Input from IceCube

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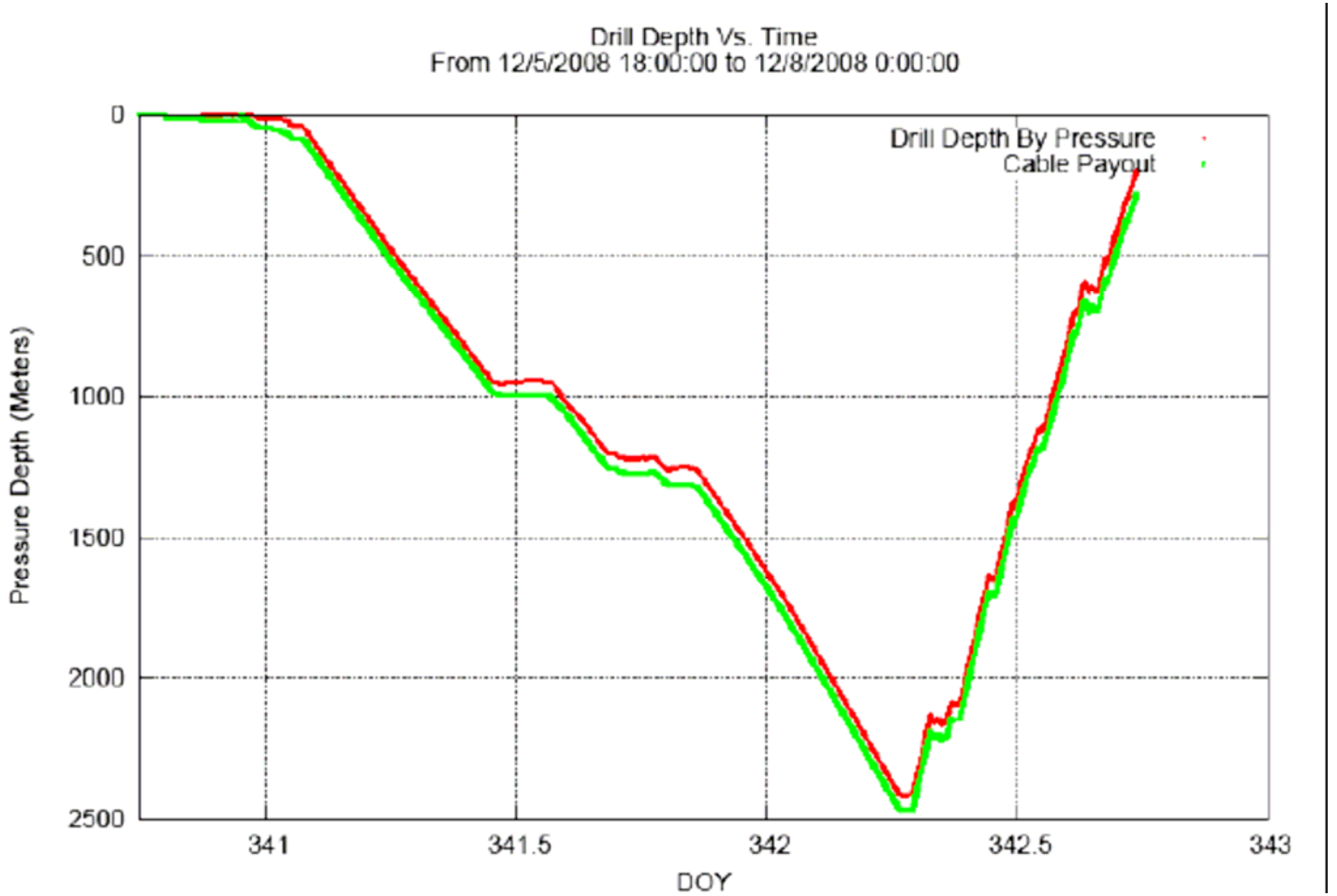
Uppsala University

two strings deployed as of Dec 8th, 6.57am NZT

IceCube consists now of 42 strings

aim of the season, to reach 56

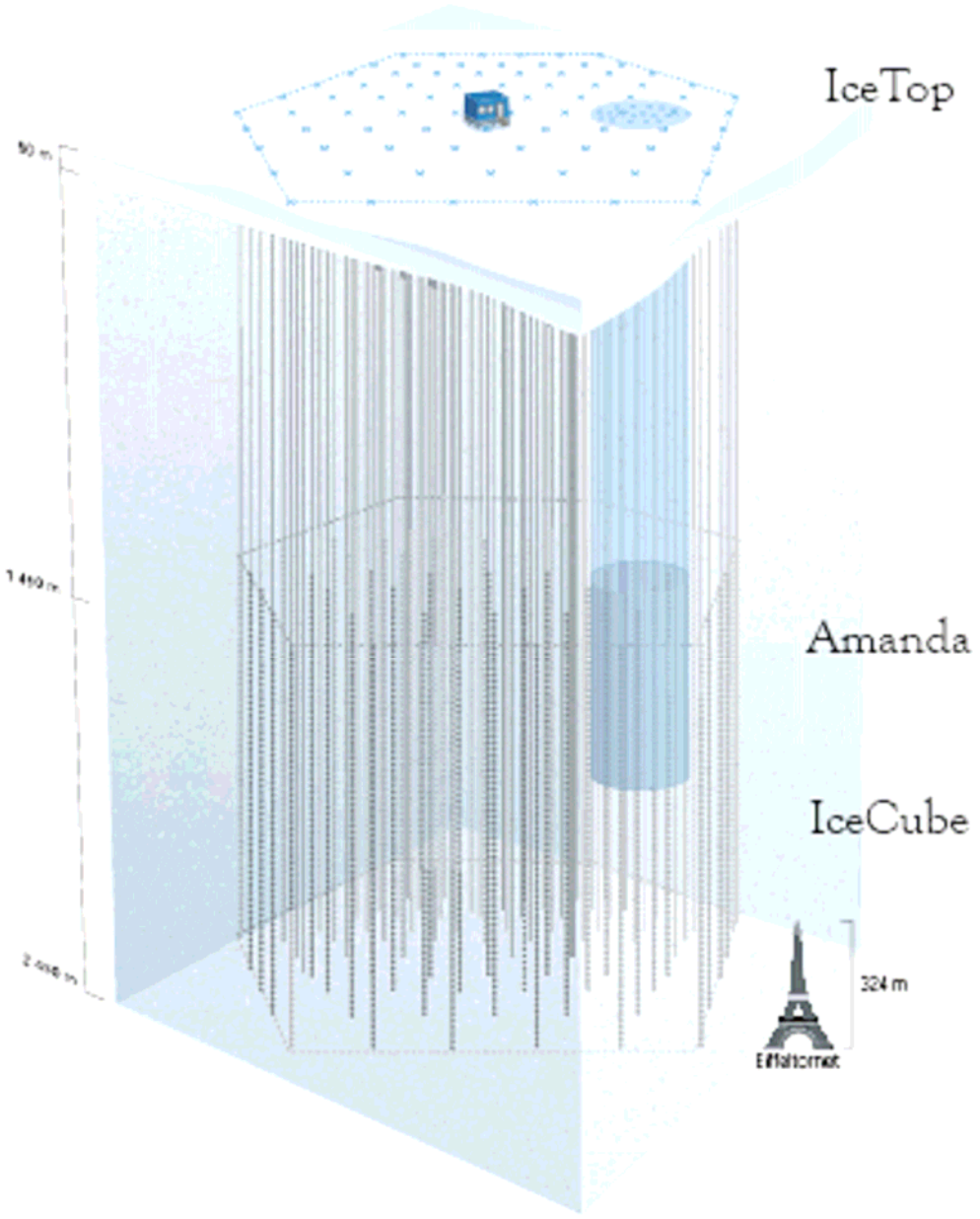

Drill Depth Vs. Time
From 12/5/2008 18:00:00 to 12/8/2008 0:00:00
Drill Depth By Pressure
Cable Payout
Pressure Depth (Meters)
0
500
1000
1500
2000
2500
341
341.5
342
342.5
343
DOY

IceCube: brief status

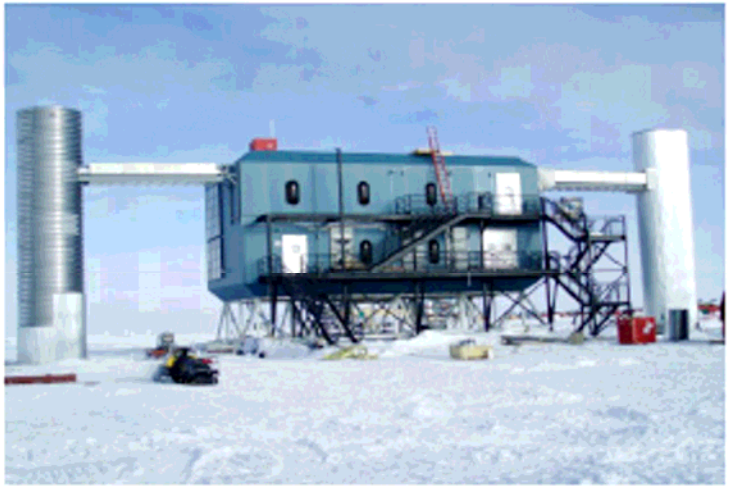
80 strings in triangular grid.

