DM-Ice: A Dark Matter Search in Antarctic Ice

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For the DM-Ice Collaboration

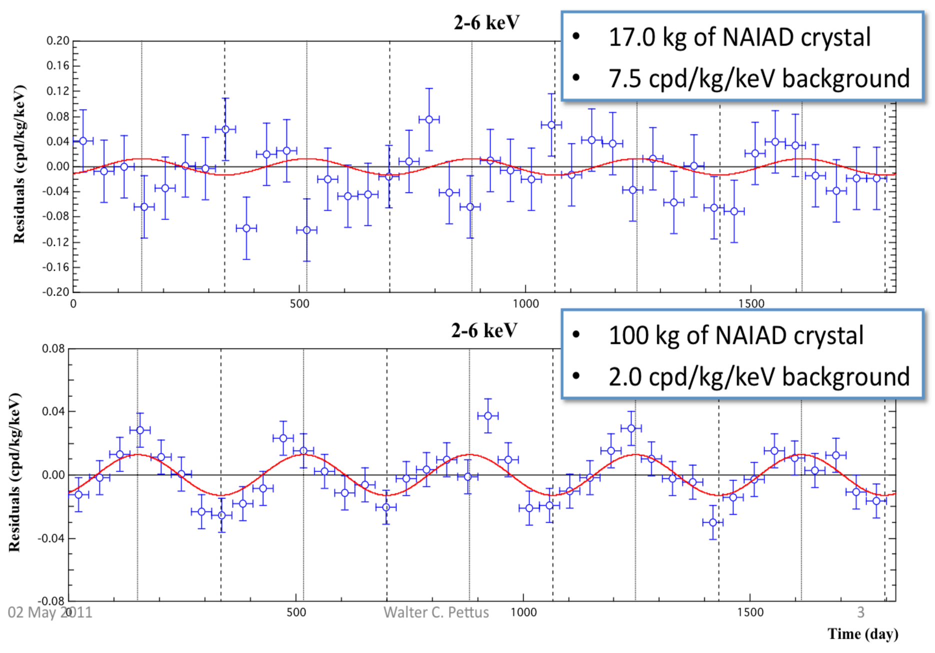
Abstract: DM-Ice is a proposed 250 kg NaI to be placed 2500 m below the surface at the South Pole. This experiment is designed to search for the annual modulation in Dark Matter flux believed to be observed by DAMA and, most recently, COGENT and CRESST. By conducting this experiment in the southern hemisphere, the expected modulation in the dark matter flux in DM-Ice has the same phase as that observed in DAMA 's, but many of the environmental effects are either absent or should be six months out of phase from one another. The Antarctic ice offers a large overburden, and is an ideal neutron moderator. Being situated within the IceCube detector allows for an excellent muon veto, thus reducing the cosmic ray background significantly for this experiment. Two 8.5 kg NaI crystal prototypes have been deployed in the ice, and their data is currently being analyzed.

See also: arxiv:1106.1156, posters by Walter Pettus and Bethany Reilly at this session

Annual Modulation

We model galactic dark matter as distributed in a diffuse, roughly spherical halo. As the Earth rotates around the Sun, the relative velocity of the dark matter changes. The net result is a small but periodic variation in the dark matter interaction event rate in an Earth-bound detector. The periodic variation would have a one-year period.

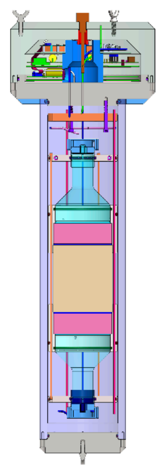
Modulation Simulation



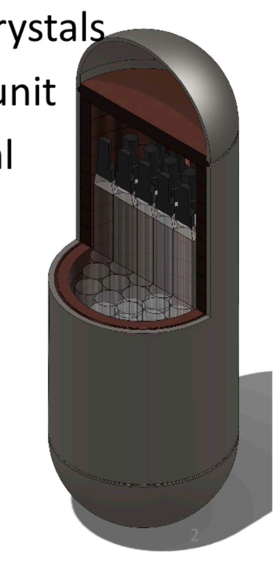
Experimental Setup

DM-Ice will consist of 250 kg NaI crystal scintillators, placed 2450 m under Antarctic ice at the base of IceCube. Current prototypes are 17 kg of NaI. The South Pole setup has different backgrounds and opposite modulation. The modulation will have same phase and opposite modulation. Antarctic ice is a radiopure and stable environment: 0.1 ppt U-238,Th-232, 0.1 ppb K-nat

