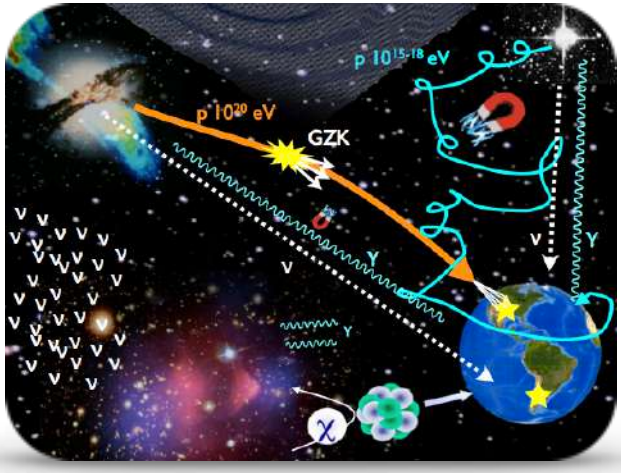


Outlook on Astro-particle Physics

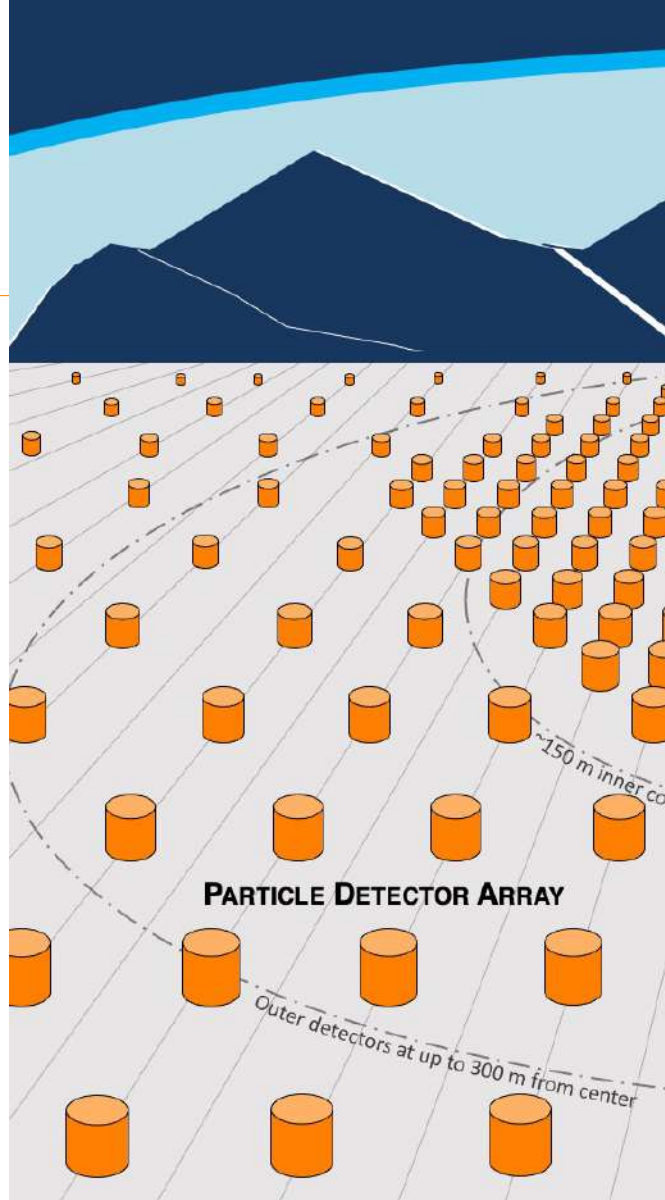
Ulisses Barres de Almeida

CBPF
Centro Brasileiro de Pesquisas Físicas

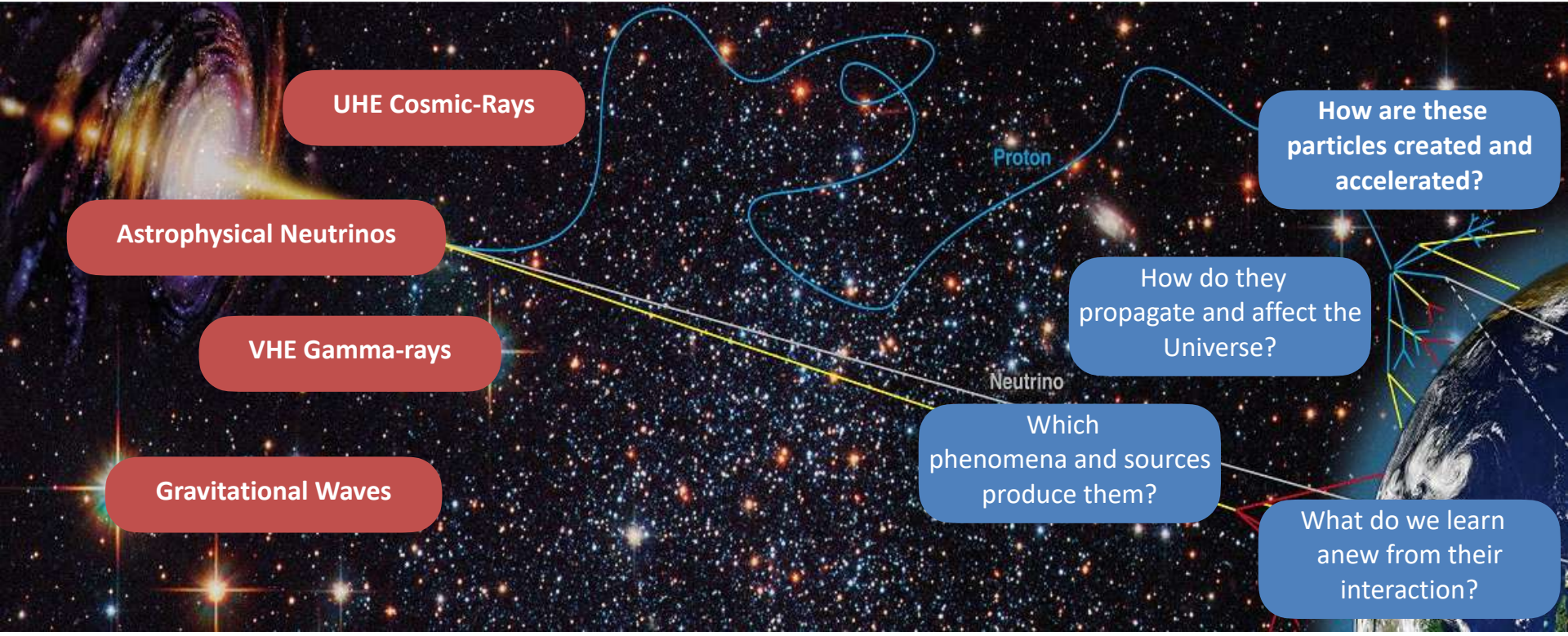
CBPF
Centro Brasileiro de Pesquisas Físicas

Content

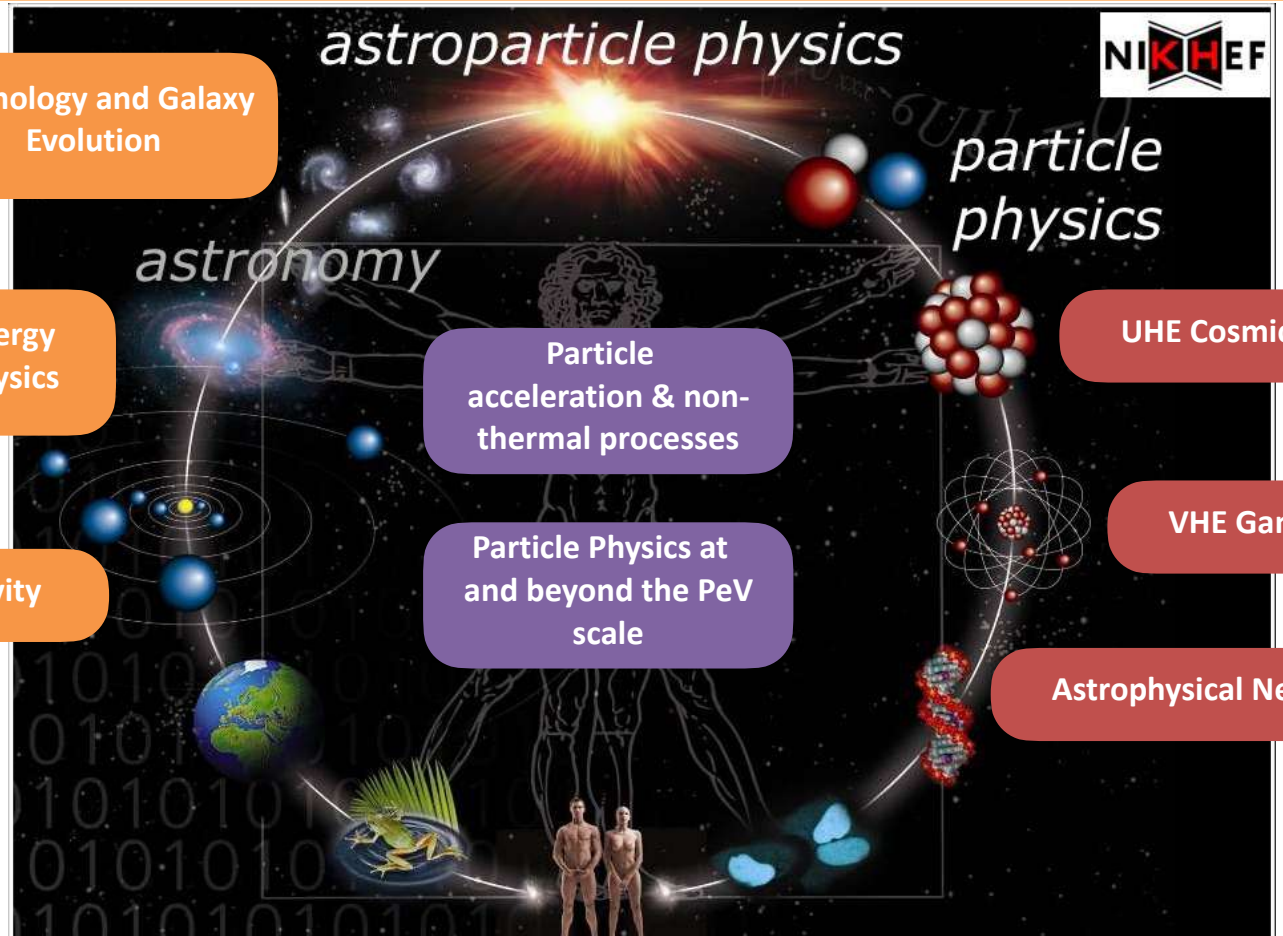
- Astroparticle Physics
- Pierre Auger Observatory
- The SWGO Project



Messengers and Messages



Messengers and Messages



Astroparticle Physics: multi-messenger scenario

sub-mm IR-UV X-rays Gamma-rays →

meV ... eV ... keV ... MeV ... GeV ... TeV ... PeV ... EeV ... ZeV

Realm of Astroparticle Physics

Astronomy with photons

Charged cosmic-ray physics: p, e-, He, Fe, ...

