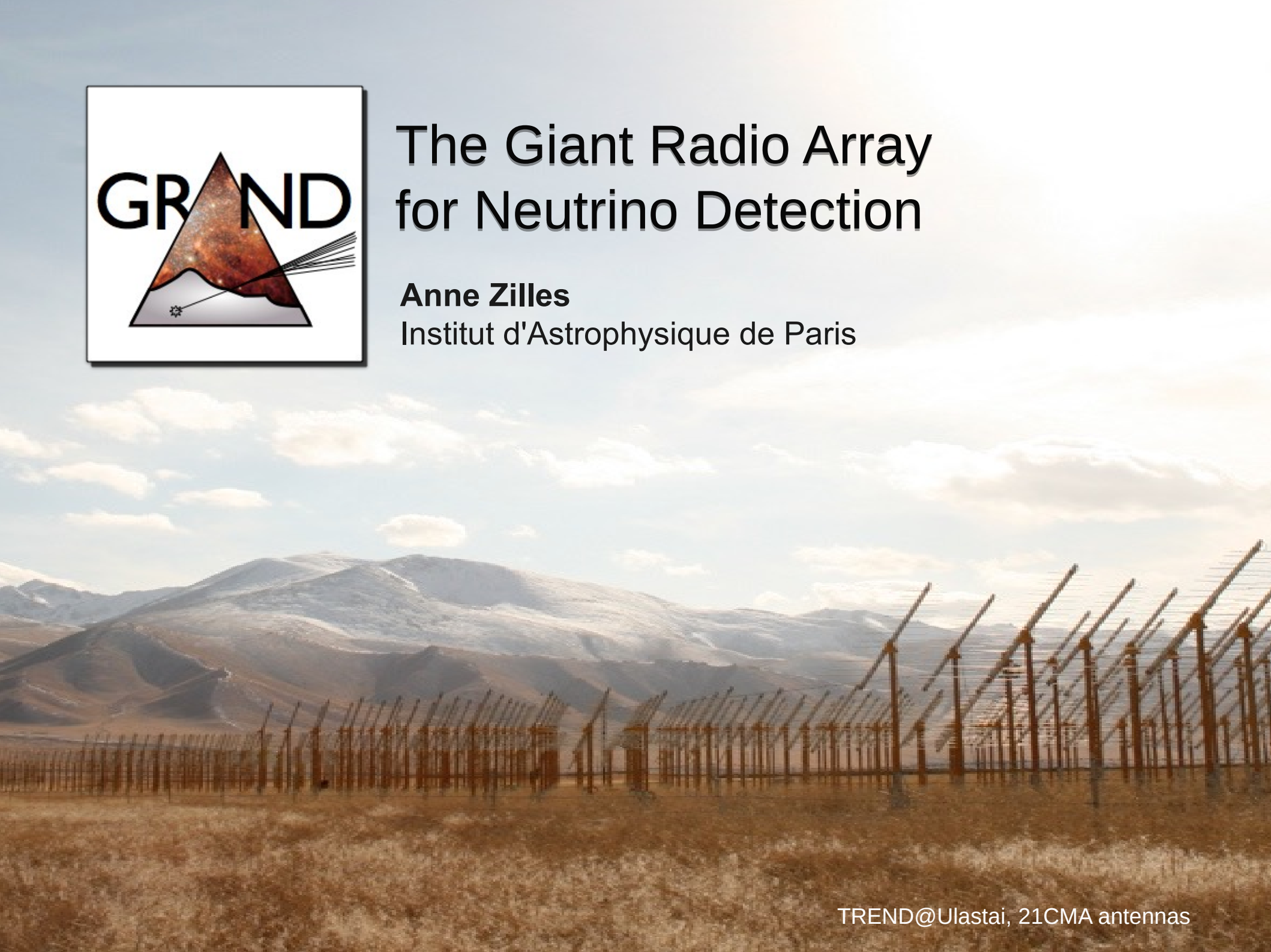


The Giant Radio Array for Neutrino Detection

Anne Zilles
Institut d'Astrophysique de Paris

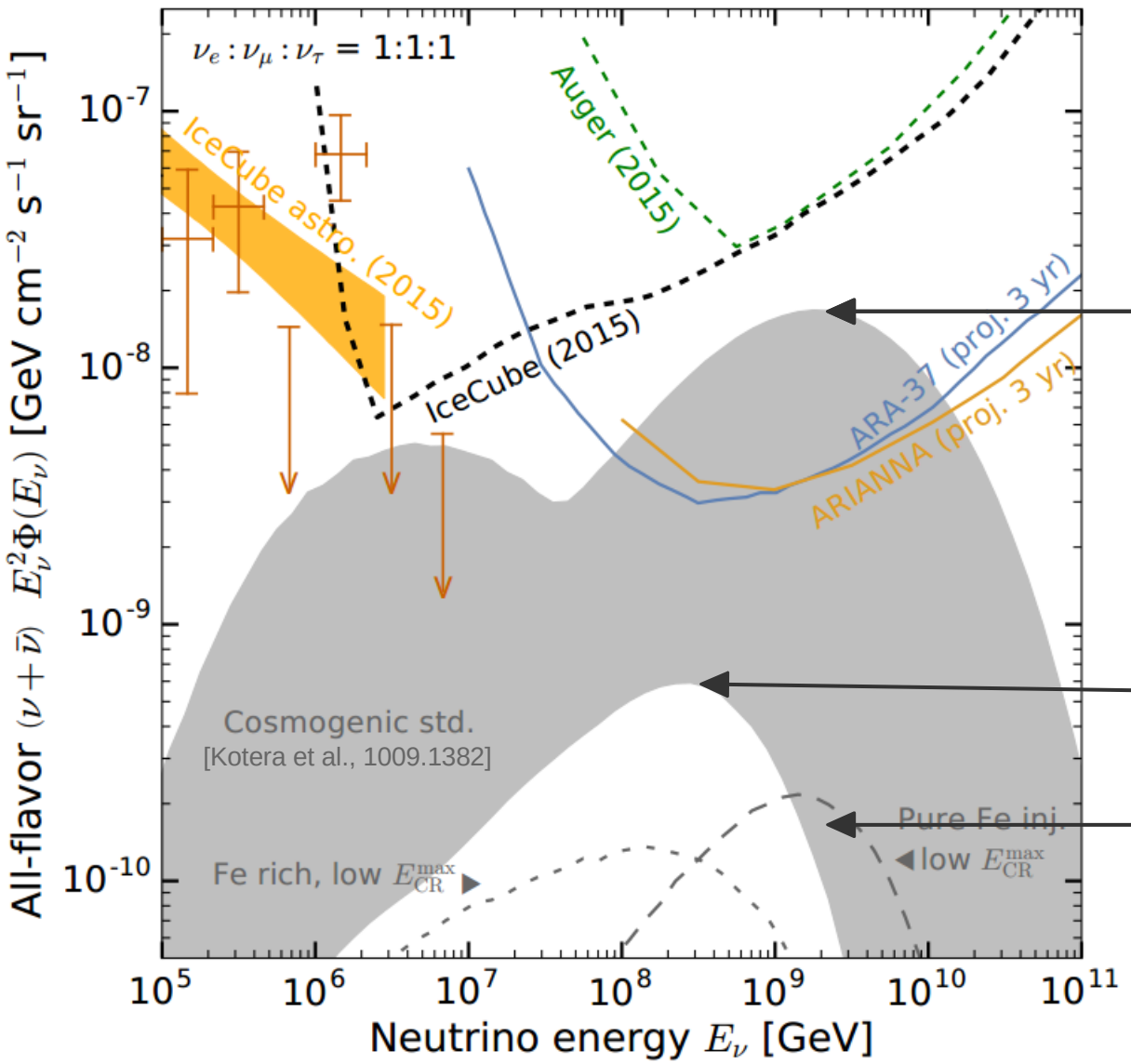
TREND@Ulastai, 21CMA antennas

Cosmogenic neutrinos

cosmogenic neutrinos: from interaction of UHECRs and CMB (guaranteed)

Study the most energetic cosmic accelerators

[M. Bustamante]



