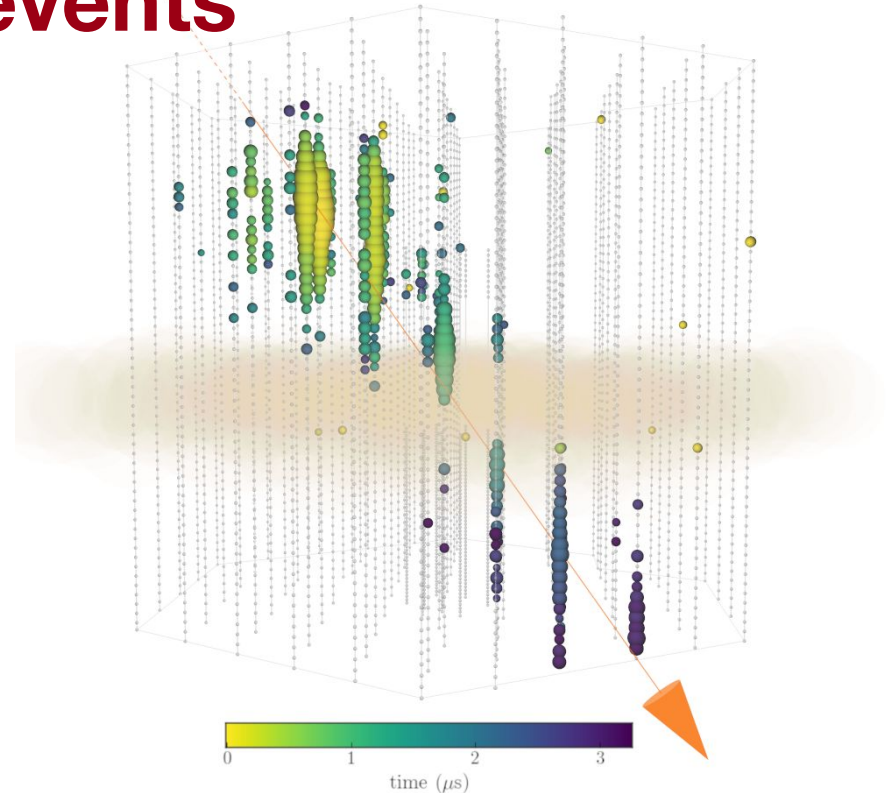


# Searches for astrophysical neutrino sources in the southern sky and galactic plane using IceCube starting track events

Sarah Mancina for the IceCube collaboration

TeVPA 2023  
Napoli, Italy  
September 14th, 2023



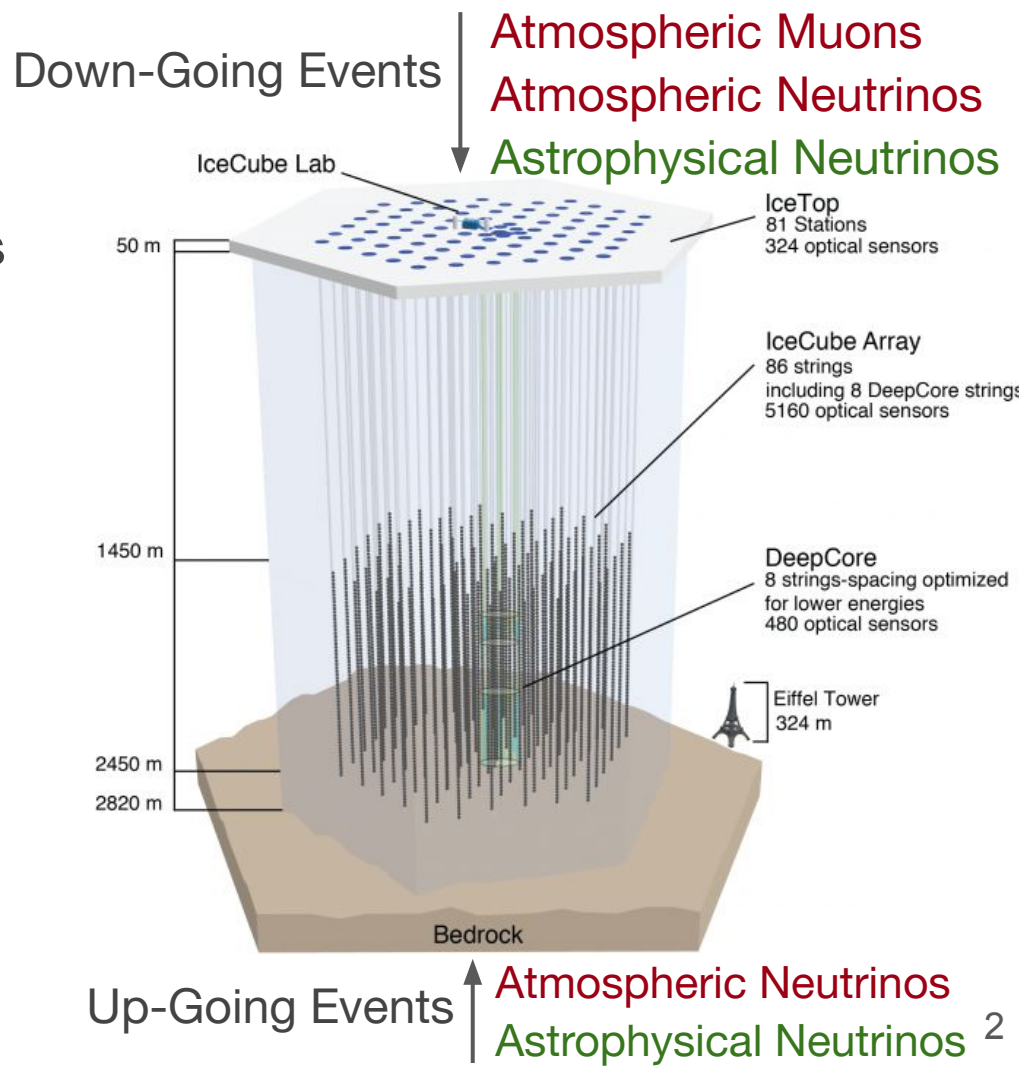
# IceCube detector

Observe charged particles, neutrinos must interact to be observed

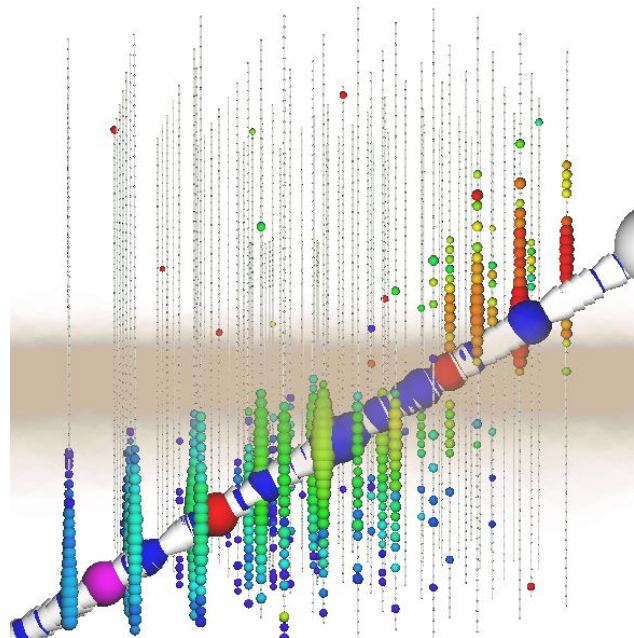
Look for signal of **astrophysical neutrinos**

