

Recent HAWC Science Results

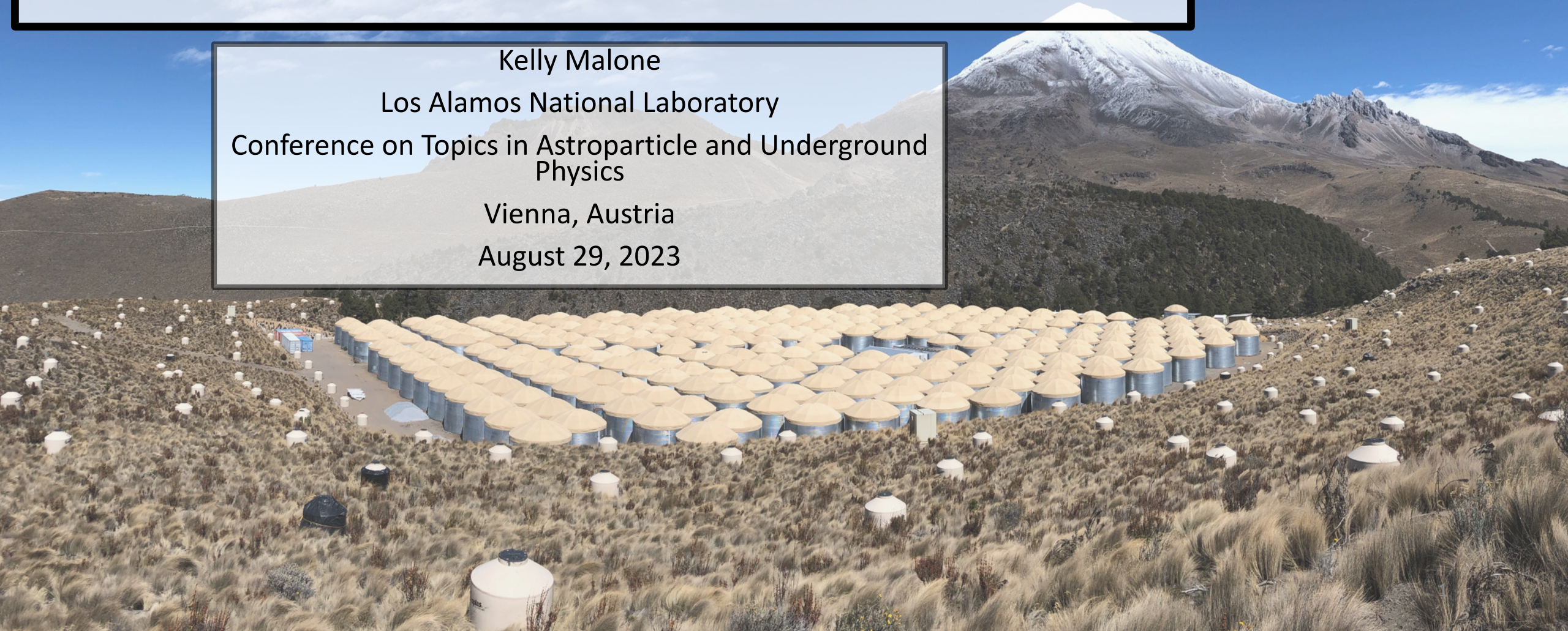
Kelly Malone

Los Alamos National Laboratory

Conference on Topics in Astroparticle and Underground Physics

Vienna, Austria

August 29, 2023



Outline

- Description of HAWC
- Science goals of HAWC
- Astrophysical science highlights (Galactic and extragalactic)
- Multi-messenger astrophysics program
- Particle physics and cosmic ray science highlights
- Future work

