# Status of IceCube and Results from AMANDA II

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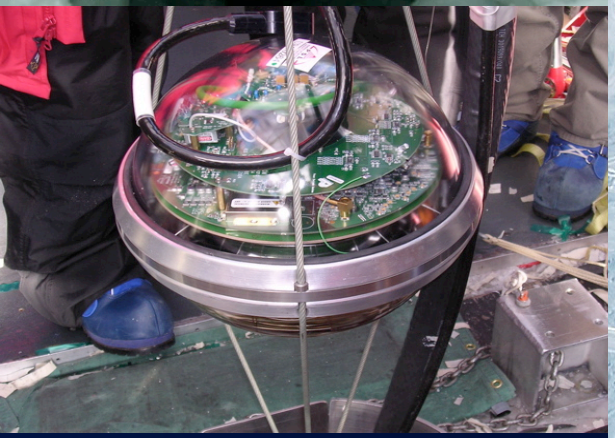
for the IceCube Collaboration



# The IceCube Collaboration

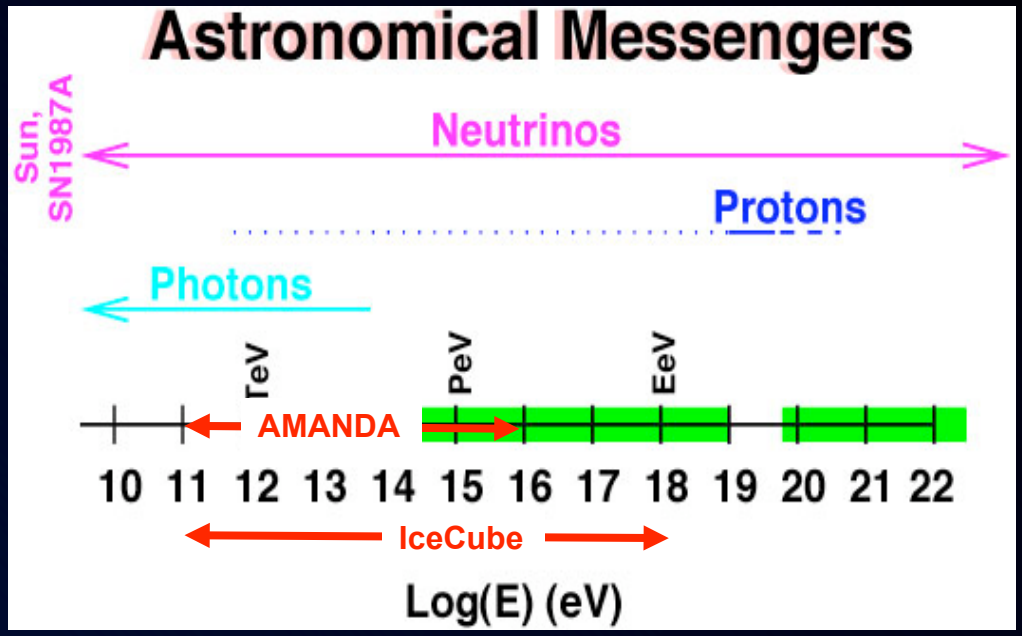
**http://icecube.wisc.edu**

Bartol Research Inst, Univ of Delaware, USA
Pennsylvania State University, USA
University of Wisconsin-Madison, USA
University of Wisconsin-River Falls, USA
LBNL, Berkeley, USA
UC Berkeley, USA
UC Irvine, USA
Univ. of Alabama, USA
Clark-Atlanta University, USA
Univ. of Maryland, USA
IAS, Princeton, USA
University of Kansas, USA
Southern Univ. and A&M College, Baton Rouge, LA, USA
Institute for Advanced Study, Princeton, NJ, USA


Université Libre de Bruxelles, Belgium
Vrije Universiteit Brussel, Belgium
Université de Mons-Hainaut, Belgium
Universiteit Gent, Belgium
Universität Mainz, Germany
DESY-Zeuthen, Germany
Universität Wuppertal, Germany
Universität Dortmund, Germany
Humbolt Universität, Germany
Uppsala Universitet, Sweden
Stockholm Universitet, Sweden
Kalmar Universitet, Sweden
Imperial College, London, UK
University of Oxford, UK
Utrecht University, Netherland

Amundsen-Scott Station,

# Physics items

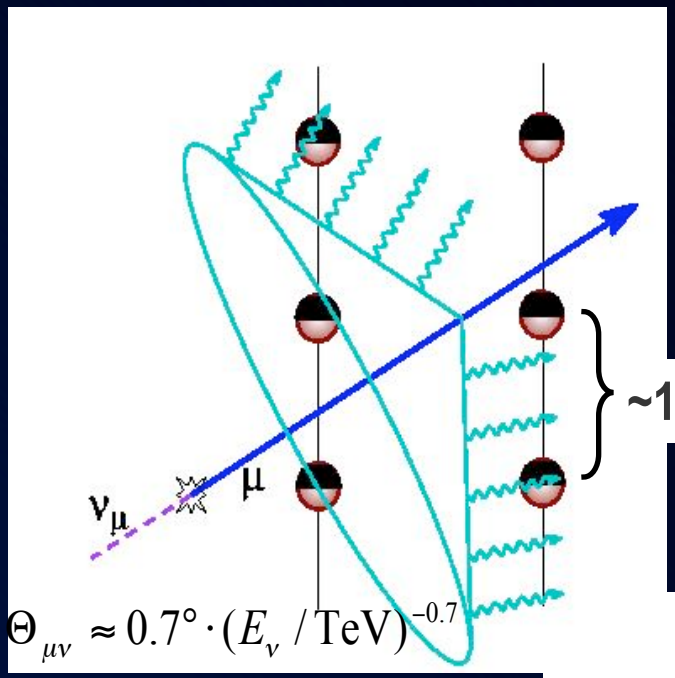



- UHE-EHE νs are a new observation channel for studying astrophysical objects and the highest energy phenomena producing UHECRs
- Atmospheric neutrinos allow investigations of fundamental ν properties and prompt νs from heavy mesons are still unknown
- Dark matter studies: WIMPs and Monopoles
- SN detection (ice is a quiet environment!)

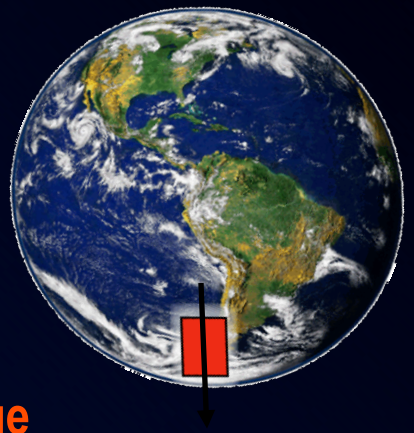
# Event Topologies

**Muon tracks**

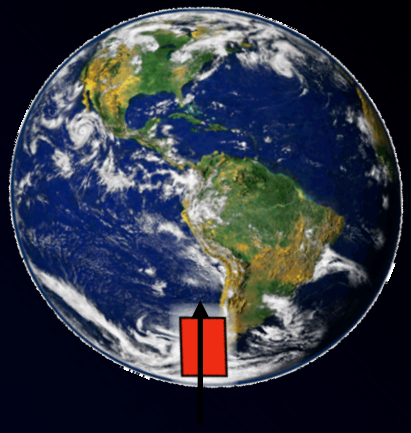
**2π coverage for νs + pointing**




"Up-going"
(from Northern sky)