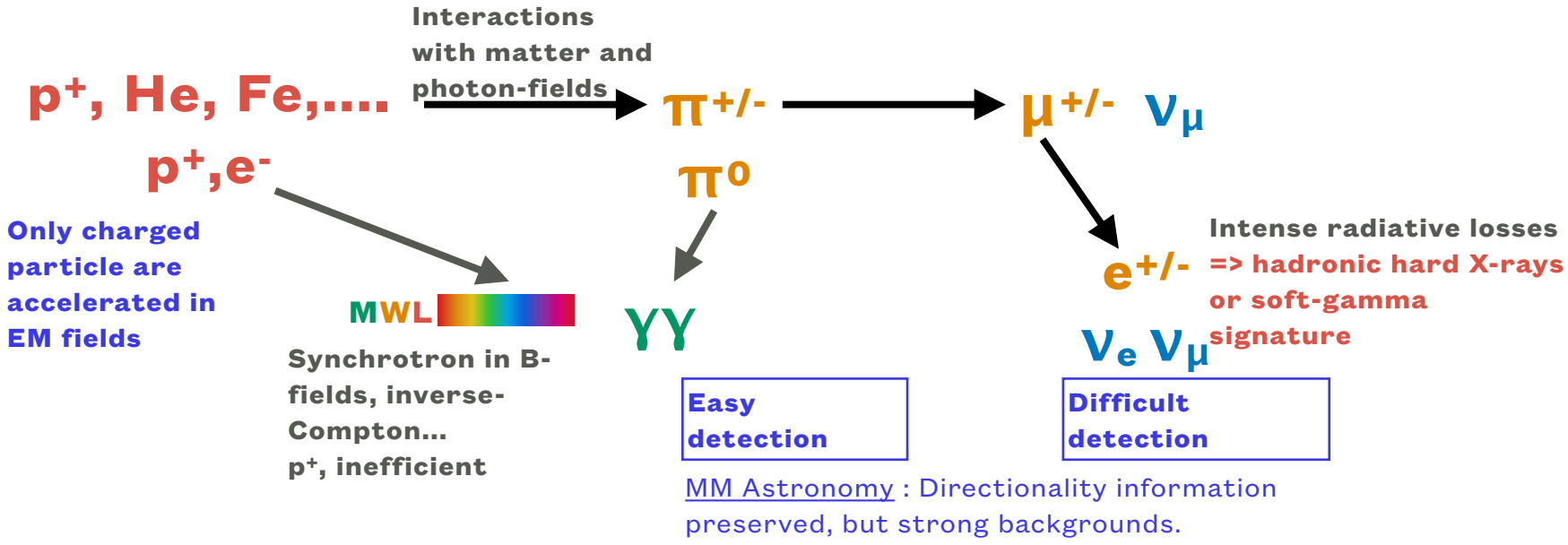
Neutrino signals

All messengers are interconnected and relate back to the same sources: multi-messenger astrophysics

GRAVITATIONAL WAVES? PROBES OF COMPACT SOURCES

Connecting the Messengers

All messengers are connected and relate back to the same sources: logic behind the multi-messenger astrophysics

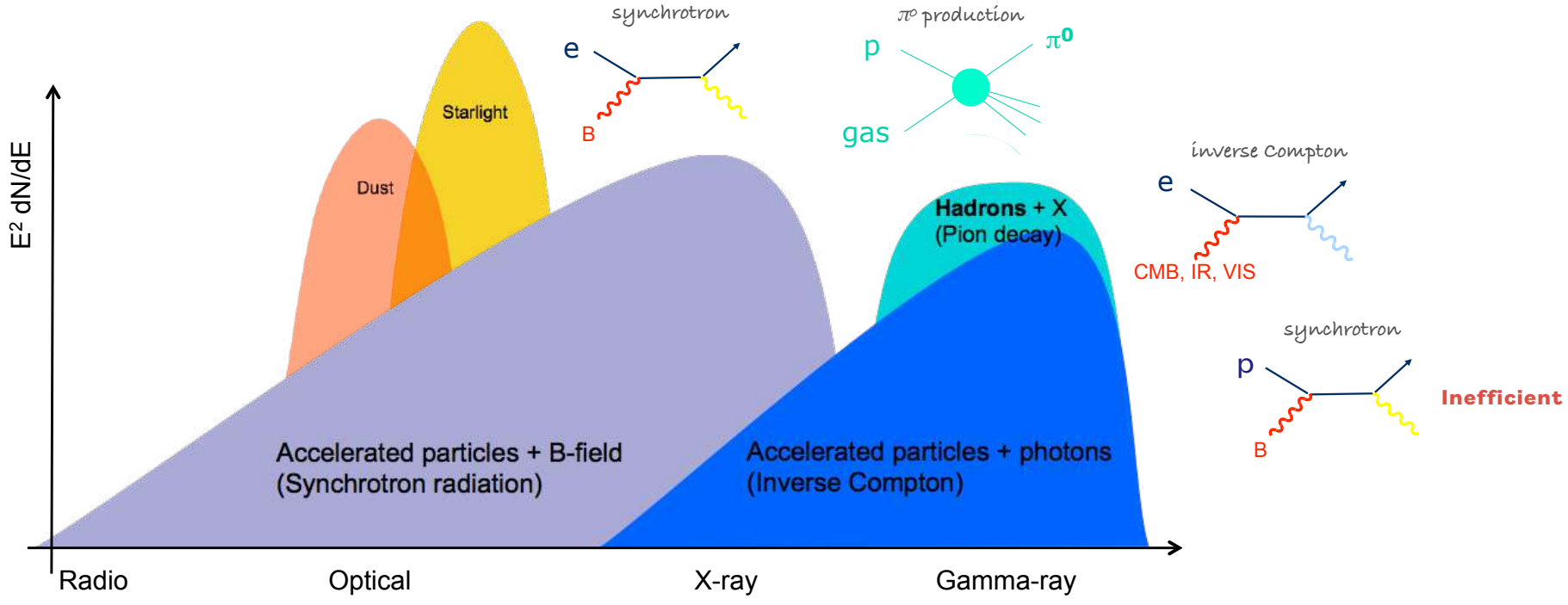


MM Astronomy : Directionality information preserved, but strong backgrounds.

Gamma-rays are the cornerstone of multi-messenger astrophysics

© adapted from a slide by Johannes Knapp

The multi-band view of Astrophysical Sources



© plot by Christian Stegmann, DESY, MG XIV Meeting 2015 (modified)

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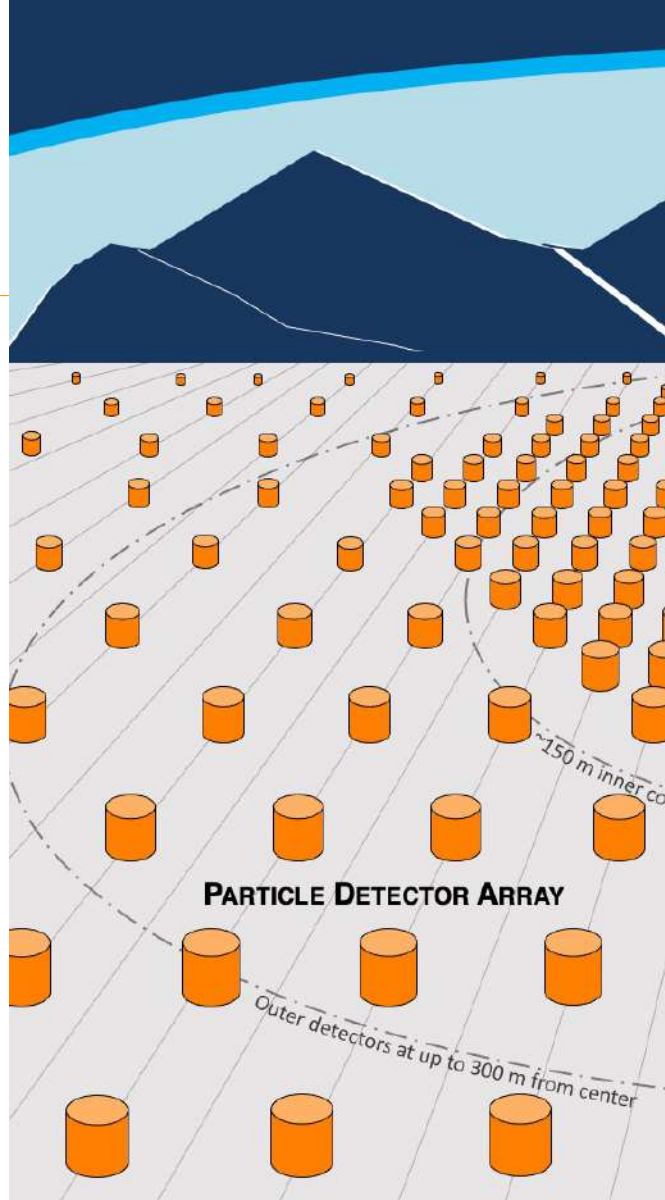
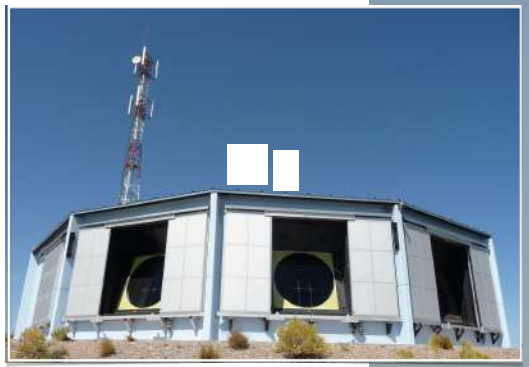
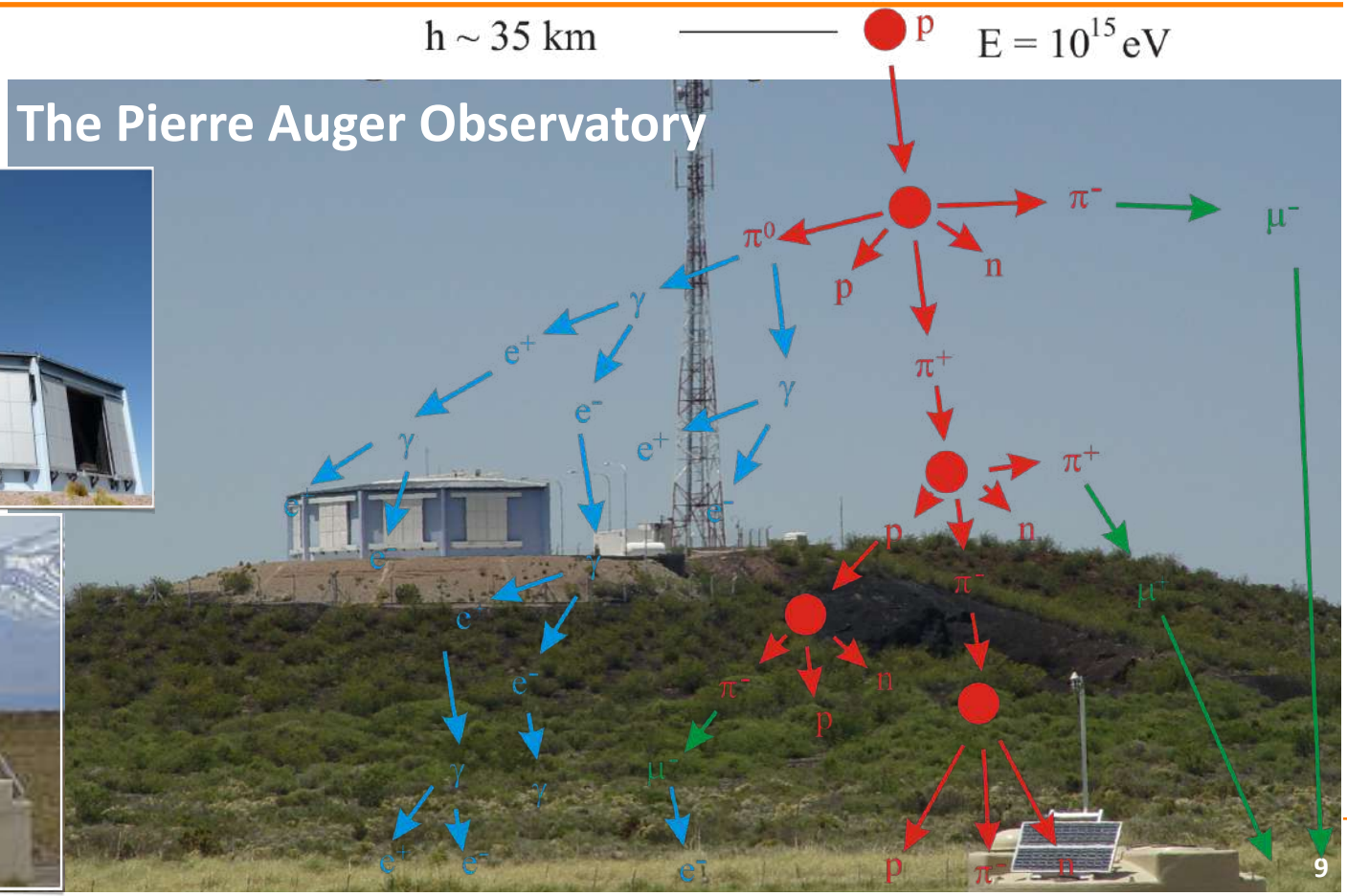