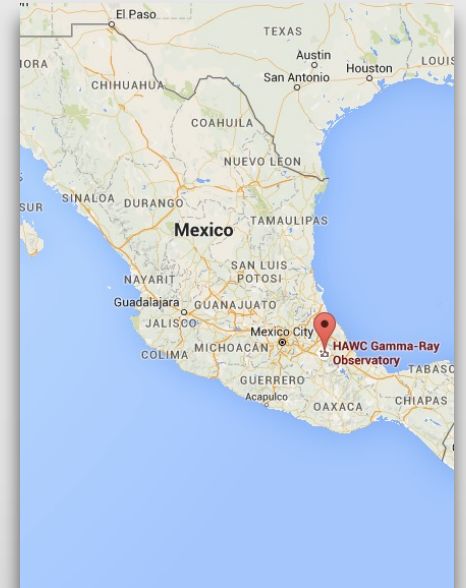


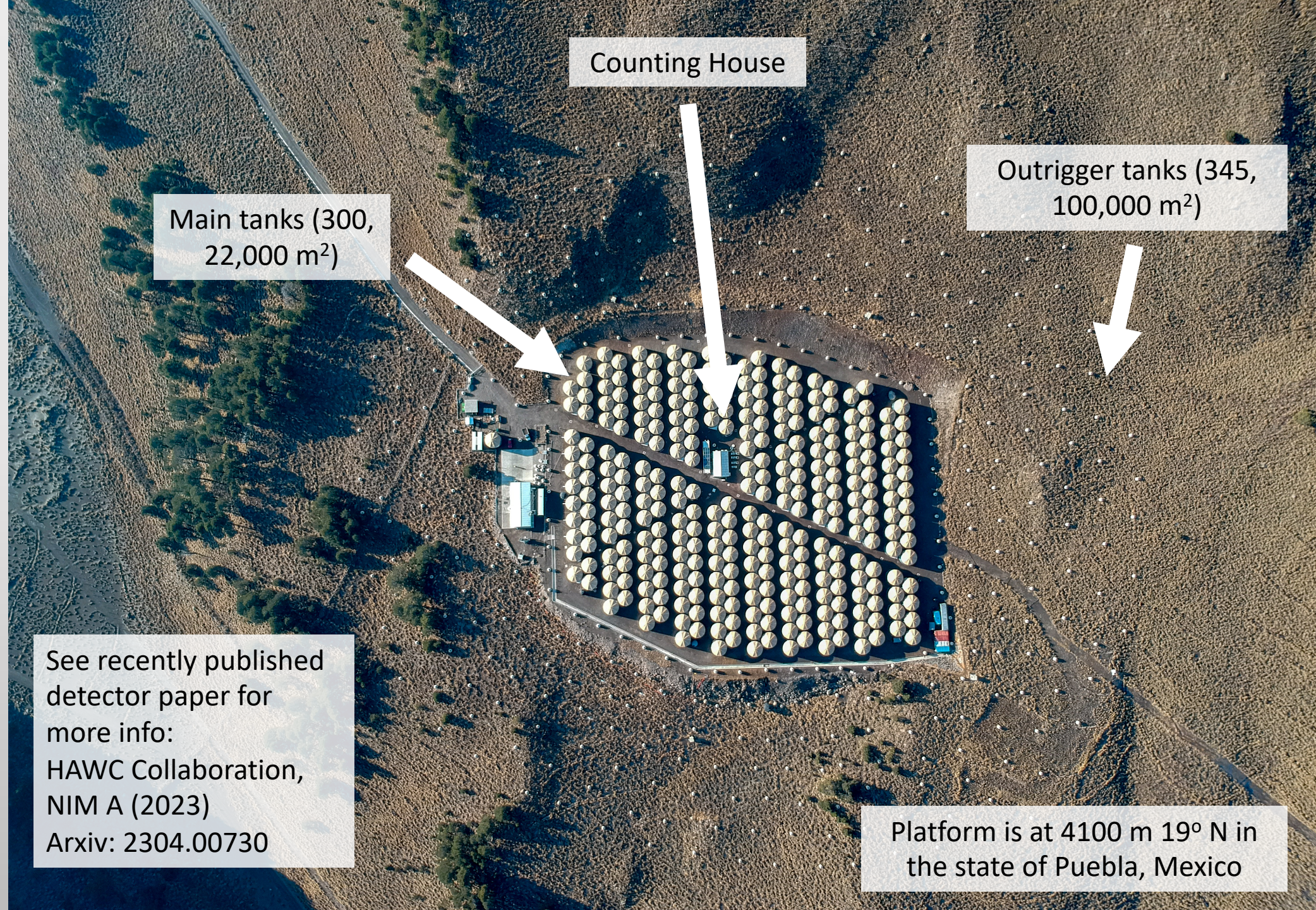
HAWC basics



HAWC with Pico de Orizaba in the background

Number of tanks	300 (4 PMTs/200,000 L of water in each) + outriggers
Main array area	22,000 m ²
Location	Puebla, Mexico (19° North)
Altitude	4100 m
Duty Cycle	> 95%
Coverage	2/3 of sky per day
Sensitivity	300 GeV to > 100 TeV
Angular resolution	> 0.1 degrees





Counting House

Main tanks (300,
22,000 m²)

Outrigger tanks (345,
100,000 m²)

See recently published
detector paper for
more info:
HAWC Collaboration,
NIM A (2023)
Arxiv: 2304.00730

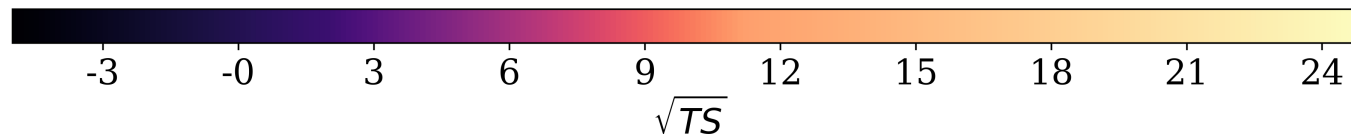
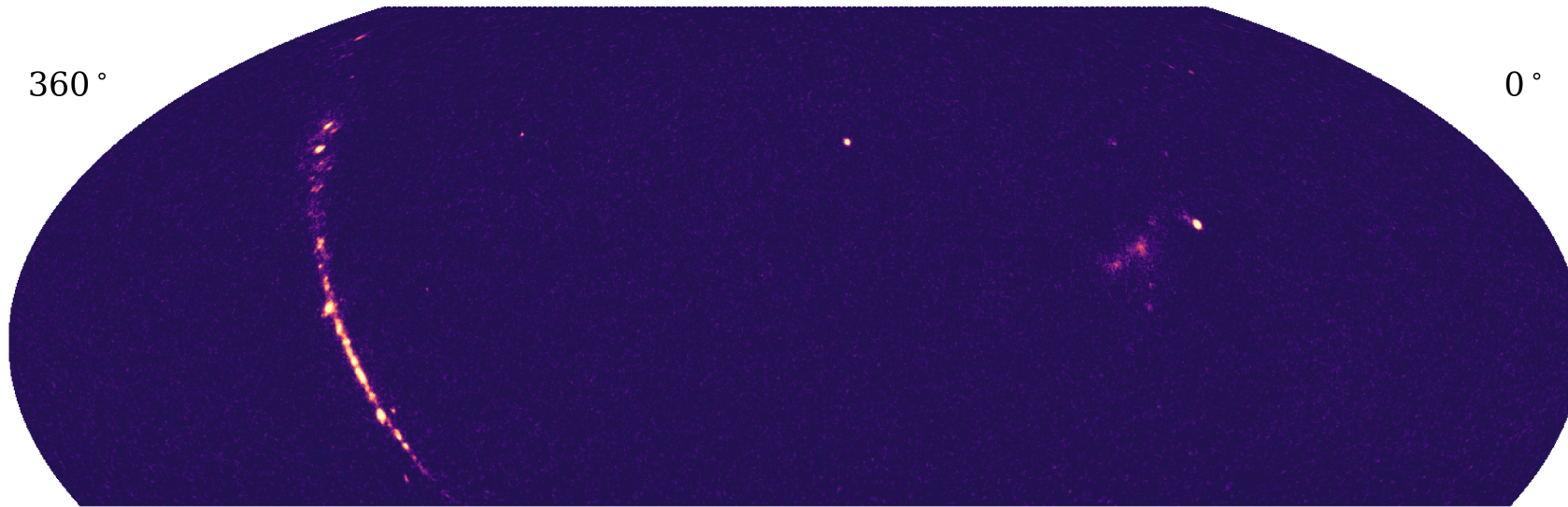
Platform is at 4100 m 19° N in
the state of Puebla, Mexico

Science goals of HAWC

- Galactic and extragalactic gamma rays
 - Distinguish hadronic vs. leptonic emission mechanisms at the highest energies, diffuse emission (neutrino origins), all-sky surveys, transient analyses
 - Active multi-wavelength and multi-messenger physics programs with other experiments
- Fundamental particle physics
 - Distinguish dark matter from astrophysical gamma rays, studies of Lorentz invariance
- Cosmic rays
 - Cosmic ray spectrum, cosmic ray anisotropy, the sun in gamma rays

