Benchmarking the Science of the Southern Wide-Field Gamma-ray Observatory (SWGO)

Ulisses Barres de Almeida[a], Gwenael Giacinti[b] and Francesco Longo[c], on behalf of the SWGO Collaboration

[a]Brazilian Center for Physics Research (CBPF), [b]Max-Planck-Institut für Kernphysik (MPIK), [c]Department of Physics, University of Trieste and INFN, Trieste

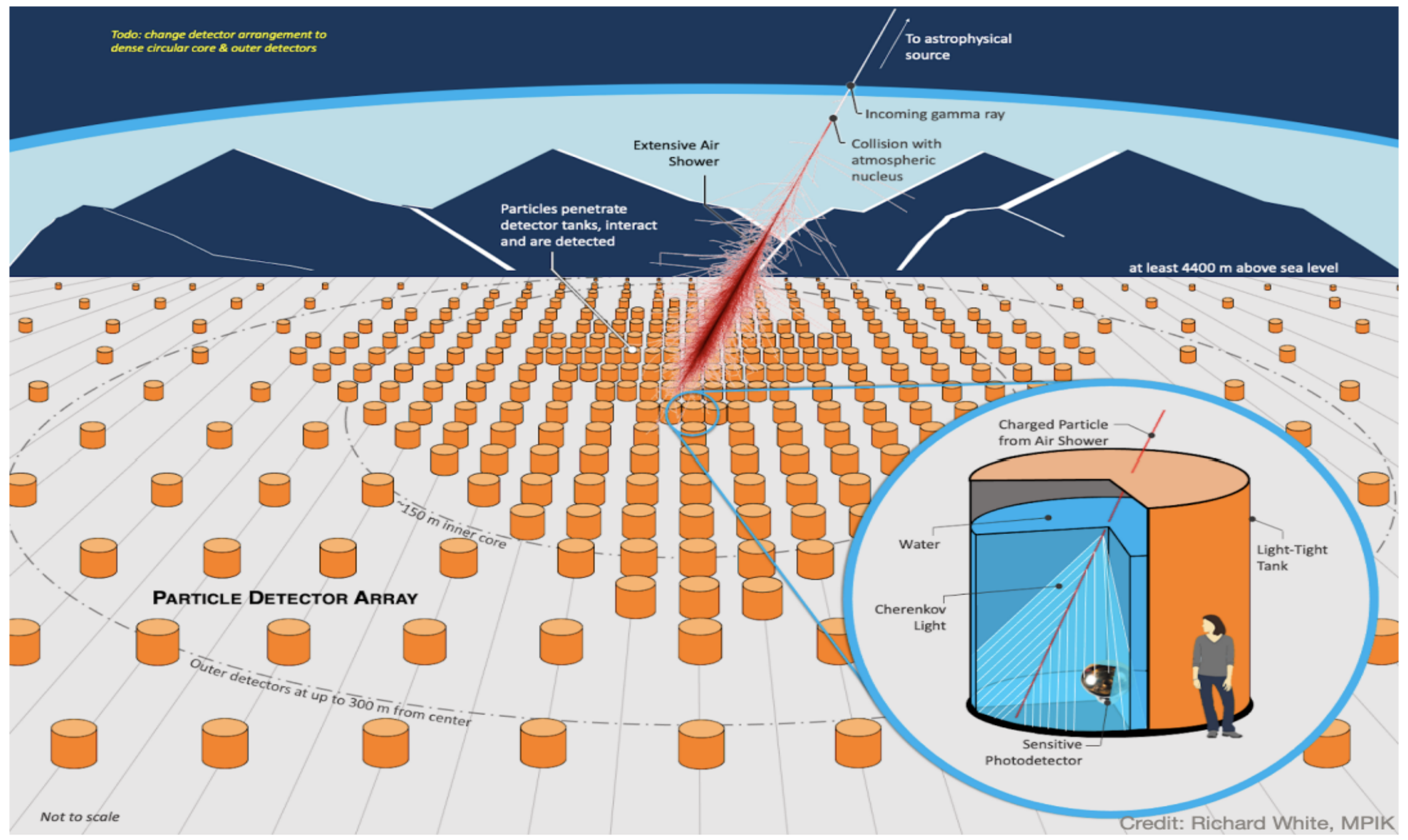
Abstract

The Southern Wide-field Gamma-ray Observatory (SWGO) is the project to build a new extensive air shower particle detector for the observation of very-high-energy gamma-rays in South America. It will complement the capabilities of CTA, working as a wide-field instrument for the monitoring of transient and variable phenomena, and expand the sky coverage of Northern Hemisphere facilities like HAWC and LHAASO, thus granting access to the entire Galactic Plane and the Galactic Center. SWGO aims to achieve excellent sensitivity over a very large target energy range, and improve on the performance of current sampling array instruments in all observational parameters.

