The Southern Wide-field Gamma-ray Observatory: *Status and Future Outlook*

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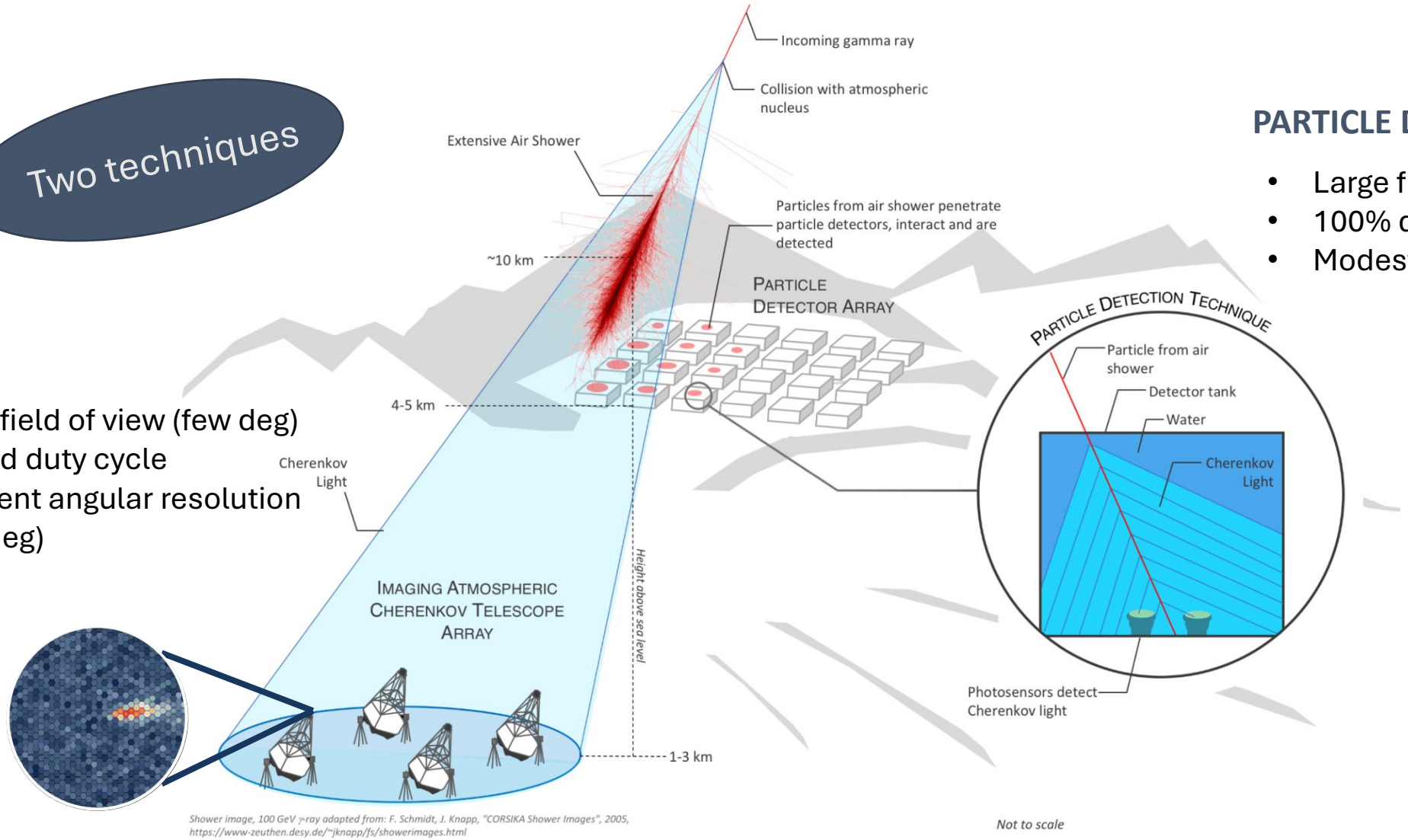
Ground-based gamma-ray astronomy

Two techniques

IACTs

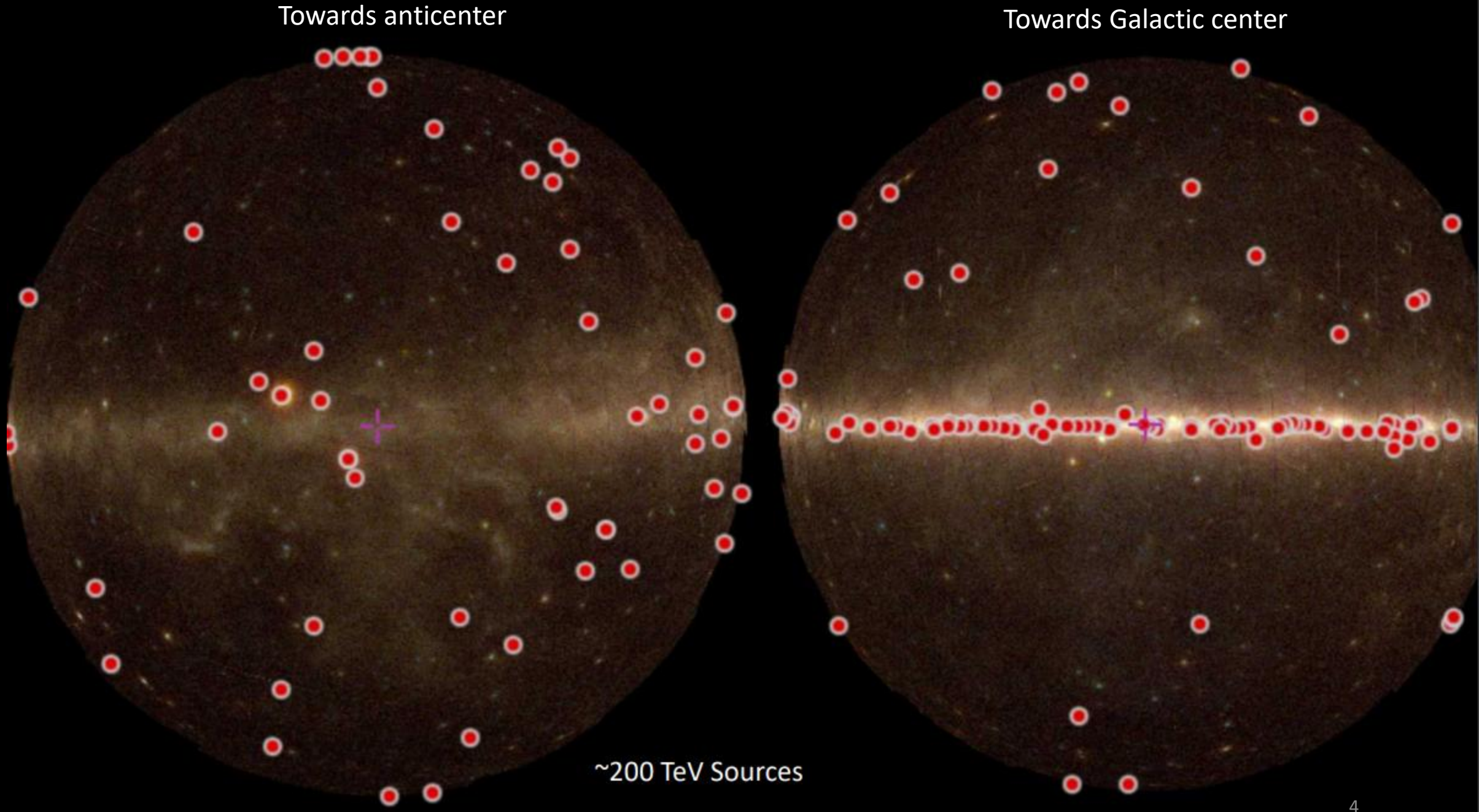
- Small field of view (few deg)
- Limited duty cycle
- Excellent angular resolution (<0.1deg)



PARTICLE DETECTOR ARRAY

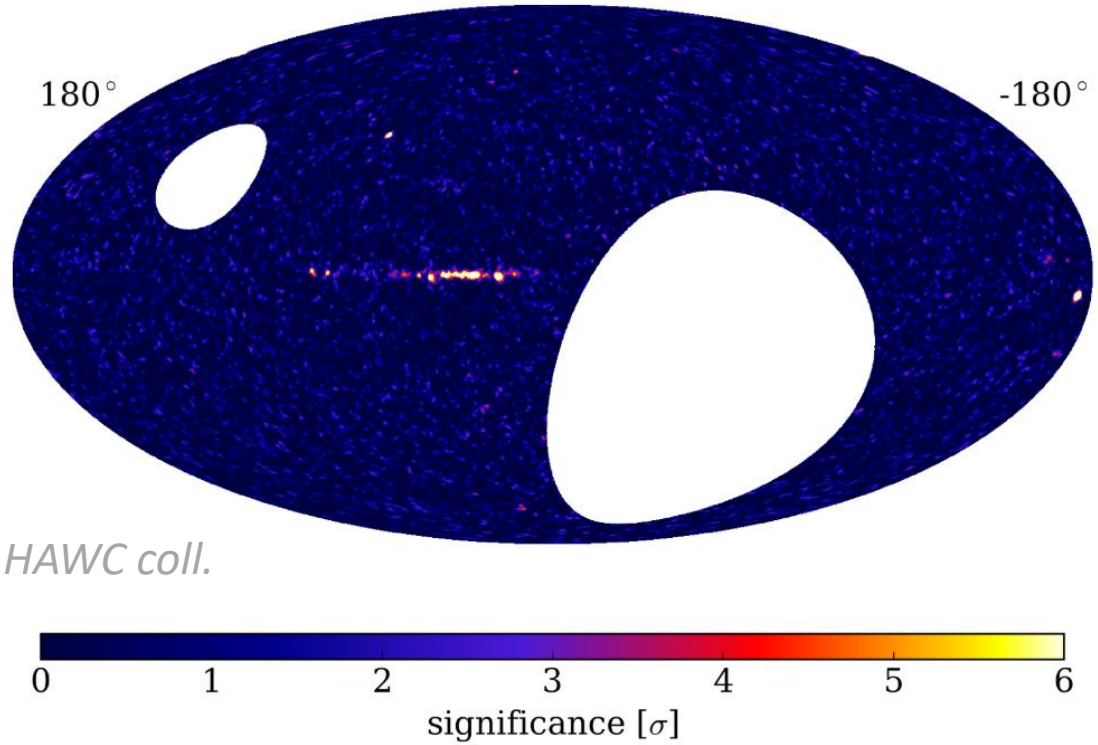
- Large field of view (~2 sr)
- 100% duty cycle
- Modest precision

