Results and Perspectives of Neutrino Astronomy in Ice

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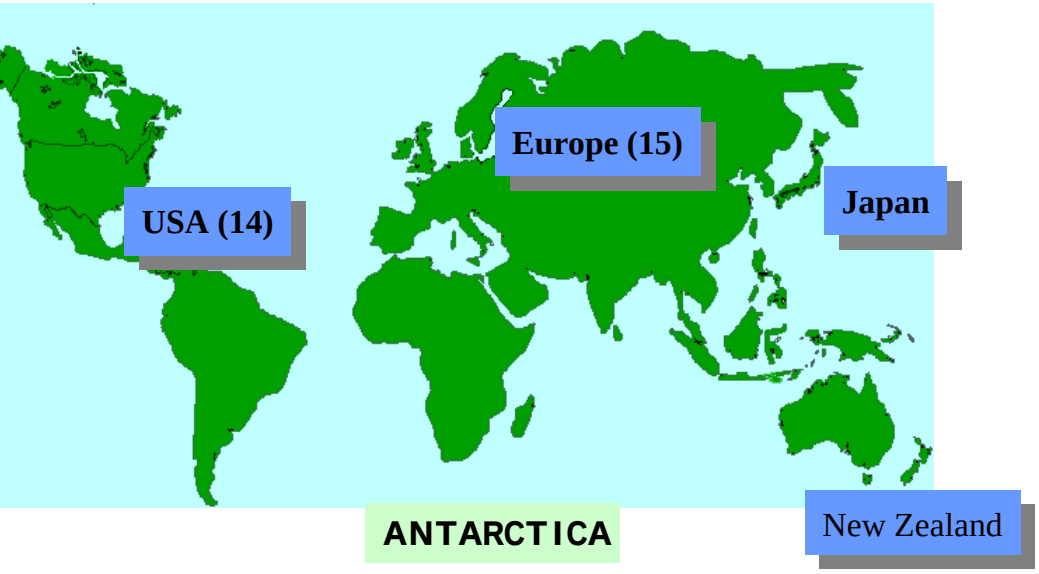
Neutrino telescopes in ice



- Alabama University, USA
- Bartol Research Institute, Delaware, USA
- Pennsylvania State University, USA
- UC Berkeley, USA
- UC Irvine, USA
- Clark-Atlanta University, USA
- University of Alaska, Anchorage, USA
- Univ. of Maryland, USA

- IAS, Princeton, USA
- University of Wisconsin-Madison, USA
- University of Wisconsin-River Falls, USA
- LBNL, Berkeley, USA
- University of Kansas, USA
- Southern University
- and A&M College, Baton Rouge, USA

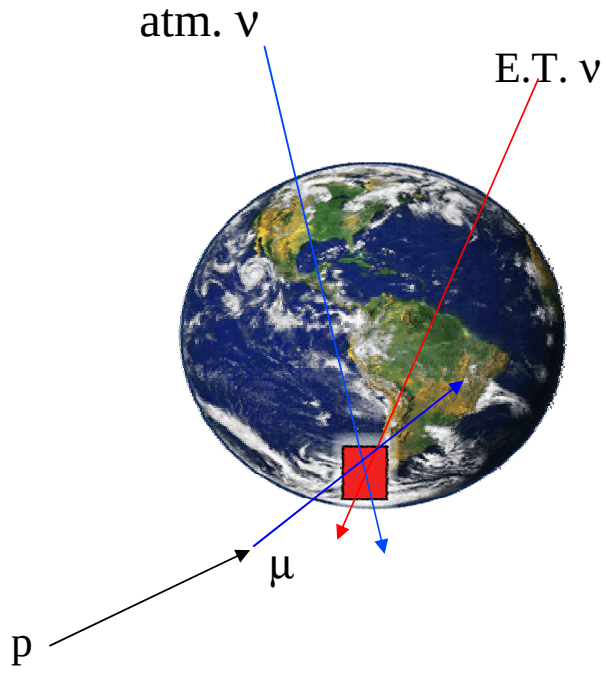
- Universite Libre de Bruxelles, Belgium
- Vrije Universiteit Brussel, Belgium
- Université de Mons-Hainaut, Belgium
- Universiteit Gent, Belgium
- Humboldt Universität, Germany
- Universität Mainz, Germany
- DESY Zeuthen, Germany
- Universität Dortmund, Germany

- Universität Wuppertal, Germany
- MPI Heidelberg, Germany
- Uppsala University, Sweden
- Stockholm University, Sweden
- Imperial College, London, UK
- Oxford University, UK
- Utrecht University, Netherlands

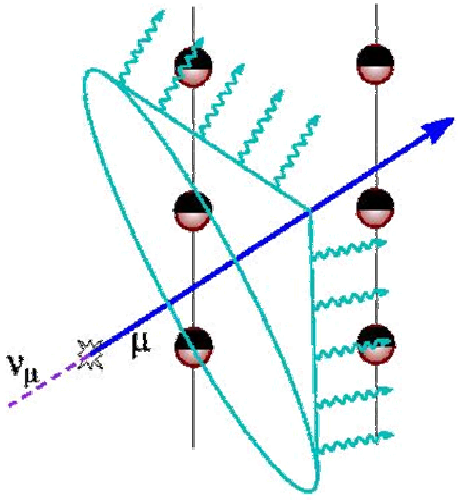
- Chiba University, Japan
- University of Canterbury, Christchurch, NZ

Neutrino telescopes in ice

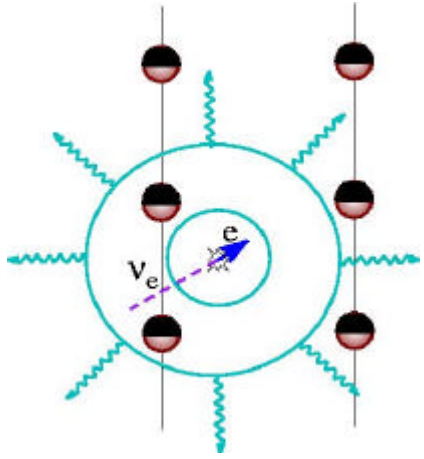
Principle of detection - Cherenkov light detection in ice



Muon track

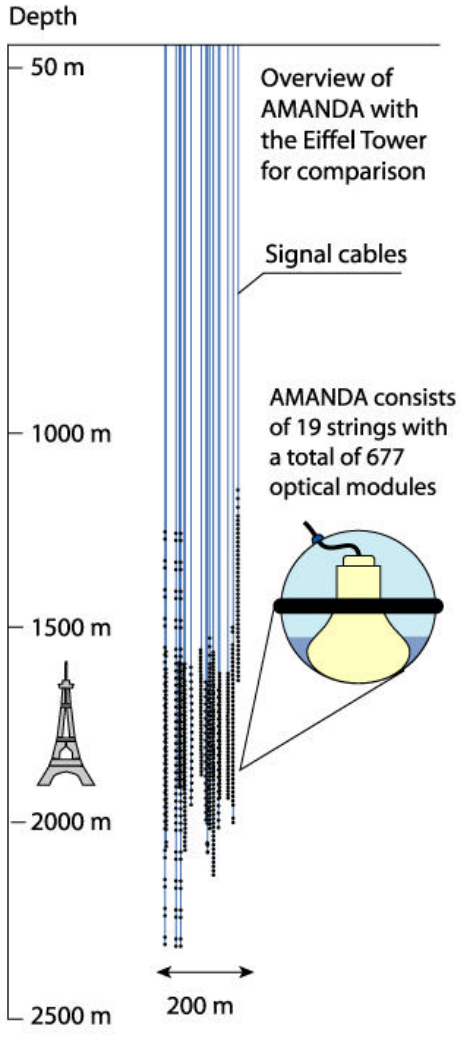


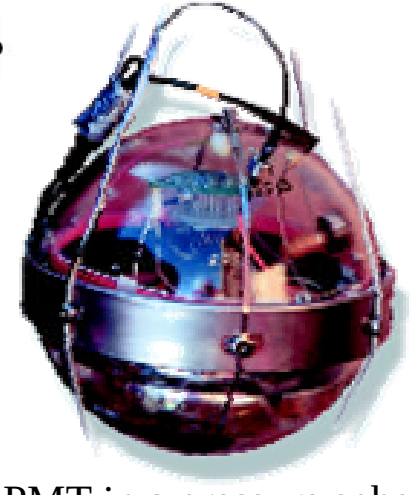
Cascade



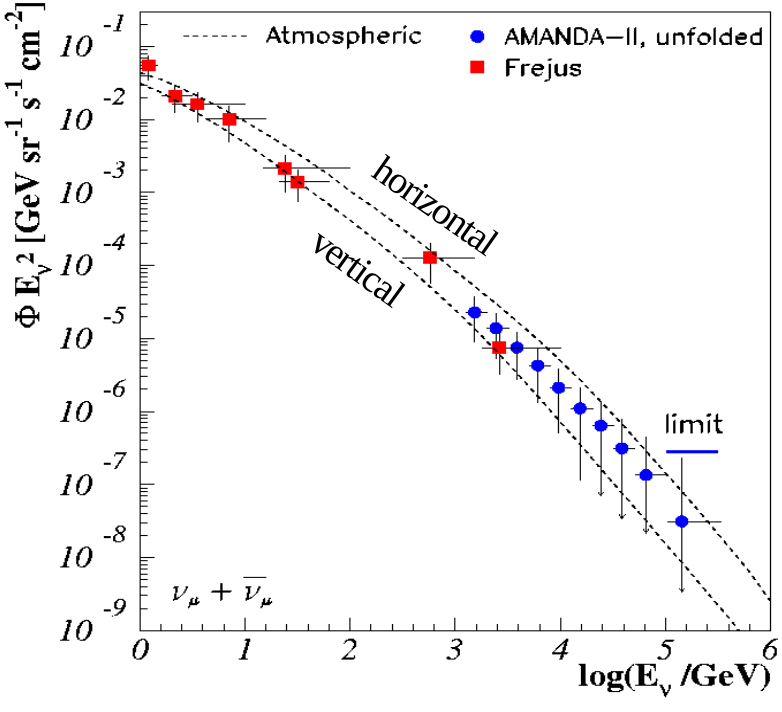
Neutrino telescopes in ice

AMANDA



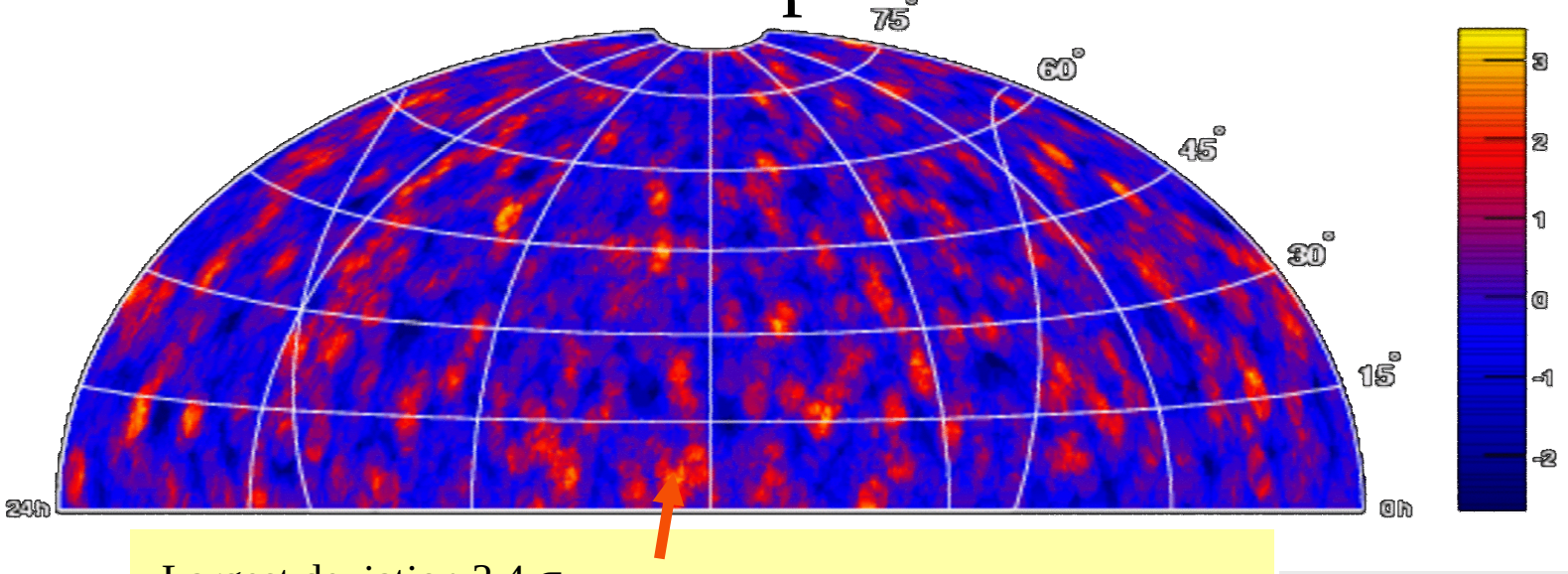


8" PMT in a pressure sphere



A few more AMANDA results...

Search for clusters in the Northern hemisphere



Largest deviation 3.4 σ.

The probability to get this excess (or higher) in any bin due to background fluctuation is 92%.

