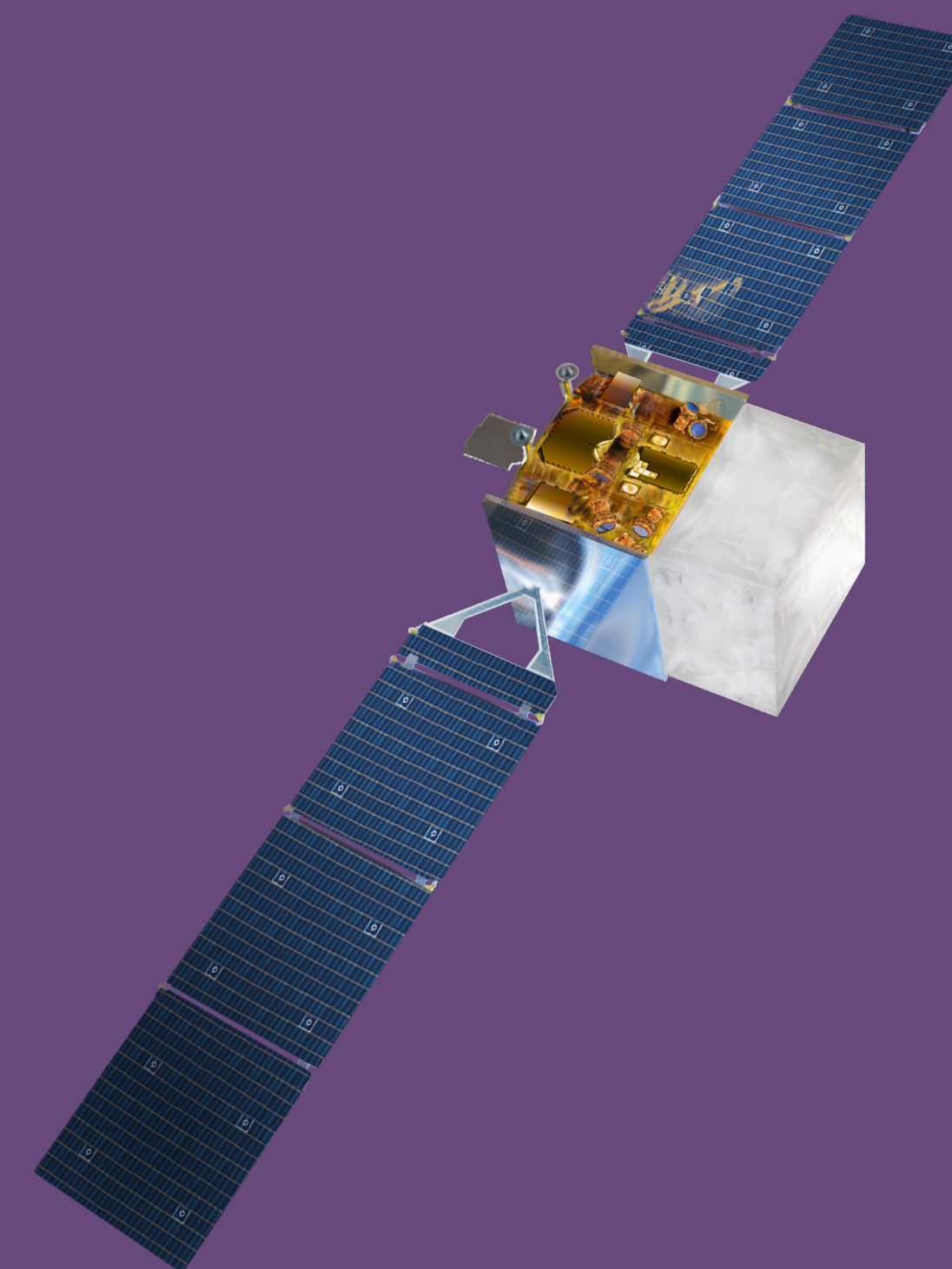
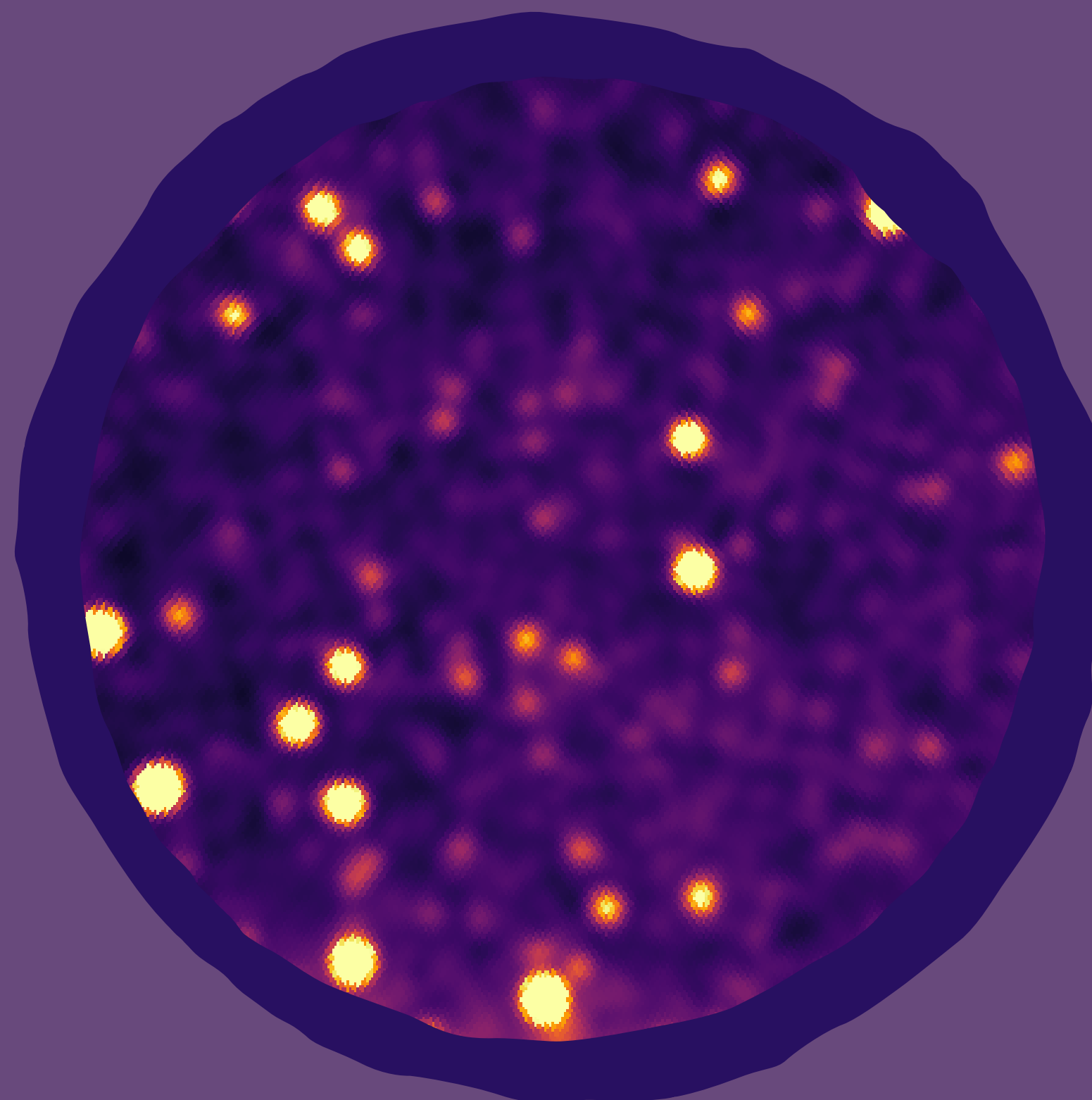
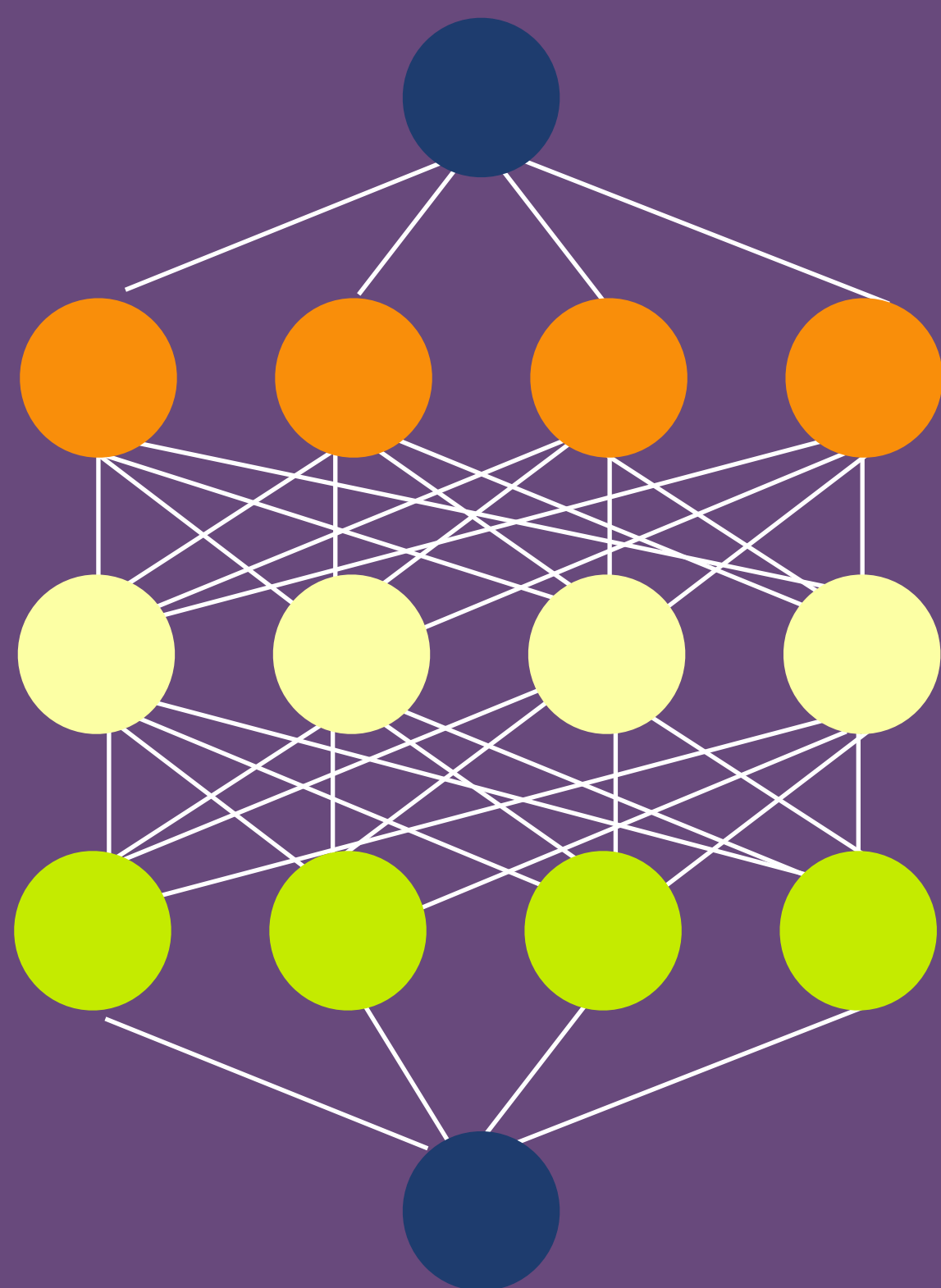




