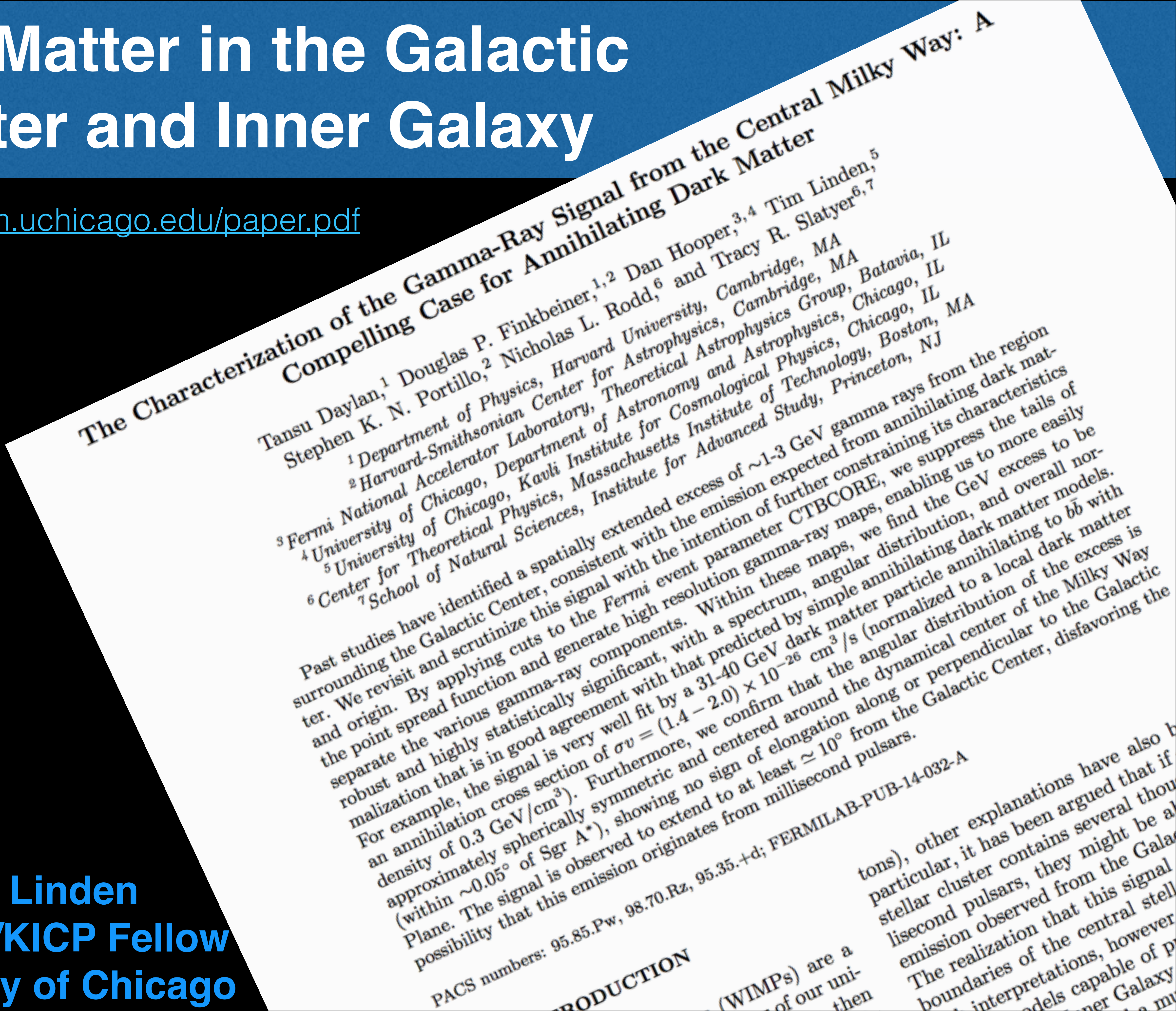
Dark Matter in the Galactic Center and Inner Galaxy

http://chasm.uchicago.edu/paper.pdf



The Characterization of the Gamma-Ray Signal from the Central Milky Way: A Compelling Case for Annihilating Dark Matter

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Past studies have identified a spatially extended excess of ~1-3 GeV gamma rays from the region surrounding the Galactic Center, consistent with the emission expected from annihilating dark matter. We revisit and scrutinize this signal with the intention of further constraining its characteristics and origin. By applying cuts to the *Fermi* event parameter CTBCORE, we suppress the tails of the point spread function and generate high resolution gamma-ray maps, enabling us to more easily separate the various gamma-ray components. Within these maps, we find the GeV excess to be robust and highly statistically significant, with a spectrum, angular distribution, and overall normalization that is in good agreement with that predicted by simple annihilating dark matter models. For example, the signal is very well fit by a 31-40 GeV dark matter particle annihilating to $b\bar{b}$ with an annihilation cross section of $\sigma v = (1.4-2.0) \times 10^{-26}$ cm^3/s (normalized to a local dark matter density of 0.3 GeV/cm^3). Furthermore, we confirm that the angular distribution of the excess is approximately spherically symmetric and centered around the dynamical center of the Milky Way (within ~0.05° of Sgr A*), showing no sign of elongation along or perpendicular to the Galactic Plane. The signal is observed to extend to at least ≃ 10° from the Galactic Center, disfavoring the possibility that this emission originates from millisecond pulsars.

PACS numbers: 95.85.Pw, 98.70.Rz, 95.35.+d; FERMILAB-PUB-14-032-A

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tons), other explanations have also b... particular, it has been argued that if... stellar cluster contains several thou... lisecond pulsars, they might be a... emission observed from the Gala... The realization that this signal... boundaries of the central stel... interpretations, however... odels capable of p... ner Galaxy

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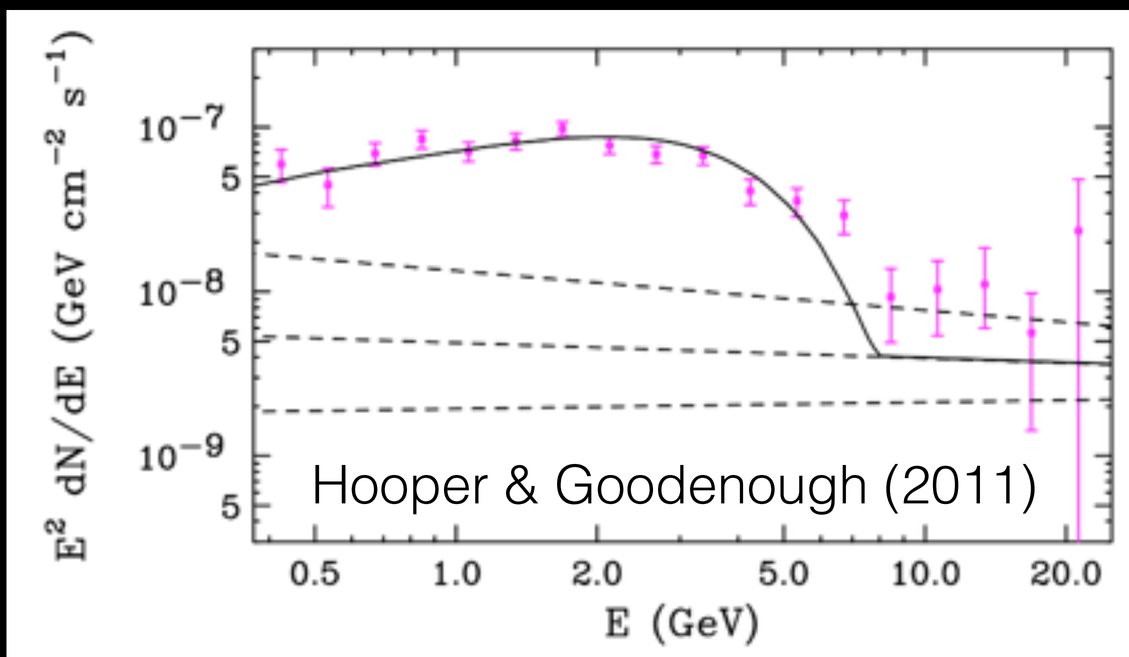
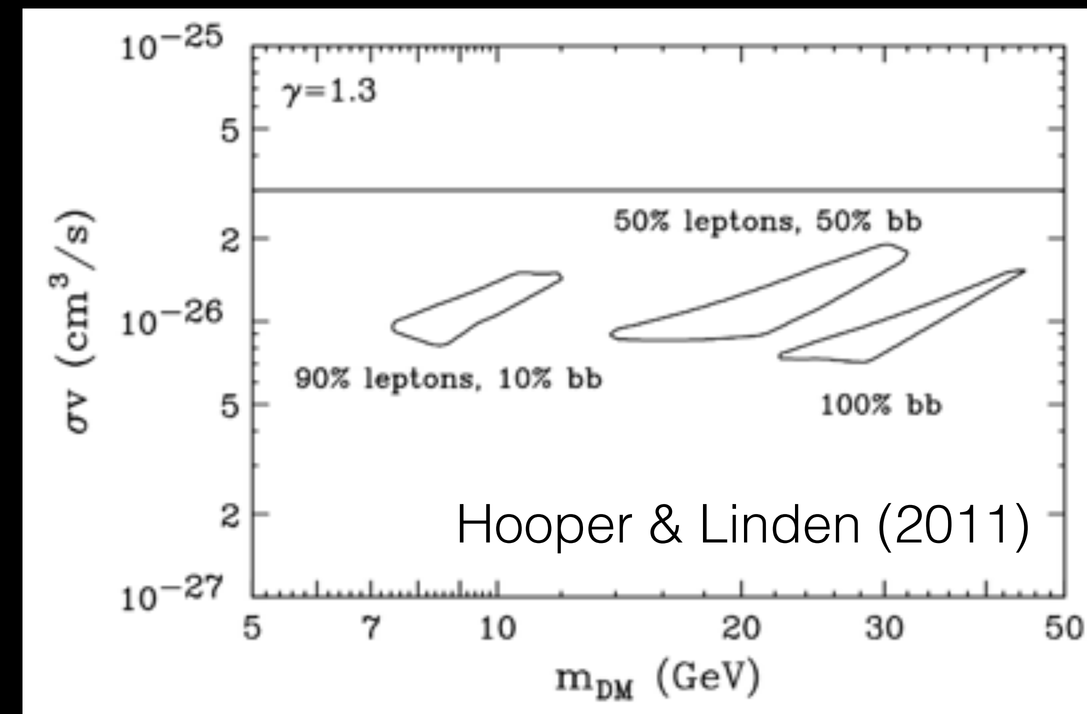
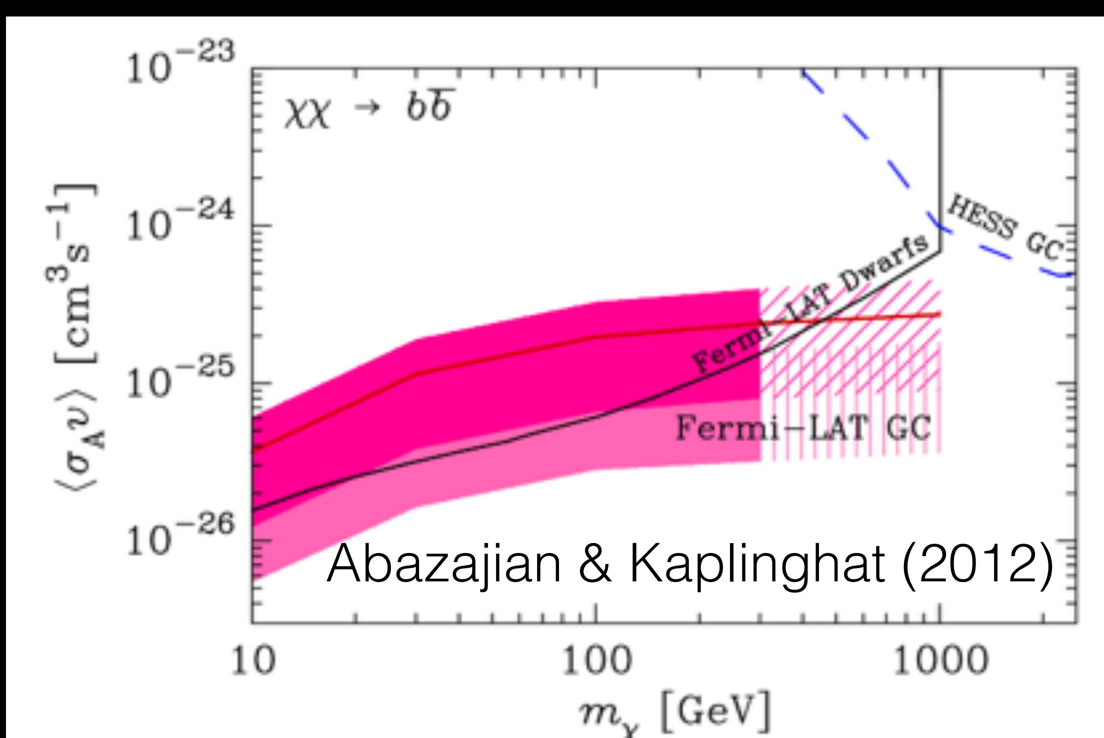
Einstein/KICP Fellow
University of Chicago

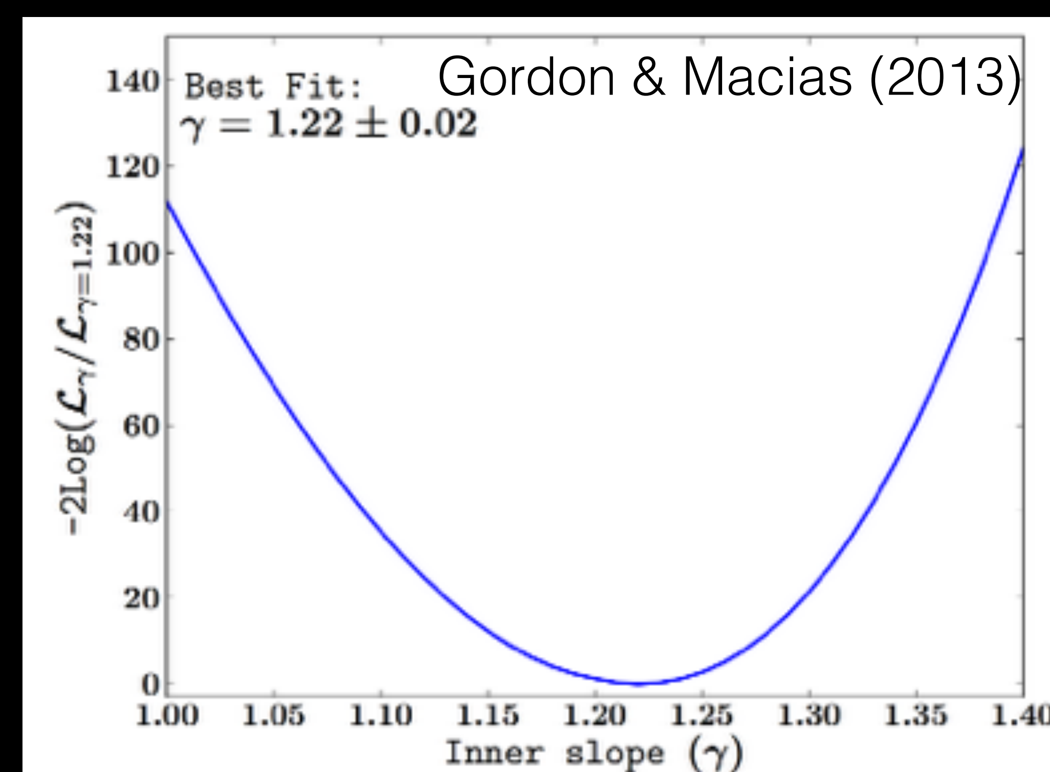
Early Observations of an Anomalous Signal at the GC

