Recent Results From the AMANDA Experiment

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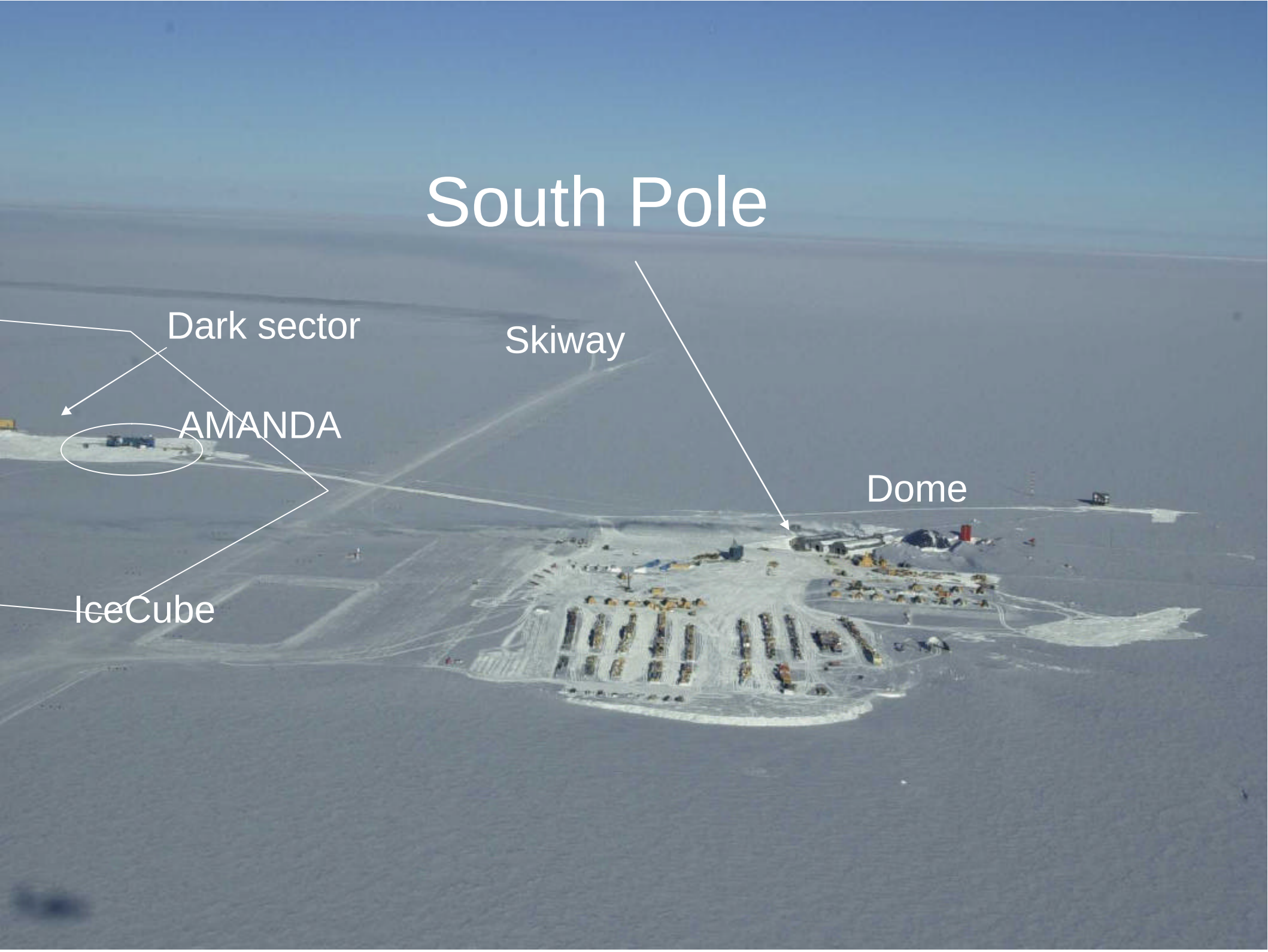
University of Wisconsin – Madison
for the AMANDA Collaboration

Rencontres du Vietnam August 6-11, 2004


South Pole
Dark sector
Skiway
AMANDA
Dome
IceCube

The AMANDA Collaboration

United States

Bartol Research Institute
UC Berkeley
UC Irvine
Pennsylvania State
UW Madison
UW River Falls
LBNL Berkeley

Europe

VUB-IIHE, Brussel
ULB-IIHE, Bruxelles
Université de Mons-Hainaut
Imperial College, London
DESY, Zeuthen
Mainz Universität
Wuppertal Universität
Stockholms Universitet
Uppsala Universitet
Kalmar Universitet

South America

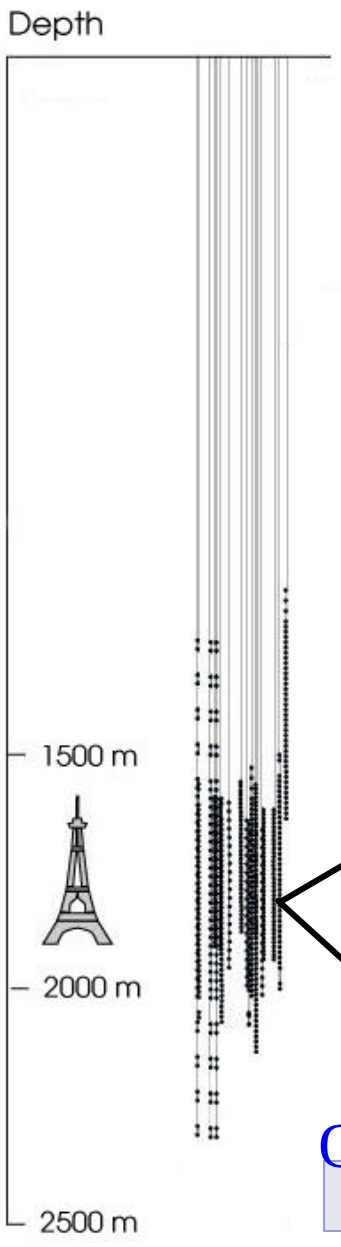
U. Simón Bolivar, Caracas

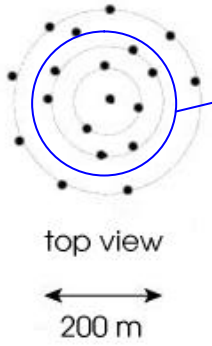
Antarctica

South Pole Station

~150 members

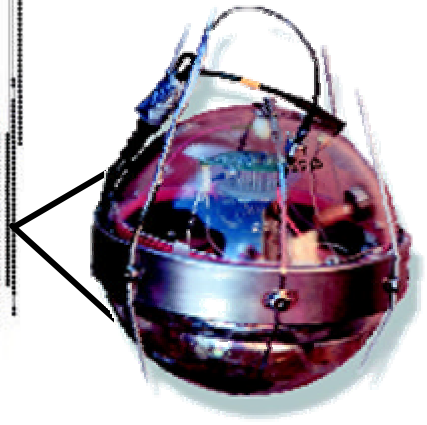
The AMANDA Detector





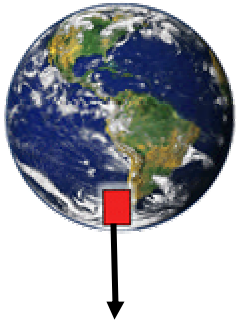
AMANDA-B10
(inner core of AMANDA-II)
10 strings
302 OMs
Data years: 1997-99

