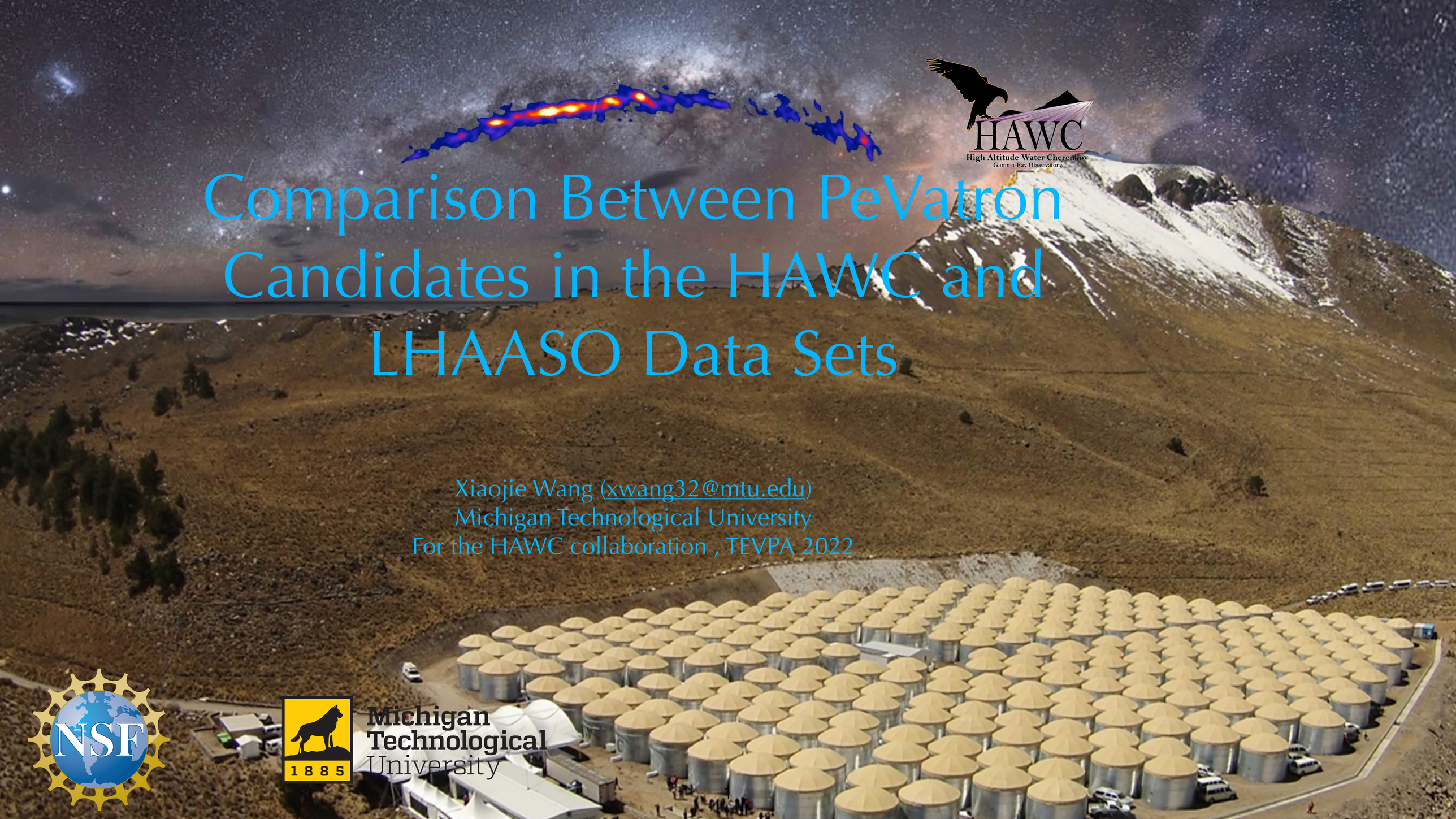
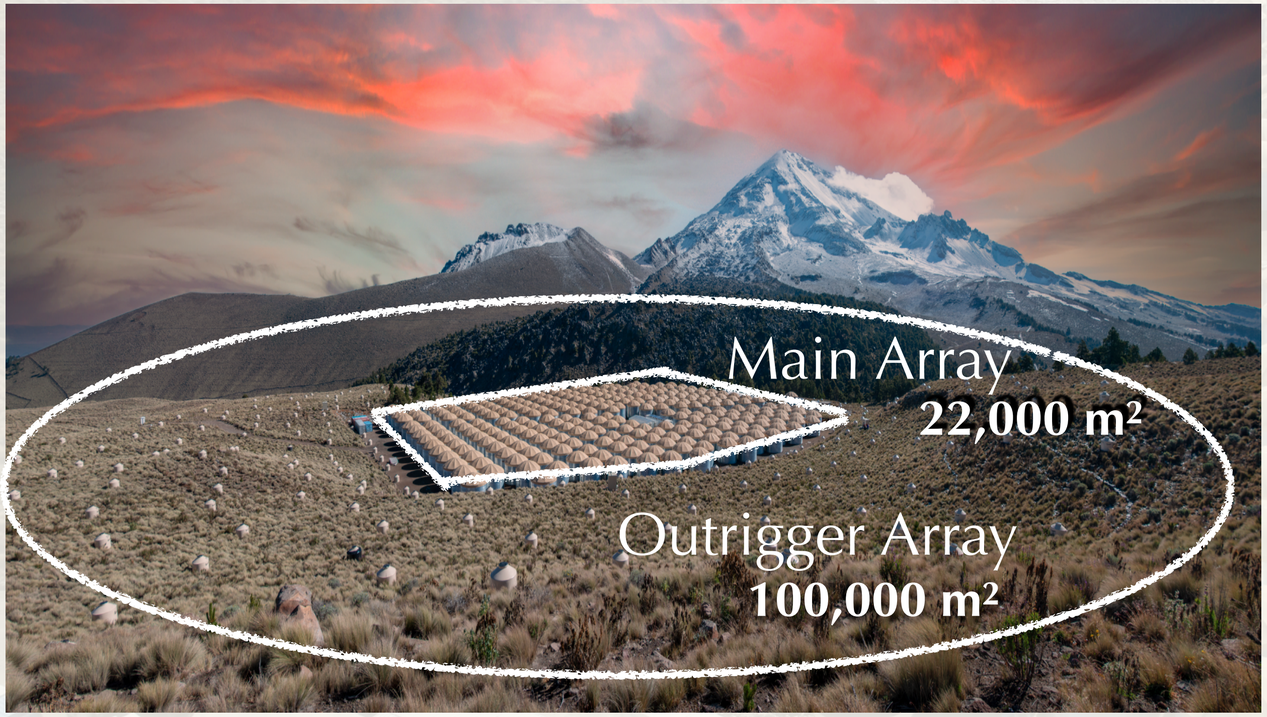
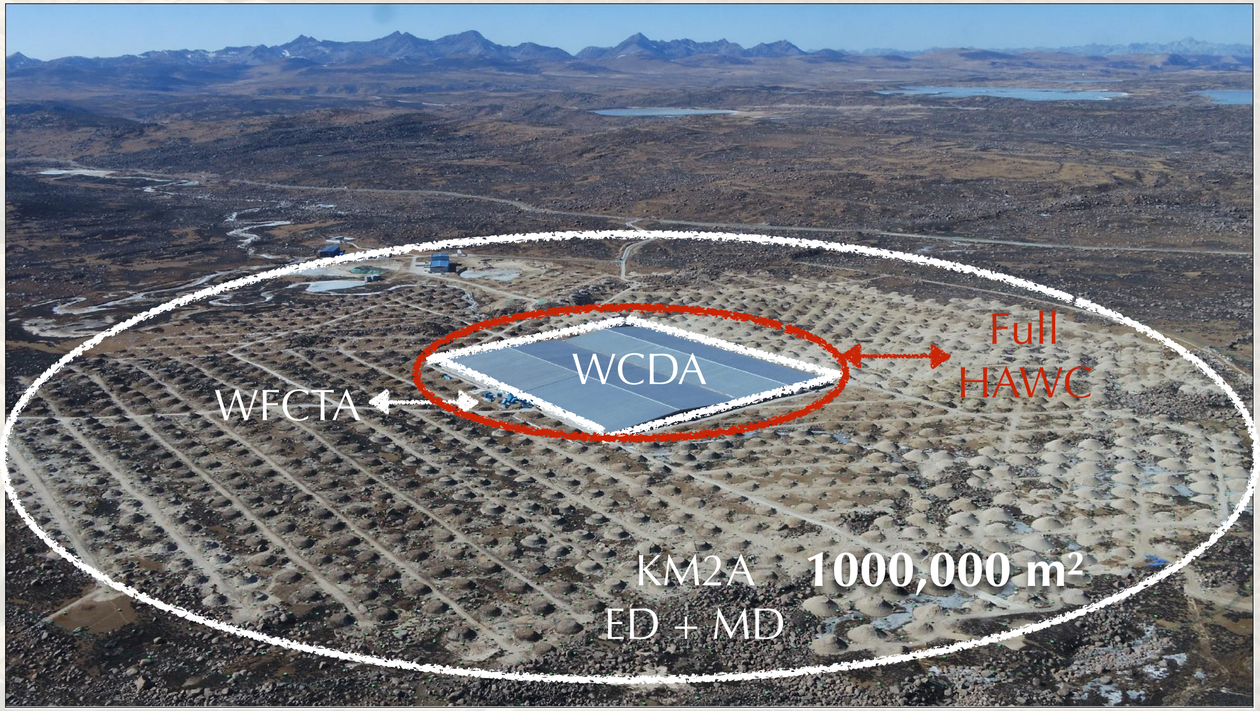


