SWGO
The Southern Wide-field Gamma-ray Observatory

Status of Project, Research & Development

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on behalf of
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CBPF
Centro Brasileiro de Pesquisas Físicas

for the SWGO Collaboration

— SILAFAE 2022 —

www.swgo.org

In Memory of Prof. Ronald Cintra Shellard (1948 – 2021)

Prof. Ron Shellard was a pioneer and leader in the fields of **Particle** and **Astroparticle Physics** in **Brazil** and **Latin America**:
He was a key scientist in:

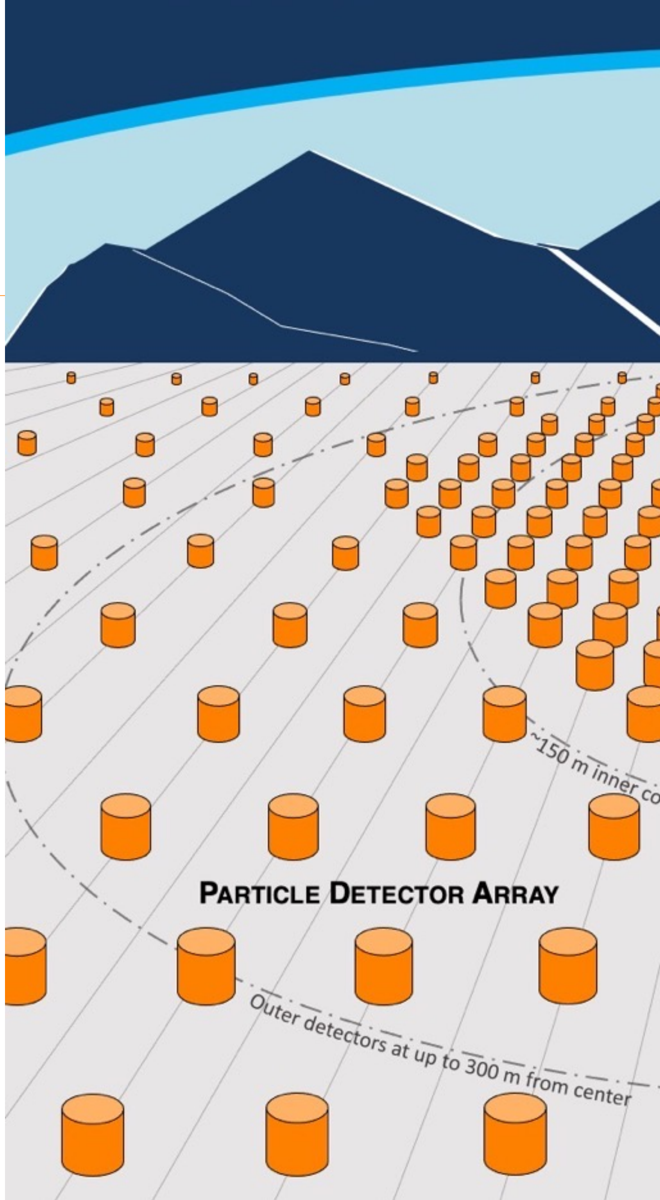
- Establishing Brazil's collaboration with **CERN**,
- Establishment of the intl' collaborations for the **Pierre Auger Observatory** and the Cherenkov Telescope Array (**CTA**),
- Representation of Brazil in the **ANDES** Lab initiative,
- Proponent of the **LATTES** project, and the convergence of the intl' community for the foundation of **SWGO.**
- Representative of Brazil in the **SWGO Steering Committee**.

We miss Ron as a great leader, a wise advisor and a dear friend.

Image: SBPMAT

Content

- The field in context
- Introduction of SWGO
- Status of R&D
- Science Outlook

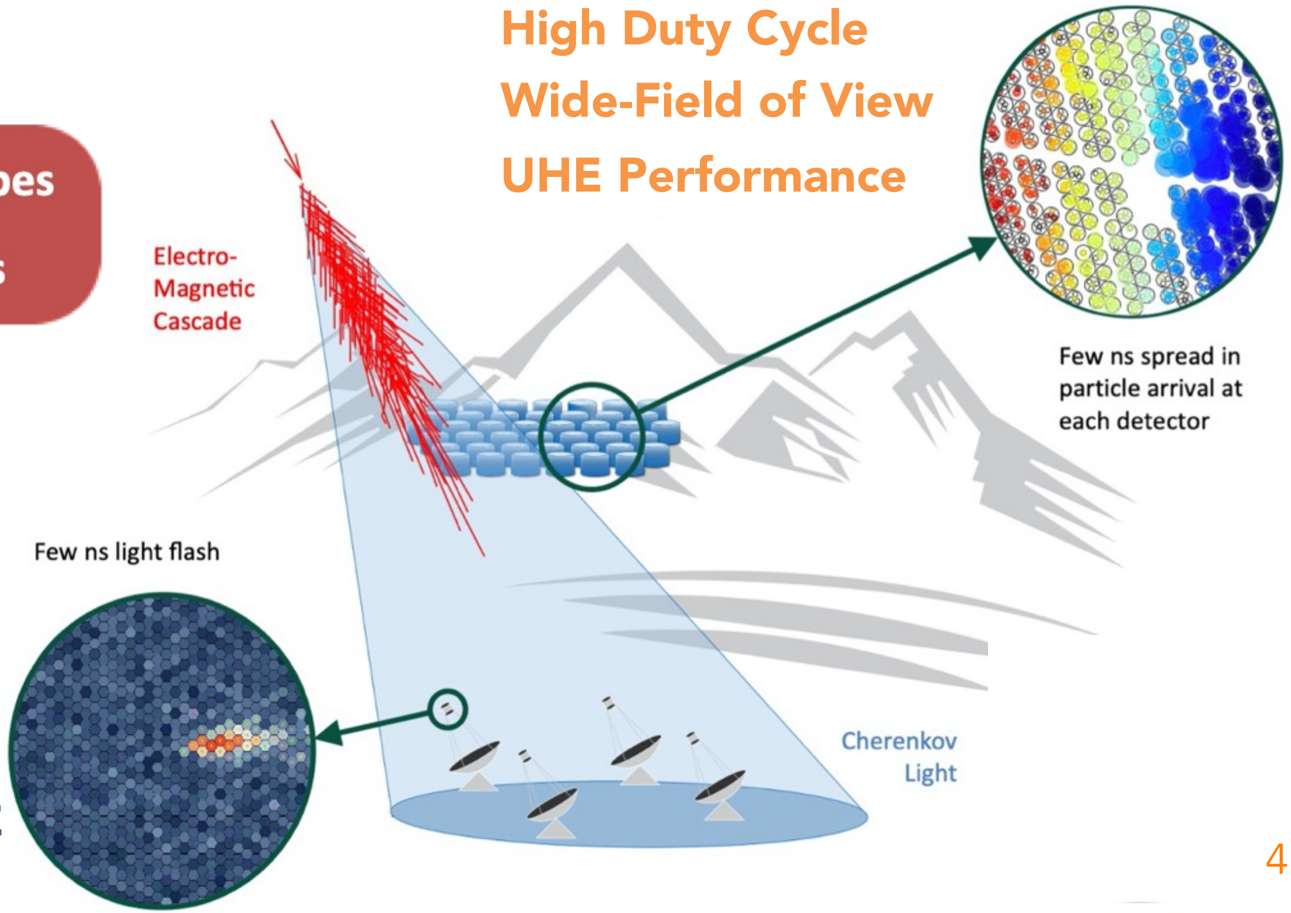


Status summary of the field

Two techniques

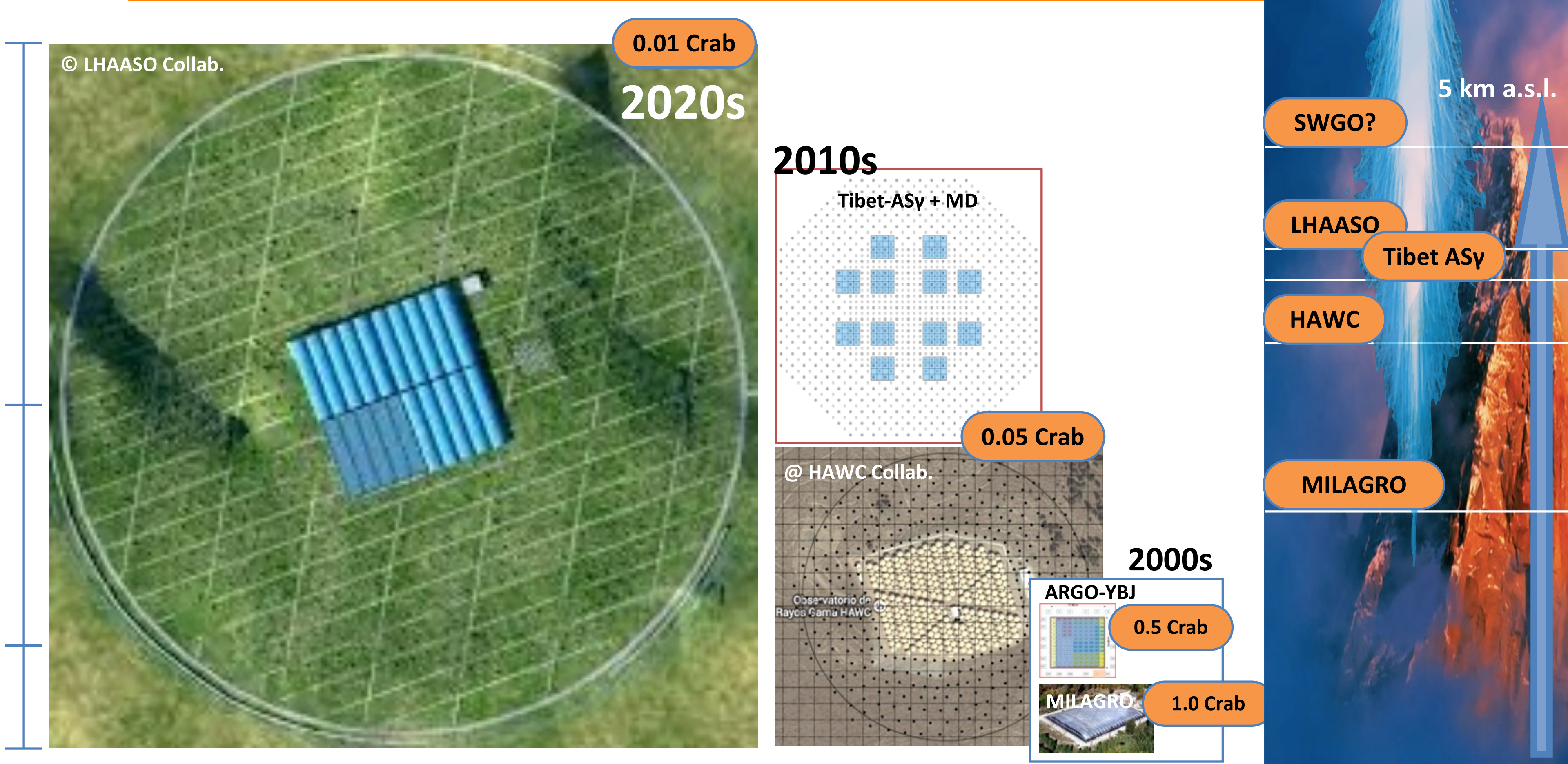
1. Air-Cherenkov telescopes
2. Altitude particle arrays

High Duty Cycle
Wide-Field of View
UHE Performance



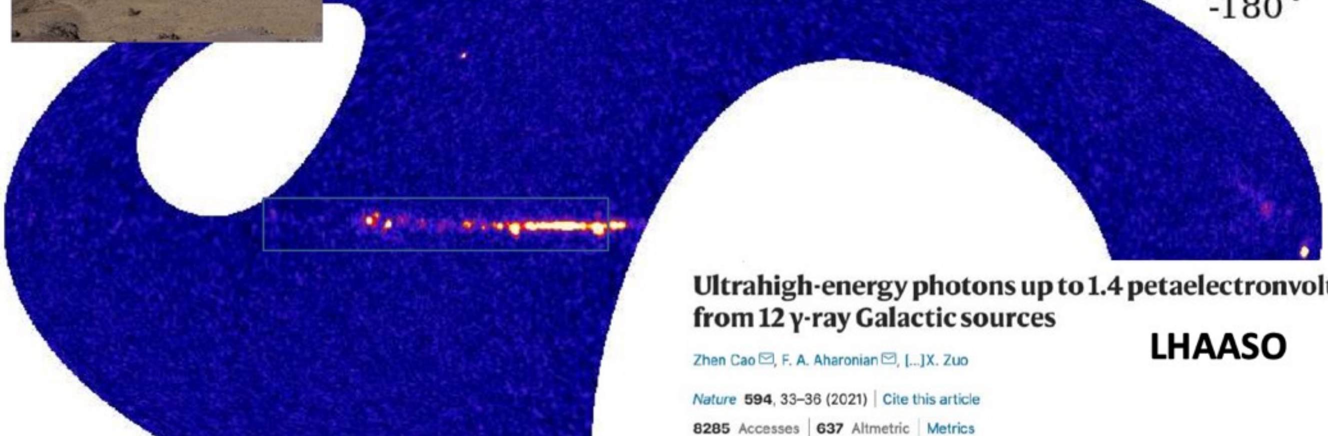
Low Duty Cycle
Pointing instruments
Precision Astronomy at VHE