125 m inter string separation

17 m OM separation



IceCube data taking scheme

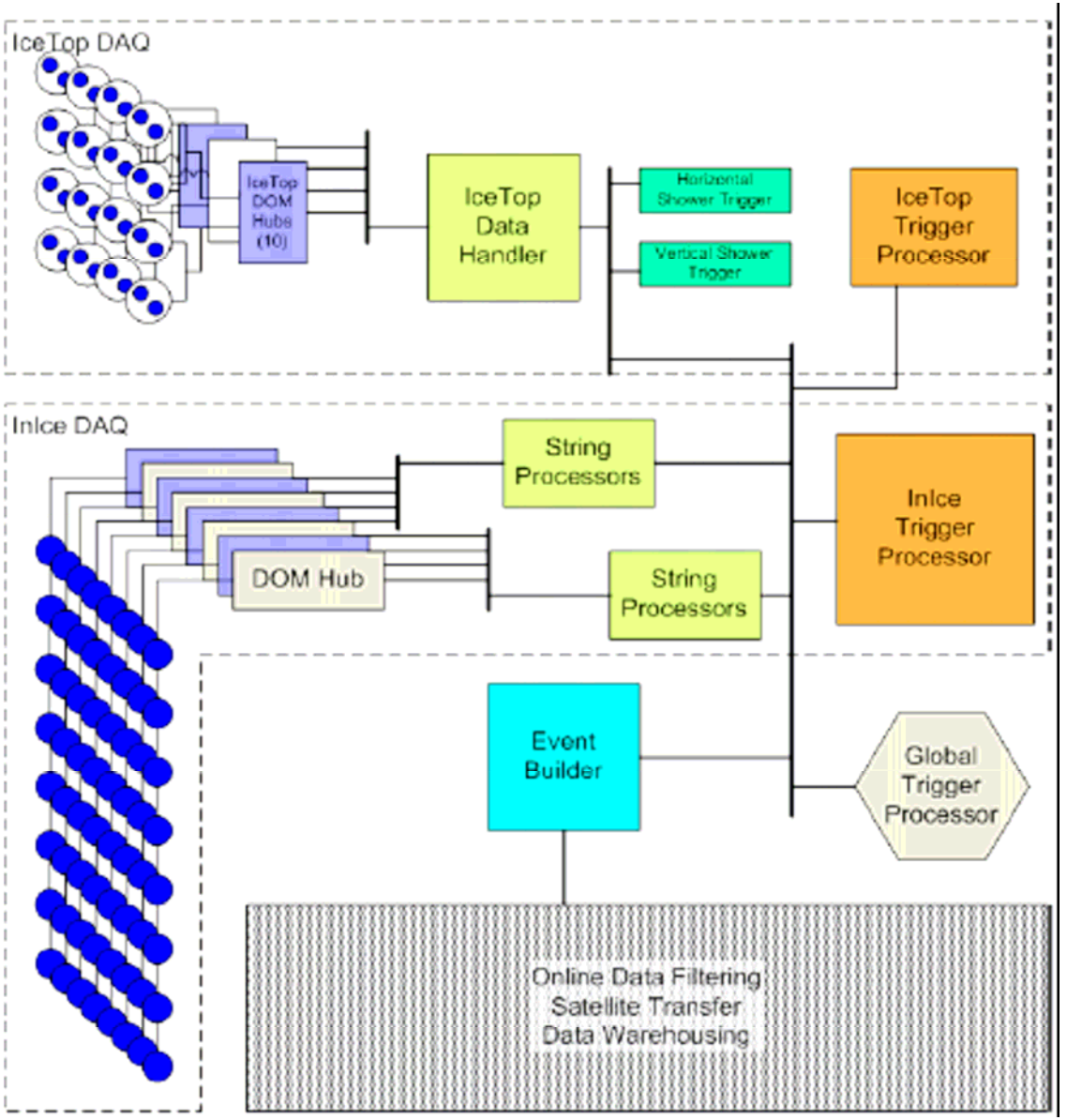


2 NN or N2N neighbours fire within 1 usec

Local coincidence communication between DOMs in ice

Triggering on surface (simple majority, etc.)

Physics filtering on data sent to the North via sattelite



IceCube trigger scheme

- Local Coincidence
  - Data currently saved if 2 nearest or next-to-nearest neighbors on a string fire within 1 μs
  - Will soon save partial information for isolated hits
- Multiplicity Trigger – 8 DOMs within 5 μs
- Single String Trigger added 2008
  - 5 of 7 adjacent DOMs within 1.5 μs
  - More sensitive for low energy ν
- Topological Trigger for low energy horizontal muons is under study

IceCube data handling scheme

Non-CPU time consuming, simple data filter (15 streams) run on-line at Pole.

30 dual core 8GB memory processors at Pole

~50 GB/day transferred north by satellite

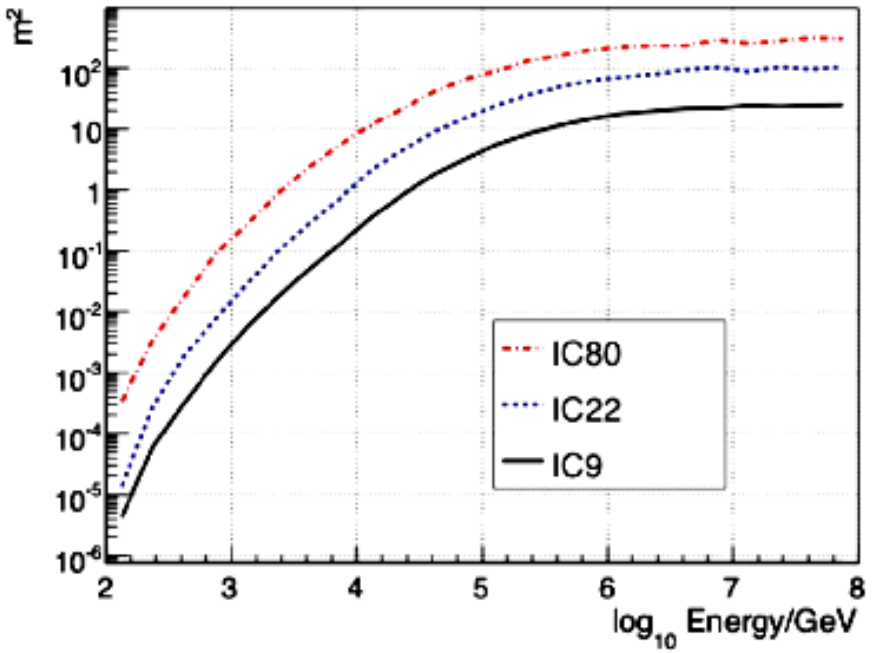
Whole data sample in tapes ($\mathcal{O}$100TB) sent north at the end of the year

Common filter run centrally on whole data sample with filters proposed by each working group (level 2)

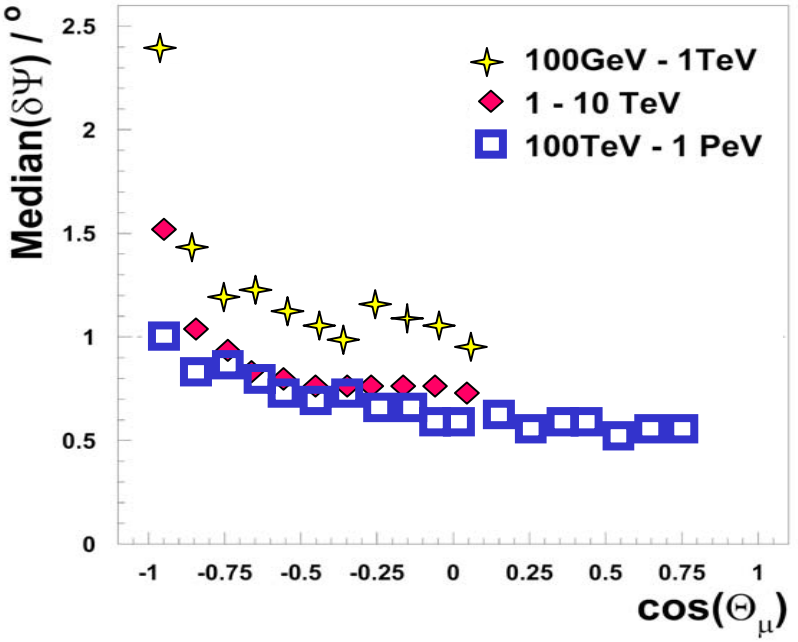
Further filters done by individual analyses

Strings	Year	Livetime	μ rate	ν rate
IC9	2006	137 days	80 Hz	1.7 / day
IC22	2007	275 days	550 Hz	28 / day
IC40*	2008	~365 days	1000 Hz	110 / day
IC80*	2011	~365 days	1650 Hz	220 / day

