

# IceCube Overview

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# Outline



- IceCube Overview
- The IceCube Detector
- Swedish Group Activities
- Some Physics Results
- Future: Deep Core
- Summary


(Science cover: 2007 vol. 315, issue 5818)

# IceCube Overview (I)

## General

- What: Neutrino telescope (optical)
- Size: Cubic kilometer ( $\sim 1 \text{ km}^3$ )
- Location: the deep glacier ice at the S.Pole
- Detector module: Digital Optical Module (**DOM**)
- Detector medium: (Antarctic) ice
- Collaboration:
  - ~250 scientists & engineers
  - 33 institutions
  - 9 countries
- Total project cost: ~272 million dollars

I'll get back to this later.




# IceCube Overview (II)

## Current Status & Plan

- **Currently under construction...**
  - construction started in 2004/2005
  - 50% completion in 2007/2008
  - **complete** detector in **2010/2011**
  
- **Data taking: since 2005**
  - 2005: 1 string
  - 2006: 9 strings
  - 2007: 22 strings
  - **2008: 40 strings**
  - =====
  - 2009: 56 strings
  - 2010: 72 strings
  - **2011: 80 + 6 strings**

I'll get back to this later.





# Amundsen-Scott South Pole Station

Antarctica

Summer: ~240 people  
Winter: ~50 people

Skyway

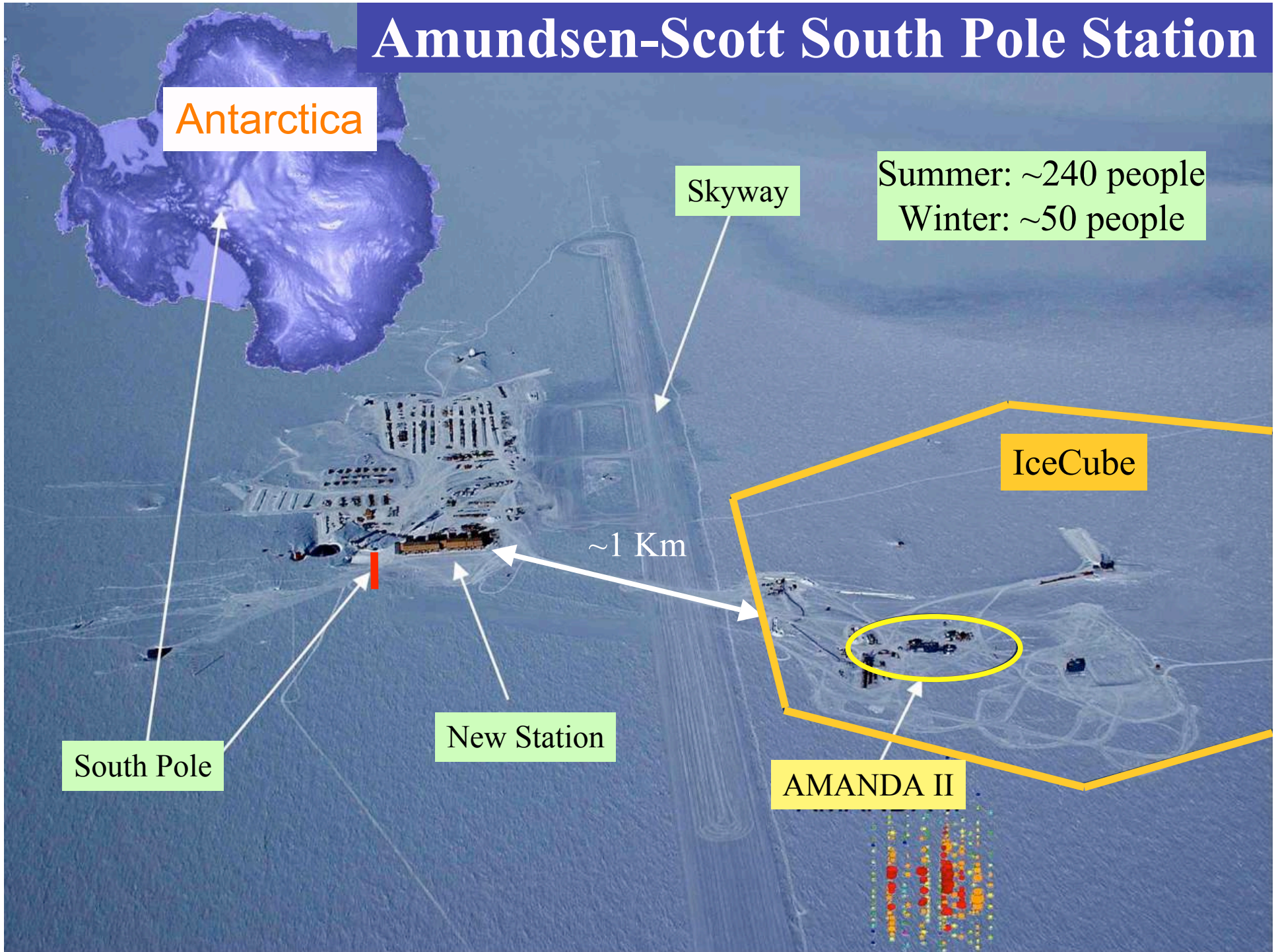
IceCube

~1 Km

New Station

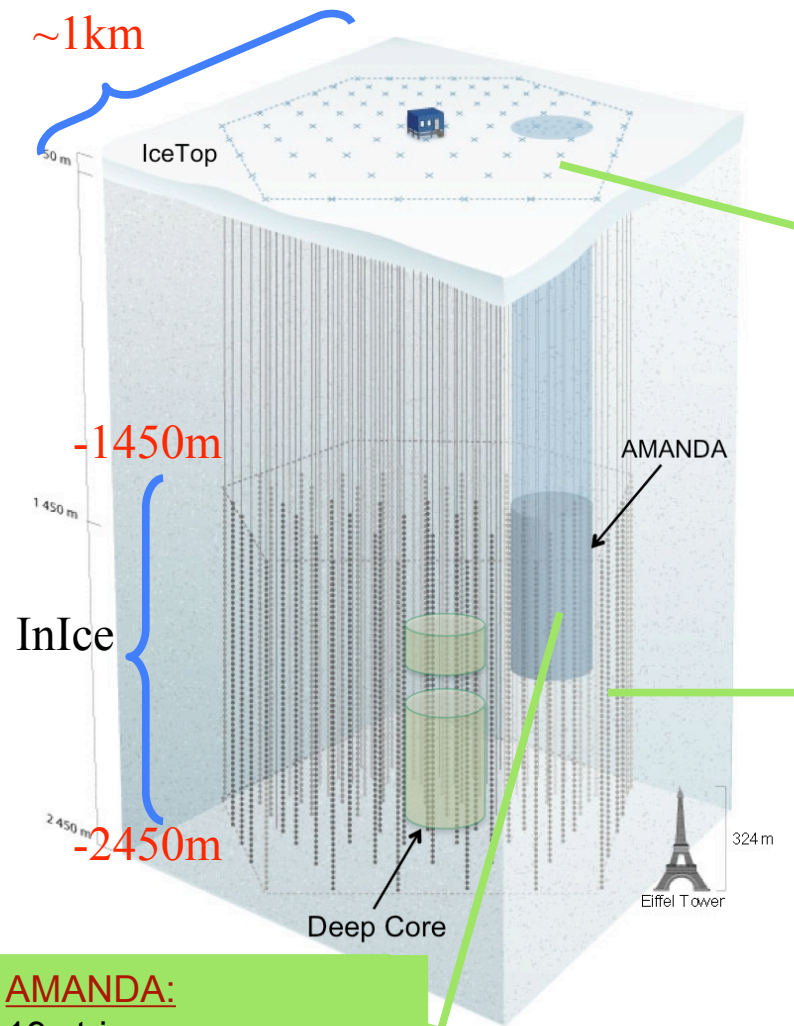
South Pole

AMANDA II

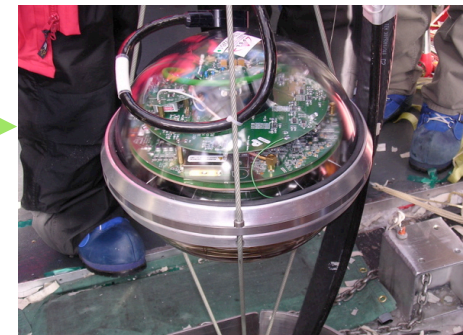




# The IceCube Detector



IceTop (air shower array):  
 80 stations  
 2 frozen-water tanks / station  
 2 DOMs / tank



AMANDA:  
 19 strings  
 677 OMs total  
 10-20 m vertical spacing  
 ~40 m between strings

InIce:  
 80 strings  
 60 DOMs / string  
 17 m vertical spacing  
 125 m between strings

Stockholm, 2008

Seo, Stockholm Univ.