Ultra-high-energy Cosmic rays

PIERRE AUGER OBSERVATORY



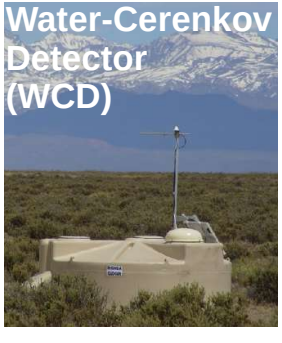


The Pierre Auger Collaboration & Observatory

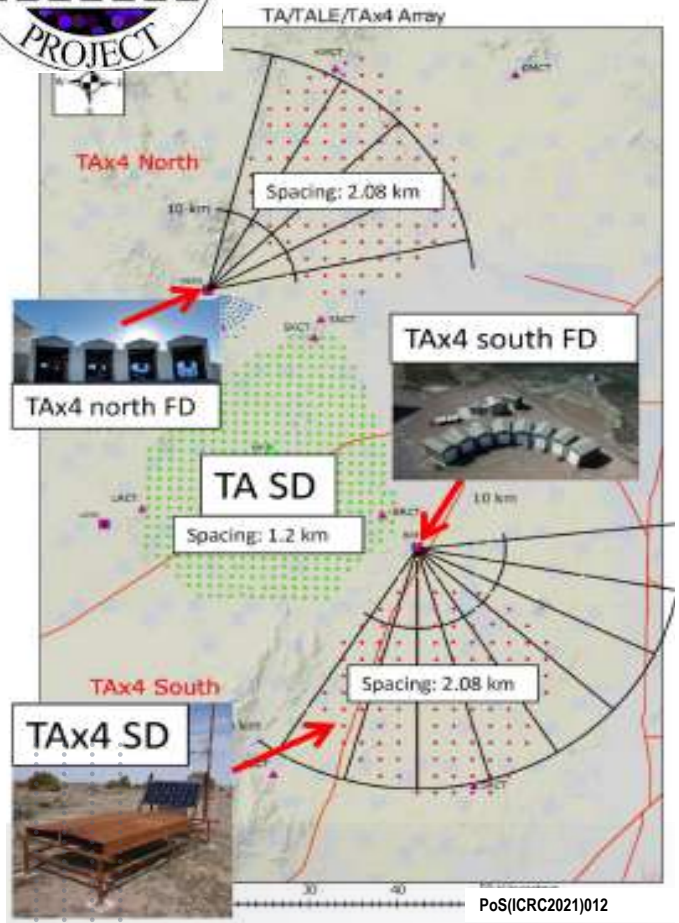
>400 scientists, technicians from 18 countries (82 institutions):

PIERRE AUGER OBSERVATORY

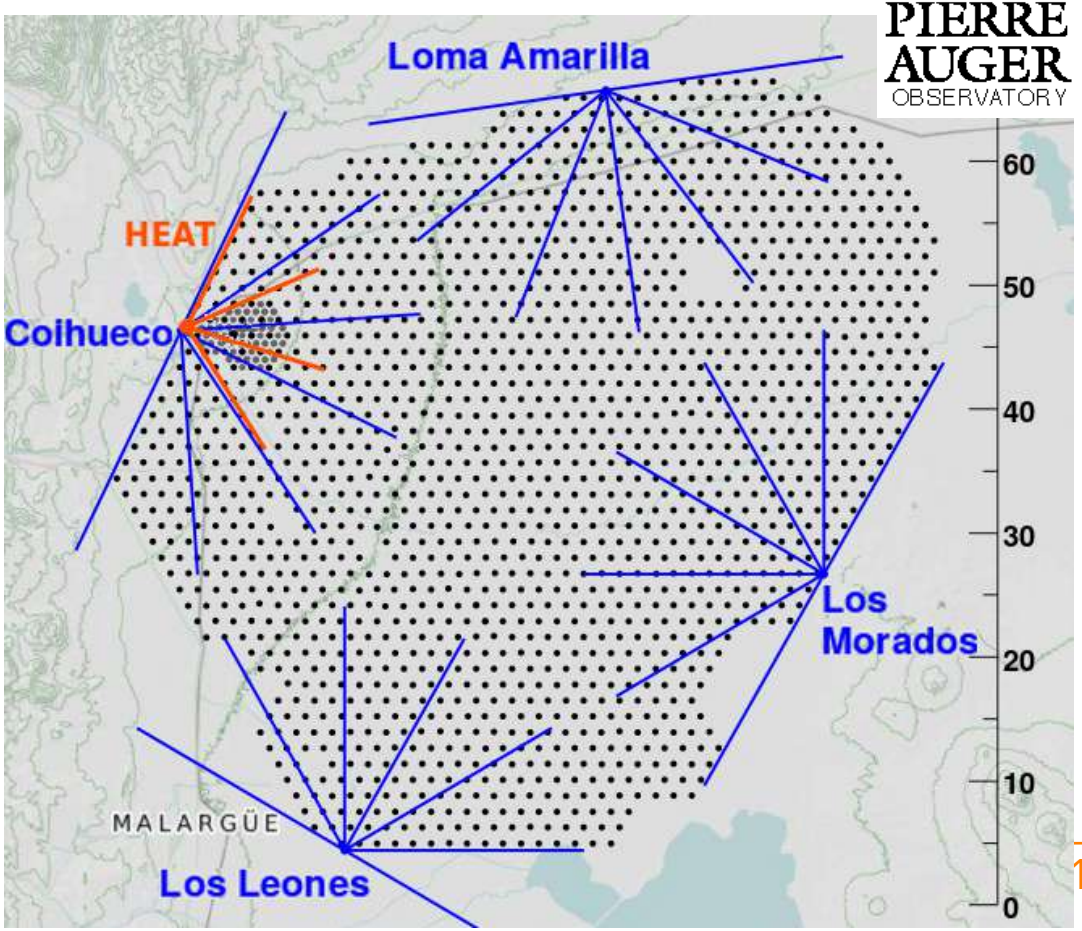
Multiple Particle-Physics Technology and Continuous Development



Ultra-high-energy Cosmic rays



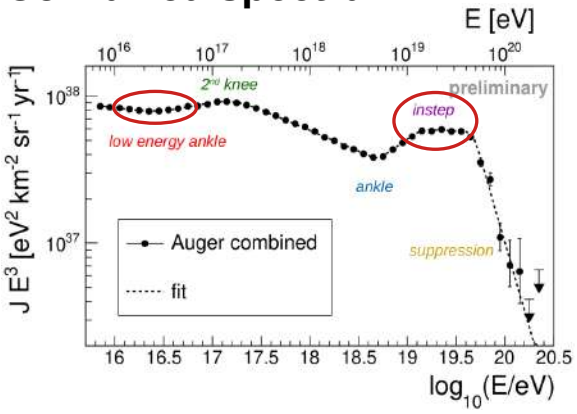
PoS(ICRC2021)012



PIERRE AUGER OBSERVATORY

Science Highlights

Combined spectrum

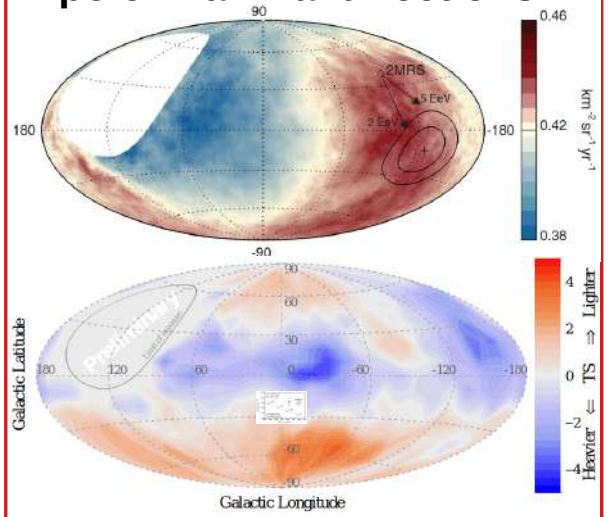


Features never seen before

New questions about the origin of these new features

Auger Coll., Phys. Rev. D 102 (2020)
Auger Coll., Phys. Rev. Lett. 125 (2020)
Auger Coll., Eur. Phys. J. C 81 (2021)
V. Novotny, PoS(ICRC2021) 324