AMANDA-II
19 strings
677 OMs
Trigger rate: 80 Hz
Data years: 2000+

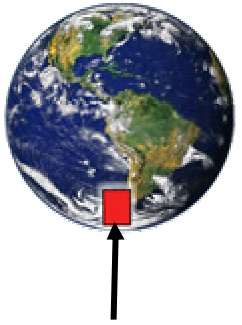


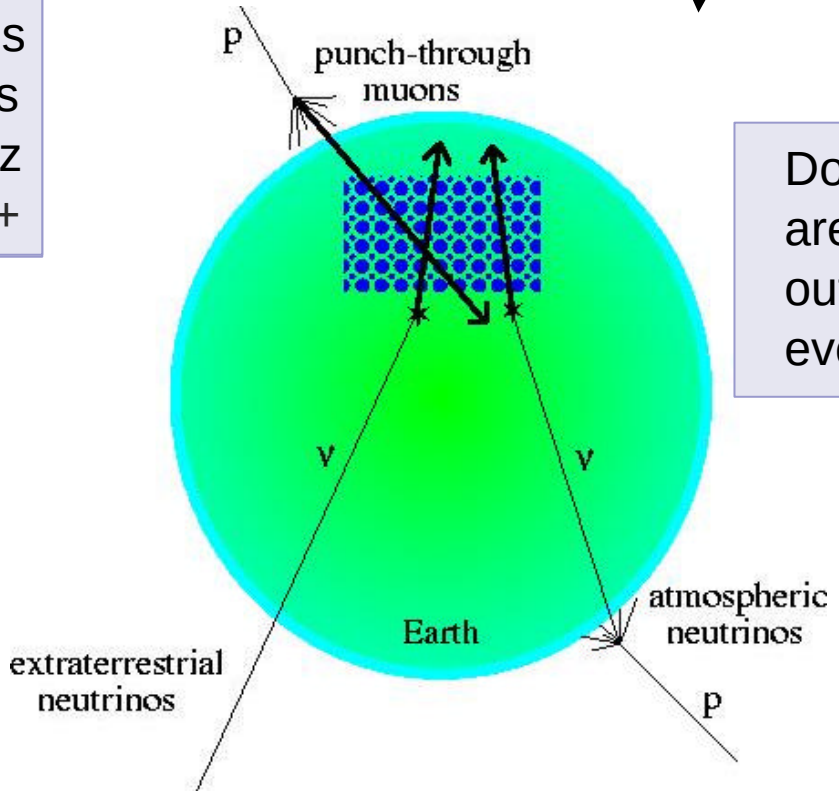
Optical Module
PMT noise: ~1 kHz

"Up-going"
(from Northern sky)



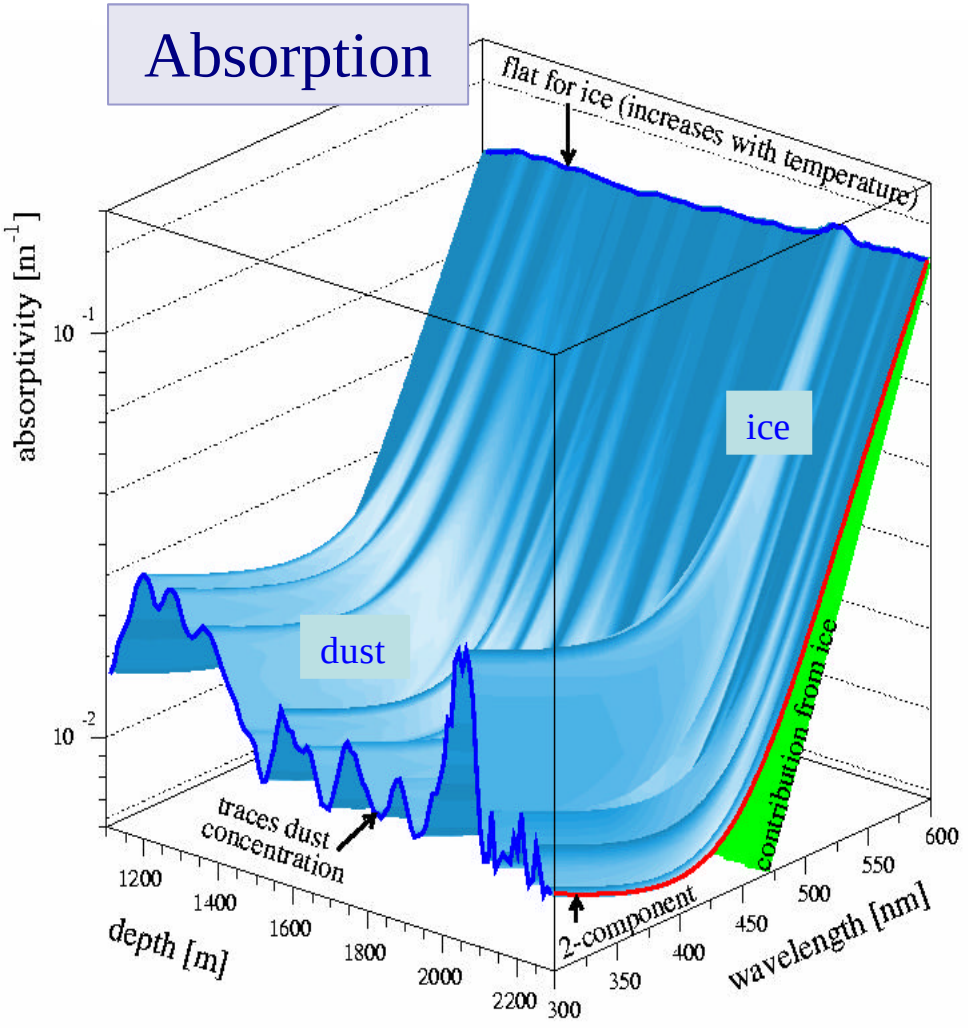
"Down-going"
(from Southern sky)

