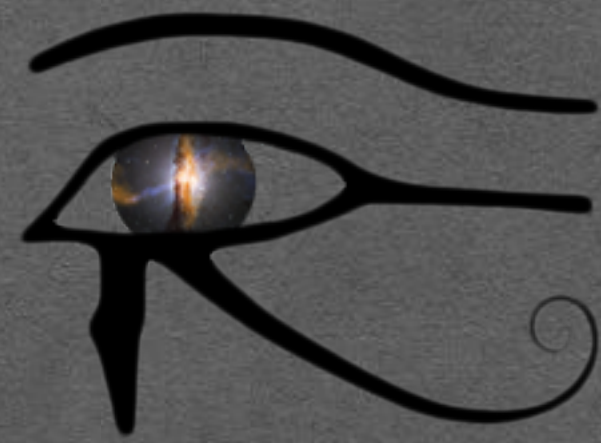


AMON

Astrophysical Multimessenger Observatory Network



The Astrophysical Multimessenger Observatory Network in the LIGO- Virgo Era

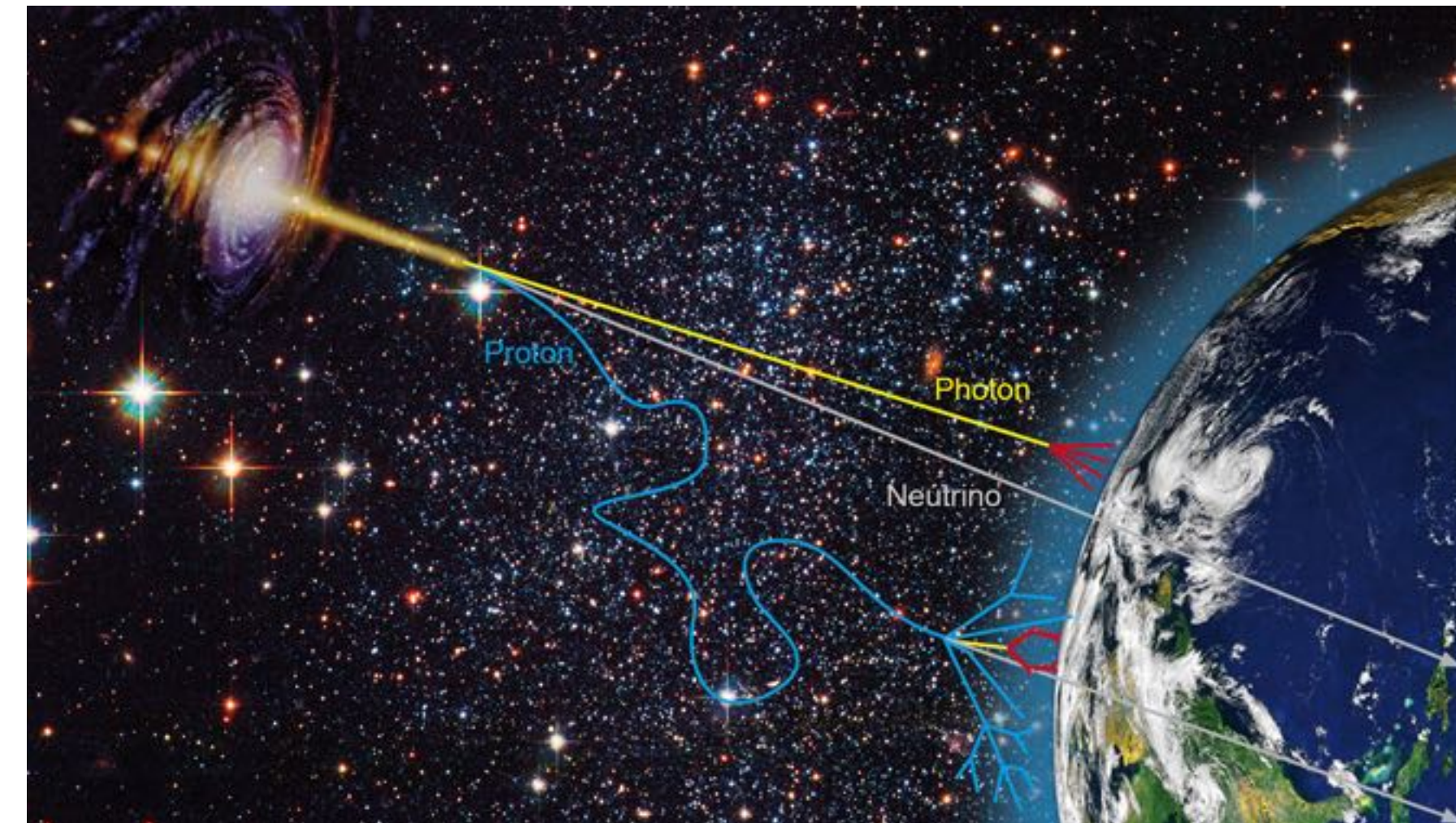
Hugo Ayala



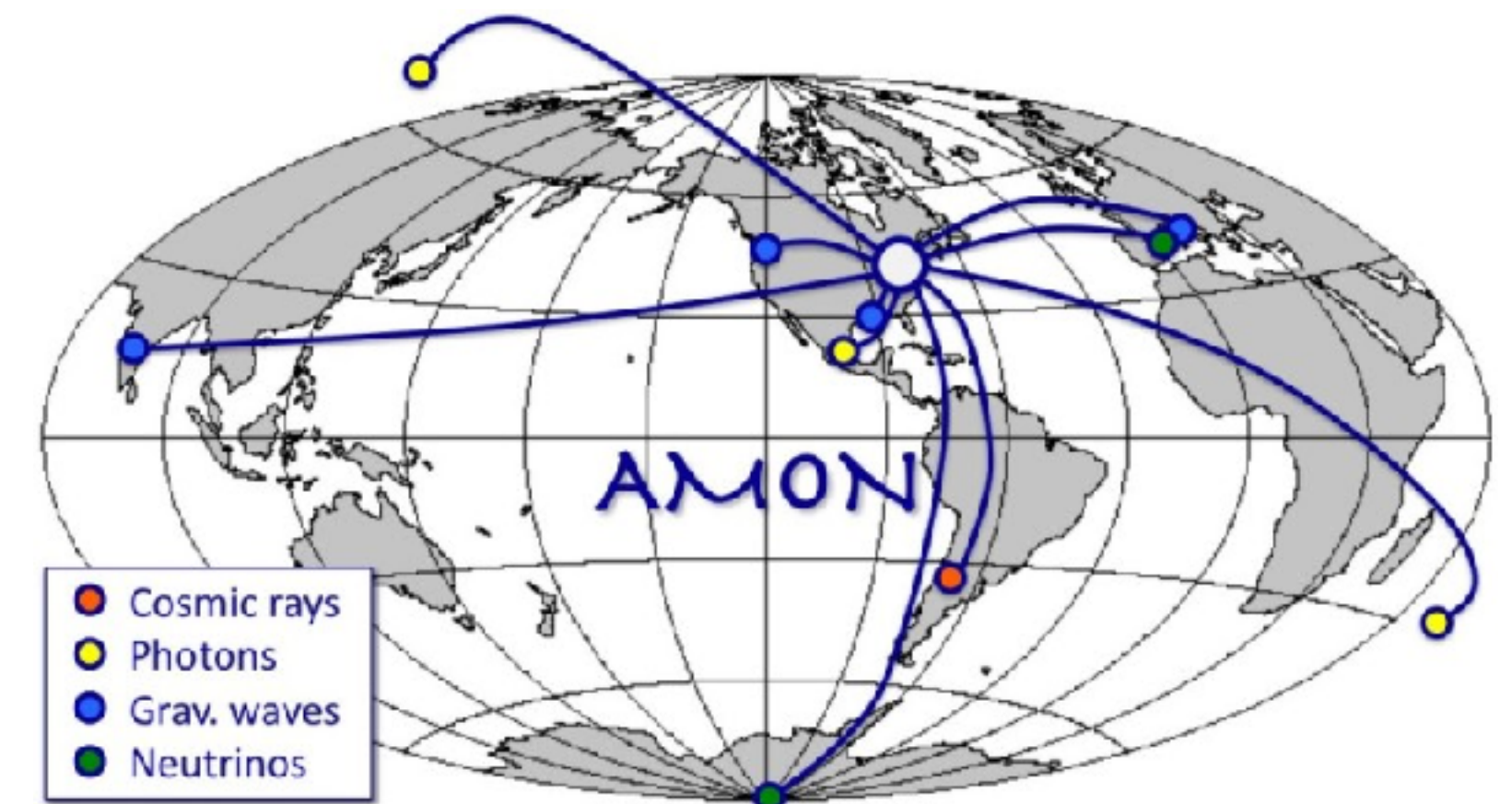
PennState
Eberly College
of Science

The principle of AMON

- Search for Astrophysical Multimessenger Sources:
 - Combine data from different observatories that focus on different messengers of the fundamental forces of nature.
 - Use “sub-threshold” data from different detectors/observatories:
 - Signal events that are statistically indistinguishable from background in the detectors
 - Coincidence analyses between different messenger channels can identify signals from sub-threshold events
- See Keivani, A., et al 2017 and M.W.E. Smith et al., 2013

