Very High Energy Sky Monitoring with SWGO

www.swgo.org

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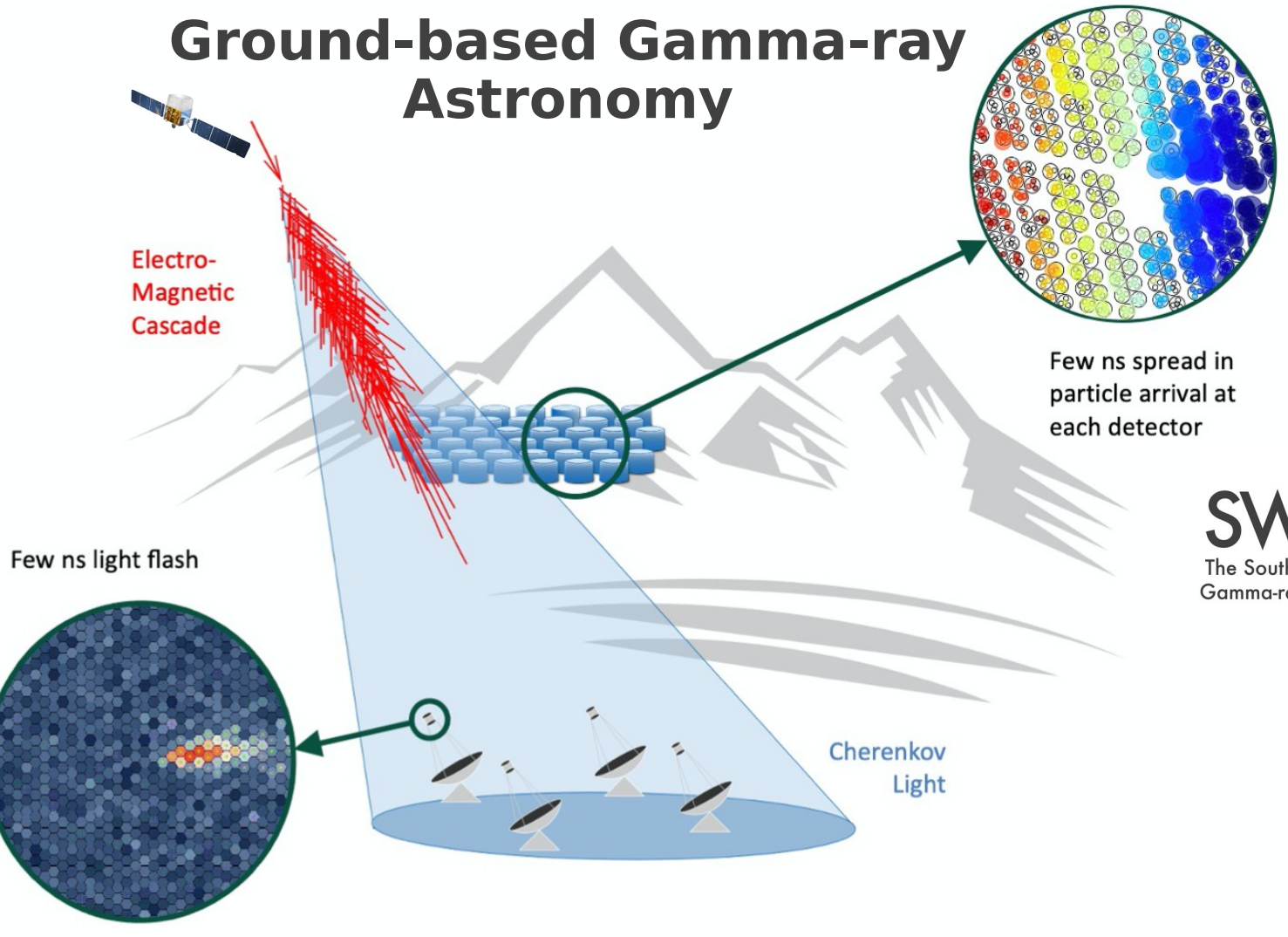
for the SWGO Collaboration

Cosmic Ray International Seminar (CRIS 2022), 12-16/09/2022, Napoli

Ground-based Gamma-ray Astronomy



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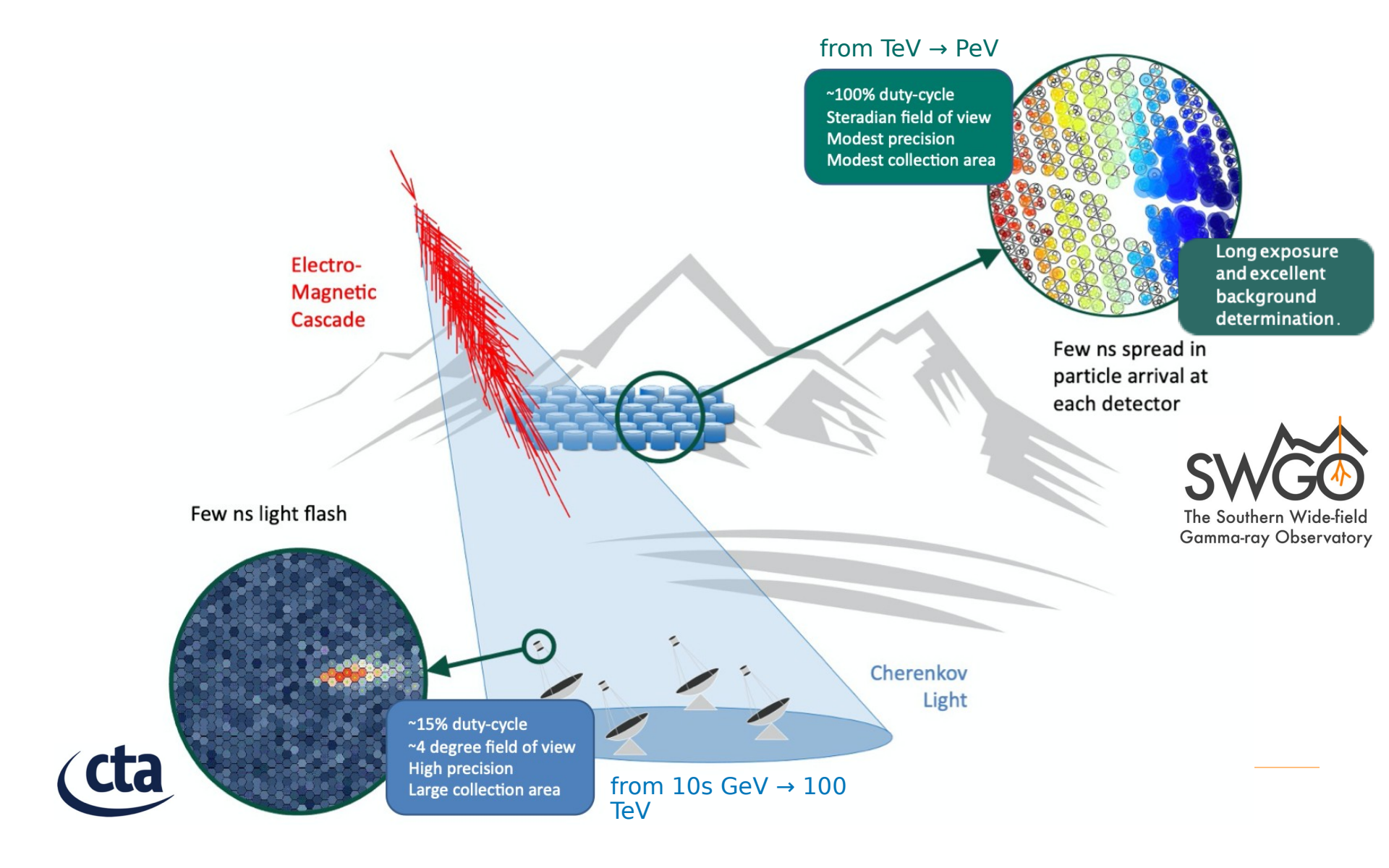
Gamma-ray Observatory

cta


from TeV → PeV
~100% duty-cycle
Steradian field of view
Modest precision
Modest collection area
Long exposure and excellent background determination.
Few ns spread in particle arrival at each detector
Electro-Magnetic Cascade
Few ns light flash
Cherenkov Light
~15% duty-cycle
~4 degree field of view
High precision
Large collection area
from 10s GeV → 100 TeV
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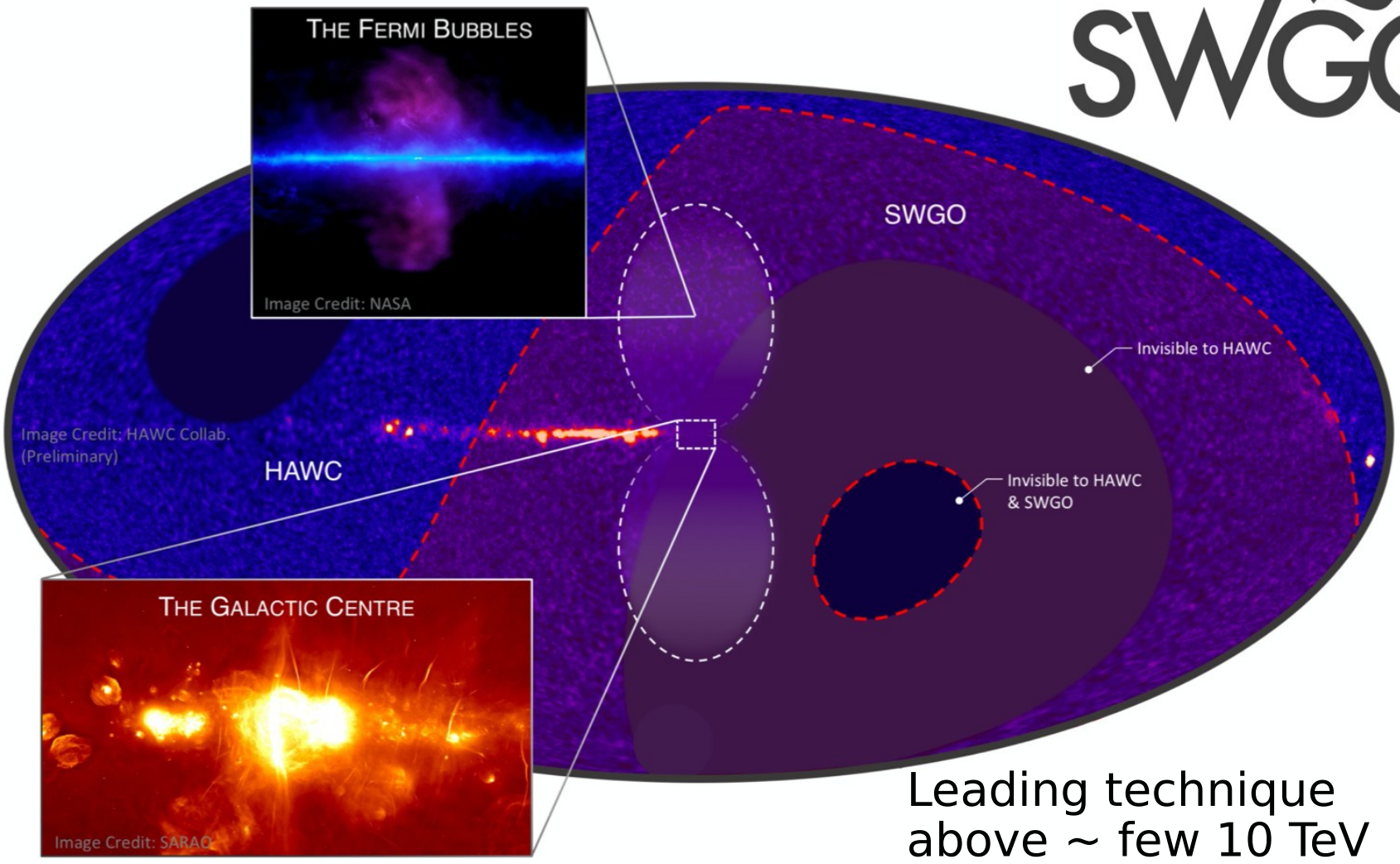
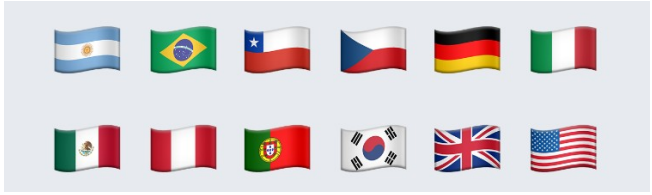
Geographic distribution