Optimistic: 100% p, SFR

30% Fe, SFR

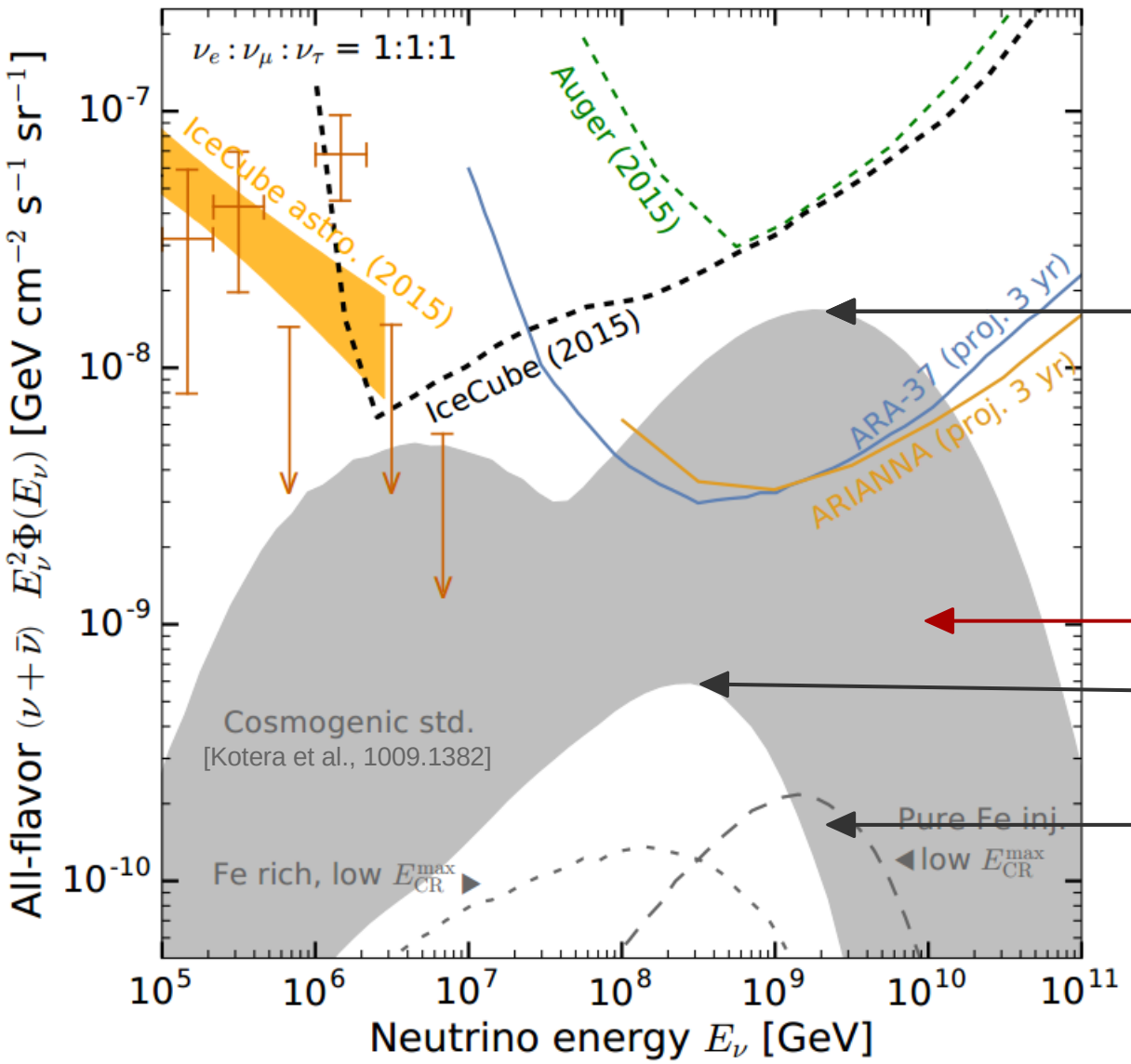
Pessimistic: Fe rich, uniform

Cosmogenic neutrinos

cosmogenic neutrinos: from interaction of UHECRs and CMB (guaranteed)

Study the most energetic cosmic accelerators

[M. Bustamante]



Optimistic: 100% p, SFR

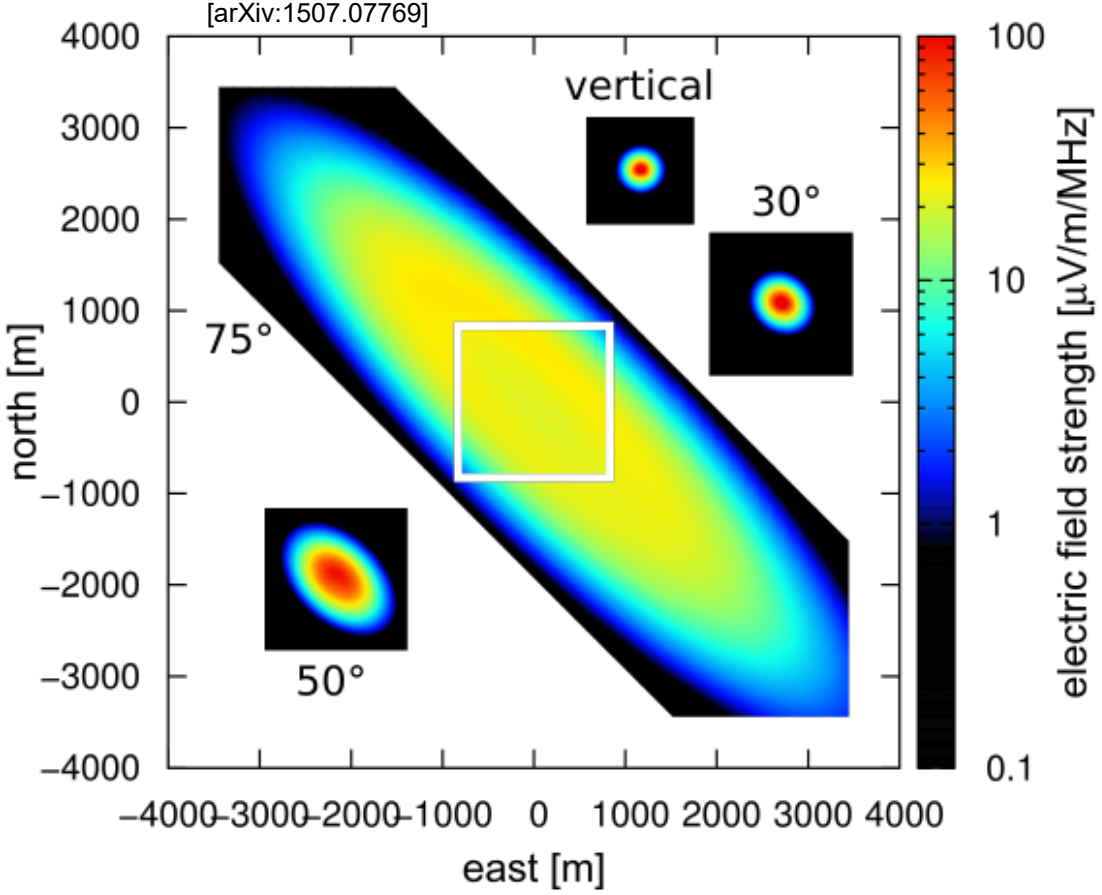
Auger “best-fit” (1612.07155)

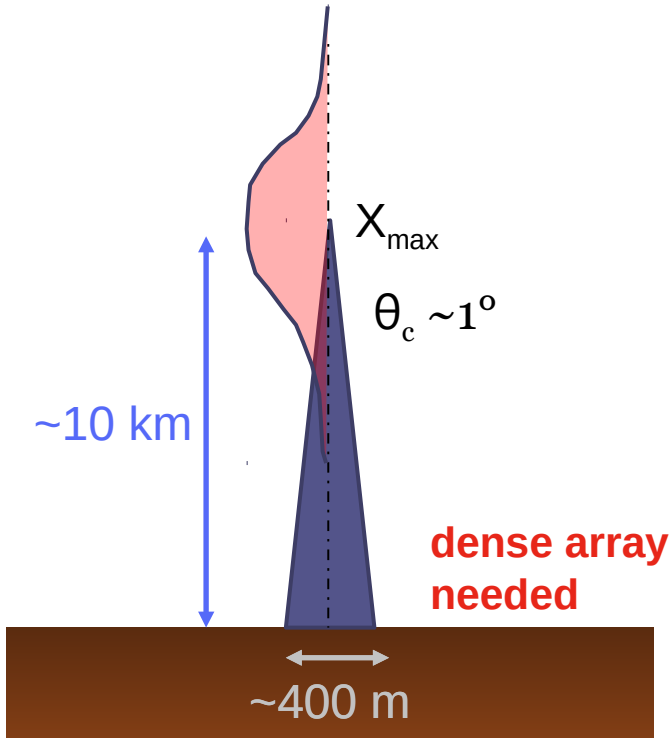
30% Fe, SFR

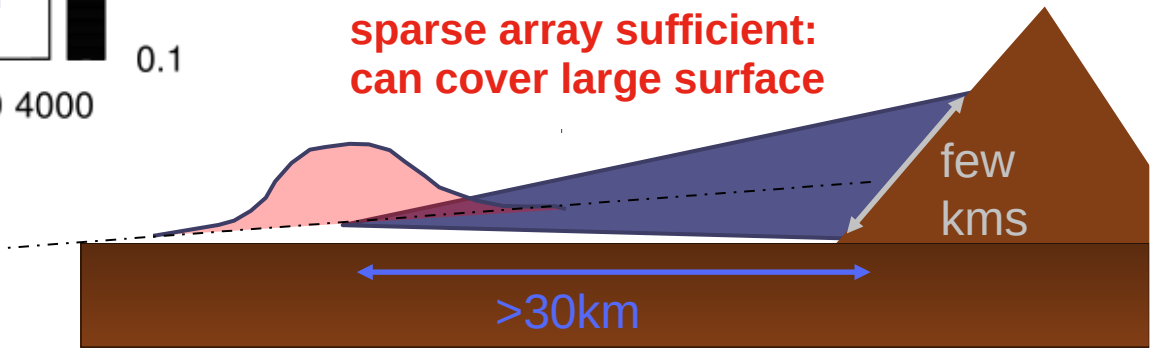
Pessimistic: Fe rich, uniform

Radio footprint of inclined showers

[arXiv:1507.07769]