Obscured by **atmospheric muon and neutrino** backgrounds

Can use direction, energy, and event morphology to distinguish signal

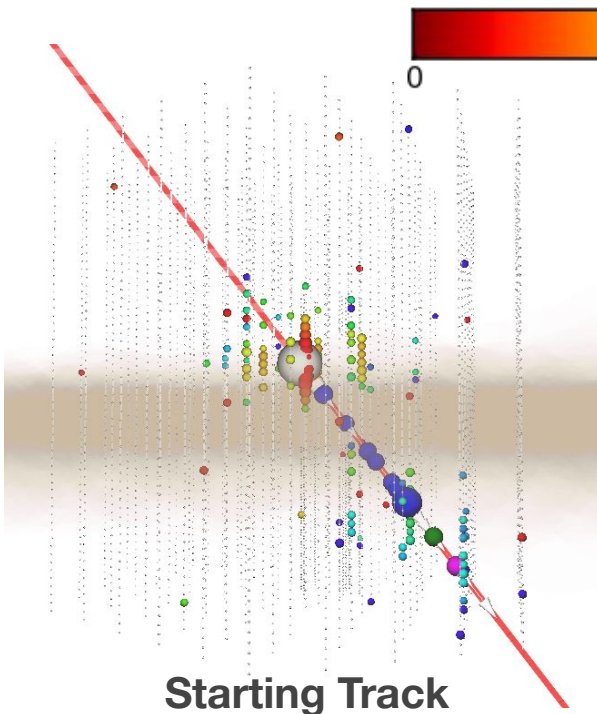


# Neutrino event morphologies in IceCube



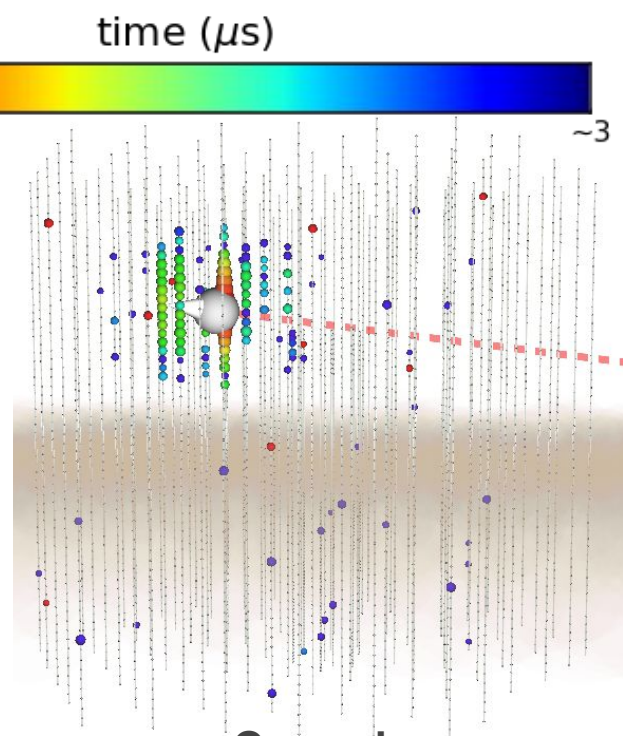
**Through-going Track**

Angular Resolution:  $0.6^\circ$   
 Energy Resolution:  $2 \times E_\nu$   
 Atmospheric  $\mu$ , CC  $\nu_\mu$ , CC  $\nu_\tau$   
 $(\tau \rightarrow \mu + \nu\text{'s})$