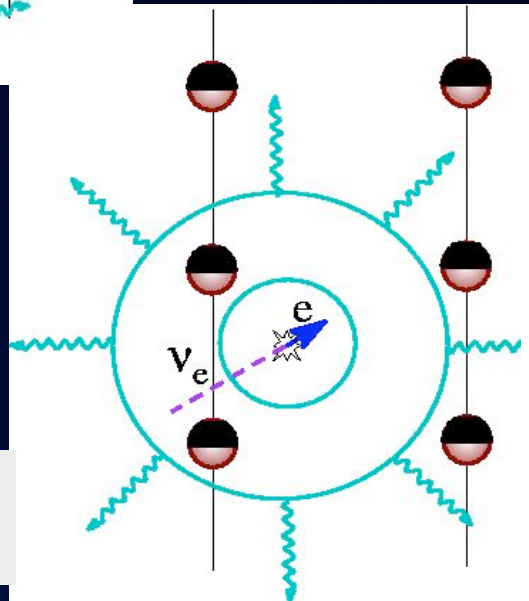


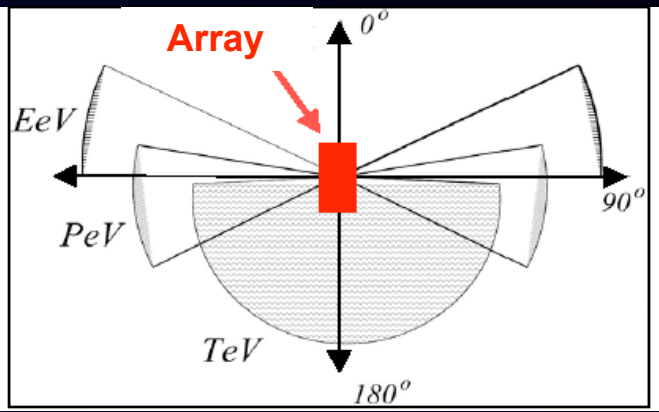
Down-going



**Cascades**

**4π coverage**



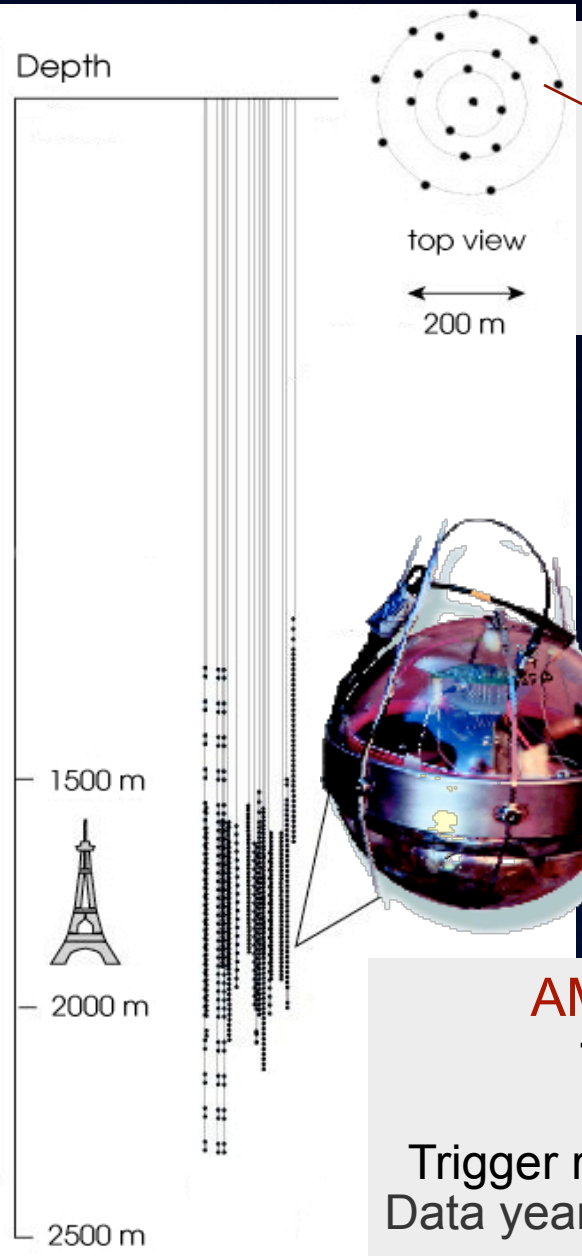




event reconstruction by Cherenkov light timing

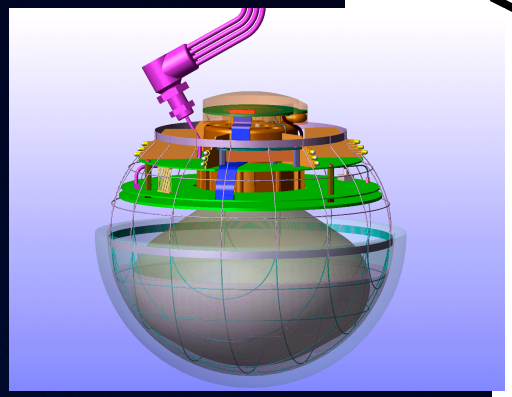
# The Site


## Amundsen-Scott South Pole Station

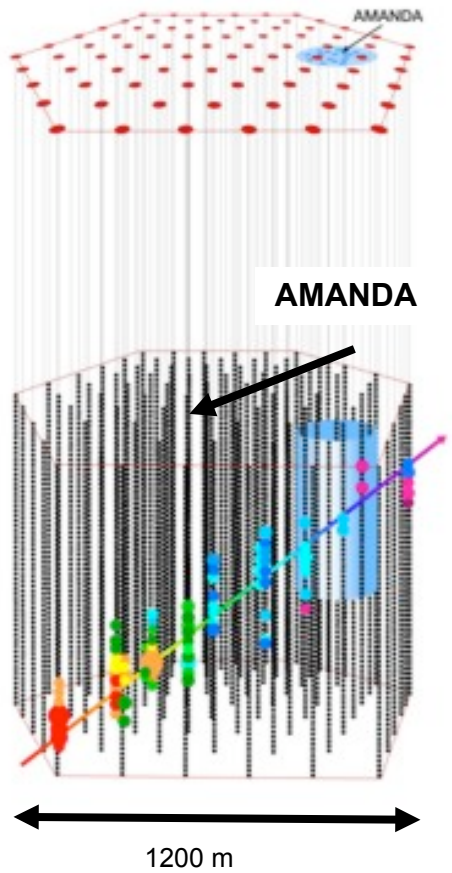
# The detector evolution




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



IceCube

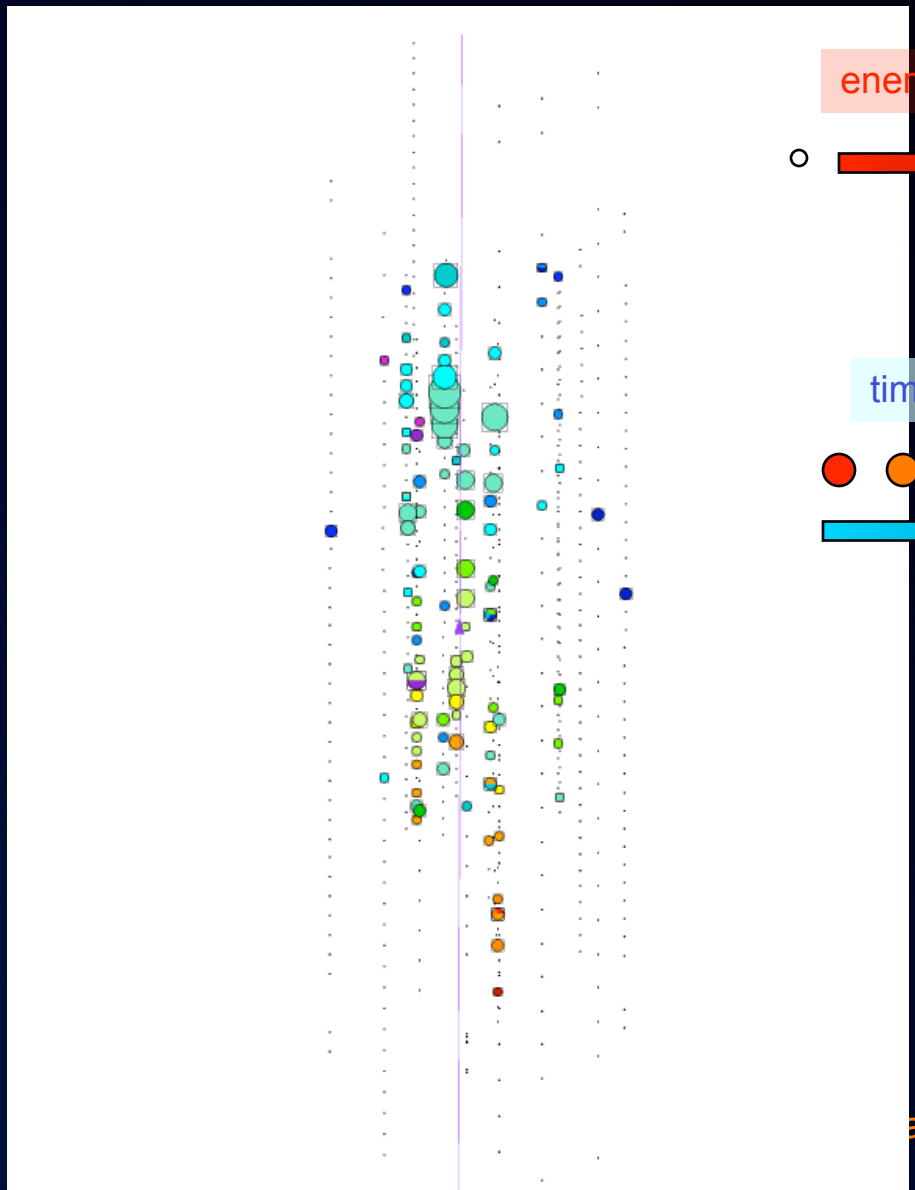



## IceTop
160 tanks
frozen-water tanks
2 OMs / tank

## AMANDA-II
19 strings
677 OMs
Trigger rate: 80 Hz
Data years: >=2000

## IceCube
80 strings 60 OMs/string
17 m vertical spacing
125 m between strings


# ν telescope : AMANDA event



energy deposited in OM

time recorded on OM

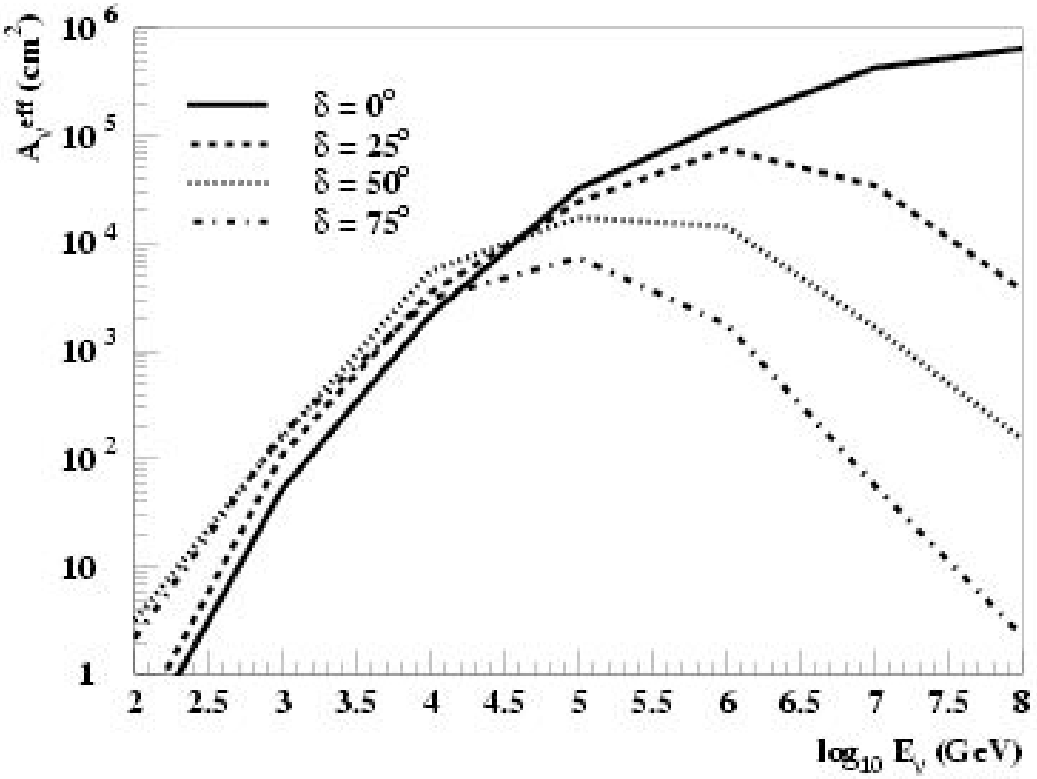
**ice optical parameters:**

$\lambda_{abs}$ ≈ 110 m @ 400 nm

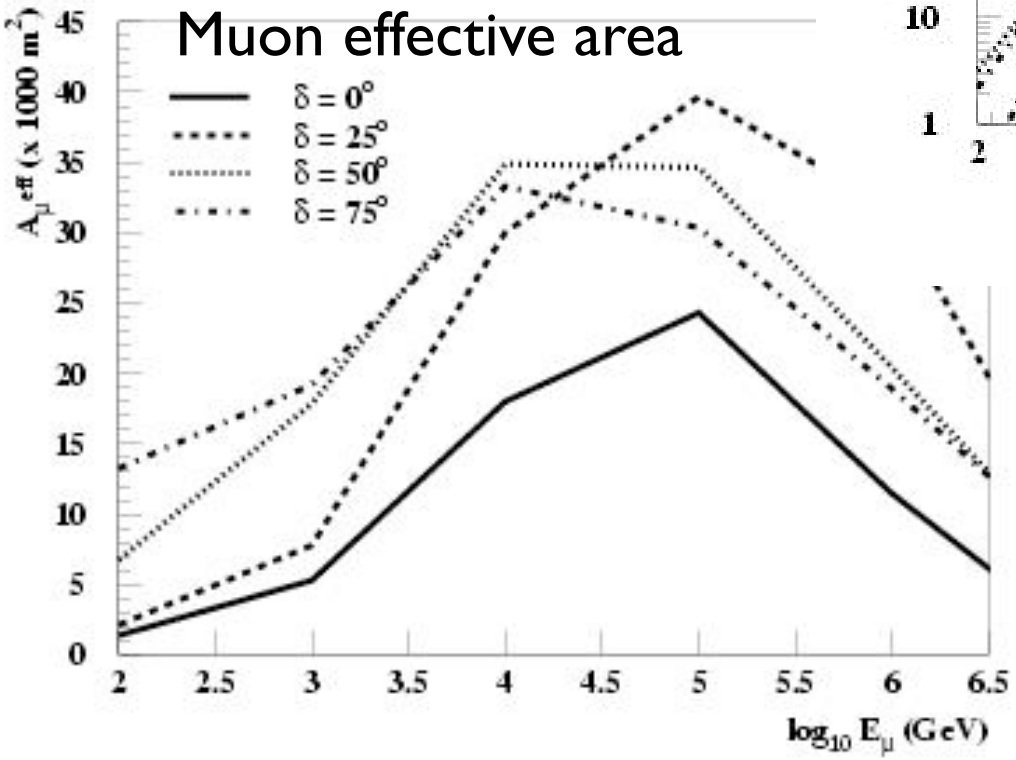
$\lambda_{eff.scatt}$ ≈ 20 m @ 400 nm

# Effective areas

Neutrino effective area




Muon effective area

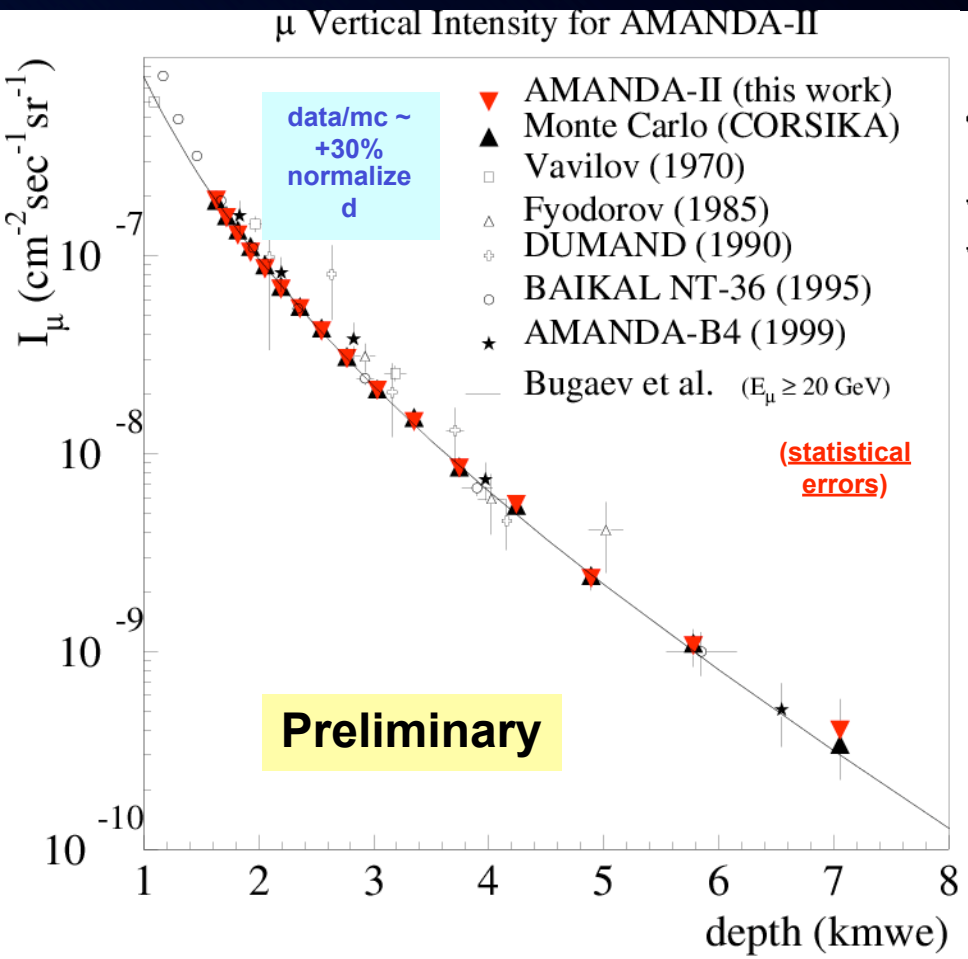


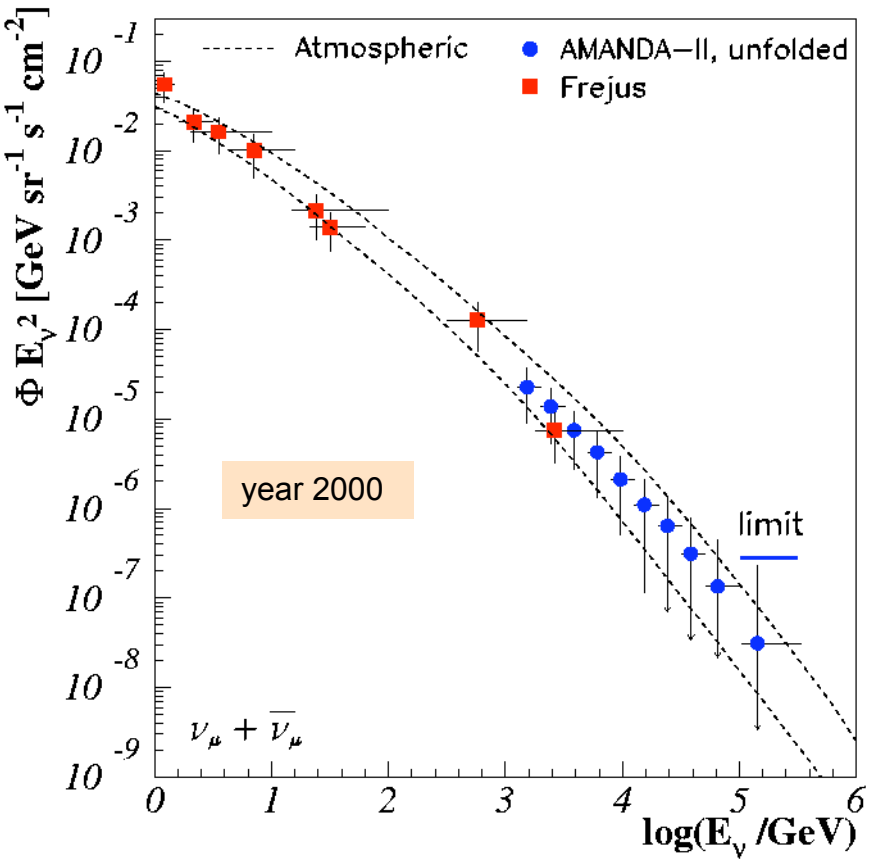

E.g. at 30 TeV:

Muon area: ≈35,000 m$^2$

Neutrino area: ≈ 1 m$^2$

# Backgrounds and calibration beams

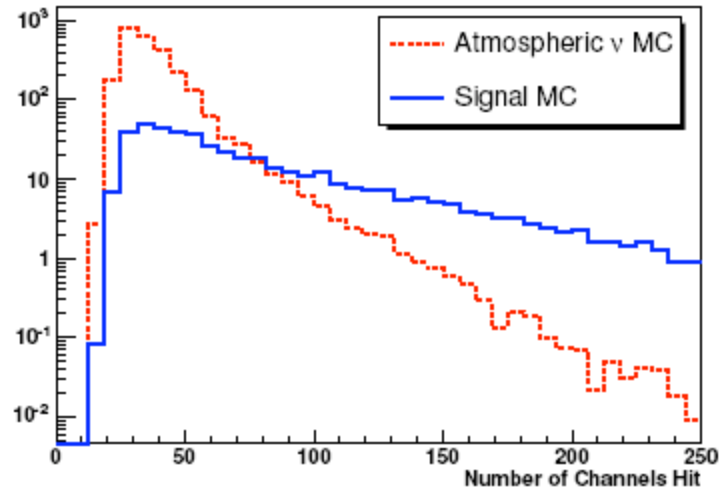


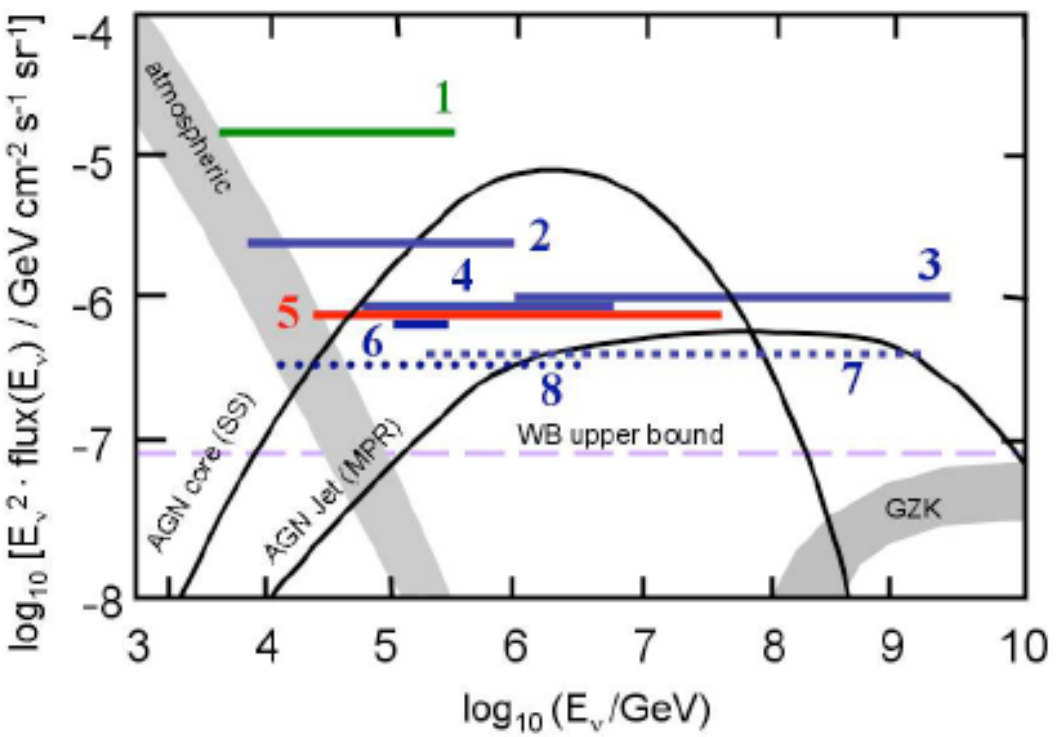



# Diffuse νμ fluxes

Signal $10^{-6}$ $E^{-2}$ $cm^{-2}$ $s^{-1}$ $sr^{-1}$ $GeV^{-1}$

Limits are for all flavors and oscillations: 1:1:1 flavor flux



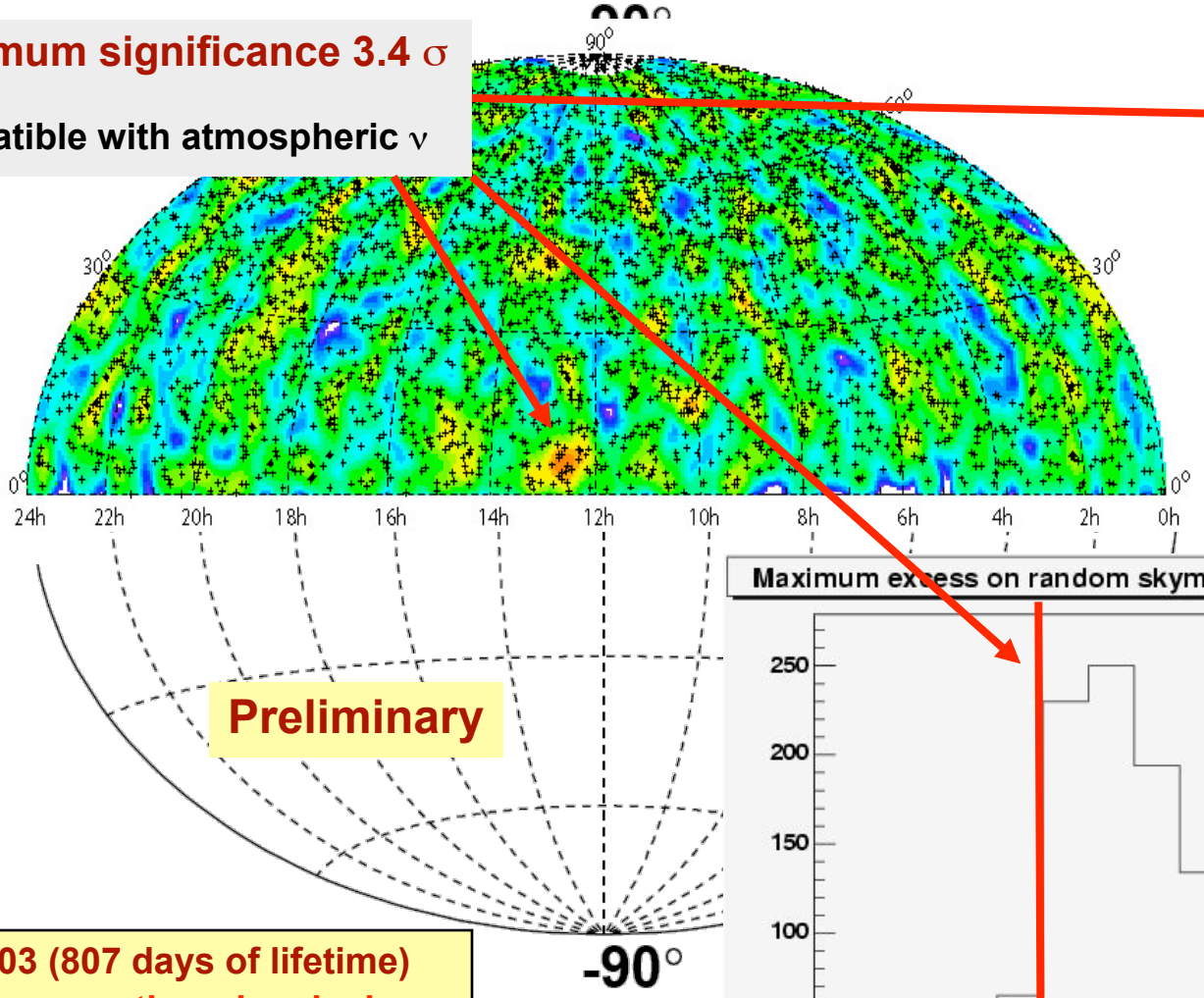




**1**: MACRO 5.8 yrs
2: AMANDA-B10, 97, ↑μ
3: AMANDA-B10 UHE
4: A-II, 2000, cascades
5: Baikal 98-03 prelim
**6**: unfolding atm νs 2000
7: sensitivity casc 2000-03
8: sensitivity ↑μ 2000-03


# ν telescope : point source search

**Maximum significance 3.4 σ**

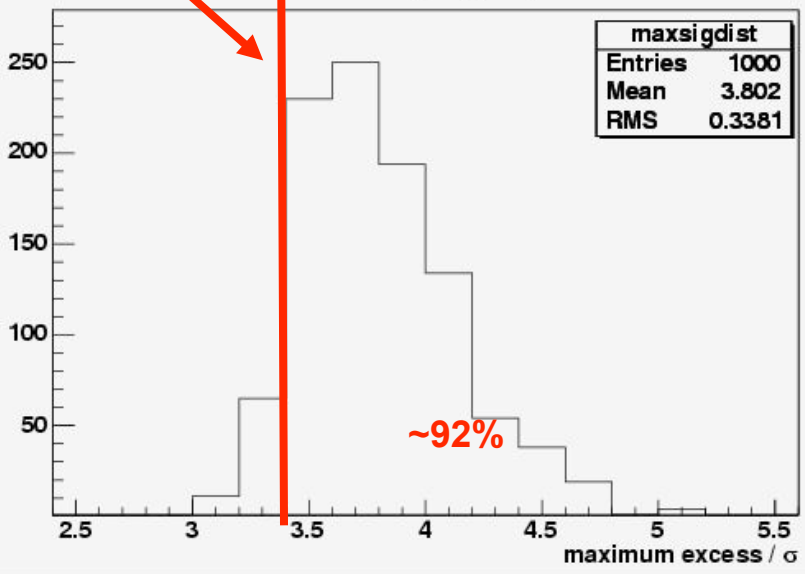
**compatible with atmospheric ν**




cluster search radius between 2.25° - 3.75°

**Preliminary**

**Maximum excess on random skymaps**




**2000-2003 (807 days of lifetime)**

**3329 ν from northern hemisphere**

**3438 ν expected from atmosphere**

# Point Source Search

## Selected Sources

Preliminary

Sensitivity $F_n/F_g \sim 2$ for 200 days of "high-state" and spectral results from HEGRA

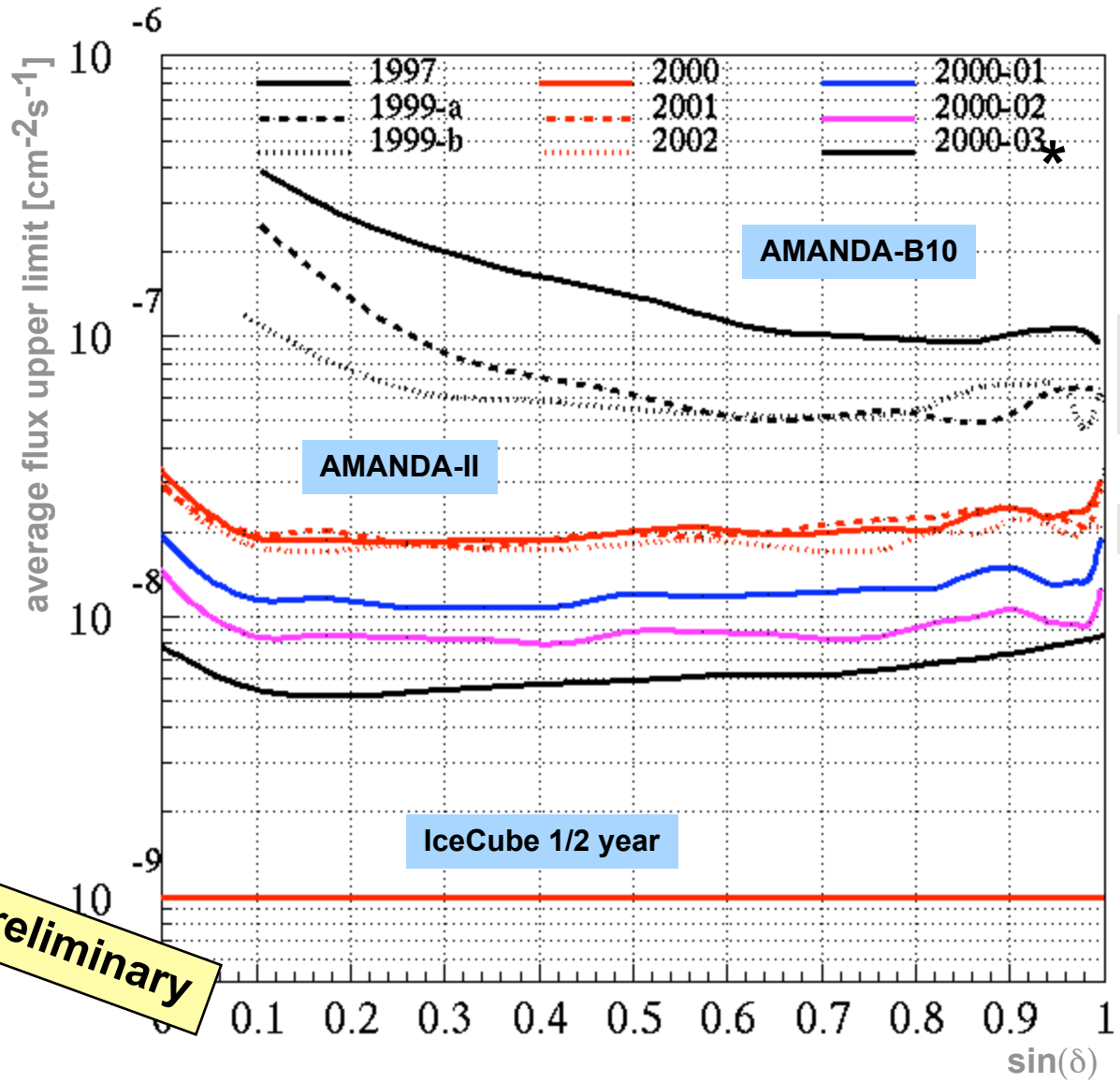
| Source | Nr. of ν events (4 years) | Expected backgr. (4 years) | Flux Upper Limit $\Phi_{90\%}(E_\nu > 10\ \text{GeV})$ $[10^{-8} \text{cm}^{-2} \text{s}^{-1}]$ |
|---|---|---|---|
| Markarian 421 | 6 | 5.58 | 0.68 |
| 1ES1959+650 | 5 | 3.71 | 0.38 |
| SS433 | 2 | 4.50 | 0.21 |
| Cygnus X-3 | 6 | 5.04 | 0.77 |
| Cygnus X-1 | 4 | 5.21 | 0.40 |
| Crab Nebula | 10 | 5.36 | 1.25 |

