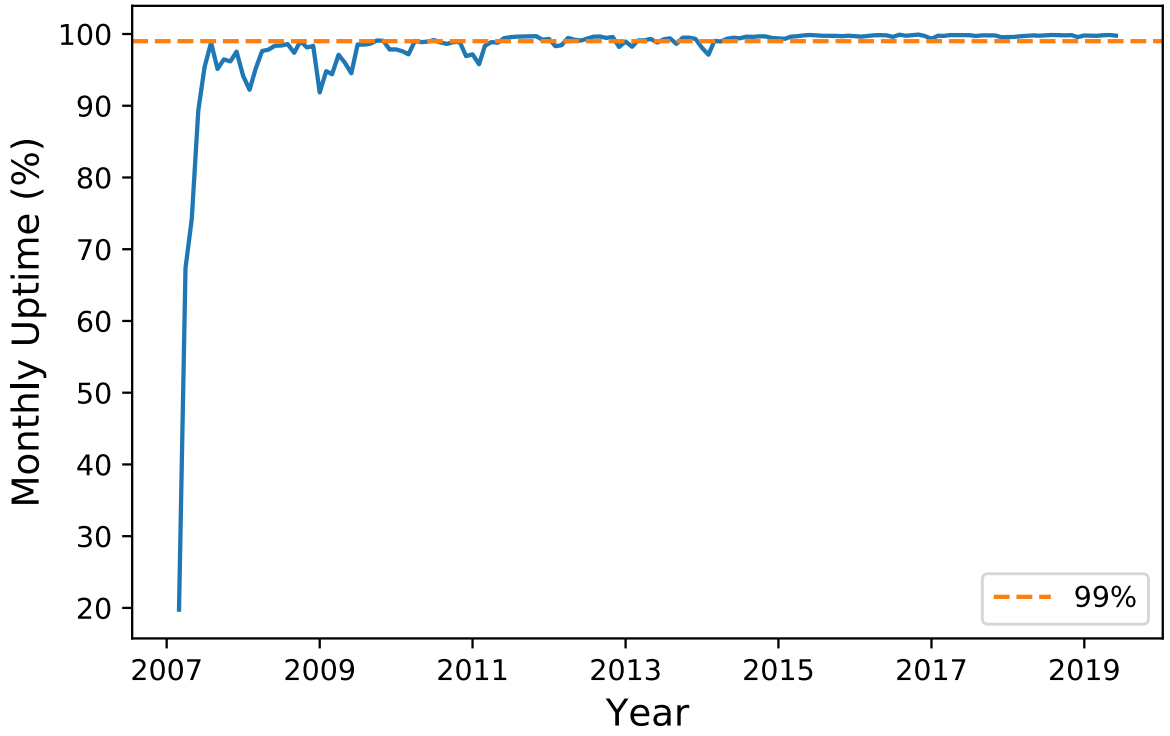
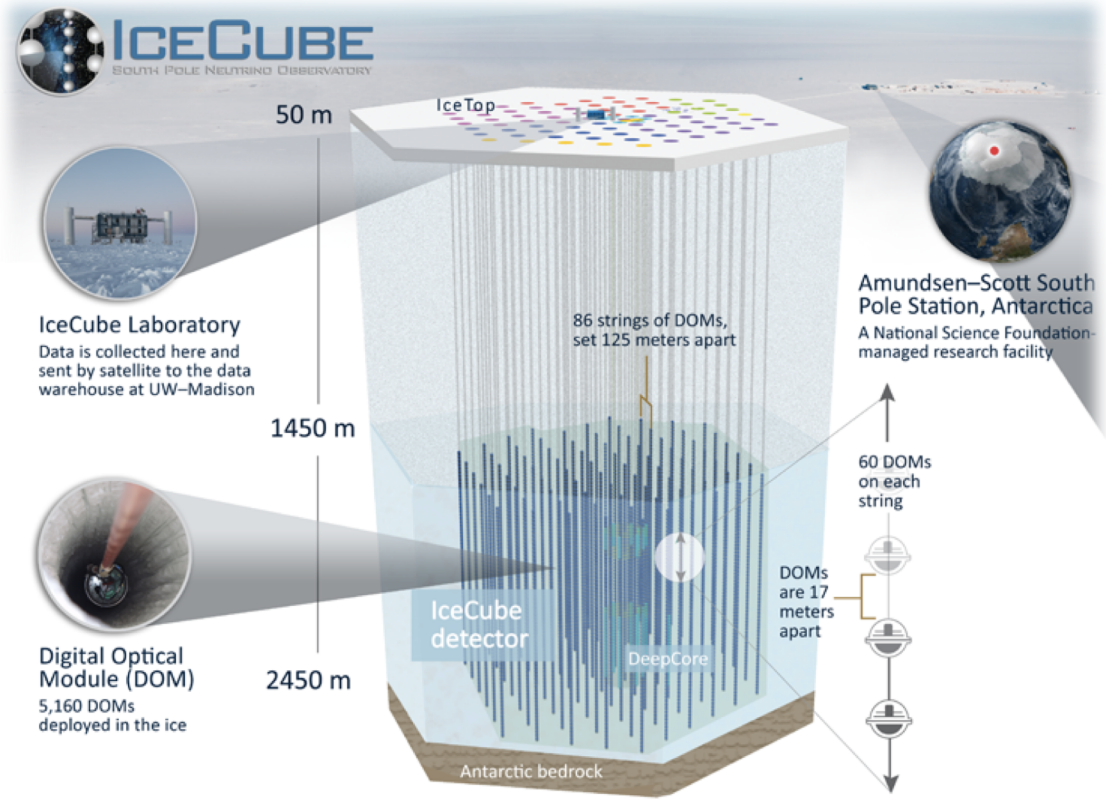
The New Generation of IceCube Realtime Neutrino Alert System

Erik Blaufuss, Thomas Kintscher, Lu Lu,
Chun Fai (Chris) Tung
for
IceCube
South Pole Neutrino Observatory
University of Maryland
DESY.
Chiba University
Georgia Tech