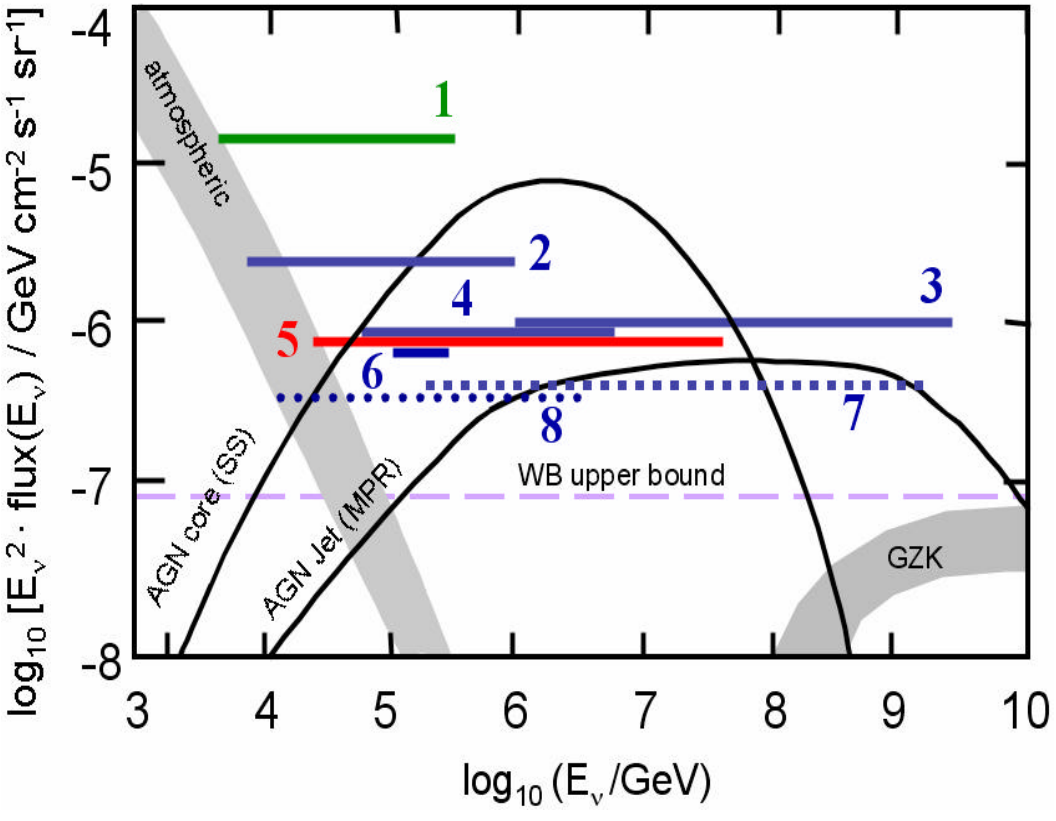
No significant excess!

$F_n^{lim} \approx 0.68 \cdot 10^{-8}\ cm^{-2}s^{-1}$

2000-2003 data

3329 neutrino events

Diffuse neutrino flux limits 2005



1. MACRO
2. AMANDA B10 ν_μ (1997)
3. AMANDA-B10 UHE (1997)
4. AMANDA-II cascades (2000)
5. Baikal cascades 1998-2002
6. AMANDA-II ν_μ-analysis (2000)
7. AMANDA-II UHE sensitivity !!
8. AMANDA ν_μ-analysis (2000-2003) sensitivity

Preliminary!

All limits multiplied by 3 for oscillations)!!

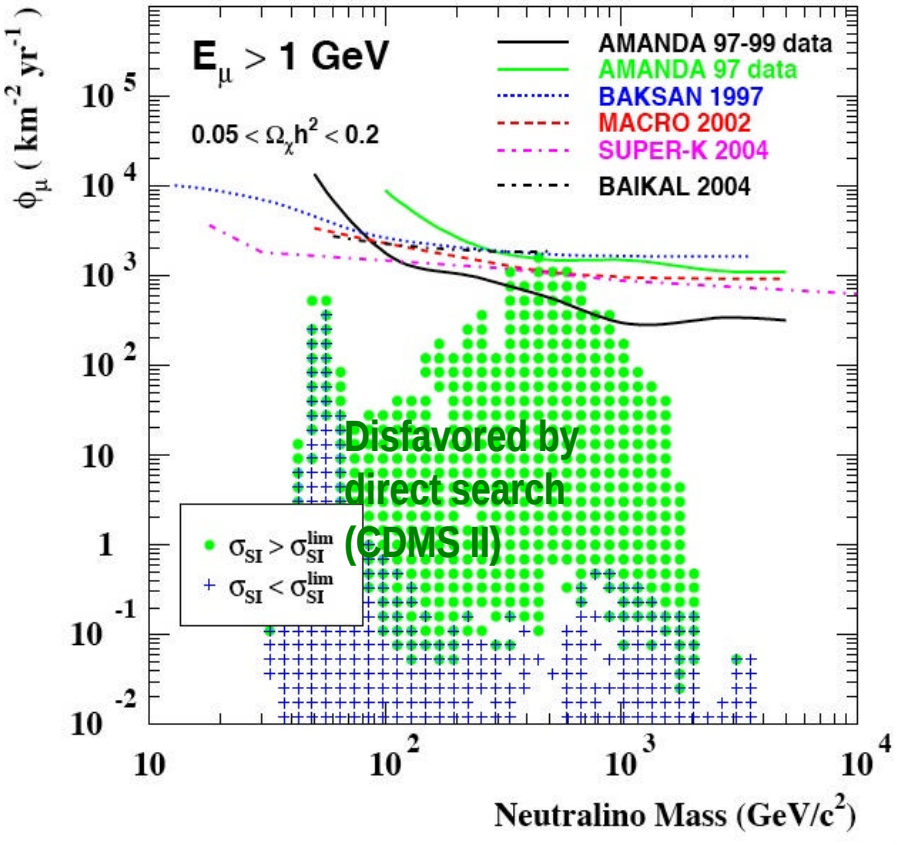
Neutrino telescopes in ice

Dark Matter (WIMP) search

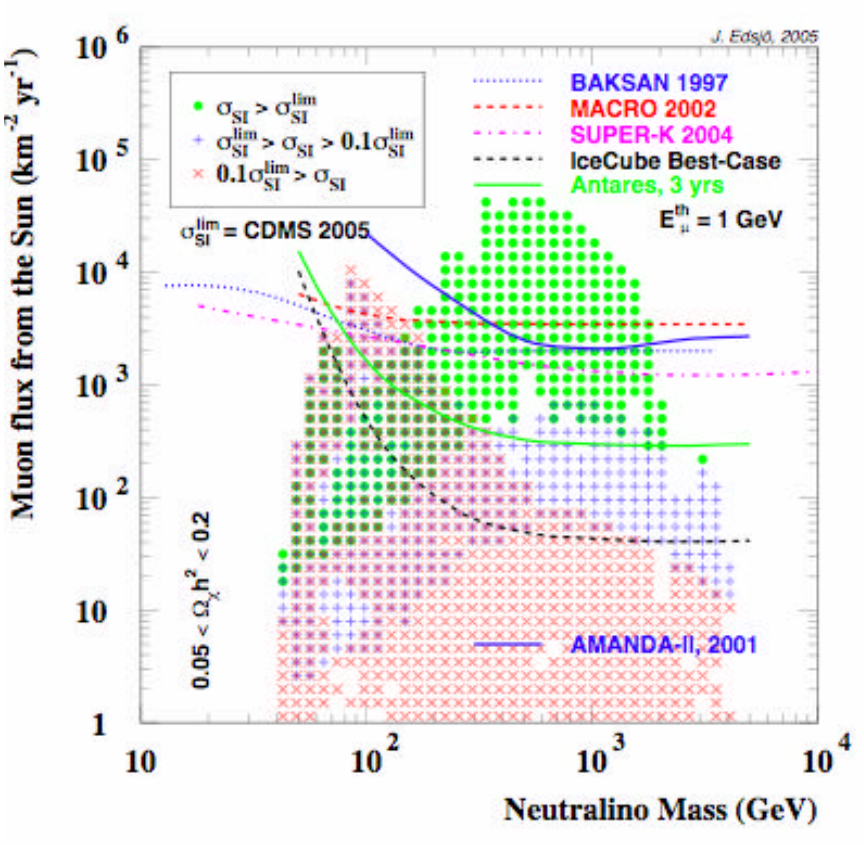
Submitted for publication

Published in Astrpart. Phys.

Limits on muon flux from Earth center



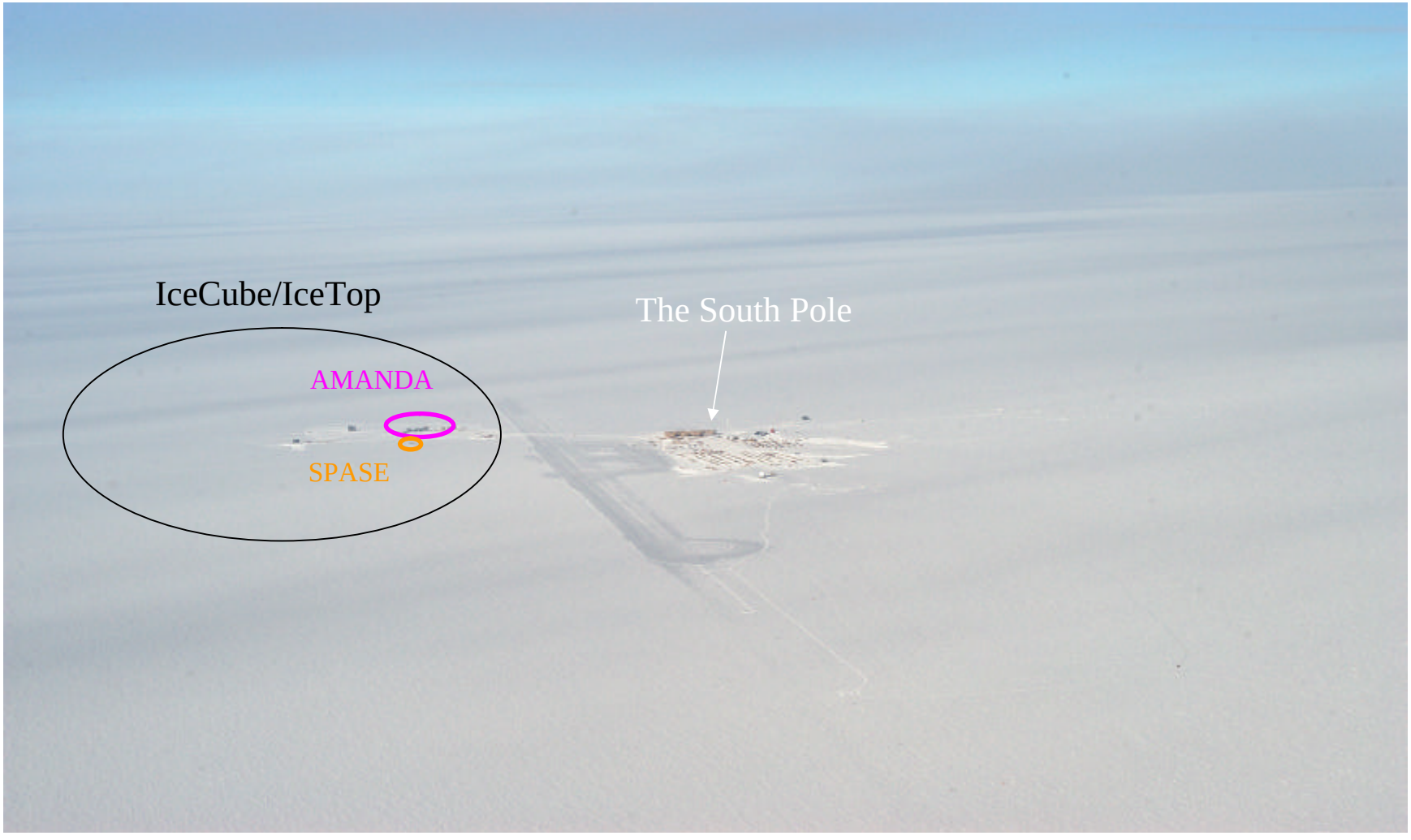
Limits on muon flux from Sun



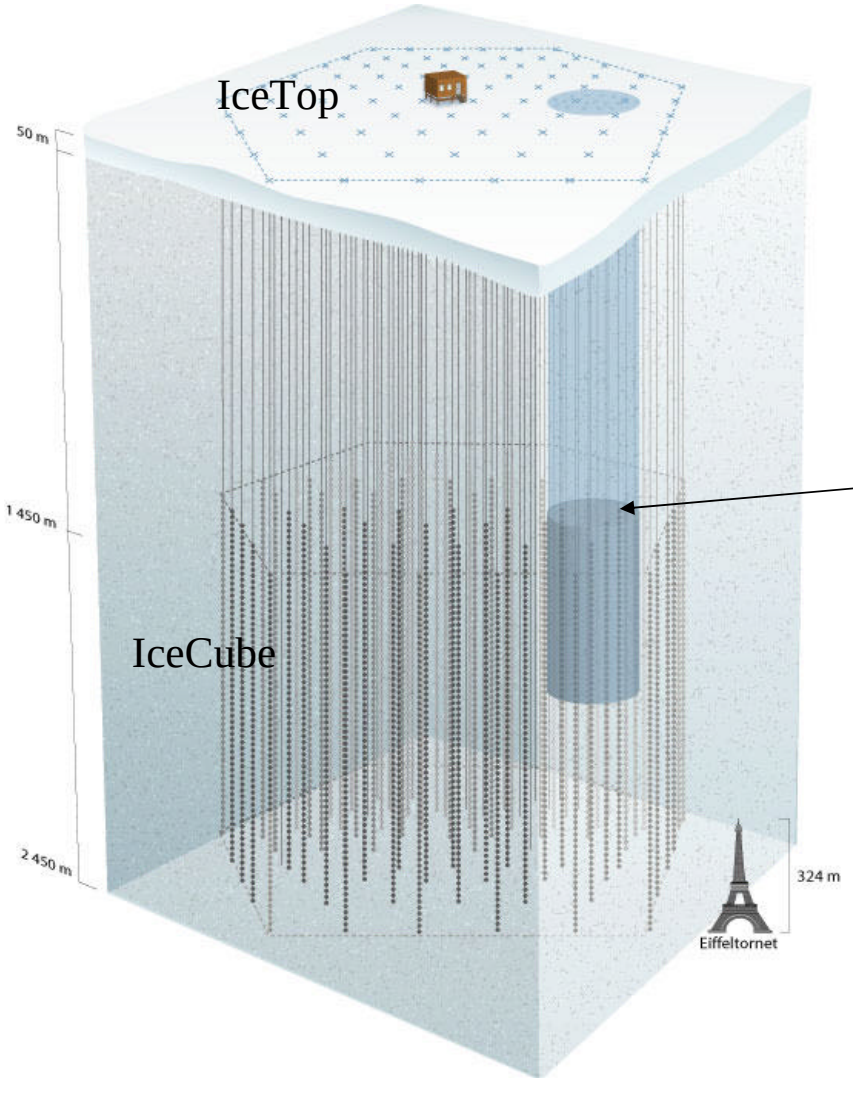
Other results:

- GRB signal search
- Search for signal from selected sources (Crab, MK421, Cygnus X3,...)
- Composition (with SPASE EAS)
- Magnetic monopoles
- Supernova monitoring

Neutrino telescopes in ice



Neutrino telescopes in ice

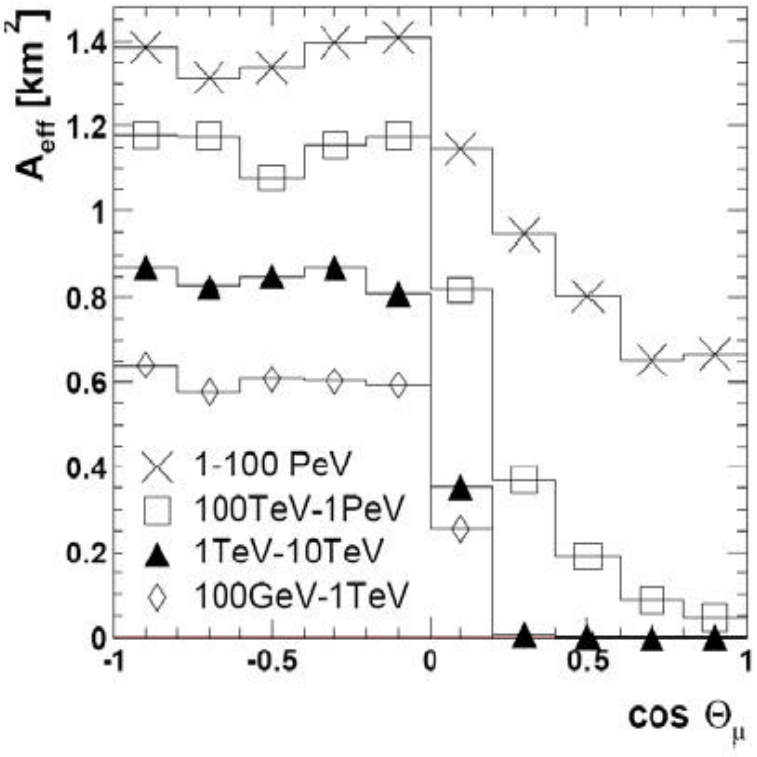


IceCube: a gigaton detector

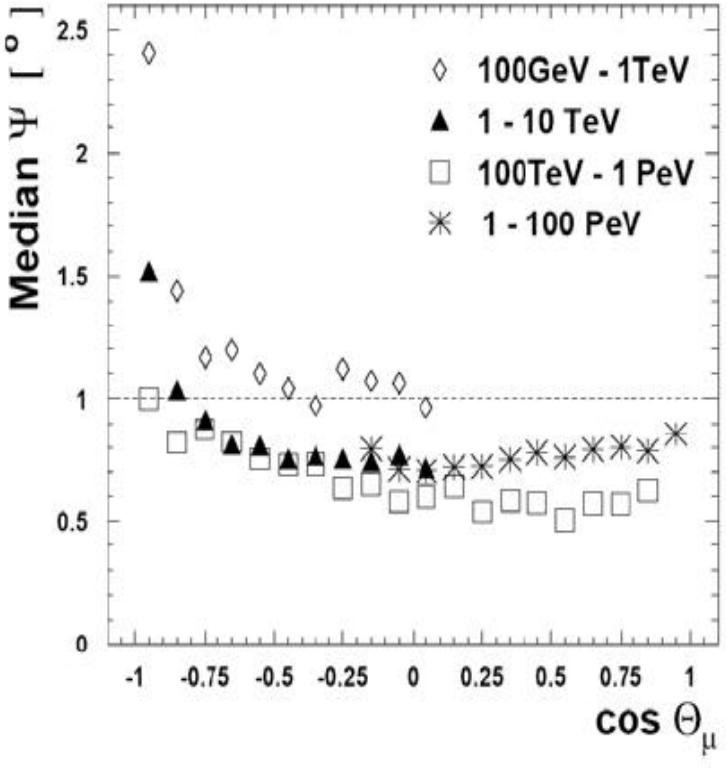
- 80 strings
- 60 modules/string
- Depth 1450-2450 m
- 125 m between strings
- Regular hexagon

IceCube...