Current gamma-ray observatories

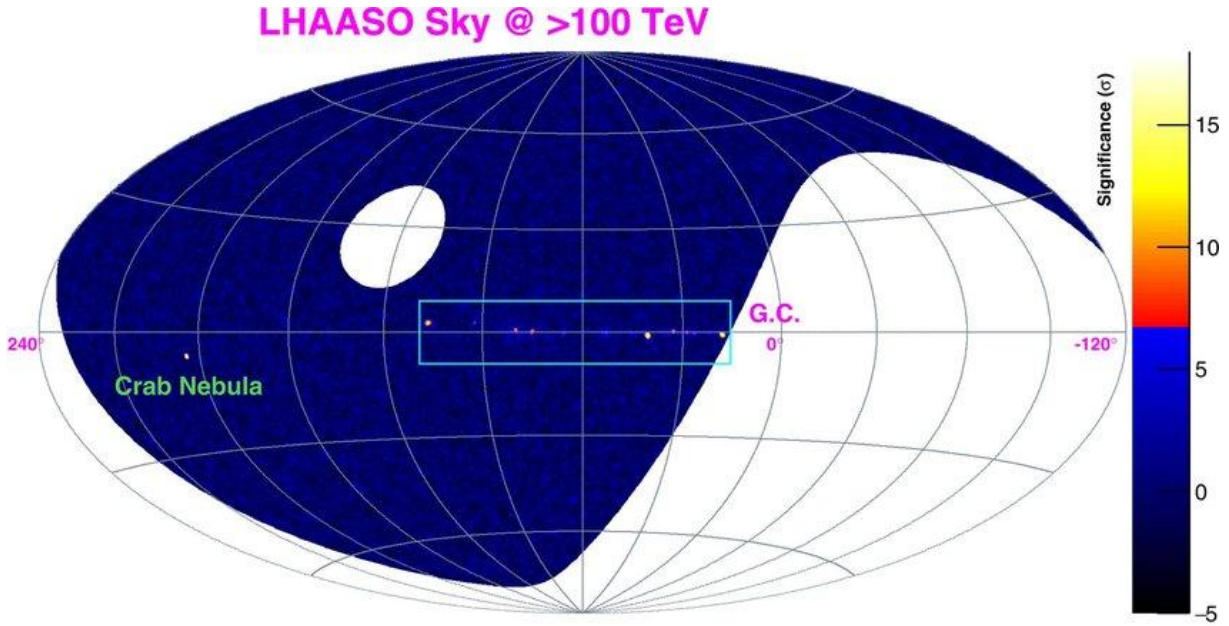

Towards anticenter
Towards Galactic center
~200 TeV Sources
Background: Fermi-LAT

Current gamma-ray observatories

- No wide-field observatory in the Southern hemisphere
- Invisible regions of high scientific interest

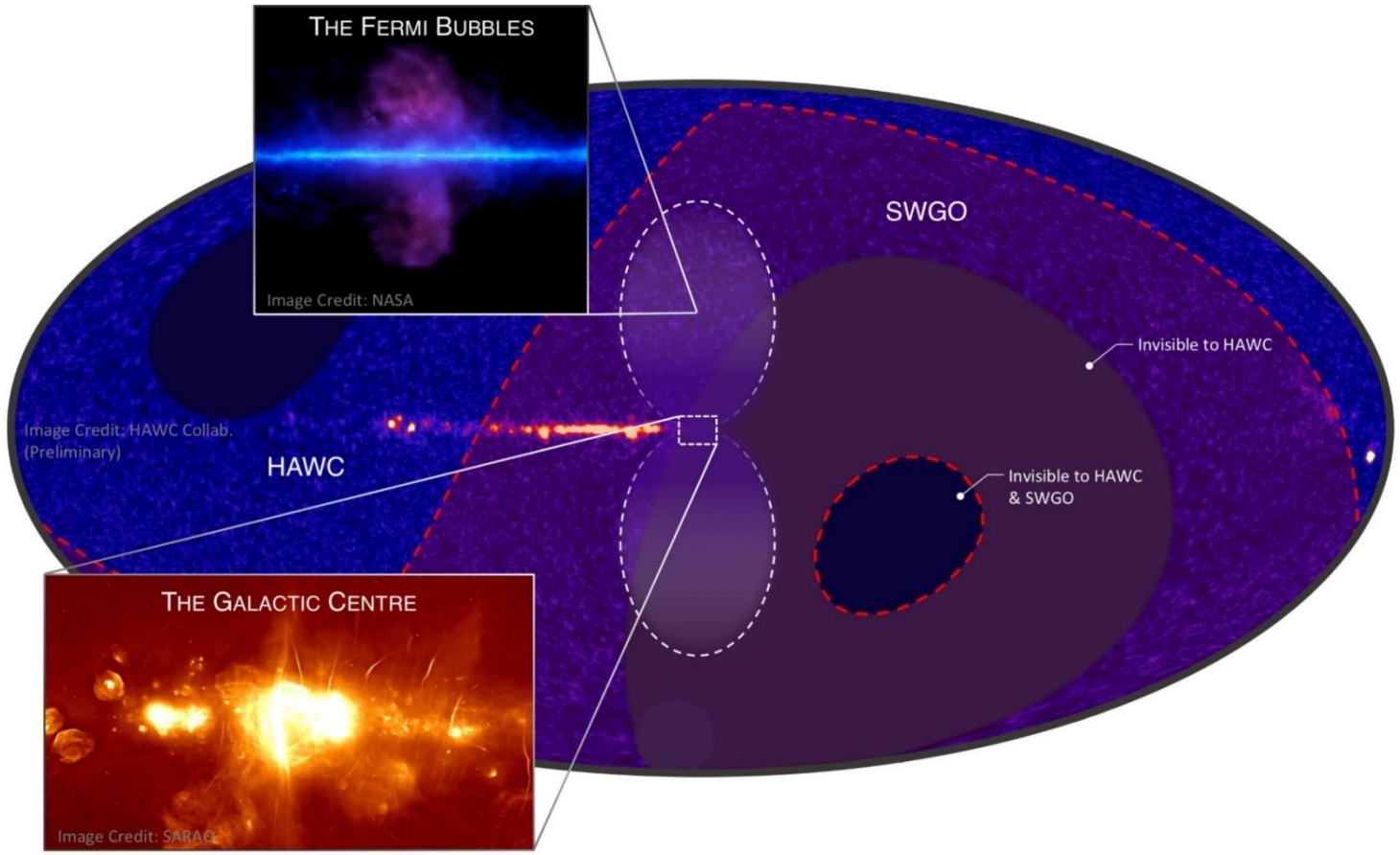


HAWC coll.



Current gamma-ray observatories

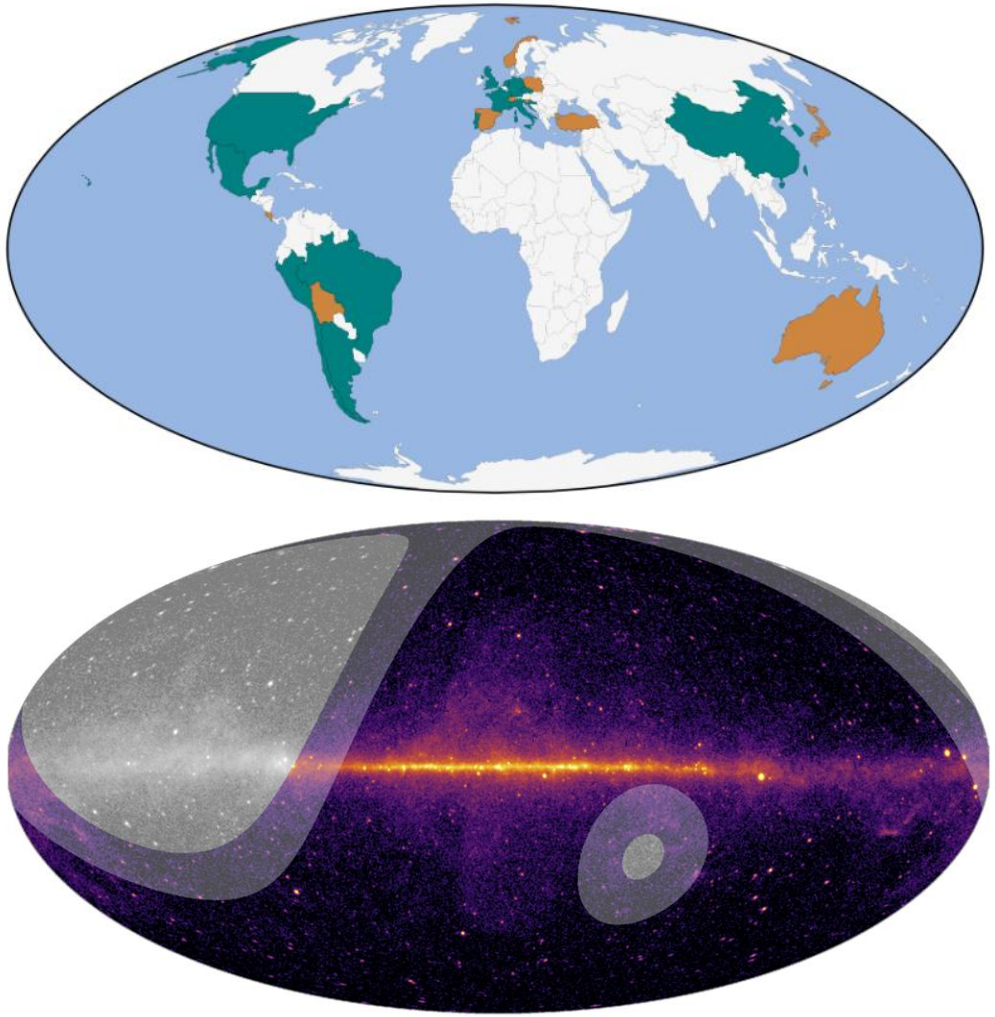
- No wide-field observatory in the Southern hemisphere – **SWGO**
- Invisible regions of high scientific interest – Galactic center, Galactic plane, Fermi bubbles



