Ultra-High-Energy Cosmic Particles

Nikhef Jamboree 2024,
Harm Schoorlemmer

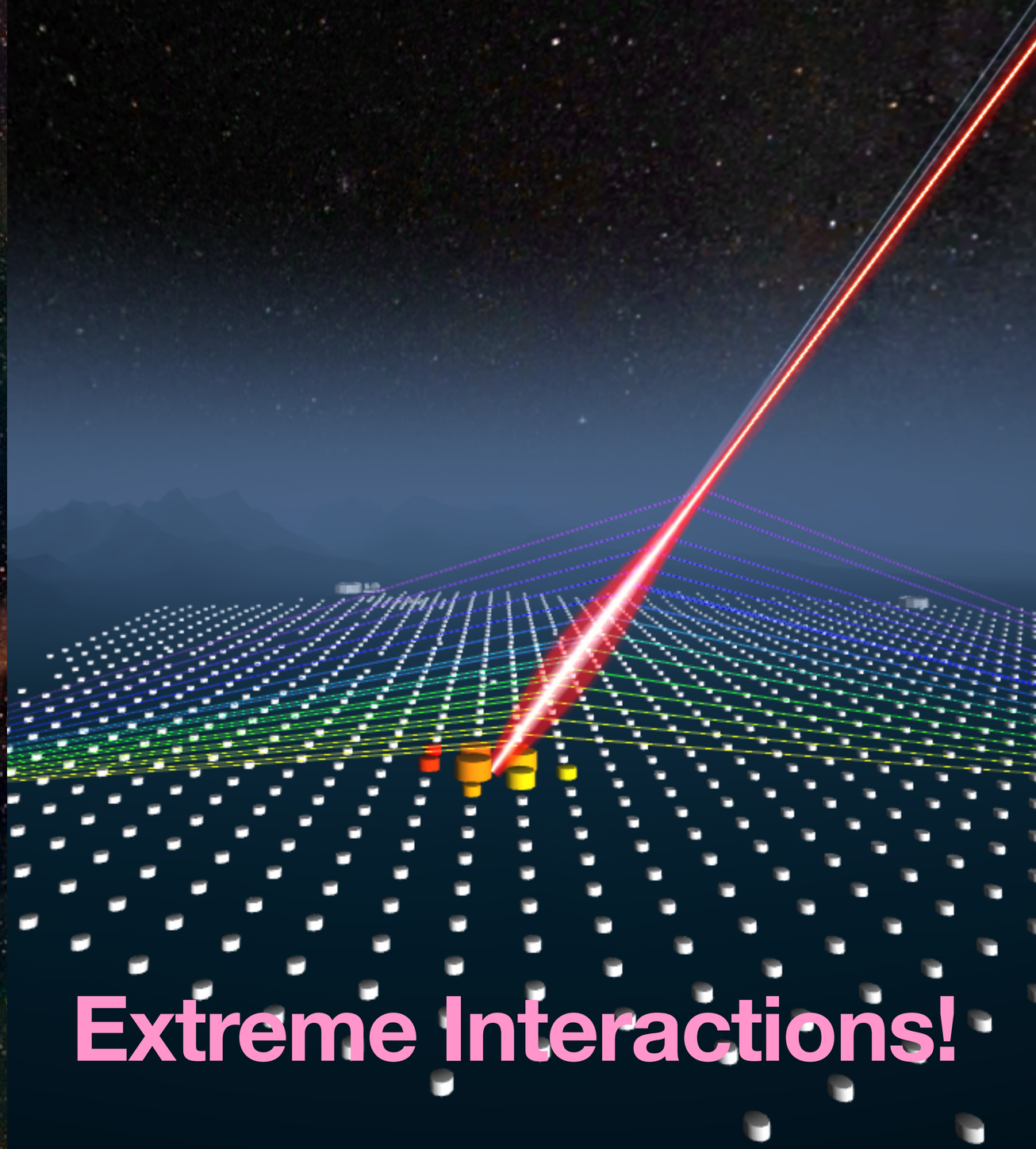
Radboud University

Centaurus A

$E = 10^8$ TeV = 100 EeV

definitely
not to scale

Extreme accelerators!



Extreme Interactions!

The Team

new face

Kevin

Pierre Auger Observatory:
Senior staff: Charles Timmermans, Sijbrand de Jong, Jörg Hörandel, Heino Falcke, Cristina Galea, Harm Schoorlemmer, Katie Mulrey
Post-doc: Bjarni Pont, Teresa Bister, **Kevin Cheminant**
PhD student: Abha Khakuridikar, Anthony Bwembya, Mohamed Emam, Mohit Saharan

GRAND:
Senior staff: Charles Timmermans, Sijbrand de Jong, Cristina Galea, Harm Schoorlemmer

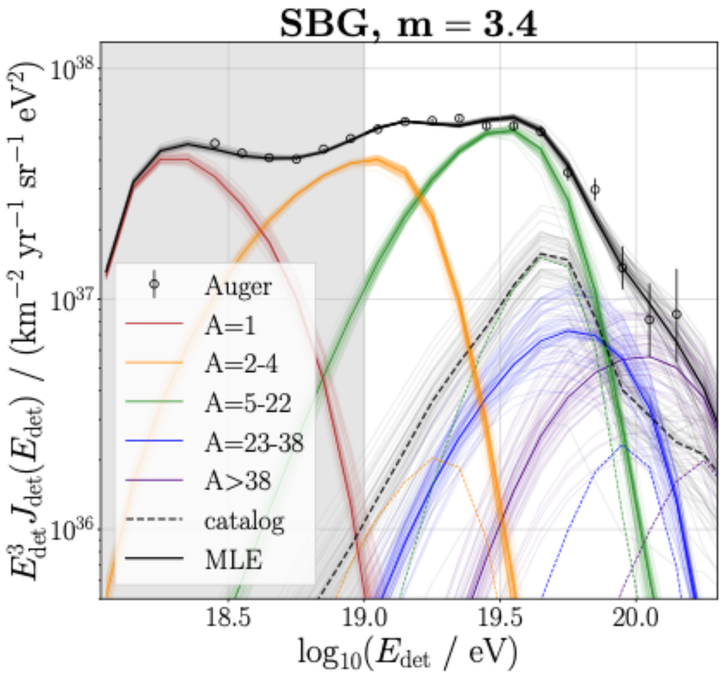
Engineers: Peter Dolron, Roel Jordans, Daniel Szalas, Sjoerd Timmer, Nicoletta Cucu Laurenciu, Rik van den Bosch, Thei Wijnen

Which astrophysical scenarios fit <u>all</u> our observables?

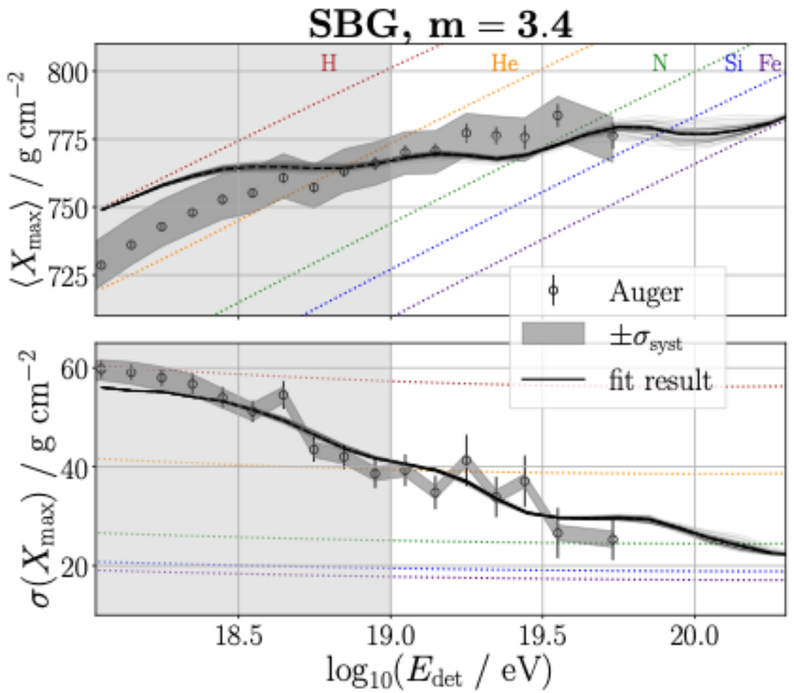
Teresa Bister

- Compare a model that predicts cosmic-ray properties at Earth to data
- Model with 20% contribution from star-burst galaxies describes data well
- Model with gamma-ray bright Active Galactic Nuclei is disfavoured