EXTRAGALACTIC γ -RAY BACKGROUND LEARNING IN FERMI-LAT

Eve Schoen | November 6th, 2025 | TeVPA

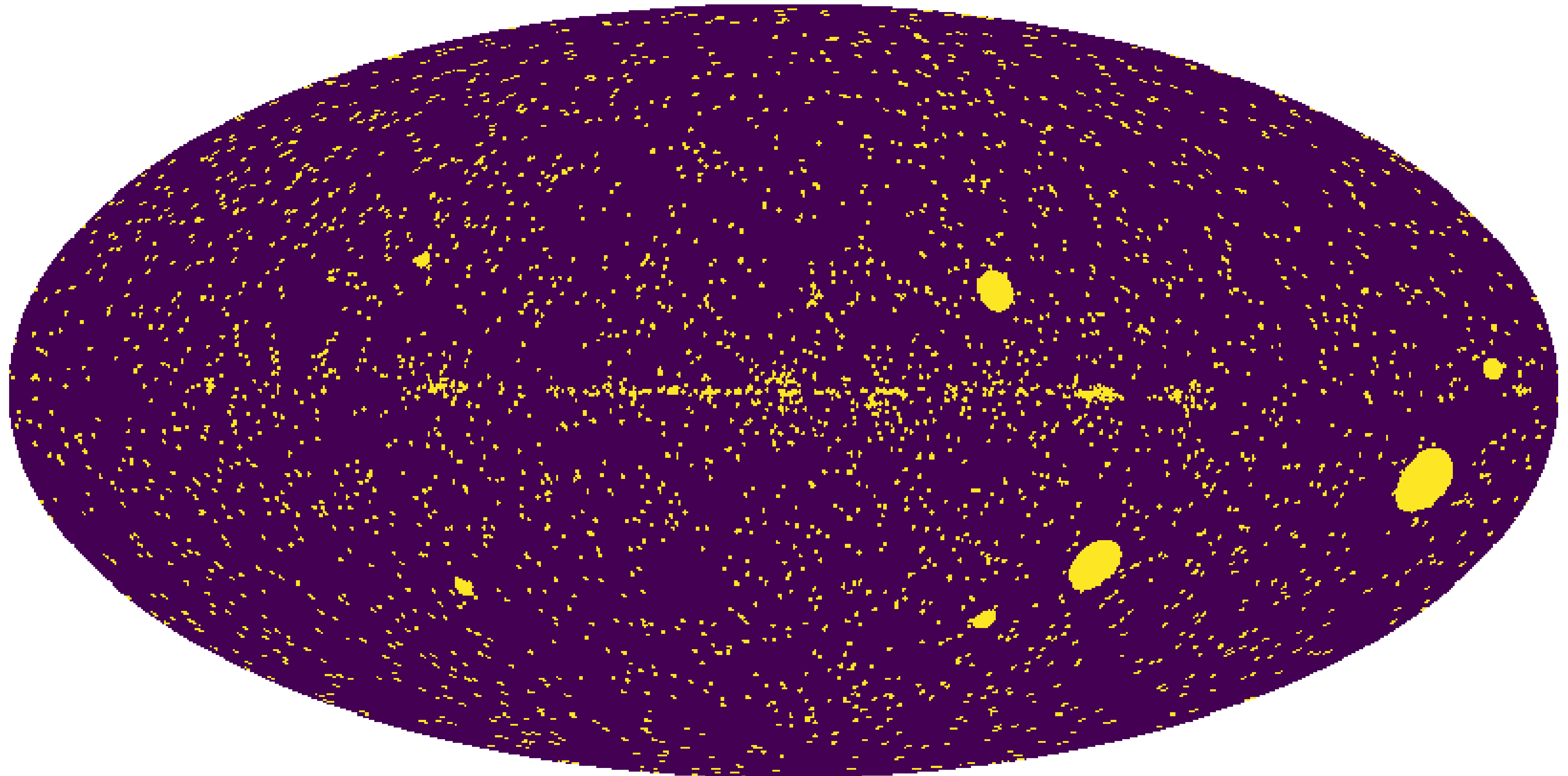
Collaborators: Florian List, Yujin Park, Nick Rodd, Florian Wolf



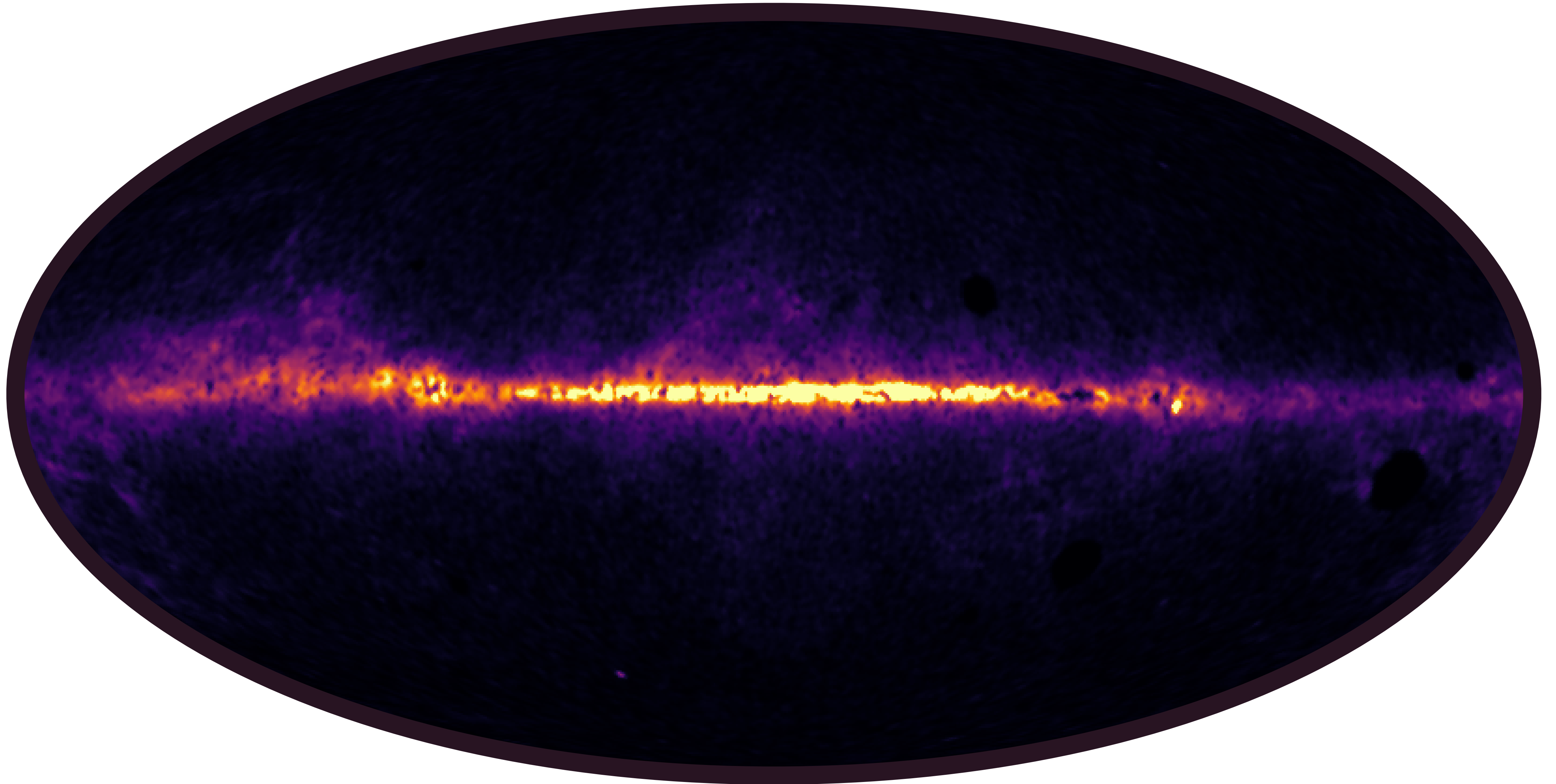
OUTLINE

1. What is a point source?
2. Preliminary results for EGB measurement in Fermi data
3. How far can we push this technique?