The Southern Wide-field Gamma-ray Observatory (SWGO)

- SWGO collaboration created in 2019
- 90 institutions/16 countries as of 2025

	Milestone	Completed
M1	R&D Phase Plan Established	Q1 2020
M2	Science Benchmarks Defined	Q2 2020
M3	Reference Configuration & Options Defined	Q4 2020
M4	Site Shortlist Complete	Q3 2022
M5	Candidate Configurations Defined	Q1 2022
M6	Performance of Candidate Configurations Evaluated	Q3 2023
M7	Preferred Site Identified	Q2 2024
M8	Design Finalised	-
M9	Construction & Operation Proposal Complete	-

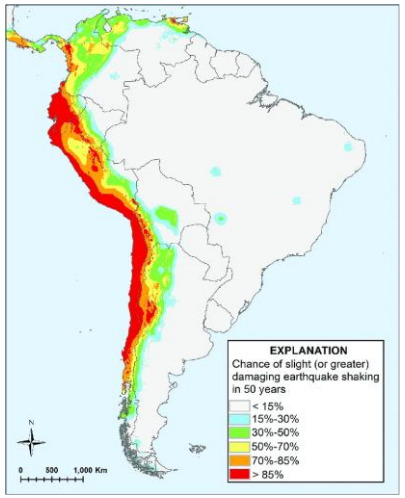


SWGO white paper arXiv:2506.01786

1. WHERE?

Site search campaign

- Alto Tocomar (Argentina)
- Cerro Vecar (Argentina)
- Chacaltaya (Bolivia)
- AAP Pajonal (Chile)
- AAP Pampa La Bola (Chile)
- Lake Sibinacocha (Peru)
- Imata (Peru)
- Yanque (Peru)



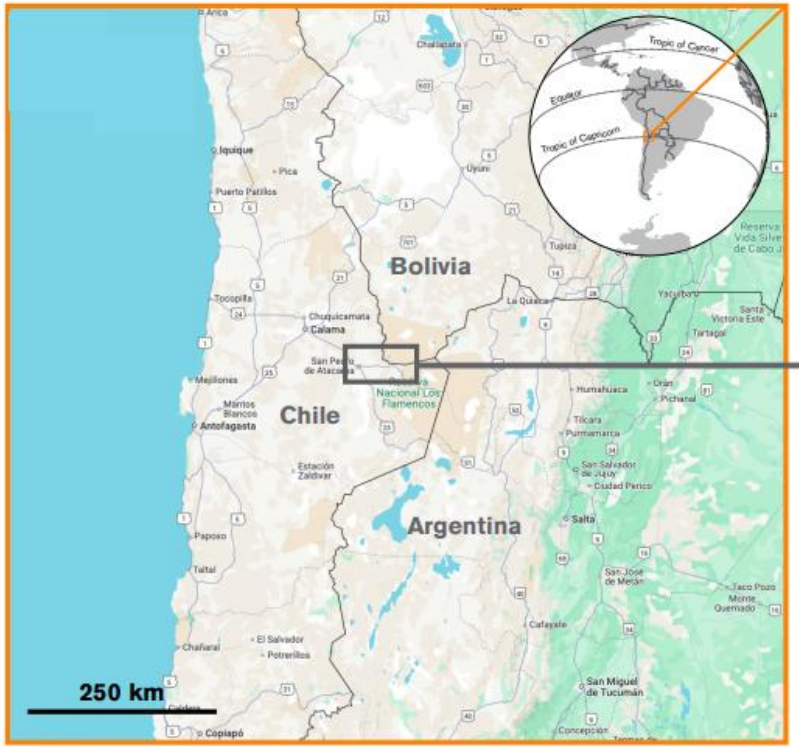
Requirements:

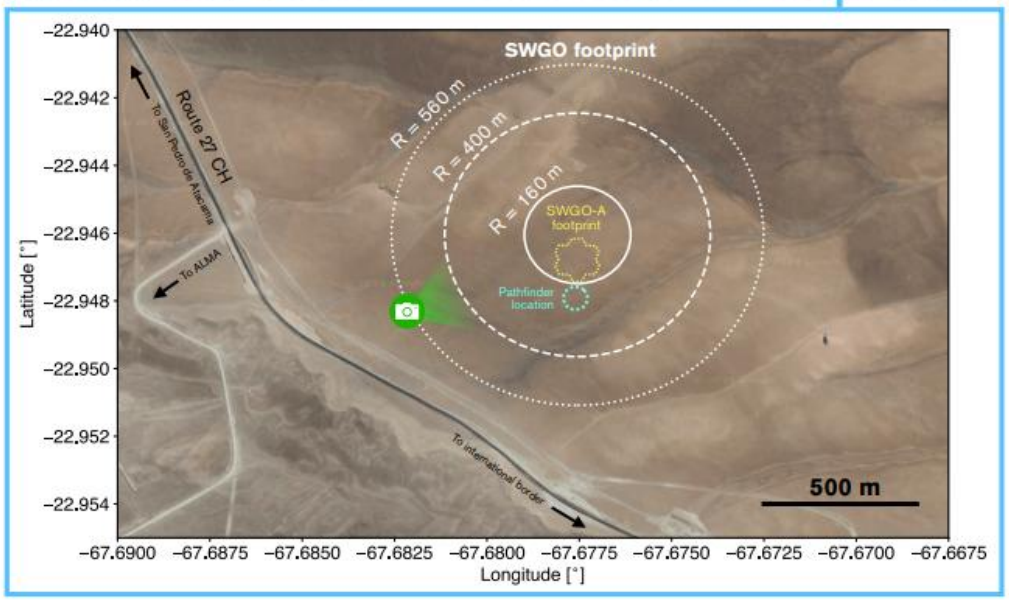
- Located in South America at a latitude of -30 to -10 degrees
- Altitude above 4500 m a.s.l.
- Flat region of area at least $1\ \mathrm{km}^2$
- Good weather conditions
- Stable subsoil, no strong earthquakes


Bolivia 4.7k
Chile 4.8 k
Peru
Bolivia
Chile
Argentina 4.8 k
Peru 4.9 k

Preferred site location

Pampa La Bola, Atacama Astronomical Park, Chile (4,770 m a.s.l.)

