Olivier Martineau for the GRAND collaboration,
Townhall KM3NeT meeting (Marseille, December 19, 2019)

http://grand.cnrs.fr/

The **G**iant **R**adio **A**rray for **N**eutrino **D**etection
and the KM3NeT connexion

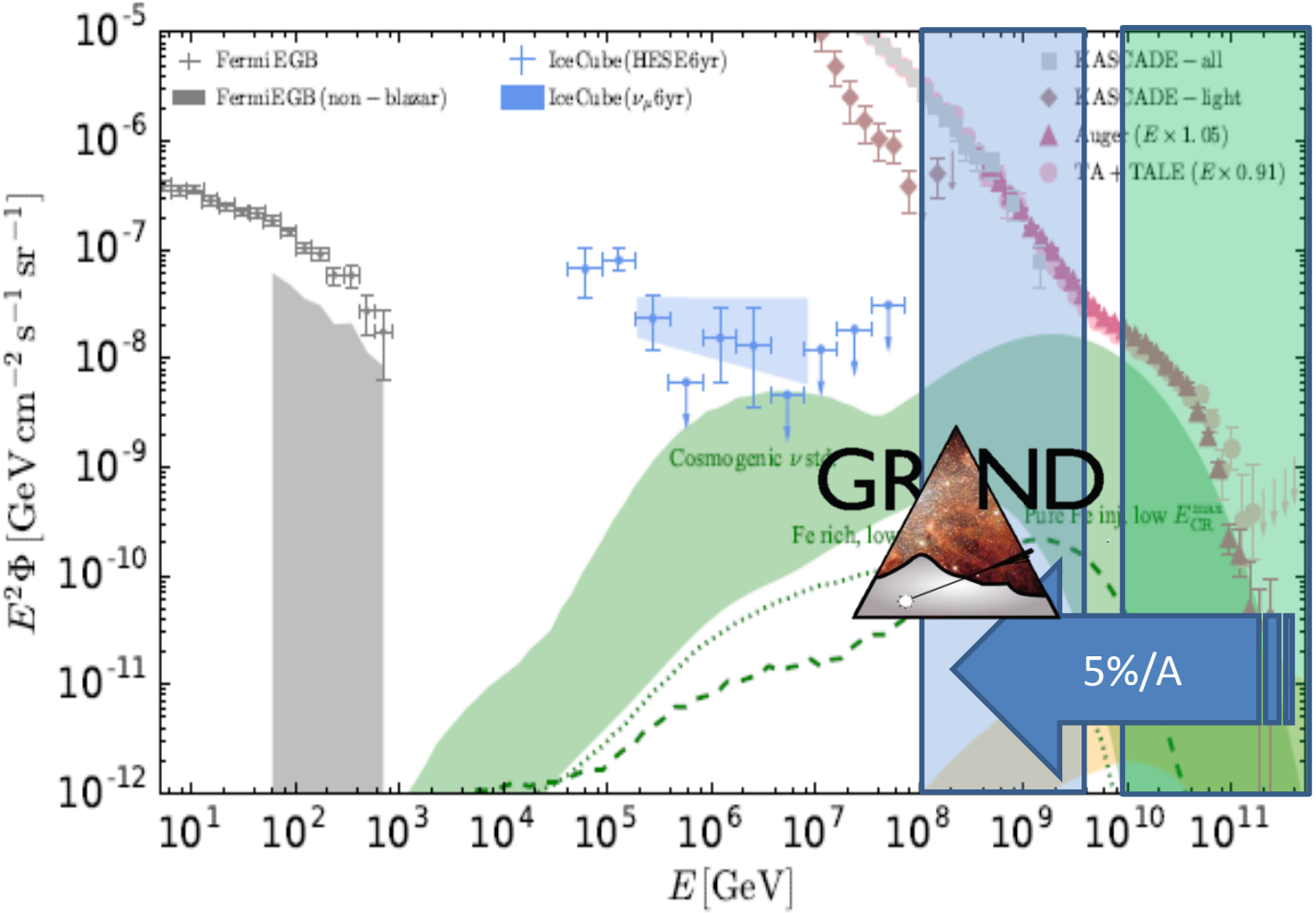
LengHu, QingHai province, China
Home of the GRANDProto300 experiment

Why UHE neutrinos?

