

# RESULTS FROM THE HIGH ALTITUDE WATER CHERENKOV OBSERVATORY

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# OUTLINE

(BRIEF) DESCRIPTION OF THE HAWC OBSERVATORY

SELECTED RECENT RESULTS

NEW TEV SOURCES

PEVATRON CANDIDATES

EXTENDED EMISSION REGIONS

SUMMARY & OUTLOOK

## HAWC Observatory

HAWC operates day and night, providing a large field of view for the observation of the highest energy gamma rays.

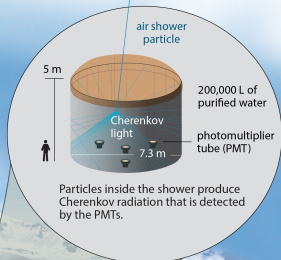


Pico de Orizaba  
(5,626 m)

# HAWC

## Water Cherenkov tank

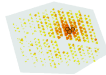
HAWC comprises an array of 300 tanks that record the particles created in gamma-ray and cosmic-ray showers.



## Gamma rays vs cosmic rays

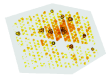
HAWC selects gamma rays from among a much more abundant background of cosmic rays.

gamma-ray shower



"hot" spots concentrate around the core

cosmic-ray shower



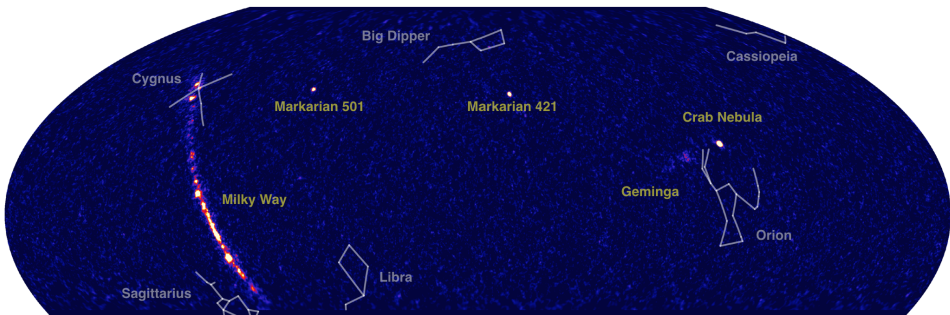
"hot" spots are more dispersed

HAWC is located at 4,100 m above sea level, covering an area of 20,000 m<sup>2</sup>.

150 m

# HAWC

- ▶ large instantaneous sky coverage
- ▶ long, uninterrupted observation periods



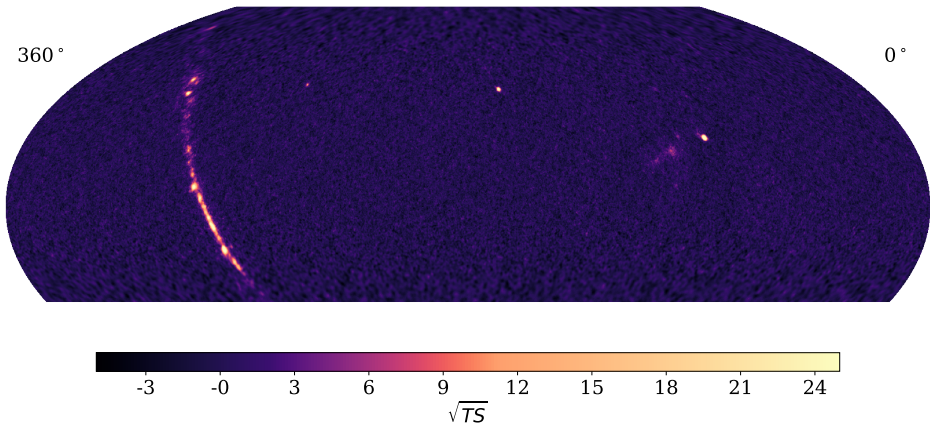
The HAWC Observatory: NIM **A1052** (2023) 168253