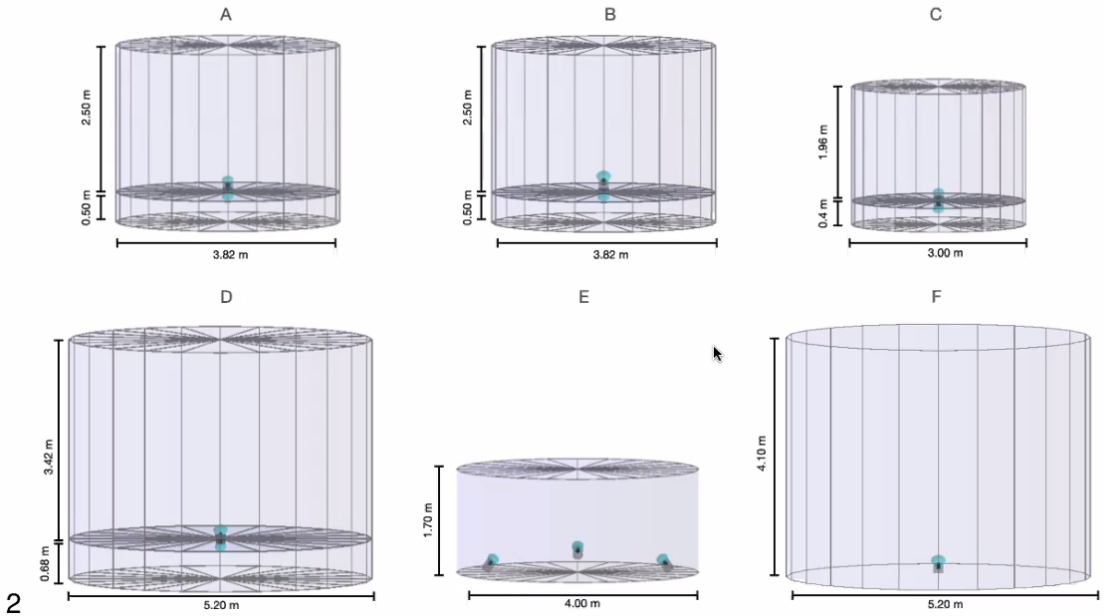


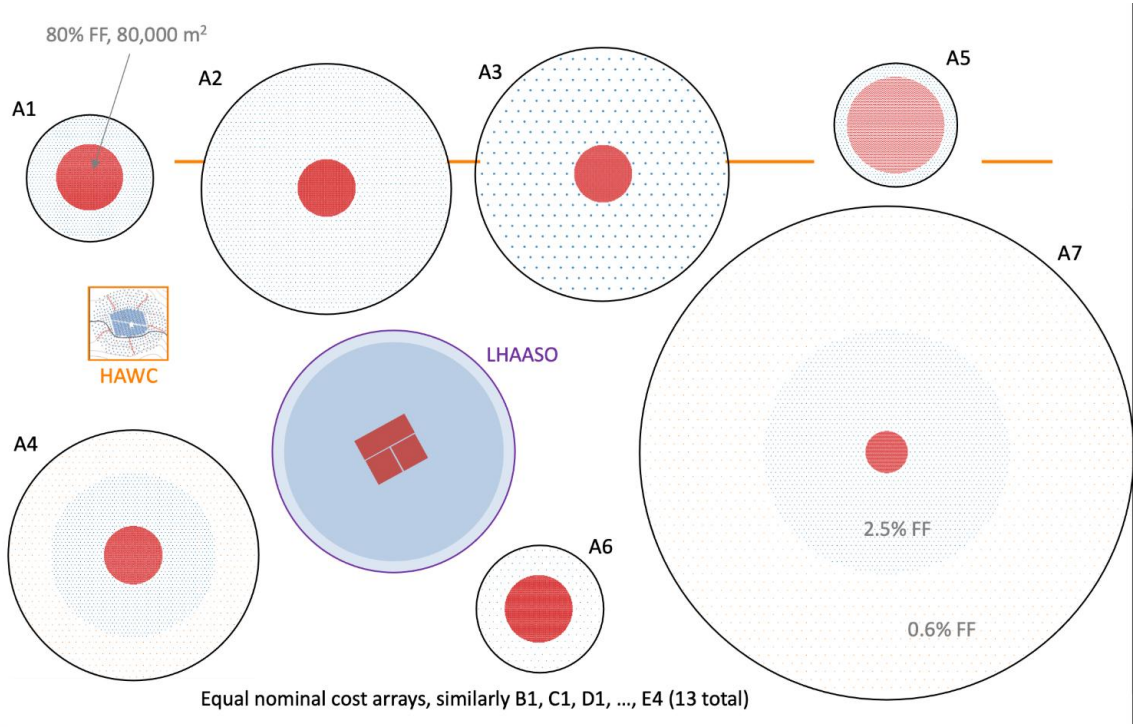


2. WHAT?

Towards the SWGO concept

- Array of independent WCD units
- Extensive simulation study
  - Multiple WCD units
  - Multiple array layouts

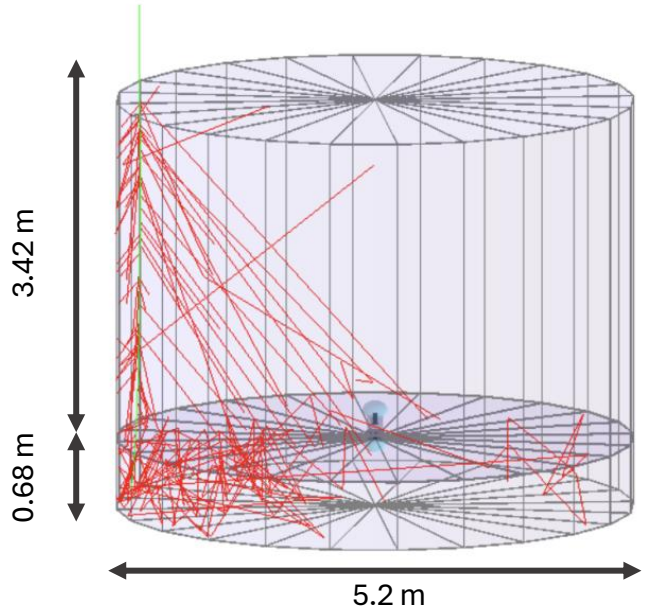




Array designs evaluated based on performance over cost

SWGO baseline design

- 3-zone configuration on 1 km^2 area
- Sensitivity from 100 GeV – 1 PeV
- $\sim$4000 WCD stations

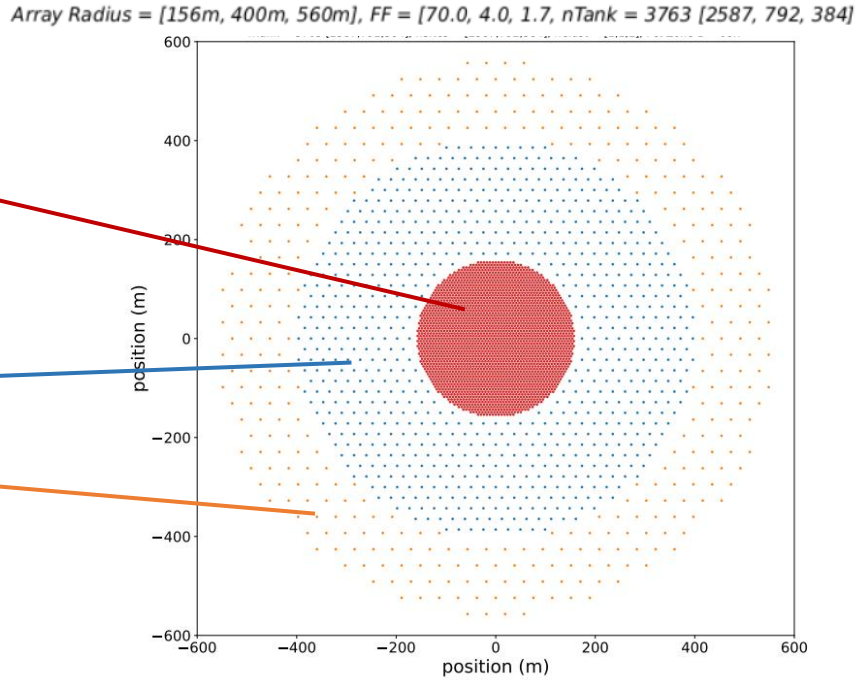


Inner zone

- Metal double layer tanks
- Fill factor $\sim$70%
- Sensitivity from hundreds of GeV to tens of TeV

Outer zones

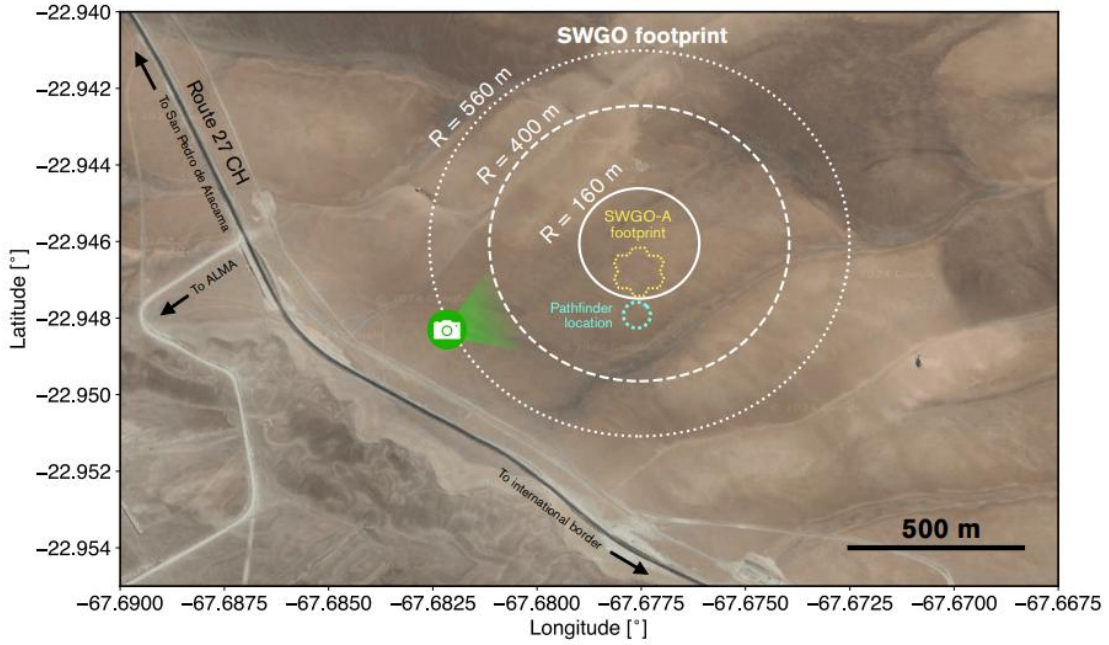
- Extending to total area of 1 km^2
- Lower fill factor
- Sensitivity up to PeV energies
- Currently under optimization – new station designs, novel optical modules

