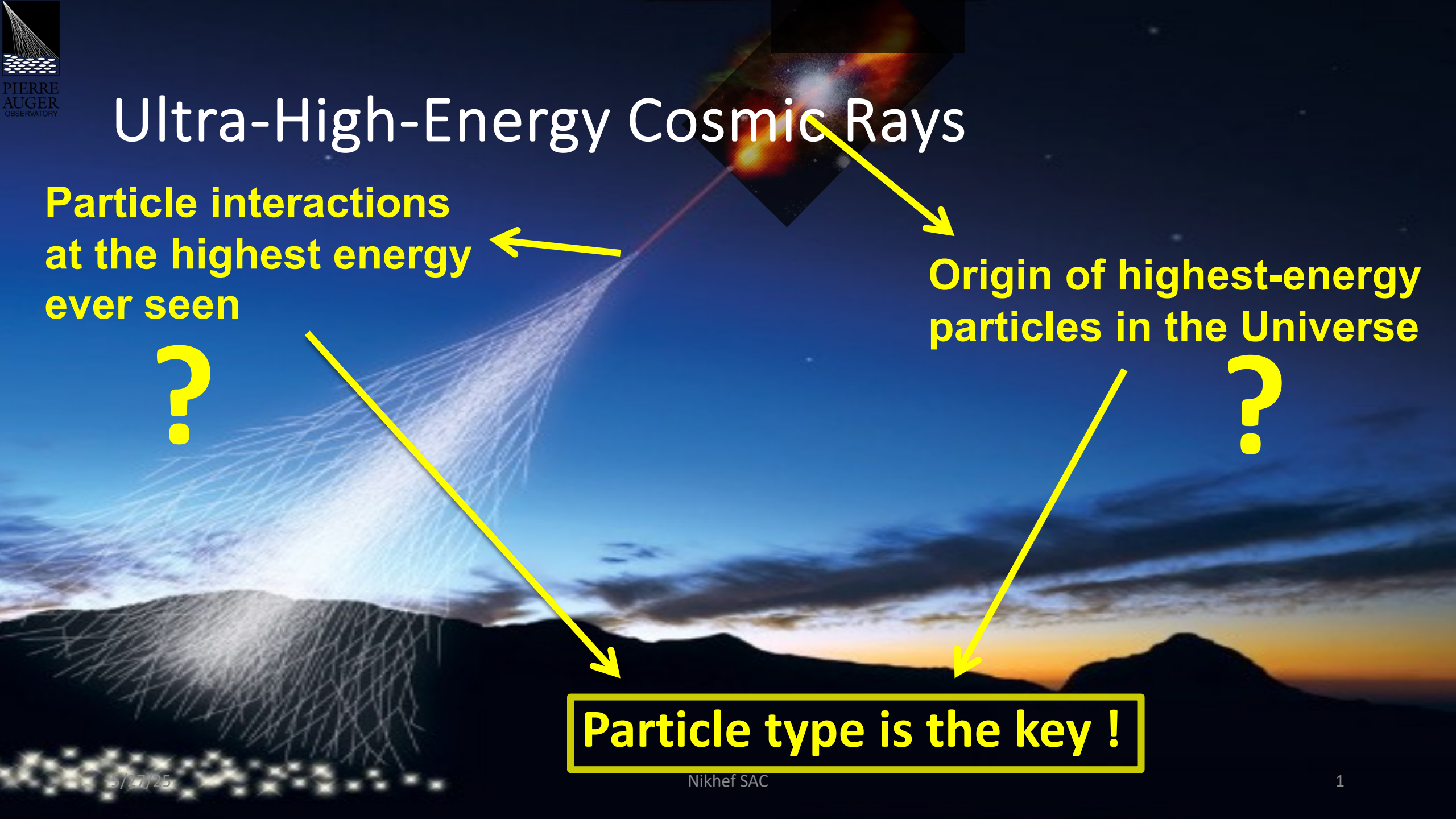

Ultra-High-Energy Cosmic Rays
Particle interactions at the highest energy ever seen
?
Origin of highest-energy particles in the Universe
?
Particle type is the key !

