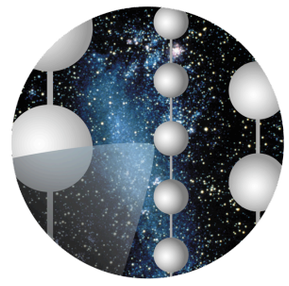
Recent Results from IceCube and AMANDA

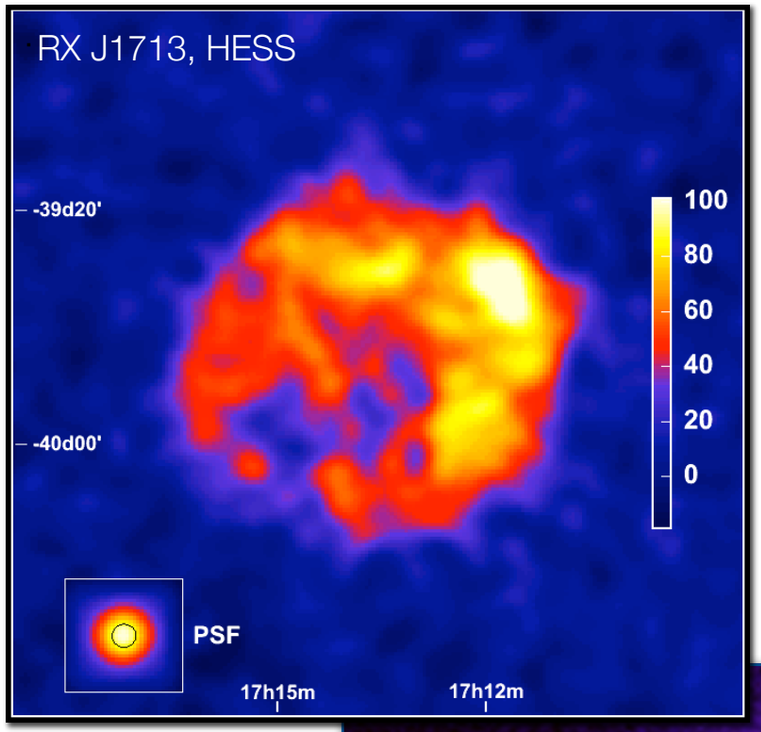


Tyce DeYoung
Department of Physics, Center for Particle Astrophysics
Pennsylvania State University

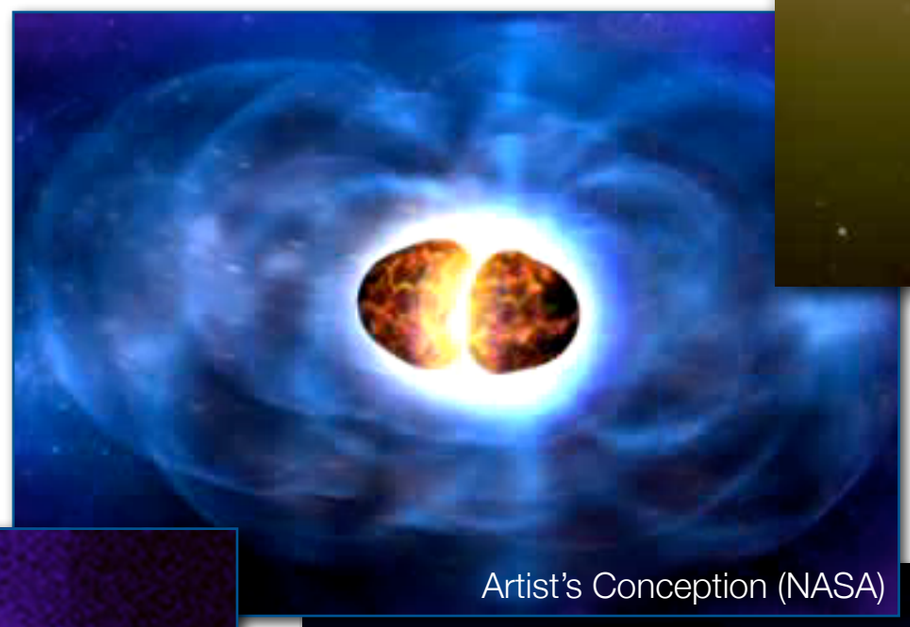
Meeting of the APS Division of Particles and Fields
Wayne State University
July 28, 2009

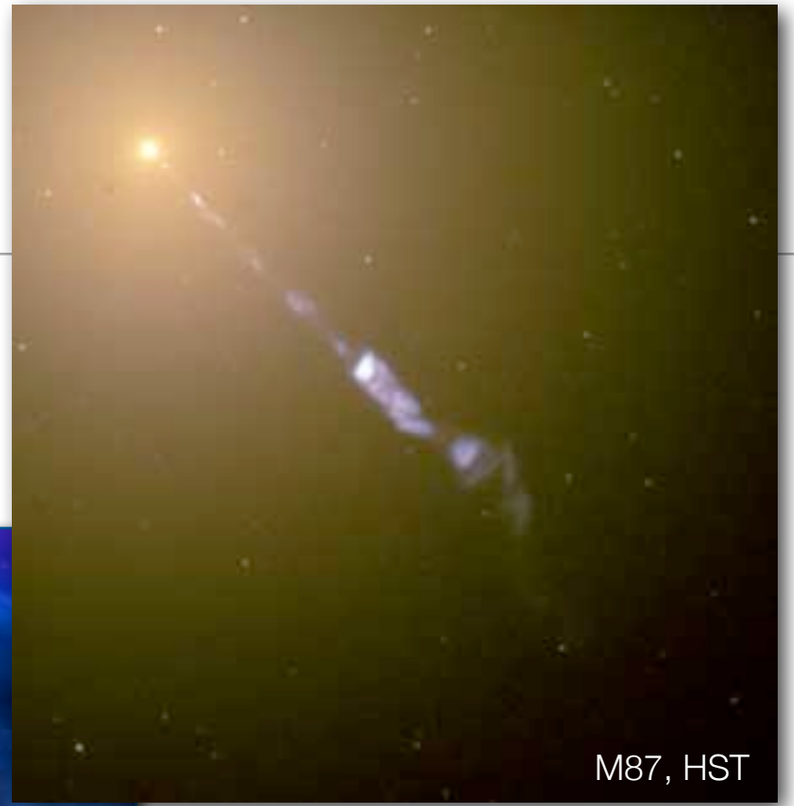
See also Kara Hoffman's talk on Thursday PM:
"Particle physics with astrophysical neutrino detectors"

