the giant radio array for neutrino detection (GRAND)

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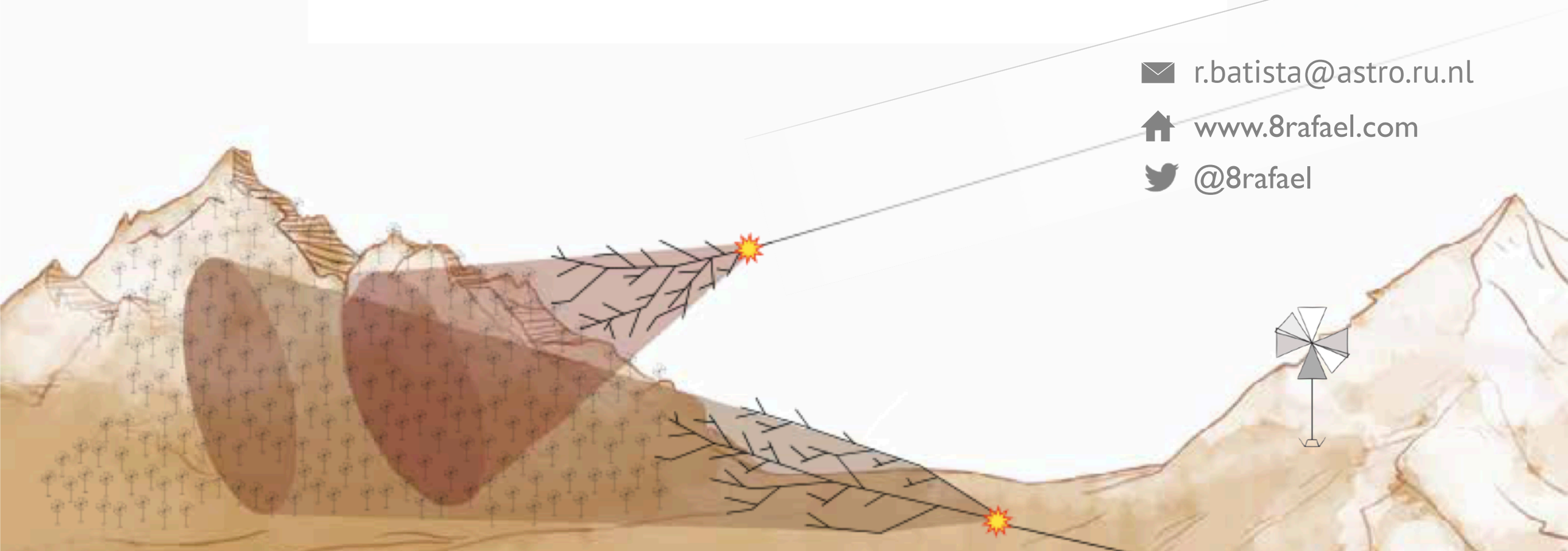
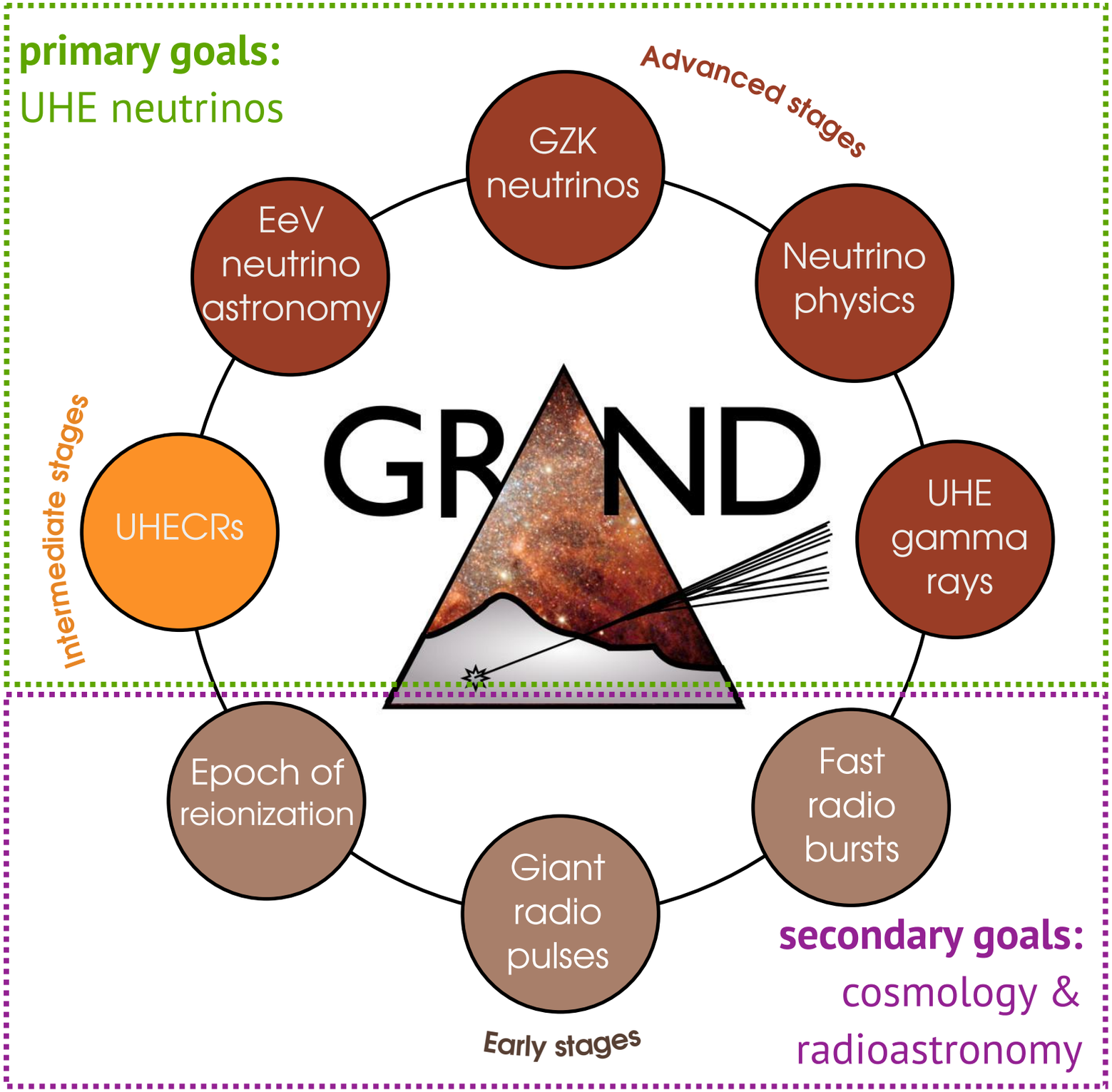
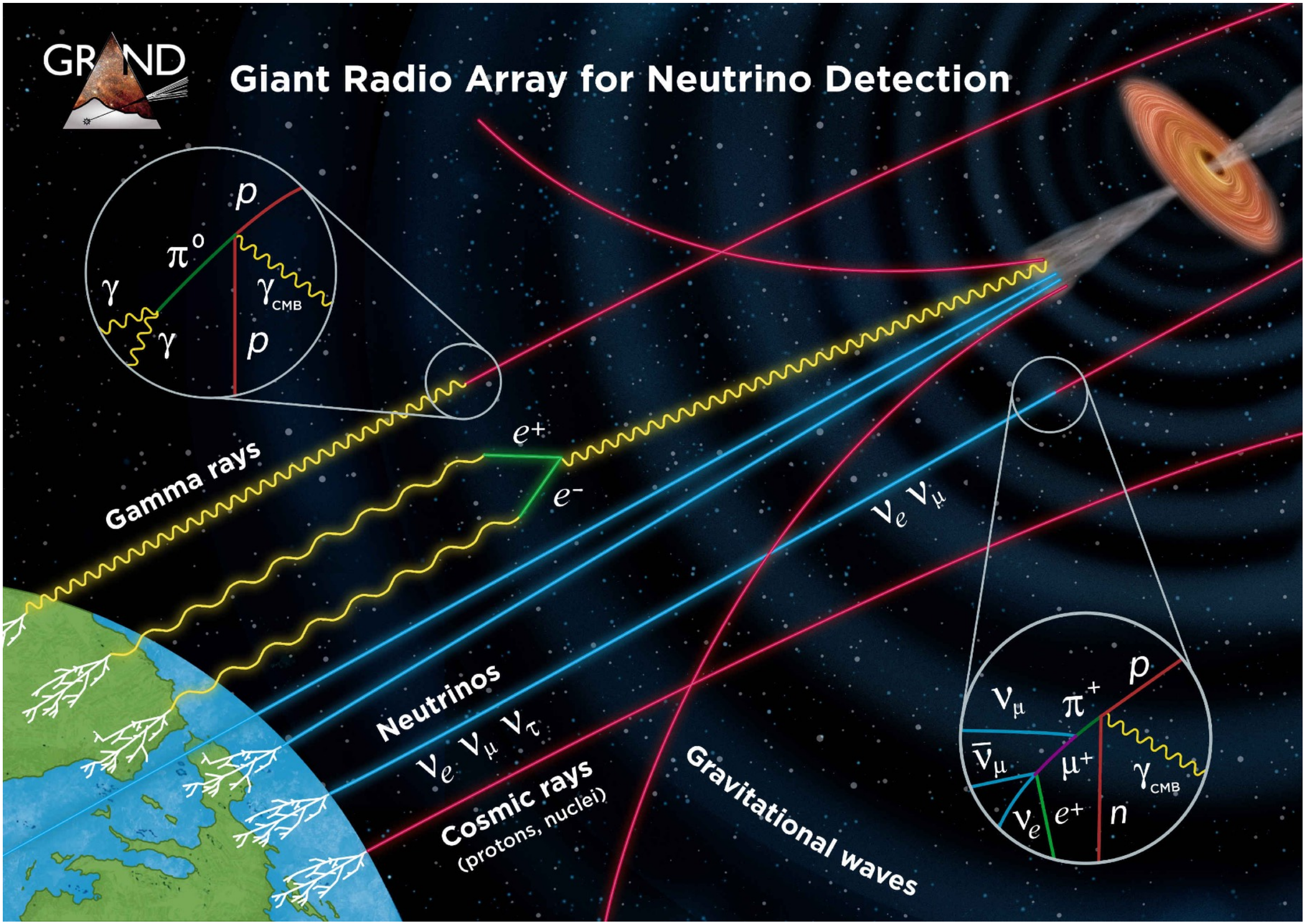



