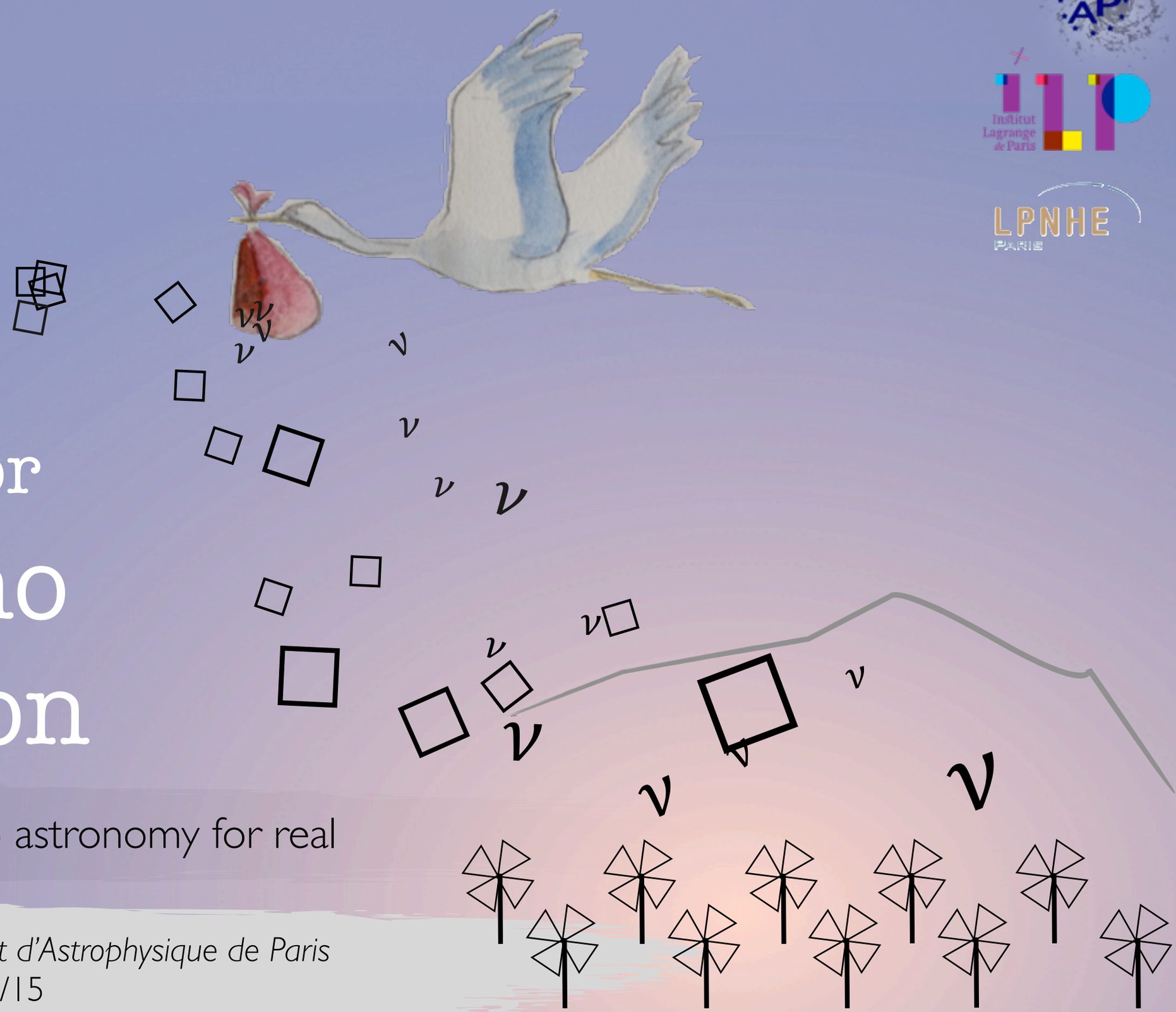
Proposal for a

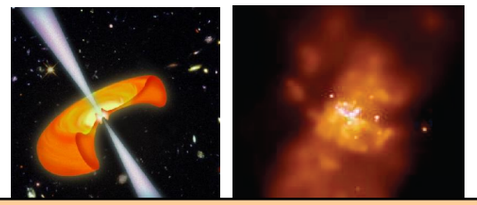
Giant Radio Array for Neutrino Detection



High-energy neutrino astronomy for real

Kumiko Kotera - *Institut d'Astrophysique de Paris*
KIAA Workshop 28/09/15

Probing the working of the most violent phenomena in the Universe



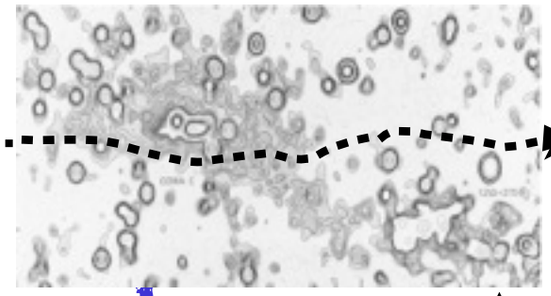
Most violent sources

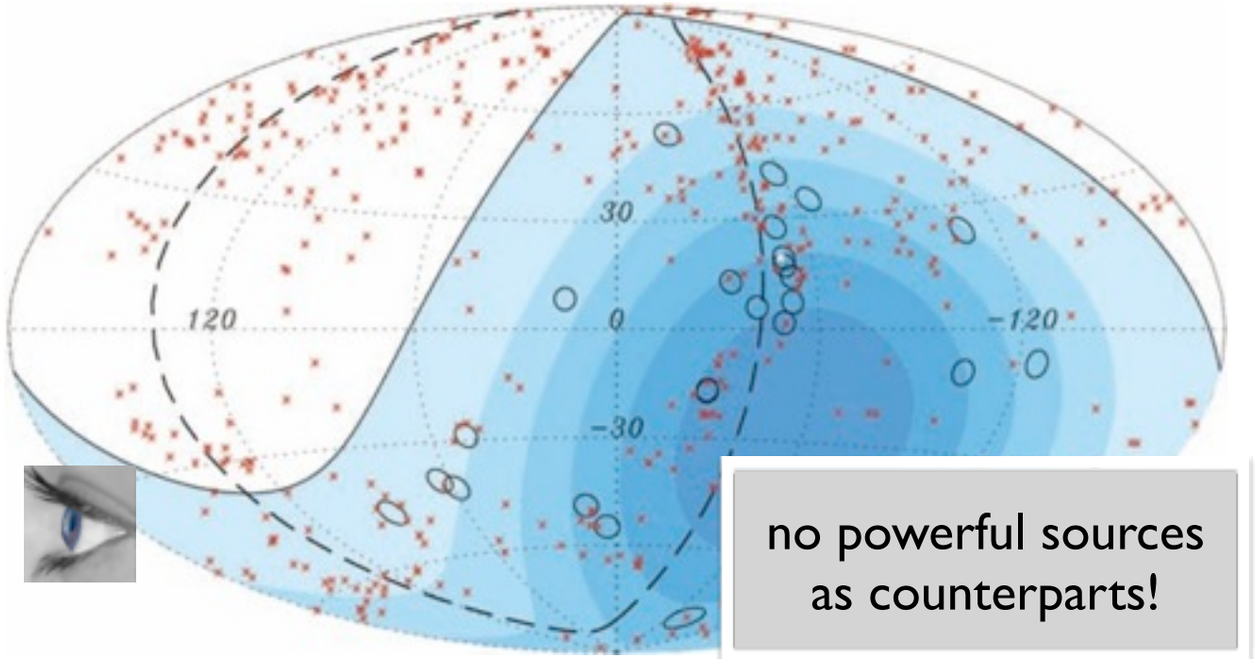
Physics of the sources?

gamma-ray bursts,
pulsars, magnetars,
AGN...

acceleration

UHECR





no powerful sources
as counterparts!

