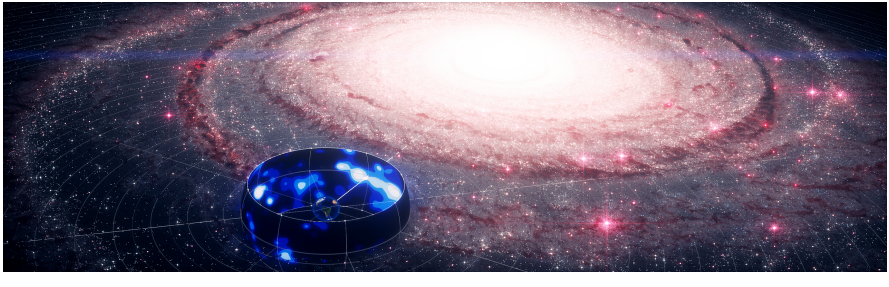
Measurement of the Neutrino Flux in Segments along the Galactic Plane with IceCube

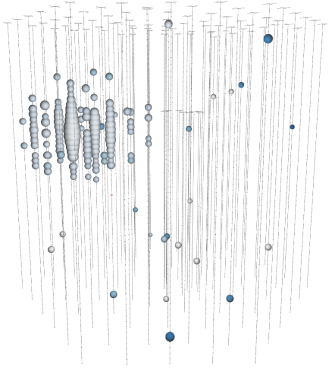
2025-11-04 — Ludwig Neste*, Mirco Hünnefeld and Chad Finley
on behalf of the IceCube Collaboration



IceCube and the Galactic Plane (GP)

Stockholm University

Using all-sky cascades



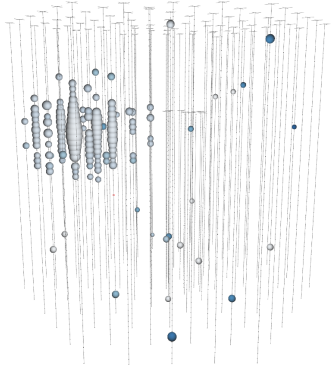
4.5σ observation of GP neutrinos (2023)[1]:

- New Machine Learning based event selection improved cascade effective area $\times 20$
- Neutrino emission template fitted to flux normalization

→ GP flux contributes $\sim 10\,\%$ to astrophysical flux

[1] DOI: 10.1126/science.adc9818

Using all-sky cascades



4.5σ observation of GP neutrinos (2023)[1]:

- New Machine Learning based event selection improved cascade effective area $\times 20$
- Neutrino emission template fitted to flux normalization

→ GP flux contributes $\sim 10\,\%$ to astrophysical flux

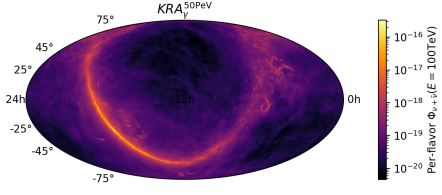
$> 5\sigma$ observation of GP neutrinos (2025):

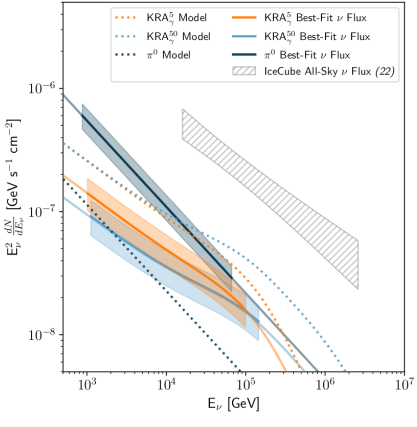
- Combined track & cascade template analysis: Riya Shah (#41)
- Combined track & cascades with improved reconstruction: Matthias Thiesmeyer (#293)

