Dark Matter searches by DEAP-3600 in SNOLAB

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For the DEAP Collaboration

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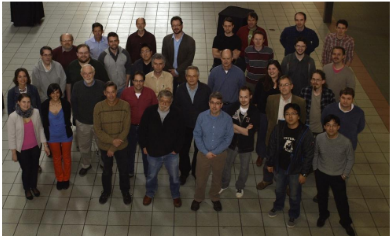


Boulay IDM 2012

Outline

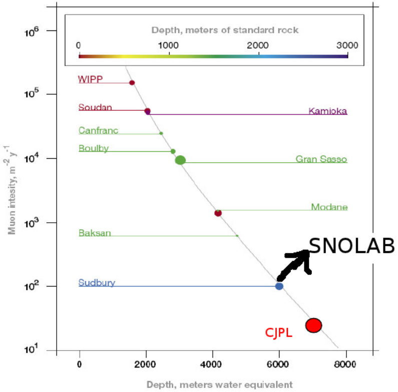
Basic information of SNOLAB

- Underground science laboratory, 2 km below the surface in the Vale/Inco Creighton Mine, near Sudbury Ontario in Canada.
- 5,000 m^2 of clean space underground for experiments and the supporting infrastructure.
- 3,100 m^2 surface facilities to support the underground experiments.

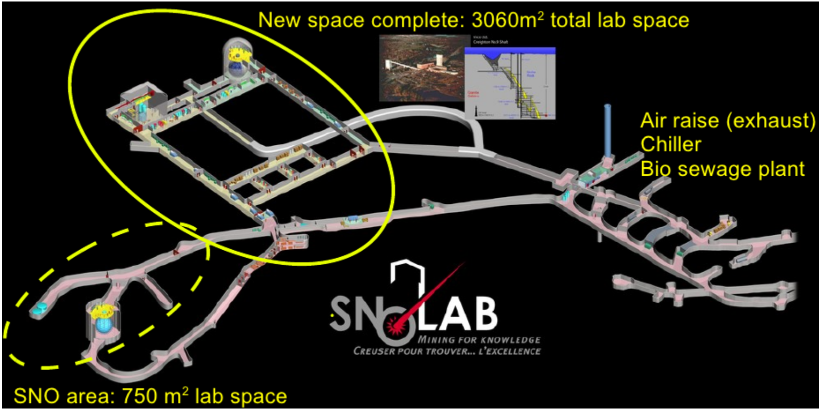
Topics in astroparticle physics

⋆ Low Energy Solar νs;
⋆ $0\nu\beta\beta$ Decay;
⋆ Cosmic DM Searches;
⋆ Supernova ν Searches.

Reference: www.snolab.ca



SNOLAB structure



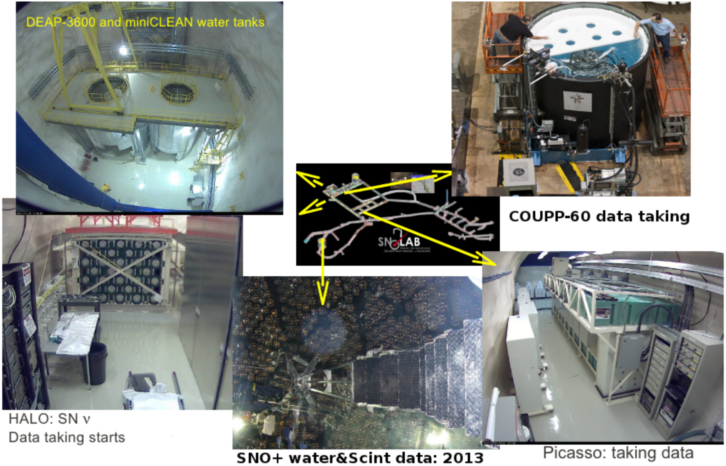
Depth = 6000 mwe. 0.3 muons/m^2/day

All experiments in SNOLAB

Experiment	Solar ν	0νββ	Dark Matter	Super nova	GeoNu	Other	Space Allocated	Status	Expt Lead
SNO+	X	X		X	X		SNO Cavern	Construction	
PICASSO			X				Ladder Labs	Running	
DEAP-1			X				J-Drift	V6/Finished	
DEAP-3600			X				Cube Hall	Construction	
MiniCLEAN			X				Cube Hall	Construction	
COUPP-4			X				J-Drift	Finished	
COUPP-60			X				Ladder Labs	Running	
SuperCDMS			X				Ladder Labs	Construction	
HALO				X			Phase III Stub	Running	
PUPS						Seismic	Various Locations	Completed	

