

Giant

Radio

Array for

Neutrino

Detection

Science and Design

GRAND

200,000 km² !!!

Presented by Sijbrand de Jong

Based on the GRAND white paper in preparation

Content:

- Science Case
- GRAND Design & Performance
- Stages of realisation
- Summary and Outlook

Cosmic Rays: Highest Energy Particles in the Universe

- **Astronomical:**

- Where are they produced ?
- How are they produced ?
- How do they propagate from the source to us ?

What are they ?

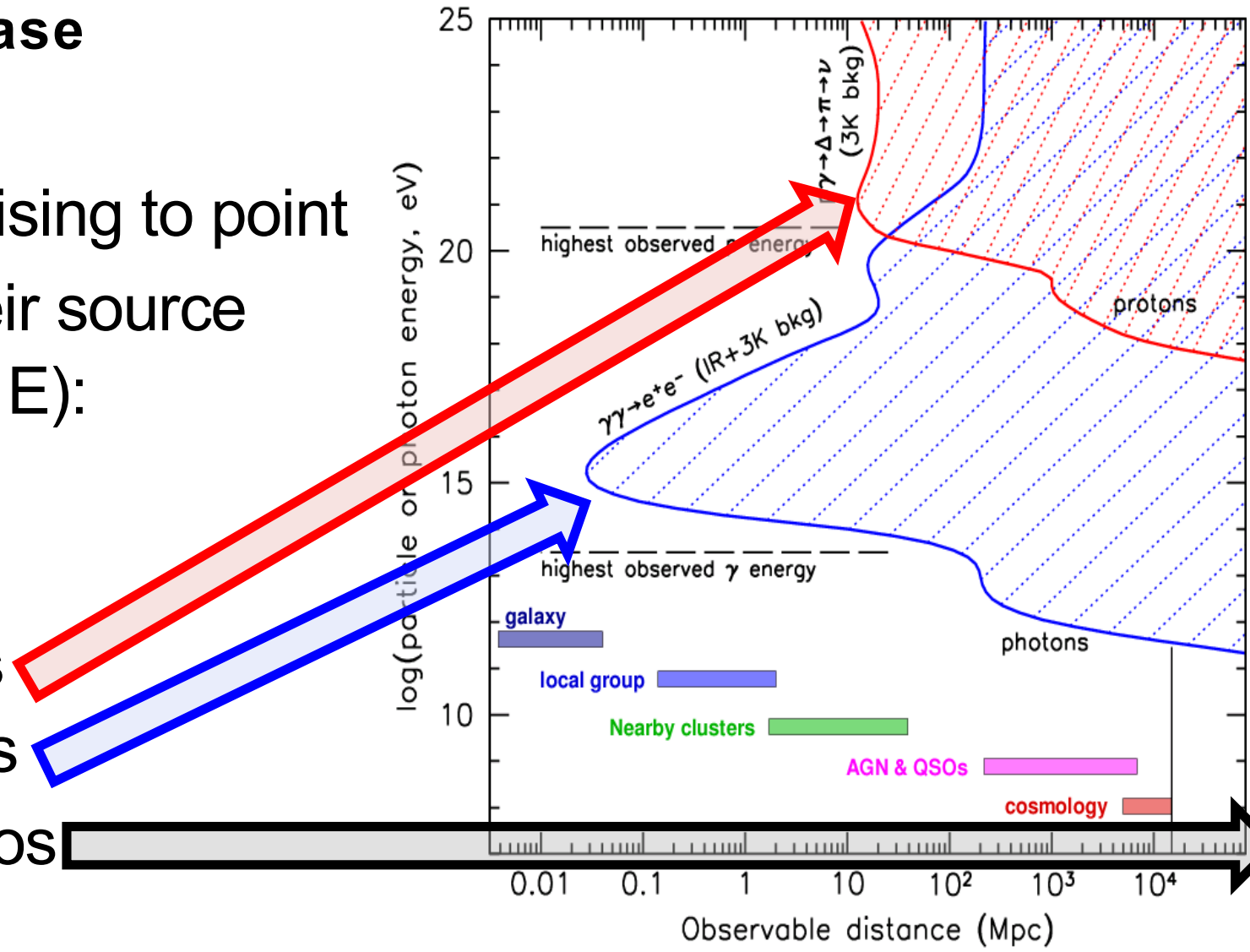
- **Particle Physics:**

- How do they interact ?
- What is produced in their collisions ?
(while propagating through space or when hitting the Earth's atmosphere)

