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- **UHECR sources** (clusters)

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it is NOT the end of the world at all!

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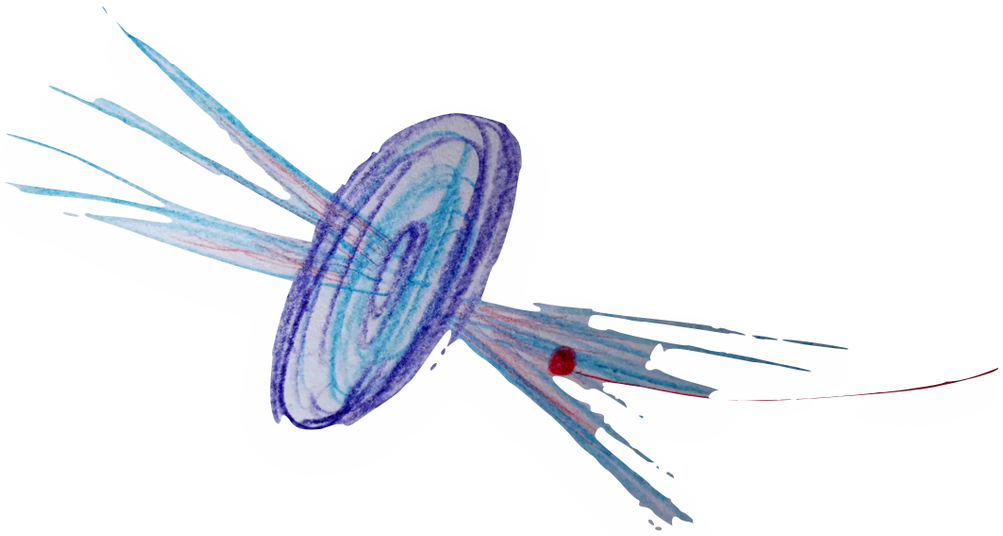

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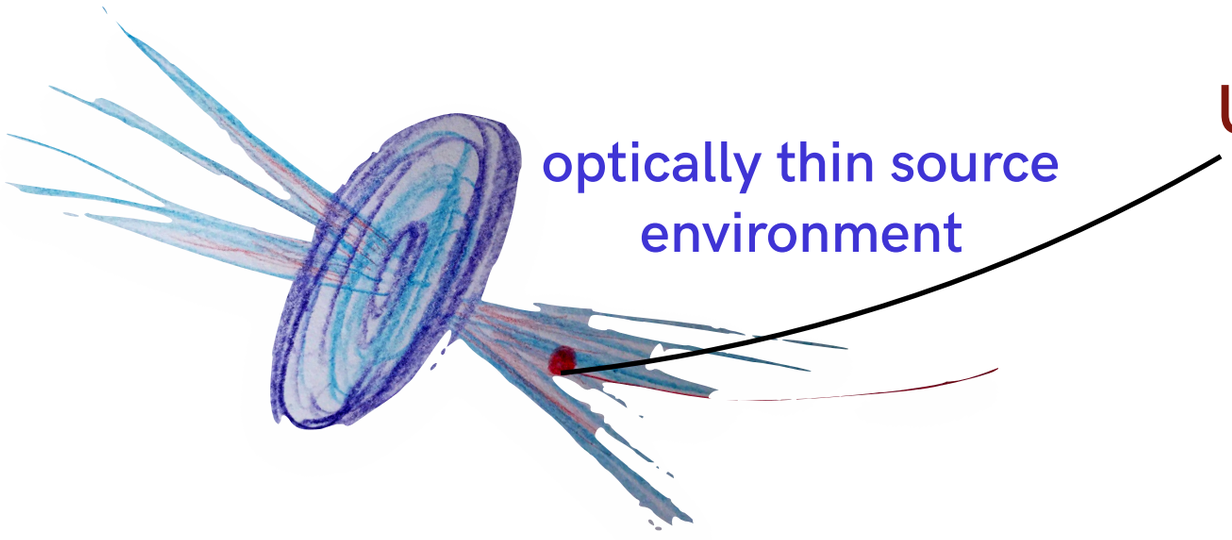

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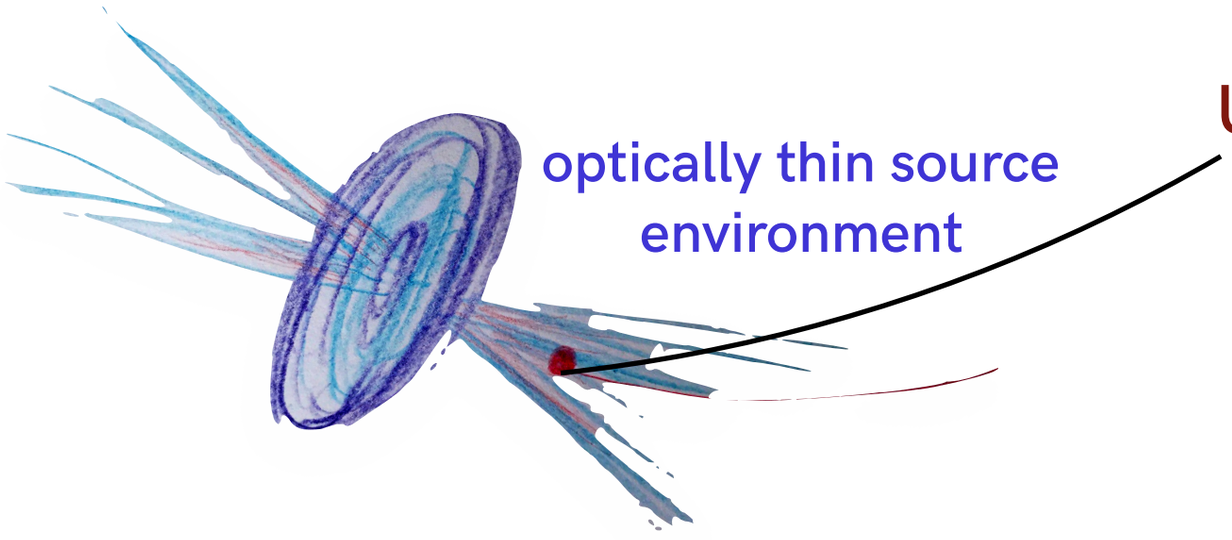

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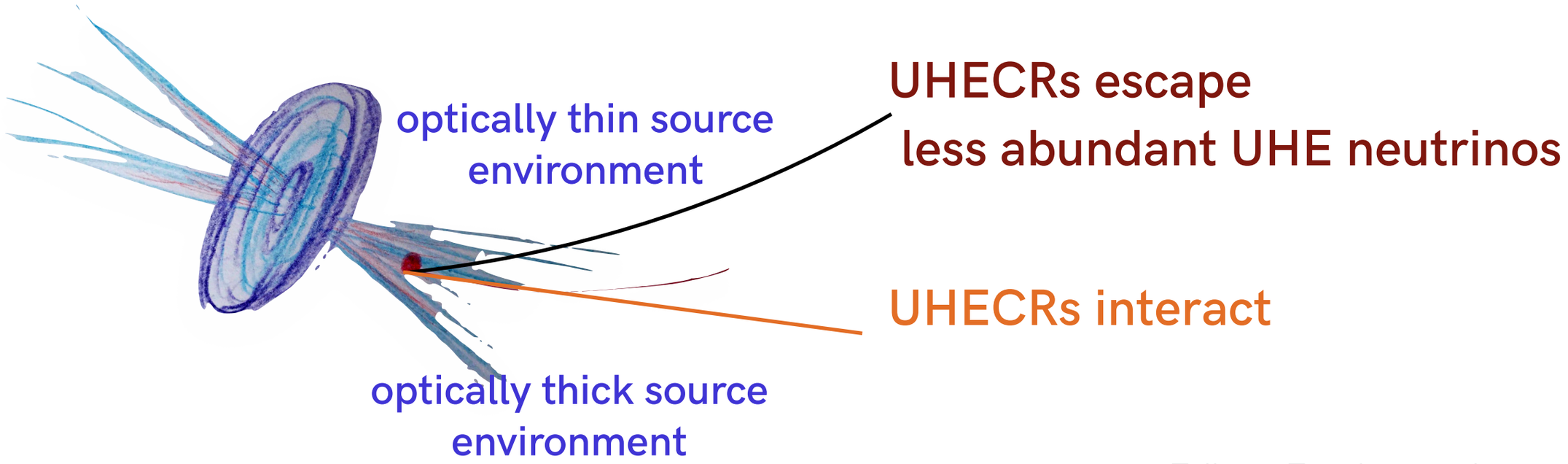