Larger and higher…



A new window for the UHE sky

HAWC



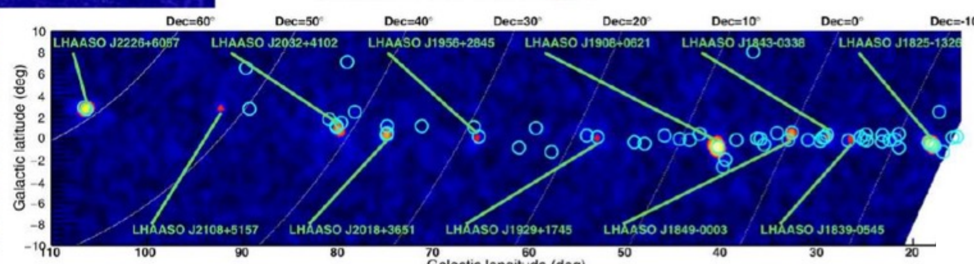
Major observational technique > 10s TeV

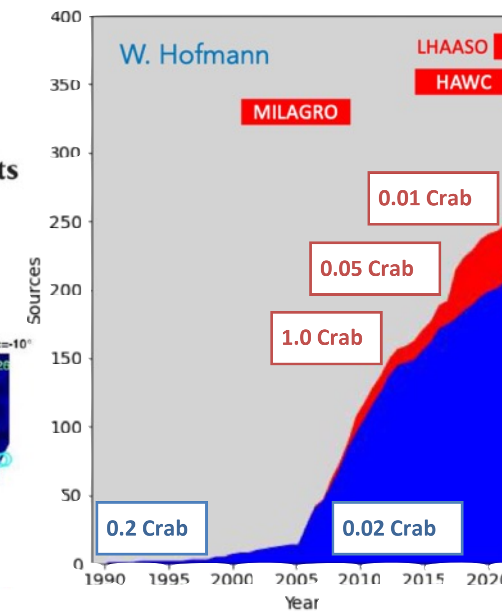
Ultrahigh-energy photons up to 1.4 petaelectronvolts from 12 γ-ray Galactic sources

Zhen Cao, F. A. Aharonian, [...]X. Zuo

Nature **594**, 33–36 (2021) | Cite this article

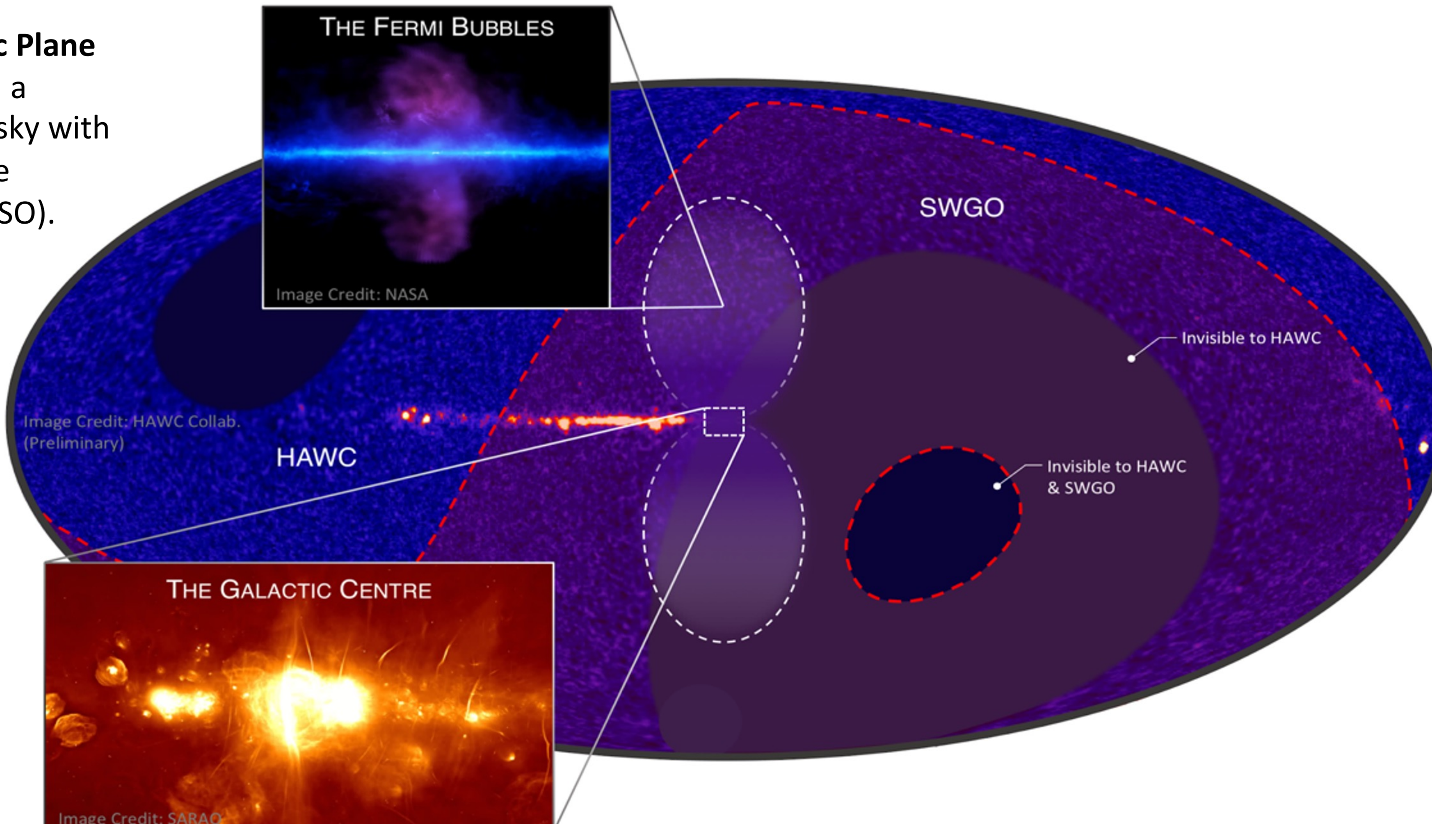
LHAASO





SWGO: a new view of the sky

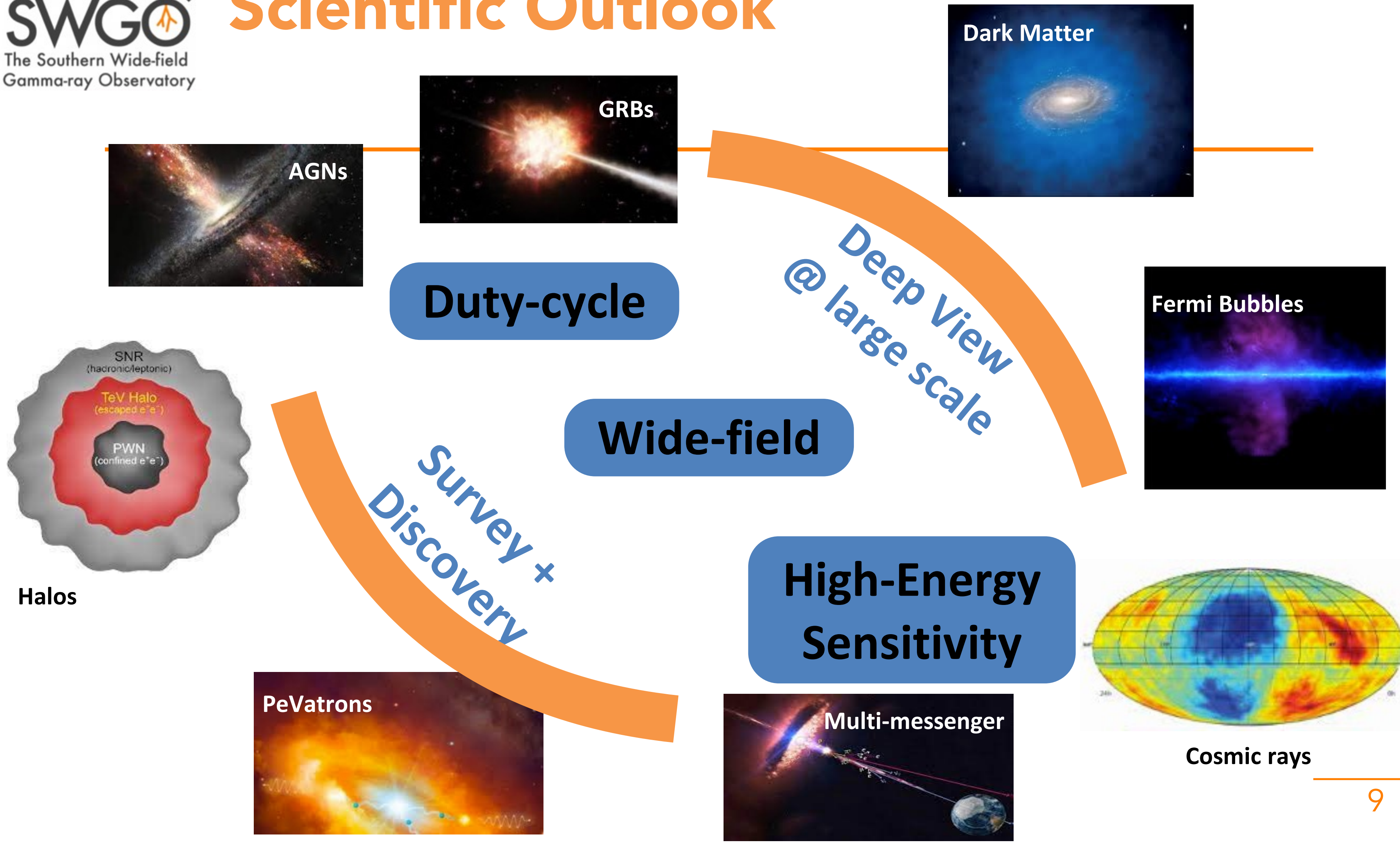
Crucial access to the **Galactic Plane** and the **Galactic Center**, and a complementary view of the sky with respect to current and future Observatories (HAWC, LHAASO).



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

GR observatories from Earth:

Scientific Outlook



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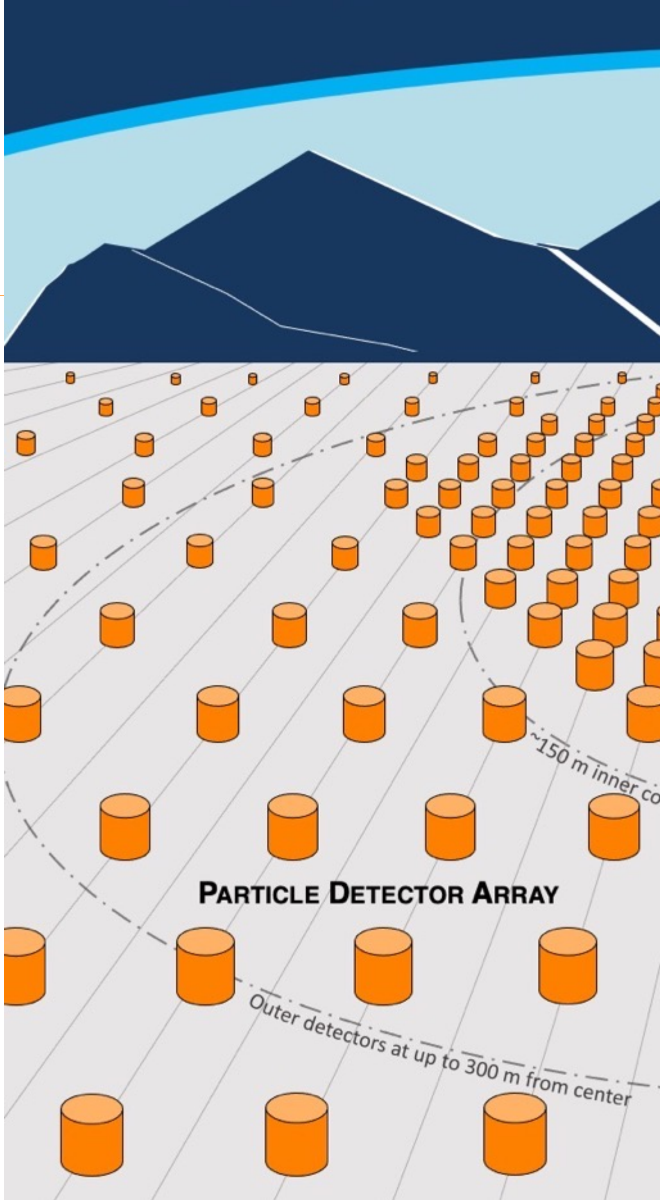
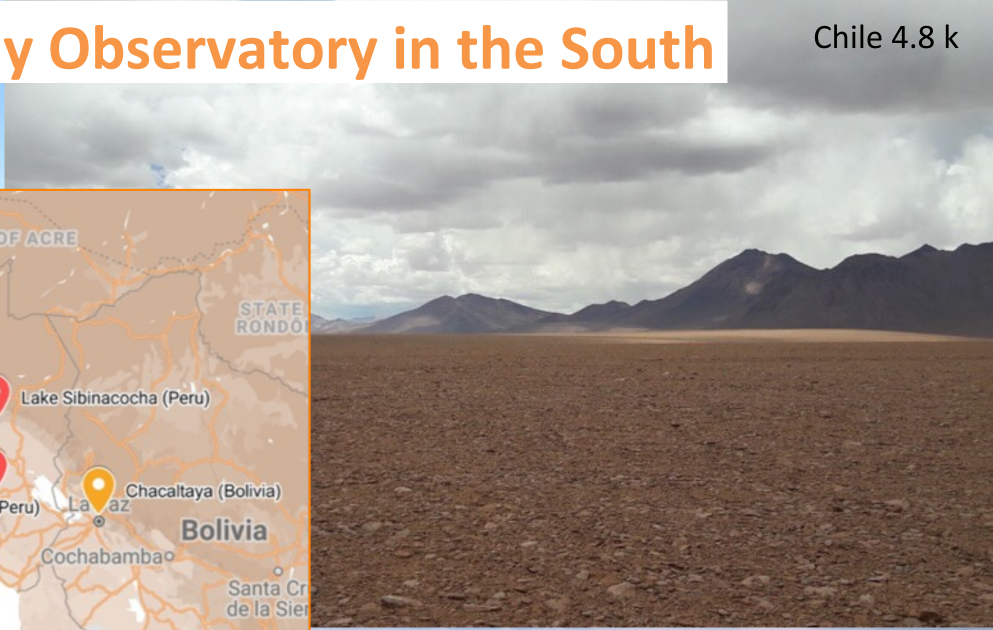