primary goals:
UHE neutrinos
Advanced stages
GZK neutrinos
EeV neutrino astronomy
Neutrino physics
Intermediate stages
UHECRs
GRAND
UHE gamma rays
Epoch of reionization
Giant radio pulses
Fast radio bursts
Early stages
secondary goals:
cosmology & radioastronomy

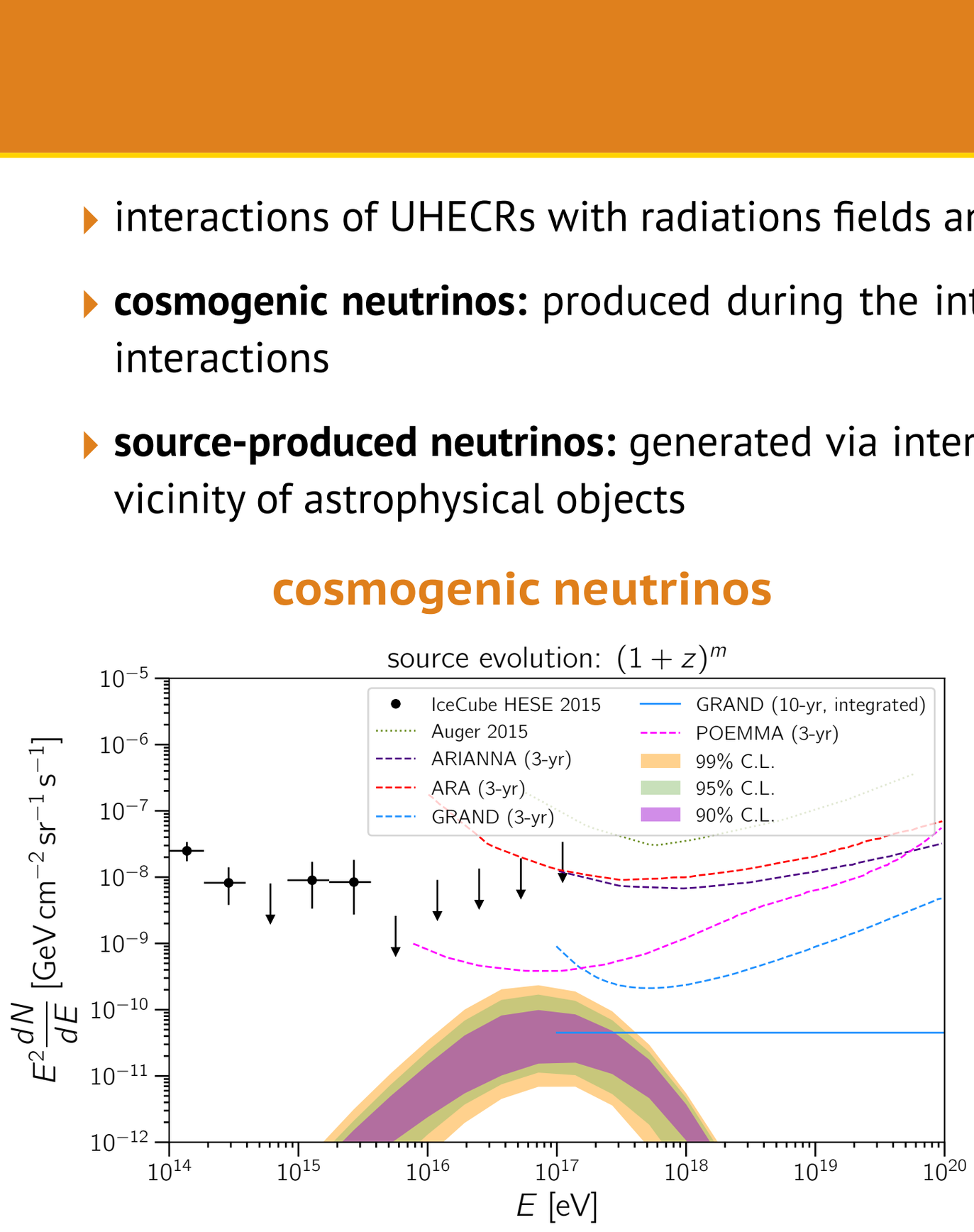
a multi-messenger glimpse into the high-energy universe



