ICRC2019 36th International Cosmic Ray Conference - Madison, WI, USA
THE ASTROPARTICLE PHYSICS CONFERENCE

Spectral and Morphological Studies of the Very High Energy Gamma-Ray Source 2HWC J1825-134

Francisco Salesa Greus (IFJ-PAN, Krakow),
Sabrina Casanova (IFJ-PAN & MPIK)
for the HAWC Collaboration

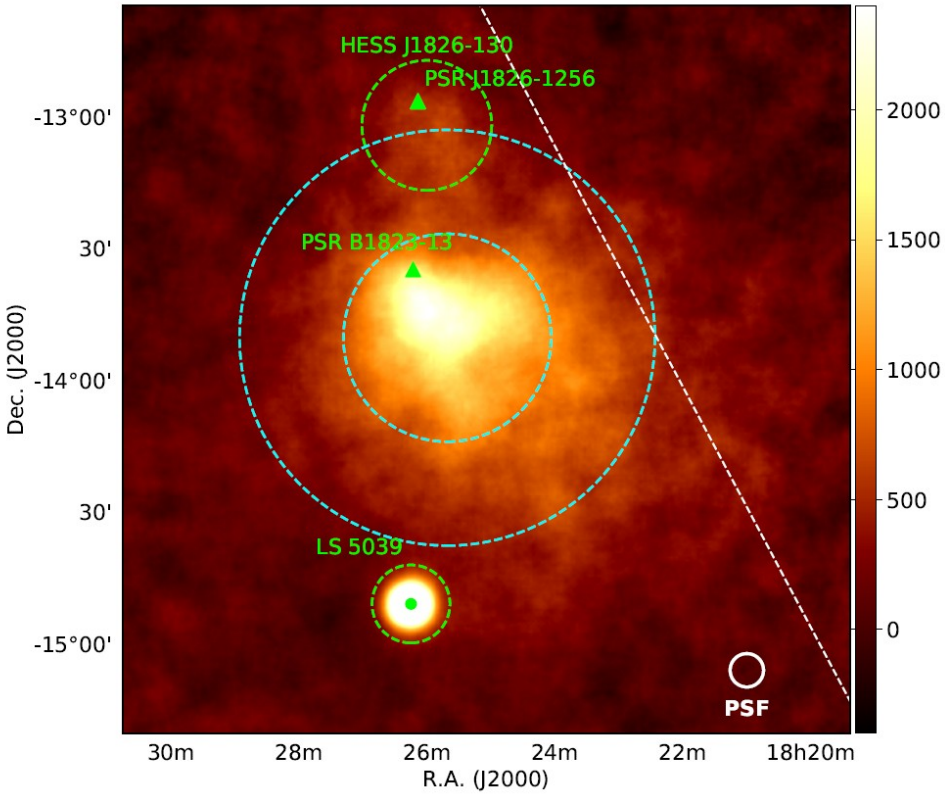
HAWC
High Altitude Water Cherenkov
Gamma-Ray Observatory

Outline

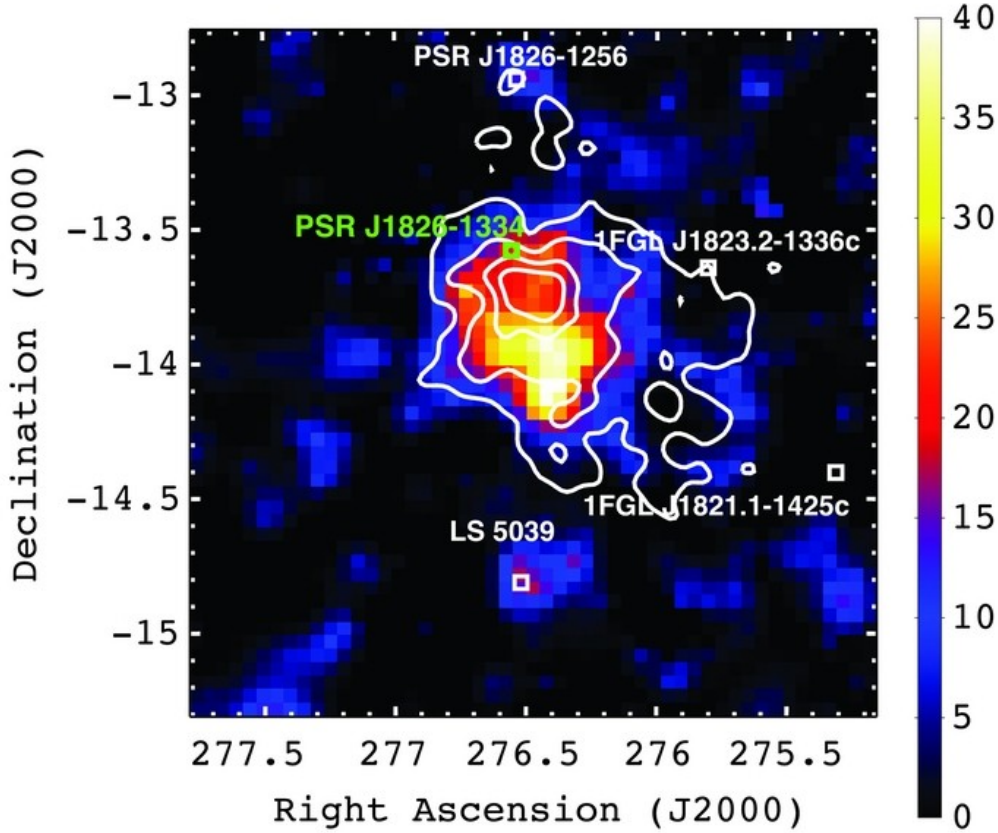
- 2HWC J1825-134 region observed by other experiments.
- The HAWC observatory.
- 2HWC J1825-134 region observed by HAWC.
- Source modeling.
- Spectral studies.
- Morphological studies.
- Associated particle spectra.
- Conclusions.