- «Cleanest probe» of the Universe (no deflection, no attenuation, hadronic…).
- Direct link to UHECRs (5% of proton primary energy goes into cosmogenic neutrinos)
- Stretches detection reach to EeV range

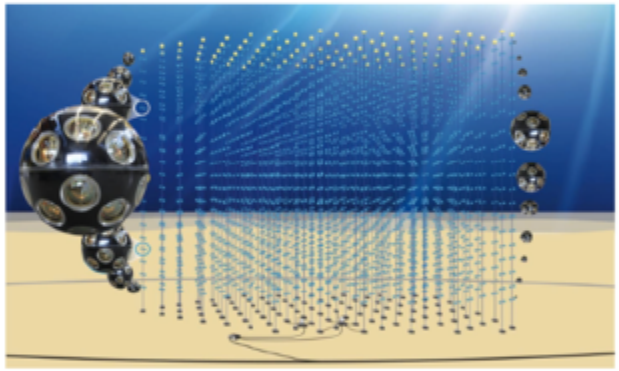
http://grand.cnrs.fr/

➔ **excellent combination with KM3NeT to constrain models.**



Future project overview

complementarity,
sensitivity to
neutrino sources
"precision frontier"



KM3NeT, GVD

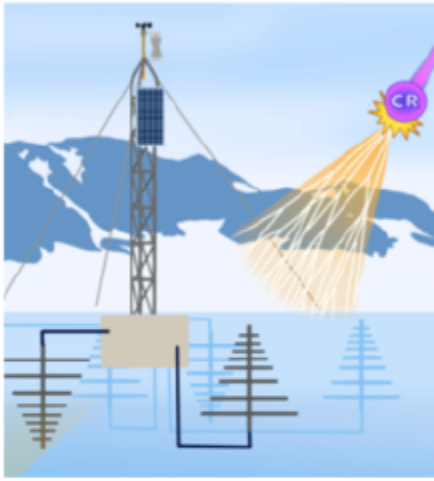
IceCube
SOUTH POLE NEUTRINO OBSERVATORY

ANTARES

PIERRE AUGER OBSERVATORY

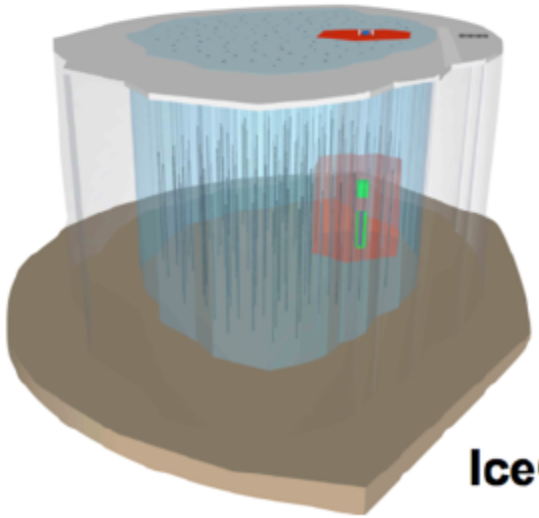
Present neutrino detectors

sensitivity at EeV
and beyond
"energy frontier"



**ARA, ARIANNA,
EVA, GRAND**

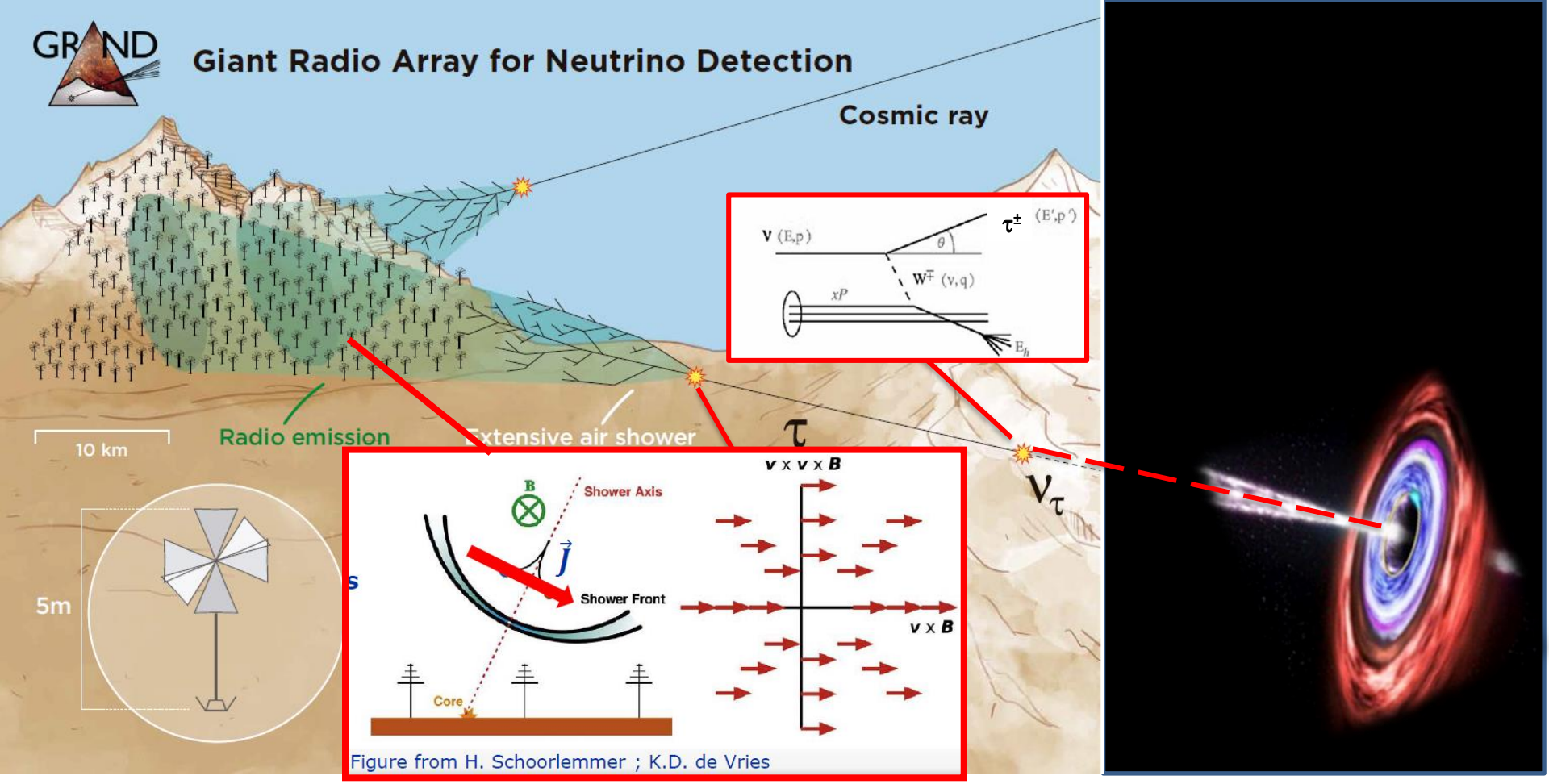
sensitivity at
PeV energies
"intensity frontier"