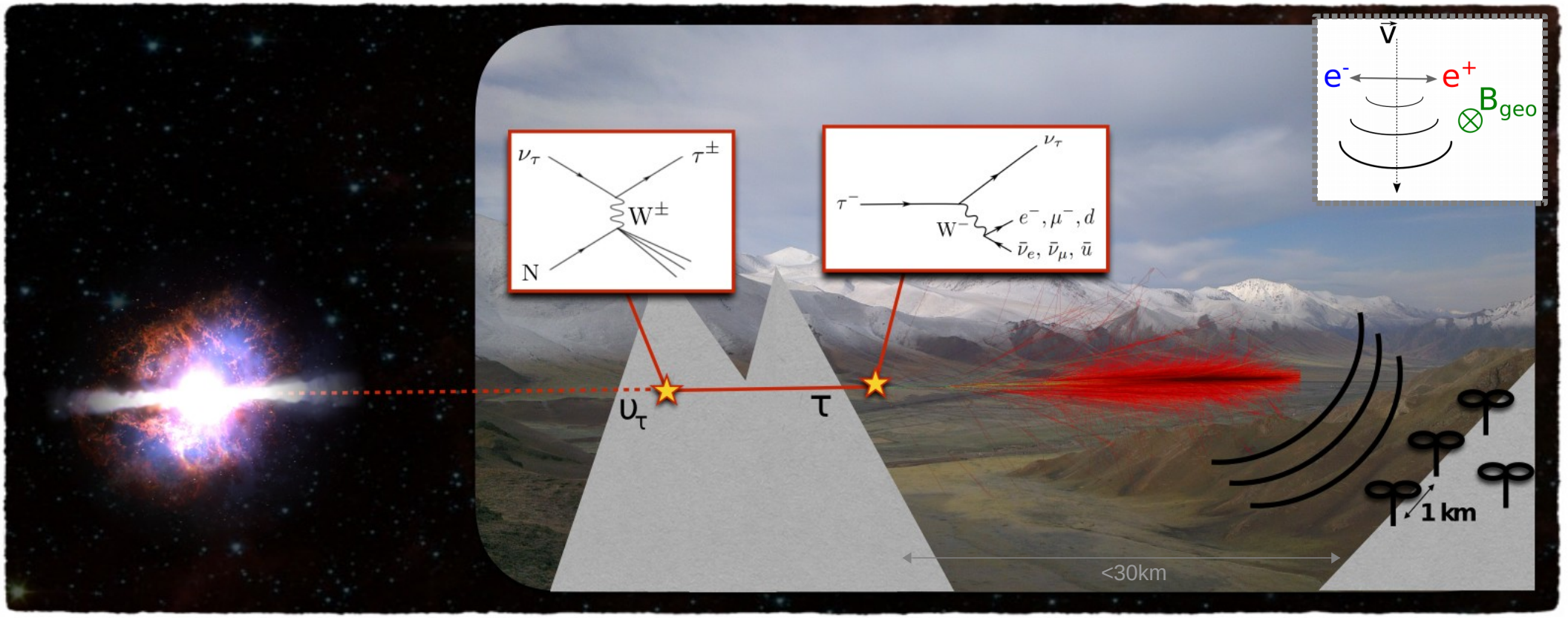


- Footprint becomes large for large zenith
- Detectable at distances of km

→ **Antenna array with kms-spacing possible**
- radio technique scalable to large areas
- large exposure for moderate costs

→ Radio as ideal technique to detect Earth-skimming neutrino trajectories!

High-energetic neutrino detection



The GRAND Project
- the Giant Array for Neutrino Detection

200,000 radio antennas over 200,000km^2

Mountainous area near Ulastai, West China

The GRAND Project
- the Giant Array for Neutrino Detection

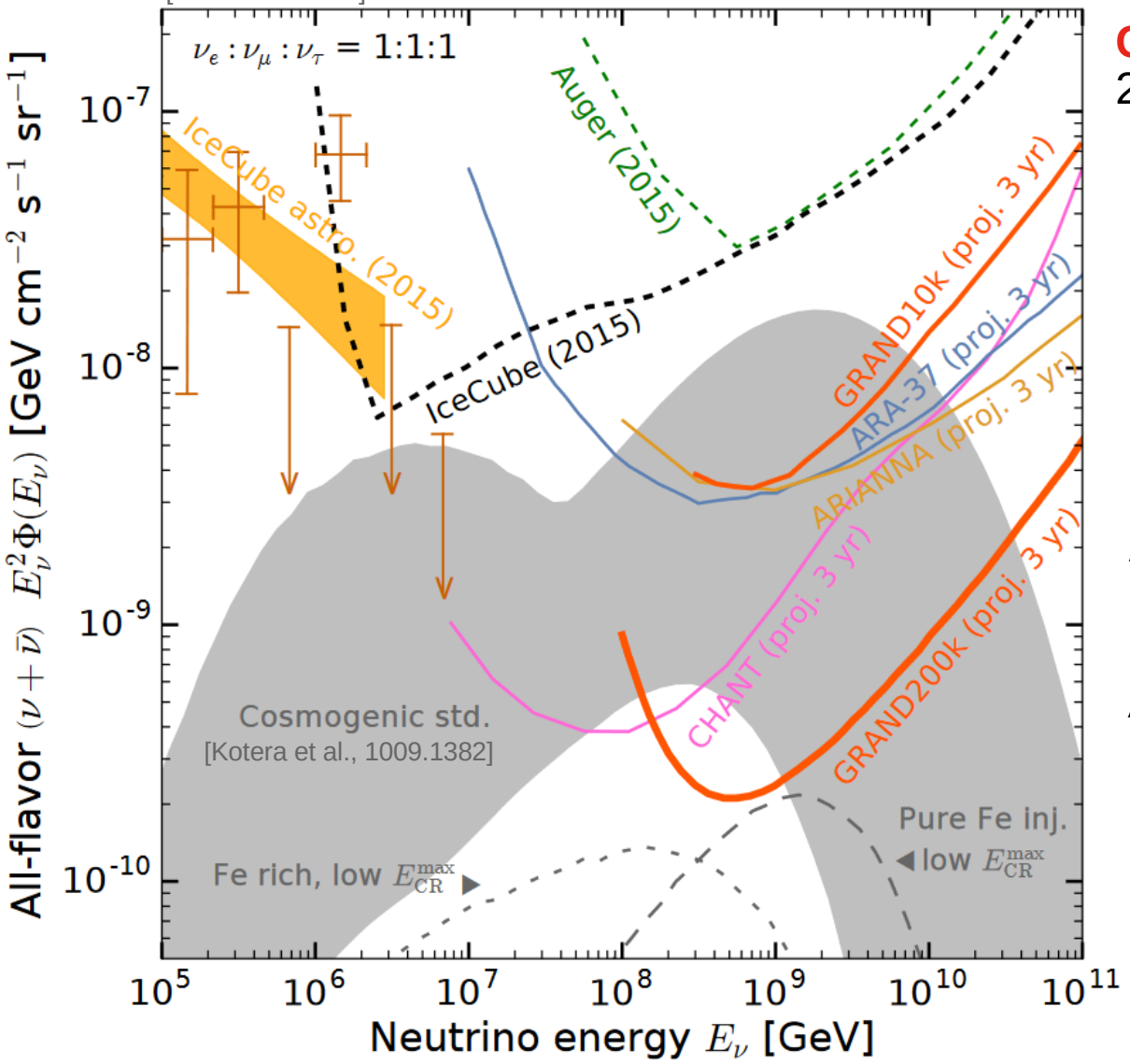
200,000 radio antennas over 200,000km²

Mountainous area near Ulastai, West China

Cosmogenic neutrinos

Preliminary simulation results on sensitivity

[M. Bustamante]



GRAND 200k
200'000 antennas over 200'000 km²

All-flavour target sensitivity:
1.5 x10^{-10} GeV cm^{-2} s^{-1} sr^{-1}

Angular resolution < 0.3 deg.

A win-win-win situation

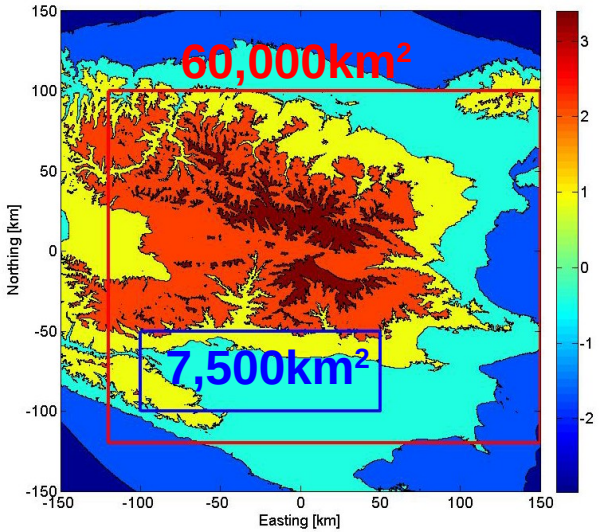
For cosmogenic neutrinos, GRAND is . . .