2HWC J1825-134 region observed by other experiments

H.E.S.S.

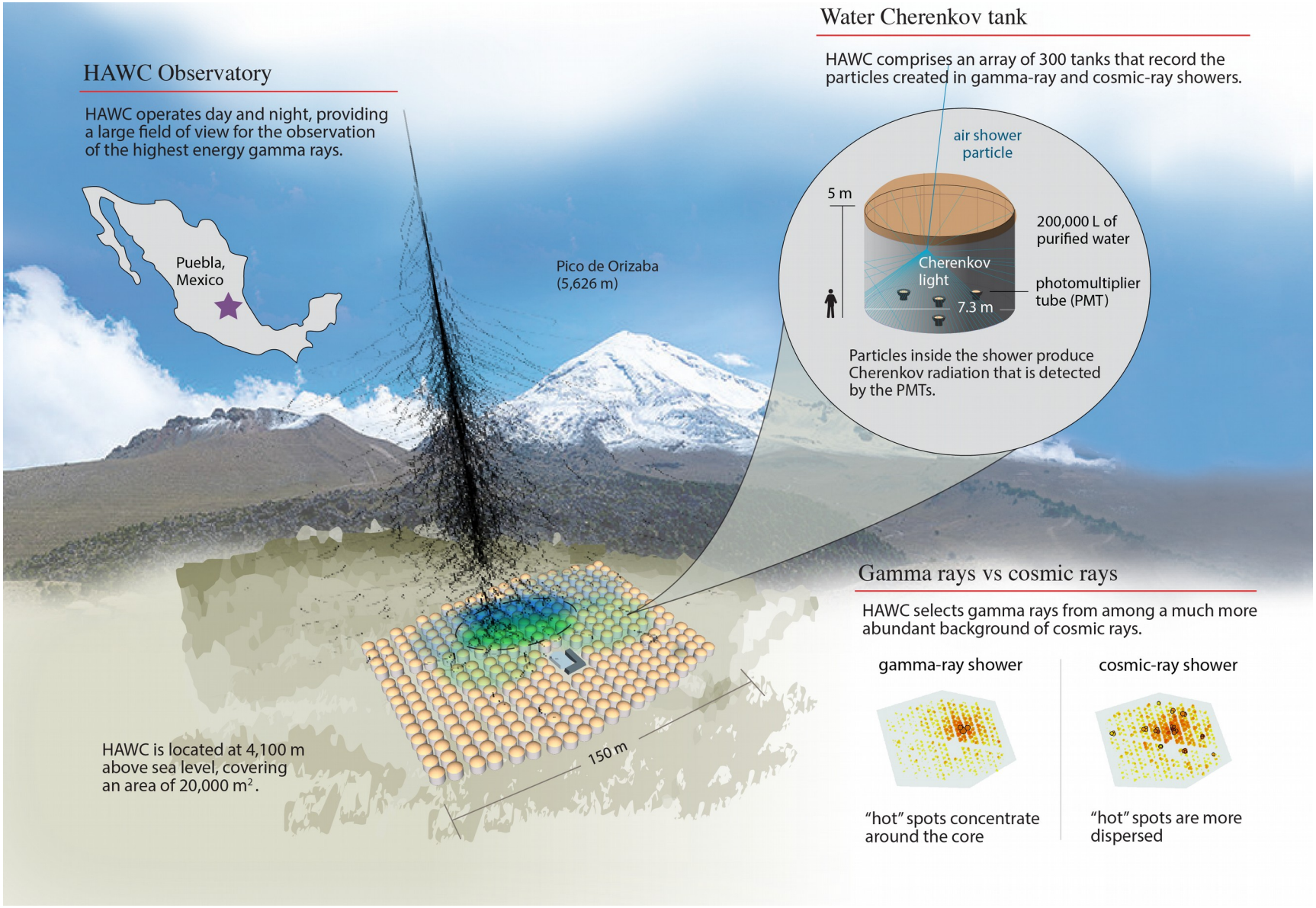


Fermi-LAT



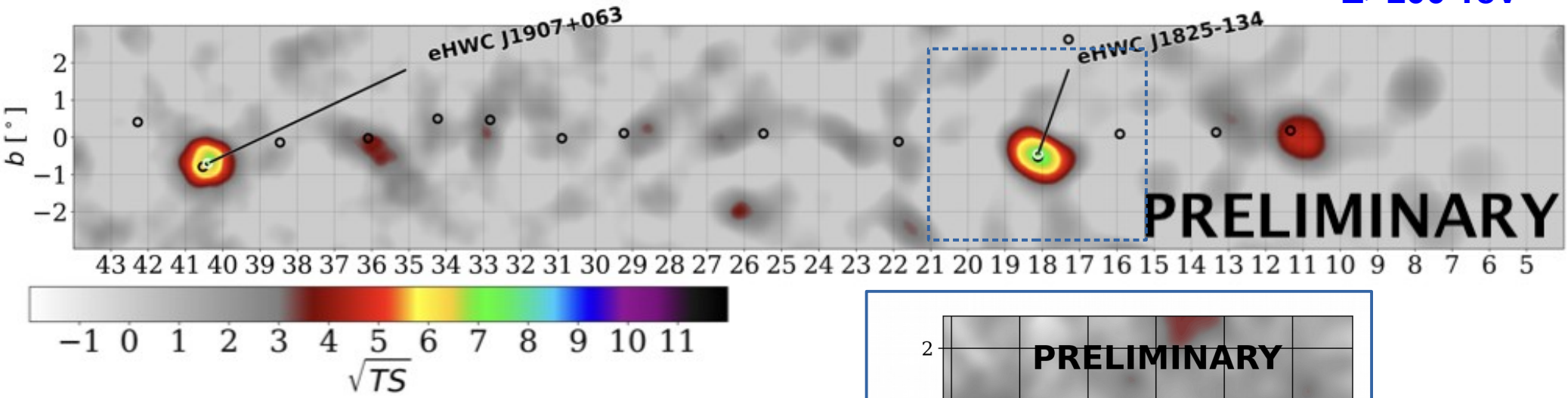
- The region has been observed by H.E.S.S. **[H.E.S.S. coll. A&A 621, A116 (2019)]** and Fermi-LAT **[Grondin, M.-H. et al., ApJ 738 (2011)].**
- Apart from LS 5039, H.E.S.S. detected 2 sources in the same region: H.E.S.S. J1825-137 (PWN), H.E.S.S. J1826-130 (UNID) **[PoS(ICRC2017)686]**.

