

IceCube Searches for Neutrino Counterparts to Gravitational Wave Events

Sam Hori for the IceCube Collaboration

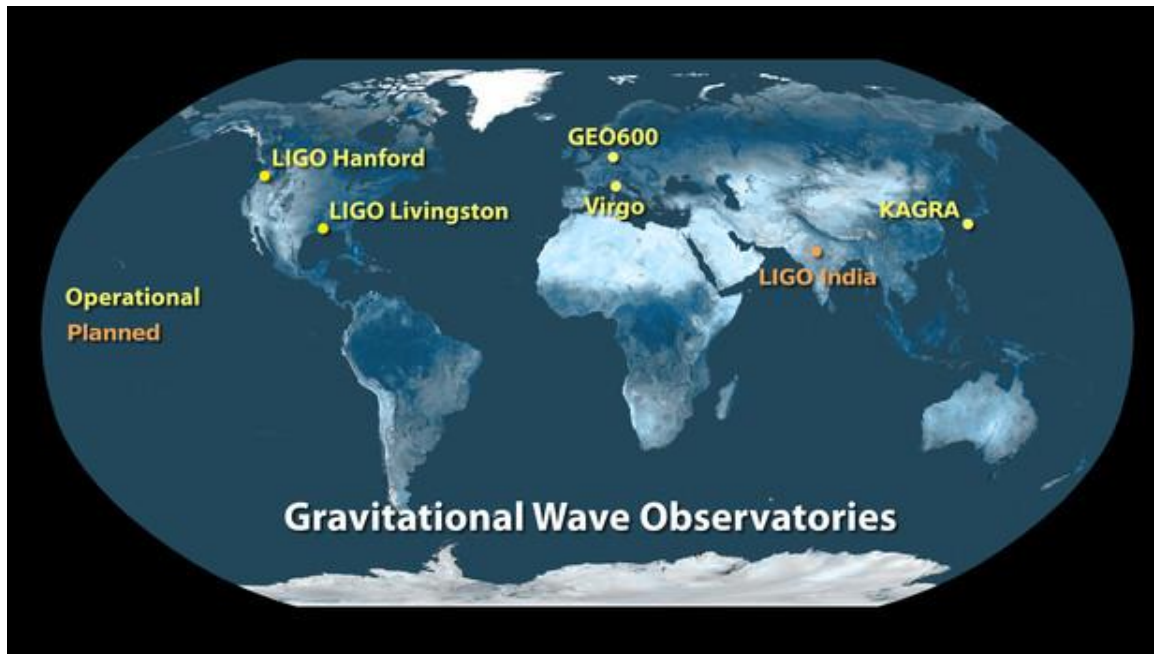
IceCube Astroparticle Symposium

10/14/2026

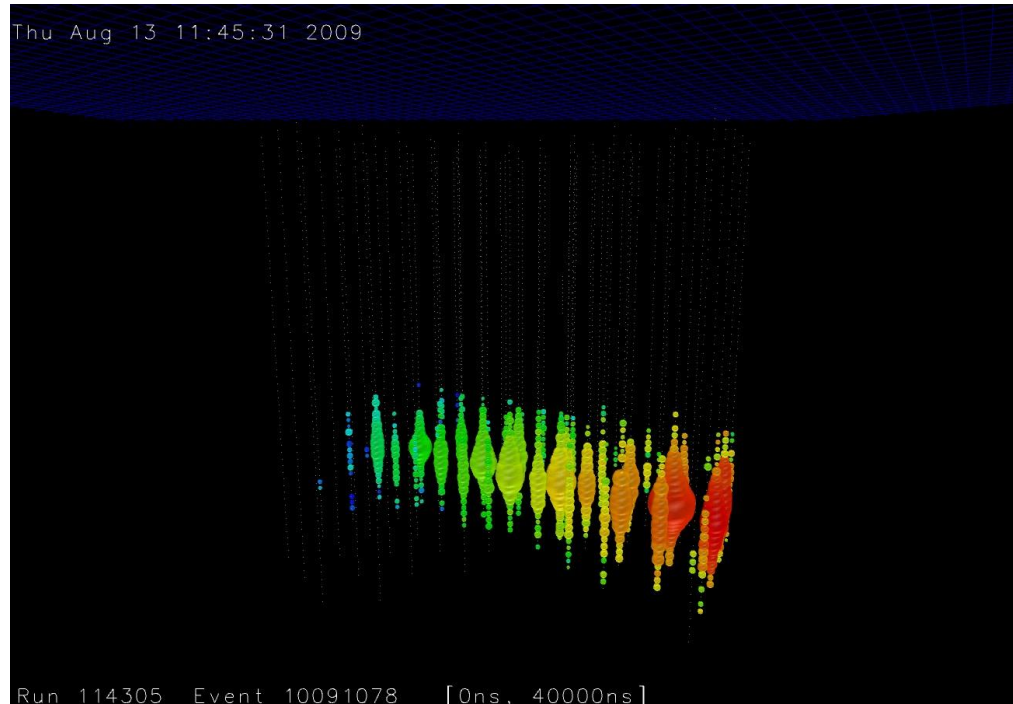


Gravitational Waves

- Binary mergers between compact objects
- 4 Observing Runs completed with LIGO-Virgo-KAGRA (LVK) detectors
- Promising cosmic ray accelerators
 - Especially when neutron stars involved
 - GW 170817 detected in electromagnetic spectrum as well
 - No neutrino counterpart yet

