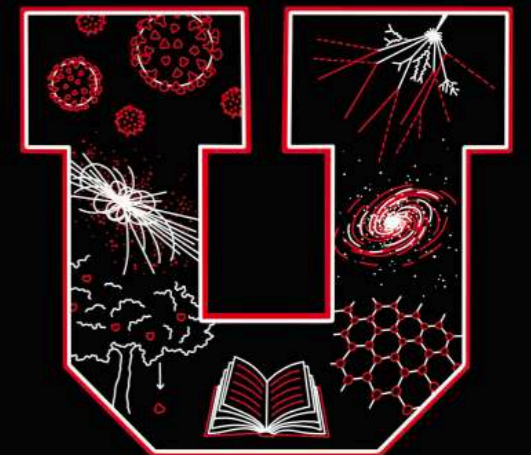


Searching for correlations between HAWC gamma-ray observations and IceCube high energy neutrino events.

Natalia Tapia Arellano · University of Utah · PHENO2024

In collaboration with:

**Jason Kumar (University of Hawai'i),
Carsten Rott (University of Utah) and
Pearl Sandick (University of Utah)**



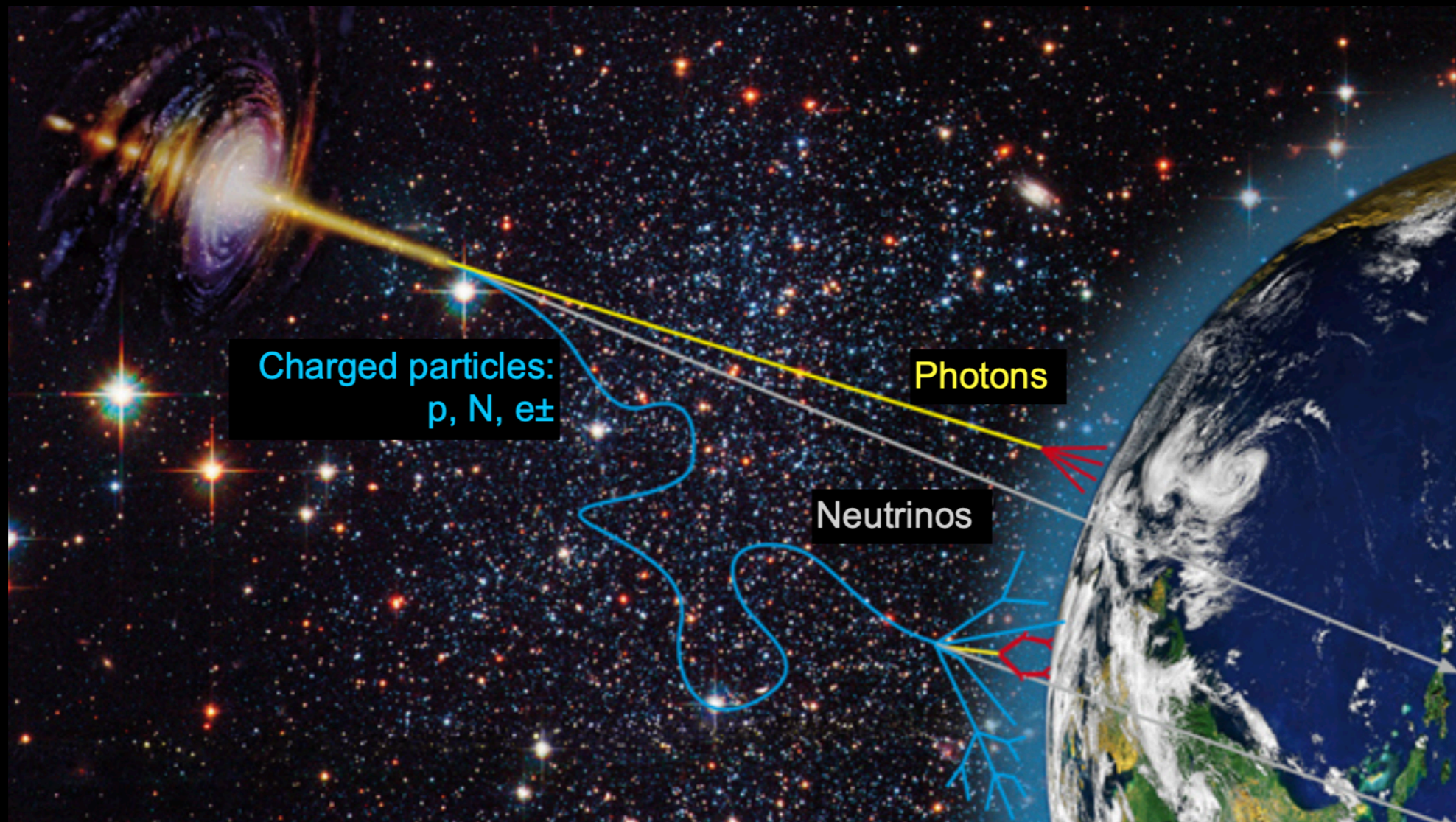
Outline

- Motivation
- What is IceCube
- What is HAWC
- Event Selection
- Results



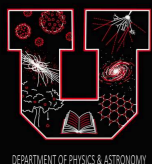
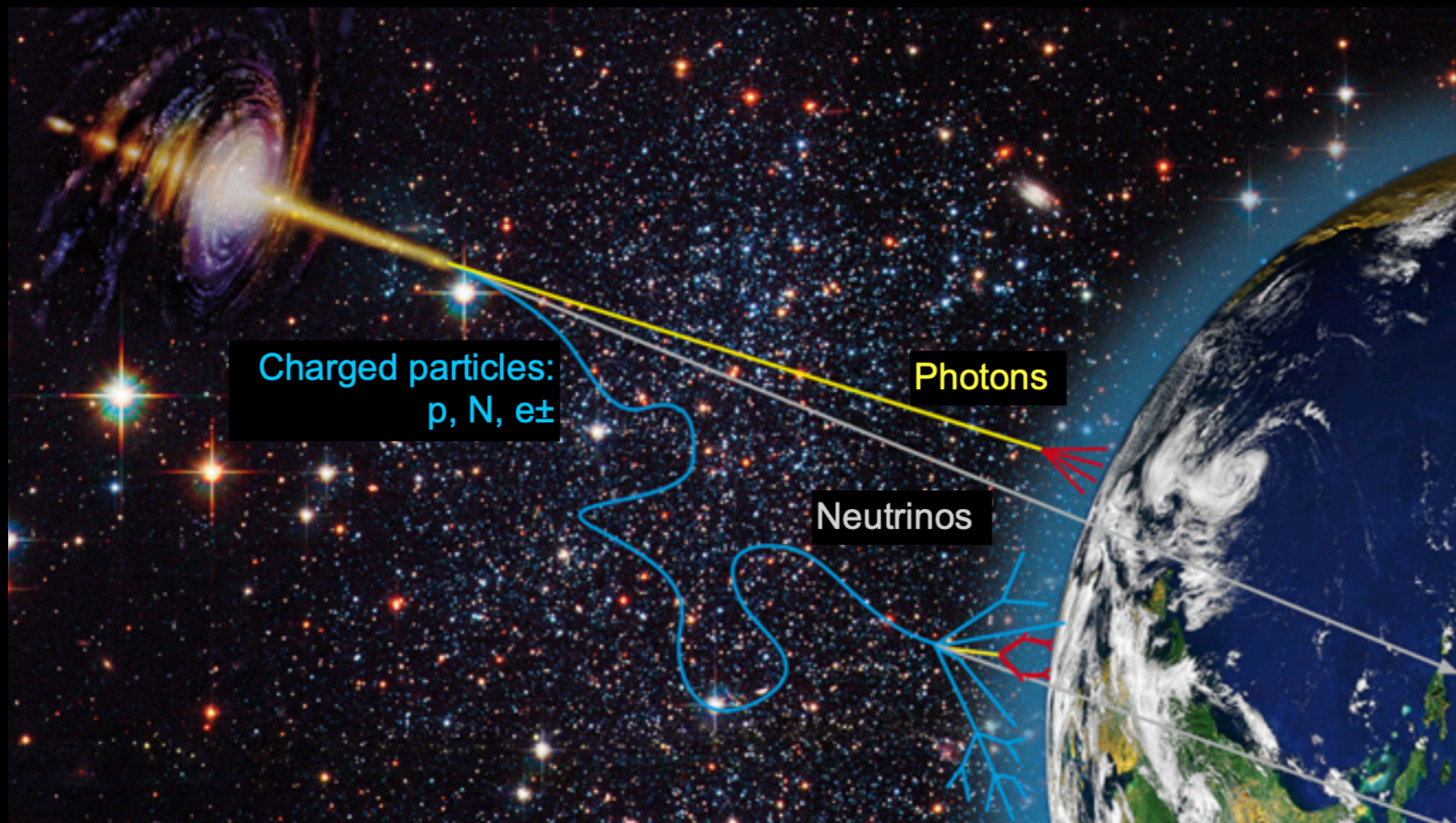
Why?

The IceCube Neutrino Observatory has identified over one hundred possible astrophysical neutrino events. Weak processes that produce high-energy neutrinos are often related to electromagnetic processes that can also generate high-energy gamma rays.



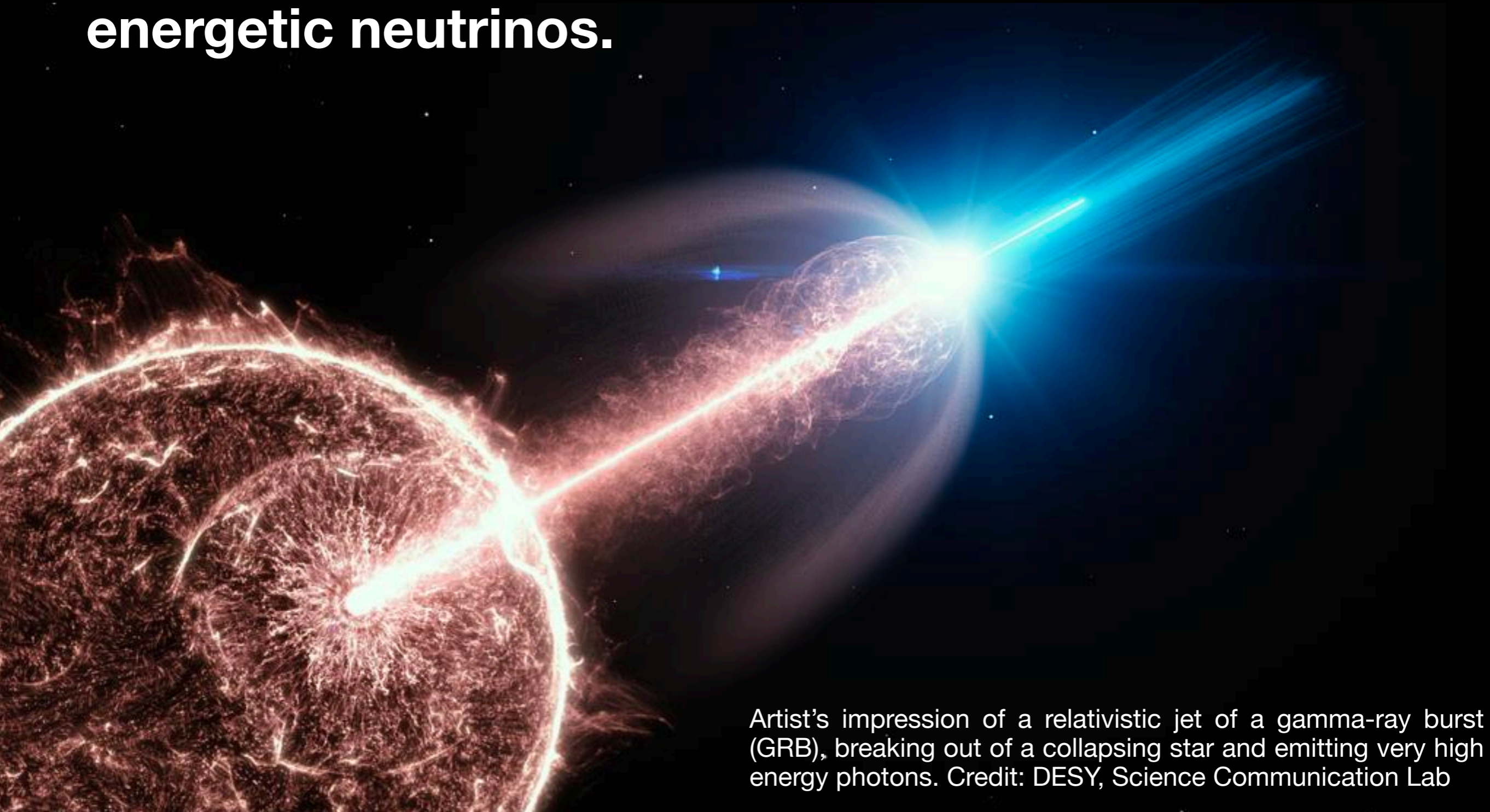
Why?

On September 22, 2017, IceCube detected a high-energy neutrino event that coincided in direction and time with a gamma-ray flare from the blazar TXS 0506+056. **This suggests that the two phenomena may be related.**



Gamma-ray correlations

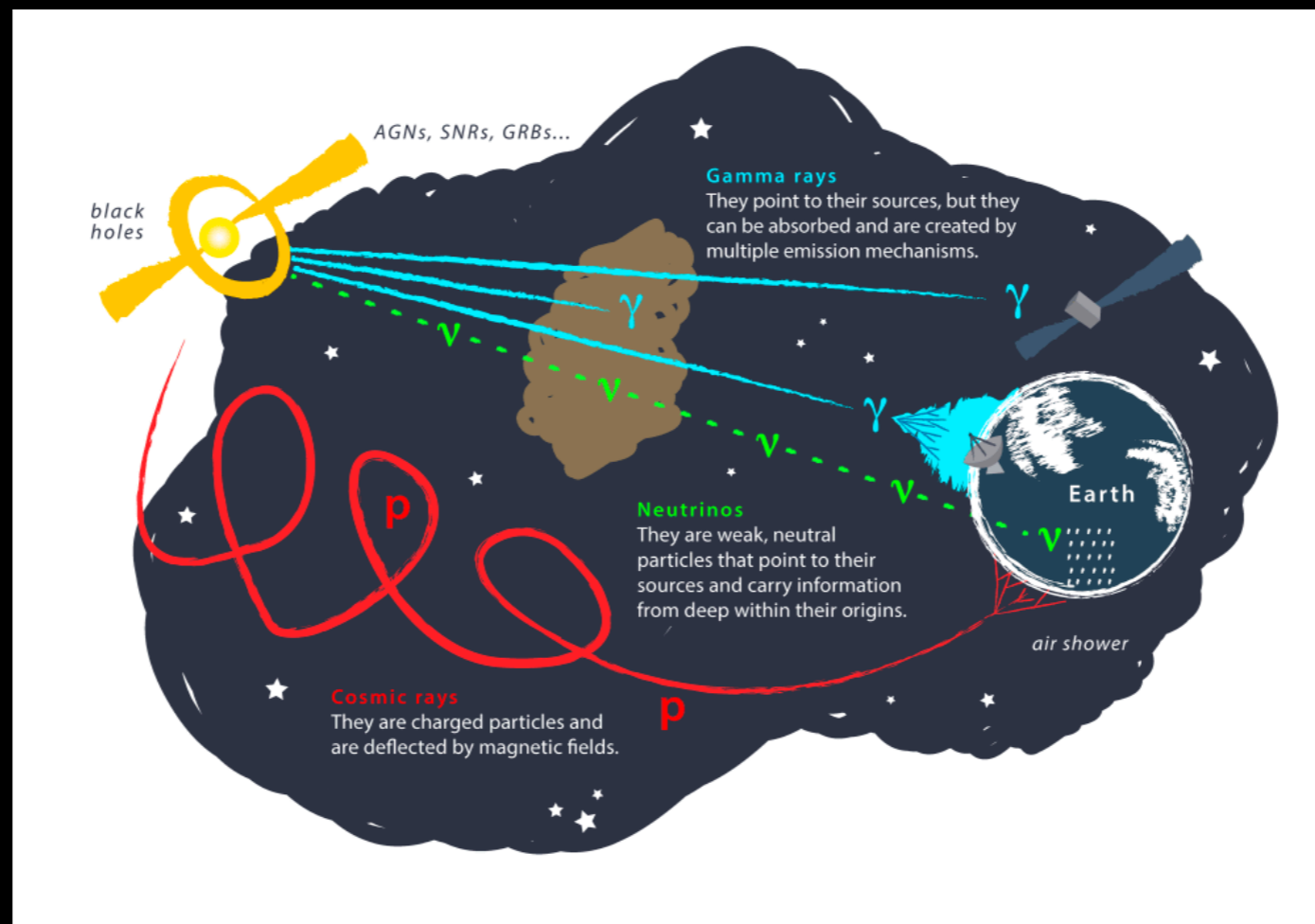
Studying gamma-ray sources and neutrino events may help us understand the origin of these highly energetic neutrinos.