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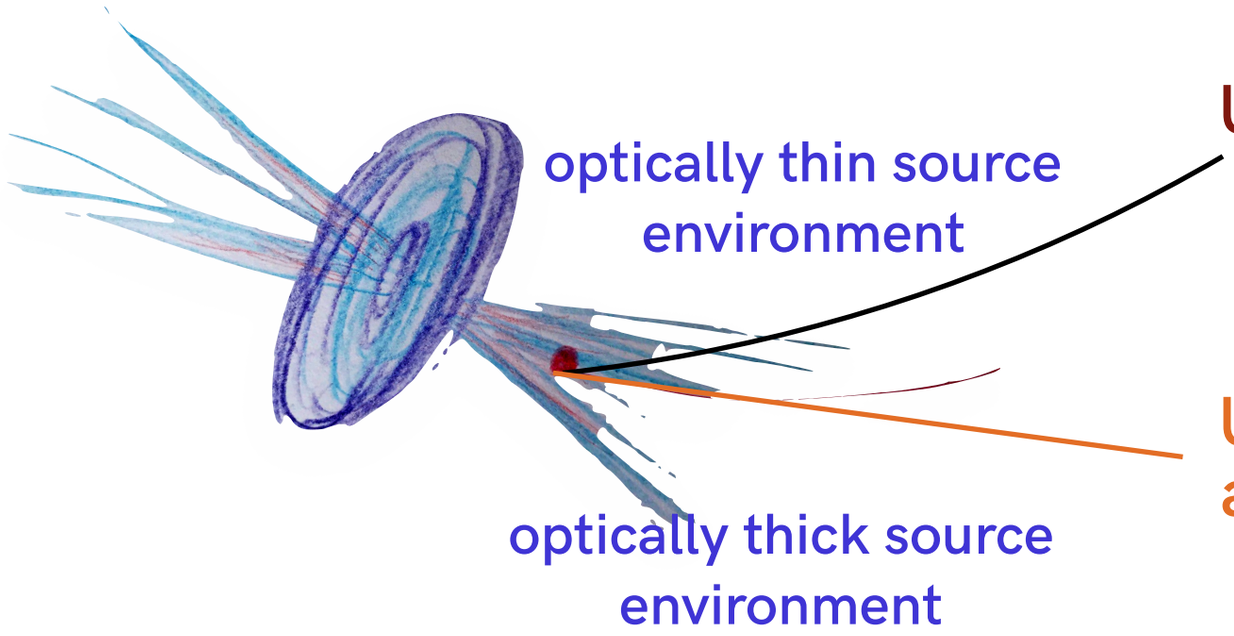

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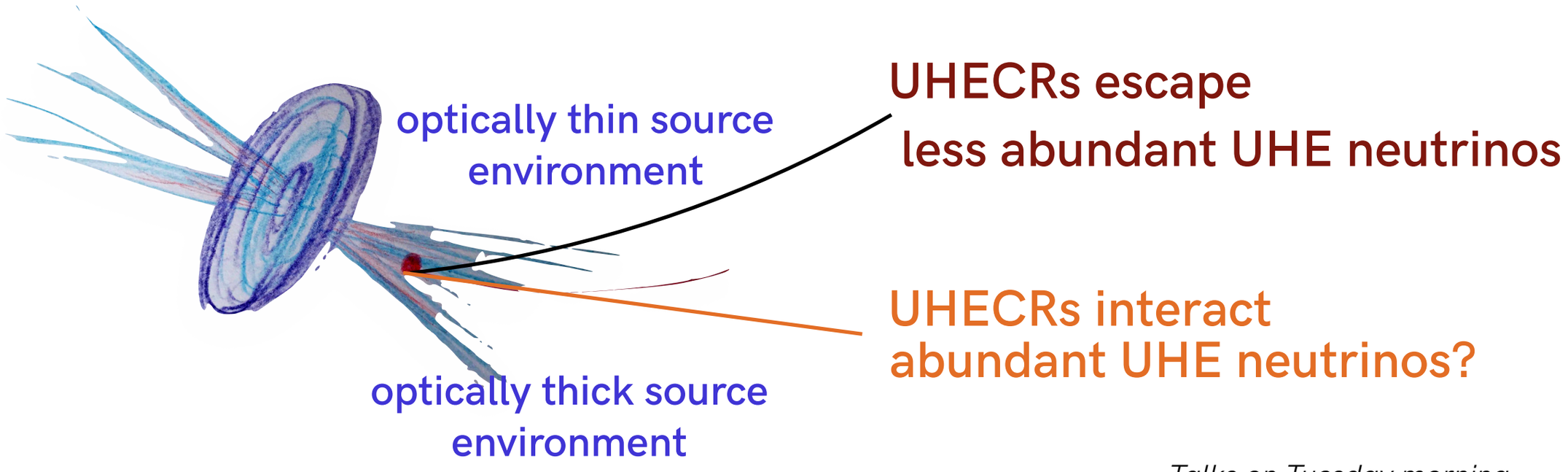
if measured **UHECR composition** heavy

UHE neutrino astronomy completely possible



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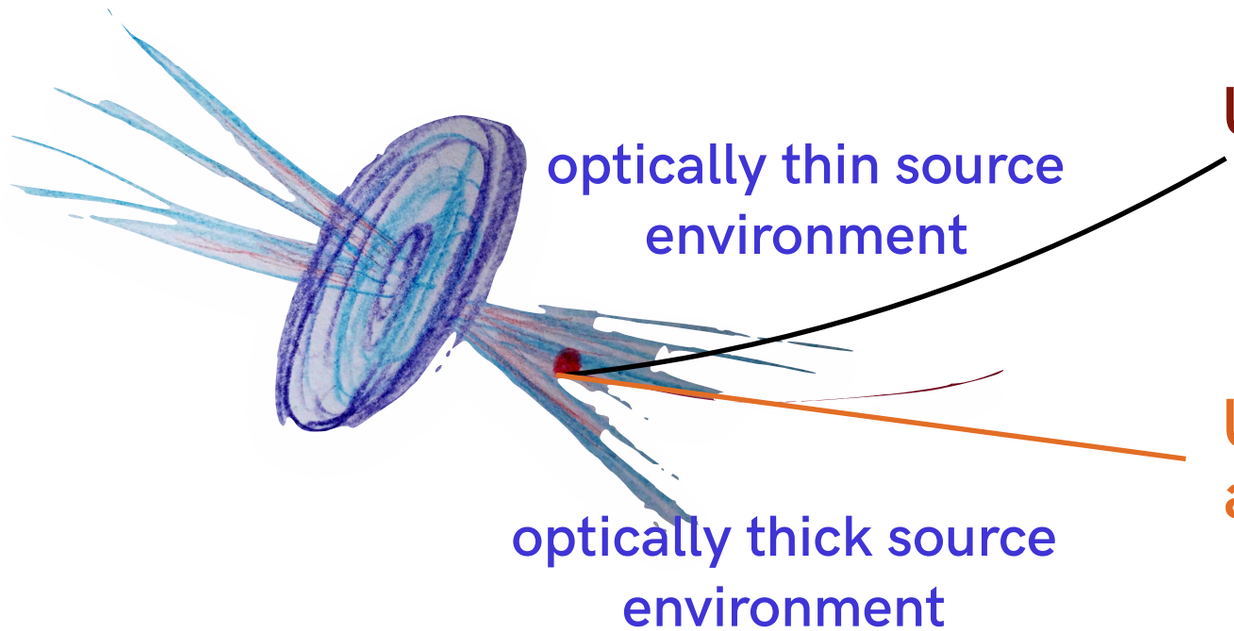
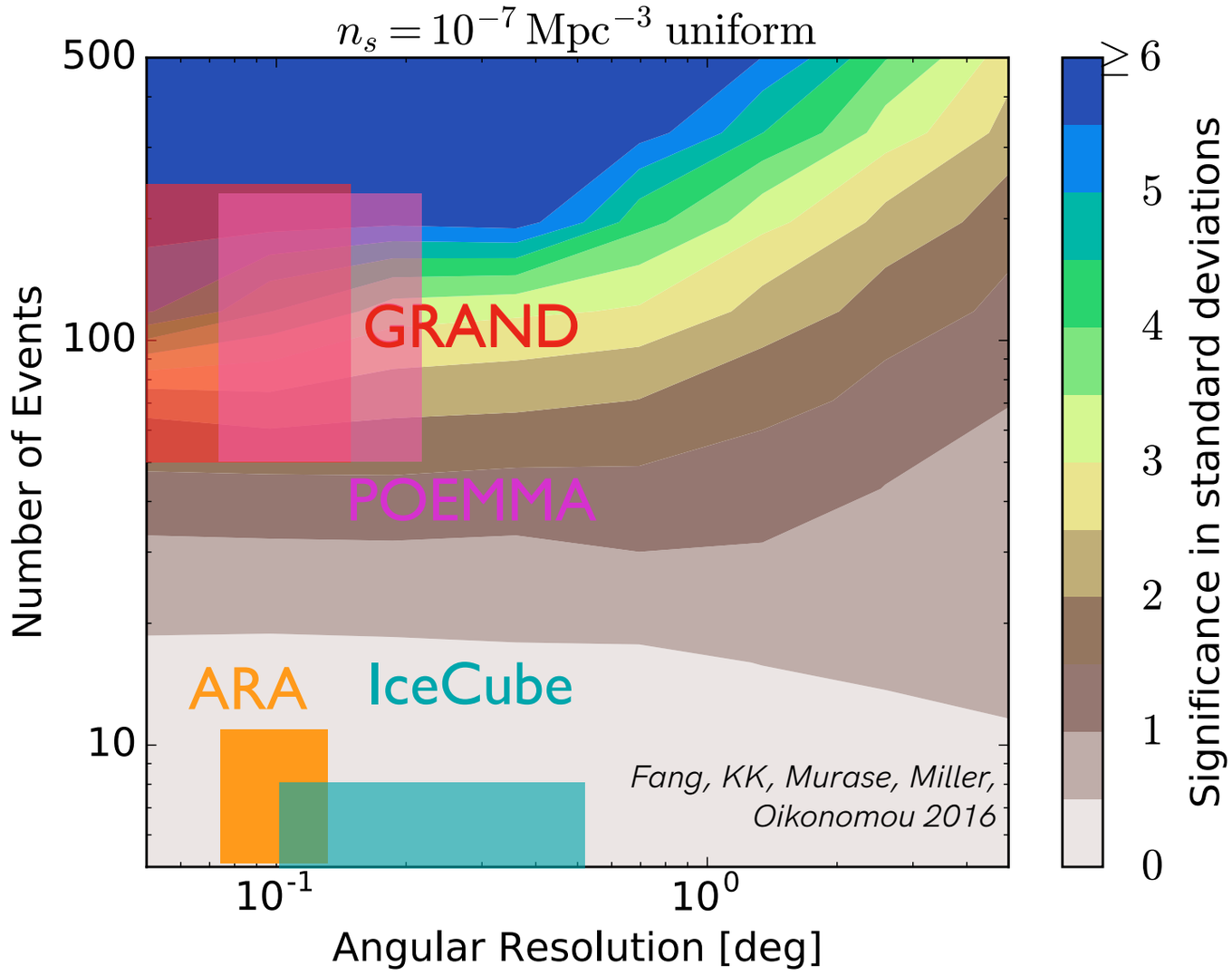


