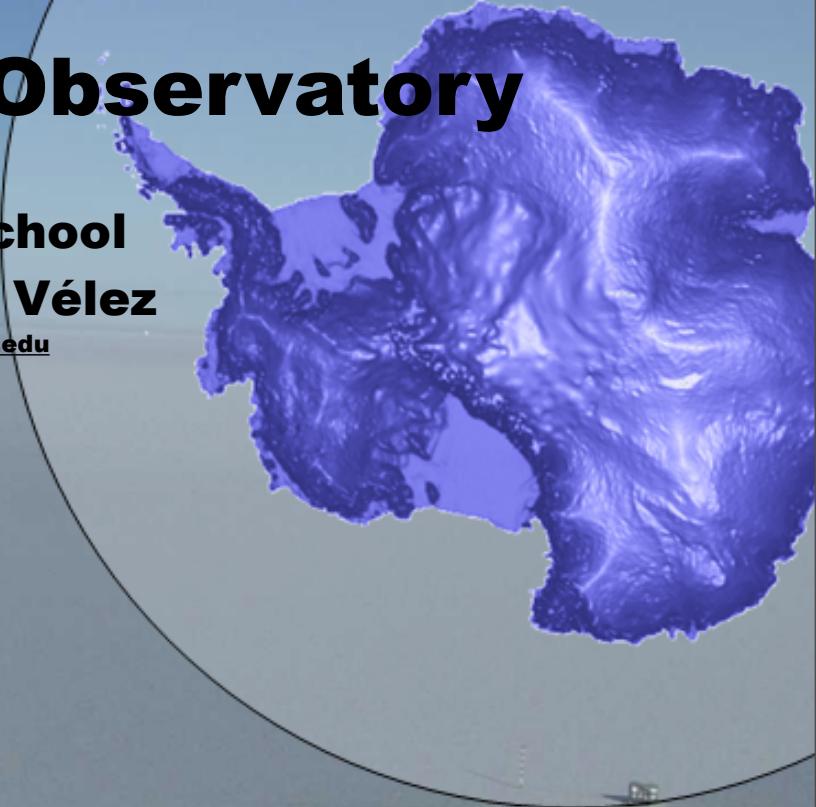


High Throughput Computing for the IceCube Neutrino Observatory

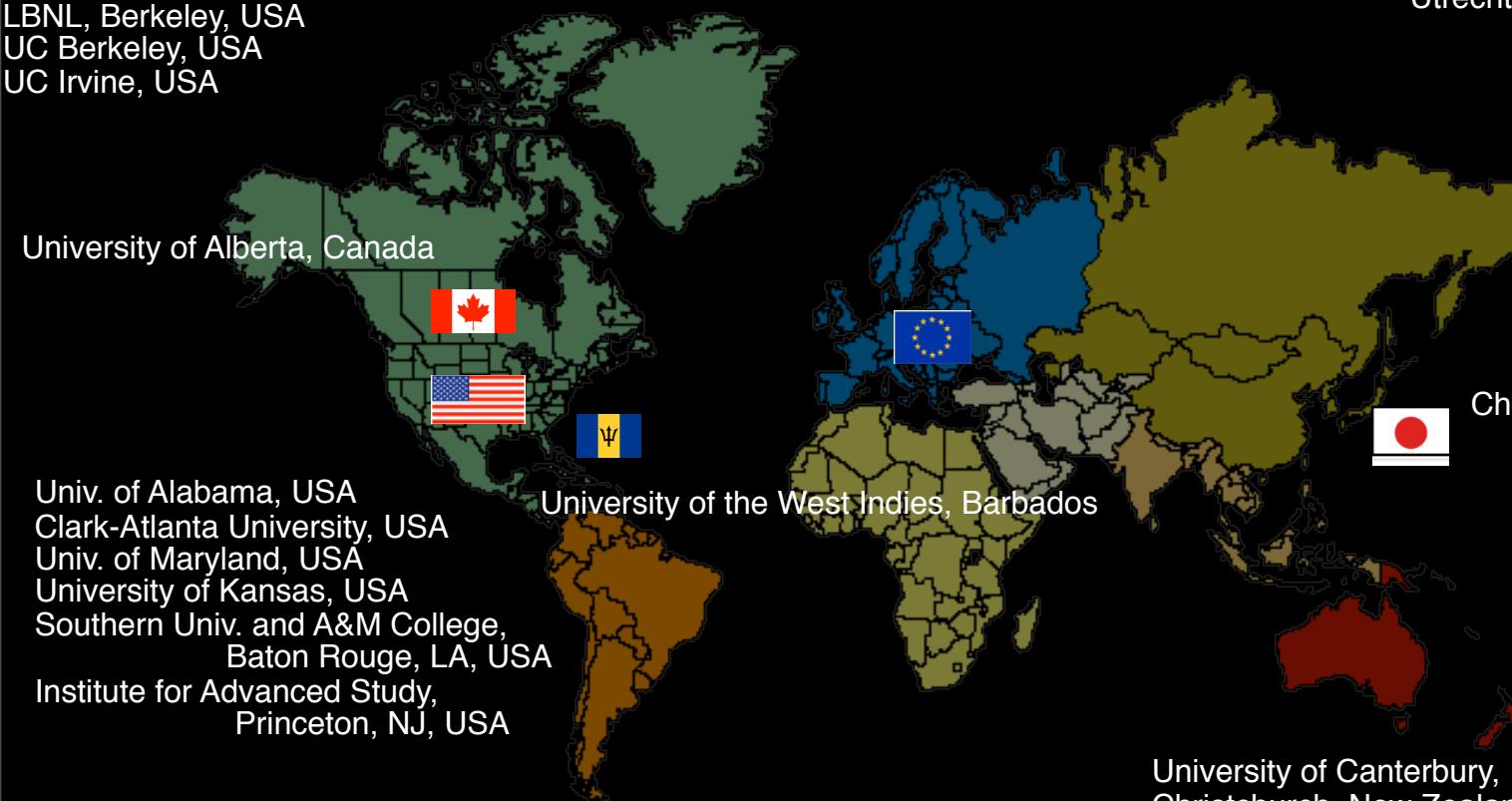
OSG Summer School
Juan Carlos Díaz Vélez

juancarlos@icecube.wisc.edu



IceCube Collaboration

Bartol Research Inst, Univ of Delaware, USA
University of Alaska Anchorage, 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



what is a neutrino ?