Artist's impression of a relativistic jet of a gamma-ray burst (GRB), breaking out of a collapsing star and emitting very high energy photons. Credit: DESY, Science Communication Lab

How?

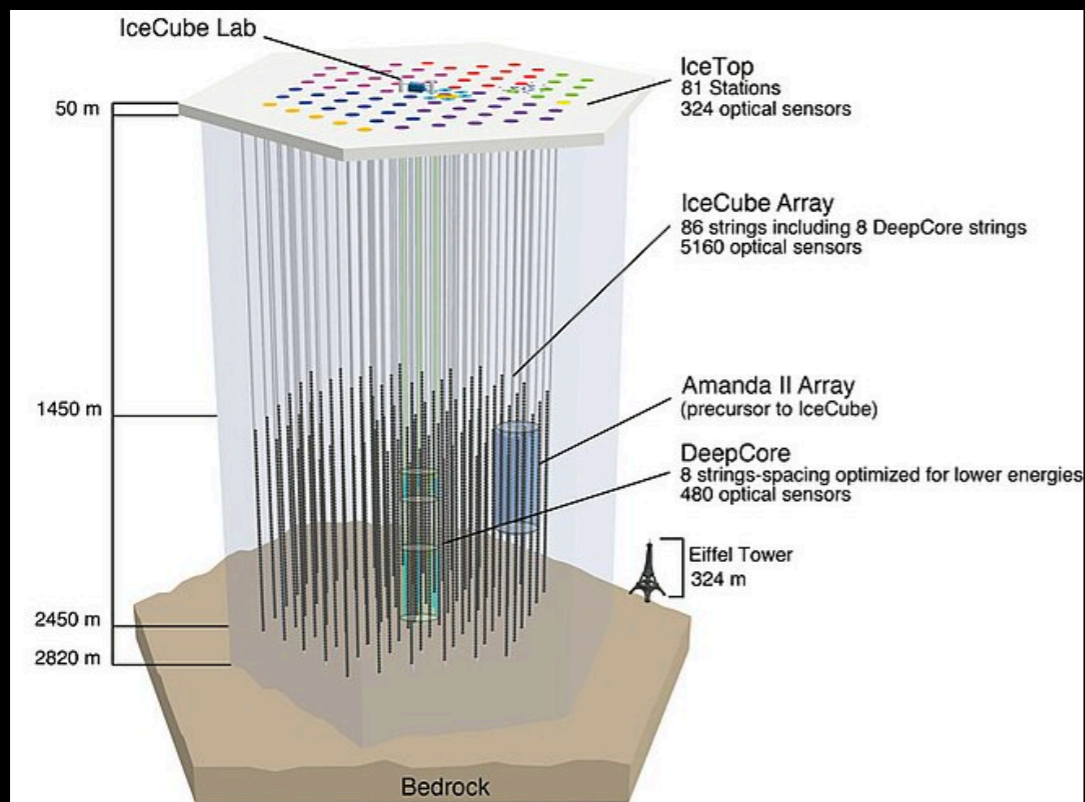
We aimed to determine a correlation between unidentified neutrino point sources and unidentified gamma-ray sources. The analysis was performed using publicly available data from IceCube and HAWC.



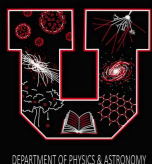
IceCube

Events

- The IceCube Neutrino Observatory is a kilometer-size neutrino detector located at the South Pole.



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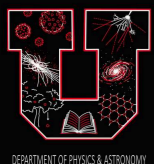
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Credit: IceCube/NSF; The IceCube Lab at the South Pole with aurora

IceCube

Events

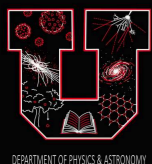
- The IceCube Neutrino Observatory is a kilometer-size neutrino detector located at the South Pole.



IceCube

Events

- The IceCube Neutrino Observatory is a kilometer-size neutrino detector located at the South Pole.
- Recently, IceCube released data regarding the TXS 0506+056 blazar event and its analysis.



IceCube

Data release

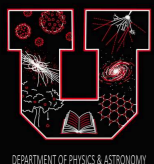
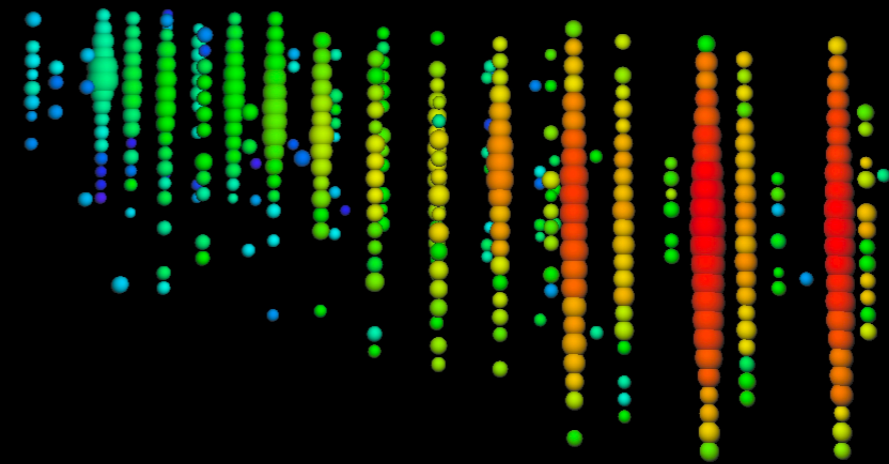
- The data used for this analysis was publicly available and covered the period from **2008 to 2017**.
- **Our analysis specifically focused on the data from 2011 to 2018.** The purpose of releasing this data was to facilitate multi-messenger searches.



IceCube

Track events

- We consider all IceCube neutrinos with track-like signatures
- Energy $E > 10^6 \text{ GeV}$
- Median angular resolution of $\leq 0.1^\circ$. The absolute pointing accuracy of IceCube has been demonstrated to be $\leq 0.2^\circ$



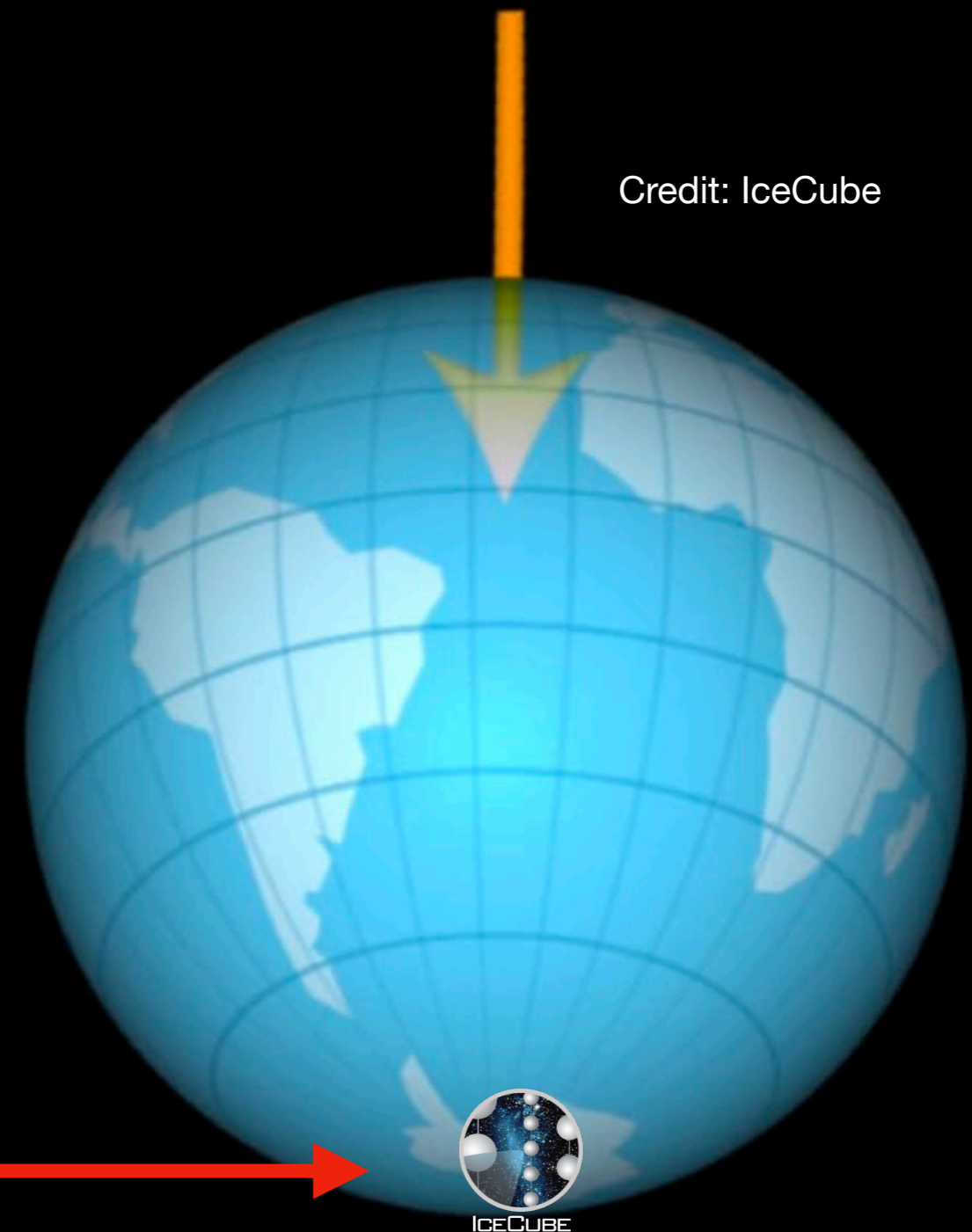
Events in the southern hemisphere

It has been demonstrated that the Earth stops very energetic neutrinos — they do not go through everything.



10^6 GeV

Credit: IceCube



IceCube

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100 trillion neutrinos pass through your body every second! (10^{12})

Events in the southern hemisphere

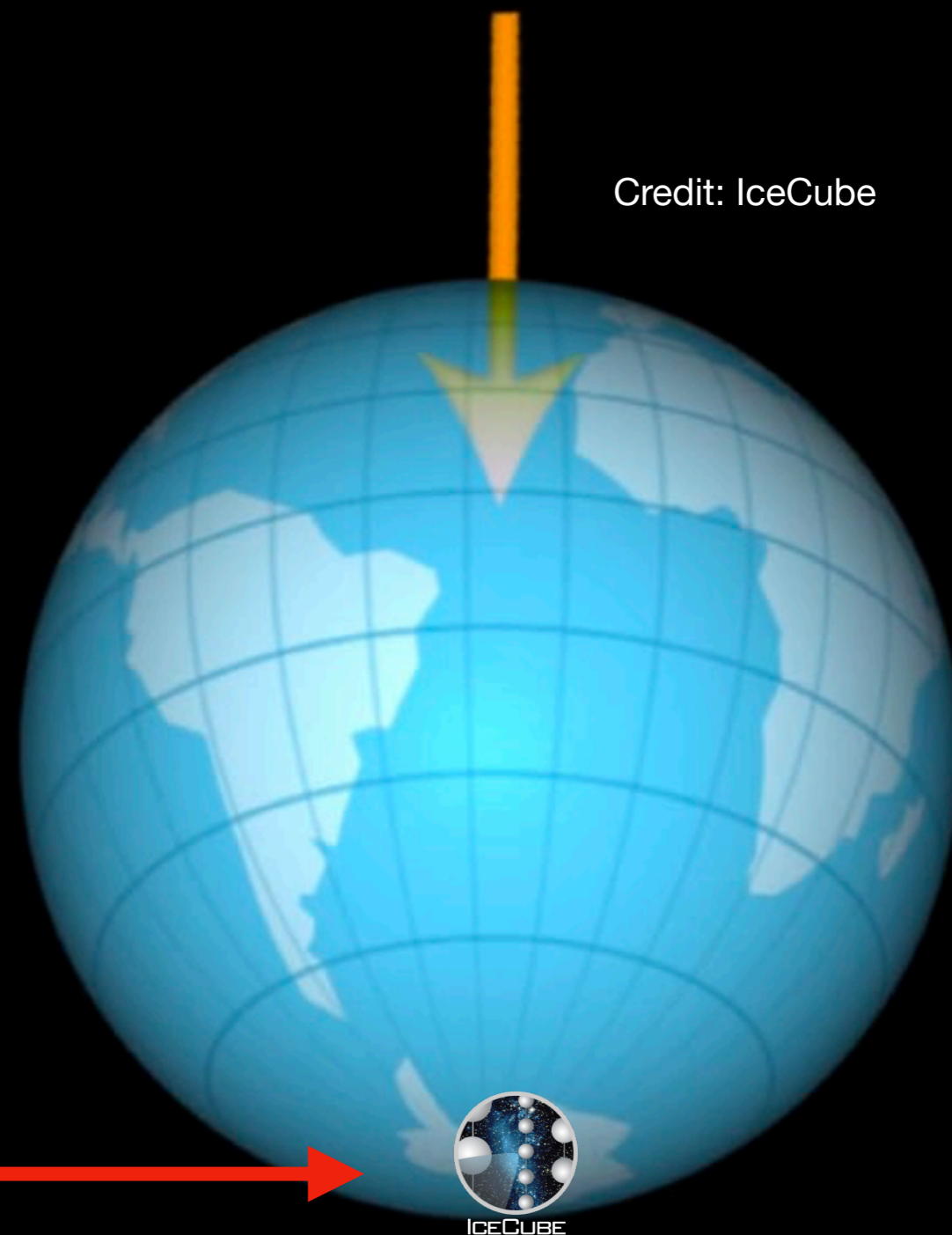
It has been demonstrated that the Earth stops very energetic neutrinos — they do not go through everything.

