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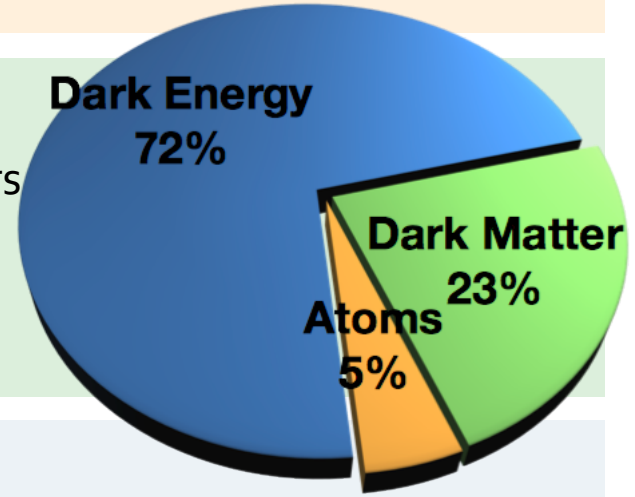
on behalf of the DM-Ice Collaboration

SCAR XXXII Open Science Conference
Astronomy and Astrophysics from Antarctica Session
18 July 2012

DM-Ice: A Search for Dark Matter at the South Pole

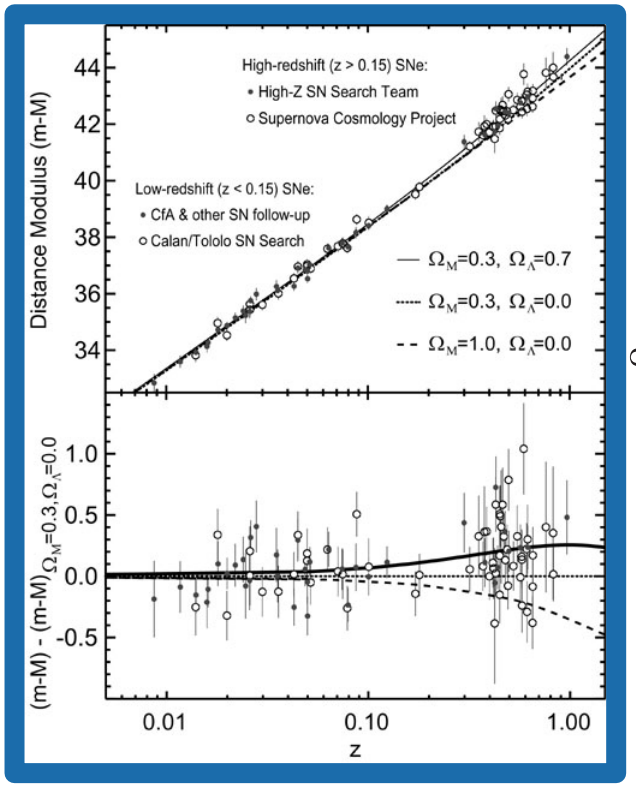
Matter Content of the Universe

- **Baryonic Matter:** ~ 5%
  - Ordinary matter composed of protons, neutrons, and electrons
    - stars, gas, planets
- **Cold Dark Matter:** ~ 23%
  - Dark matter halos that surround galaxies & galaxy clusters
  - Aids in the formation of the structures in the universe
    - several candidates: WIMPs, axions, etc…
- **Dark Energy:** ~72%
  - Responsible for the acceleration of the expansion of the universe
    - "antigravity" effect

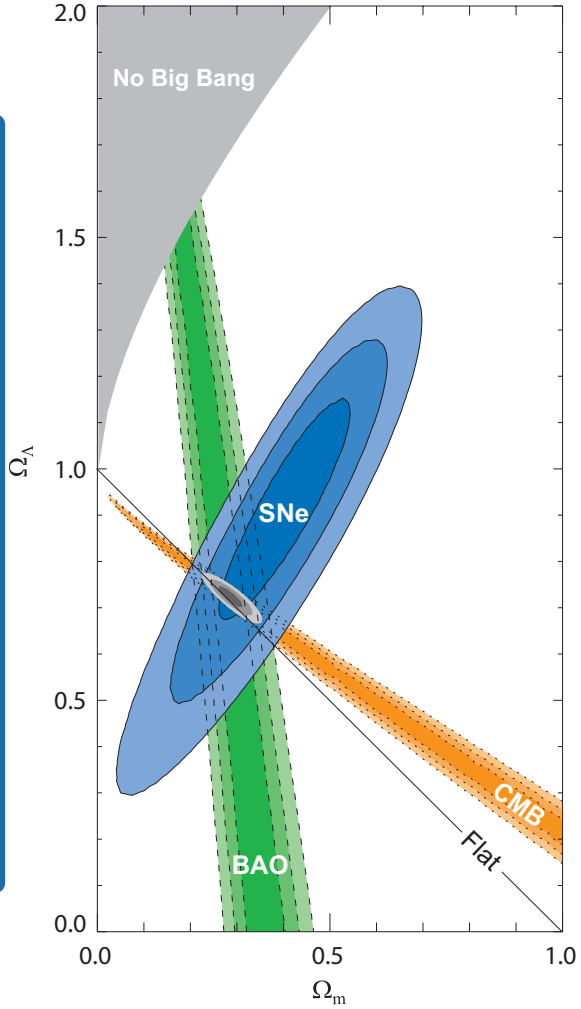


The identity of the majority of the cosmos is still a mystery!

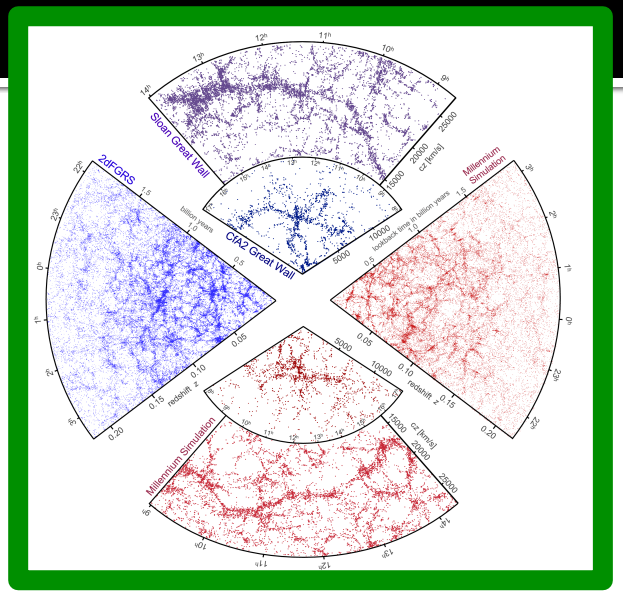
Evidence for Dark Matter

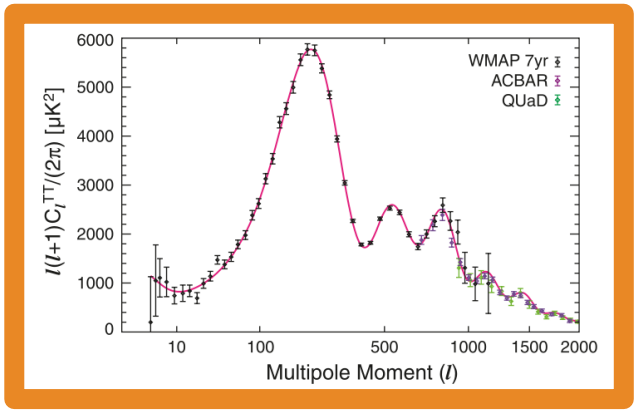


Riess *et al*. Astron J, (1998)
Perlmutter *et al*. ApJ, (1999)