First noted as a feature in the Galactic Center region by Goodenough & Hooper (2009)



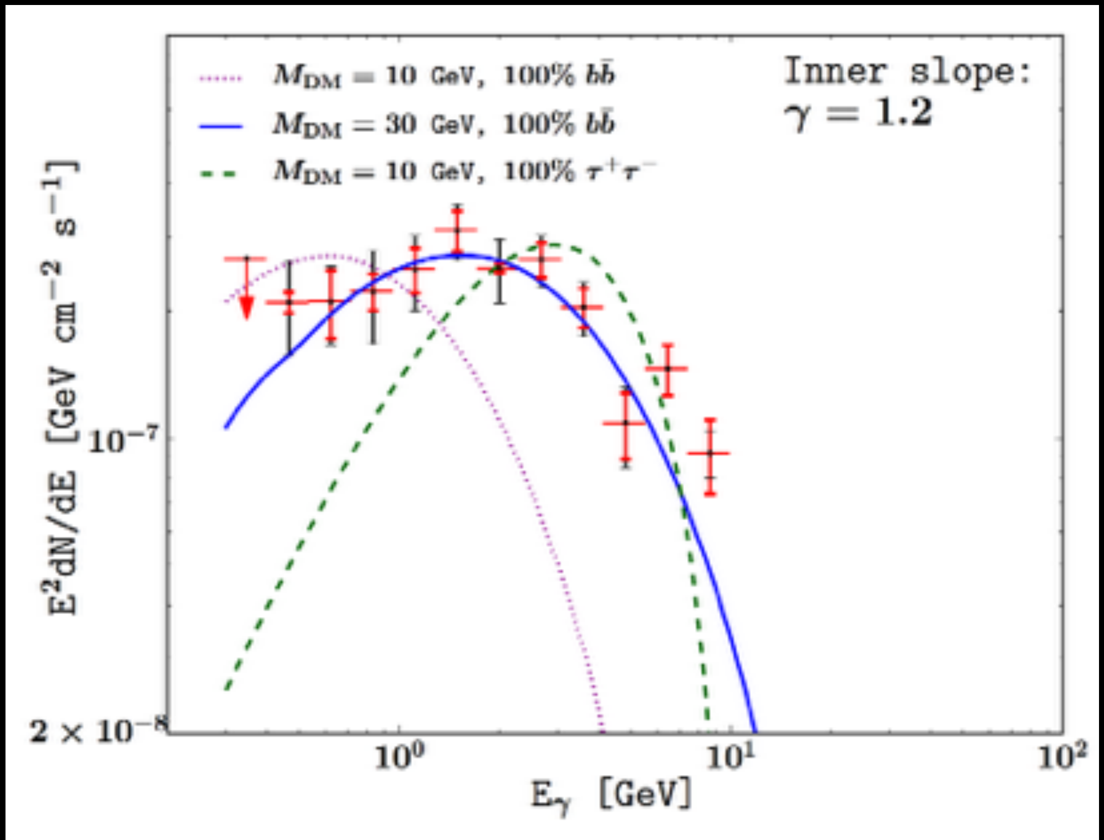






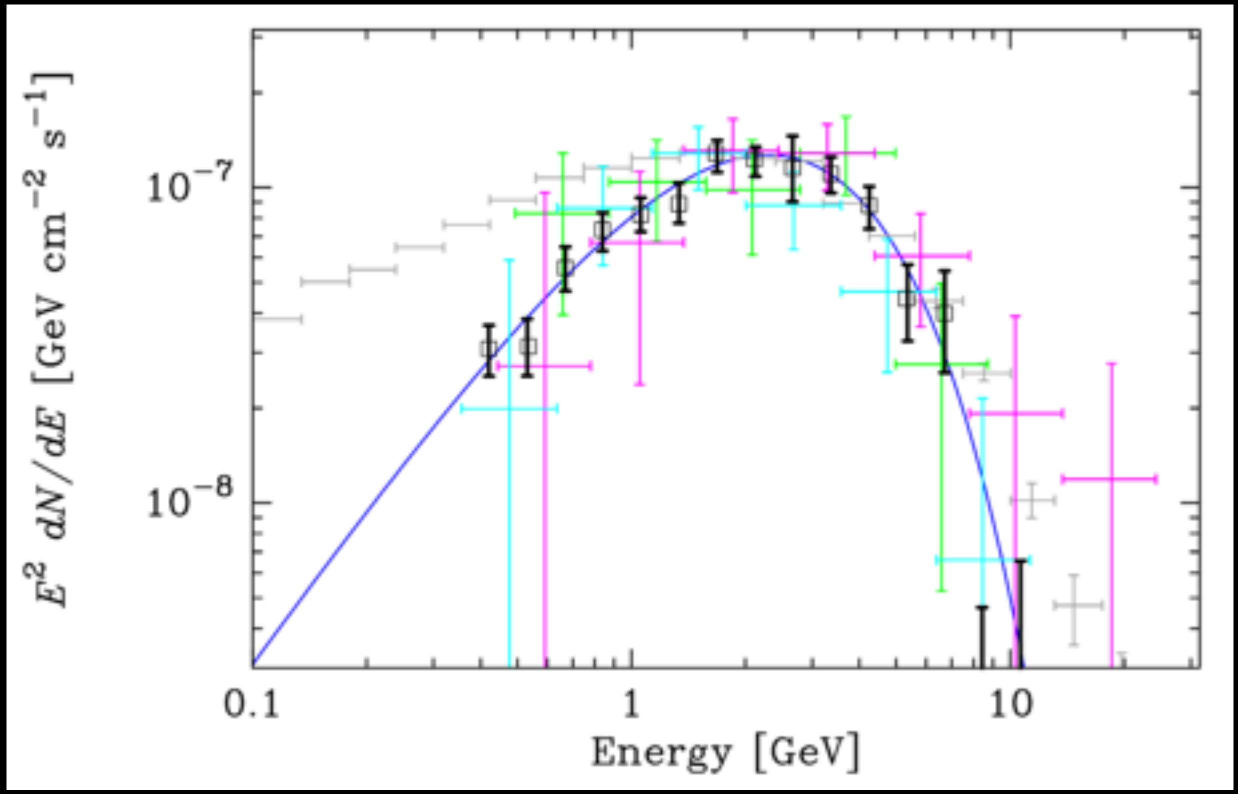
Two Interpretations of the Old Data

Dark Matter



Gordon & Macias (2013)

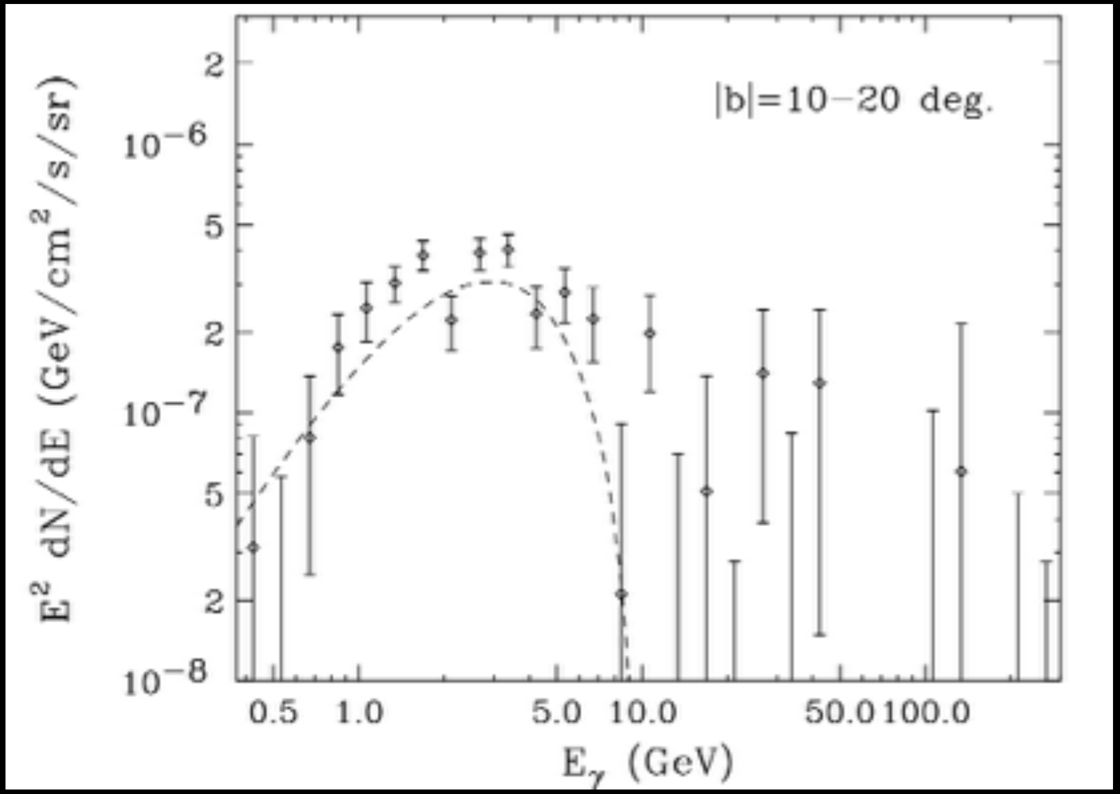
Millisecond Pulsars

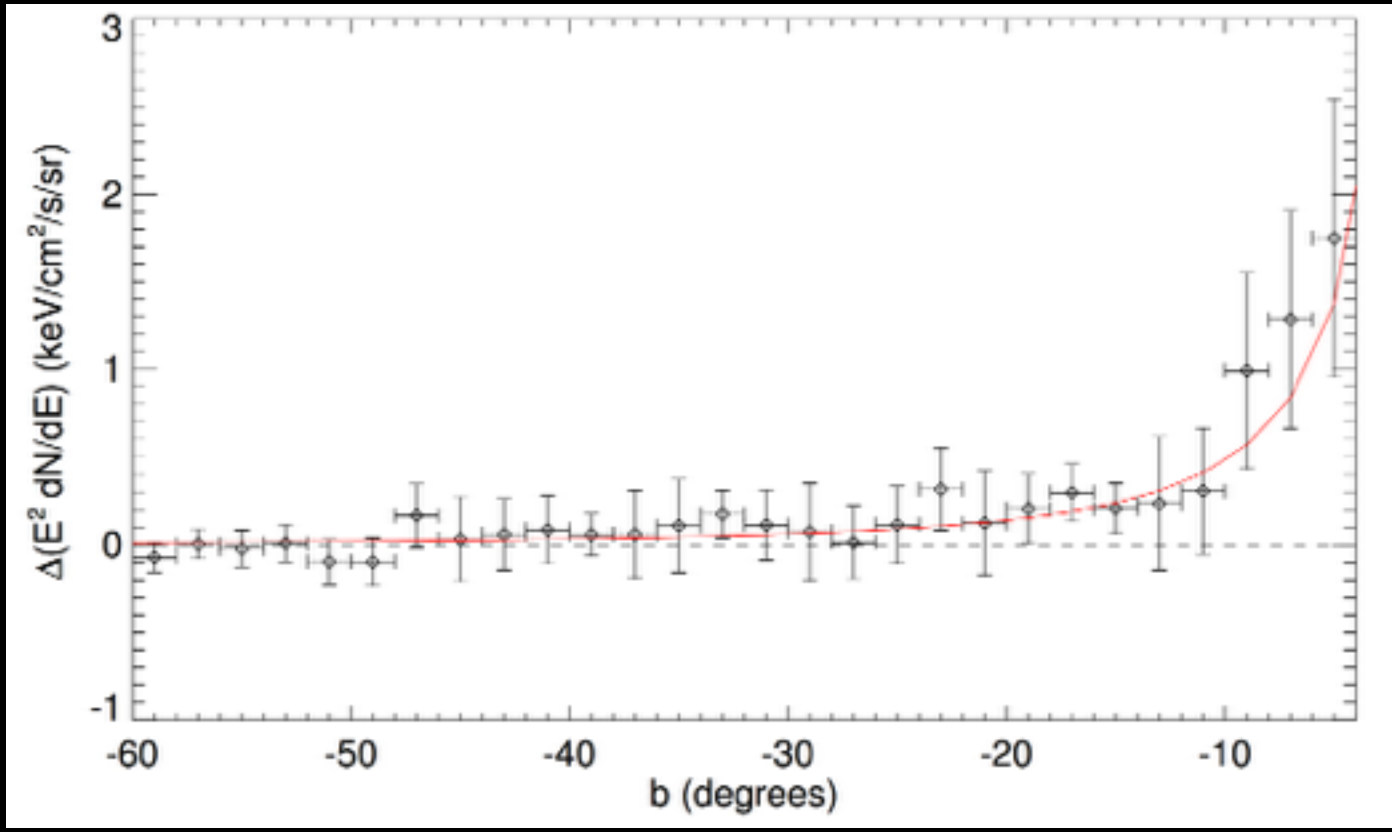


Abazajian (2011)

Early Observations of an Anomalous Signal at the GC

Work by Hooper & Slatyer found this signal in a greatly expanded range, out to at least 10 degrees from the GC





This disfavors the pulsar interpretation. A large population of MSPs 10 degrees from the GC should be observable by Fermi

Three Objectives

1.) Produce a significantly enhanced version of the Fermi dataset, using only photons with the best directional reconstruction

2.) Test the compatibility of the excess in the Galactic Center and Inner Galaxy

3.) Produce multiple tests of the dark matter interpretation of the data - concentrating on tests which can differentiate a dark matter or pulsar signal

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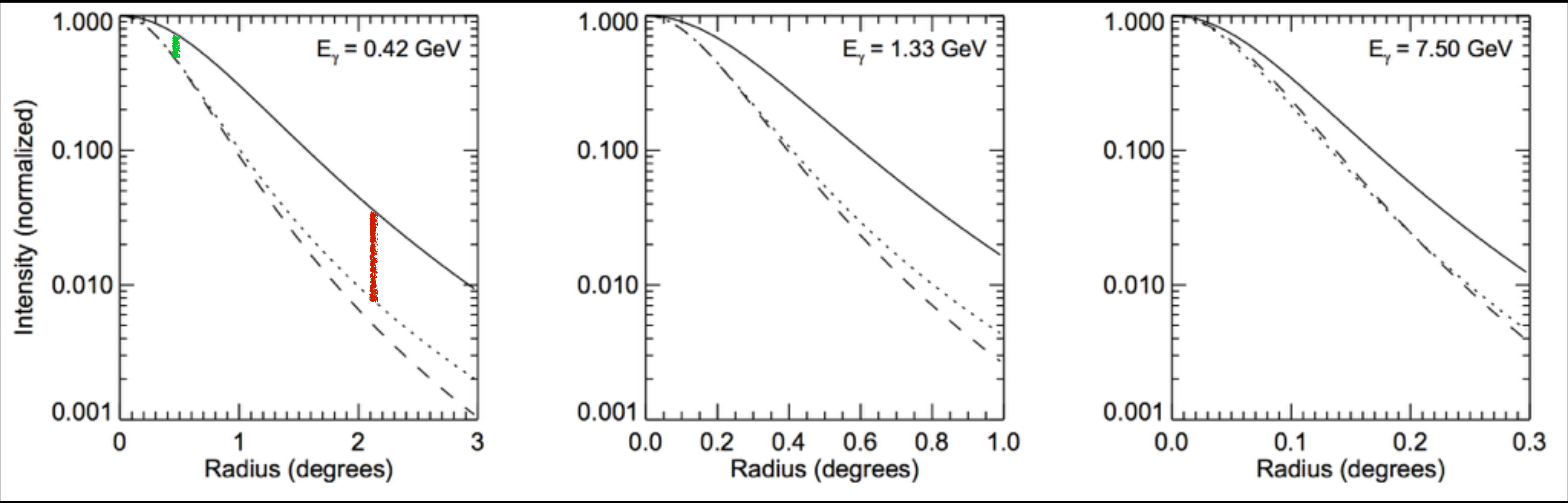
CTBCORE QUALITY CUTS



