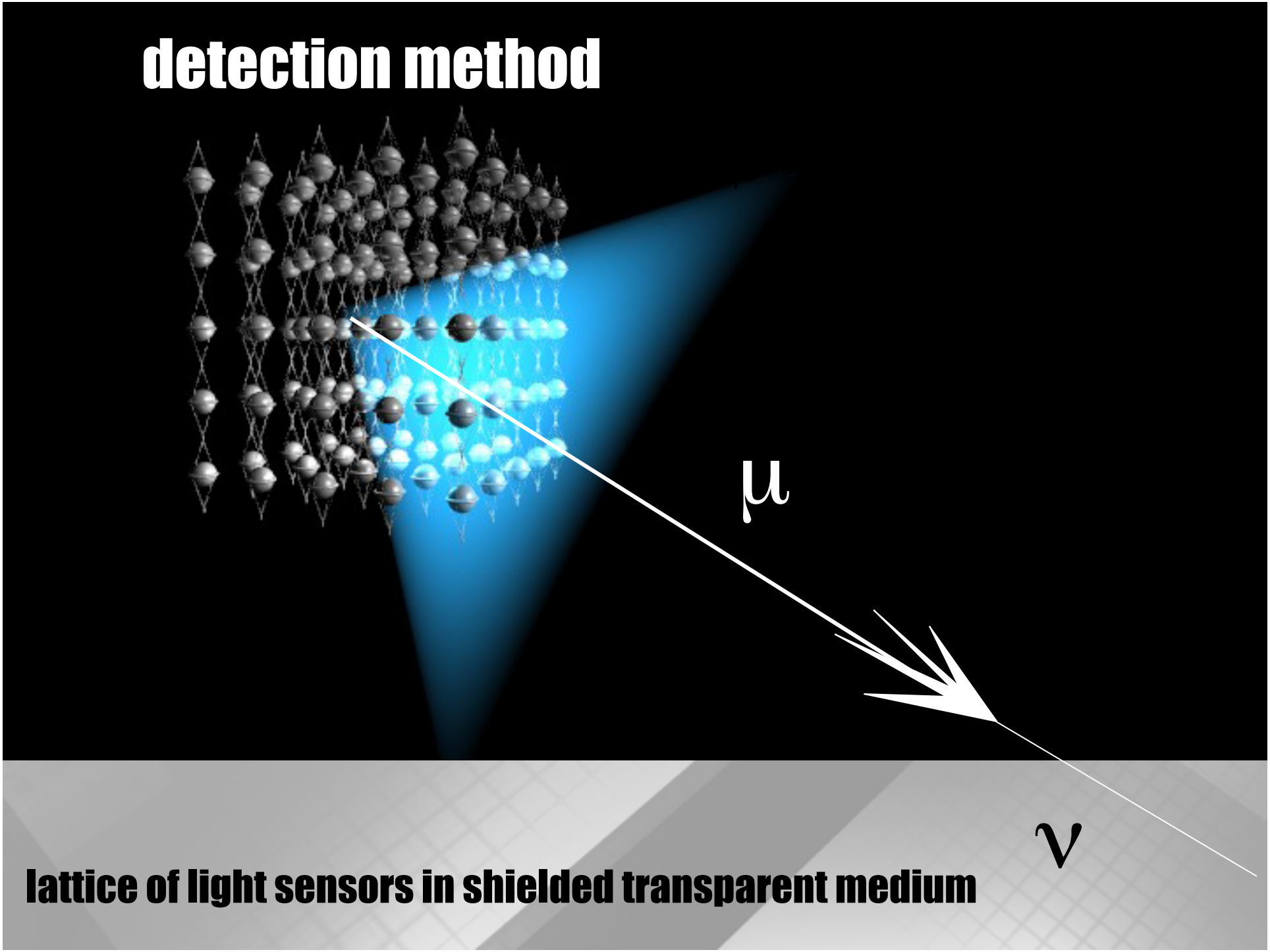
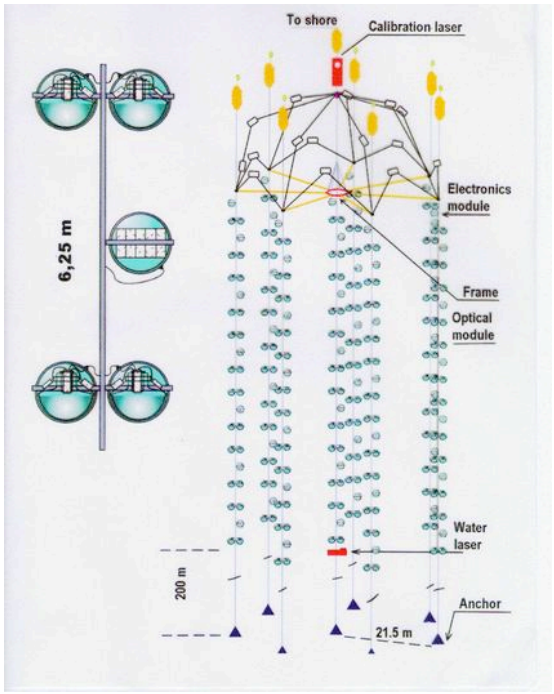
# detection method



# northern hemisphere detectors

## Baikal NT200

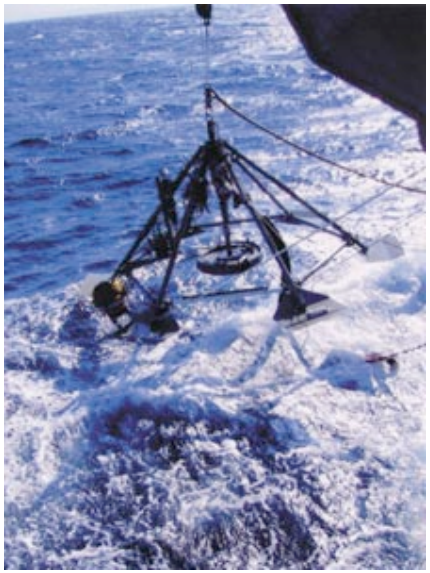



1100 m deep
data taking since 1998
new: 3 distant strings

## Antares

**March 17, 2003**
2 strings connected
2400 m deep
completion: start 2006

## Nestor

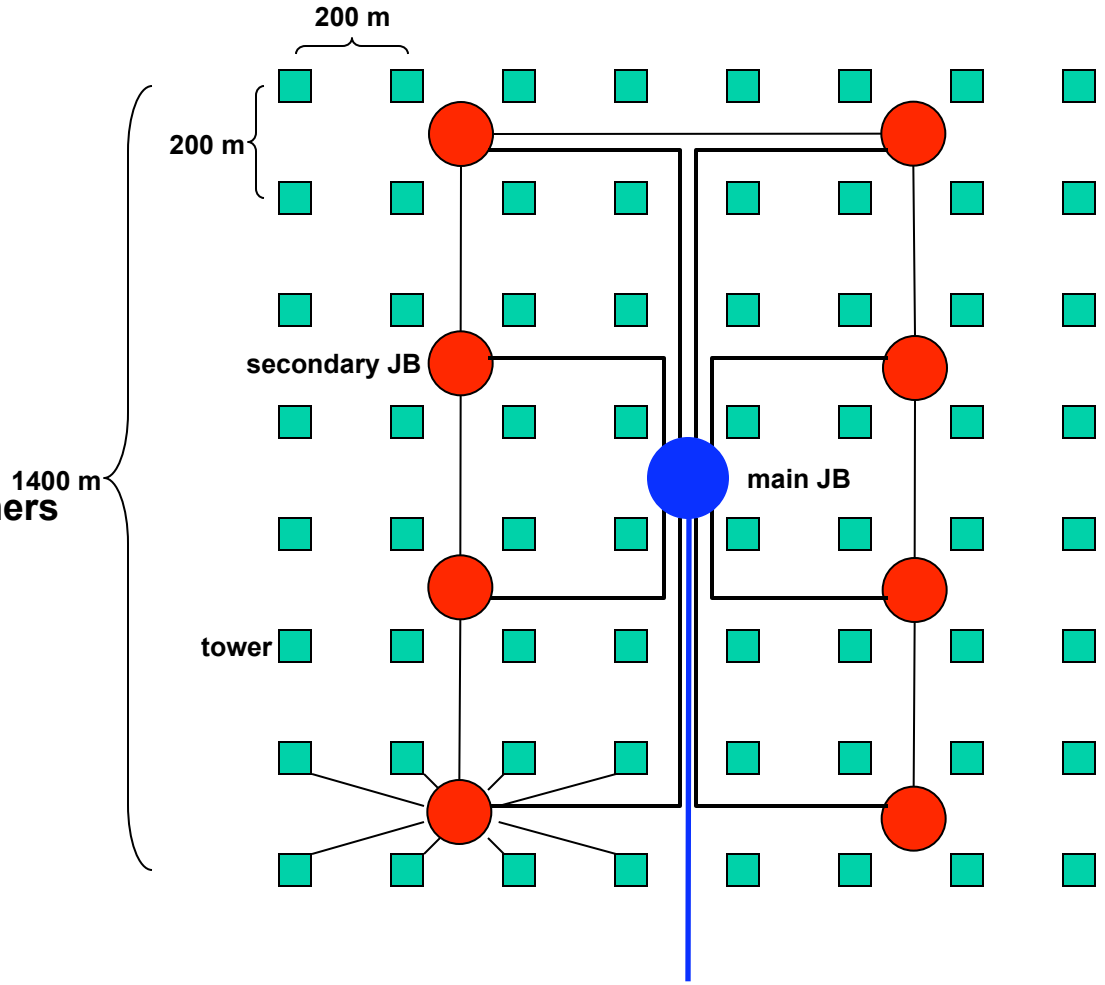


**March 29, 2003**
1 of 12 floors deployed
4000 m deep
completion: 2006

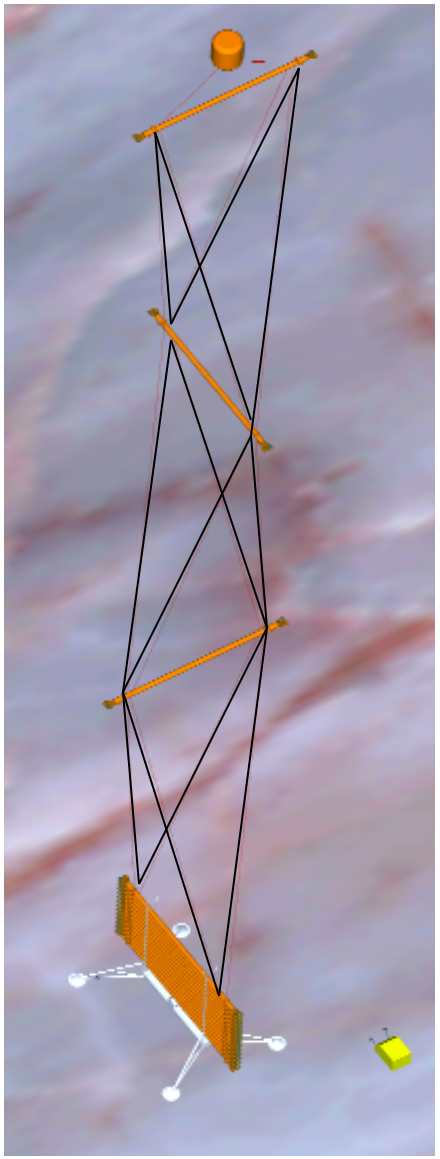
# NEMO

## Actual proposal of general layout for Km$^3$ detector

- n. 1 main Junction Box
- n. 8 secondary Junction Box
- n. 64 towers
- 200 m between each row and the others
- 200 m between each columns and the others
- 16 storeys for each tower
- 64 PMT for each tower
- 4096 PMT

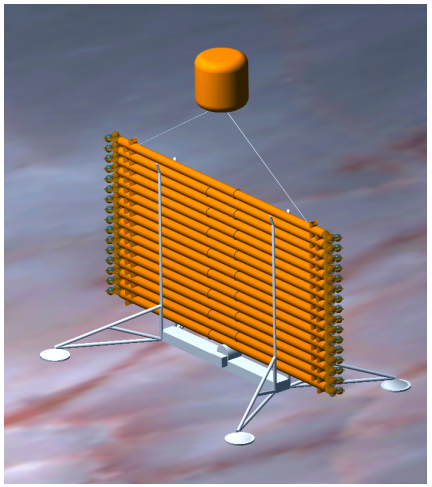


# NEMO



The use of pipes to realize the storeys gives a very low resistance to the water flow.

The largest estimated movement of the upper part of the structure due to the currents are lower than 20m.



