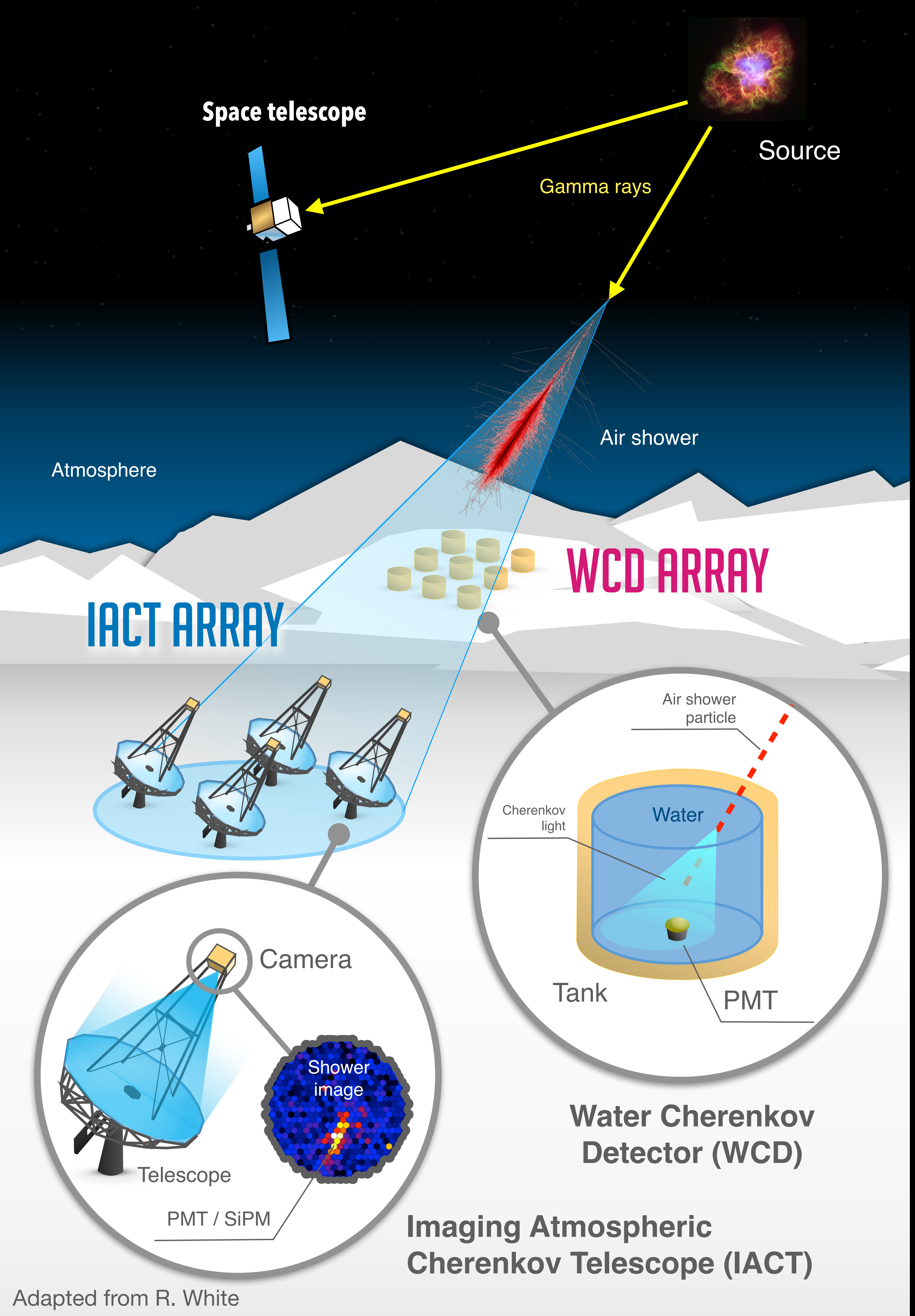
The Southern Wide-field Gamma-ray Observatory

Marcos Santander (University of Alabama)



Detection techniques in VHE astronomy

- VHE astronomy requires **large effective areas (>10^5 m^2)**, mostly limited to ground-based options.
- **Particle detection technique**
  - Wide field of view (~ 2 sr)
  - High duty cycle (~100%)
- **Imaging Atmospheric Cherenkov technique**
  - Good angular resolution (0.1° or better)
  - Good energy resolution O(10%)
  - Low energy threshold (> 20 GeV)

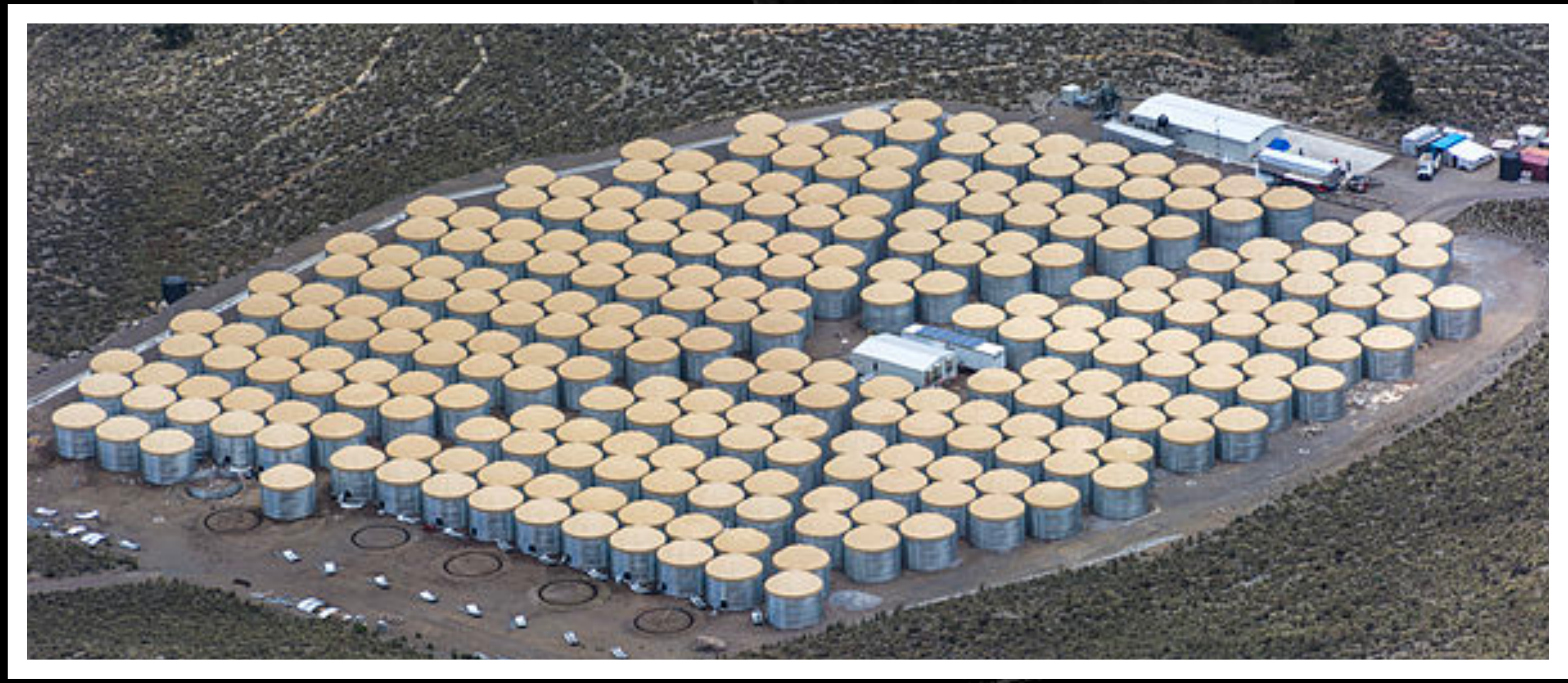
CURRENT VHE INSTRUMENTS

LHAASO
(Sichuan province, China)
4,410 m.a.s.l.