IceCube as a Monitor

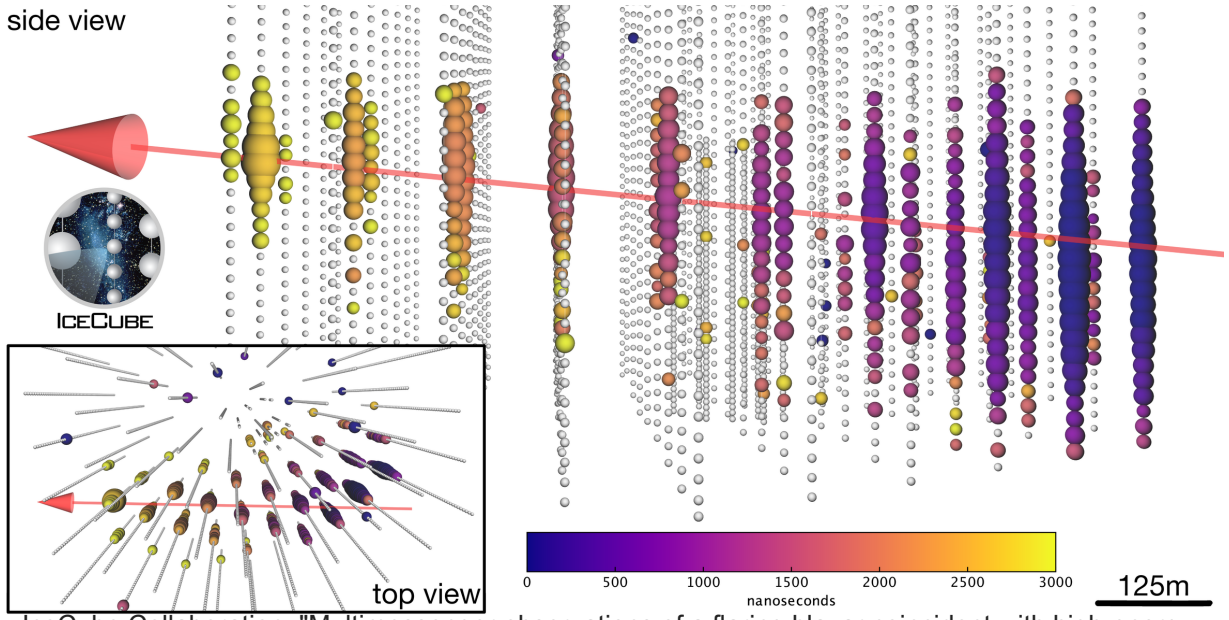
- All-sky F.O.V., >99% uptime
- Notify the community when “interesting” neutrinos are observed
- Perform follow-up observations





IceCube Realtime Neutrino Alert

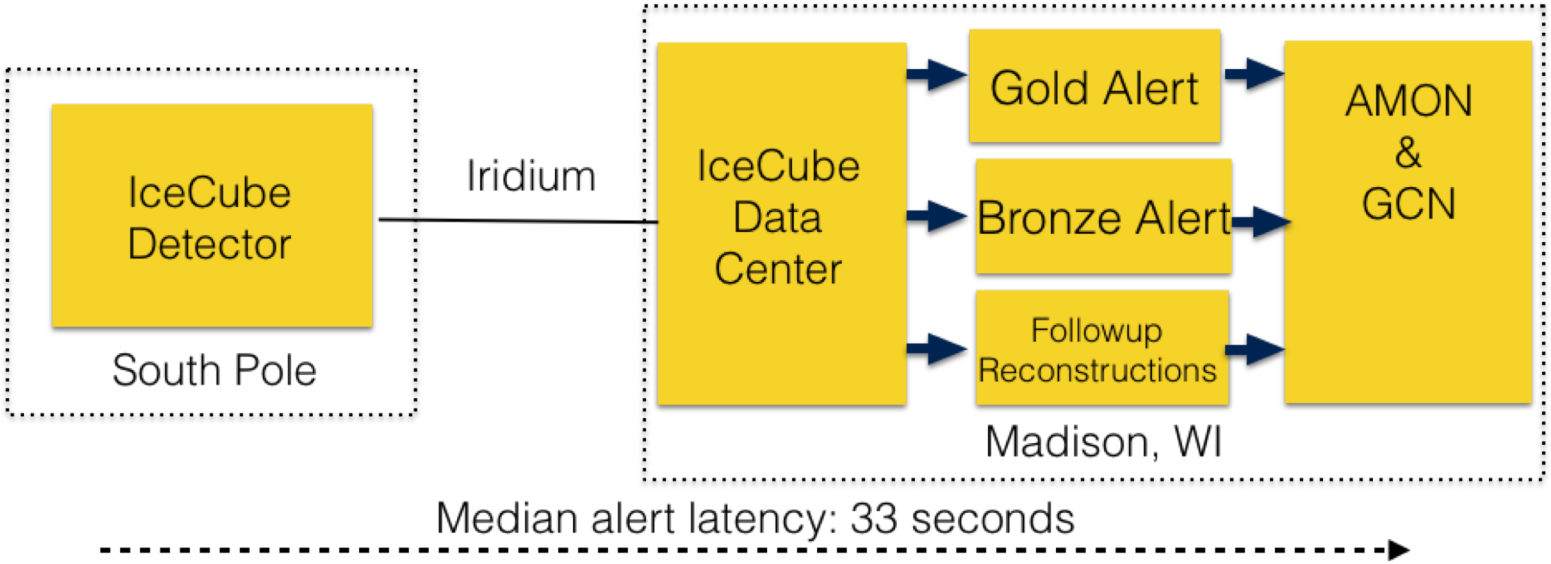
- Since April 2016
- Sent out 27 neutrino alerts through GCN/AMON
  - ~30% signal purity
- E.g. IceCube-170922A
  - Coincident observation made by Fermi LAT, MAGIC, …
  - First neutrino source – TXS 0506 +056



IceCube Collaboration. "Multimessenger observations of a flaring blazar coincident with high-energy neutrino IceCube-170922A." *Science* 361.6398 (2018): eaat1378.

Update to IceCube's Realtime Alert System

- Goals:
  - More neutrino alerts
  - Fewer retracted alerts
  - More user-friendly contents
- Changes:
  - New event selections
  - Gold and Bronze Streams
  - New parameters:
    e.g. Signalness

