

# icebound neutrinos



**francis halzen**

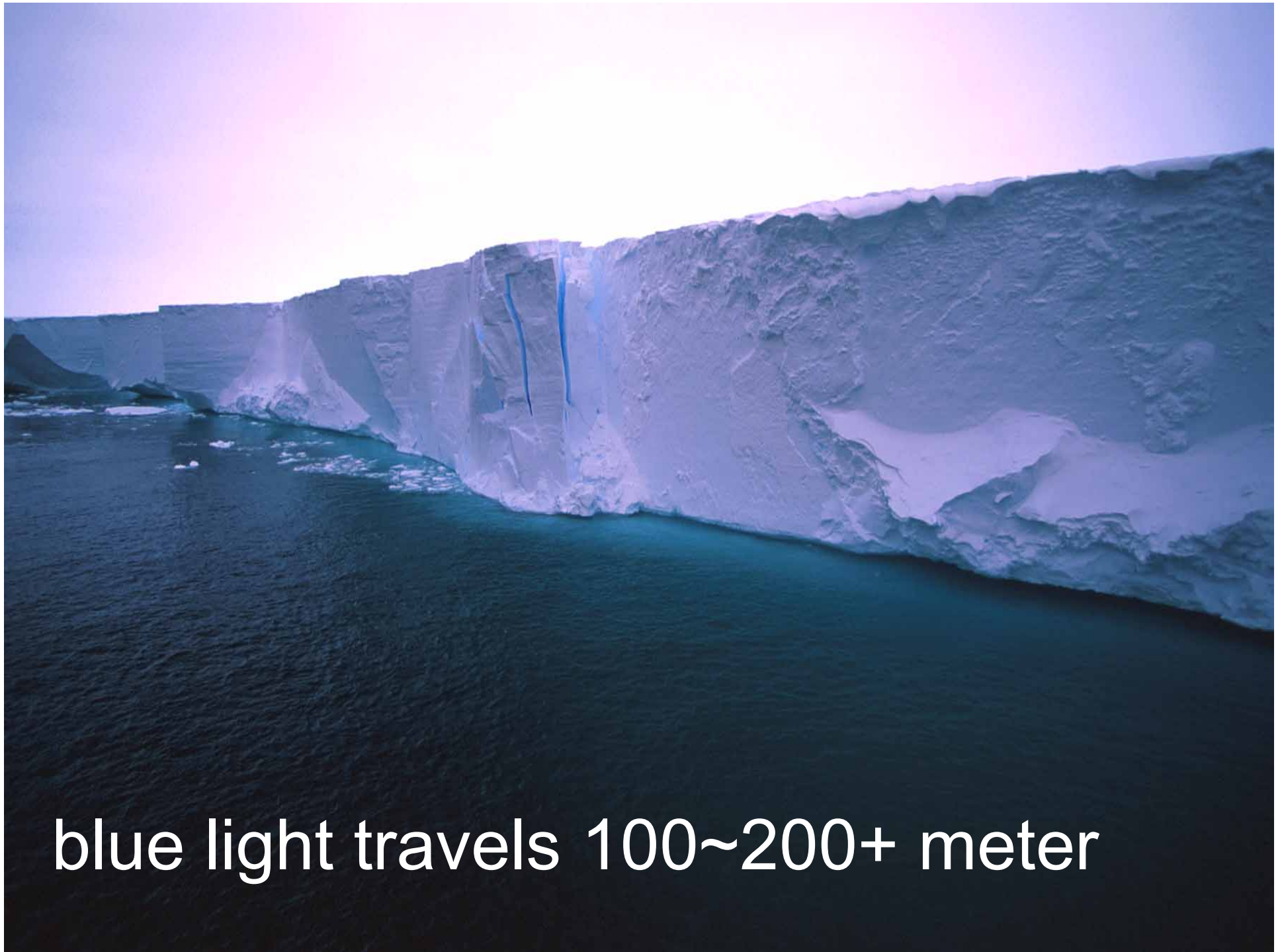
University of Wisconsin  
<http://icecube.wisc.edu>