Leading technique above ~ few 10 TeV

Status & Plan



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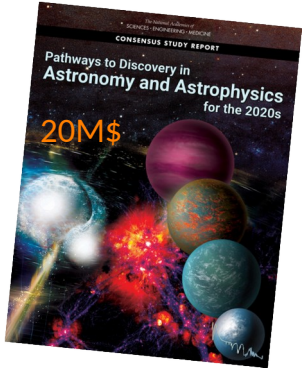
	SWGO R&D Phase Milestones	
✓	**M1**	R&D Phase Plan Established
✓	**M2**	Science Benchmarks Defined
✓	**M3**	Reference Configuration & Options Defined
	M4	Site Shortlist Complete
✓	**M5**	Candidate Configurations Defined
	M6	Performance of Candidate Configurations Evaluated
	M7	Preferred Site Identified
	M8	Design Finalised
	M9	Construction & Operation Proposal Complete

- SWGO partners
  - 47 institutes in 12 countries
  - \+ supporting scientists

- 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+


Bolivia 4.7k
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Chile 4.8 k
STATE OF ACRE
Peru
13º S
Lake Sibinacocha (Peru)
Yanque (Peru)
Imata (Peru)
Chacaltaya (Bolivia)
Bolivia
Cochabamba
AAP Pajonal (Chile)
24º S
Alto Tocomar (Argentina...
Chile
Argentina 4.8 k
Peru 4.9 k

Bolivia 4.7k

Chile 4.8 k

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Site short-listing: September 2022
Site team visits: October 2022
Preferred Site identified: Fall 2023
On-site prototyping activities: from 2022

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

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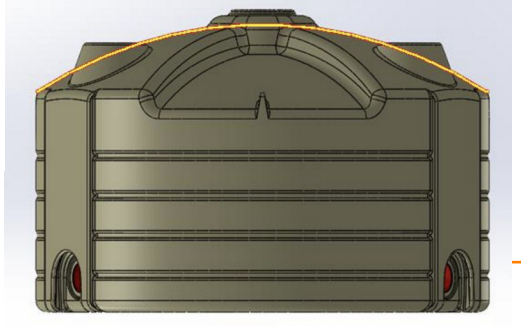
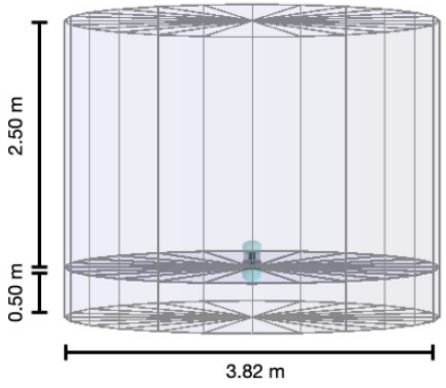
Detector Design

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



WCD
UNITS

A



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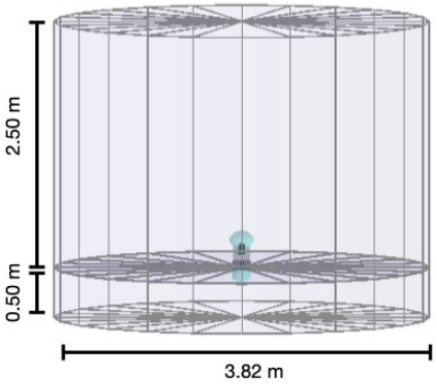

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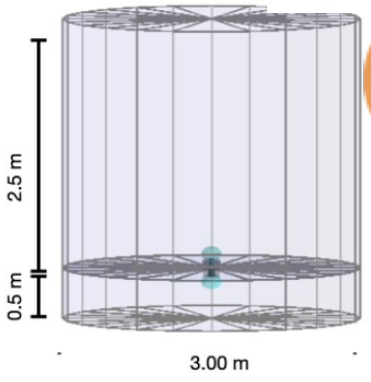

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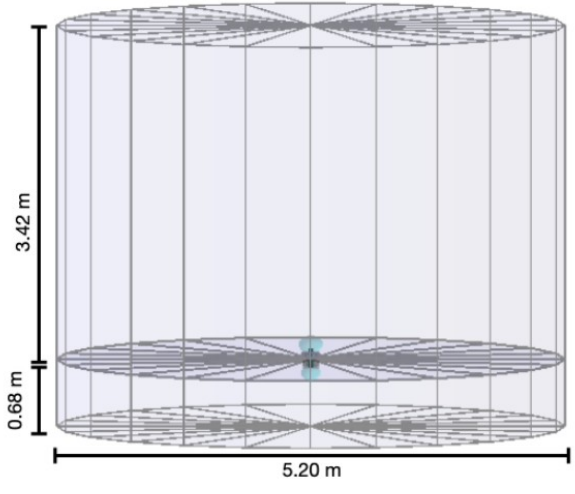

E

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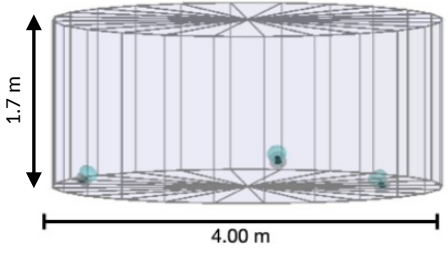

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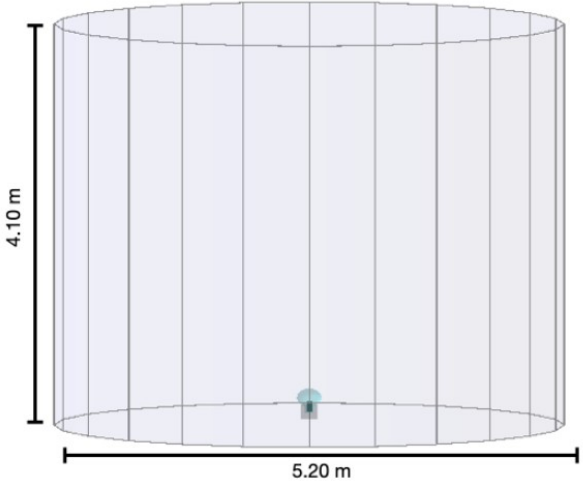
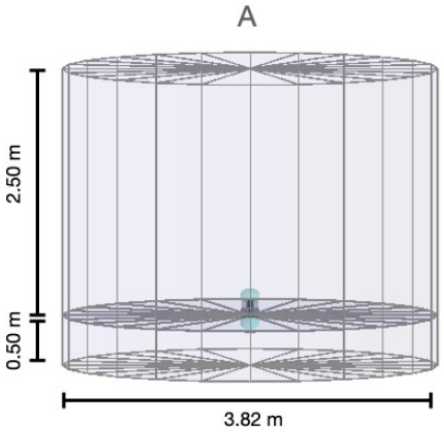
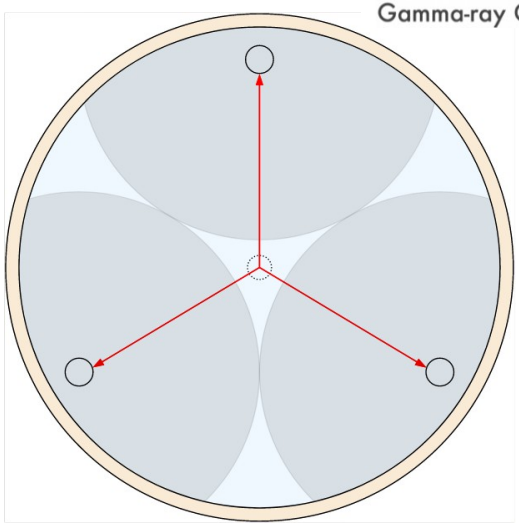
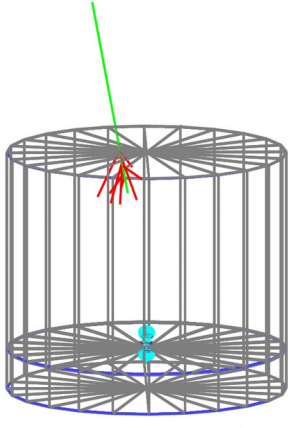


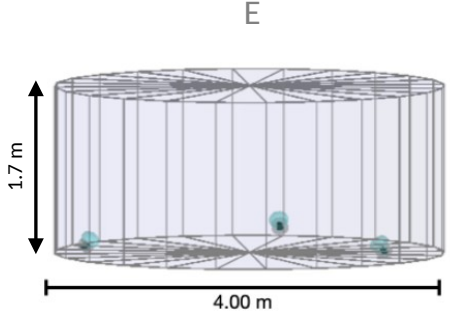


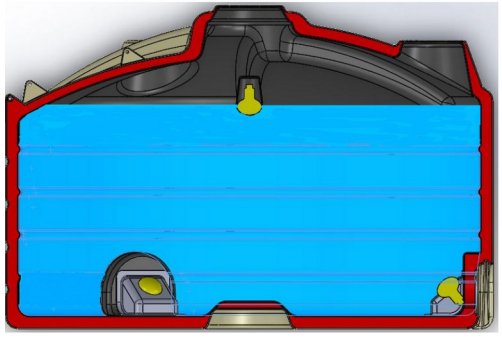
MUON IDENTIFICATION is a key element of background rejection

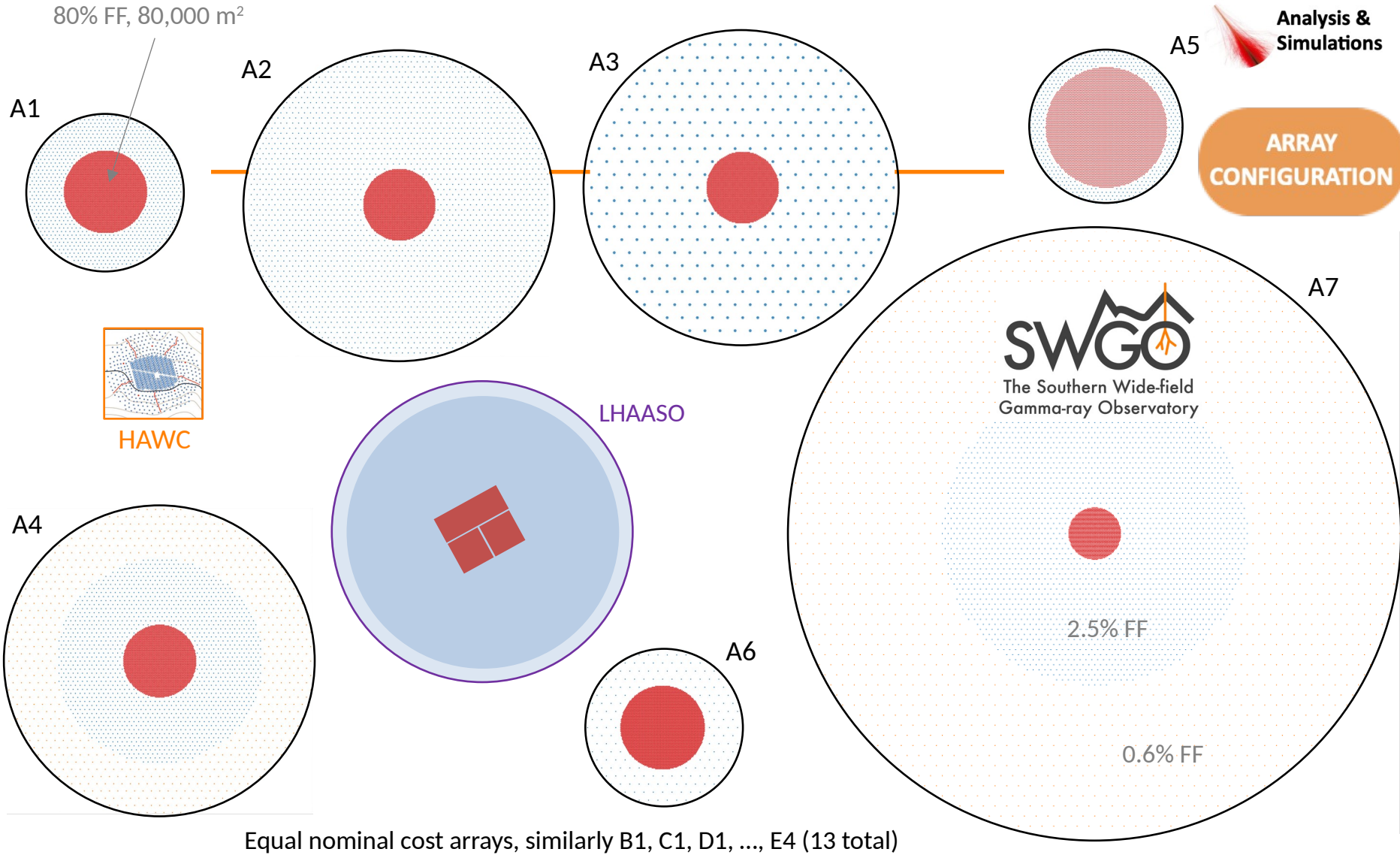
Approaches under evaluation:
— double layer WCDs
— multi-sensor WCDs