Science Case

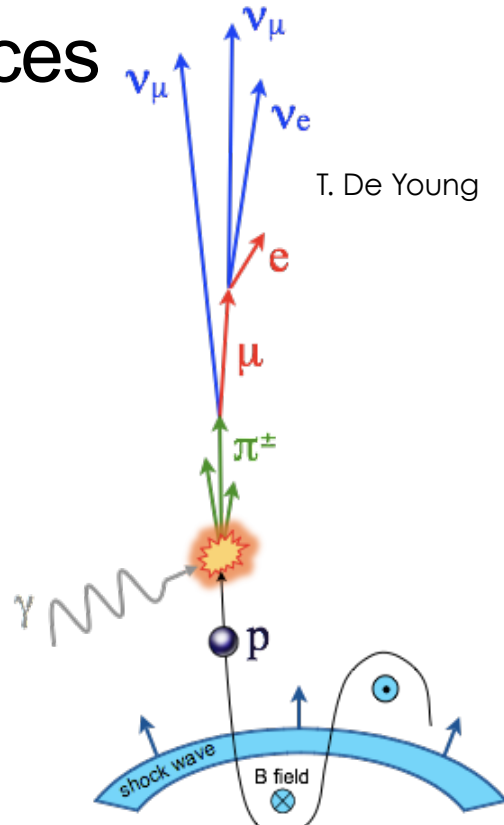
Most promising to point back to their source (at highest E):

4. ...
3. Protons
2. Photons
1. Neutrinos

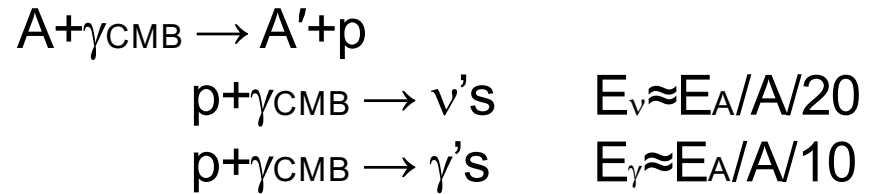
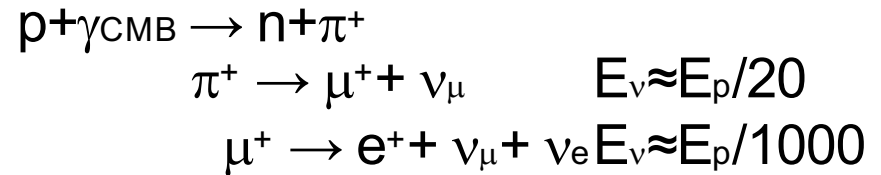
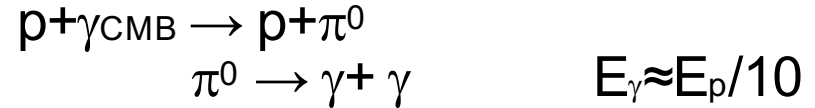


Science Case: Sources of UHE neutrinos

Point sources



Cosmogenic



Rate & energy distribution depend on:

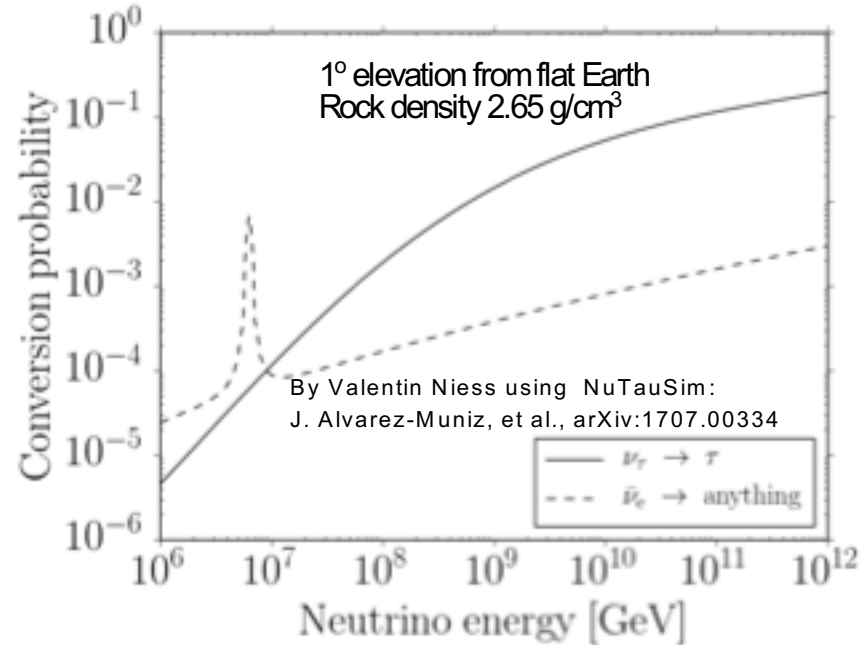
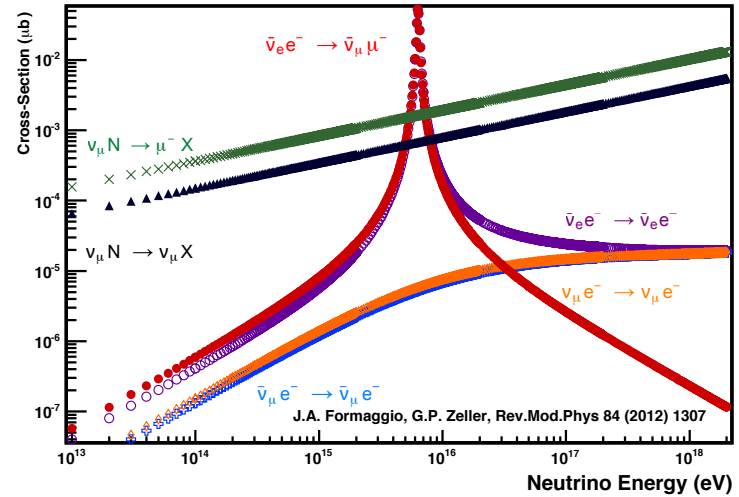
- Cosmic ray rate (known)
- Source conditions & cosmic evolution

