Testing for a “Crab-like“ Emission Tail above 10 GeV from the Vela Pulsar and PSR B1706-44 using combined H.E.S.S. and Fermi-LAT data

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Introduction

- Measuring curvature in the GeV tail of pulsar is important to constrain radiation scenarii:
  - Synchrotron Radiation (SR)
  - Curvature Radiation (CR)
- These two radiation mechanisms usually fit properly Fermi-LAT data
- But the Crab is an exception !
- Crab vs Vela:
  - Crab: Extension of the GeV emission as a power-law tail
  - Vela: Second component, distinct from the GeV one
- Fermi-LAT alone lack statistics above tens of GeV
- Using Fermi-LAT + H.E.S.S. in a joint analysis with Gammapy [6]

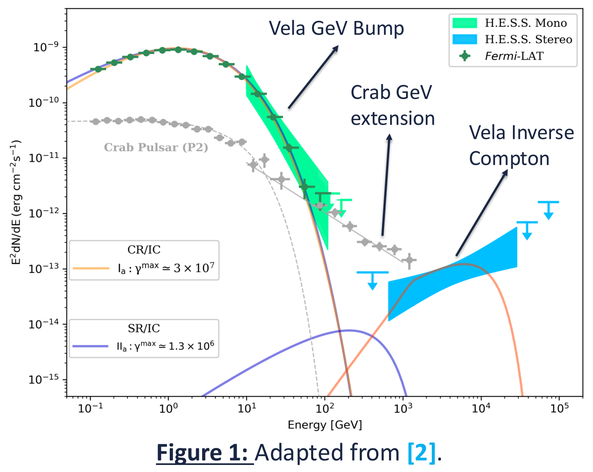


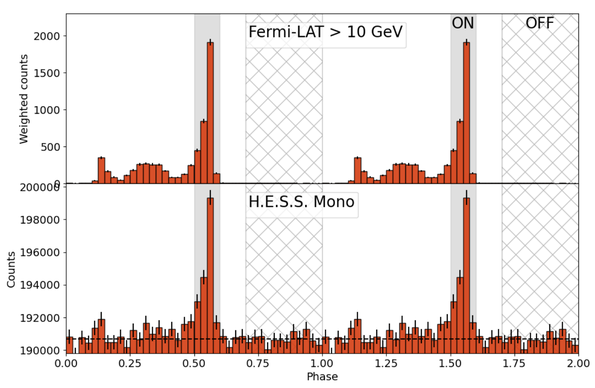
Figure 1: Adapted from [2].

- **Is the GeV tail of pulsars a power-law or not ?**
- **Is there curvature in the GeV tail of pulsars ?**

- Log-parabola is used as a tool to test for local curvature in the GeV tail above threshold energies (10, 15, 20 GeV)
  - Likelihood ratio between a power-law and a log-parabola through a joint analysis of Fermi-LAT and H.E.S.S. data
  - Method validated on the Crab.

- Vela and PSR B1706-44 with H.E.S.S. data only [3], [5]:
  - Not enough statistics to test for curvature

Vela Pulsar

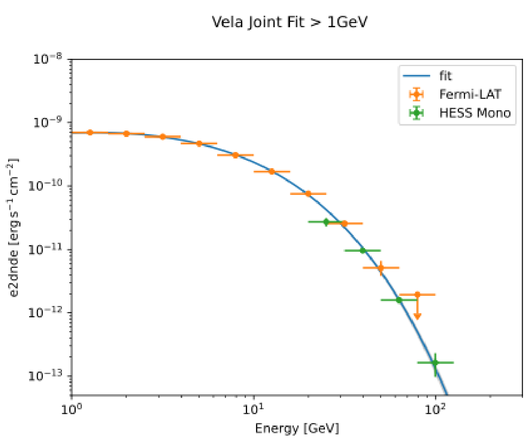


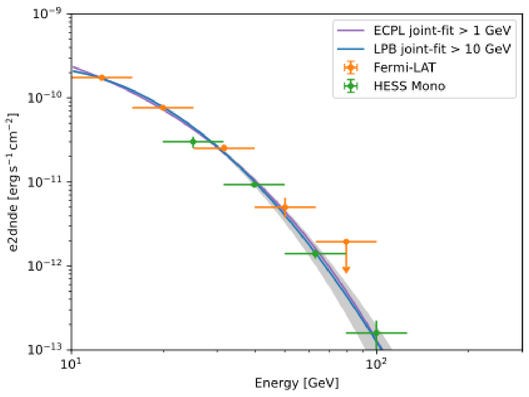
Datasets:
- 12 years of Fermi-LAT data
- 3PC events FITS files [1]

