SWGO

The Southern Wide-field Gamma-ray Observatory

II EU Workshop on Water Cherenkov Experiments for Precision Physics – Sept. 2025

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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

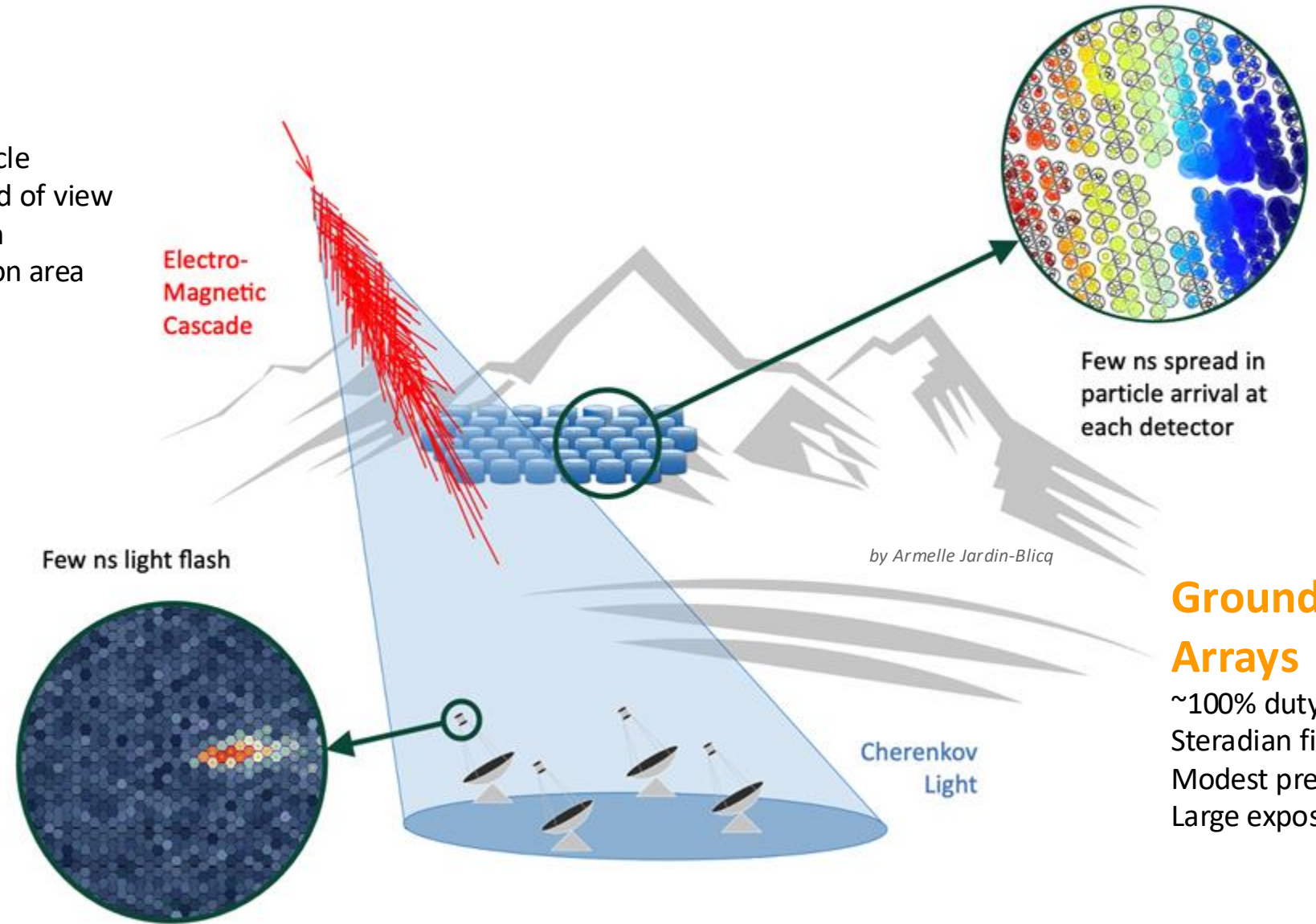
Axion-like Particles
Lorenz Invariance Violation
Dark Matter

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

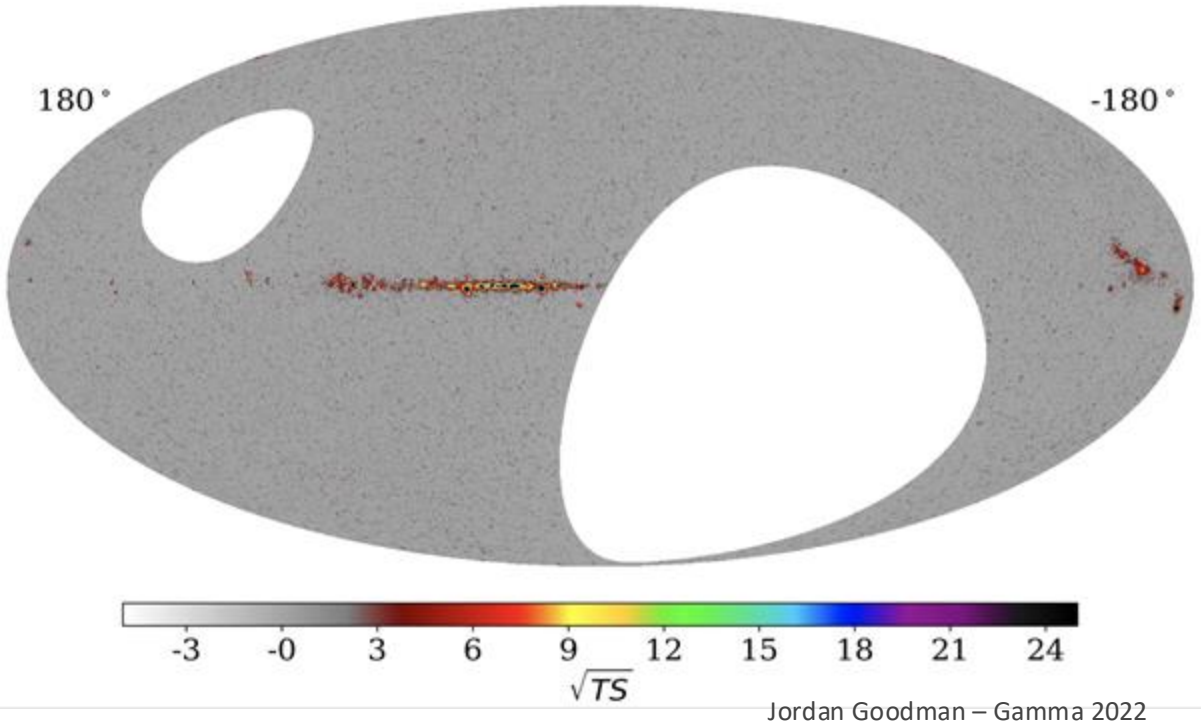


Ground Particle Arrays

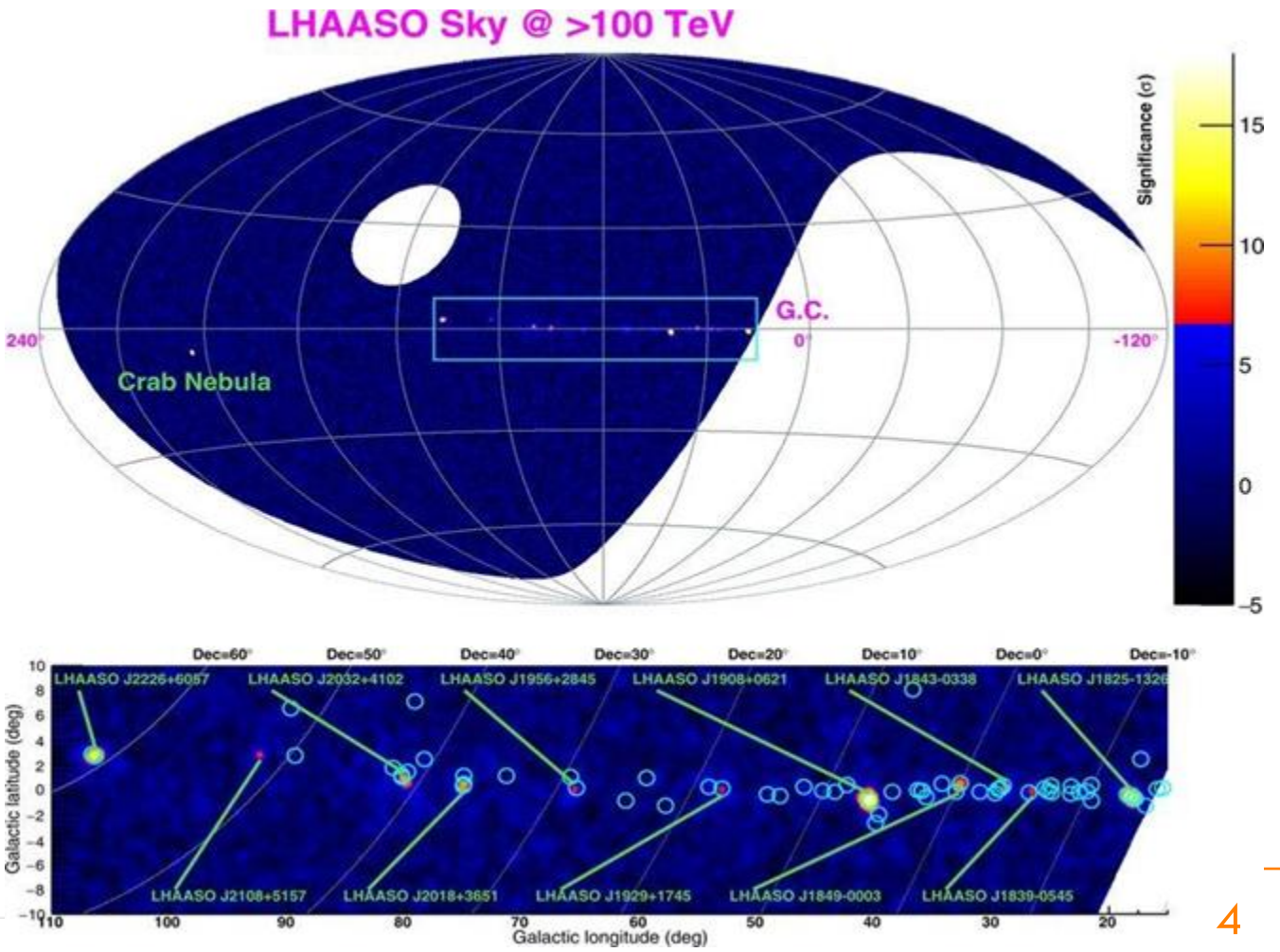
~100% duty-cycle
Steradian field of view
Modest precision
Large exposure