… out of **33** Sources

Systematic uncertainties under investigation

**no statistically significant effect observed**


# ν telescope : point source search




Preliminary

**Average upper limit = sensitivity (δ>0°)**
**(integrated above 10 GeV, $E^{-2}$ signal)**

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

Sensitivity independent of direction

increases almost linearly with exposure

1997 : ApJ 583, 1040 (2003)

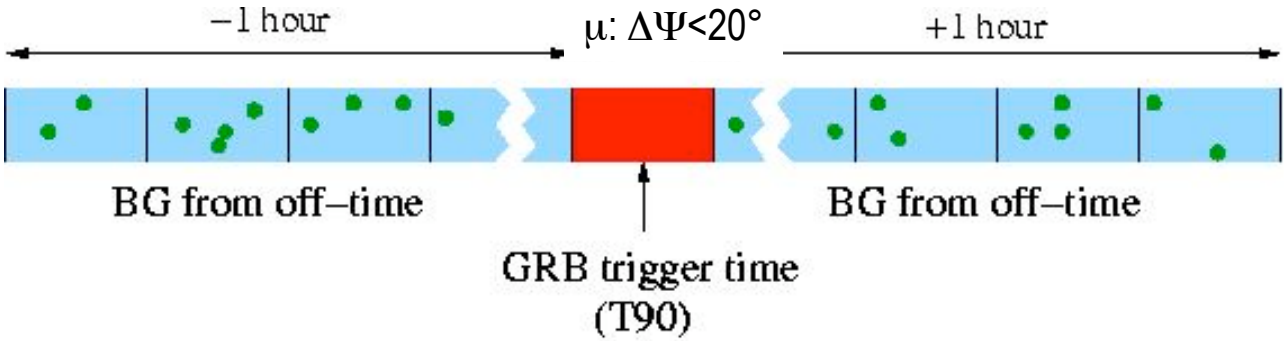
~~2000 : PRL 92, 071102 (2004)~~

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

δ declination { δ=0° →  δ=90° ↑

# GRB n search in AMANDA

Search for νμ candiates correlated with GRBs - background established from data




PRELIMINARY

| | Year | #GRB | bkg | observed |
|---|---|---|---|---|
| muon | 97-00 | 312 | 1.30 | 0 |
| muon | 01-03 | 51 | 0.24 | 0 |
| cascades | 2000 | 73 | 0.005 | 0 |

Cascade channel:
worse pointing but 4π!

- effective area ≈ 50000 $m^2$ (μ)
- limit assuming WB spectrum: $E_\nu^2 \Phi_\nu < 3 \times 10^{-8}$ GeV $cm^{-2}$ $s^{-1}$ $sr^{-1}$ (μ)

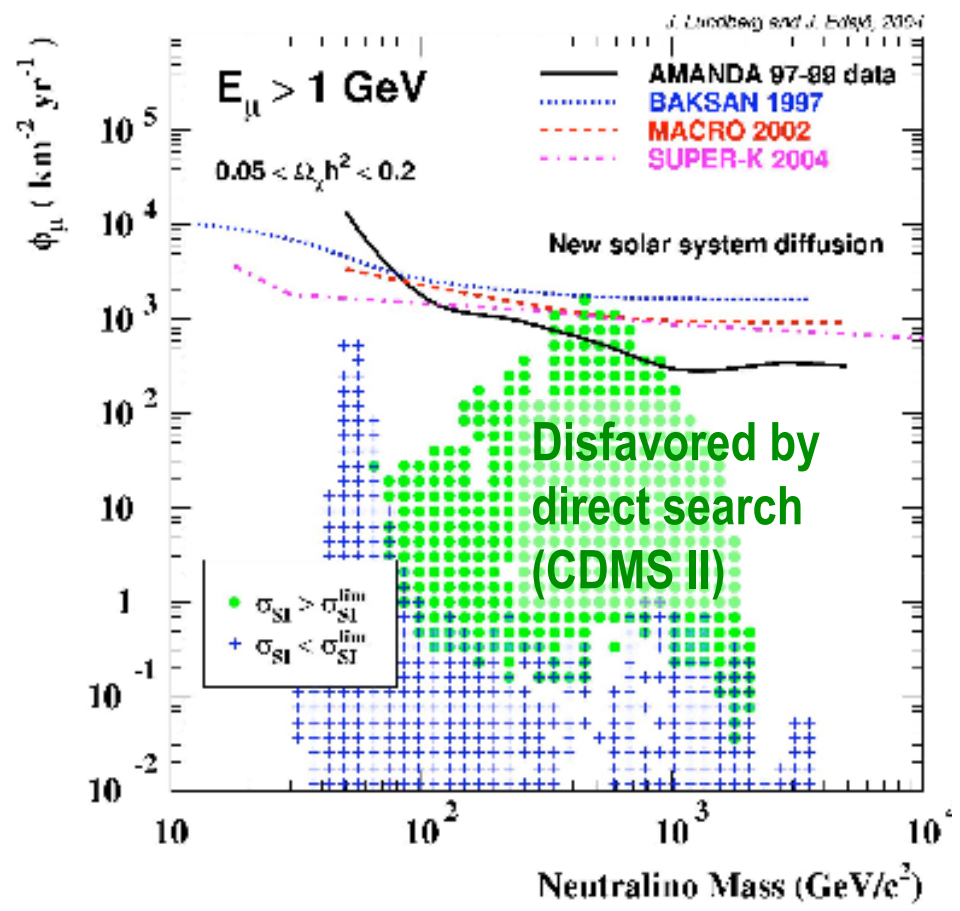
$< 9.5 \times 10^{-8}$ GeV $cm^{-2}$ $s^{-1}$ $sr^{-1}$ (cascades)

# WIMP search in AMANDA

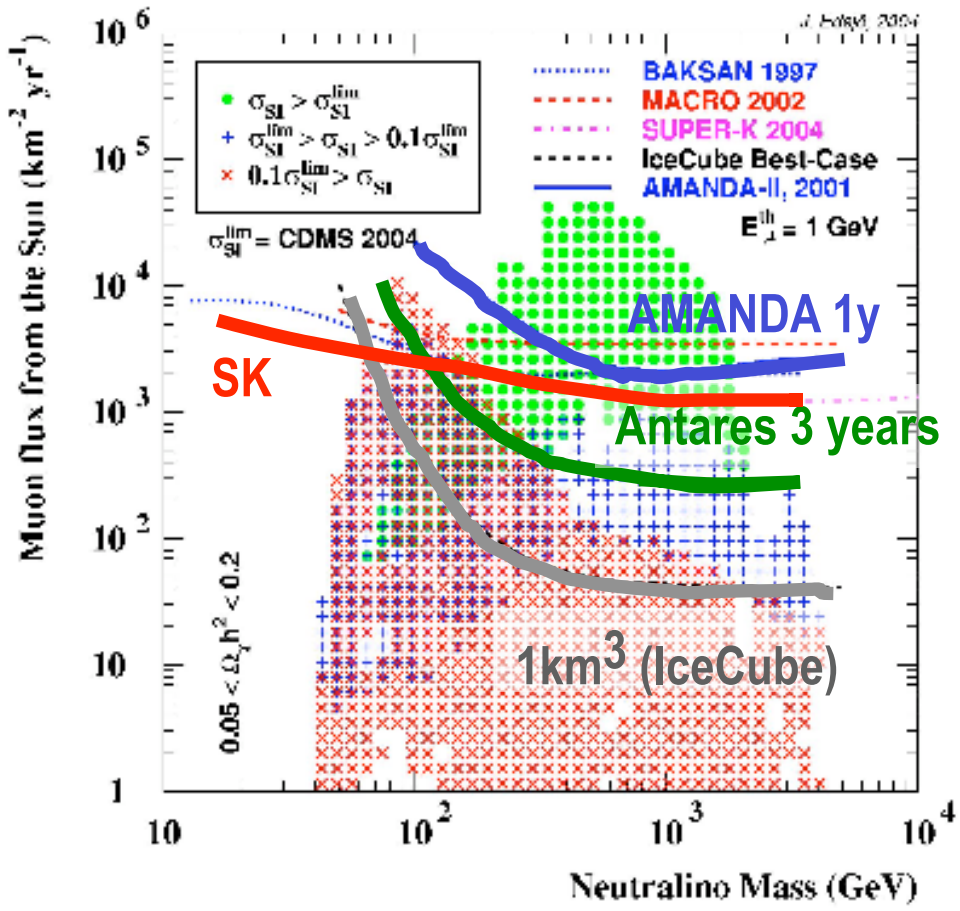
PRELIMINARY

*submitted for publication*

## Limits on muon flux from Earth center

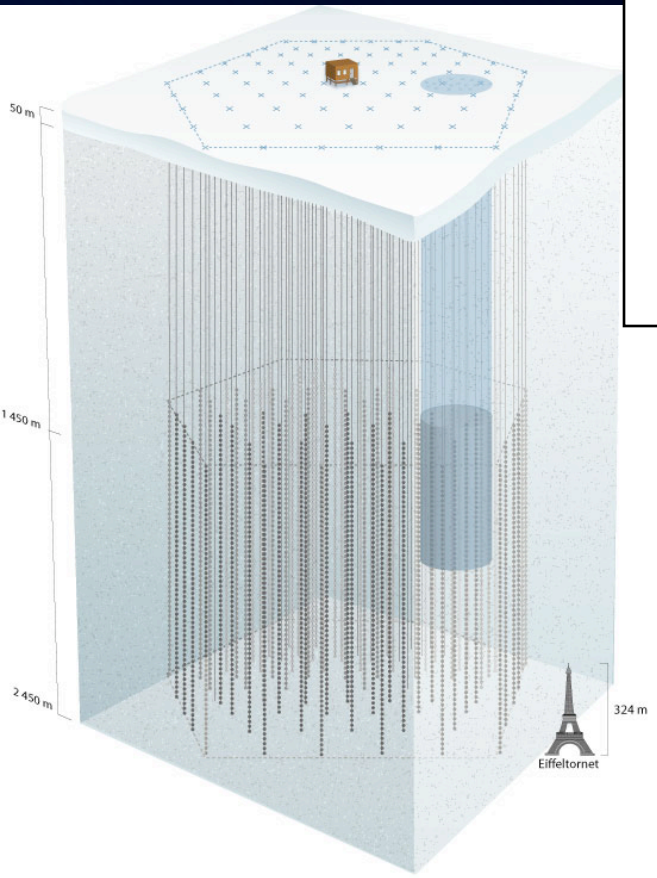


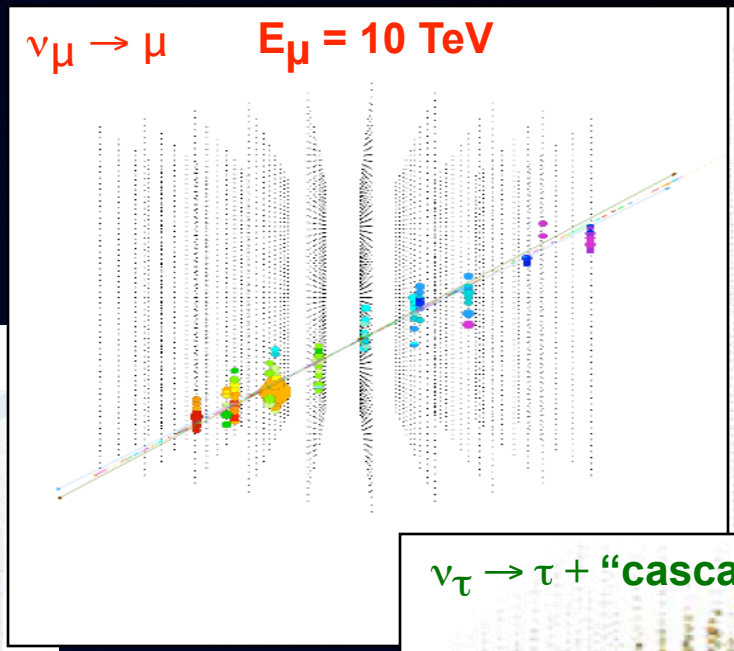

## Limits on muon flux from Sun

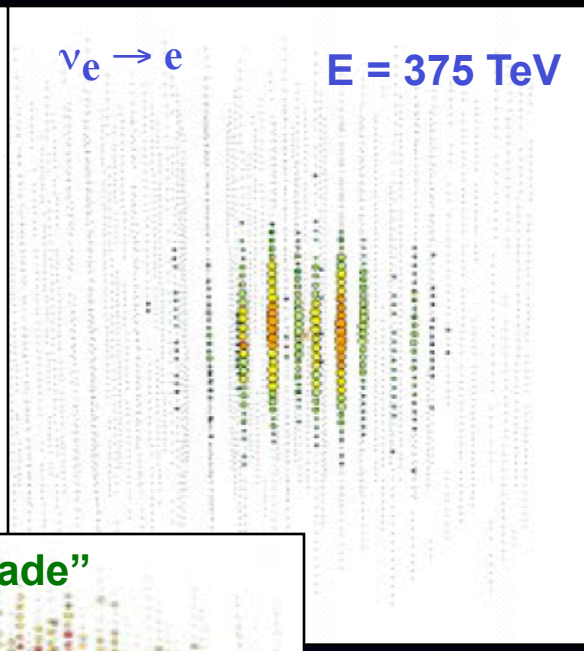


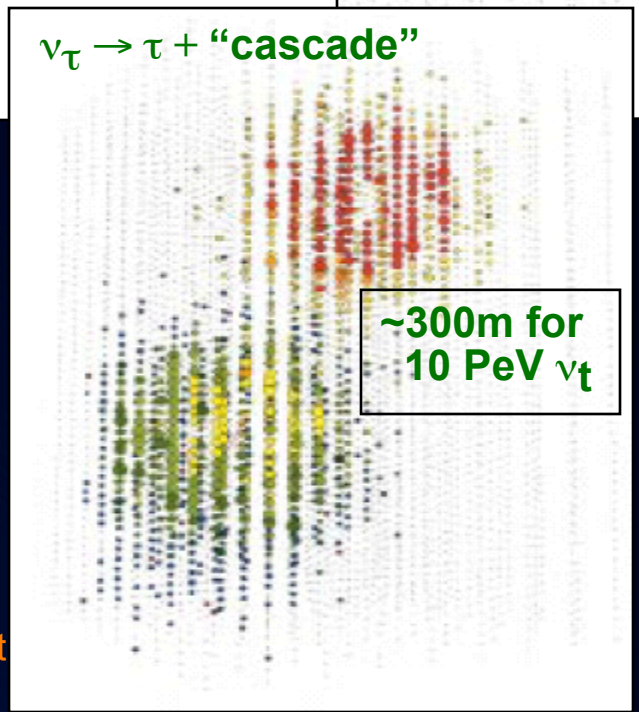
# The future: IceCube

Factor of 40 compared to 4 yrs of AMANDA-II for point-sources in 1 yr!!

