Searching for Neutrino Sources In the Galactic Plane with IceCube

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The IceCube Neutrino Observatory

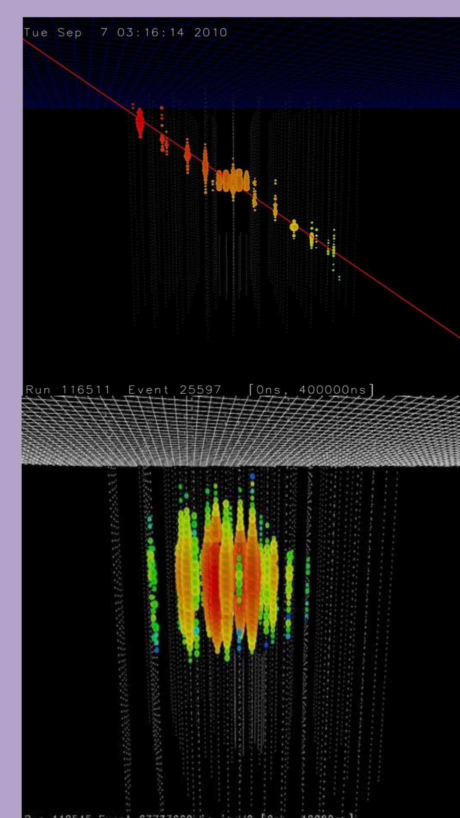
IceCube is a neutrino detector located at the South Pole designed to detect astrophysical neutrinos in the range of GeV to PeV. IceCube detects neutrinos using Cherenkov radiation produced by secondary particles traveling faster than the speed of light through the ice.

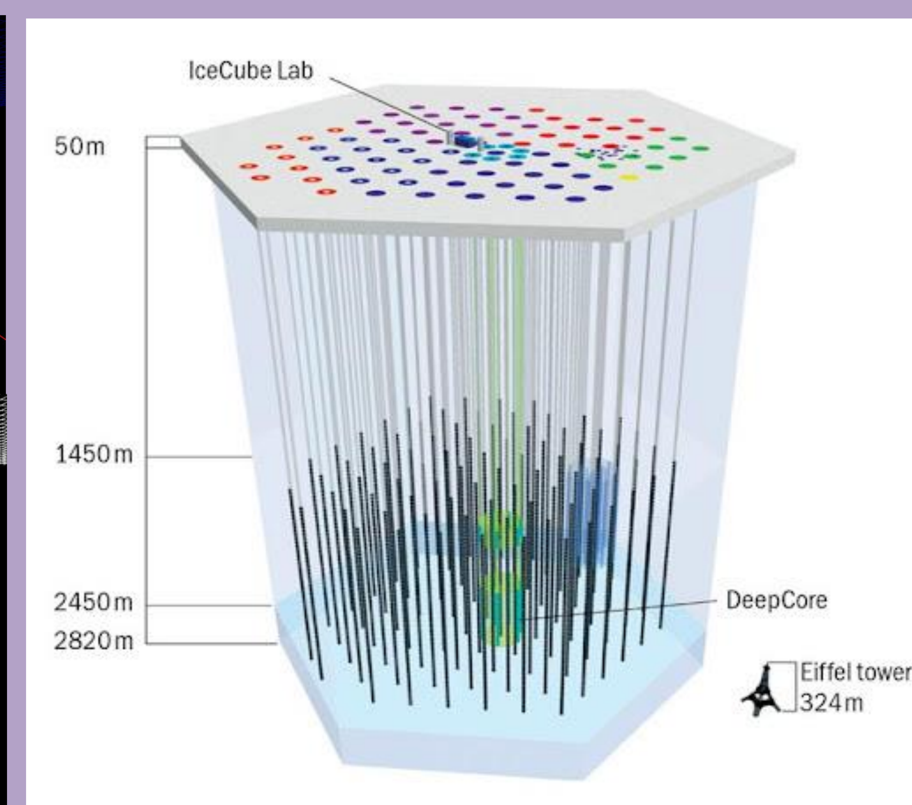
There are two main types of events:

Tracks: elongated light patterns produced by high-energy muons.

