Status of SWGO

The Southern Wide-field Gamma-ray Observatory

XII International Workshop on Ring Imaging Cherenkov Detectors – September 2025

Hazal Göksu

MAX-PLANCK-INSTITUT FÜR KERNPHYSIK

Ground-based Gamma-rays

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

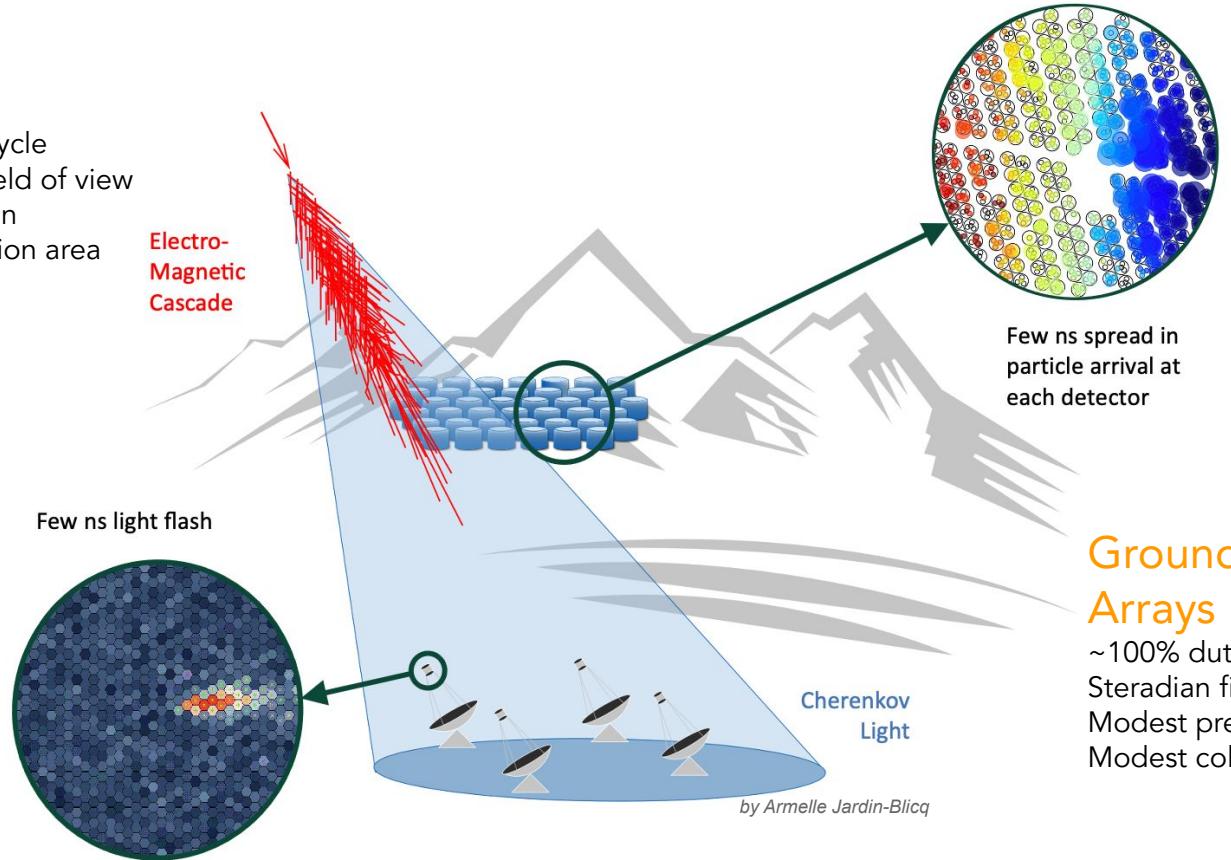
Beyond Standard Model Physics

Adapted from Jim Hinton

Two Methods from Ground

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
Modest collection area

Two Methods from Ground

IACTs

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~4 degree field of vie
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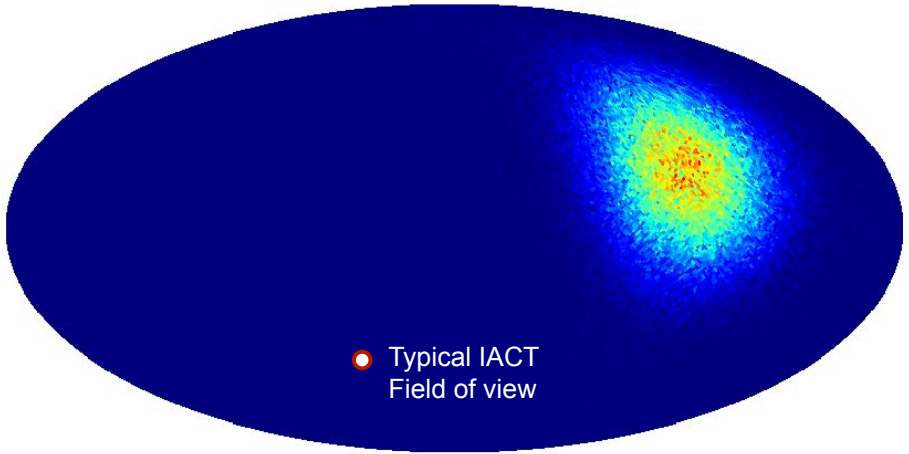
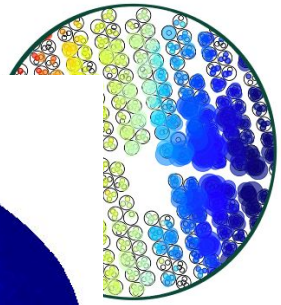
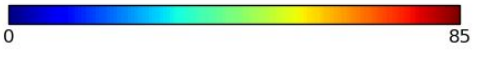




ns spread in
icle arrival at
h detector

Few ns



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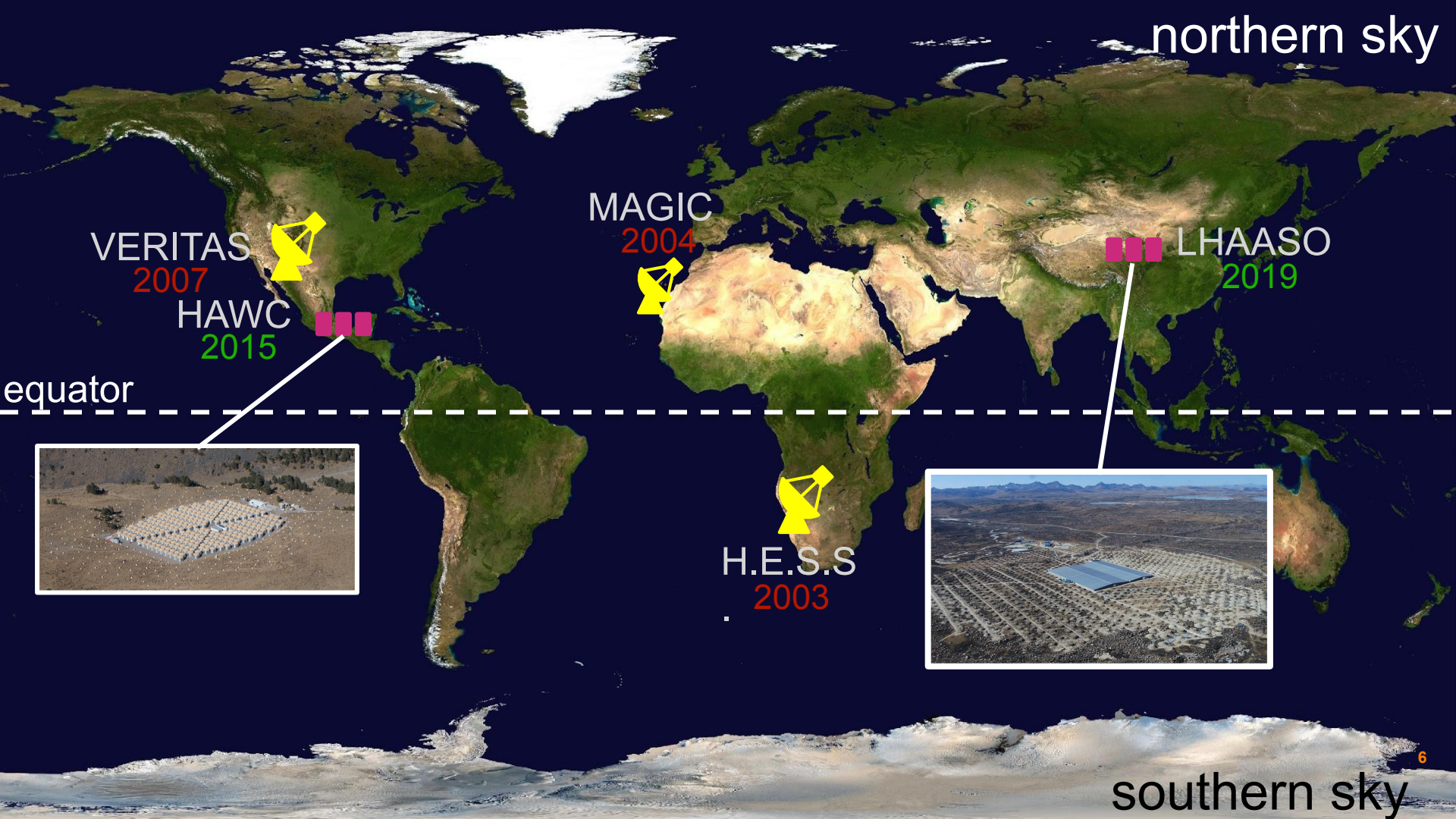
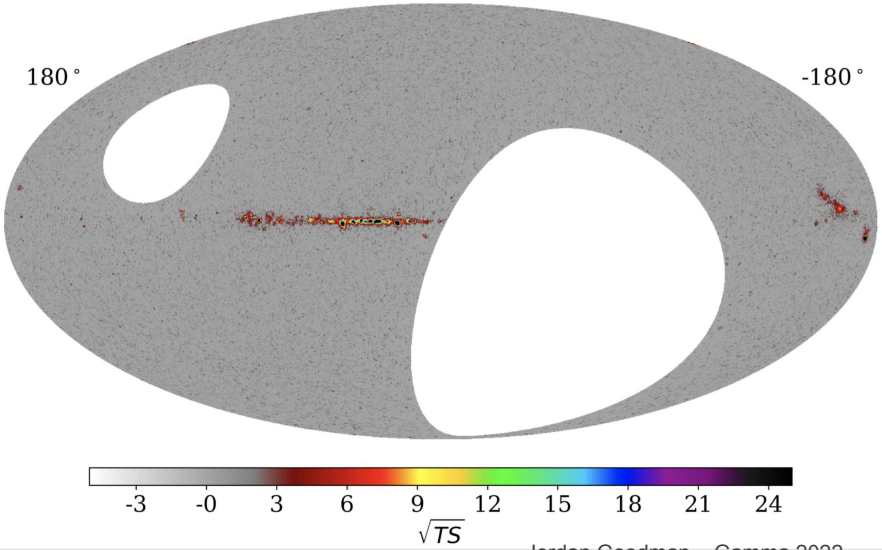