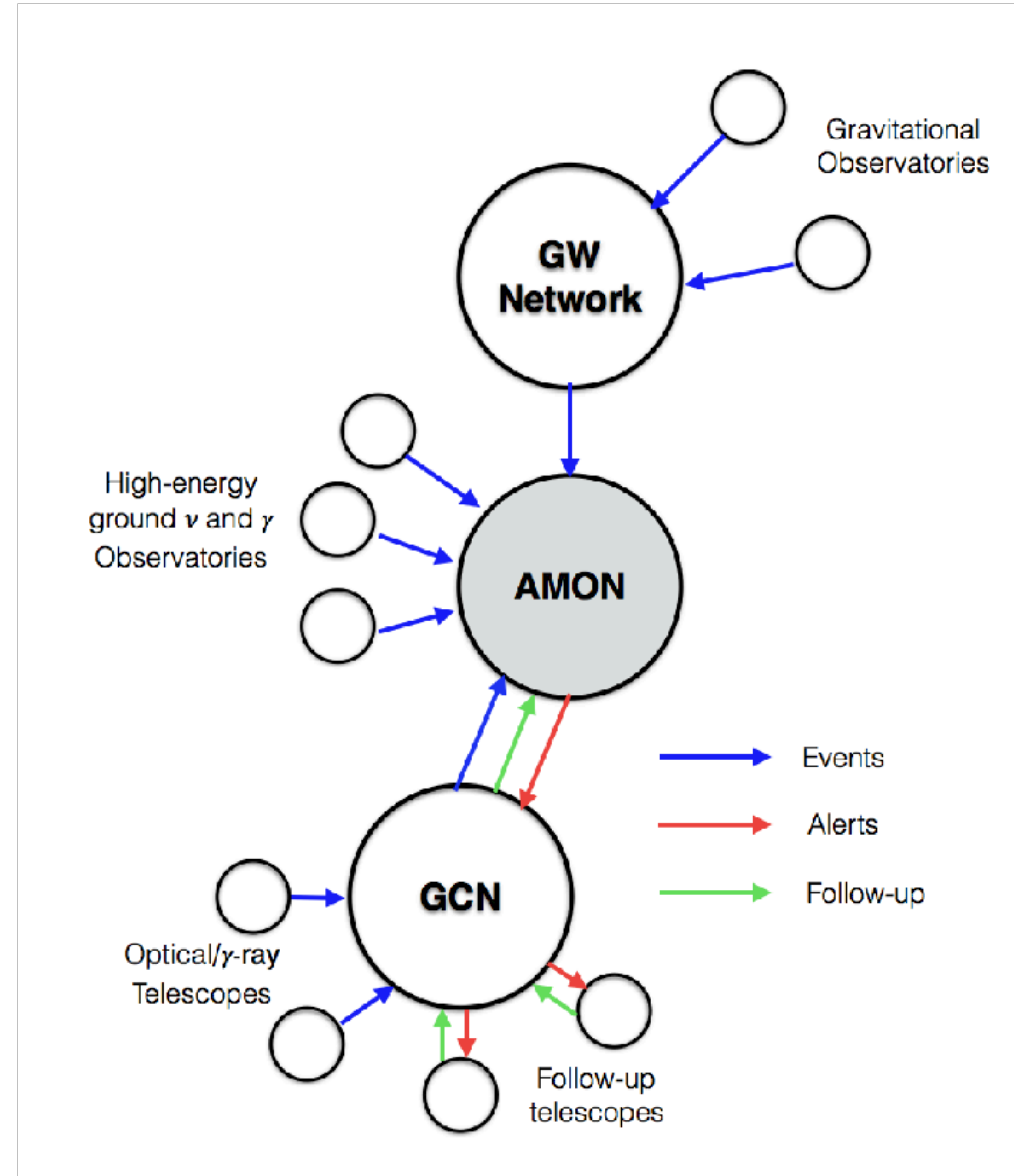


https://astro.desy.de/theory/multi_messenger_astrophysics/index_eng.html



Basic Design

- Trigger observatories:
 - Send “sub-threshold” events to AMON
- Within AMON:
 - Archival Searches: Perform coincidence searches in archival data
 - “Pass-through”: Use AMON as a way to send alerts to GCN
 - Real-Time Searches: Perform coincidence searches in real-time.
- Follow-up observations: AMON sends alerts to the community through GCN