* Predicted



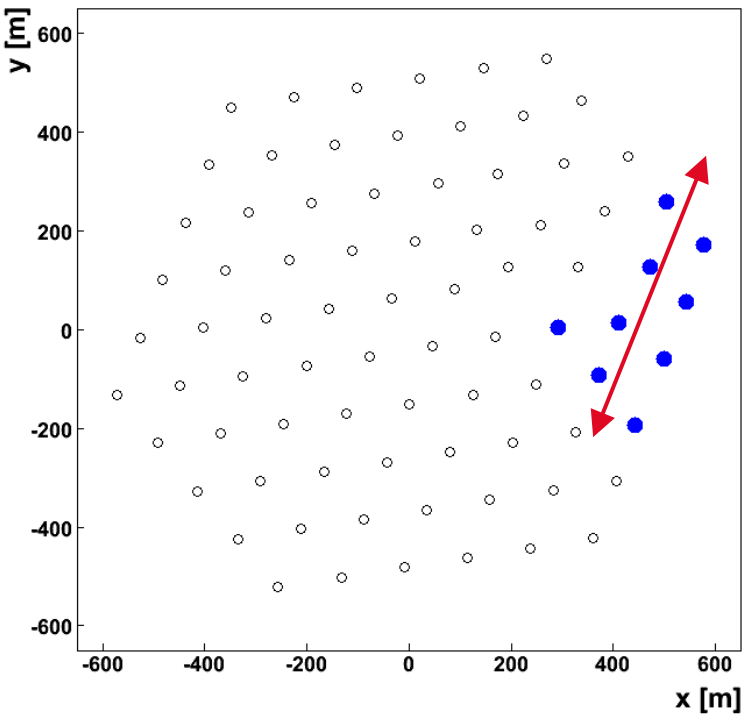
IceCube effective area vs. energy



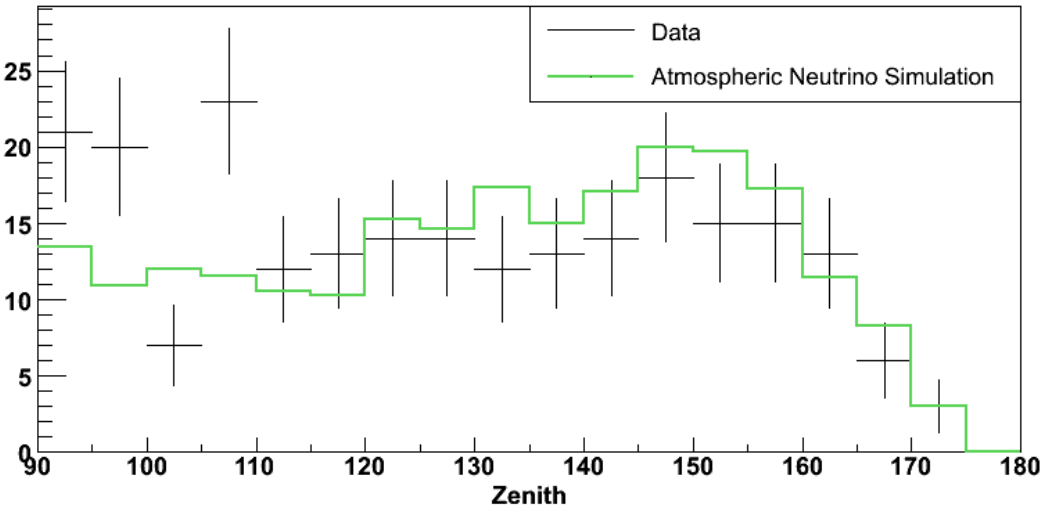
IC-80 angular resolution vs zenith angle

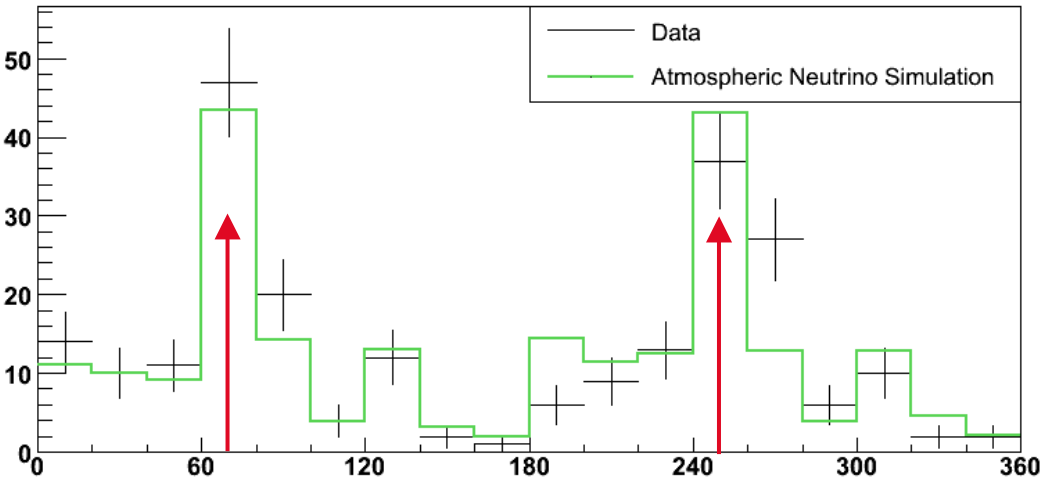
- Mis-reconstructed background predominantly near horizon

- **2006: nine-string detector configuration**



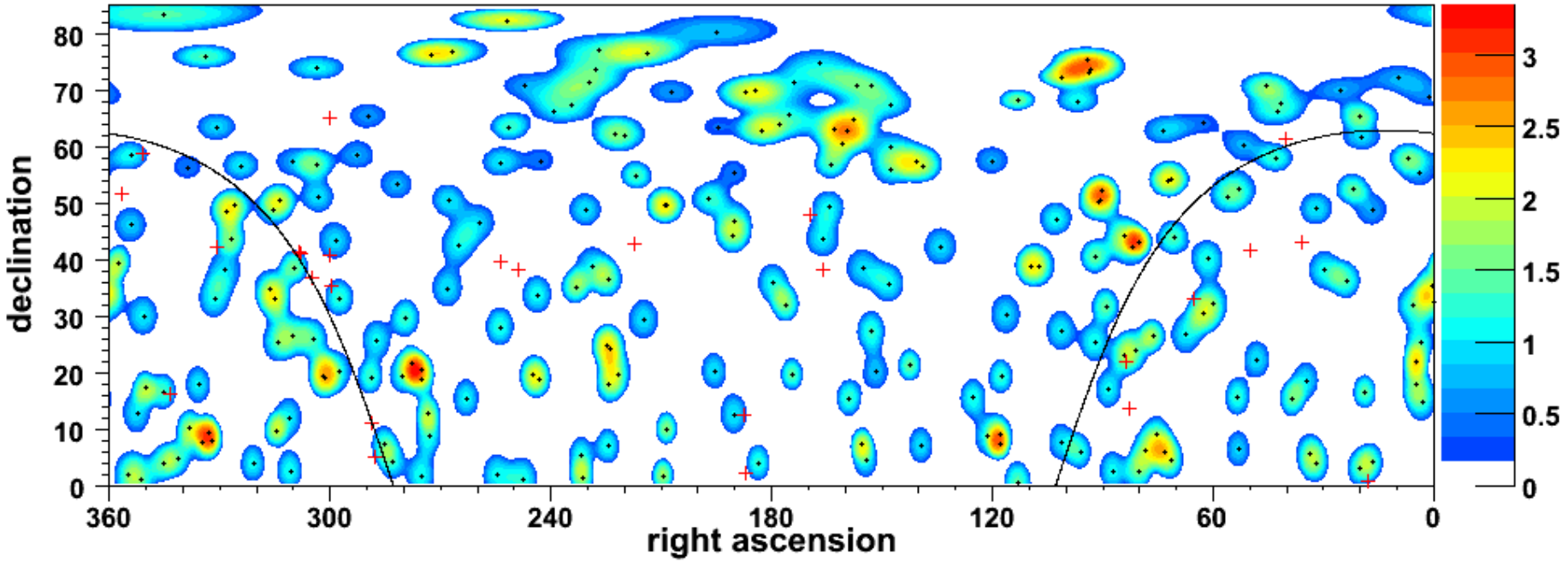
Zenith





Azimuth

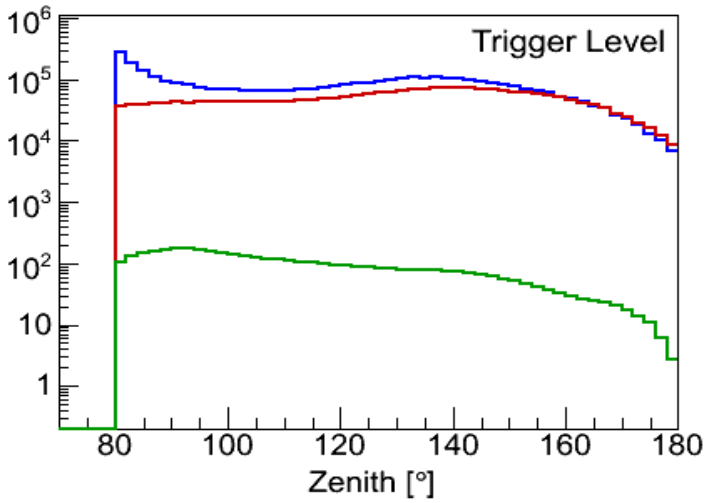
IceCube-9 skymap

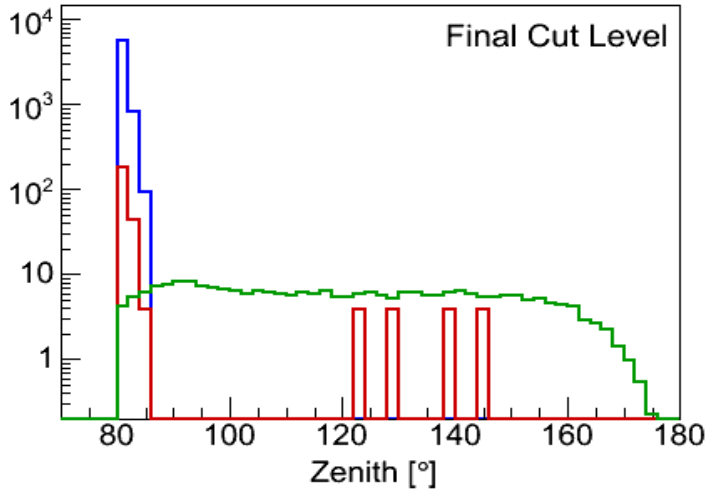


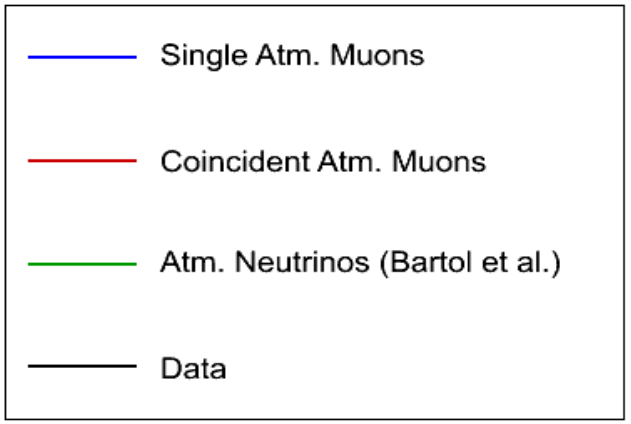
IC-9 found 233 ν in 137 d

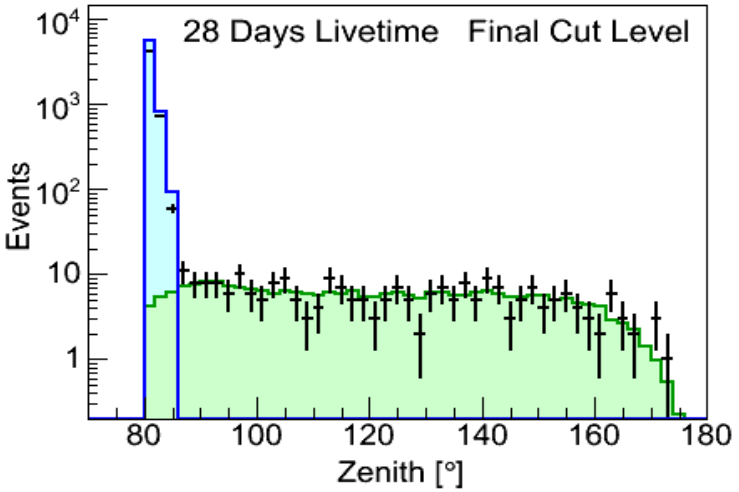
- Rate ~ for atmospheric ν
- No Sources Seen
  - All-sky search
  - 26 source list