# THE 3<sup>rd</sup> HAWC CATALOG OF VHE $\gamma$ -RAY SOURCES

## ► Significance map (point-source hypothesis)

All-sky view; 0.0°; 1523 days

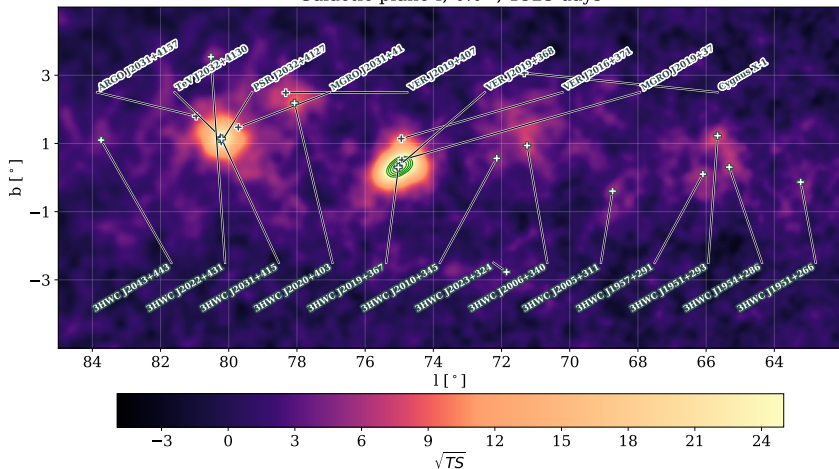


The 3HWC Catalog, HAWC Collaboration: *ApJ* **905** (2020) 76

# THE 3<sup>rd</sup> HAWC CATALOG OF VHE $\gamma$ -RAY SOURCES

## ► Significance map (point-source hypothesis)

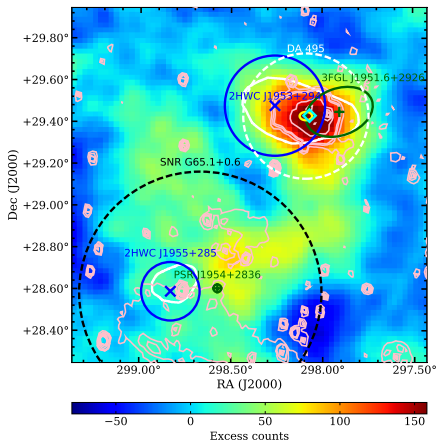
Galactic plane I;  $0.0^\circ$ ; 1523 days



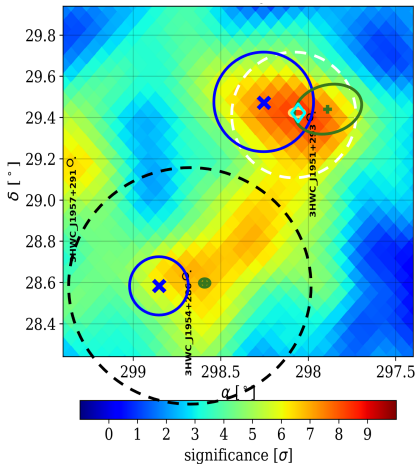
The 3HWC Catalog, HAWC Collaboration: *ApJ* 905 (2020) 76

# NEW TEV $\gamma$ -RAY SOURCES

## ► PWN DA 495 (2HWC J1953+294)



VERITAS counts map

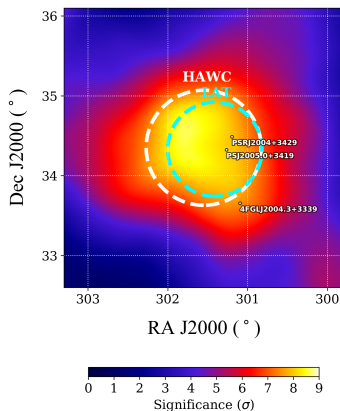


3HWC significance map

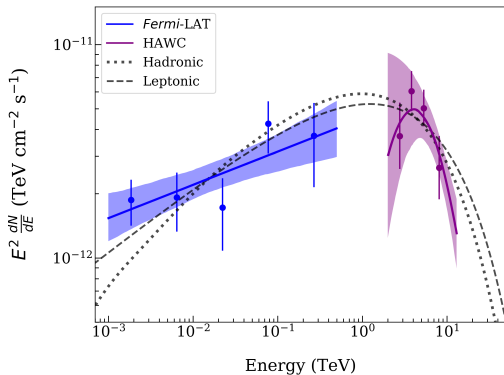
VERITAS+Fermi-LAT+HAWC: *ApJ* 866 (2018) 24

