Southern Wide-Field Gamma-ray Observatory

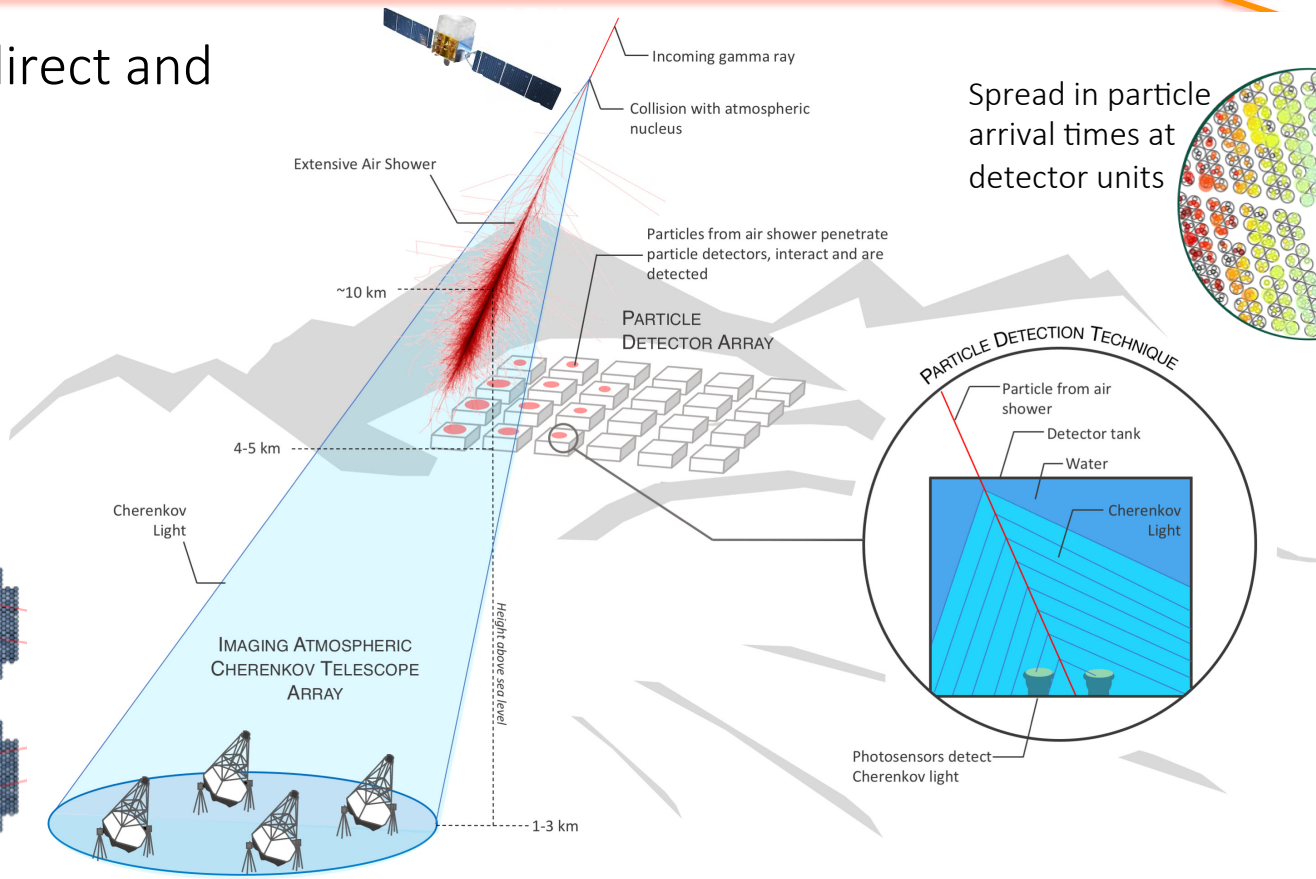
Francesco Longo, University of Trieste

For the SWGO Collaboration

SWGO
The Southern Wide-field Gamma-ray Observatory

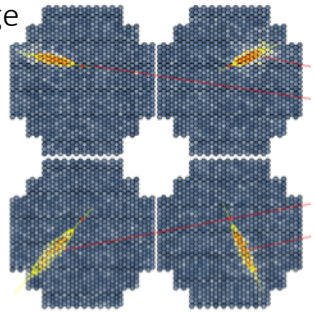
Gamma-ray Astronomy

Complementary direct and indirect detection techniques



Spread in particle arrival times at detector units

Atmospheric Cherenkov light image



Shower image, 100 GeV γ-ray adapted from: F. Schmidt, J. Knapp, "CORSIKA Shower Images", 2005, https://www-zeuthen.desy.de/~jknapp/fs/showerimages.html

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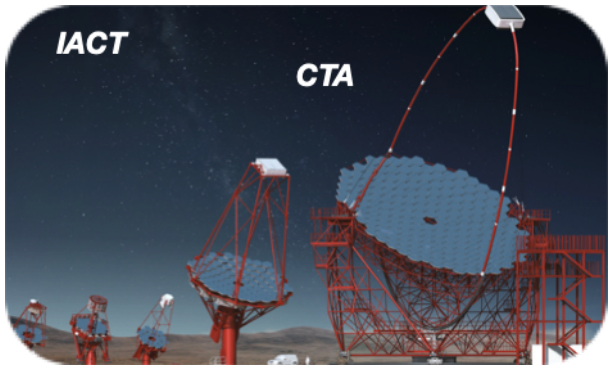
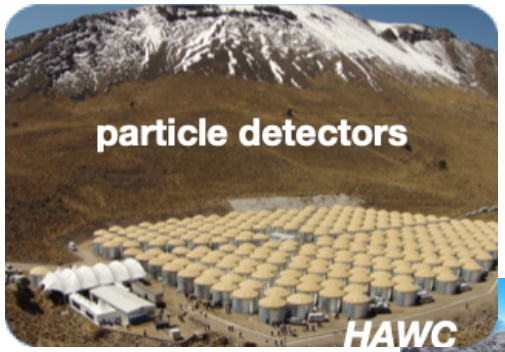
Observational Panorama

- Cherenkov Atmospheric Telescopes
  - 20% duty-cycle
  - Pointing (few degrees FoV)
  - Energy threshold down to 10s GeV
  - Good energy and angular resolution





- Particle Detector Arrays
  - → 100% duty-cycle
  - → Wide-field of View (~ steradian)
  - → Energy range 100s GeV up to 100s TeV
  - → Continual view and accurate background determination

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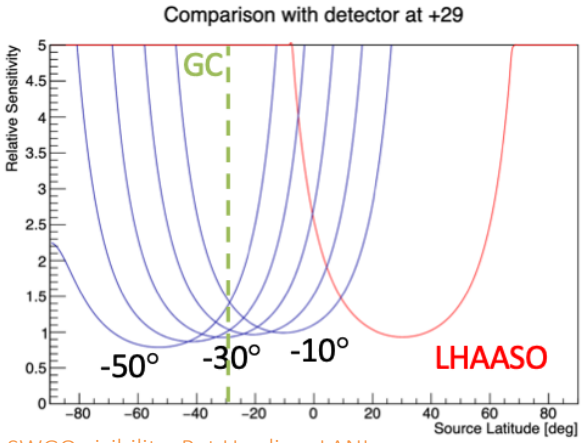
Geographic distribut