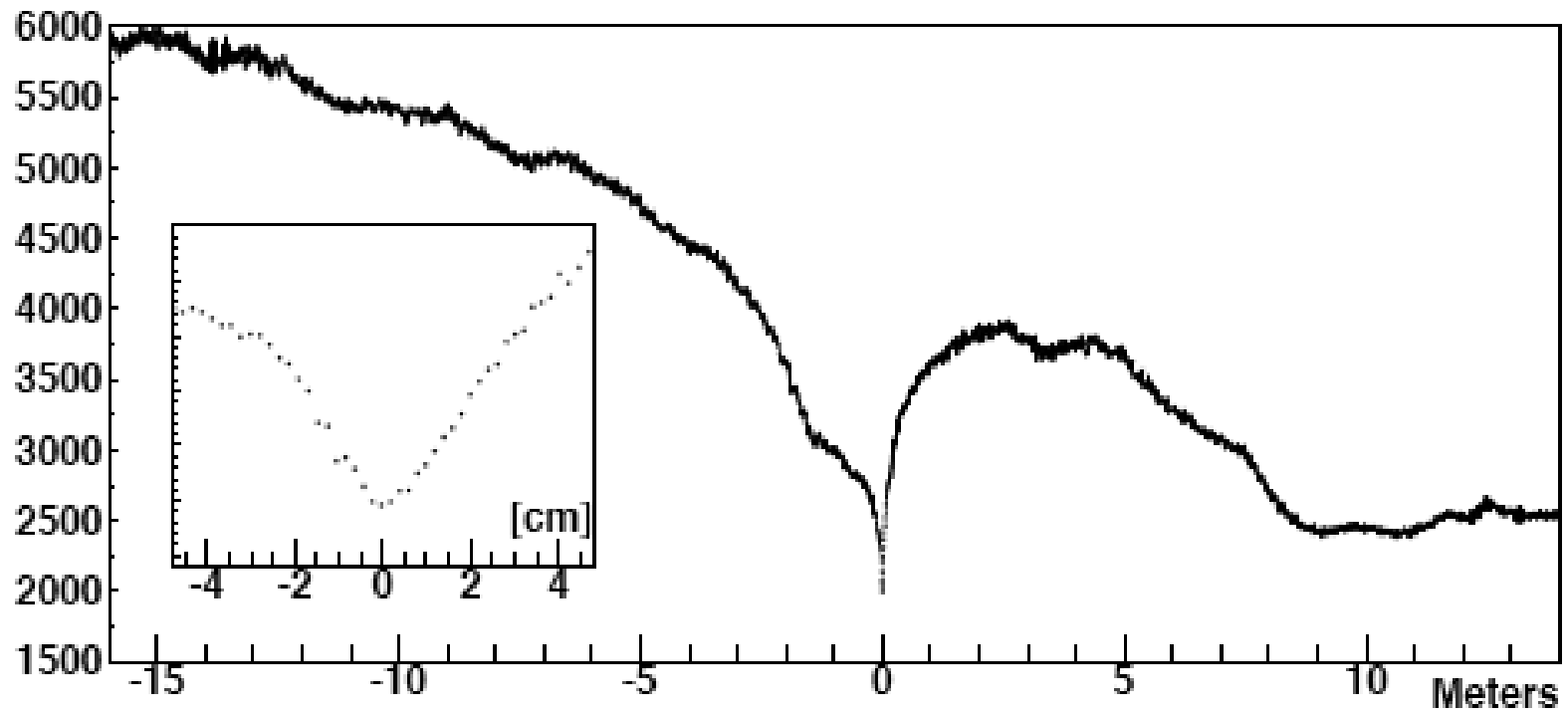


**a billion ton neutrino detector**





blue light travels 100~200+ meter



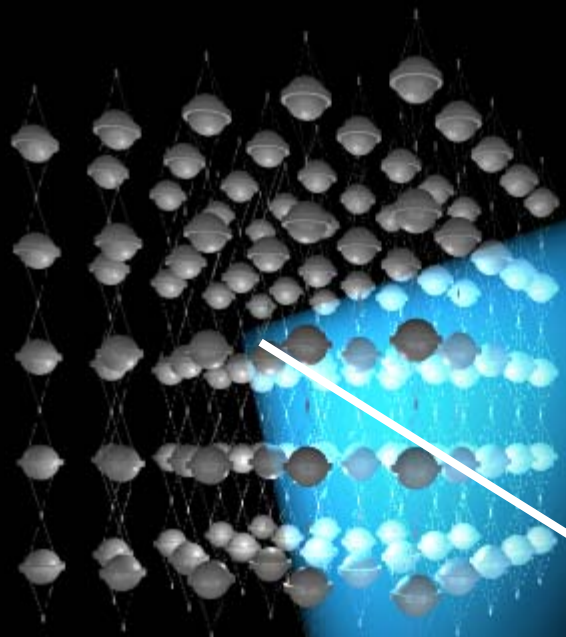
volcanic ash layer



deep detector shielded  
by water or ice

neutrino travels  
through the earth  
and ...  
through the detector

- shielded and optically transparent medium



*ice converts a neutrino to blue light*

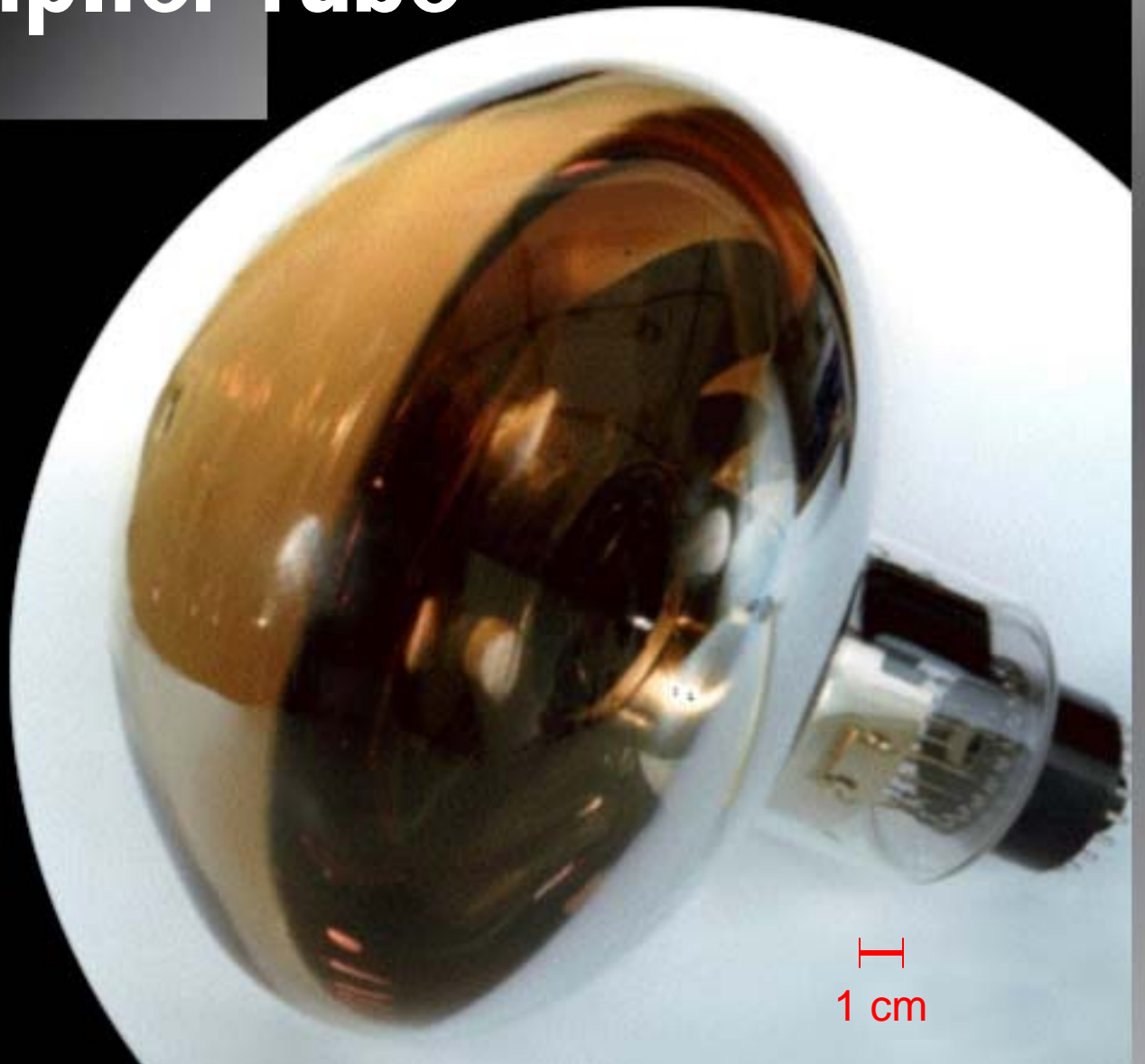
muon

nuclear interaction

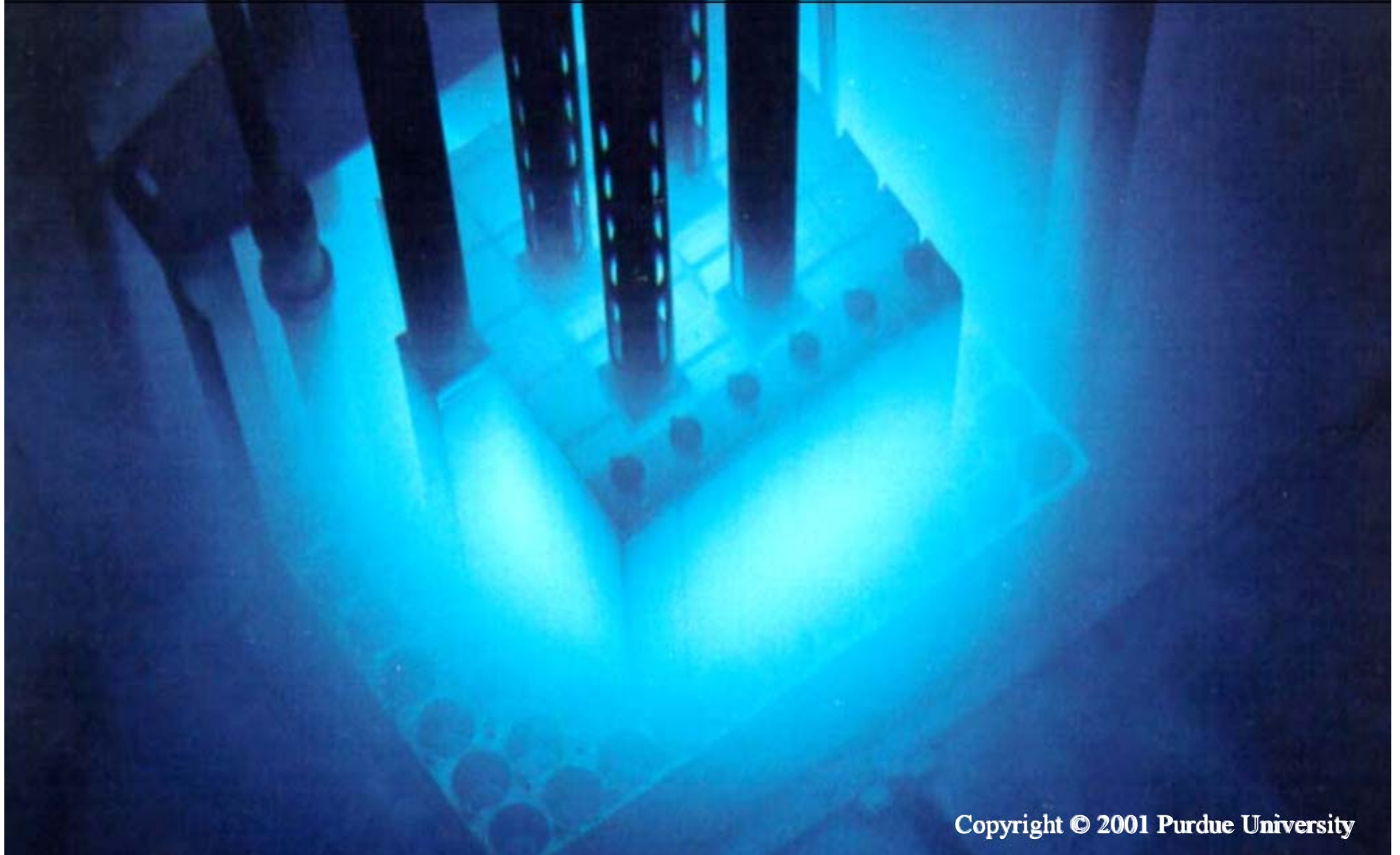
neutrino

- lattice of photomultipliers

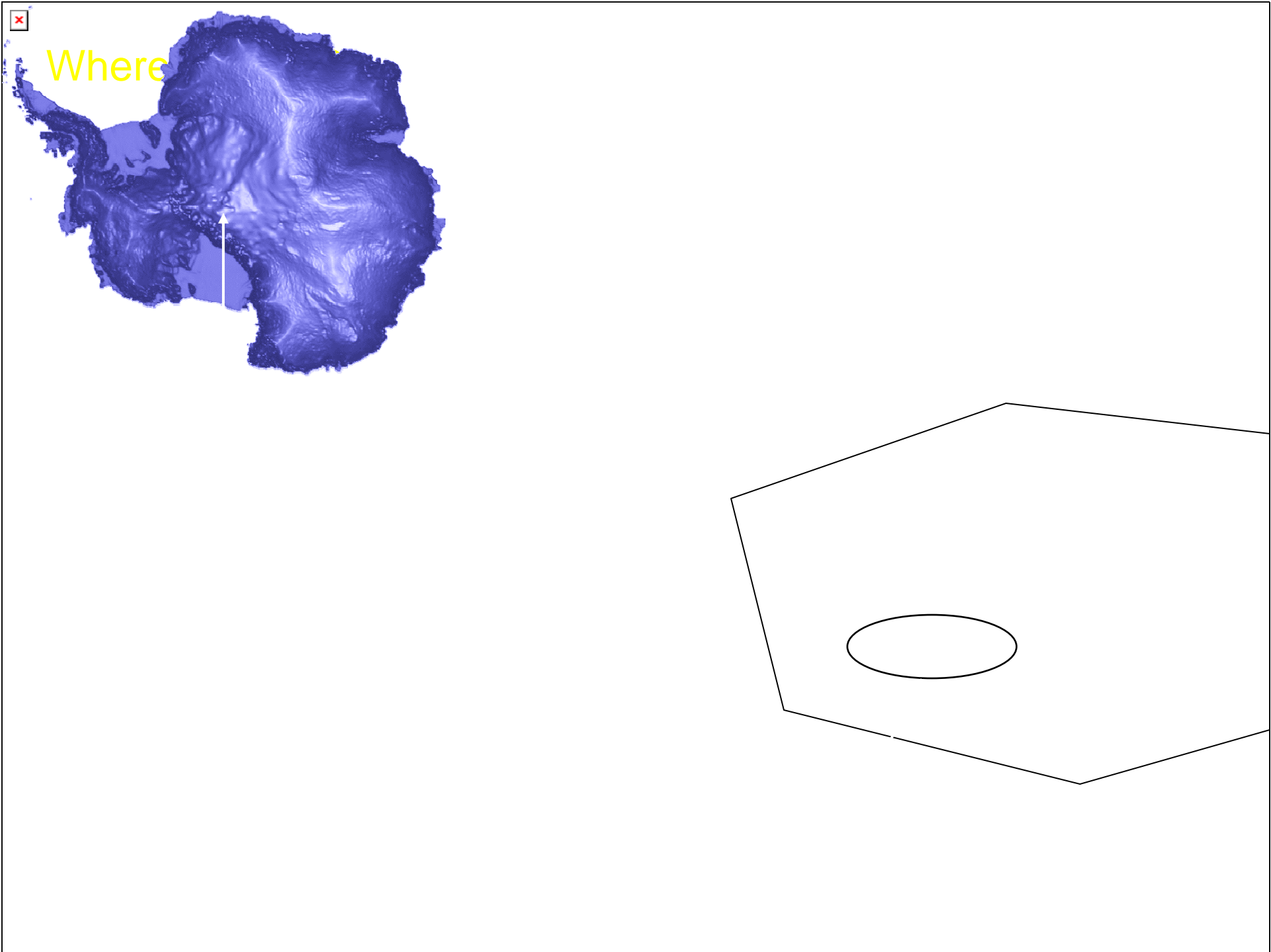
# Photomultiplier Tube

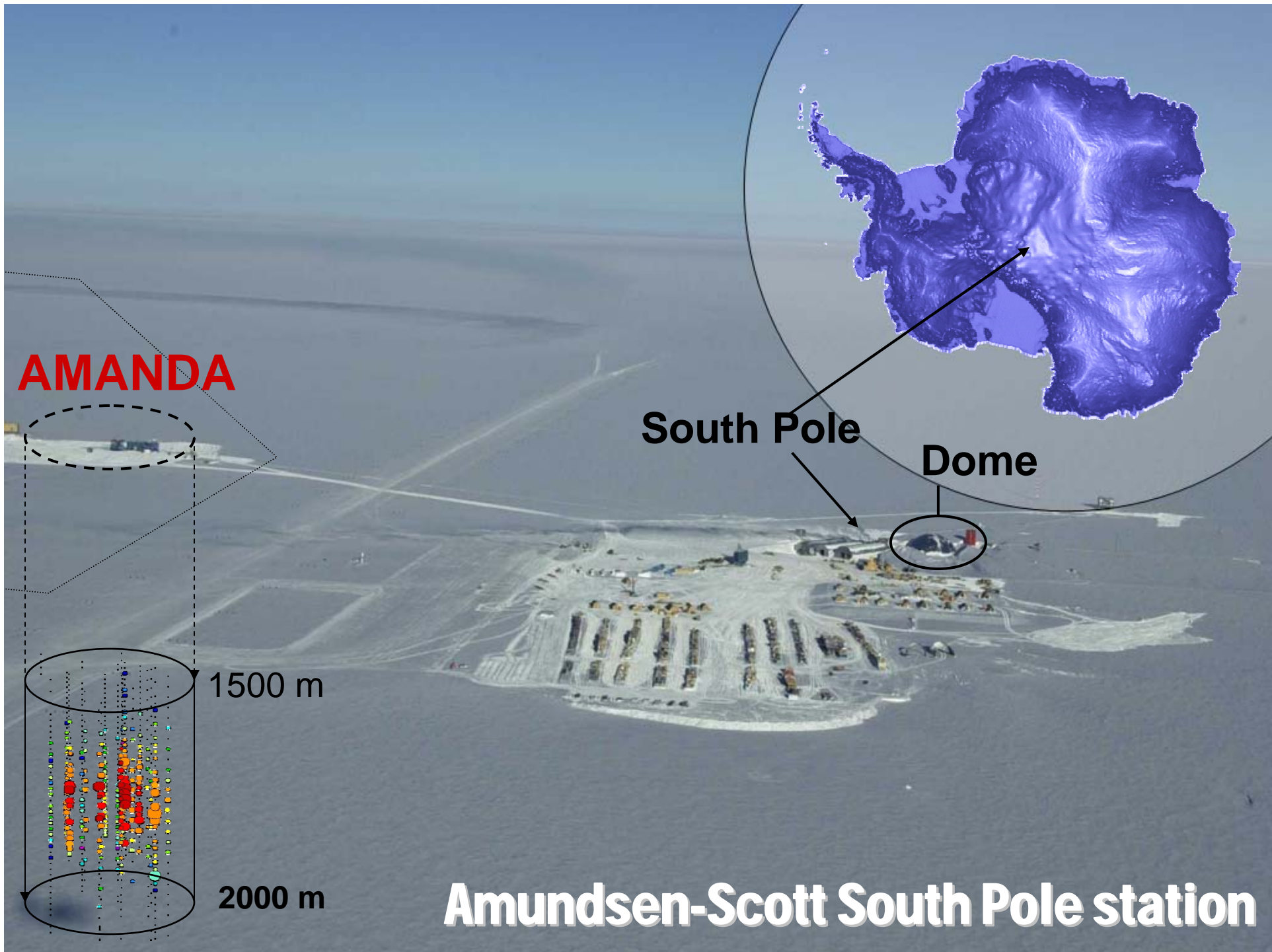


**particles produced in a nuclear reactions produce blue  
light in water**



