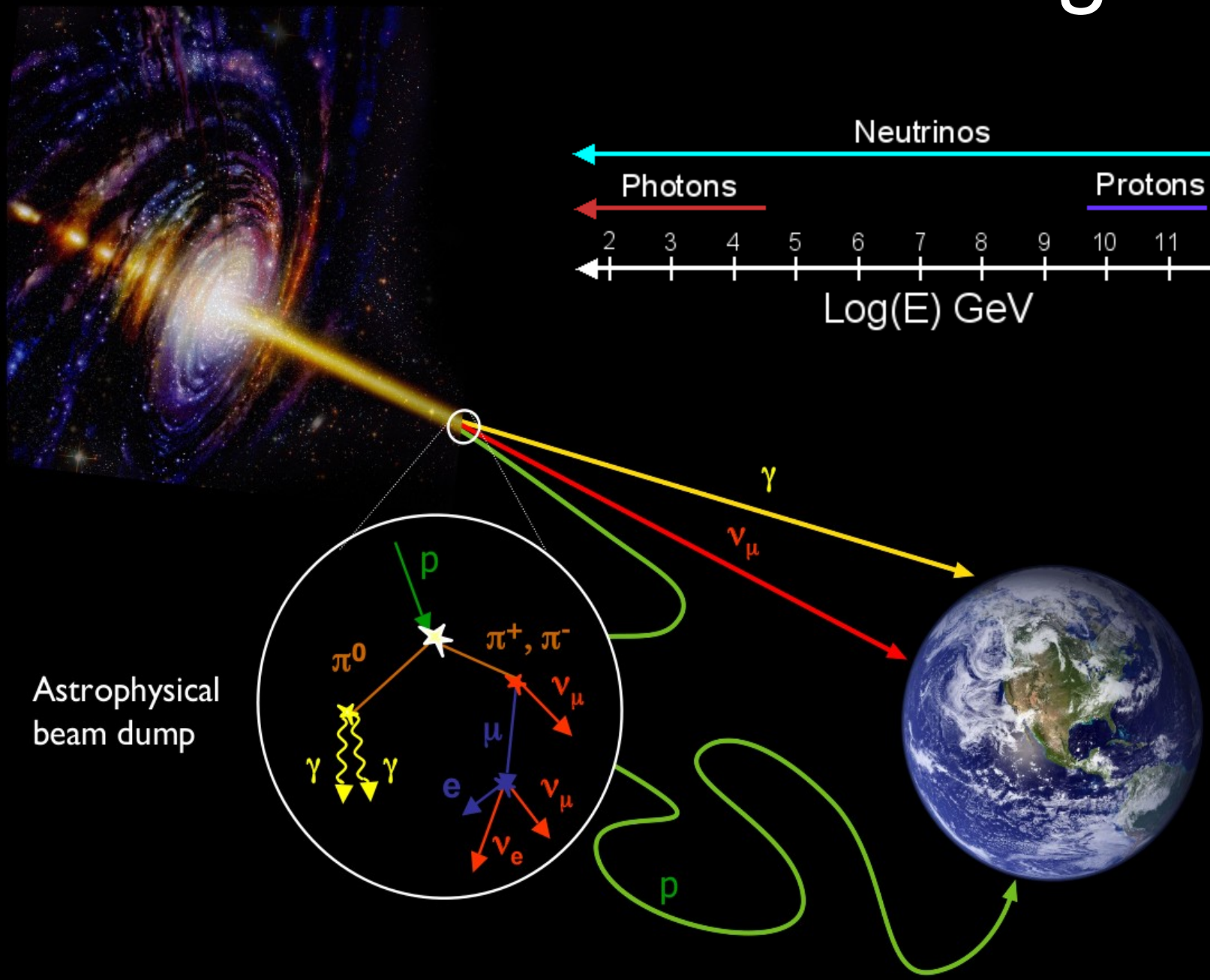
Searches for Neutrino Point Sources with AMANDA-II and IceCube