science case: UHE particles

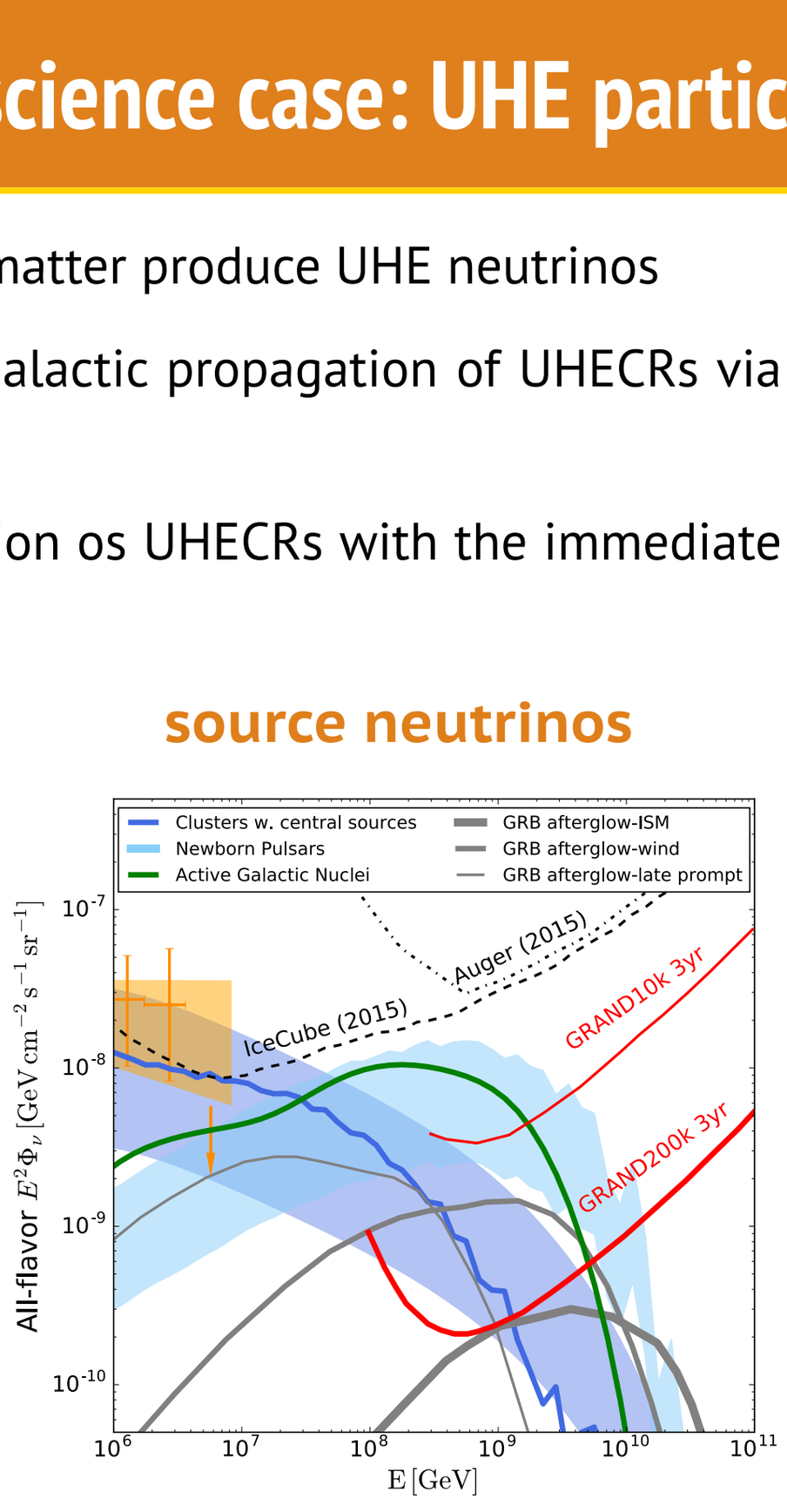
- interactions of UHECRs with radiations fields and matter produce UHE neutrinos
- **cosmogenic neutrinos:** produced during the intergalactic propagation of UHECRs via interactions
- **source-produced neutrinos:** generated via interaction os UHECRs with the immediate vicinity of astrophysical objects