Extragalactic magnetic fields?

deflection : spatial decorrelation
time delay : temporal decorrelation if transient source

interactions on baryonic and
photonic backgrounds

at the source

neutrinos

- neutrinos are not deflected by magnetic fields
- neutrinos allow us to see farther in the Universe
- neutrinos allow us to see deeper in objects
- clear hadronic acceleration signature

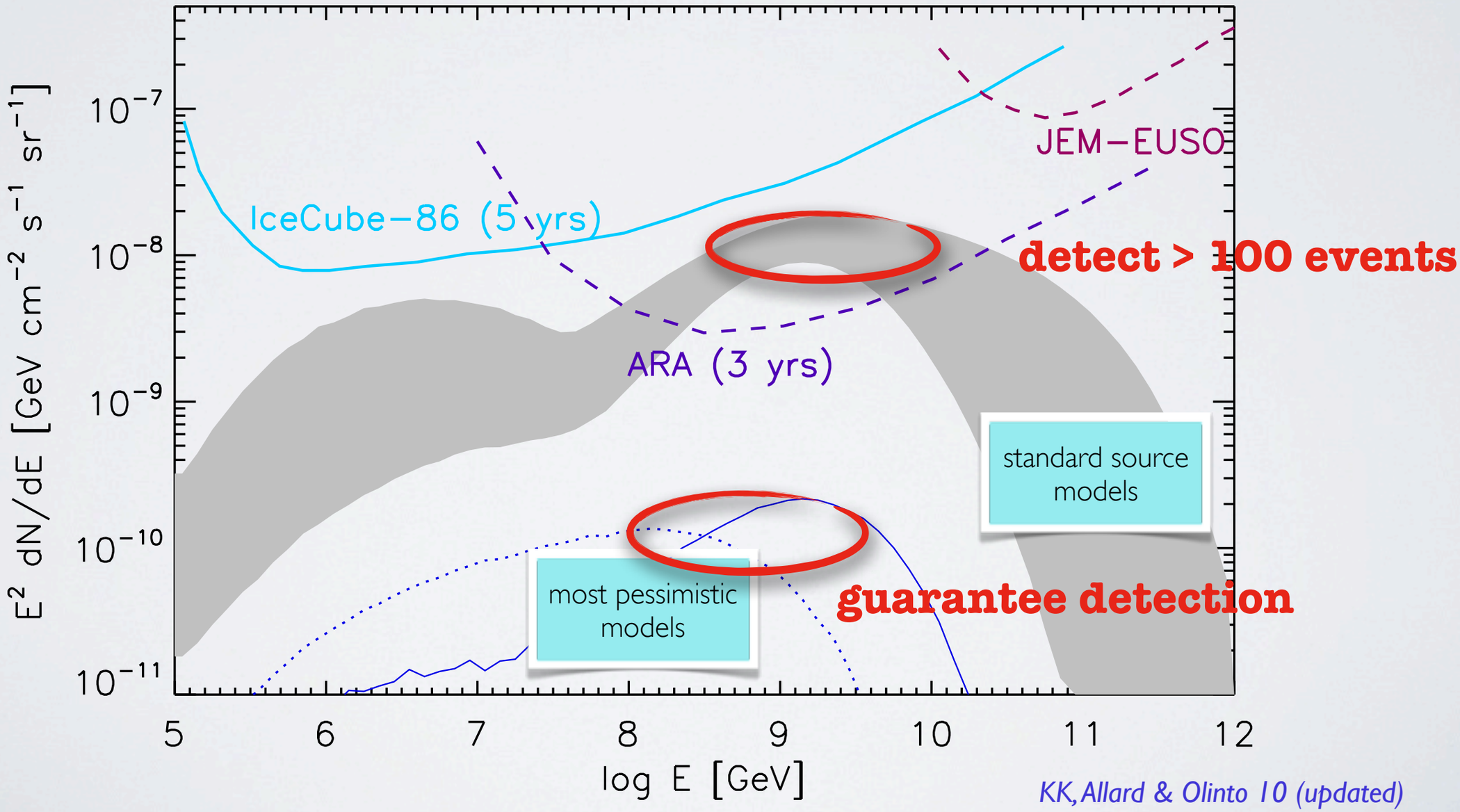
The guaranteed cosmogenic neutrino flux

UHECRs sunt *ergo* cosmogenic neutrinos sunt

UHECRs exist *hence* cosmogenic neutrinos exist

neutrinos produced when UHECRs interact with the cosmic photon backgrounds

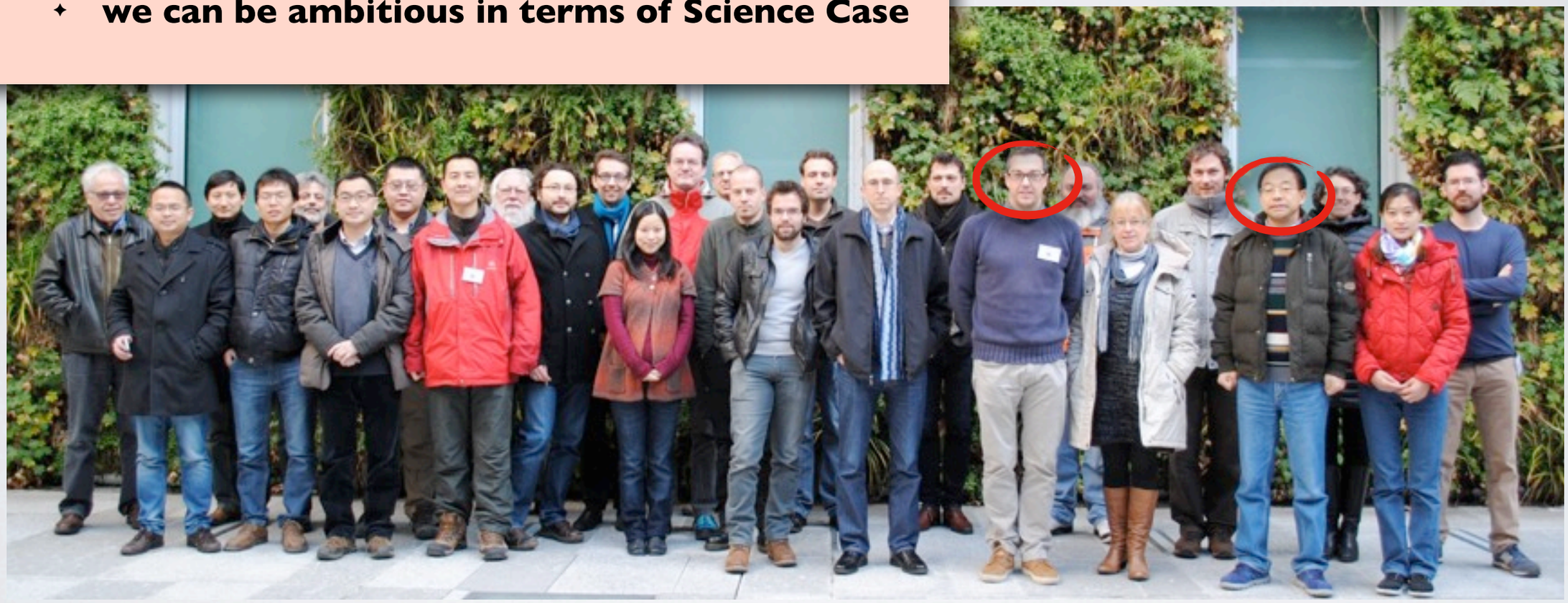
Let's be ambitious



KK, Allard & Olinto 10 (updated)

A giant array on ground for UHE neutrino detection?

- GRAND workshop, LPNHE, Paris, Feb 2015
  https://indico.in2p3.fr/event/10976/
- 35 participants from the field
  (UHECRs, γ and ν, radio detection of air showers, …)
- Main outputs: overall very promising
  - technical challenges could be overcome
  - Chinese funding and manpower
  - **we can be ambitious in terms of Science Case**



