Update on the MiniCLEAN Dark Matter Experiment

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Pulse-Shape Discrimination in LAr

- Noble liquids have singlet and triplet excited states
- For argon and neon, decay times for these states are different and long enough to provide discrimination between electronic and nuclear recoils
- Electronic recoils result in creation of more triplet states so more late light
- Data shows pulse shape discrimination of $10^{-10}$ achievable, demonstrated $10^{-8}$
MiniCLEAN Goals

• Based on the 95% (almost $4\pi$) coverage design:
  • Measurement of light yield compared to simulation
  • Demonstration of 3D position reconstruction

• At that light yield:
  • High statistics measurement of background PDF due to PSD leakage of 39Ar decays
  • Informs future performance of large argon detectors

• With MiniCLEAN:
  • Measure backgrounds (surface alphas, neutrons, etc.)
  • Test analysis and background rejection techniques

• With additional funding:
  • Replace argon target with liquid neon to inform future large detector designs for dark matter, p-p solar neutrino experiments
Conceptually Simple Detector

- Sphere of argon or neon serves as target for WIMPs
- Scintillation light from recoils at 80-128 nm
- Converted to visible by wavelength shifter on acrylic
- Light guide brings visible light to photomultiplier tube where signal recorded
MiniCLEAN Detector

- Liquid cryogen can be argon or neon
- ~150 kg fiducial volume, 500 kg active volume
- PMTs - Hamamatsu R5912-02MOD operating in cryogenic liquid
- Cryogen, PMTs and wavelength shifters contained in stainless steel Inner Vessel (IV)
- IV is surrounded by stainless steel Outer Vessel with vacuum insulation and thermal blanket
- PMT and wavelength shifter (TPB) on acrylic plate are part of modular optical cassette
- 92 optical cassettes
- Operates 6800’ underground at the SNOLAB underground laboratory in Sudbury, Ontario, Canada
MiniCLEAN Conceptual Design

Not Shown:
- Magnetic Compensation
- Process Systems
- Cable Bundles

Tank 18' dia. x 25' tall
47,600 gallons

~1.5m water top & sides
~3.5m water bottom
MiniCLEAN Conceptual Design

- Outer Vessel
- Inner Vessel
- Calibration Ports
- Optical Module
- Target Volume
- LAr/LNe
- PMT
- Top Hat
- Light Guide
- Acrylic Plug
Outer Vessel Progress

Underground in January, installed in May
Inner Vessel Progress

- Manufacturing completed and tested in September 2012
Inner Vessel Progress

- Cleaned - April
- Spools added - May
- Under vacuum - July
Optical Cassette Progress

Light guide - test fit

Light guide/acrylic assembly

WLS

PMT assembly
Optical Cassette Progress

First optical cassettes installed last week
Subsystem Progress

Magnetic Compensation System

Argon Purification System

Electronics/DAQ
PSD Demonstration with Enriched Argon

• Spike the detector with a sample of 39Ar to increase the level of this background ~8x (and shorten time to perform measurement)

• Use to extract ultimate PSD leakage rate achievable

• DOE isotope program produced 39Ar as byproduct in irradiated KCl target
  • About 138 MBq (need 25kBq)

• Extraction and purification will be performed at LANL soon
MiniCLEAN Schedule

- Assembly and initial commissioning complete in late Fall 2013
- 4-5 weeks to condense argon gas into LAr
- ~8 weeks of calibration and running:
  - Energy scale
  - Position reconstruction
  - Neutron calibration
  - Preliminary PSD
- Then ~100 days of enriched argon running
  - Produce at least $10^{10}$ $^{39}$Ar events in the fiducial volume
- Use PSD run to compare to DEAP-3600, Darkside-50, etc
- Pursue addition of LNe
Utility of LNe Run for Dark Matter

- Running with two different $^{39}\text{Ar}$ rates, combined with neon run offers a powerful test of any possible WIMP signal.
Analysis Techniques

- Bayesian Single PE counting:
  - deals with PE pile-up in prompt region
  - better performance than simple charge division
  - determines number of PE and time for each waveform to improve energy resolution at low energy
Analysis Techniques

- **Position Reconstruction**: using likelihood based approach to predict location of event
- **Pulse shape discrimination**: \(F_{\text{prompt}}\) vs. \(L_{\text{recoil}}\)
  - \(L_{\text{recoil}}\) uses PE times from PE counter, singlet and triplet ratios and lifetimes as inputs
  - most improvement at low energy
Summary

- Assembly of MiniCLEAN is in final stage
- Expect to begin LAr fill by end of 2013
- Will study backgrounds and position reconstruction
- Enhance with 39Ar for PSD measurement
- Will pursue liquid neon R&D
- New analysis techniques will be tested
- MiniCLEAN will provide valuable data for future argon experiment plans
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