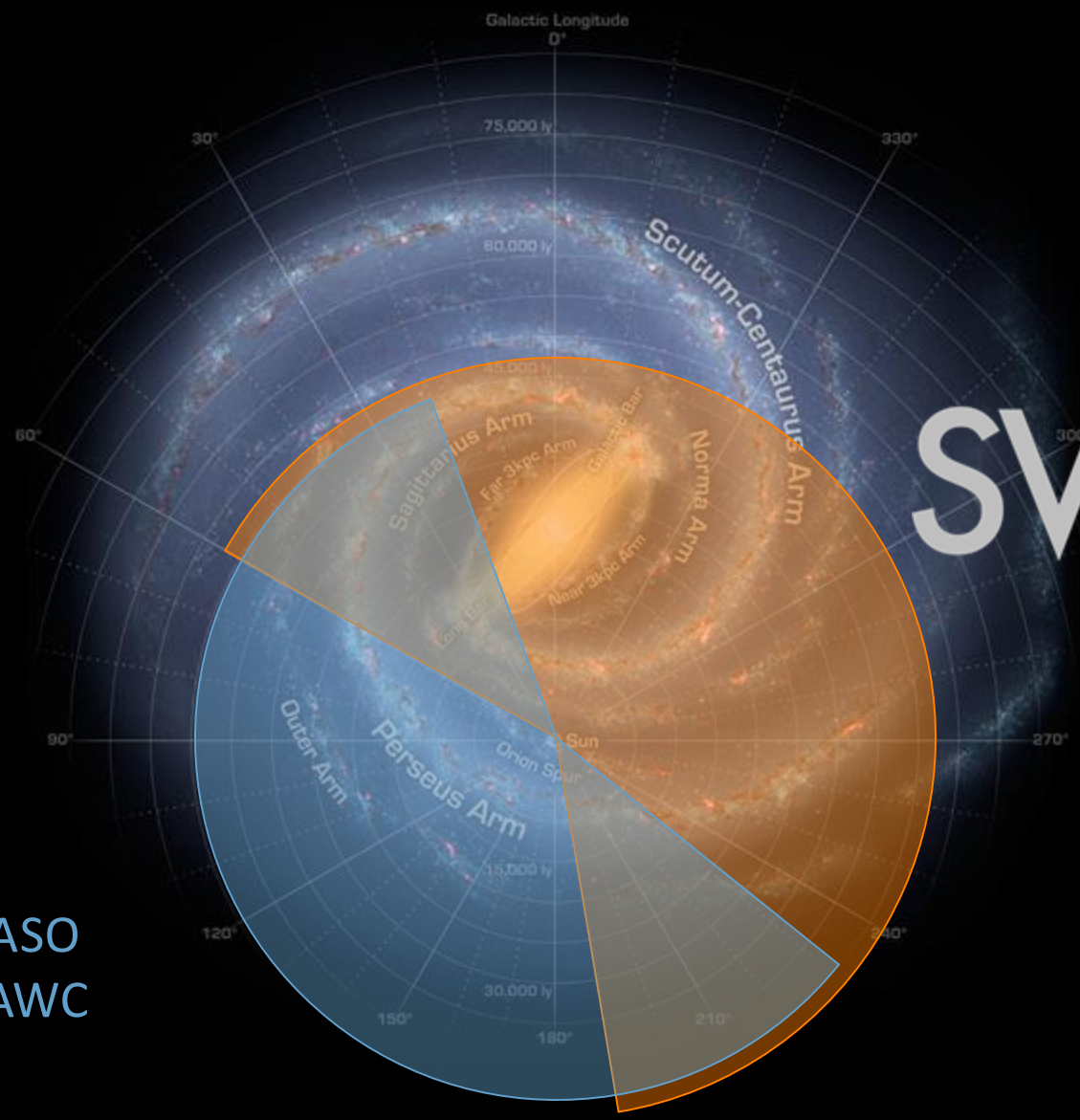
Current Water Cherenkov Detector Arrays

HAWC



LHAASO

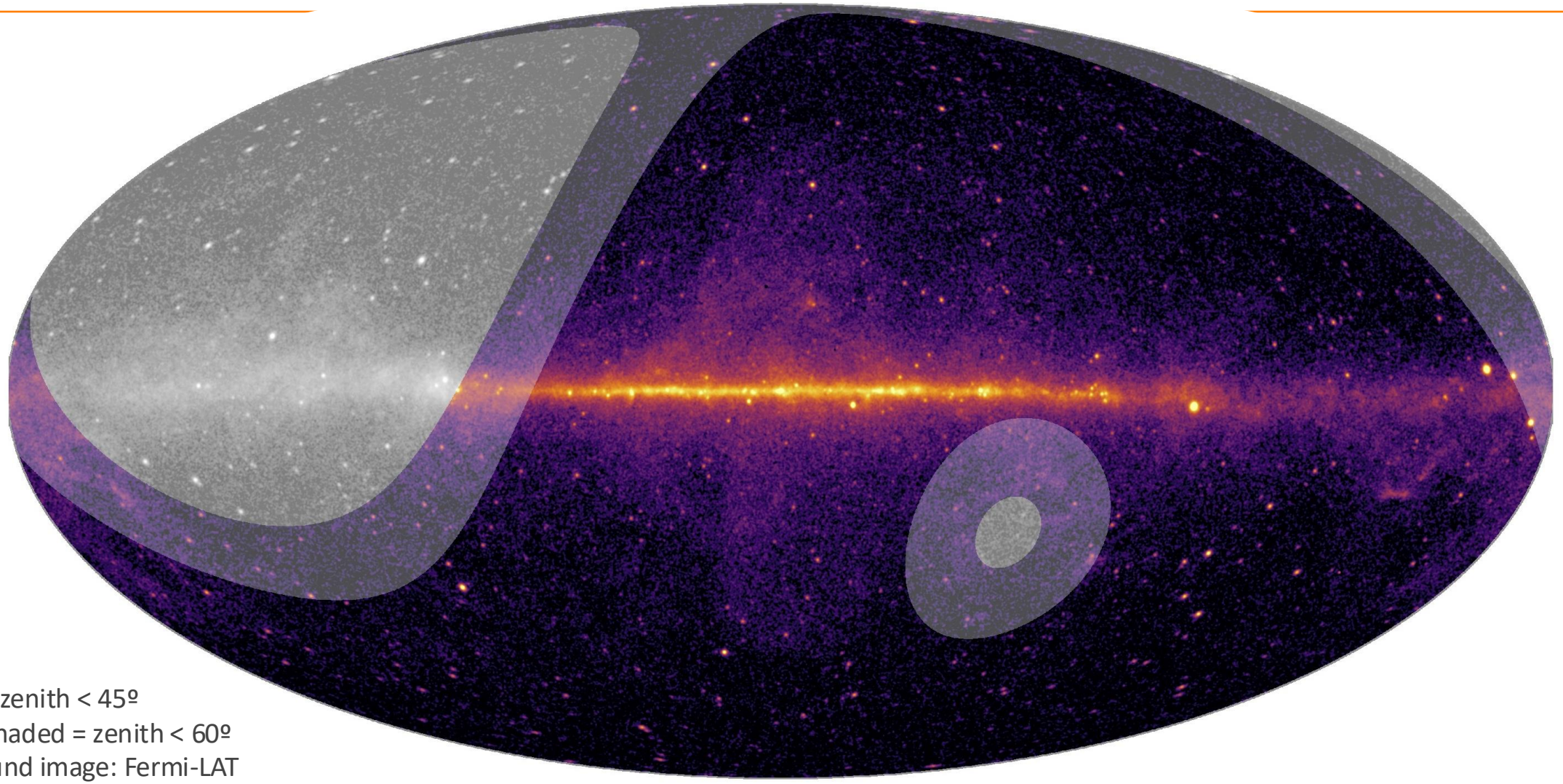




LHAASO
& HAWC

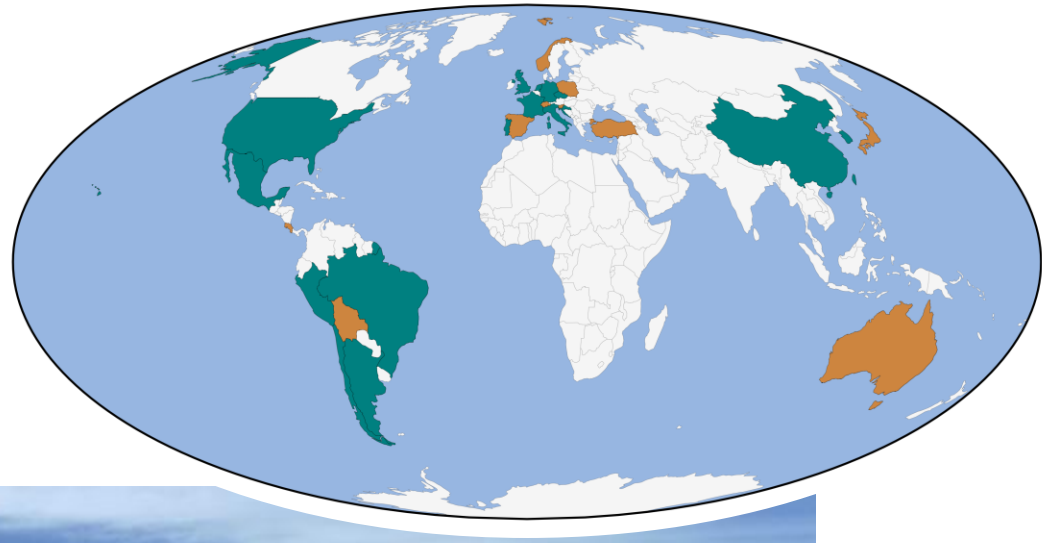
Up to 45 degree zenith angle

The SWGO Field



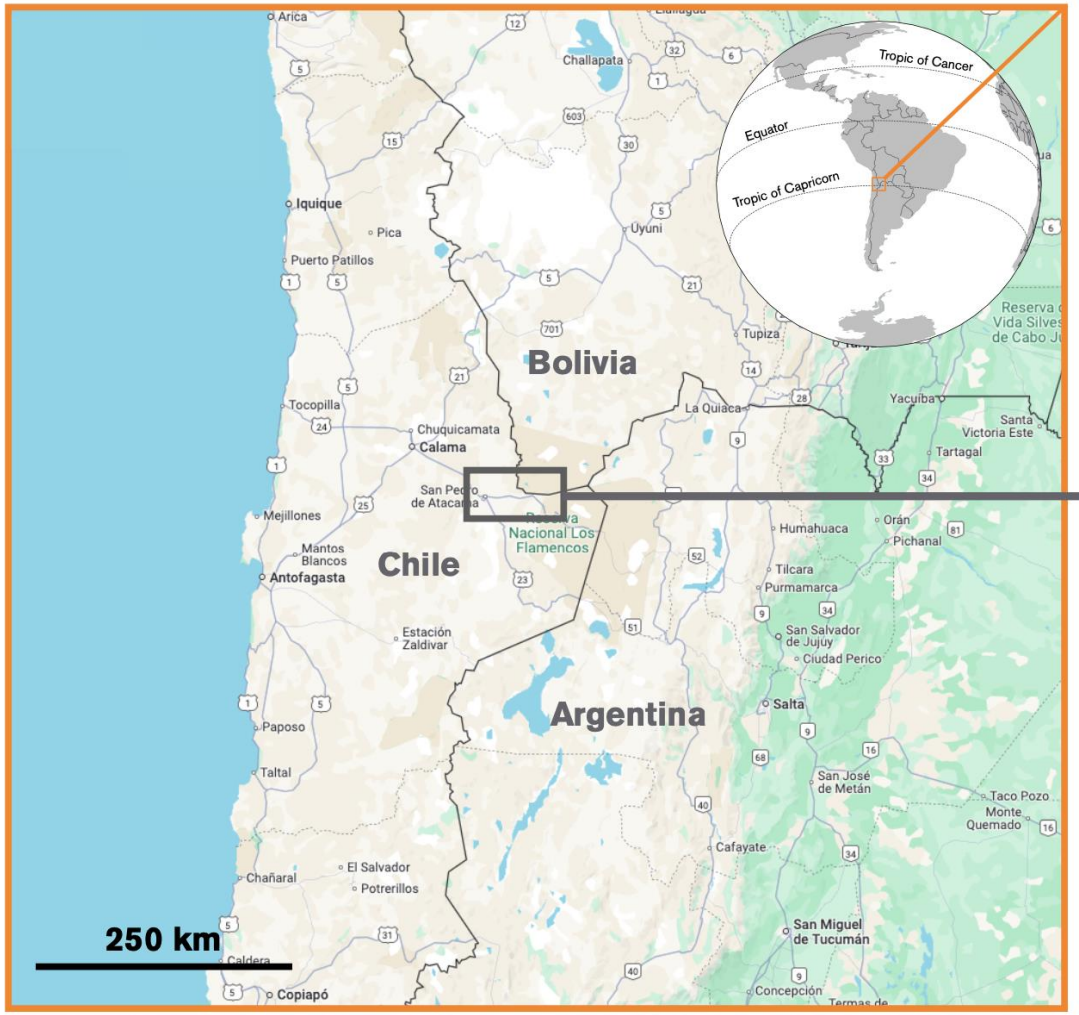
Colour = zenith < 45º
Colour-shaded = zenith < 60º
Background image: Fermi-LAT

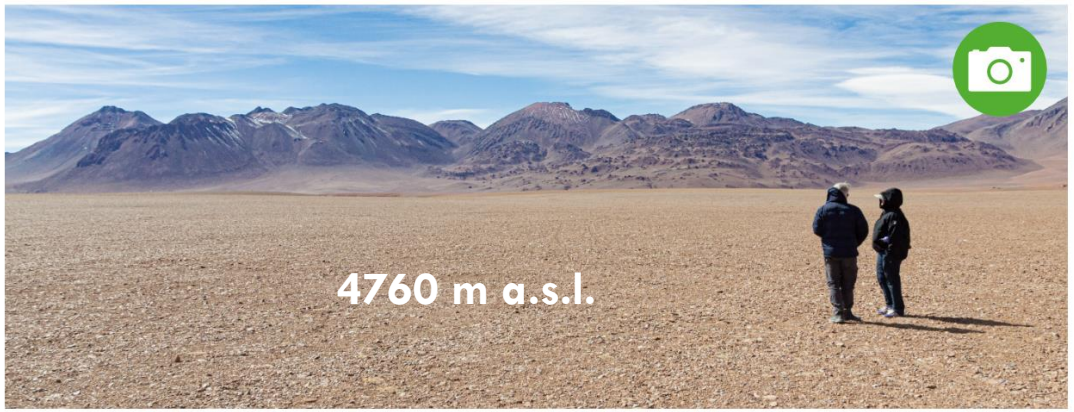
The Collaboration

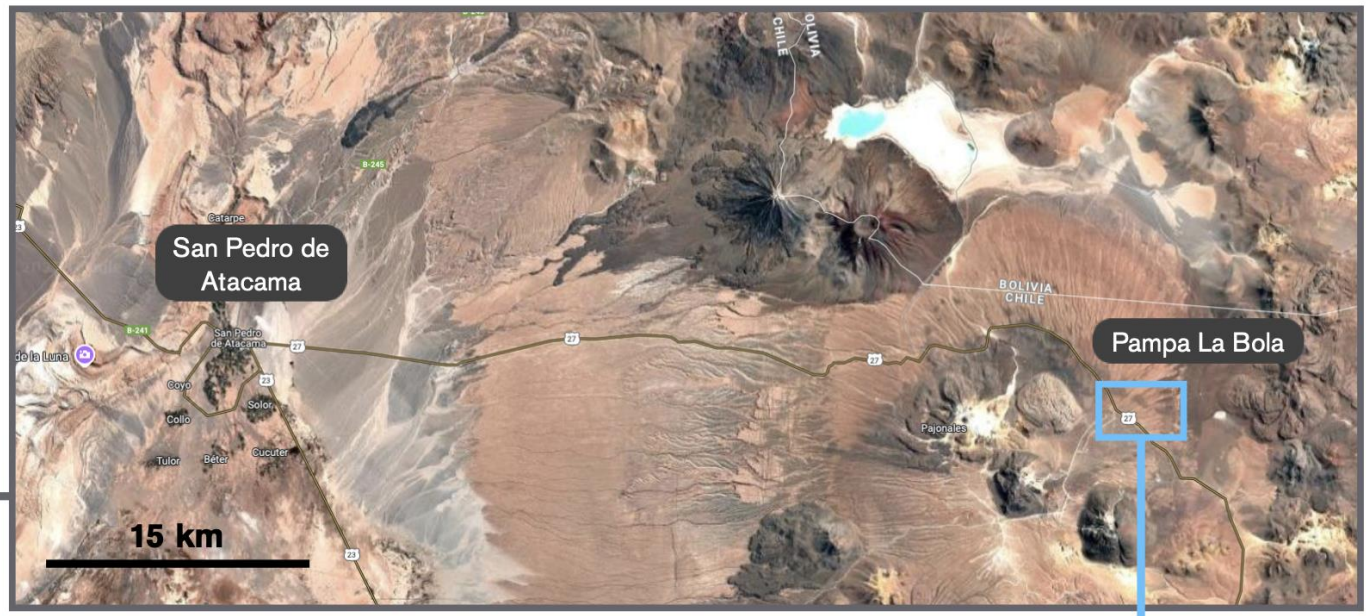


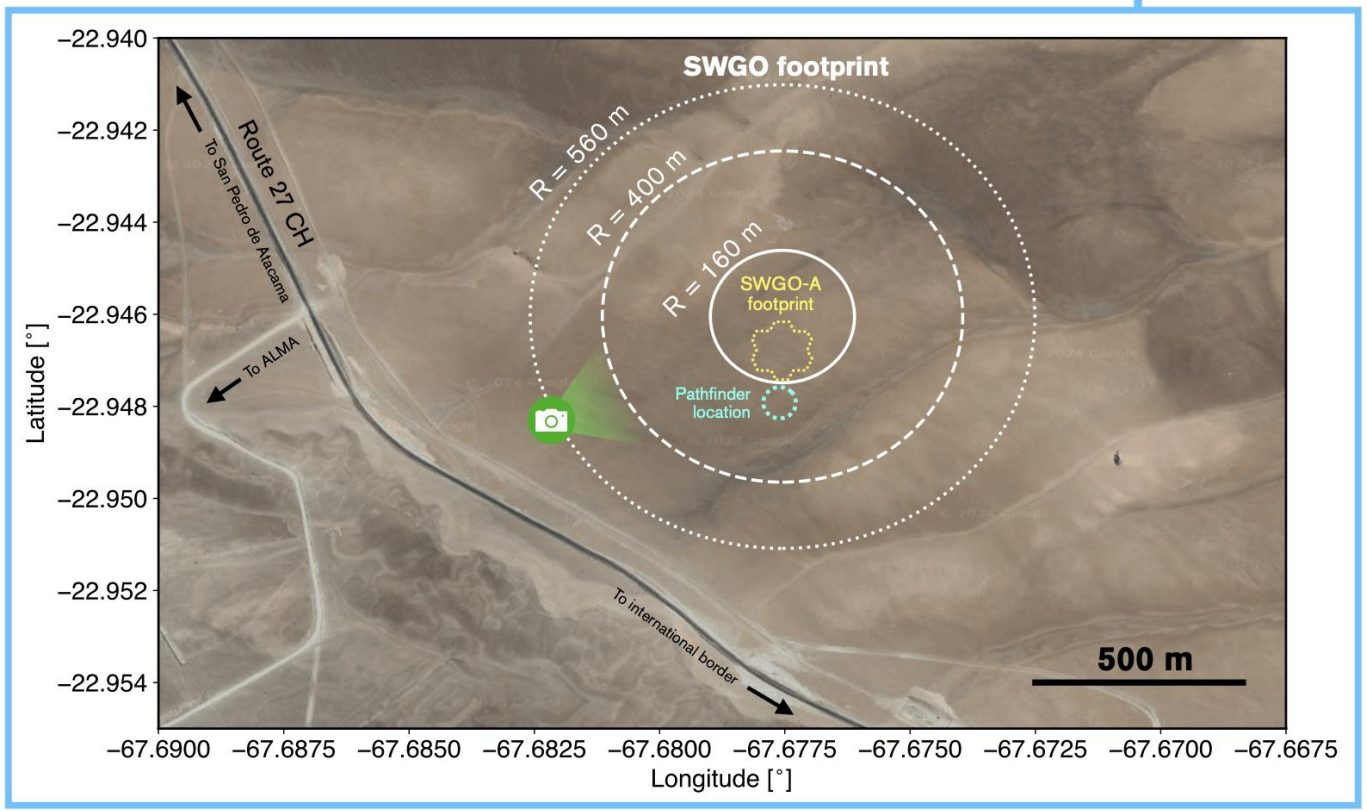
- Founded 2019, now 16 Countries

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


Tropic of Cancer
Equator
Tropic of Capricorn
Bolivia
Chile
Argentina
Iquique
Pica
Puerto Patillos
Uyuni
Tupiza
Tocopilla
Chuquicamata
Calama
La Quiaca
Yacuiba
Santa Victoria Este
Tartagal
San Pedro de Atacama
Mejillones
Reserva Nacional Los Flamencos
Humahuaca
Orán
Pichanal
Mantos Blancos
Antofagasta
Tilcara
Purmamarca
San Salvador de Jujuy
Ciudad Perico
Estación Zaldivar
Salta
Paposo
Taltal
San José de Metán
Taco Pozo
Monte Quemado
Cafayate
El Salvador
Chañaral
Potrerillos
San Miguel de Tucumán
Caldera
Copiapó
Concepción
250 km


4760 m a.s.l.