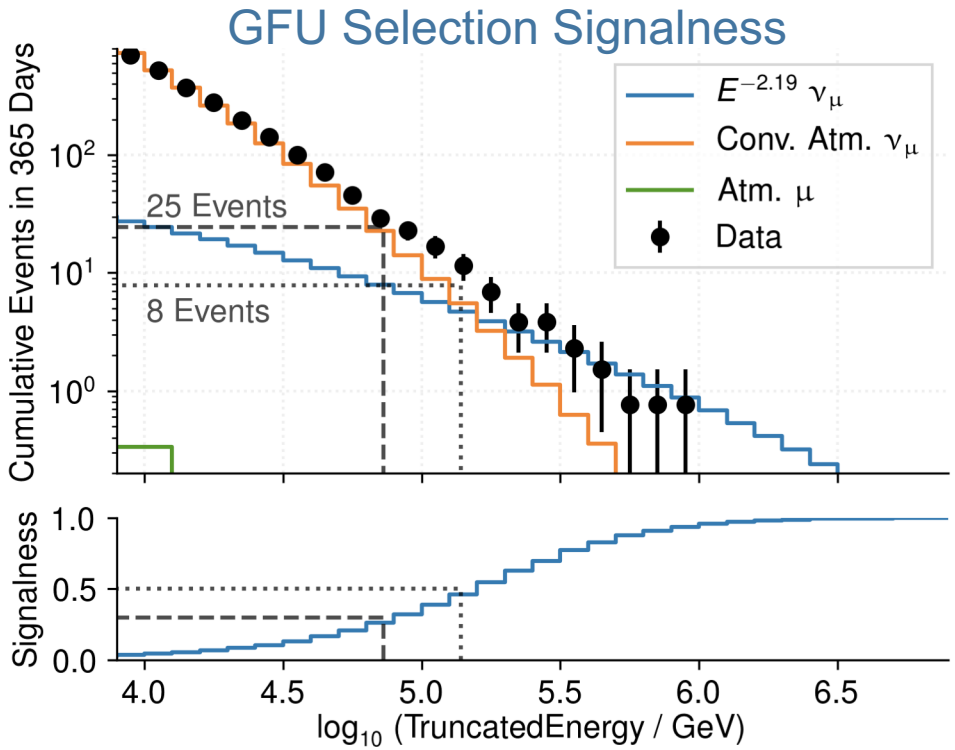


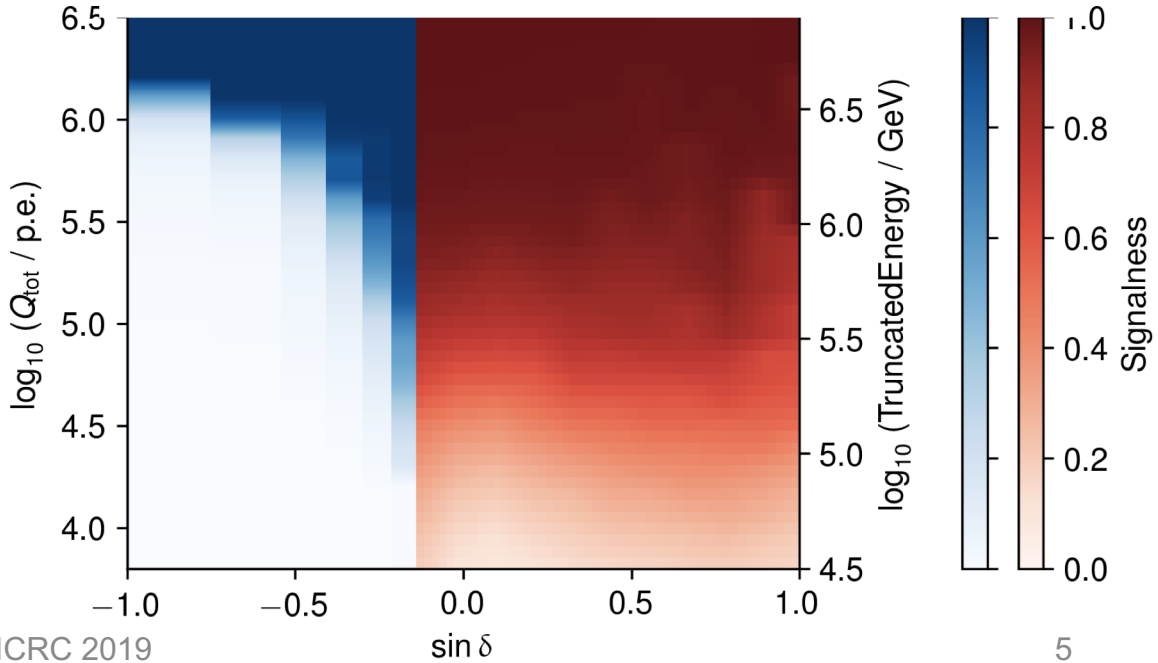
Signalness and Streams

$$Signalness = \frac{N_{astro\ \nu}(E;\delta)}{N_{astro\ \nu}(E;\delta) + N_{atm.\ background}(E;\delta)}$$