The HAWC Observatory

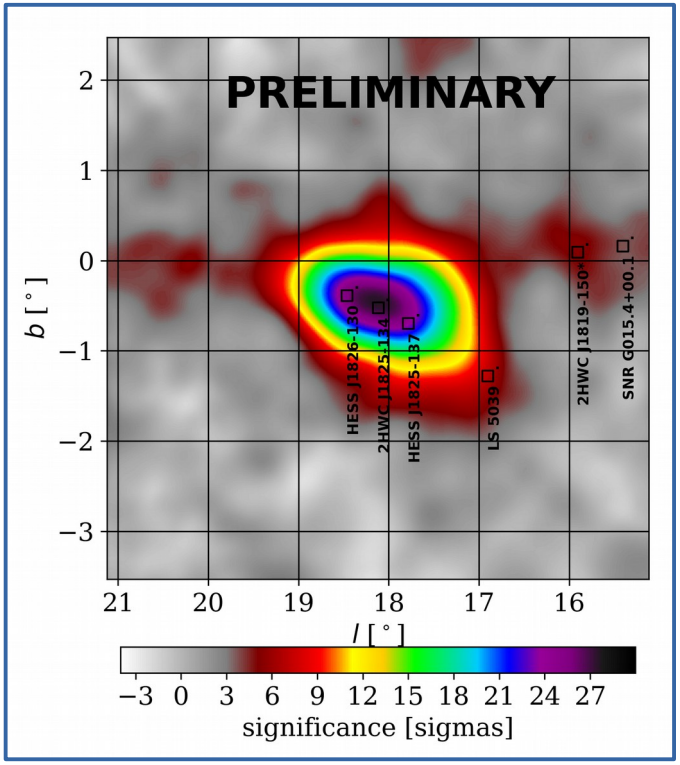


2HWC J1825-134 region in HAWC

E>100 TeV

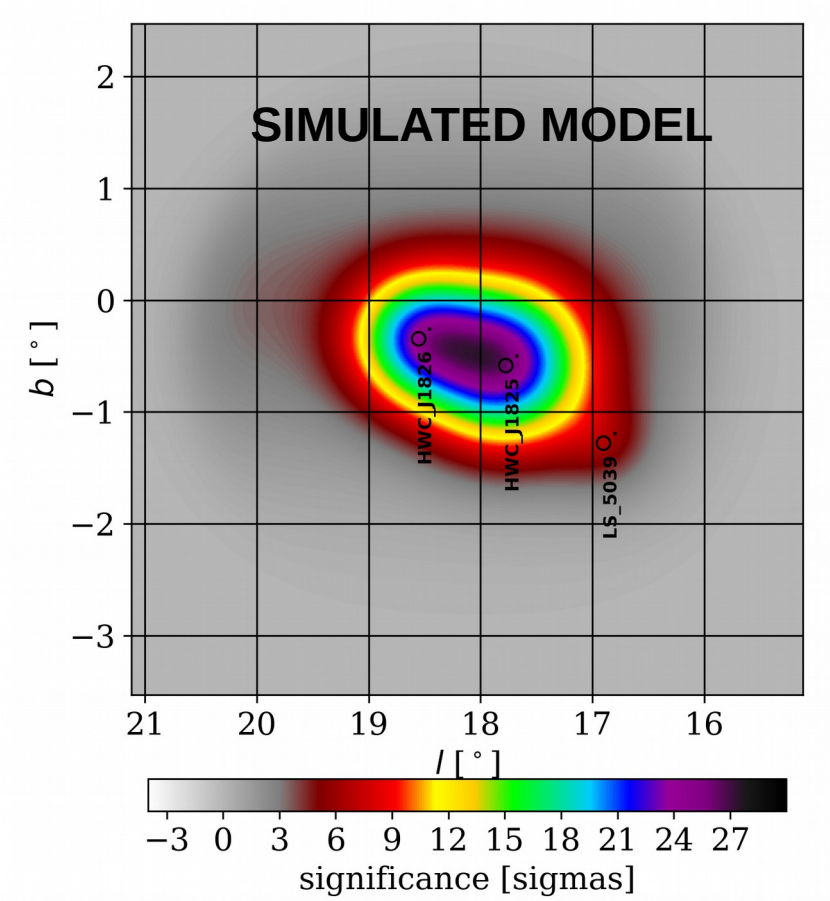


- Complex region which contains one of the brightest sources (**2HWC J1825-134**) in the 2nd HAWC catalog **[HAWC coll. ApJ 843:40 (2017)]**.
- Also it is the most significant region in the new high-energy HAWC catalog (**eHWC J1825-134**) and candidate to emit >100TeV **[GAI2b, K. Malone]**.
- More on very high-energy photons in **[GAI9c, J. T. Linnemann].**
- Contamination from the nearby source LS 5039 may be relevant for the analysis.