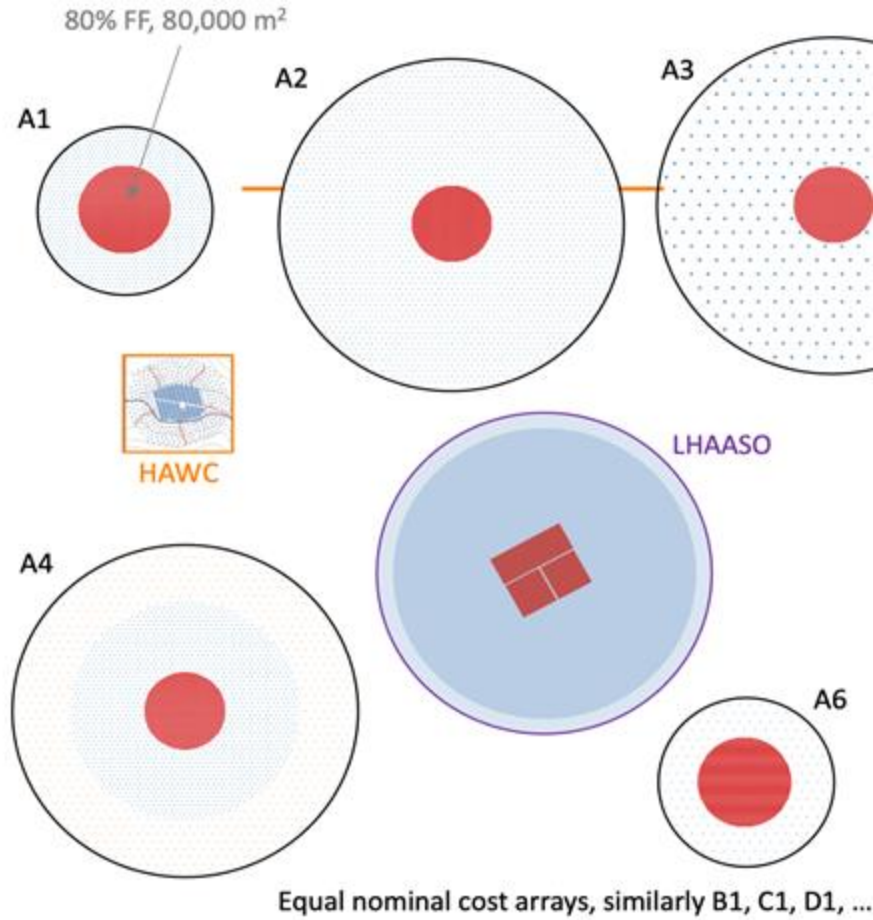

San Pedro de Atacama
Pampa La Bola
BOLIVIA
CHILE
Catarpe
Coyo
Solor
Collo
Tulor
Béter
Cucuter
Pajonales
15 km


SWGO footprint
Route 27 CH
To San Pedro de Atacama
To ALMA
To international border
R = 560 m
R = 400 m
R = 160 m
SWGO-A footprint
Pathfinder location
500 m
Latitude [°]
−22.940
−22.942
−22.944
−22.946
−22.948
−22.950
−22.952
−22.954
Longitude [°]
−67.6900
−67.6875
−67.6850
−67.6825
−67.6800
−67.6775
−67.6750
−67.6725
−67.6700
−67.6675

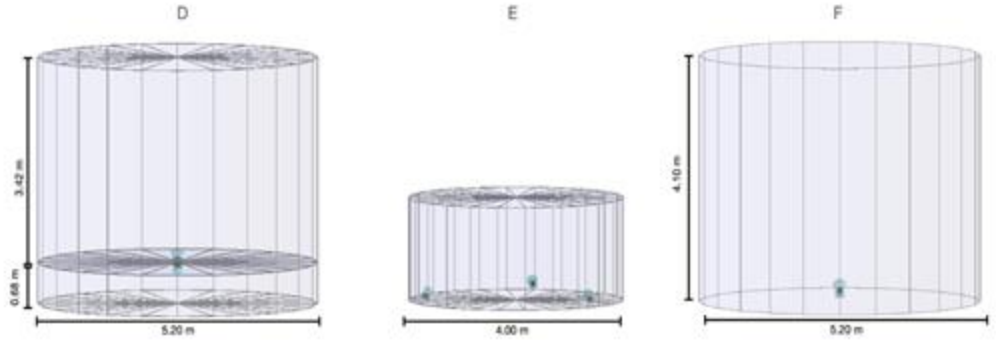
Design Optimisation

- Science performance based optimisation in a wide phase space
- Large scale simulations with
  - → 6 detector unit options, single and double layer Cherenkov detectors
  - → 7 layouts, now fine-tuning
- Convergence on inner (>50% fill factor) array
- Optimisation work still ongoing for the outer (0.5-5% fill factor) array

Water Cherenkov clearly favoured on cost/performance grounds

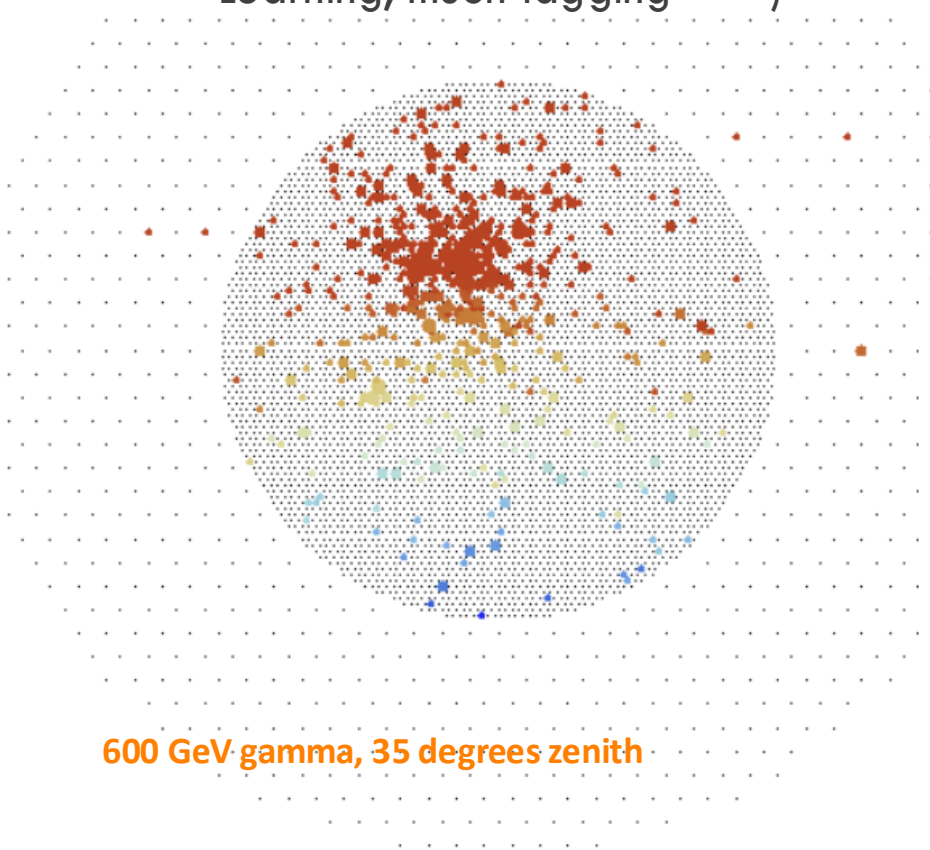


Equal nominal cost arrays, similarly B1, C1, D1, ...

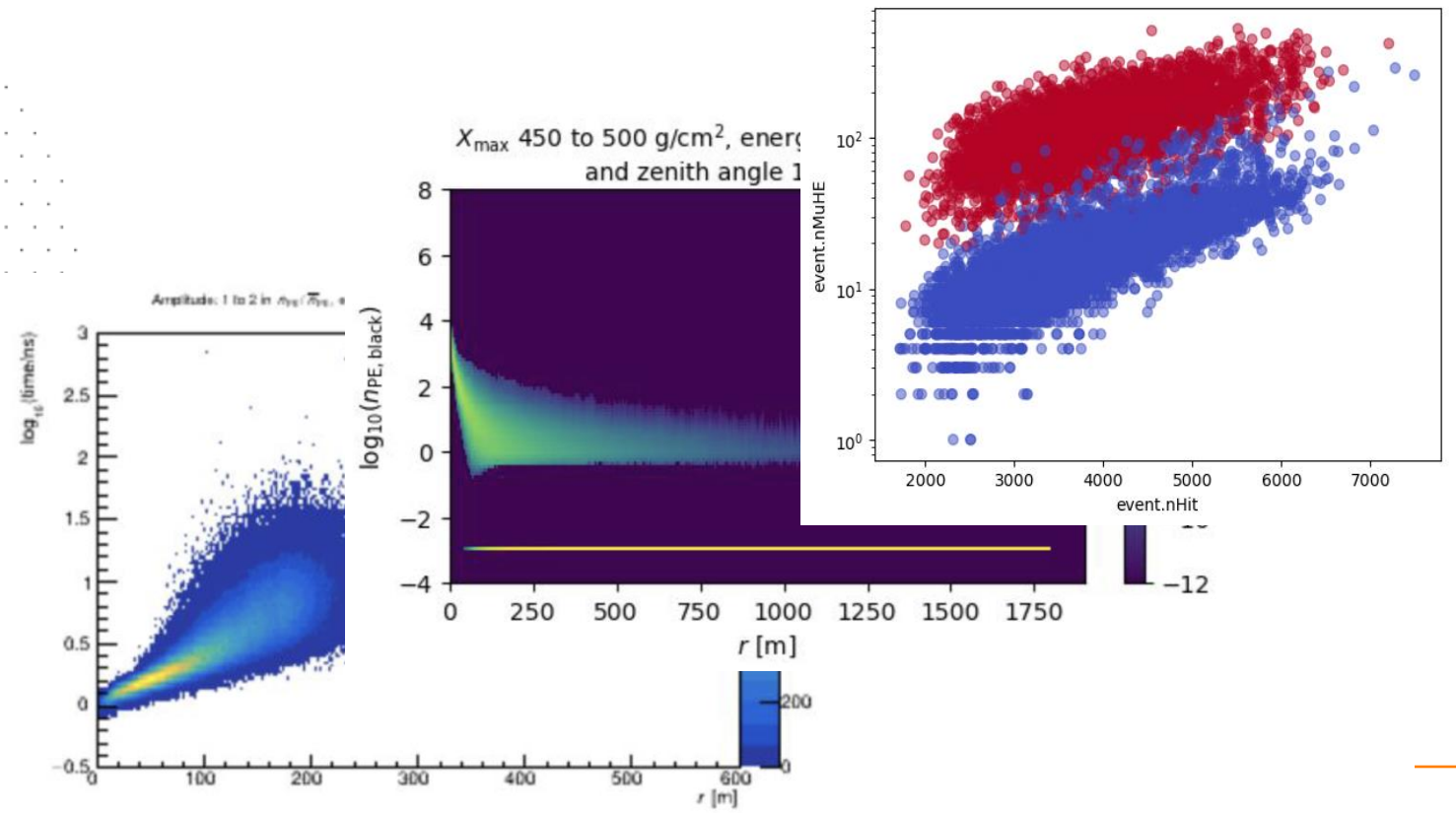


Data Analysis

- 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+++)