IceCube-Gen2

Kowalski@TeVPA2017

credit: M. Ackerman



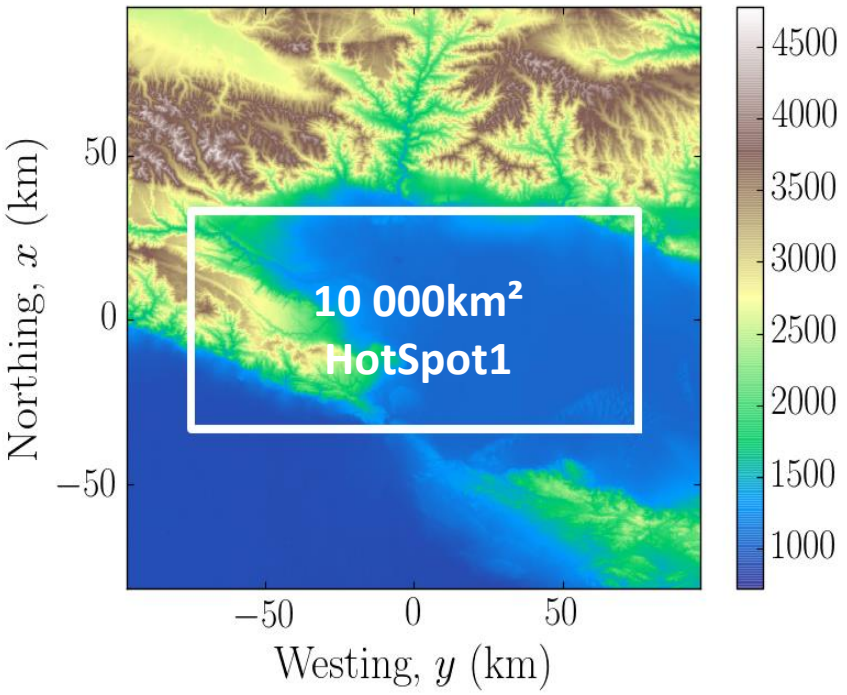
- Detection principle:
  - ν-induced tau decays in atmosphere generate ~horizontal extensive air showers [Fargion 9906450]
- Very indirect process ⇔ very unlikely ⊗ low flux ➔ need a **GIANT**$^{\mathbf{2}}$ detector.
- Earth opaque to neutrinos at these energies. The tau particle has to be produced less than ~100km from Earth surface in order to emerge ➔ short underground travels ➔ Earth-skimming trajectories.