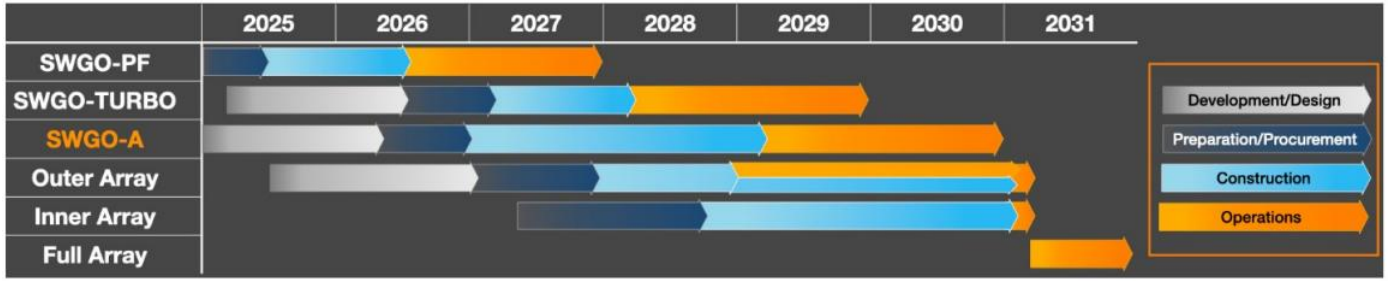


First activities at the site

SWGO-PF → SWGO-A

1. Pathfinder – SWGO-PF
   - Validation of chosen technologies
   - Assembly plans and operation procedures
   - 4-6 WCDs
   - Water storage and purification system
   - Power systems
2. SWGO-A
   - First component of the high fill factor innermost array zone next to the SWGO-PF
   - 385 WCD units
   - First science phase





Expected sensitivity and performance

Angular resolution

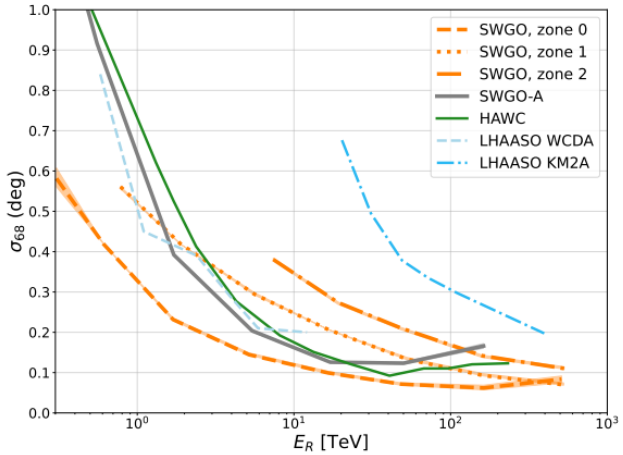
- Based on Gaussian Fitter
- Good angular resolution, reaching 0.1°

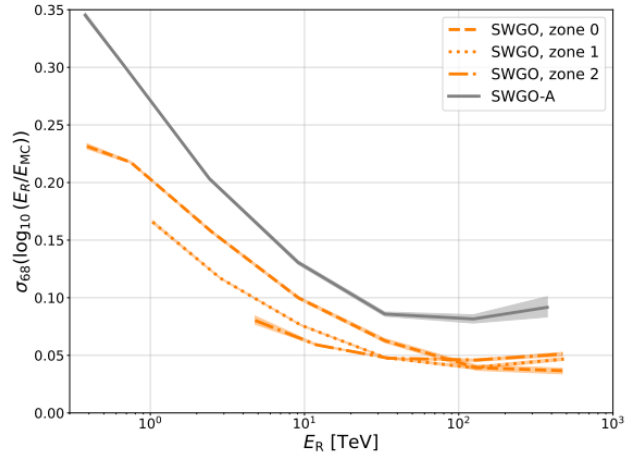
Energy resolution

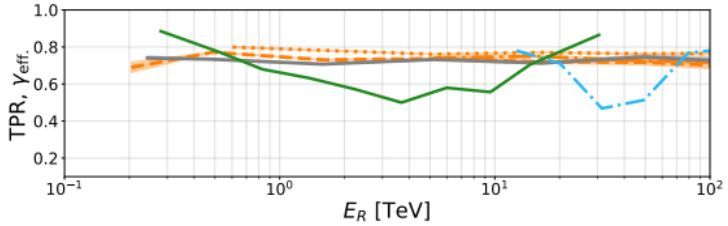
- Based on template method
- Above 10 TeV energy resolution below 20%

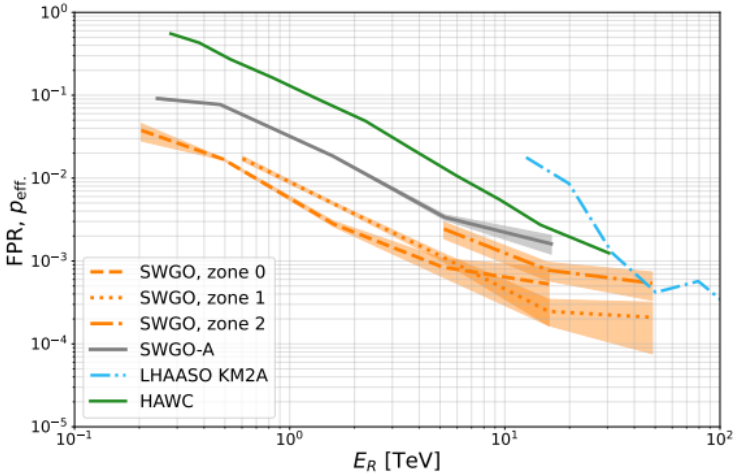
Gamma hadron separation

- Based on multiple high level and low level observables and performed by a neural network
- Significant improvement wrt HAWC
- Matching LHAASO performance at the highest energies

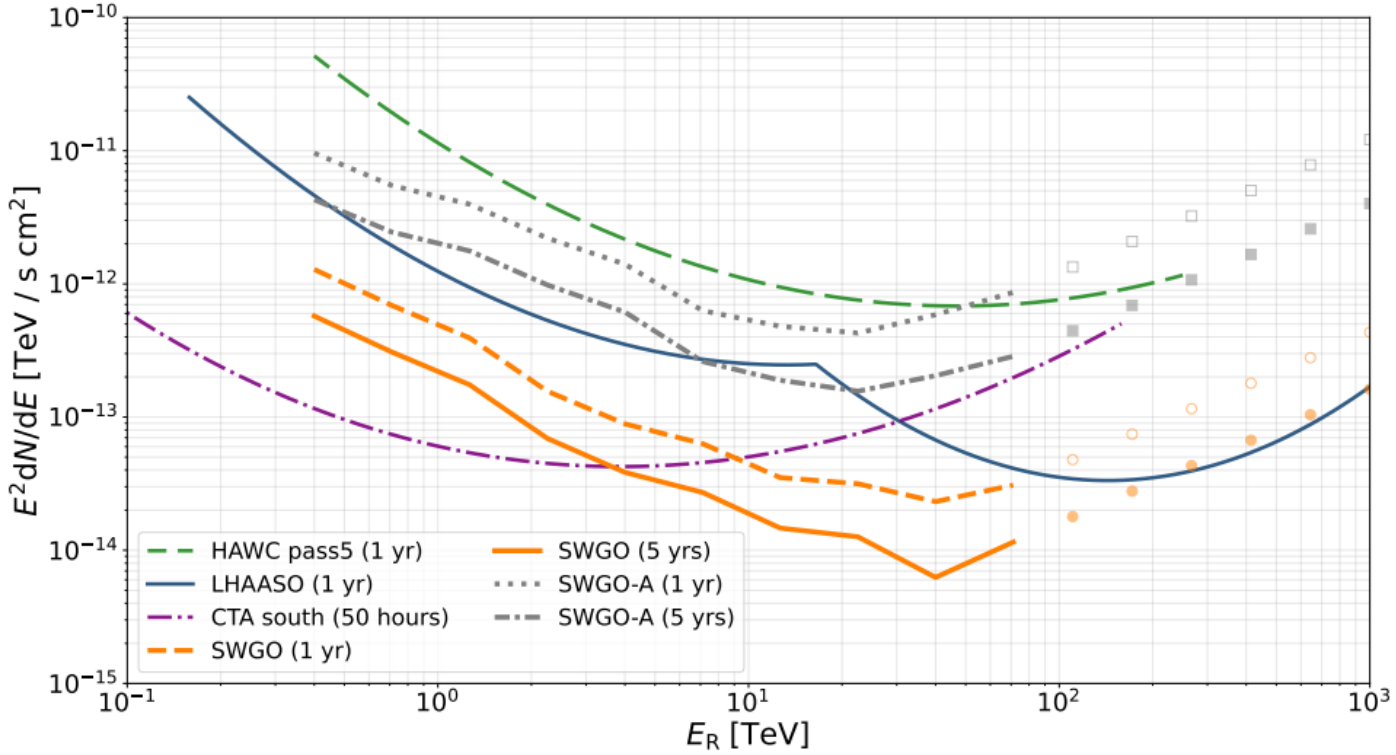








Expected sensitivity and performance



SWGO-A

- First science phase
- Improvement over HAWC

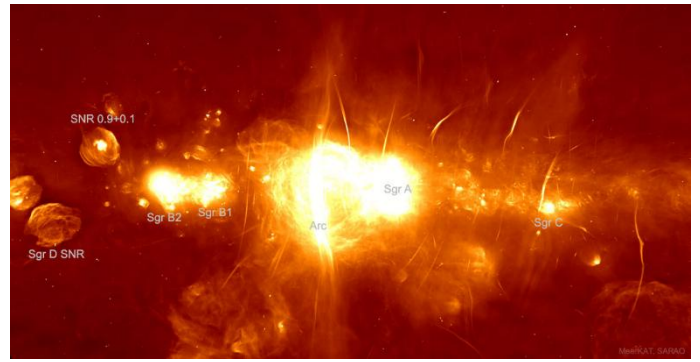
SWGO baseline

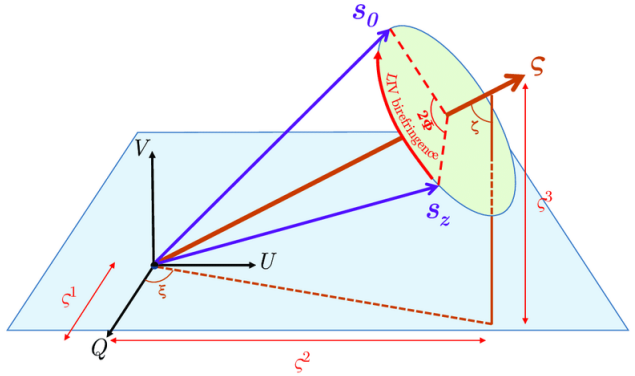
- Improvements over LHAASO up to mid energies