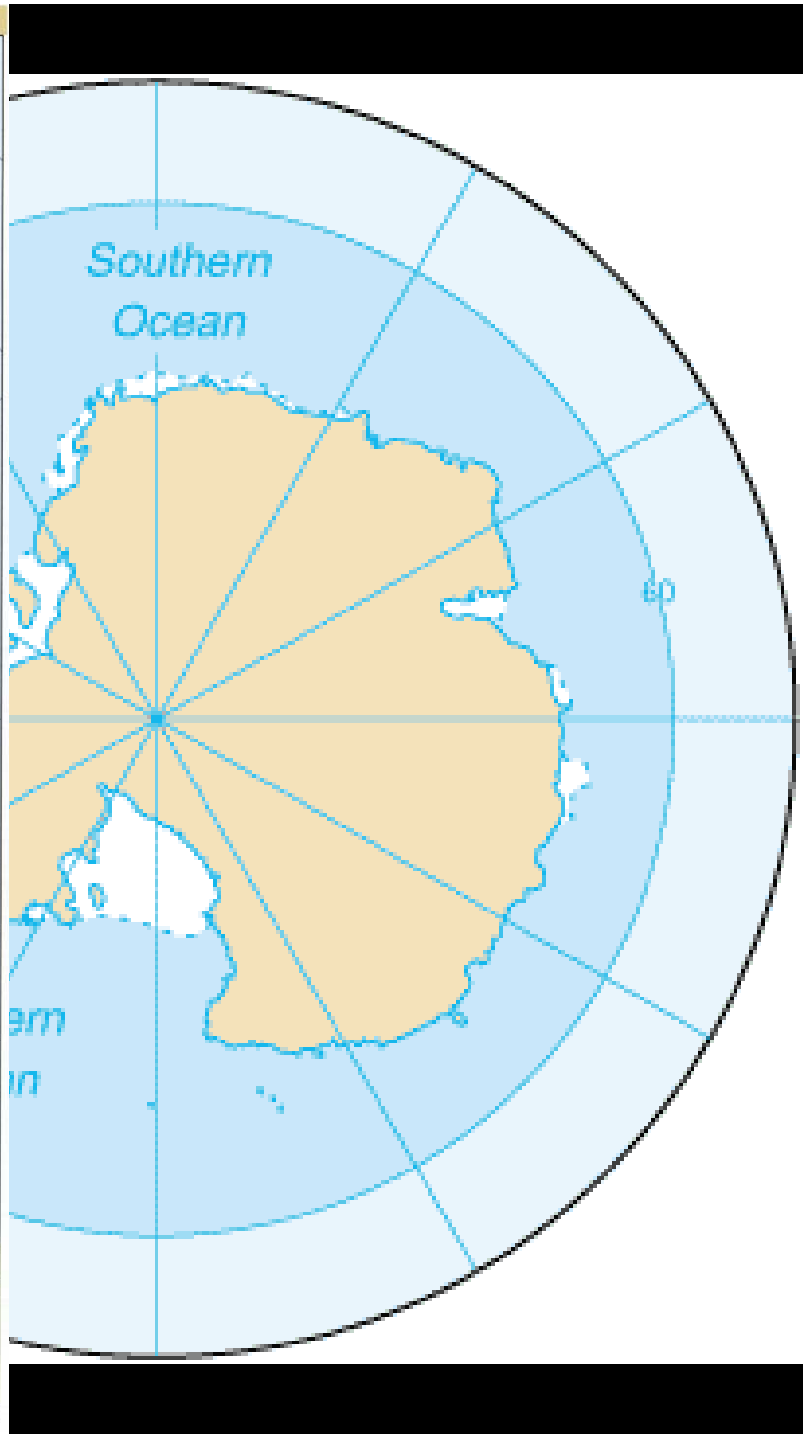
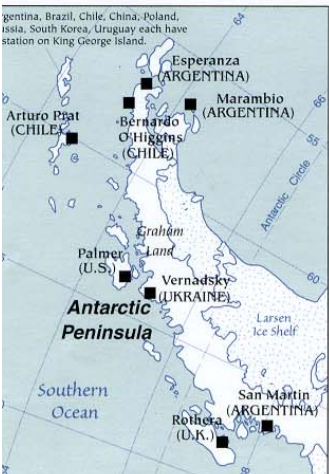
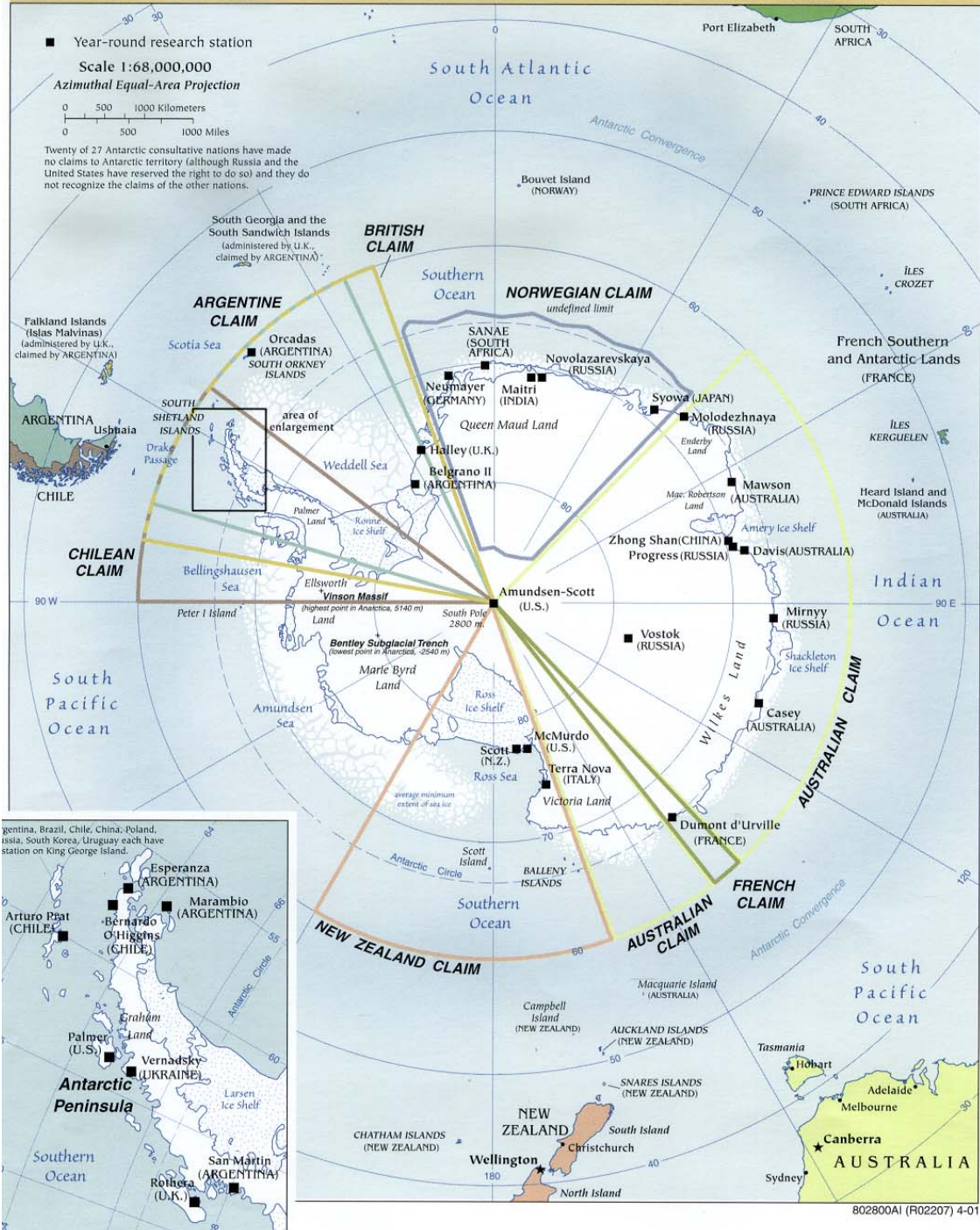


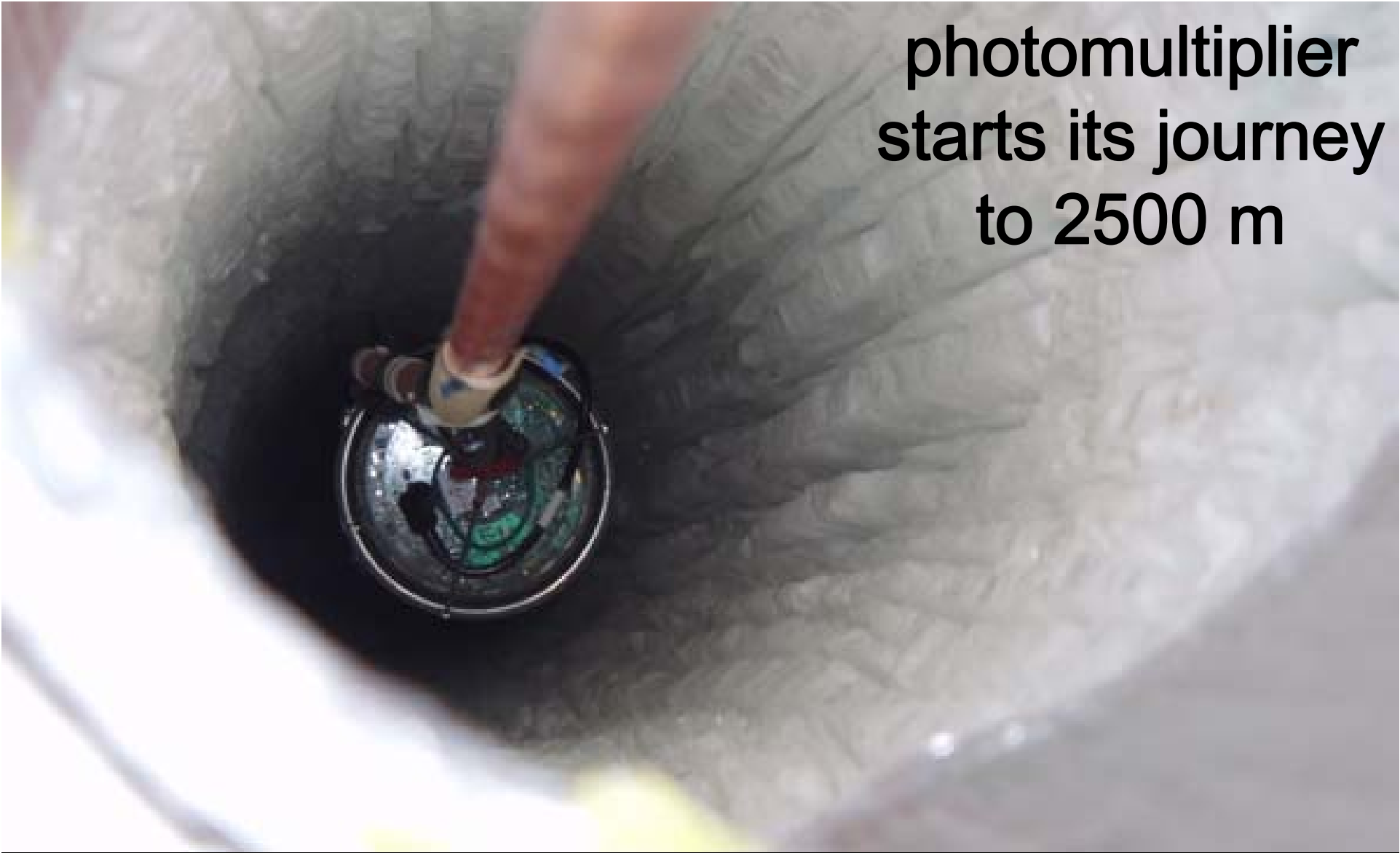




*IceCube detects the faint  
blue glow from the nuclear  
reaction resulting from the  
head-on crash of a neutrino  
with an atom of ice*

# ANTARCTIC REGION



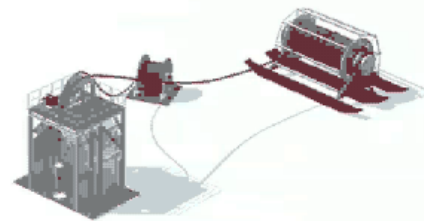


photomultiplier  
starts its journey  
to 2500 m

**the IceCube project transforms  
a billion tons of ice into a particle physics detector**

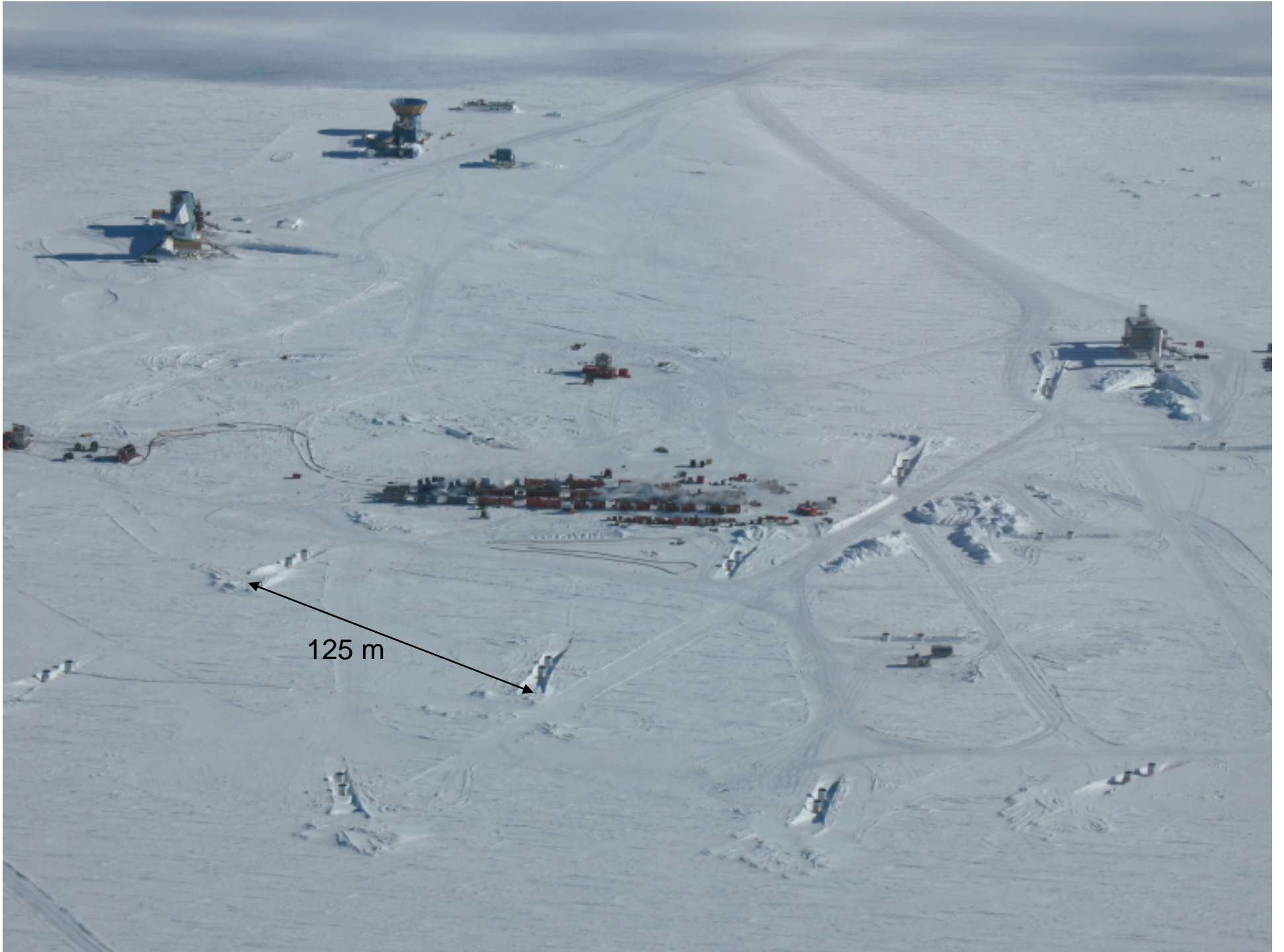
# drilling and deployment











125 m

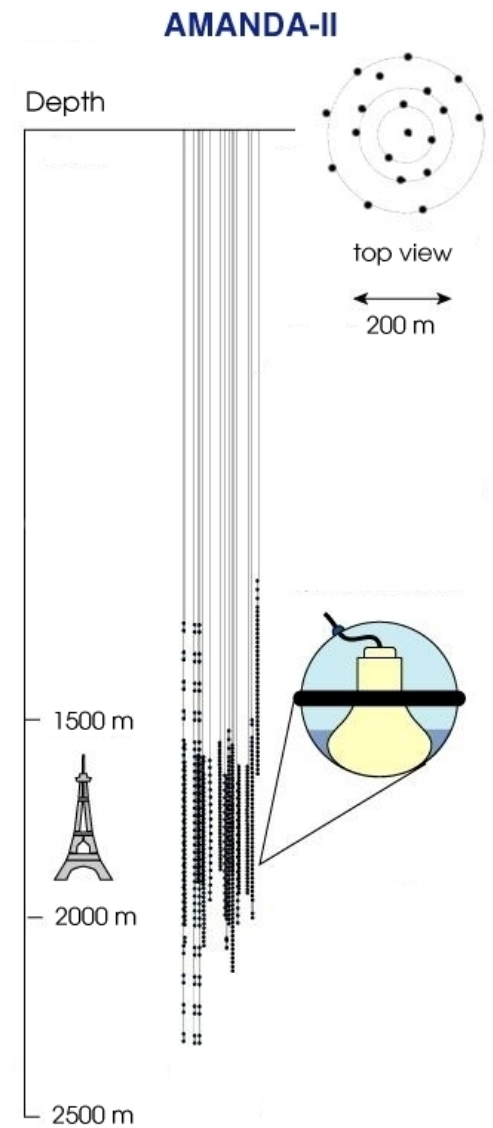
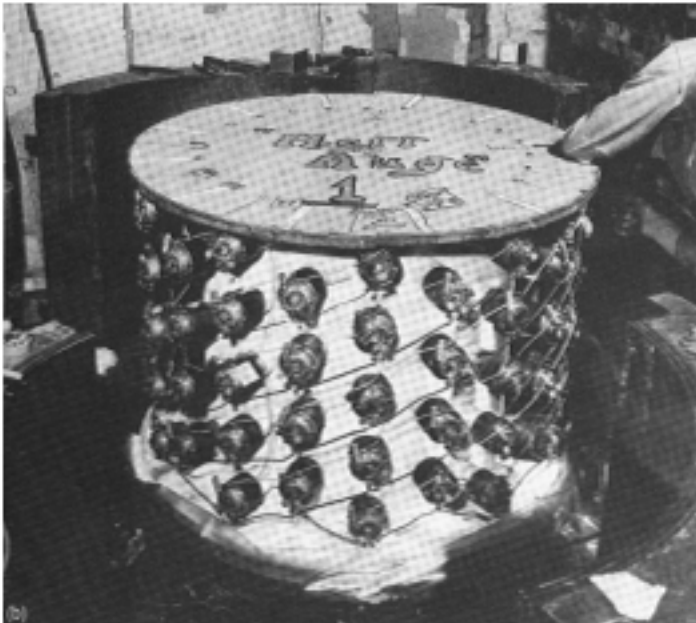