Consistent with the Standard Model of Particle Physics.



10^6 GeV

Credit: IceCube



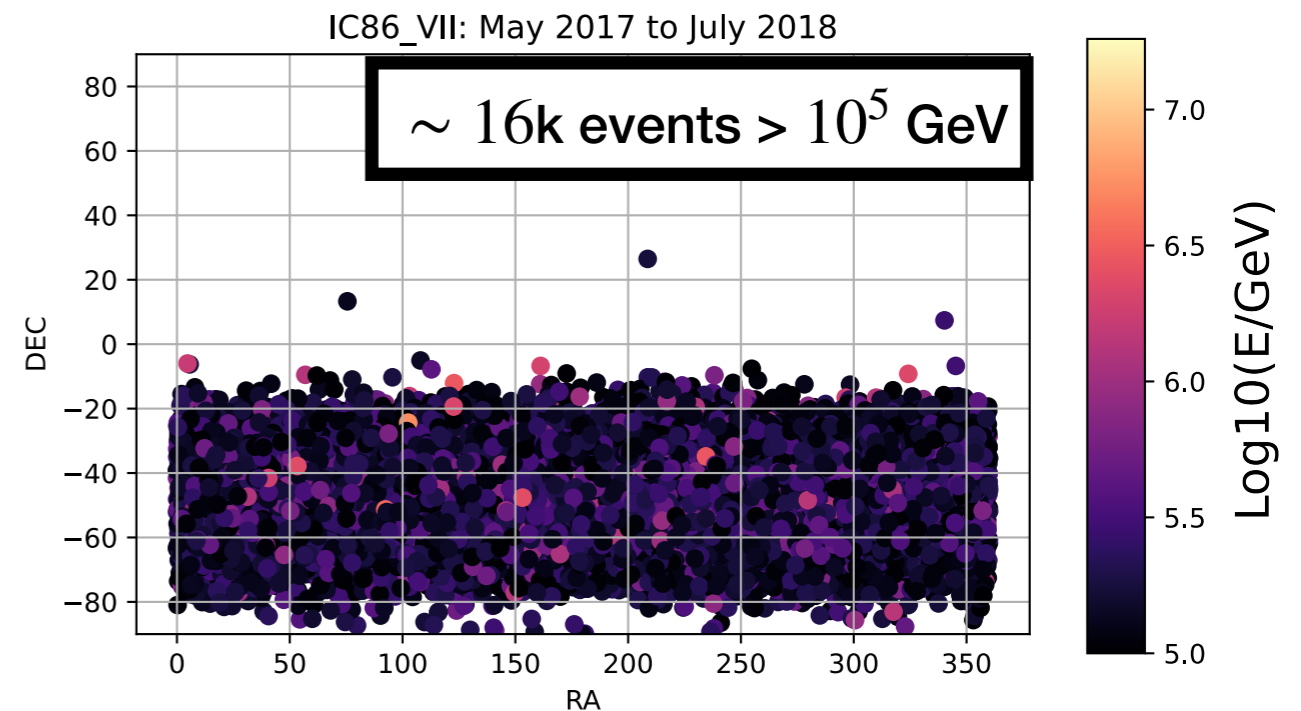
IceCube

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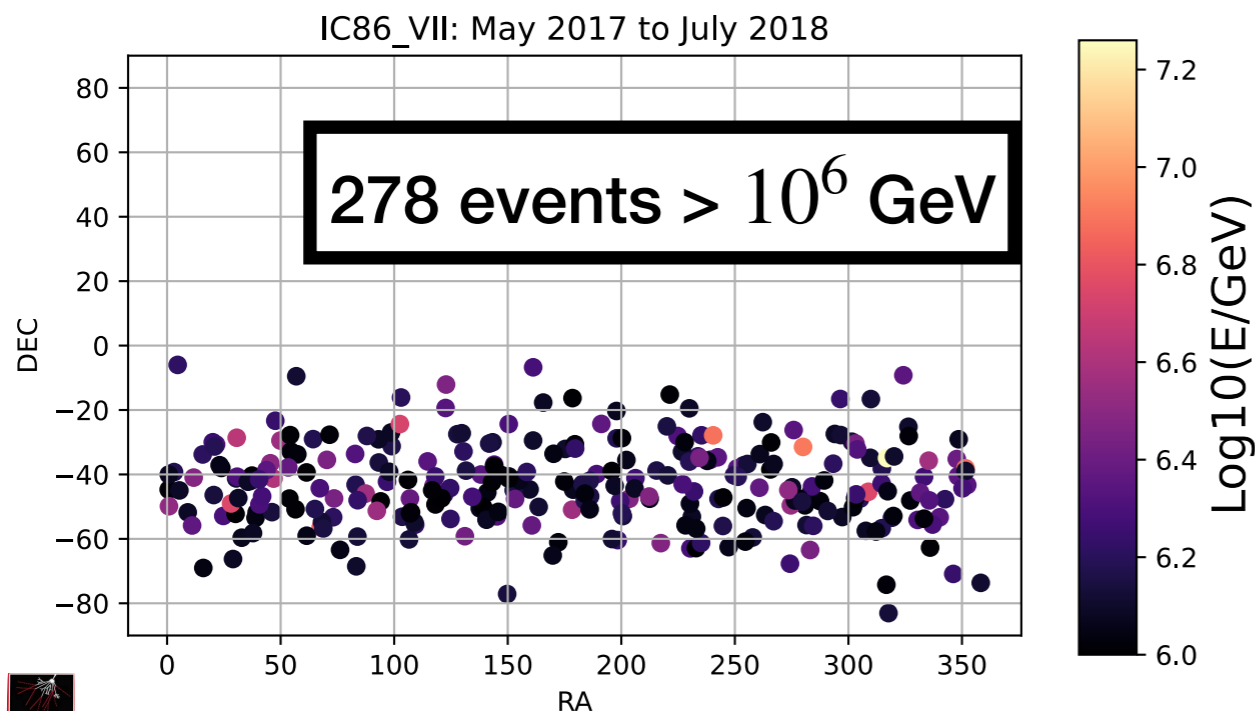
100 trillion neutrinos pass through your body every second! (10^{12})

As an example: The spatial distribution of events depends on the energy

Number of events for energies between $10^5 > E_\nu$ GeV's \implies



Events for the last year of data collection



\Leftarrow Number of events for energies

$E_\nu > 10^6 \text{ GeV's}$



The HAWC Observatory (J. Goodman, Nov. 2016).



HAWC

High Altitude Water Cherenkov, Gamma-ray observatory

HAWC

Detector



- Designed to detect gamma and cosmic rays between 100 GeV and 100 TeV, including some of the highest energy photons ever observed.



Located on the flanks of the Sierra Negra volcano near Puebla, Mexico at an altitude of 4100 meters (13,500 feet)

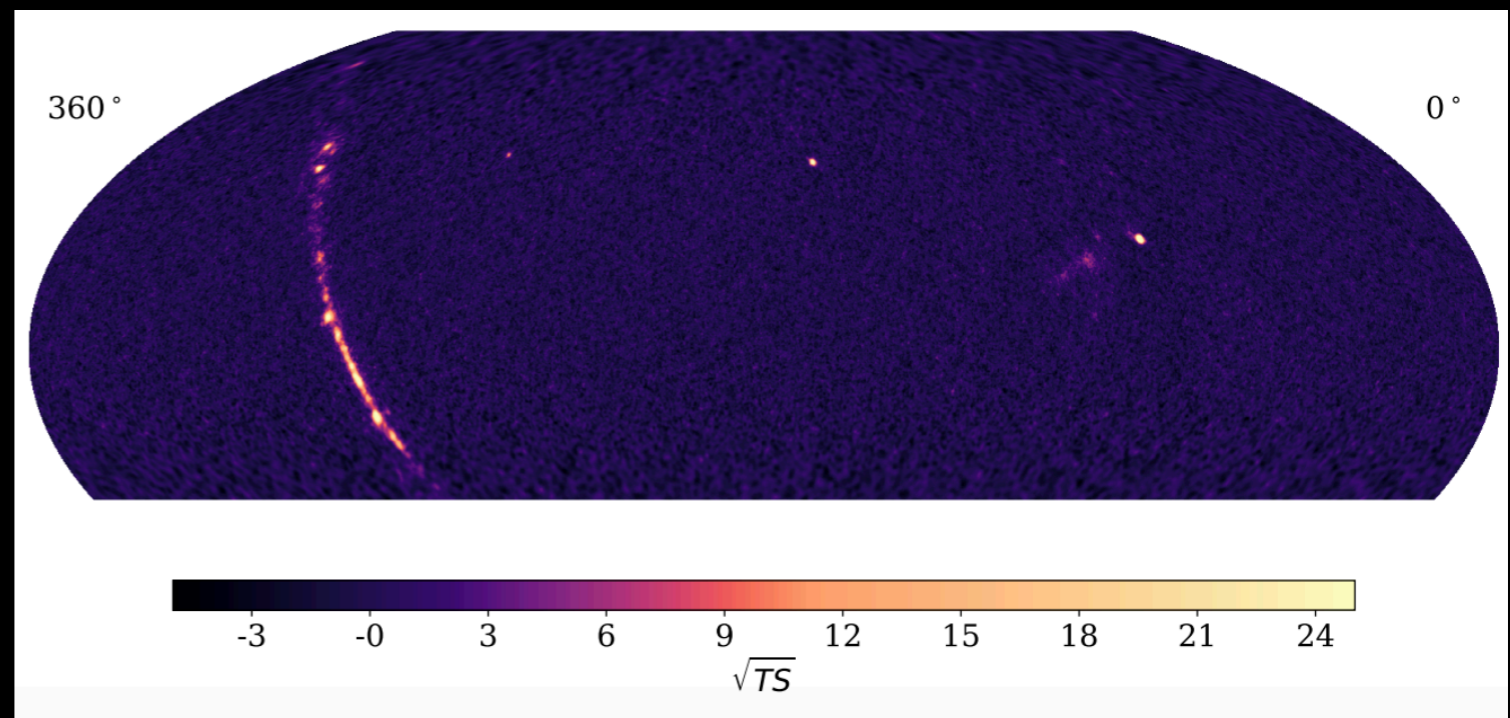


HAWC

Data release



- 3HWC survey: 1523 days of operation
- We used the skymaps from the 3HWC catalog, for point source searches
- Specifically, the Significances map



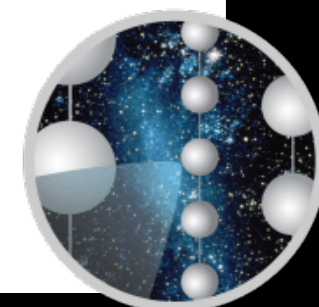
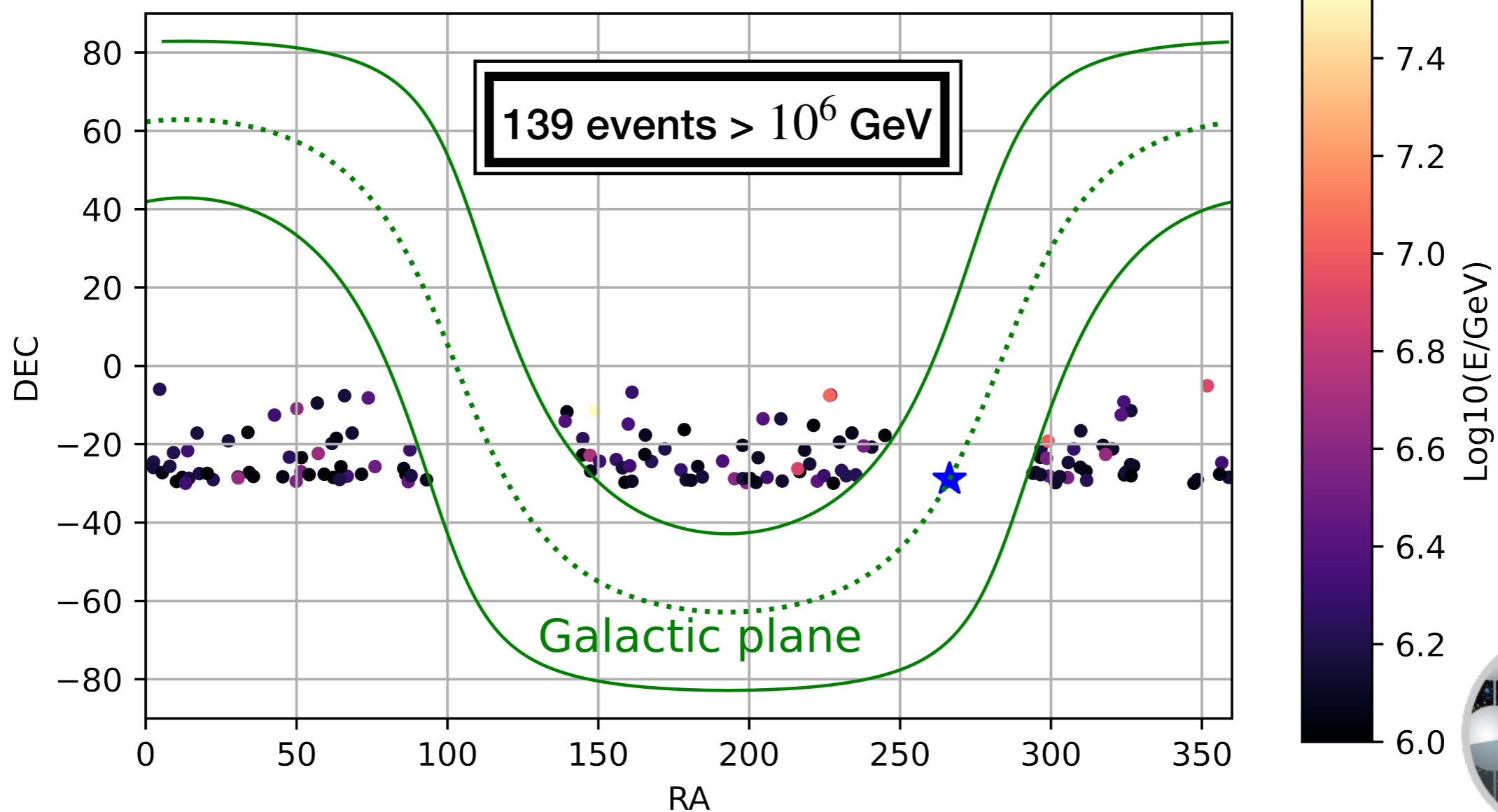
All-sky significance map in celestial coordinates, assuming a point-source hypothesis from 3HWC catalog paper arXiv:2007.08582