Newest all-sky maps

All-sky view; 0° ; 2090 days

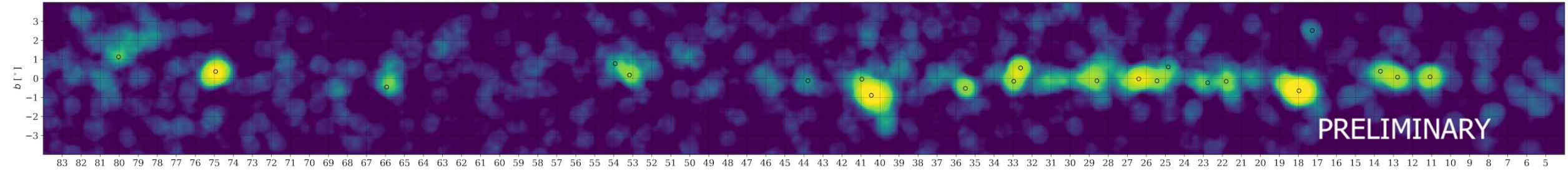


- Previous “pass 4” catalog (arxiv 2007.08582): 1523 days, 65 TeV gamma-ray sources
 - Interactive tool on our website:
<https://data.hawc-observatory.org/datasets/3hwc-survey/coordinate.php>
- New map (on left): pass 5
 - Improved background rejection, angular resolution, wider field-of-view (out to 60 degrees)
 - Updated catalog with multi-search fitting in progress.

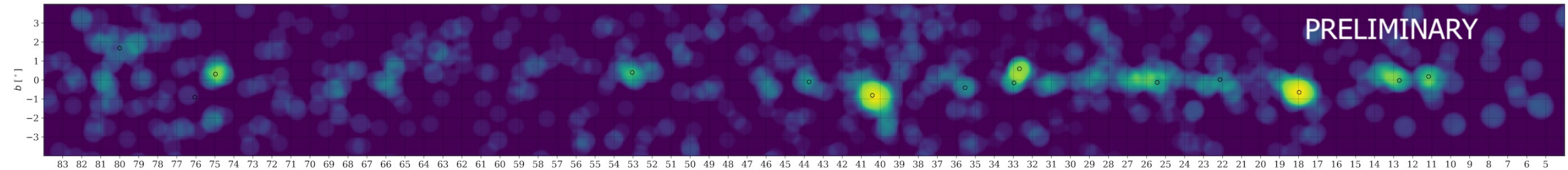
Newest ultra-high-energy sky maps

> 56 TeV

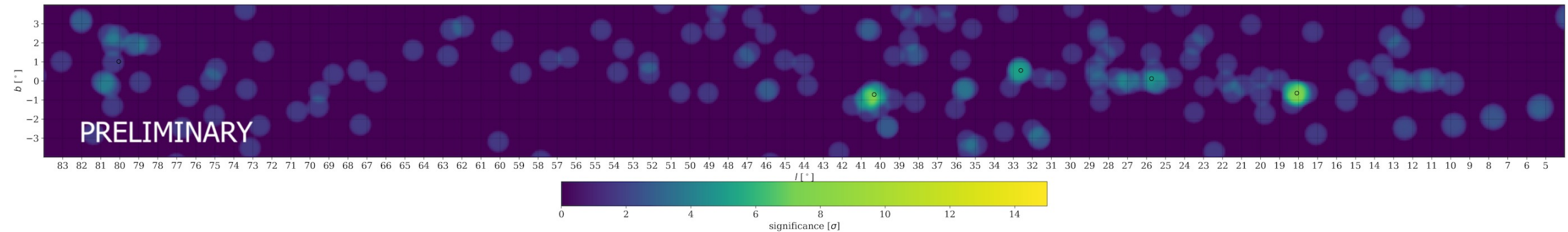
All maps assume a 0.5 degree extended source



> 100 TeV

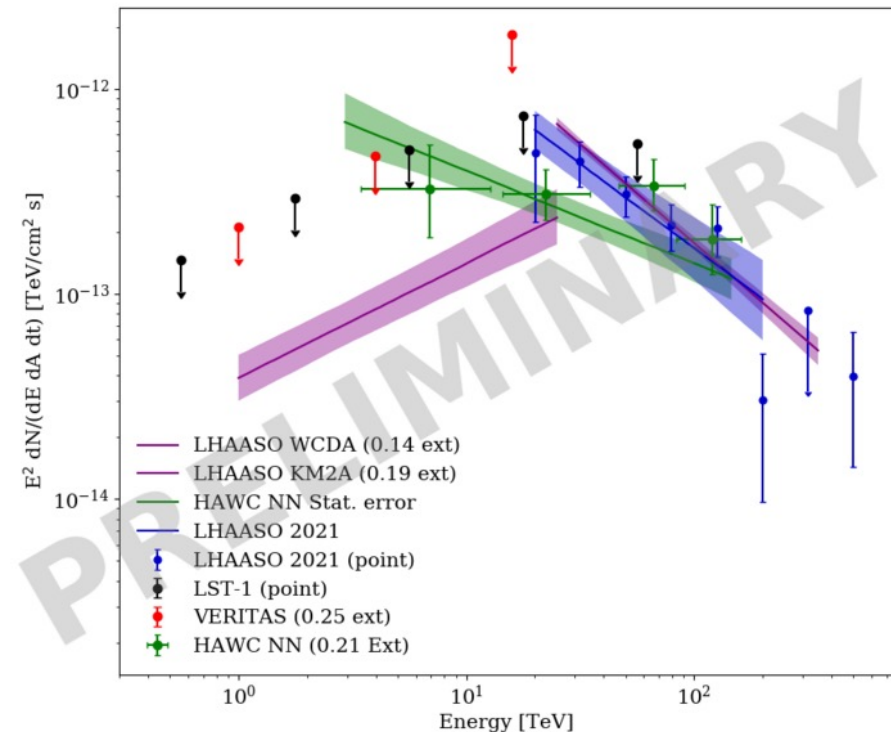
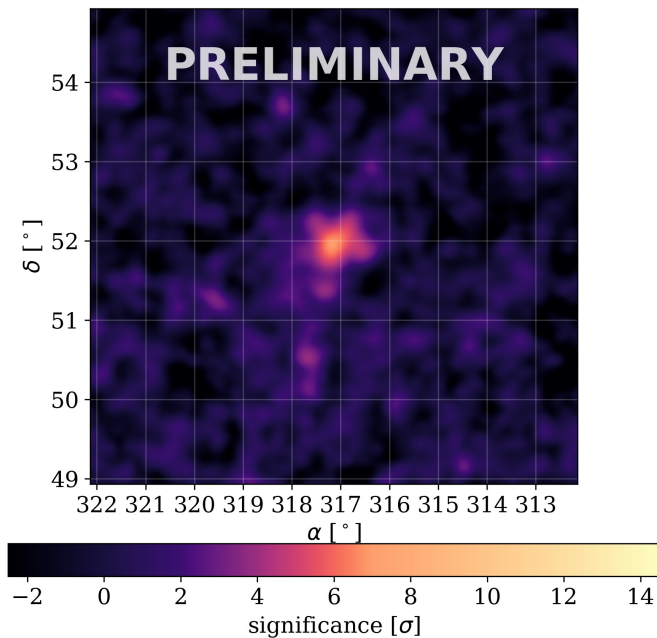


