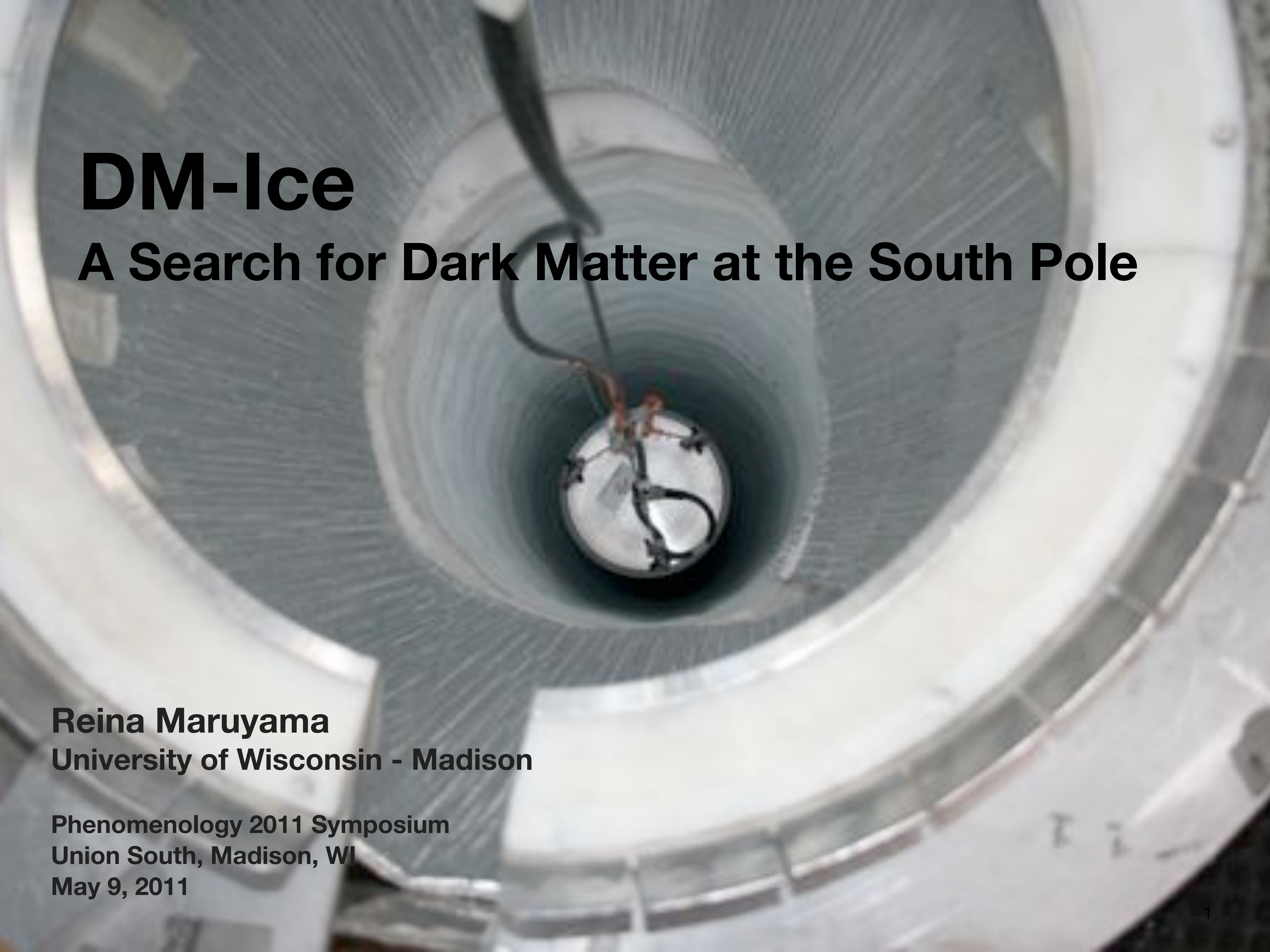


DM-Ice

A Search for Dark Matter at the South Pole

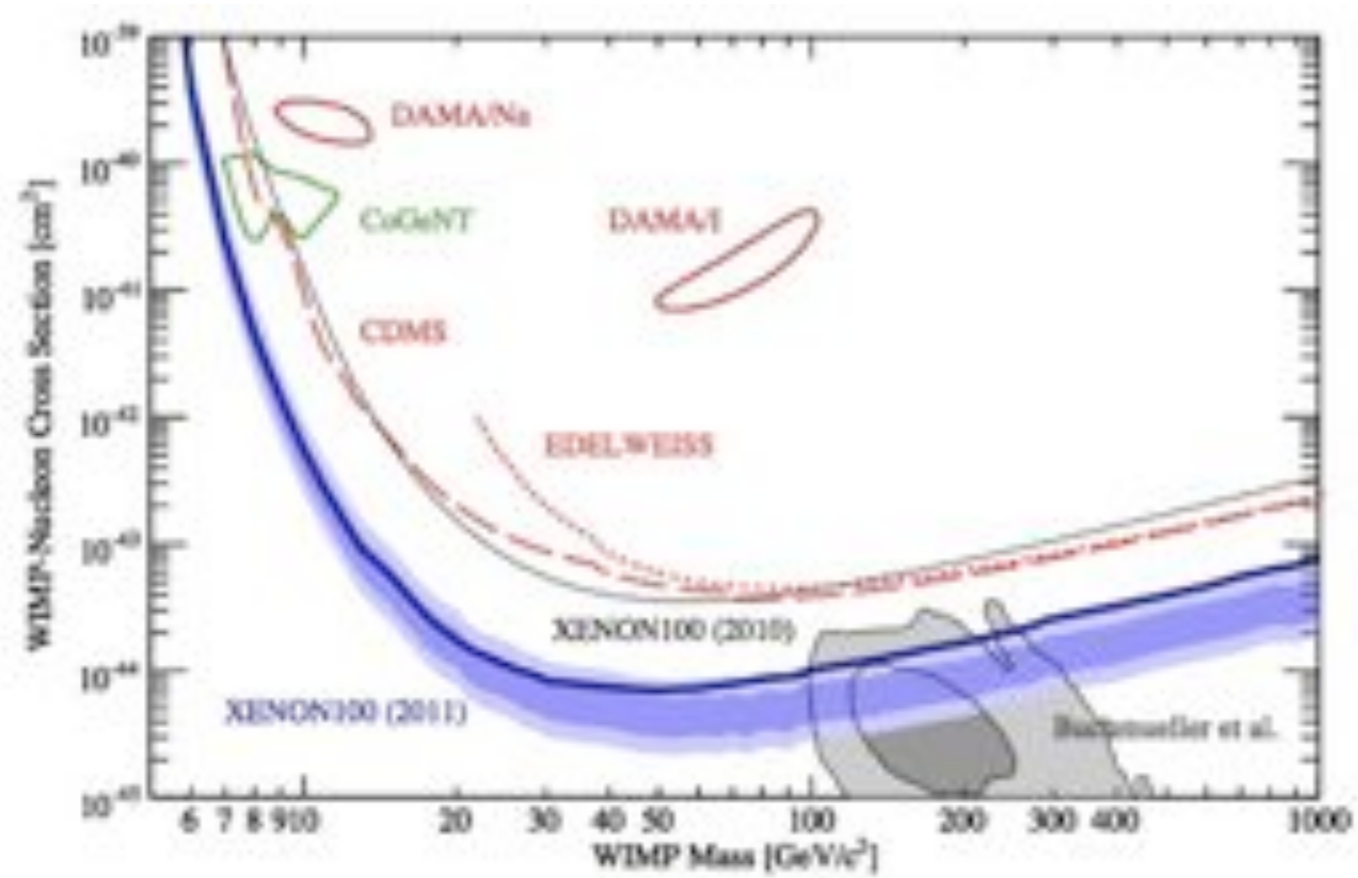
Reina Maruyama

University of Wisconsin - Madison

Phenomenology 2011 Symposium
Union South, Madison, WI
May 9, 2011

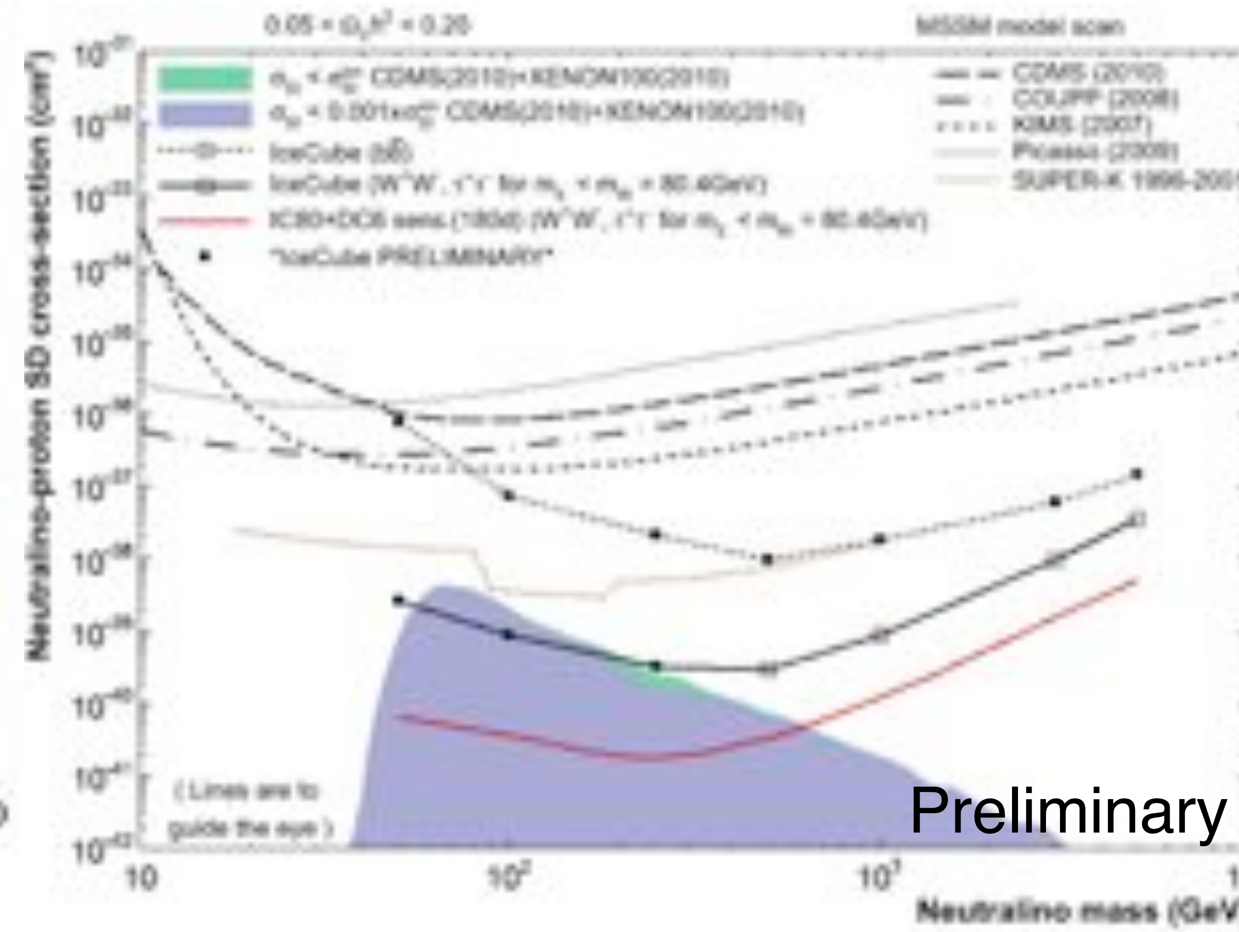
Current Status of Bounds on Dark Matter from Terrestrial experiments

Spin-Independent



Aprile et al., arXiv:1104.2549v1 (2011)

Spin-Dependent



One claim for discovery: DAMA

and what about CoGeNT?

What is going on?

- Experimental issues?
  - These experiments are extremely challenging. We need to understand our detectors and uncertainties on quenching factors, energy scale, threshold effects, backgrounds, etc. etc....
  - Build bigger and better experiments or look for annual / daily modulation.
- Modify astrophysics?
  - f(v)? v_{esc}? v_0? co-rotating?
- More exotic particle?
  - spin-dependent, inelastic scattering, momentum-dependent scattering...
- Proposed solution: look for annual modulation with NaI in the Southern Hemisphere.