# NEW TEV $\gamma$ -RAY SOURCES

## ► 2HWC J2006+341



3HWC significance map



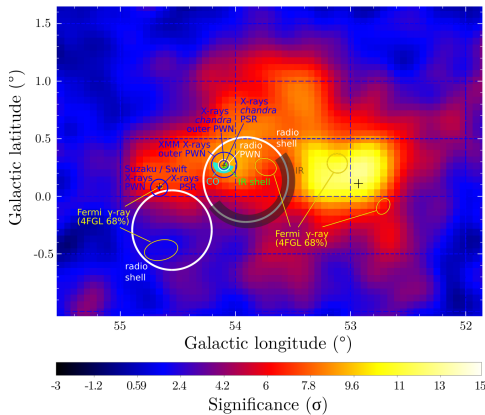
SED from HAWC and LAT data

HAWC+Fermi-LAT detection of J2006: *ApJL* **903** (2020) L14

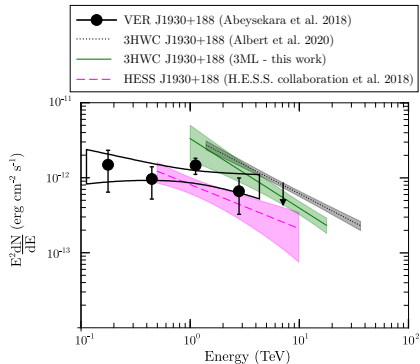


# NEW TEV $\gamma$ -RAY SOURCES

## ► 3HWC J1928+178 and HAWC J1932+192



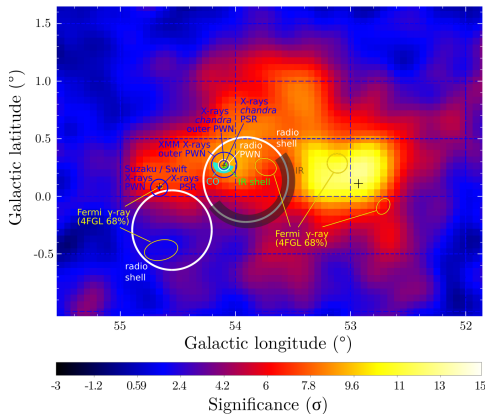
3HWC significance map



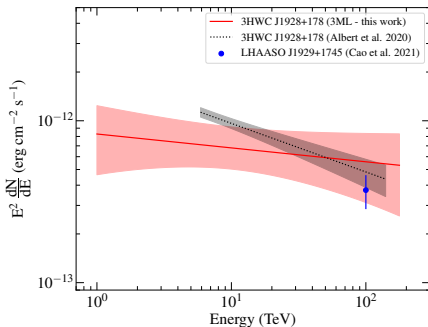
SED of 3HWC J1930+188

# NEW TEV $\gamma$ -RAY SOURCES

## ► 3HWC J1928+178 and HAWC J1932+192



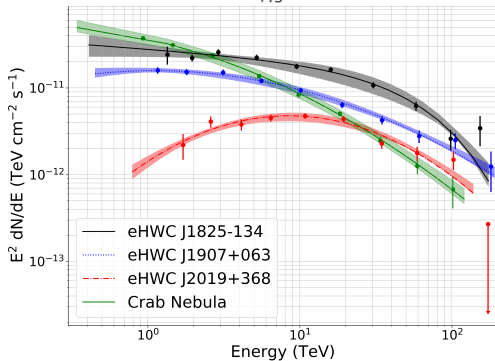
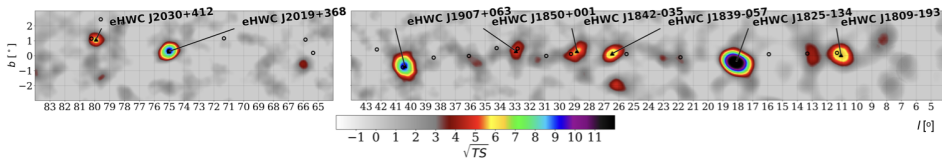
3HWC significance map



SED of 3HWC J1928+178

# CATALOG OF $\gamma$ -RAY SOURCES ABOVE 56 TeV

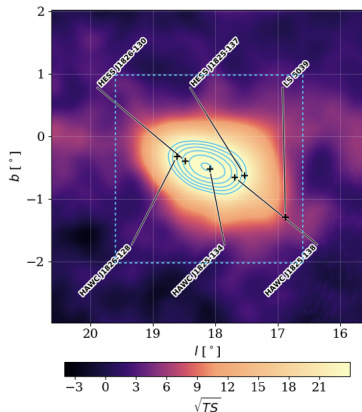
► Significance map ( $E > 56$  TeV,  $0.5^\circ$  hypothesis)