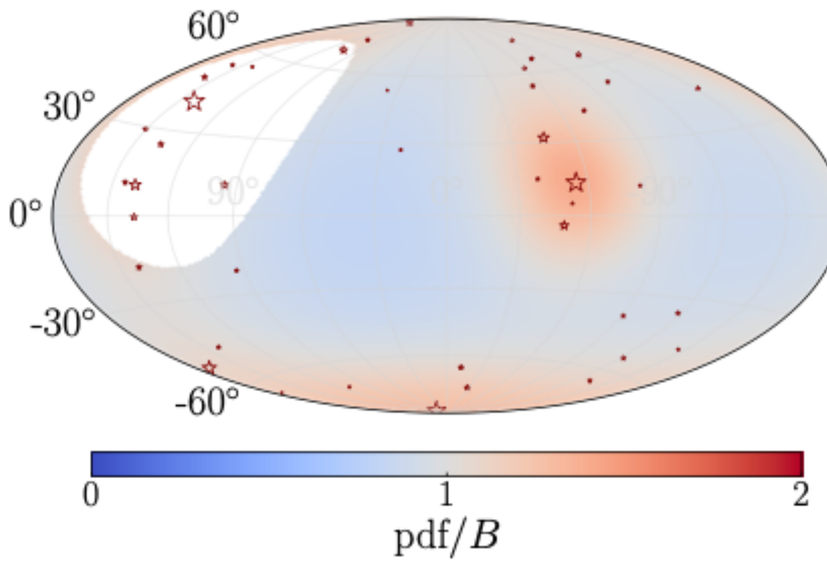
Energy Spectrum



Mass composition

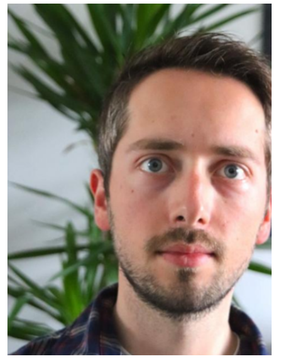


Arrival direction



The Pierre Auger Collaboration, JCAP01(2024)022

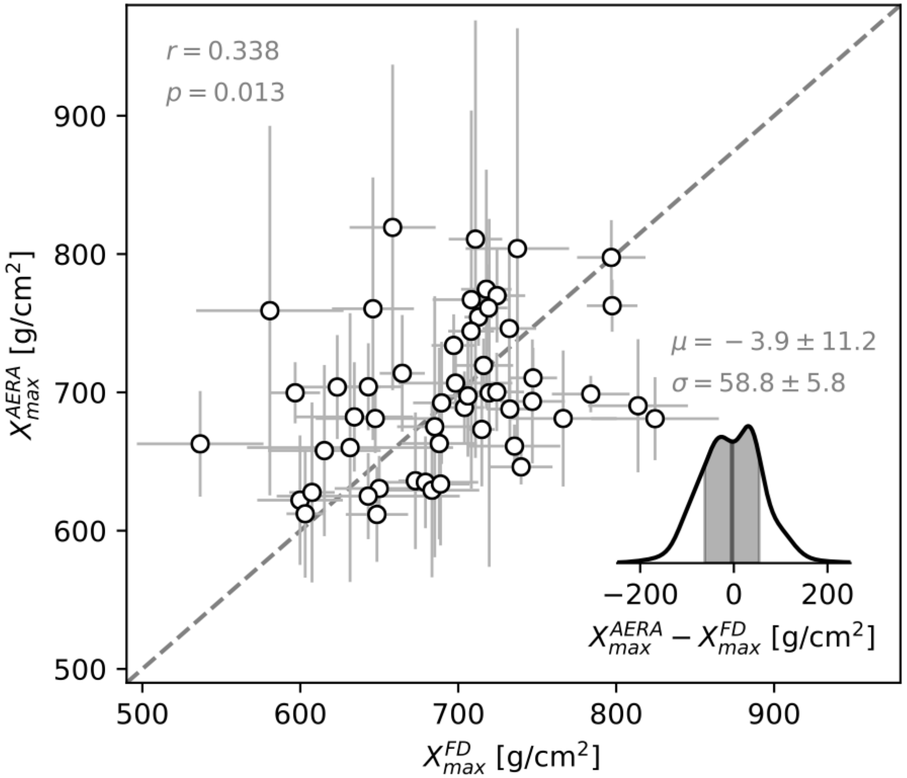
Agreement between different methods

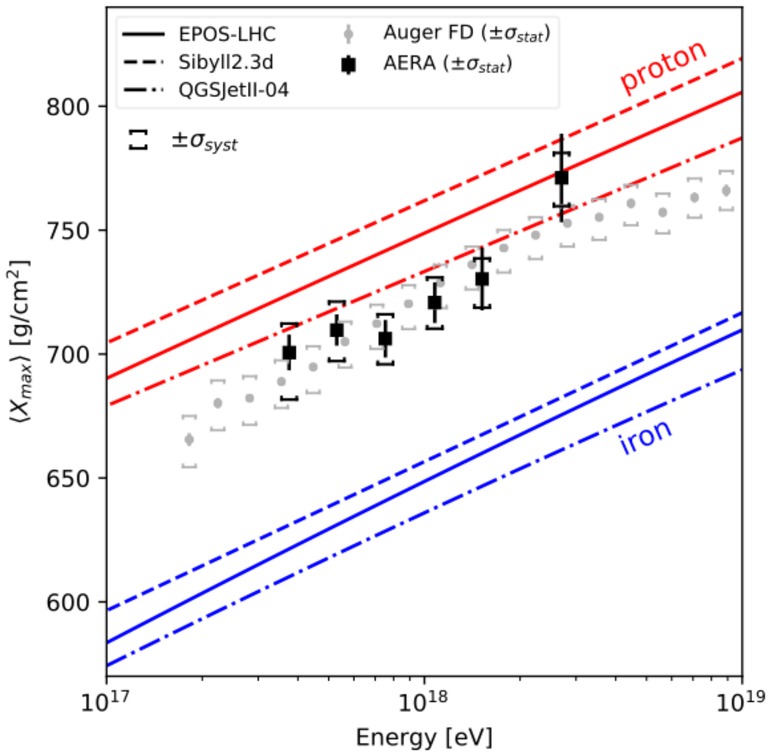


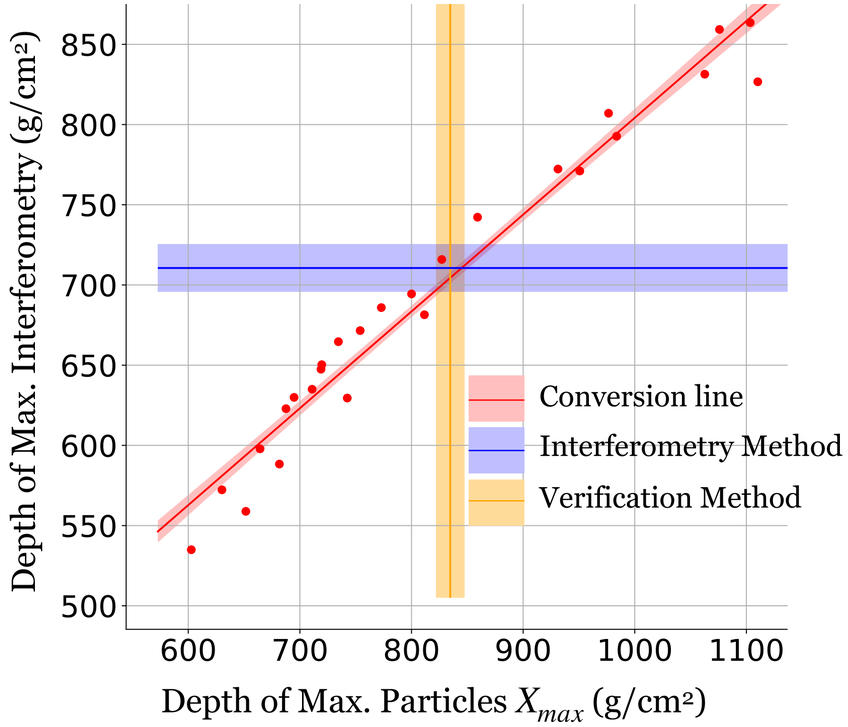
Bjarni Pont

- For the first time comparison between depth of air shower maximum with radio and fluorescence emission.
- The two methods correlate, without significant bias.
- Interferometry now can also be used to obtain depth of shower maximum

(HS, Anthony for AugerPrime)