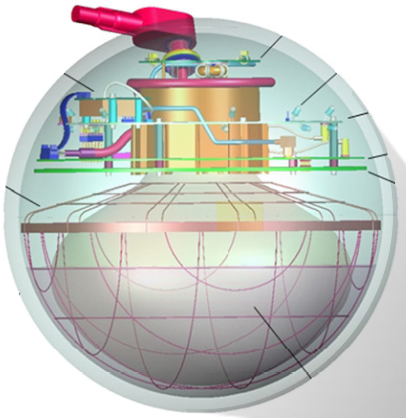
Jim Braun for the IceCube Collaboration

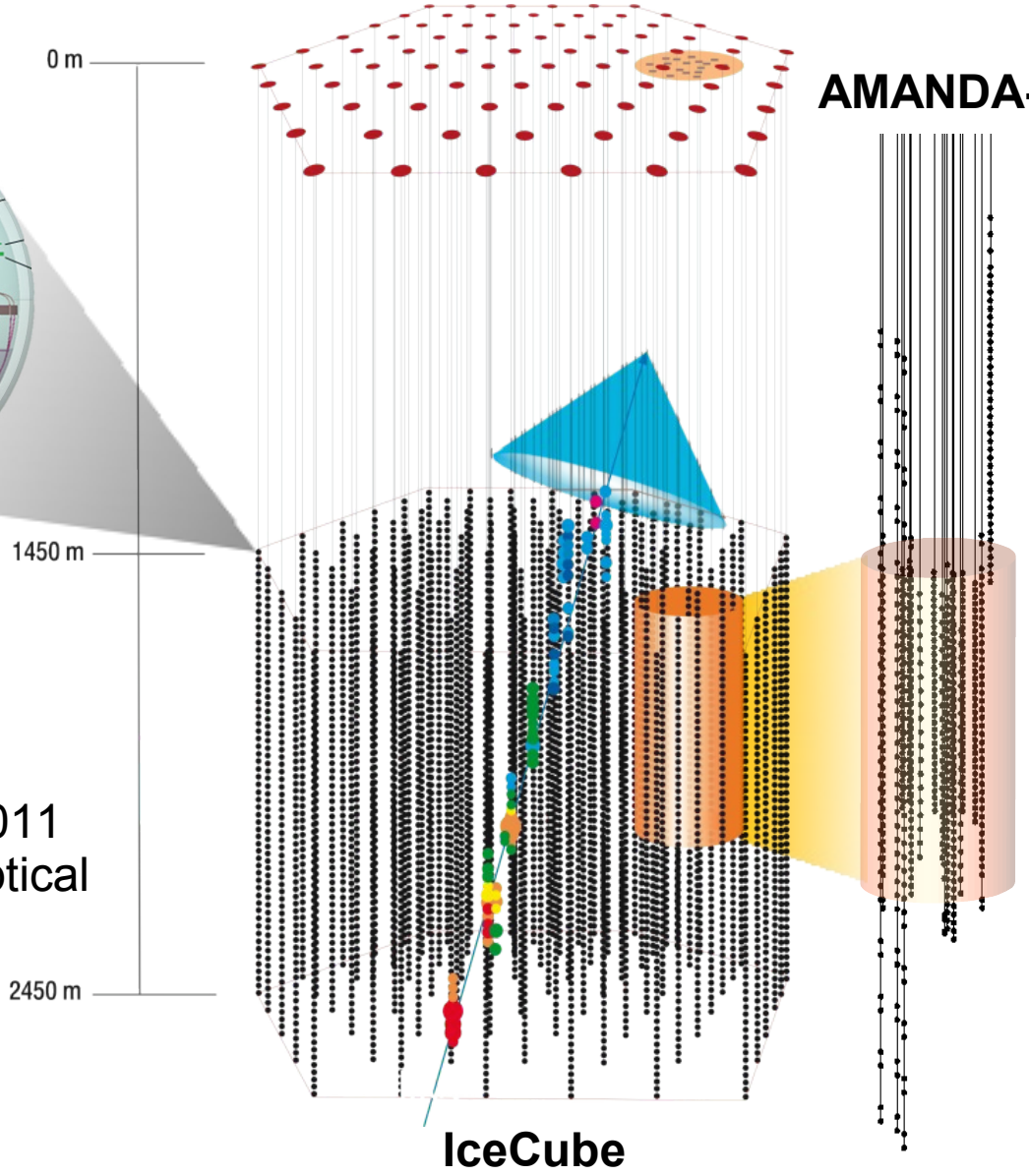
Cosmo 2008

Astronomical Messengers