Cascades: spherical light patterns produced by particle showers.

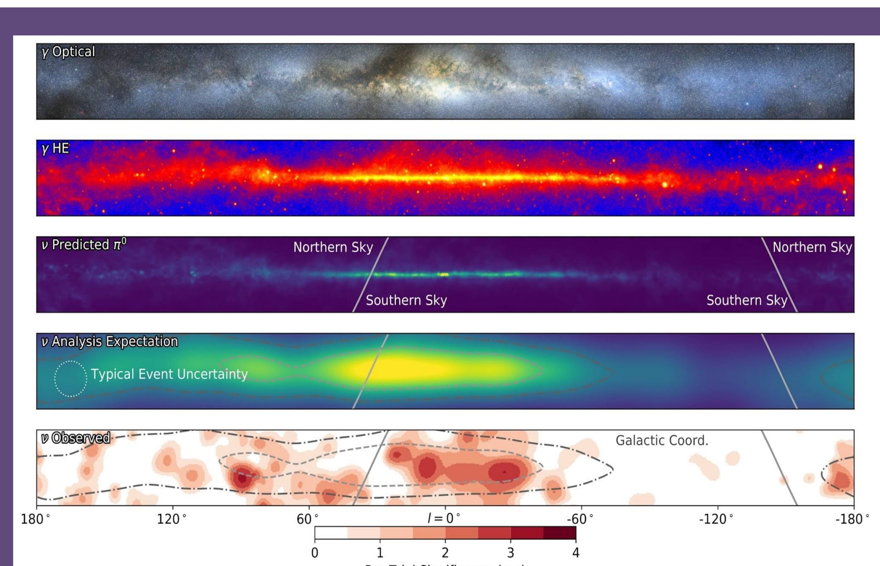
Color indicated arrival time: red first, green last





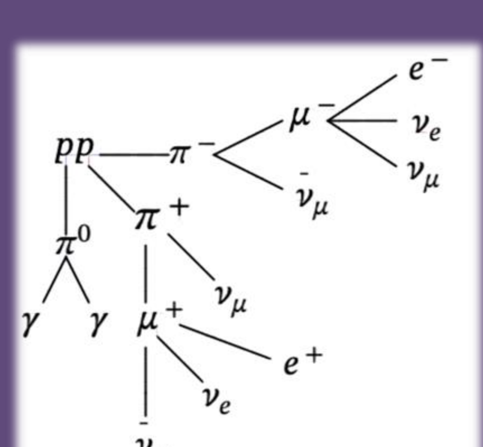
Images: IceCube

Neutrinos in the Galactic Plane

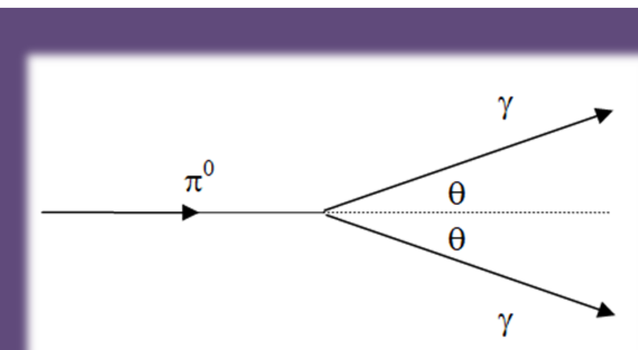


IceCube has observed a diffuse flux of neutrinos from the Galactic Plane[1], but it has not identified any point sources of astrophysical neutrinos in the Milky Way. Identifying neutrinos from a localized source would offer clear evidence into one of the oldest questions of high energy astrophysics: the origin of cosmic rays.

Cosmic rays interact with matter or radiation, via hadronic processes, producing charged and neutral pions which then decay to neutrinos and gamma rays respectively.

