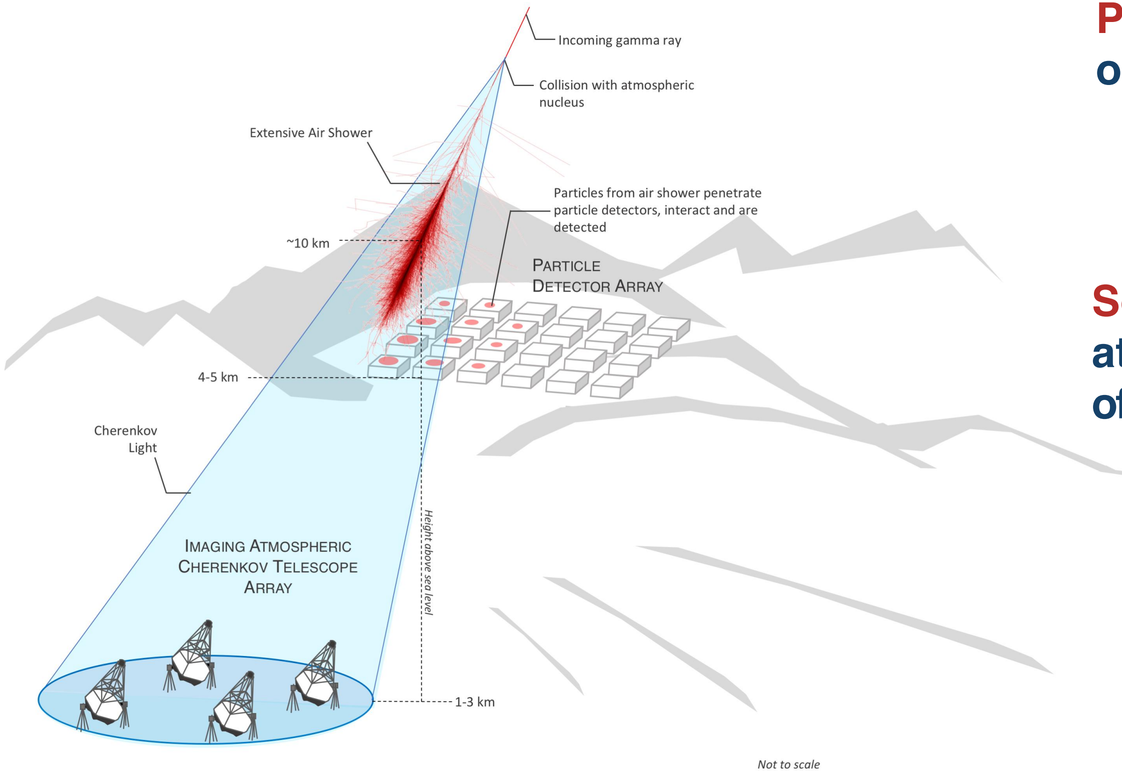
SWGO
The Southern Wide-field Gamma-ray Observatory

南天大视场伽马射线望远镜项目

周浩
上海交通大学李政道研究所

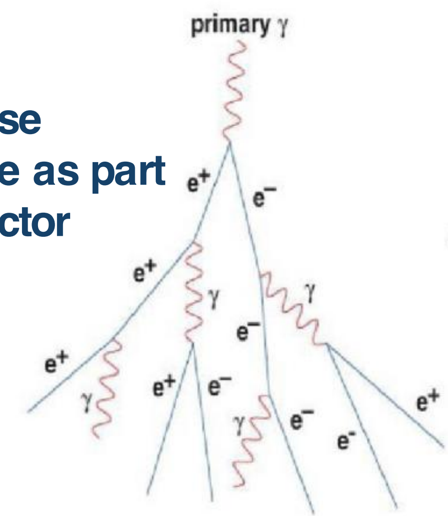
2024-08-15 青岛

How to detect gamma rays from ground?

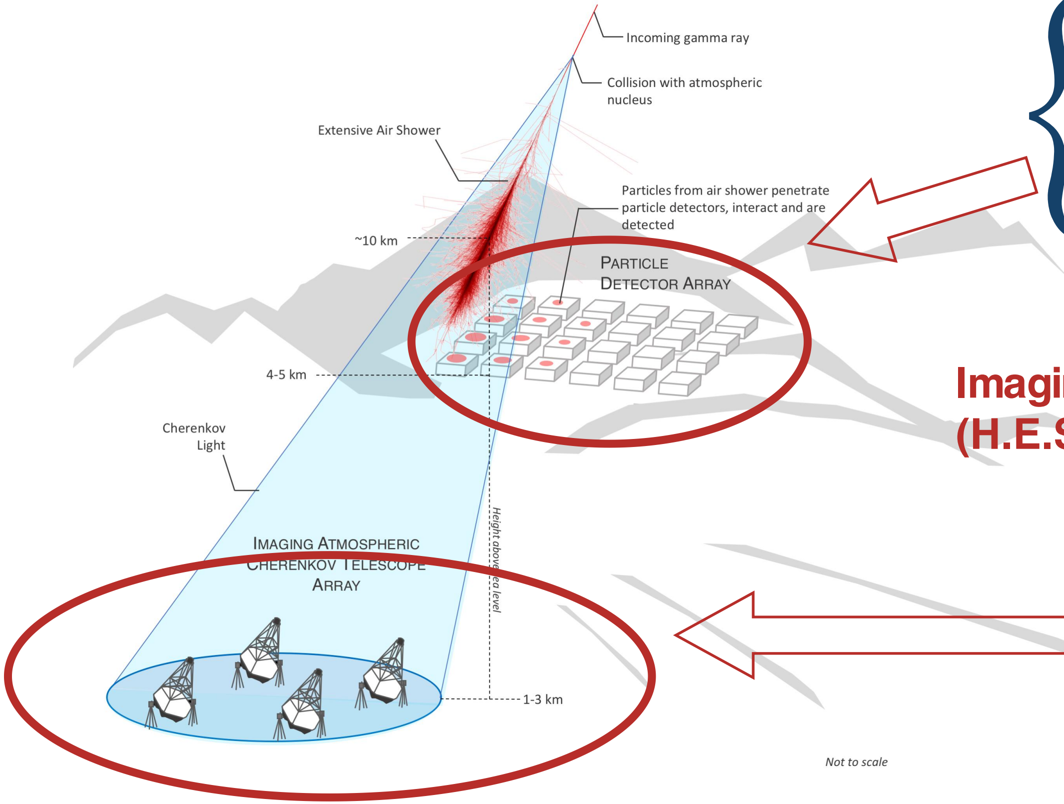


Problem: **Our atmosphere is opaque to gamma rays.**

Solution: **use atmosphere as part of the detector**



Two Major Techniques



Particle Detector Array (HAWC, LHAASO, Tibet-ASγ)

- large FOV (2 sr)
- high (~100%) duty cycle
- good sensitivity on higher energies

Imaging Atmospheric Cherenkov Telescope (H.E.S.S., MAGIC, VERITAS)

- good angular resolution
- good energy resolution
- small FOV (<5°)
- low (~10%) duty cycle

How to detect gamma rays from ground?