What is going on?

- Experimental
  - These exp[…] to understand our detectors a[…]gy scale, threshold effects, ba[…]
  - Build bigg[…] daily modulation.
- Modify astrop[…]
  - f(v)? v_{esc}?
- More exotic p[…]
  - spin-deper[…]ndent scattering...

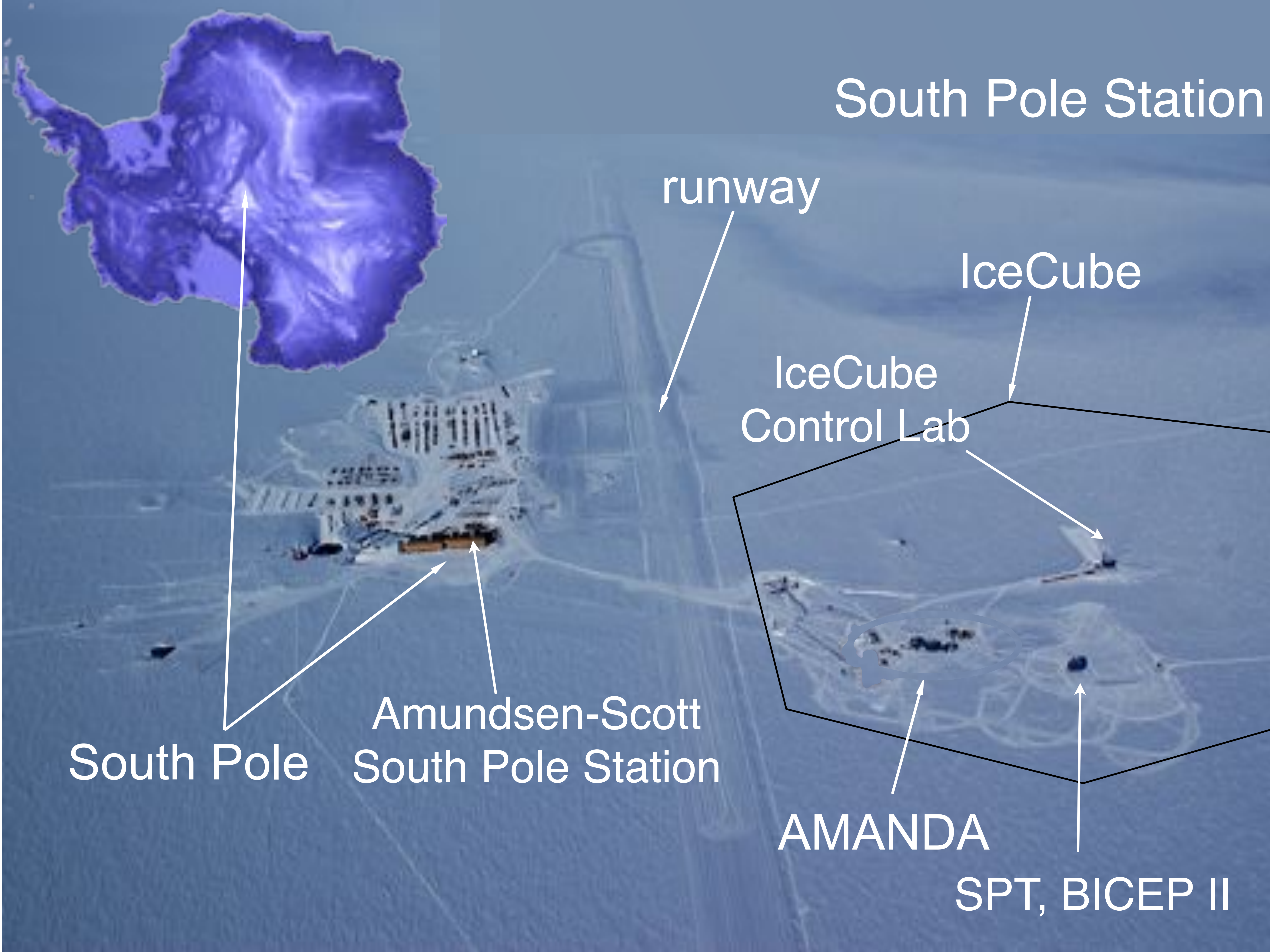
- Proposed solution: look for annual modulation with NaI in the ~~Southern Hemisphere.~~

South Pole

Why South Pole?

- The phase of the dark matter modulation is the same.
- Many environmental variations are either opposite in phase (e.g. muon rate) or absent (e.g. temperature, neutrons).
- > 2500 m.w.e. of overburden with clean ice.
  - Clean ice → no lead/copper shielding necessary. No radons.
  - Ice → neutron moderator.
  - Ice as an insulator → No temperature modulation.
- Existing infrastructure
  - NSF-run Amundsen-Scott South Pole Station
  - Ice drilling down to 2500 m developed by IceCube
  - Muon veto by IceCube/DeepCore
  - Infrastructure for construction, signal readout, and remote operation