➔ **Radio-detection**

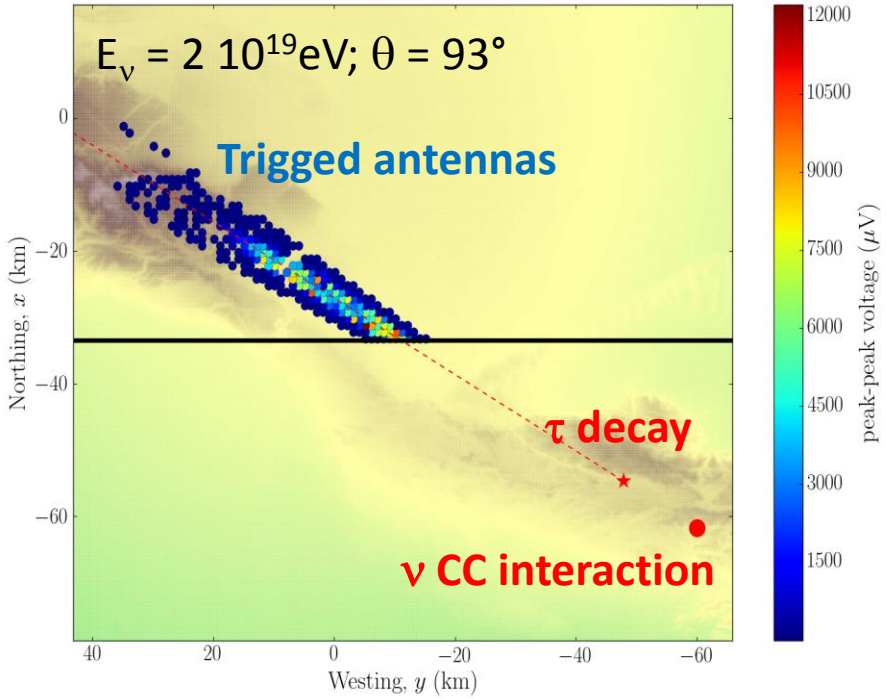
Radio detection of very inclined showers

The GRAND proposal

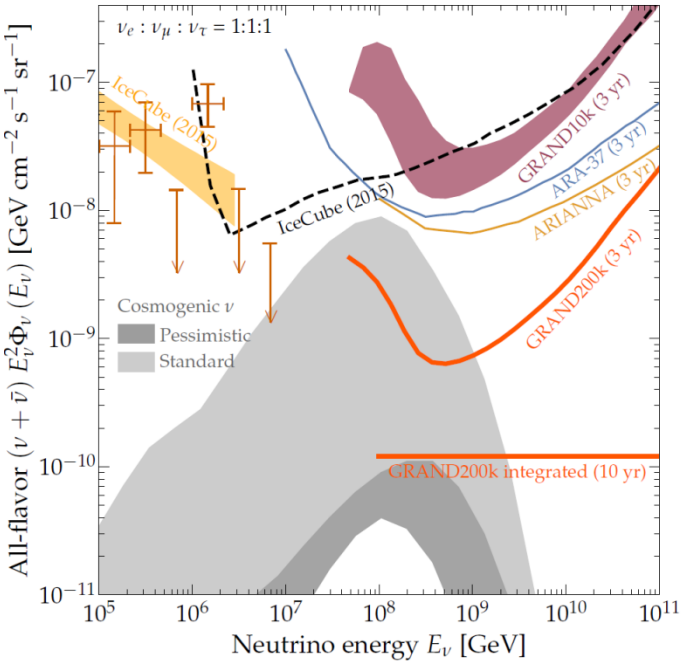
- Network of o(20) subarrays of o(10000) antennas with sparse density (1/km²) at various favorable locations around the world (« hotspots »)



A simulated neutrino event in a GRAND hotspot

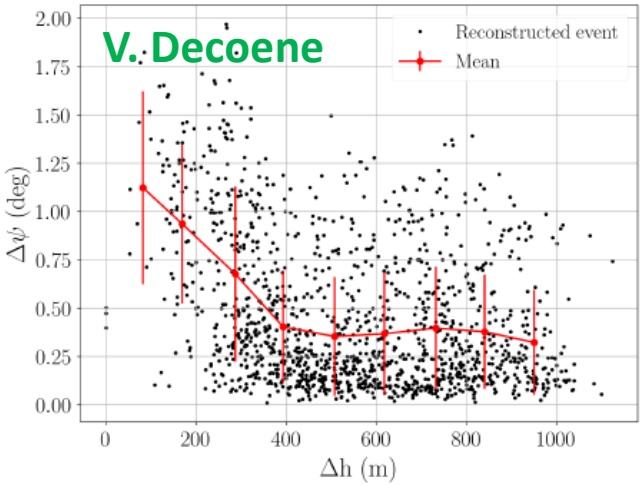


GRAND science case

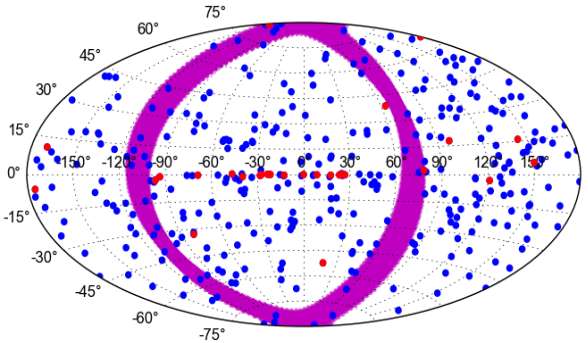


- GRAND10k (10'000 km²) in IceCube2015 range.
- **Aiming at ~20 such subarrays deployed on areas with favorable topography at different locations in the world ➔ GRAND200k (20x10 000 km²)**
- Sensitivity of full array good enough for GRAND to detect cosmogenic neutrinos for standard hypothesis