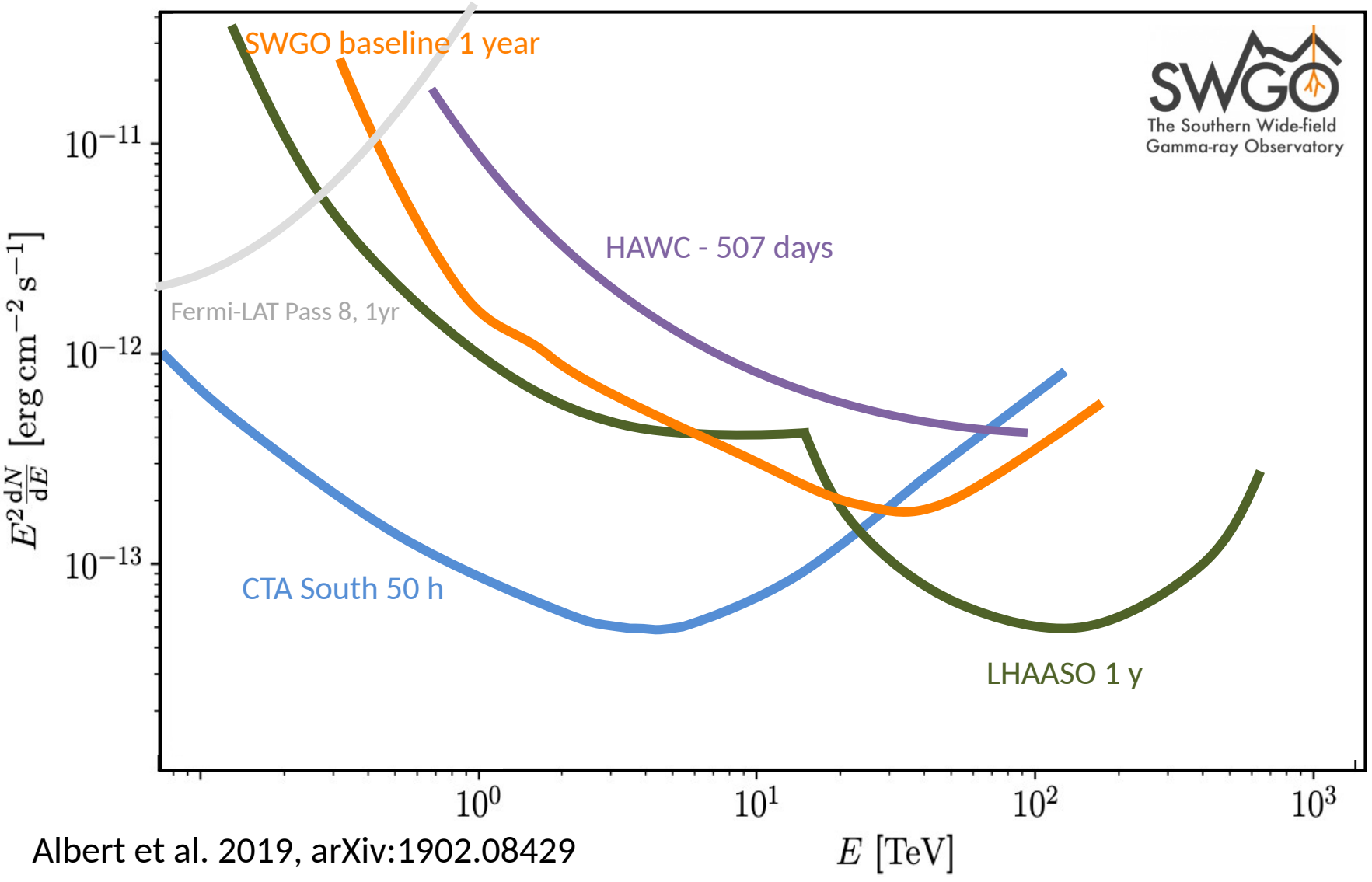




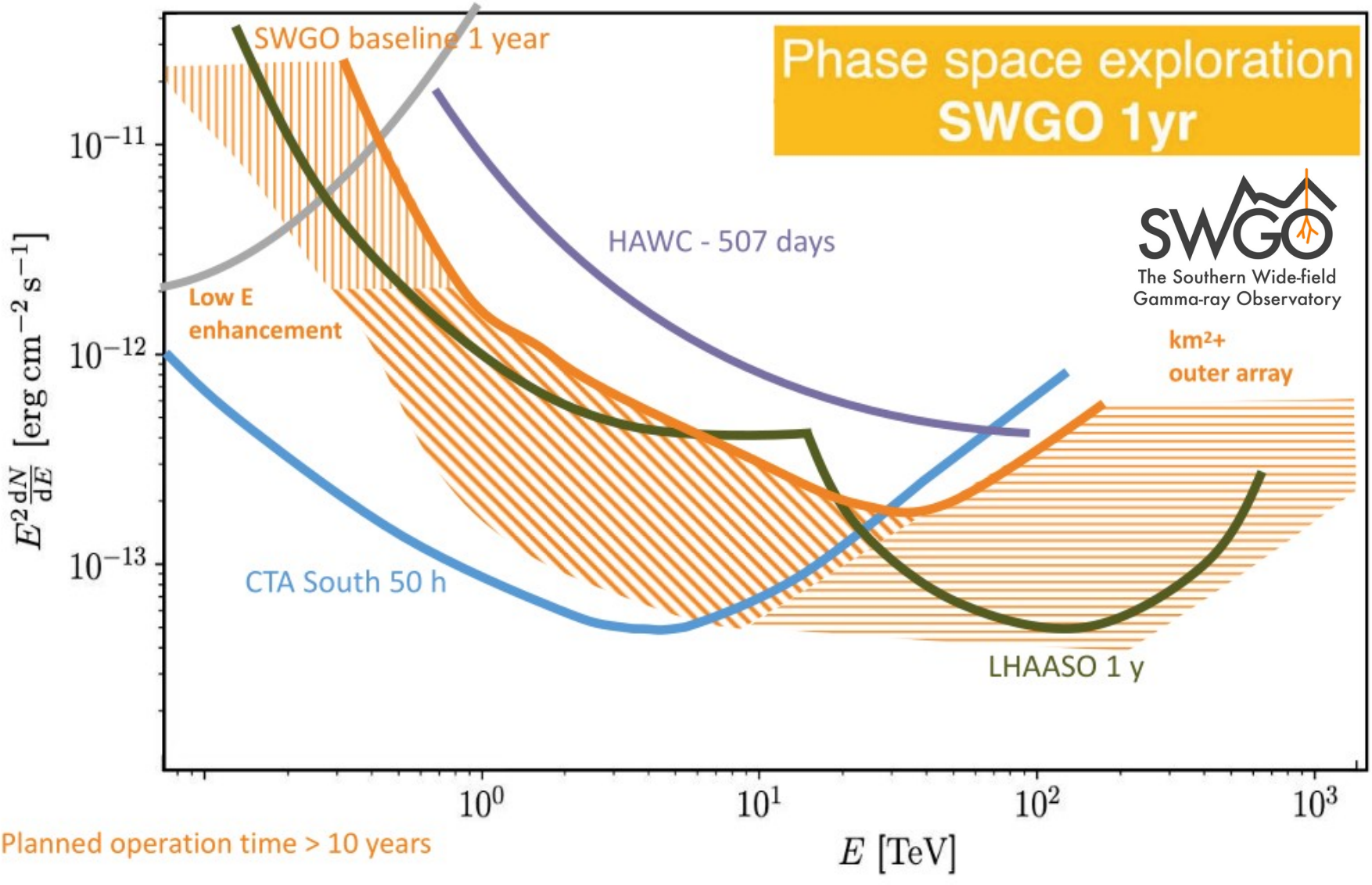




Equal nominal cost arrays, similarly B1, C1, D1, …, E4 (13 total)



Albert et al. 2019, arXiv:1902.08429

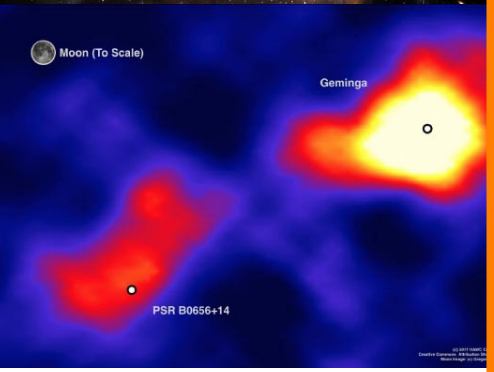


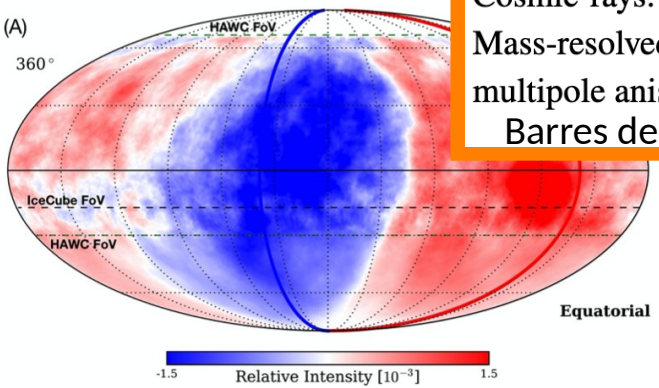
Planned operation time > 10 years

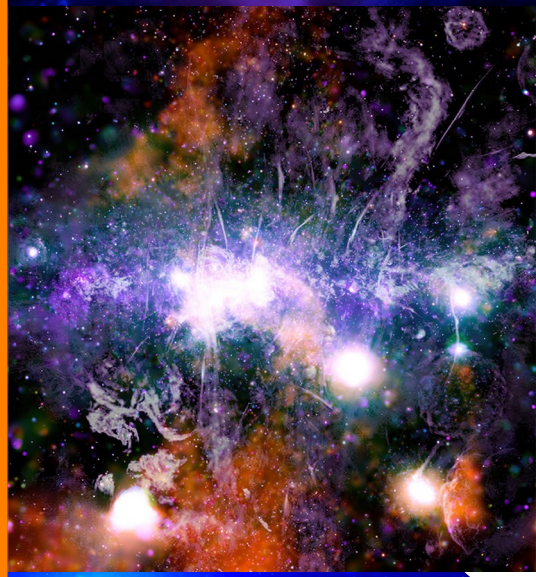
Science

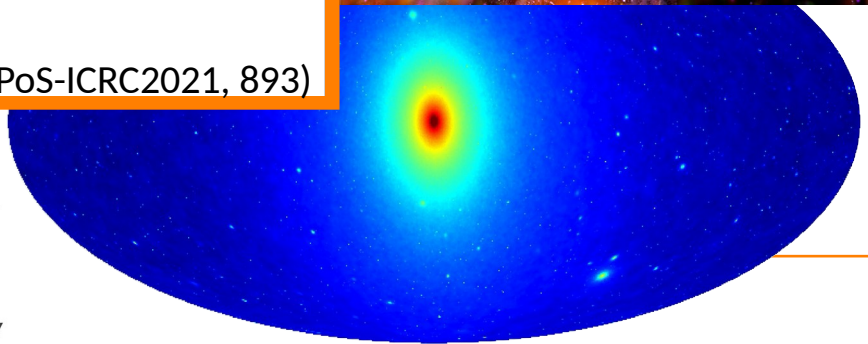
Science Case	Design Drivers
Transient Sources: Gamma-ray Bursts	Low-energy sensitivity & Site altitude[a]
Galactic Accelerators: PeVatron Sources	High-energy sensitivity & Energy resolution[b]
Galactic Accelerators: PWNe and TeV Halos	Extended source sensitivity & Angular resolution[c]
Diffuse Emission: 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]