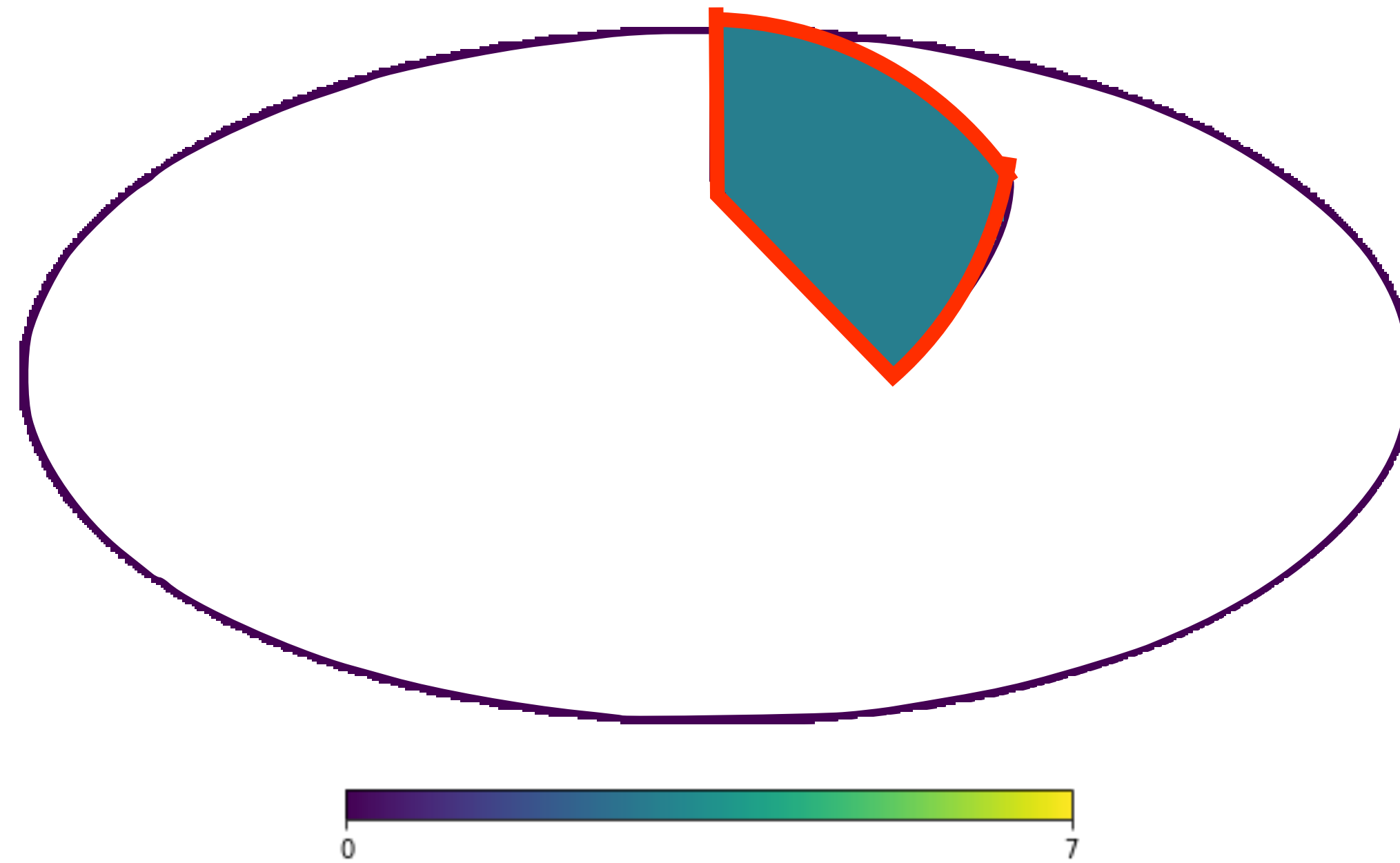
RESOLVED POINT SOURCES



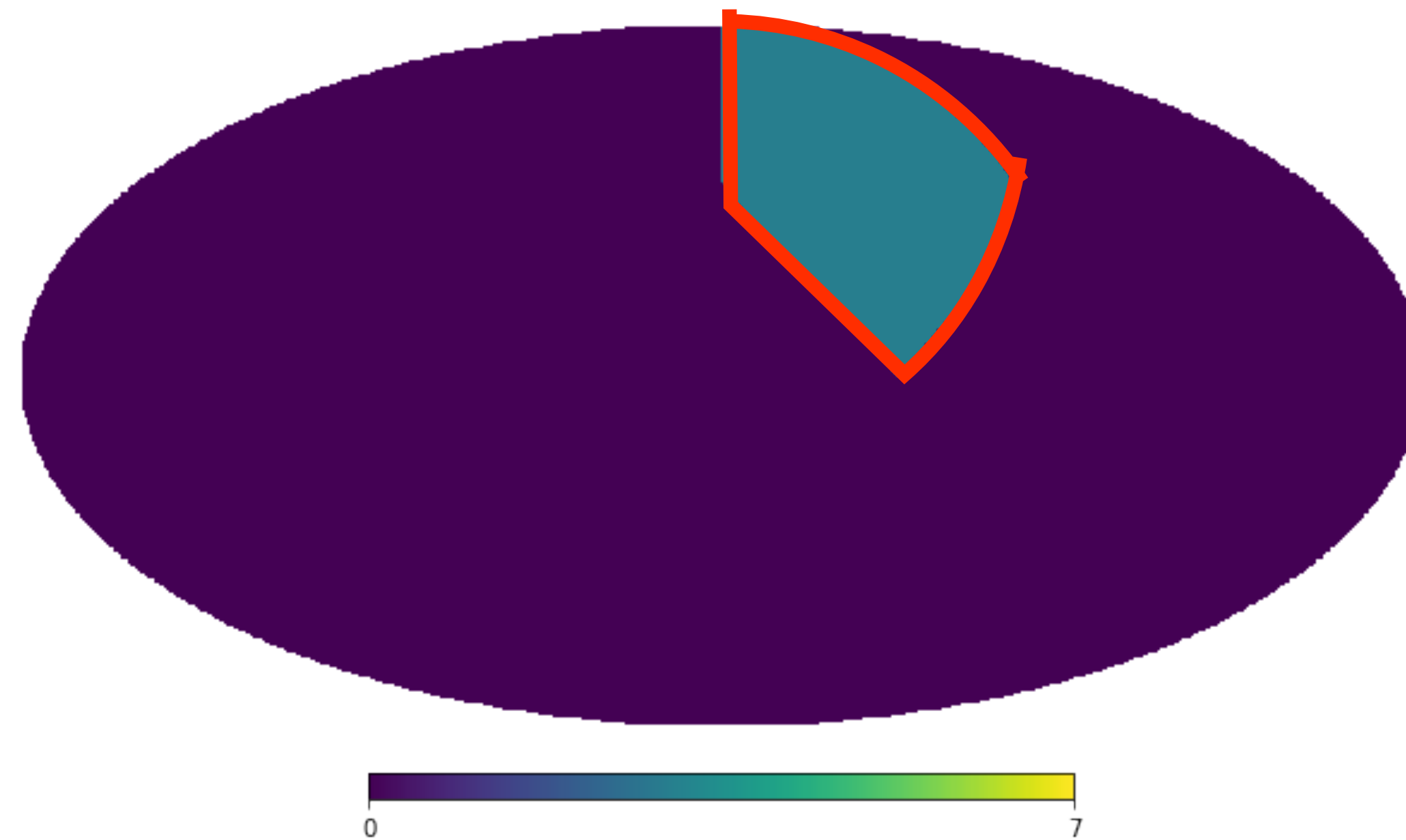
WHAT IS LEFT BEYOND POINT SOURCES?



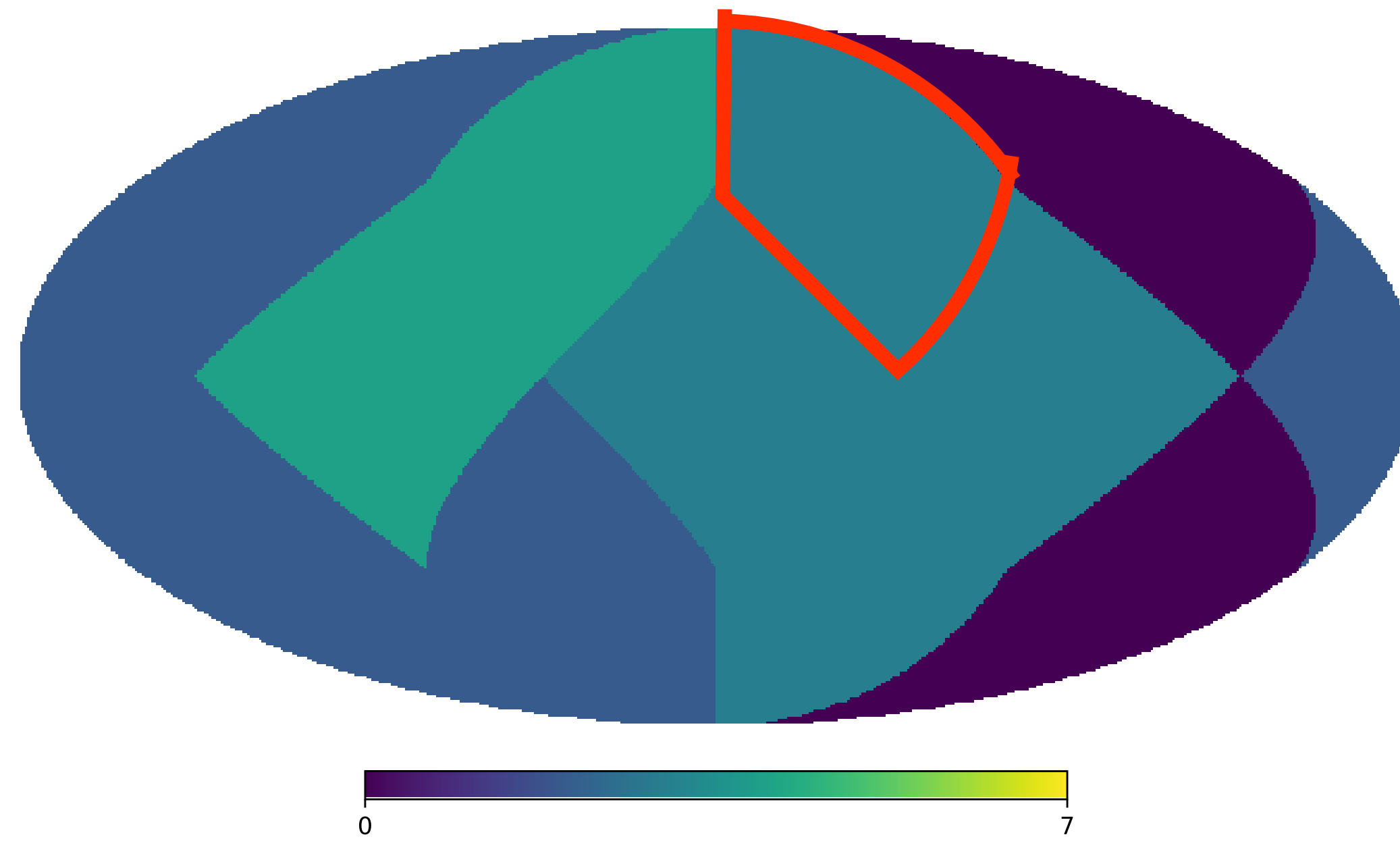
DETECTING AN UNRESOLVED POINT SOURCE



DETECTING AN UNRESOLVED POINT SOURCE



DETECTING AN UNRESOLVED POINT SOURCE



PREVIOUS ANALYTICAL LIKELIHOOD ATTEMPTS

- E.g. 1pPDF, NPTF, or CPG (*Zechlin et al., Misha-Sharma et al., Collin et al.*)

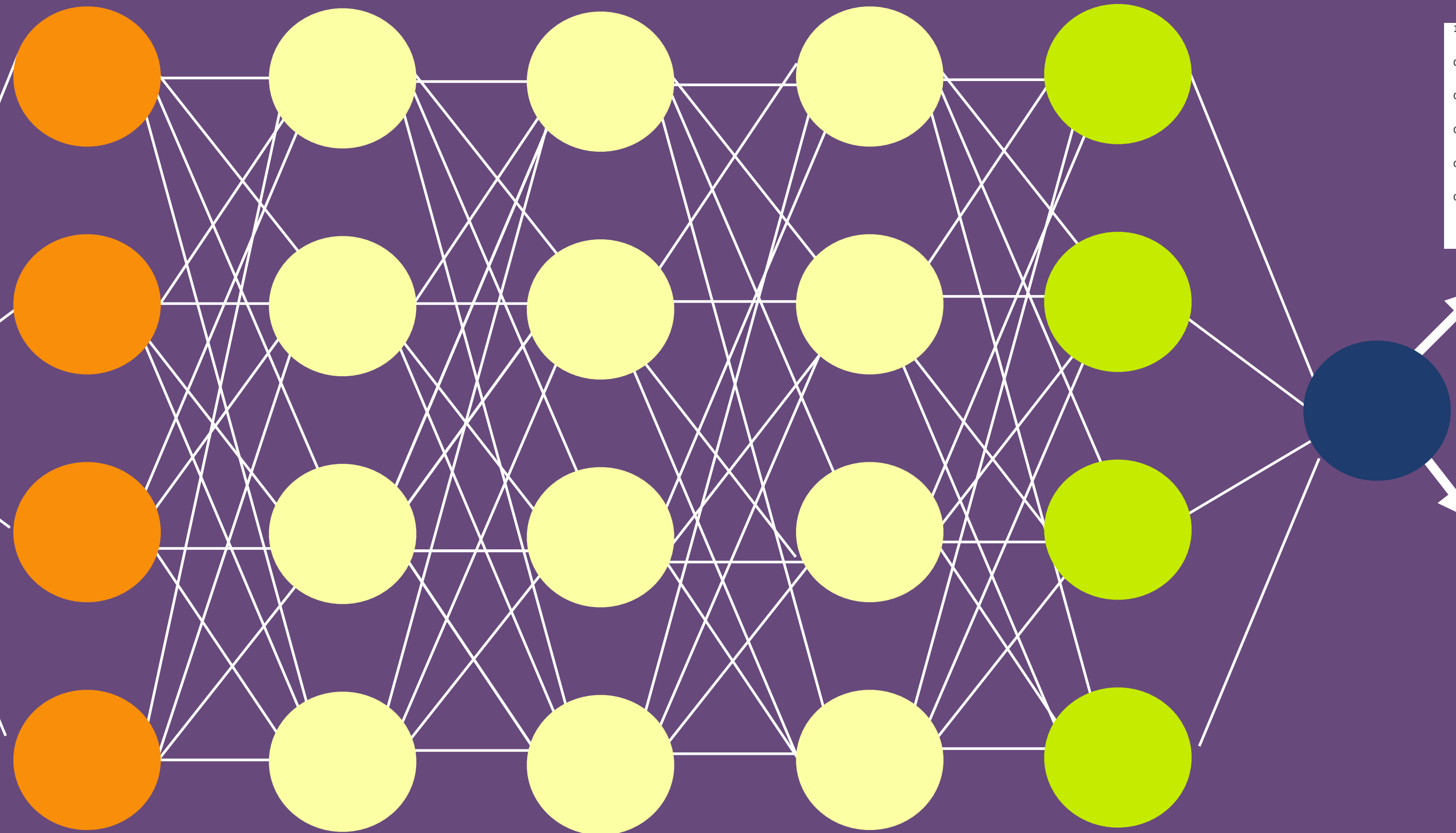
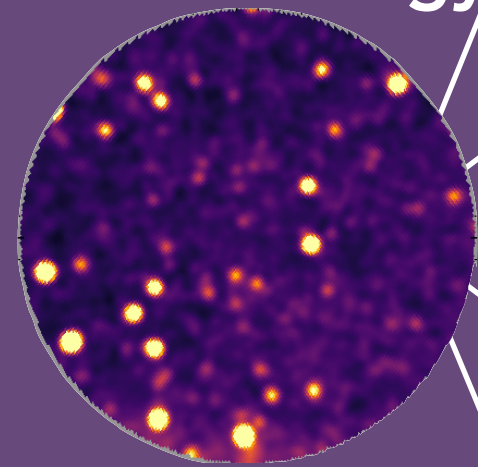
$$\rightarrow \mathcal{L}(\theta) = \prod_{p=1}^{N_{pix}} P(n_p)$$

