Results from AMANDA

Albrecht Karle
University of Wisconsin-Madison
karle@alizarin.physics.wisc.edu

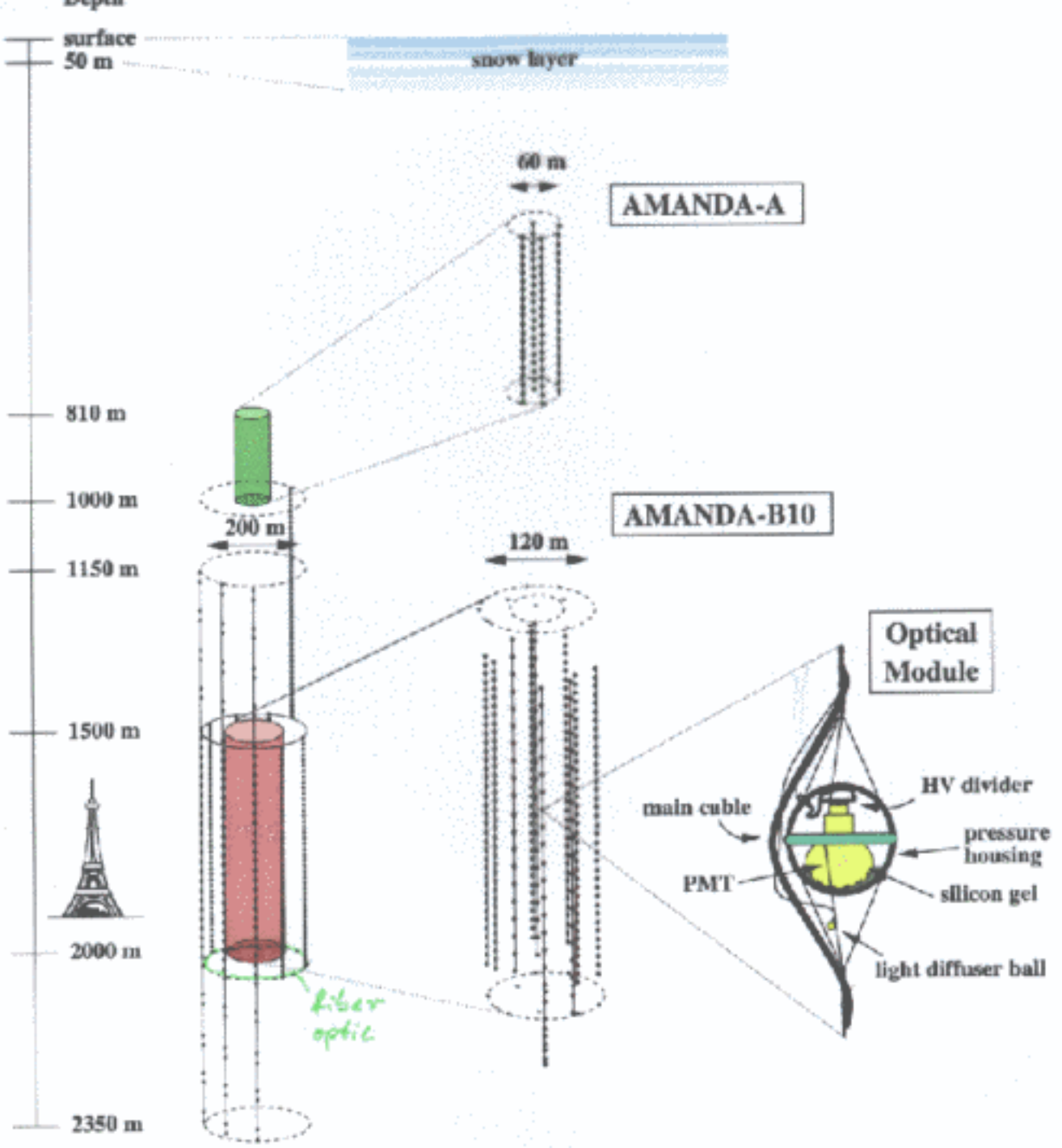
- Introduction
- Observation of Atmospheric Neutrinos
- Search for diffuse HE Neutrinos
- WIMPS
- Astrophysical Point Sources
- Gamma Ray Bursts

THE AMANDA Collaboration

E. Andres[11], P. Askebjer[3], G. Barouch[8], S. W. Barwick[6], X. Bai[11], K. Becker[5], R. Bay[5], L. Bergström[4], D. Bertrand[12], D. Besson[13], A. Biron[2], J. Booth[6], O. Botner[14], A. Bouchta[7], S. Carius[3], M. Carlson[8], W. Chinowsky[10], D. Chirkin[7], J. Conrad[14], C. Costa[8], D. F. Cowen[7], E. Dalberg[4], J. Dewulf[12], T. DeYoung[8], J. Edsjö[4], P. Ekström[4], G. Frichter[13], A. Goobar[4], L. Gray[8], A. Hallgren[14], F. Halzen[8], Y. He[5], R. Hellfie[8], G. Hill[8], P. O. Hulth[4], S. Hundertmark[2], J. Jacobsen[10], V. Kandhadai[8], A. Karle[8], J. Kim[8], B. Koci[8], M. Kowalski[2], I. Kravchenko[13], J. Lamoureux[10], P. Leaiza[14], H. Leich[2], P. Lindahl[3], T. Liss[7], I. Liubarsky[8], M. Leuthold[2], D. M. Lowder[5], J. Ludvig[10], P. Marciniewski[14], T. Miller[1], P. Miocinovic[5], P. Mock[6], F. M. Newcomer[7], R. Morse[8], P. Niessen[2], D. Nygren[10], C. Pérez de los Heros[14], R. Porrata[6], P. B. Price[5], G. Przybylski[10], K. Rawlins[8], W. Rhode[9], S. Richter[11], J. Rodriguez Martino[6], F. Romenesko[8], D. Ross[6], H. Rubinstein[4], E. Schneider[6], T. Schmidt[2], R. Schwarz[11], A. Silvestri[2], G. Smoot[10], M. Solarz[5], G. Spiczak[1], C. Spiering[2], N. Starinski[11], P. Steffen[2], R. Stokstad[10], O. Streicher[2], I. Taboada[7], T. Thon[2], S. Tilav[8], M. Vander Donckt[12], C. Walck[4], C. Wiebusch[2], R. Wischnewski[2], K. Woschnagg[5], W. Wu[6], G. Yodh[6], S. Young[6]