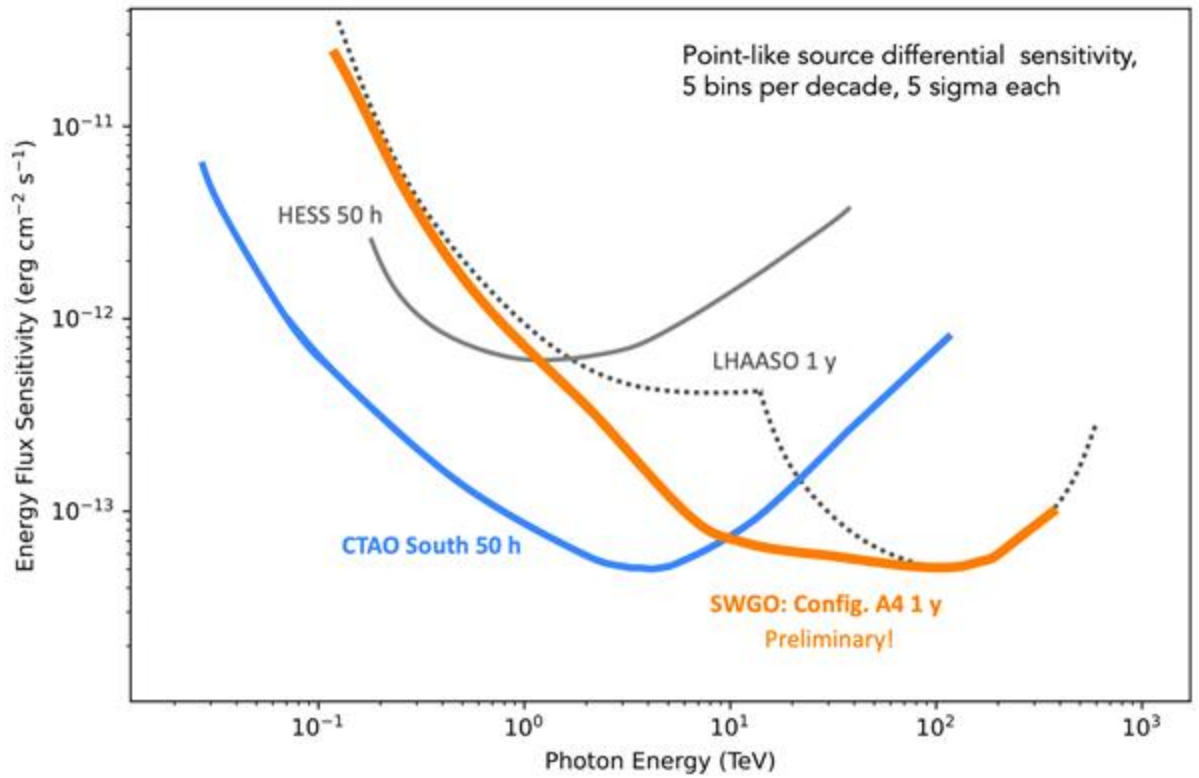


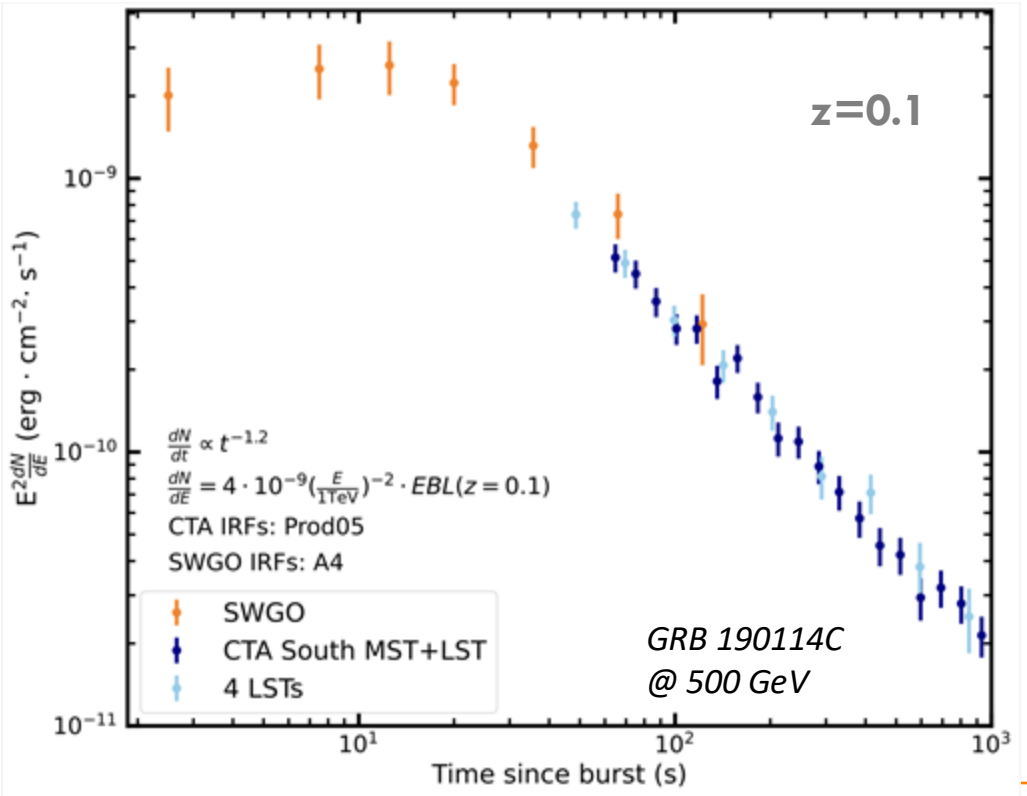
600 GeV gamma, 35 degrees zenith



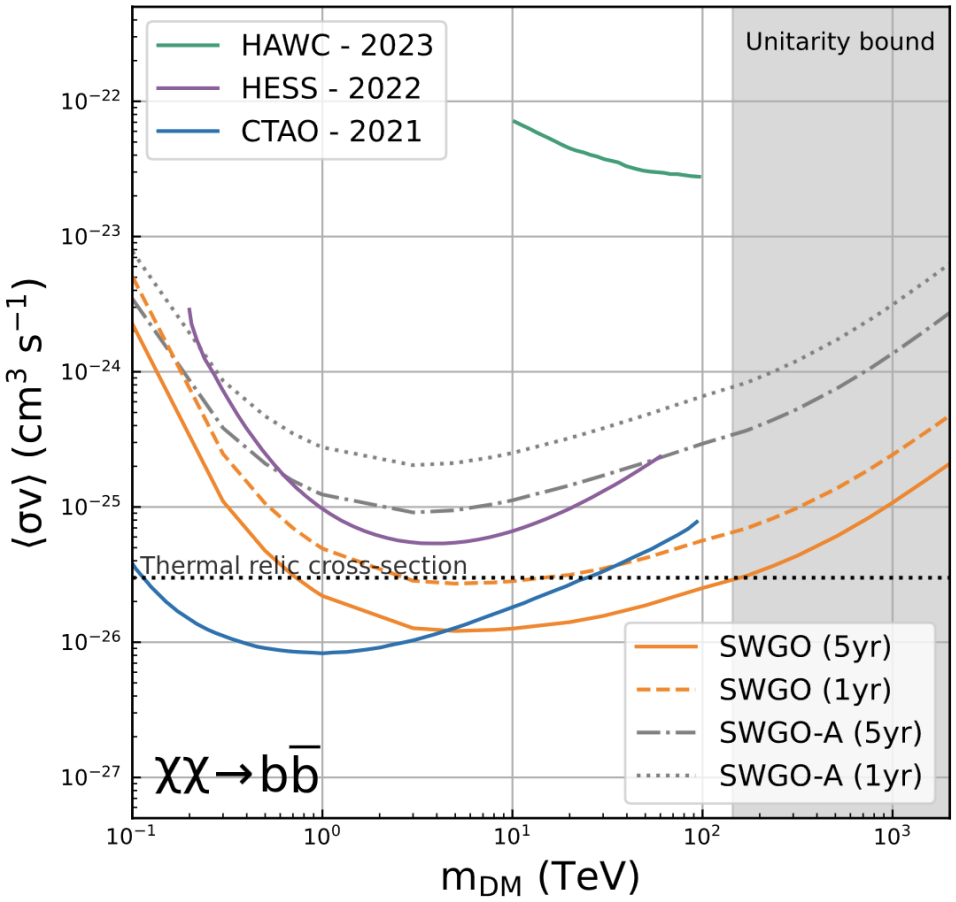
Expected Science Performance

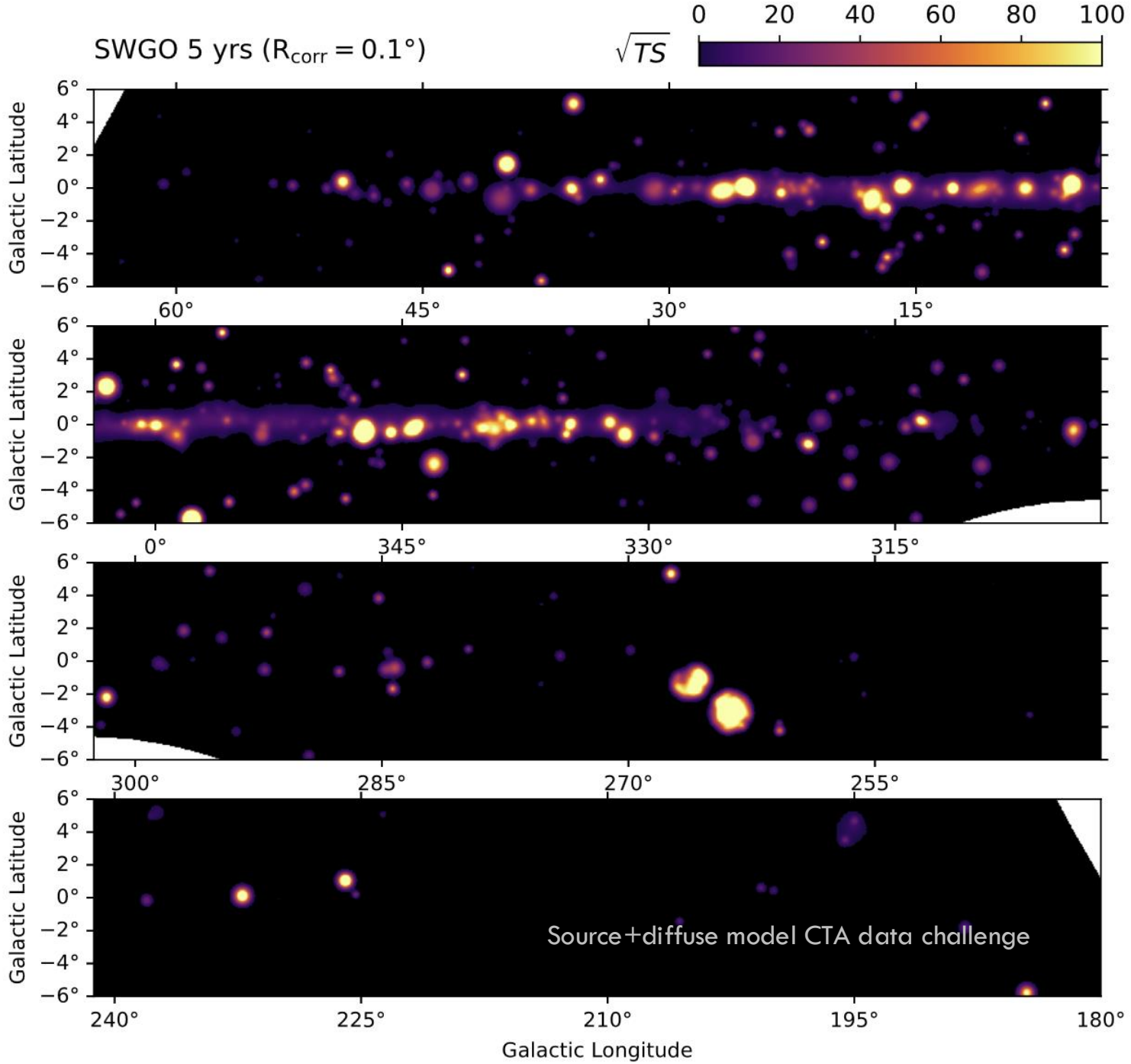
- Strong complementary at CTAO South
  - SWGO: High duty cycle & no trigger, UHE sensitivity, CTA: low E and resolution