Cosmic Rays in the Universe

Proton

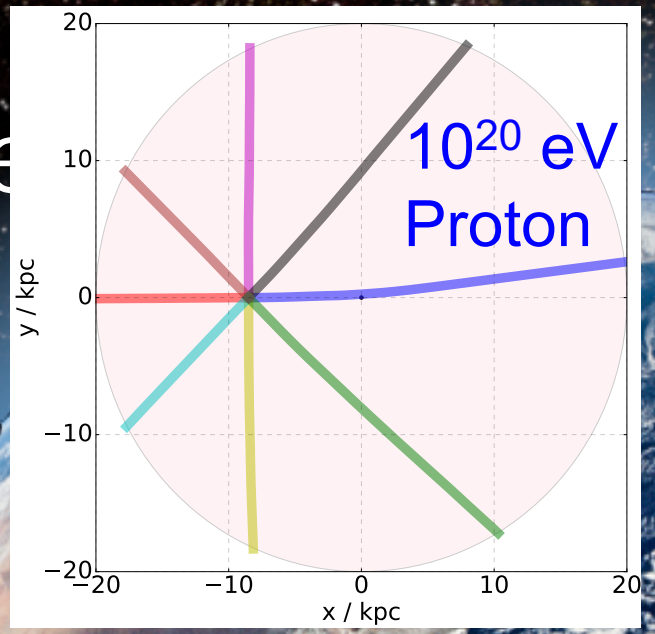
Photon

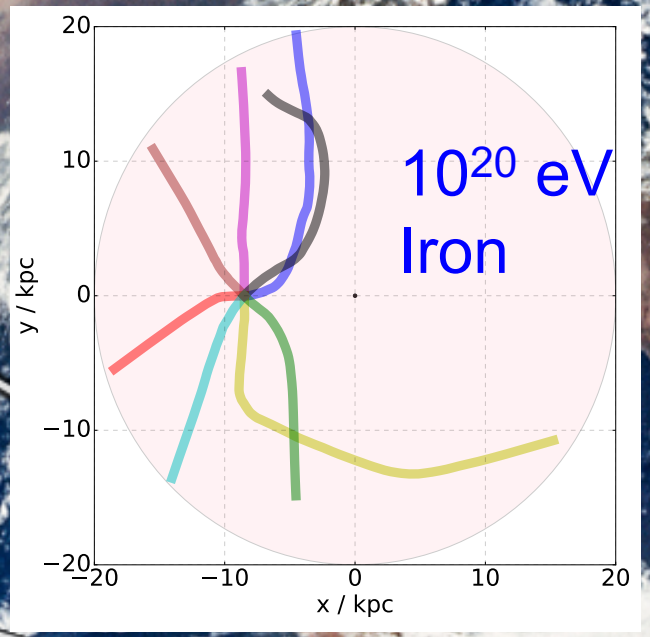
Neutrino

Nucleus

$\vec{B}$

$\vec{B}$





Plans/Ambitions 2023

- Installation and completion of the radio detector in AugerPrime
- Sign the int. agreement to run AugerPrime until mid 2030s
- Continue our leading role in radio detection at Auger
- Take a leading role in point source search in Auger
- Analysis on shower development using radio and particle information
- Get the GRAND prototype in Auger (G@A) operational
- Continue to define GCOS