SWGO visibility, Pat Harding, LANL

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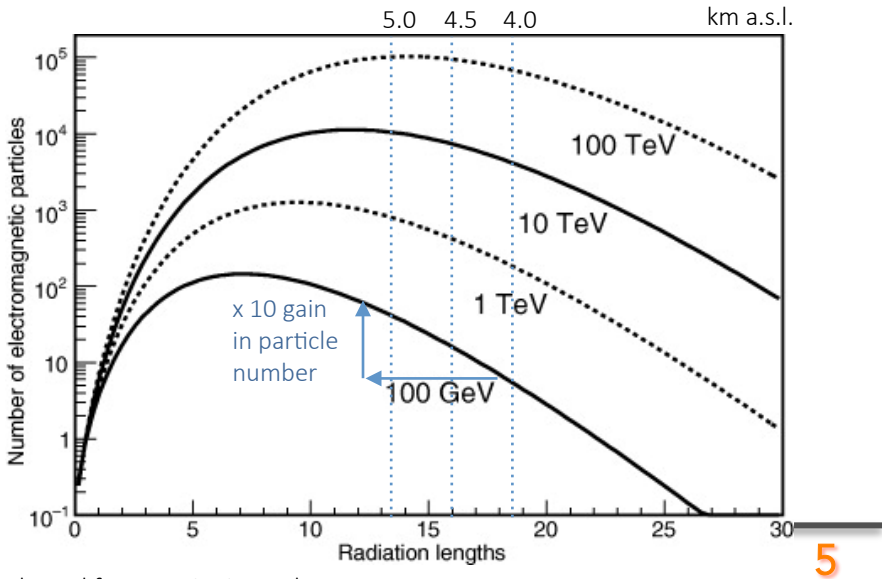
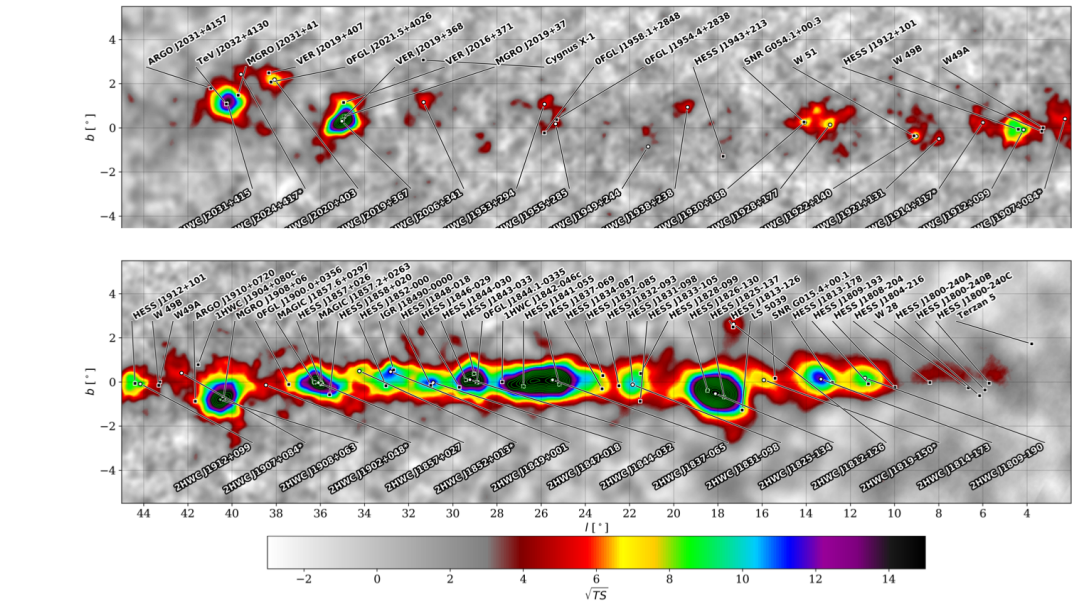
The high-altitude frontier

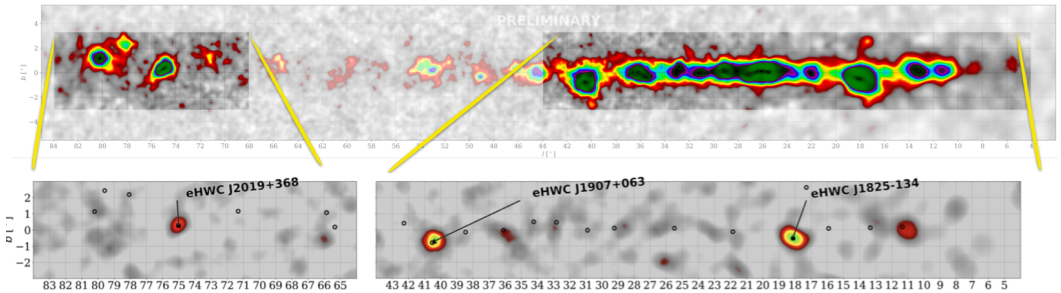
The Andes provides a number of high-altitude plateaus and high-altitude lakes that constitute suitable sites for a particle array aiming to extend the low-energy frontier for Wide-Field Observatories.



Adapted from G. Sinnis, NJPh, 2009

Status at the highest energies





HAWC 2nd source catalogue

Abeysekara et al, ApJ, 2017

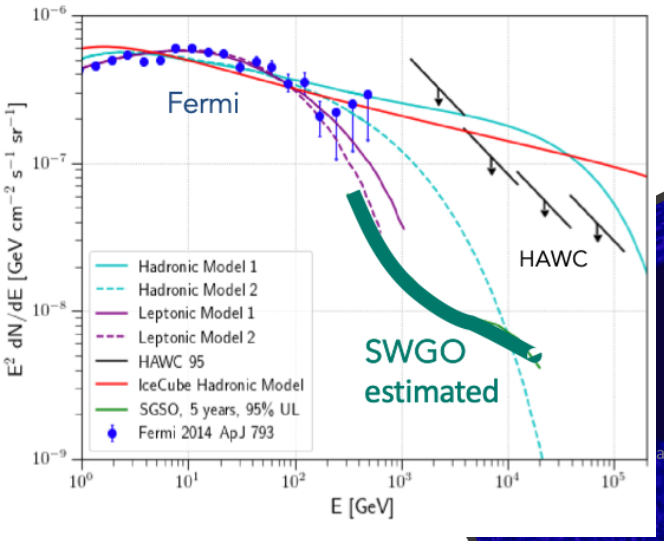
40 sources
16 of which new in the TeV range
Large variety of Galactic objects, plus few AGN.