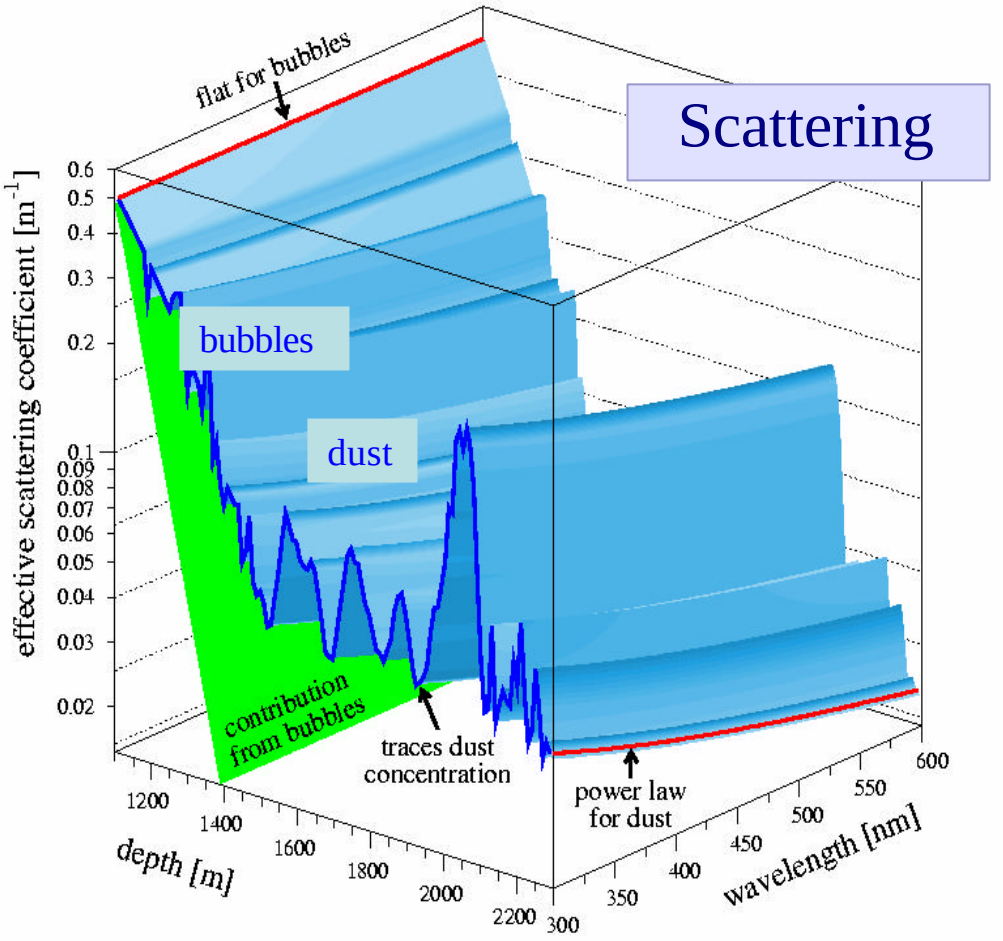




Downgoing muons are primary background: outnumber upgoing events 10^6:1

Ice Properties



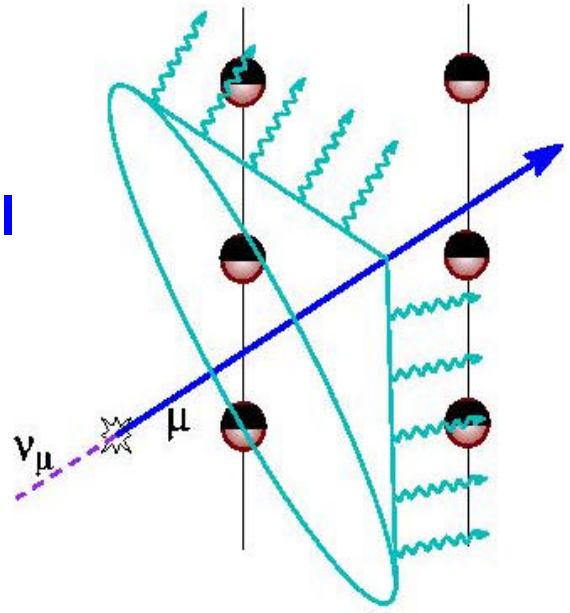


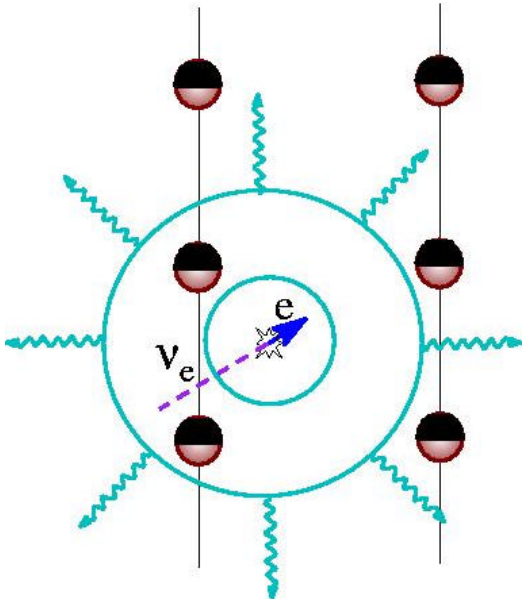
South Pole ice:

- **Very transparent**
- **Absorption length ~ 100 m at 400 nm**
- **Scattering length ~ 20 m at 400 nm**
- **Measured with in-situ light sources and with atmospheric muons**

Event Reconstruction

muon channel





cascade channel

Reconstruction accuracies :

- **Muons:**
  - **directional error: 2.0º - 2.5º**
  - **σ [$\log_{10}$(E/TeV)] : 0.3 - 0.4**
  - **coverage: 2π**
- **Cascades:**
  - **directional error: 30º - 40º**
  - **σ [$\log_{10}$(E/TeV)] : 0.1 - 0.2**
  - **coverage: 4π**
- **Primary cosmic rays (with SPASE-2):**
  - **σ [$\log_{10}$(E/TeV)] : 0.07 - 0.1**

AMANDA Topics

Primary Cosmic Ray Spectrum

- atmospheric muons/neutrinos
- Cosmic Ray composition (with SPASE-2 surface array)

Cosmic Ray origins (acceleration sites: AGN, GRBs)

- extra-terrestrial flux at > TeV energies

Dark matter/ exotic particles

- WIMP annihilation in the Sun/Earth
- magnetic monopoles

Supernova monitor of the Milky Way

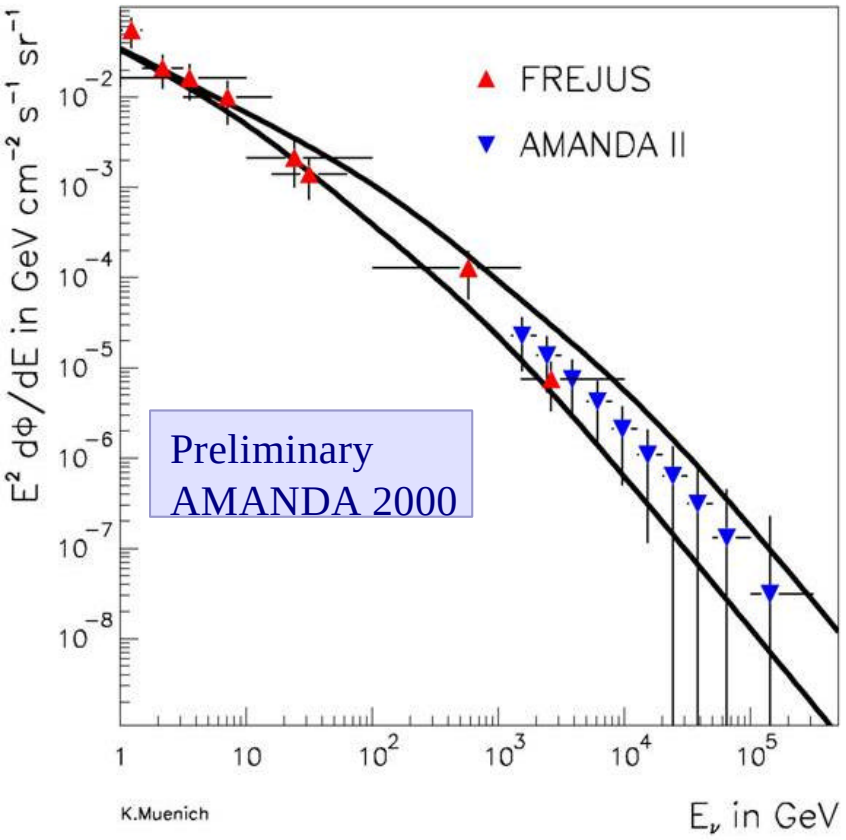
- burst of low energy cascades leads to overall noise increase
- AMANDA will join Super Nova Early Warning System (SNEWS) later this year

Energy Ranges For AMANDA Analyses

Energy range	analysis	production site(s)
~MeV	SN ν	Supernovae
GeV - ~TeV	atm ν	atmosphere
	Dark matter	Sun/Earth
TeV - PeV	diffuse	AGN, GRB…
	cascades	
	point sources	
PeV – EeV	UHE	AGN, TD…
> EeV	EHE	?