→ Assumes pixels are independent

→ Energy independent

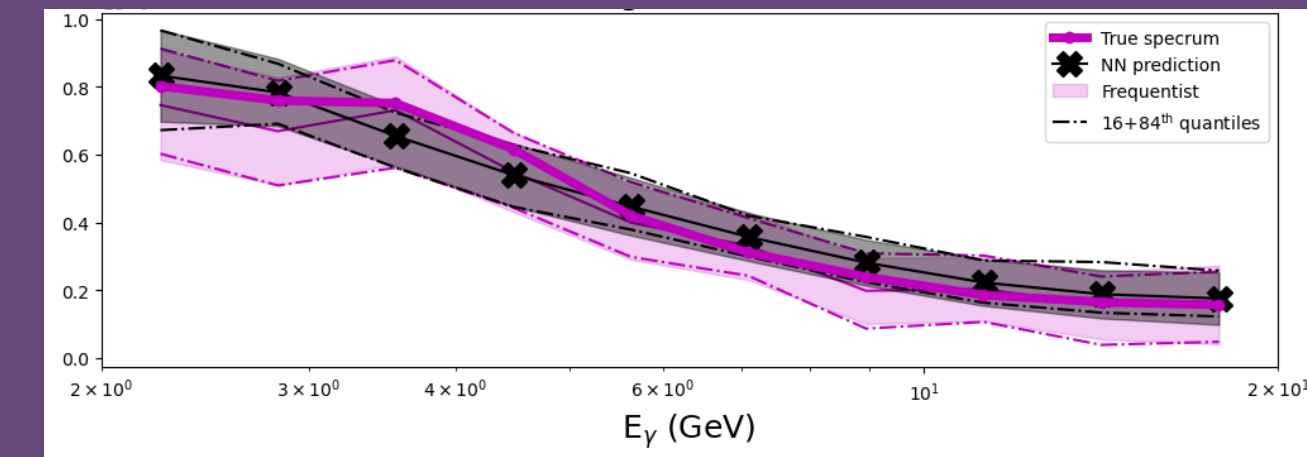
THE CNN

Count map
(one for each energy bin)

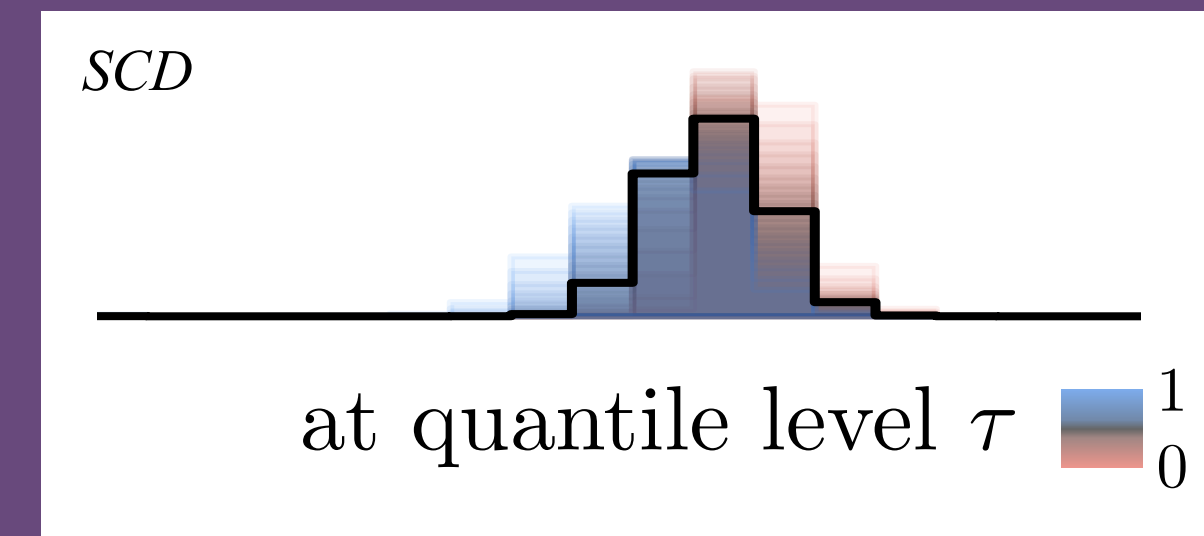


Layers (non-linear transformations)

Energy spectra



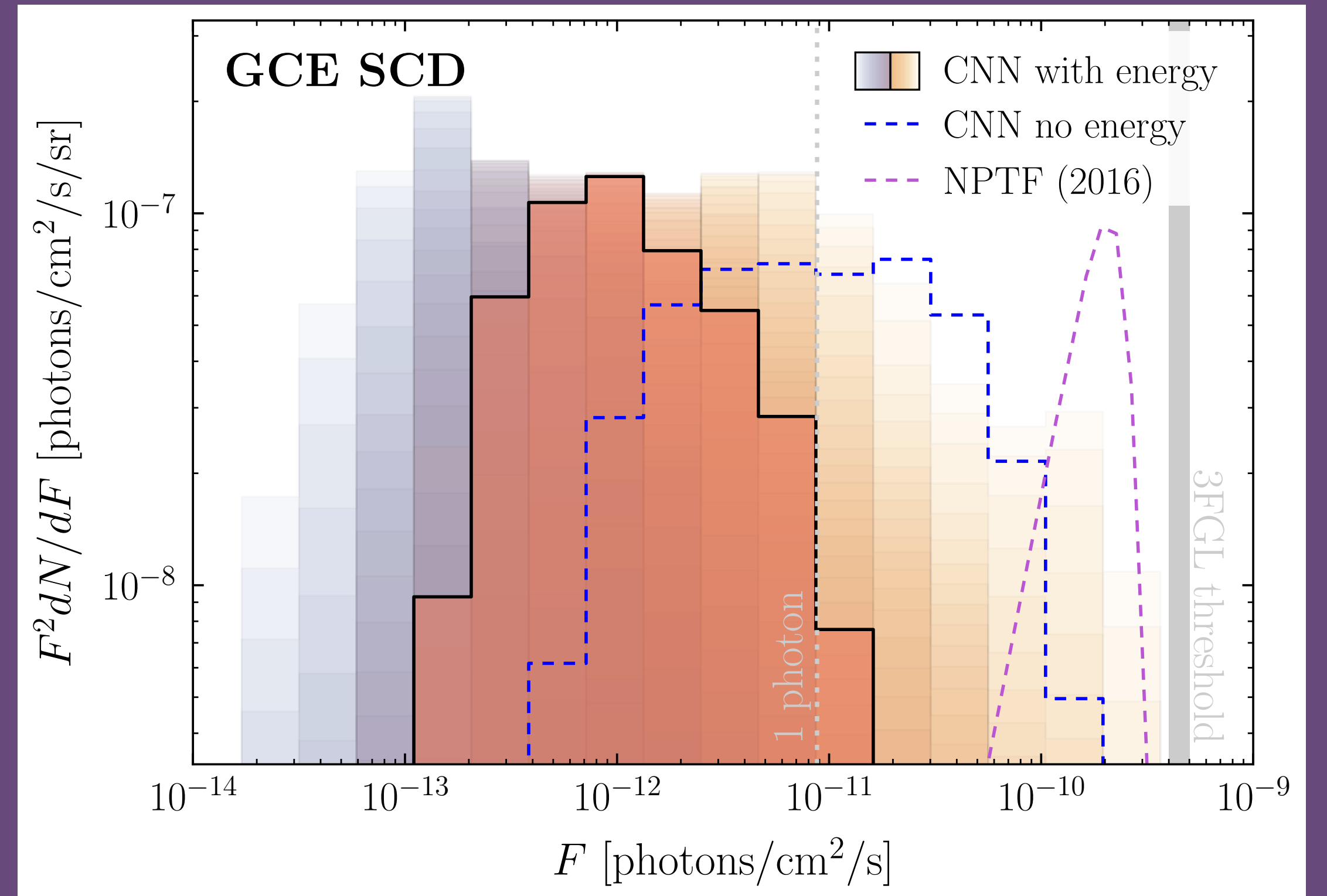
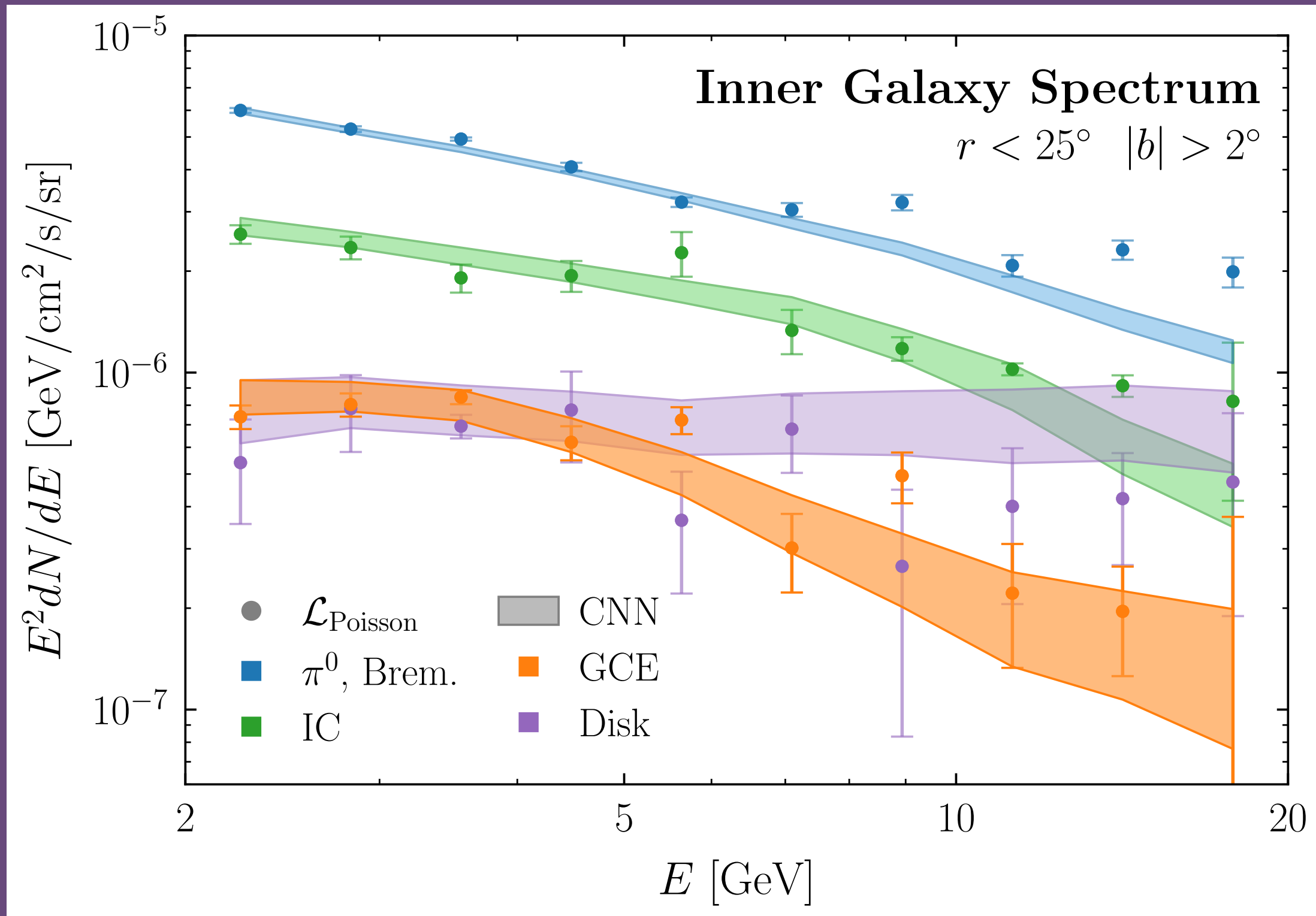
Source Count Distribution



