H.E.S.S. FITS validation paper

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Gammapy Coding Sprint
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Open-source science tools in very-high-energy γ-ray astronomy: background model construction for template analysis and tool validation using public H.E.S.S. data

ABSTRACT

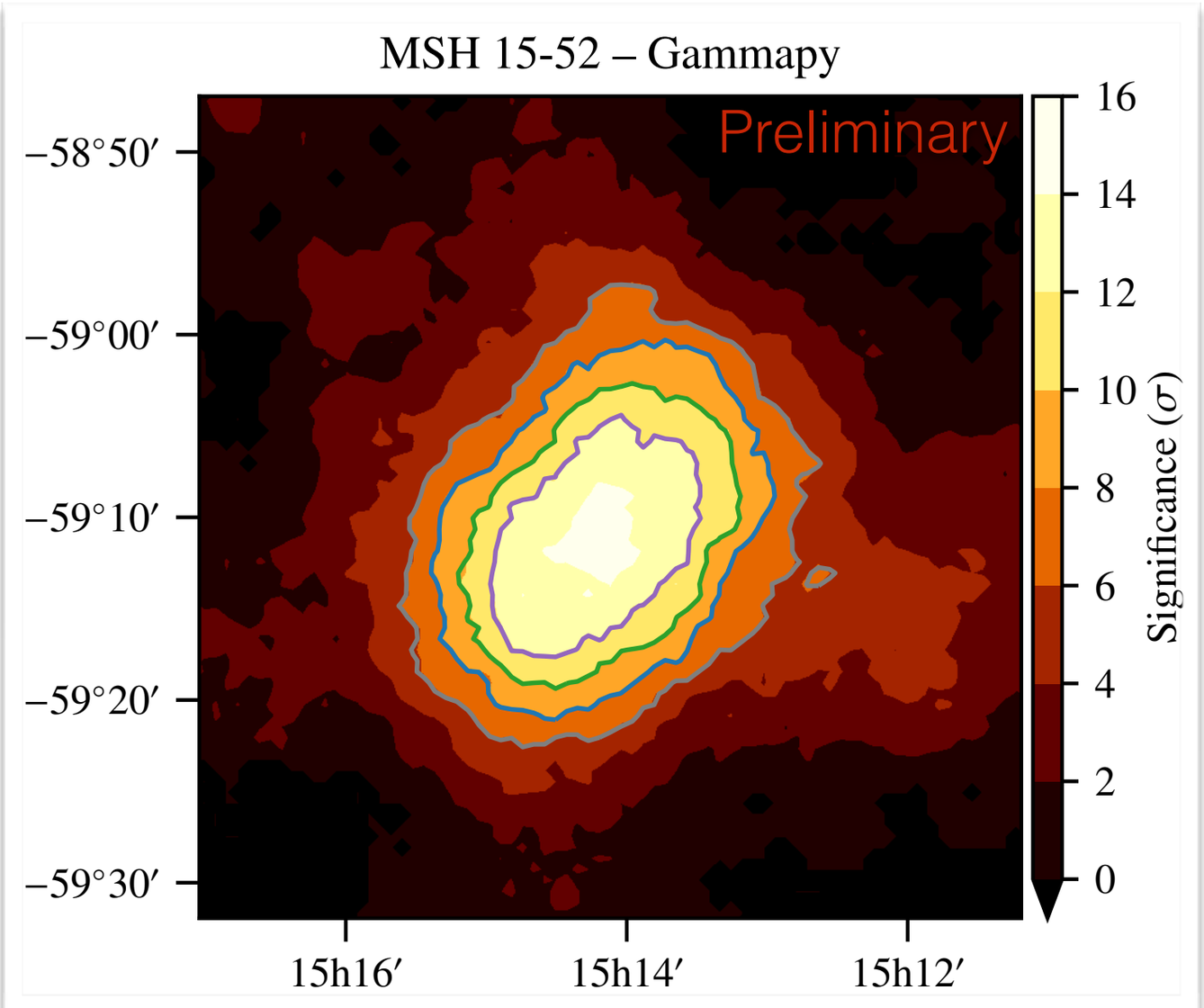
In classical analyses of γ-ray data from imaging atmospheric Cherenkov telescopes (IACTs) such as H.E.S.S., aperture photometry, i.e. photon counting, is applied in a (typically circular) region of interest (RoI) encompassing the source. A key element in the analysis is to estimate the amount of background in the RoI due to residual cosmic ray-induced air showers in the data. Various standard background estimation techniques have been developed in the last decades, most of them relying on a measurement of the background from source-free regions within the observed field of view. However, in particular in the Galactic plane, source analysis and background estimation are hampered by the large number of (sometimes overlapping) γ-ray sources and large-scale diffuse γ-ray emission.

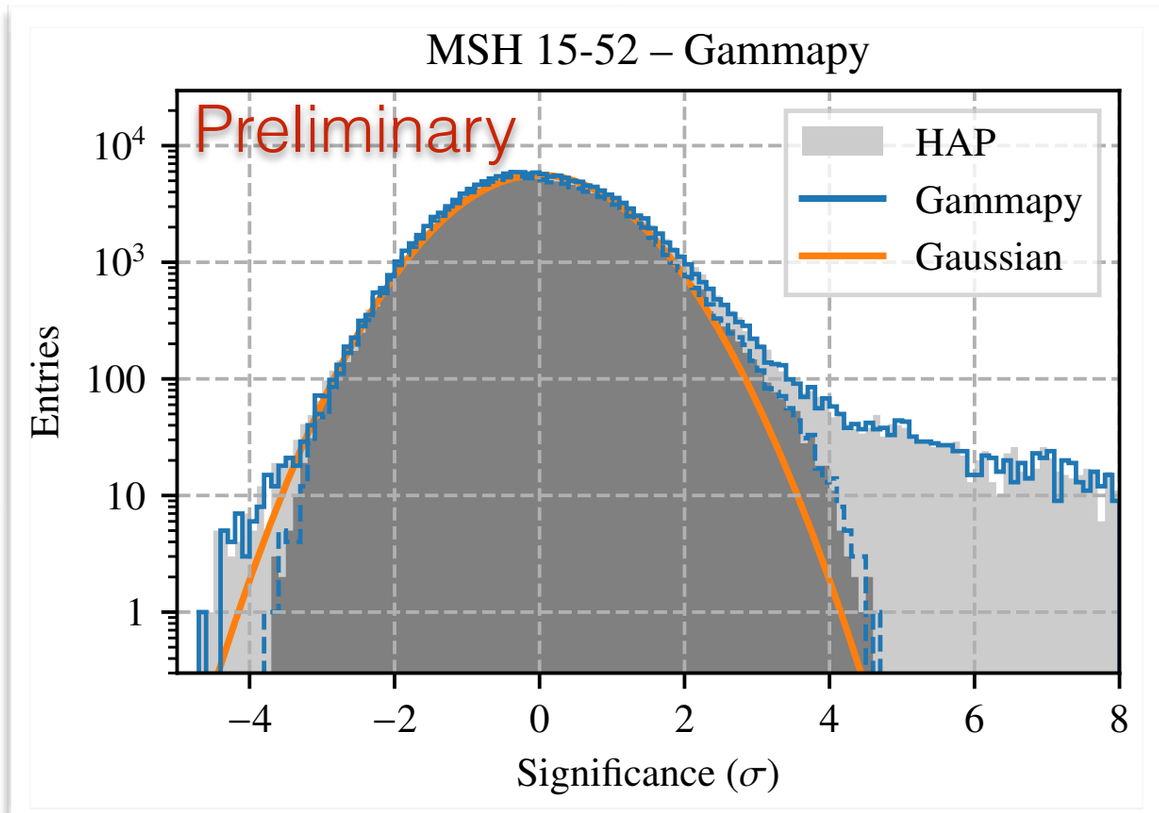
For complicated fields of view, template analysis shows the potential to be superior to classical analysis. In the template approach, a spectromorphological model template, consisting of one or multiple source components and a background component, is fit to the γ-ray data, resulting in a complete spectral and spatial description of the field of view. For the application to IACT data, the major challenge of such approach is the construction of a robust background model.