- 40.6h of H.E.S.S. Mono data [3]
- ~300 events between 80 and 110 GeV

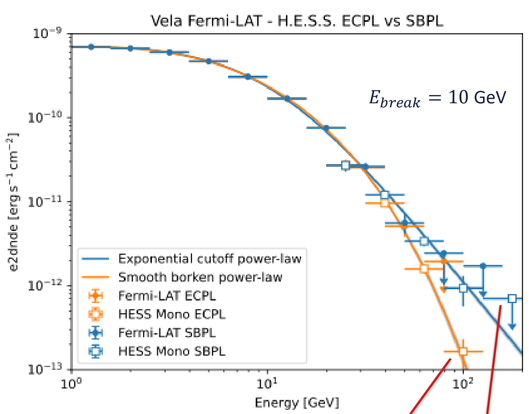
$$\phi(E) = \phi_0 \cdot \left(\frac{E}{E_0}\right)^{-\Gamma} \exp(-(\lambda E)^{\alpha})$$

Joint fit:
- Fit of an exponetially cutoff power-law above 1 GeV
- Sub-exponential factor of 0.56.





Tests for local curvature (>10 GeV, …):
- Likelihood ratio between a power-law and a log-parabola
- Above energy threshold of 10, 15 and 20 GeV (cf. table below)



Model dependent flux points

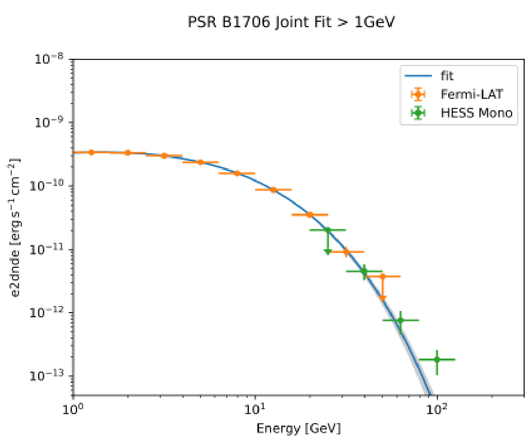
ECPL vs SBPL [4] :
- SBPL fit gives an E_{break} of 38 GeV but not statistically favoured

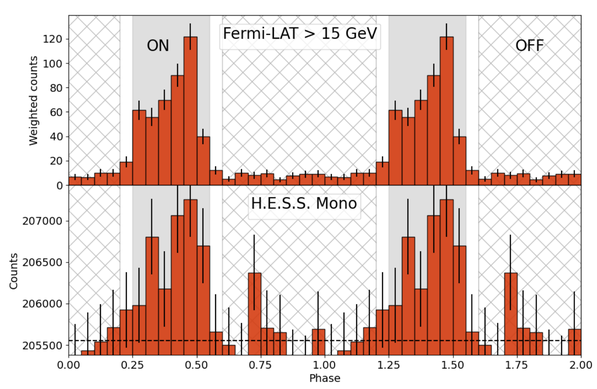
- Further tests favour ECPL, e.g.:
  Fixing E_{break} to 10 GeV
  $\Delta TS(AIC) = 8.2$,
  $\Delta TS(BIC) = 8.2$

PSR B1706-44

Datasets:
- 10.9 years of Fermi-LAT data
- 3PC events FITS file [1]