**Starting Track**

Angular Resolution:  $1.0^\circ$   
 Energy Resolution:  $.25 \times E_\nu$   
 CC  $\nu_\mu$ , CC  $\nu_\tau$  ( $\tau \rightarrow \mu + \nu\text{'s}$ )



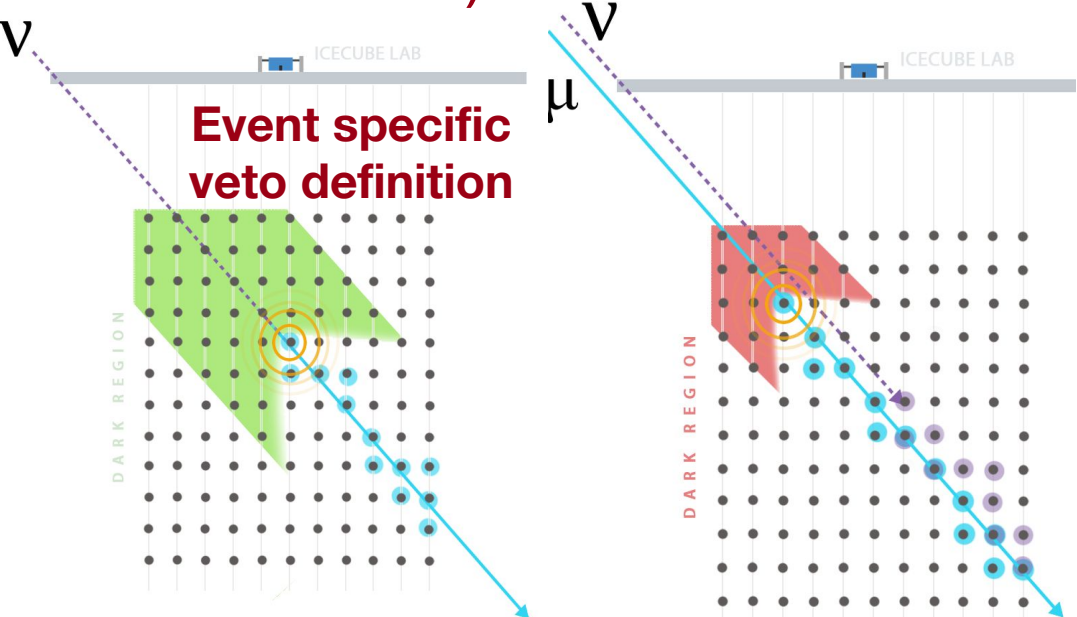
**Cascade**

Angular Resolution:  $5^\circ\text{-}15^\circ$   
 Energy Resolution:  $.15 \times E_\nu$   
 NC  $\nu$ , CC  $\nu_e$ , CC  $\nu_\tau$  ( $\tau \rightarrow e/h + \nu\text{'s}$ )

(+ more) <sup>3</sup>



# ESTES (Enhanced Starting Track Event Selection)



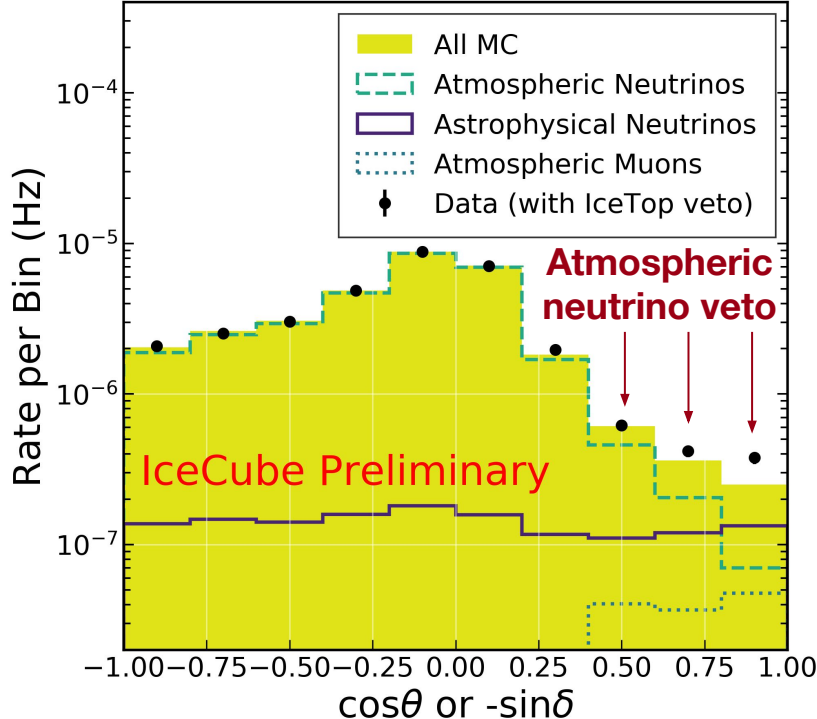
Calculate probability that DOMs in the “dark region” would not have seen light from incoming muon

Look for signs of hadronic cascade



Flux assumed from [PoS\(ICRC2023\)1008](https://arxiv.org/abs/2301.1008)