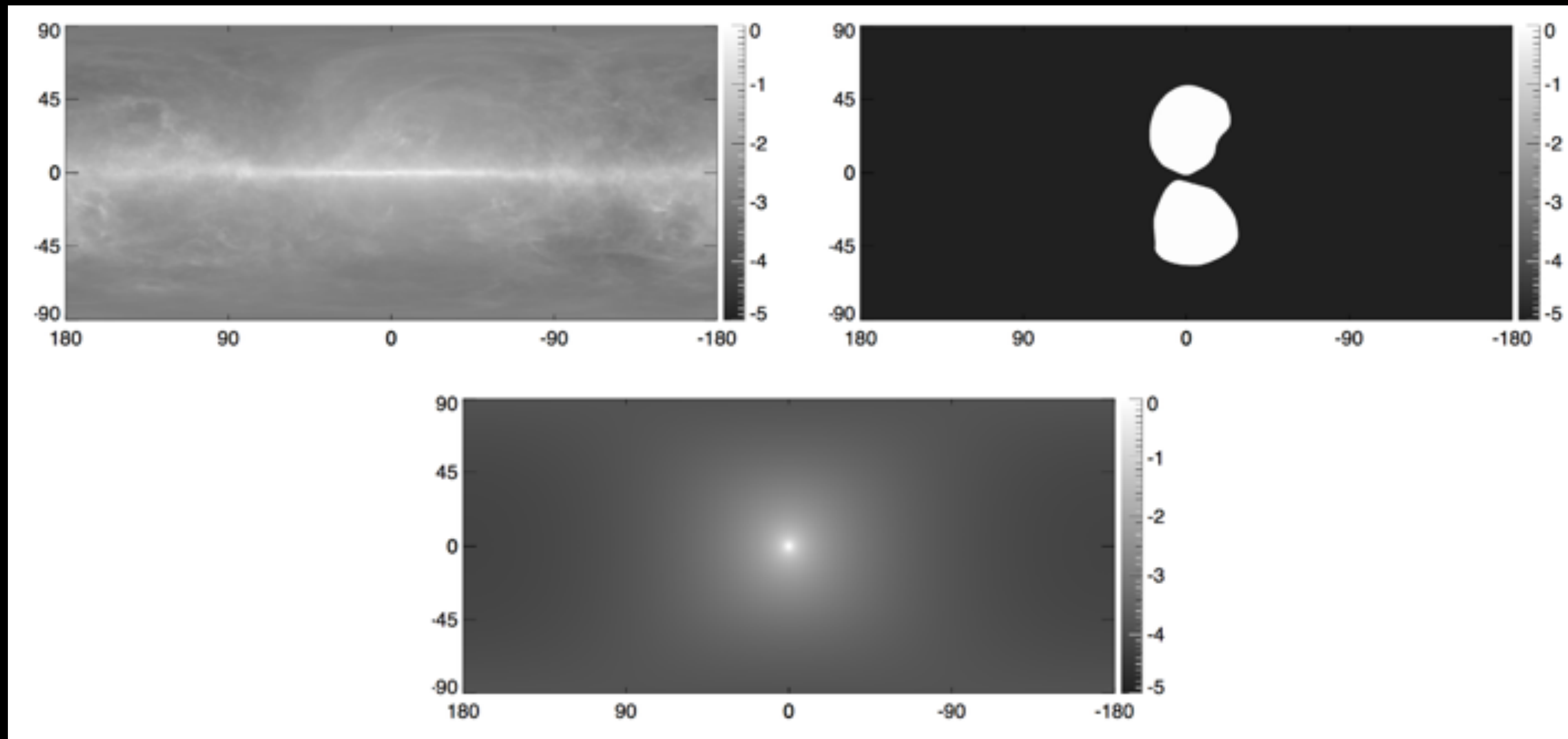
1.) Each photon observed by the Fermi-LAT has a different uncertainty in the directional reconstruction

2.) The Pass 7 analysis includes a parameter, CTBCORE, which indicates how well each individual photon was measured

3.) We select only the 50% of photons with the best CTBCORE values, this not only improves the overall PSF, but greatly diminishes the non-Gaussian tails

Portillo & Finkbeiner (2014, TBS)

The Inner Galaxy Excess

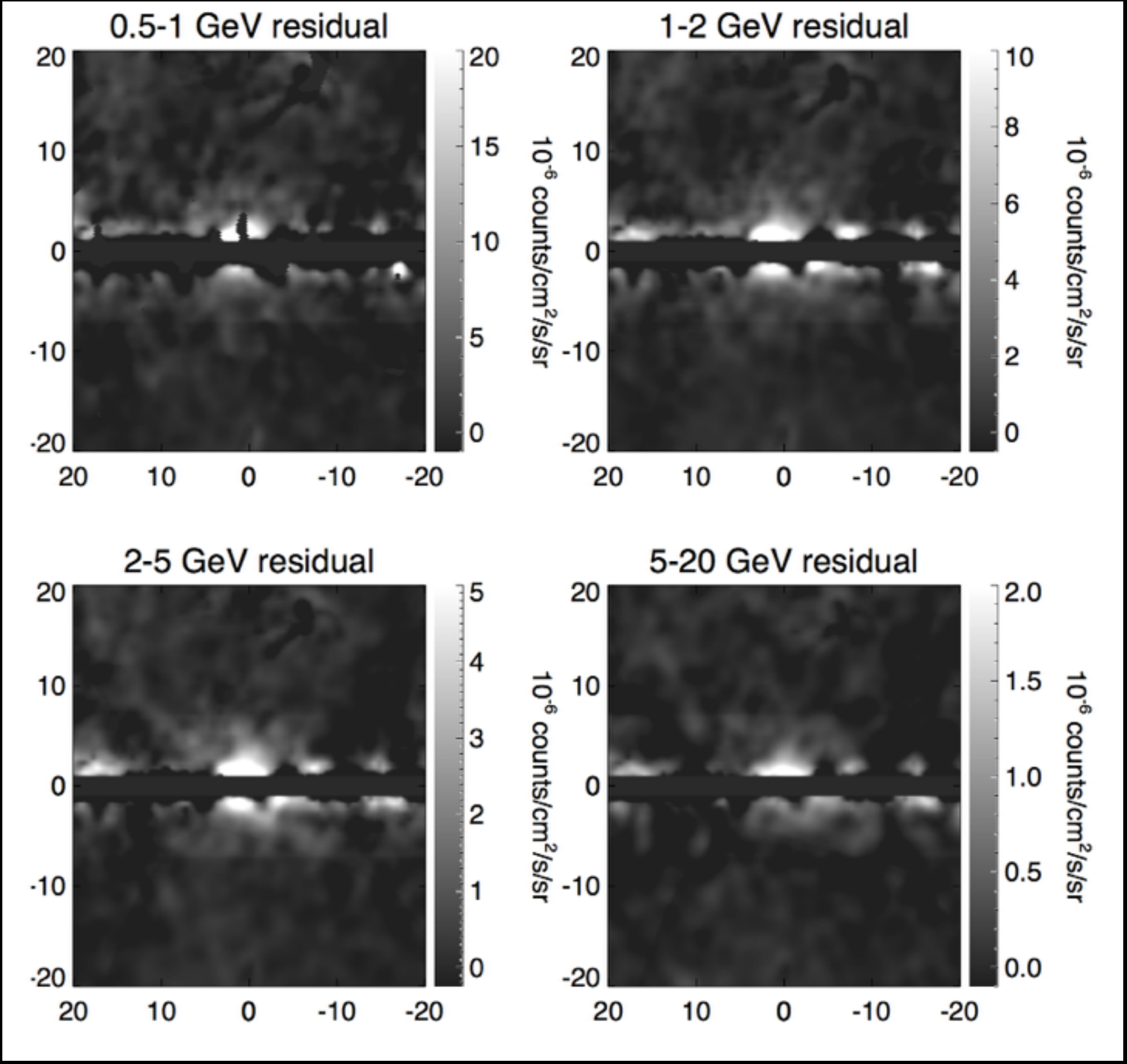


1.) Mask |b| < 1°, and a 2° radius around all 1FGL sources

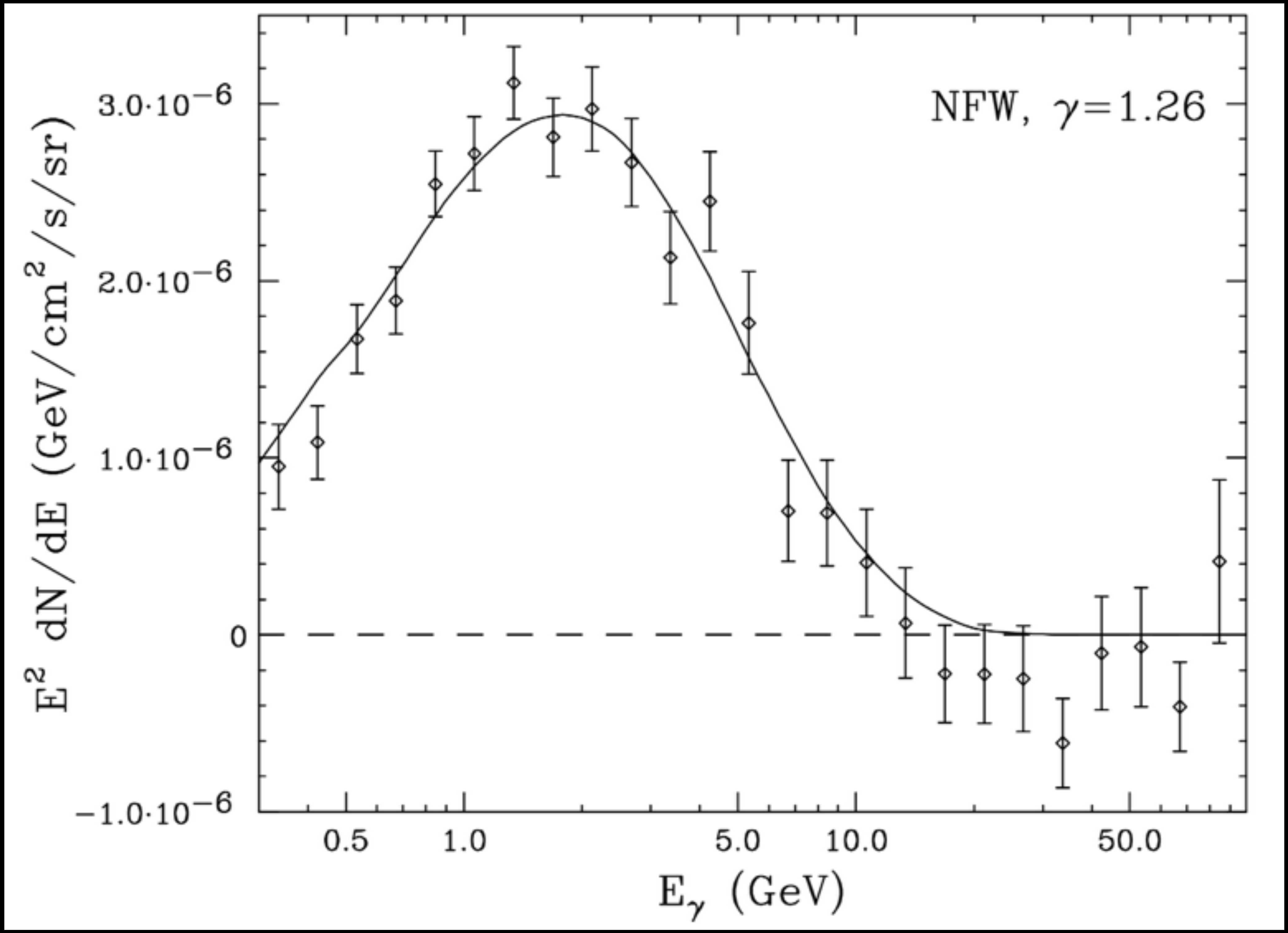
2.) Employ models for the diffuse emission, isotropic emission, Fermi bubbles, and a dark matter component

3.) Allow the normalization of each component to float in 25 different energy bins, from 300 MeV - 100 GeV

