SWGO
The Southern Wide-field Gamma-ray Observatory

Los Alamos NATIONAL LABORATORY

Science Perspectives of the Southern Wide-field Gamma-ray Observatory (SWGO)

Kristi L. Engel for the SWGO Collaboration

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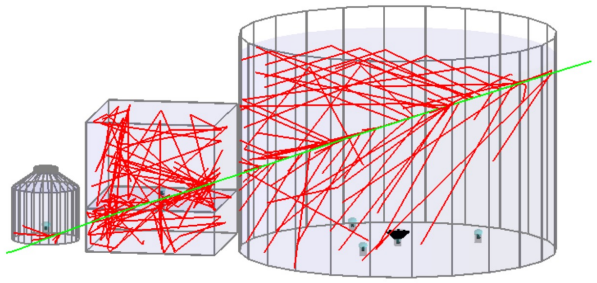
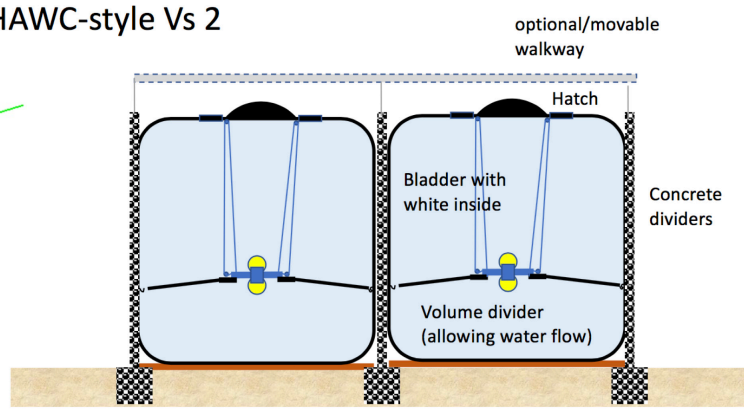
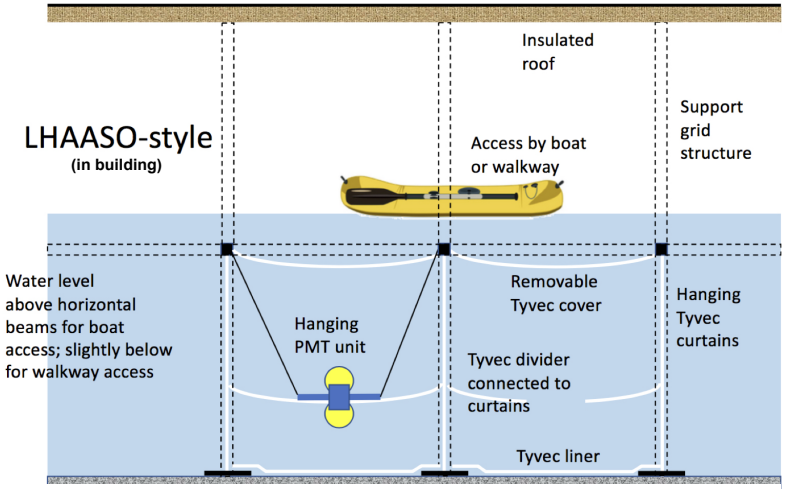
The SWGO Concept

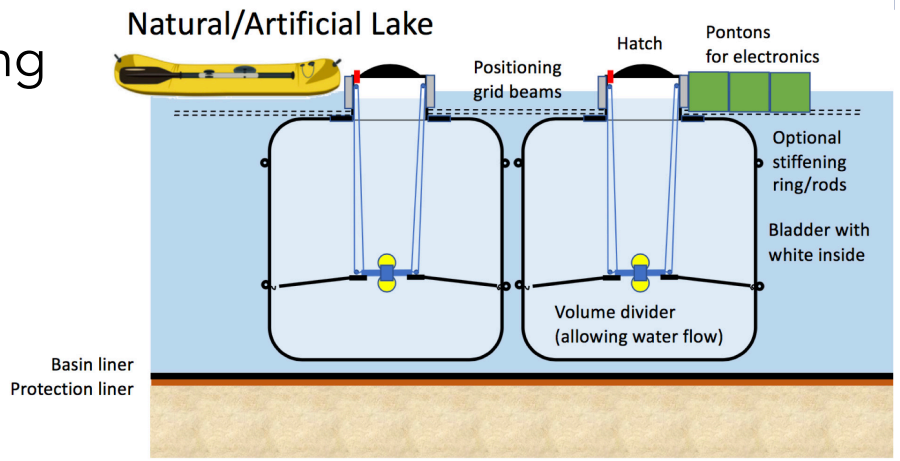


PoS (ICRC2019) 720

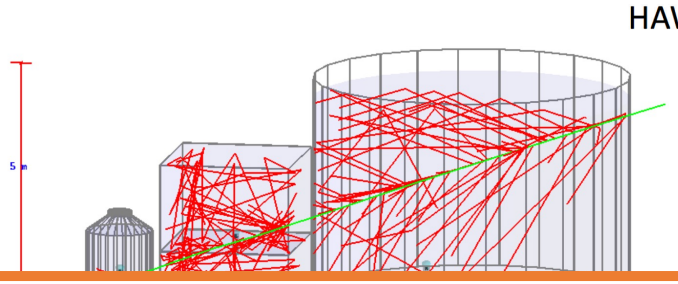


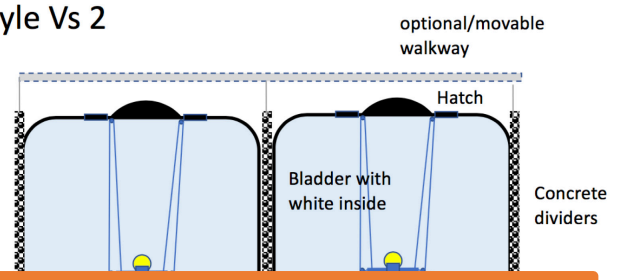
- Core unit is a water Cherenkov detector
  - Options being investigated based on tanks (HAWC-like), ponds (LHAASO-like), and lakes
- Simulations currently ongoing to constrain all aspects of the detector options
- Design potentially dependent on site choice
  - Water access, construction costs, infrastructure feasibility, compatibility with science-driven main design goals
- Strong muon-detection capability
  - Large potential for gamma/hadron separation above 1 TeV and consequently background-free conditions driving high sensitivity in the 100+ TeV range
- Possibly muon tagging in all units
  - Design option: double-layer WCDs
  - Time-intensity tagging of single through-going particles





The SWGO Concept



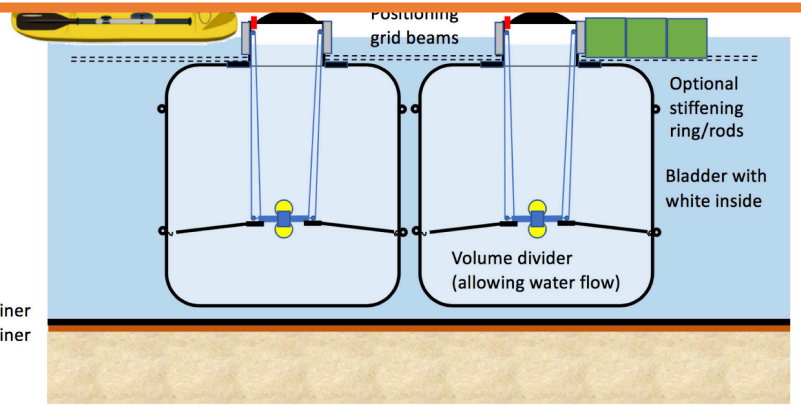


	IACT Arrays	Ground-particle Arrays
Field of view	3°–10°	90°
Duty cycle	10%–30%	>95%
Energy range	30 GeV – >100 TeV	~500 GeV – >100 TeV
Angular resolution	0.05°–0.02°	0.4°–0.1°
Energy resolution	~7%	60%–20%
Background rejection	>95%	90%–99.8%