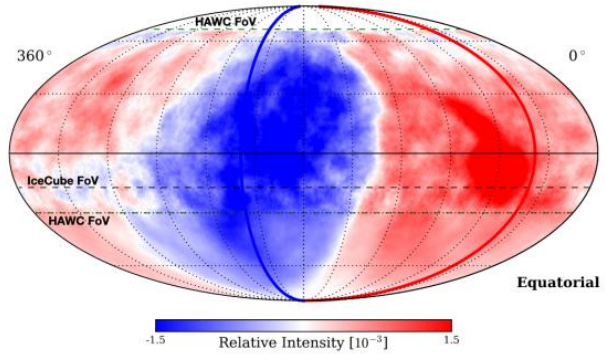
3. WHY?

Science case of SWGO

1. Galactic Particle Acceleration and Transport
2. Transients and Variable Sources
3. Particle Physics and Beyond the Standard Model
4. Cosmic-Ray Measurements
5. Multi-Messenger and Multi-Wavelength (MM/MWL) Program

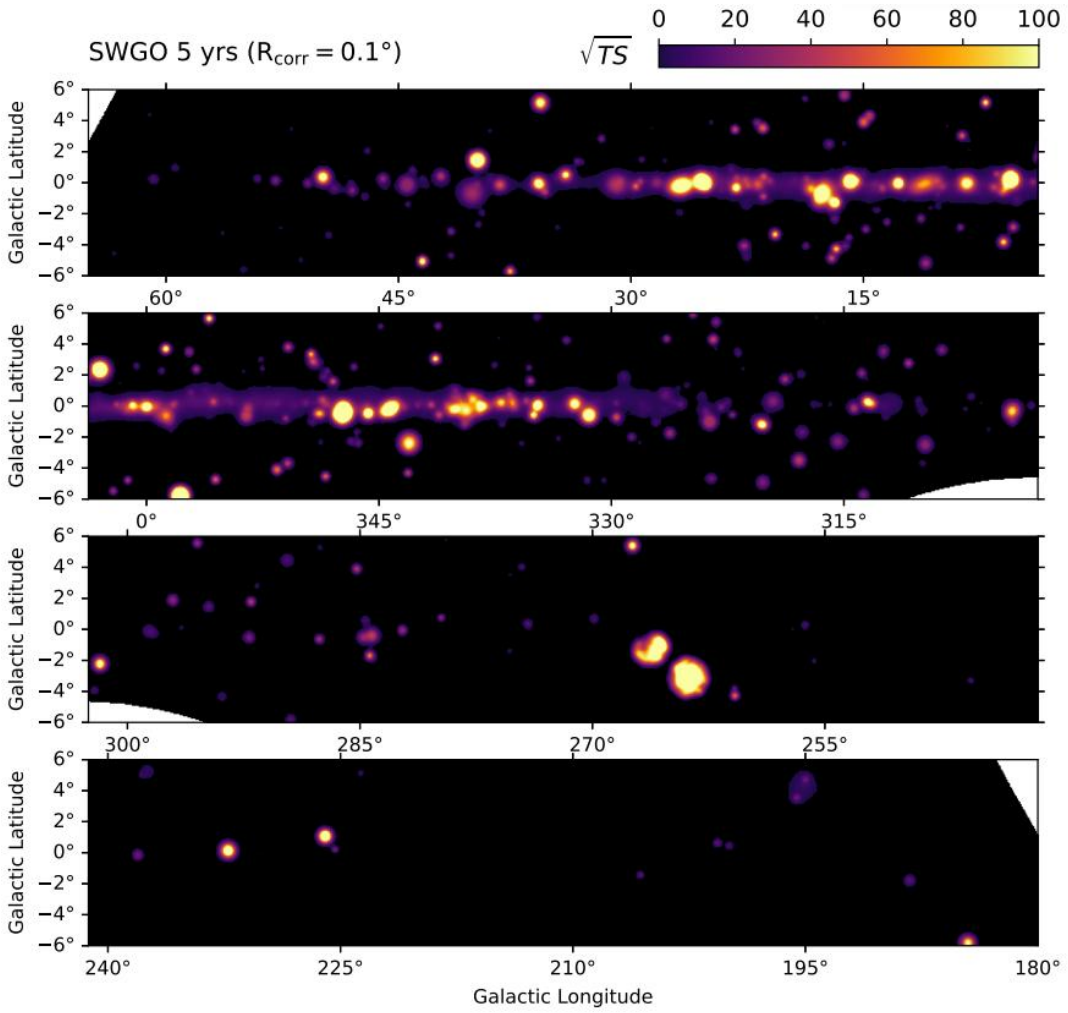






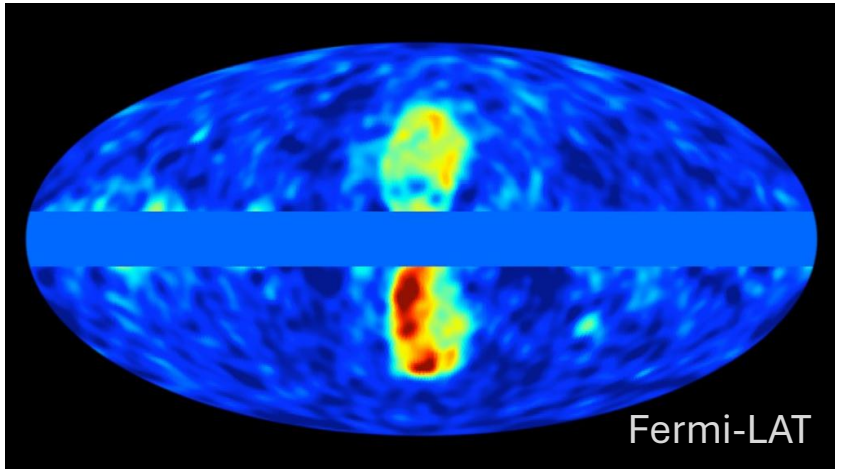
Galactic plane survey

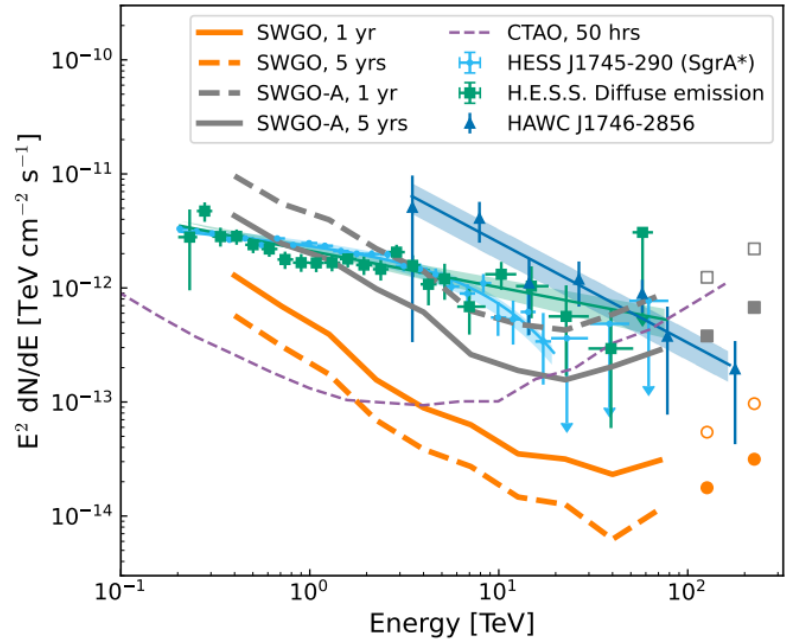
- Unbiased survey of the galactic plane: $-180° < l < 70°$, $|b| < 6°$
- Source population and interstellar emission models from CTA Galactic Plane Survey simulations
- Number of expected detections with $\sqrt{TS} > 25$
  - **SWGO 5 years**: 487 sources
  - **SWGO 10 years**: 536 sources
  - **CTA-GPS**: 461 sources
  - **CTA-GPS + SWGO 10 years**: 603 sources
- SWGO highly complementary with CTAO



Extended sources

- Galactic diffuse emission
  - Signatures of galactic CR transport
- Fermi bubbles
  - Most prominent large scale gamma structure in the Galaxy (~10 kpc)
  - VHE and UHE regimes of the Fermi bubbles
- Galactic center and the central molecular zone
  - Innermost 200 pc of our galaxy
  - Multiple TeV-bright sources, Sgr A*
  - Detection of the GC region in less than one year of observation