- ICRC 2015: ***arXiv:1508.01919***

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SUBATECH
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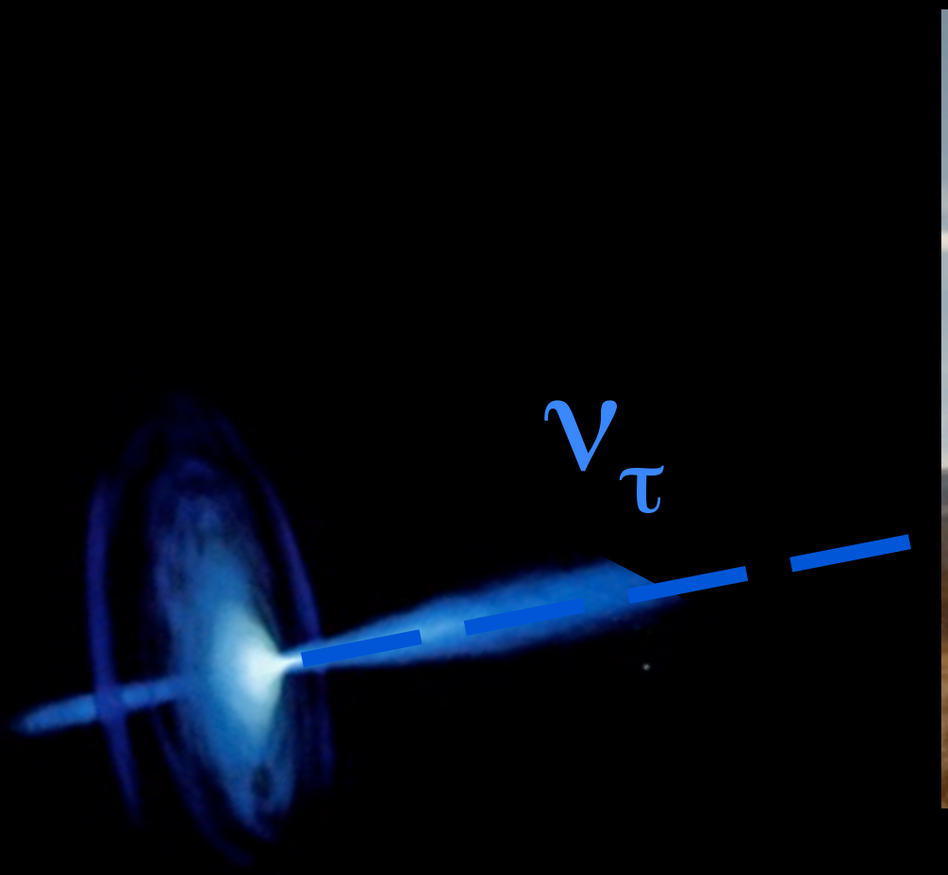
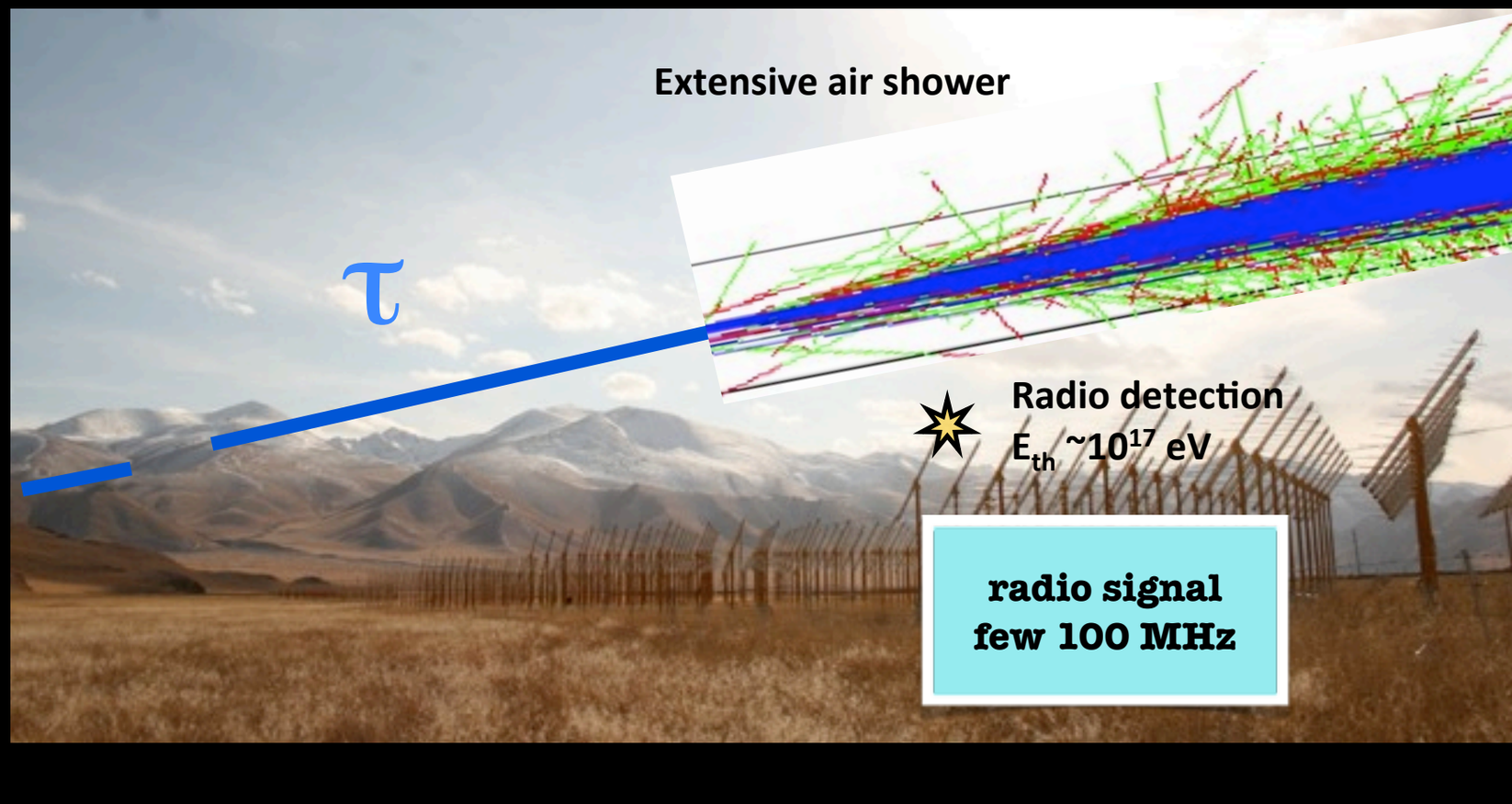
Belgium
Vrije U. Brussels

the Netherlands
Nikhef/Radboud U.