ν

- Proposed in 1930 by Pauli to explain missing energy in beta decay.
- Don't interact electro-magnetically.
- small mass ($m_e < 3 \text{ eV}$)
- Very small cross section for weak nuclear interactions
- Neutrinos come in three flavors
- mean free path (in lead) $\sim 1 \text{ ly}$

Standard Model: Leptons

e	μ	τ
ν_e	ν_μ	ν_τ

ν source candidates

?

ν source candidates

supernova remnants



Photo credit: FORS Team, 8.2-meter VLT, ESO

?

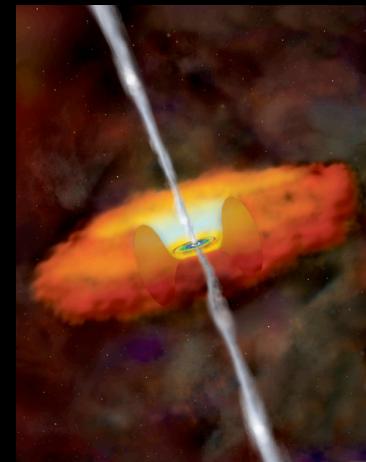
ν source candidates



Photo credit: FORS Team, 8.2-meter VLT, ESO

supernova remnants

AGNs



?

ν source candidates



Photo credit: FORS Team, 8.2-meter VLT, ESO

supernova remnants

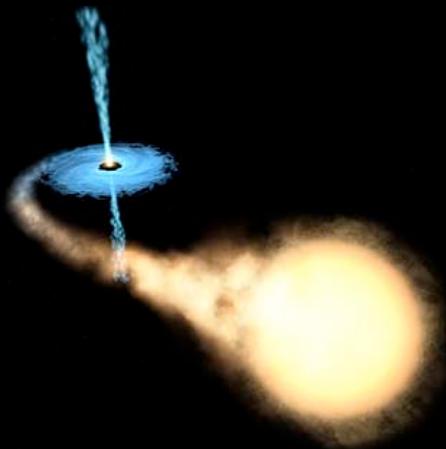
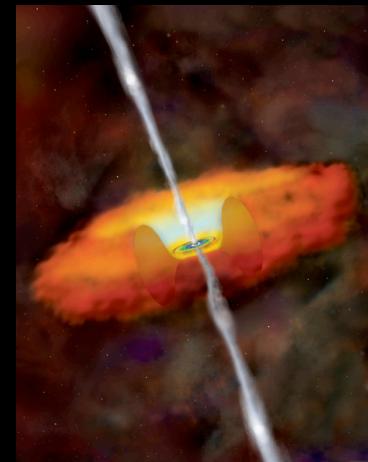


Photo Credit: ESA/NASA/F. Mirabel (CEA)