Talks on Tuesday morning (Kimura, Decoene, Guépin —> neutrino production in various sources)

Can we hope to detect very high-energy neutrino sources?

Neutrinos don't have a horizon: won't we be polluted by background neutrinos?

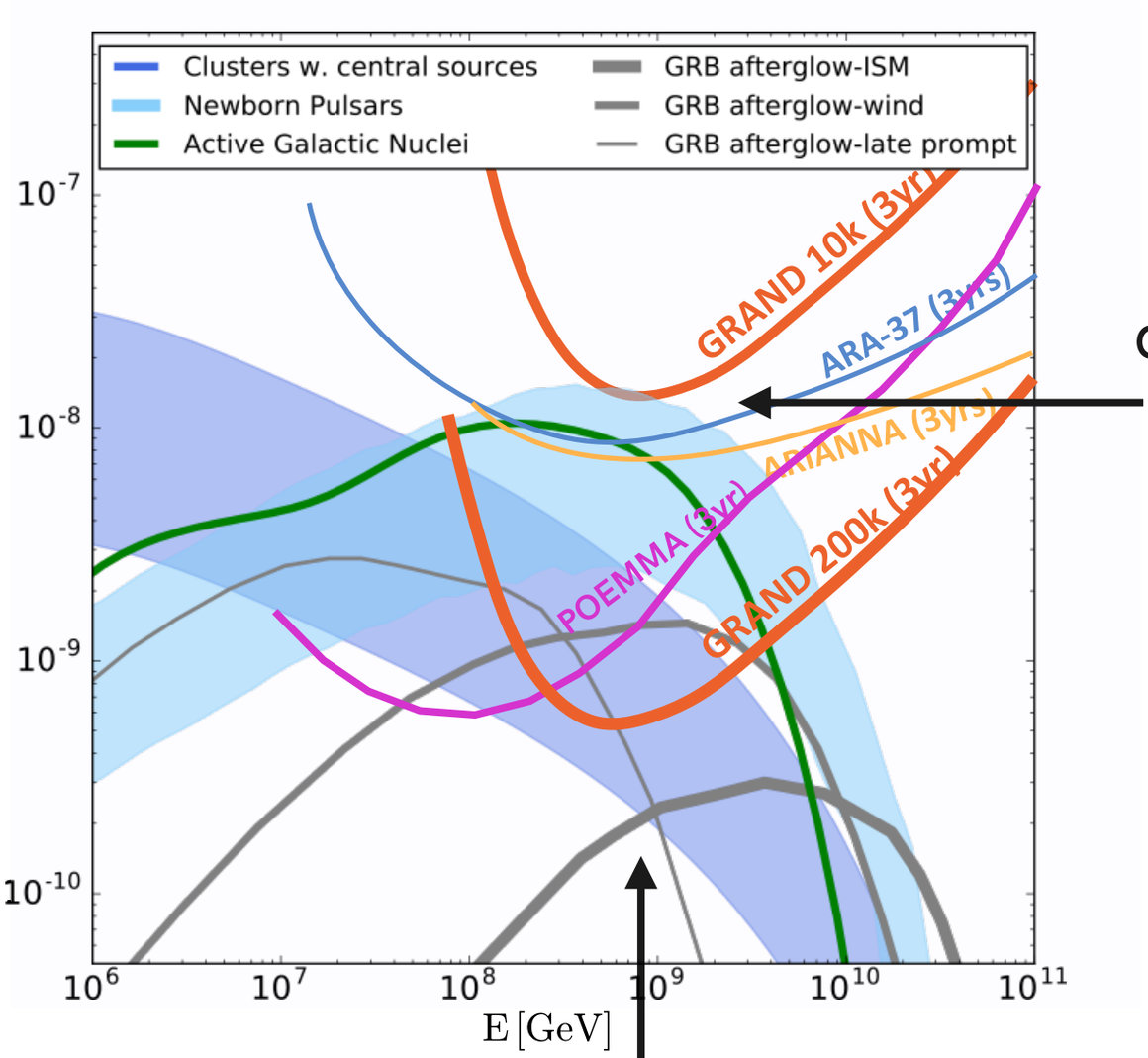


boxes for experiments assuming neutrino flux: 10^{-8} GeV cm^{-2} s^{-1}

YES if

- good angular resolution (< fraction of degree)
- number of detected events > 100s

