Status of the DM-Ice Dark Matter Search

More than 10^9 dark matter particles are streaming through your body while reading this sentence. Don't worry, they would rather not stop to interact.

How do we hope to detect the illusive particles which make up 26.8% of the universe?

Dark Matter Basics

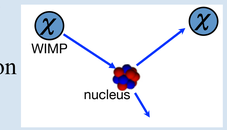
Cosmological models estimate dark matter is 26.8% of the energy density of the universe.

Theoretical particle physics models favor the weakly interacting massive particle (WIMP) class of dark matter – particles with mass 1 GeV – 1 TeV.

Direct Detection

WIMPs can coherently scatter off atomic nuclei

- Scattering deposits a few keV of recoil energy
- Kinematics and interaction rate vary with choice of target nucleus



Strategy: Build large (hundreds of kg) detectors with sensitivity to low energy nuclear recoils and low intrinsic background

- Use different targets to measure different scattering and interaction dynamics
- Employ techniques to eliminate and discriminate backgrounds

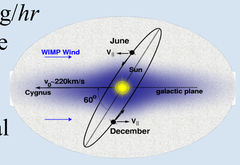
Detection Problem

Signal: few events/kg/*year*

Background: few events/kg/*hr*

Question: What signals are uniquely identifiable as dark matter?

Strategy: Search for annual modulation.



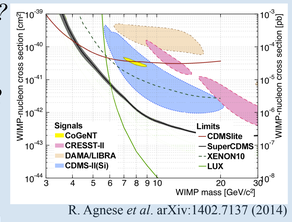
Experimental Problems

Experiments have made conflicting measurements while using different detection technologies and measuring different signals.

What are we missing?

- Background?
- New physics?
  - Particle physics?
  - Astrophysics?

Strategy: Validate or refute strongest signal claim (from DAMA) by replicating experimental setup while altering systematic backgrounds.



R. Agnese *et al.* arXiv:1402.7137 (2014)

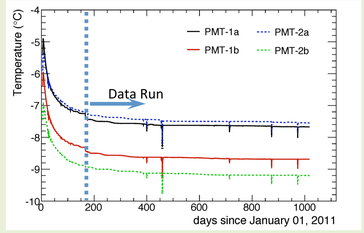
DM-Ice17

Prototype detectors operating at 2450 m depth under the ice at the geographic South Pole.

- First and only dark matter experiment operating in the Southern Hemisphere.
- Collecting physics data since June 2011 (following December 2010 deployment)

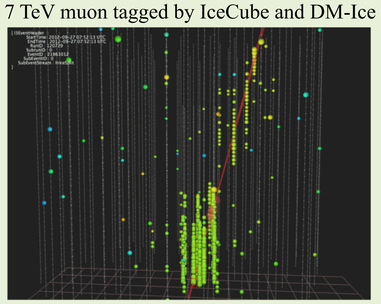
Demonstrated stable operating environment.

Glacial ice temperature stable to 0.06°C *RMS*



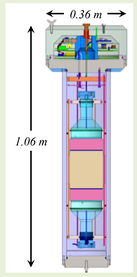
Demonstrated muon identification and rejection.

7 TeV muon tagged by IceCube and DM-Ice



Demonstrated detector design and deployment.

DM-Ice17 schematic



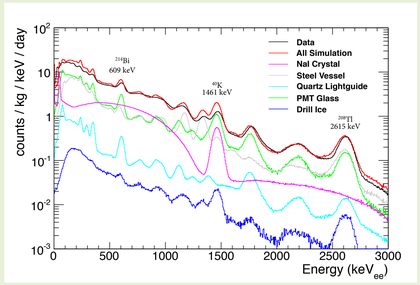
DM-Ice17 deployment to depth of 2450 m in water-filled hole



Demonstrated remote calibration technique.

Demonstrated low environmental backgrounds.

Spectrum match of simulation and data.



Concerns of running low-background experiment at the South Pole answered!

Crystal R&D

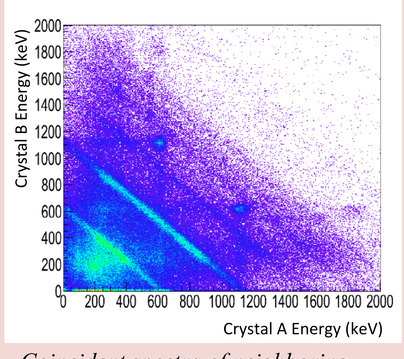
Working with vendors to grow new low-background NaI(Tl) crystals.