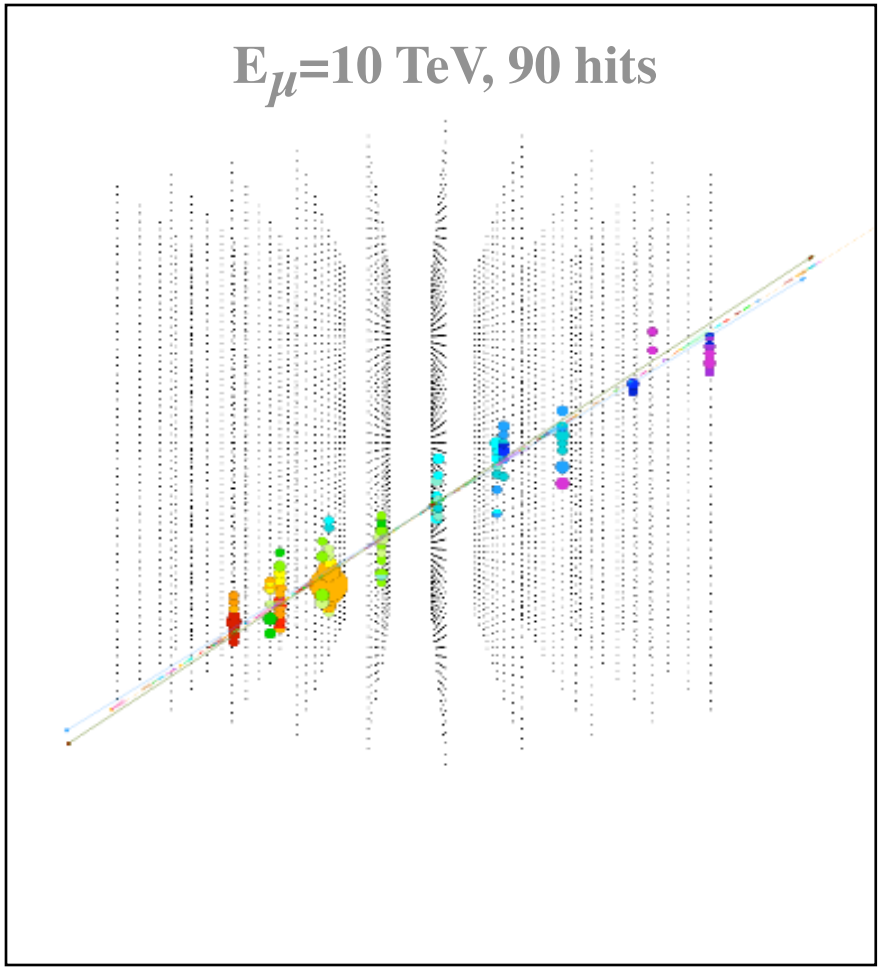


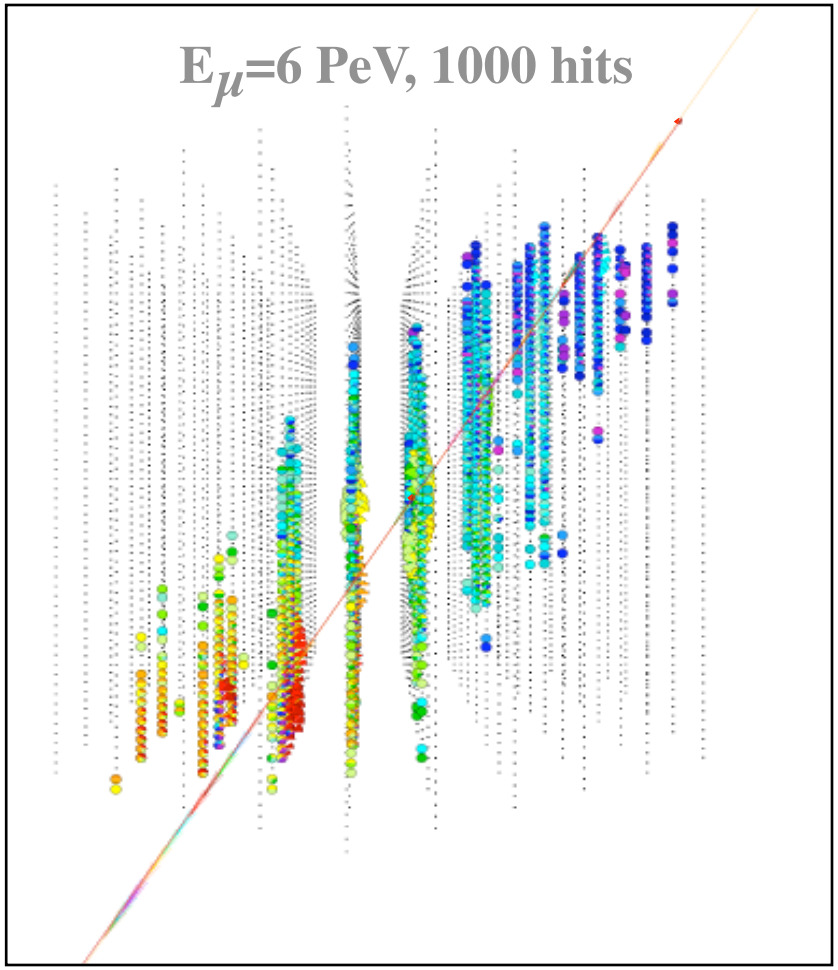



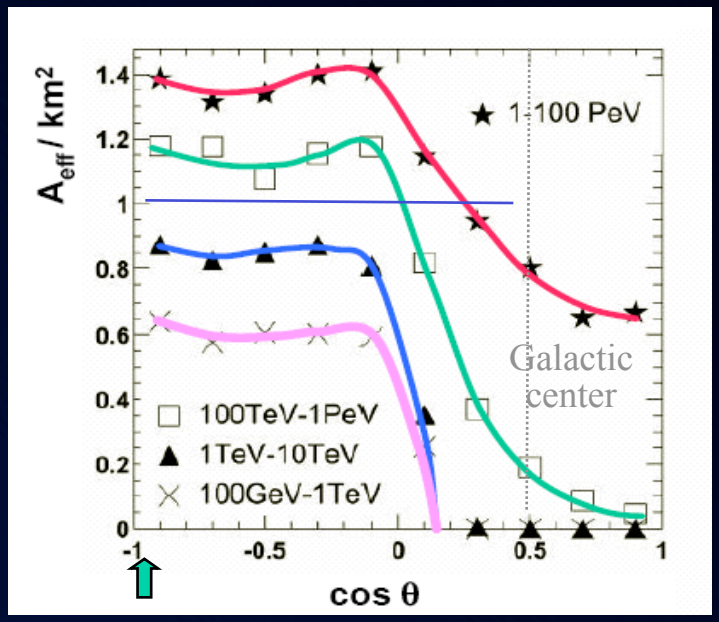



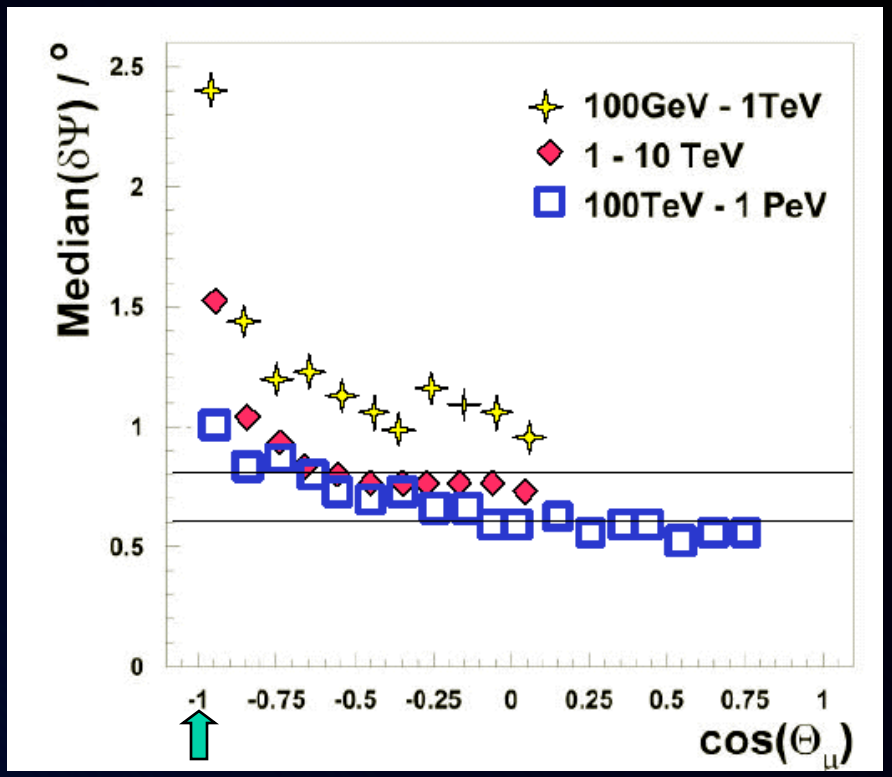

# IceCube : simulated μ track events

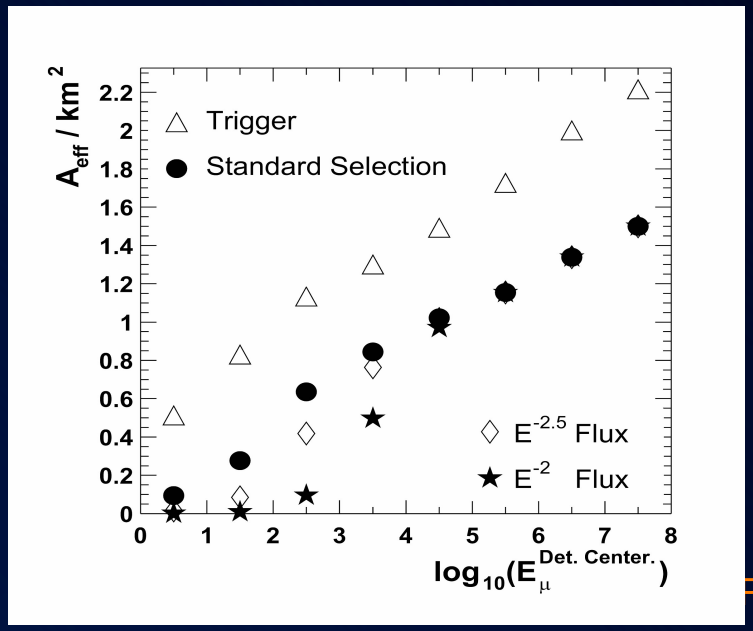


# IceCube : μ Aeff & resolution



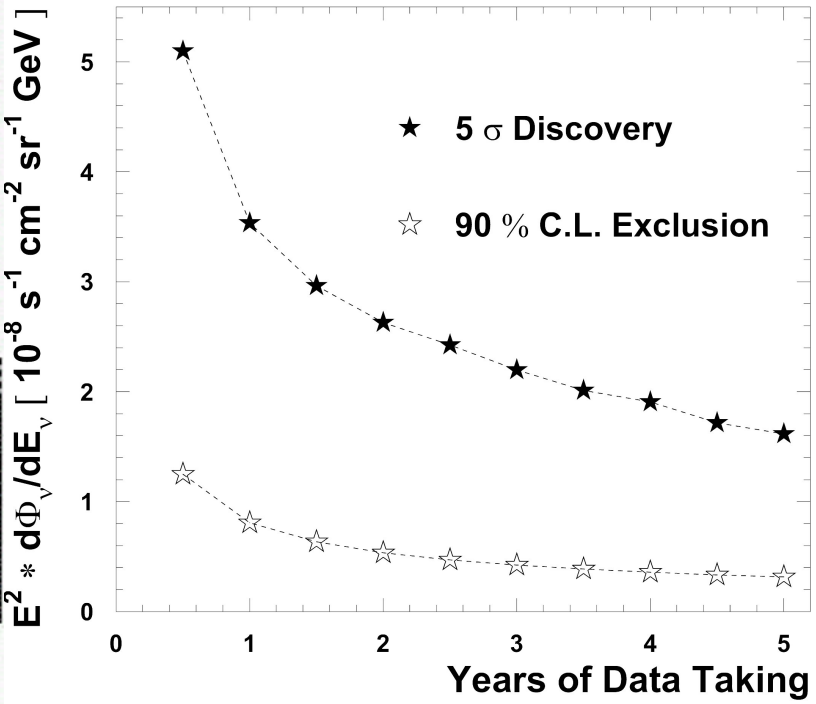



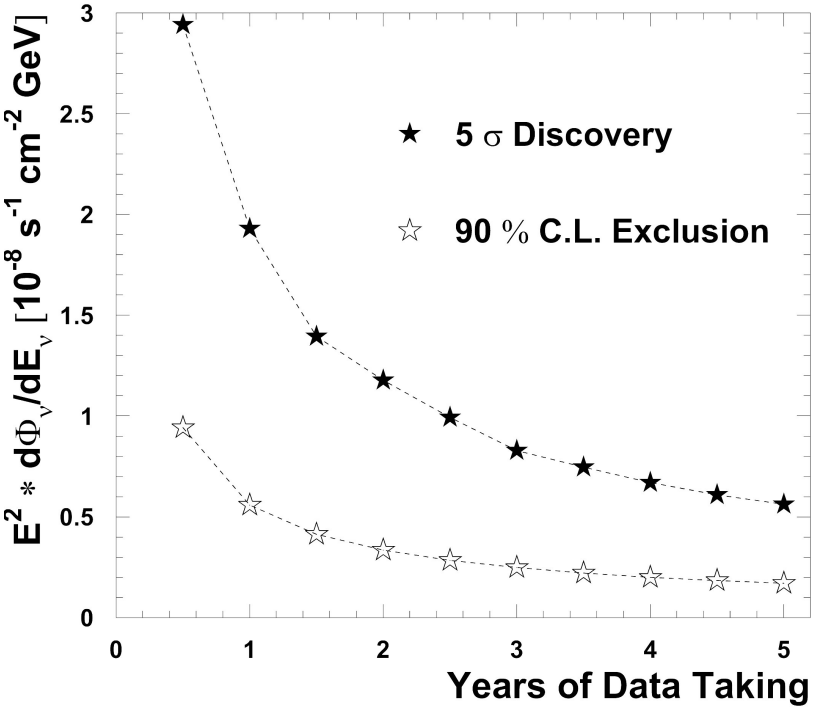

Angular resolution: ~0.7° (not using waveforms)
Verify angular resolution using the Cosmic ray shadow of the Moon on a monthly basis.