What we can aim to do
with future observatories

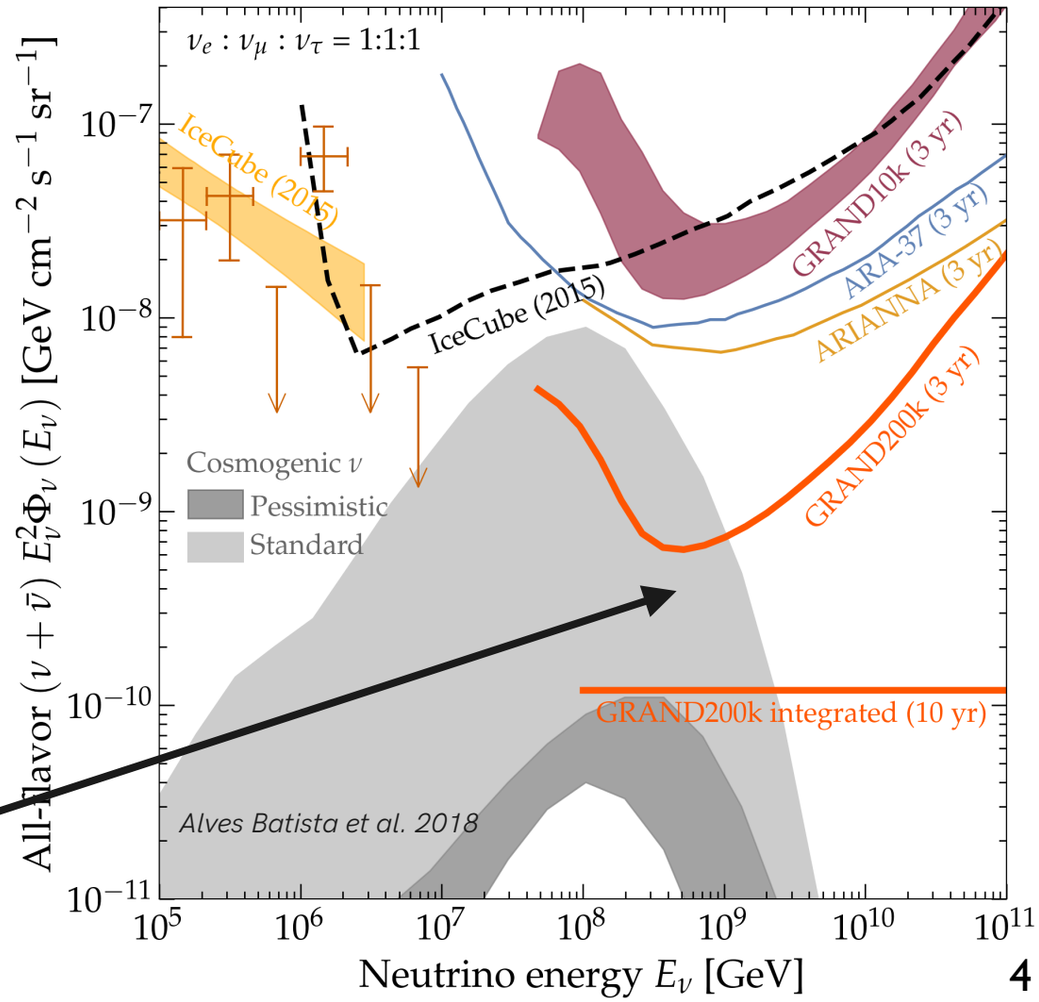


detect the first EeV neutrinos

detect EeV neutrino **point sources**

100s of events
~0.3° angular resolution

detect **cosmogenic** neutrinos



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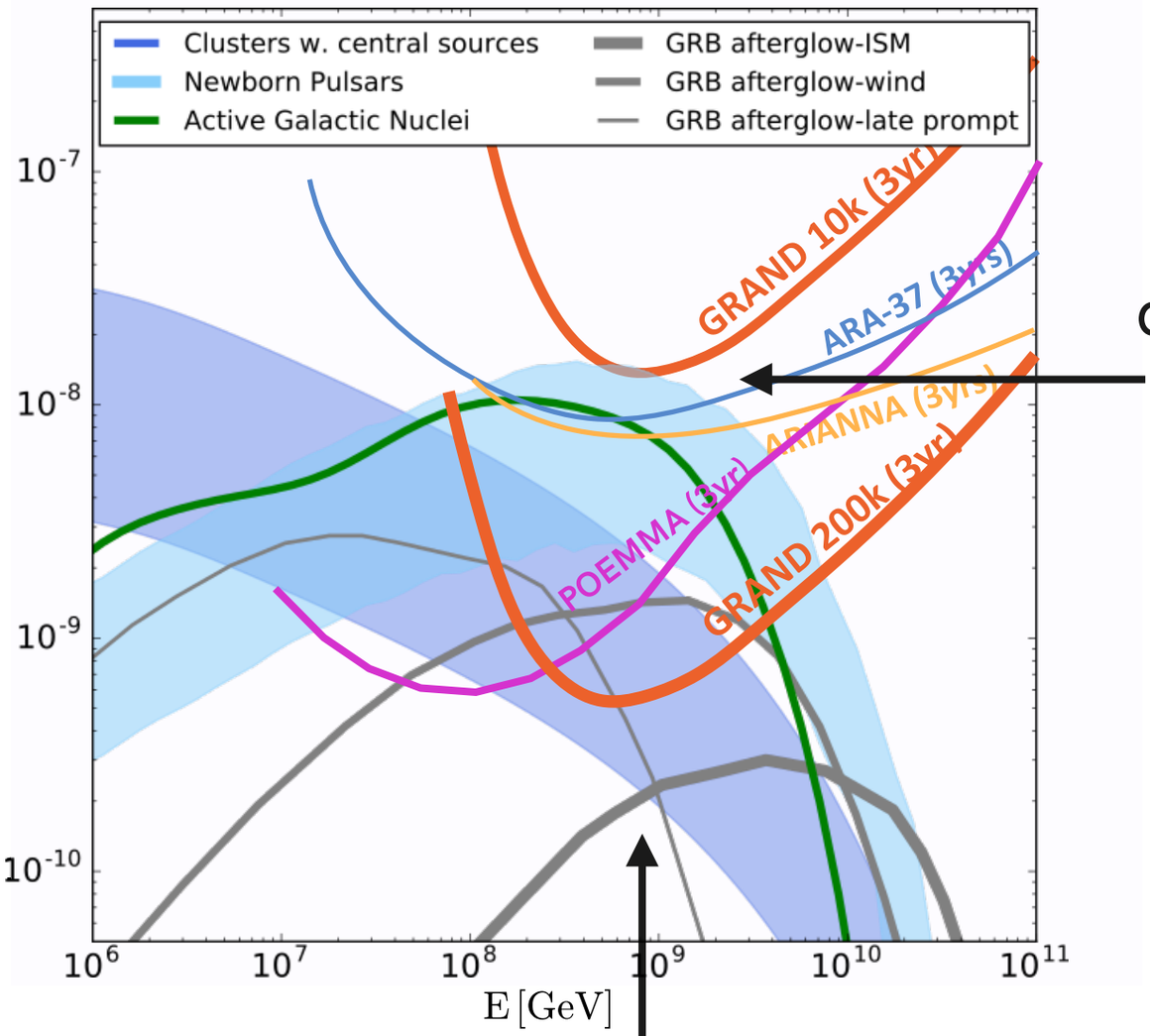

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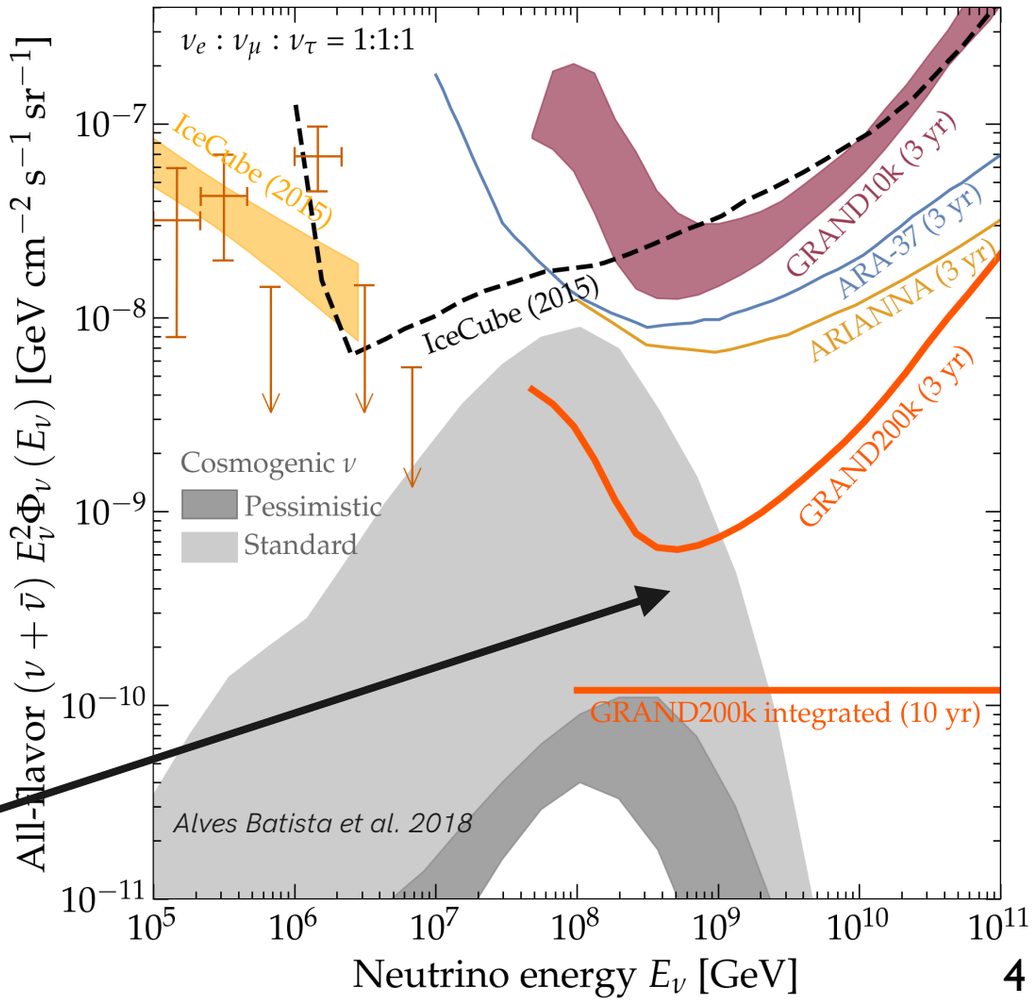
cosmogenic:
guaranteed

direct from source:
likely more abundant

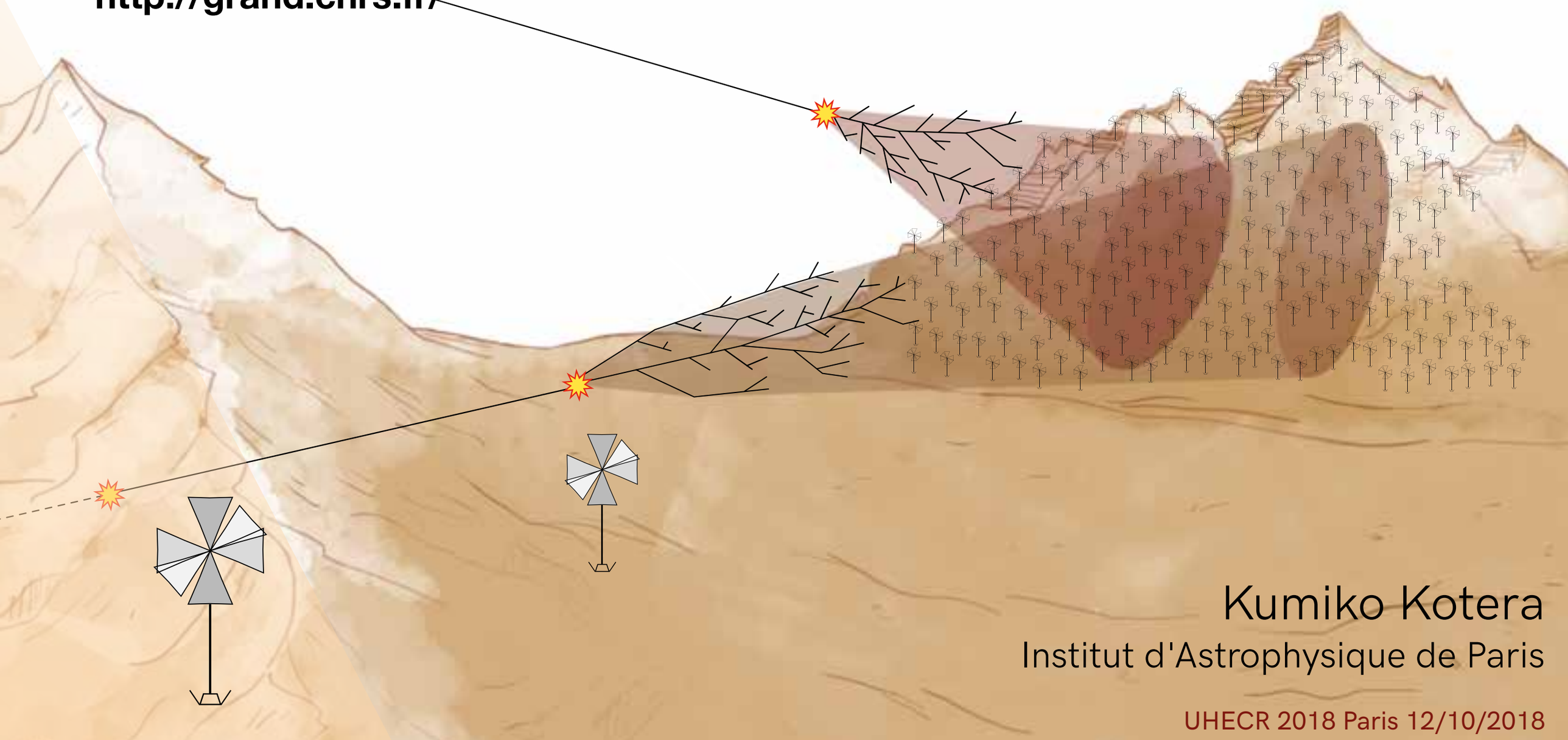
pessimistic scenarios
of cosmogenic neutrinos = good!