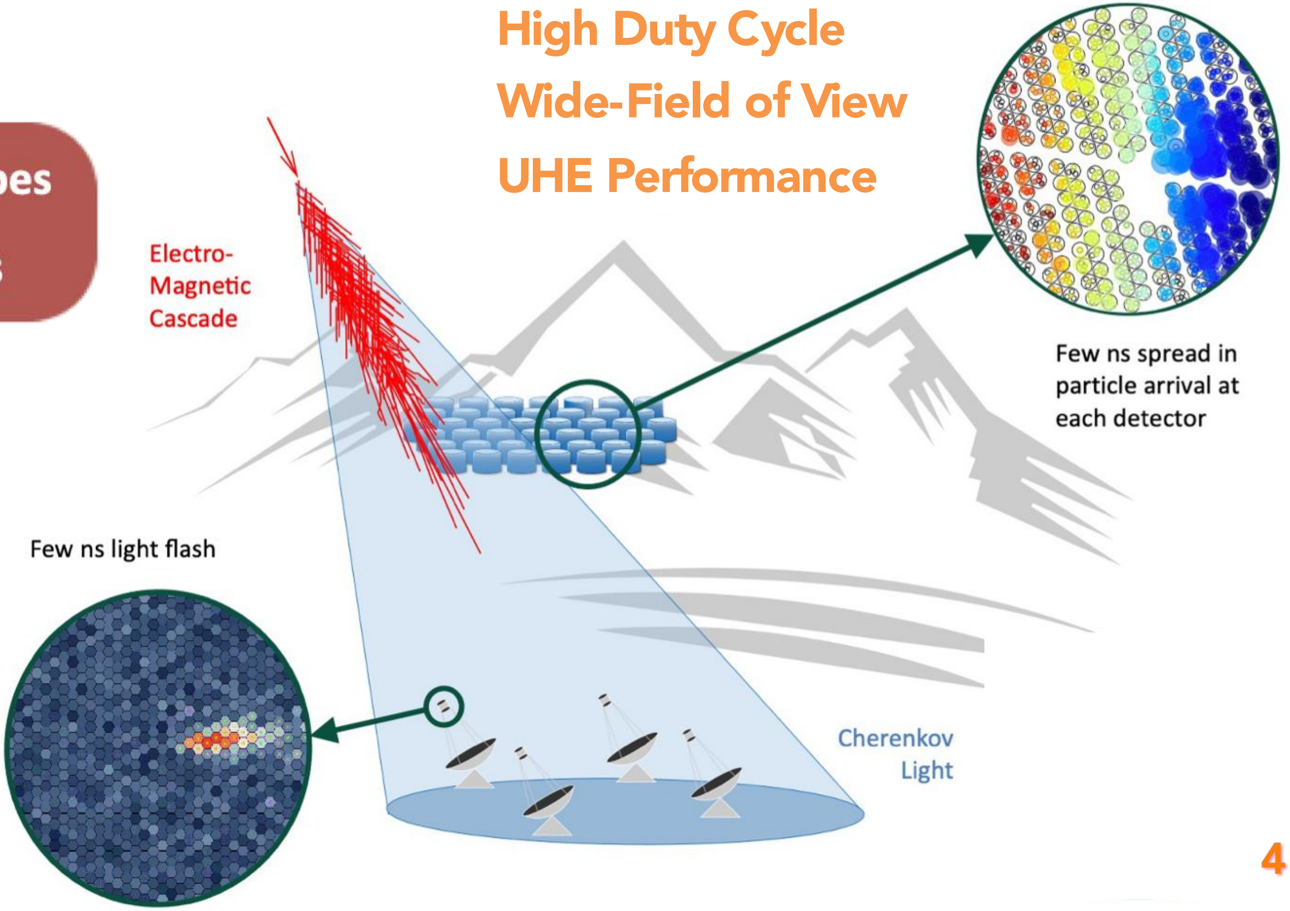
Two techniques

1. Air-Cherenkov telescopes
2. Altitude particle arrays

High Duty Cycle

Wide-Field of View

UHE Performance

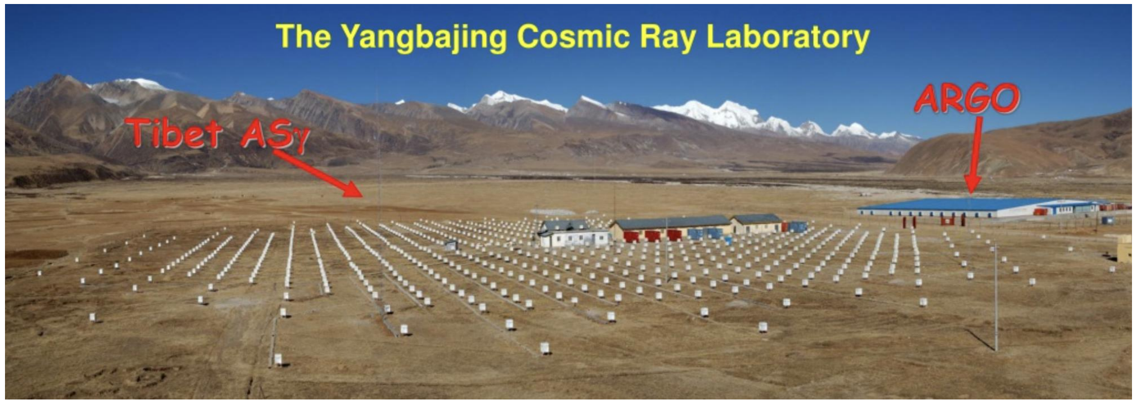


Low Duty Cycle

Pointing instruments

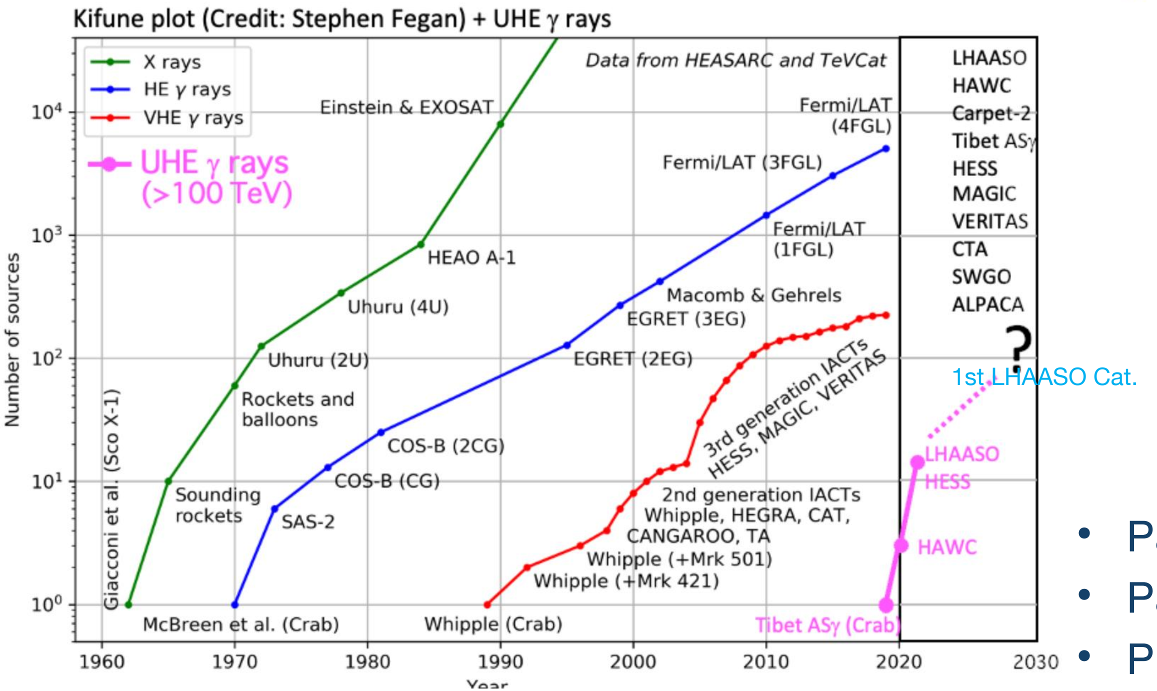
Precision Astronomy at VHE

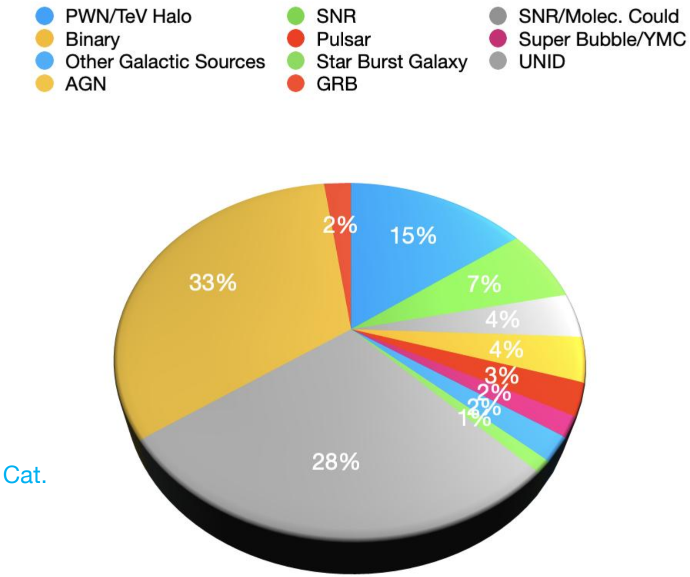
How to detect gamma rays?



What we have seen so far?