- . . . a discovery *and* precision instrument for optimistic fluxes:
  $600–1400$ events yr^{-1}
- . . . a discovery instrument for pessimistic fluxes:
  $6–15$ events yr^{-1}
- . . . and a strong-exclusion instrument, if < 1 event yr^{-1}

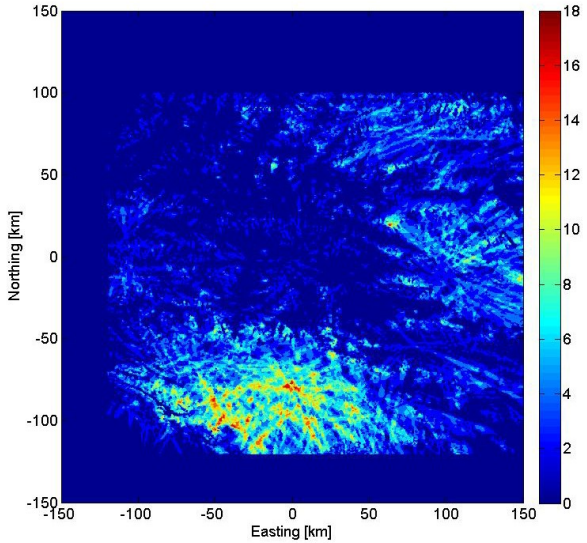
Preliminary results of sensitivity study

90,000 antennas over 60,000km²

topology

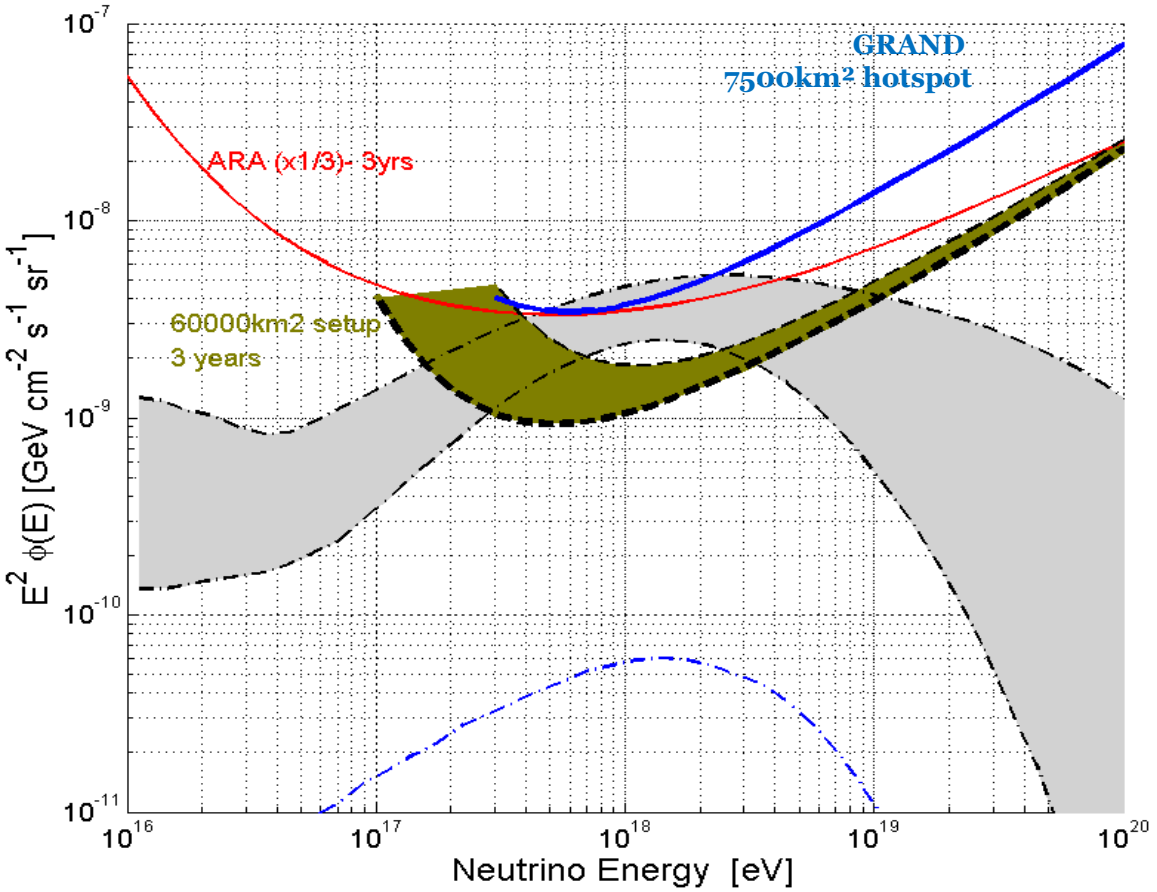


trigger rate



Hotspot with favourable topology

⇒ enhanced detection rate!

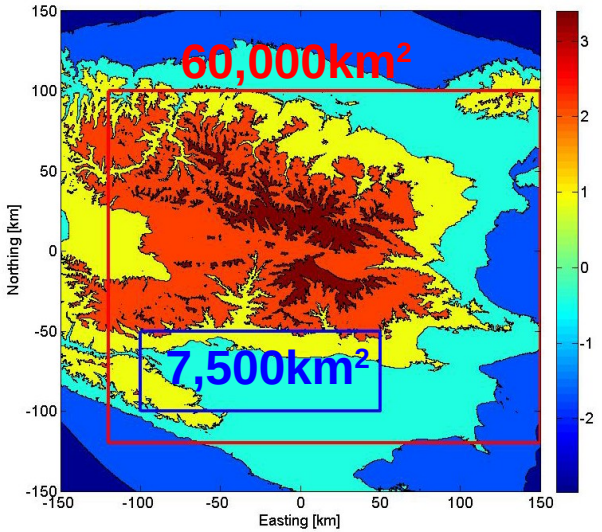


a ~10'000km² array deployed over hotspot may have potential to discover EeV neutrinos

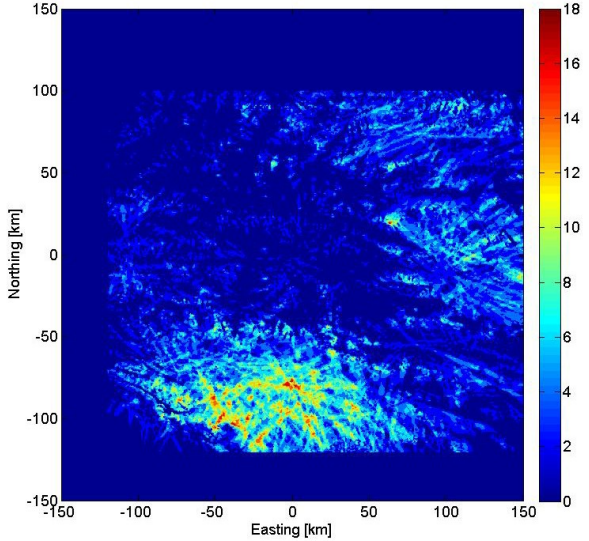
Preliminary results of sensitivity study

90,000 antennas over 60,000km²

topology



trigger rate

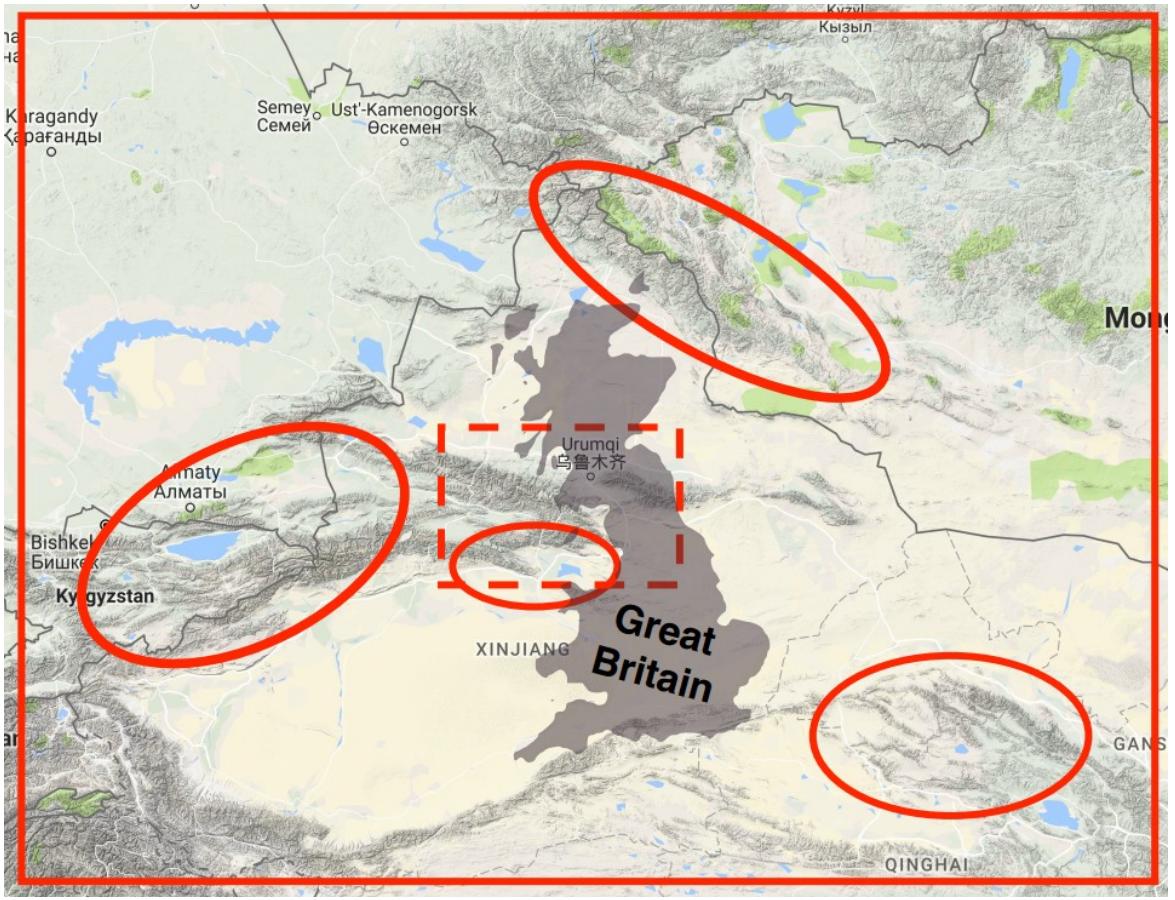


Hotspot with favourable topology
⇒ enhanced detection rate!