Dipole in arrival directions



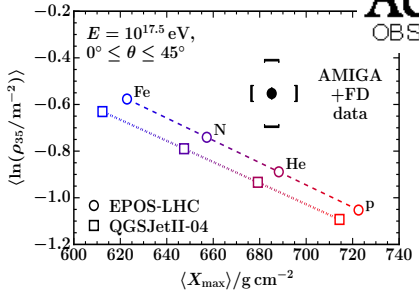
Dipole above 8 EeV suggesting extra-Galactic origin
Lighter elements from out the galactic plane (**charge particle astronomy**)

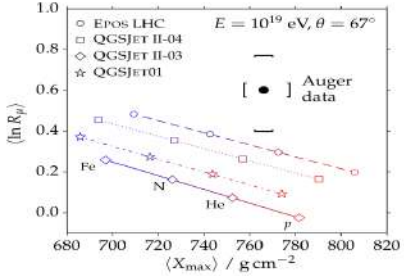
Auger Coll., Science 357 (2017)
Auger Coll., ApJ. 868 (2018)
Auger Coll., ApJ. 891 (2020)
R. De Almeida, PoS(ICRC2021) 335

Auger Coll., Phys.Rev.D90 (2014) 122005
Auger Coll., Phys.Rev.D96 (2017) 122003
E. Mayotte, PoS(ICRC2021) 321

Hadronic physics

PIERRE AUGER OBSERVATORY





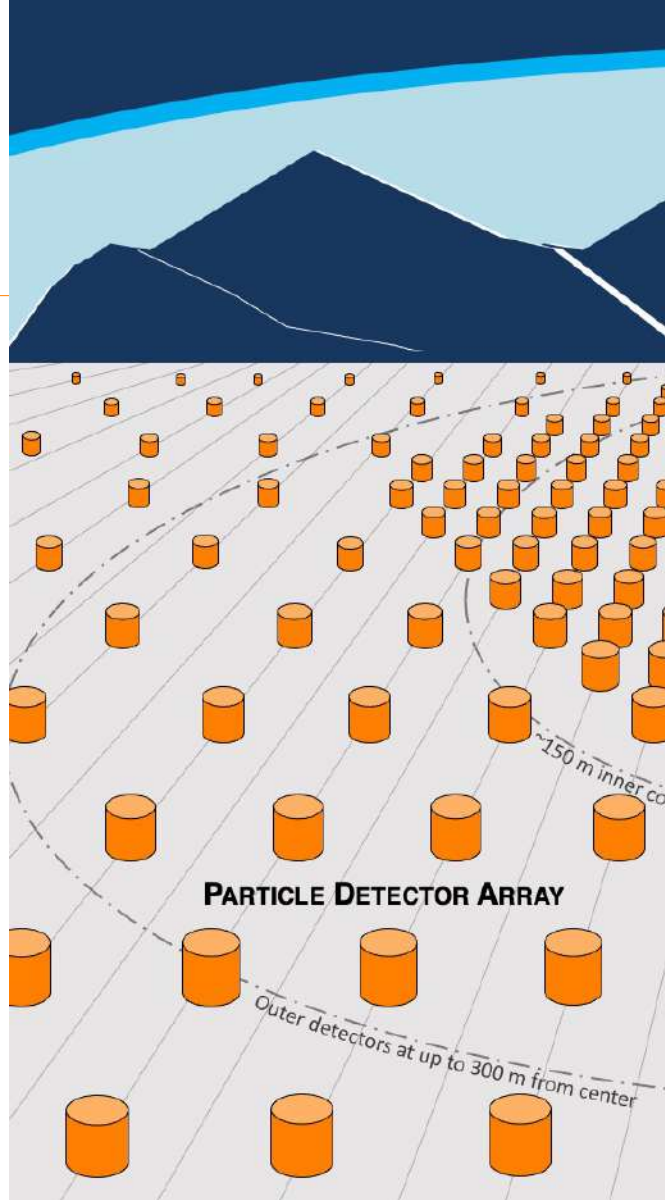
Muons observed in air showers are **not reproduced by hadronic models** tuned after LHC data.

Auger Coll., PRD. 91 (2015)
Auger Coll., EPJ C. 751 (2020)

SWGO
The Southern Wide-field Gamma-ray Observatory

Content

- Astroparticle Physics
- Pierre Auger Observatory
- The SWGO Project



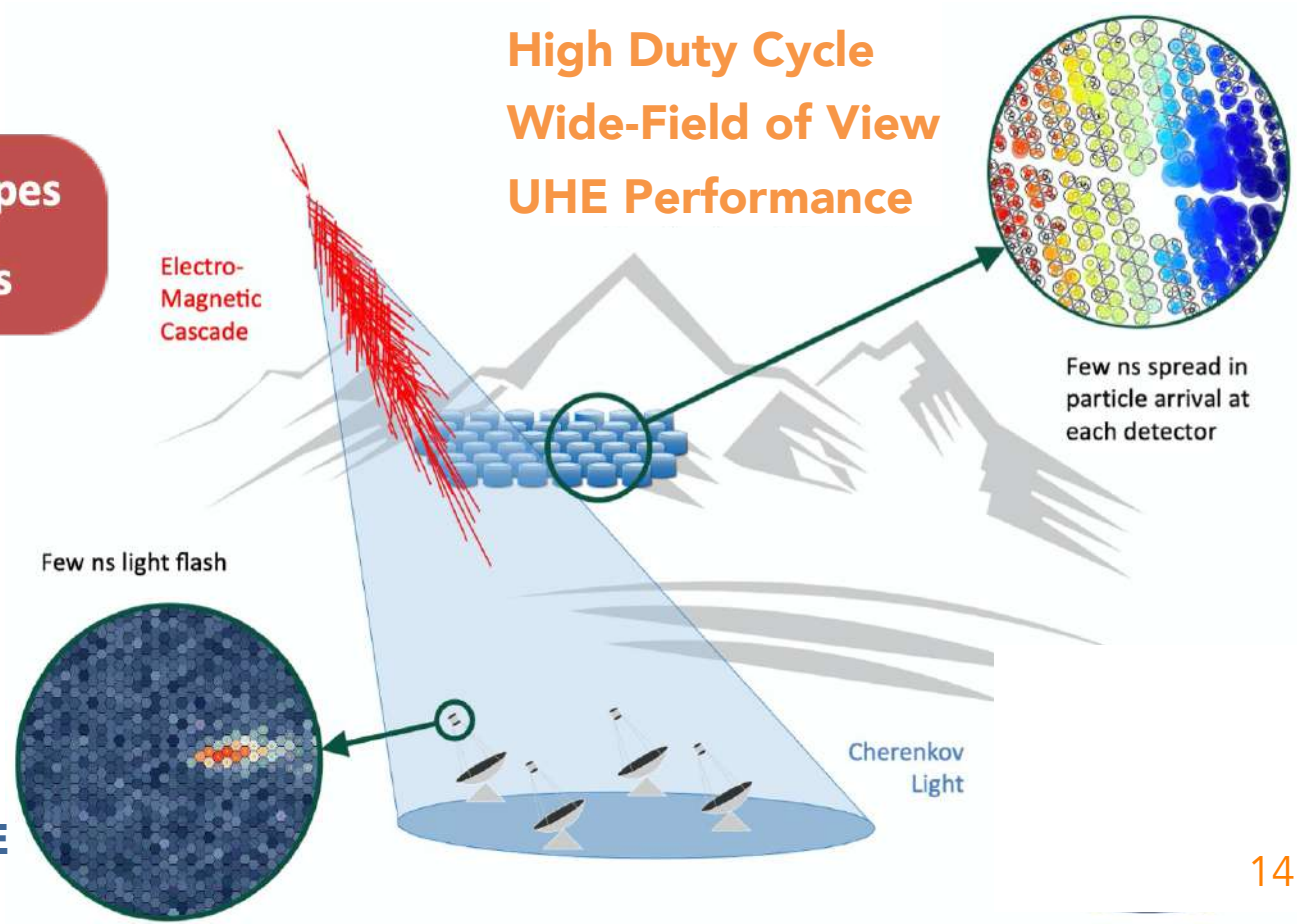
SWGO
The Southern Wide-field Gamma-ray Observatory

