SWGO

The Southern Wide-field Gamma-ray Observatory

The Multimessenger Sky at Extreme Energies:
From Sources to Fundamental Physics – Trieste – Sept. 2026

Jim Hinton
MAX-PLANCK-INSTITUT
FÜR KERNPHYSIK

Gamma-ray Science Themes

Cosmic Particle Acceleration
Cosmic Ray Impact

Non-Thermal Astrophysics

Multi-Messenger Astronomy

Gravitational Wave Transients
The Cosmic Neutrino Sky
UHE Cosmic Ray Origin

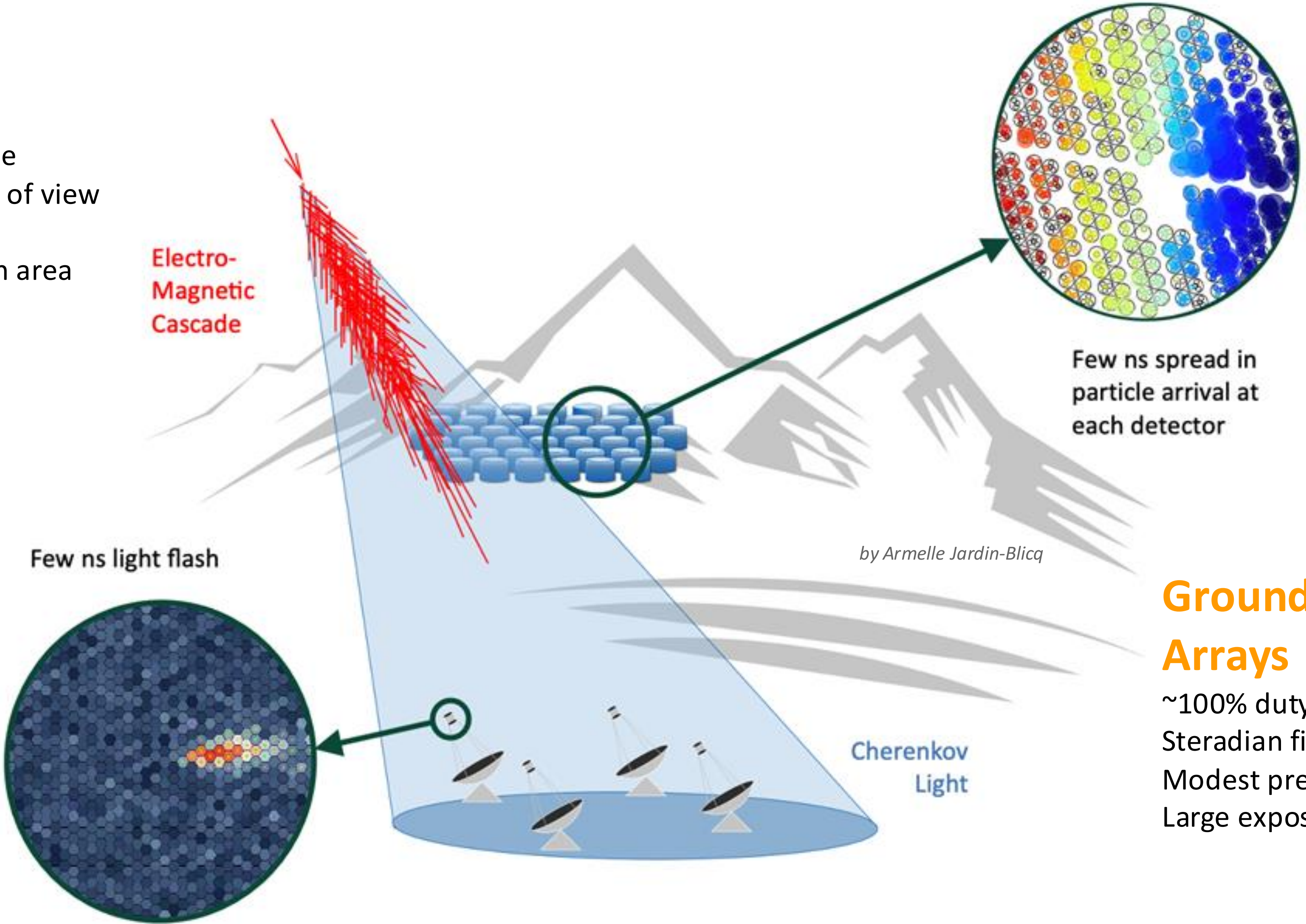
Axion-like Particles
Lorenz Invariance Violation
Dark Matter

Beyond Standard Model Physics

Approaches to Ground-based γ-ray Astronomy

IACTs

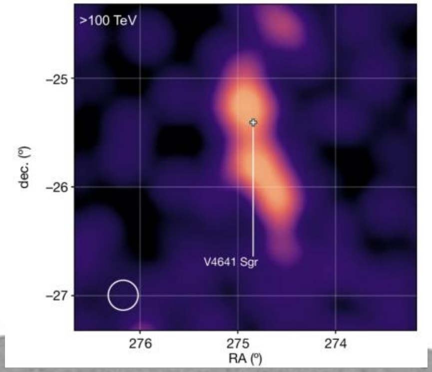
~15% duty-cycle
~4 degree field of view
High precision
Large collection area

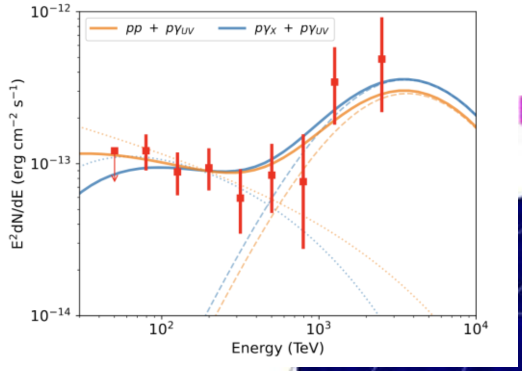


Ground Particle Arrays

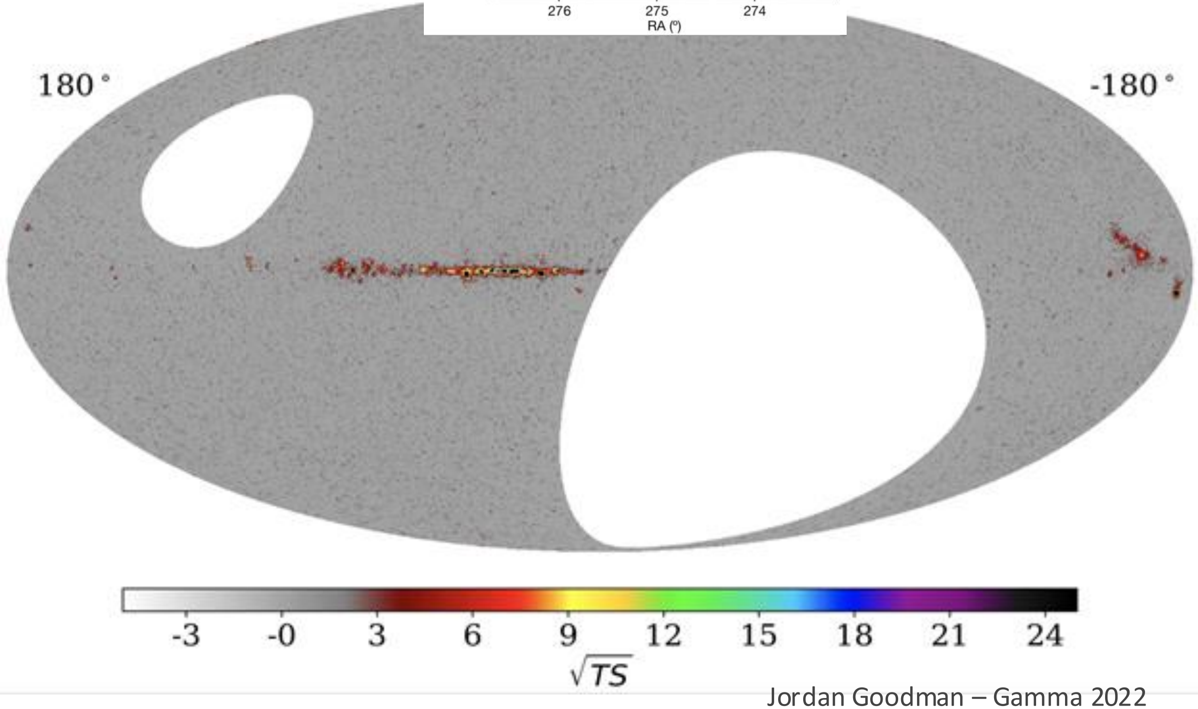
~100% duty-cycle
Steradian field of view
Modest precision
Large exposure