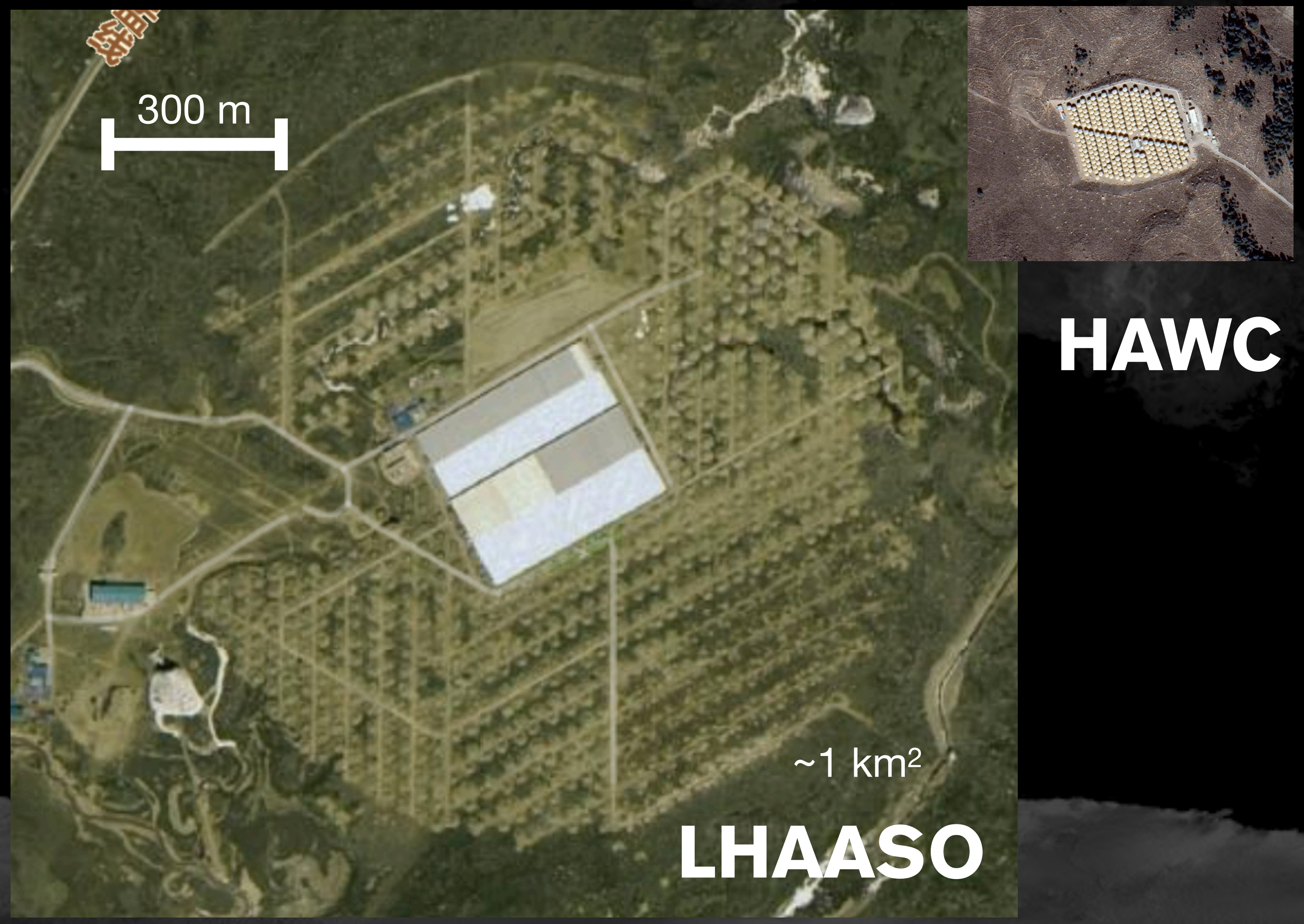
LHAASO

HAWC

Equator



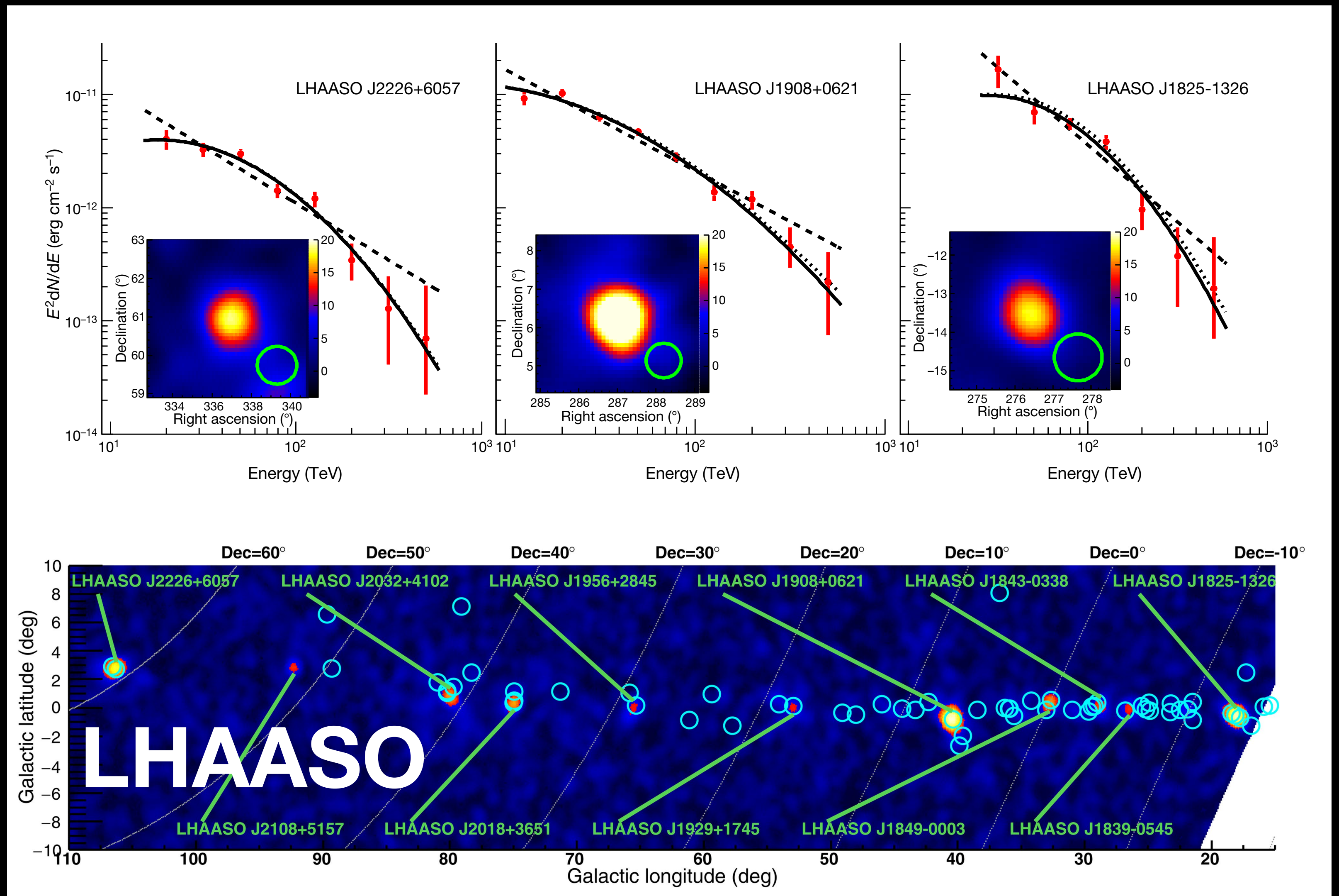
HAWC
(near Puebla, Mexico)
4,100 m.a.s.l.

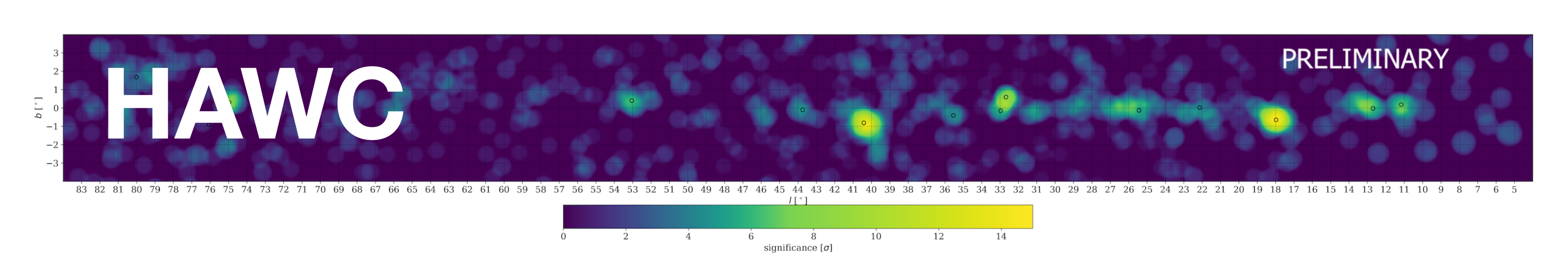


Recent highlights from HAWC and LHAASO

Observations of gamma-ray sources > 100 TeV

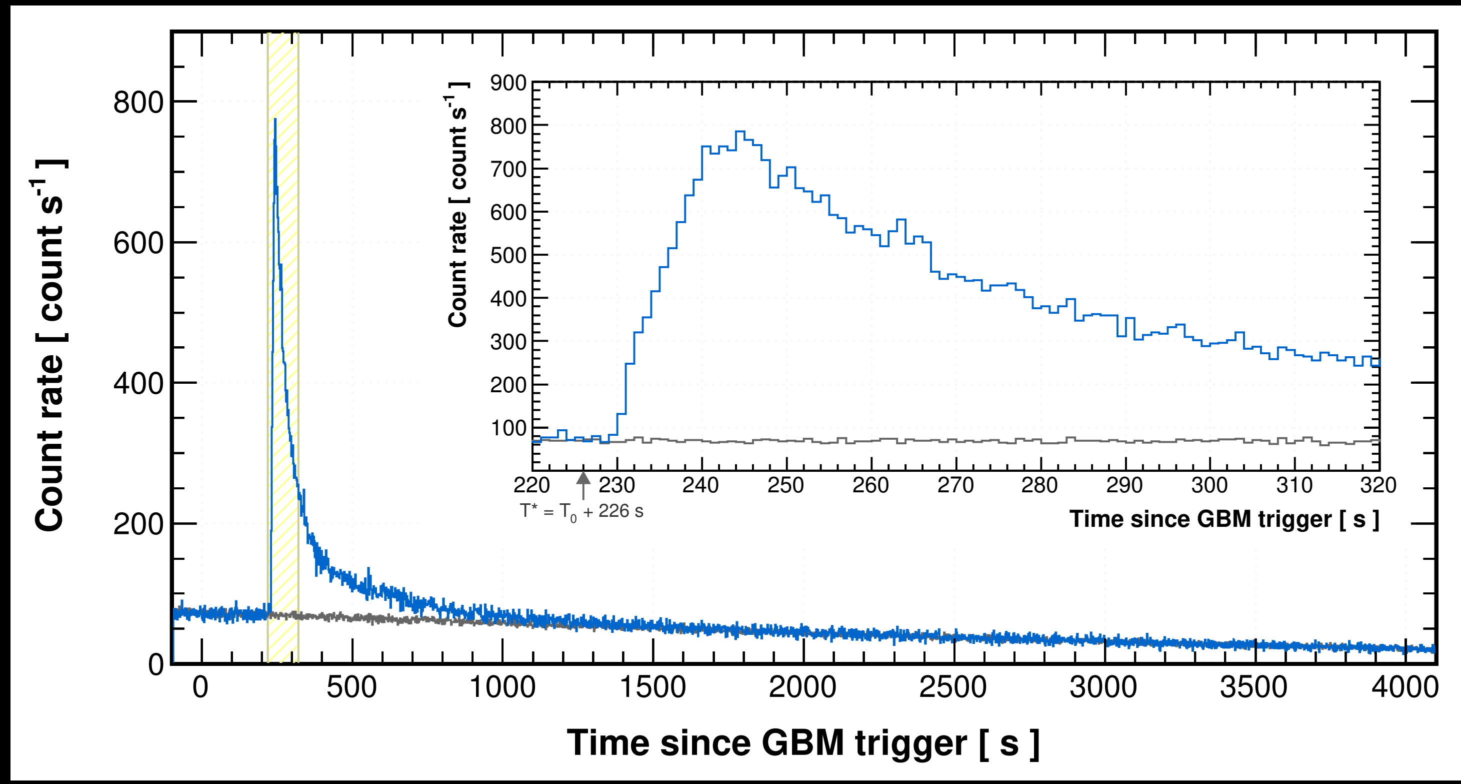
Nature (2021)





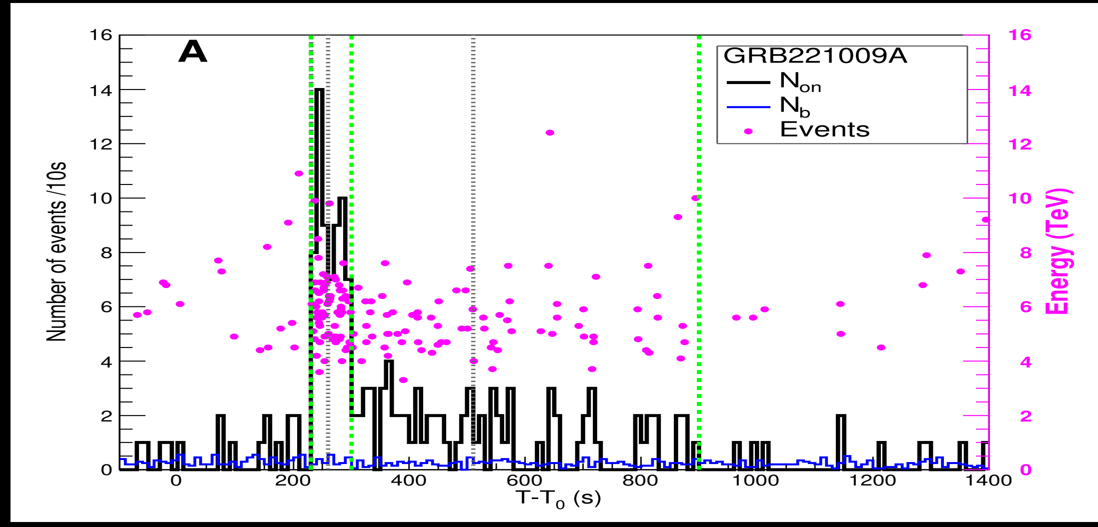
arXiv/2311.00861

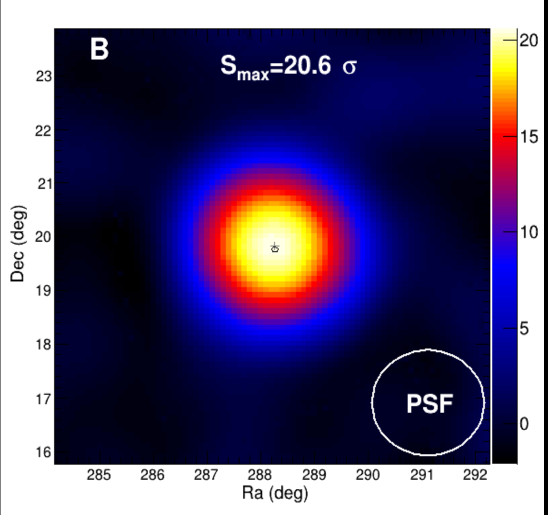
Photons with 0.2 < E (TeV) < 7 (WCDA)



arXiv/2306.06372

Detection of GRB 221009A up to 13 TeV (LHAASO)