low background for source neutrinos
talk by Heinze Tuesday PM



The Giant Radio Array for Neutrino Detection

http://grand.cnrs.fr/



Kumiko Kotera

Institut d'Astrophysique de Paris

UHECR 2018 Paris 12/10/2018

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- in an ideal world, projects like the giant air-shower array (J. Hörandel), GCOS (R. Engel) and GRAND should work together to try to solve issues related to building giant arrays.
In ~2025: we should see where/how we can get funding and merge everything…

A staged approach with self-standing pathfinders

Olivier's talk Friday morning

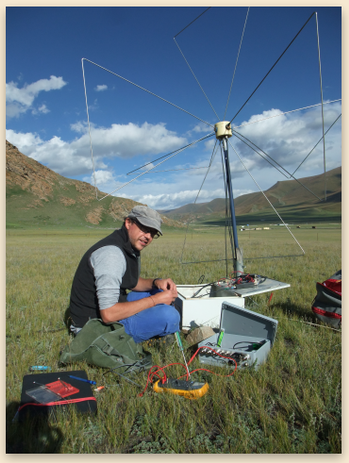
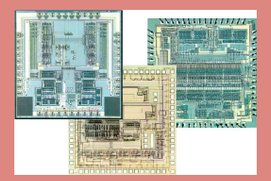
GRANDProto300

GRANDProto35

GRAND10k

GRAND200k

2018 2020 2025 203X

	GRANDProto35	GRANDProto300	GRAND10k	GRAND200k
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 km² • Fast DAQ (AERA+ GRANDproto35 analog stage) • Solar panels (day use) + WiFi data transfer • Ground array (a 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
Budget & stage	160k€, fully funded by NAOC+IHEP, deployment ongoing @ Ulastai	1.3 M€ to be deployed in 2020	1500€ / detection unit 	Industrial scale allows to cut down costs: 500€/unit ➔ 200M€ in total  ASIC Cost ~10M€ ➔ few 10€/board Consomption < 1W Reliability

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GRANDProto300

GRANDProto35 | GRAND10k | GRAND200k

2018 → 2020 → 2025 → 203X

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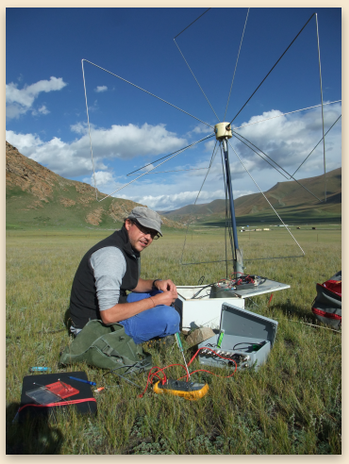
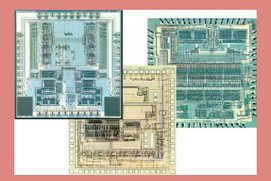
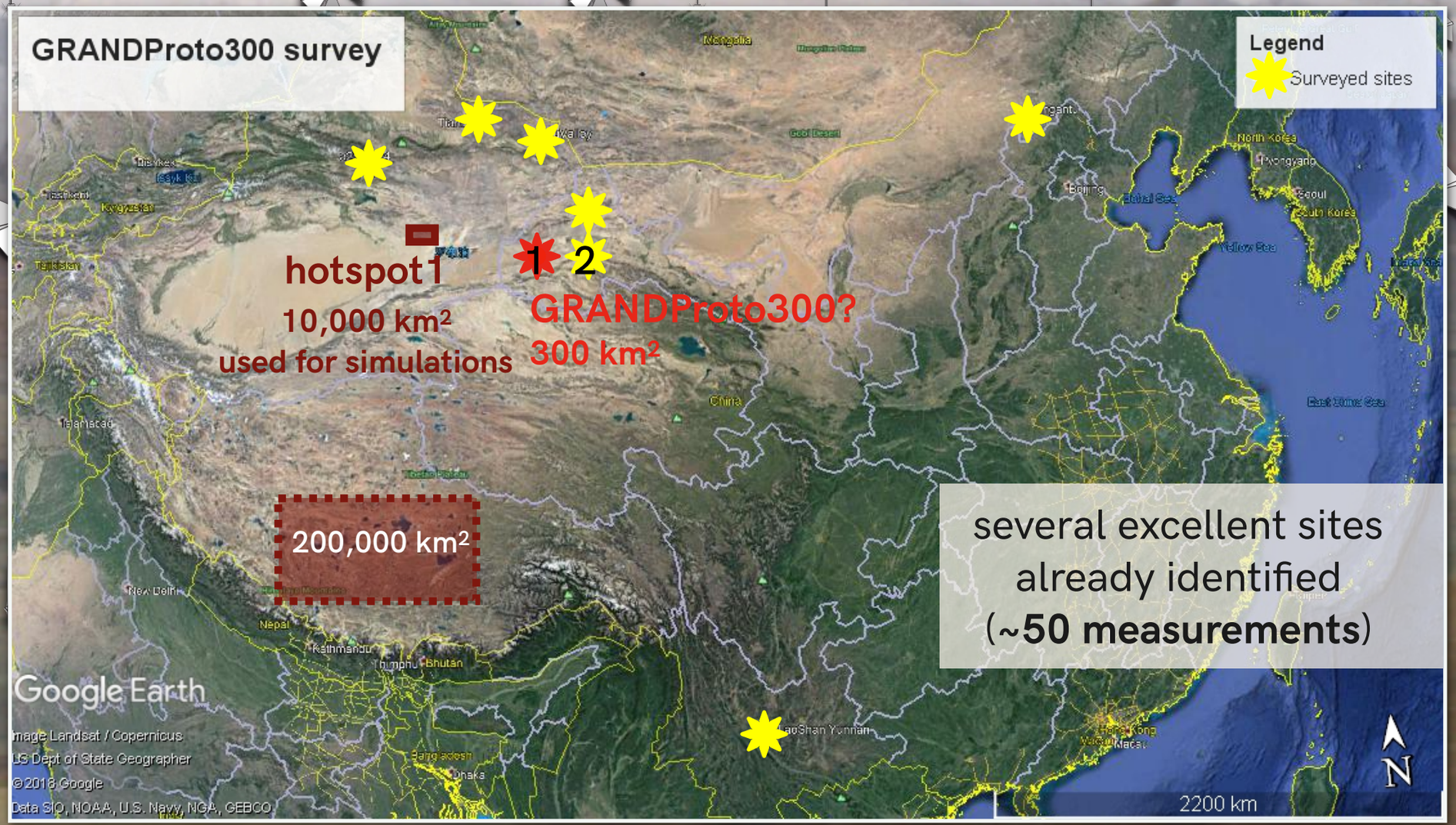
Setup	35 radio antennas 21 scintillators 	• 300 HorizonAntennas over 300 km² • Fast DAQ (AERA+ GRANDproto35 analog stage) • Solar panels (day use) + WiFi data transfer • Ground array (a la HAWC/Auger)	DAQ with discrete elements, but mature design for trigger, data transfer, consumption	200,000 antennas over 200,000 km², ~ 20 hotspots of 10k antennas, possibly in different continents
Budget & stage	160k€, fully funded by NAOC+IHEP, deployment ongoing @ Ulastai	1.3 M€ to be deployed in 2020	1500€ / detection unit 	Industrial scale allows to cut down costs: 500€/unit ➔ 200M€ in total  ASIC Cost ~10M€ ➔ few 10€/board Consomption < 1W Reliability

The GRAND Concept

200,000 radio antennas over 200,000 km²
~20 hotspots of 10k antennas
in favorable locations in China & around the world