> 177 TeV



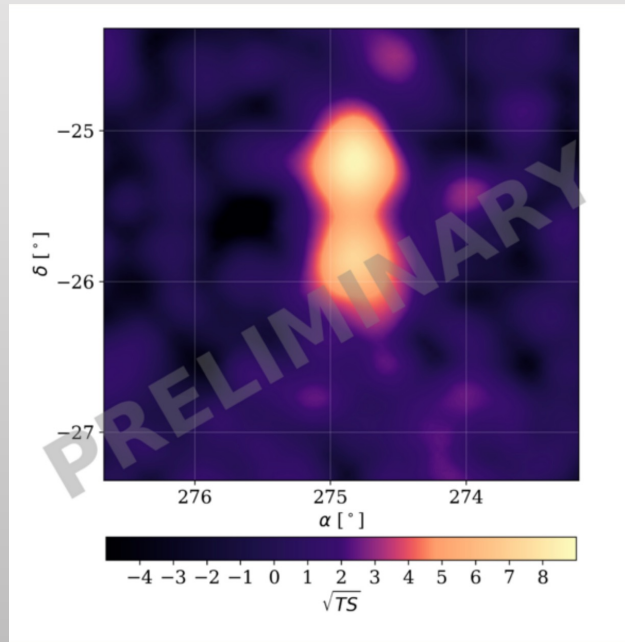
Searches for PeVatrons: An example

- LHAASO J2108+5157 – discovered by LHAASO, confirmed by HAWC
- Origin unclear – leptonic and hadronic (molecular clouds present) both possible
- HAWC currently doing a joint analysis with VERITAS, preliminary results presented at ICRC in July – discrepancies with the LHAASO reported spectrum



Gamma-ray binaries

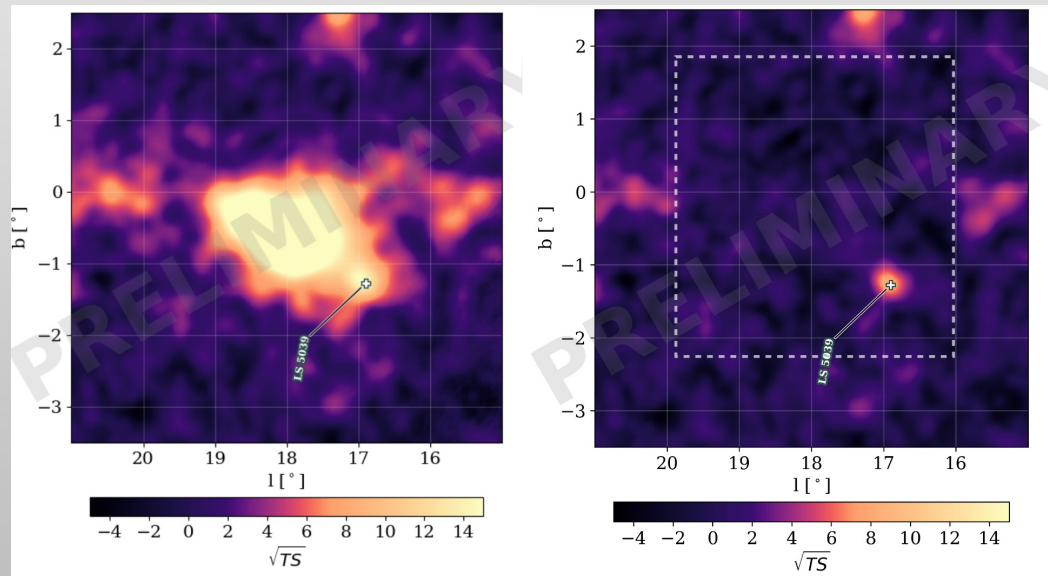
- Microquasar SS433 results published in Nature in 2018, individual lobes resolved, leptonic particle acceleration beyond 100 TeV → now working on spectra of individual lobes
- Now also see two additional gamma-ray binaries: V4641 Sgr and LS 5039