...effective area

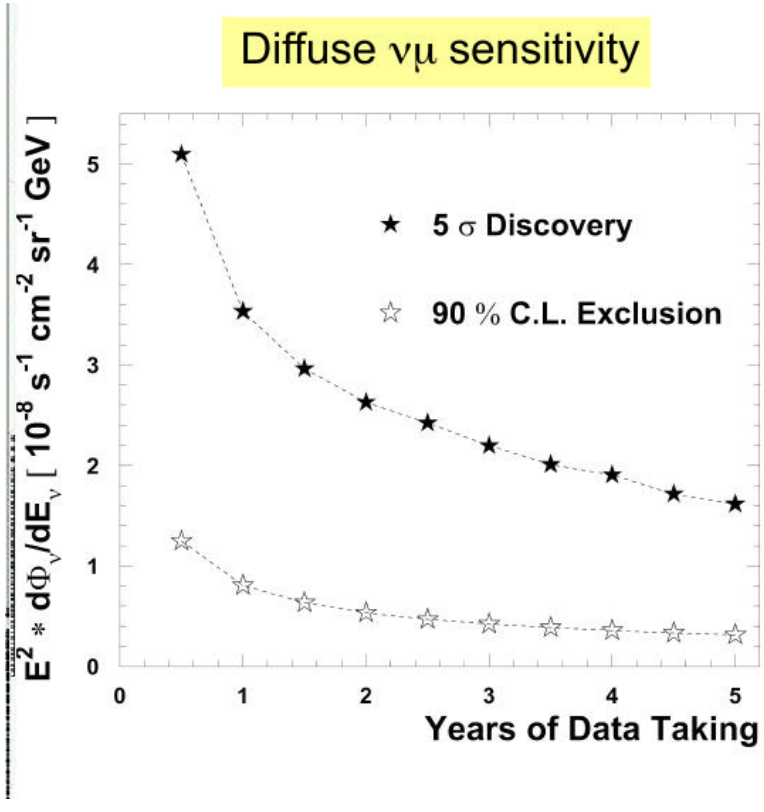


...resolution

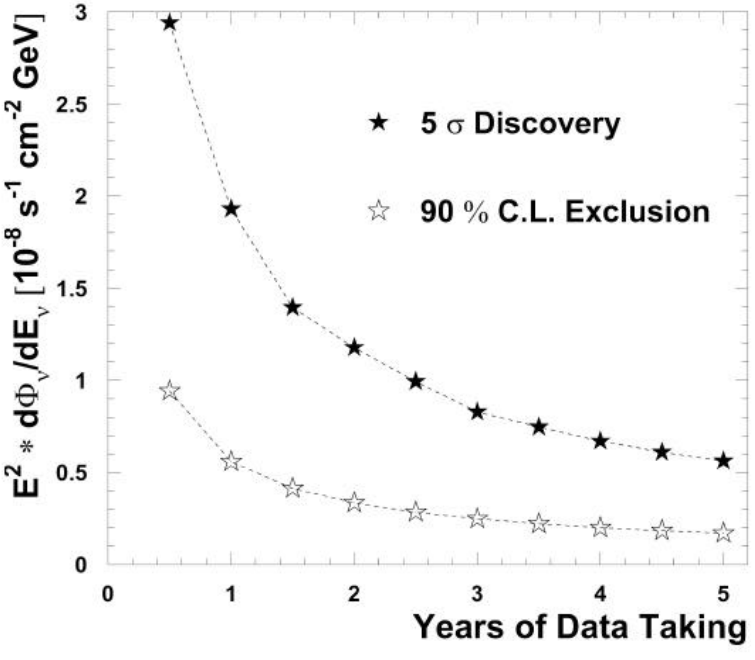


Neutrino telescopes in ice

Diffuse νμ sensitivity

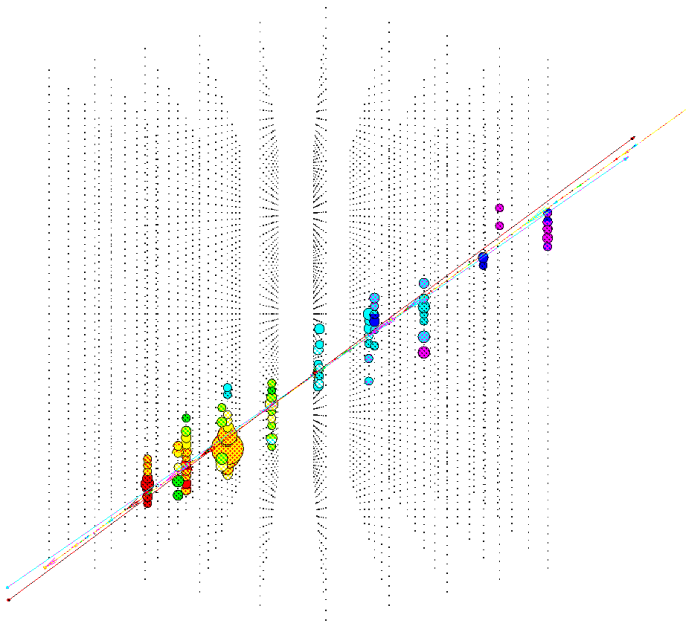


Point source νμ sensitivity

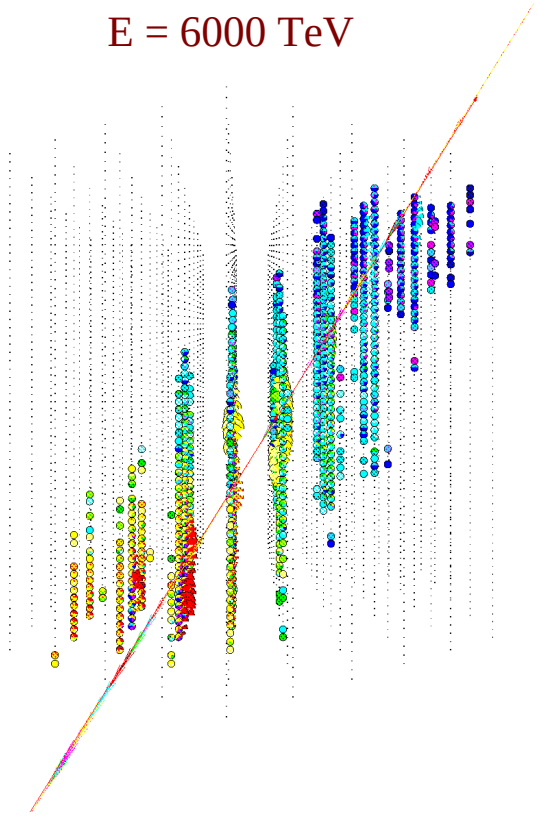


ν_μ detection in IceCube

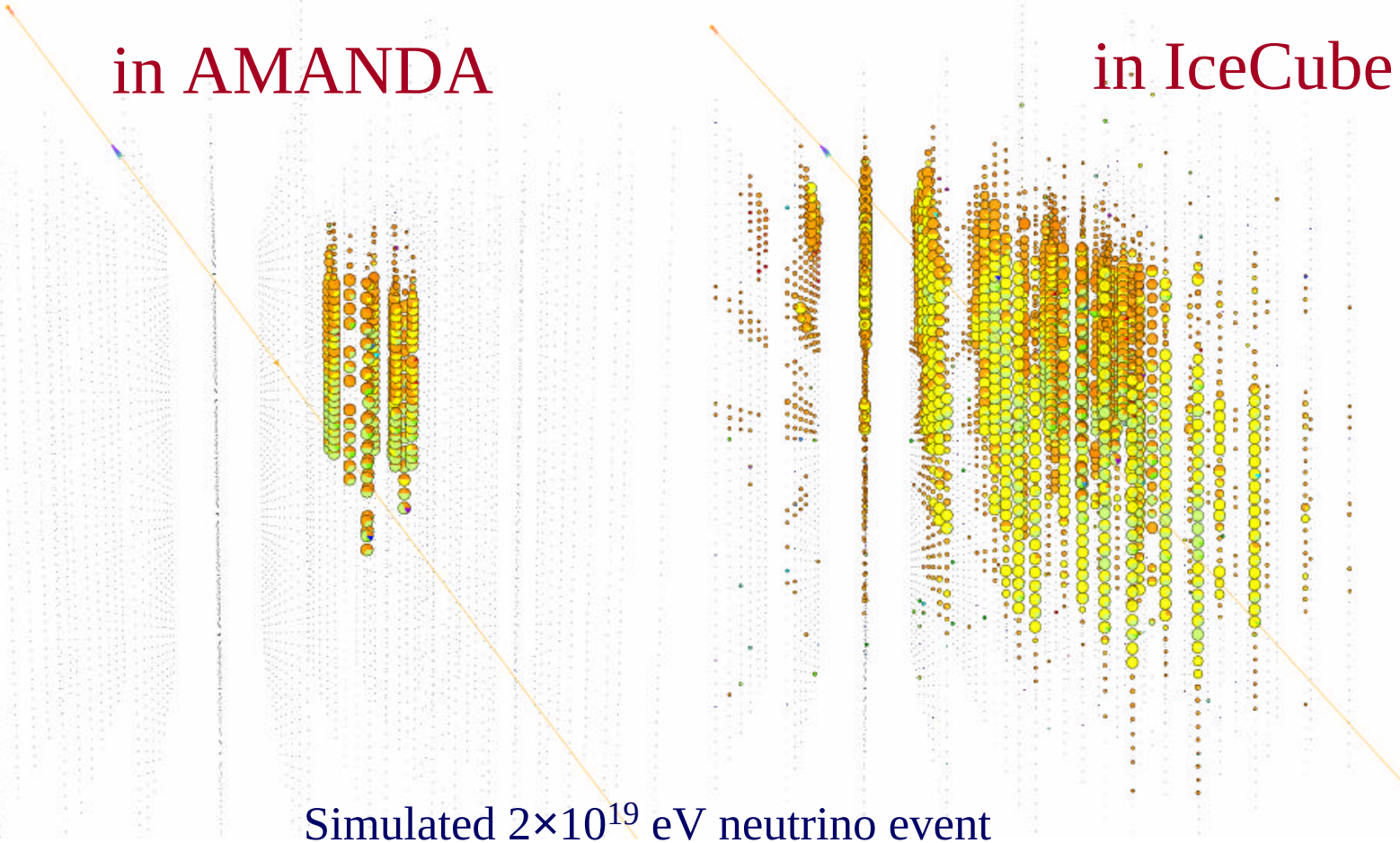
E = 6 TeV



E = 6000 TeV



Highest energies



Simulated 2×10^{19} eV neutrino event

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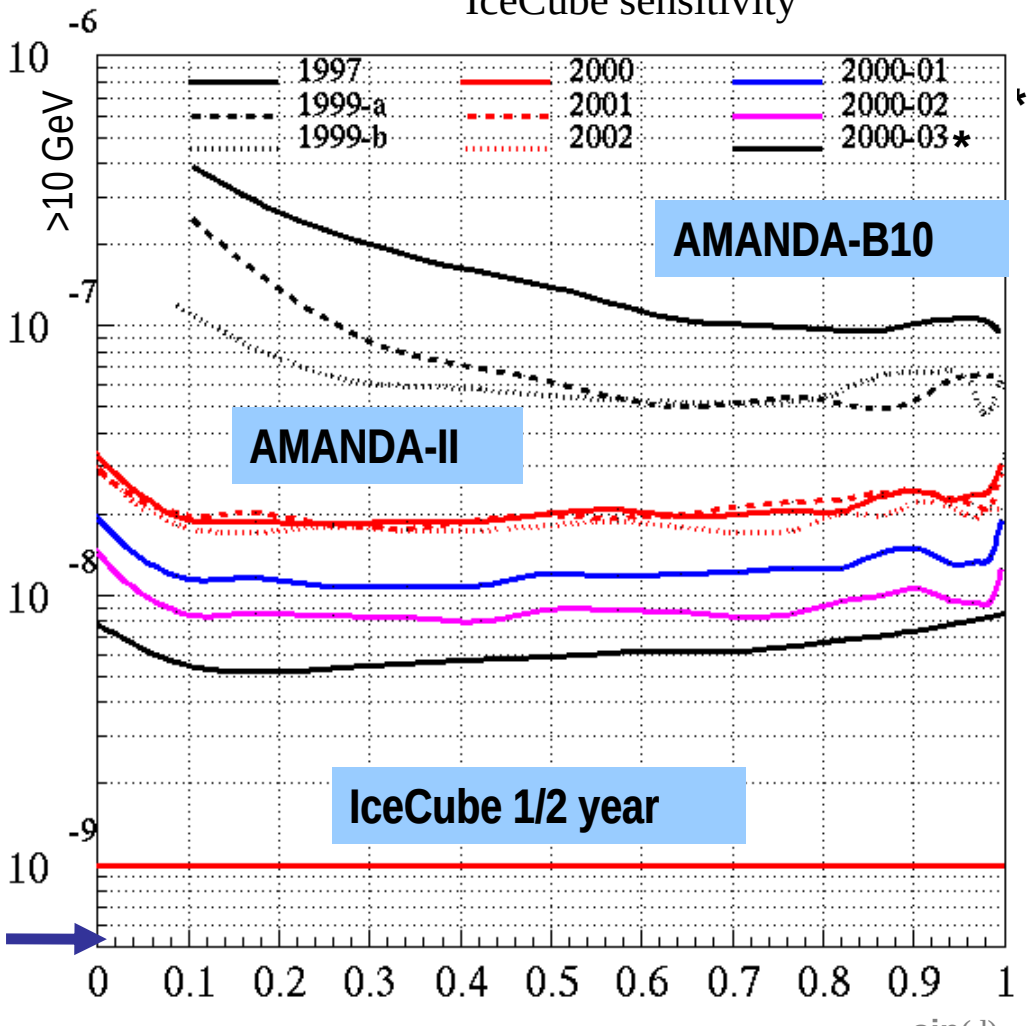
IceCube sensitivity



optimized for E^{-2}, (*) $E^{-2,3}$ signal

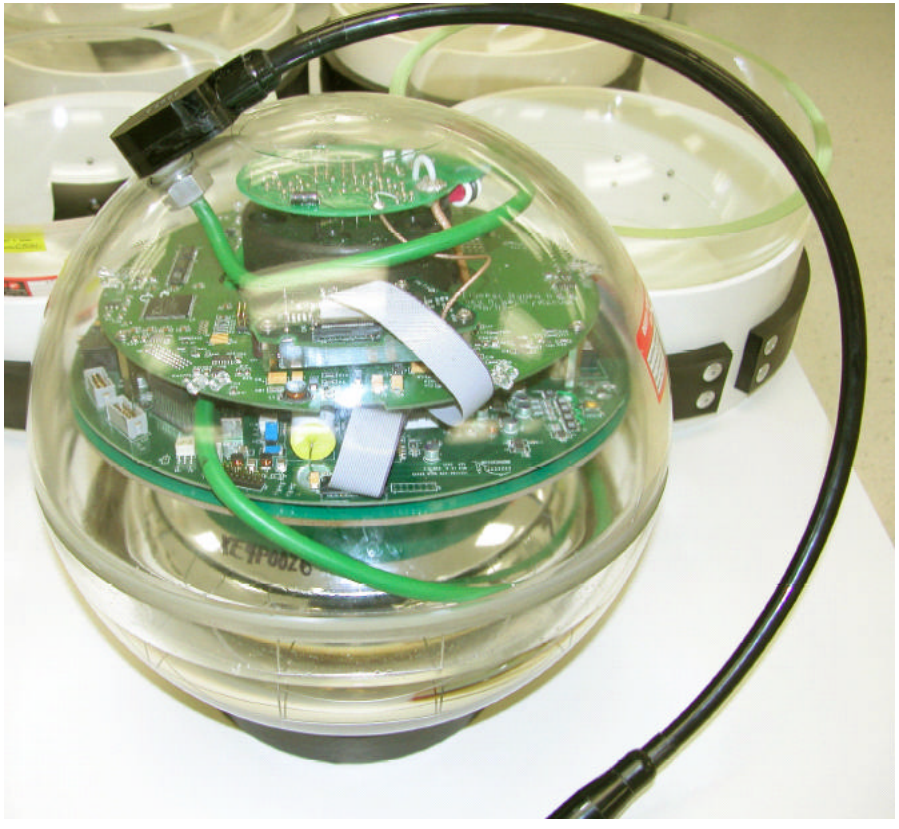
1997 : ApJ 583, 1040 (2003)
2000 : PRL 92, 071102 (2004)
2000-02 : PRD 71 077102 (2005(
2000/2003: ICRC (2005)

IceCube: Astrop Phys 20, 507 (2004)

$F_n^{lim} \approx 0.68 \cdot 10^{-8}\ cm^{-2}s^{-1}$

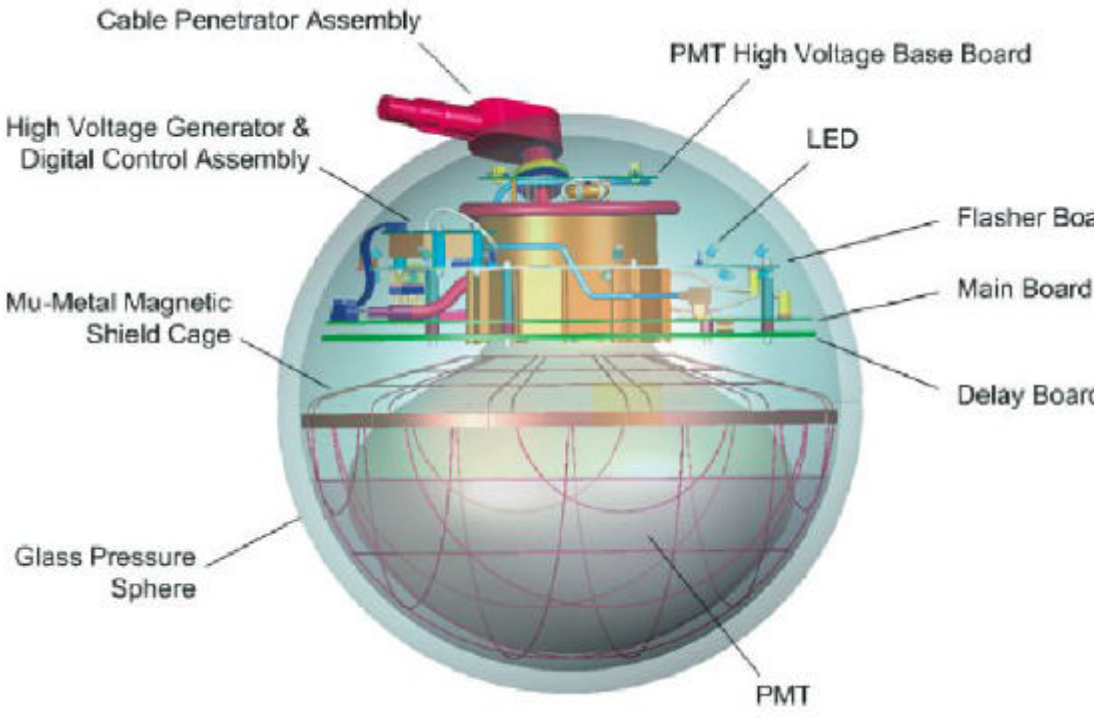
Preliminary

The IceCube Digital Optical module (DOM)

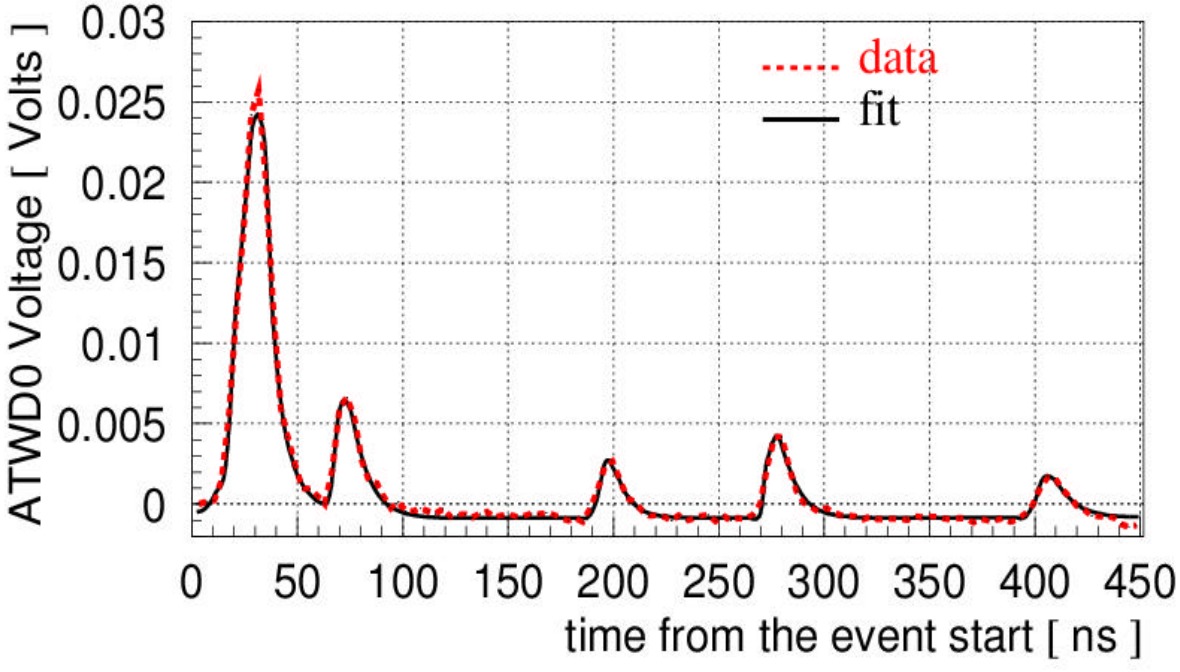


Neutrino telescopes in ice

10" 10-stage Hamamatsu PMT
Benthos pressure glass sphere
Dynamic range 400 p.e./15ns
Timing accuracy<7 ns
Dark noise rate 650 Hz
Two 128-sample ATWD digitizers w/
.5ns binwidth
40Msamples/sec FADC
All DOMs functions tested at low
emperature



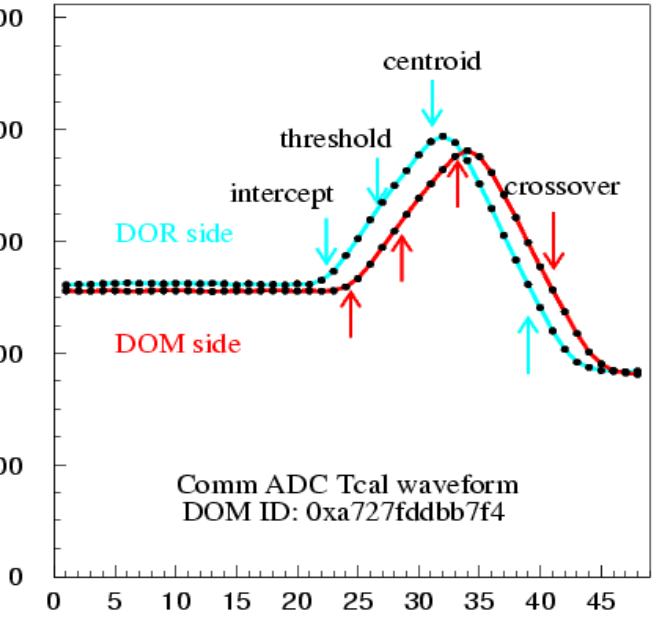
(An example of the trace in one DOM, caused by a triggering muon)