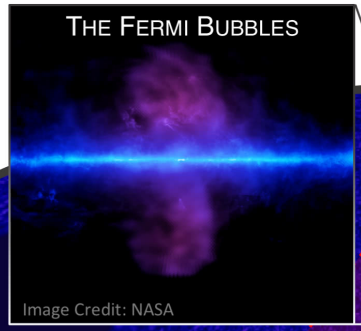
HAWC Collaboration+19

4 sources detected at 100+ TeV, potential galactic CR accelerators.
MGRO 2019+371
MGRO 1908+06
HESS J1825+137
Crab Nebula

The Southern Wide-field Gamma-ray Observatory

A wide-field observatory in the South



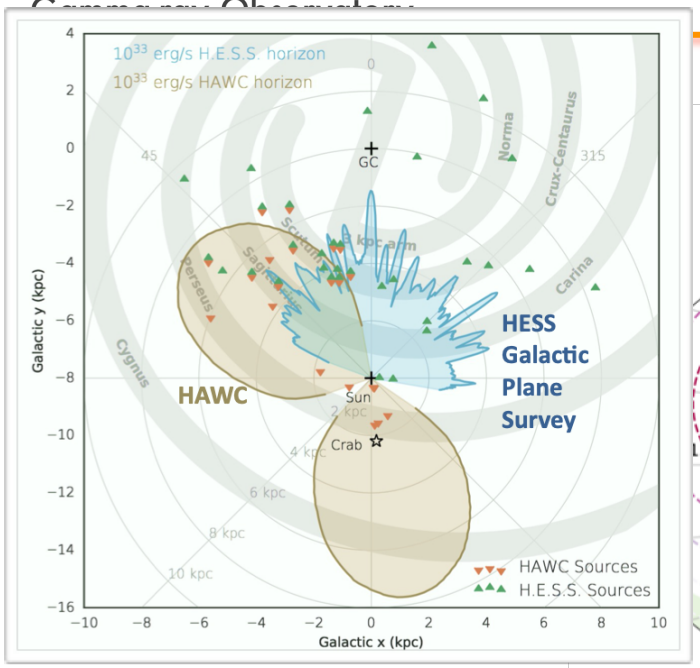


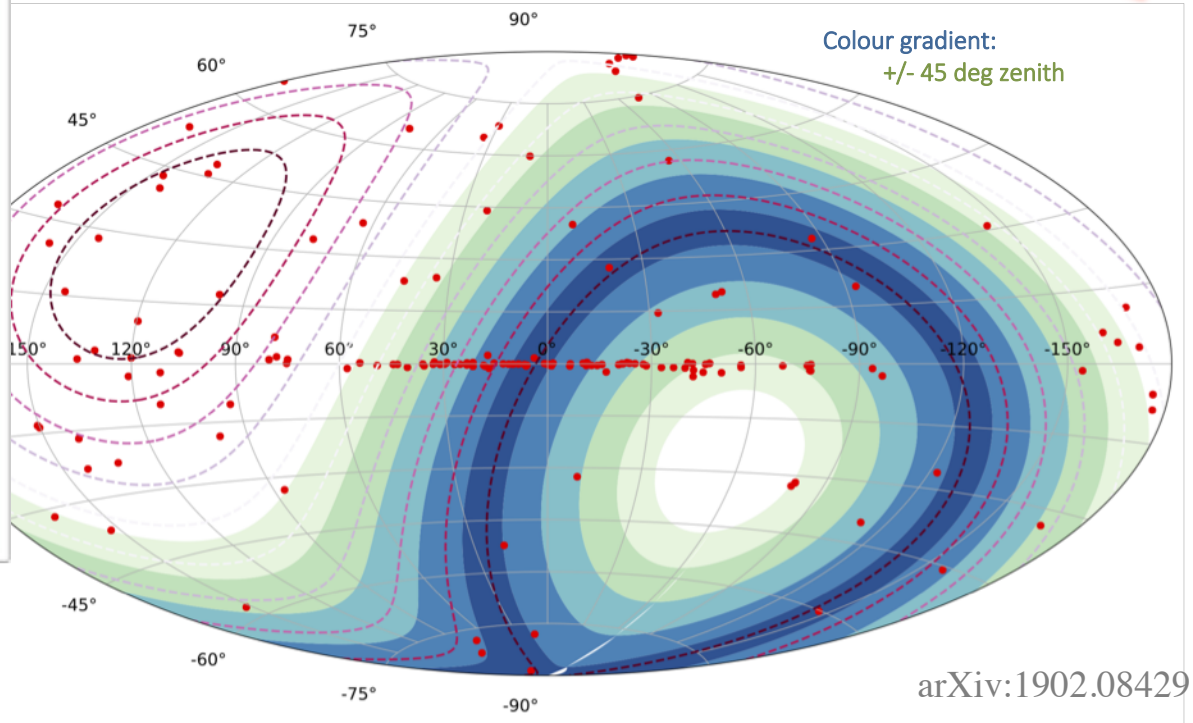
Crucial access to the Galactic Plane and GC.

Complementary view of the sky with HAWC and LHAASO for cosmic-rays and diffuse emission studies.

Science Case: https://arxiv.org/abs/1902.08429

A wide-field observatory in the South





SWGO will complement the view of the Galaxy towards the highest energies and will greatly expand our reach to study Galactic high-energy accelerators.

25 degree south location

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The Core Science Case

- Detection of short-timescale phenomena
  - Low-energy threshold for detection of short-timescale (< 1hr) transient events down to 100 GeV
- Search for PeVatrons
  - Improved sensitivity up to a few 100s TeV to search for PeV Galactic particle accelerators.
- PWNe and Gamma-ray Halos
  - Unique potential for accessing the high-energy end of the Galactic Population.
- Dark Matter and Diffuse Emission
  - Unique access to the Galactic Center and Halo at the high-energy end of the spectrum.
- Cosmic-rays
  - Unique complement to LHAASO for anisotropy studies, with capability to reach low-angular scale.
  - Good muon tagging implies good mass resolution for composition studies up to the knee.

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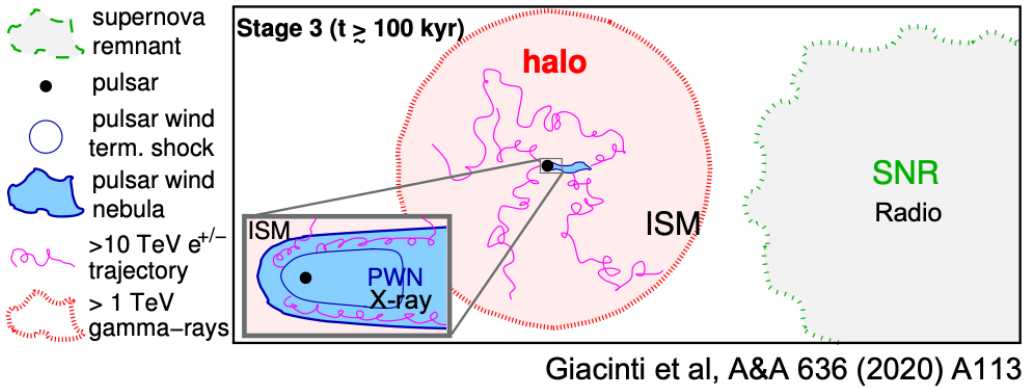
Design Implications

- Decreasing of the low-energy threshold to c. 100 GeV, at ~10^{-11} erg/cm^2.s (5-year)
  - Combination of Improved design and background rejection, plus high-altitude site > 4.5 km a.s.l.
- Large array (> 200.000 m^2) to achieve good sensitivity > 100 TeV
  - Aim is to push sensitivity <10^{-13} erg/cm^2.s in the range 100-300 TeV.
- Muon counting capability
  - For cosmic-ray studies and background subtraction.
- Improved angular (0.2 deg) and energy resolutions (<30%) above 10 TeV.