AGNs

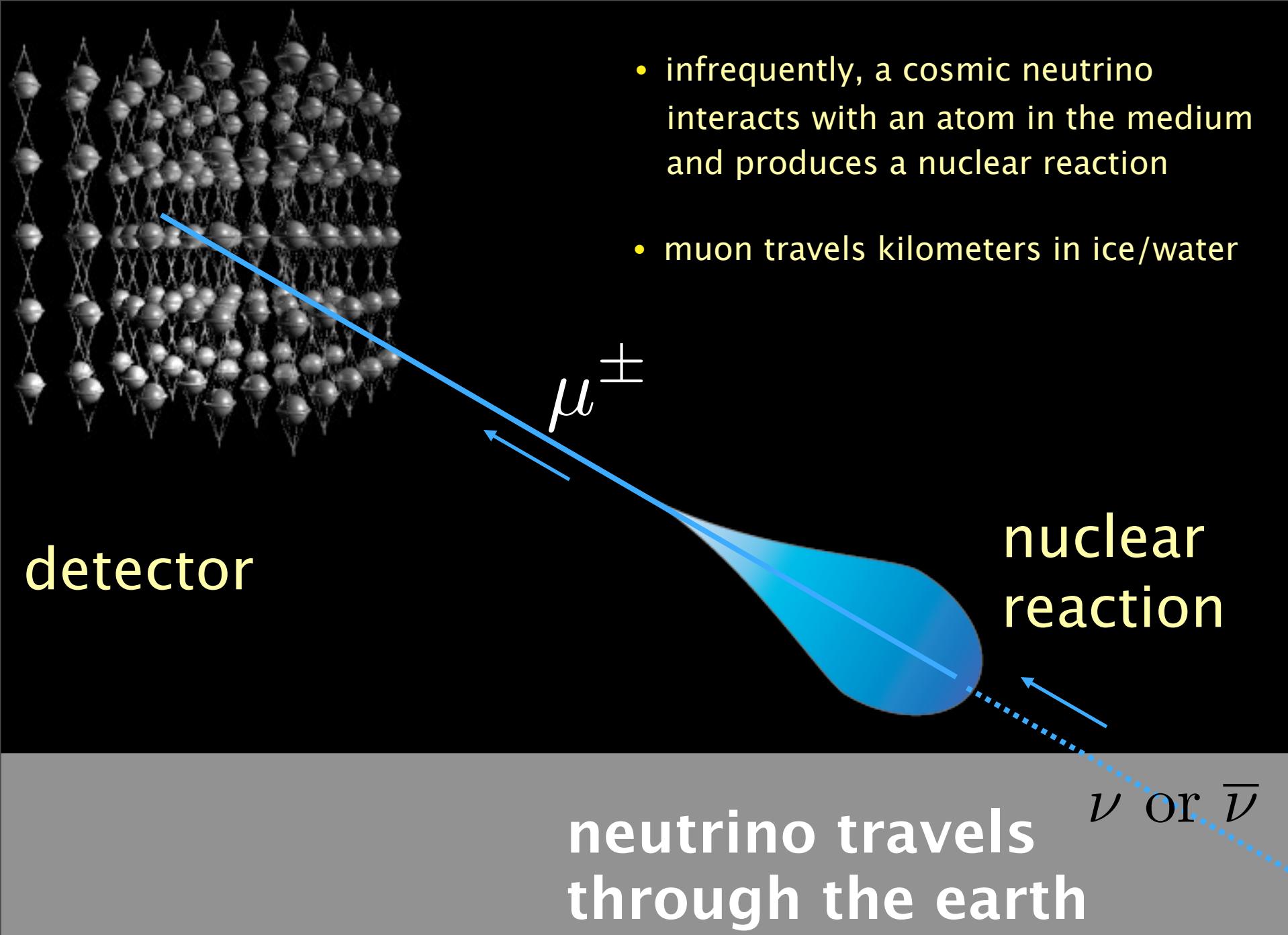


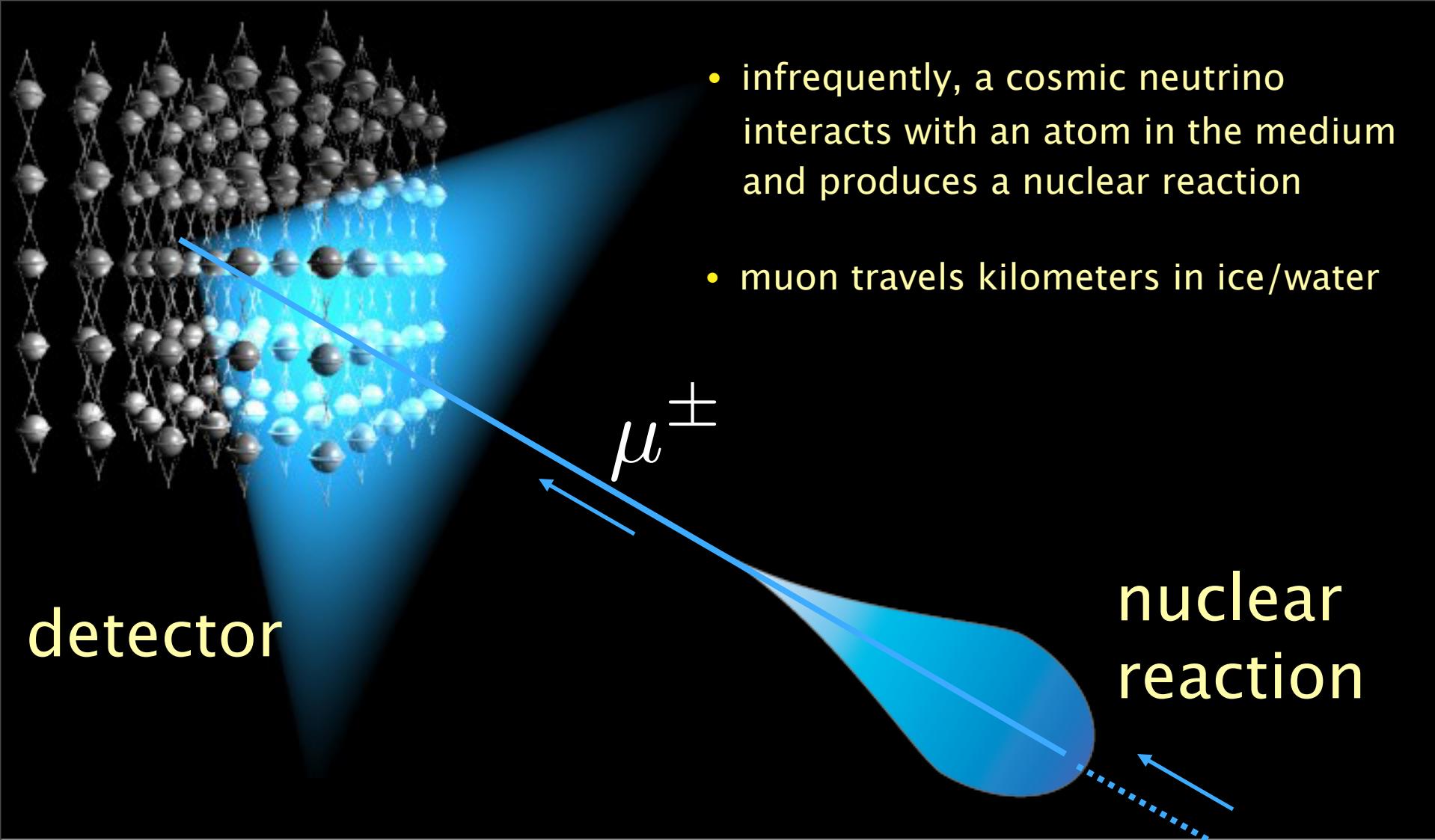
micro-quasars

unexpected sources

?

how do we detect neutrinos ?