Astrophysical Accelerators



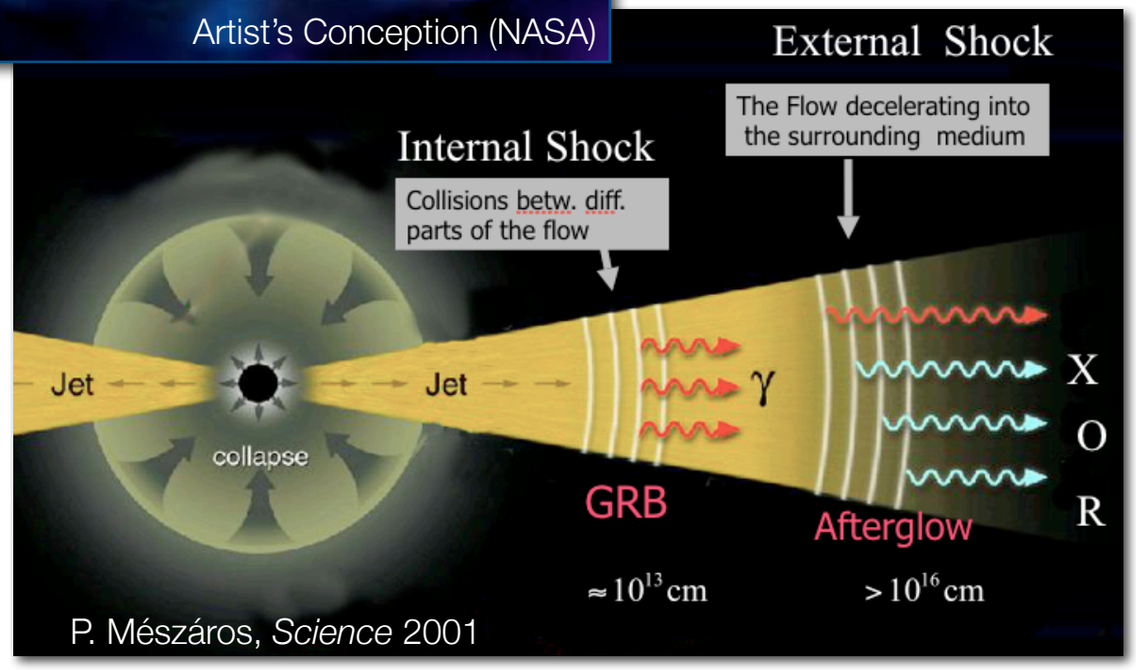
SNRs & PWN





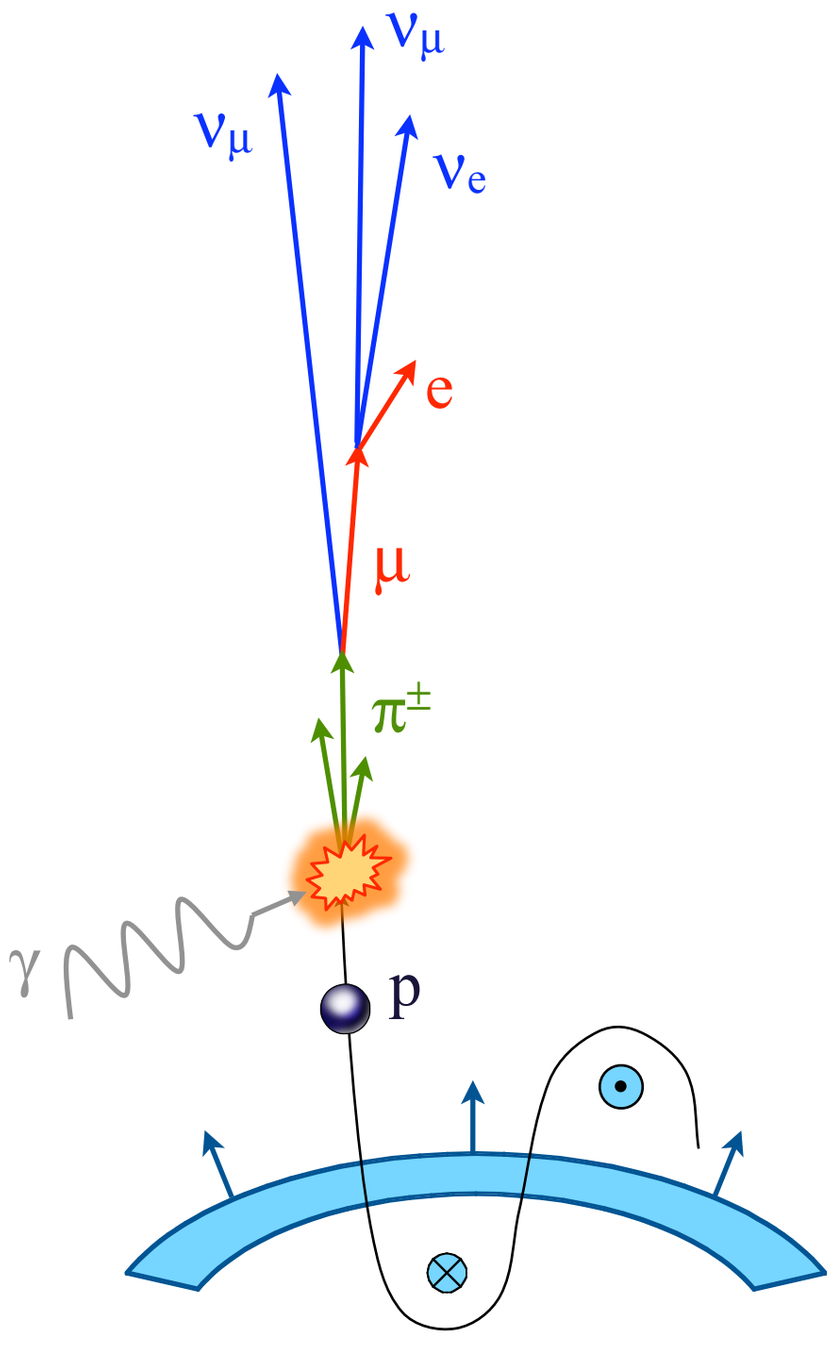
AGN

GRBs



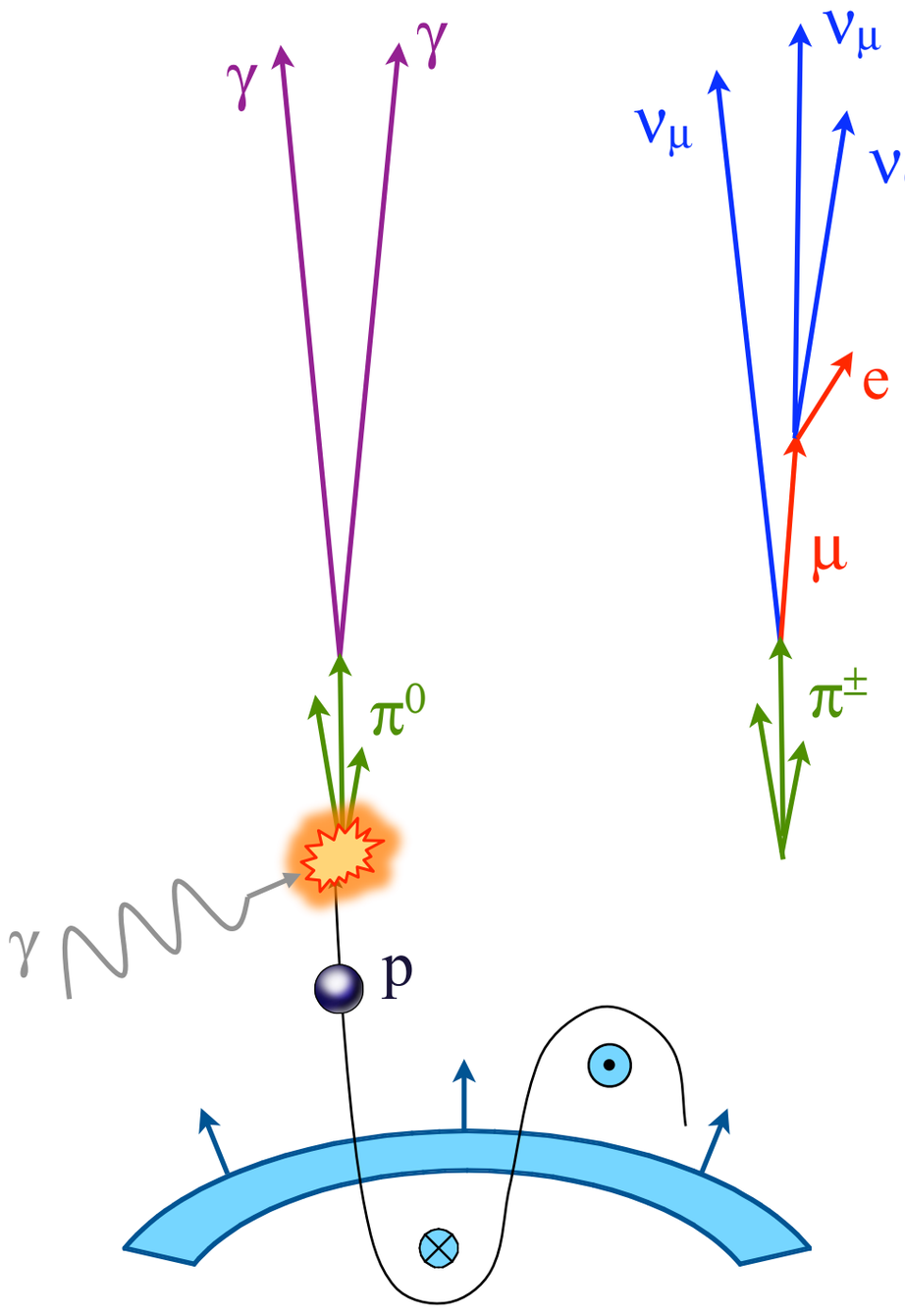
Neutrinos, Gamma Rays, & Cosmic Rays

- Accelerated cosmic rays are likely to interact with matter or radiation fields
    - Neutrino production via decay of charged pions and kaons