## Neutrino Source Event Selection

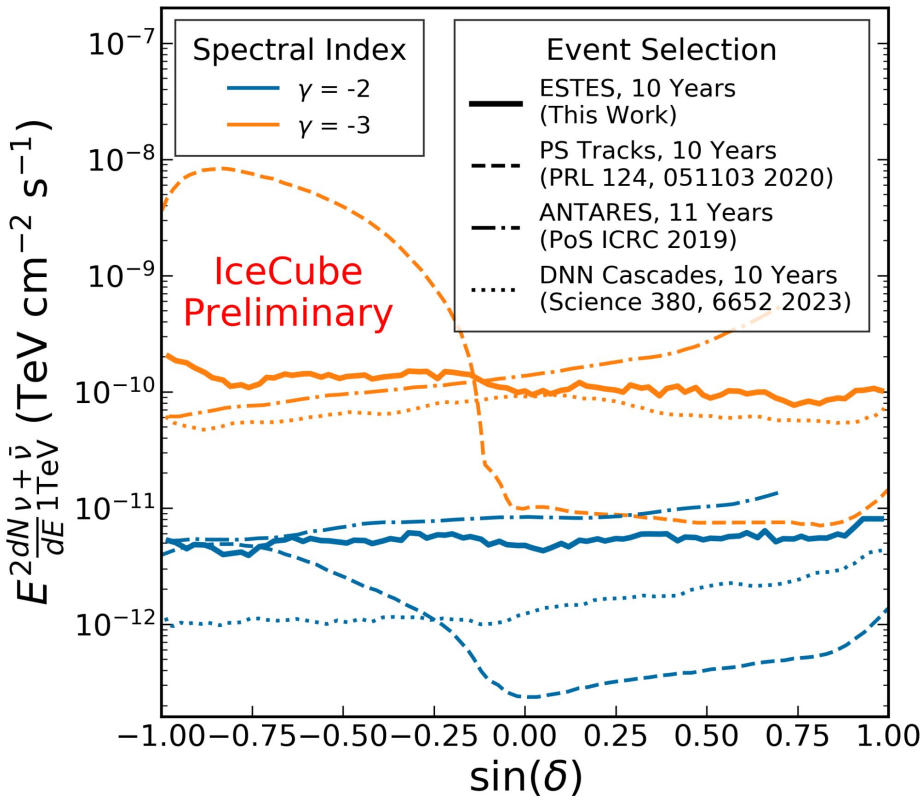
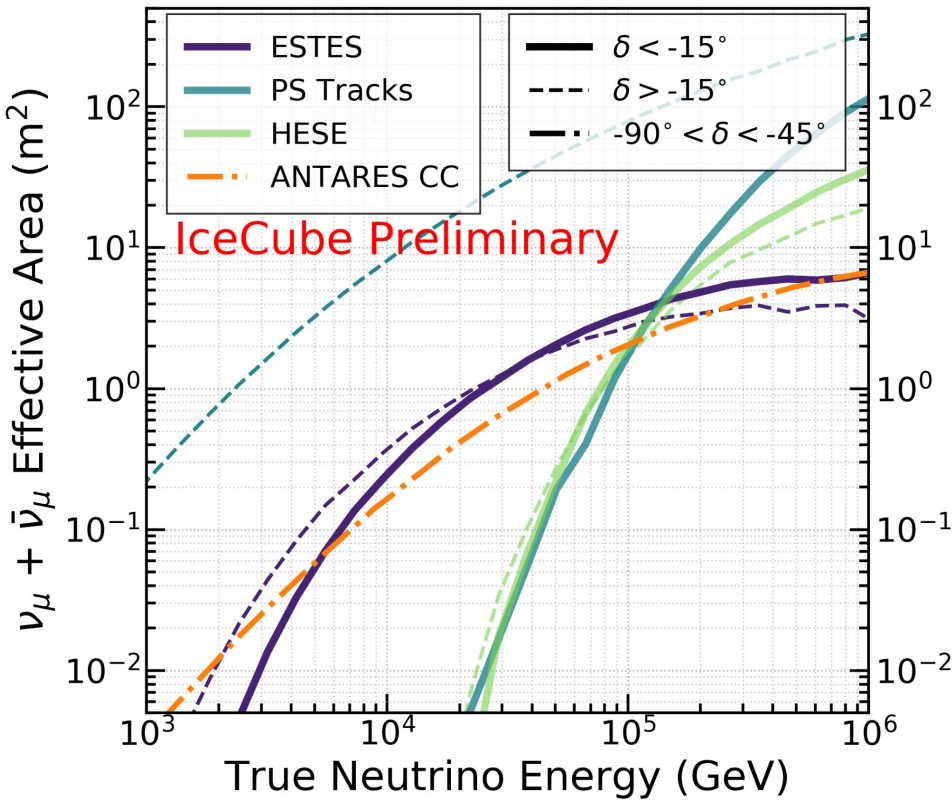


**Reject atmospheric neutrinos** with light from muons

Suppresses atmospheric background in southern sky

~10,000 events in 10.3 years

# Comparison of ESTES to other astrophysical neutrino samples



Improve sensitivity in the southern sky with track events

Minimal overlap of events in the southern sky with other event selections (<2%)