5 megawatt power plant

**one of 21 drill modules arrive in antarctica**



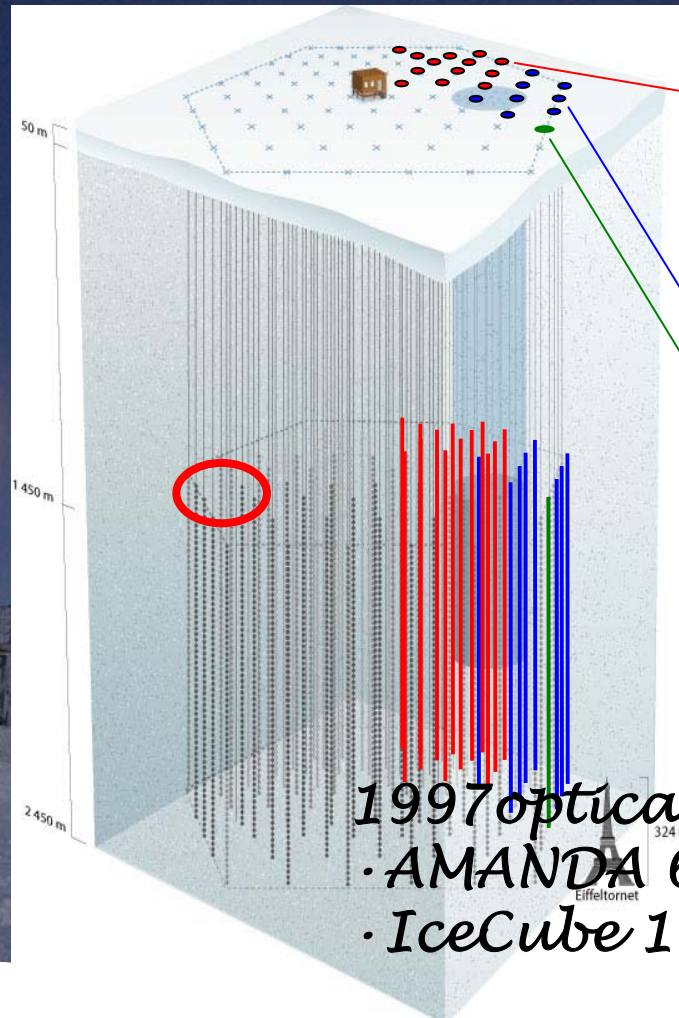
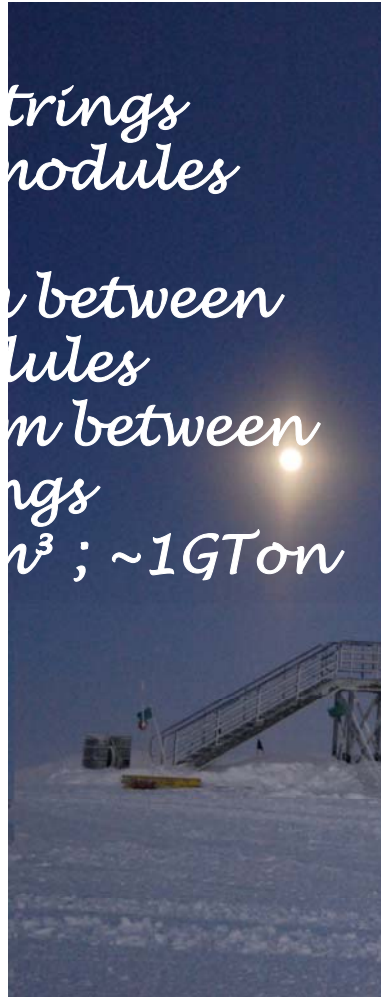
# Requires Kilometer-Scale Neutrino Detectors



# IceCube deployments

Completed

- 80 strings  
60 modules  
each
- 17 m between  
modules
- 125 m between  
strings
- 1 km<sup>3</sup> ; ~1G Ton



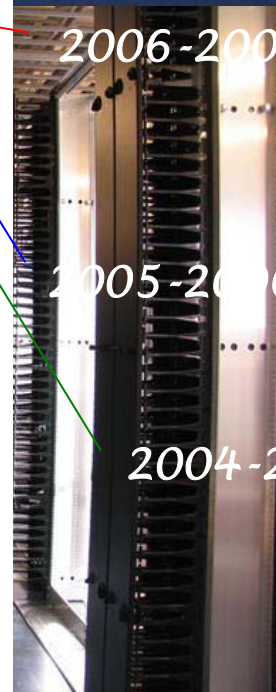
1997 optical modules in ice:  
• AMANDA 677  
• IceCube 1320