The Inner Galaxy Excess

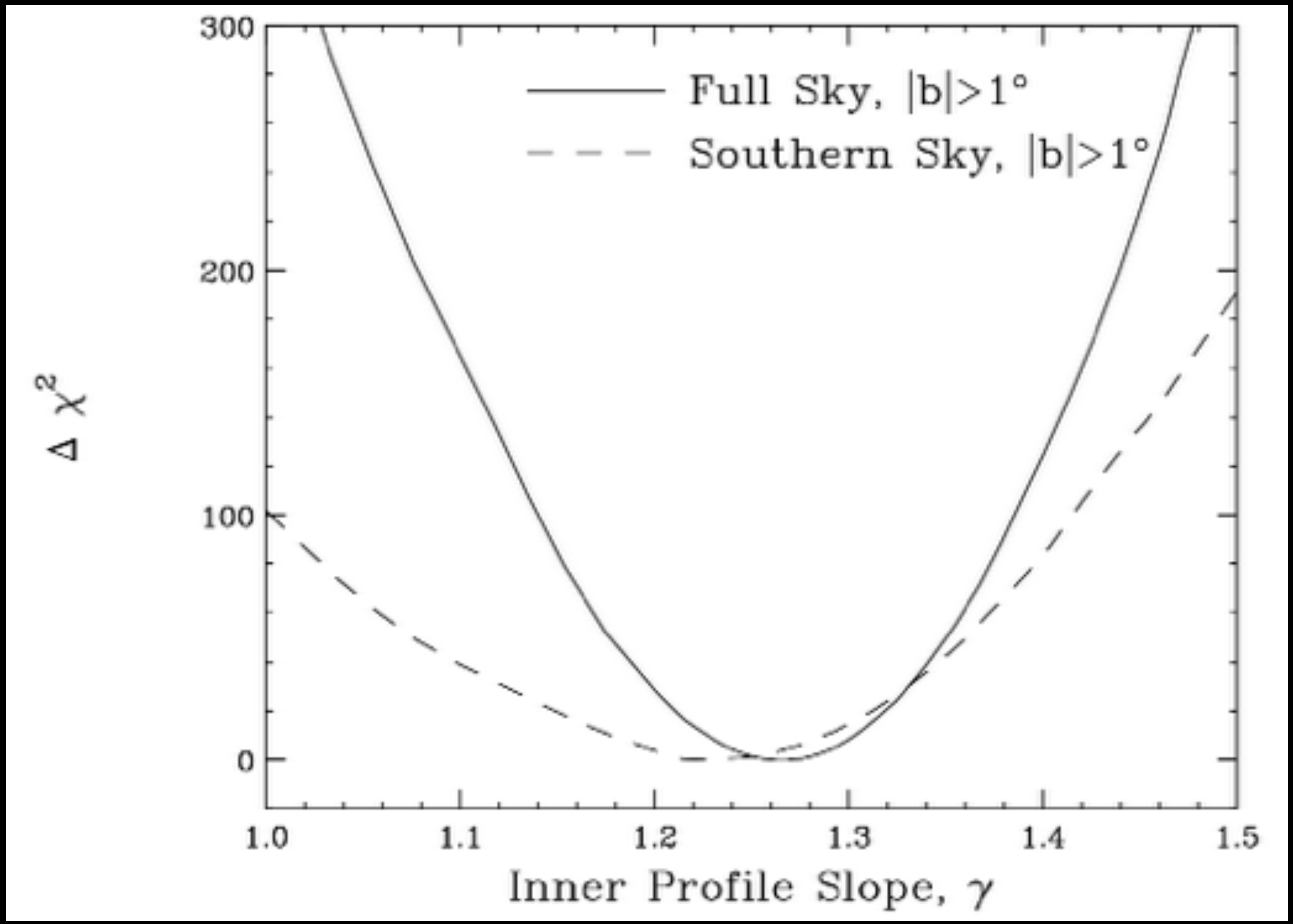


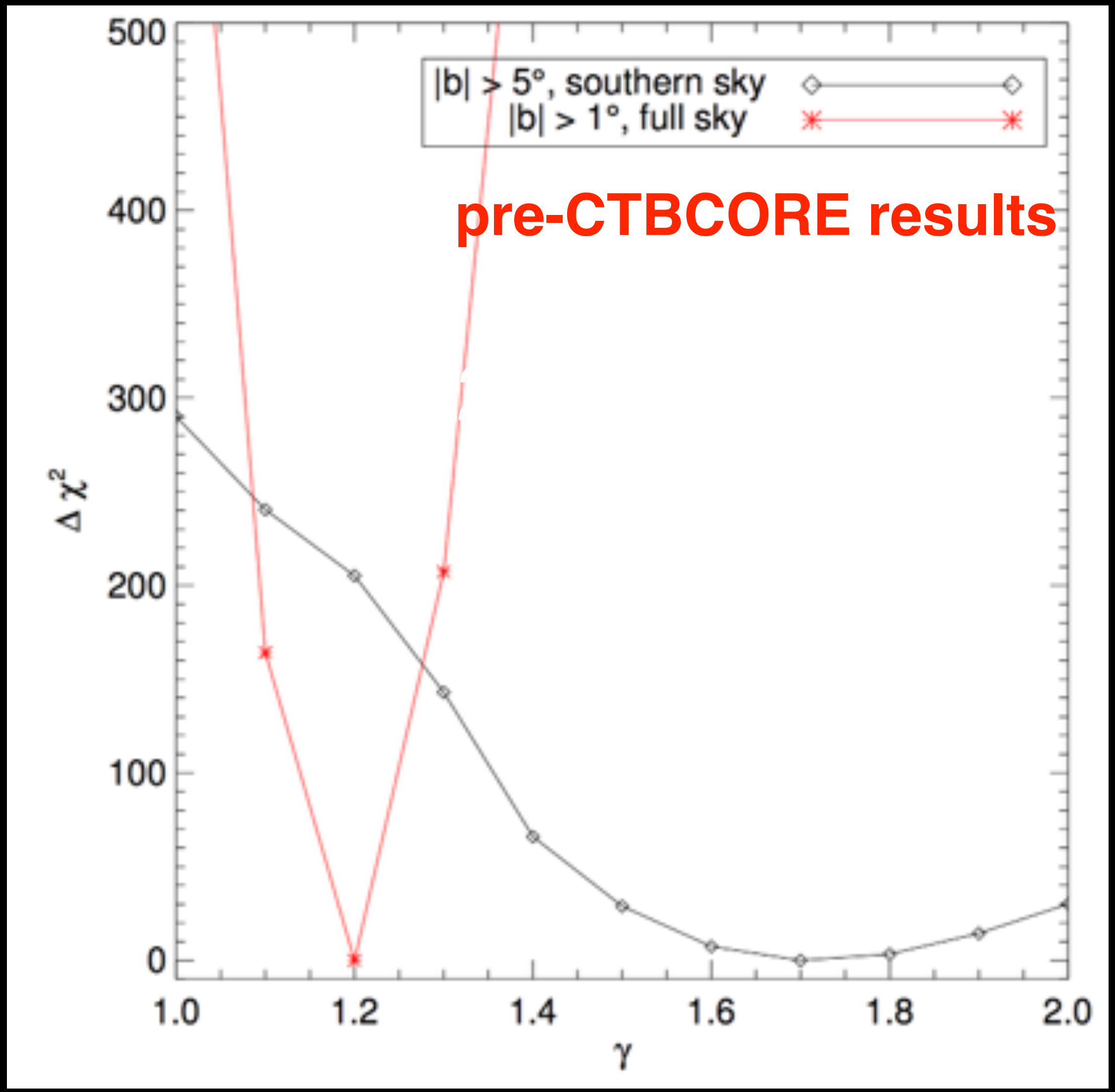
The Inner Galaxy Excess



The DM template naturally picks up the following spectral shape - the spectral shape is not forced into the template in any way

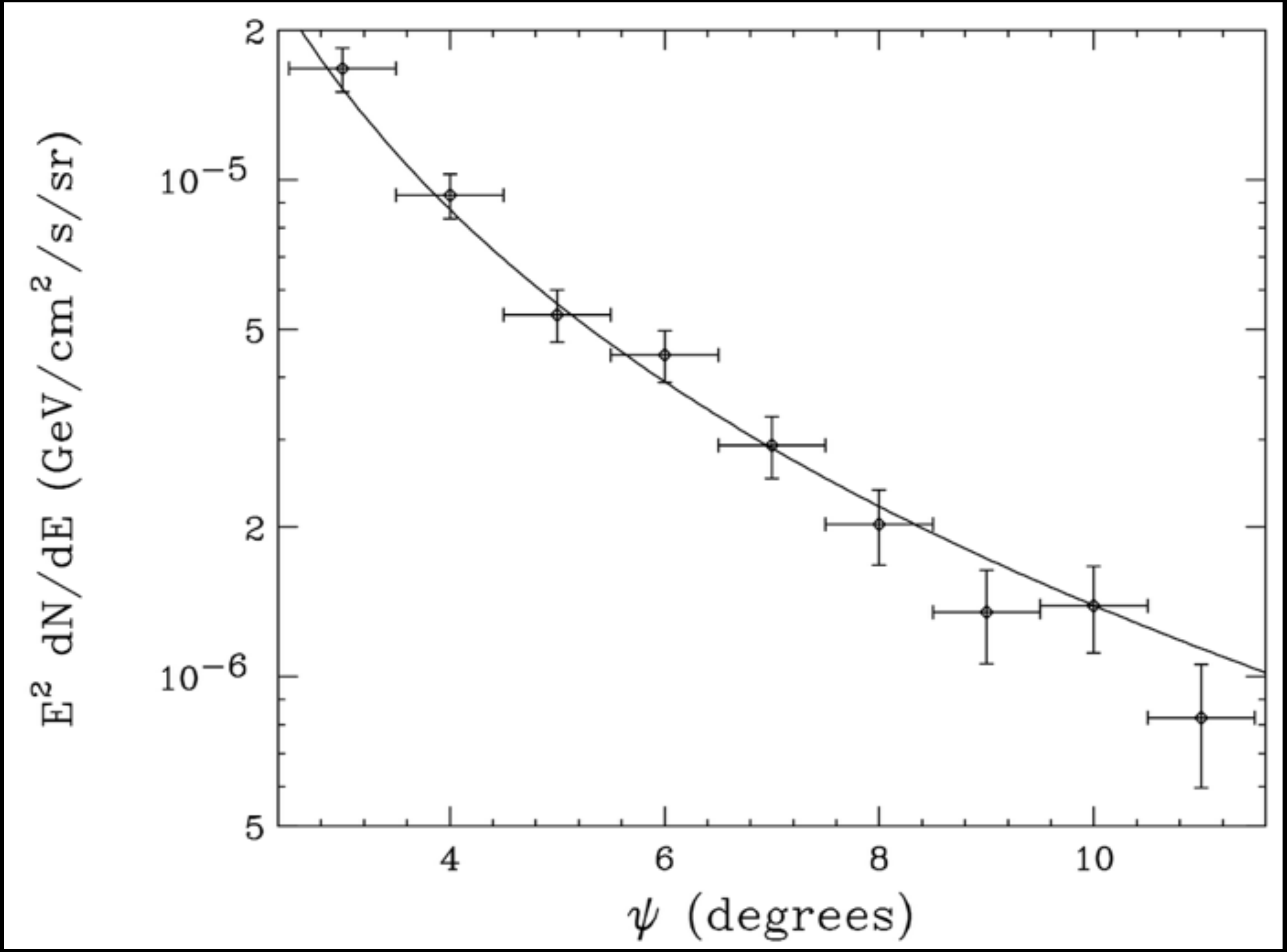
The Inner Galaxy Excess





The profile slope of the excess is best fit by a generalized NFW with **γ**=1.26. The north/south and latitude cut asymmetries have been eliminated when using the higher quality, CTBCORE data set.

The Inner Galaxy Excess



The morphology of the excess is resilient when each individual 1° ring is allowed to float independently. It becomes slightly steeper (**γ**=1.4), probably due to oversubtraction of the diffuse component at high latitudes