The Pierre Auger Collaboration, PRD 109 (2024) 022002 + PRL 132 (2024) 021001

The Pierre Auger Collaboration, PoS(ICRC2023)380

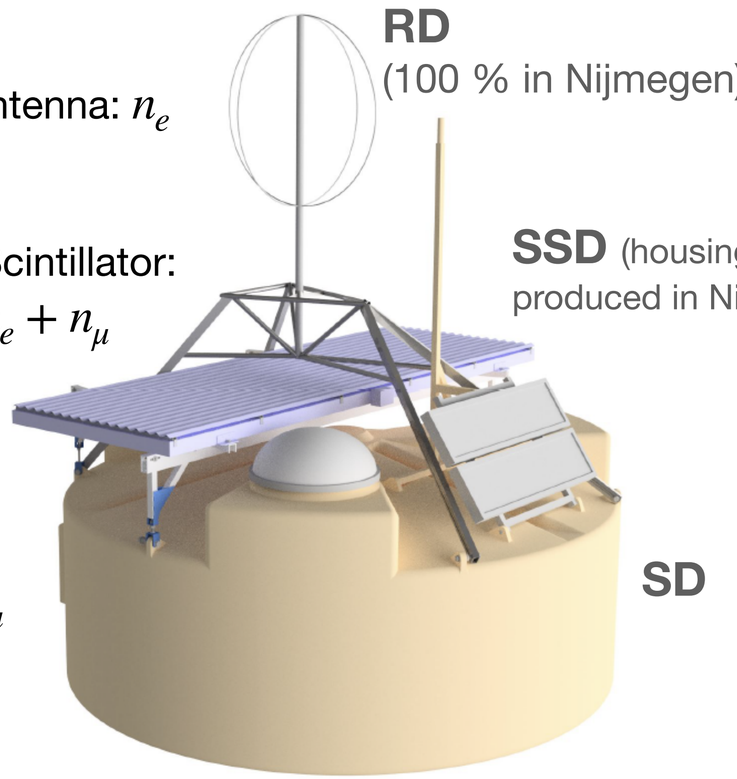
AugerPrime: Upgrade

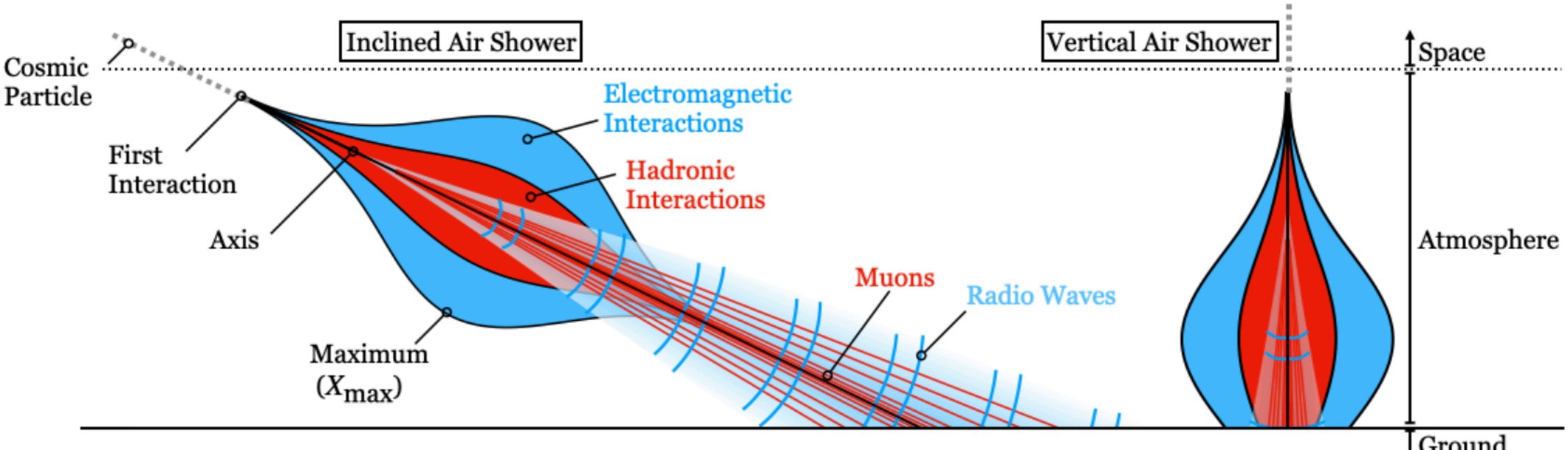
Vertical $0^\circ < \theta < 60^\circ$

Combination of Scintillators + WCD
to disentangle muonic and electromagnetic component

Horizontal $\theta > 60^\circ$

WCD “only” muons
Radio “only” electromagnetic

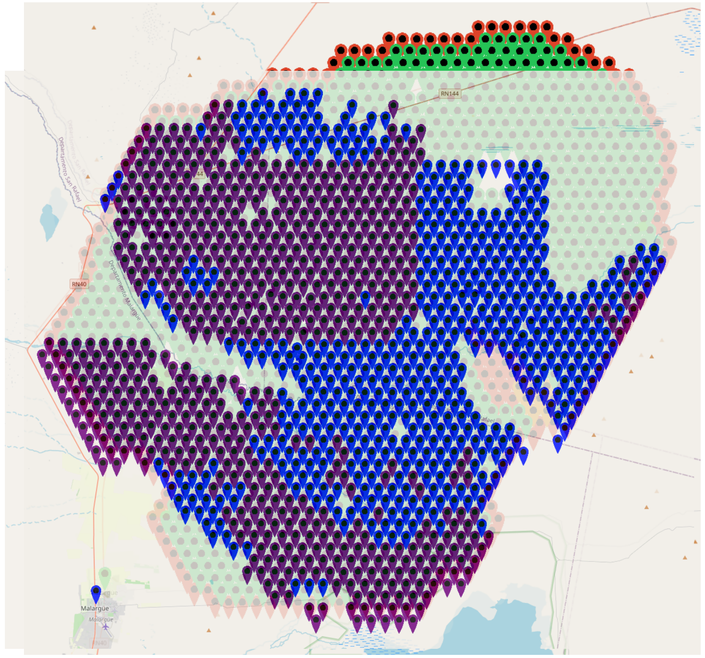




PIERRE AUGER OBSERVATORY

AugerPrime: Radio Detector

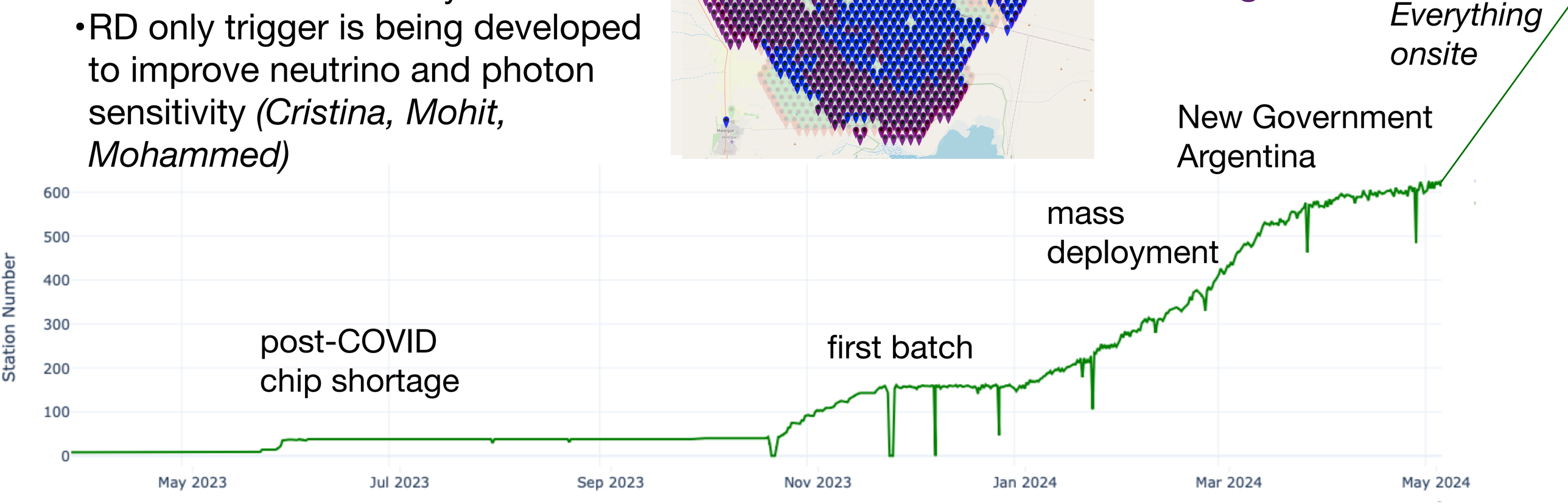
- Deployment of the radio detector has been plagued with “some” external issues. **Now all components on site.**
- Currently **world largest** radio detector for cosmic rays
- RD only trigger is being developed to improve neutrino and photon sensitivity *(Cristina, Mohit, Mohammed)*



