http://www.ps.uci.edu/~amanda/nu2000.pdf

AMANDA

Search for HE sources of ν s

Steven W. Barwick

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(for the AMANDA collaboration)

Neutrino 2000

Sudbury, Canada

AMANDA Collaboration -99

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AMANDA Collaboration-99

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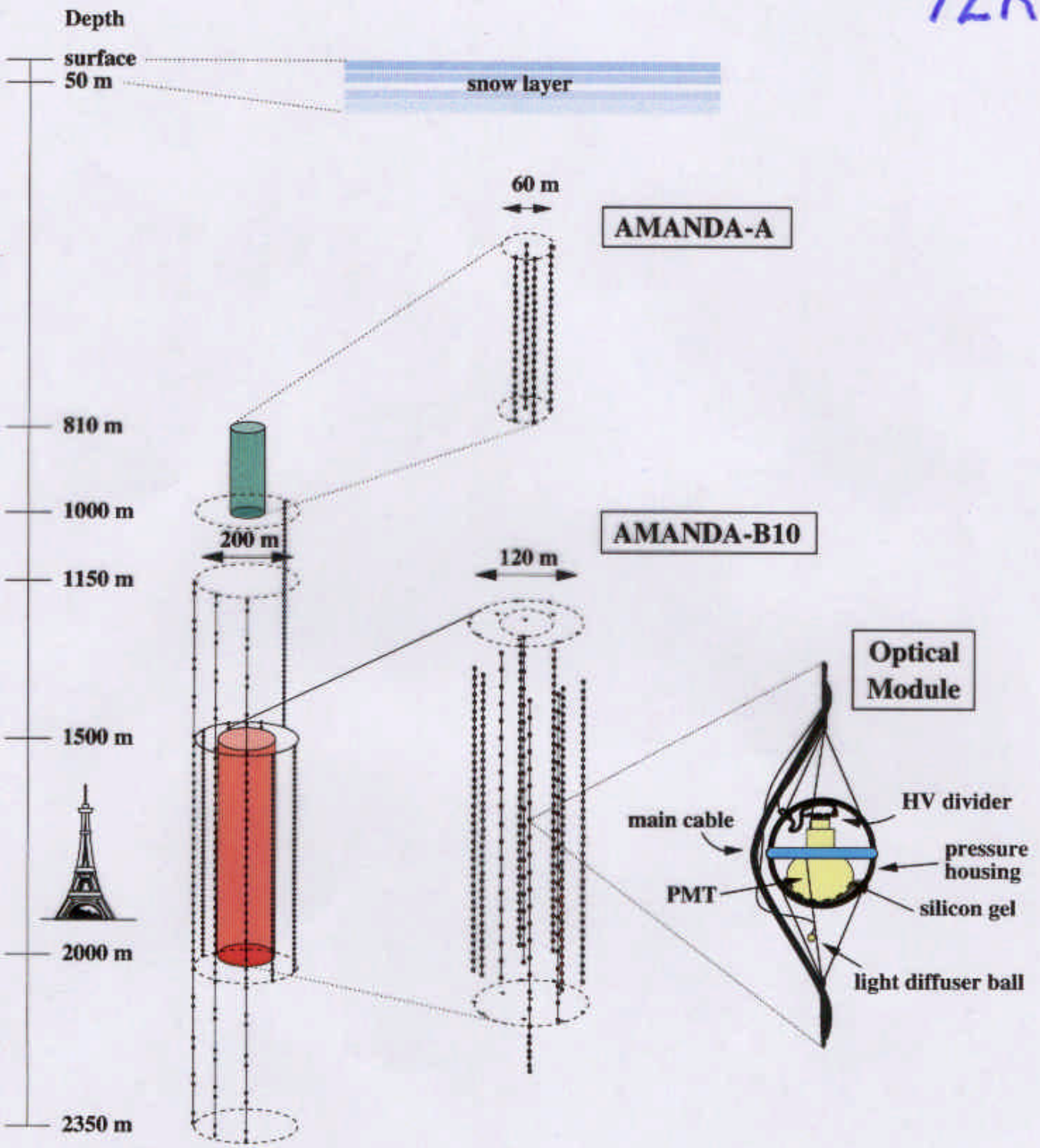
Y2K

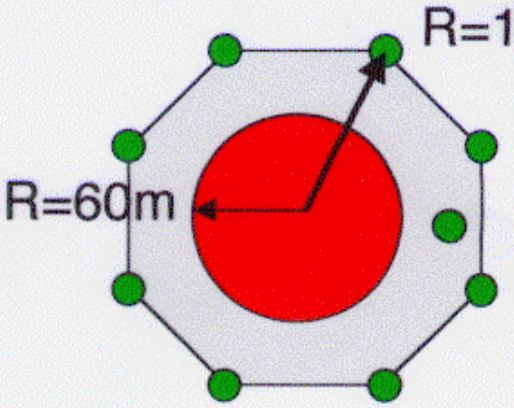


AMANDA as of 2000
Eiffel Tower as comparison
(true scaling)

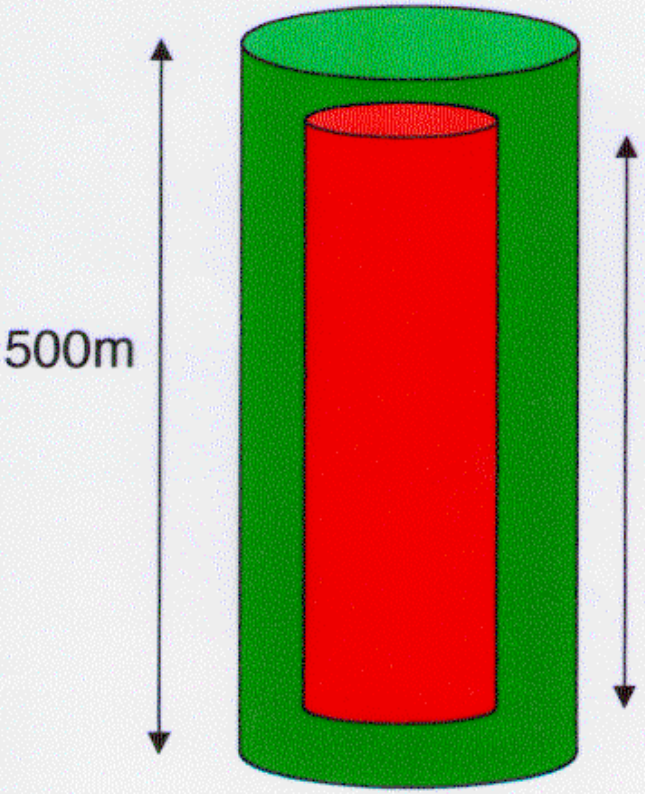
zoomed in on
AMANDA-A (top)
AMANDA-B10 (bottom)

zoomed in on one
optical module (OM)

AMANDA-II



- AM-II string ('00) - Finished
- Am-B array ('97)



-42 Hybrid OMs/string
-Test bed for new technology
-Good ice 1400m-2300m

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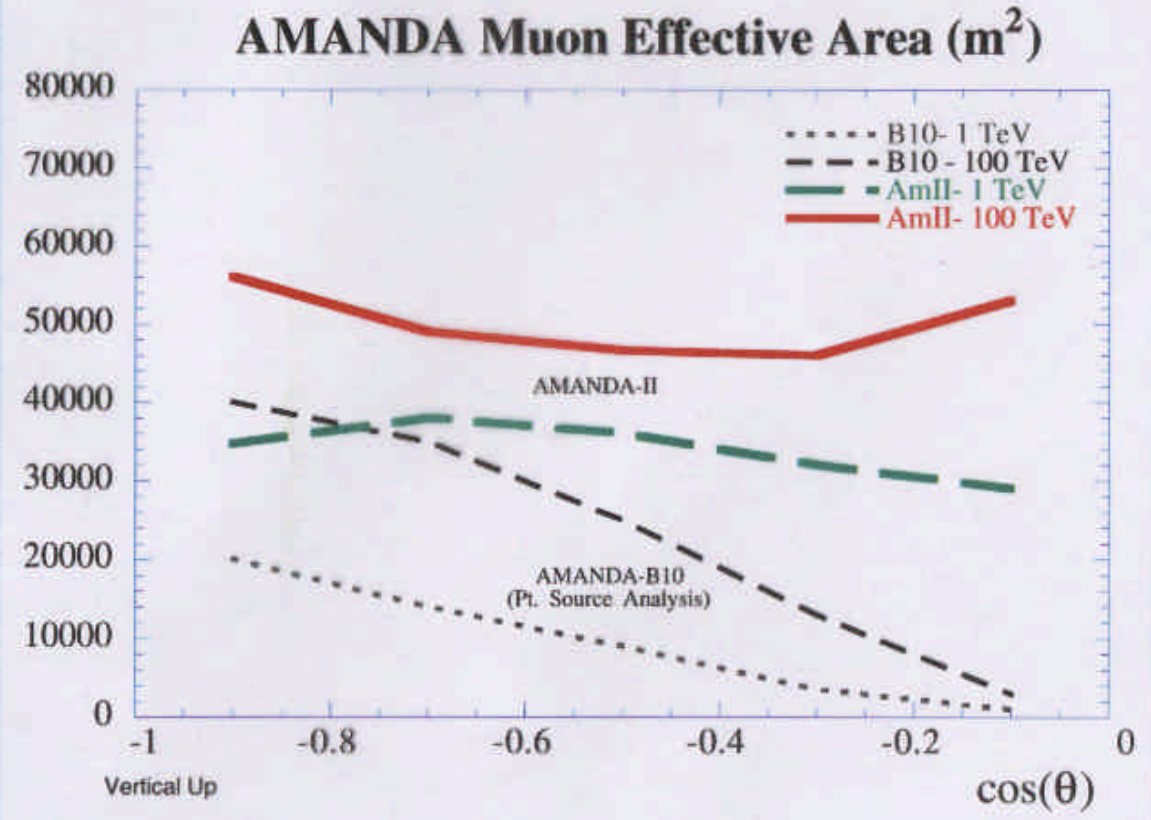
AMANDA Effective Area