SWGO Science

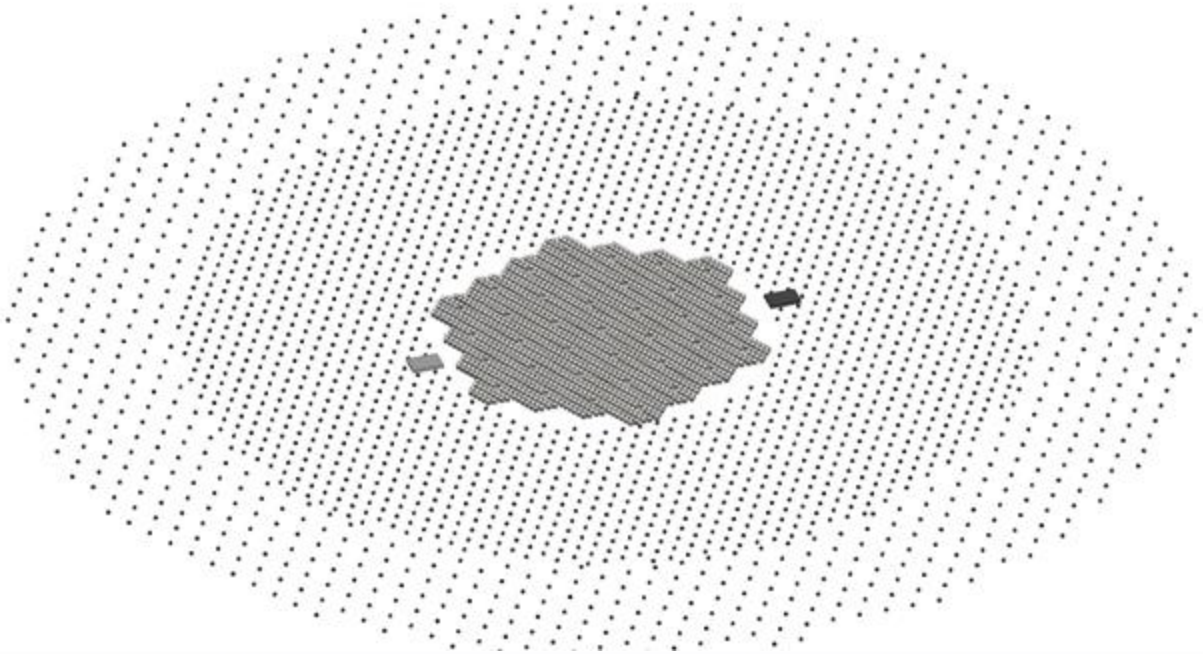




Baseline Array Layout

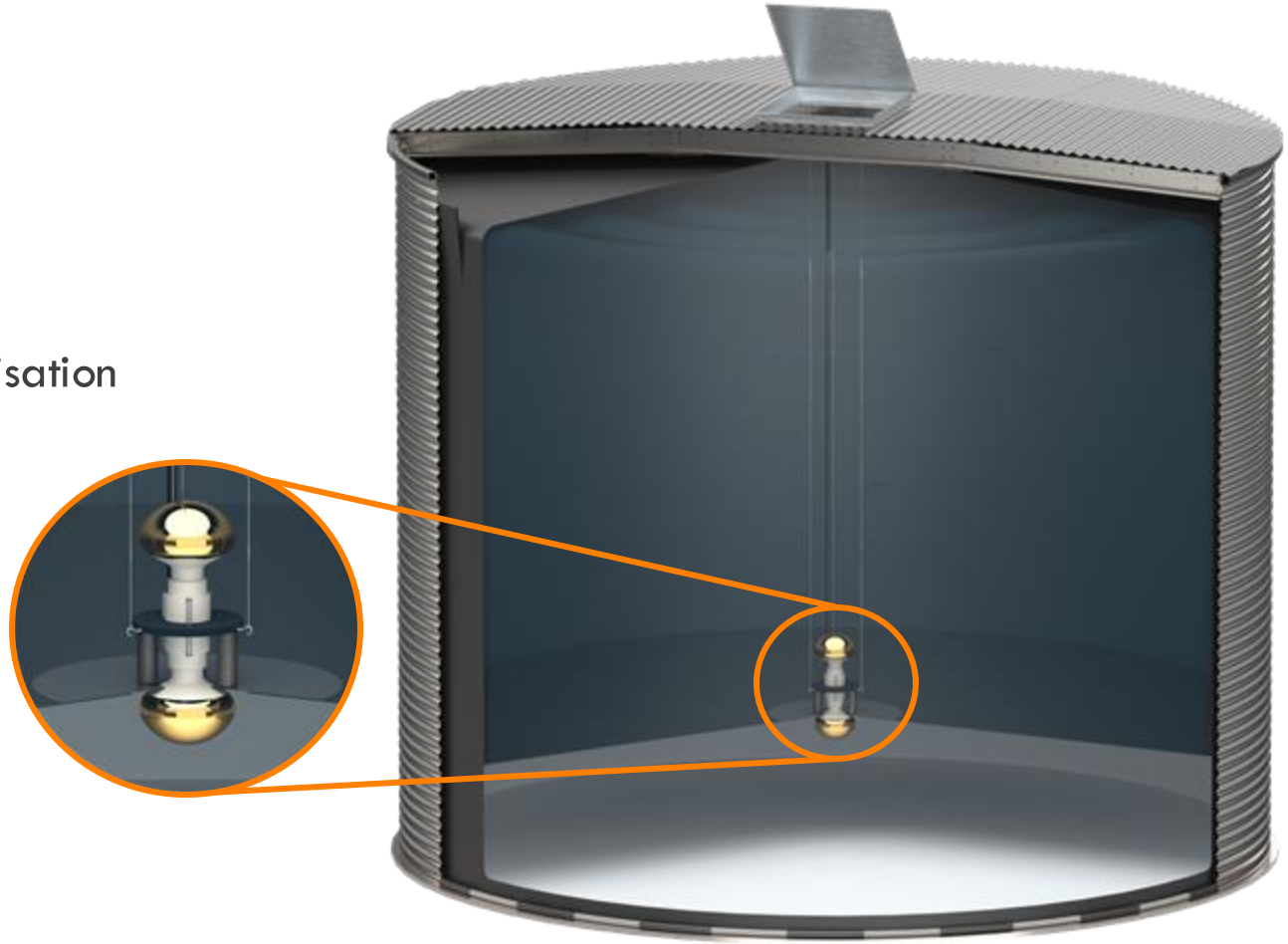
Three zones:

- Inner array:
  - FF=65%, R= 156 m, 2587 tanks
- Outer array:
  - FF= 4%, R= 400 m, 792 tanks
  - FF= 1.6%, R= 560 m, 384 tanks



Inner Array Baseline Design

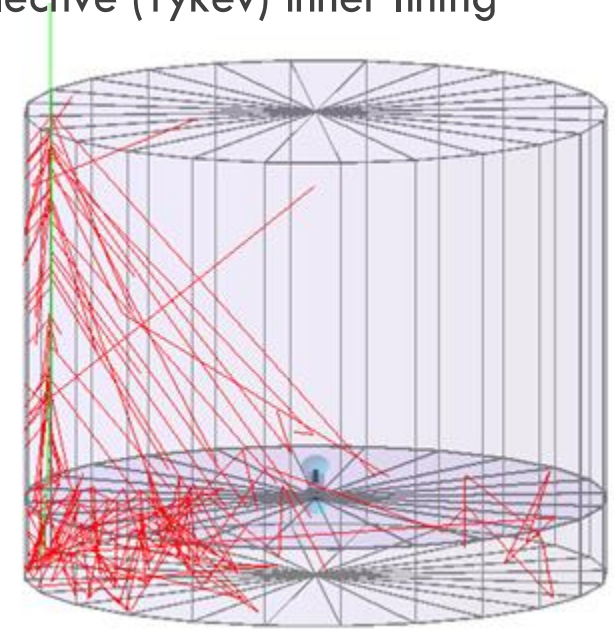
- Steel tanks assembled on site
  - 5.2 m Ø, 4.1m height
- Double-PMT unit in each detector
  - 10-inch PMTs
- Signals collected at Field Nodes
  - Serve 55 WCDs each, 250 MS/s digitisation