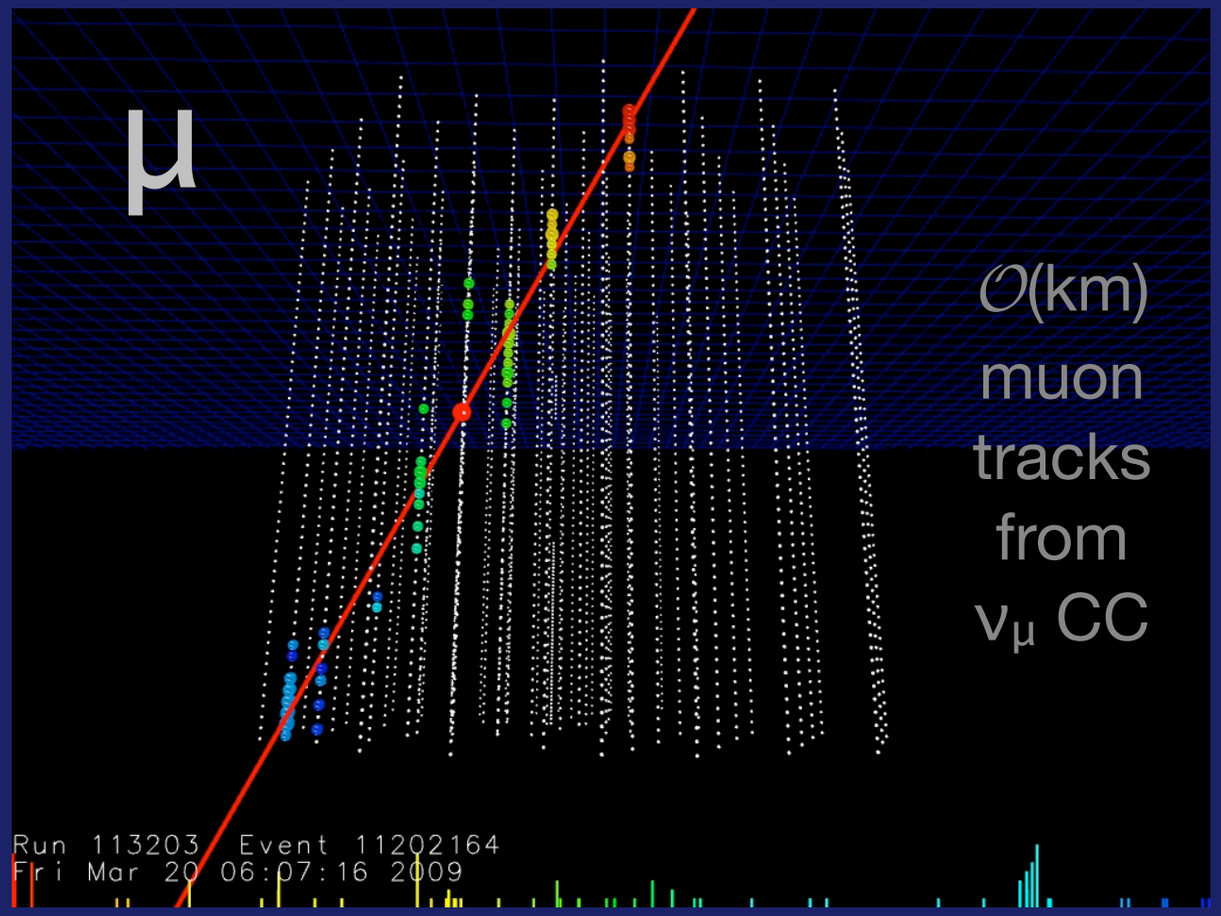


Neutrinos, Gamma Rays, & Cosmic Rays

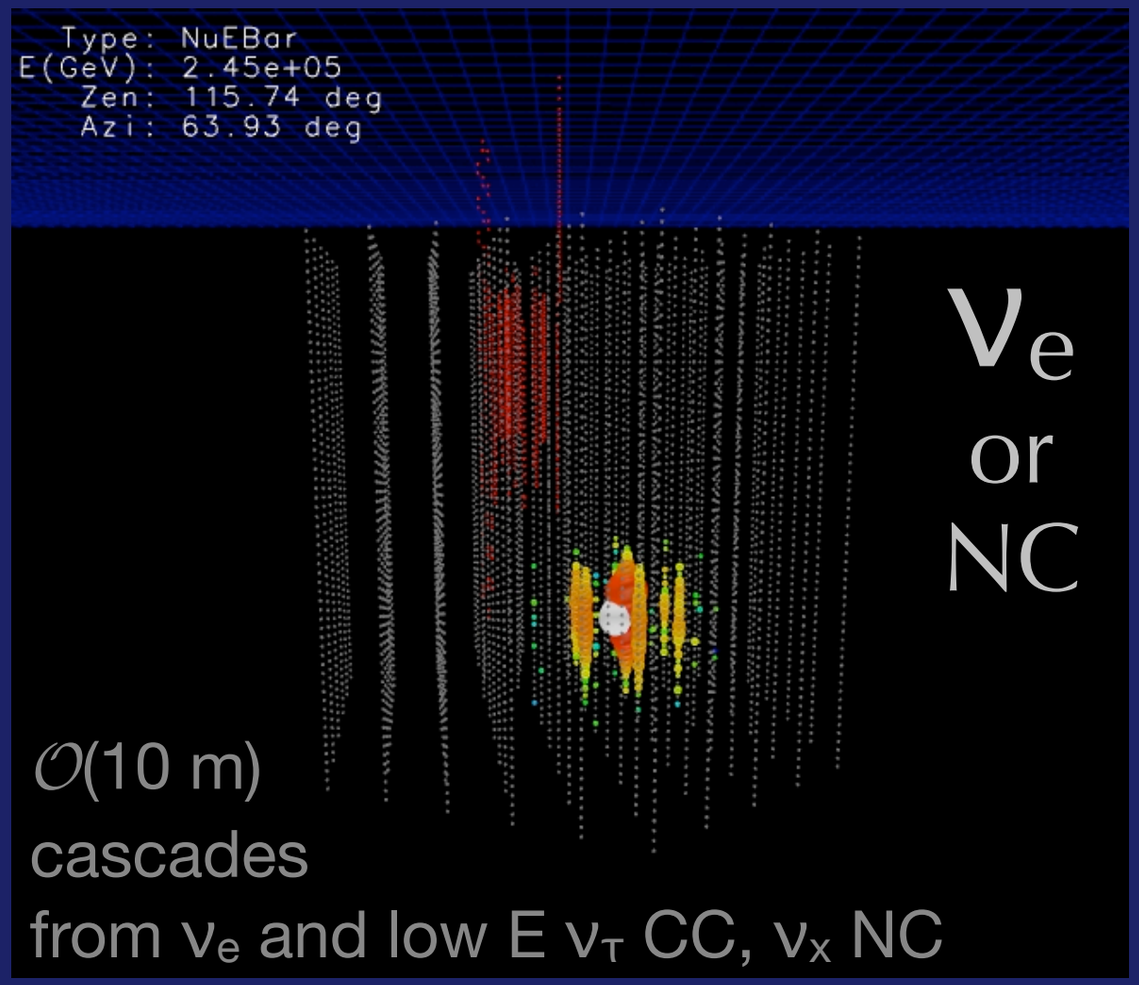
- Accelerated cosmic rays are likely to interact with matter or radiation fields
  - Neutrino production via decay of charged pions and kaons
  - Gamma ray production from neutral π, K
- Secondaries have $\mathcal{O}$(10%) of the cosmic ray's energy
- Gamma production may be π^0 decay or IC – neutrinos are an unambiguous tag of hadronic acceleration



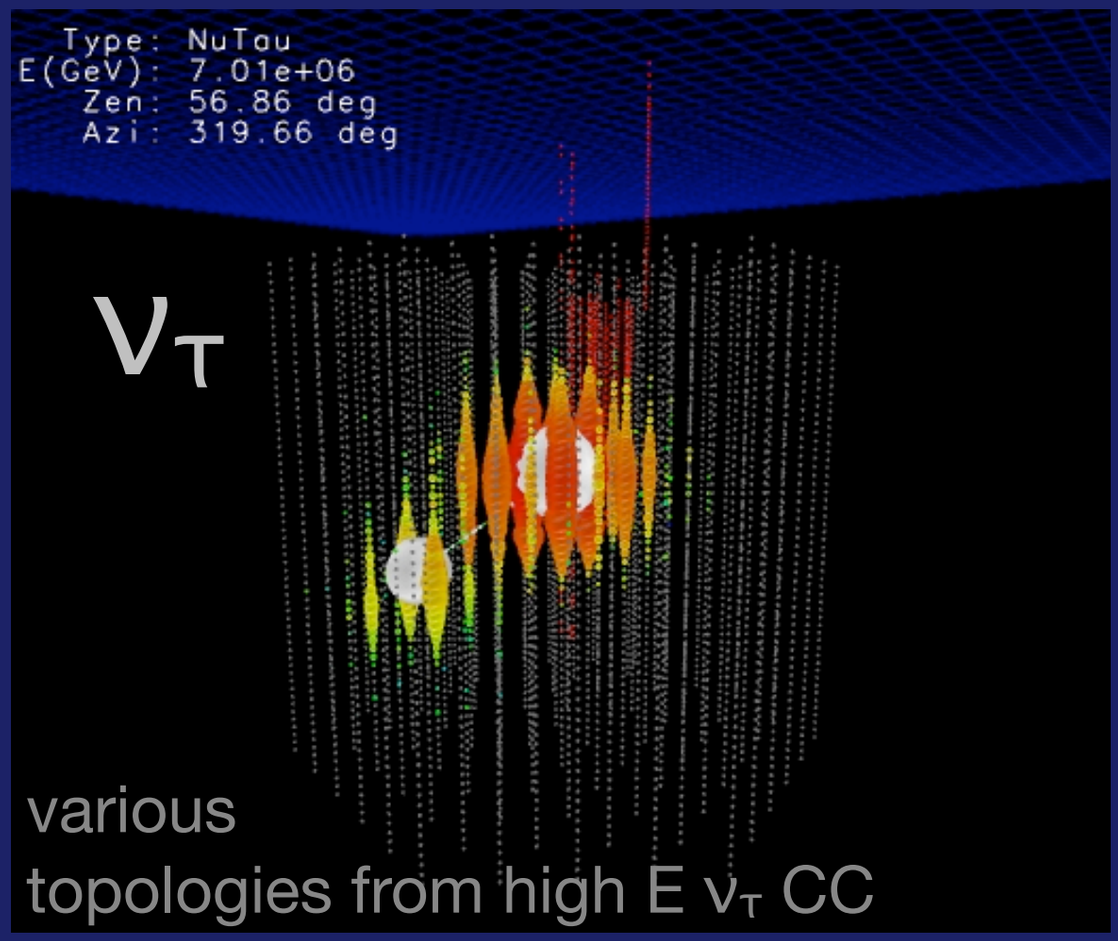
Neutrino Detection via Cherenkov Radiation



$\mathcal{O}$(km) muon tracks from ν_μ CC



$\mathcal{O}$(10 m) cascades from ν_e and low E ν_τ CC, ν_x NC



various topologies from high E ν_τ CC

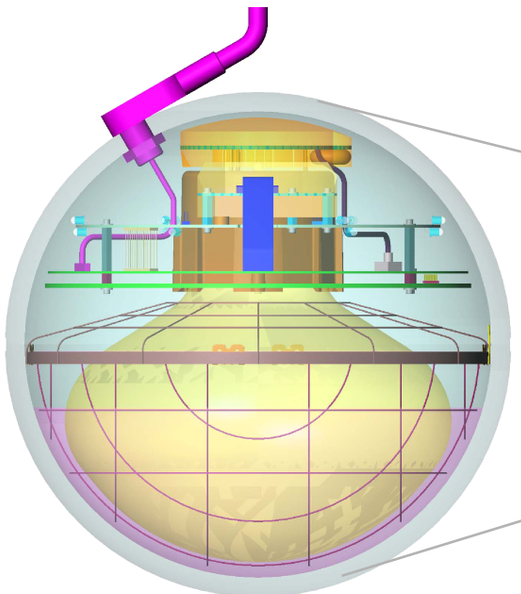
IceCube

5160 DOMs on 86 strings

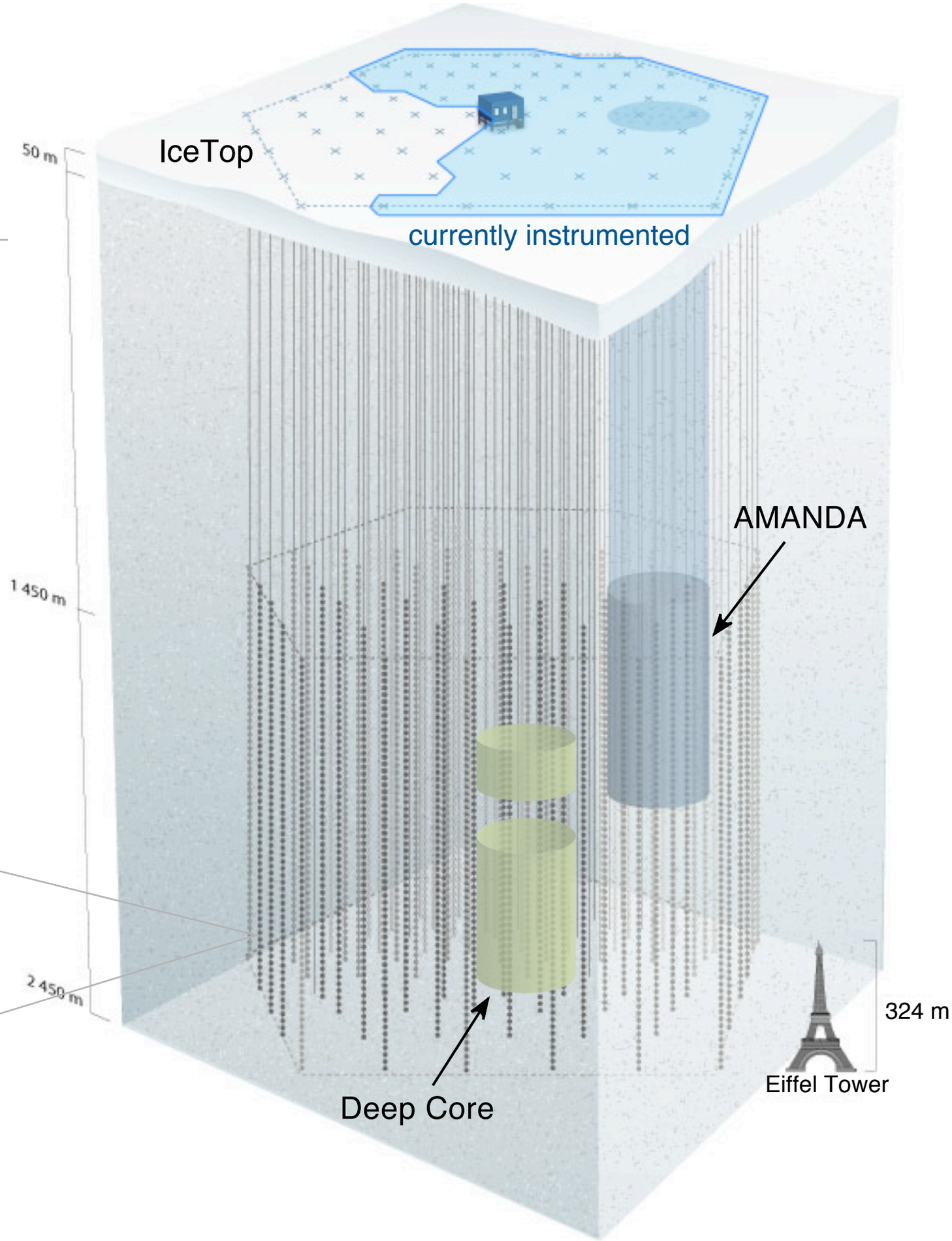
160 Ice-Cherenkov tank surface array (IceTop)

