DM-Ice: Dark Matter Search at the South Pole

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For the DM-Ice Collaboration

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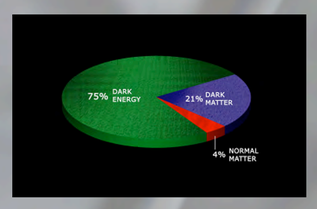
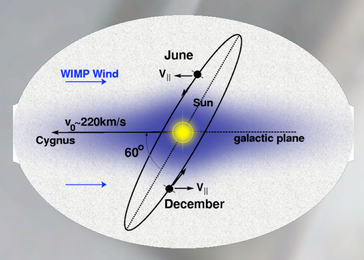
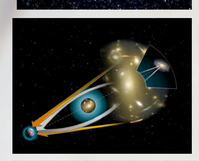
What is Dark Matter?





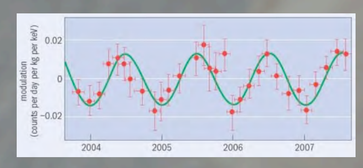


Astronomical Evidence

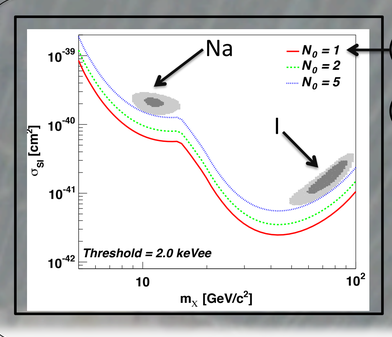
- Galaxy rotation
  - Baryonic matter can't account for rotation speed
- Gravitational lensing
  - Light is bent by the gravity of the dark matter
- Galaxy collision
  - Dark matter and baryonic matter separated

Detecting Dark Matter

- Indirect detection
- Colliders
- Direct detection
  - Nuclear recoil from WIMPs
  - Annual modulation in signal



DAMA/LIBRA signal



(DAMA level)

(NAIAD level ~ 7-10)

The curves show the sensitivity of hypothetical 500kg-year exposures with varying total event rates (in cpd/kg/keVee). The gray regions show the 90% (dark) and 99.7% (light) DAMA/LIBRA allowed regions for interactions with Na and I.

DM-Ice Experiment

- NaI crystal – 250 kg
- PMTs collect light from WIMP collisions
- Look for annual modulation seen by DAMA at the South Pole
- To be installed at the South Pole near the center of IceCube
  - Same DM modulation as DAMA
  - Opposite phase seasonal muons etc
  - Can use IceCube detector for muon veto
  - Clean ice, 2200 mwe of overburden
    - Ice temperature is stable
    - No radons, neutrons moderated

DM-Ice Conceptual Design

DM-Ice Concept
- Large Pressure Vessel
- Segmented Crystals

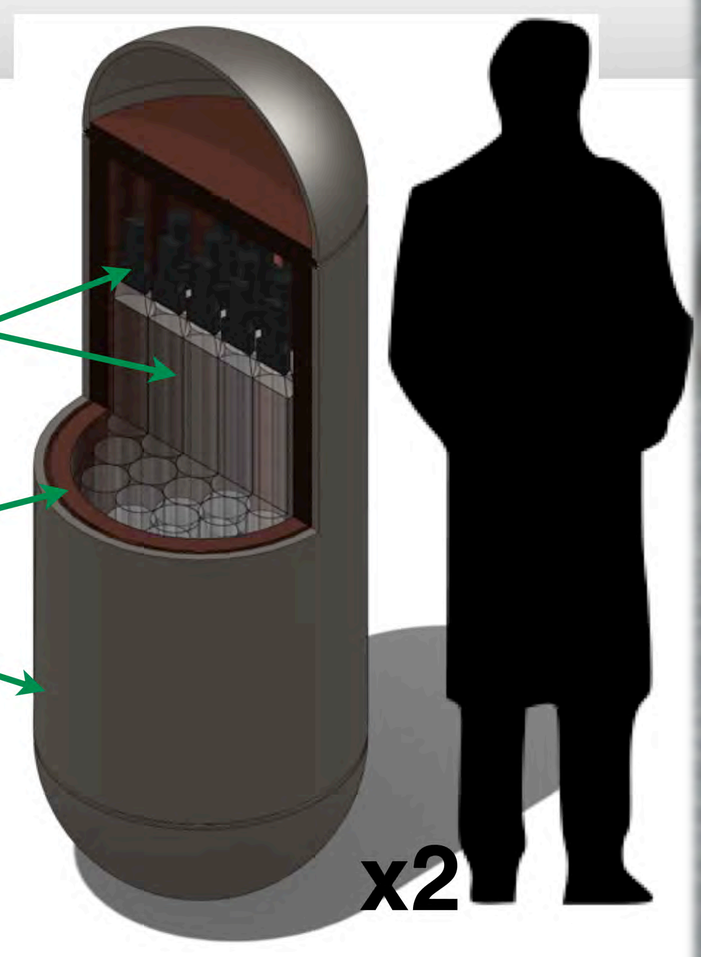
38 NaI Crystals (each vessel contains 19)
- 95.6 mm Diameter
- 250 mm Long
- 6.5 kg each
- 2 PMTs each

