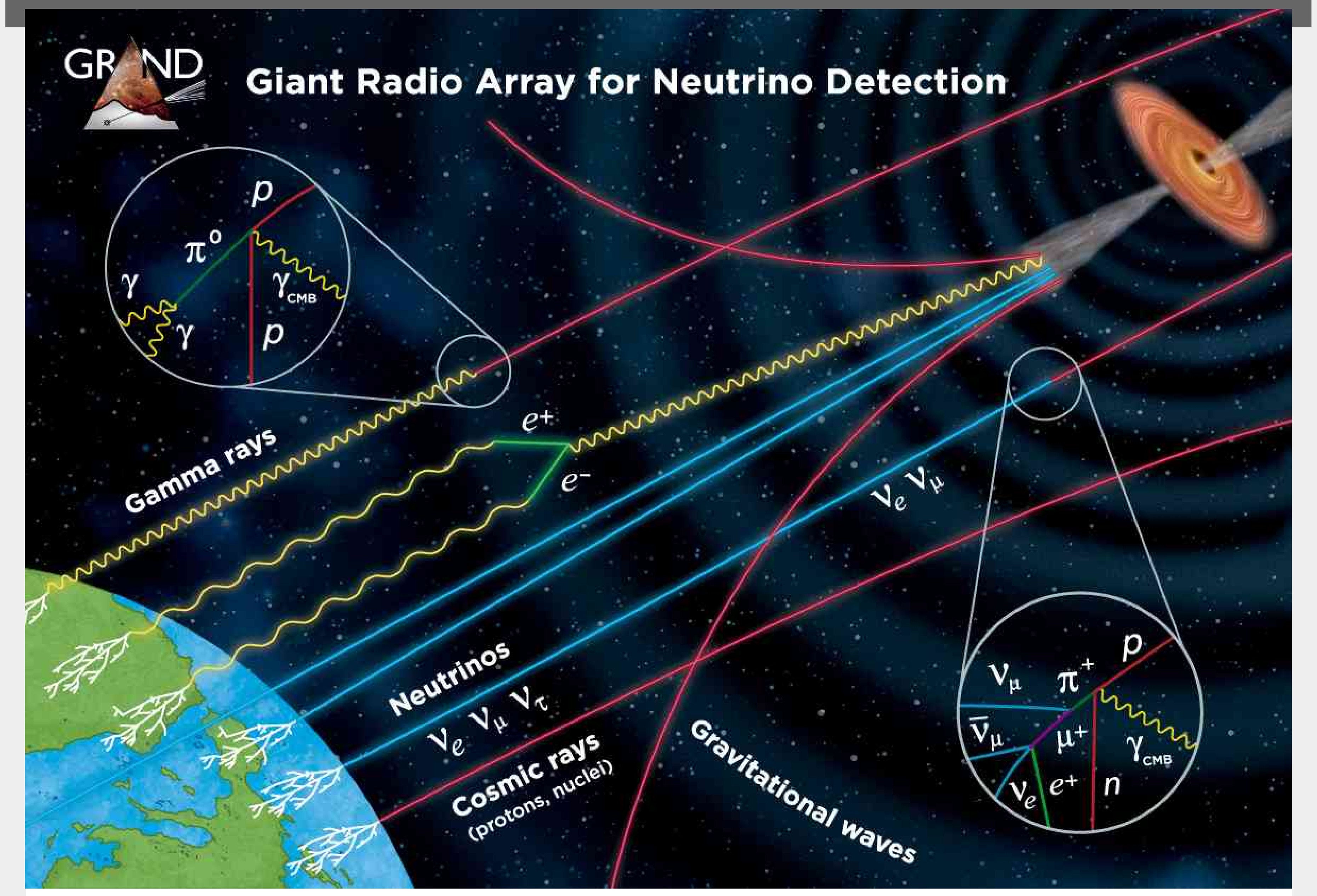
At a glance

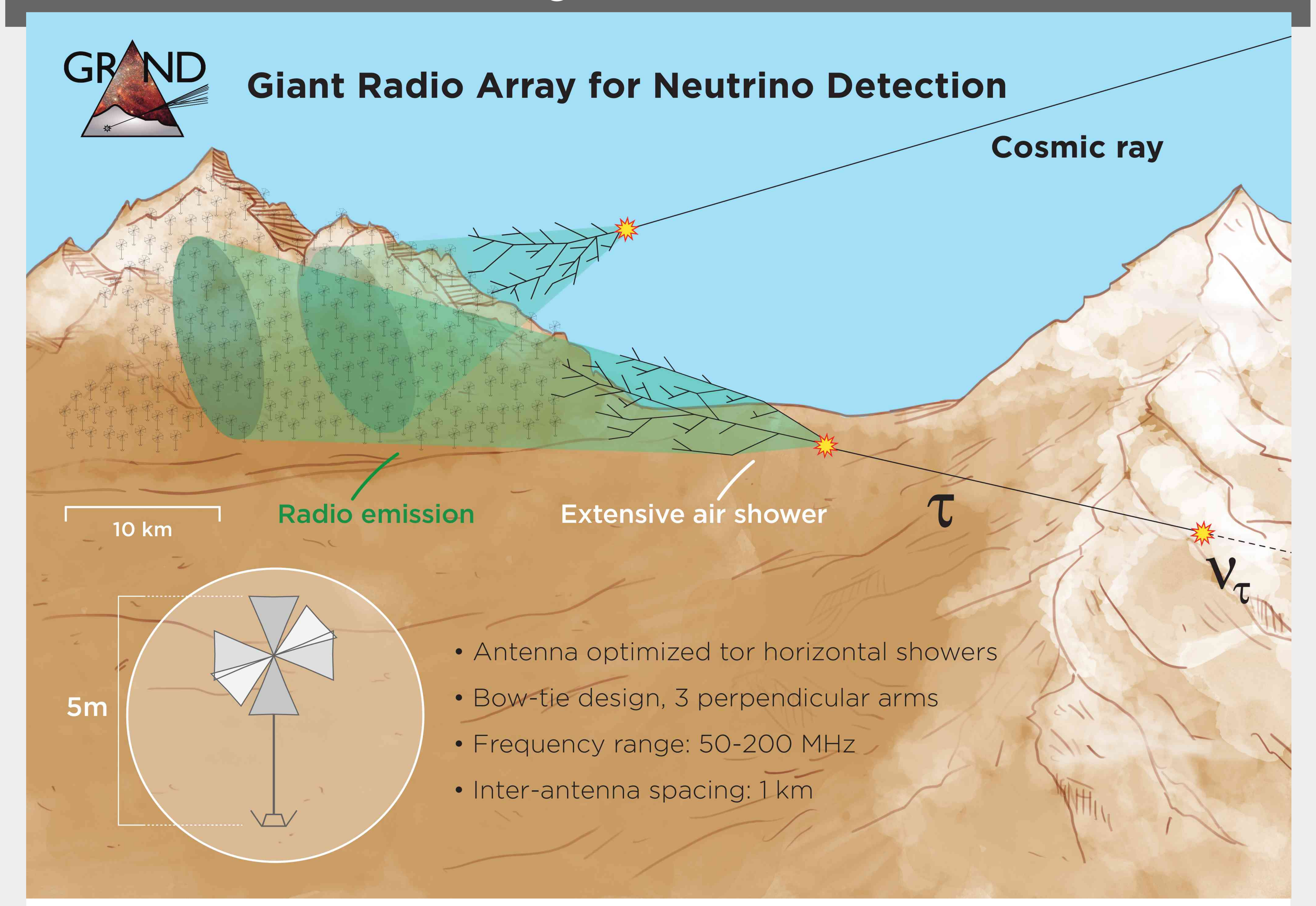
- **Goal:** Discover sources of ultra-high-energy (UHE) cosmic rays (CRs) by
  1 — Reaching 10–100 better sensitivity to UHE neutrinos (> 10^8 GeV)
  2 — Improving × 20 UHECR statistics (> 10^{10} GeV)
- **Strategy:** Detect radio emission from extensive air showers triggered by UHE neutrinos and CRs using arrays of 10k–200k simple antennas
- Can discover cosmogenic neutrinos even if their flux is very low
- **Status:** First prototype antenna array under deployment