In this work, we apply template analyses to various test data recently made public by the H.E.S.S. collaboration, using the open analysis frameworks *ctools* and *Gammapy*. First, we show that, when using these tools in a classical analysis approach and comparing to the proprietary H.E.S.S. analysis framework, virtually identical high-level analysis results, such as field-of-view maps and spectra, are obtained. We then describe the construction of a generic background model from data of H.E.S.S. observations, and demonstrate that template analysis using this background model yields high-level analysis results that are highly compatible with those obtained from the classical analyses. This validation of the template analysis approach on experimental data is an important step towards using this method for IACT data analysis, and in particular for the analysis of data from the upcoming Cherenkov Telescope Array (CTA).

Classical analyses

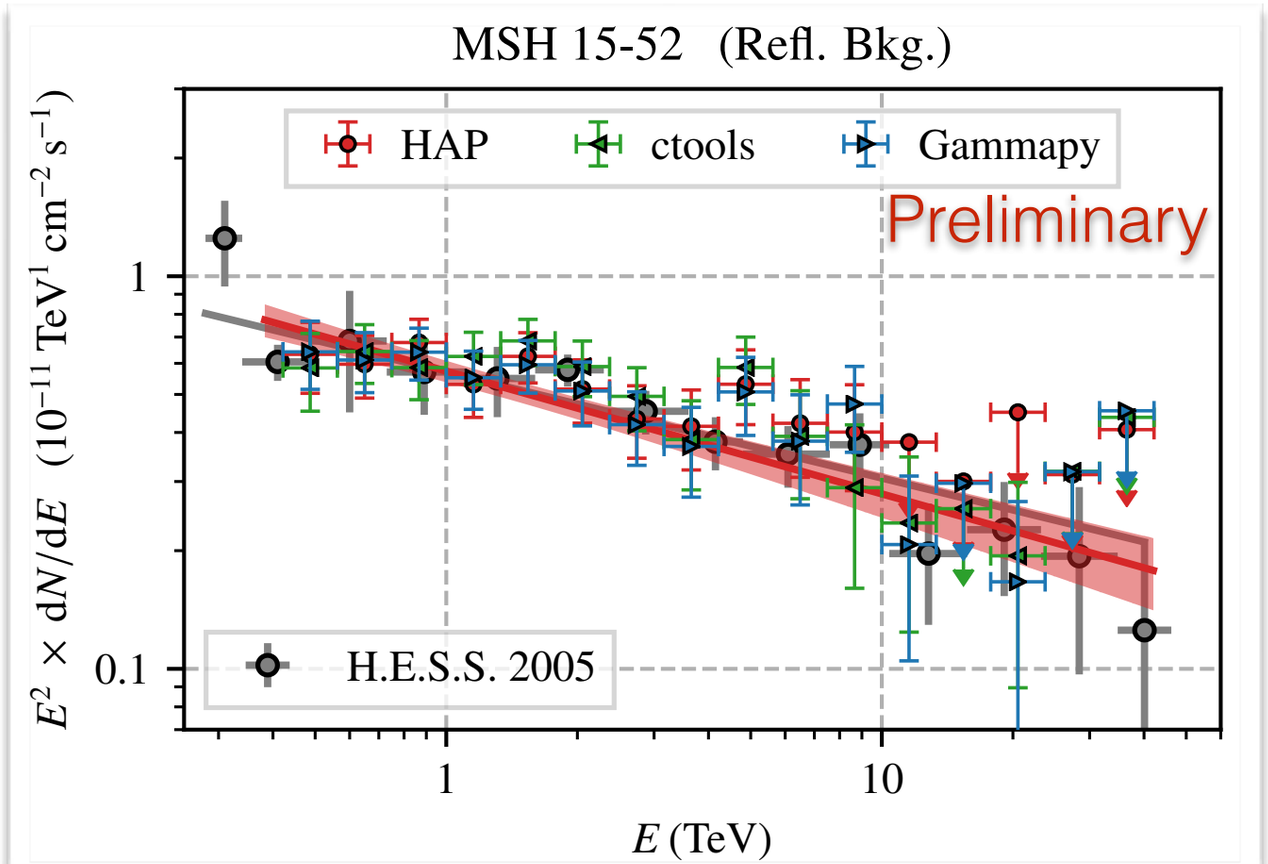
- Sky maps from ring background method
- Here: pulsar wind nebula MSH 15-52
- Background: Gammapy; contour lines: HAP (H.E.S.S. tool)