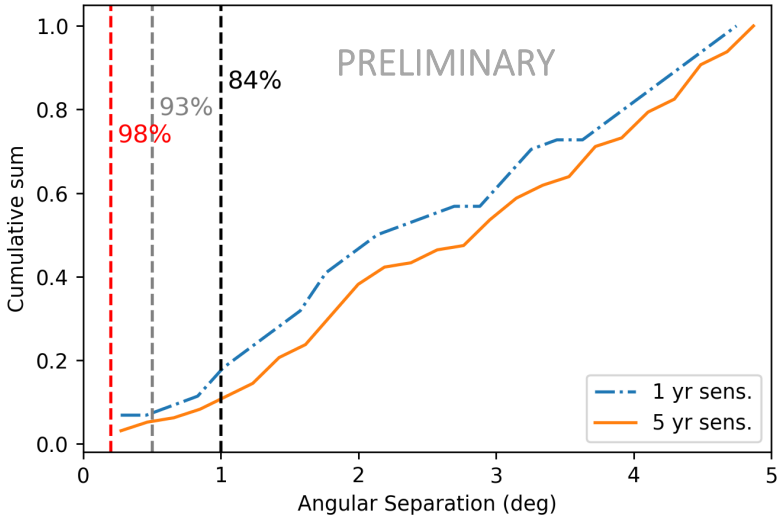
The Galaxy and Large-scale emission

- CTA will provide a detailed view of the Galactic Plane
- SWGO will be a complementary observatory
  - Improved sensitivity to sources with large angular sizes (> 0.5°), such as PWNe and Halos



Giacinti et al, A&A 636 (2020) A113

- SWGO should expand the energy reach of known sources and probe deeper into more extended sources, with excellent angular separation capabilities < 0.5°



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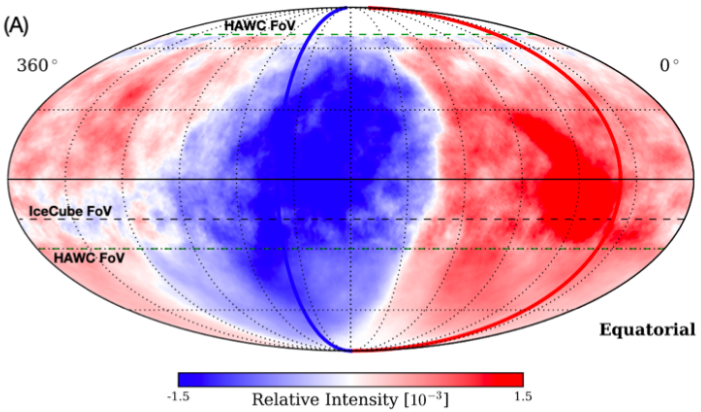
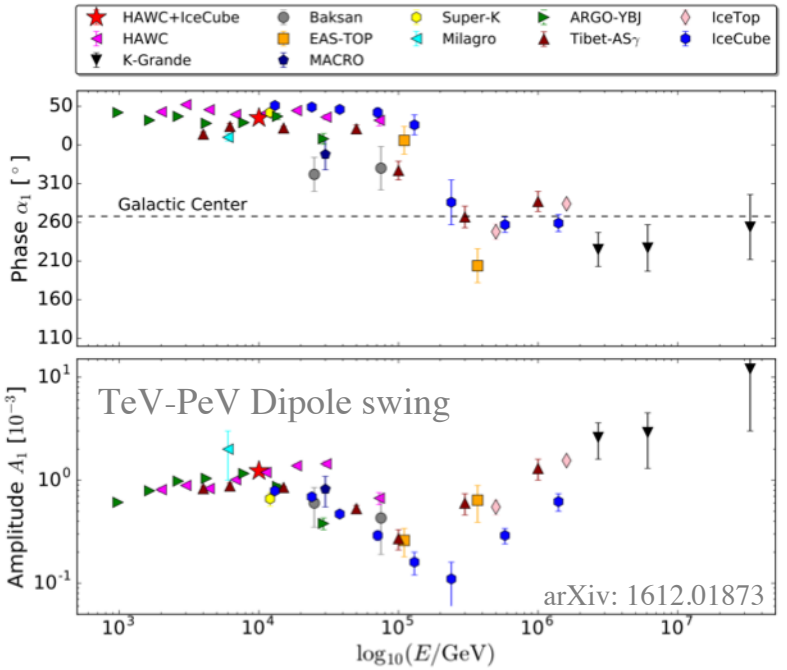
Cosmic-ray Measurements

- Anisotropy Studies
  - Complementary to LHAASO, HAWC, IceCube for dipole studies at the highest energies
  - Low-scale anisotropy, and understanding of ISM turbulence and local CRs
- Unprecedented mass-separation potential
  - For composition studies
  - Joint mass-dependent anisotropy studies