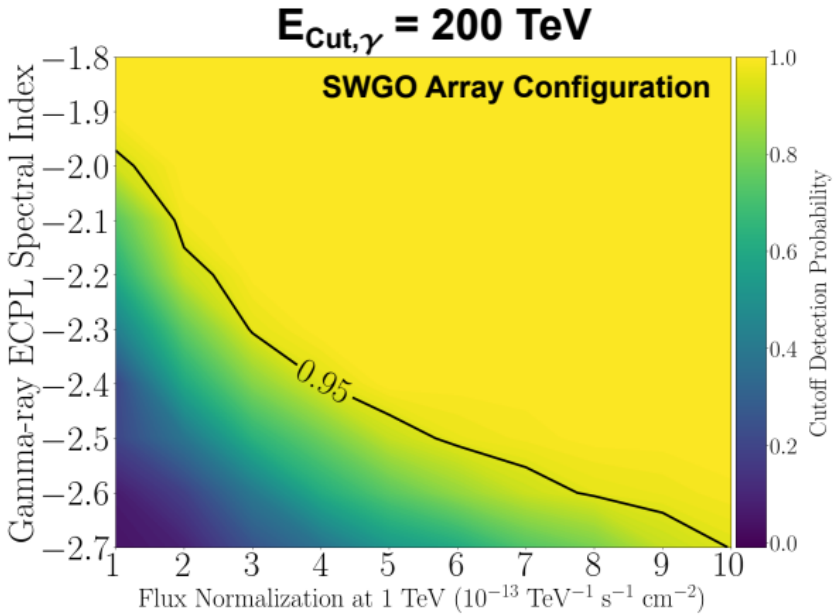


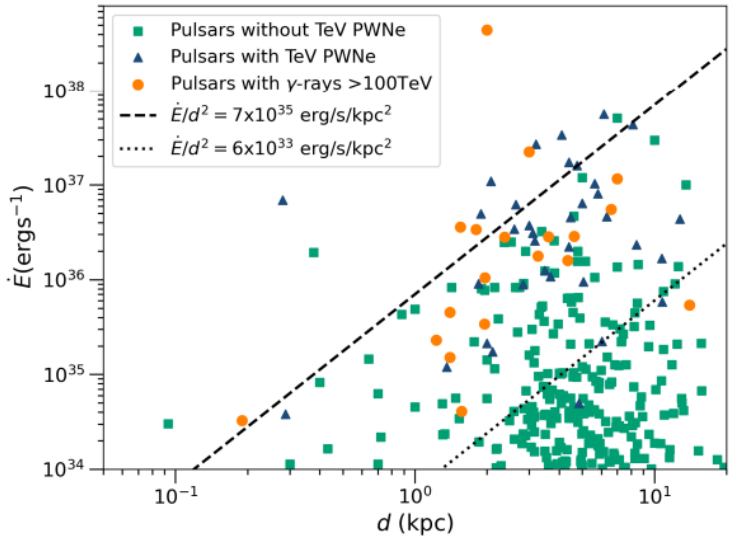
UHE sources, PeVatrons, Galactic populations

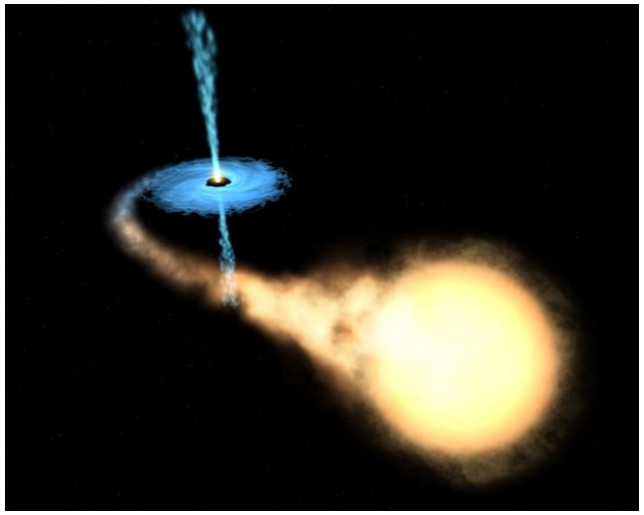
- **PeVatrons**: accelerators of CR above 10^{15} eV
- *hadronic* vs. *leptonic* PeVatrons
- Measuring spectral cutoffs from point-like PeVatron sources

$$\phi(E_\gamma) = \phi_0 \left(\frac{E_\gamma}{E_0}\right)^{-\Gamma^\gamma} \exp\left(-\left(\frac{E_\gamma}{E_{cut,\gamma}}\right)^{\beta_\gamma}\right)$$

- Higher energy spectral cut-off → more likely a source could be a PeVatron







- **SNRs**: UHE gamma-ray emissions from SNRs
- **Pulsars**: many gamma-ray bright sources are pulsars
- **Binaries and microquasars** : SWGO could double the known number of μQSRs

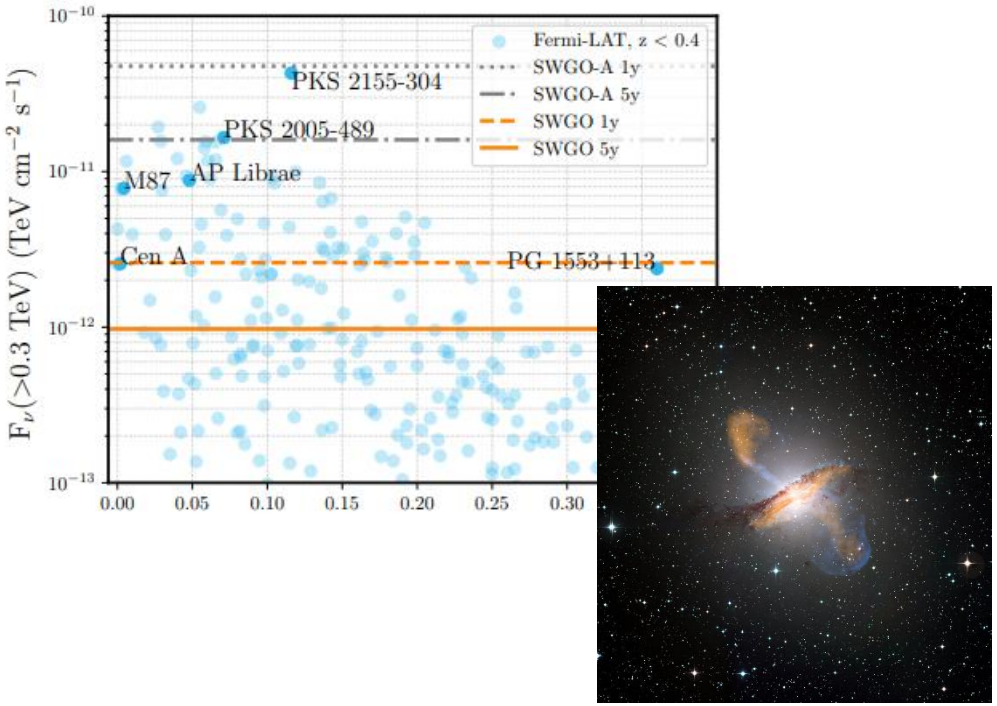
Transients and Variable Sources

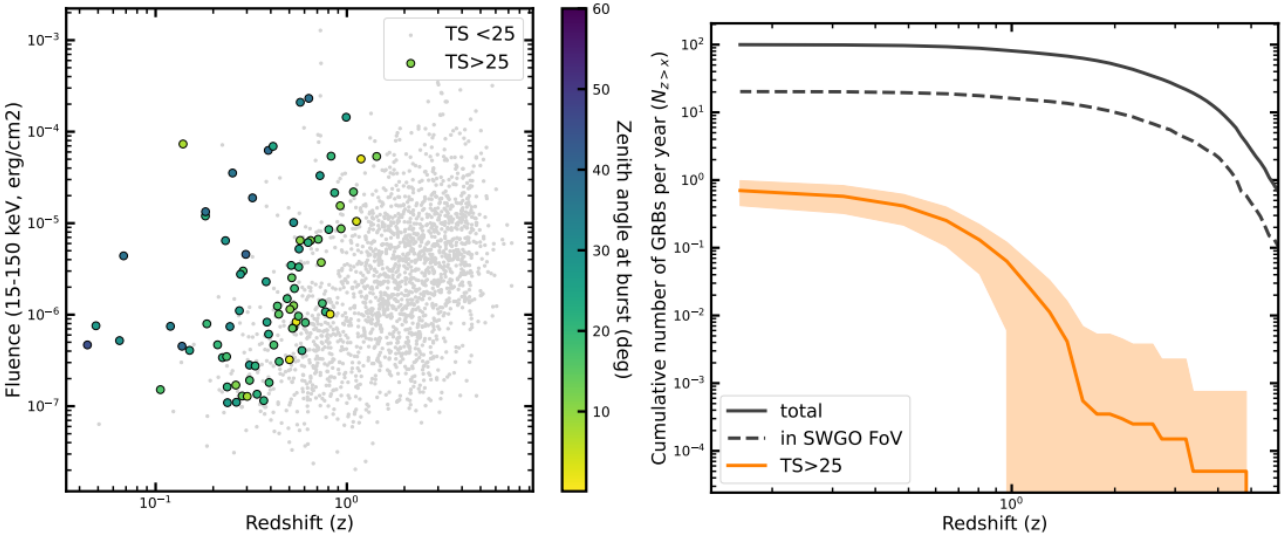
- Wide field of view allows observations of transient phenomena without prior warnings
- Extragalactic sources are attenuated due to the extragalactic background light (EBL) – limitations in energy/distance horizons

