The Southern Wide-field Gamma-ray Observatory

www.swgo.org

Claudio O. Dib
UTFSM & CCTVal

UNIVERSIDAD TECNICA
FEDERICO SANTA MARIA

CCTVal
CENTRO CIENTÍFICO
TECNOLÓGICO
DE VALPARAÍSO

on behalf of
Ulisses Barres de Almeida
co-spokesperson

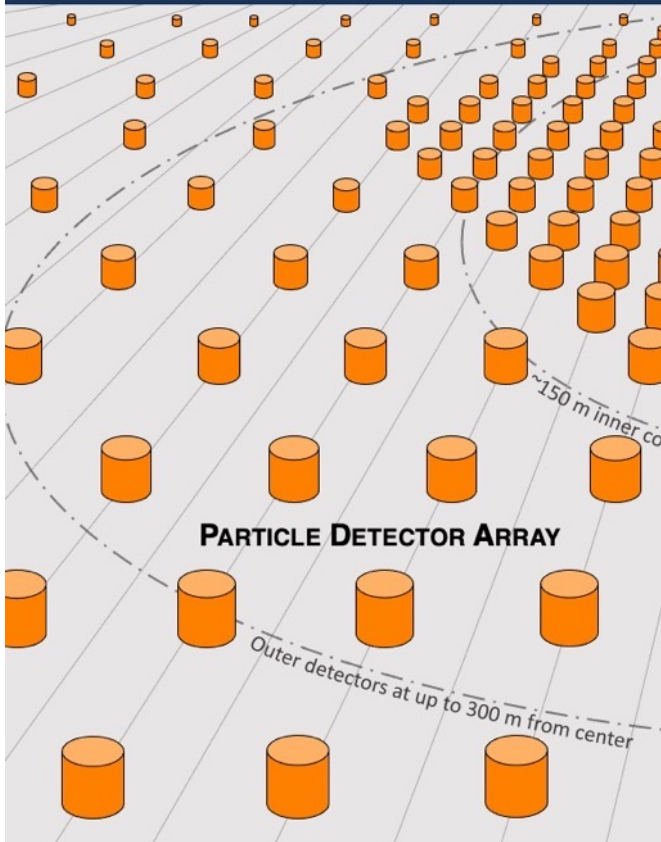
CBPF
Centro Brasileiro
de Pesquisas Físicas

for the SWGO Collaboration

SWGO
The Southern Wide-field Gamma-ray Observatory

Content

- The field in context
- SWGO:
  - the driving science
  - the design
  - the site



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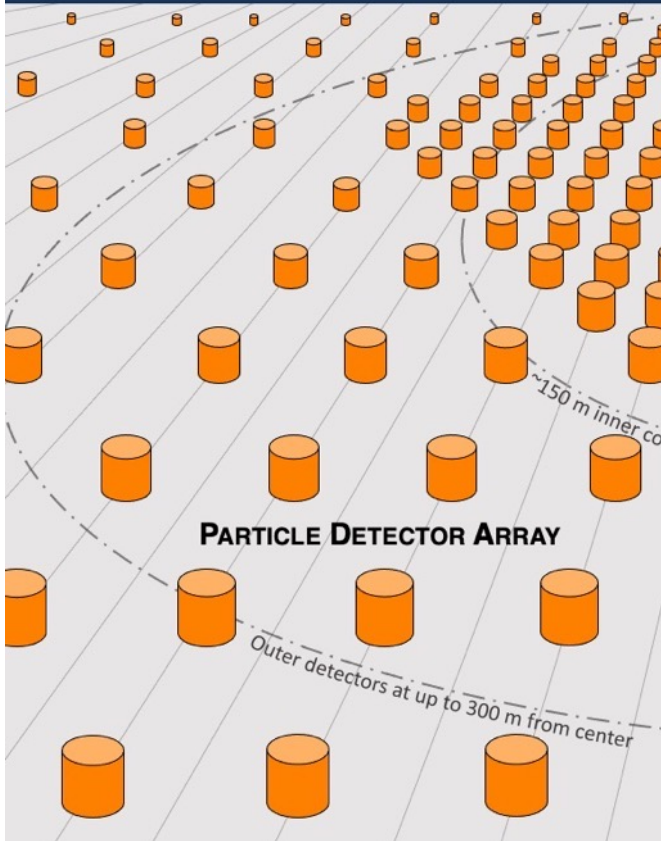
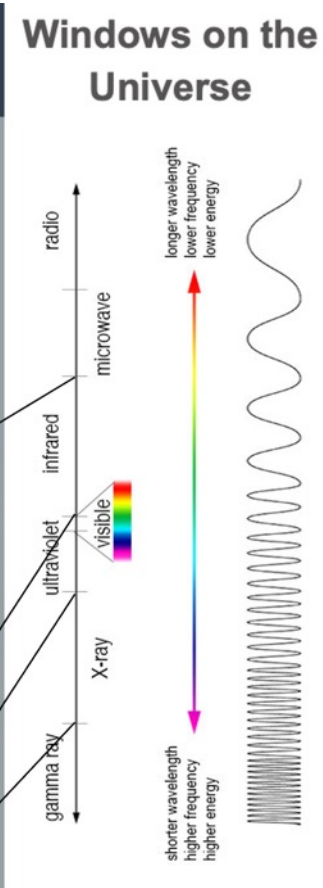


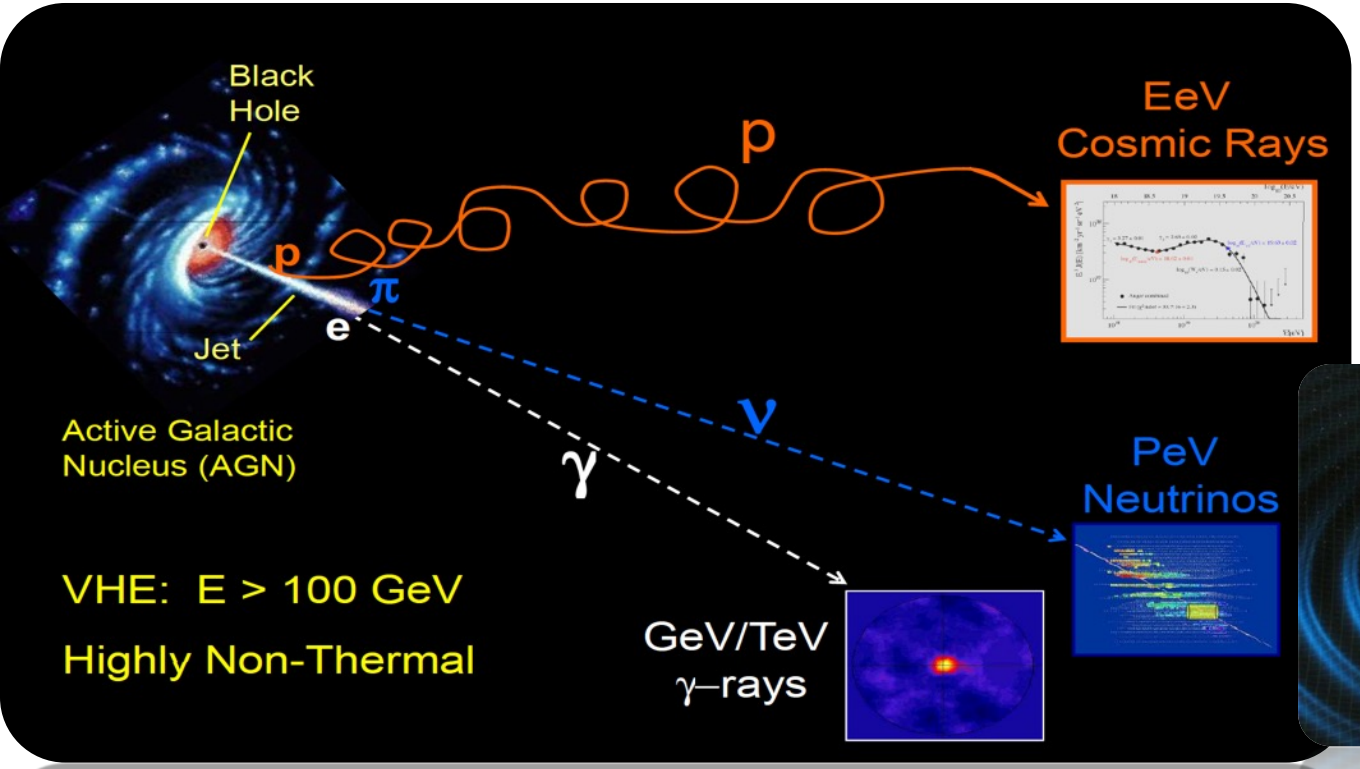
Multi-Wavelength & Multi-Messenger

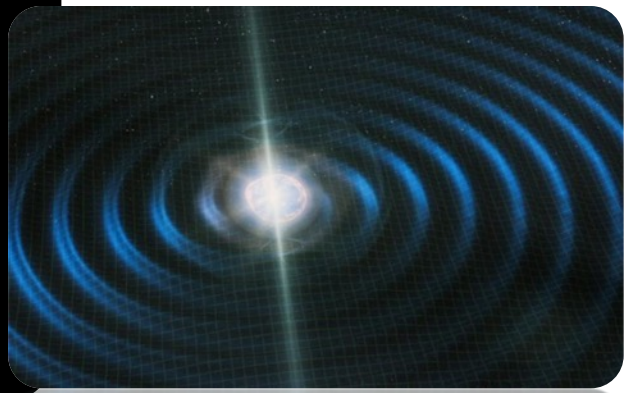


Poster from 1996

Multi-Wavelength & Multi-Messenger

Multi-Wavelength & Multi-Messenger



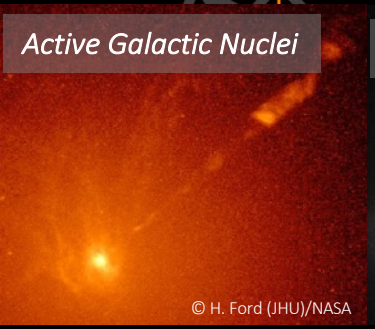


Gamma-Ray* Sources

Windows Into the Non-Thermal Universe

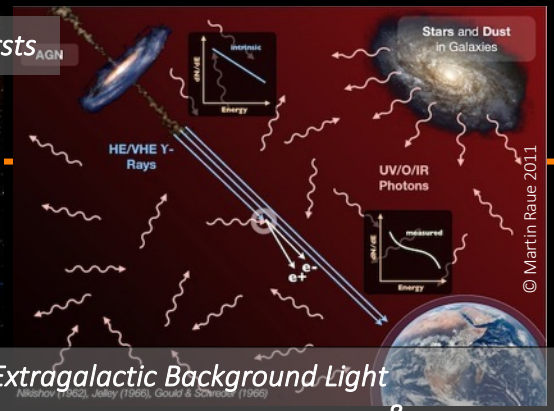
* (also sources of cosmic rays, neutrinos & gravitational waves)

Active Galactic Nuclei

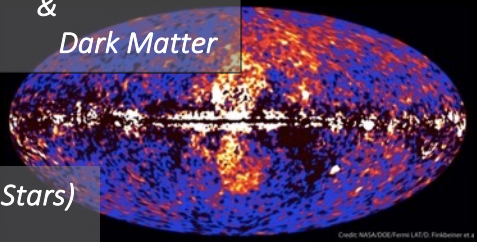


Starburst Galaxies

"Naked Eye" Gamma-Ray Bursts



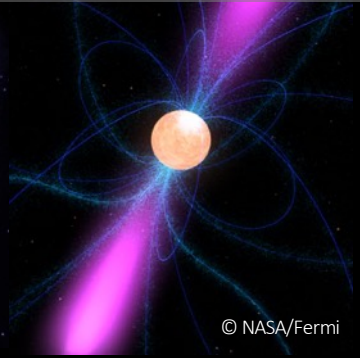
Extragalactic Background Light
&
Dark Matter