Achievements since 2023

- Sign the int. agreement to run AugerPrime until mid 2030s
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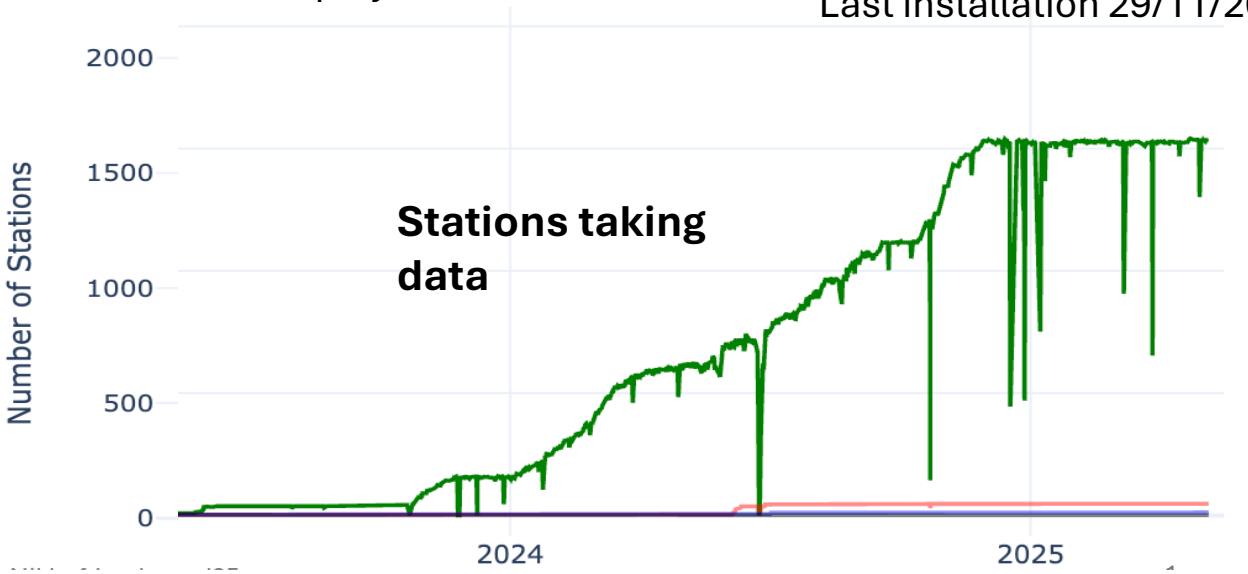
Deployment