Status of ground-based gamma-rays

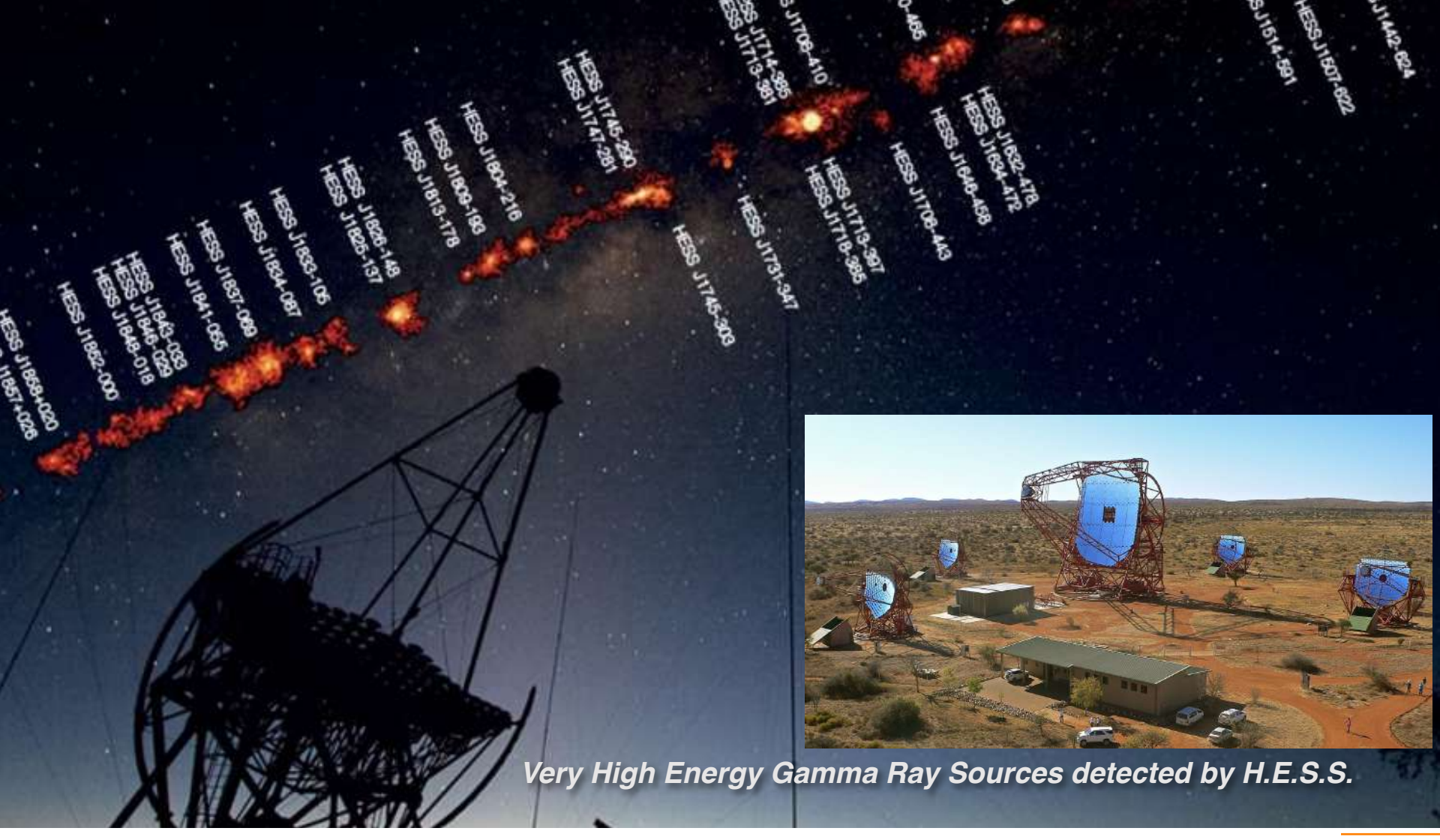
Two techniques

1. Air-Cherenkov telescopes
2. Altitude particle arrays

High Duty Cycle
Wide-Field of View
UHE Performance

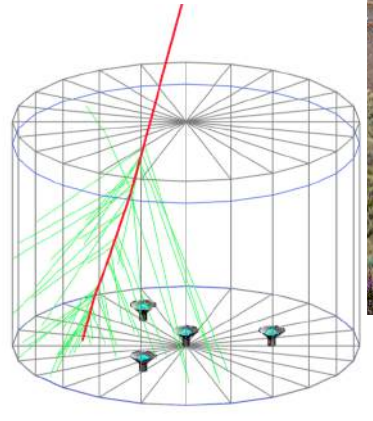


Low Duty Cycle
Pointing instruments
Precision Astronomy at VHE



Very High Energy Gamma Ray Sources detected by H.E.S.S.

HAWC - The High-Altitude Water Cherenkov Experiment



LHAASO
Large High Altitude Air Shower Observatory

A new window into the UHE sky

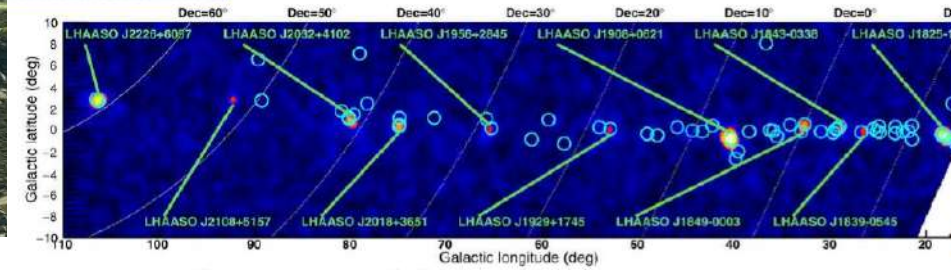
Ultrahigh-energy photons up to 1.4 petaelectronvolts from 12 γ-ray Galactic sources

LHAASO

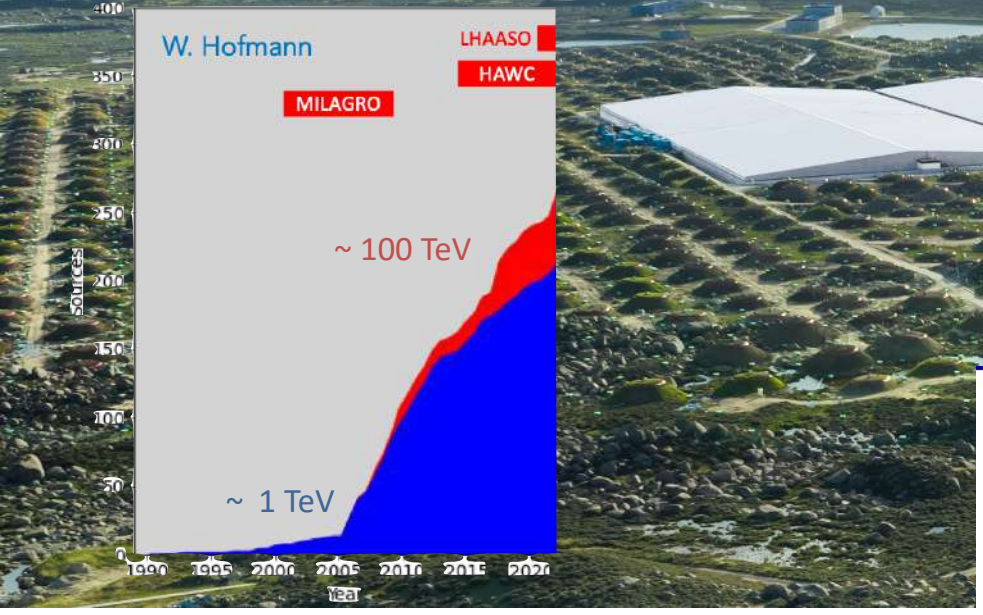
Zhen Cao, F. A. Aharonian, [...]X. Zuo

Nature **594**, 33–36 (2021) | Cite this article

8285 Accesses | 637 Altmetric | Metrics



LHAASO
Large High Altitude Air Shower Observatory



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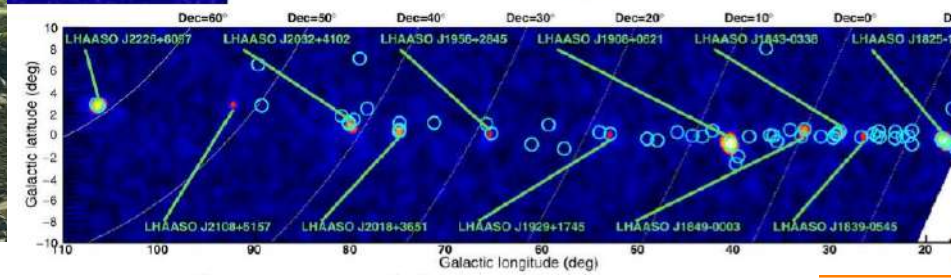
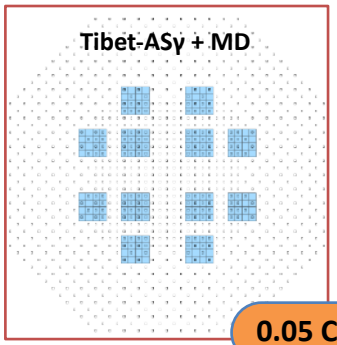
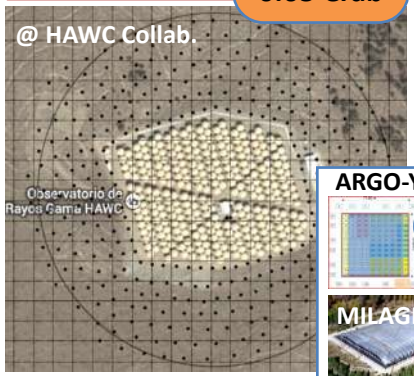


EAS arrays: larger and higher...

2010s



0.05 Crab

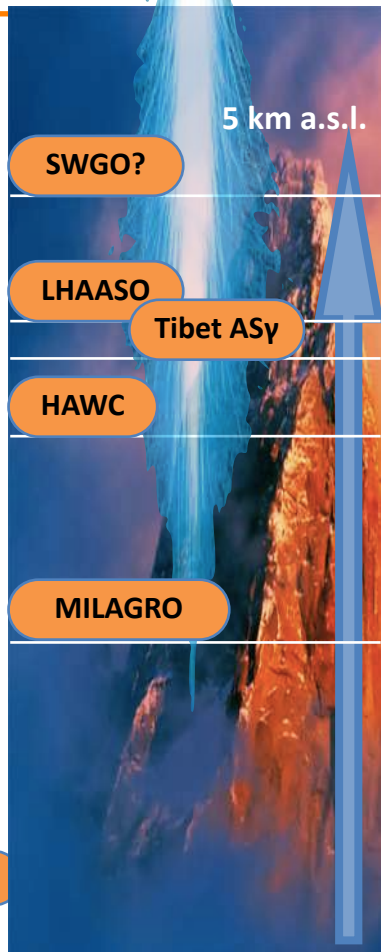


2000s

ARGO-YBJ

0.5 Crab

1.0 Crab

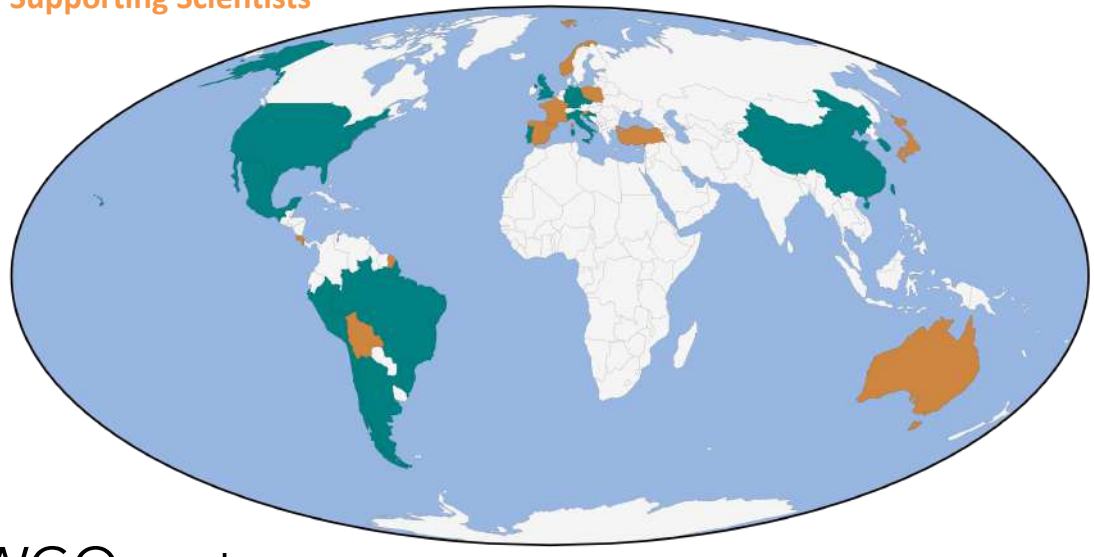


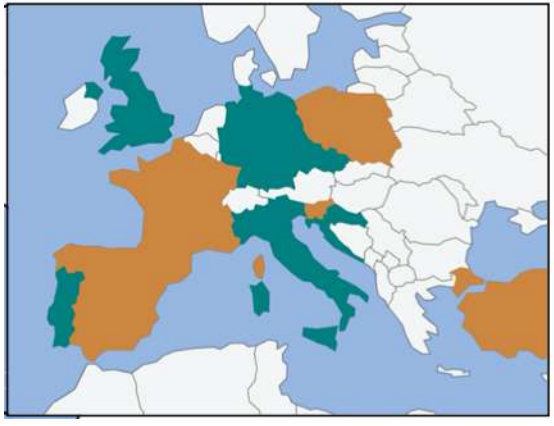
Ground-based Gamma-ray Astronomy Network