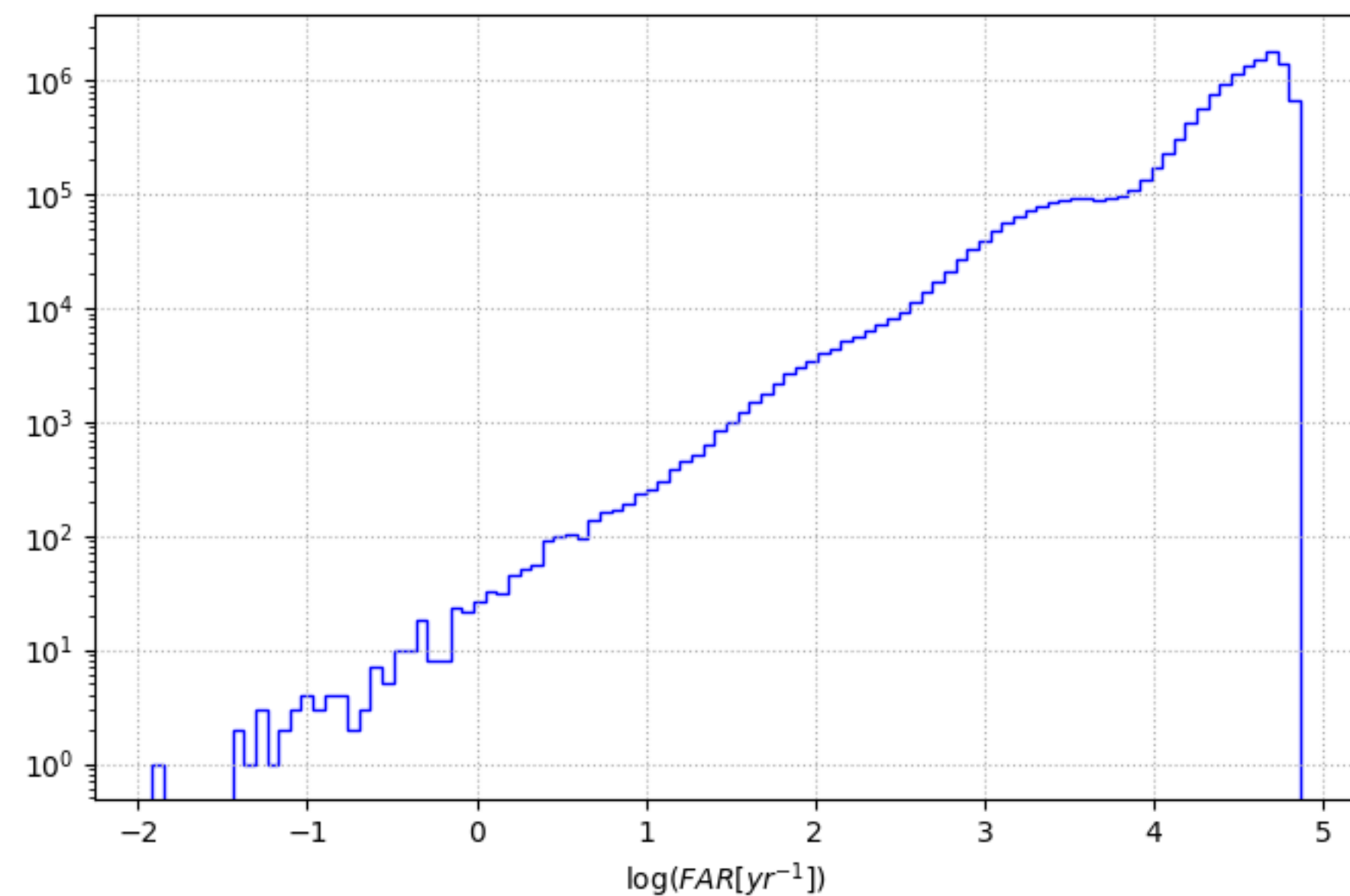
Current Status

- Pass-through IceCube events:
 - Four Swift searches for transient sources of high-energy neutrinos (<https://pos.sissa.it/301/1015/pdf>)
 - Multi-wavelength follow-up of a rare IceCube neutrino multiplet (<https://arxiv.org/pdf/1702.06131.pdf>)
- Archival analyses:
 - A Coincidence Search for Cosmic Neutrino and Gamma-Ray Emitting Sources Using IceCube and Fermi LAT Public Data (<https://arxiv.org/abs/1802.08165>)