Last installation 29/11/2024



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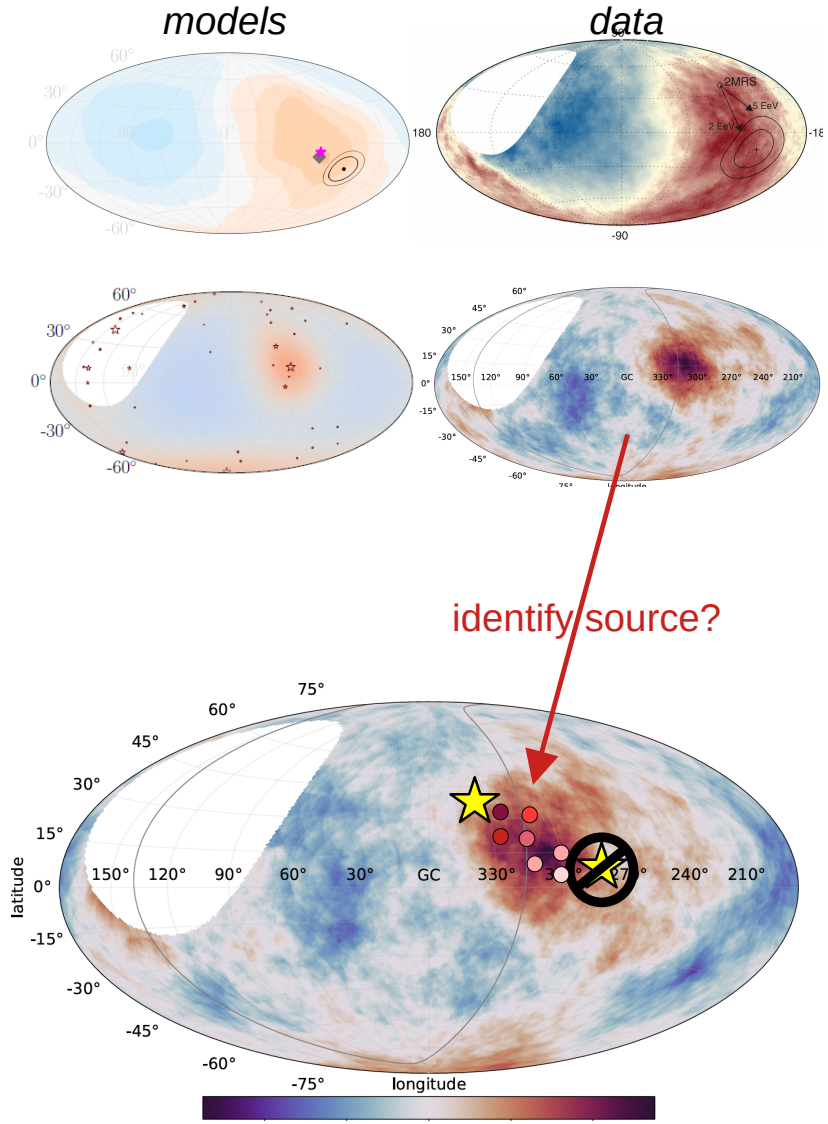
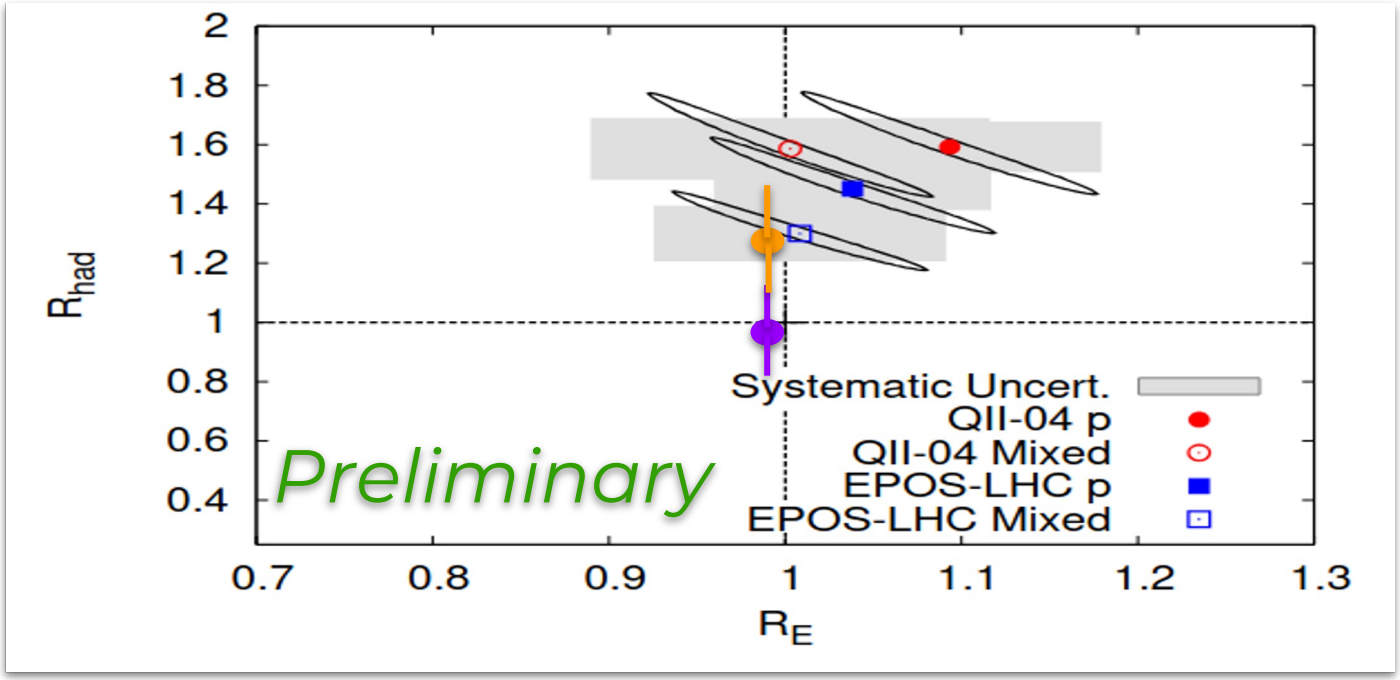