(1) Bartol Research Institute, University of Delaware, Newark, DE, USA
(2) DESY-Zeuthen, Zeuthen, Germany
(3) Dept. of Physics, Kalmar University, Sweden
(4) Dept. of Physics, Stockholm University, Stockholm, Sweden
(5) Dept. of Physics, UC Berkeley, Berkeley, CA, USA
(6) Dept. of Physics, UC Irvine, Irvine, CA, USA
(7) Dept. of Physics, University of Pennsylvania, Philadelphia, PA, USA
(8) Dept. of Physics, University of Wisconsin, Madison, WI, USA
(9) Dept. of Physics, University of Wuppertal, Wuppertal, Germany
(10) Lawrence Berkeley Laboratory, Berkeley, CA, USA
(11) South Pole Station, Antarctica
(12) ULB - IIHE - CP230, Boulevard du Triomphe, B-1050 Bruxelles, Belgium
(13) University of Kansas, Lawrence, KS, USA
(14) University of Uppsala, Uppsala, Sweden

+ new collaborators:
  - Univ. of Maine, Germany



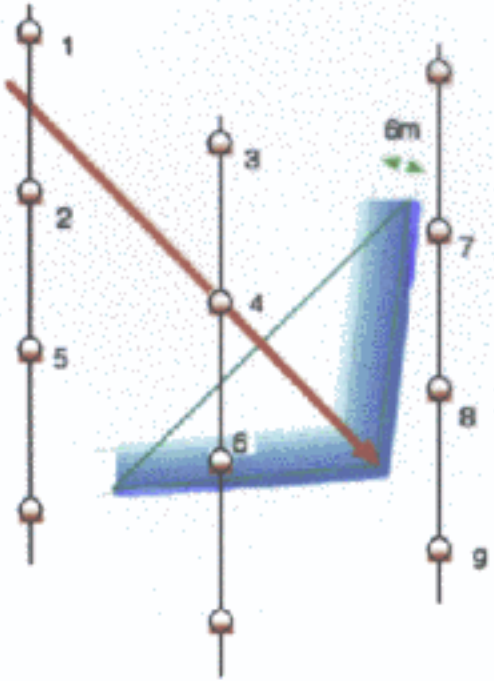
AMANDA as of 2000
Eiffel Tower as comparison
(true scaling)

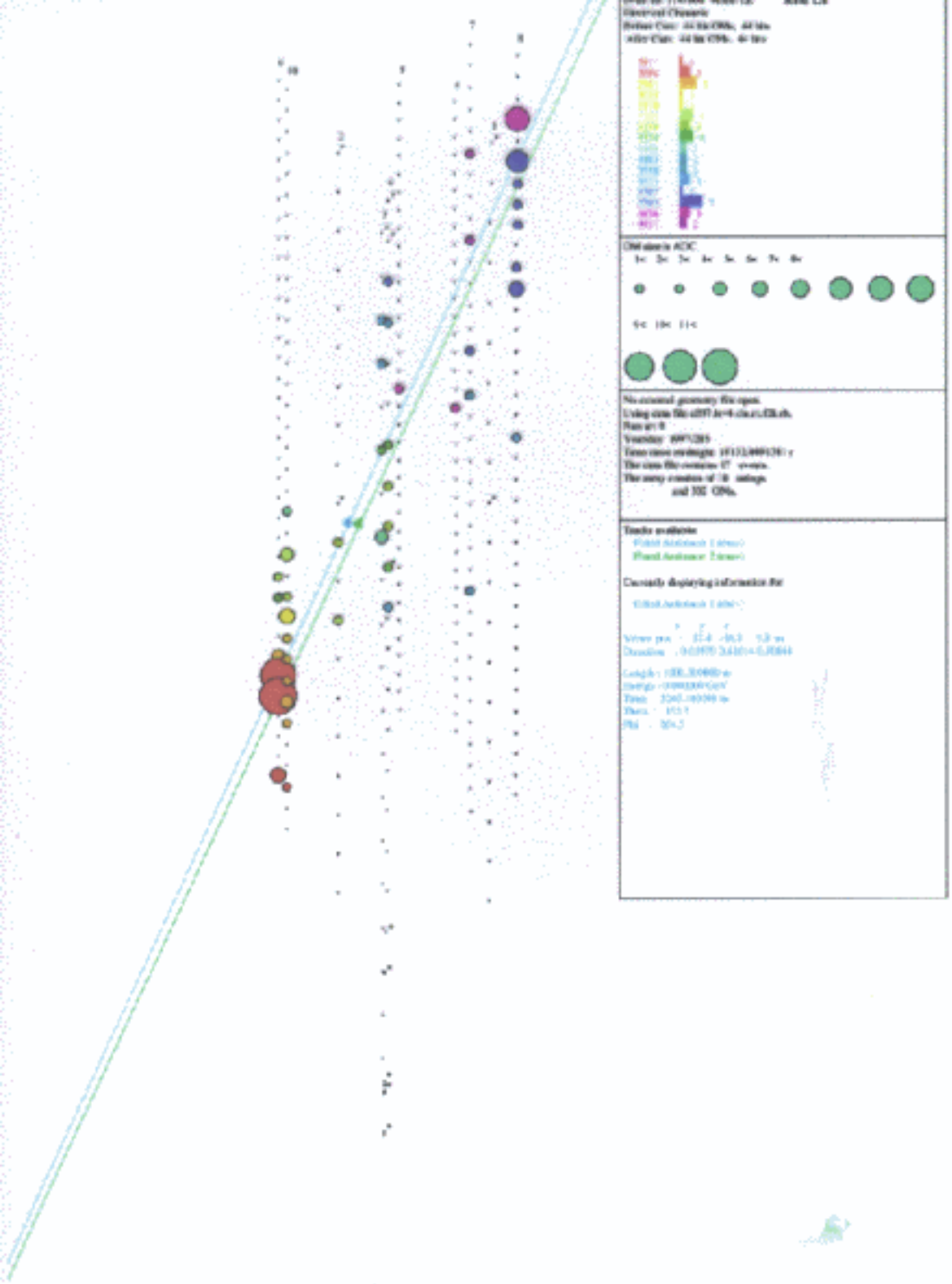
zoomed in on
AMANDA-A (top)
AMANDA-B10 (bottom)