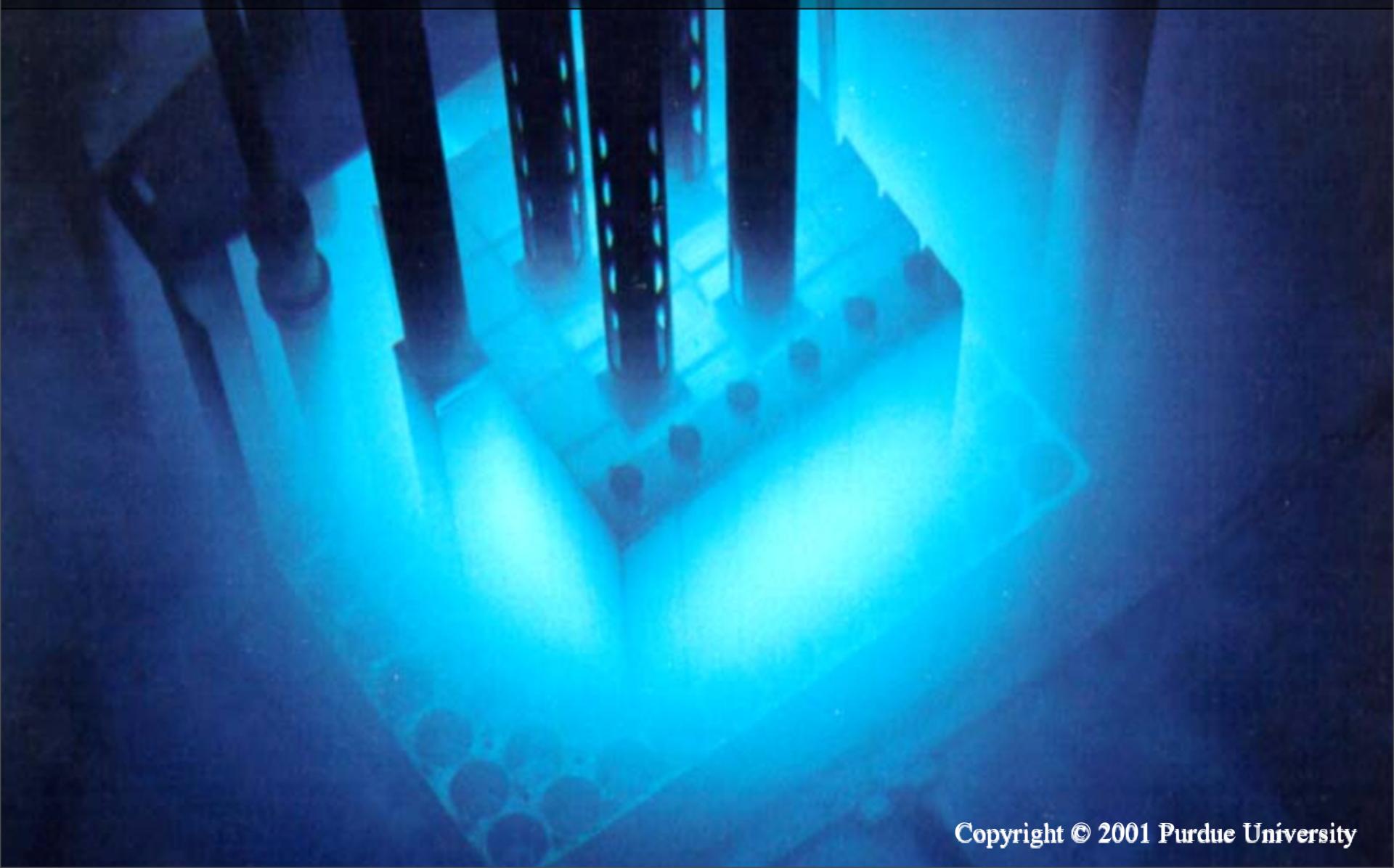




- muon track produces Cherenkov light
- optical sensors capture (and map) the light

ν or $\bar{\nu}$

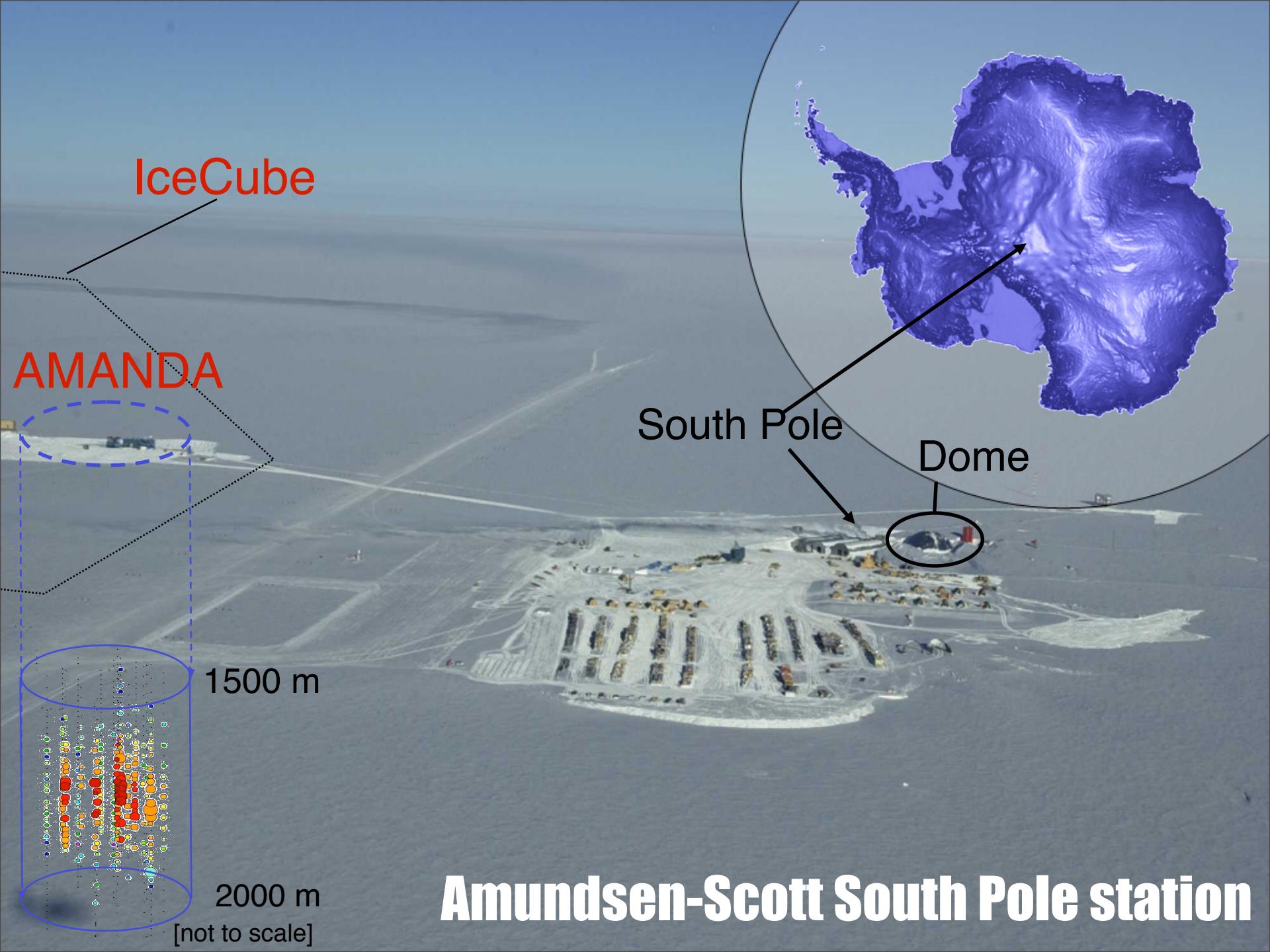
Blue Cherenkov light is produced that streams through the water after a nuclear reaction