Achievements since 2023



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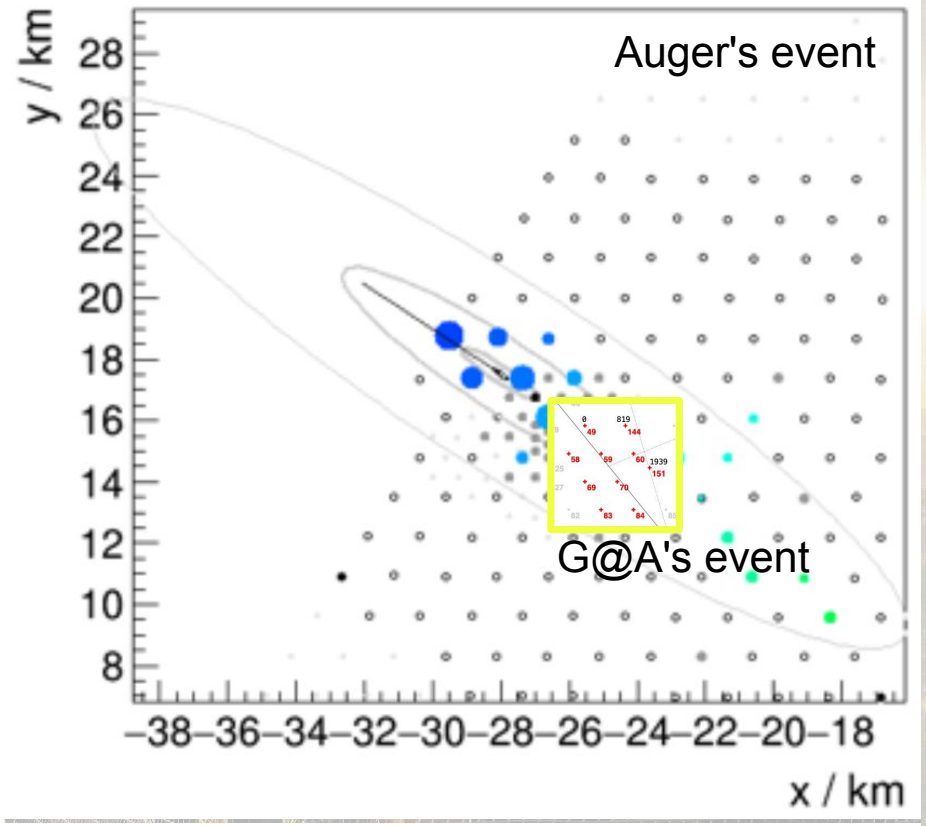
Achievements since 2023



G@A

-> ***September 16th, 2024 at 20h06min08s (UTC)***

-> ***Plane wave fit:***

θ = 77.589°

ϕ = 143.4°

Auger

-> ***September 16th, 2024 at 20h06min08s (UTC)***

-> ***Spherical wave fit***

θ = 80.36 +- 0.05

ϕ = 142.91 +- 0.02

- Get the GRAND prototype in Auger (G@A) operational
- Continue to define GCOS

Evolution Group

SCIENTIFIC STAFF:

- NWO/Nikhef: NN
- Radboud University/Nikhef: Falcke, Galea, Hörandel, De Jong, Mulrey, **Schoorlemmer (ERC CoG**, Timmermans
- University of Amsterdam: Vink

TECHNICAL STAFF:

- NWO/Nikhef: 1.1 FTE + 1 FTE from investment budget
- Radboud University: *3.0 FTE*

POST-DOCS:

- Teresa Bister **(VENI)**
- Bjarni Pont (until July 2025)
- Kevin Almeida Cheminant
- **Juan Ammerman (starting 1/7/2025)**

GRADUATE STUDENTS

- Tomas Fodran (Sep 2024)
- Abha Kakurdikar (April 2025)
- Mohit Saharan (2025)
- Mohamed Emam (2025)
- Anthony Bwembya (2025)
- **Pim van Dillen (2029)**

Dutch Investments:

Entrance FEE	120k		ASTRON/RU/KVI/Nikhef
AERA	808k =	532k	ERC Heino Falcke
		130k	Nikhef
		116k	KVI Groningen
		30k	RU Nijmegen
Auger comms:	19k		RU Nijmegen
AugerPrime:	4142k =	450k	Nikhef
		40k	RU Nijmegen
		1000k	ERC Jörg Hörandel
		2500k	NWO-Groot
		145k	KIT
GRAND:		7k	KNAW
		22k	CAS
		10k.	RU Nijmegen
SWGO:		**800k**	**ERC Harm Schoorlemmer**

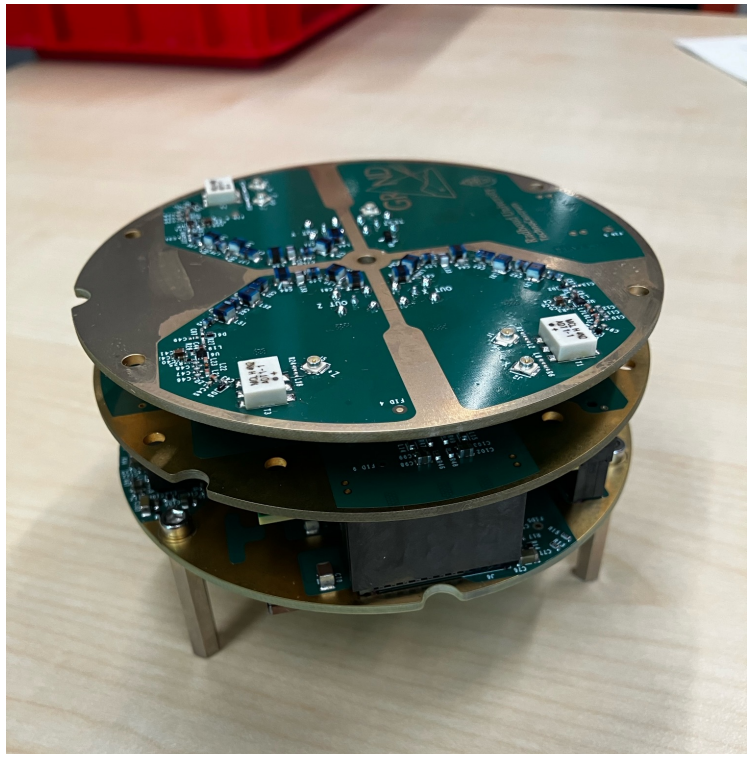
Dutch investment so far 5921k€

Running science projects

- Point source searches with Auger making use of all information including the galactic magnetic field
- Using the upgraded detector for better determination of shower depth
- Establish interferometry to measure shower development
- Combine radio and particle information to better test air shower models

Running Technology projects

- Design low power electronics for new detectors using conventional silicon technology
- **Evaluate the use of graphene for several tasks to further reduce power consumption**
- **Design and installation of radio detection in GCOS (ERC-CoG, Schoorlemmer)**