Target sensitivity: $\varphi_0 = 1.5 \times 10^{-10}$ GeV/cm²/sr/s

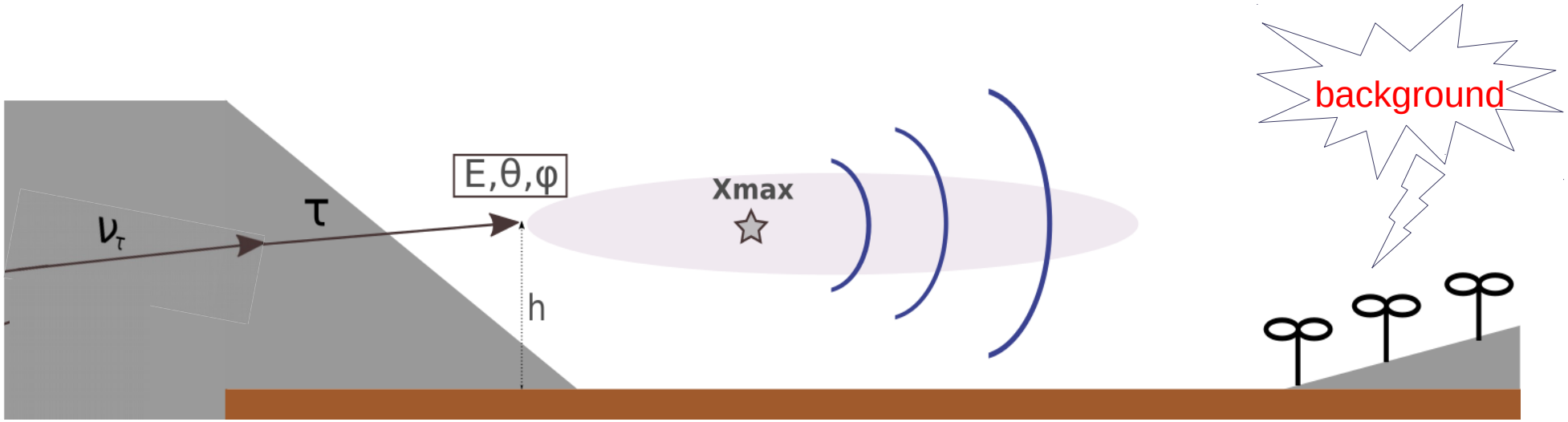
→ Driver: **go for hotspots**!
Then 200'000km² may be enough to reach target sensitivity

Disclaimer: **to be confirmed by full end-to-end simulation.**
Giant simulation area to identify hotspots.
(1'000'000 antennas over 1'000'000 km²? Full Earth?)



GRAND end-to-end simulation chain

→ can we achieve that sensitivity?
→ do we profit from mountains as targets and screens?
→ find hot-spots!



- Topography along track
- CC & NC ν_τ interactions
- τ energy losses
- τ decay

→ **Danton**

- Shower development
- Radio emission

→ **ZhaireS + EVA**

- Antenna response
- Antenna trigger (background noise sim)

→ **NEC**

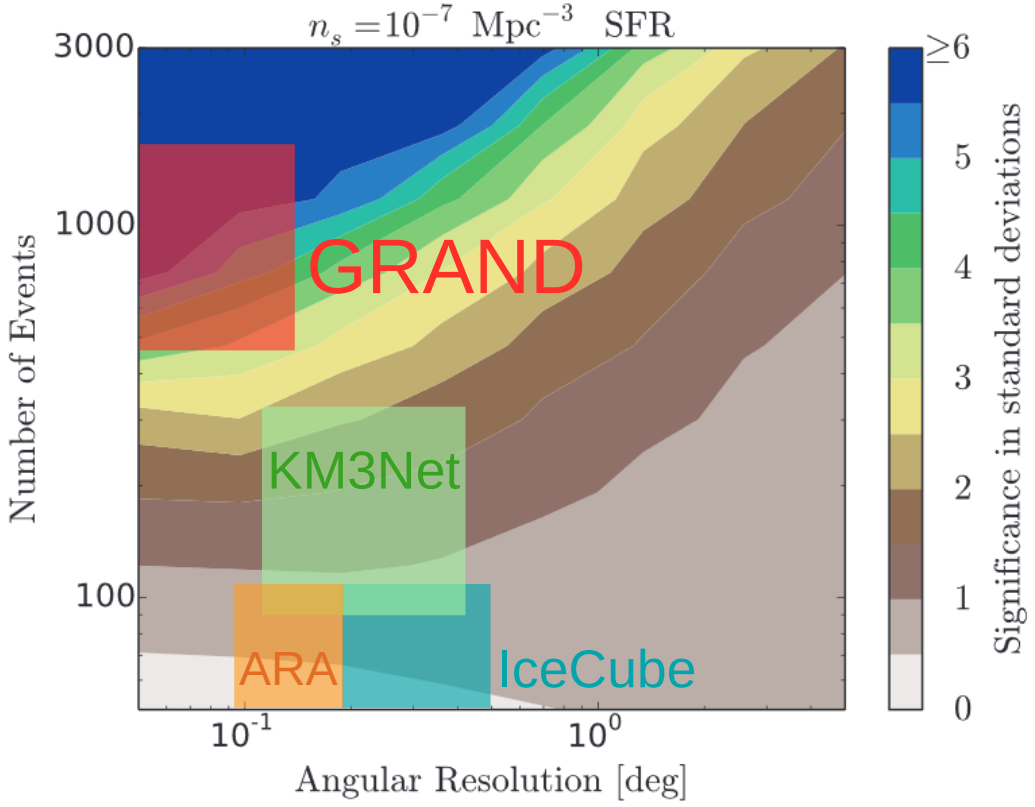
Substituted by radio morphing

Point sources of UHE neutrinos

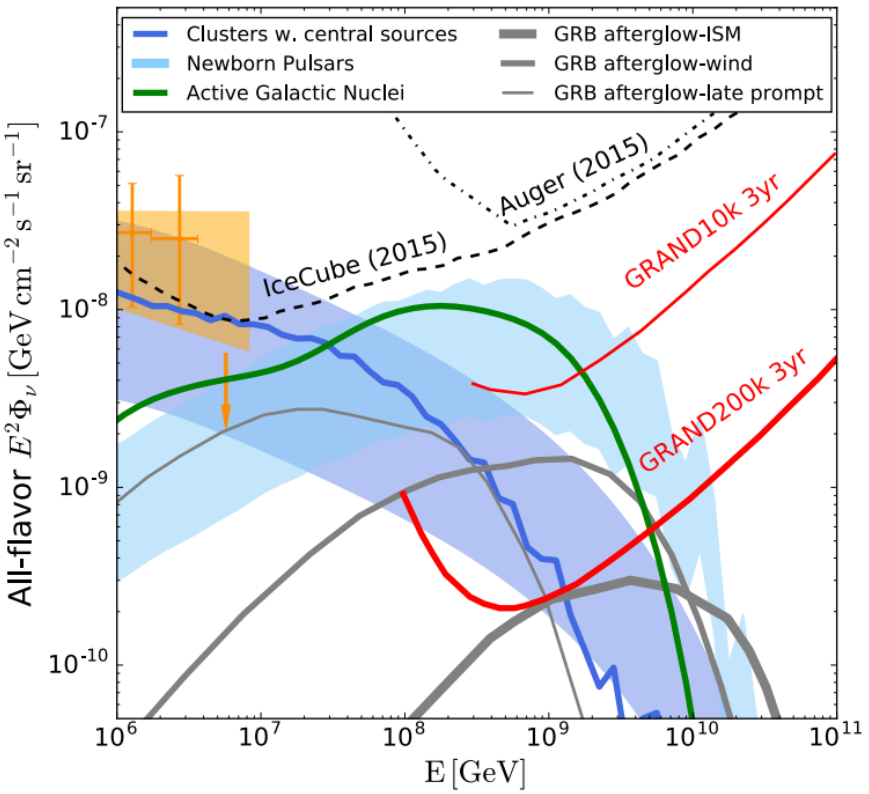
Needed:

- good angular resolution (fraction of degree)
- number of detected events > 100s
  to allow point source to stand out of diffuse background

significance of detection of a neutrino point source



estimates neutrino production directly from various sources



Neutrino astronomy!

Fang, Kotera, Murase, Miller, Oikonomou 2016

What else can GRAND do?

VHE phenomena in the Universe
- Cosmogenic neutrinos
- Neutrino astronomy
- UHECRs & gammas - going to be the largest ground-based detector for CRs

Radio astronomy
- Fast Radio Bursts + Giant Pulses (f> 100 MHz) - original and powerful instrument
- Epoch of Reionisation

Fundamental physics
- Fundamental physics test: neutrino flavour
- Glashow resonance(?)
- EAS physics

Others
- Extreme electromagnetic atmosphere events (Elfs, Sprites, etc.)