Comparison Between PeVatron Candidates in the HAWC and LHAASO Data Sets

Xiaojie Wang (xwang32@mtu.edu)
Michigan Technological University
For the HAWC collaboration , TEVPA 2022

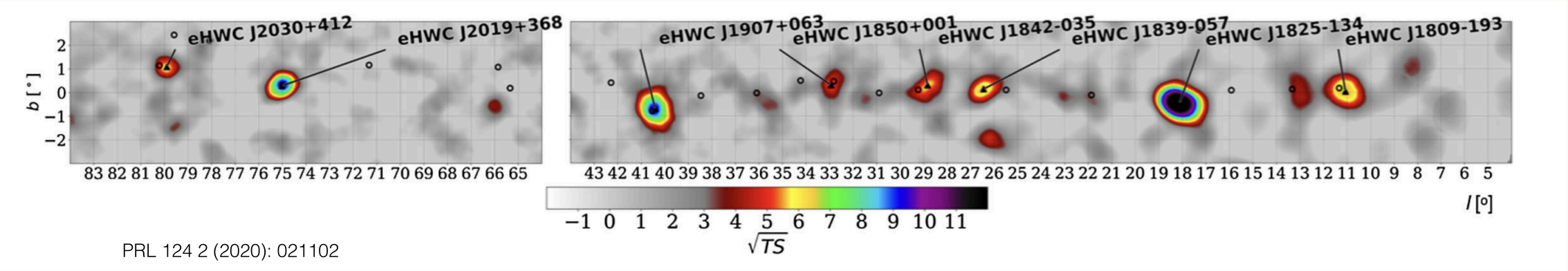


- Puebla, Mexico at 4100 meters a.s.l., 19°N
- 300 WCDs for Main array + 345 WCDs for outrigger
- γ-ray 300 GeV - >100 TeV
- >95% duty circle
- Instantaneous field of view: ~ 2sr



- Daocheng, China at 4410 meters a.s.l., 29° N
- 18 WFCTAs + 3 WCDA ponds + KM2A (5195ED, 1188MD)
- Cosmic-ray and γ-ray sub TeV - 1000 TeV
- >95% duty circle
- Instantaneous field of view: ~ 2sr

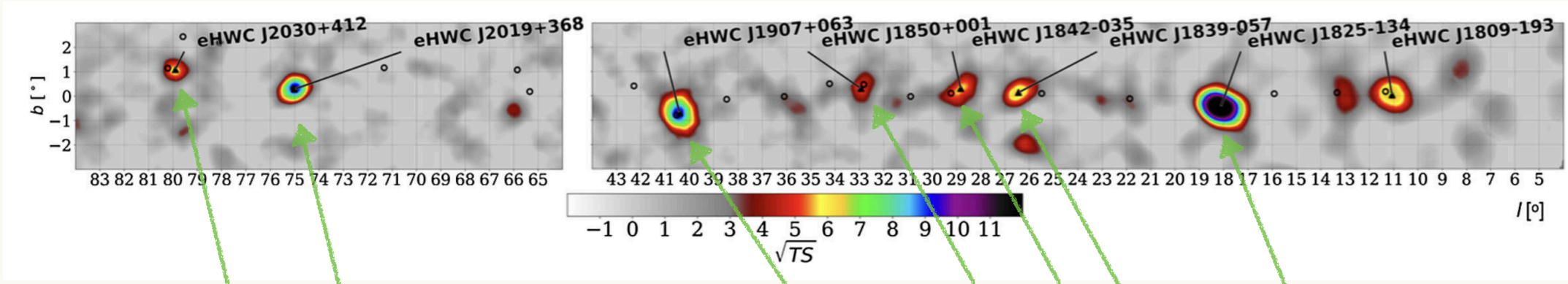
Search PeVatrons In HAWC's FOV



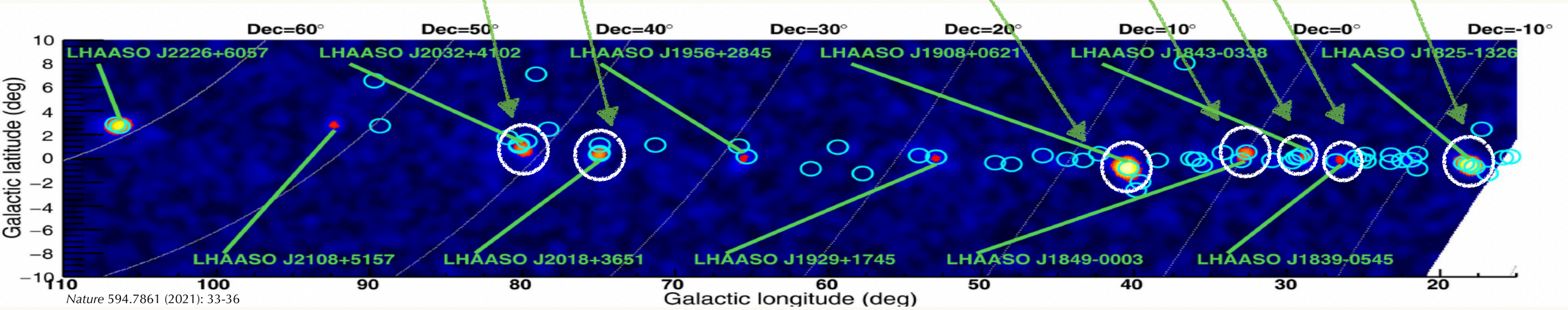
PRL 124 2 (2020): 021102

- ~1038.8 days of data
  - June 2015 to July 2018
- 9 sources are detected with energy above 56 TeV