Instrument with few "DOMs" externally for veto

50 - 60 mm Copper Radial Shield

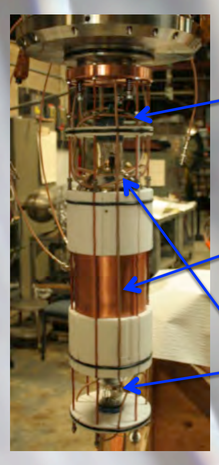
SS External Pressure Vessel Shell
- 65 cm (25.6 inch) Outer Diameter
- 1.7 m (67 inch) Length

250 kg NaI (38@6.5 kg crystals)
1500 kg total including pressure vessel



DM-Ice prototype

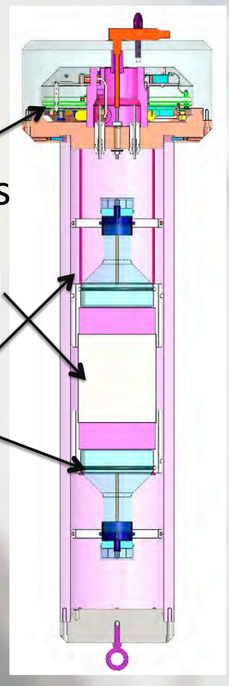
- Already installed at South Pole
- Presently taking data, with full waveforms



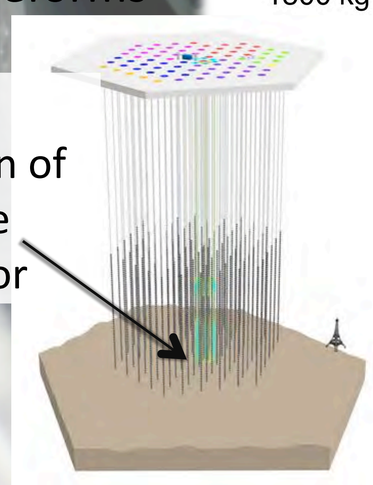
IceCube mainboards

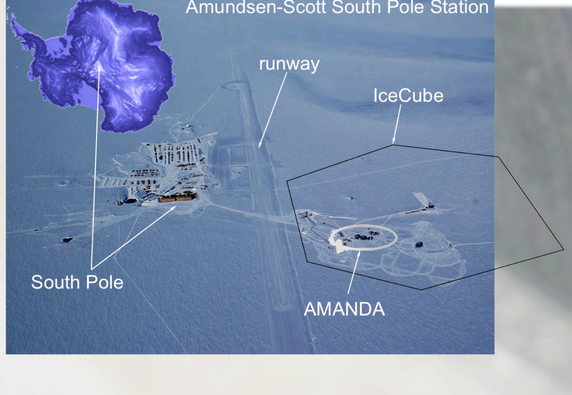
NaI crystal

PMTs



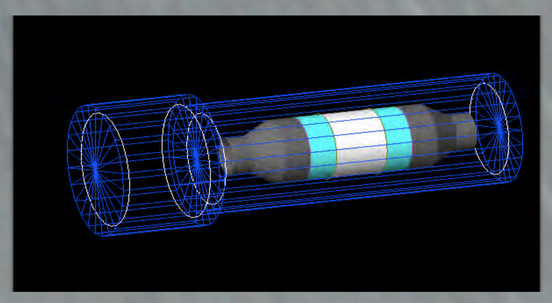
Future location of full-size detector





Geant4 Simulation

- Placing various backgrounds in and around the crystal in order to understand how they behave in that environment



Geant4 visualization of detector prototype

Table 1: Assumed concentrations of ^{238}U, ^{232}Th and ^{nat}K, in ppb for major components of a NaI assembly and the surrounding ice. Details on the estimate for contamination in Antactic ice are in the text.