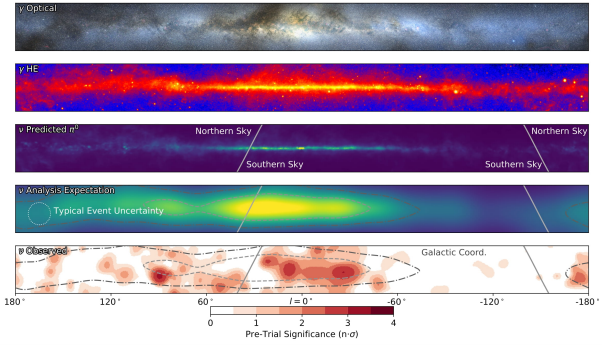
⇒ Cascades still the driving part

[1] DOI: 10.1126/science.adc9818

Template Fitting

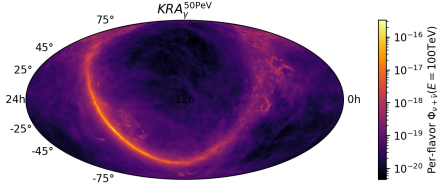


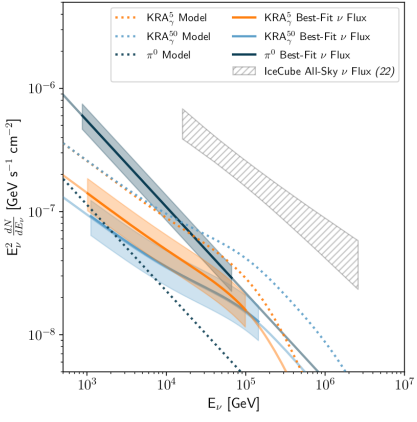


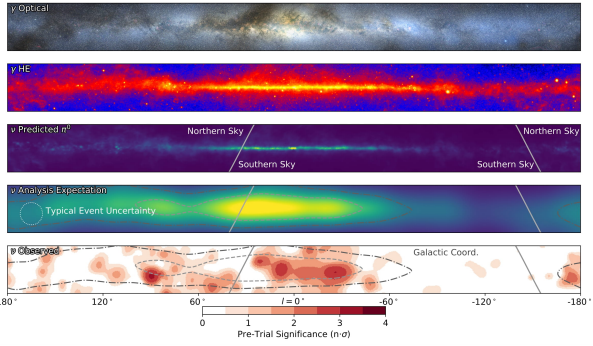


- Fit scale factor relative to predicted flux
- Use three models ($\pi^0, \mathrm{KRA}_\gamma^{50\mathrm{PeV}}, \mathrm{KRA}_\gamma^{5\mathrm{PeV}}$)
- **Assume spatial** distribution of ν flux
- **Assume energy** distribution of ν flux

Template Fitting







- Fit scale factor relative to predicted flux
- Use three models ($\pi^0, \mathrm{KRA}_\gamma^{50\mathrm{PeV}}, \mathrm{KRA}_\gamma^{5\mathrm{PeV}}$)
- **Assume spatial** distribution of ν flux
- **Assume energy** distribution of ν flux

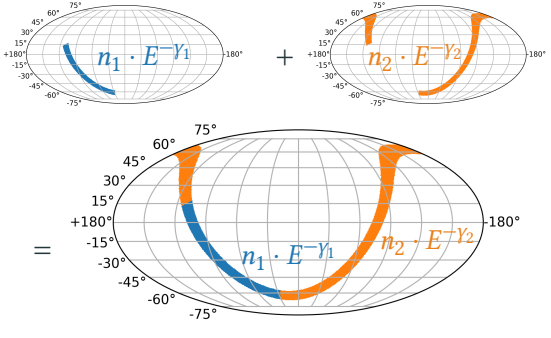
$\Rightarrow$ Large dependence on template prediction

Unbinned maximum likelihood fit with data-driven background:

$$\mathcal{L}(\gamma, n_s) = \prod_{i=1}^{N} \left[\frac{n_s}{N} S_i(\gamma) + \frac{N - n_s}{N} B_i \right]$$

Segmented Template Analysis

$$n_s S_i(\gamma) \rightarrow n_1 S_i^1(\gamma_1) + n_2 S_i^2(\gamma_2) + \cdots + n_M S_i^M(\gamma_M)$$

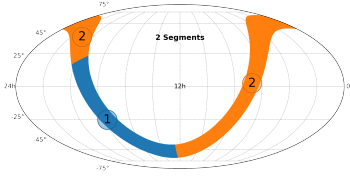


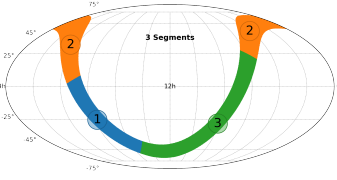
New Features

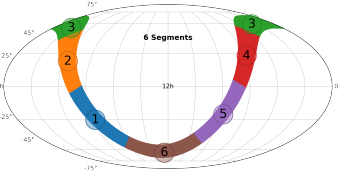
- Assume uniform emission in each segment
- Fit flux normalization n_k
- **Fit spectral index γ_k**
- 2 fit parameters per segment

Stockholm University

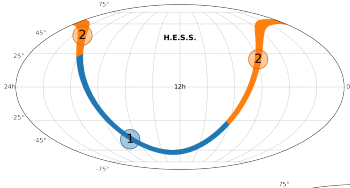
Generic segmentation schemes:

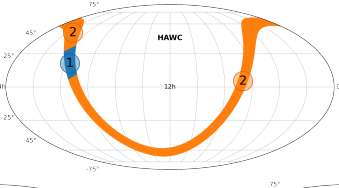


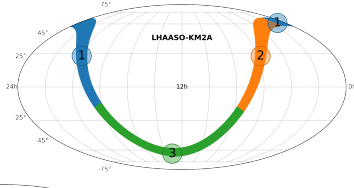


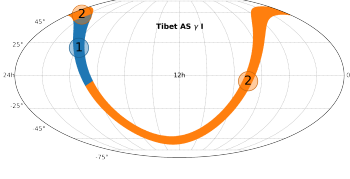


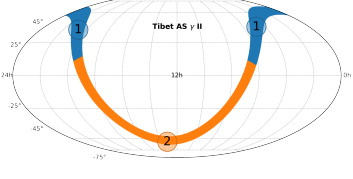
Aligning with γ ray GP measurements:





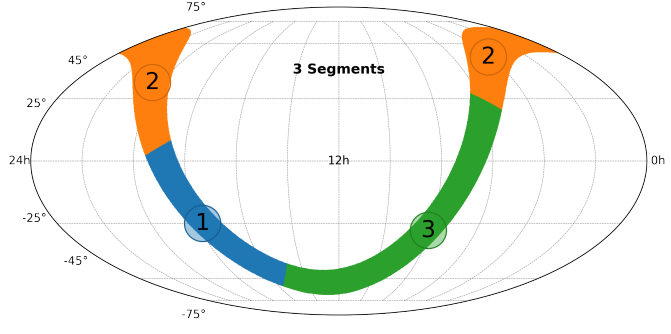




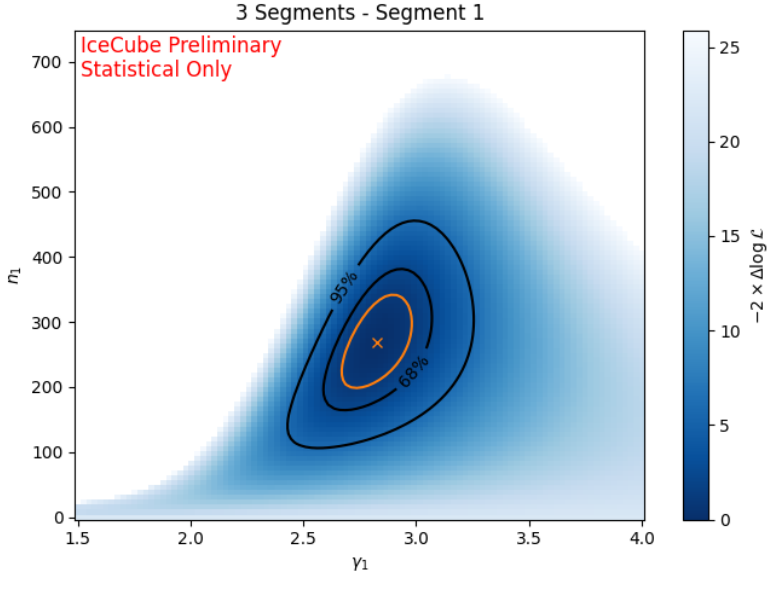


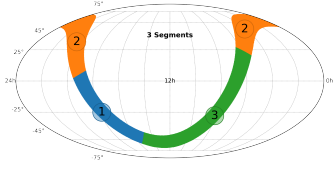
Generic segmentation schemes:

Today: Results for 3-segments segmentation scheme

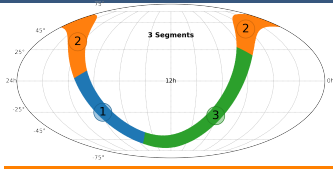


Result: Inner Galaxy

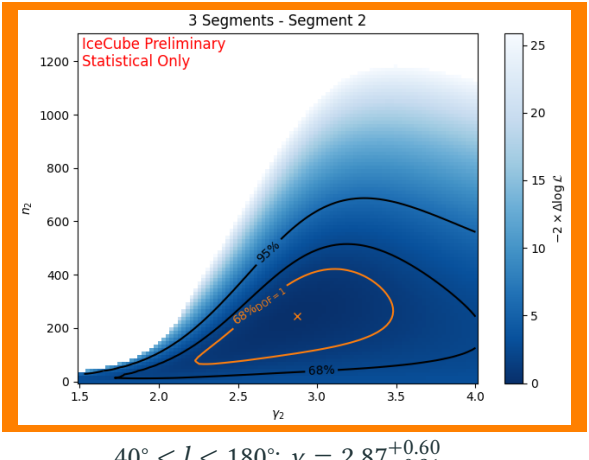


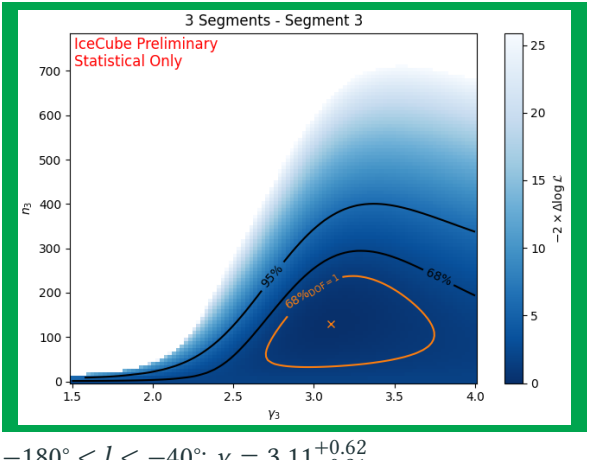


- Region:
  $-40^\circ < l < 40^\circ,\ |b| < 8^\circ$
- Likelihood contours assume Wilks' theorem
- $\gamma = 2.83^{+0.14}_{-0.12}$



Still non-zero flux in the outer galaxy, larger uncertainty on γ



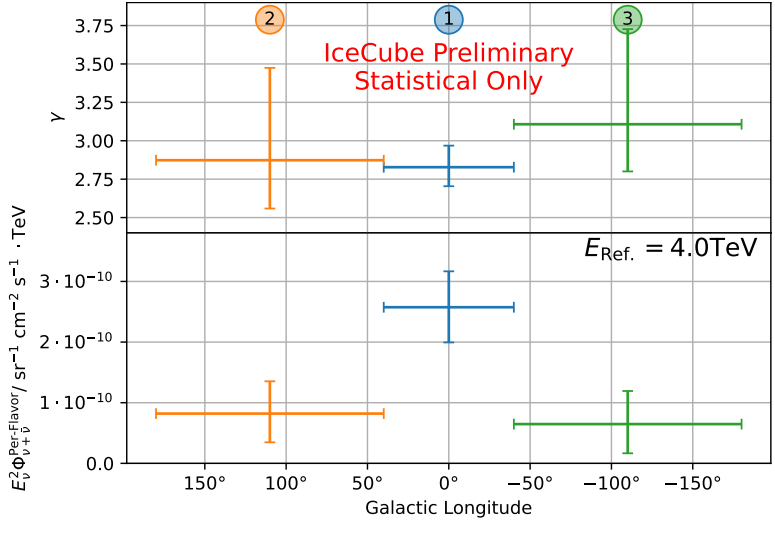


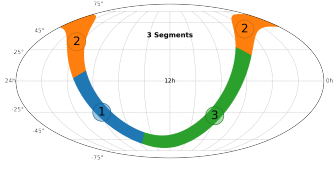
$40^\circ < l < 180^\circ$: $\gamma = 2.87^{+0.60}_{-0.31}$

$-180^\circ < l < -40^\circ$: $\gamma = 3.11^{+0.62}_{-0.31}$

Stockholm University

Compact way of visualizing the result:

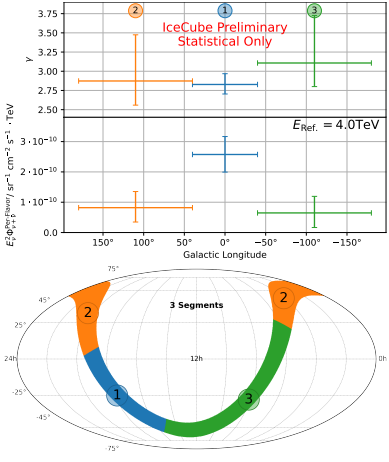




- Higher emission from the galactic center
- 68% 1D intervals assuming Wilks' theorem
- Flux @4 TeV per steradian

Conclusions and Outlook

- New method for a model independent analysis of IceCube GP data
- Same dataset as the 2023 analysis[1]
- First IC measurement of the ν spectral index in the inner galaxy