ROI: $r < 20^\circ$; $(l, b) = (135, 60)$
Mask 3FGL at 95% containment

ALREADY APPLIED TO THE GCE

EXTENSIVELY TESTED IN MONTE CARLO



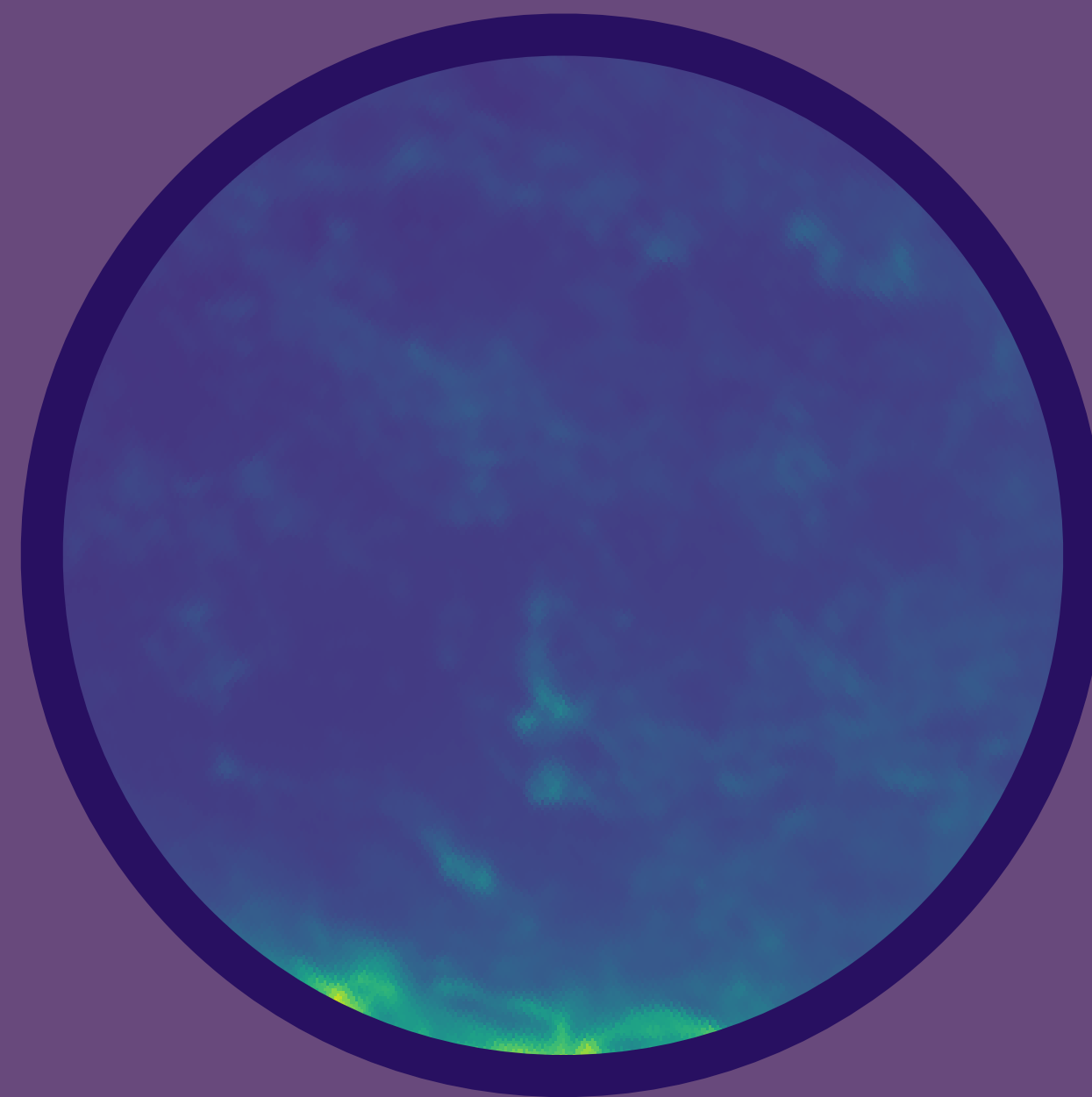
THE EXTRAGALACTIC γ -RAY BACKGROUND (EGB) & THE ISOTROPIC DIFFUSE γ -RAY BACKGROUND (IGRB)



DATA GENERATION

ROI: $r < 20^\circ$; $(l, b) = (135, 60)$
Mask 3FGL at 95% containment

Templates:



Galactic



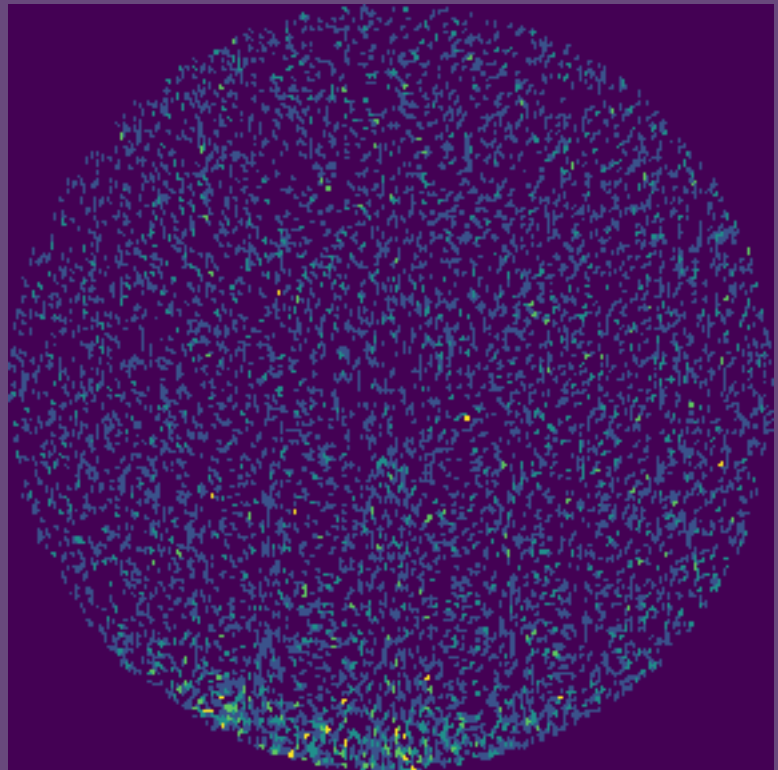
Isotropic

**Fermi Galactic model p6v11*

DATA GENERATION

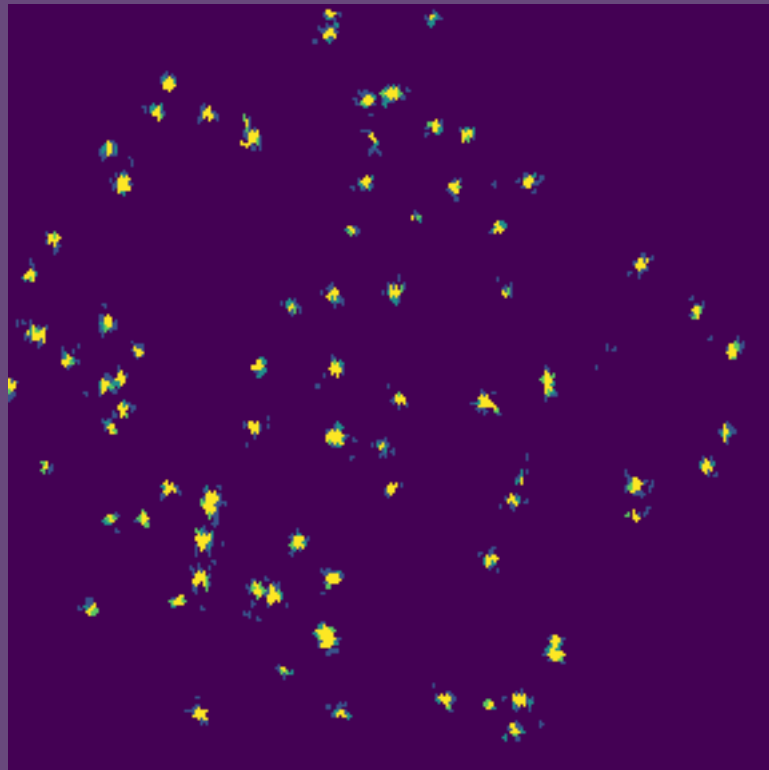
X Number Energy Bins
Following Power Law Spectra