1660 stations

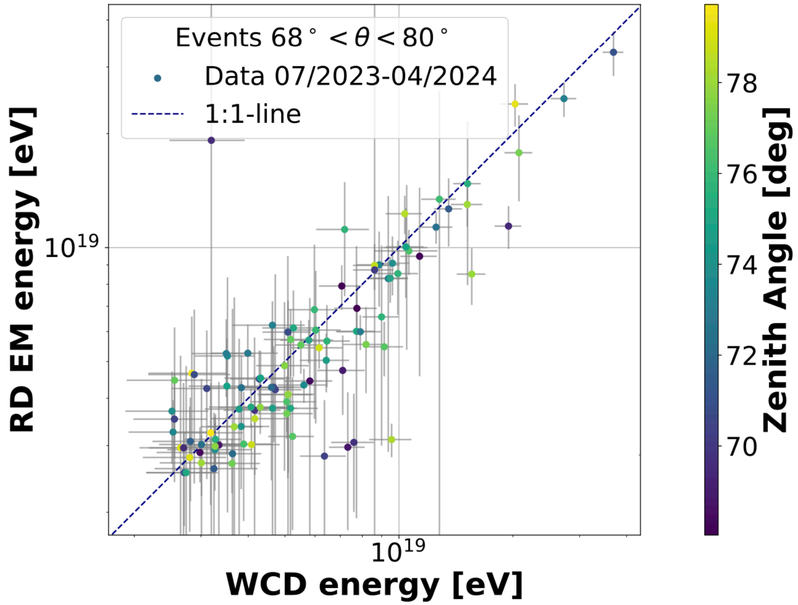
1130 Antennas

610 Digitisers



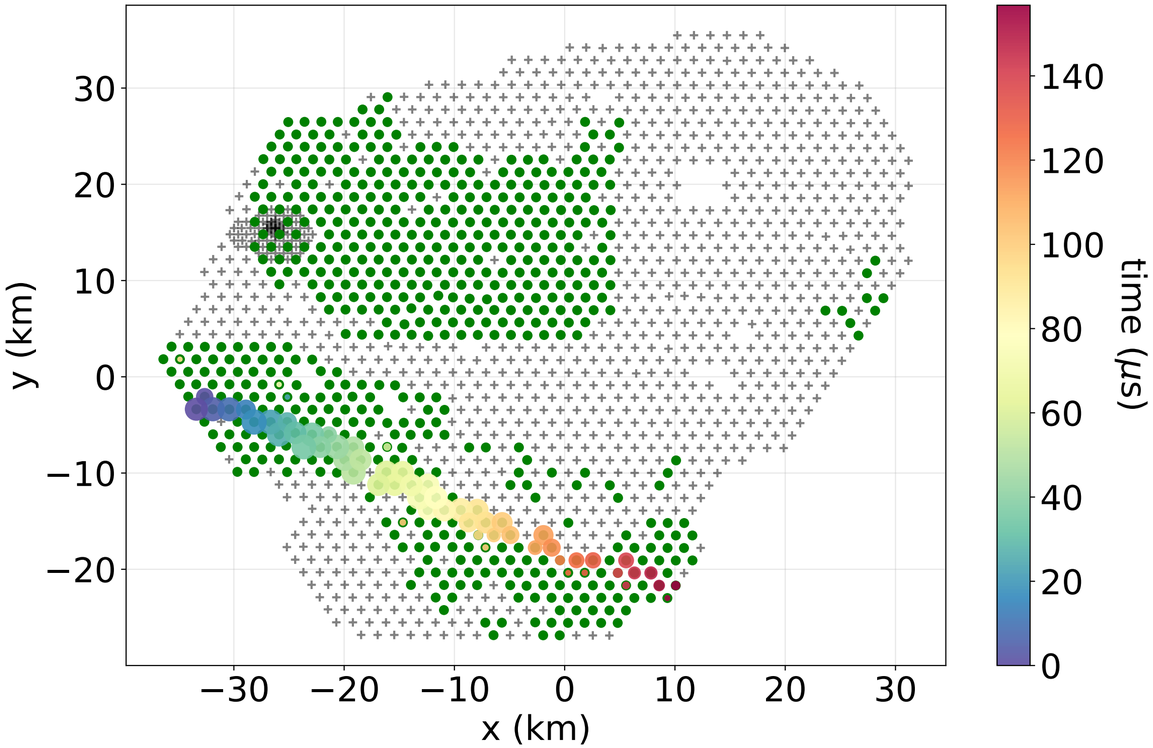
A look at first data

- Good agreement with direction and energy reconstruction between RD and SD



An nice example event

- Angle from zenith: 85°
- Estimation of the energy: $\sim 3 \times 10^{19}$ eV
- Consistent reconstruction between particle detectors and radio
- More detailed information for these extremely inclined events.




Heemskerk
Purmerend
Markermeer
Lelystad
Beverwijk
Zaandam
Haarlem
Amsterdam
Nikhef
Almere
Hoofddorp
Huizen
Bussum
Noordwijk
Hilversum
Nijkerk
Leiden
Amersfoort
Alphen aan den Rijn


Kiel
Lübeck
Hamburg
Sheffield
Groningen
Bremen
Norwich
Hanover
Amsterdam
Nikhef
Cambridge
Netherlands
Bielefeld
Oxford
Rotterdam
London
Dortmund
Essen
Kassel
Antwerp
Düsseldorf
Germany
Cologne
Brussels
Lille
Liège
Belgium

The Giant Radio Array for Neutrino Detection

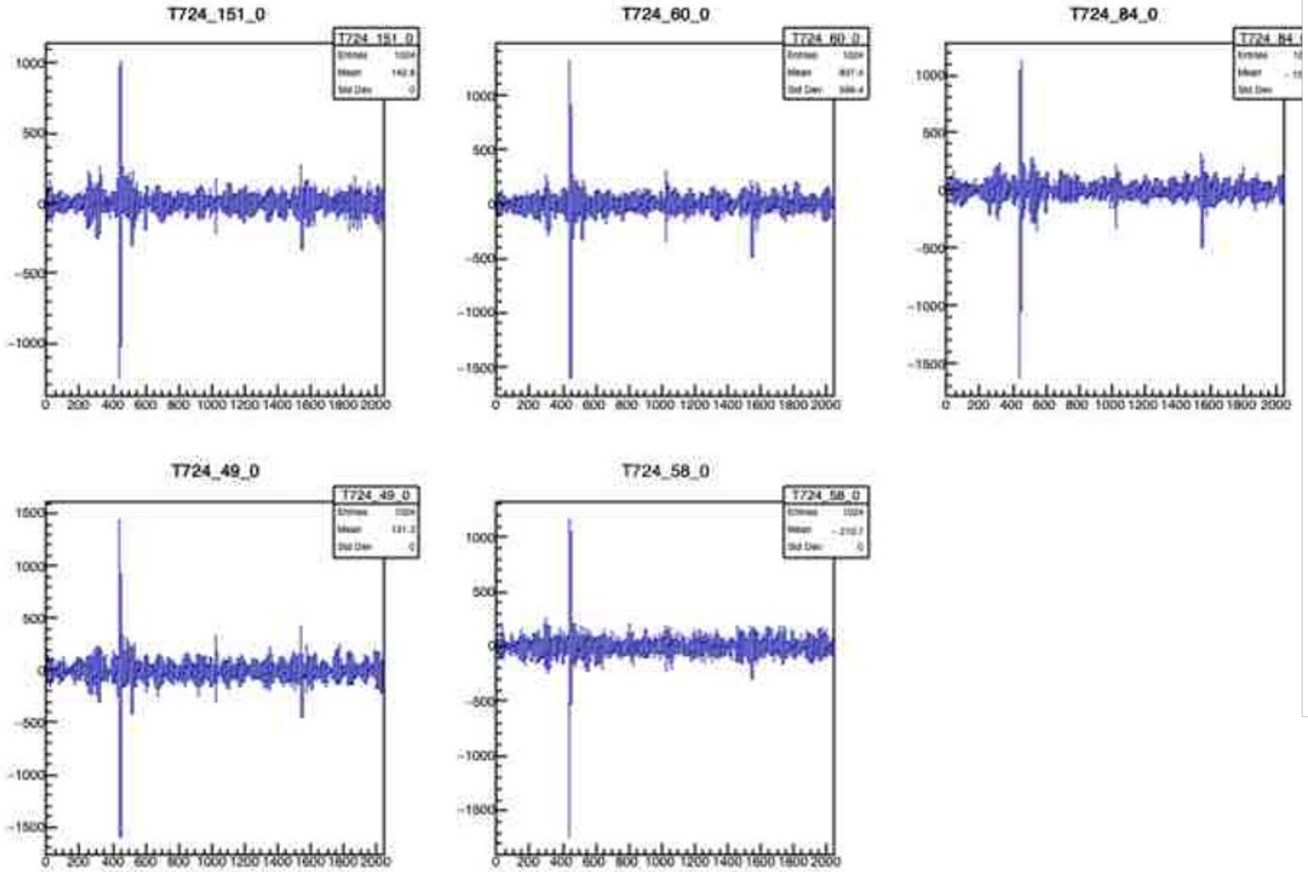
Reminder: GRAND = Next-generation gigantic array of radio antennas for cosmic particle detection