- Spectral index $\Gamma = -2.19$ for the reported value
- Selection based

- Signalness > 50% → Gold Stream
- 50% > Signalness > 30% → Bronze Stream

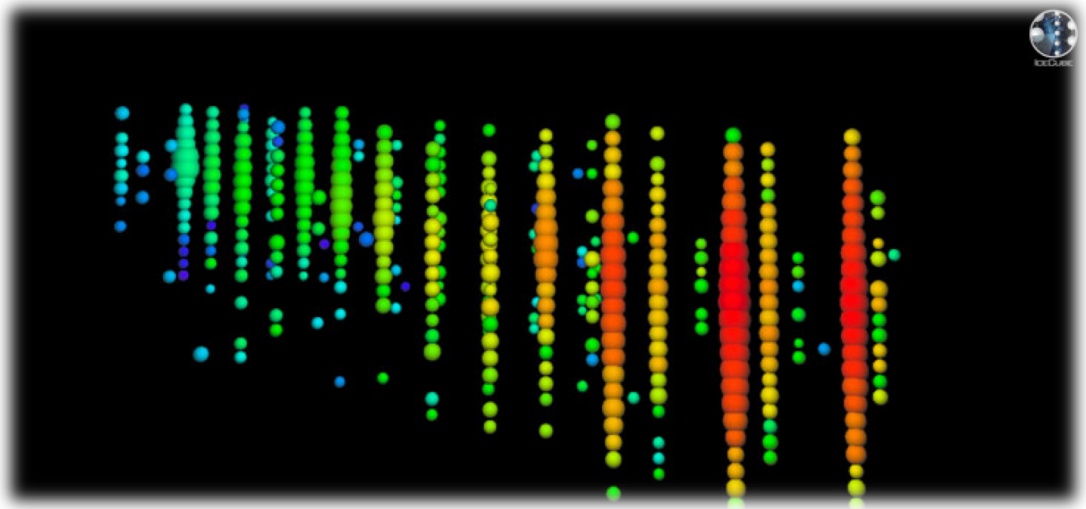


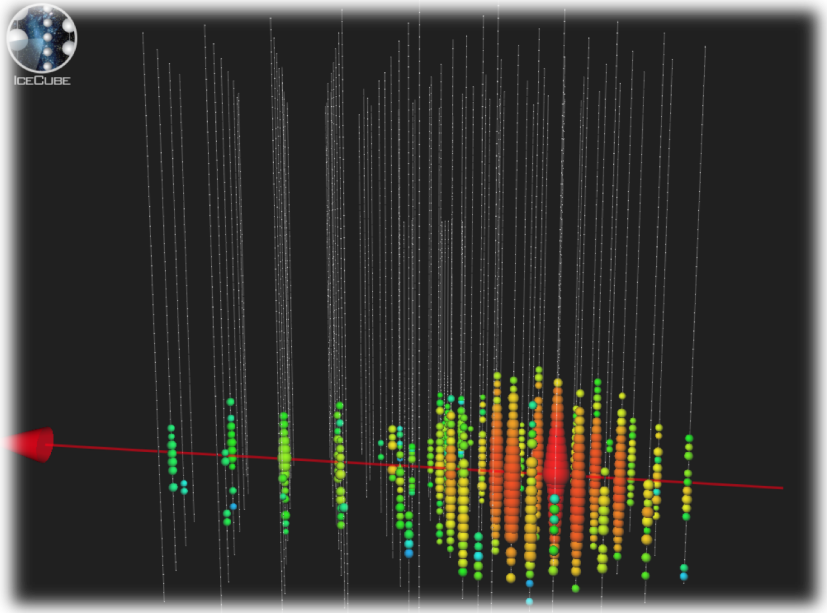


Event Selections

New

	GFU	EHE	HESE
Target	Through-going tracks		Starting tracks
Method	• Boosted Decision Trees • High energy (Northern) • High charge (southern)	• Large Number of Photoelectron (NPE) • Track reconstruction parameter	• Veto region • High charge • Long reconstructed track length





Expected Rate

	Gold	Bronze	Combined
Signal ($\Gamma = -2.19$)	• 6.6 /yr	• 2.8 /yr	• 9.4 /yr
Atmospheric Background	• 6.1 /yr	• 14.7 /yr	• 20.8 /yr

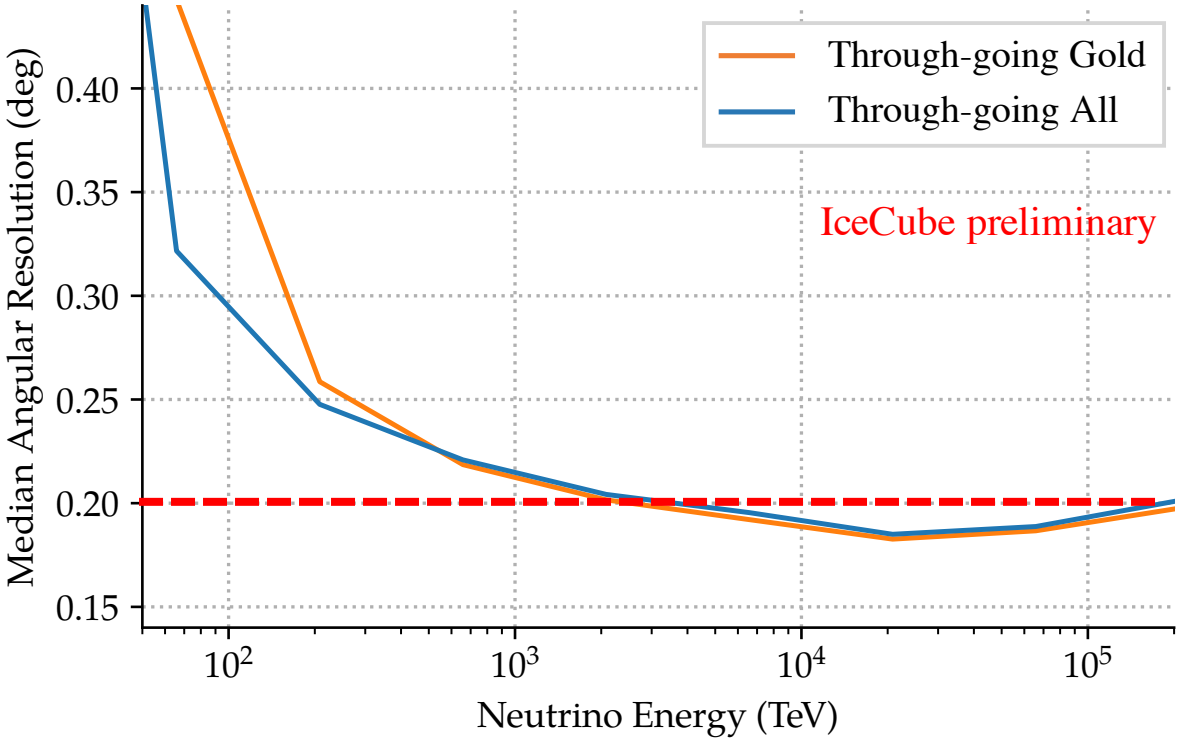
	Old System
Signal	• ~3.2 /yr
Atmospheric Background	• ~5.63 /yr

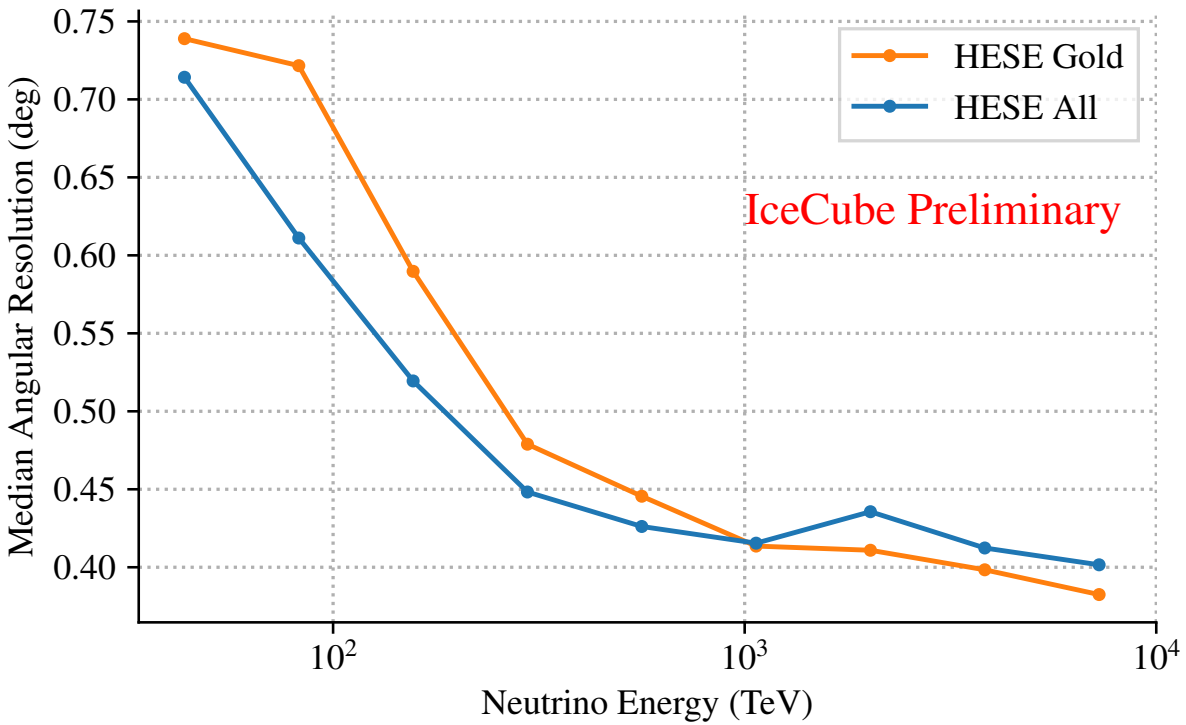
Observed Rate

	Gold	Bronze	Combined
Observed from Archival Data	• 9.9 /yr	• 19.5 /yr	• 29.4 /yr

Angular Resolution

Statistics only. No systematics.