- AMANDA-II 30,000-50,000 m^2
- AMANDA-II has nearly uniform response over all zenith angles



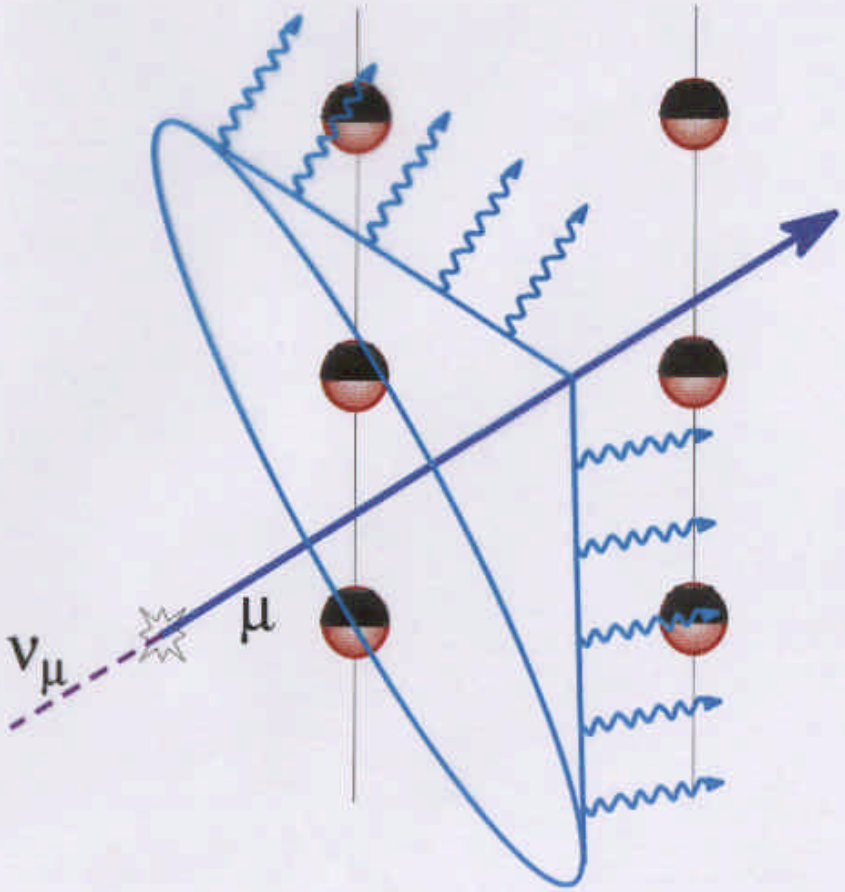
Technical Achievements 00

- Completed AMANDA-II (19 strings, 680 OMs)
- Streamlined deployment of strings
- Improved DAQ (trigger, front end electronics, readout)
- Developed and deployed Ice3 technologies
  - Laser Diode transmitters using optical fiber
  - In situ HV, digital control
  - Full digitizing within OM
- Upgraded satellite link (6 GB/day)
- Detector and background simulations vastly improved

AMANDA

Detection Method for ν_μ

- Cherenkov photons are detected by array of PMTs
- Tracks are reconstructed by maximum likelihood method of photon arrival times.



AMANDA Results

(Data from 1997 only)

- Supermassive Black Holes (AGN)
  - E^{-2} point source: ϕ_ν (>10 GeV) $<10^{-7}$ ($cm^{-2}s^{-1}$)
  - E^{-2} diffuse flux : $E^2\phi_\nu < 1.6\times10^{-6}$ GeV $cm^{-2}s^{-1}sr^{-1}$
- GRB in coincidence with BATSE
  - Cumulative $\text{Fluence}_\nu < 4\times10^{-4}$ cm^{-2}TeV
- Atmospheric neutrinos (138 live days)
  - ~170 events from 1997, depends on analysis
  - Calibration of sensitivity within factor 2
- WIMPs from the earth

Also, see ICRC99 for limits on relativistic monopoles, search for SNa, ice properties

Search for HE ν Point Sources

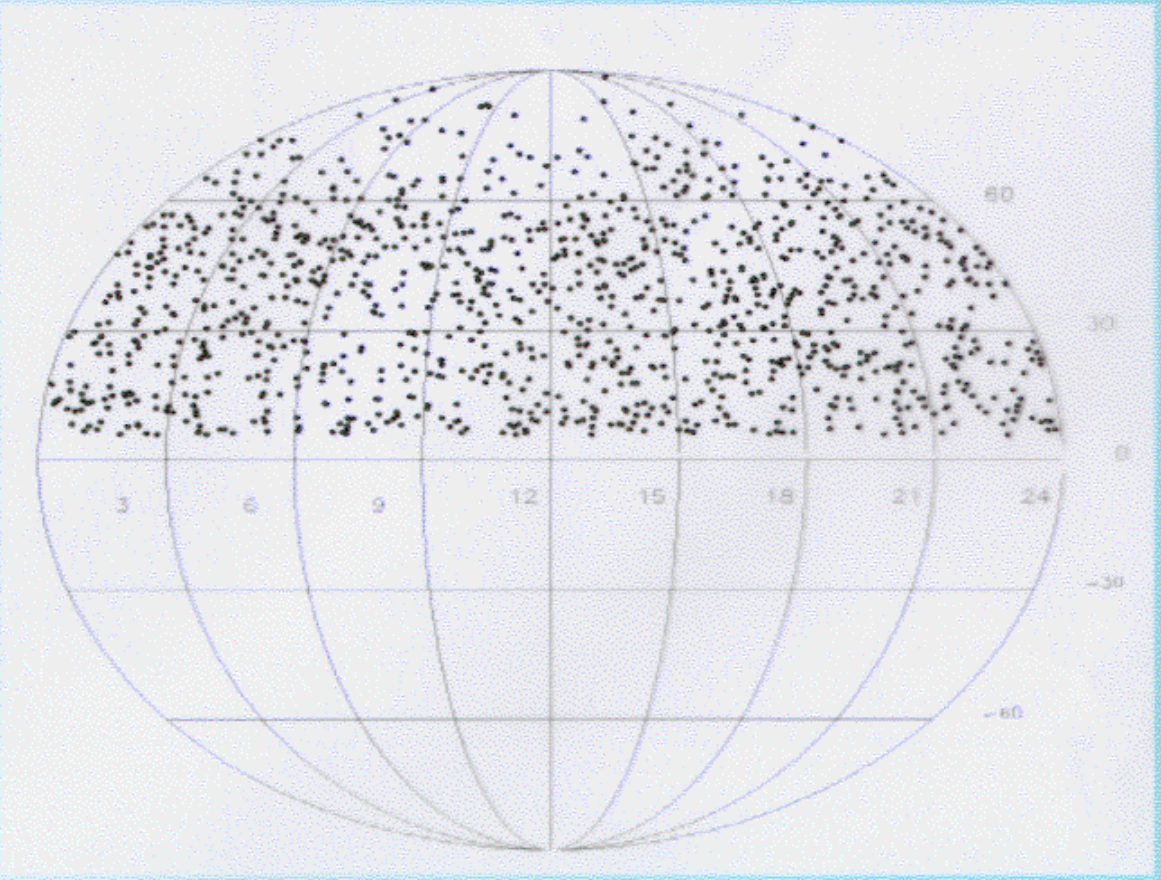
- Concentrate on continuous emission from sources with hard spectra (~E^{-2})
- Optimize search on Signal to Noise Ratio
  - A_{eff} depends on rejection requirements
  - Iterative procedure defined *a priori*
- Background for this search
  - Poorly reconstructed atmospheric muons
  - Atmospheric neutrinos

AMANDA

Sky Plot of Events

Equatorial Coordinates

- 1097 events
- No obvious clustering
- Event sample consists of atm. ν and atm. muons.