South Pole Station

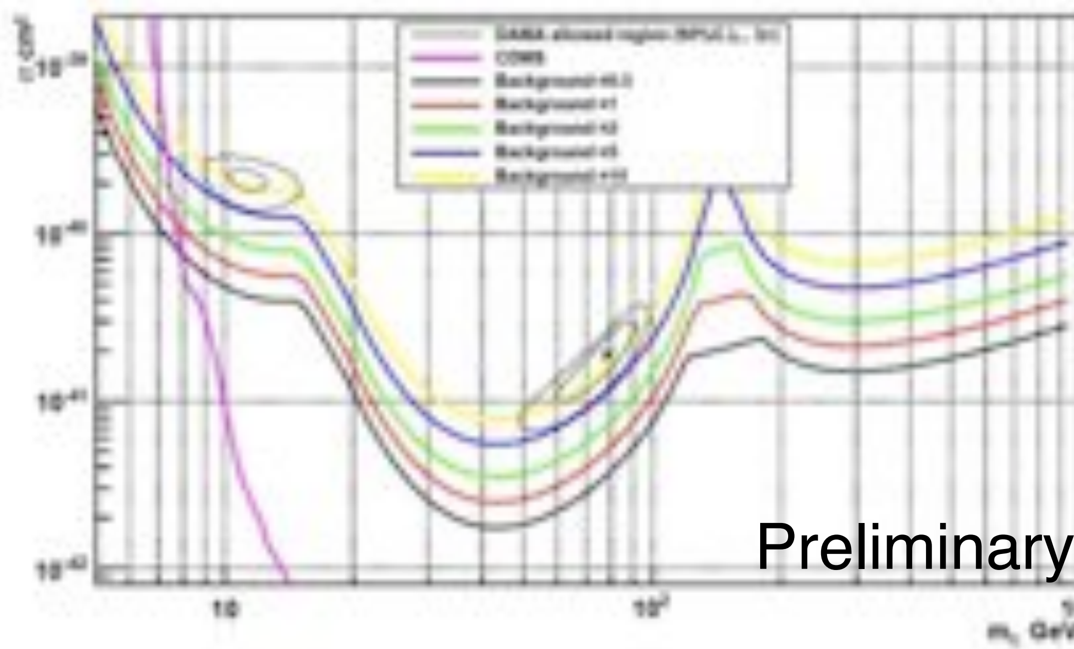


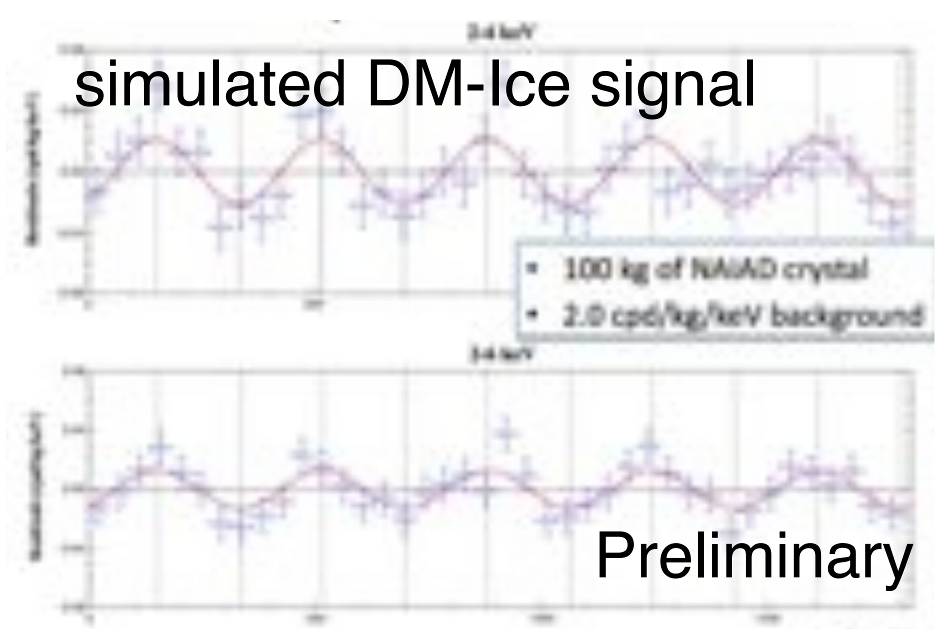
Requirements for Testing DAMA

- If DAMA signal is there, we can do a 5-sigma measurement in 2 years with 250 kg and comparable background as DAMA.

	Years	2 NAIAD 17.0 kg	NAIAD size 44.5 kg	DAMA size 250 kg
NAIAD background	1	0.45	0.72	1.71
	3	0.77	1.25	2.96
	5	1.00	1.61	3.82
	7	1.18	1.91	4.52
50% NAIAD background	1	0.63	1.02	2.42
	3	1.09	1.77	4.18
	5	1.41	2.28	5.40
	7	1.67	2.70	6.39
Double DAMA background	1	0.85	1.37	3.26
	3	1.47	2.38	5.64
	5	1.90	3.07	7.29
	7	2.25	3.64	8.62
DAMA background	1	1.20	1.94	4.61
	3	2.08	3.37	7.98
	5	2.69	4.35	10.31
	7	3.18	5.14	12.19
1/10 DAMA background	1	3.80	6.15	14.57
	3	6.58	10.65	25.24
	5	8.50	13.75	32.59
	7	10.06	16.27	38.56

5-σ detection of DAMA signal with a 250-kg / 2-year running time (2 - 4 keV)





DM-Ice Concept

38 NaI Crystals (each vessel contains 19)
- 95.6 mm Diameter
- 250 mm Long
- 6.5 kg each
- 2 PMTs each

Instrument with few “DOMs” externally for veto

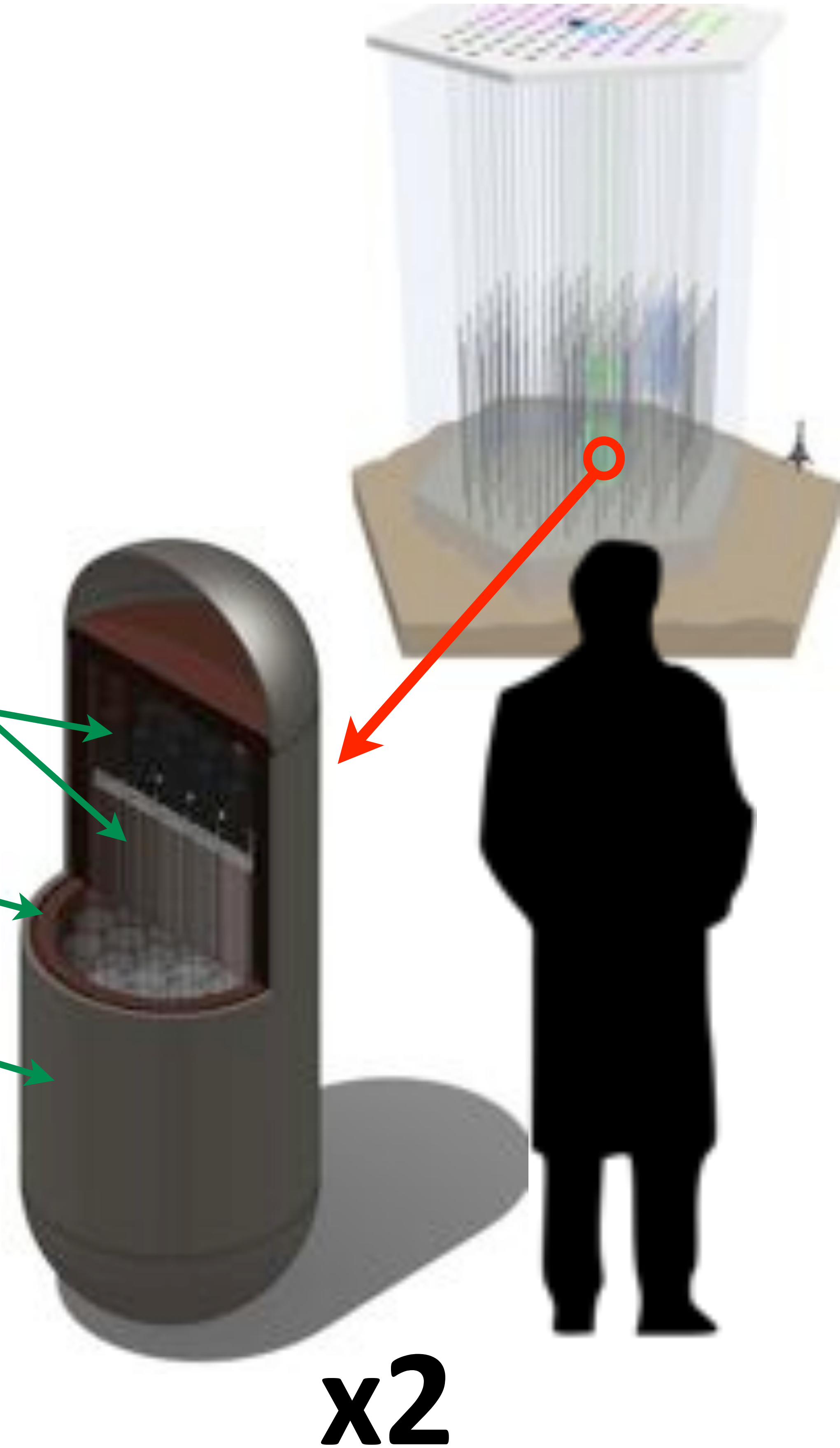
50 - 60 mm Copper Radial Shield

SS External Pressure Vessel Shell
- 65 cm (25.6 inch) Outer Diameter
- 1.7 m (67 inch) Length