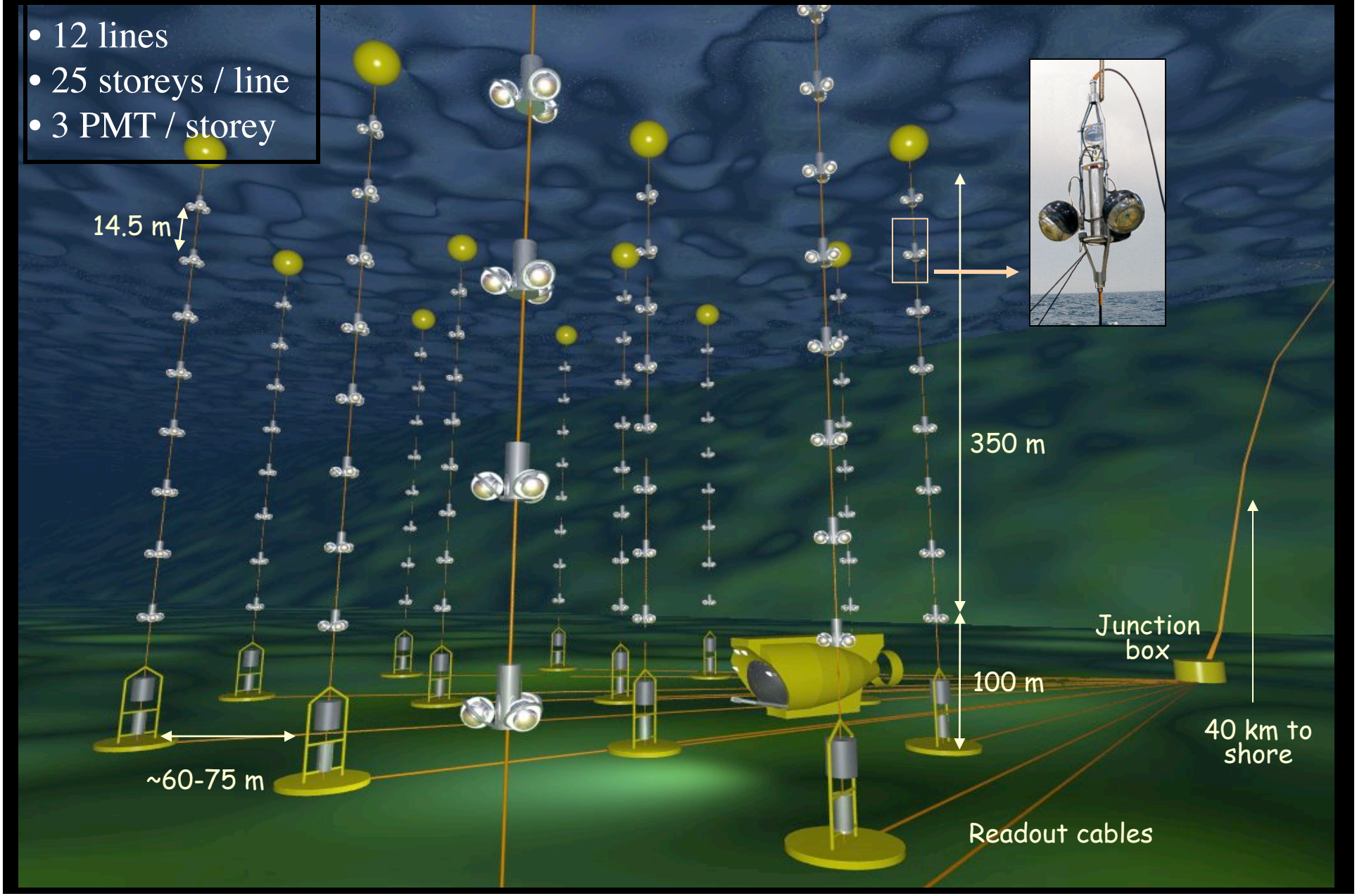
The mechanical stresses on the rigid part of the structure are:

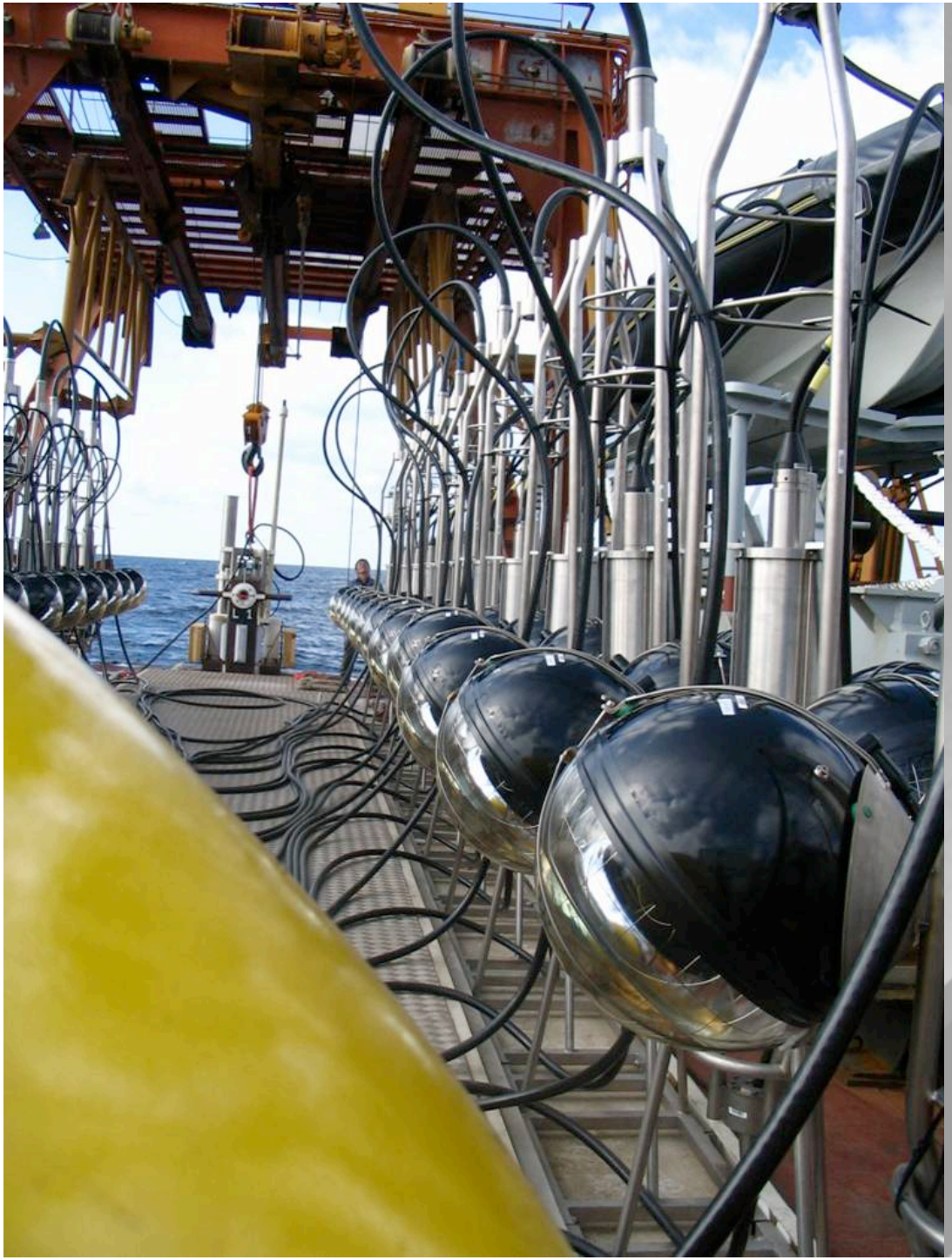
- a bending due to the weight of the spheres when it is out of the sea water;
- an axial load during the useful life due to the draught of the upper buoy.

The electro optical cables can be easily fixed on the ropes.

During the deployment the main ropes can be kept in position on the pipes by means of small breakable ropes.

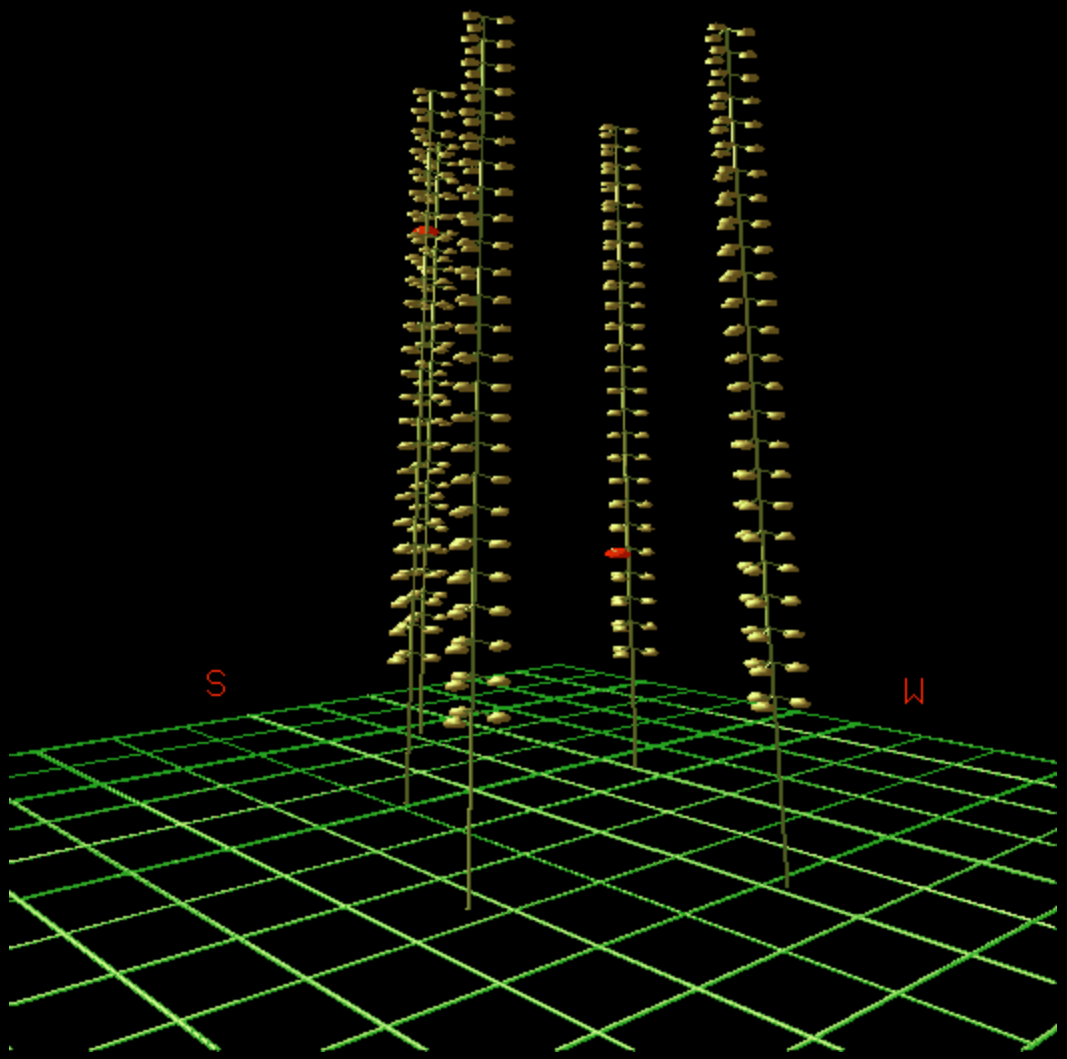
# ANTARES : a 1950's proposal becoming reality