Science Case White Paper arXiv:1902.08429

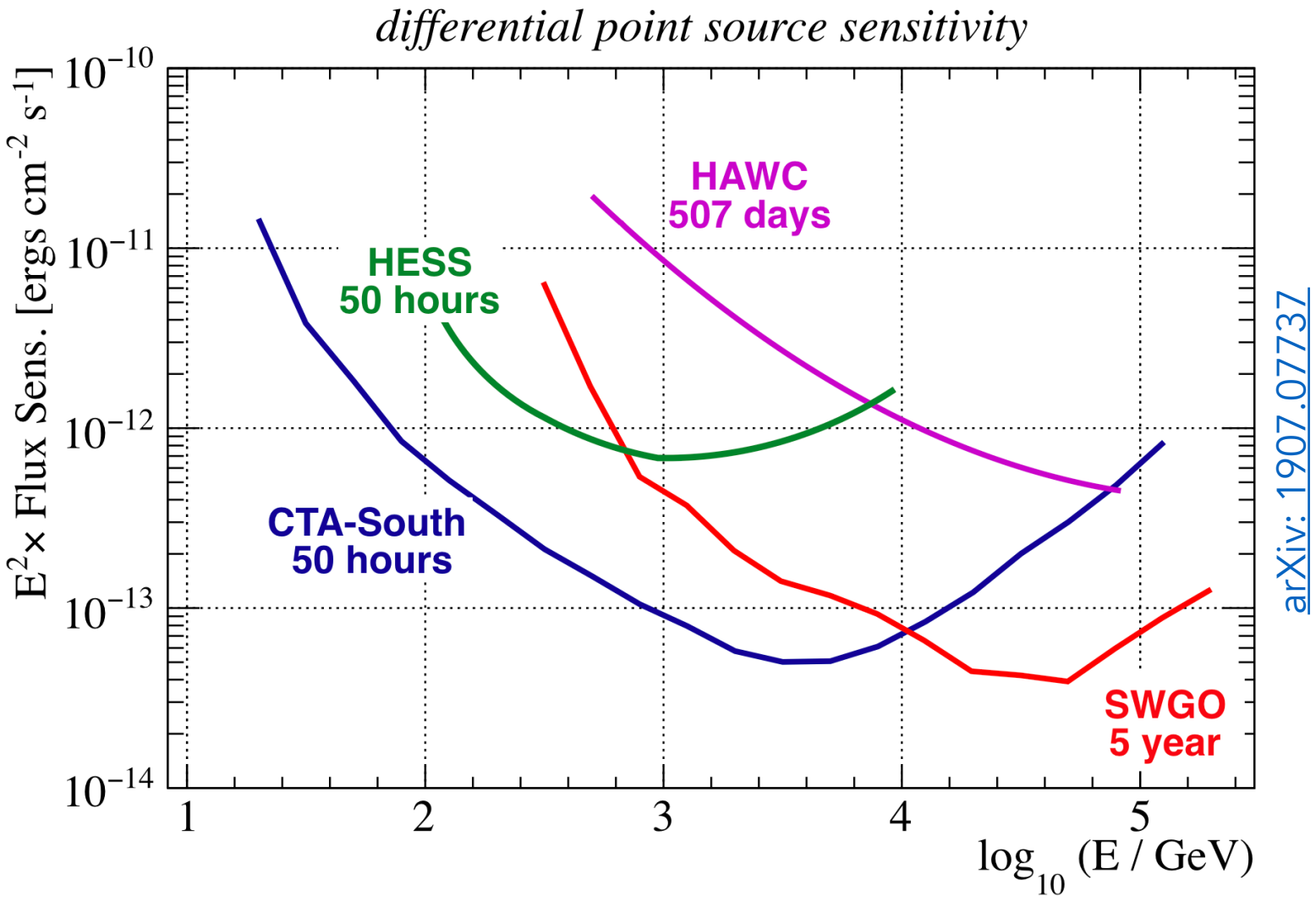
→Possibly muon tagging in all units

- Design option: double-layer WCDs
- Time-intensity tagging of single through-going particles

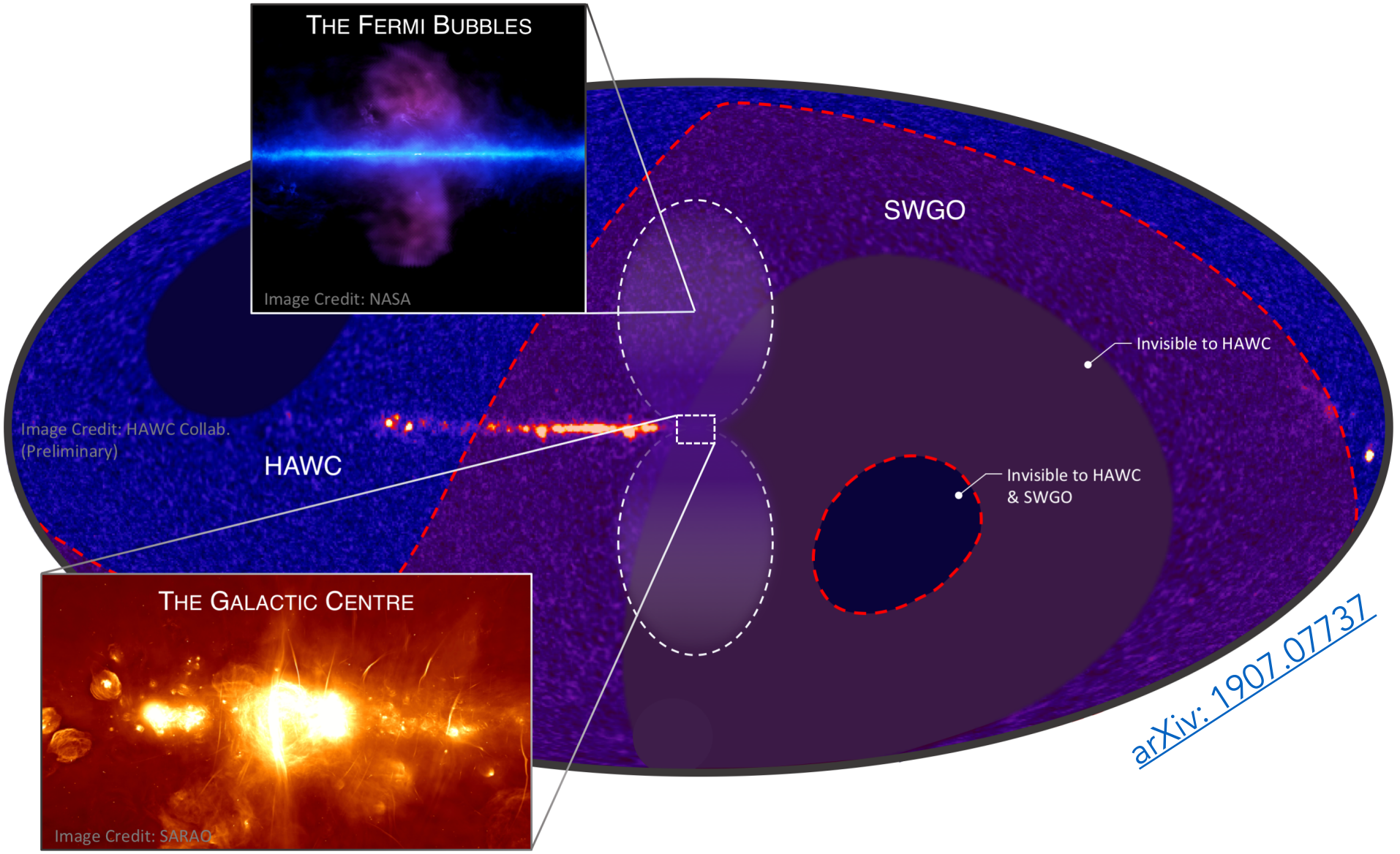


Slide from U. Barres, Centro Brasileiro de Pesquisas Físicas | IWARA (2020)

SWGO Differential Sensitivity

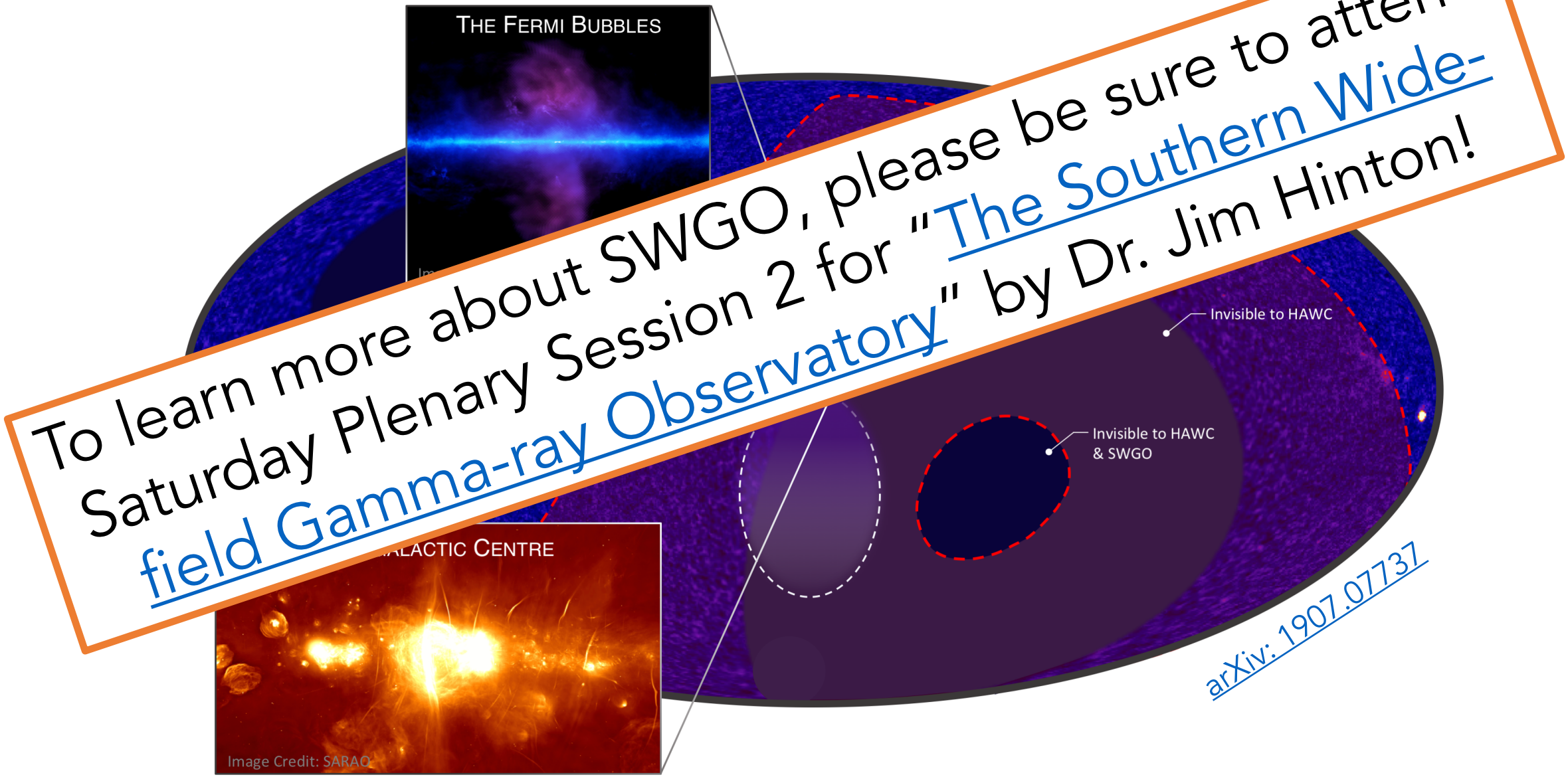


SWGO Field of View



arXiv: 1907.07737

SWGO Field of View



To learn more about SWGO, please be sure to attend Saturday Plenary Session 2 for "The Southern Wide-field Gamma-ray Observatory" by Dr. Jim Hinton!