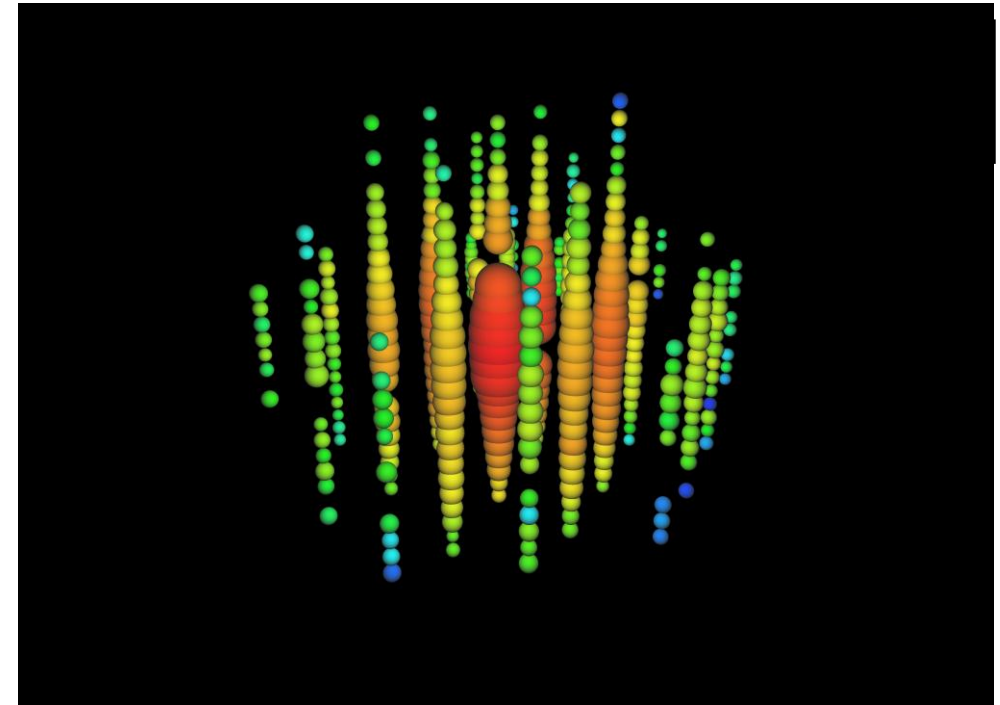


IceCube Event Morphologies and Transient Source Searches



Tracks

Charged-Current muon neutrino interactions
Great angular resolution (<1 degree)
Low purity, especially for low energies in Southern Hemisphere

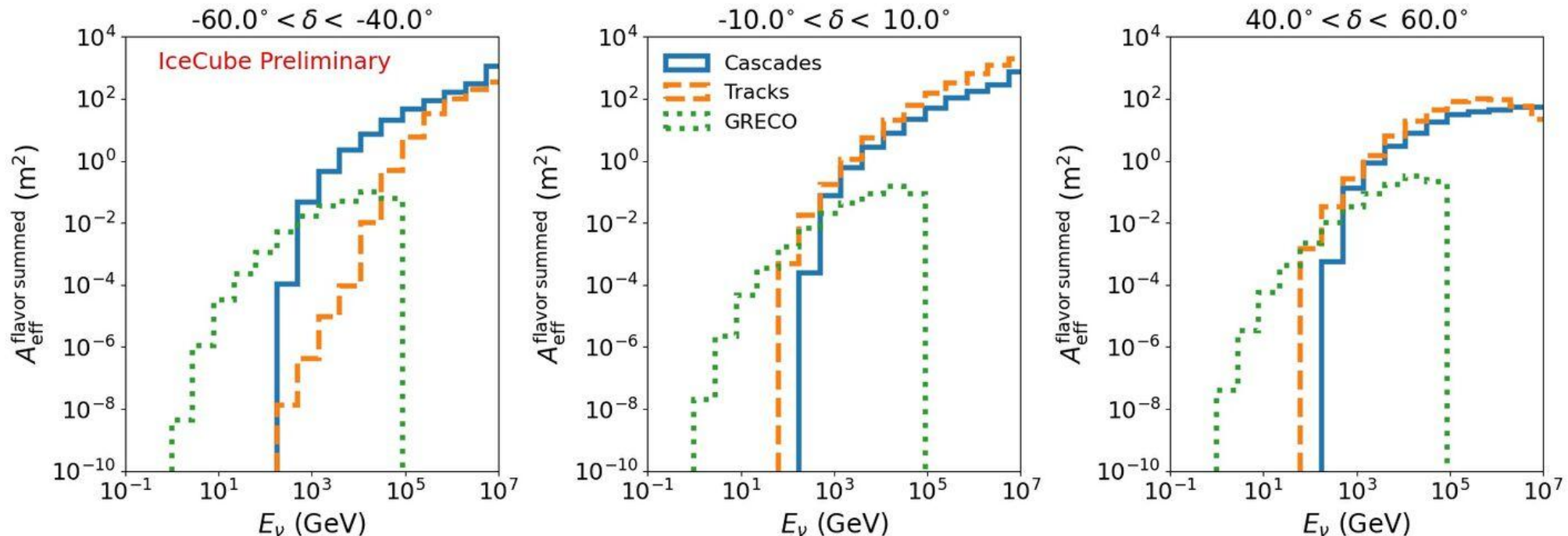


Cascades

All-flavor neutral current + CC electron/tau neutrino
Worse angular resolution (~ 10 degrees)
Better purity, particularly in Southern Hemisphere

