DEAP-3600 Dark Matter Search With Argon





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Liquid Argon as a Scintillation Detector for Dark Matter



Scattered nucleus (with several 10's of keV) is detected via scintillation in liquid argon

Well-separated singlet and triplet lifetimes in argon allow good pulse-shape discrimination (PSD) of β/γ's using only scintillation time, projected to 10⁻¹⁰ at 15 keV_{ee} (see Astroparticle Physics 25, 179 (2006) and arxiv/0904.2930) (Removes β's from ³⁹Ar through to solar neutrino scatters)

•Position reconstruction allows removal of surface events

•Very large target masses possible, since no absorption of UV scintillation photons in argon, and no e-drift requirements (1 tonne to ~hundreds of tonnes)

•1000 kg argon target allows 10⁻⁴⁶ cm² sensitivity (SI) for 100-GeV mass WIMP (3 year run)

Xenon and argon for direct WIMP scattering



- Potential for very large and very sensitive searches
- Complementary

DEAP-3600 will be sensitive to much of the remaining SUSY parameter space for the simplest models, similar sensitivity to XENON-1T for high-mass WIMPs



Figure adapted from C. Strege et al., JCAP04(2013)013

DEAP-3600 Background Budget (3 year run)

Background	Raw No. Events in Energy ROI	Fiducial No. Events in Energy ROI	
Neutrons	30	<0.2	- Acr+H ₂ O shield
Surface α 's (²¹⁰ Po)	150	<0.2	Resurfacer
³⁹ Ar β 's (nat. argon)	1.6x10 ⁹	<0.2	
³⁹ Ar (depleted Ar)	8.0x10 ⁷	<0.01	∽ PSD
Total		<0.6	

Need to resurface inner vessel and ensure purity of acrylic.

- ➤ o removal of 1 mm acrylic
 - ²¹⁰Pb < 1.1x10⁻¹⁹ g/g for 0.1 events/3 years (strict control of Rn exposure)

All materials have been assayed/controlled (2007-2013)

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DEAP-3600 Design Parameters and Background Target Levels

Parameter	Value	
Light Yield	8 photoelectrons per keV_{ee}	
Nuclear Quenching Factor	0.25	
Analysis Threshold	15 keV _{ee} , 60 keV _r	
Total Argon Mass (Radius)	3600 kg	
Fiducial Mass (Radius)	1000 kg	
Position Resolution at threshold (conservative, design spec)	10 cm	
Position Resolution at threshold (ML fitter)	5 cm	
Background	Target	
Radon in argon	< 1.4 nBq/kg	
Surface α 's (tolerance using conservative pos. resolution)	< 0.2 µBq/m²	
Surface α 's (tolerance using ML position resolution)	< 100 µBq/m²	
Neutrons (all sources, in fiducial volume)	< 2 pBq/kg	
Bg events, dominated by ³⁹ Ar	< 2 pBq/kg	
Total Backgrounds	< 0.6 events in 3 Tonne-y	

arXiv/1203.0604

Background suppression with PSD in DEAP-1 Prototype



PSD studies with tagged ²²Na source in DEAP-1



Expect order 10⁸ events before random pileup of nuclear recoil backgrounds (in small detector) with tag

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PSD with triple-tagged γ 's in DEAP-1





α and Surface Backgrounds in Liquid Argon



DEAP-1 and DEAP-3600 surface profile

 α Backgrounds in LAr (DEAP-1)

High-energy spectrum described by

²²²Rn (15 μBq/kg) and ²²⁰Rn (3 μBq/kg)





Low-energy peak described by surface events

Expect upper cutoff **above** WIMP window

PSD leakage due to lower light yield (4 pe/keVee)

arXiv:1211.0909 (under revision)



DEAP-3600 Detector

3600 kg argon target (1000 kg fiducial) in sealed ultraclean Acrylic Vessel

Vessel is "resurfaced" in-situ to remove deposited Rn daughters after construction

255 Hamamatsu R5912 HQE PMTs 8-inch (32% QE, 75% coverage)

50 cm light guides + PE shielding provide neutron moderation

Detector in 8 m water shield at SNOLAB

Top and Bottom Steel Shell Hemispheres in SNOLAB Cube Hall (Dec. 2012) 23,000 L vacuum vessel



Cleaning Electropolished "Steel Shell" Vessel



Steel Shell Installation and Vacuum Testing



Steel Shell in final installation position, hanging from deck

"Bag" for helium leak test of large equatorial O-ring seal, welded together underground



Purification rack on deck (installed May 2013)



Electronics, Trigger, Purification and Cryogenics Installed

3500L LN₂ dewar with 3KW cryocoolers, for cooling argon

Trigger and CAEN v1720 WFDs

150 LPM purification system(ultralow radon) and Rn scrubber3000 LAr dewar for target storage

DEAP-3600 Acrylic Panel Production



Strict control of exposure to Radon, with collaboration oversight of production. Panels cast in 2011.

Pure-monomer cast panels for AV (RPT-Asia) and Light Guides (Spartech, USA)



²¹⁰Pb distribution in acrylic from deposition, diffusion



Will remove 1mm with Resurfacer

DEAP-3600 Acrylic Vessel Resurfacer



Removes 1 mm acrylic in-situ after construction

Radon-scrubbed N₂ purge gas and UPW flushing to extract residue

Surface contamination returns to bulk purity level



24% uniformity demonstrated



4π TPB (Organic WLS) deposition source developed for DEAP-3600



20-inch test vessel, 1/3 scale



Spartech and RPTA samples – Transparency of DEAP production acrylic



DEAP RPTA acrylic is most transparent we have ever "seen", close to Rayleigh limit

DEAP Spartech acrylic also clean, but excess Rayleigh scattering (anneal to correct)

At high wavelengths, only C-H features seen, expected from PMMA itself

AV Fabrication (RPT Colorado and University of Alberta) 2011 to present



AV Neck Bond (Reynolds Polymer, Tech. (RPT) at SNOLAB Jan 2013)



Vessel sealed and purged, approx. 50 LGs bonded (September 2013)



Large LAr Detector (Conceptual) 10⁻⁴⁸ cm² Sensitivity...



Summary

- DEAP-3600 construction nearing completion, 1000-kg fiducial liquid argon with < 0.2 background events/year background budget
- Extensive backgrounds and assay program, in particular ultralow background acrylic inner vessel and low radon emanation inner detector and purification system
- 10⁻⁴⁶ cm² sensitivity for 100-GeV WIMP (first run natural argon, then DAr)
- Assembly will be "mostly" complete end of 2013, commissioning/filling by Spring 2014
- Potential for v. large target mass with argon, 50-tonnes for 10⁻⁴⁸ cm² sensitivity, precision measurements...