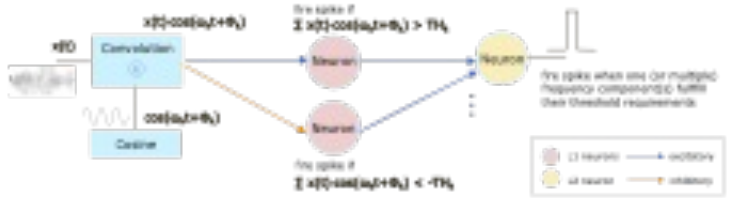
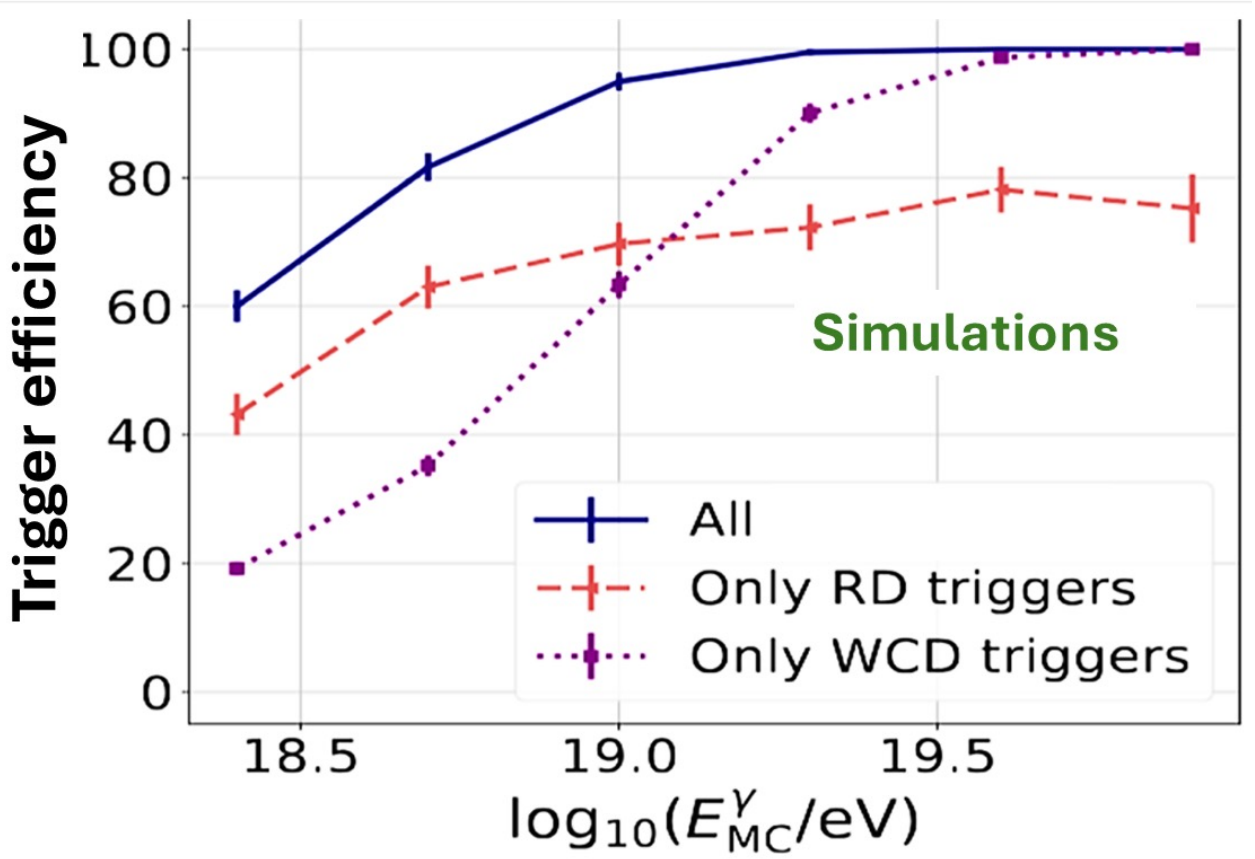


Fig. 3: Proposed frequency-domain trigger method architecture for one frequency component.

Ambitions (short term)

- Run AugerPrime and analyze its data
- Create a trigger on radio in AugerPrime
- Further include ML in point source searches
- Improve shower development to event-by-event probability on nature of primary
- Join SWGO (Schoorlemmer ERC)
- Use SWGO for further air shower studies using a dense detector
- Decide on next generation detector (GCOS, GRAND, …)



Coherence

- Mass determination, leading to hadronic interaction and point sources remain our overarching theme
- Auger is, and will be, the working horse for physics output
- Auger provides testing grounds for new ideas leading to a next generation detector design
- The study on neutral particles using radio within Auger is fruitful in itself and serves as a testing ground for future implementation in SWGO
- We have (unsuccessfully) applied for common funding with KM3NeT in the past, but will look for opportunities for Multi-Messenger studies in the Universe

Challenges and Opportunities

- C: Keeping a coherent program while funding requires new initiatives
- O: New initiatives (SWGO/Graphene) help shed new light and improvement on current activities
- C: Dutch funding landscape is drying up
- O: New (young) hire can apply for new funding (eg VIDI)
- C: At the end of the year we have only 1 PhD student
- C: The sectorplan money for universities has disappeared, implications are not yet clear
- O: Data analyses as well as hardware developments are needed, diverse training ground for PhD students and postdocs