northern sky
VERITAS
2007
HAWC
2015
MAGIC
2004
LHAASO
2019
equator
H.E.S.S
2003
southern sky

Current Water Cherenkov Detector Arrays

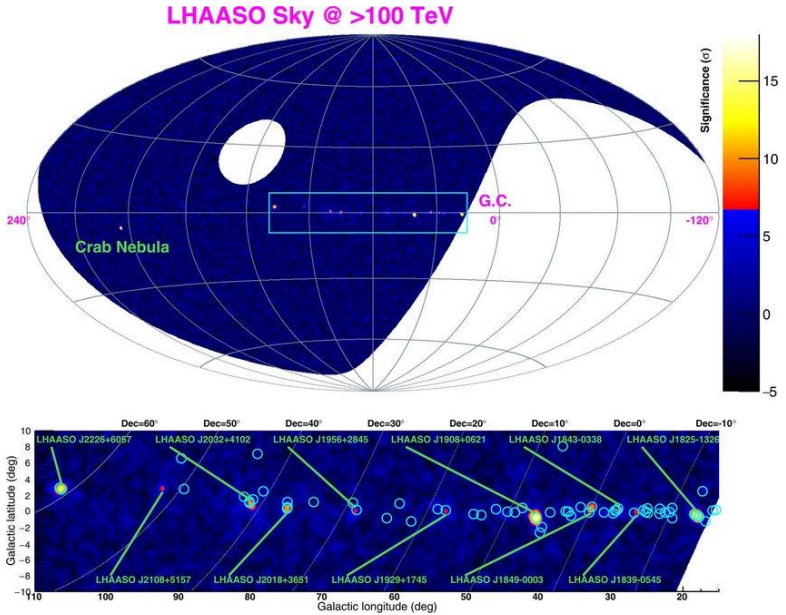
HAWC

- Extended emission around Geminga
- First detection of SS433 in gamma-rays
- Ultra-high-energy (UHE) sources