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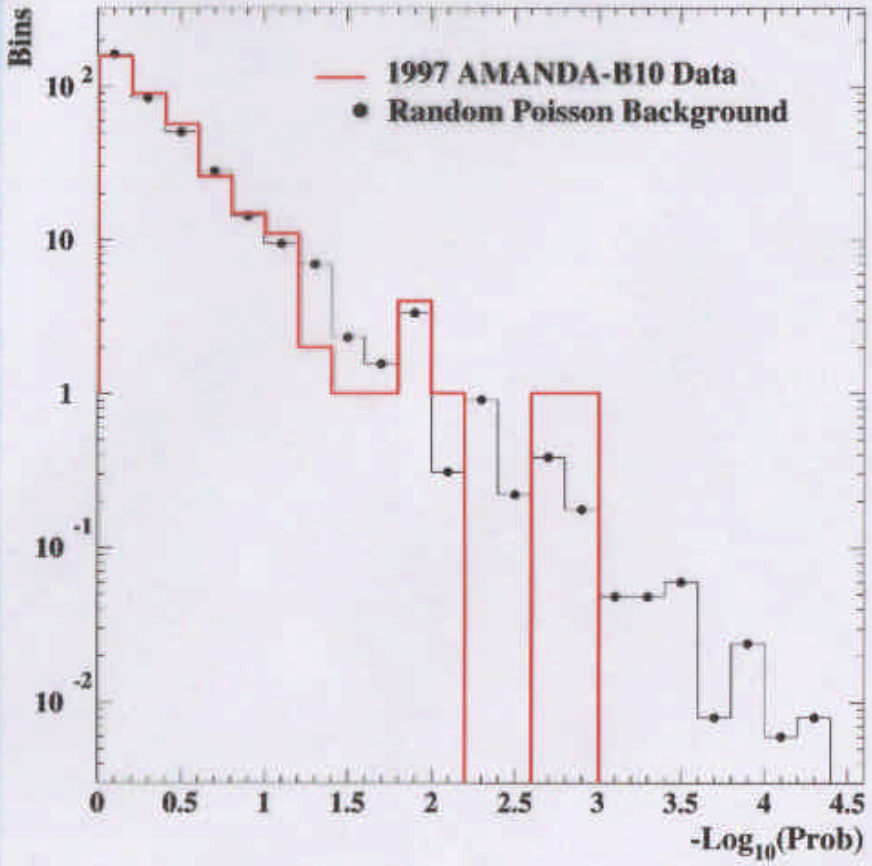
Significance distribution

- Bin sky according to angular resolution
- Use declination band to estimate background
- No statistically significant excess



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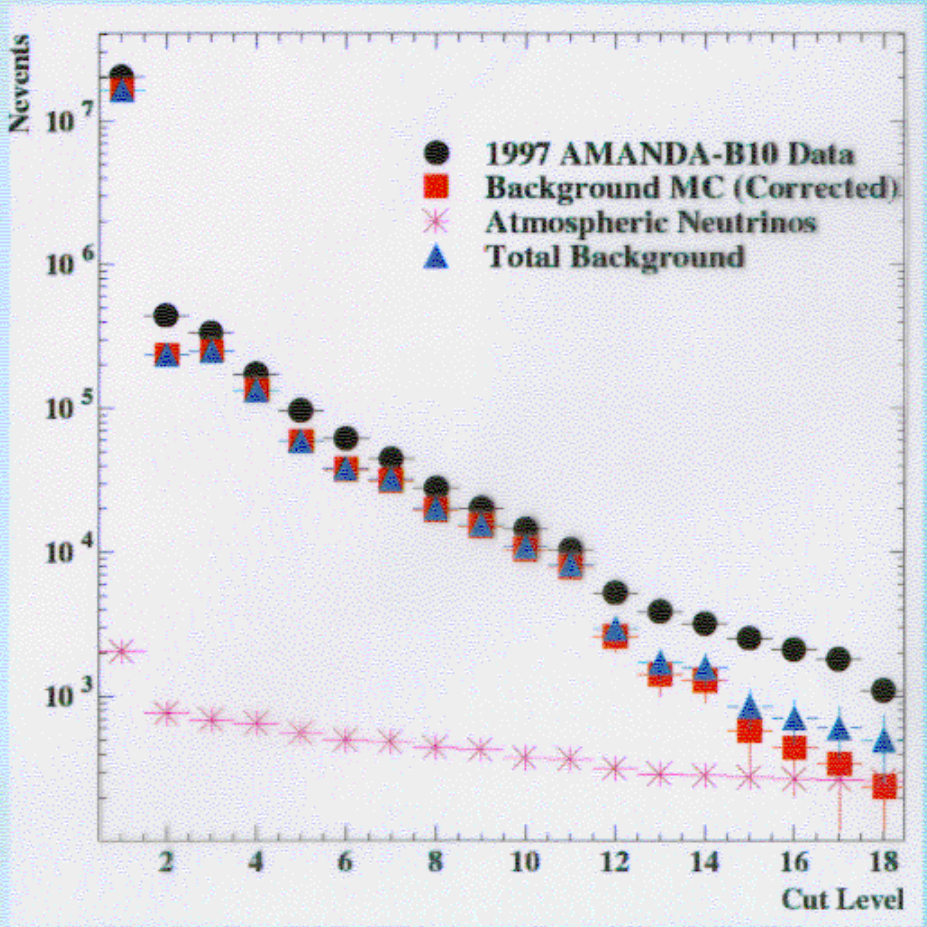
Background rejection

- Poorly reconstructed atmospheric muons
- Atmospheric ν_μ (Atm ν_e are negligible)
- Relative to trigger level, agreement at factor of 2.
- Simulations describe detector performance



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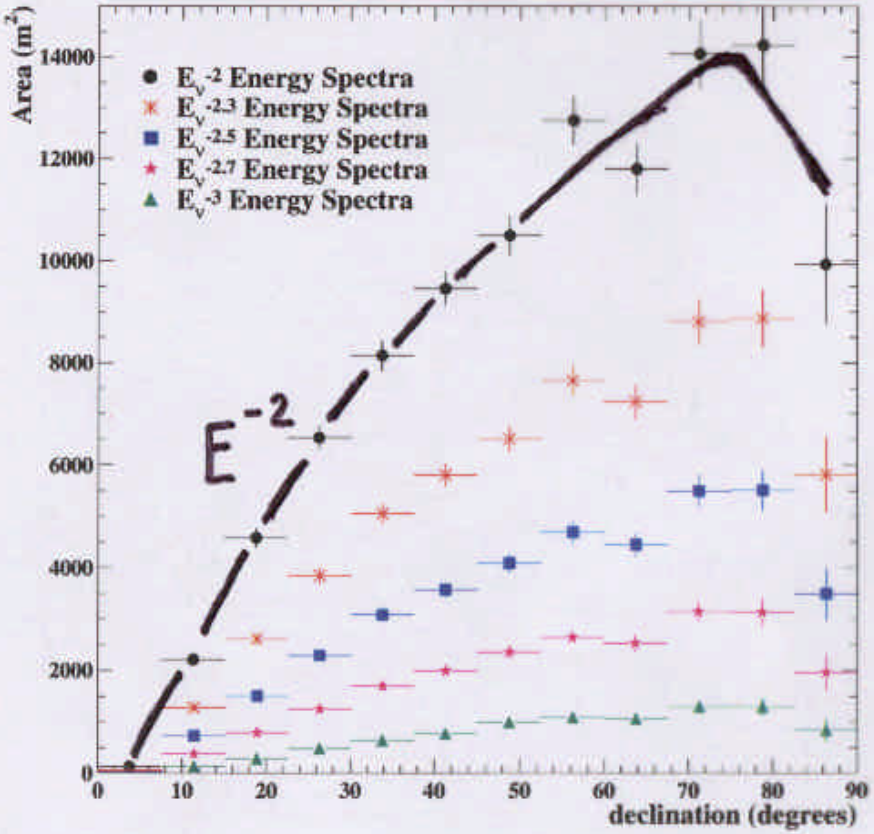
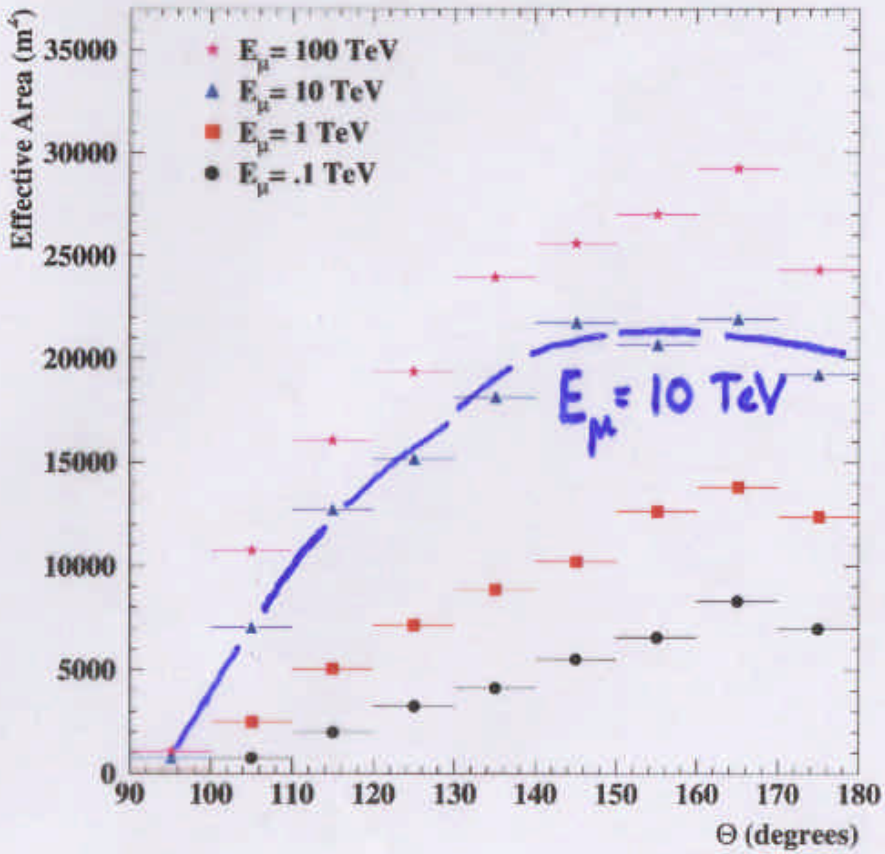
Effective Area for Muons