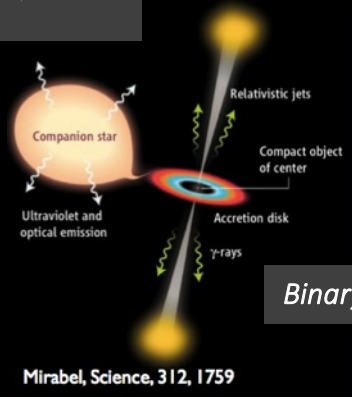


Super Nova Remnants

Pulsar Wind Nebulae

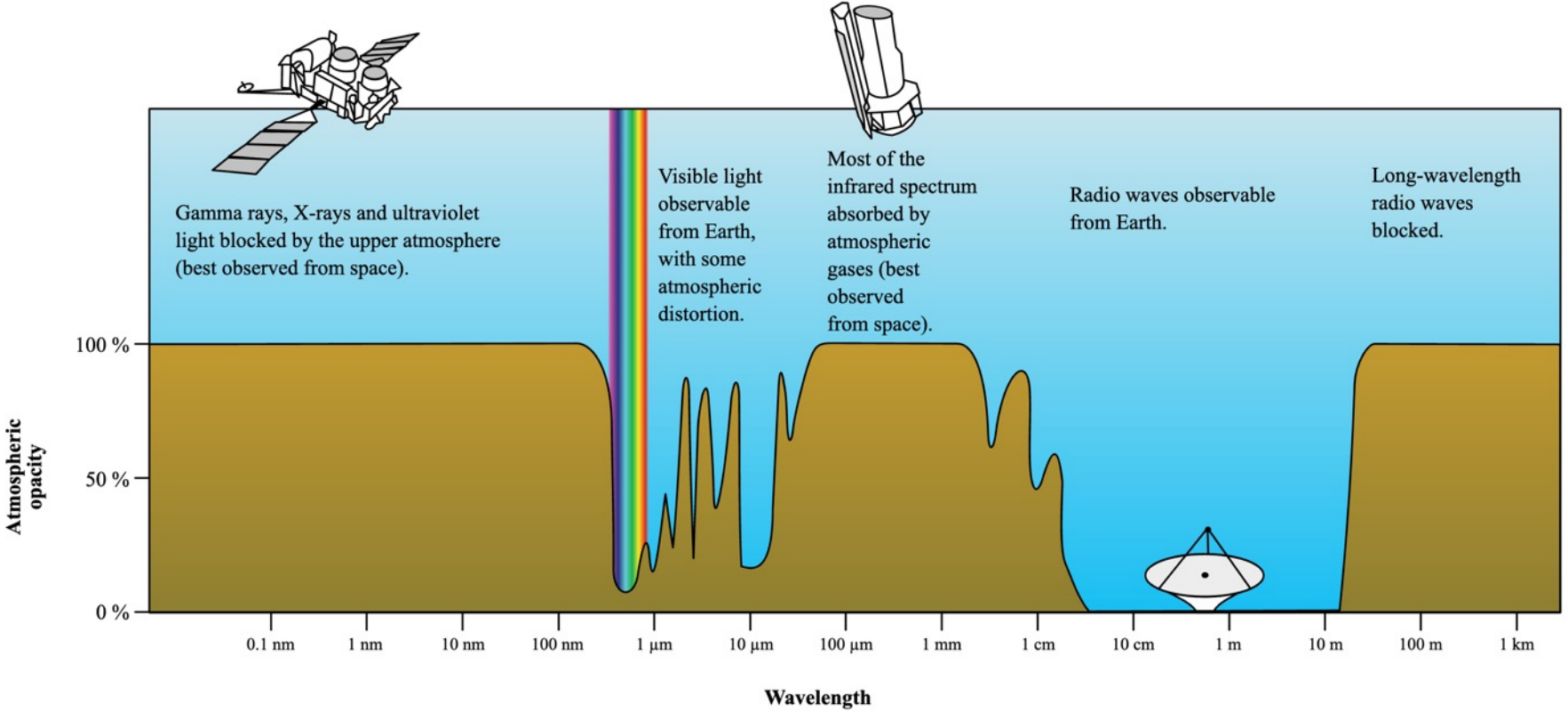
Pulsars (Fast Spinning Neutron Stars)
&
Lorentz Invariance



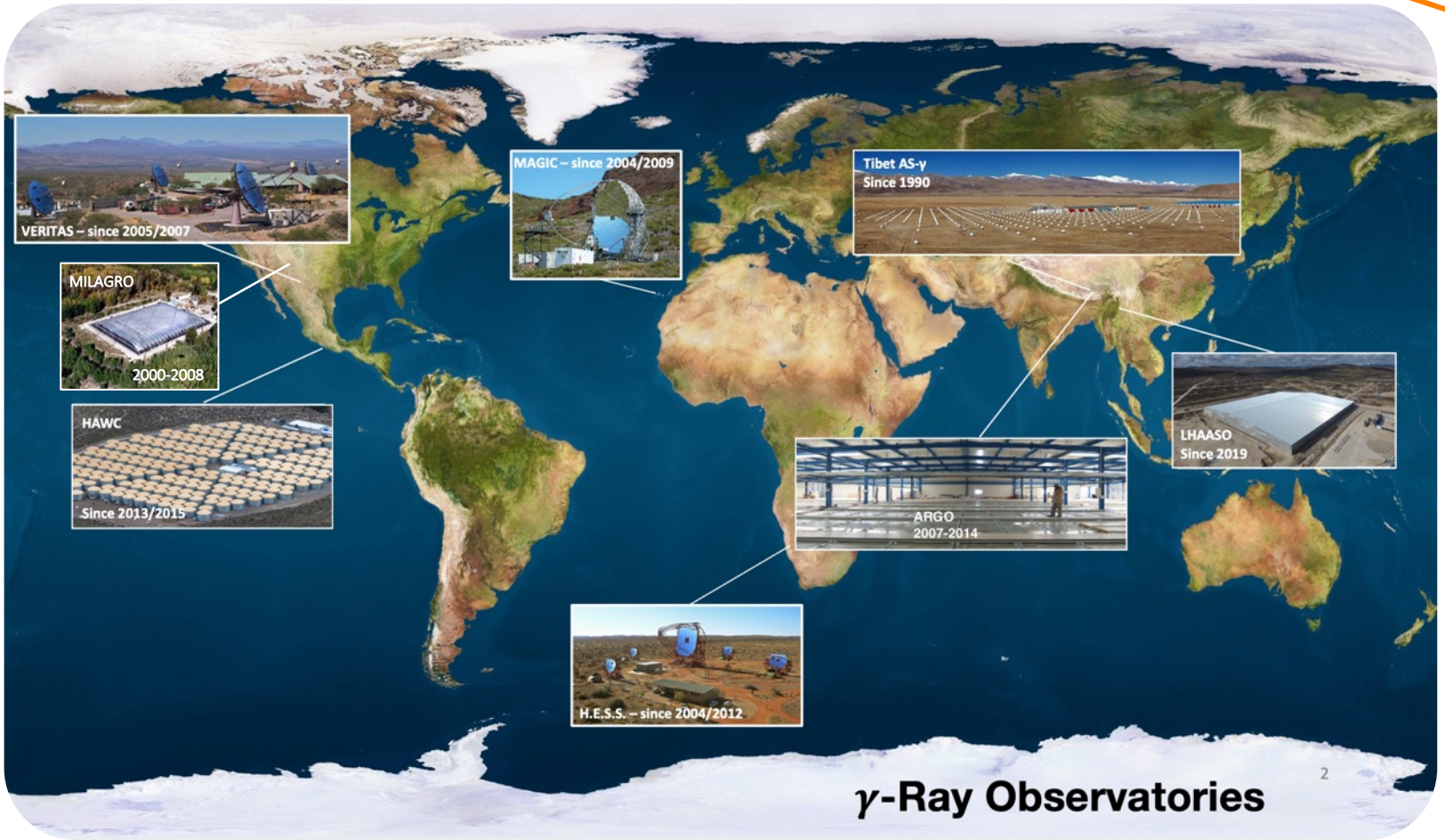


Binary Systems

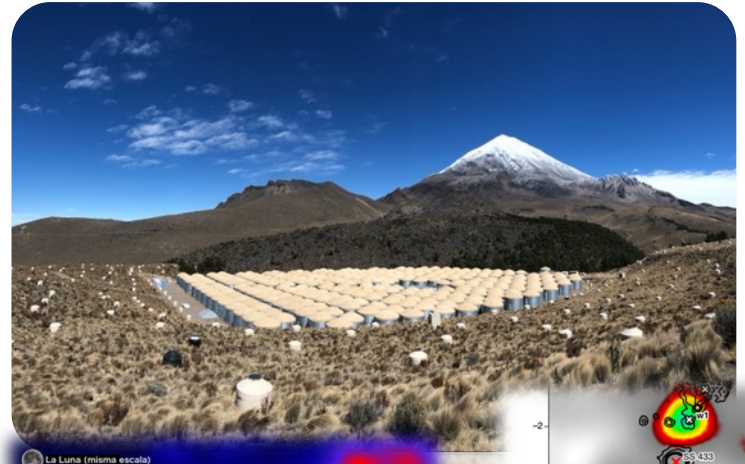
How do we detect gamma-rays?



Past & Current VHE Gamma-Ray Observatories



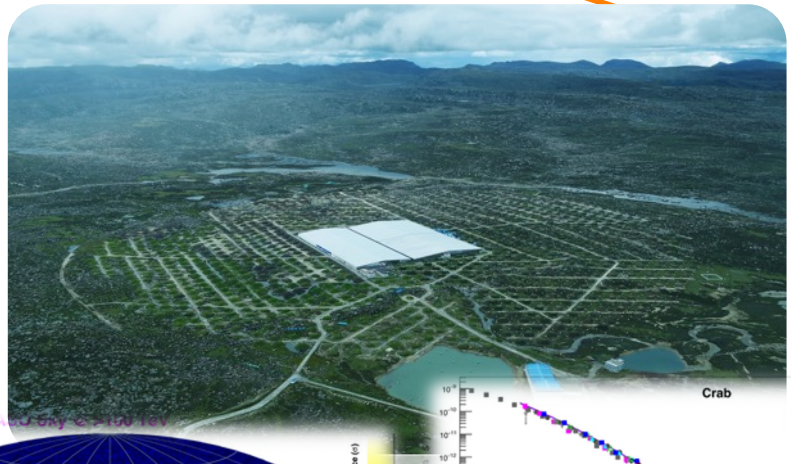
High Impact Results: HAWC & LHAASO

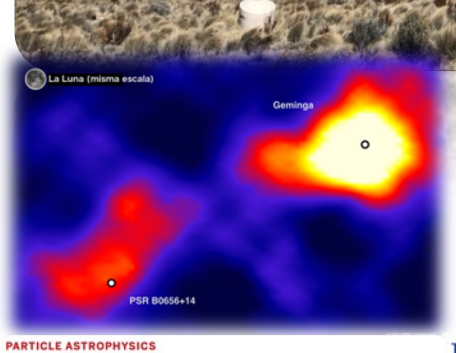


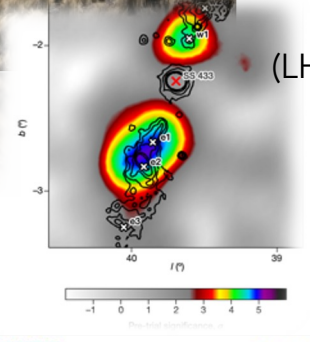
# of Sources

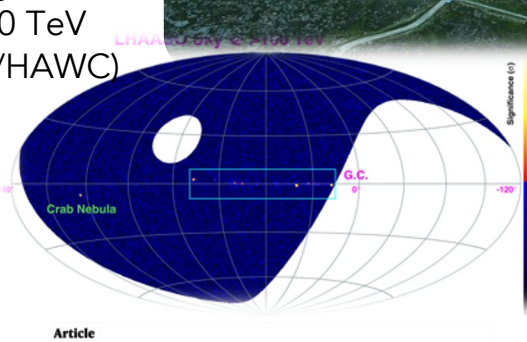
2007: 8 (Milagro survey)

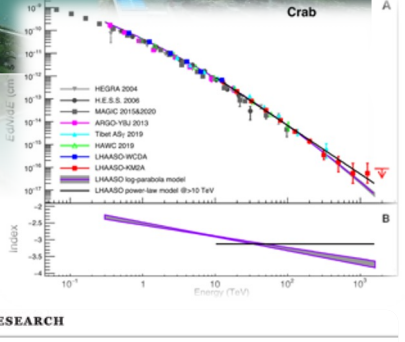
2022: >100 (HAWC survey), >~ 20 emitting with E_γ> 100 TeV (LHAASO/HAWC)











PARTICLE ASTROPHYSICS

Extended gamma-ray sources around pulsars constrain the origin of the positron flux at Earth

Abeysekara *et al.*, *Science* **358**, 911–914 (2017) 17 November 2017

LETTER

Corrected: Publisher Correction

Very-high-energy particle acceleration powered by the jets of the microquasar SS 433

82 | NATURE | VOL 562 | 4 OCTOBER 2018

Article

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

34 | Nature | Vol 594 | 3 June 2021

RESEARCH

ASTROPARTICLE PHYSICS

Peta–electron volt gamma-ray emission from the Crab Nebula

Cao *et al.*, *Science* **373**, 425–430 (2021) 23 July 2021

High Impact Results: HAWC & LHAASO

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```
TITLE:   GCN CIRCULAR
NUMBER:  32677
SUBJECT: LHAASO observed GRB 221009A with more than 5000 VHE photons up to around 18 TeV
DATE:    22/10/11 09:21:54 GMT
FROM:    Judith Racusin at GSFC  <judith.racusin@nasa.gov>

Yong Huang, Shicong Hu, Songzhan Chen,  Min Zha, Cheng Liu, Zhiguo Yao and
Zhen Cao report on behalf of the LHAASO experiment

We report the observation of GRB 221009A, which was detected by Swift (Kennea
et al. GCN #32635), Fermi-GBM (Veres et al. GCN #32636, Lesage et al. GCN #32642),
Fermi-LAT (Bissaldi et al. GCN #32637), IPN (Svinkin et al. GCN #32641) and so on.