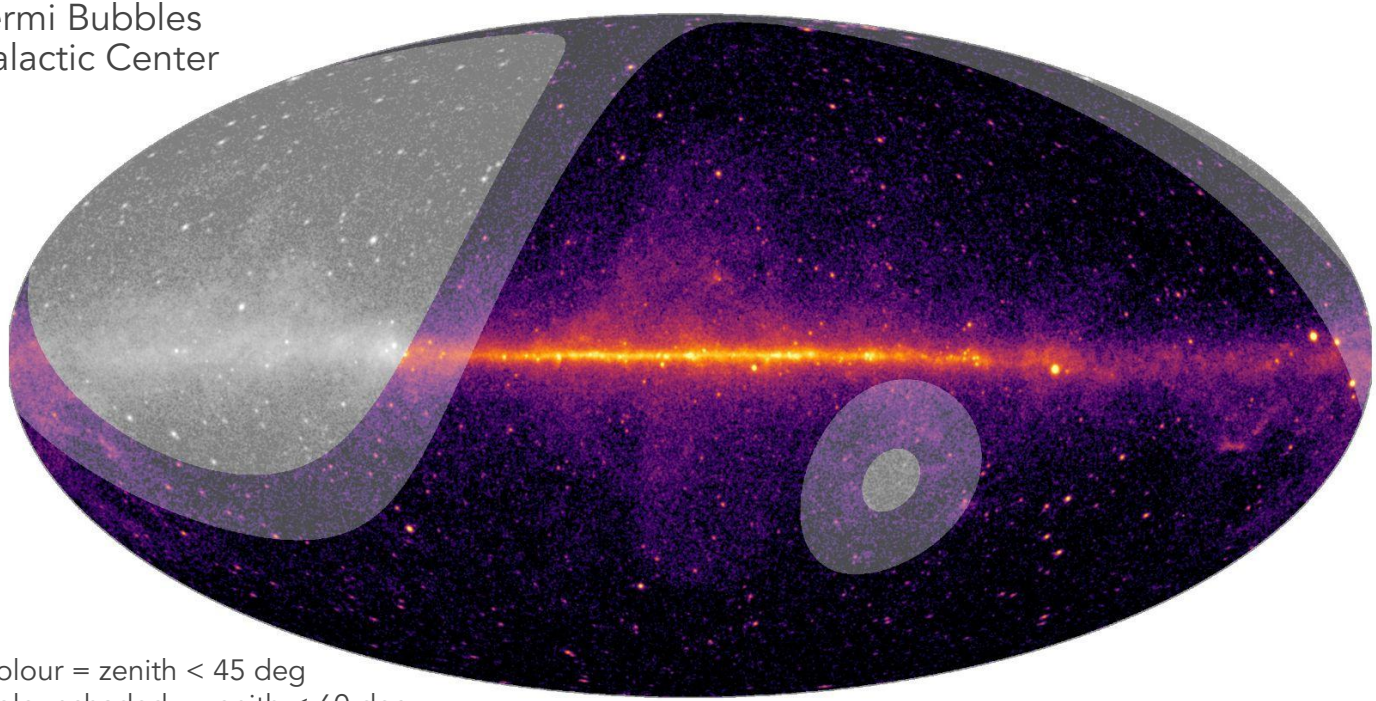
LHAASO

- Even more UHE sources
- Up to PeV energies
- Gamma ray burst (GRB) 221009A

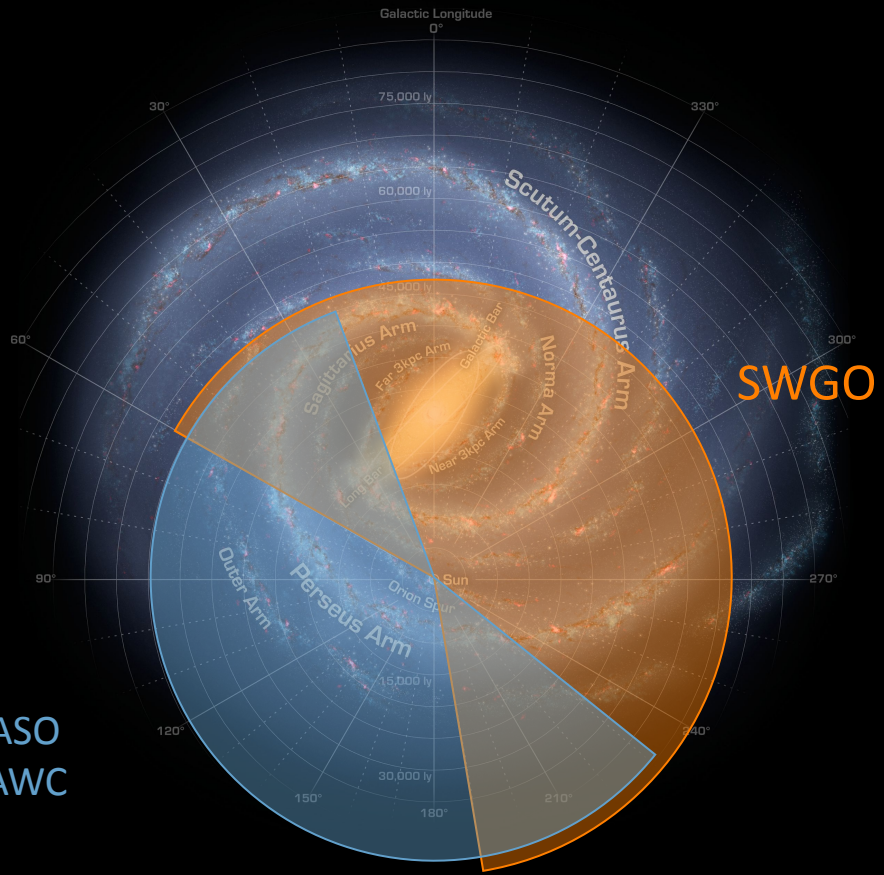


SWGO Visibility

- Fermi Bubbles
- Galactic Center
- …



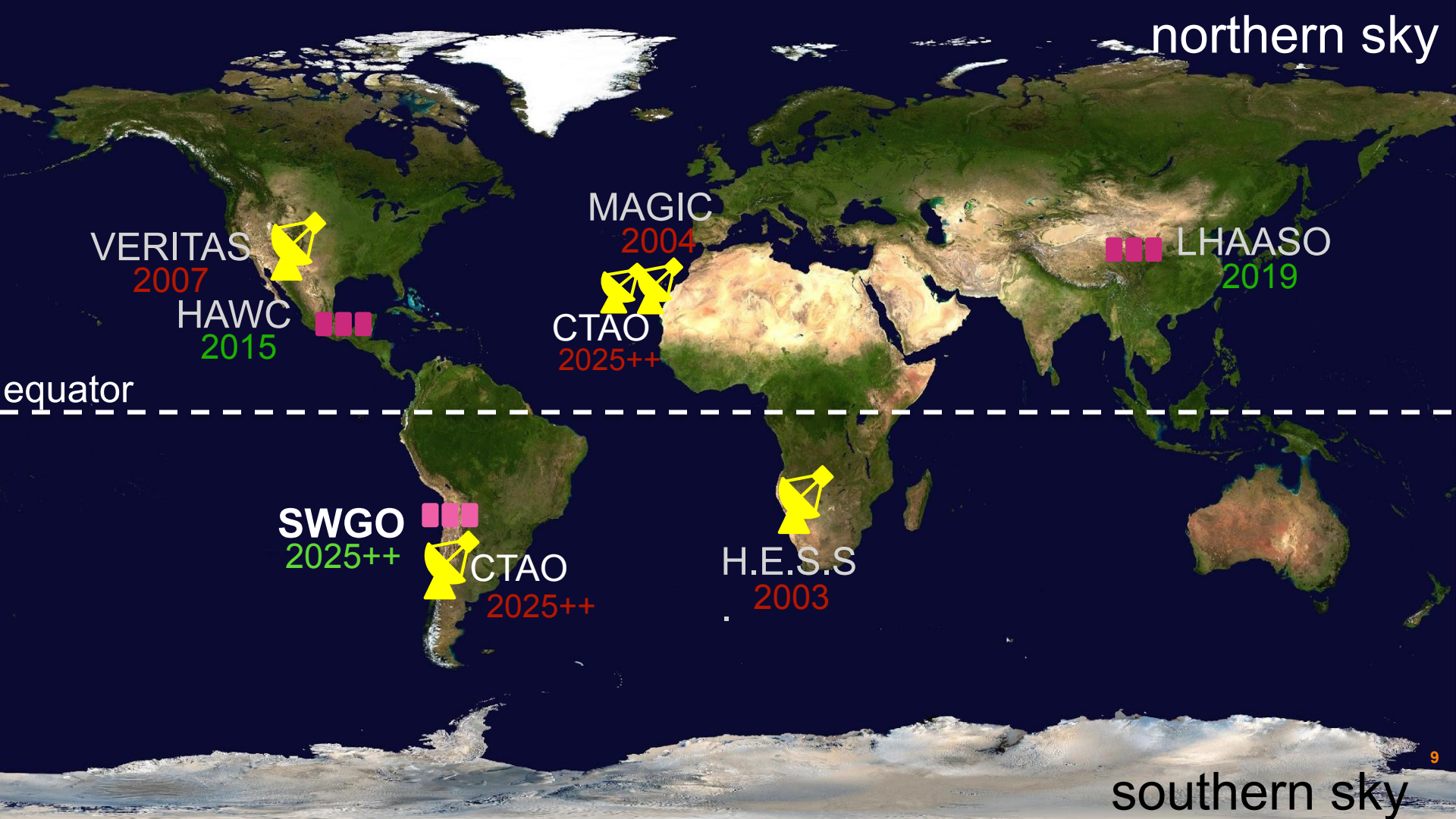
Colour = zenith < 45 deg
Colour-shaded = zenith < 60 deg



SWGO

LHAASO
& HAWC

Adapted from Jim Hinton


northern sky
VERITAS
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2019
equator
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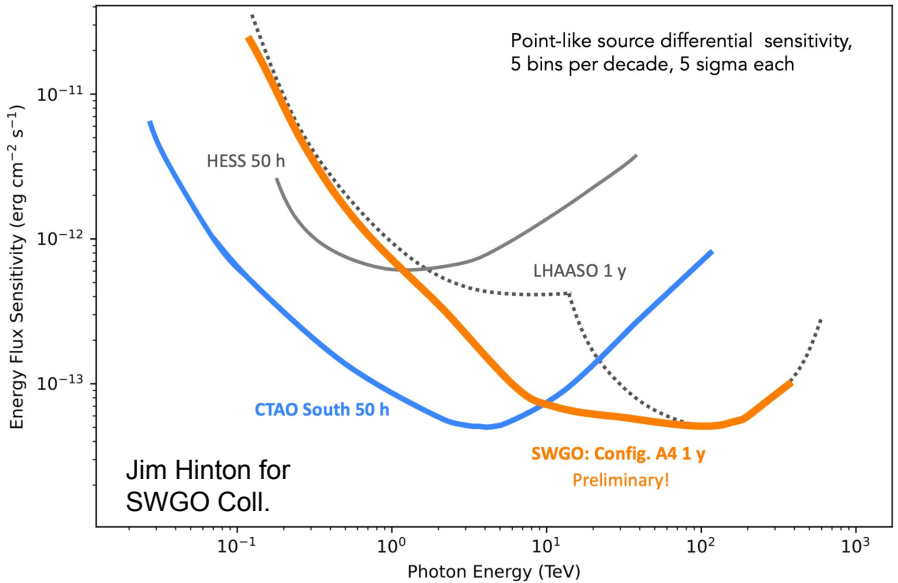
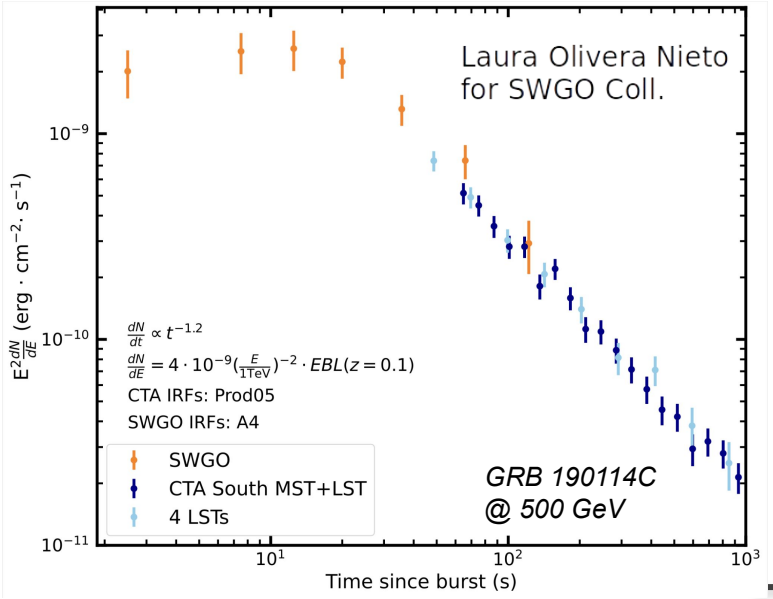
CTAO
2025++
H.E.S.S
2003
southern sky