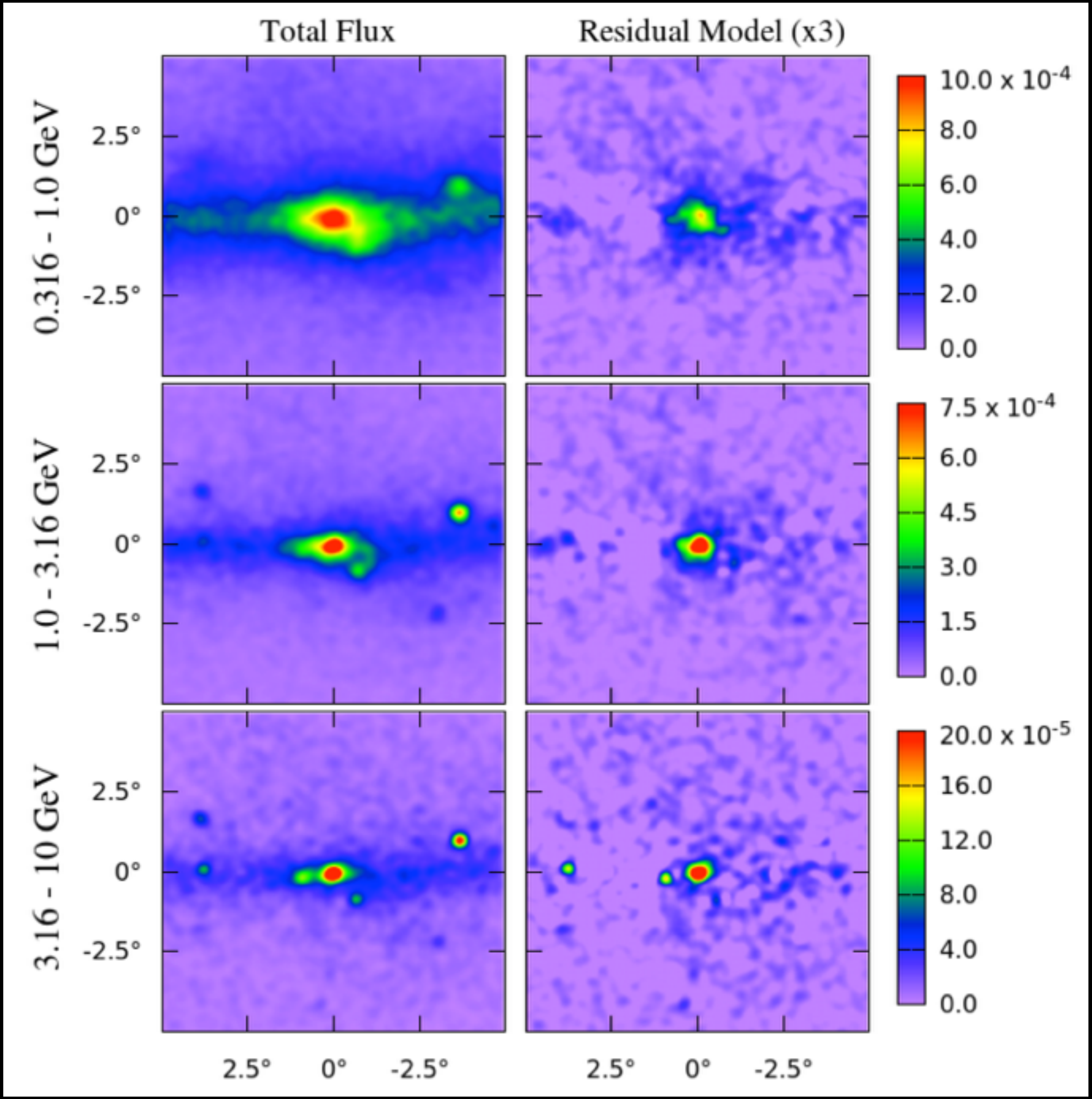
Galactic Center Modeling

1.) Instead model the inner $|l| < 5^o$, $|b| < 5^o$

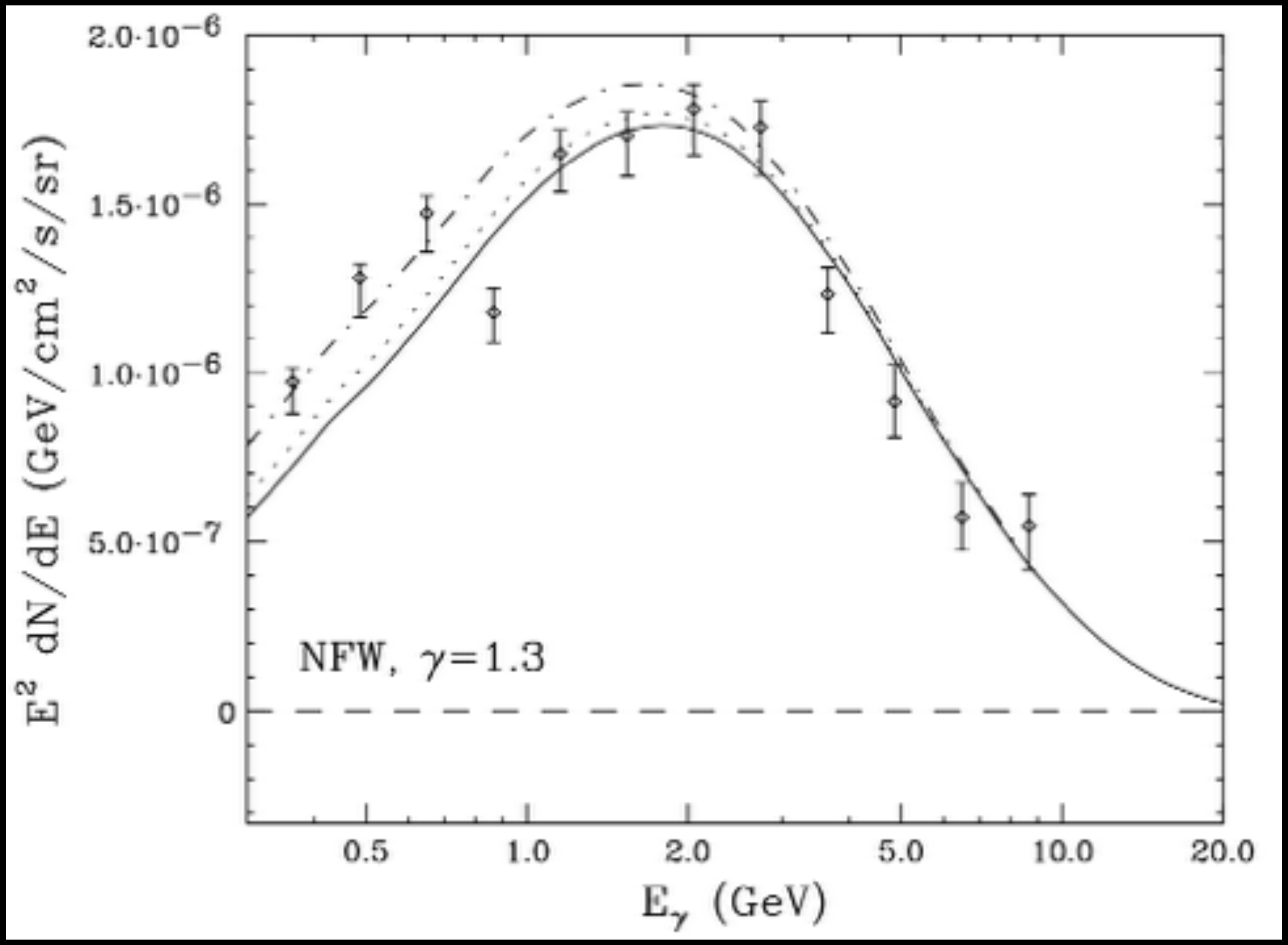
2.) Must include all point sources in the model - along with models for the diffuse emission, isotropic emission, 20cm map

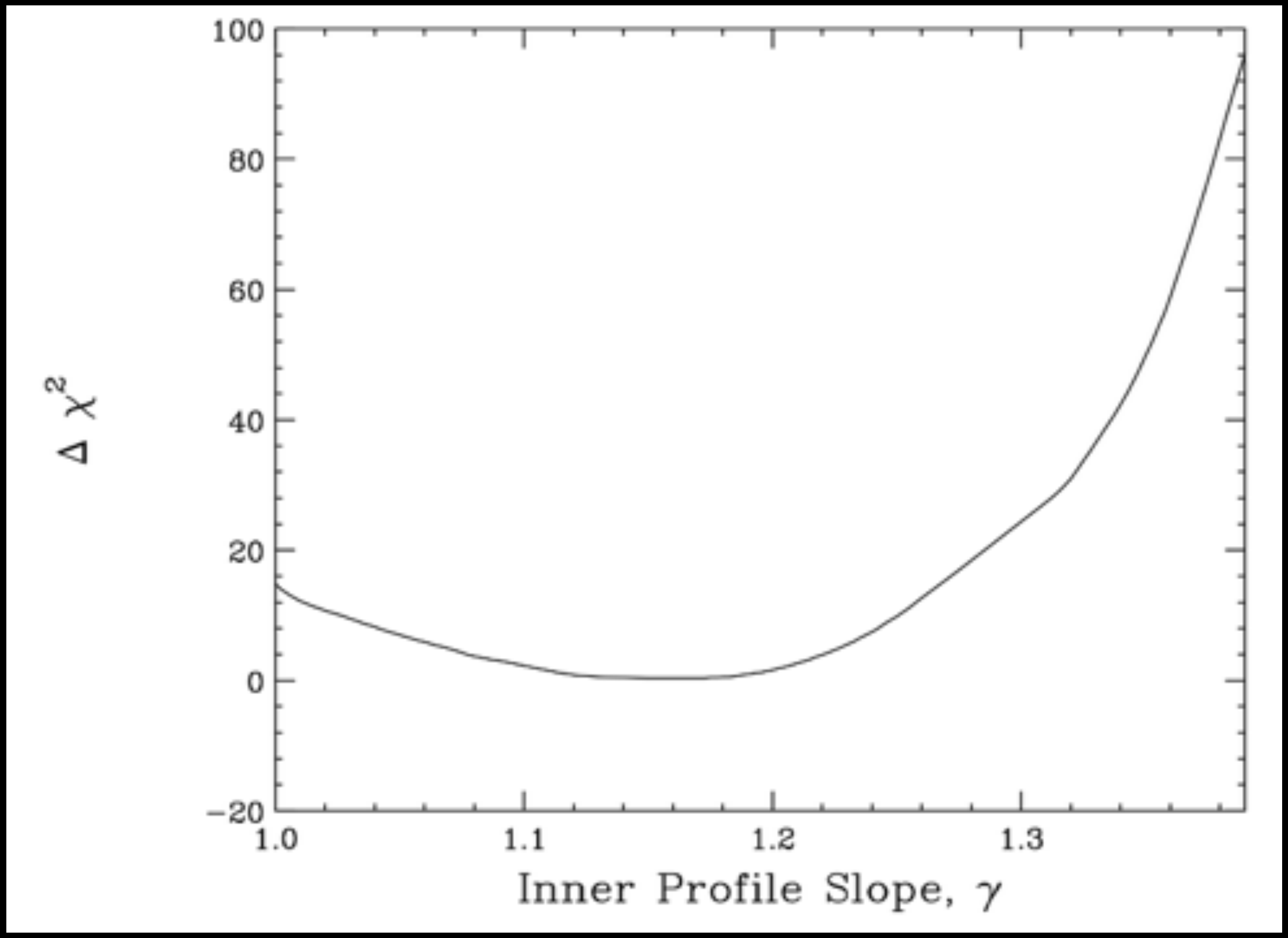
3.) In order to obtain the best fitting model, we allow the normalizations and spectra of multiple sources to vary, using the Fermi tool *gtlike* (and the MINUIT algorithm) to determine the best model for each component

Galactic Center Excess



Galactic Center Excess

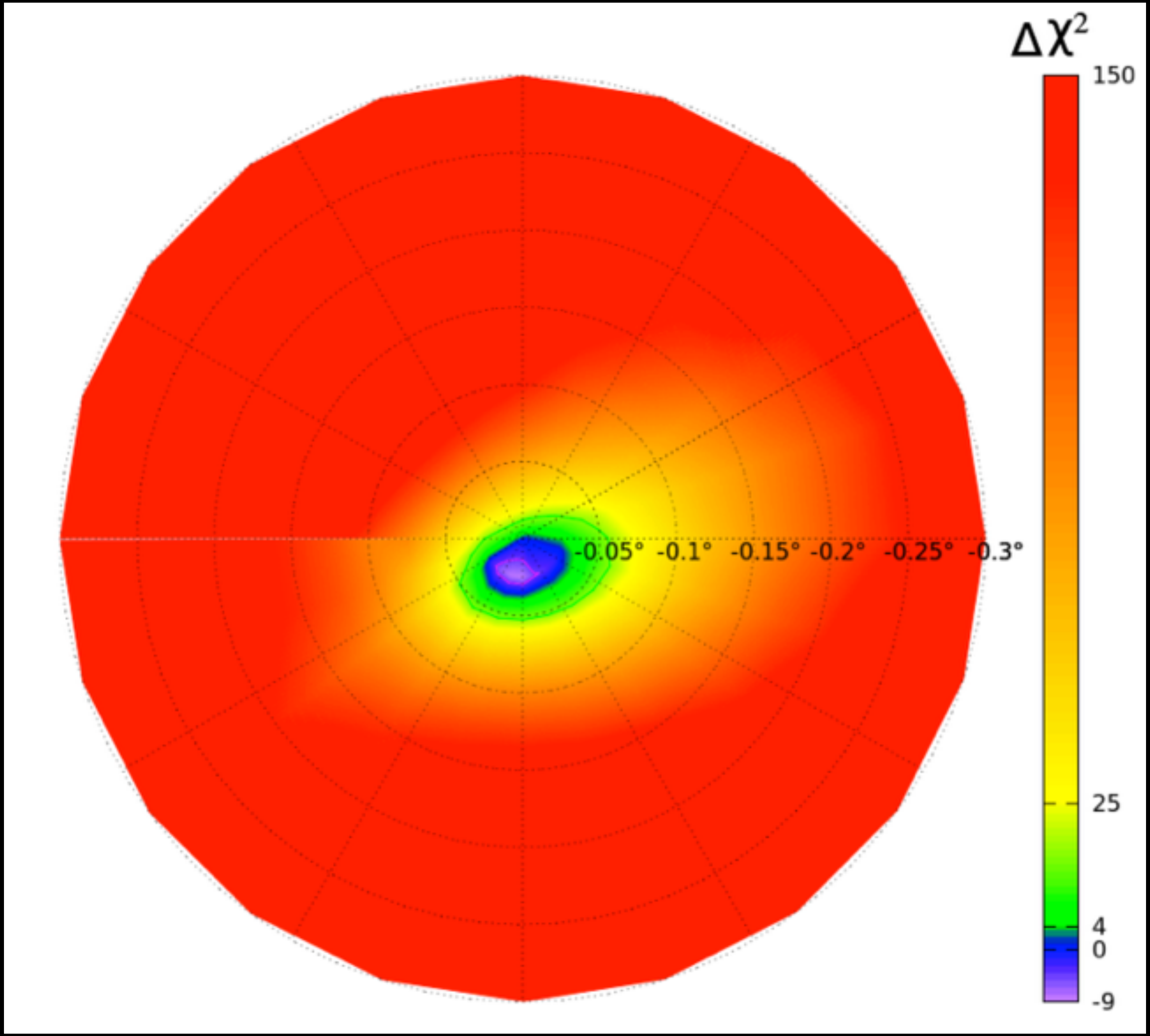




1.) The spectrum of the residual looks very similar to the spectrum of the Inner Galaxy analysis.

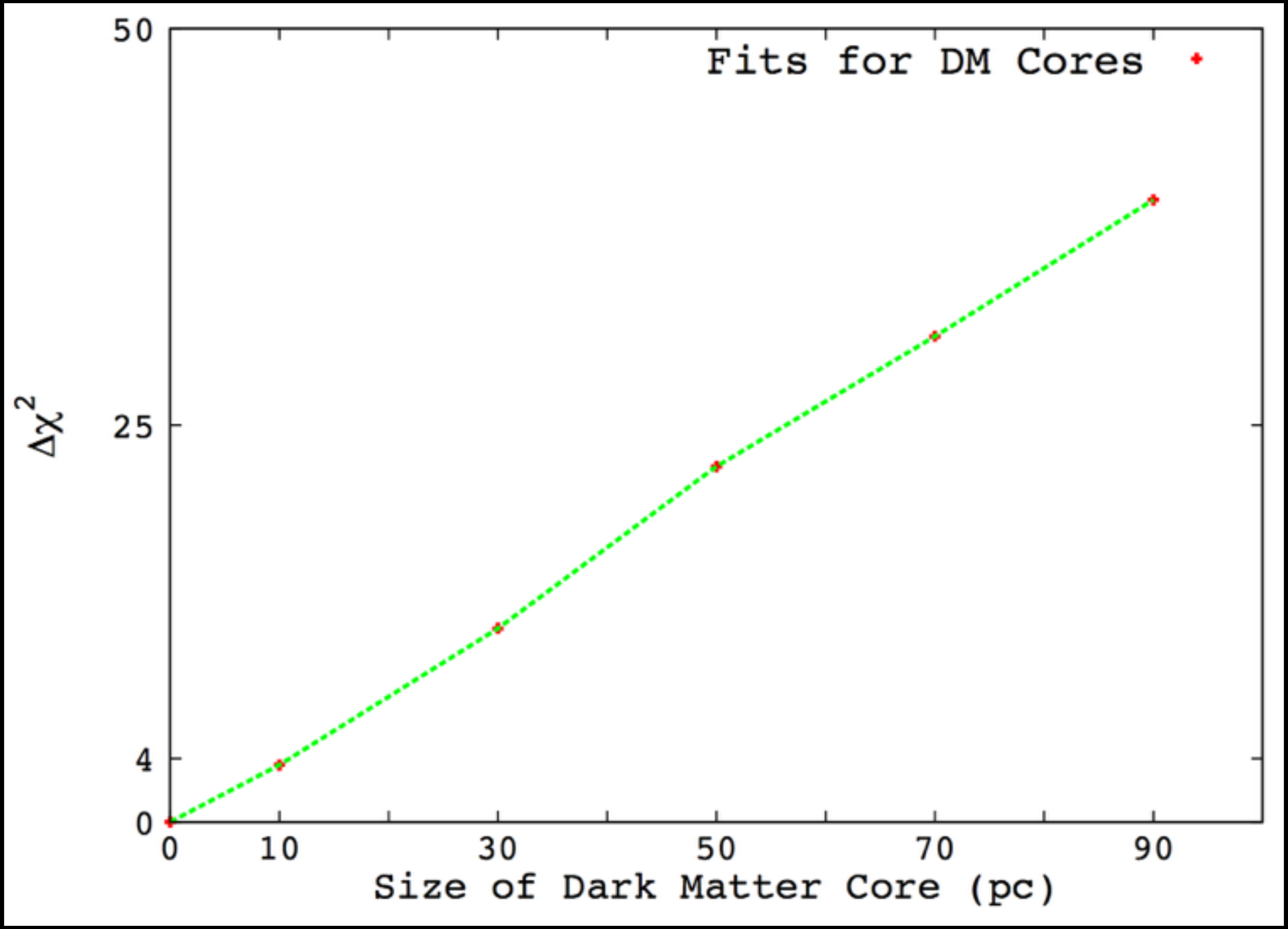
2.) The slope of the NFW profile looks to be less peaked very close to the GC (**γ**=1.17) — this is not at odds with simulations.