- **Left**: Without cuts, data sample is dominated by down-going events that are mis-reconstructed as up-going. **Right:** With hard cuts on track quality (harder than final IC-22 point source cuts), almost no mis-reconstructed down-going events remain.





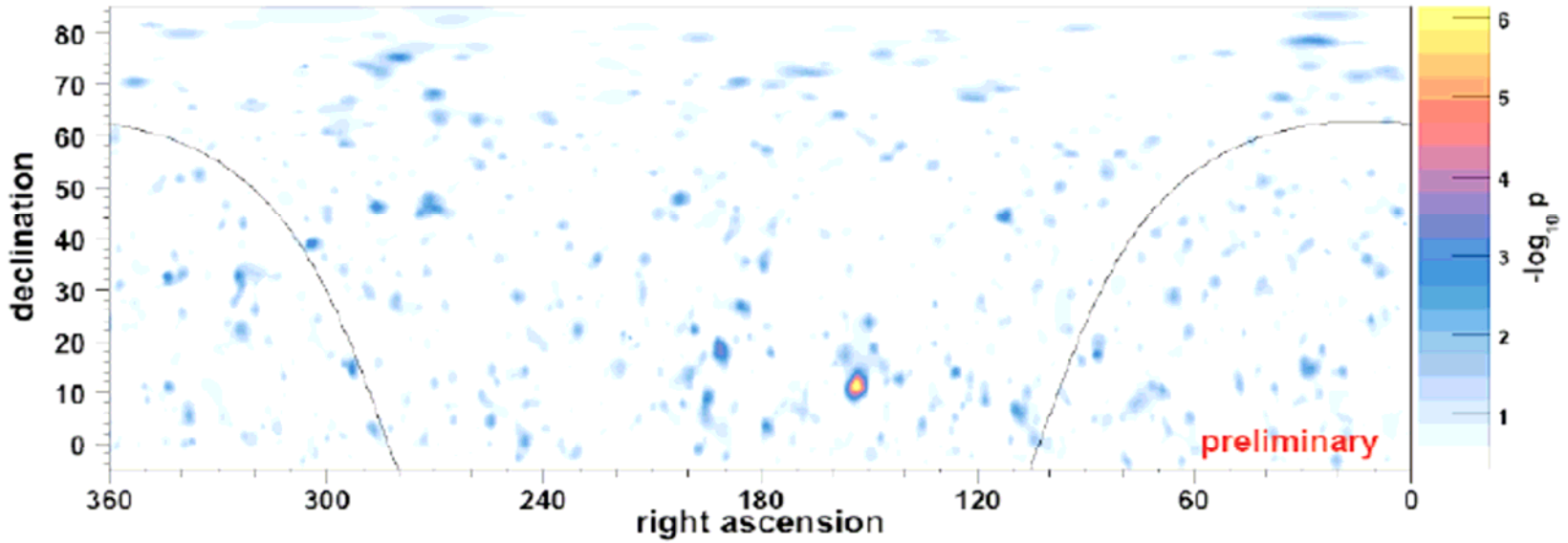




skymap IceCube-22

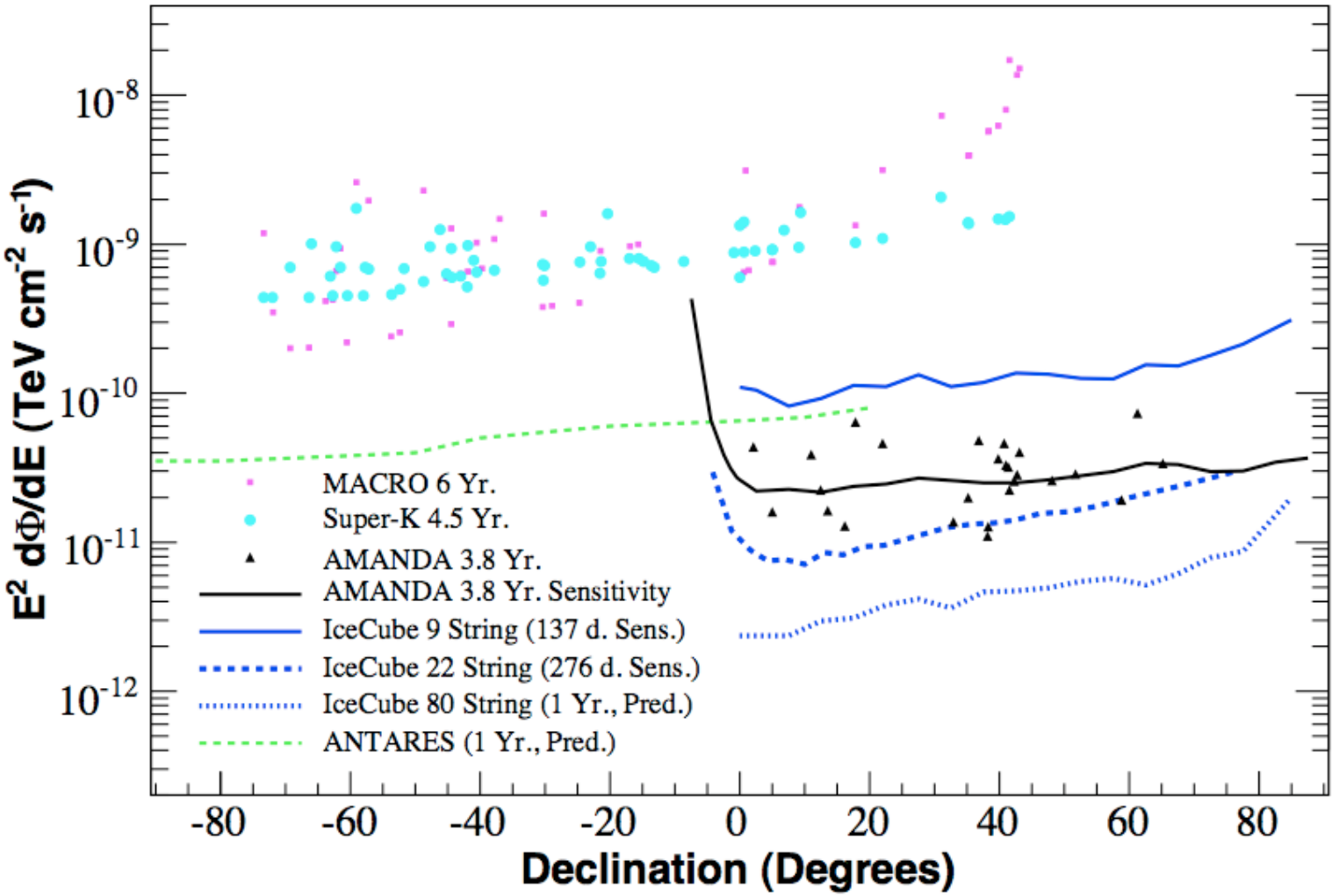
22 strings for 250 days
- ~ 20 ν_μ/ day

1.5 degree resolution
~ 5* as sensitive as IC-9 (for E^{-2} spectrum)



- **Newest IceCube point source analysis**
- **Largest excess: pre-trial significance is 4.8σ**
- **After accounting for all trials, significance is 2.2σ**
- **This is consistent with background fluctuation**