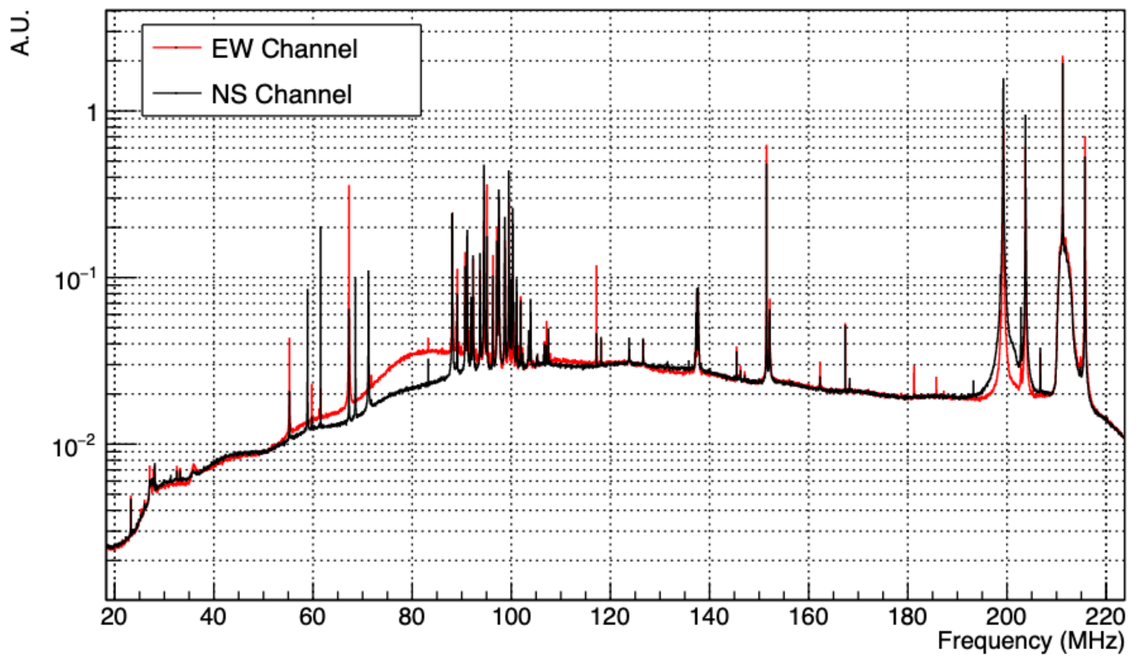
Progress: 2 sites for prototyping are being commissioned


GRAND@Auger: 10 antennas in the Pierre Auger Observatory


GP13: 13 antennas near DunHuang, China

The Giant Radio Array for Neutrino Detection





Spectra and coincident events available from both setups.

Next steps: filtering and searching for coincidences with Auger (in GRAND@Auger) and signatures of air showers from direction and polarization (in GP13)

Summary

The Pierre Auger Observatory

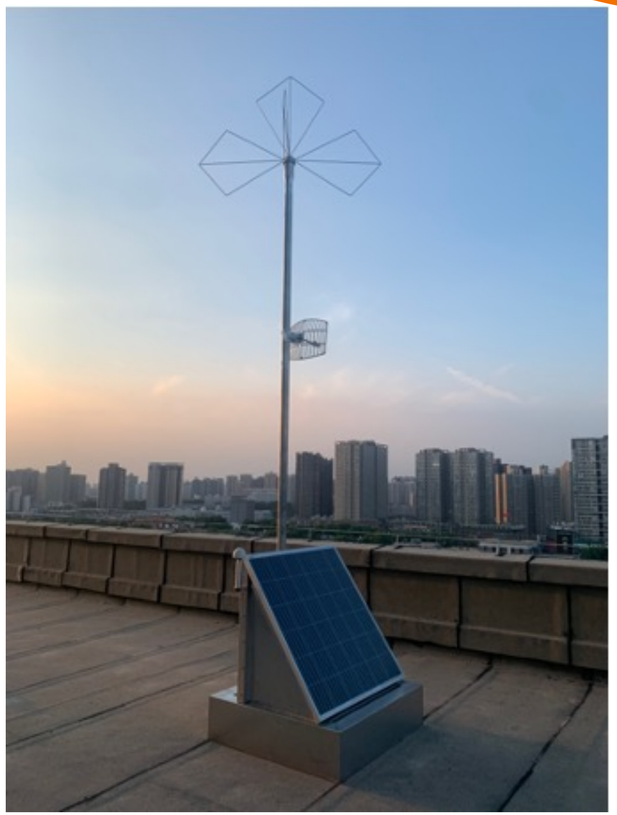
- Will finish its major upgrade this year, and is producing interesting results already.
- **Leading contribution from NIKHEF/RU**
- Further improvements expected from radio trigger & interferometry

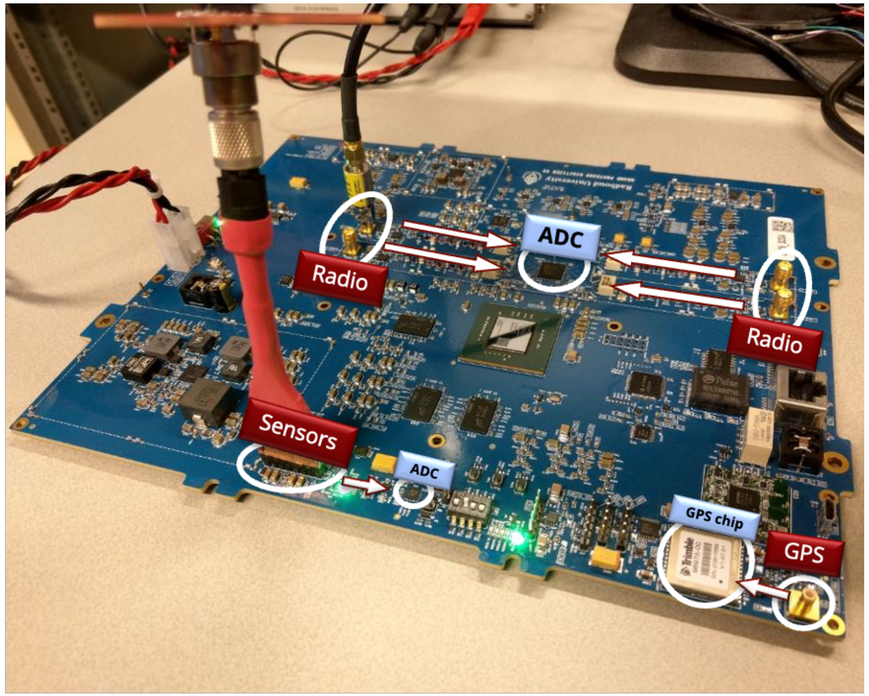
GRAND & G-COS

- **Logic step for mainly NL developed radio technique**
- GRAND: Next station version under development (NL lead)
- Global Cosmic Ray Observatory, next generation: (10-20)xPAO.