# IceCube : sensitivities

## Diffuse νμ sensitivity




## Point source νμ sensitivity



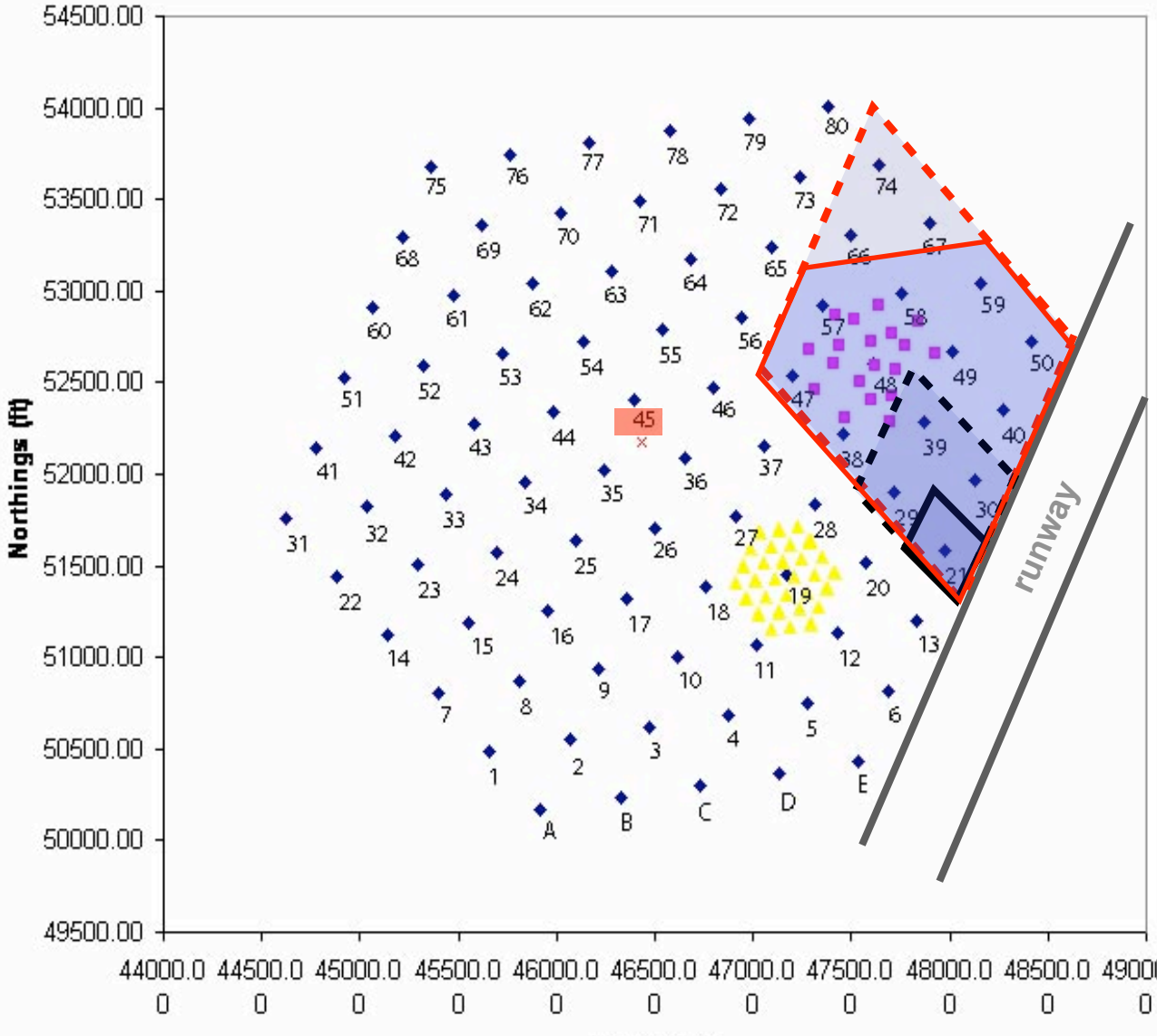
# Construction status and plan for the next season

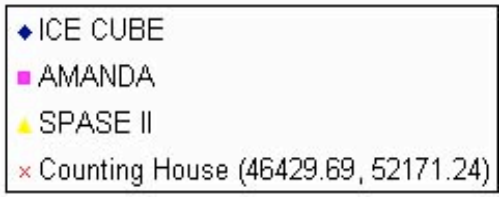
January 2005:

- Strings: 1
- Tanks/stations: 8/4

**2005/06 Plan*:**

- **Strings: 10 - 12**
- **Tanks/stations: 24/12**
- **Completion 2010**



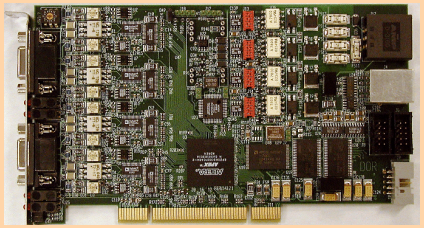



# The drill site with tower

Hot water drill, thermal power 5 MW
Plan to drill 16+ holes per season

# Fundamental detector elements

Digital Receiver (PCI card)



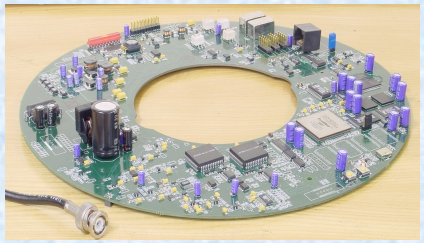
IT
(TCP-IP)

+20°C

~ 3.3 km copper, 0.9mm
(one twisted pair: for 2 sensors,
power, data, time synchronization)

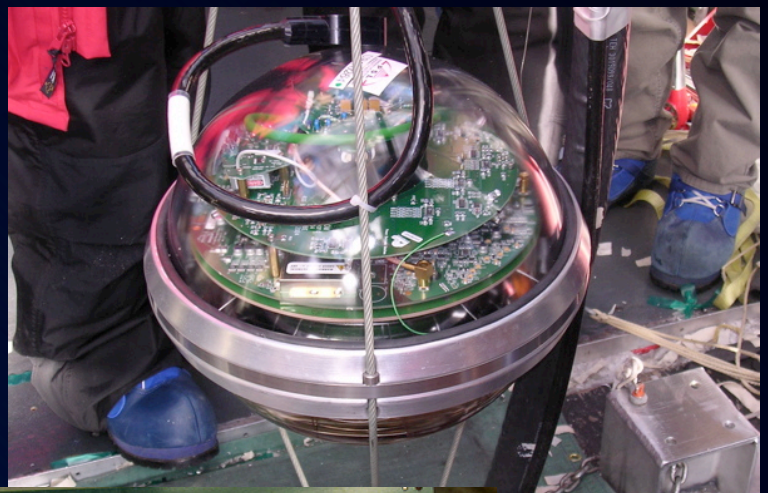
-40°C

PMT

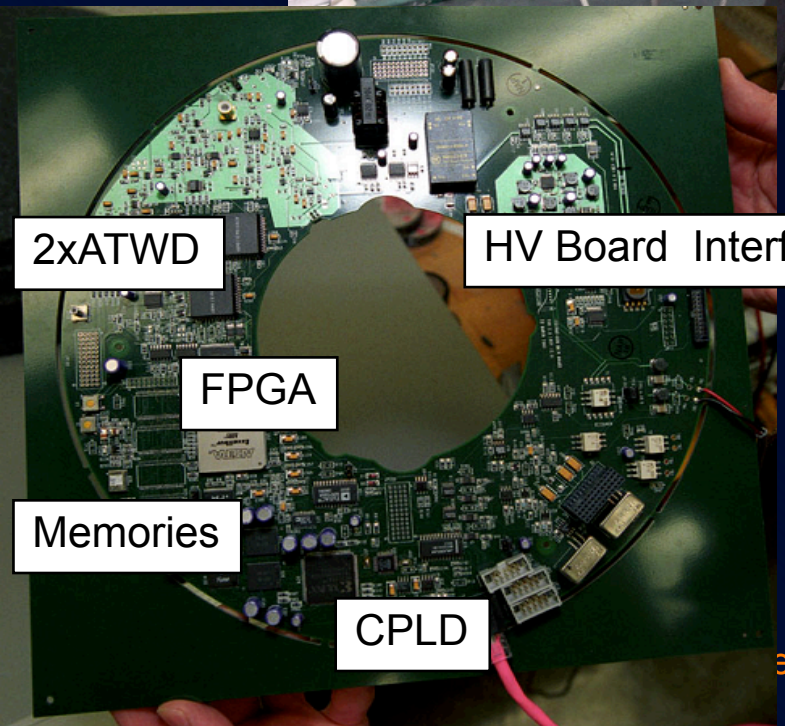


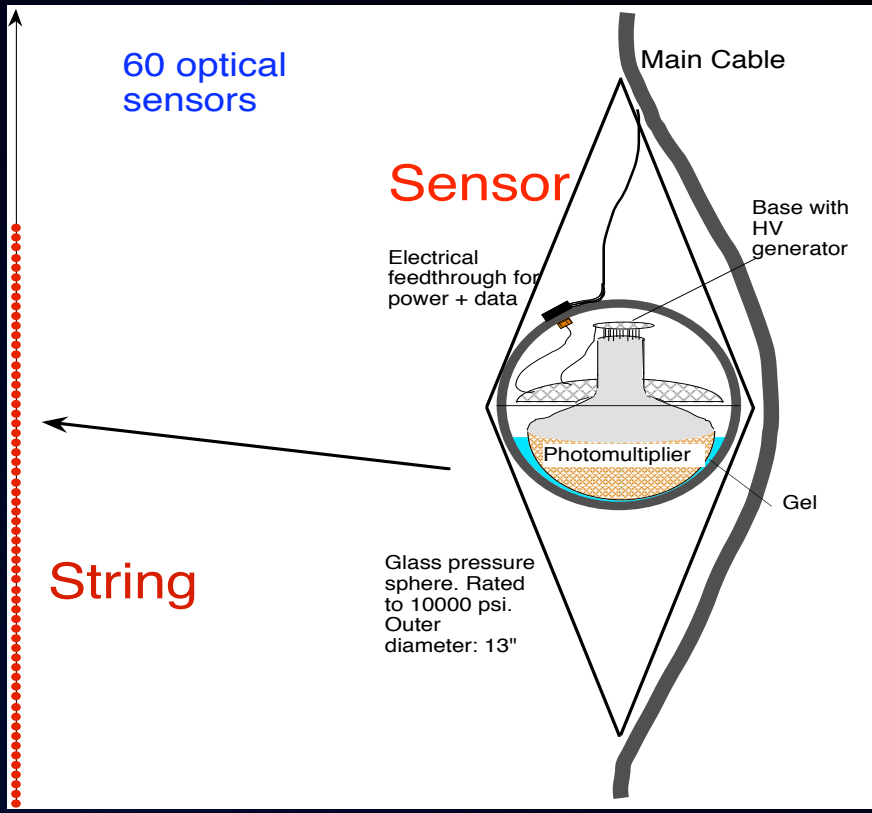
Intelligent Digitizer (DOM)

# The IceCube 1st string

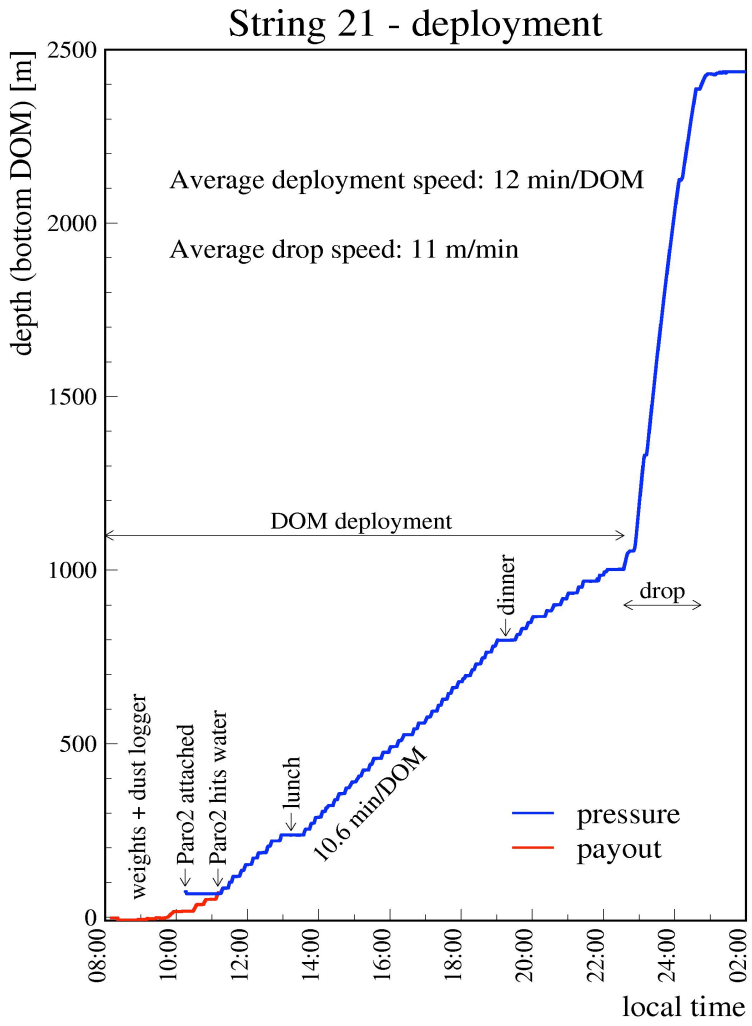


First IceCube string deployed
(60 Digital OMs)