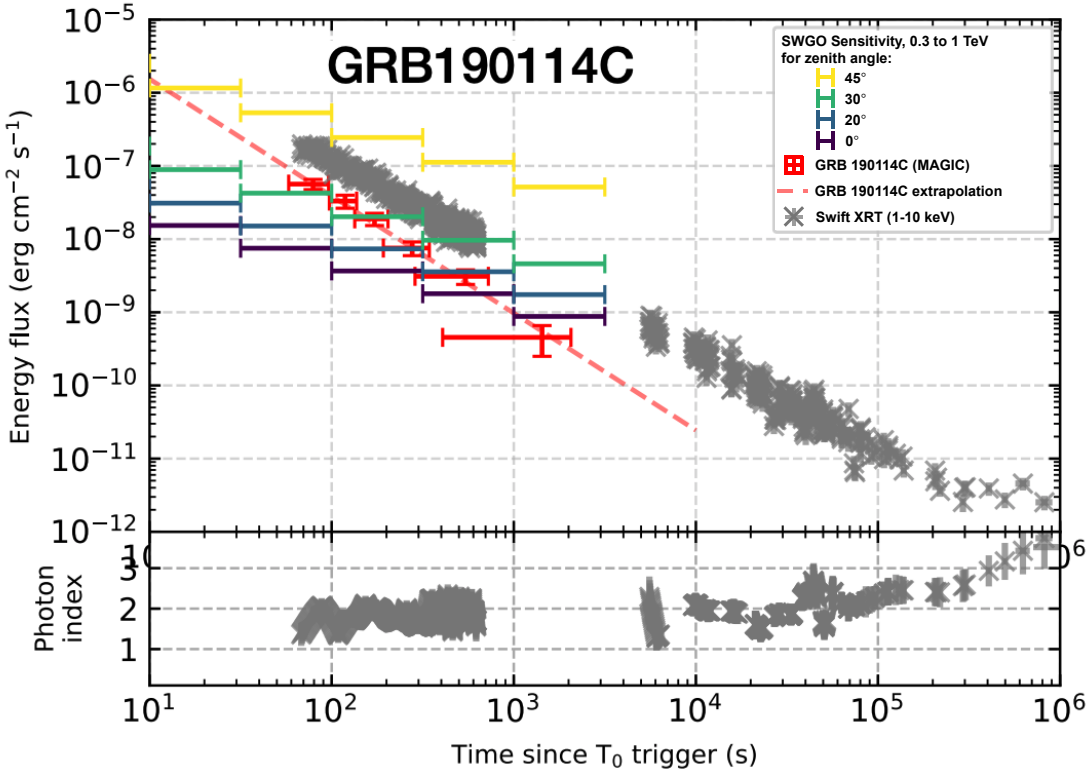
The Core Science Case

- Detection of short-timescale phenomena
  - Low-energy threshold for detection of short-timescale (<1 hr) transient events down to 100 GeV
- Search for PeVatrons
  - Improved sensitivity up to a few 100s of TeV to search for PeV Galactic particle accelerators
- PWNe and gamma-ray halos
  - Unique potential for accessing the high-energy end of the Galactic population
- Dark matter and diffuse emission
  - Unique access to the Galactic Center and Halo at the high-energy end of the spectrum
- Cosmic rays
  - Unique complement to LHAASO for anisotropy studies, with the capability to reach low angular scale
  - Good muon tagging implies good mass resolution for composition studies up to the *knee*

Slide from U. Barres, Centro Brasileiro de Pesquisas Físicas | IWARA (2020)

The High-Energy Transient Sky

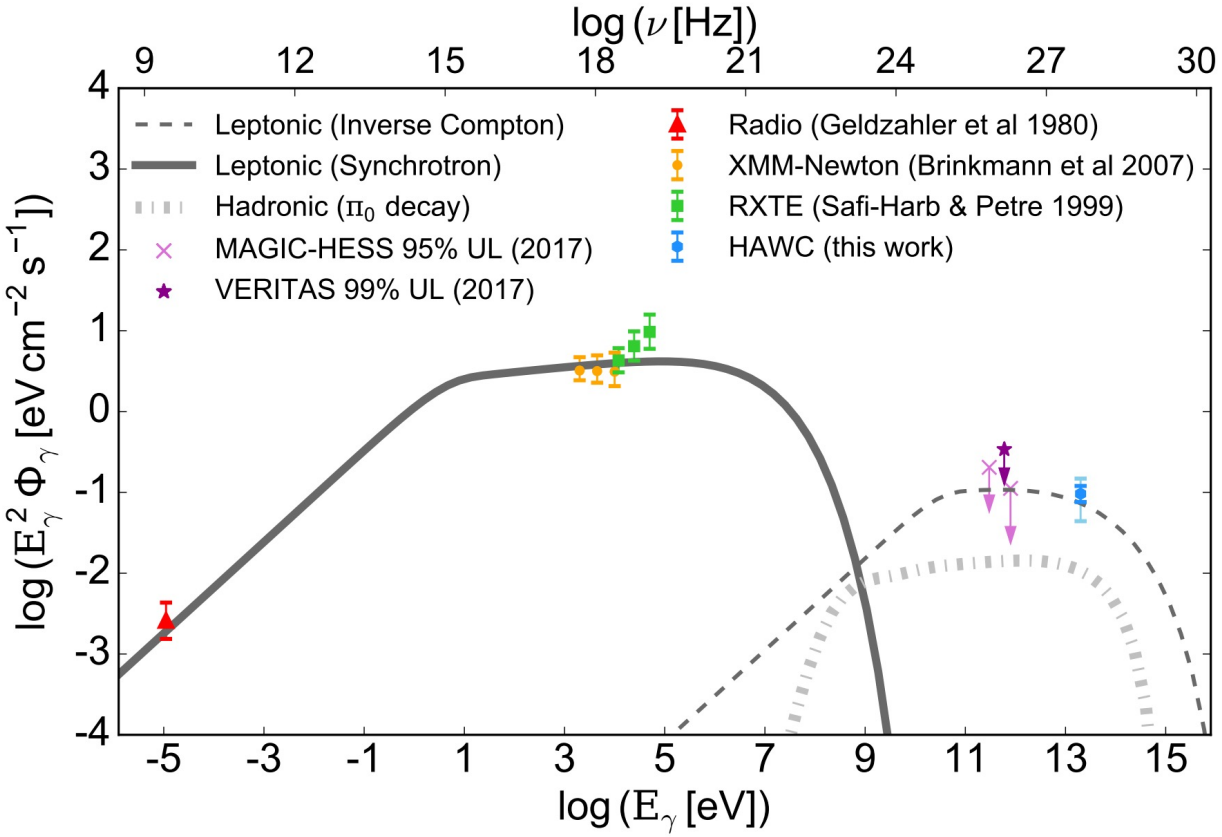
- Gravitational Waves (GWs)
  - Coverage of high-uncertainty regions, locate VHE counterparts, and currently unmodeled burst-like GW signals
- Fast Radio Bursts (FRBs)
  - A wide-field-of-view survey instrument is ideal for Galactic FRB follow-up and monitoring for repeaters
- High-Energy Neutrinos
  - Multimessenger approach to determine source of the astrophysical flux of high-energy neutrinos
- Gamma-Ray Bursts (GRBs)
  - Follow-up and triggered observations in SWGO's energy range to potentially allow discrimination between proposed emission scenarios



SWGO's sensitivity to a GRB like GRB190114C, including results from MAGIC for comparison (arXiv: 2006.07249)

Galactic Particle Acceleration

- Want to search the Galactic plane for astrophysical particle accelerators, including PeVatrons
- The design of SWGO is well equipped to handle the source confusion, diffuse gamma-ray backgrounds, and spatially extended emission regions typically complicating these analyses