Agreed collaboration strategy: **Analyses are done 'blind'**.
cuts optimized on a % of data or on a time-scrambled data set.
(except for SN searches where analysis is based on detector noise rate monitoring)

Atmospheric Neutrinos



Atmospheric spectrum provides test of detector

Matches lower energy Frejus data

Downgoing muon background rejected using a neural network

First spectrum above 1 TeV

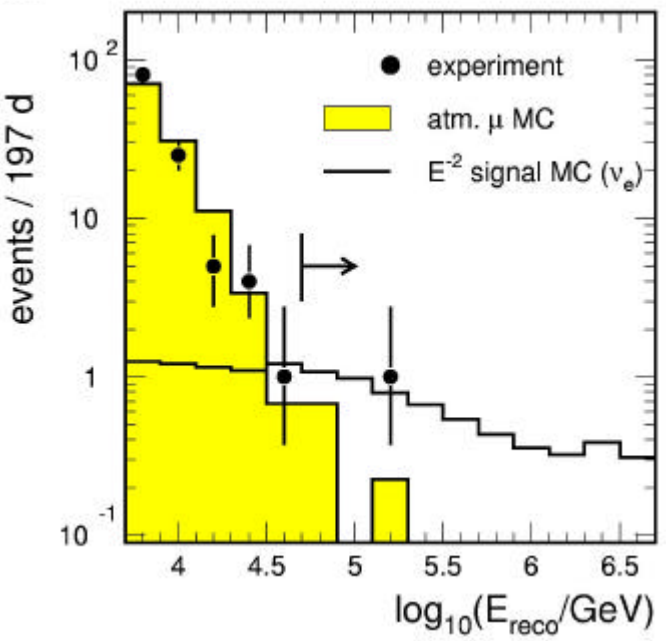
Used to set limit on extraterrestrial E^{-2} diffuse flux in the range 100-300 TeV

$$E^2 F_{n_m}(E) < 2.87 \cdot 10^{-7}\ \text{GeV cm}^{-2}\,\text{s}^{-1}\,\text{sr}^{-1}$$

Includes 33% systematic uncertainty

1997 results
PRL 90, 251101 (2003)

Diffuse Flux Search using Cascades



2000 data
197.2 days livetime

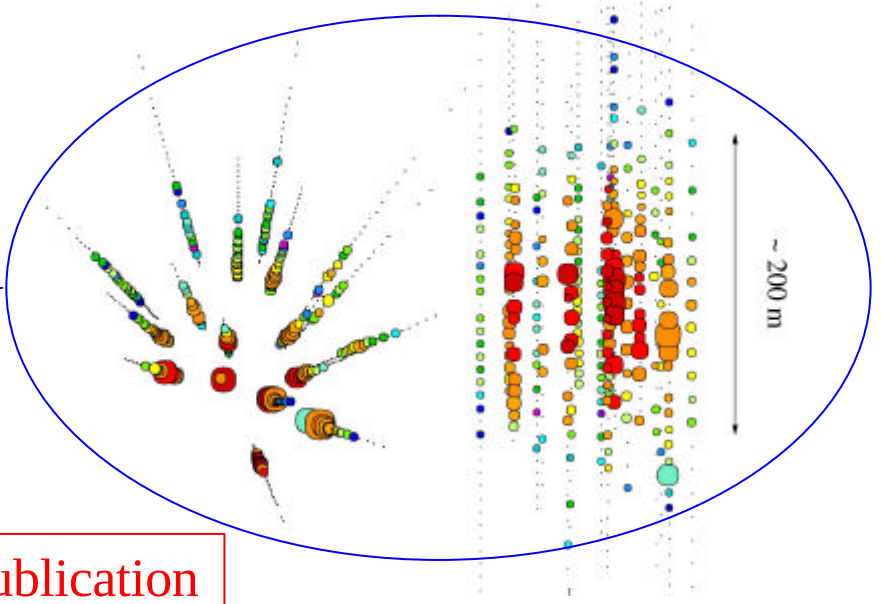
Cascade analysis has 4p coverage

Event selection based on
-energy
-topology

Signal MC: E^{-2} energy spectrum

$$E^2 F_{all\ n}(E) < 8.6 \cdot 10^{-7}\ GeV\ cm^{-2}\ s^{-1}\ sr^{-1}$$

flavor mixing $\nu_e:\nu_\mu:\nu_\tau = 1:1:1$ $50\ TeV < E_\nu < 5\ PeV$



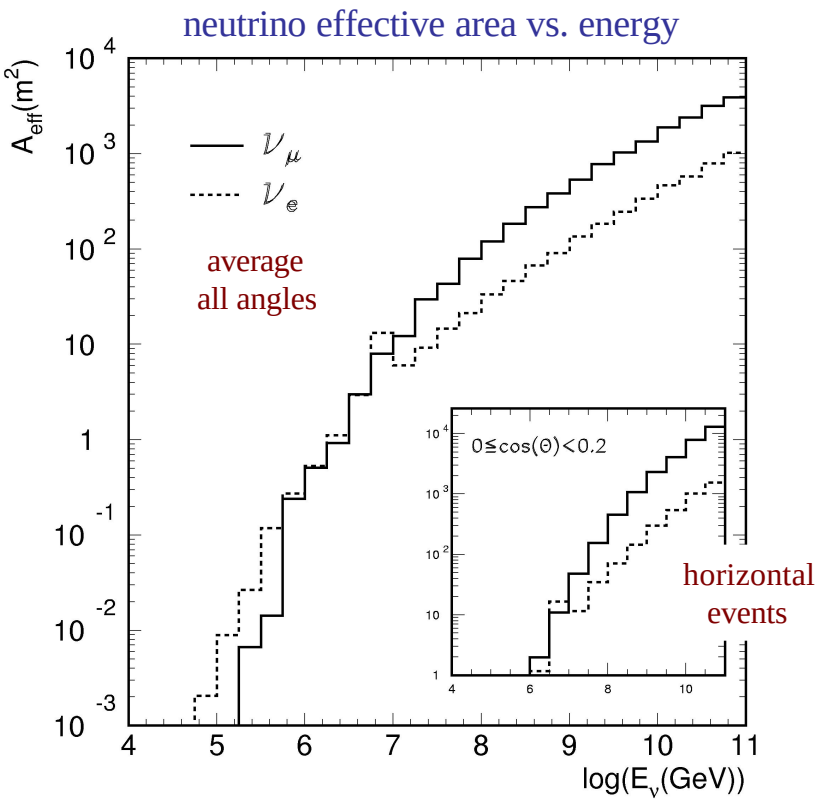
$N_{obs} = 1$ event

$N_{atm\ \mu} = 0.90\ ^{+0.69}_{-0.43}$

$N_{atm\ n} = 0.06\ ^{+0.09}_{--0.04} \pm 25\%_{norm}$

Accepted for Publication
Astroparticle Physics

Ultra-High Energy Search (PeV - EeV)

