

# Discovery of 100 TeV $\gamma$ -rays from HESSJ1702-420: a new PeVatron candidate

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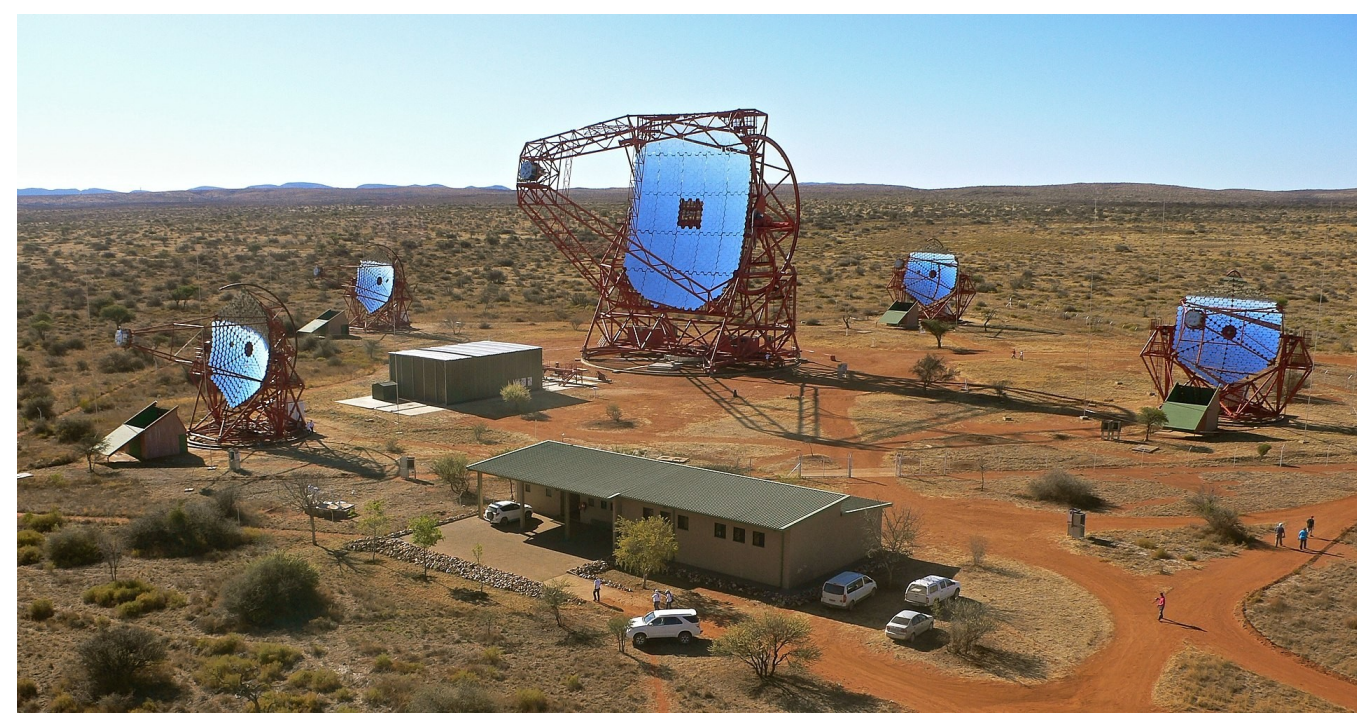
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## Abstract

The identification of active PeVatrons, hadronic particle accelerators reaching the knee (at the energy of few PeV), is crucial to understand the origin of cosmic rays in the Galaxy. In this context, we report on new H.E.S.S. observations of the PeVatron candidate HESS J1702-420, an unidentified TeV source with **no multi-wavelength counterpart**, that have revealed the presence of  **$\gamma$ -rays up to 100 TeV at 5 sigma confidence level**. This is the first time in H.E.S.S. history that photons with such high energy are clearly detected. Remarkably, the new deep observations allowed the discovery of a **new  $\gamma$ -ray source component**, called **HESS J1702-420A**, that was previously hidden under the bulk emission traditionally associated with HESS J1702-420. This new object has a power-law spectral slope  $< 2$  and a gamma-ray spectrum that, extending with **no sign of curvature up to 100 TeV**, makes it an excellent candidate site for the presence of extremely high-energy cosmic rays. This discovery brings new information to the open debates on the nature of the unidentified source HESSJ1702-420, **one of the most compelling PeVatron candidates in the  $\gamma$ -ray sky**, and on the origin of Galactic cosmic rays.