- ✓ Radio environment: radio quiet
- ✓ Physical environment: mountains
- ✓ Access
- ✓ Installation and Maintenance
- ✓ Other issues (e.g., political)



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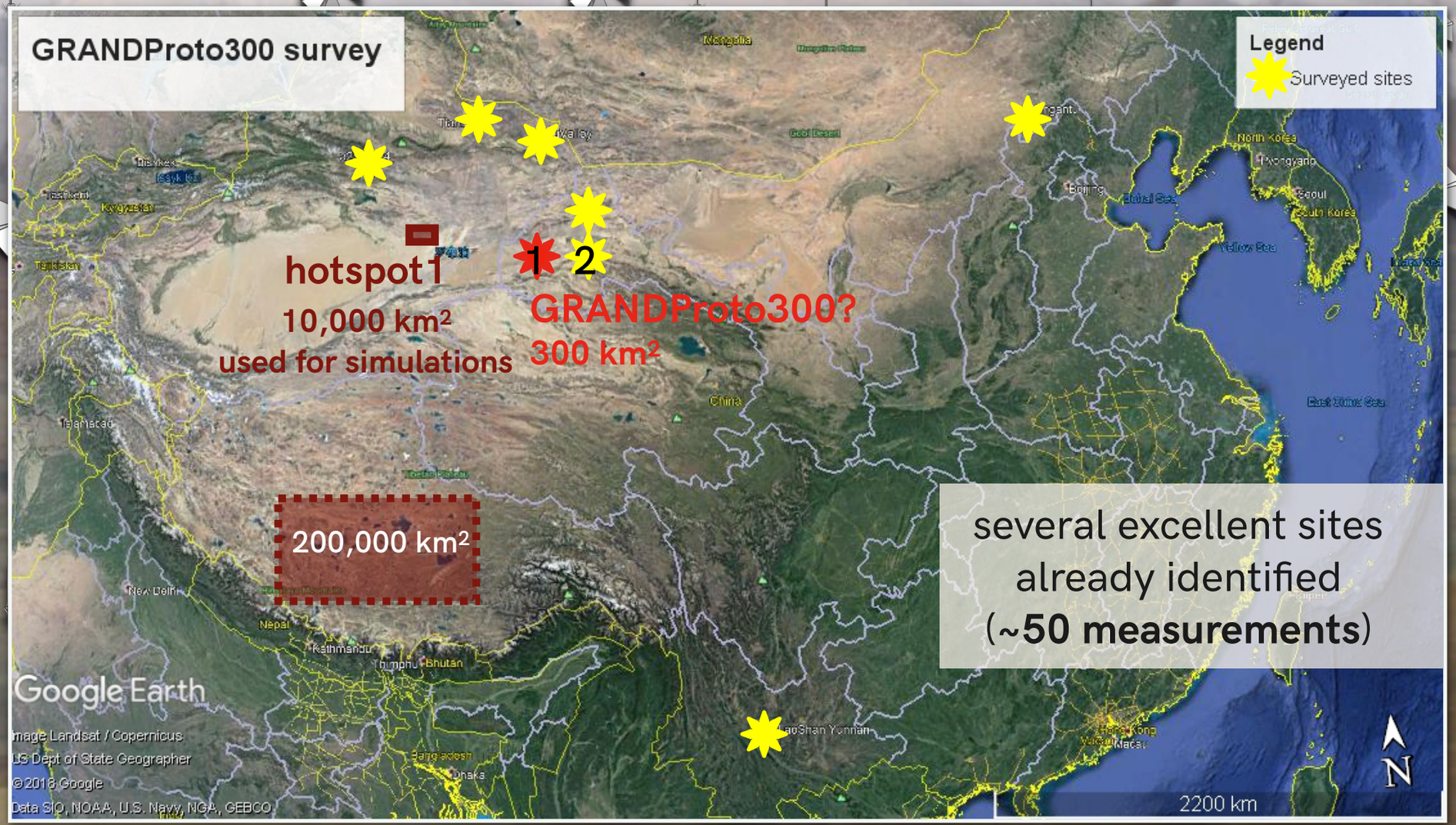
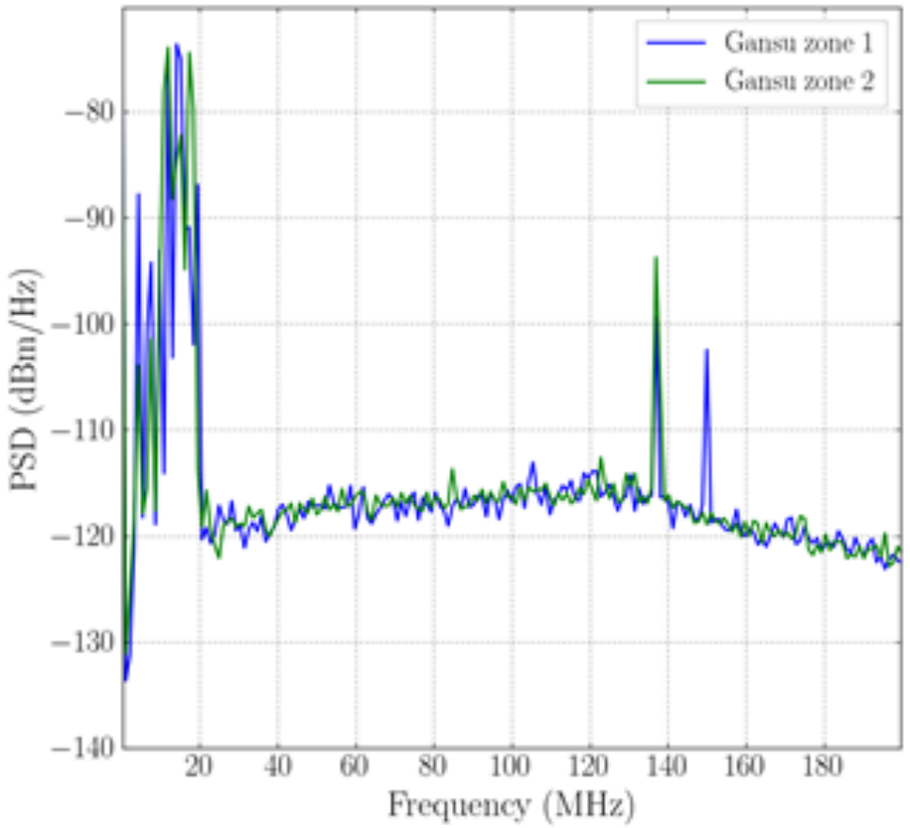
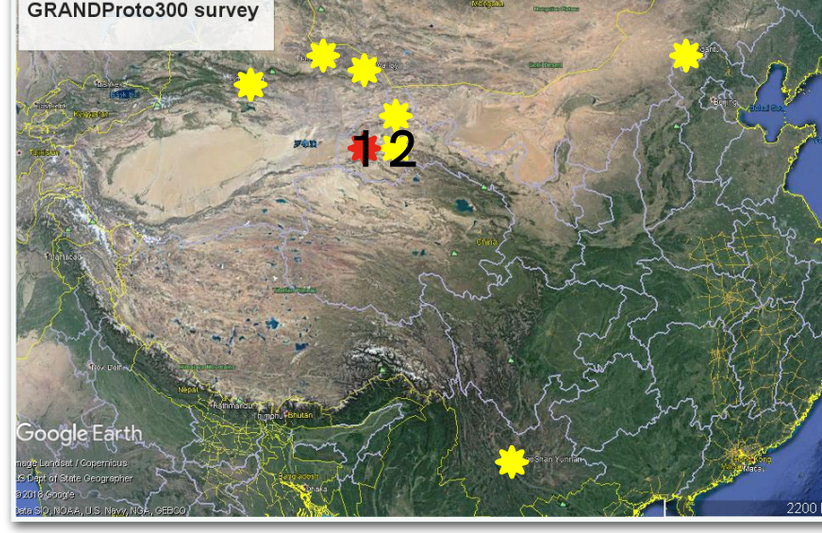


Radio environment measurements in China





Transient measurements
50-200MHz:

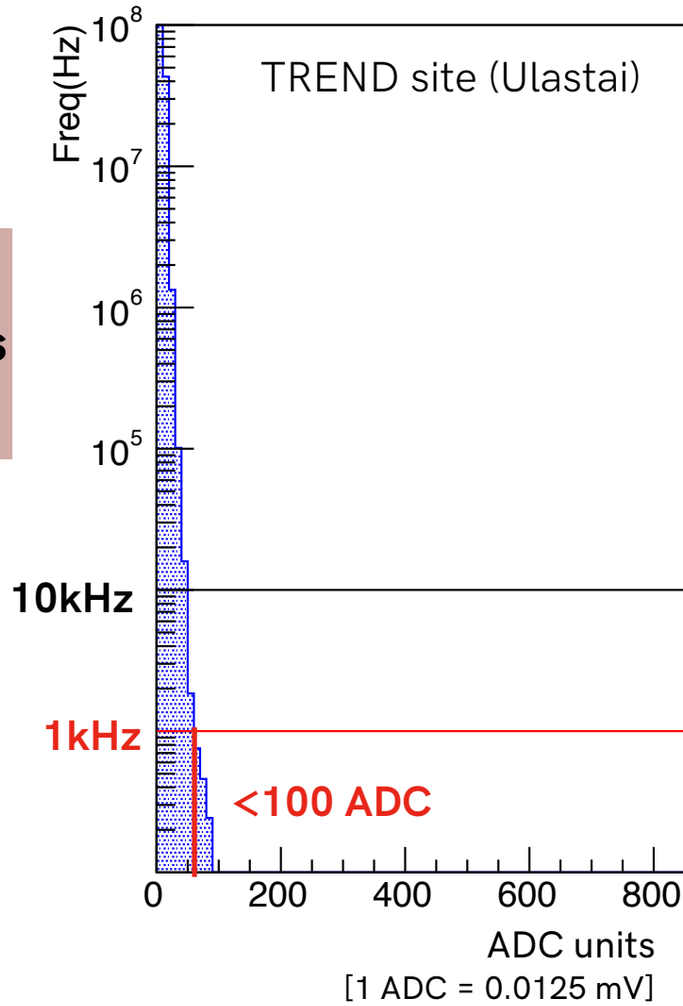
- For threshold beyond 5 x noise level, few transients left within ~20 seconds
- high trigger rates close to power line in zone 1