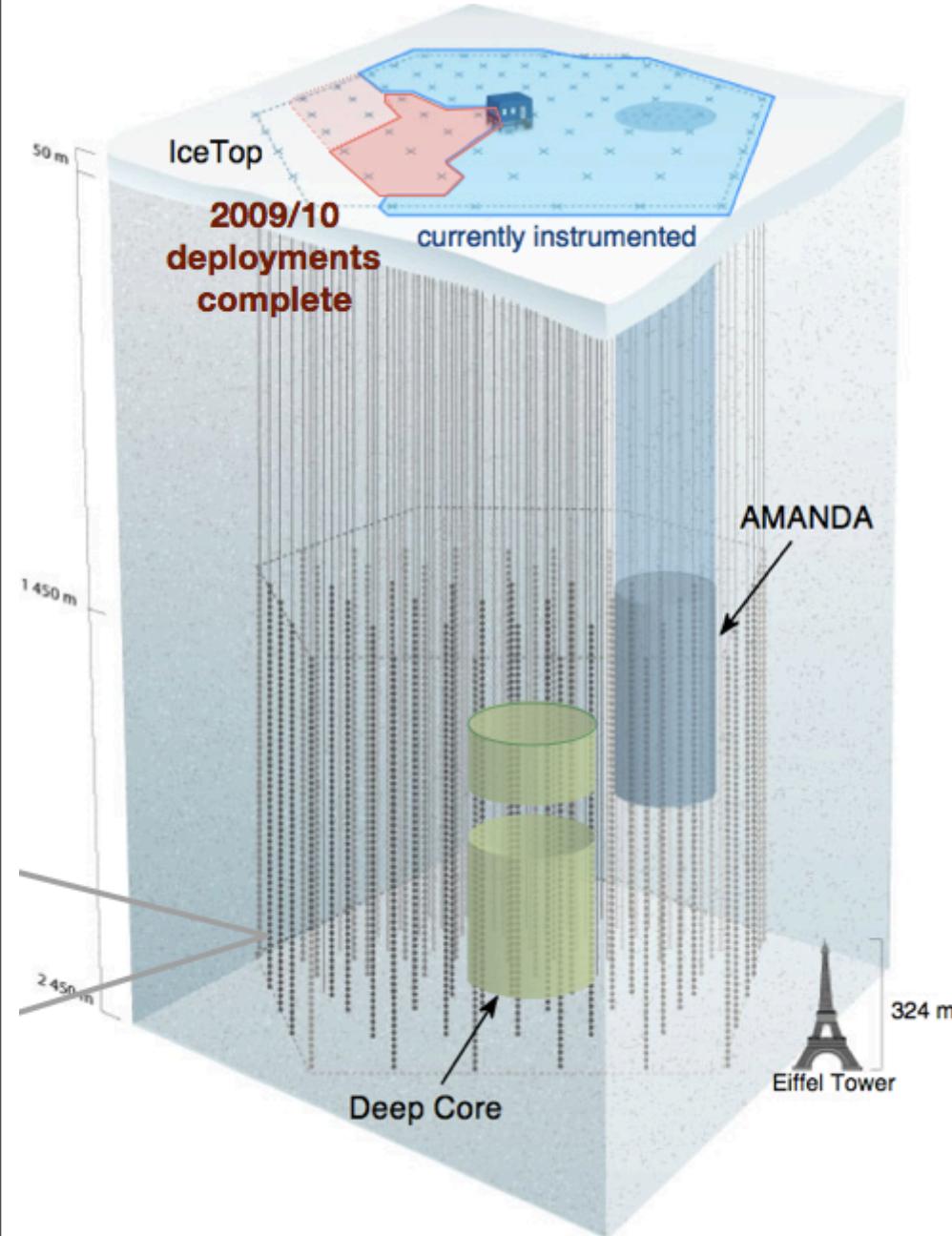
Photomultiplier Tube



IceCube



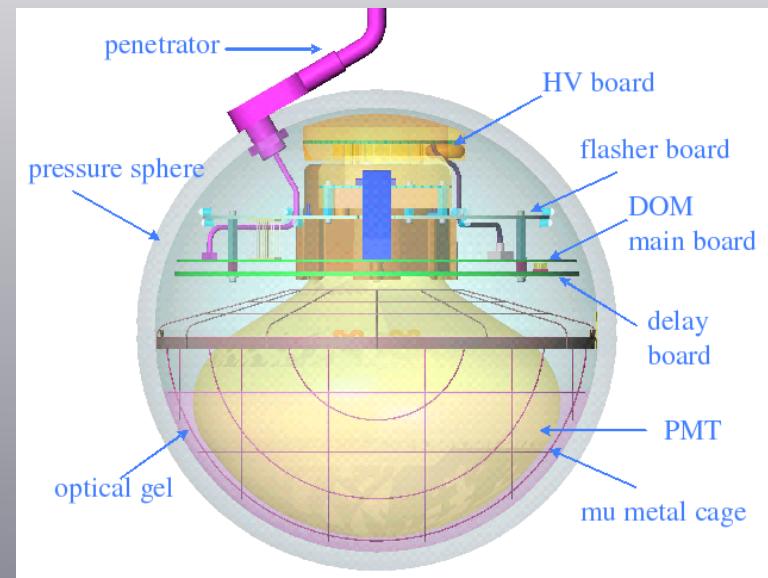
IceCube



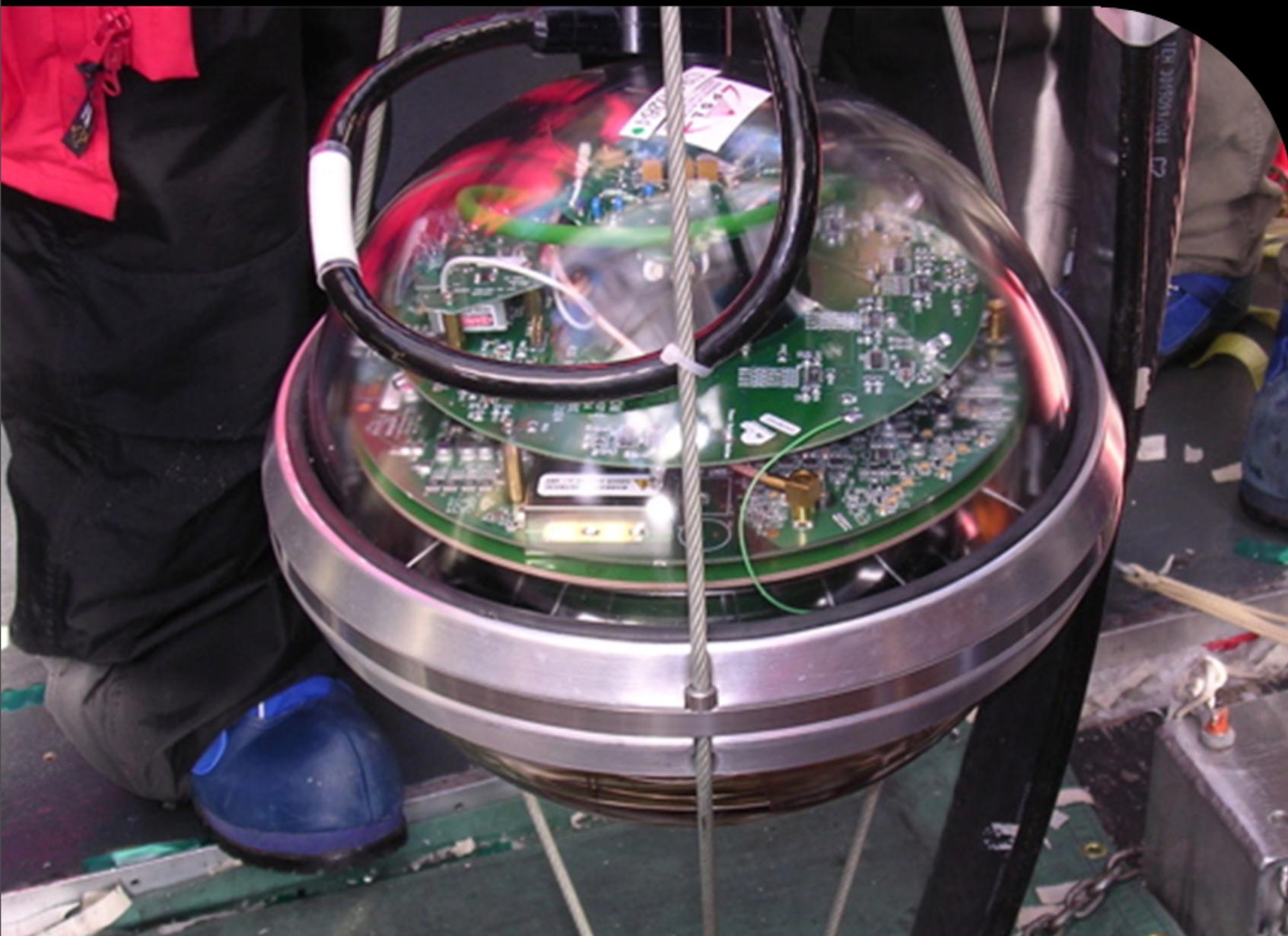
- 79 strings deployed to date
- final configuration: 5160 modules on 86 strings
- between 1.4 and 2.4 km depth
- Trigger rate:
 - ~100 neutrinos
 - 1.7×10^8 muons per day
- 10 GeV threshold
- angular resolution of 0.4~1 deg.