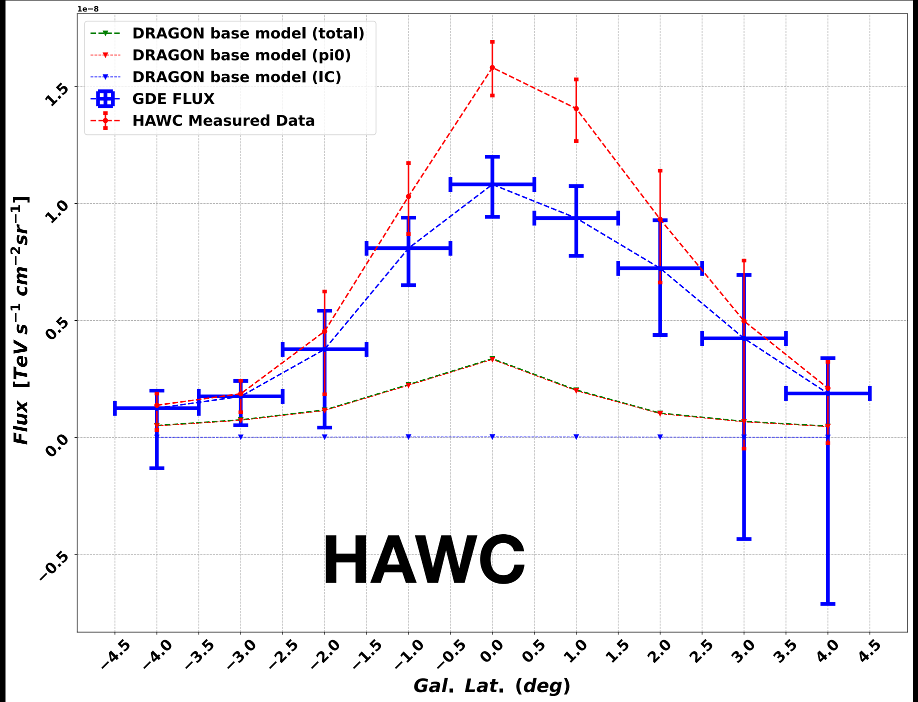




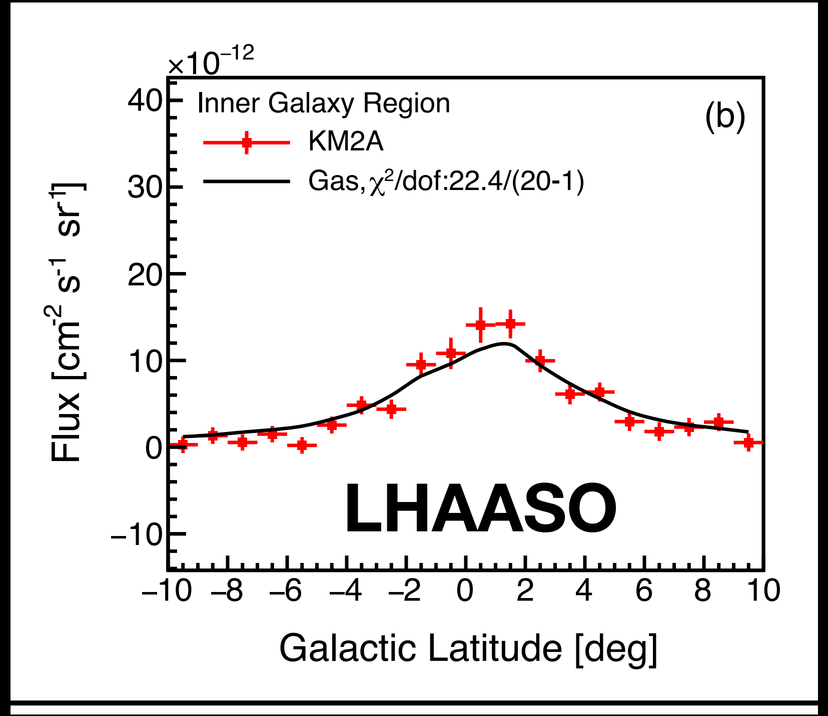
arXiv/2310.08845

Photons with KM2A

VHE Galactic diffuse emission

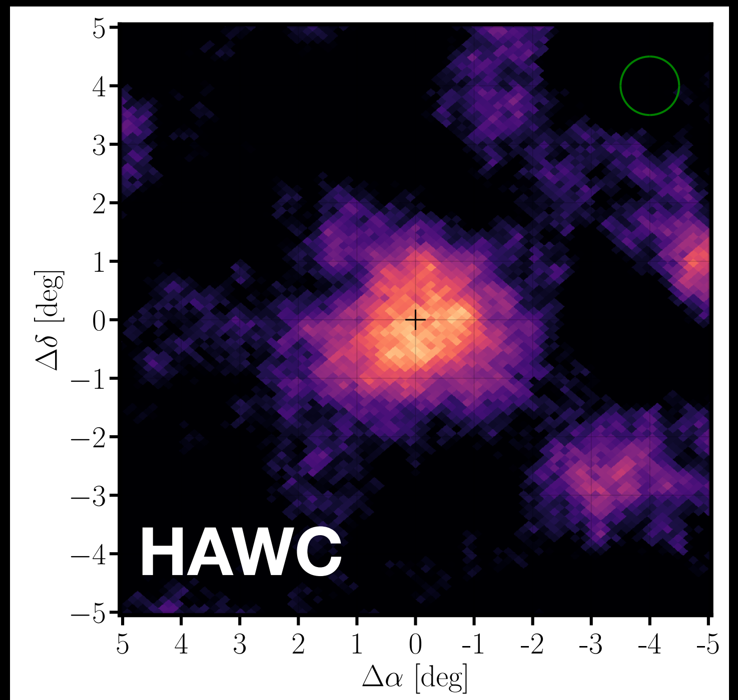


arXiv/2310.09117



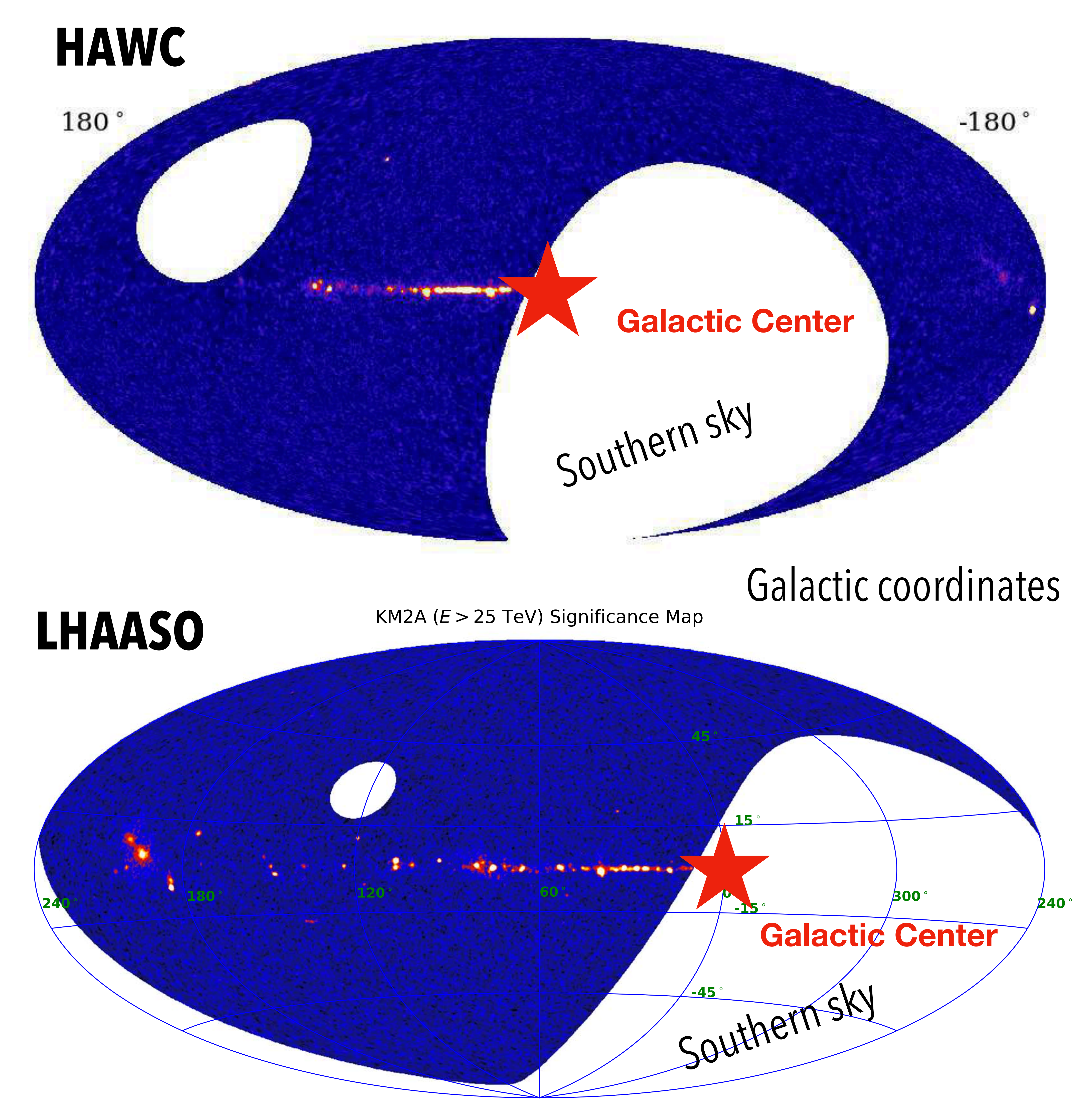
arXiv/2305.05372

TeV Sun! (HAWC)



arXiv/2212.00815

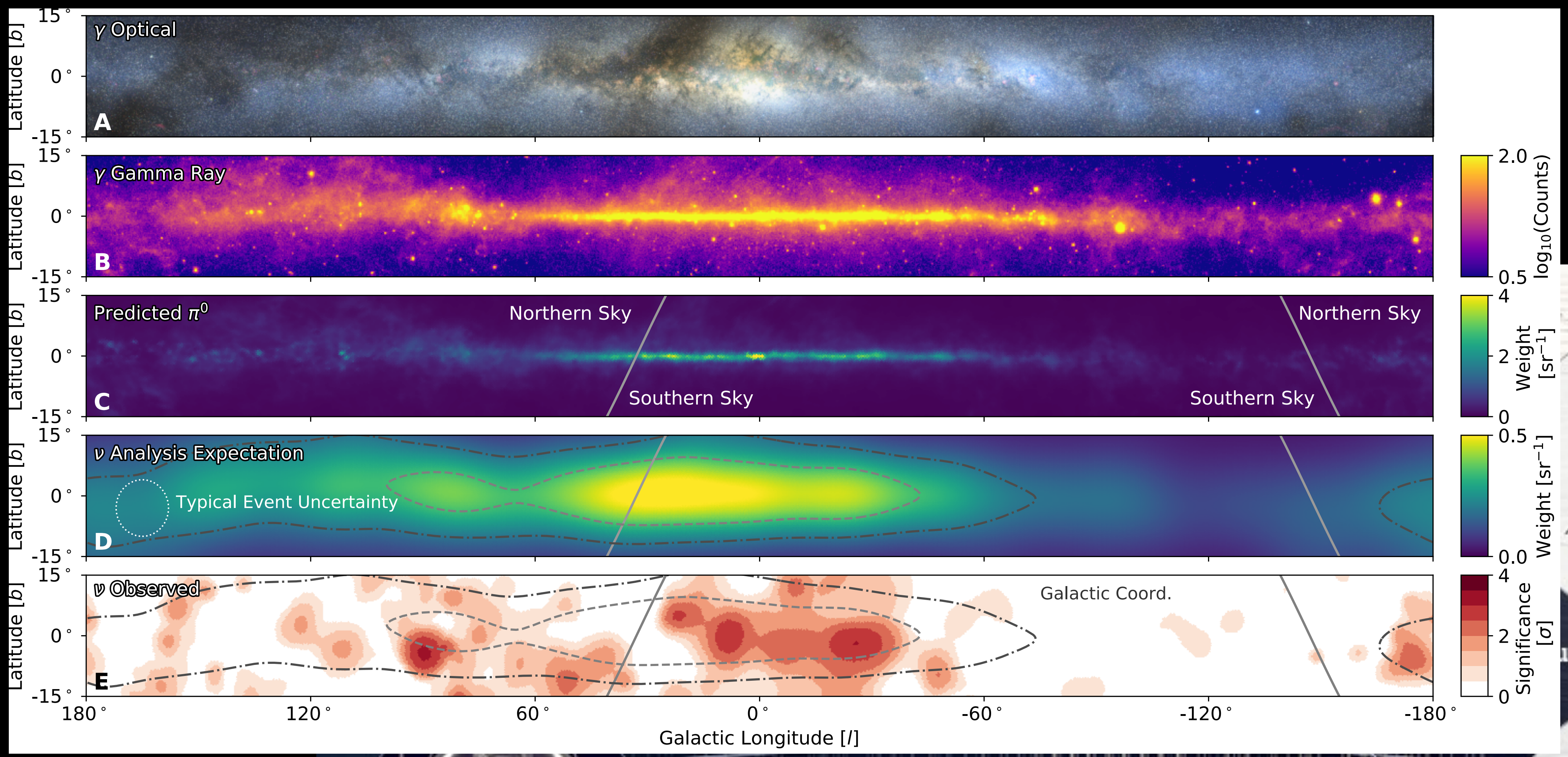
The need for a southern wide–field instrument



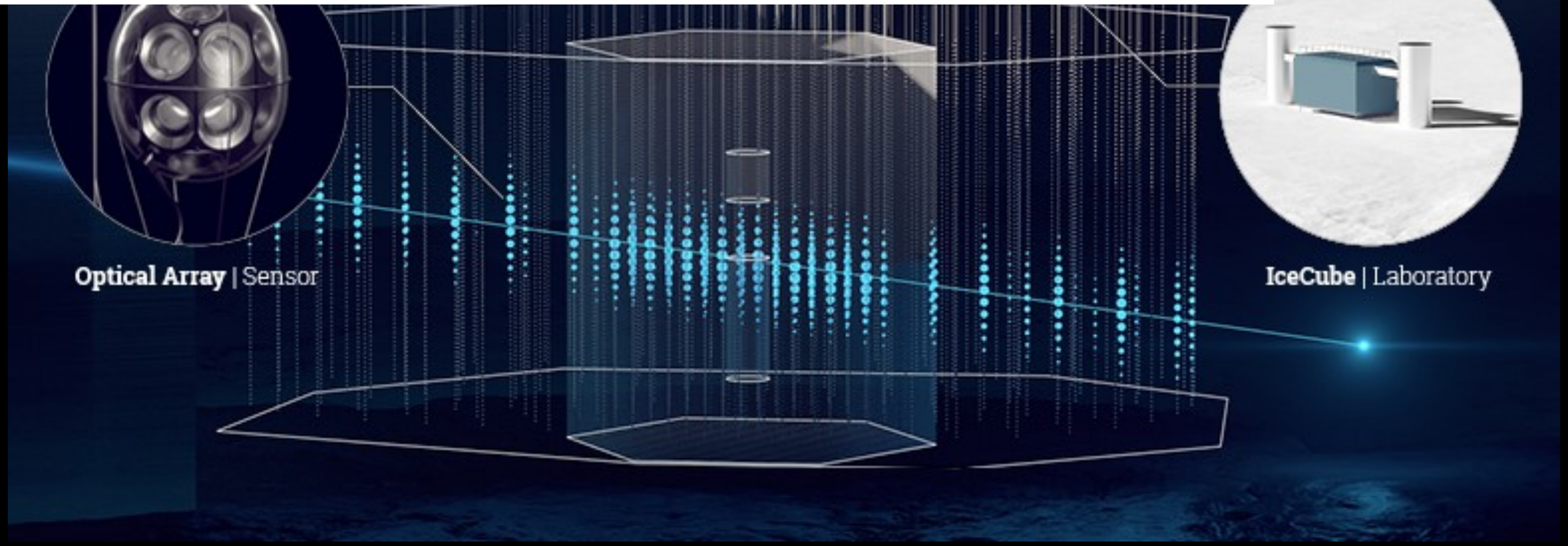
- **Advantages of a southern detector**
  - Visibility of the inner Galaxy (including the Galactic Center)
  - Full-sky coverage for multimessenger and multiwavelength transients.
  - Cosmic-ray anisotropy studies.
- **A wish list**
  - High elevation (>4400 m) for low energy threshold.
  - 10° - 30° S latitude for good GC visibility, overlap with North)
  - Large area (up to km^2 or above) for UHE performance
  - Good angular resolution, O(0.1°)