Barres de Almeida et al. (2022, PoS-ICRC2021, 893)









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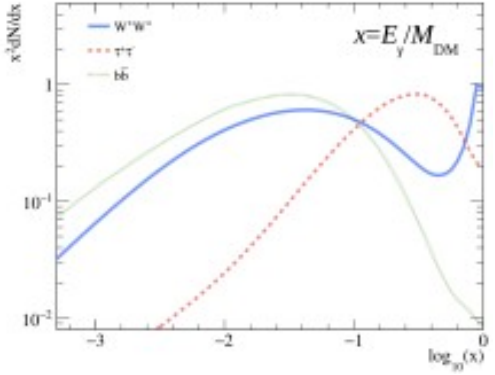
Dark Matter benchmarks

- Wide FoV
  - Some targets highly-extended
  - Others have lots across the sky
- Spectral shapes can be quite peaked
  - Good energy resolution useful
- Spectra peak in energy at $M_{DM}/30 - M_{DM}/3$
  - High-E sensitivity for high masses
    - SWGO is most competitive here
  - Low-E sensitivity for low masses
    - SWGO not very competitive here

CREDIT: P. Harding

Requirements
☑ Wide FoV
☐ Low E Thresh.
☐ Low E Sens.
☑ High E Sens.
☑ Energy Res.
☐ Angular Res.
☐ Low Latitude
☐ Good 29°S Sens.



Dark Matter annihilation in Galactic Centre

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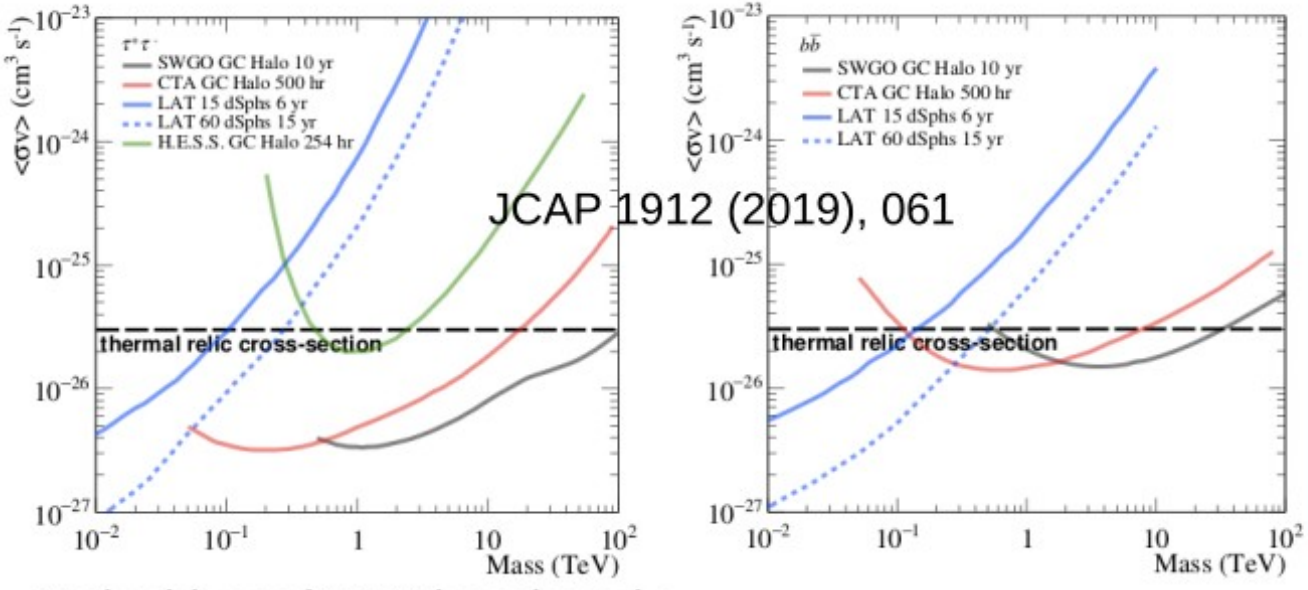
CREDIT: P. Harding



JCAP 1912 (2019), 061

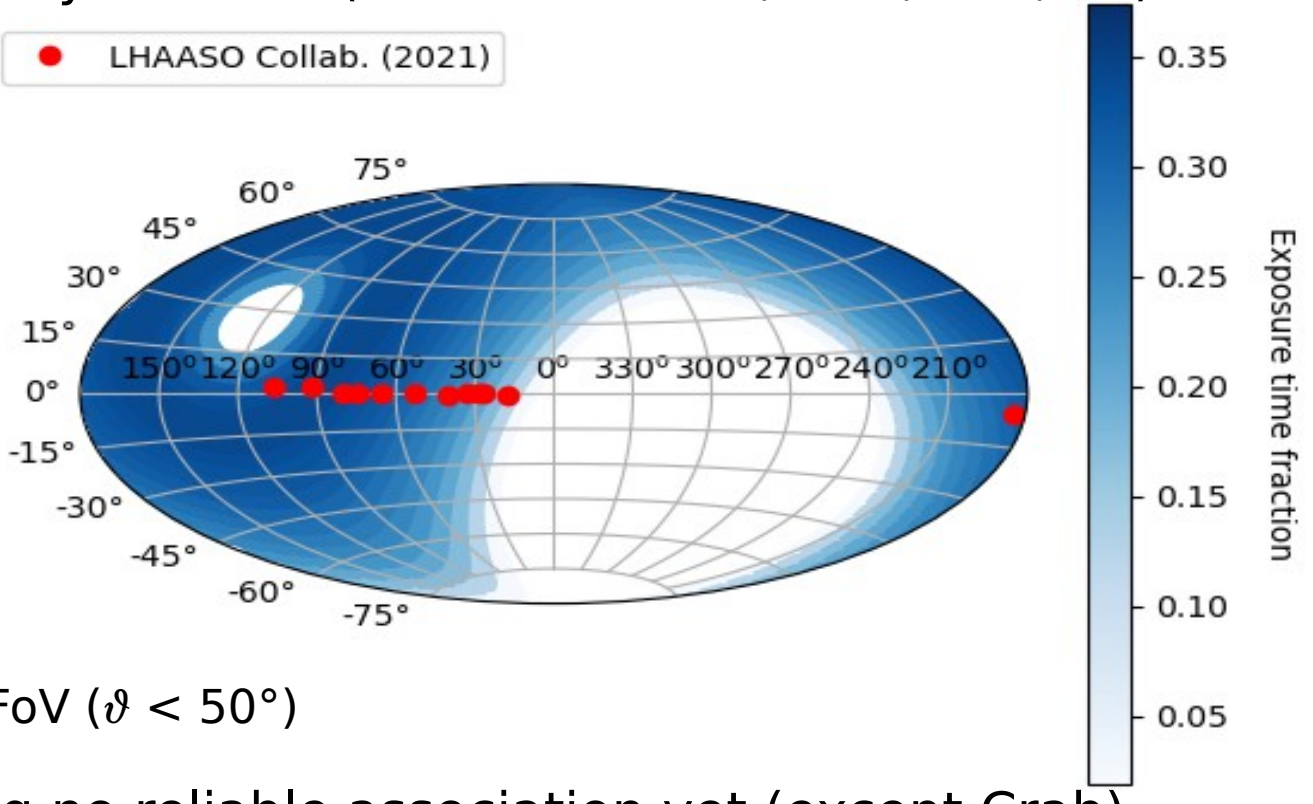
Requirements

- ☑ Wide FoV
- ☐ Low E Thresh.
- ☐ Low E Sens.
- ☑ High E Sens.
- ☑ Energy Res.
- ☑ Angular Res.
- ☐ Low Latitude
- ☑ Good 29°S Sens.

- Main driver of BSM benchmarks
- Can reach thermal DM ~100TeV masses for WW and ττ spectra with strawman model
- Better high-E sensitivity by 2x would do it for bottom quarks too (stretch goal)
- Extra benchmarks for GC DM annihilation
  - Southern location (29°S) optimal sensitivity
  - Improves (weakly) with improved angular resolution

PeVatrons and TeV halos

12 sources detected by LHAASO (Cao et al. 2021, *Nat.*, 594, 33)

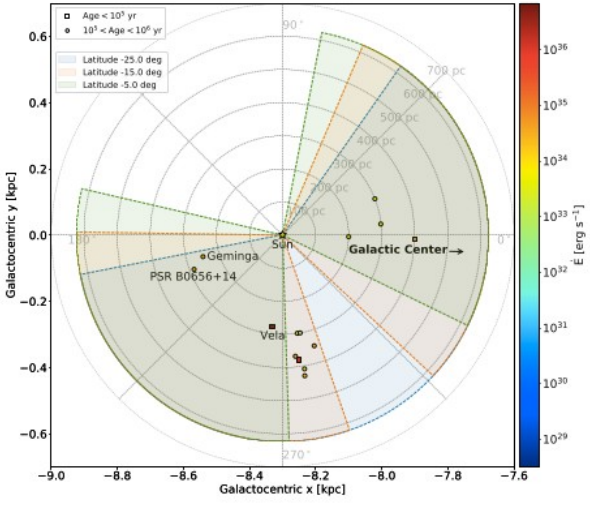


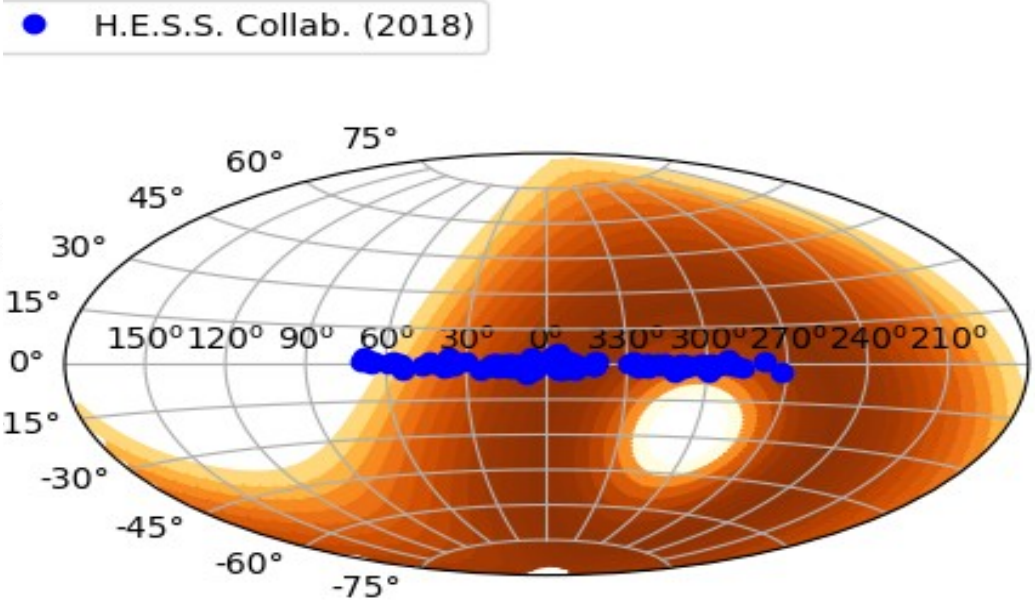
LHAASO effective FoV ($\vartheta < 50°$)