zoomed in on one
optical module (OM)

Event reconstruction

- Maximum Likelihood method
- Take into account time profiles of expected photon flight times
- Bayesian approach - use prior knowledge of expected backgrounds and signals





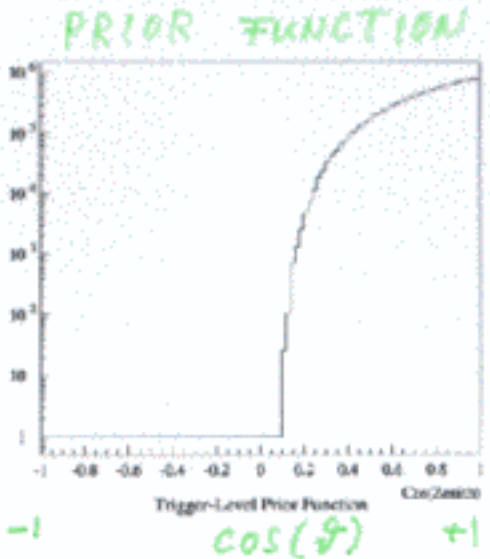
Background rejection strategies

Type of Neutrino source	Rejection method
Diffuse source	Up/Down: <1E-8 and energy
Point Sources (AGN)	AND Direction
Burstlike Point Sources (GRB or AGN with time structure)	AND Time Stamp (GRB: secs, AGN: h,d)

Measu
Backgr

Bayesian Event Reconstruction

- Bayesian approach - use prior knowledge of expected backgrounds and signals
- Minimise L(E|H) P(H) where P(H) reflects expected zenith distribution of hypotheses
- Eg expect more downgoing than near horizontal background muons



Quality Parameters

- Likelihood
- Zenith angle mismatch between two types of fits.
- Sphericity of Hits (Brem?)
- Track Length (is an energy cut, too) ≥100 m
- Smoothness of hits along the track
- Number of unscattered photons

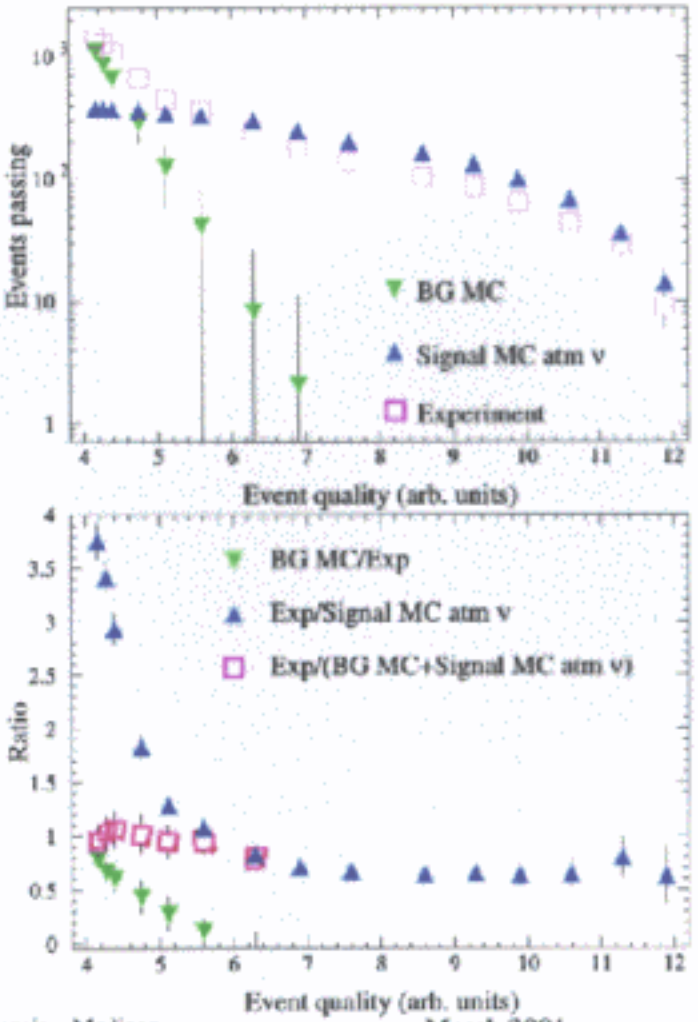
Combine to a

Single event quality parameter.