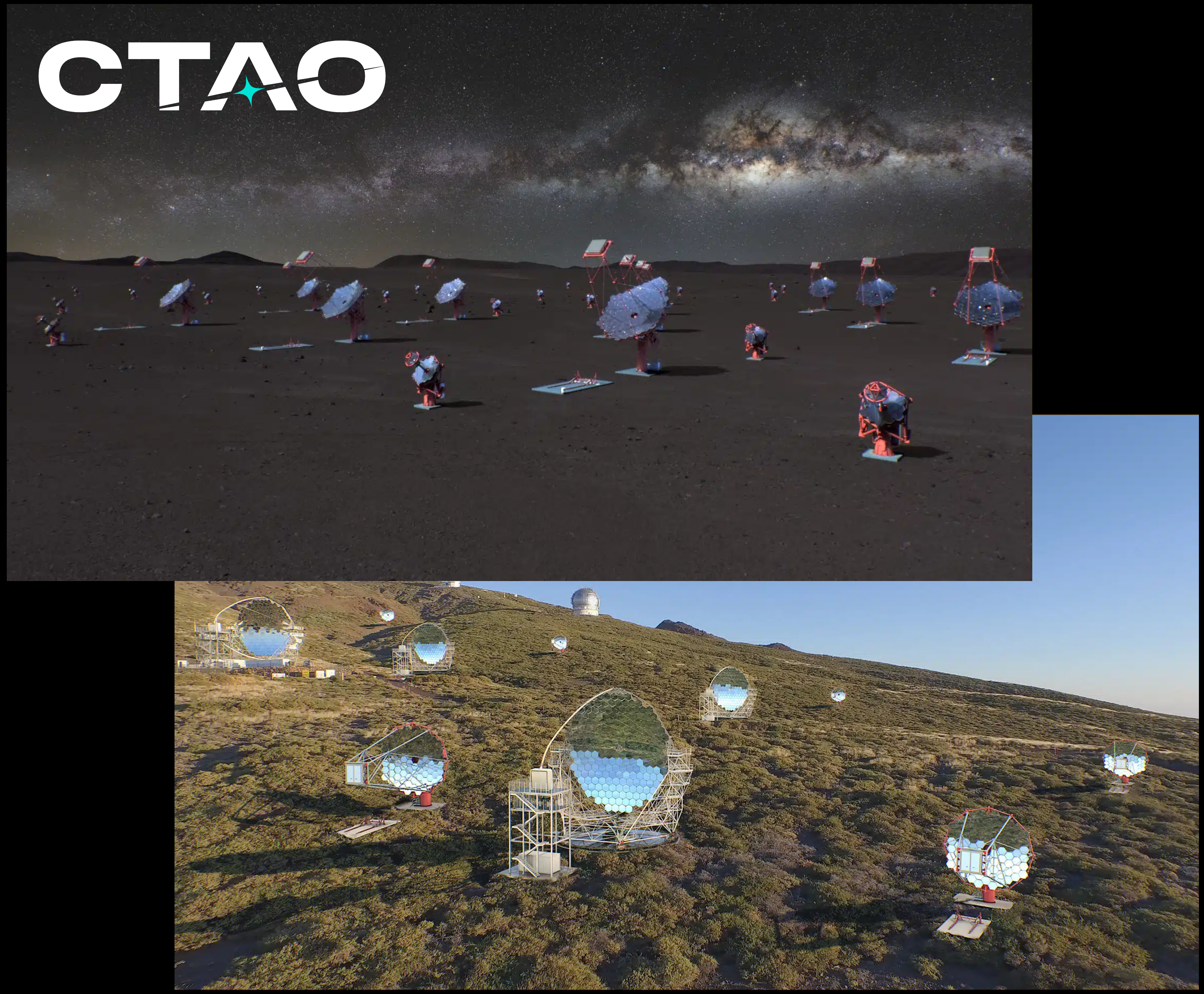
Synergistic opportunities for SWGO

arXiv/2307.04427



IceCube

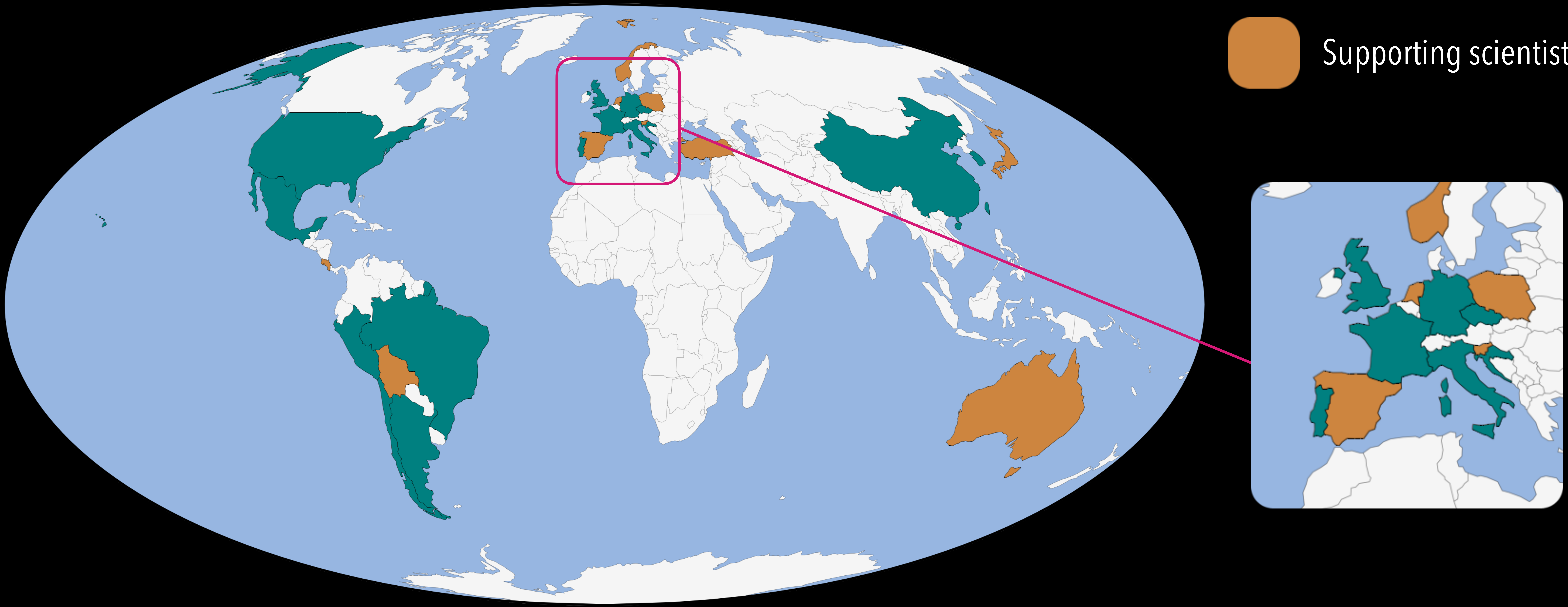




- Current and future neutrino telescopes (Galactic neutrino emission detected).
- **Strong synergy with CTAO.**

CURRENT AND FUTURE

SWGO Collaboration



- 15 countries. 90+ institutes.
- **Partner countries**: Argentina, Brazil, Chile, China, Croatia, Czech Republic, France, Germany, **Italy**, Mexico, Peru, Portugal, South Korea, United Kingdom, United States.

SWGO Collaboration meeting
(April 2024)

Site search

- Candidate sites identified in Argentina, Chile and Peru at latitudes between 14° and 24° S and elevations between 4,400 and 4,850 m.a.s.l.
- All sites should be able to host a ~1 km^2 array.
- Candidate sites were originally defined as best suited for WCD tanks, or for deployment in an artificial pond, or a natural lake.
- All primary candidate visited in Oct-Nov 2022 by an SWGO team. Findings here.

Site search

Sites under evaluation as primary candidates for a tank array

Cerro Vecar, Argentina
4,800 m.a.s.l.

Pampa La Bola, Chile
4,750 m.a.s.l.

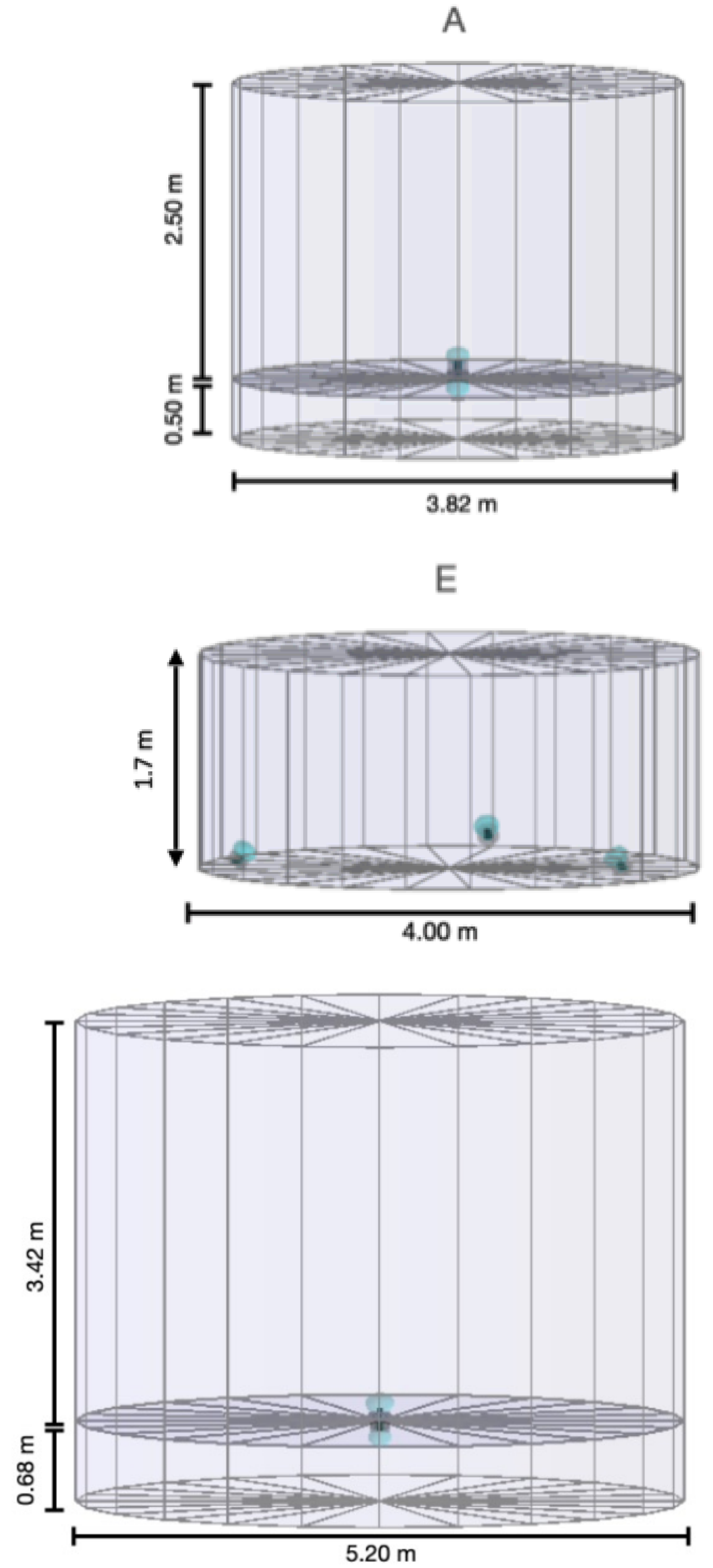
Imata, Peru
4,450 m.a.s.l.