## H.E.S.S. observations and data analysis

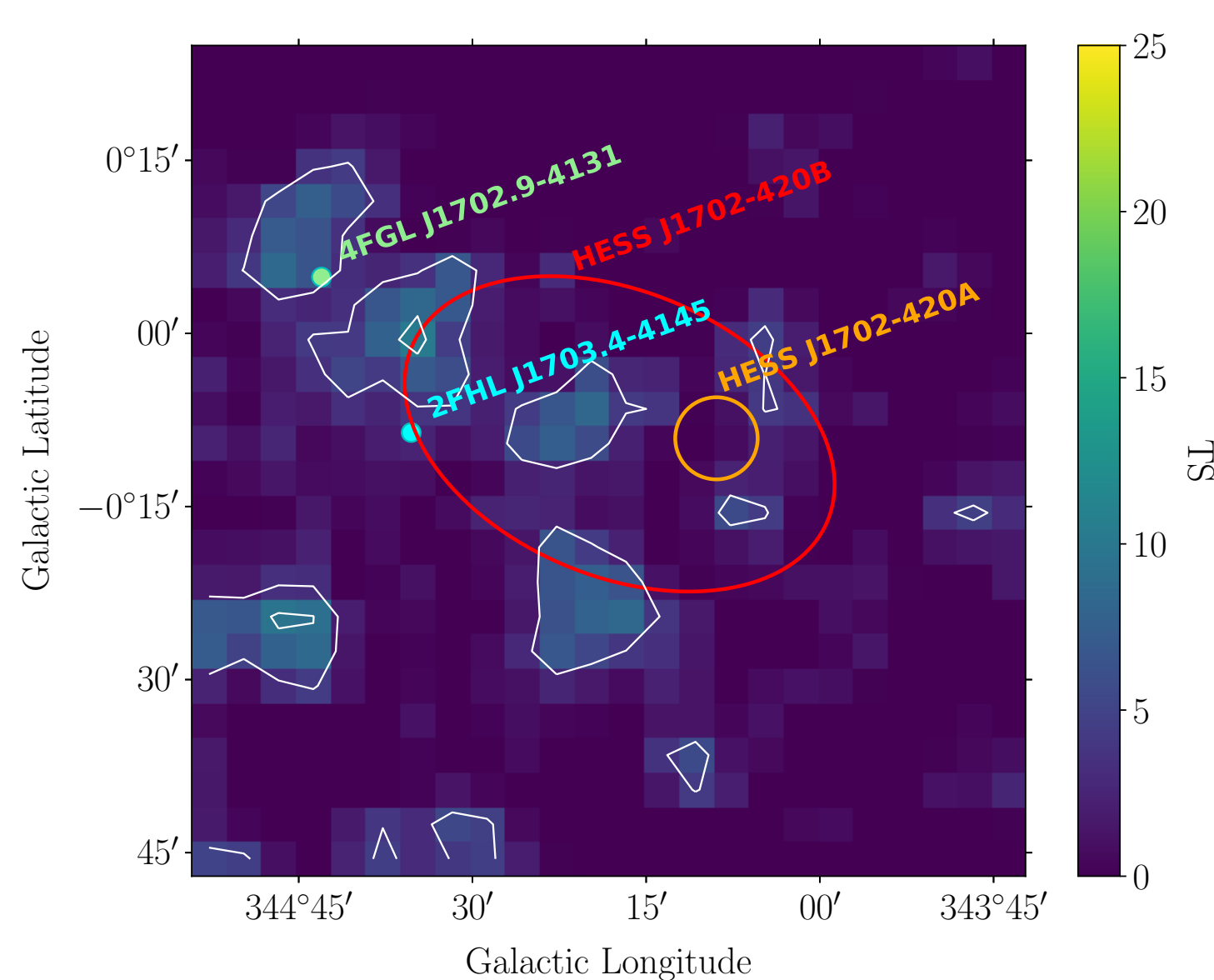


- The data were collected between 2004 and 2019
- The on-source observation livetime amounts to 44.9° h (~35 h more than the latest published analysis)
- The analysis configuration was optimized to enhance the collection area at the highest energies
- We applied a three-dimensional (3D) likelihood analysis, to model the source region and adjust non-thermal radiative spectral models to the  $\gamma$ -ray data.