Event Selection



Overlap with HAWC footprint and removing the galactic plane: 139 events

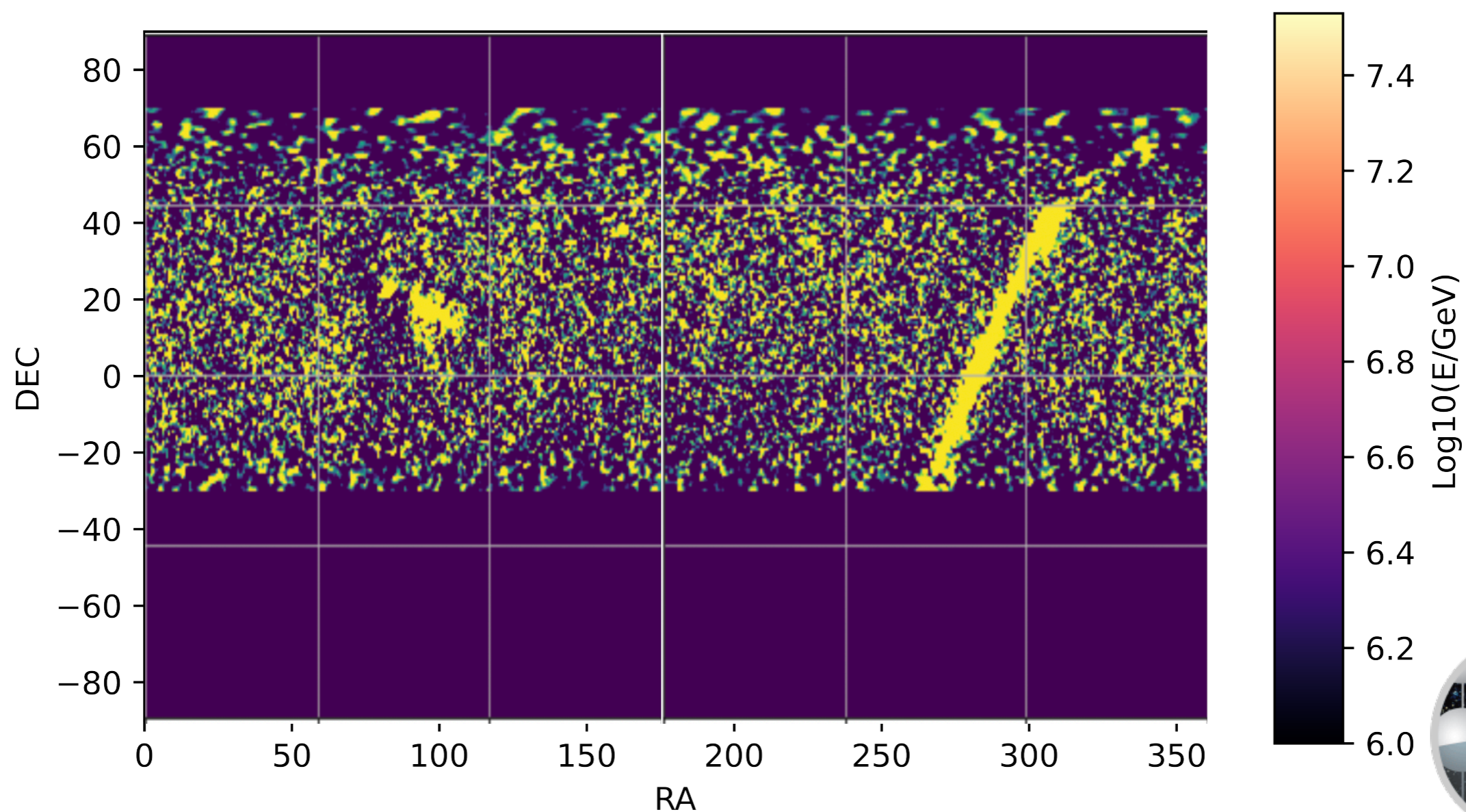


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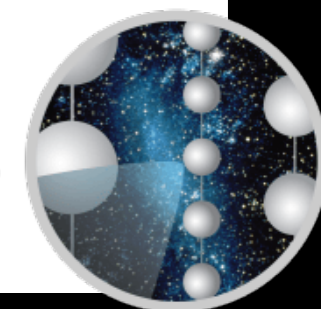
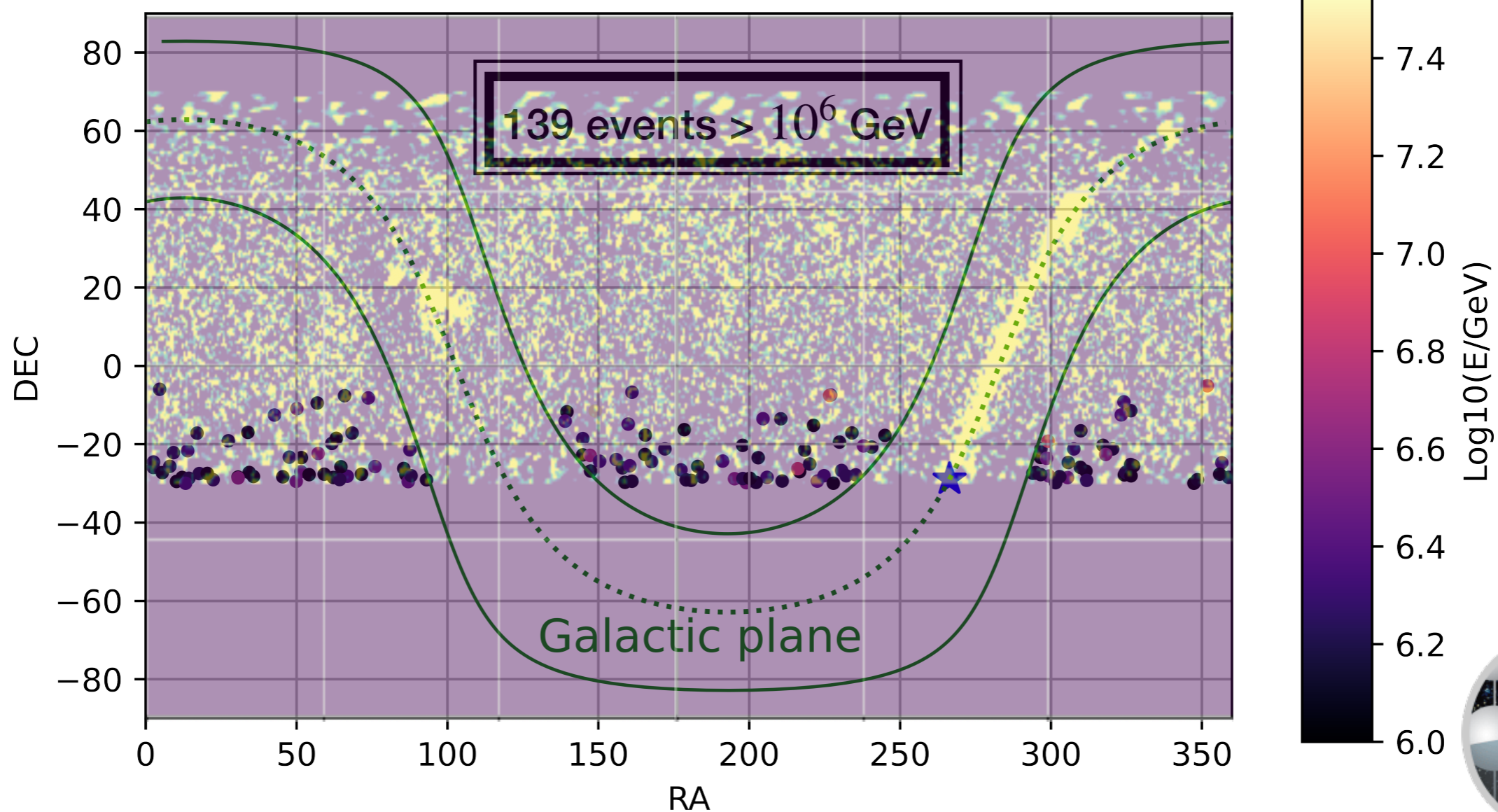


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Overlap with HAWC footprint and removing the galactic plane: 139 events



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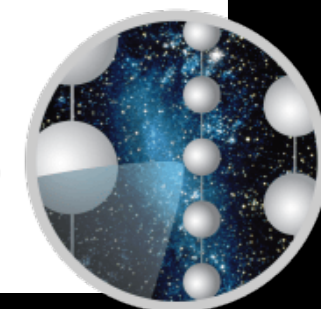
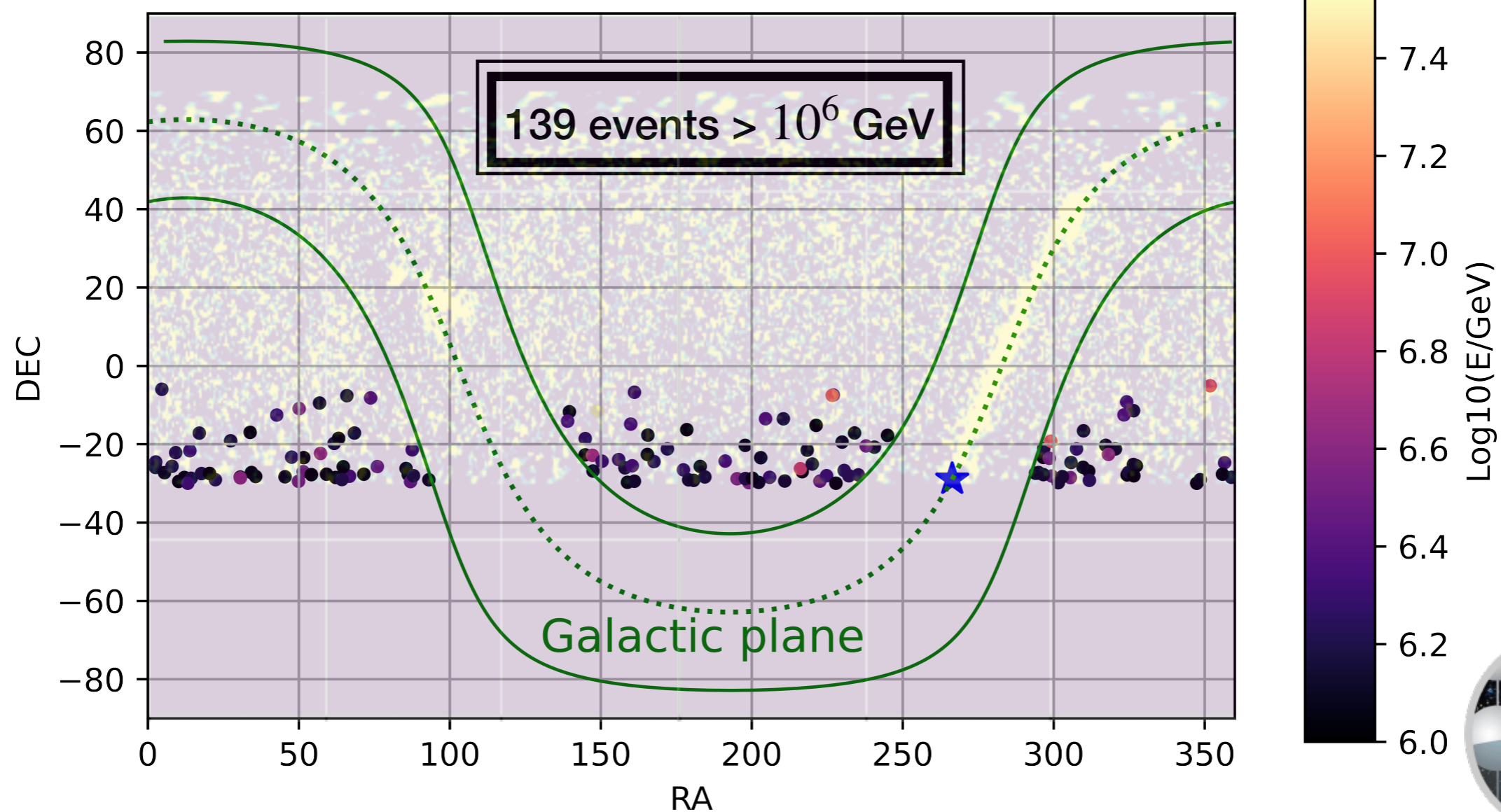
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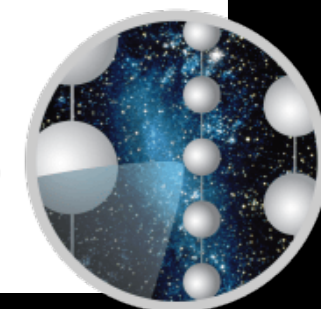
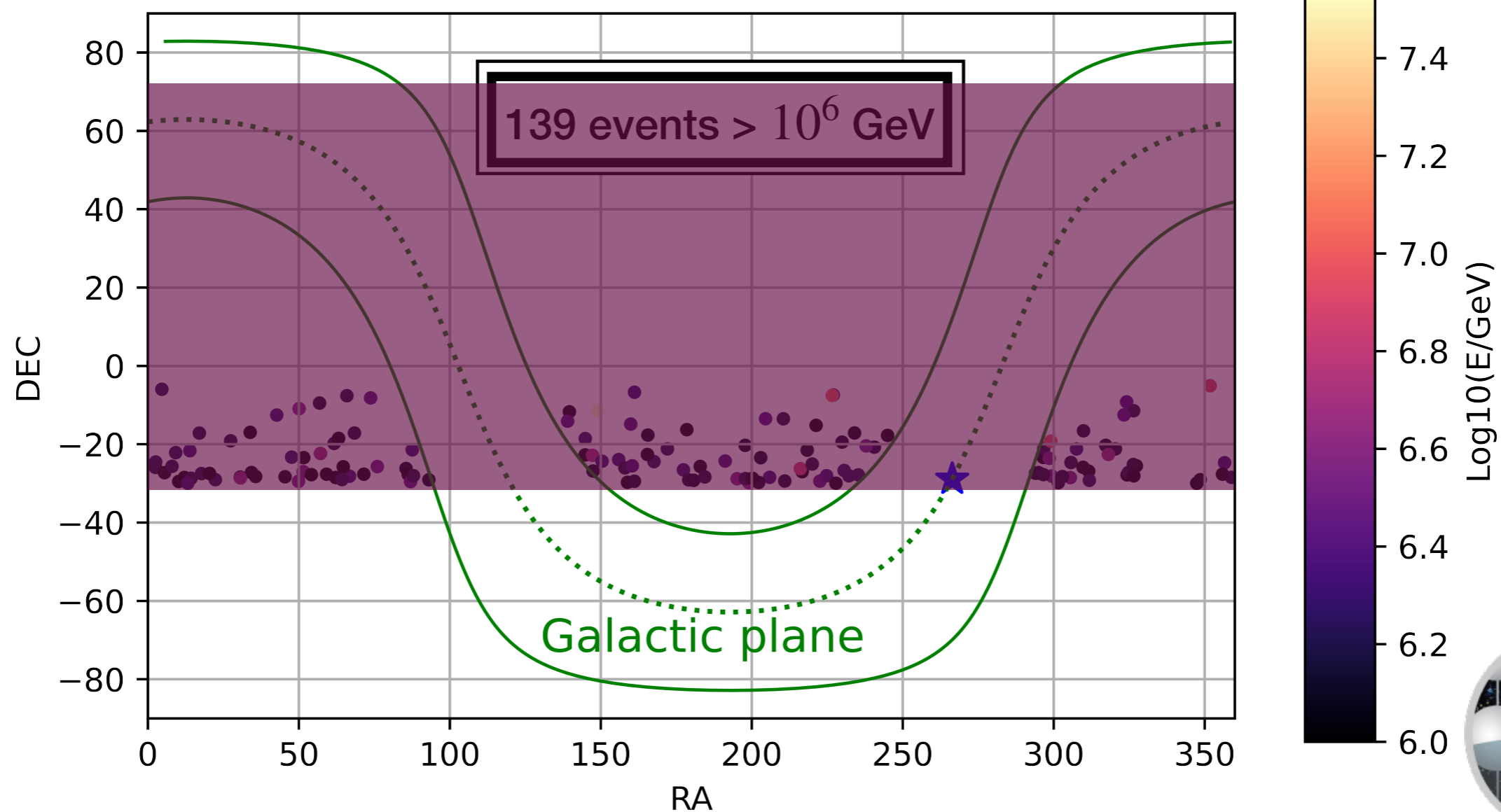