AGNs

Flux variability of AGNs at VHE

Monitoring flare episodes



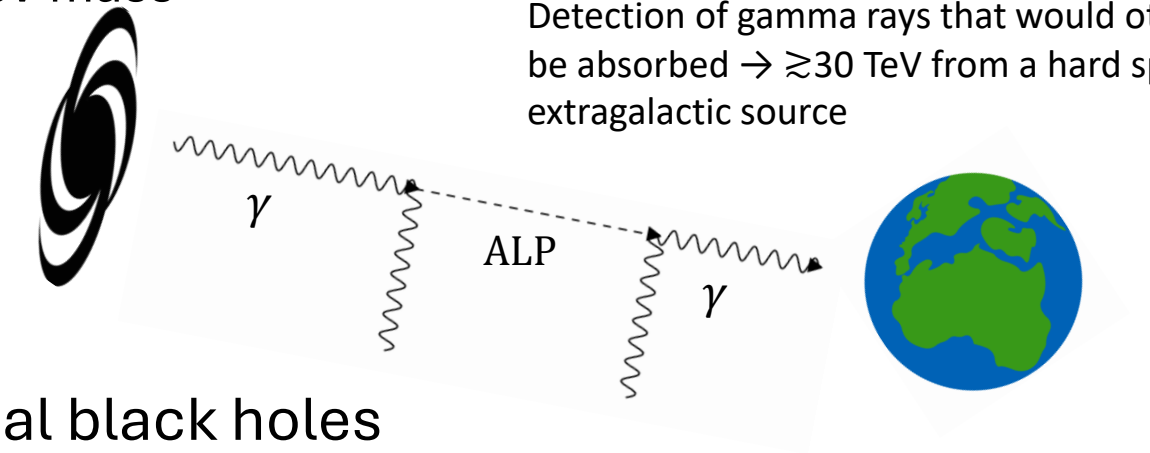


GRBs

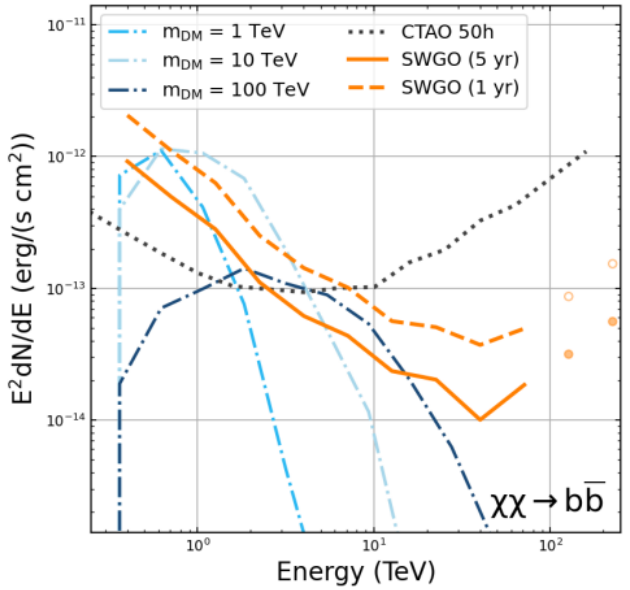
- **Short GRBs** (< 2 s) - compact object mergers
- **Long GRBs** (> 2 s) - massive star collapses
- New observations show energies beyond 10 TeV (GRB 221009A)
- MWL follow-up with SWGO – GW events

Particle Physics and Beyond the Standard Model

- Dark matter
  - Testing various dark matter candidates (WIMPs, PBHs, ALPs)
  - Constraints on the annihilation cross-section of WIMPs up to 100 TeV mass

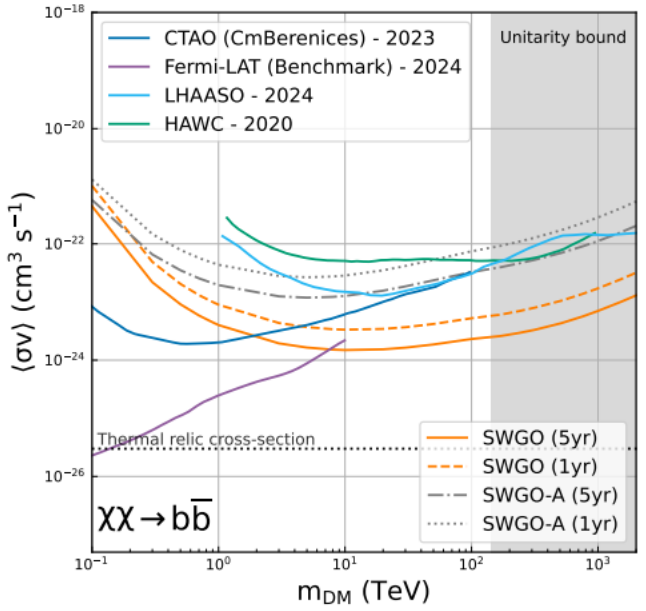


Detection of gamma rays that would otherwise be absorbed → ≳30 TeV from a hard spectrum extragalactic source



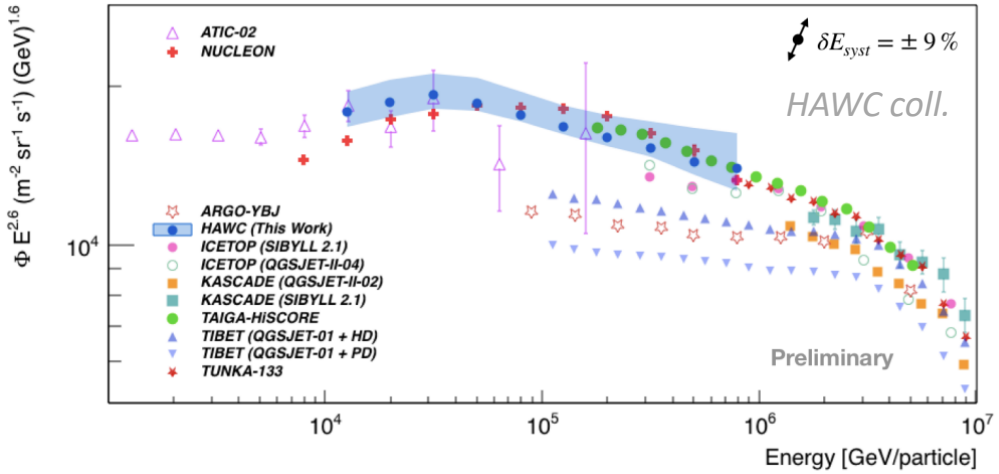
- Primordial black holes
  - PBH with initial mass 10^{15}g should be evaporating now
  - Gamma rays from MeV to TeV energies
- Lorentz invariance violation
  - Modifying the photon dispersion relation

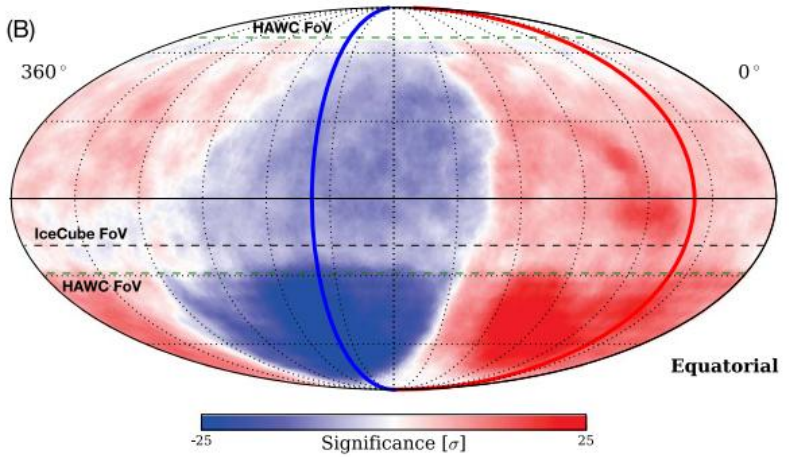
$$E_\gamma^2 - p_\gamma^2 = \pm \frac{E_\gamma^{n+2}}{\left(E_{LIV}^{(n)}\right)^n}$$



Cosmic-ray measurements

- Energy range for CRs: ~1 TeV – ~10 PeV
- Energy spectrum and mass composition
  - Filling gap between direct and indirect measurements
  - Enhanced muon-counting capabilities → determination of the primary CR composition (H-like, He-like, N-like, and Fe-like)
- Anisotropy
  - Significant dipole anisotropy with small amplitude $\sim 10^{-3}$
  - SWGO will contribute to the full-sky studies of CR anisotropies
- Measurements of the muon component
- Heliosphere and Solar physics





HAWC + IceCube coll.

Summary

- Clear scientific need for **a wide-field VHE/UHE gamma-ray instrument** in the Southern hemisphere
- SWGO is completing its development phase
  - **Preferred site**: Pampa La Bola, Chile (4770 m a.s.l.)
  - **Energy range**: from 100s GeV to PeV energies
  - **Array design**: dense inner array with FF ~70 % with lower-density outer array
- Wide variety of scientific goals and key science cases
  - **Galactic science:** Galactic plane survey, Fermi bubbles, Galactic center, PeVatrons, SNR
  - **Transient and variable sources:** AGNs, GRBs
  - **Fundamental physics / BSM:** DM, PBHs, LIV
  - **Cosmic rays:** energy spectrum, mass composition, anisotropies
- Complementarity with CTAO, Multi-Messenger and Multi-Wavelength (MM/MWL) program

Thank you for your attention!

www.swgo.org