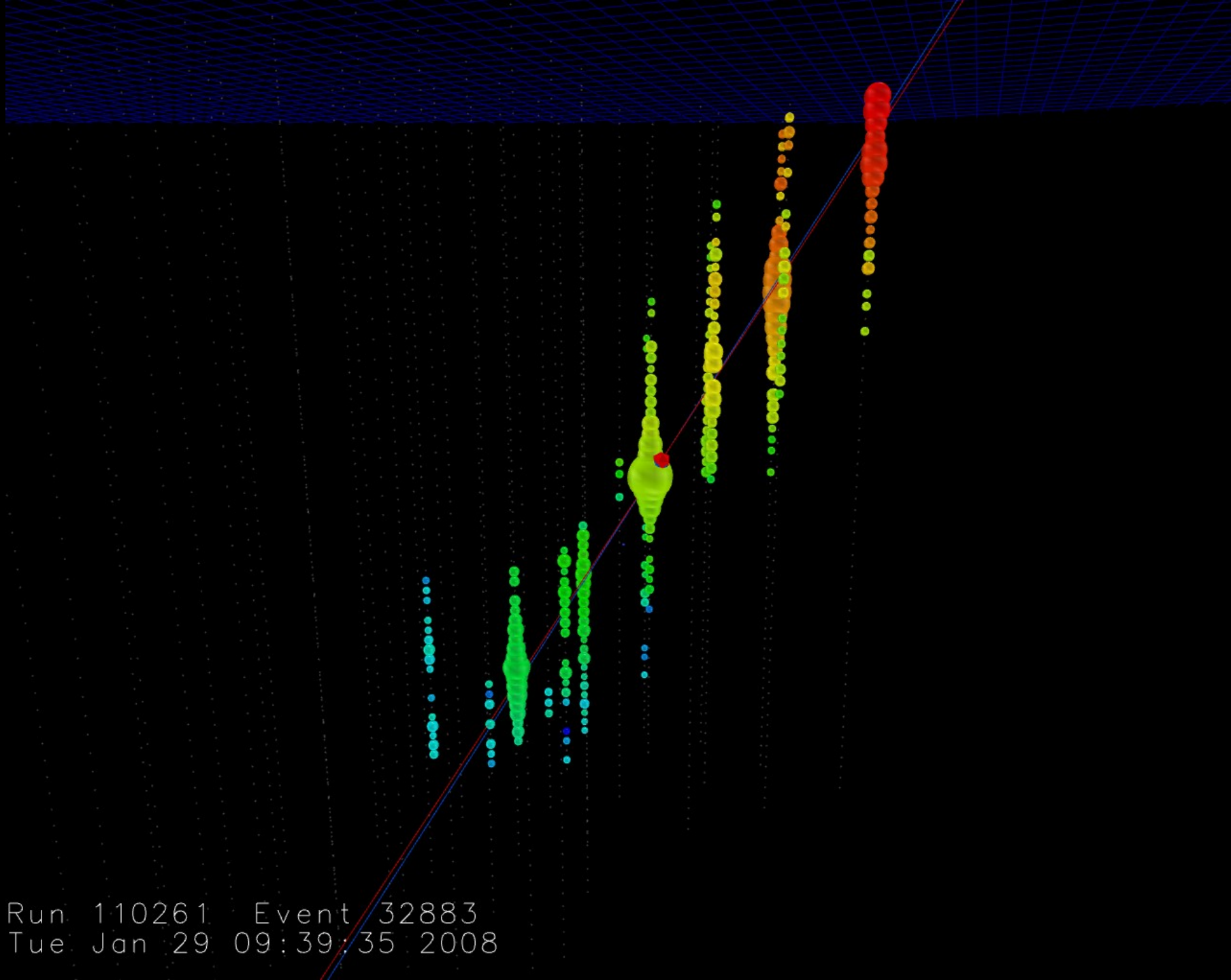
IceCube



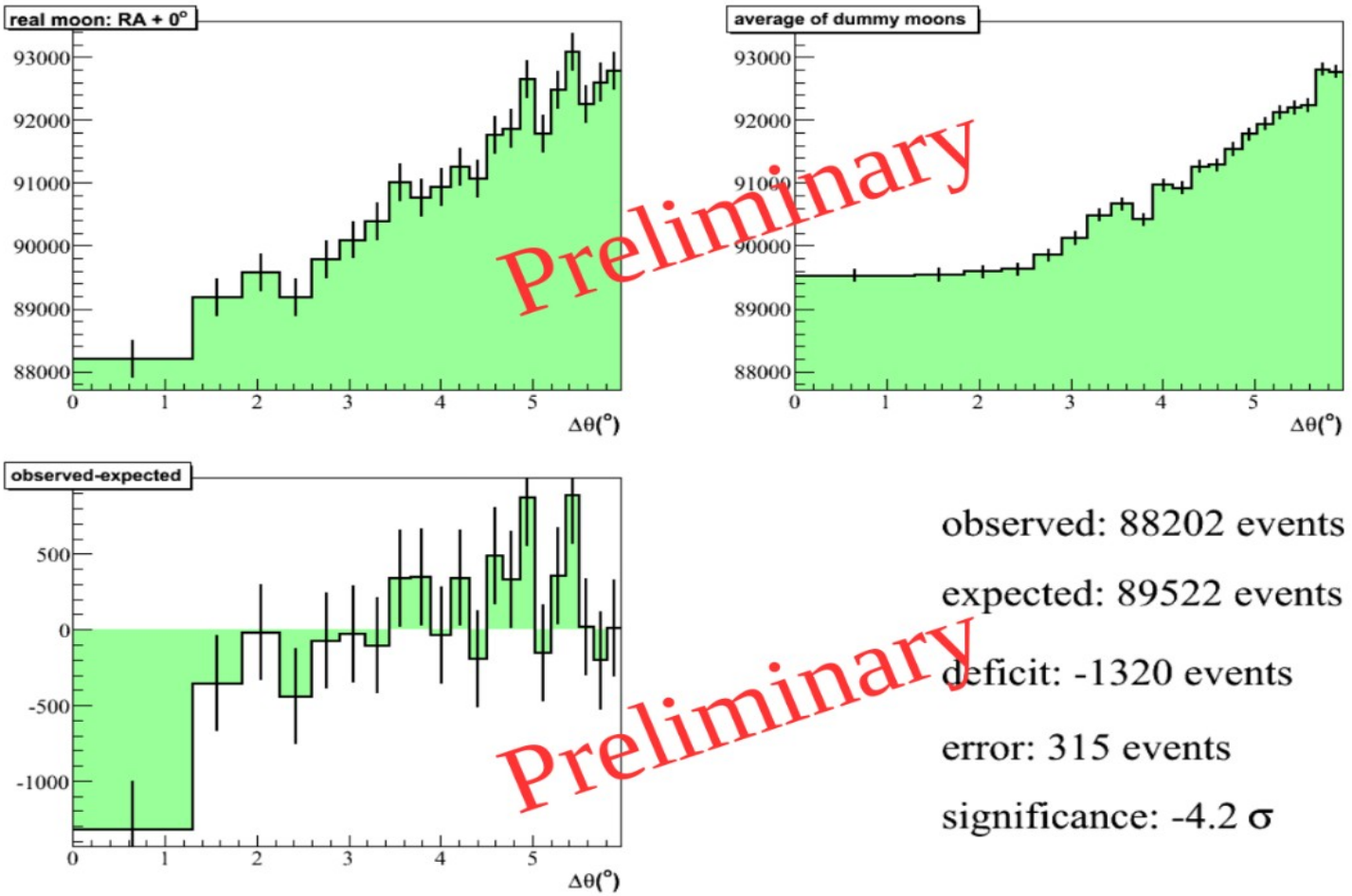


- 40 of 86 strings complete
- Completion in 2011 (>5000 digital optical modules)