- Cosmic ray spectrum (known)
- Cosmic ray composition

← Interesting ! →

UHE neutrino detection

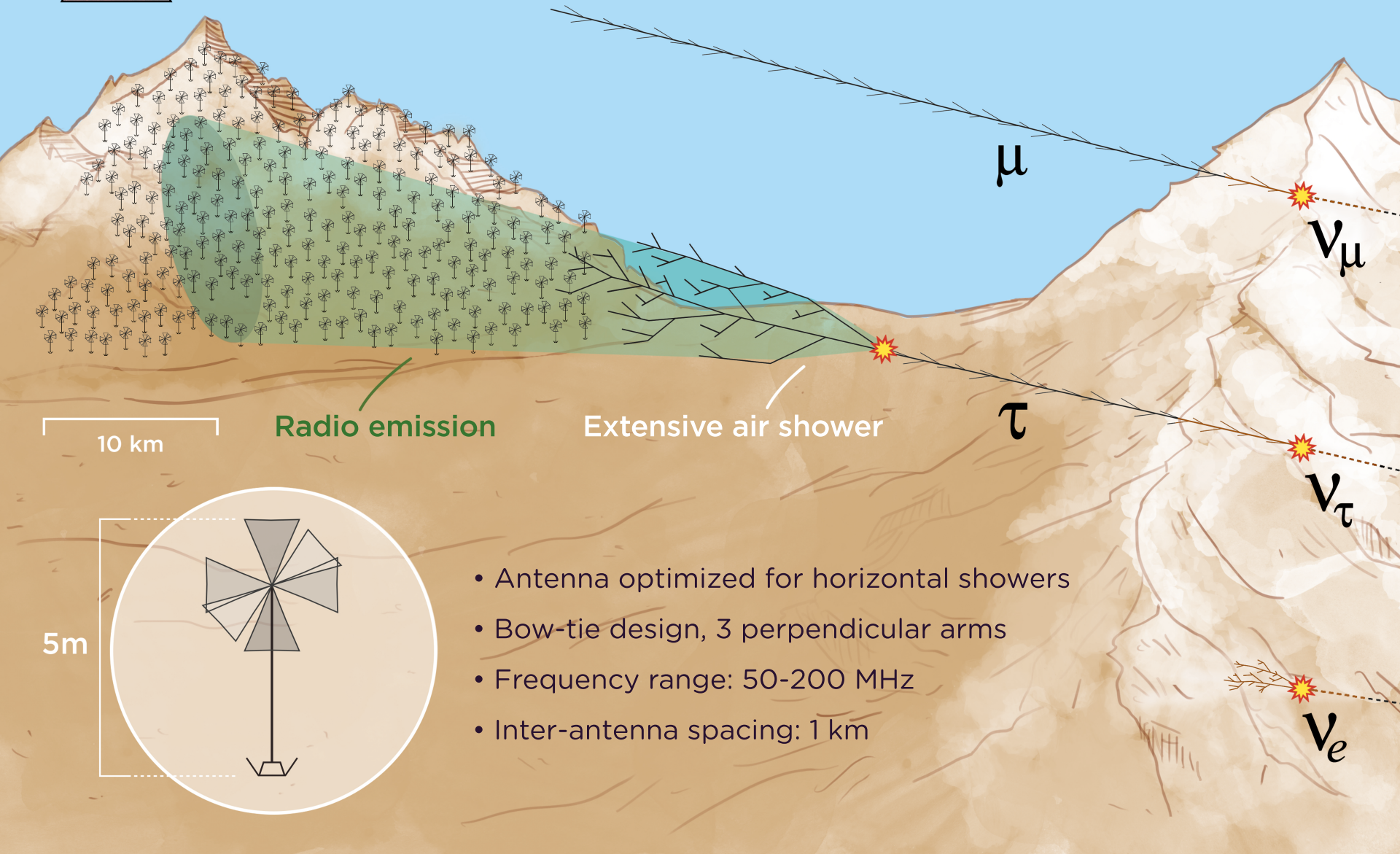
- Cross Section Increases with Energy
 - 3-D \rightarrow 2-D detector: large surface
- Conversion rate in
 - Earth crust: high \checkmark
 - Charged lepton interacts in rock \times
 - Mountains: high \checkmark
 - e likely to shower in mountain \times
 - μ stable and hard to detect \times
 - $\tau \rightarrow$ hadronic shower in ~ 50 km \checkmark
 - Atmosphere: low \times