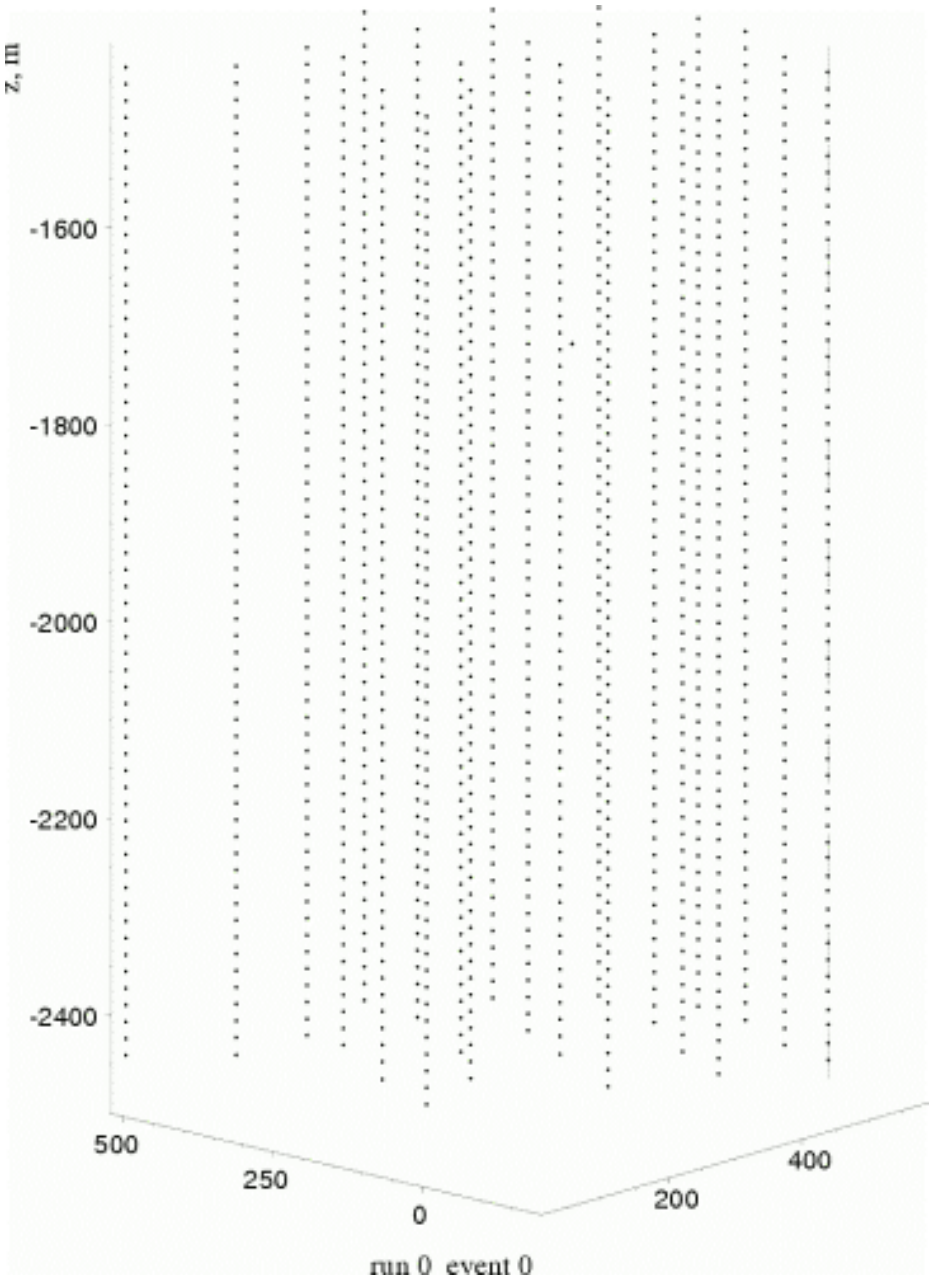
sensitivity comparison



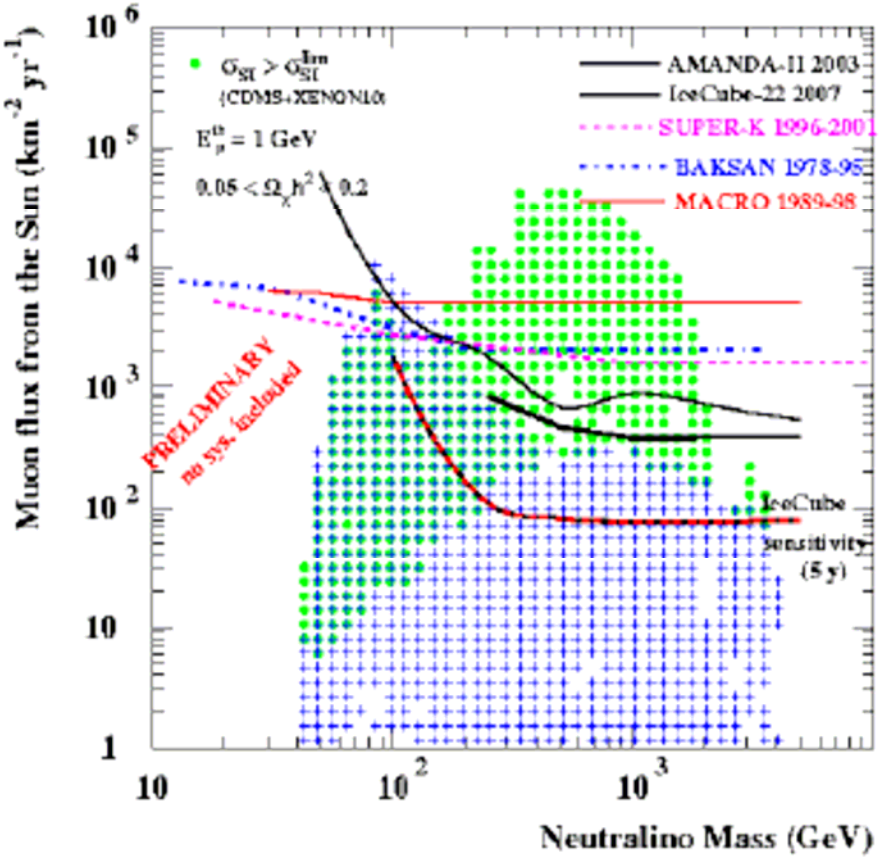
up-going event

Number of hit modules: 148

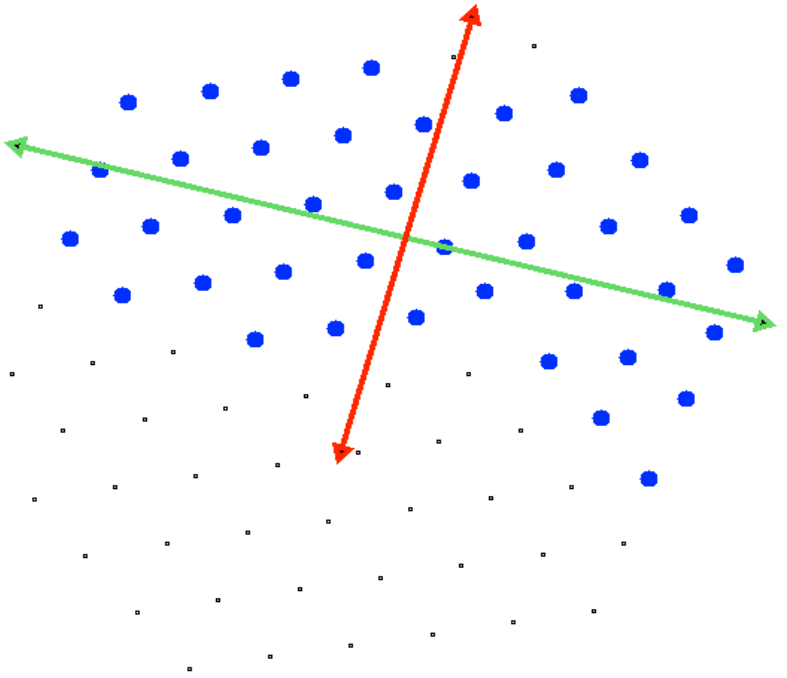
est. angular error: 0.84°



- Today: IC22 Results from Sun
- Sun is below horizon
  - June 1- Sept. 23
- Model WIMPs
  - Mass (100 GeV to 5 TeV)
  - Hard or soft ν spectrum
- Select upgoing μ
- Count events w/in ~ 3^0 of sun
  - Exact cut is WIMP mass dependent



IceCube currently running with 40 strings deployed.

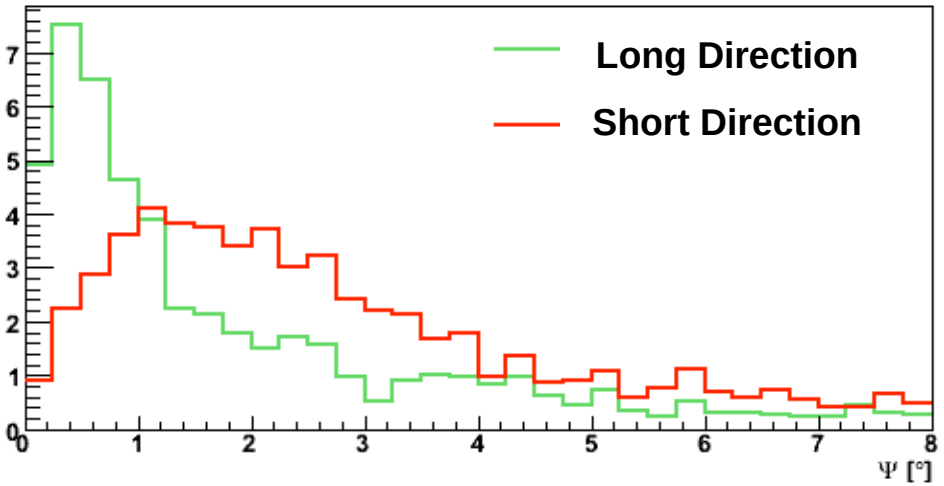


~ 2x effective area of 22 strings.

More fully contained strings.

Short direction: angular resolution comparable to IceCube 22.

Long direction: angular resolution comparable to full IceCube 80 configuration.