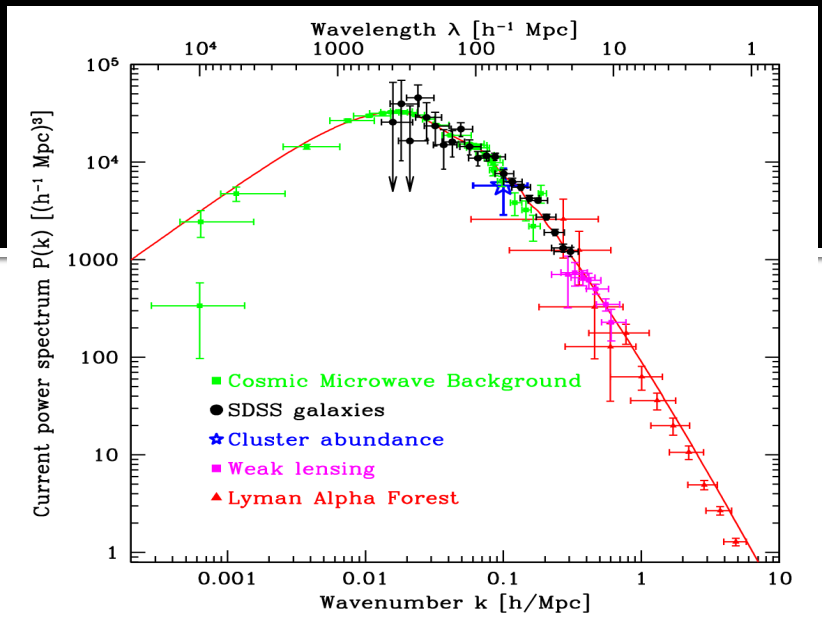
Nakamura *et al*. (PDG), JP G, (2010)



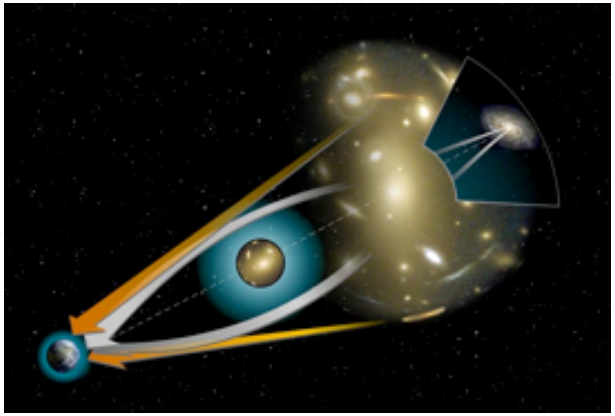


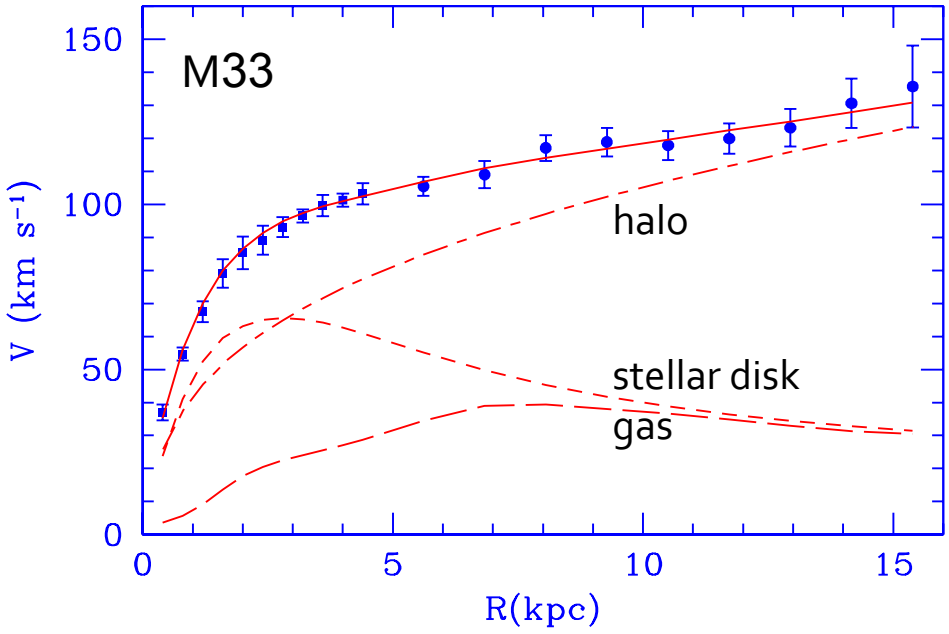
Komatsu *et al*. Ap J Supp S, (2011)

Abundant Evidence



+ Many more:
  - Distance Measurements (H_0)
  - Gravitational Lensing
  - Cluster Measurements
  - Lyman Alpha Forest
  - Large Scale Structure
  - Galactic Rotation Curves



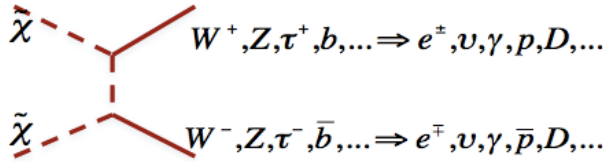


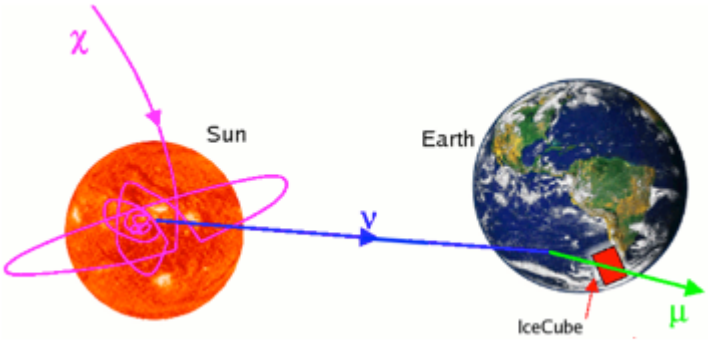
Detecting WIMPs

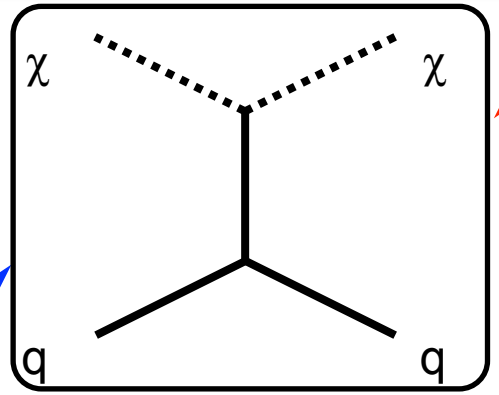
Indirect Searches

Search for annihilation products from massive objects

(gamma rays, e^-/e^+, neutrinos...)