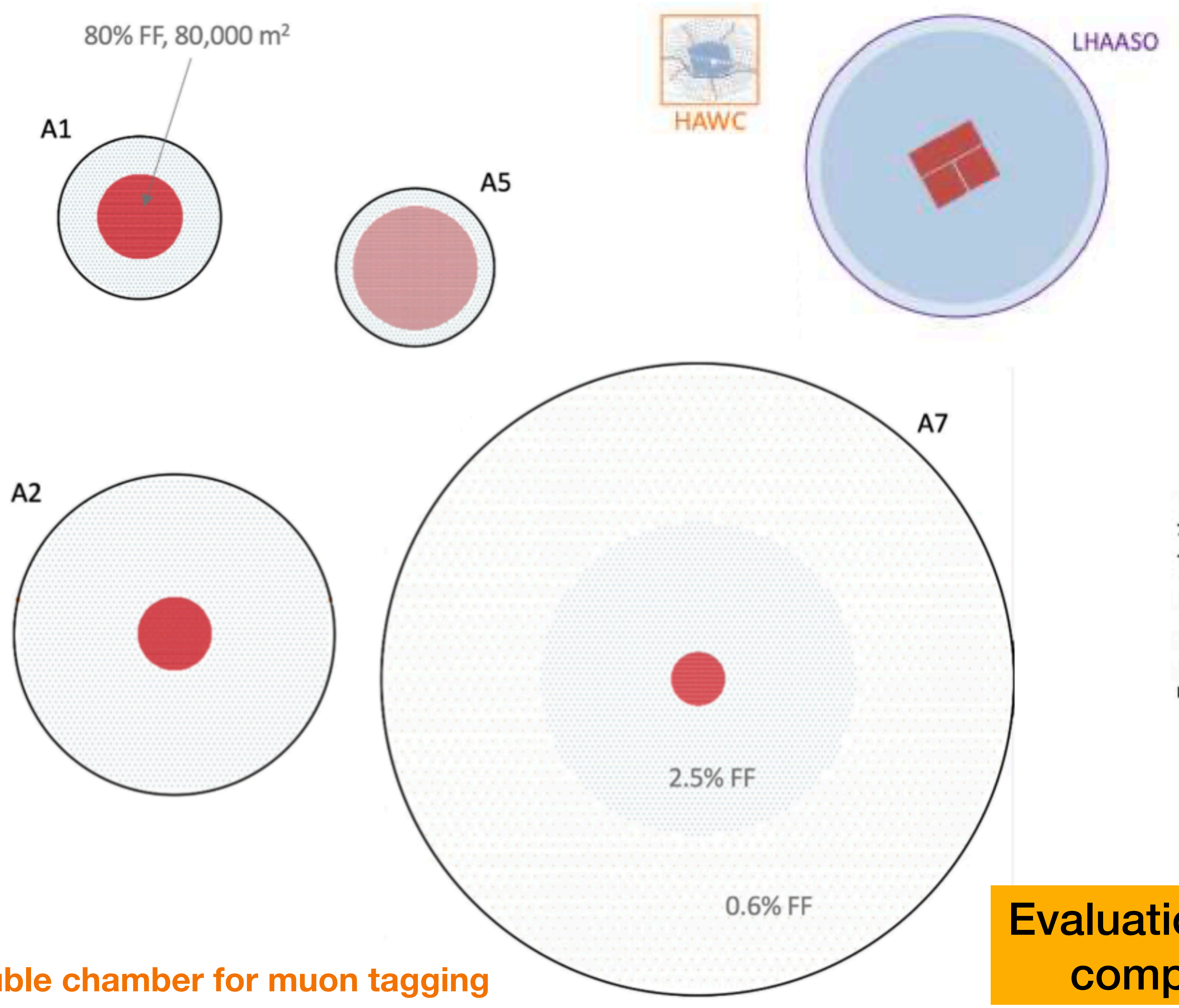
- A shortlist of sites is being further evaluated for performance, costs, risks and environmental/societal impacts towards a site decision expected in Q3 of this year.
- **We aim to maintain a close engagement with the local community at these sites during our site selection process.**

Array optimization studies

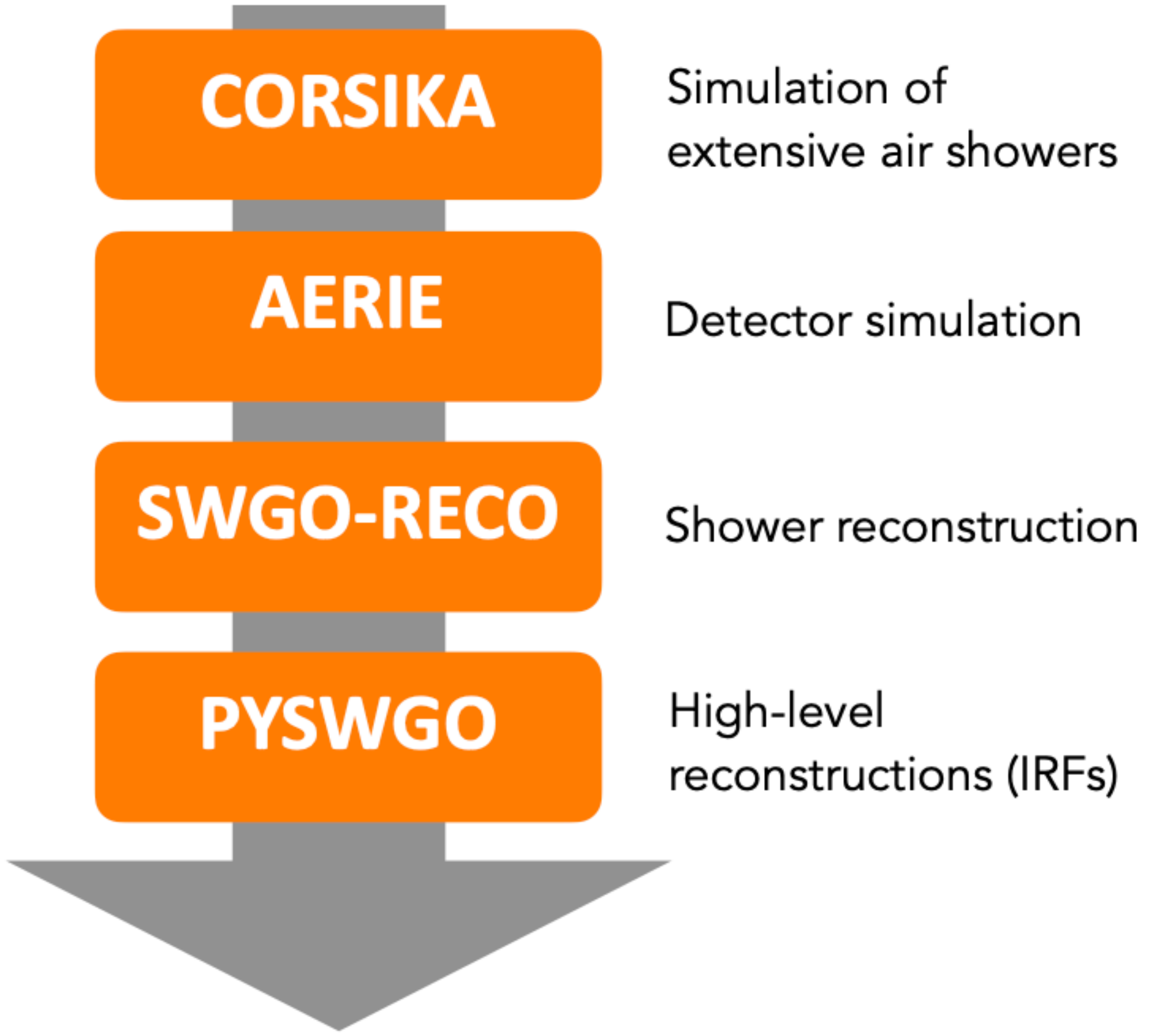
Ruben Conceição (ICRC 2023)

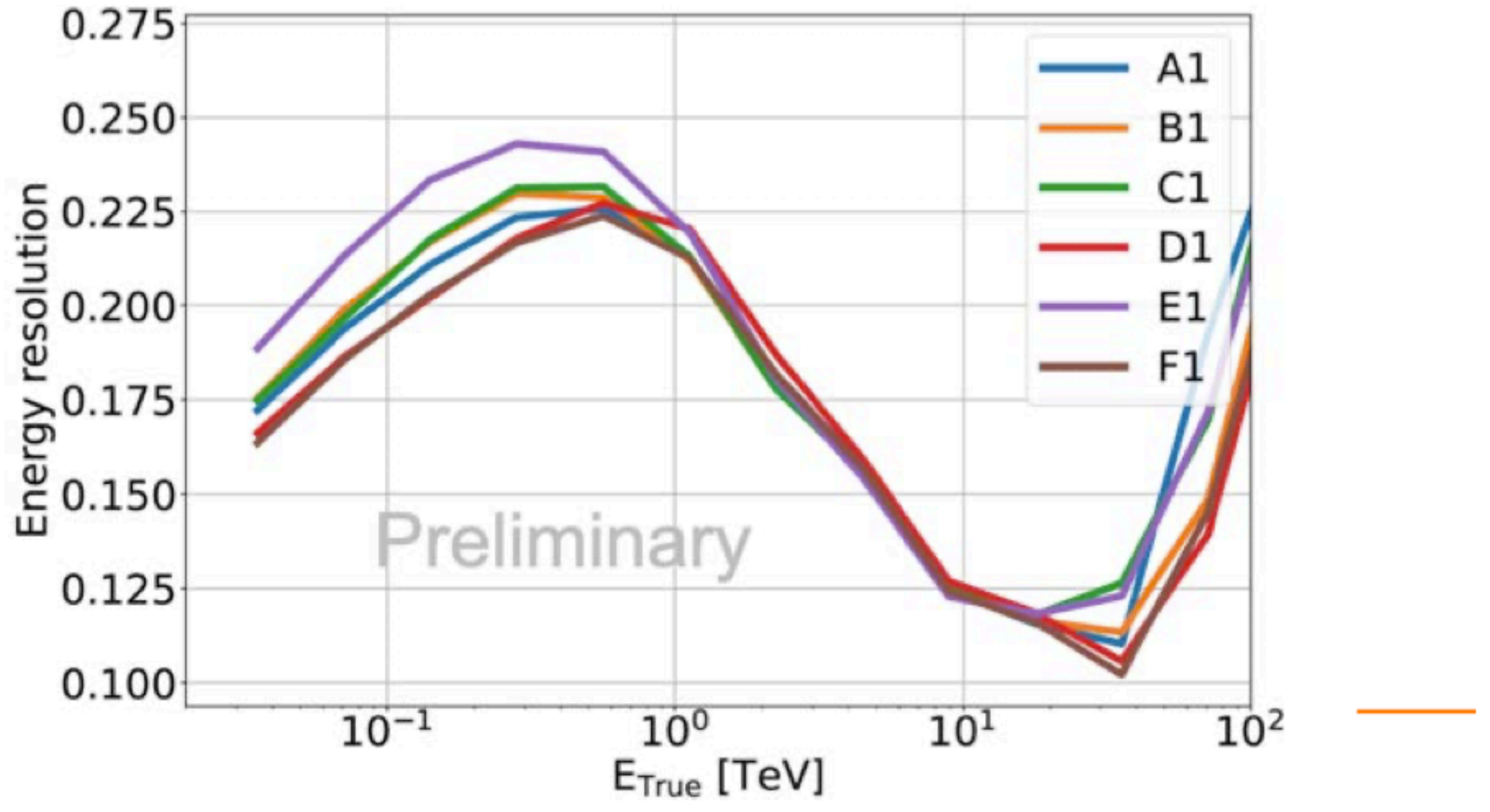
Simulation studies with different **WCD concepts** and **array configurations** to select most promising candidates





Double chamber for muon tagging





Evaluation of candidate configuration performance completed this month (major R&D milestone)

Try the 3D visualizer!