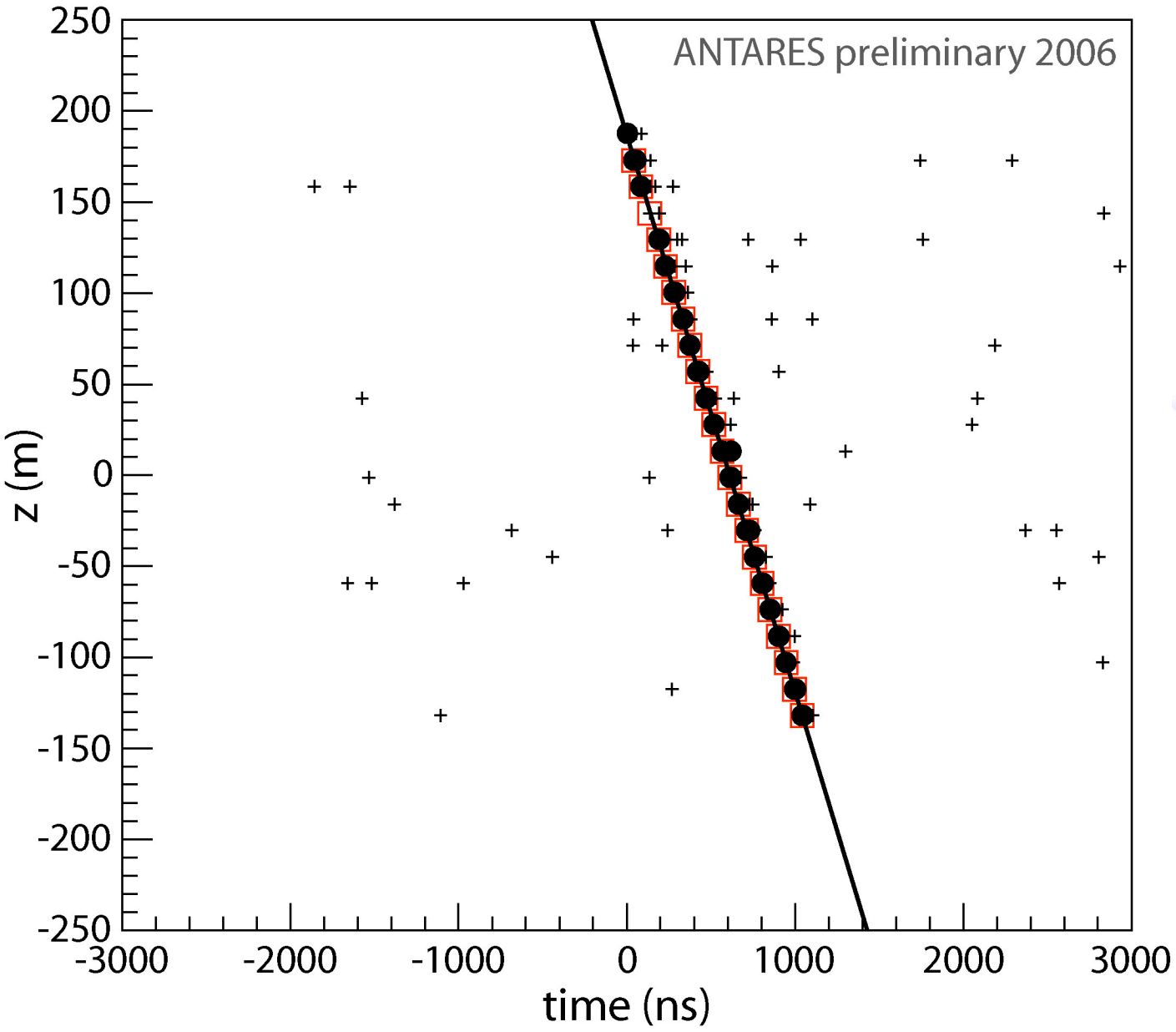


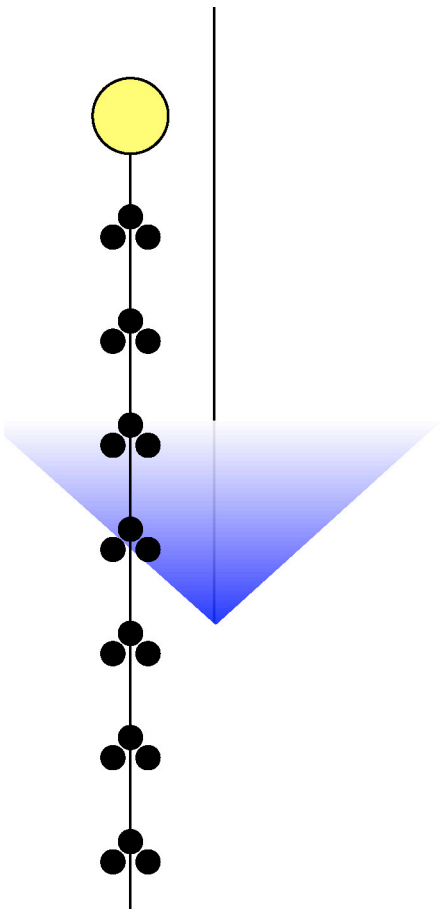
# ANTARES

# antares



# Downgoing muon



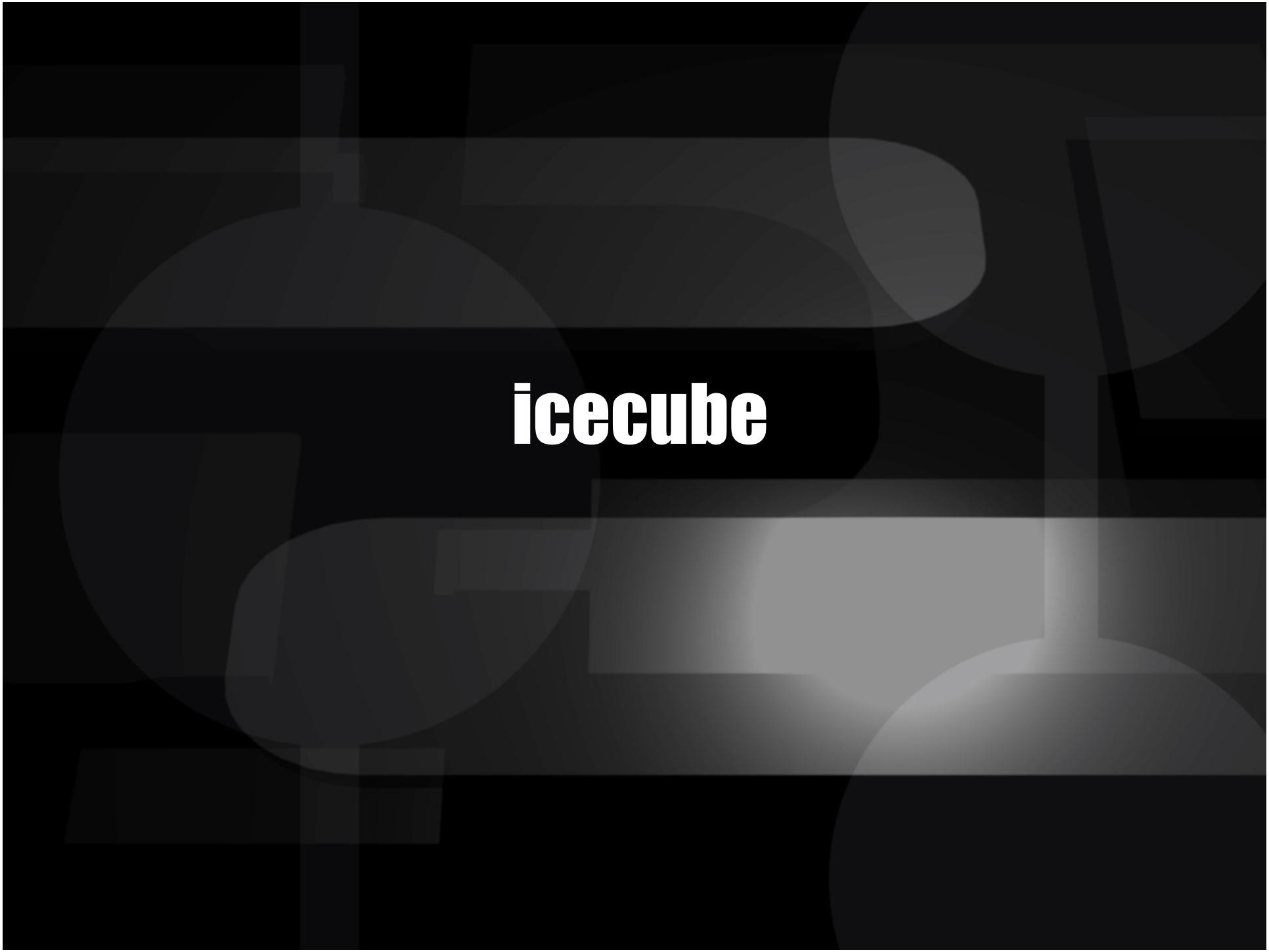



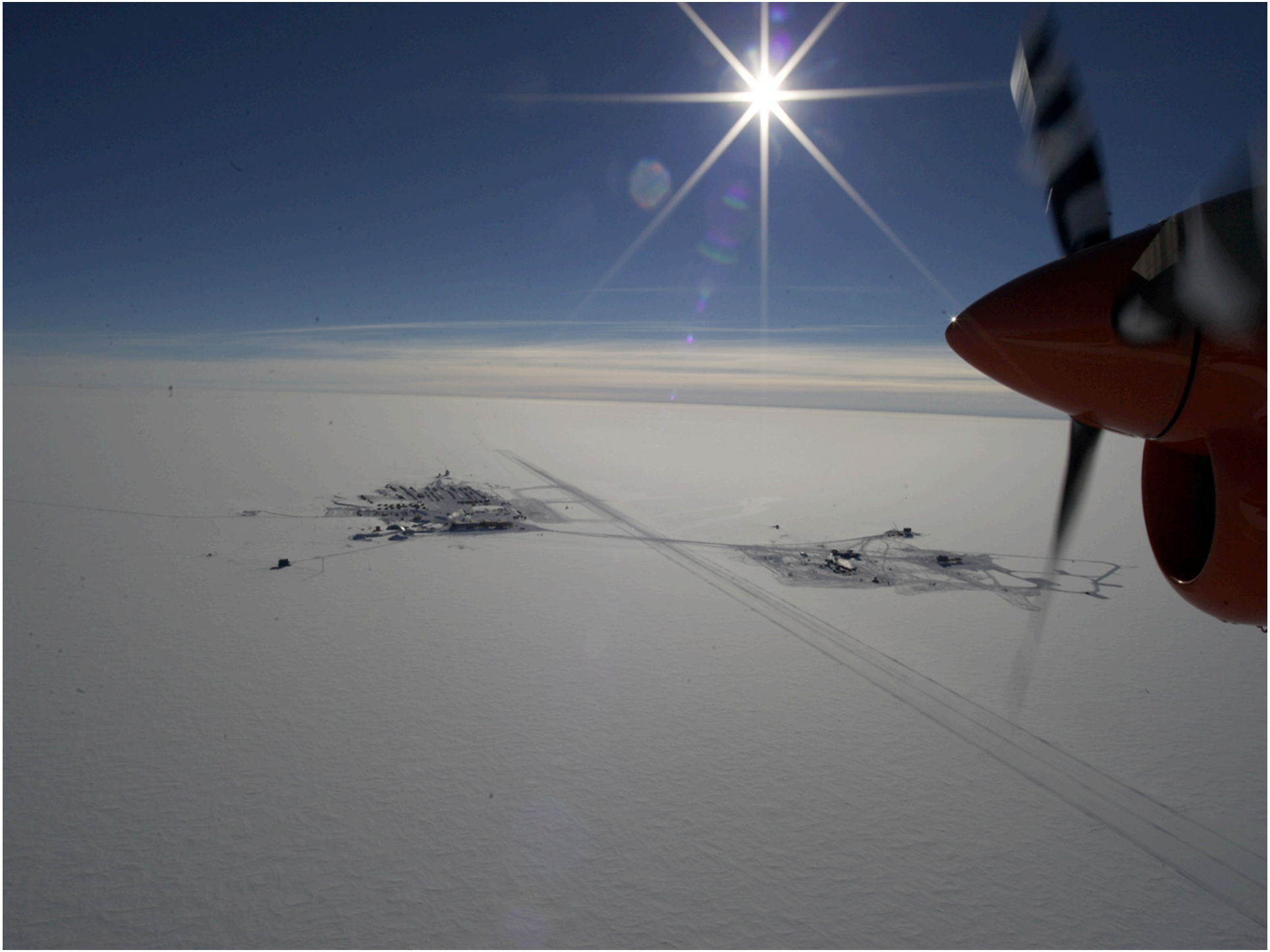
| | IceCube | AMANDA-II | ANTARES |
|---|---|---|---|
| # OF PMTS | 4800/10 INCH | 600/8 INCH | 900/10 INCH |
| point source sensitivity (muons per year) | 5 x $10^{-17}$ $cm^{-2}$ $s^{-1}$ | 1.4 x $10^{-15}$ $cm^{-2}$ $s^{-1}$ weakly dependent on declination | 0.4--5 x $10^{-15}$ $cm^{-2}$ $s^{-1}$ depending on declination |
| diffuse limit* (muons per year) | 1~3 x $10^{-9}$ GeV $cm^{-2}$ $s^{-1}$ $sr^{-1}$ | $10^{-7}$ GeV $cm^{-2}$ $s^{-1}$ $sr^{-1}$ | 0.8 x $10^{-7}$ GeV $cm^{-2}$ $s^{-1}$ $sr^{-1}$ |

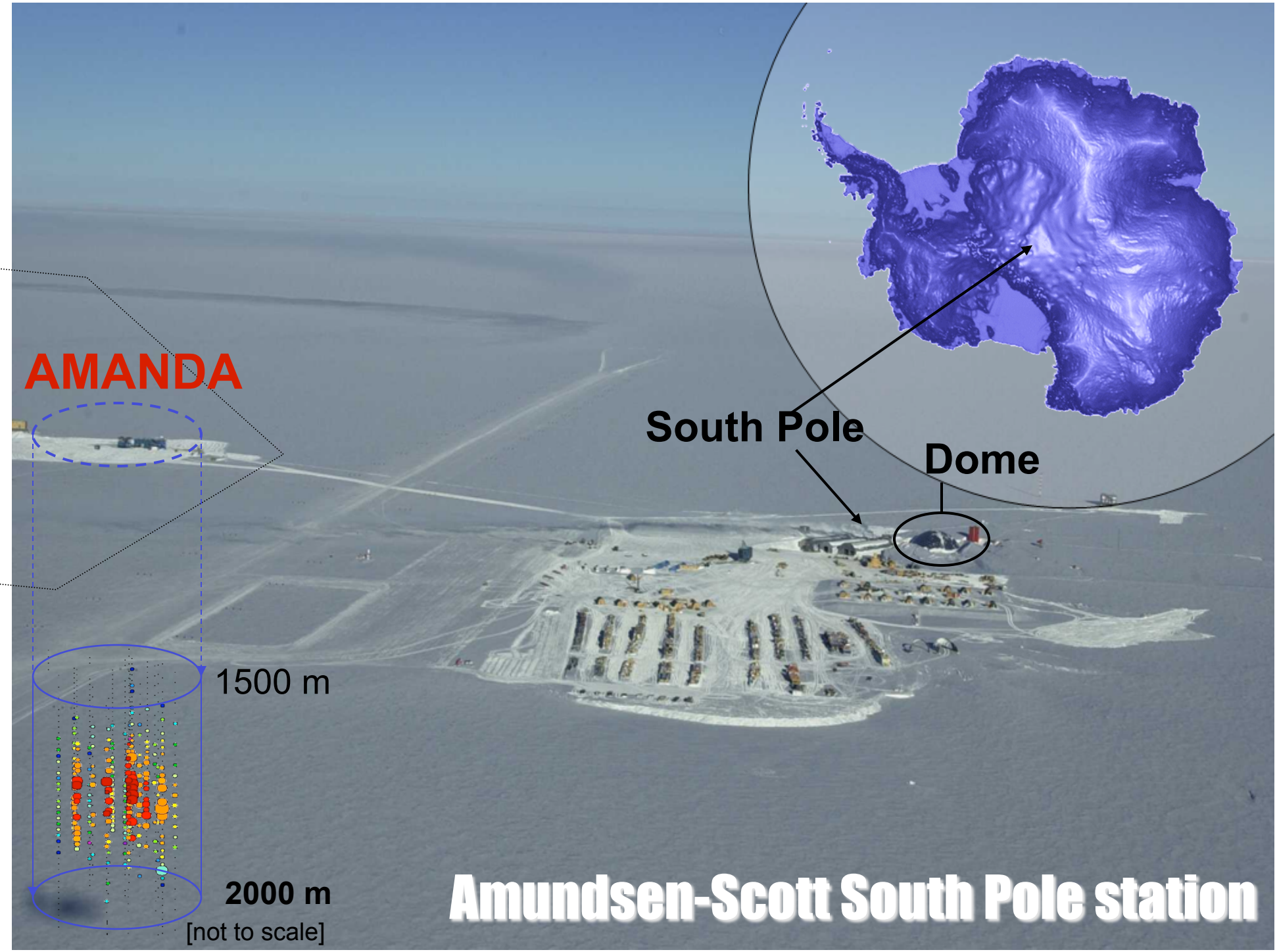
* Depends on assumption for background from atmospheric neutrinos from charm