Surrounds existing AMANDA detector (677 OMs)

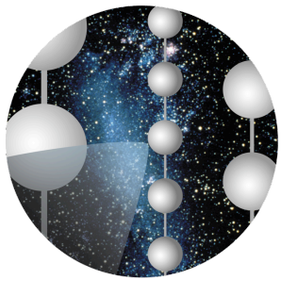
59 strings deployed to date in 5 construction seasons



Digital Optical Module (DOM)



The IceCube Collaboration

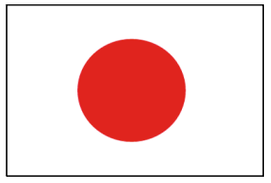


University of Alabama
University of Alaska, Anchorage
University of California, Berkeley
University of California, Irvine
Clark-Atlanta University
Bartol Research Institute
Georgia Institute of Technology
University of Kansas
Lawrence Berkeley Natl. Laboratory
University of Maryland
Ohio State University
Pennsylvania State University
Southern University and A&M College
University of Wisconsin, Madison
University of Wisconsin, River Falls

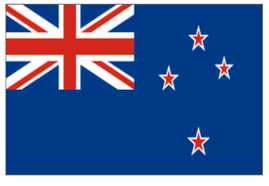
RWTH Aachen
DESY, Zeuthen
Universität Dortmund
MPIfK Heidelberg
Humboldt Universität, Berlin
Universität Mainz
BUGH Wuppertal

Stockholms Universitet
Uppsala Universitet

Vrije Universiteit Brussel
Université Libre de Bruxelles
Universiteit Gent
Université de Mons-Hainaut