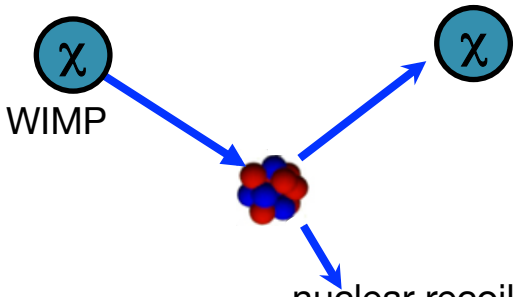




Direct Searches

WIMP-nucleon scattering

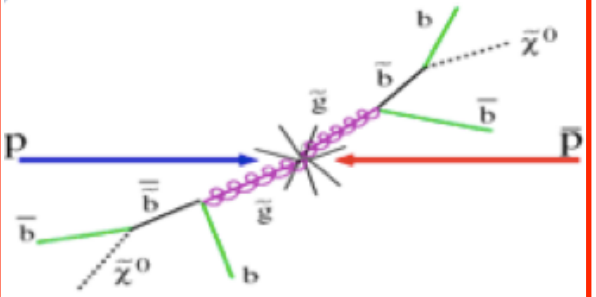
Look for nuclear recoil

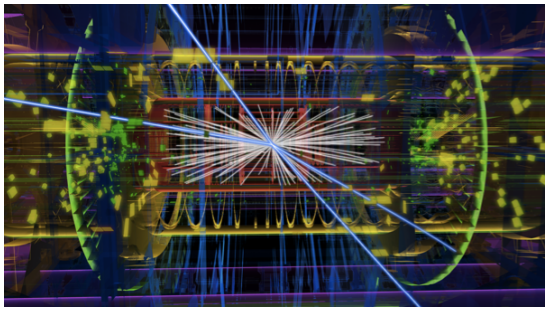


Production

Colliders

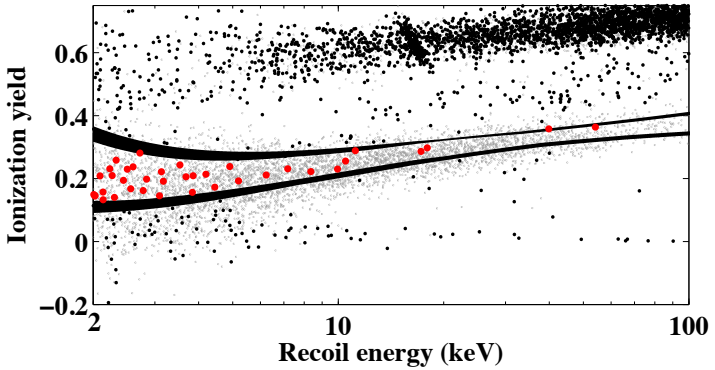
Look for the missing energy



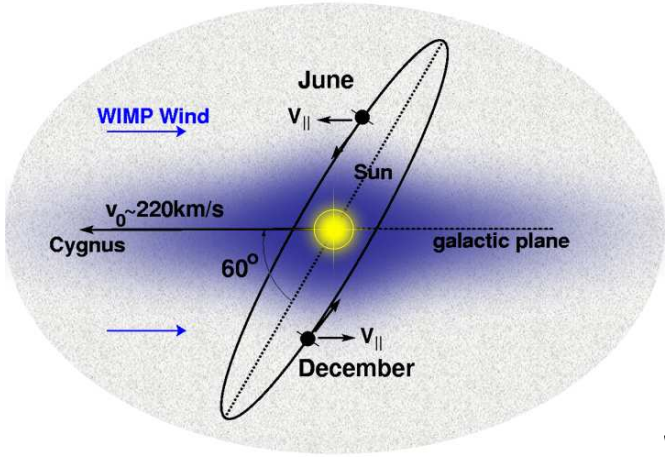


Direct Detection Techniques

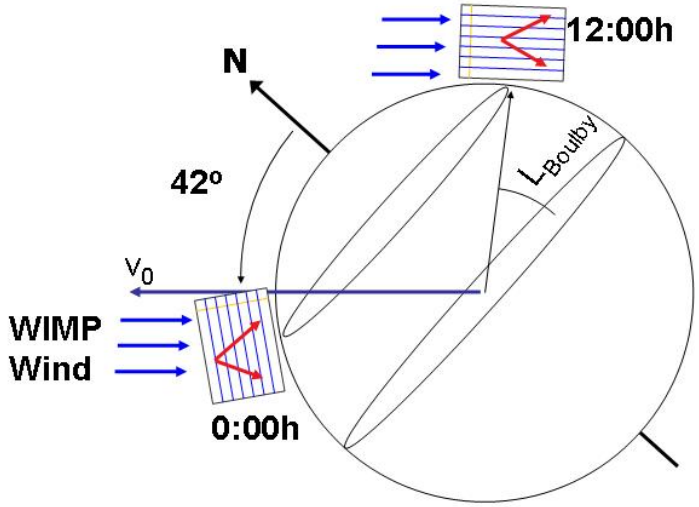
- Recoil type discrimination



- Annual modulation



- Diurnal modulation

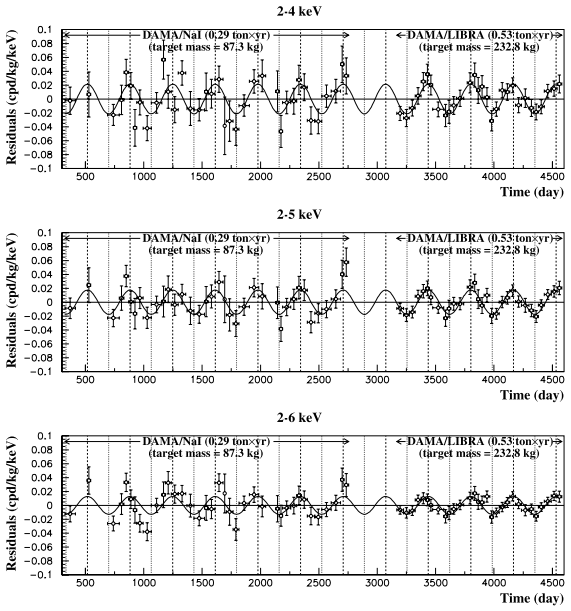


- Directional Sensitivity

Together, these signals will provide compelling demonstration of dark matter detection

Dark Matter Detection/Hints

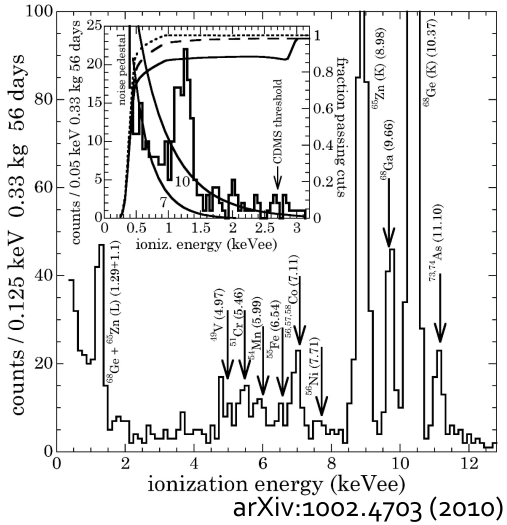
DAMA (NaI(Tl)):