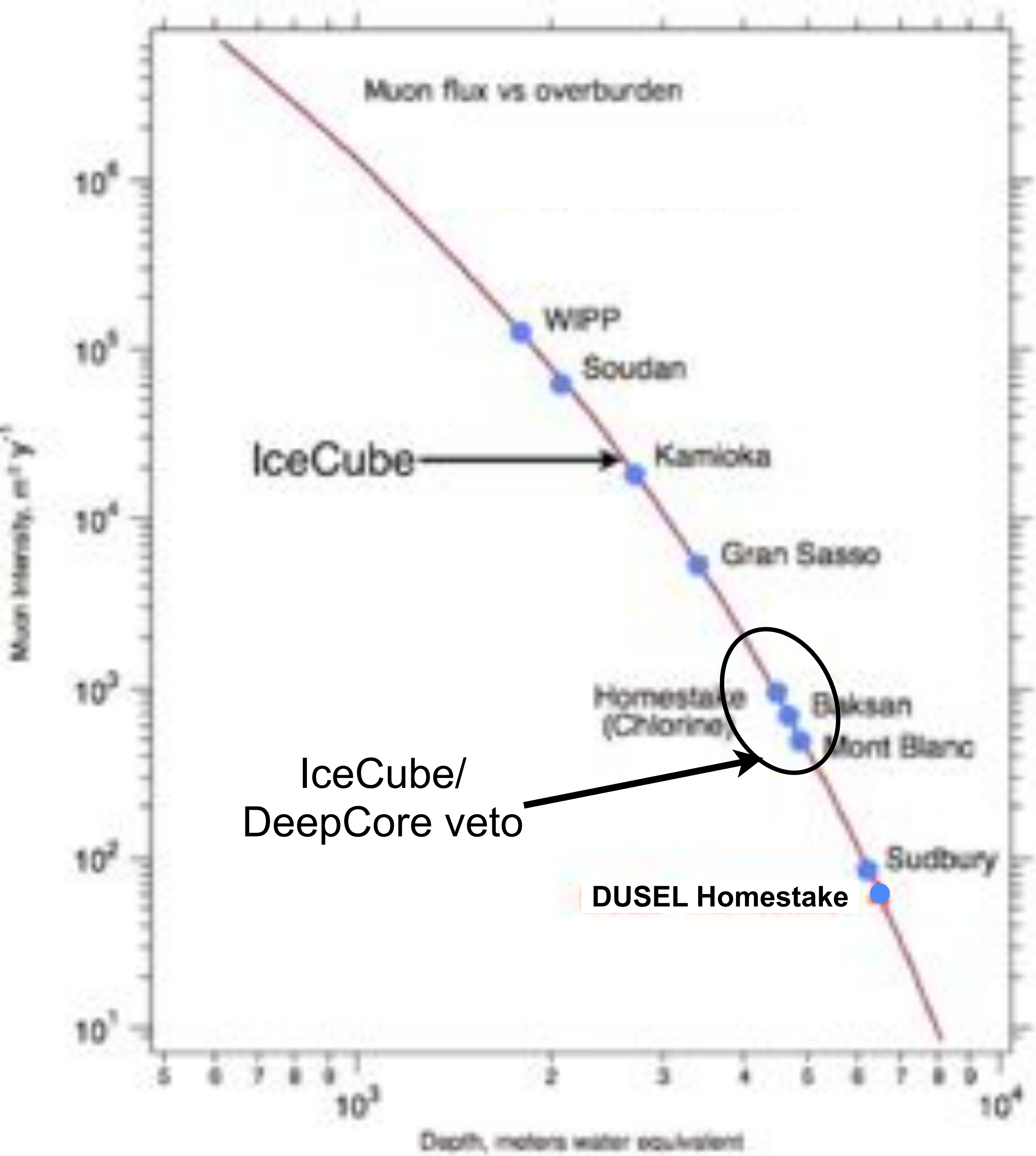
250 kg NaI

1500 kg total including pressure vessel

Additional details:
- Communication cable to surface similar to IceCube
- PMTs outside the vessel for self-contained muon veto

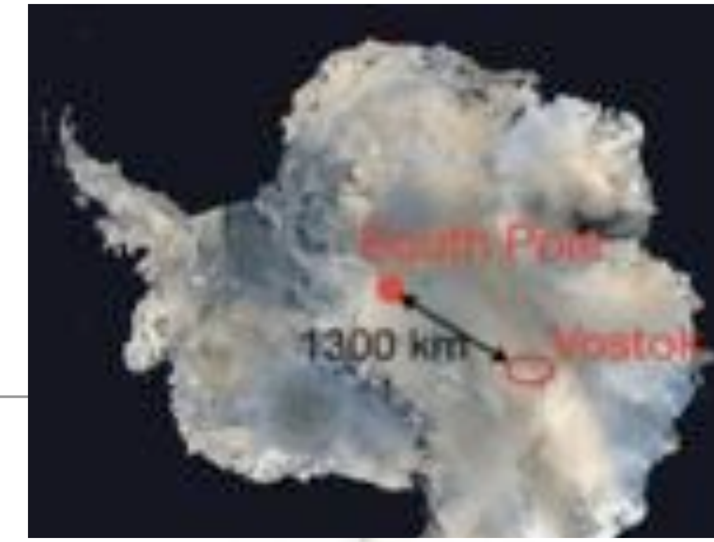


Overburden at -2500 m (2200 m.w.e.)



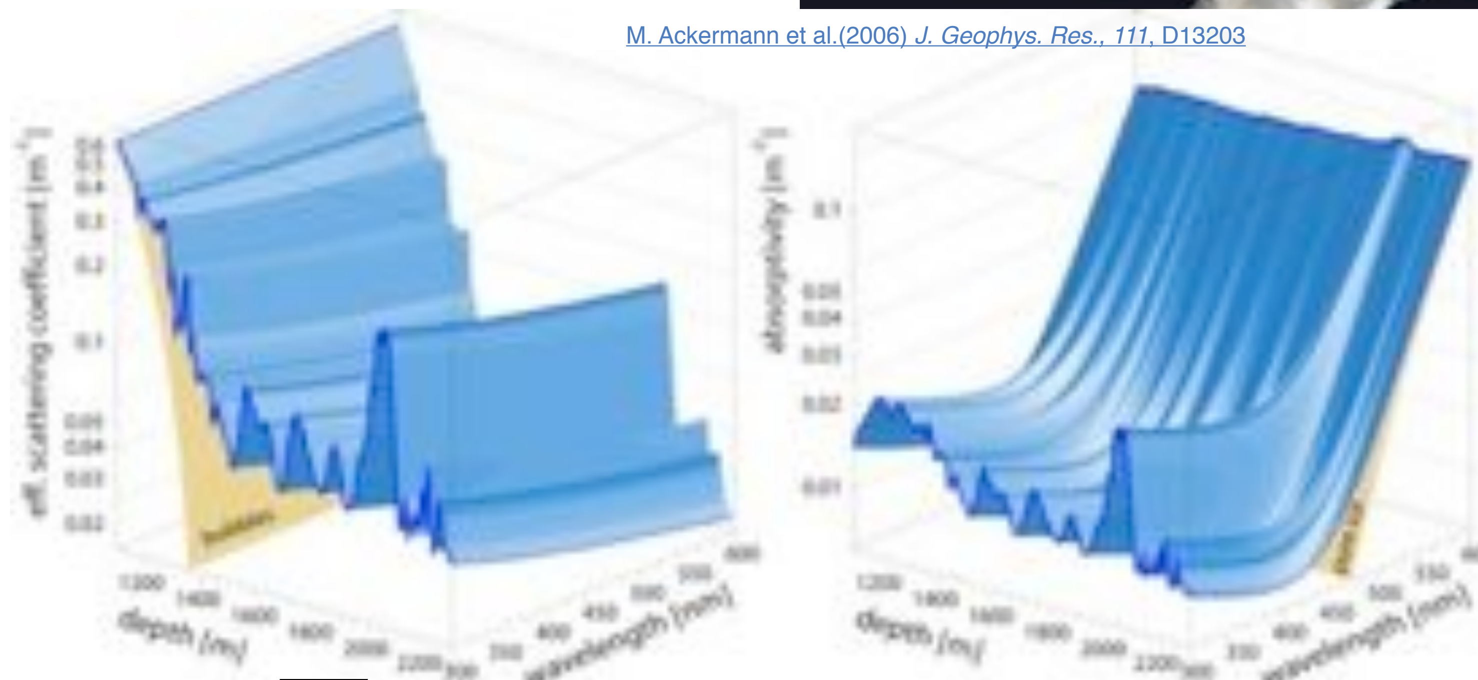
- ~85 muons/m^2/day at bottom of IceCube
- IceCube/DeepCore veto reduces rate by ~1-2 orders of magnitude.
- Ice is a neutron moderator