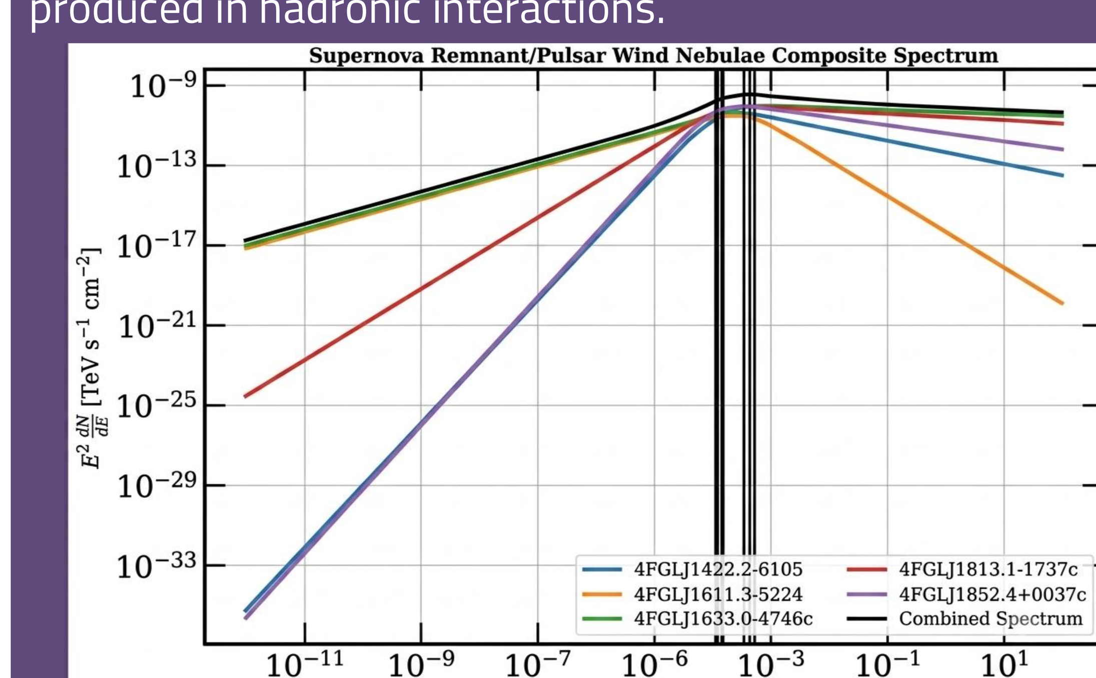


The Pion Bump

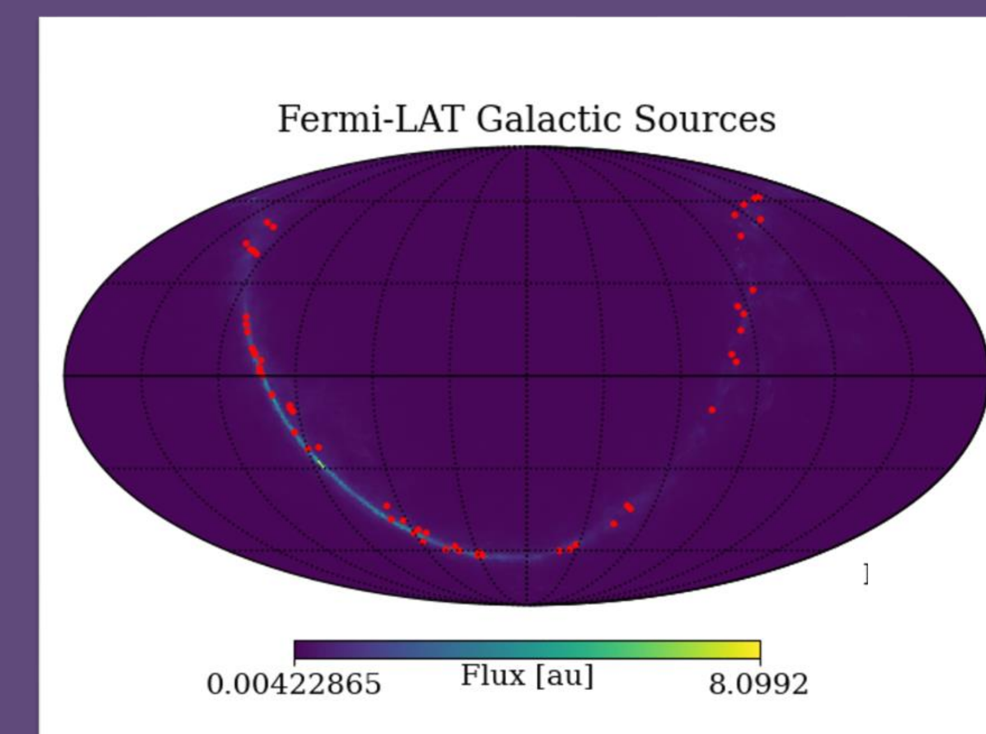


The pion bump is a characteristic spectral feature of gamma-ray sources that peaks between 100 MeV and a few GeV. It is produced when neutral pions decay into two gamma rays, each with an energy of 67.5 MeV in the pion rest frame.

This feature is important because it helps distinguish between hadronic and leptonic