Point Source Analysis

Average Muon effective area ($E_\nu \geq 10$ GeV)



Muon Effective Area versus Zenith Angle



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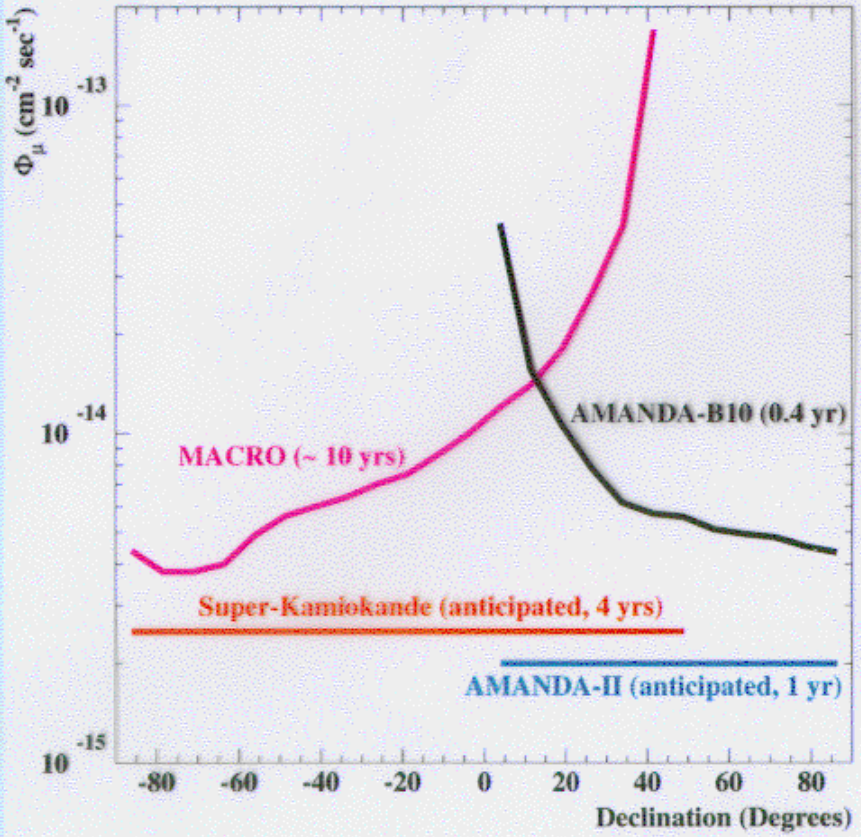
Flux Limit (preliminary)

- AMANDA B10 limits are compared to MACRO limits. SuperK curve is estimated!
- AMANDA-II will complement sky coverage of SuperK