## Fermi-LAT upper limit

- We analyzed ~12 yr of events with energies  $> 10$  GeV, using Pass 8 data products and *fermipy* [2]
- In the absence of a clear detection (significance  $< 4.3\sigma$ ), we estimated the 99% c. l. upper limit for the HE emission:

$$(E^2 \text{ dN/dE})_{95 \text{ GeV}} \sim 7.6 \cdot 10^{-9} \text{ GeV cm}^{-2} \text{ s}^{-1}$$



## Bibliography

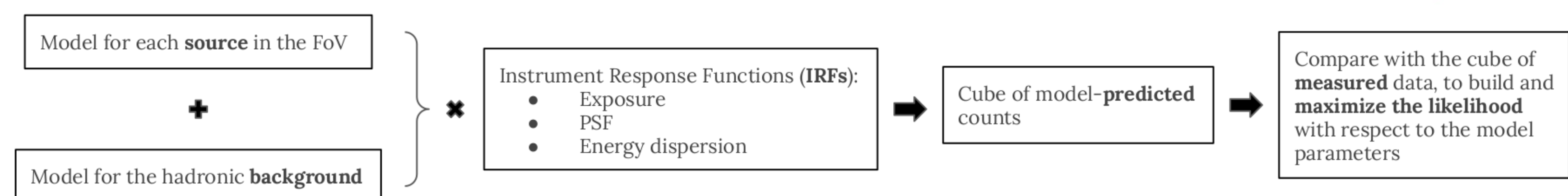
[1] <https://gammapy.org/>

[2] Wood et al. 2007, *Fermipy: An open-source Python package for analysis of Fermi-LAT Data*

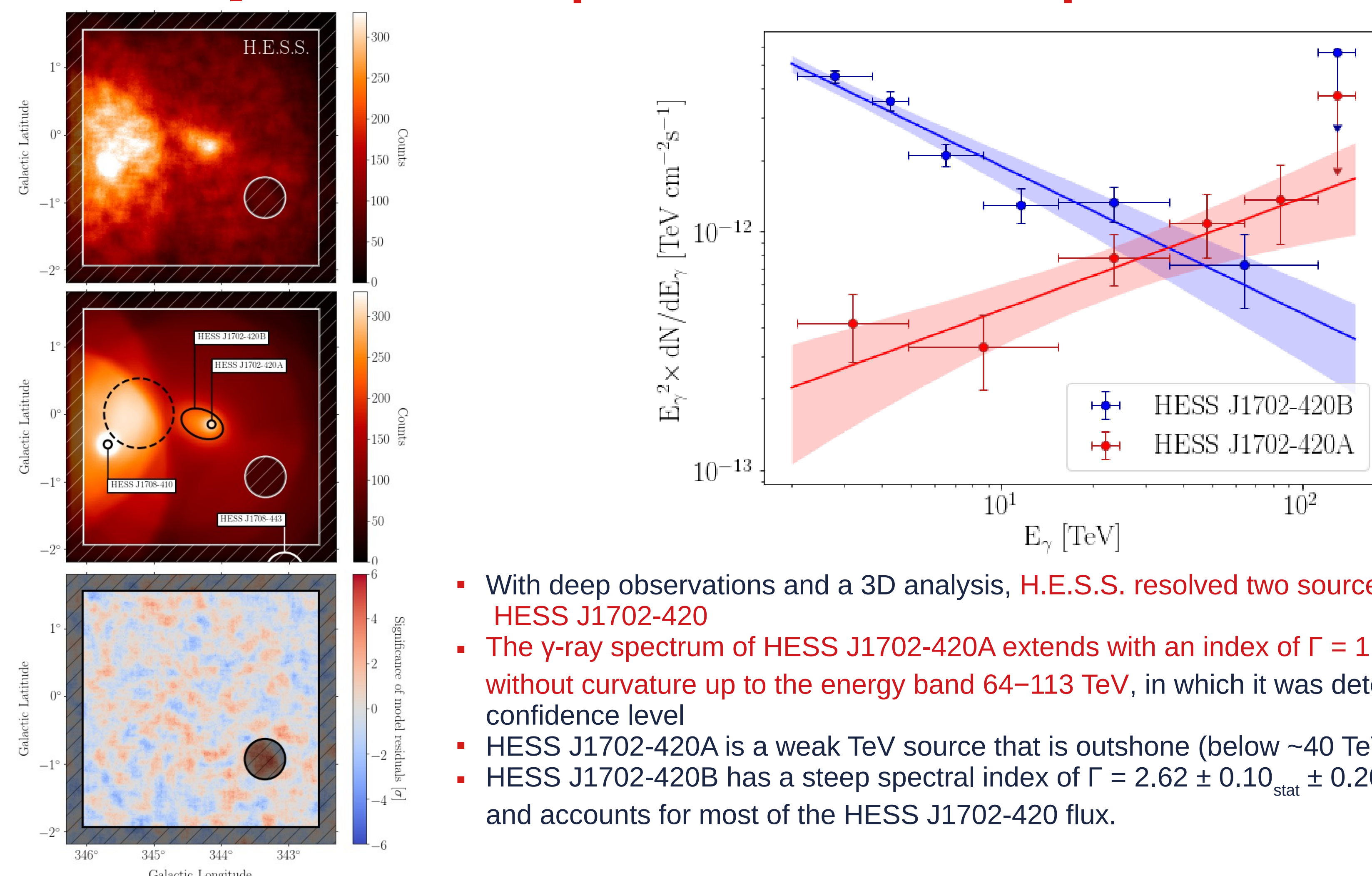
[3] Zabalza 2015, *naima: a Python package for inference of relativistic particle energy distributions from observed nonthermal spectra*