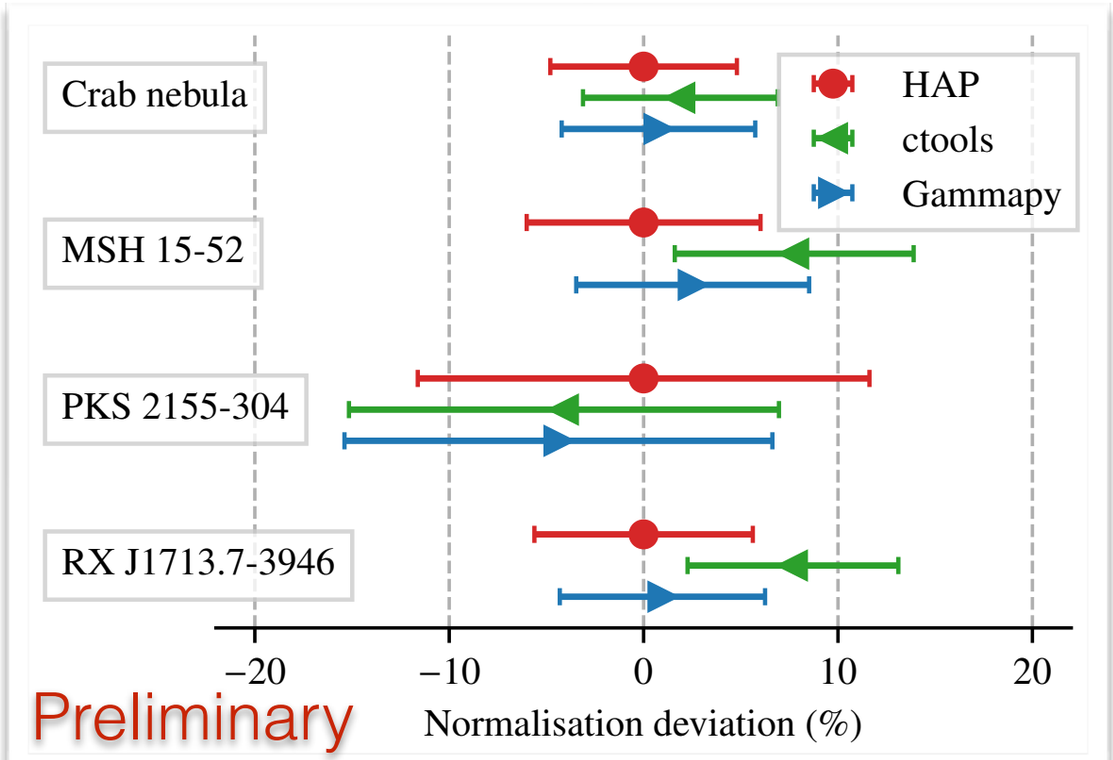


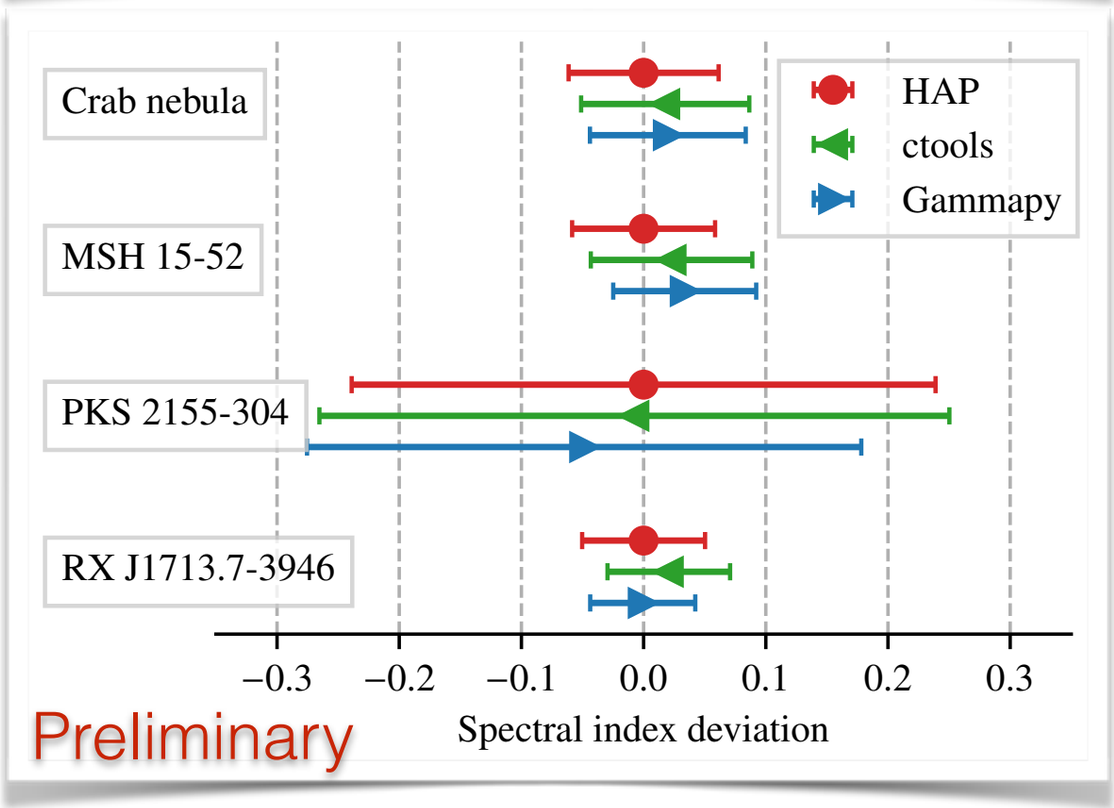


Classical analyses

- Spectrum from reflected background method
- Spectral model: power law



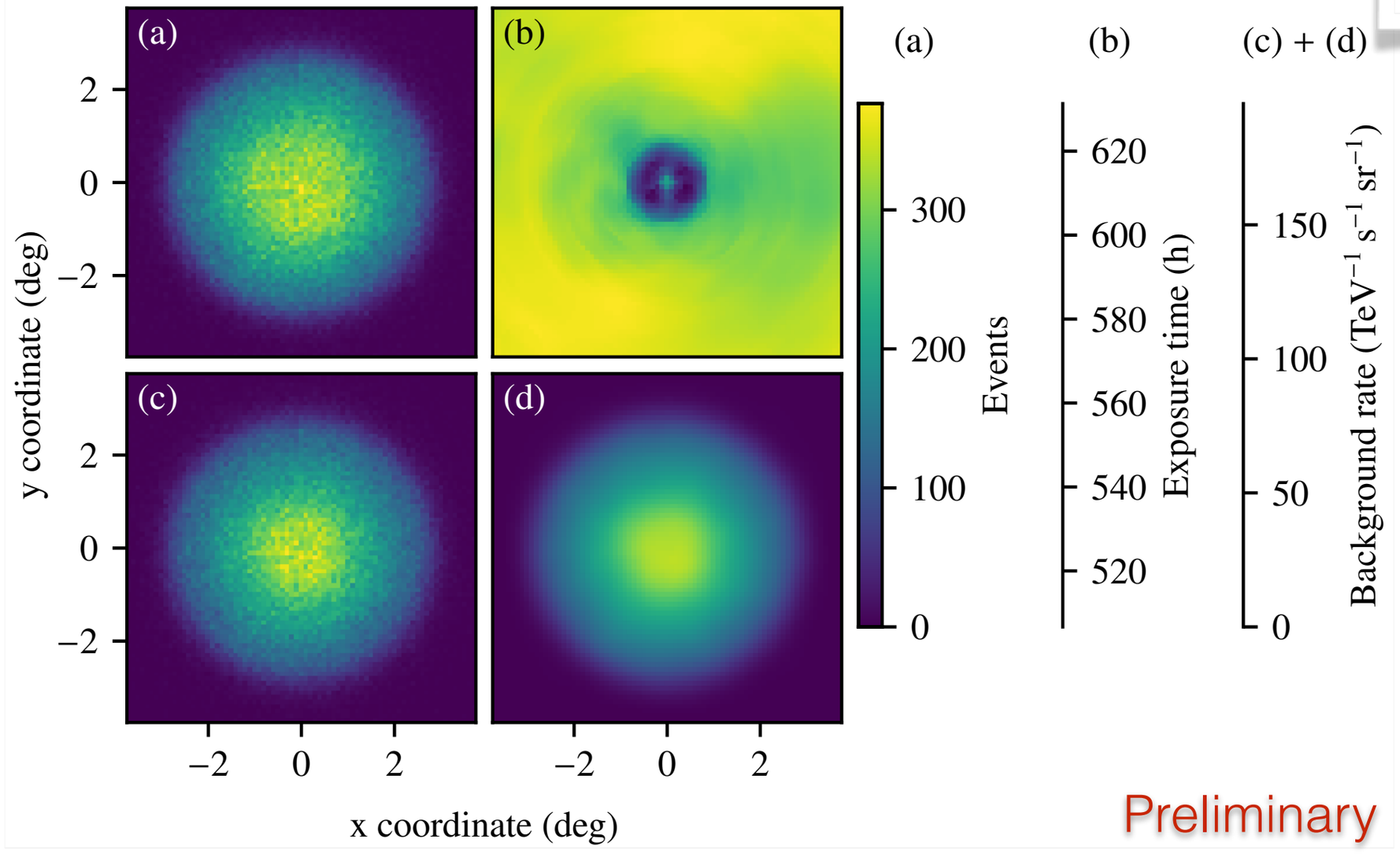




Background model

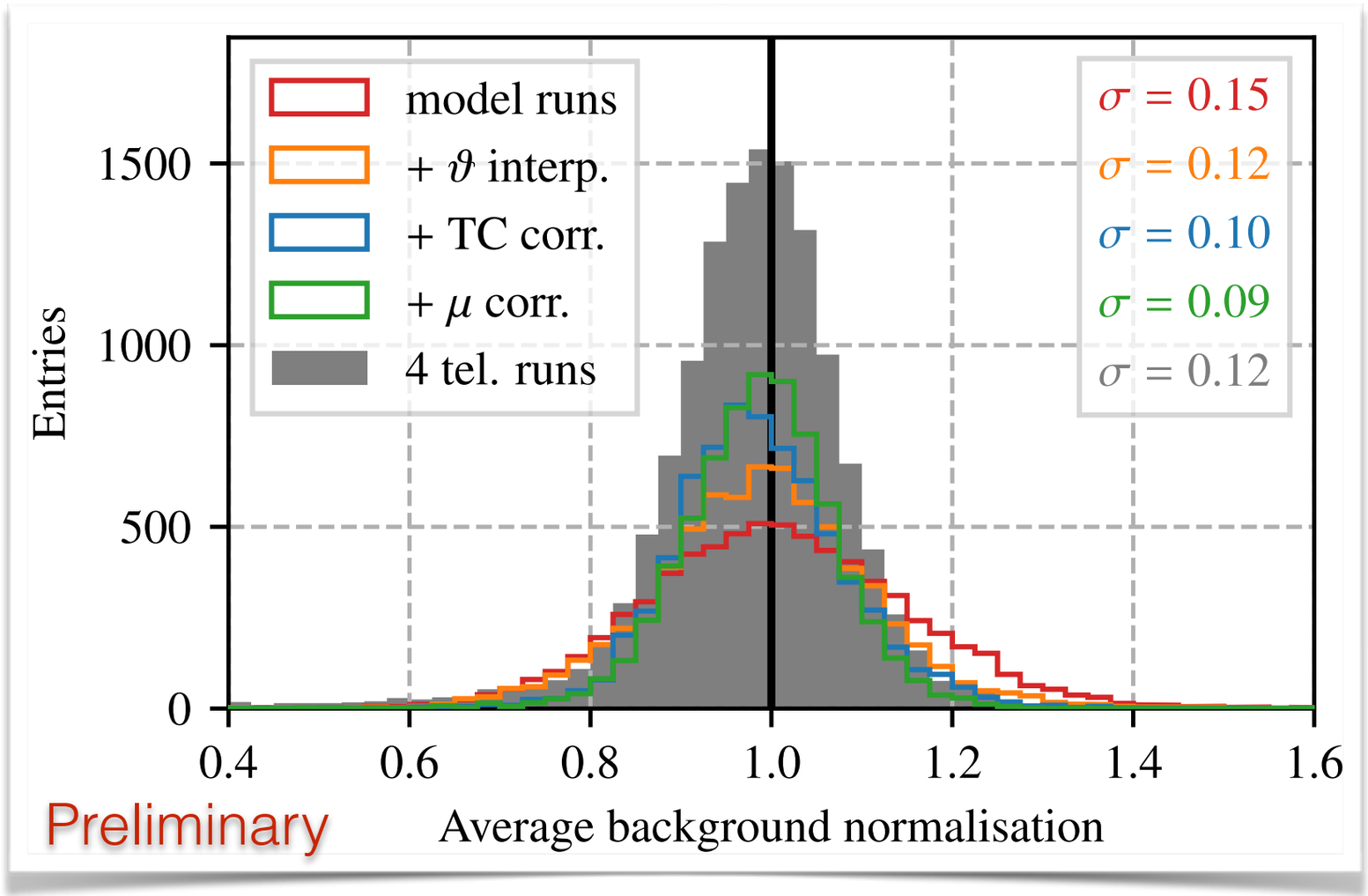
- 3D model for residual cosmic-ray background in arbitrary observations
- Constructed from archival H.E.S.S. data

	$-90° < \phi < 90°$		$90° < \phi < 270°$	
ϑ (deg)	N_{obs}	t_{live} (hours)	N_{obs}	t_{live} (hours)
0 – 10	99	44.5	660	301.8
10 – 20	392	177.8	994	455.6
20 – 30	650	297.0	1378	632.2
30 – 40	444	201.4	790	367.6
40 – 45	300	135.8	242	110.9
45 – 50	306	140.0	448	204.9
50 – 55	150	68.4	124	57.3
55 – 60	61	28.2	25	12.2