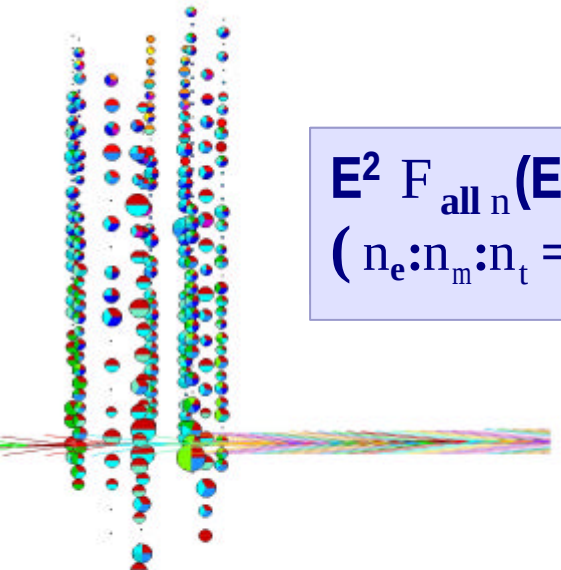


Earth opaque above 10^{16} eV
Look at downgoing muons and events near horizon

Characteristics: few 1 p.e. Peaks
long muon tracks and bright events

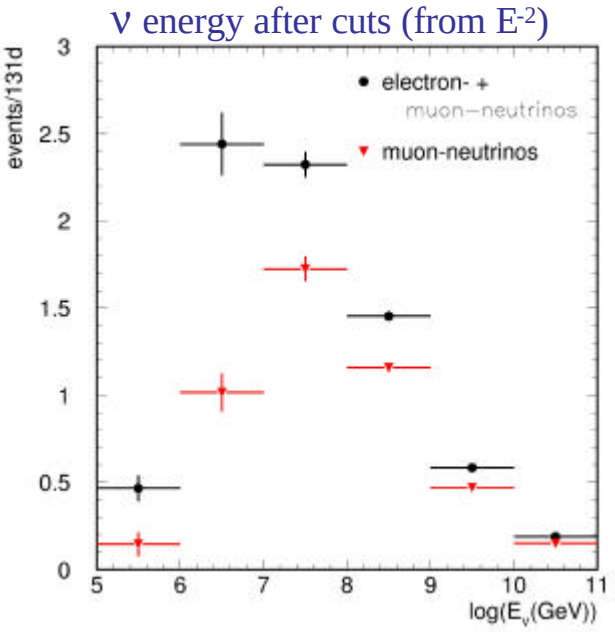
N_{obs} = 5 events

N_{bgr} = 4.6 ± 36% events

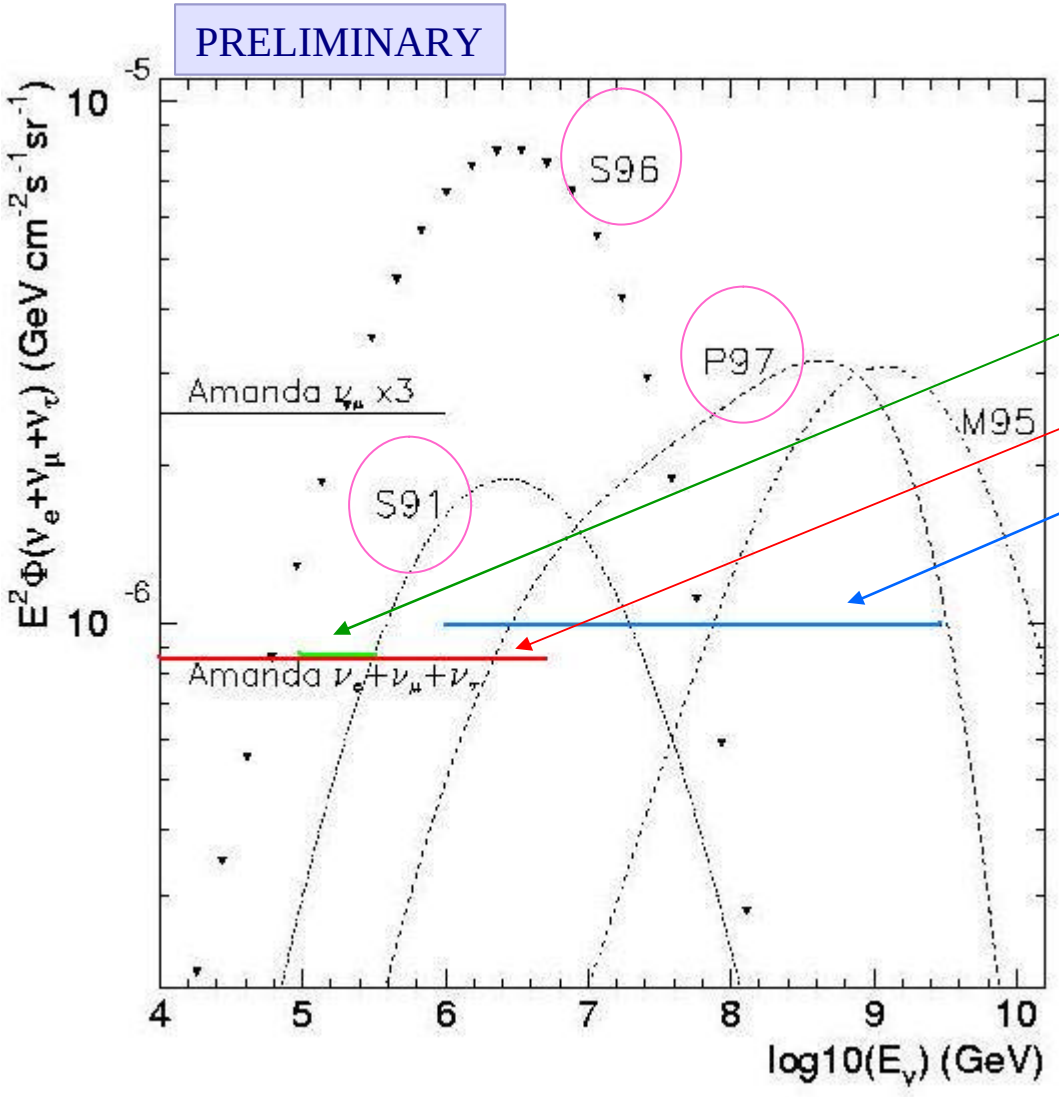


$E^2 F_{all\ n}(E) < 9.9 \times 10^{-7}$ GeV cm^{-2} s^{-1}
(n_e:n_m:n_t = 1:1:1)

Paper in progress



Diffuse Results Summary

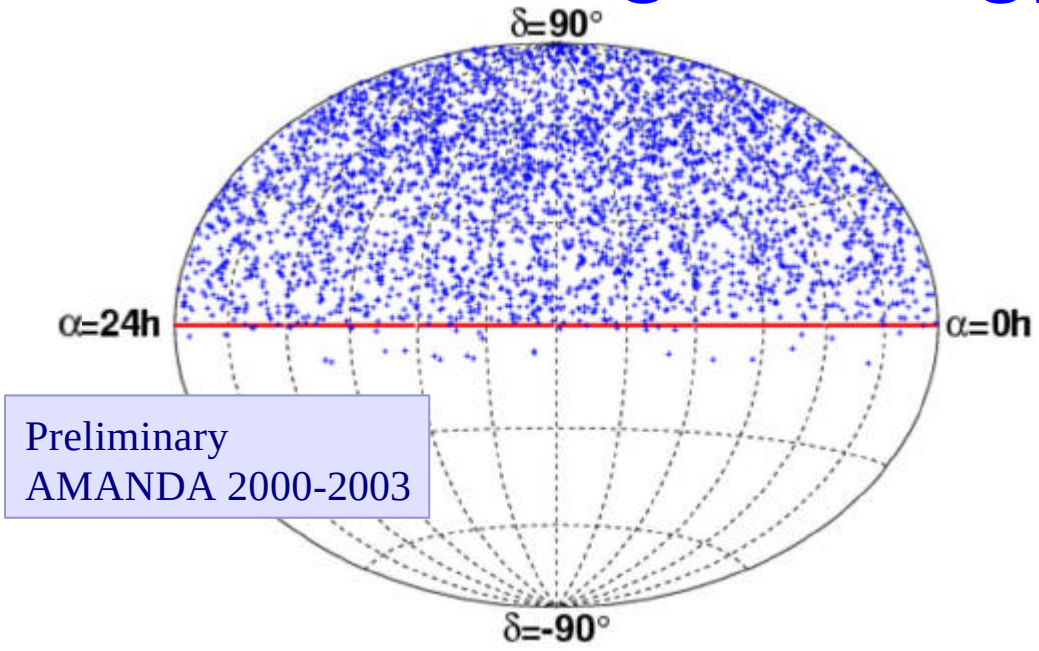


AMANDA 90% CL upper limits to a diffuse E^{-2} all neutrino flux obtained from :