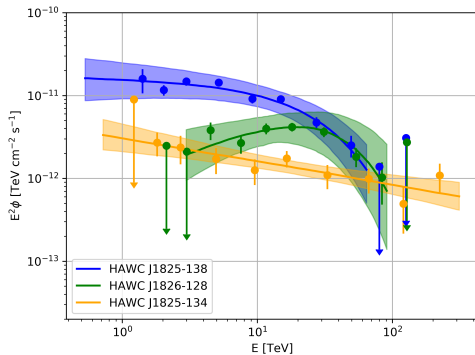


EVIDENCE OF 200 TeV  $\gamma$  RAYS

## ► eHWC J1825-134



Significance map

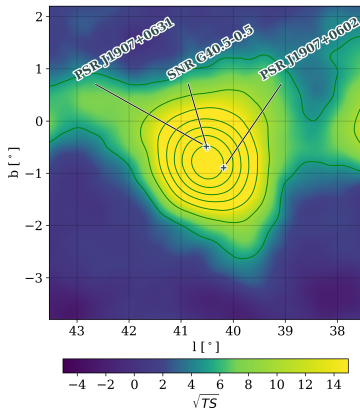


SED from HAWC data

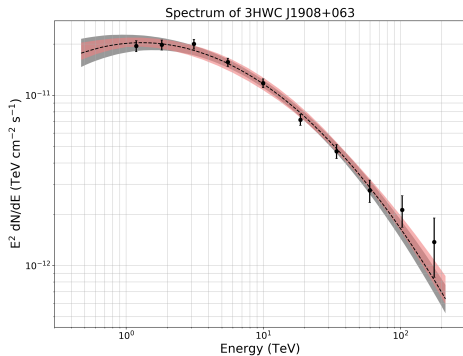
HAWC J1825-134, HAWC Collaboration: *ApJL* **907** (2021) L30

HE  $\gamma$ -RAY SPECTRA

## ► MGRO J1908+06



Significance map

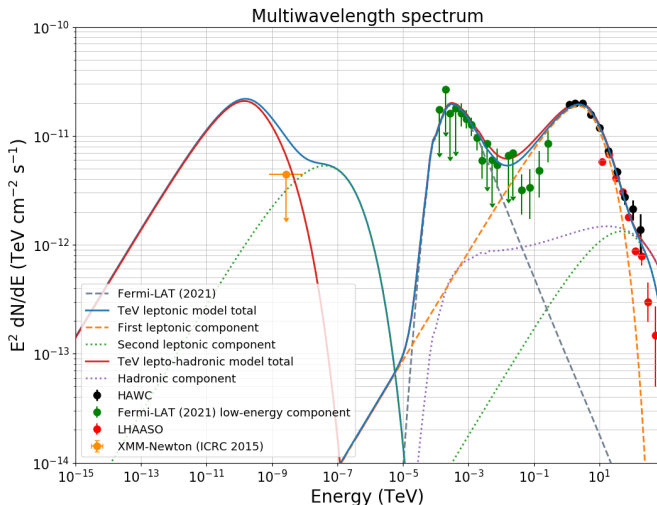


SED from HAWC data

MGRO J1908+06, HAWC Collaboration: *ApJ* **928** (2022) 116

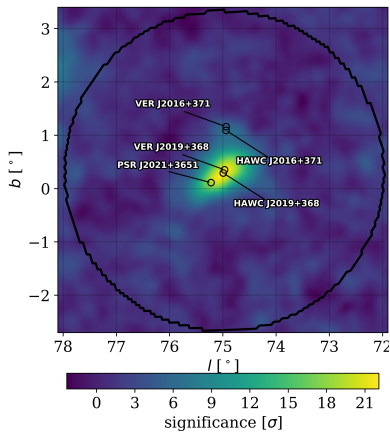
HE  $\gamma$ -RAY SPECTRA

## ► MGRO J1908+06

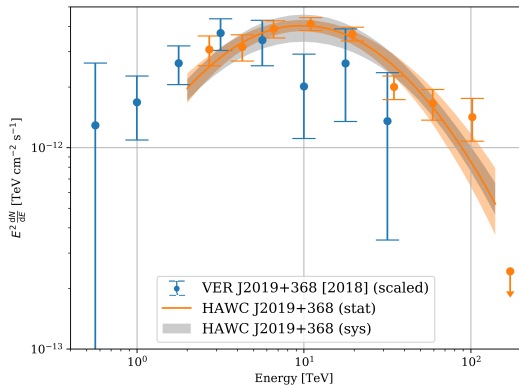
MGRO J1908+06, HAWC Collaboration: *ApJ* **928** (2022) 116

