Next Generation of IceCube Real-Time Alerts.

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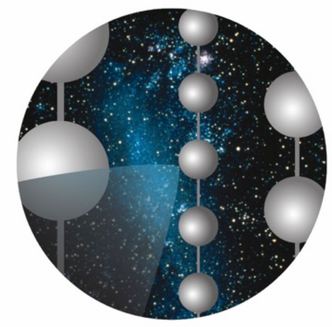
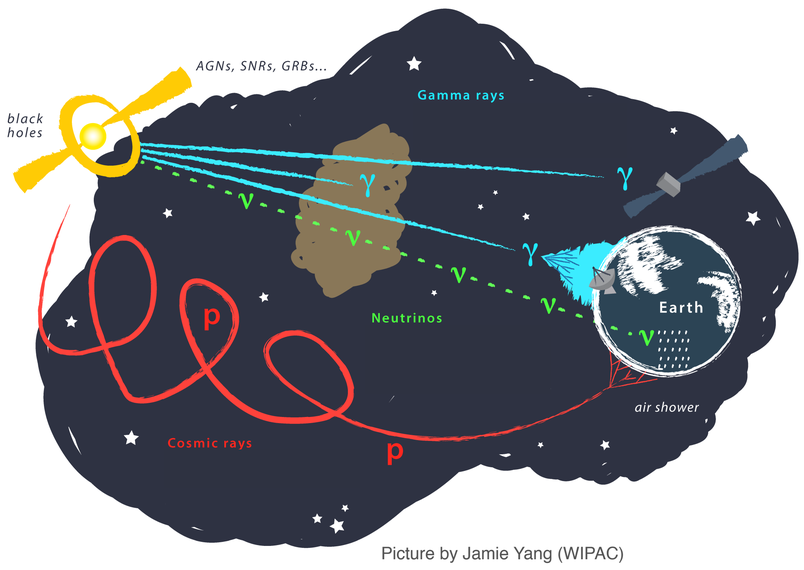
for the IceCube Collaboration



Completing the Picture of Astrophysical Accelerators

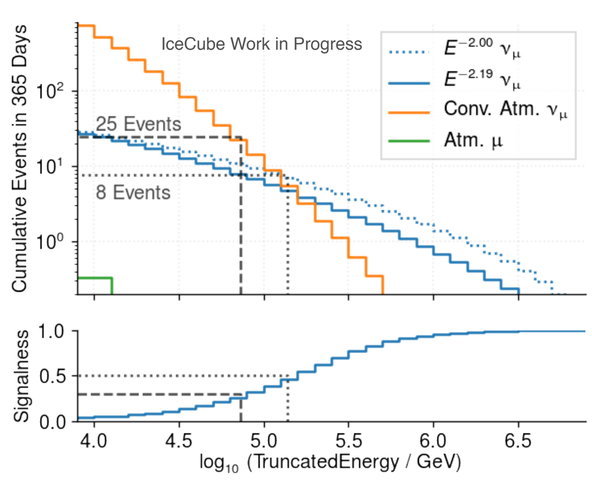


Picture by Jamie Yang (WIPAC)

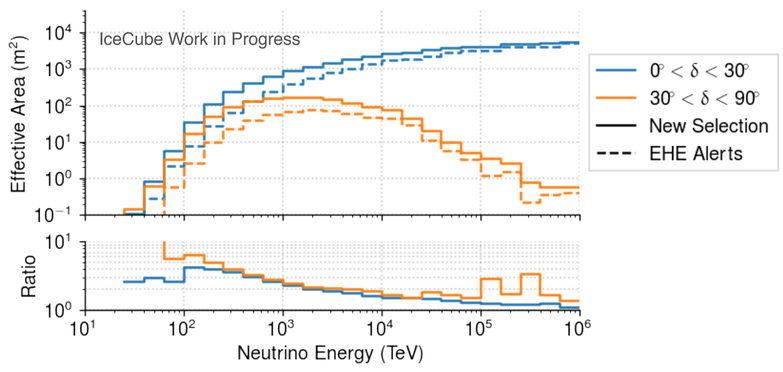
- Already discovered: diffuse flux of astrophysical neutrinos (1)
- So far undiscovered: point-like sources of neutrinos
- Online event selection and immediate analysis helps:
  - Trigger follow-up observations with other messengers (e.g. x-rays, optical, gamma-rays)
  - Identify counterparts of most-significant events
  - Increase availability of multi-messenger data
  - Boost discovery potential for point-like sources
  - Obtain complete picture of mechanisms for cosmic accelerators, especially in case of time-dependent (variable or transient) behavior