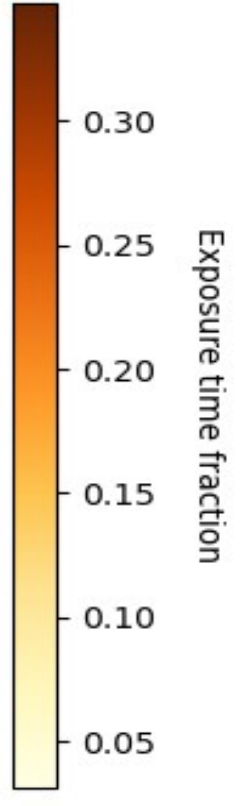
Many sources having no reliable association yet (except Crab)

Prospects for SWGO

H.E.S.S. detected SNRs (H.E.S.S. Collab., *A&A*, 612, A3)







CREDIT: R. López-Coto

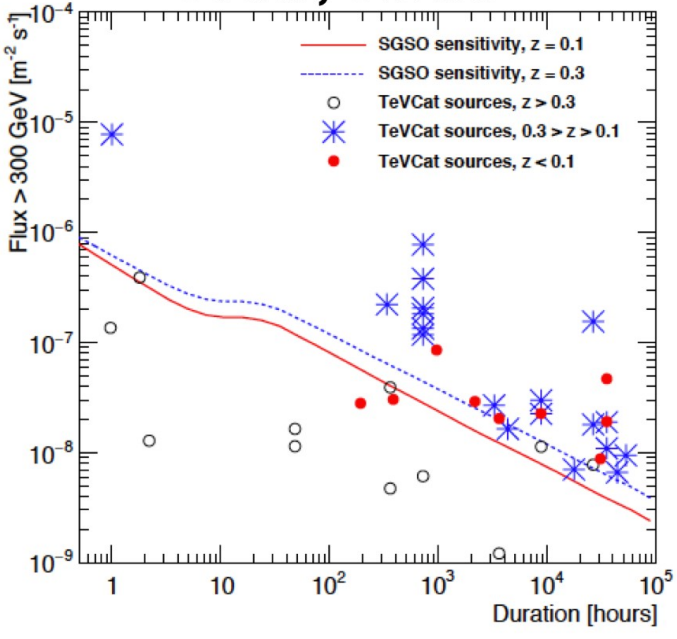
SWGO effective FoV ($\vartheta < 50°$), assuming 23°S latitude

Transients

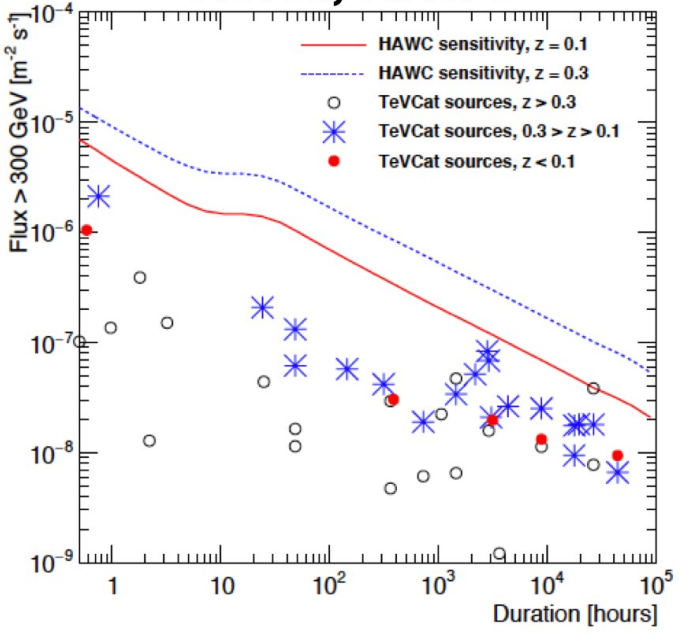
- Short time-scale sensitivity of ground-particle detectors is much worse than IACTs at low E! But room for improvement!

Albert et al. 2019, arXiv:1902.08429

South, SWGO



North, HAWC



Phase space exploration SWGO 1yr

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SWGO baseline 1 year

HAWC - 507 days

Low E enhancement

CTA South 50 h

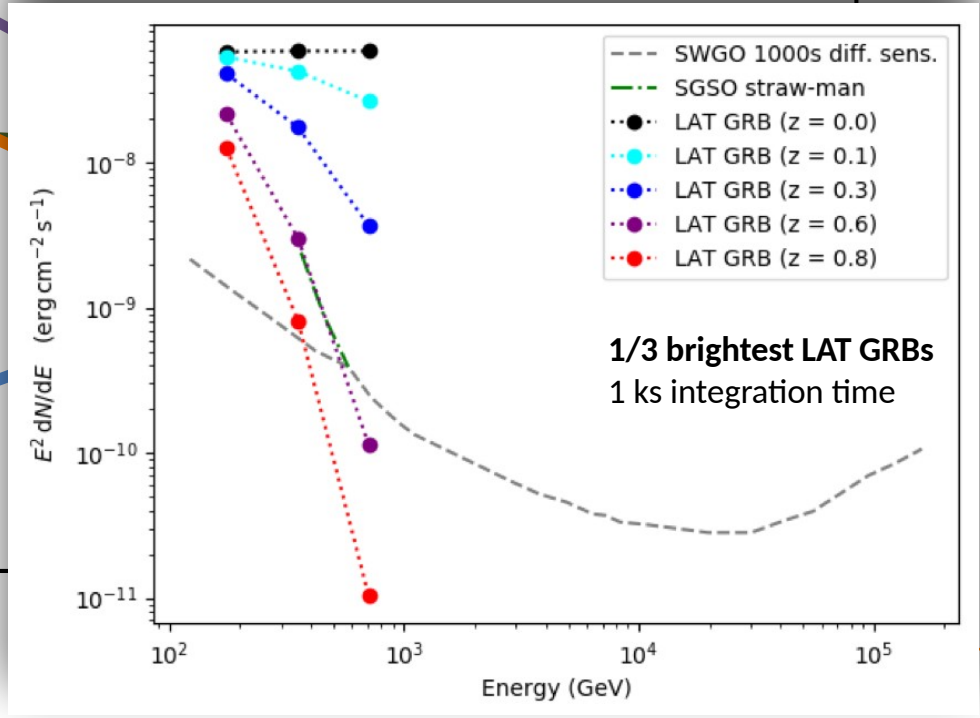
$E^2 \frac{dN}{dE}$ [erg cm^{-2} s^{-1}]

10^{-11}

10^{-12}

10^{-13}

10^{0}

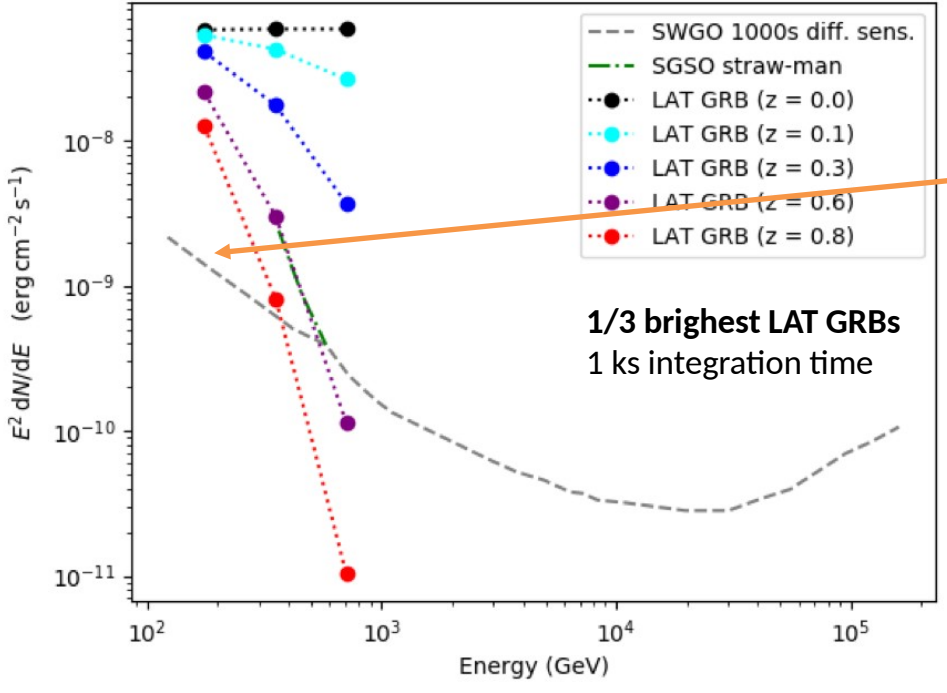


1/3 brightest LAT GRBs
1 ks integration time

Planned operation time > 10 years

Transients

◎ Short time-scale sensitivity of ground-particle detectors is much worse than IACTs at low E! But room for improvement!



✧ Order of magnitude **1 minute sensitivity**:

- Fermi-LAT: 10^{-7} erg/cm^2/s @ 1 GeV
- SWGO: 10^{-9} erg/cm^2/s @ < 300 GeV
- CTA: 10^{-11} erg/cm^2/s @ 100 GeV

Transients

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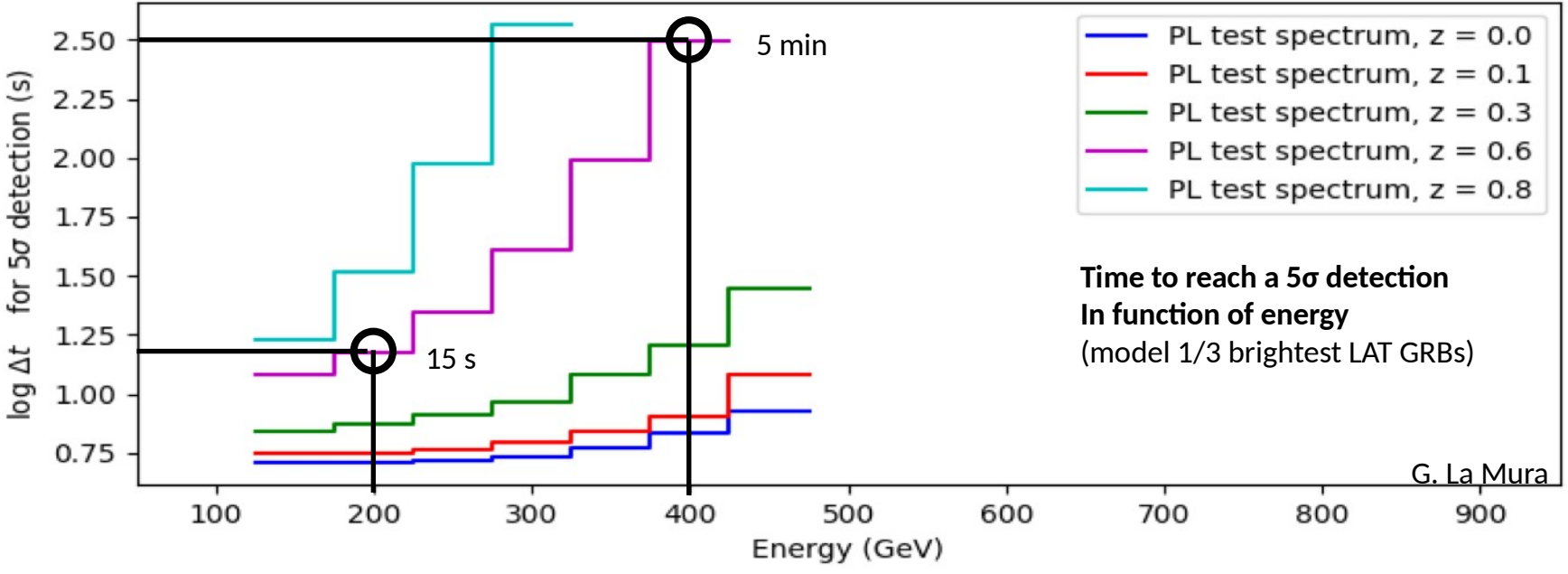
- Energy threshold is critical for transient studies, specially GRBs