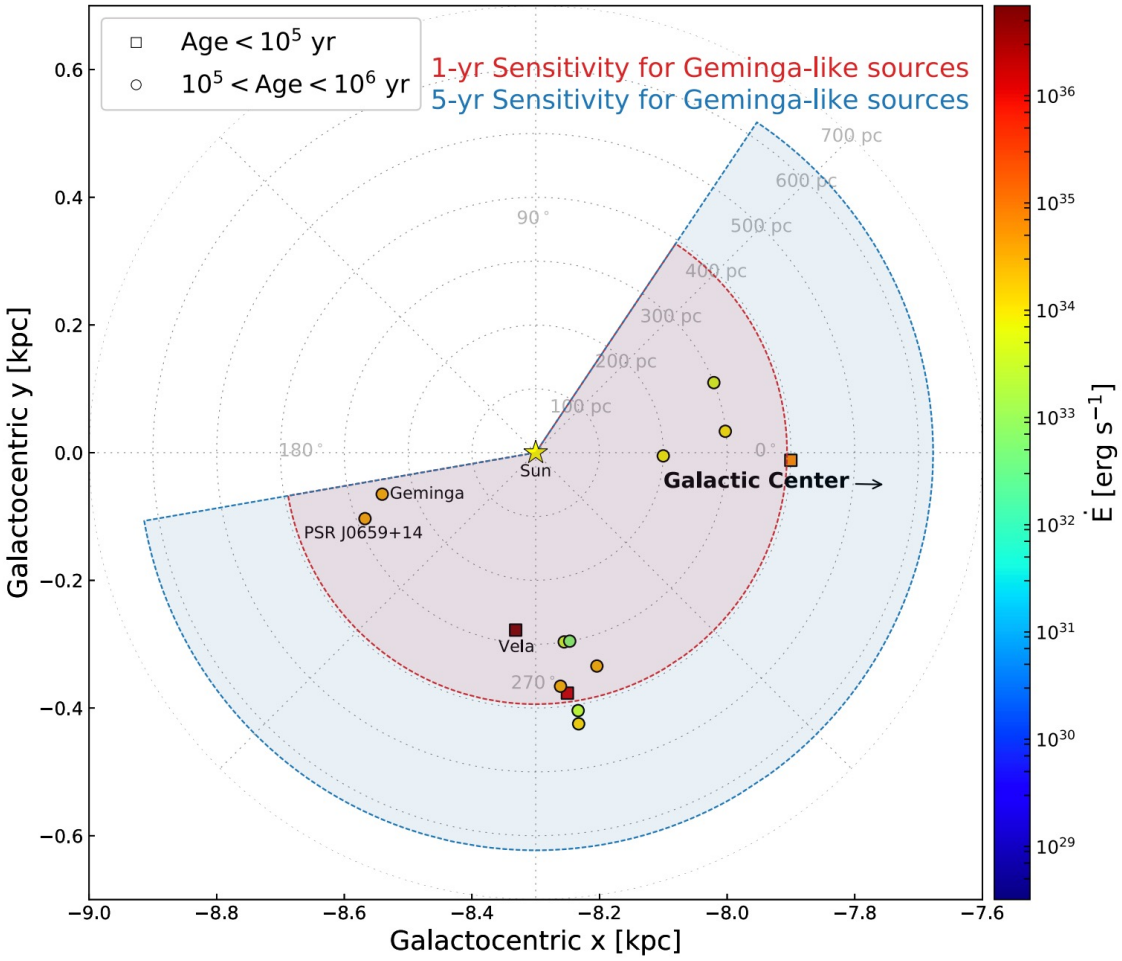


arXiv: 1810.01892

The broadband spectral energy distribution of the eastern emission region of microquasar SS433. Studies of VHE emission to discover such sources would be optimally performed by a detector such as SWGO.

PWNe & Gamma-Ray Halos

- SWGO will survey nearby pulsars (age < 10^6 yr.) in the Southern Hemisphere
- The large angular extents of these gamma-ray halos allow us to study the propagation of particles within them in unprecedented detail
  - First observed by HAWC [6]
- Its large FoV will allow observation of potential halos from all pulsars, including millisecond pulsars not (yet [7]) discovered with current instruments
  - Unveil the properties of the accelerators and the medium around them

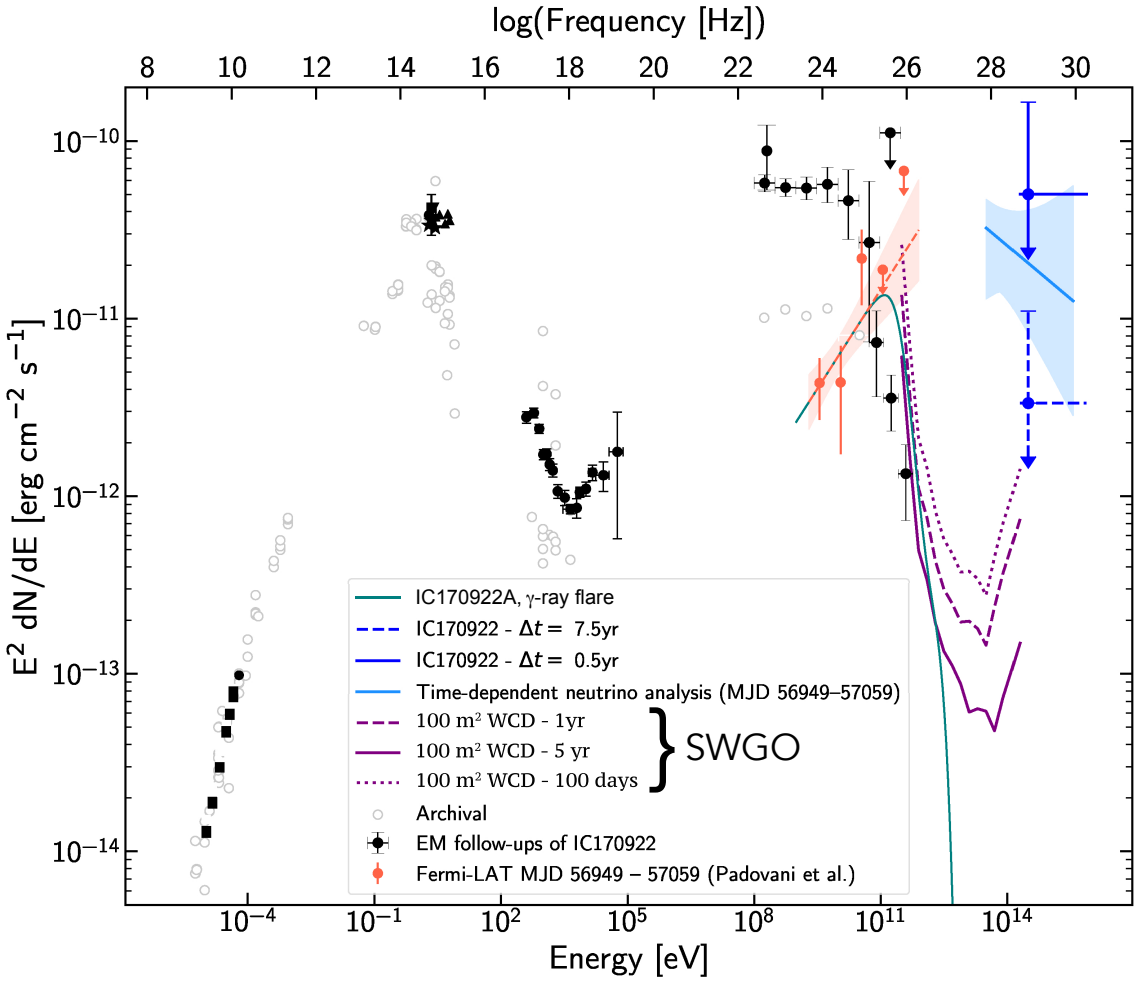


Pulsars, age < 10^6 yr., within 500 pc, showing the one-year (red) and five-year (blue) sensitivity of SWGO to Geminga-like sources at these locations.