Preliminary Point Spread Function for IceCube-40

some history and IceCube organization

IceCube studied geometries

Main idea:

to cover 1 km^2,

be within budget (ie, # of strings/DOMs was pretty fixed from the begining),

fall in phase with US funding calendar and deployment restrictions (ie, we were in a hurry: IceCube deployment seasons are quantized)

Strategy for decision: For each geometry evaluate:

- what event rates from atms neutrinos and a E^{-2} spectrum can be detected?
- what pointing accuracy can be reached?
- what trigger rate is expected?
- what background rejection (atms μ) can be achieved? (with point 1 ➔ S/B)
- what gain/loss in data quality results by doubling/halving the number of DOMs?
- what is the effect of DOMs noise on passing rates?
- what energy resolution can be obtained?

what was simulated

signal: E^{-2} spectrum

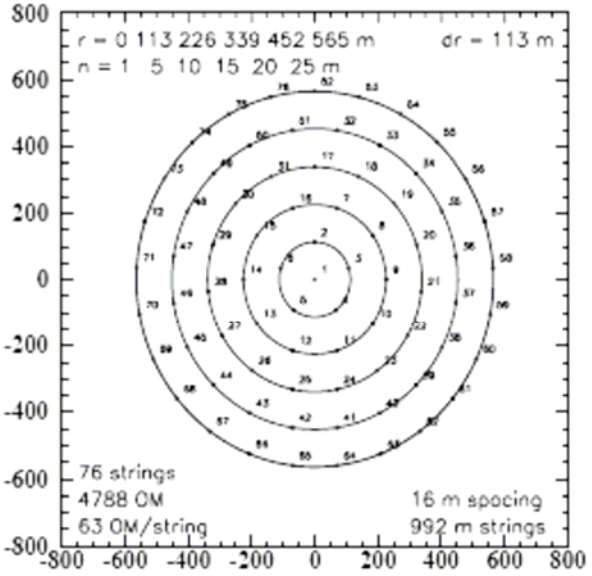
atmospheric neutrinos (you want them!)

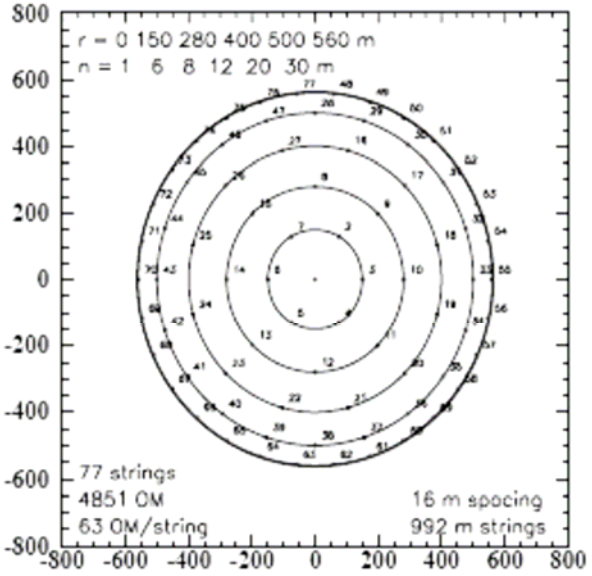
background: atmospheric muons, with double coincidences

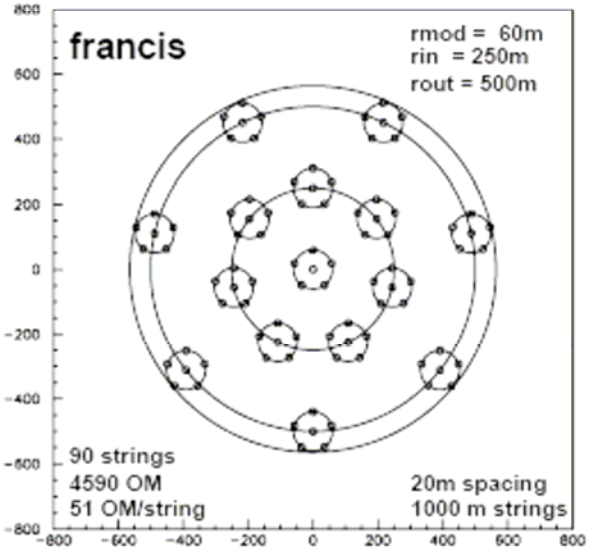
full detector simulation, with AMANDA software, mimicking IceCube running conditions (1999!)

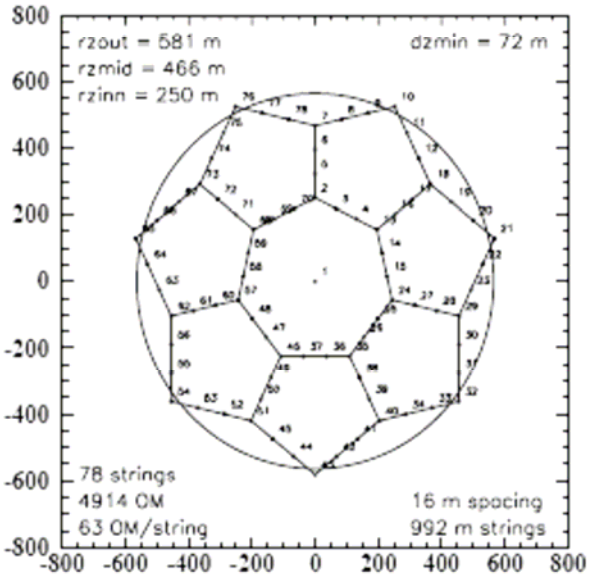
we had only one ‘software’ package (detector simulation+reconstruction), but well tested in AMANDA

reconstruction and a set of ‘reasonable’’ cuts to select events

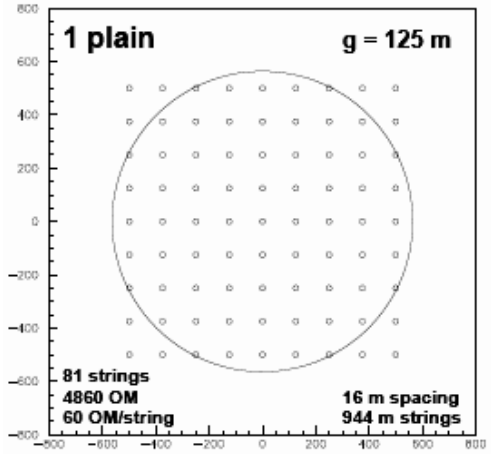

r = 0 113 226 339 452 565 m
dr = 113 m
n = 1 5 10 15 20 25 m
76 strings
4788 OM
63 OM/string
16 m spacing
992 m strings

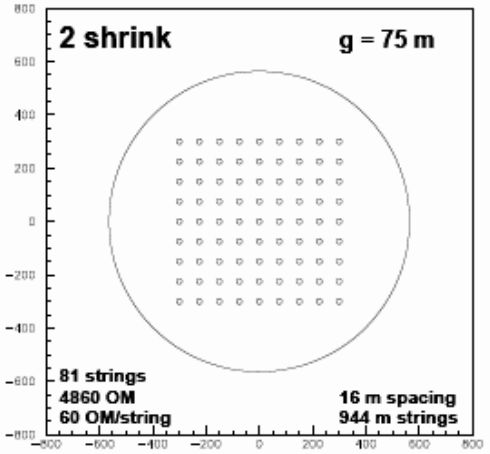

r = 0 150 280 400 500 560 m
n = 1 6 8 12 20 30 m
77 strings
4851 OM
63 OM/string
16 m spacing
992 m strings

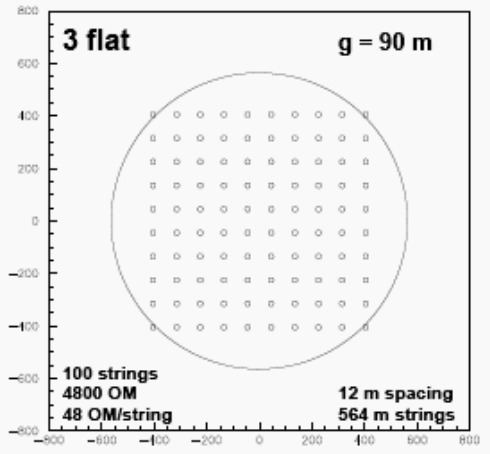

francis
rmod = 60m
rin = 250m
rout = 500m
90 strings
4590 OM
51 OM/string
20m spacing
1000 m strings

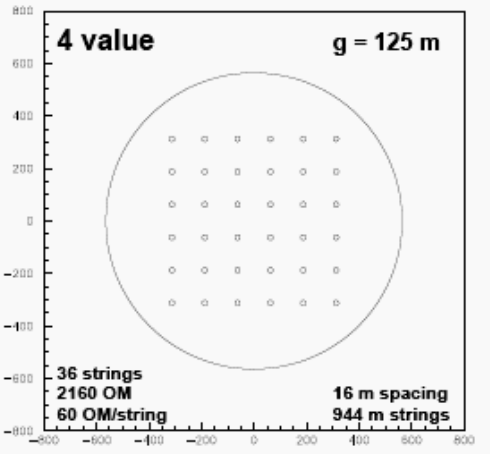

rzout = 581 m
dzmin = 72 m
rzmid = 466 m
rzinn = 250 m
78 strings
4914 OM
63 OM/string
16 m spacing
992 m strings