Search PeVatrons In HAWC's FOV



LHAASO-KM2A



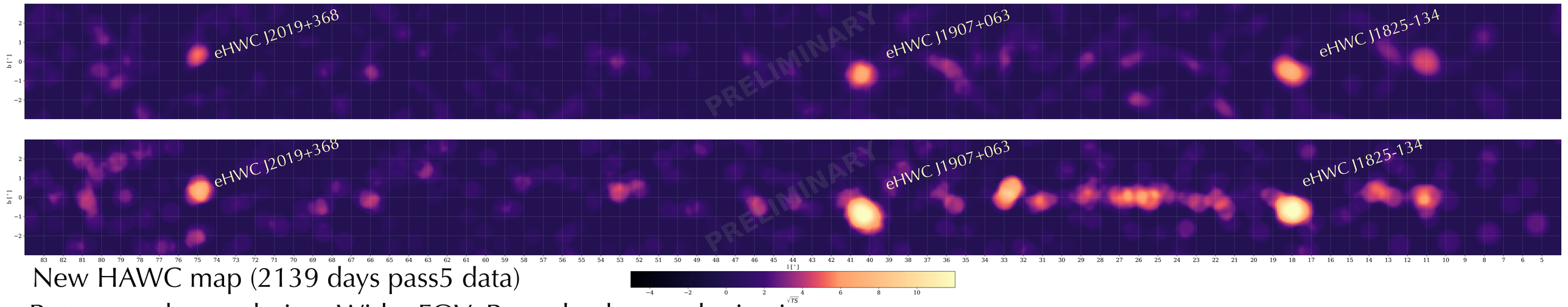
Nature 594.7861 (2021): 33-36

- LHAASO confirm all eHWC sources in the overlap region with energy > 100 TeV

Pushing to the highest energies (>100 TeV)

High-energy paper (1038 days pass4 data)

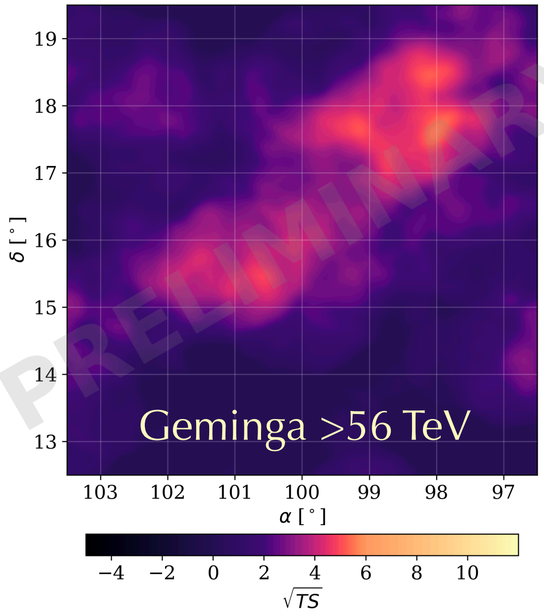
0.5° Extended Source Map

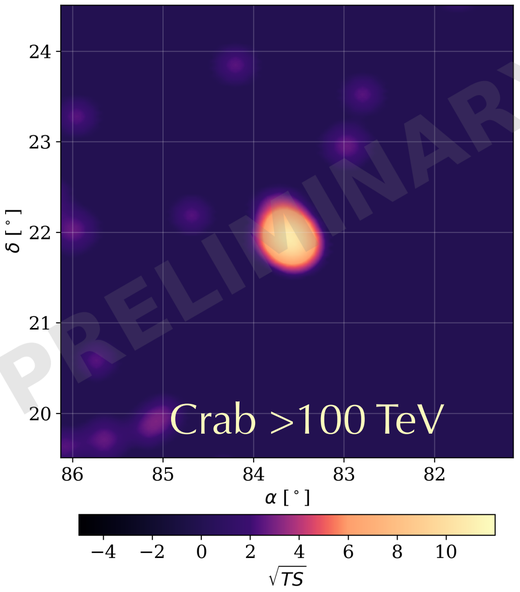


New HAWC map (2139 days pass5 data)

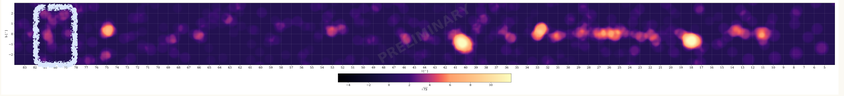
Better angular resolution; Wider FOV; Better background rejection

- New Map - **25** sources are identified above **56 TeV**
- New Map - **18** sources are identified above **100 TeV**
- New Map - **4** sources are identified above **177 TeV**
- The majority of UHE gamma-ray sources appear to be associated with PWN, but that detailed morphology studies to clearly distinguish associations are needed