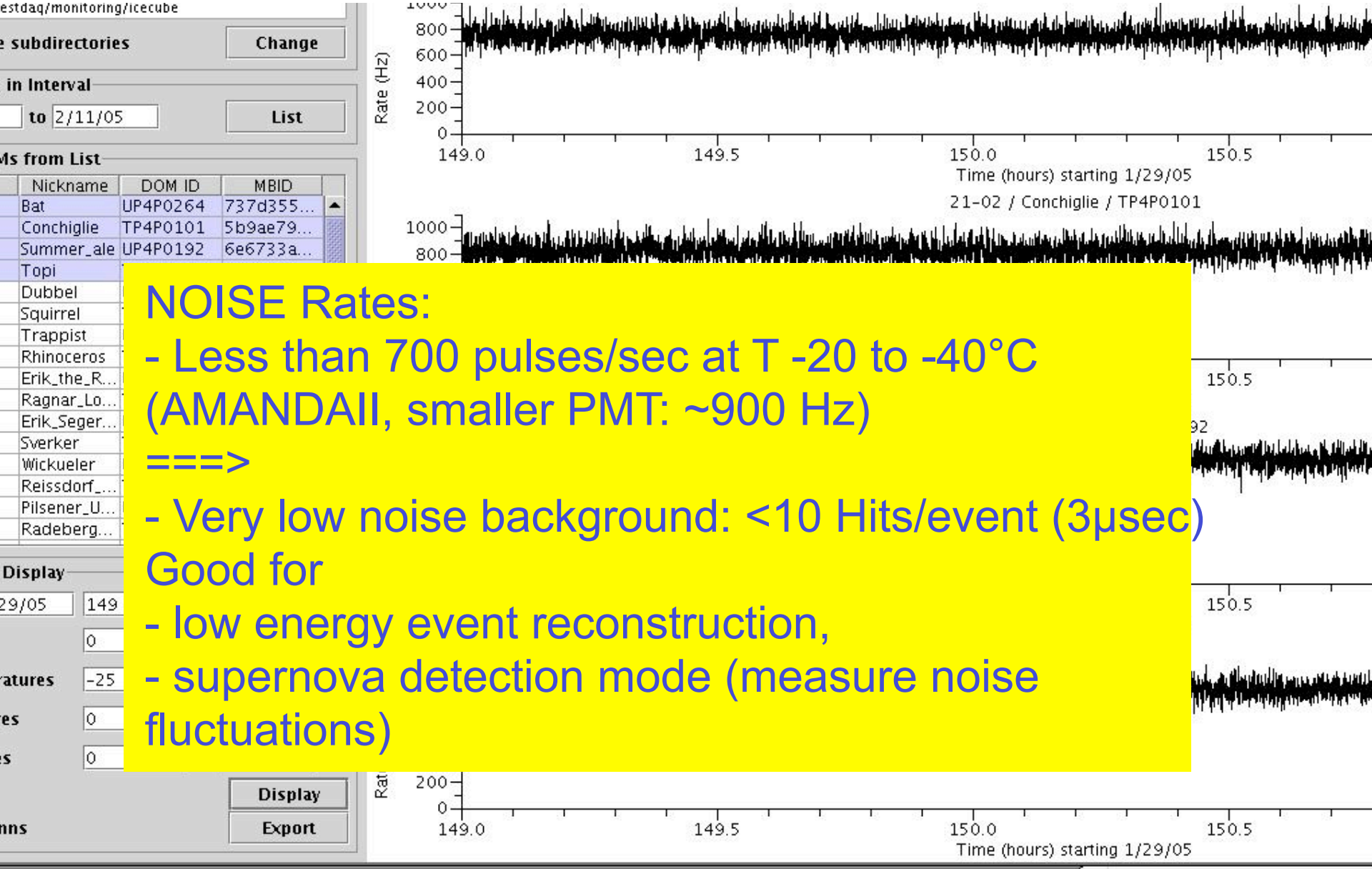



# String installation: 60 sensors in 18 hours to target depth of 2450m




# Results from first string:

## Noise rates after freeze-in: ~0.65 kHz




NOISE Rates:

- Less than 700 pulses/sec at T -20 to -40°C (AMANDAII, smaller PMT: ~900 Hz)

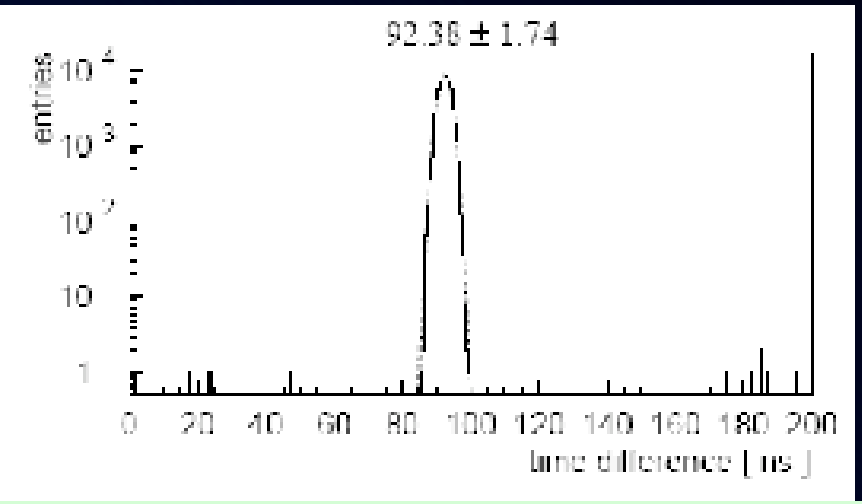
===>

- Very low noise background: <10 Hits/event (3μsec)

Good for

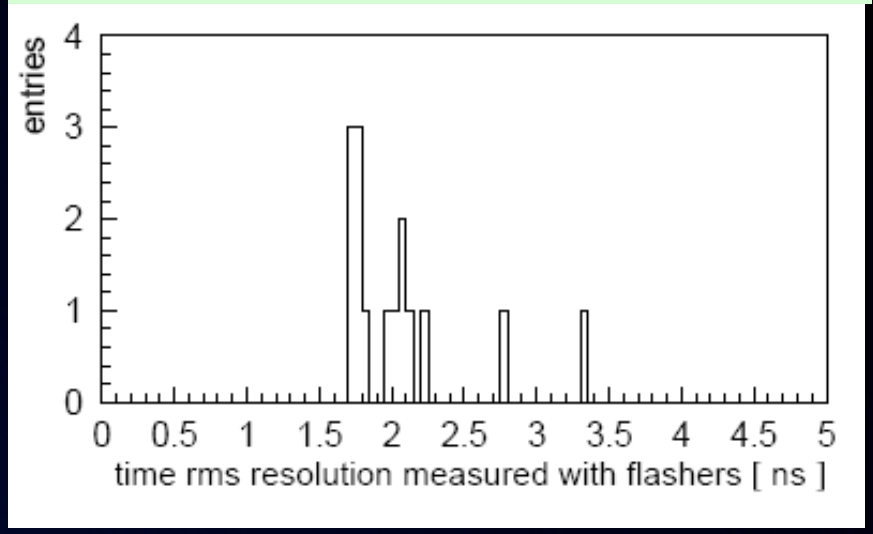
- low energy event reconstruction,
- supernova detection mode (measure noise fluctuations)

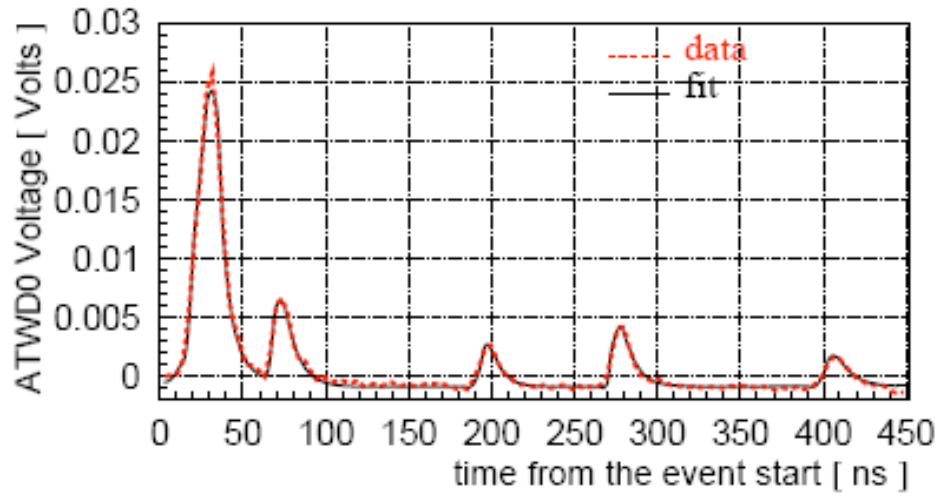
# Results from the 1st string




Difference of time of hits on DOM 58 and 59 when DOM 60 is flashing (spacing between sensors: 17 m)

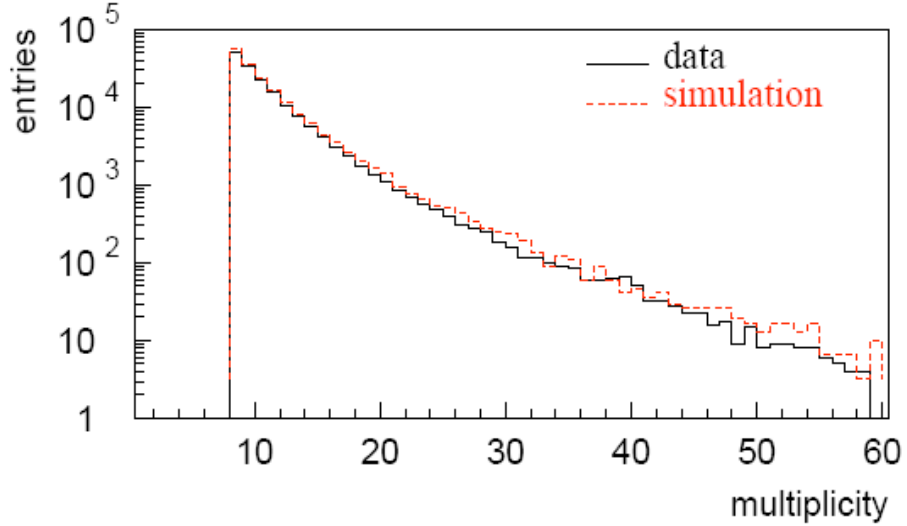
Demonstrated time resolution (RMS) for some DOMs: ~2ns in clear ice