- 19 strings
- 677 total optical modules

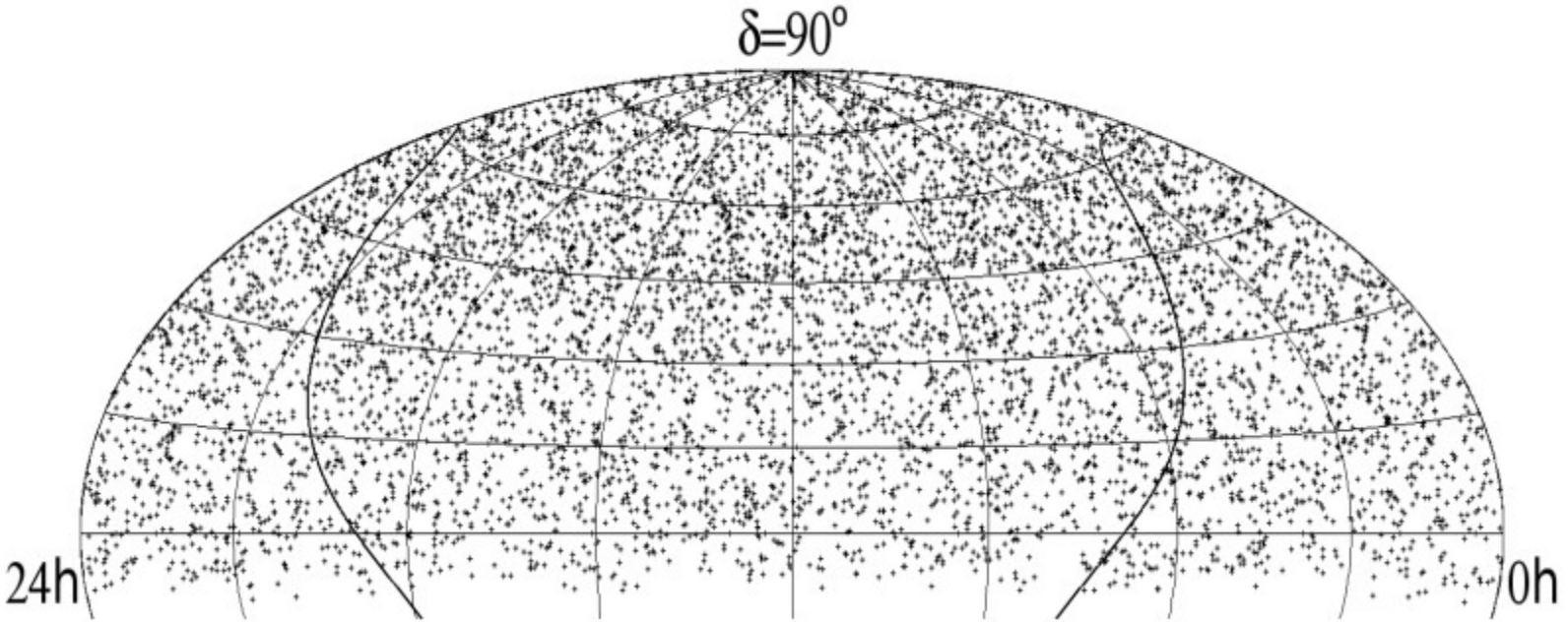

Run 110261 Event 32883
Tue Jan 29 09:39:35 2008

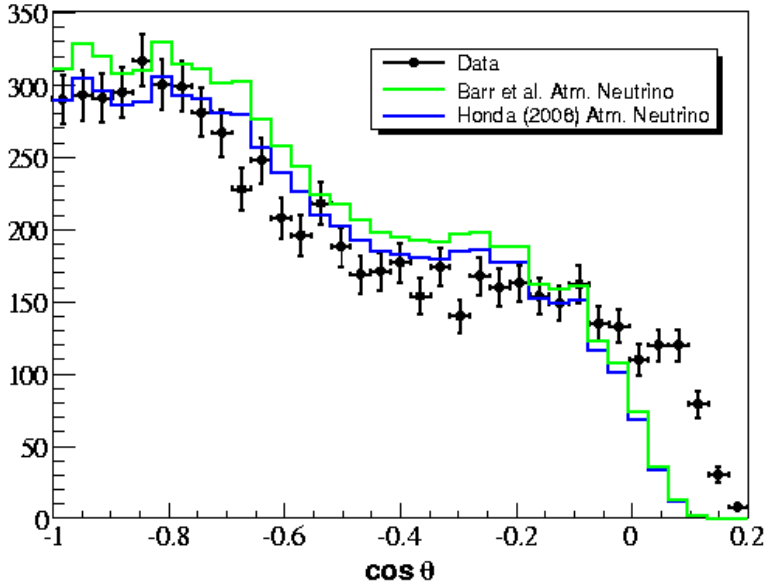
Moon Shadow



- IceCube observes the cosmic ray shadow of the moon at 4.2σ
  - Poster by Laura Gladstone

AMANDA-II Sky Map

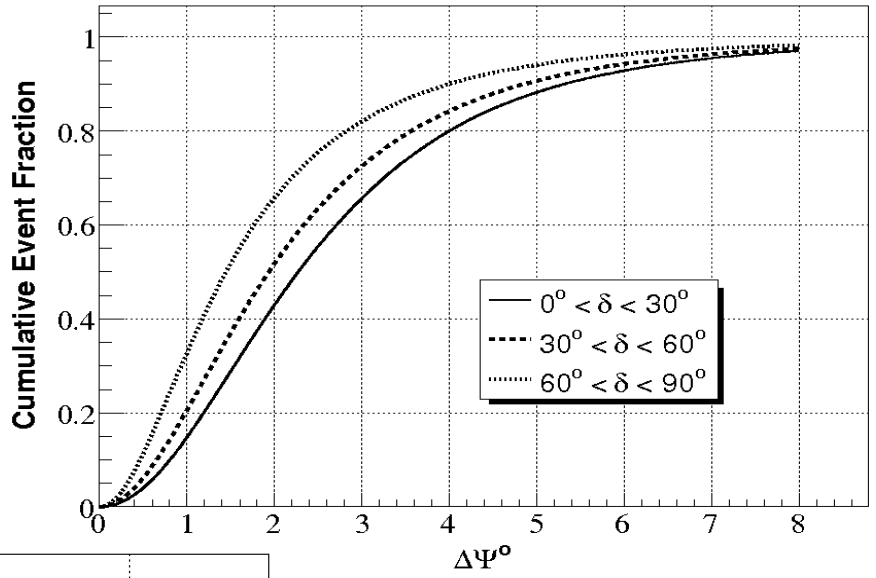


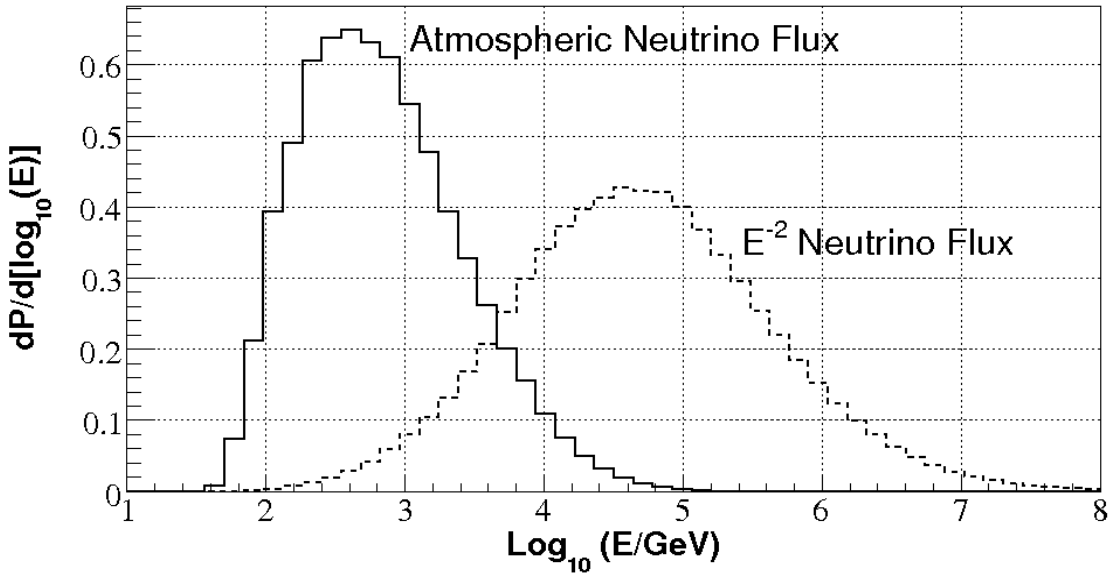


- 6595 neutrino candidates selected from O(10^{10}) events obtained during 2000-2006 (3.8 years livetime)
- Mostly atmospheric neutrinos

Search for Extraterrestrial Neutrinos

- Atmospheric neutrinos are the main background
- Search for excesses:
  - Direction
  - Event Energy