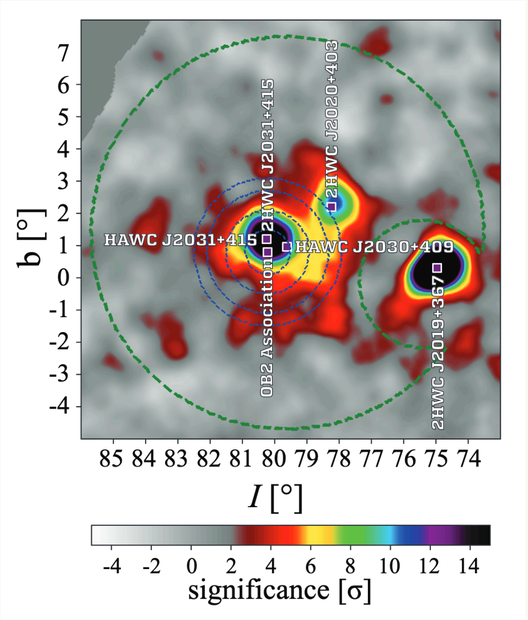




Cygnus Cocoon

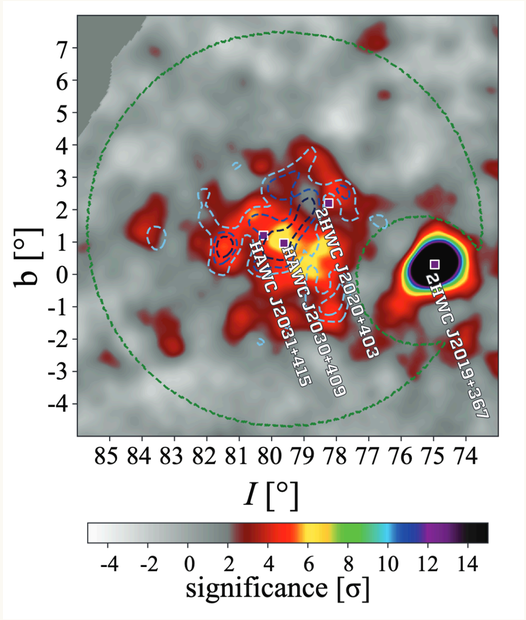


HAWC Data



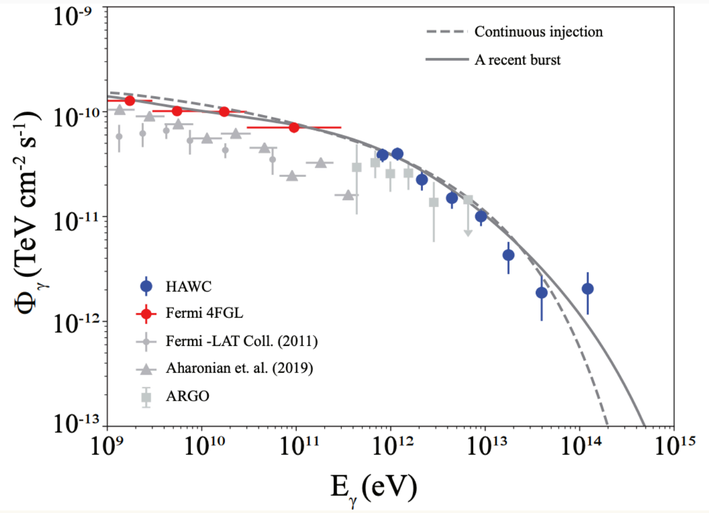
Subtract

PWN & Gamma Cygni



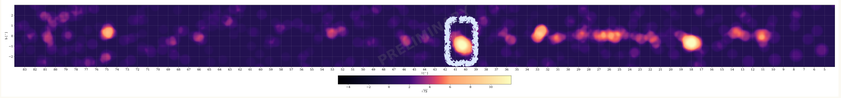
Nat Astron 5, 465–471 (2021)

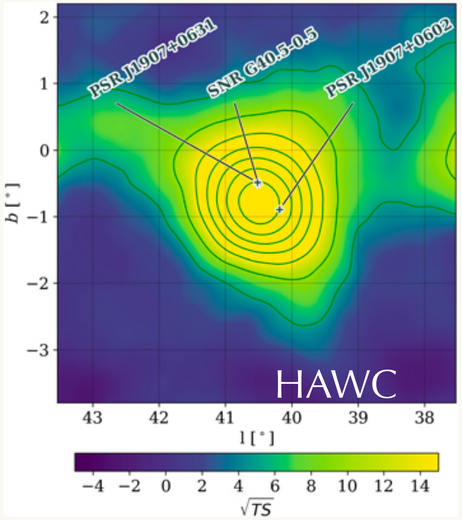
- Resolved three sources from 1343 days of data
  - PWN, Cocoon, Gamma Cygni
- First time revealed star forming region (Cyg OB2) could accelerate particles to PeV
- Cocoon spectrum have good agreement with ARGO and Fermi result
- LHAASO found the 1.4 PeV photon from Cocoon region (Looking forward with morphological study)
- HAWC flux at 100 TeV match with LHAASO measurement if using same morphology to calculate flux



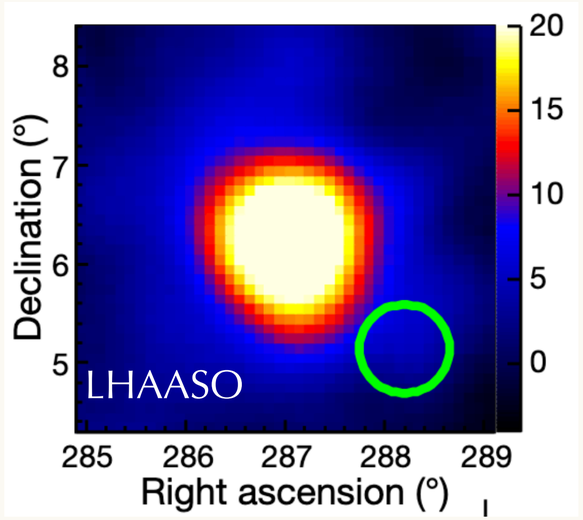
- Pass 5 analysis agree with three components model
- Results coming soon!

eHWC J1907+63

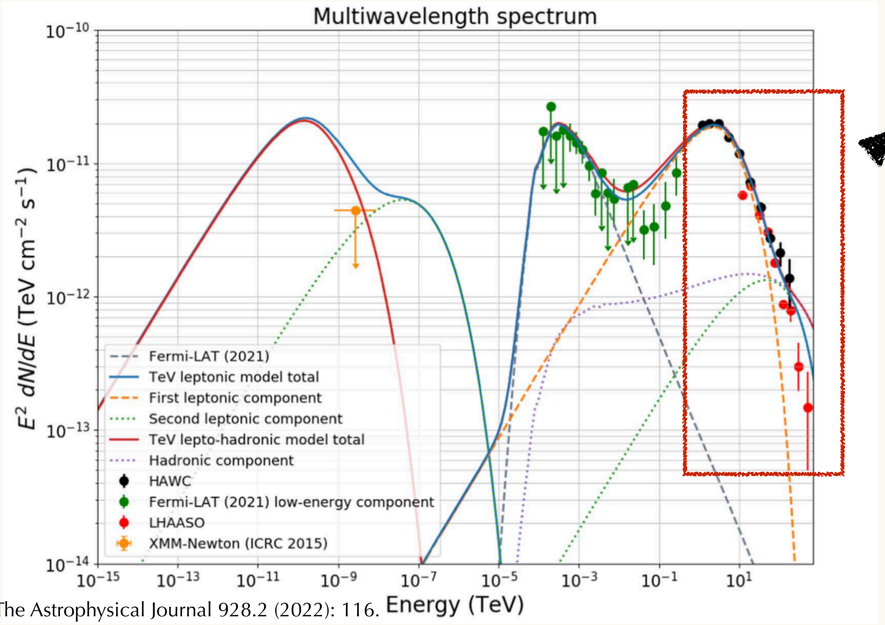




The Astrophysical Journal 928.2 (2022): 116.



Nature 594.7861 (2021): 33-36

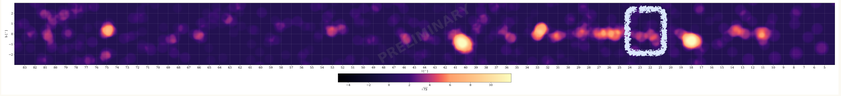


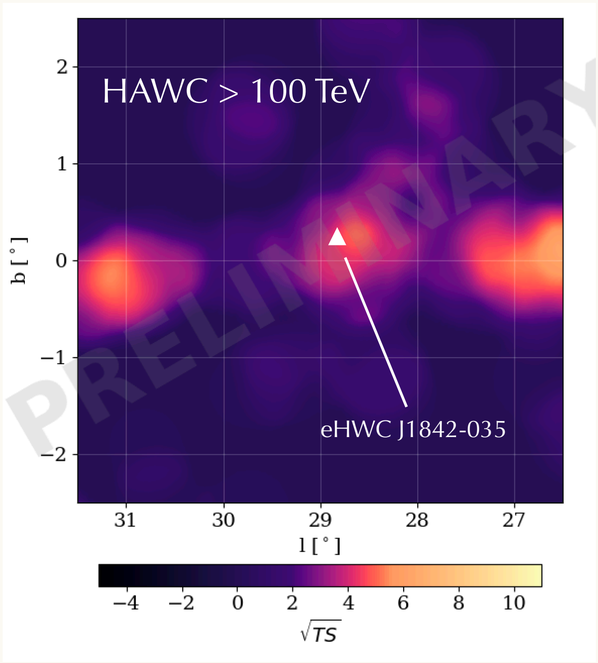
The Astrophysical Journal 928.2 (2022): 116.