SWGO Collaboration

Member Institutes

Supporting Scientists

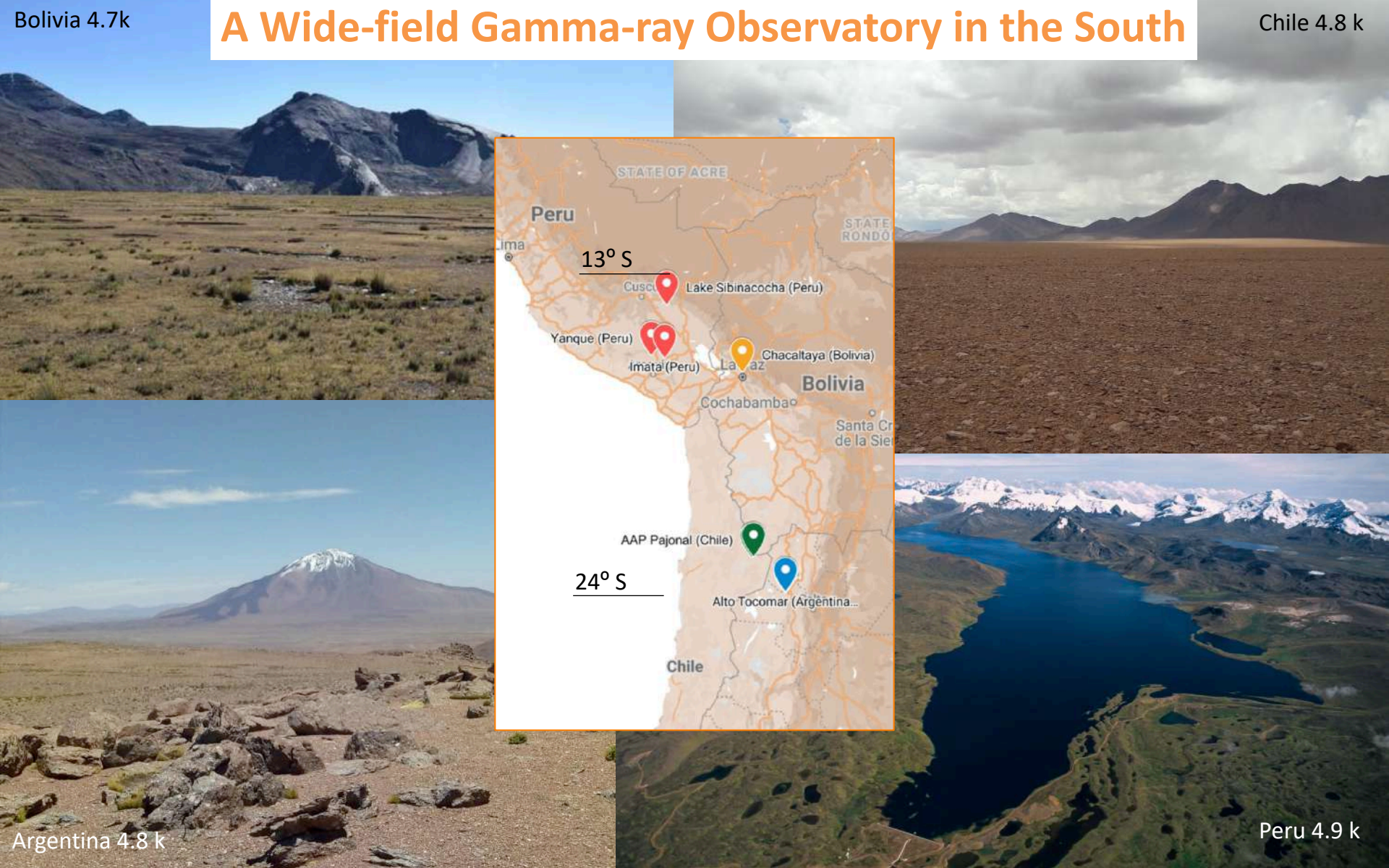




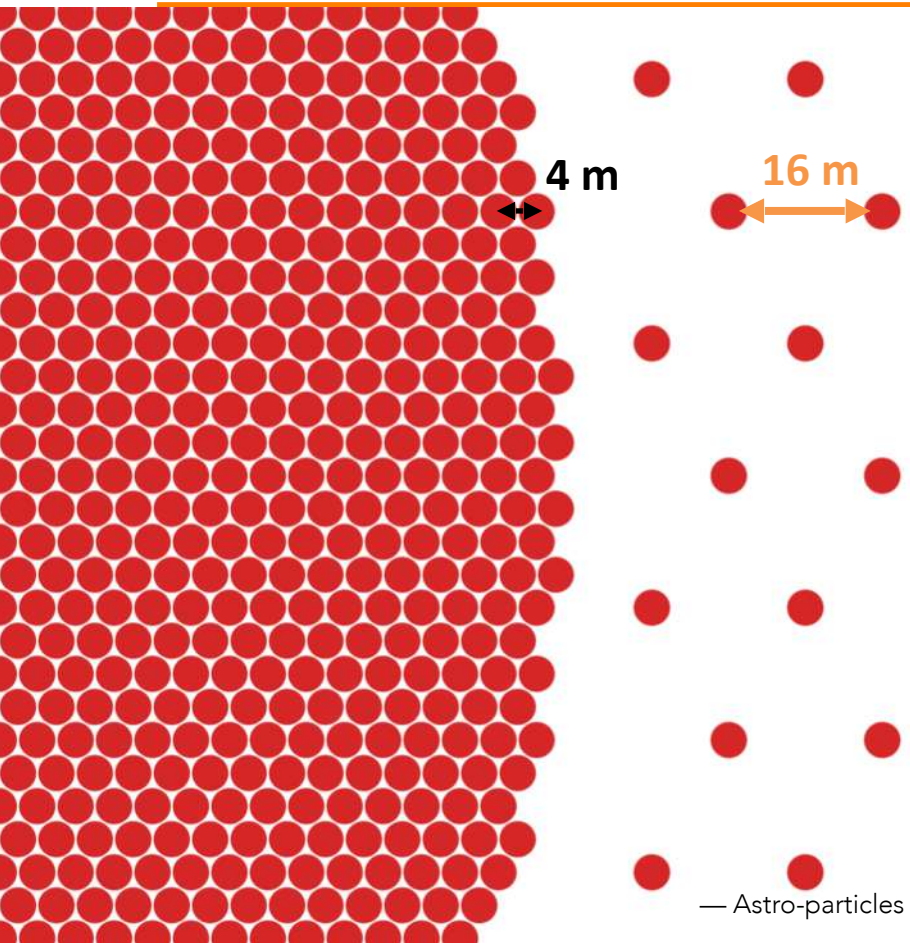
Argentina	Italy
Brazil	Mexico
Chile	Peru
China	Portugal
Croatia	South Korea
Czech Republic	United Kingdom
Germany	United States

- SWGO partners
  - → 14 countries, 66 institutes, c. 200 scientists*
  - → + supporting scientists

A Wide-field Gamma-ray Observatory in the South



The baseline detector concept

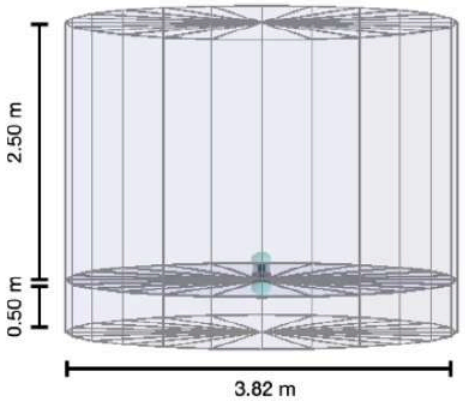


Core: Ø 320 m, FF = 80%
5,700 WCD units

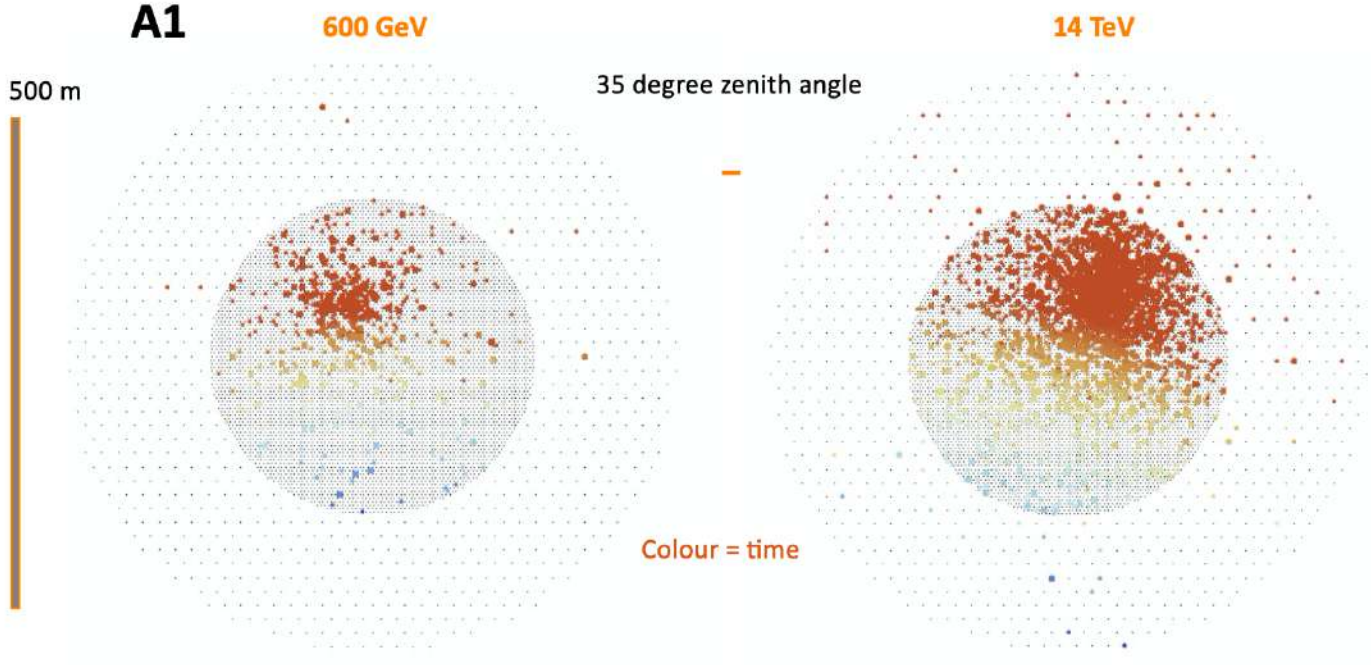
Outer: Ø 600 m, FF = 5%
880 WCD units

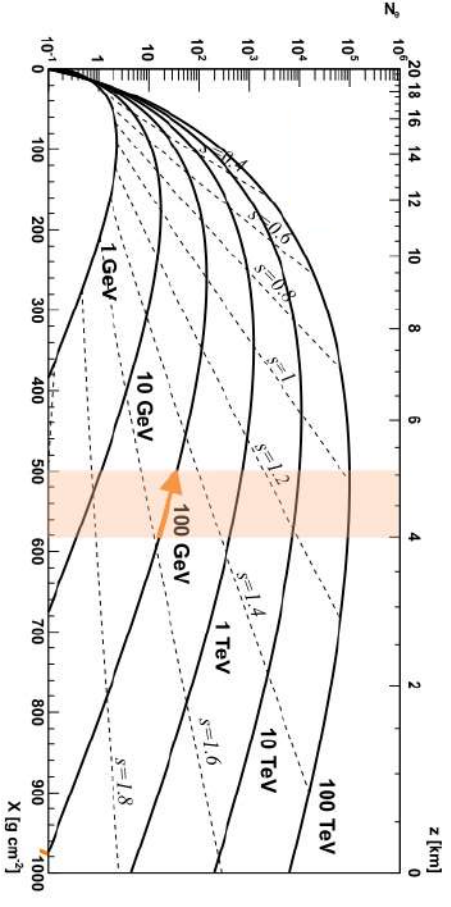
Altitude: 4,700 m a.s.l.