gamma-ray production mechanisms. As a result, the pion bump provides evidence for hadronic cosmic-ray acceleration. This is especially relevant for neutrinos searches, since neutrinos are produced in hadronic interactions.



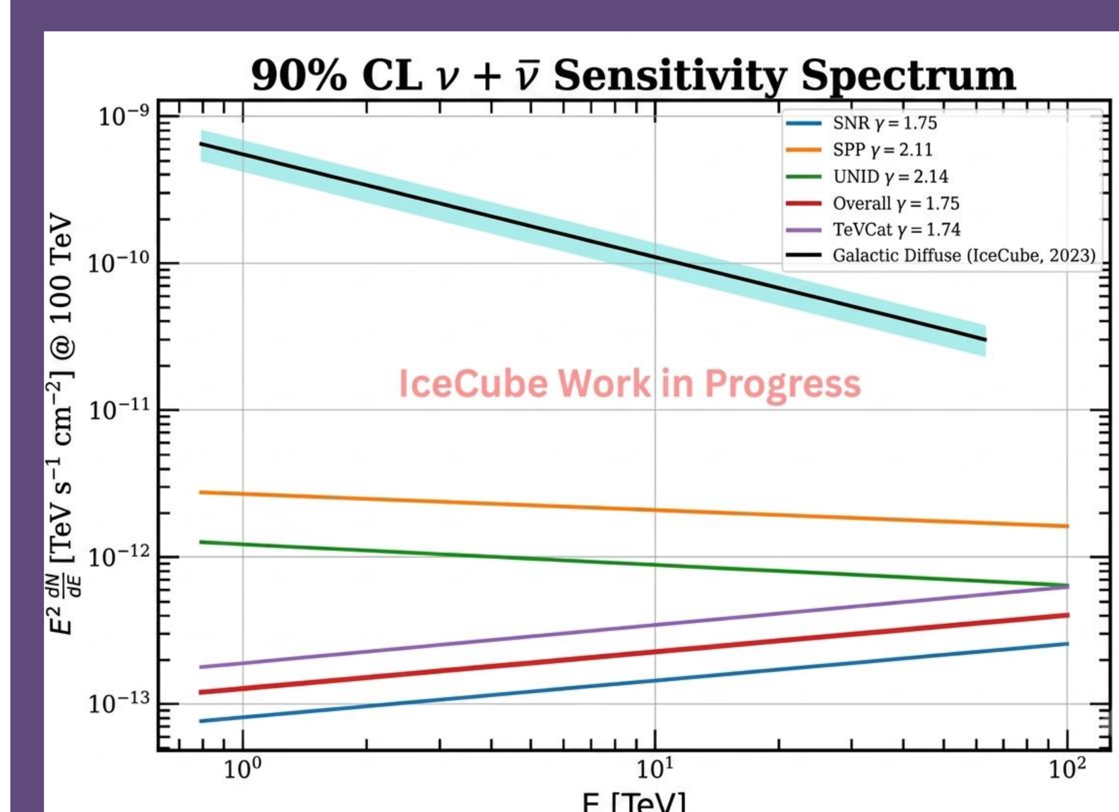
Methodology



We are working with 56 sources reported by Fermi-LAT with the characteristic "pion bump" spectral break between 50 MeV and 1 GeV [2].