Transients

SWGO
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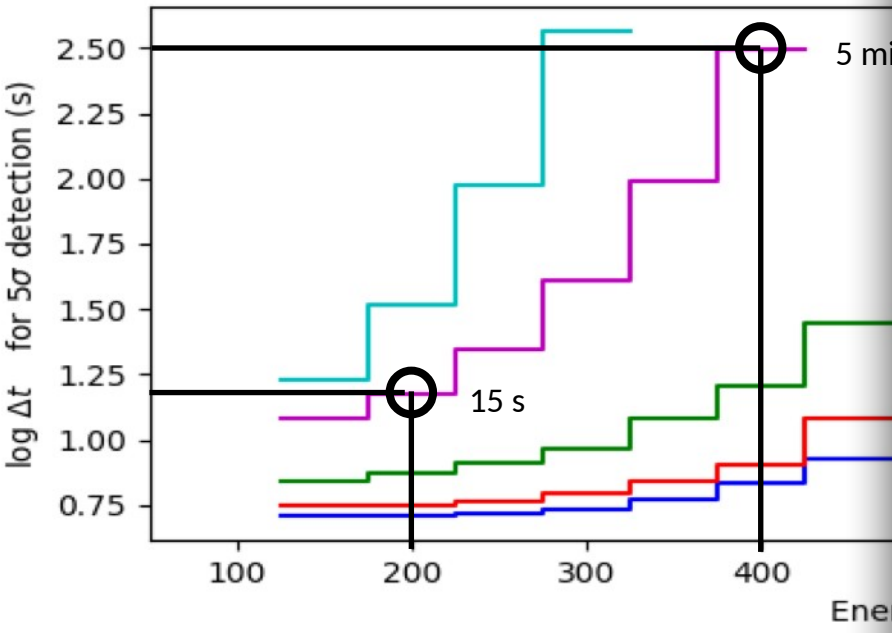
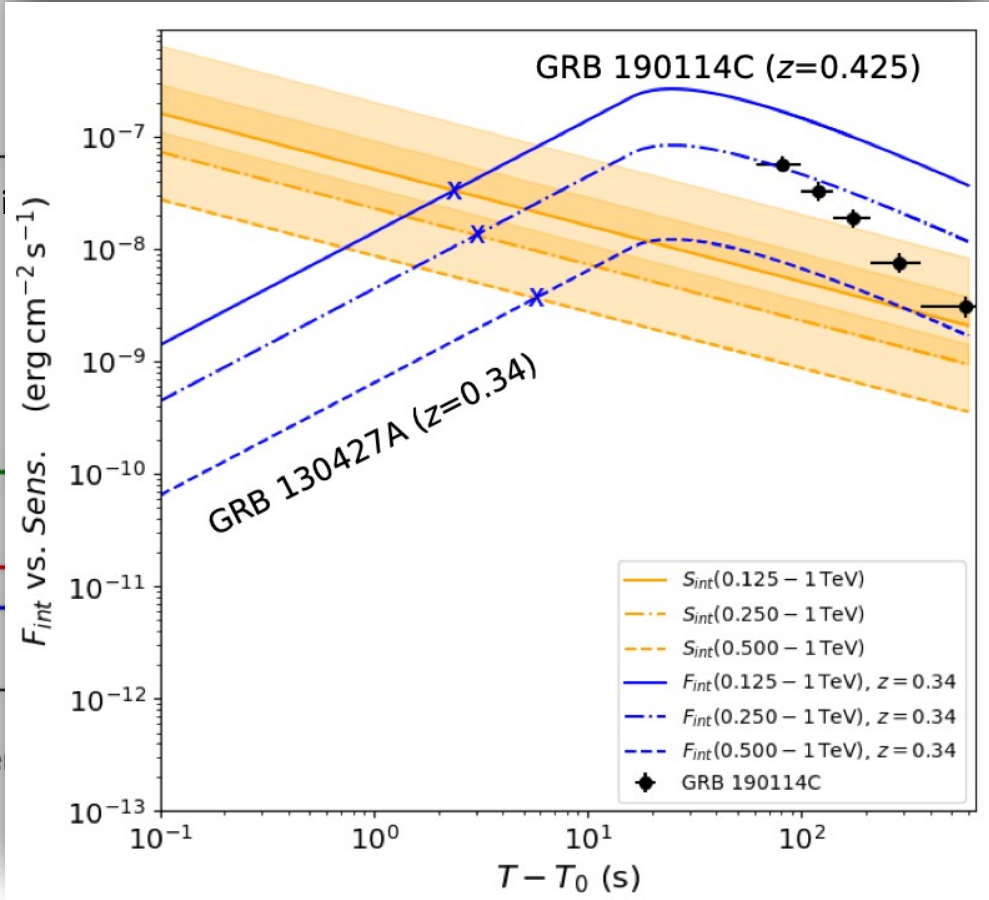
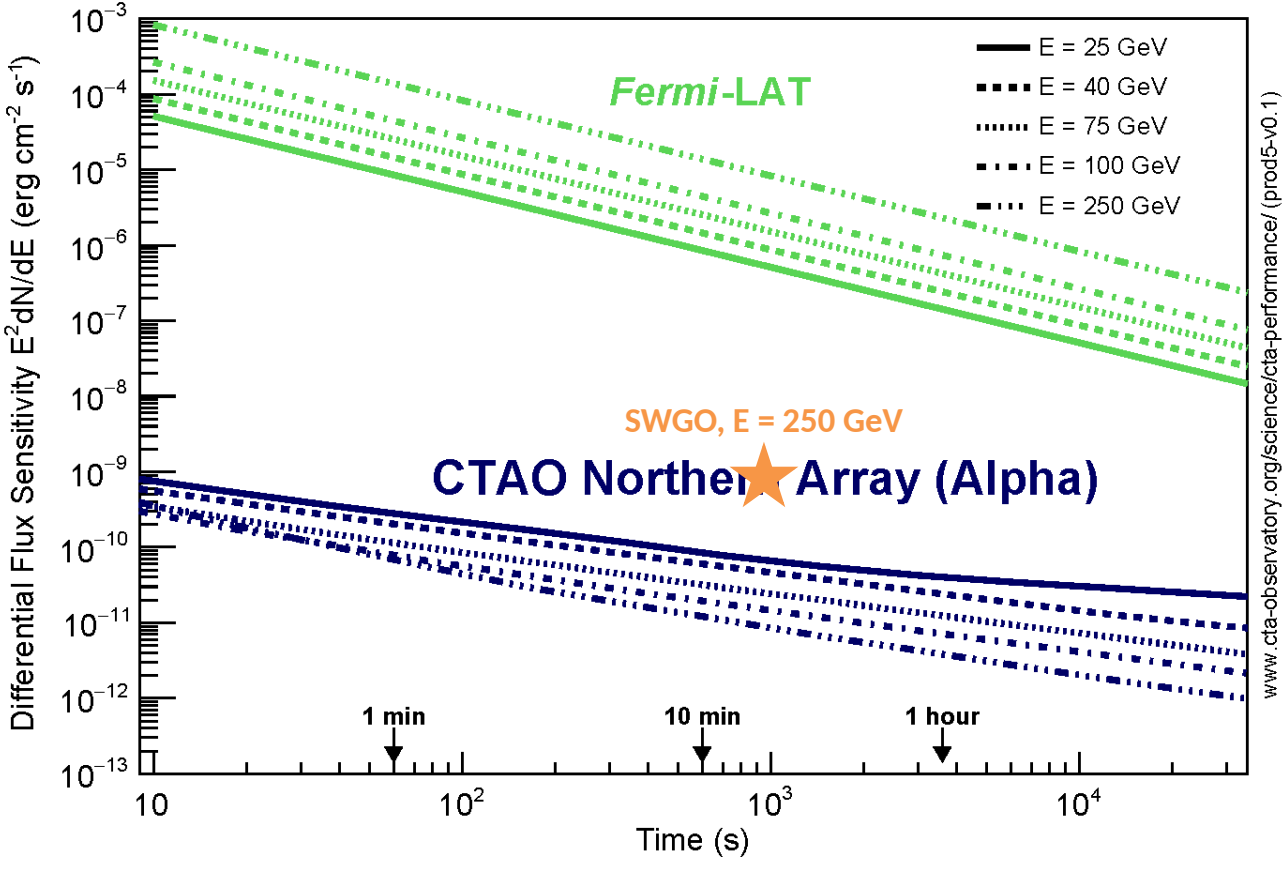
- Energy threshold is critical specially for GRBs





Short time-scale resolution?

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

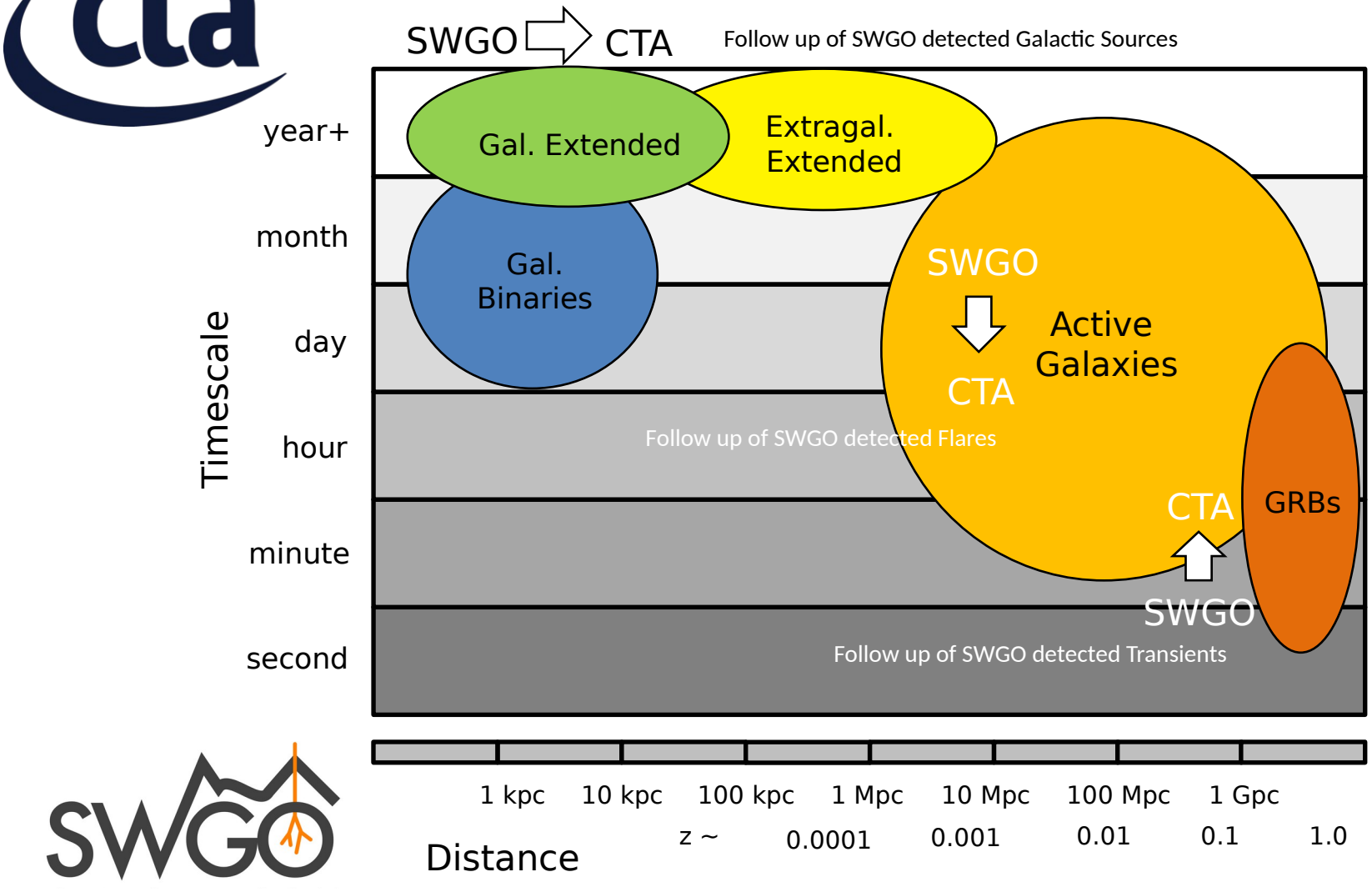


Transients

- Short time-scale sensitivity of ground-particle detectors is much worse than IACTs at low E! But room for improvement!