https://wminho.lip.pt/swgo/

A next-generation instrument

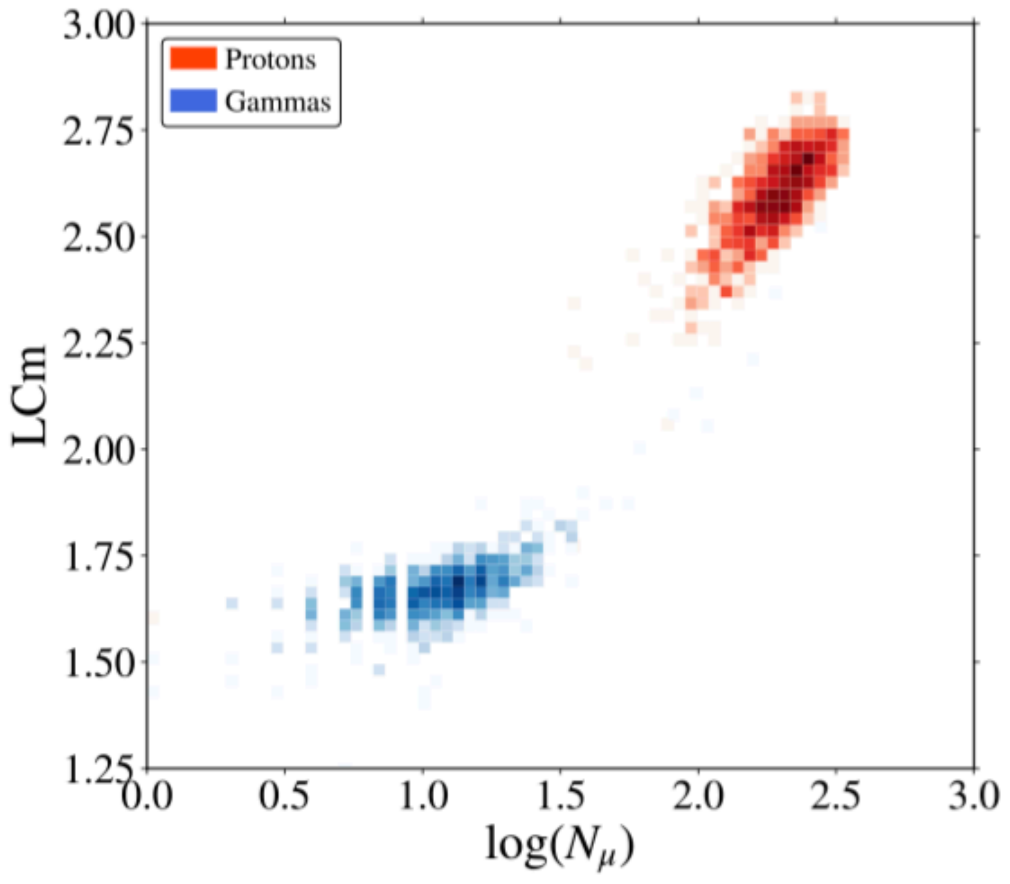
Ruben Conceição (ICRC 2023)

Novel shower observables for gamma/hadron discrimination

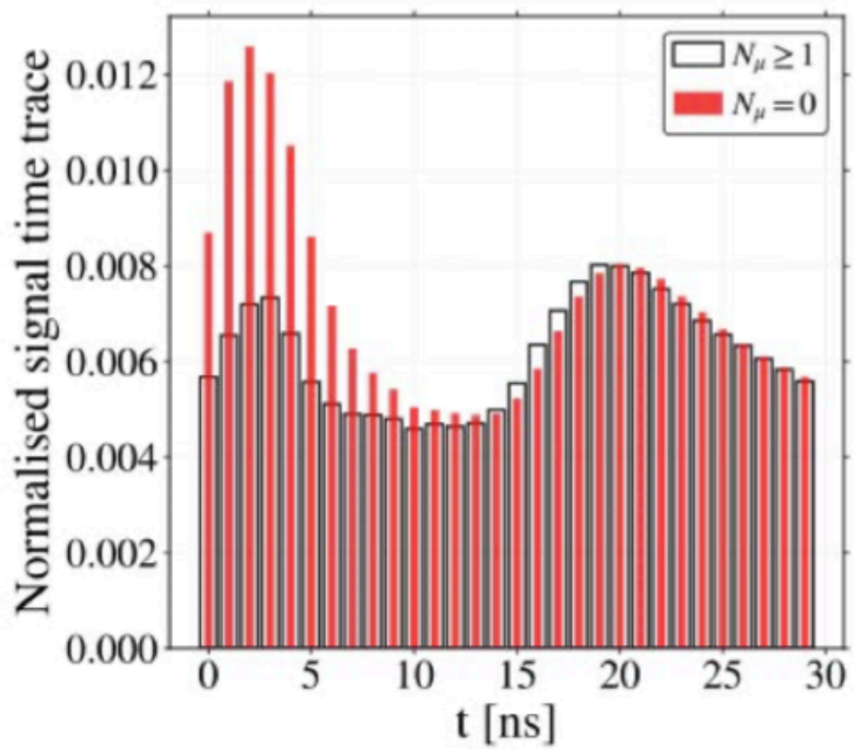
Improved data analysis with integrate machine learning algorithms

Alternative configurations for the array layout

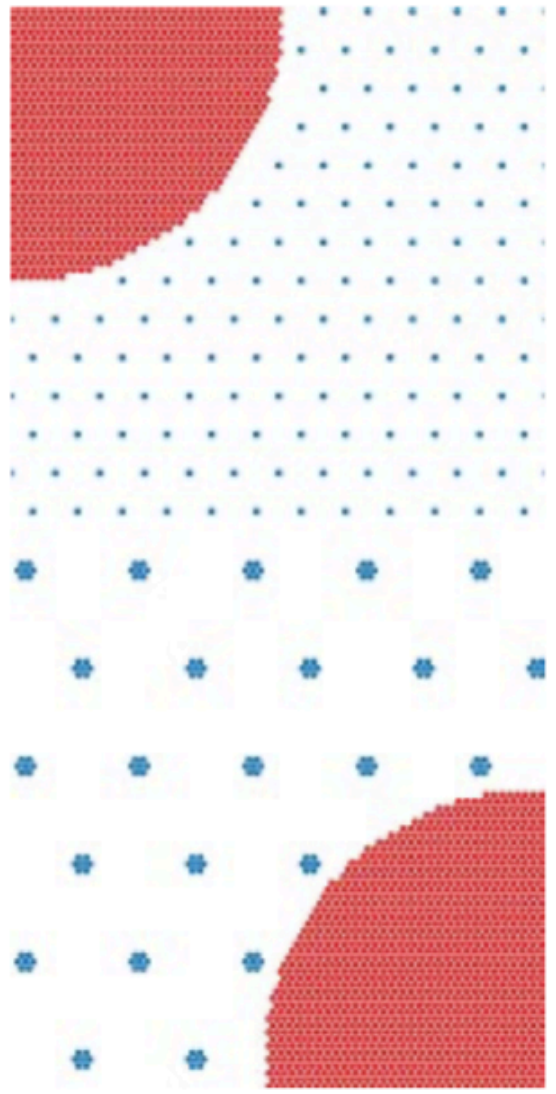
Novel engineering solutions to build double-layered WCD



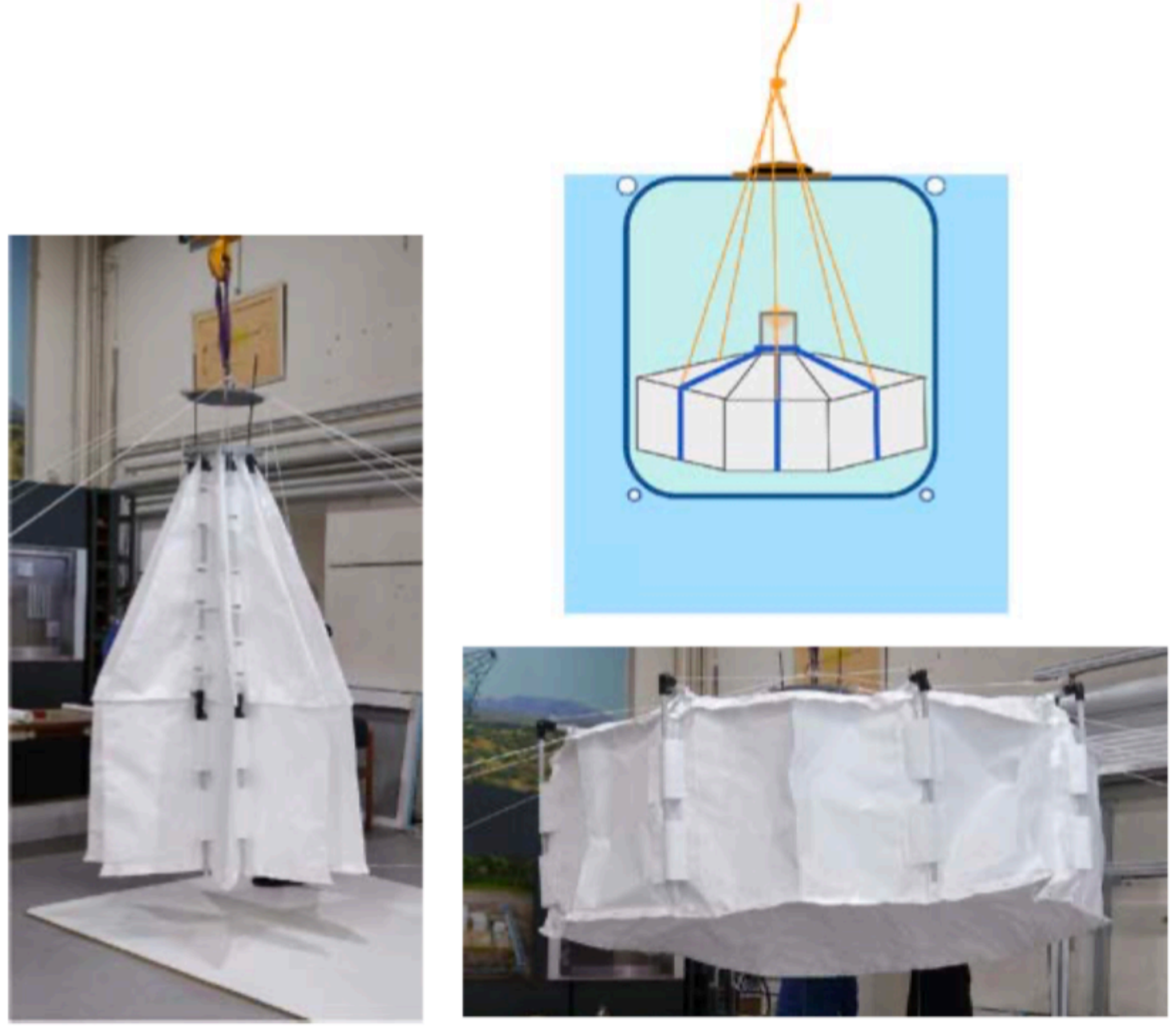
LCm - the shower footprint azimuthal fluctuations