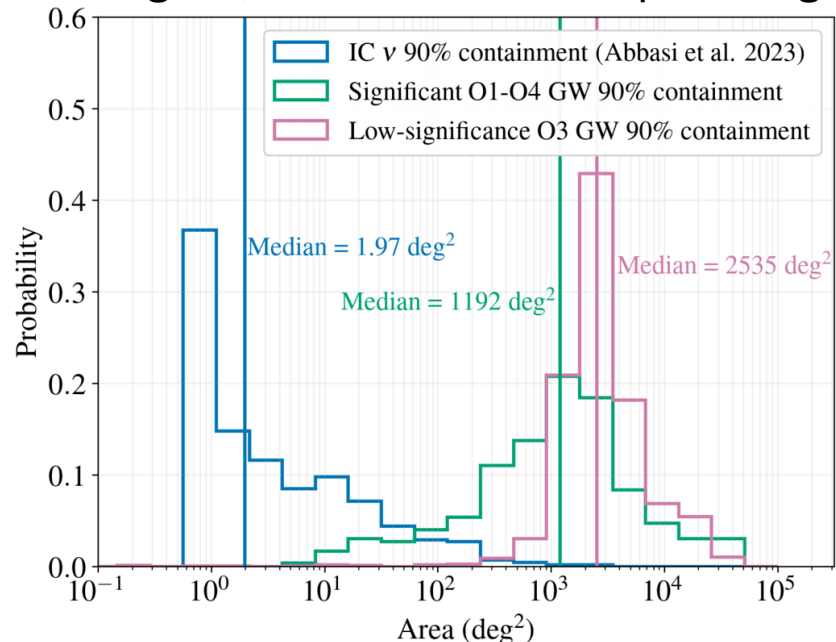
Transient Analyses

- At short time windows, lots of signal separation power comes from time
- Effective area is the most important property of a dataset



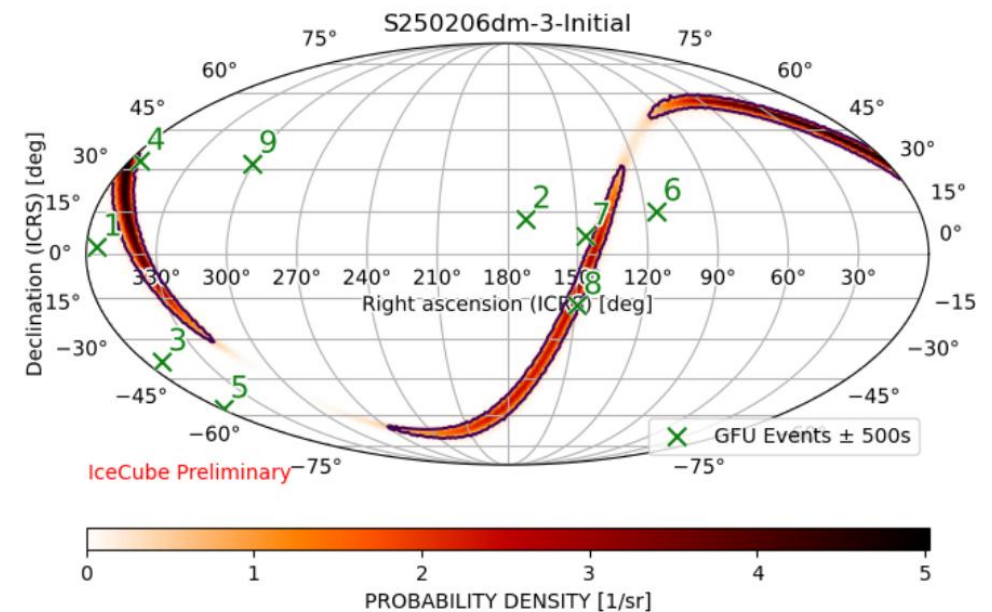
IceCube Follow-Up of GW Events with Tracks

- 2 analyses
 - Unbinned Maximum Likelihood (UML): likelihood-ratio based test statistic
 - Low-Latency Algorithm for Multi-messenger Astrophysics (LLAMA): bayesian-based analysis
- Using a real-time track-based dataset
- Search for a point source compatible with GW map for 1000 second time window
 - If event includes neutron star, a two-week UML search is also included
- During O4, LLAMA followed-up low-significance LVK candidate events