GRB 221009A is detected by LHAASO-WCDA at energy above 500 GeV, centered at
RA = 288.3, Dec = 19.7 within 2000 seconds after T0, with the significance above
100 s.d., and is observed as well by LHAASO-KM2A with the significance about 10 s.d.,
where the energy of the highest photon reaches 18 TeV.

This represents the first detection of photons above 10 TeV from GRBs.

The LHAASO is a multi-purpose experiment for gamma-ray astronomy (in the energy
band between 10^11 and 10^15 eV) and cosmic ray measurements.
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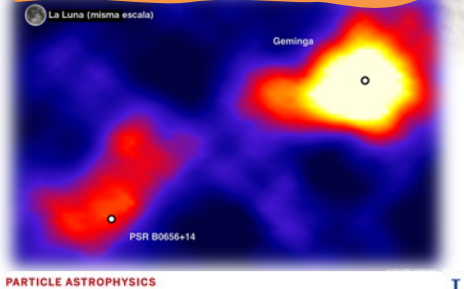

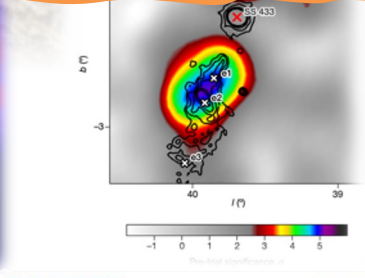

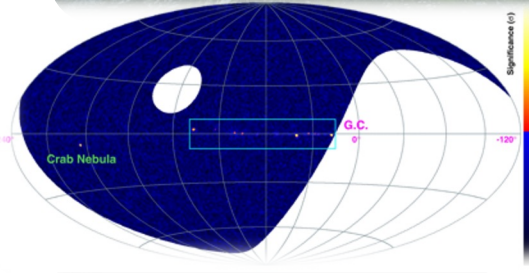

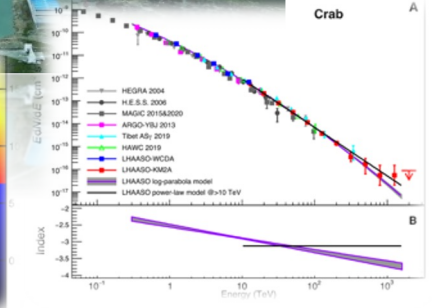

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How to detect gammas from the ground

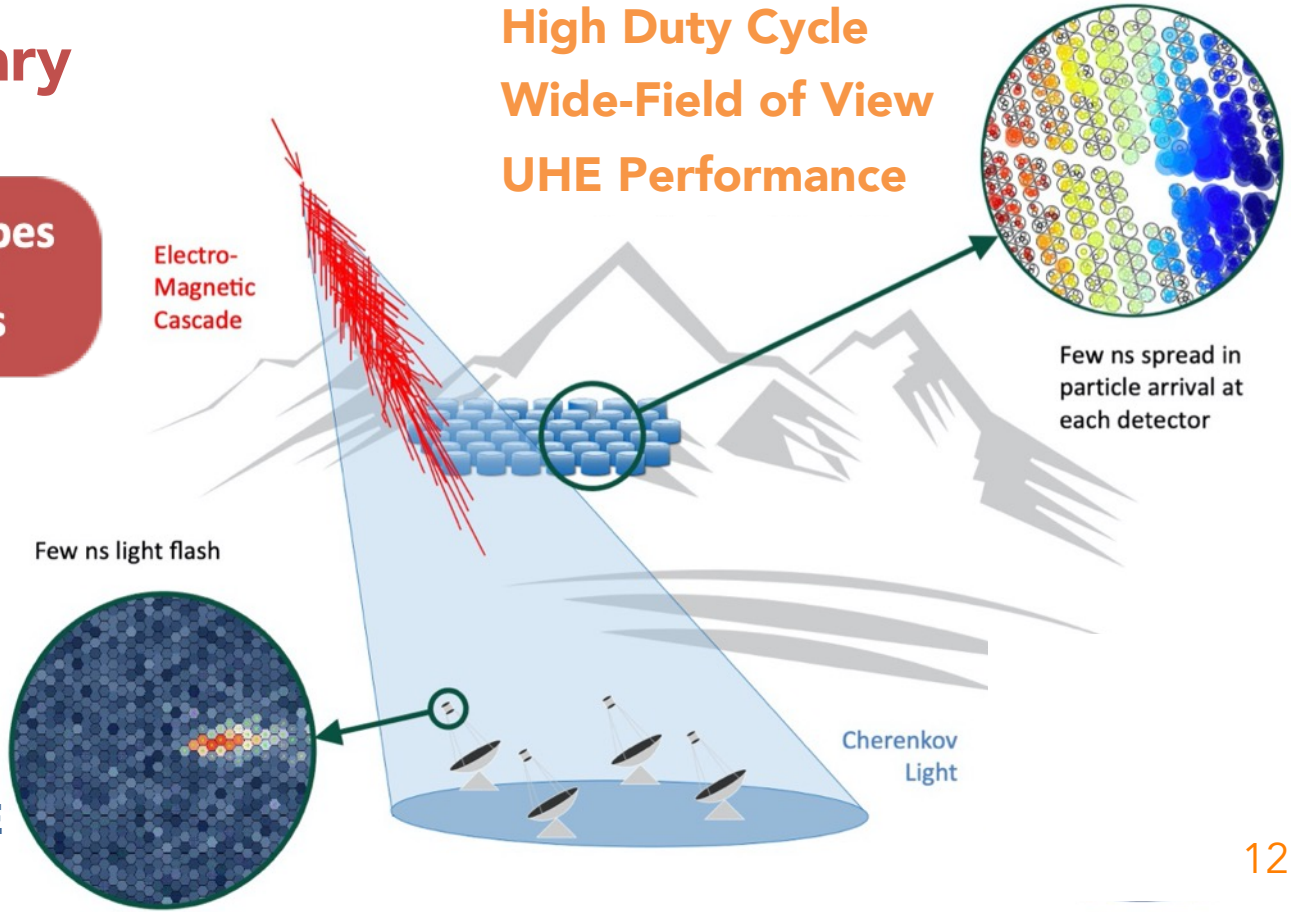
Two complementary Techniques:

1. Air-Cherenkov telescopes
2. Altitude particle arrays

High Duty Cycle

Wide-Field of View

UHE Performance

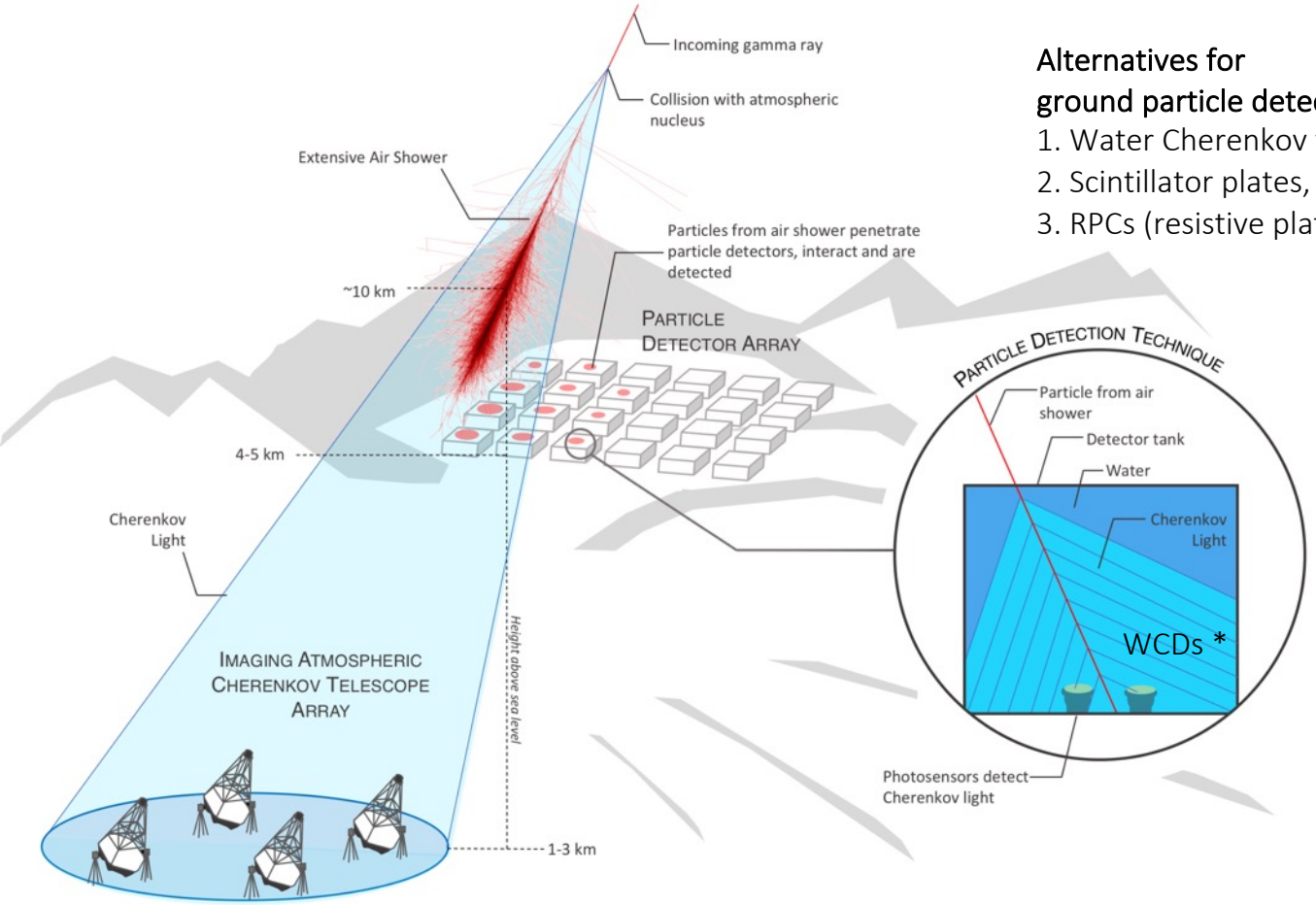


Low Duty Cycle

Pointing instruments

Precision Astronomy at VHE

Cherenkov radiation (in air and in water)



Alternatives for ground particle detectors:

1. Water Cherenkov tanks,
2. Scintillator plates,
3. RPCs (resistive plate chambers)

anced Test Reactor – daho/Argonne National Lab

Made by H. Seldon, wikipedia.org/public domain

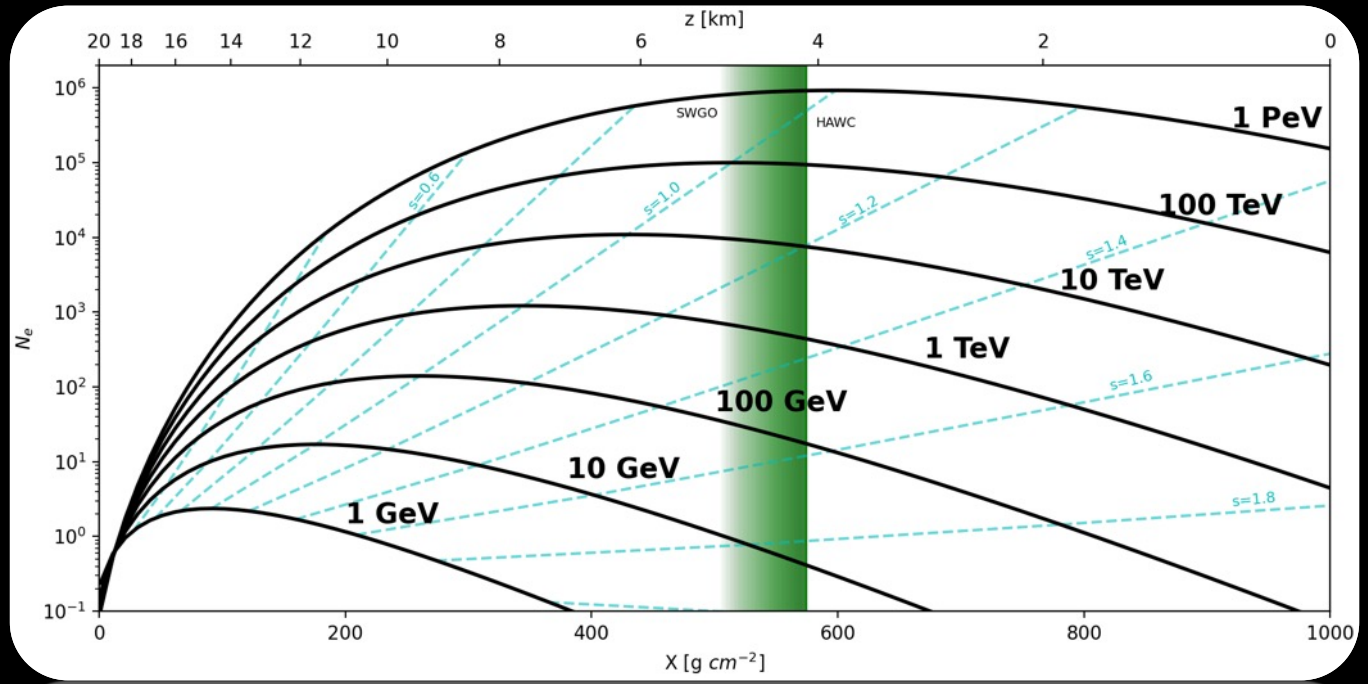
Shower image, 100 GeV γ-ray adapted from: F. Schmidt, J. Knapp, "CORSIKA Shower Images", 2005, https://www-zeuthen.desy.de/~jknapp/fs/showerimages.html