Current Wide-field Gamma-ray Detectors

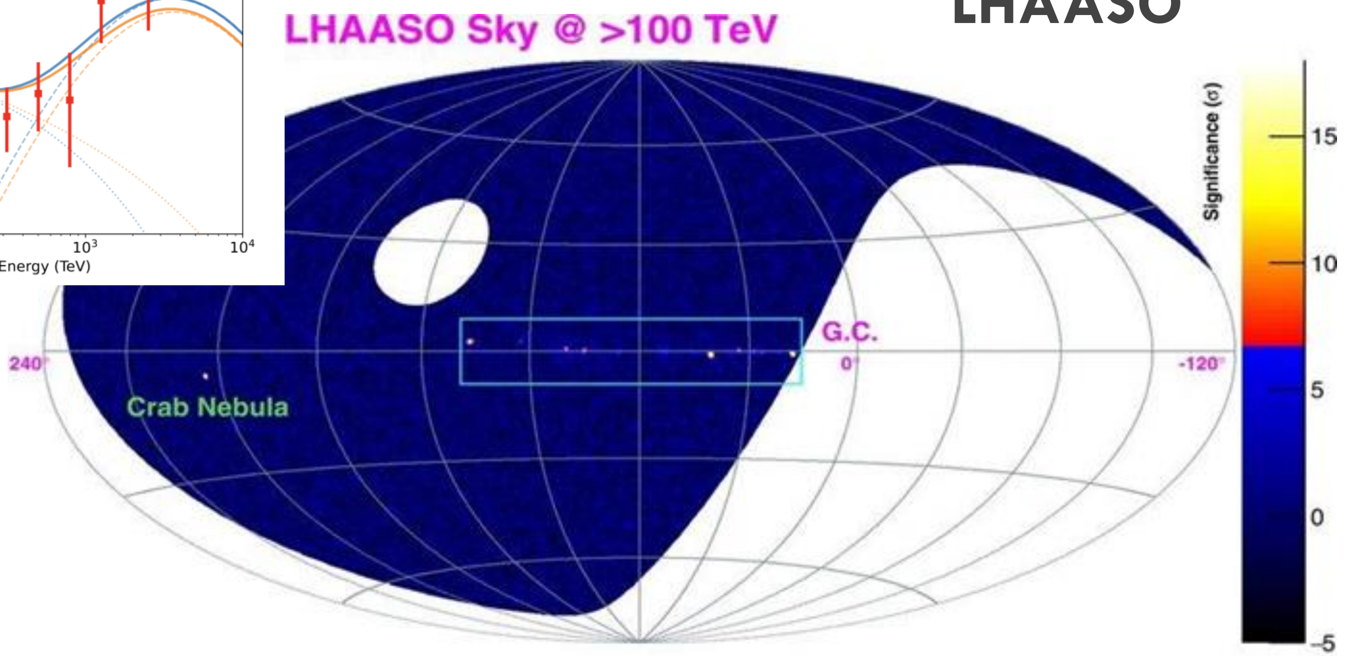


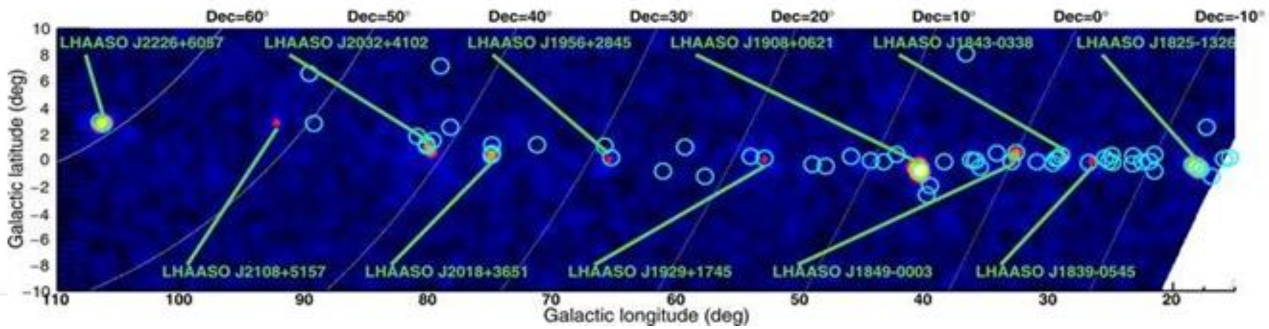


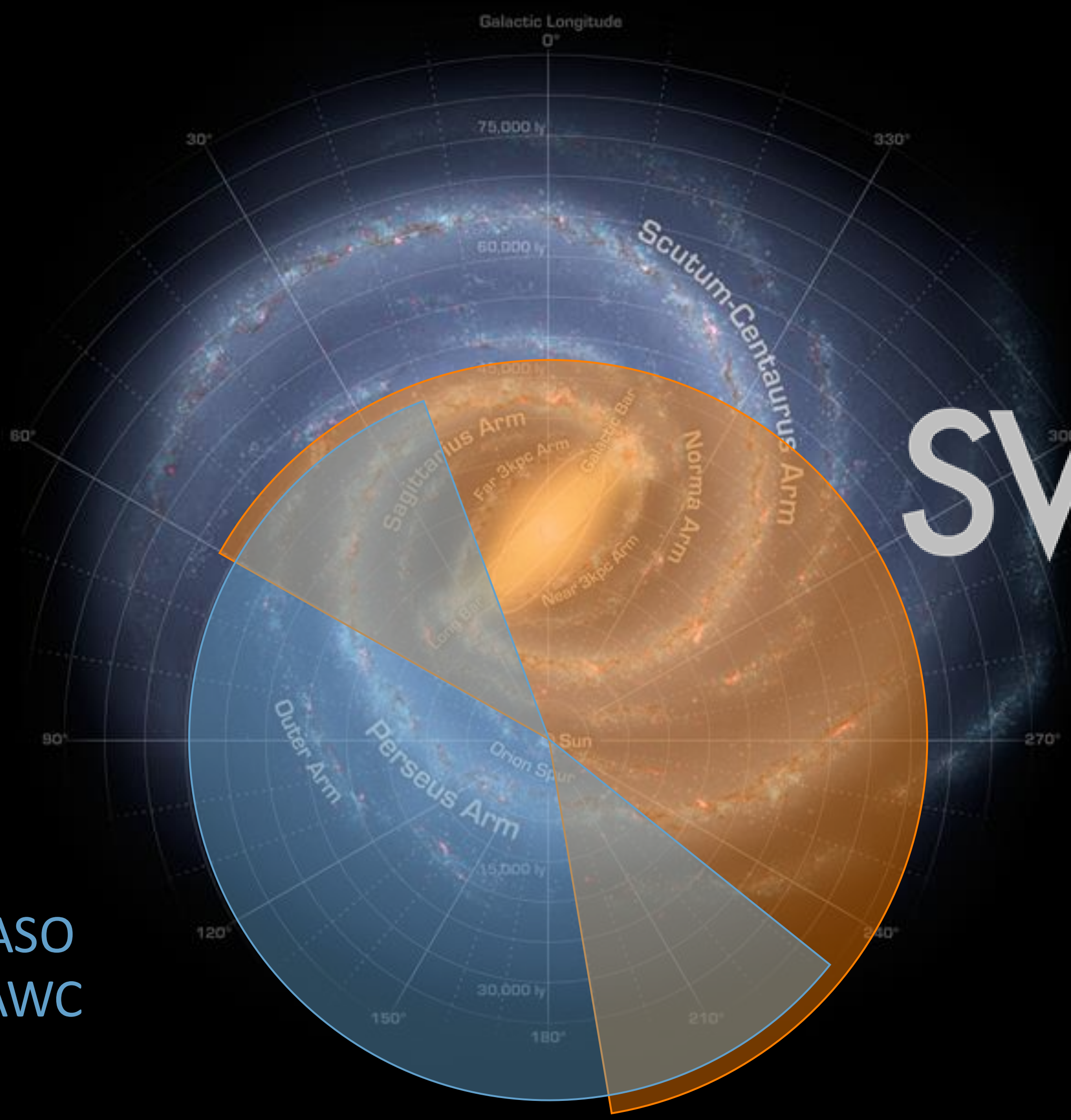
HAWC



LHAASO







LHAASO
& HAWC

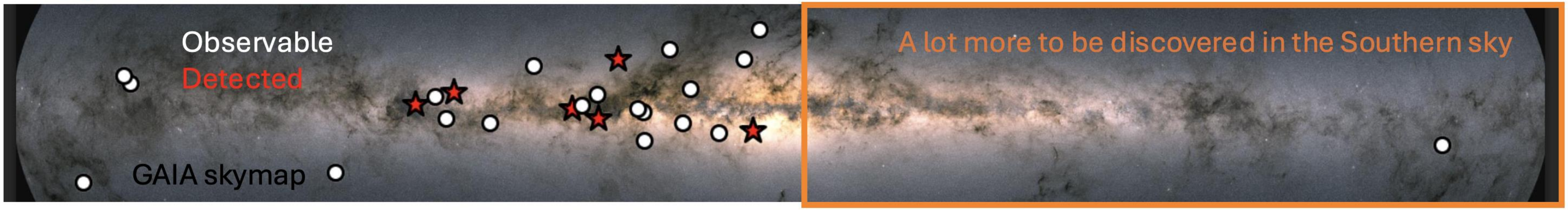
Up to 45 degree zenith angle

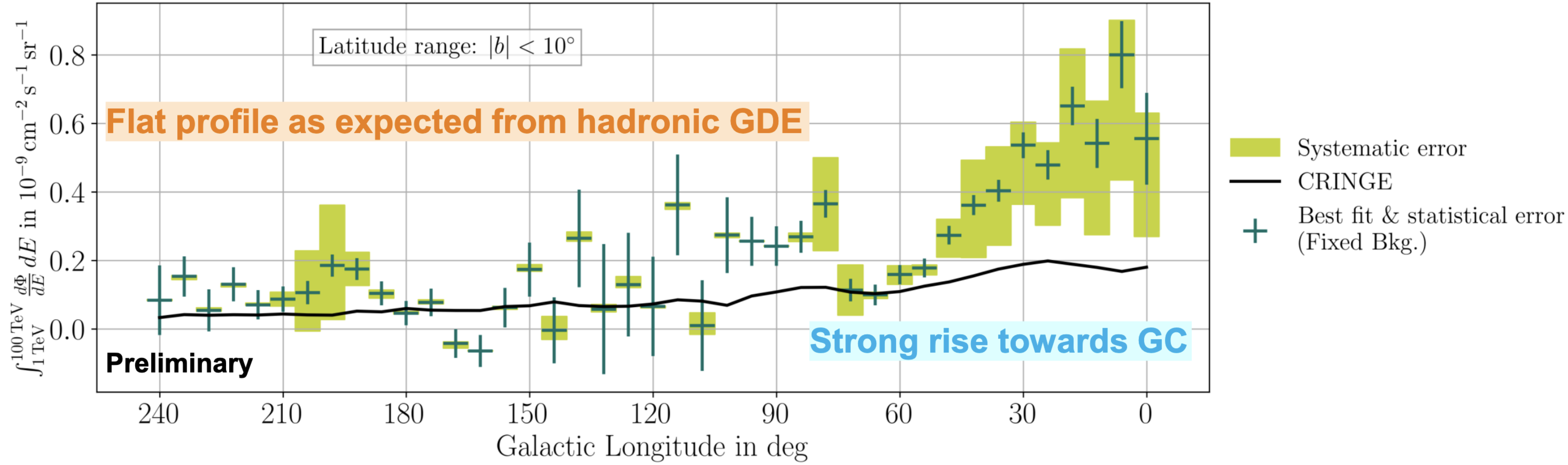
Few other source classes to probe

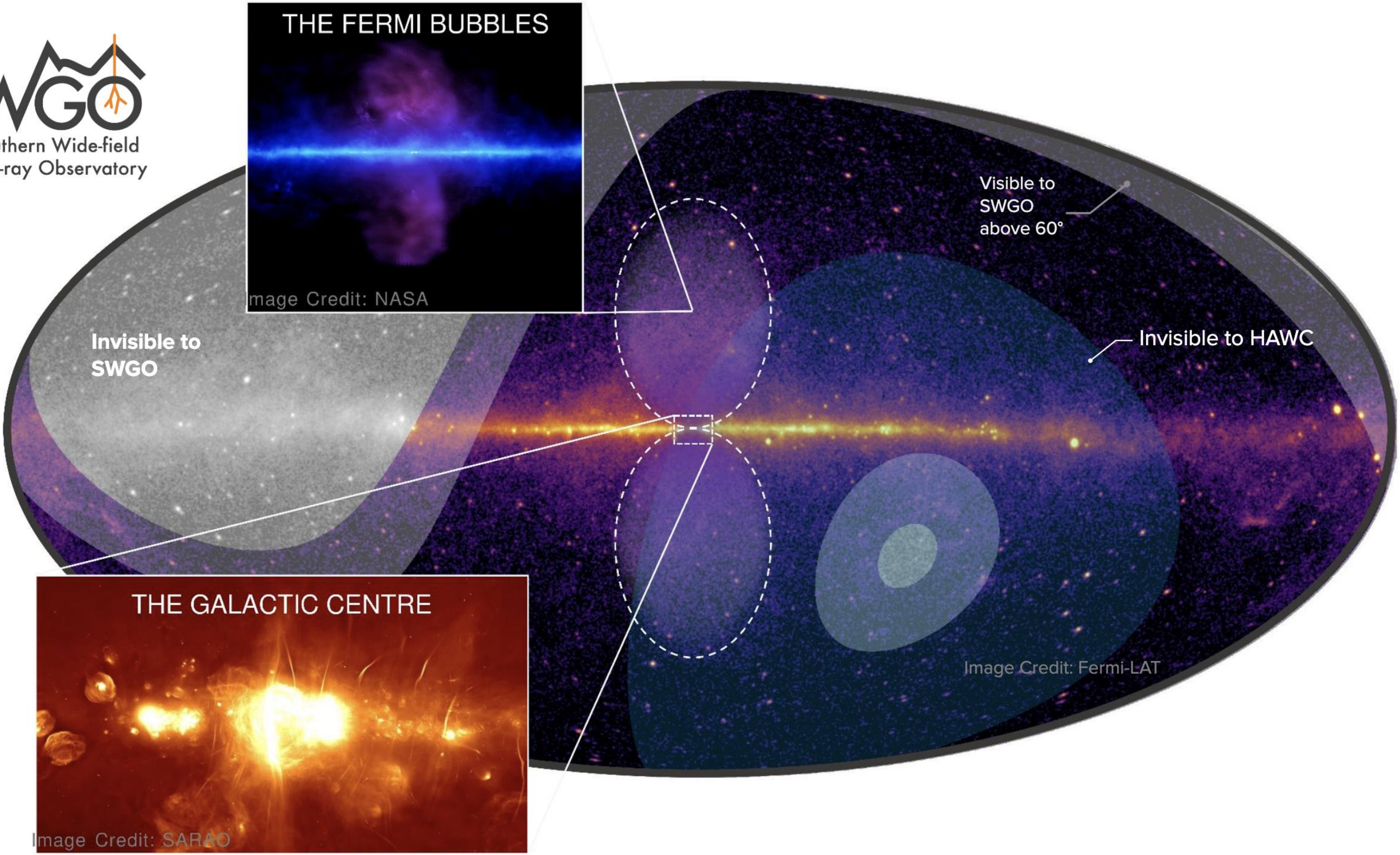
Quentin Remy (Gamma26, Synergies SWGO/CTAO)

Microquasars

See talk by Laura Olivera-Nieto

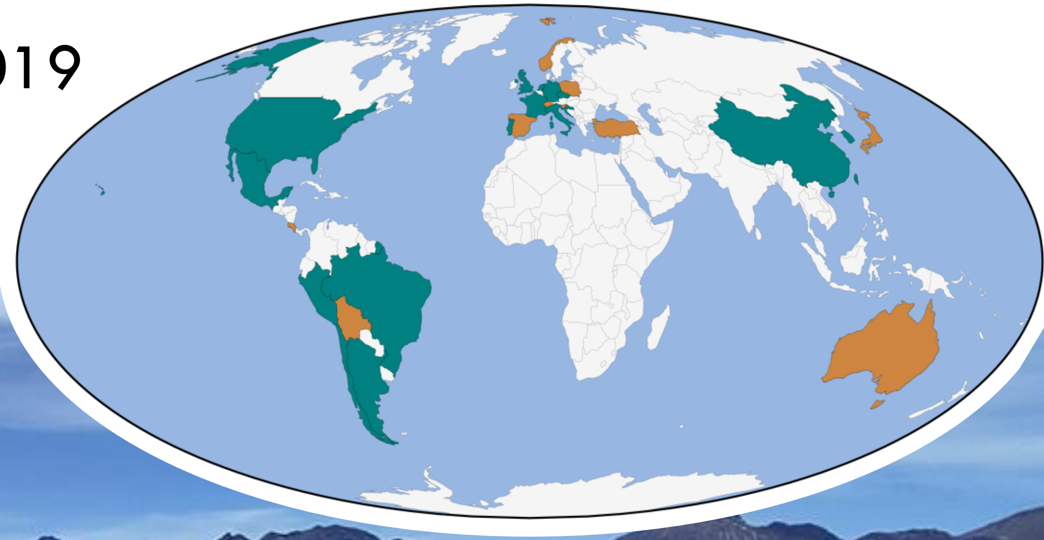





The Southern Wide-field
Gamma-ray Observatory
THE FERMI BUBBLES
Image Credit: NASA
Visible to
SWGO
above 60°
Invisible to
SWGO
Invisible to HAWC
THE GALACTIC CENTRE
Image Credit: Fermi-LAT
Image Credit: SARAO

The Collaboration

- Founded 2019
  now 16
  Countries

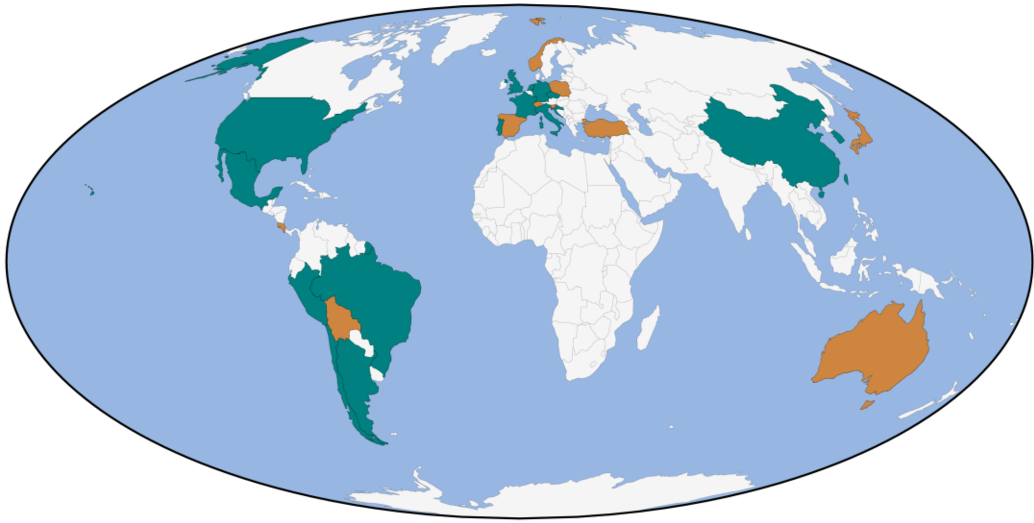


SWGO
The Southern Wide-field
Gamma-ray Observatory

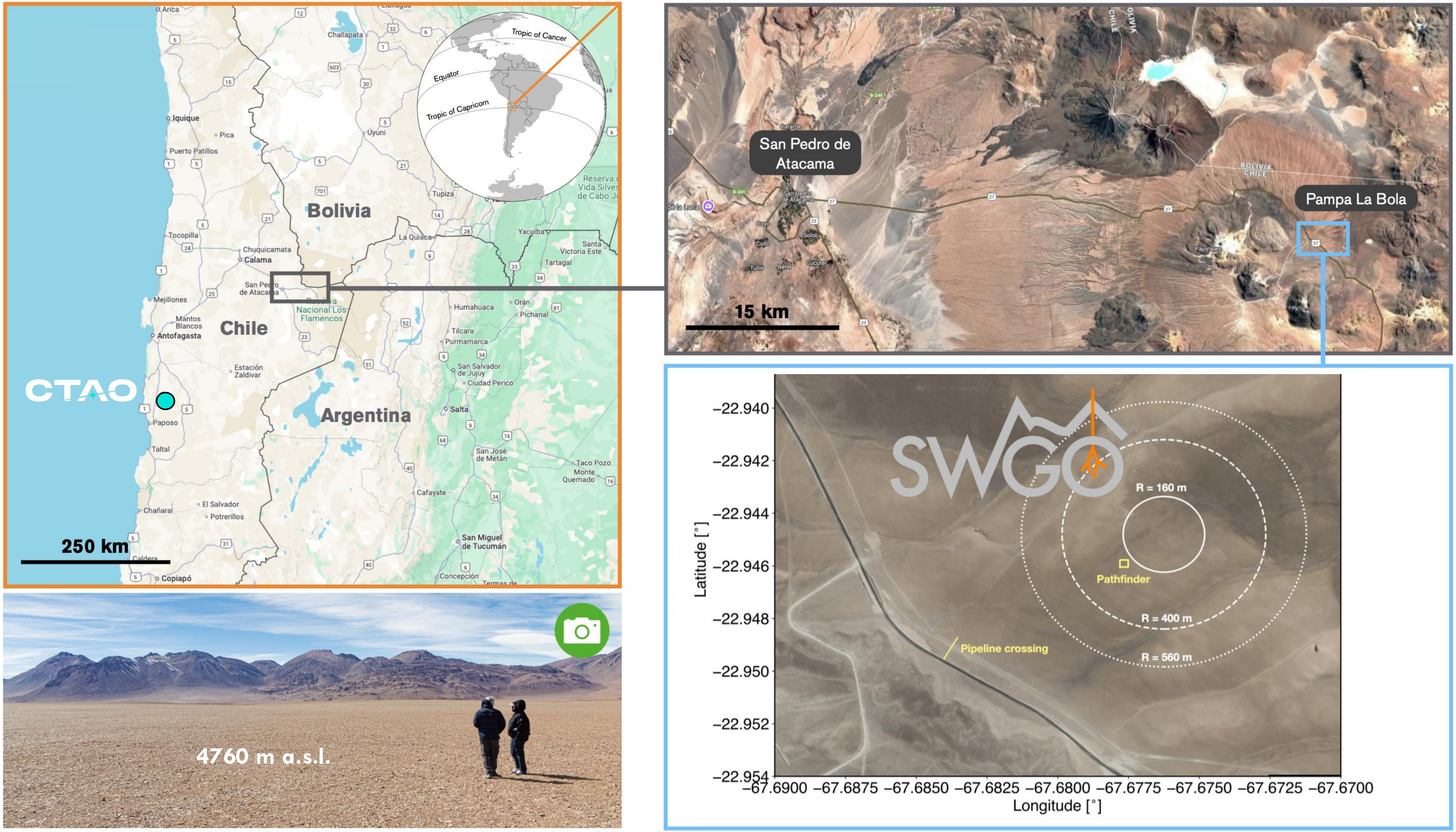
SWGO members and guests at the site of the project, Pampa La Bola
(12th Collaboration Meeting, San Pedro de Atacama, 5-9 May, 2025)

SWGO Development

- 2019: R&D phase starts
- May 2020: Science Benchmarks defined
- Feb 2022: Candidate Configs defined
- May 2024: Inner Array Baseline
- July 2024: Site Selection
- June 2025: Science White Paper
- Aug 2026: Outer Array Baseline
- Design Report and on-site prototypes by early 2027 → entering a New Phase



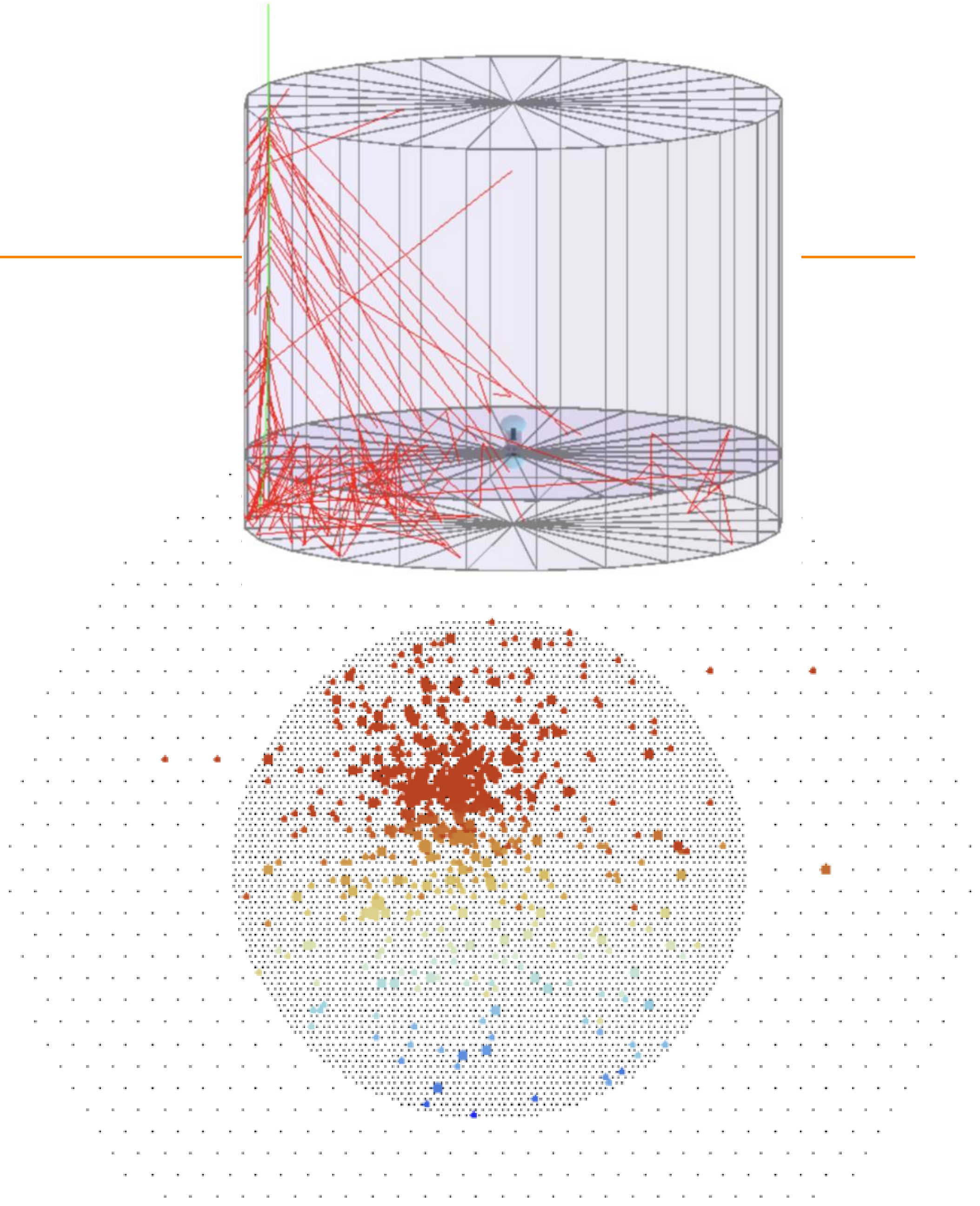
	SWGO R&D Phase Milestones	
✓	M1	R&D Phase Plan Established
✓	M2	Science Benchmarks Defined
✓	M3	Reference Configuration & Options Defined
✓	M4	Site Shortlist Complete
✓	M5	Candidate Configurations Defined
✓	M6	Performance of Candidate Configurations Evaluated
✓	M7	Preferred Site Identified
✓	M8	Design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



Tropic of Cancer
Equator
Tropic of Capricorn
Arica
Challapata
Iquique
Pica
Puerto Patillos
Uyuni
Tupiza
Bolivia
Tocopilla
Chuquicamata
Calama
La Quiaca
Yacuiba
Santa Victoria Este
Tartagal
San Pedro de Atacama
Reserva Nacional Los Flamencos
Mejillones
Mantos Blancos
Antofagasta
Chile
Humahuaca
Orán
Pichanal
Tilcara
Purmamarca
San Salvador de Jujuy
Ciudad Perico
Estación Zaldivar
CTAO
Paposo
Taltal
Argentina
Salta
San José de Metán
Taco Pozo
Monte Quemado
Cafayate
Chañaral
El Salvador
Potrerillos
San Miguel de Tucumán
250 km
Caldera
Copiapó
Concepción
4760 m a.s.l.
San Pedro de Atacama
Pampa La Bola
BOLIVIA
CHILE
Catarpe
Coyo
Solor
Cucuter
Tulor
Pajonales
15 km
SWGO
R = 160 m
Pathfinder
R = 400 m
R = 560 m
Pipeline crossing
Latitude [°]
Longitude [°]
−22.940
−22.942
−22.944
−22.946
−22.948
−22.950
−22.952
−22.954
−67.6900
−67.6875
−67.6850
−67.6825
−67.6800
−67.6775
−67.6750
−67.6725
−67.6700

Simulations

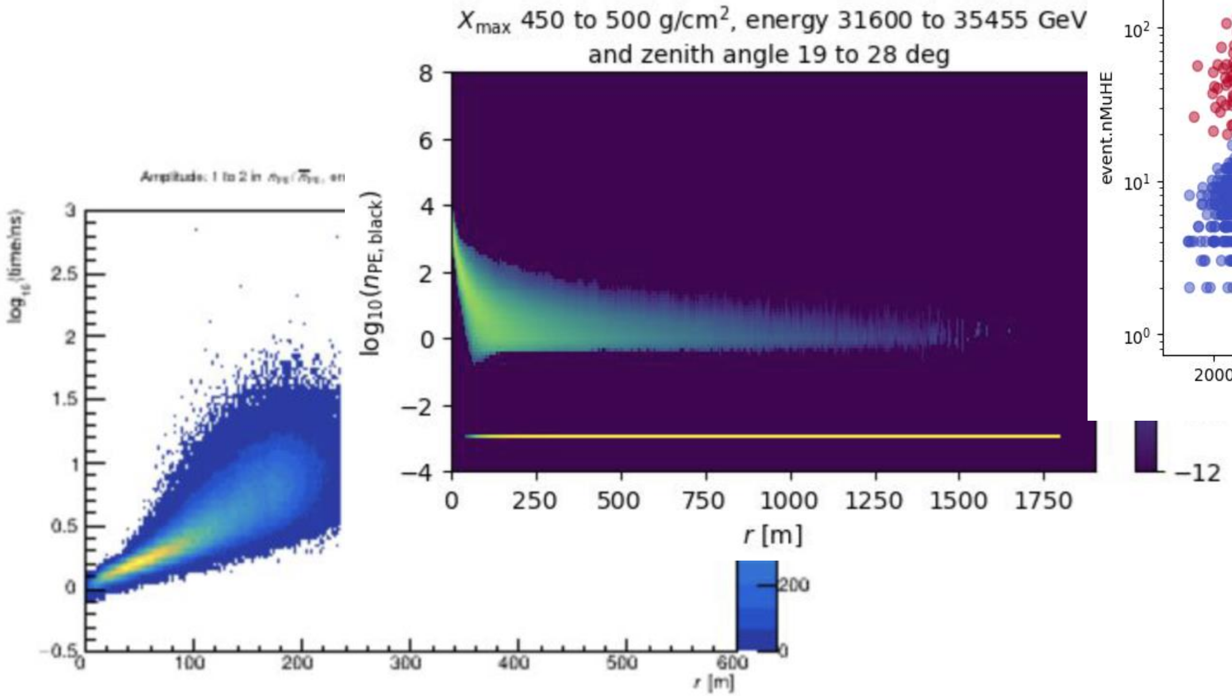
- CORSIKA air shower simulations
- Geant4 detector simulation (HAWC heritage)
  - Follow particles - follow photons
- and recent alternative: parametrized simulation for UHE (FastSim)
  - A. Chiavassa & A. Negro 2026, 10.1016/j.nima.2026.171921
- Large scale effort at many computing centres around the collaboration