Cosmic-ray TeV dipole skymap

arXiv: 1812.05682

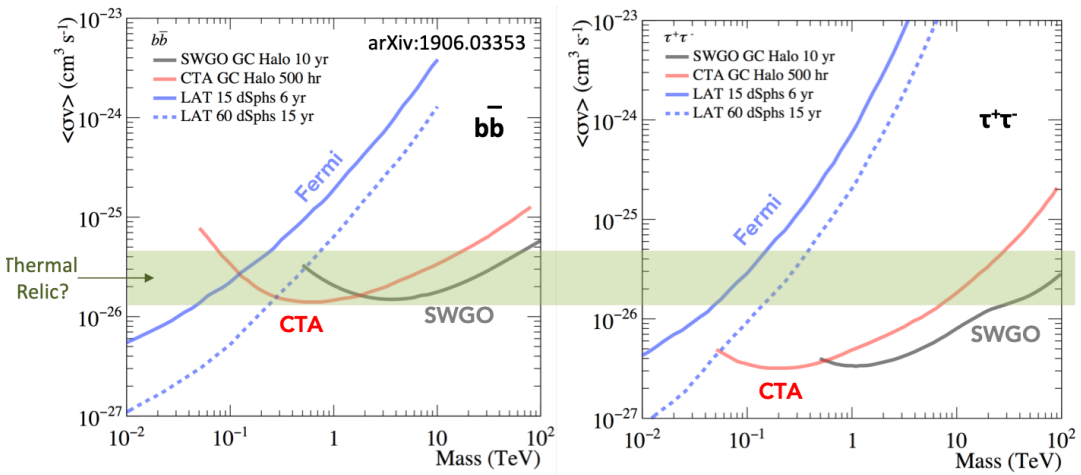


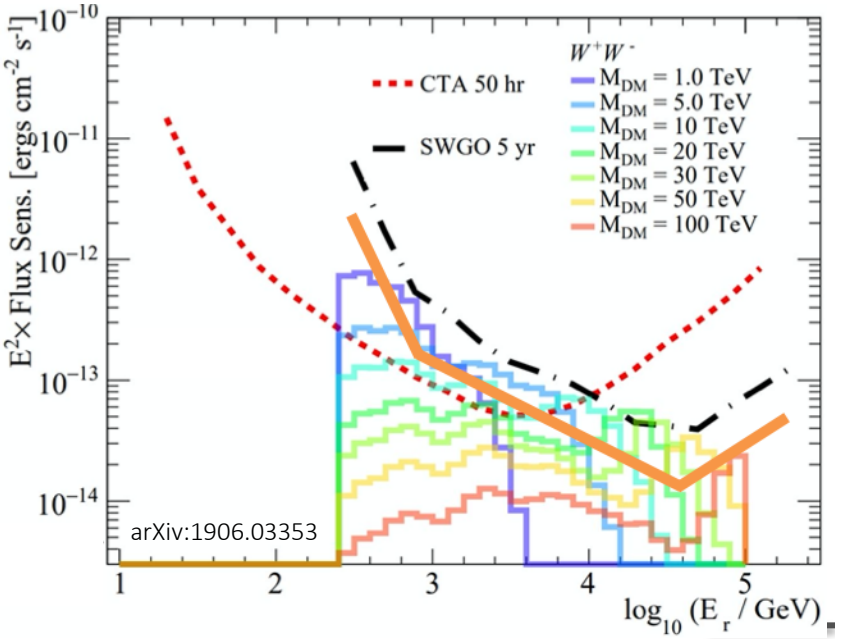


The Southern Wide-field Gamma-ray Observatory

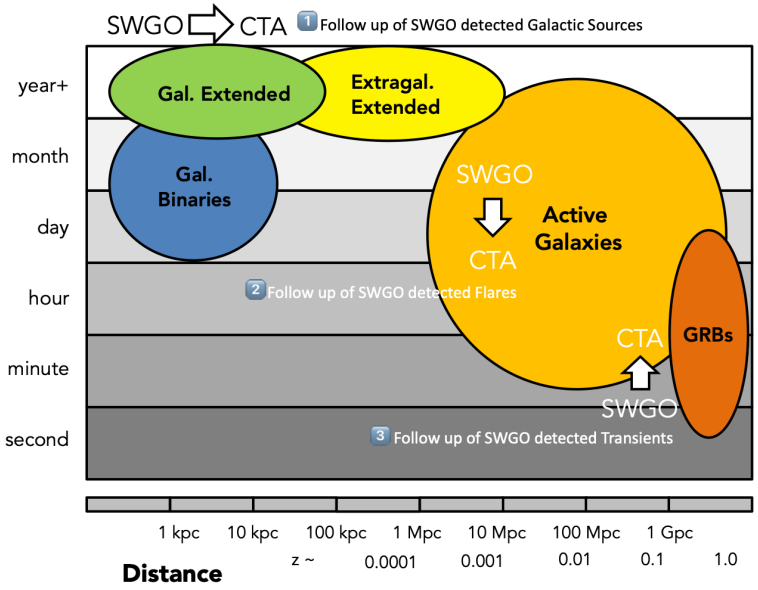
WIMP Annihilation

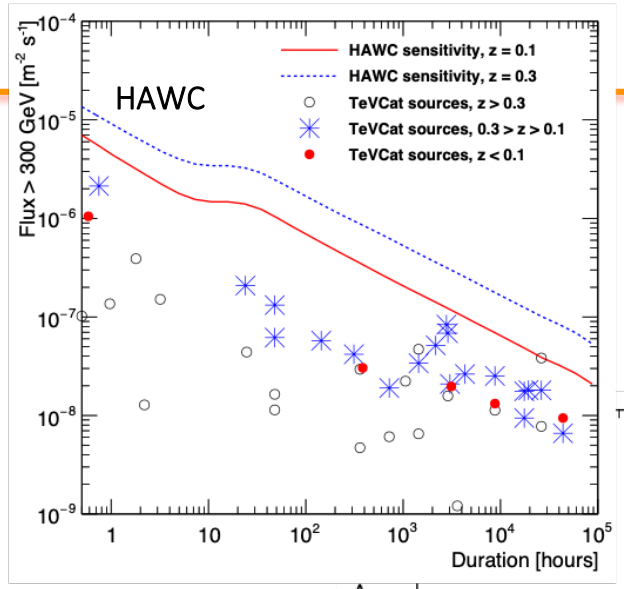
- New Generation of instruments will reach critical sensitivity
- Thermal relic WIMP accessible over a wide mass range with combination of CTA and SWGO
  - Experimental focus on Galactic Centre / Halo observations at VHE in the Southern Hemisphere



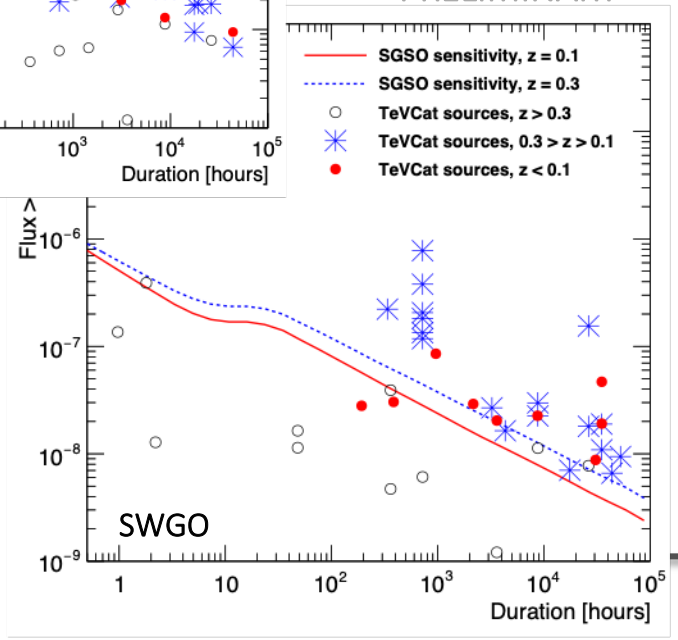


Gamma-ray transients





PRELIMINARY

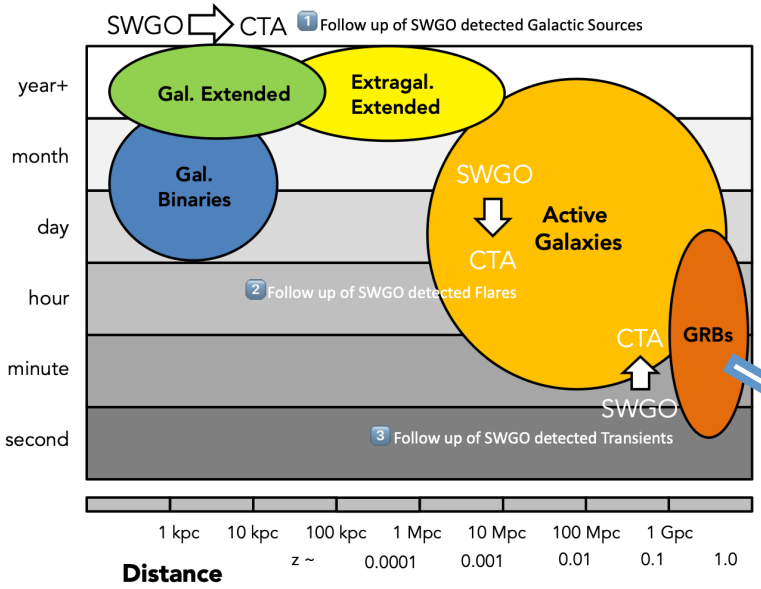


- Flaring sources dominate the VHE sky.
- In a decade of observations, Fermi-LAT has detected several dozens hard spectrum flaring sources.