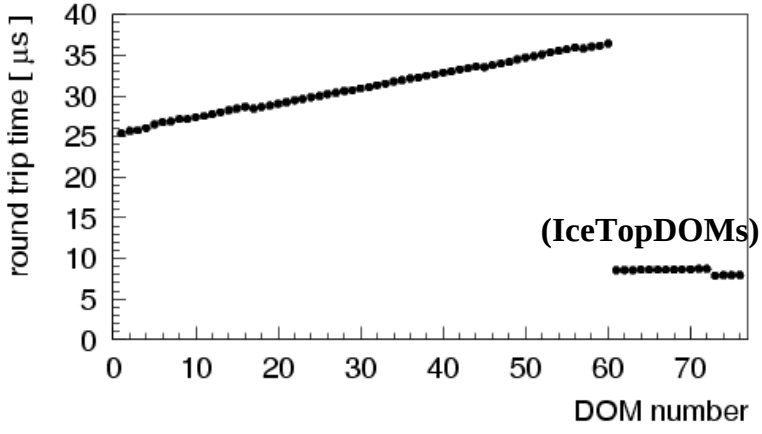
Acquired and reconstructed waveform

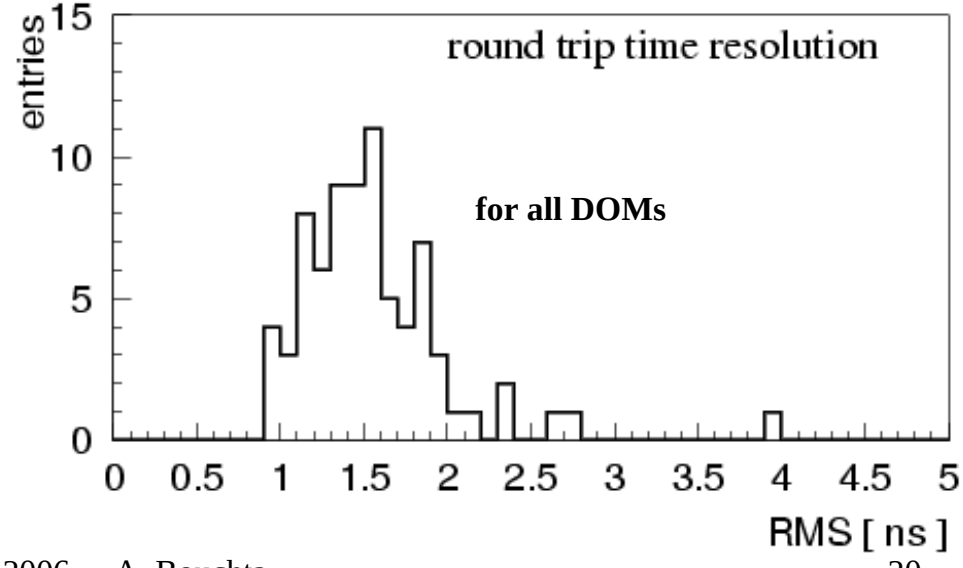
Neutrino telescopes in ice

Time calibration:
by sending a known-shape pulse from the surface to the DOM and measuring the round-trip time

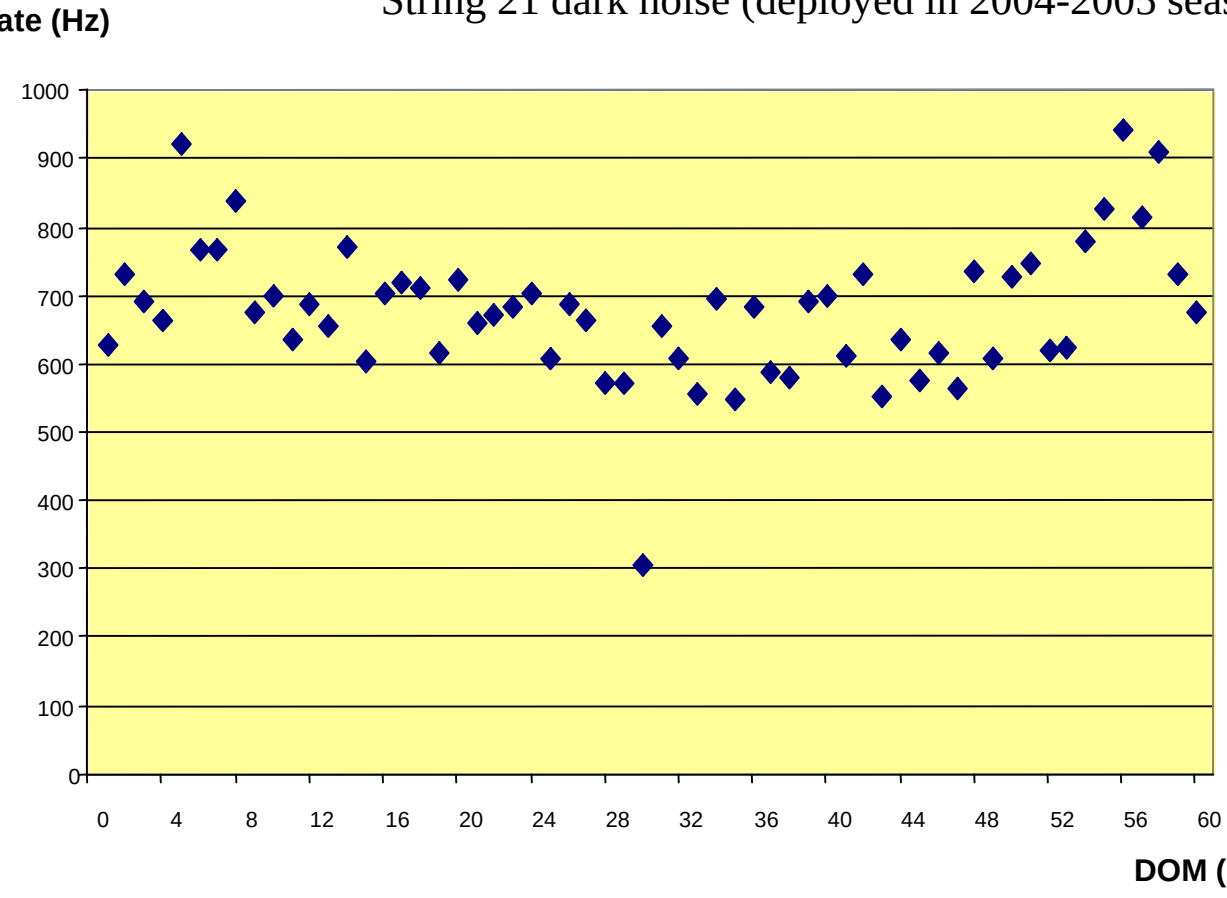


ig. 7. Time calibration waveform





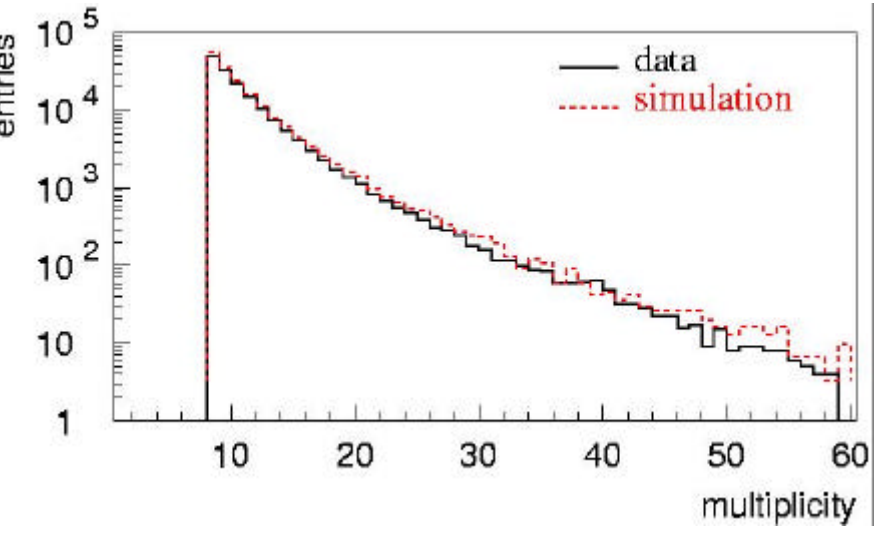
String 21 dark noise (deployed in 2004-2005 season)

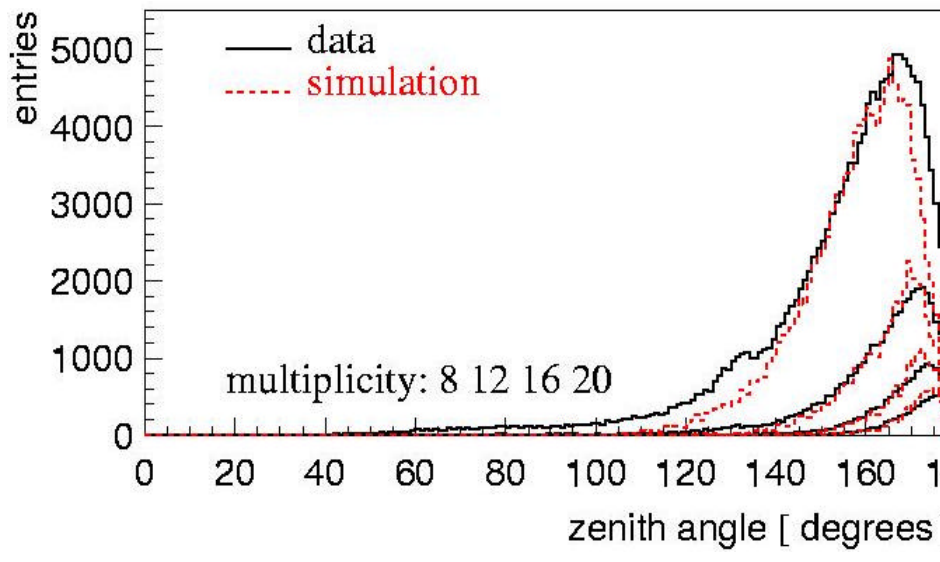


~650Hz dark noise (without after-pulse suppression)

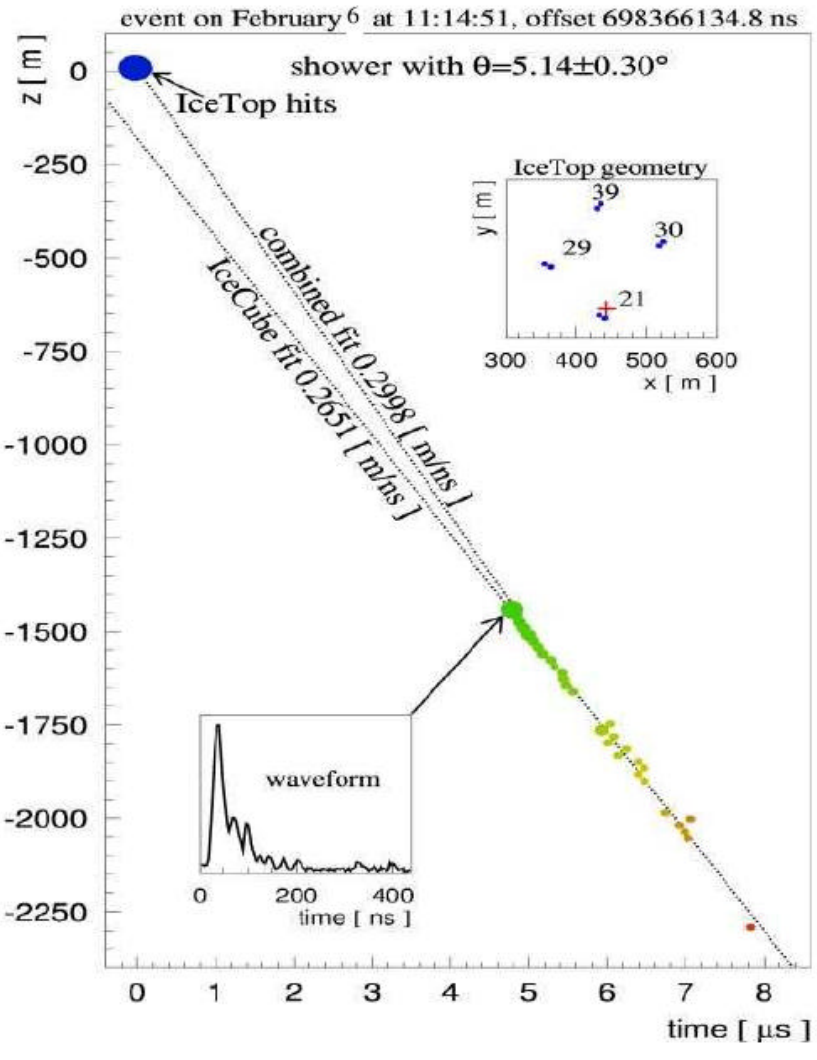
Advantageous for:
- bandwidth
- supernova detection

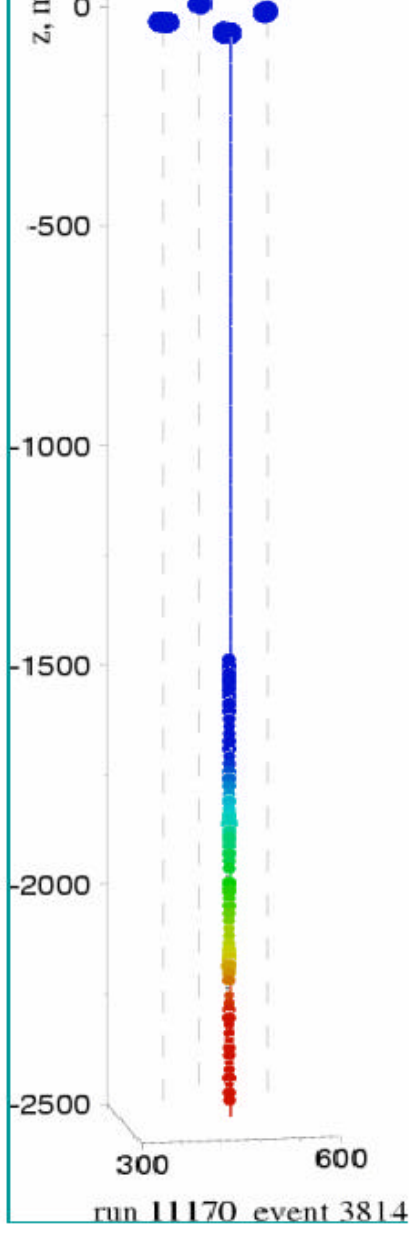
First string (string 21) muon reconstruction