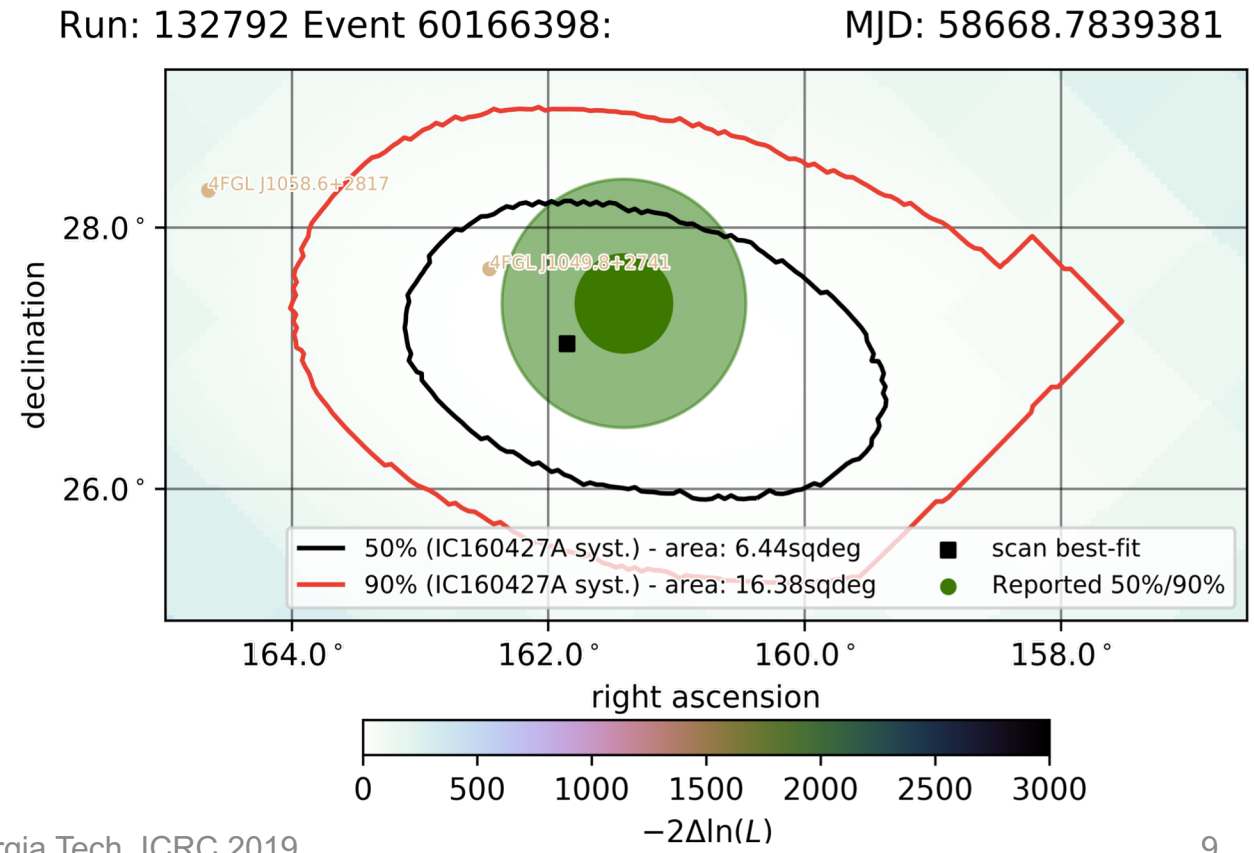


For GFU, a minimum of 0.2 deg is imposed for the median angular uncertainty

Old Realtime Alert System:
Through-going Track: 0.22 deg
Starting Track: 0.55 – 1.6 deg

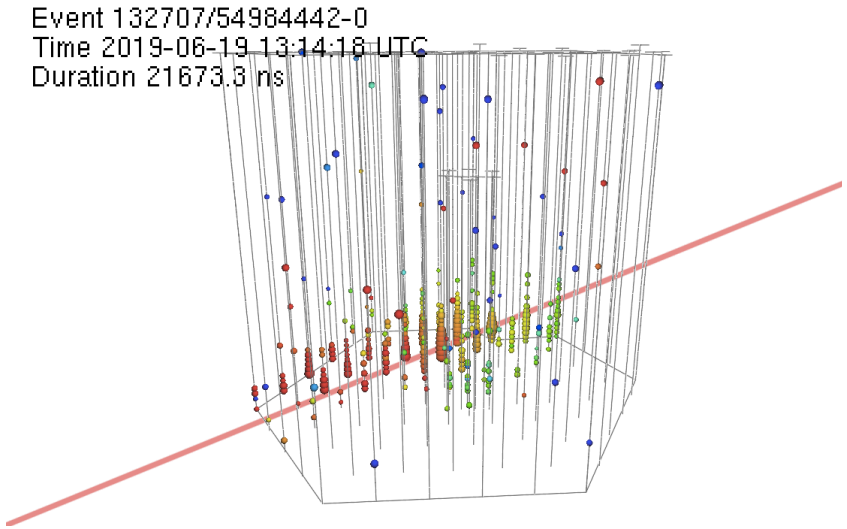
Information Distribution

- First notice sent out through GCN Notice
- Refined direction and error after a few hours
  - Similar to treatment for IC170922A
  - Sent out GCN Notice and GCN Circular
- Verified by human