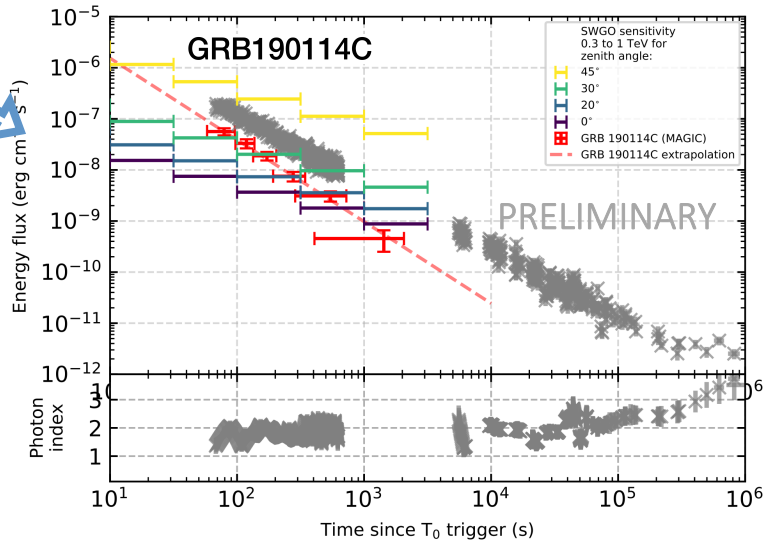
- SWGO will represent significant improvement with respect to HAWC in the detection of short-time variability.

- It will be a pivot instrument for triggering follow-up observations of HE AGN flares and in the multi-messenger domain.

Gamma-ray transients



- GRBs were recently detected by ground-based telescopes.
- An important multi-messenger link.
- Since 2019: afterglow emission of 4 GRBs of detected by IACTs > 100 GeV
- SWGO will provide triggers with the early afterglow and observe the prompt emission



SWGO will complement observations of the Southern transient sky, filling-up a missing niche in the global network of multi-messenger astronomy.

It will be a powerful trigger for GRB transients, down to < 1 ks timescales.

The Core Concept for the Observatory

- High-altitude particle detector above 4.4 km a.s.l
- Latitude range between 15 and 30 degrees South
- Wide energy range reaching down to 100 GeV and 100+ TeV
- High fill-factor core (4x HAWC) for significantly better > 10x sensitivity, plus large low-density outer array
- WCD units with good muon tagging capability
- Goal for R&D study conclusion in 2022

The Southern Wide-field Gamma-ray Observatory

Progress status

- Despite the Pandemics, the project continues as planned, on course to conclude the 3-year R&D Phase by the end of 2022.

SWGO R&D Phase Milestones	
M1	R&D Phase Plan Established
M2	Science Benchmark Cases Chosen
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

Milestone	2019	2020				2021				2022			
	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
R&D Phase Plan Established		M1											
Science Benchmarks Defined			M2										
Reference Configuration & Options Defined				→	M3								
Site Shortlist Complete					→		M4						
Candidate Configurations Defined							M5						
Perf. of Candidate Configurations Evaluated								M6					
Preferred Site Identified									→	M7			
Design Finalised											→	M8	
Construction & Operation Proposal Complete													M9

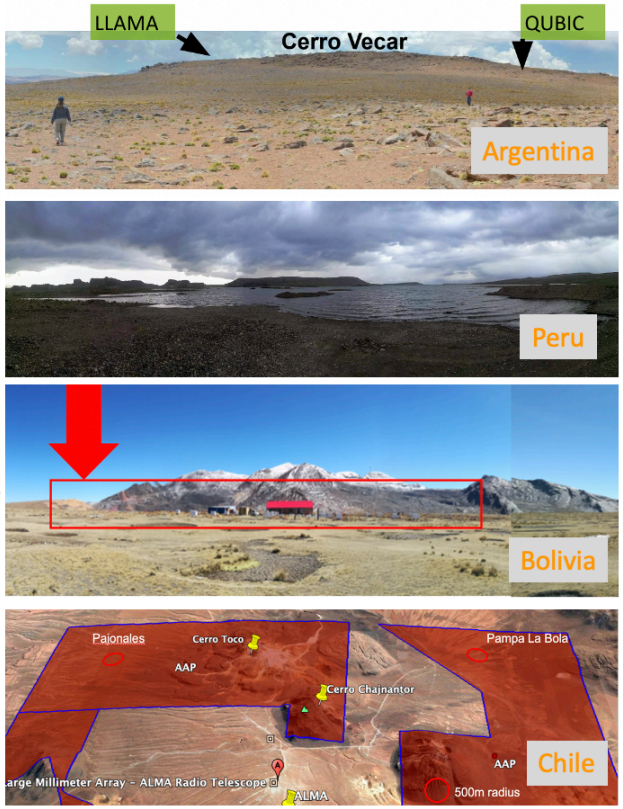
Candidate Sites

lat. 15 S

lat. 23 S

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

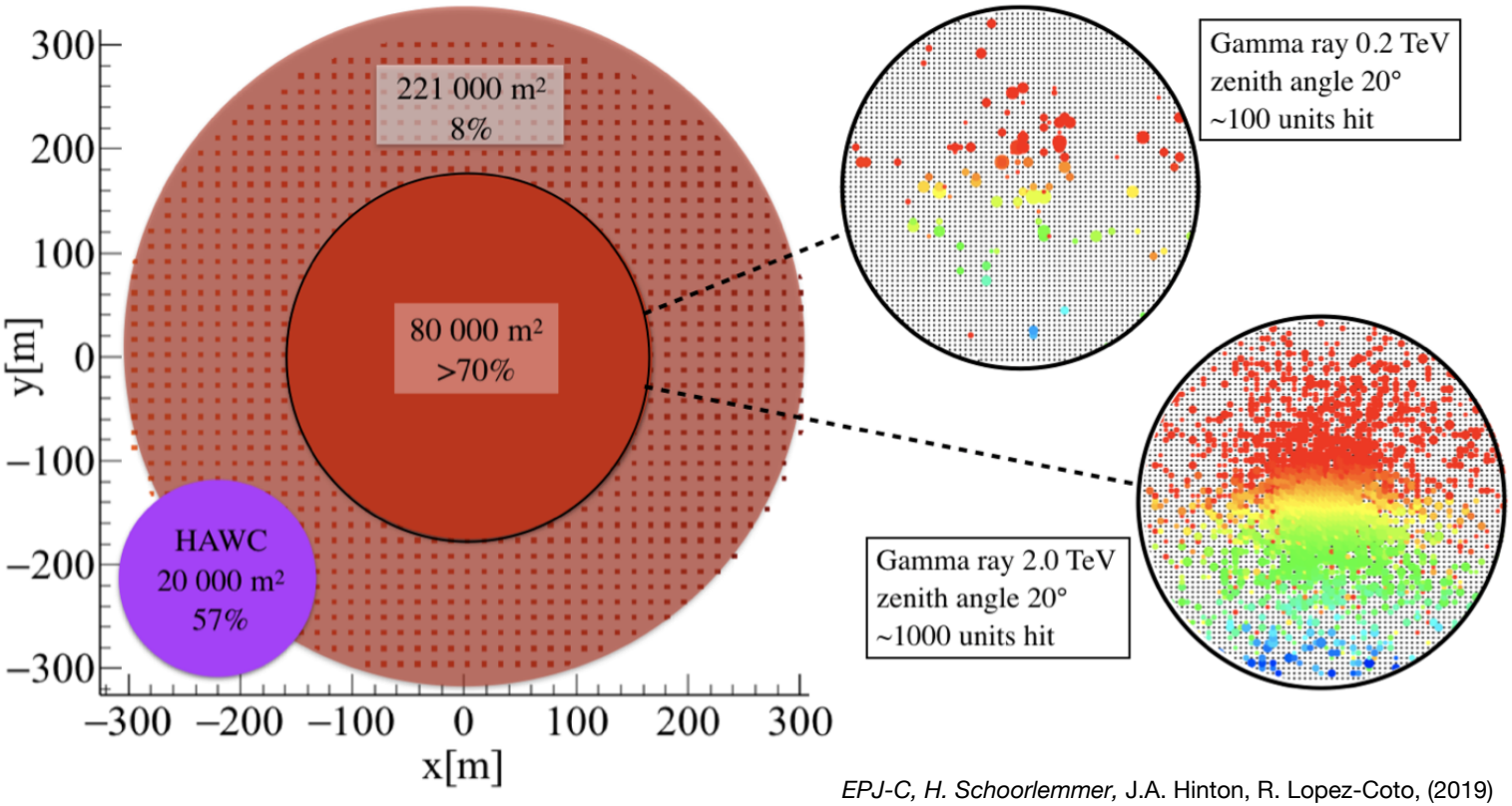
The complete list of potential sites is still under investigation, aiming at an evaluation for site choice by 2021.