GRAND Today

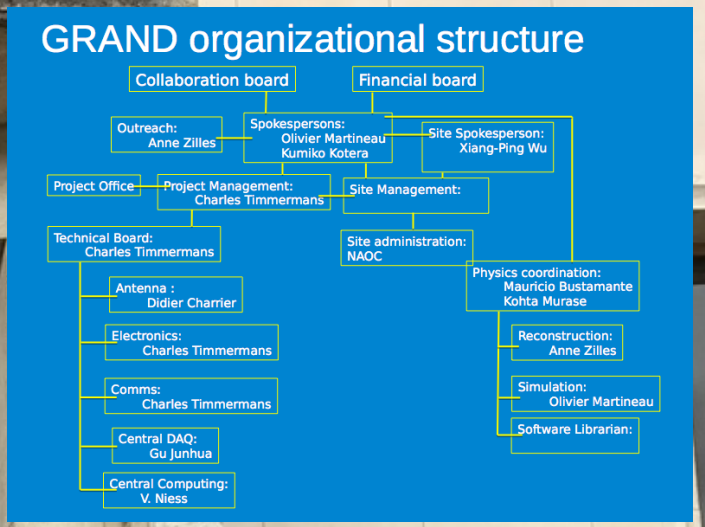
France China Particle Physics Laboratory

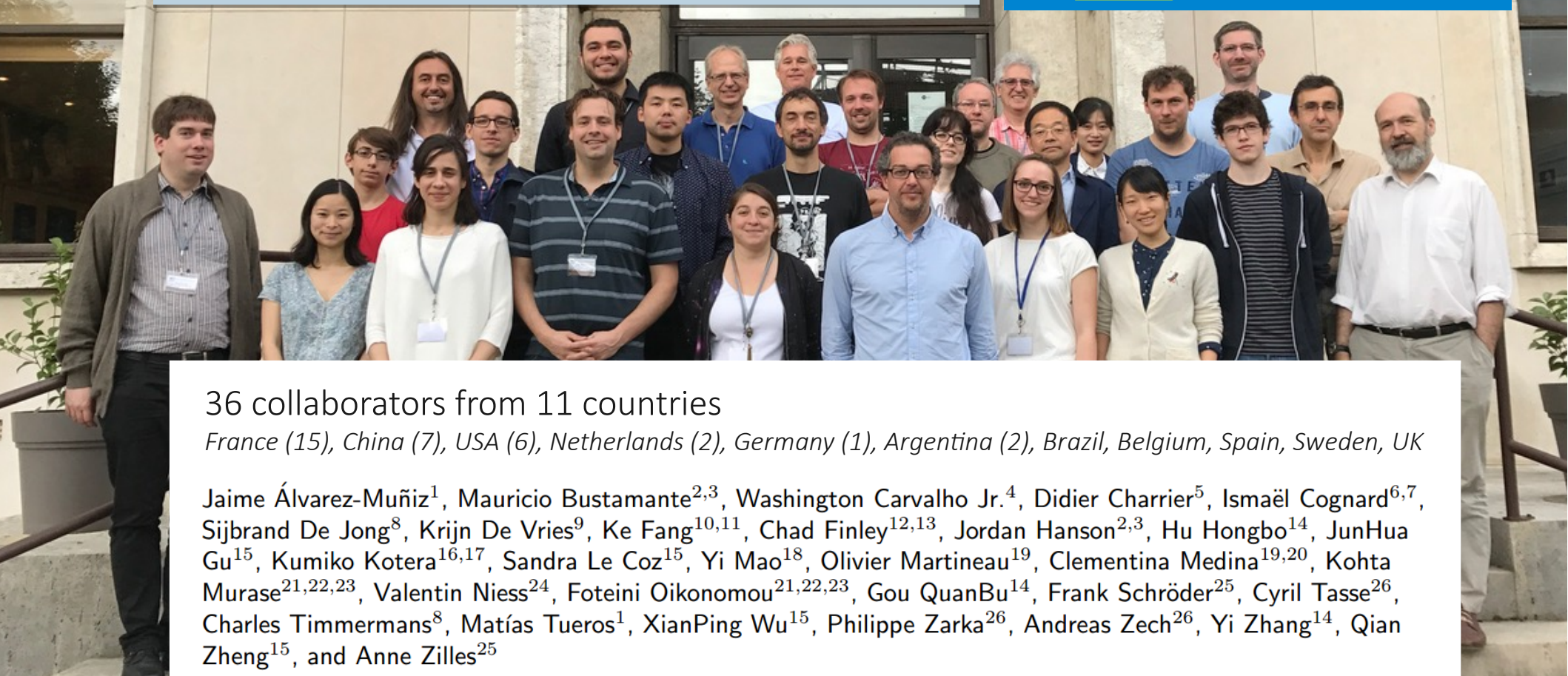
Natural Science Foundation of China

France China Particle Physics Laboratory

Chinese Academy of Science

GRAND organizational structure





36 collaborators from 11 countries

France (15), China (7), USA (6), Netherlands (2), Germany (1), Argentina (2), Brazil, Belgium, Spain, Sweden, UK

Jaime Álvarez-Muñiz[1], Mauricio Bustamante[2,3], Washington Carvalho Jr.[4], Didier Charrier[5], Ismaël Cognard[6,7], Sijbrand De Jong[8], Krijn De Vries[9], Ke Fang[10,11], Chad Finley[12,13], Jordan Hanson[2,3], Hu Hongbo[14], JunHua Gu[15], Kumiko Kotera[16,17], Sandra Le Coz[15], Yi Mao[18], Olivier Martineau[19], Clementina Medina[19,20], Kohta Murase[21,22,23], Valentin Niess[24], Foteini Oikonomou[21,22,23], Gou QuanBu[14], Frank Schröder[25], Cyril Tasse[26], Charles Timmermans[8], Matías Tueros[1], XianPing Wu[15], Philippe Zarka[26], Andreas Zech[26], Yi Zhang[14], Qian Zheng[15], and Anne Zilles[25]

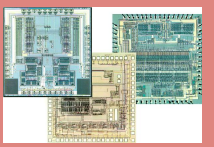
GRAND roadmap

GRANDproto300

GRANDproto35 | GRAND10k | GRAND200k

2017 | 2020 | 2025 | 203X

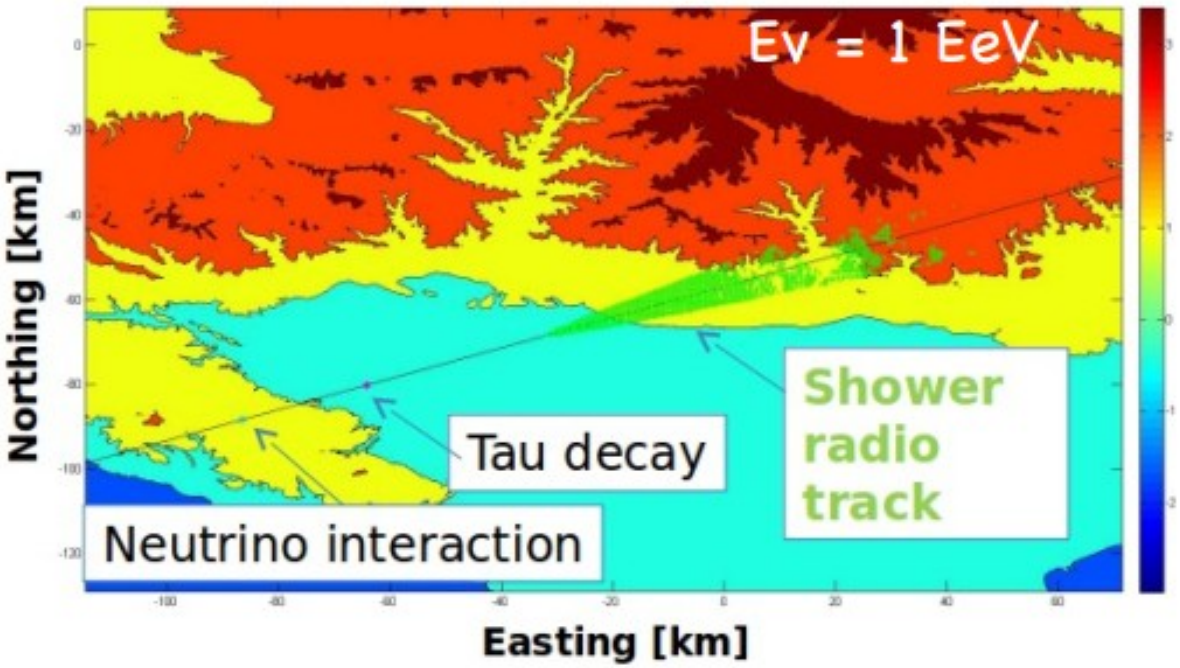
	GRANDproto35	GRANDproto300	GRAND10k	GRAND200k
Goals	demonstrate that EAS can be detected on standalone radio array with high efficiency & very good background rejection	establish detection & identification by standalone radio array of very inclined showers ($\theta>70°$) induced by high energy cosmic rays ($>10^{18}$eV). Includes background rejection, EAS reconstruction, etc.	first GRAND subarray, sensitivity comparable to ARA/ARIANNA on similar time scale, allowing 1st discovery of cosmogenic neutrinos (if lucky)	first neutrino detection at 10^{18} eV and/or **neutrino astronomy** for real!
Setup	35 radio antennas 21 scintillators 	• 300 Horizon Antennas over 300 km² • Fast DAQ (AERA+ GRANDproto35 analog stage) • Solar pannels (day use) + WiFi data transfer	DAQ with discrete elements, but mature design for trigger, data transfer, consumption	200'000 antennas over 200'000 km² hotspots could be in different continents Industrial scale allows to cut costs down: 500€/unit → 120k€ in total
Budget & stage	160kE, fully funded by NAOC+IHEP, deployment fall 2017 @ Ulastai	1.3 ME (reasons to be optimistic for Chinese funding) to be deployed in 2019	1500€ /detection unit	ASIC Cost ~10M$ → few 10$/board Consomption < 1W Reliability ☺