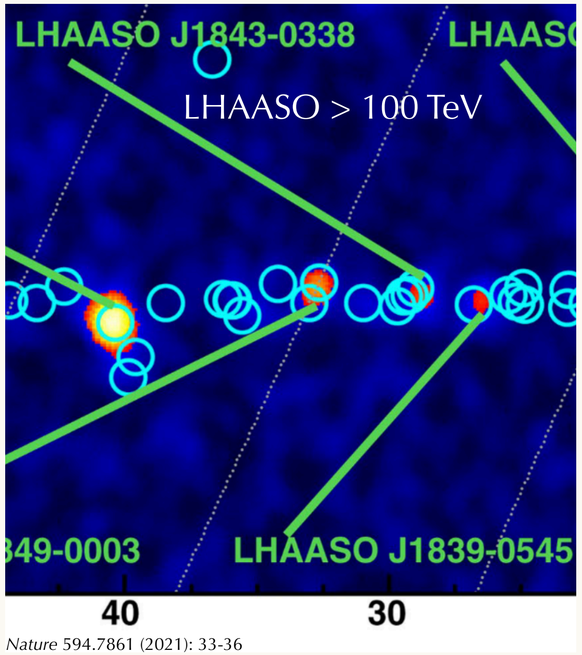
HAWC & LHAASO
flux points
from 1 TeV to 440 TeV

	HAWC	LHAASO
Location	**R.A. 287.05° Dec. 6.39°**	**R.A. 287.05° Dec. 6.35°**
Maximum measured energy	>200 TeV	440 TeV
Origin of TeV emission	Suggest leptonic in nature. Powered by PSR J1907+0602 one-population leptonic, two-population leptonic, and lepton-hadronic allowed	Both hadronic and leptonic origin are tested in LHAASO data No preference in current data

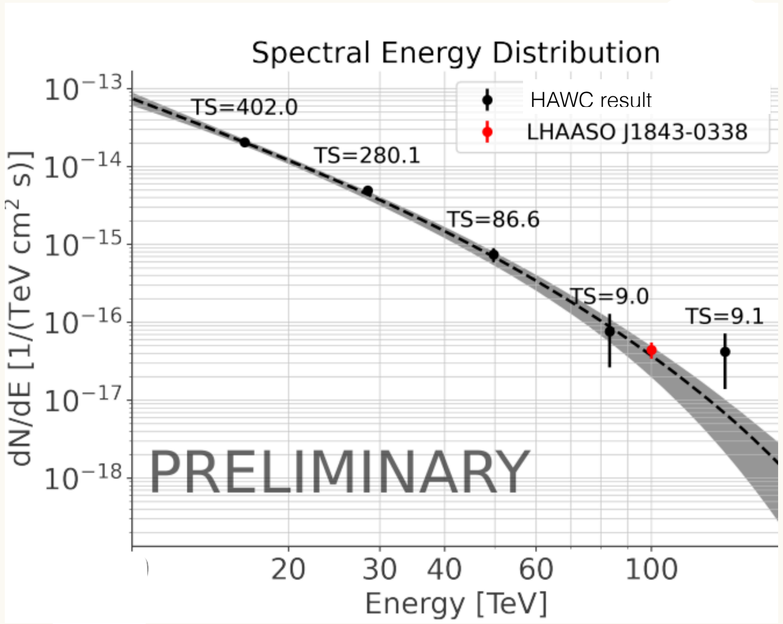
eHWC J1842-035







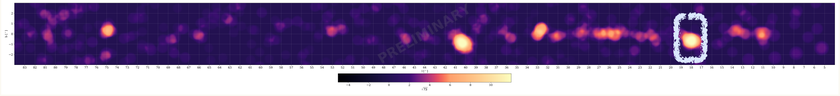
Nature 594.7861 (2021): 33-36

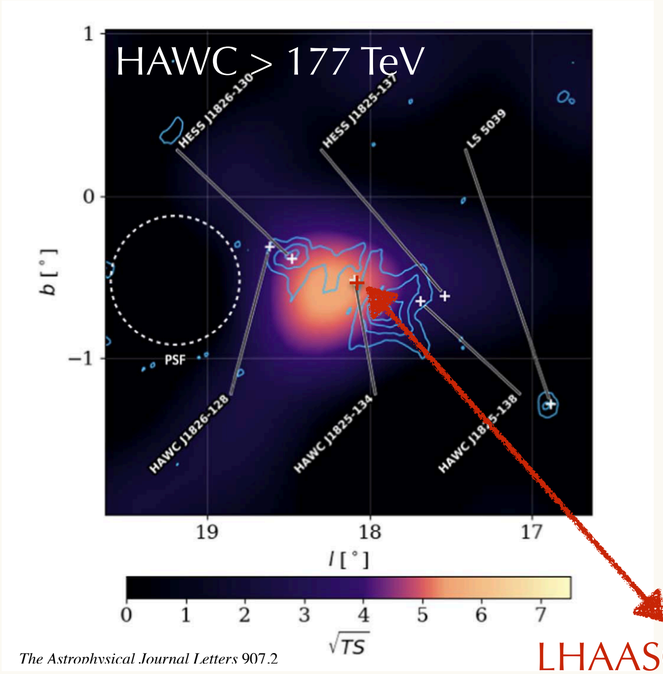


	HAWC	LHAASO
Location	**R.A. 280.72° Dec. -3.51°**	**R.A. 280.75° Dec. -3.65°**
Maximum measured energy	>56 TeV	260 TeV
Morphology	0.39° extension	0.3° extension template

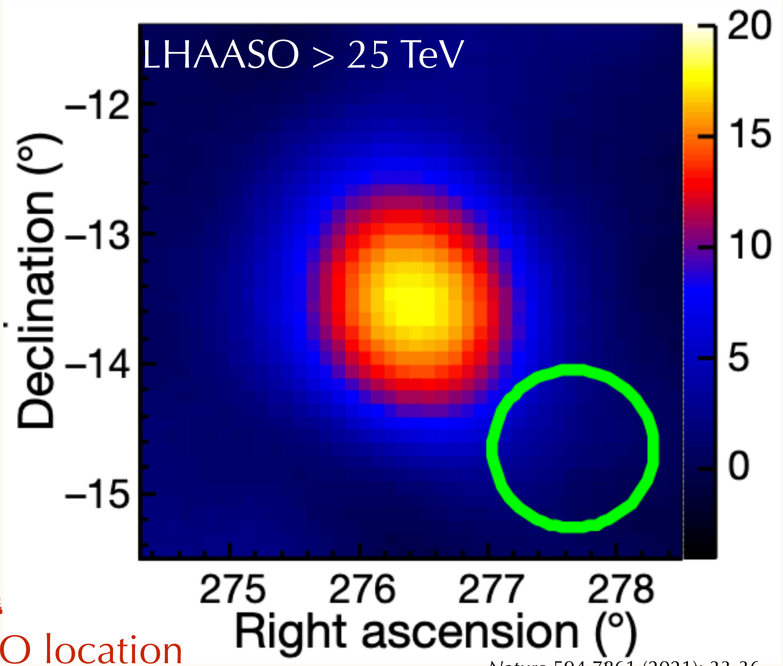
- Multi-source analysis reveal 3 components in Pass5 data
- The extended component spectrum shows great agreement with LHAASO flux point at 100 TeV