Radiopurity of Antarctic Ice

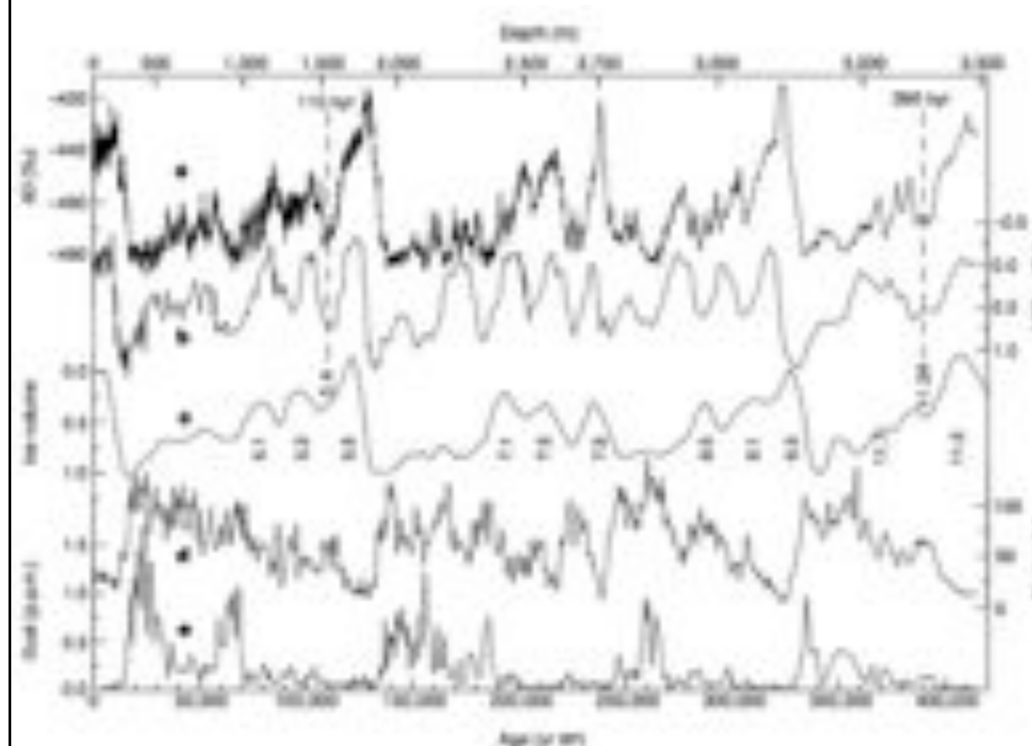


M. Ackermann et al.(2006) *J. Geophys. Res.*, *111*, D13203

- Measurements from ice cores at Vostok.
- Absorption and scattering lengths measured by AMANDA/ IceCube
- -2500 m at South Pole is ~100,000 years old
- Most of the impurities come from volcanic ash, < 0.1 ppm
- Radioactive contaminants in ice:
  - U ~ ppt
  - Th ~ ppt
  - K ~ ppb



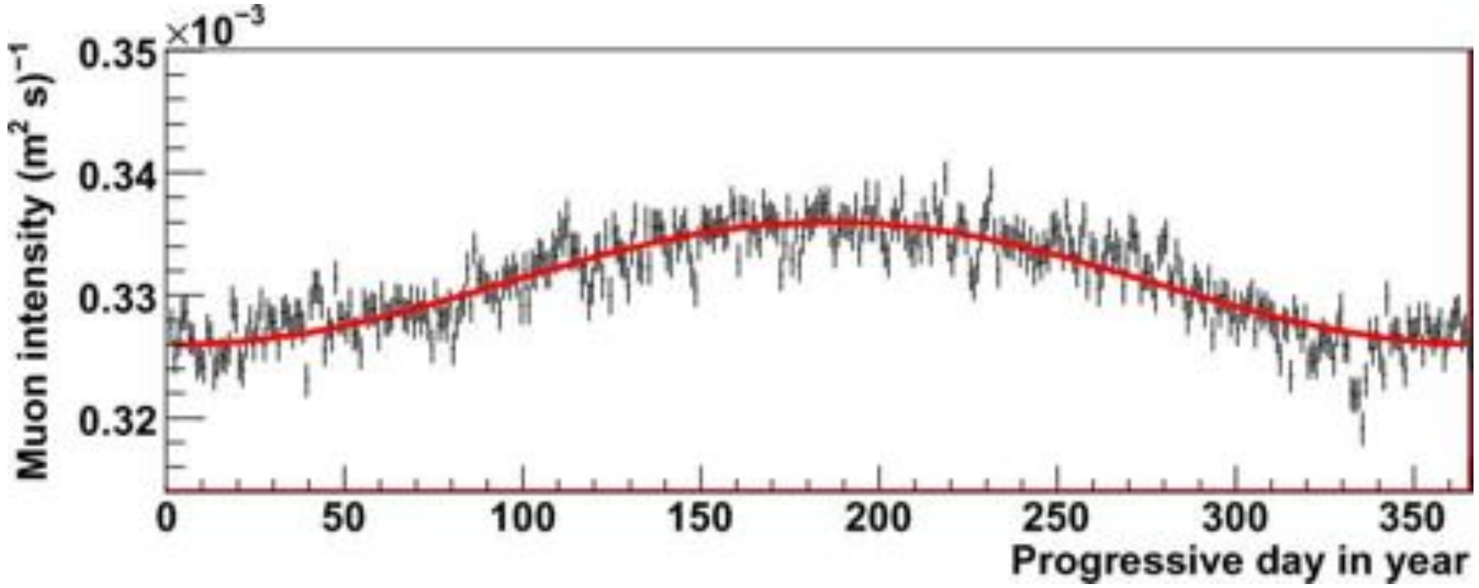
Petit et al, (1999) Nature 399 p. 429



Muon Rate at Gran Sasso vs. South Pole

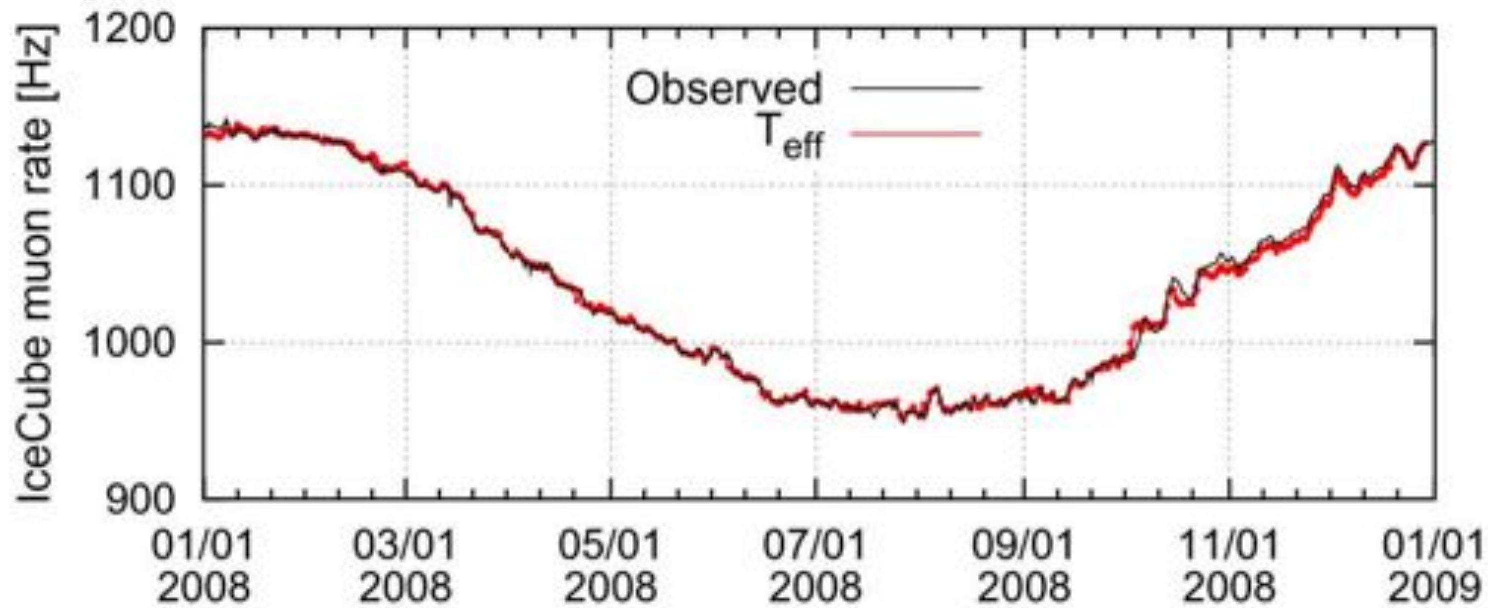
- LVD:

Selvi, Proc. 31st ICRC. (2009)



- Opposite Muon modulation at the South Pole:

Tilav, Proc. 31st ICRC. (2009)