Back-up

Preliminary sensitivity Study

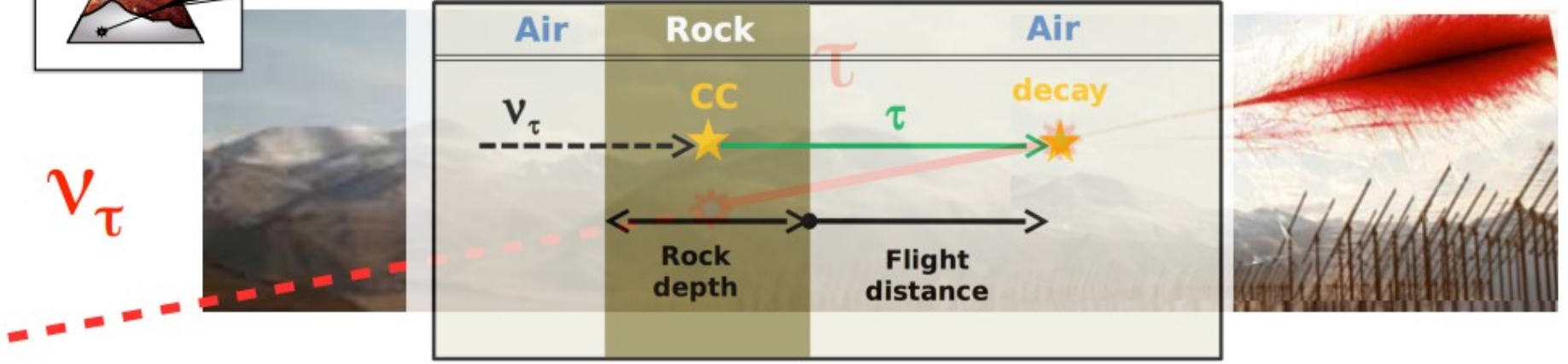
ν Propagation—> tau Decay —> EAS Development (not yet with antenna response)

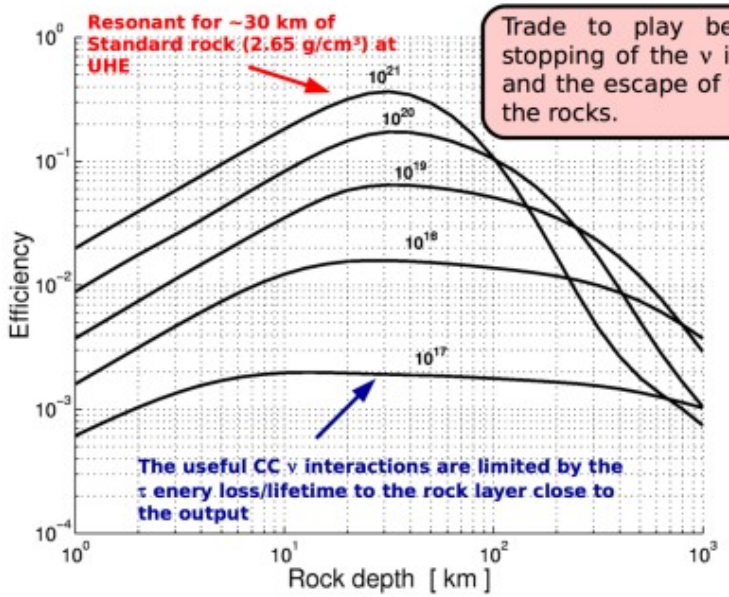


Simulation setup: 90,000 antennas over 60,000 km2 with 800 m step size in Tianshan Mountain

Showers detected if >=8 neighboring antennas are inside a light cone of a few degrees & In direct view decay point

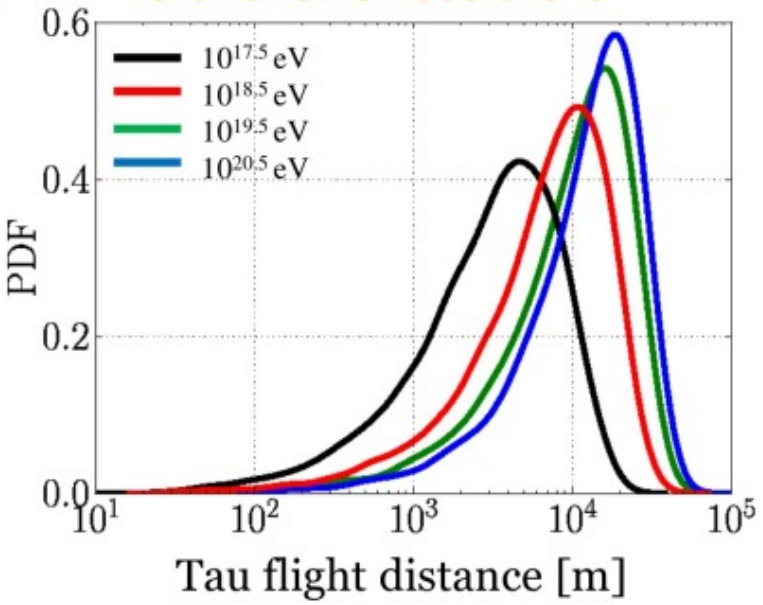
From Neutrino to Lepton





Conversion efficiency from neutrino to tau lepton decaying in the air

Grand ICRC 1508.01919

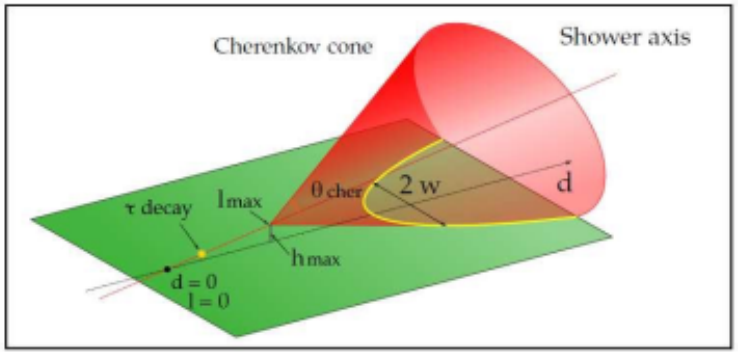


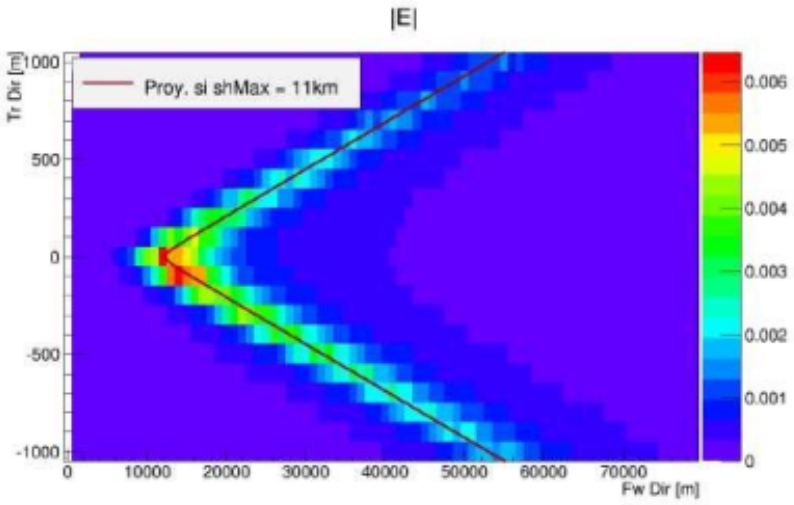
Prob. Distribution of flight distance

Background Rejection

Terrestrial backgrounds expected at rate of 1 Hz

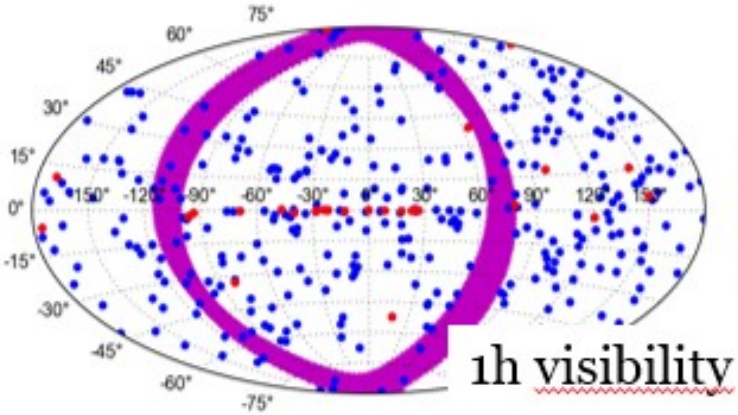
- **Trigger pattern at ground** (started inside array + beamed emission with flat wavefront + reconstructed source below horizon)
- **Polarization pattern** (perpendicular both to geomagnetic field & direction of propagation of shower)
- **Cherenkov cone**