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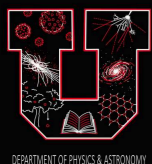


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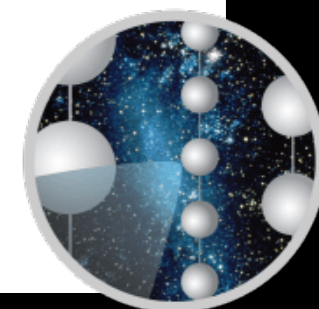
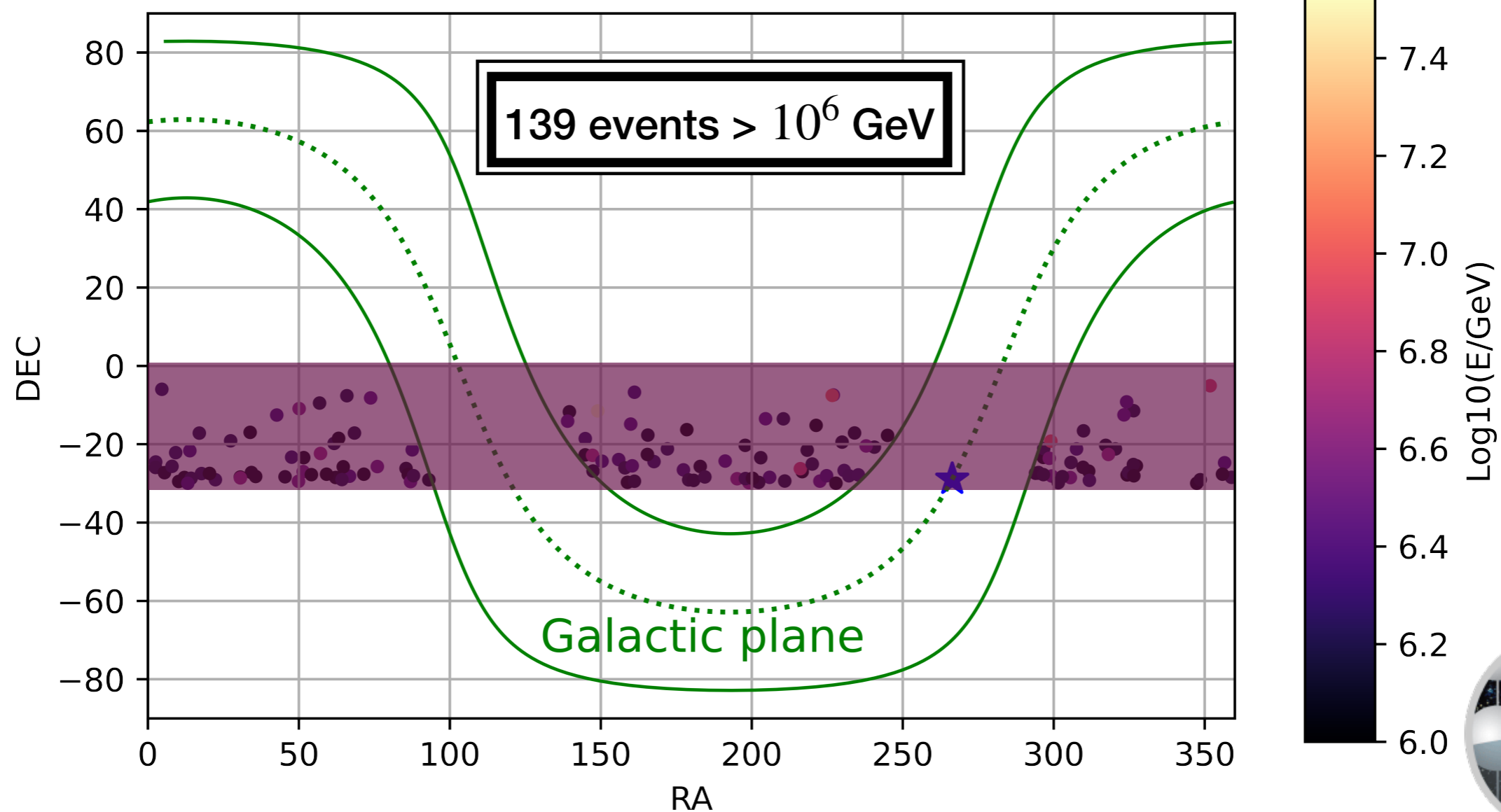


ICECUBE



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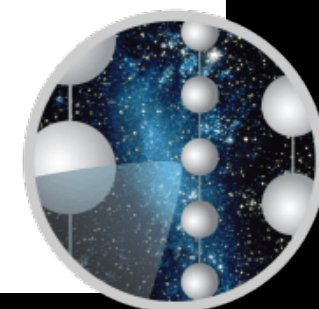
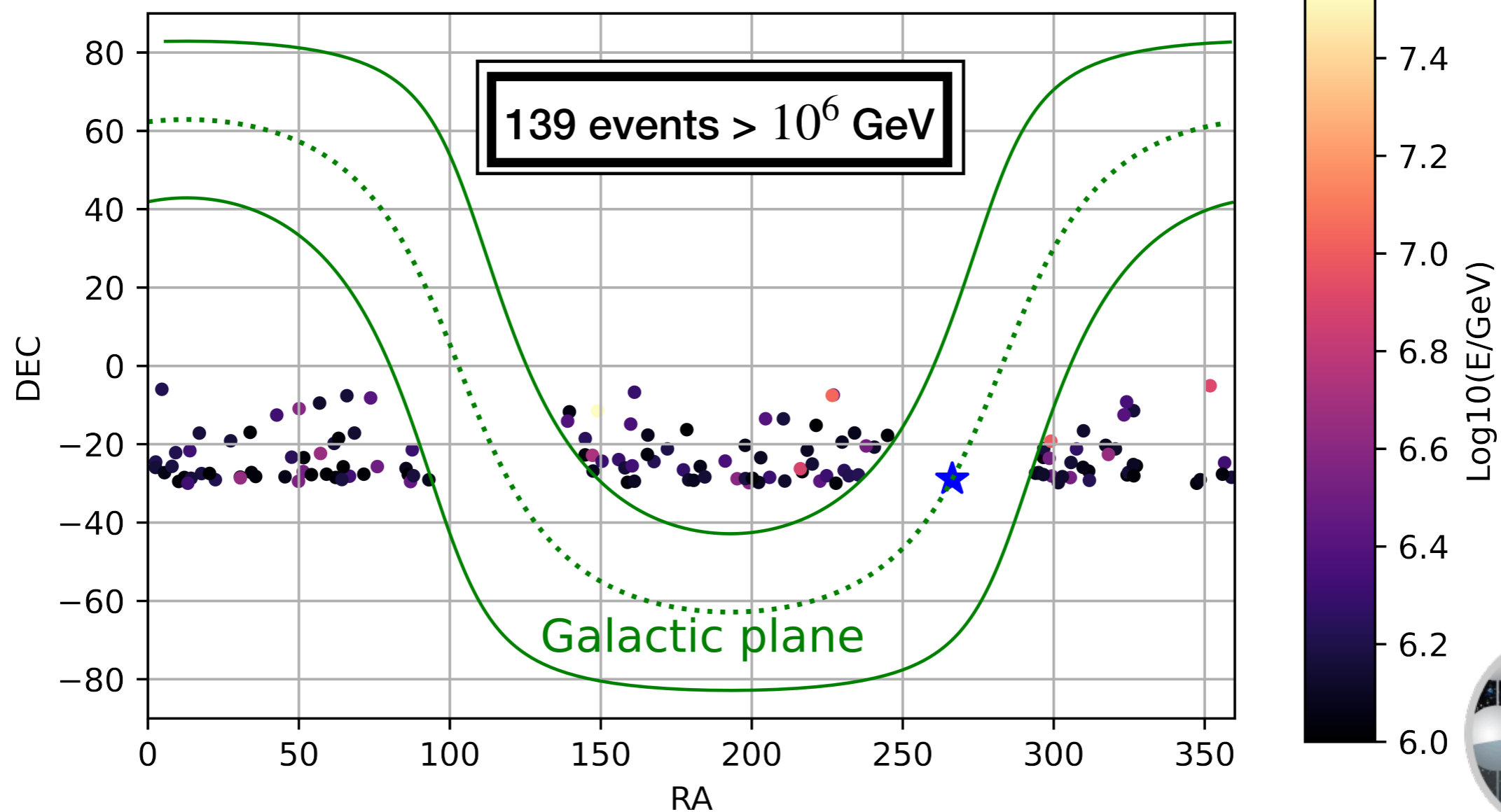
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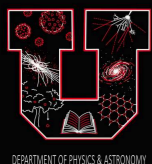
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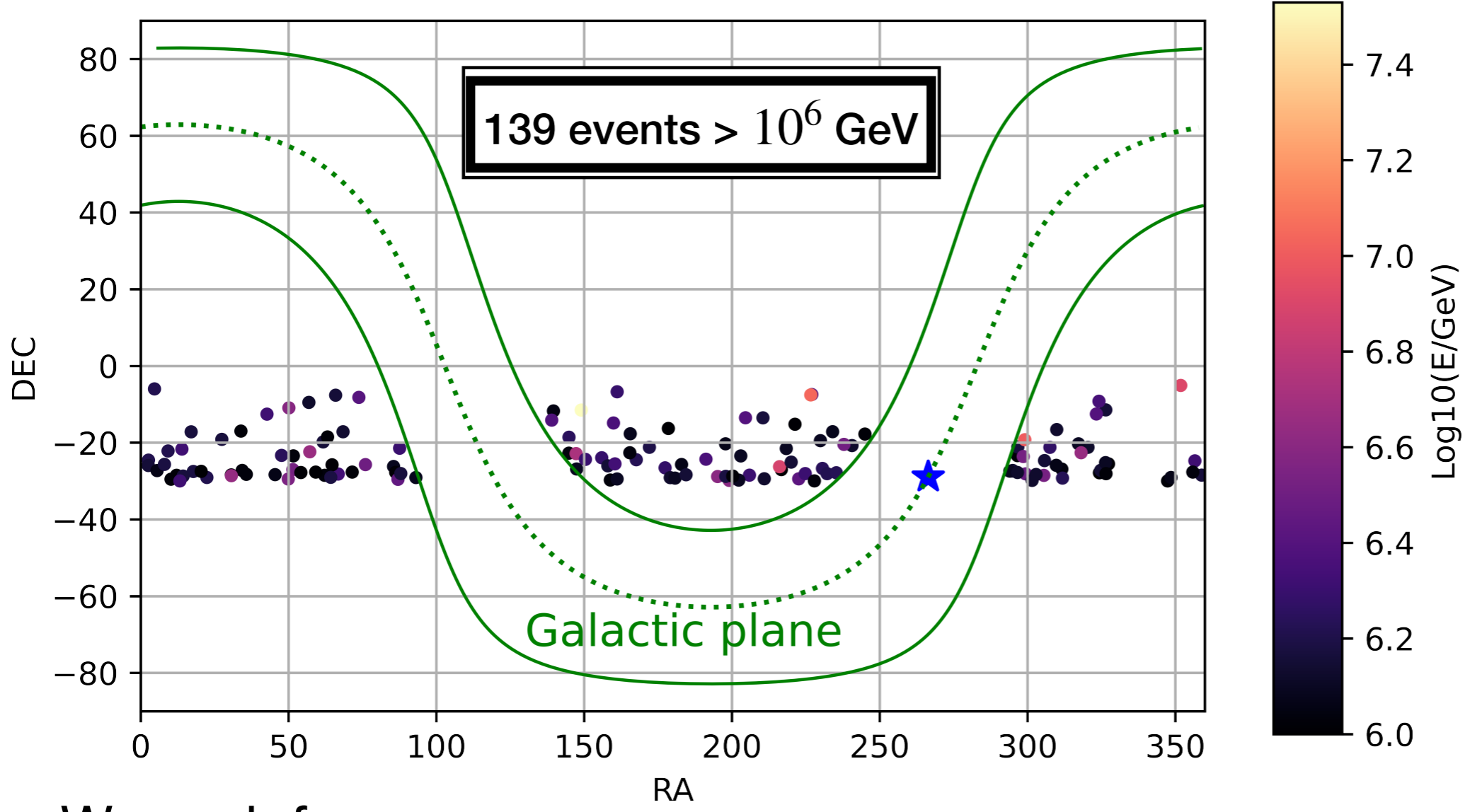
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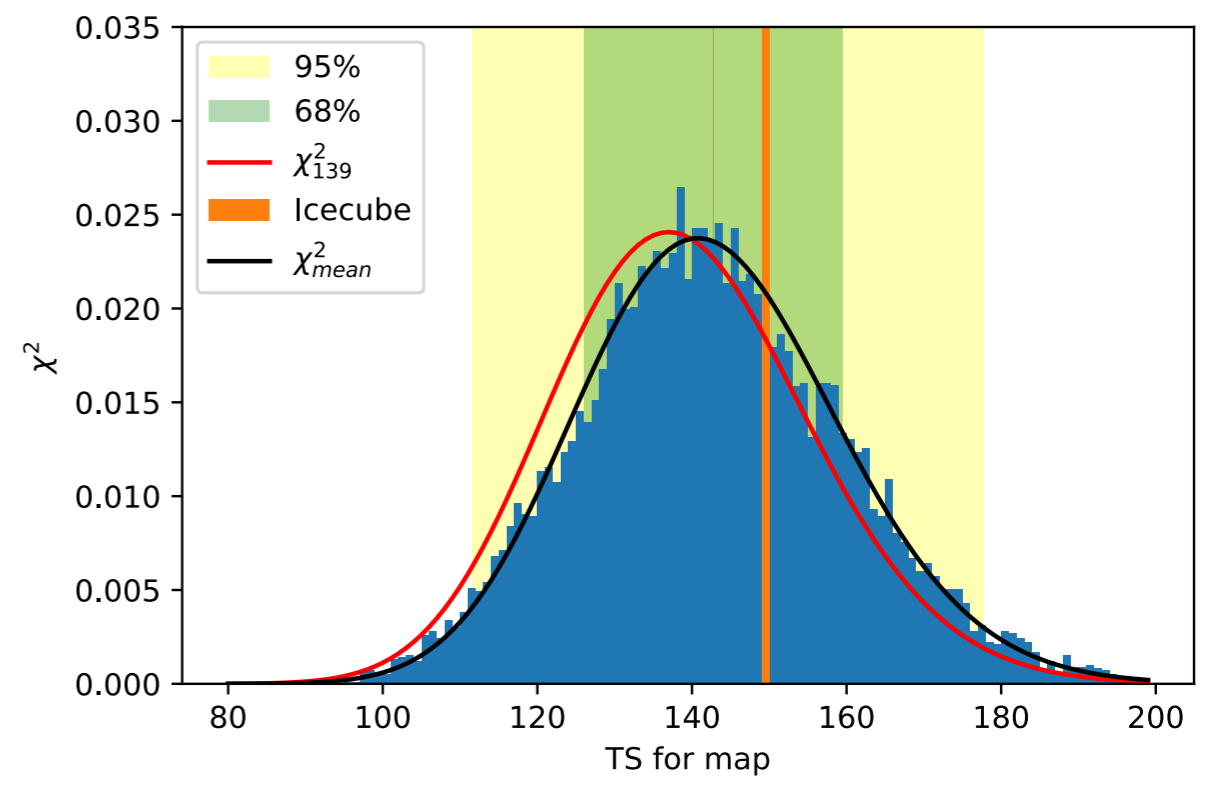
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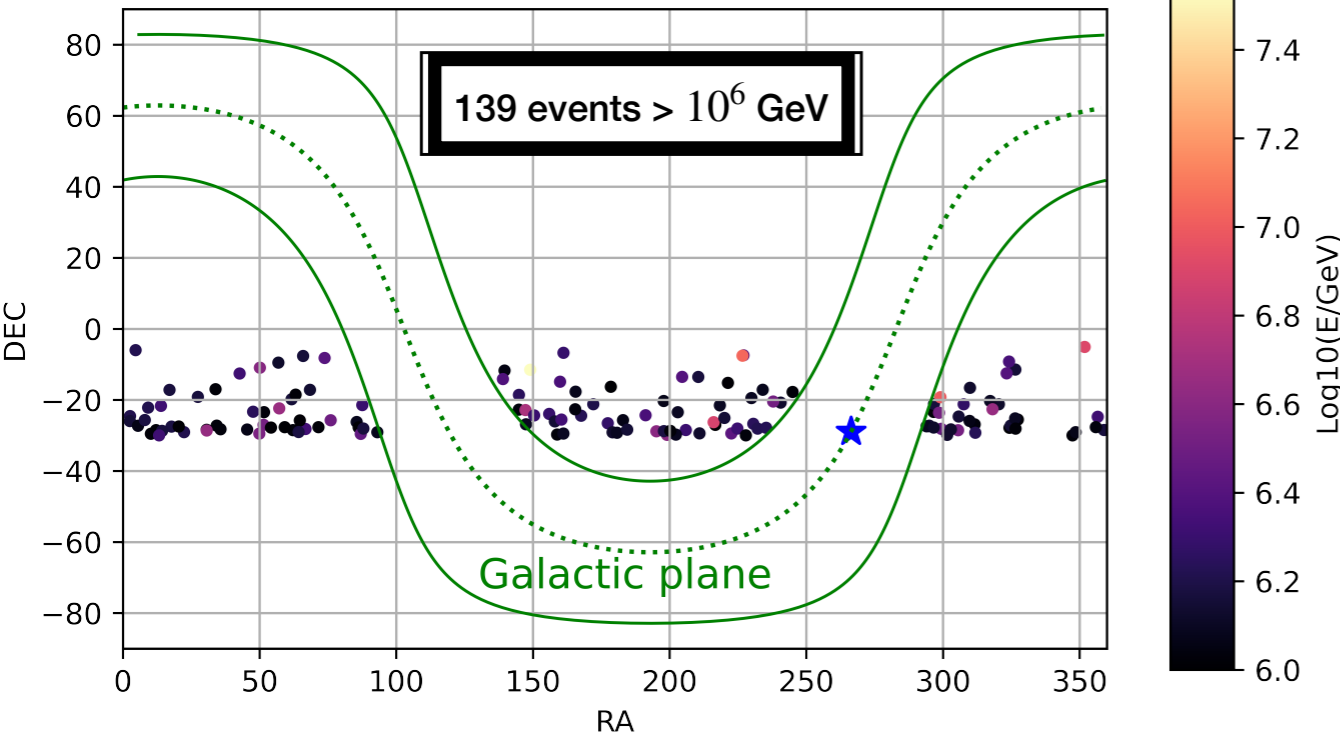
Results