Analyse the PMT signal time trace with NN to tag muons

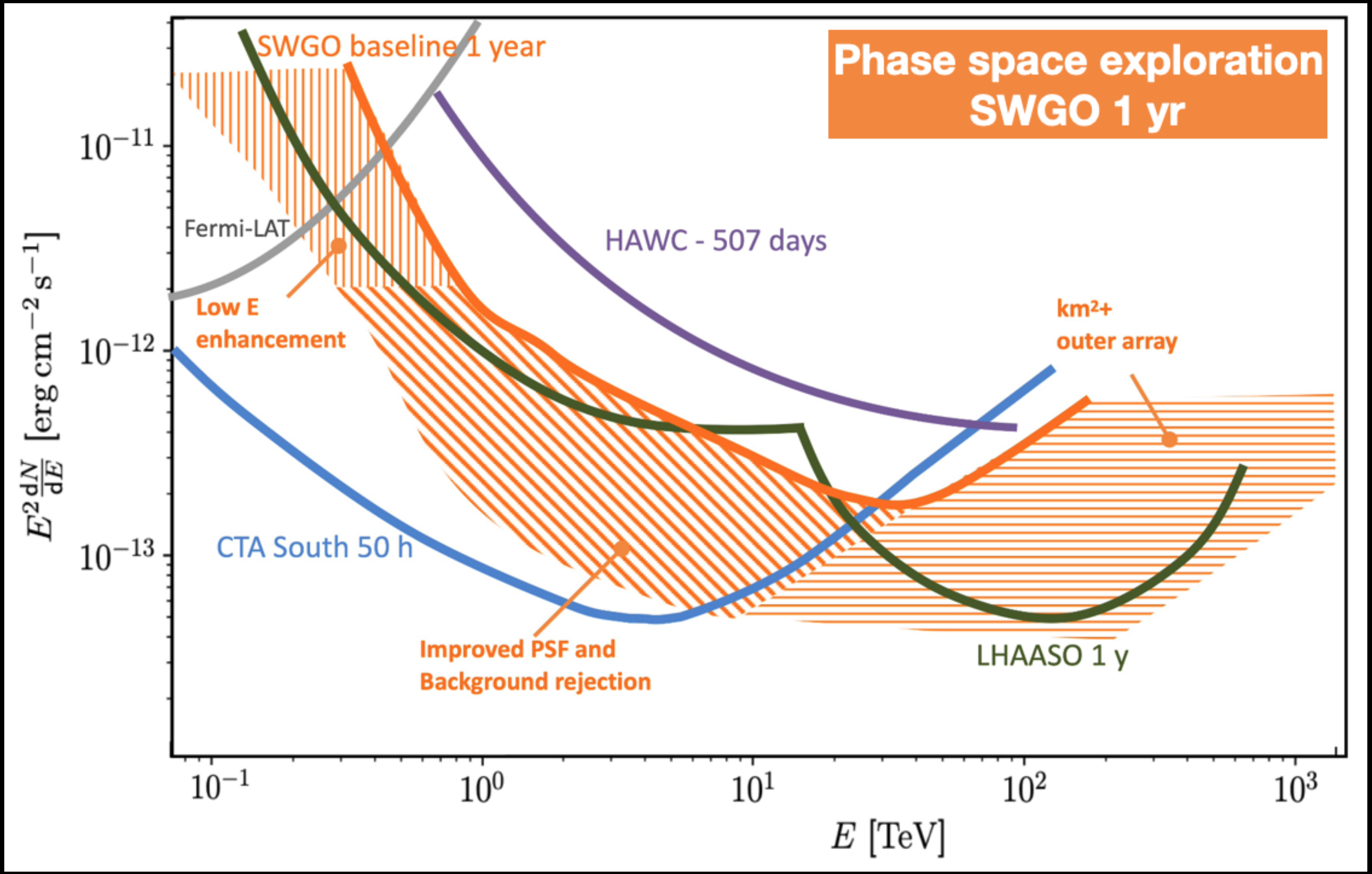


Uniform vs isles distribution for the outer array



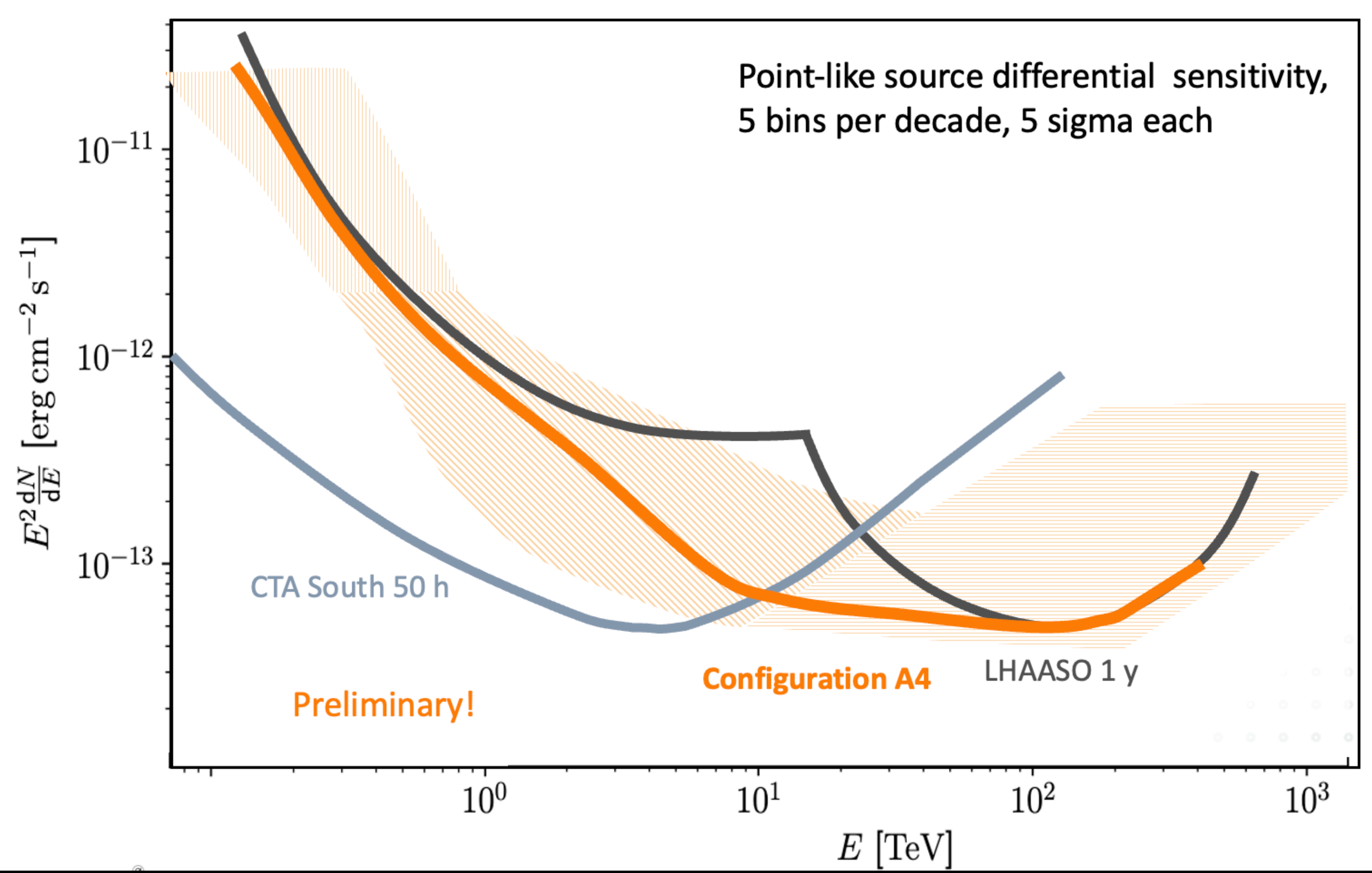
Matryoshka double-layered bladder

Expected SWGO sensitivity



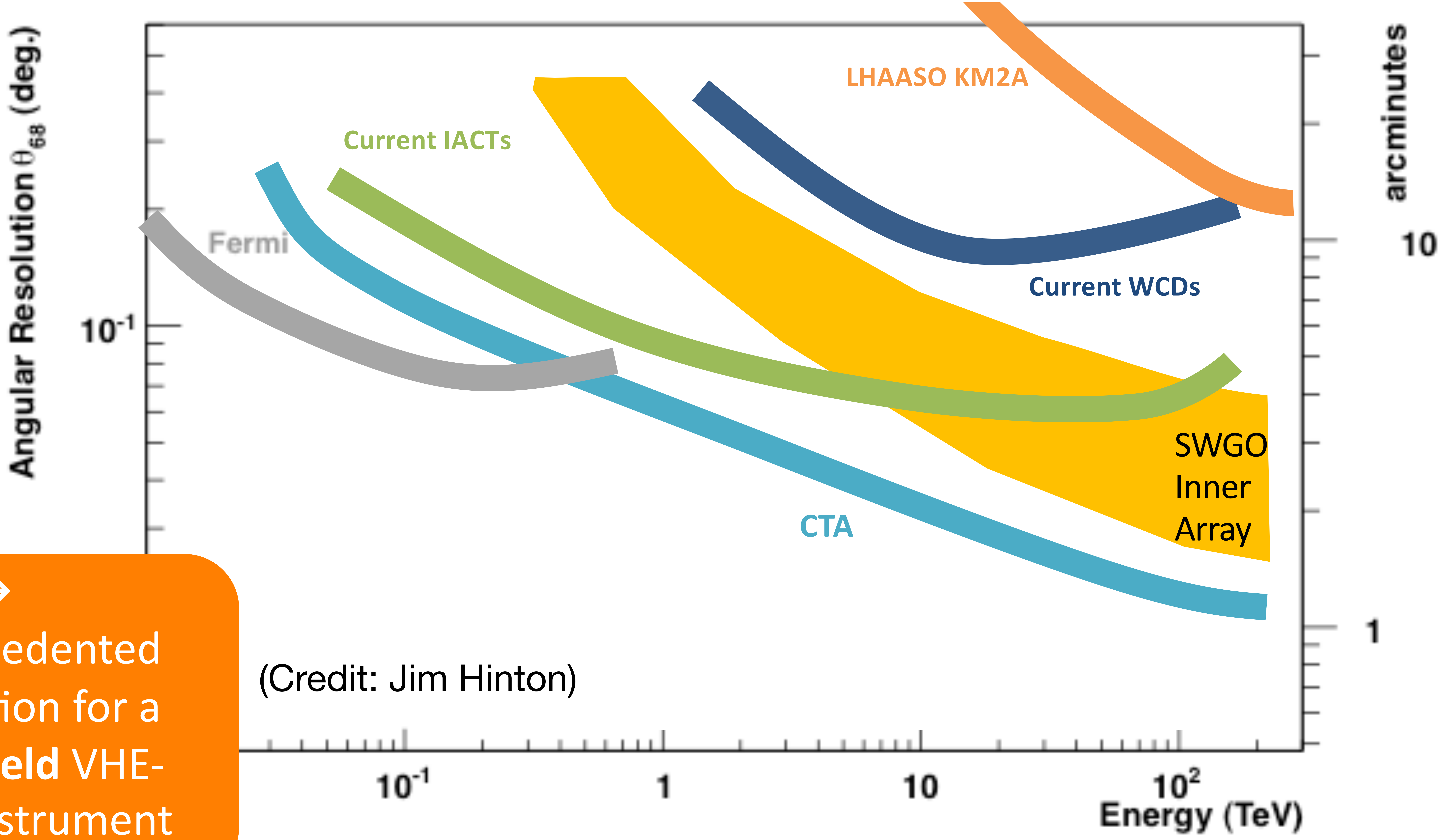
Conceição et al. (SWGO) - ICRC 2023

Expected SWGO sensitivity



Recent progress: perfomance example for one configuration (A4)

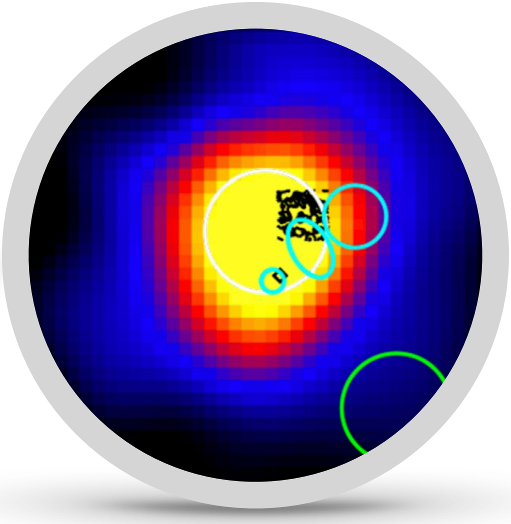
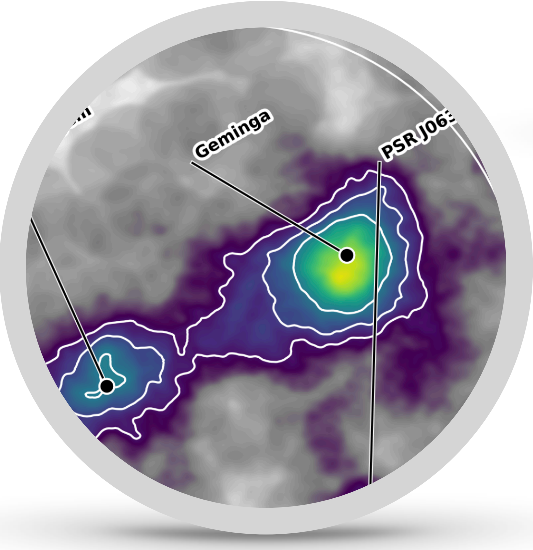
Angular resolution goal

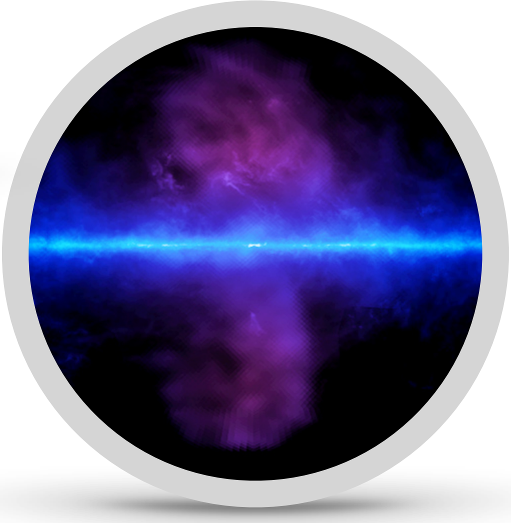


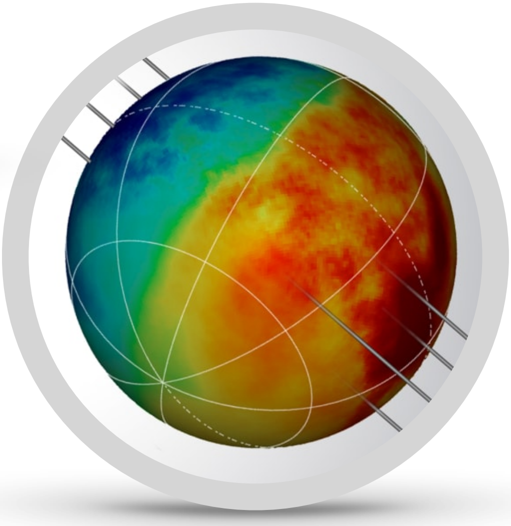
(Credit: Jim Hinton)