✧ muon counting



SWGO Baseline Requirements



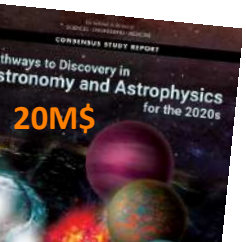


- **Large and dense detector array at high altitude**
  - → Very precise measurements possible below 1 TeV

Status & Plan

		SWGO R&D Phase Milestones
✓	M1	R&D Phase Plan Established
✓	M2	Science Benchmarks Defined
✓	M3	Reference Configuration & Options Defined
→	M4	Site Shortlist Complete
✓	M5	Candidate Configurations Defined
→	M6	Performance of Candidate Configurations Evaluated
	M7	Preferred Site Identified
	M8	Design Finalised
	M9	Construction & Operation Proposal Complete

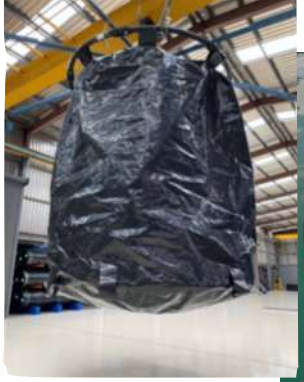
- R&D Phase
  - → Kick off meeting Oct 2019
  - → Expected completion 2024
    - ✓ Site and Design Choices made
  - → Then:
- Preparatory Phase
  - → Detailed construction planning
  - → **Engineering Array**
- (Full) Construction Phase
  - → 2026+

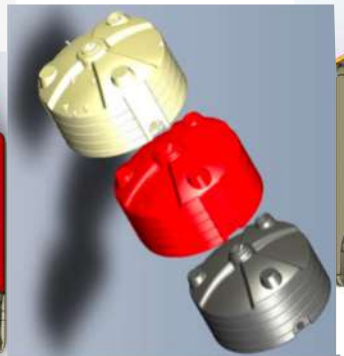


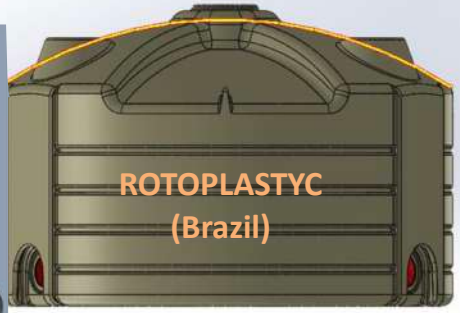
- Roadmaps
  - → US Decadal Review
  - → SNOWMASS, APPEC, Astronet

WCD unit Solutions

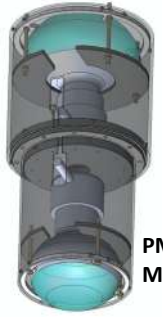
- WCD Unit
  - Lake
    - Natural Lake
    - Artificial Lake/Pond
  - Tank
    - Steel Tank
    - Rotomolded Plastic





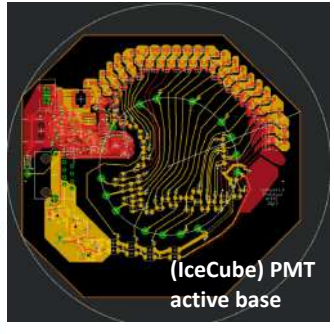


More Detector Options and Prototyping

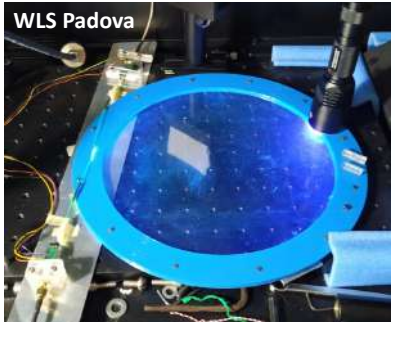


PMT module
MPIK

HAWC
Bladders

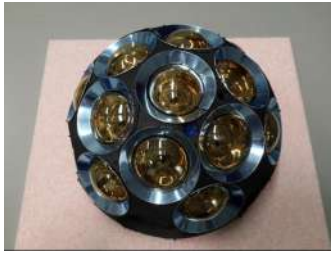


(IceCube) PMT
active base



WLS Padova

PMTs
Naples



HyperK-style
multi-PMT

Other White Rabbit Node examples:

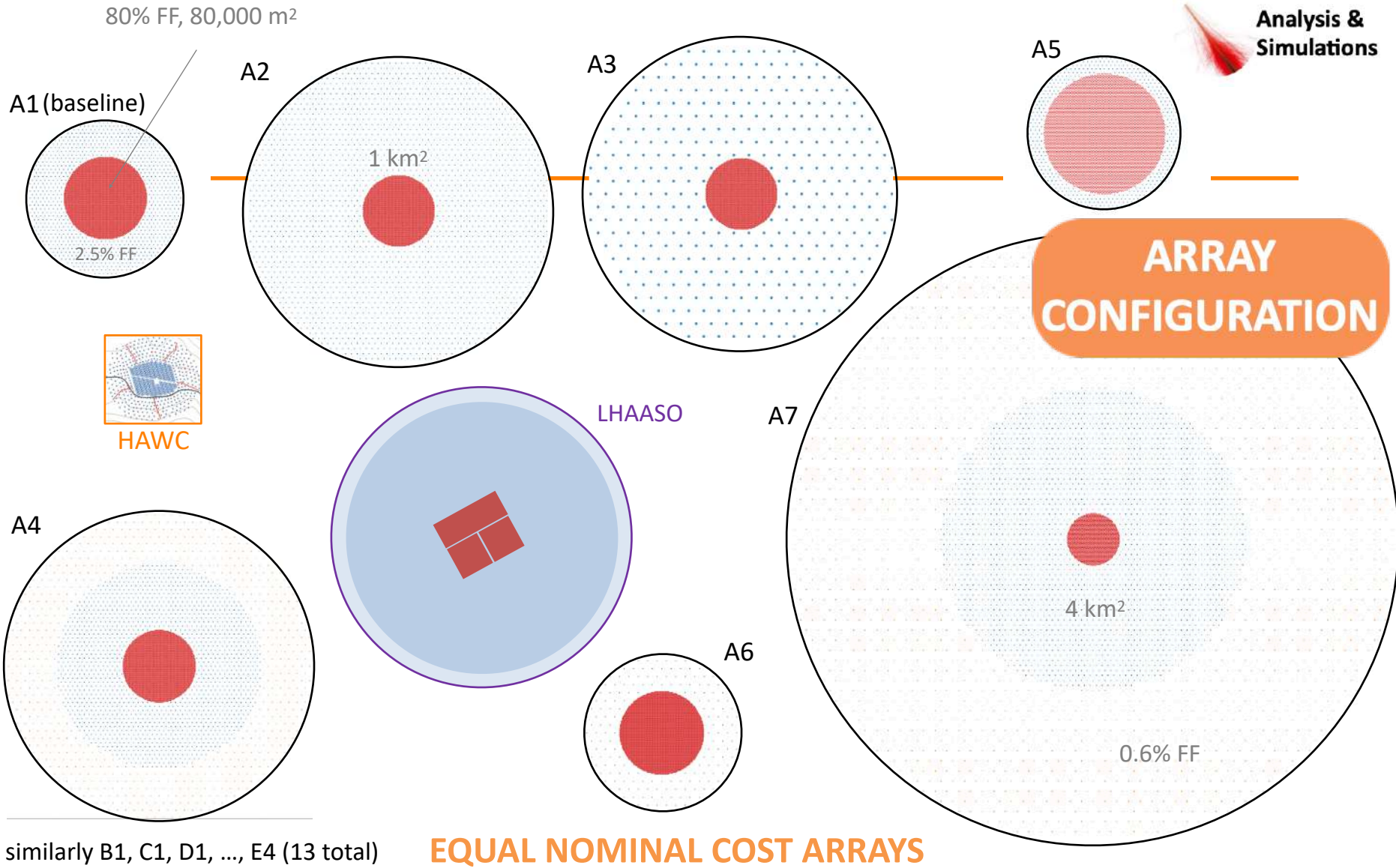
Central Logic Board (KM3NeT)

CUTE-WR (LHAASO)

SVEC (CERN)