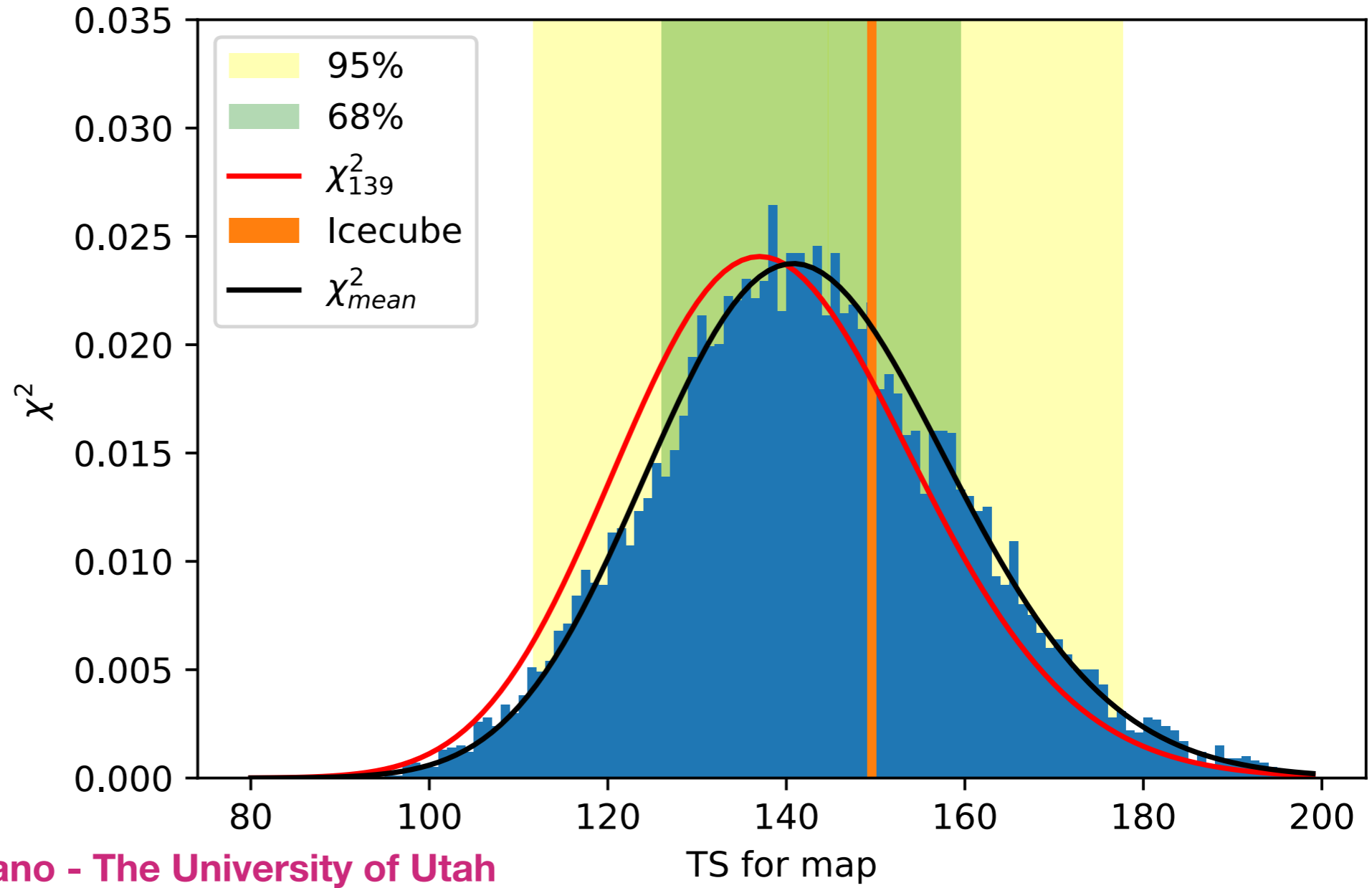
We seek for statistical excess of gamma rays in the locations of high-energy neutrinos.

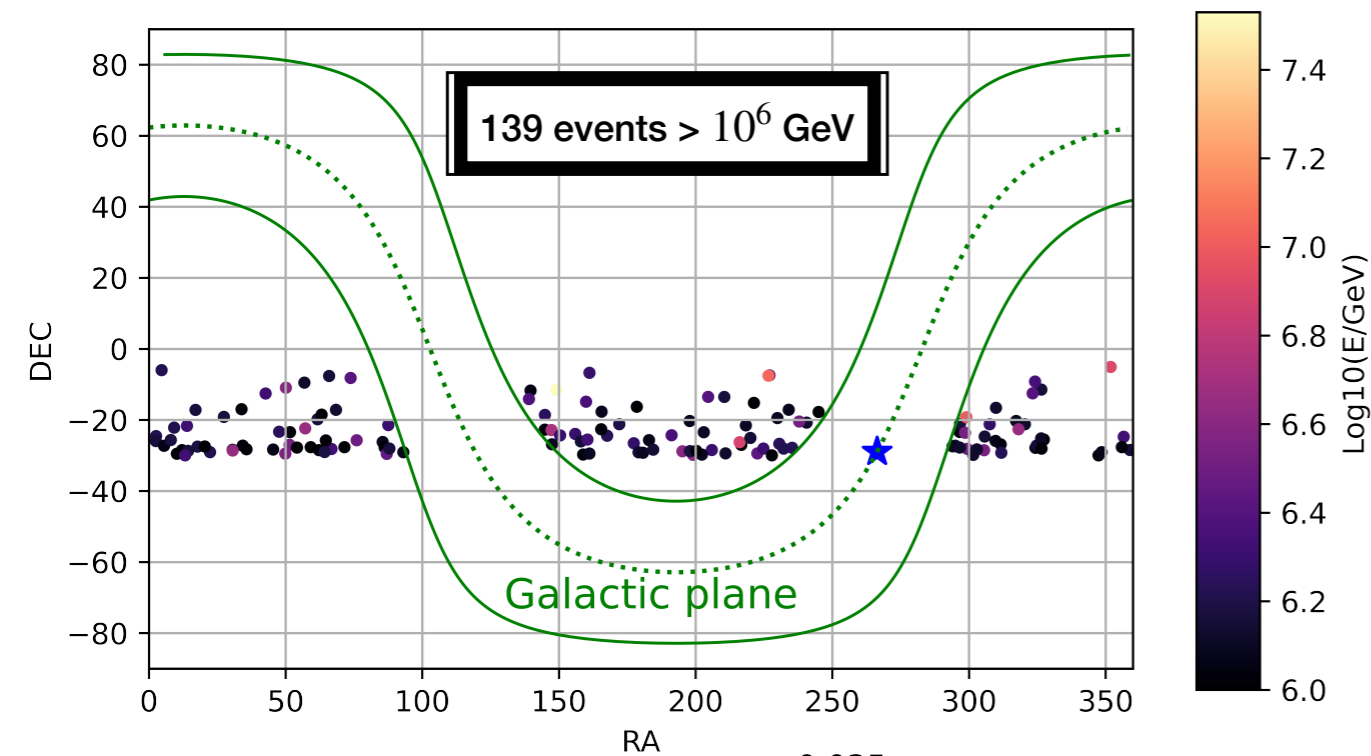




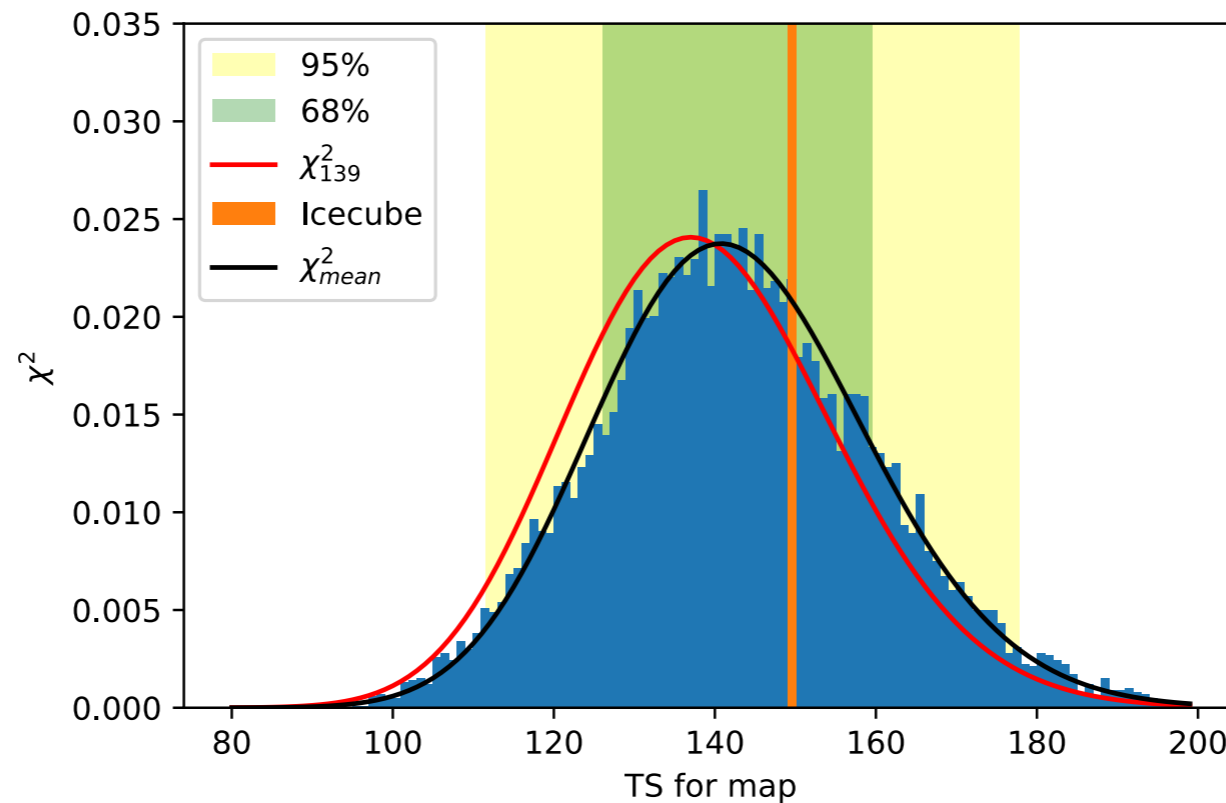
And we compare it to a sample of 10^4 random regions

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And we compare it to a sample of 10^4 random regions