Inner Array 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

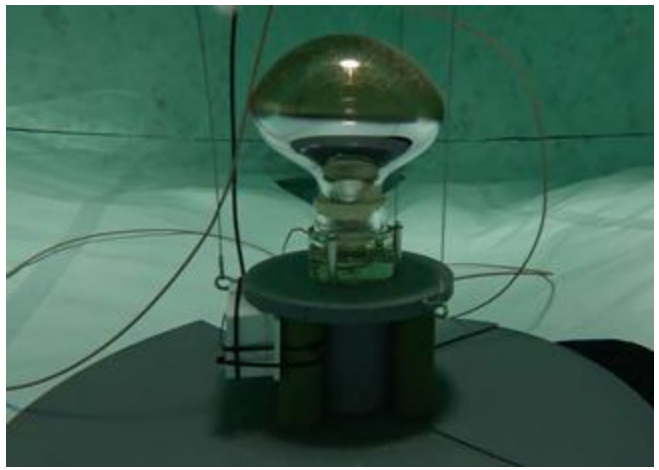


Inflated with air to check for light leaks

Prototyping work

- Low Altitude Test Sites: MPIK

Scintillator based muon-taggers in a trench under the tank



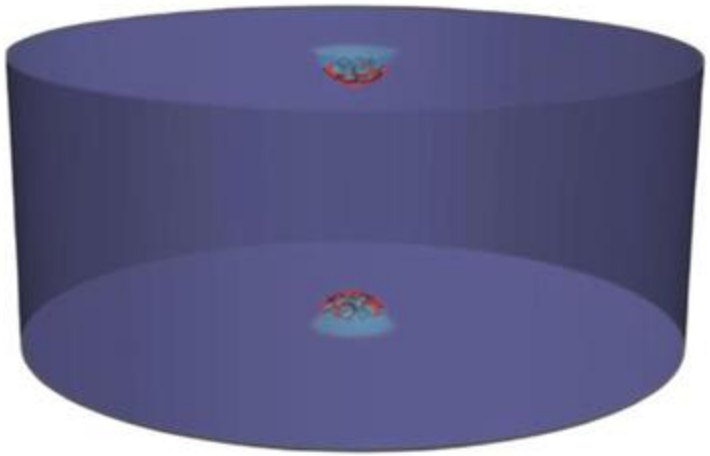
Also in Brazil, Italy, USA

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 multiple 3” PMT module

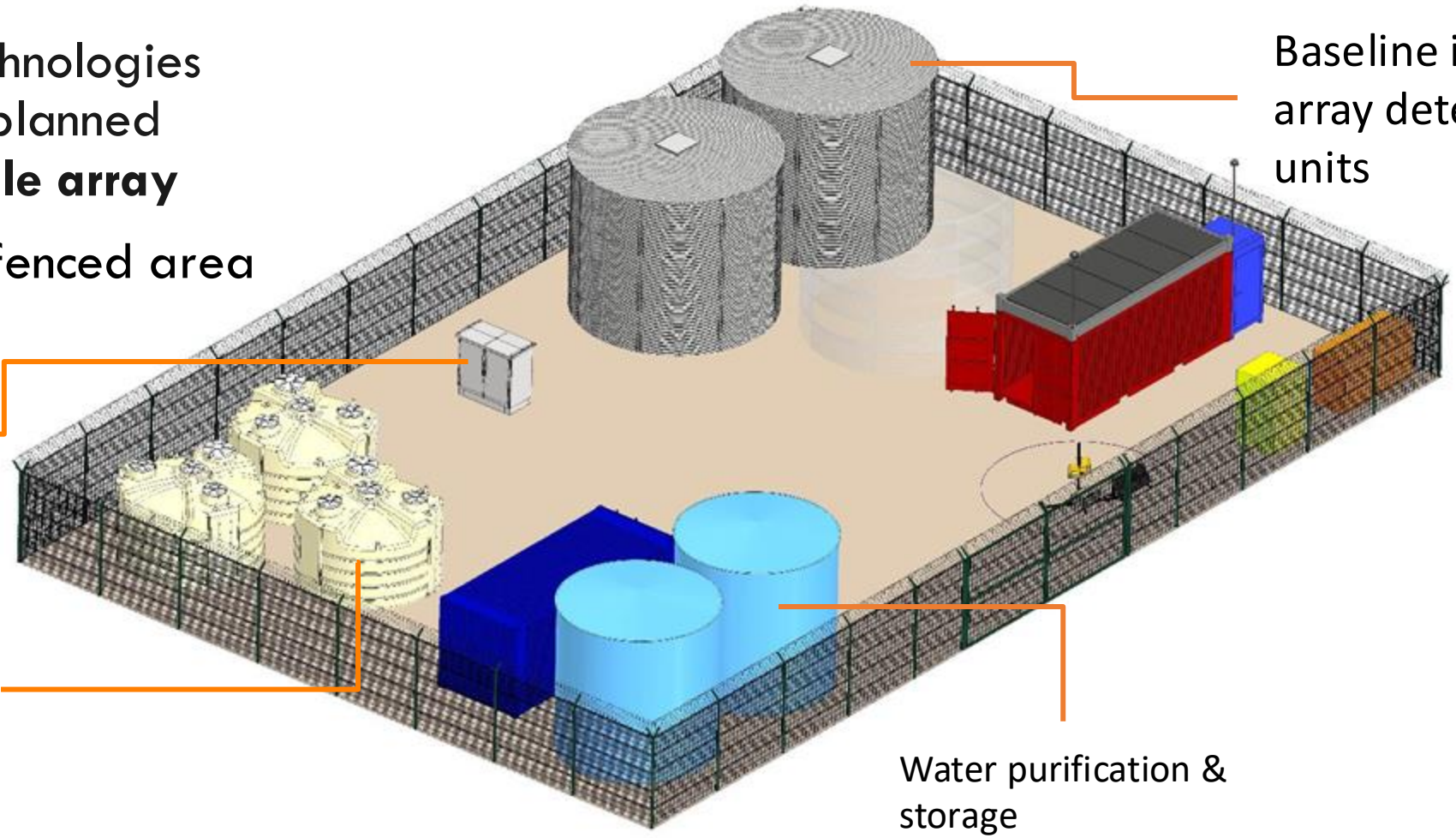
    Heritage from KM3Net, Hyper-K, ++



First step on-site: the Pathfinder

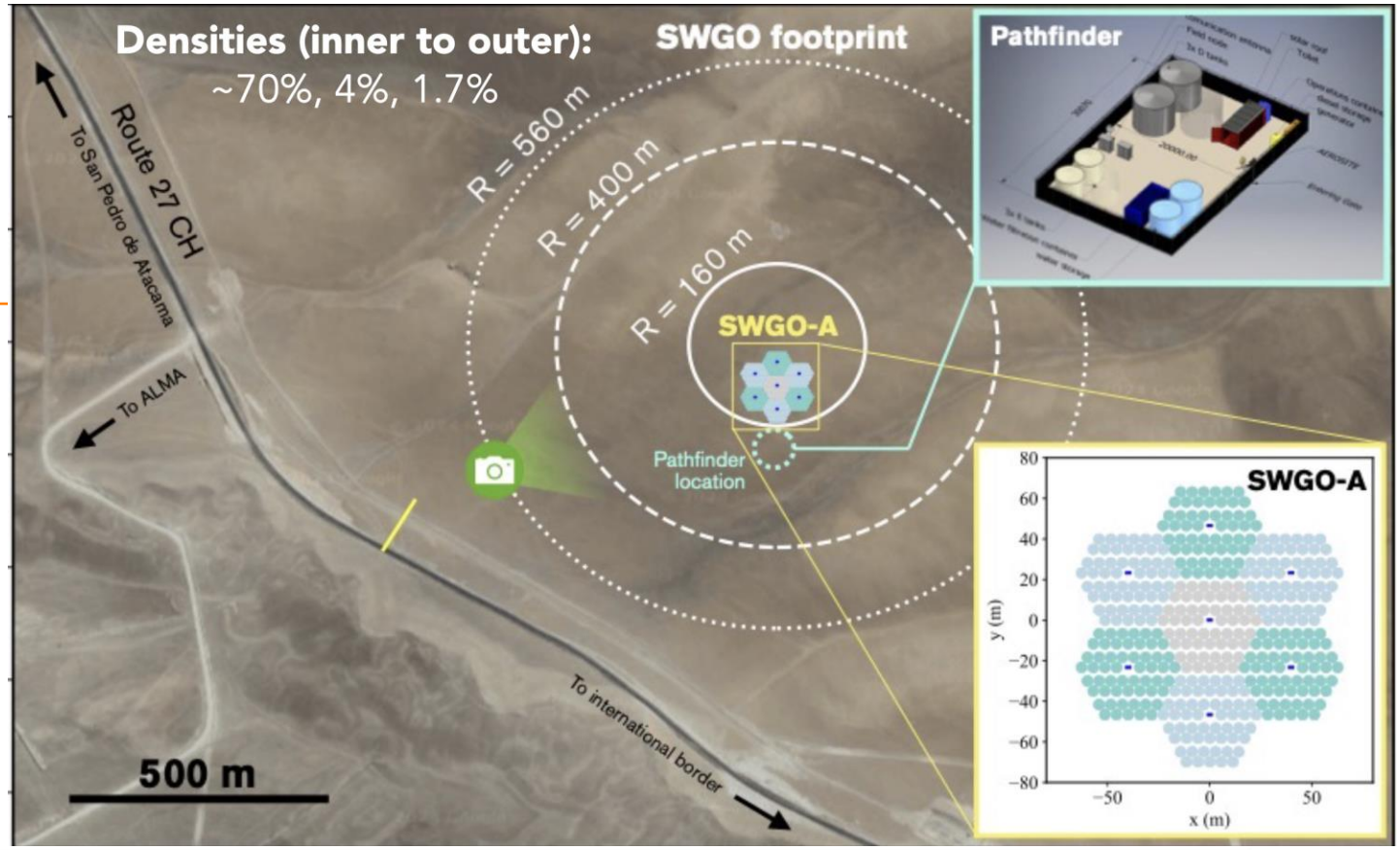
To validate technologies & procedures planned for the **full-scale array**

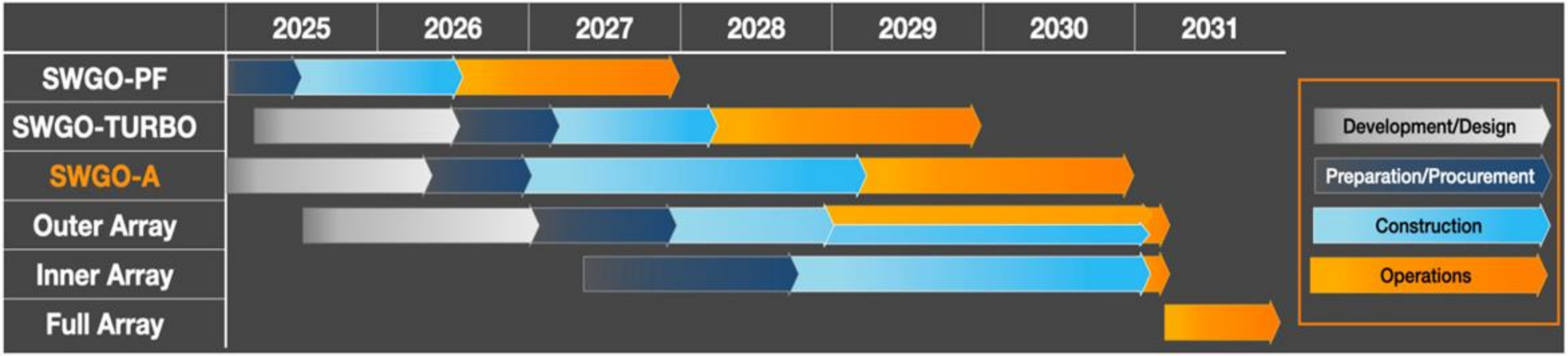
- 20x30m fenced area



SWGO Stages

- Beyond the pathfinder:
  - SWGO-A – 385 WCDs in inner array
  - Outer WCD engineering array ~50 tanks
  - 800 radio antennae array (SWGO-TURBO)
  - Construction to full scale as funding allows