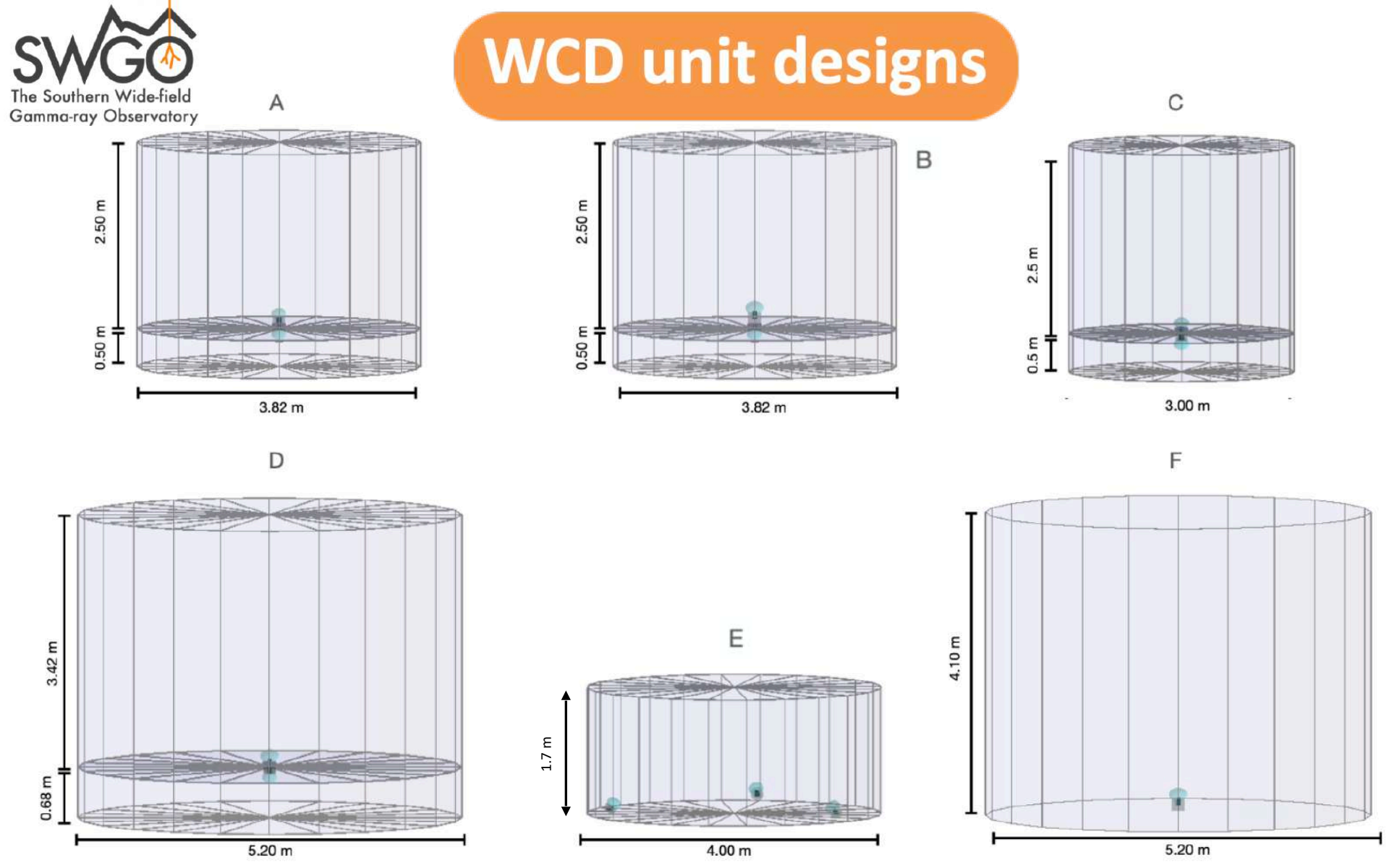
SPEXI (CERN)

CRIO-WR (CERN)


80% FF, 80,000 m²
A1 (baseline)
2.5% FF
A2
1 km²
A3
A5
Analysis & Simulations
ARRAY CONFIGURATION
HAWC
LHAASO
A7
4 km²
0.6% FF
A4
A6
similarly B1, C1, D1, …, E4 (13 total)
EQUAL NOMINAL COST ARRAYS

SWGO
The Southern Wide-field Gamma-ray Observatory

WCD unit designs



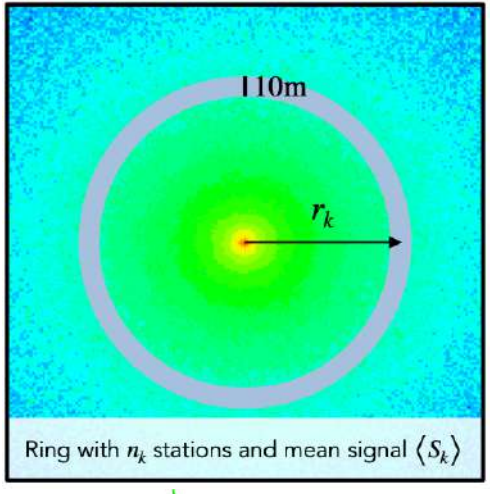
SWGO
The Southern Wide-field Gamma-ray Observatory

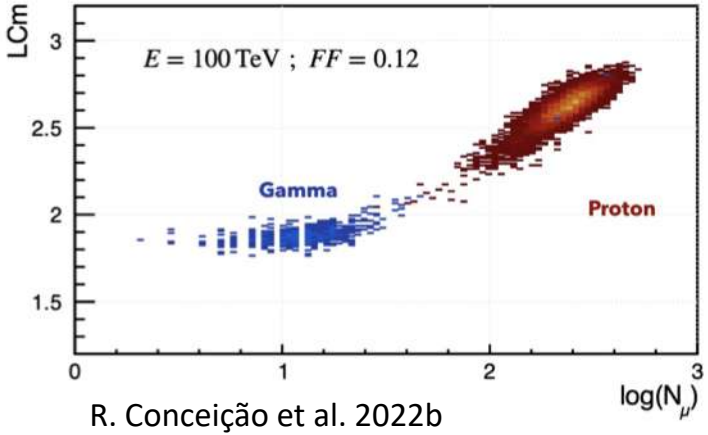
Shower footprint

γ/CR selection

μ detection

Shower azimuthal asymmetries

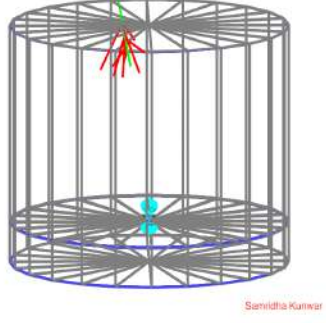




R. Conceição et al. 2022b

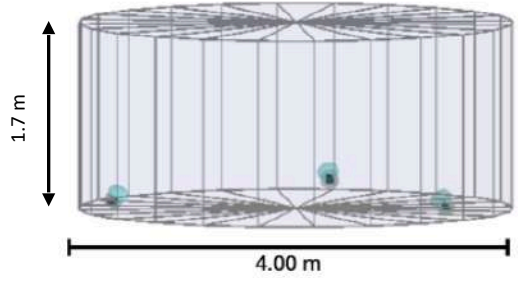
$$C_k = \frac{2}{n_k(n_k-1)} \frac{1}{\langle S_k \rangle} \sum_{i=1}^{n_k-1} \sum_{j=i+1}^{n_k} (S_{ik} - S_{jk})^2$$

Double-layer WCDs

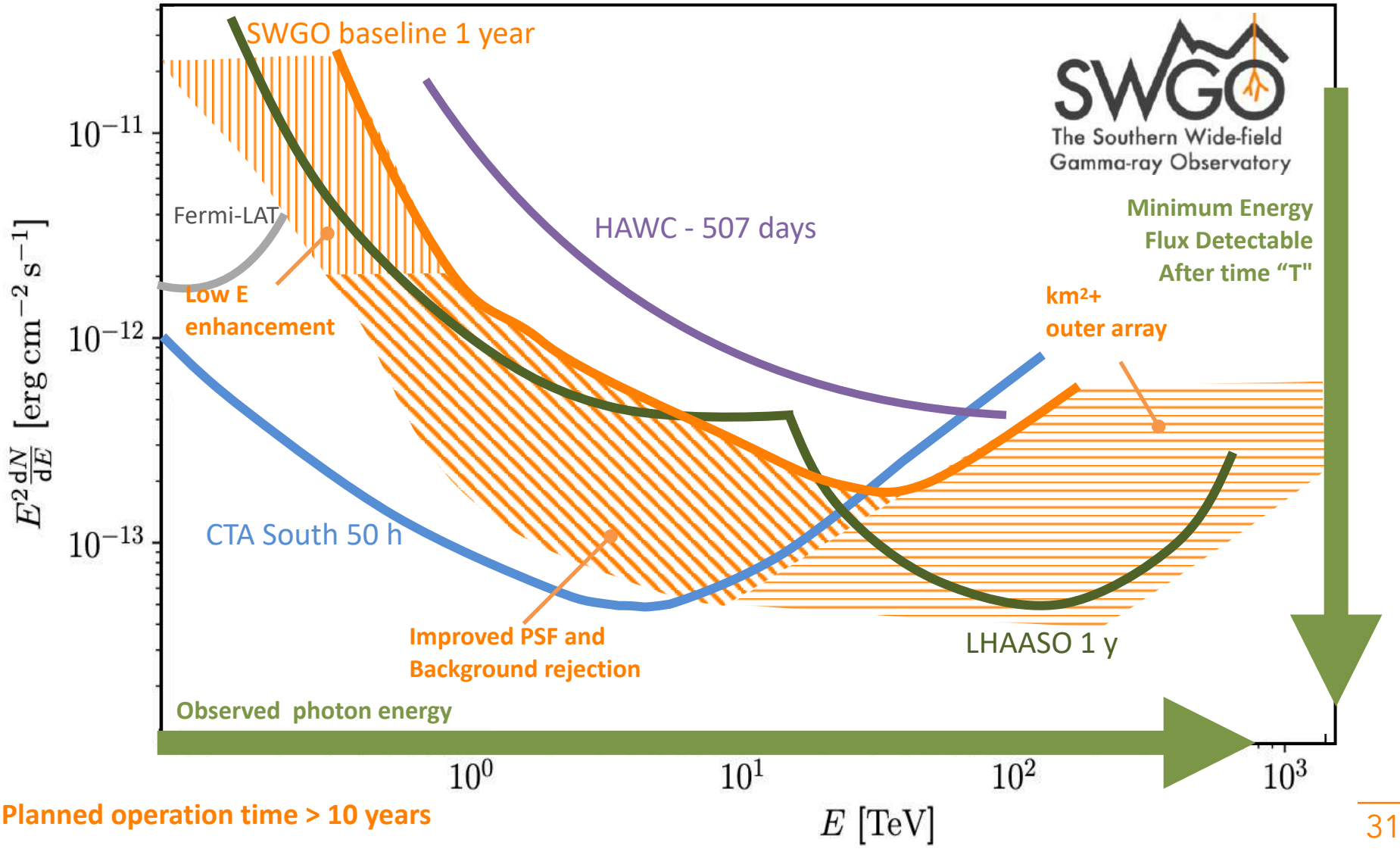


F. Bisconti & A. Chiavassa 2022
S. Kunwar et al. 2022

Multi-PMT WCDs



R. Conceição et al. 2022a



Planned operation time > 10 years

Summary

- Astroparticle Physics is in its golden age
  - → Major infrastructures in all fronts, with worldwide support in US, EU and LA
- LIP / Portugal has a long experience + leadership in Pierre Auger
- **SWGO is the next step**
  - → New window for PeVatron astronomy in the southern hemisphere
    - ✓ Complementary to LHAASO's sky view
    - ✓ Origin of Galactic Hadronic Cosmic-rays
  - → Wide-energy range coverage 100 GeV - 1 PeV
    - ✓ Complementary to CTA
    - ✓ Bridging the satellite all-sky monitoring capabilities
  - → The next major Astroparticle Facility in South America, after Pierre Auger
- SWGO will be a key instrument in the future Astroparticle Physics scenario

Obrigado! Thank you!