CTAO and SWGO: The Future

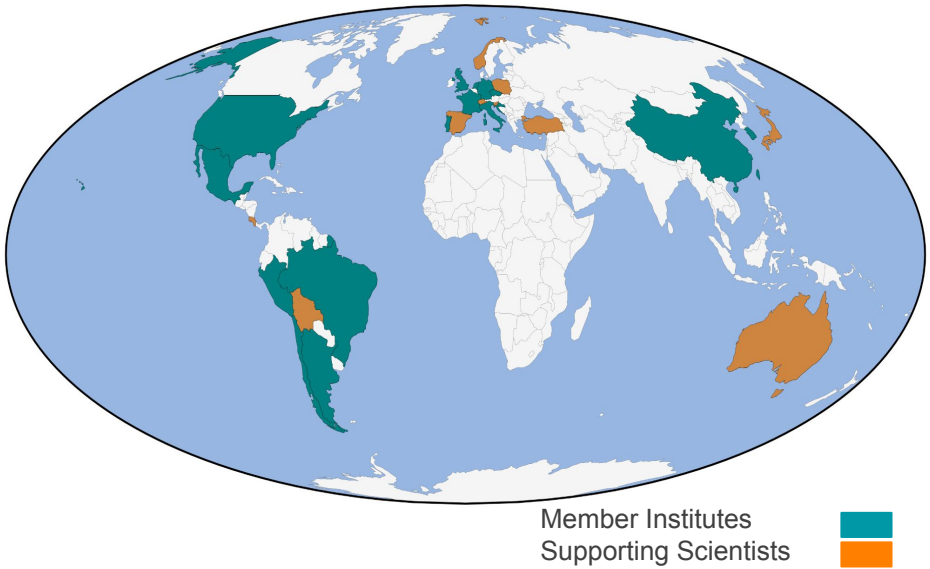
- Complementary observatories
- SWGO: High duty cycle & no trigger



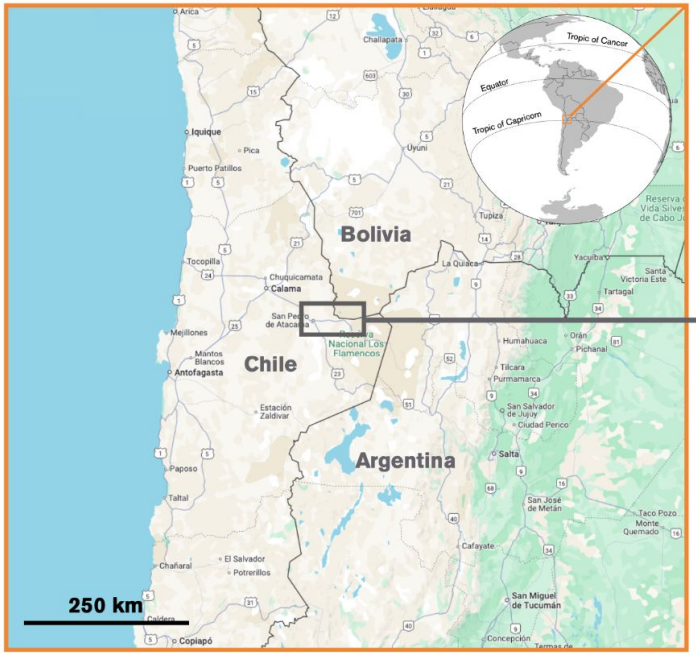


SWGO Progress Overview

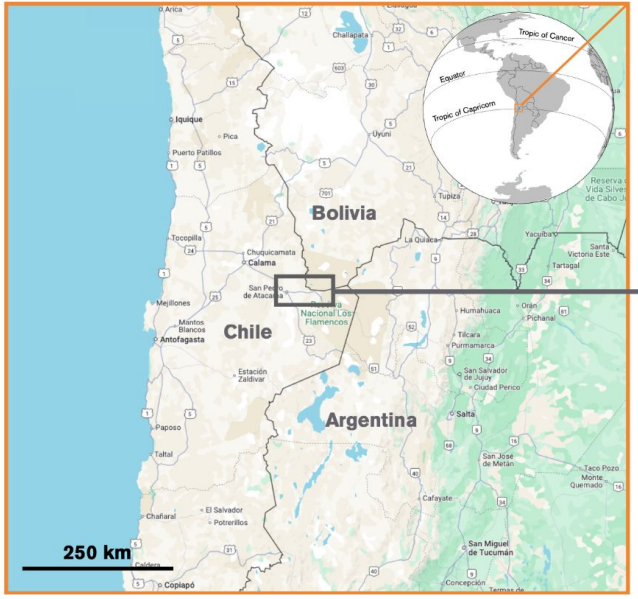
- November 2019:
  R&D phase started
- September 2022:
  Complete site shortlist
- April 2024:
  Evaluation of performance of candidate configurations
- July 2024:
  Identification of Preferred Site
- Next stage:
  Preparatory Phase
  Construction Phase