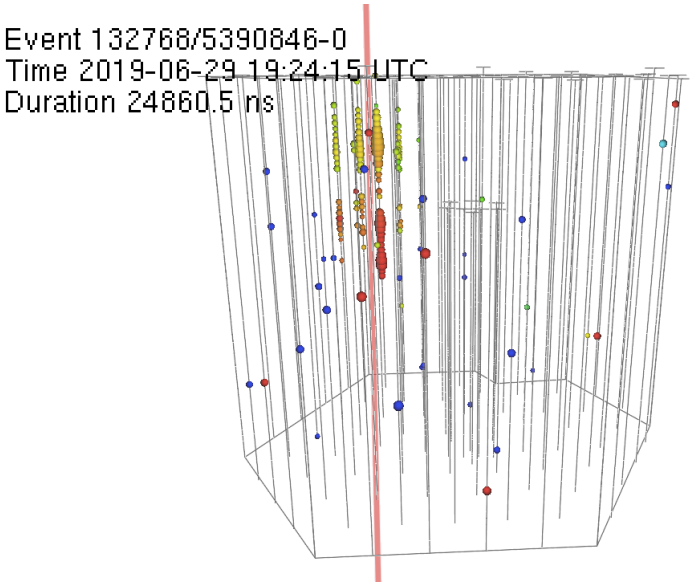


Operation

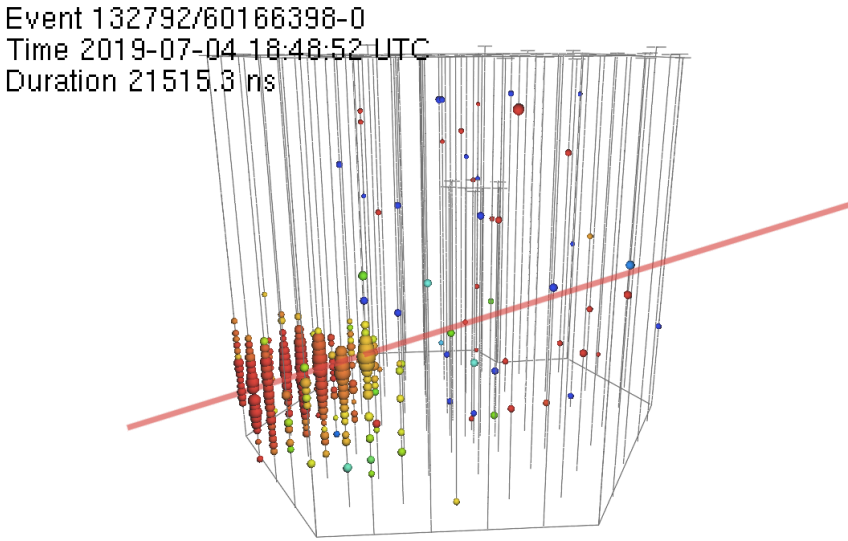
- Upgrade implemented on 17th June
- To date: 1 Gold, 4 Bronze alerts



IC190619A – Gold GFU
- Neutrino energy = 198 TeV
- Signalness ~ 54%



IC190629A – Bronze GFU
- Neutrino energy = 107 TeV
- Signalness ~ 33%



IC190704A – Bronze GFU
- Neutrino energy = 155 TeV
- Signalness ~ 49%

Summary

- The IceCube Realtime Neutrino Alert System has been updated
- New Selection
- About 30 alerts per year in total
- New content in alerts
- Expect refined information in a few hours

Photo credit:
Sam Fahey

- More info: https://gcn.gsfc.nasa.gov/amon_icecube_gold_bronze_events.html

Thank You!

Extra

Alert GCN Notice Content

```
////////////////////////////////////////////////////////////////////
TITLE:            GCN/AMON NOTICE
NOTICE_DATE:      Wed 19 Jun 19 13:14:44 UT
NOTICE_TYPE:      ICECUBE Astrotrack Gold
STREAM:           24
RUN_NUM:          132707
EVENT_NUM:        54984442
SRC_RA:           342.7772d {+22h 51m 07s} (J2000),
                  343.0209d {+22h 52m 05s} (current),
                  342.1514d {+22h 48m 36s} (1950)
SRC_DEC:          +10.0547d {+10d 03' 17"} (J2000),
                  +10.1583d {+10d 09' 30"} (current),
                   +9.7892d {+09d 47' 21"} (1950)
SRC_ERROR:        40.28 [arcmin radius, stat-only, 90% containment]
SRC_ERROR50:      15.69 [arcmin radius, stat-only, 50% containment]
DISCOVERY_DATE:   18653 TJD;   170 DOY;   19/06/19 (yy/mm/dd)
DISCOVERY_TIME:   47658 SOD {13:14:18.04} UT
REVISION:         0
ENERGY:           1.9870e+02 [TeV]
SIGNALNESS:       5.4551e-01 [dn]
FAR:              0.9829 [yr^-1]
SUN_POSTN:         87.81d {+05h 51m 14s}  +23.42d {+23d 25' 15"}
SUN_DIST:          99.23 [deg]   Sun_angle= 7.0 [hr] (West of Sun)
MOON_POSTN:       295.38d {+19h 41m 32s}  -22.05d {-22d 02' 42"}
MOON_DIST:         56.73 [deg]
GAL_COORDS:        80.71,-42.74 [deg] galactic lon,lat of the event
ECL_COORDS:       348.11, 16.03 [deg] ecliptic lon,lat of the event
COMMENTS:         IceCube Gold event.
COMMENTS:         The position error is statistical only, there is no systematic added.
```