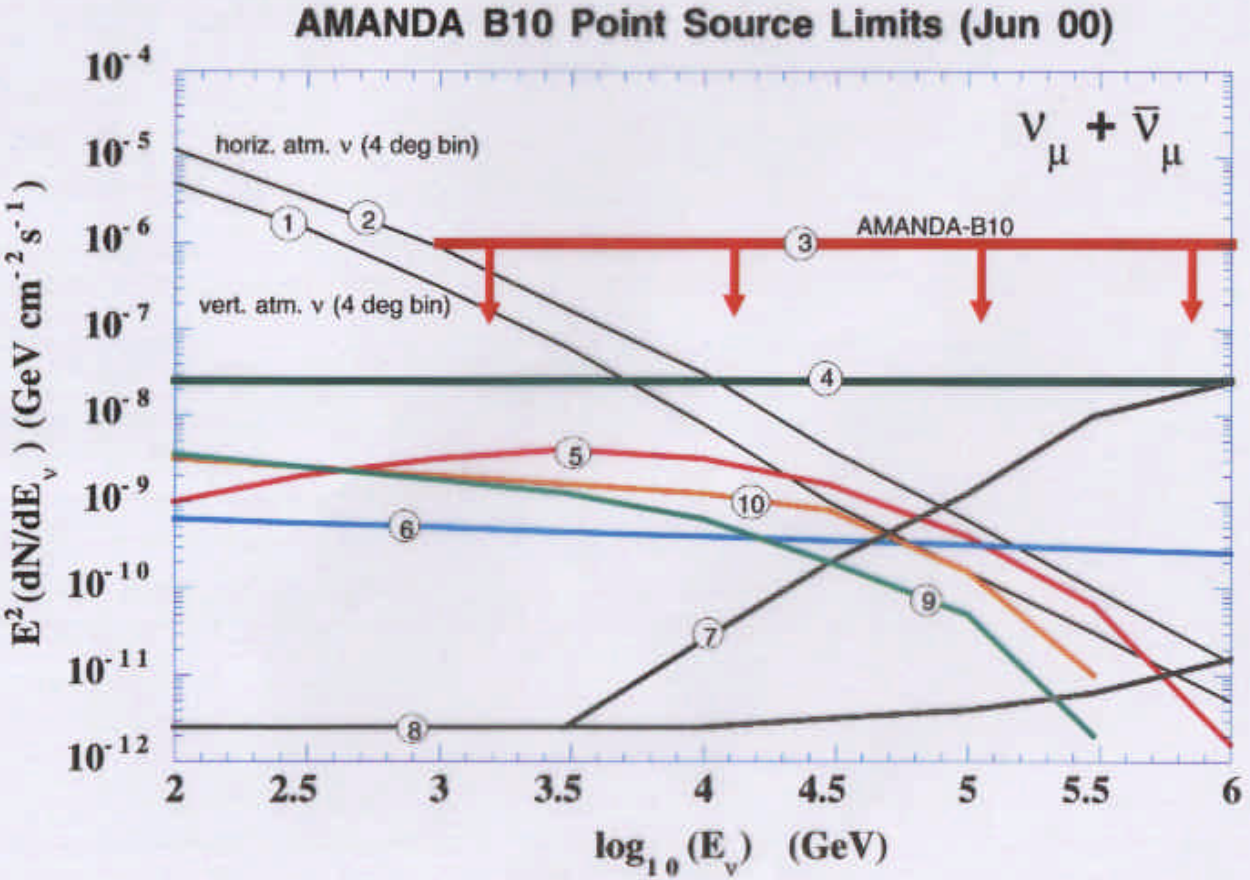


AMANDA

Point Source Fluxes

Figure adopted from Mannheim & Learned

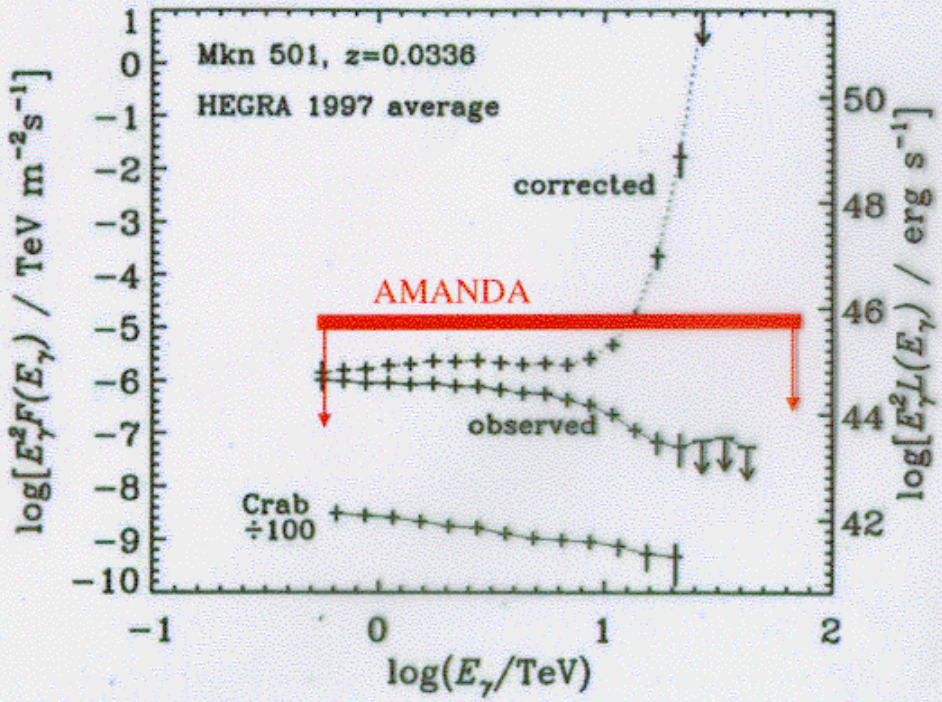
- Theoretical predictions are very small
- AMANDA limit assumes source with E^{-2} spectrum



Mk 501 Flux Limit

- Recent diffuse IR measurements imply strong attenuation of TeV photons
- AMANDA can rule out similar neutrino spectrum.

Figure adapted from Protheroe and Meyer, astro-ph/0005349



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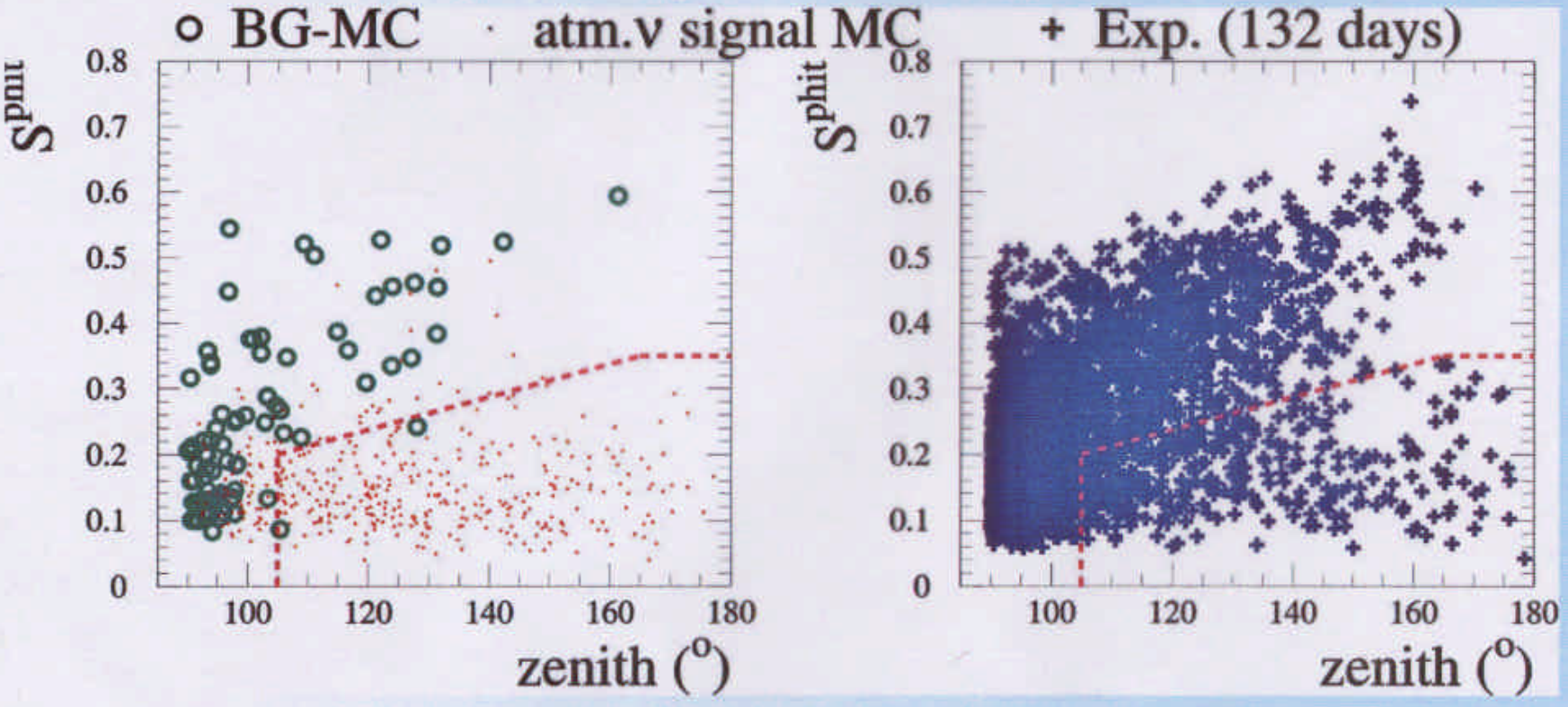
Signal-background Separation

Arb. normalization between signal and BG



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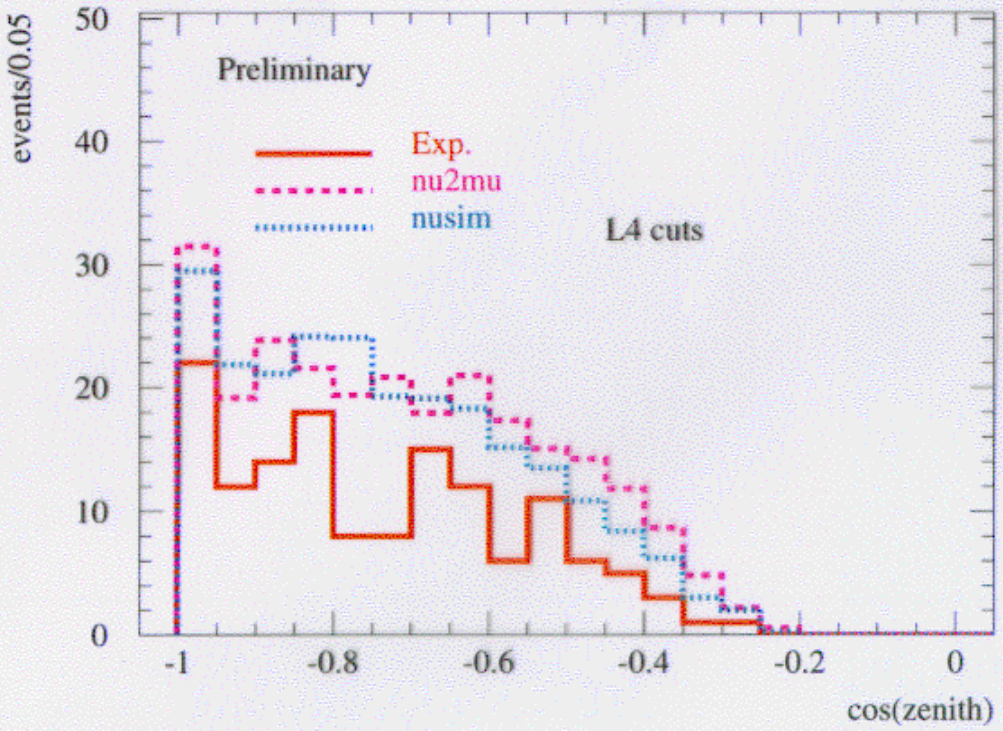
Atm. ν s: angular distribution

- ~ 1 event/day, shape exhibits good agreement
- < 50% discrepancy in normalization
- Atm. ν flux, ice properties, PMT collection efficiency, obscuration by cables may explain normalization