Ground-based Gamma-ray Astronomy Network

A Wide-field Gamma-ray Observatory in the South


Bolivia 4.7k


Chile 4.8 k

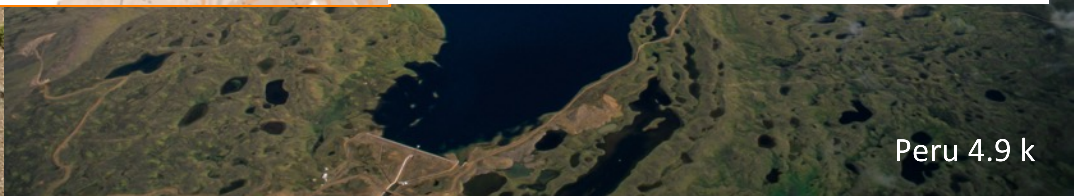

Argentina 4.8 k


Peru 4.9 k

A Wide-field Gamma-ray Observatory in the South

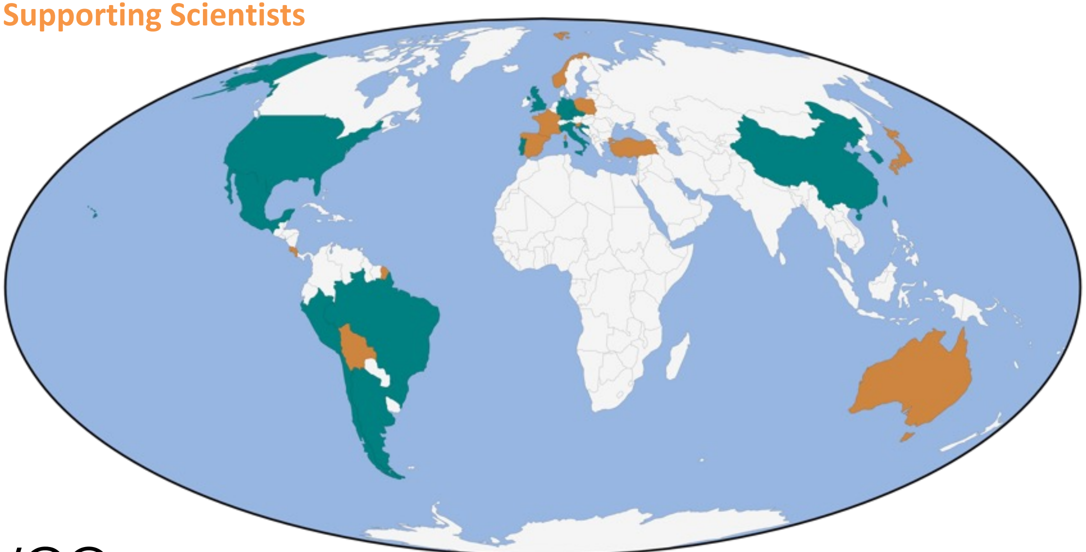
Shortlisting: Fall 2022
Site visits: October
Site selection: Fall 2023

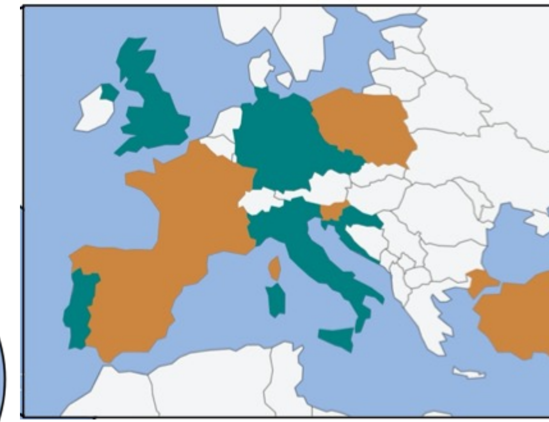
Country	Elevation	Location:
Peru	4900	Laguna Sibinacocha
Peru	4450	Imata
Peru	4450	Yanque
Argentina	4800	Cerro Vecar
Argentina	4450	Alto Tocomar
Chile	4700	ALMA Pampa La Bola
Chile	4400	AAP Pajonales
Bolivia	4700	ALPACA area



SWGO Collaboration

Member Institutes
Supporting Scientists

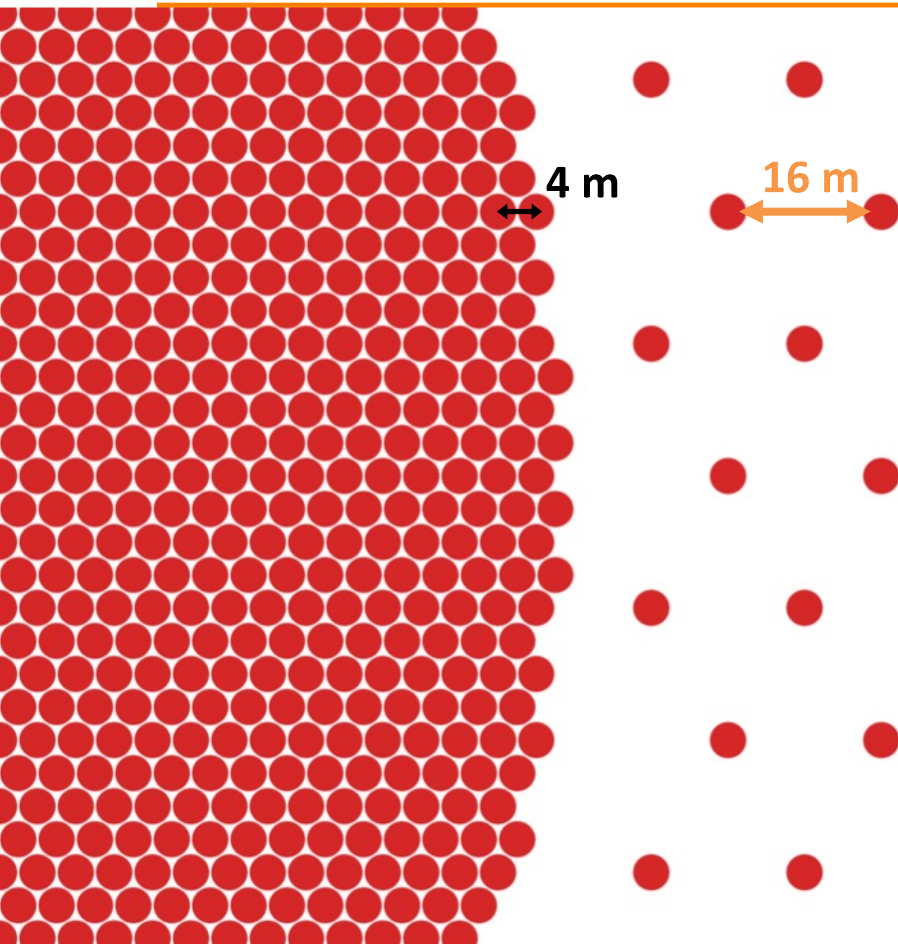




- SWGO partners
  - → 14 countries, 66 institutes*
  - → + supporting scientists

Argentina	Italy
Brazil	Mexico
Chile	Peru
China	Portugal
Croatia	South Korea
Czech Republic	United Kingdom
Germany	United States

The baseline detector concept

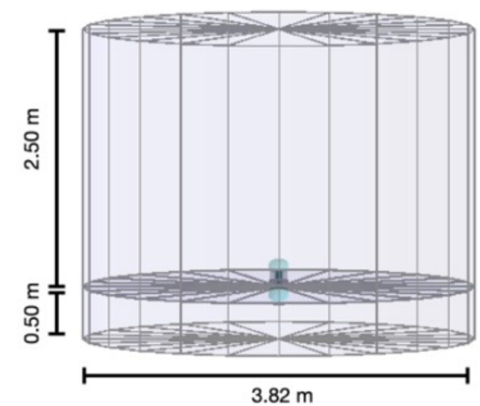


Core: Ø 320 m, FF = 80%
5,700 WCD units

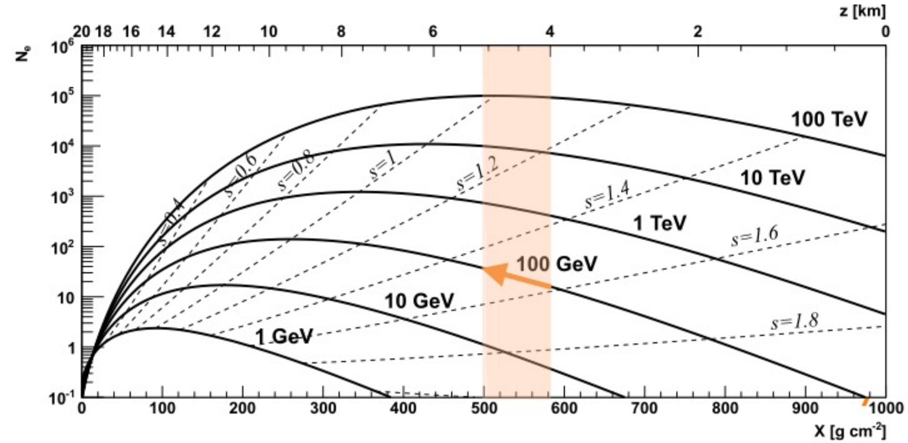
Outer: Ø 600 m, FF = 5%
880 WCD units

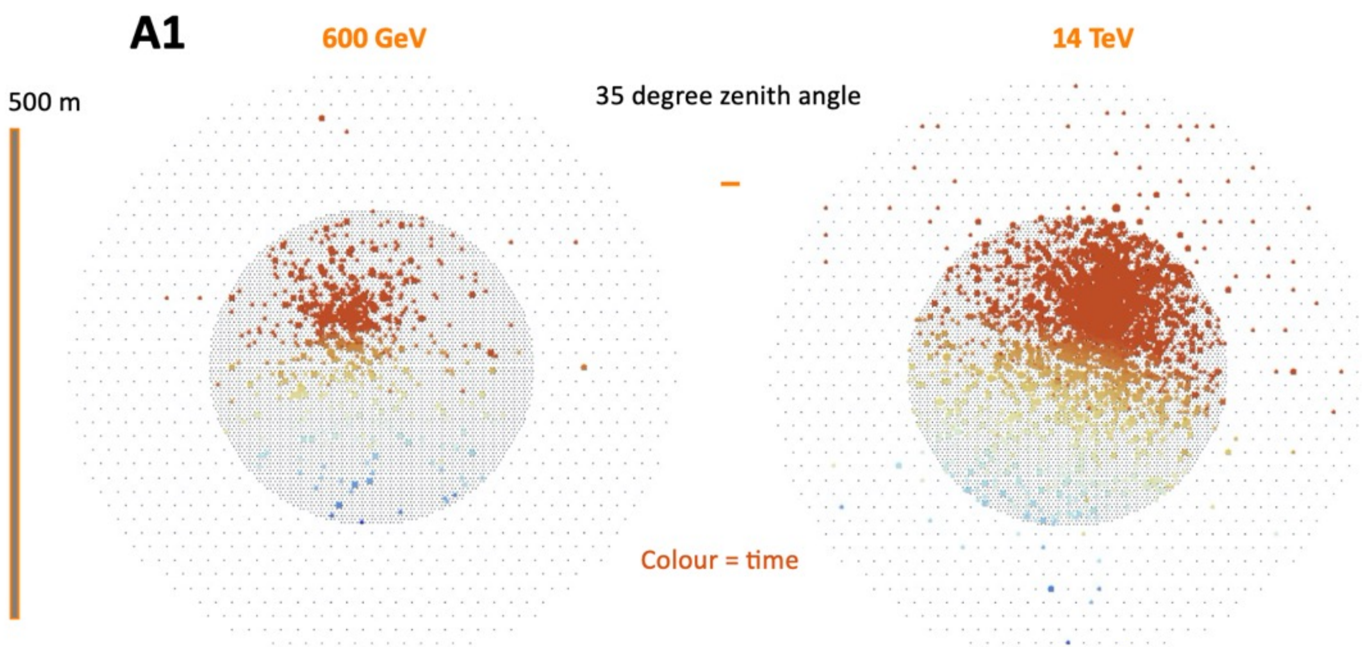
Altitude: 4,700 m a.s.l.