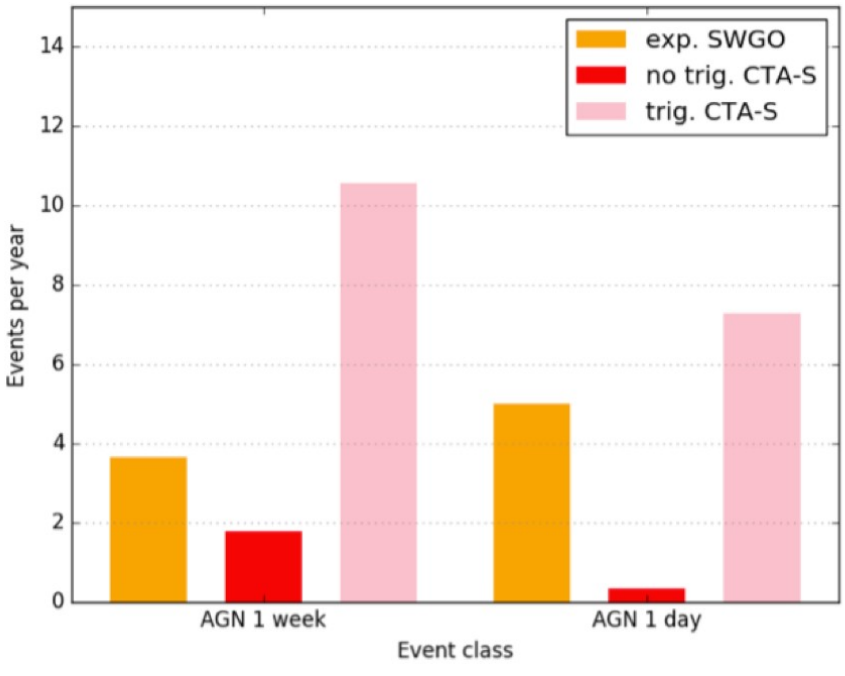
- And a number of other advantages…
  - → 100% duty cycle → higher rate and monitoring capability of transients → AGNs, GRBs, MM,…
  - → Serendipitous view - observation of onset / prompt emission, a regime not probed in the VHE regime by IACTs
  - → A trigger instrument!
    - ✓ Blind searches and offline checks for afterglow triggers
      - Critical synergy with IACTs and other MWL instruments

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


SWGO
CTA
Follow up of SWGO detected Galactic Sources
Timescale
year+
month
day
hour
minute
second
Gal. Extended
Extragal. Extended
Gal. Binaries
SWGO
Active Galaxies
CTA
Follow up of SWGO detected Flares
CTA
GRBs
SWGO
Follow up of SWGO detected Transients
1 kpc
10 kpc
100 kpc
1 Mpc
10 Mpc
100 Mpc
1 Gpc
Distance
z ~
0.0001
0.001
0.01
0.1
1.0

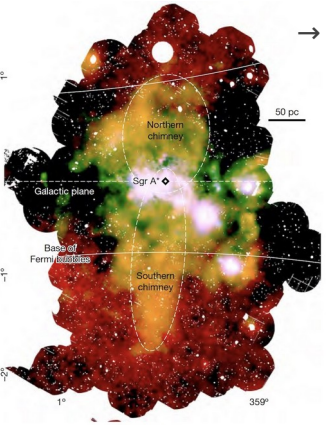
Synergies with IACTs / CTA

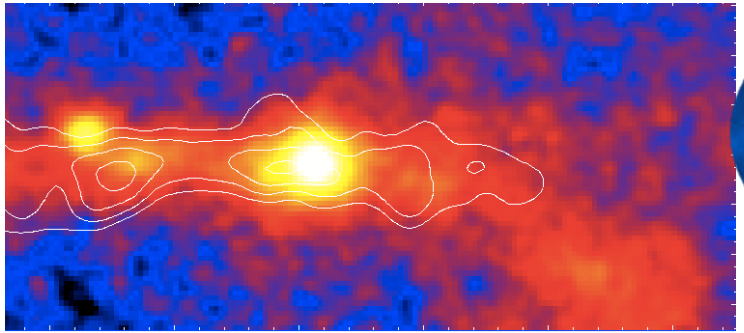
- An effective trigger instrument at VHEs will be very relevant to boost CTA transient science!

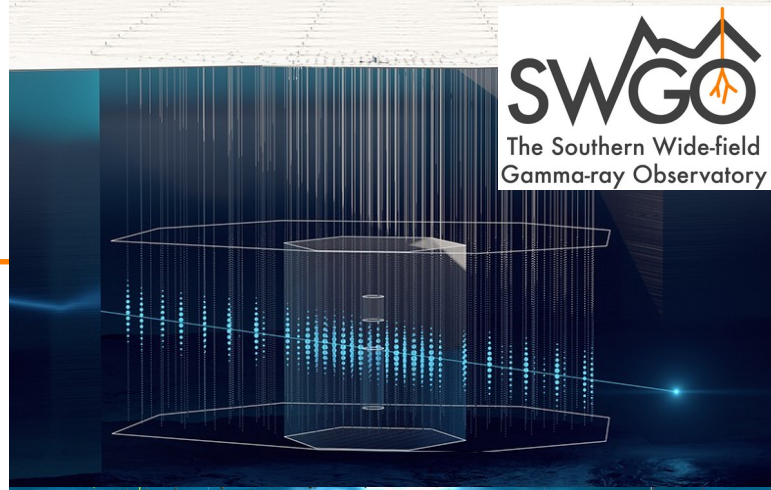


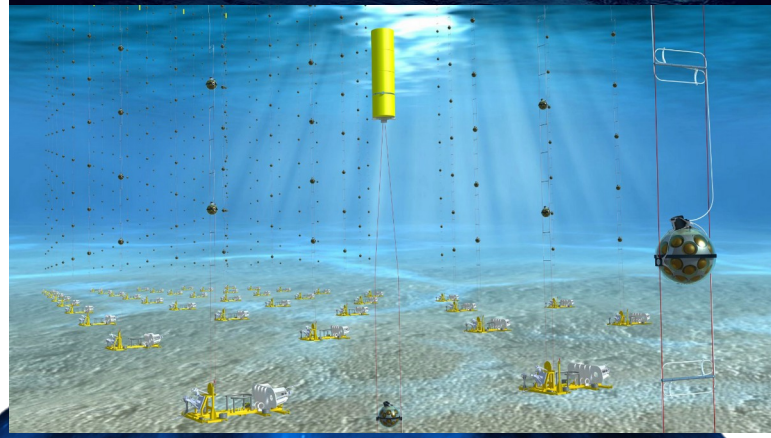
Neutrino Synergies

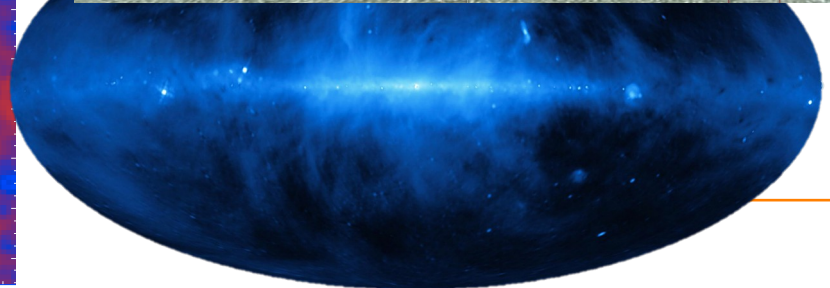
- SWGO+LHAASO
  - → Full sky map of TeV-PeV γ emission
- Strongly complements new generation of neutrino instruments
  - → Mapping out diffuse emission / separating IC from pion decay emission, Dark Matter search +++
    - → Nearby transients/flares











Thank you!

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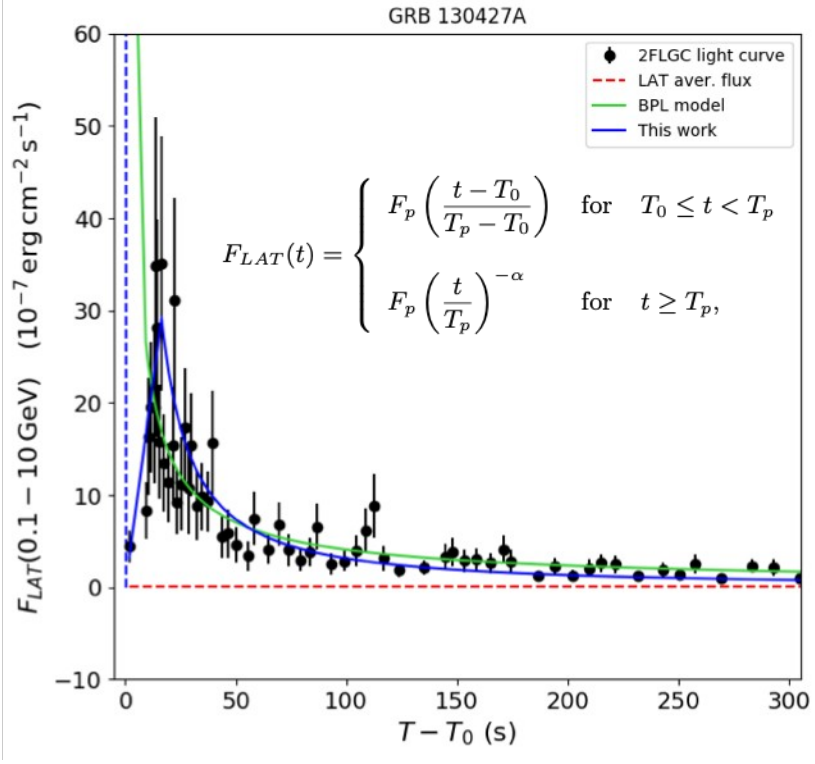
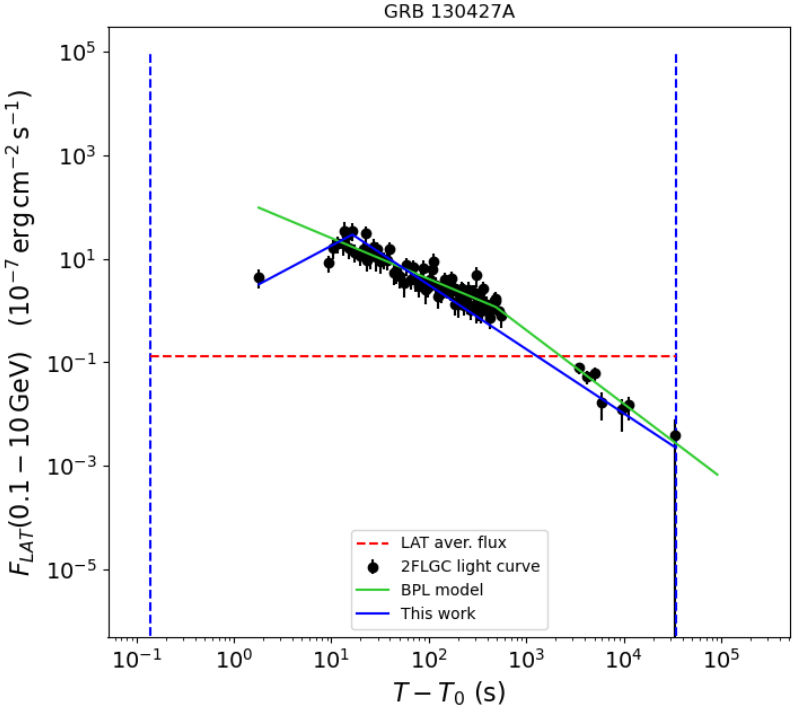
Acknowledgements