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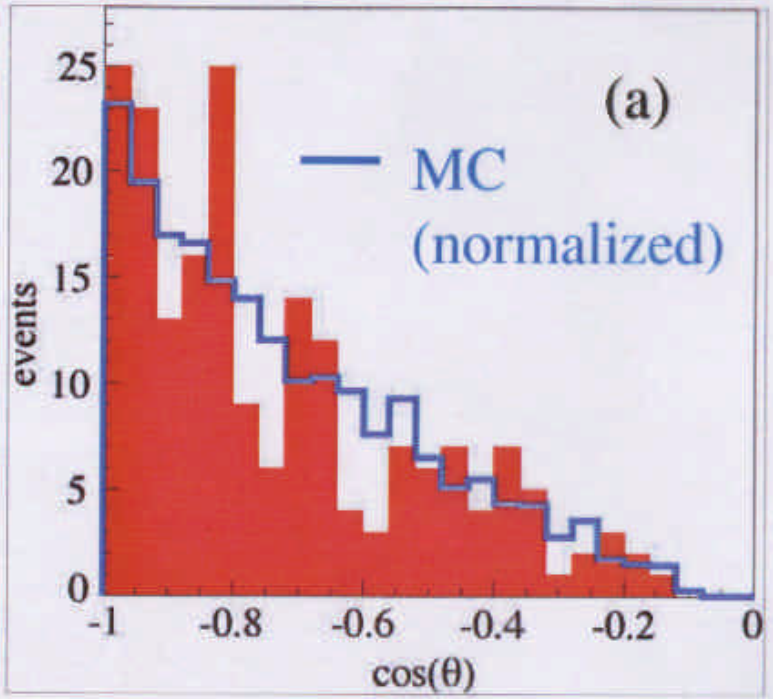
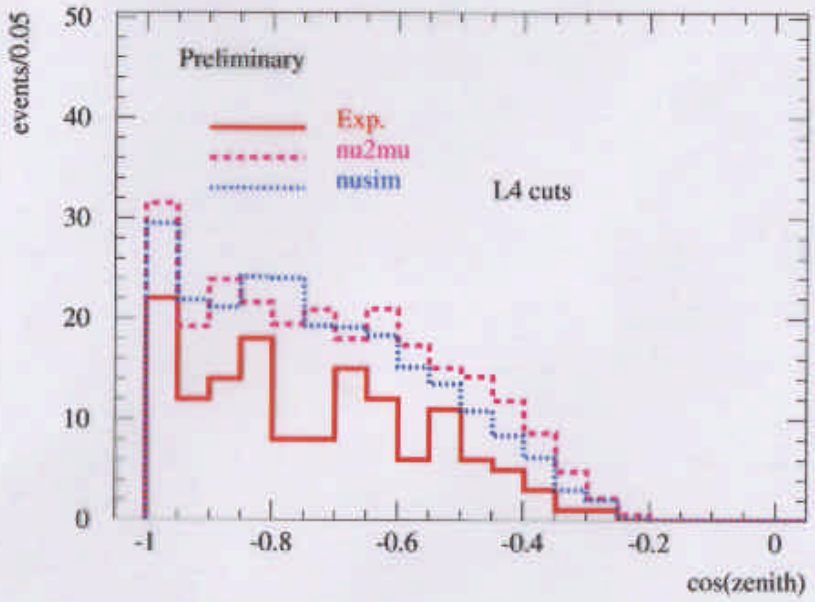
Angular Distributions

Two distinct analysis techniques, but not independent





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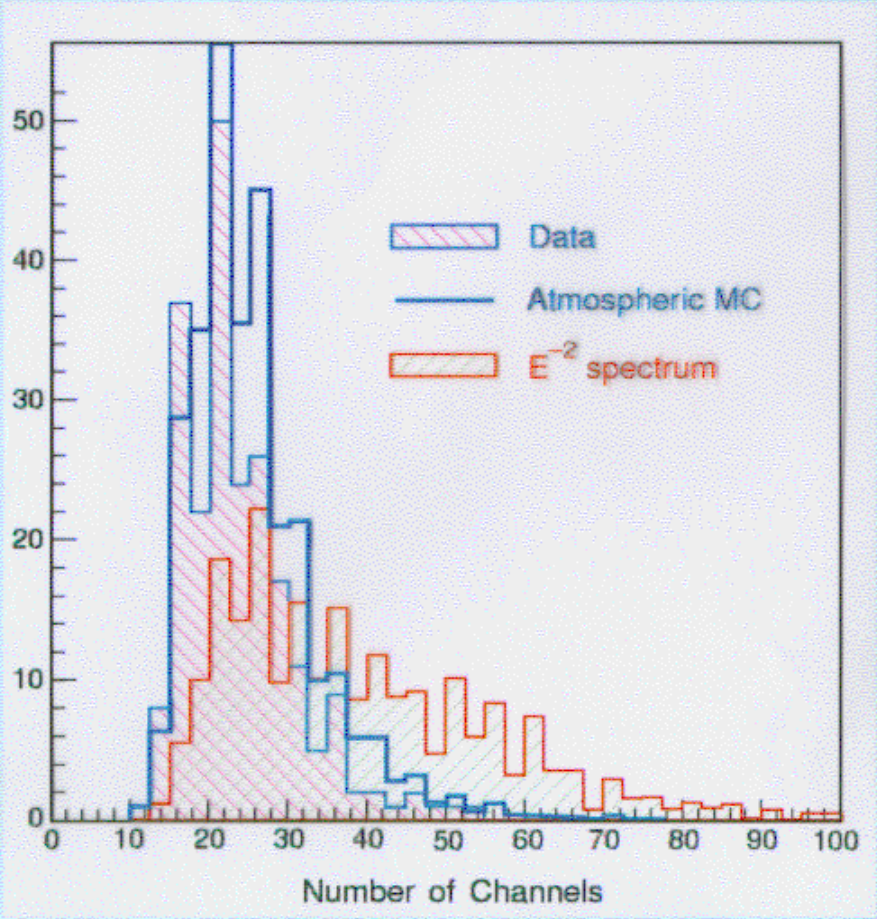
Search for Diffuse Flux

- OM multiplicity distribution is (weakly) related to energy deposition.
- Distribution is consistent with atm ν
- New energy estimators will lead to improved limits



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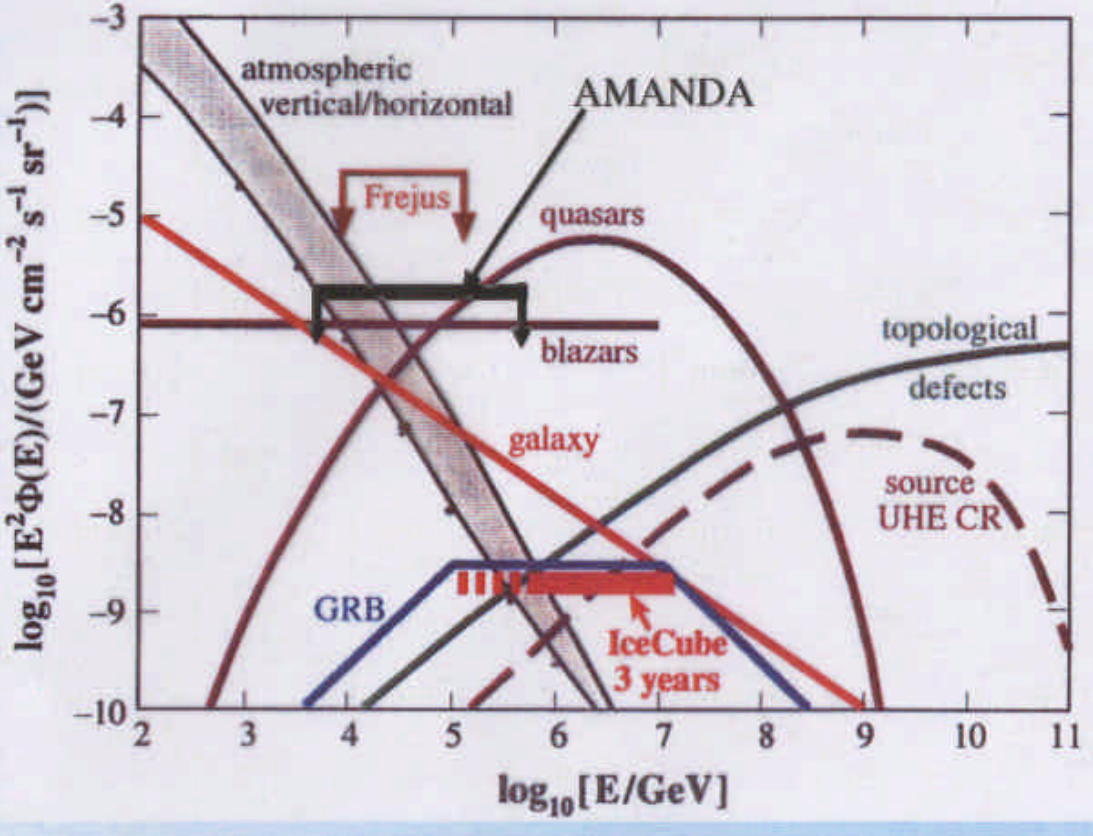
Diffuse Flux

- Generally 10^3 larger than point fluxes
- Atm. ν backgrounds 10^3 worse
- $E^2\Phi_\nu < 1.6\times10^{-6}$ $GeVcm^{-2}s^{-1}sr^{-1}$