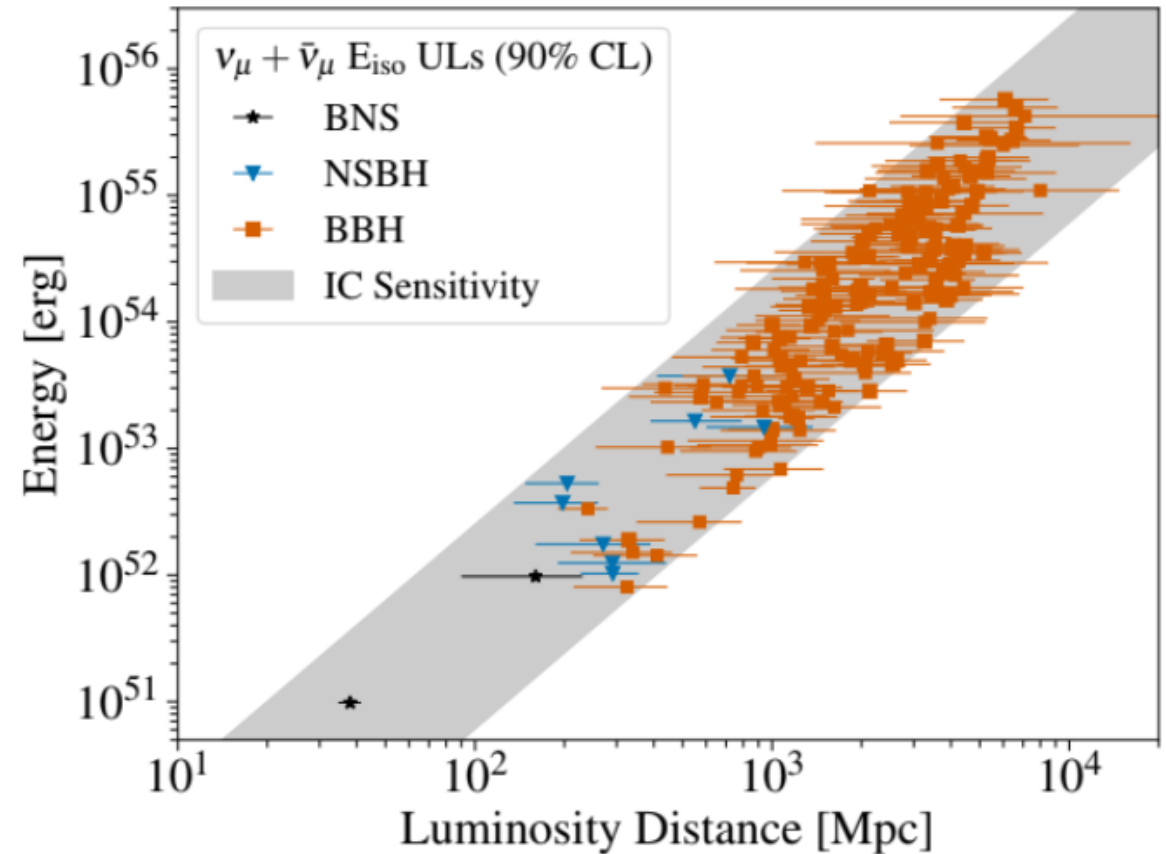
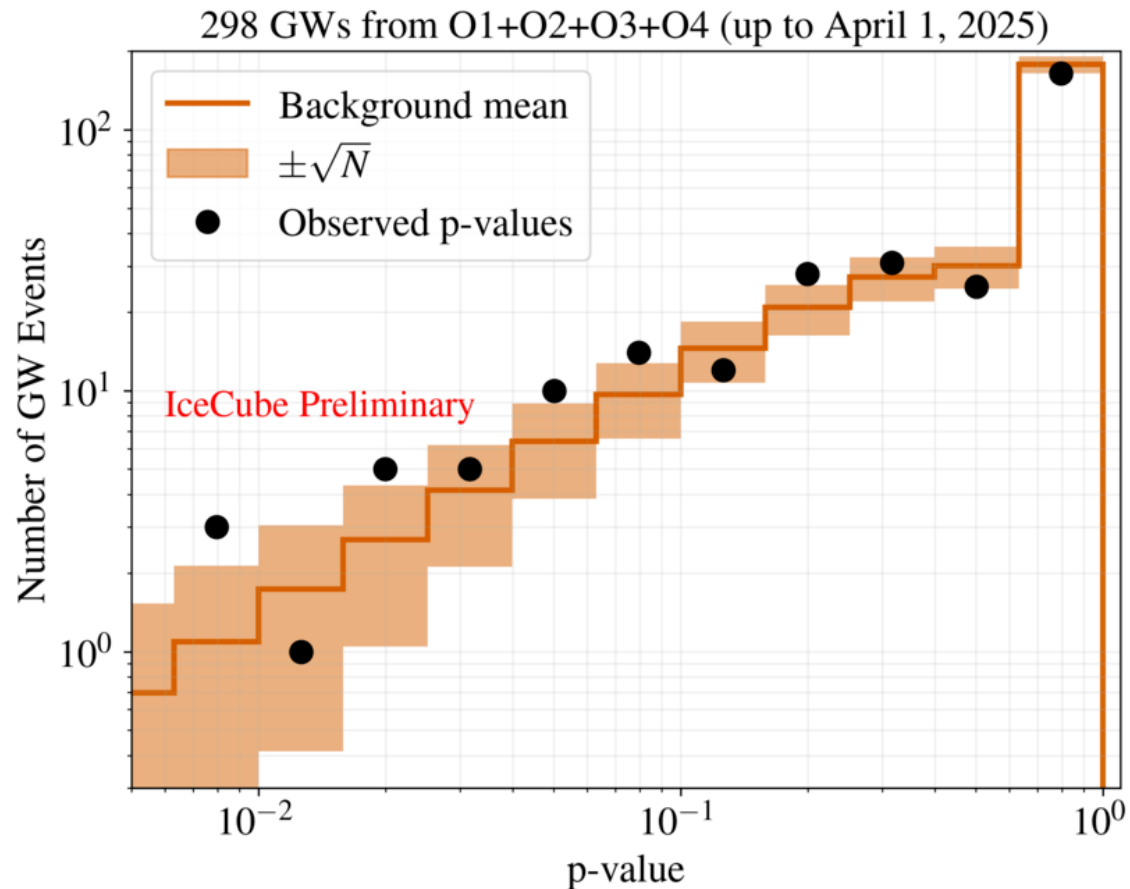
[arXiv:2606.13762](https://arxiv.org/abs/2606.13762)