Material	^{238}U	^{232}Th	^{nat}K
drill ice [27]	0.076±0.046	0.47±0.14	<262
Antarctic ice	10^{-4}	10^{-4}	0.1
PMT [26]	30	30	60000
steel PV [27]	0.2	1.6	442
NaI	0.005	0.005	10

Table 2: Shown are the estimated contribution to event rate from 1-10 keV$_{ee}$ in a single 8 kg NaI crystal. The first three items are calculated using the Geant4 simulation of a simple 8 kg assembly. The internal NaI contamination is taken from [18] where the energy spectrum of events from radioactivity was simulated for the DAMA experiment assuming radioisotope concentrations reported in [32].

Material	event rate in NaI (cpd/kg/keV$_{ee}$)
drill ice	0.8
Antarctic ice	< 0.001
photomultiplier tubes	0.01-0.02
steel PV	0.2-0.6
NaI crystal	~0.3

Backgrounds

- Simulating gammas from:
  - ^{238}U
  - ^{60}Co
  - ^{232}Th
  - ^{40}K

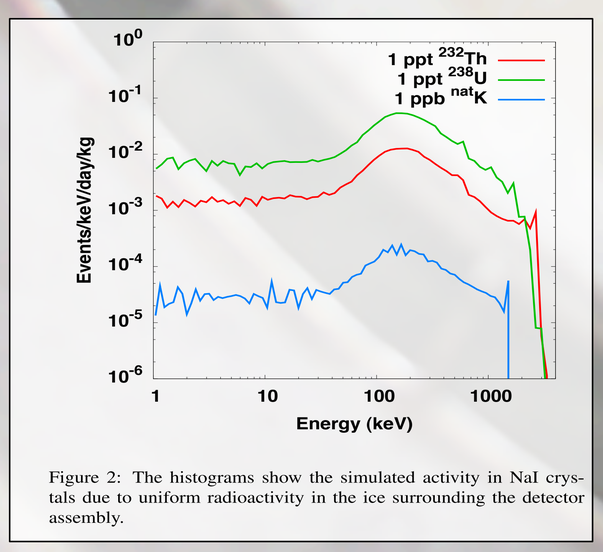
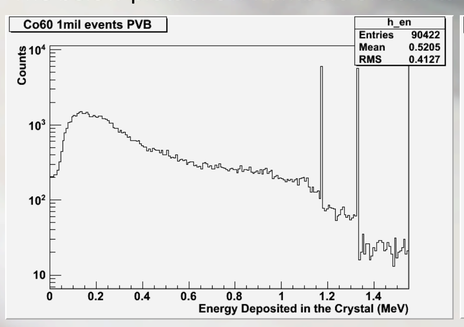
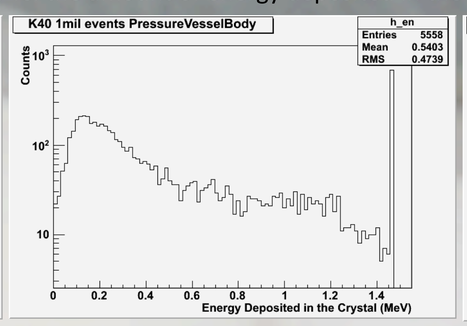


Figure 2: The histograms show the simulated activity in NaI crystals due to uniform radioactivity in the ice surrounding the detector assembly.

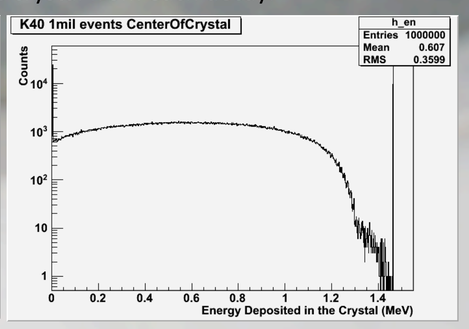
The below plots show numbers of counts vs. the amount of energy deposited in the crystal from each decay.



Simulating 1 million ^{60}Co decays, distributed throughout the pressure vessel which surrounds the detector.



Here 1 million ^{40}K simulated decays are distributed throughout the pressure vessel which surrounds the detector.



Simulating 1 million ^{40}K decays, with each located at the center of the crystal

Acknowledgments

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