January 2007

2006-2007: 13 strings

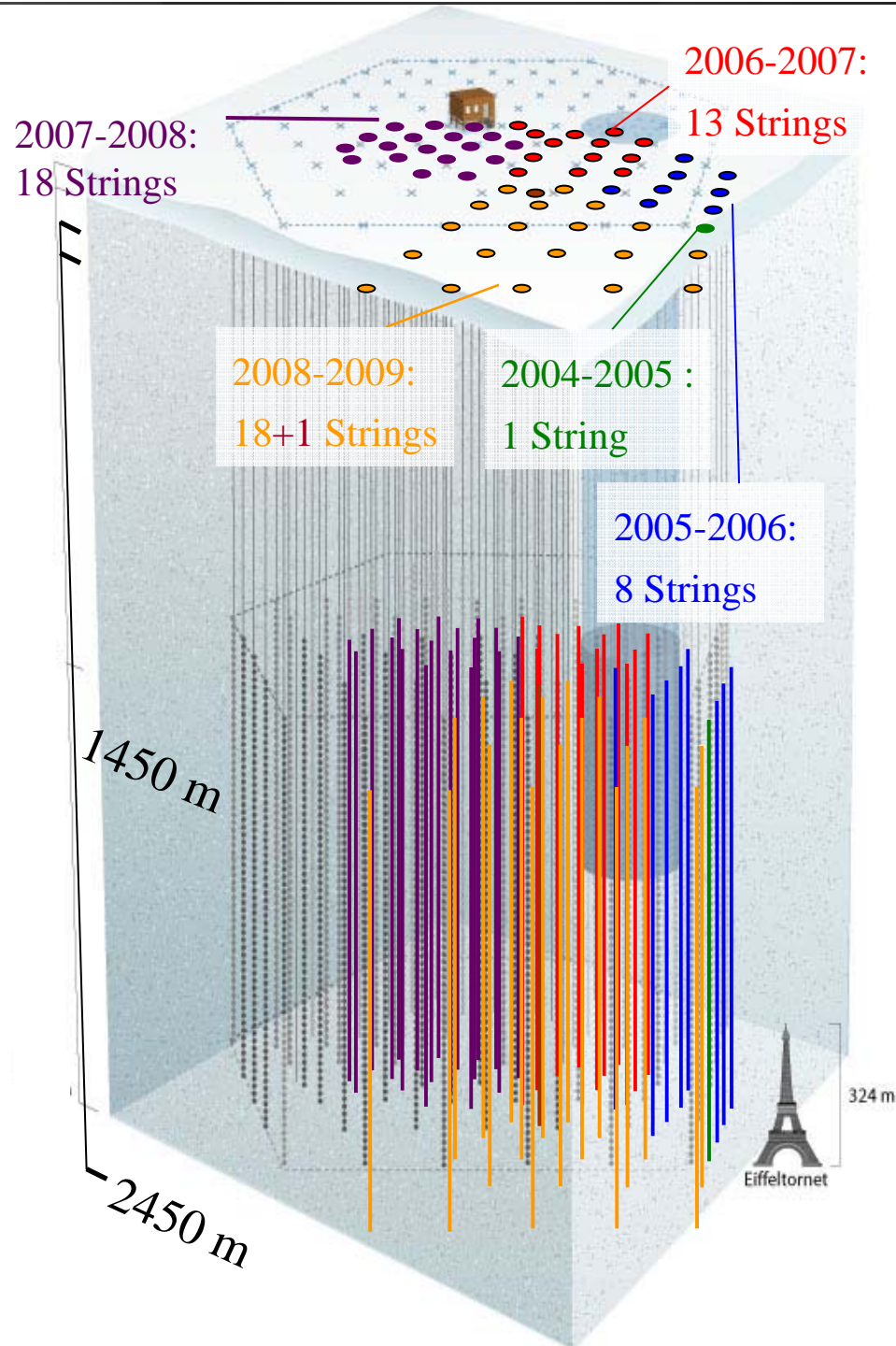
2005-2006: 8 strings

2004-2005 : 1 string



since jan 09 →

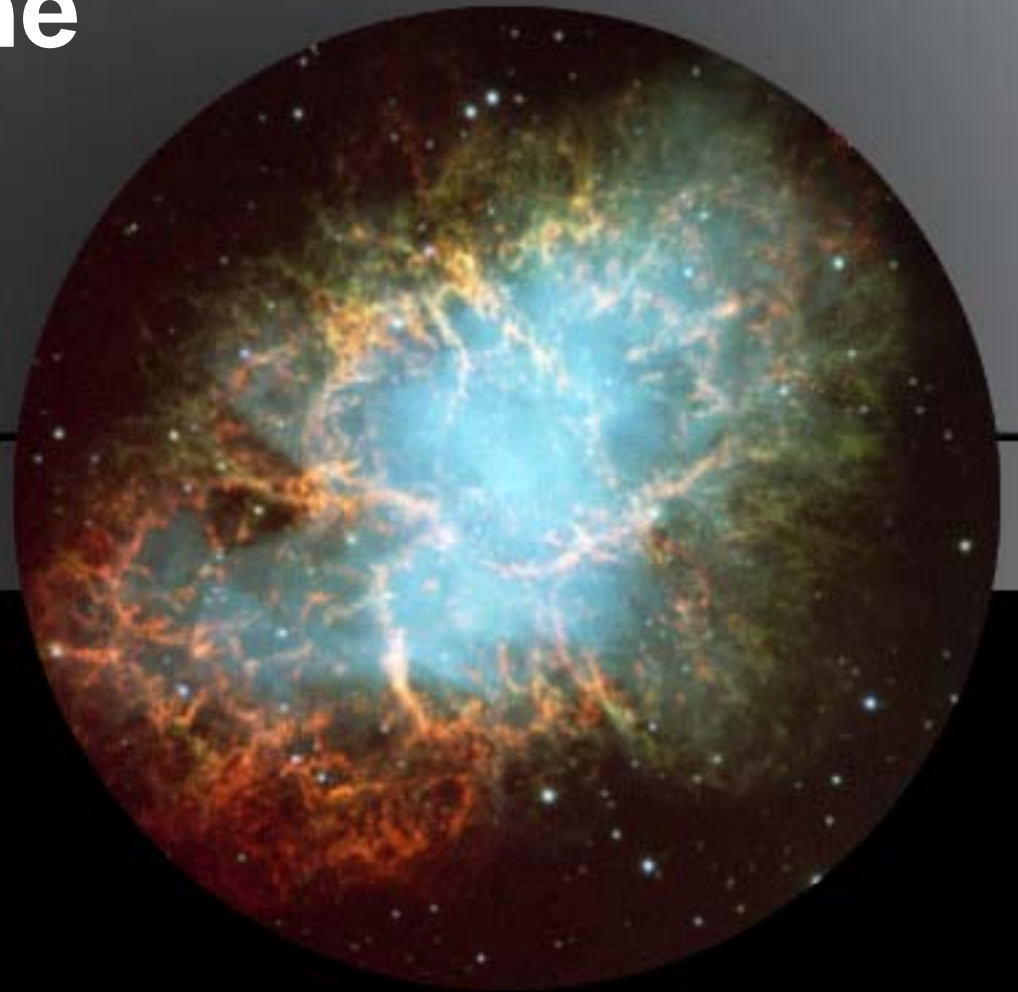
59 out of 86



# Seeing: Cosmic Messengers

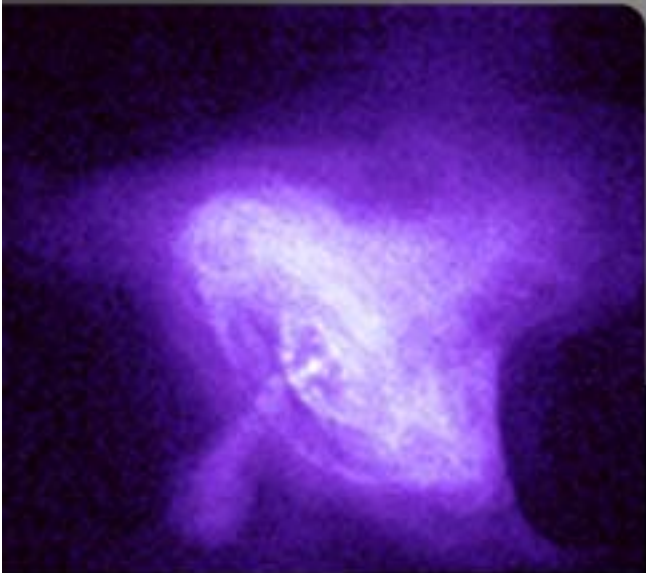
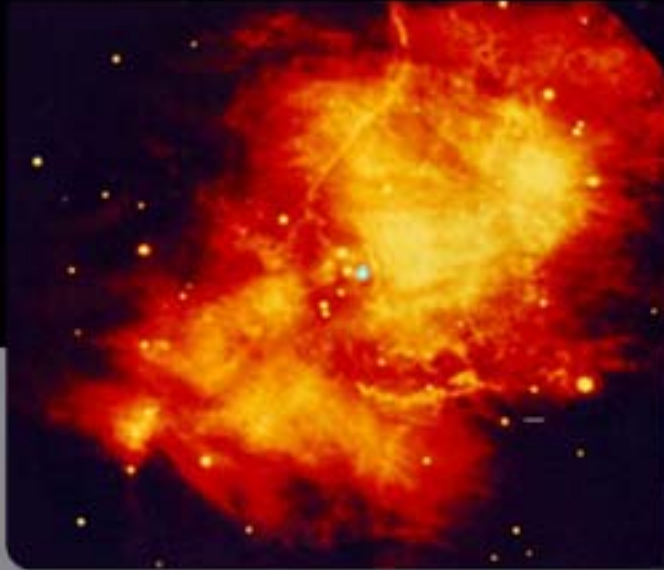
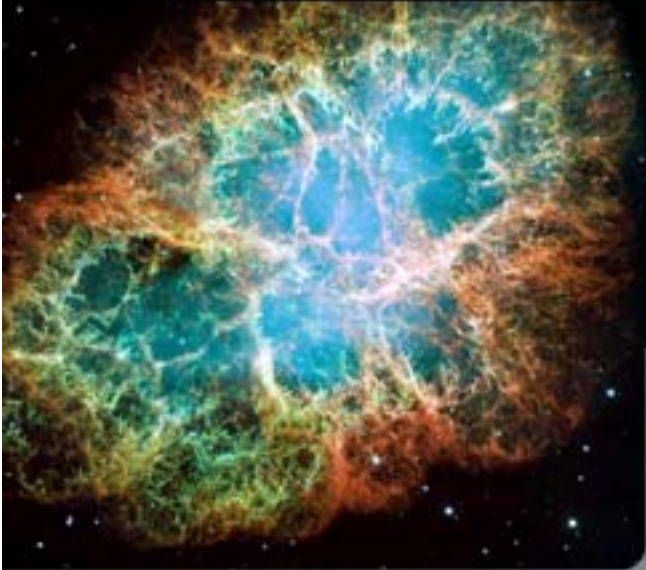
- visible light ( Alhassan 1000 )
- light of other wavelengths:  
blue, red, infrared,  
X-rays, radiowaves,.....

**in 1054 a star  
explodes in the  
constellation  
Taurus**



**Crab Nebula**





neutrinos ?

# Seeing: Cosmic Messengers

- light ( Alhassan 1000 )
- light of other wavelengths:  
blue, red, infrared,  
X-rays, radiowaves...
- **neutrinos** instead of  
photons (particles of light)

# New Window on the Universe

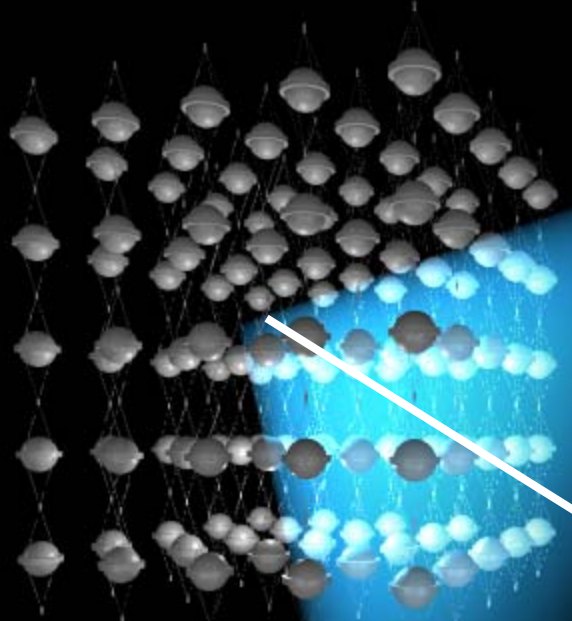
## Expect Surprises

Telescope	User	date	Intended Use	Actual use
Optical	Galileo	1608	Navigation	Moons of Jupiter
Optical	Hubble	1929	Nebulae	Expanding Universe
Radio	Jansky	1932	Noise	Radio galaxies
Micro-wave	Penzias, Wilson	1965	Radio-galaxies, noise	3K cosmic background
X-ray	Giacconi ...	1965	Sun, moon	neutron stars accreting binaries
Radio	Hewish, Bell	1967	Ionosphere	Pulsars
$\gamma$ -rays	military	1960?	Thermonuclear explosions	Gamma ray bursts

You can see a lot by looking

**Yogi Berra**

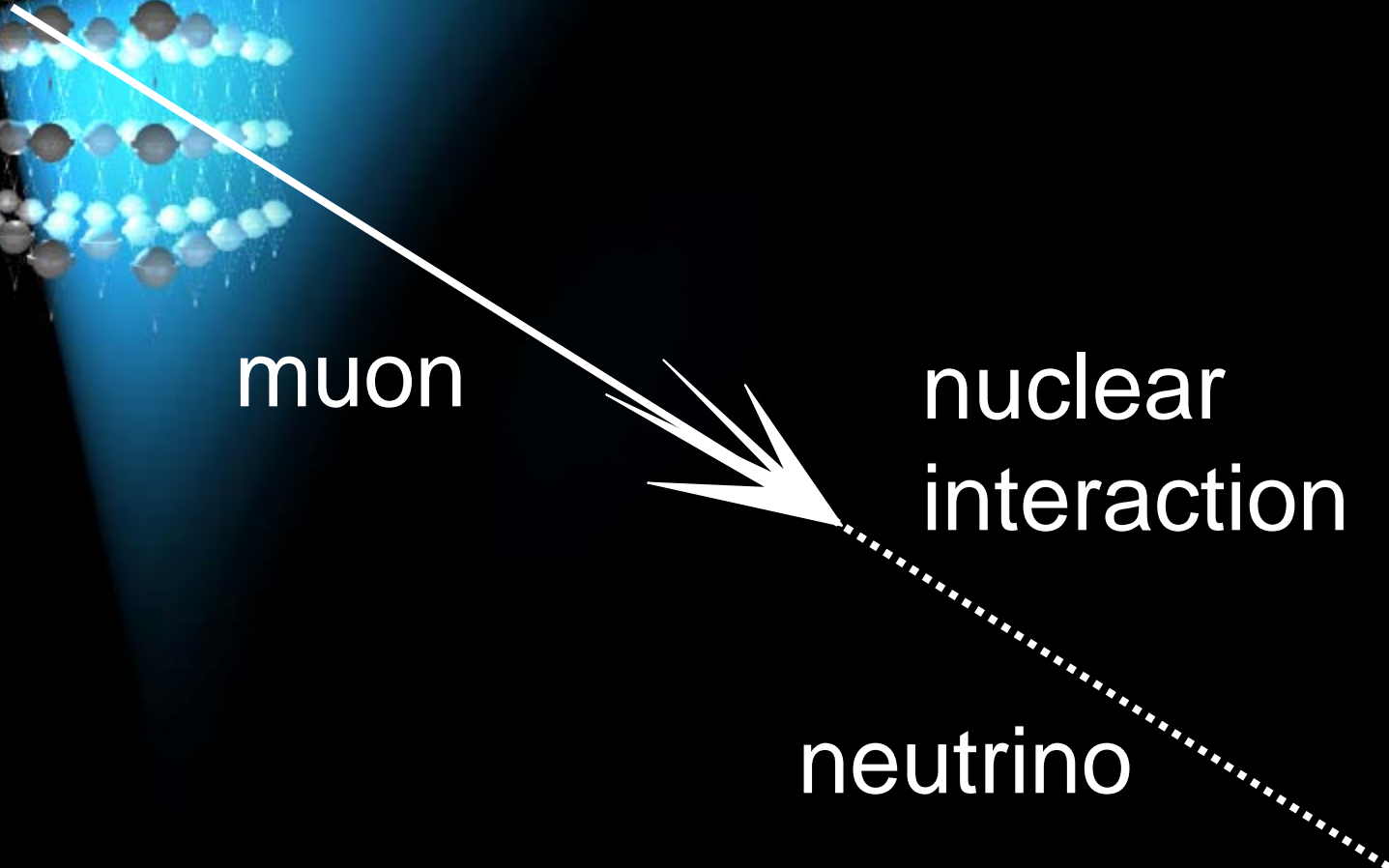
once in a while...



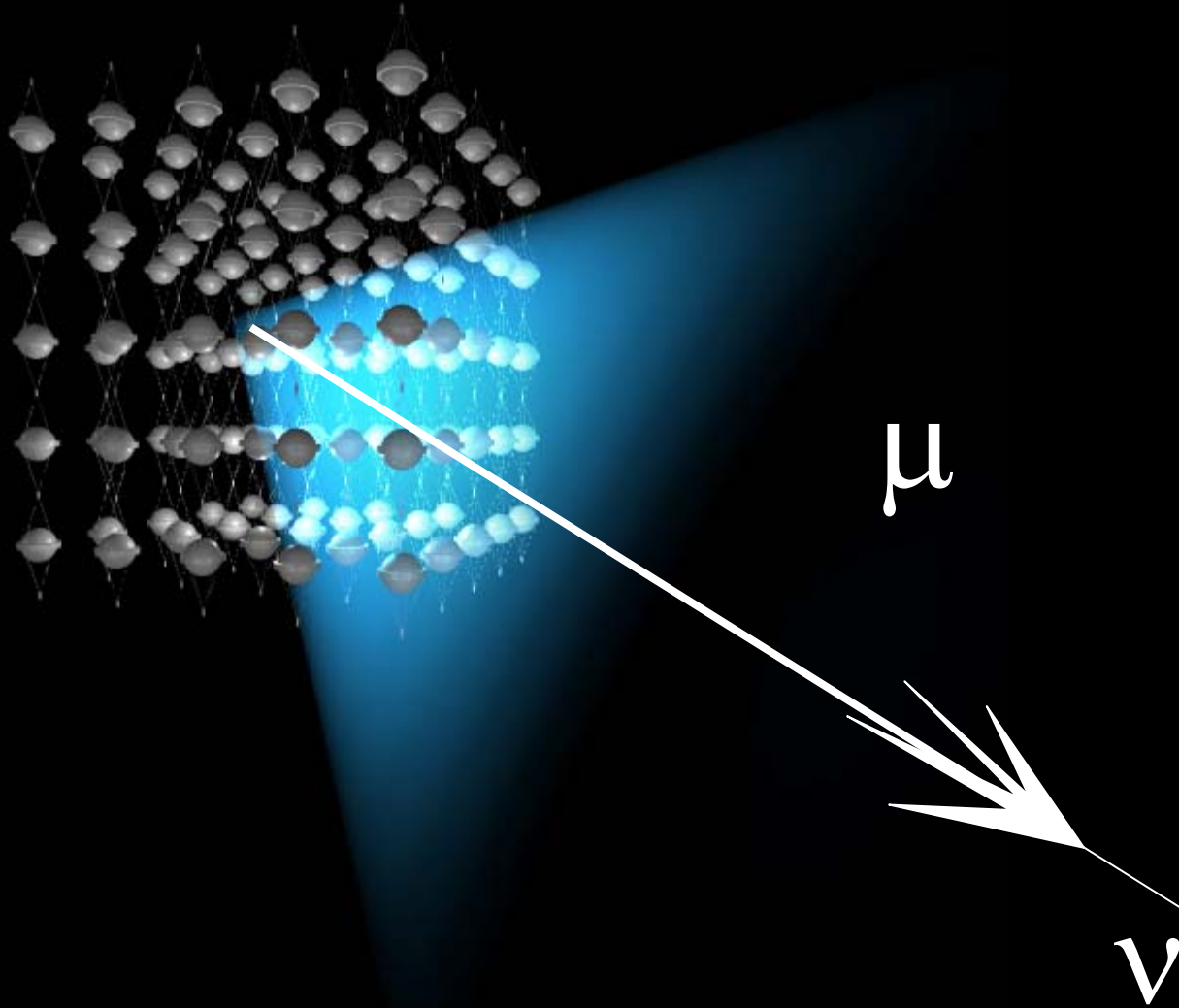
muon

nuclear  
interaction

neutrino



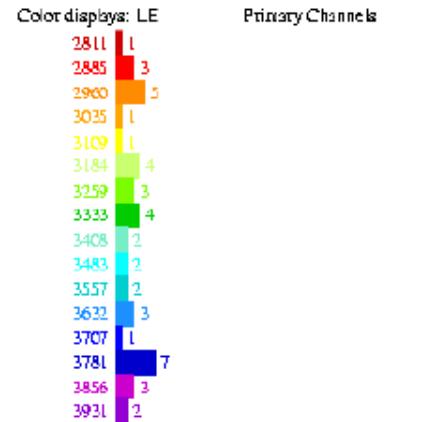
- shielded and optically transparent medium