The SWGO Concept

Detector array

Large array for low-energy events
Compact core with large instrumented area



EPJ-C, H. Schoorlemmer, J.A. Hinton, R. Lopez-Coto, (2019)

- ‘Strawman’ - reference detector layout

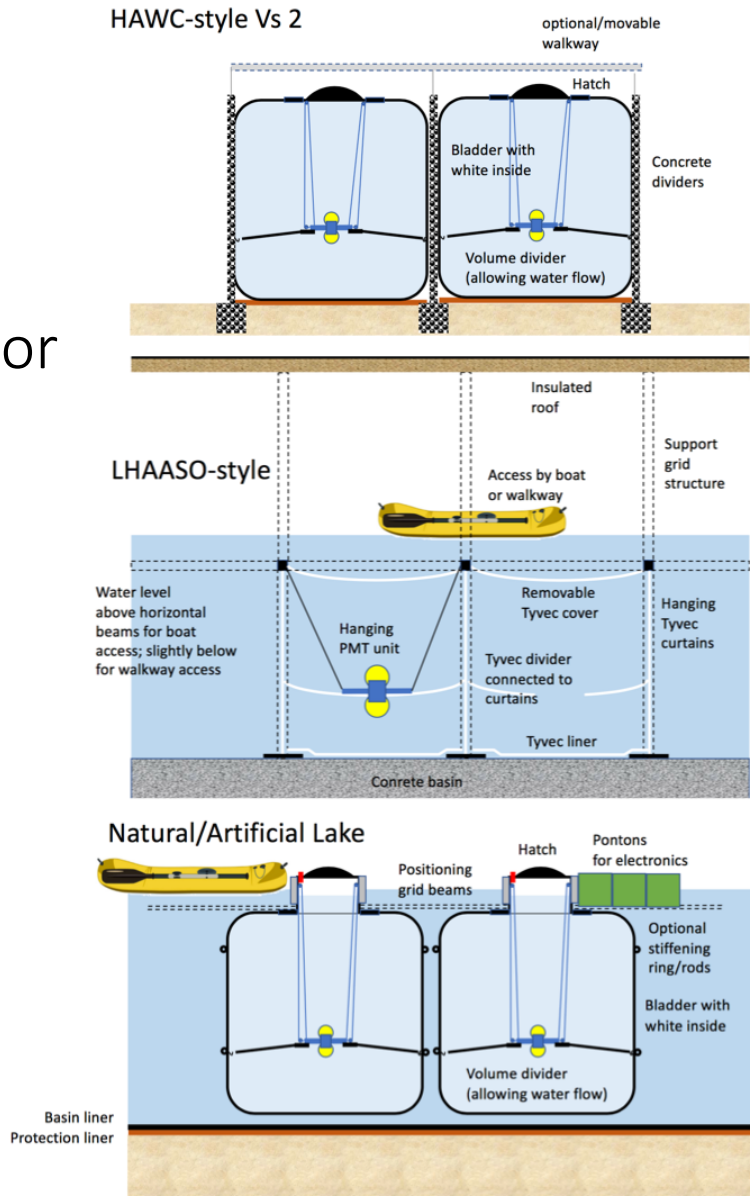
The SWGO Concept

The Southern Wide-field Gamma-ray Observatory

Multiple detector options to be investigated

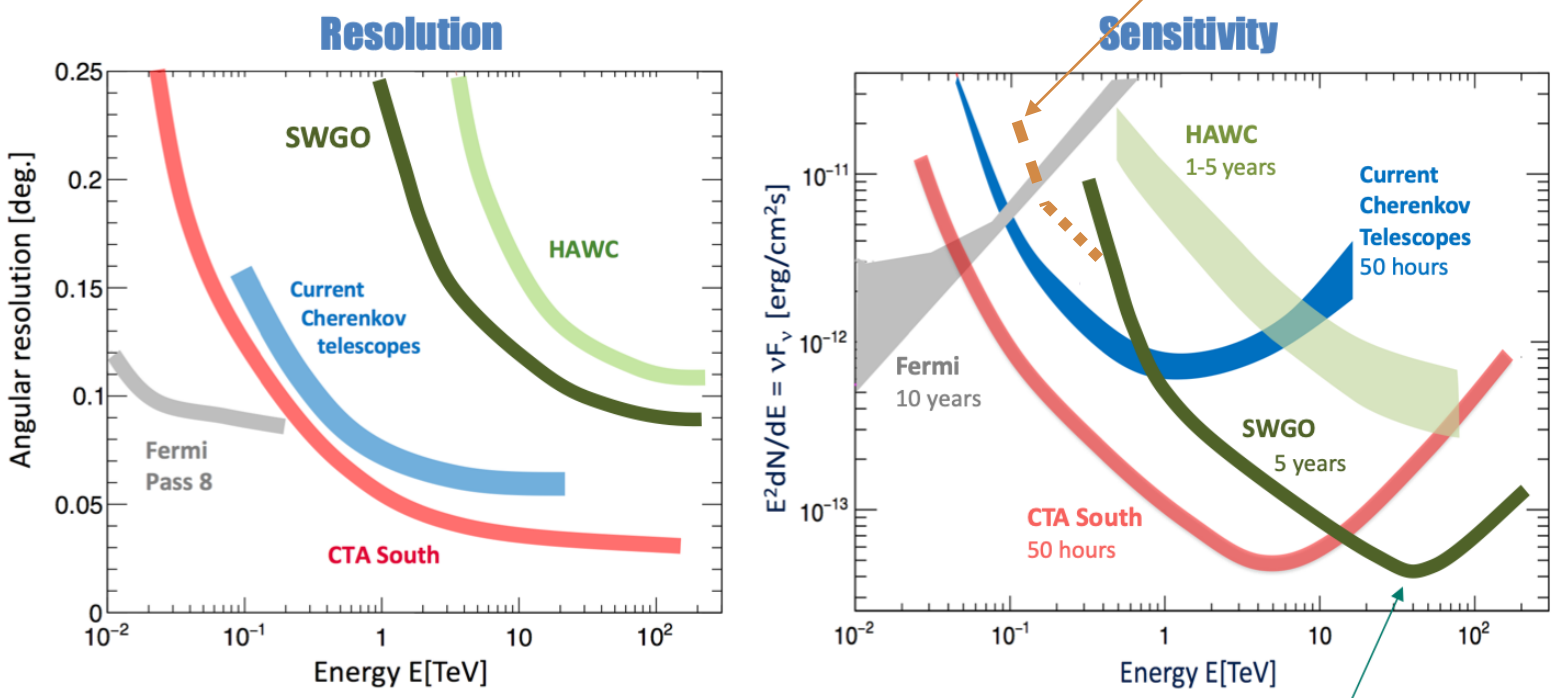
- Core unit is a water-Cherenkov Detector
  - Options being investigated based on tanks (HAWC-like), ponds (Milagro-like) and lake-base (test pool under construction at MPIK-Heidelberg)
- Simulations currently ongoing to constrain all aspects of the detectors
- Design strongly dependent on site choice
  - Water access, construction costs, infrastructure feasibility, compatibility with scientific driven main design goals…