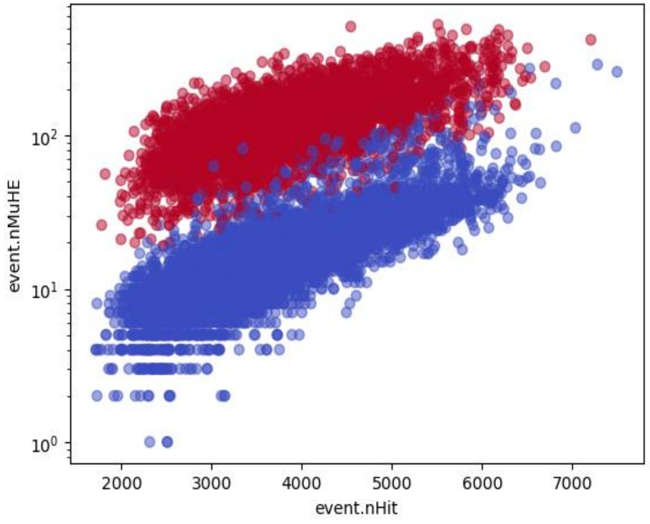


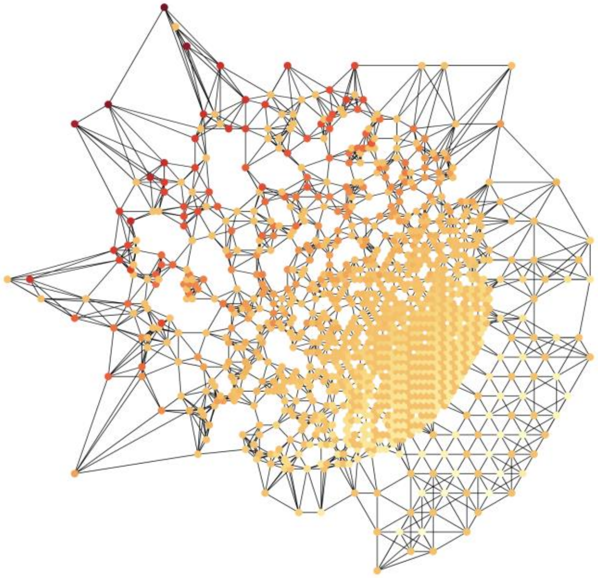
600 GeV gamma, 35 degrees zenith

Data Analysis

- Arrival time and number of photoelectrons at each tank/layer →
  - Direction reconstruction (PDF → ML fit), Core+Energy reconstruction (PDF→ML fit), Background rejection (Machine Learning, muon tagging+++)







GNN: Glombitza et al 2024
See also 'DeepEASTER' Pirke et al 2026

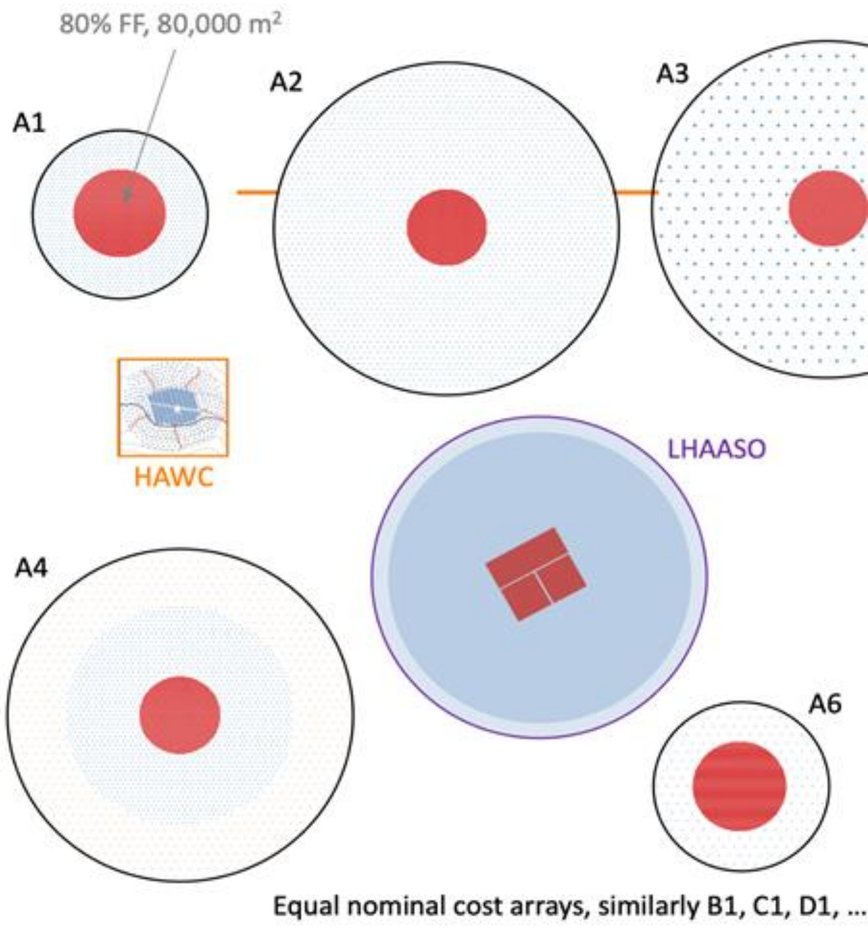
Design Optimisation

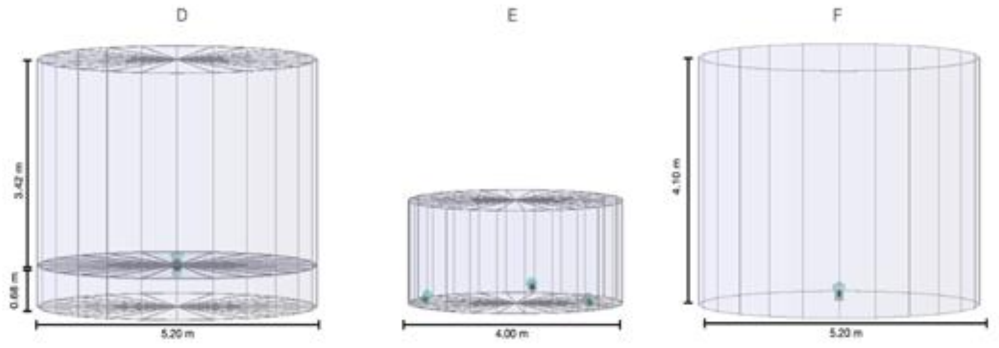
◎Science performance based optimisation in a wide phase space

◎Step 1: Large scale simulations with

- 6 detector unit options, single and double layer Cherenkov detectors
- 7 layouts, with inner and outer array
- Convergence on inner (>50% fill factor) array in 2024
  - ✓ 5.2 m dual layer tanks for best gamma/hadron separation
- and on 1km^2 3-zone array layout

◎Step 2: recent effort to finalise the Baseline design





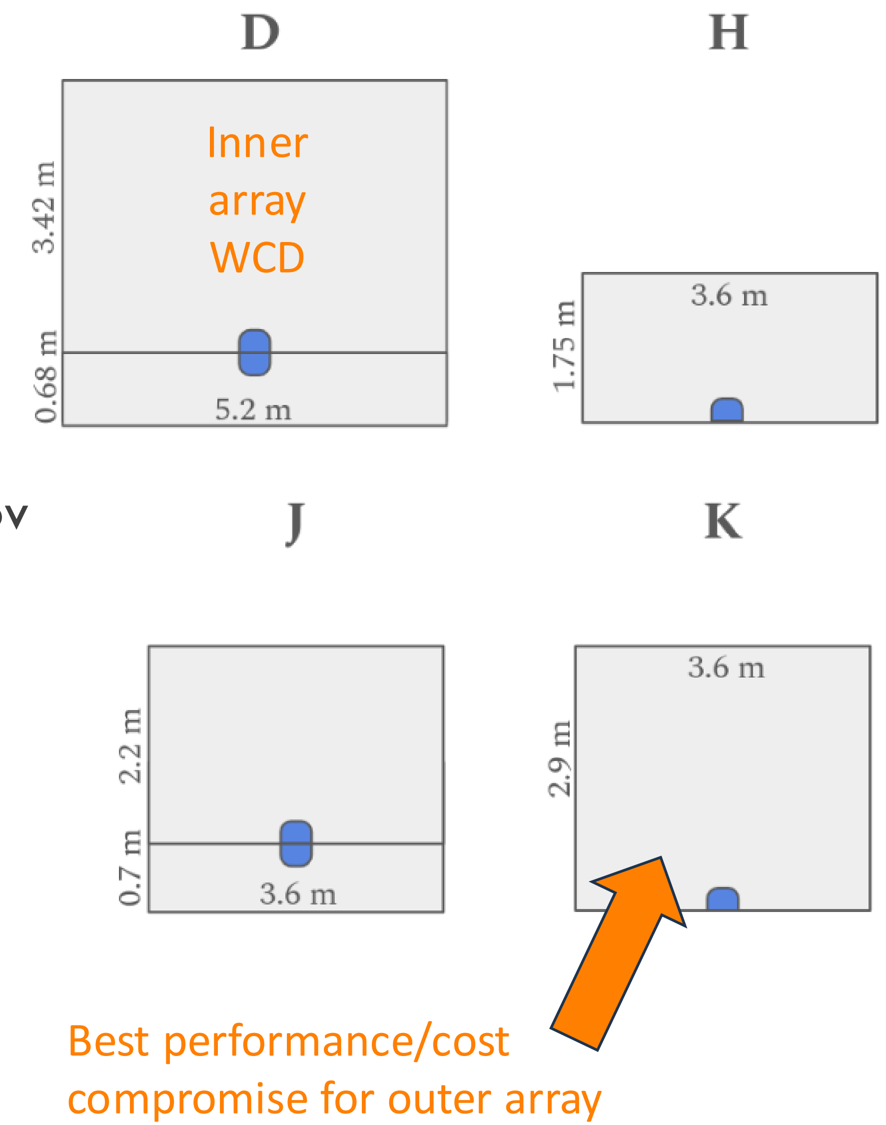
Step 2 WCD alternatives
1-4% FF simulations over 1 km^2

Design Optimisation

- Science performance based optimisation in a wide phase space
- Step 1: Large scale simulations with
  - → 6 detector unit options, single and double layer Cherenkov detectors
  - → 7 layouts, with inner and outer array
  - → Convergence on inner (>50% fill factor) array in 2024
    - ✓ 5.2 m dual layer tanks for best gamma/hadron separation
  - → and on 1km^2 3-zone array layout
- Step 2: recent effort to finalise the

  Baseline design

  simulating outer array WCD options at different FF

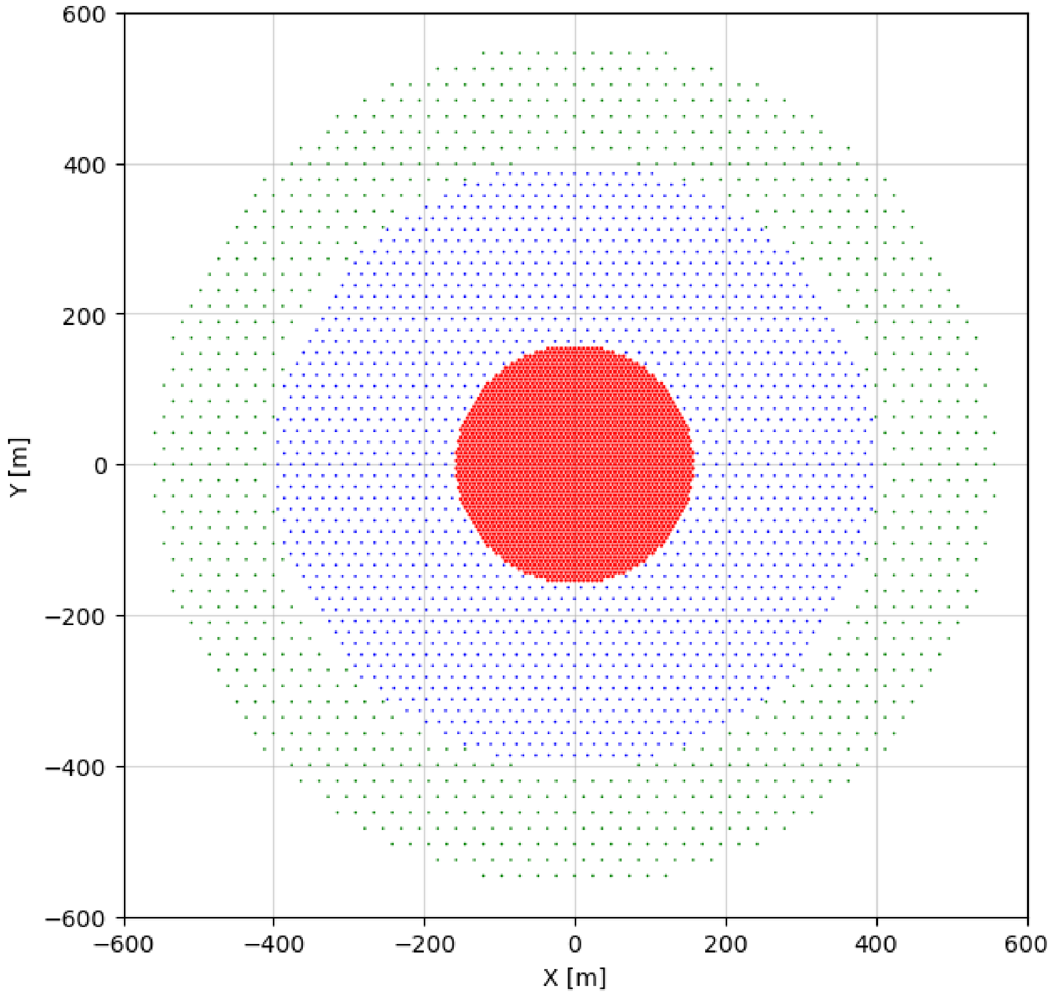


Baseline Array Layout

Three zones:

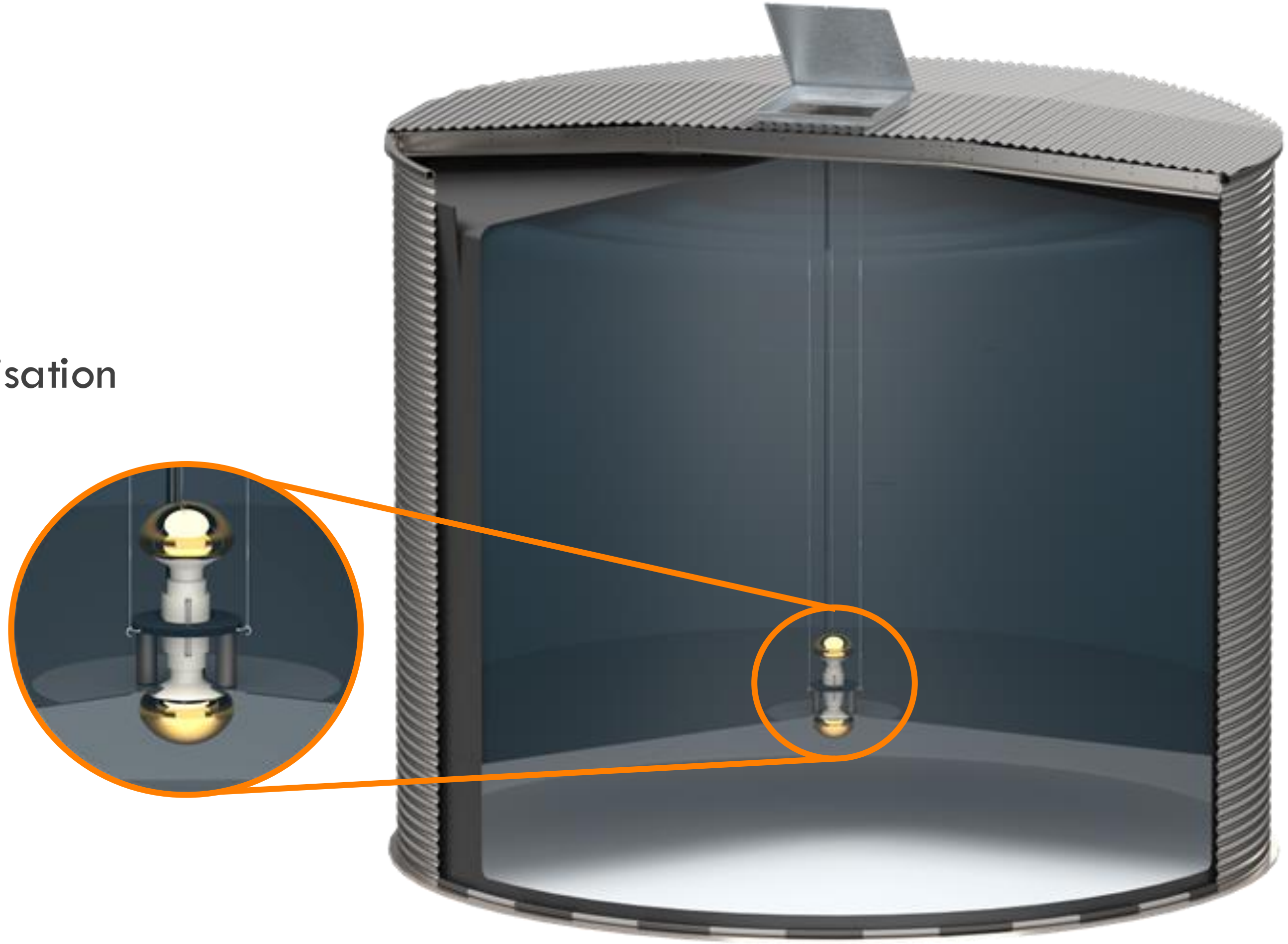
- Inner array:
  - FF=65%, R= 156 m, 2587 5.2 m tanks
- Outer array:
  - FF= 4%, R= 400 m, 1656 3.6 m tanks
  - FF= 1.7%, R= 560 m, 804 3.6 m tanks

(with modest 'mixed' zone outside inner array)



Inner Array WCD Baseline Design

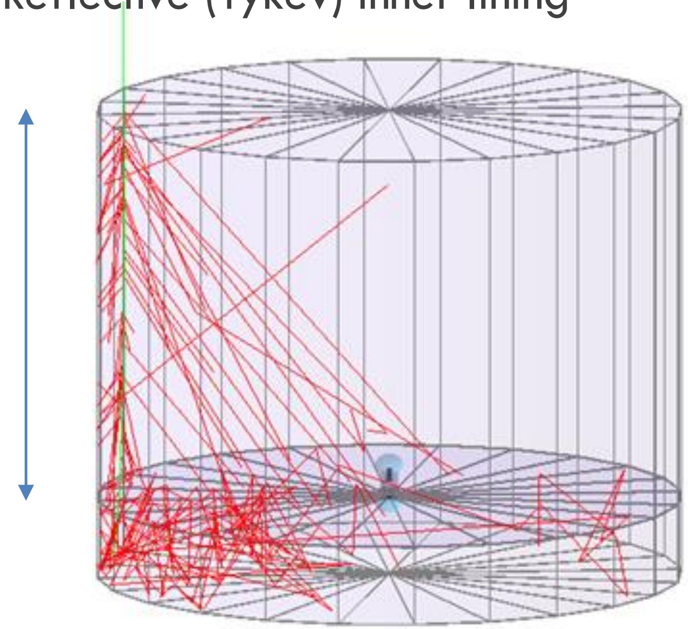
- Steel tanks assembled on site
  - 5.2 m Ø, 4.0 m water depth
- Double-PMT unit in each detector
  - 10-inch PMTs (900 available)
- Signals collected at Field Nodes
  - Serve 55 WCDs each, 250 MS/s digitisation



Inner Array WCD Baseline Design

- Custom LDPE Bladders inside each steel tank
- Double-layered detectors
  - Separated by membrane
- Lower chamber is for background rejection → muon tagging
  - Reflective (Tykev) inner lining