# Search for point sources with ESTES

Used standard IceCube maximum likelihood approach to search for sources

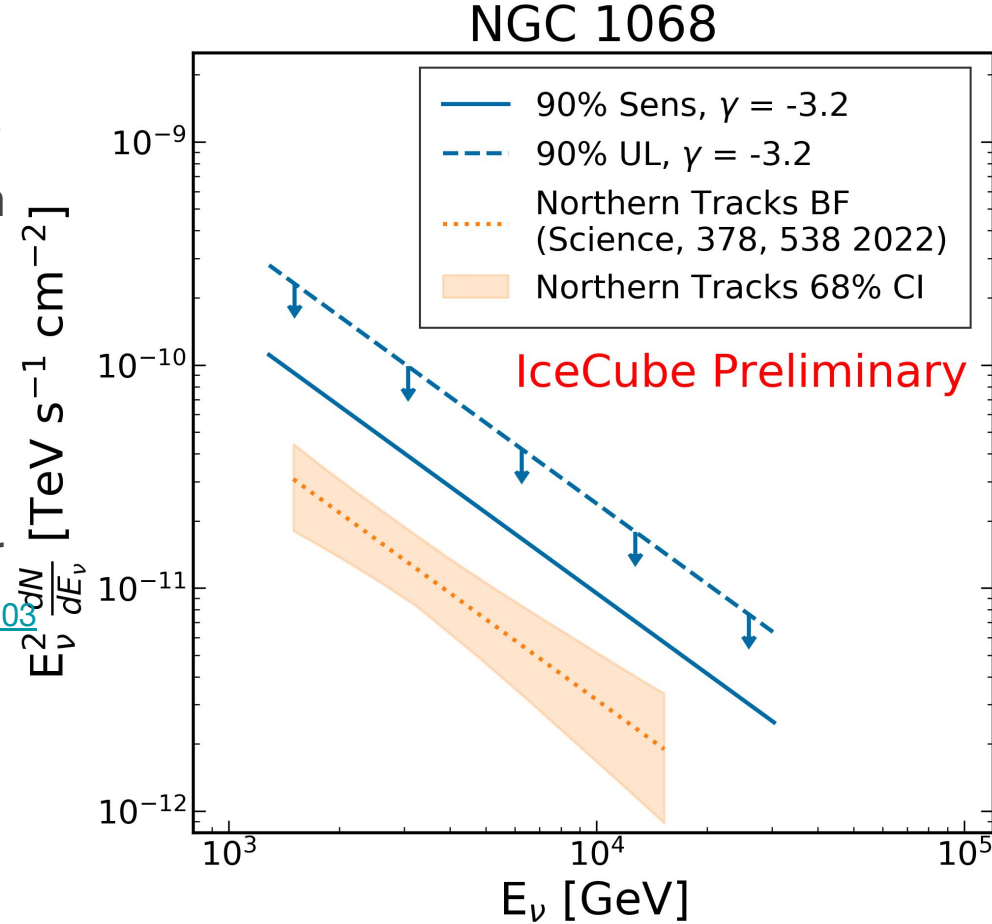
No statistically significant source found in all sky search after post-trials correction

Most significant source in list **1ES 0647+250**  $1.71\sigma$  post-trial significance

Cannot reject null hypothesis

Source located in northern sky and upper limits set by previous analyses ([PRL 124, 051103 2020](#))

Results for NGC 1068 consistent with Northern Tracks measurement ([Science, 378, 538 2022](#))

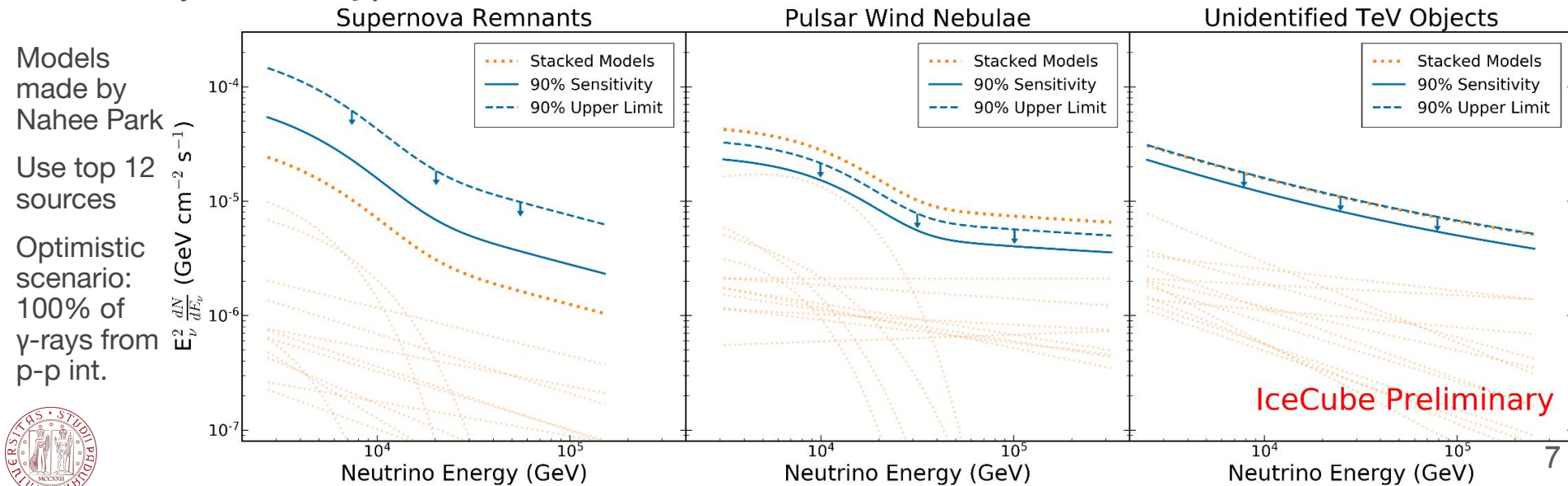


# Galactic plane source stacking analysis

Tested for correlations between locations of know TeV gamma-ray emitting galactic plane objects and our neutrinos