# String Deployment

Hose reel

Drill tower

5 MW Hot  
water  
generator

Hot-water drilling

Drilling to 2500 m < 40h  
String deployment ~ 12h



speed: ~90m/hr



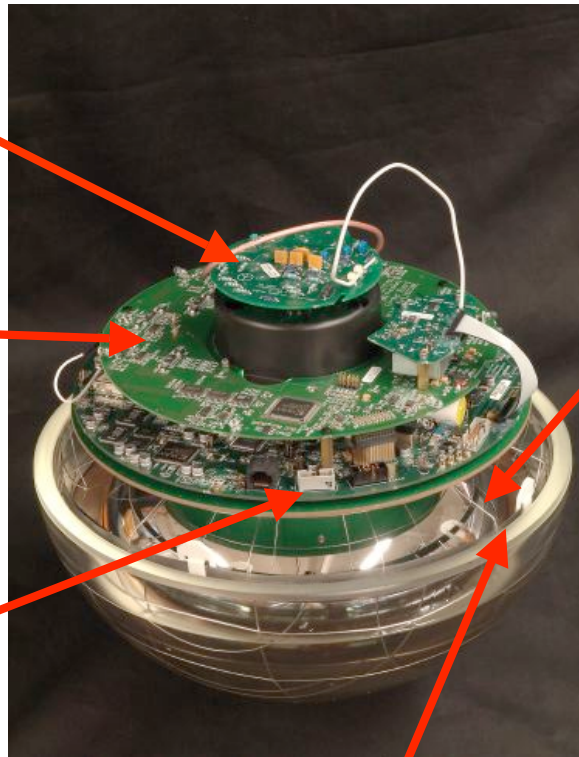


# Digital Optical Module (DOM)

**PMT base**

**LED flasher board**

**main board**



*Housed in  
33 cm Benthosphere*

- Time-stamp at the DOM
- Capture complex waveforms at PMT anode with Analog Transient Waveform Digitizer (ATWD) & fADC

**PMT**



Hamamatsu R7081-02  
(10", 10-stage,  $10^7$  gain)

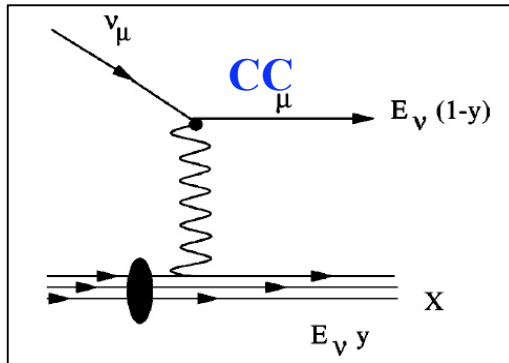
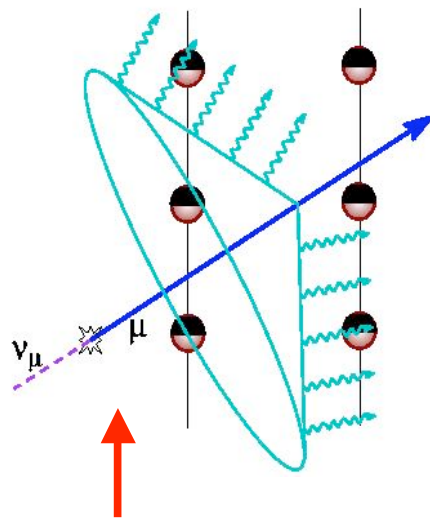
Pressure: 1/2 atmosphere  
Temperature:  $-8^{\circ}\text{C} \sim -30^{\circ}\text{C}$

**~20% DOMs  
built & tested  
In Sweden**

# Neutrino Detection

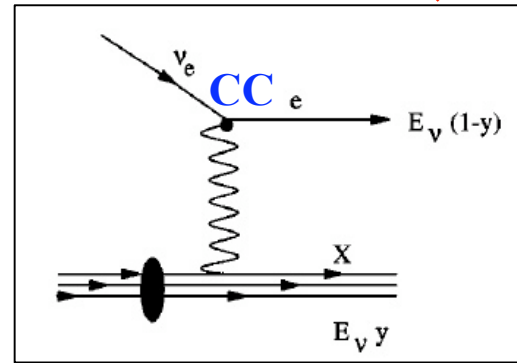
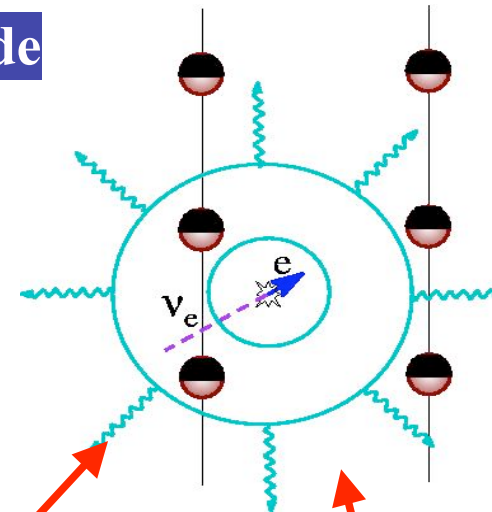
Method: detect Cherenkov light from secondary particles produced by neutrino interaction

**Track**

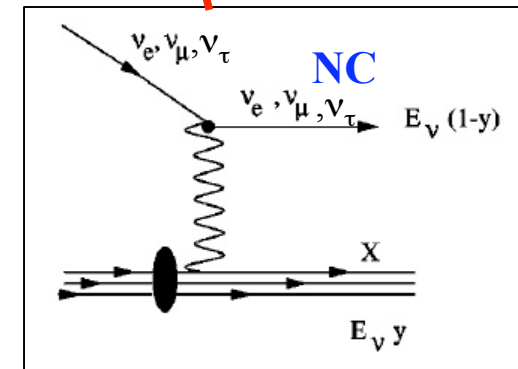


Partikeldagarna,  
Stockholm, 2008

**Cascade**



Seo, Stockholm Univ.