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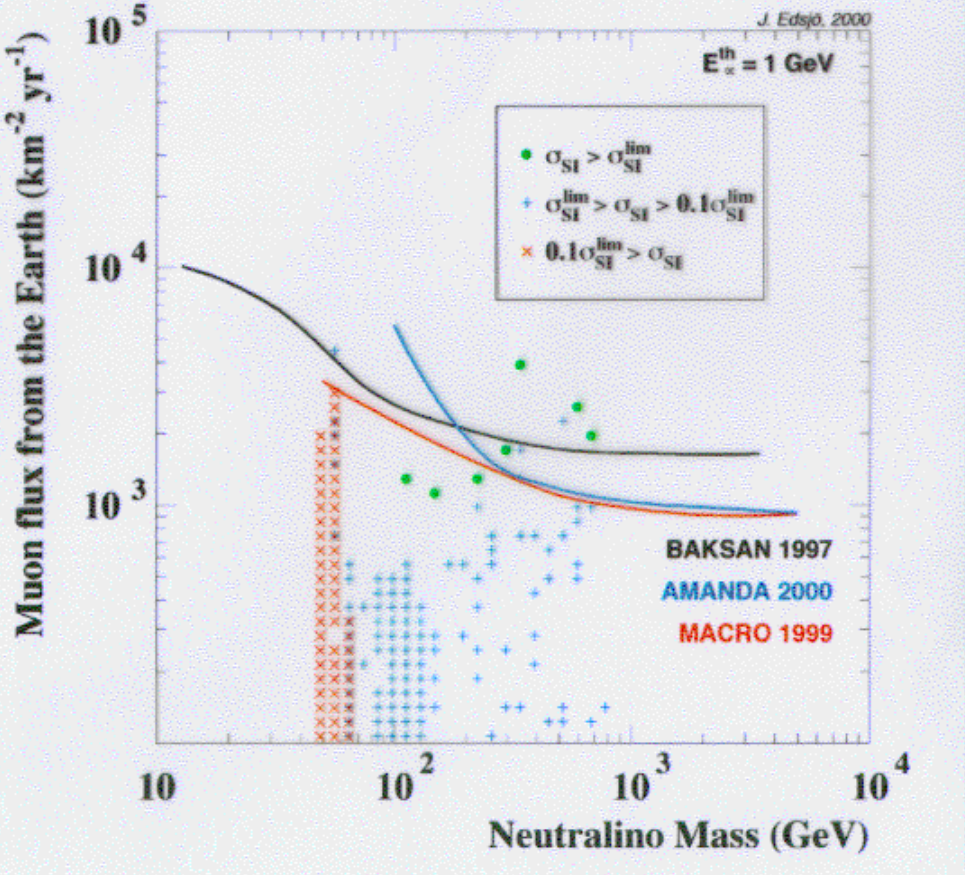
WIMPs from the Earth

Optimized search for vertical neutrinos

- AMANDA limits comparable to MACRO and Baksan
- Limits beginning to exclude relevant parameter space

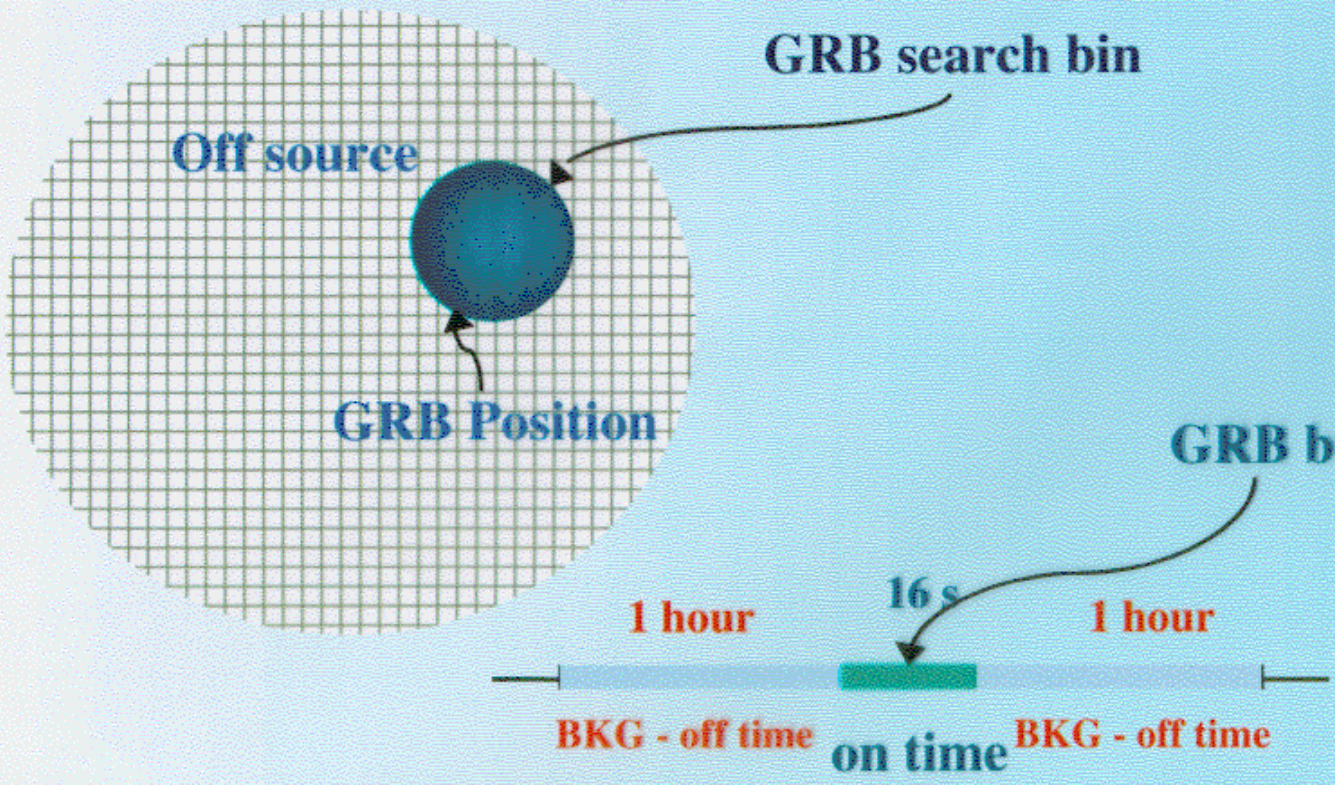


GRB Science

- Verify fireball model
- GRBs may be sources of highest energy cosmic rays
- Test of special relativity
- Search for ν_τ appearance at $\Delta m^2 > 10^{-17}$ eV^2

- Search for ν emission in coincidence with BATSE or MILAGRO

Search for HE ν from GRB



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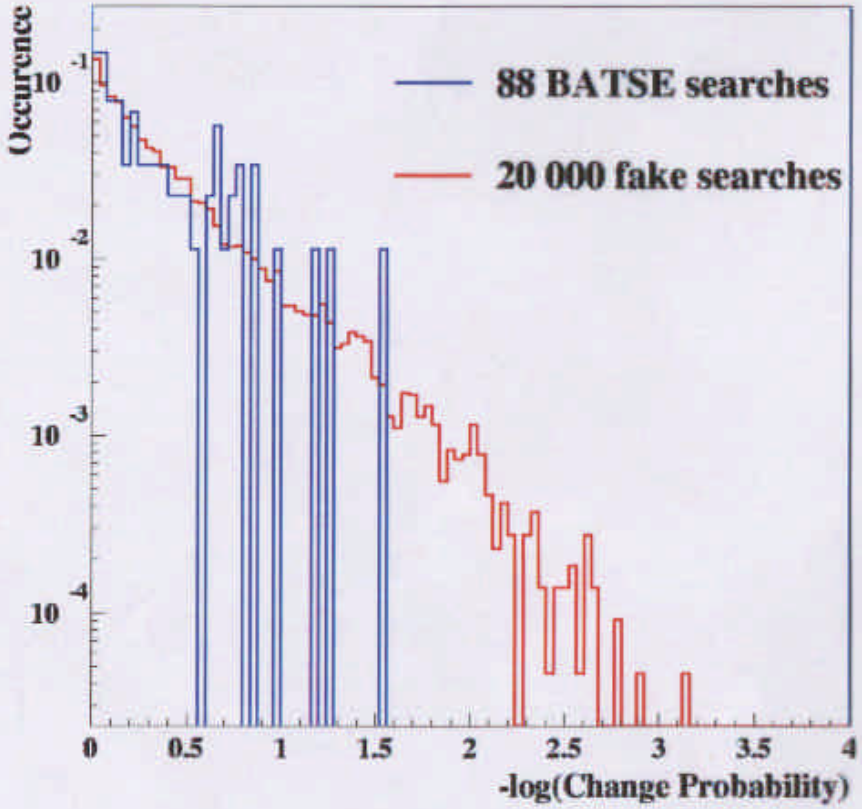
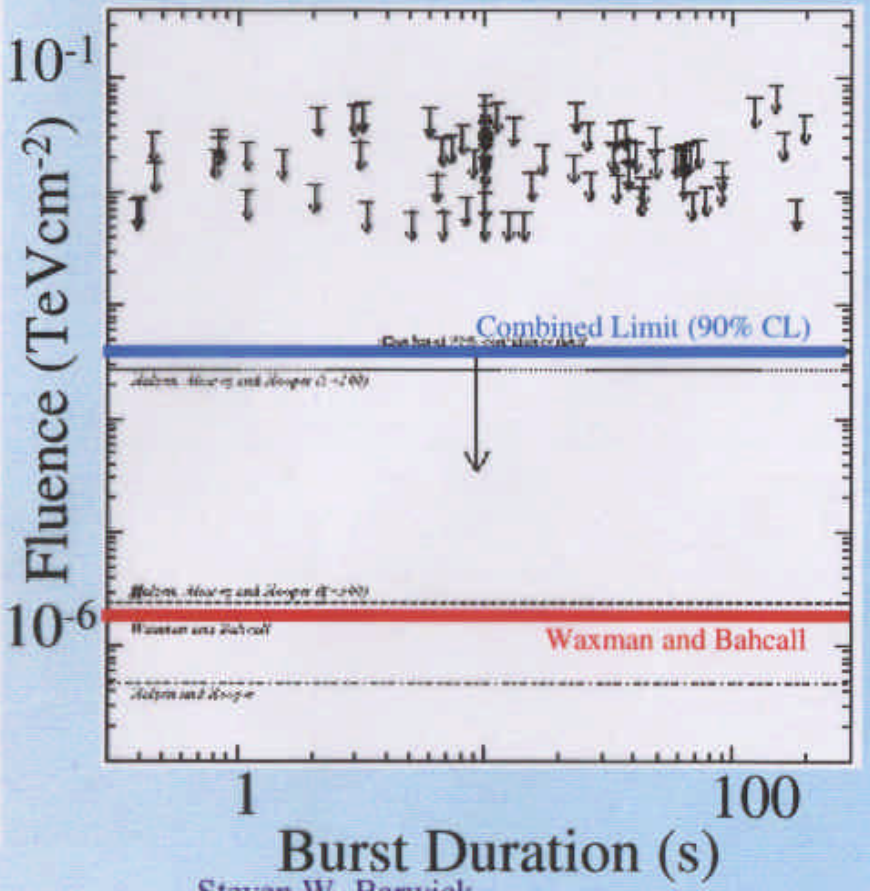
HE ν emission from GRB s ?