Tested four catalogs: Supernova Remnants, Pulsar Wind Nebulae, Unidentified TeV Objects, and TeV Binaries

**Supernova Remnants** had most significant result with **1.58 $\sigma$  post-trial** significance, cannot reject null hypothesis



# Diffuse neutrino emission from the galactic plane

Test for excess of neutrinos from cosmic ray interactions with the galactic plane material

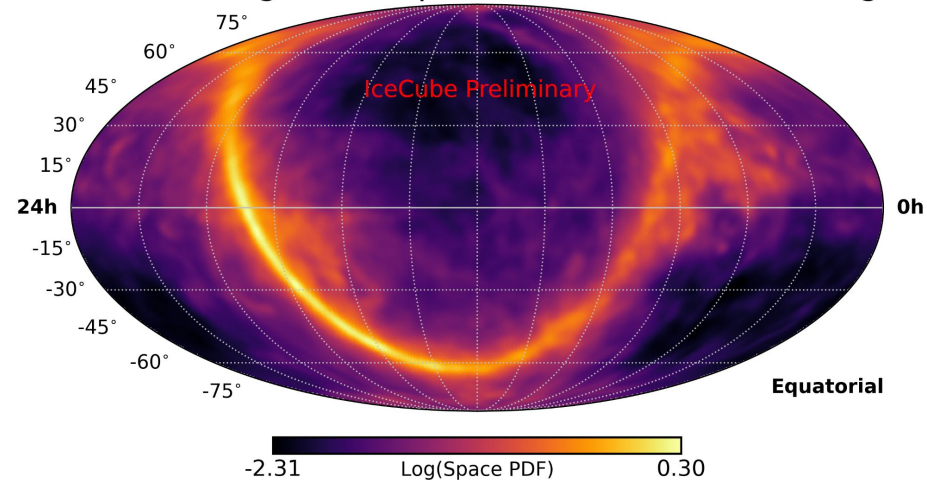
Two models: Fermi  $\pi^0$  ([ApJ 750 2012 3](#)) and KRA $\gamma$  ([10.5281/zenodo.7070823](#))

Test Fermi  $\pi^0$  assuming energy spectrum is single power law with spectral index -2.7

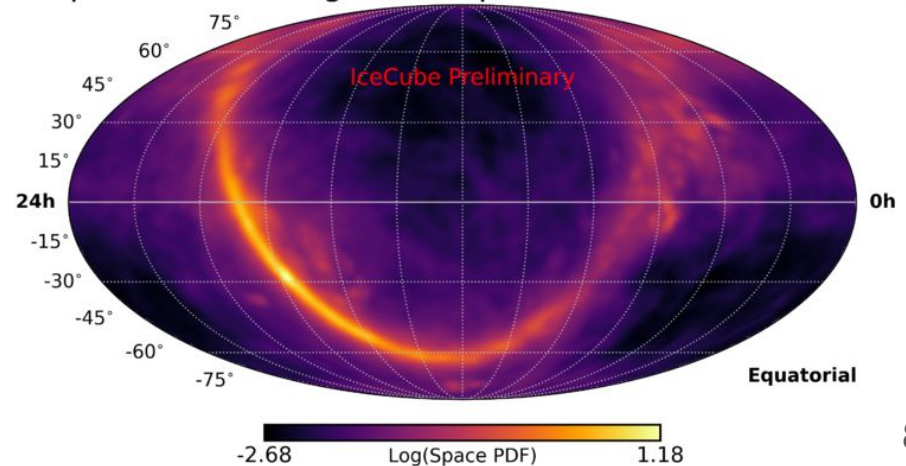
Test KRA $\gamma$  using model energy spectrum and 5 PeV and 50 PeV exponential cutoff