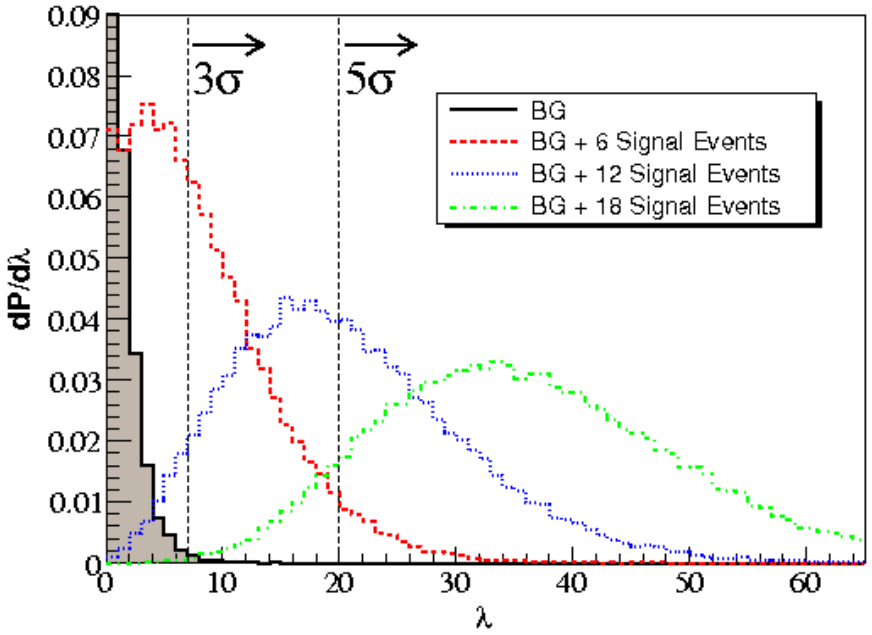


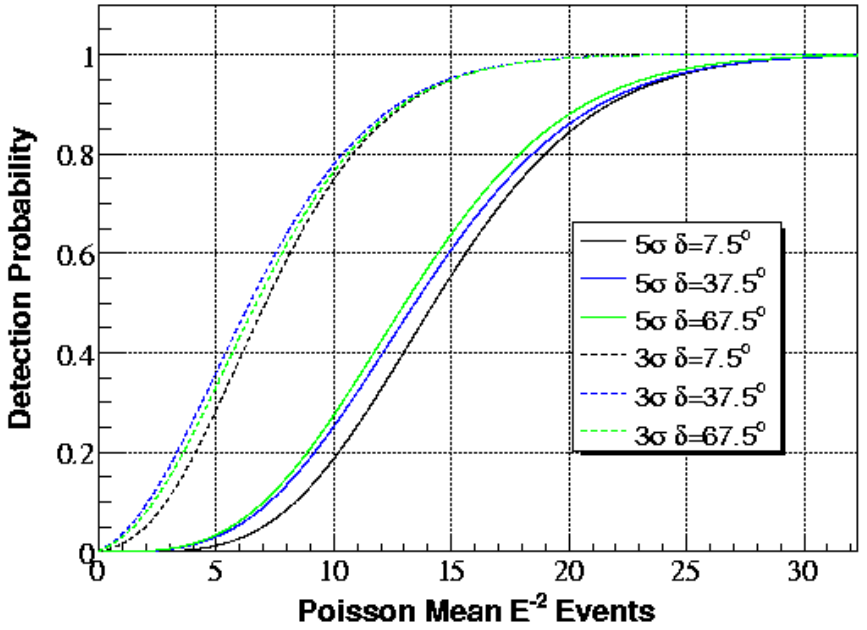


Search for Extraterrestrial Neutrinos

- Use unbinned maximum-likelihood search method
  - Incorporate event angular resolution and event energy estimate

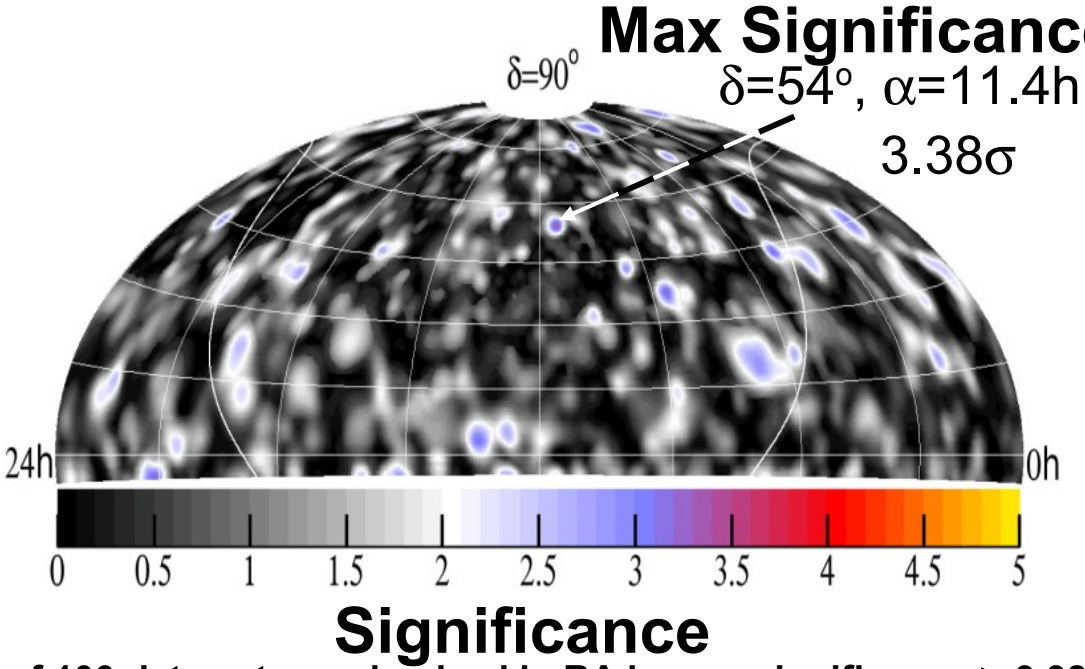
$$\mathcal{L}(\vec{x}_s, n_s, \gamma) = \prod_{i=1}^{N} \left(\frac{n_s}{N} \mathcal{S}_i + (1 - \frac{n_s}{N}) \mathcal{B}_i \right) \qquad \lambda = -2 \cdot sign(\hat{n}_s) \cdot log \left[\frac{\mathcal{L}(\vec{x}_s, 0)}{\mathcal{L}(\vec{x}_s, \hat{n}_s, \hat{\gamma})} \right]$$





Astropart. Phys. **29**, 299 (2008)