Courtesy: C. Jilling

Projects active on site



Courtesy: C. Jilling

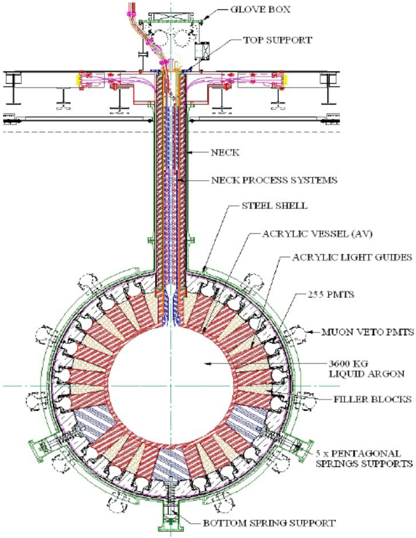
Outline

DEAP-3600 Hall

DEAP-3600 Detector

Courtesy: K. Dering.

DEAP-3600 Detector



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)

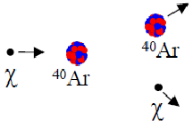
50 cm light guides +
PE shielding provide
neutron moderation

Detector in 8 m water
shield at SNOLAB

Courtesy: K. Dering.

Outline

Direct WIMP detections with LAr



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

Pulse-shape discrimination (PSD) is very powerful in argon, allows for suppression of background β/γ events.

Projected pulse shape discrimination (PSD) in argon allows threshold of approx. 20 keV_{ee} (60 keV_r)

1000 kg argon target allows 10^{-46} cm^2 sensitivity (spin-independent) with ~20 keV_{ee} threshold (~65 keVr) threshold, sufficient to mitigate ^{39}Ar

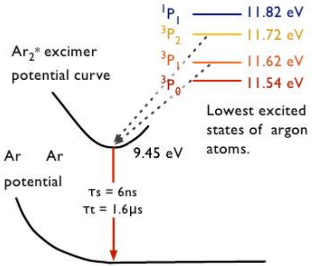
Liquid argon
- is easily purified and has a high light yield
- is well-understood, allows for very simple scintillation detector
- has an easily accessible temperature (85K)
- allows a very large detector mass (~tonne) with uniform response (few % light yield uniformity)

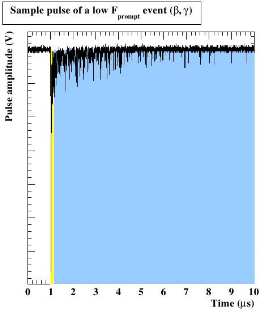
} DEAP-1 (7 kg)
DEAP-3600 (3600 kg)

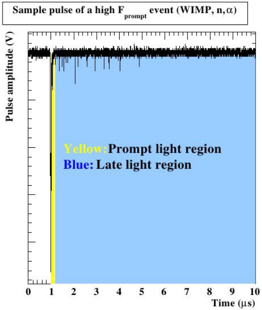
Courtesy: M. Boulay

How to identify WIMP signals?

- Only detect scintillation light by PMTs. Output: pulse waveforms.
- A particle passing through LAr will lead to excited Ar Excimers. $E_{\text{deposited}} \propto N_{\text{PE}} \Longrightarrow M_{\text{in}}$ and p_{in}.
- Discriminate between nuclear recoils and EM backgrounds.
- A definition of F_{prompt}: $F_{\text{prompt}} = \frac{\text{prompt light (150 ns)}}{\text{total light (9}\mu\text{s)}}$
  PSD uses F_{prompt} combined with Energy cuts and Radial cuts







Backgrounds

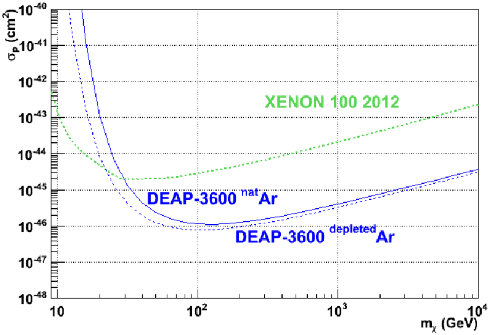
- **Source of β/γ events**: dominated by ^{39}Ar $\approx$ 1 Bq/kg
  $\Rightarrow$Removal with PSD possible up to 1000 kg of argon;
  $\Rightarrow$Can also use argon depleted in ^{39}Ar (DAr):collaboration with Princeton for a $\times$12 depleted argon.
- **Source of neutron recoils**: (α,n)+fission, μ-induced.
  $\Rightarrow$Need very strict materials control, and SNOLAB depth + “Onion” layers for shielding
- **Source of surface events**: Rn daughters and other surface impurities
  $\Rightarrow$clean surfaces in-situ (resurfacer), position reconstruction, limit radon