The Giant Radio Array for Neutrino Detection

GRANDProto → GRAND 10k → GRAND 200k





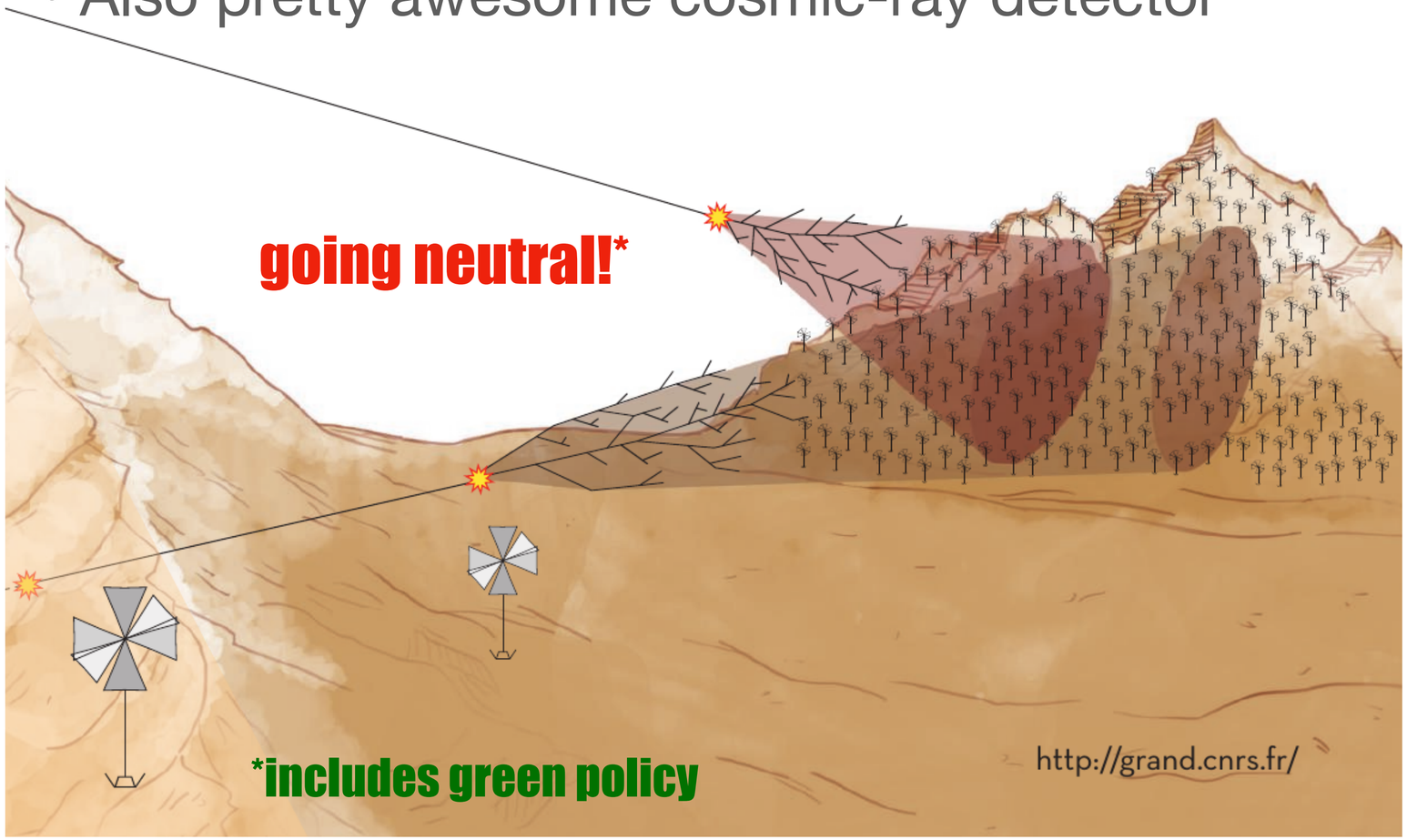
4 channels, 500 MHz, 14bit, 12 Watt

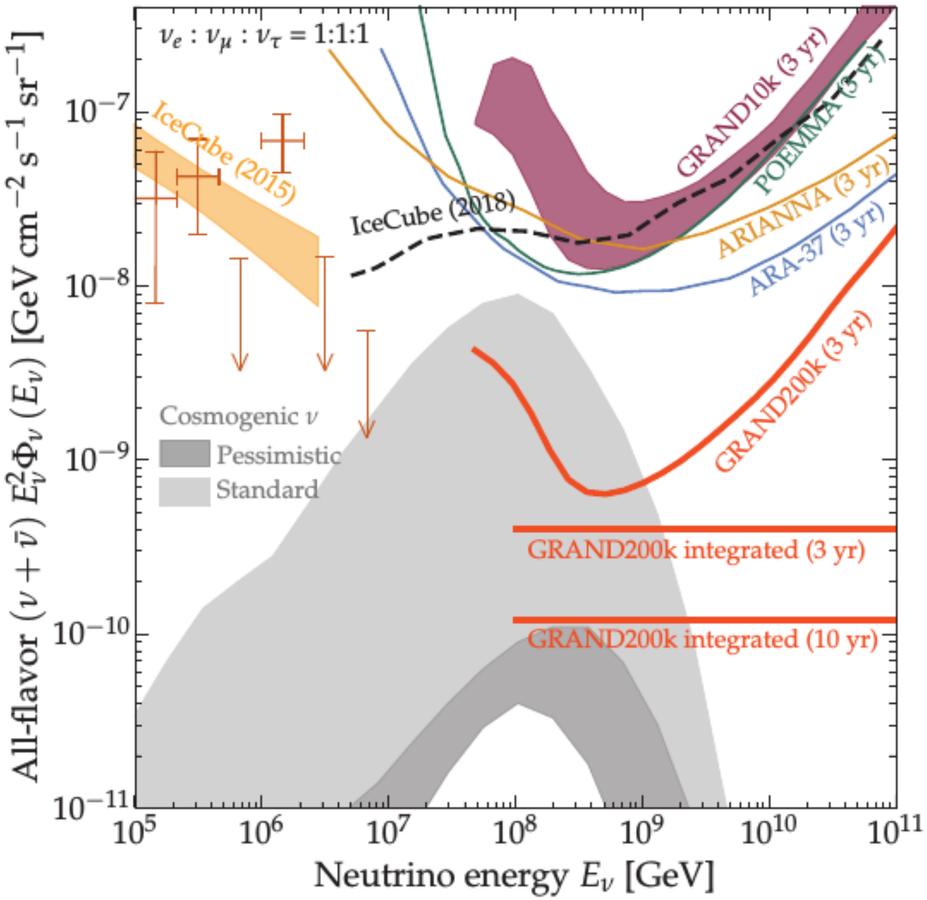
- Station mechanical design and electronics in Nijmegen
- 100 Stations ready for deployment (China)*
- 5 stations setup in Nançay Radio Observatory, France (coming months)

* delay due to COVID

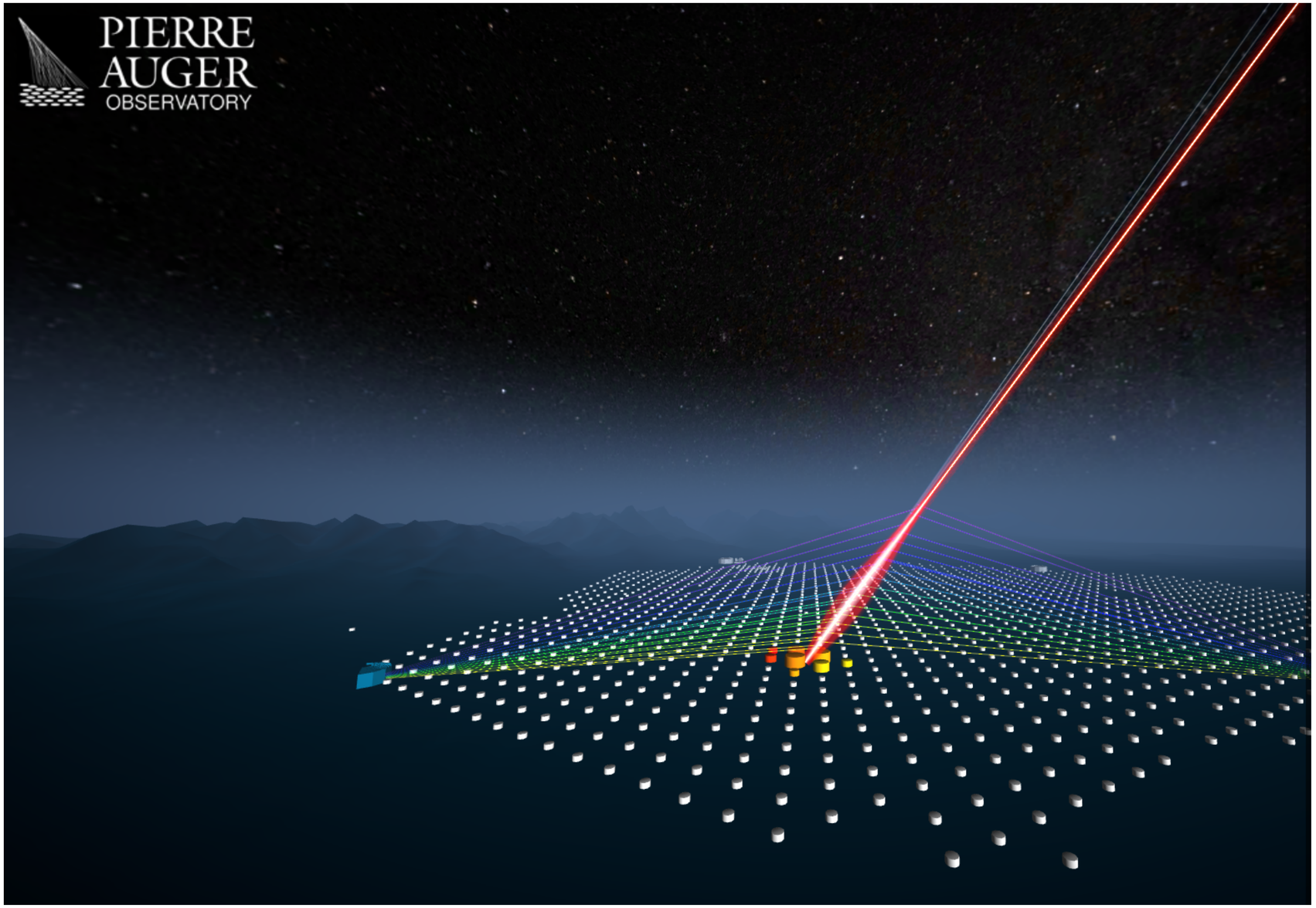
The Giant Radio Array for Neutrino Detection