- Prototype
  - 8.5 kg NaI per unit
  - 17 kg total



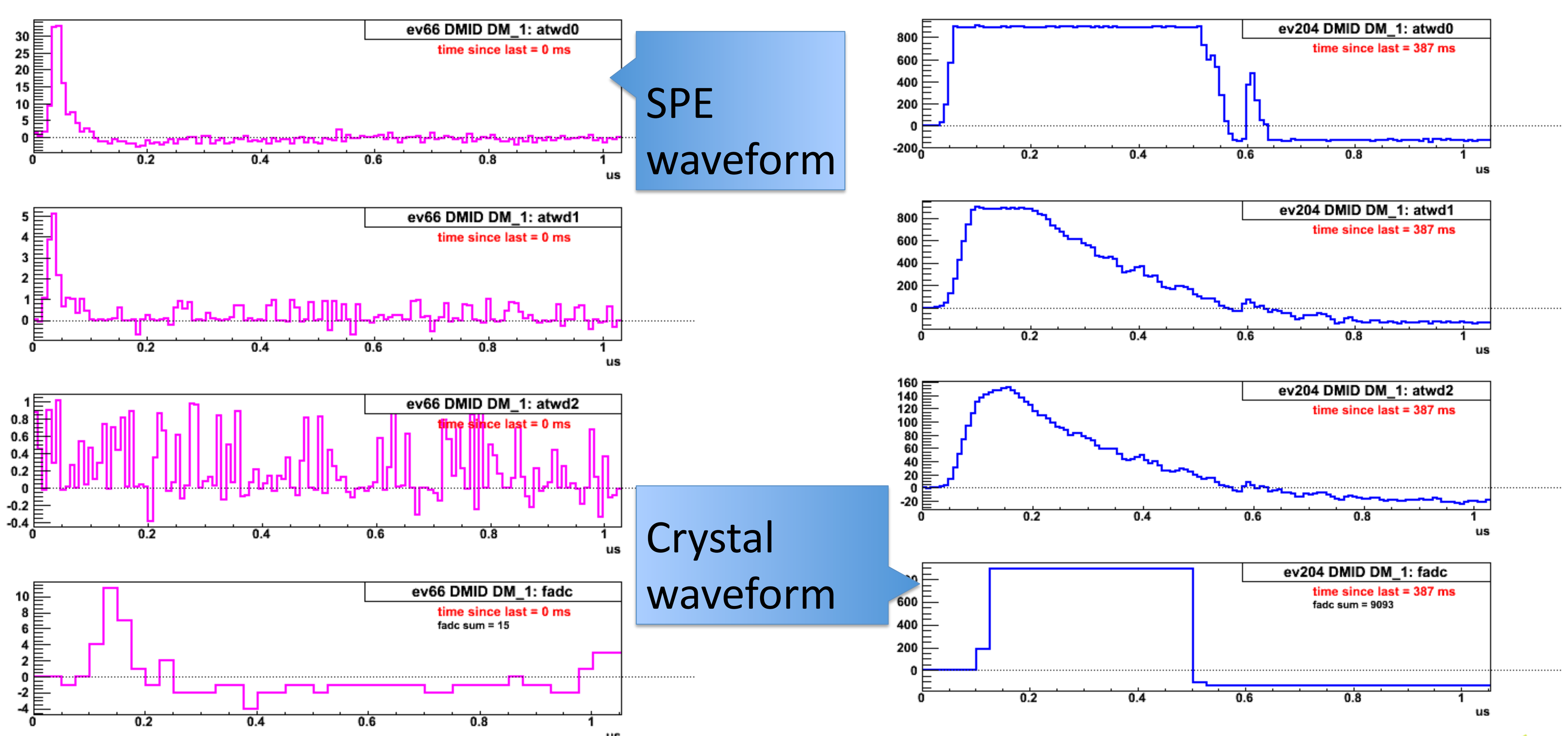
- Full-Scale
  - Arrays of crystals
    - 19 per unit
  - 250 kg total



02 May 2011 Walter C. Pettus

Prototype Data Acquisition

The prototypes have two 8.5-kg crystals, each with 2 PMTs. They run with IceCube mainboards. (The full scale detector will use different electronics.) These mainboards have four channel readouts: 1 FADC channel (6.4 us, 10 bit resolution) and 3 ATWD channels (10 bit resolution). The ATWD channels have different gain paths (16x, 2x, 0.25x) to increase the dynamic range. The high voltage and sampling speeds are programmable from the surface.