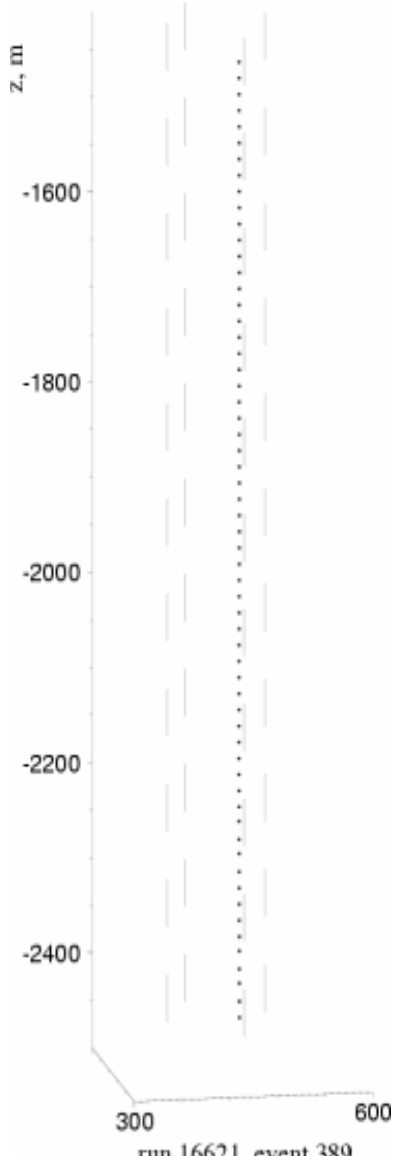
First IceCube string deployed in 2004-2005





Neutrino telescopes in ice

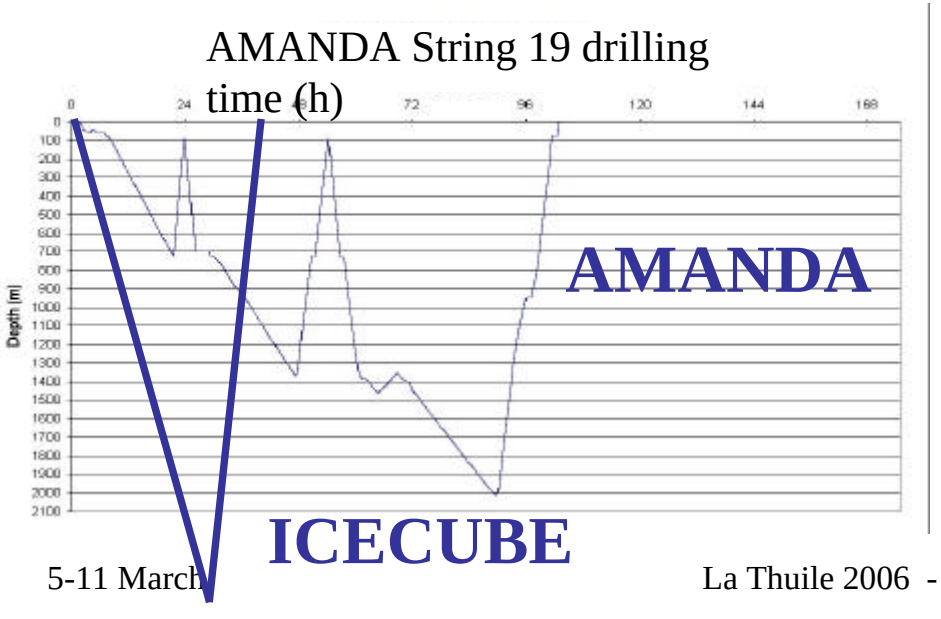
An up-going event in
string 21 in 2005



Neutrino telescopes in ice

Hot water drilling

Neutrino telescopes in ice

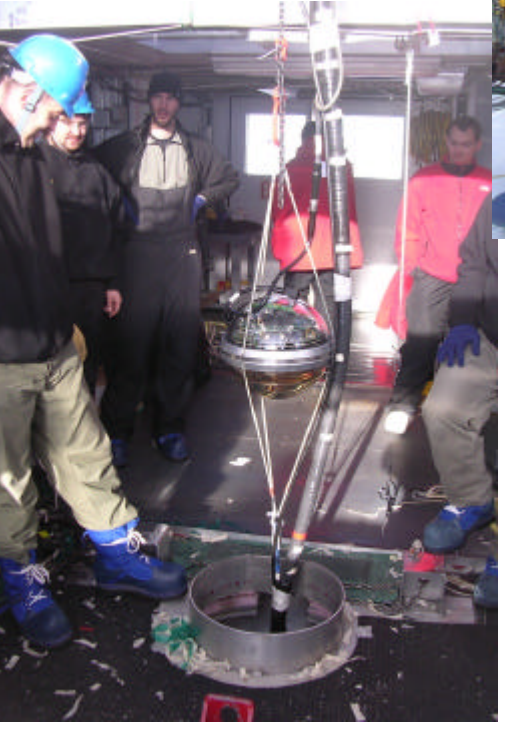


- 5 MW hot water drill
- 60 cm holes
- 2500 m deep
- 40 hours
- Deployment : 12 hrs
- 8 strings deployed this season
- IceCube completed in 2010

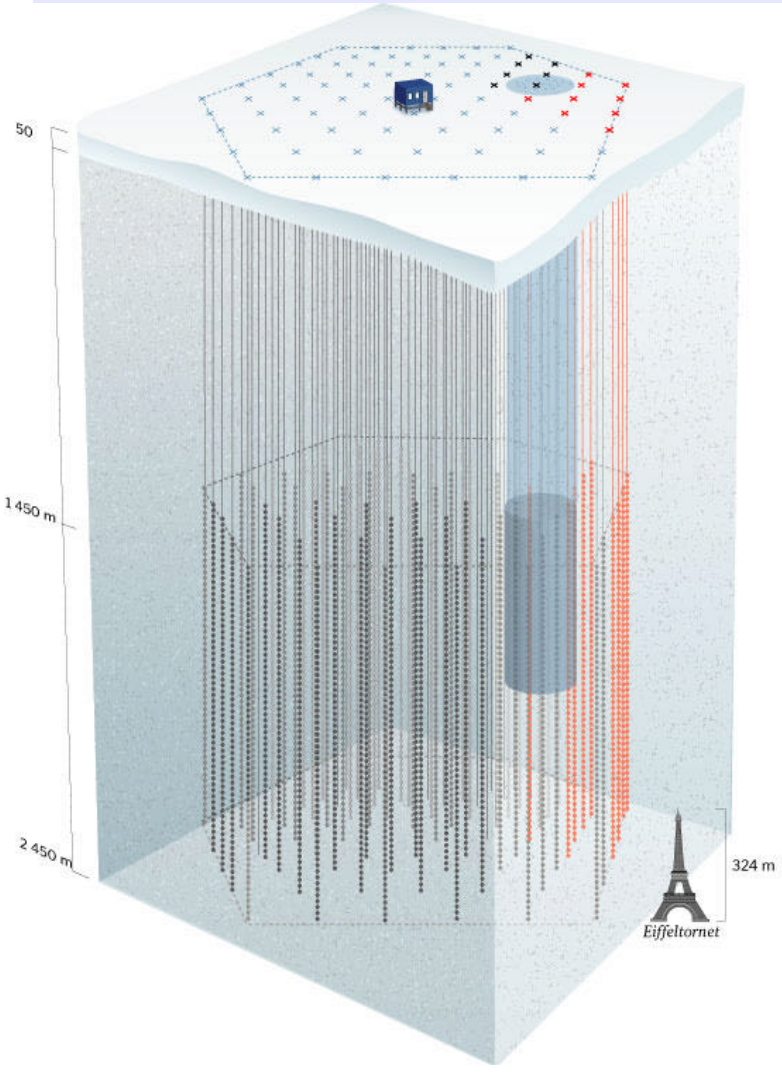
tring cable 2500 m

Veight ~6 tons

Neutrino telescopes in ice



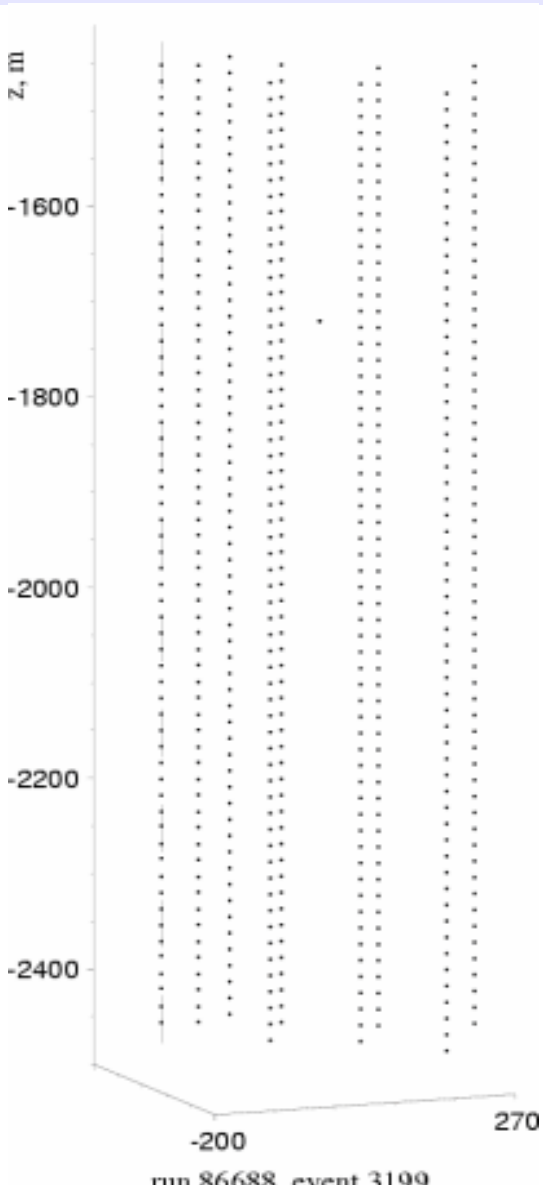
Neutrino telescopes in ice



Nine IceCube strings completed so far (February 2006)