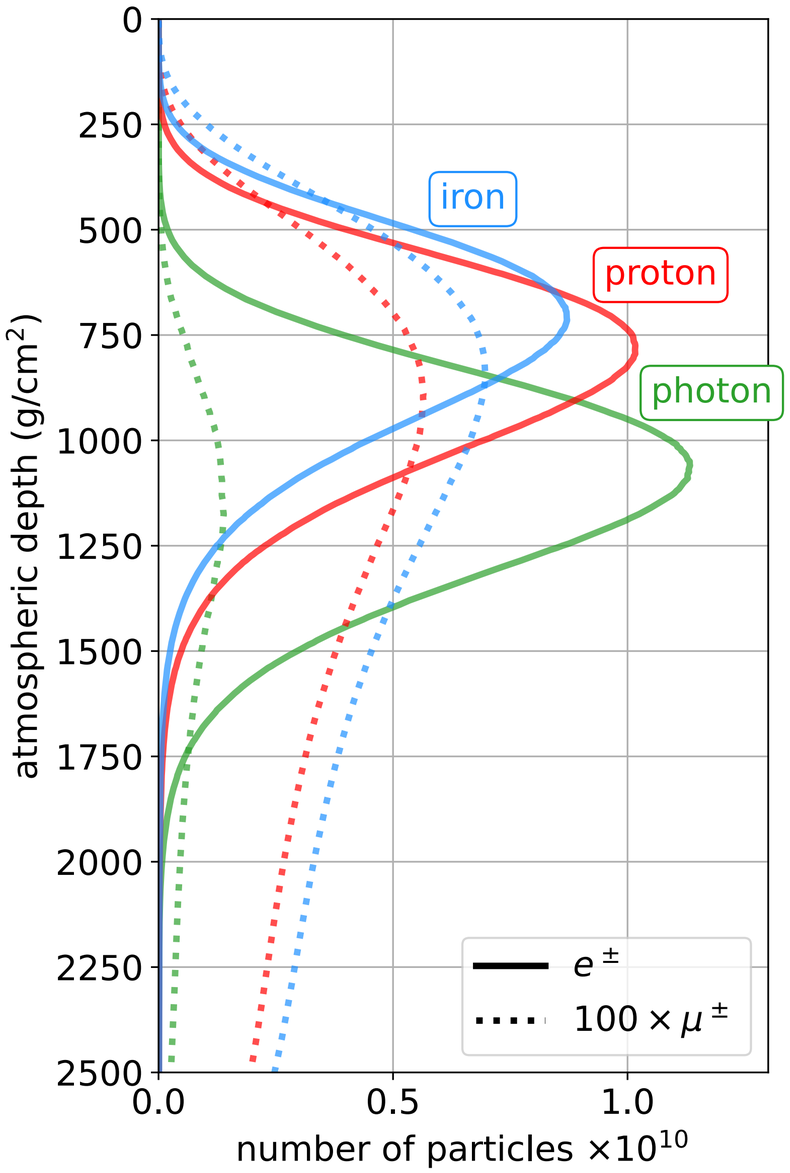
- Large radio array(s) focussing on “horizontal” air showers
- Hunt for Ultra-High-Energy neutrinos
- Also pretty awesome cosmic-ray detector



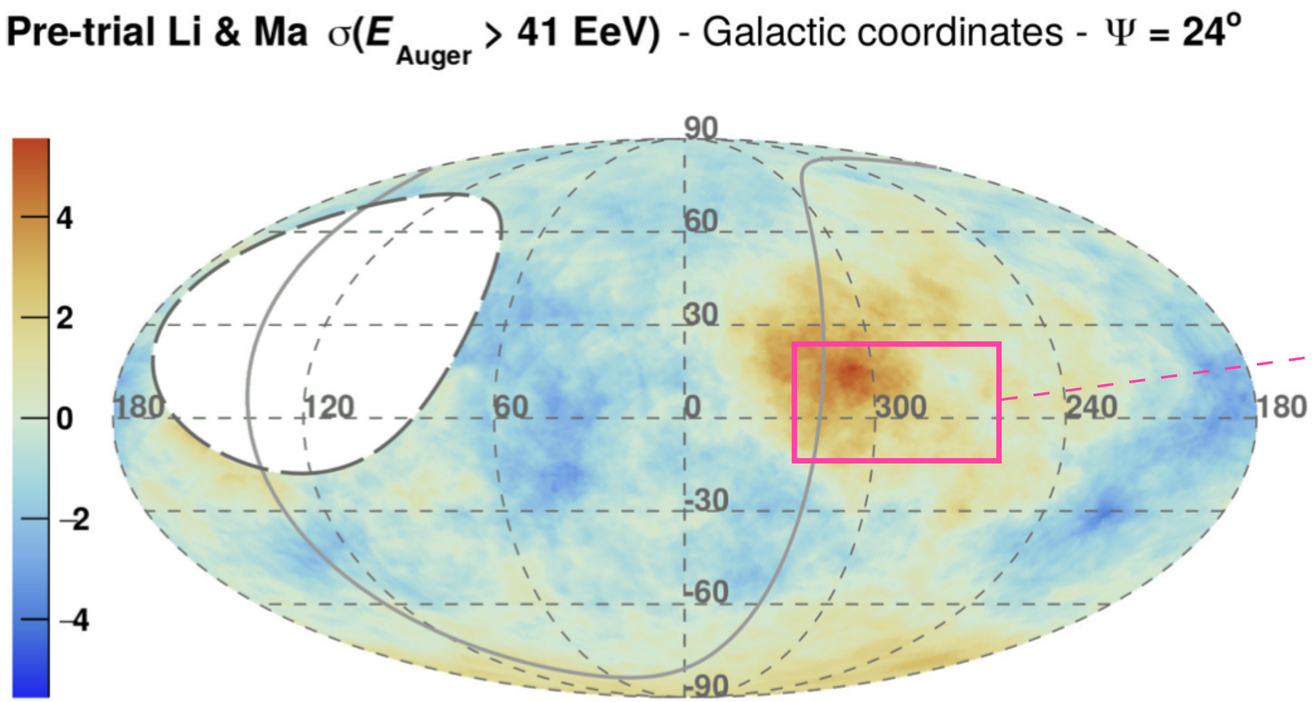


Extensive Air Showers





What are these accelerators?