Poisson realization

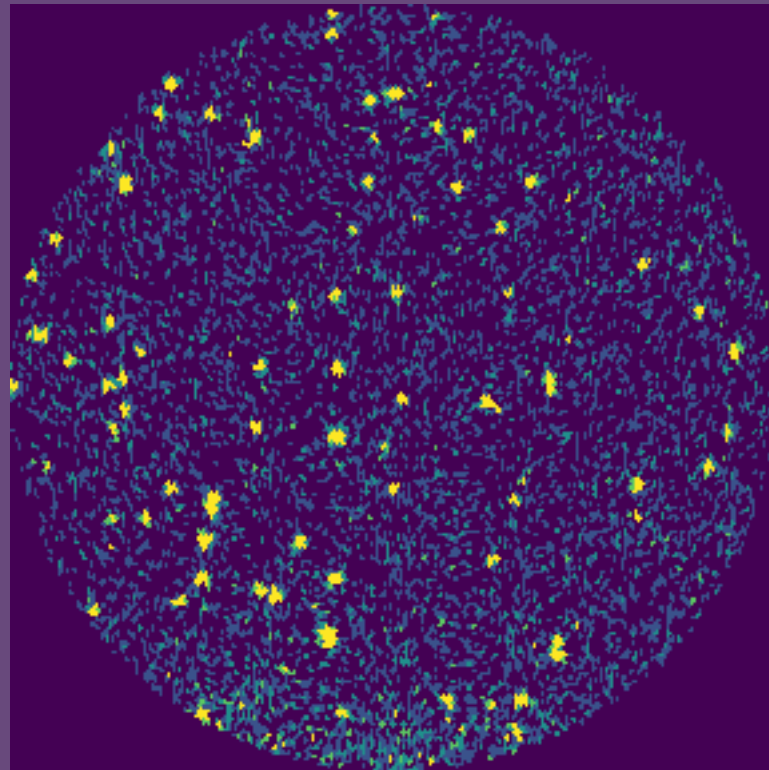


+

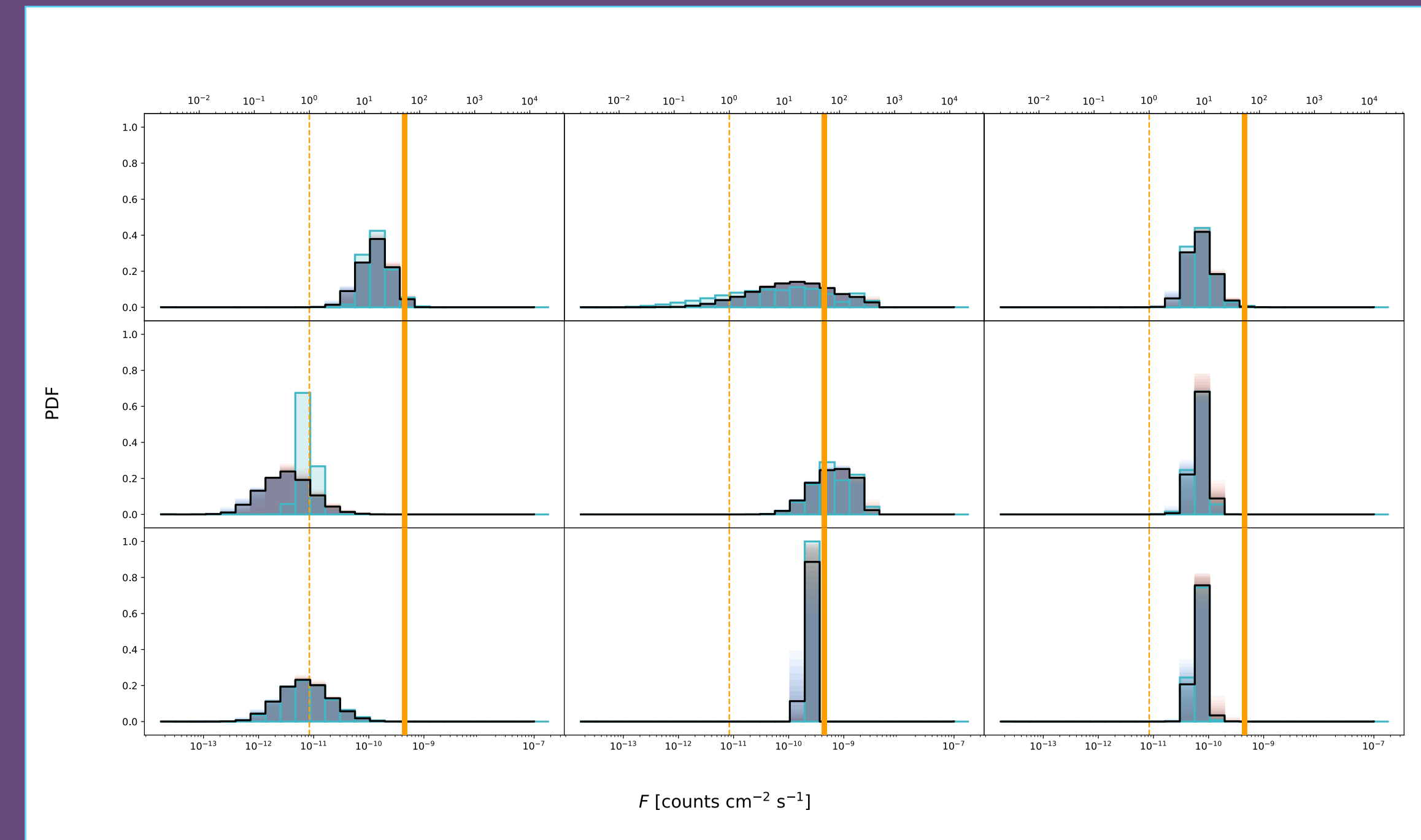
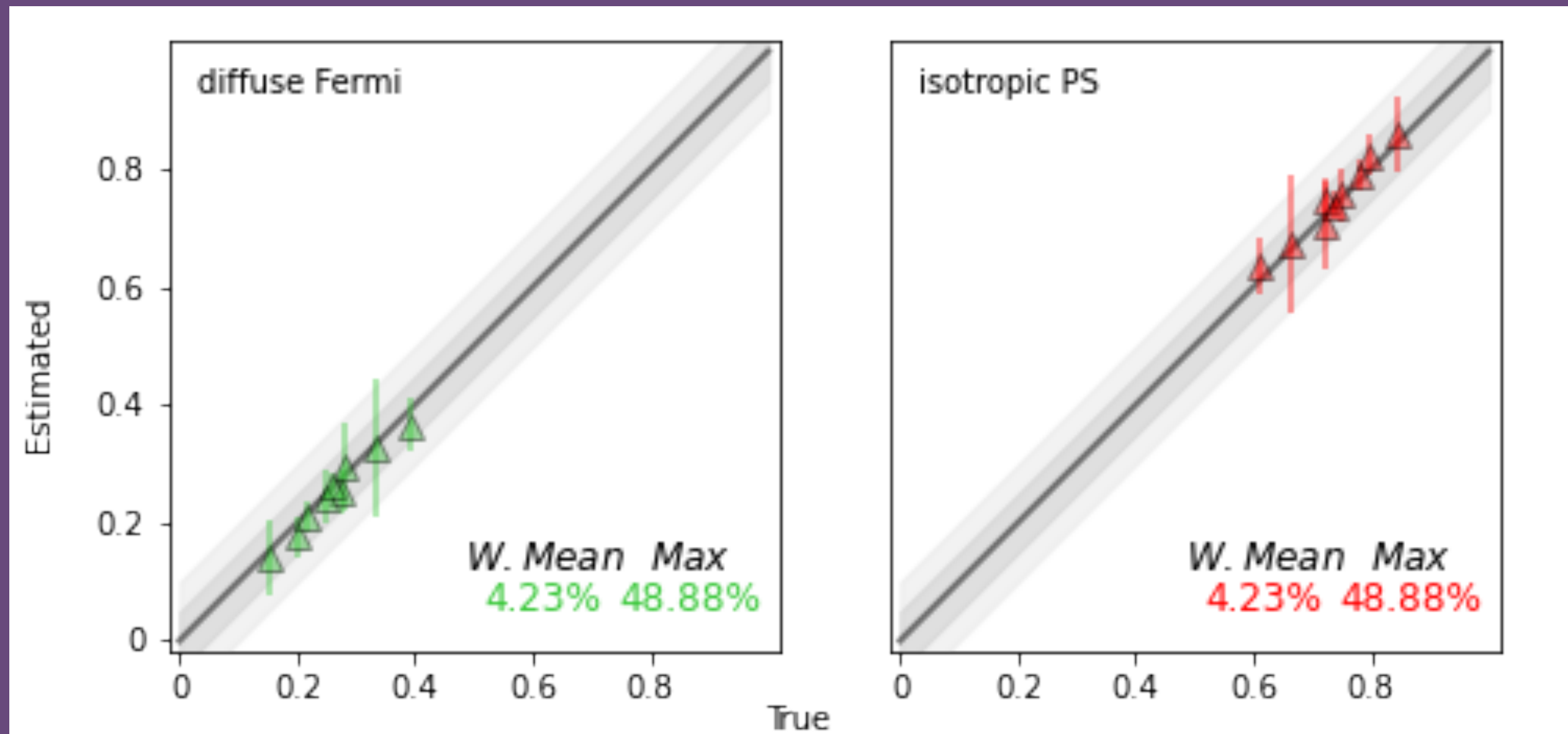
Point Source Simulation