Number of sources vs. Time

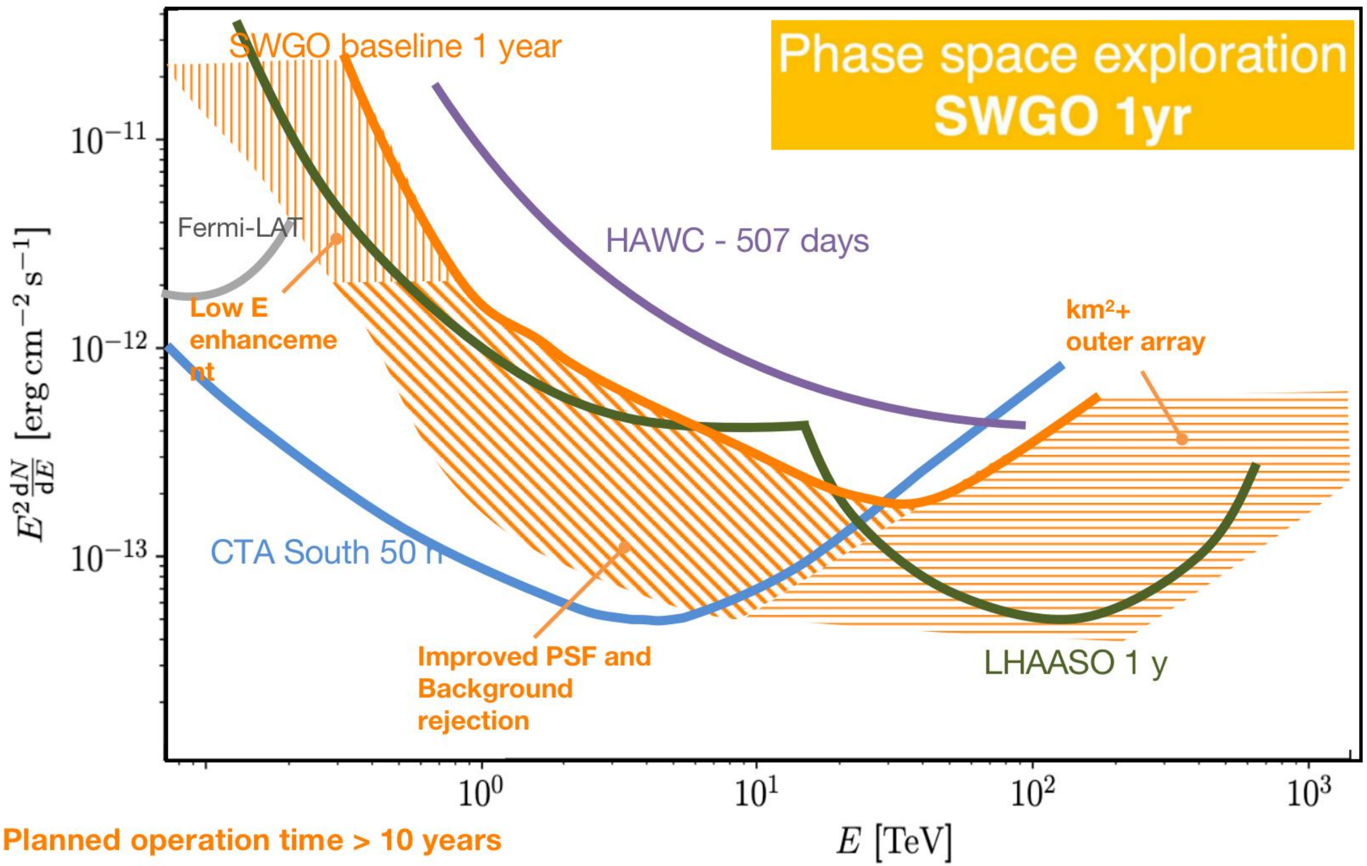


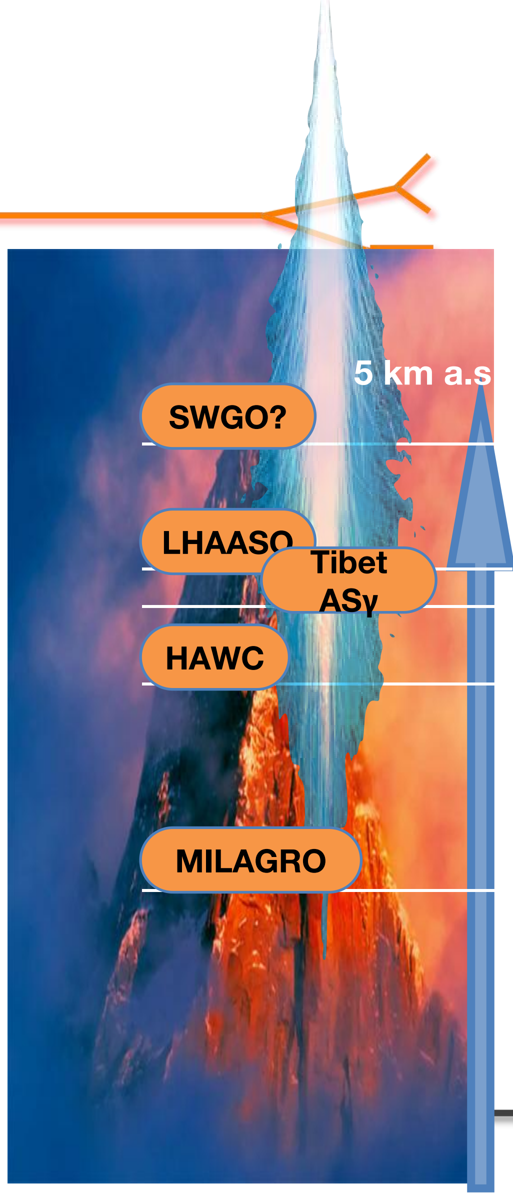


- Particle acceleration at the source
- Particle escaping from their sources
- Propagation of CRs across the Galaxy

The Southern Wide-field Gamma-ray Observatory

Larger and higher…





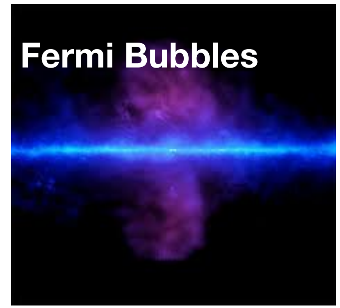
Planned operation time > 10 years

Ground-based Gamma-ray Astronomy Network

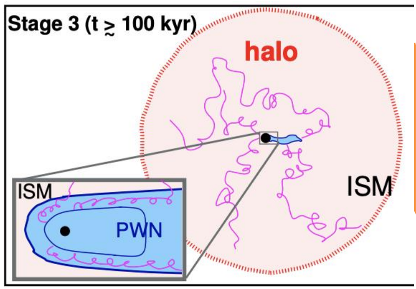
Scientific Outlook

Duty-cycle

Deep View @ large scale



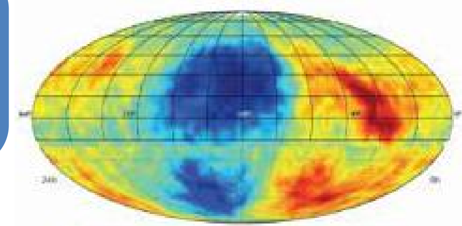
Wide-field



Halos

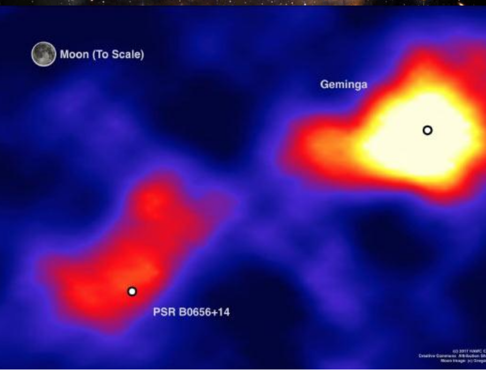
Survey + Discovery

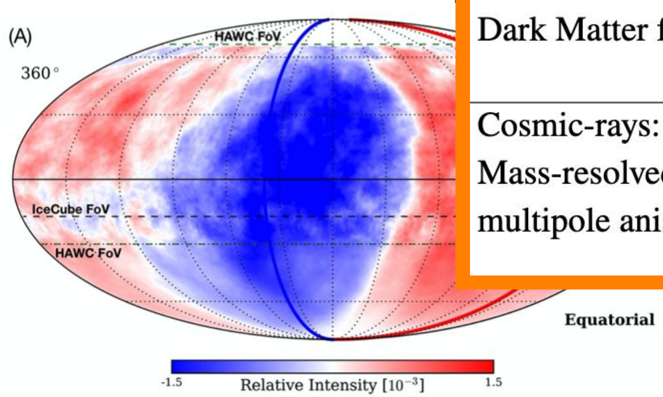
High-Energy Sensitivity



Cosmic rays

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]