- lattice of photomultipliers

# AMANDA Event Signatures: Muons

muon neutrino interaction  $\rightarrow$  track

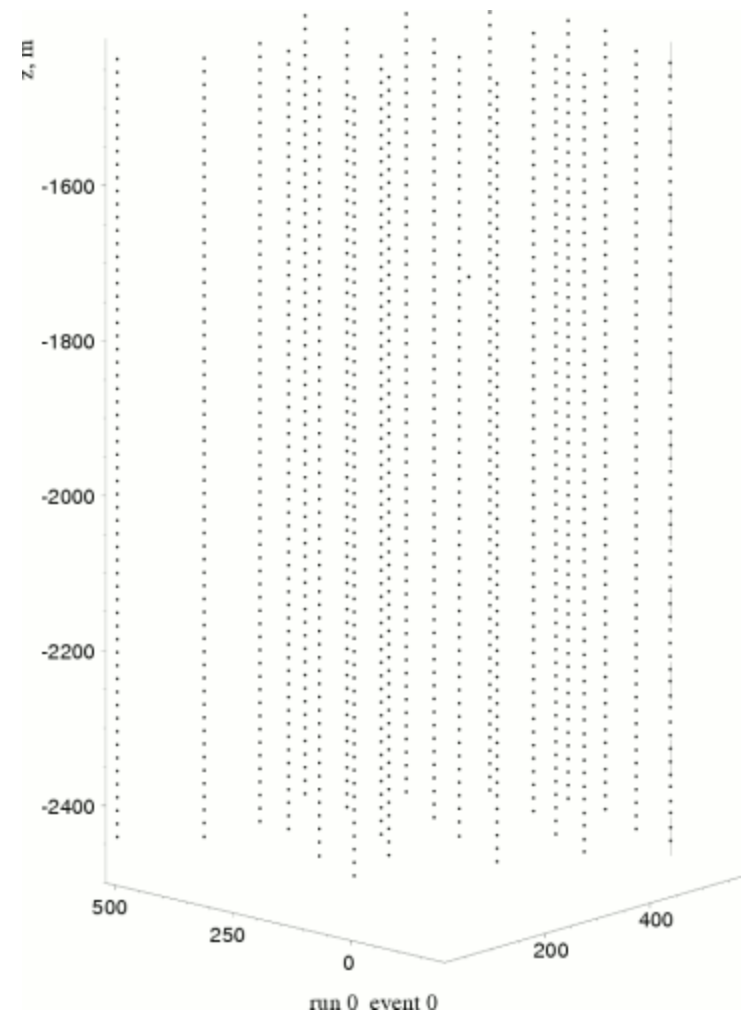


No external geometry file is opened.  
 Detector: amanda-b-10, 10strings, 302 modules  
 Data file: /home/itsboards/ana\_events/strick119.fzk  
 File contains 19 events.  
 Displaying data event 1197960 from run 0  
 Recorded y/d/y: 1997/285  
 18132.0091381 seconds past midnight.  
 Before cuts: 44 hits, 44 OMs  
 After cuts: 44 hits, 44 OMs

An in-run  

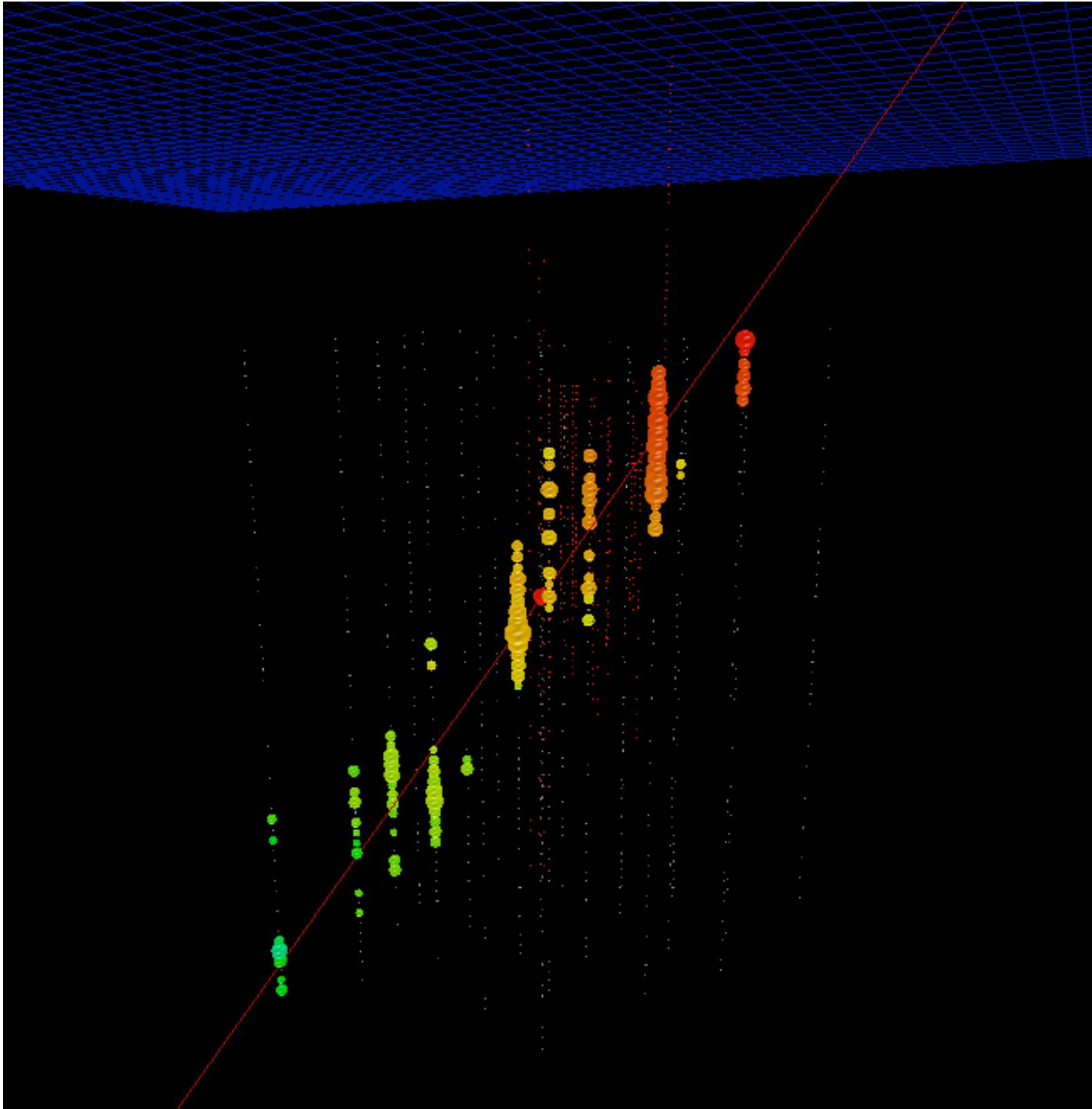
	x	y	z
Vertex pos. :	12.4	-16.1	6.8 m
Direction :	0.03970	0.41614	0.90844
Length :	Inf m		
Energy :	? GeV		
Time :	3205.100000 ns		
Zenith :	155.3°		
Azimuth :	264.6°		





**IceCube 22**



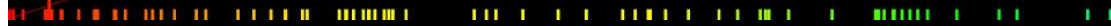


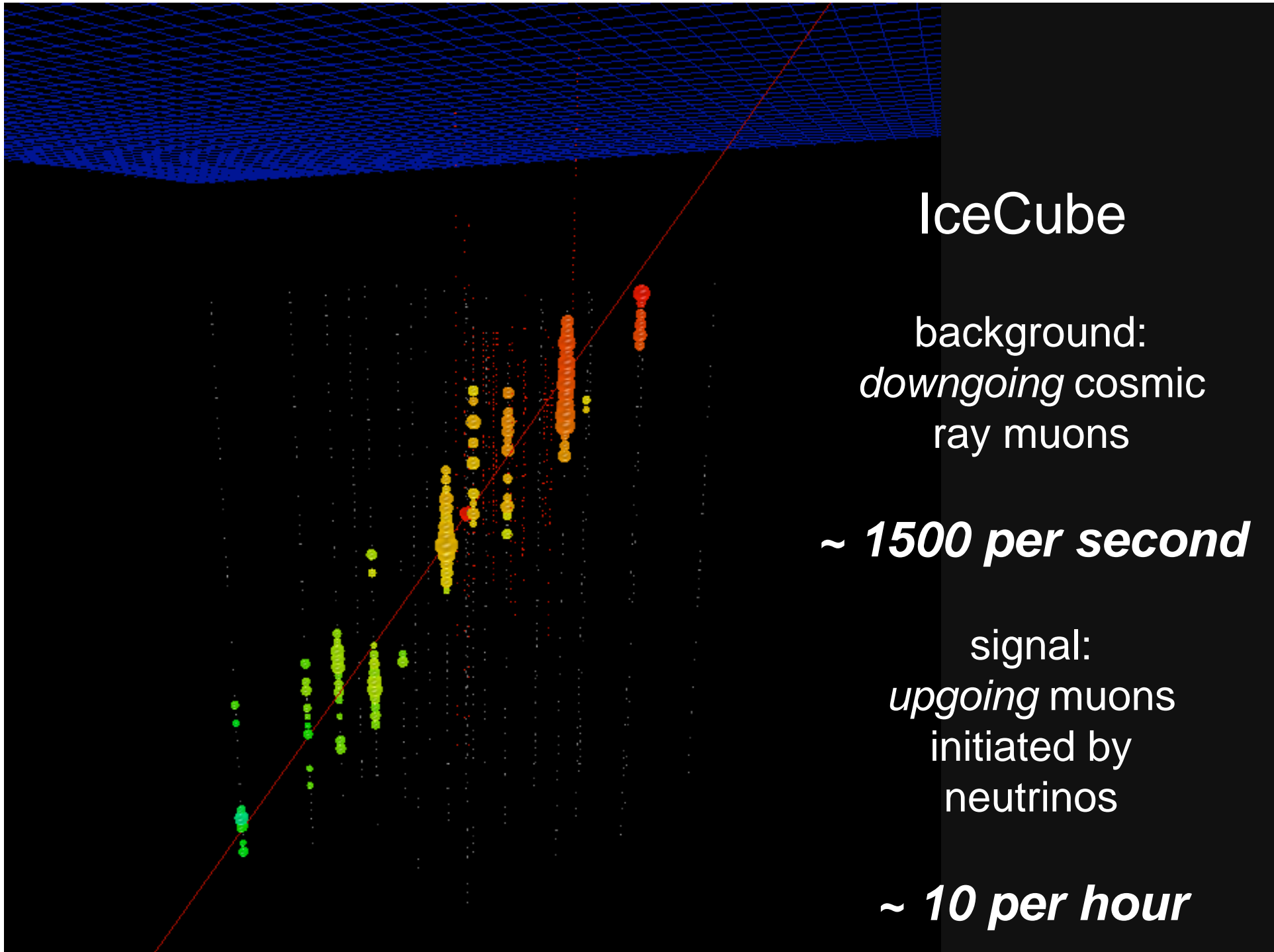
IceCube  
event

22 strings

Zenith 1.8093  
Azimuth 0.220556

Run 111397 Event 30208471  
Fri Aug 1 19:00:17 2008





# IceCube

background:  
*downgoing* cosmic  
ray muons

***~ 1500 per second***

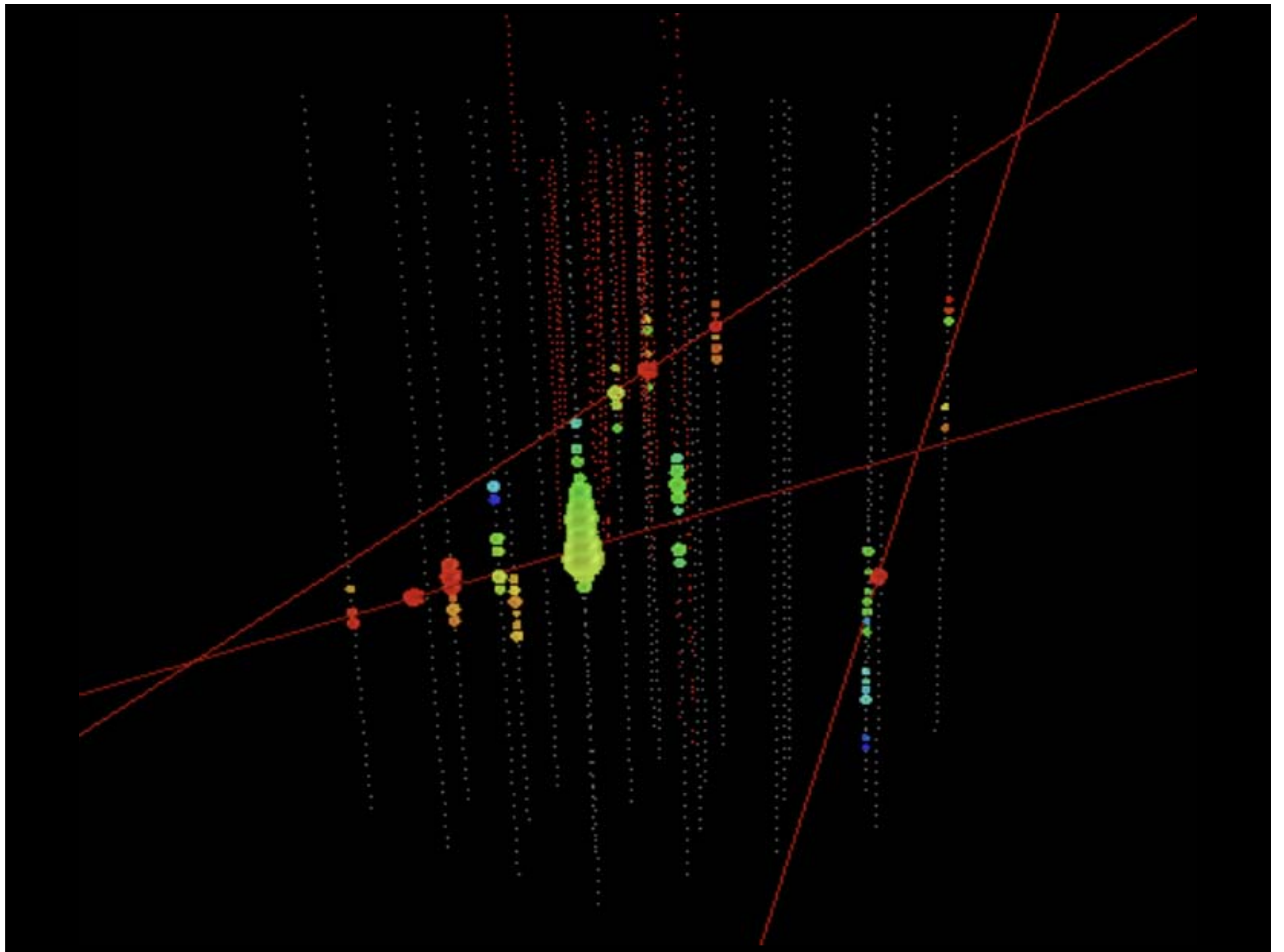
signal:  
*upgoing* muons  
initiated by  
neutrinos