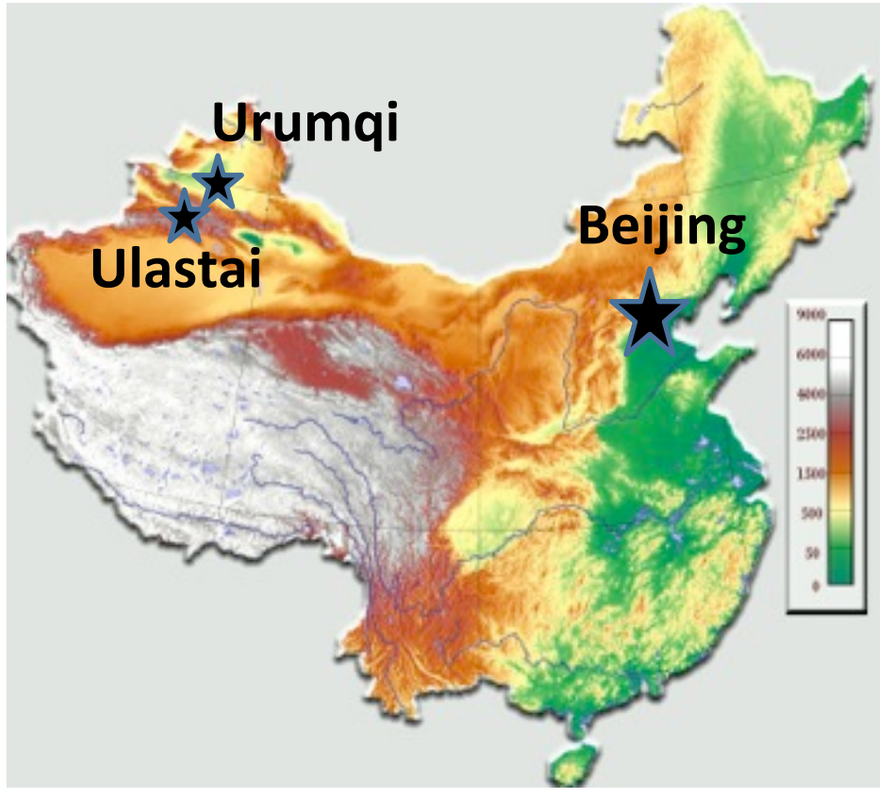
GRAND neutrino detection principle



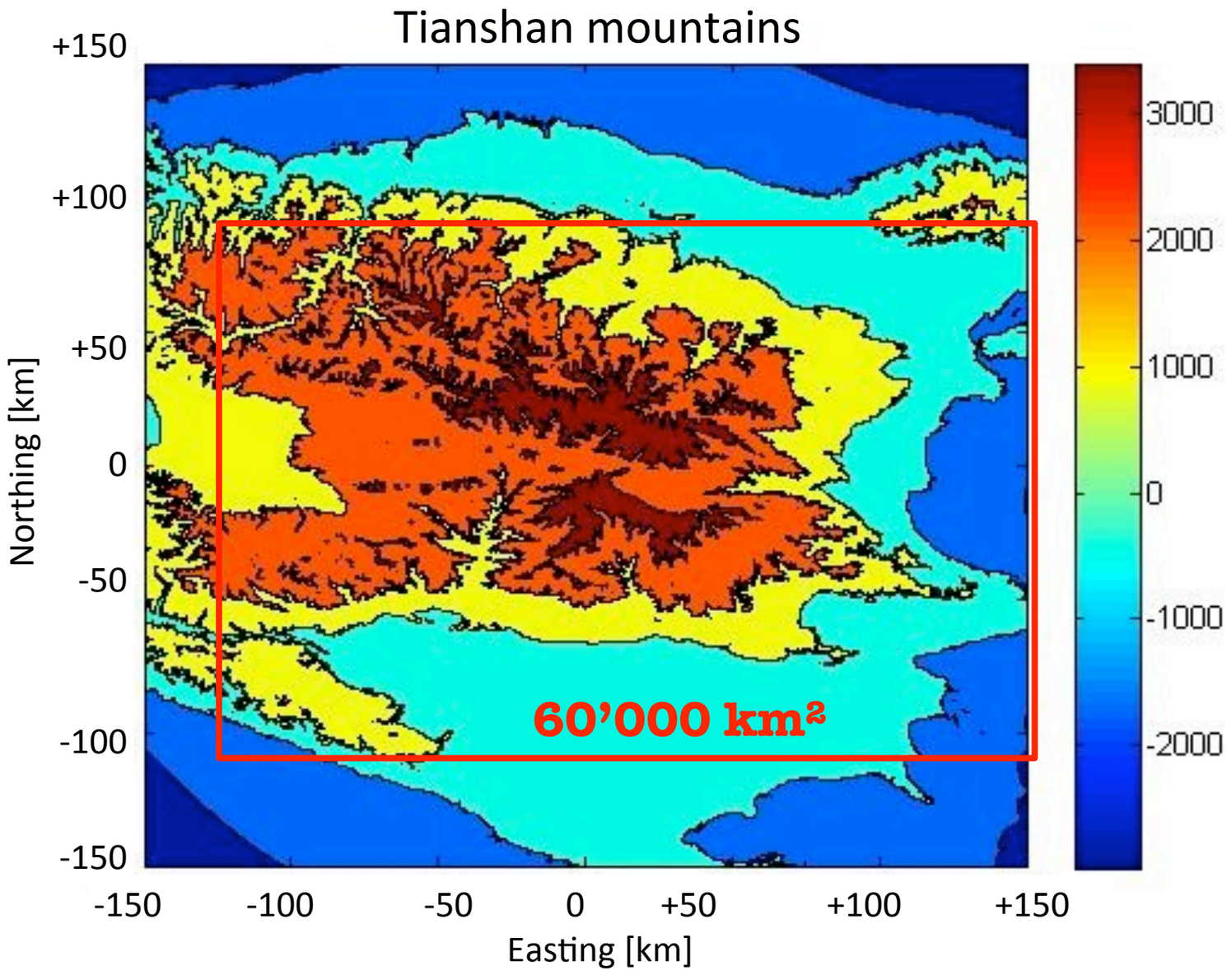


- Earth + mountains as target for neutrino interaction
  Fargion et al. (2000), Bertou et al. (2001)
- Radio detection of subsequent Extensive Air Shower (good at large zenith angles) on a HUGE array [o(100'000 km^2)]

GRAND ν sensitivity preliminary study (**toy setup**)

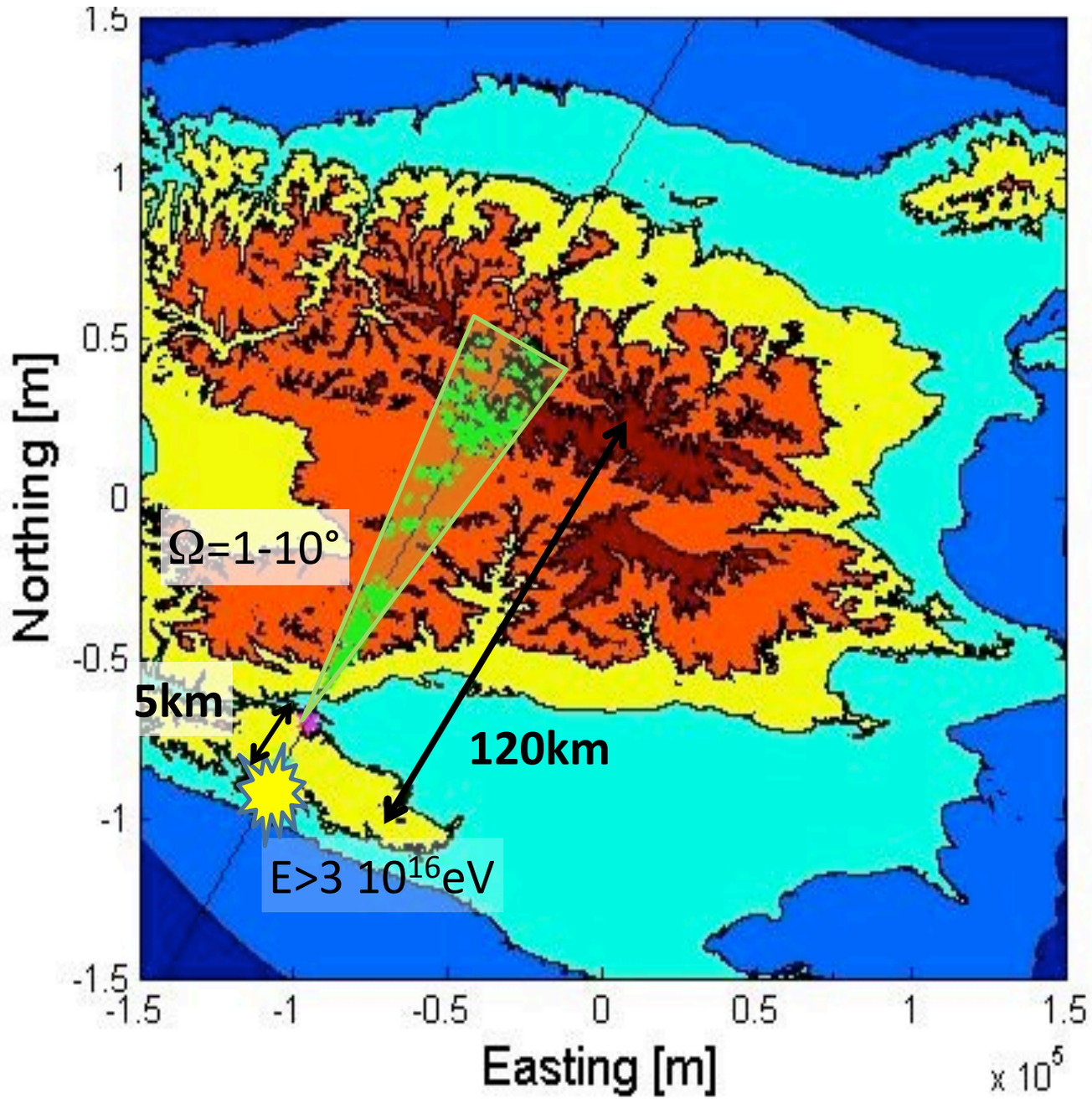


60’000 antennas
deployed over 220 x 270 km^2
in Tianshan mountains (Western China)