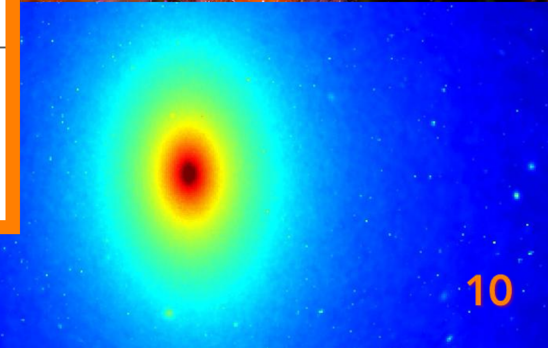
PRELIMINARY DESIGN TARGETS

$E_{th} \rightarrow 100$ GeV

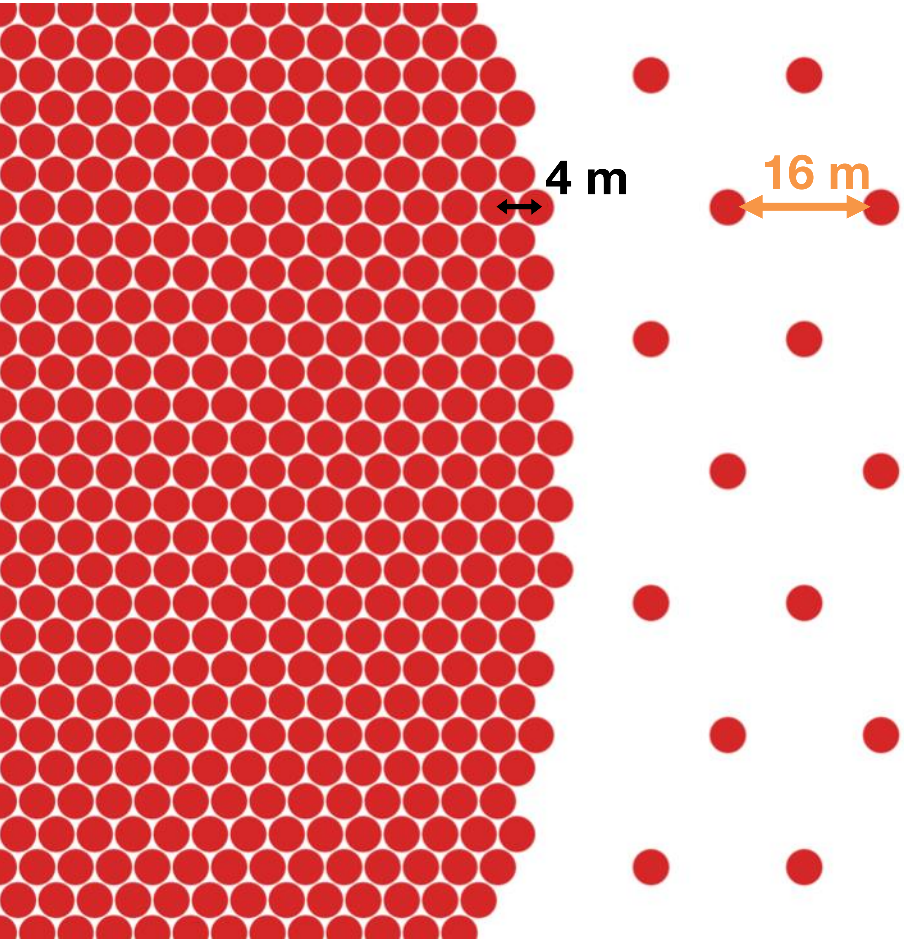
$E_{res} < 20\%$

$\Theta_{res} \sim 0.1°$

CR_{res} @ 10^{-4}



The baseline detector concept

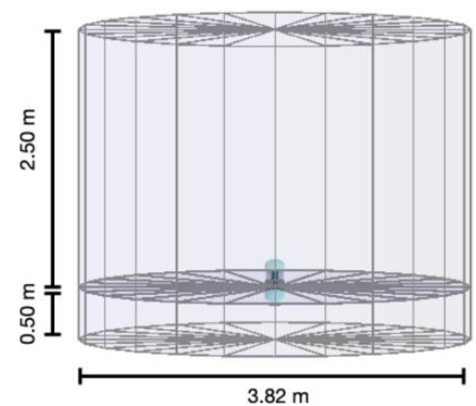


Core: Ø 320 m, FF = 80%
5,700 WCD units

Outer: Ø 600 m, FF = 5%
880 WCD units

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

✧ muon counting



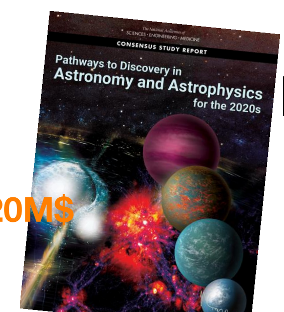
SWGO The Southern Wide-field Gamma-ray Observatory

Status & Plan

SWGO

		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

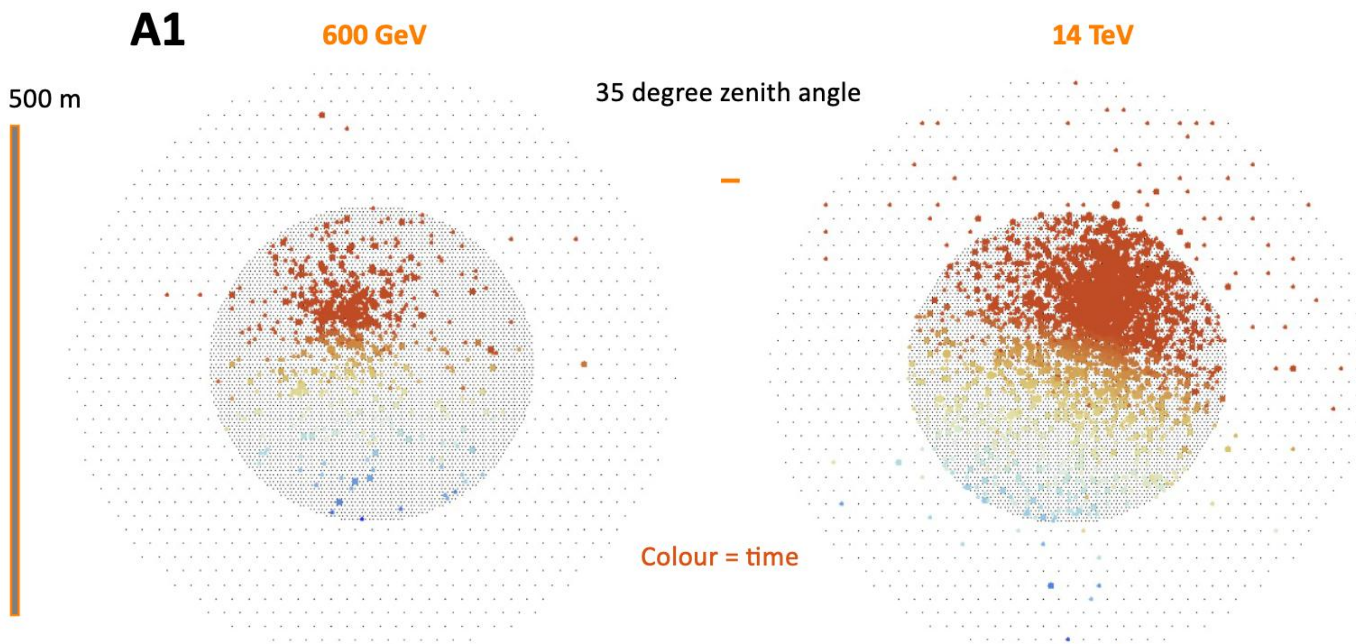
- R&D Phase
  - → Kick off meeting Oct 2019
  - → Expected completion 2025
    - ✓ Site and Design Choices made
  - → Then:
- Preparatory Phase
  - → Detailed construction planning
  - → **Engineering Array**
- (Full) Construction Phase
  - → 2027+