[4] Lau et al. 2018, *Probing the origin of the unidentified TeV  $\gamma$ -ray source HESS J1702-420 via the surrounding interstellar medium*

## 3D analysis (2D morphology $\times$ 1D spectrum) with $\gamma\pi$ [1]

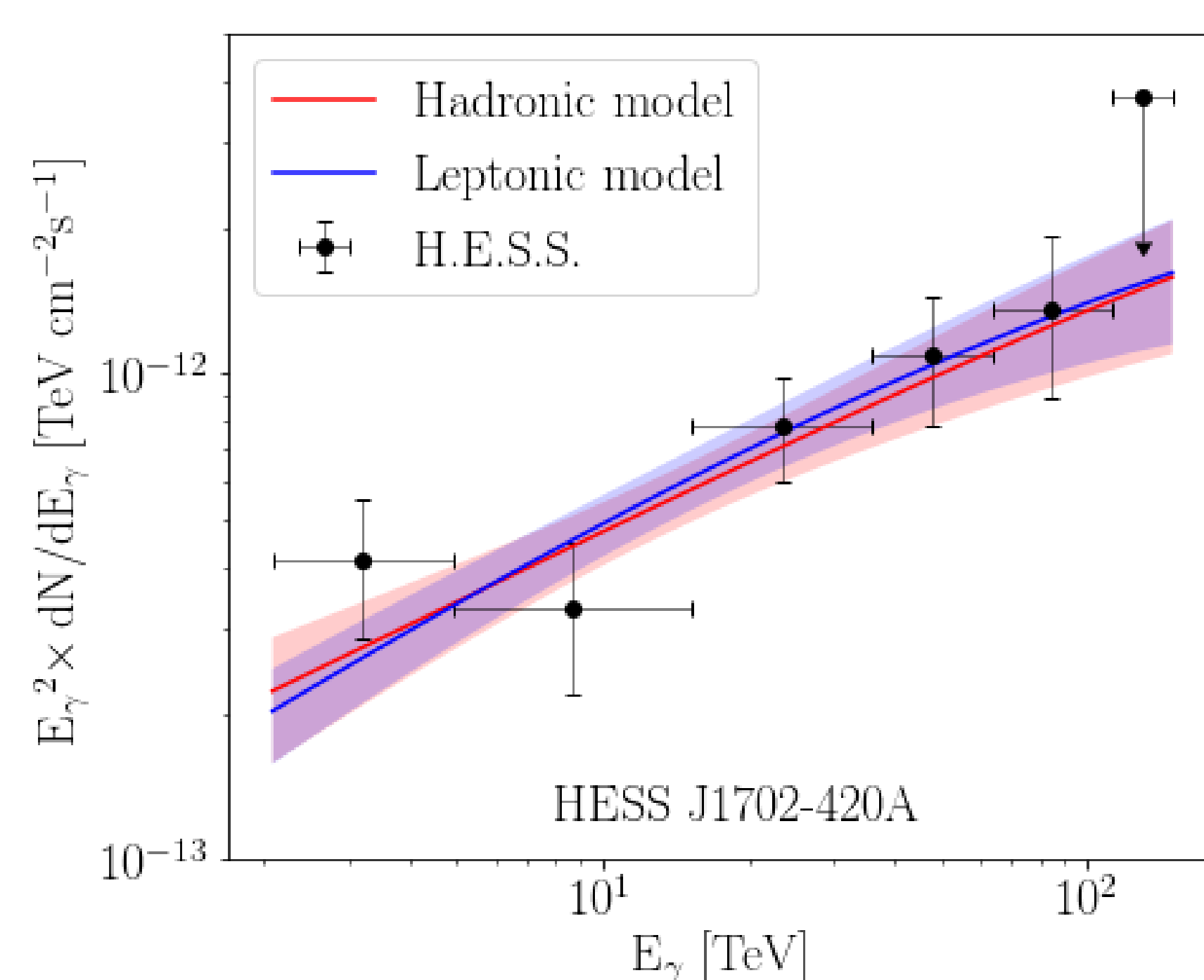


## Discovery of two-component emission up to 100 TeV



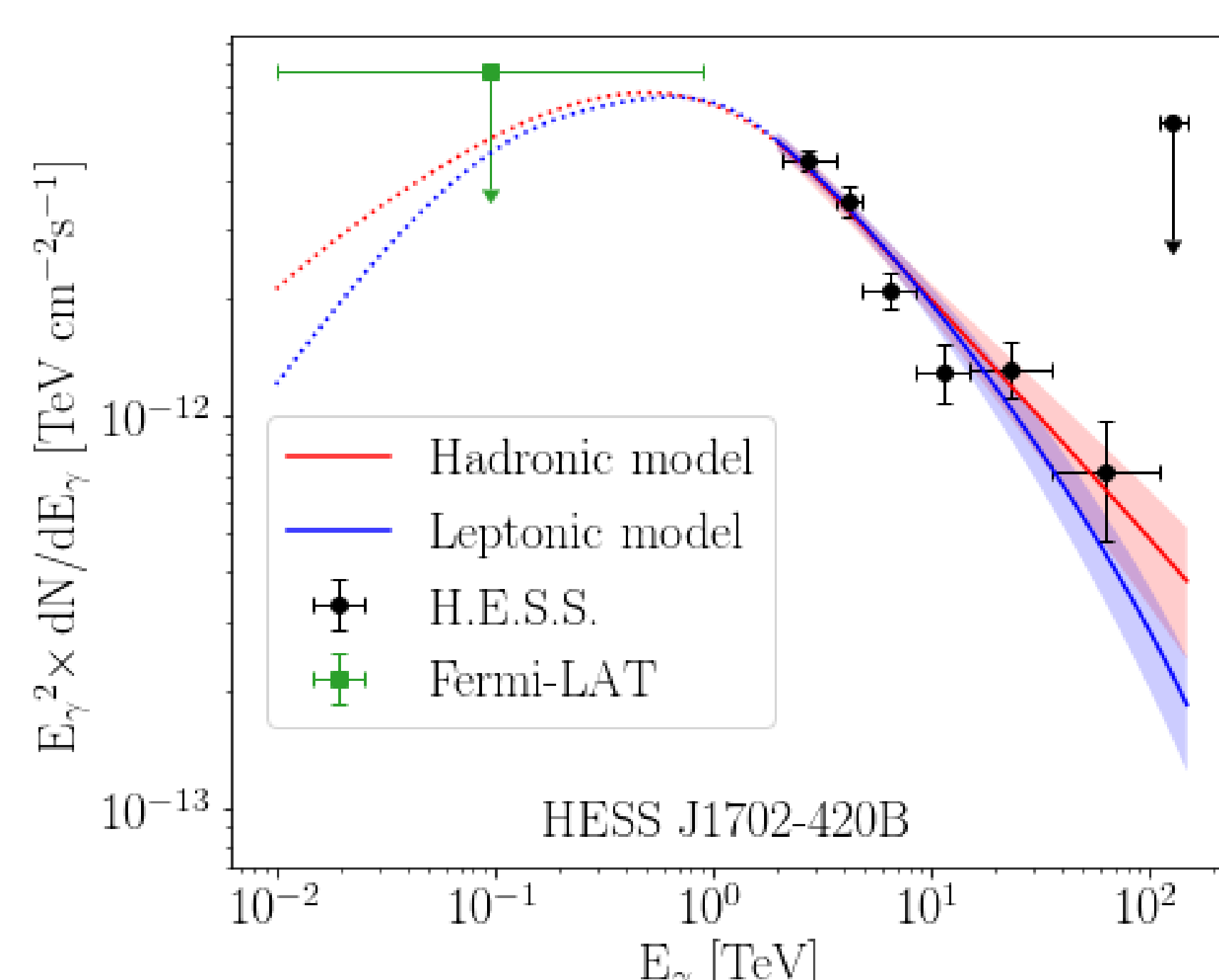
- With deep observations and a 3D analysis, H.E.S.S. resolved two source components within HESS J1702-420
- The  $\gamma$ -ray spectrum of HESS J1702-420A extends with an index of  $\Gamma = 1.53 \pm 0.19_{\text{stat}} \pm 0.20_{\text{sys}}$  and without curvature up to the energy band 64–113 TeV, in which it was detected by H.E.S.S. at 4.0 $\sigma$  confidence level
- HESS J1702-420A is a weak TeV source that is outshone (below ~40 TeV) by HESS J1702-420B
- HESS J1702-420B has a steep spectral index of  $\Gamma = 2.62 \pm 0.10_{\text{stat}} \pm 0.20_{\text{sys}}$ , an elongated shape and accounts for most of the HESS J1702-420 flux.