E>1 TeV
(note scale change)

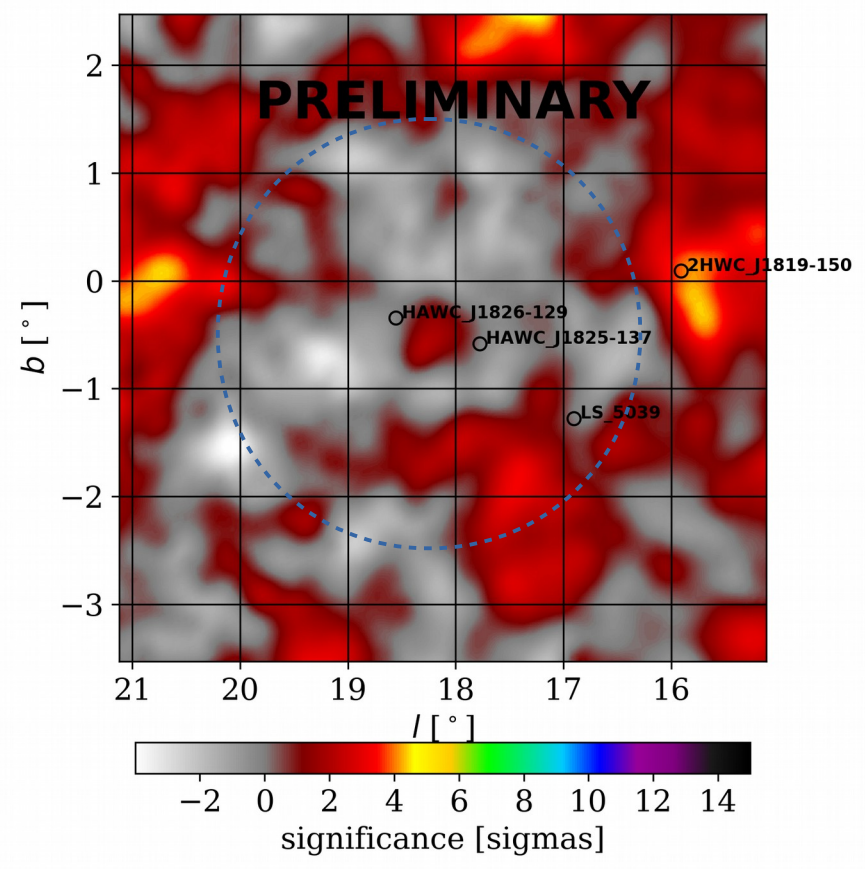
Source Modeling

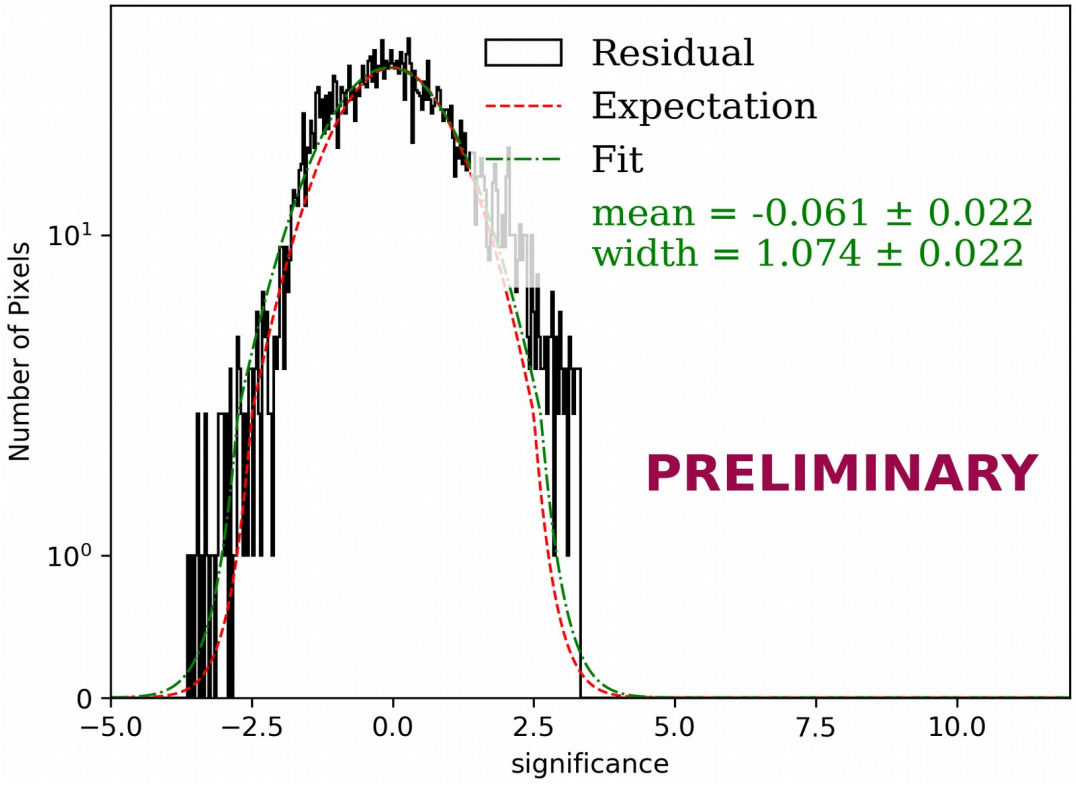


source	RA [deg] J2000	Dec [deg] J2000
HAWC J1825-137	276.35 ± 0.03	-13.73 ± 0.05
HAWC J1826-129	276.51 ± 0.03	-12.93 ± 0.05

- Analysis with The Multi-Mission Maximum Likelihood framework (3ML) https://github.com/threeML/
- Gaussian extended morphology with power law with E cutoff spectrum.
- LS 5039 modeled as point source with power law spectrum.
- GDE template: Gaussian from the Galactic plane (1˚ width), power law spectrum as in **[PoS(ICRC2017)741]**
- **2 sources (HAWC J1825-137 & HAWC J1826-129) favored** (>5σ) w.r.t. 1 source (2HWC J1825-134).