eHWC J1825-134





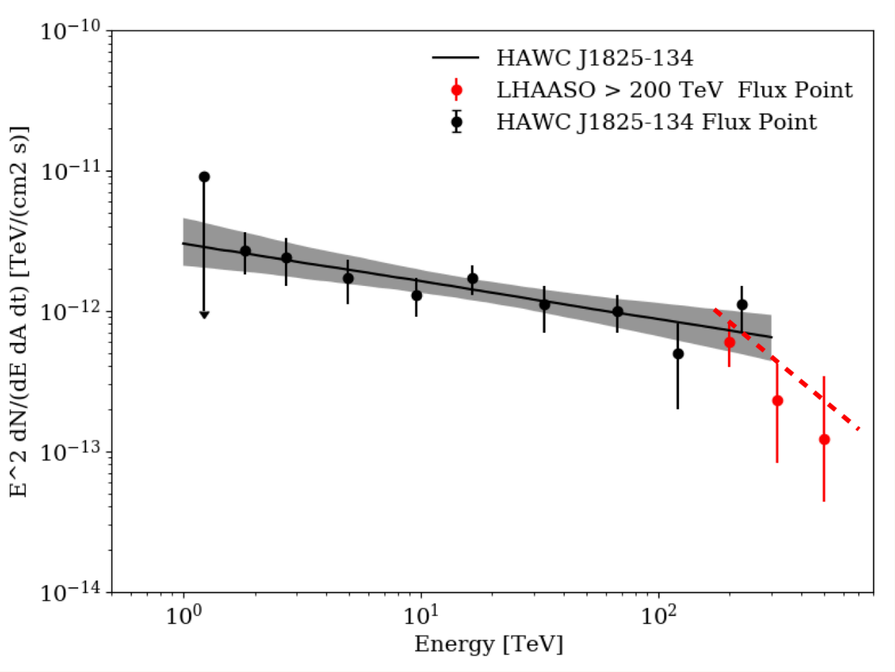
The Astrophysical Journal Letters 907.2



LHAASO location

Nature 594.7861 (2021): 33-36

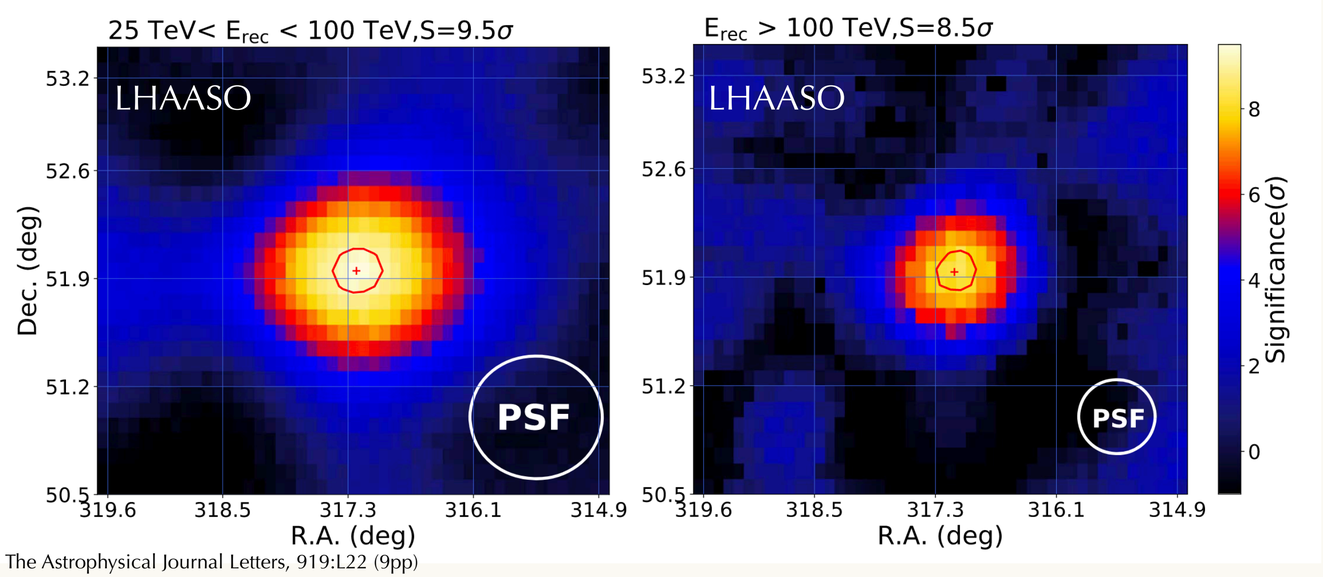
Point source spectrum



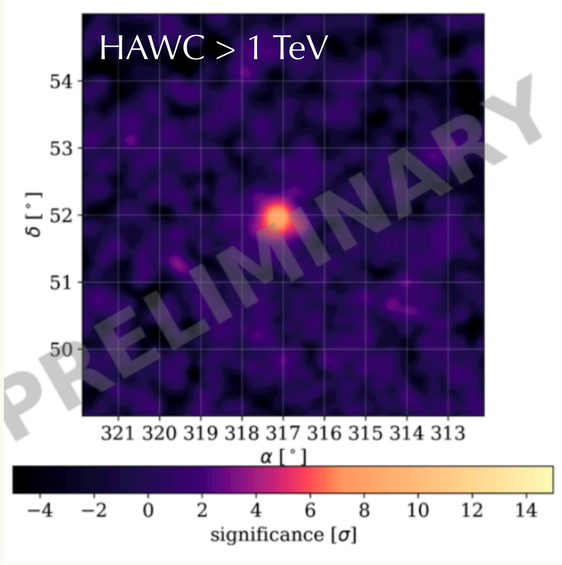
	HAWC (point source)	LHAASO
Location	**R.A. 276.44° Dec. -13.42°**	**R.A. 275.45° Dec. -13.45°**
Morphology	2 extended sources + 1point source	0.3 ° extension template
Maximum measured energy	>200 TeV	420 TeV
Origin of TeV emission	Proton accelerated by SFR Electron accelerated by PSR J1826-1334	

- Two extended HAWC sources are cutoff around 25 TeV
- Assume LHAASO > 200 TeV flux associate with HAWC point source
- LHAASO spectrum shows good continuity with HAWC

LHAASO J2108+5157

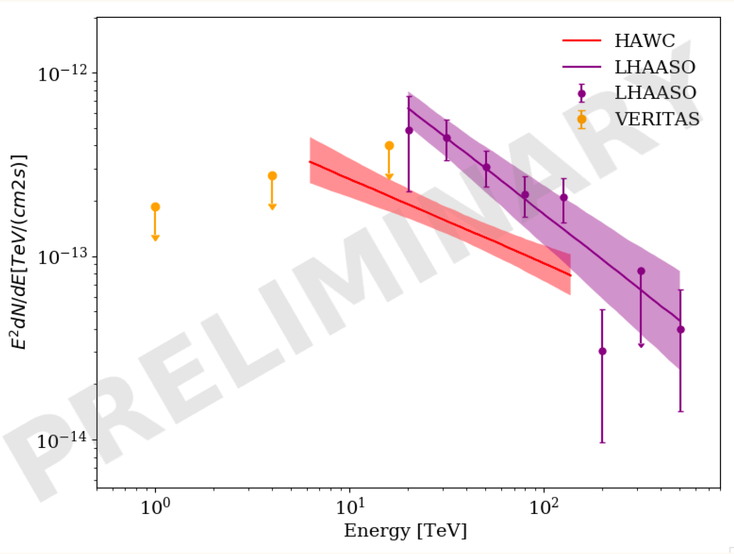


The Astrophysical Journal Letters, 919:L22 (9pp)