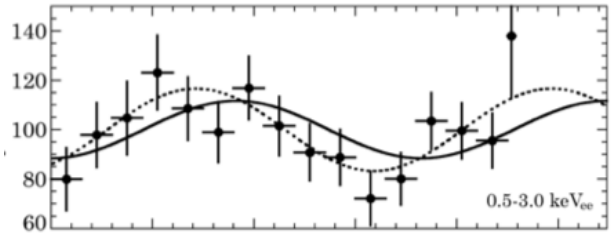
arXiv:0804.2741 (2008)

Other NaI(Tl) experiments: ANAIS, DM-Ice

CoGeNT (Ge):



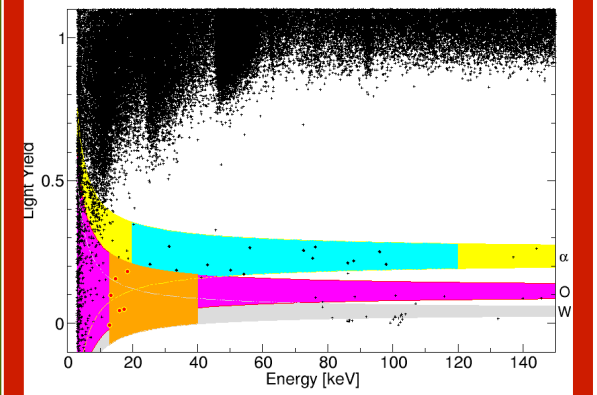
arXiv:1002.4703 (2010)



arXiv:1106.0650 (2011)

Other Ge experiments: CDMS, EDELWEISS

CRESST ($CaWO_4$):

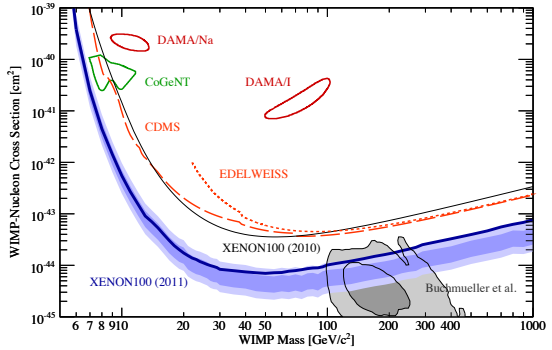


arXiv:1109.0702 (2011)

Other $CaWO_4$ experiments: None

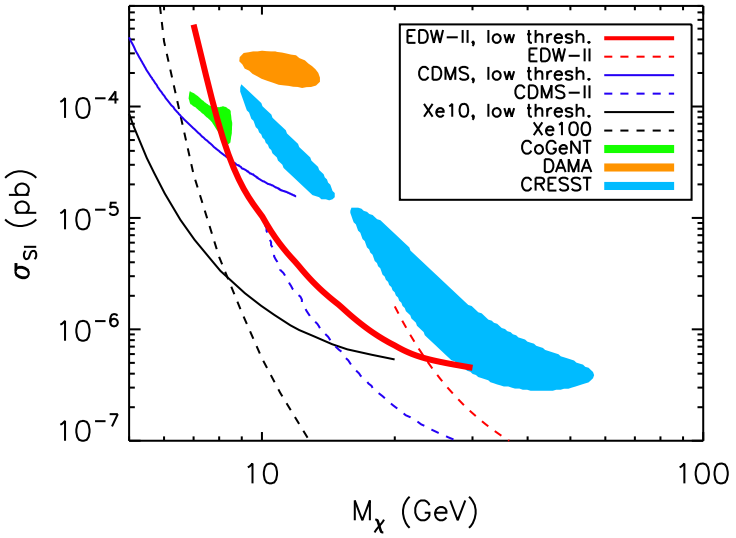
Exclusion Limits

XENON (Xe)



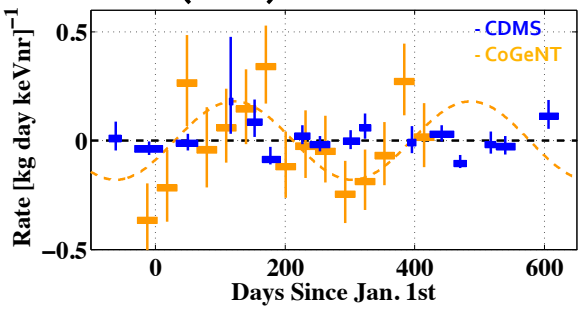
arXiv:1104.2549 (2011)

EDELWEISS (Ge):



arXiv:1207.1815 (2012)

CDMS (Ge):



arXiv:1203.1309 (2012)

Is DAMA seeing Dark Matter?

Change systematics

Signals (other modulation source)
- Muon flux (depends on temp/pressure in upper atmosphere)
- Ambient temperature
- Spallation neutrons from muons in rock
- Radon diffusion from rock
- Scintillator delayed phosphorescence

Is muon-dark matter phase difference significant?
- arXiv:1202.4179
- arXiv:1110.0857

Astrophysical Models
- Uncertainty in f(v), v_o, v_{esc}
- Streams? Co-rotating?