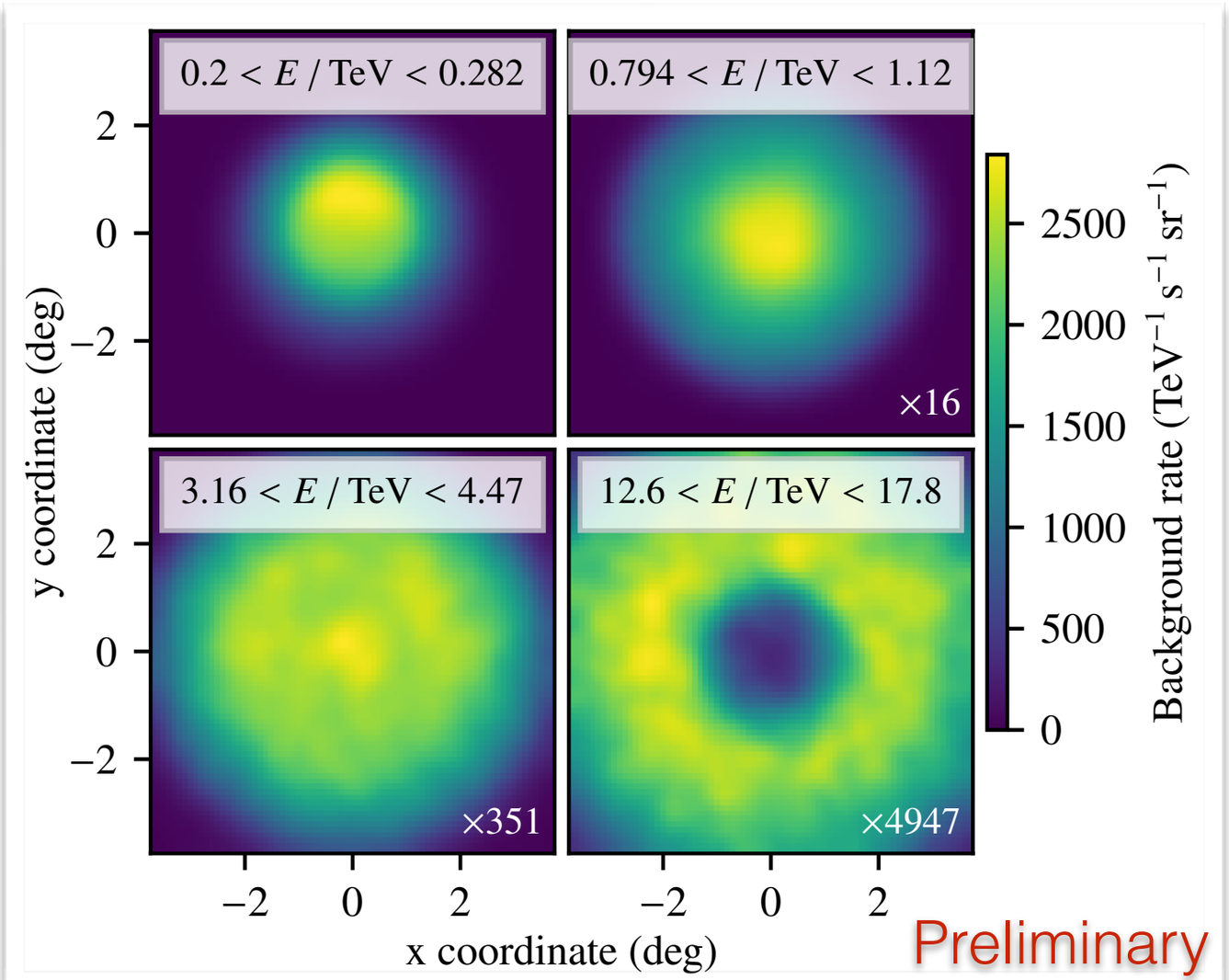
Background model

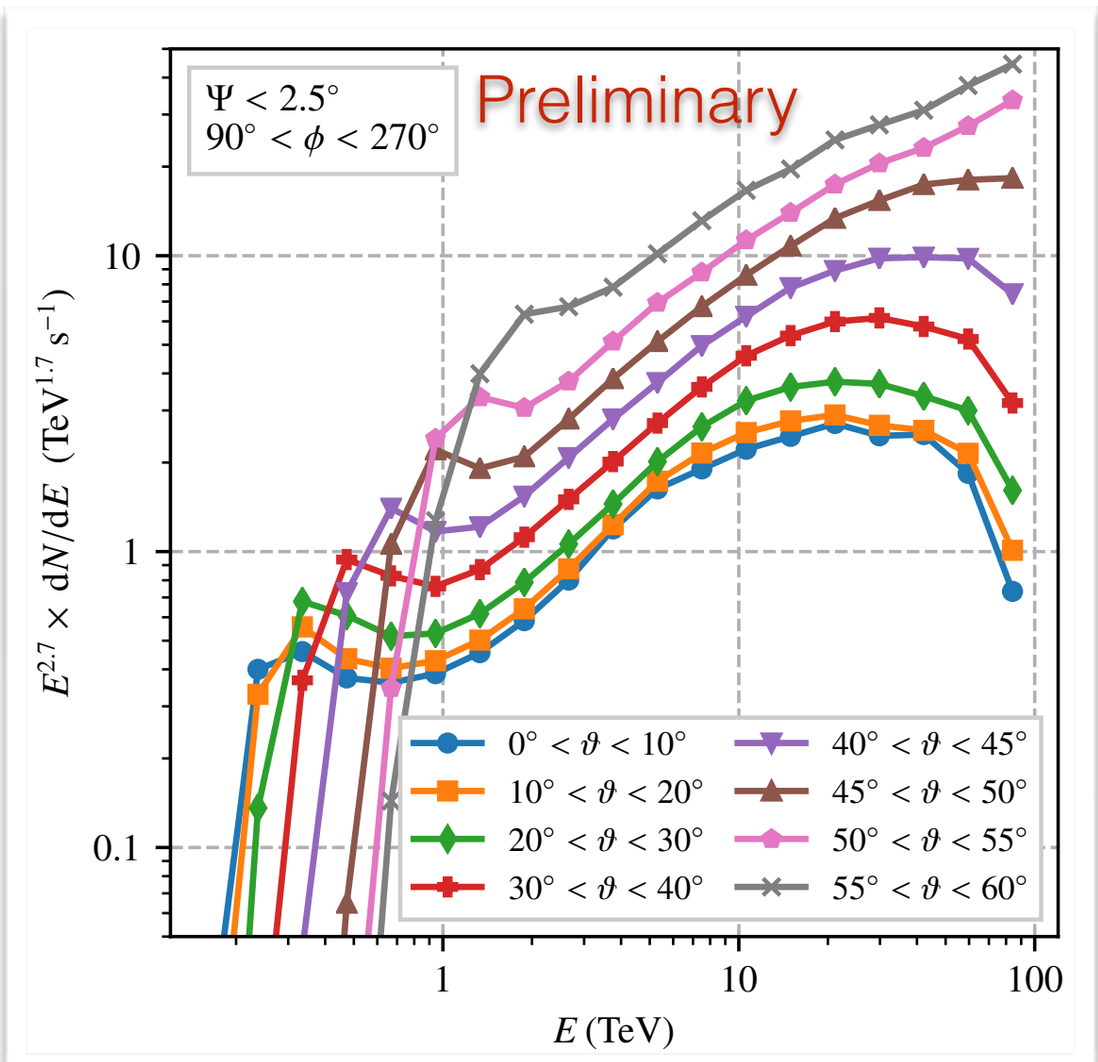
- Assign model to individual observations
- Perform various corrections
- Average fitted background normalisation:



Background model

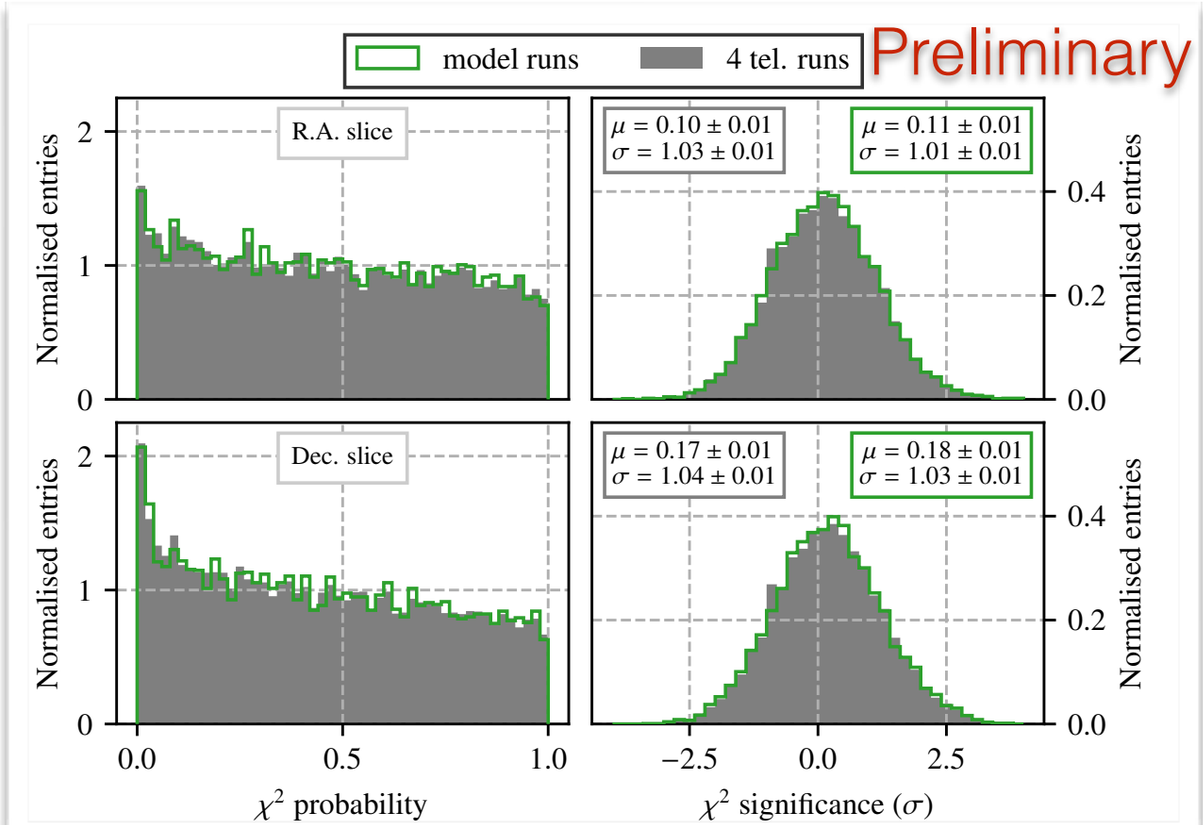
- Characterise spatial and spectral shape of the model