V 4641 Sgr: LMXB with small-scale jets observed in radio

Gamma-ray binaries

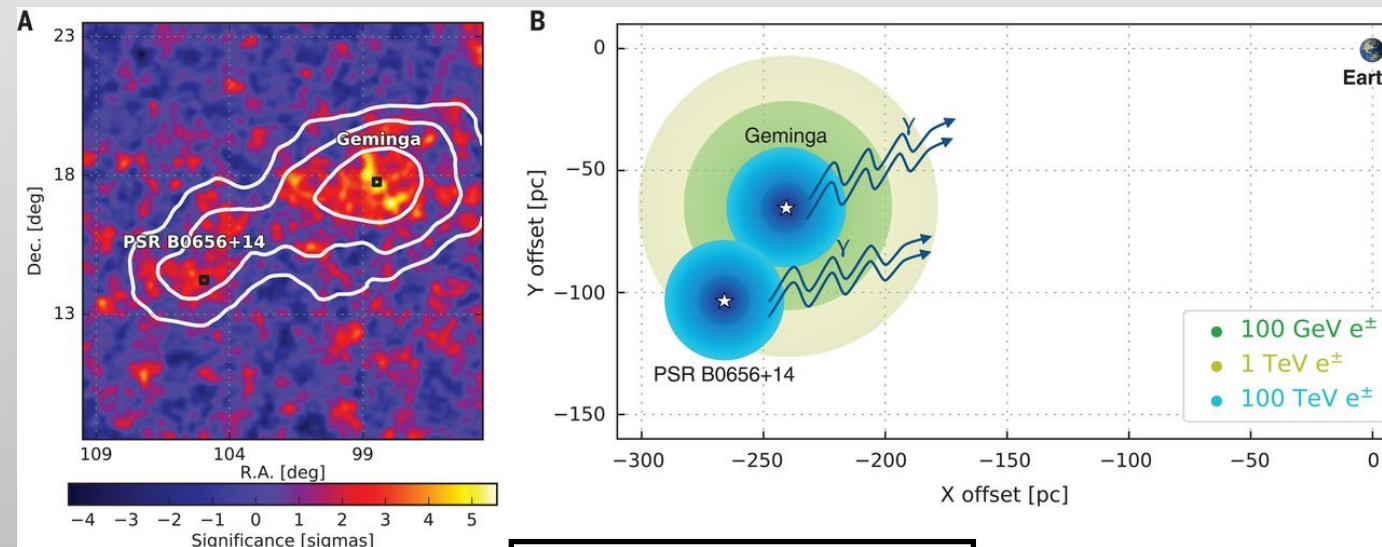
- Microquasar SS433 results published in Nature in 2018, individual lobes resolved, leptonic particle acceleration beyond 100 TeV → now working on spectra of individual lobes
- Now also see two additional gamma-ray binaries: V4641 Sgr and LS 5039



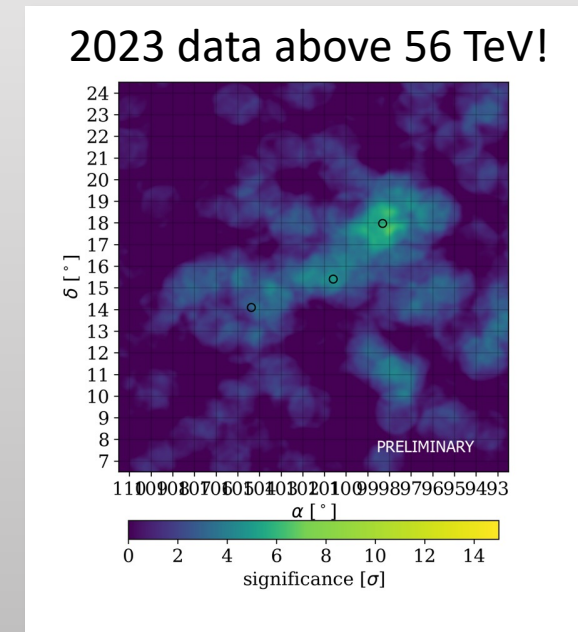
- LS 5039, disentangled from the much brighter J1825/J1826 region sources
- HAWC detects the high- and low- states of this periodic source

TeV halos

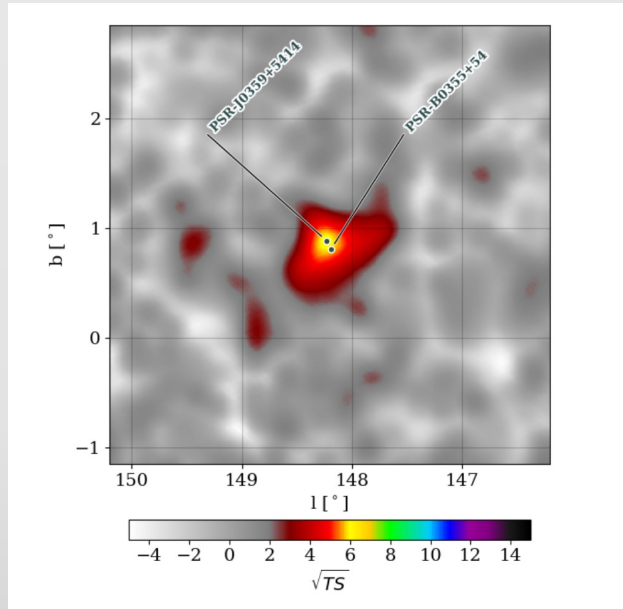
- New source class: TeV halos, first discovered by HAWC
- Extended gamma-ray sources such as these can be used to constrain the origin of the positron excess
- Original 2017 paper had an energy range of 8 to 40 TeV, overall source ~ 5 sigma
- With new "pass 5" HAWC data, these two sources are > 5 sigma above 56 TeV alone!



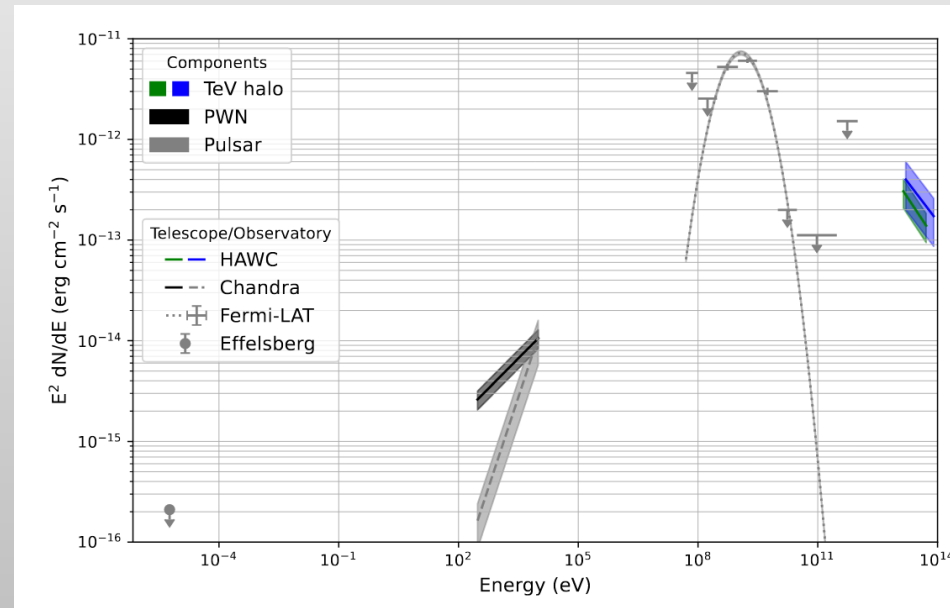
HAWC Collaboration, Science
358, 2017 (6365)