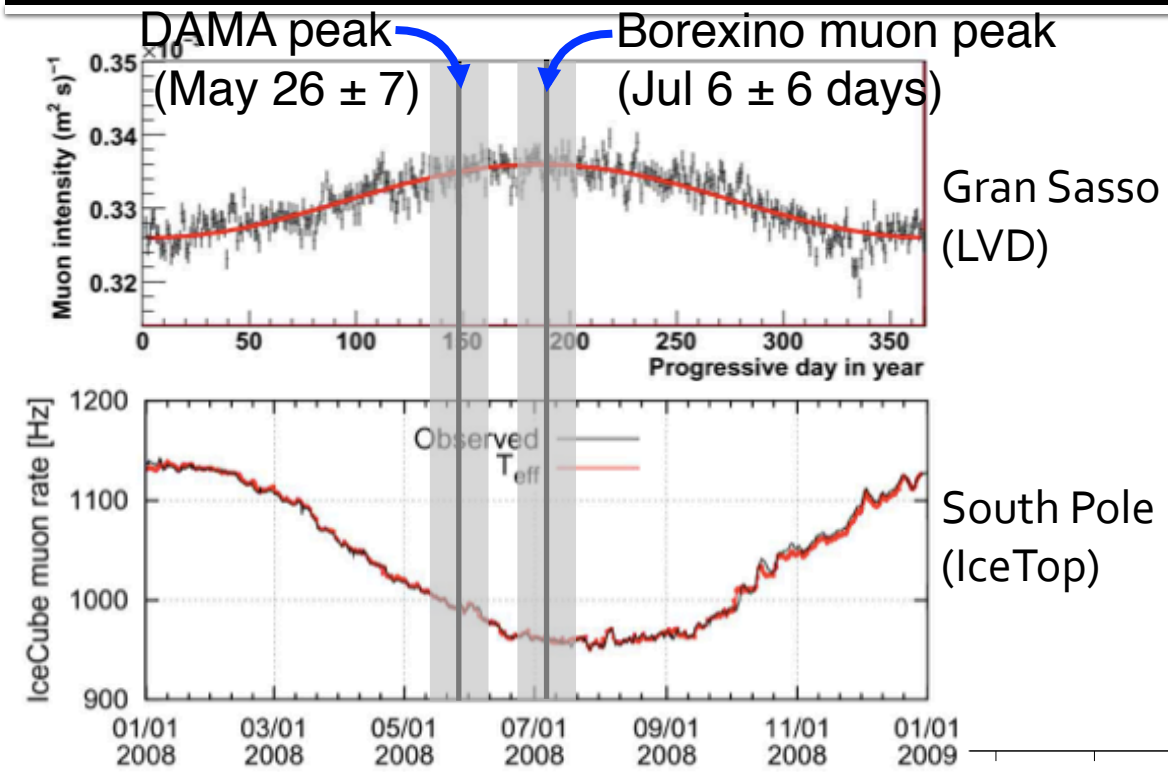
Same target material

Detector Effects
- Channeling (in crystals)
- Quenching factor/ L_{eff}
- Threshold effects

Particle Theory
- Dark Matter coupling?

Additional experimental data needed to resolve controversy!

Is DAMA seeing Dark Matter?



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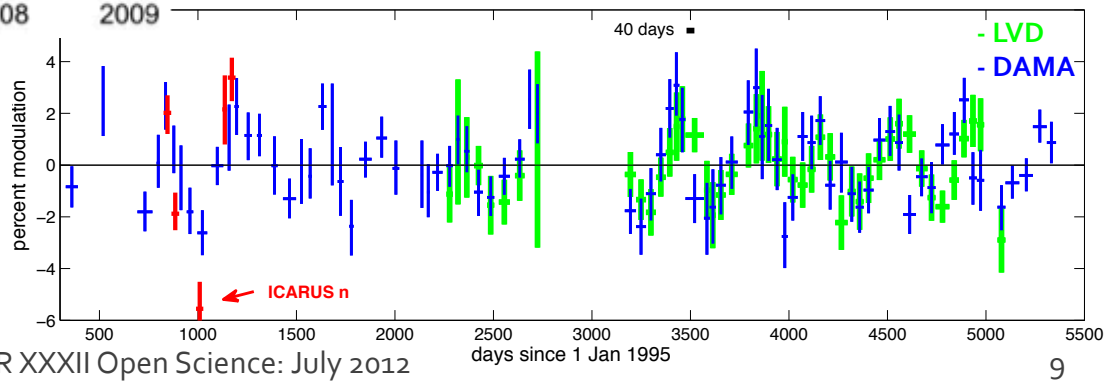

DM-Ice Concept

- Utilize NaI(Tl) detectors
  - Same detector type as DAMA
- Deploy at ~2500m in-ice at South Pole
  - Opposite or removed seasonal modulation
- Test of DAMA possible
  at 5-σ with 500 kg*yr