All-Sky Search



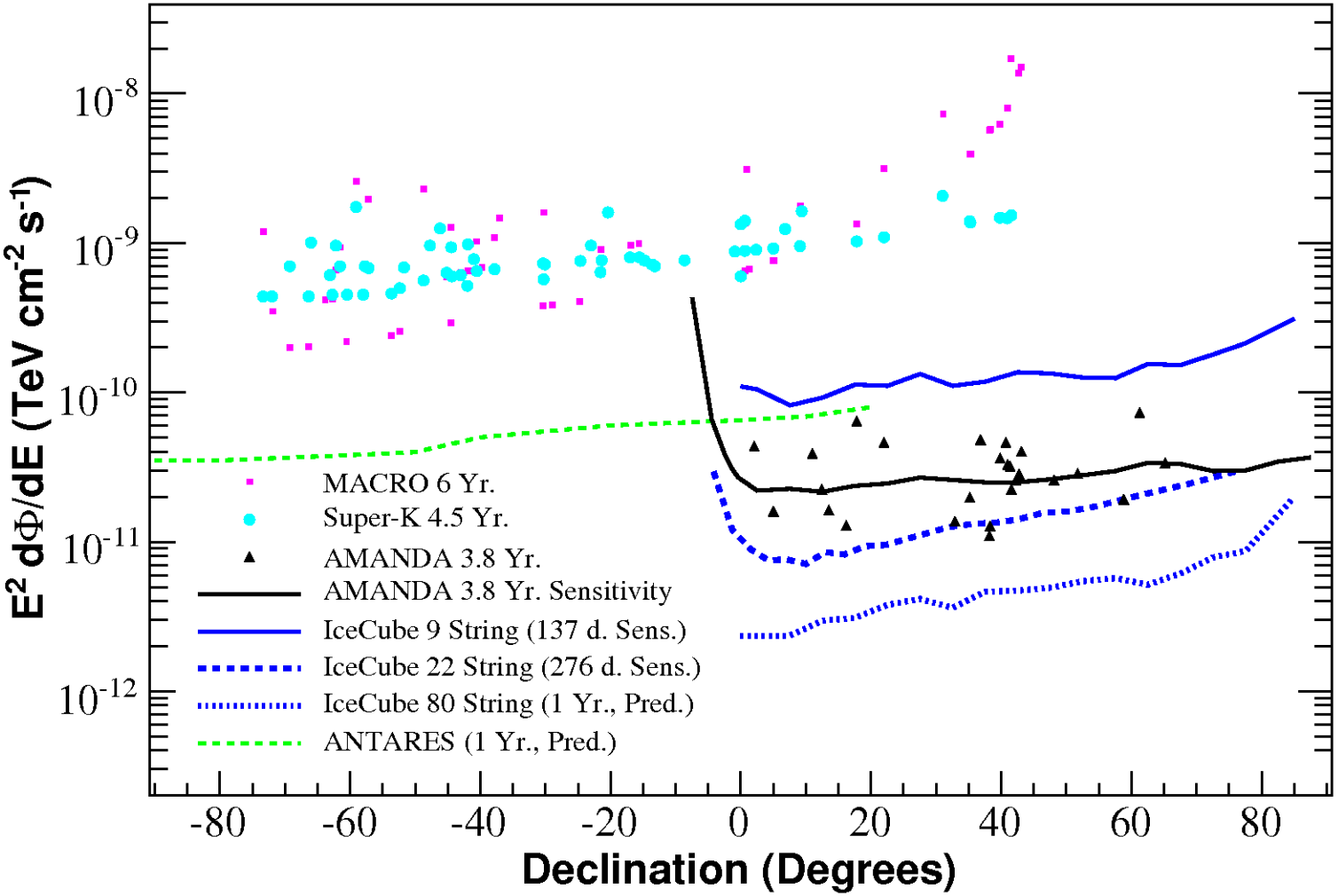
95 of 100 data sets randomized in RA have a significance ≥ 3.38σ

Source	μ_{90}	P-value
Crab	9.27	0.10
MGRO J2019+37	9.67	0.077
Mrk 421	2.54	0.82
Mrk 501	7.28	0.22
LS I +61 303	14.74	0.03
Geminga	12.77	0.0086

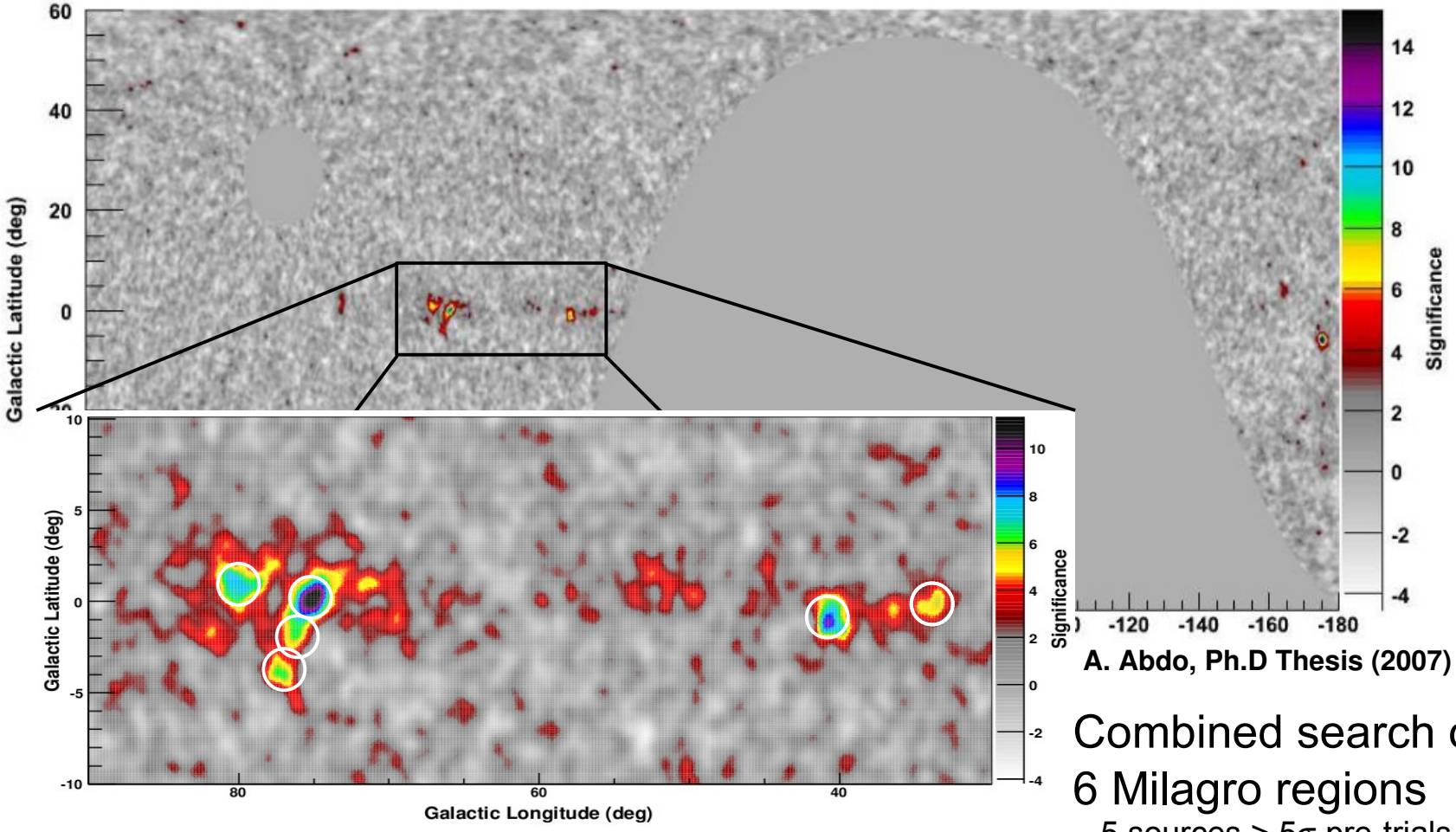
$E^2\Phi < \mu 90 * 10^{-11}$ TeV cm^{-2} s^{-1}