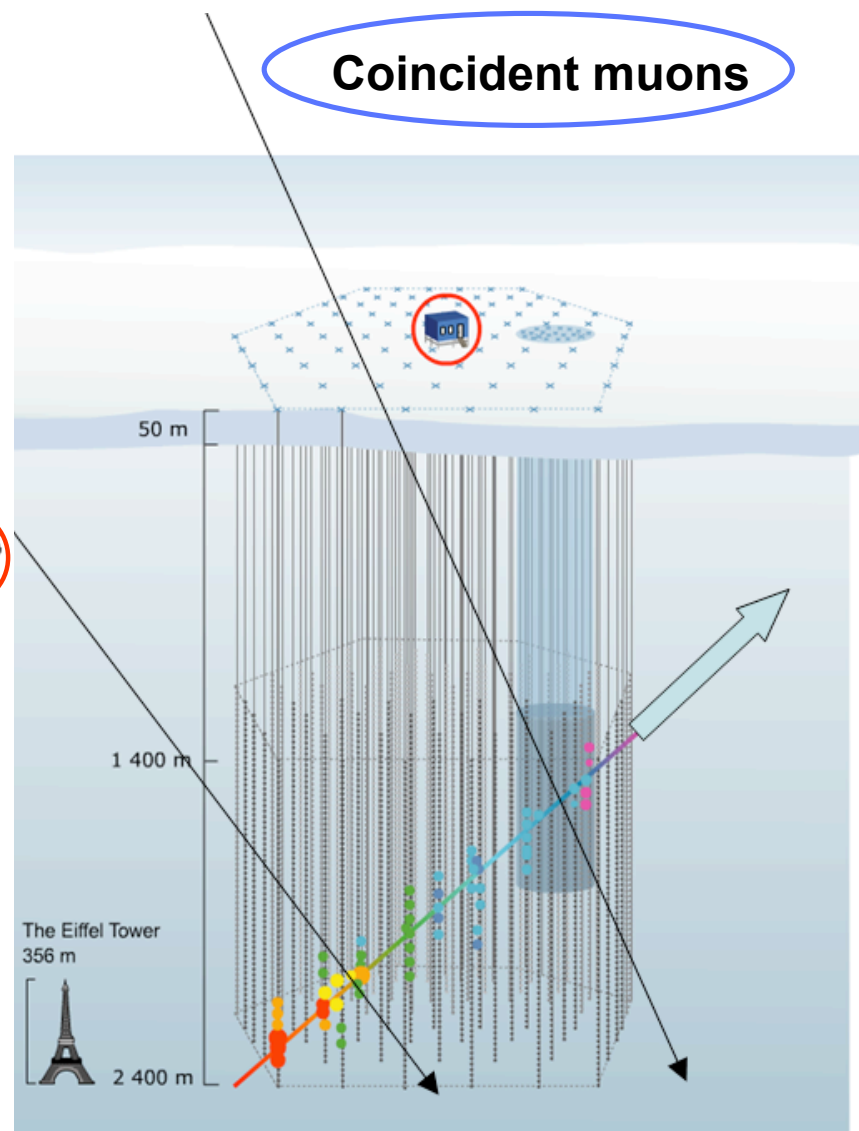
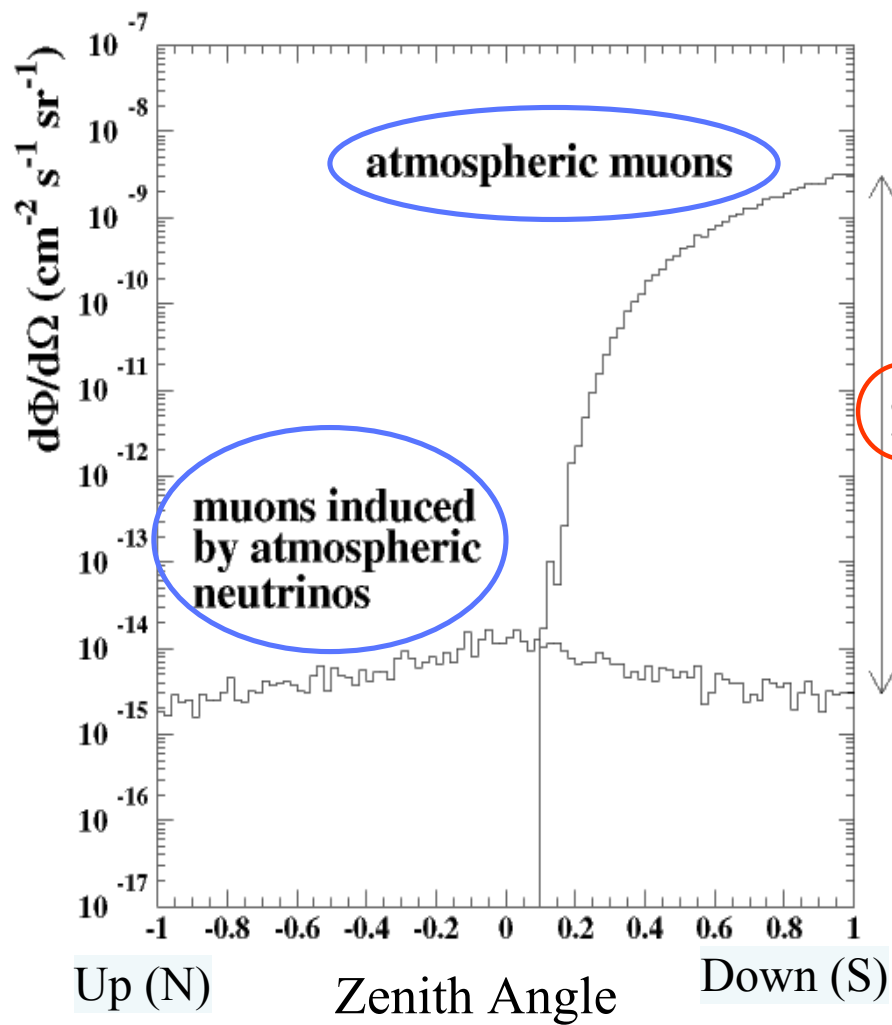
# Event Rates

Year	#Strings	Run Length	Trigger Rate	atm $\nu$ rate	CR $\mu$ Rate
2005	IC1	-	-	2	-
2006	IC9	137 days	150 Hz	$\sim 1.5/\text{day}$	80 Hz
2007	IC22	319 days	670 Hz	$\sim 20/\text{day}$	550 Hz
2008	IC40	$\sim 1\text{year}$	1400 Hz		1000 Hz
2011	IC80	10 years	TBD	$\sim 200/\text{day}$	1650 Hz

# Data Transfer

- Satellite:  $\sim 32.5$  GB/day (Y2008), (pre-scaled) filtered events
- Ship: once a year for all filtered events in tapes

# Backgrounds



# IceCube Physics Reach

## Astronomy/Astrophysics:

- point source search: **GRB**, AGN, etc...
- diffuse search: *e.g.*, **EHE  $\nu$**

## Cosmic ray physics:

- compositions, energy spectrum

## Exotics:

- **WIMPs**, **monopoles**, nuclearites, Q-balls, stau pairs

## HEP:

- neutrino oscillations over cosmologically long baseline:  
 **$\nu_\tau$  search**
- atmospheric neutrino oscillations?
- charm production from high energy atmospheric neutrinos
- etc...

## New physics...?

(for our published papers)

<http://www.physto.se/~walck/amanda/amanda-pub.html>



# Current SU-IceCube Members (I)

Deep core  
wg leader



Prof. Per Olof Hulth



Asso. Prof. Christian Walck

Simulation  
wg leader



Prof. Klas Hultqvist

Low E trigger



Prof. Christian Bohm

DOM production



Eng. Lars Thollander

Low E trigger



Dr. Dave Nygren

Visiting scientist  
from LBNL

## Current SU-IceCube Members (II)



### -- **Seon-Hee Seo**

- FoAss (started Oct. 2007)
- IC22 High E  $\nu_\tau$  search (on going)
- Simulation software release management
- deep core study soon and WIMP search in future



### -- **Gustav Wikström**

- PhD Student (started spring 2005)
- IC22 Solar WIMP search (*finished!*)
- IC40 + AMANDA Solar WIMP search (just started)
- initial deep core study, simulation work



### -- **Henrik Johansson**

- PhD Student (started spring 2006)
- EHE  $\nu$  Search (will start soon)
- verification work, EHE event reconstruction

# Current Uppsala-IceCube Members (I)



Publication  
committee



Prof. Olga Botner



Acoustic  
Detector  
R&D,  
AMANDA  
trigger



Prof. Allan Hallgren



WIMP  
wg leader



Asso. Prof. Carlos de los Heros



DOM production  
& test



Dr. Leif Gustafsson

# Current Uppsala-IceCube Members (II)



-- **Martino Olivo**

- PhD student (started fall 2006)
- GRB Search (on going)
- Muon tomography



-- **Olle Engdegård**

- PhD Student (started spring 2007)
- IC56 Solar WIMP Search (will start next year)
- DOM testing