HE  $\gamma$ -RAY SPECTRA & MORPHOLOGY

## ► HWC J2019+368



Significance map

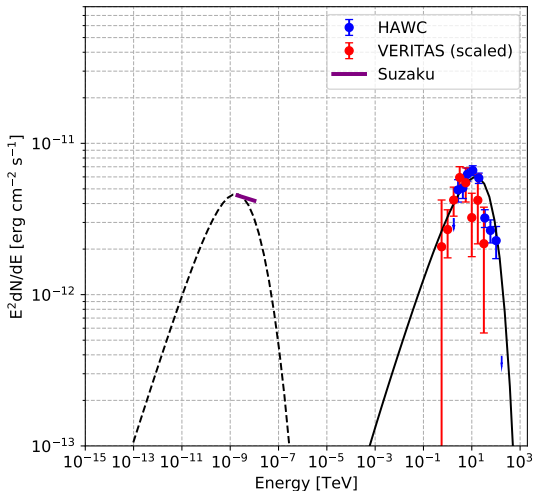


SED from HAWC data

HWC J2019+368, HAWC Collaboration: *ApJ* **911** (2021) 143

# HE $\gamma$ -RAY SPECTRA & MORPHOLOGY

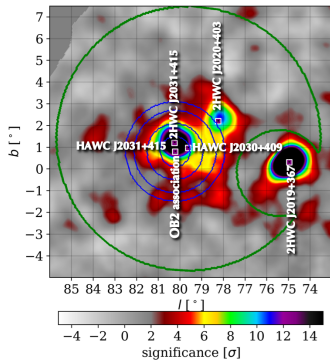
## ► HWC J2019+368



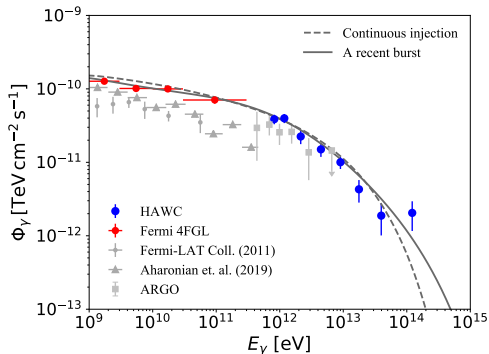
HWC J2019+368, HAWC Collaboration: *ApJ* **911** (2021) 143

# VHE COSMIC-RAY ACCELERATORS

## ► Cygnus Cocoon



3HWC significance map

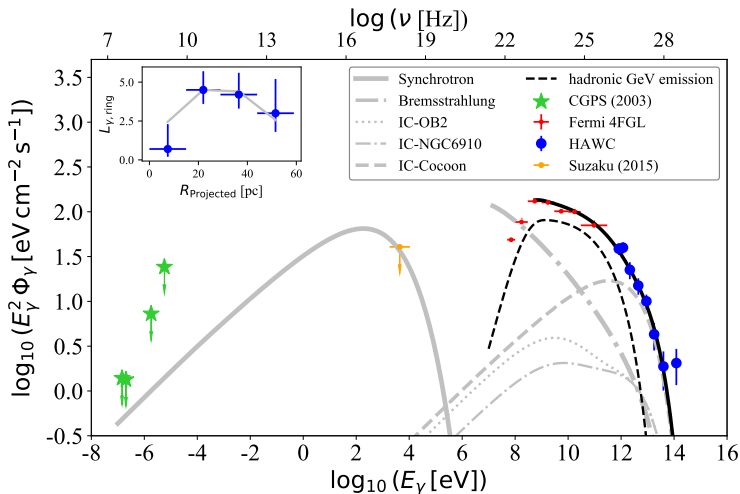


SED from HAWC and LAT data

Cygnus Cocoon, HAWC Collaboration: *Nat. Astro.* 5 (2021) 465

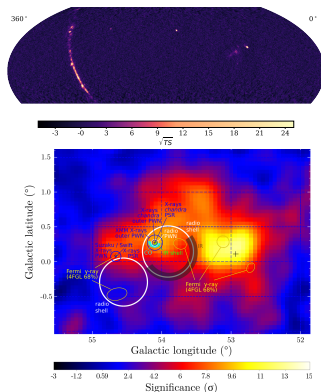
## VHE COSMIC-RAY ACCELERATORS

## ► Cygnus Cocoon

Cygnus Cocoon, HAWC Collaboration: *Nat. Astro.* 5 (2021) 465

# SUMMARY & OUTLOOK

- ▶ HAWC catalog **public!**  
New TeV sources  
Pevatron candidates
- ▶ Other **science** contributions  
Dark matter, CRs, solar physics,  
particle physics,  
multi-messenger studies,  
diffuse emission, extended  
regions, EBL, realtime alerts...
- ▶ Outrigger array **completed**  
Enhanced sensitivity above  
10 TeV





