A Search for Point Sources of High Energy Neutrinos with AMANDA-B10

Scott Young, for the AMANDA collaboration
UC-Irvine

PhD Thesis: http://area51.berkeley.edu/manuscripts
Goals

- Perform an “all-sky” search for point sources of HE neutrinos with maximum sensitivity
- Optimize on $E^{-2}$ spectra
  - BG from cosmic rays is much softer
  - Eliminate low energy events, while retaining HE $\nu$
- Maximize sensitivity over large solid angle
Experimental Challenges

- Demonstrate pointing accuracy
- Estimate angular resolution, $\Psi$
- Demonstrate sensitivity for high energy muons induced from neutrinos
  - $\Rightarrow$ Atmospheric neutrino spectrum is very soft
- Determine systematic errors contributing to flux uncertainties
Strategy to the Point Source Analysis

- Concentrate on continuous emission from sources with hard spectra ($\sim E^{-2}$)
  - Identify variables with strong discrimination between experimental data and expected signal.
  - Avoid variables with strong zenith dependence.

- Optimize search on Signal to Noise Ratio
  - $S/N$ improves if signal sensitivity grows faster than $\sqrt{B}$.
  - Iterative procedure defined \textit{a priori}.

- Background for this search
  - Poorly reconstructed atmospheric muons.
  - Atmospheric neutrinos.
Data Processing and Background Rejection

- Experimental data from 1997 (B10) and MC simulation processed in parallel.

- Excellent agreement over 6 orders of magnitude

Absolute normalization at trigger level (0)

Agreement to ~30% a complete analysis
Sky Plot (RA vs Declination)

- 815 events
- ~25% atmospheric neutrinos
- ~75% poorly reconstructed atmospheric muons
- No obvious clustering
Distribution of chance probability

- MC used to account for trial factor
- Bin shifting used to account for boundary effect
- No statistically significant excess

Fake source producing 25 events produces large excess
Space Angle Resolution and comparison to SPASE coincidence events

- Small systematic deviation in average zenith angle

- Space angle resolution ~3.5 deg. Confirmed by SPASE/AMANDA coincidence events

- Optimal bin size determined by MC (~10 degrees in zenith)
Effective Area of AMANDA-B10 (point source analysis)

\[ A_{\text{eff}}(\theta) \]

for neutrino-induced muons

\[ E_\mu = \text{Energy of muon at detector} \]
Spectral dependence of $\nu$–induced muon flux limit

Large dependence on spectral index is related to the energy dependence of the $A_{\text{eff}}(E_\mu)$
Impact of Systematic Errors

Primary sources of systematic error:

1. Inhomogeneous ice properties
2. Local optical properties of in refrozen hole
3. Modeling of photon propagation
4. Modeling of muon propagation and energy loss
5. Angular dependence of photon collection by Optical Modules (OMs)
6. Absolute sensitivity of OMs

Systematics introduce ±40% variation
Results

Averaged over RA, includes systematic uncertainties.
Experimental Checks
(see thesis for details)

- Checks on Pointing and Angular Resolution
  ➔ Confirmed with SPASE-AMANDA coincident data
  ➔ Compared with MC predictions

- Checks on Signal Sensitivity
  ➔ Atmospheric neutrino analysis
  ➔ Exp. Data and BG MC passing efficiency comparisons
  ➔ SPASE-AMANDA relative passing rates
Conclusions

- 1997 data is analysed: no evidence for neutrino point sources.
- Competitive flux limits with only 0.4 years of livetime.
- First search for neutrino sources at large positive declinations.
- Performance checks confirm MC predictions to within 40%.
  - Atms. neutrino analysis establishes confirms sensitivity predictions of signal to within 40%.
  - BG MC agrees with data to within 30% to the highest cut level.
  - SPASE-AMANDA confirms angular pointing and resolution predicted by MC.
  - SPASE-AMANDA also confirms passing efficiency predictions to within 50%.
- All goals achieved: Promising future with AMANDA-II.
Observation of High Energy Gamma Ray Point Sources

- Detection of TeV Gamma ray Point Sources
- EGRET Detection of MeV and GeV Gamma rays
- Is High energy emission from Proton or Electron acceleration?