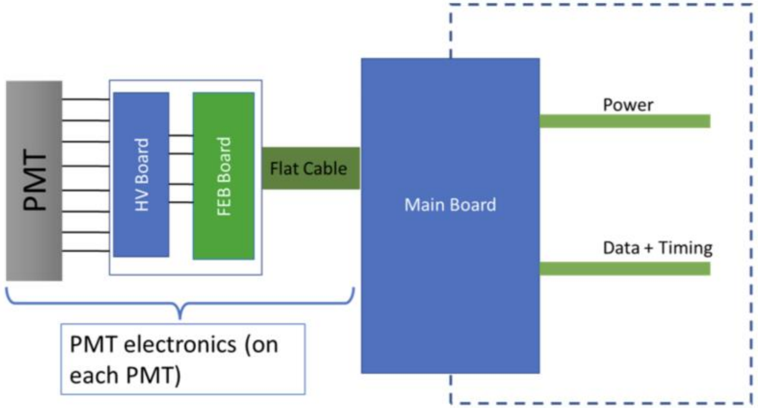
8 radiation lengths



Inflated with air to check for light leaks

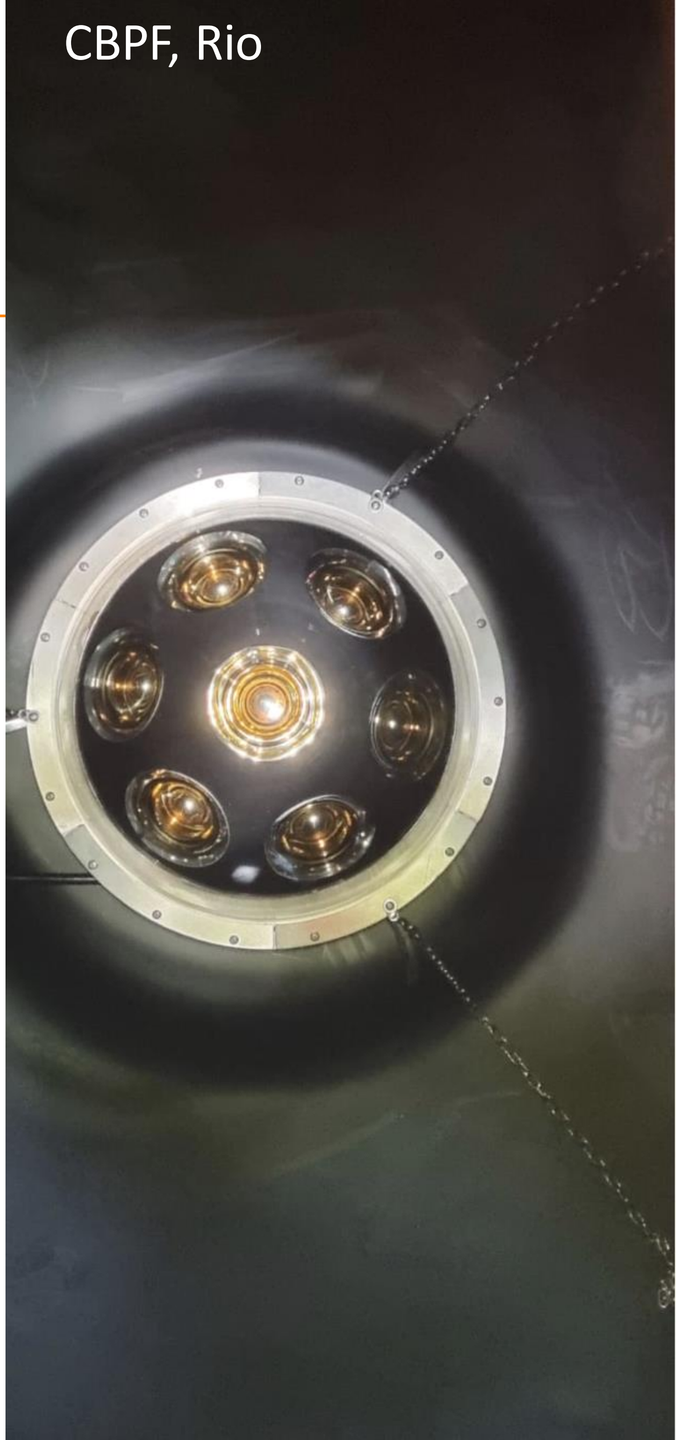
Outer Array WCD Baseline Design

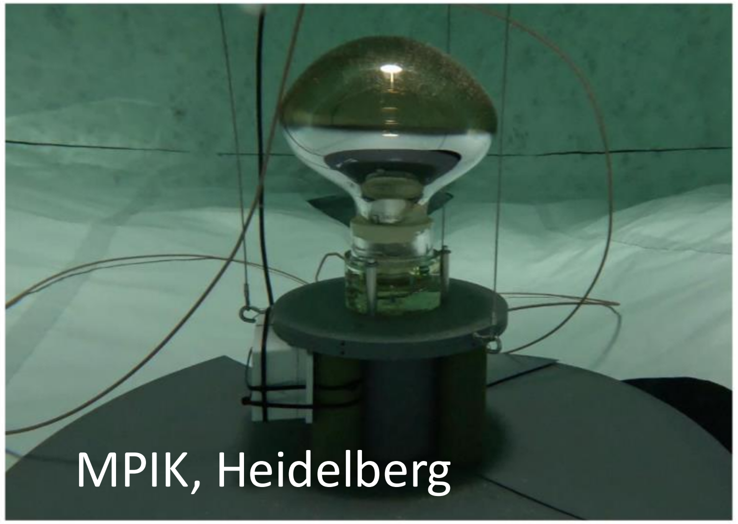
- 3.6 m diameter, 2.9 m (water) depth
  - Improving Gamma/Hadron separation power with depth (more than) compensates for additional cost c.f. shallower tanks
  - Rotomolded tank with Auger heritage
- Single layer with multi-PMT sensor
  - 7x 3” PMTs with on-board digitisation, development led by Napoli/INFN, heritage from neutrino projects



Prototyping work

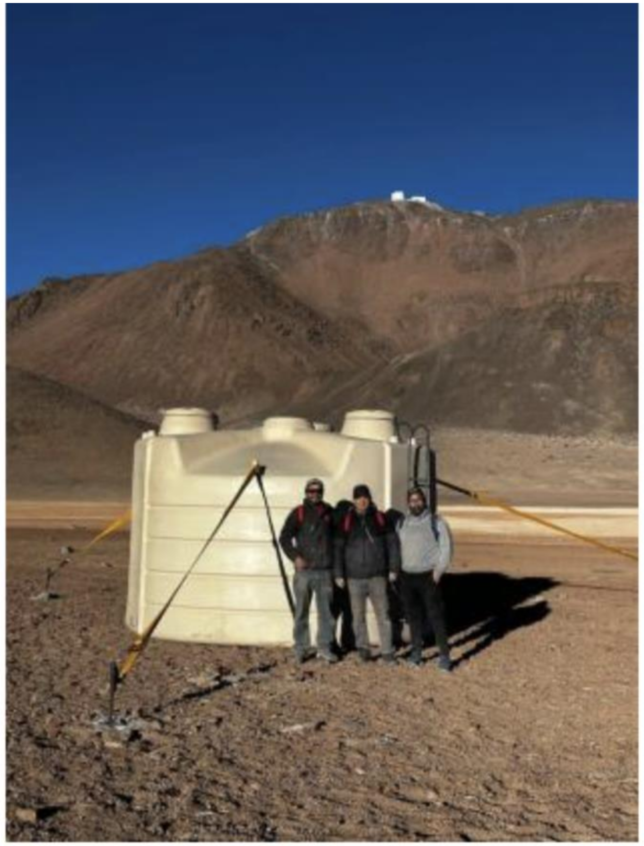
- Low Altitude Test Sites:
  - → Rio, Heidelberg, Milano, Temple Uni. USA
- Plus HAWC and Atacama





Test Installation above SWGO

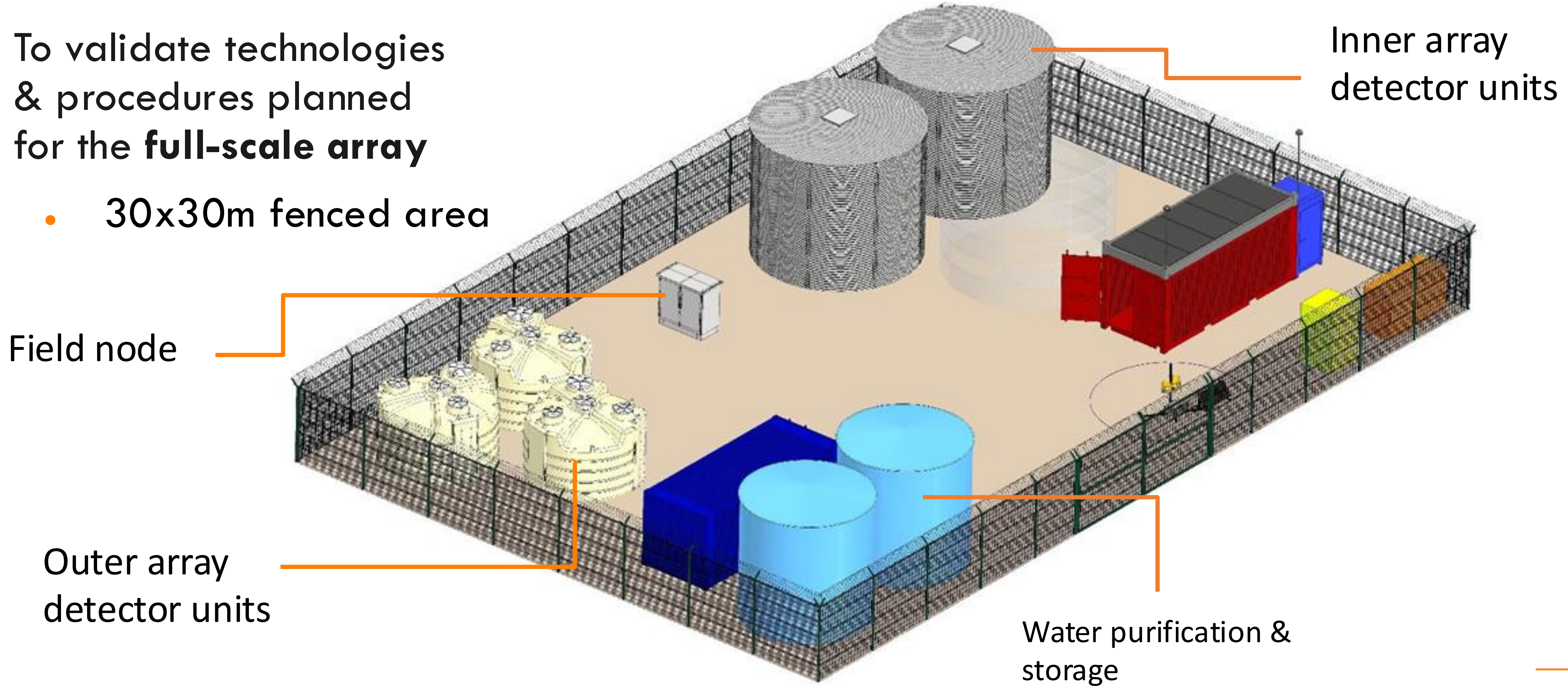
5000 m a.s.l. – test impact of freezing++



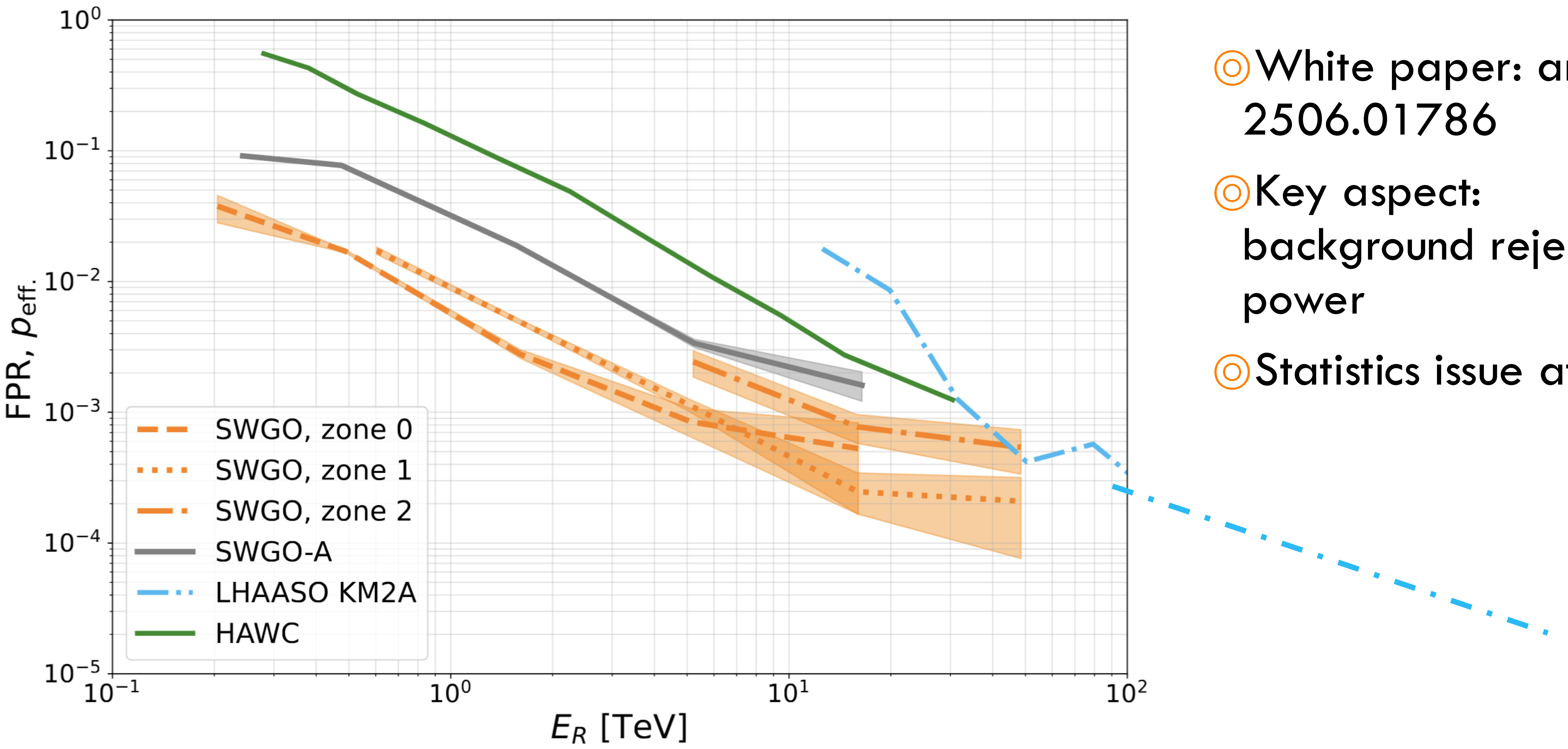
First step on-site: the Pathfinder

To validate technologies
& procedures planned
for the **full-scale array**

- 30x30m fenced area



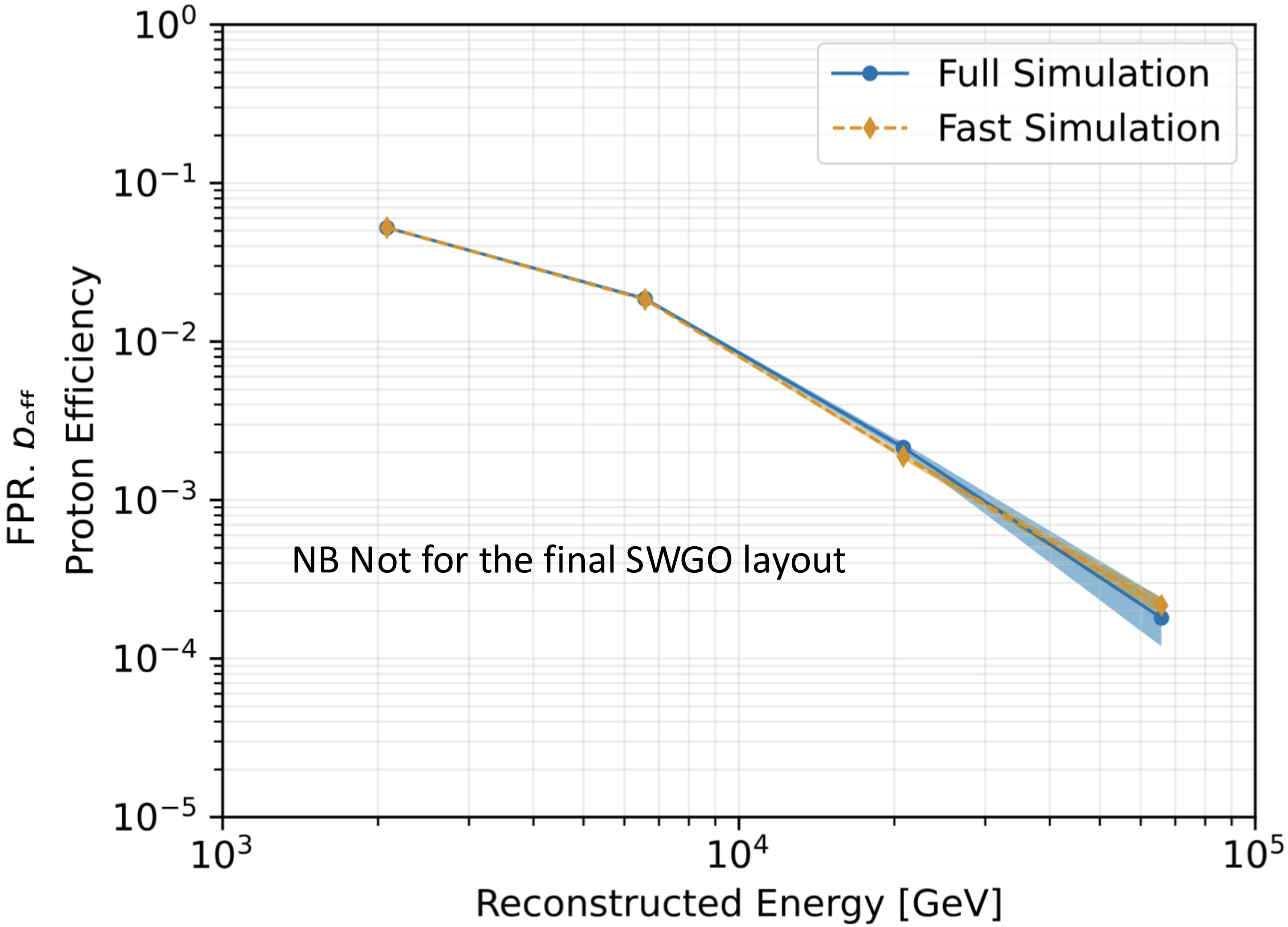
Performance?



- White paper: arXiv 2506.01786
- Key aspect: background rejection power
- Statistics issue at UHE

Performance?