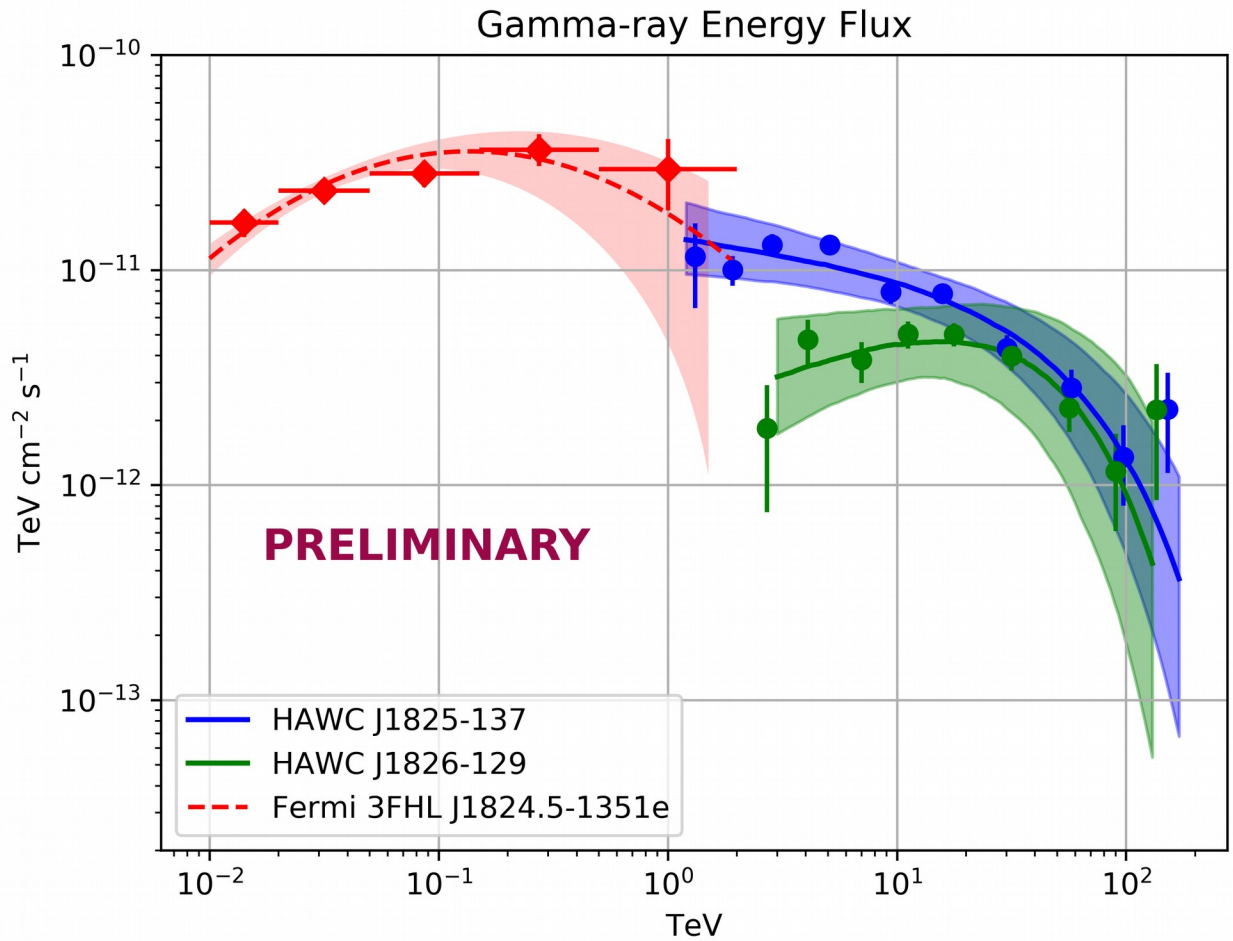
Source Modeling





- Model testing: We expect a Gaussian centered at 0 and width 1 from background fluctuations.
- There is a ~4σ region (discussed later) and a ~2σ between the HAWC sources which may indicate that the Gaussian morphology used is not elaborated enough to perfectly reproduce the observed emission.