Testing candidate optical assemblies.

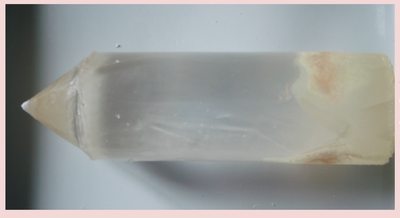
Experimental setups operating at

- Fermilab, USA (100 m overburden)
- Boulby, UK (1100 m overburden)

Capability to test 75 kg array (4 crystals)



Coincident spectra of neighboring crystals constrains multiple-scatter events to understand background levels



Newly-grown NaI(Tl) crystal ingot prior to cleaning (SICCAS)



Encapsulated NaI(Tl) crystal (Alpha Spectra Inc)

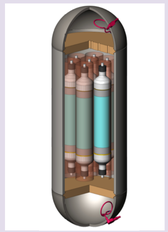


Test setup with two crystals in nitrogen purge at Fermilab

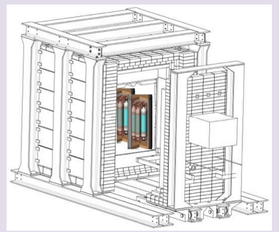
DM-Ice250

Planned future phase of DM-Ice experiment

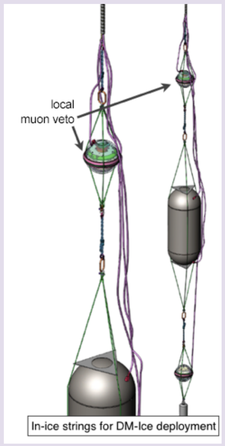
- Consists of 14 separate NaI(Tl) crystals, distributed between two pressure vessels
  - Total sensitive (crystal) mass of 250 kg
- Phased deployment in Northern Hermisphere (Gran Sasso, Italy), followed by Southern Hemisphere (South Pole, Antarctica) deployment as necessary
  - Operate detectors for two-year physics run



Conceptual design of DM-Ice250 detector



Northern deployment inside existing lead shielding (from XENON)

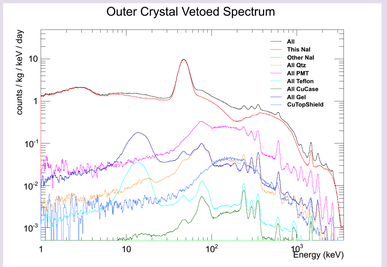


Southern deployment at South Pole in glacial ice

Detector Simulation

DM-Ice250 background model from Geant4 simulation, based on DM-Ice17 and crystal R&D, validates experimental potential.

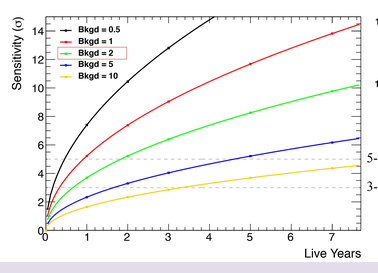
Background of 2 counts/kg/kev/day predicted for DM-Ice250



DM-Ice250 Sensitivity

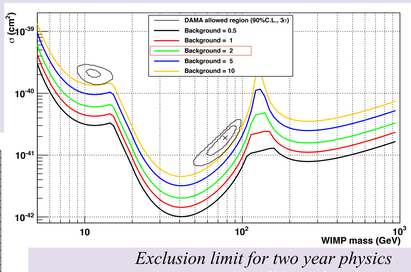
Deliver definitive statement on dark matter controversy within two years of running.

Sensitivity in testing signal hypothesis



5-σ "discovery"

3-σ "evidence"



Exclusion limit for two year physics run (testing null hypothesis)

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Matt Kauer, Walter Pettus, Antonia Hubbard, Zachary Pierpoint
leading an international collaboration of ~30 scientists from 5 countries

Recent Publications:

First Data from DM-Ice17 [Phys. Rev. D 90 (2014) 092005]

A Search for the Dark Matter Annual Modulation in South Pole Ice [Astropart.Phys. 35 (2012) 749-754]

LUX ET VERITAS