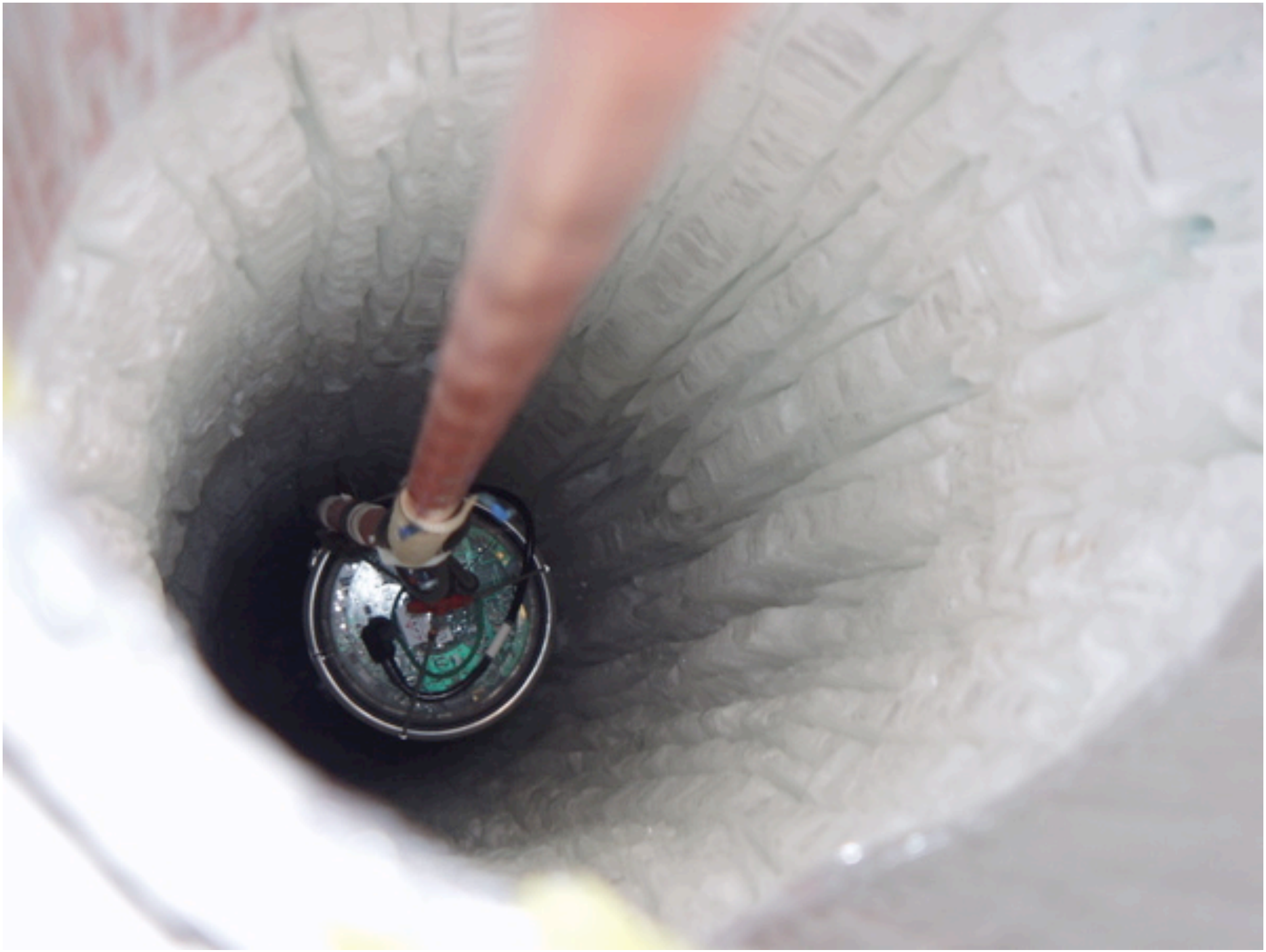
# effective telescope area at 100 TeV

- AMANDA ~ ANTARES ~ 5 $m^2$
- IceCube 23 strings (now) ~ 30 $m^2$
- IceCube 80 strings (final) ~ 100 $m^2$


icecube




AMANDA
South Pole
Dome
1500 m
2000 m
[not to scale]
Amundsen-Scott South Pole station

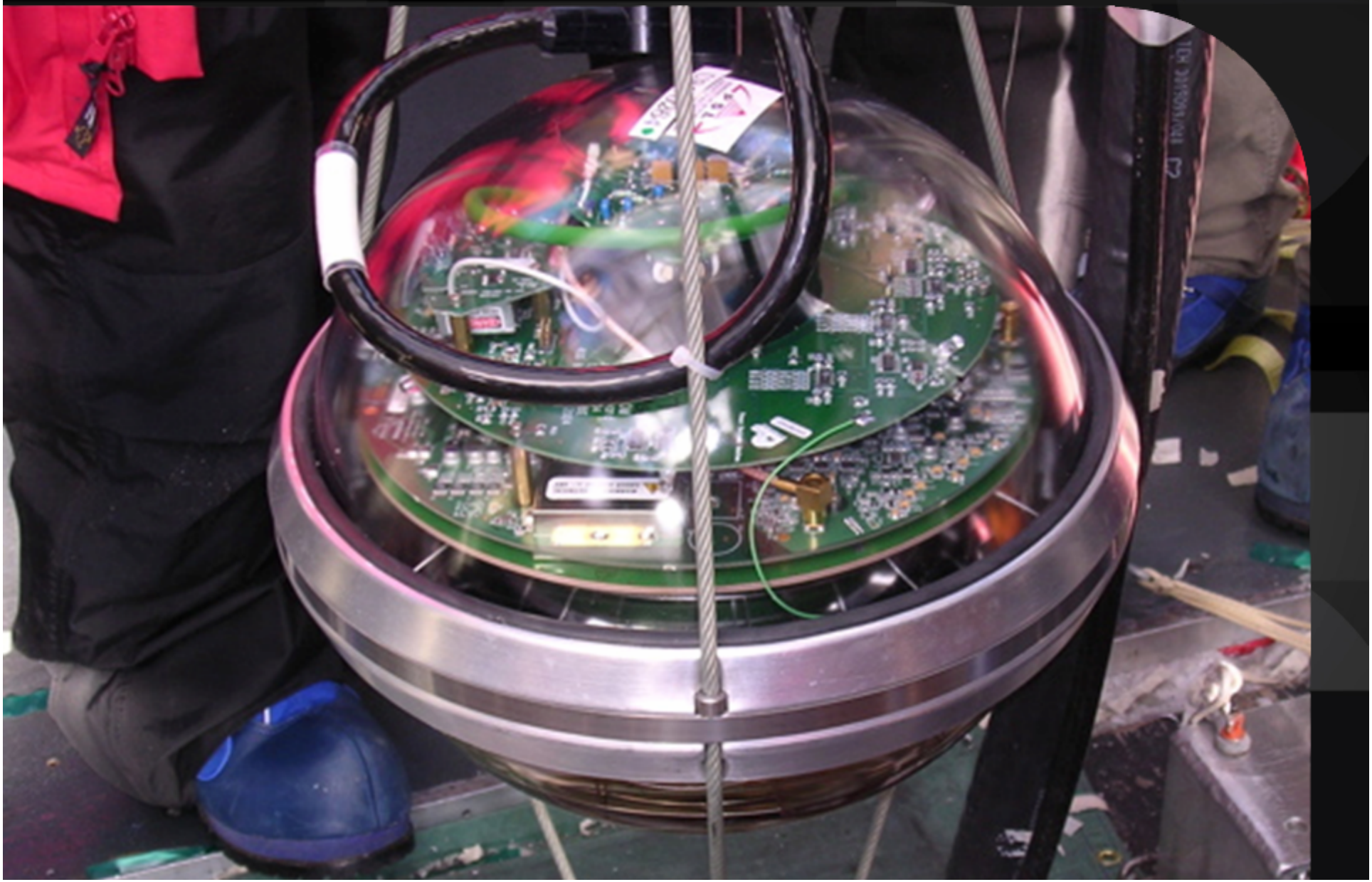


# Building AMANDA

## Drilling Holes with Hot Water


## The Optical Module

# optical sensor



# AMANDA vs. IceCube

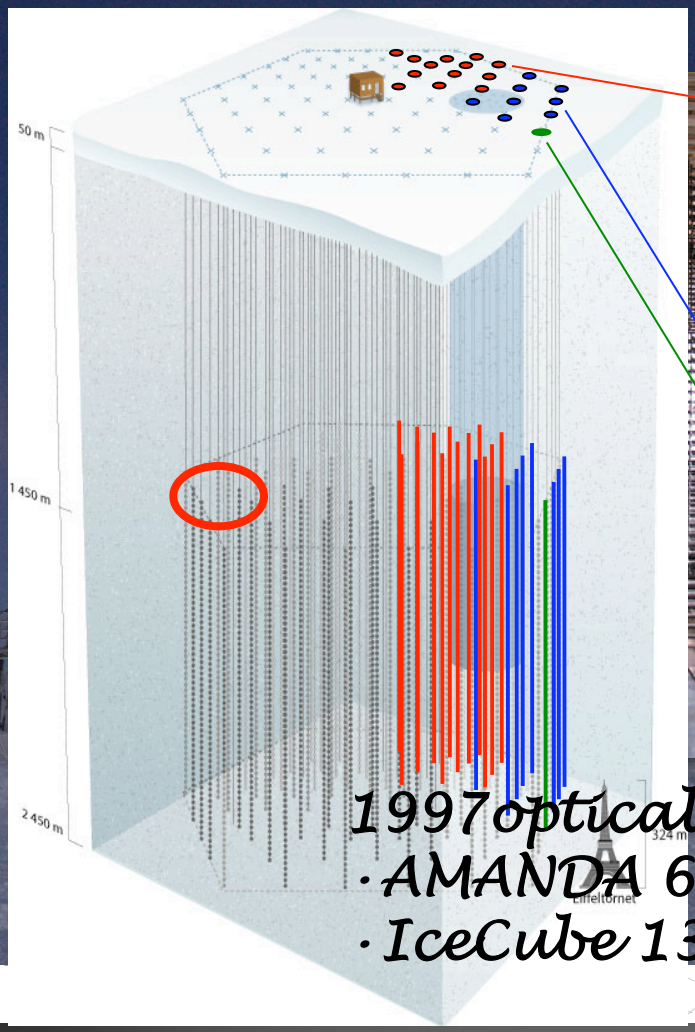
| | |
|---|---|
| Analog signals to surface | In-ice signal digitization |
| ADC/TDC | Full Waveform recording |
| Saturation for multiple p.e. signals | Larger dynamic range |
| 1 ms deadtime | No deadtime |
| Hardware Trigger | Software Trigger |
| Depth ~ 1500-2000m | Depth 1450-2450 m |
| String spacing<br>Vertical: 10-20 m<br>Horizontal: 55-75 m | String Spacing<br>Vertical: 17 m<br>Horizontal: 125 m |
| Instrumented Volume .015 $km^3$ | Instrumented Volume ~ 1 $km^3$ |

**IceCube is both larger and technologically superior**

# IceCube deployments

Compl… …uary 2007

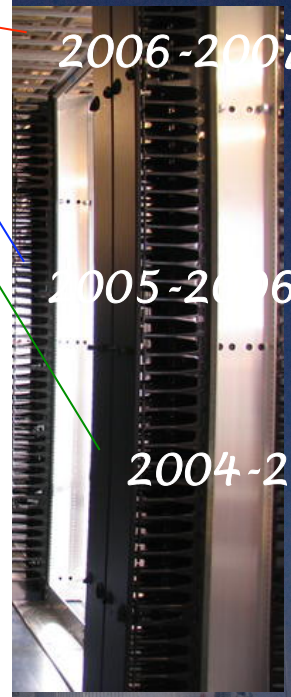
- 80 strings
  60 modules
each
- 17m between modules
- 125m between strings
- 1 km³ ; ~1GTon