Digital Optical Modules

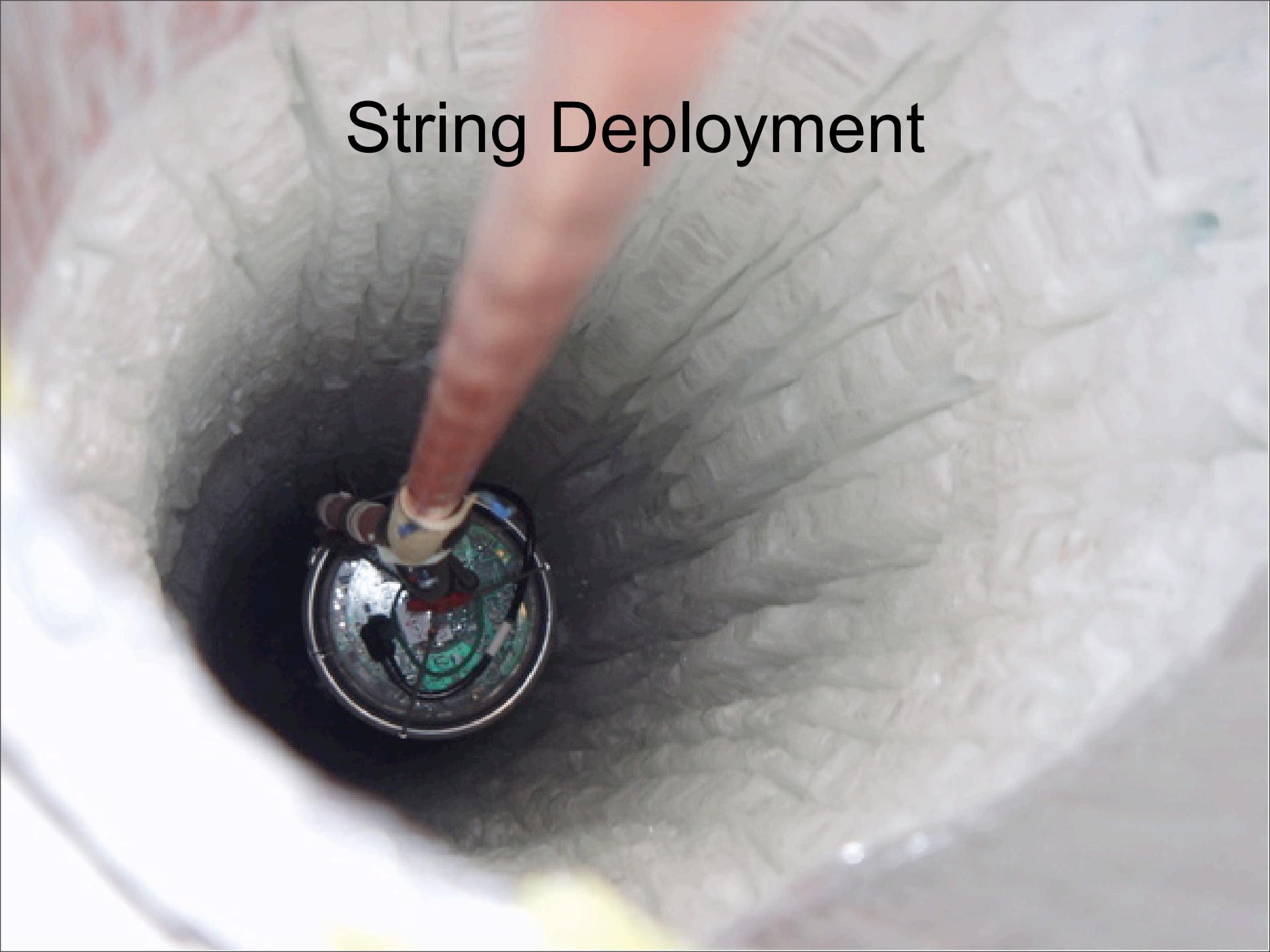
- PMT signal digitized by ATWD at ~280MHz
 - Accurate charge/time measurement
- Array time measurement is self-calibrating
 - DOM clock synchronized to surface GPS clock
 - Accuracy ~1-2ns
- Flasherboard light pulses visible >200m in clear ice layers
 - Geometry calibration
 - Study of hole ice



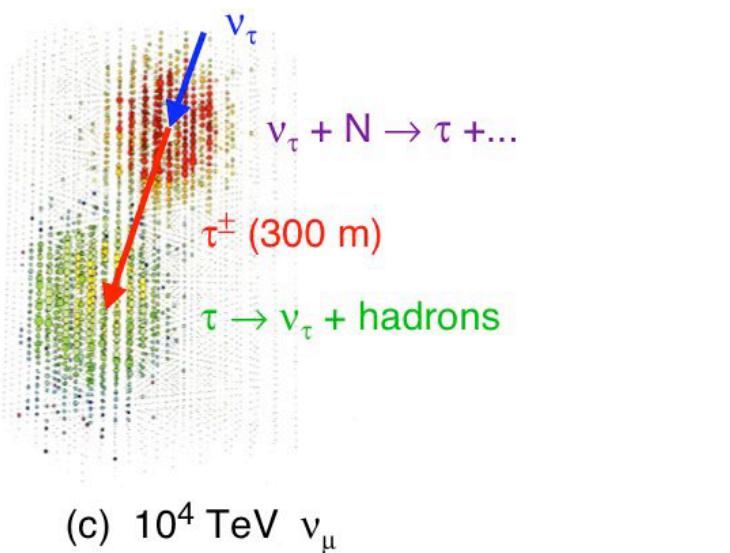
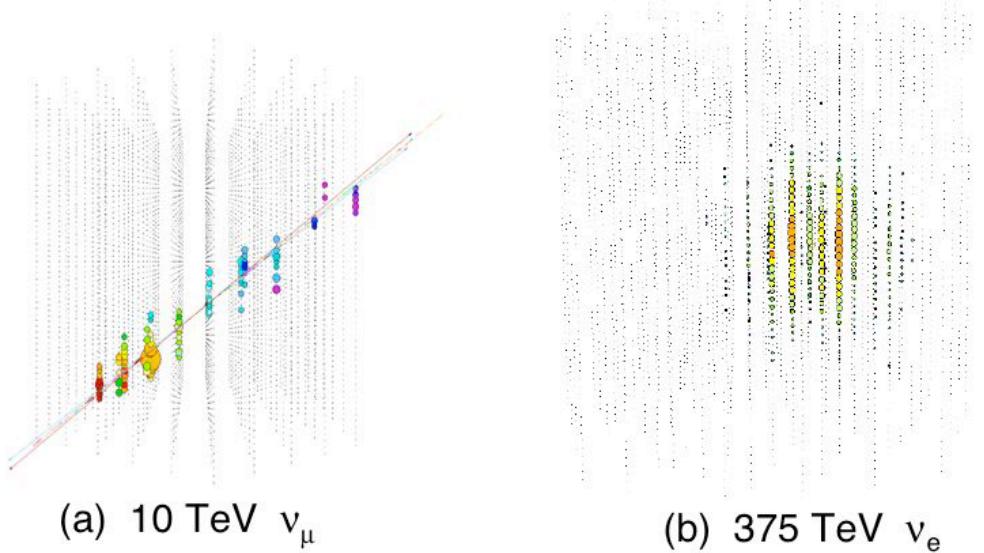
optical sensor