10/13/2026



IceCube Collaboration, "Results from IceCube Searches for High-Energy Neutrinos Coincident with Gravitational-Wave Alerts in LVK O4," *Proceedings of Science*, vol. 501, 39th International Cosmic Ray Conference (ICRC2025), PoS(ICRC2025) 1113. 5

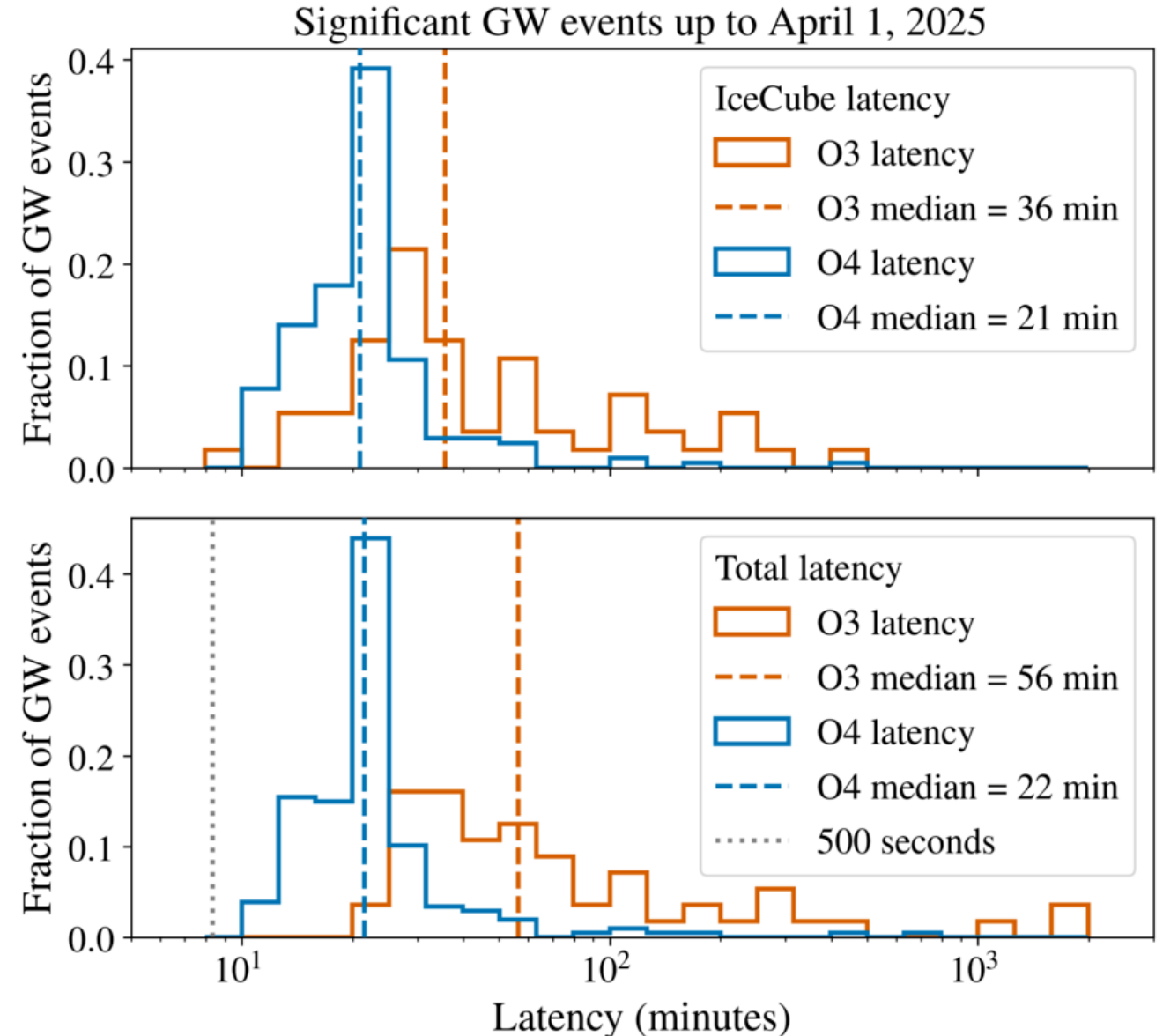
Previous Track Results



[arXiv:2606.13762](https://arxiv.org/abs/2606.13762)