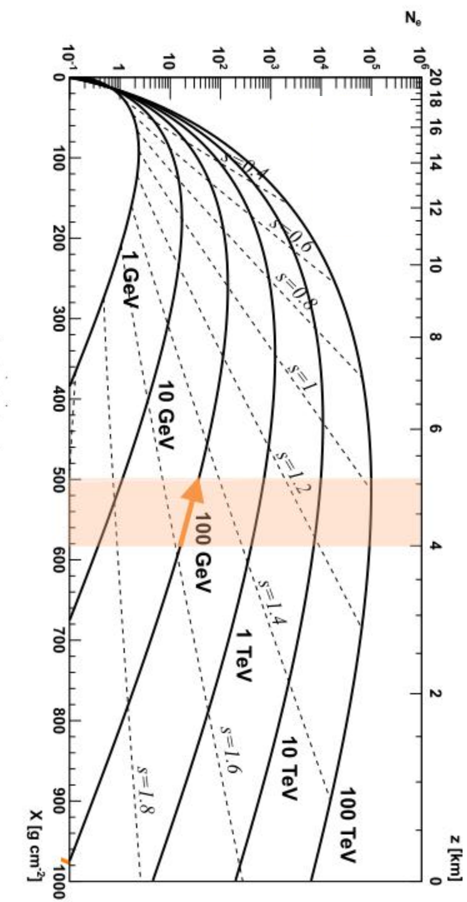


20M$

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

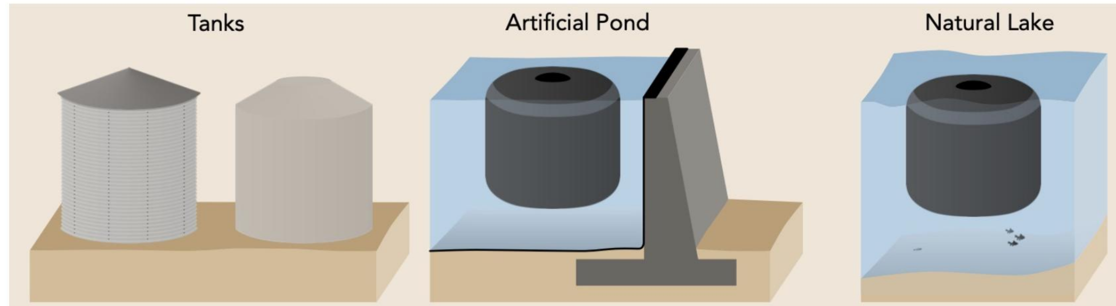
SWGO Baseline Requirements



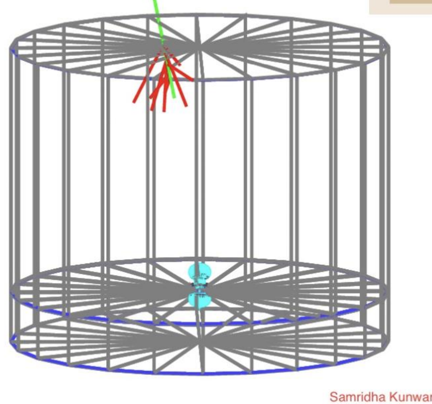


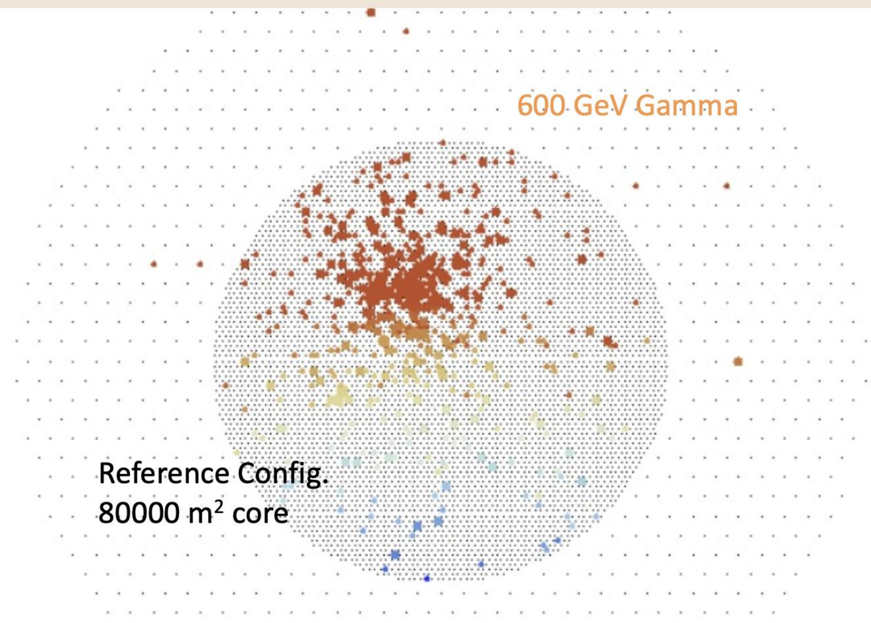
- Larger and dense detector array at increased altitude with respect to HAWC
  - → Very precise measurements possible below 1 TeV

WCD unit Solutions



Reference Config.
Two-layer tank

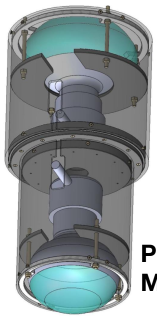




Reference Config.
80000 m^2 core

Muon identification a key element of background rejection

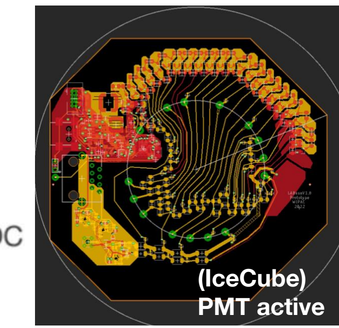
More Detector Options and Prototyping

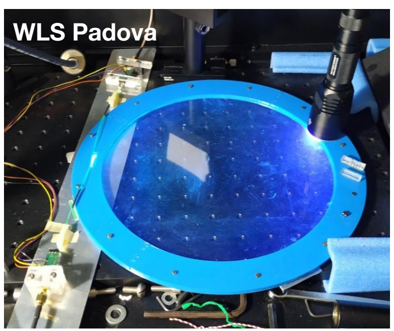


PMT module
MPIK

- 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:

Transients with SWGO

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

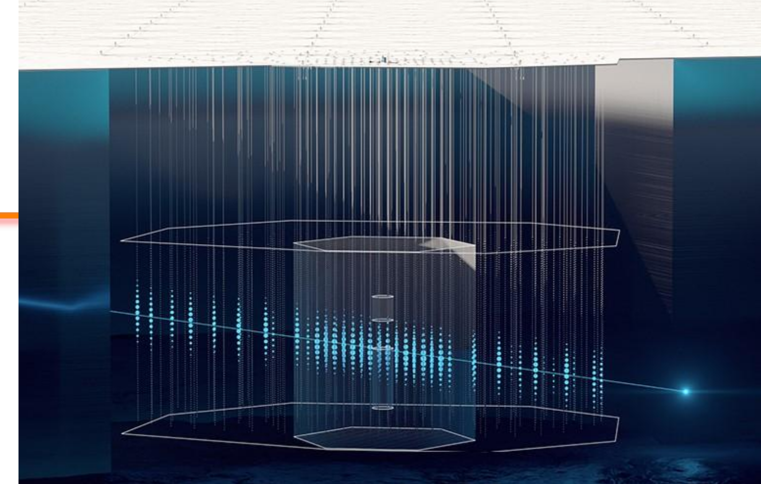
1 min sensitivity:
- Fermi-LAT: 10^{-7} erg/cm^2/s @ 1 GeV
- SWGO: 10^{-9} erg/cm^2/s @ < 500 GeV
- CTA: 10^{-11} erg/cm^2/s @ 100 GeV

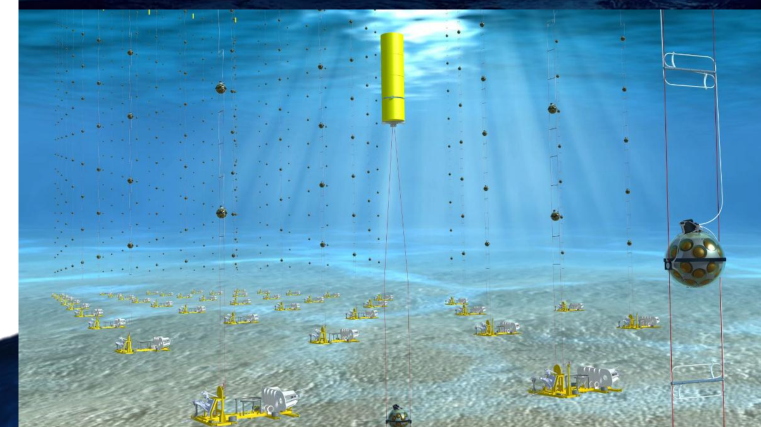
- And a number of other advantages…
  - **100% duty cycle** → higher rate and monitoring capability of transients → bridging the gap with satellite facilities
  - **Serendipitous view** - observation of onset / prompt emission of GRBs
  - **A trigger instrument**!
    - ✓ Blind searches and offline checks 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**