Spectral studies

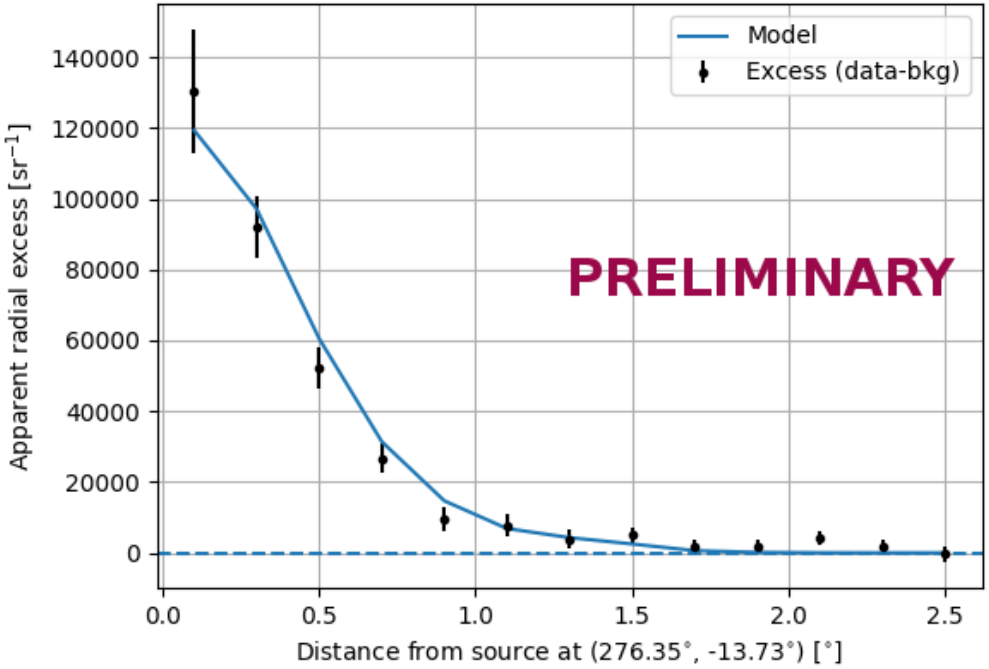


- HAWC J1825-137 dominates at low energies but the fluxes are comparable at E>30TeV.
- Hard spectrum (index =-1.5) measured for HAWC J1826-129.
- Fermi 3FHL J1824.5-1351e connects well with HAWC J1825-137 at ~1TeV.
- Flux points computed as in: https://arxiv.org/abs/1905.12518
- Systematics uncertainties:
  1) 50% flux.
  2) 15% spectral index.
  3) (+100%, -20%) energy cutoff.

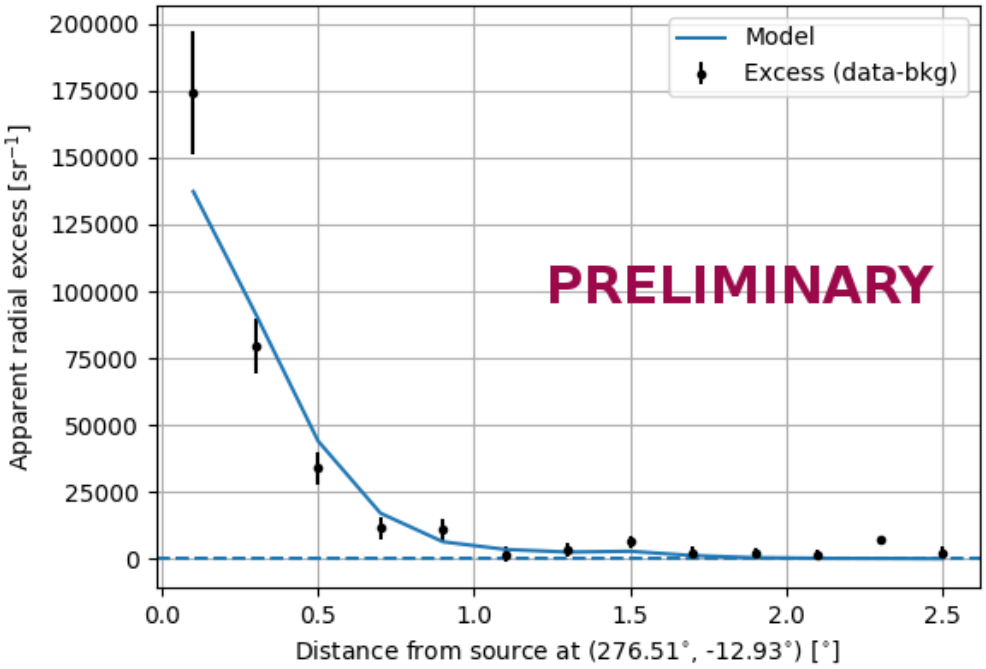
GDE	HAWC J1825-137				HAWC J1826-129			
N(10TeV) 10^{-11} [cm^{-2} TeV^{-1} s^{-1} sr^{-1}]	σ [deg]	N(18TeV) 10^{-14} [cm^{-2} TeV^{-1} s^{-1}]	index	E_{cut} [TeV]	σ [deg]	N(18TeV) 10^{-14} [cm^{-2} TeV^{-1} s^{-1}]	index	E_{cut} [TeV]
2.0 ± 0.2	0.34 ± 0.03	$2.9^{+0.7}_{-0.6}$	-2.16 ± 0.12	60^{+30}_{-20}	0.23 ± 0.03	$2.6^{+1.1}_{-0.8}$	-1.5 ± 0.3	33^{+20}_{-12}