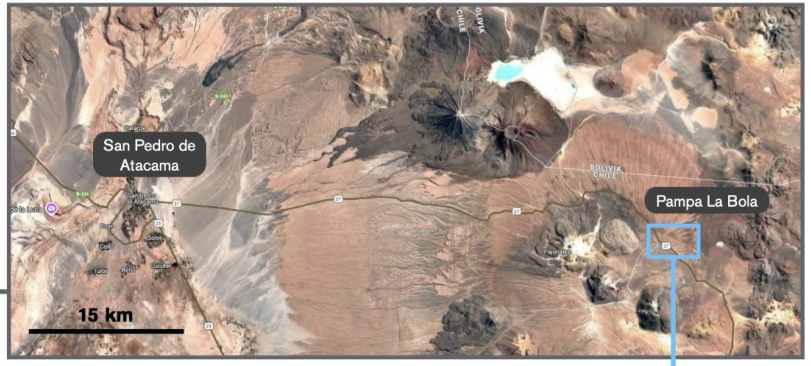


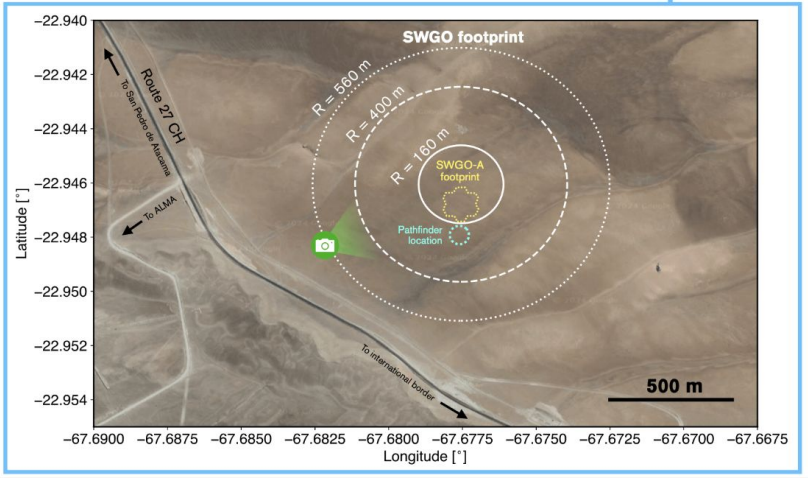
Site: Pampa La Bola



Site: Pampa La Bola







Site: Pampa La Bola

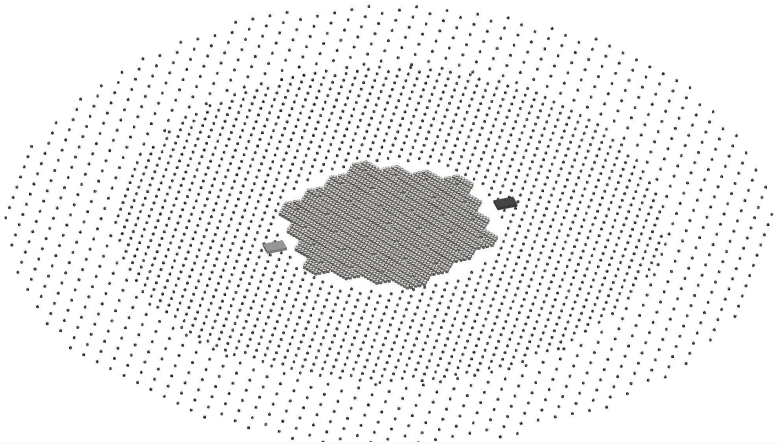
The SWGO Collaboration

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

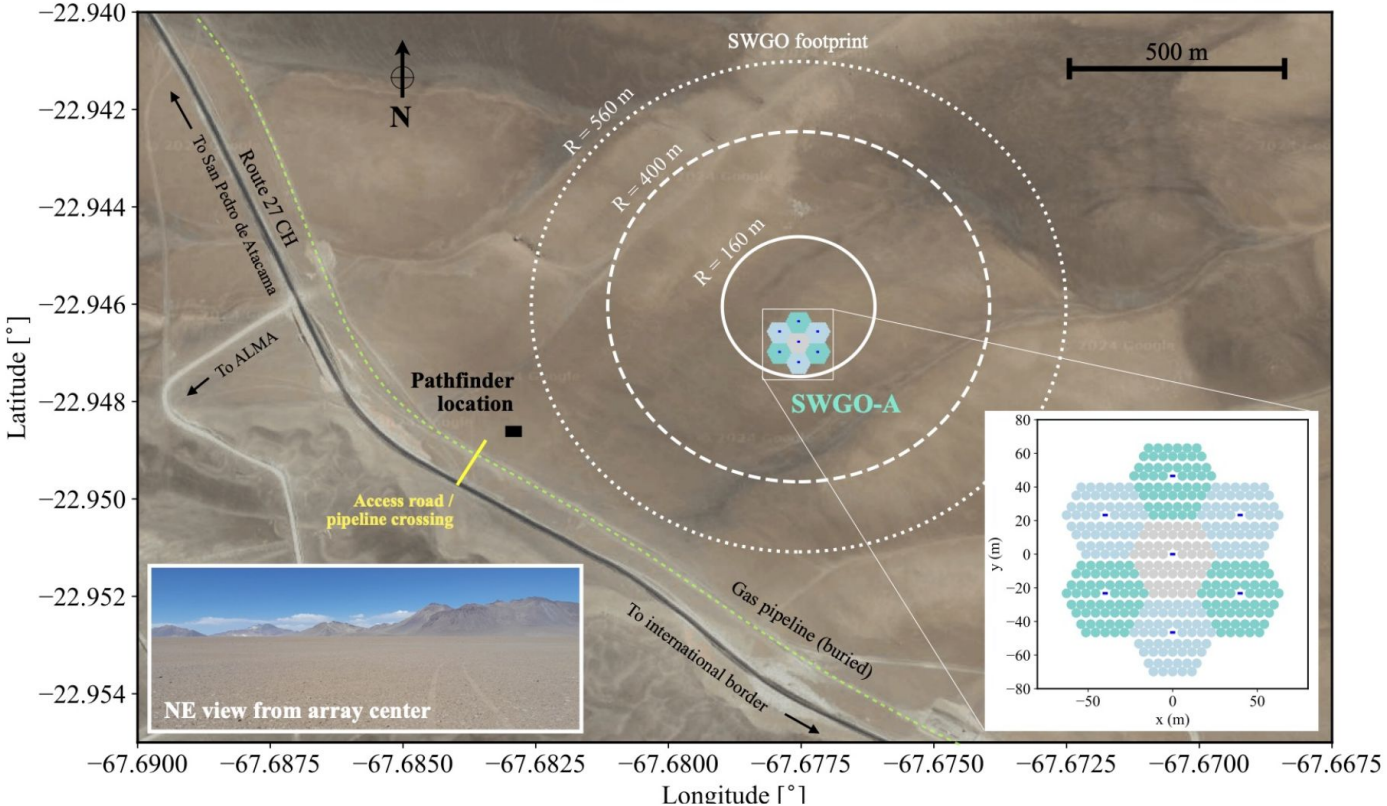
Array Layout

Three zones:

- Inner array:
  - FF=70%, R= 156 m, 2587 tanks
- Outer array:
  - FF= 4%, R= 400 m, 792 tanks
  - FF= 1,7%, R= 560 m, 384 tanks

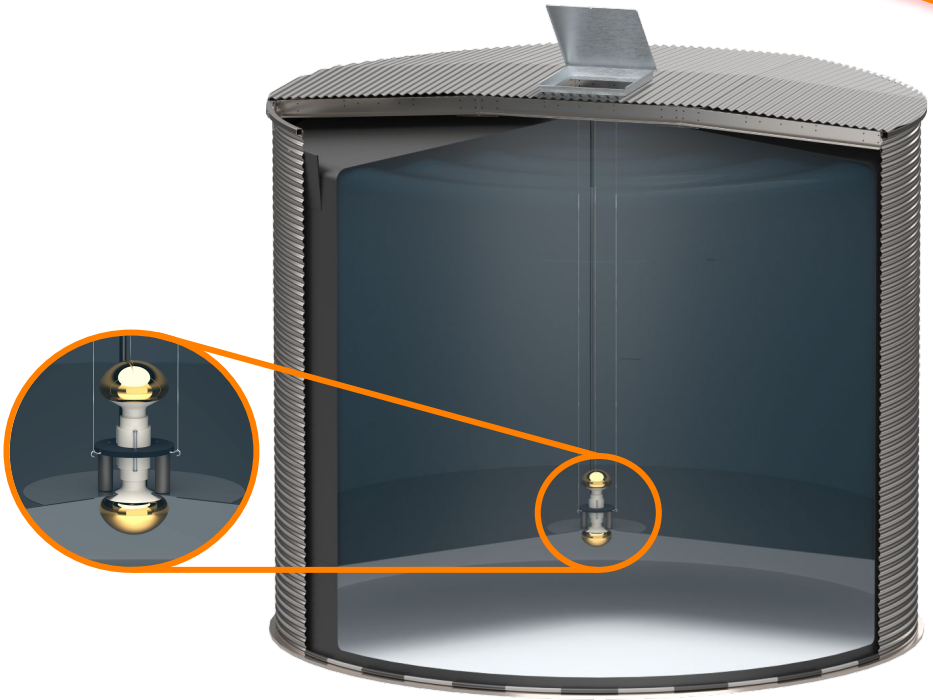


Array Layout



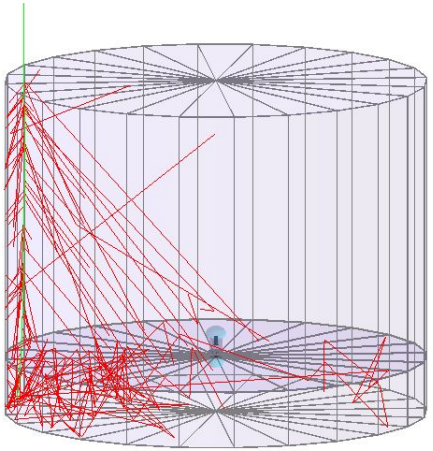
Design of Inner Array

- Steel tanks assembled on site
  - 5.2 m ⌀, 4.1m height
- Double-PMT unit in each detector
  - 10-inch PMTs
- Signals collected at Field Nodes
  - Serve 55 WCDs each



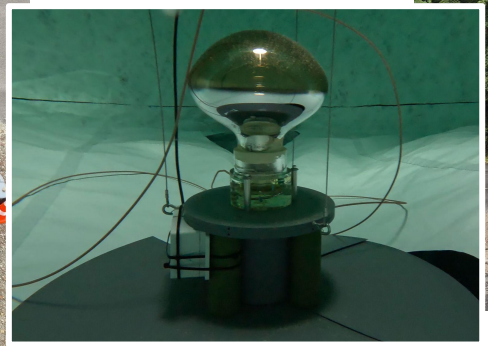
Design of Inner Array

- Custom LDPE Bladders inside each steel tank
- Double-layered detectors
  - Separated by membrane
- Lower chamber is for background rejection
  - Reflective inner lining