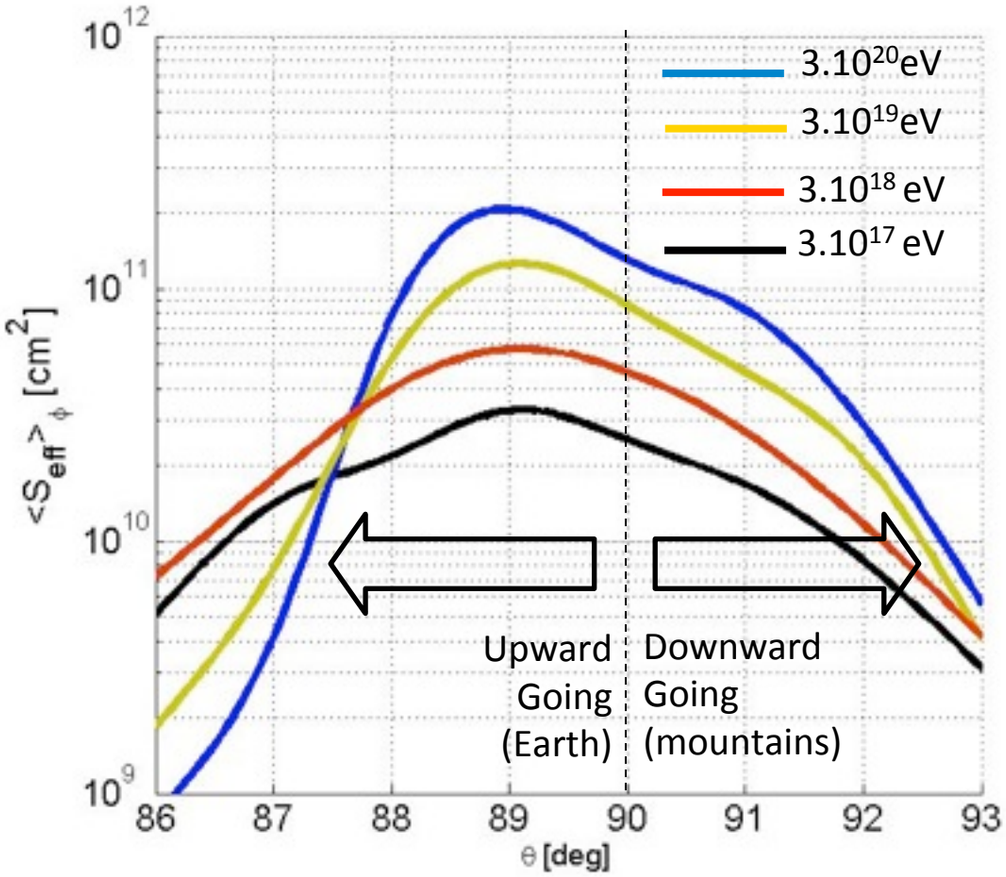
GRAND ν sensitivity preliminary study (**toy setup**)

- neutrino energy $E_\nu \sim 3\times10^{16}$ -10^{21} eV
  neutrino arrival direction: zenith angles θ~[85-95°]



- MC simulations down to τ decay
- Simplified criteria for subsequent shower detection:
  - Antenna triggered if:
    - in direct view of shower
      in a light cone of few deg.
      Ω=f(E), [1-10°]
    - Tau decay point distant of [5,120] kms
  - Detection if:
    - one cluster of 8+ antennas triggered
    - Shower energy > 3×10^{16} eV -10^{17}eV

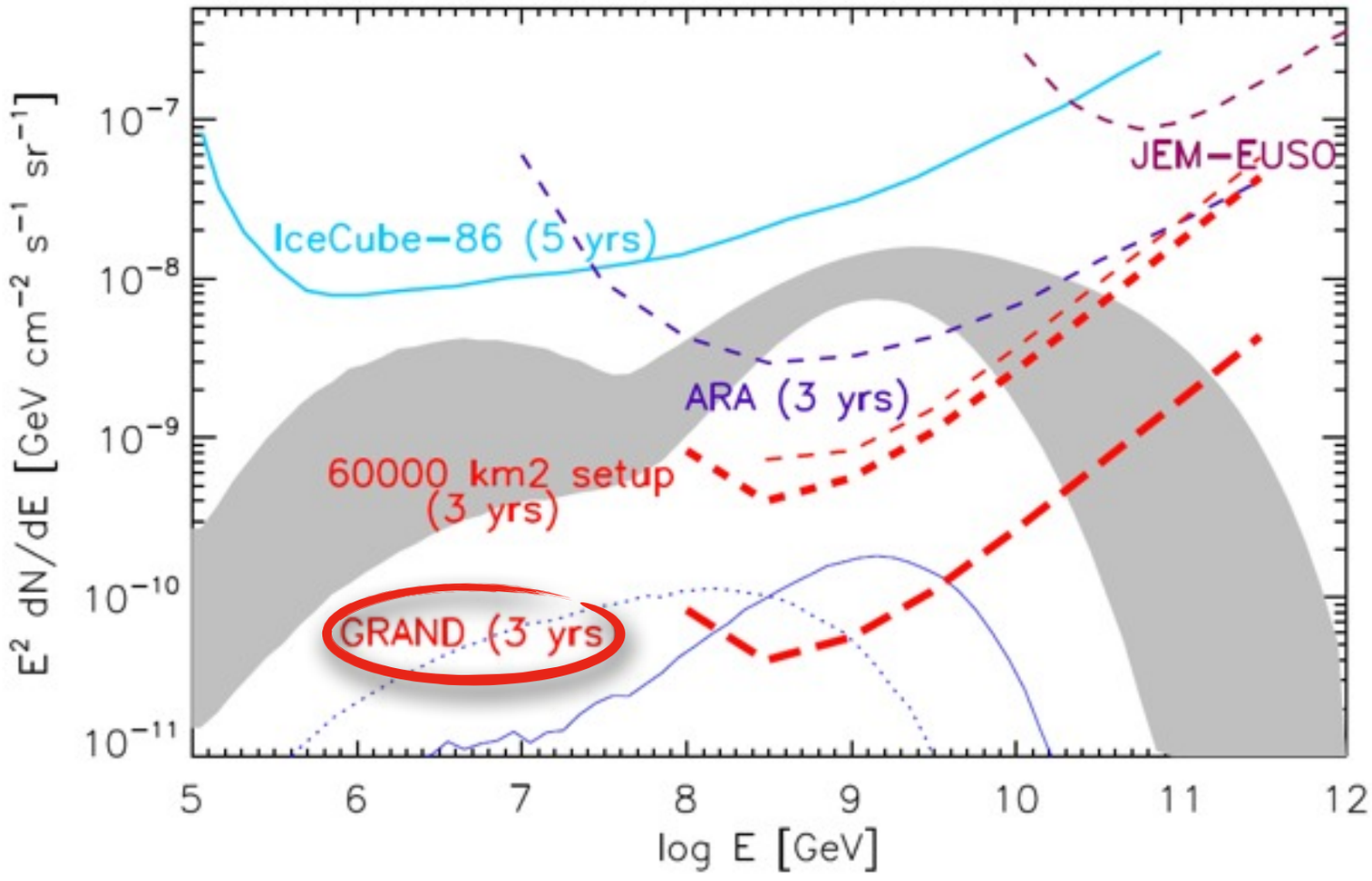
GRAND ν sensitivity preliminary study



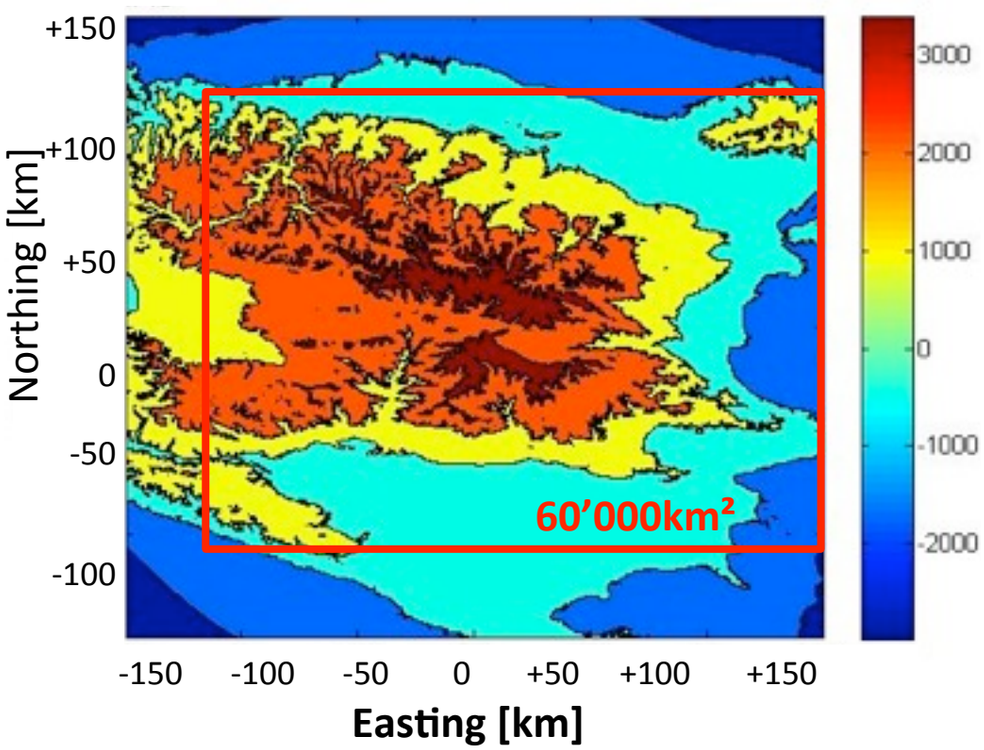
- ~ Horizontal trajectories
- Mountains are sizeable targets
- Earth becomes opaque at higher energies