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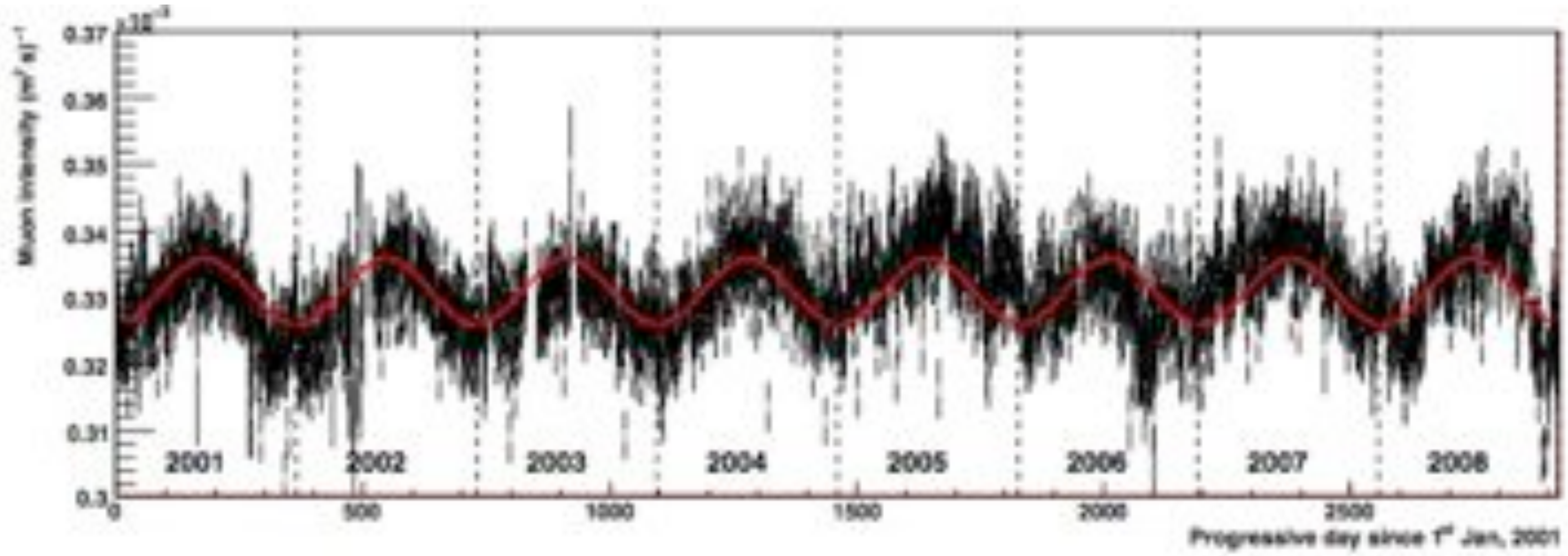

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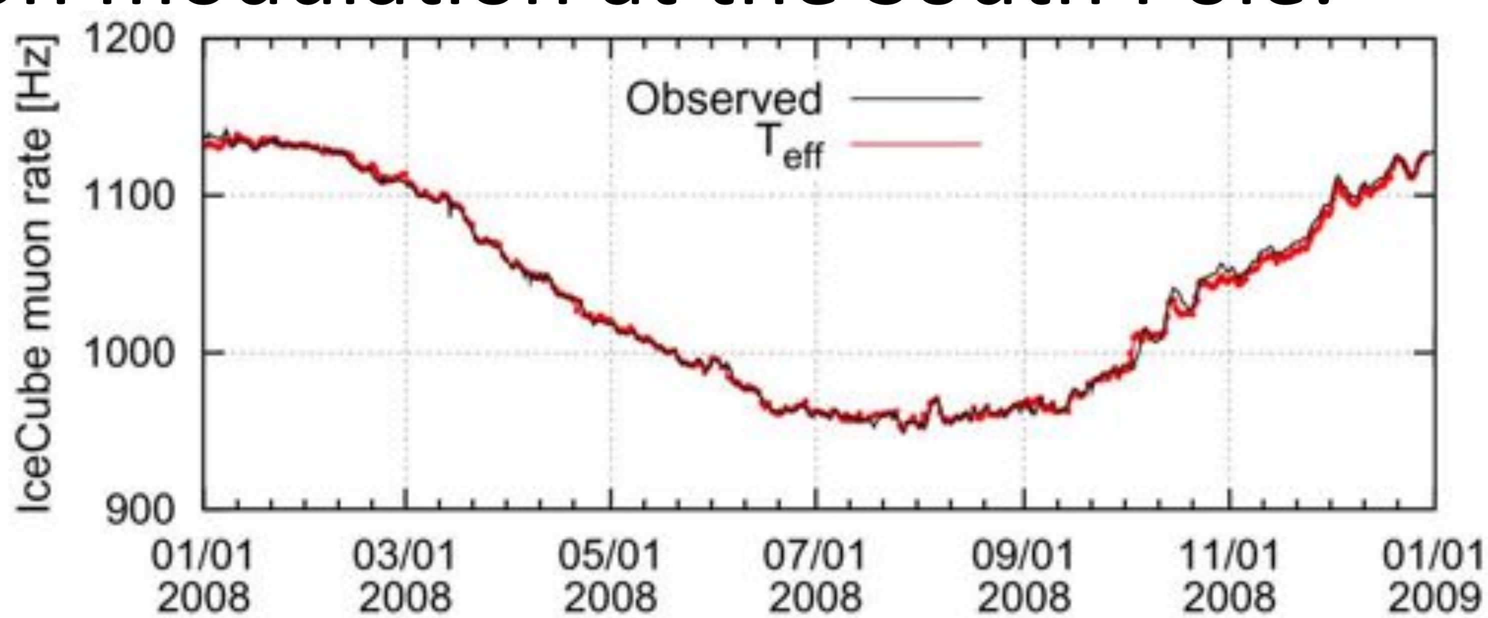


ark atter
DM-Ice prototype deployed in 2010

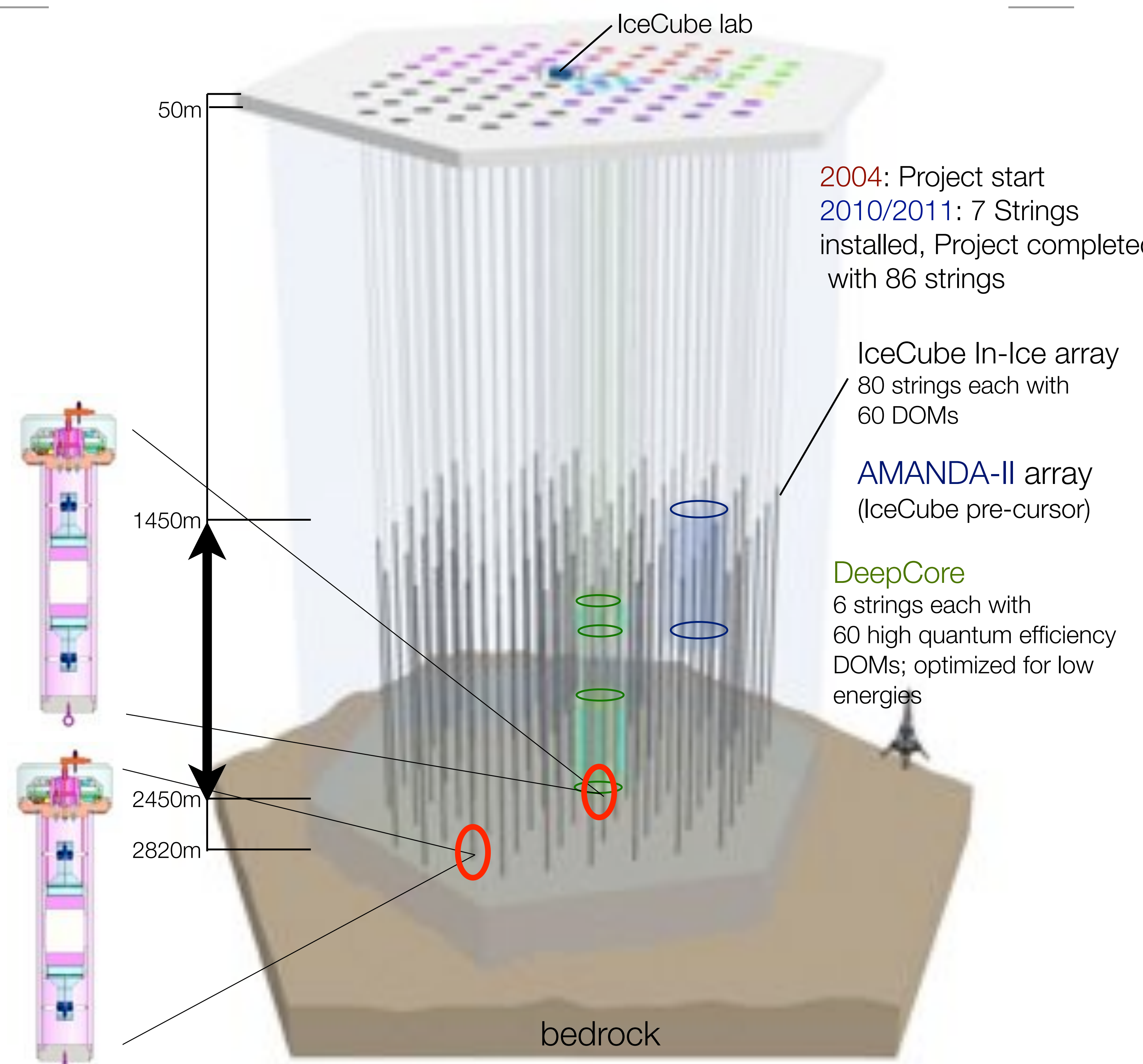
Detectors:

- Two 8.5 kg NaI detectors from NAIAD

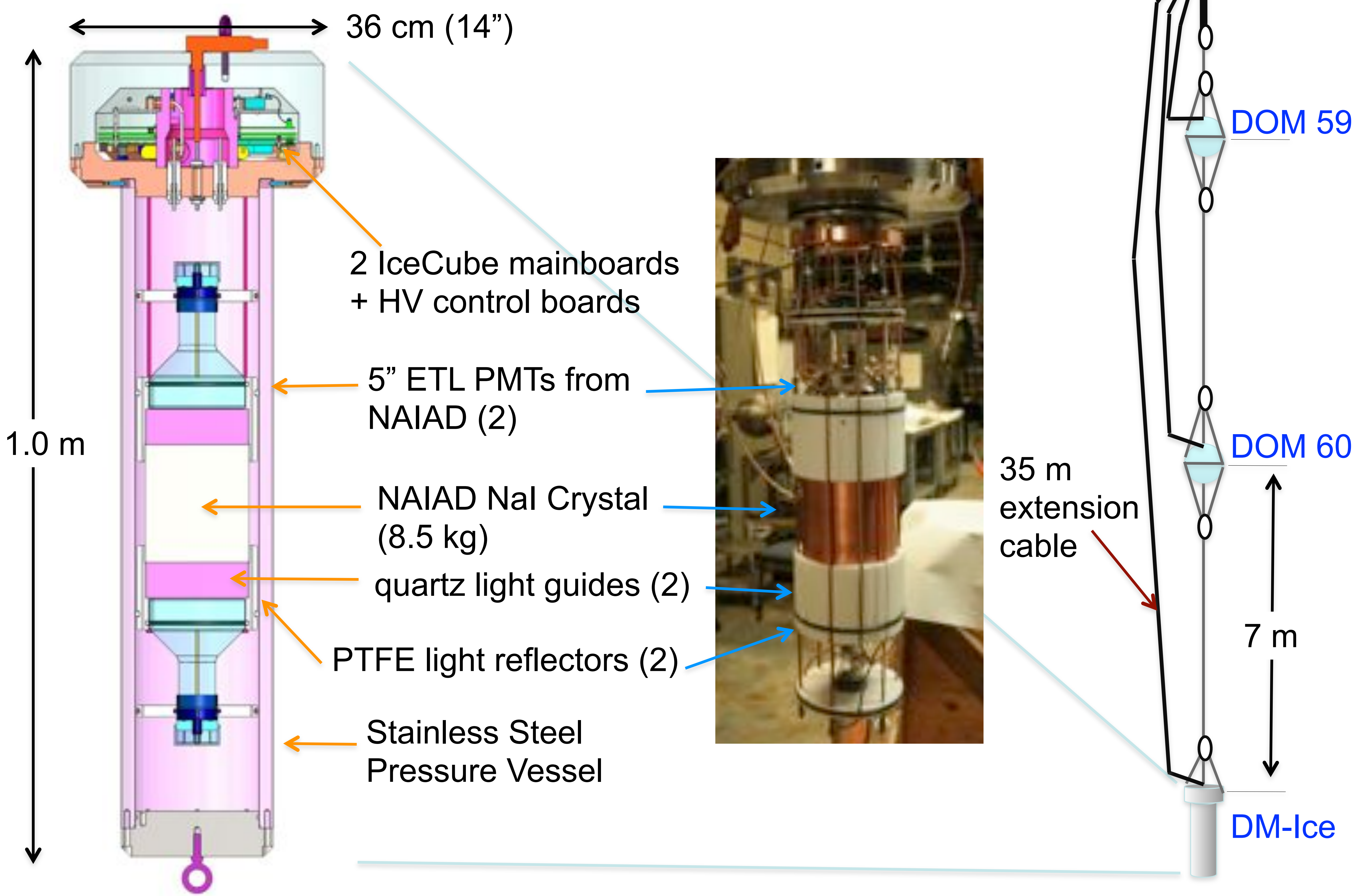
Goals:

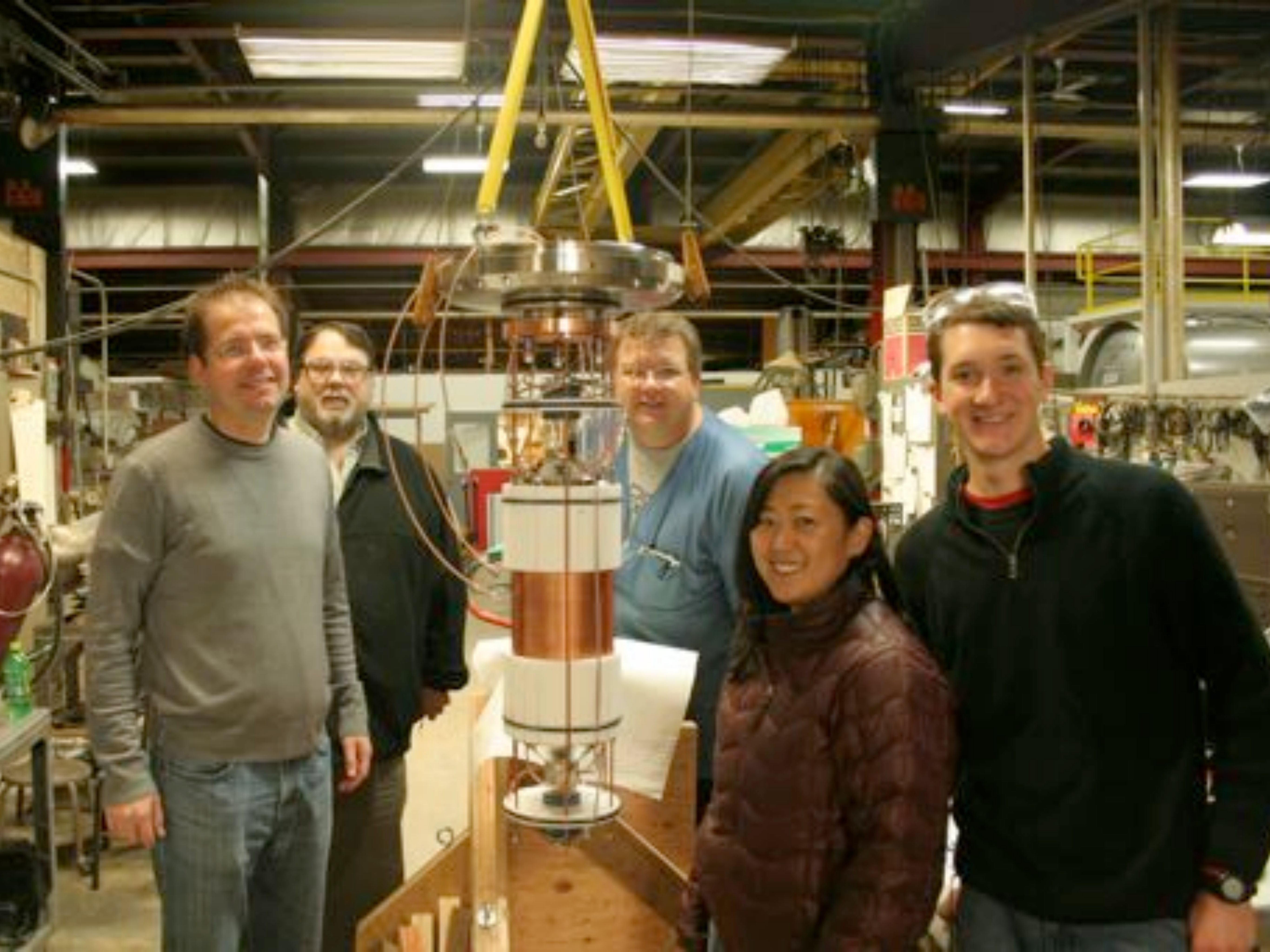
- Assess the feasibility of deploying NaI(Tl) crystals in the Antarctic Ice for a dark matter detector
- Establish the radiopurity of the antarctic ice / hole ice
- Explore the capability of IceCube to veto muons