Frequency domain: very quiet beyond 30MHz

- ~50 measurements in 50-200 MHz range (April 2017-August 2018)
- **6 out of the 8 tested sites are very good candidates for 10k-antenna hotspots**
- deployment of several antennas next spring in Gansu Province

- How to deal with the huge transient event rate ⇔ self-triggering?
  - ➔ Surveyed sites: stationary noise within factor 2 of (irreductible) Galactic radiation and <1kHz antenna transient rate in 30-80MHz
  - ➔ Include this constraint in **DAQ design** (**100% livetime up to 1kHz transient rate**)
  - ➔ machine learning techniques (*Führer et al. arXiv:1809.01934*)

GRANDProto300 test bench

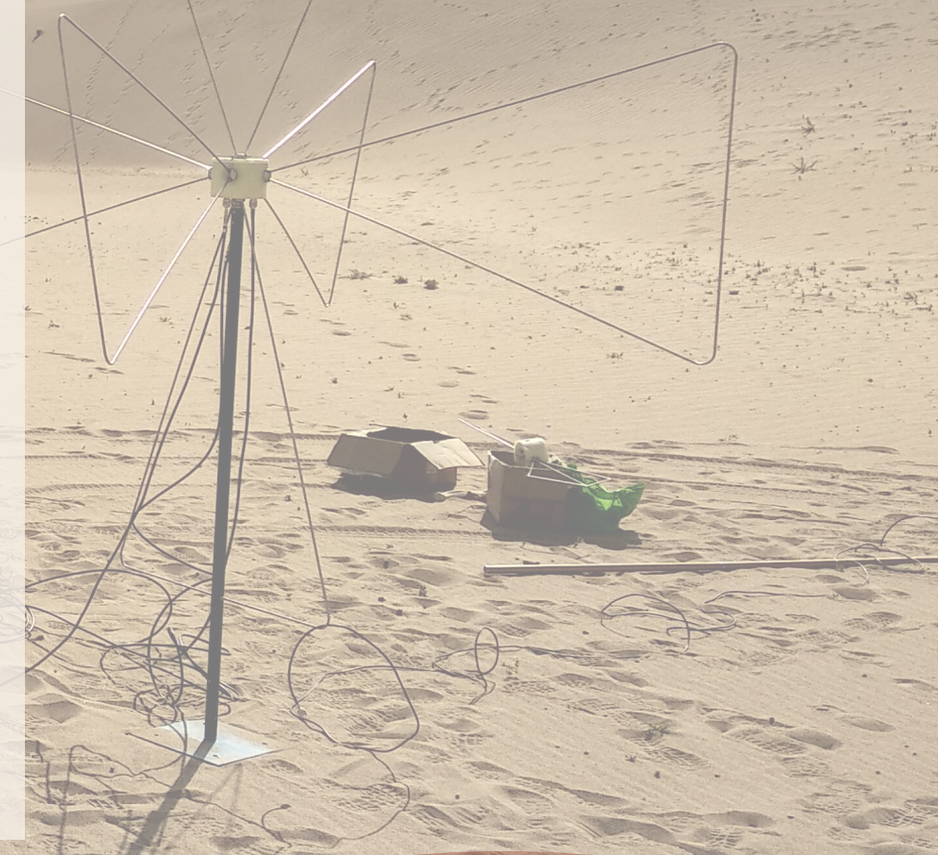


GRAND Technical Challenges

- How to collect data?
  - Optimised trigger (machine learning (?), see Führer et al. ARENA2018) to improve selection @ antenna level
  - Optimised informations to be transmitted to central DAQ
- How to identify air showers out of the ultra dominant background ?
  - Specific signatures of air shower radio signals vs background transients demonstrated (TREND offline selection algorithm: 1 event out 10^8 pass & final sample background contamination < 20%)
  - Improved setup (GRANDproto35, being deployed) should lead to even better performances
  - Deep learning techniques
- How well can we reconstruct the primary particle information
  - Simulations promising (similar performances as for standard showers) + deep learning technique

Need for an experimental setup to test and optimize techniques

GRANDProto300

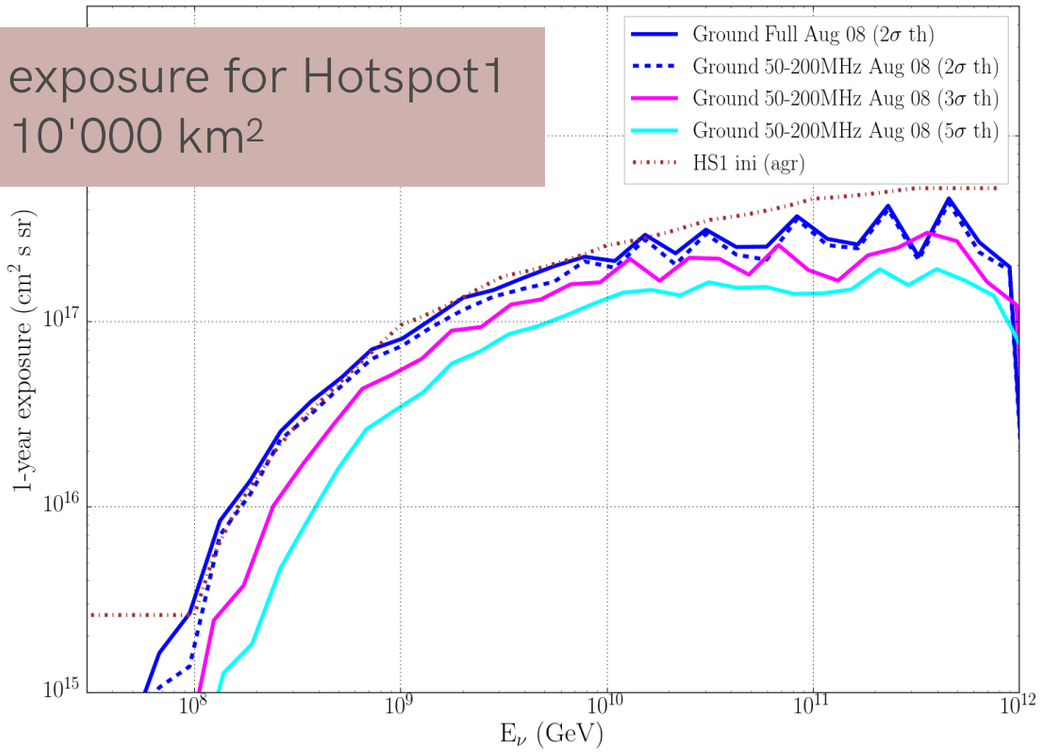


- How to deploy and run 200,000 units over 200,000km²?
- How much will it cost? Who will pay for it?

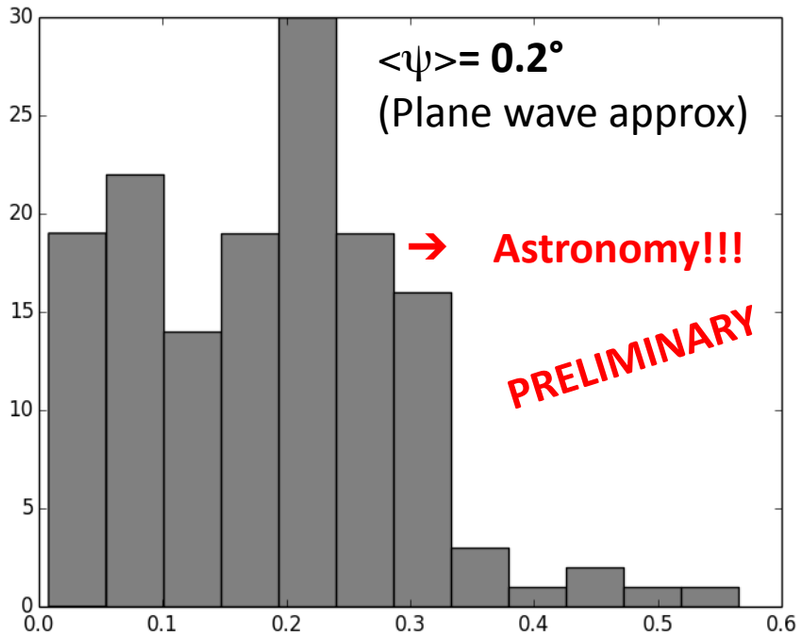
go for industrial approach! answers to be studied at later stage