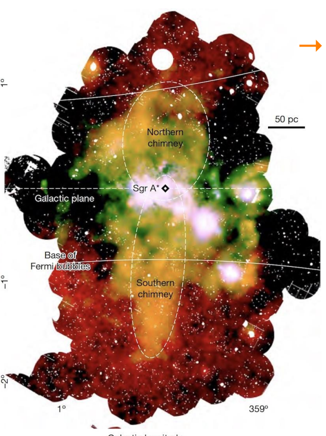
Synergies

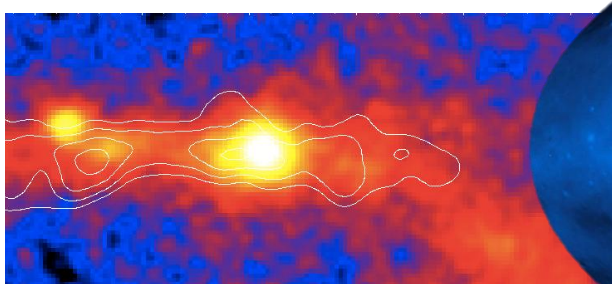
- SWGO+LHAASO
  - → **Full sky map of TeV-PeV γ emission**
- Strongly complements new generation of **neutrino instruments**
  - → Mapping out diffuse emission / separating IC from pion decay emission, Dark Matter search +++

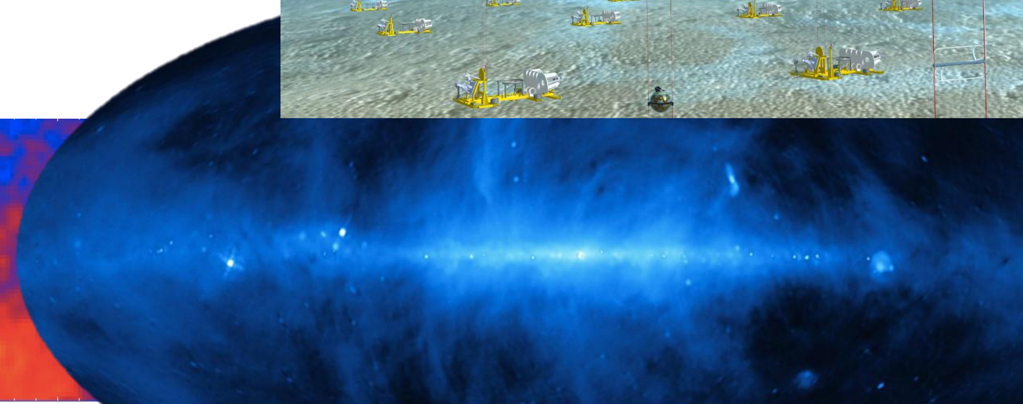




→ Nearby transients/flares



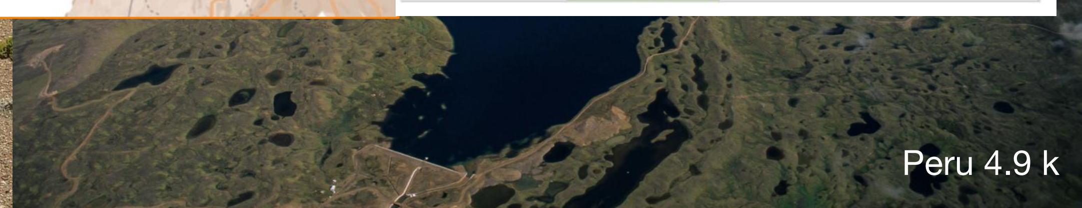




A Wide-field Gamma-ray Observatory in the South

Shortlisting: Fall 2022
Site visits: October 2022
2nd Site visit: July

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 site selection 2024.07.31

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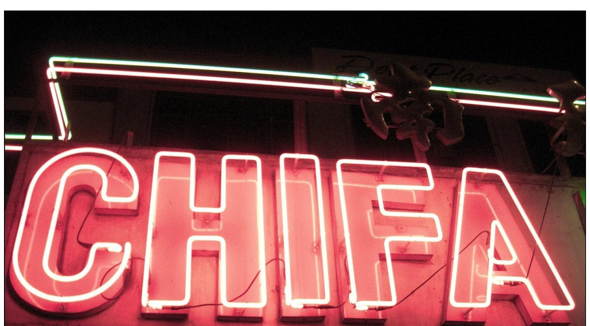
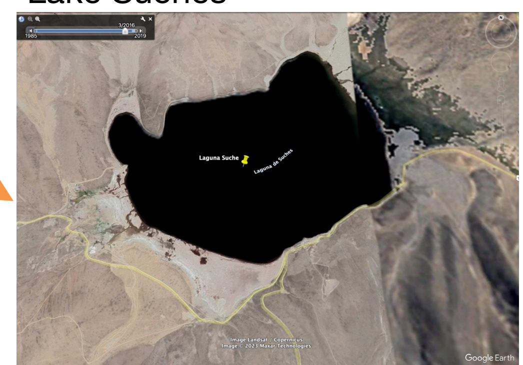
The Southern Wide-field Gamma-ray Observatory

Potential Lakes



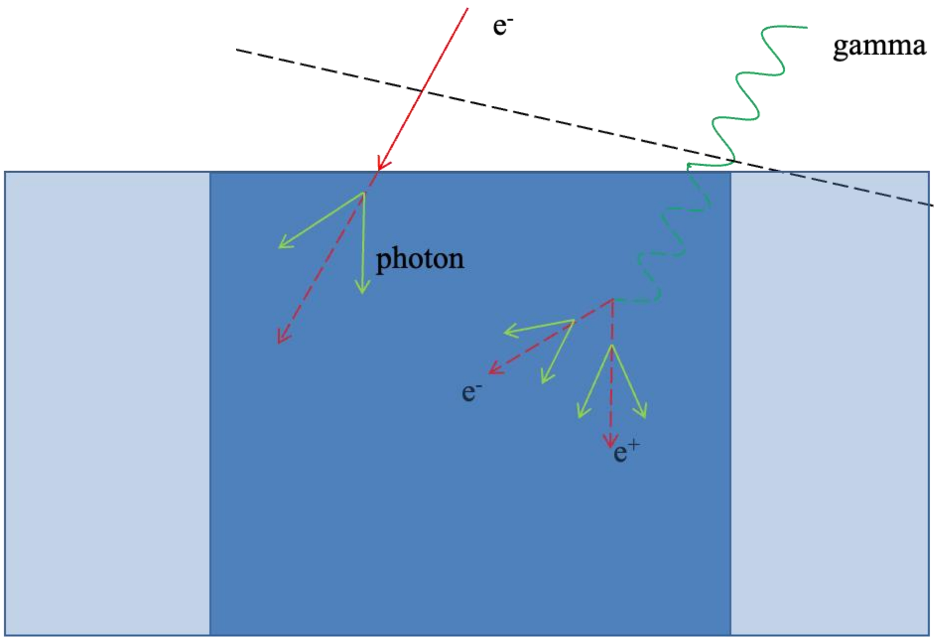
Lake Sibinacocha

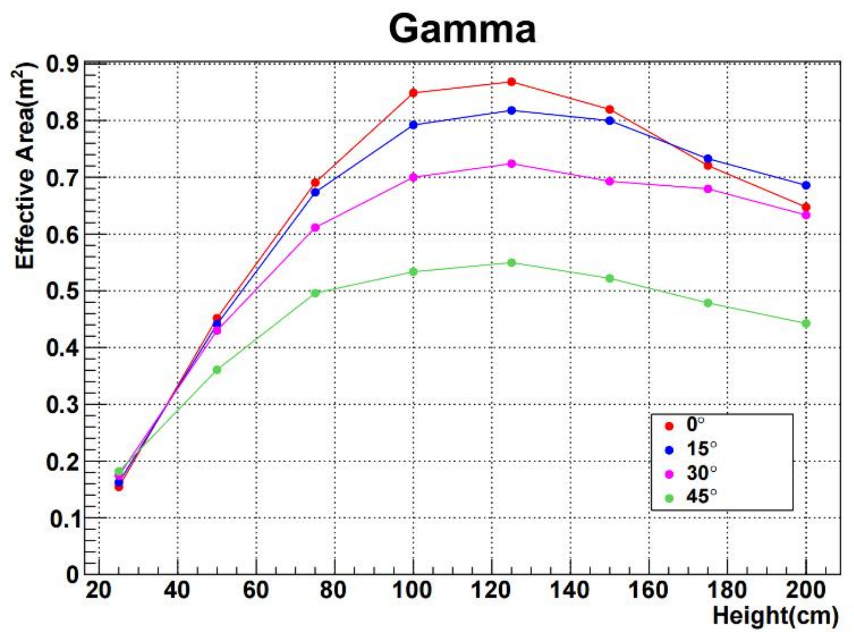
Lake Suches



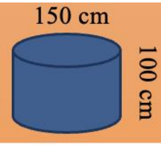
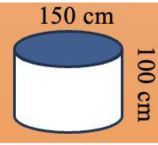
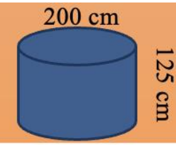
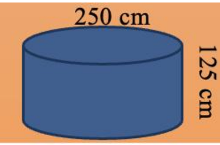
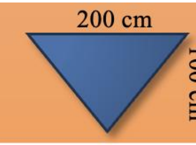
Simulation for an Lake Array