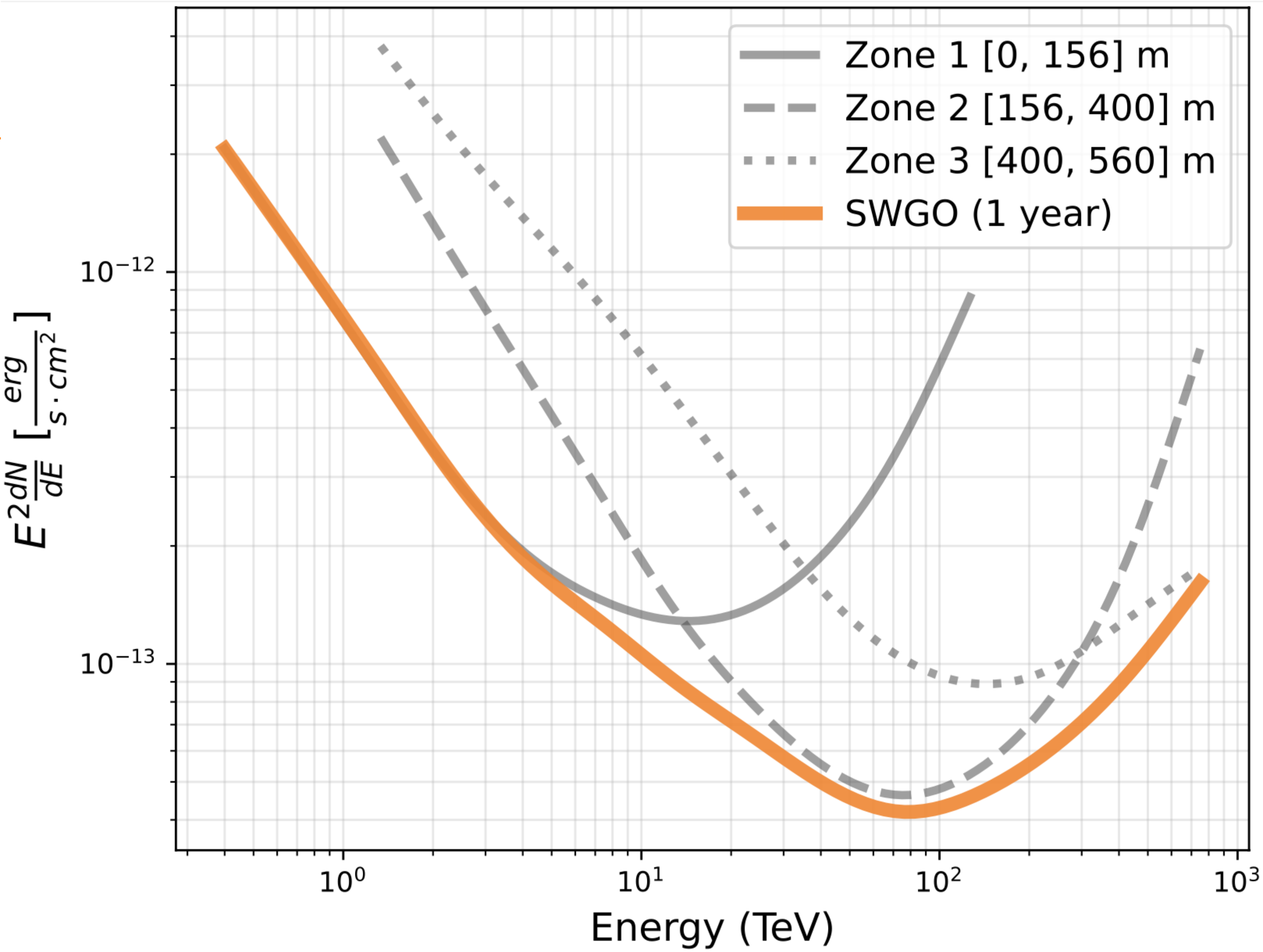
Nuclear Inst. and Methods in Physics Research, A 1093 (2027) 171921



- White paper: arXiv 2506.01786
- Key aspect: background rejection power
- Statistics issue at UHE
  - → Solved with increased CPU power and fast simulation

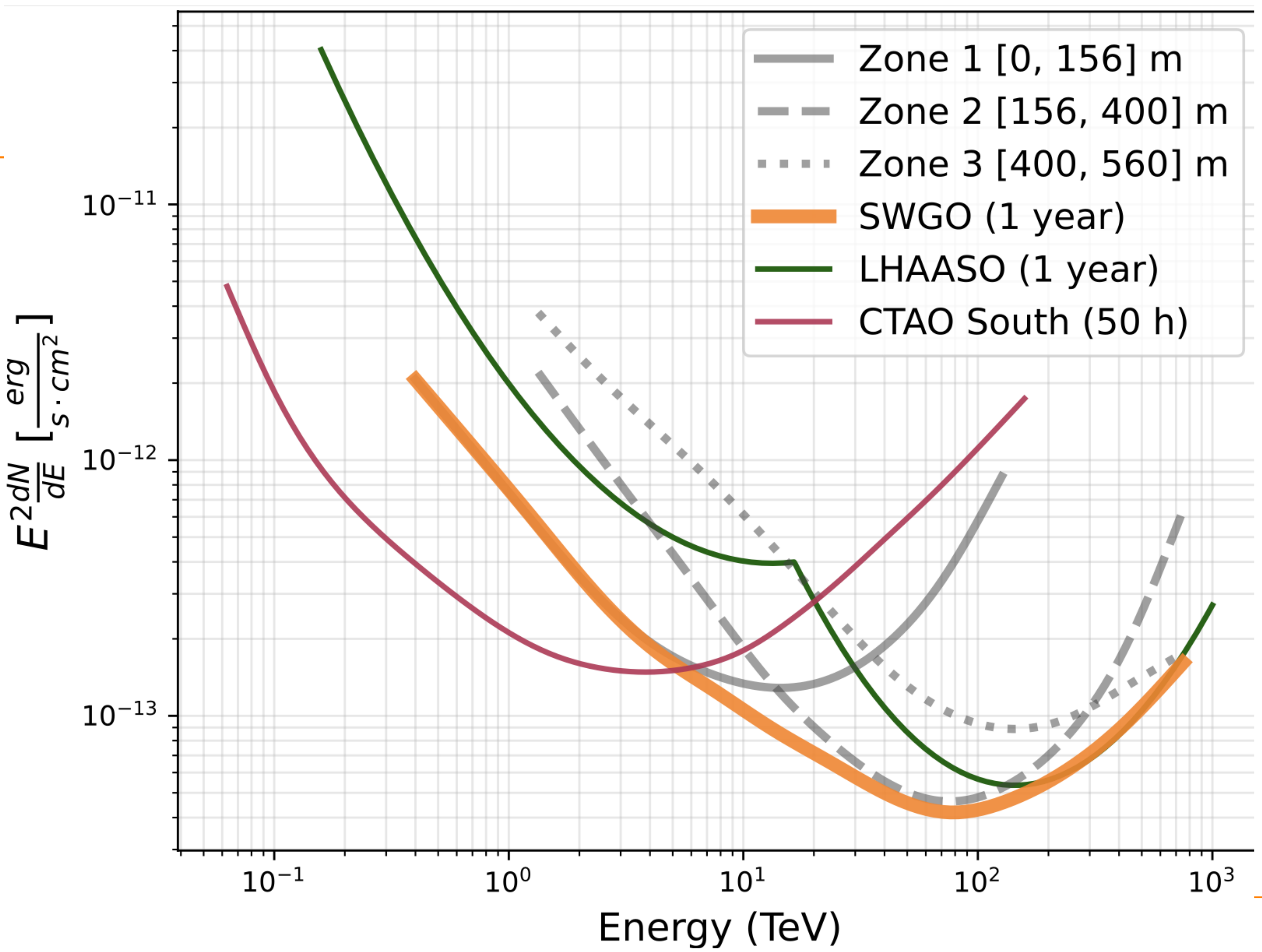
Sensitivity

- With newly established outer array baseline can put together the array sensitivity curve

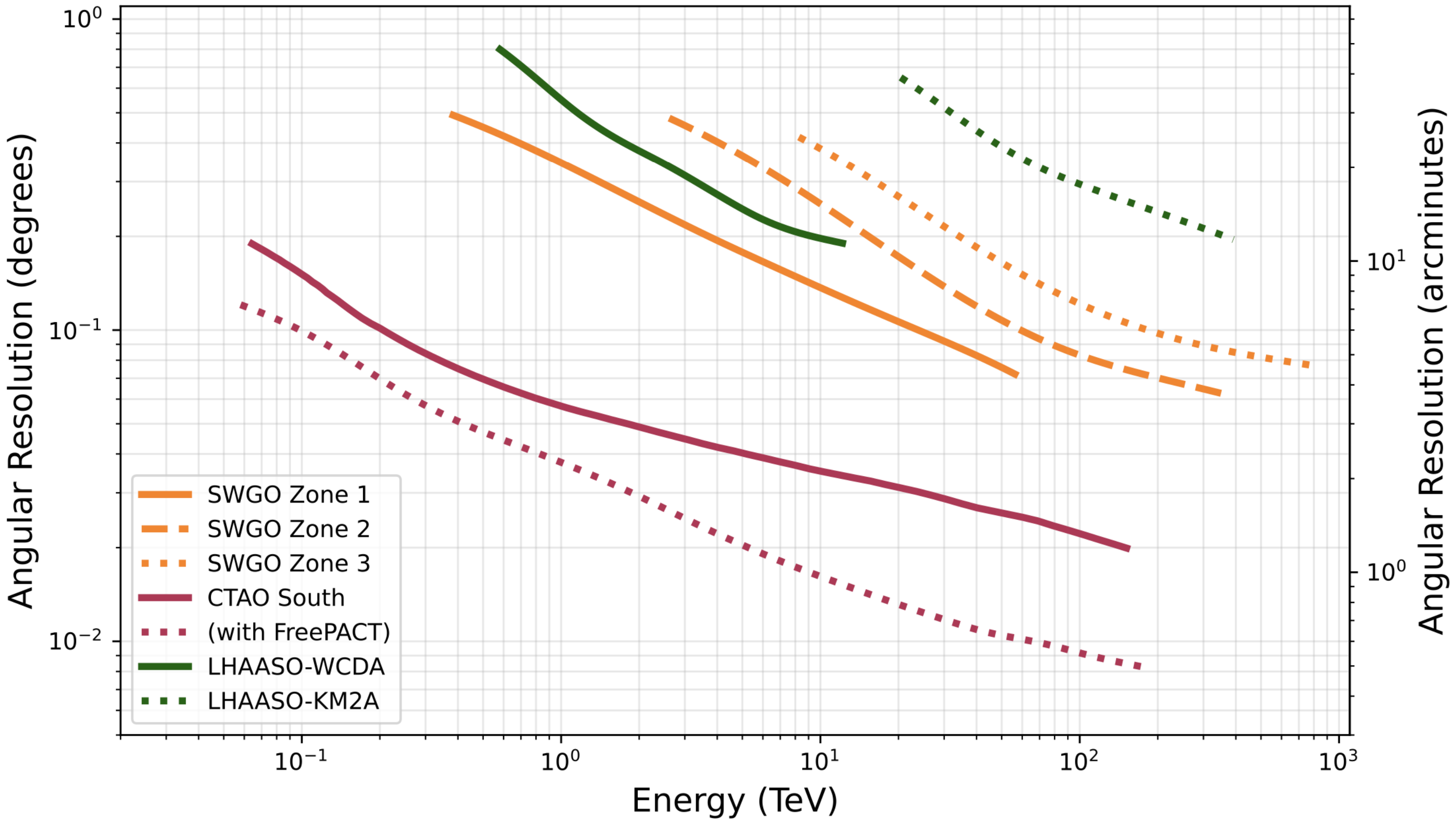


Sensitivity

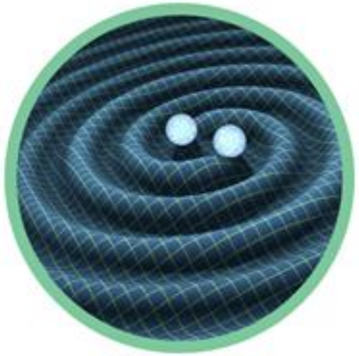
- Cf LHAASO and CTAO-South



Angular Resolution



Multi-messenger astronomy with SWGO

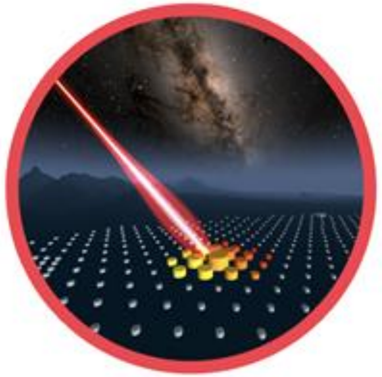


Gravitational Waves

- Compact object mergers in the local universe ($z<0.1$) → gamma-ray bursts

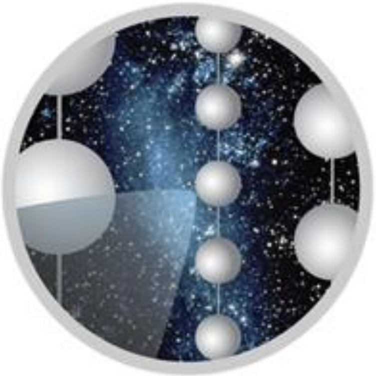
Cosmic Rays

- Composition and hadronic interaction models
- Nearby extragalactic accelerators (GZK)



Neutrinos

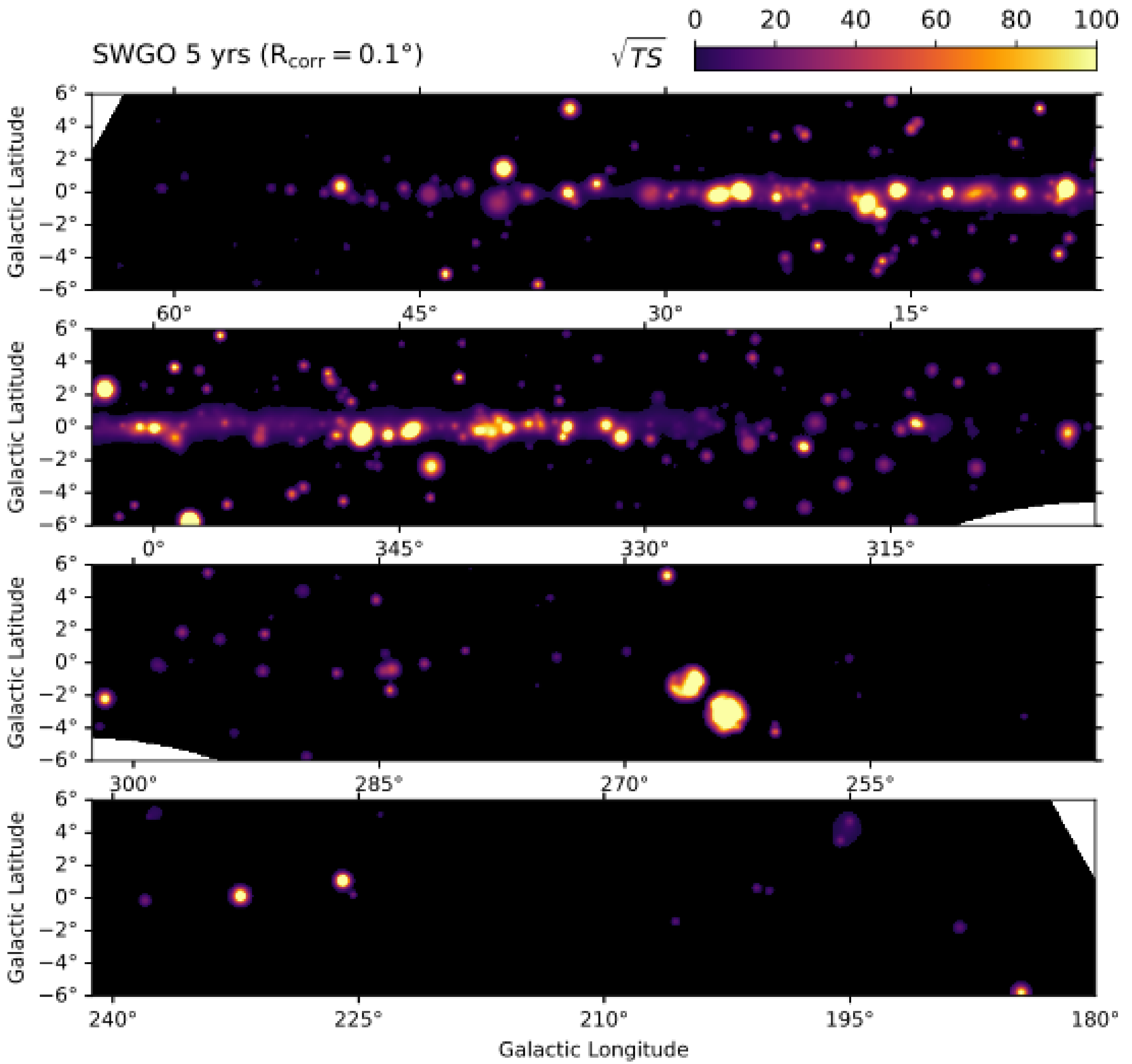
- Diffuse Galactic emission
- PeV+ hadron accelerators



Our Galaxy

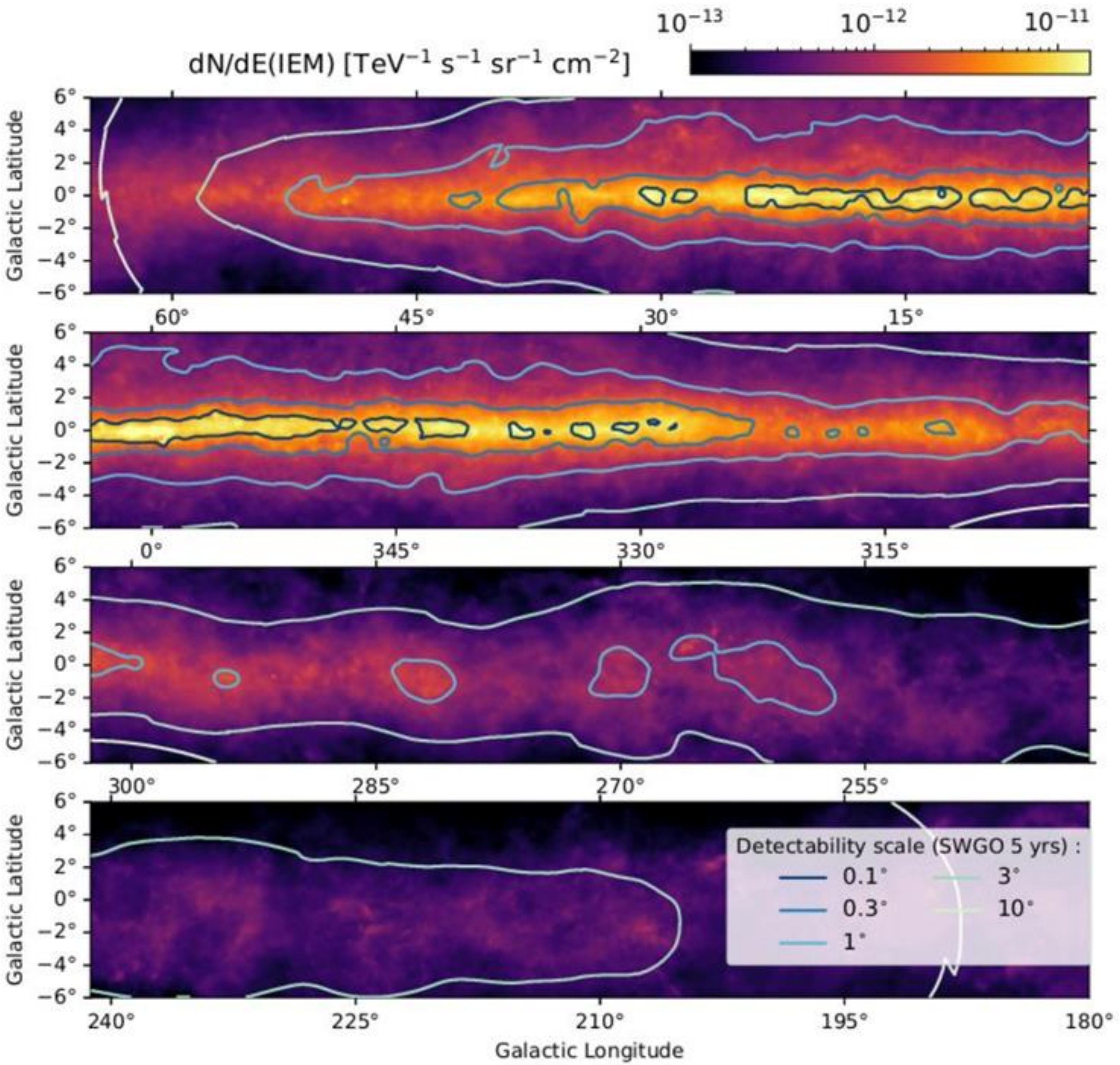
- Simulated Galactic Plane Observation with SWGO
  - Use CTAC pop. Model
    - ✓ 499 CTA dets
    - ✓ 461 detections in SWGO FoV
    - ✓ SWGO 5 years: 487
  - Very similar source statistics
    - ✓ Strong complementarity in terms of E-range and source scale
    - ✓ CTAO resolution critical – SWGO will extend spectra

Massive stellar clusters, microquasars, PWN, SNR +++



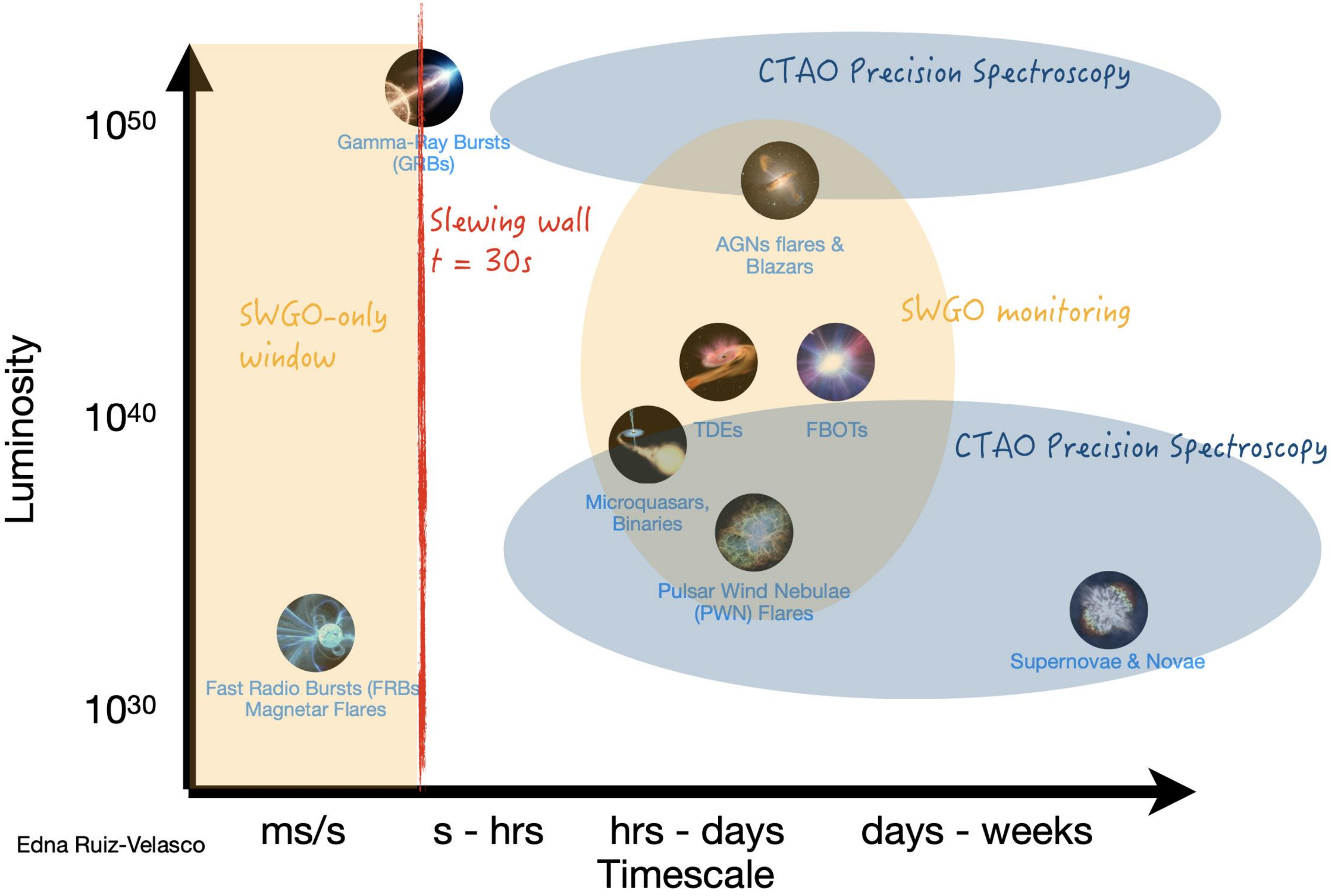
Diffuse Emission

- ◎Strongly complementary to neutrino diffuse measurement
  - → And northern coverage from LHAASO and HAWC
- ◎Can measure flux of well localised features
  - → e.g. Bania Clump → CR density spot checks