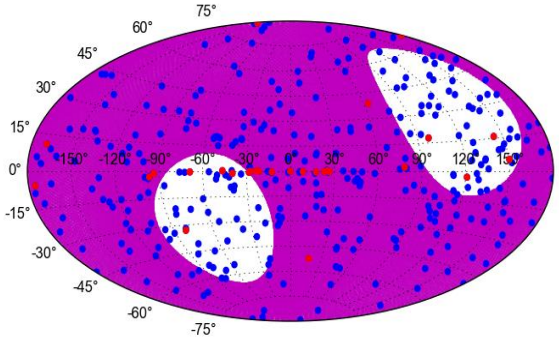
Also: <0.5° angular resolution expected thangs to topography & shower extension (in progress)



1h visibility (for <u>one subarray</u> @ 43°N)



24h visibility (for one subarray@ 43°N)

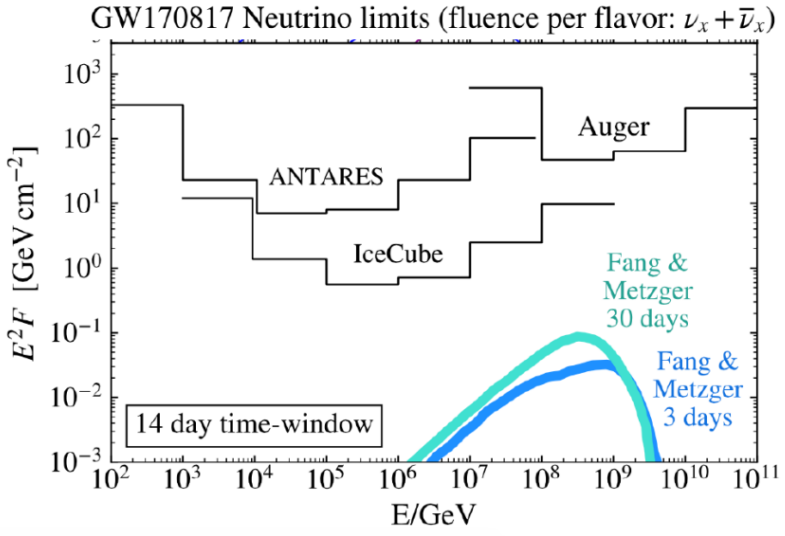


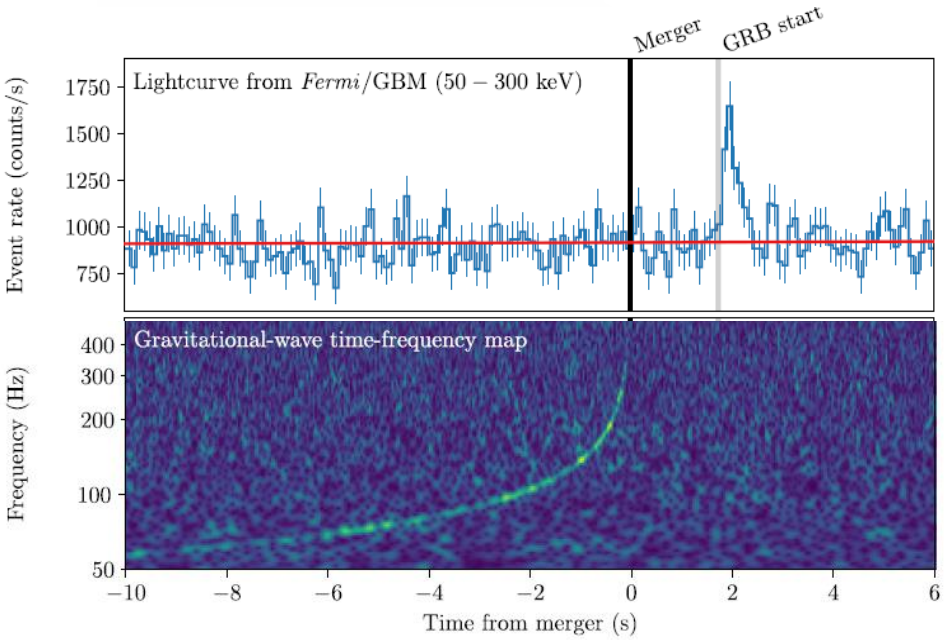
➔ ~ full sky coverage in 24h time window

GRAND & multimessenger, time-domain astronomy

- « Large » sky coverage
- Passive detector (ie no pointing)
- Hope for fast (~online) reconstruction