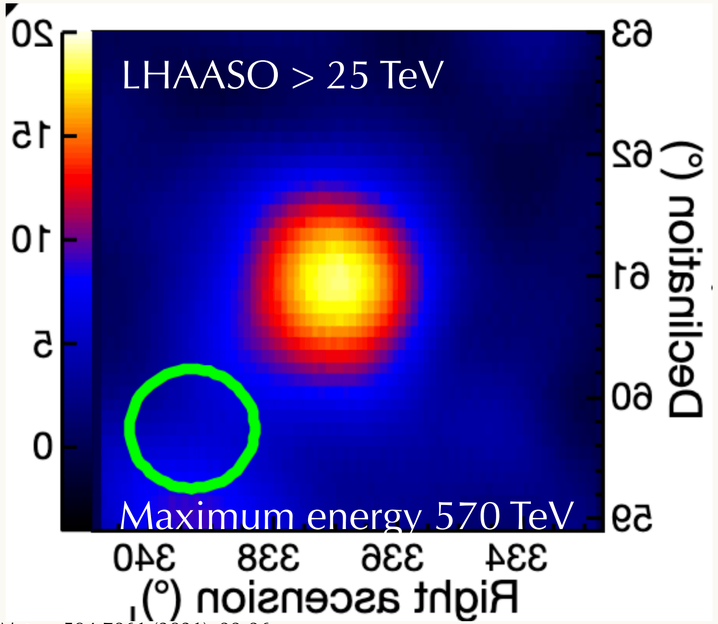


- HAWC detected LHAASO J2108+5157 in new Pass5 data
- Joint analysis with VERITAS is undergoing.
  - See more on Wednesday 15:50 Bangale. P, Galactic Source

	HAWC	LHAASO
Location	**R.A. 317.14° Dec. 51.93°**	**R.A. 371.22° Dec. 51.95°**
Maximum measured energy	>137 TeV	430 TeV
Morphology	Point-like	Point-like

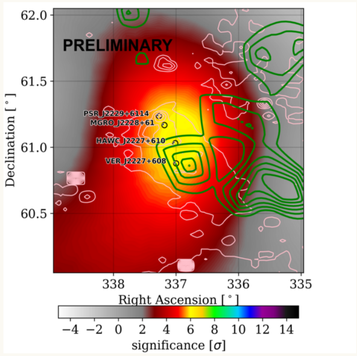


HAWC J2227+ 610 (Boomerang region)

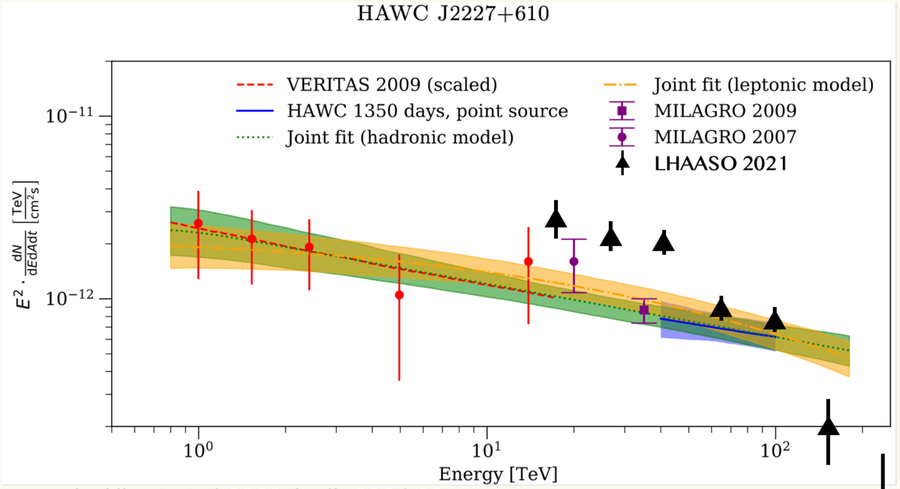


Nature 594.7861 (2021): 33-36

HAWC 1347 days



Maximum energy 180 TeV



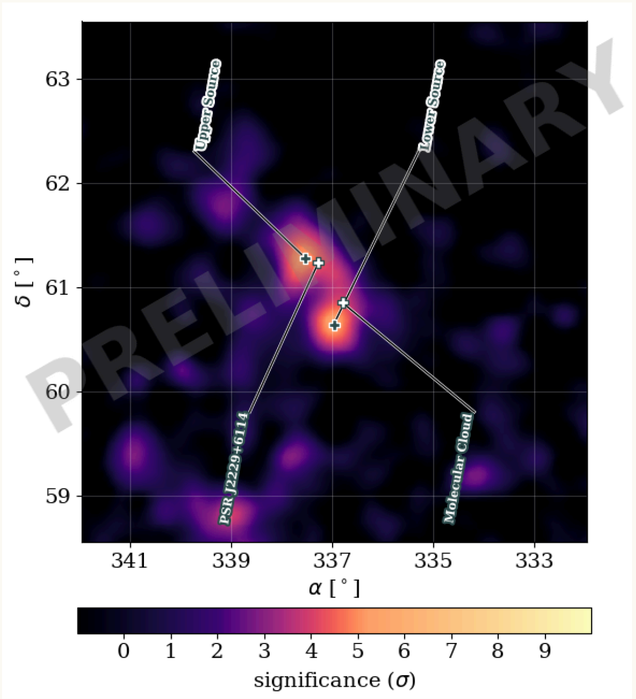
A. Albert et al 2020 ApJL 896 L29

- SNR G106.3+2.7 is a comet-shaped radio source
- PSR J2229+6114, seen in radio, X-rays, and gamma rays and it's pulsar wind nebula(PWN), Boomerang Nebula is contained in the remnant
- Pass 4 analysis
  - HAWC morphology and location are consistent with VERITAS
  - The joint VERITAS-HAWC spectrum is well fit by a power law from 900 GeV to 180 TeV
  - If hadronic, the cutoff energy in the underlying proton spectrum is constrained to be above 800 TeV

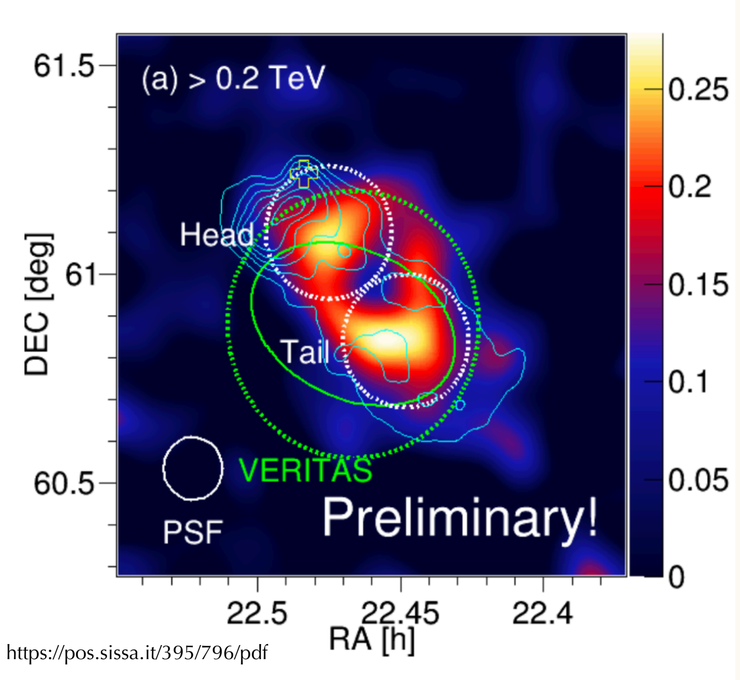
HAWC J2227+ 610 (Boomerang region)