Chiba University



University of Canterbury

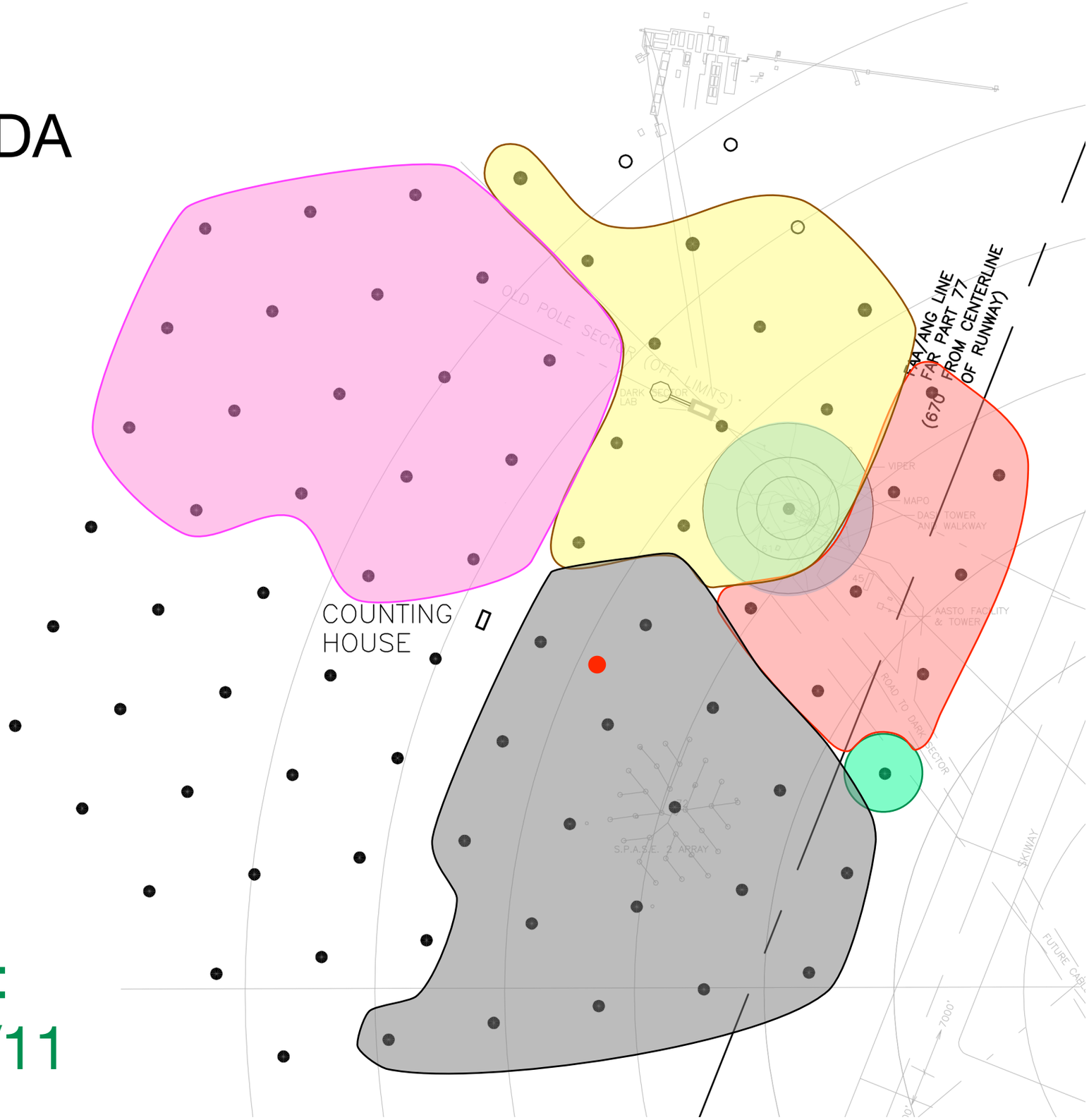
Universiteit Utrecht

EPF Lausanne

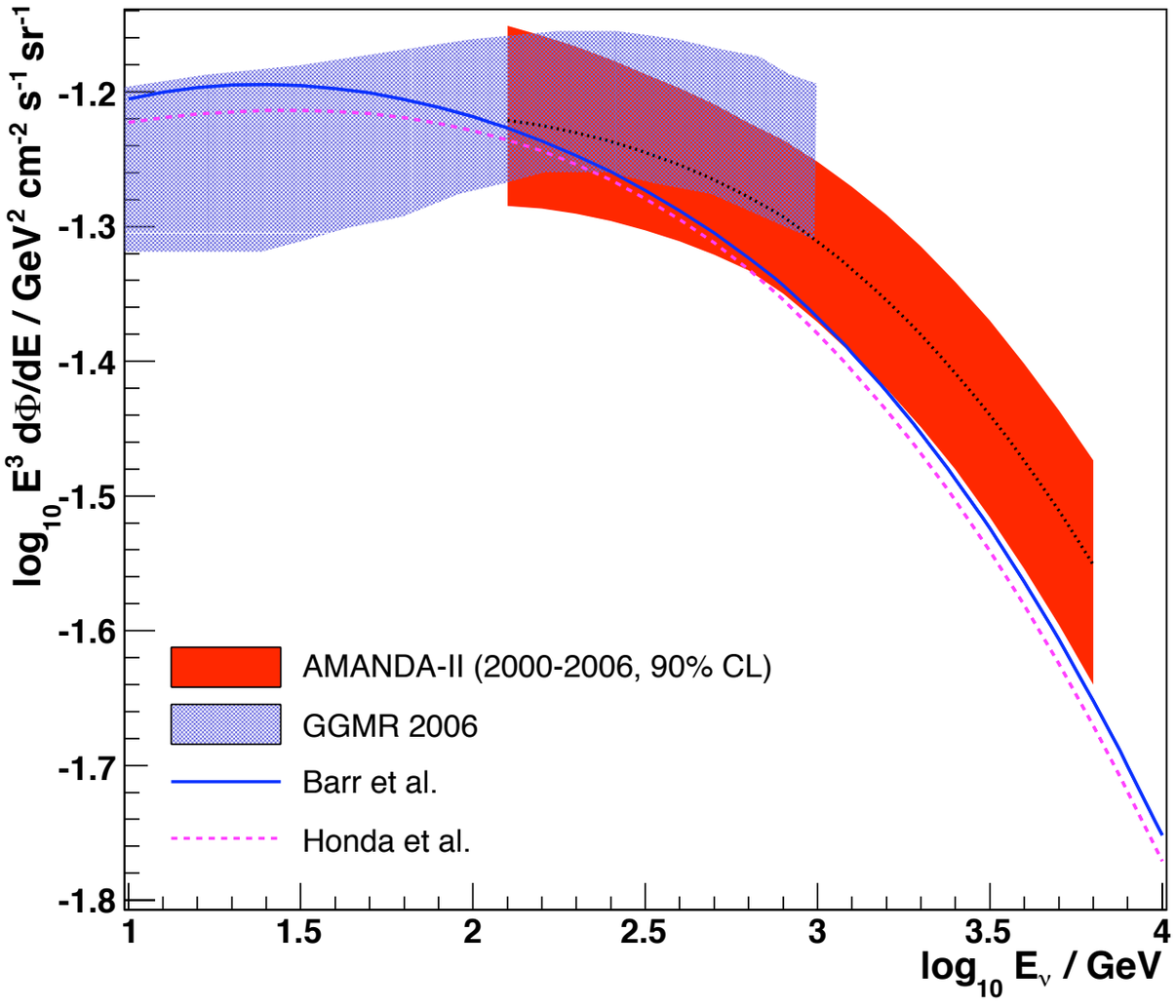
Oxford University

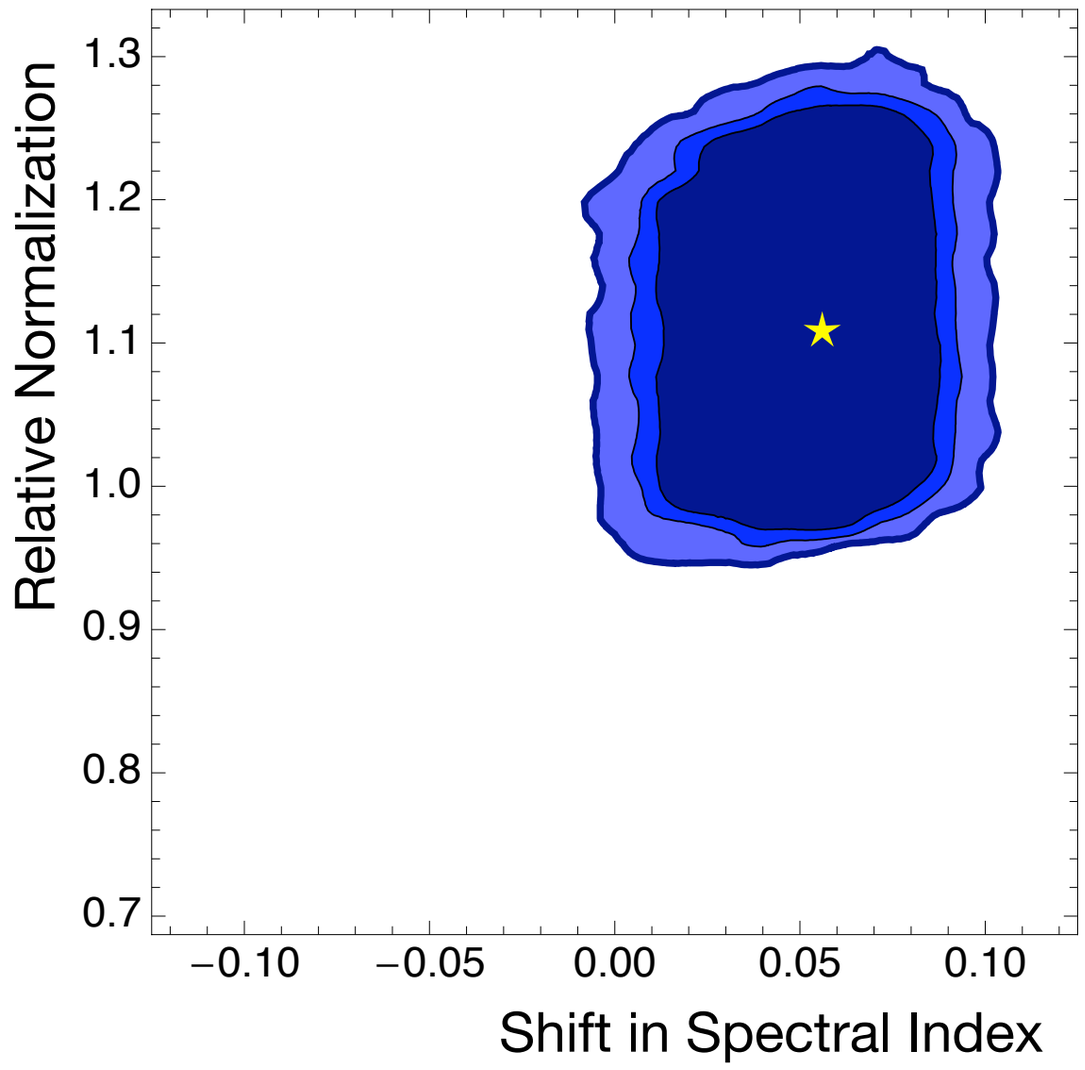
Construction Status

- 1996-2001: AMANDA
- 2004/5: 1 string
- 2005/6: 8
- 2006/7: 13
  - 12 planned
- 2007/8: 18
  - 14 planned
- 2008/9: 19
  - 16 planned
- Two more seasons: 2009/10 and 2010/11



Atmospheric Muon Neutrinos



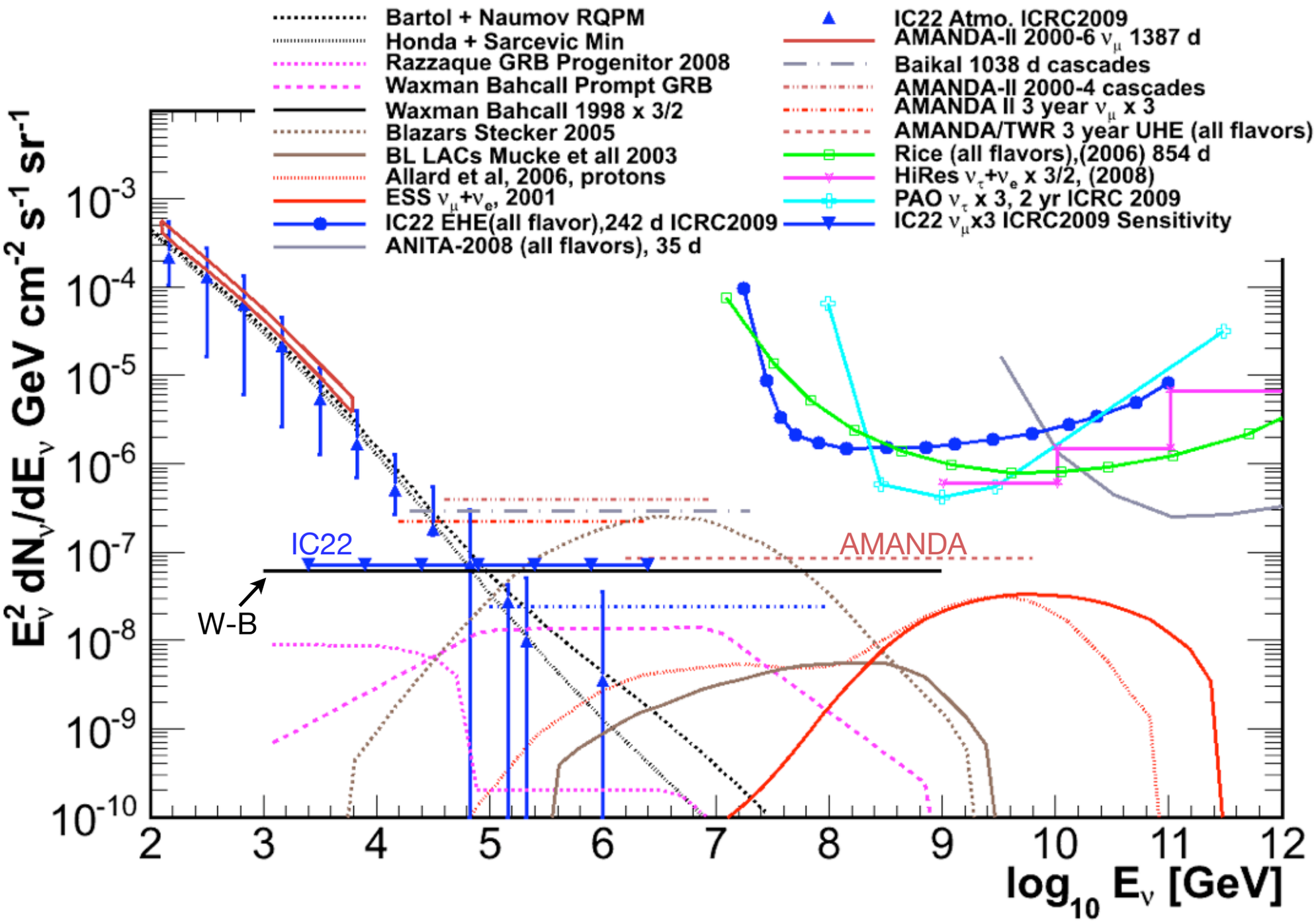


Based on complete 7-year AMANDA-II data set (3.8 years exposure)