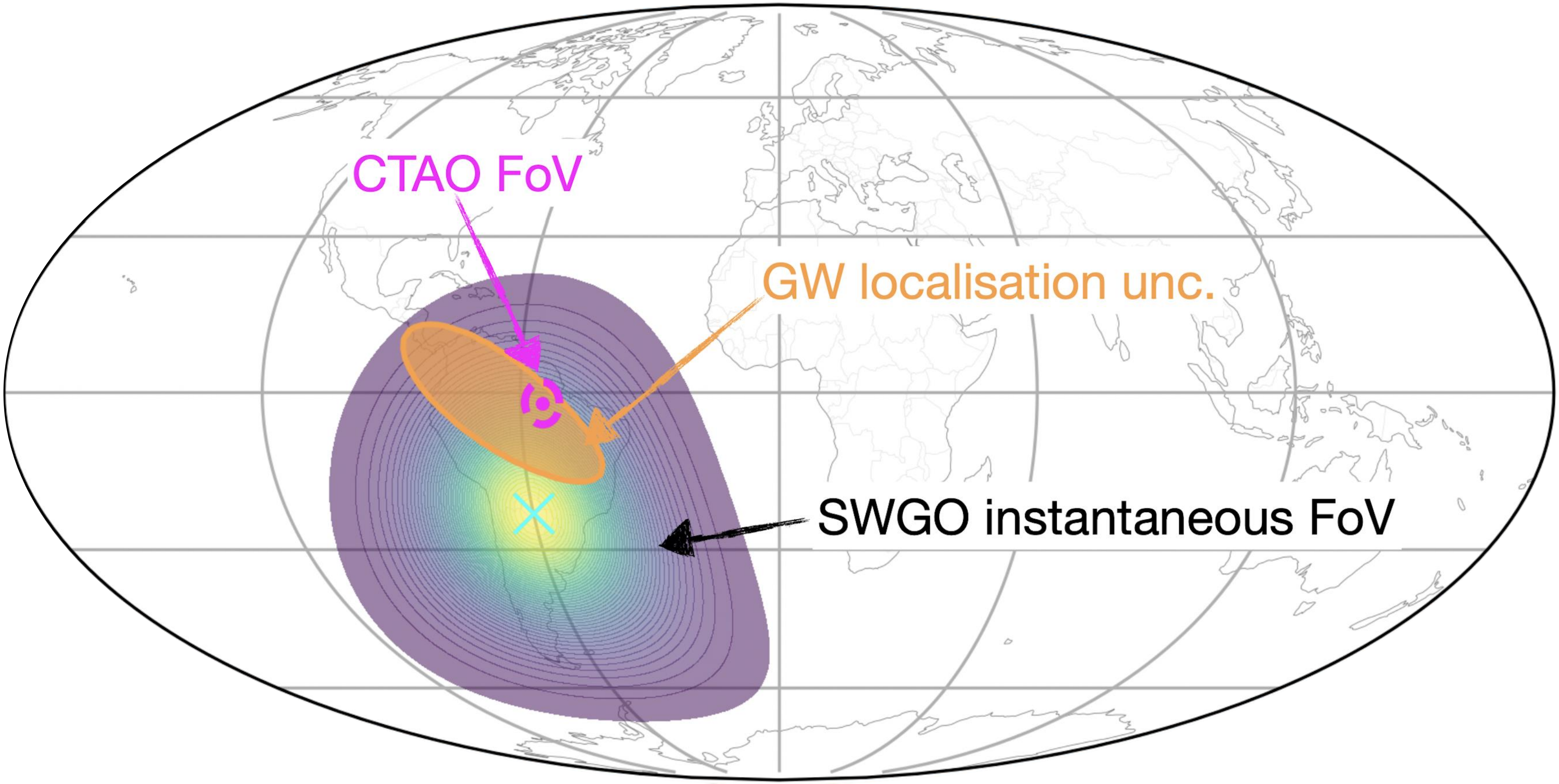


(and of course source/diffuse intermediate cases like Cygnus Bubble, Westerlund 1 outflow, +++)

Transients & Variable Sources

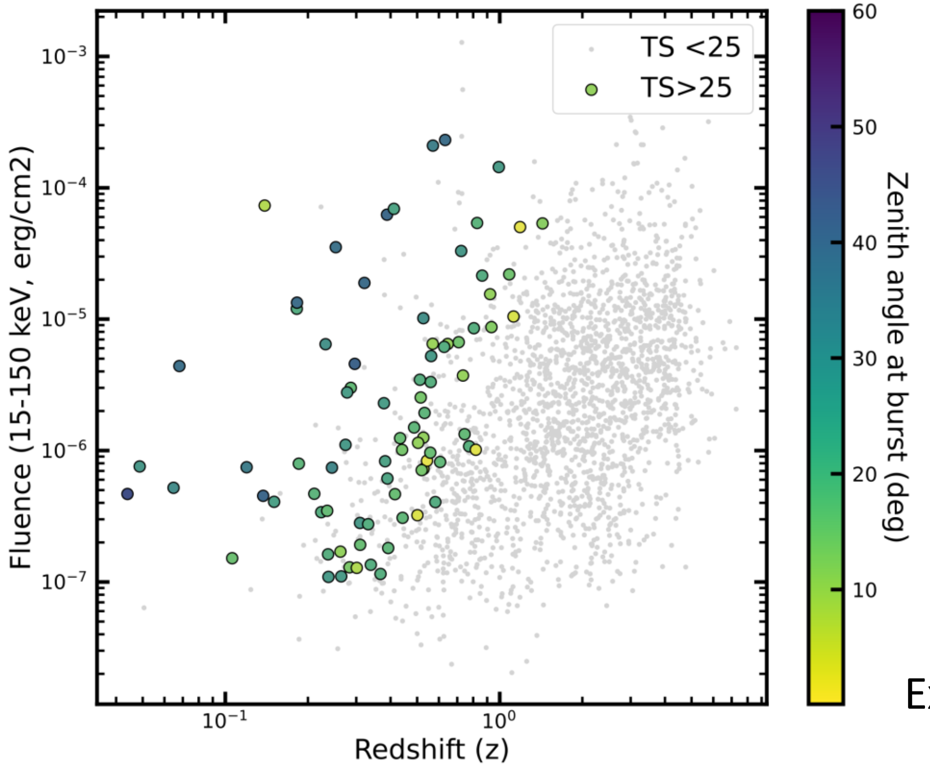


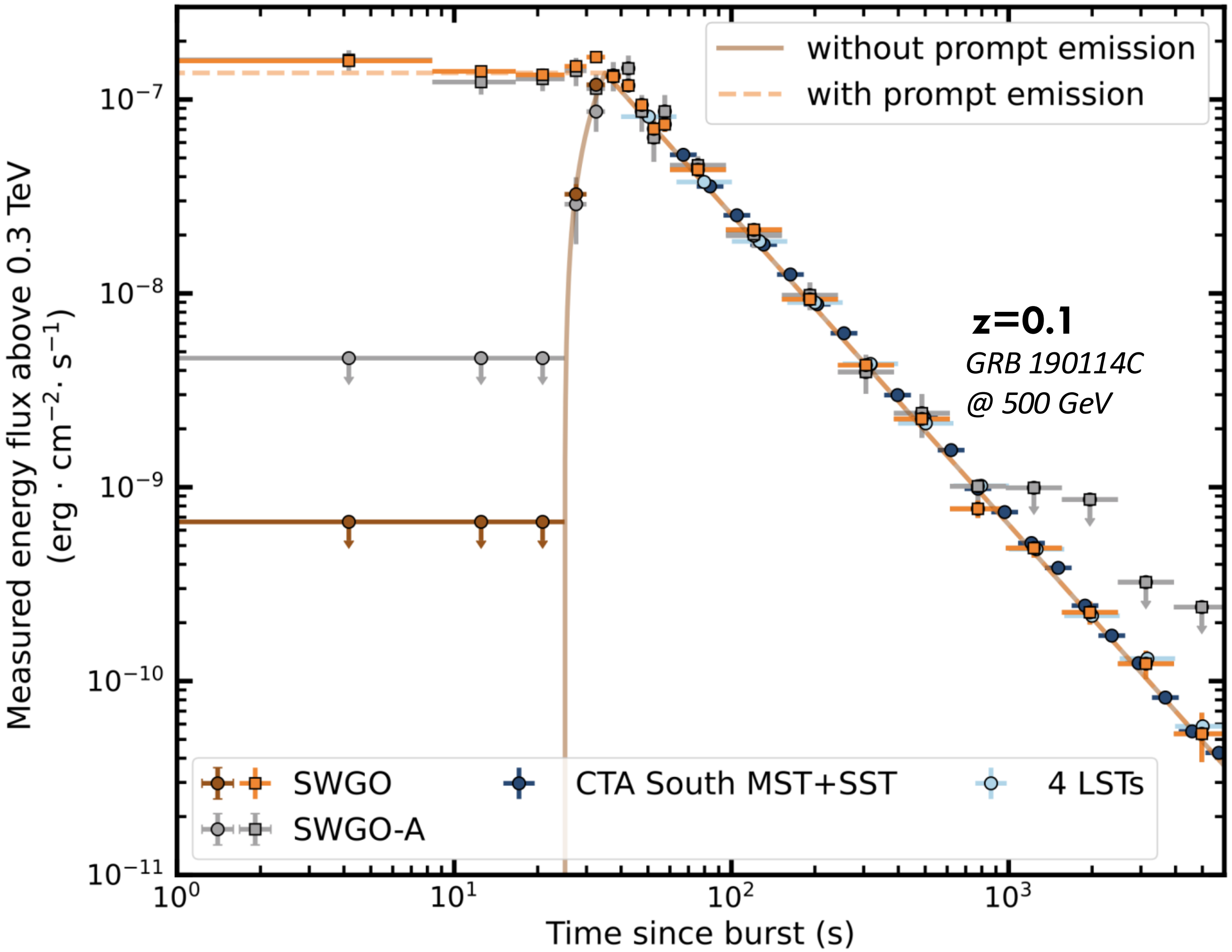
Edna Ruiz-Velasco


CTAO FoV
GW localisation unc.
SWGO instantaneous FoV

Transients: GRBs

- Prompt phase observations
  - SWGO+CTAO observations to cover full light-curve !

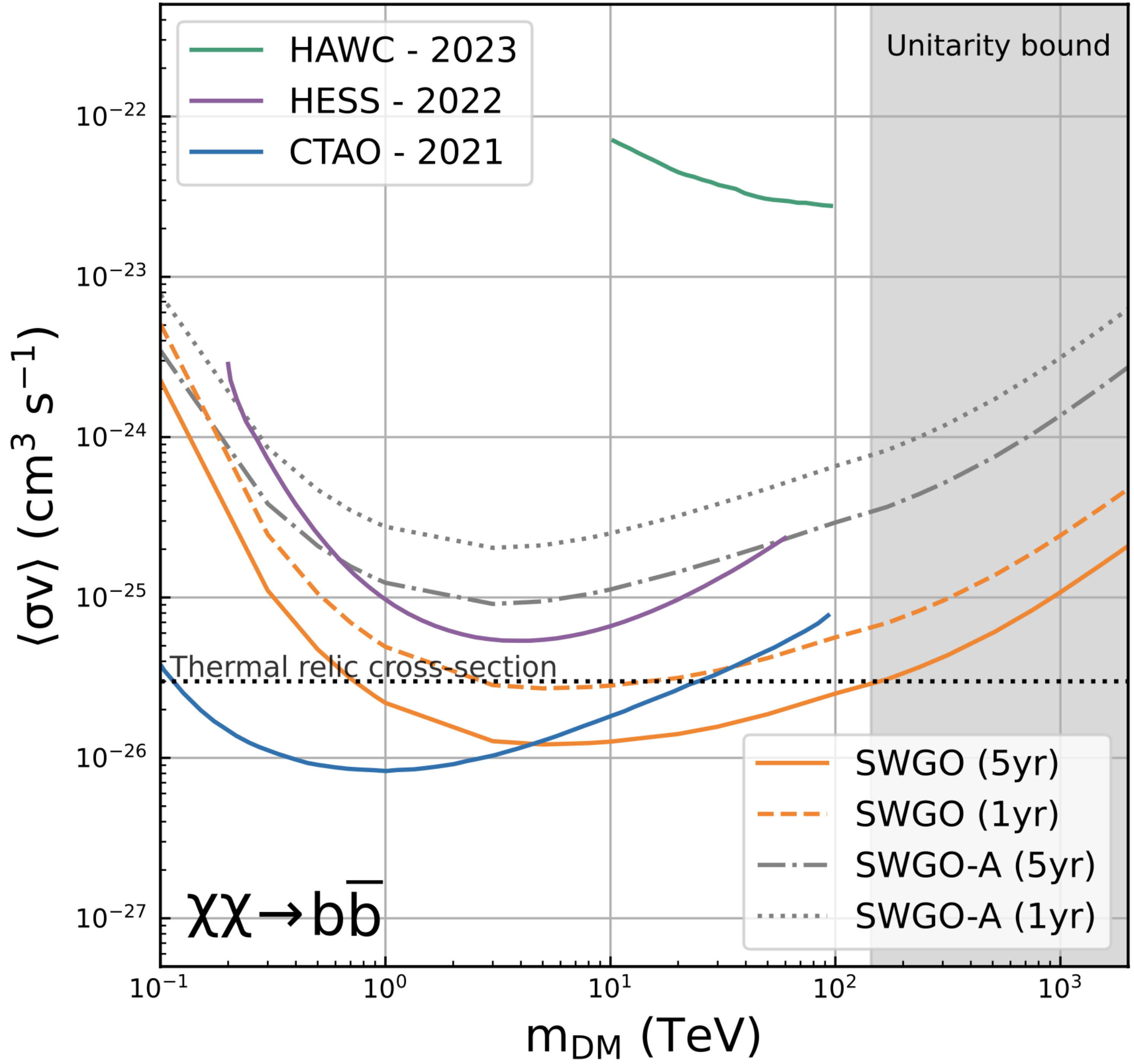




Expect ~0.7 GRBs/year

Dark Matter

- ◎WIMPs as a Thermal Relic of the Big Bang
  - Still a strong DM candidate
  - cf recent LZ event !
- ◎Indirect detection with gammas reaching critical sensitivity for Gal. Centre
  - SWGO advantages: wide field, BG systematics, higher energies
  - Again CTAO+SWGO extremely powerful
    - ✓ joint study in prep.



In to a new phase…

- Beyond the pathfinder:
  - Engineering array ~30 tanks – operating by early 2029
  - 800 radio antennae array (SWGO-TURBO)
  - and now…
- Good news from Brazil
  - $10M allocated for rotomolded tank production in Brazilian industry
    - ✓ Allows a large fraction of the outer array tanks to be built during 2029-2030
  - NB a large number of PMTs (3” and 10”) already available for construction
- Recent APPEC recommendation:
  - APPEC strongly supports the construction of the Southern Wide-field Gamma-ray Observatory (SWGO) on a sustainable path

Summary

- SWGO brings the successful wide-field gamma-ray approach to a new hemisphere – the first major instrument of this type in the south
  - → Targeting inner galaxy, galactic centre, dark matter, GRBs, PeV sources, +++
  - → Strongly complementary to neighbouring CTAO South
  - → See science case white paper for details: https://arxiv.org/abs/2506.01786
- Now approaching construction
  - → Pathfinder at Pampa La Bola about to be established
  - → Outer array construction will start in 2029 – Brazilian contribution confirmed

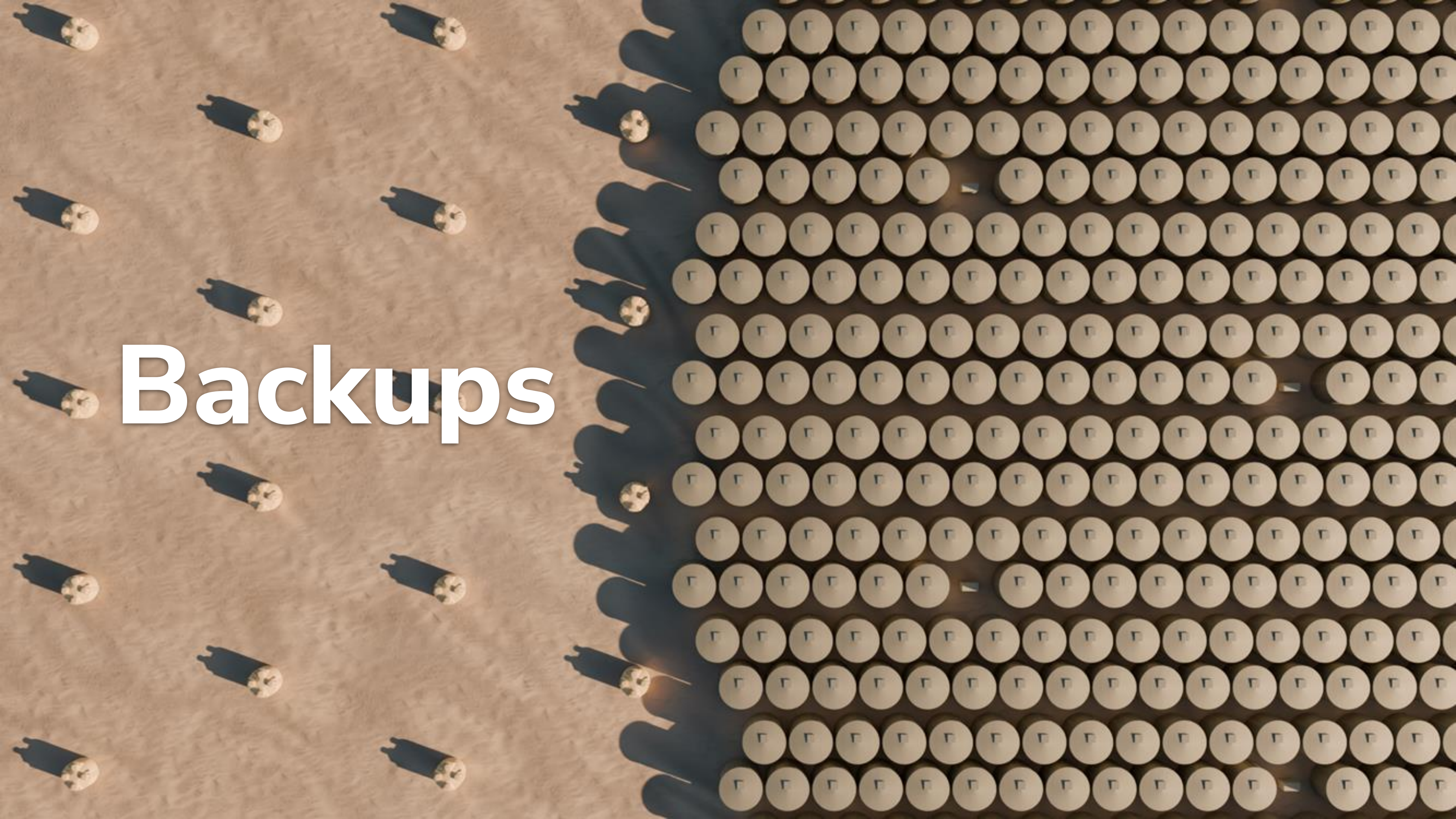
SWGO
The Southern Wide-field Gamma-ray Observatory

MAX-PLANCK-INSTITUT FÜR KERNPHYSIK

Thank you!