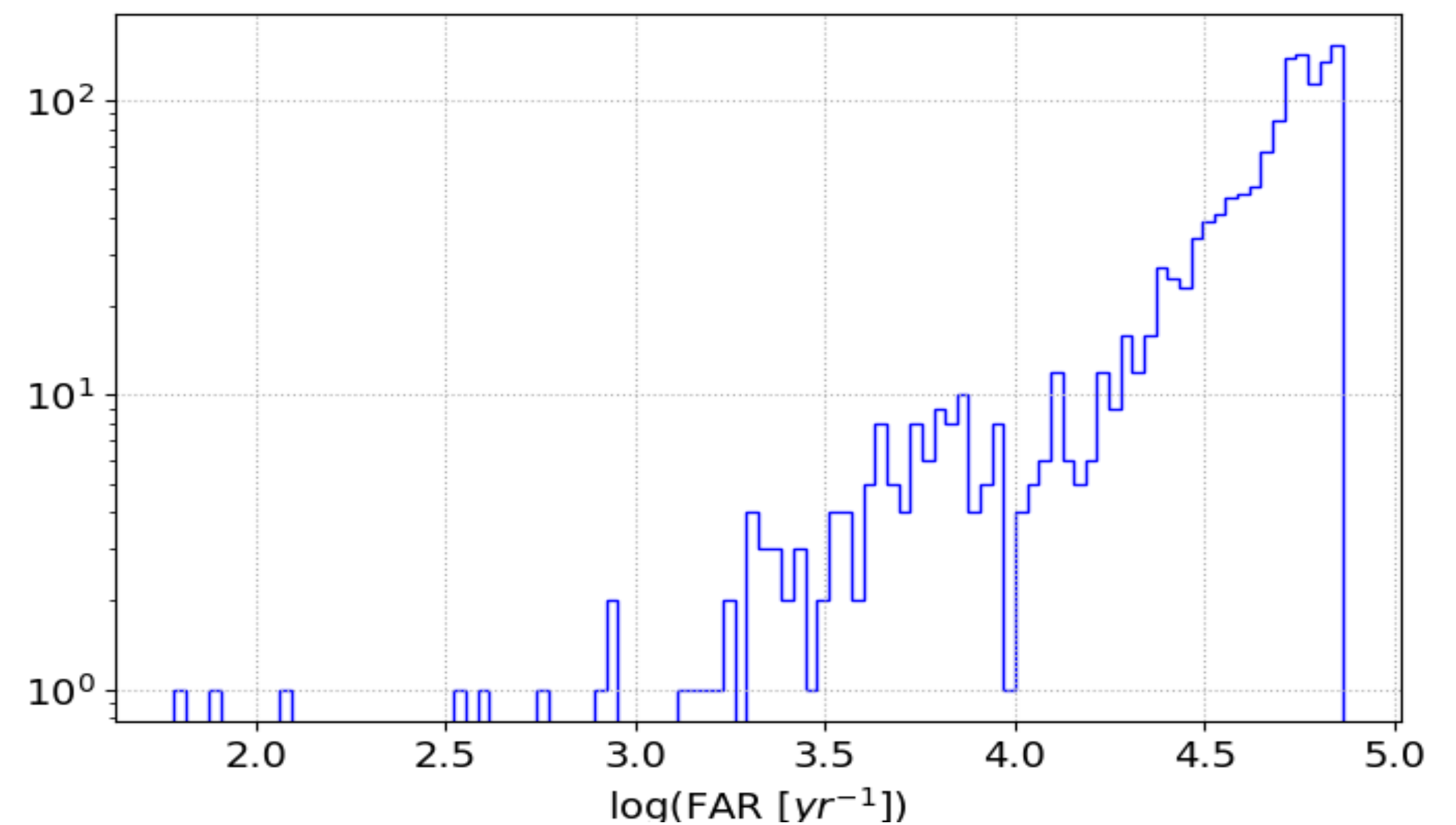
Current Status

- Under development:
 - IceCube-HAWC Coincidence:
 - Have used scrambled data from both observatories to setup threshold to send alerts.
 - Currently testing the real-time mode (AMON gets scrambled data in real time)