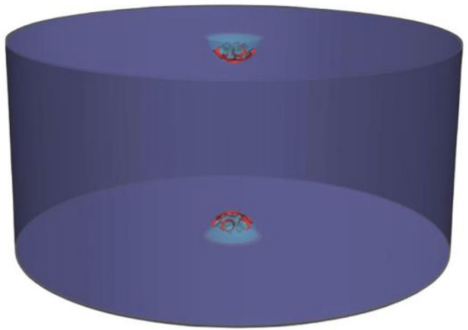
Prototyping for Inner Array

- Multiple Low Altitude Test Sites



Outer Array Studies

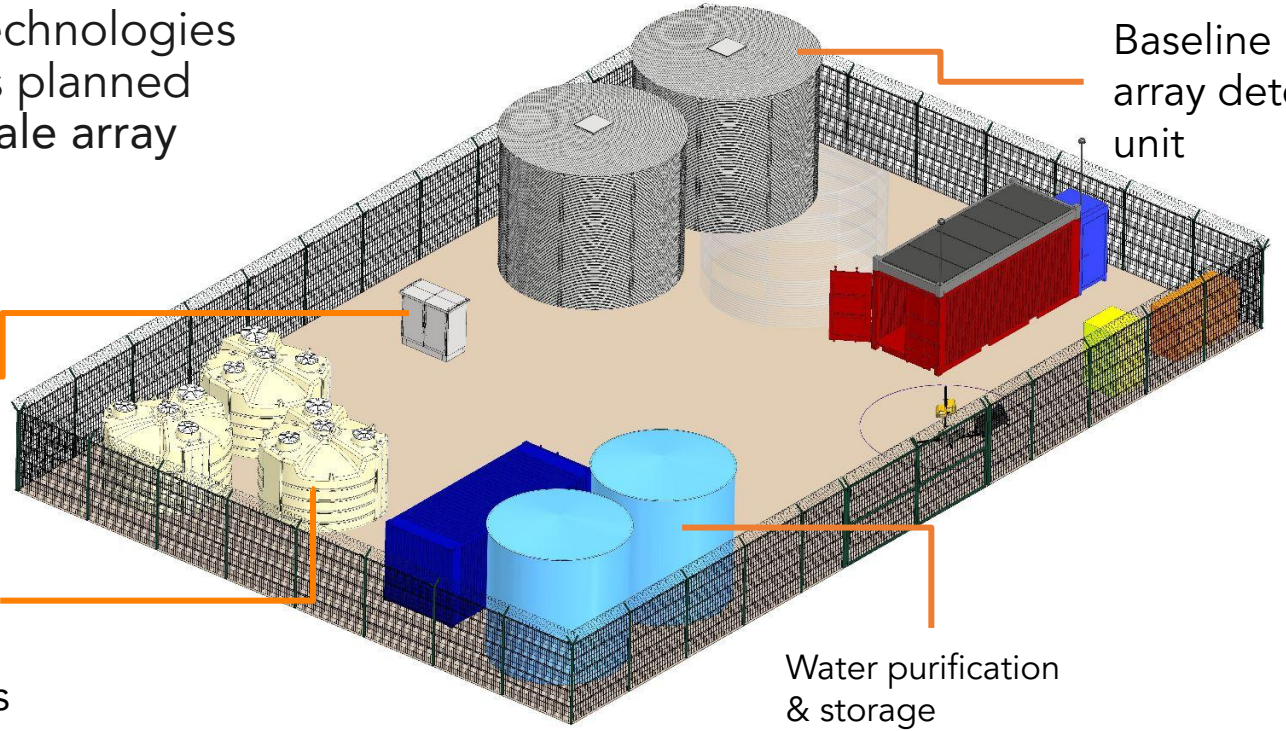
- Large dual layer tanks as for the inner array is one option, but also considering
  - Smaller tanks as potentially more cost-effective for low fill factor (1-4%)
    - Potentially rotomolded (plastic) rather than steel
  - Single layer with multi-PMT
    - Heritage from KM3Net +



Pathfinder

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

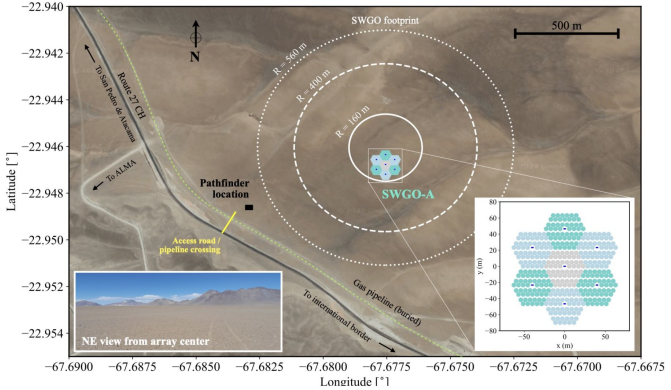
- 20x30m



Plan

- Currently focusing on Pathfinder studies

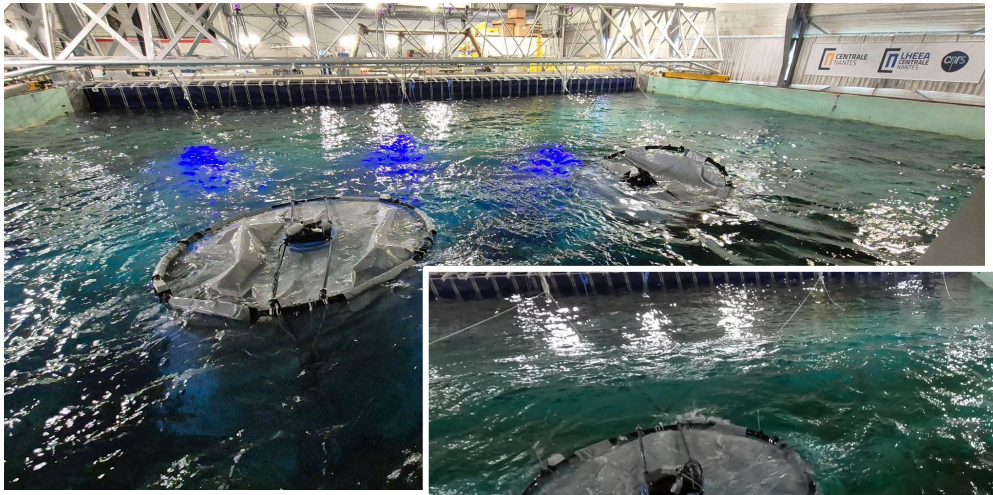
SWGO-TURBO:
The Utility for Radio Beam-formed Observations



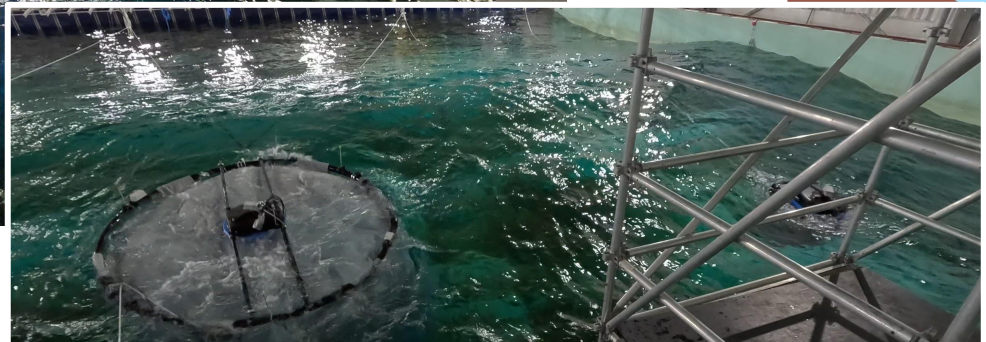
by Tiffany Lewis

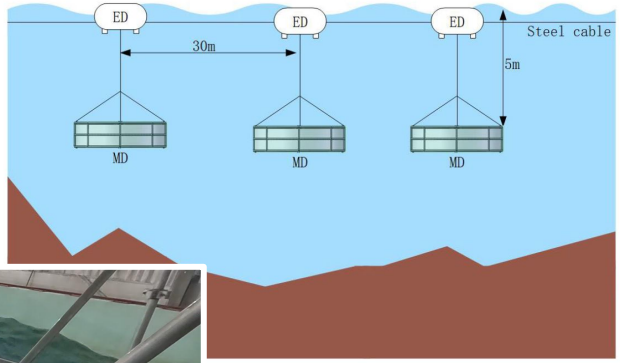
UHE Extension

- A multi-km^2 array as a possible future extension enhancing UHE capabilities
- To be 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
- As a future development, after the completion of main array