arXiv:1902.08429

The Extragalactic VHE Sky

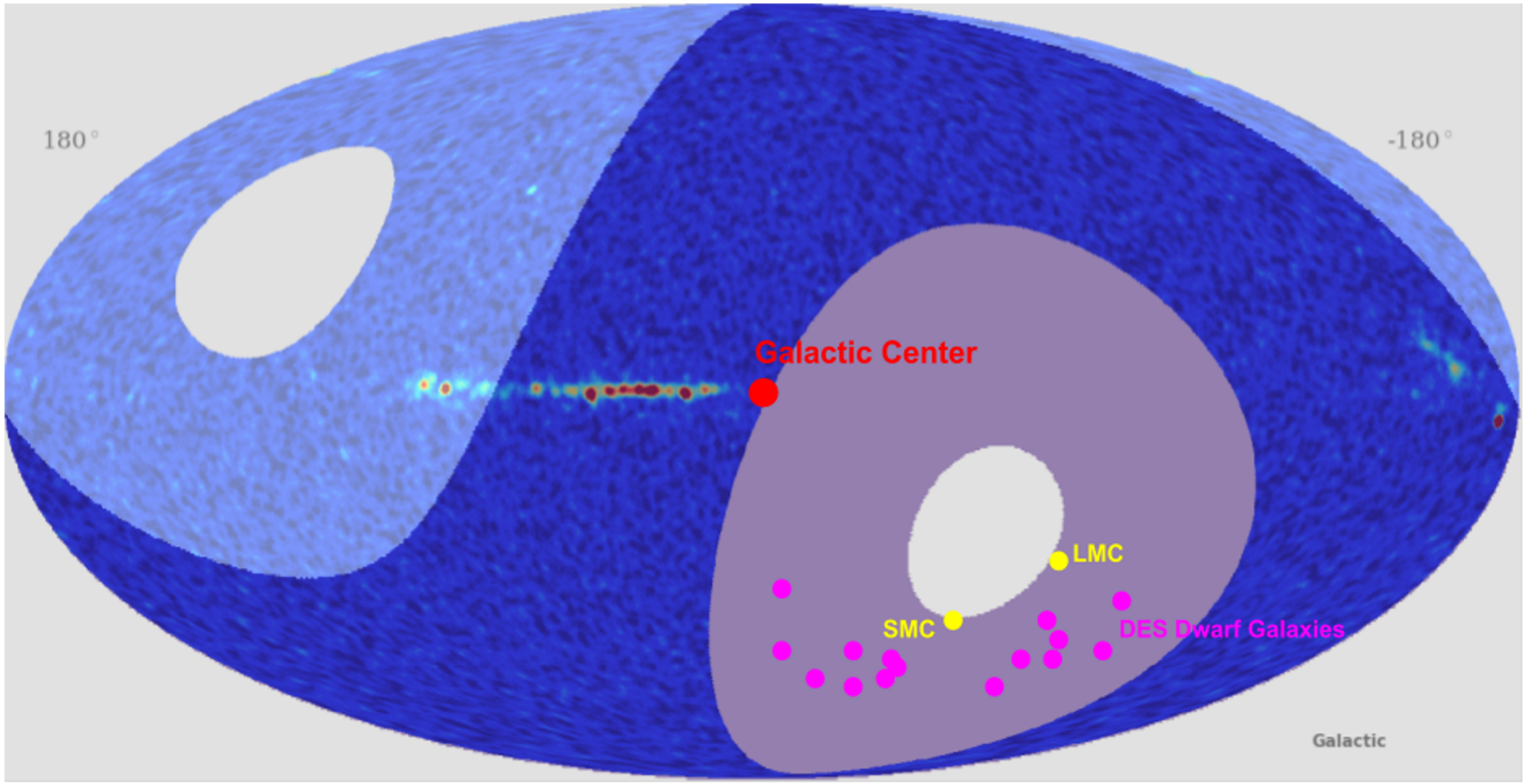
- VHE gamma rays are expected from blazars and some radio galaxies (special AGN subclasses)
  - Provide information on the intergalactic magnetic field, radiative processes and acceleration mechanisms, periodicity, and BSM physics
- Special focus on extreme high-energy peaked BL Lacs ($E_{peak} \geq 1\ keV$)
  - SWGO's characteristics ideal for the crucial evaluation of the significance of neutrino-blazar flare correlations, such as implied by observations of TXS 0506+056



Modified from arXiv: 1812.01036

Multimessenger observations of TXS 0506+056 illustrating the crucial energy and sensitivity range SWGO will cover

SWGO FoV: Fundamental Physics Targets

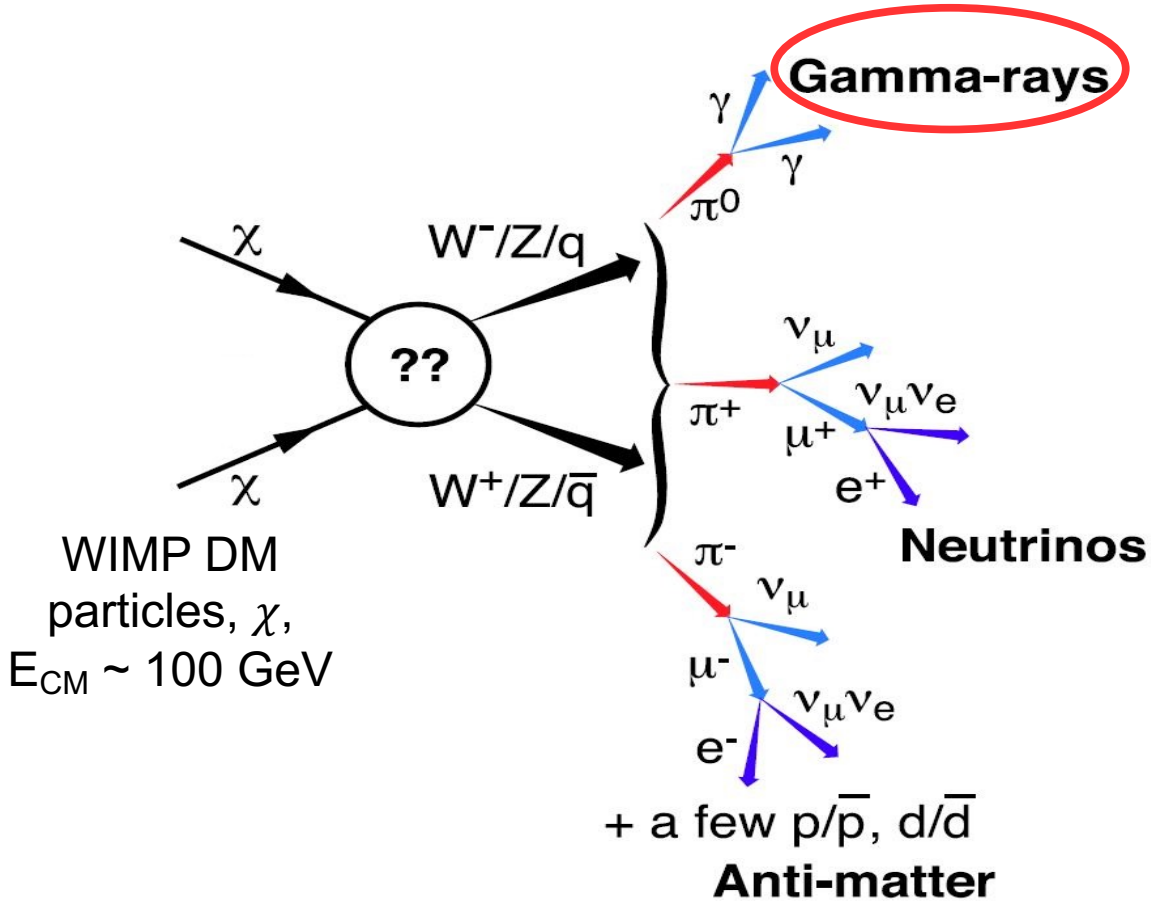


HAWC skymap with SWGO view (shaded) overlaid

Slide from A. Albert, Los Alamos National Laboratory | APS April (2021)

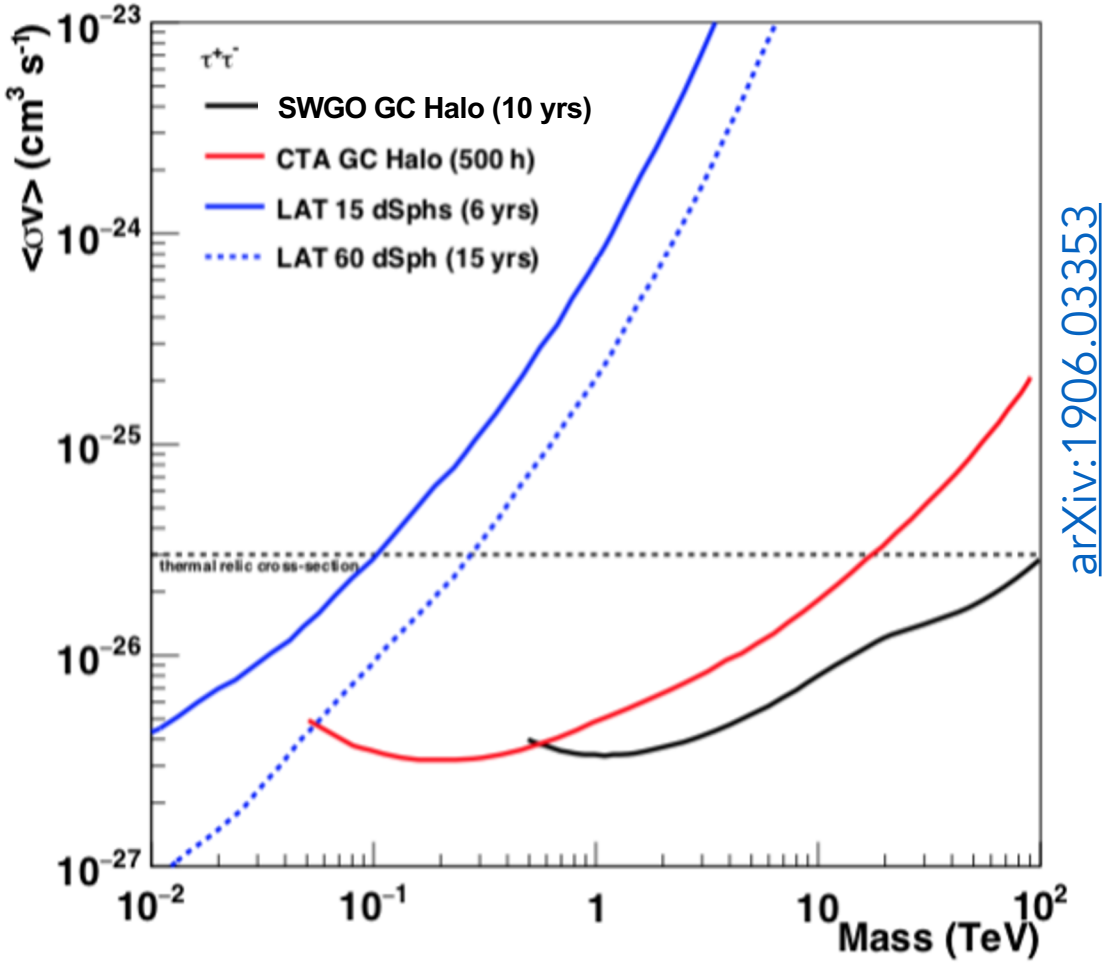
Searching for Dark Matter with Gamma Rays