New TeV halo candidates



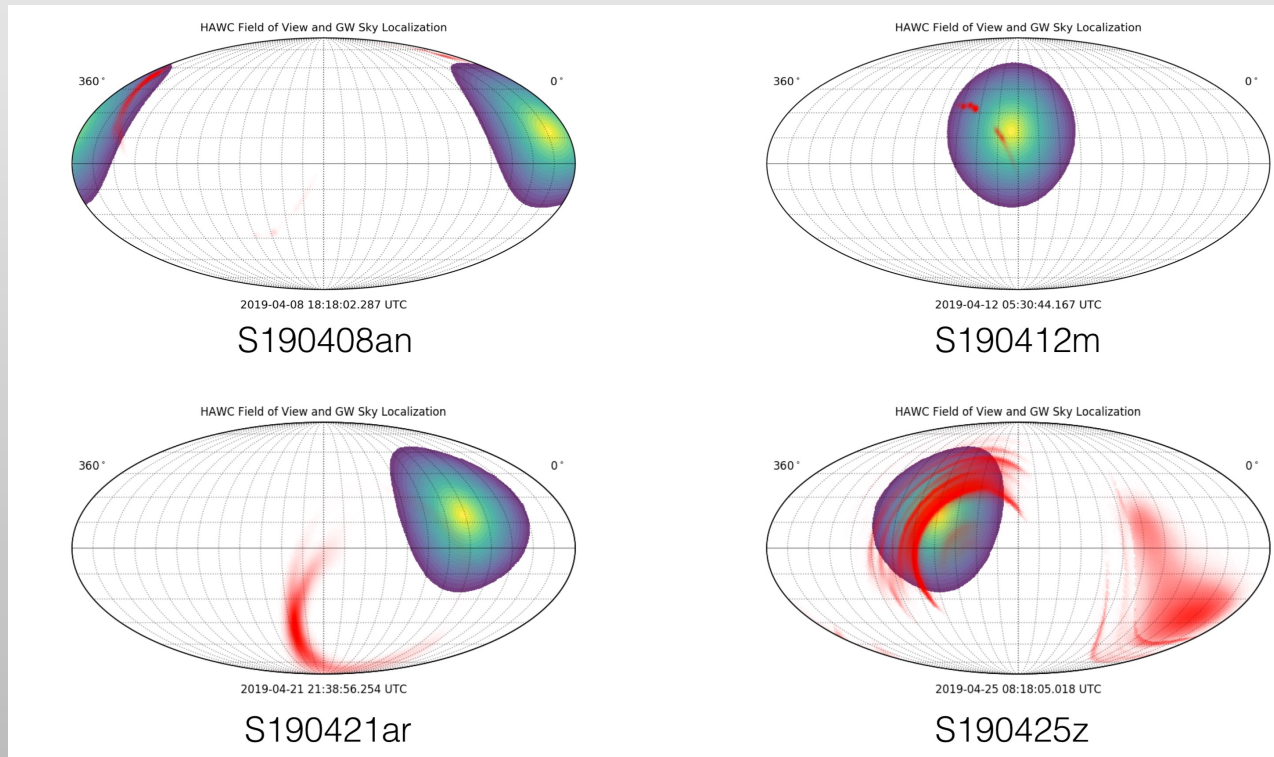
HAWC
Collaboration, ApJ
Letters 944 (2023)
Arxiv: 2301.04646



- HAWC has since discovered other TeV halo candidates – ubiquitous in the universe?
- Example: J0359+5414
- Near a radio-quiet pulsar, 75 kyr old (younger than Geminga/Monogem), high spin-down power