- Not so far





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Steven W. Barwick

Calibration of Sensitivity

- SPASE-AMANDA
  - MC/data = 0.86 for inverted an gular cuts
- Atmospheric neutrinos
  - MC/data = 1.5
- Atm. muon rates relative to trigger rates
  - MC/data = 0.9-0.5 as rejection criteria becomes more selective

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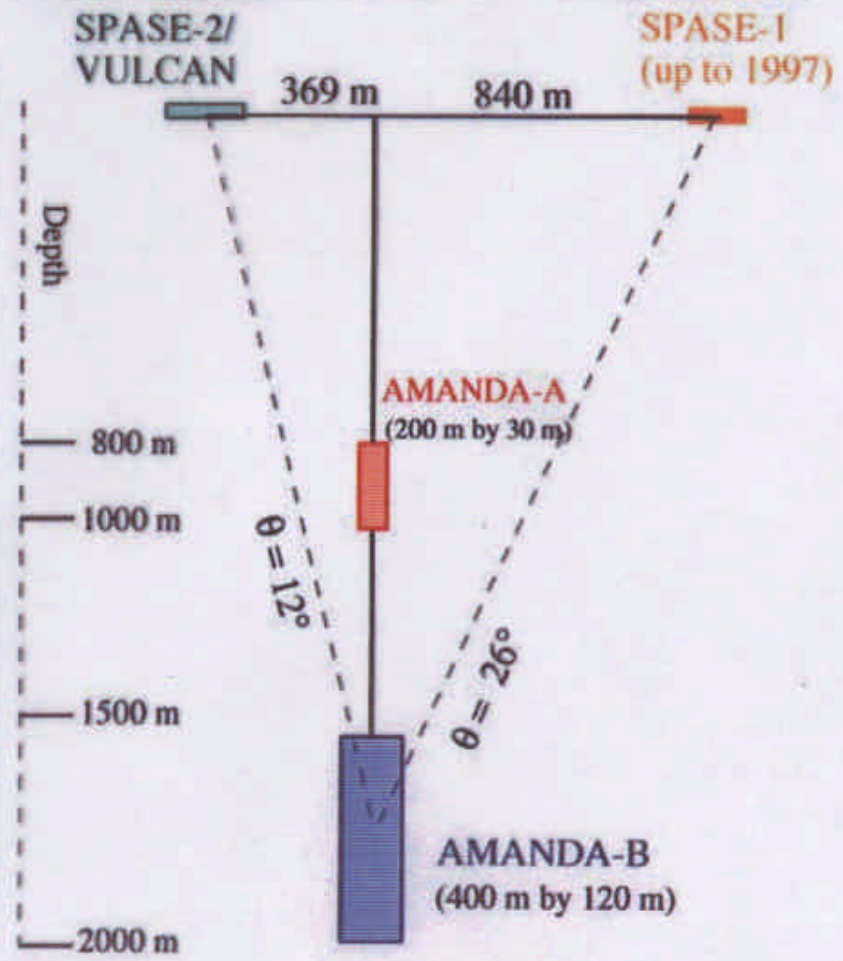
SPASE-AMANDA

SPASE: South Pole Air Shower Experiment

- Calibration of absolute pointing
- Calibration of pointing resolution
- Calibration of signal efficiency



Relative Efficiency = 0.86

Fraction of events remaining as a function of rejection criteria, normalized to number of triggers.

Data = SPASE-AMANDA coincidence events.
SPASE-MC = Monte Carlo simulation
Full analysis = point source analysis with inverted angle

Level	SPASE-MC	Data	Data/MC
Trigger	1.00	1.00	1.00
Filter-1	0.57	0.57	1.00
Filter-2	0.39	0.35	0.90
Full analysis	0.22	0.19	0.86

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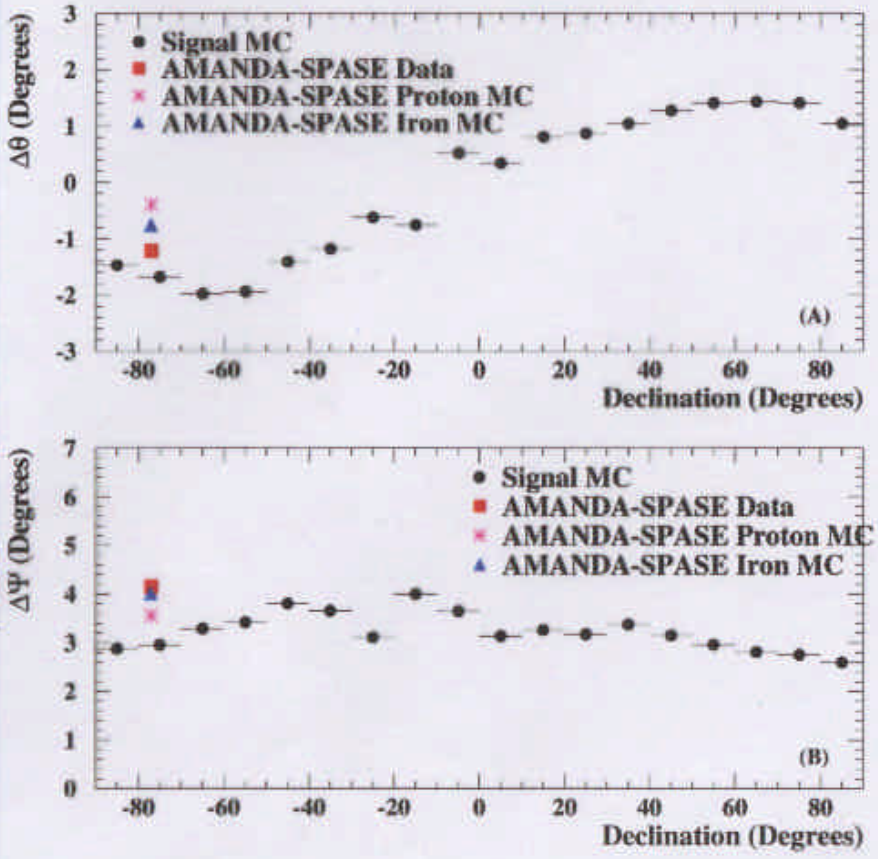
Space Angle Resolution/Offset

- SPASE events calibrate MC simulation of signal
- Absolute pointing $\Delta\Psi \sim 3$ degrees
- Offset $\Delta\theta \sim 1$ degree
- Multi-muon SPASE events similar to signal



Summary and Outlook

- No point sources (AGN, GRB or WIMPS) detected, but limits starting to impact models
  - more data on tape with bigger array (1998, 1999)
- ~170 atmospheric neutrinos candidates
  - Rate depends on efficiency of analysis
- Sensitivity and performance confirmed (to within factor of 2) by atm ν, background studies, and Spase-AMANDA coincidence events
- AMANDA-II is now taking data