**Fermi  $\pi^0$  returns  $1.58\sigma$  post-trial significance, cannot reject null hypothesis**

Fermi  $\pi^0$  signal acceptance with  $1.4^\circ$  smoothing

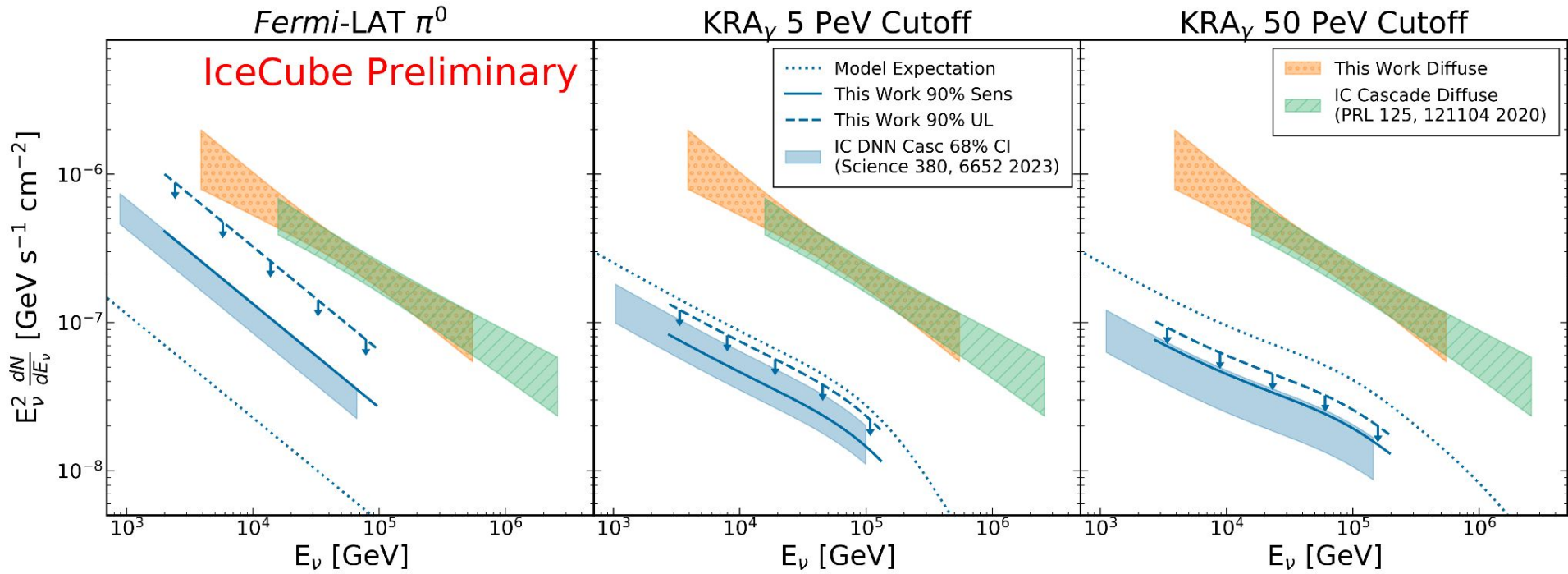


KRA $\gamma$  5PeV Cutoff signal acceptance with  $1.4^\circ$  smoothing





# Upper limits on diffuse galactic plane emission



Limits and sensitivity for ESTES relative to the Cascade result ([Science 380, 6652 2023](#)) and diffuse measurements

Upper limits and results **consistent** with Cascades results

ESTES diffuse flux from [PoS\(ICRC2023\)1008](#)



# Conclusions and next steps

Introduce first neutrino source search results from ESTES, a starting track sample

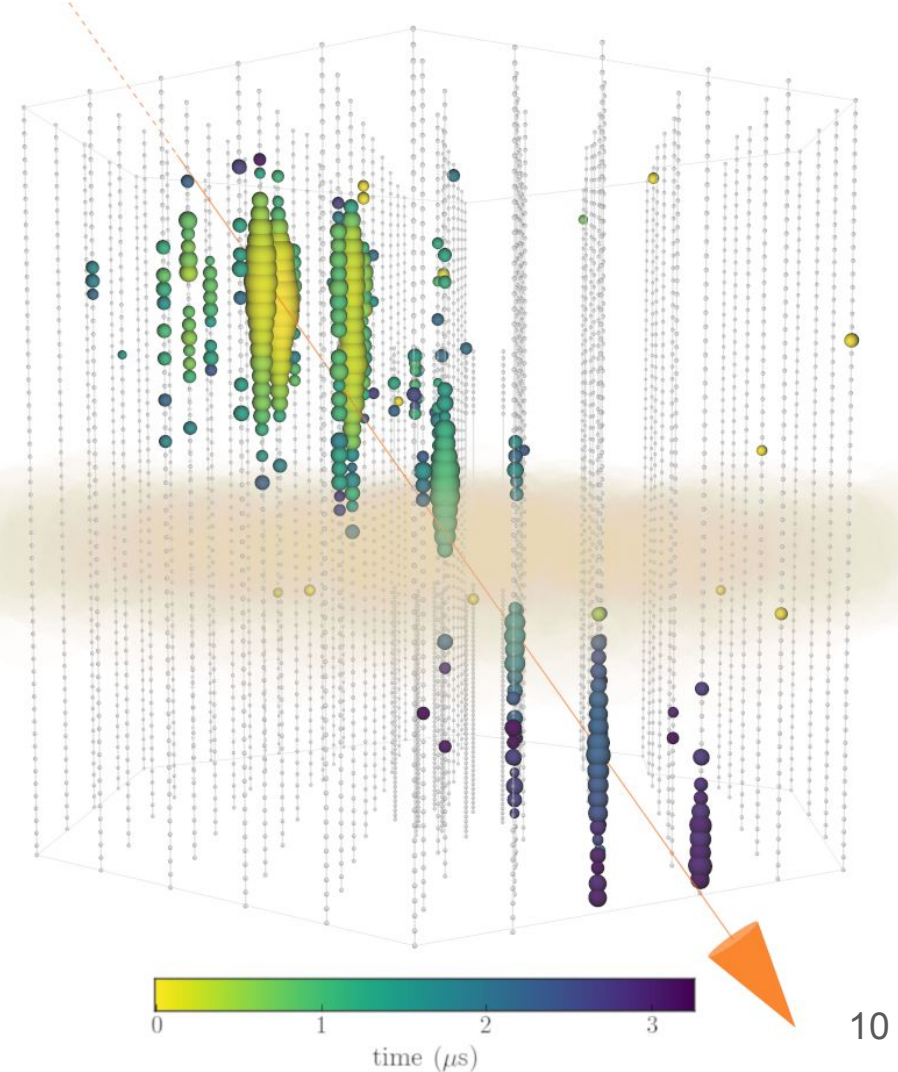
Can reject atmospheric neutrino background in southern sky