Tests in a Wave Basin in Nantes, France





Summary

- SWGO is moving towards construction phase after 5 years of R&D
- It will be built at **Pampa La Bola, Chile (4700 m a.s.l.)**
- First km²-scale wide-field gamma-ray observatory in the Southern Hemisphere
  - Unprecedented sensitivity at tens of TeV
  - Strong synergies with CTAO, IceCube, KM3NeT, LVK, and others
- SWGO-A would be already more sensitive than HAWC at 300 GeV–1 TeV
- Key science topics: Galactic Center, bright sources, dark matter, GRBs …

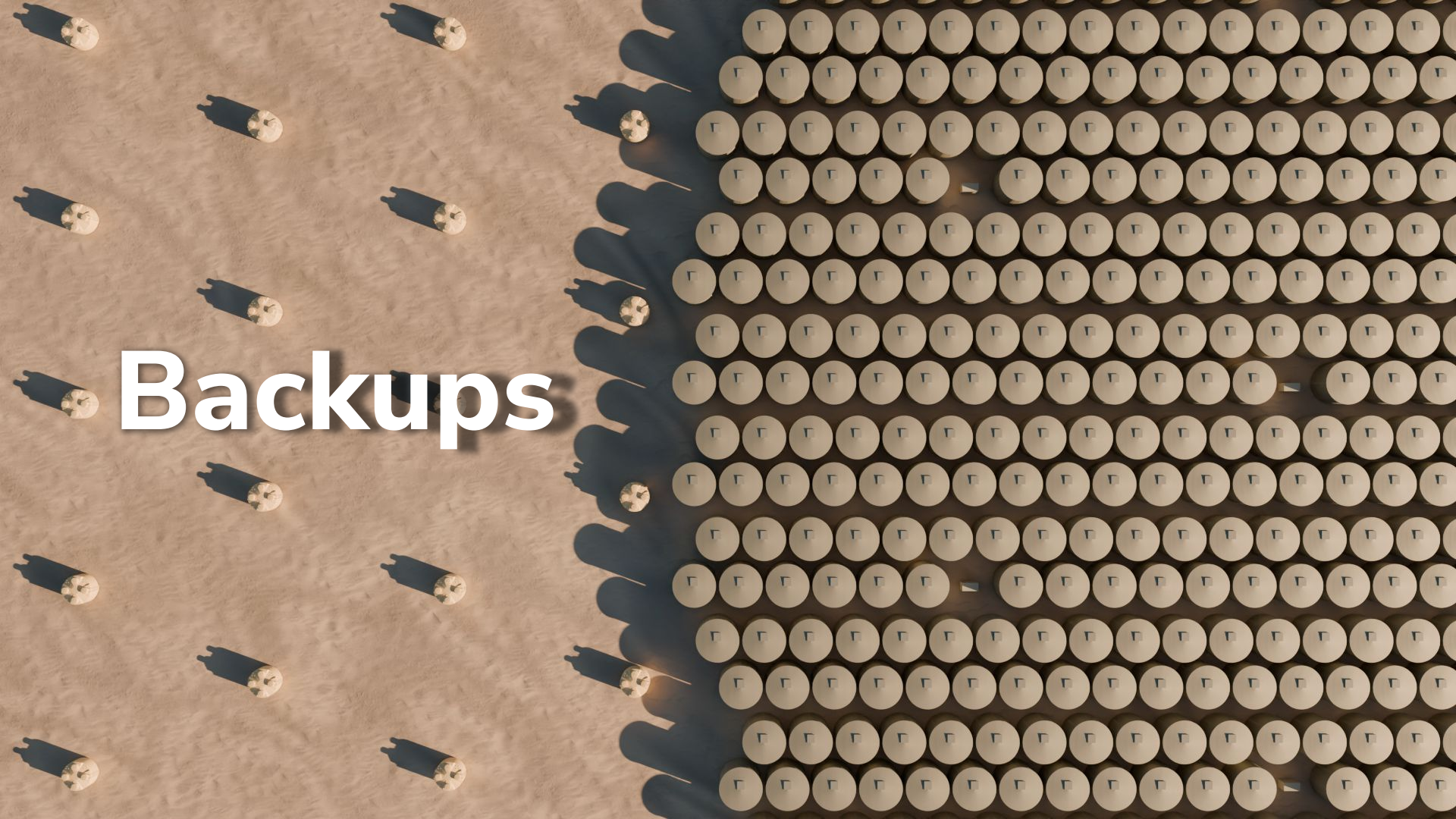
See science case white paper for details:
https://arxiv.org/abs/2506.01786

SWGO
The Southern Wide-field Gamma-ray Observatory

MAX-PLANCK-INSTITUT FÜR KERNPHYSIK

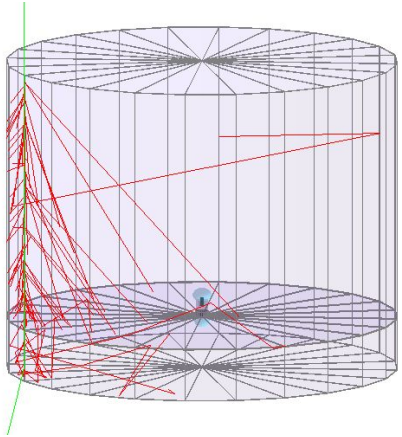
Thank you!

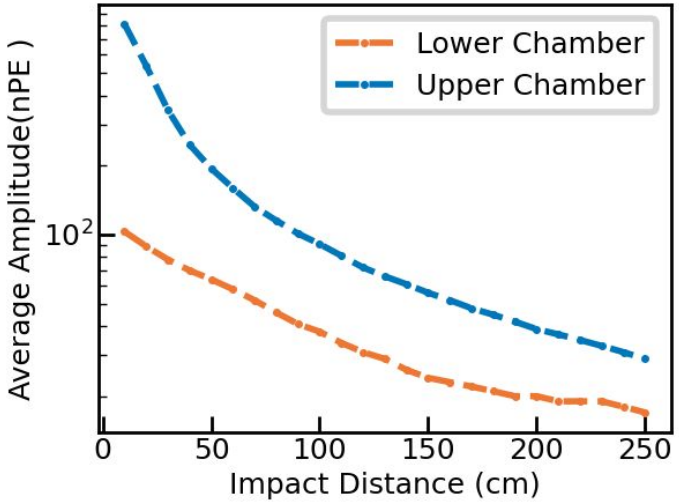
11th Collaboration Meeting -
Heidelberg, Germany, September 2024


Backups

Expected Tank Response

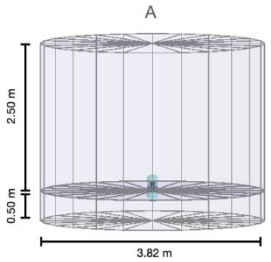
- 1-2 GeV vertical muons
- Nonuniformity

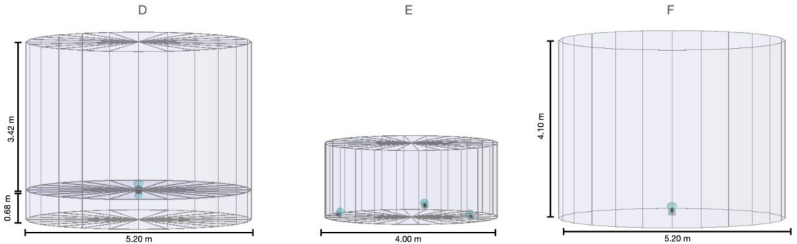


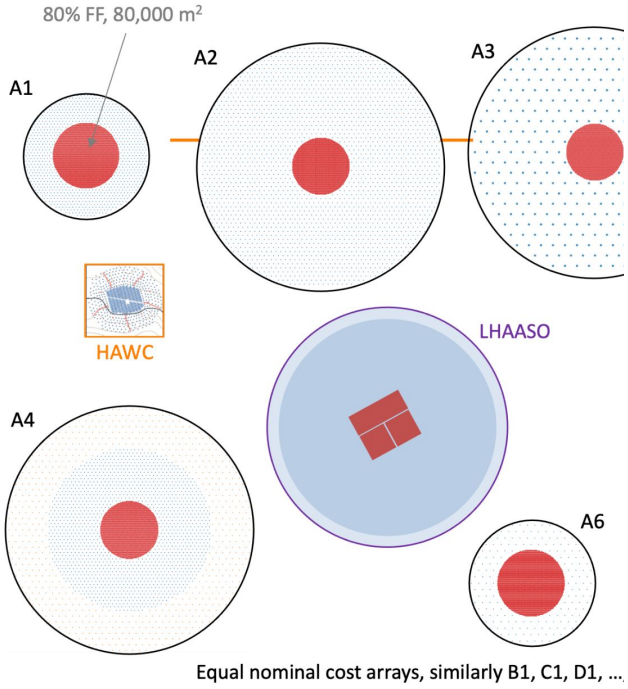


SWGO: Design

- Extensive simulations
- Array layouts:
  - Inner array
  - Outer array
- Detector unit dimensions