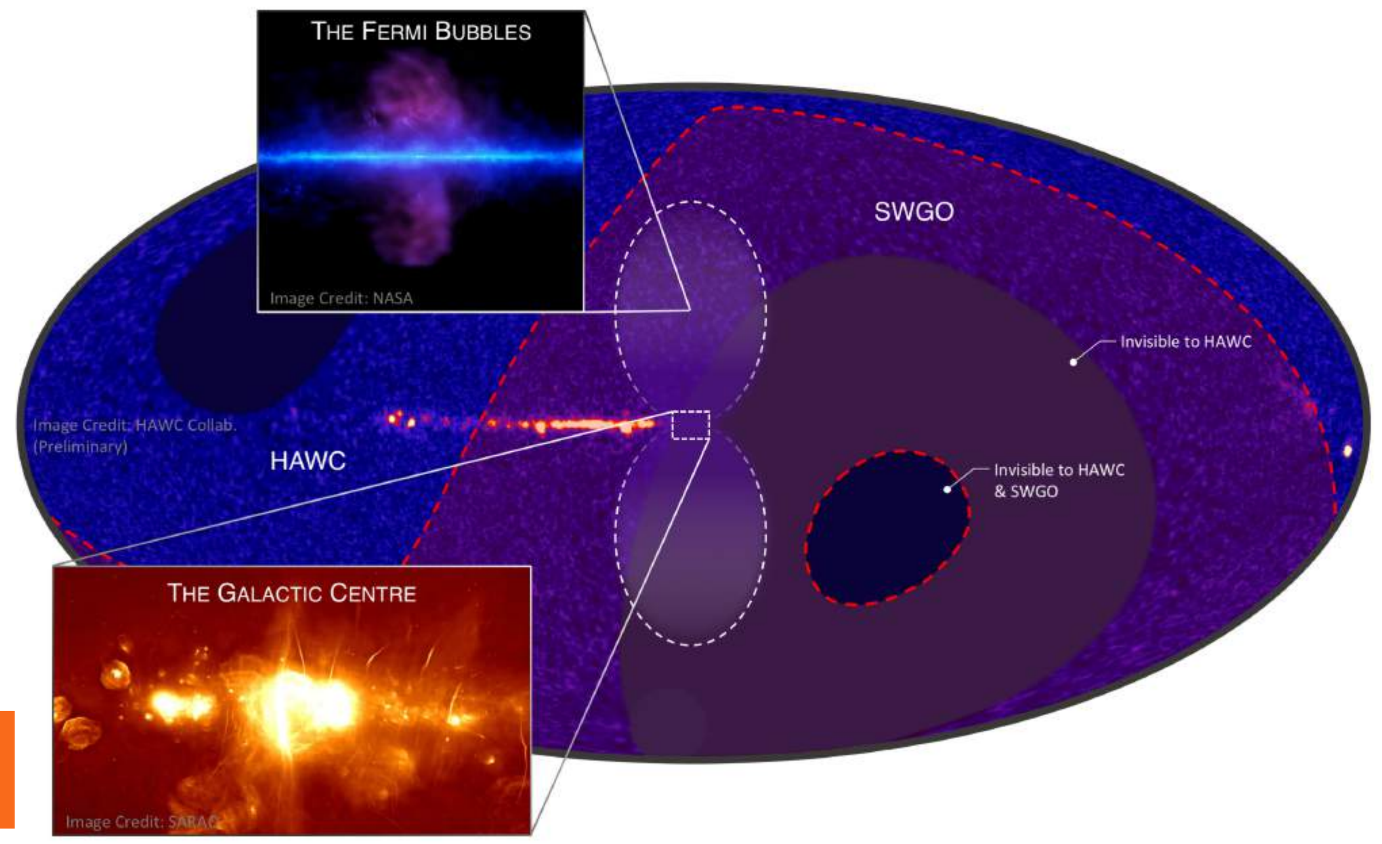
The SWGO Concept

The SWGO aims to cover **an extended energy range**, from around 100 GeV, to the PeV scale. Its **general design concept** consists in a large (circa 80,000 m^2) and high fill-factor (~ 80%) core array of water Cherenkov detector (WCD) units, surrounded by an outrigger array of WCDs, arranged in a low fill-factor grid and covering an area of minimum 200,000 m^2. The array is to be deployed above 4.4 km a.s.l. in the Andes.