## 2 exchange students:

- to learn DarkSUSY
- Acoustic detector R&D

## 2 PhD students got PhD degree recently:

- UHE  $\nu$  search
- exotic particle search

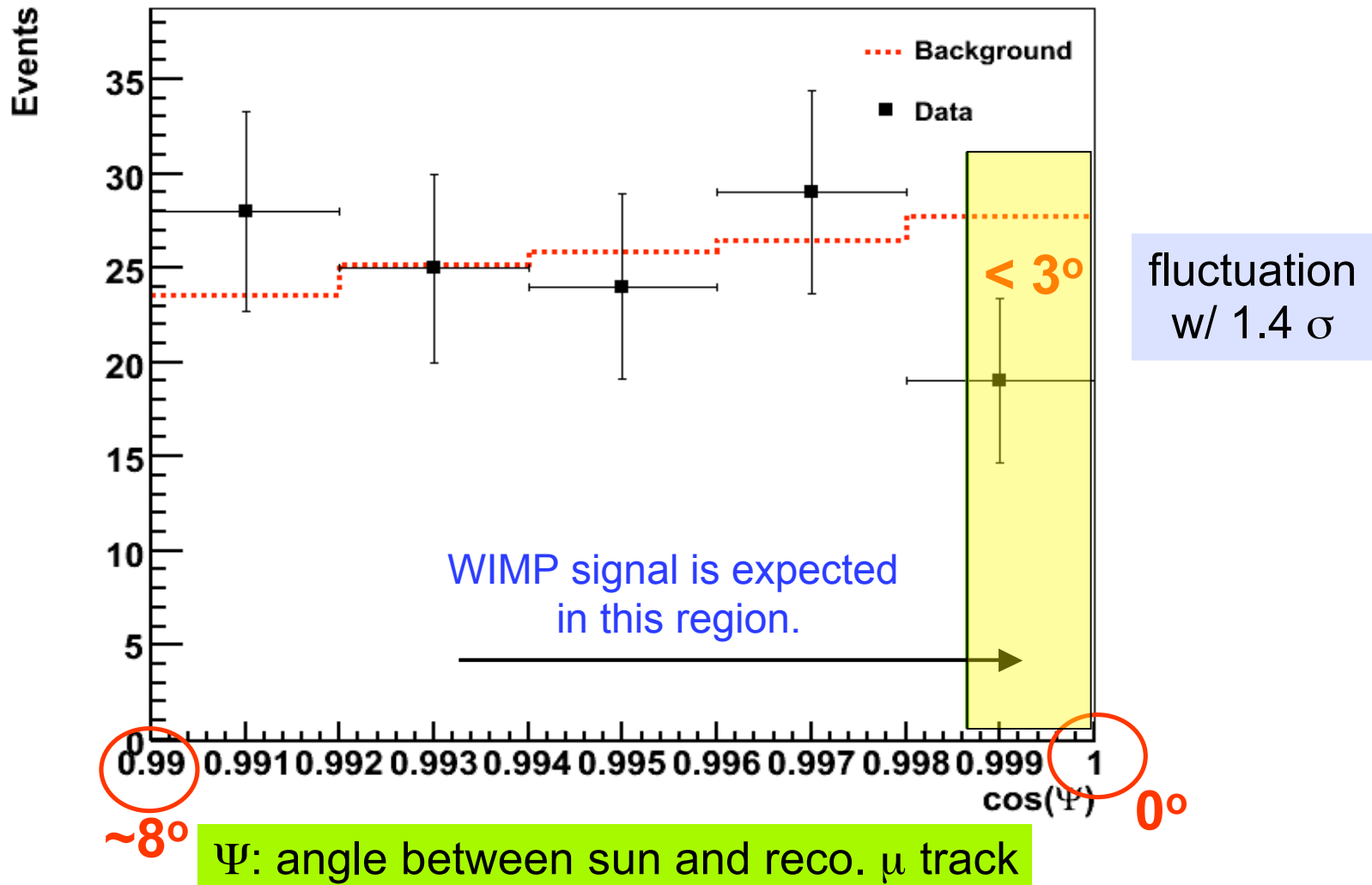




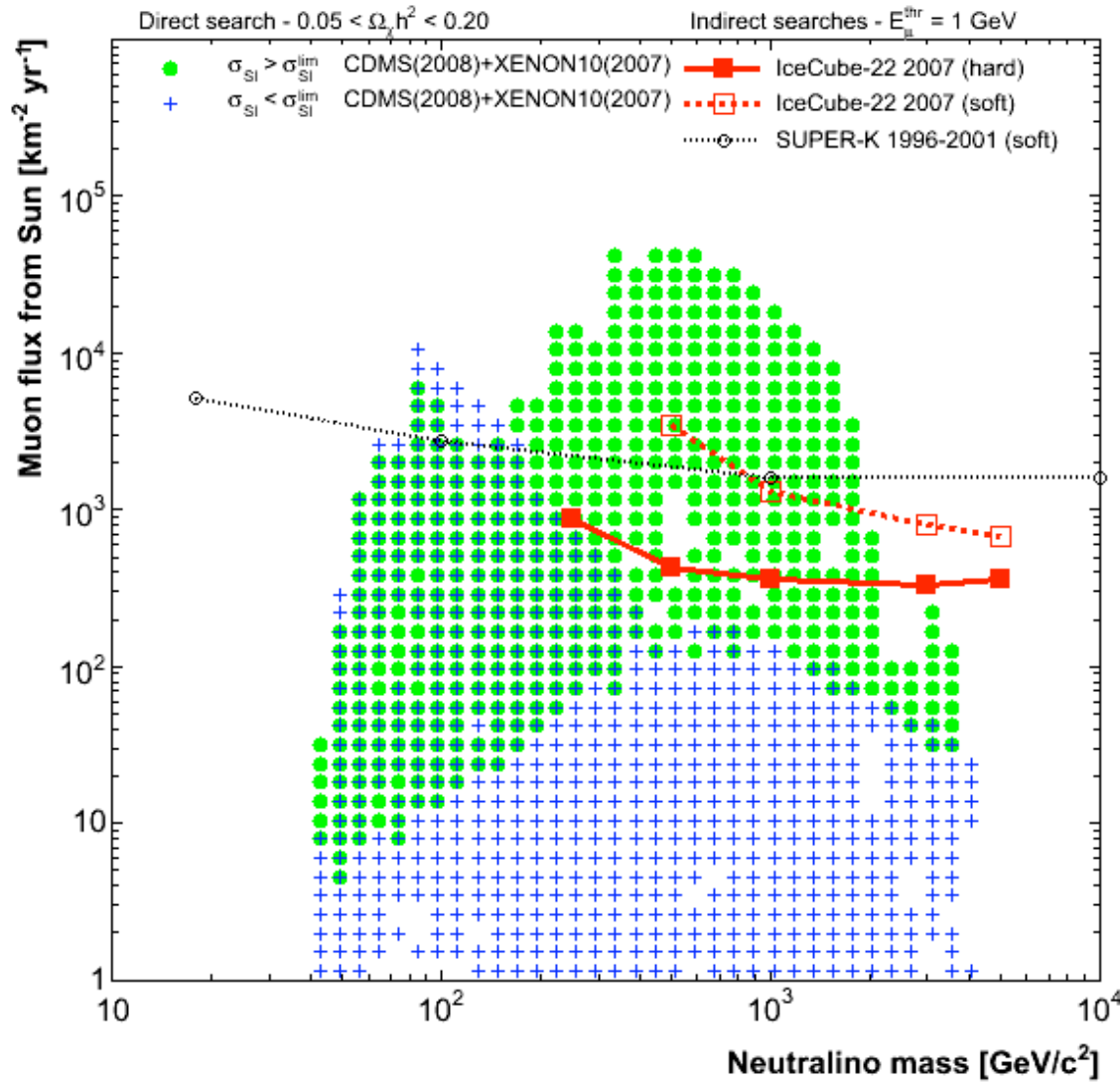
Data: 104.3 live days w/ IC 22 strings

*preliminary*

No excess was observed in Sun direction.