cosmogenic neutrinos



Alves Batista, de Almeida, Lago, Kotera. JCAP 01 (2019) 002. arXiv:1806.10879

source neutrinos



Alves Batista et al. Front. Astron. Space. Sci. 6 (2019) 23. arXiv:1903.06714

Giant Radio Array for Neutrino Detection

Cosmic ray

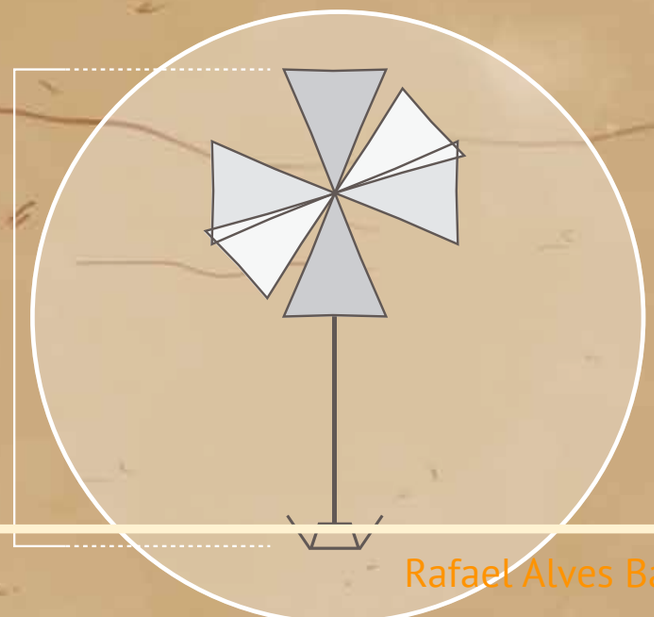
10 km