(Diagonal in a 6 dimensional parameter space)

Background rejection

- Upward reconstructed events are plotted versus event quality parameter
- Experimental data dominated by atmospheric neutrinos for increased quality parameter



Atmospheric muons and neutrinos

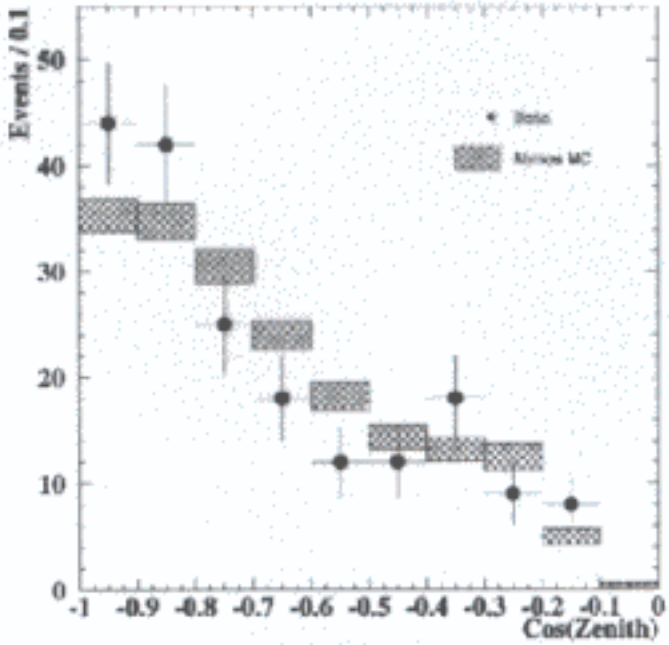
- Atm. Neutrinos (ν_μ): 60/day
- Atm. Muons: $8.6*10^{10}$/day

16 Hits / 2 μsec →

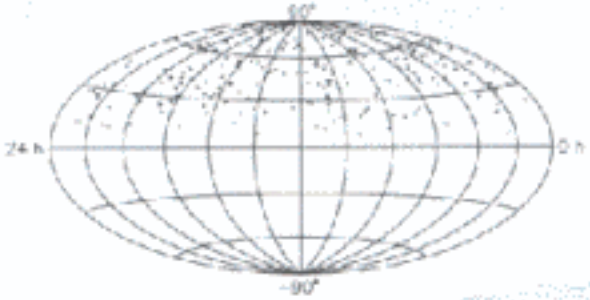
Lifetime: 135 days		
	Observed Data	**Predicted Neutrinos**
Triggered	1,200,000,000	8000
Reconst. Upgoing	5000	590
Pass Cuts	**156**	**220**

Atmospheric neutrinos

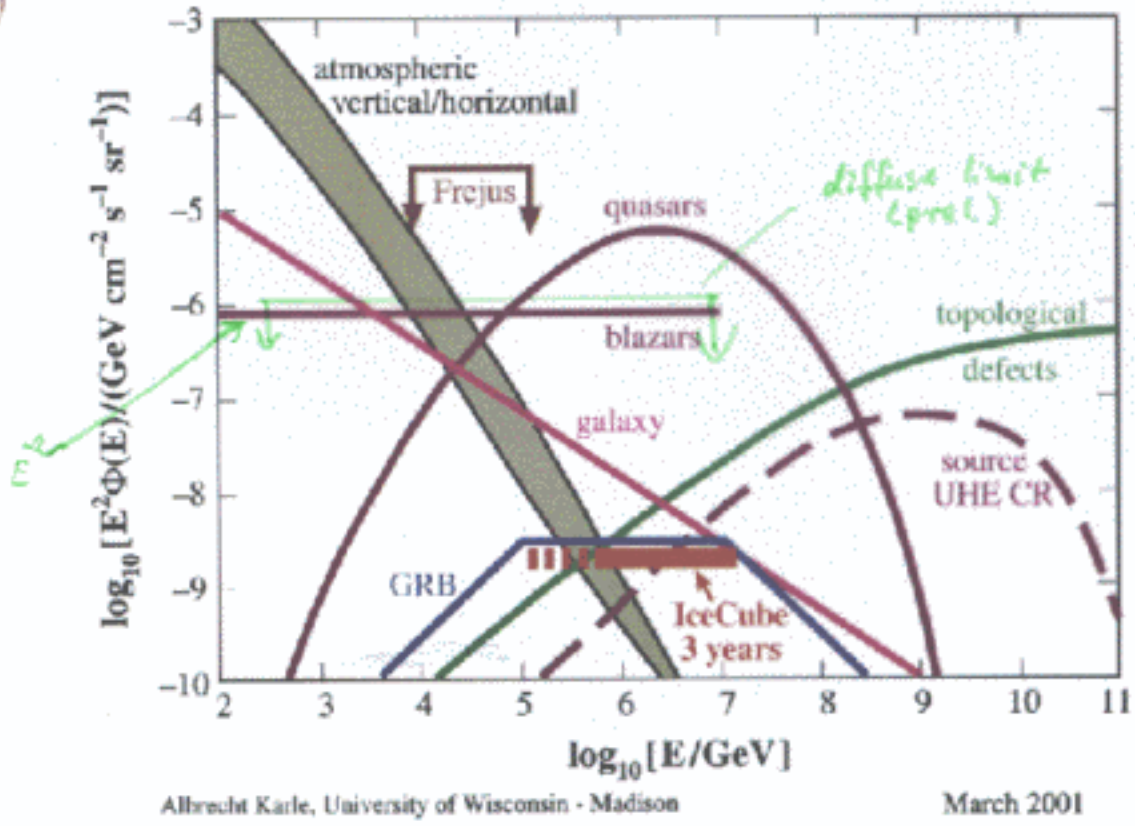
Zenith angle:
Data and MonteCarlo



Skyplot



Sources of astrophysical neutrinos

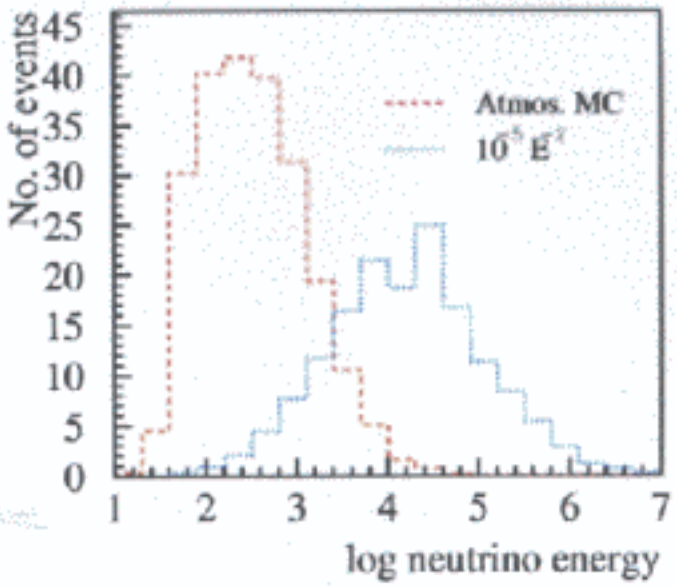


Atmospheric neutrino and E^{-2} type energy spectrum triggered by AMANDA

Monte-Carlo Simulation:
Compare AMANDA detector response of:

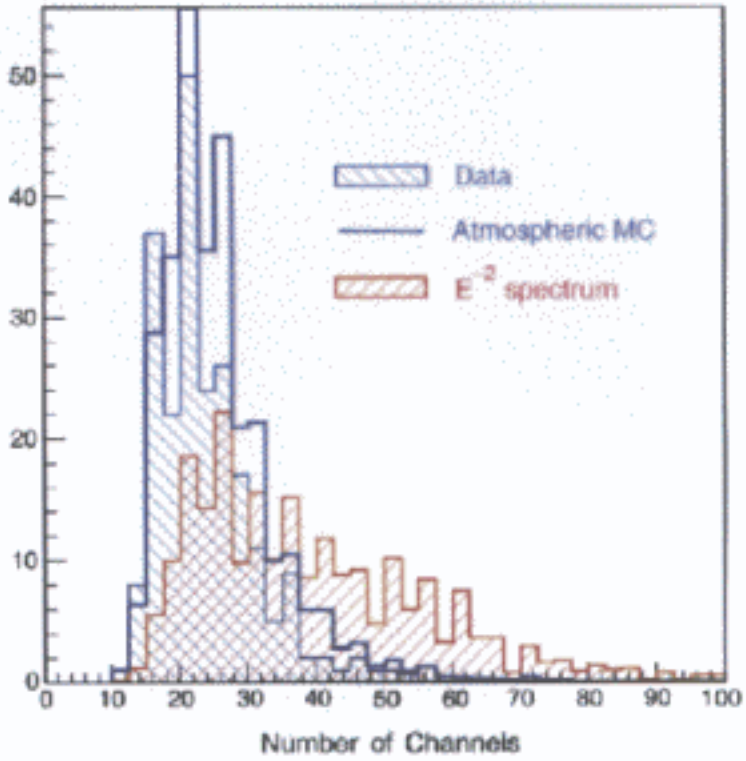
1.) E^{-2} type energy spectrum:
$dN/dE = 10^{-5} * E^{-2}/(cm^2 \text{ sec GeV})$
Spectrum gives max. detector response at about 20 TeV.

2.) Atmospheric neutrino Background.
Typical energy: 0.05 - 2 TeV.



Use the # of fired PMT (nch) as energy parameter

- Normalize (calibrate) MonteCarlo to atmospheric neutrino signal (absolute flux)
- Energy cut: nch > 45
- No signal seen above atmospheric background.
- Place upper limit



Diffuse upper limit result

PRELIMINARY!

- Cut Optimization is done by Monte-Carlo only
- Upper limit on diffuse HE neutrino flux (90% c.l., F/C)

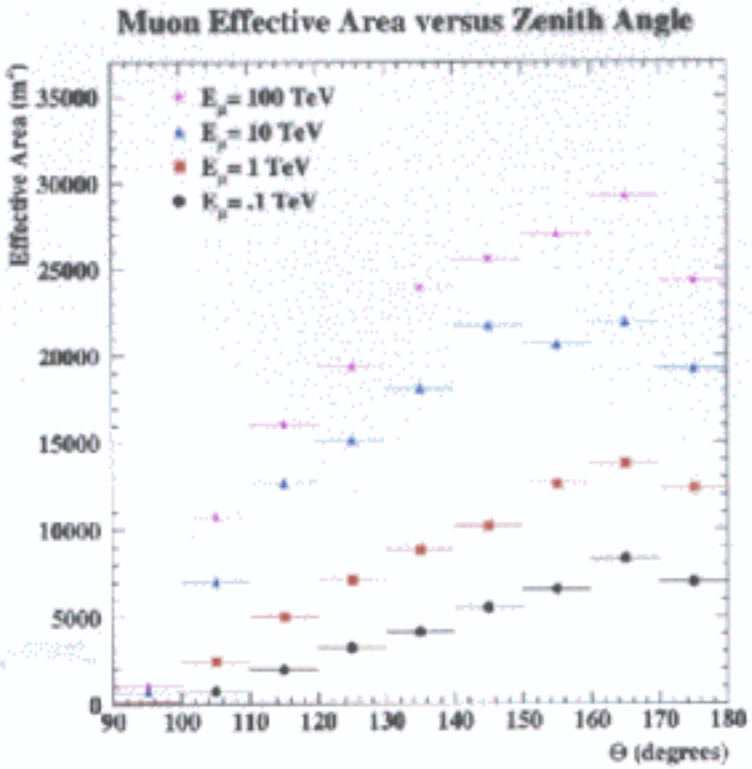
$$dN/dE \leq E^{-2}\ 1.6 \times 10^{-6}\ /(cm^2 s^1 sr^1 GeV$$

Searches for point sources

- Look for event excesses from known or unknown point sources
- Looser cuts than atmospheric search
- 1097 events - atmospheric neutrinos and mis-reconstructed atmospheric muons