*preliminary*



90% CL

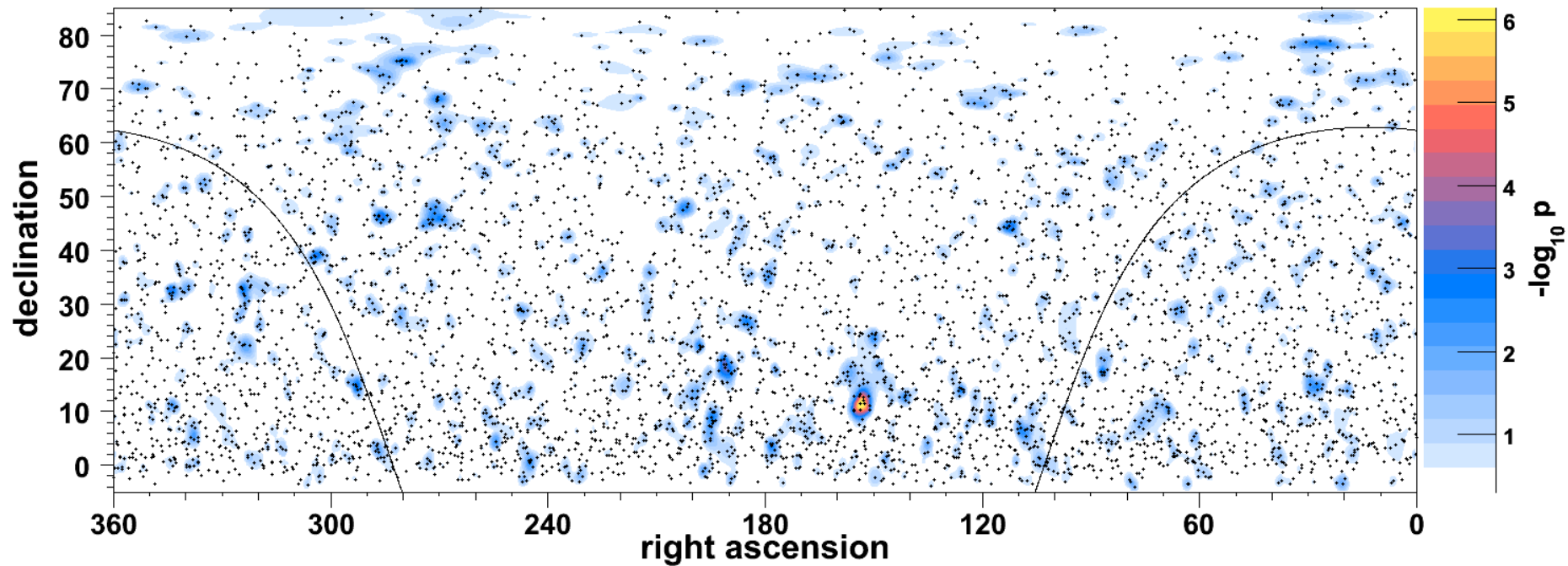
Adjusted for  
systematic errors

A paper on this analysis is being prepared.

# IceCube 22 string Sky Map

*preliminary*

275.7 live days



Location: Ra:  $153.375^\circ$  , Dec:  $11.375^\circ$

Estimated # of source events = 7.7

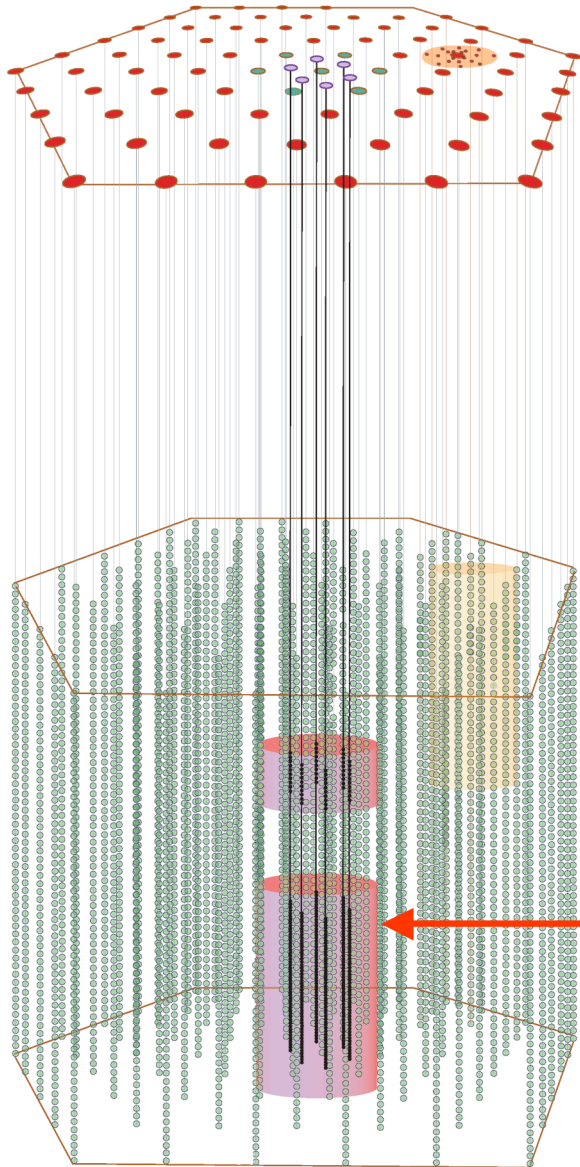
Estimated pre-trial significance (p-value):  $-\log_{10}(p)$ : **6.13995**

**Post-trials of p-value:  $\sim 1.34\%$**



# Future: Deep Core

To improve *low E event* efficiency

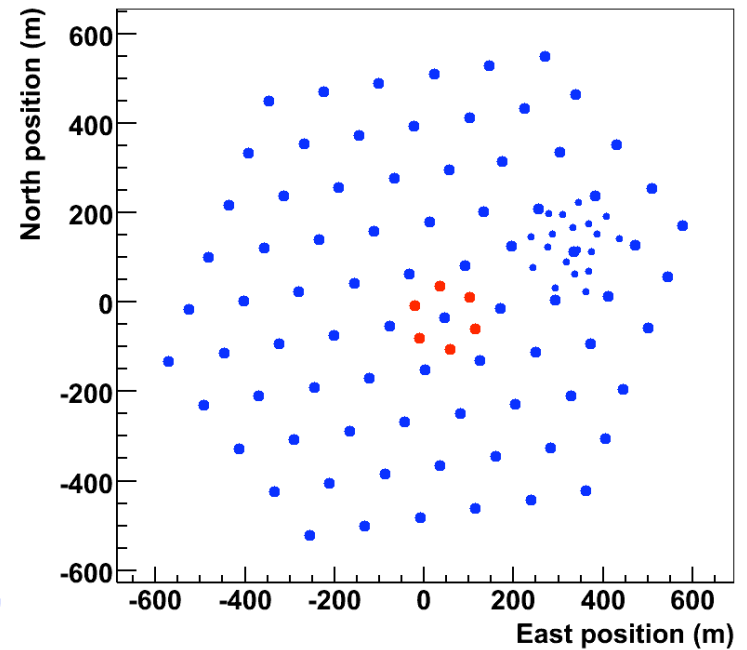


side view

Deep core

Swedish idea,  
~60% cost  
from Sweden

String locations with Deep Core



top view

# IceCube Deep Core Geometry

- **total 6 strings (75 m apart)**

  - surrounding central IceCube string
  - cf. nominal strings: **125 m** apart

- **60 DOMs/string**

  - **high QE DOMs** (~ **35%** more light yield)