➔**Neutrino alerts achiveable within o(10)seconds?**





The road to GRAND

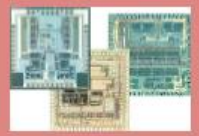
GRANDProto300

GRANDProto35

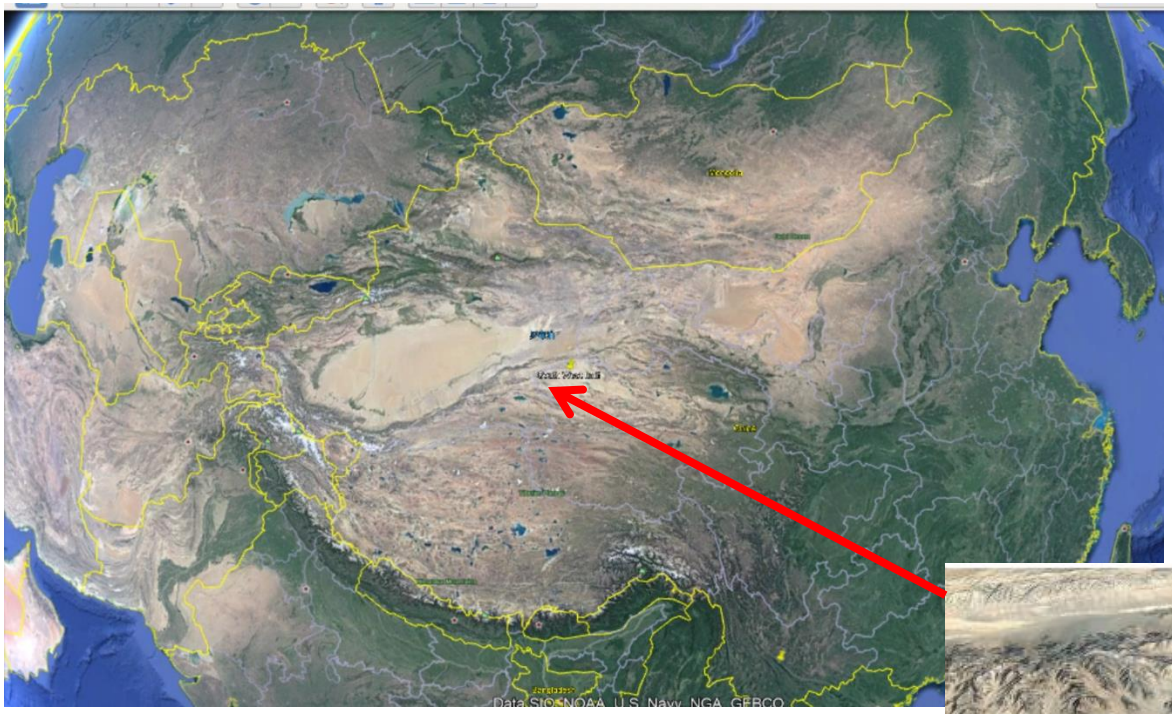
GRAND10k

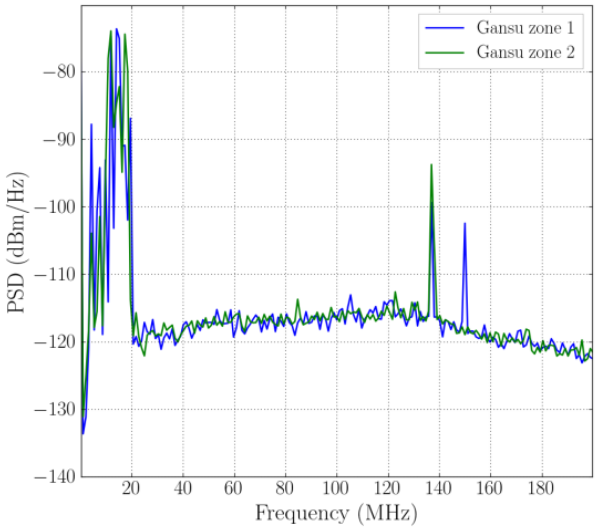
GRAND200k

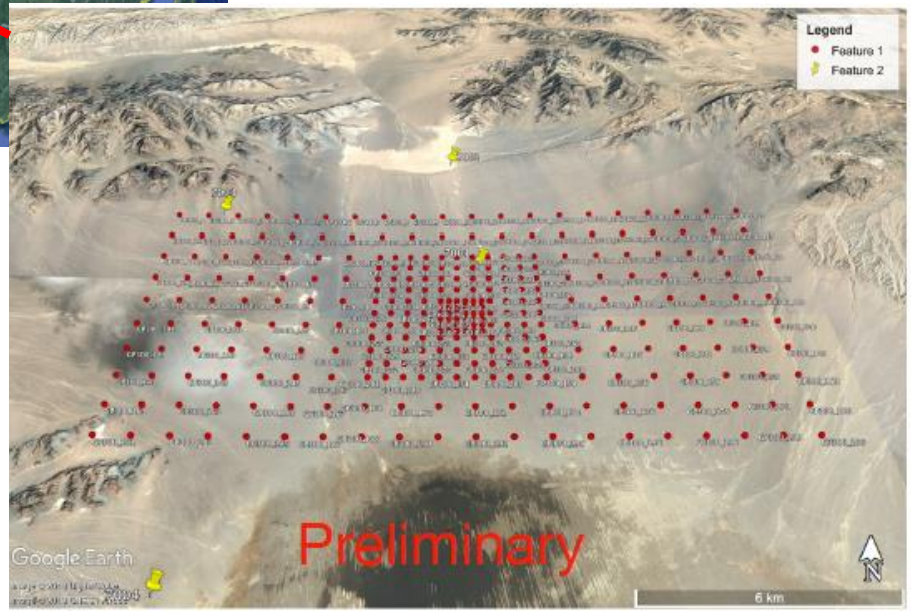
2018 | 2020 | 2025 | 203X

	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 (>$10^{16.5}$ 