Radio emission

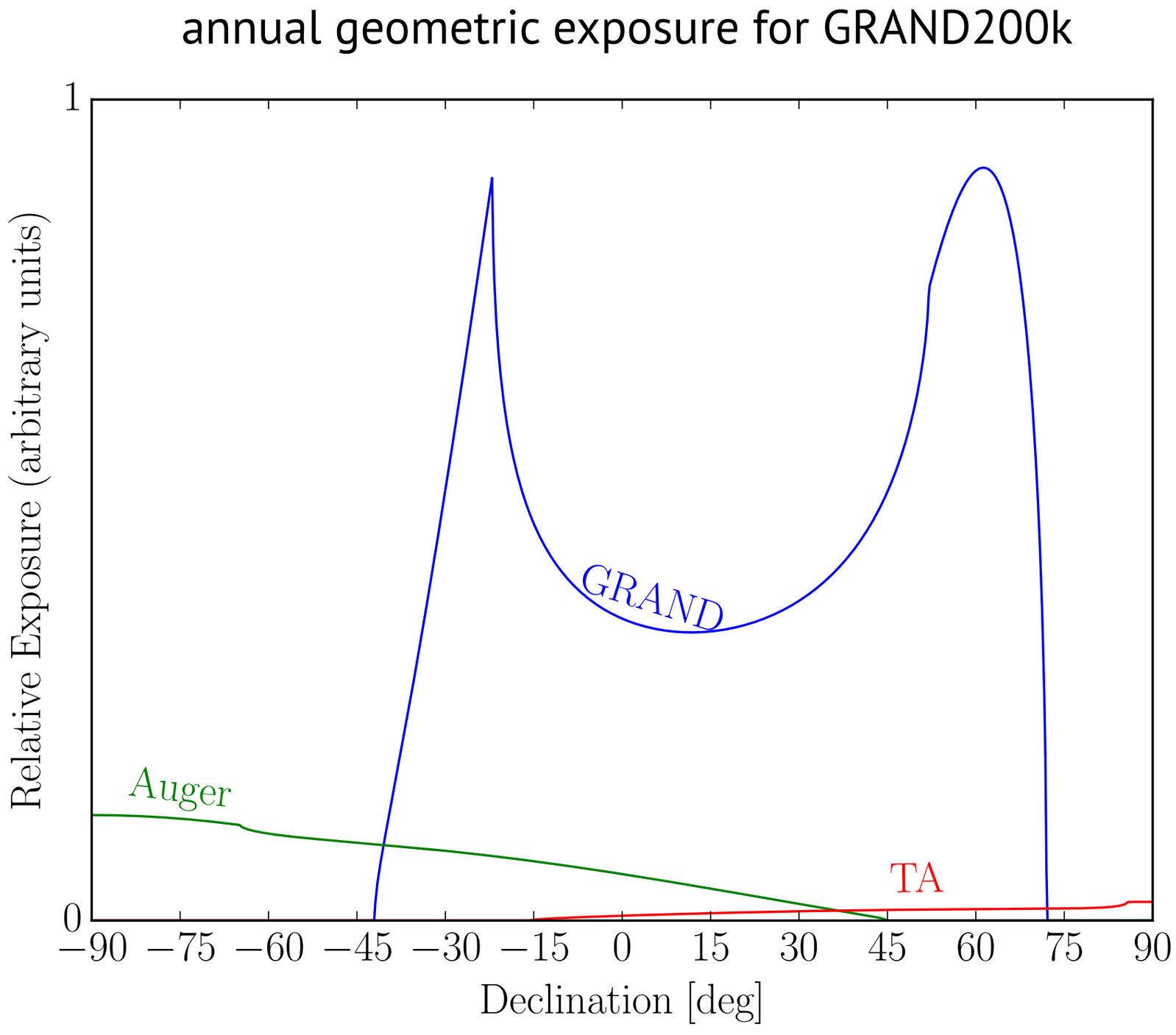
Extensive air shower

τ

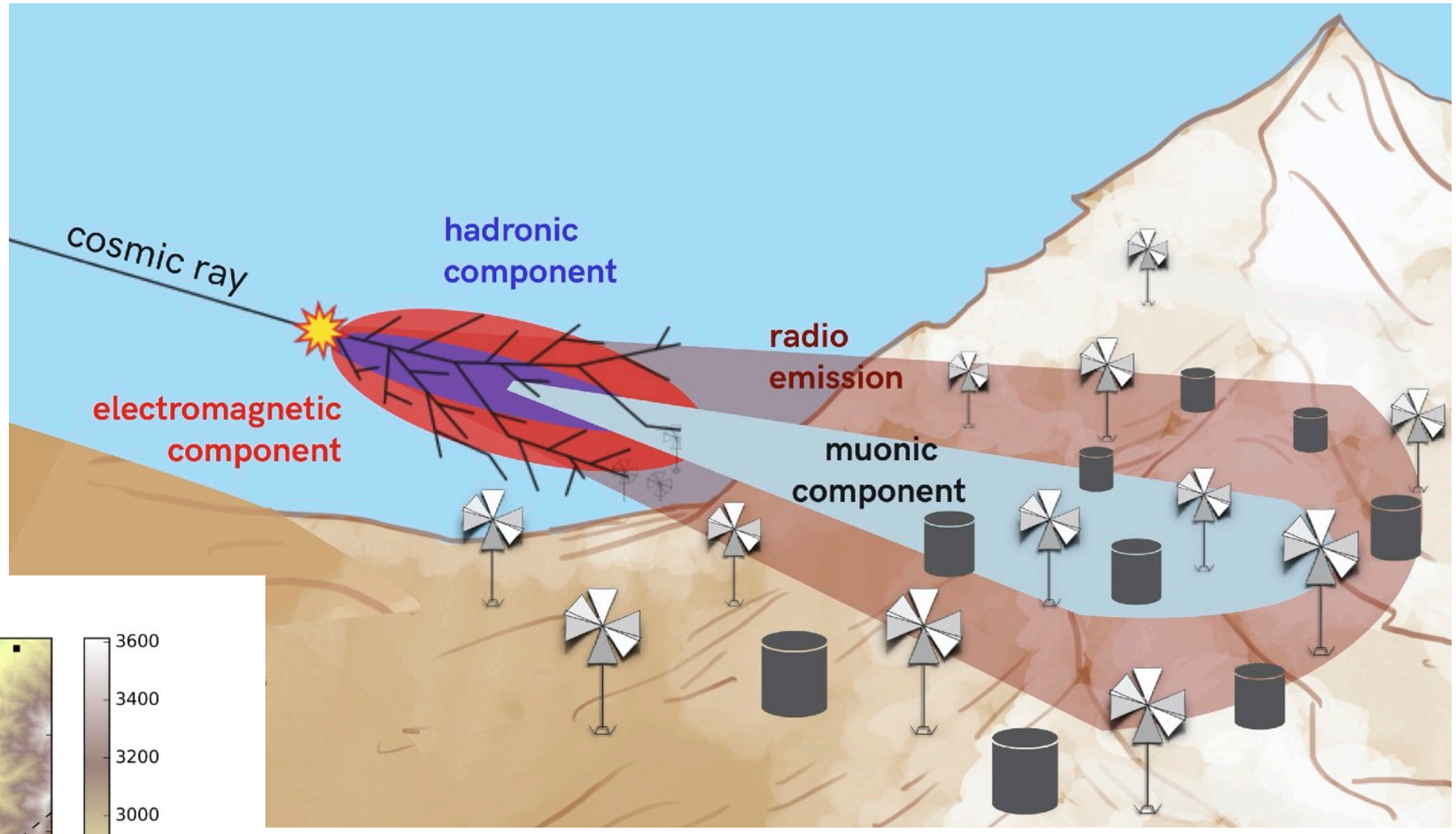
ν_τ

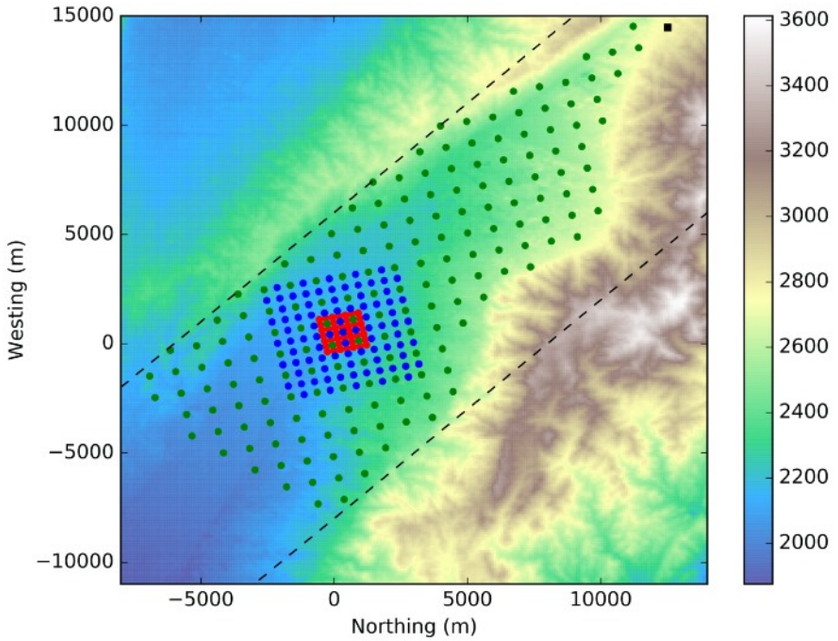


- Antenna optimized tor horizontal showers
- Bow-tie design, 3 perpendicular arms
- Frequency range: 50-200 MHz
- Inter-antenna spacing: 1 km