Galactic Center Excess



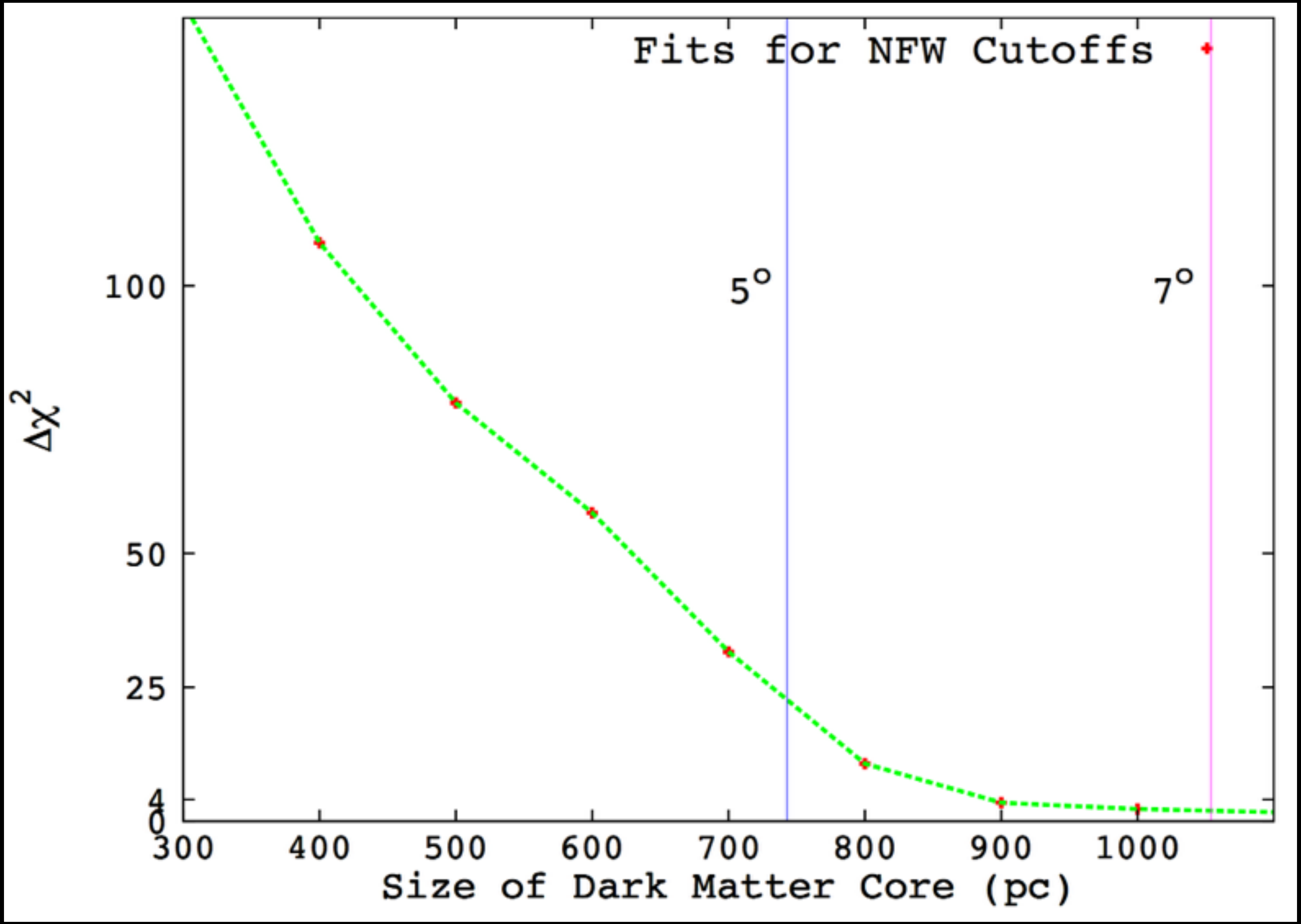
The excess is remarkably centered on the position of Sgr A*

Galactic Center Excess



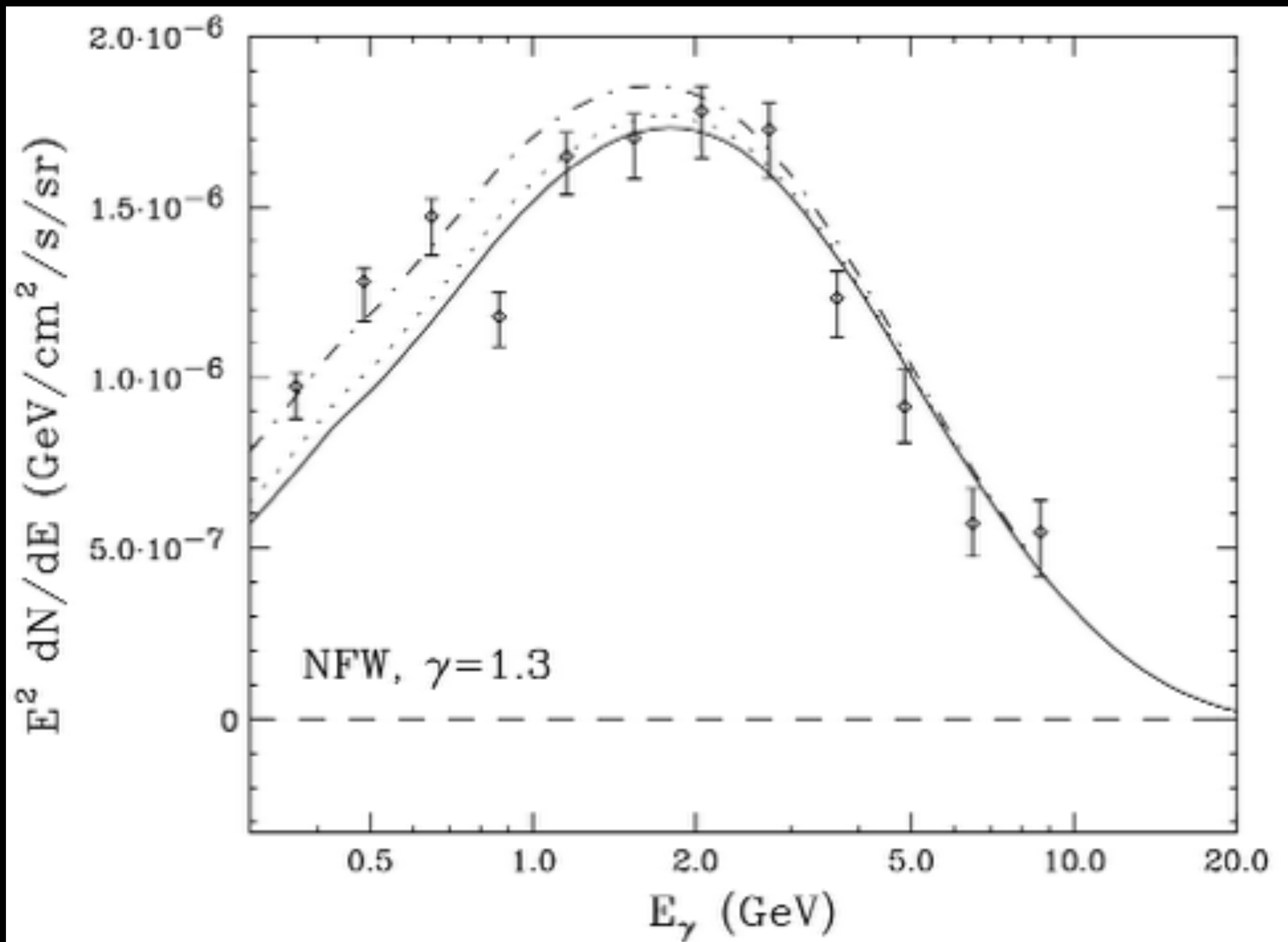
The morphology of this excess does not appear to have a core, even a core of only ~15 pc can be rejected at more than 2σ

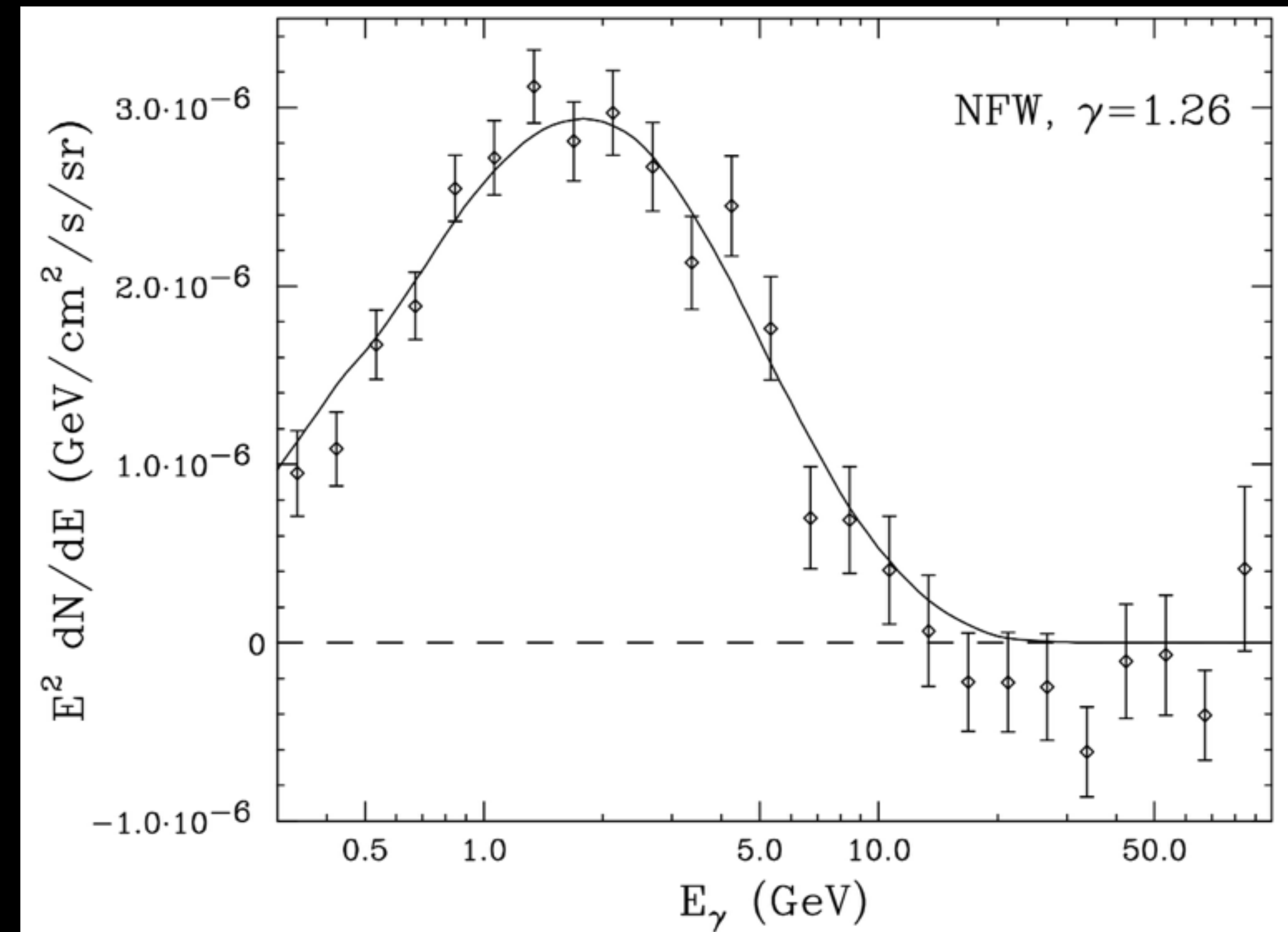
Galactic Center Excess



The dark matter model can also be found out to at least 800 pc from the GC (where the simulation cuts off). We have isolated a steeply falling morphology over nearly than two orders of magnitude in GC distance.

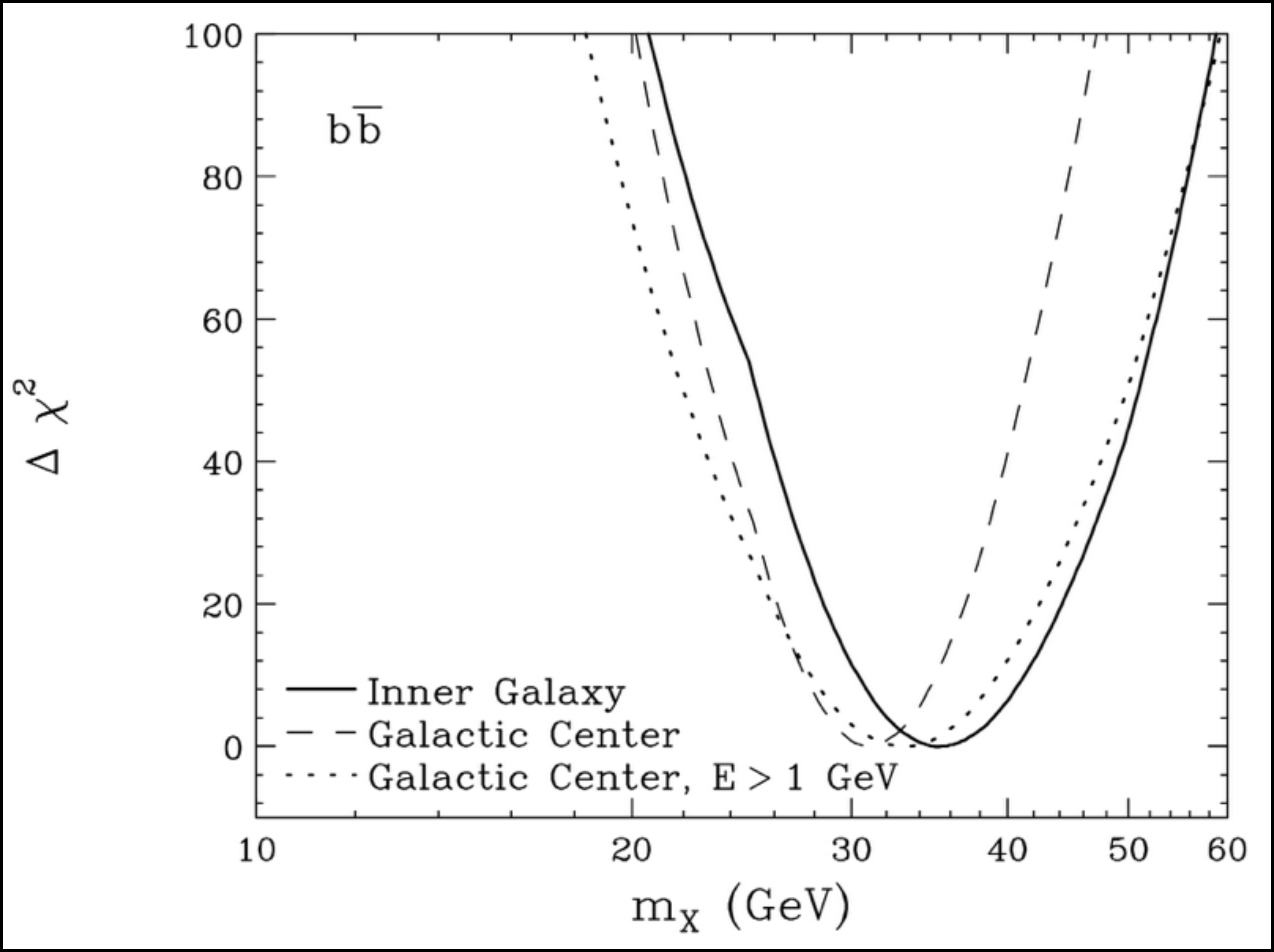
The Similar Spectrum of the Excesses





With two different, independent analysis techniques —- and using photons primarily from different regions of the sky, the spectra of these excesses looks almost identical.