## UPCOMING RESULTS (THAT YOU DON'T WANT TO MISS)

- ▶ Update on SS 433 (a.k.a. *HAWC observations of microquasars as powerful particle accelerators*)
- ▶ Exploring molecular clouds (a.k.a. *The Boomerang PWN and its SNR G106.3+2.7 viewed with HAWC*)
- ▶ Emission and morphology of the unassociated  $\gamma$ -ray source TeV J2032+4130
- ▶ Update on the cosmic-ray spectrum between 10 TeV and 1 PeV
- ▶ Observation of the Galactic Center beyond 100 TeV
- ▶ Multi-wavelength study of MGRO J1908 (HAWC, VERITAS, Fermi-LAT)
- ▶ Update on Geminga and Monogem and TeV Halo searches

An aerial photograph of a large, conical mountain, likely a volcano, with a forested base and a small rectangular field in the foreground. The mountain is the central focus, with its peak illuminated by a bright light source, possibly the sun, creating a lens flare effect. The surrounding landscape is a mix of brownish-yellow earth and green forest. The sky is a clear blue with some light clouds.

THANK YOU VERY MUCH!

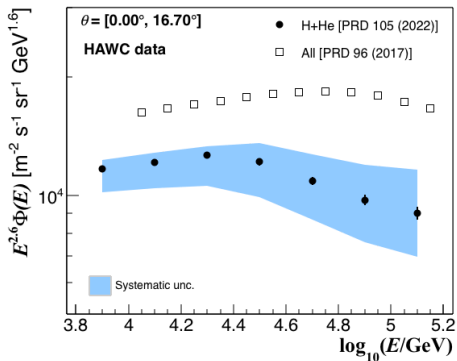
# BACK-UP SLIDES

## MOST RECENT HAWC PAPERS

- ▶ “Search for decaying dark matter in the Virgo cluster of galaxies with HAWC,” PRD **109** (2024) 043034
- ▶ “Galactic Gamma-Ray Diffuse Emission at TeV Energies with HAWC Data,” ApJ **961** (2024) 104
- ▶ “HAWC Study of the Very-high-energy  $\gamma$ -Ray Spectrum of HAWC J1844-034,” ApJ **954** (2023) 205
- ▶ “Discovery of Gamma Rays from the Quiescent Sun with HAWC,” PRL **131** (2023) 051201
- ▶ “HAWC Detection of a TeV Halo Candidate Surrounding a Radio-quiet Pulsar,” ApJL **944** (2023) L29
- ▶ “An optimized search for dark matter in the galactic halo with HAWC,” JCAP **12** (2023) 038
- ▶ “Searching for TeV Dark Matter in Irregular Dwarf Galaxies with HAWC Observatory,” ApJ **945** (2023) 25.
- ▶ “Search for Gamma-Ray and Neutrino Coincidences Using HAWC and ANTARES Data,” ApJ **944** (2023) 166.

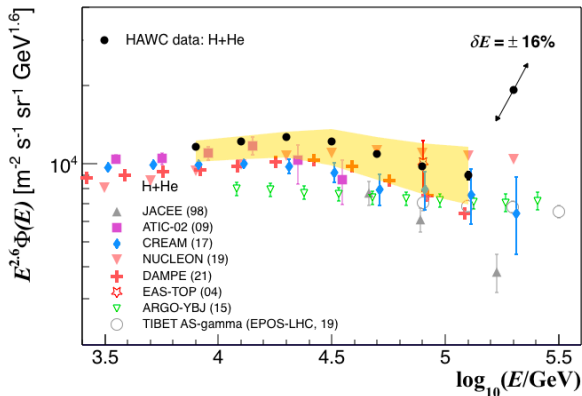
# COSMIC RAY SPECTRUM

- ▶ H + He nuclei between 6 and 158 TeV



# COSMIC RAY SPECTRUM

- ▶ H + He nuclei compared to other data



# COSMIC RAY SPECTRUM

- ▶ all particle spectrum between 10 TeV and 1 PeV