- In new HAWC data, HAWC resolves two sources
- MAGIC sees two sources
  - Head Region (Upper Source)
    - Contains PWN and PSR
    - IC scattering in the PWN
  - Tail Region (Lower Source)
    - Molecular cloud nearby
    - Both pion decay and IC scattering are plausible

HAWC Pass5 Data

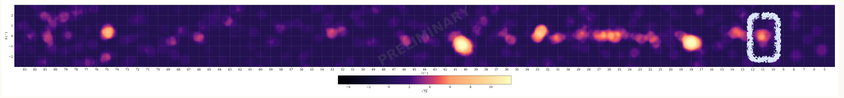


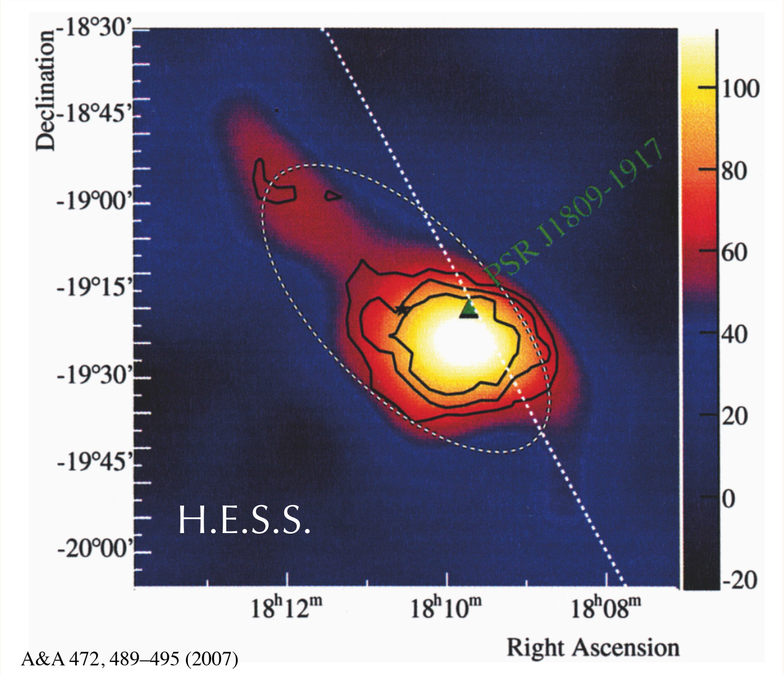
MAGIC



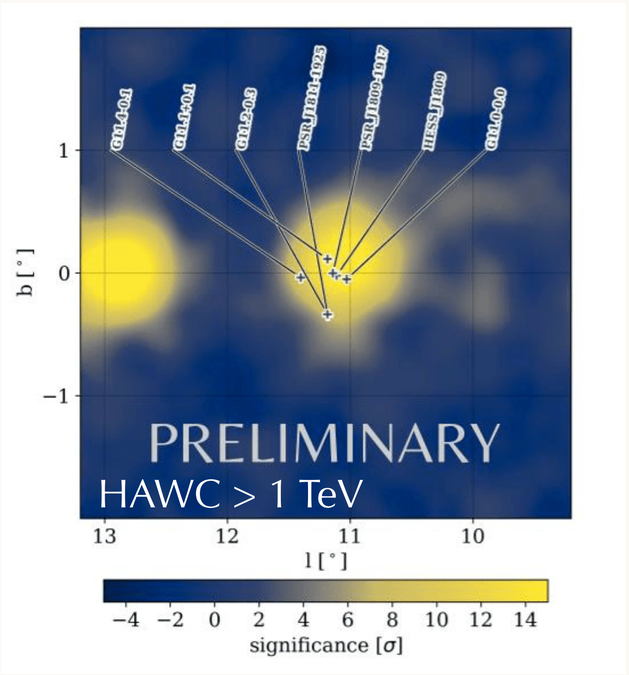
https://pos.sissa.it/395/796/pdf

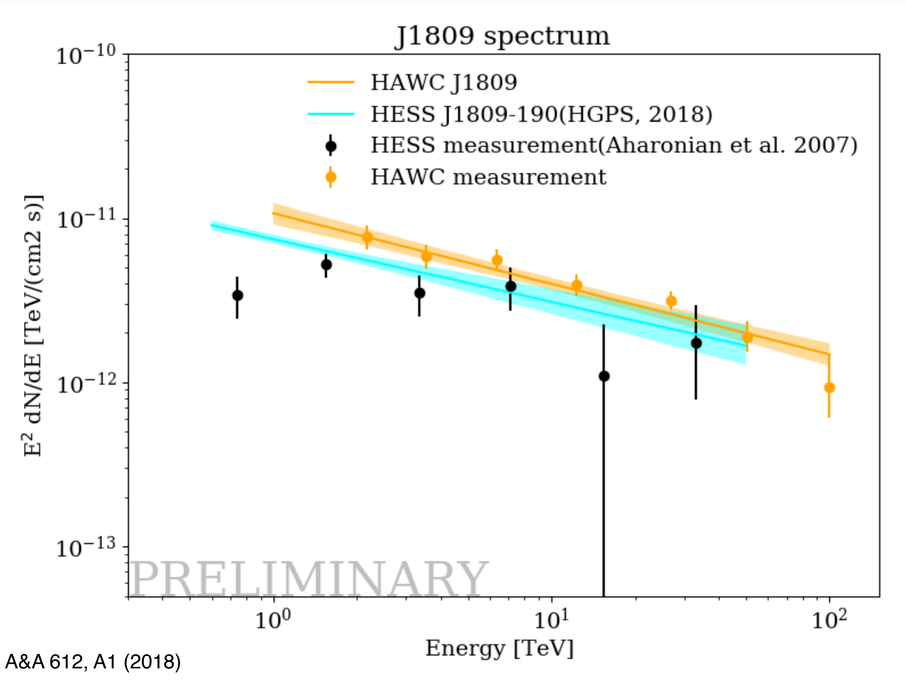
HESS J1809-1917





A&A 472, 489–495 (2007)





A&A 612, A1 (2018)

- Not detected by LHAASO's 12 UHE sources, at the edge of their FOV
- PSR J1809-1917 is a young (age = 51 kyr) pulsar, E = 1.8 x 10^{36} $erg\ s^{-1}$
- Several SNRs are in the region, G11.0-0.0 is spatially coincident with the peak of the H.E.S.S. emission
- Possibly Hadronic PeVatron
- Preliminary analysis shows good agreement with H.E.S.S., SED extended to 100 TeV without cutoff

Conclusion and Outlook

- eHWC sources are confirmed by LHAASO with higher energies
- More PeVatron candidates found in HAWC pass5 dataset
- Improved angular reconstruction allows to associate γ-ray source with accelerator
- More sensitivity results using outriggers are coming!

THANKS!