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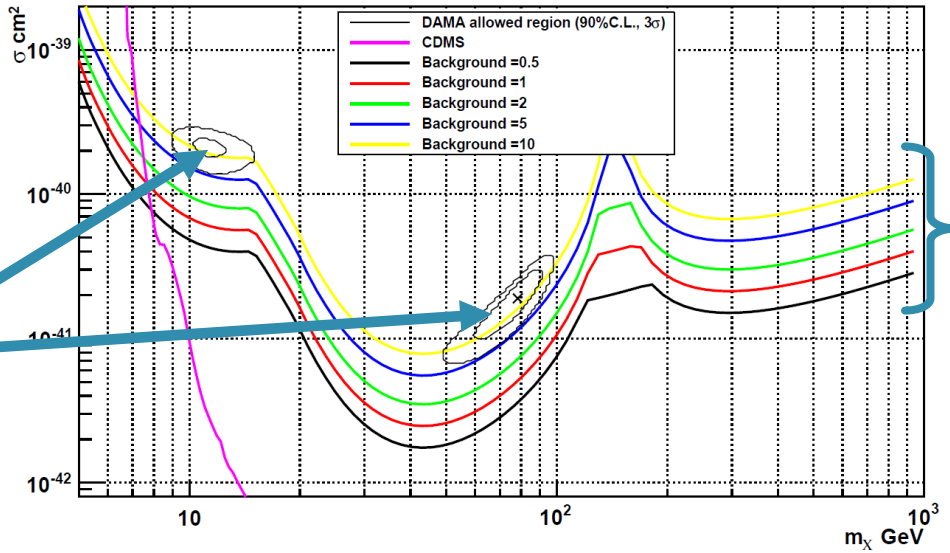
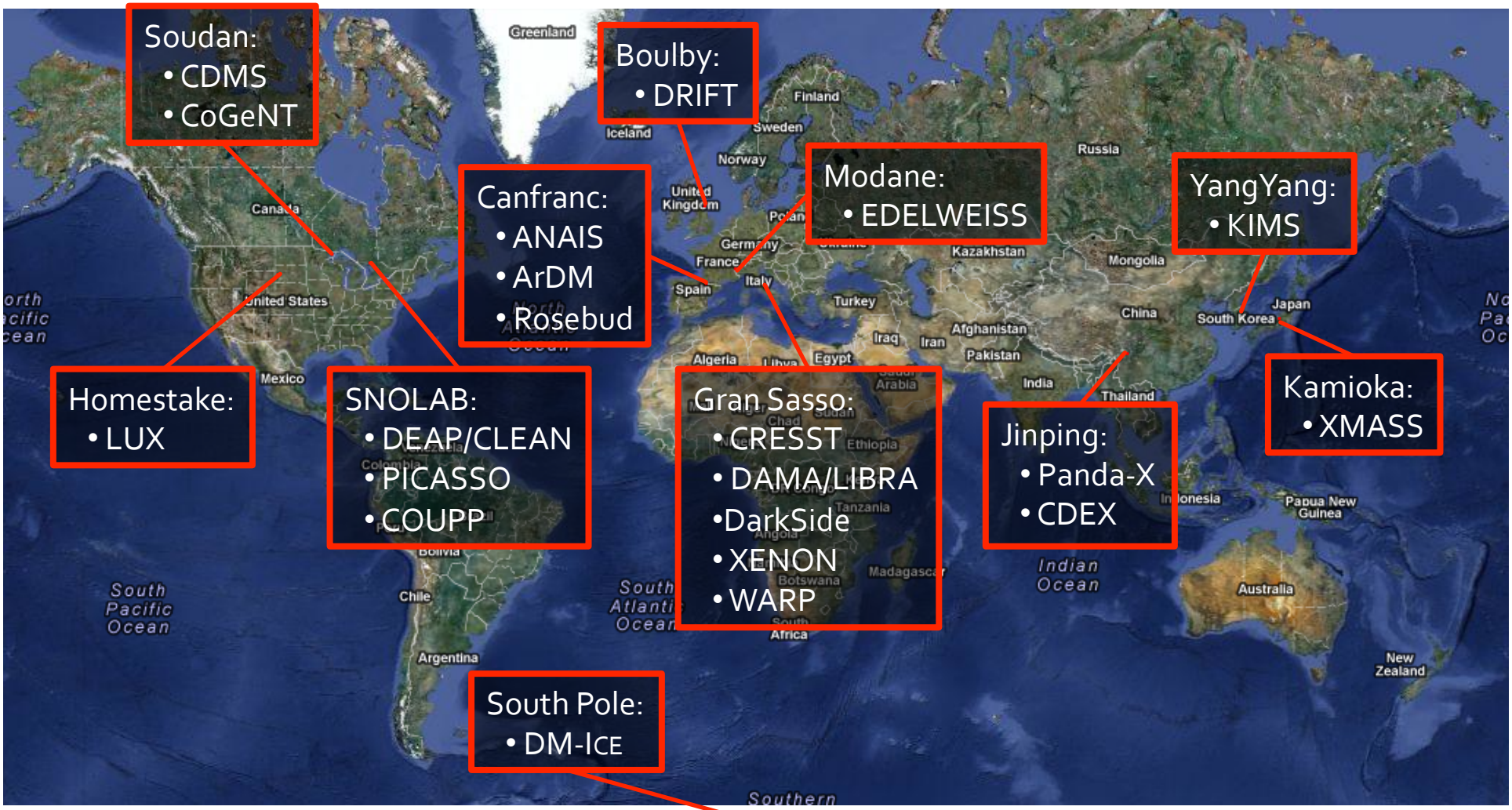
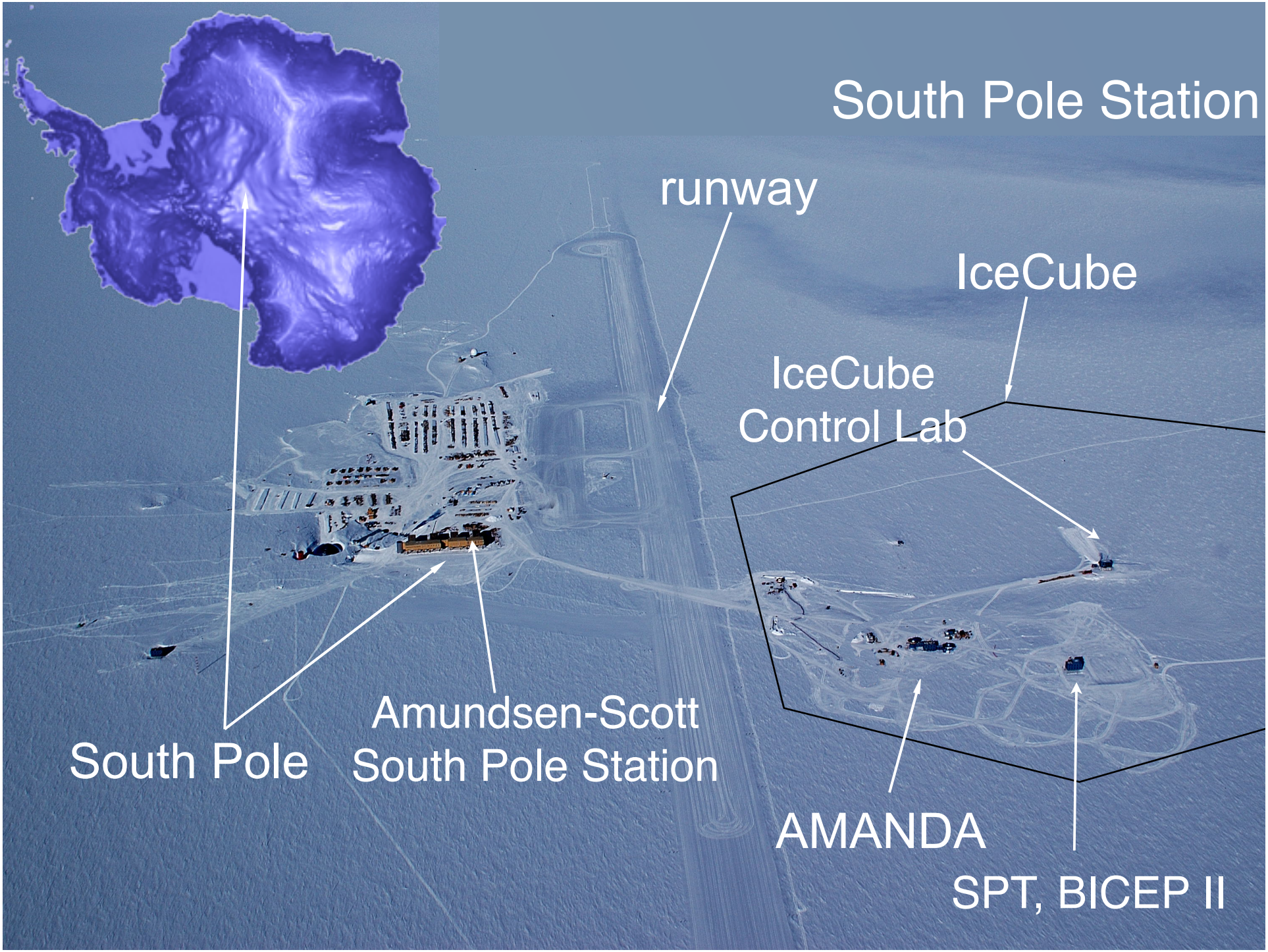
Projected DM-ICE sensitivity

DAMA signal regions



A World of Dark Matter Searches




South Pole Station
runway
IceCube
IceCube
Control Lab
South Pole
Amundsen-Scott
South Pole Station
AMANDA
SPT, BICEP II

The experiment goes South

Signal

- Identical Dark Matter signal
- Opposite muon phase
- Stable detector response
  - No temperature variation

Location

- Infrastructure of Amundsen-Scott South Pole Station
- Expertise of IceCube drilling to 2500 m

Background

- Radiopure ice
  - ppt $^{238}U/^{232}Th$, ppb ^{nat}K
  - No Radon
- Muon tagging by IceCube/ DeepCore