11th Collaboration Meeting - Heidelberg, Germany, September 2024

Backups



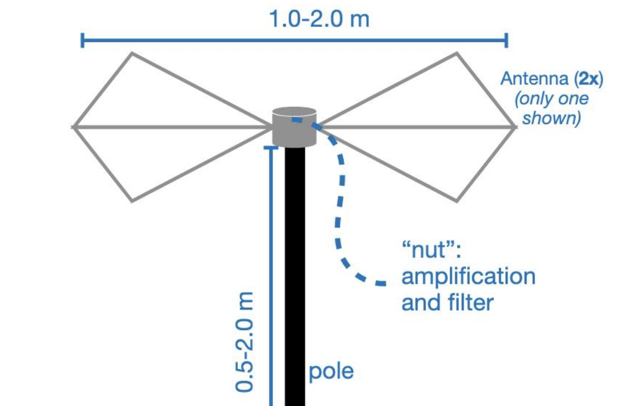
SWGO TURBO:

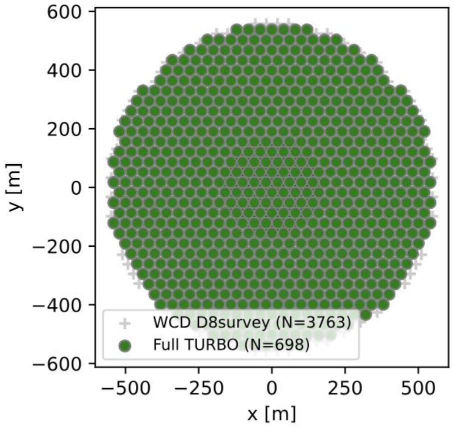
The Southern Wide-field Gamma-ray Observatory

The Utility for Radio Beam-formed Observations

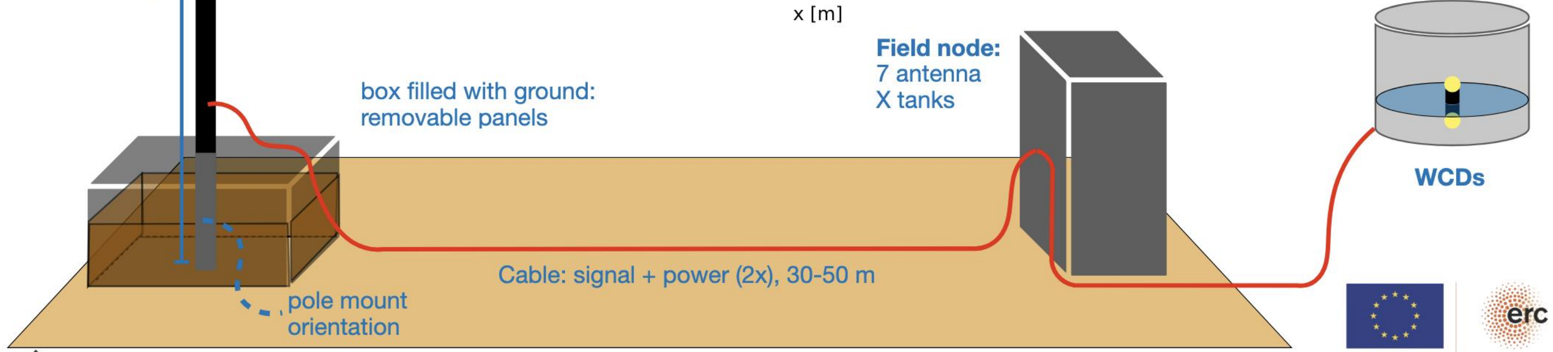
Conceptual design

Radboud University



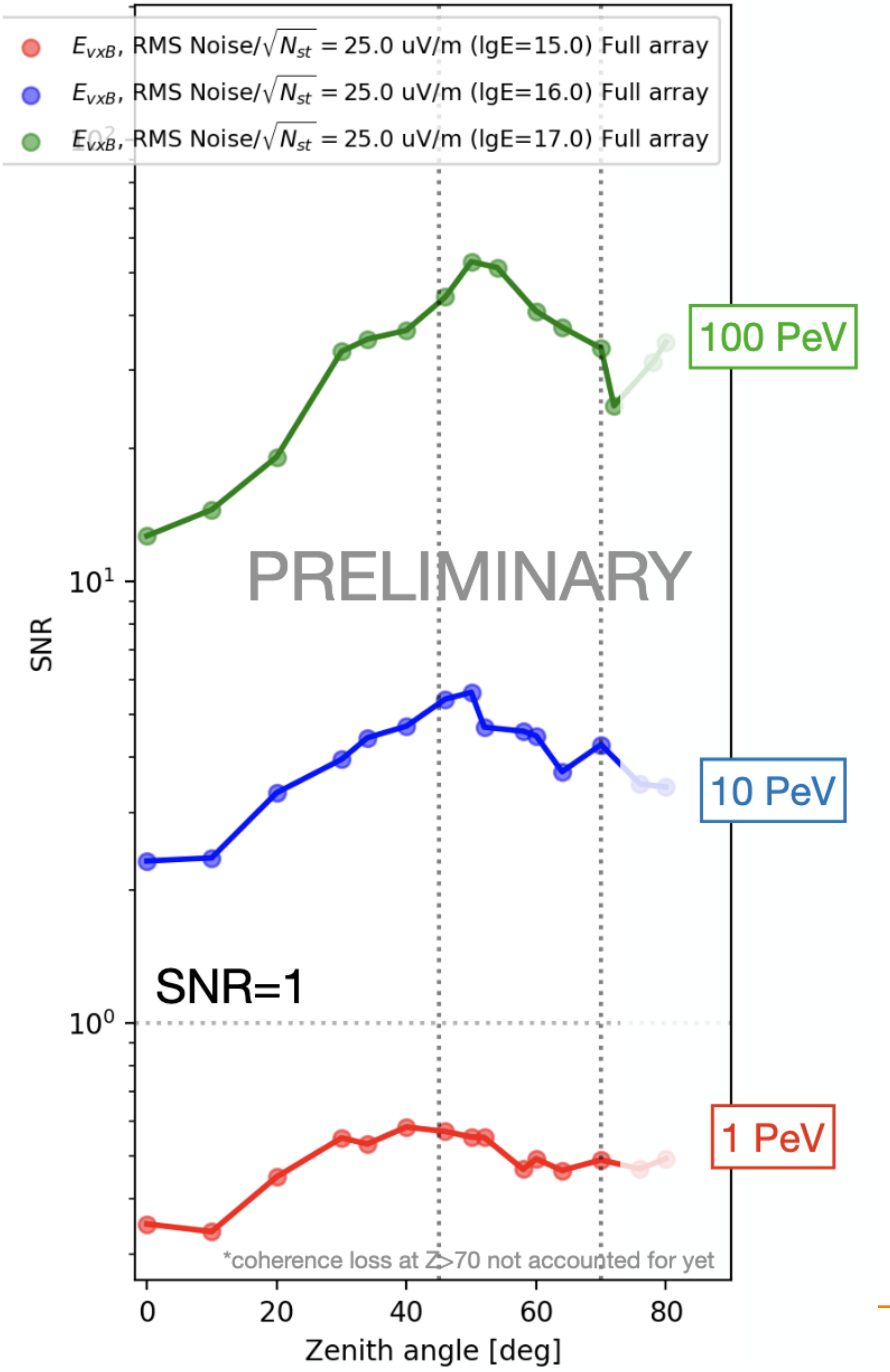


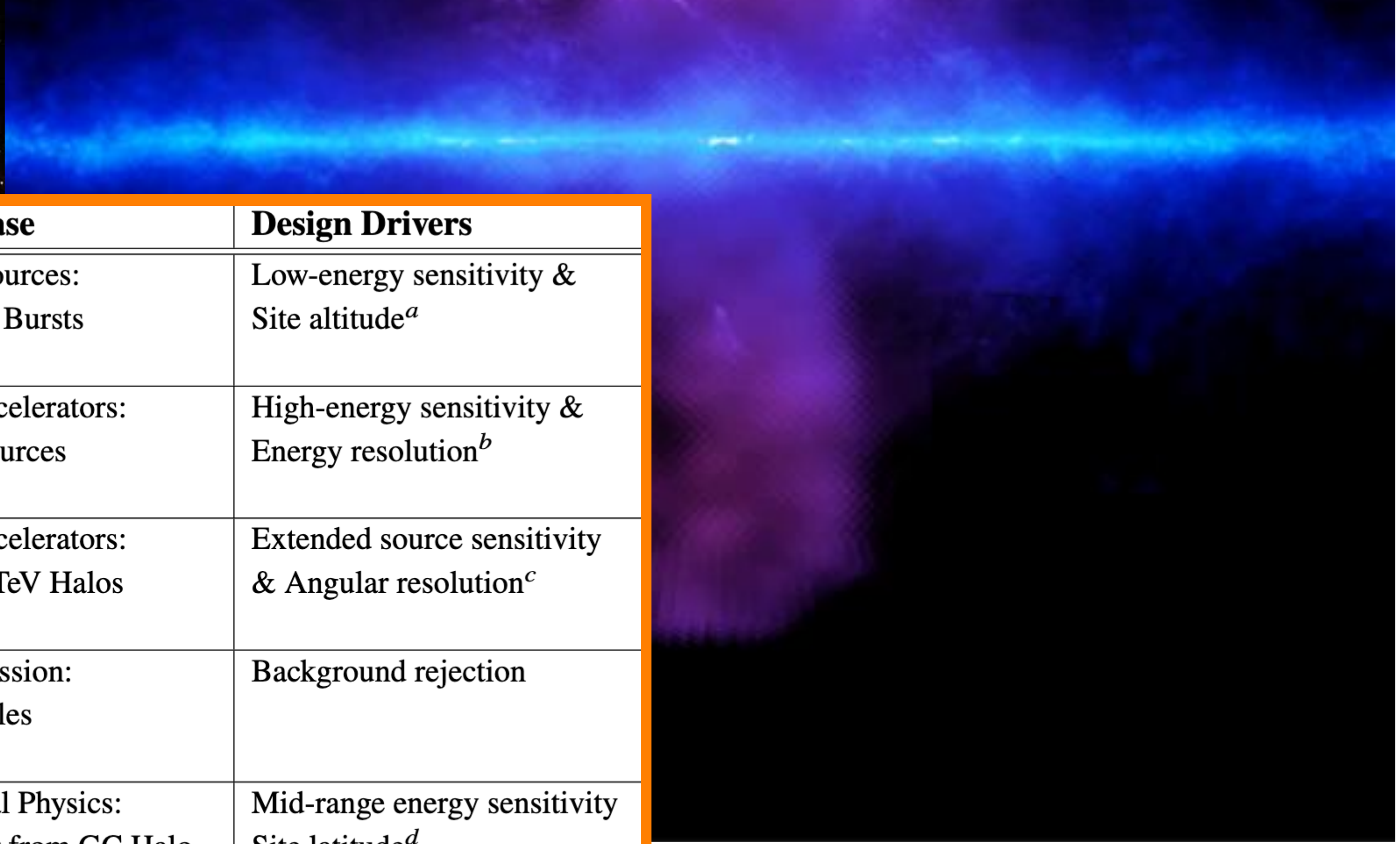
- Based on *horizon antenna*
- ~700-800 stations
- Uniform grid (1km²)
- Integrated **within** SWGO (shared timing
- Frequency band: 50-200MHz



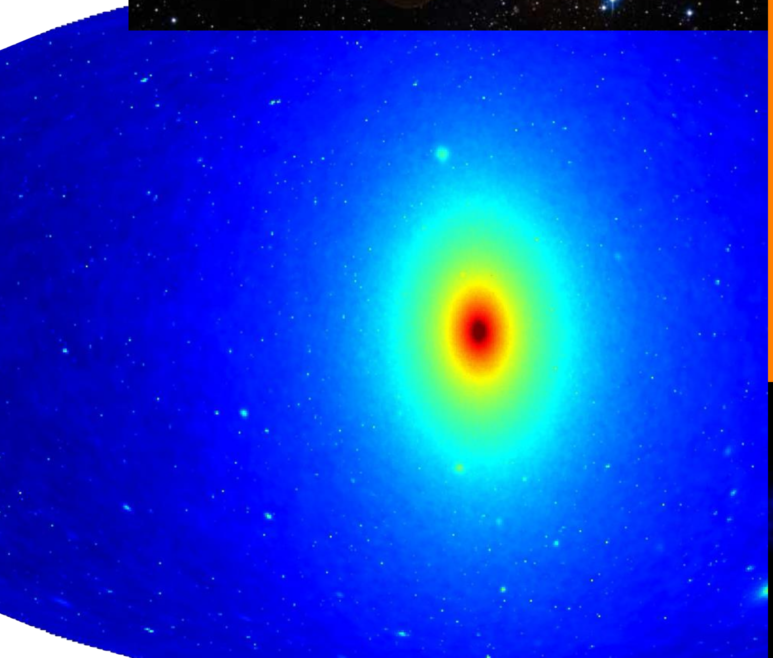
Funded by the European Union

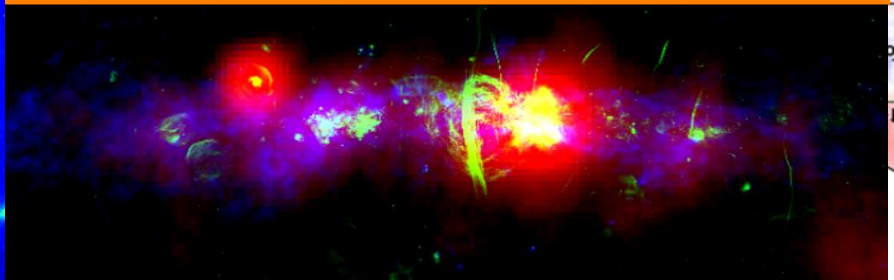
erc European Research Cou

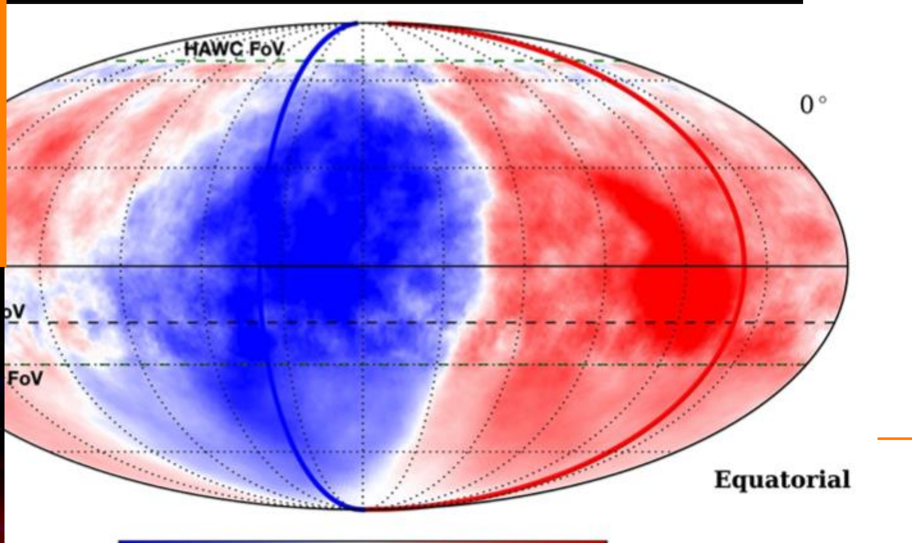




Science Case	Design Drivers
Transient Sources: Gamma-ray Bursts	Low-energy sensitivity & Site altitude[a]
Galactic Accelerators: PeVatron Sources	High-energy sensitivity & Energy resolution[b]
Galactic Accelerators: PWNe and TeV Halos	Extended source sensitivity & Angular resolution[c]
Diffuse Emission: Fermi Bubbles	Background rejection
Fundamental Physics: Dark Matter from GC Halo	Mid-range energy sensitivity Site latitude[d]
Cosmic-rays: Mass-resolved dipole / multipole anisotropy	Muon counting capability[e]