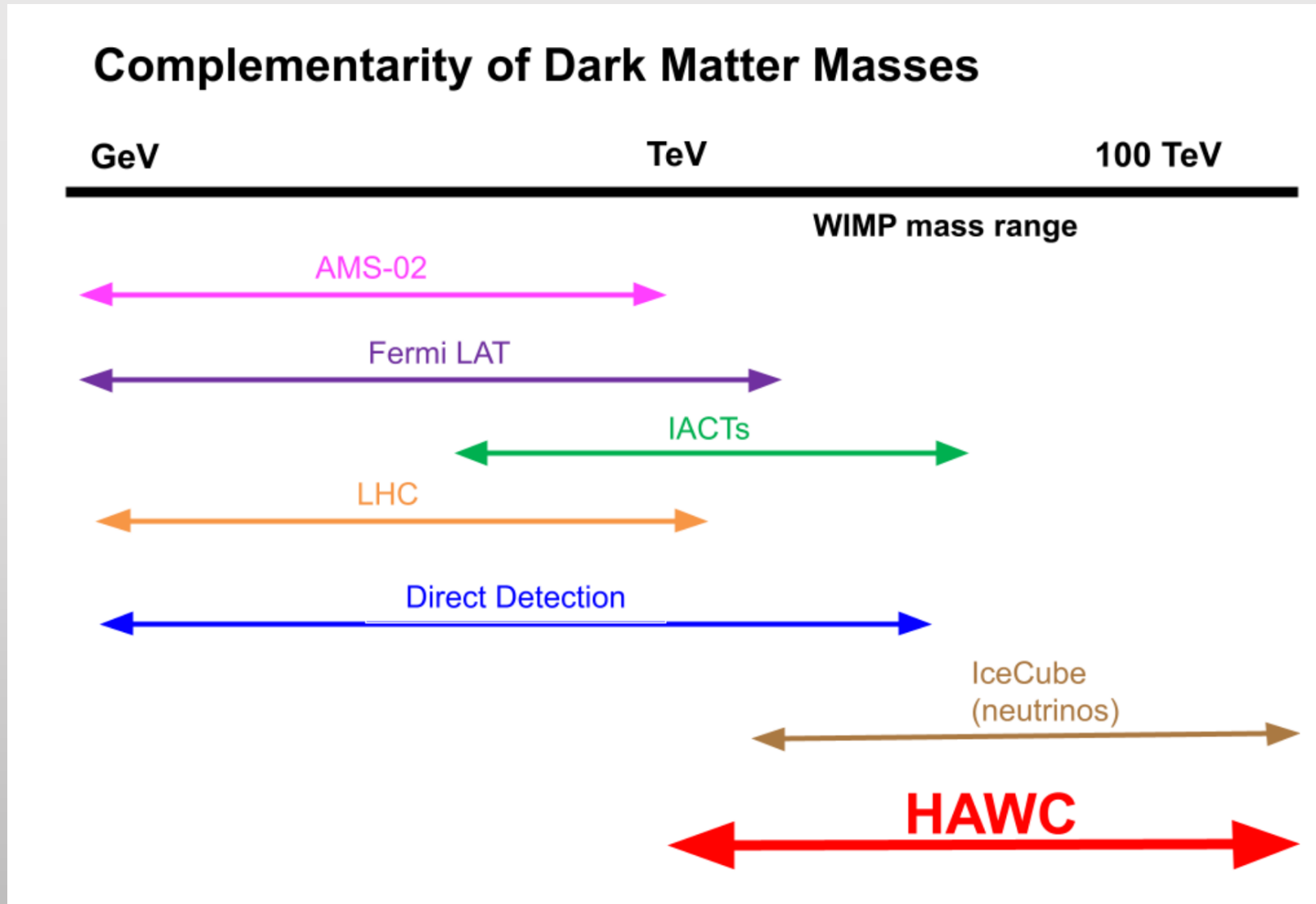
Multi-messenger and multi-wavelength

- HAWC can both follow-up alerts from other experiments and send alerts
- Programs to search for GRBs, coincidences with gravitational waves and IceCube neutrinos, searches for flaring sources, etc.
- Collaborations welcome! Contact us: <https://www.hawc-observatory.org/collaboration/>

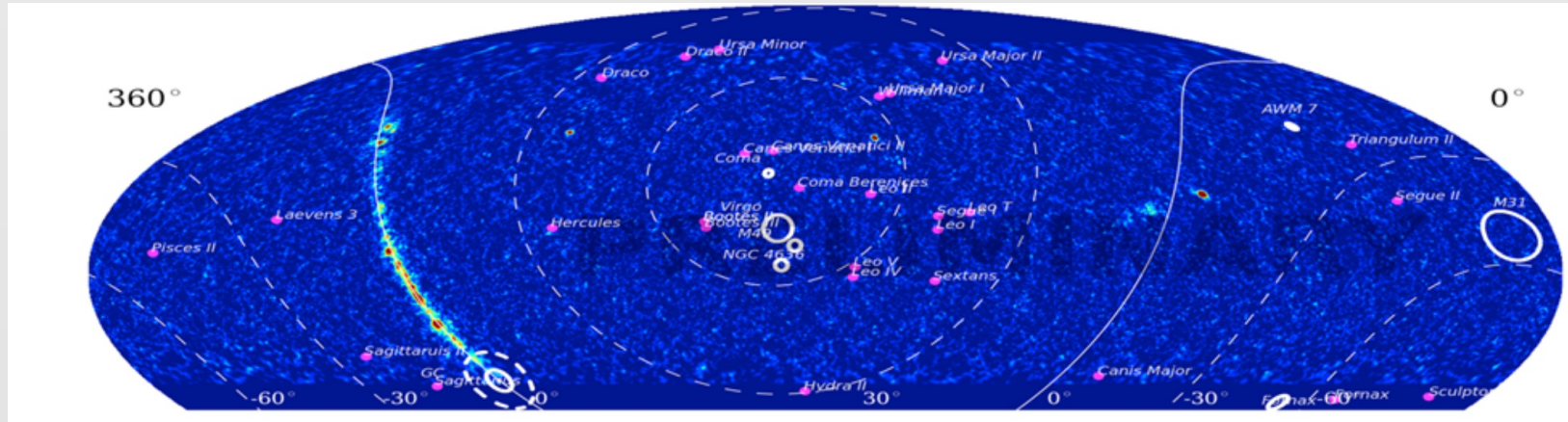


- HAWC instantaneous FOV with LIGO error bands for several LIGO O3 events
- When an alert is received, perform automatic analysis for a variety of different time windows (from 0.3 s to 100 s)