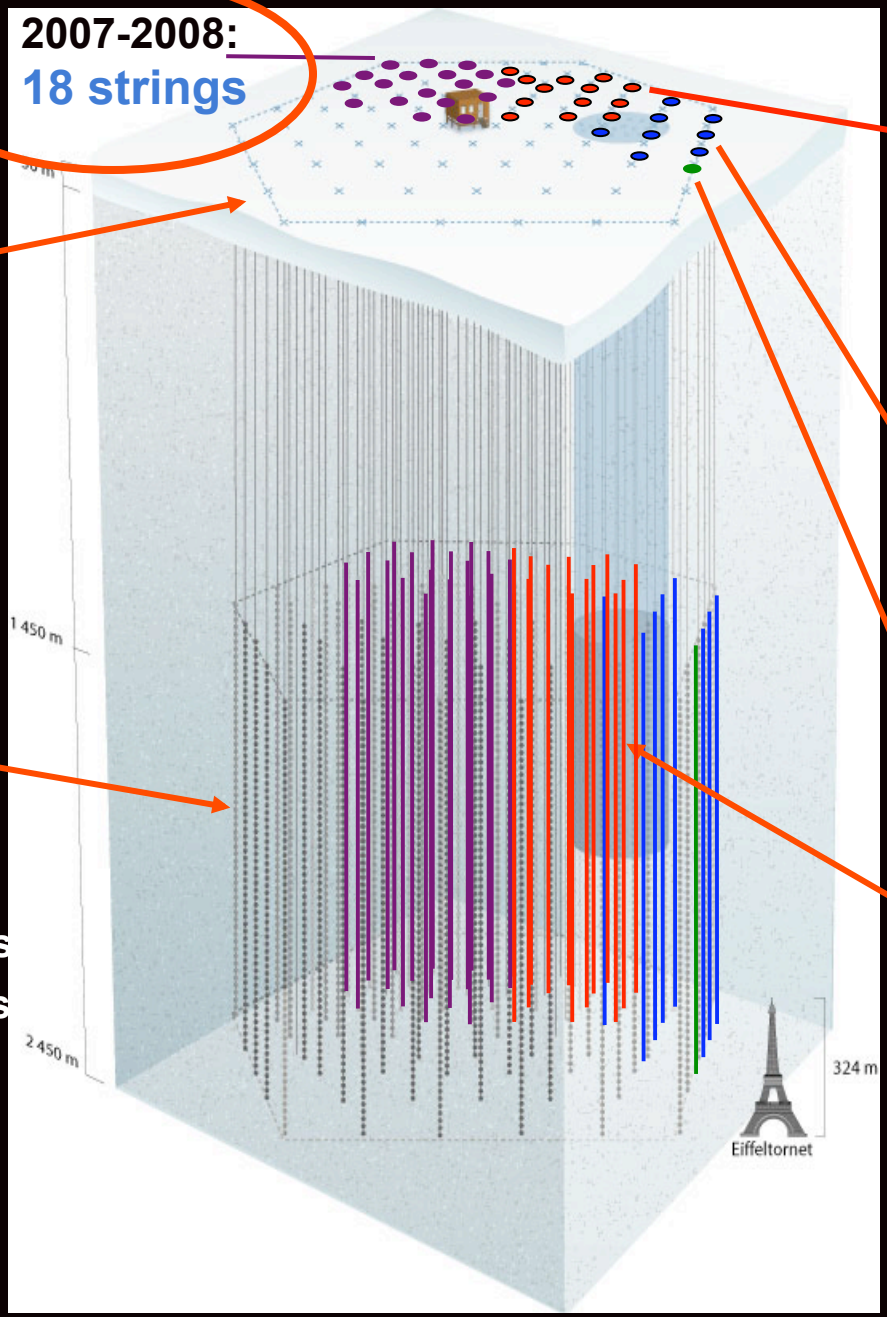

2006-2007: 13 strings

2005-2006: 8 strings

2004-2005 : 1 string



1997optical modules in ice:
·AMANDA 677
·IceCube 1320




**IceTop**

Air shower detetor

threshold ~ 300 TeV

**InIce**

70-80 Strings ,

60 Optical Modules

17 m between Modules

125 m between Strings

2006-2007:
13 Strings

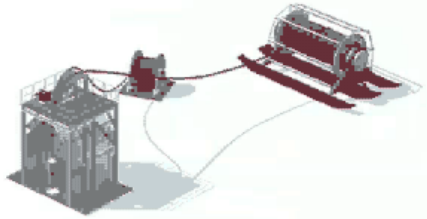
2005-2006: 8 Strings

2004-2005 : 1 String

**AMANDA**

19 Strings

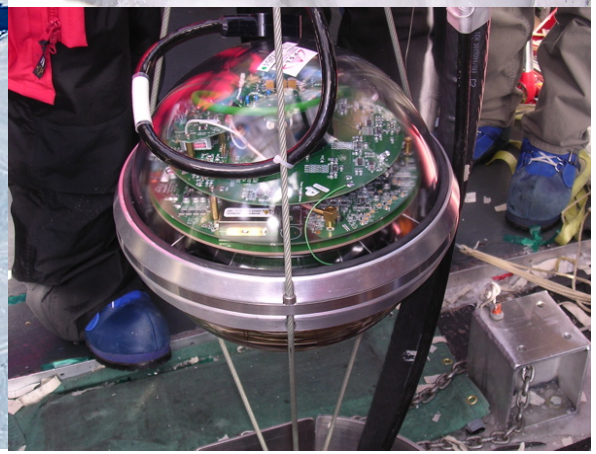
677 Modules



# IceCube construction

**5 megawatt hot water drilling system**

# IceCube construction

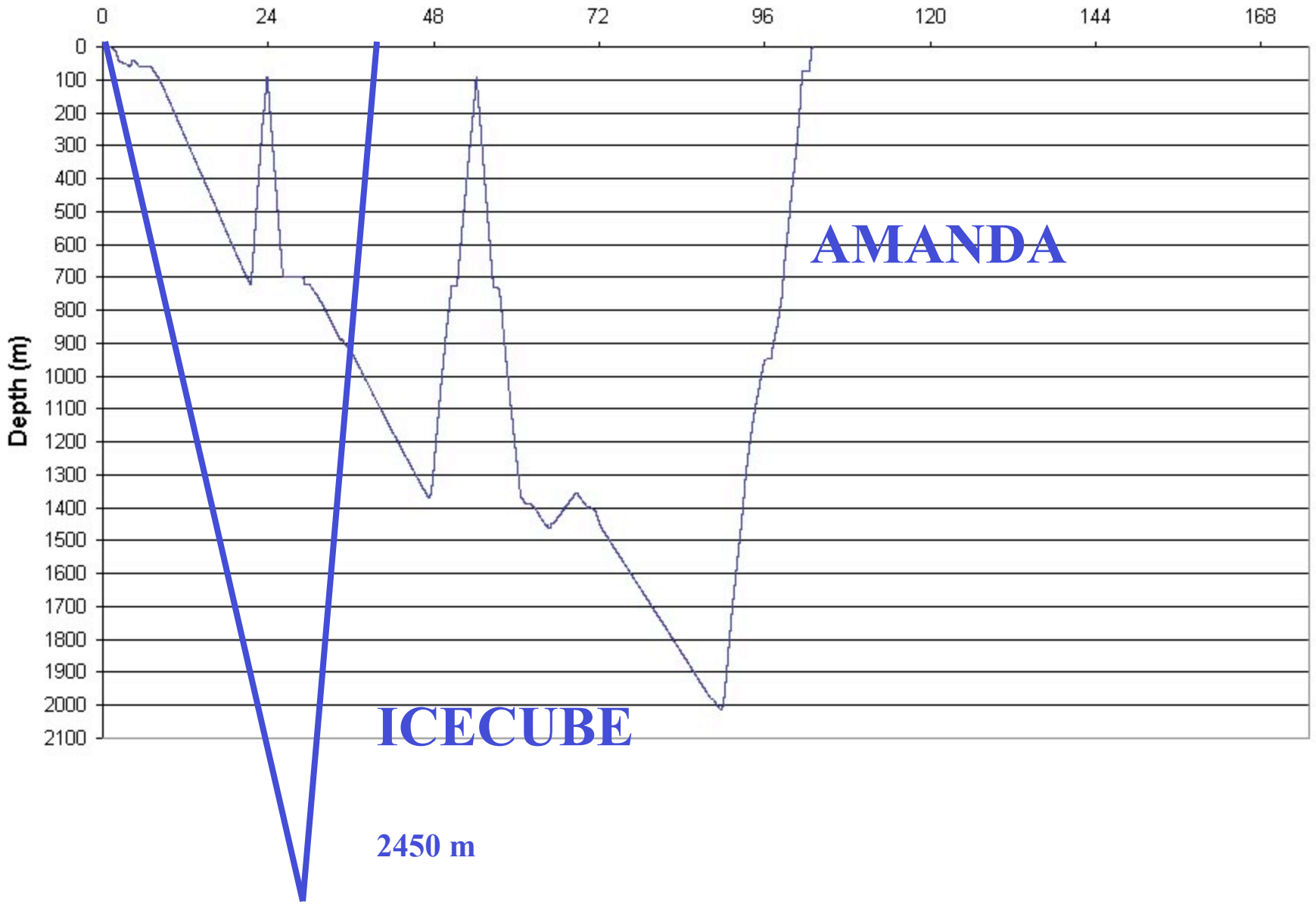


- 1 million pounds of cargo
- C-130 planes: > 50 flights

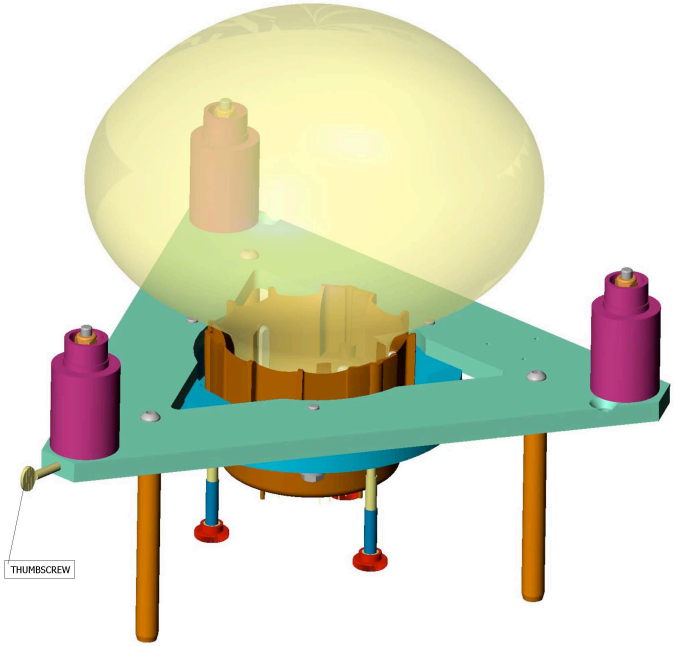
# one of 21 drill modules arrive in antarctica

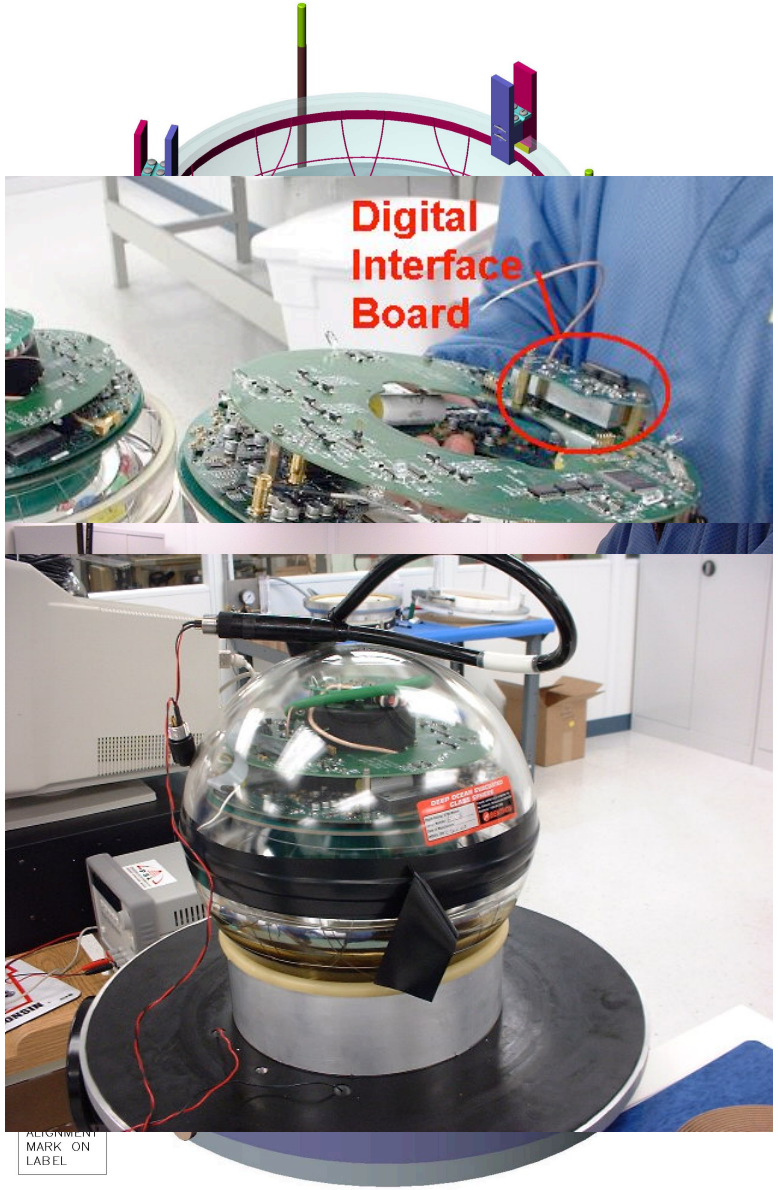

# 5 megawatt hot water drilling system

# AMANDA String 19 drilling time (h)



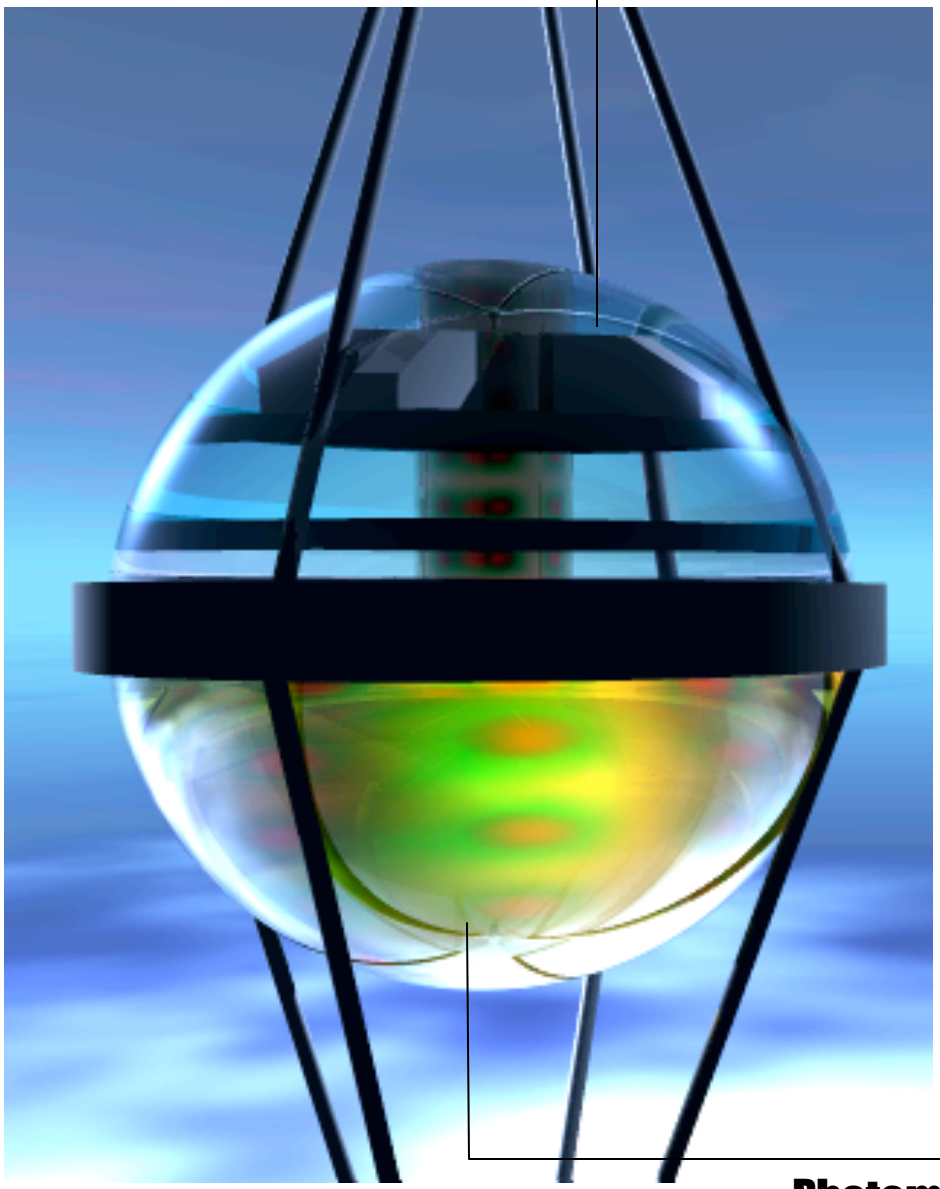
# DOM Assembly

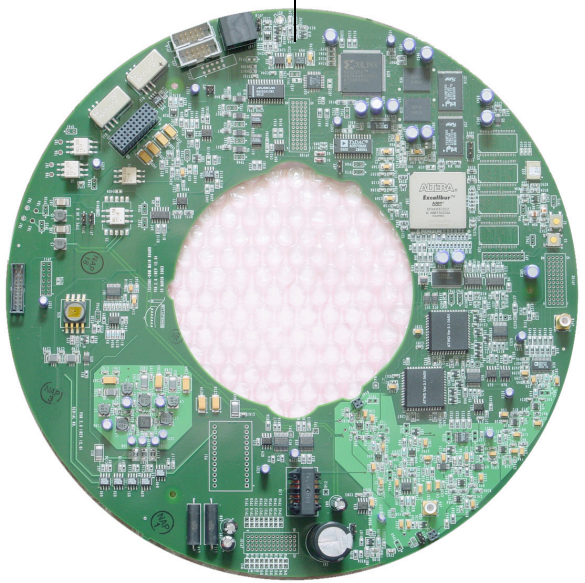



| DOMs Shipped to Pole | |
|---|---|
| Year | # DOMs |
| 2004 | 270 |
| 2005 | 701 |
| 2006 | 900 |