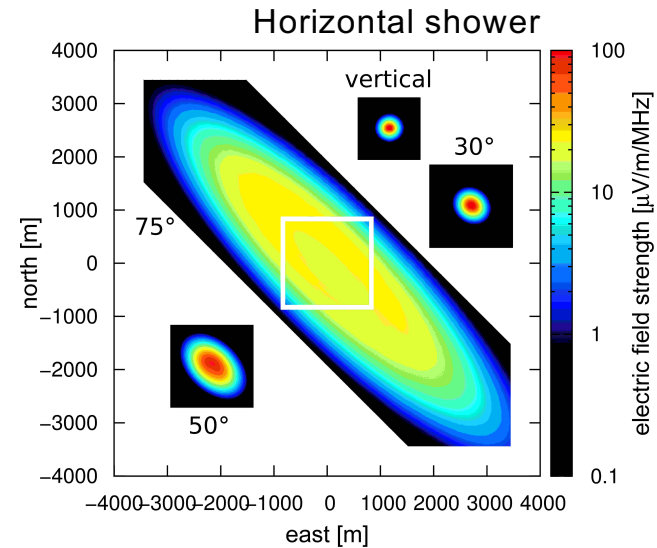
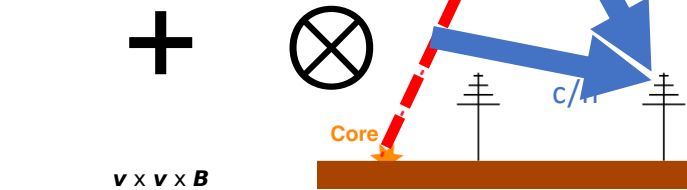
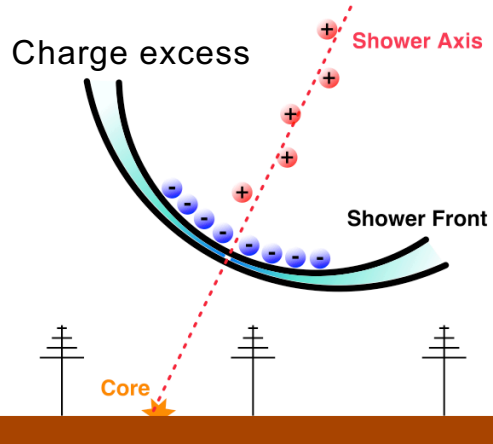
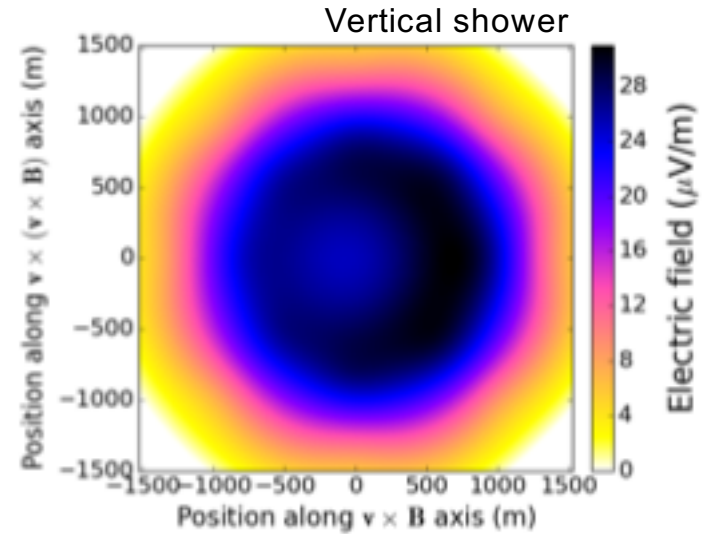
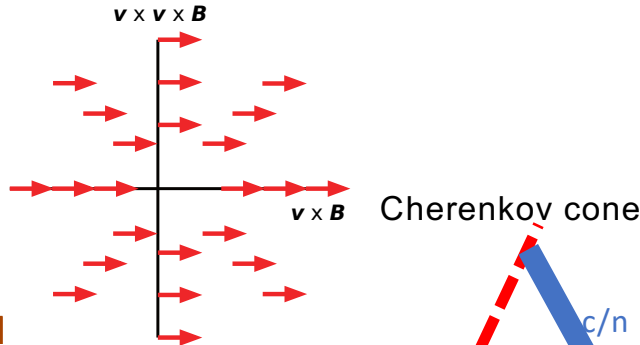
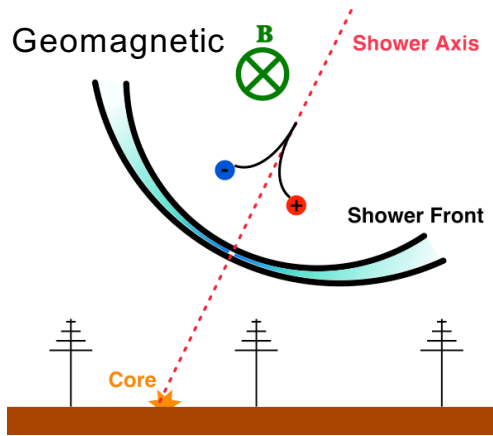
\Rightarrow Go for: **200,000 km² ν_τ detector in mountains**