- Weakly Interacting Massive Particle
  - Promising DM candidate
  - Particle beyond the Standard Model
    - Being searched for at the LHC, underground experiments (e.g., LUX), and in space
  - Mass appx. 5–100 TeV [9, 10]
    - **>10 TeV mass only space searches can probe with high sensitivity**
- Heavy DM is also theorized
  - 100 TeV–100 PeV
  - Can be produced with observed abundance if early Universe was matter dominated or if there was late-time inflation [11]



WIMP Searches with Cosmic Gamma Rays

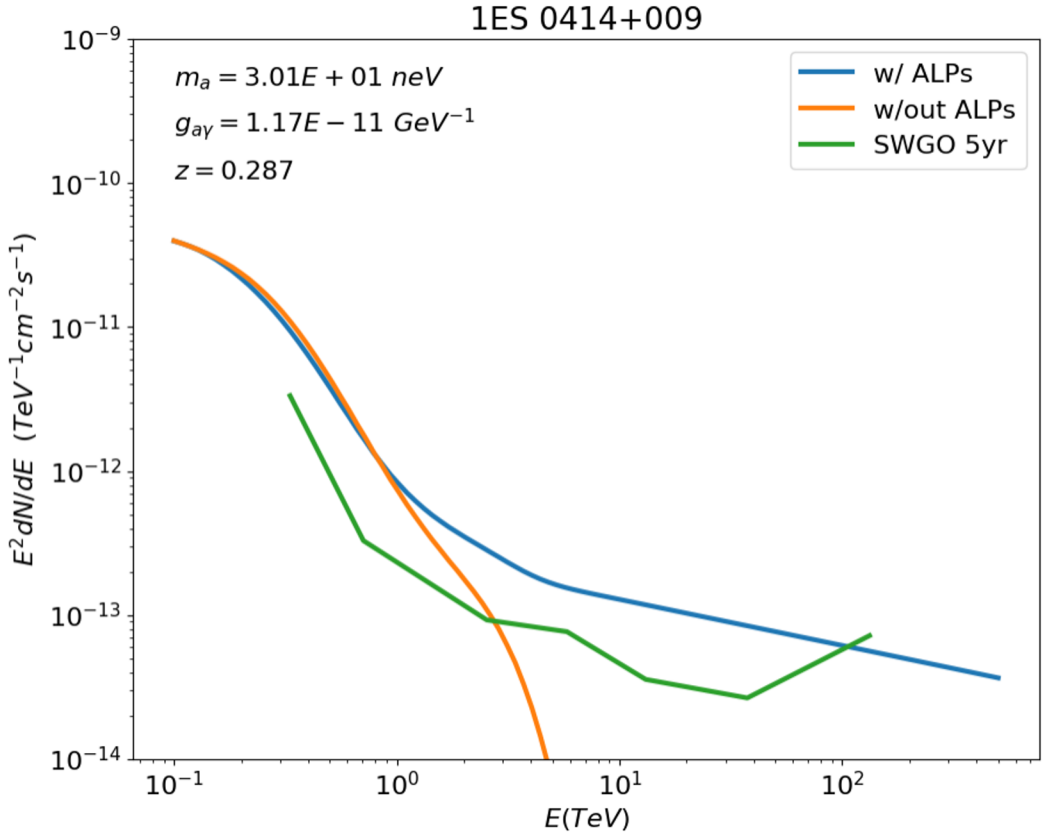
- The Galactic Center is the closest dense region of DM
- The *Fermi*-LAT + CTA + SWGO will explore thermal WIMPs from 5 GeV–100 TeV
- There is overlap in mass between experiments which will allow for multiple potential detections



arXiv:1906.03353

Axion-Like Particles

- ALPs are a generalization of the Axion
  - Well-motivated DM candidates
- Gamma rays from AGN can convert to ALPs in magnetic fields
  - ALPs travel unattenuated through EBL and convert back to gamma rays in the Milky Way's magnetic field
  - Results in a high-energy tail in the observed energy spectrum

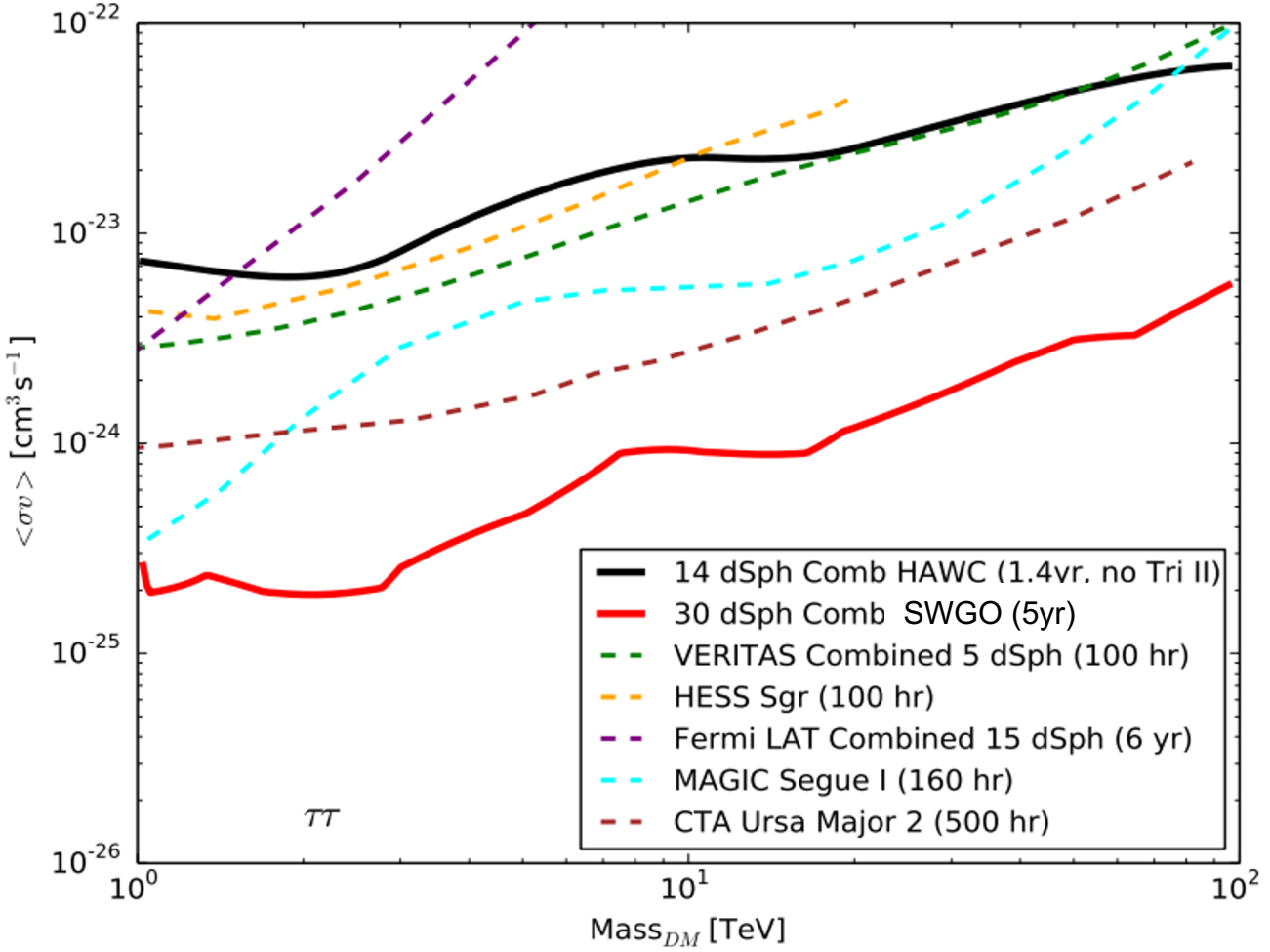


arXiv: 1902.08429

Slide from A. Albert, Los Alamos National Laboratory | APS April (2021)