Cosmogenic neutrinos: The next frontier



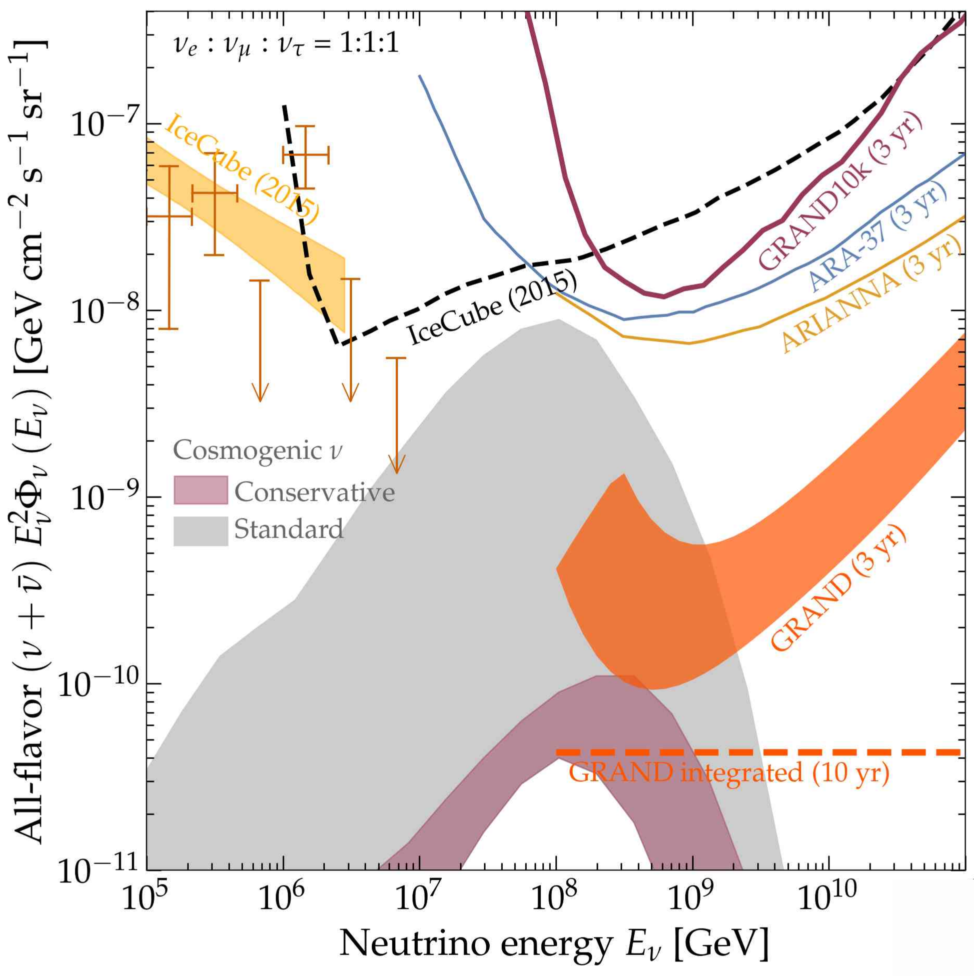
- UHECRs (> 10^{10} GeV) interact with cosmic photon backgrounds to make UHE *cosmogenic* neutrinos (> 10^8 GeV), still undiscovered
- Cosmogenic neutrinos uniquely reveal information about the most energetic UHECRs, which themselves are suppressed during propagation
- UHE neutrinos can also be made in the sources → UHE ν astronomy