Giant Radio Array for Neutrino Detection



Radio Frequency Emission of Air Showers

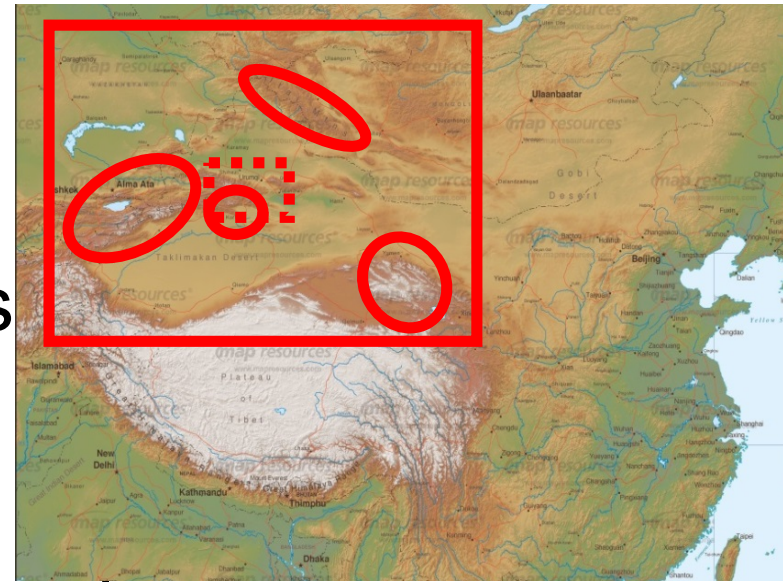


Footprints for 30-80 MHz

<https://arxiv.org/abs/1806.05386>

GRAND set-up

- Distributed observatory with
 - 20,000-50,000 km² hot spots
 - total area of **200,000 km²**
- Location: TBD, largely in China
- Site screening (noise, etc.) being done