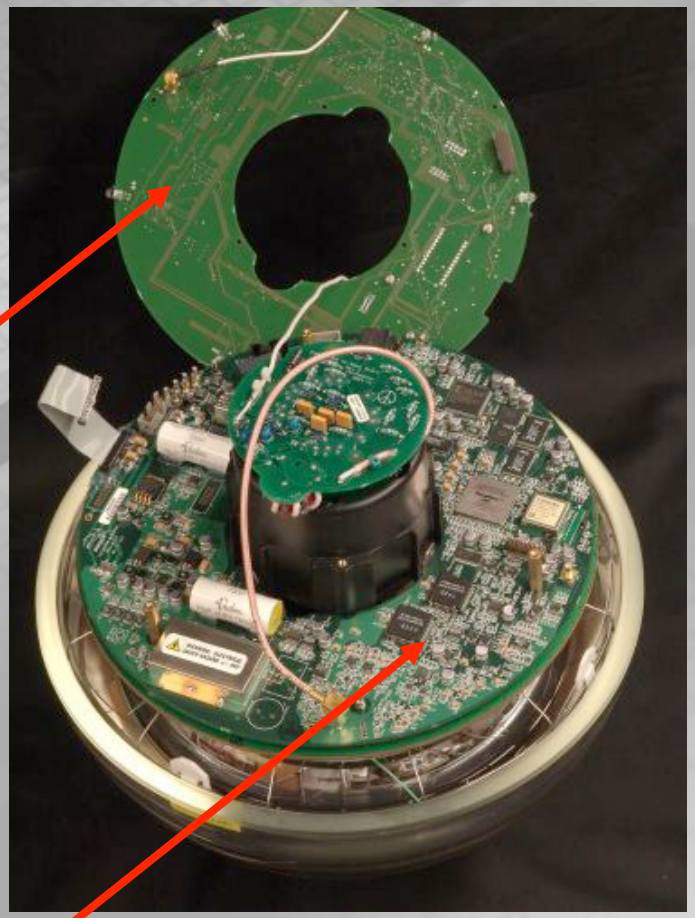
Digital Optical Module





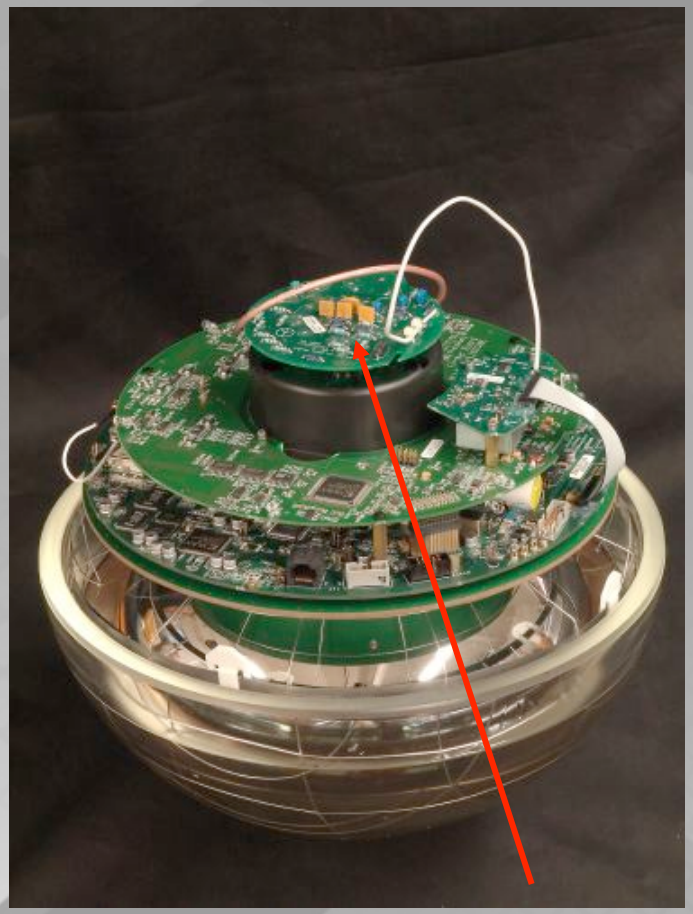
Photomultiplier Tube

# Digital Optical Module



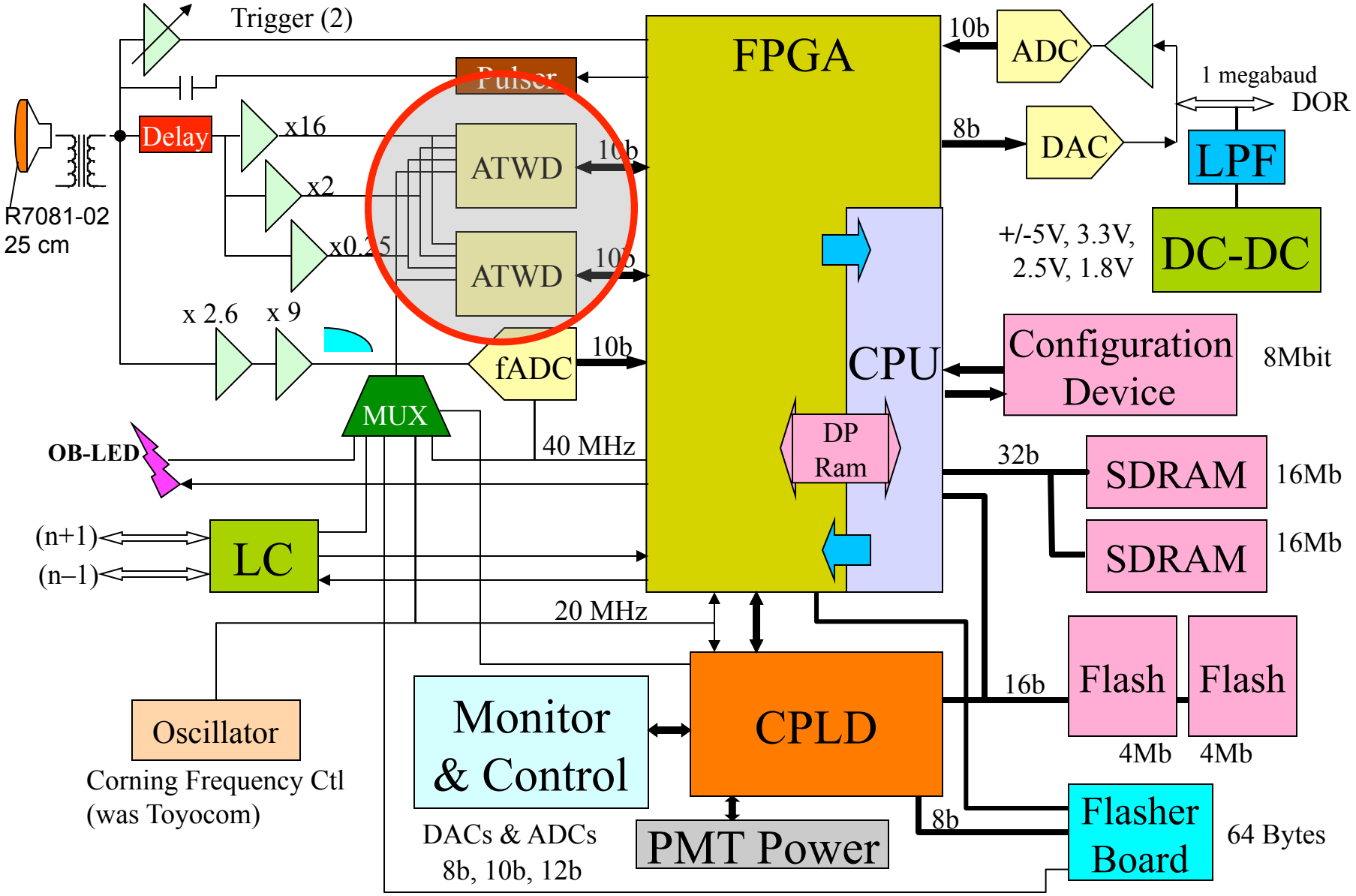
LED flasher board

main board

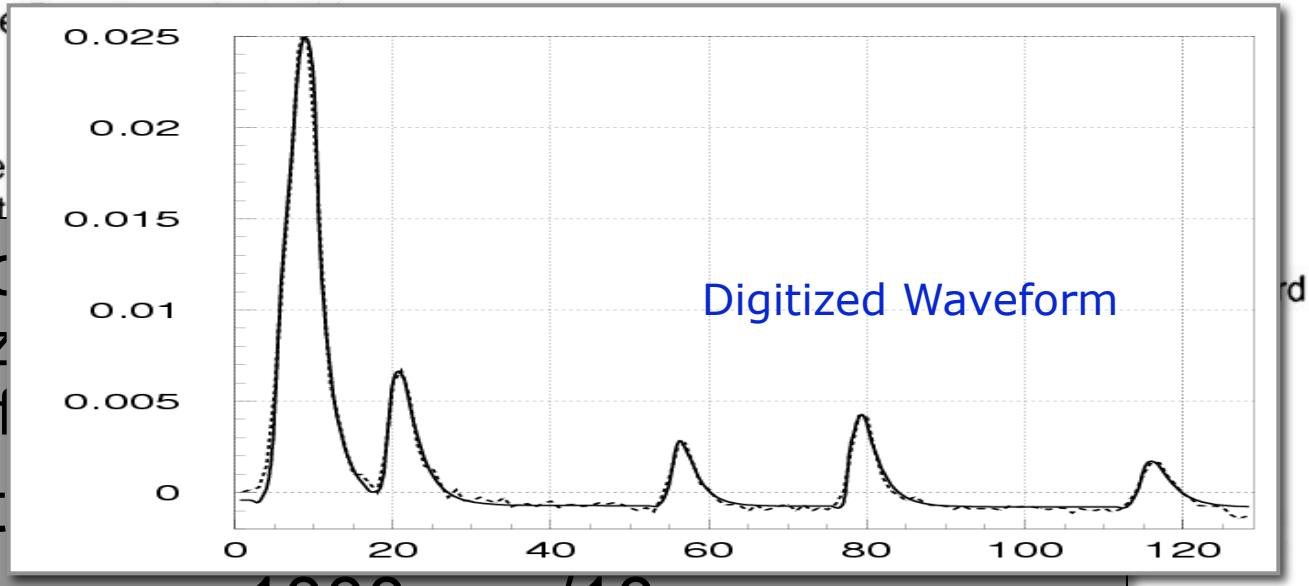


HV board

# DOM MB Block diagram

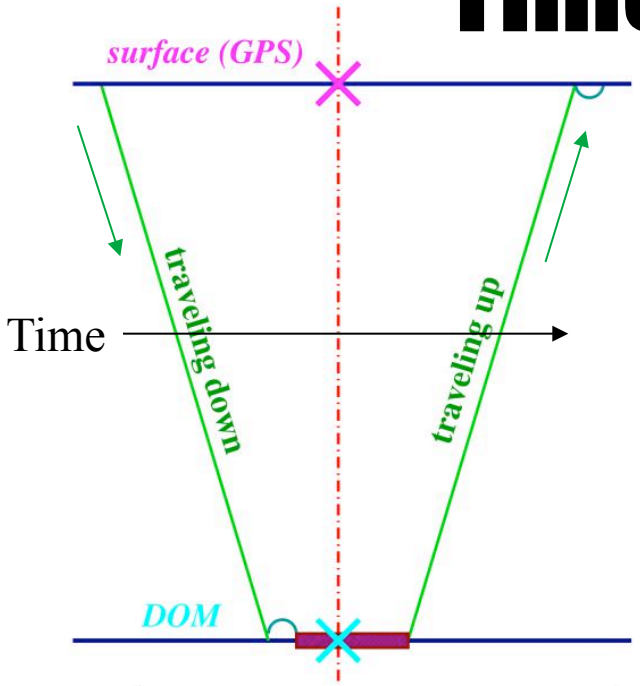


# The Digital Optical Module (DOM)

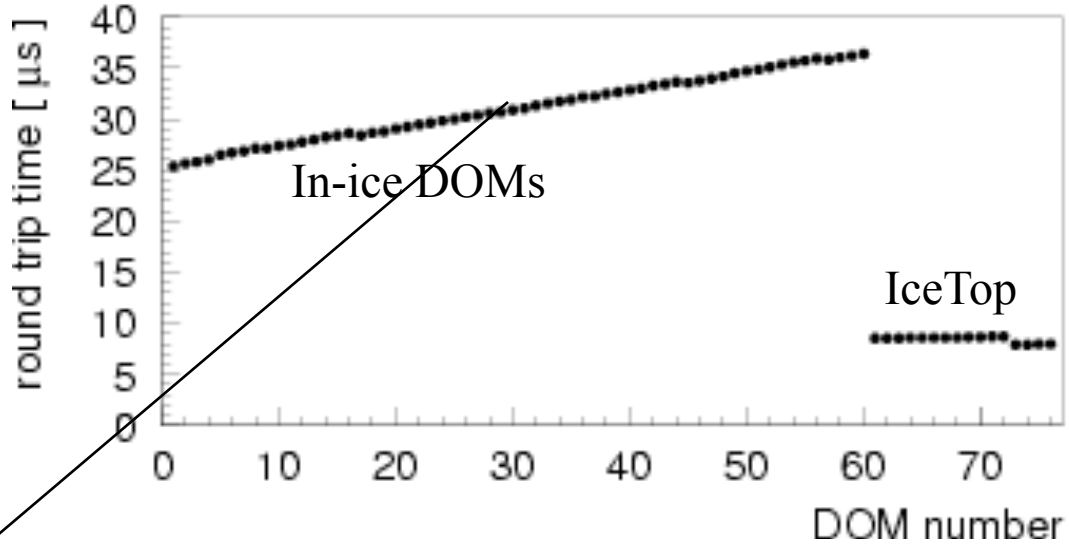


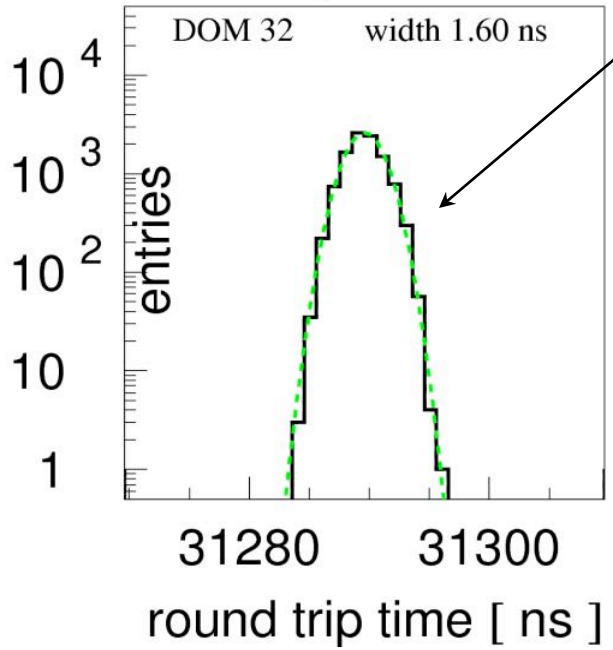

- Onboard c
  - 300 MHz
  - 40 MHz f
- Absolute t
- Dynamic range ~1000 p.e./10 ns
- Deadtime < 1%
- Noise rate ~700 Hz (260 Hz w/ artif. deadtime)
- Failure rate < 1%