Morphology

HAWC J1825-137

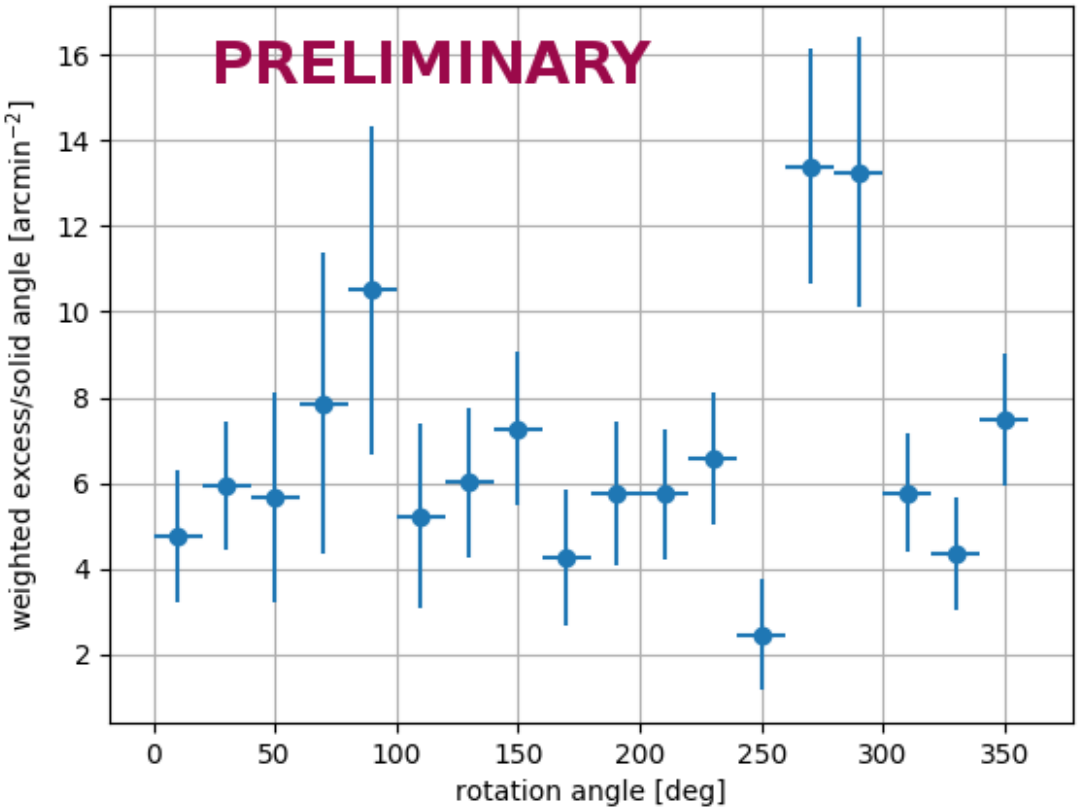


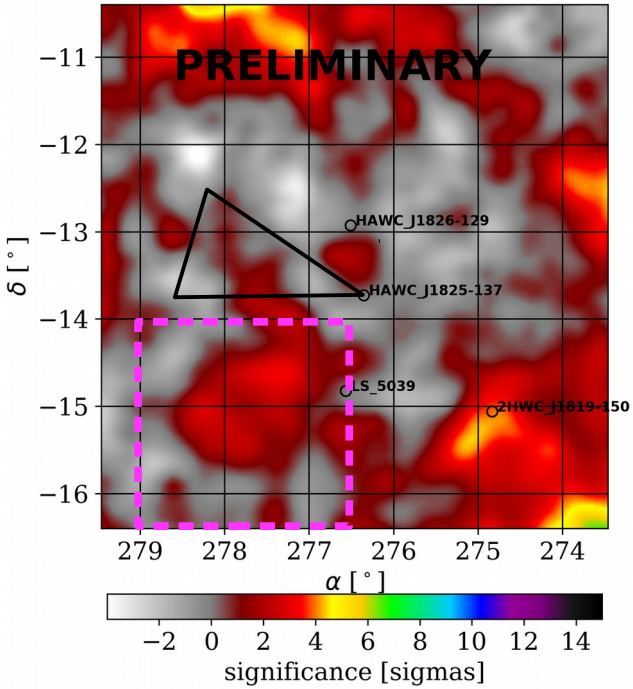
HAWC J1826-129

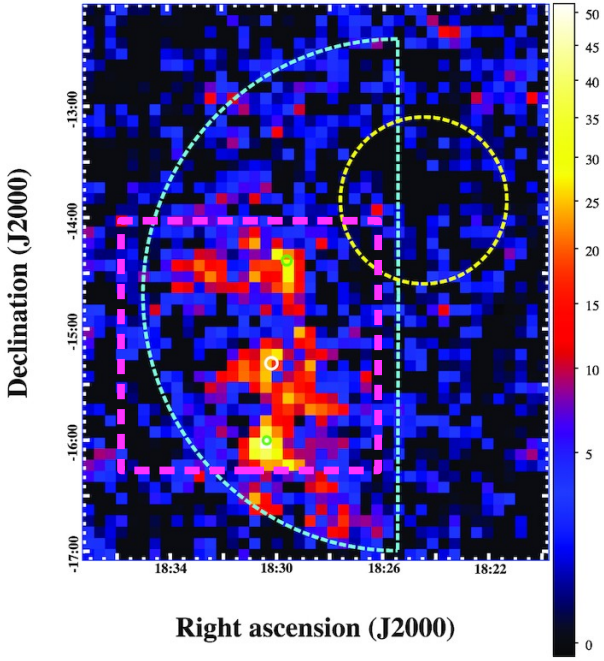


- Contributions from other sources were masked.
- We tested a disk morphology for HAWC J1825-137 but Gaussian is preferred (>5σ).
- HAWC J1825-137 (width 0.34˚) is larger than HAWC J1826-129 (width 0.23˚).
- Good agreement between data (black points) and modeling (blue line).
- Energy dependent morphology study. Tested in 3 energy bins:
  - **HAWC J1825-137**. Gaussian width: 0.38 ± 0.04° [1-10TeV], 0.29 ± 0.04° [10-56 TeV], 0.21 ± 0.07° [>56 TeV]. **Hint of energy dependent morphology.**
  - **HAWC J1826-129 inconclusive.**