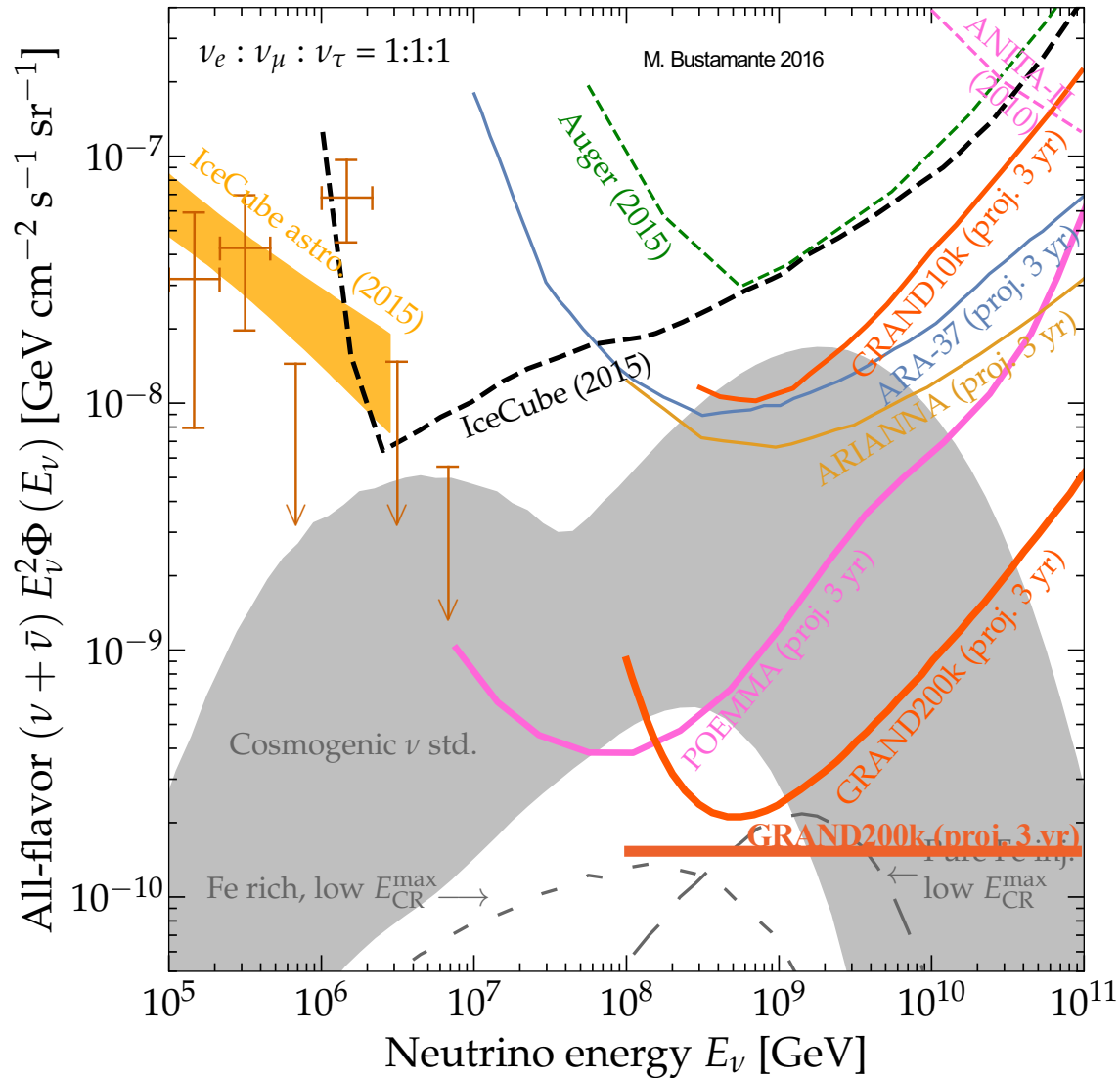


Science Reach

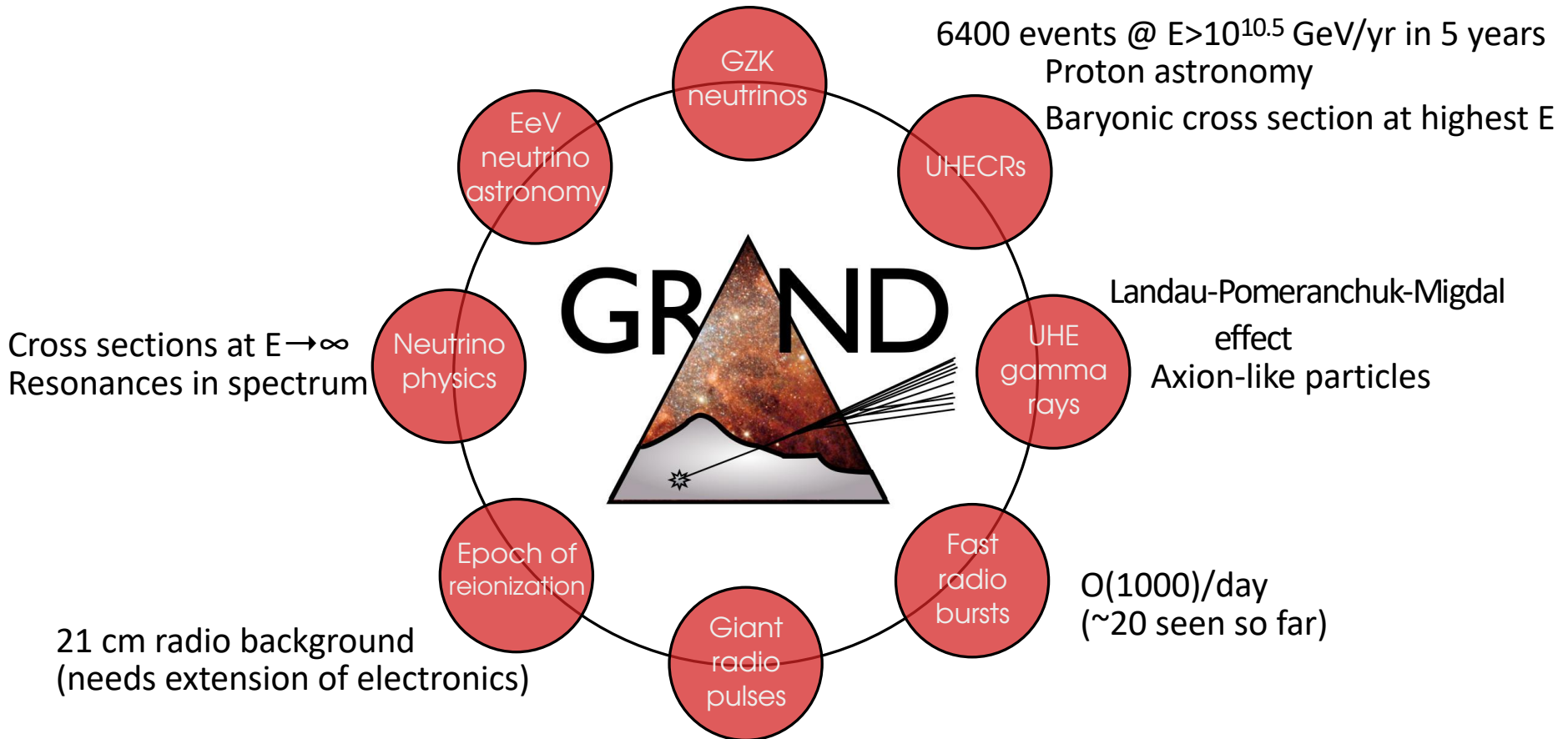
- First (?) $E_\nu > 10^8$ GeV
- Point Sources:
multi-messenger APP
- Cosmogenic Origin:
distinguish scenarios

Neutrinos with:

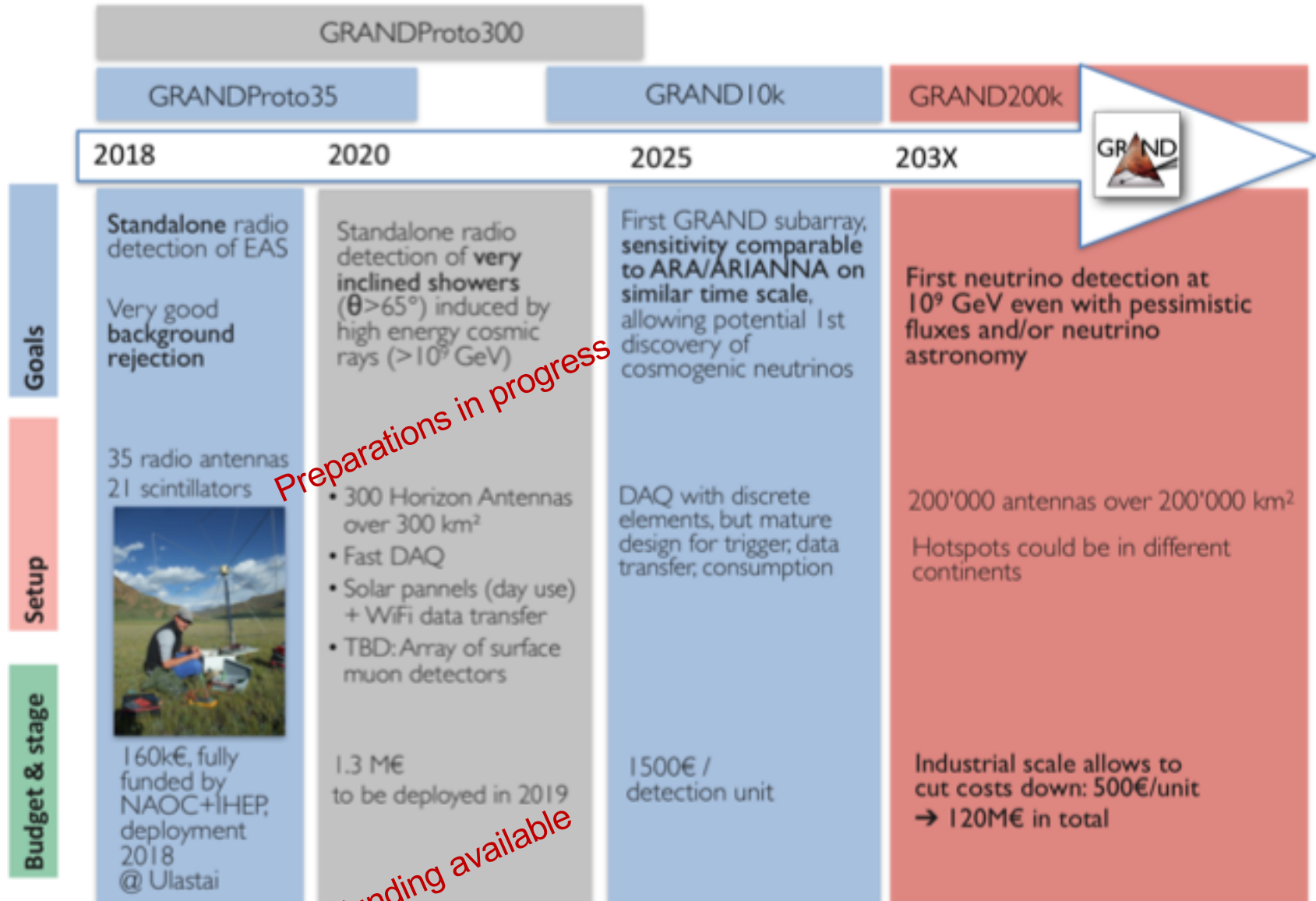
- Highest energies
- Longest baseline



GRAND: A Versatile Astroparticle Observatory



GRAND: Timeline and staging



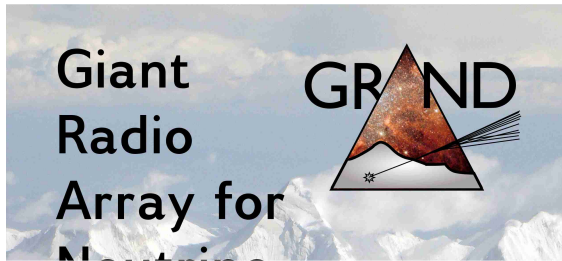
Preparations in progress

Funding available



White Paper and Proto-Collaboration

- White paper being written
- To be published in few months



White Paper Editor

Jaime Álvarez-Muñiz¹, Rafael Alves Batista^{2,3}, Mauricio Bustamante^{4,5,6,†}, Washington Carvalho Jr.⁷, Didier Charrier⁸,
 Ismaël Cognard^{9,10}, Valentin Decoene¹¹, Peter B. Denton⁴, Sijbrand De Jong^{12,13}, Krijn D. De Vries¹⁴, Ralph Engel¹⁵,
 Ke Fang^{16,17}, Chad Finley^{18,19}, QuanBu Gou²⁰, Junhua Gu²¹, Claire Guépin¹¹, Hongbo Hu²⁰, Yan Huang²¹,
 Kumiko Kotera^{11,22,*}, Sandra Le Coz²¹, Jean-Philippe Lenain²³, Guoliang Lü²⁴, Olivier Martineau-Huyvnh^{23,21,*},
 Miguel Mostafa^{25,26,27}, Fabrice Mottez²⁸, Kohta Murase^{25,26,27}, Valentin Niess²⁹,
 Foteini Oikonomou^{30,25,26,27}, Tanguy Pierog¹⁵, Xiangli Qian³¹, Bo Qin²¹, Duan Ran²¹, Nicolas Renault-Tinacci¹¹,
 Frank G. Schröder³², Fabian Schüssler³³, Cyril Tasse³⁴, Charles Timmermans^{12,13}, Matías Tueros³⁵,
 Xiangping Wu^{36,21,*}, Philippe Zarka³⁷, Andreas Zech²⁸, Bing Theodore Zhang^{38,39}, Jianli Zhang²¹, Yi Zhang²⁰,
 Qian Zheng^{40,20}, Anne Zilles¹¹