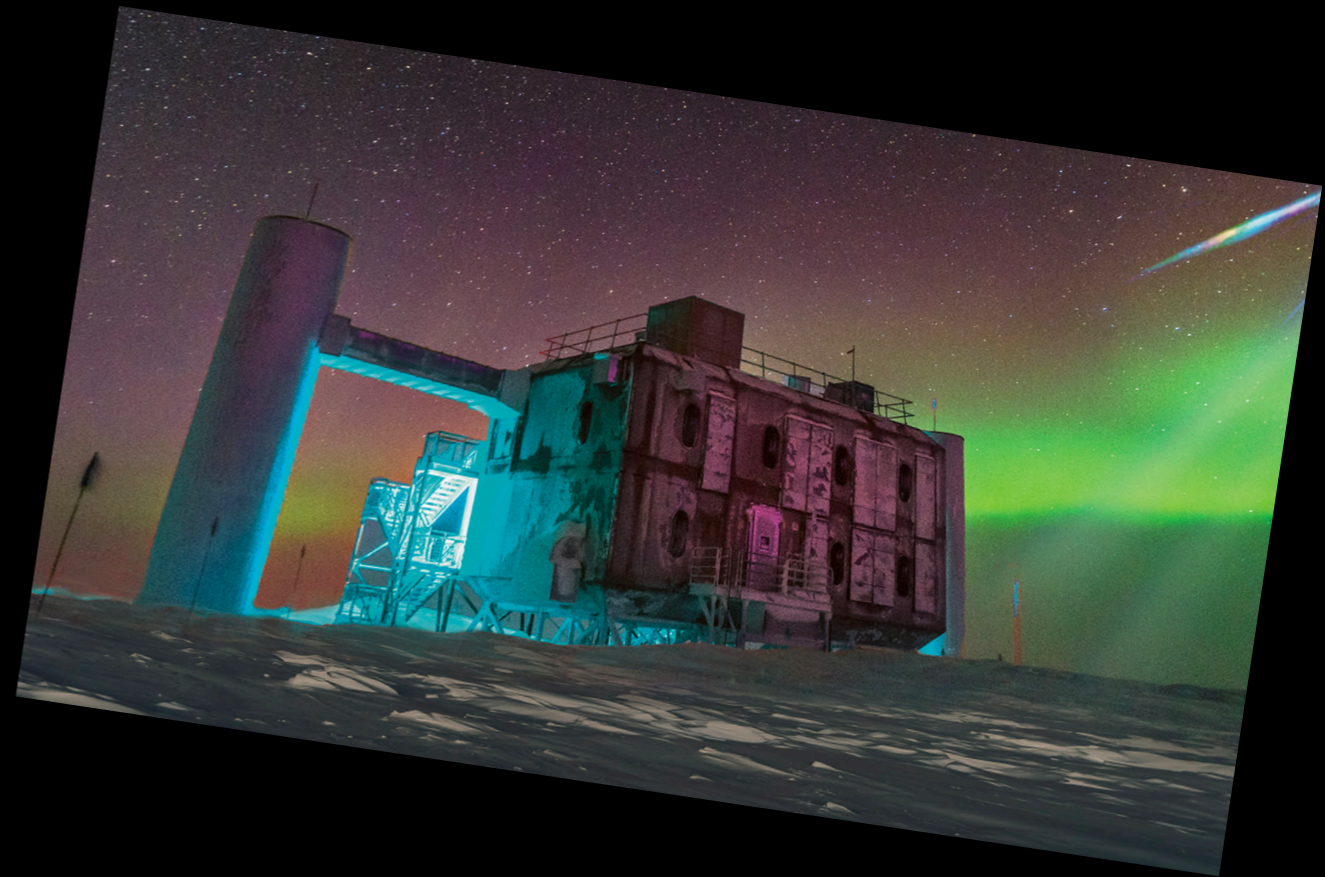
We seek for statistical excess of gamma rays in the locations of high-energy neutrinos.

We found no significant statistical evidence of a correlation between the high-energy events from HAWC with the high-energy neutrinos from IceCube.

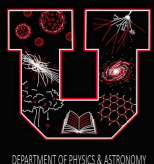
**Jason Kumar,
Carsten Rott,
Pearl Sandick,
NTA.**



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Future prospects



Future prospects



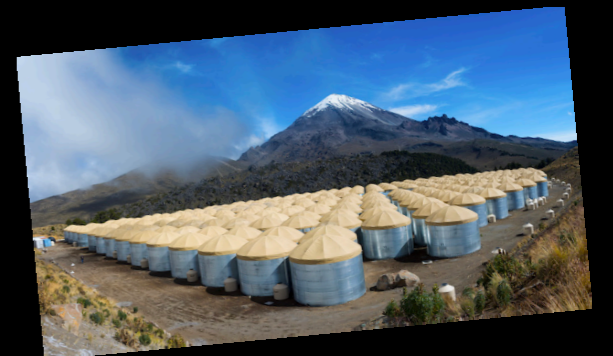
Analysis including the neutrino energy spectra

- We have used the locations of the high-energy neutrino events, future analysis can include spectral information and provide greater sensitivity

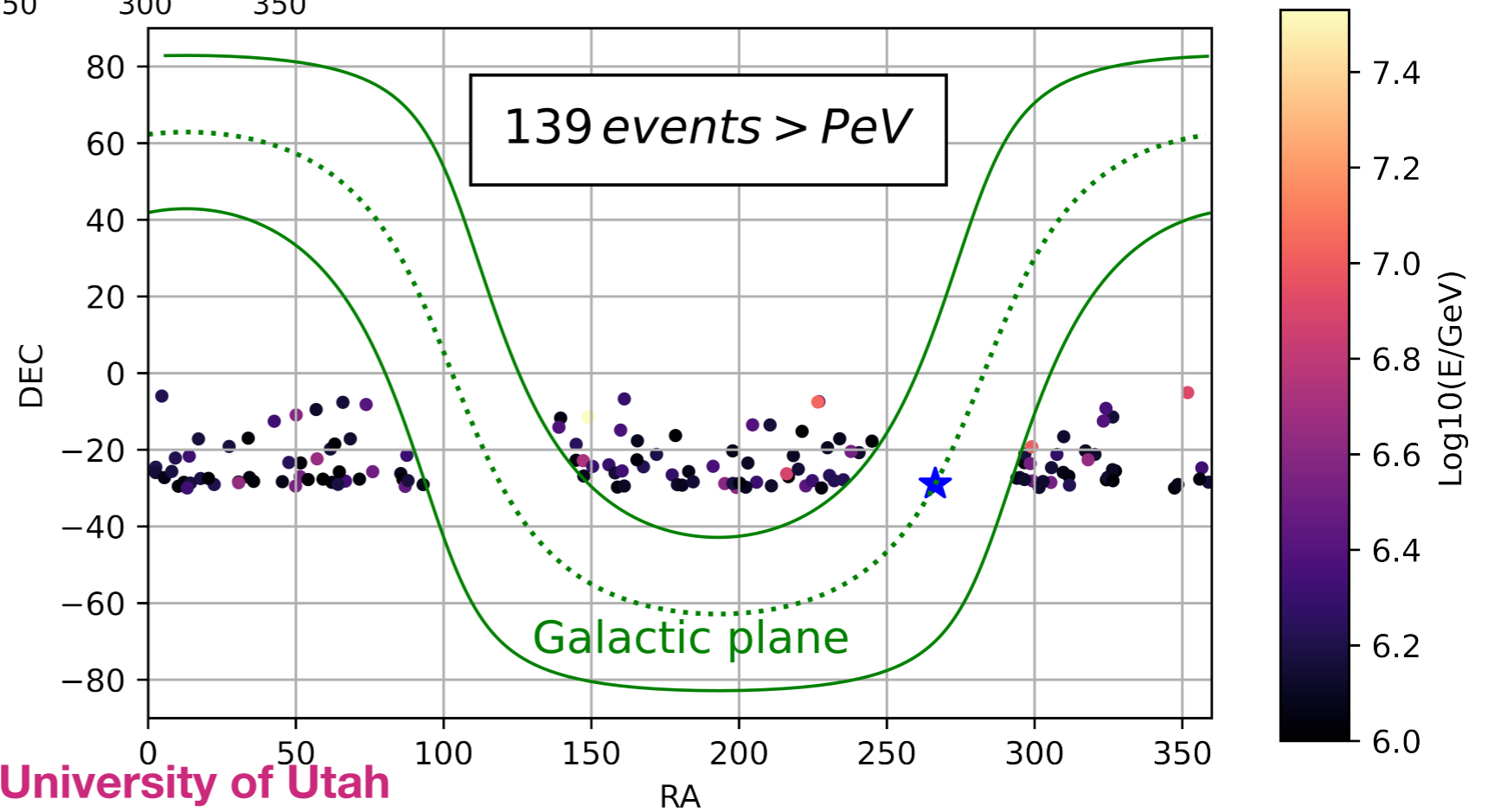
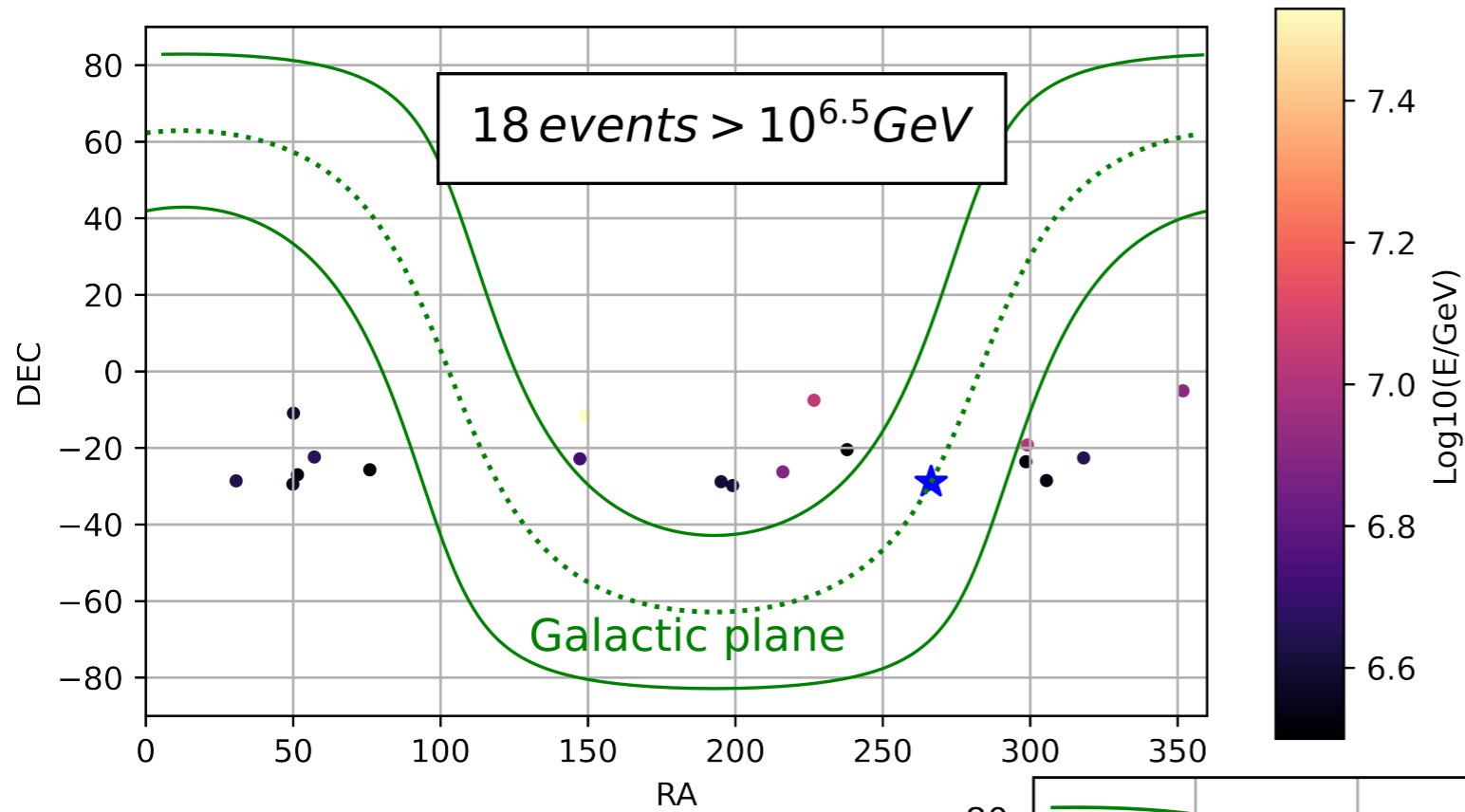
More extensive searches in the south hemisphere:

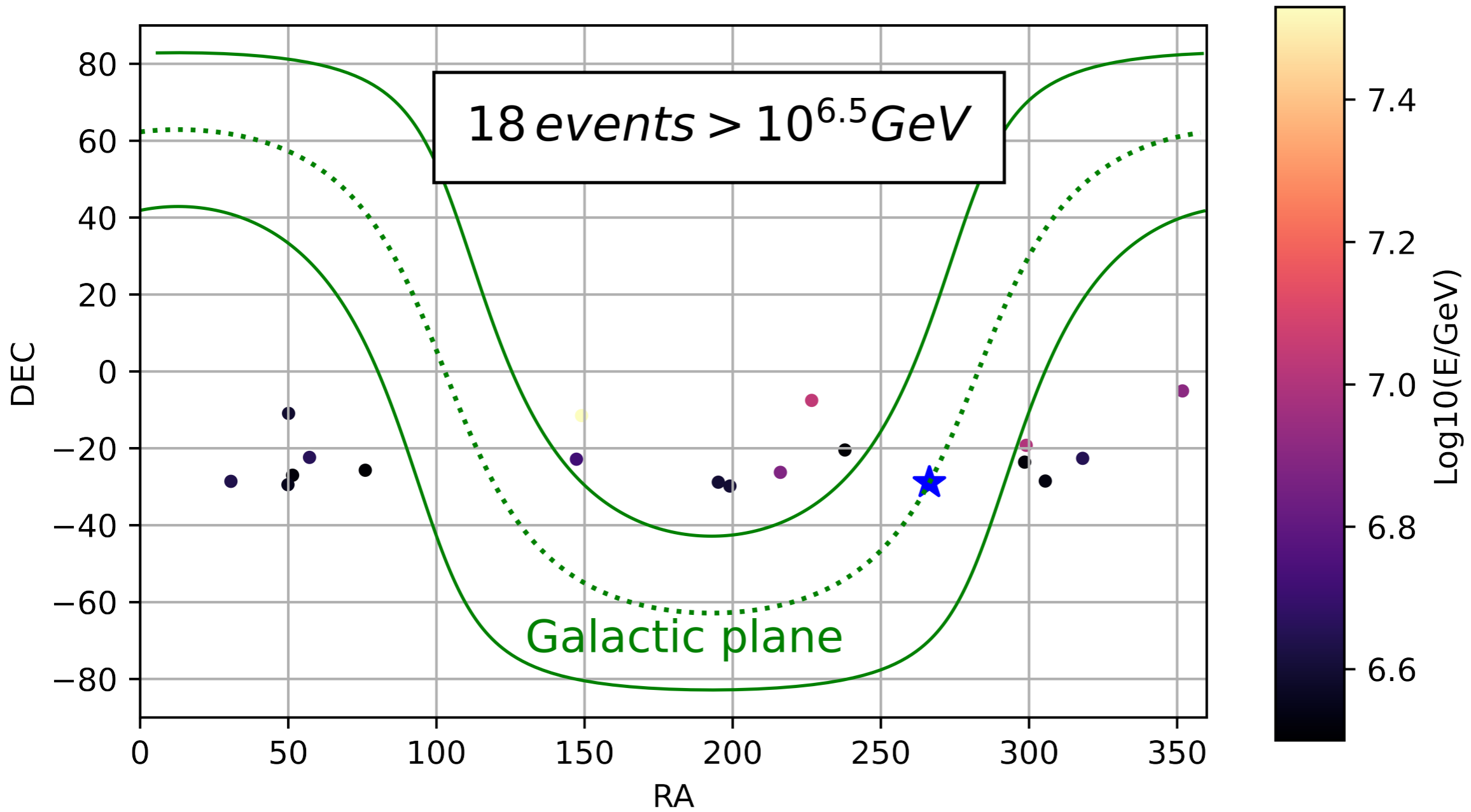
- HAWC only access up to -30 degrees from the equator.