Abbasi et al., Phys. Rev. D **79**, 102005 (2009), arXiv:0902.0675

Search for Diffuse Astrophysical Neutrino Fluxes

compilation by S. Grullon & T. Montaruli

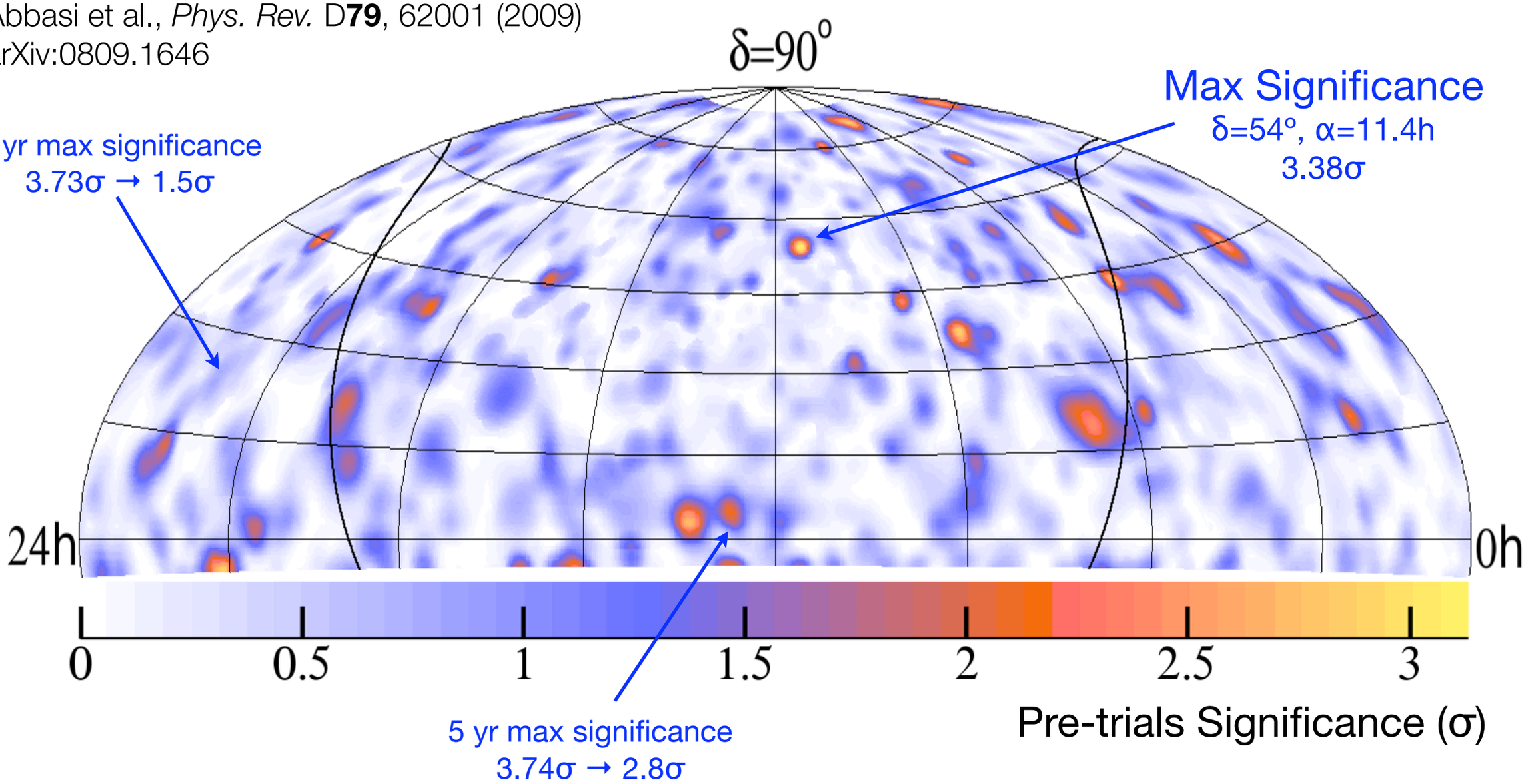


all flavor, assuming 1:1:1 ratio

Note: UHE limits are differential, not directly comparable to integral limits

AMANDA-II Full Sky Source Search

Abbasi et al., *Phys. Rev.* D**79**, 62001 (2009)
arXiv:0809.1646

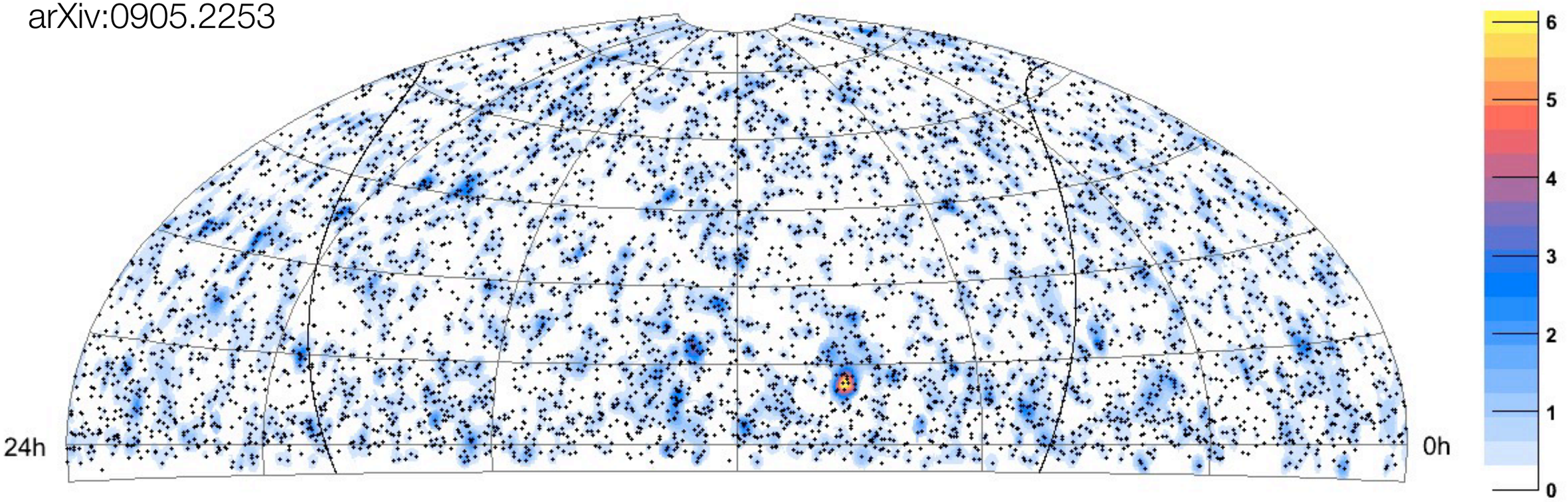


Based on 3.8 years exposure, 2000-2006

95% of randomized sky maps have a point with significance ≥ 3.38σ

IceCube 2007 (22 String) Full Sky Source Search

Ap. J. Lett. in press,
arXiv:0905.2253



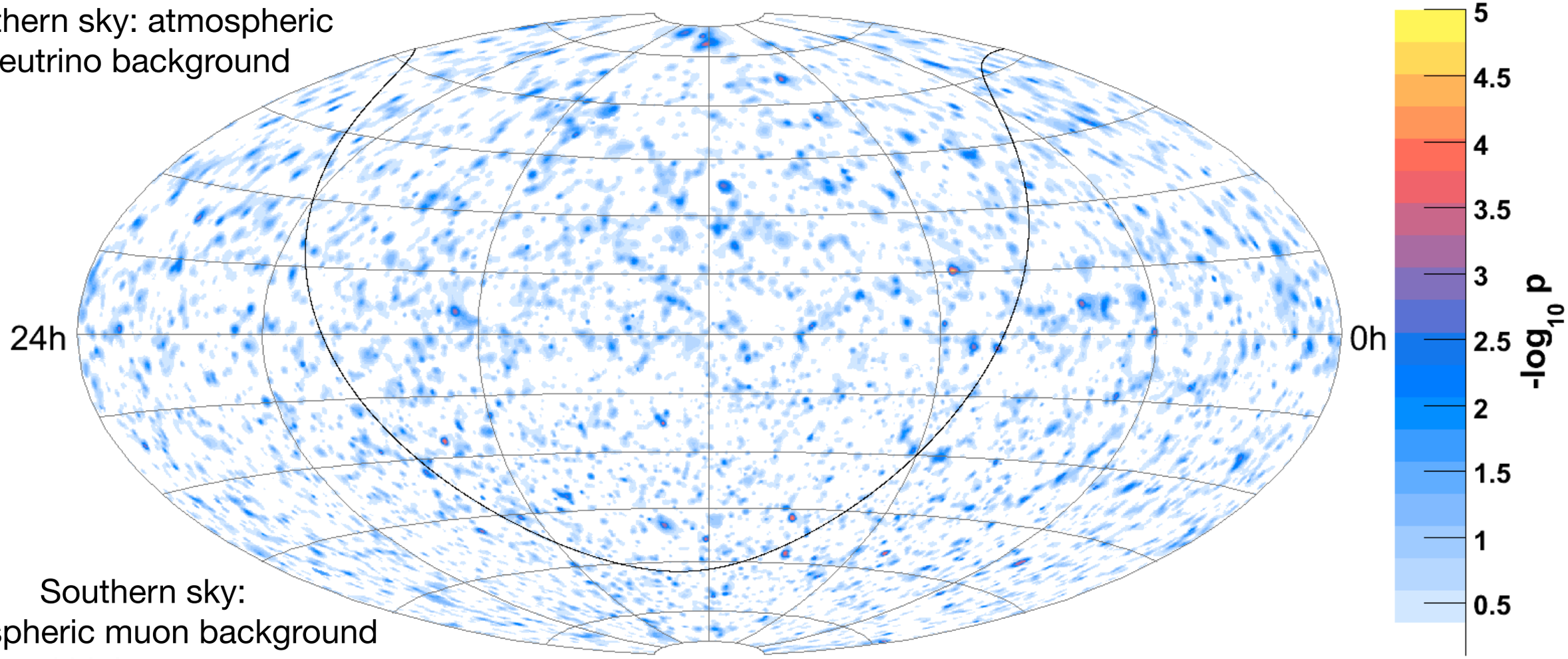
Based on 276 days exposure, May 2007 to April 2008

22 IceCube strings operational (¼ of full array)

Maximum deviation from background 7 x 10^{-7}, 1.34% probability as determined with randomized sky maps → consistent with background

IceCube 2008 (40 String) Full Sky Source Search

Northern sky: atmospheric neutrino background



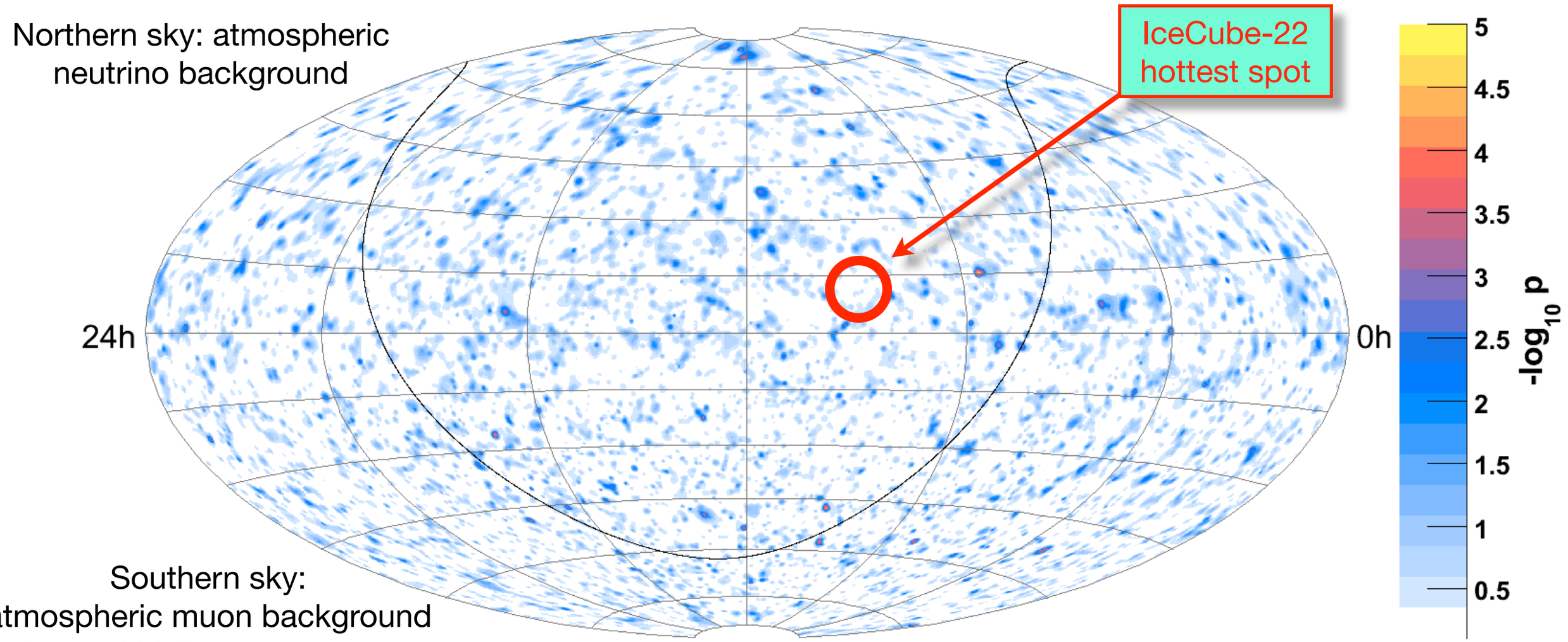
Southern sky: atmospheric muon background demand high energy events

Based on only 1st six months of 2008 data (remainder forthcoming)