✧ muon counting

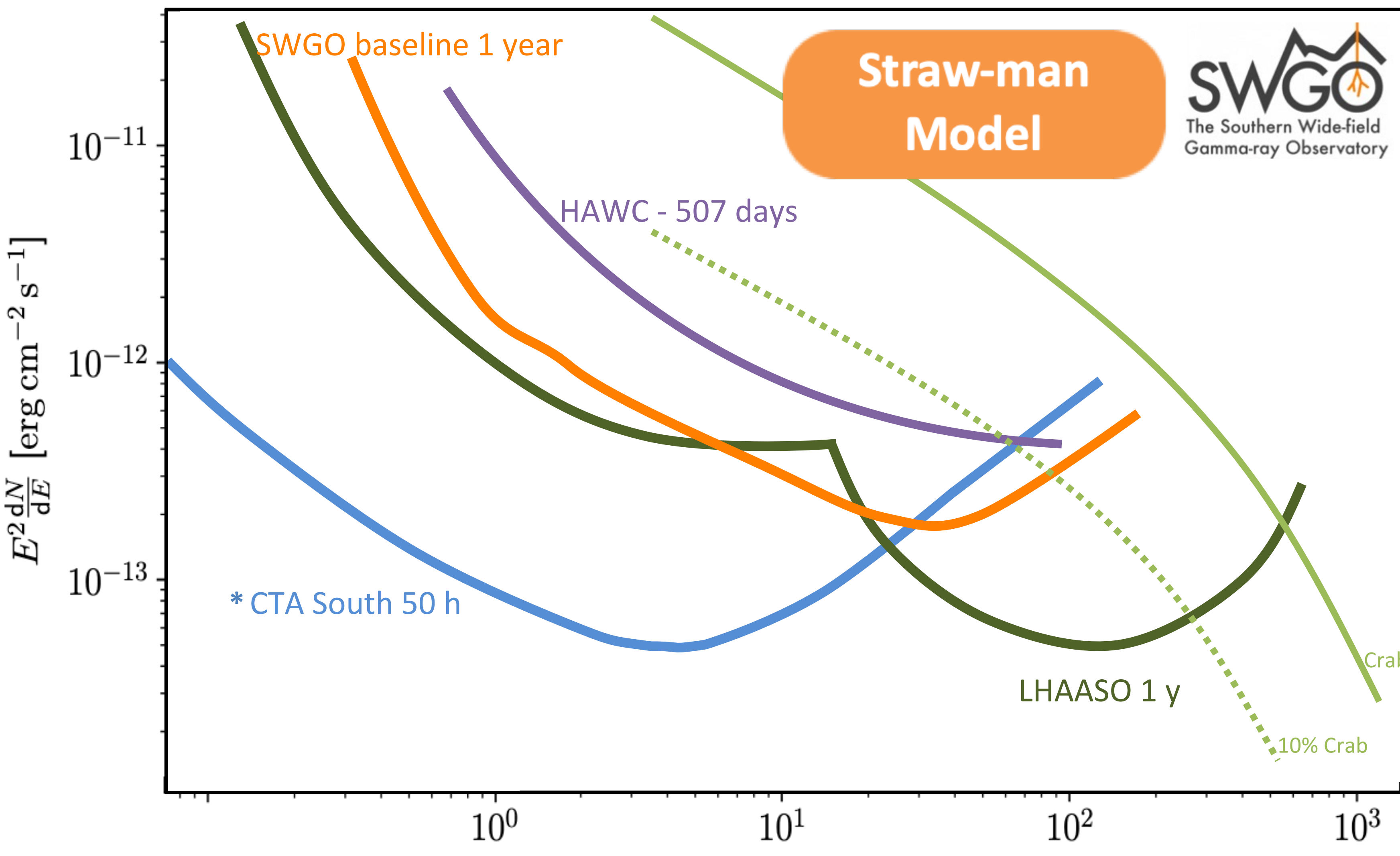


SWGO Baseline Requirements





- **Larger and denser detector array at higher altitude w.r.to HAWC**
  - → Very precise measurements possible below 1 TeV

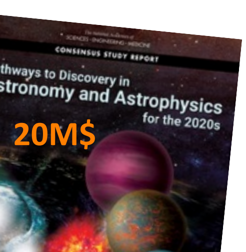


***50 h = "typical" 1-year IACT exposure**

Status & Plan

	SWGO R&D Phase Milestones	
✓	M1	R&D Phase Plan Established
✓	M2	Science Benchmarks Defined
✓	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

- R&D Phase
  - → Kick off meeting Oct 2019
  - → Expected completion 2024
    - ✓ Site and Design Choices made
  - → Then:
- Preparatory Phase
  - → Detailed construction planning
  - → **Engineering Array**
- (Full) Construction Phase
  - → 2026+



- Roadmaps
  - → US Decadal Review
  - → SNOWMASS, APPEC, Astronet

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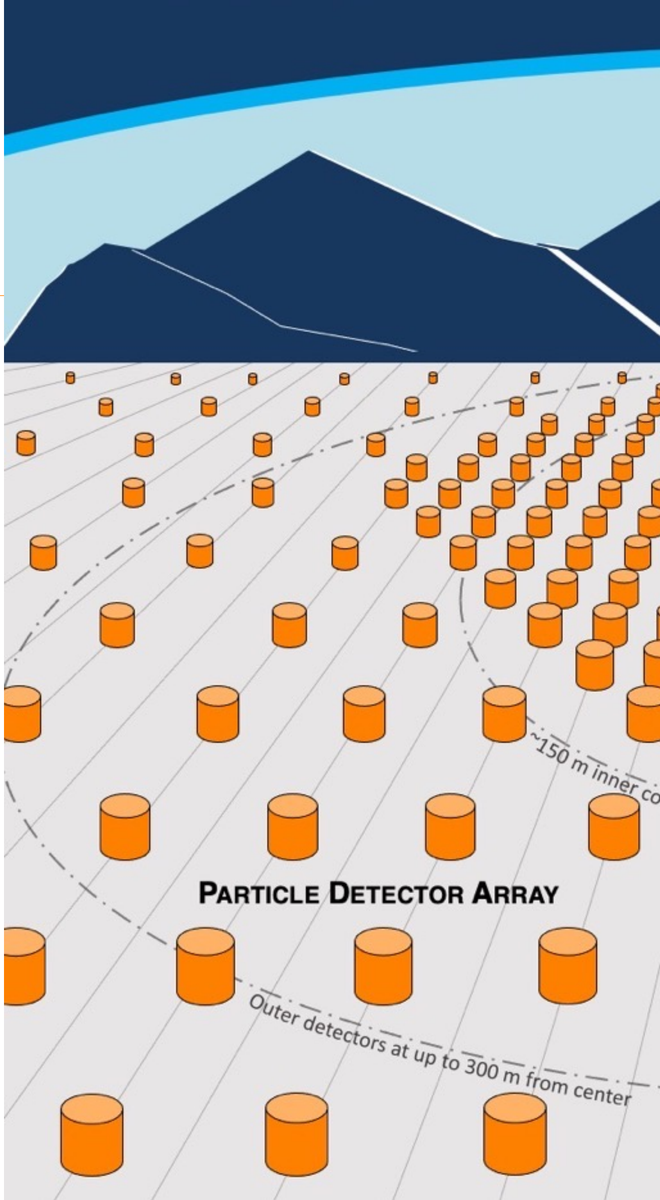
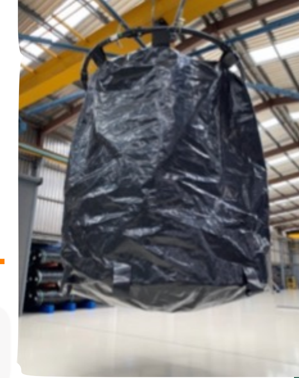
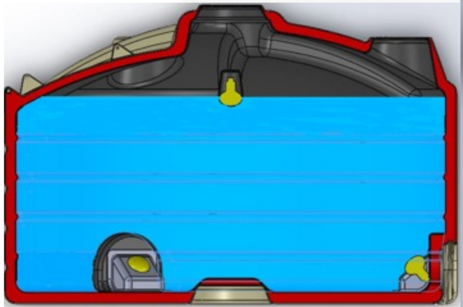


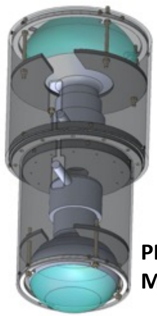
WCD unit Solutions

- WCD Unit
  - Lake
    - Natural Lake
    - Artificial Lake/Pond
  - Tank
    - Steel Tank
    - Rotomolded Plastic



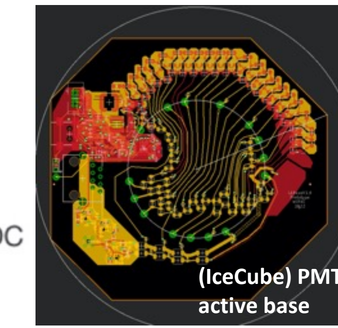


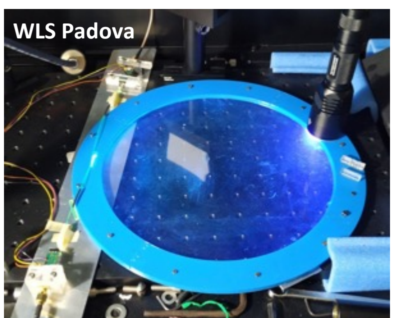
More Detector Options and Prototyping



PMT module MPIK

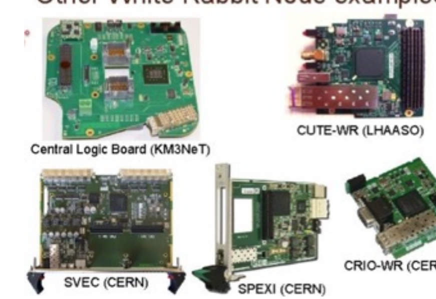
- Photodetectors
  - Detector
    - Large-area PMT
    - SiPM array
    - Multi-sensor
    - Distributed sensor
  - Light guide
    - None
    - Winston cone
    - WLS plate or fibres
- Electronics chain
  - Photodetector supply
    - Active base
    - Multi-channel HV
  - Digitiser
    - High-rate sampling
    - Medium-rate sampling + TDC
    - Time-over-threshold (ToT)
  - Clock distribution
    - White Rabbit
    - RapCal

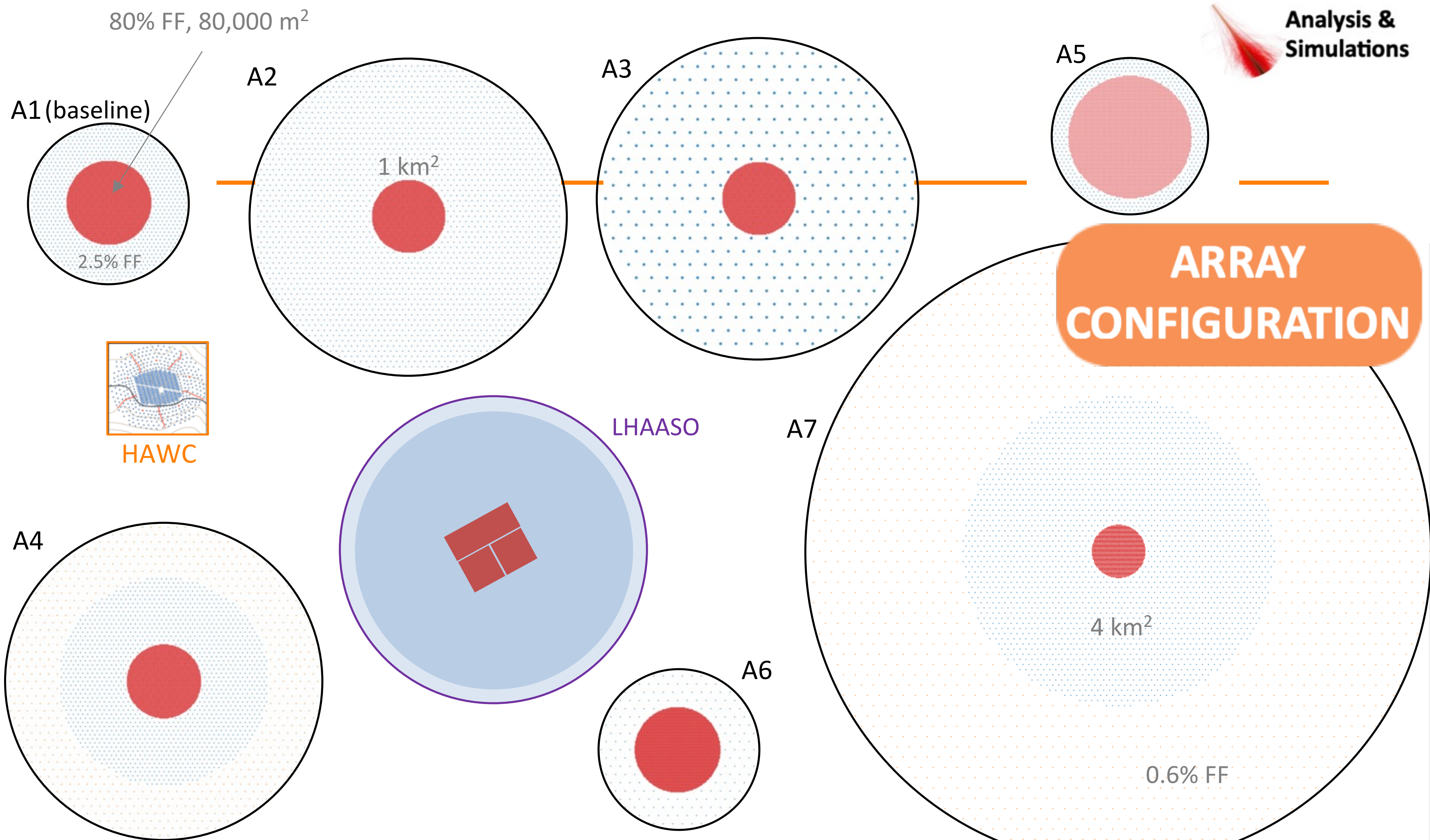




HyperK-style multi-PMT

Other White Rabbit Node examples:

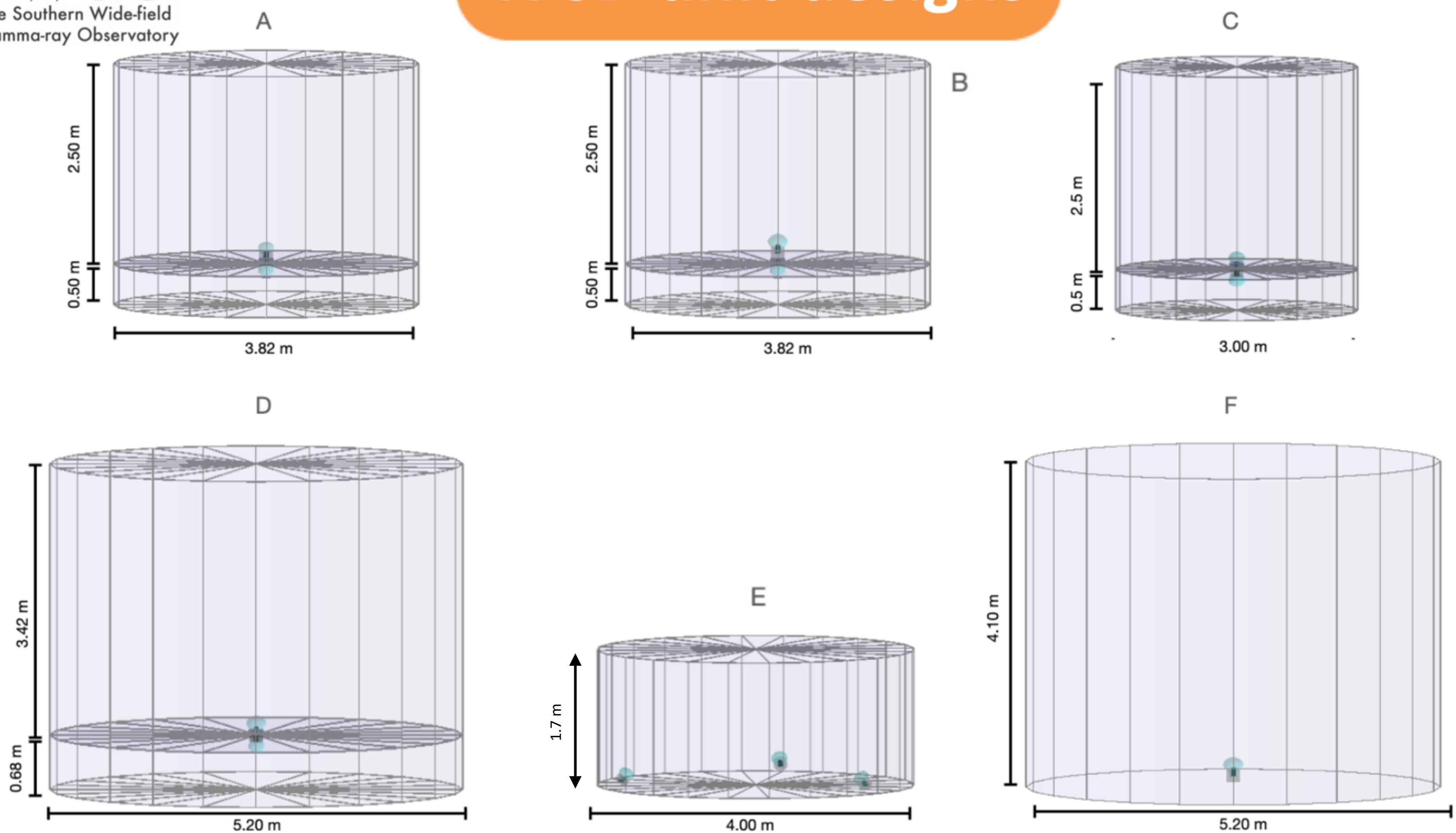




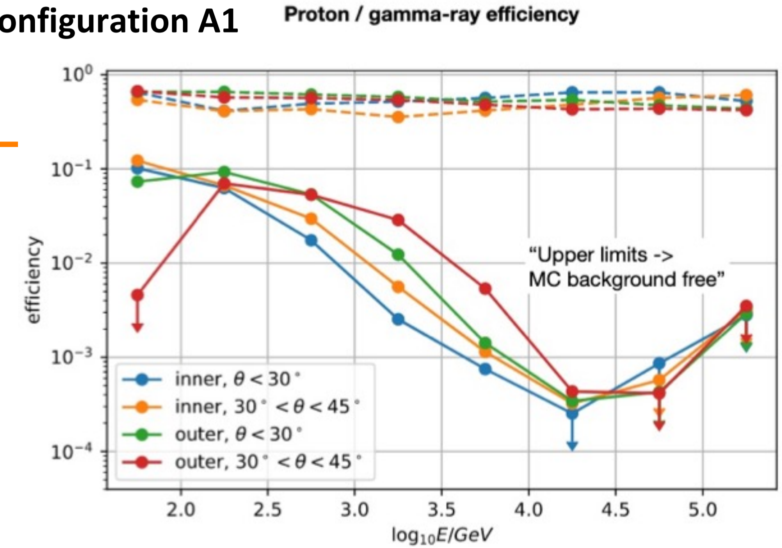
similarly B1, C1, D1, …, E4 (13 total)

EQUAL NOMINAL COST ARRAYS

WCD unit designs



PRELIMINARY
Full-array sims
Configuration A1



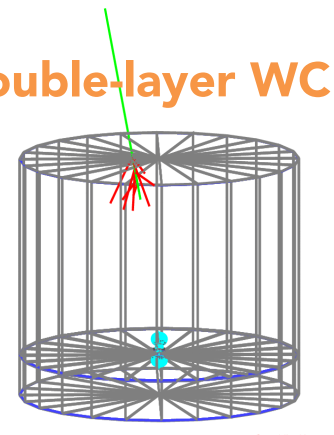
Muon content in the showers

- Muon cuts effective > 10 TeV
- Multiple strategies under investigation

γ/CR selection

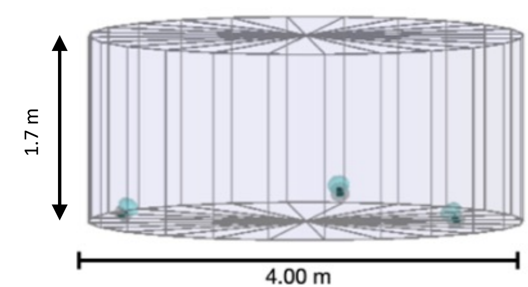
μ detection

Double-layer WCDs



F. Bisconti & A. Chiavassa 2022
S. Kunwar et al. 2022

Multi-PMT WCDs



R. Conceição et al. 2022a

SWGO
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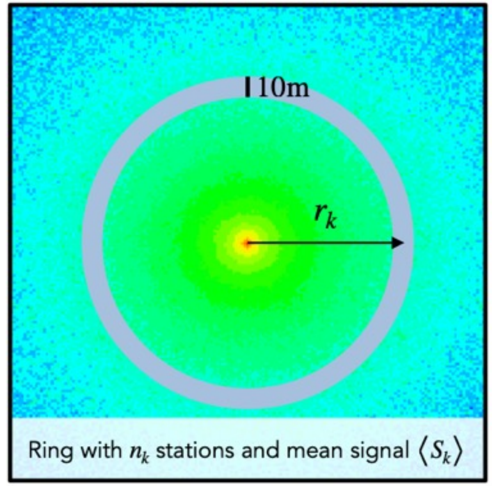
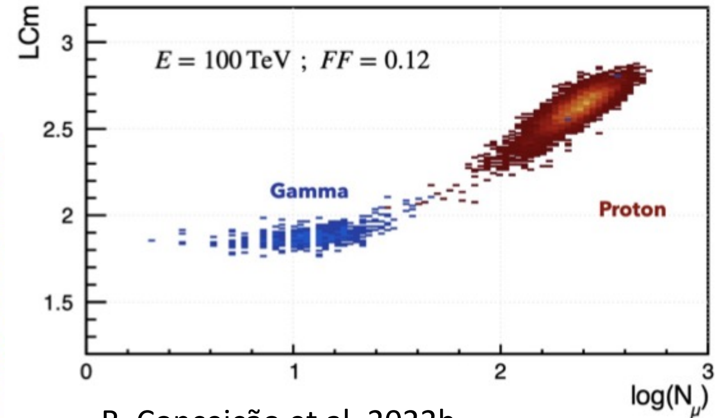
γ/CR selection

Shower footprint

μ detection

Shower azimuthal asymmetries



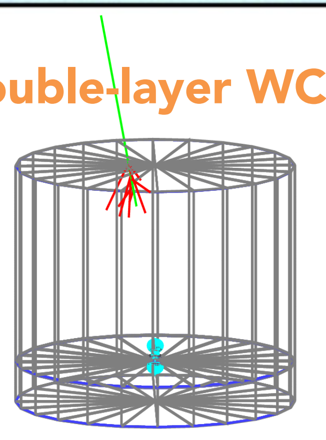


R. Conceição et al. 2022b

$$C_k = \frac{2}{n_k(n_k-1)} \frac{1}{\langle S_k \rangle} \sum_{i=1}^{n_k-1} \sum_{j=i+1}^{n_k} (S_{ik} - S_{jk})^2$$