Radio-detecting extensive air showers



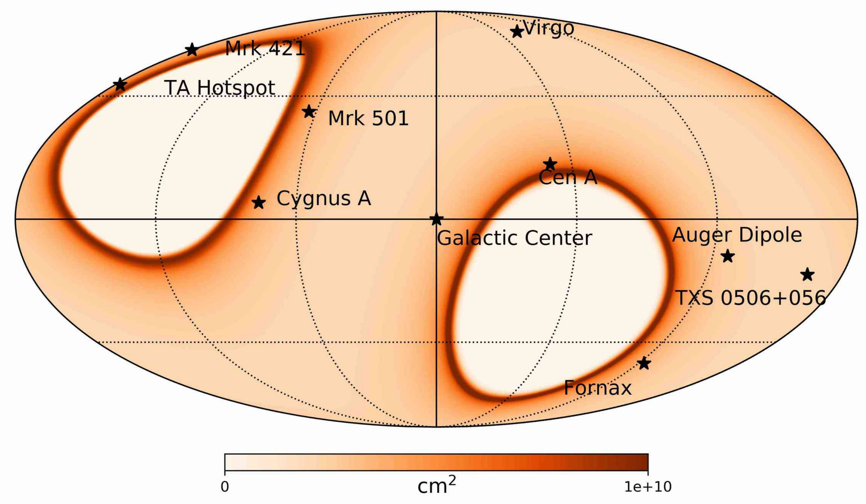
- Earth-skimming ν_τ interactions underground make horizontal showers
- UHECR interactions in the atmosphere make less inclined showers
- Radio emission is due to Earth's magnetic field acting on moving charges
- Radio-detection is mature, relatively affordable, scalable

Ultra-high-energy neutrinos



- Sensitive to ν in 85° < θ_z < 95°
- Cosmogenic ν flux is uncertain due to UHECR unknowns:
  - Mass composition
  - Injected spectrum
  - Source redshift evolution
- GRAND can discover even conservative fluxes
- **Event rates:** 1–50 ν yr^{-1} (*vs.* 0.6–2 in ARA/ARIANNA)

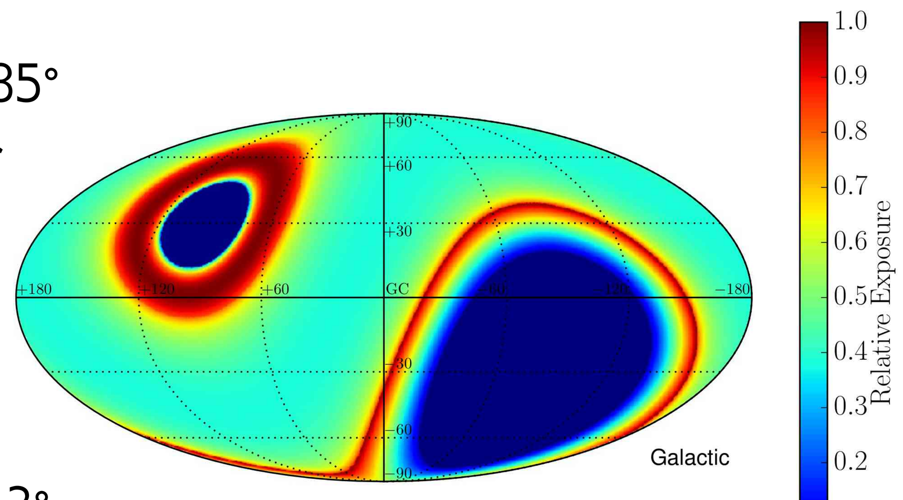
- **Angular resolution:** 0.05°
  → Allows for UHE ν astronomy
- **Steady-state point sources:** Discovery possible within 3 yr
- **Transient point sources:** 80% of sky monitored every day



3-yr exposure, > 3 × 10^9 GeV

Ultra-high-energy cosmic rays

- Sensitive to UHECRs in 65° < θ_z < 85°
- **Exposure:** 5 × 10^5 km^2 sr yr in 5 yr (10× 9-yr Auger exposure)
- **Event rates:** 6,400 evts yr^{-1} above $10^{10.5}$ GeV (*vs.* 320 in Auger)
- From its planned location, GRAND will sweep declinations -43° < δ < 63°