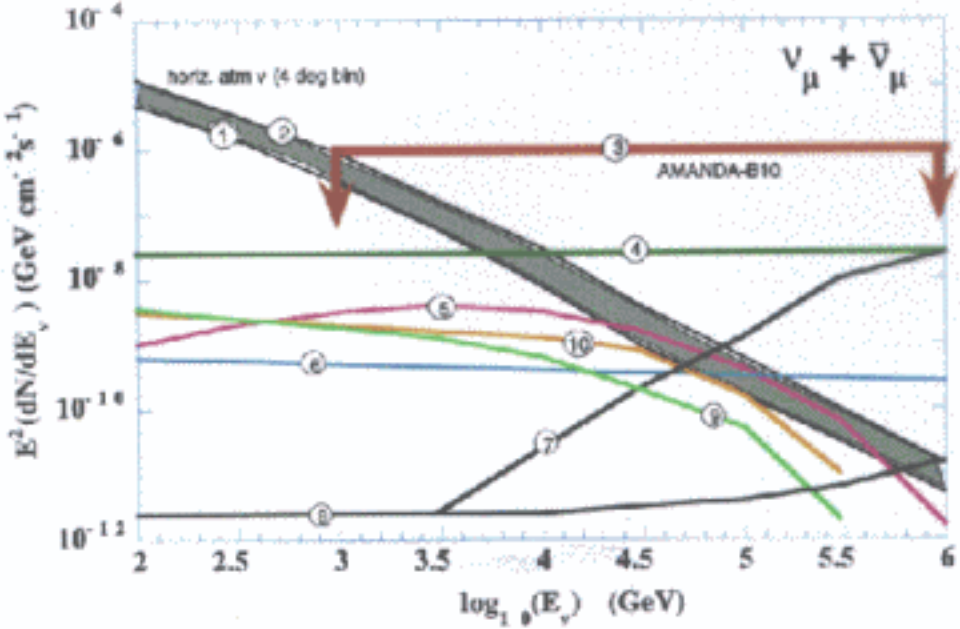
Effective Area for upgoing Muons

- Effective area increases with energy
- Optimize search strategy with power law spectra, e.g. E^{-2}
- At 10 TeV effective area about 20000 m^2 (after all cuts)



AMANDA Limit on Point Sources

PRELIMINARY

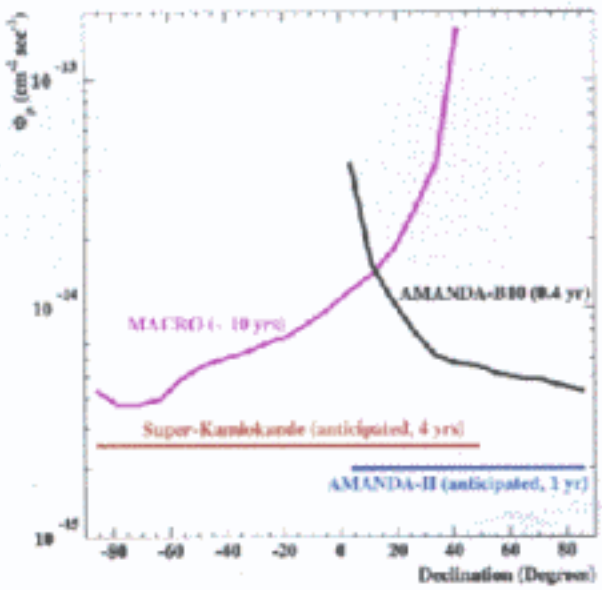


1. Atmospheric Neutrinos (vertical)
2. Atmospheric Neutrinos (horizontal)
3. AMANDA preliminary limit
4. AGN Core (Nellen et al.)
5. Crab Nebula (Bednarek & Protheroe model I)
6. Coma Cluster (Colafrancesco & Blasi)
7. AGN Core (Stecker & Salamon)
8. AGN Jet (Mannheim)
9. SNR g Cygni (Gaisser et al)
10. SNR IC444 (Gaisser et al)

Figure adapted from Mannheim & Learned)