  - 50 DOMs below dust layer w/ 7.5 m spacing

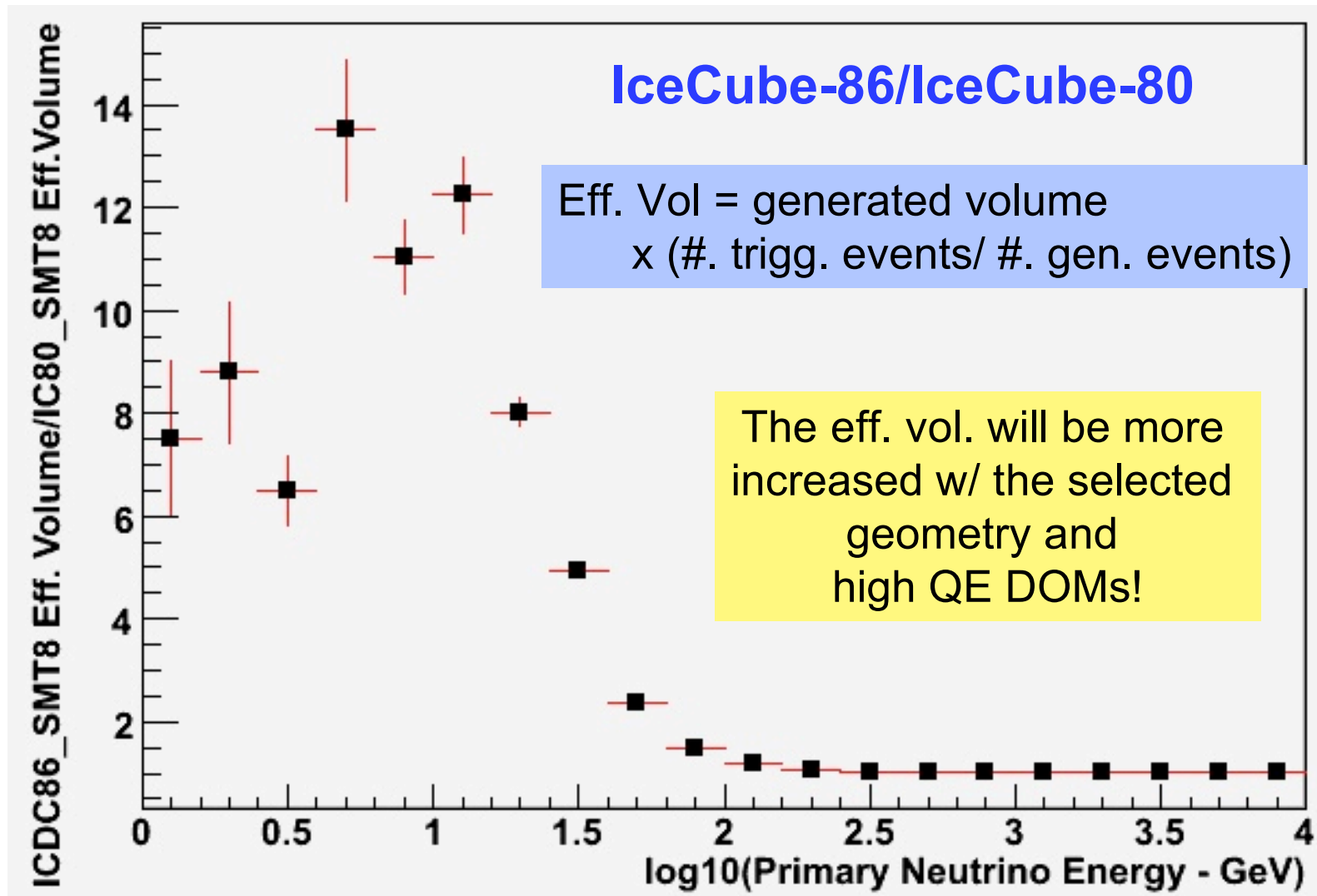
  - 10 DOMs above dust layer w/ 10 m spacing:  
serve as veto

- **4  $\pi$  detector:**

  - explore southern sky as well as Galactic Center  
(outer Icecube strings as veto for atm. muons)

- improvements in **low E event** efficiency

# Effective Volume Comparison

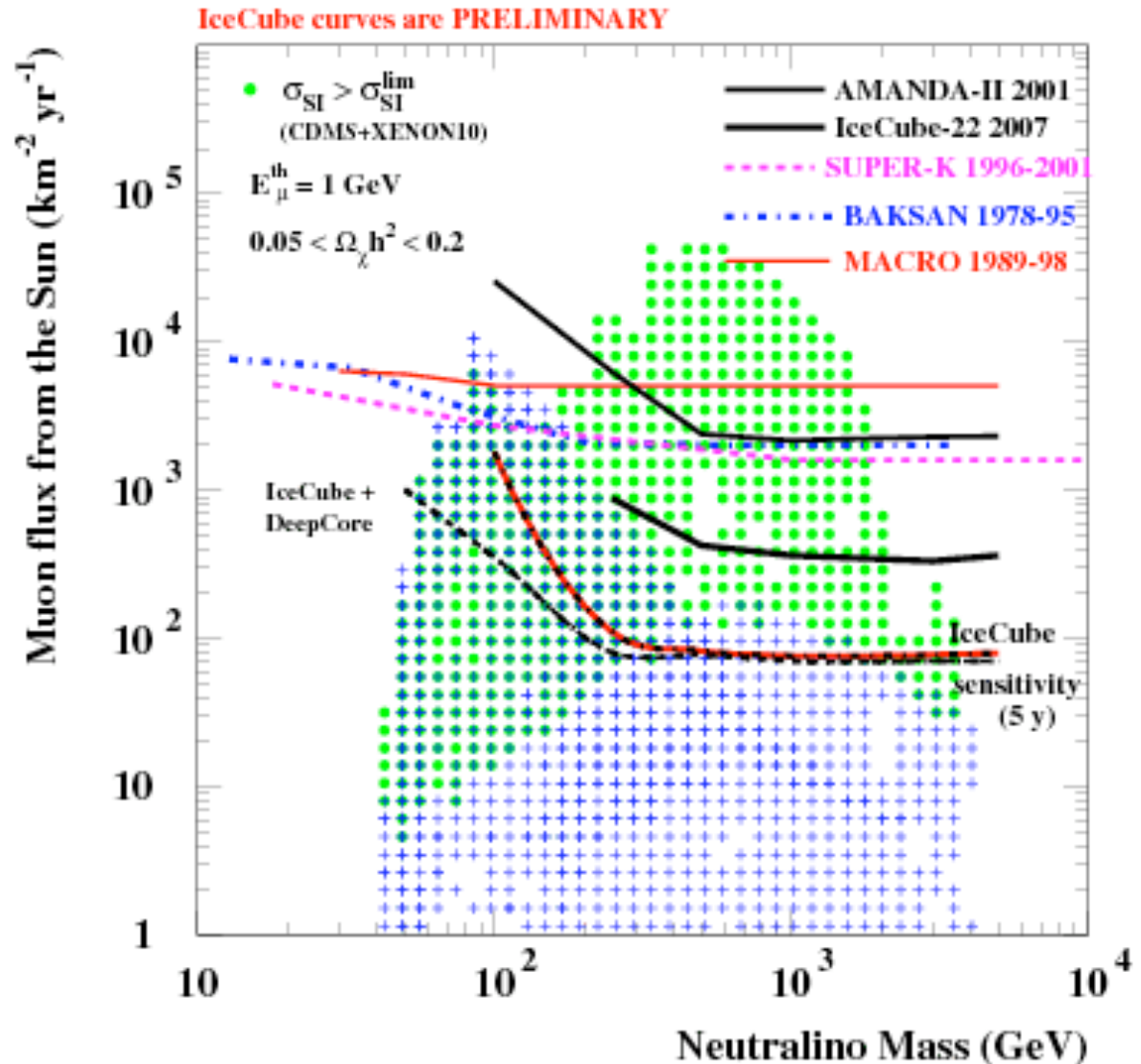


# Solar WIMP Sensitivity

Note: deep core geom.  
in the plot:

6 extra strings with **40 standard DOMs** below dust layer  
(**10 m** spacing).

The sensitivity will be better w/ the selected geometry and high QE DOMs!



# Summary

- IceCube is already the largest neutrino telescope in the world. It's still under construction at the S.Pole while continuously taking data.
- Stockholm and Uppsala IceCube groups play a critical role in analysis, software-development/management, and hardware supplies and tests in IceCube.
- Preliminary result on solar WIMP search w/ 22 strings was obtained giving the best limit in indirect search ( $\nu$  channel).
- HE  $\nu_\tau$  analysis is ongoing and EHE analysis will start soon.
- The deep core will improve low E physics in IceCube.