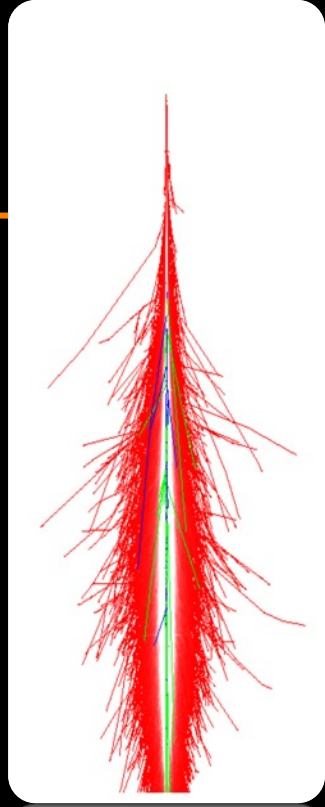
Not to scale

Why so High?

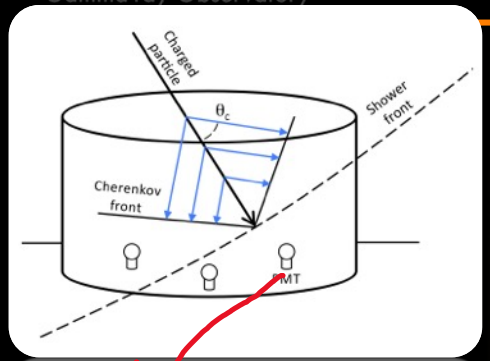
More particles Detected

- ✓ More accurate & precise measurements





How to build an array?



e.g. HAWC (Mexico)

How to build an array?

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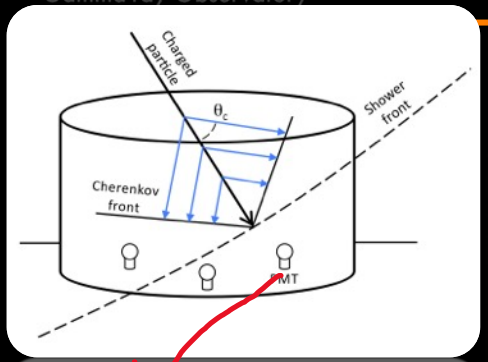
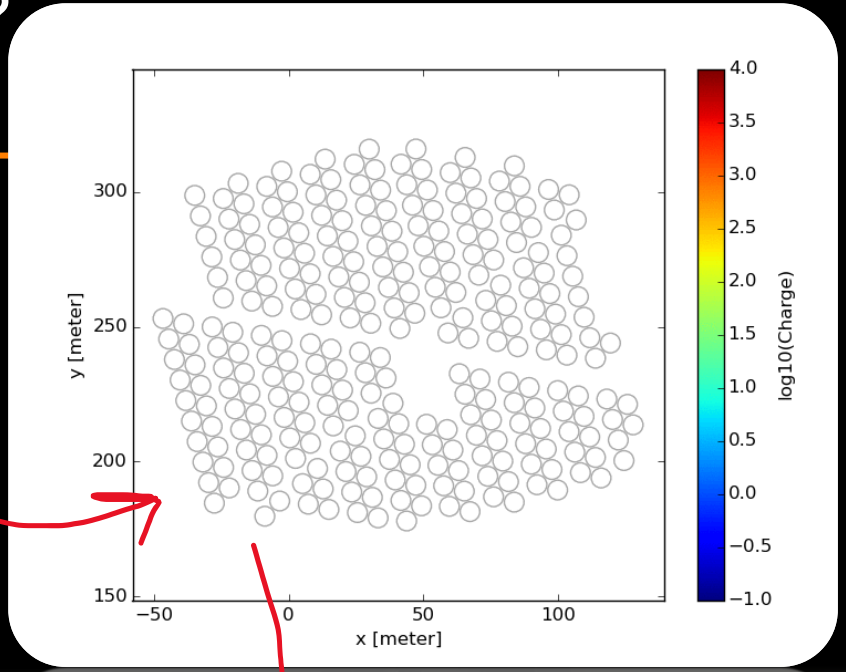
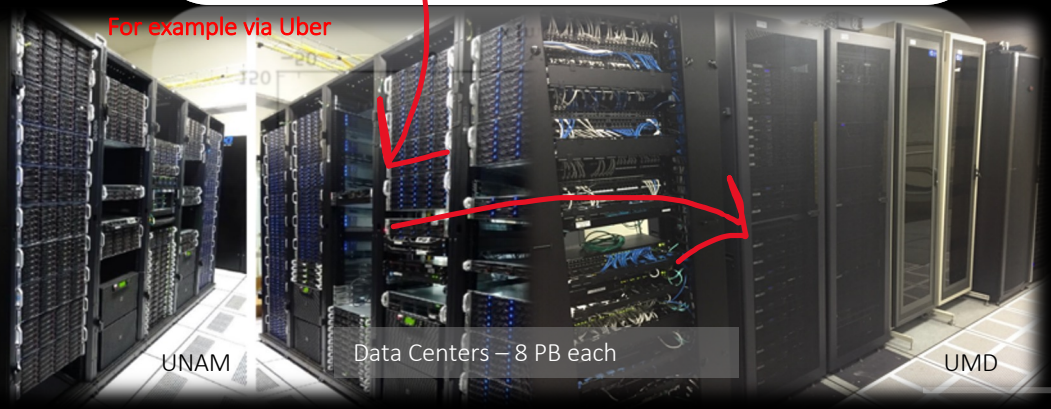


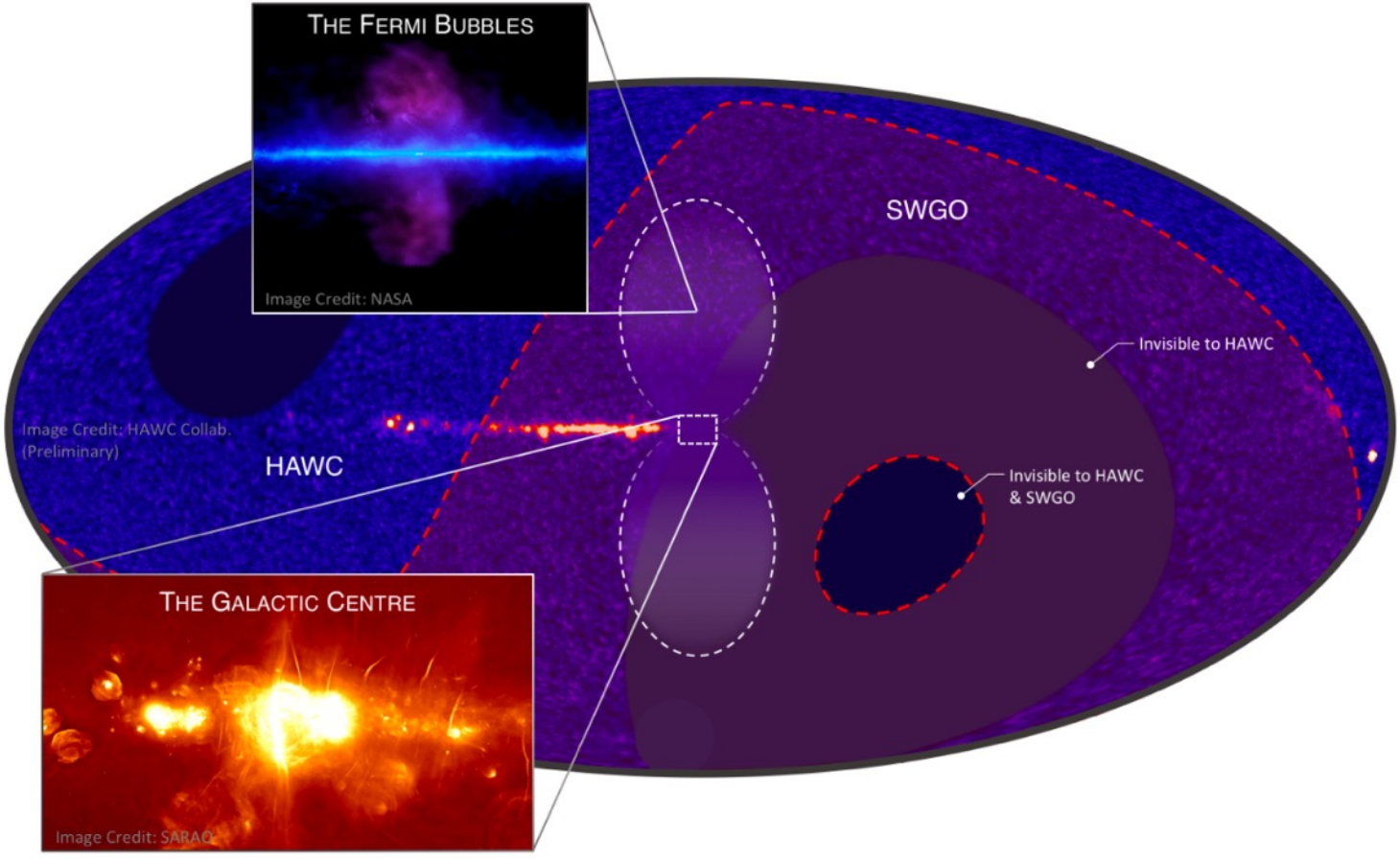


For example via Uber



e.g. HAWC (Mexico)

Next step:
- A Wide-field experiment in the South



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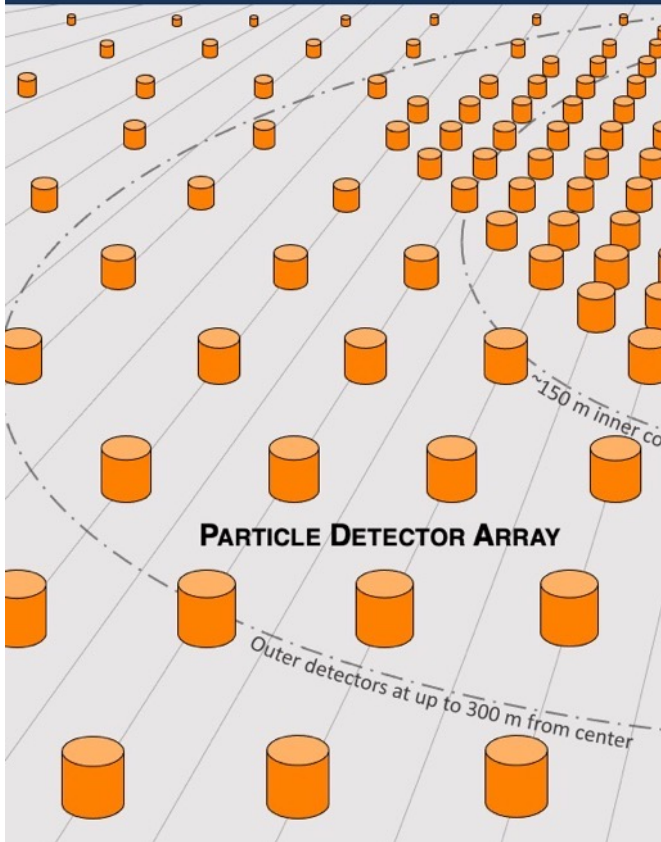
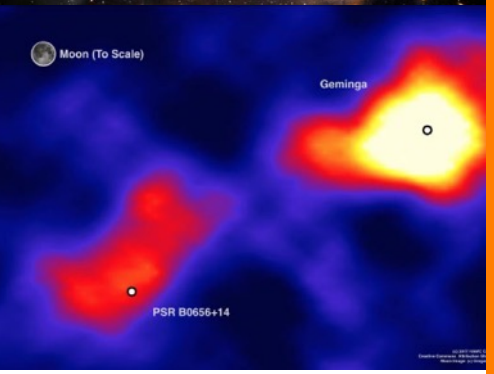
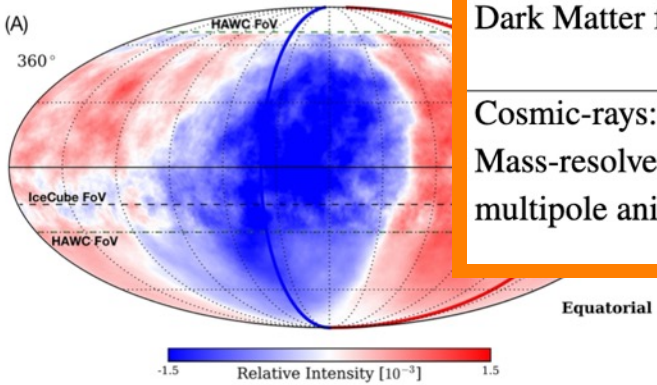