Detector units



The Southern Wide-field Gamma-ray Observatory

Performance goals



Low-energy enhancement

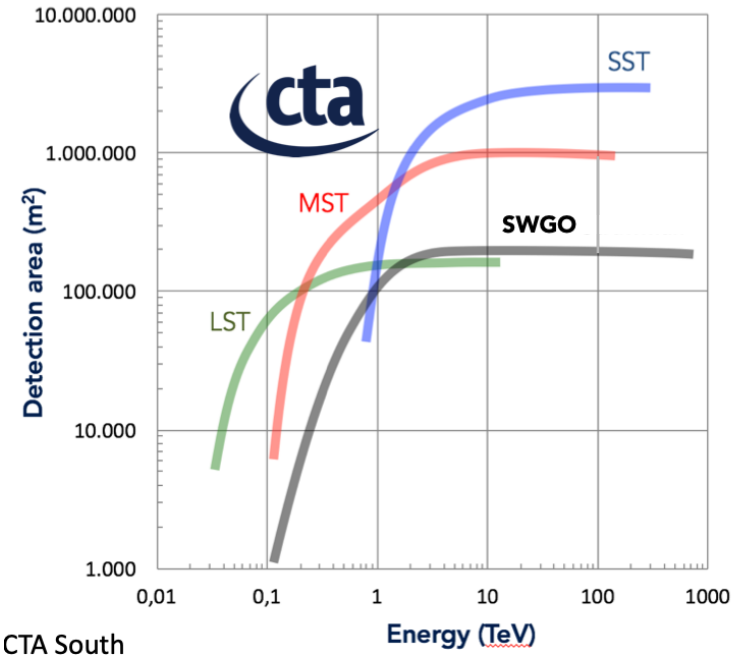
Background free above about 30 TeV for point-like sources, even after 5 years

www.cta-observatory.org

www.swgo.org

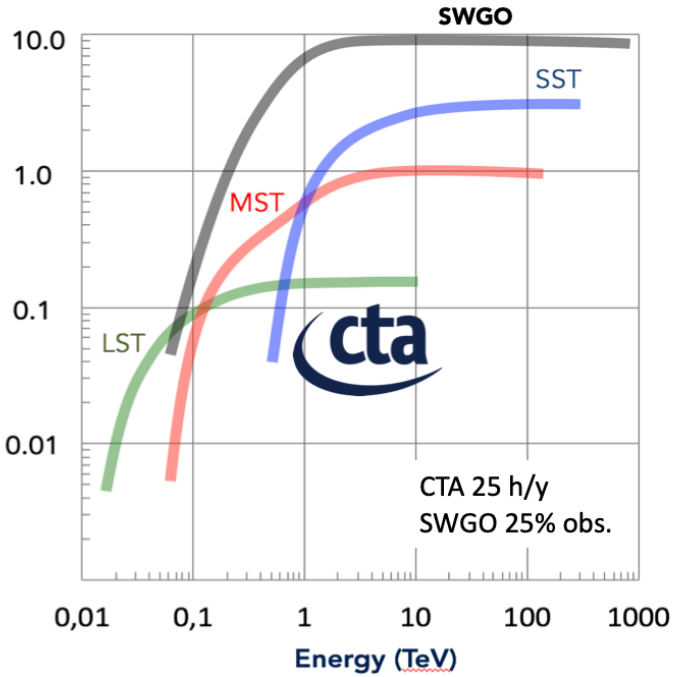
The Southern Wide-field Gamma-ray Observatory

Performance goals



CTA South

Detection Area



Annual Exposure

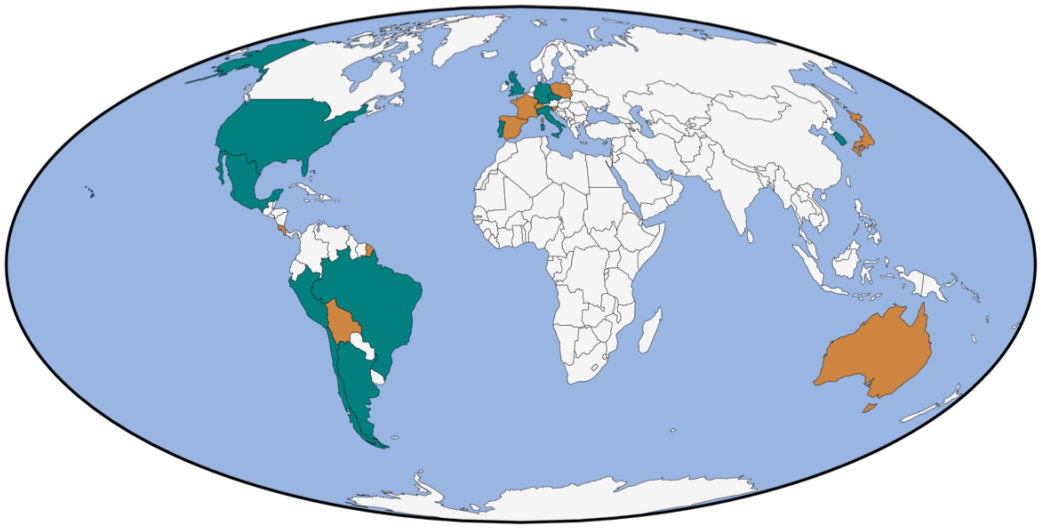
Potentially more sensitive than CTA over several years integration time provided good background suppression is achieved.

The Collaboration

- Southern Wide-Field Gamma-ray Observatory
  - + higher altitude (4400+ m asl) and larger area
  - + more efficient detector units + muon tagging capability
  - ⇒ improved sensitivity and lower E threshold

Established in July 2019
3 year R&D Programme

www.swgo.org



Institutes

Argentina*, Brazil, Chile, Czech Republic, Germany*, Italy, Mexico, Peru, Portugal, South Korea, United Kingdom, United States*

Supporting scientists

Australia, Bolivia, Costa Rica, France, Japan, Poland, Slovenia, Spain, Switzerland

**also supporting scientists*

Member institutes signed the SoI.

Any interested individual can become supporting scientist.

SWGO
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Conclusions

- Strong motivation for a Southern-Hemisphere, wide field of view, high duty-cycle detector
  - **SWGO is in the middle of its 3 year R&D period towards project launch**
  - **and has recently defined its science benchmarks**
- Strong complementarity between SWGO & CTA
  - **Detection of hard spectrum sources for CTA follow-up**
  - **Triggering CTA on flares and transients / multi-messenger events**
  - **Large scale emissions complementing CTA's detailed view of the Galaxy**
- SWGO & LHAASO / HAWC
  - **Huge potential for scientific and technological synergies**
  - **Complementary location for joint all-sky and cosmic-ray studies.**