DM-Ice: A Dark Matter Search in Antarctic Ice

Fermilab New Perspectives Meeting 2011

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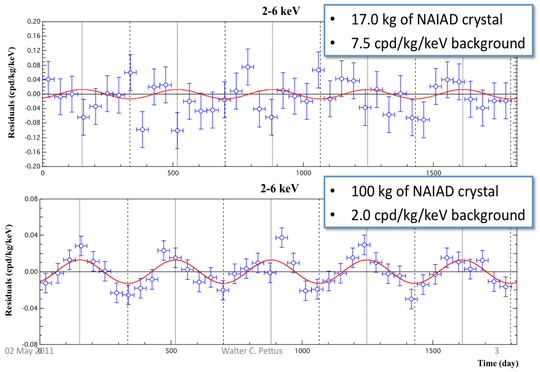
Abstract: DM-Ice is a proposed 250 kg NaI to be placed 2500 m below the surface at the South Pole. This experiment is designed to search for the annual modulation in Dark Matter flux believed to be observed by DAMA and, most recently, COGENT and CRESST. By conducting this experiment in the southern hemisphere, 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.

Annual Modulation

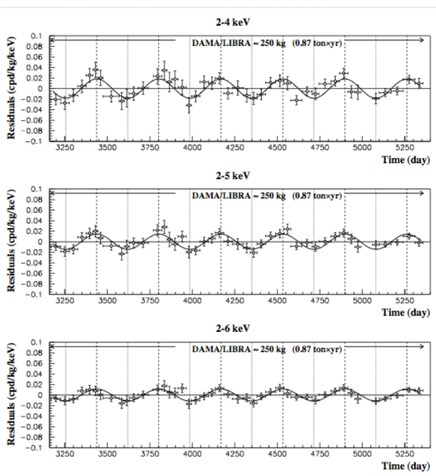
We model galactic dark matter as distributed in a diffuse, roughly spherical halo. As the Earth rotates around the Sun, the relative velocity of the dark matter changes. The net result is a small but periodic variation in the dark matter interaction event rate in an Earth-bound detector. The periodic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

Modulation Simulation



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

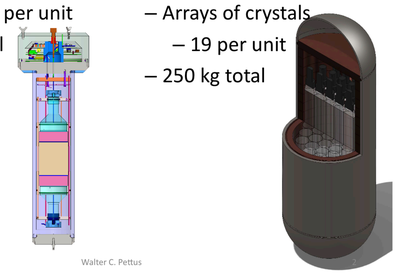


Experimental Setup

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: 1 ppt U-238,Th-232, 1 ppb K-nat

DM-Ice Detector Size

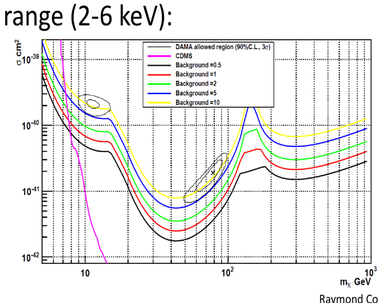
- Prototype
  - 8.5 kg NaI per unit
  - 17 kg total
- Full-Scale
  - Arrays of crystals
    - 19 per unit
  - 250 kg total



Sensitivity

Sensitivity to annual modulation from spin-independent elastic scattering of WIMPs: $R(t) = S_o + S_m \cos(\omega(t-t_c))$,
where S_o= constant DM signal; S_m = modulation sign
NaI cannot discriminate between nuclear and electronic recoils, so data is displayed in keVee. Energy range is 2-6 keVee: 2 keVee from thresholds of previous experiments. Above 6 keVee, recoil rate drops below background rates of 0.5-5.0 cpd/kg/keVee

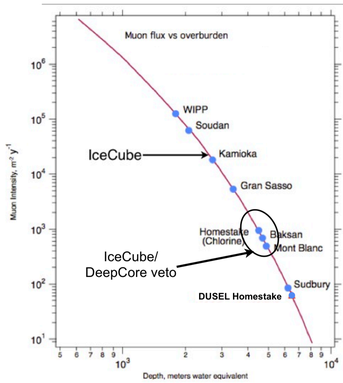
- 500 kg-yr exposure
- DAMA energy range (2-6 keV):



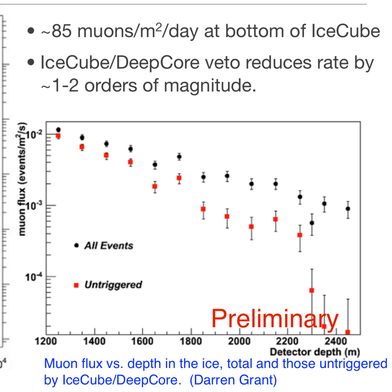
Backgrounds

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.

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



- ~85 muons/m²/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)

IceCube as Muon Veto

We can use IceCube as a muon veto. It can be used to disentangle cosmogenic background from potential DM signal as it has observed and characterized muon flux modulation.