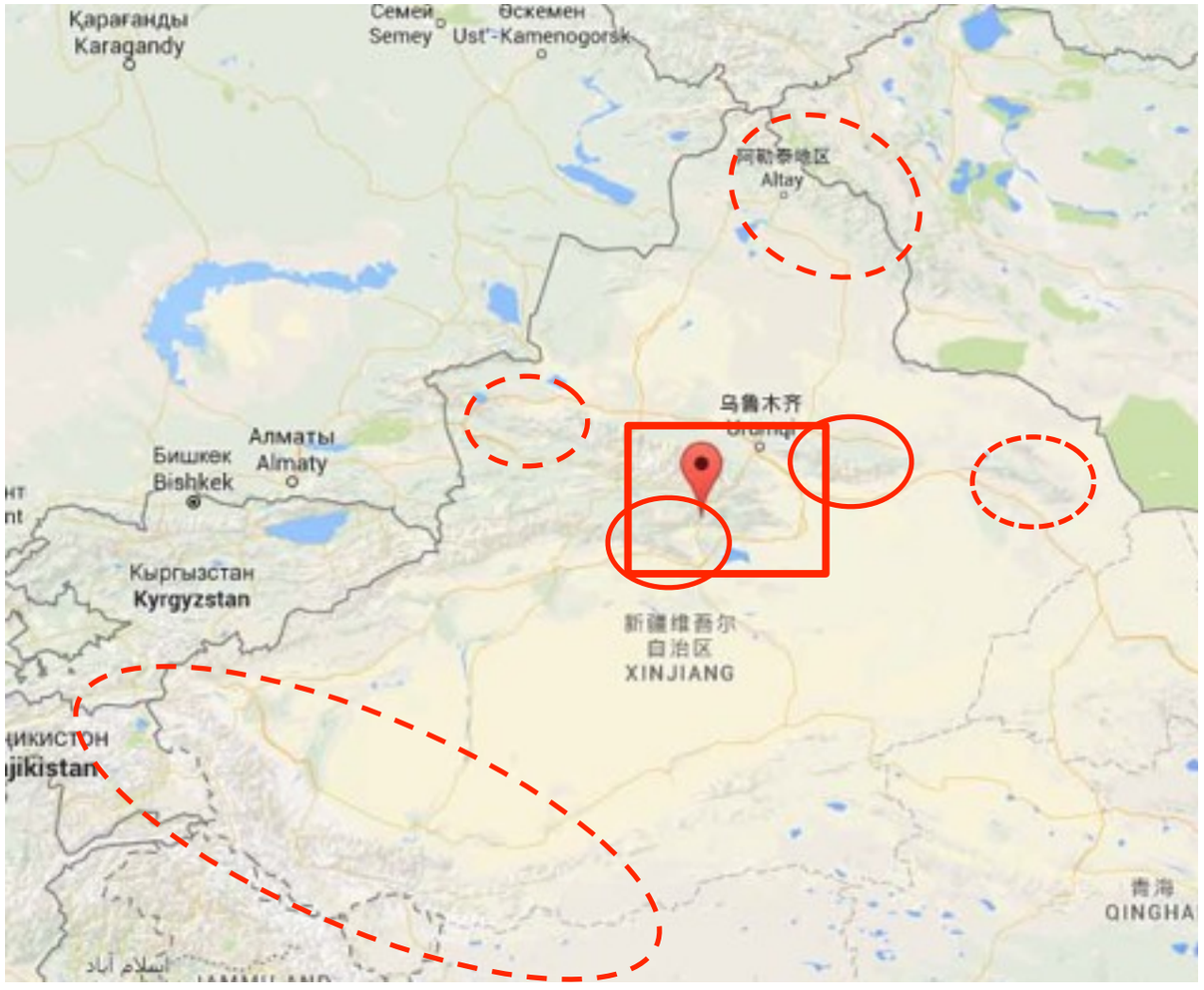
Toy setup:
factor 3 to 10 better sensitivity
compared to ARA for $E_\nu \sim 10^{17}$-10^{19} eV

envisioned GRAND



GRAND 200'000 km^2 layout





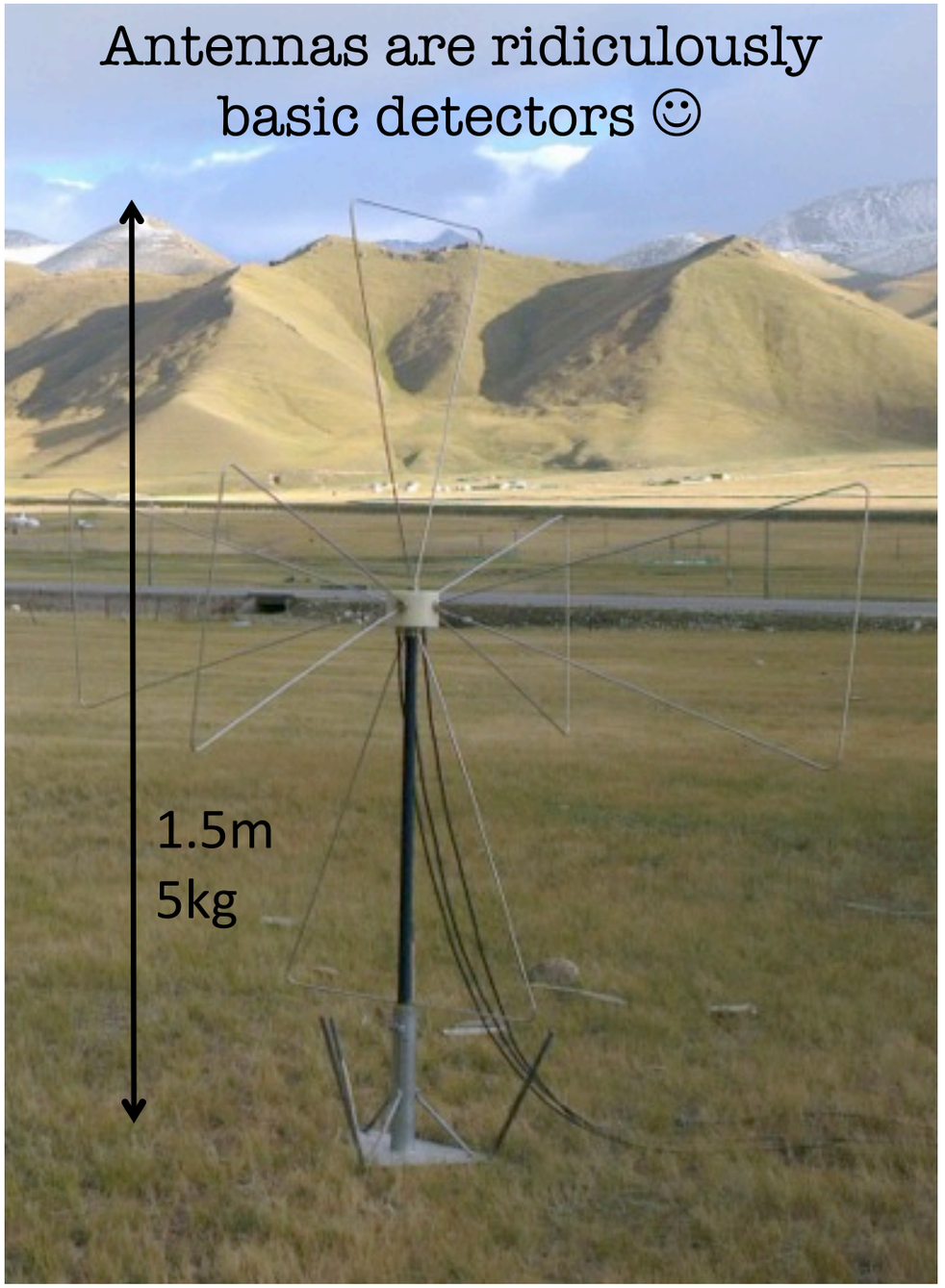
- "Hotspots" with event rates well above average
- Possible strategy: deploy sub-arrays on hotspots only [size = o(10'000 km^2)?]
  Total detection area x3 (~200'000 km^2) should result in x10 in sensitivity
- Sub-arrays could be separated by large distances…
  and very well be on different continents!
- Strategy to be validated/refined through MC

Challenges: antenna deployment

- How realistic/affordable is it to deploy, run & maintain a 200'000 antenna array?
- Possible answer: keep it as basic as possible!
  - Basic (analog) trigger (T0) on transient signal
  - Record 4 words/trigger
    [Max amplitude x 3 channels + trig time by GPS]
  - Rely on commercial solutions for electronics & data transfer

- <1W & <200$ / antenna achievable.
- … Probably not as crazy as it first sounds!