Science

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]





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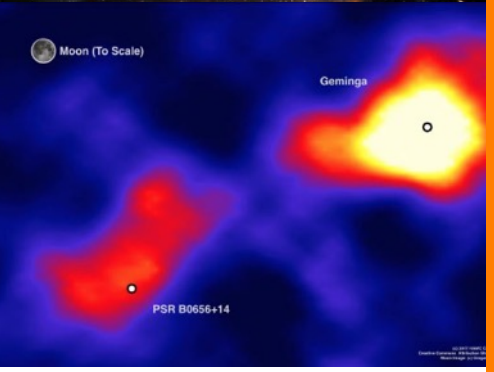
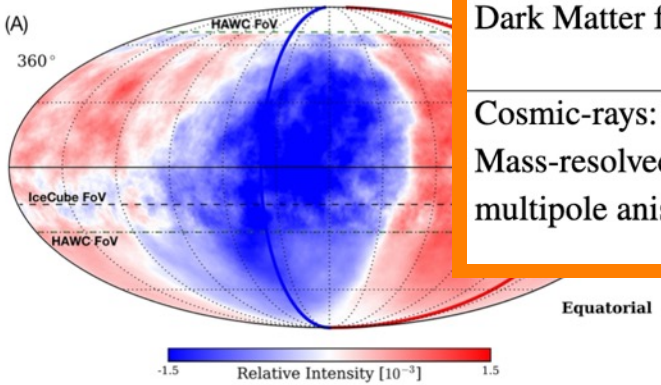




PRELIMINARY DESIGN TARGETS

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

The SWGO Collaboration

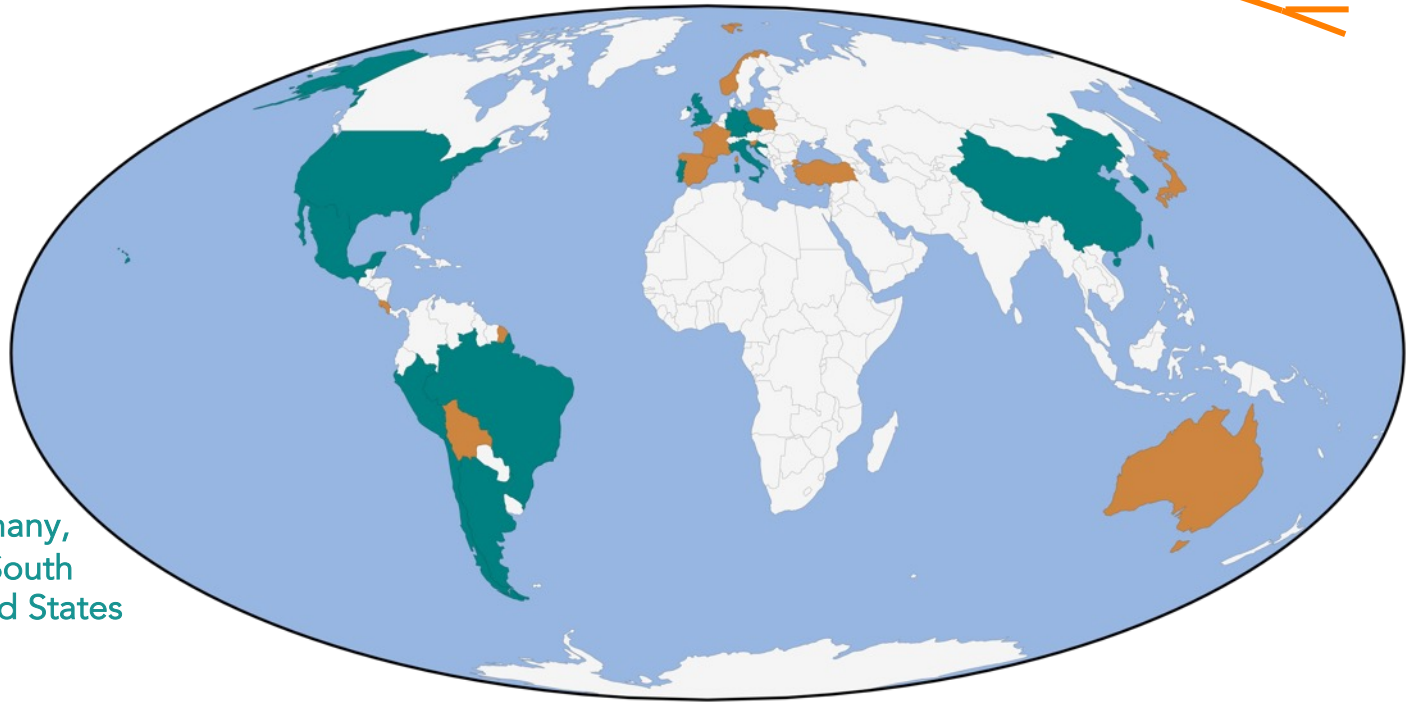
- Spokespersons

swgo_spokespersons@swgo.org

→ Jim Hinton (Germany),

Petra Huentemeyer (USA),

Ulisses Barres (Brazil)



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

Supporting Scientists
Australia, Bolivia, Costa Rica, France, Japan, Poland, Slovenia, Spain, Switzerland, Turkey

- >70 institutions in14 countries

swgo.org

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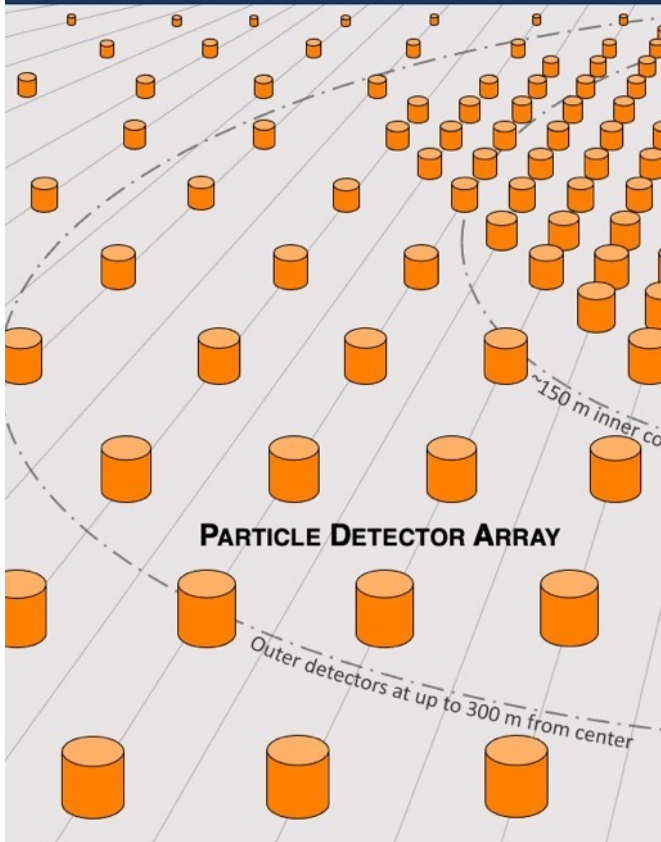
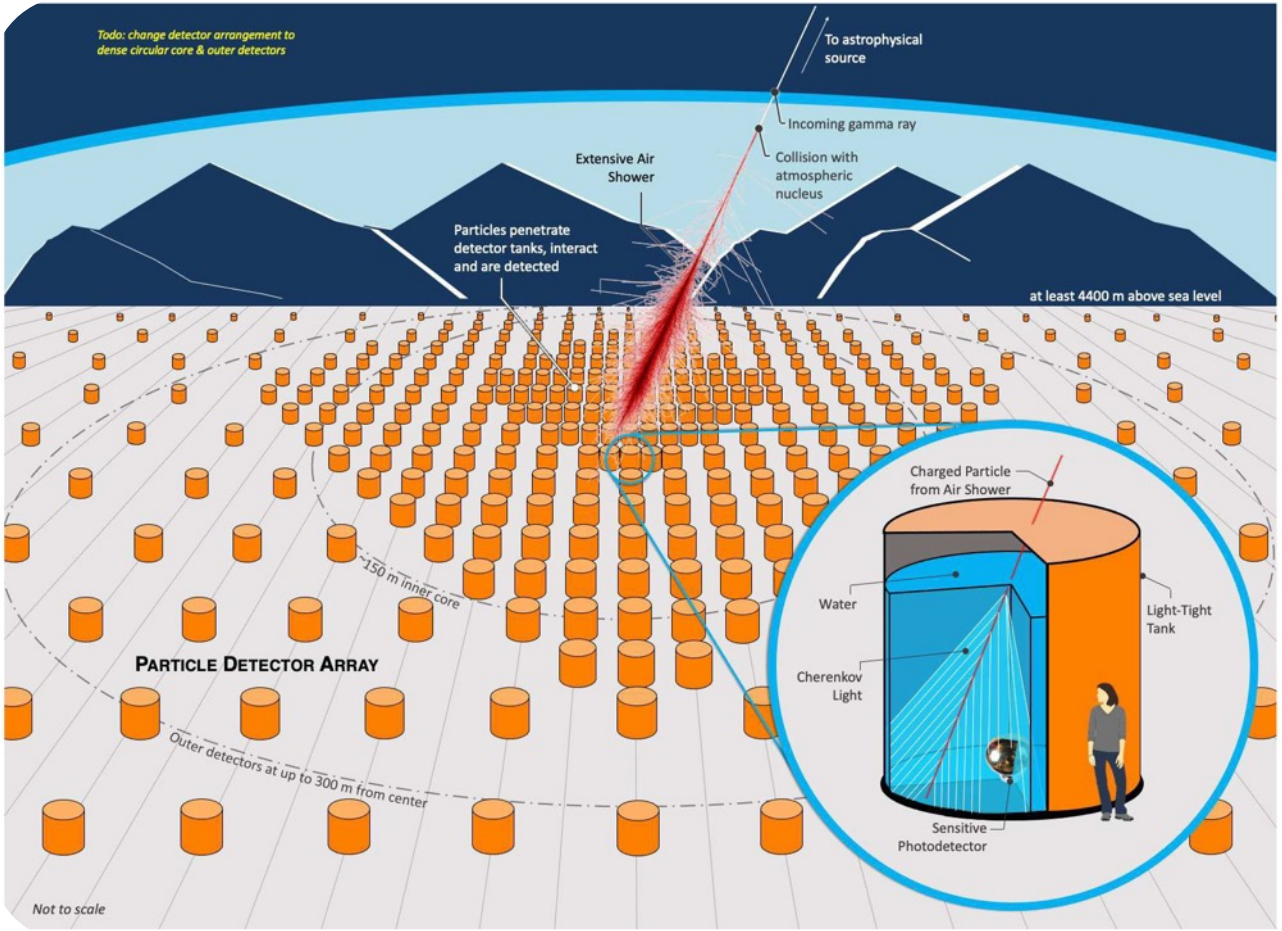
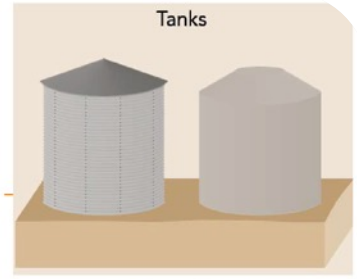
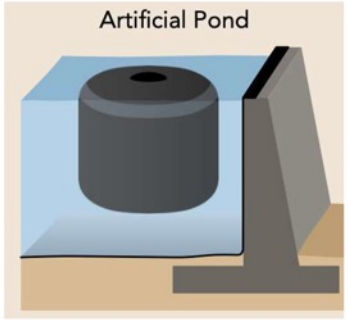
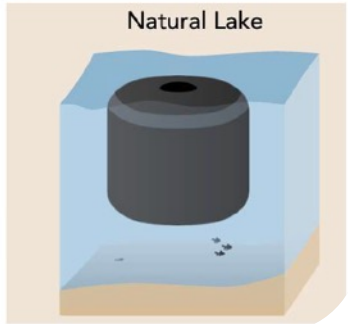