## Evidence for the discovery of proton PeVatron(s)?



Scenario	PL index	$E_{\text{cut}}$ (95% c. l.)	Total energy in particles ( $E > 1$ TeV)
Hadronic	$1.58 \pm 0.14_{\text{stat}}$	$\geq 550$ TeV	$\geq 1.8 \cdot 10^{47}$ erg @ $d=3.5$ kpc and $nH=100 \text{ cm}^{-3}$
Leptonic	$1.61 \pm 0.15_{\text{stat}}$	$\geq 64$ TeV	$\geq 8.1 \cdot 10^{45}$ erg @ $d=3.5$ kpc

- We used *naima* [3] to derive the present-age proton/electron spectra powering HESS J1702-420A and HESS J1702-420B, assuming simple one-zone models. The particle spectra were forward-folded directly on 3D  $\gamma$ -ray data
- In a simple hadronic emission scenario the hard  $\gamma$ -ray spectrum of HESS J1702-420A implies that the source likely harbors PeV protons
- **HESS J1702-420A becomes one of the most solid PeVatron candidates detected so far in H.E.S.S. data**
- However, a leptonic origin of the observed TeV emission cannot be ruled out either.



Scenario	PL index ( $E > E_{\text{break}}$ )	$E_{\text{break}}$ [TeV]	Total energy in particles ( $E > 1$ GeV)
Hadronic	$2.66 \pm 0.11_{\text{stat}}$	$6.77 \pm 3.64_{\text{stat}}$	$\sim 2.8 \cdot 10^{48}$ erg @ $d=3.5$ kpc and $nH=100 \text{ cm}^{-3}$
Leptonic	$3.39 \pm 0.11_{\text{stat}}$	$4.19 \pm 1.25_{\text{stat}}$	$\sim 4.5 \cdot 10^{47}$ erg @ $d=3.5$ kpc

- The unknown relationship between HESS J1702-420A and HESS J1702-420B, as well as the **absence of clear correlations of the TeV images with the ISM** [4], prevent a confirmation of the hadronic emission scenario
- **Future deep observations with CTA, SWGO and KM3NeT will help constraining the spectrum near the cut-off region, probing the hadronic origin of the emission and determining whether either of the two detected components operates as a real cosmic ray PeVatron.**