3-yr exposure, > 10^{10} GeV

Design and construction plans

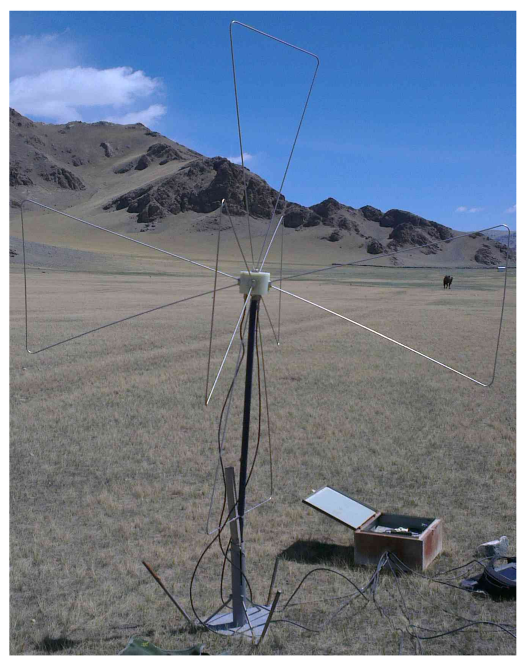
- First-generation antenna and DAQ built
- Custom end-to-end simulation chain developed

- **GRANDProto35 (funded, under deployment):**
  - 35 antennas, 2 km^2 in radio-quiet site in China
  - Test of antenna, electronics, and background
  - Cross-check using co-located particle detectors

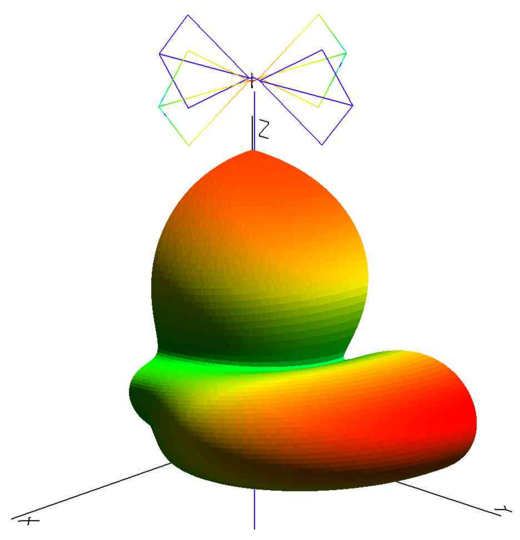
- **GRANDProto300 (2020):**
  - 300 antennas, 200 km^2, site under prospection
  - First UHECR physics + simulation calibration

- **GRAND10k (2025):**
  - 10,000 antennas, 10,000 km^2
  - Matches projected ARA/ARIANNA sensitivity

- **GRAND200k (203x):**
  - 200,000 antennas, 200,000 km^2
  - Discovery of even low flux of cosmogenic ν



GRANDProto35 antenna



Antenna pattern at 50 MHz

More information: grand.cnrs.fr

Conclusions

By instrumenting a large area with well-tested radio technology, GRAND is the affordable, scalable way to thoroughly search for the sources of the most energetic UHECRs directly — by detecting cosmic rays — and indirectly — by discovering UHE neutrinos

Selected references

The Giant Radio Array for Neutrino Detection (GRAND), Ke Fang for the GRAND Collab., PoS ICRC2017, 996 (2018) [1708.05128] • *The GRANDProto35 Experiment*, Quanbu Gou, PoS ICRC2017, 388 (2018) • *Cosmogenic Photon and Neutrino Fluxes in the Auger Era*, Rafael Alves et al. [1806.10879] • *Radio Detection of Cosmic-Ray Air Showers and High-Energy Neutrinos*, Frank Schröder, Prog. Part. Nucl. Phys. 93, 1 (2017) [1607.08781]

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