Requirements of DEAP-3600

DEAP-3600: 1000 kg LAr, 3-year exposure < 0.2 events from each source (i.e. 1 background event per 5 Gg-days) for 10^{-46} cm^2 sensitivity.

Expected sensitivity

Assuming that we can lower the backgrounds up to the required level, here comes with the expected Spin-independent sensitivity:



Credits: M. Boulay's talk at IDM2012

Outline

Status of DEAP-3600

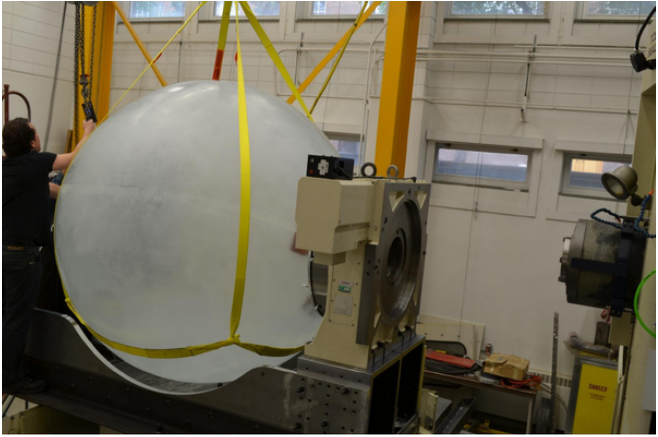
- The steel shell is near completion.
- The PMTs are being characterized at Queen's University.
- Light Guides are being machined at TRIUMF.
- The bonding processing light guides to the AV is being finalized at U of Alberta.
- The filler blocks are being assembled at SNOLAB.
- TRIUMF is developing the DAQ.
- The UK groups are developing the calibration systems.
- The cooling process system is being assembled by SNOLAB & Carleton.

Status and recent highlights

Acrylic Vessel (AV) at Reynolds Polymer Technology (RPT)

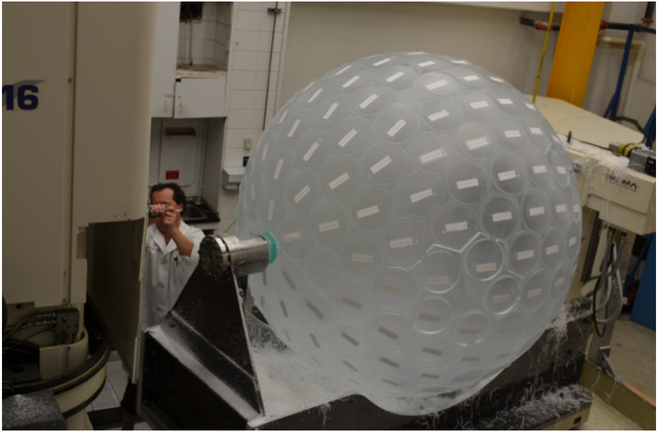
The AV being fabricated from large acrylic gores at an RPT facility.

The AV after first arrival at the U. of Alberta



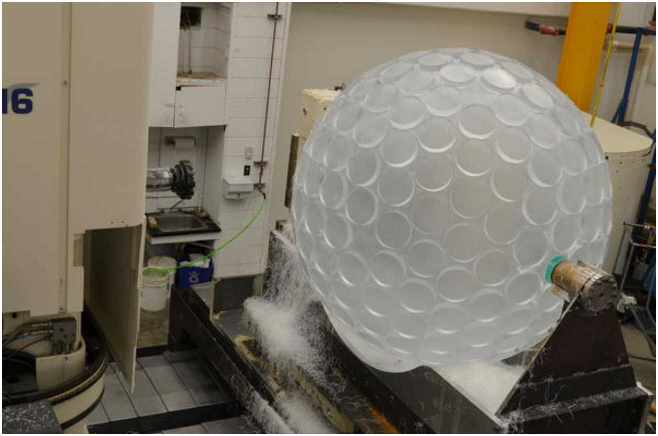
Courtesy: P. Gorel

The AV after the first machining passes to outline the light guide stubs



Courtesy: P. Gorel

The recently completed AV (September 6th, 2012)