Increase sensitivity of IceCube to southern sky sources

Cannot reject null hypotheses but **consistent with other IceCube measurements**

Can combine with other neutrino samples in future for source searches with all neutrino streams ([PoS\(ICRC2023\)1010](#))

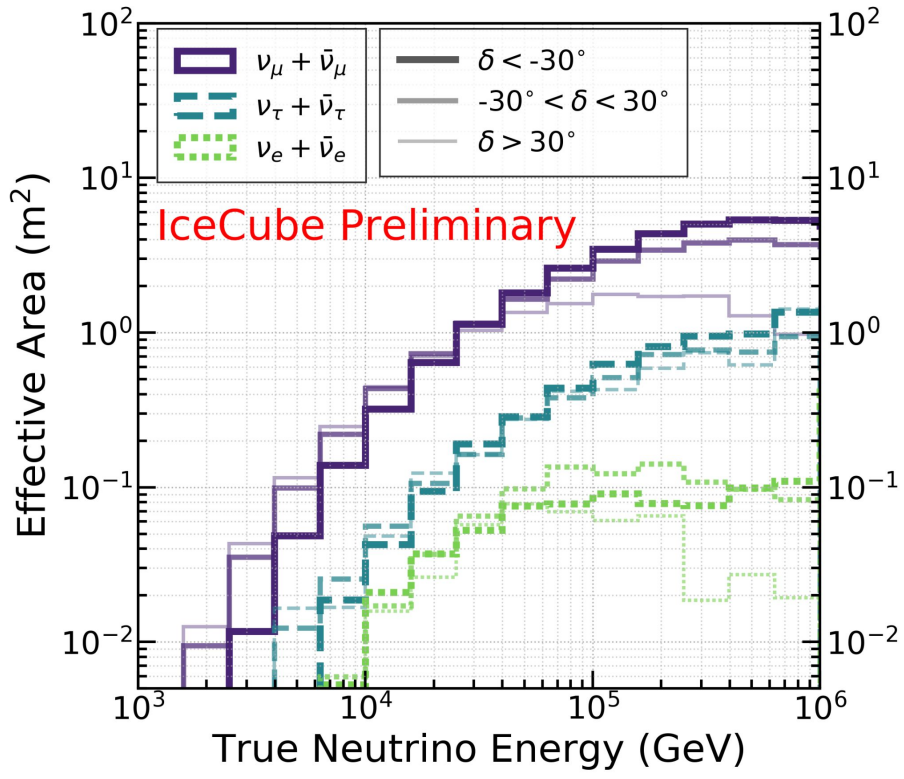
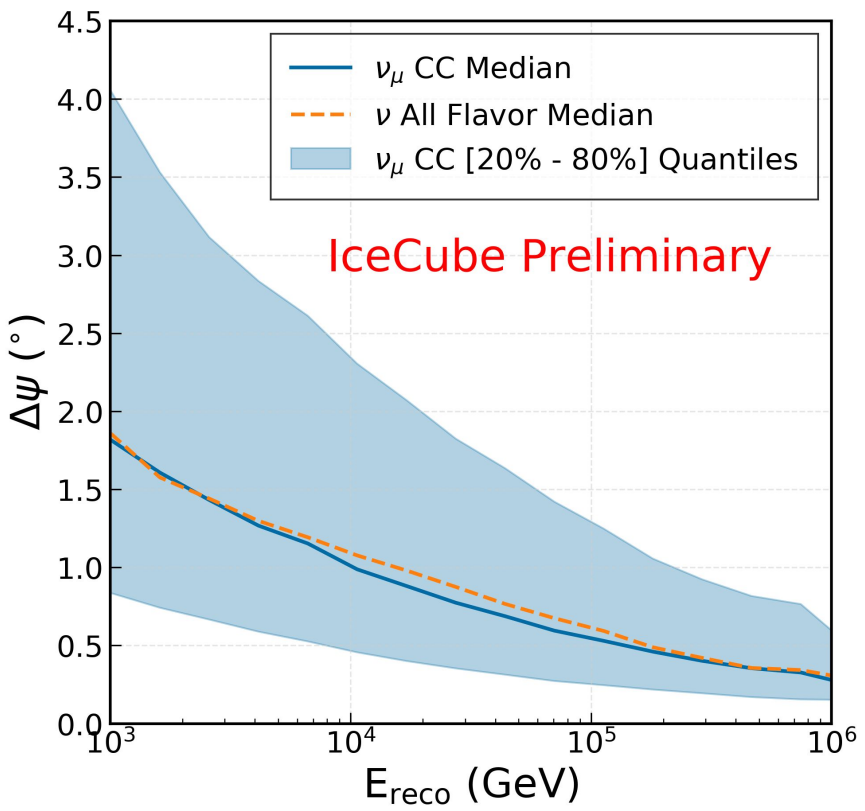
Producing a high purity realtime alert stream with energies below 100 TeV with ESTES ([PoS\(ICRC2023\)1464](#))



# Backup Slides



# More ESTES event selection properties



# All-flavor effective area comparison