Scrambled Test



Real-time Test

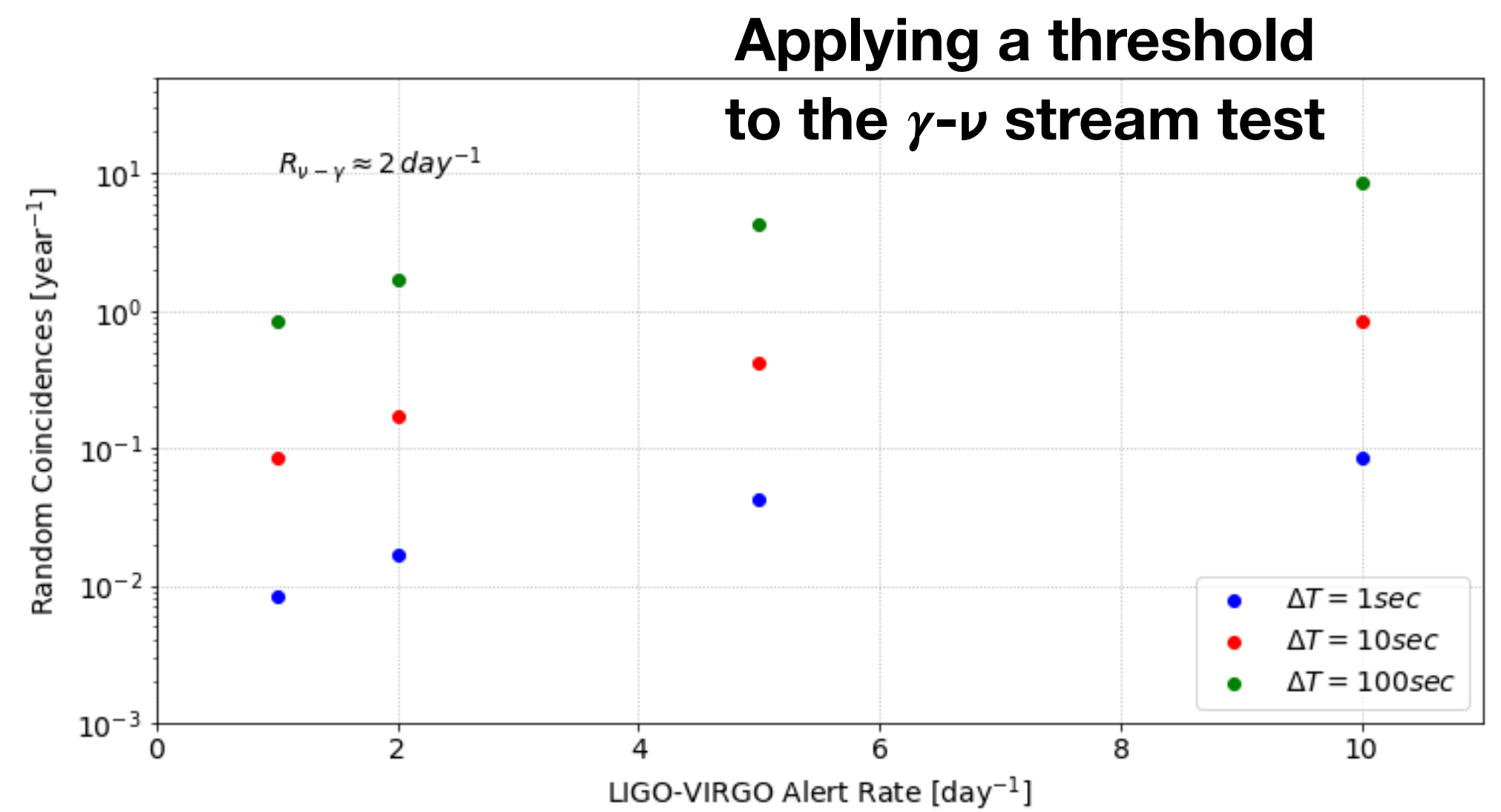