- **High energy tail of atmospheric neutrino spectrum**
- **search for cascade events**
- **search for UHE events**

Several Models of AGN neutrino emission ruled out

Search for High Energy Point Sources

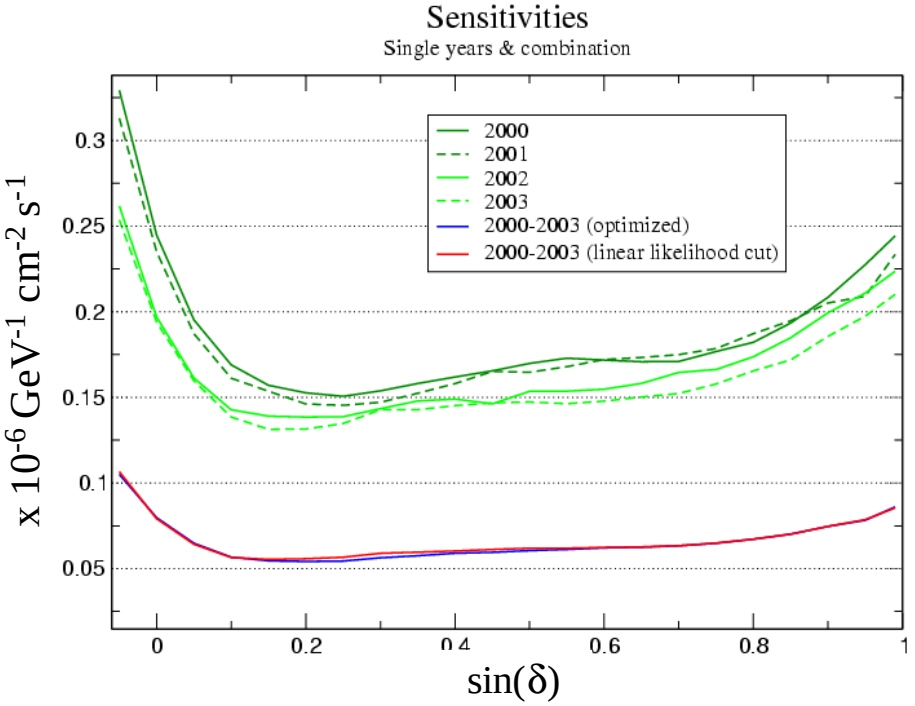


Preliminary
AMANDA 2000-2003

Skymap in equatorial coordinates

No Excess observed
results consistent with atmos. background

3369 events observed
3438 events expected background

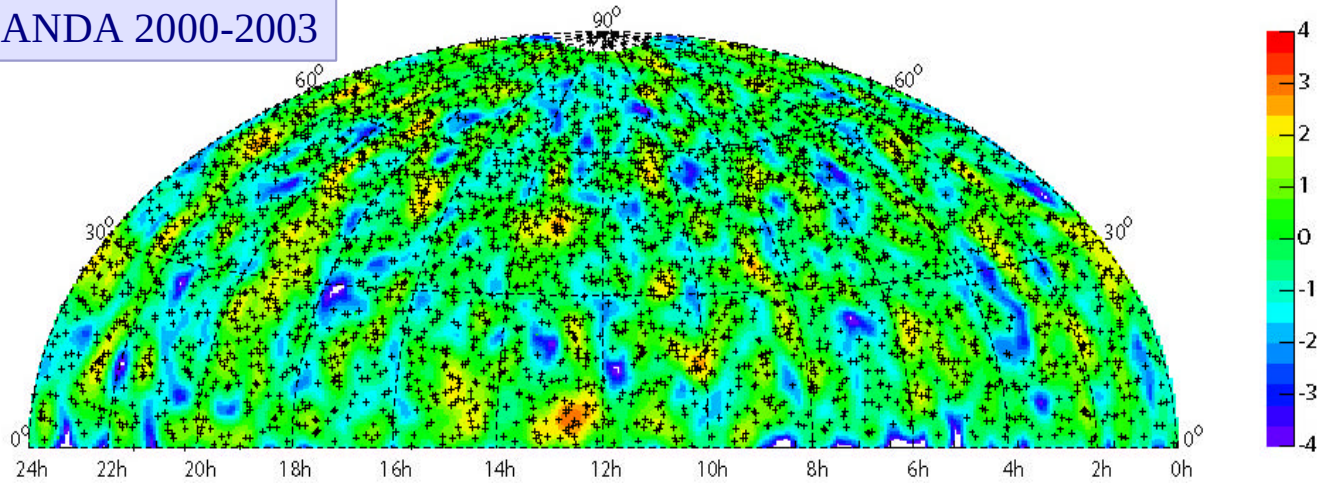


Search in sky for clustering of events :

- Grid search : sky subdivided in 300 bins of ~ 7° x 7°
- Shift grid to cover boundaries
- Pointing resolution ~ 2.5 °
- Optimized in each declination band
- Optimized for E^{-2} and E^{-3} spectra