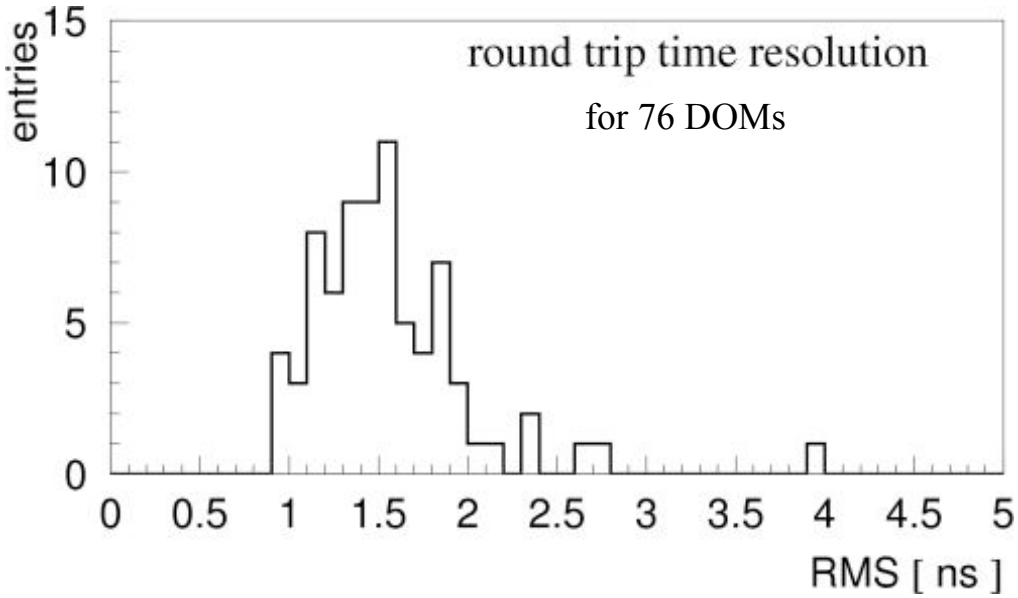
# Time Calibration



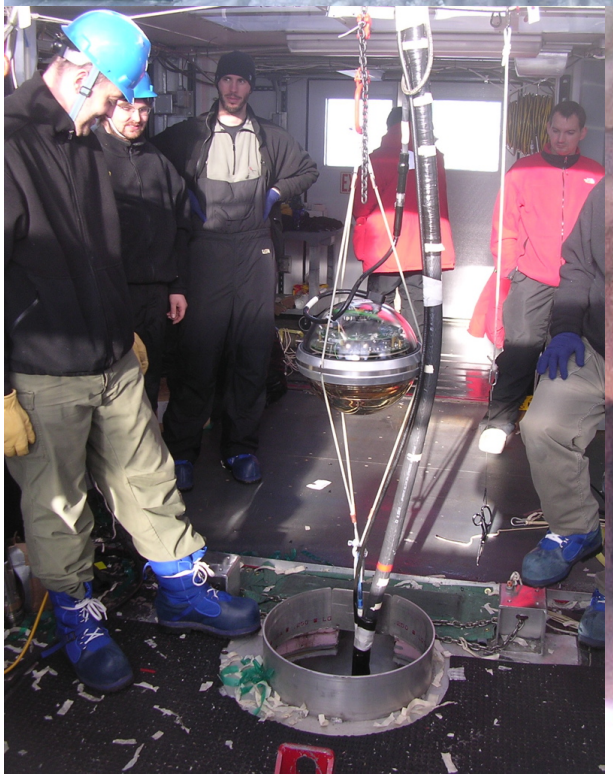

automatic, every few seconds

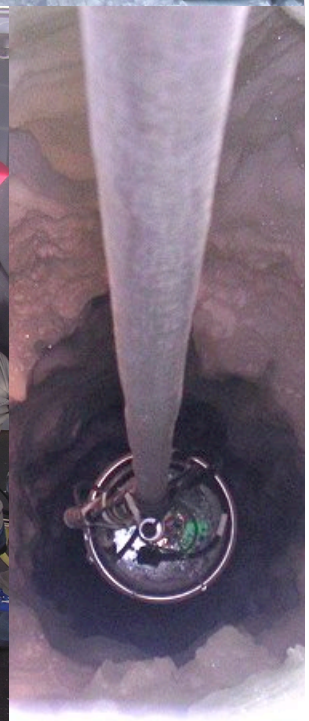


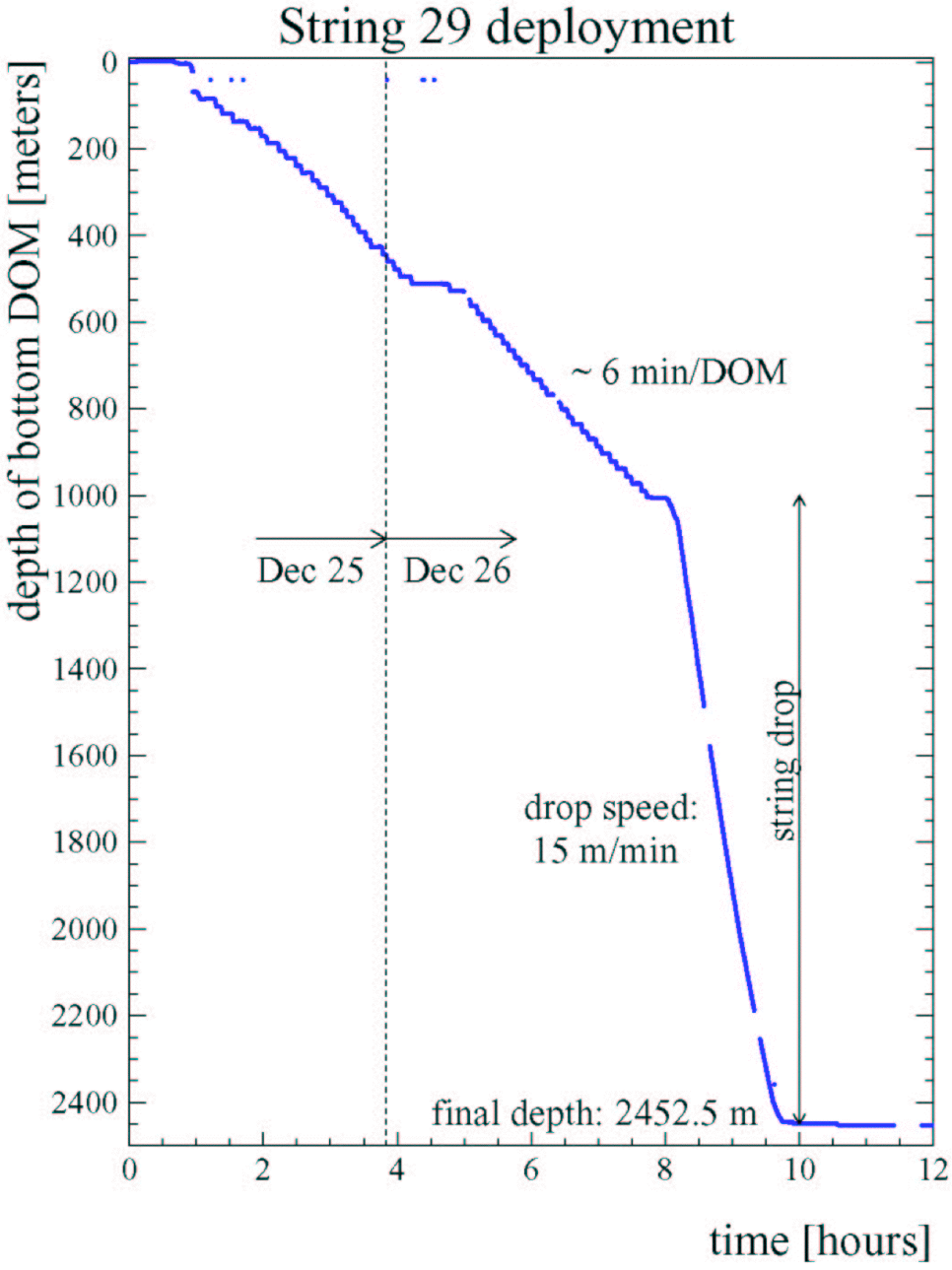



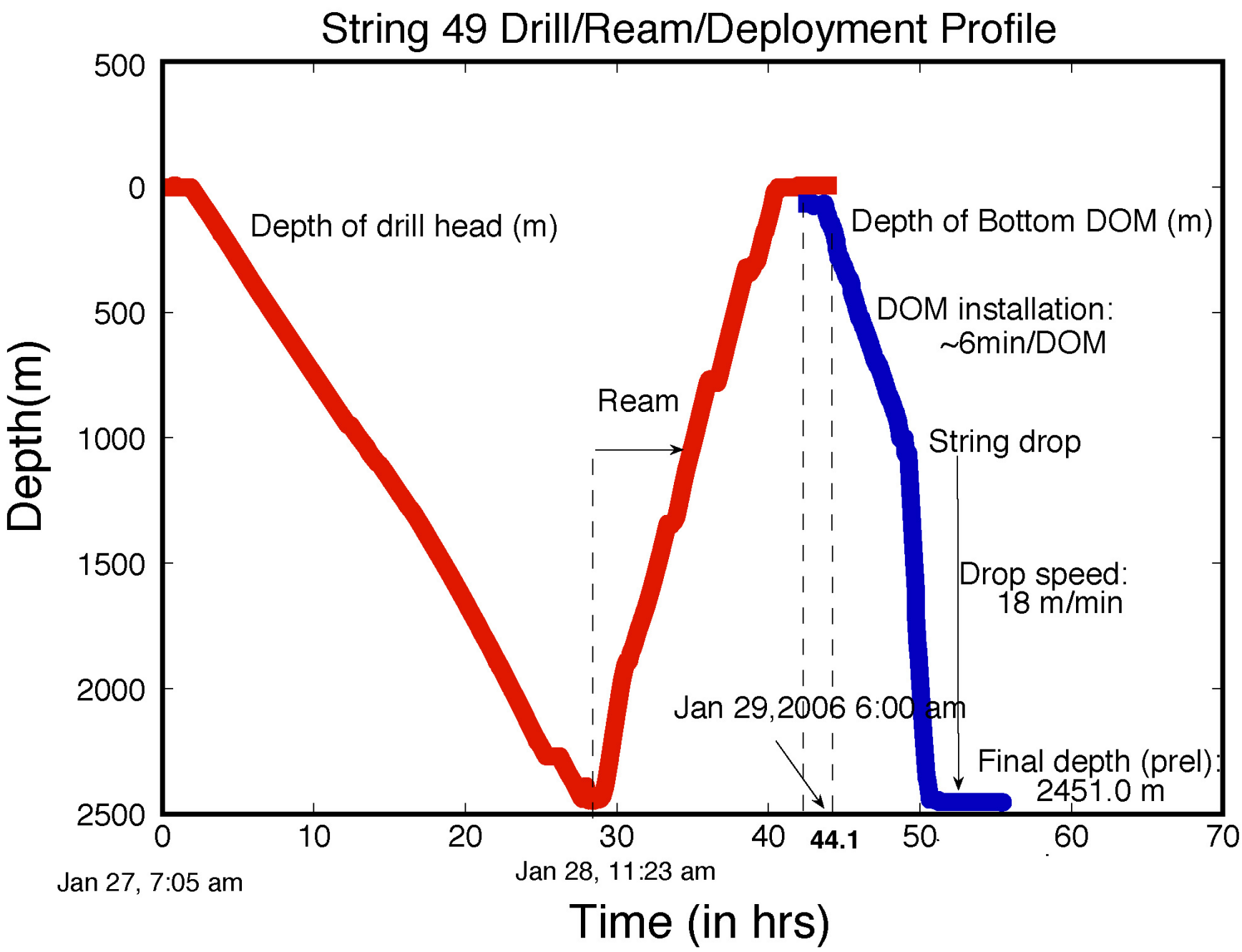



String cable 2500 m  Weight ~6 tons

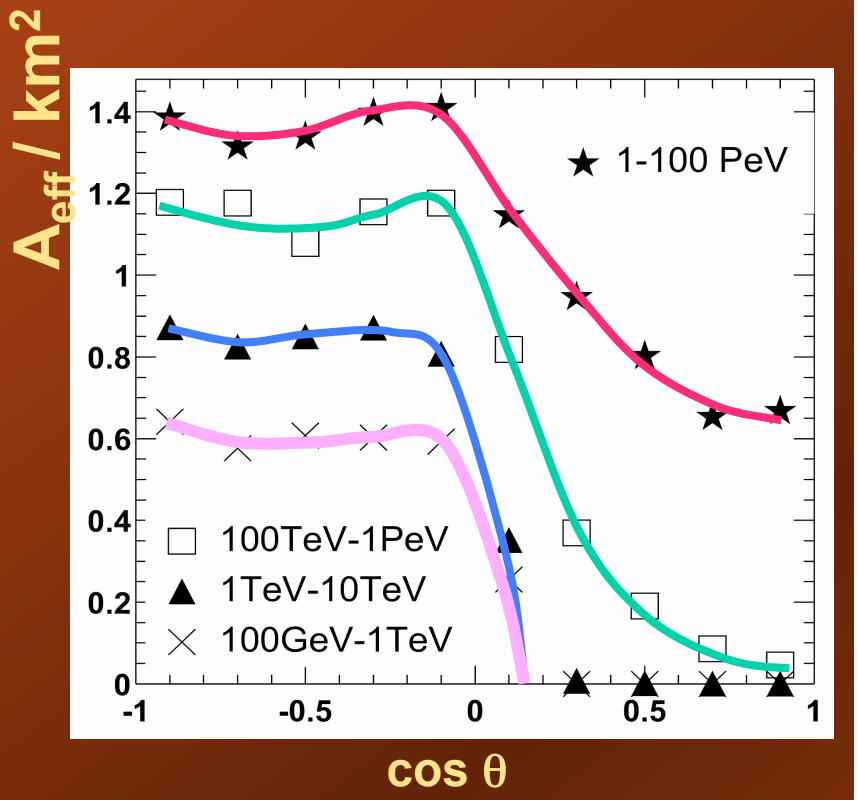



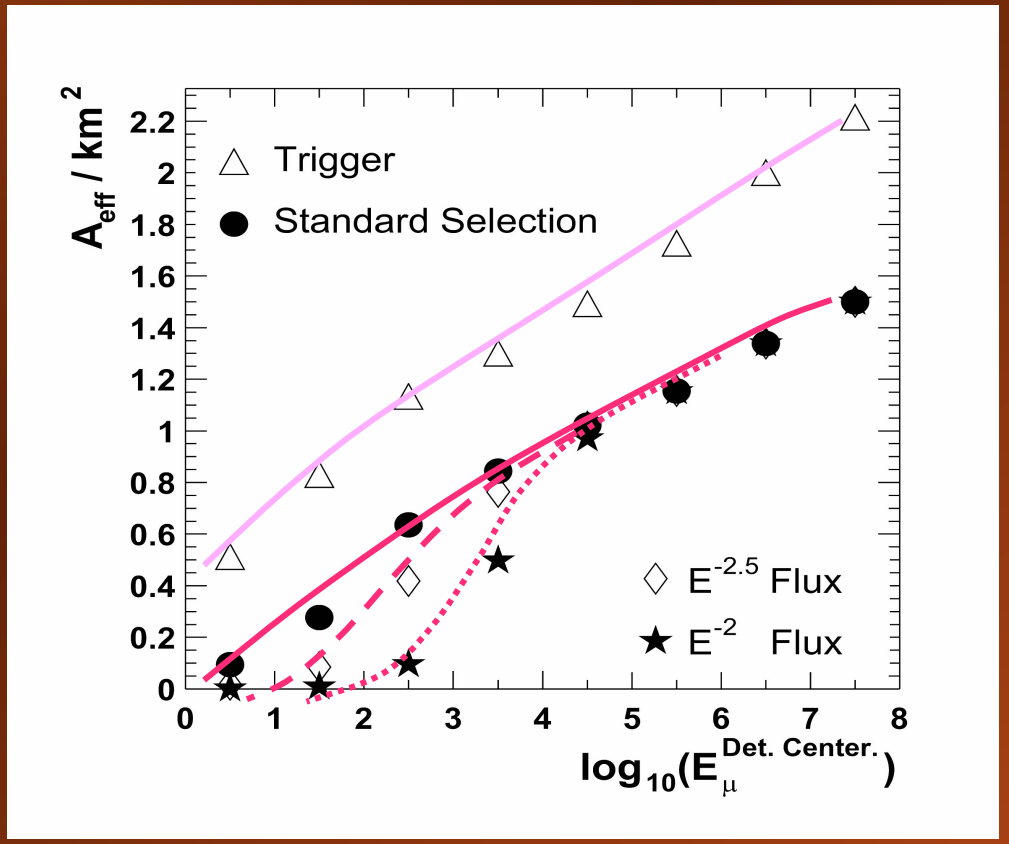





String 49 Drill/Ream/Deployment Profile
Depth(m)
500
0
500
1000
1500
2000
2500
Depth of drill head (m)
Depth of Bottom DOM (m)
DOM installation:
~6min/DOM
Ream
String drop
Drop speed:
18 m/min
Jan 29,2006 6:00 am
Final depth (prel):
2451.0 m
0
10
20
30
40
44.1