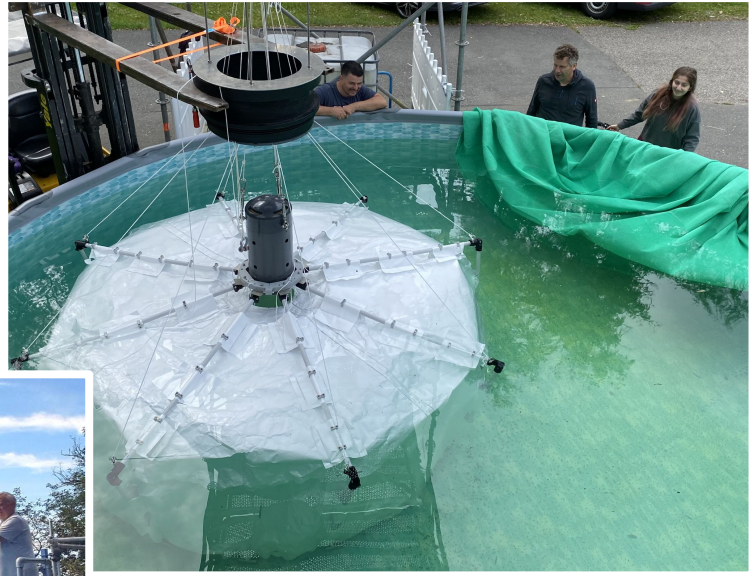
SWGO
The Southern Wide-field Gamma-ray Observatory

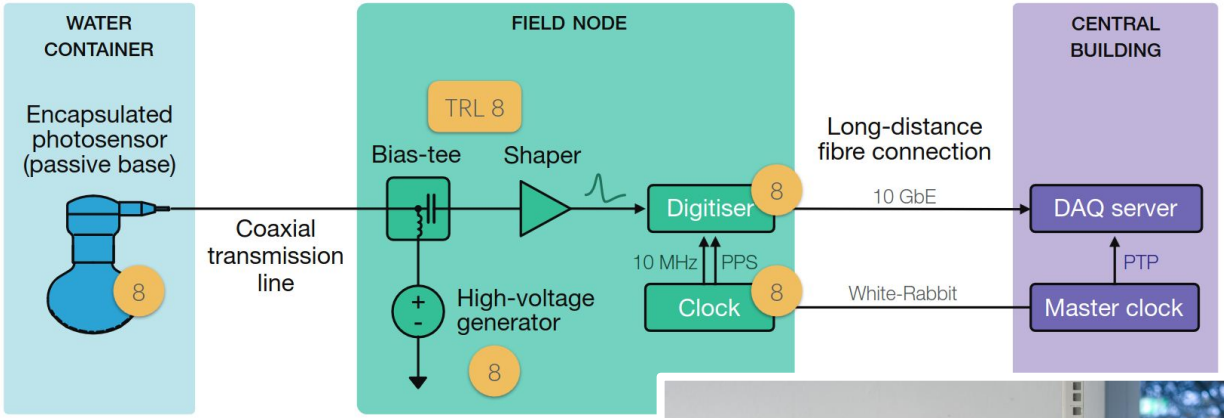
ALPACA

- Bolivia, 4750 m a.s.l.
- Fill factor 4% MDs, 0.5% scintillators → area 0.08 km^2
- ALPAQUITO: ¼ completed so far

SWGO
The Southern Wide-field Gamma-ray Observatory

Lake Prototyping



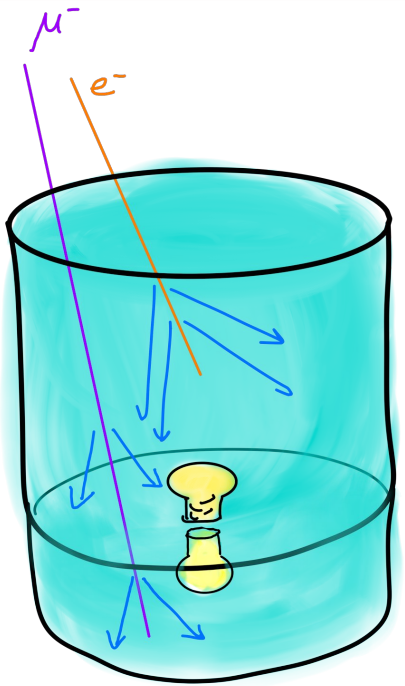

WATER CONTAINER
Encapsulated photosensor (passive base)
8
Coaxial transmission line
FIELD NODE
TRL 8
Bias-tee
Shaper
Digitiser
8
10 MHz
PPS
Clock
8
High-voltage generator
8
Long-distance fibre connection
10 GbE
White-Rabbit
CENTRAL BUILDING
DAQ server
PTP
Master clock

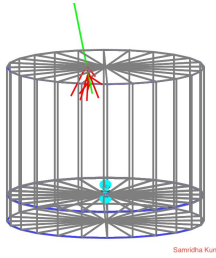
Double-layered Detector Units

- Background rejection through muon identification
- ~3.2m upper chamber ~ 8 radiation lengths (X ~ 40 g/cm2)
- EM showers contained in upper chamber except for highest energy shower particles
- Muons pass through without interaction – long path length → to the lower chamber

Cherenkov light Angle: acos (1/n)
~ 41°

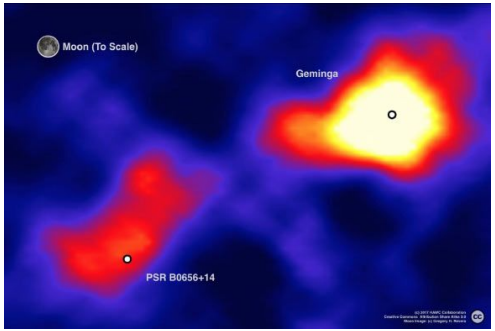
Yield: $(\Delta h\nu)2\pi\alpha(1-1/n2)/hc$
300 photons / cm

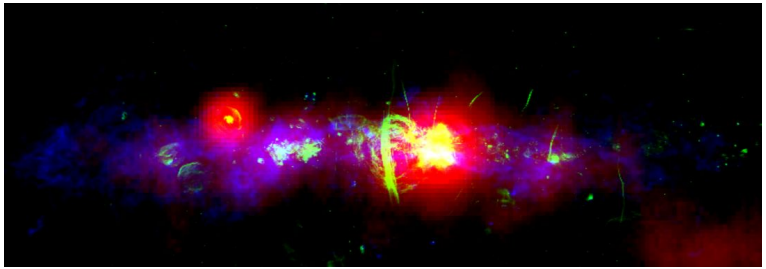




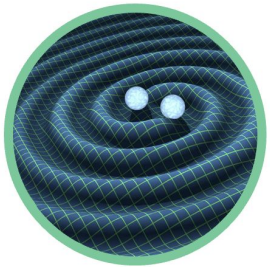
SWGO Science Benchmarks

- Transient sources: Gamma-ray bursts
- Galactic Accelerators:
  - PeVatrons
  - Pulsar Wind Nebulae and TeV Halos
- Diffuse Emission: Fermi Bubbles
- Fundamental Physics:
  - Dark matter from Galactic Center halo
- Cosmic rays: Mass-resolved dipole multi-pole anisotropy





Multi-messenger Astronomy

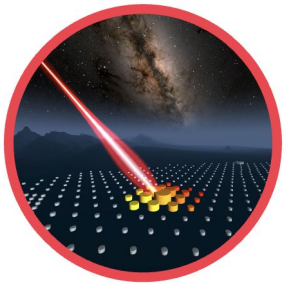


Gravitational Waves

- 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

Adapted from Jim Hinton

Comparison of WCD Options

A. White DLWCD (3.8 m diameter and 2.5 m depth)
   a. black top and an 8-inch PMT
B. A HAWC-like single-layered unit (7.3 m diameter and 4 m depth)
   a. black walls, central 10-inch PMT and three 8-inch PMTs
C. A LHAASO-like black unit (5 m × 5 m square, 4.5 m depth)
   a. open top and an 8-inch PMT
D. White DLWCD with alternative geometry (3.4 m diameter and 3.0 m depth)
   a. black top and an 8-inch PMT

Kunwar, et al.
A Double-layered Water Cherenkov Detector array for Gamma-ray astronomy,
Nuclear Instruments and Methods in Physics Research Section A,
Volume 1050,2023, 168138,