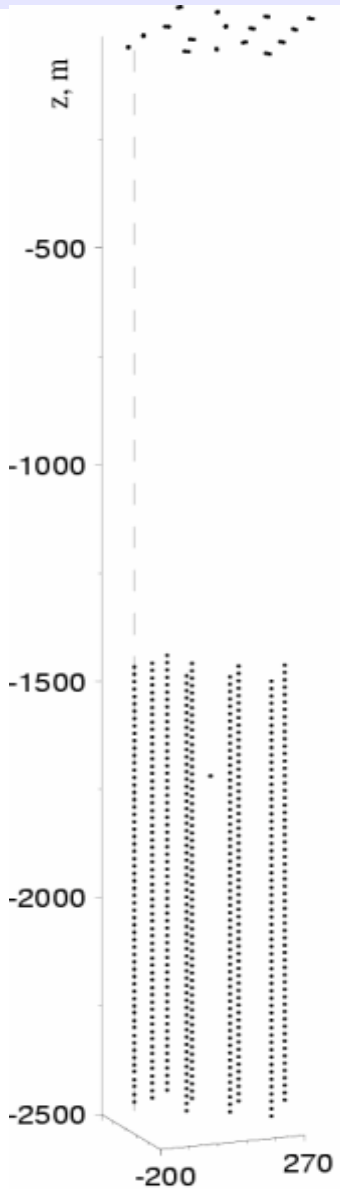
Neutrino telescopes in ice

A downgoing event in the 9 string IceCube detector



Neutrino telescopes in ice

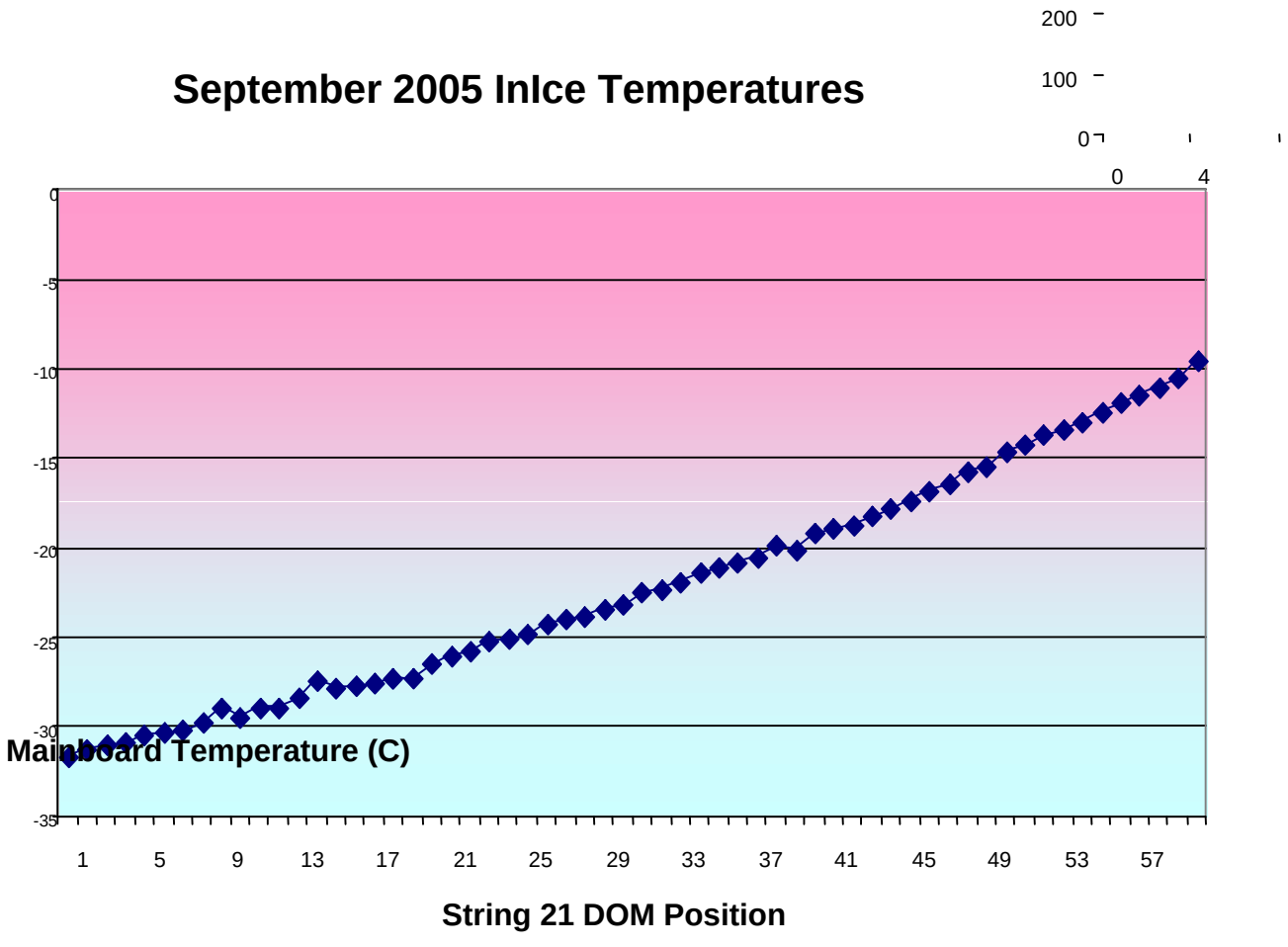
IceTop-IceCube coincident event



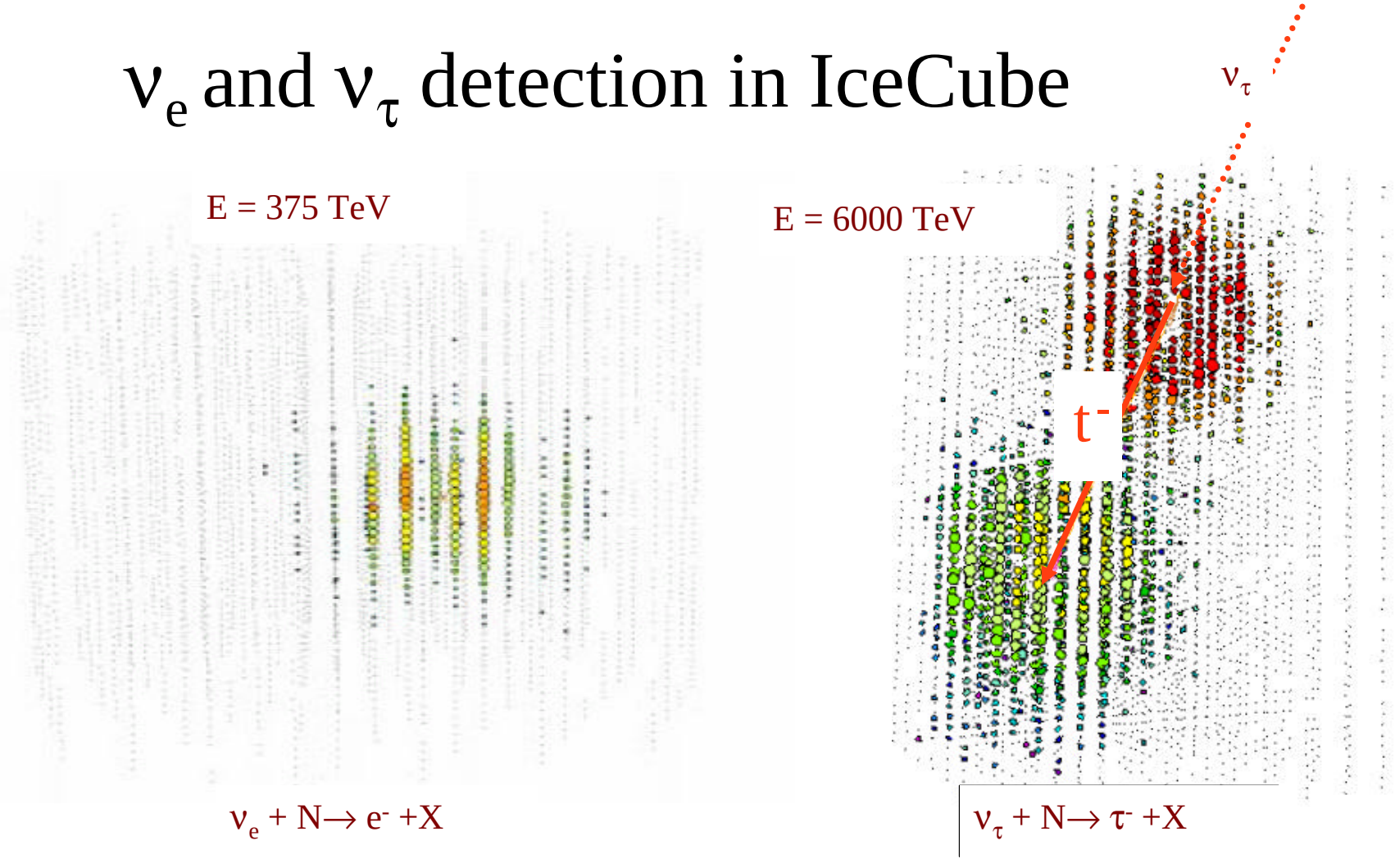
Conclusions

- AMANDA continues to operate
- IceCube is next step after AMANDA
- One year experience of operation of one string
- New drill tuned to expectations
- 480 DOMs and 12 IceTop stations deployed
- Verification of 8 additional strings underway
- Deployed Icecube already larger than AMANDA

Extra material


September 2005 InIce Temperatures
Mainboard Temperature (C)
String 21 DOM Position
0
-5
-10
-15
-20
-25
-30
-35
1
5
9
13
17
21
25
29
33
37
41
45
49
53
57
200
100
0
0
4

ν_e and ν_τ detection in IceCube



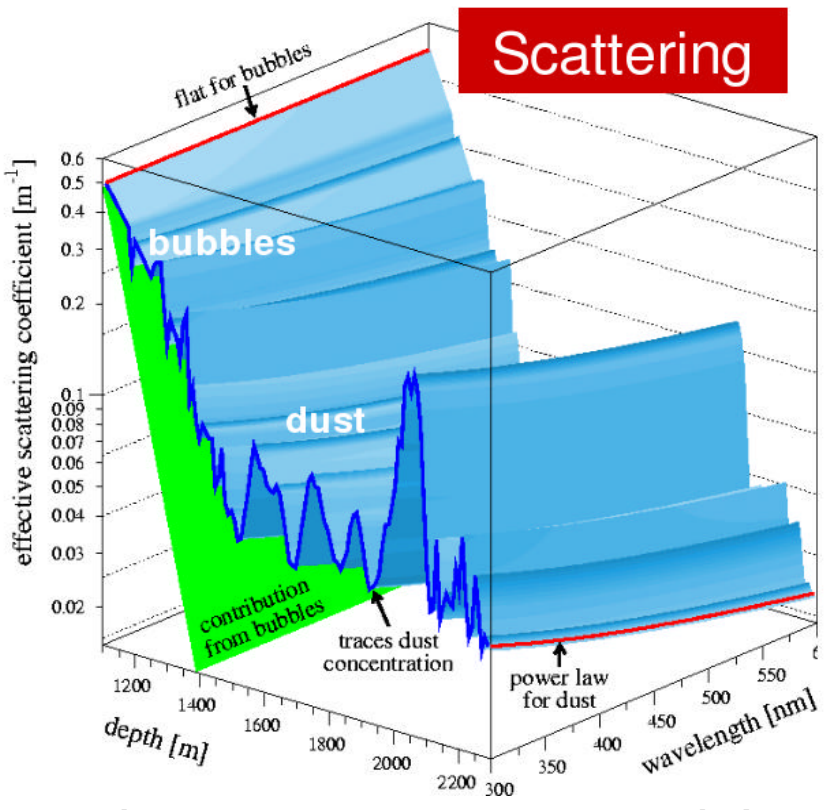
Neutrino telescopes in ice

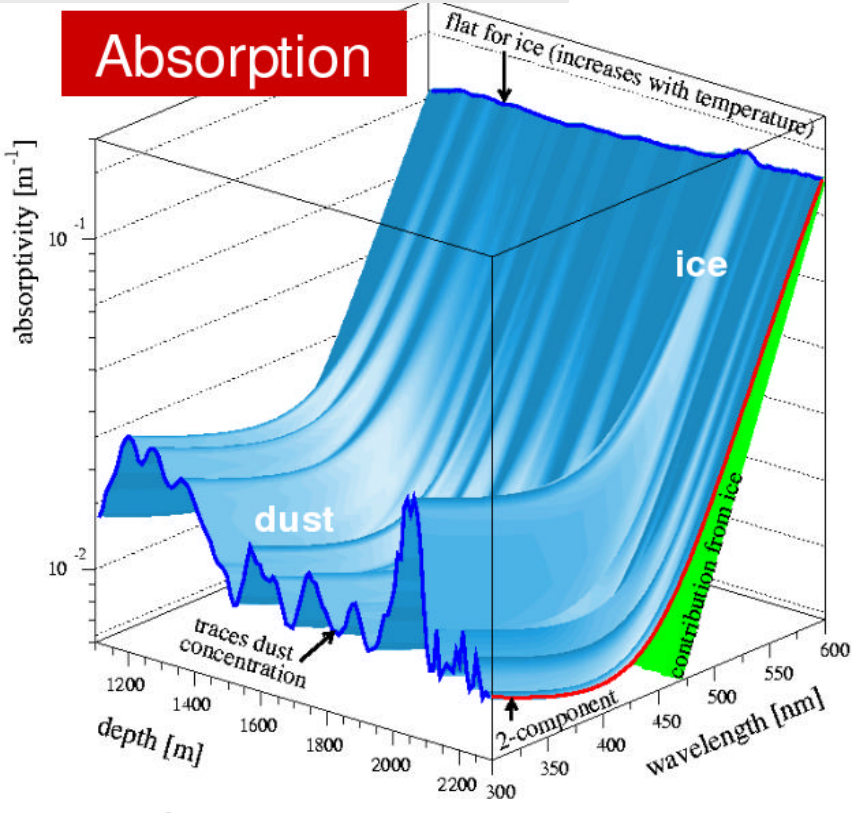
Neutrino telescopes in ice

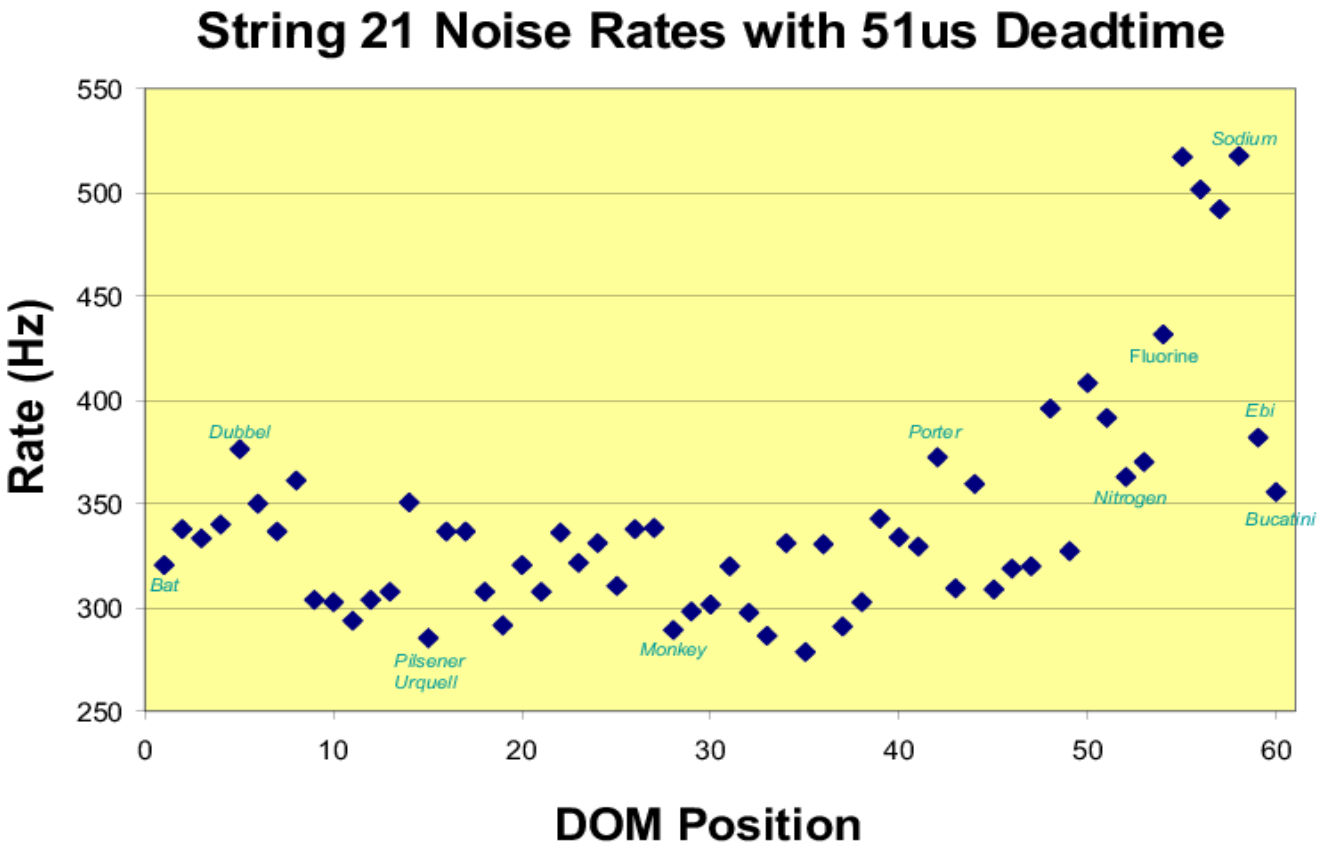
Ice properties:

Average optical ice parameters:

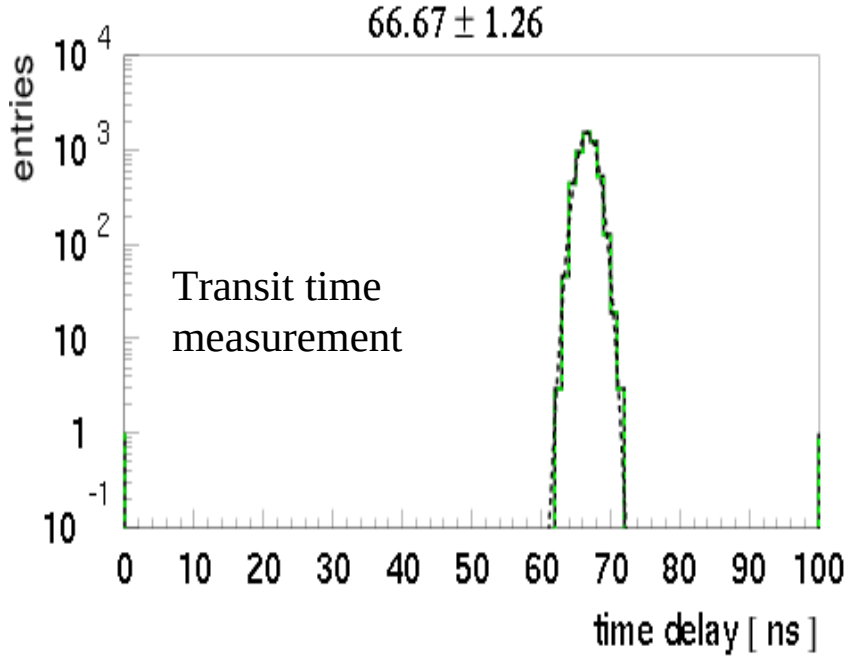
l_{abs} ~ 110 m @ 400 nm
l_{sca} ~ 20 m @ 400 nm
l_{prop} ~ 27 m @ 400 nm

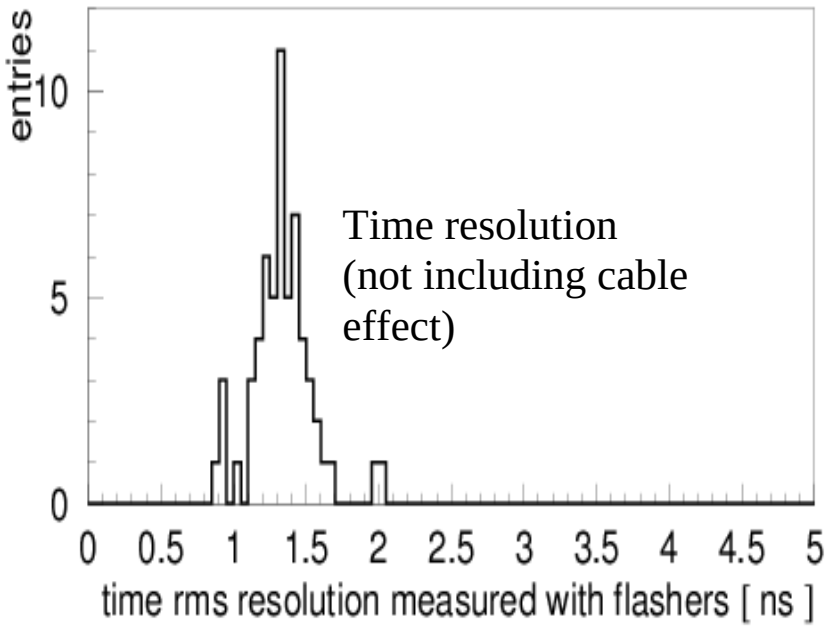





String 21 Noise Rates with 51us Deadtime
Rate (Hz)
550
500
450
400
350
300
250
0
10
20
30
40
50
60
DOM Position
Sodium
Fluorine
Ebi
Bucatini
Nitrogen
Porter
Dubbel
Bat
Pilsener
Urquell
Monkey

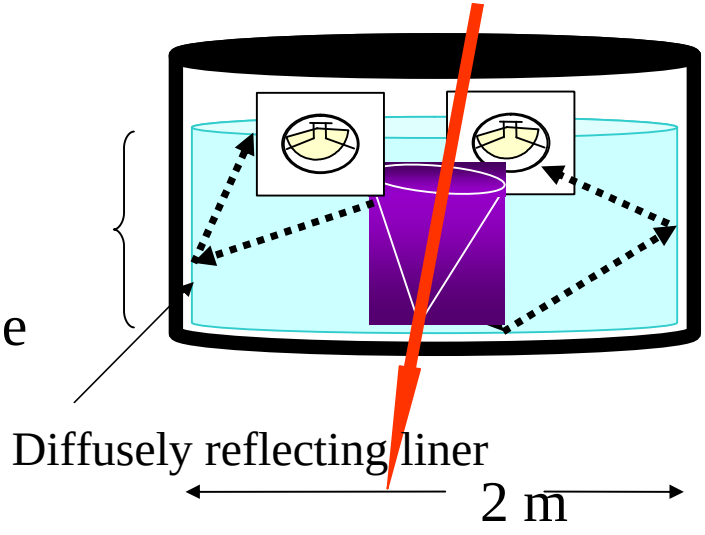
Intrinsic PMT time calibration





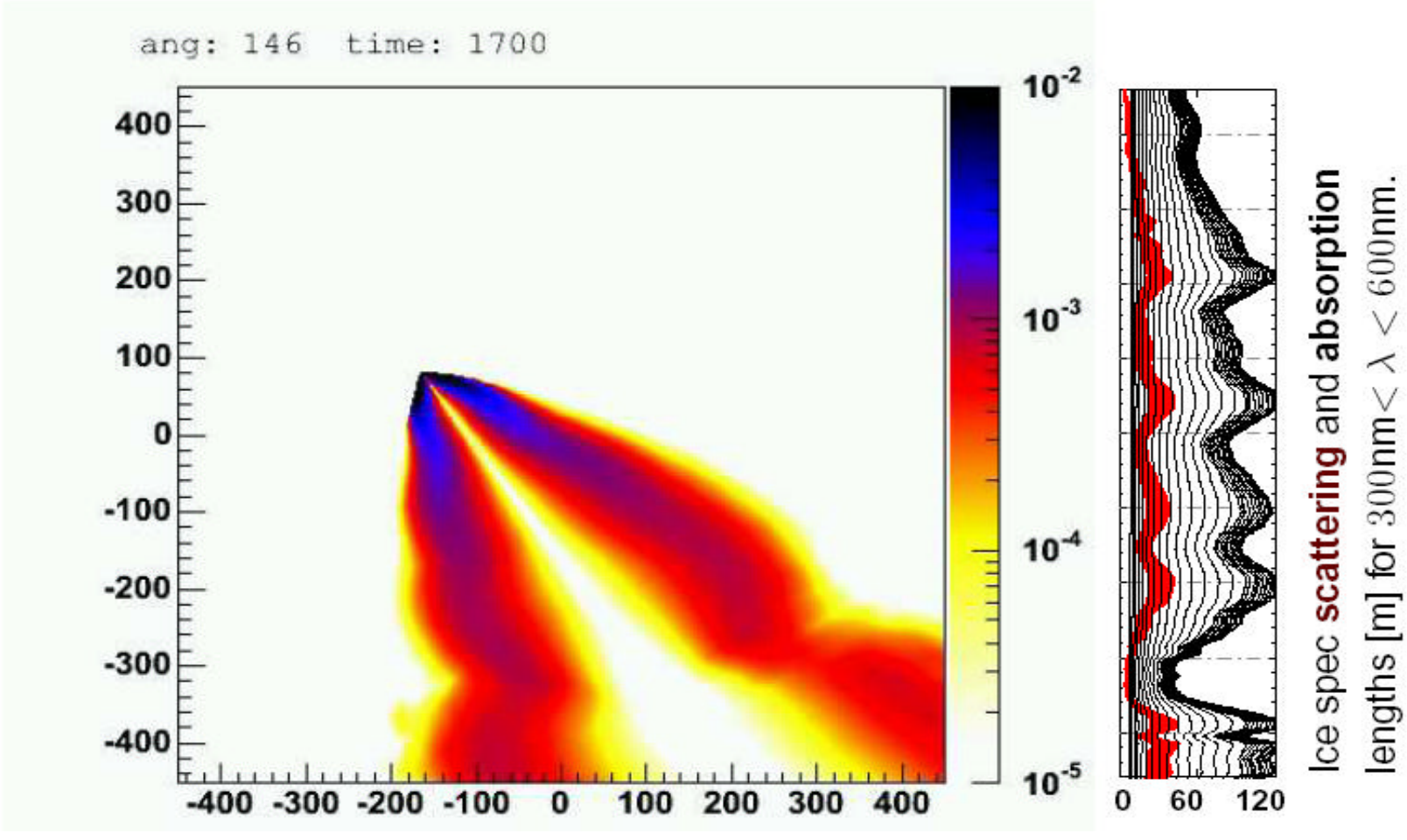
IceTop

Ice Cherenkov Tank

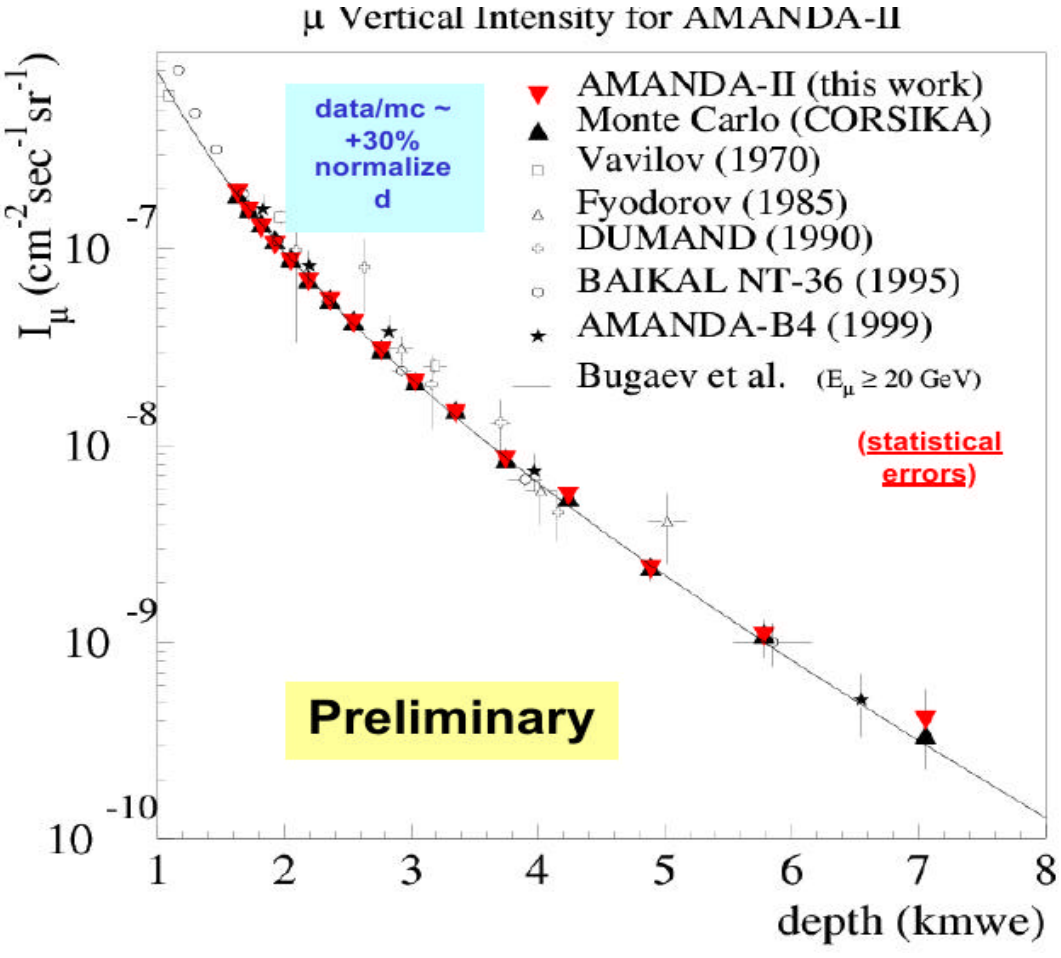


- 2 tanksabove each string (1 station/string)
- 2 DOMs/tank
- Veto effective for muons from above
- 16 stations deployed

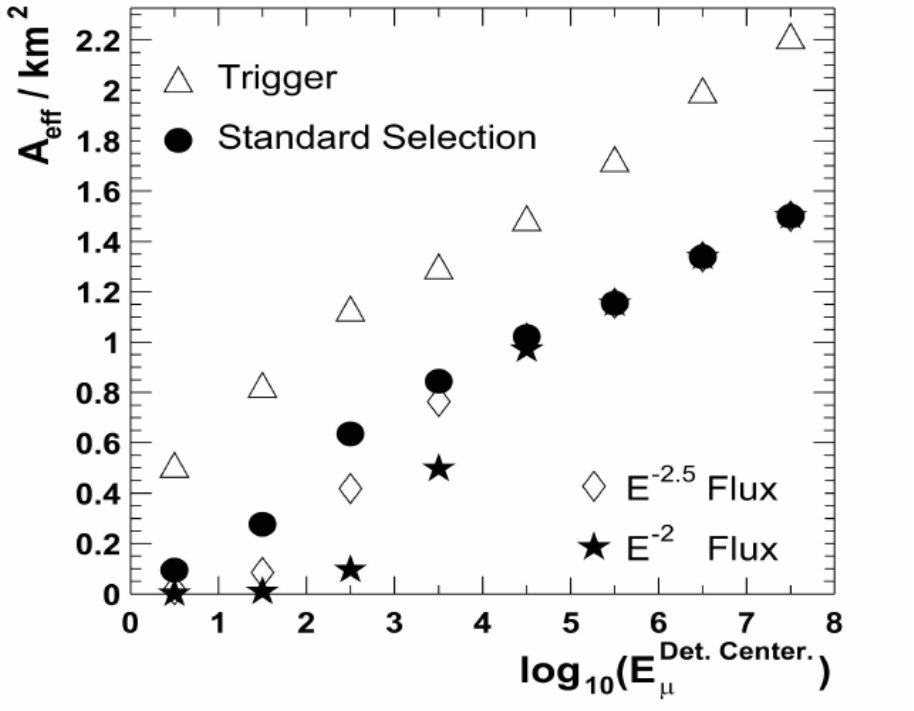
Infinite up going muon in the layered ice.

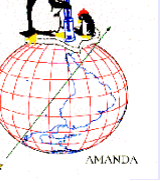


Neutrino telescopes in ice

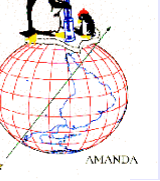


Neutrino telescopes in ice





Neutrino telescopes in ice



Neutrino telescopes in ice