$$LCm \equiv \log(C_k)|_{r_k = r_m} \qquad r_m = 360\,m.$$

Double-layer WCDs



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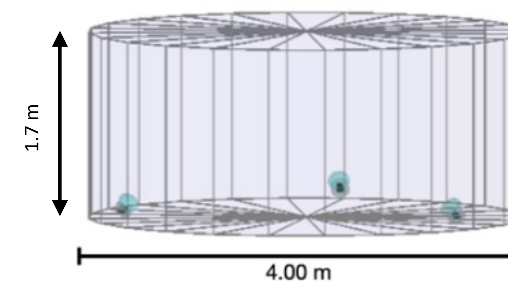
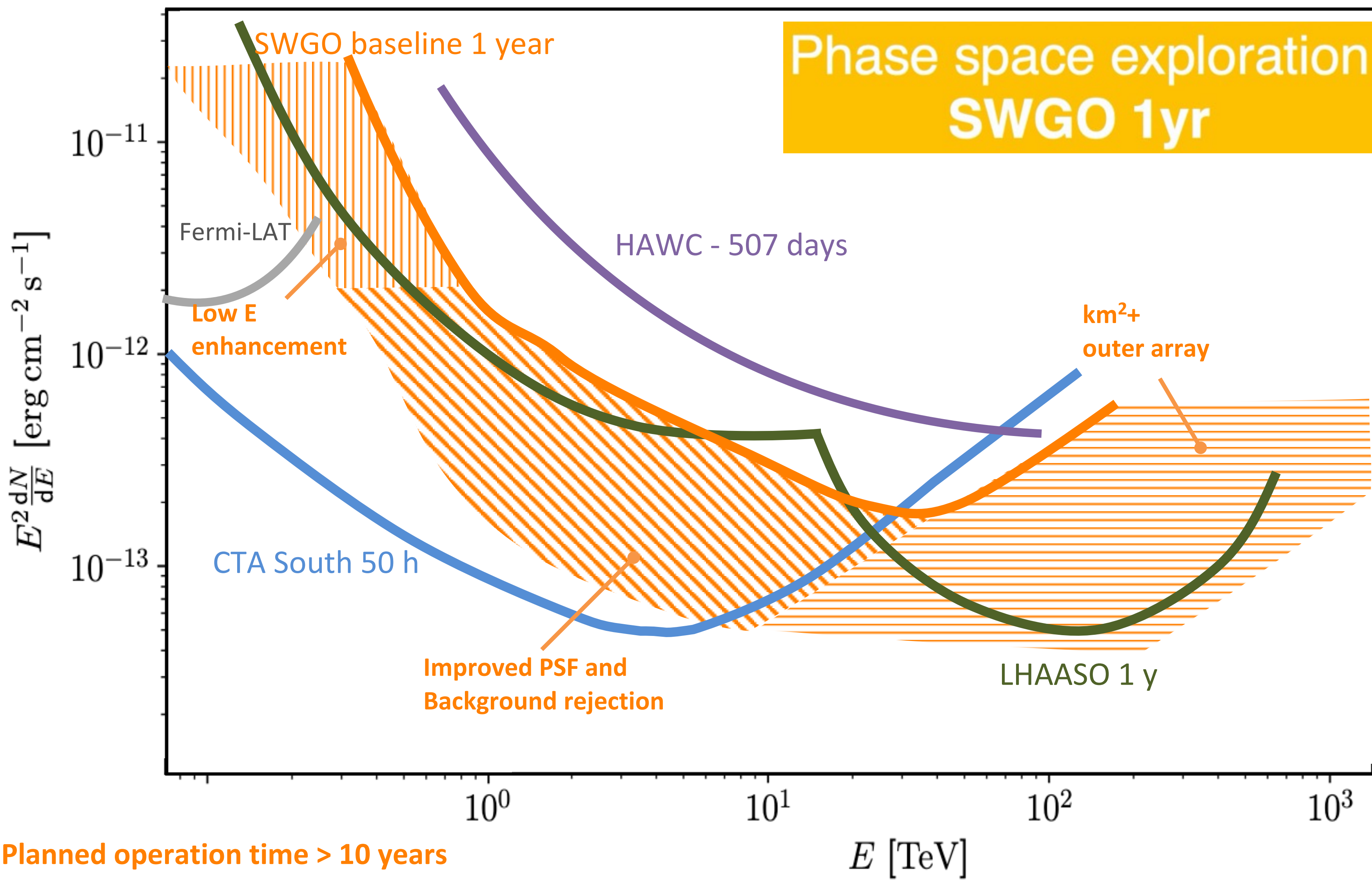
S. Kunwar et al. 2022

Multi-PMT WCDs

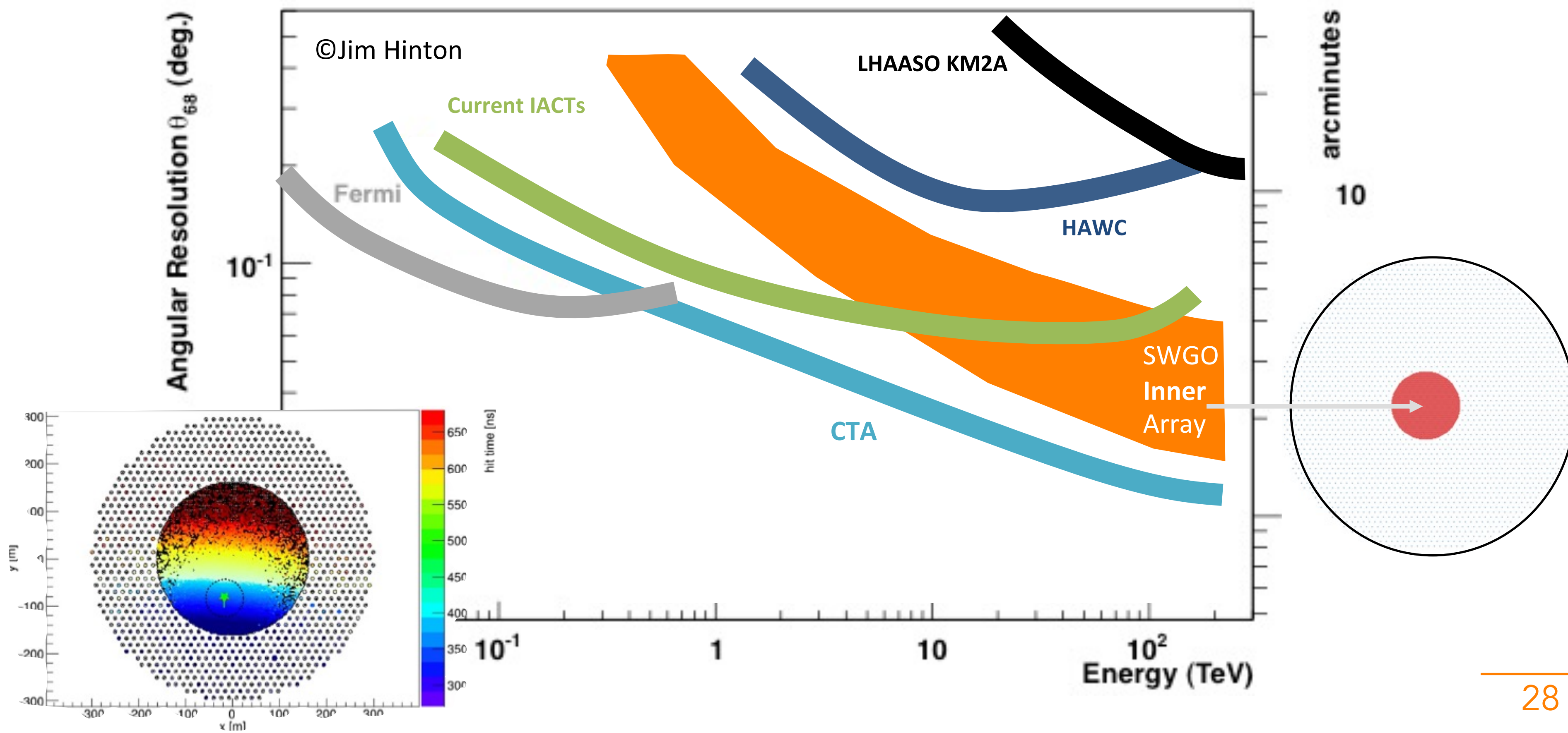


R. Conceição et al. 2022a



Planned operation time > 10 years

SWGO Performance Goal
Angular Resolution



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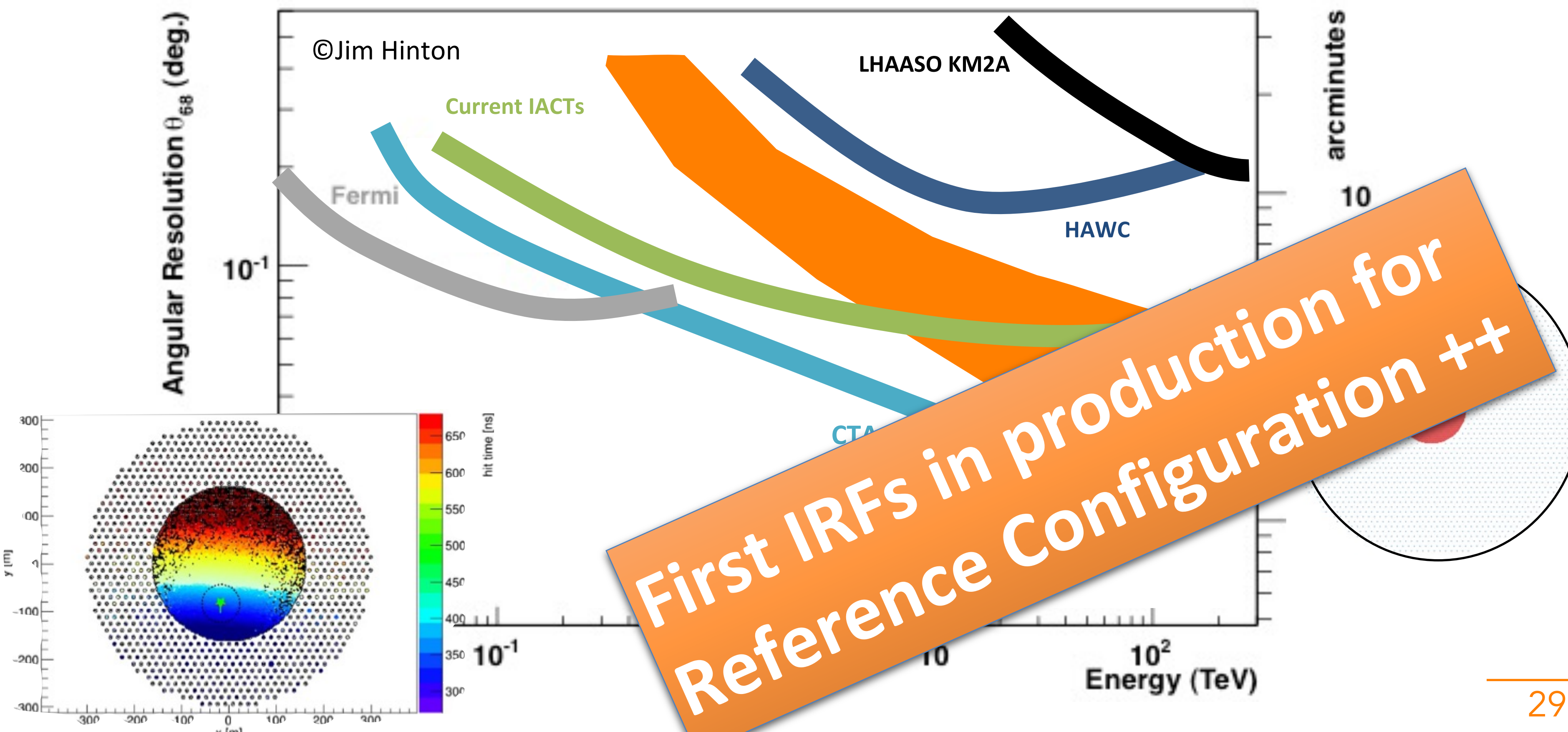

First IRFs in production for Reference Configuration ++

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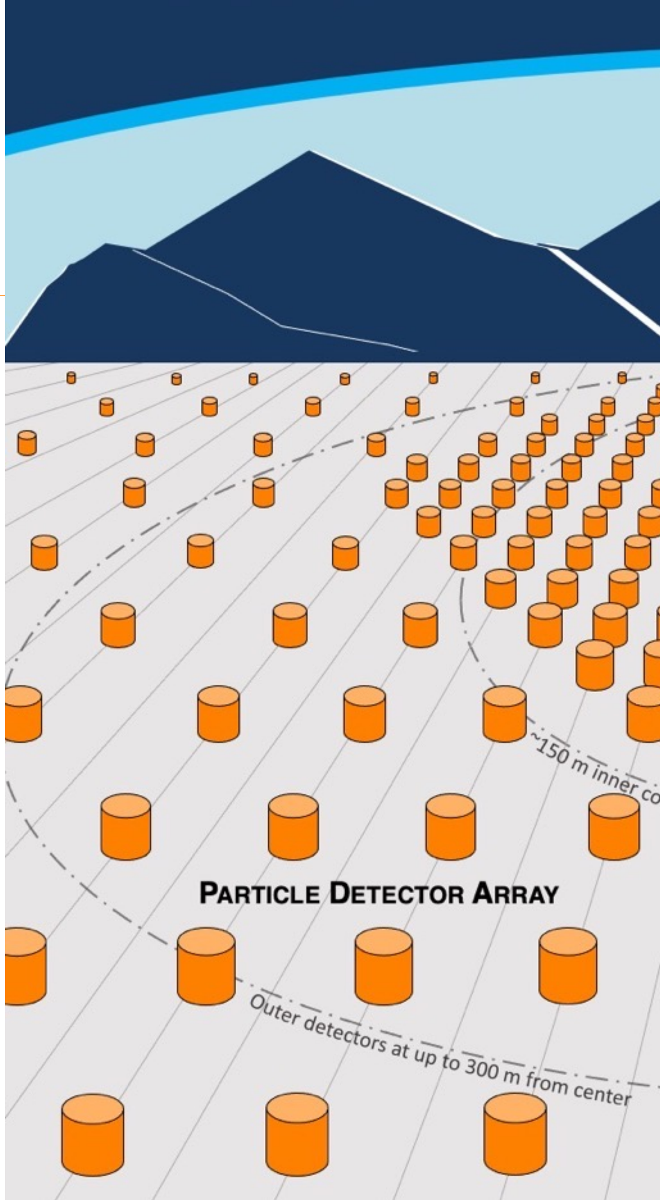
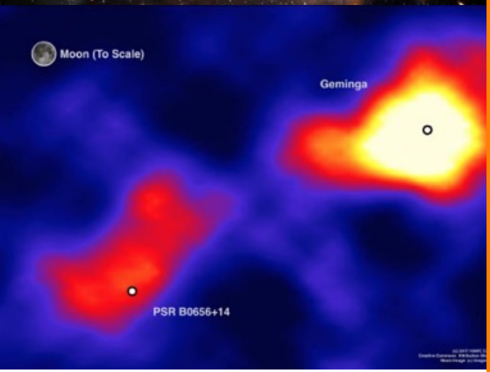
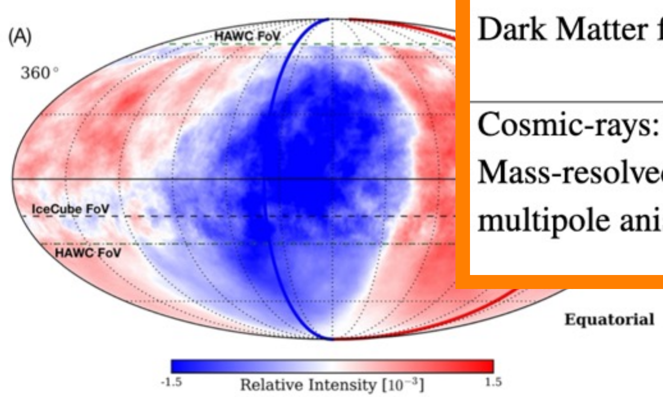
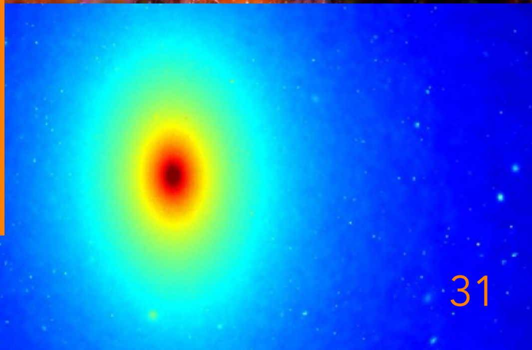