Morphology

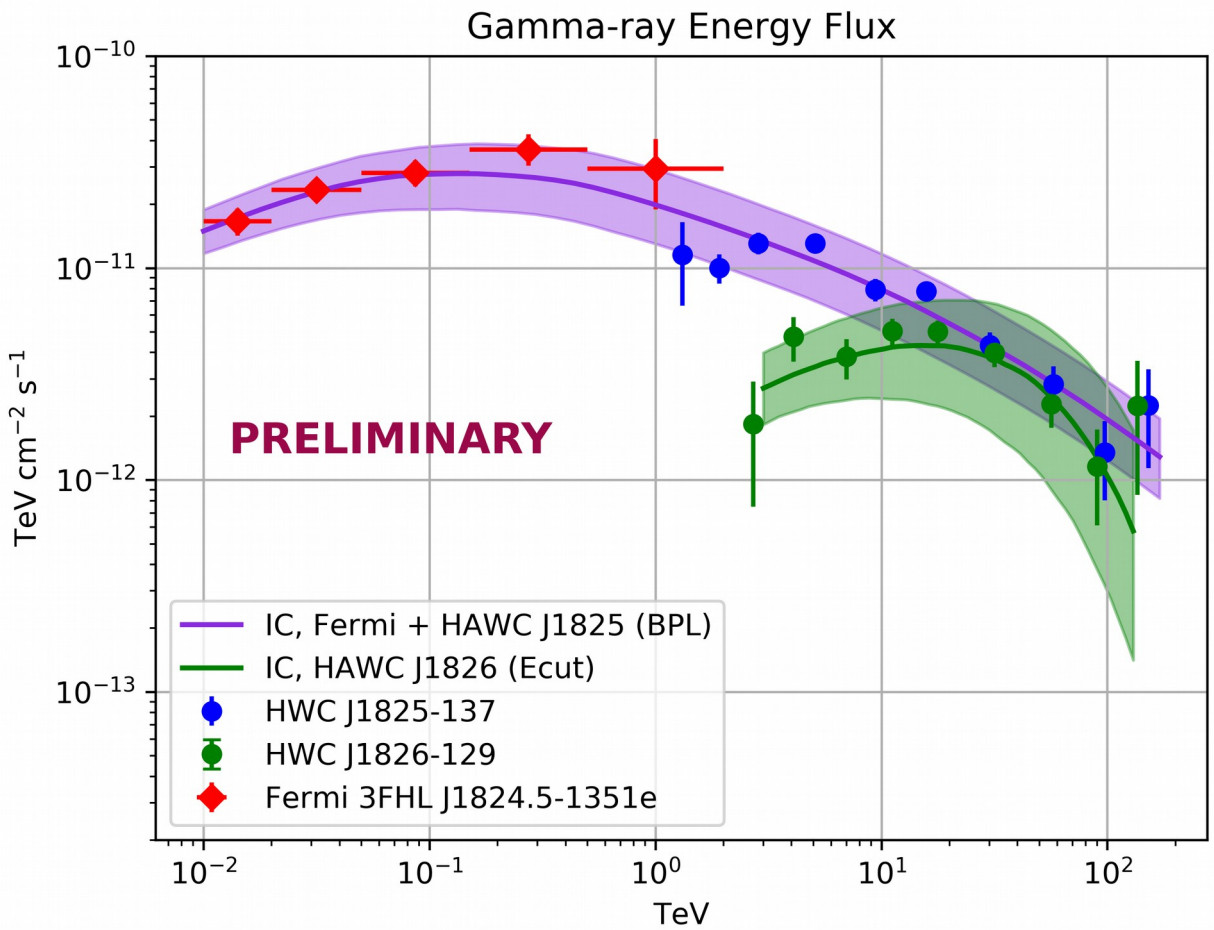






- Looking for anisotropic emission we scanned the region around **HAWC 1825-137** in steps of 20 degrees (e.g. black triangle).
- Contributions from other sources were masked.
- We found a ~4σ excess spatially coincident with Fermi-LAT observations (magenta boxes) **[M. Araya et al. MNRAS, Vol 485, Issue 1 (2019), 1001-1007]**.

Particle spectra



- Used Naima to derive the particle spectrum **[PoS (ICRC2015) 922].**
- HAWC J1825-137 assumed PWN, modeled with Inverse Compton **[Khangulyan et al, ApJ 783 (2014)]** with paremetrization from **[Popescu et al MNRAS 470 (2017)]** and 4kpc distance **[ATNF pulsar catalog].**
- HAWC J1826-129 is unidentified. We tested:
  - IC with parametrization **[Vernetto & Lipari PRD D94 (2016)]** and distance 1.5kpc **[ATNF]**.
  - π_0 **[Kafexhiu et al PRD 90 (2014)]** with density n_h=550 cm^{-3} and distance 4kpc **[Voisin et al MNRAS 458 (2016)]**.
- Broken power law is preferred for Fermi 3FHL J1824.5 + HAWC J1825-137.
- Power law with E cutoff preferred for HAWC 1826-129. **IC slightly (2σ) preferred** over π_0.

Broken power law, IC model	W 10^{48} [erg]	E_{break} [TeV]	index_1	index_2
HAWC J1825-137 + Fermi 3FHL J1824.5-1351e	(5.0 ± 1.0)	0.75 ± 0.18	$1.3^{+0.3}_{-0.4}$	3.01 ±0.04

Power law * E cutoff, IC model	W 10^{46} [erg]	index	E_{cut} [TeV]
HAWC J1826-129	$1.4^{+0.5}_{-0.3}$	1.2 ± 0.4	51^{+14}_{-11}

Conclusions

- 2HWC J1825-134 from the 2nd HAWC catalog contains two sources: HAWC J1825-137 & HAWC J1826-129.
- Gaussian morphology gives a fair modeling for both.
- Hint of E dependent morphology for HAWC J1825-137.
- Emission detected at ~4σ around HAWC J1825-137 spatially coincident with Fermi-LAT detection.
- Inverse Compton modeling slightly preferred over π_0 for HAWC 1826-129.
- Data from outriggers array coming up soon, key to improve the analysis.