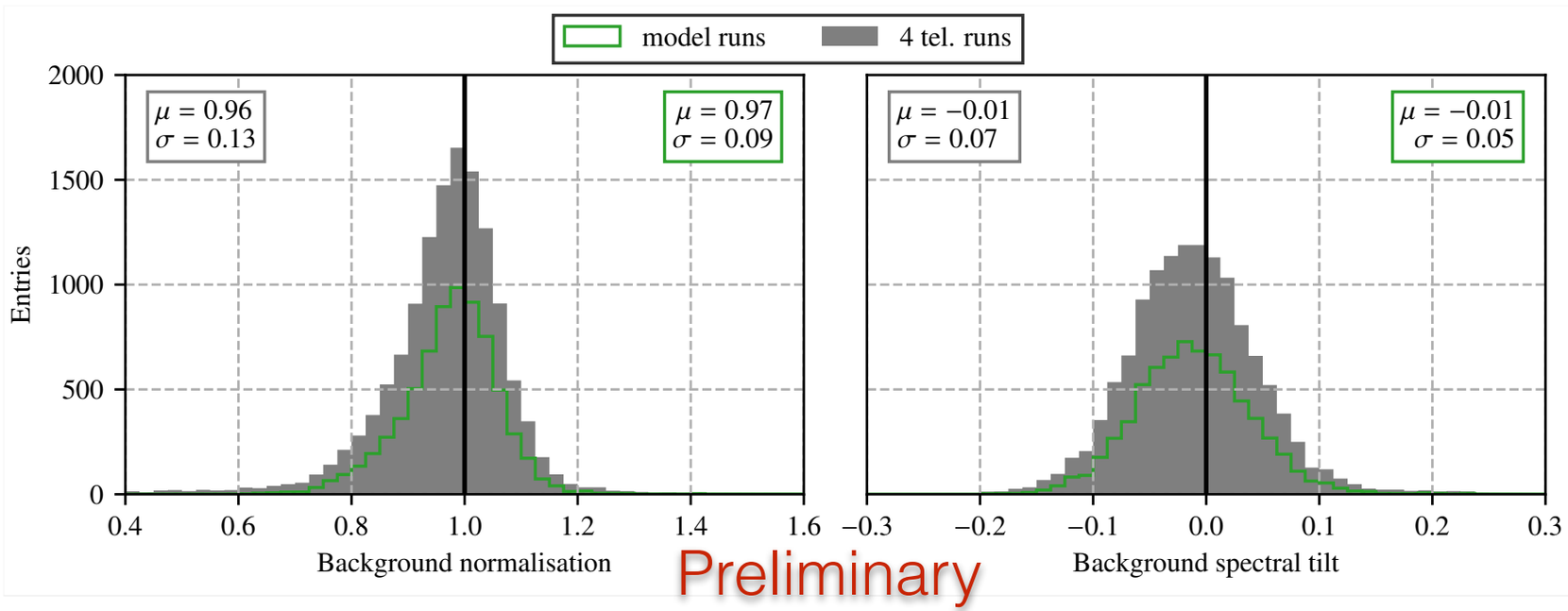


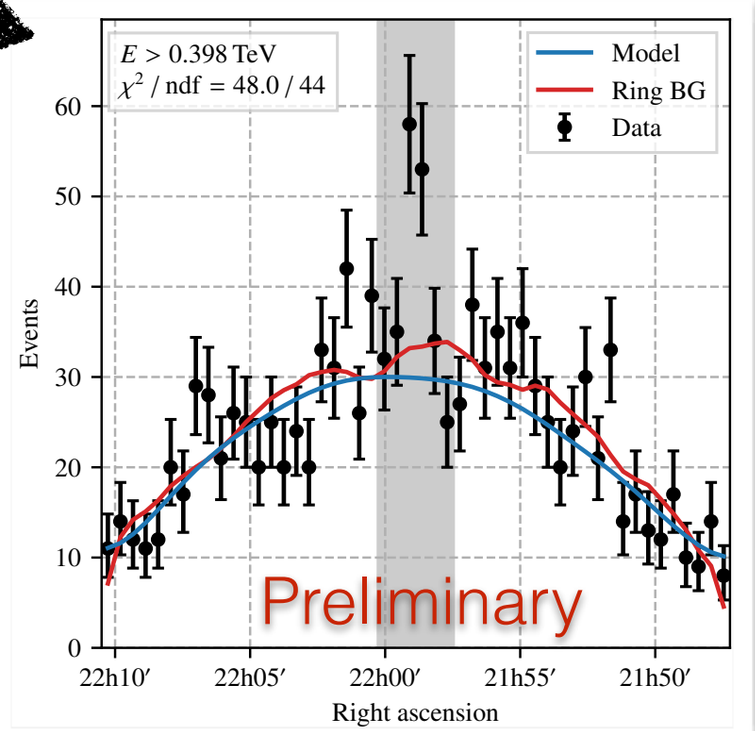


Background model

- Validate model by fitting it to all available observations
- Look at distribution of normalisation & spectral tilt
- Compute chi² to assess agreement in spatial shape