Swedish ice breaker



LC-130 Hercules landing at S Pole



**Thank you!**



IceCube Counting House



Myself

01.31.2006

# *Backup Slides*

# IC-22 Solar WIMP Data & Simulation

## ▪ Experimental data:

- IceCube **22** strings
- **104.3 live days** (June 1st - Sept. 23rd, 2007; Sun below horizon)

## ▪ Signal MC:

- WimpSim software (uses DarkSUSY and Pythia) by Edsjo *et al.*
- 3 flavor neutrino oscillations considered
- hard ( $W^+W^-$ ) & soft ( $bb$ ) channels
- 250 GeV (hard), 500 GeV, 1TeV, 3TeV, and 5 TeV for each channel

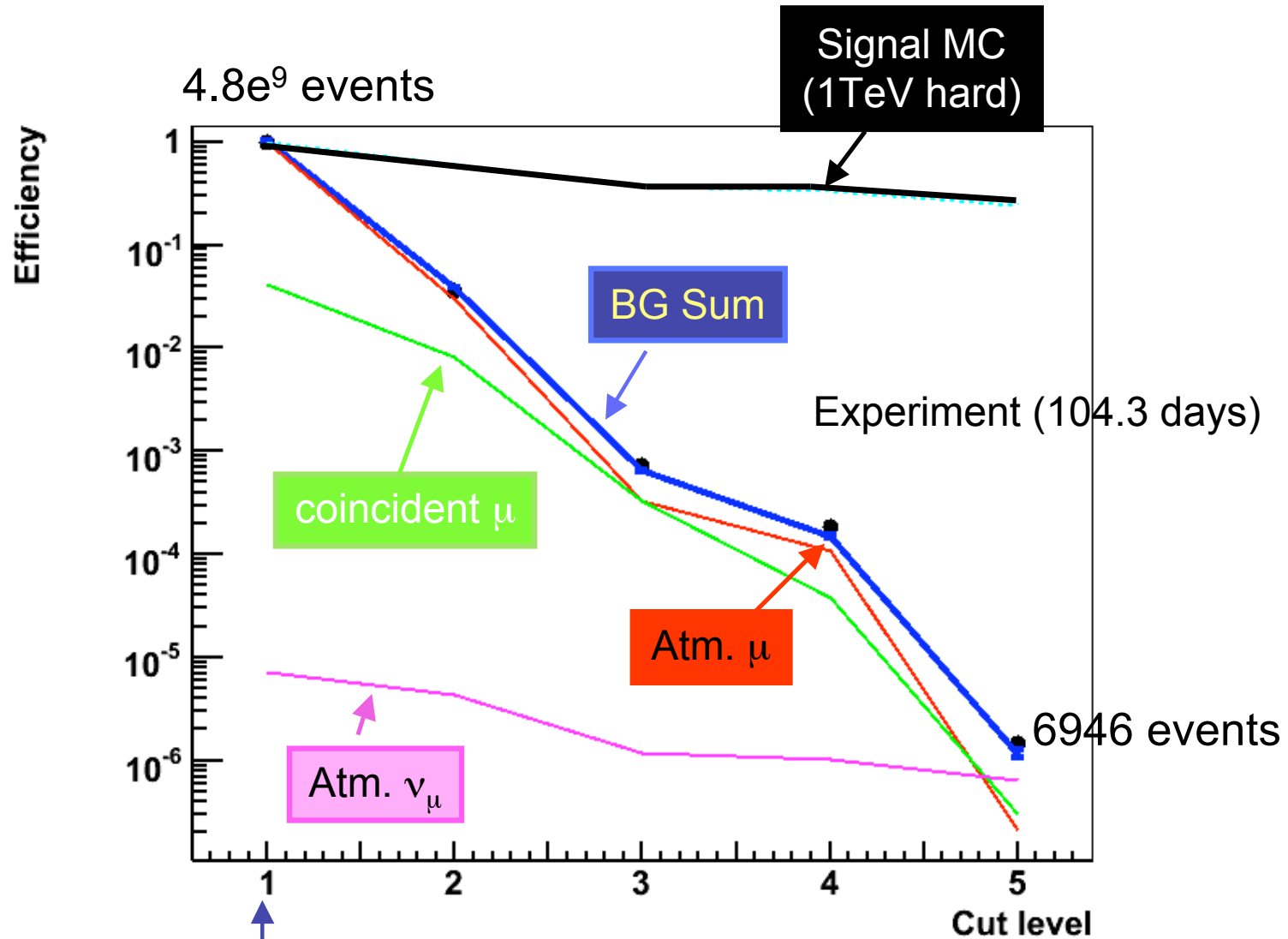
## ▪ BG MC:

- atmospheric  $\nu_\mu$  : neutrino generator
- atmospheric  $\mu$  : CORSIKA
- coincident  $\mu$  : CORSIKA



# IC-22 WIMP Cut Efficiency

preliminary



Trigger level

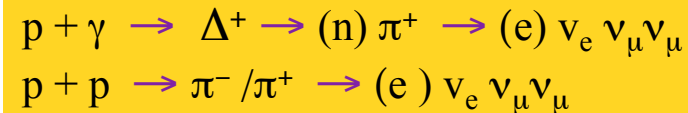
# Motivation for $\nu_\tau$

- Astrophysical  $\nu_\tau$  can be observed in Earth because of **neutrino oscillation** in cosmological scale.

(Note:  $\nu, \bar{\nu}$  are treated the same.)

$$\nu_e : \nu_\mu : \nu_\tau = 1 : 2 : 0$$

at source



**oscillation**

(maximal  $\nu_\mu \leftrightarrow \nu_\tau$  mixing)