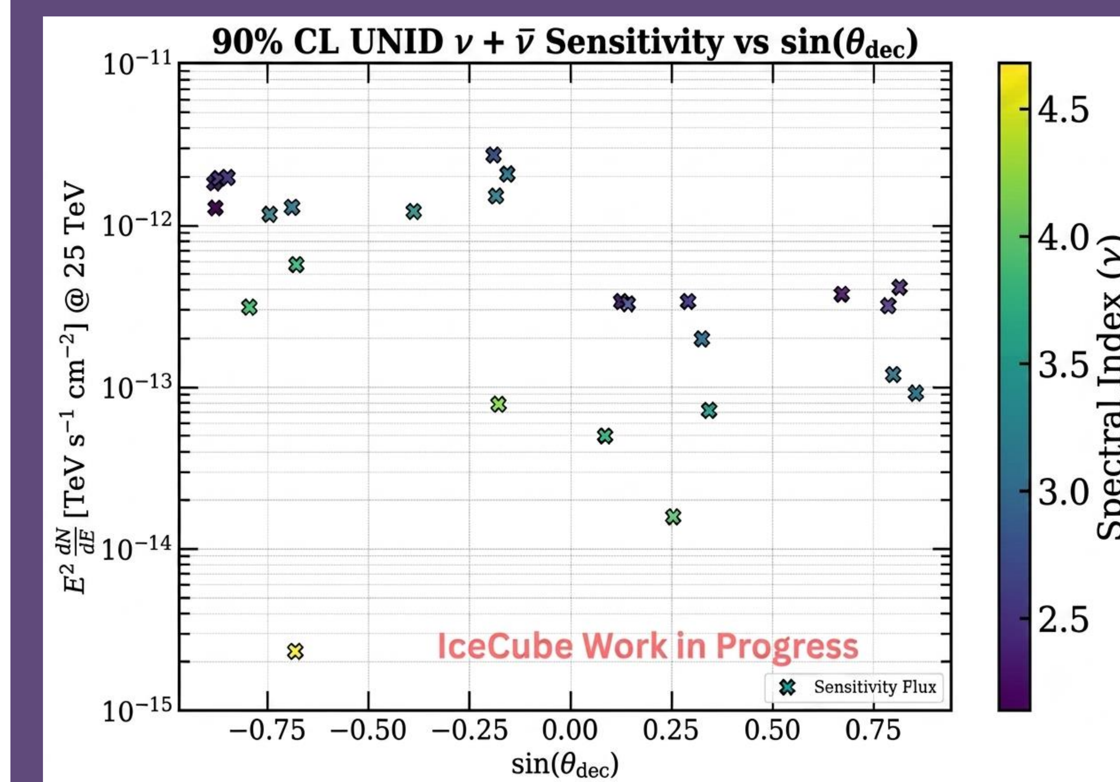
We conduct a dedicated search for astrophysical neutrinos from these sources using 13 years of IceCube tracks and cascades.

At the core of our analysis is the likelihood function, which has been widely used in IceCube point-source searches. From this framework, we perform two main types of analysis: a stacking search, and a catalog search.



The stacking analysis improves sensitivity by combining multiple sources in a single likelihood. In this work, we analyze source classes collectively.

Our stacking search shows significantly better sensitivities by two order of magnitude below the Galactic diffuse emission [1]. This will help us constraint their contribution of various sources classes to the Galactic Plane.



The catalog analysis analyzes all 56 sources individually. The sensitivity improves toward the northern sky roughly by one to two orders of magnitude compared to the southern sky.

Discussion

- **Galactic Source Search:** We conduct a dedicated neutrino search targeting sources with spectral features consistent with hadronic gamma-ray emission.
- **Diffuse Flux Constraint:** By evaluating 56 Fermi-LAT sources, we constraint their total contribution to the Galactic diffuse flux.
- **Unidentified Sources**: These results can contribute to the characterization of currently unidentified sources, regardless of whether a hadronic model is ultimately confirmed.

References and Acknowledgements

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[1 IceCube Collaboration, Science 380, 1338-1343, 2023

[2] S. Abdollahi et al, ApJ 933-204, 2022

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