Simulated performances

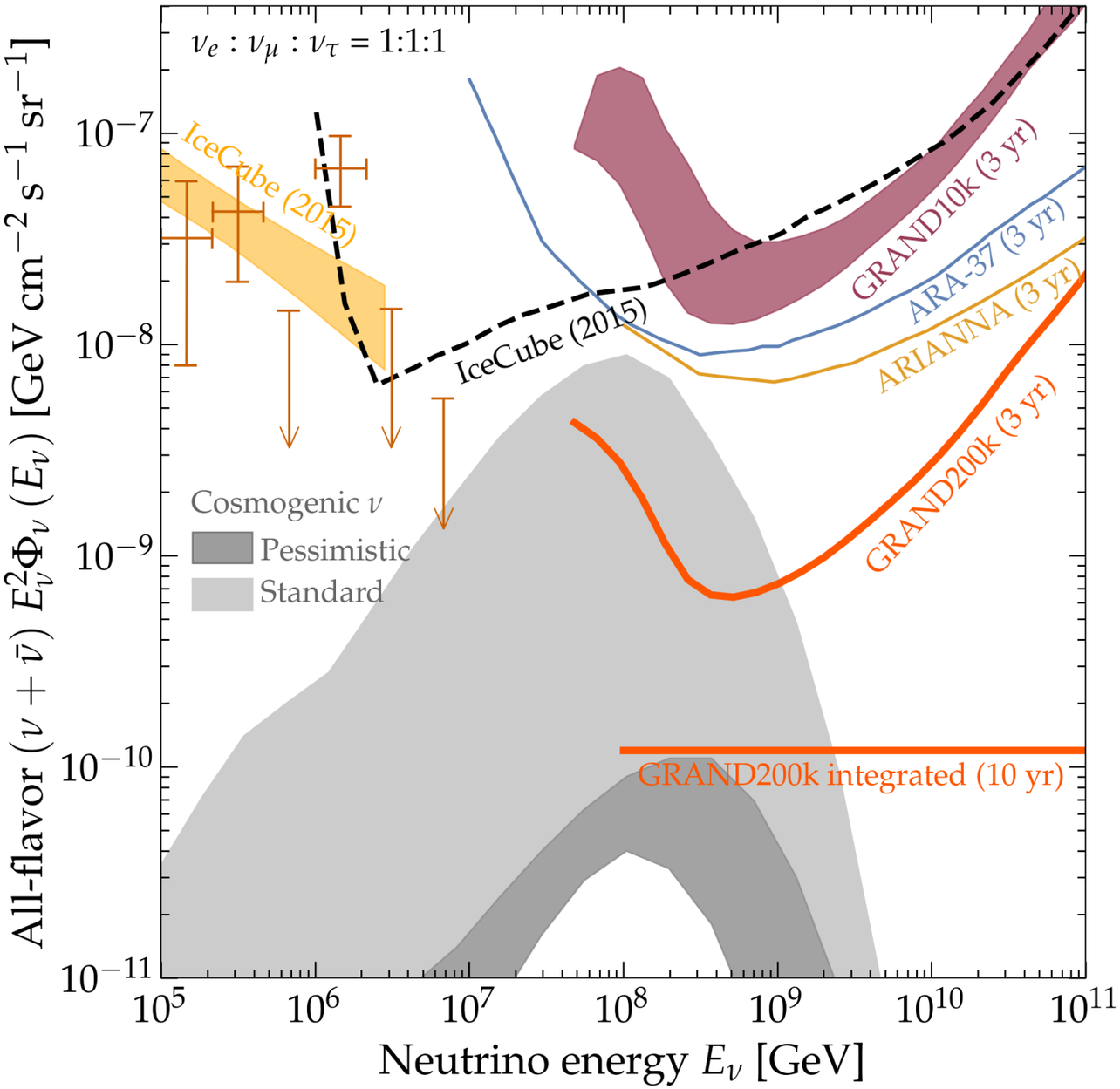
exposure for Hotspot1
10'000 km²



~0.1-0.3° angular resolution for GP300
also achievable for Hotspot1



V. Decoene (IAP)



GRAND full sensitivity (E>10^{17} eV)
~4x10^{-10} GeV cm^{-2} s^{-1} sr^{-1}

X_{max} resolution:
< 40 g/cm² achievable for
E>10^{19} eV
with GP300 & further stages

C. Guépin (IAP)

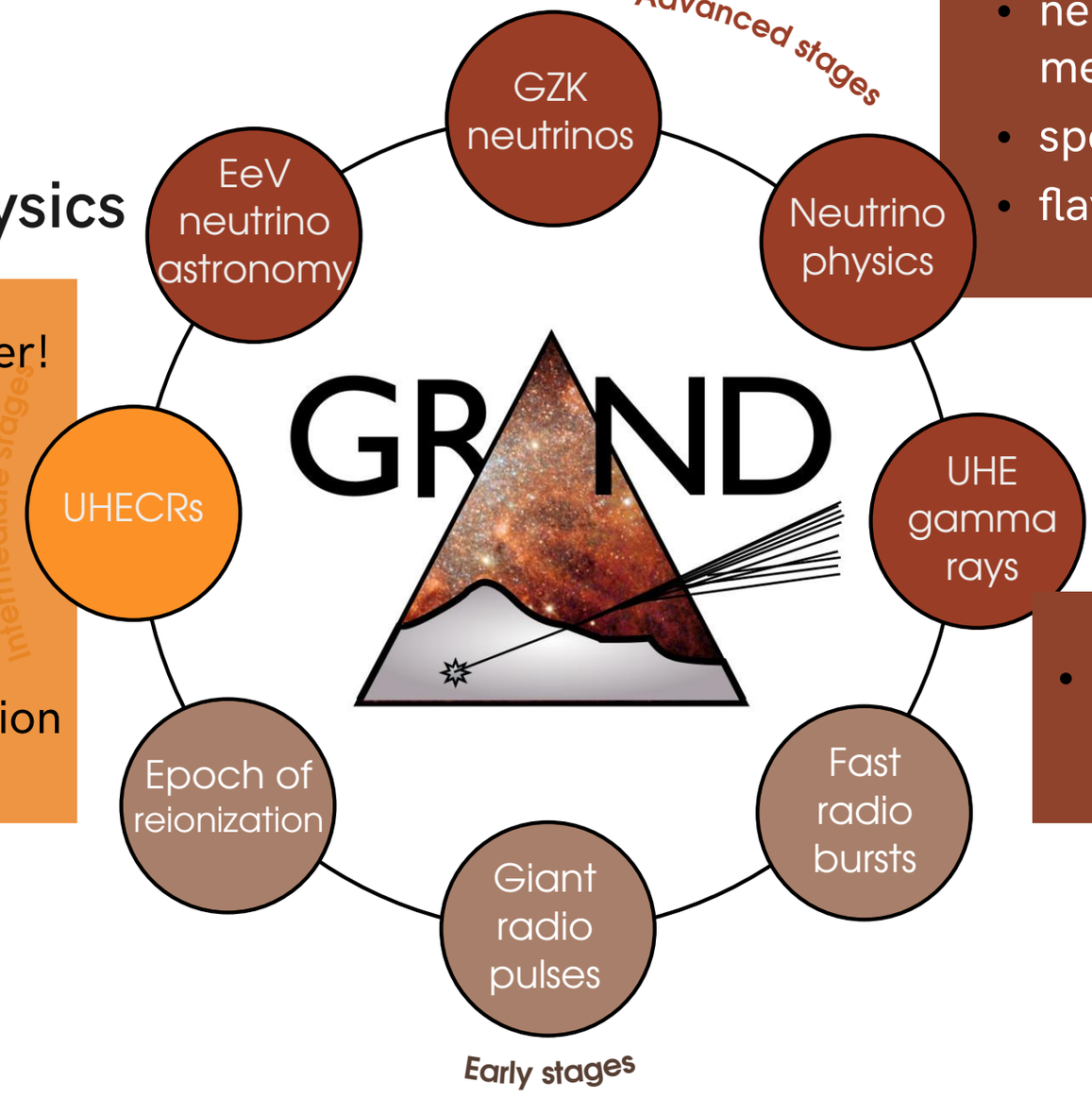
A rich science case

neutrino physics

- neutrino cross-section measurements
- spectral, angular distortions
- flavor ratios

UHECR, hadronic physics

- 20 times the exposure of Auger!
- GRANDProto300: transition from Galactic/ extragalactic
- hadronic physics: muon discrepancy, UHECR mass composition, p-air cross-section



UHE gamma rays

- competitive with Auger at GRANDProto300 stage

radio-astronomy in a novel way

- unphased integration of signals: an almost full-sky survey of radio signals
- can detect FRBs and Giant Radio pulses of the Crab already at the GRANDProto300 stage

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- beyond GRANDProto300, **challenges** are related to **large arrays**
(e.g. communication, power supply)**: common to all other large-array projects**
- in an ideal world, projects like the giant air-shower array (J. Hörandel), GCOS (R. Engel) and GRAND should **work together** to try to solve issues related to building giant arrays.
In ~2025: we should see where/how we can get funding and merge everything…