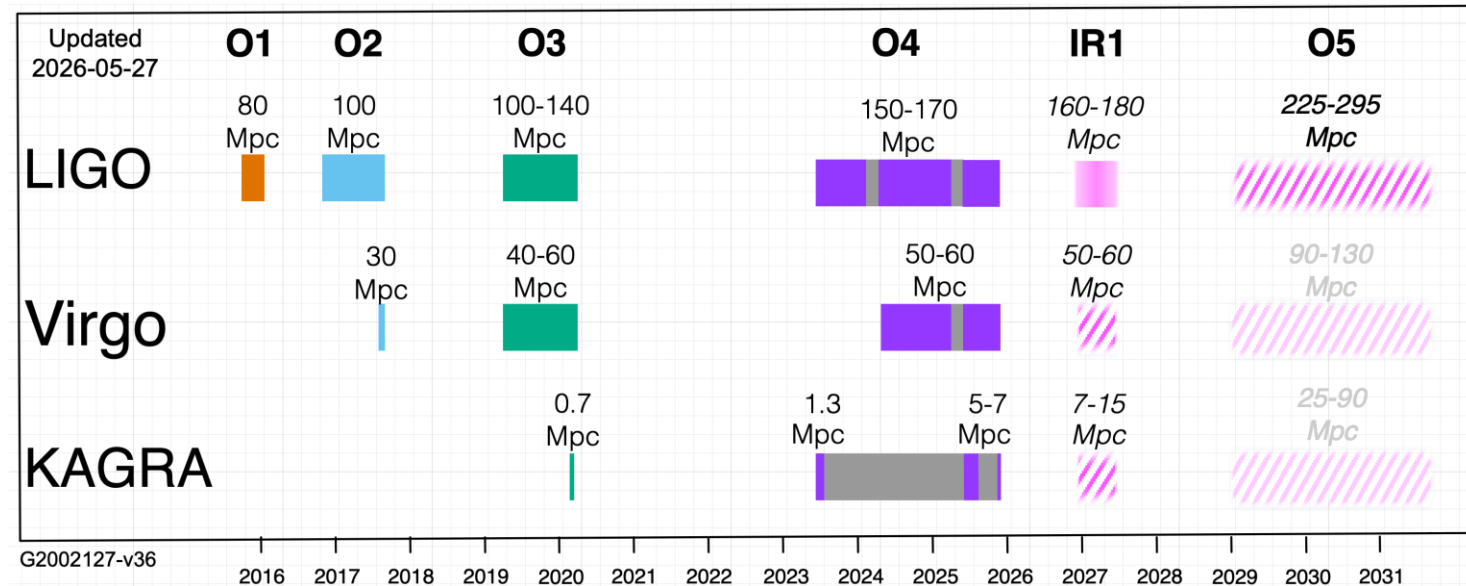
O4 Latency

- Latency down to only median of 21 minutes
 - Time window of 1000 seconds
- Results communicated over General Coordinate Network (GCN)
 - Webpage with results at <https://roc.icecube.wisc.edu/public/LvkNuTrackSearch/>