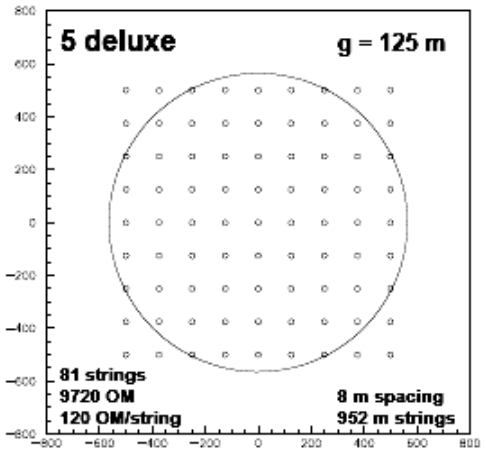
the final six candidates

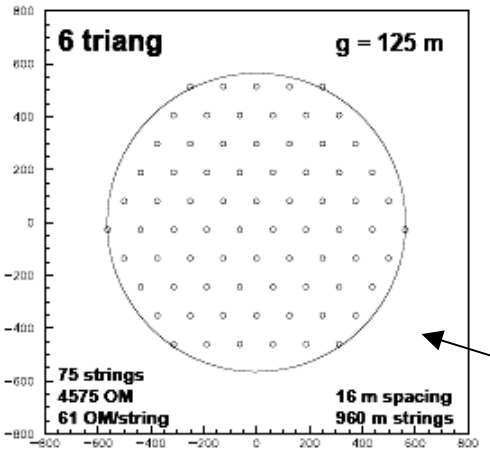








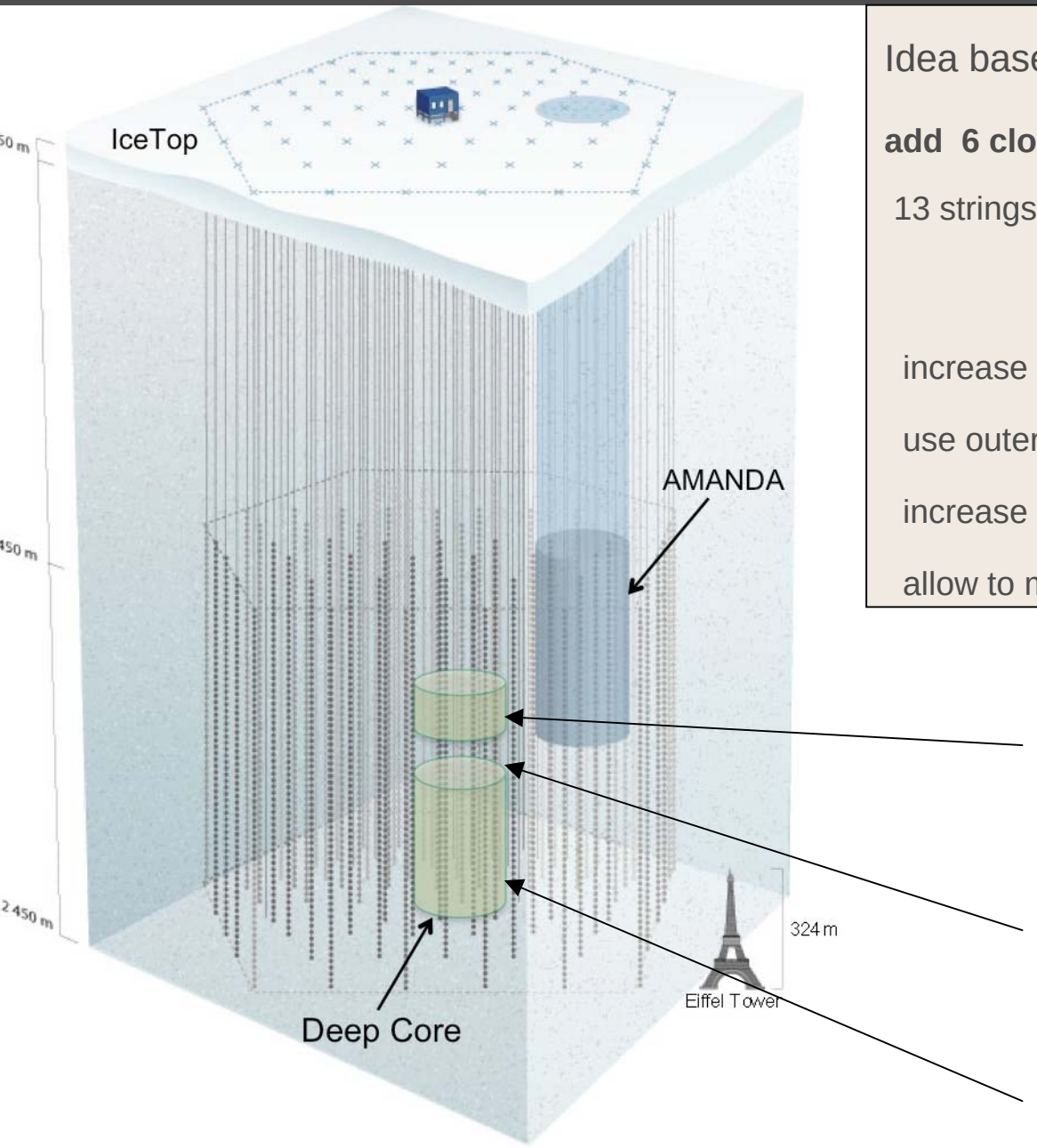




the winner

“the ratio of good events after cuts to triggered events shows that sharp corners should be avoided”

post scriptum I: DeepCore, IceCube low energy extension



Idea based on common IceCube/AMANDA running

add 6 closely packed strings in the middle of IceCube

13 strings form a denser core:

70m inter string separation (125m for IceCube)

7m/10m DOM vertical separation

increase sensitivity to low energy events (E⩽ ~100 GeV)

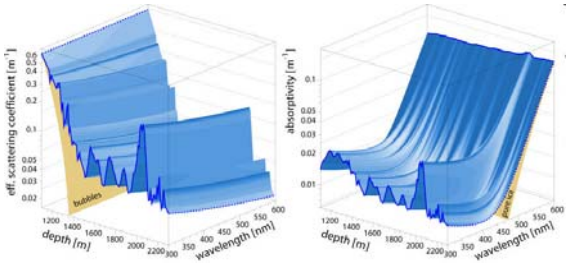
use outer strings as a veto → contained/starting events