Point source upper limits

All-sky search



Markarian 501

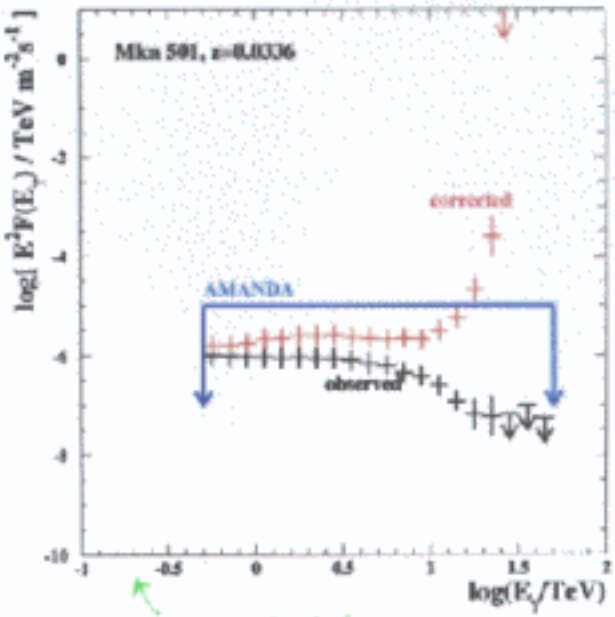


Fig. adapted from Matthias Mayer

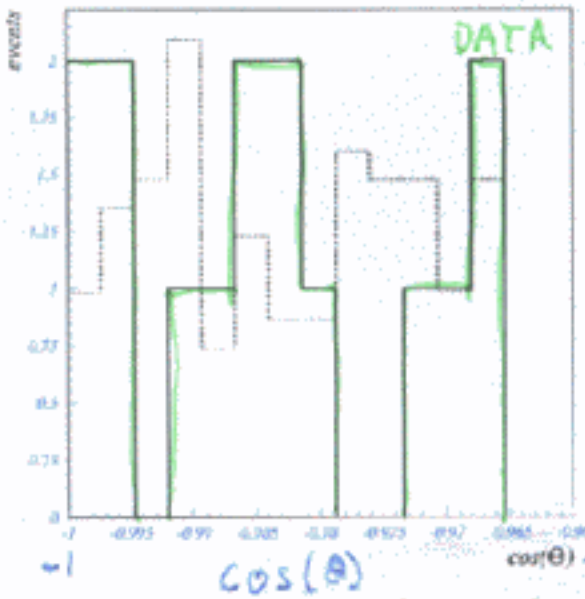
Searches for WIMPS

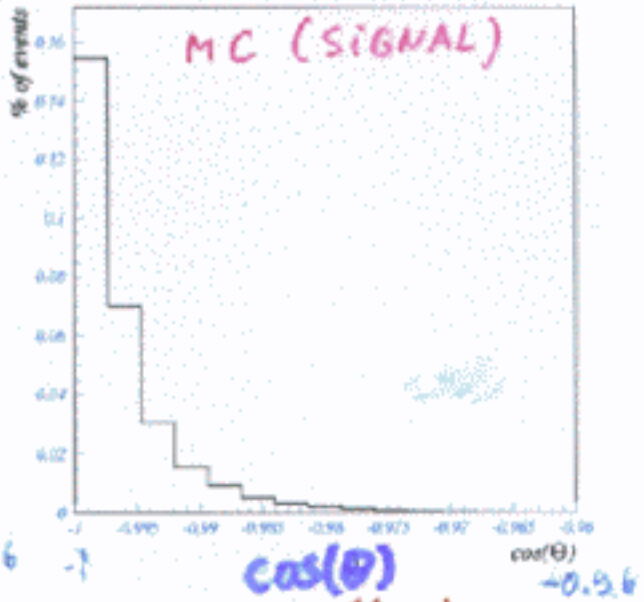
- Candidate particle is the neutralino from supersymmetric extensions of the standard model
- Search for neutrino-induced muons from neutralino annihilations in the earth's centre
- Background - vertical atmospheric neutrino-induced muons

Vertical neutrino events

Data vs atmos neutrino MC
Solid - data
Dashed - MC

WIMP prediction - 250GeV
hard annihilation channel





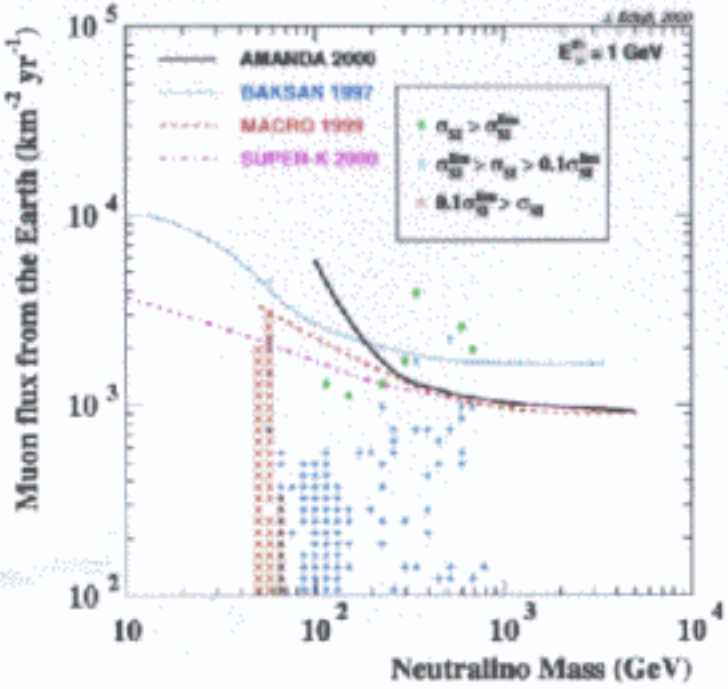
No excess of vertical events upper limit

Albrecht Karle, University of Wisconsin - Madison

March 2001

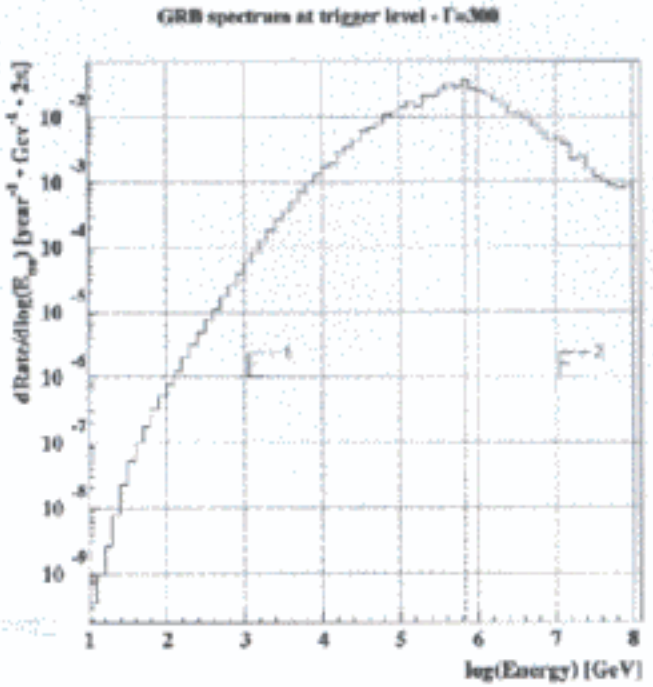
Neutrino-induced muon upper limits from the earth's centre for hard annihilation channel

- o - models excluded by direct direction experiments
- + - models explored with 10x sensitivity increase
- x - models not reachable with 10x sensitivity increase