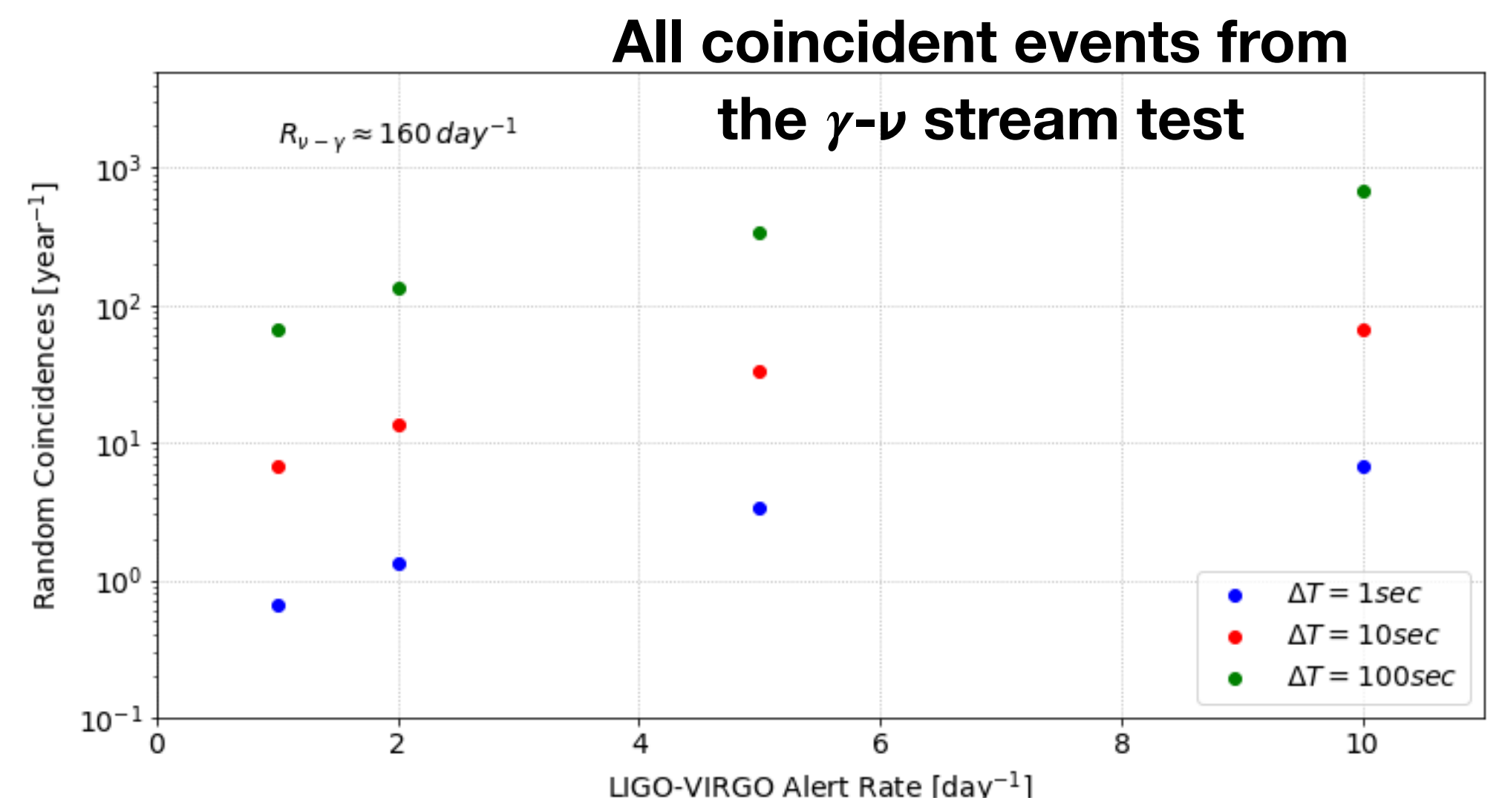
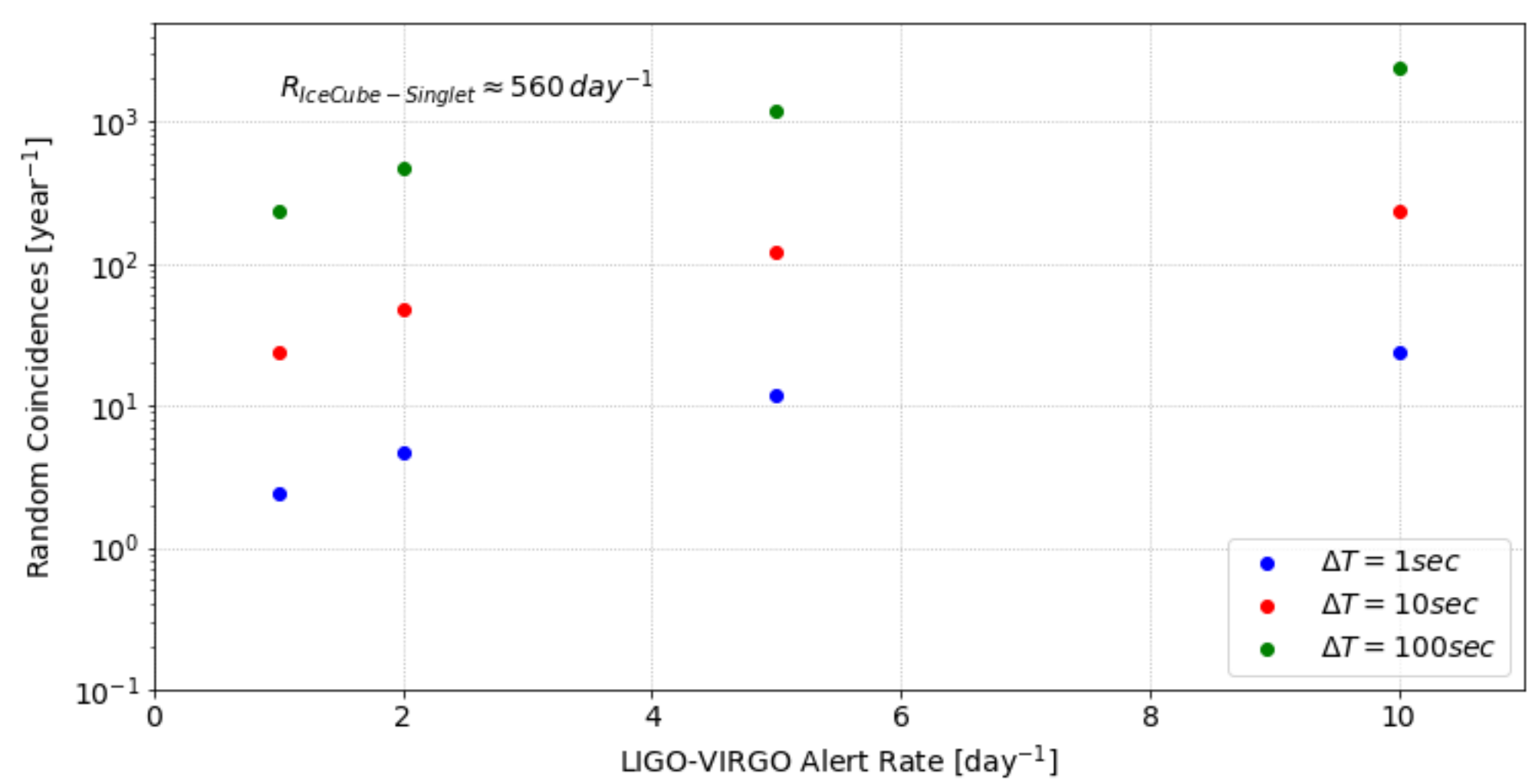