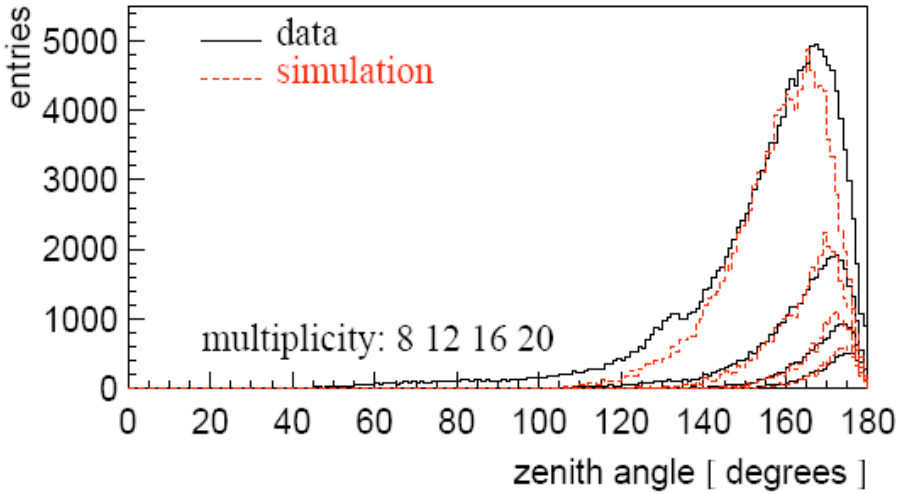



Typical waveform ⇒ waveform decomposition yields single photoeelectrons

# Single string analysis: Muon data/MC



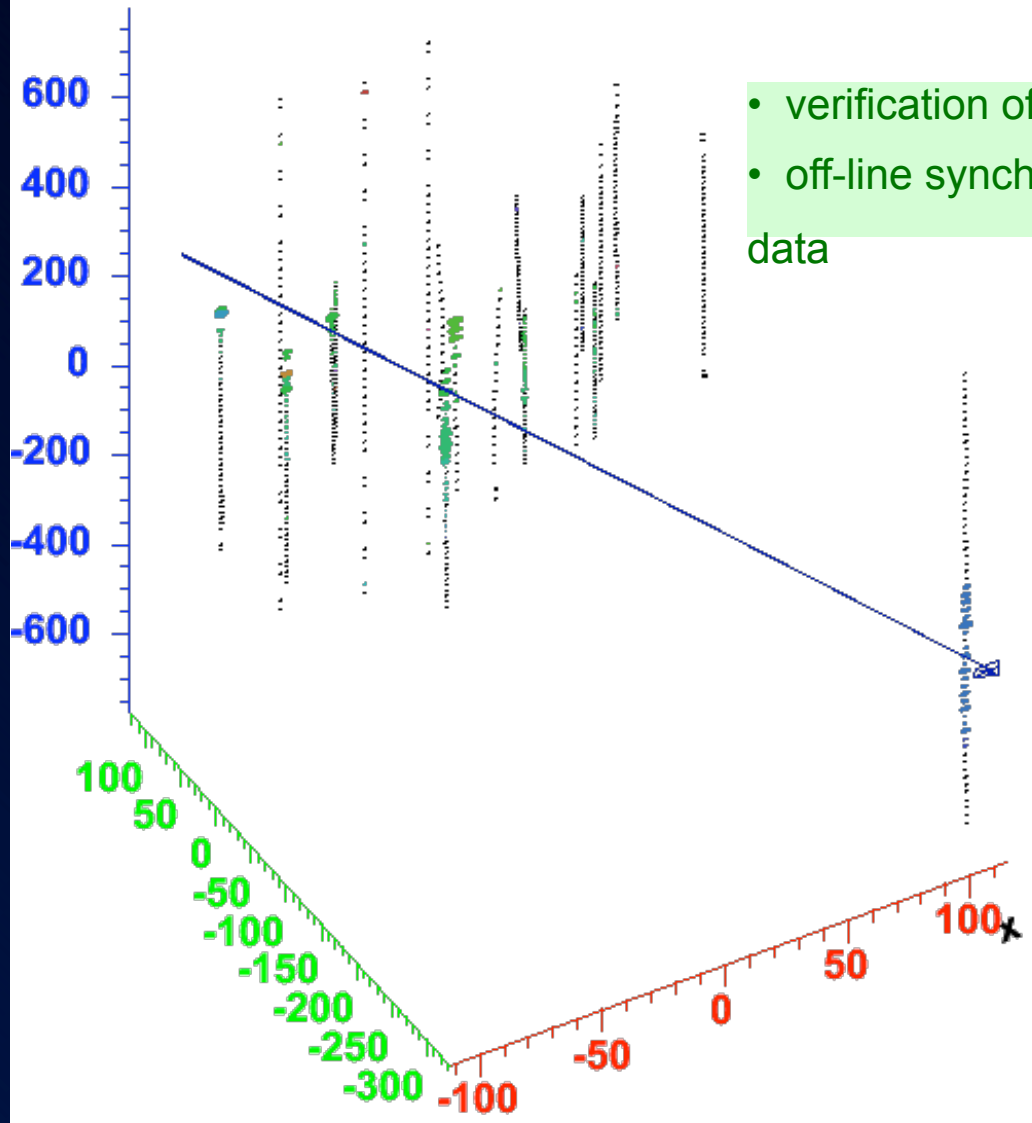

Muon zenith angle resolution: 9.7˚ for events with > 8 hits

3.0˚ > 20 hits

1.6˚ > 40 hits

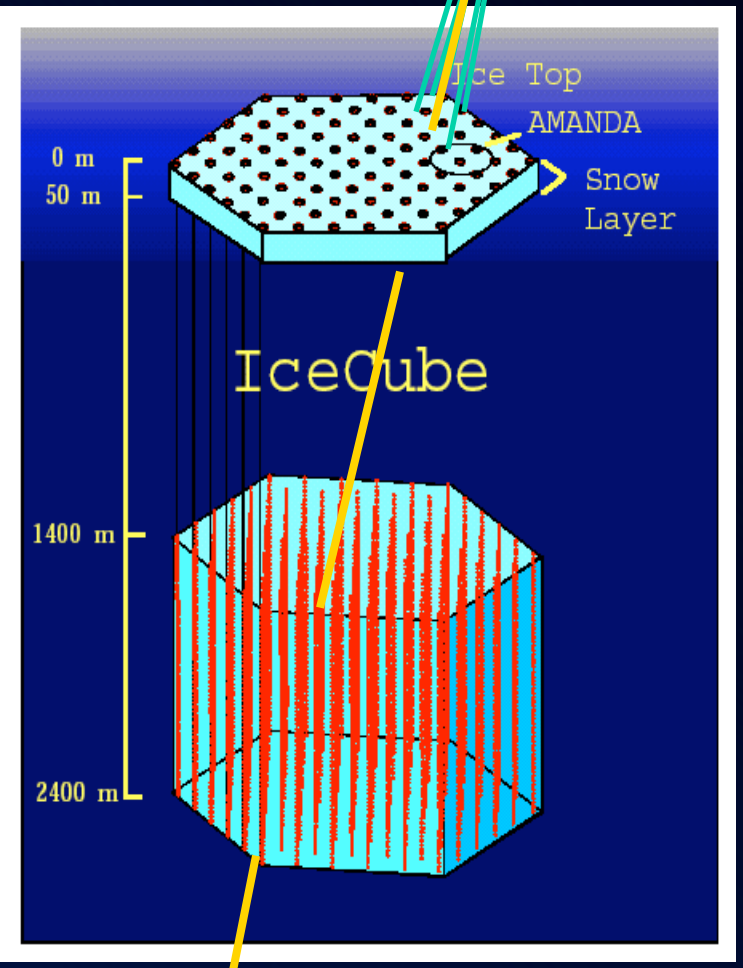
Physics analysis will start next year!

# AMANDA-IceCube coincident event




- verification of newly deployed string
- off-line synchronization of AMANDA and IceCube data

# IceTop: The surface air shower array




**IceTop - IceCube**

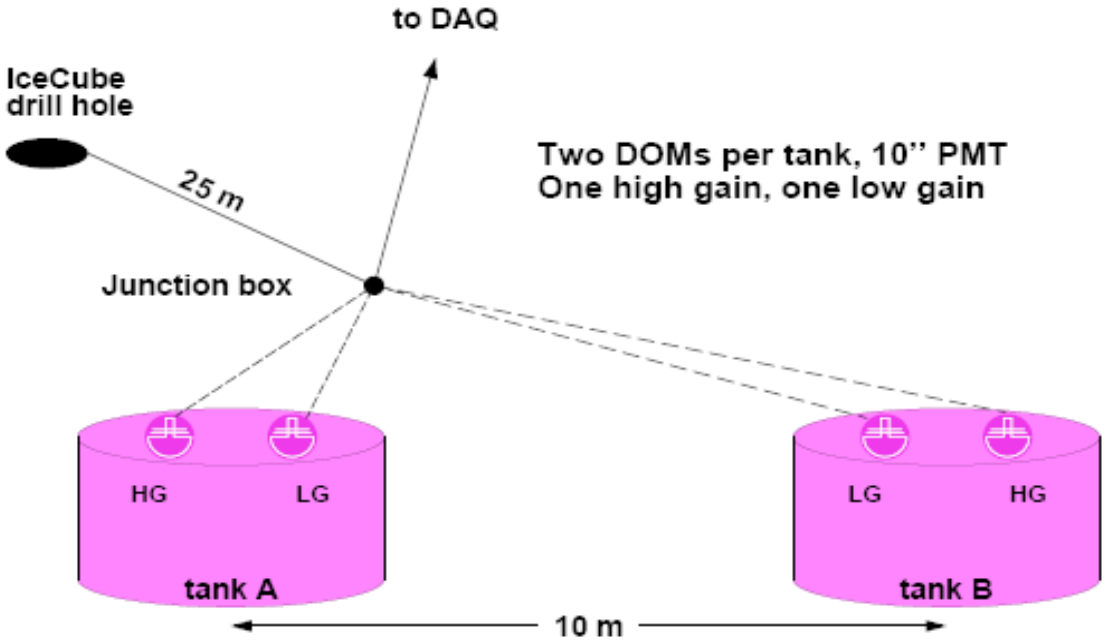
**1.) Calibration and verification of angular resolution and simulations**
**2.) Veto for backgrounds by high energy air showers.**
**3.) Cosmic Ray Physics at energies 1e15 to 1e18 eV: Mass composition, high presicion mass independent energy resolution.**

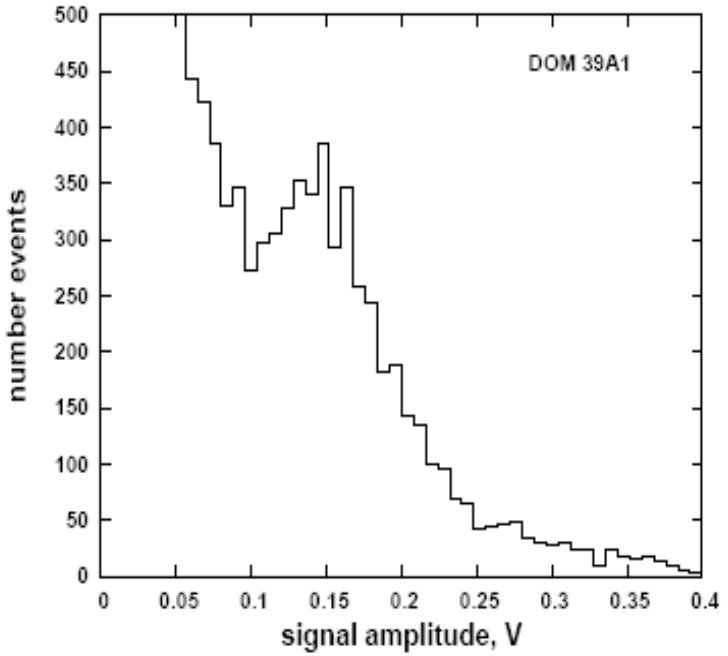
**Concept of the above analyses demonstrated by coincidences between the SPASE-II air shower array and AMANDA-II.**

**8 IceTop tanks (4 pairs) deployed in Dec 2004**
**Total: 160 ice tanks with 2 sensors each.**

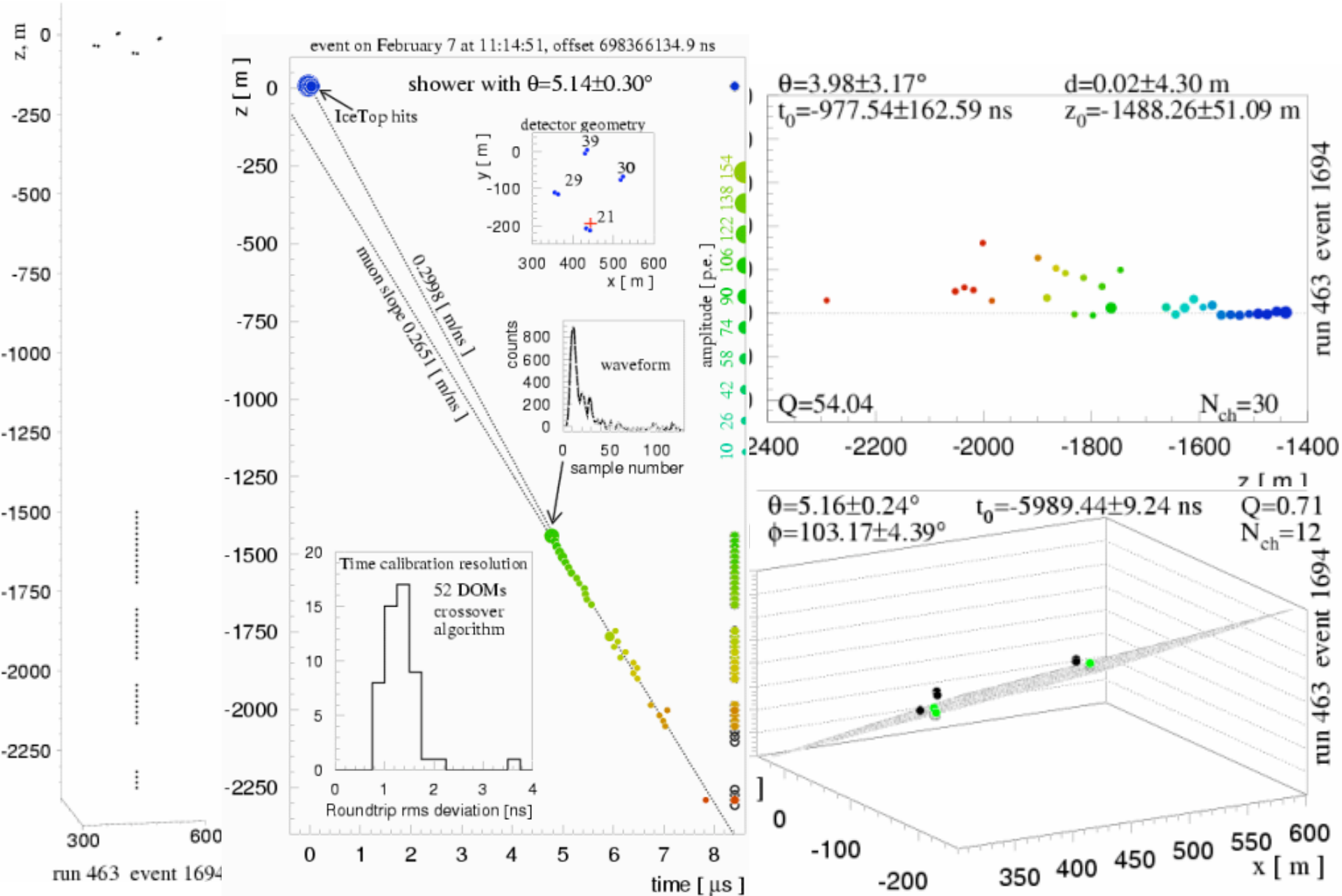
# IceTop

## 8 IceTop tanks (4 pairs) deployed in Dec 2004

# IceCube-IceTop coincident event



# Summary/Conclusions

- AMANDA-II continues to analyze data and improve data analysis.
- IceCube has proved the drilling of more than 10 strings/year is feasible.
- IceTop has demonstrated that 12 stations/year can be built. IceCube is taking science quality data from 76 sensors from one String and 8 tanks - no show stoppers seen.
- Plan to deploy 10 to 12 strings next season, Dec 05/ Jan 06 - a detector larger and better than all of AMANDA II.
- On track with construction of up to 80 strings by 2010.

- The data analysis is already on going and the performance of the sensors, the DOMs are meeting the design specs.