Gold or Bronze

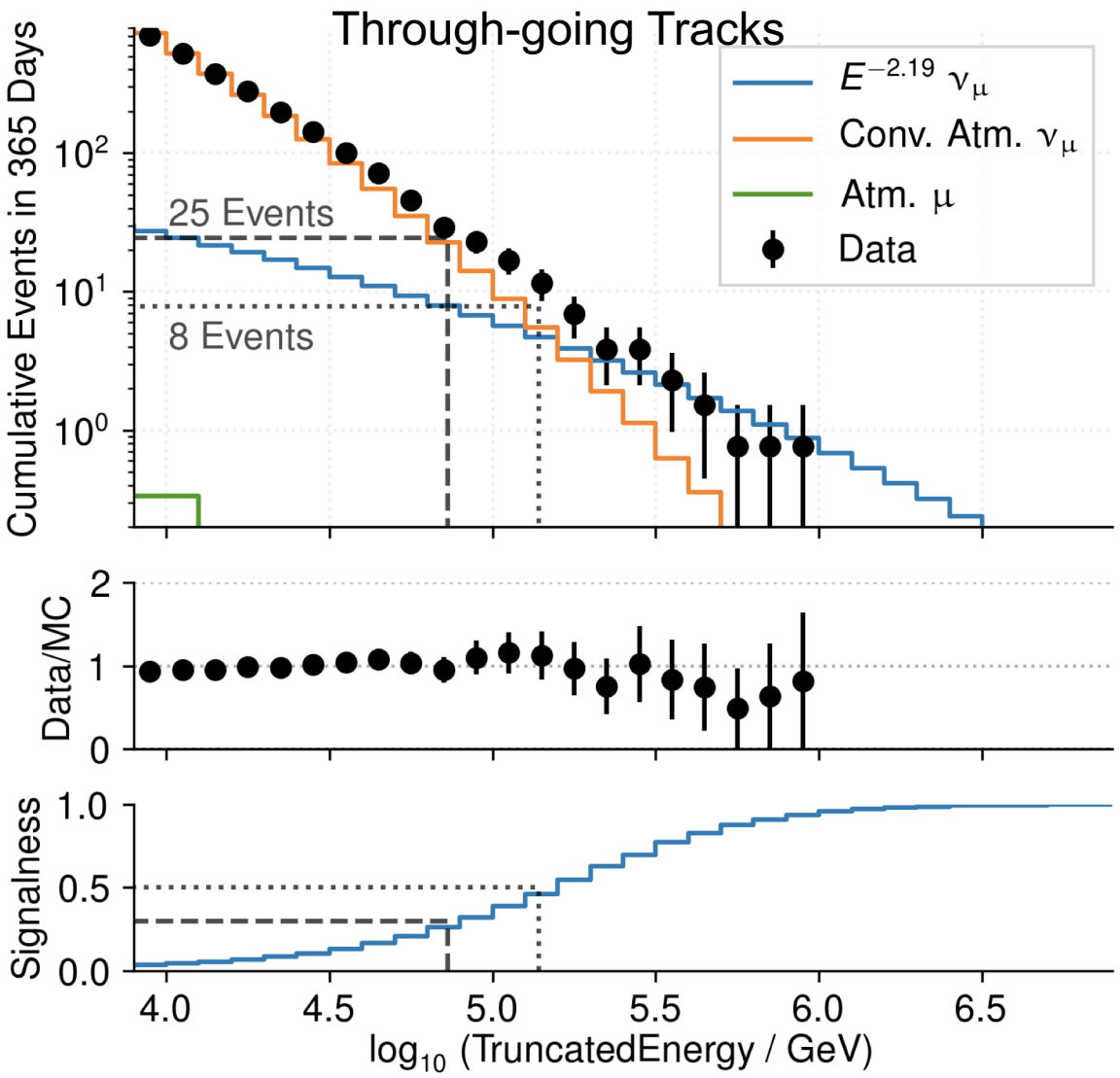
Source position

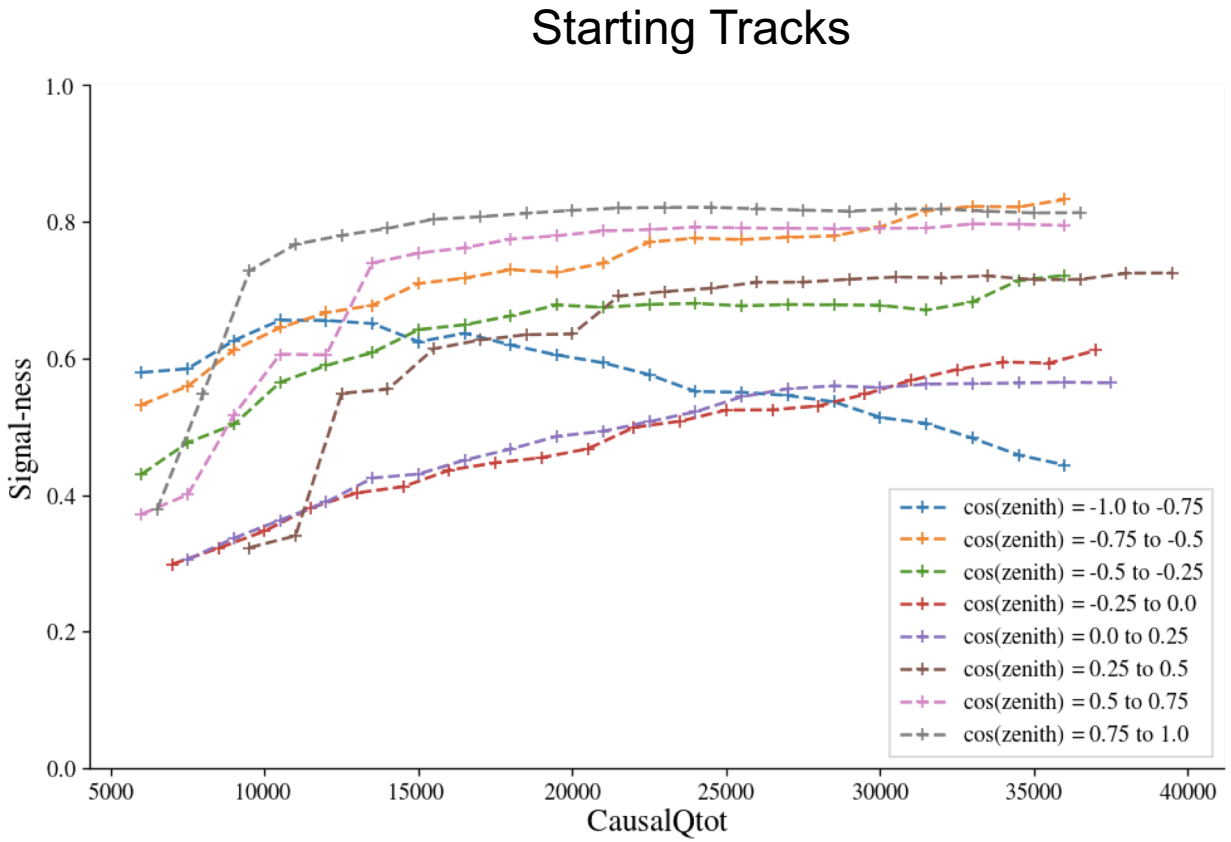
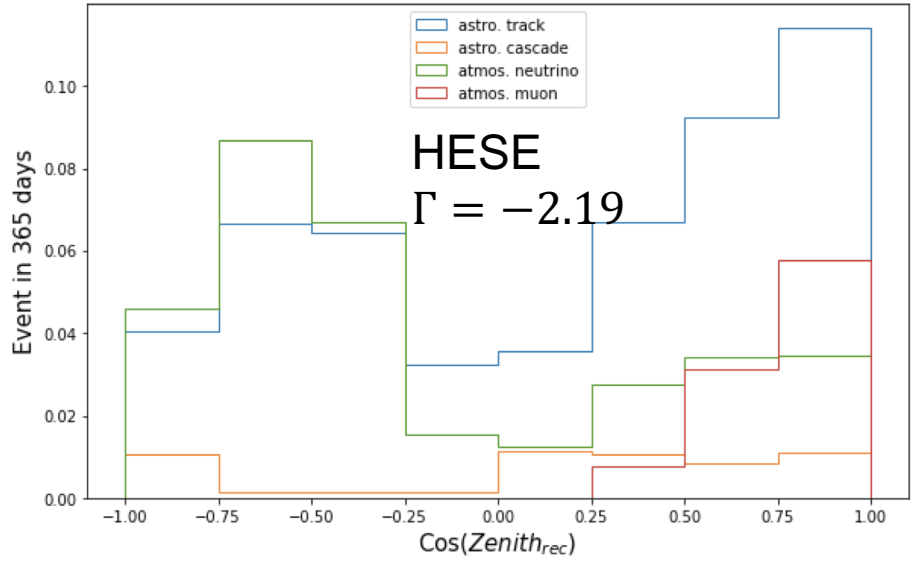
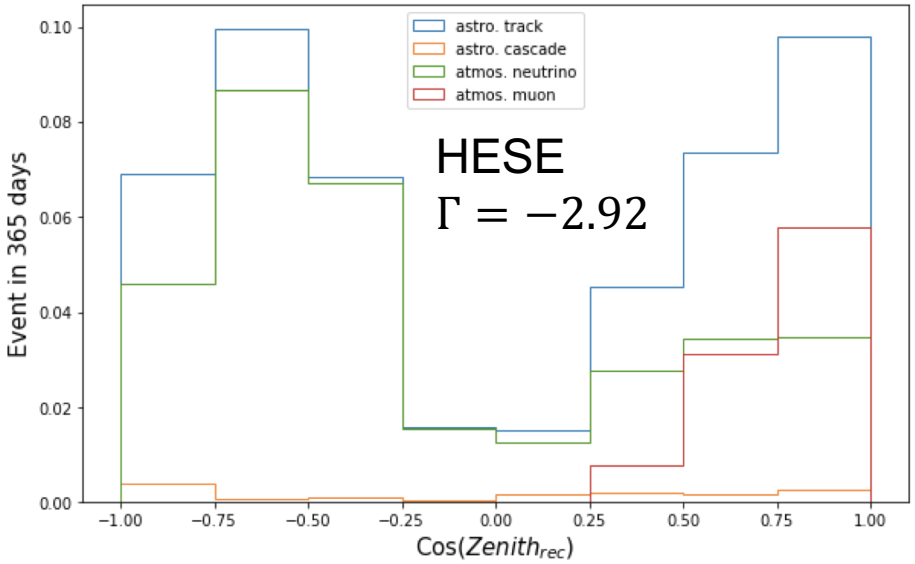