Proposal

- Use sub-threshold data from LIGO-Virgo for coincident analysis.
 - E.g. Data from one interferometer could be consider sub-threshold. O3 alerts with FAR of 1 per day or 1 per week (see for example <https://arxiv.org/pdf/1803.02880.pdf>).
 - Get at least daily sub-treshold events. Combine this dataset with:
 - Sub-threshold data from large-field-of-view detectors (e.g. HAWC or IceCube)
 - An already combined alert stream, e.g. γ - ν coincidence search.
- Pointing Resolution of Detectors:
 - IceCube $\sim 1^\circ$ HAWC $\sim 0.1^\circ$ Swift $\sim 0.06^\circ$ FermiLAT = $< 3.5^\circ$ (100 MeV) - $< 0.15^\circ$ (> 10 GeV)

Proposal

- Simple estimation of random coincidences between LIGO/Virgo and other event/alert streams



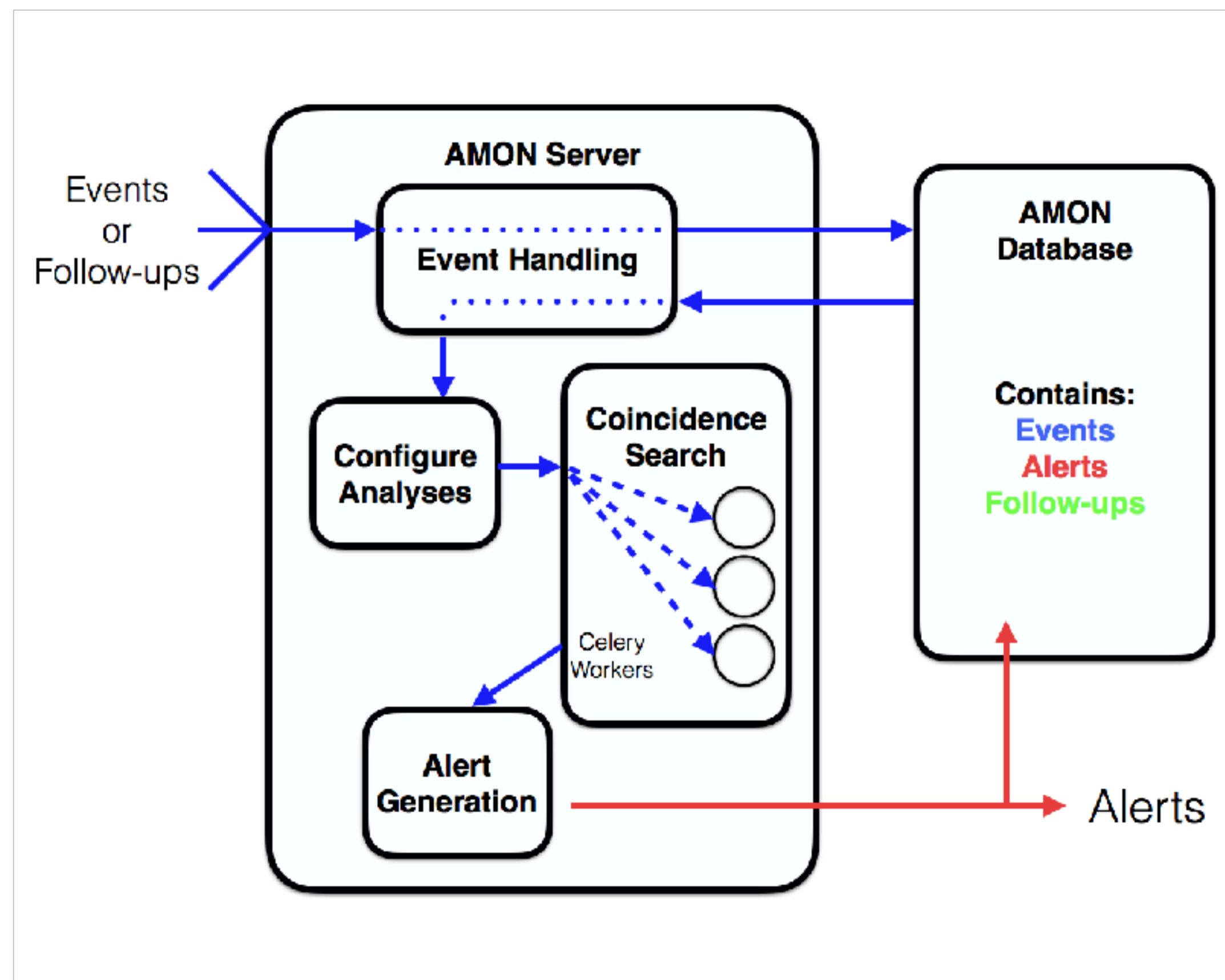
Summary and Discussion

- AMON has the ability to combine data from different observatories to search for multimessenger sources.
- “Sub-threshold” events can be used for near real-time searches for temporal and spatial coincidences.
 - Possibility to identify and potentially achieve high significant signal events
- A LIGO/Virgo “sub-threshold” event rate of ~ 1 per day is promising if combined with one event stream or one AMON alert stream.
- More AMON information: <http://www.amon.psu.edu/>

Back-up Slides

Functionality

- Diagram describing the AMON system



Current Analysis

- Archival study with scrambled data of coincidences between HAWC and IceCube sub-threshold events
 - HAWC events: >2.75 sigma; IceCube events: track events
- Use a ChiSquare test statistic to rank coincidences.
- Plots below are for a null-distribution (No sources).