The probability of obtaining p ≤ 0.0086 for at least one of the 26 sources is 20%

Experimental Limits



Milagro Stacking

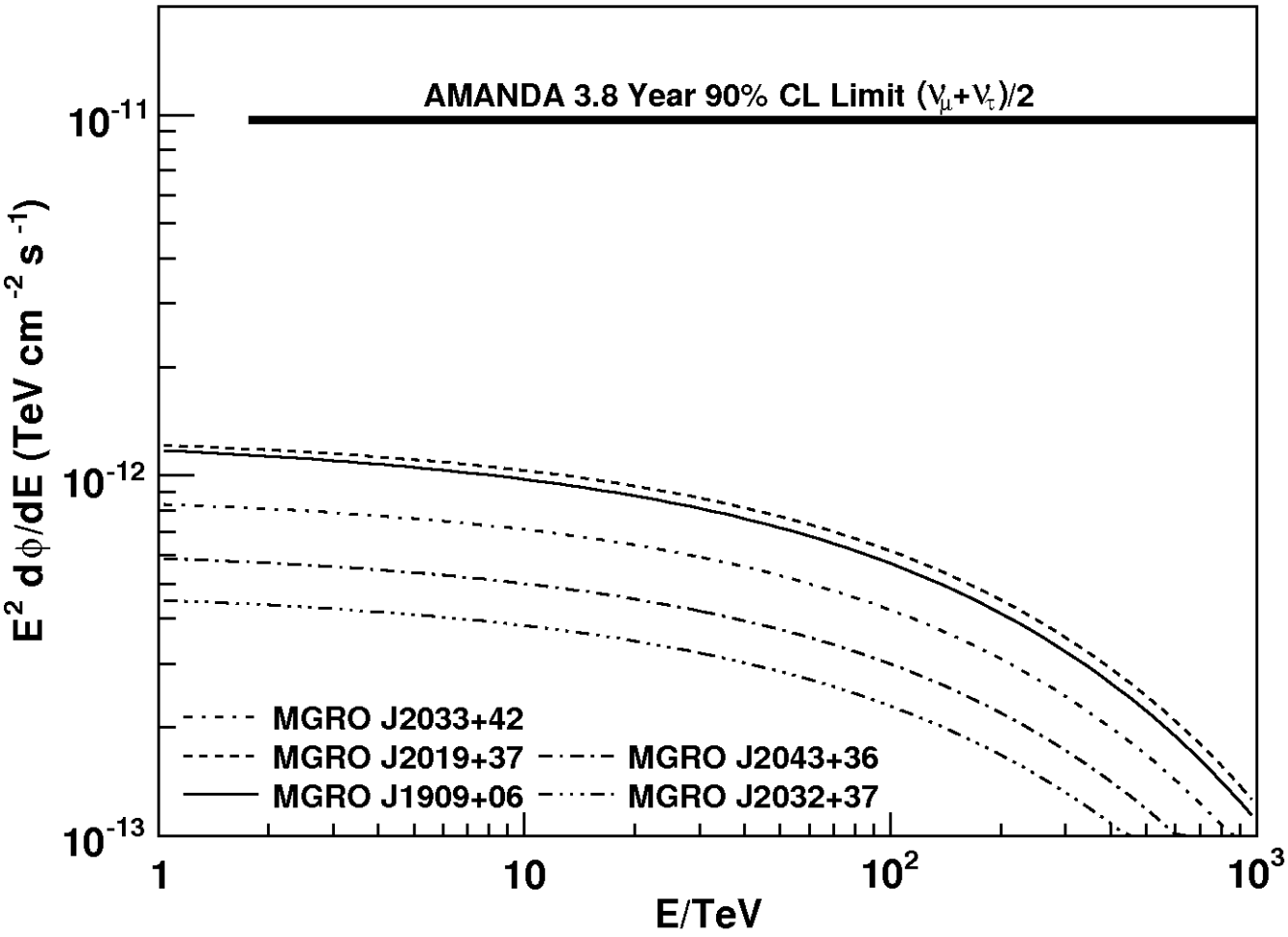


Combined search over 6 Milagro regions

5 sources > 5σ pre-trials

- Improves per-source flux sensitivity and discovery potential by a factor of 4 compared to a fixed-point search for any of the six sources

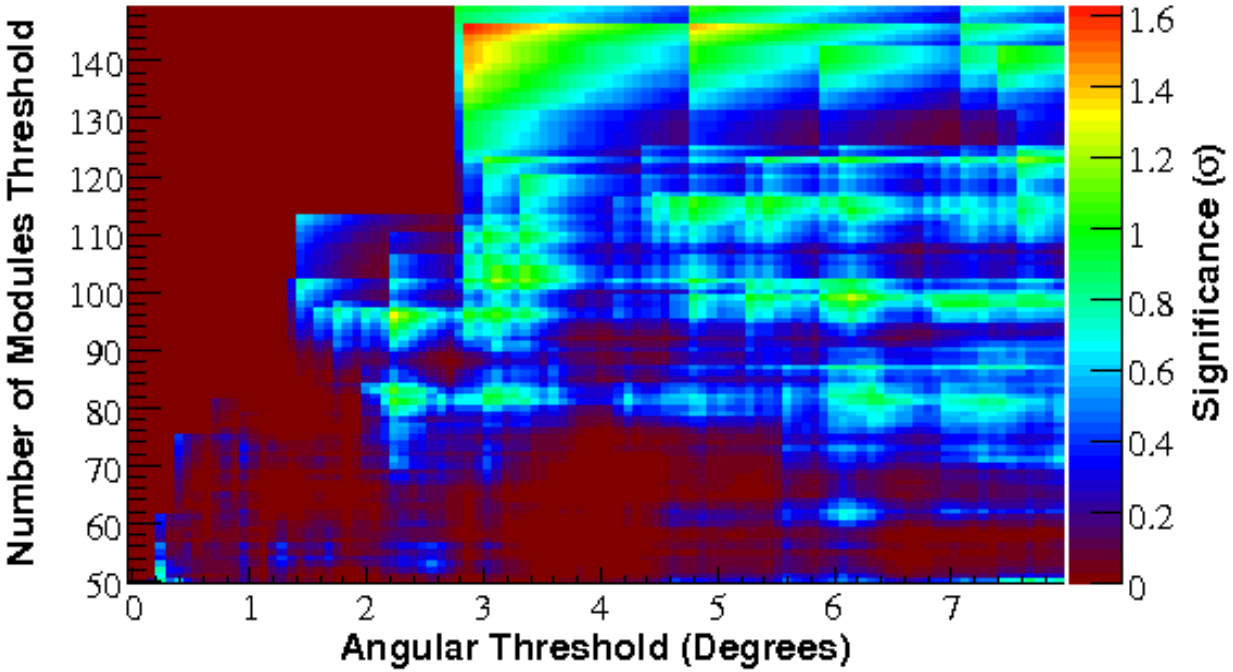
Milagro Stacking



Halzen, Kappes, O'Murchada [arXiv:0803.0314]