Initiators

Core Team

Author list

⁴⁰ Jaime Álvarez-Muñiz¹, Rafael Alves Batista^{2,3}, Mauricio Bustamante^{4,5,6,†}, Washington Carvalho Jr.⁷, Didier Charrier⁸,
⁵⁰ Ismaël Cognard^{9,10}, Valentin Decoene¹¹, Peter B. Denton⁴, Sijbrand De Jong^{12,13}, Krijn D. De Vries¹⁴, Ralph Engel¹⁵,
⁵¹ Ke Fang^{16,17}, Chad Finley^{18,19}, QuanBu Gou²⁰, Junhua Gu²¹, Claire Guépin¹¹, Hongbo Hu²⁰, Yan Huang²¹,
⁵² Kumiko Kotera^{11,22,*}, Sandra Le Coz²¹, Jean-Philippe Lenain²³, Guoliang Lü²⁴, Olivier Martineau-Huyvnh^{23,21,*},
⁵³ Miguel Mostafa^{25,26,27}, Fabrice Mottez²⁸, Kohta Murase^{25,26,27}, Valentin Niess²⁹,
⁵⁴ Foteini Oikonomou^{30,25,26,27}, Tanguy Pierog¹⁵, Xiangli Qian³¹, Bo Qin²¹, Duan Ran²¹, Nicolas Renault-Tinacci¹¹,
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⁵⁷ Qian Zheng^{40,20}, Anne Zilles¹¹
⁵⁸

⁵⁹ ¹Departamento de Física de Partículas & Instituto Galego de Física de Altas Enerxías,
⁶⁰ Universidad de Santiago de Compostela, 15782 Santiago de Compostela, Spain
⁶¹ ²Instituto de Astronomía, Geofísica e Ciencias Atmosféricas, Universidade de São Paulo – Rua do Matão, 1226, 05508-090,
⁶² São Paulo-SP, Brazil
⁶³ ³Department of Physics – Astrophysics, University of Oxford, DWB, Keble Road, OX1 3RH, Oxford, UK
⁶⁴ ⁴Niels Bohr International Academy, Niels Bohr Institute, Blegdamsvej 17, 2100 Copenhagen, Denmark
⁶⁵ ⁵Center for Cosmology and AstroParticle Physics (CCAPP), Ohio State University, Columbus, OH 43210, USA
⁶⁶ ⁶Department of Physics, Ohio State University, Columbus, OH 43210, USA
⁶⁷ ⁷Universidade de Santiago de Compostela, 15782 Santiago de Compostela, Spain
⁶⁸ ⁸SUBATECH, IN2P3-CNRS, Université de Nantes, IMT-Atlantique, Nantes, France
⁶⁹ ⁹Laboratoire de Physique et Chimie de l'Environnement et de l'Espace LPC2E CNRS-Université d'Orléans,
⁷⁰ F-45071 Orléans, France
⁷¹ ¹⁰Station de Radioastronomie de Nançay, Observatoire de Paris, CNRS/INSU F-18330 Nançay, France
⁷² ¹¹Sorbonne Universités, UPMC Univ. Paris 6 et CNRS, UMR 7095, Institut d'Astrophysique de Paris, 98 bis bd Arago,
⁷³ 75014 Paris, France
⁷⁴ ¹²Institute for Mathematics, Astrophysics and Particle Physics (IMAPP), Radboud Universiteit, Nijmegen, Netherlands
⁷⁵ ¹³Nationaal Instituut voor Kernfysica en Hoge Energie Fysica (NIKHEF), Netherlands
⁷⁶ ¹⁴IHE/ELEM, Vrije Universiteit Brussel, Pleinlaan 2, 1050 Brussels, Belgium
⁷⁷ ¹⁵Institute for Nuclear Physics (IKP), Karlsruhe Institute of Technology (KIT), D-76021 Karlsruhe, Germany
⁷⁸ ¹⁶Department of Astronomy, University of Maryland, College Park, MD 20742-2421, USA



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⁴⁰ School of Engineering and Computer Science, PO Box 600, Victoria University of Wellington, Wellington 6140, New Zealand
[†] Spokesperson / †: Corresponding author (mbustamante@nbi.ku.dk)

GRAND Summary and Outlook

• Challenges:

- Highest energy cosmic rays still a mystery in many respects
- UHE neutrinos and photons must exist, but not yet observed
- Need orders of magnitude more exposure than Auger/TA

• GRAND:

- Observe **UHE cosmogenic neutrinos**:
 - **Neutrino astronomy**
 - **neutrino physics** far beyond current reach
- Versatile **multi-messenger observatory**: A, p, γ , ν , ...
- Cosmology & astronomy bonuses: FRB, GP, 21cm
- Has already started, follows **ambitious timeline**
- Requires substantial funding and human resources: **Join Us !**