Neutrino Point Sources: Unbinned Analysis

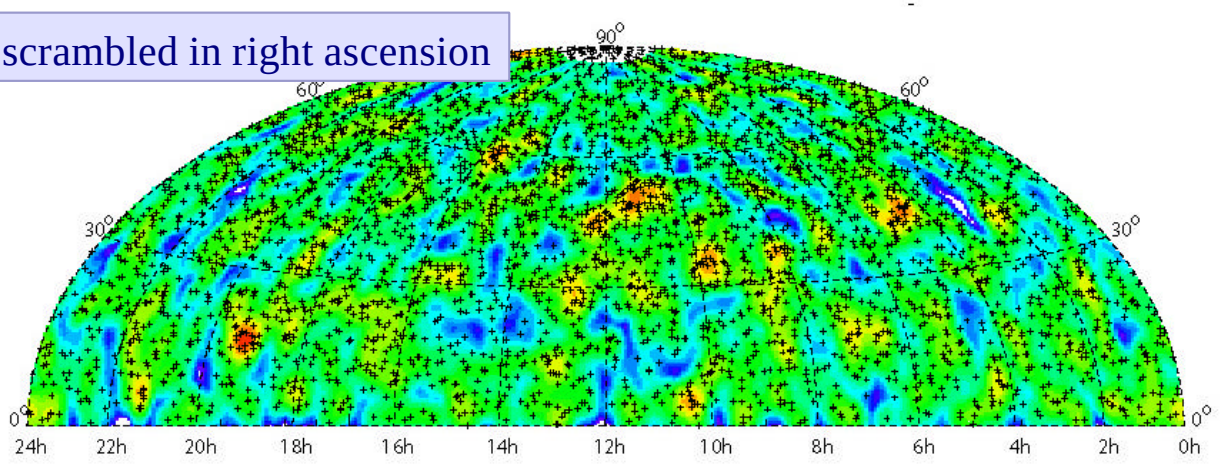
Preliminary
AMANDA 2000-2003



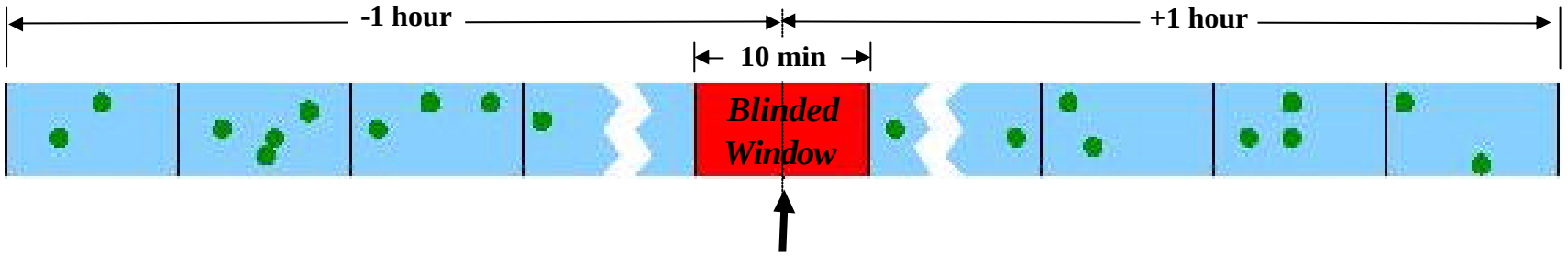
Significance of local fluctuations compared to expectation of all being atmospheric neutrinos

Max 3.4 sigma: consistent with background fluctuation

Data scrambled in right ascension



Search for n coincident with GRBs



Preliminary
AMANDA 1997-2000

Year	Detector	N_{Bursts}	$N_{BG, Pred}$	N_{Obs}	Event U.L.
1997	B-10	78 (BT)	0.06	0	2.41
1998	B-10	94 (BT)	0.20	0	2.24
1999	B-10	96 (BT)	0.20	0	2.24
2000	A-II (2 analyses)	44 (BT)	0.83/0.40	0/0	1.72/2.05
97-00	B-10/A-II	312 (BT)	1.29	0	1.45
2000	A-II	24 (BNT)	0.24	0	2.19
2000	A-II	46 (New)	0.60	0	1.88
2000	A-II	114 (All)	1.24	0	1.47

(BT = BATSE Triggered BNT = BATSE Non-Triggered New = IPN & GUSBAD)

Low background analysis due to space and time coincidence!

Data required to be stable within an hour on either side of GRB

Background taken ±5 minutes around burst

97-00 Flux Limit at Earth*: $E^2 F_n = 4 \cdot 10^{-8}$ GeV cm^{-2} s^{-1} sr^{-1}

*For 312 bursts w/ WB Broken Power-Law Spectrum (E_{break}= 100 TeV, G_{Bulk}= 300)

Cascade Channel Rolling GRB Search

2-step process:

1.) use Support Vector Machine to reject muon and atmospheric neutrino backgrounds using signal Monte Carlo based on assumption of 300 TeV break energy broken power law energy spectrum

2.) scan through entire data set looking for significant clumping of surviving events ("significant" defined as 99% unlikely to have a random poissonian fluctuation to this level)

Complements satellite-coincident searches:

more difficult background rejection due to lack of space-time constraints, but satellites miss many GRBs, especially since loss of BATSE in early 2000