Most-Energetic Single Neutrino Events

- Multivariate online selection of track-like events
- Sensitivity comparable to offline analyses (2, 3)
- High-purity (>99.9%) sample of upgoing neutrinos, "signal-ness" ($\phi_{astro}/(\phi_{astro}+\phi_{atmo})$) directly related to muon energy proxy:



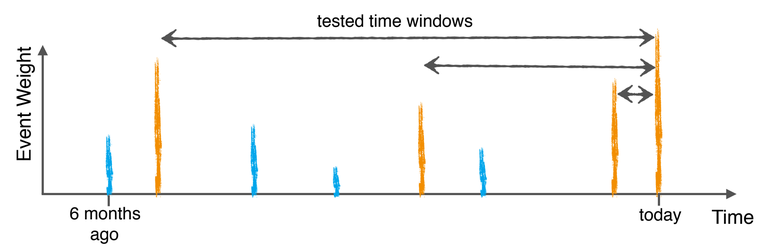
- Selecting muons above 139 TeV:
  - Probability of being astrophysical: ≥ 50%, assuming $E^{-2.19}$ spectrum (2)
  - Angular resolution: 0.2° (median), 0.7° (90%)
  - Expected alert rate: 8 / year



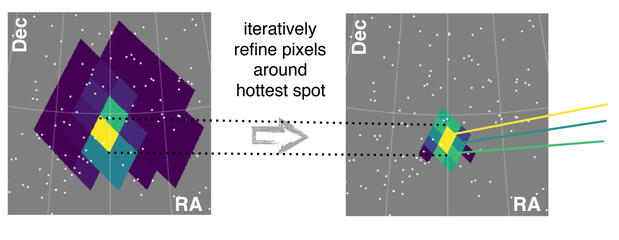
- Improvements in comparison to existing alert streams:
  - Starting events ("HESE"): signal probability twice as high (25% → 50%)
  - Extreme high energy ("EHE") events: effective area doubled

Clustering of Neutrinos on Variable Timescales

- Unbinned maximum-likelihood analysis (5), considering each event's direction, angular uncertainty and energy estimate
- Searching for excess of clustered neutrinos on variable timescales, spanning from most-recent event up to 6 months ago

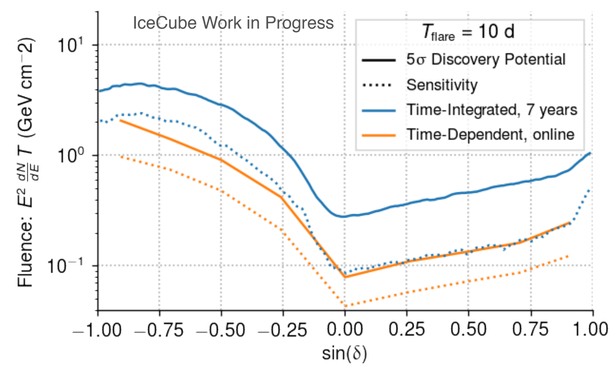


- Monitoring list of known very high-energy gamma-ray emitters:
  - Private alert channels with Imaging Air Cherenkov Telescopes (IACTs)
  - Expected alert rate: 12 alerts / year (corresponding to 3.3 σ significance)
- Monitoring the entire sky:
  - Scan pixels around most-recent event with time-clustering analysis



Likelihood fit optimizing:
- location
- time-window
- signal strength
- spectrum

  - Identify hotspots as they grow and notify community within one minute of neutrino observation at the South Pole (4)



- Potentially reveal previously unknown sources or phenomena
- Expected public alert rate: 1 alert / year

Outlook

- Upcoming online alerts… most-significant events and clusters with least delay!
- Higher alert rates → increase chance of successful follow-up observations
- Expected to run online with the next detector data-taking season (by this summer)
- Apply clustering analysis to archival IceCube data (2011 — 2018):
  Reveal most-significant flares in the entire sky, and also per source … stay tuned!

References

(1) Aartsen et al., Phys. Rev. Lett., 113, 101101 (2014)
(2) C. Haack, C. Wiebusch, ICRC 2017
(3) Aartsen et al., Astrophys. J., 835, 151 (2017)
(4) Aartsen et al., Astropart. Phys., 92, 30 (2017)
(5) J. Braun et al., Astropart. Phys., 29, 299 (2008)