Science Case definition could interfere (see next)



Challenges: background rejection

HE muons

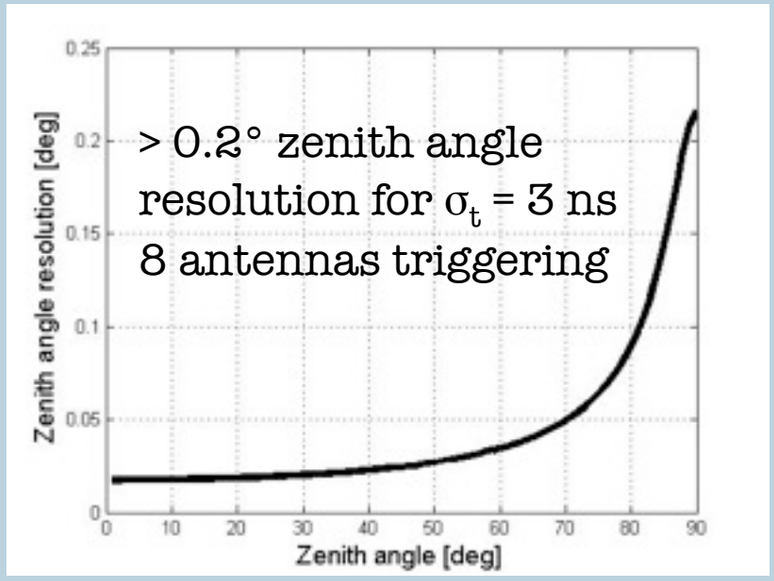
Chirkin (2004): 3×10^{-6} decays/yr over full array above 10^{16} eV

atmospheric neutrinos

negligible > 10^{16} eV

standard cosmic ray air-showers

- Cut 1° below horizon (mountains!)
- 1° --> 5σ for 0.2° angular resolution
  --> 5×10^{-7} suppression factor
- Affects marginally detection efficiency: <10%



terrestrial background

from the TREND experiment (2009-2014, *Martineau et al. 2010*):
~ 3×10^8 events/year (?)

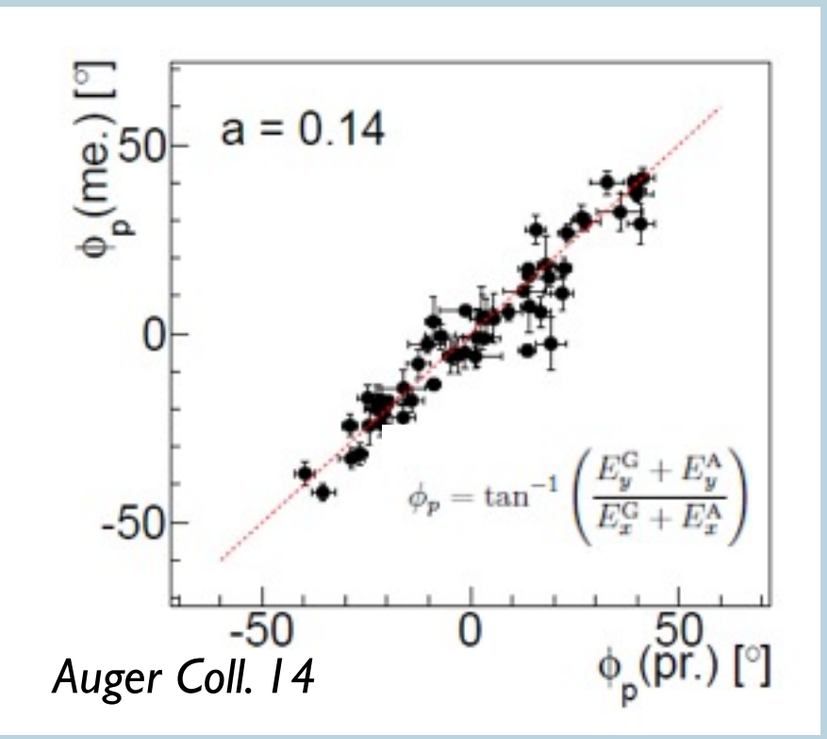
Terrestrial background
3×10^8 events/year (?)

- Neutrino signal: 0-100 events/year

⇨ Rejection factor: R~10^9

Discriminating parameters

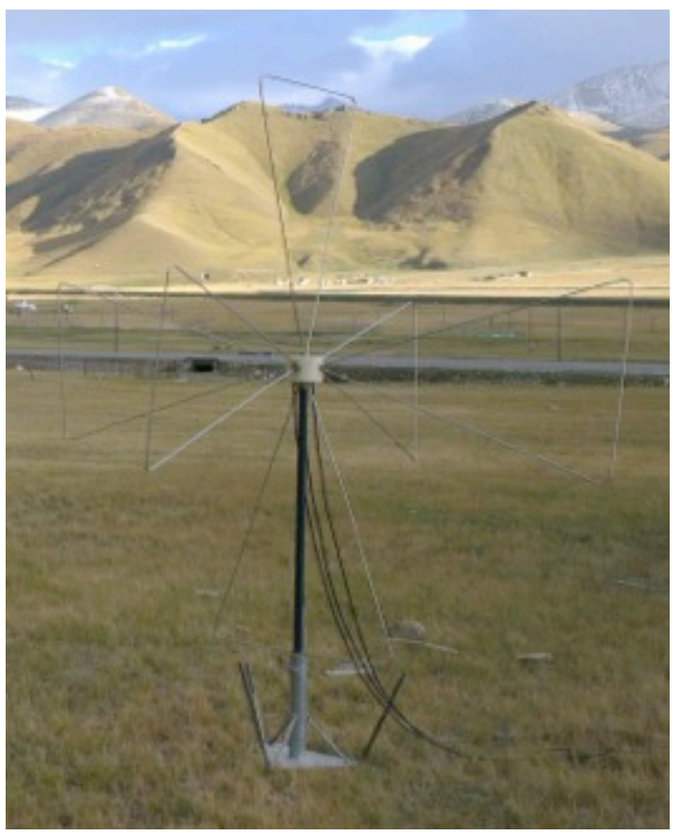
Trigger pattern at ground? Polarisation?