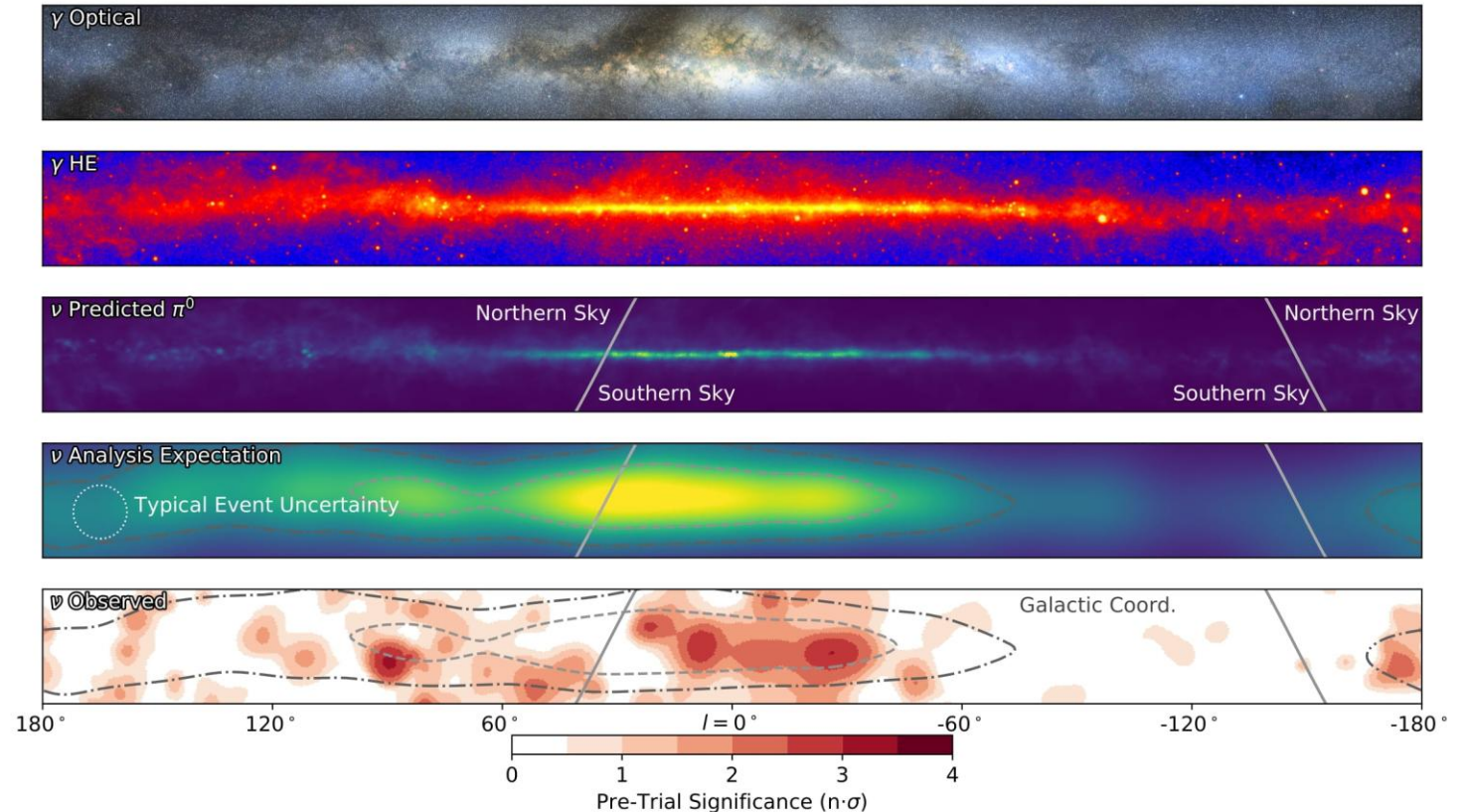
Intermediate Run 1

- 6 month LIGO-Virgo-KAGRA run planned for November
- IceCube conducting a follow-up program
- For all events, both analyses run with tracks
- For significant events only, a new online cascade-based analysis is planned
- New improvements
 - UML operations on low-significance events
 - Cascade dataset



Cascade Dataset

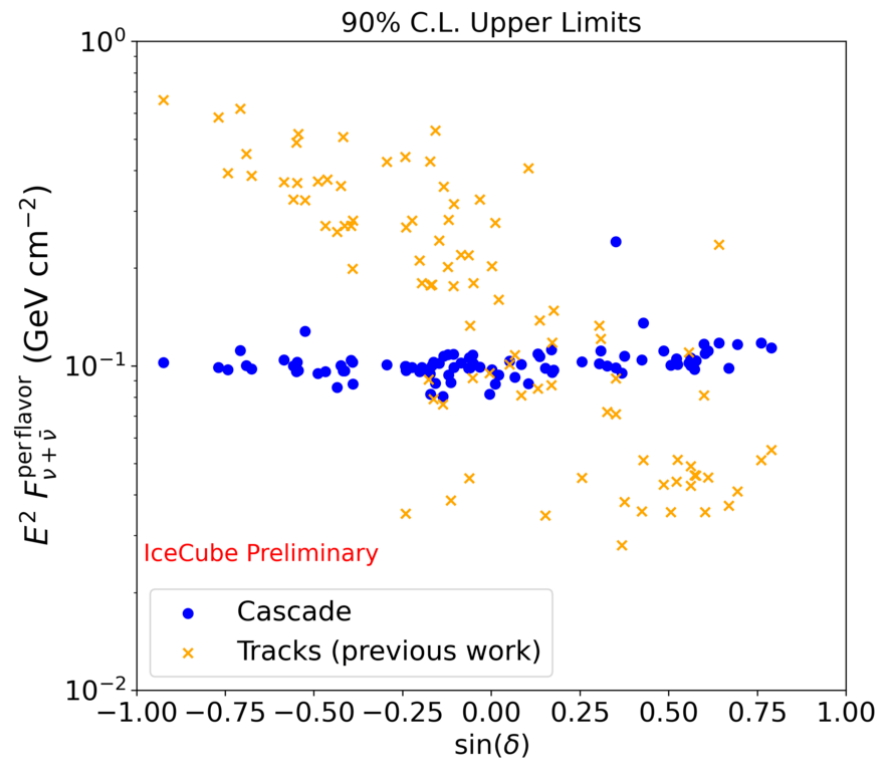
- “DNNCascades Online” event selection based on dataset produced for galactic plane result
- Operations planned for IR1
 - Longer latency (~day) expected for technical reasons transferring data north