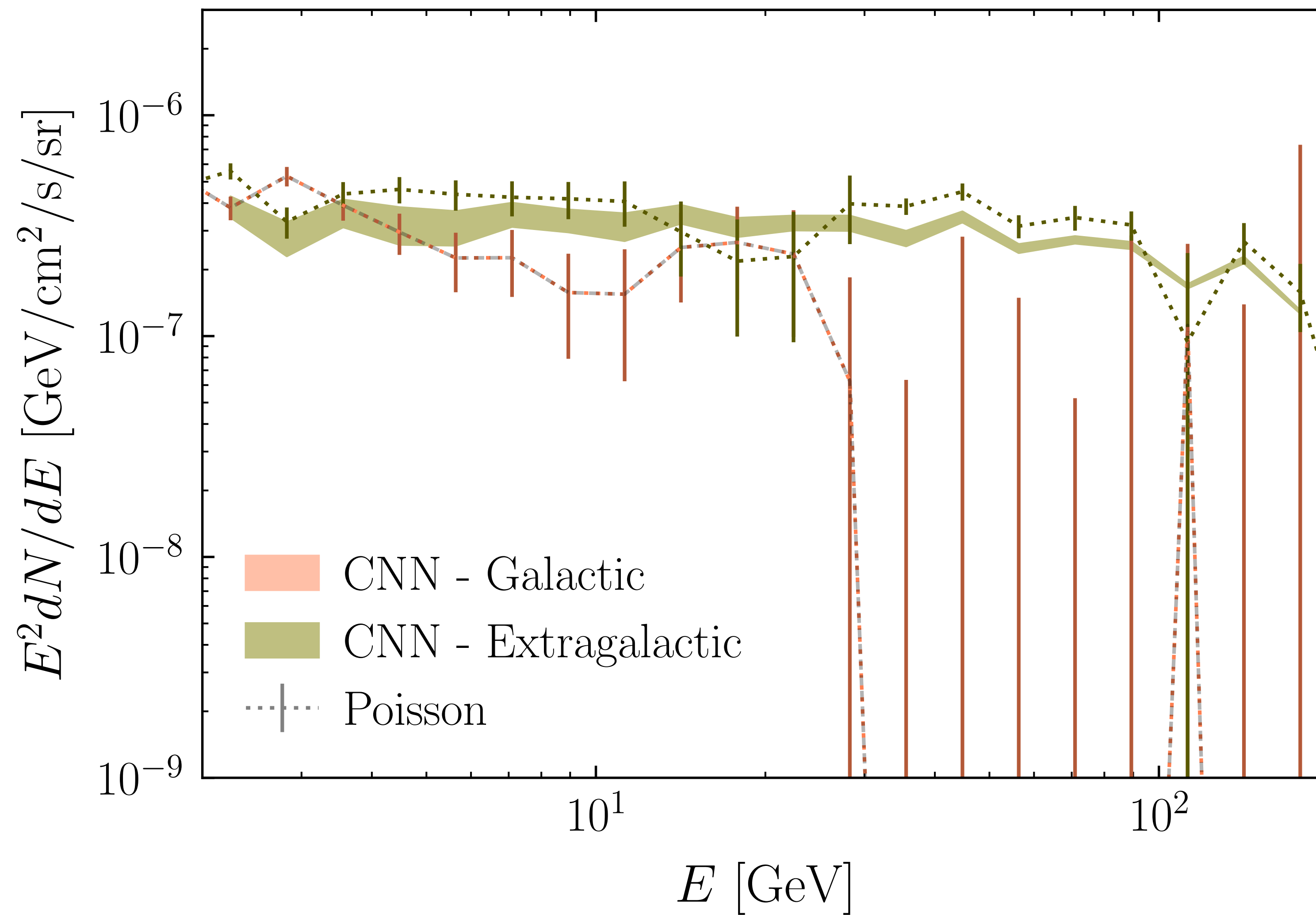
=



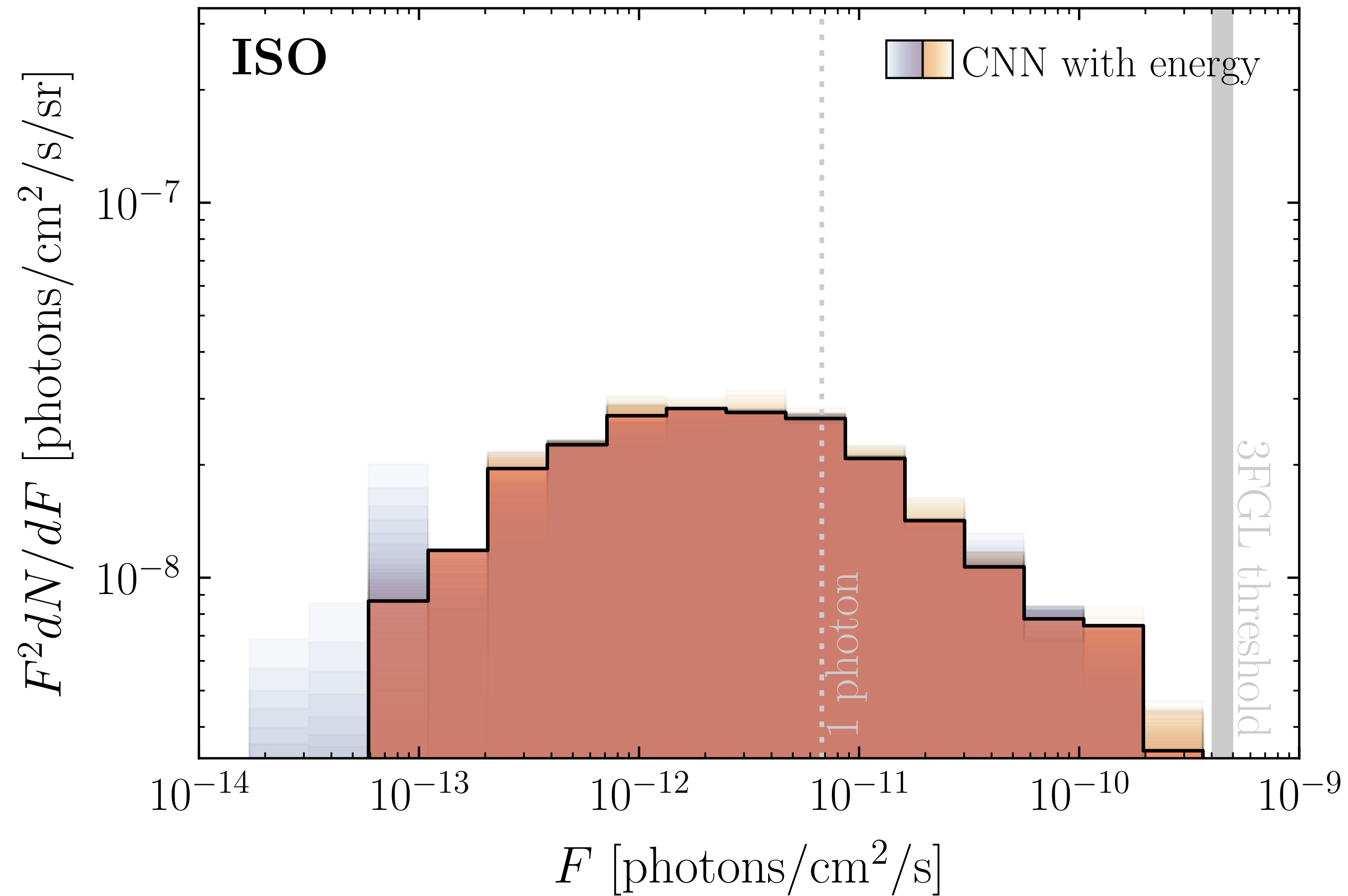
MODEL VALIDATION



RESULTS - ENERGY SPECTRA



RESULTS - SOURCE FLUX DISTRIBUTION



EXTENSIONS

- ☐ Extend to full high latitude ROI ($|b| \geq 30^\circ$)
- ☐ Use full energy range of Fermi (200 MeV - 2 TeV)
- ☐ Unmask Fermi data $\rightarrow$ one consistent analysis for the full EGB including IGRB and resolved point sources
- ☐ Consistency check: using 1 month of data and 17 years

FUTURE METHODS

- Flow matching: use ML to learn a likelihood formula
 - Can use transformer network or CNN as the ML

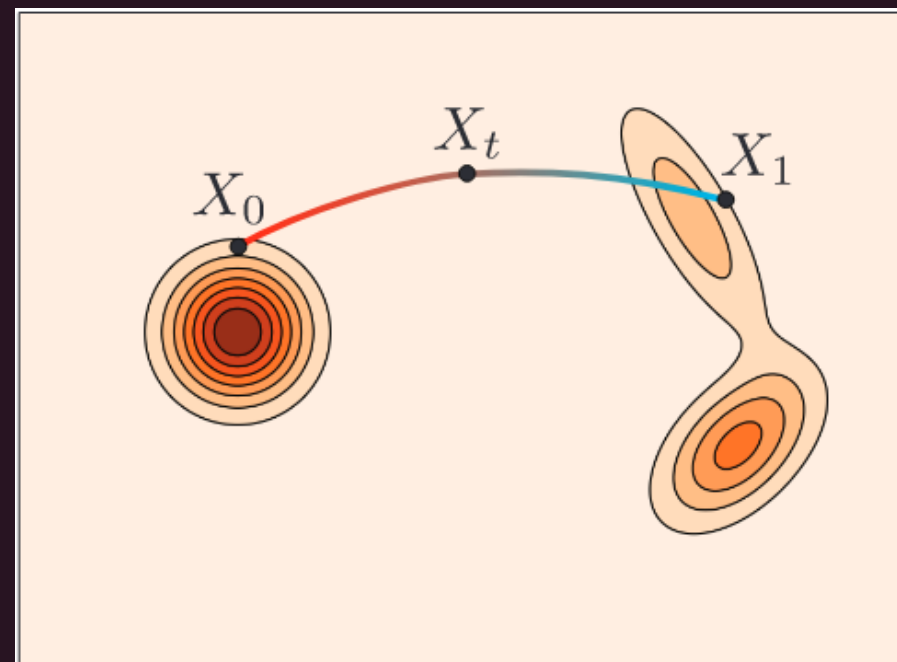
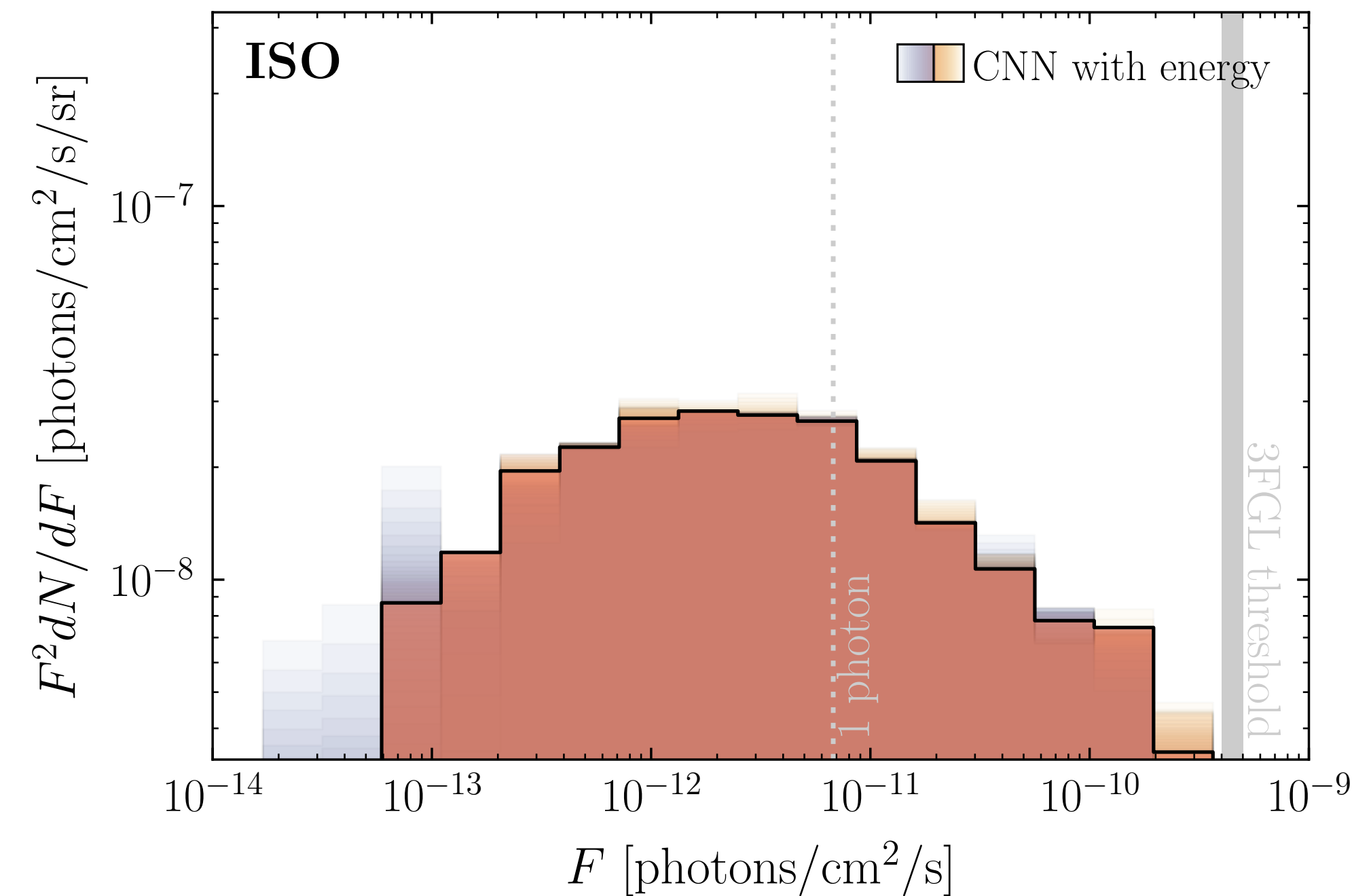
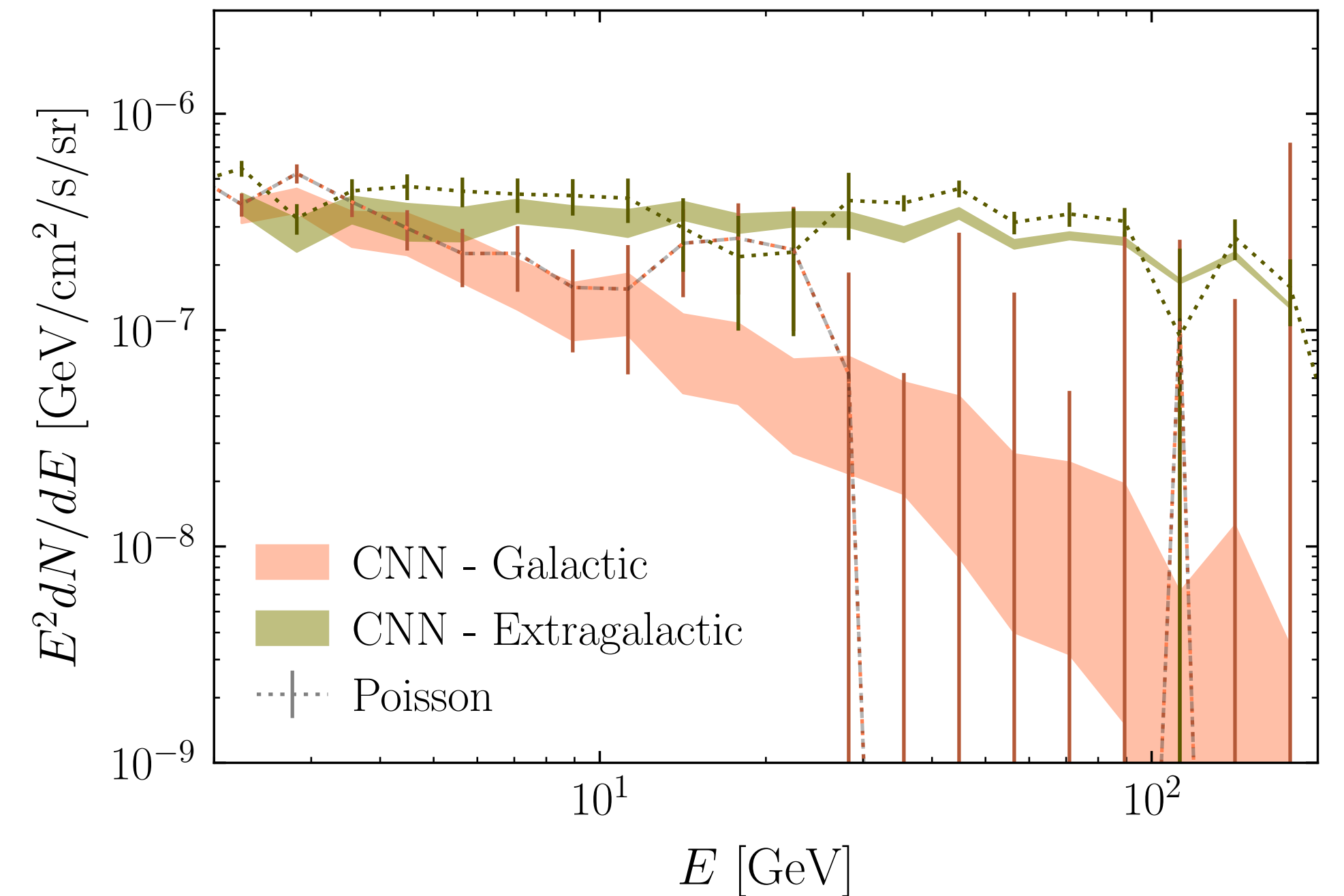