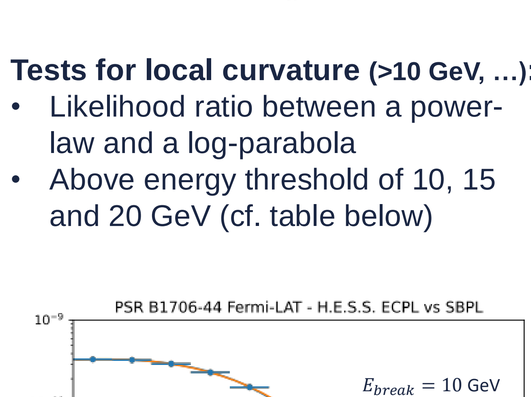
- 21.7h of H.E.S.S. Mono data [5]
- ~1100 events between 62 and 100 GeV





$$\phi(E) = \phi_0 \cdot \left(\frac{E}{E_0}\right)^{-\Gamma} \exp(-(\lambda E)^{\alpha})$$

Joint fit:
- Fit of an exponetially cutoff power-law above 1 GeV
- Sub-exponential factor of 0.62.



Tests for local curvature (>10 GeV, …):
- Likelihood ratio between a power-law and a log-parabola
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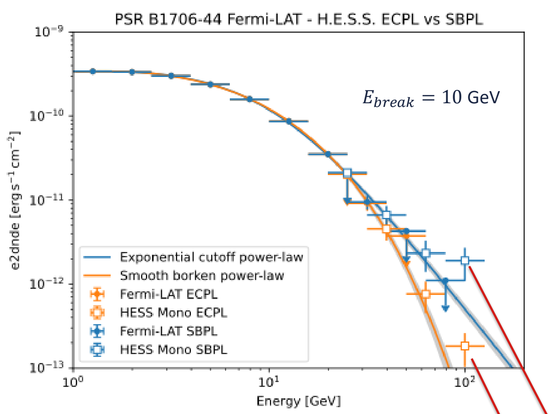

Model dependent flux points

ECPL vs SBPL [4] :
- SBPL fit gives an E_{break} of 22.6 GeV but not statistically favoured

- Further tests favour ECPL, e.g.:
  Fixing E_{break} to 10 GeV
  $\Delta TS(AIC) = 7.7$,
  $\Delta TS(BIC) = 7.7$

Source	Vela (H.E.S.S. – Fermi-LAT)			PSR B1706-44 (H.E.S.S. – Fermi-LAT)			Crab (Fermi-LAT)
Energy threshold	> 10 GeV	> 15 GeV	> 20 GeV	> 10 GeV	> 15 GeV	> 20 GeV	> 10 GeV
$E_{thresh} \rightarrow E_{peak}$	7	11	15	7	10	14	X
Log-parabola significance	**7.3 σ**	**5.7 σ**	**3.1 σ**	**3.8 σ**	**1.8 σ**	**0.8 σ**	**0.1 σ**

Conclusion & references

Conclusion:
- **Local curvature is detected in the spectrum of Vela above 20 GeV and PSR B1706-44 above 10 GeV**
- **This excludes the onset of a power-law below and up to those energies**
- **Vela HE acceleration and emission mechanisms are different from the Crab**
- **Curvature in PSR B1706-44 spectrum also favours a Vela-like scenario**
- **Points towards Crab-like vs Vela-like classification**

References:

[1] Smith, D. A., Abdollahi, S., Ajello, M., et al. 2023, ApJ, 958, 191, doi: 10.3847/1538-4357/acee67
[2] H.E.S.S. Collaboration (2023). *Nature Astronomy*, 7, 1341–1350 . https://doi.org/10.1038/s41550-023-02052-3
[3] Abdalla, H., et al. 2018, Astronomy & Astrophysics, 620, A66, https://doi.org/10.48550/arXiv.1807.01302
[4] CTA-LST Project: Abe, K., et al. 2024, https://doi.org/10.48550/arXiv.2407.02343
[5] Spir-Jacob, M., Djannati-Ata¨ı, A., Mohrmann, L., et al. 2019, https://doi.org/10.48550/arXiv.1908.06464
[6] Donath, A., et al. 2023, Astronomy & Astrophysics, 678, A157, https://doi.org/10.1051/0004-6361/202346488