String Deployment



IceCube : simulated events



simulation demands

simulation	livetime	runtime (2.67GHz)
single shower	~10 sec	3.5 h/core
signal ν_μ (E^{-1})*		9.4 sec/event
signal ν_μ (E^{-2})		5.5 sec/event
signal ν_e (E^{-1})		12.7 sec/event
signal ν_e (E^{-2})		5.3 sec/event

*) estimated : runtime depends on configuration

data processing demands

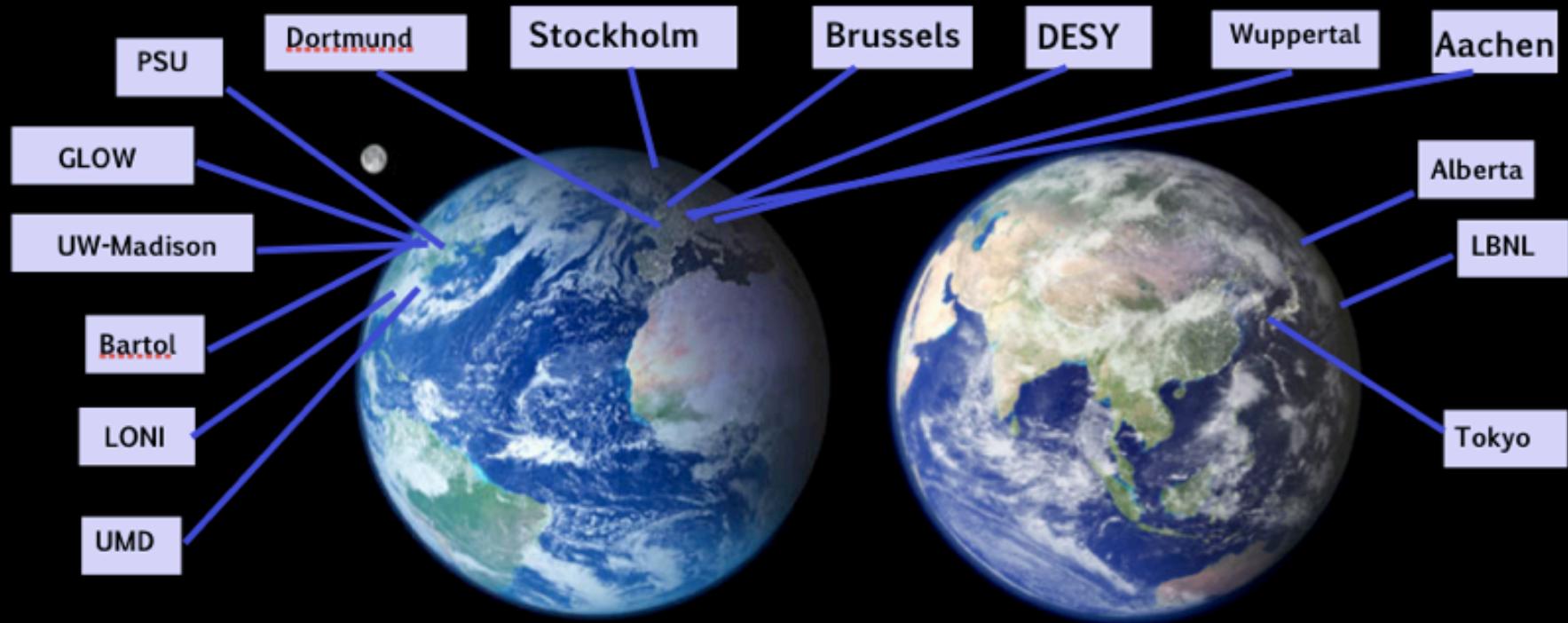
Bulk of data filtering is performed at South Pole before satellite transfer on 152 cores (to be expanded to ~300 cores)

FilterLevel	livetime	runtime (2.67GHz)
L1	~8 hrs/run	2 CPU-hr/min
L2		19.7 CPU-hr/min
L3 (μ)		0.031 CPU-hr/min
L3(cscd)		0.021 CPU-hr/min

icecube computing resources



The IceCube “grid”



The IceCube “grid”

1. Heterogeneous collection of clusters, grids through member institutions.
2. Different batchsystems/middleware
3. Different operating systems/platforms