17,777 events: 6,796 upgoing and 10,981 downgoing

Maximum deviation 3.7 x 10^{-5}, seen in 61% of randomized sky maps

IceCube 2008 (40 String) Full Sky Source Search

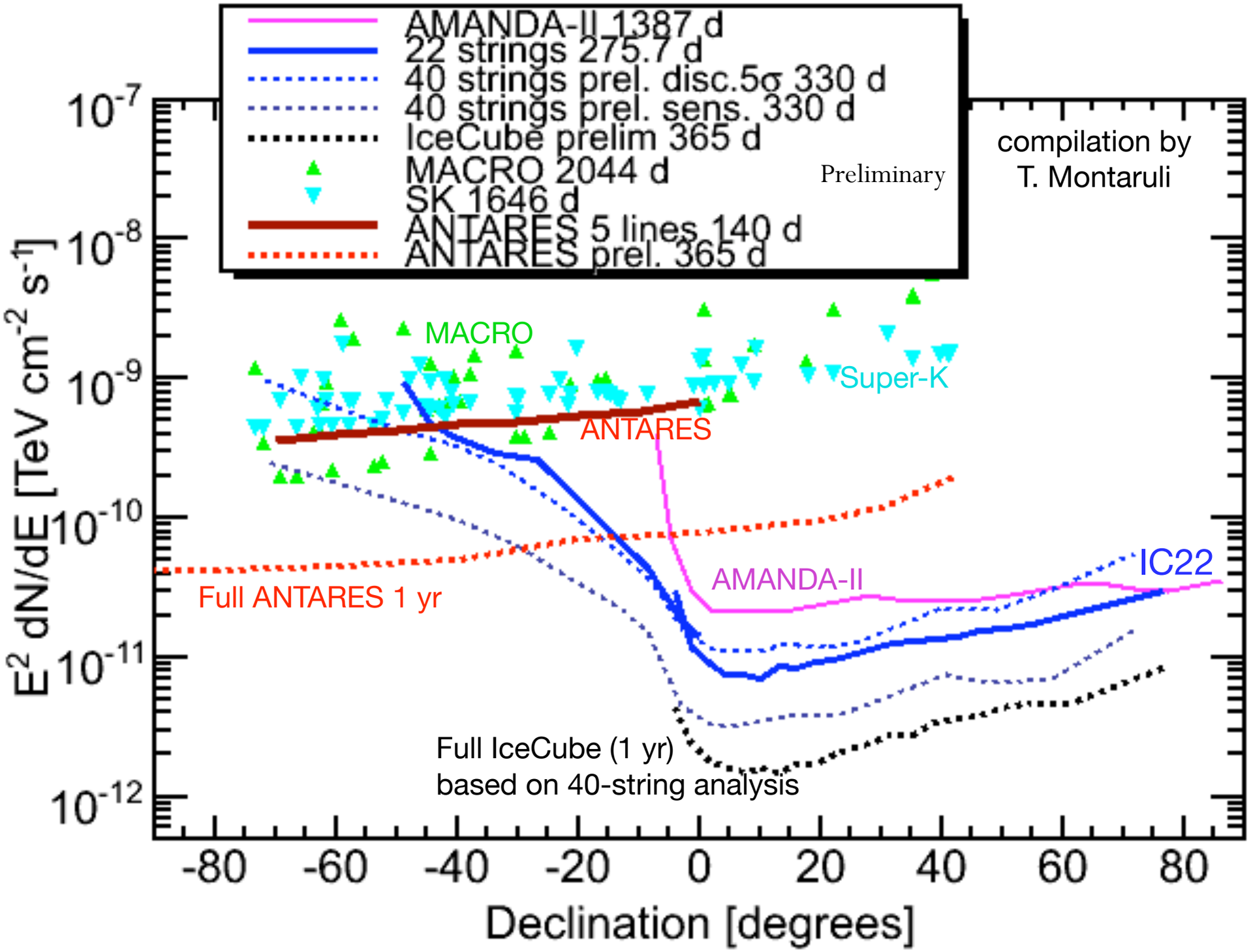


Based on only 1st six months of 2008 data (remainder forthcoming)

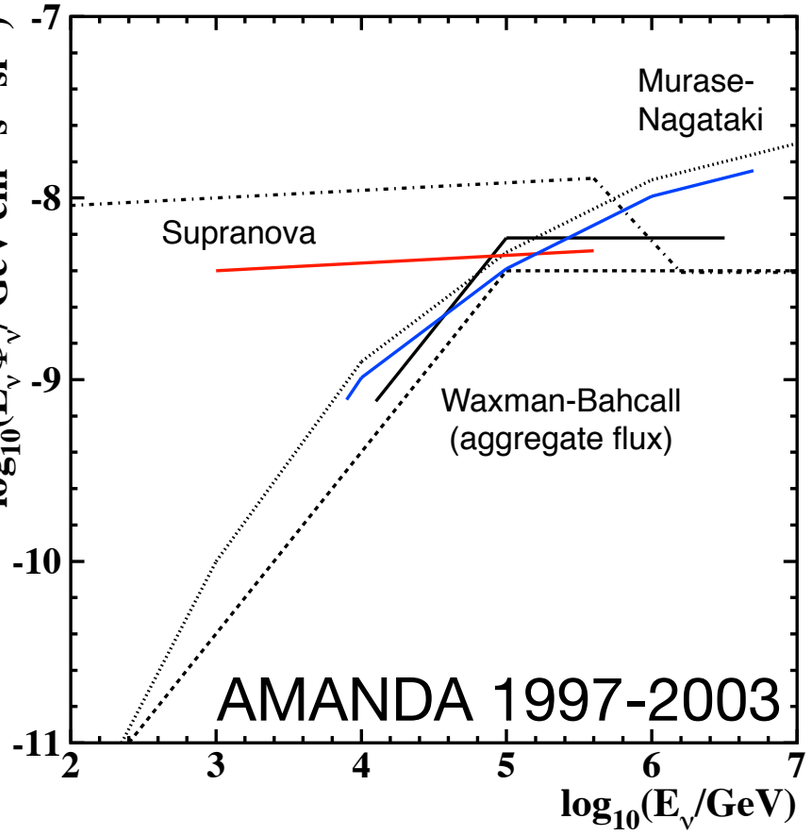
17,777 events: 6,796 upgoing and 10,981 downgoing

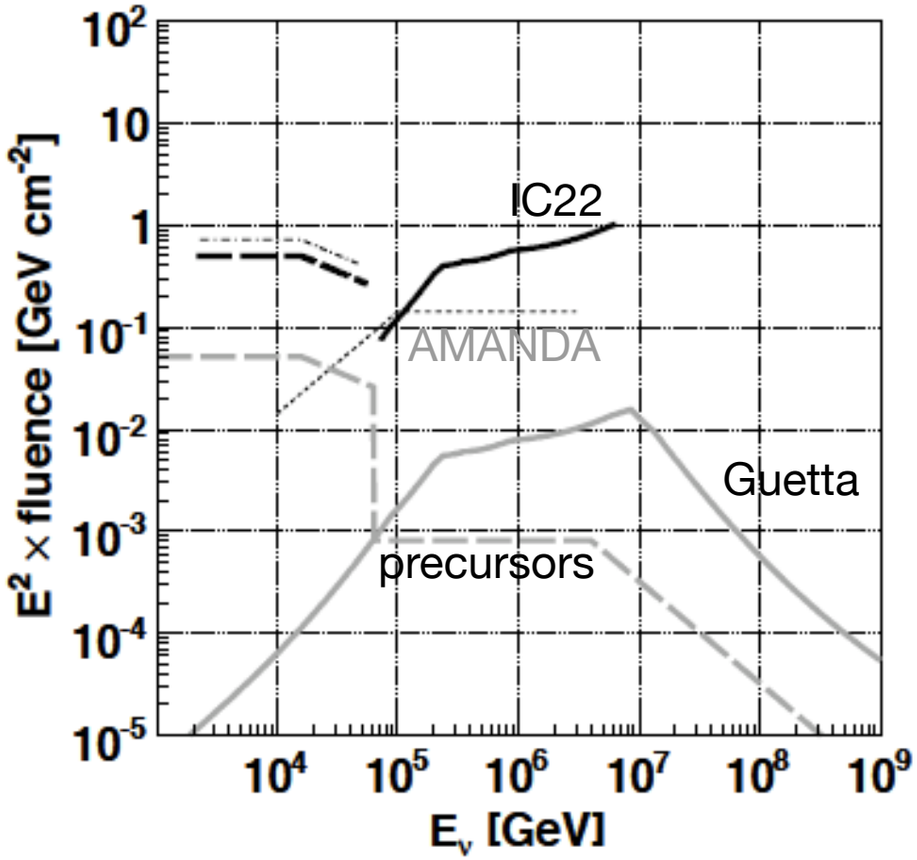
Maximum deviation 3.7 x 10^{-5}, seen in 61% of randomized sky maps

Relative Sensitivities to E^{-2} Spectra



Neutrinos from Gamma Ray Bursts





Waxman & Bahcall, 1997
Phys. Rev. Lett. **78**, 2292

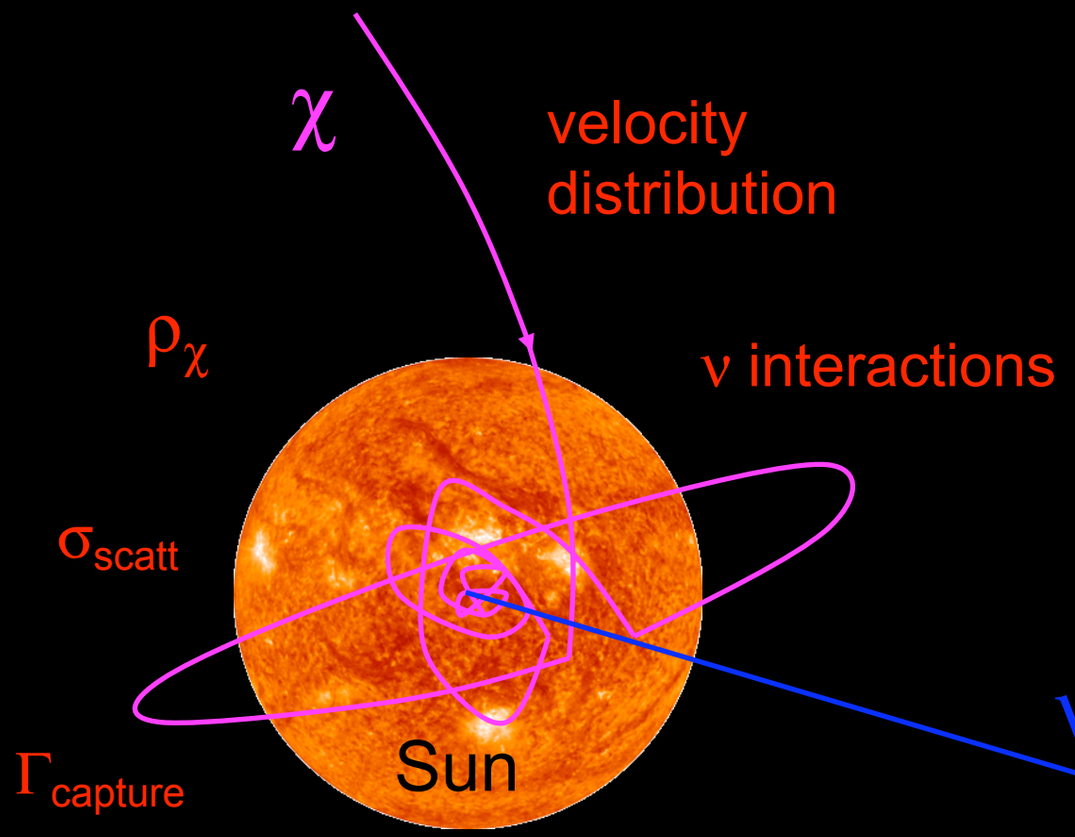
Razzaque, Mészáros
& Waxman, 2003
Phys. *Rev*. D **68**, 083001