Template for GRB simulations

- GRB 130427A





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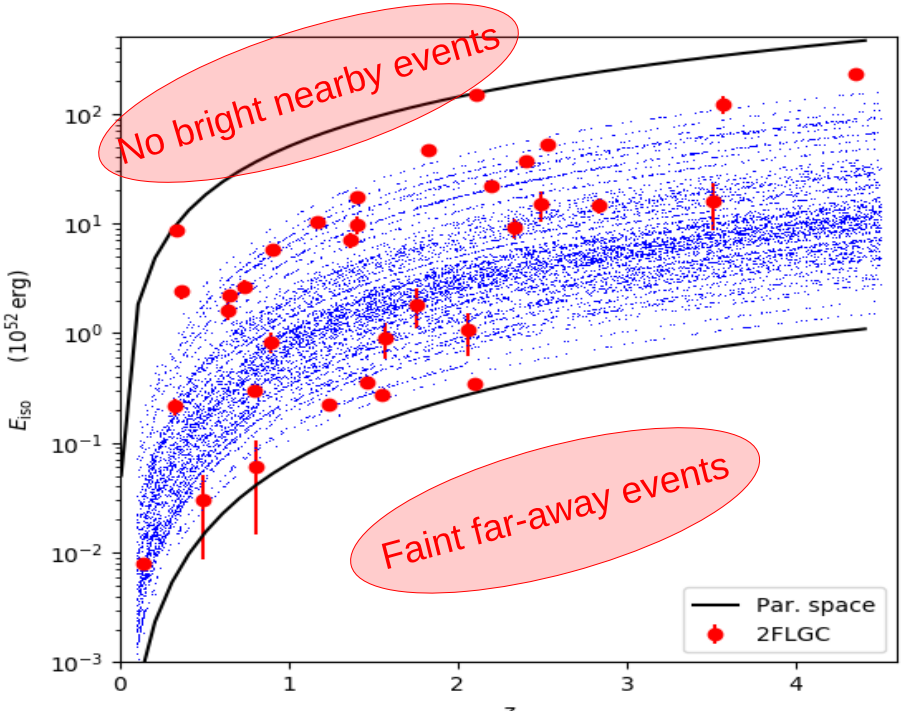
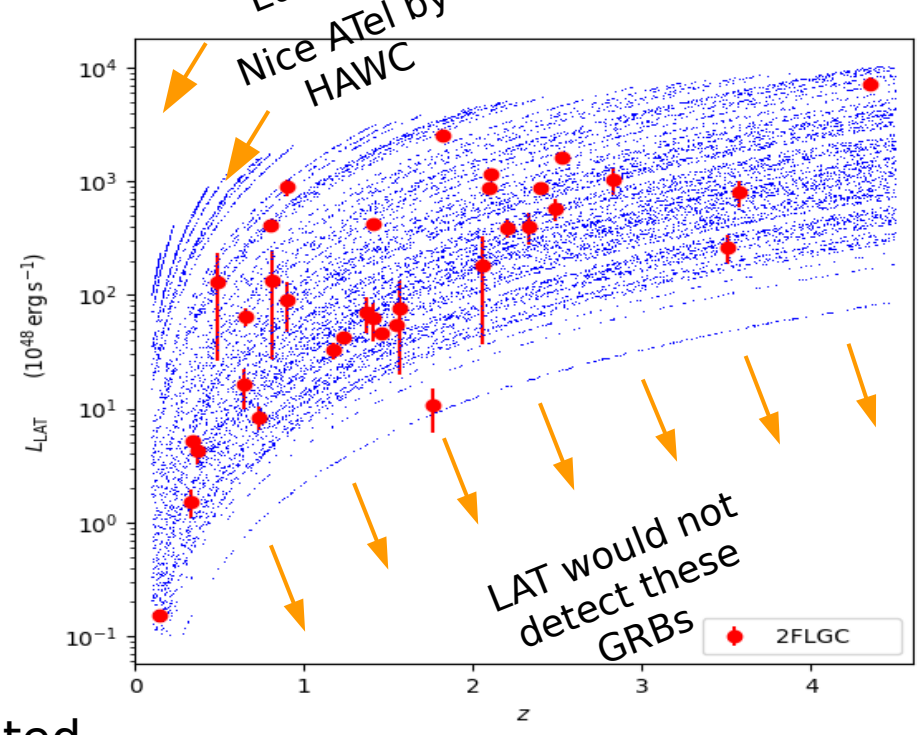
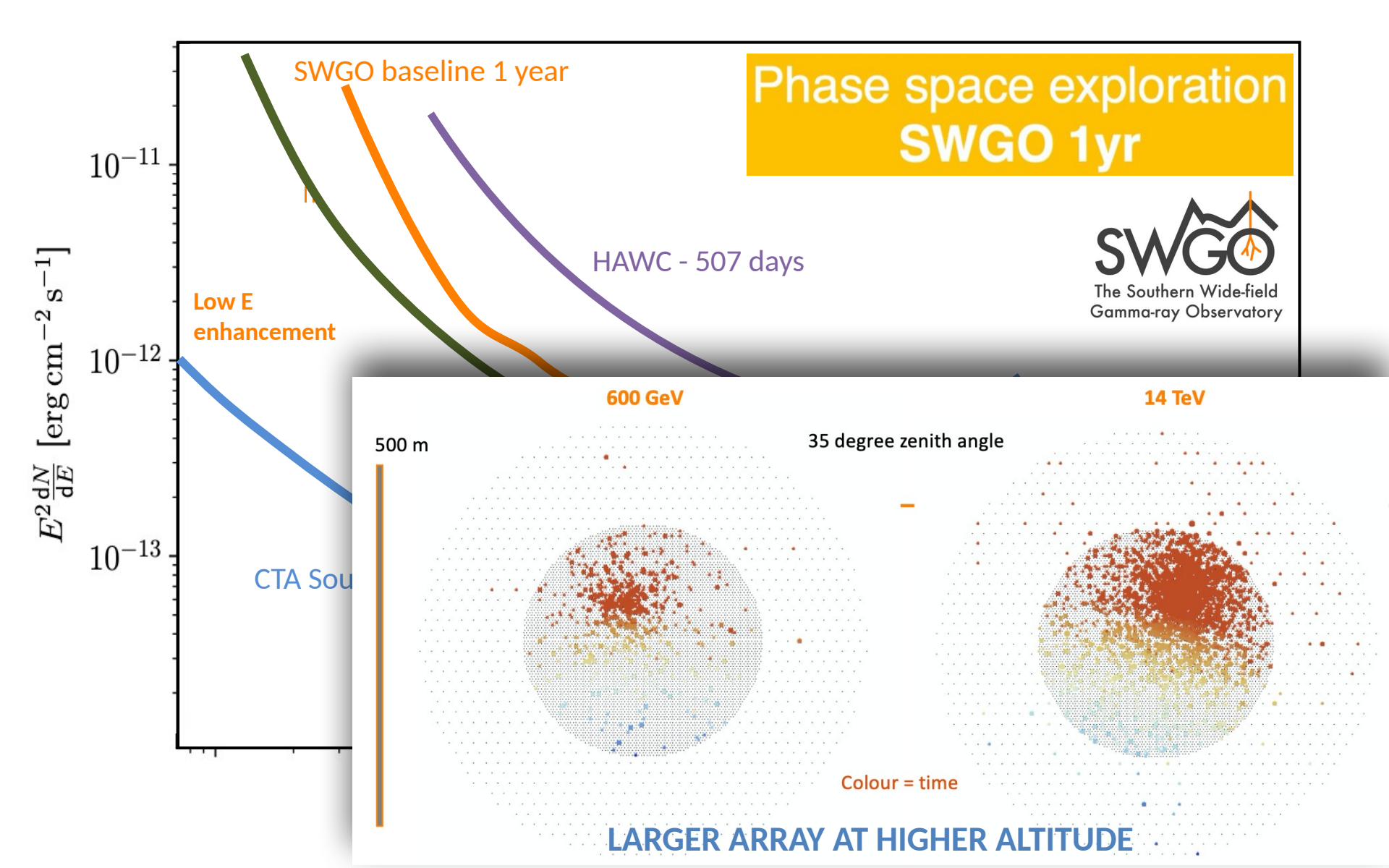
Redshift effects





For GRBs with unknown z, we simulated 1000 distributions, constraining E_{iso} between the minimum fluence detected by LAT and 10^{54} erg.

$$E_{iso} = \frac{4\pi d_L^2}{1+z}(T_1 - T_0)\int_{E_1/(1+z)}^{E_2/(1+z)} E\frac{\mathrm{d}N}{\mathrm{d}E}\mathrm{d}E$$


Phase space exploration
SWGO 1yr
SWGO baseline 1 year
HAWC - 507 days
Low E
enhancement
CTA Sou
10^{-11}
10^{-12}
10^{-13}
$E^2 \frac{dN}{dE}$ [erg cm^{-2} s^{-1}]
SWGO
The Southern Wide-field
Gamma-ray Observatory
600 GeV
14 TeV
500 m
35 degree zenith angle
Colour = time
LARGER ARRAY AT HIGHER ALTITUDE

Phase space exploration SWGO 1yr

SWGO baseline 1 year

HAWC - 507 days

Low E enhancement

CTA South 50 h

SWGO
The Southern Wide-field Gamma-ray Observatory

$E^2 \frac{dN}{dE}$ [erg cm^{-2} s^{-1}]

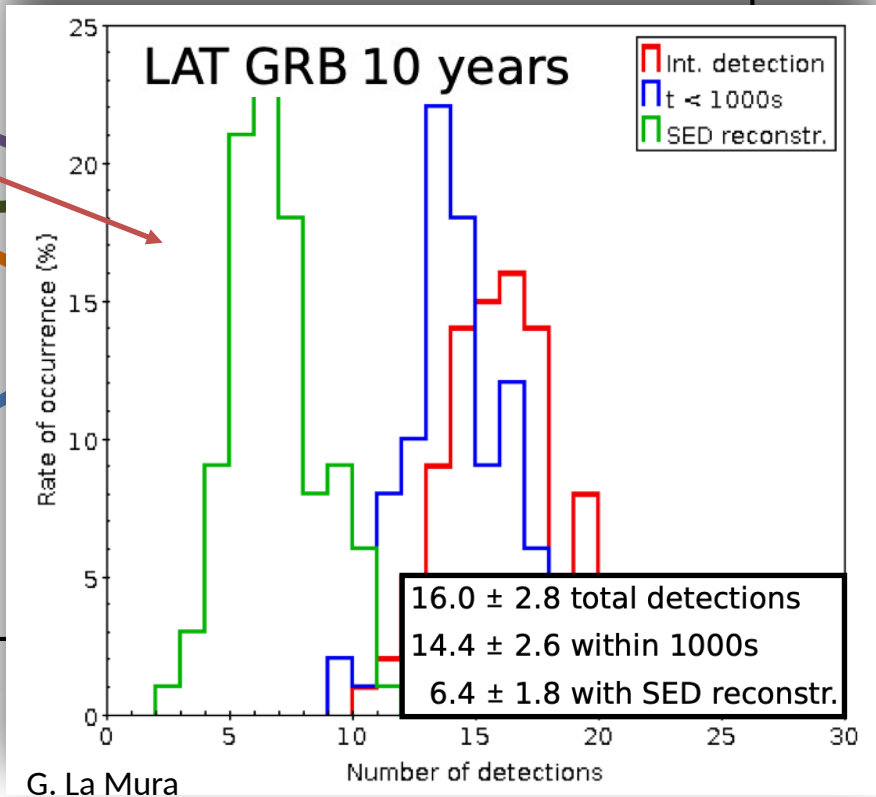
10^{-11}

10^{-12}

10^{-13}

10^{0}

10^{1}



Planned operation time > 10 years

G. La Mura