Dark Matter Searches in Dwarf Galaxies

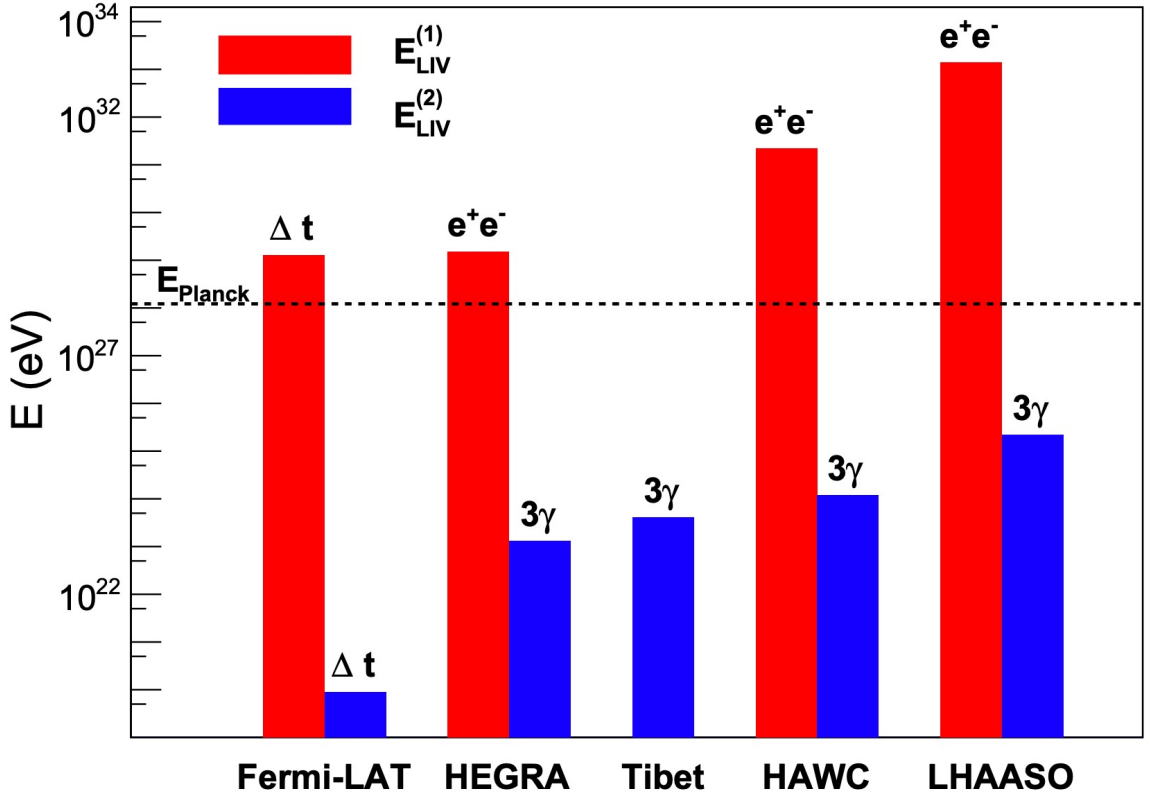
- Dwarf spheroidals are DM-rich Milky Way satellites
  - Nearby and essentially background free
- With its wide FoV and large duty cycle, SWGO will observe dozens of dSphs every day
  - Able to perform joint analysis of dSphs



Slide from A. Albert, Los Alamos National Laboratory | APS April (2021)

Lorentz Invariance Violation

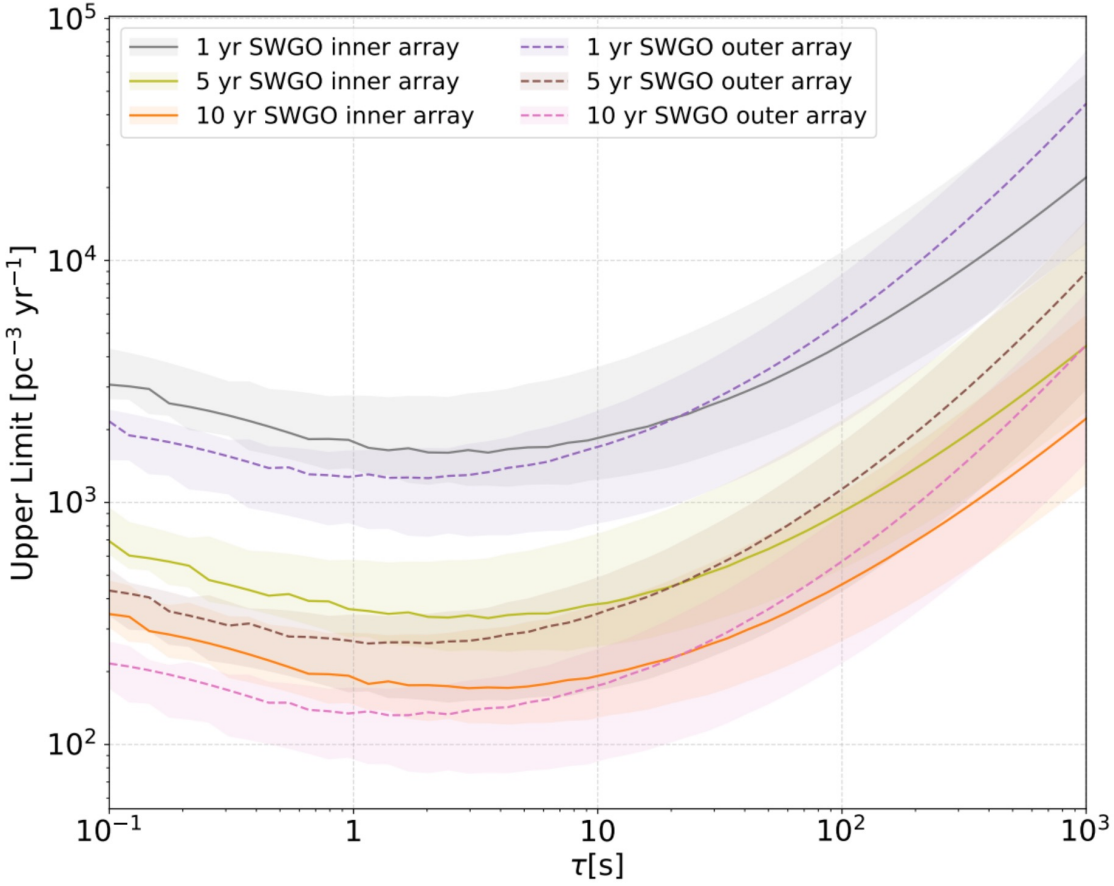
- SWGO will be sensitive to gamma rays up to several PeV
  - Current highest-energy gammas are 1,140 TeV seen by LHAASO [13]
- The detection of multiple PeV gamma rays will provide world leading constraints on LIV
  - If Lorentz Invariance is violated, then gamma rays above an energy threshold ($E_{LIV}^{(n)}$) rapidly decay into e^+e^- pairs



Comparison of the current constraints on $E_{LIV}^{(1)}$ and $E_{LIV}^{(2)}$ from different experiments. arXiv:2106.12350

Primordial Black Holes

- PBHs can constitute some of the observed DM
  - PBHs are created in the early Universe
- Emit gamma rays during end of life
  - Evaporation increases substantially at the end of their lives, producing a burst of gamma rays
- With its wide FoV and large duty cycle, SWGO is an optimal instrument to look for PBHs
  - Sensitive to $m_{PBH} \sim 5\times10^{14}$ g
  - Expected limits are 30x better than those from HAWC [14]