Unit detector simulation



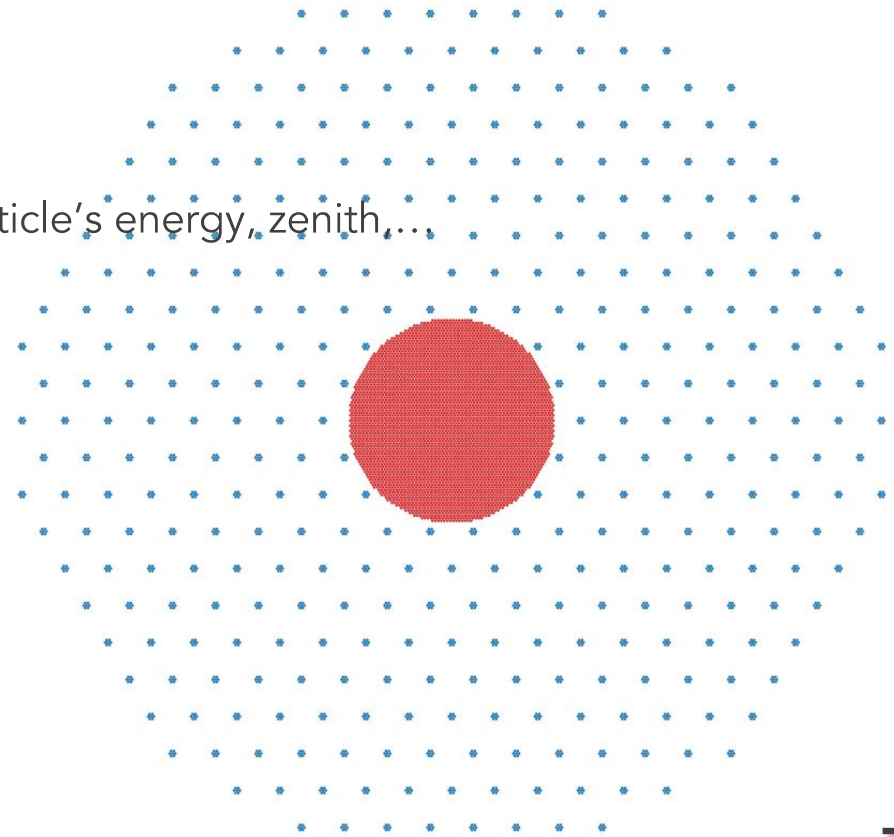


Simulation for an Lake Array

@100TeV						
First Arrival Time Spread(ns)	0.58 (1.04)	3.81 (4.46)	0.75 (1.28)	0.96 (1.54)	0.93 (1.55)	0.62 (0.93)
NPE	5.74 ± 11.96 (4.63±9.03)	6.34 ± 12.76 (4.63 ± 7.26)	4.06 ± 7.64 (3.40 ± 5.68)	3.79 ± 7.50 (3.18 ± 6.15)	2.26 ± 2.44 (2.02±1.90)	5.72 ± 10.25 (5.22±17.64)
NPE Per Particle Energy(MeV^{-1})	0.18 ± 0.30 (0.15±0.22)	0.20 ± 0.24 (0.16 ± 0.16)	0.12 ± 0.20 (0.11 ± 0.14)	0.11 ± 0.15 (0.11 ± 0.14)	0.06 ± 0.07 (0.06±0.05)	0.17 ± 0.22 (0.16±0.29)
Effective area(m^2)	0.90 (0.55)	1.17 (0.91)	1.39 (0.79)	1.87 (0.97)	0.83 (0.45)	0.99 (0.52)

Simulation for an Lake Array

- Unit detector simulation
  - → surface detector, muon detector
  - → parameterized detector
    - ✓ response binned in secondary particle's energy, zenith,…
- Fast array simulation
  - → test different array layouts



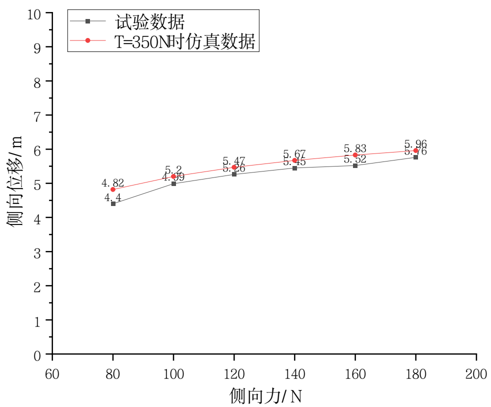
SWGO阵列固定的实验研究进展

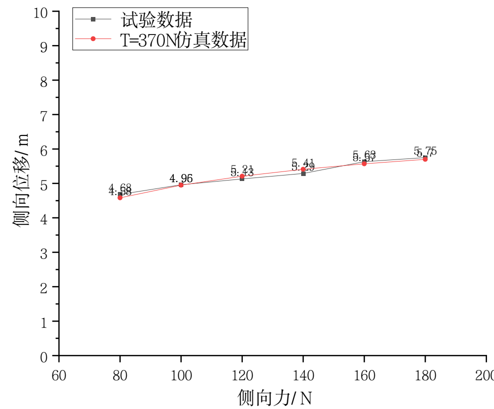
在水上实验平台进行直线型阵列连接实验

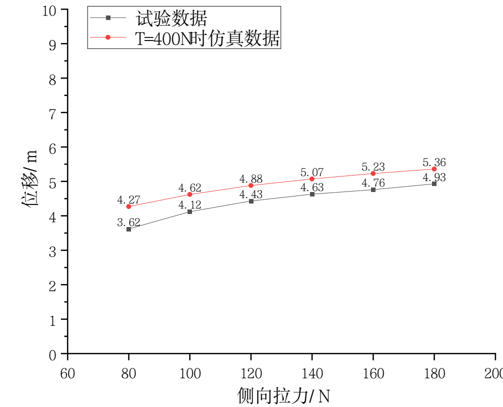
Credit: Jia Liu (IHEP) jialiu@ihep.ac.cn