The **WCD detector units** are optically isolated water volumes instrumented with photo-detectors and able to sample the shower front to provide time and particle energy density information, as well as muon tagging for background rejection.



The SWGO Science Case



SWGO is well placed to probe extreme phenomena and astrophysical environments such as the origin of PeV cosmic rays and the nature of DM thanks to the observatory's southern location. The new observatory will also be a powerful time-variability monitor, due to its aimed lower-energy threshold.

- **PeVatrons and galactic accelerators**, identified by means of a high-energy spectral cutoff signature (or lack thereof), poses a requirement on the energy resolution of ~ 30% above 50 TeV
- **Gamma-ray Bursts and transients,** exploiting the wide-FoV and duty cycle, along with its southern location, to complement CTA.

Dark Matter searches, where the niche of SWGO is the possibility to constrain the entire range of WIMP models, up to 100 TeV

Cosmic-ray studies, where the capability to detect single muons is crucial for mass-resolved charged cosmic-ray studies up to PeVs

Science Case	Design Drivers	Benchmark Description
Transient Sources: Gamma-ray Bursts	Low-energy sensitivity & Site altitude^a	Min. time for 5σ detection: F(100 GeV) = 10^{-8} erg/cm^2.s, PWL index = -2., F(t) $\propto t^{-1.2}$
Galactic Accelerators: PeVatron Sources	High-energy sensitivity & Energy resolution^b	Maximum exp-cutoff energy detectable 95% CL in 5 years for: F(1TeV) = 5 mCrab, index = -2.3
Galactic Accelerators: PWNe and TeV Halos	Extended source sensitivity & Angular resolution^c	Max. angular extension detected at 5σ in 5-yr integration for: F(>1TeV) = 5×10^{-13} TeV/cm^{-2}.s
Diffuse Emission: Fermi Bubbles	Background rejection	Minimum diffuse cosmic-ray residual background level. Threshold: < 10^{-4} level at 1 TeV.
Fundamental Physics: Dark Matter from GC Halo	Mid-range energy sensitivity Site latitude^d	Max. energy for $b\bar{b}$ thermal relic cross-section limit at 95% CL in 5-years, for Einasto profile.
Cosmic-rays: Mass-resolved dipole / multipole anisotropy	Muon counting capability^e	Max. dipole energy at 10^{-3} level; Log-mass resolution at 1 PeV – goal is A={1, 4, 14, 56}; Maximum multipole scale > 0.1 PeV

Table 1: SWGO Science Benchmarks. ^{a}Site altitude to be greater than 4.4 km above sea level. ^{b}Energy resolution < $O(30\%)$ throughout core energy range 1-100 TeV. ^{c}Angular resolution ~ 0.15° throughout core energy range 1-100 TeV. ^{d}Site latitude not constraining among candidates under consideration. ^{e}WCD units with muon identification capability for γ/hadron discrimnation.

Science Benchmarks for SWGO

A set of **core science cases** has been defined to guide the R&D studies of SWGO. They reflect a minimum set of science goals. **Quantitative benchmarks** were derived to assess and compare the performance of the different SWGO candidate array configurations under investigation (see Table 1), and directly translate into detector performance requirements.

(i) **a dense array core** and excellent γ/hadron separation for low-energy detection, < 300GeV;

(ii) **an extended sparse array** with peak sensitivity at ~ 100 TeV;

(iii) **muon tagging capability** at WCD units for cosmic-ray studies and improved background suppression;

(iv) **improved angular** (~ 0.15deg) and energy (< 30%) resolutions throughout the core energy range 1-100 TeV.

Conclusion

VHE astrophysics requires wide-FoV instruments operating in a multi-messenger context. The recent detection of photons of extreme energies from the Galaxy further strengthens the necessity of a large survey instrument with access to the Galactic Plane and sensitivity above several 100 TeV. SWGO is expected to cover a wide energy range, from 100 GeV and up to the PeV, and its location in the Andes will provide a window into a still unexplored sector of the sky. Currently in its R&D Phase, the project plans to deliver a consolidated proposal for the Observatory by 2023.