South Pole experimental challenges

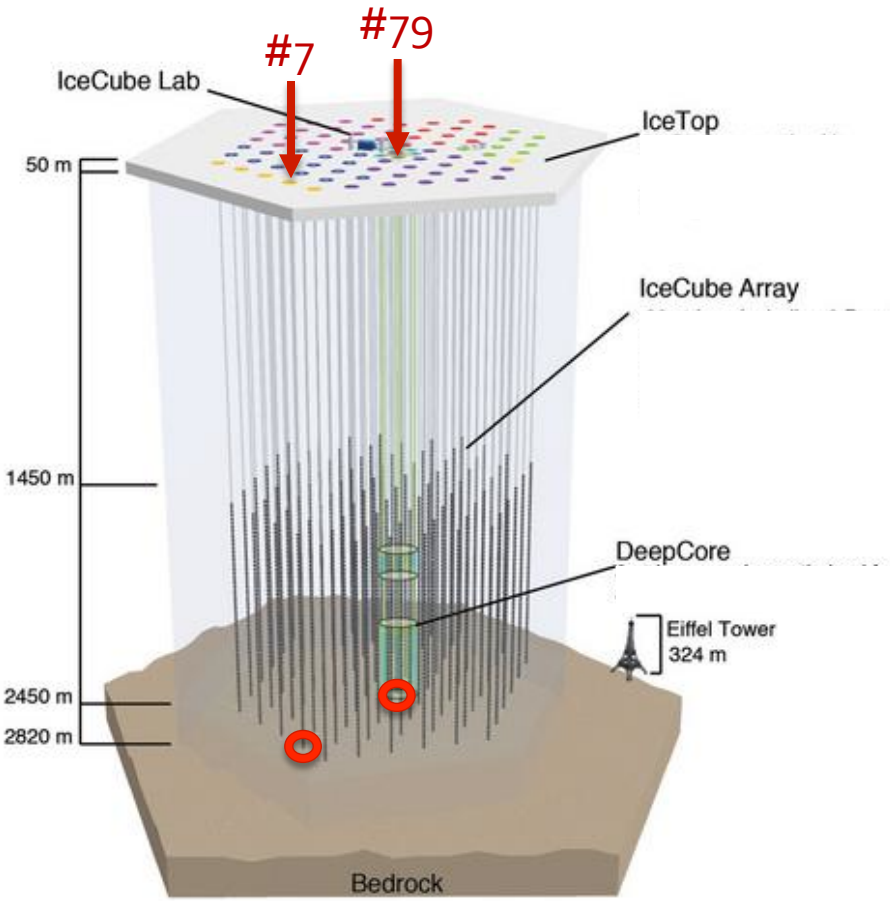
- Detector inaccessible after deployment
  - How to calibrate
  - Impossible to fix
- Extreme environment
  - Freeze-back pressure
  - Low temperature
- Cosmogenic Activation

South Pole experimental challenges

- Detector inaccessible after deployment
  - How to calibrate
    - LED calibration
    - Internal γ-lines
  - Impossible to fix
    - NaI is a well-tested detector (sent to space on Fermi-LAT)
- Extreme environment
  - Freeze-back pressure
    - Stainless steel pressure vessel
  - Low temperature
    - NaI well-characterized at -20° C
- Cosmogenic Activation
    - Limit surface exposure, shipment plan

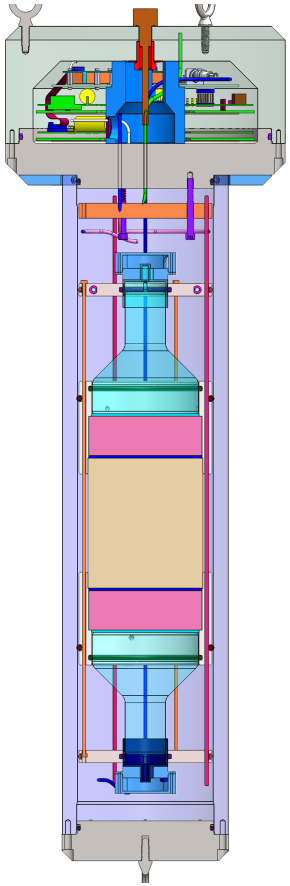
DM-Ice 17

- Two 8.5-kg NaI detectors
- Installed Dec 2010
- Data since Jan 2011
- Goals:
  - Demonstrate the feasibility of deploying NaI(Tl) crystals in the Antarctic Ice for a dark matter detector
  - *In-situ* measurement of the radiopurity of the Antarctic ice / hole ice at 2450 m depth
  - Study the capability of IceCube to veto muons
  - Study environmental stability