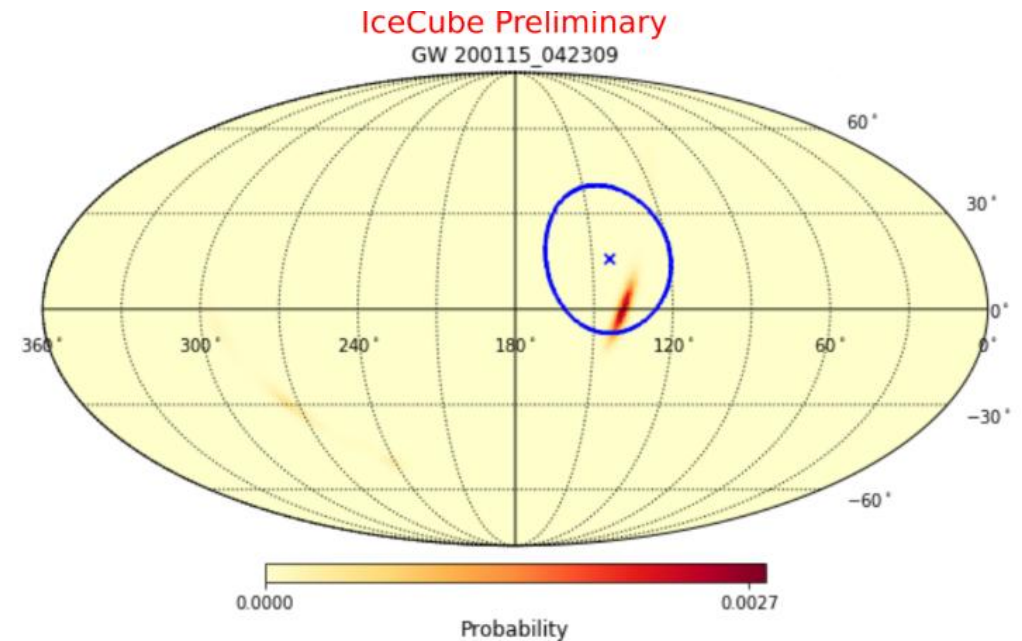
IceCube Collaboration. “Observation of high-energy neutrinos from the Galactic plane.” *Science* Vol 380 (2022)

Cascade Follow-Ups of GW

- Improved sensitivity in southern hemisphere and independent dataset in the north



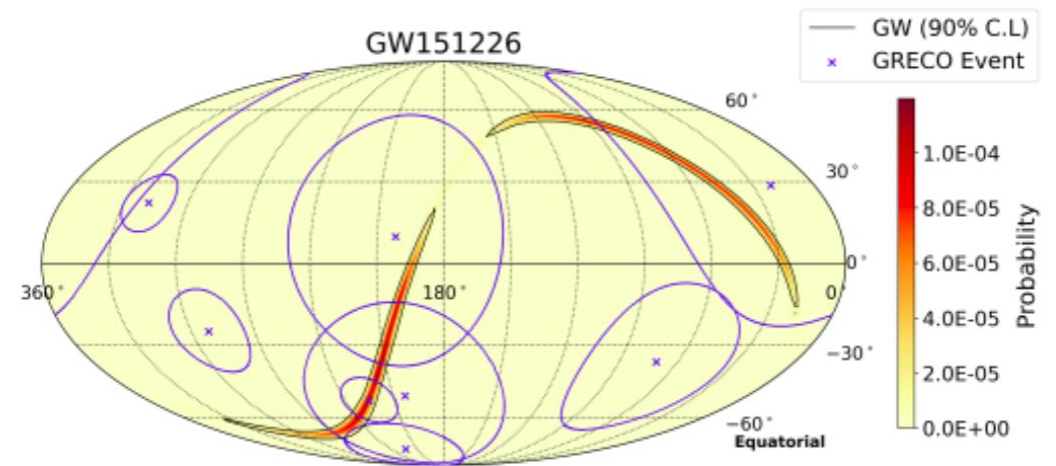
Cascades results from O1-O3



Balagopal V. et al., “Multi-Energy and Multi-Sample Searches for IceCube Neutrinos from LIGO/Virgo/KAGRA Gravitational Wave Events,” PoS ICRC2025 (2025), 915. <https://doi.org/10.22323/1.501.0915>

Other Real-time Improvements

- Implemented for IR1
 - Improved IceCube localization product with full skymap
- Future plans
 - Lower latency cascade follow-up
 - Sub-TeV dataset using Deepcore+Upgrade in real-time
 - Real-time multi-dataset operations



R. Abbasi *et al* 2023 *ApJ* **959** 96

Sub-TeV archival follow-up example

Summary

- Compact binary mergers are promising multi-messenger sources
 - LVK detectors detect mergers and communicate candidates in real-time
- IceCube follows up every LVK candidate GW in real-time
 - Offline analyses have been done for O1-3 with all-morphology GeV-scale and a TeV-scale cascade datasets
- Previous runs were followed-up with tracks
 - Excellent latency with potential to improve LVK localization dramatically if a signal is detected
- Additional cascade pipeline being added for IR1
 - Dramatic improvement in southern hemisphere sensitivity