***~ 10 per hour***

Tue Jan 29 08:39:34 2008

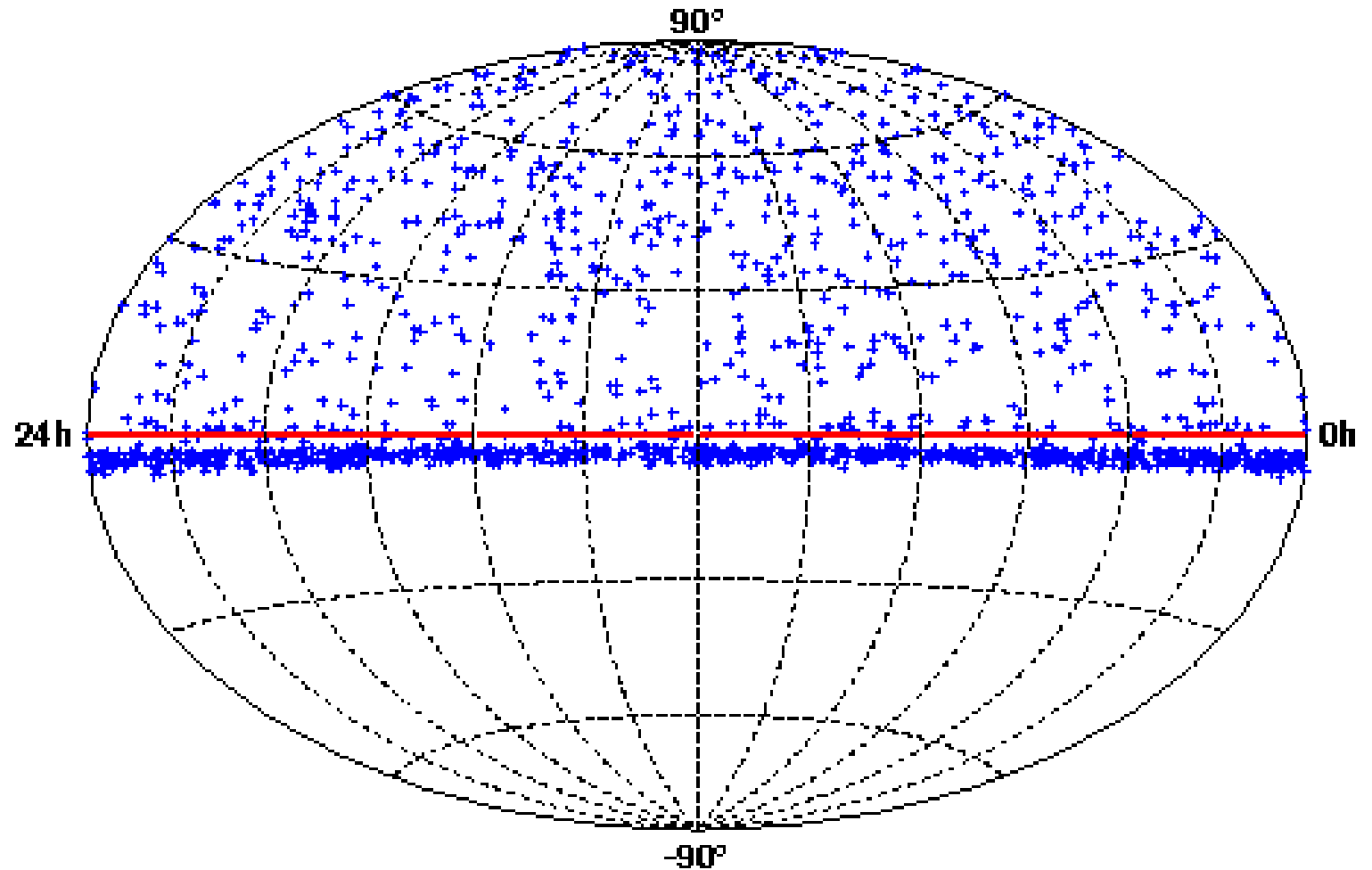
Run 110261 Event 32391 [0ns, 13012ns]