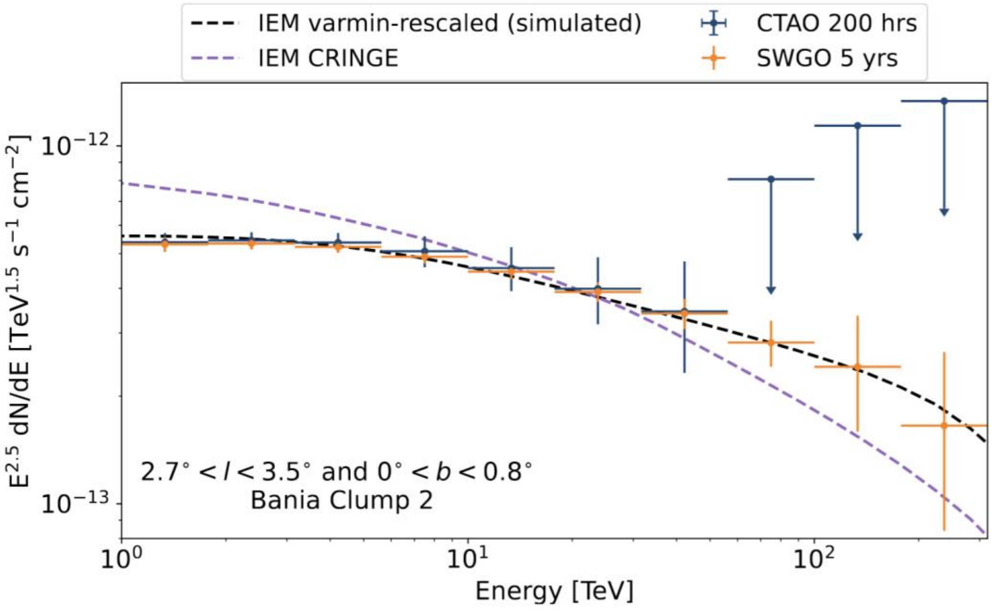
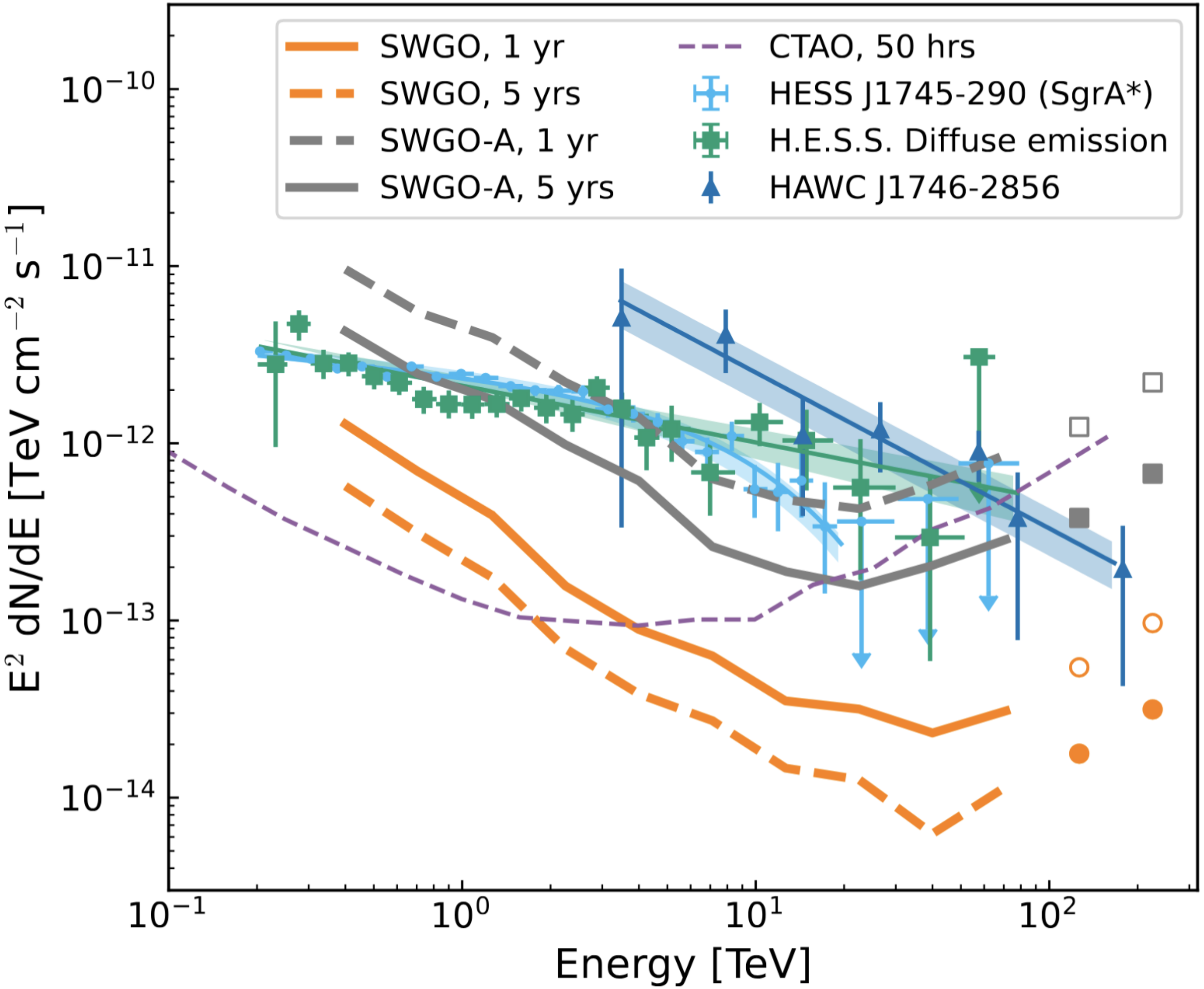
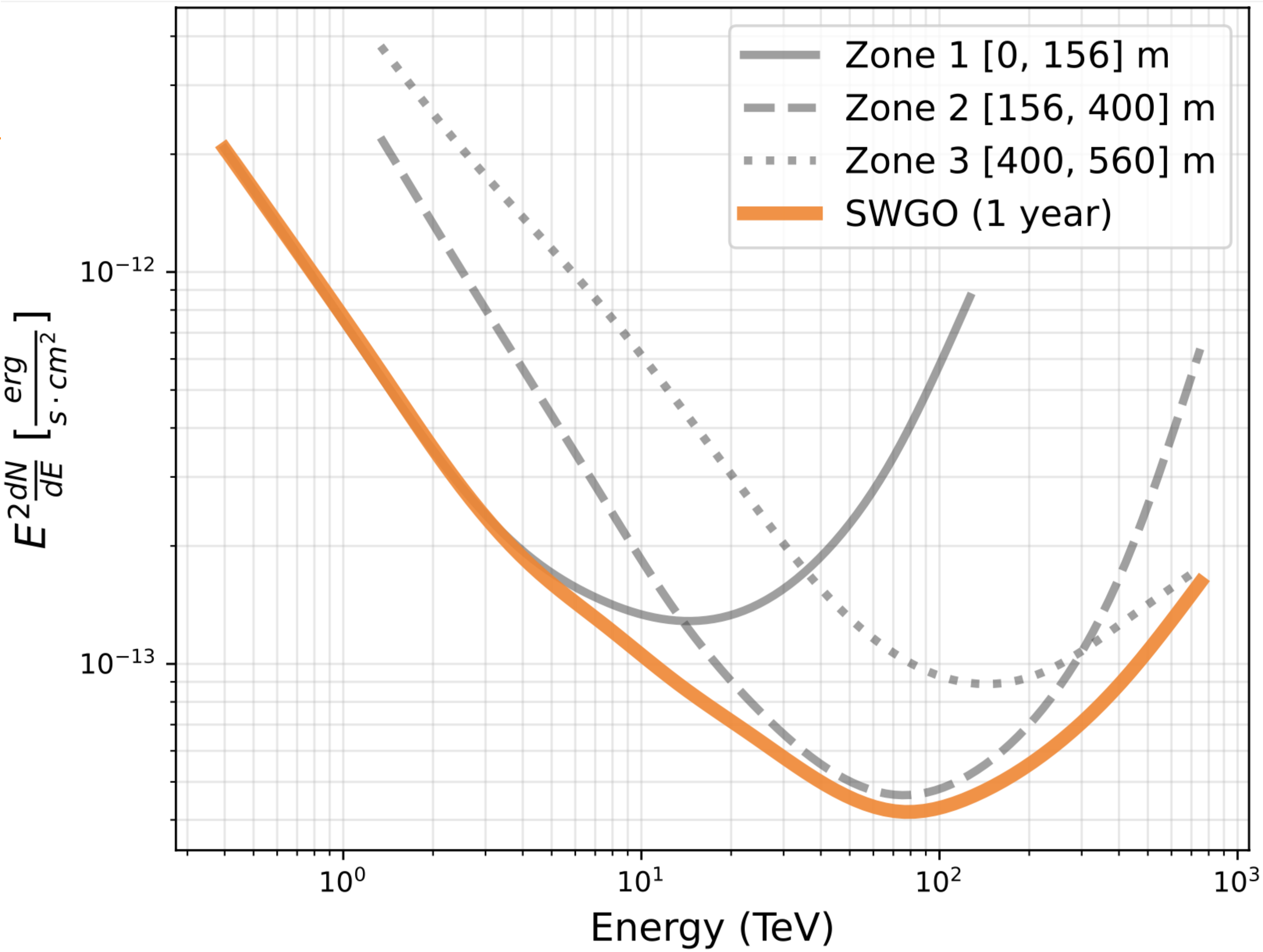


Figure 14: Differential flux of the diffuse emission toward Bania clump 2 measured by SWGO in 5 years and 200 hours of CTAO observation. SWGO could significantly detect this molecular cloud up to 300 TeV. The two interstellar emission models considered featuring different CR transport properties could be discriminated even above 50 TeV with SWGO.

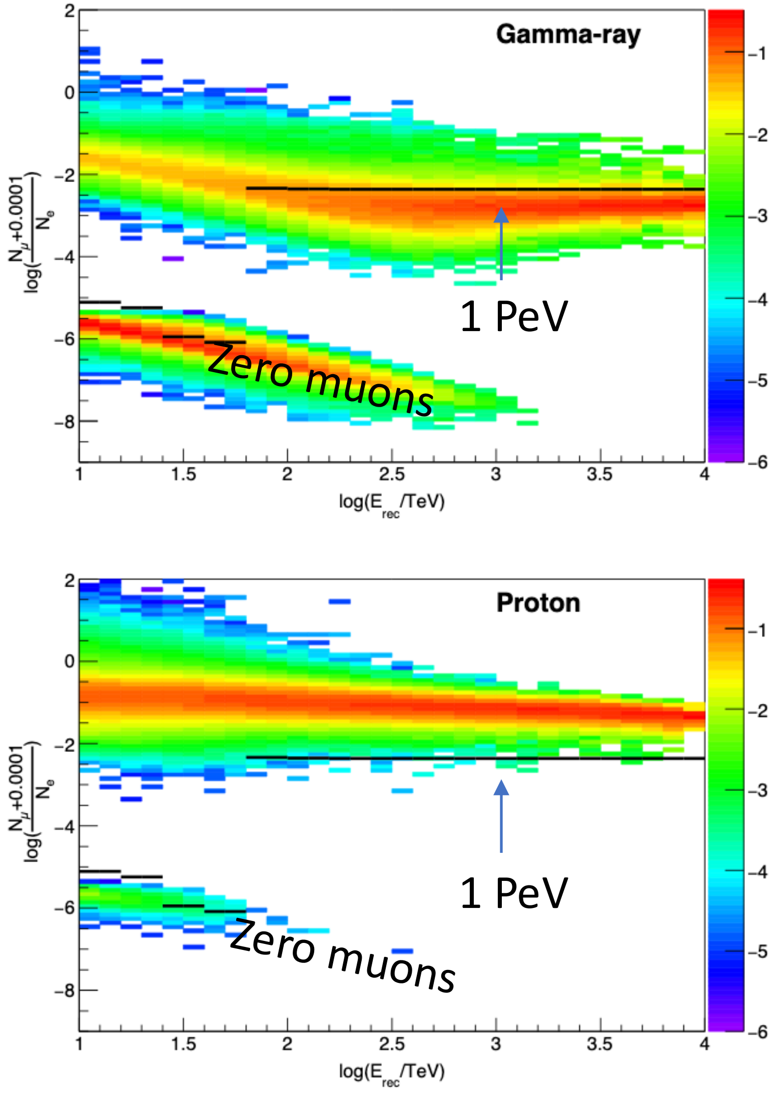


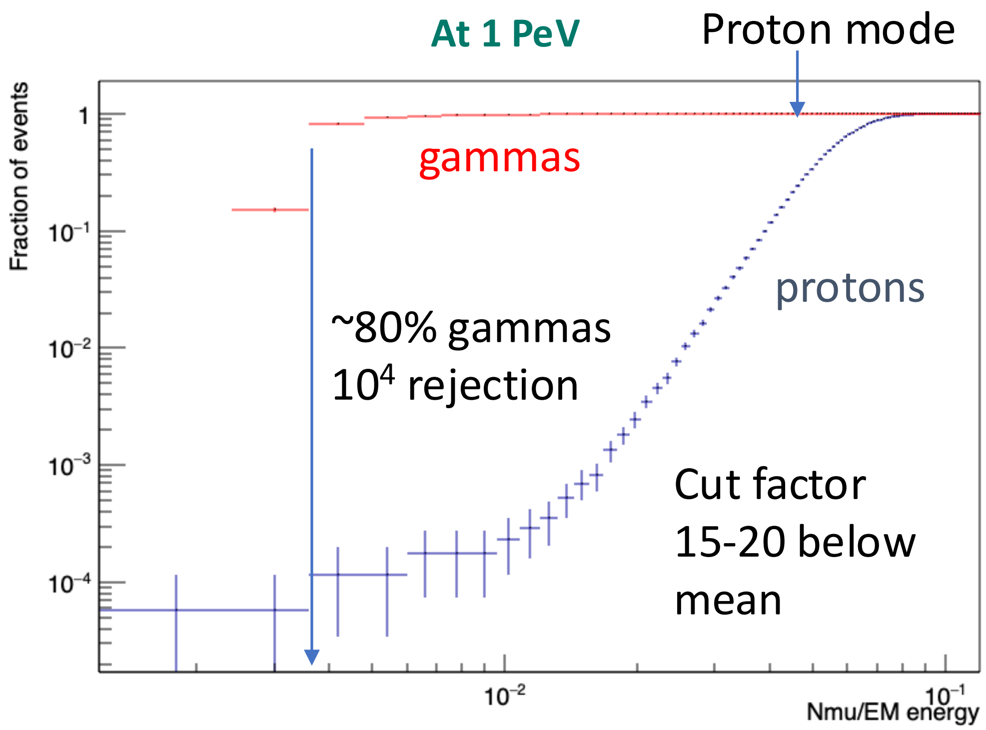
Sensitivity

- With newly established outer array baseline can put together the array sensitivity curve



Muon Counting

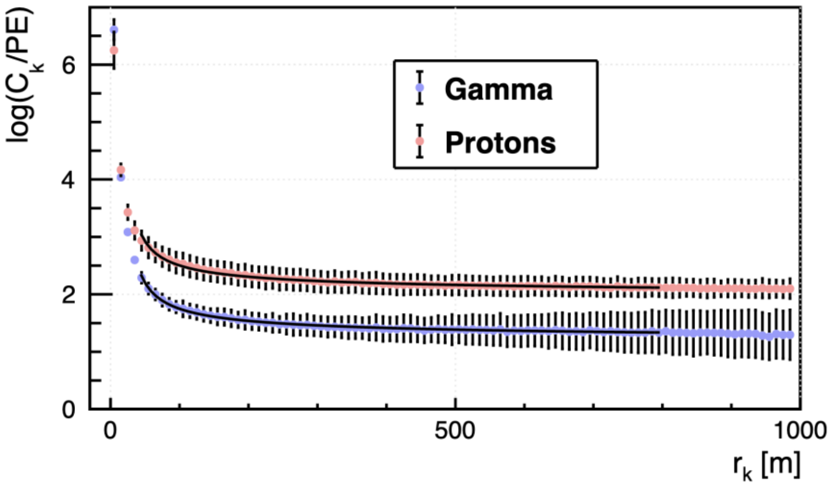


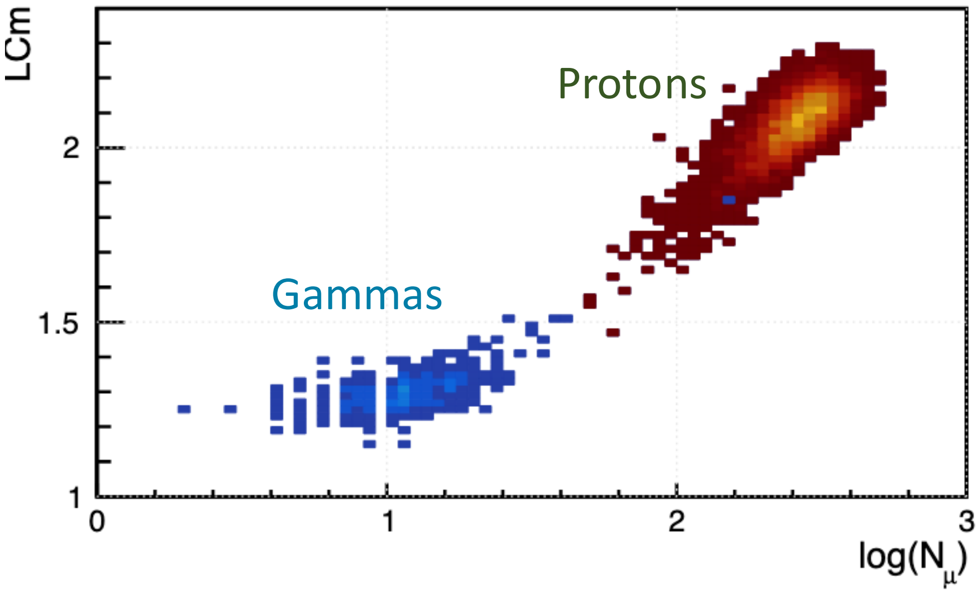


- Jim
- LHAASO

EM Fluctuations

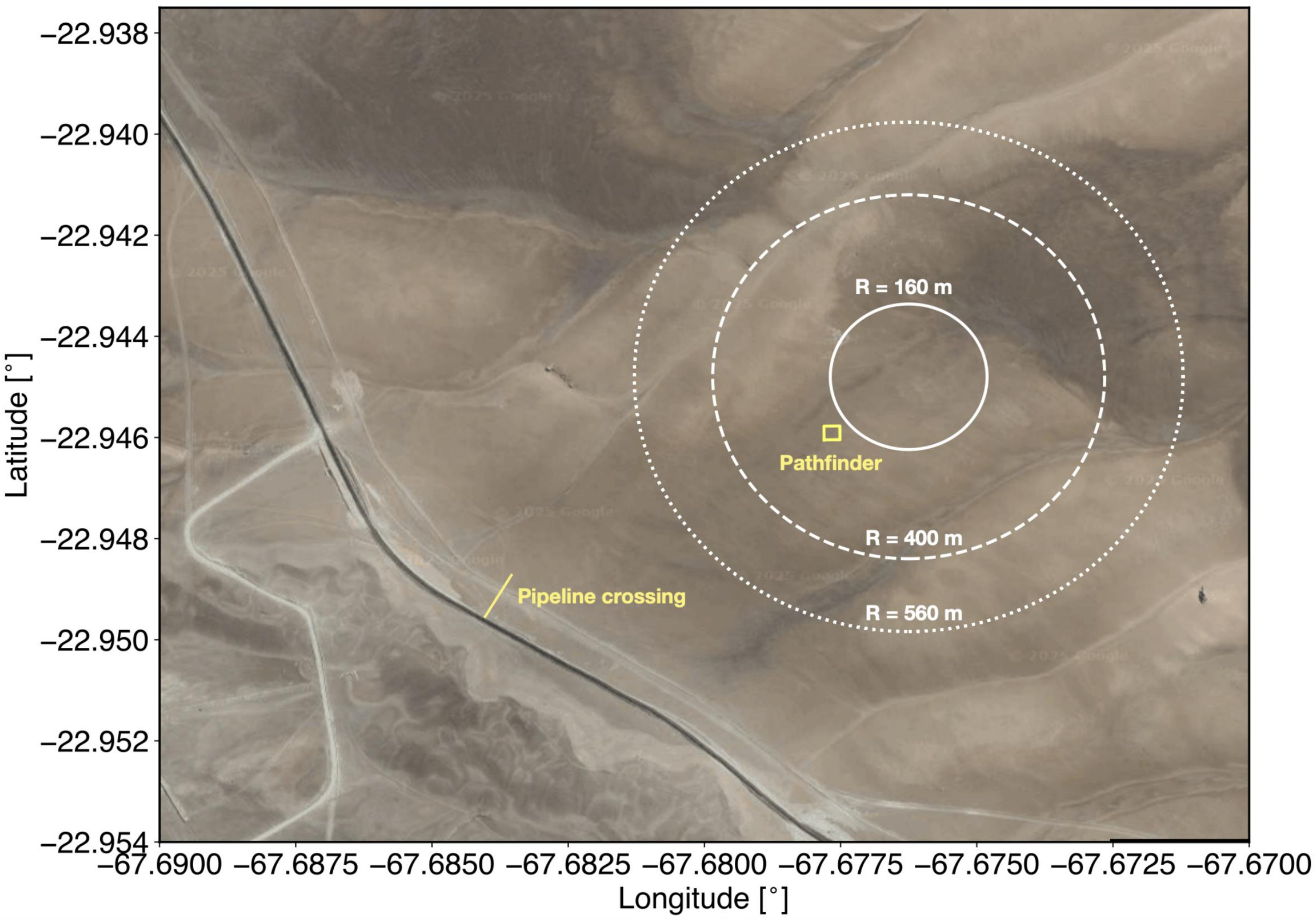
Conceição et al arXiv 2204.12337





$$C_k = \frac{1}{2n_k(n_k-1)}\frac{1}{\langle S_k\rangle}\sum_{i=1}^{n_k-1}\sum_{j=i+1}^{n_k}(S_{ik}-S_{jk})^2 \qquad LCm \equiv \log\left(C_k\right)\big|_{r_k=r_m}$$

- LDF, sub-structure, azimuthal asymmetry
  - Sub-showers in hadronic showers produce additional fluctuations, closely correlated with muon number – tail of very gamma-like protons



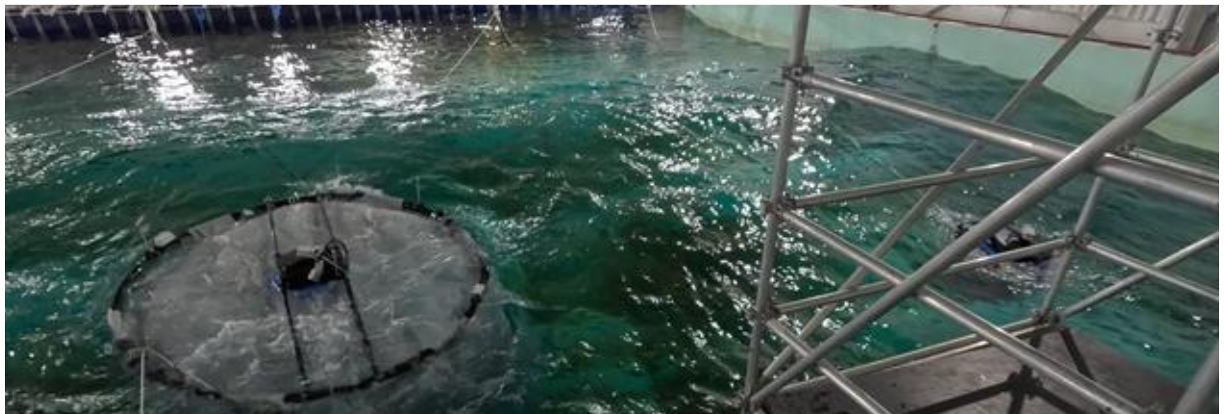
−22.938
−22.940
−22.942
−22.944
−22.946
−22.948
−22.950
−22.952
−22.954
Latitude [°]
−67.6900
−67.6875
−67.6850
−67.6825
−67.6800
−67.6775
−67.6750
−67.6725
−67.6700
Longitude [°]
R = 160 m
R = 400 m
R = 560 m
Pathfinder
Pipeline crossing

ALPACA

- Bolivia, 4750 m a.s.l.
- Fill factor 4% MDs, 0.5% scintillators → area 0.08 km^2
- ALPAQUITO: ¼ of ALPACA → now complete except for muon det.

UHE Extension in a Lake under study

- A multi-km^2 array as a possible future extension enhancing UHE capabilities
- One option is lake-based, in addition to main site
- R&D effort within SWGO over the years: prototyping, tests with waves in France, at a pond in LHAASO site
- Cost benefit comparison to be done cf extending at Pampa La Bola



Tests in a Wave Basin
in Nantes, France