Science

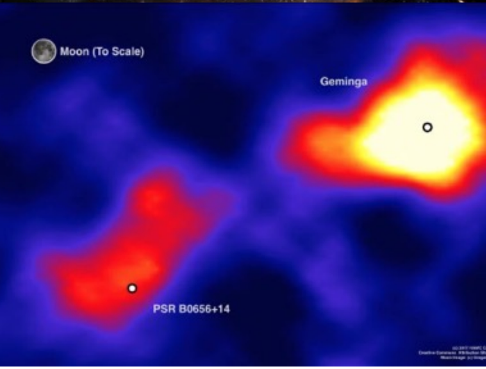


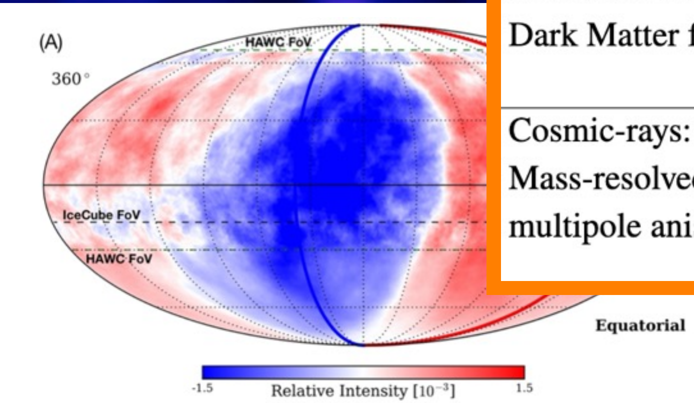


Science Case	Design Drivers
Transient Sources: Gamma-ray Bursts	Low-energy sensitivity & Site altitude[a]
Galactic Accelerators: PeVatron Sources	High-energy sensitivity & Energy resolution[b]
Galactic Accelerators: PWNe and TeV Halos	Extended source sensitivity & Angular resolution[c]
Diffuse Emission: Fermi Bubbles	Background rejection
Fundamental Physics: Dark Matter from GC Halo	Mid-range energy sensitivity Site latitude[d]
Cosmic-rays: Mass-resolved dipole / multipole anisotropy	Muon counting capability[e]



Science





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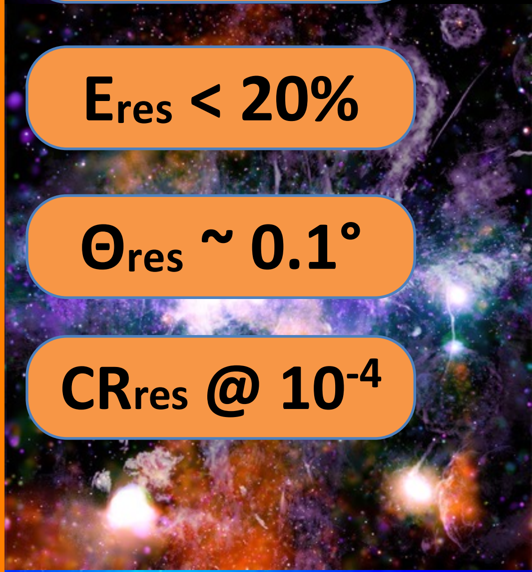
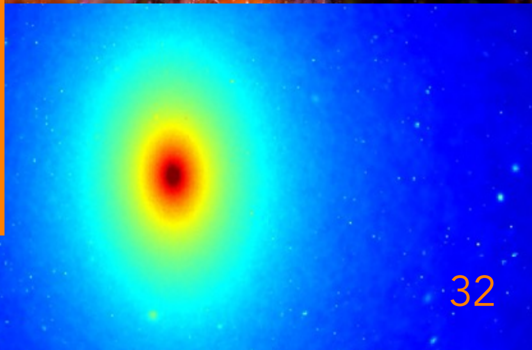
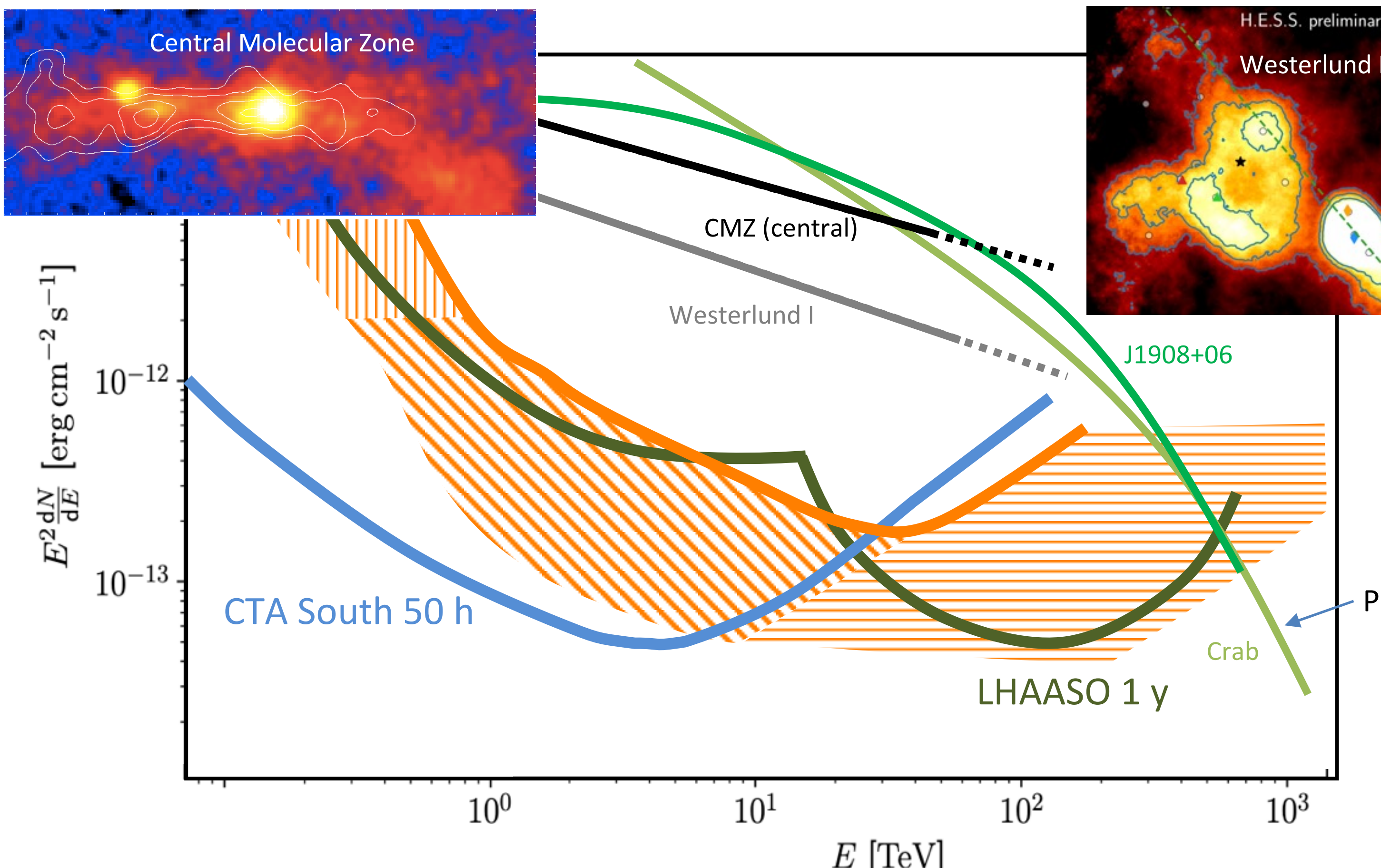
PRELIMINARY DESIGN TARGETS



- $E_{th} \rightarrow 100$ GeV
- $E_{res} < 20\%$
- $\Theta_{res} \sim 0.1°$
- CR_{res} @ 10^{-4}



Extended and UHE sources



A young super star cluster with star-forming regions

PeVatron

Transients with SWGO

- Short-timescale sensitivity of ground-particle detectors is much worse than IACTs at low E! ..but room for improvement < 1 TeV

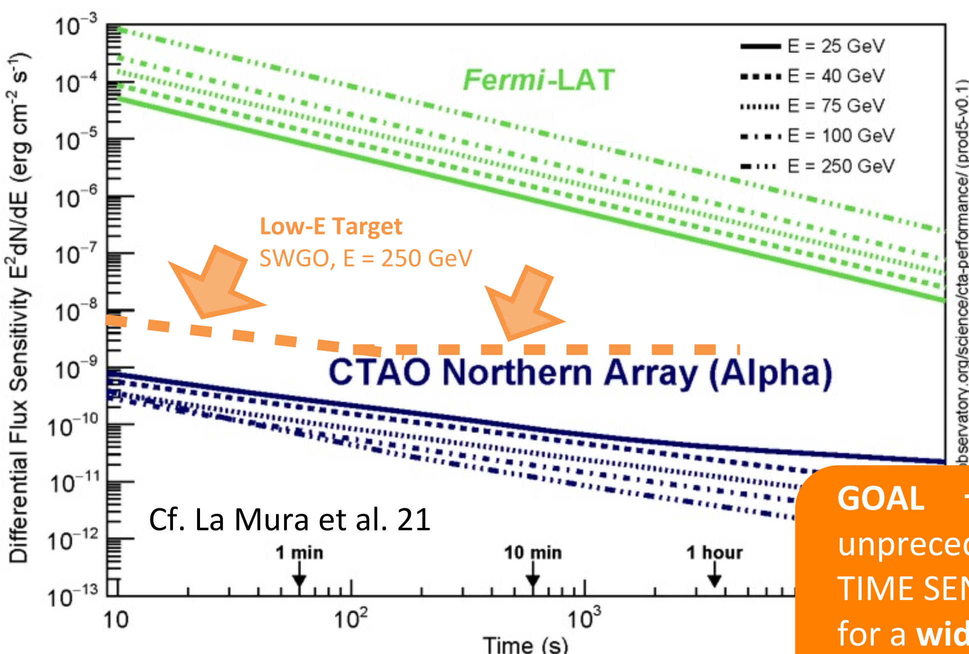
1 min sensitivity:
- Fermi-LAT: 10^{-7} erg/cm^2/s @ 1 GeV
- SWGO: 10^{-9} erg/cm^2/s @ < 500 GeV
- CTA: 10^{-11} erg/cm^2/s @ 100 GeV

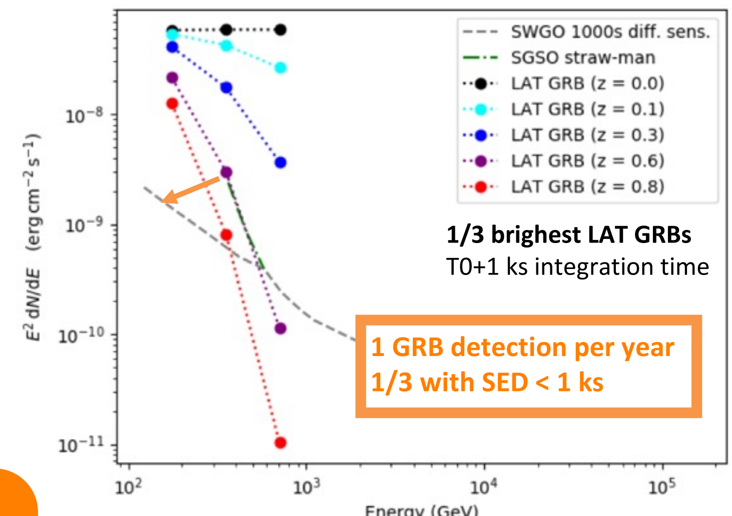
- And a number of other advantages…
  - **100% duty cycle** → higher rate and monitoring capability of transients → bridging the gap with satellite facilities
  - **Serendipitous view** - observation of onset / prompt emission of GRBs
  - **A trigger instrument**!
    - Blind searches and offline checks for afterglow triggers
      - Critical synergy with IACTs and other MWL + MM instruments