Detector Options

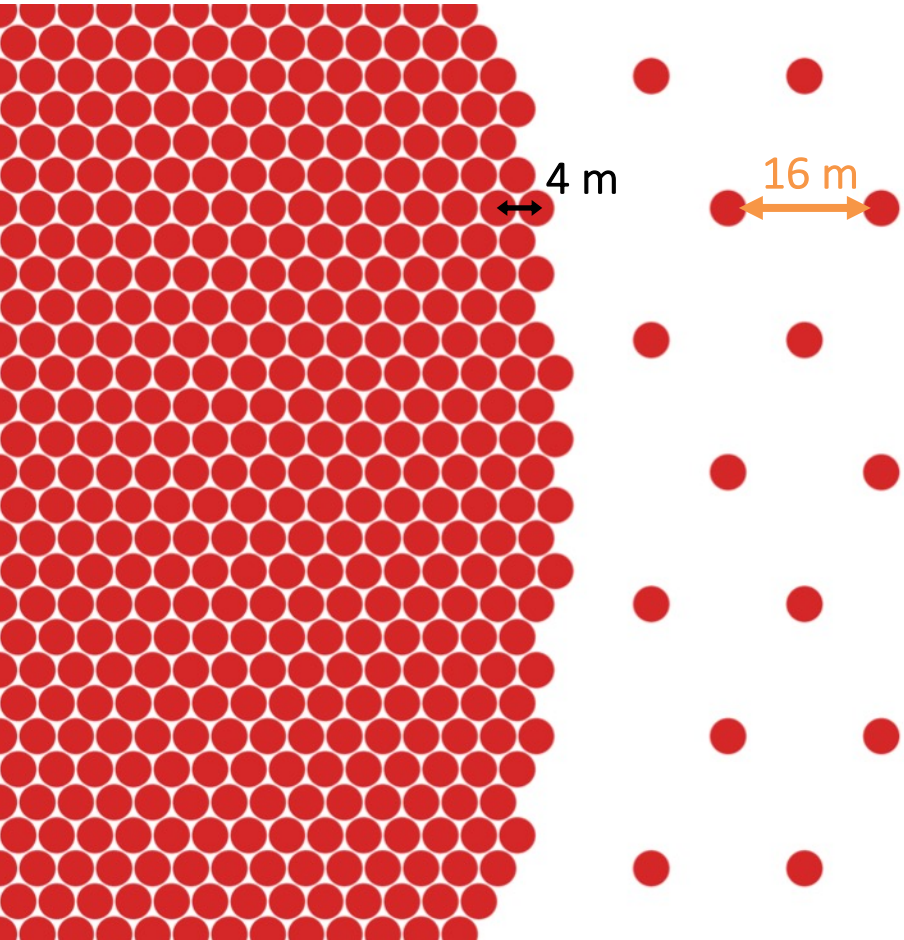








The baseline detector concept

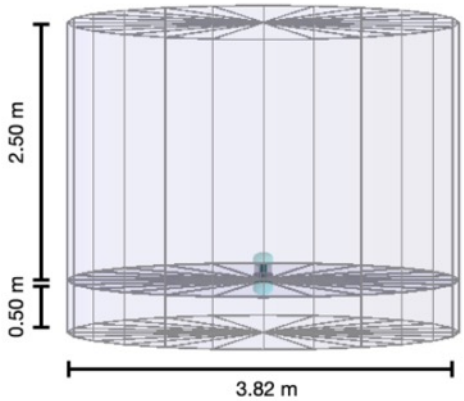


Core: Ø 320 m, FF = 80%
5,700 WCD units

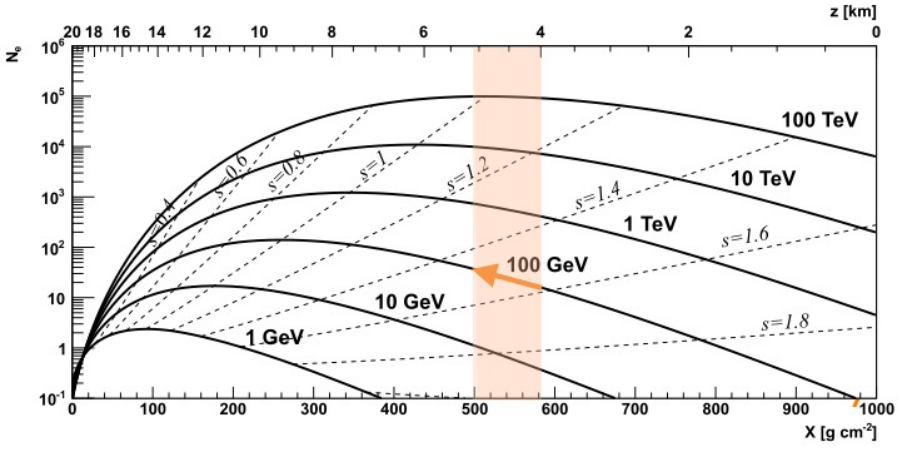
Outer: Ø 600 m, FF = 5%
880 WCD units

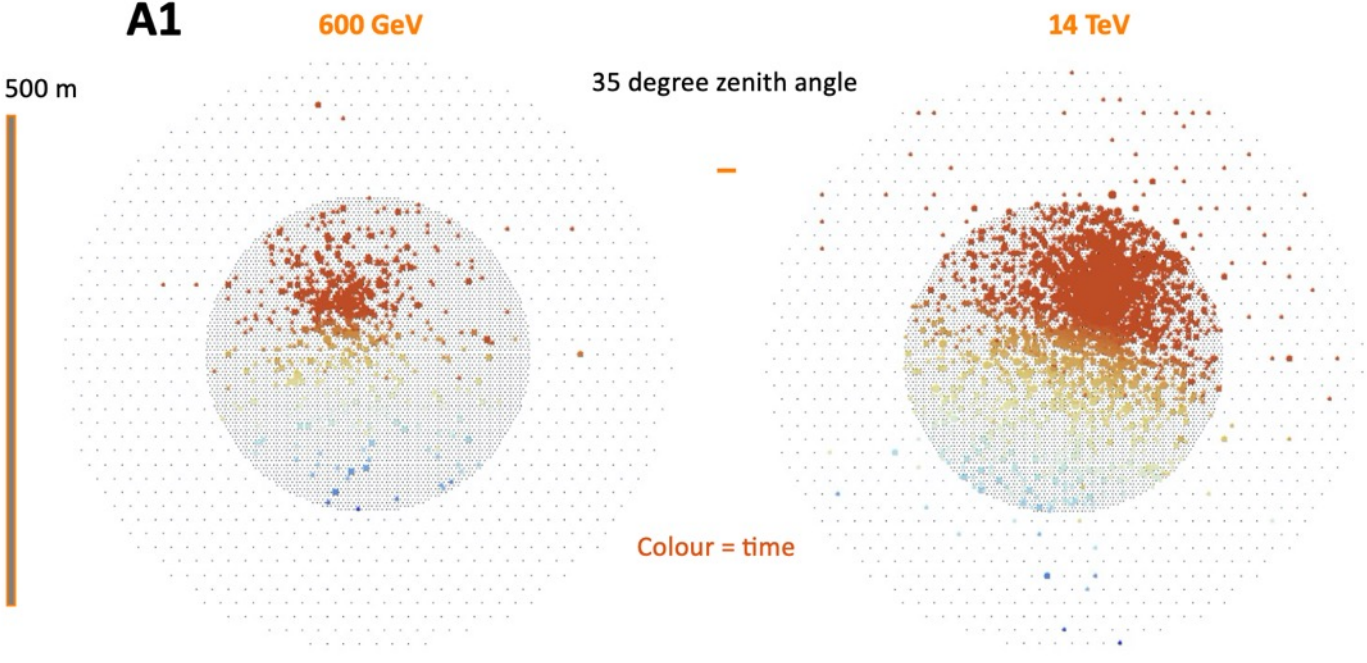
Altitude: 4,700 m a.s.l.