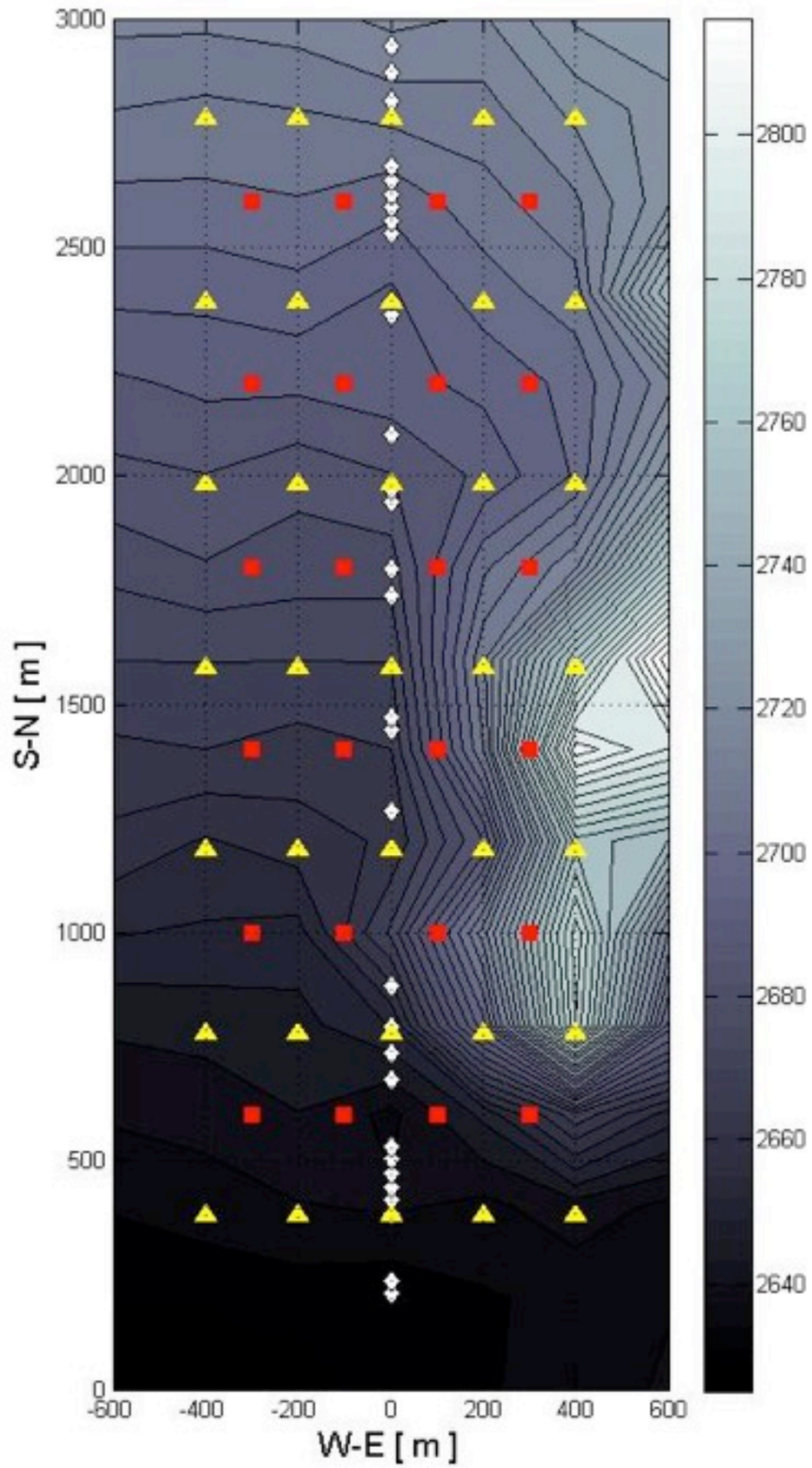


Auger Coll. 14

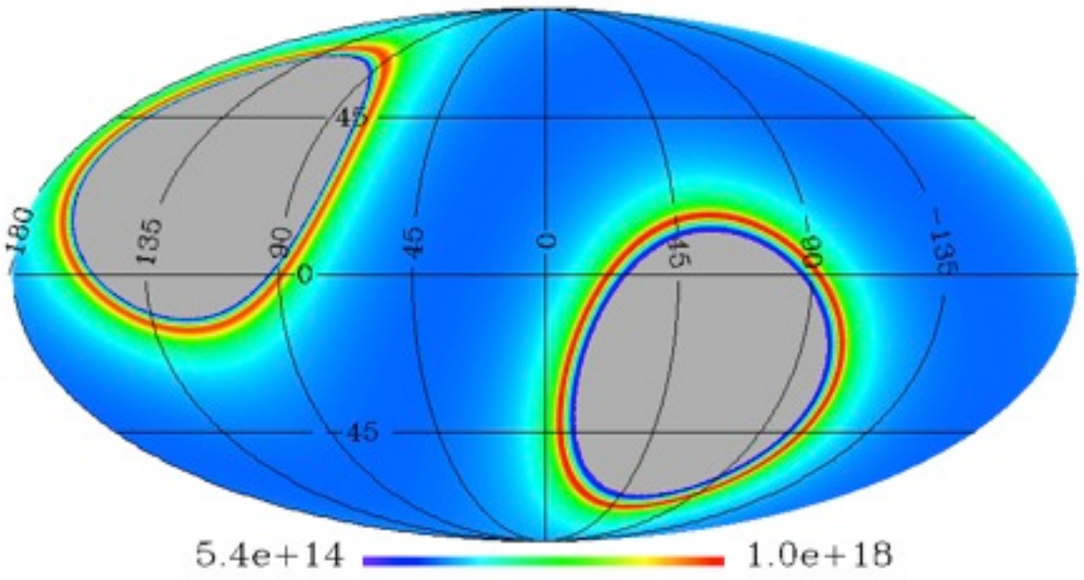
GRANDproto

- Hybrid setup with 35 3-polar antennas + 24 scintillators
- Target: (standard) air showers coming from North with $40° < \theta < 70°$
- Principle: select radio candidates from polar info, use scintillator array as a cross-check
  --> qualitative determination of rejection factor
- Deployment on-going, to be completed before June 2016
- Proposal to perform similar tests @ AUGER-AERA





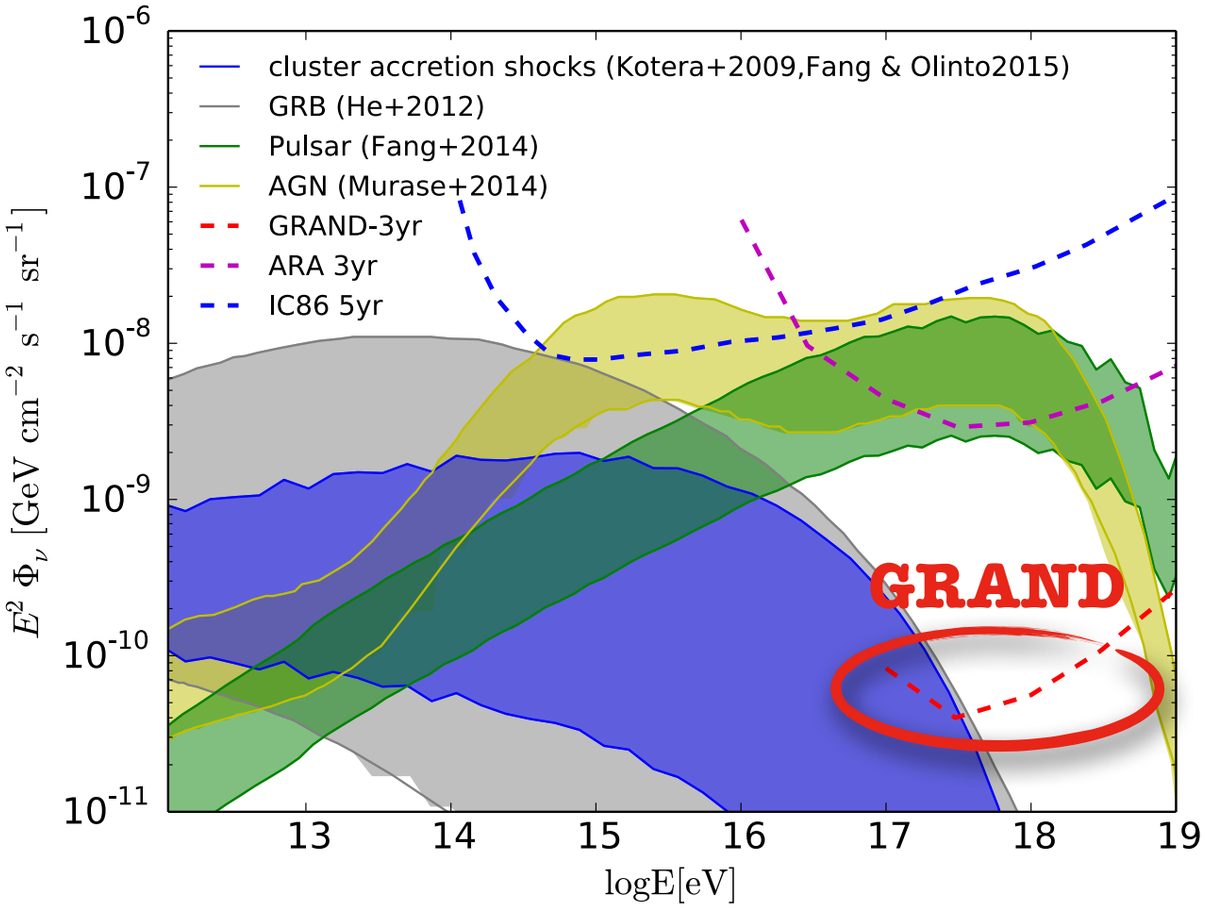
Neutrino astronomy and other Science Cases with GRAND



integrated exposure map GRAND test setup

E=$10^{18\text{-}18.5}$ eV, Galactic coordinates, 3 yrs, in cm^2s

by F. Oikonomou



expected neutrino fluxes directly from sources

by K. Fang

- **ν** sensitivity + angular resolution <0.1° would launch neutrino astronomy @VHE
- Huge effective area + performances for EAS reconstruction: great tool for UHECR physics above 10^{19} eV
- Epoch of reionization (?)
- Fast Radio Bursts (?)

Science case to be defined in more details!
Work in progress.

Perspectives

- GRAND: a dream tool for multi-messenger astronomy at VHE
- GRAND proposal being set-up (science case + ν sensitivity)
- Possible timeline:
  - 2016: proposal
  - 2018: engineering array (o(1000km^2))
  - 2021: GRAND deployment
- Join us! ☺

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KIAA Workshop 28/09/15