increase rejection of atmospheric muons

allow to monitor the Galactic center and the Sun continuously

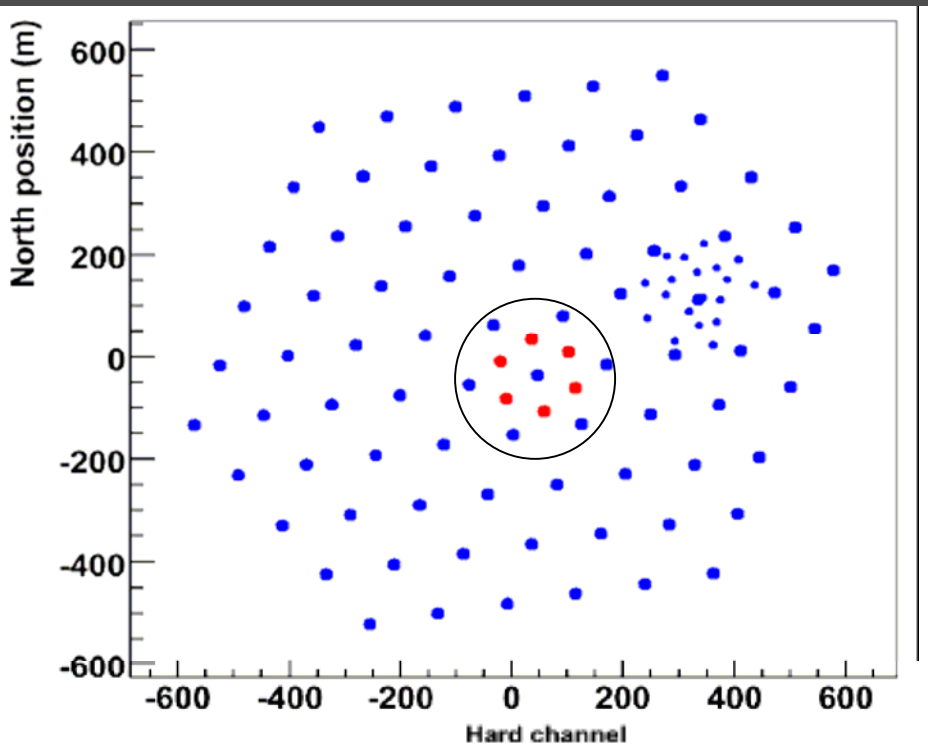
10 DOMs 10m spacing

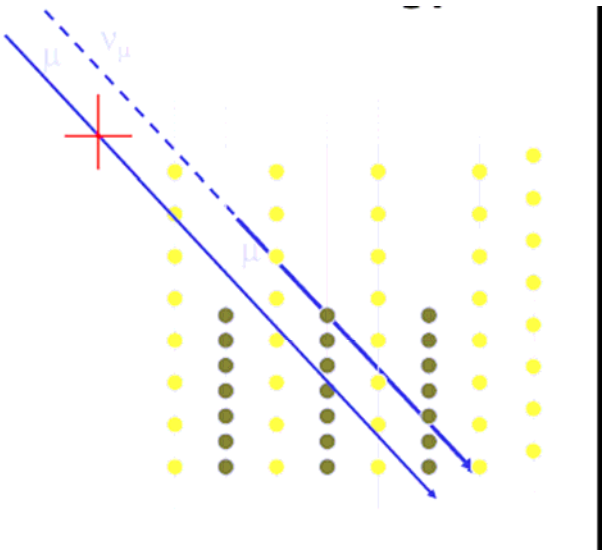
dust layer

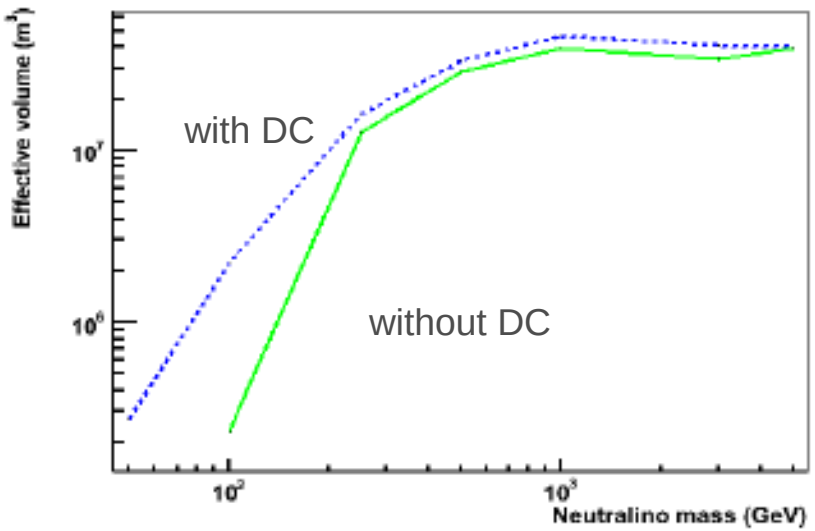


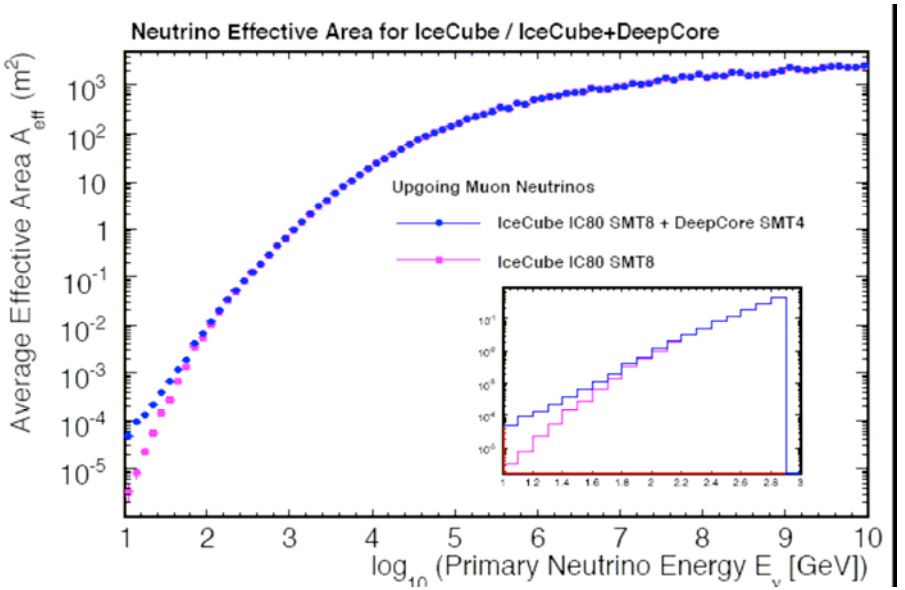
50 DOMs 7.0 m spacing

DeepCore capabilities at low energies









DeepCore status

Concept proposed in spring 2007

- several geometry simulations until deciding on the final one
- use new Hamamatsu 10'' HQ efficiency PMTs (x2 price, +25%-30% gain in QE)

Funded by Sweden (2.8 M$=60%), Belgium and Germany

In time to be integrated in the general IceCube deployment schedule

First DC string to be deployed this season (3 'normal' IceCube strings also, so we will have DC-4strings during 2009 running)

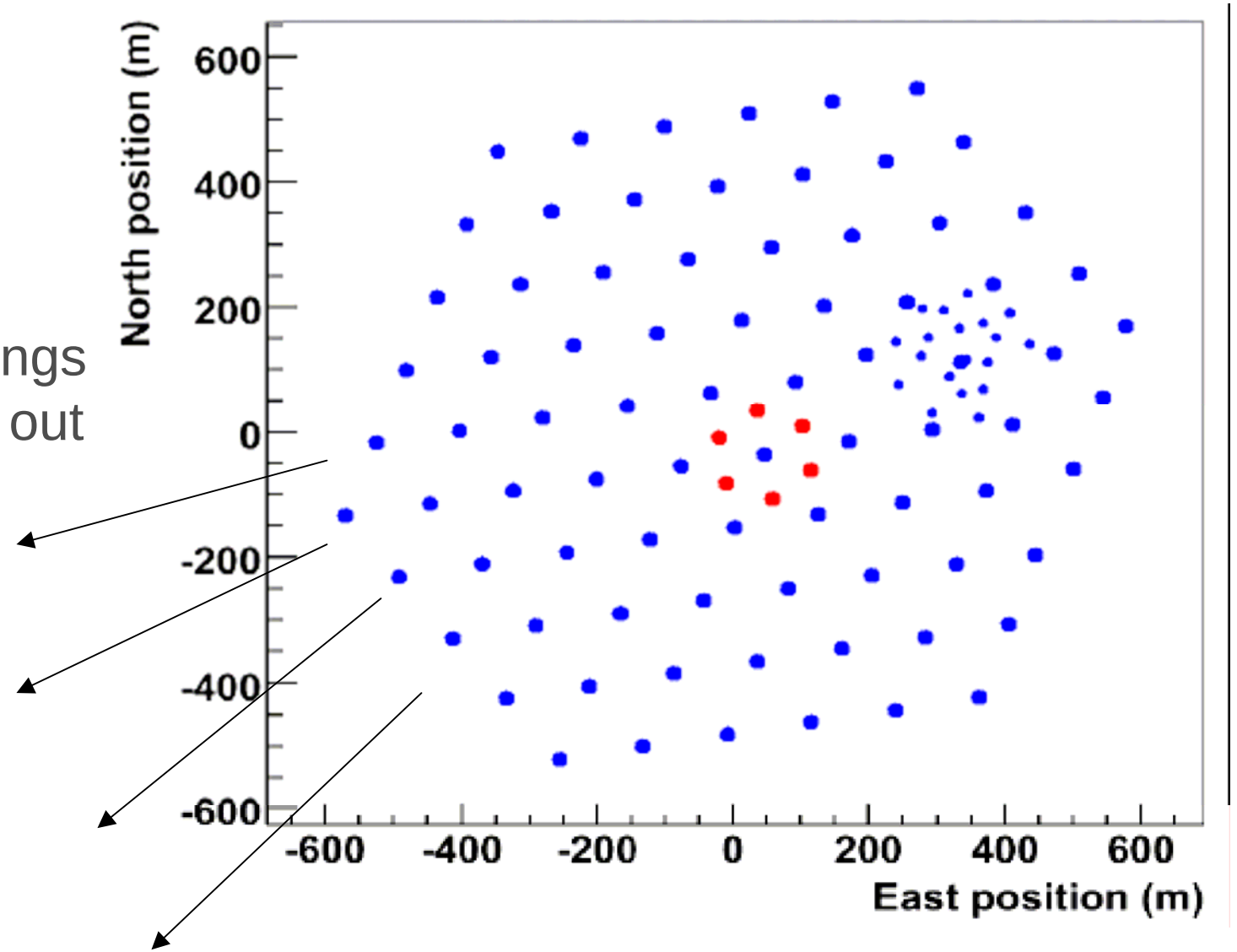
<u>DeepCore physics:</u>

low energy in general (low mass WIMPs, oscillations, low E side of atm nus...)

Observation of Sun and the GC year-around using contained/starting events

Post scriptum II: proposed IceCube high energy extension

move last strings
a few 100 m out



one can simulate and simulate and not find THE optimal geometry. But:

To avoid in a geometry:

- ‘corridors’ if part of the detector is intended to be used as a veto
- regular grid to avoid reconstruction ‘pull’ towards string planes. A (quasi-)random pattern better than grid
- sharp corners (square grid)

To have (ideally):

- a dense core for low energies and an increasingly separated outer layers for high energies (see Baikal, SuperIceCube)

an optimal geometry for low and high energies?

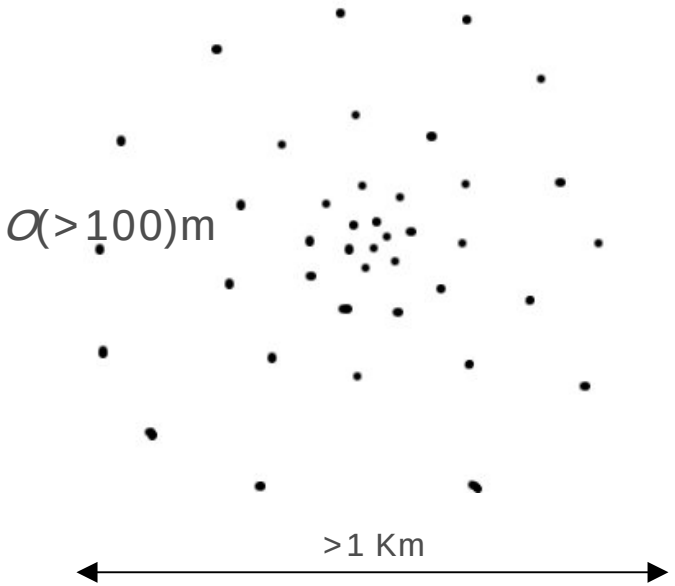
→ Original IceCube geometry could (have) be(en) optimized for lower and higher energies
(for historical and technical reasons we use a triangular grid with equal string spacing)

denser core → low energies

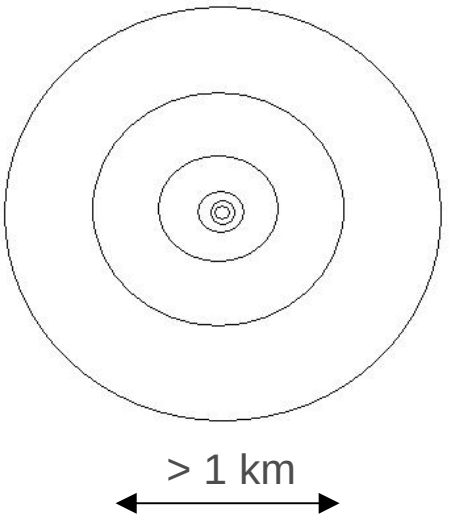
sparser strings → high energies

} hybrid geometry can cover both energy ends

possible optimal choice?:



or, equivalently, this?:



IceCube organization issues

WG structure:

Physics working groups:

- Cosmic rays
- Point sources
- Atmospheric neutrinos
- Diffuse sources
- Exotics
- Dark matter
- Supernova
- Extreme high energy
- GRBs

Detection channel working groups

- Muons
- Cascades

+ calibration and verification groups

IceCube organization issues

centralized repository + wiki pages

we use docushare (docushare.xerox.com) as repository

IMPORTANT: avoid personal pages with results, reports, studies...

we have an institution that acts as a ‘’center’’ (UW) and who maintains the repository, web pages and computing issues in general, with dedicated personnel