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 km^2 • 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 km^2, ~ 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

GRANDProto300

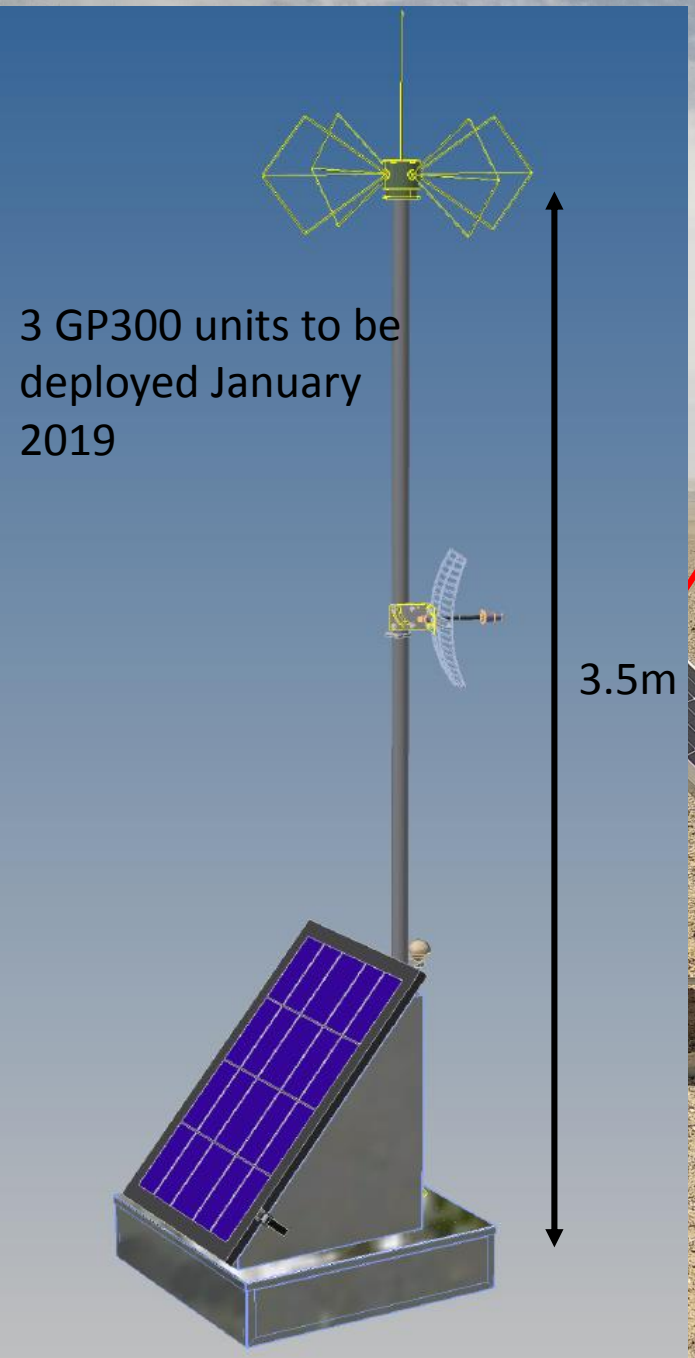




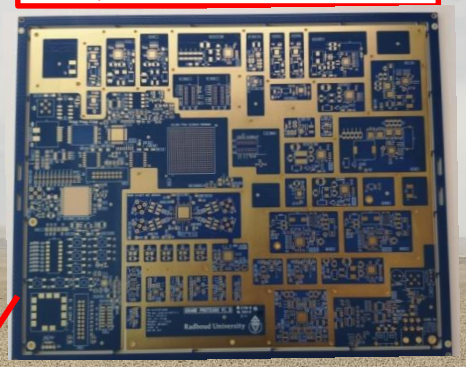


- Radio-quiet site
- At the crosspoint of Gobi desert & Tibetan Plateau
- 300 antenna with 3 layouts