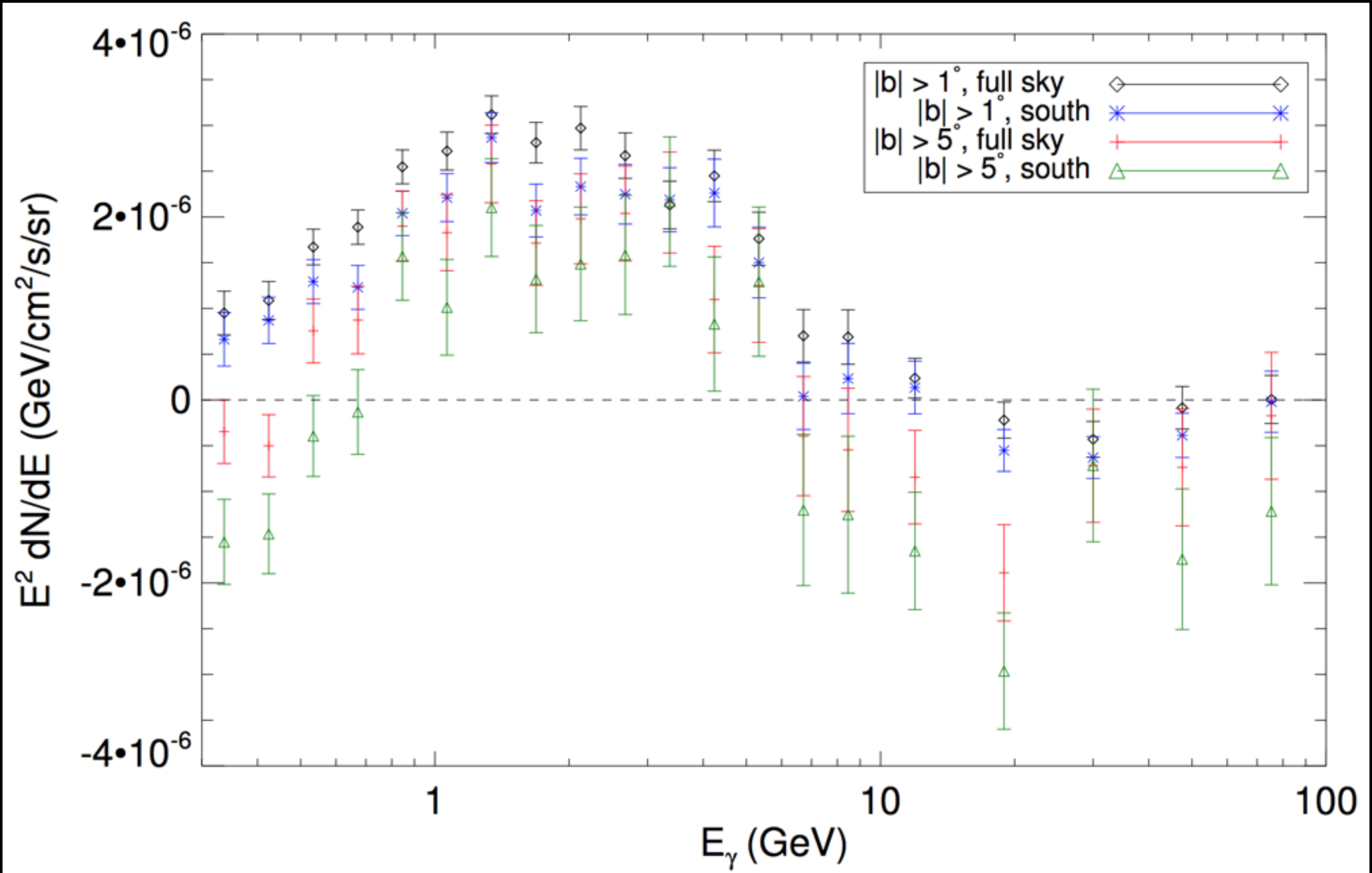
The Similar Spectrum of the Excesses



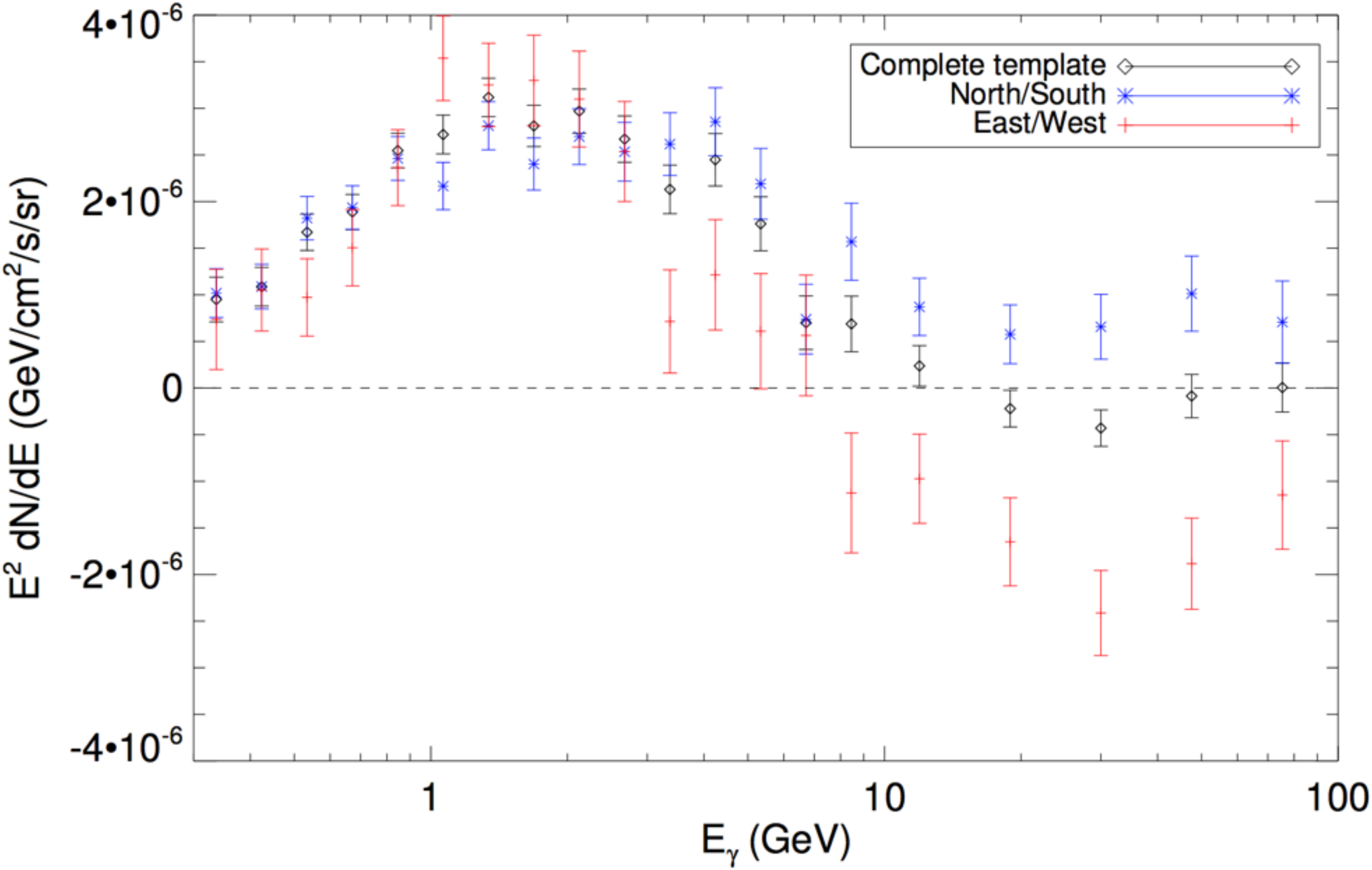
And it looks a lot like dark matter…

Extra Slides

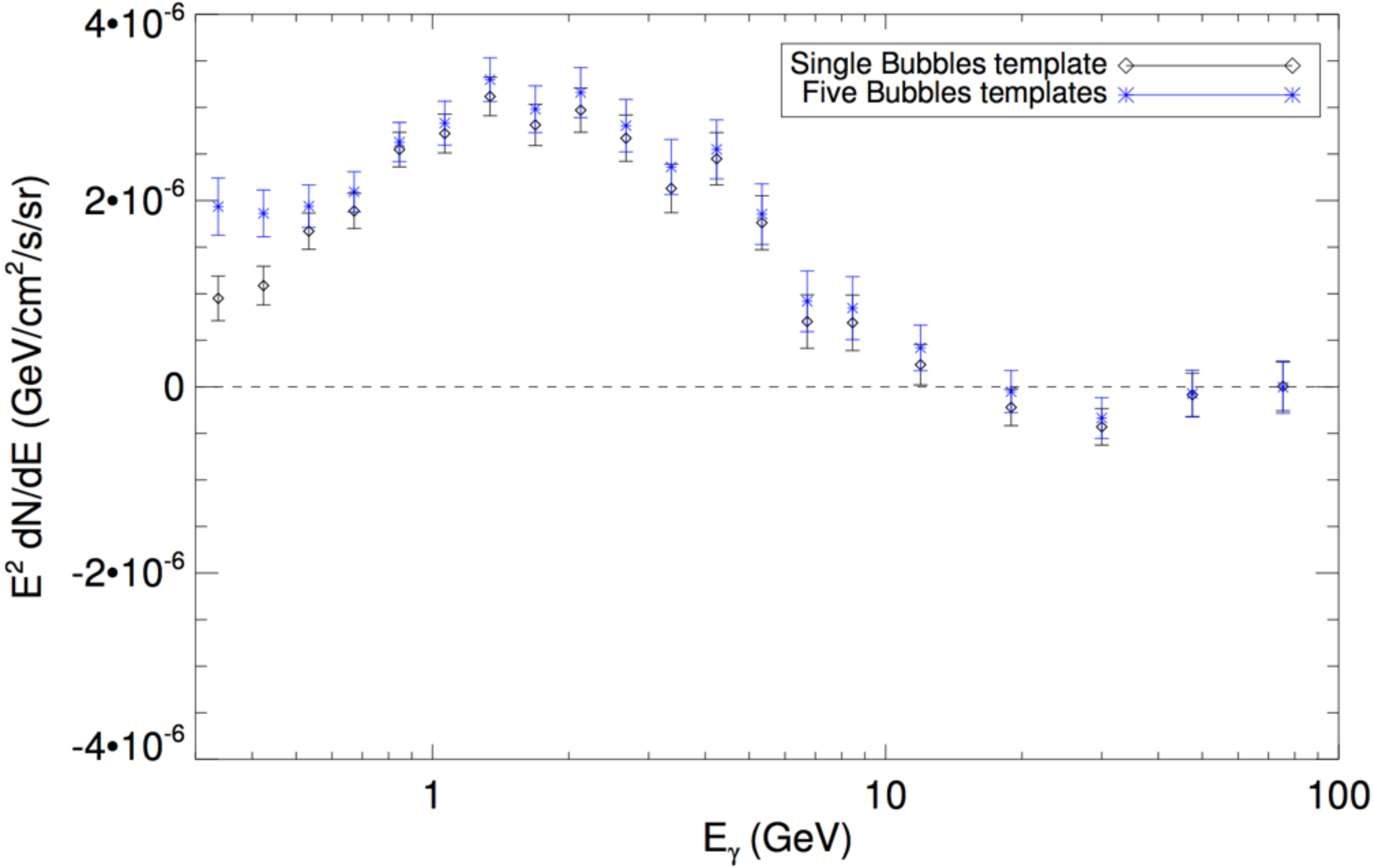
Wait, Some of the Same Photons are in Each Sample?



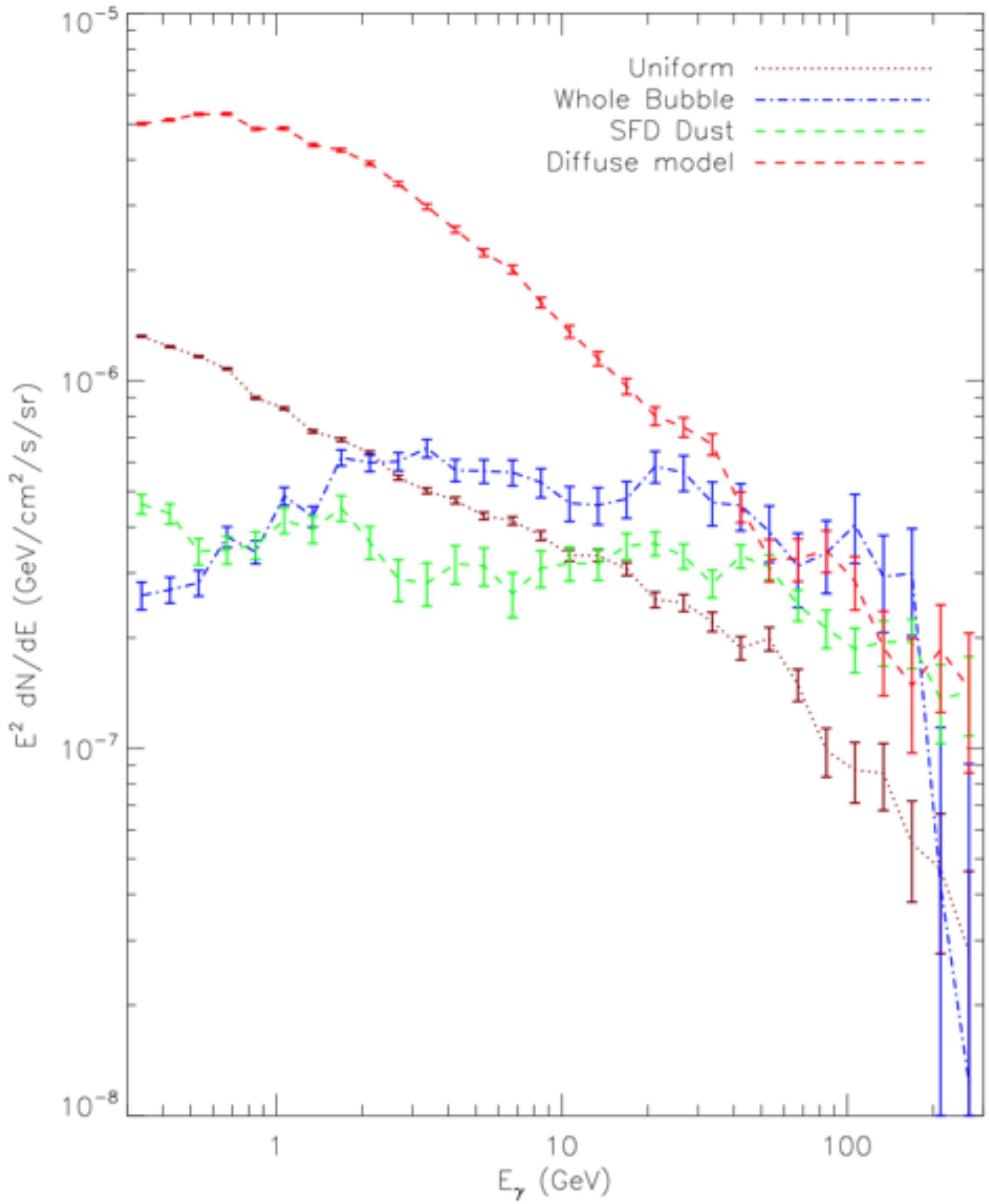
Maybe it's just part of the Bubbles?