**one in  $10^6$  muon tracks is produced by a neutrino**



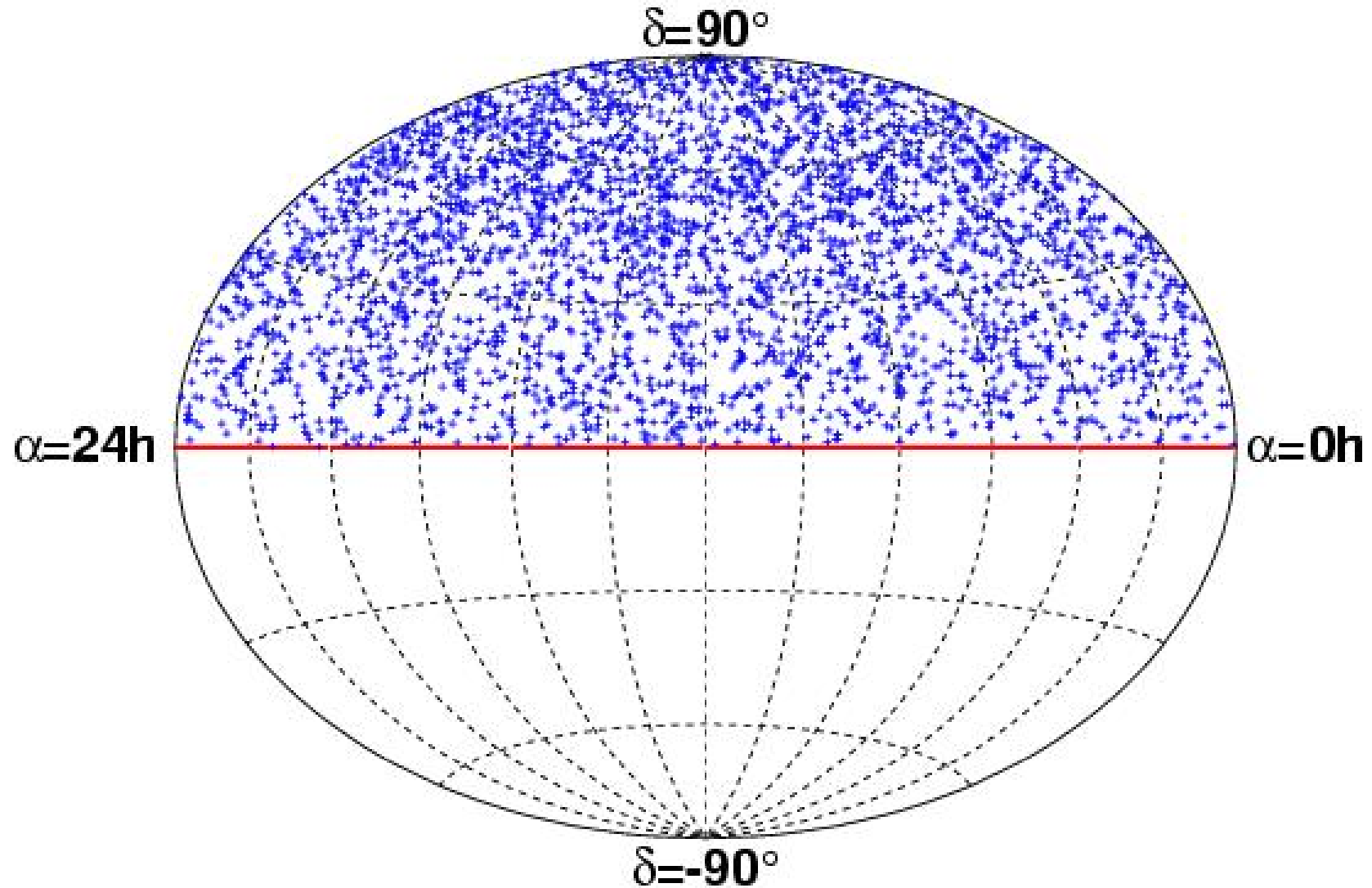
# AMANDA II 2000

1555 Events



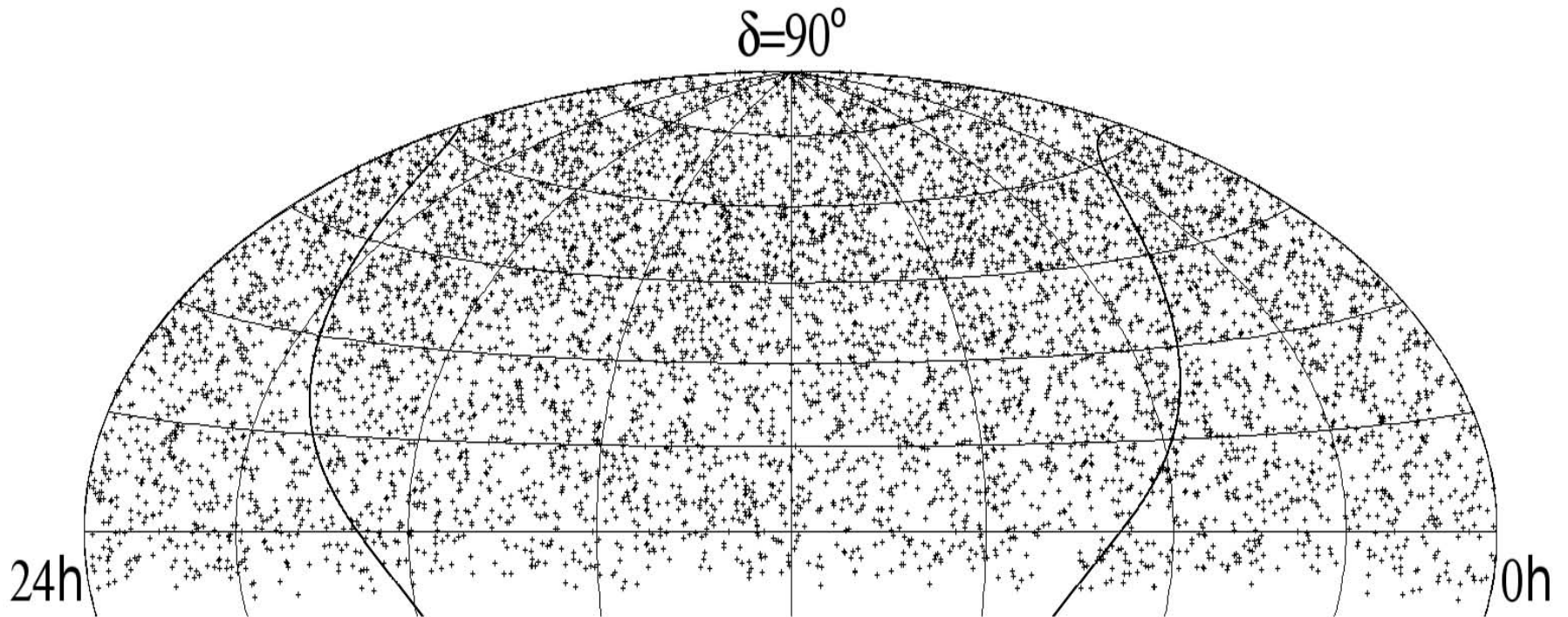
# AMANDA skyplot 2000-2003

3369 events below horizon



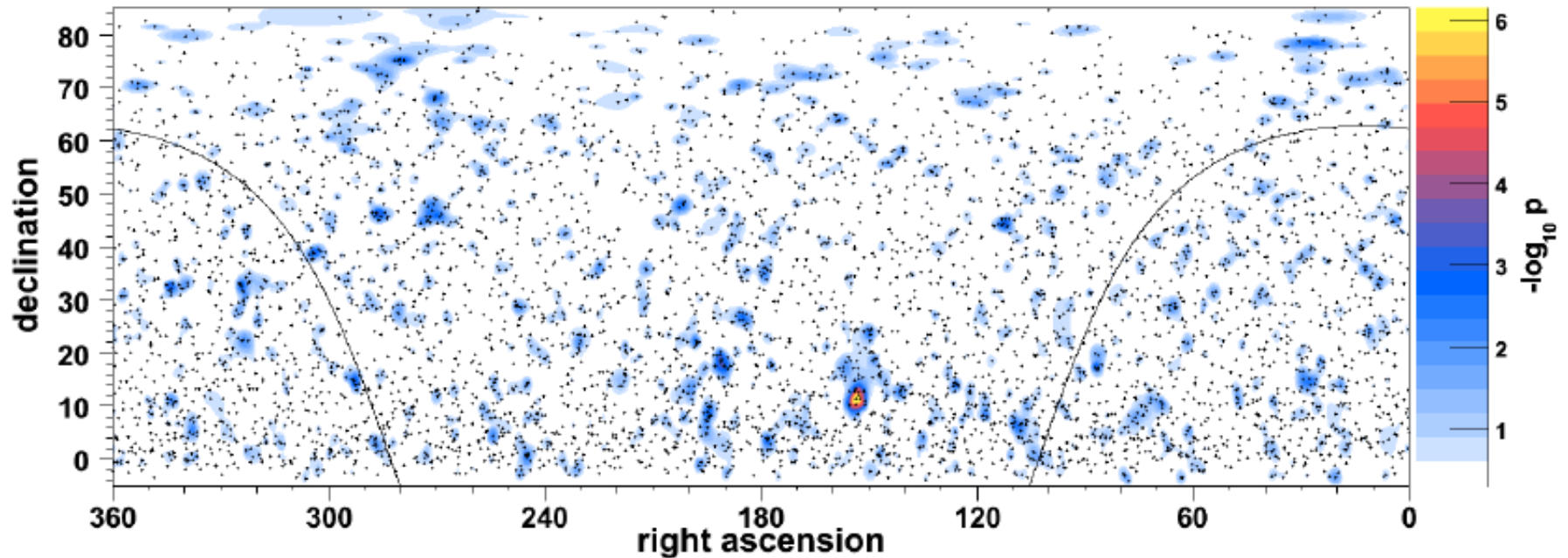
# AMANDA skyplot 2000-2007

6695 events below horizon





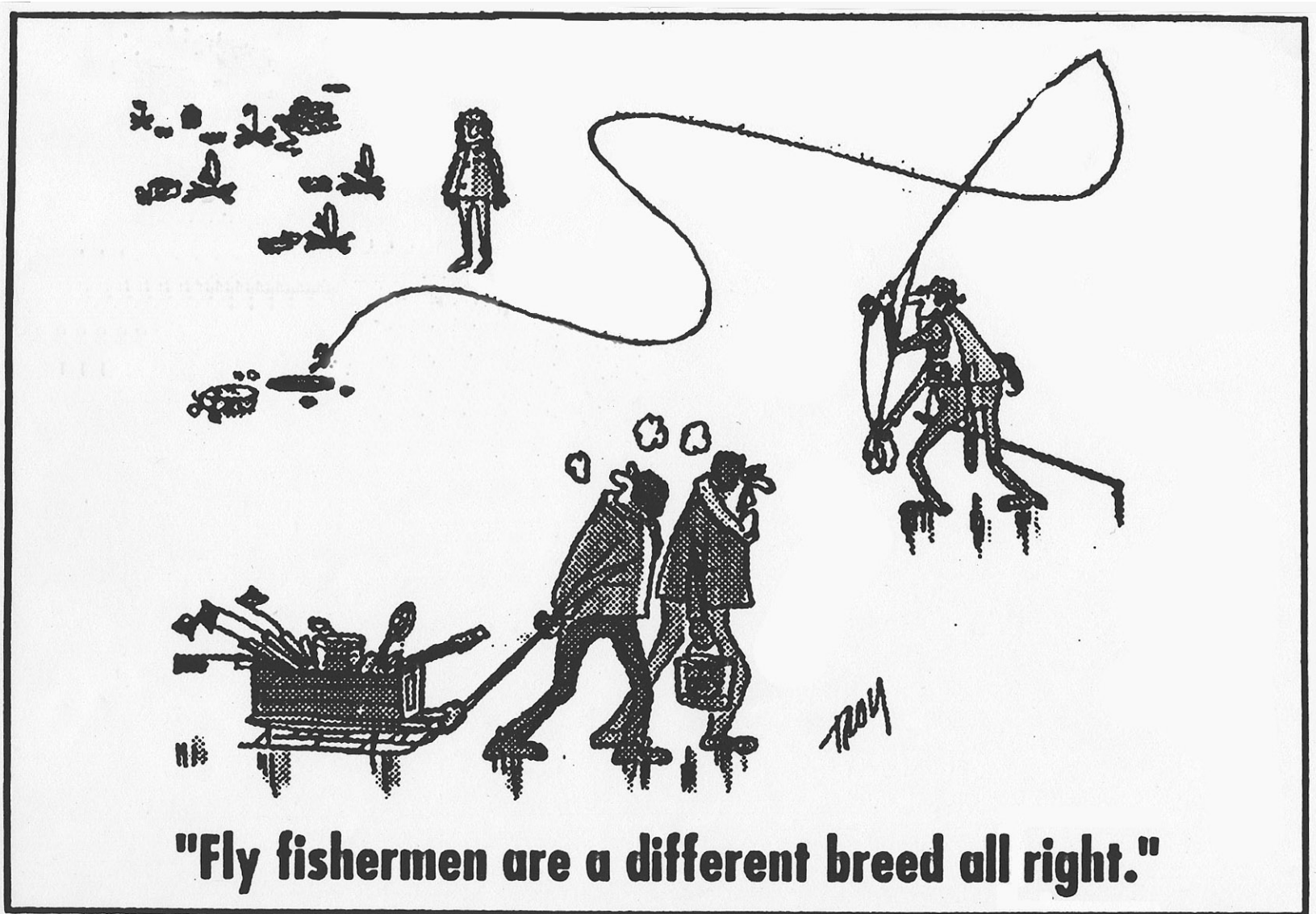
# IceCube 22 String



the hottest spot location is: Ra 153.5 , Dec 11.5  
events: 11      background: 3.3  
 $-\log_{10}(\text{p-value})$  : 6.14 (4.8 sigma)

**happens in 63 out of  $10^4$  scrambled maps, or the probability is  $\sim 0.01$**

# Is ice the solution, really...?

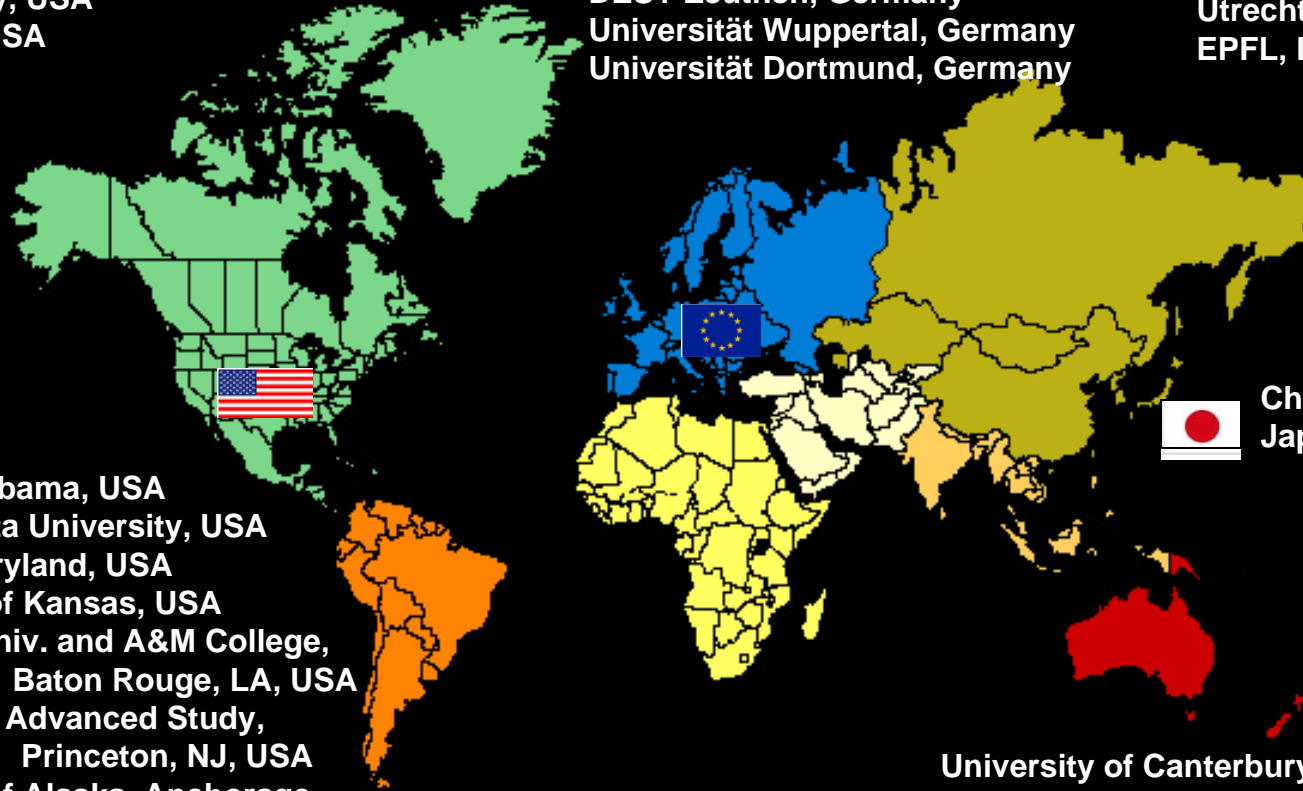


# IceCube Collaboration

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

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

Humboldt Universität, Germany  
MPI, Heidelberg  
Uppsala Universitet, Sweden  
Stockholm Universitet, Sweden  
Kalmar Universitet, Sweden  
Imperial College, London, UK  
University of Oxford, UK  
Utrecht University, Netherlands  
EPFL, Lausanne, Switzerland

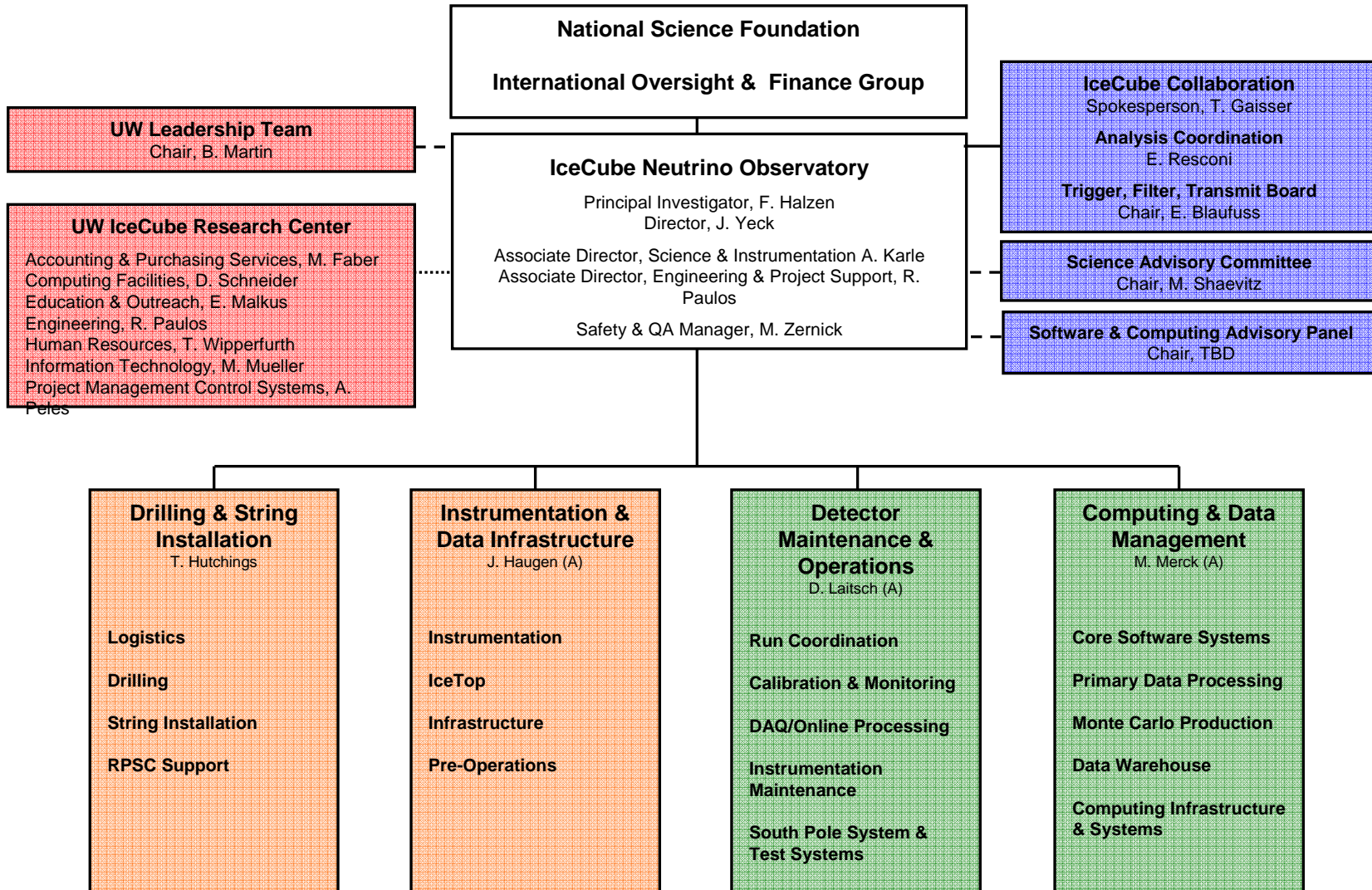


Univ. of Alabama, USA  
Clark-Atlanta University, USA  
Univ. of Maryland, USA  
University of Kansas, USA  
Southern Univ. and A&M College,  
Baton Rouge, LA, USA  
Institute for Advanced Study,  
Princeton, NJ, USA  
University of Alaska, Anchorage

 Chiba University,  
Japan

 University of Canterbury,  
Christchurch, New  
Zealand

# UW-Madison IceCube Organization



Legend	
—	Direction and Reporting
- - - - -	Advice and Recommendations
.....	UW IceCube Support
(A)	Acting