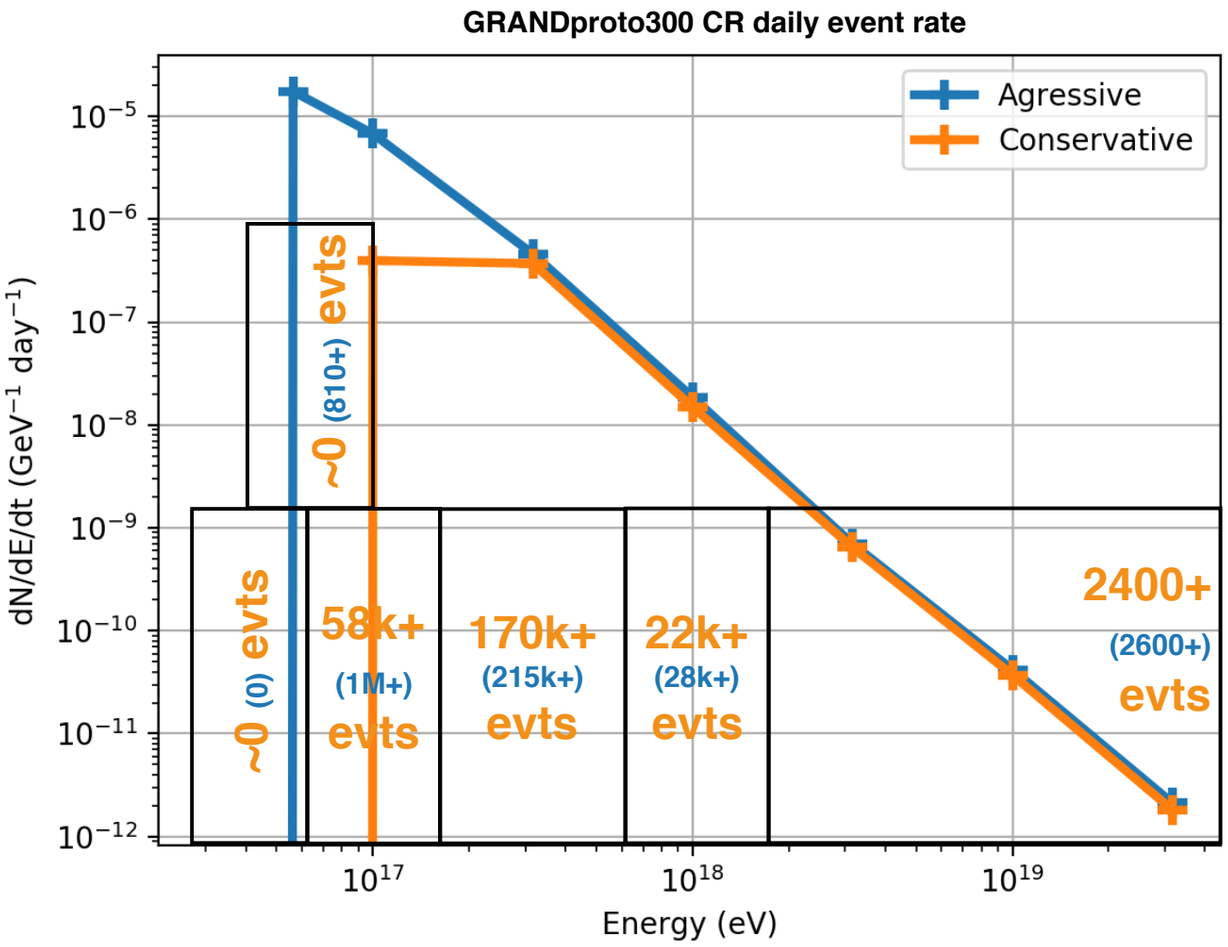

annual geometric exposure for GRAND200k
Relative Exposure (arbitrary units)
1
0
GRAND
Auger
TA
−90 −75 −60 −45 −30 −15 0 15 30 45 60 75 90
Declination [deg]