Photo attr: Flow Matching Guide and Code. Lipman et al.

SUMMARY

- Method allows for consistent treatment of fitting with point source & poisson emission
- EGB provides an opportunity to study non-thermal universe and improve techniques relevant for DM
- Thank you for your attention!



BACK-UP SLIDES

The full loss functions used to train the NN

Spectra:

$$\mathcal{L}(\tilde{\mathbf{y}}_{\theta}(\mathbf{x}), \mathbf{y}) = \sum_{t=1}^T \sum_{e=1}^E \left[\frac{1}{2(\tilde{\sigma}_{\theta}^{t,e}(\mathbf{x}))^2} (\tilde{y}_{\theta}^{t,e}(\mathbf{x}) - y^{t,e})^2 + \frac{\ln[(\tilde{\sigma}_{\theta}^{t,e}(\mathbf{x}))^2]}{2} \right]$$

Histograms:

$$\mathcal{L}^{\tau}(\tilde{\mathbf{u}}_{\theta}(\mathbf{x}, \tau), \mathbf{u}) = \frac{1}{N} \sum_{n=1}^N [(\tilde{U}_{\theta}^n(\mathbf{x}, \tau) - U^n)(\tau - I[\tilde{U}_{\theta}^n(\mathbf{x}, \tau) < U^n])]$$

e =energy bin

t =template

$\tilde{\mathbf{y}}_{\theta}(\mathbf{x})$ = estimated SCD of all models

$\mathbf{y}$ = true SCD of all models

$\tilde{\sigma}_{\theta}^{t,e}(\mathbf{x})$ = statistical uncertainty

$\tilde{y}_{\theta}^{t,e}$ = estimated counts per model, per bin

$y^{t,e}$ = true counts per model per bin

n = the probability bin

τ = histogram quantile level

$\tilde{\mathbf{u}}_{\theta}^n$ = estimated SCD histogram for all models

$\mathbf{u}$ = true SCD histogram for all models

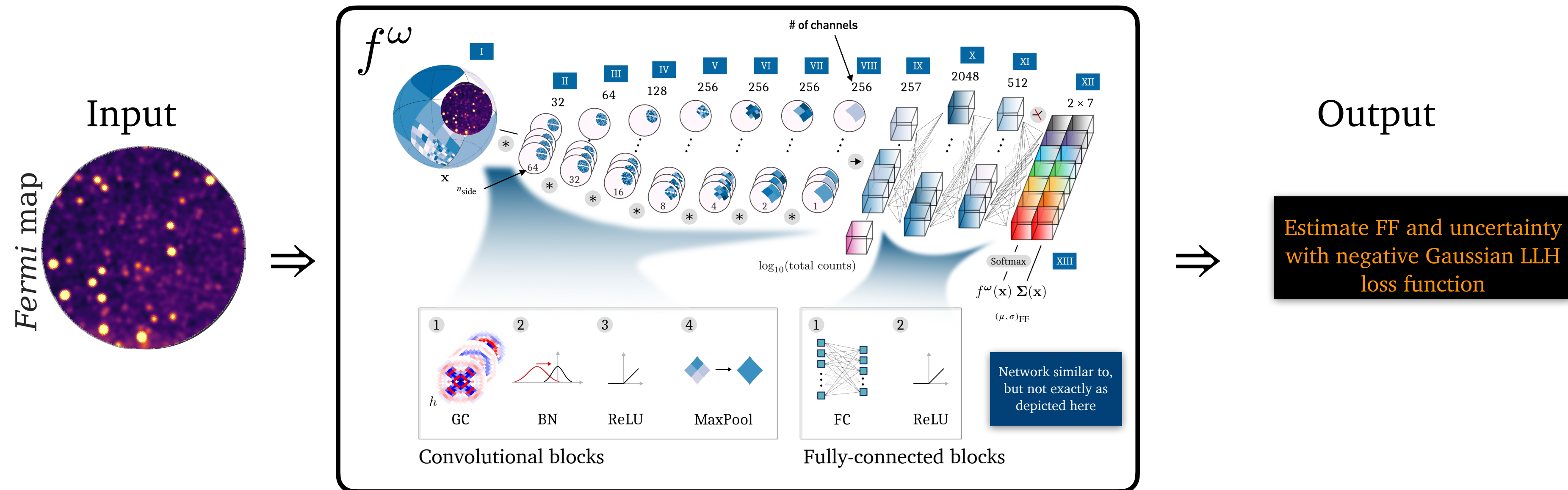
$\tilde{U}_{\theta}^n(\mathbf{x}, \tau)$ = Estimated cumulative histogram

U^n = True cumulative histogram

$I[. .]$ = the indicator function

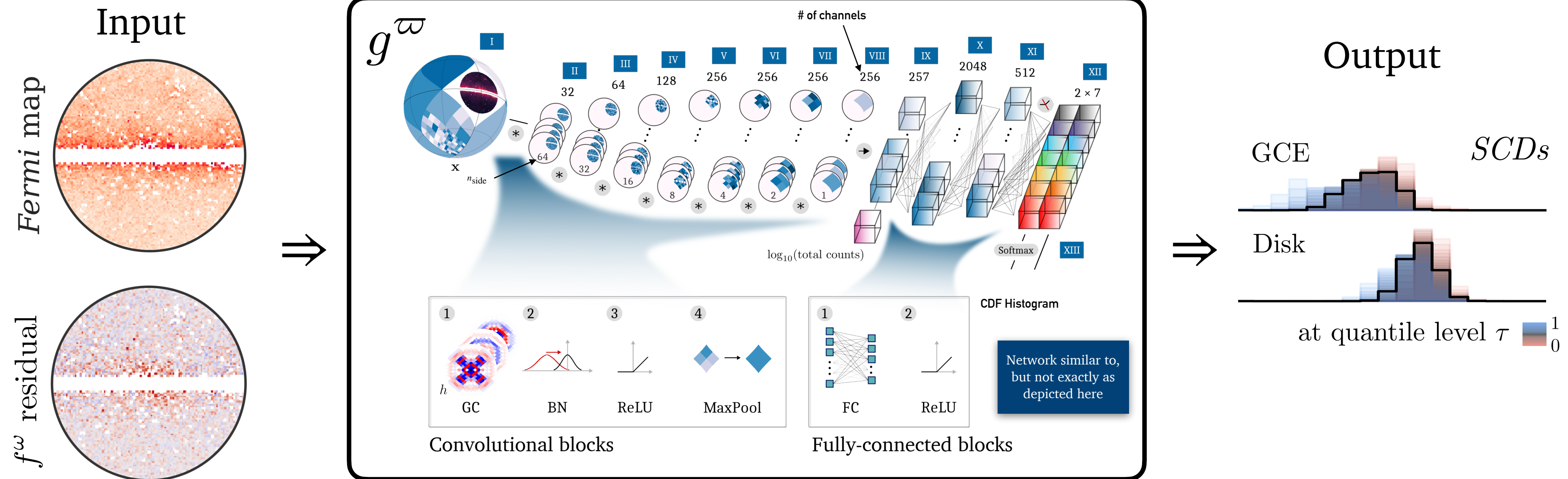
NN Architecture

Step 1: estimate template flux fractions



NN Architecture

Step 2: estimate GCE & disk dN/dF (SCD)



THE EGB AND IGRB

- IGRB: True extragalactic poisson emission as well as unresolved point sources
- EGB: The sum of all extragalactic gamma ray radiation

TEST YOUR UNDERSTANDING:

The IGRB is fundamental or detector dependent

The EGB is..... fundamental or detector dependent

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