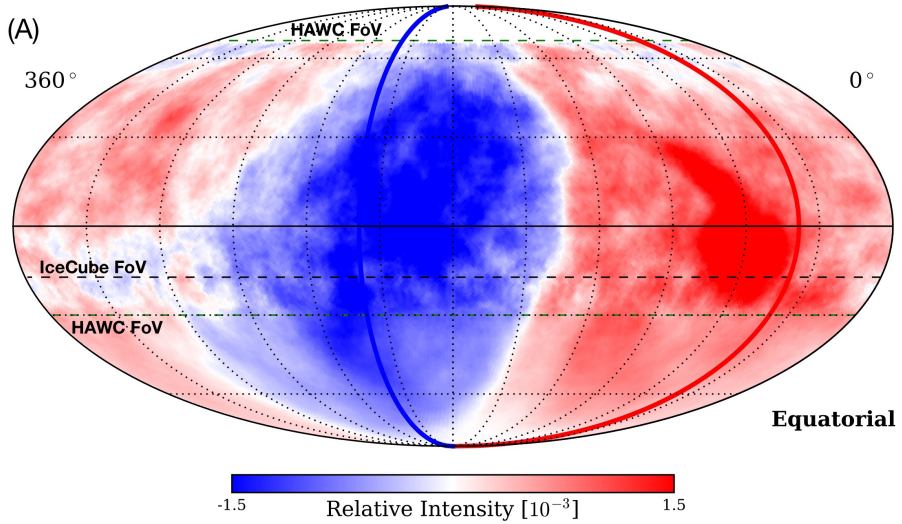


arXiv:2103.16895

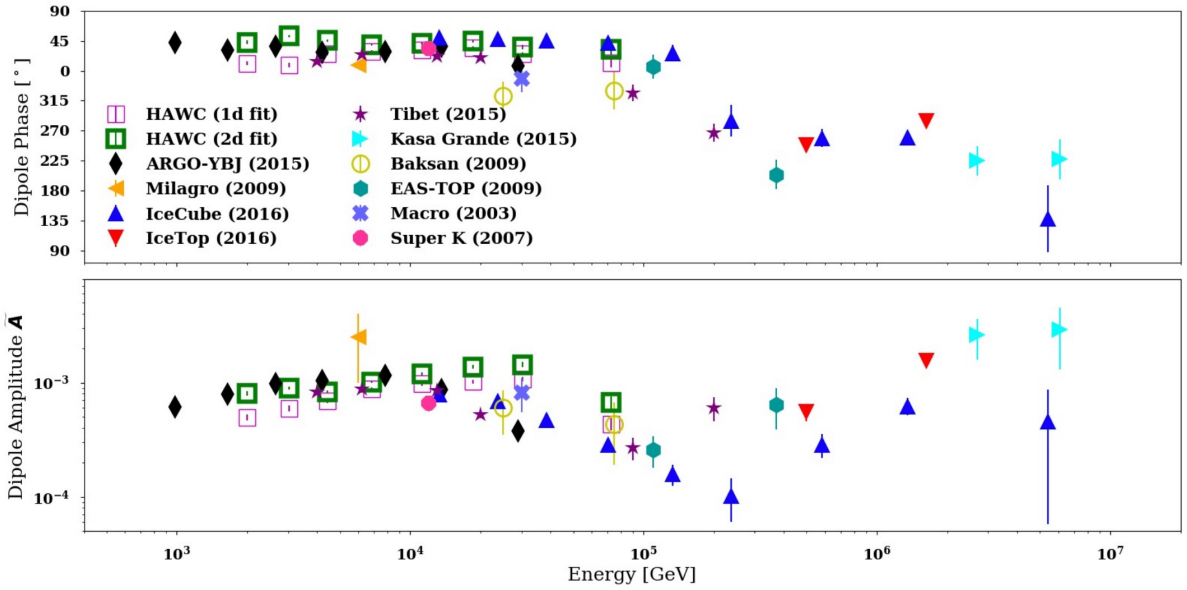
Slide adapted from A. Albert, Los Alamos National Laboratory | APS April (2021)

Cosmic Rays

- Anisotropy Studies
  - Complementary to LHAASO, HAWC, and IceCube for dipole studies at the highest energies
  - Low-scale anisotropy and understanding of ISM turbulence and local CRs
- Unprecedented mass-separation potential
  - For composition studies
  - Joint mass-dependent anisotropy studies



Cosmic-ray TeV dipole skymap (arXiv:1812.05682)



Comparison of fit phase and amplitude of the all-sky cosmic-ray anisotropy from recent measurements. (arXiv:1805.01847)

Summary

- SWGO is a proposed cosmic-gamma-ray observatory that would be located in the Southern Hemisphere
- SWGO will use the water-Cherenkov technique to observe intensive air showers from gamma rays
  - SWGO is expected to be sensitive up to PeV energies and would be the most sensitive gamma-ray observatory in the Southern Hemisphere above 10 TeV
- With its wide field of view, near 100% duty cycle, and high-energy reach, SWGO will provide the world's best sensitivity to emission from high-energy transients, propagation of particles within gamma-ray halos, PeVatrons in the galactic plane, several DM candidates, as well as Lorentz Invariance Violation

Slide adapted from A. Albert, Los Alamos National Laboratory | APS April (2021)

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Thank you! Miigwetch!

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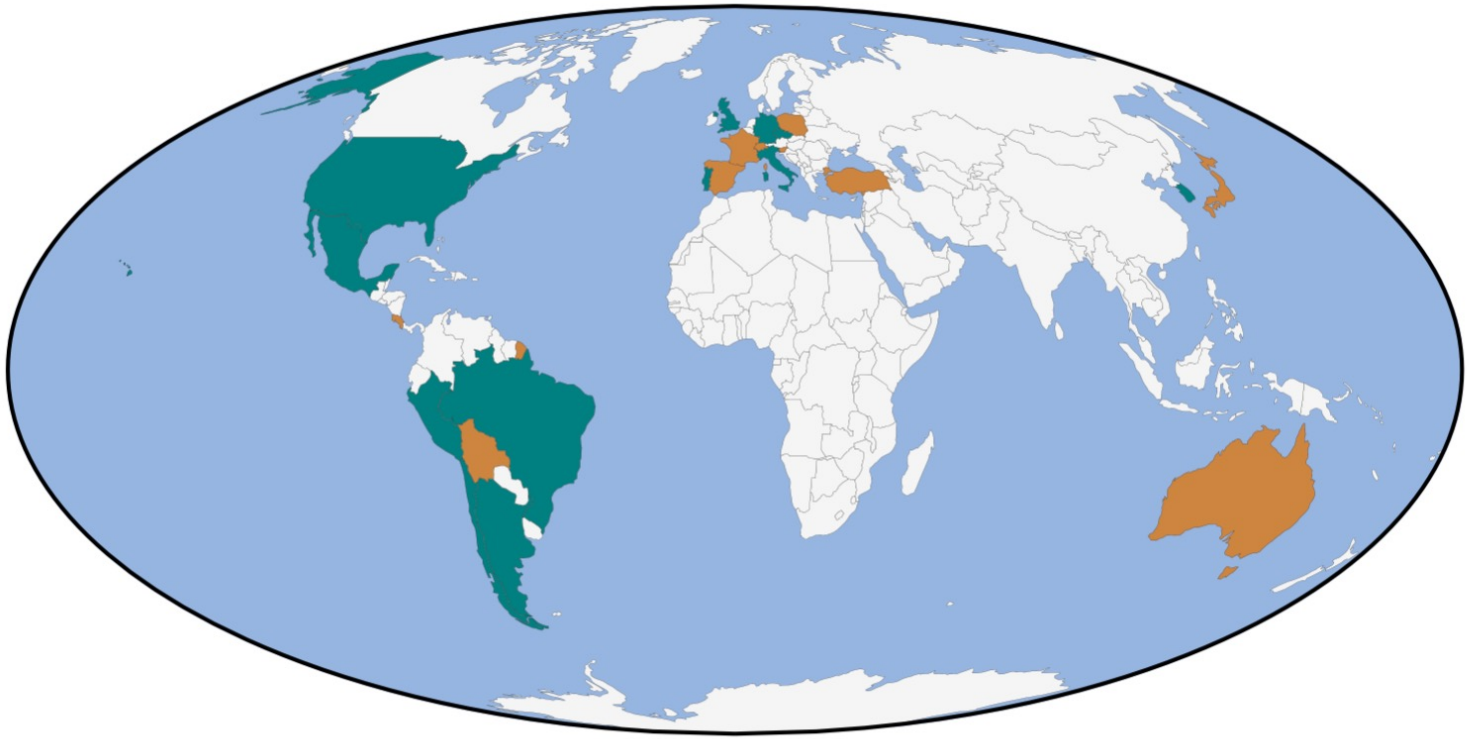
Acknowledgements

- Thanks to the entire SWGO Collaboration for their tireless work towards the next generation of gamma-ray astrophysics



Countries in SWGO

Institutes

Argentina*, Brazil, Chile, 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

**also supporting scientists*

SWGO Science at ICRC2021

- Benchmarking the Science for the Southern Wide-field Gamma-ray Observatory (SWGO)— *U. Barres de Almeida*
- The Southern Wide-field Gamma-ray Observatory reach for Primordial Black Hole evaporation— *R. Lopez Coto*
- Galactic Science with the Southern Wide-field Gamma-ray Observatory— *R. Lopez Coto*
- Monitoring Gamma-Ray Burst VHE emission with the Southern Wide-field-of-view Gamma-Ray Observatory— *G. La Mura*
- Searching for Dark Matter with the Southern Wide-field Gamma-ray Observatory (SWGO)— *A. Viana*
- Cosmic ray studies with SWGO— *G. Giacinti*
- Beyond the Standard Model searches with the Highest Enrgy Gamma rays with SWGO— *A. Albert*

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[2] A. Albert et al. (2019) Science Case for a Wide Field-of-View Very-High-Energy Gamma-Ray Observatory in the Southern Hemisphere, arXiv: 1902.08429

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[4] V.A. Acciari et al. (2019) Teraelectronvolt emission from the γ-ray burst GRB 190114C, arXiv: 2006.07249

[5] A.U. Abeysekara et al. (2018) Very high energy particle acceleration powered by the jets of the microquasar SS 433, arXiv: 1810.01892

[6] A.U. Abeysekara et al. (2017), Extended gamma-ray sources around pulsars constrain the origin of the positron flux at Earth, DOI: 10.1126/science.aan4880

[7] D. Hooper & T. Linden (2021) Evidence of TeV Halos Around Millisecond Pulsars, arXiv:2104.00014

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[11] C. Blanco et al. (2017) Novel Gamma-Ray Signatures of PeV-Scale Dark Matter, arXiv:1712.02805

[12] A. Viana et al. (2019) Searching for Dark Matter in the Galactic Halo with a Wide Field of View TeV Gamma-ray Observatory in the Southern Hemisphere, arXiv:1906.03353

[13] Z. Cao et al. (2021) Exploring Lorentz Invariance Violation from Ultra-high-energy Gamma Rays Observed by LHAASO, arXiv:2106.12350

[14] A. Albert et al. (2020) Constraining the Local Burst Rate Density of Primordial Black Holes with HAWC, arXiv:1911.04356

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[15] R. López-Coto et al. (2021) Prospects for the Observation of Primordial Black Hole evaporation with the Southern Wide Field of View Gamma-ray Observatory, arXiv:2103.16895

[16] A.U. Abeysekara et al. (2019) All-Sky Measurement of the Anisotropy of Cosmic Rays at 10 TeV and Mapping of the Local Interstellar Magnetic Field, arXiv:1812.05682

[17] A.U. Abeysekara et al. (2018) Observation of Anisotropy of TeV Cosmic Rays with Two Years of HAWC, arXiv:1805.01847