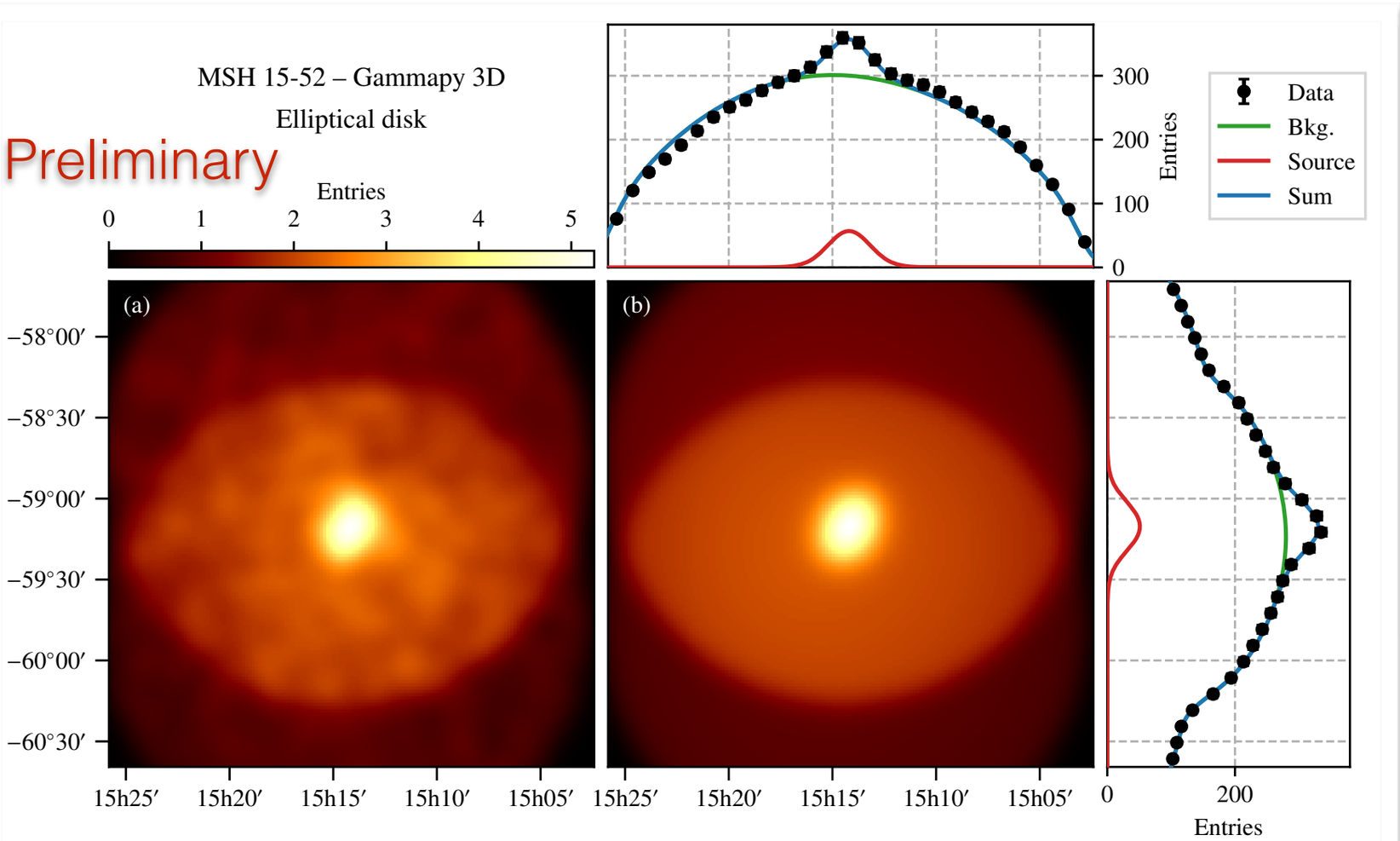


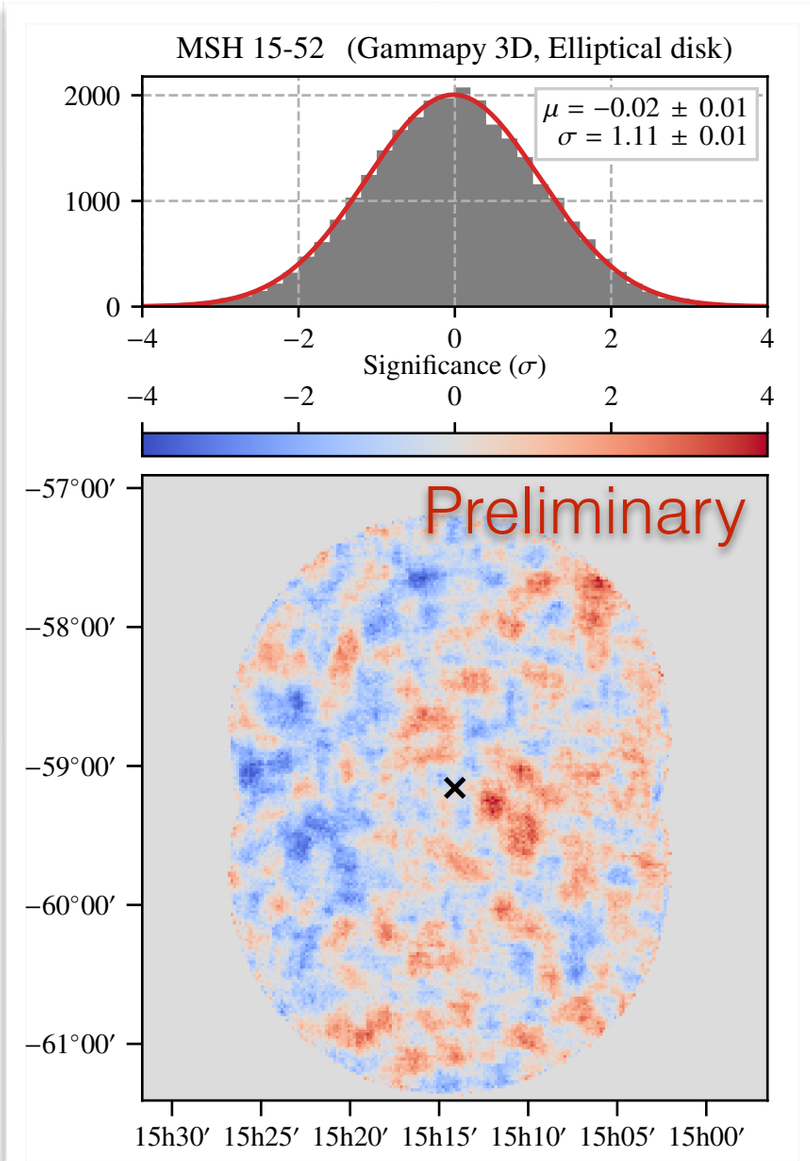




Template analysis

- Employ background model in 3D analysis
- Example: MSH 15-52

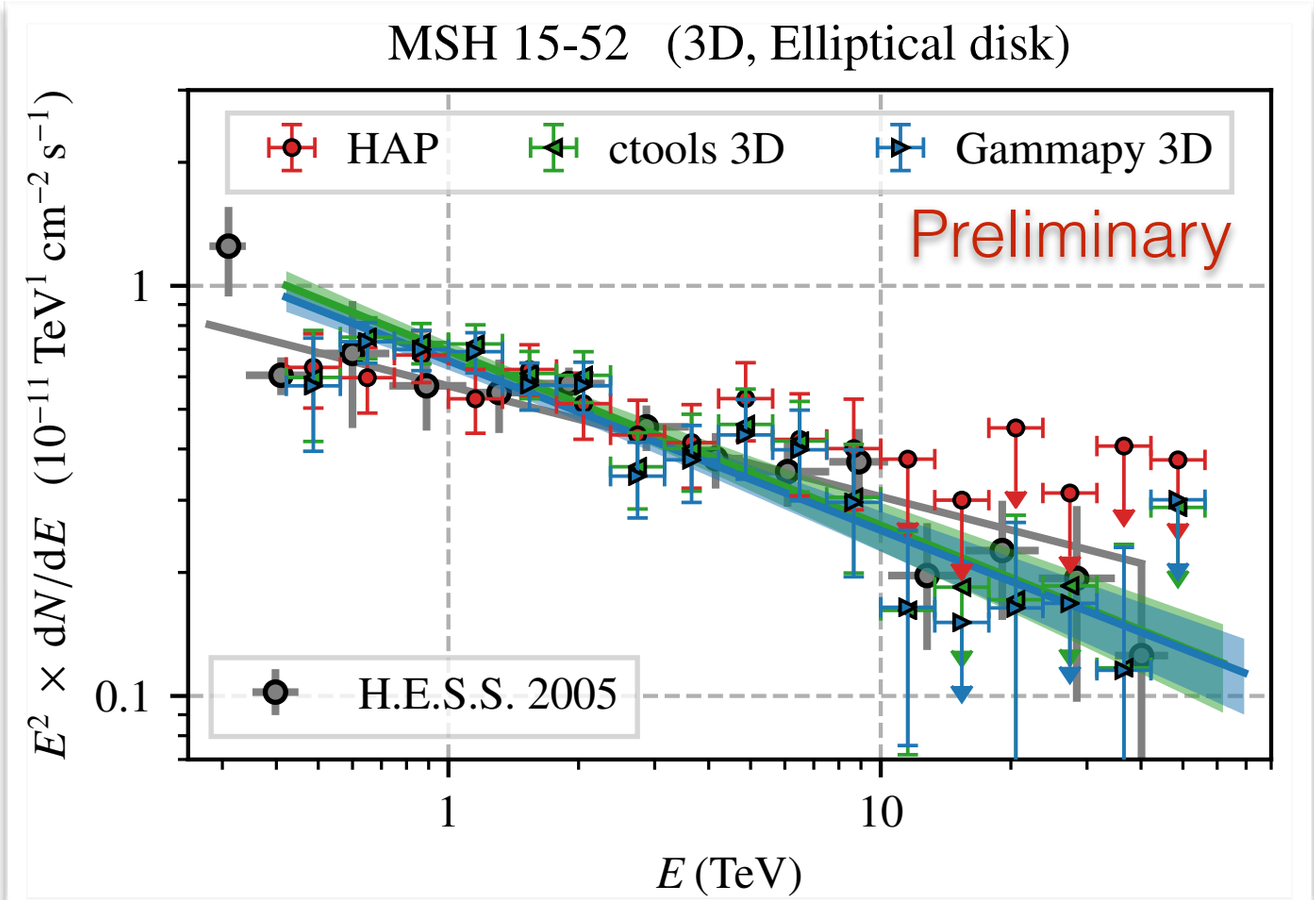


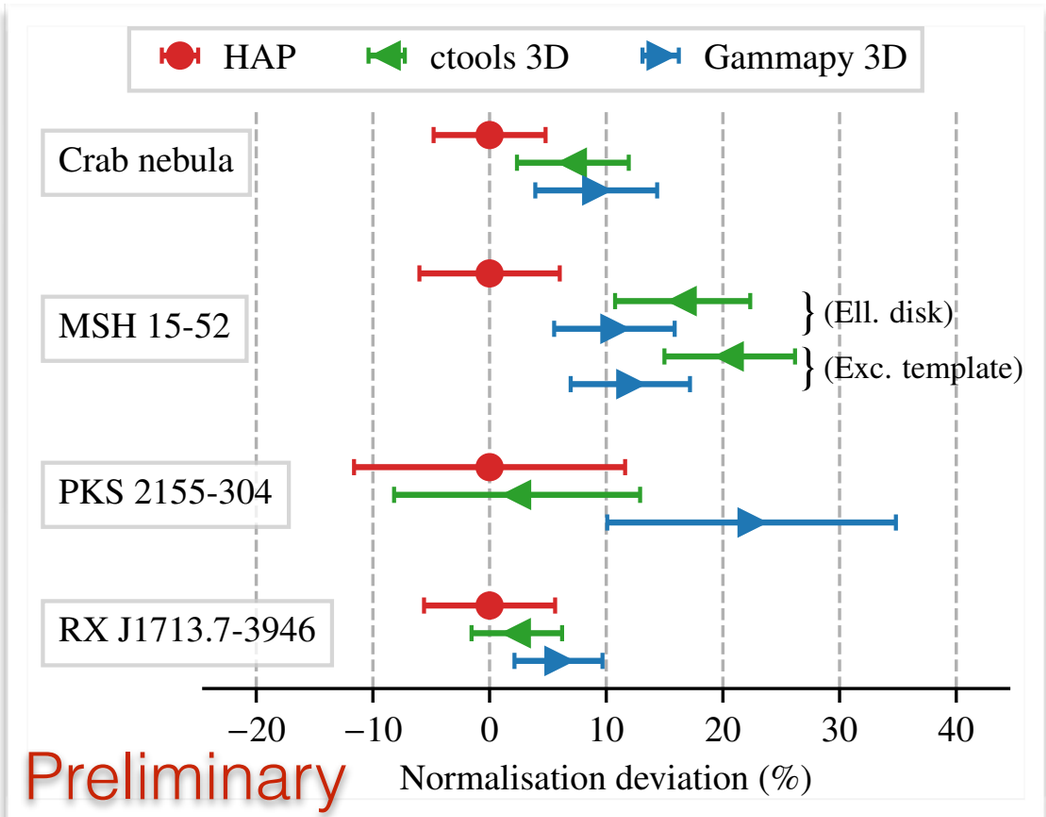


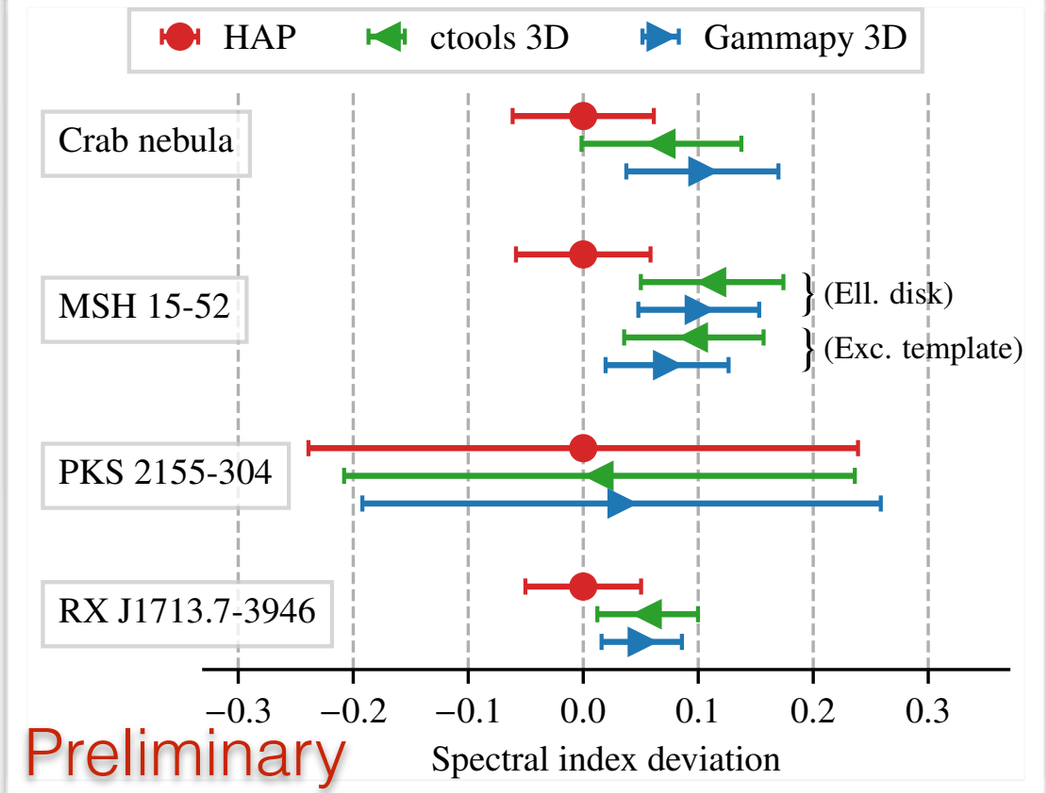
Gradient caused by Gammapy bug (see #2276)

Template analysis

- Spectrum agrees well with classical methods
- However, some systematic bias (currently under investigation)







Conclusion

- H.E.S.S. FITS validation paper well on track
- Important step towards using Gammapy
  for H.E.S.S. and CTA data analysis

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