✧ **SWGO can bring the 10s deg^2 error boxes (GBM, GW) down to ~ deg^2**

Transients with SWGO

- Short-timescale sensitivity of ground-particle detectors is much worse than IACTs at low E! But room for improvement < 1 TeV

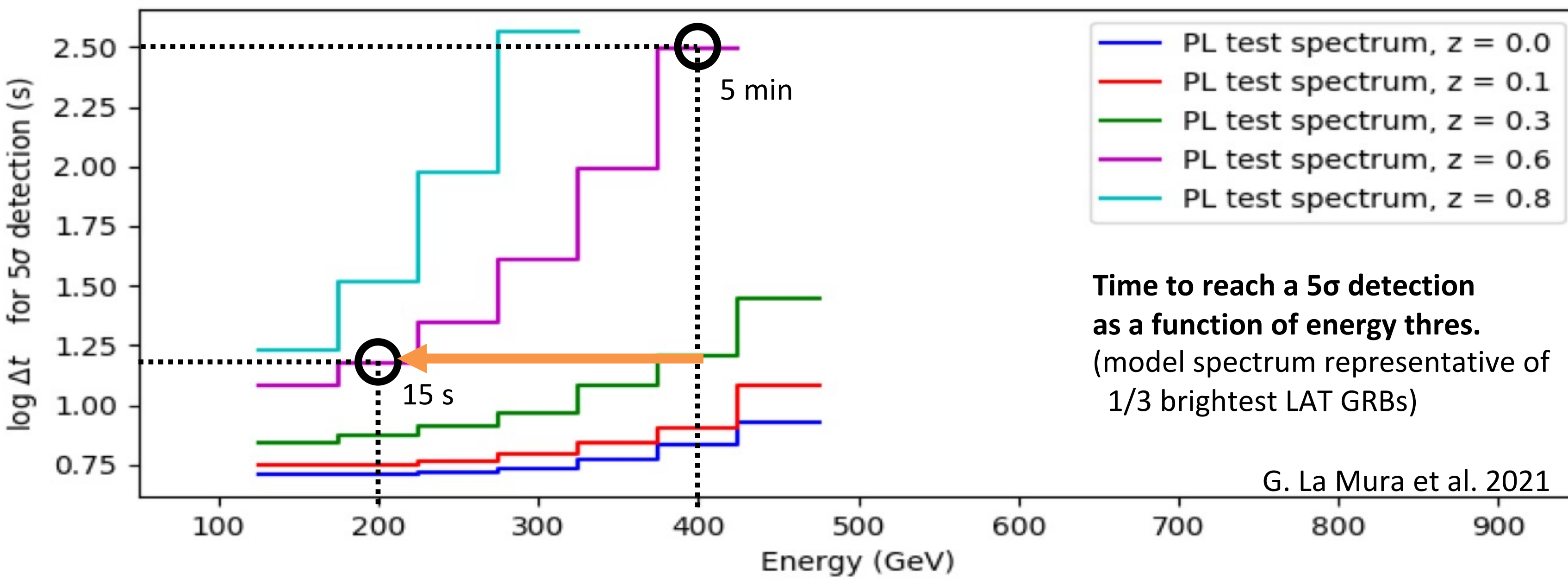




GOAL →
unprecedented
TIME SENSITIVITY
for a **wide field**
VHE instrument

Transients with SWGO

- Energy threshold is crucial for variability studies, in particular short-transient events such as GRBs

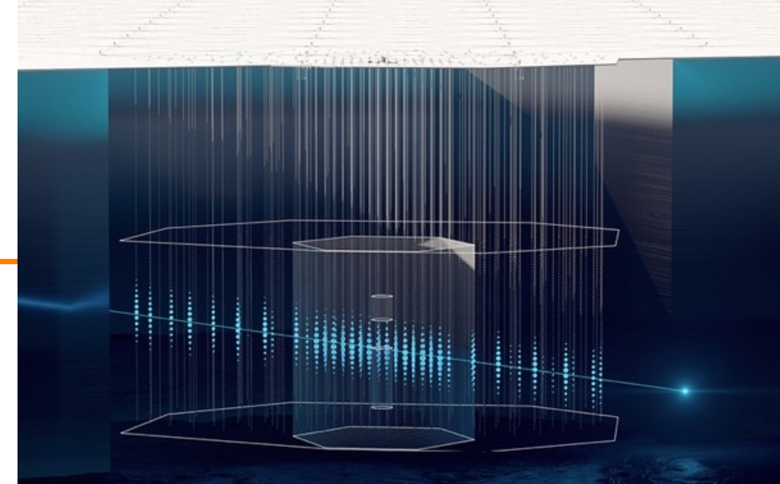


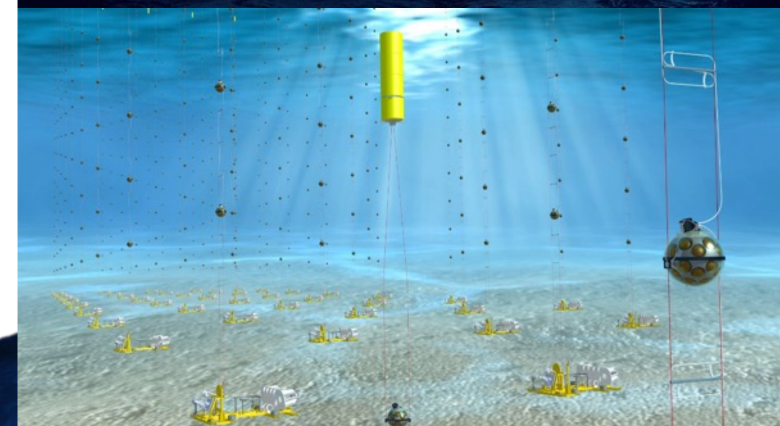
Time to reach a 5σ detection as a function of energy thres.
(model spectrum representative of 1/3 brightest LAT GRBs)

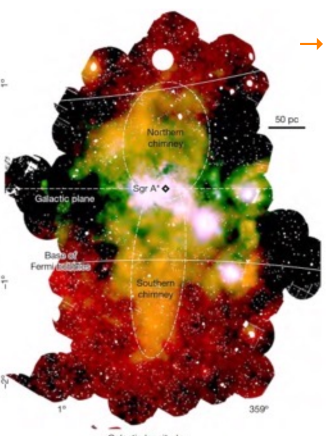
G. La Mura et al. 2021

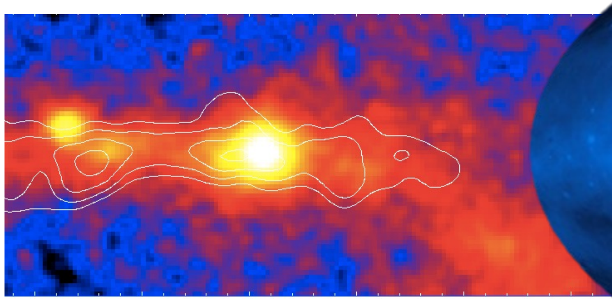
Neutrino Synergies

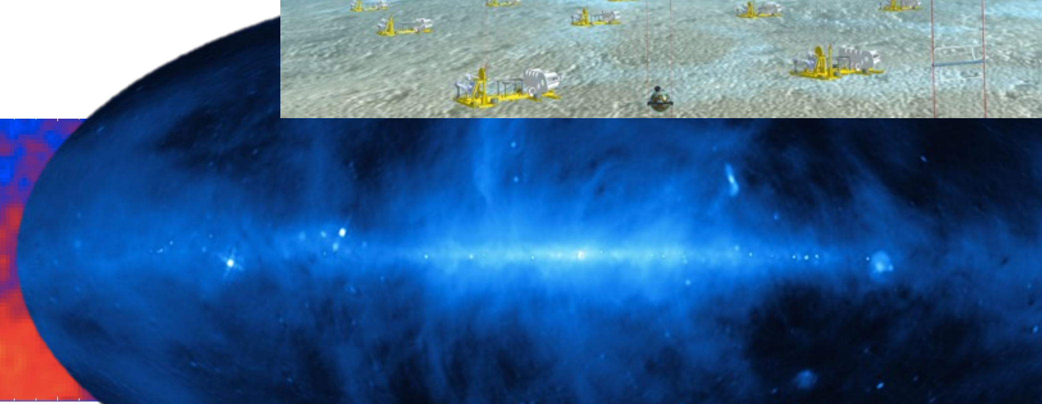
- SWGO+LHAASO
  - → **Full sky map of TeV-PeV γ emission**
- Strongly complements new generation of **neutrino instruments**
  - → Mapping out diffuse emission / separating inv. Compton vs. pion decay emission, Dark Matter search +++
  - → Nearby transients/flares





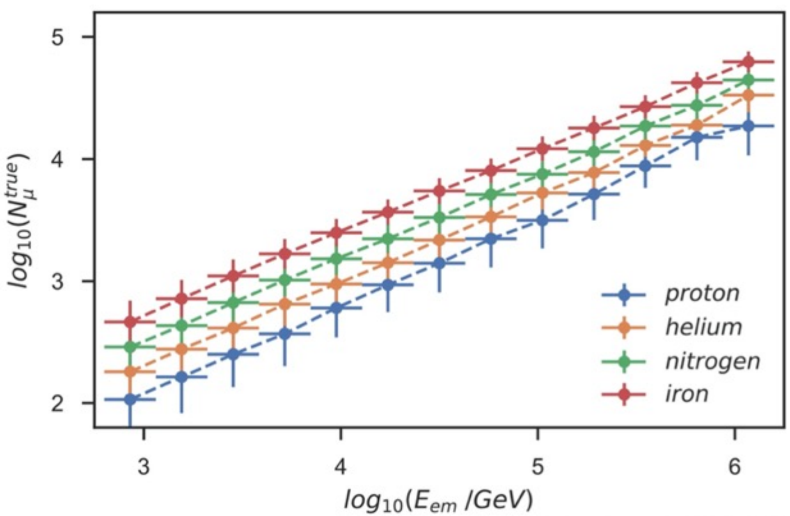






Cosmic rays

- Charged cosmic ray physics at the knee
  - → **Mass-resolved anisotropy studies**
- Measuring μ-content with WCDs
  - → Tagging of single muons at detector unit



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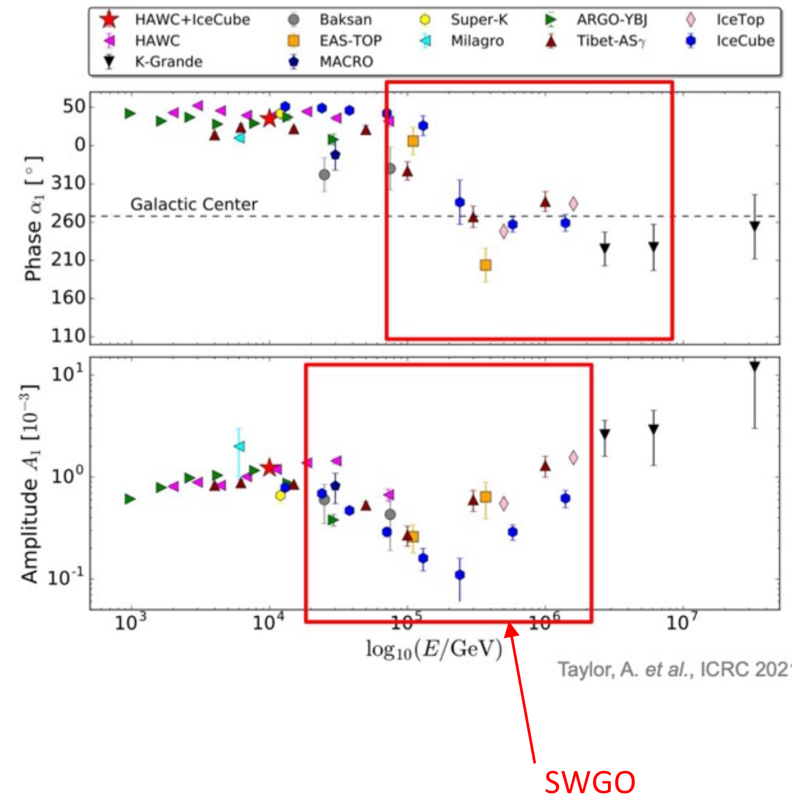
CR Dipole vs. energy



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Summary

SWGO
The Southern Wide-field Gamma-ray Observatory

- SWGO is deep into the R&D phase
  - → Figuring in the **future infrastructure roadmaps** in the US, EU and LA
- Engineering array at few-% scale planned after CDR, in 2024+
- **Science and performance goals**
  - → New window for PeVatron astronomy in the southern hemisphere
    - ✓ Complementary to LHAASO's sky view
    - ✓ Origin of Galactic Hadronic Cosmic-rays
  - → Wide-energy range coverage 100 GeV - 1 PeV
    - ✓ Complementary to CTA
    - ✓ Bridging the satellite all-sky monitoring capabilities
  - → Sensitivity for transient phenomena below 1 TeV
  - → Crucial mass-resolved CR data at the knee region
- A key instrument for MM astrophysics for the next decades!

Thank you!

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