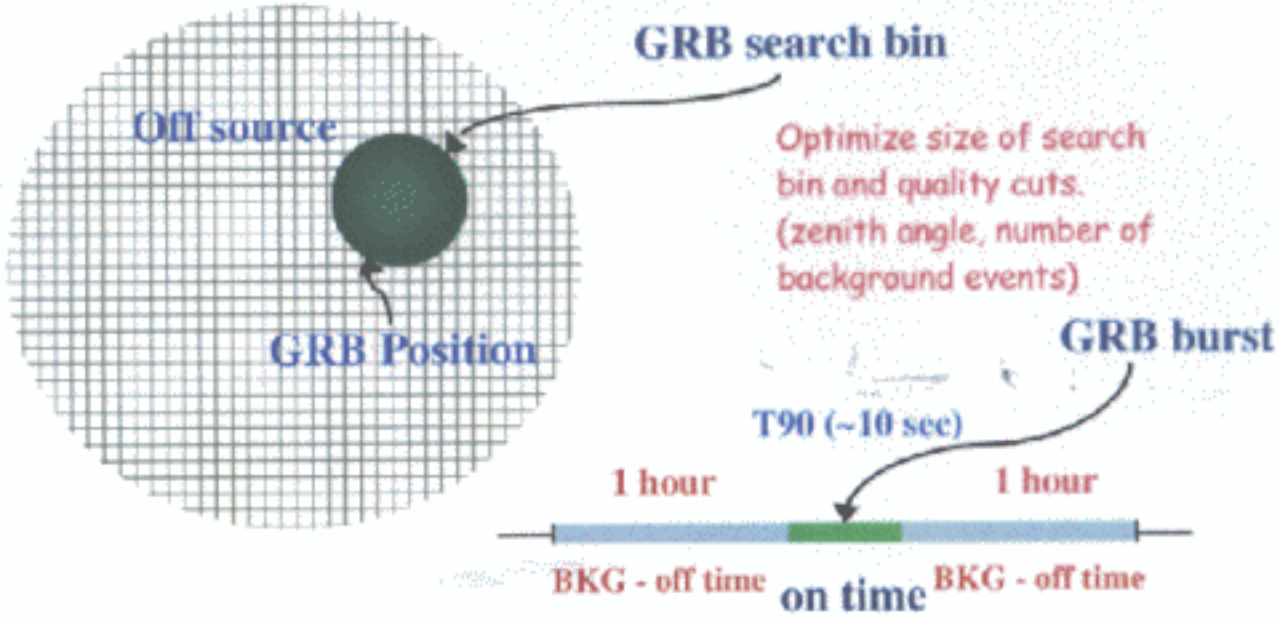
Searches for neutrinos from Gamma-ray bursts

- MC Simulation: Energy spectrum* for GRB neutrinos triggered with AMANDA
- Use this spectrum to optimize search strategy.



*According to Waxman,Bahcall, Phys. Rev D 62

Search for ν from GRB



GRB Search - Results

Events and upper limit

For 78 Bursts	Events
Background	17.2
Observed	11
$<N_{UL}(90\%\ C.L.)>$	8.3
N_{pred}* (Γ=100/300)	(1.1/0.024
$N_{UL}(90\%\ C.L.)$	2.5

*Alvarez, Hooper, Halzen
Phys. Rev D 62093015

Note: Large Burst to Burst Fluctuations.
Analysis of AMANDA-II data will improve sensitivity

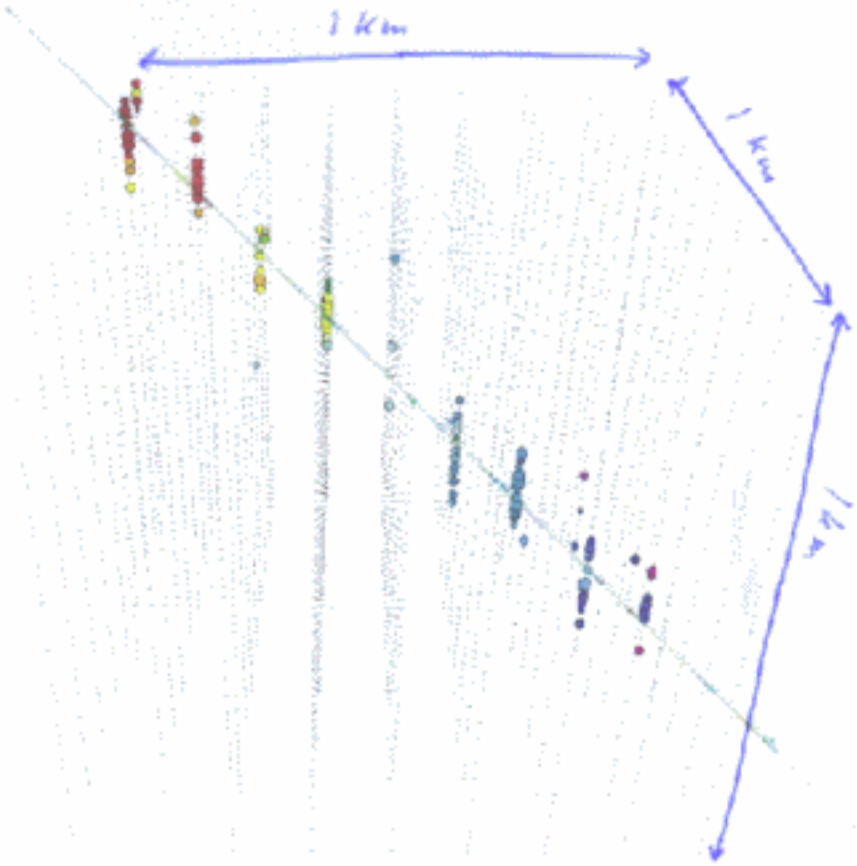
AMANDA-II and Icecube

- AMANDA-II deployment was completed in January 2000 - 19 strings
- First data analyses underway now
- Much better sensitivity, especially to horizontal events
- Icecube proposal well advanced, first deployment 2003-2004

ICECUBE MC

~20 TeV ν_μ

~80 PMT pulses



AMANDA Results Summary

- 1997 AMANDA B10 data analysed
- Atmospheric neutrinos observed consistent with expectations
- Limits on astrophysical neutrinos - point sources, diffuse fluxes, WIMPS, Gamma-ray bursts
- (Supernova search, Monopols not discussed)
- AMANDA-II completed, Icecube planned