  (1km-500m-150m steps)



GP300 *DAQ*
500MS/s ADC
FPGA
Quad-core CPUs



August 2019:
4 prototype antennas installed

Firsty physicist

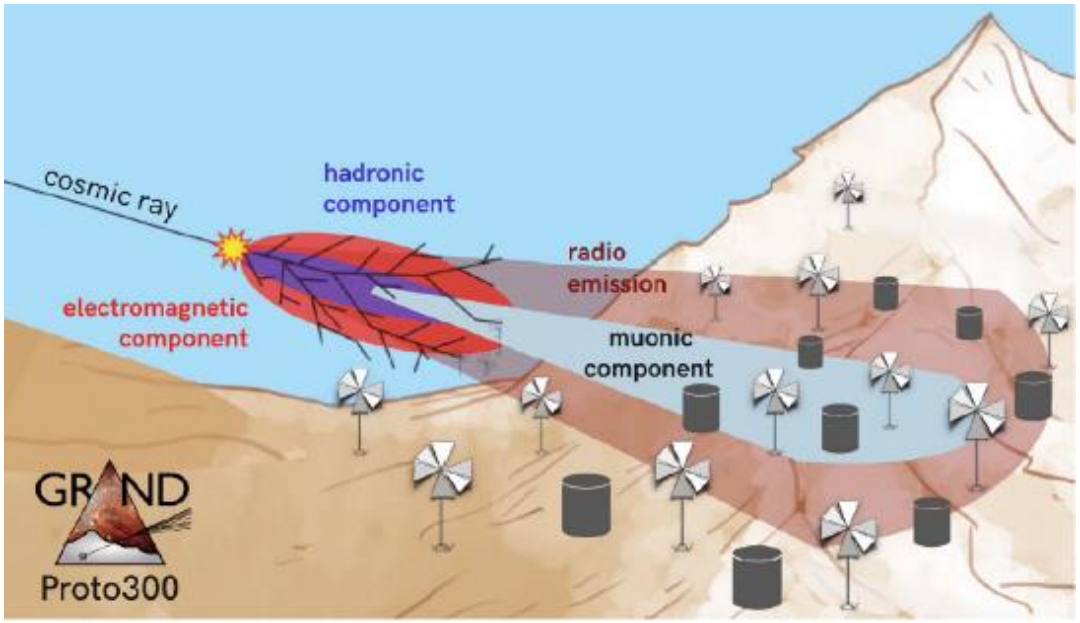
DAQ room

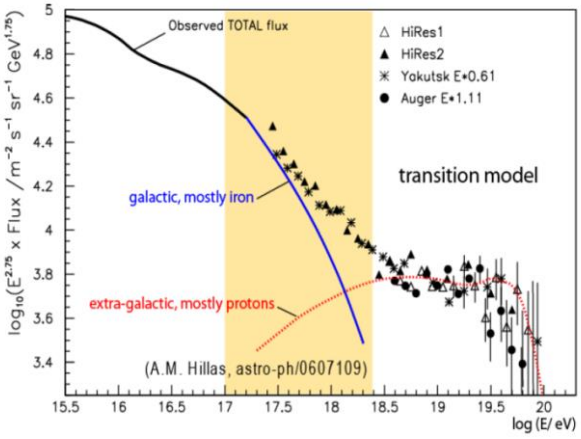
Receiving WiFi antenna (coms)

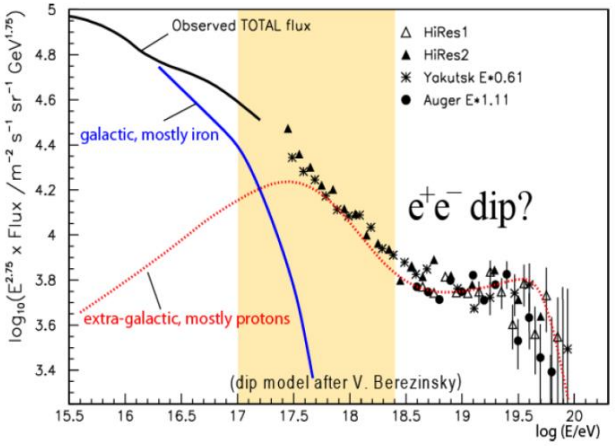
GRANDProto300 goals

- Demonstrate autonomous radiodetection of air showers
- Physics of air showers*
- Physics of CRs at the Gal-Extragal transition*

*: if radio array complemented with ground detector







The GRAND collaboration

MoU in preparation between

- IAP
- KIT
- Nanjing U.
- NAOC
- Penn State U.
- Radboud U. (Nijmegen)
- U. Federal Rio

Author list

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Take-away message

- GRA network of ra g a total of 20
- Sensi rgy range
  → eCube and an domain HE astr
- Grea very) long st stage.
- Dyna me ☺
- Read more at http://grand.cnrs.fr/