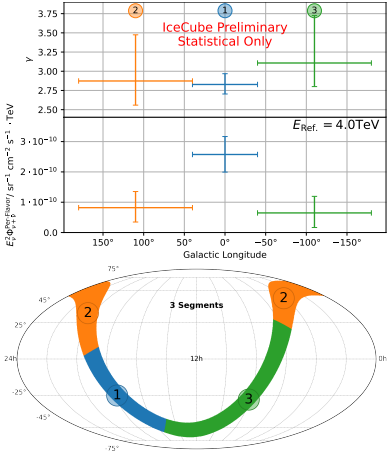
[1]For updated Template analyses see IC talks by Matthias and Riya

Conclusions and Outlook

- New method for a model independent analysis of IceCube GP data
- Same dataset as the 2023 analysis[1]
- First IC measurement of the ν spectral index in the inner galaxy

→ Paper: Treatment of systematics

→ Paper: Comparison to very high energy diffuse γ-rays



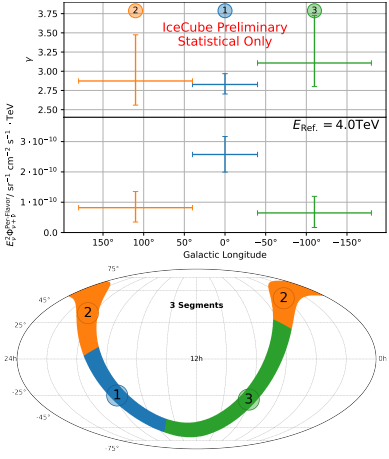
[1]For updated Template analyses see IC talks by Matthias and Riya

Conclusions and Outlook

- New method for a model independent analysis of IceCube GP data
- Same dataset as the 2023 analysis[1]
- First IC measurement of the ν spectral index in the inner galaxy

→ Paper: Treatment of systematics

→ Paper: Comparison to very high energy diffuse γ-rays

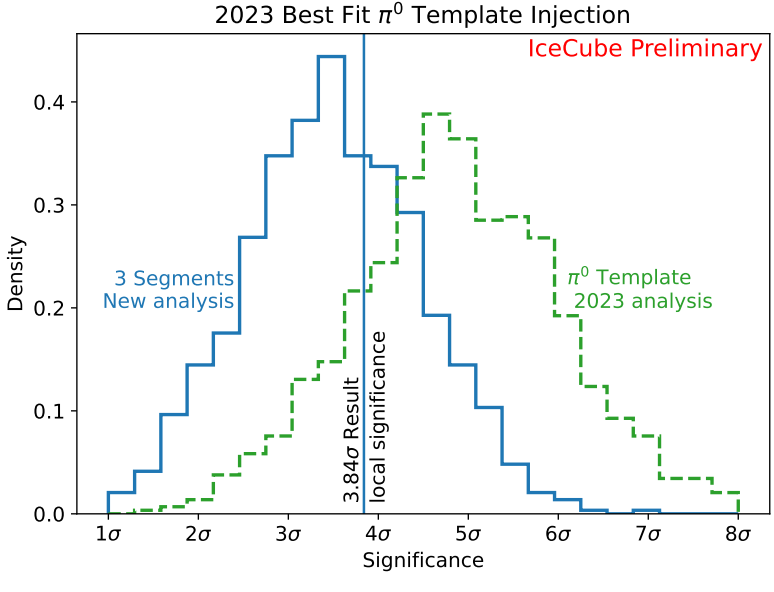


Thanks for your attention

[1] For updated Template analyses see IC talks by Matthias and Riya

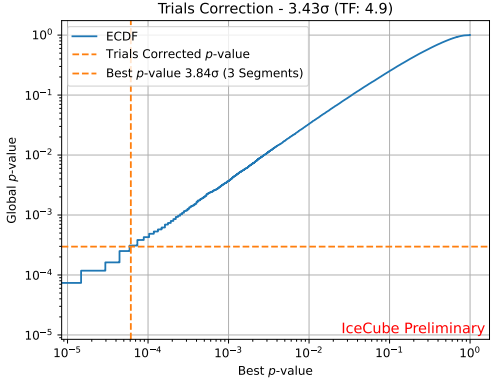
Backup

Expected Significance



Trials Correction

Scheme	Significance	n_s
2-segments	3.81 σ	643
3-segments	3.84 σ	643
6-segments	3.58 σ	808
H.E.S.S.	3.06 σ	569
HAWC	3.01 σ	664
LHAASO-KM2A	2.73 σ	371
Tibet AS γ I	2.96 σ	660
Tibet AS γ II	2.98 σ	626
Trials-corrected	3.43 σ	



p-values **are not** the focus of the analysis, rather a model-independent measurement.