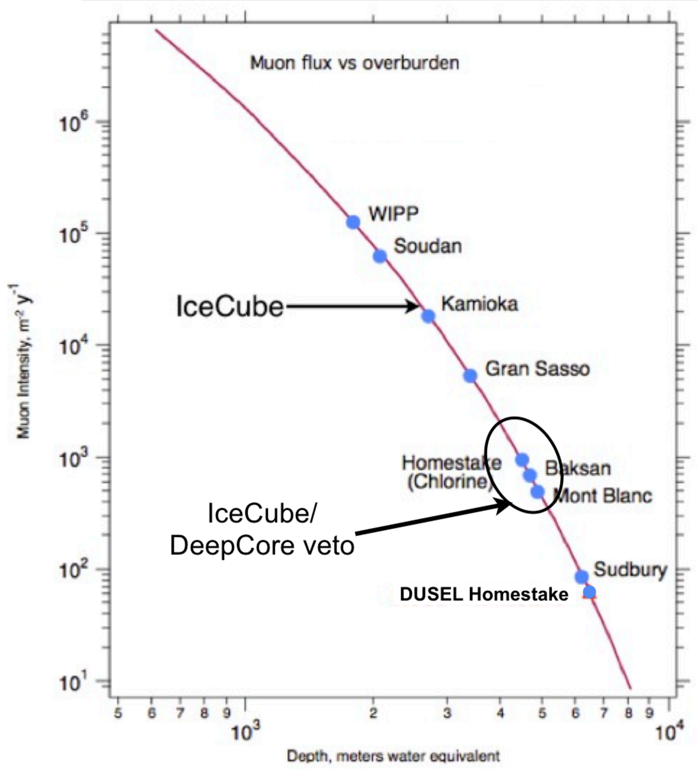
DAMA

Reported statistically significant observation of annual modulation with NaI crystals. These results have been inconsistent with other experimental results, although recent results from CoGeNT indicate potential modulation. DM-Ice will confirm or exclude DAMA in 2 years

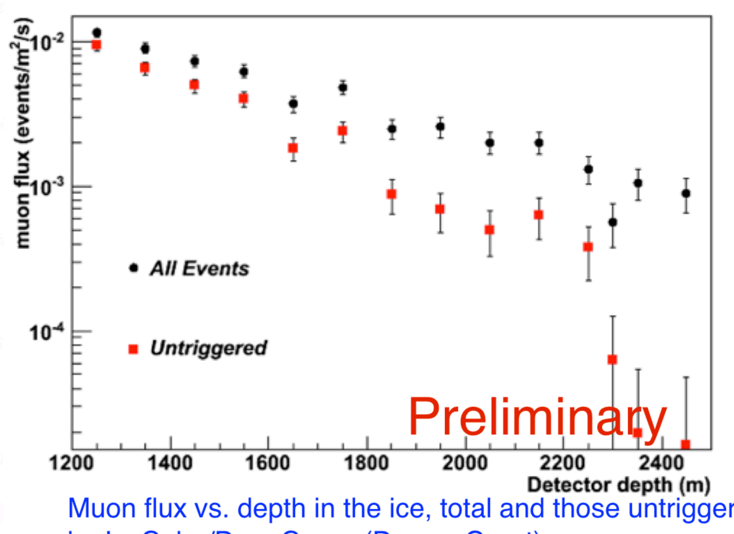
Backgrounds

Backgrounds come from cosmic rays and radioactive contaminants in the crystal and experiment materials. The crystals must have equal or less intrinsic radiogenic contamination than DAMA which observed 2 cpd/kg/keVee. This is the conservative net predicted rate for DM-Ice. Cosmic muons produce background from spallation neutrons and excited nuclei. We can use IceCube as a muon veto. It can be used to disentangle cosmogenic background from potential DM signal as it has observed ad characterized muon flux modulation. Recent interest in muons as a possible source of long-lived phosphorescent NaI activity mimicking dark matter (arxiv:1102.0815) increases our need to understand the muon modulation.

Antarctic Ice: Overburden at -2500 m (2200 m.w.e.)