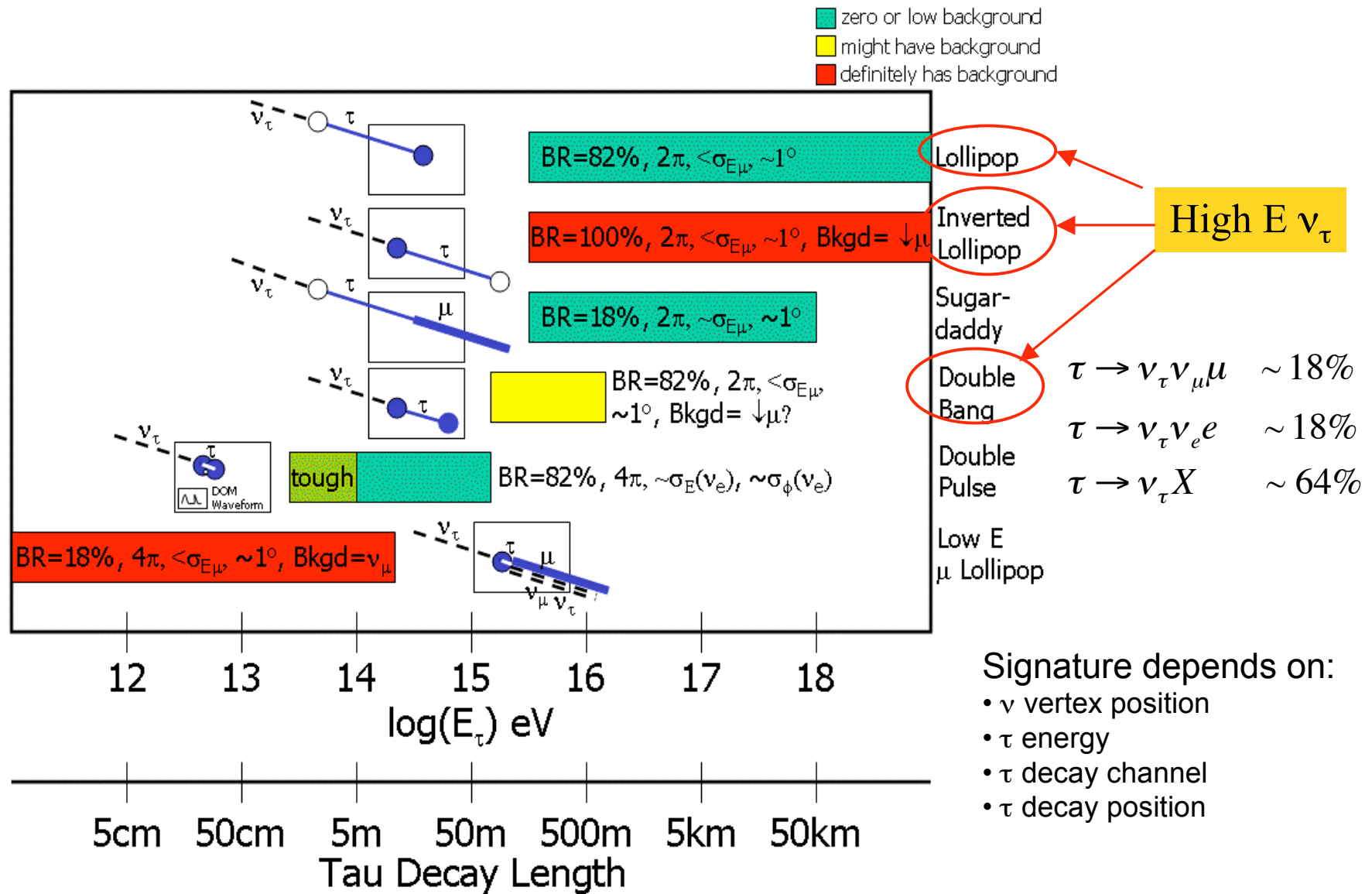
at earth

$$\nu_e : \nu_\mu : \nu_\tau = 1 : 1 : 1$$

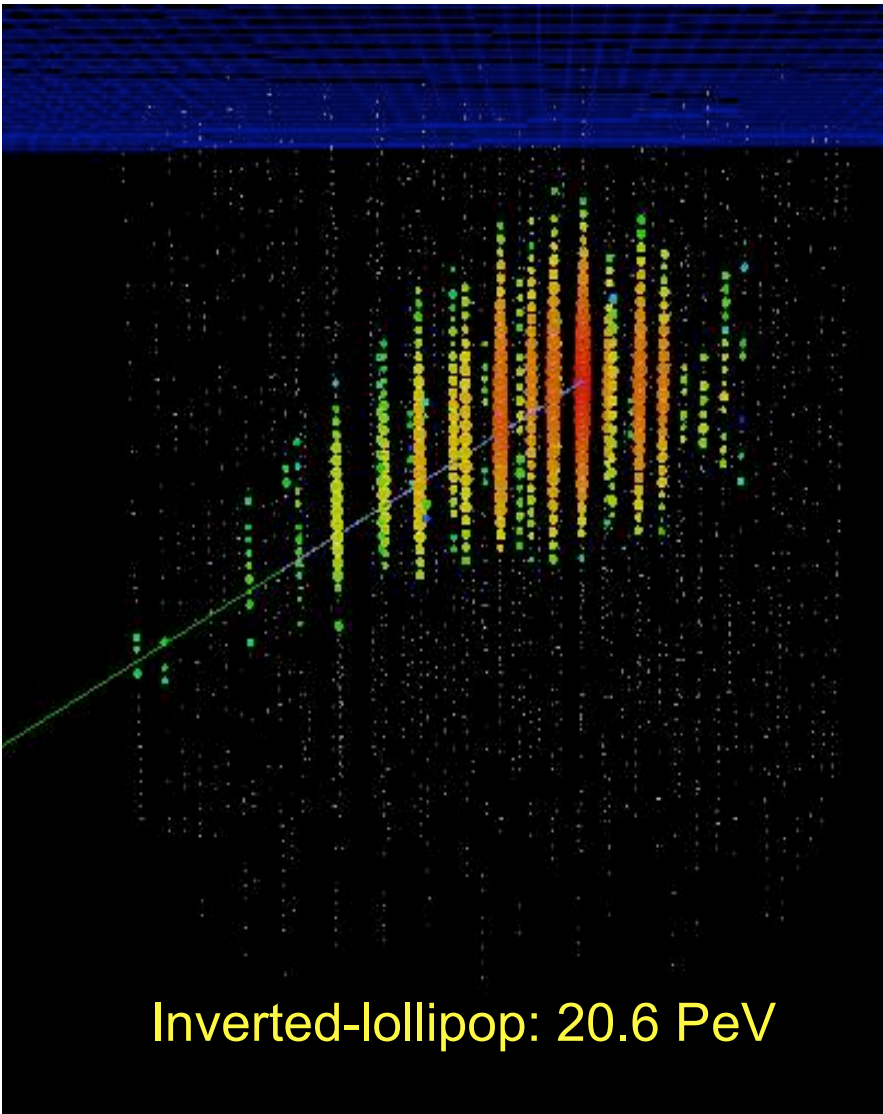
(Note: all other non standard physics predict  $\nu_\tau$  observation but w/ different flavor ratios.)

- IceCube has a capability to **detect all flavors of neutrinos** due to its large size ( $\sim 1 \text{ km}^3$  scale).
- almost background free
- distinctive signatures

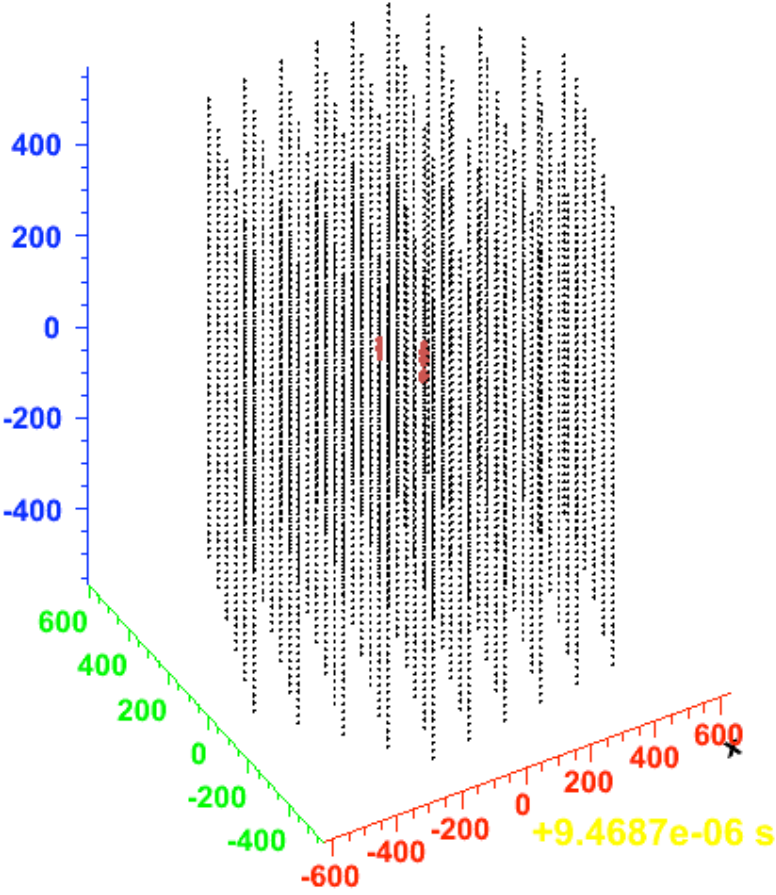
# $\nu_\tau$ Signatures



# “Simulated” $\nu_\tau$ Event View



Double bang: 2.6 PeV



# IceCube Publications (refereed)

## 2008

-- 3 papers

on Solar flare w/ IceTop, UHE  $\nu$  w/ AMANDA II, GRB  $\nu$  w/ AMANDA  
in *Astrophysical Journal Lett.*, *Astrophysical Journal*

## 2007

-- 5 papers

on Photonics, Diffuse  $\nu_\mu$  search w/ AMANDA II, GRB  $\nu$ ,  
atm.  $\nu$ , astrophysical point source w/ AMANDA II  
in *NIMA*, *PRD*, *Astrophysical Journal*

**2006** -- 4 papers

**2004** -- 1 paper

<http://www.physto.se/~walck/amanda/amanda-pub.html>