✧ **muon counting**



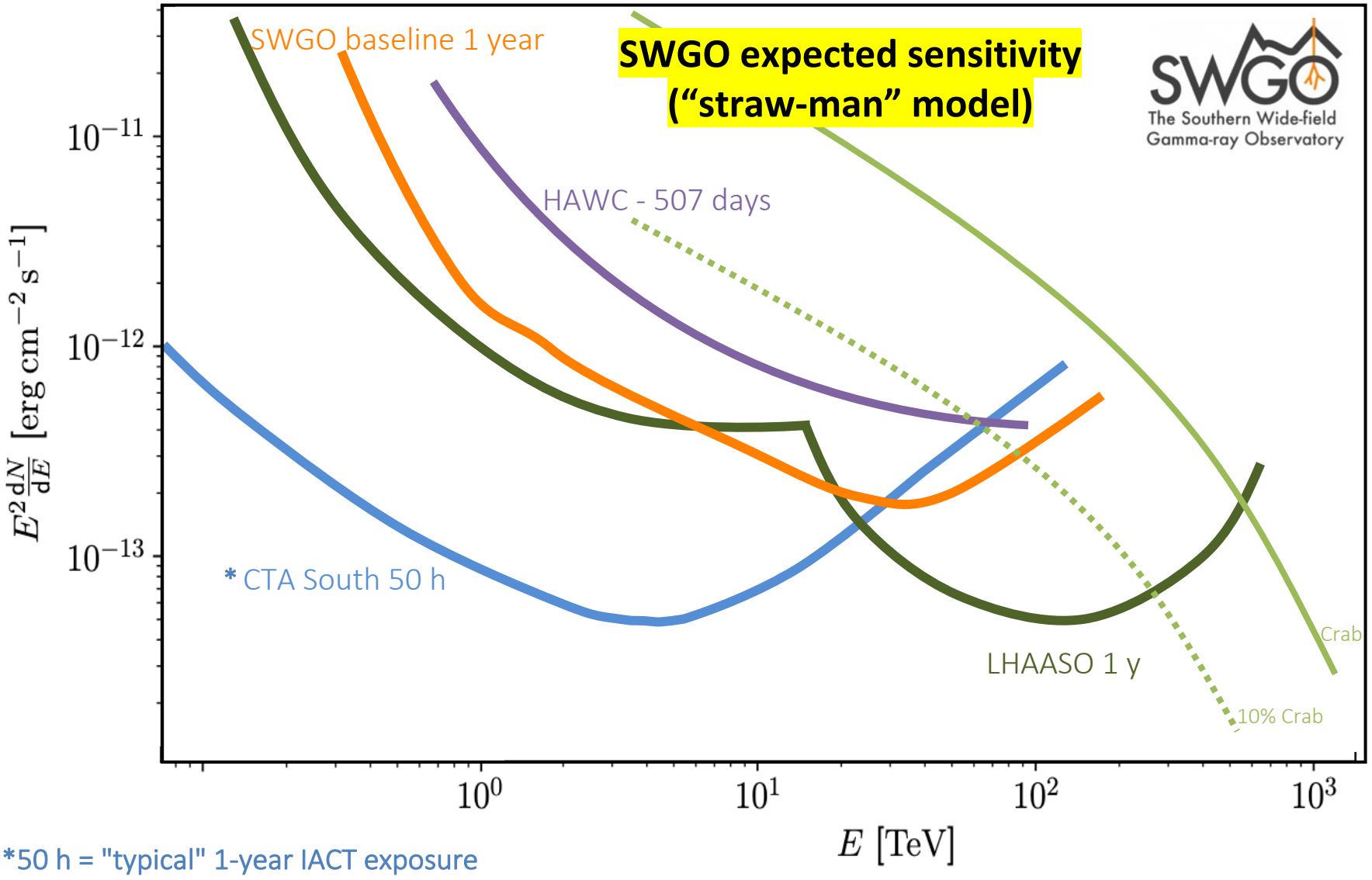
SWGO Baseline Requirements



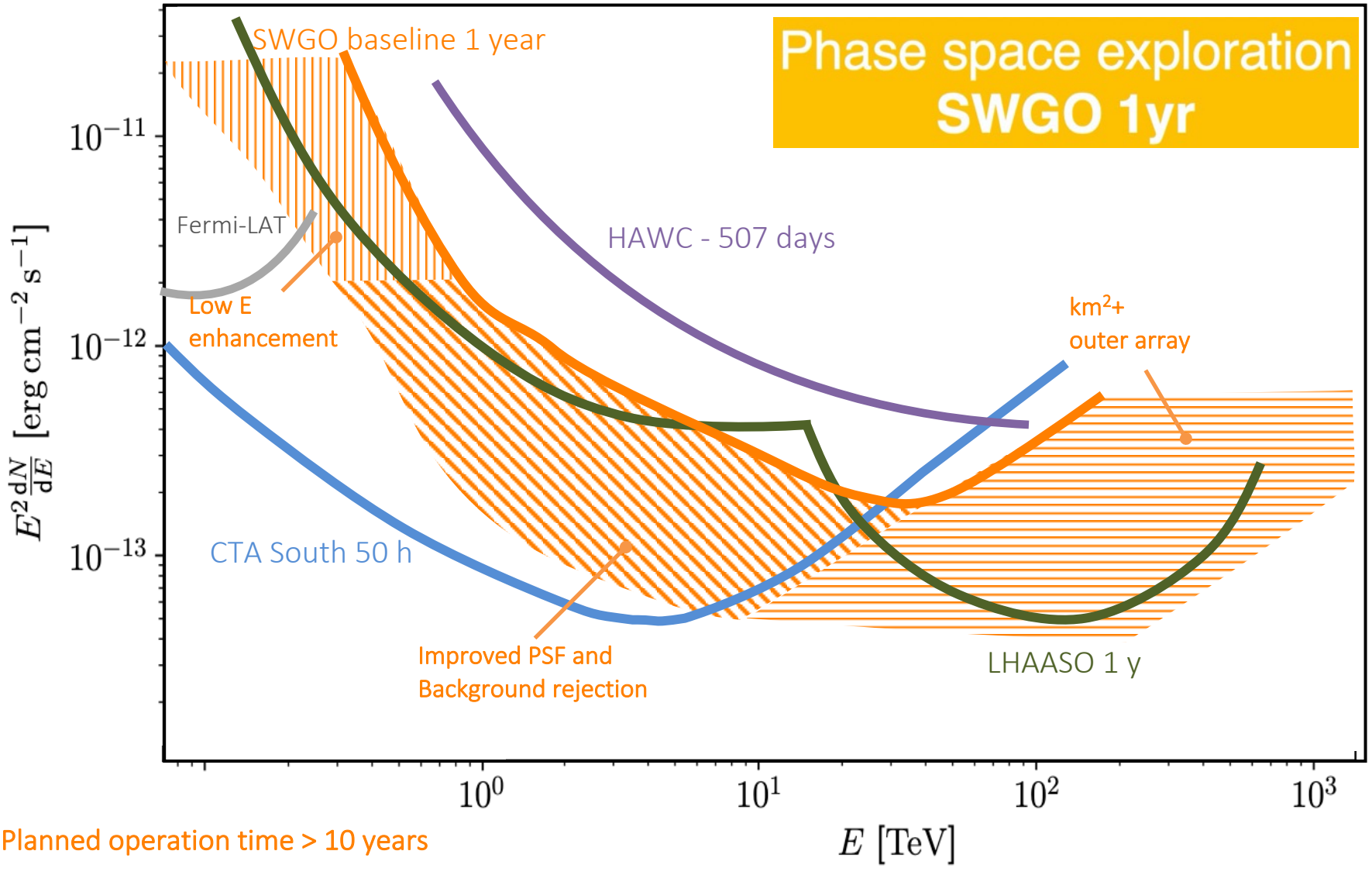


- **Larger and denser detector array at higher altitude w.r.to HAWC**

  → Very precise measurements possible below 1 TeV



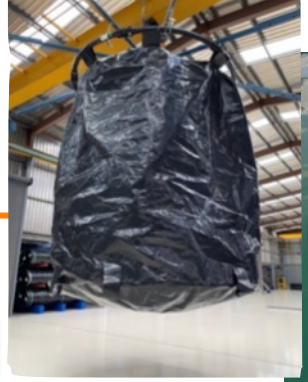
*50 h = "typical" 1-year IACT exposure



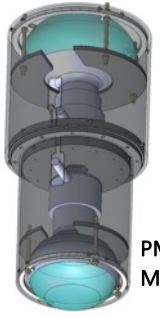
Planned operation time > 10 years

WCD unit Solutions

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



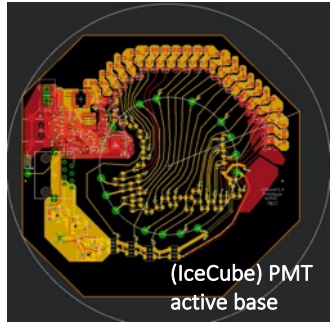
More Detector Options and Prototyping



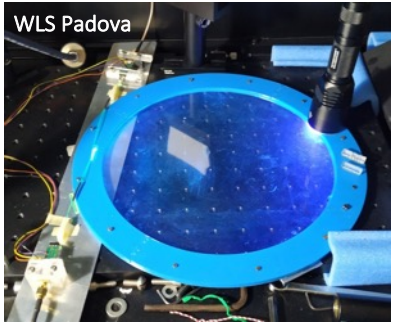
PMT module
MPIK

HAWC
Bladders

- **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

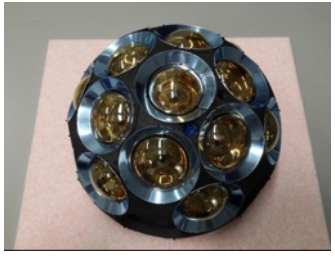


(IceCube) PMT
active base



WLS Padova

PMTs
Naples



HyperK-style
multi-PMT

Other White Rabbit Node examples:

Central Logic Board (KM3NeT)

CUTE-WR (LHAASO)

SVEC (CERN)

SPEXI (CERN)

CRIO-WR (CERN)

Analysis & Simulations

ARRAY CONFIGURATION

80% FF, 80,000 m^2

A1 (baseline)

2.5% FF

A2

1 km^2

A3

A5

HAWC

LHAASO

A4

A6

A7

4 km^2

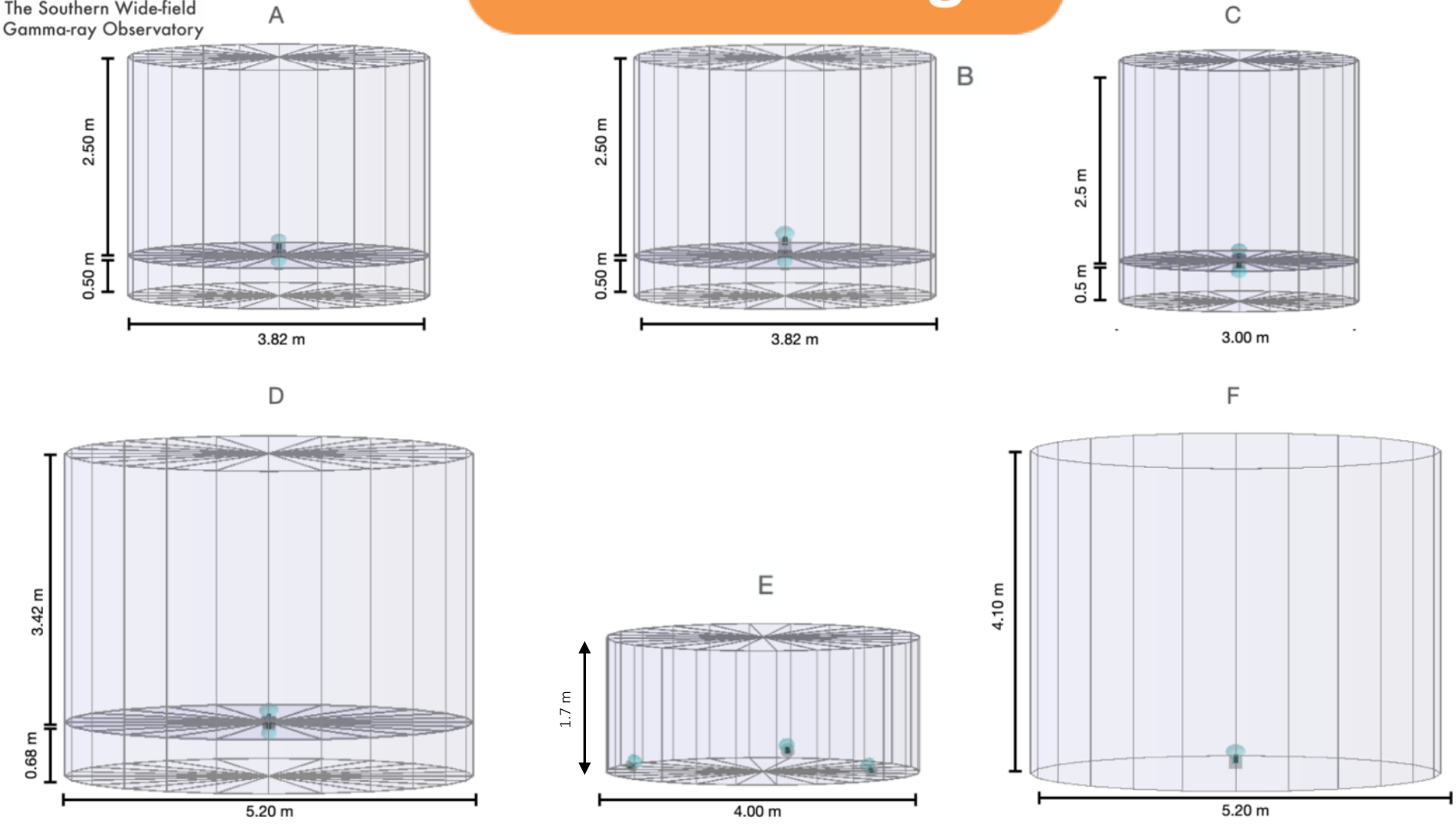
0.6% FF

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

EQUAL NOMINAL COST ARRAYS

SWGO
The Southern Wide-field Gamma-ray Observatory

WCD unit designs

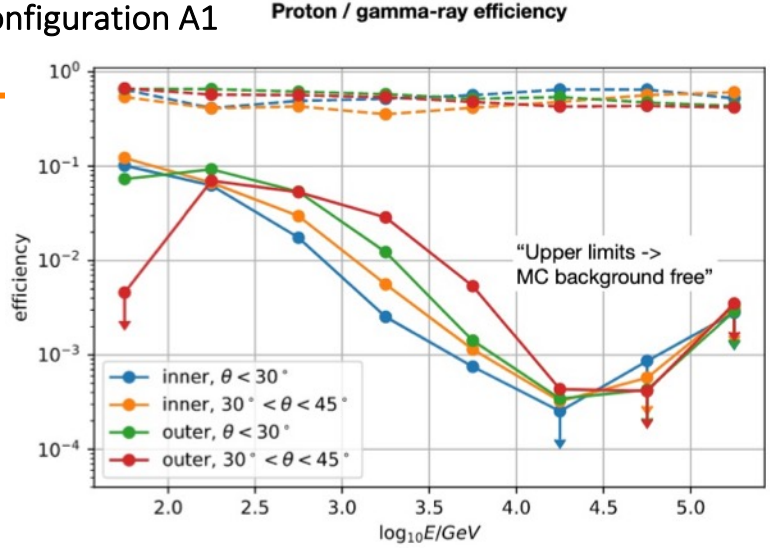


PRELIMINARY

Full-array sims

Configuration A1

- Muon content in the showers
  - → Muon cuts effective > 10 TeV
  - → Multiple strategies under investigation



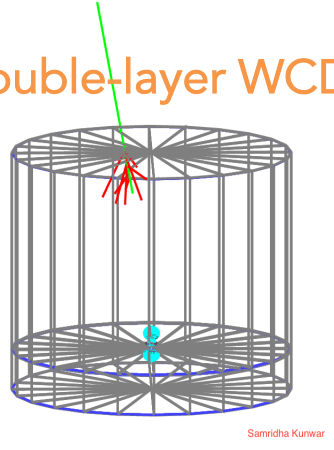
Gamma/ CR selection:

Muon detection

or

Shower footprint

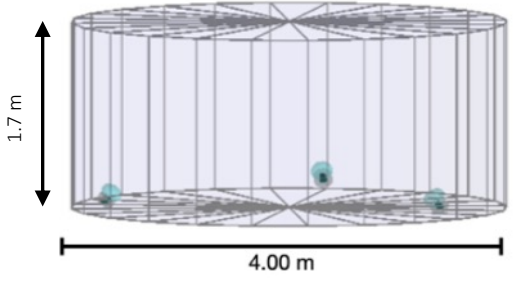
Double-layer WCDs



F. Bisconti & A. Chiavassa 2022

S. Kunwar et al. 2022

Multi-PMT WCDs



R. Conceição et al. 2022a

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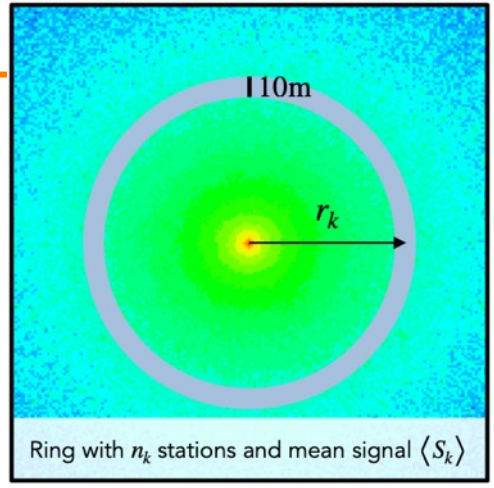
How to do Gamma/ CR selection:

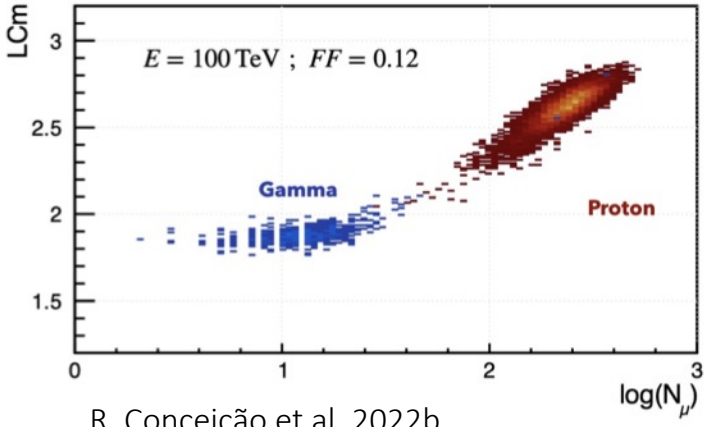
Muon detection

or

Shower footprint

Shower azimuthal asymmetries



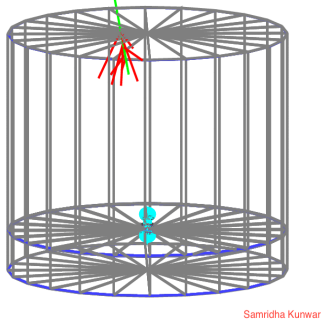


R. Conceição et al. 2022b

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

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

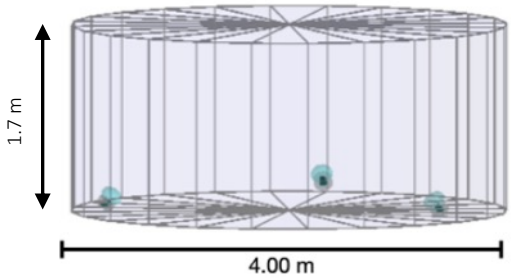
Double-layer WCDs



F. Bisconti & A. Chiavassa 2022

S. Kunwar et al. 2022

Multi-PMT WCDs

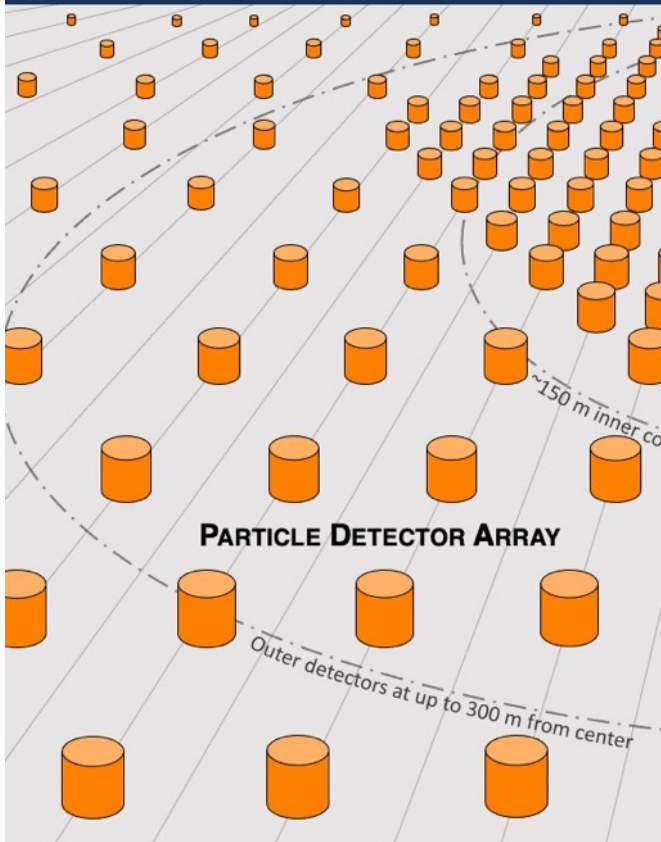


R. Conceição et al. 2022a

SWGO
The Southern Wide-field Gamma-ray Observatory

Content

- The field in context
- SWGO:
  - the driving science
  - the design
  - the site



Site Options

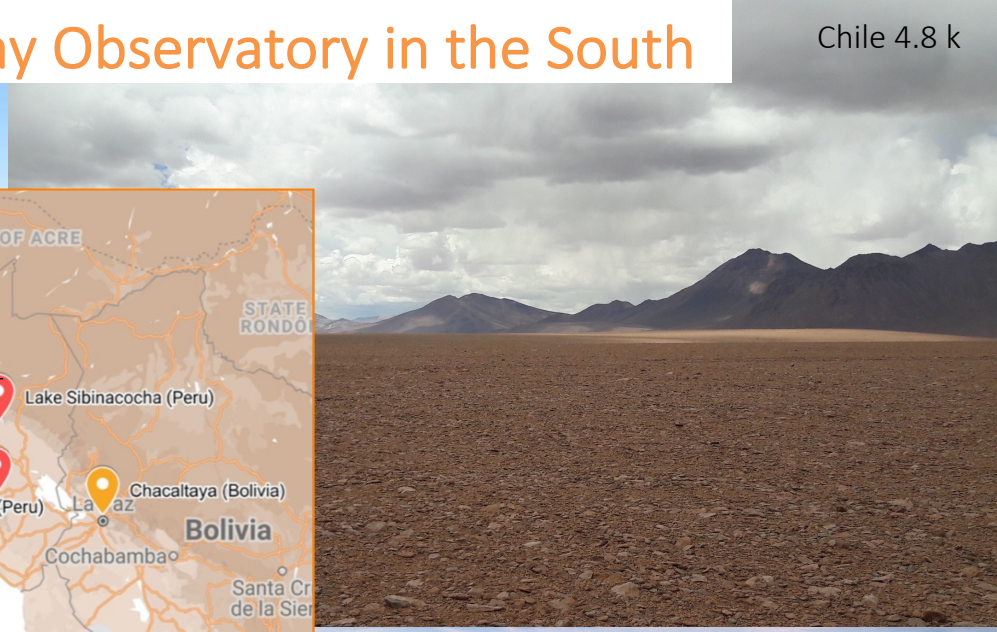
lat. 15 S

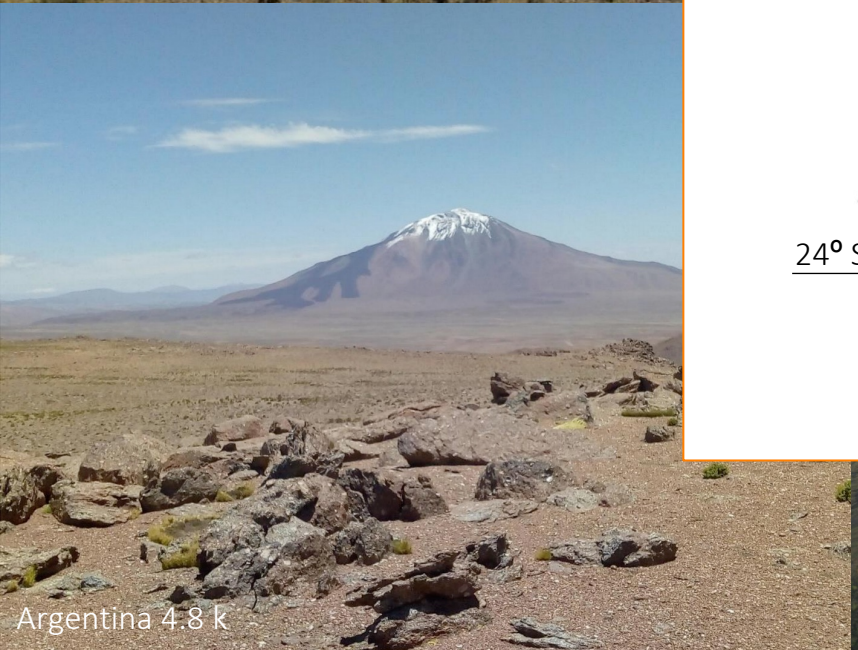
lat. 23 S

- Alto Tocomar (Argentina)
- Cerro Vecar (Argentina)
- Chacaltaya (Bolivia)
- AAP Pajonal (Chile)
- AAP Pampa La Bola (Chile)
- Lake Sibinacocha (Peru)
- Imata (Peru)
- Yanque (Peru)
- Peru National Observatory
- Yanque (Peru)

Country	Elevation	Location:
Peru	4900	Laguna Sibinacocha
Peru	4450	Imata lake
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

A Wide-field Gamma-ray Observatory in the South





A Wide-field Gamma-ray Observatory in the South

Bolivia 4.7k

Chile 4.8 k

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

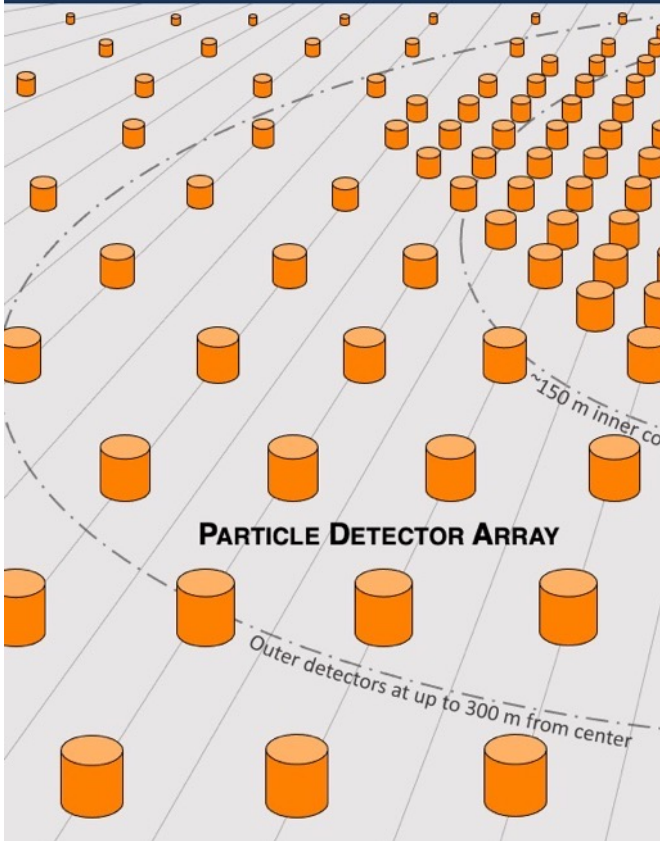
Argentina 4.8 k

Peru 4.9 k

SWGO
The Southern Wide-field Gamma-ray Observatory

Content

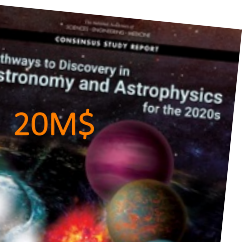
- The field in context
- SWGO:
  - Status and Plan



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
    - ü Site and Design Choices made
  - → Then:
- Preparatory Phase
  - → Detailed construction planning
  - → **Engineering Array**
- (Full) Construction Phase
  - → 2026+



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

Summary

- SWGO is a key instrument for **Multimessenger Astrophysics**

- First Gamma-Ray Observatory of its kind in the **Southern Hemisphere** (observation of the Galactic Center)
- Major **Astro-Particle Research Facility in South America**

- Wide-energy range coverage **100 GeV - 1 PeV**
- Trigger for **Transient sources** (complementary to CTA)
- Complementary to LHAASO's sky view

SWGO
The Southern Wide-field Gamma-ray Observatory

Thank you!

CONTACT:
swgo_spokespersons@swgo.org

www.swgo.org