Summary

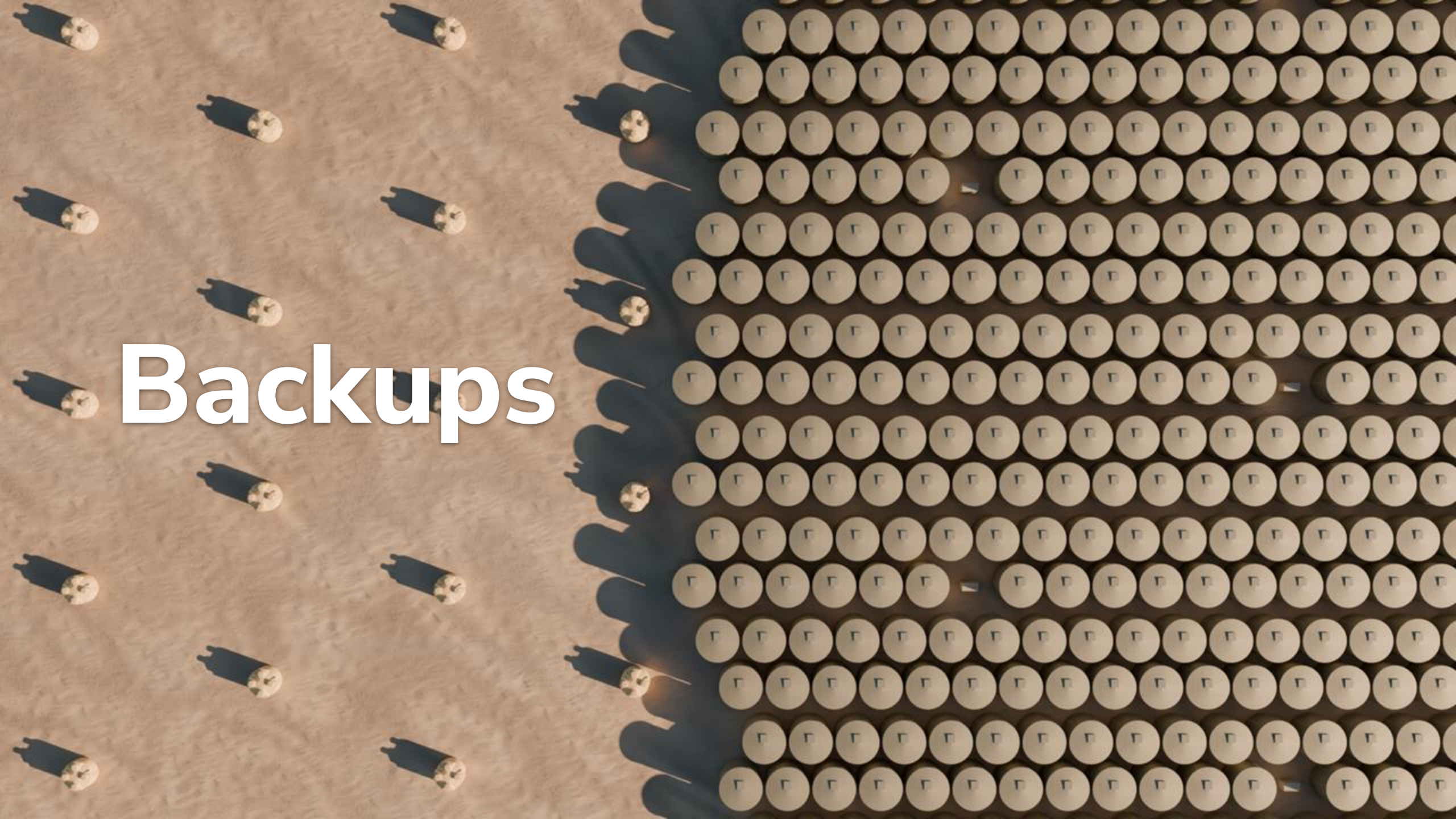
- SWGO brings the successful wide-field gamma-ray approach to a new hemisphere – the first major instrument of this type in the south
  - → Targeting inner galaxy, galactic centre, dark matter, GRBs, PeV sources, +++
  - → Strongly complementary to neighbouring CTAO South
  - → See science case white paper for details: https://arxiv.org/abs/2506.01786
- Now approaching construction
  - → Pathfinder at Pampa La Bola completed 2026
  - → SWGO-A construction from 2027 with NSF support
    - ✓ Sensitivity >HAWC in a new hemisphere

SWGO
The Southern Wide-field Gamma-ray Observatory

MAX-PLANCK-INSTITUT FÜR KERNPHYSIK

Thank you!

11th Collaboration Meeting -
Heidelberg, Germany, September 2024



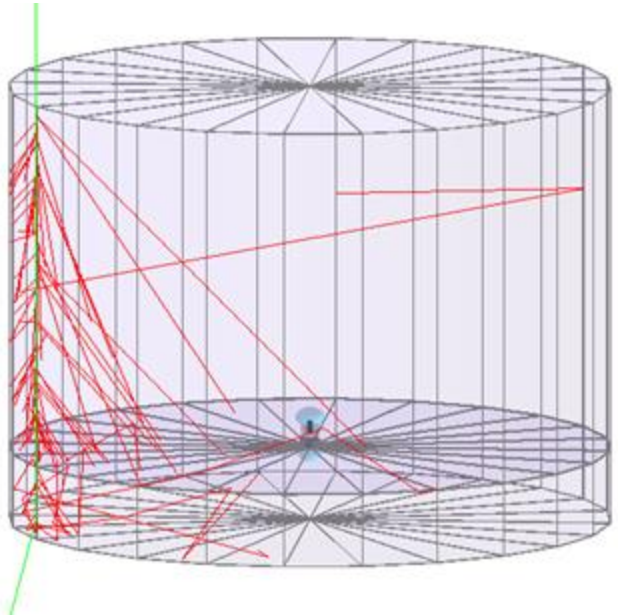
Backups

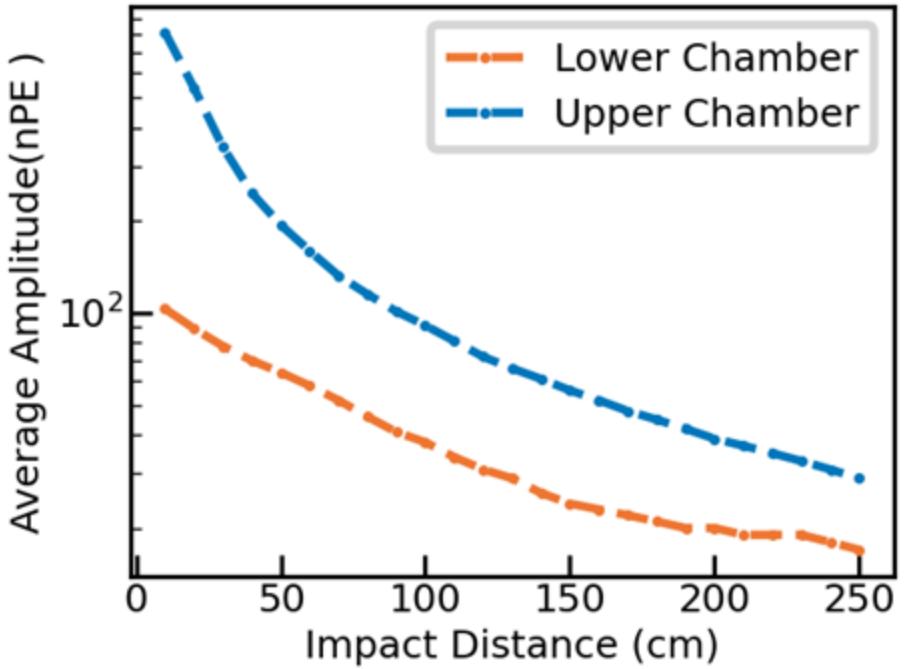
ALPACA

- 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.

WCD response

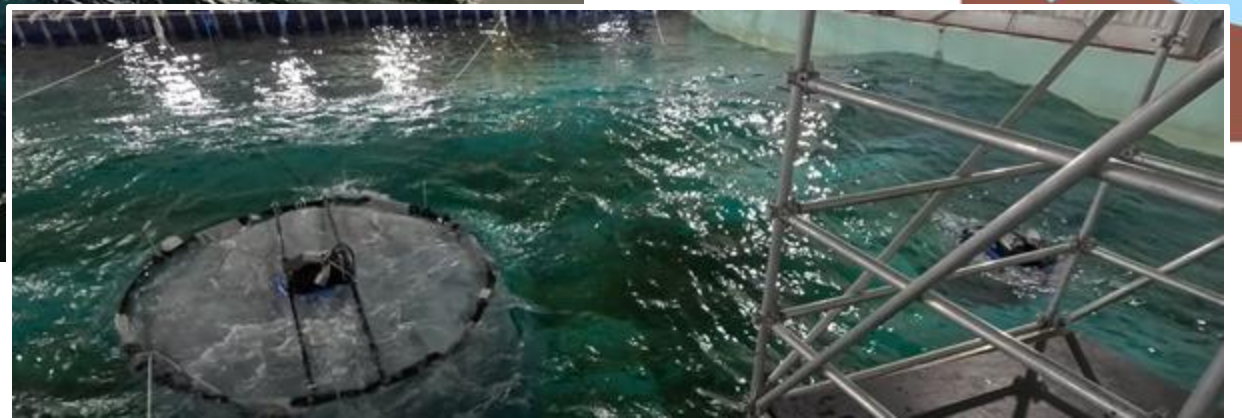
- 1-2 GeV vertical muons
- Response uniformity:



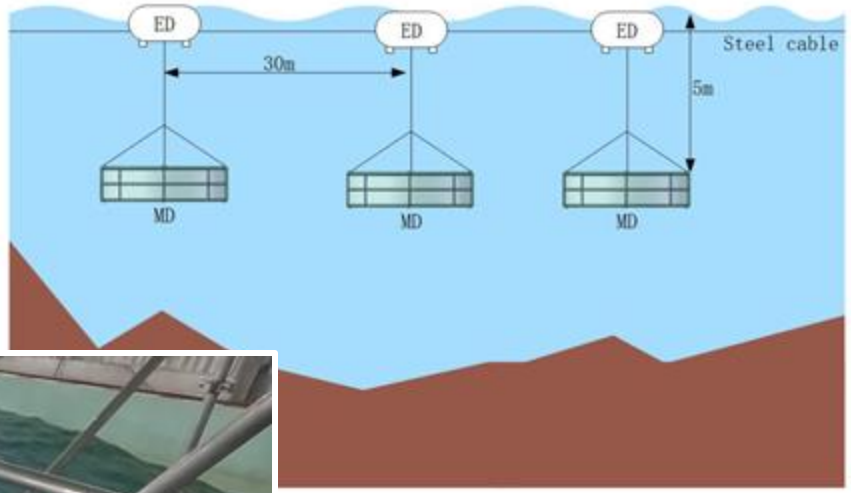


UHE Extension in a Lake under study

- 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



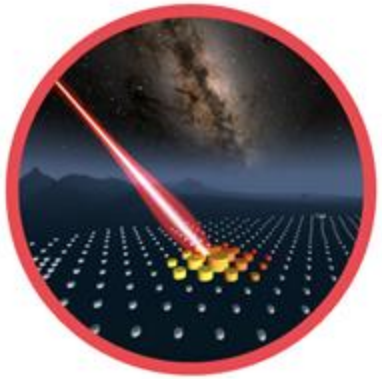
Multi-messenger astronomy with SWGO+

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

Electronics