Courtesy: P. Gorel

Summary

- DEAP-3600 has the potential to be one of the world's first tonne-scale direct detection dark matter experiments with a WIMP-nucleon cross-section sensitivity near 10^{-46} cm^2.
- Extensive radio purity and quality assurance programs for all detector components, including the AV, have been put in place.
- Most primary components are nearing completion.
- Deployment at SNOLAB is imminent beginning with the AV in Fall, 2012.
- Anticipated start of detector commissioning and physics data taking in late 2013.
- The liquid argon technology may be scalable to very large target masses and is being investigated.
  Let's go "DEAPer"!

SNOLAB underground facilities

Laboratory Space	Style	Length (ft)	Width (ft)	Height	Area
SNO Cavern (Existing)	Cavern	72		85	3848
	Utility Drift	187	23		4300
	Control Room	57	20		1140
South Drift (Existing)	Drift	106	17	10/17	1802
Ladder Labs (Phase I)	Drift C1	105	20	12/19	2100
	Drift C2	75	25	17/25	1875
	Drift B&D	360	15	10/15	5400
Cube Hall (Phase I)	Hall	60	50	50/65	3000
	Utility Drift	115	20	10/17	2300
	Staging Area	45	16	10/15	720
	Control Room	62	18	10/16	992
Cryopit (Phase II)	Cavern	50		50/65	1963
	Utility Drift	141	20	10/15	2820
	Staging Area	66	16	10/15	1056
	Control Room	64	16	10/15	1024
Existing Phase I					11090
Phase II					27477
					34340

Reference: www.snolab.ca

DEAP-3600 material radiopurity requirements

Component	Material	^{238}U g/g	^{232}Th g/g	^{210}Pb g/g	Rate
Acrylic Vessel	acrylic	2×10^{-12}	9×10^{-12}	10^{-20}	
Light Guides	acrylic	1×10^{-11}	4×10^{-11}	10^{-18}	
PMTs (255)	glass +	75×10^{-9}	30×10^{-9}		
Rn emanation					5 μBq
Internal surface					0.2 μBq/m^2

Detailed G4 MCs set light guide length = 50 cm for neutron moderation

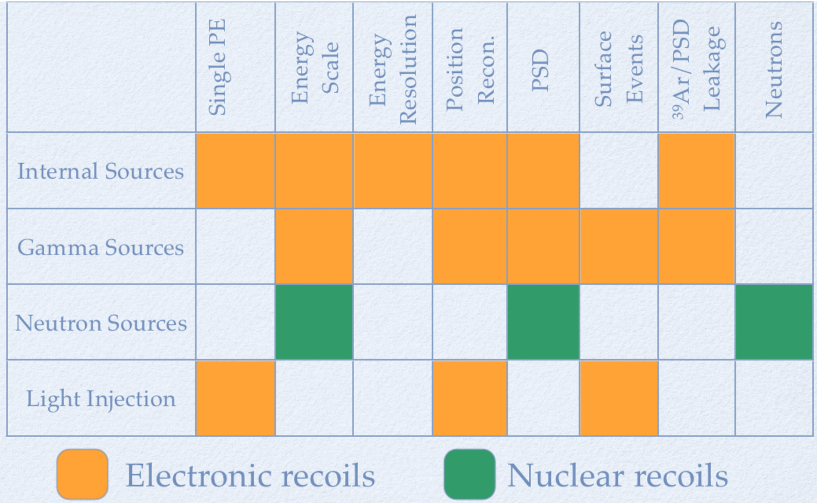
Neutron production cross-checked with SOURCES (and SNO codes), neutron detection and shielding efficiency verified with DEAP-1 LAr detector

Active assay program (U/Th/Pb/Rn emanation). Most other materials require ~ppb

Developed system to vaporize many kg's of acrylic and count residue with Ge well detector for ^{210}Pb assay

Target levels are for 1 background event or less per 15 tonne-yr in energy ROI, total background budget is < 0.6 events in 3 tonne-years from all sources

DEAP-3600 calibration goals



Sources: dd-neutrons, light injecton, $^{83}Kr^{m}$, gammas (^{23}Na, ^{60}Co, ^{137}Cs, AmBe) ··· *Courtesy: K. Palladino*