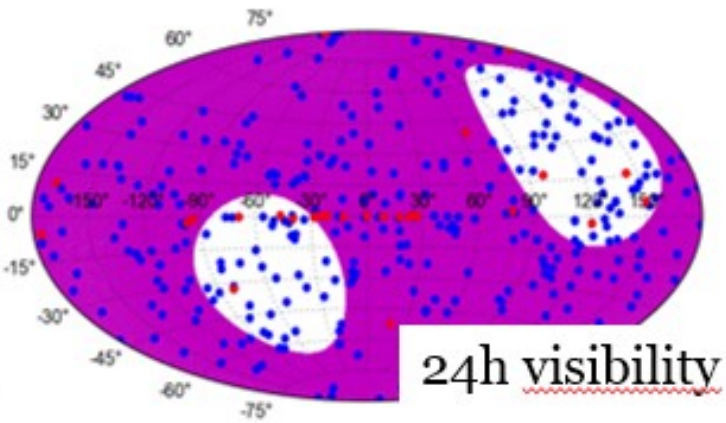


GRAND ν sensitivity study - Results

- Field of view

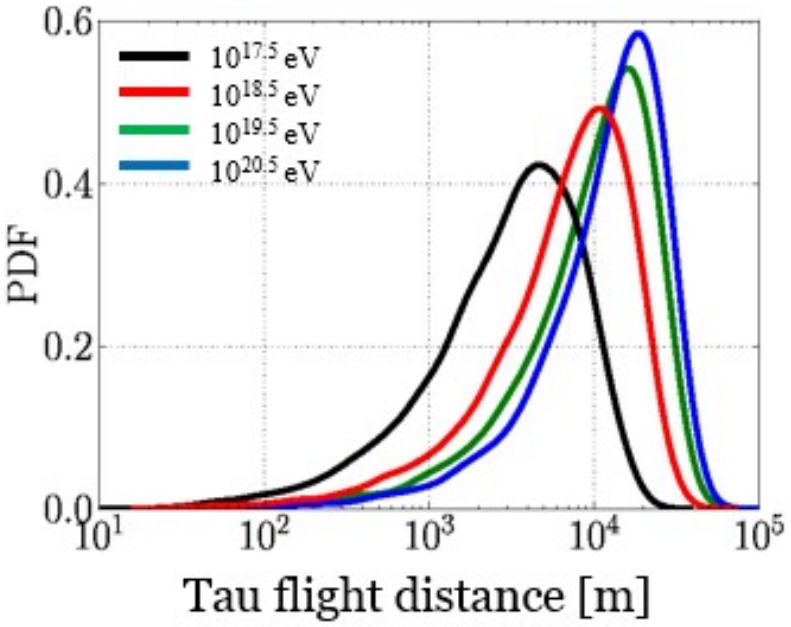


1h visibility

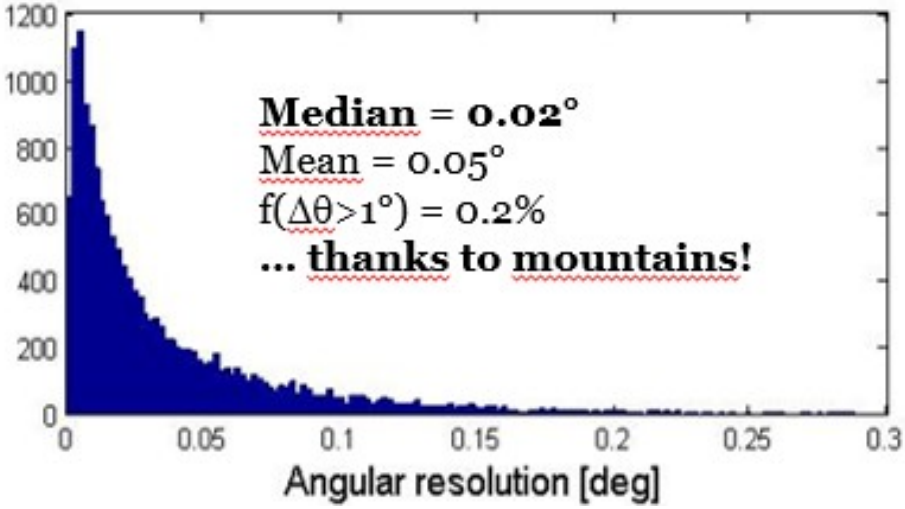


24h visibility

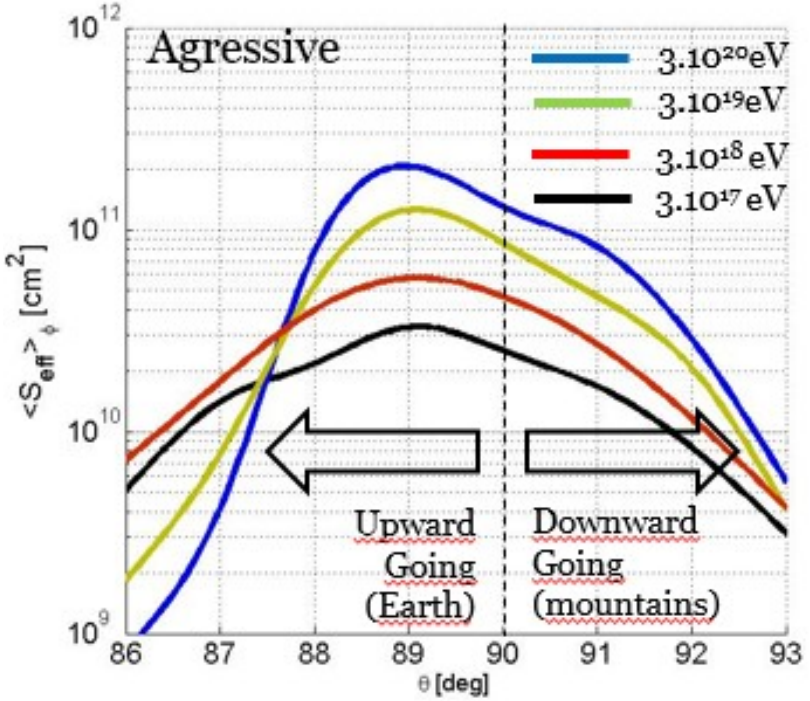
- Energy reconstruction
  - … is not possible
  - But at least we know $E_\nu > E_{sh}$
  - Do better thanks to E_ν correlation with τ time of flight (?)



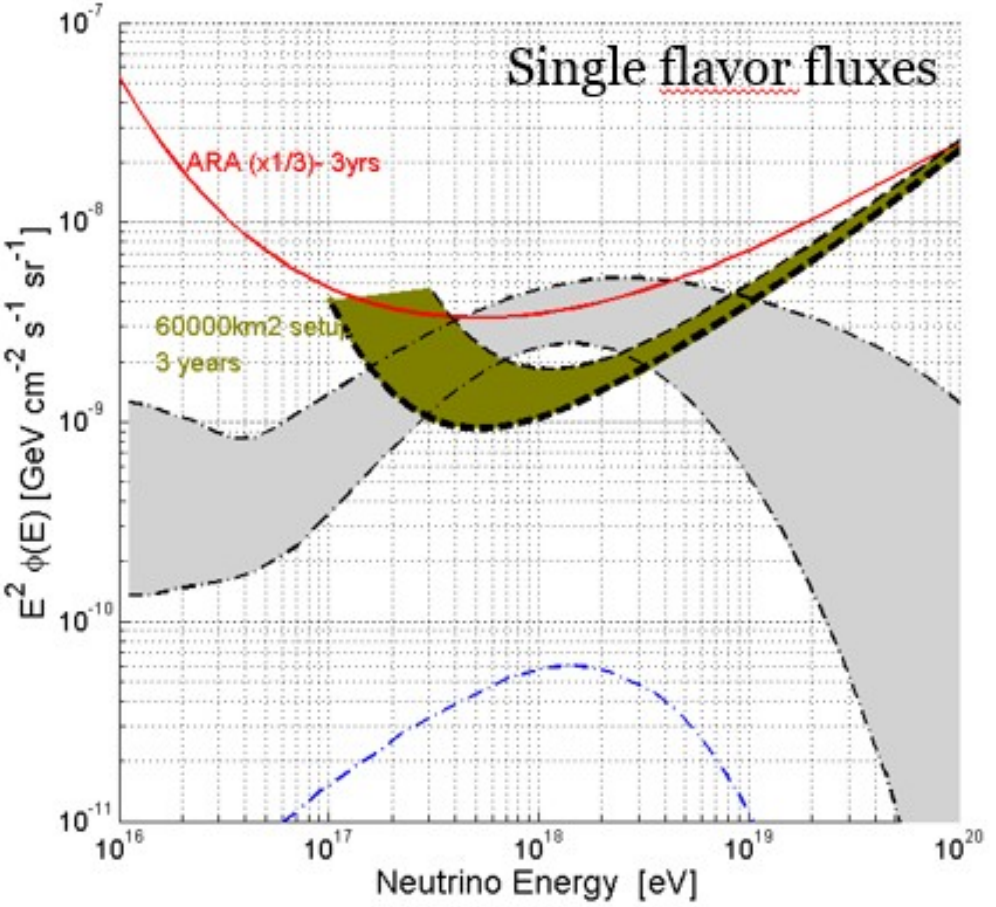
- Angular resolution
  - Analytical computation assuming 3ns trigger timing precision (no noise).
  - Mean = 0.05°: full benefit of extended trigger zone & denivelation.



GRAND ν sensitivity study - Results



- Sensitivities > 0 for zenith values = ±4° around horizontal ⇨ Earth-skimming trajectories only.
- Mountains are sizable tragets (~40% of total).
- Earth becomes opaque at higher energies



- 60'000km² simulation setup
- single flavor flux $\phi(E) = \phi_0 E^{-2}$
- no candidate in 3 years

⇨ 90% CL integral limit:

$\phi_0 < 6.6\ 10^{-10} - 1.3\ 10^{-9}$ Gev/cm²/sr/s

... not good enough!