Pierre Auger Observatory, ICRC 2021 (Berlin)

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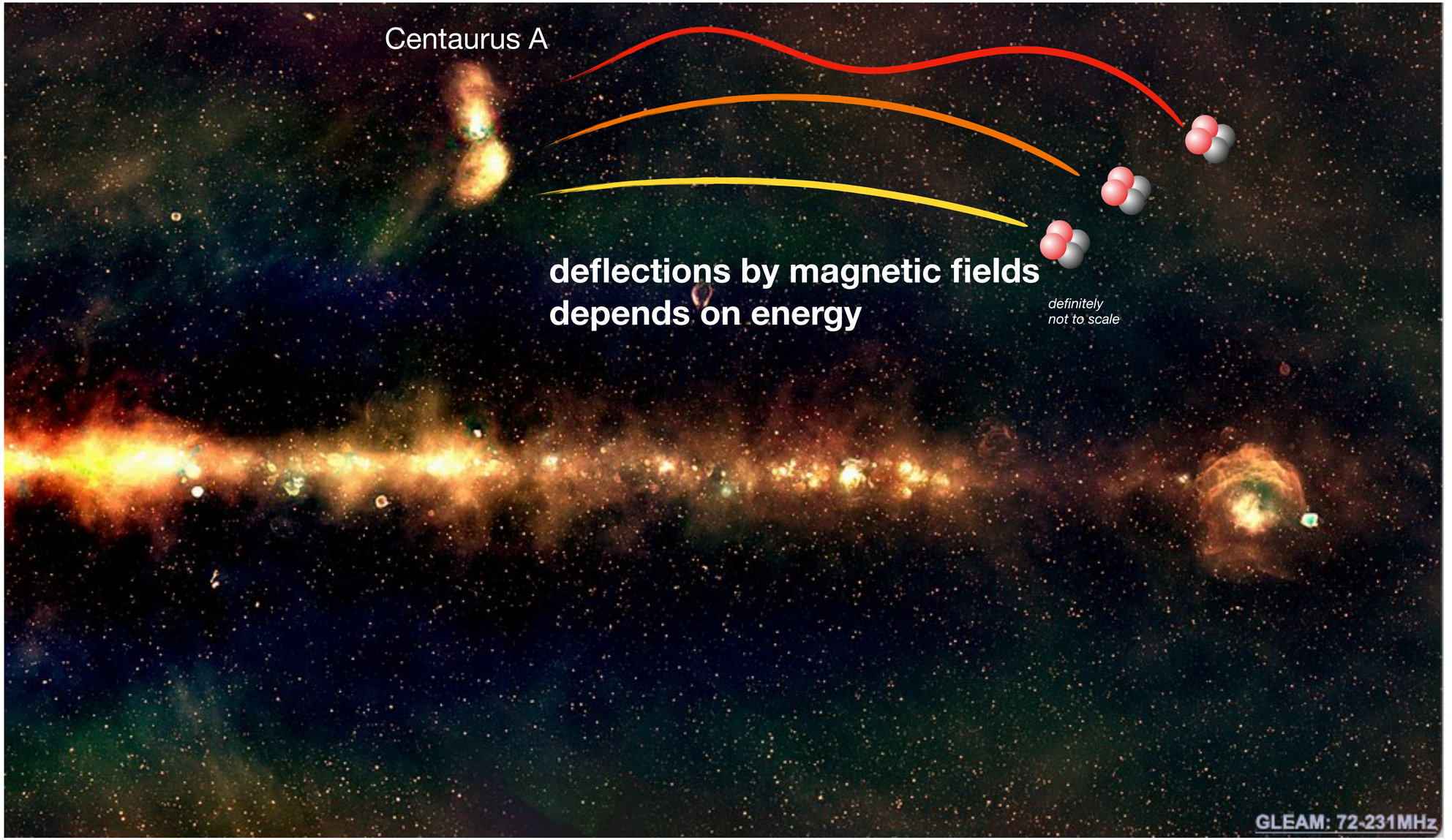
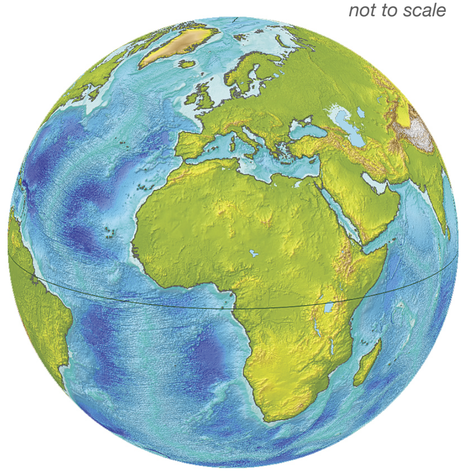
Why the fuzzy picture? Charged particle astronomy



not to scale

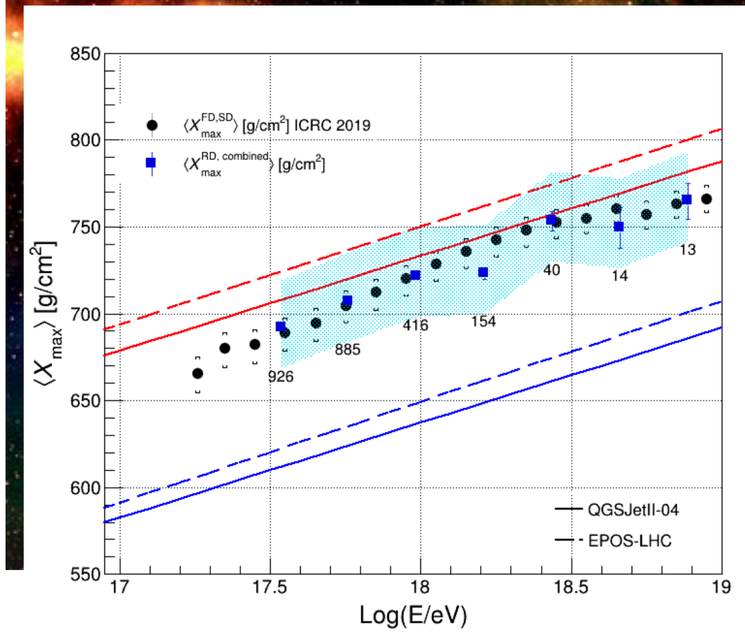


Earth

Why the fuzzy picture? Charged particle astronomy

Centaurus A

Both acceleration and propagation processes depend on particle composition



deflections by magnetic fields depends on charge

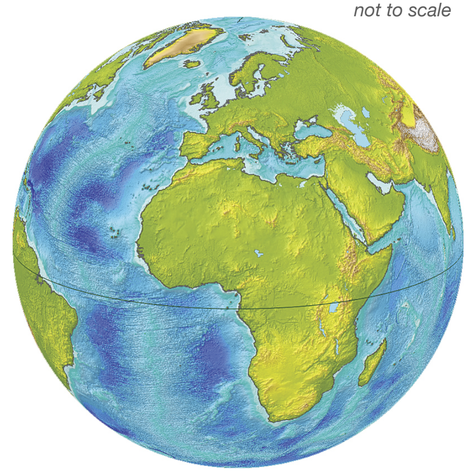
definitely not to scale

F. Canfora

(PhD Thesis 2021)

GLEAM: 72-231MHz

not to scale



Earth

AugerPrime: Radio Detector

Digitisers developed by RadioLab @ Radboud University

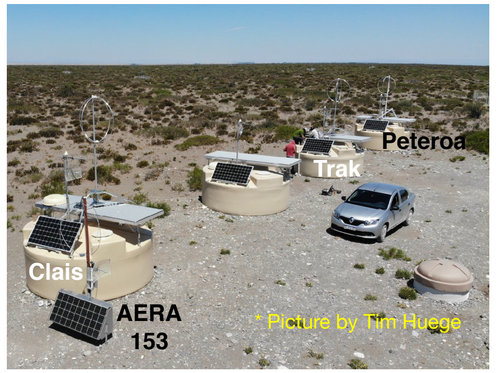
Schedule RD Deployment:

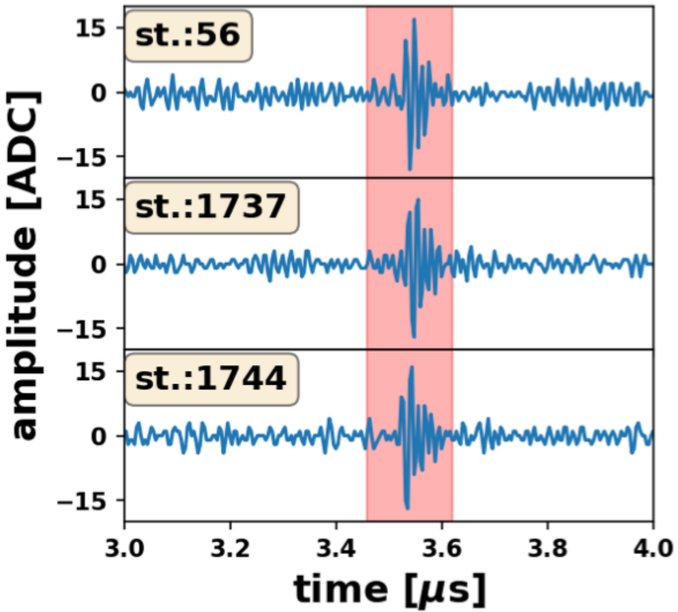
Phase 1
Antenna + Solar panels + Structure: June - November

Phase 2
Digitisers + Cables + Amplifiers: November - January

Full Array Early 2023

First events from engineering array





Radio trigger development

Dave Nitz (MTU)

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