50
60
70
Jan 27, 7:05 am
Jan 28, 11:23 am
Time (in hrs)

# Effective area of IceCube

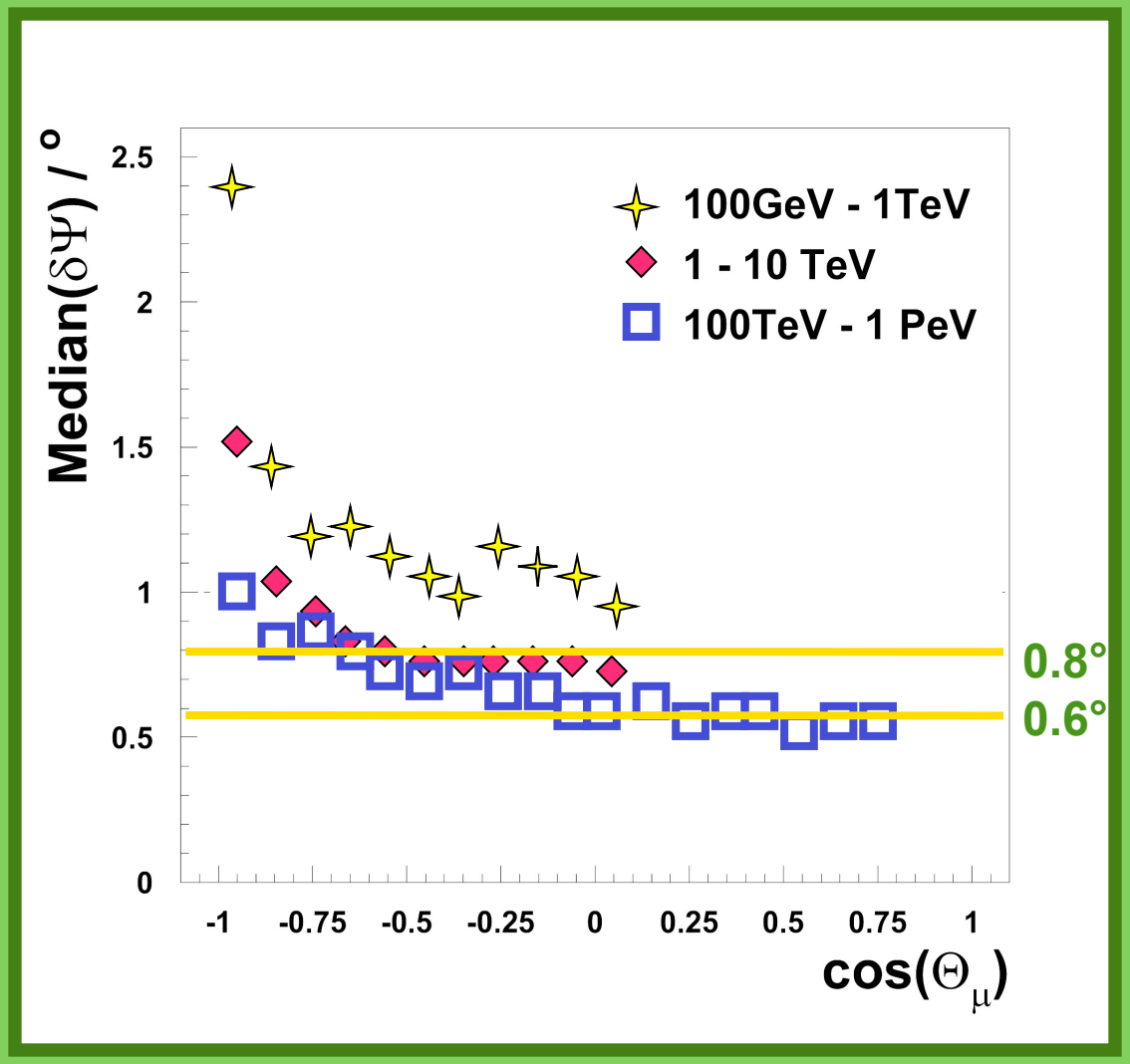



Effective area vs. zenith angle (downgoing muons rejected)

Effective area vs. muon energy (trigger, atm μ, pointing cuts)

# angular resolution as a function of zenith angle

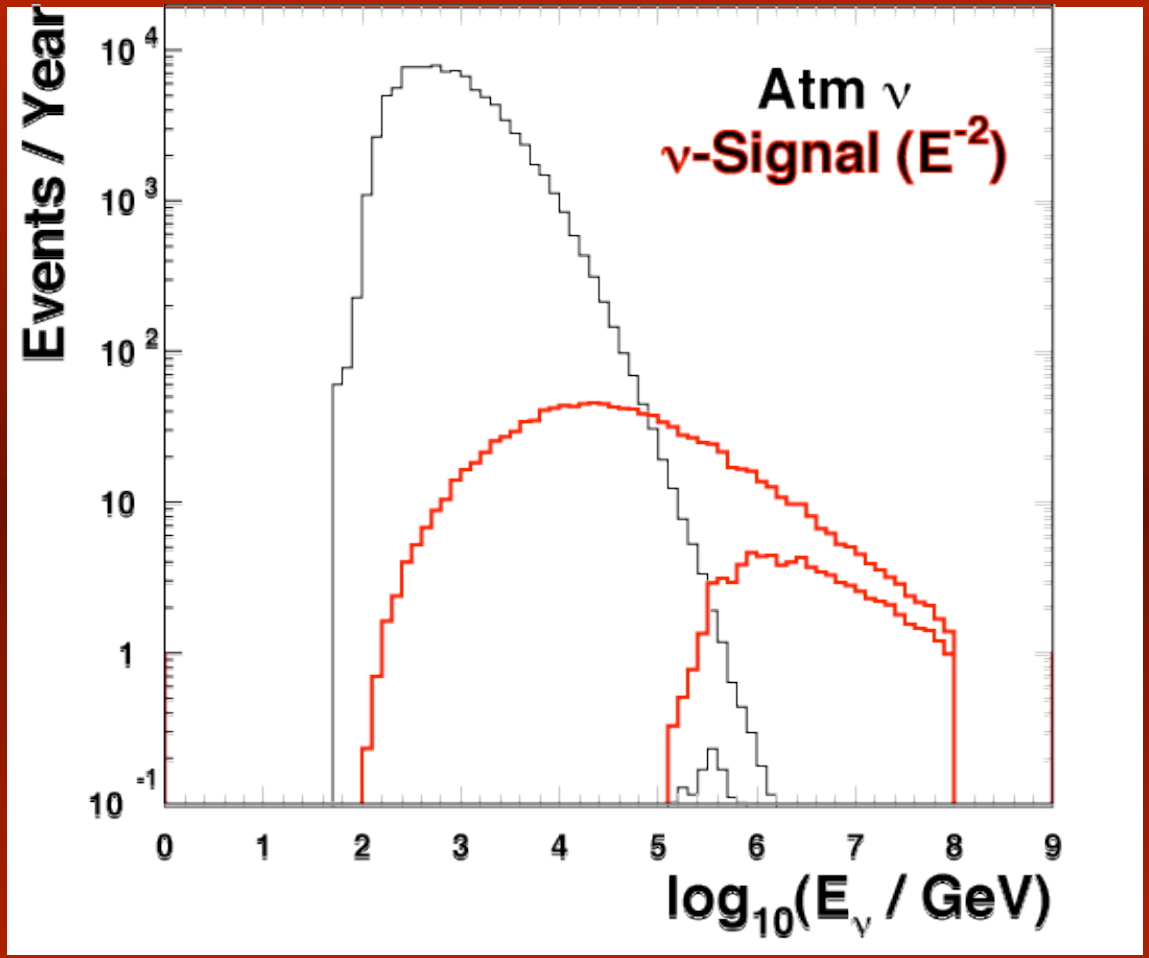



Waveform information not used. Will improve resolution for high energies !

→ above 1 TeV, resolution ~ 0.6 - 0.8 degrees for most zenith angles

# event rates before and after energy cut

Events per year at the ultimate AMANDA sensitivity




Note: 300,000 atmospheric neutrinos per year (TeV range)