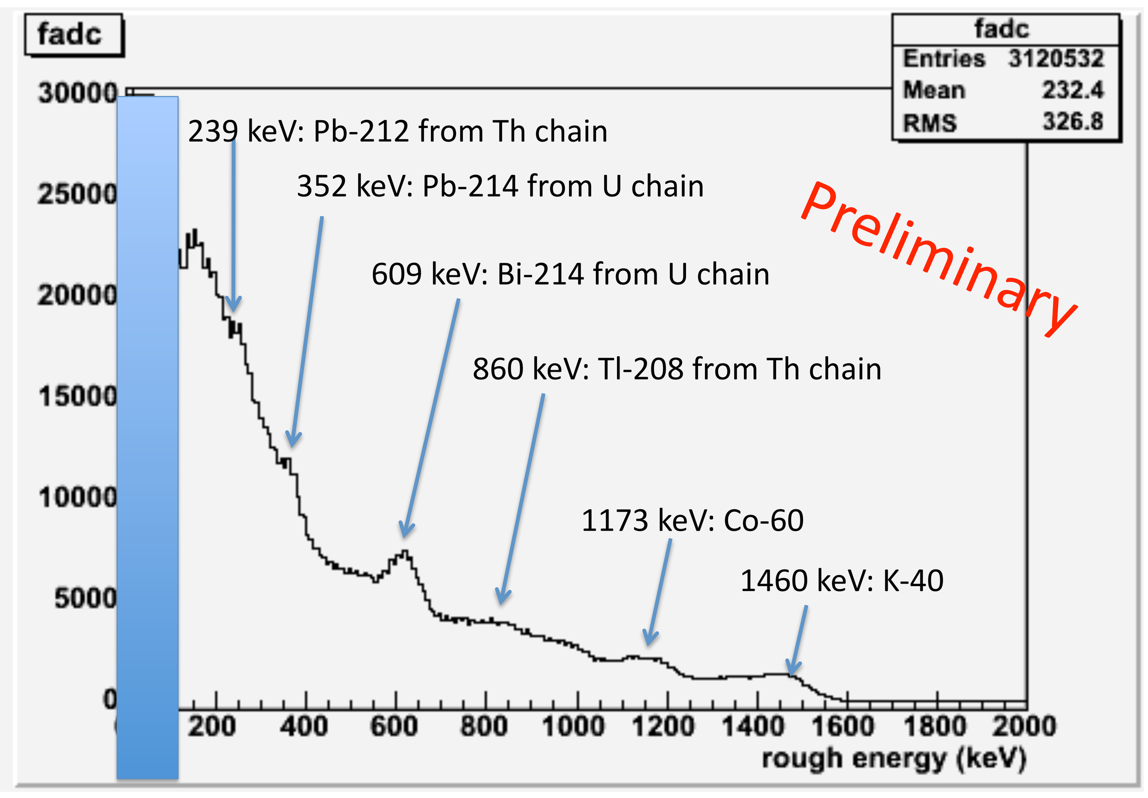
- ~85 muons/m^2/day at bottom of IceCube
- IceCube/DeepCore veto reduces rate by ~1-2 orders of magnitude.



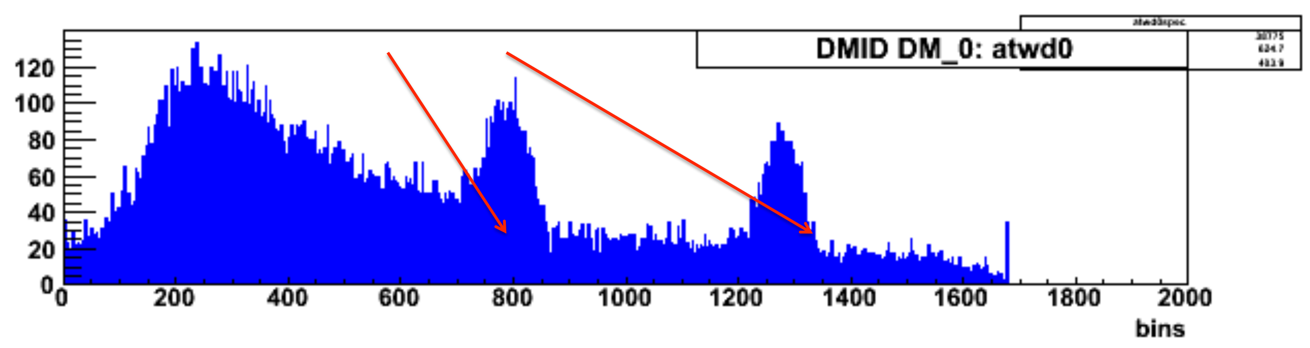
Muon flux vs. depth in the ice, total and those untriggered by IceCube/DeepCore. (Darren Grant)

Prototype Data Calibration

The DM-Ice prototype has been running continuously since January 5th, and has yielded 3067 kg-days of data to date. Pedestal subtraction is applied to waveforms. Initial energy calibration done with a Bi-207 source, with further calibration from the identification of background peaks.



Bi-207 lines from calibration in Madison, WI with source



DM-Ice Collaboration: University of Wisconsin, Madison, USA; University of Sheffield, UK; University Alberta, Canada; Pennsylvania State University, USA; Fermilab, USA; University of Stockholm, Sweden
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