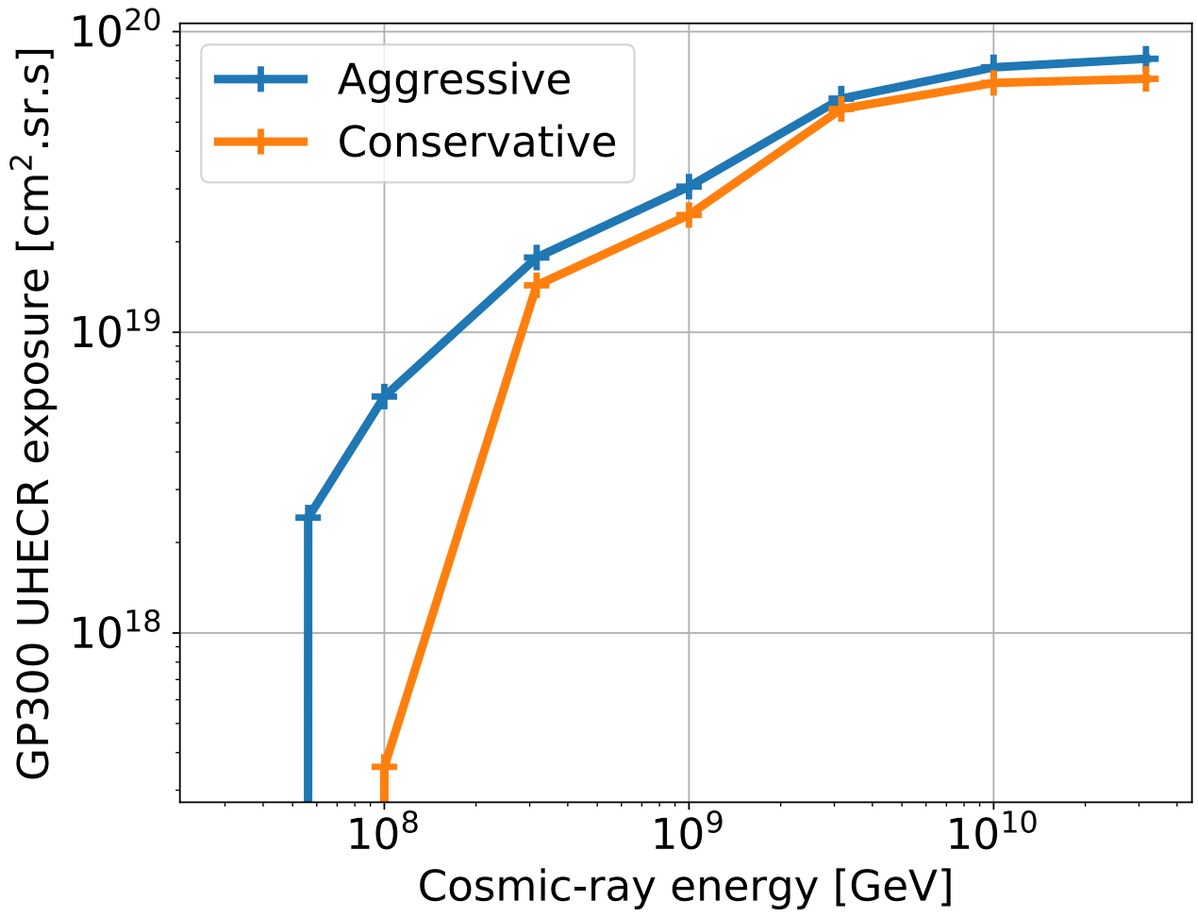
GRANDProto300





- 300 detection units (radio antennas + surface detectors) over ~200 km^2 with denser infill array
- prospective site: QingHai province, China
- transition between galactic and extragalactic cosmic rays
- muon content of showers at E~$10^{16.5}$ -10^{18} eV
- cosmology: epoch of reionisation





- transition between galactic and extragalactic cosmic rays
- muon content of showers at E~$10^{16.5}$ -10^{18} eV
- cosmology: epoch of reionisation

fully funded

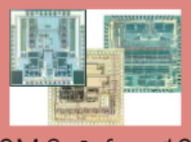
GRANDProto300

GRANDProto35

GRAND10k

GRAND200k

2018 | 2020 | 2025 | 203X

	2018	2020	2025	203X
Goals	standalone radio array: test efficiency & background rejection	standalone radio array of very inclined showers (θ_z>70°) from cosmic rays (>10^{18} eV) + ground array to do UHECR astro/hadronic physics	first GRAND subarray, sensitivity comparable to ARA/ARIANNA on similar time scale, allowing discovery of EeV neutrinos for optimistic fluxes	first neutrino detection at 10^{18} eV and/or neutrino astronomy!
Setup	35 radio antennas 21 scintillators 	• 300 HorizonAntennas over 300 km² • Fast DAQ (AERA+ GRANDproto35 analog stage) • Solar panels (day use) + WiFi data transfer • Ground array (à la HAWC/Auger)	DAQ with discrete elements, but mature design for trigger, data transfer, consumption	200,000 antennas over 200,000 km², ~ 20 hotspots of 10k antennas, possibly in different continents Industrial scale allows to cut down costs: 500€/unit ➔ 200M€ in total
Budget & stage	160k€, fully funded by NAOC+IHEP, deployment ongoing @ Ulastai	1.3 M€ to be deployed in 2020	1500€ / detection unit 	ASIC Cost ~10M€ ➔ few 10€/board Consomption < 1W Reliability 

outlook

- **GRAND200k:** ~20 arrays of ~10000 km^2 with all-sky coverage
- expected timeline for completion: 2030s
- radio detection: cheap and efficient way to detect air showers
- science cases: **ultra-high-energy cosmic particles,** fundamental neutrino physics, cosmology, and radioastronomy
- **GRANDProto300:** pathfinder for GRAND with a well-defined science case of its own
- GP300 will start taking data within the next couple of years
- **major technical challenge**: improve self-triggered detection rate