Thank you!

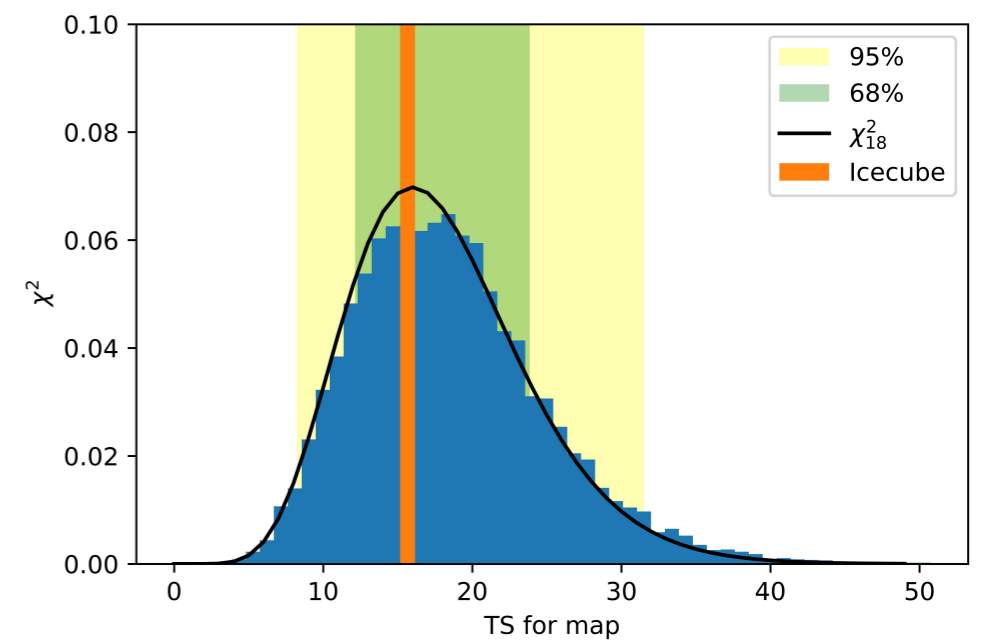


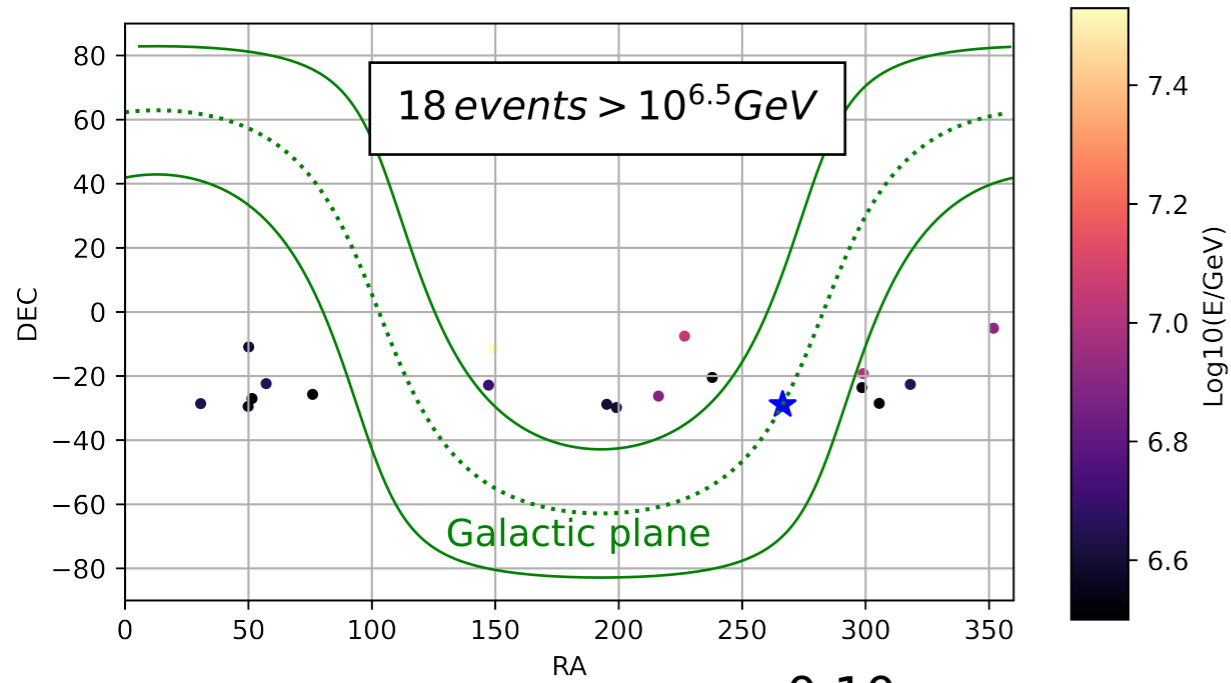
We look at two energy ranges



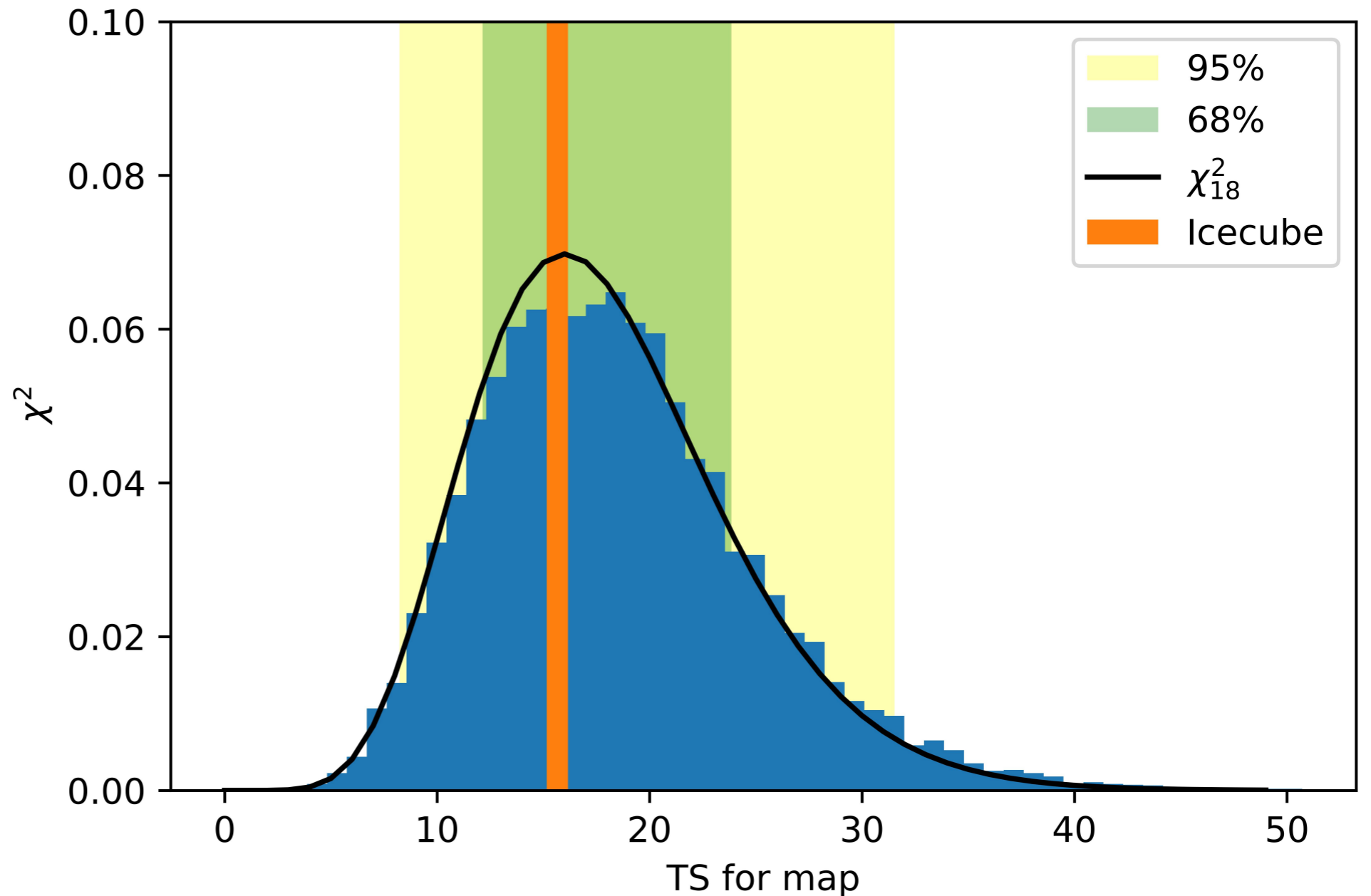


We perform a similar analysis for a higher energy cut



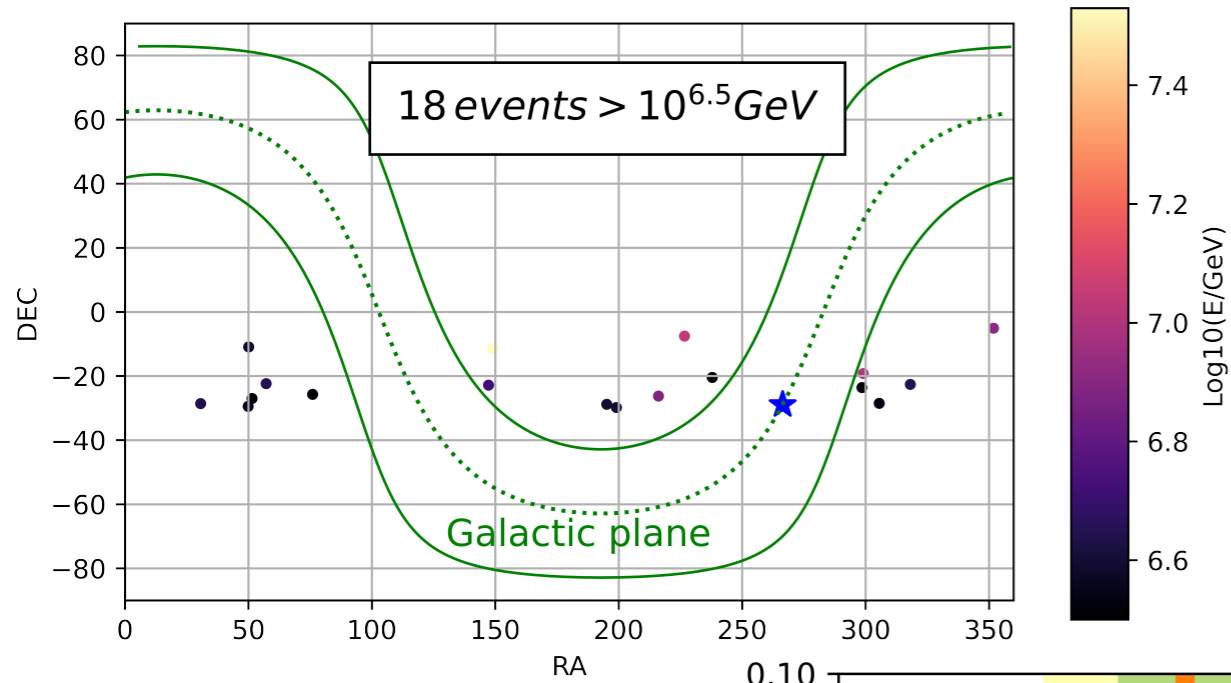


We find a better fit for the expected distribution χ^2 with 18 events

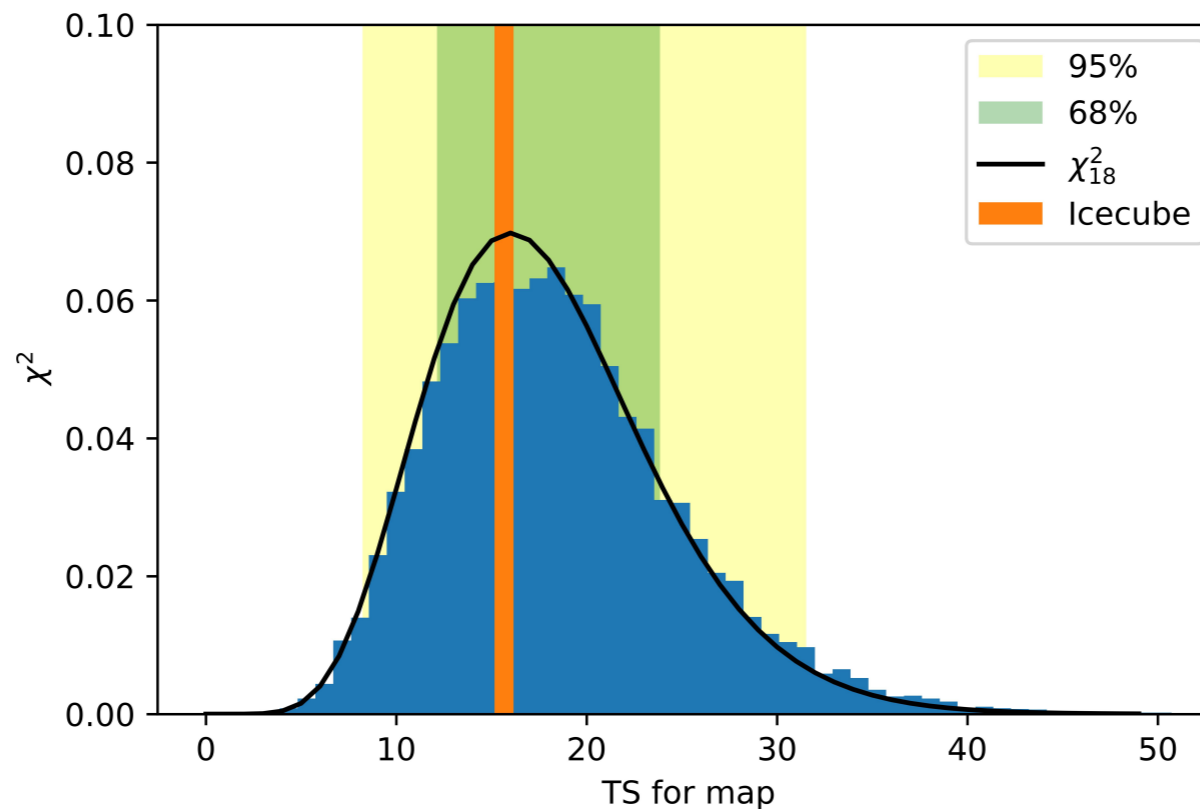


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