Goal → unprecedented resolution for a **wide field** VHE-UHE instrument

Science benchmarks

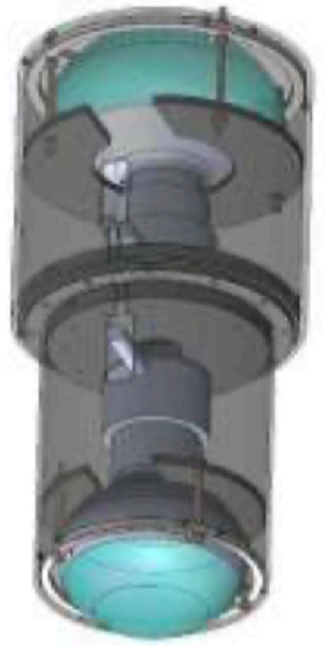




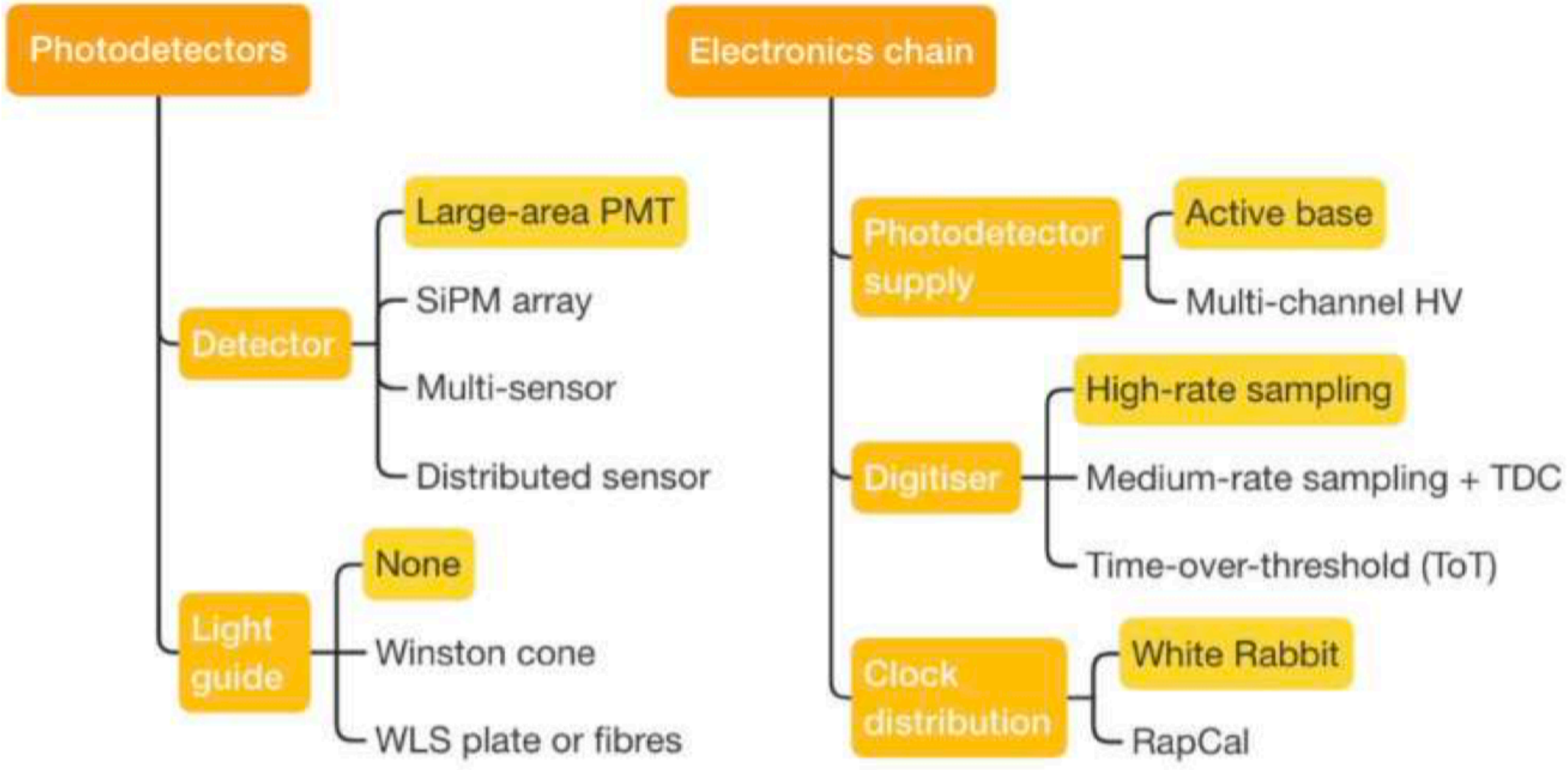


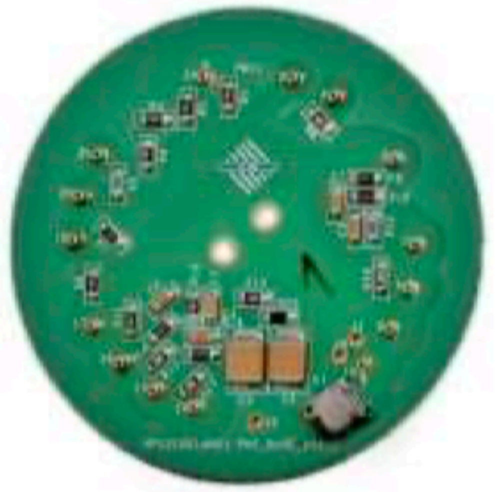


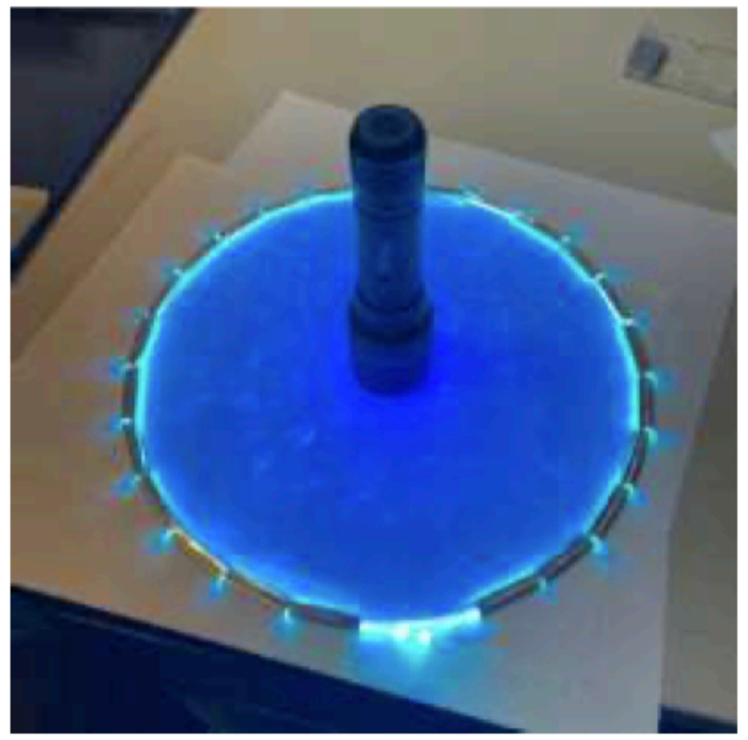
Core Science Case	Design Drivers	Benchmark Description
Transient Sources: Gamma-ray Bursts	Low-energy Site altitude	Min. time for 5σ detection F(100 GeV)= 10^{-8} erg cm^{-2} s^{-1}
Galactic Accelerators: PeVatron Sources	High-energy sensitivity Energy resolution	Maximum exp-cutoff energy detectable 95% CL in 5 years for: F(1 TeV)= 5 mCrab, index= –2.3
Galactic Accelerators: PWNe and TeV Halos	Extended source sensitivity Angular resolution	Max. angular extension detected at 5σ in 5-yr integration for: F(>1 TeV)= 5 × 10^{-13} TeV cm^{-2} s^{-1}
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	Max. energy for $b\bar{b}$ thermal relic cross-section at 95% CL in 5-yr, for Einasto profile.
Cosmic-rays: Mass-resolved dipole Multipole anisotropy	Muon counting capability	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.

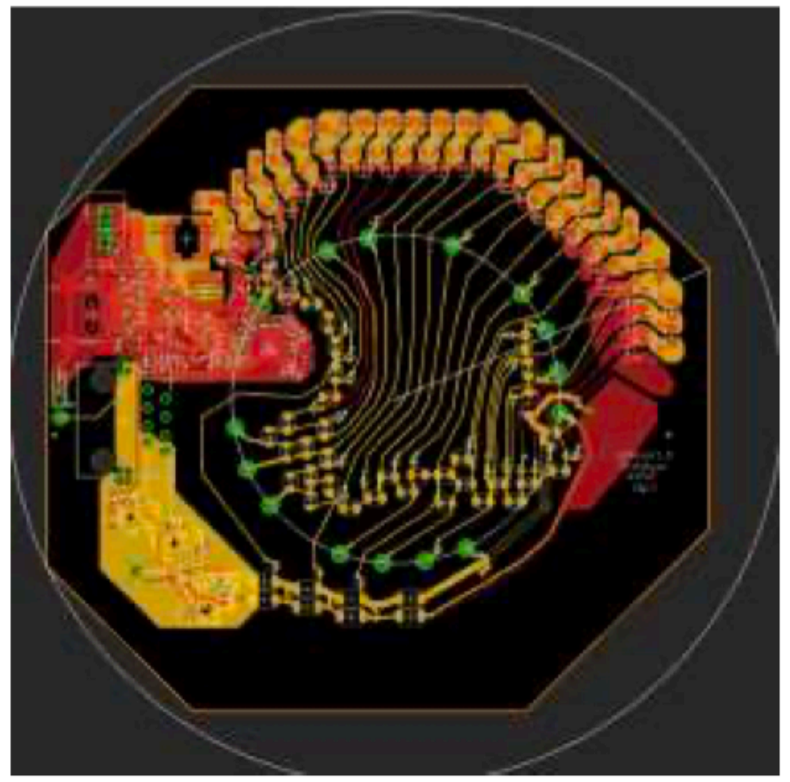
Detector options and prototyping





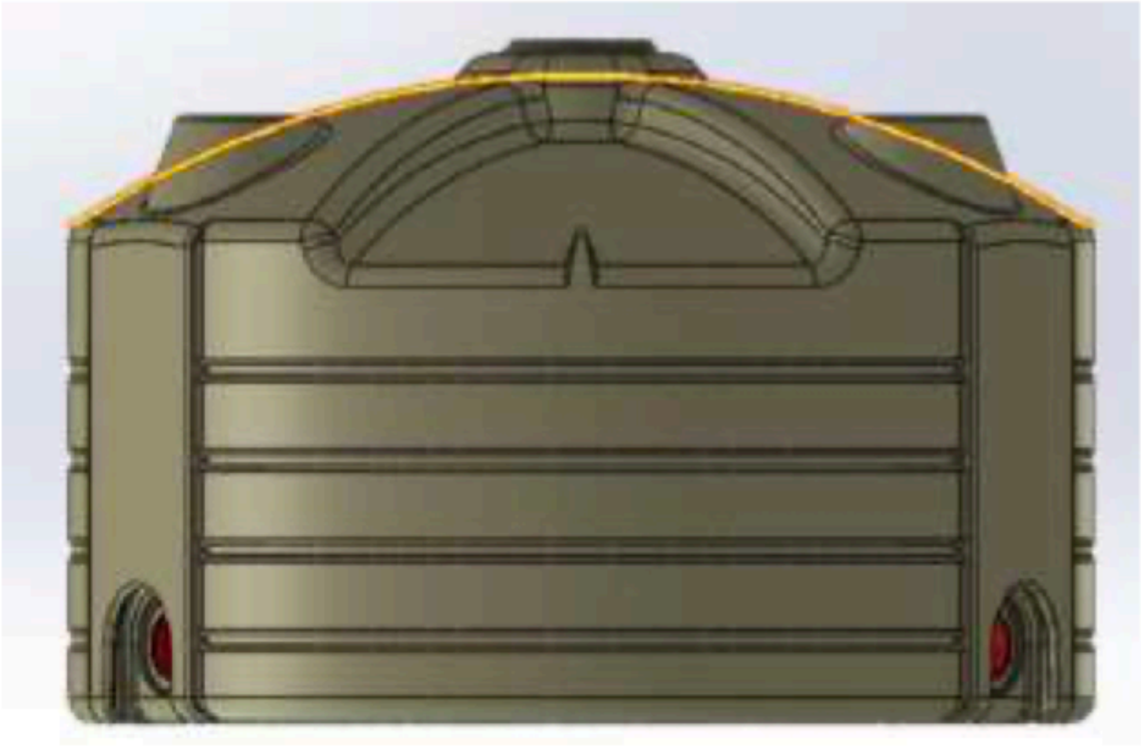






- **Strong push for consolidation of detector options.**

Different WCD designs under consideration



- Options evaluated so far include plastic and metal tanks, and R&D work for lake or pond-based WCDs.
- Evaluated for performance and cost.

Timeline

SWGO R&D Phase Milestones

M1	R&D Phase Plan Established
M2	Science Benchmarks Defined
M3	Reference Configuration and Options Defined
M4	Site Shortlist Complete
M5	Candidate Configurations Defined
M6	Performance of Candidate Configurations Evaluated
M7	Preferred Site Identified
M8	Design Finalized
M9	Construction and Operations Proposal Complete

- R&D phase completion in early 2025.
- Preparatory phase
  - Detailed construction planning
  - Engineering Array
- Full construction phase (2027+)

Summary

- SWGO currently in an advanced R&D phase.
- Unique science opportunities and strong synergies with current and future instruments:
  - Capabilities for joint MMA studies, follow-up of transients (high duty cycle, wide field of view).
  - Gamma-ray observations spanning four orders of magnitude in energy (0.1 - 1 PeV).
  - Capable of setting strong DM constraints up to the unitarity bound and enable other BSM searches (e.g. axion, LIV)
  - Critical energy range for CR anisotropy, composition and spectrum studies.
- Set to become a critical component of the MMA / MWL landscape in the near future.