DM-Ice 17 Detectors

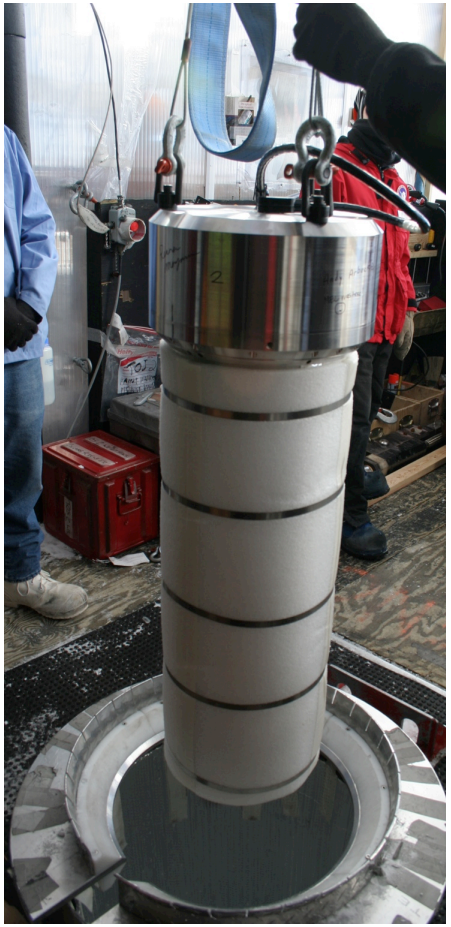
Summer 2010



October 2010

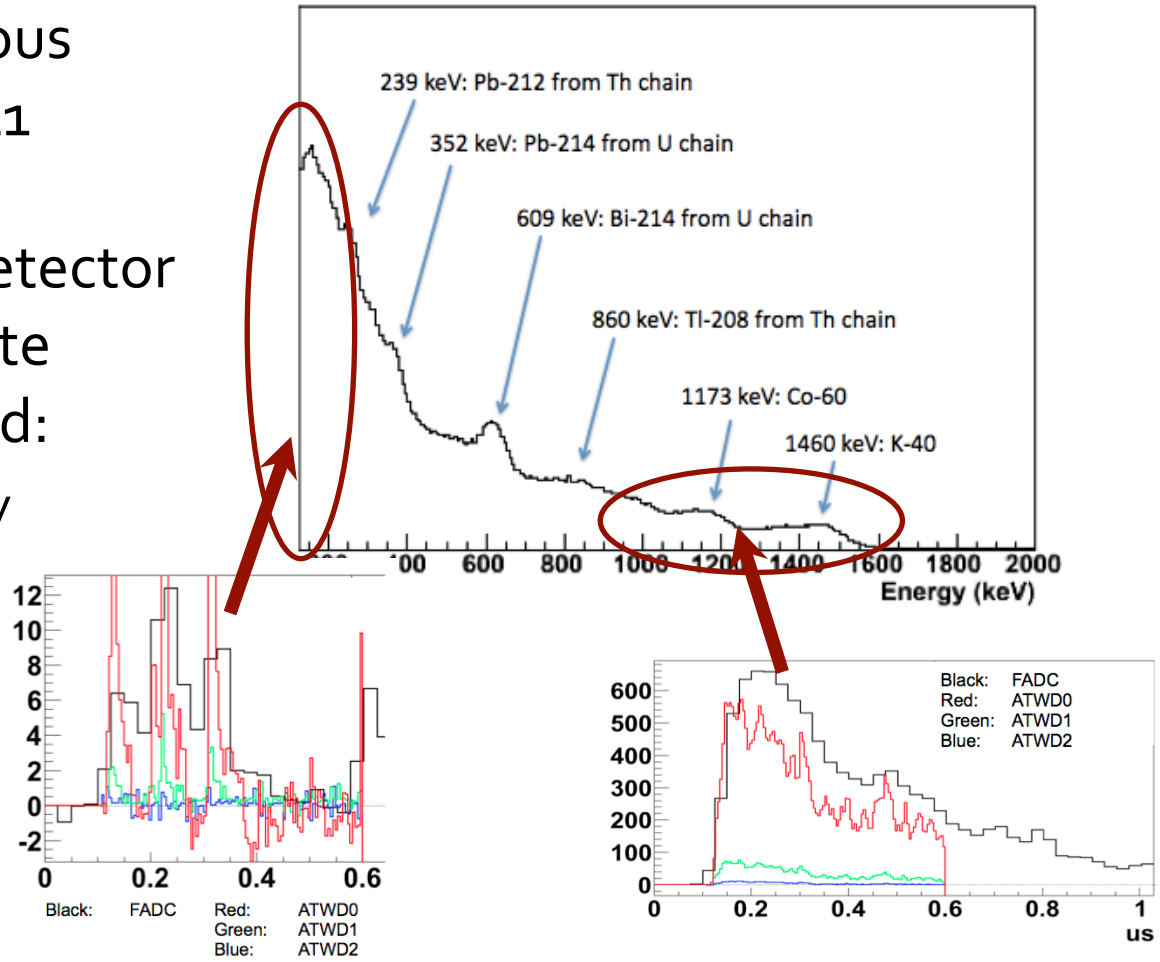


December 2010



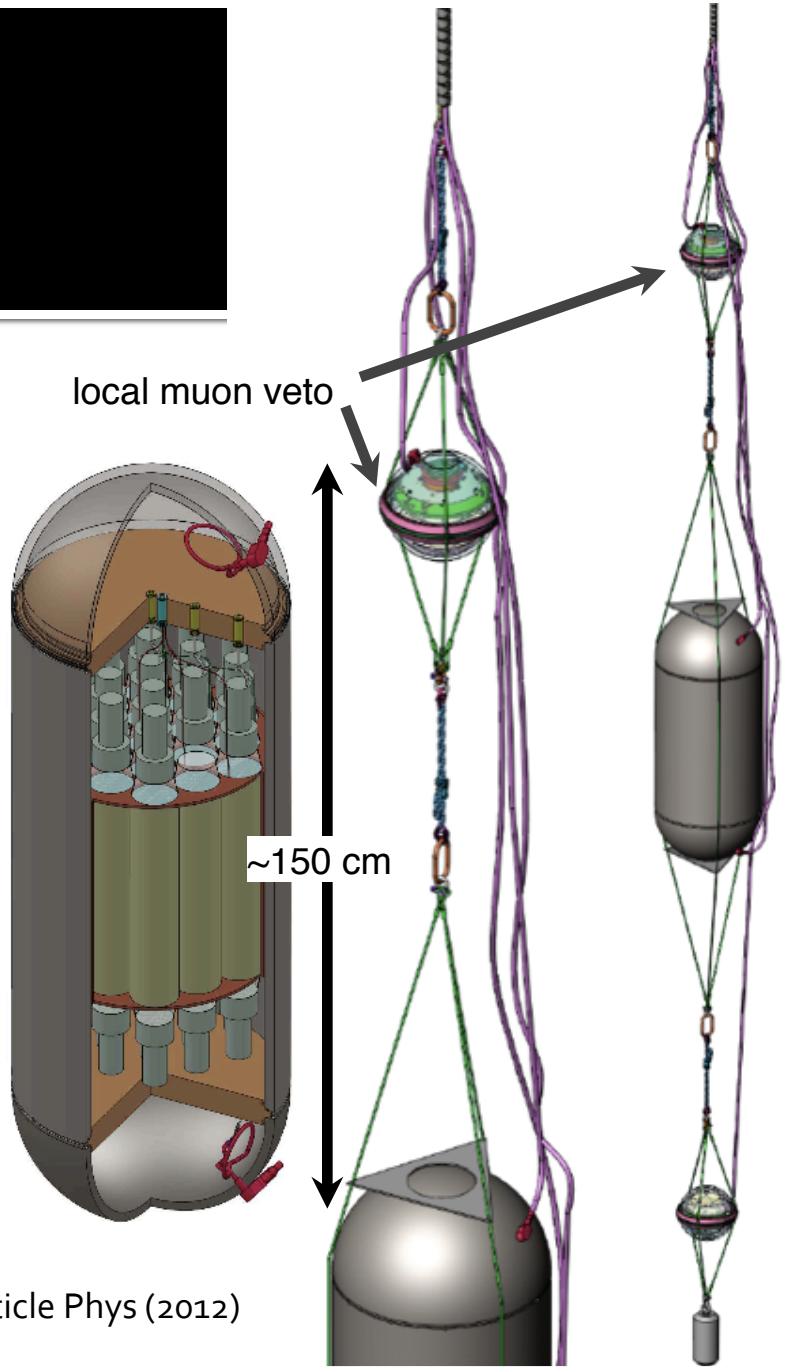
DM-Ice 17 Status

- Taking data, continuous running since Jan 2011
  - 24 kg*yr
- Data transmission, detector monitoring via satellite
- Initial spectra released:
  - Calibrated high-energy
  - Low-energy analysis coming



Future DM-Ice

- **Detector**
  - 250–500 kg NaI(Tl)
  - Closely-packed inside pressure vessel for coincidence veto
  - Two PMTs/Crystal
- **Location**
  - South Pole, ~ 2500 m deep in the ice
  - Near the center of IceCube for additional veto
- **Electronics**
  - Pulse digitization inside the vessel
  - Power from SP Station or IceCube Counting Lab
  - Remotely controllable
- **Pressure vessel**
  - Withstand > 7000 psi of freeze-back pressure
  - Low-background stainless steel
  - Low background copper shielding where needed



Cherwinka *et al.* Astroparticle Phys (2012)

In-ice strings for DM-Ice deployment

DM-Ice Collaboration

- **University of Wisconsin – Madison**
  - Francis Halzen, Karsten Heeger, Albrecht Karle, Reina Maruyama, Carlos Pobes, Walter Pettus, Zachary Pierpoint, Antonia Hubbard, Bethany Reilly
- **University of Sheffield**
  - Neil Spooner, Vitaly Kudryavtsev, Dan Walker, Matt Robinson, L. Thompson, Sam Telfer
- **Boulby Underground Science Facility**
  - Sean Paling
- **SNOLAB**
  - Bruce Cleveland
- **University of Alberta**
  - Darren Grant
- **Penn State**
  - Doug Cowen, Ken Clark
- **Fermilab**
  - Lauren Hsu
- **Shanghai Jiao Tang University**
  - Xiangdong Ji, Changbo Fu
- **University of Illinois at Urbana-Champaign**
  - Liang Yang
- **NIST-Gaithersburg**
  - Pieter Mumm
- **University of Stockholm**
  - Chad Finley, Per Olof Hulth, Klas Hultqvist, Christian Walck
- **University of Washington**
  - Sanshiro Enomoto, Jarek Kasper, Andreas Knecht
- **DigiPen**
  - Charles Duba, Eric Mohrmann

Special thanks to the IceCube team!