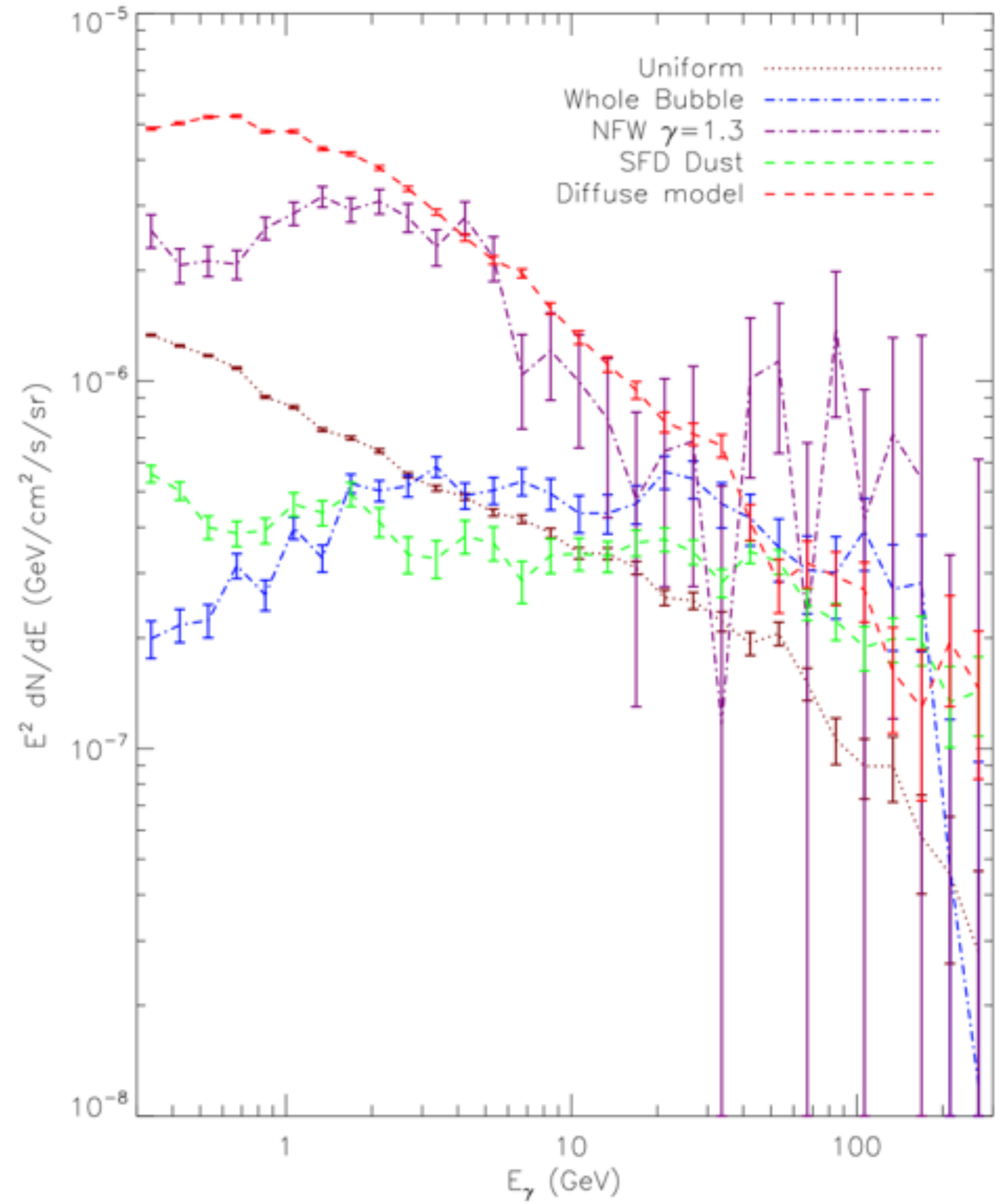


Maybe the Bubbles Have A Spectral Variation?



Does it Correlate with Gas?





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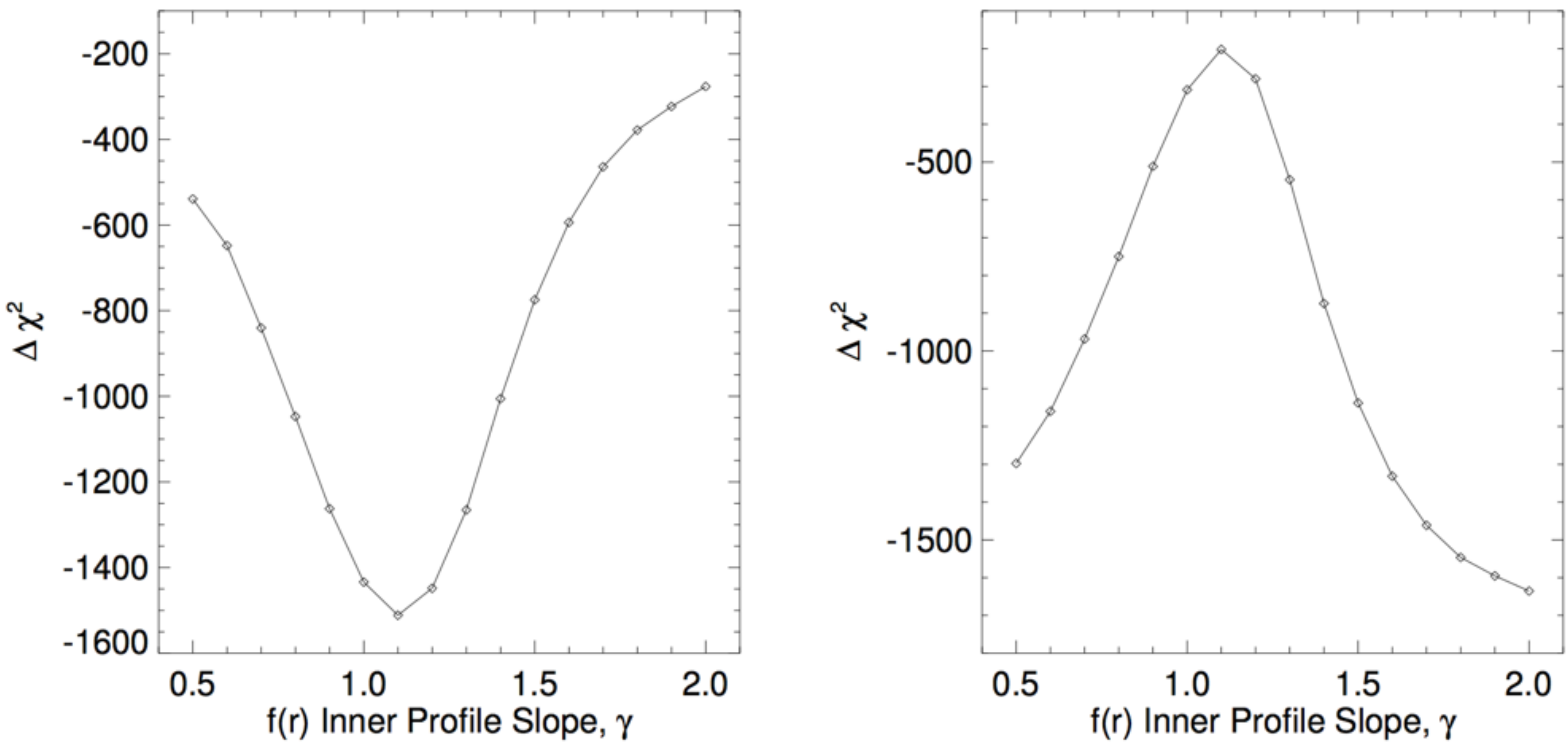
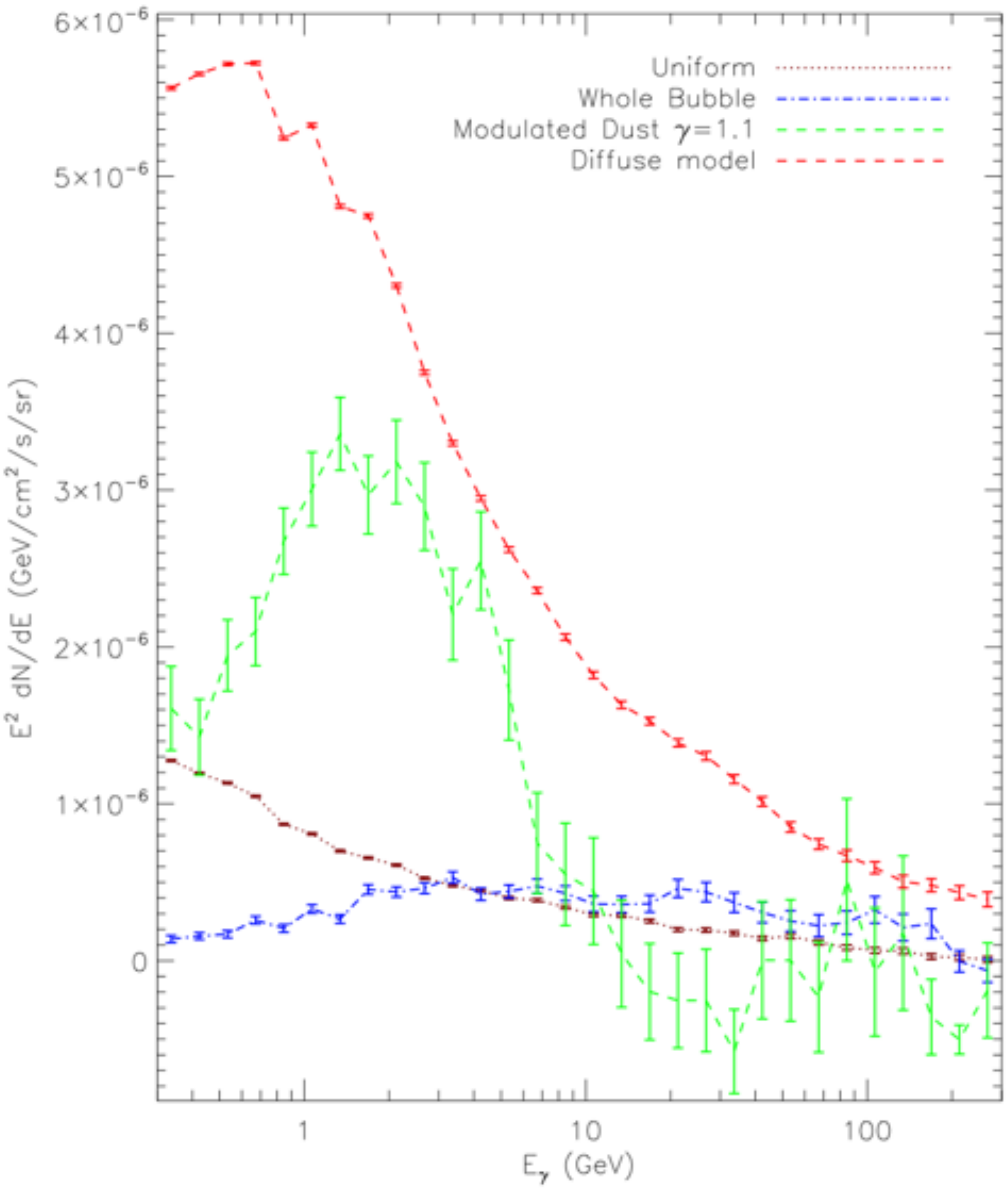
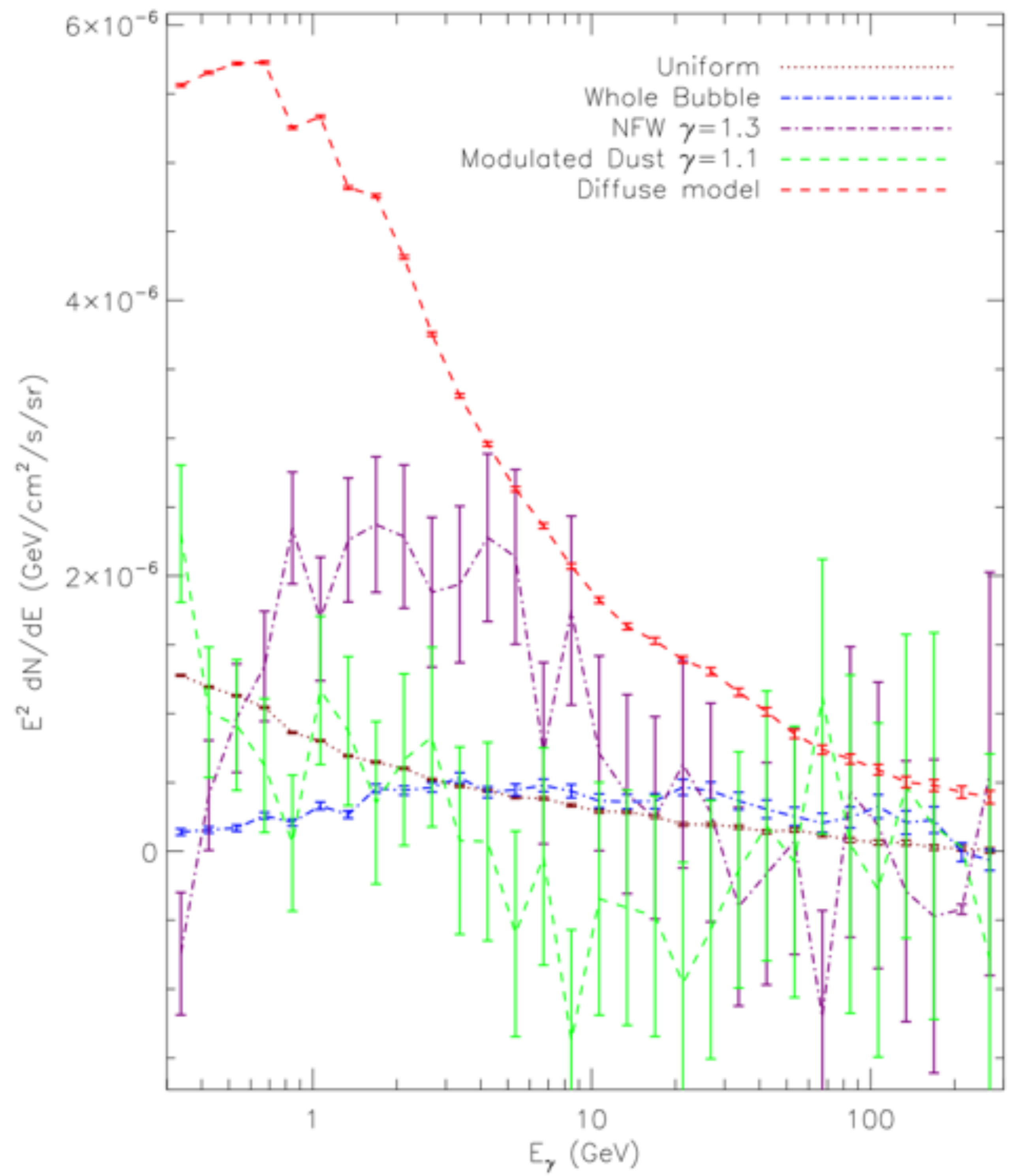


Even more generically, you can add an f(r) α r^(-gamma) profile for the SFD template, this is highly preferred in the model with no dark matter (left), but the dark matter template is still highly preferred even when gamma can float freely (right)

Does it Correlate with Gas?





With the best fit modulated SFD map, the dark matter fit is still highly preferred

Maybe the Models of the Diffuse Emission in the GC are Wrong