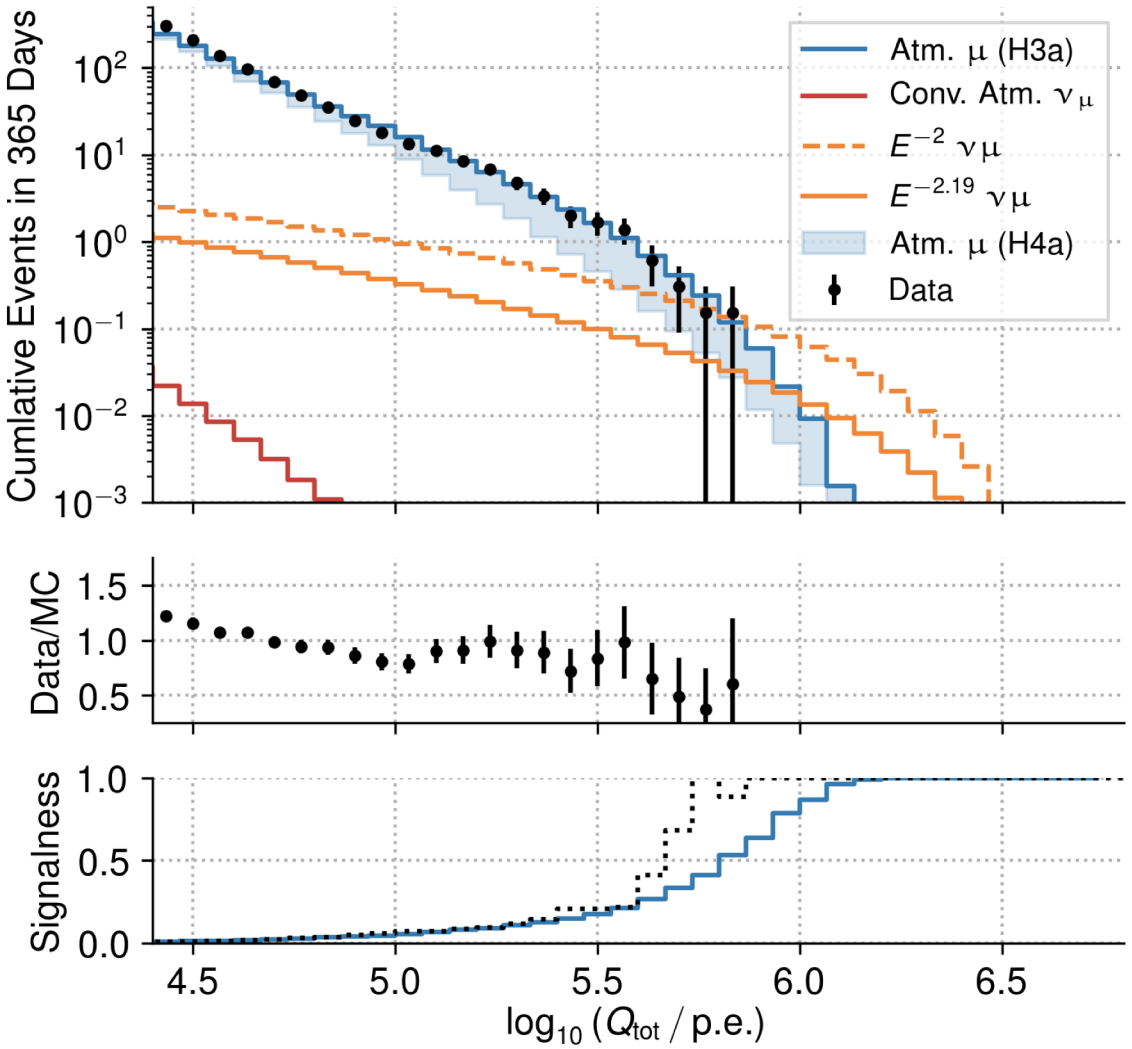
Position error, symmetric

Neutrino energy, $\Gamma = -2.19$

FAR: rate of observing a similar event

More on Signalness





Effect of Spectral Index on Signalness