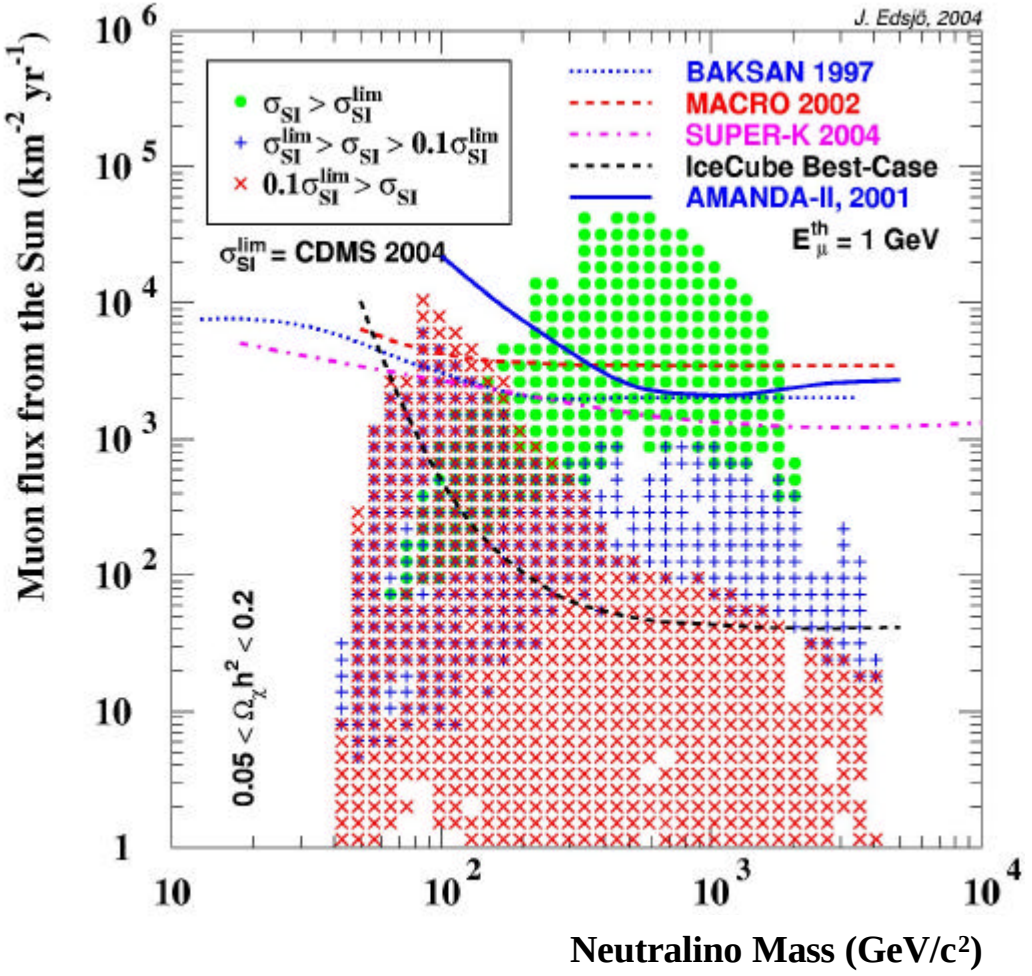
WIMP Annihilations in the Sun/Earth

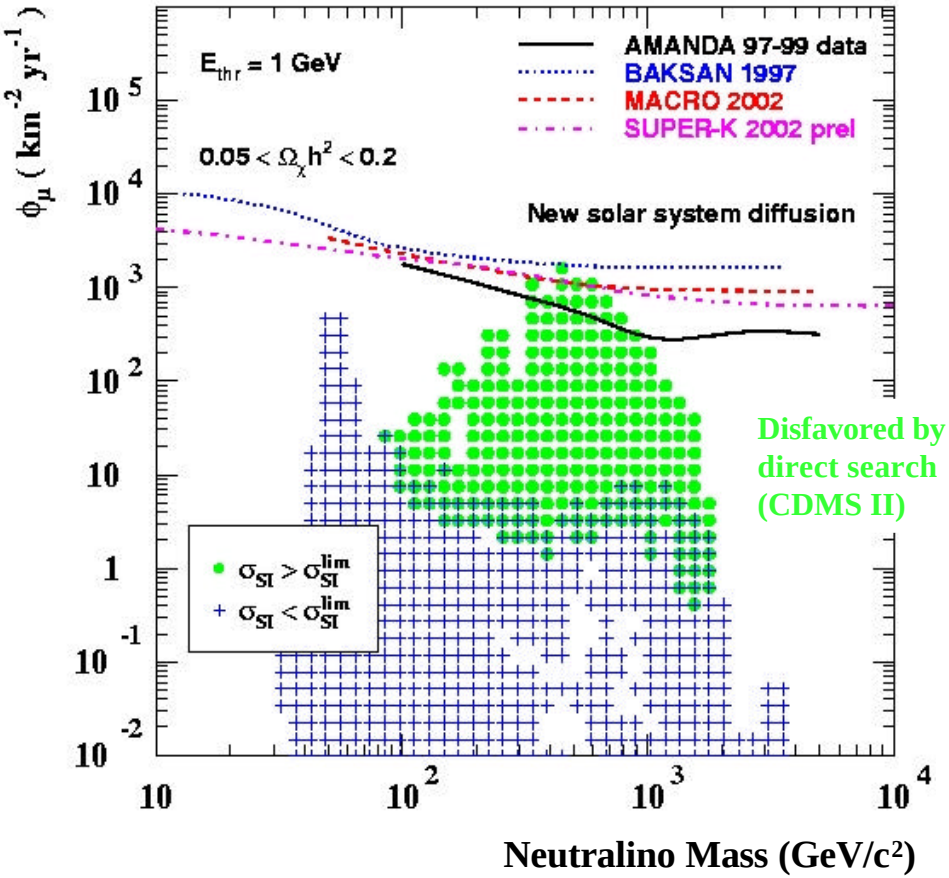
$c\bar{c} \longrightarrow$ **qq, WW, ZZ, HH** $\longrightarrow \nu$

Sun analysis possible due to improved reconstruction capability for horizontal tracks in AMANDA-II compared with B10 Current results from 2001 data set

Combined 1997-99 data sets for Earth WIMP searches.

Preliminary





Disfavored by direct search (CDMS II)

No WIMP signal found

Outlook

No extraterrestrial signals observed yet, but limits are tightening

First Results from AMANDA-II now published

- 2000 point source analysis in PRL 92 no. 7 (071102)

Multi-year papers and analyses in progress

Detector improvements

- Digitized Waveform readout since 2003
- Understanding of ice properties reduces systematic errors

IceCube on horizon.....

IceCube

First strings deploy in January 2005

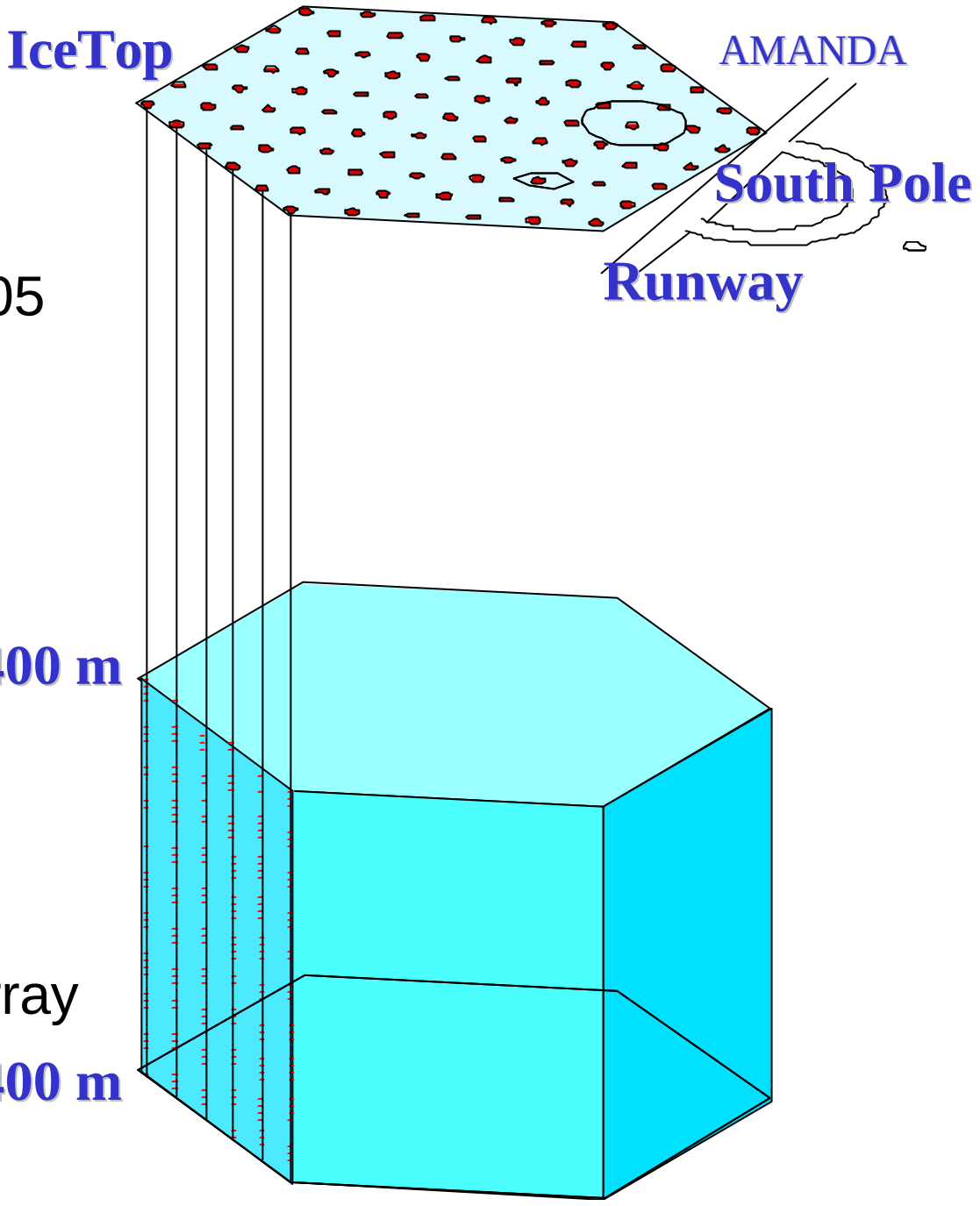
Completed in 2010

70-80 strings

Up to 4800 OMs in deep ice

1 km^3 instrumented volume

IceTop: 320 OM, 1 km^2 surface array



- Shown on diffuse limits summary plot

- S91

  F.W. Stecker et al., Phys. Rev. Lett. 66 (1991) 2697 and Erratum-ibid. 69 (1992) 2738

- S96

  F.W. Stecker and M.H. Salamon, Space Sci. Rev. 75 (1996) 341

- P97

  R.J. Protheroe, arXiv: astro-ph/9607165

- M95

  K. Mannheim, Astropart. Phys. 3 (1995) 295