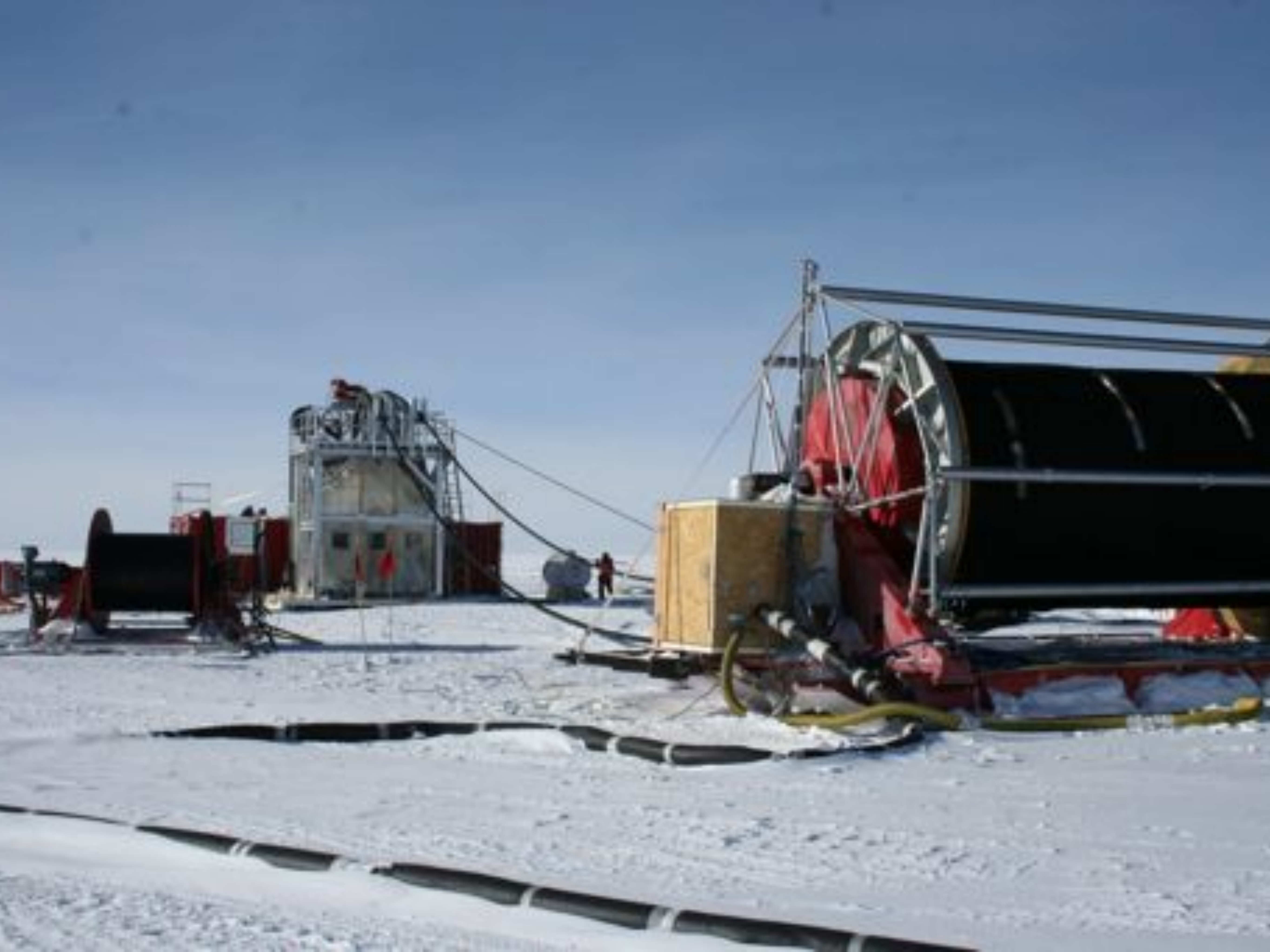
Installation in Dec. 2010



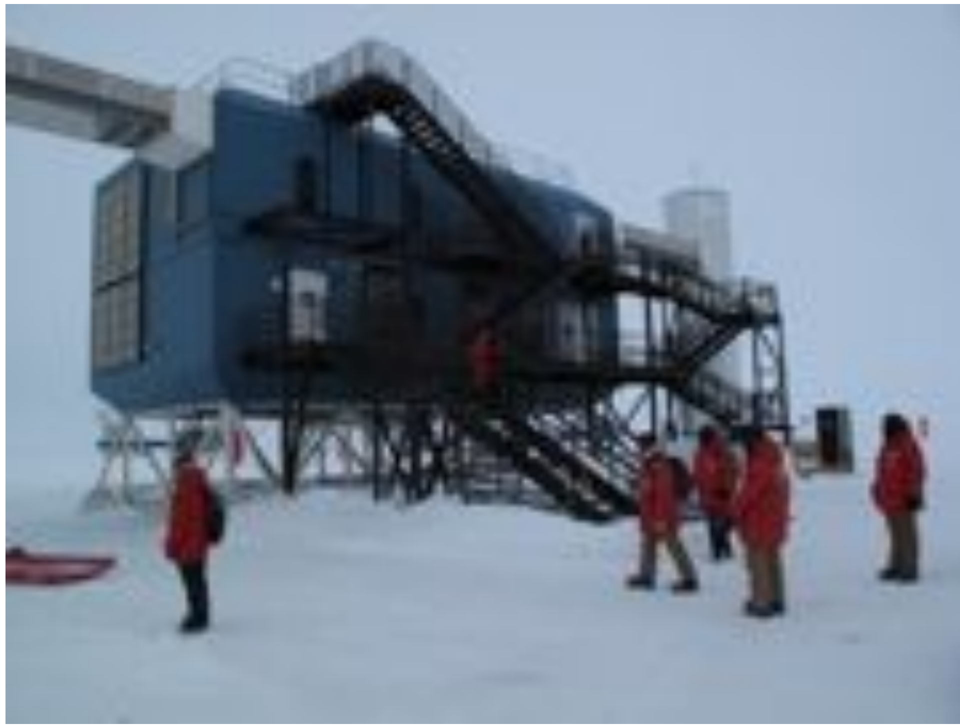
DM-Ice Feasibility Study Detector







DM-Ice Electronics in ICL

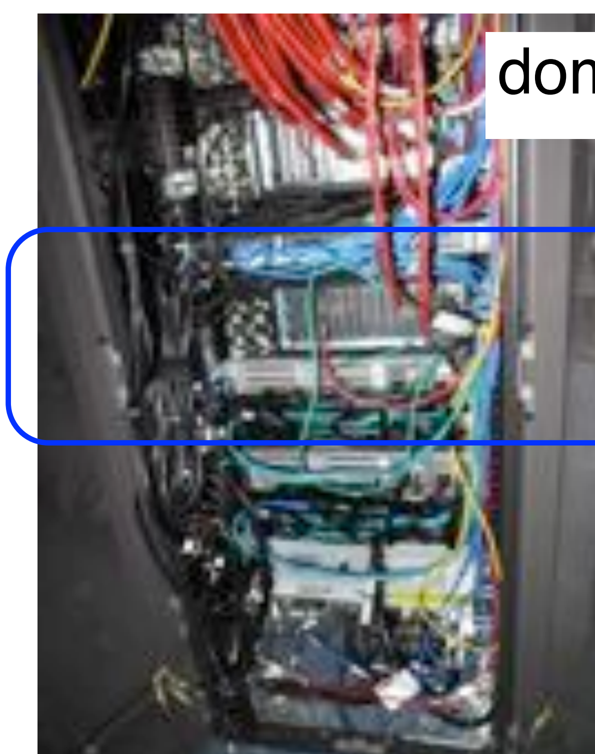


ICL

“beer can” with string cables

string cable penetrations into ICL

patch panels

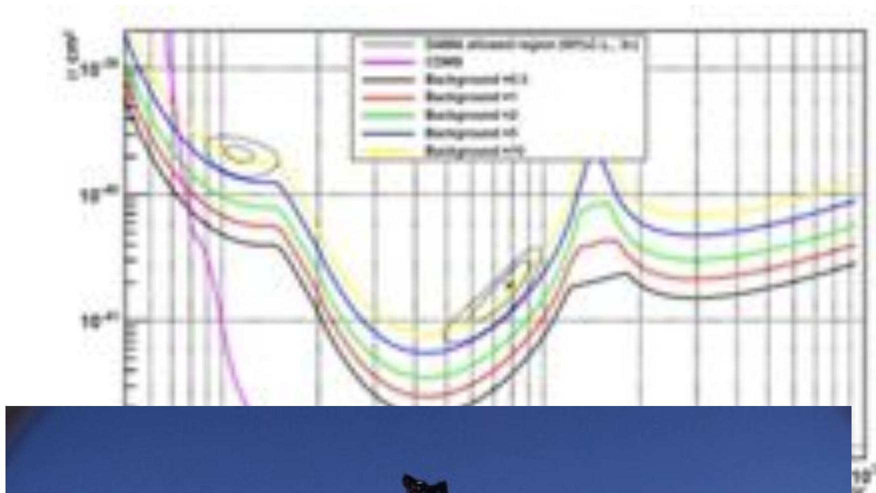


domhubs

event building

Current Status & Future Outlook

- DM-Ice prototype (17 kg) deployed in December 2010
  - Currently taking data, tweaking operating parameters
  - data transmitted over satellite
  - optimizing analysis, background studies with radio-assay & monte carlo simulation
- >250-kg scale detector under consideration
  - R&D for low background crystals
  - low background PMTs, pressure vessel
  - Calibration
  - Optimize (simplified) daq board and electronics
  - IceCube drill moth-balled at SP



DM-Ice

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  - Francis Halzen*, Karsten Heeger, Albrecht Karle*, Reina Maruyama*, Walter Pettus, Antonia Hubbard*, Bethany Reilly, Benjamin Broerman
- University of Sheffield
  - Neil Spooner, Vitaly Kudryavtsev, Dan Walker, Sean Paling, Matt Robinson
- University of Alberta
  - Darren Grant*
- Penn State
  - Doug Cowen*
- Fermilab
  - Lauren Hsu
- University of Stockholm
  - Seon-Hee Seo*