Murase & Nagataki, 2006
Phys. *Rev*. D **73**, 063002

D. Guetta, D. Hooper,
J. Alvarez-Muñiz, F. Halzen,
& E. Reuveni, 2004
Astropart. *Phys*. **20**, 429

- AMANDA observations of 419 GRBs, plus 41 by 22-string IceCube
  - AMANDA limits exclude M-N (parameter set A – high neutrino production) and supranova (ideal case – all GRBs expand into SN shell)
  - IceCube 22-string limits comparable to AMANDA with 10% the statistics
  - Exceptional GRBs (e.g. 080319b) produce $\mathcal{O}(1)$ event *individually*

Indirect Search for Dark Matter

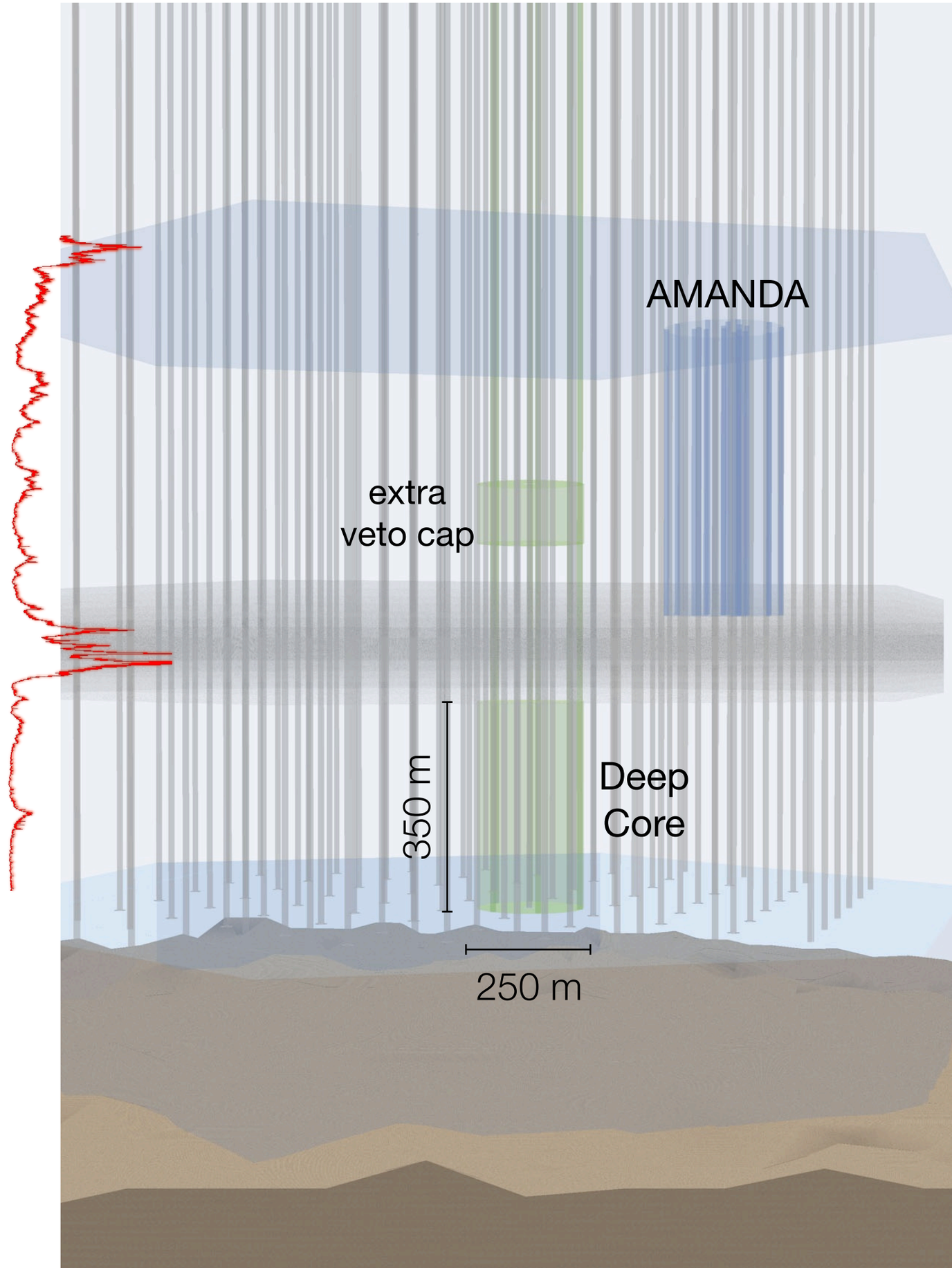


Silk, Olive and Srednicki, ’85
Gaisser, Steigman & Tilav, ’86
Freese, ’86

Krauss, Srednicki & Wilczek, ’86
Gaisser, Steigman & Tilav, ’86

IceCube Deep Core

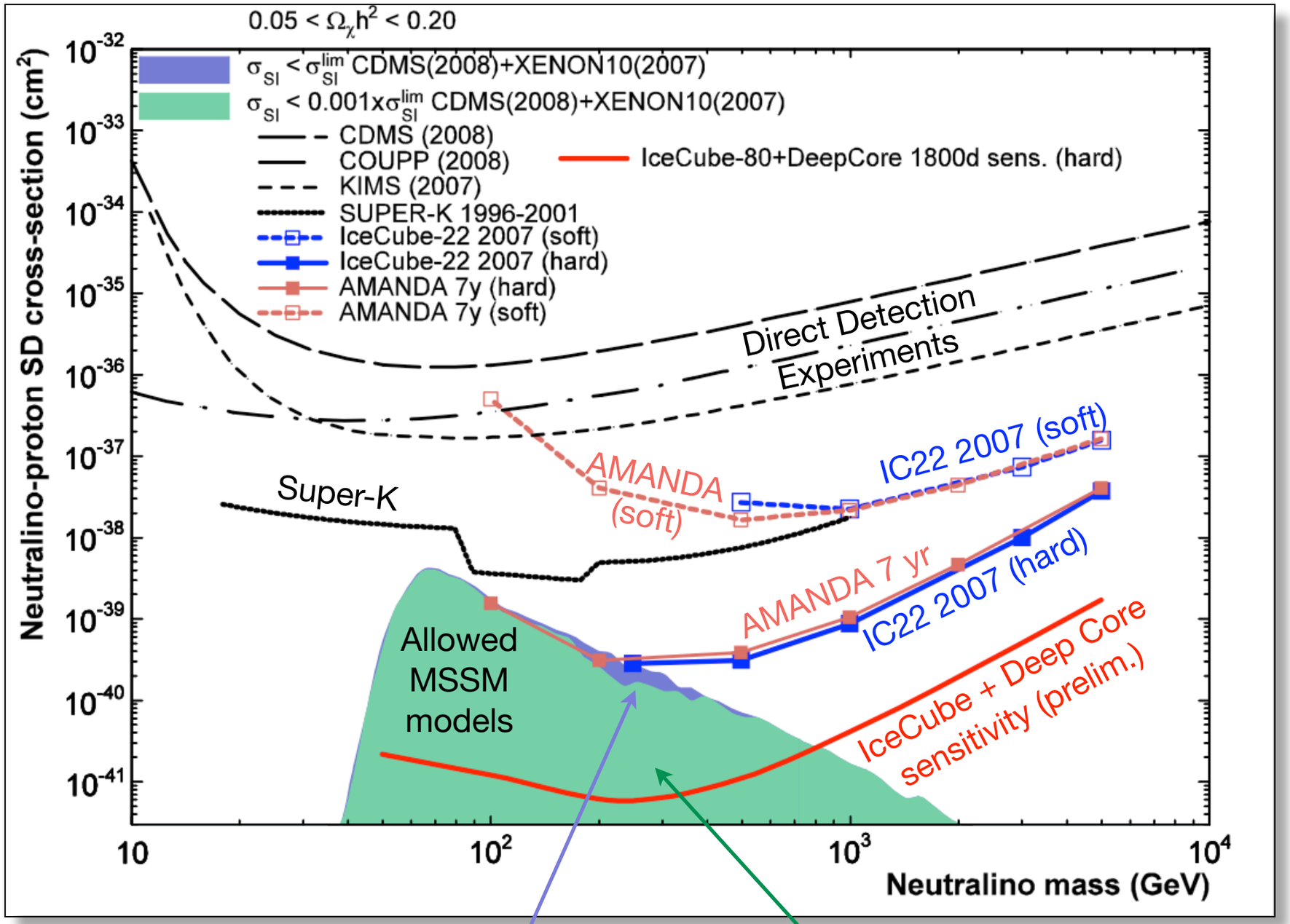
- Six special strings plus 7 nearest standard IceCube strings
  - 72 m interstring spacing
  - 7 m DOM spacing
  - High Q.E. PMTs
  - ~10x higher effective photocathode density
- In the clearest ice, below 2100 m
  - $\lambda_{atten} \approx$ 40-45 m (cf. 20-25 m in shallower ice)



WIMP Searches

Abbasi et al., *Phys. Rev. Lett.* **102**, 201302 (2009)
arXiv:0902.2460

- Solar WIMP searches probe SD scattering cross section
- IC-22 limits arXiv:0902.2460
  - PRL accepted
- Sensitivity depends on annihilation mode
  - hard W^+W^-, soft $b\bar{b}$



Corresponding σ_{SI} within factor 10^3 of current direct limits

Corresponding σ_{SI} more than factor 10^3 beyond current direct limits

Summary

- IceCube construction is on track
  - Very successful season, 59 strings now operating
- Final results from AMANDA, initial results from IceCube appearing
  - Atmospheric neutrinos, diffuse astrophysical fluxes, gamma ray bursts
  - IceCube point source searches rapidly increasing in sensitivity
  - Approaching Waxman-Bahcall flux, gamma ray burst flux predictions, MSSM spin-dependent WIMP cross-sections
- Deep Core construction underway
  - Reduce threshold to ~10 GeV
  - Dark matter, neutrino oscillations, Galactic neutrino sources,…