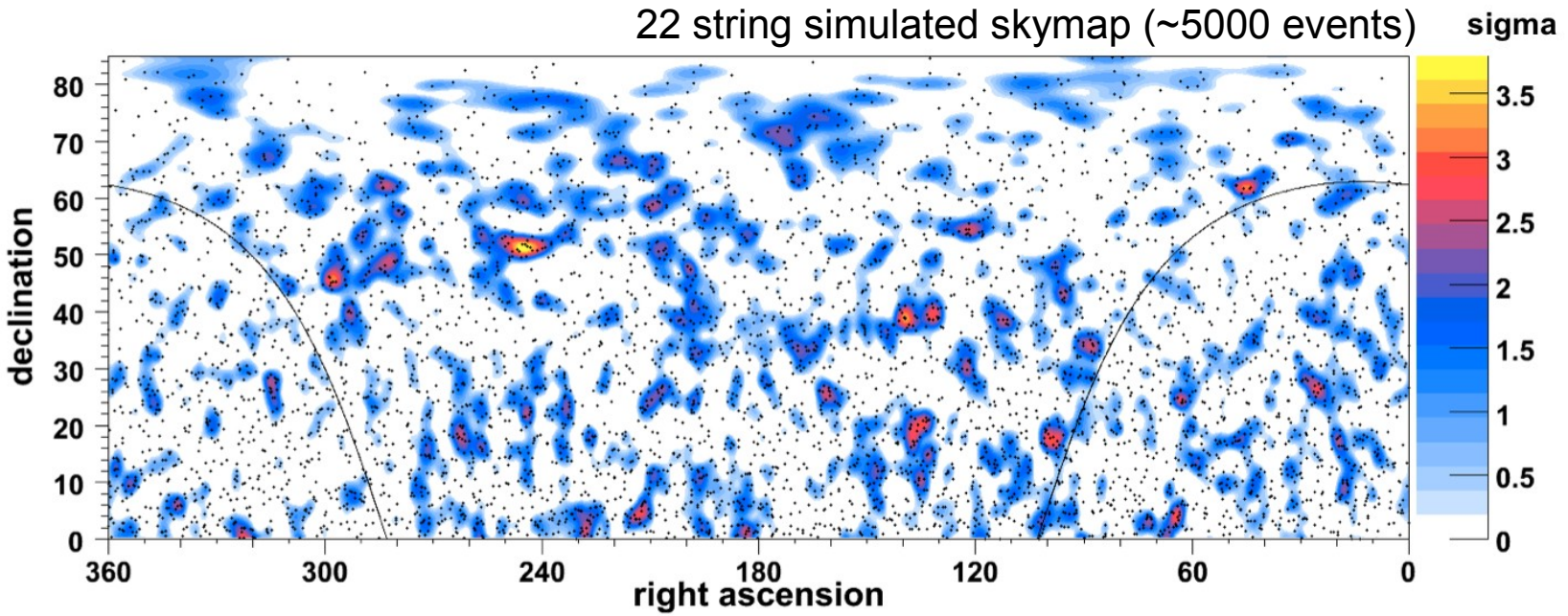
Search for Event Autocorrelations

- Search for event clustering at angular scales comparable to detector resolution
  - Signal scenario: A number of small event clusters
- Method: Count the number of event pairs given a maximum angular separation and minimum Nch and compare to distributions from data with randomized RA



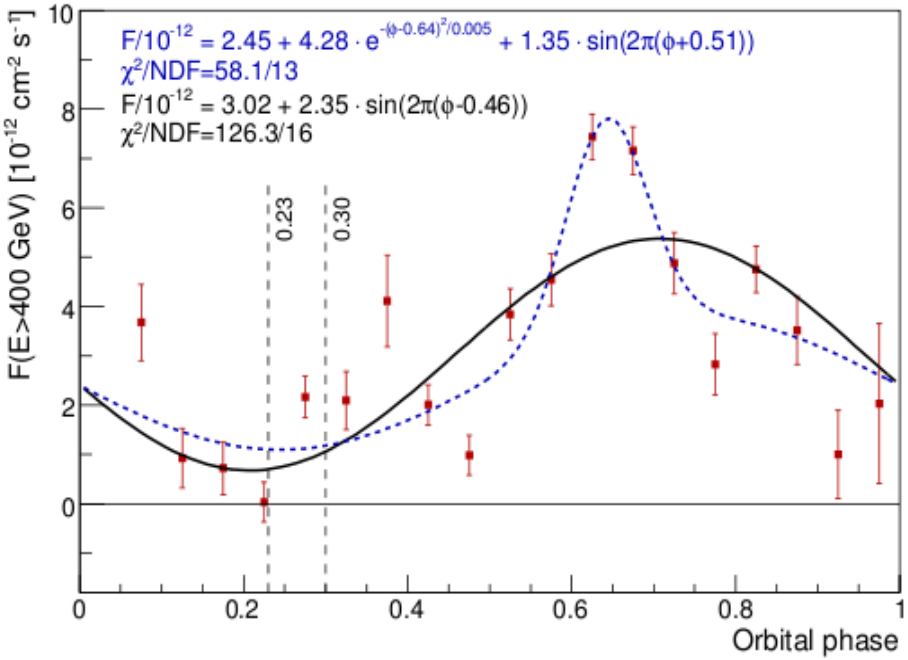
- Max significance: 1.6σ
- 99 out of 100 sets of randomized data have a max significance of 1.6σ or greater

IceCube



- 22 string IceCube analysis nearly complete
- Current 40 string configuration improves angular resolution and sensitivity

Time-Dependent Searches



J. Albert et al. arXiv:0806.1865v1

- Use time dependence to improve signal-to-noise
  - Periodic analysis for LS I +61 303
  - Multi-messenger Approach
    - Look for correlations with gamma ray flares

Conclusions

- No evidence of neutrino point sources observed by AMANDA in 3.8 years of livetime.
  - Currently the most stringent flux limits
- 22 string IceCube analysis will improve this sensitivity by a factor of 2
- Further IceCube construction should yield an order of magnitude improvement in sensitivity within a few years