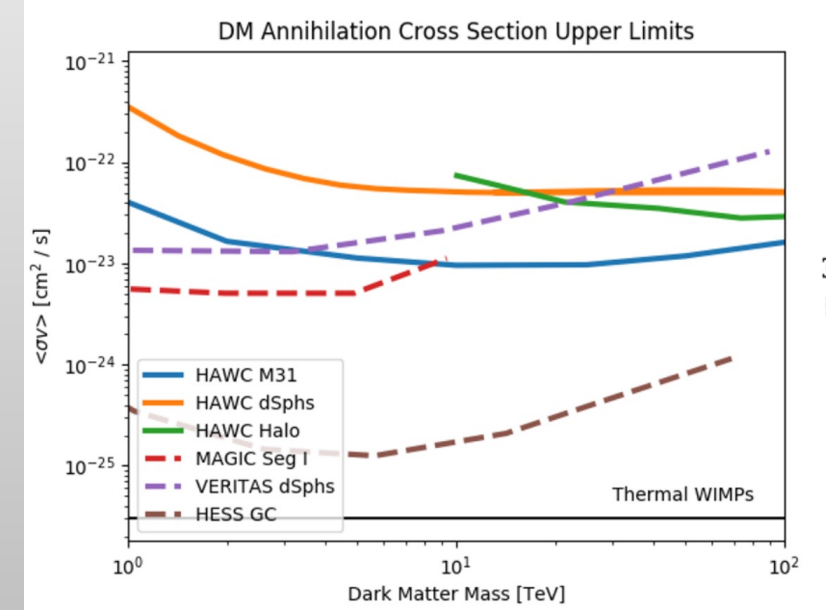
Dark matter searches



Dark matter searches

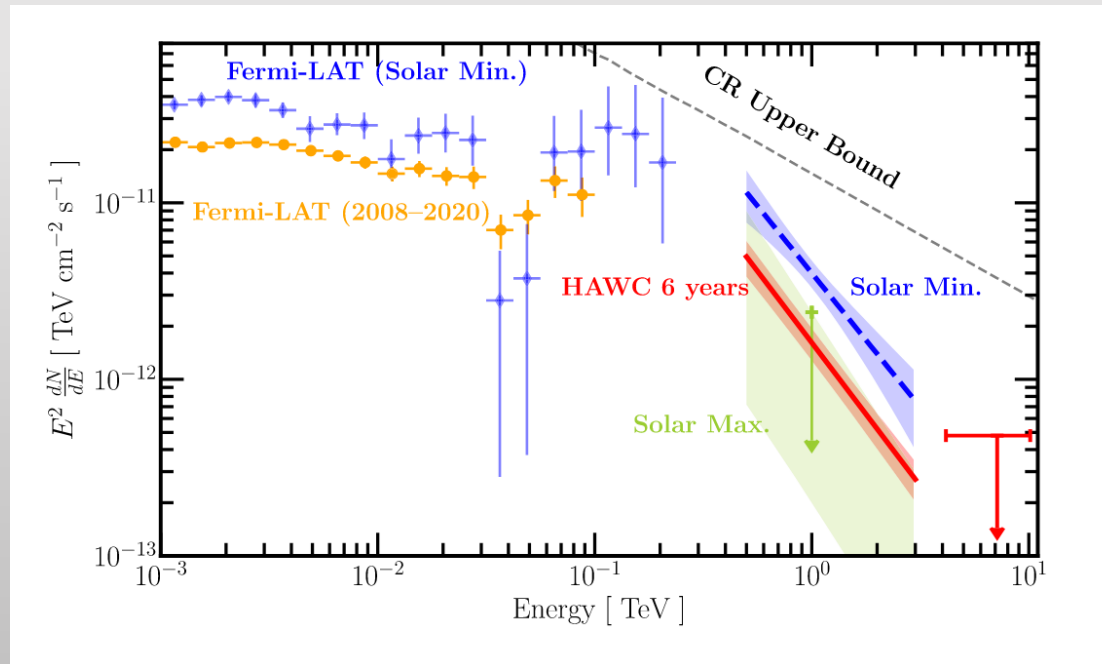
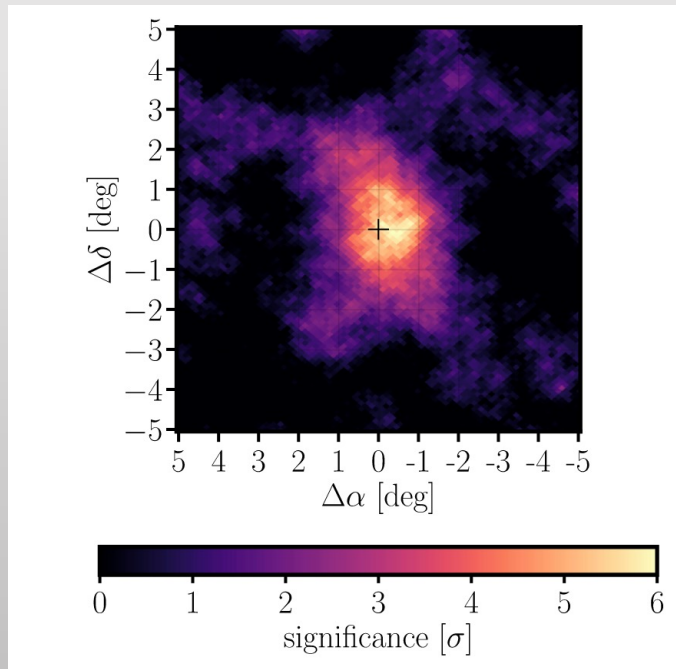


- Searches using different dark-matter rich areas of the sky: dwarf galaxies, Andromeda, Virgo galaxy cluster, etc.
- Set annihilation and lifetime limits



The sun in TeV gamma rays

- First detection of the solar disk in TeV gamma rays, 6.3σ , anticorrelated with solar activity
- Extension of observed GeV emission; hadronic Galactic CRs showering on nuclei in the solar atmosphere
- How solar magnetic fields shape these interactions still unknown



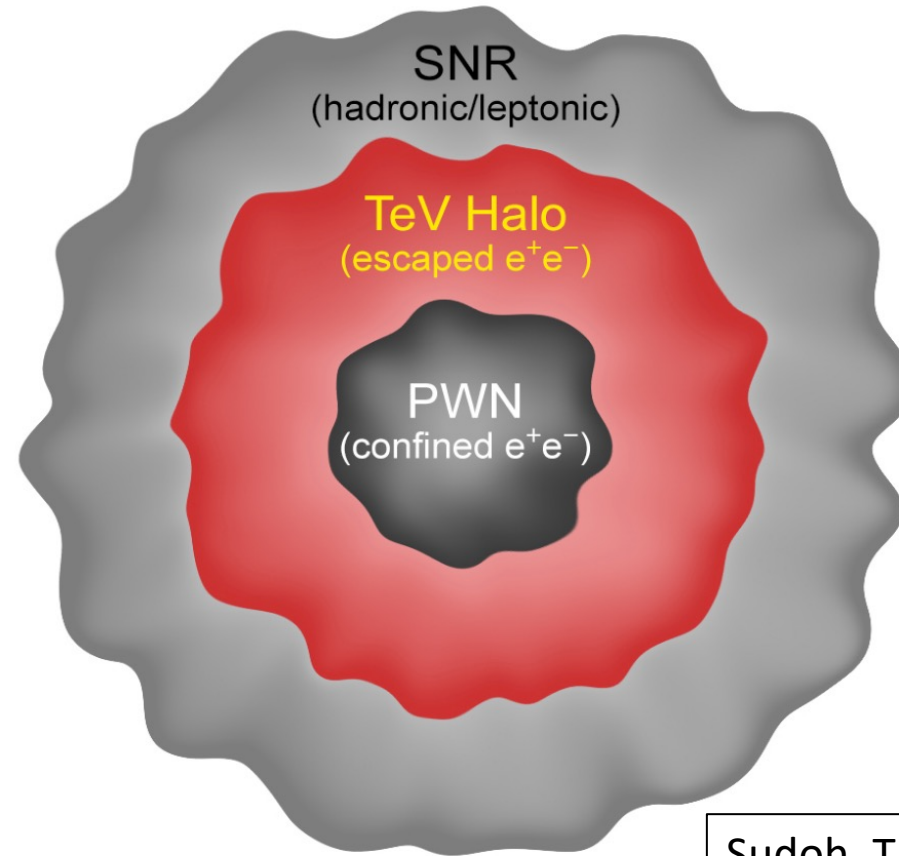
HAWC
Collaboration,
Physical Review
Letters (2023)
Arxiv: 2212.00815

Conclusions



- HAWC has a far-reaching science program covering many different astrophysical and fundamental physics phenomena
- Multi-messenger and multi-wavelength studies key to deciphering the nature of many sources

Backup: TeV halo definition



Sudoh, T. et al, Phys. Rev. D
100, 043016 (2019), ArXiv:
1902.08203