The Southern Wide-field Gamma-ray Observatory

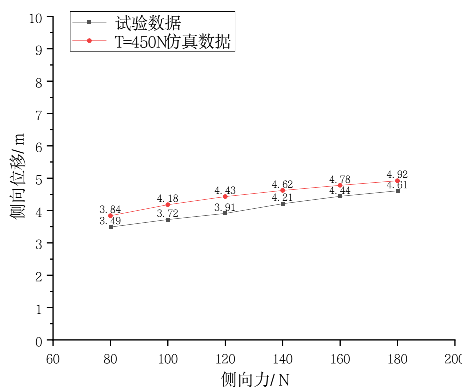
SWGO阵列固定的实验研究进展

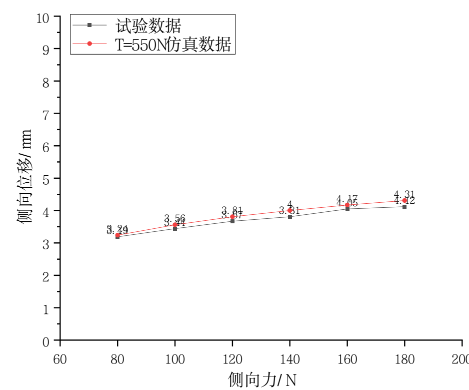






浮筒横向荷载实验结果与仿真算法匹配性



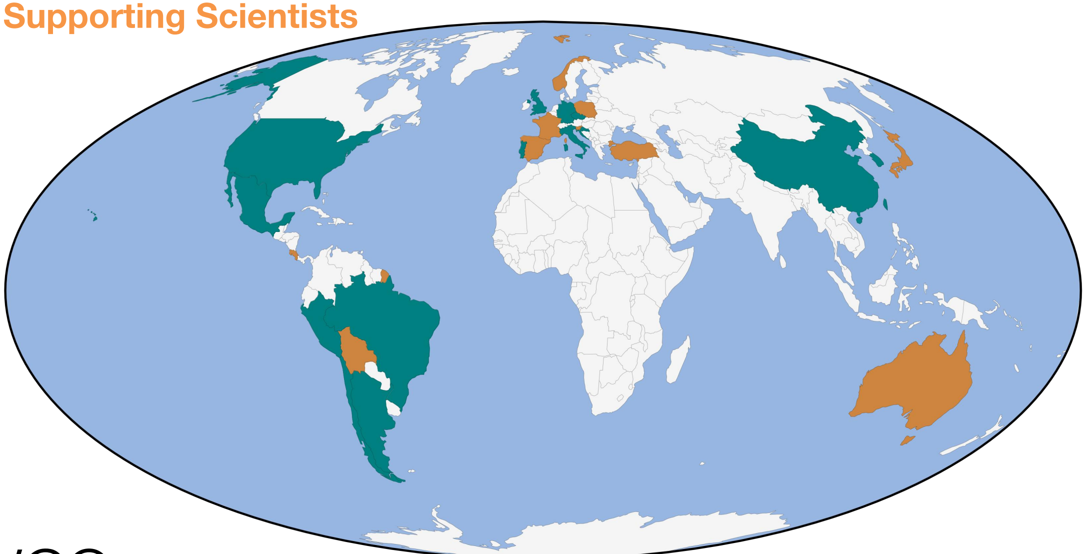


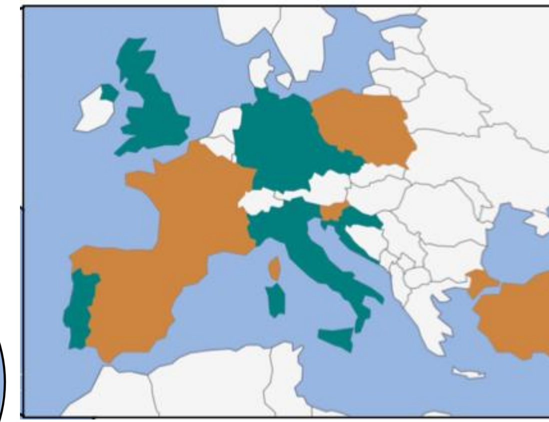
Credit: Jia Liu (IHEP) jialiu@ihep.ac.cn

SWGO Collaboration

Member Institutes

Supporting Scientists



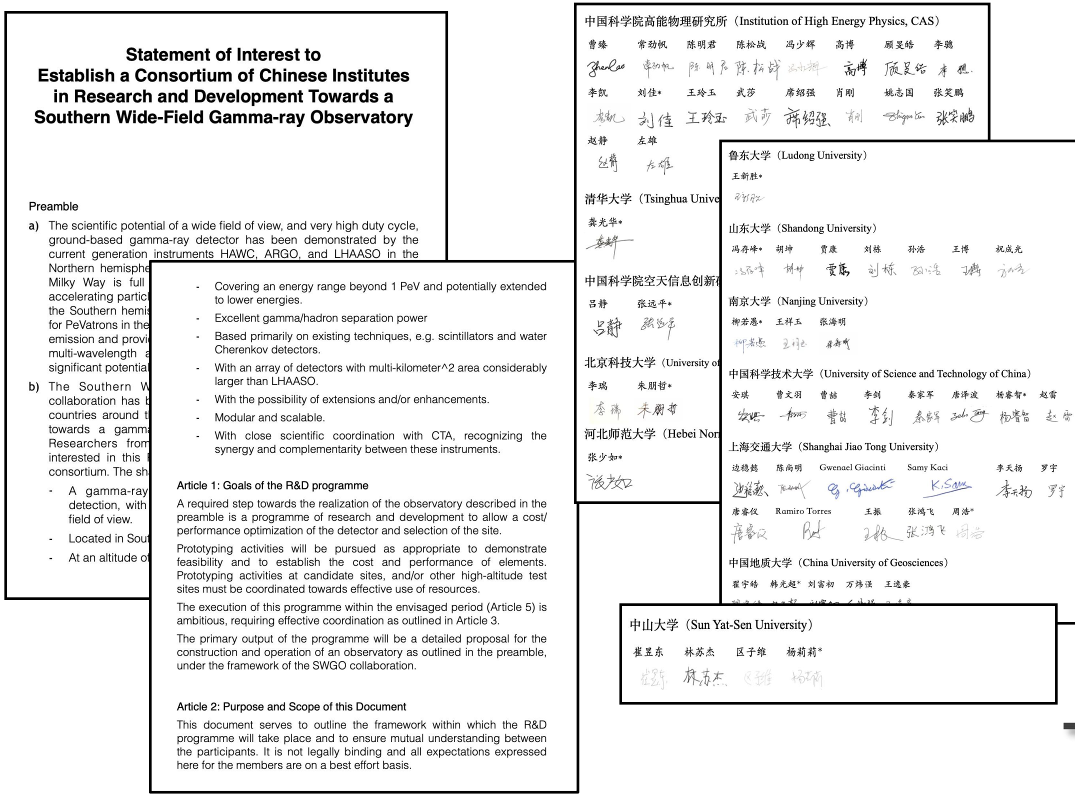


- SWGO partners
  - → 14 countries, 66 institutes*
  - → + supporting scientists

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

The Chinese Consortium

- Signed by 65 faculty members, postdocs, and grad students from 12 institutes
    - SoI are expected to be made at the level of individual researchers



Statement of Interest to Establish a Consortium of Chinese Institutes in Research and Development Towards a Southern Wide-Field Gamma-ray Observatory

Preamble

a) The scientific potential of a wide field of view, and very high duty cycle, ground-based gamma-ray detector has been demonstrated by the current generation instruments HAWC, ARGO, and LHAASO in the Northern hemisphe
Milky Way is full
accelerating partic
the Southern hemis
for PeVatrons in the
emission and provi
multi-wavelength a
significant potentia

b) The Southern W
collaboration has b
countries around t
towards a gamm
Researchers from
interested in this
consortium. The sh

- A gamma-ray detection, with field of view.
- Located in Sou
- At an altitude o

- Covering an energy range beyond 1 PeV and potentially extended to lower energies.
- Excellent gamma/hadron separation power
- Based primarily on existing techniques, e.g. scintillators and water Cherenkov detectors.
- With an array of detectors with multi-kilometer^2 area considerably larger than LHAASO.
- With the possibility of extensions and/or enhancements.
- Modular and scalable.
- With close scientific coordination with CTA, recognizing the synergy and complementarity between these instruments.

Article 1: Goals of the R&D programme

A required step towards the realization of the observatory described in the preamble is a programme of research and development to allow a cost/performance optimization of the detector and selection of the site.

Prototyping activities will be pursued as appropriate to demonstrate feasibility and to establish the cost and performance of elements. Prototyping activities at candidate sites, and/or other high-altitude test sites must be coordinated towards effective use of resources.

The execution of this programme within the envisaged period (Article 5) is ambitious, requiring effective coordination as outlined in Article 3.

The primary output of the programme will be a detailed proposal for the construction and operation of an observatory as outlined in the preamble, under the framework of the SWGO collaboration.

Article 2: Purpose and Scope of this Document

This document serves to outline the framework within which the R&D programme will take place and to ensure mutual understanding between the participants. It is not legally binding and all expectations expressed here for the members are on a best effort basis.

中国科学院高能物理研究所（Institution of High Energy Physics, CAS）

曹臻 常劲帆 陈明君 陈松战 冯少辉 高博 顾旻皓 李骢

李凯 刘佳* 王玲玉 武莎 席绍强 肖刚 姚志国 张笑鹏

赵静 左雄

清华大学（Tsinghua Unive

龚光华*

中国科学院空天信息创新

吕静 张远平*

北京科技大学（University of

李瑞 朱朋哲*

河北师范大学（Hebei Nor

张少如*

鲁东大学（Ludong University）

王新胜*

山东大学（Shandong University）

冯存峰* 胡坤 贾康 刘栋 孙浩 王博 祝成光

南京大学（Nanjing University）

柳若愚* 王祥玉 张海明

中国科学技术大学（University of Science and Technology of China）

安琪 曹文羽 曹喆 李剑 秦家军 唐泽波 杨睿智* 赵雷

上海交通大学（Shanghai Jiao Tong University）

边稳懿 陈尚明 Gwenael Giacinti Samy Kaci 李天扬 罗宇

唐睿仪 Ramiro Torres 王振 张鸿飞 周浩*

中国地质大学（China University of Geosciences）

翟宇皓 韩光超* 刘富初 万炜强 王逸豪

中山大学（Sun Yat-Sen University）

崔显东 林苏杰 区子维 杨莉莉*

Summary

- 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!

hao_zhou@sjtu.edu.cn

Thank you