Projected Sensitivities for Future Upgrade Scenarios of SuperCDMS SNOLAB

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SuperCDMS SNOLAB

The Super Cryogenic Dark Matter Search (SuperCDMS) collaboration uses cryogenic semiconductor detectors to search for interactions of dark matter (DM) with regular matter. While the next generation of the experiment is under construction at SNOLAB, we forecast sensitivities for several DM interaction types for different upgrade options based on the SuperCDMS detector technology and use of the facility currently under construction.

Upgrade Scenarios

- Background improvement: three levels were considered but only one (reduced electron recoil (ER) background from U/Th and radon plate-out) was found to provide significant benefits at acceptable costs.
- Various detector sizes (~1cm^3; ~10cm^3, and present size) and modes (0V, HV).
- Improved detector parameters: three scenarios ("Det A, B, and C") with improving resolution and decreasing instrumental background.

Quantity	Detector Type	Detector Size	SuperCDMS SNOLAB Si	SuperCDMS SNOLAB Ge	A Si	A Ge	B Si	B Ge	C Si	C Ge
phonon energy resolution (baseline) [eV]	0V	1 cm^3			0.5		0.13	0.28	0.013	
		10 cm^3			2.5	4.5	0.7	1.5	0.07	0.14
	HV	10 cm^3			3.3	4.5				
		SNOLAB-sized	13.	34.	12.	21.	4.	6.	0.6	0.7
	iZIP	10 cm^3			2.5	4.5	0.7	1.5		
		SNOLAB-sized	19.	33.	12.	21.	3.4	6.		
	piZIP	10 cm^3			3.3	4.5	1.2	1.5	0.19	0.21
		SNOLAB-sized			12.	21.	4.	6.	0.6	0.7
ionization energy resolution [eV_{ee}]	iZIP	10 cm^3			60.	50.	17.	17.		
		SNOLAB-sized	160.	180.						
	piZIP	10 cm^3			8.	11.	3.	4.		
		SNOLAB-sized			30.	53.	10.	15.	1.5	1.8

Table 1: Baseline resolution for the different detector scenarios. Empty boxes indicate scenarios which provide no benefit, or not implemented. .

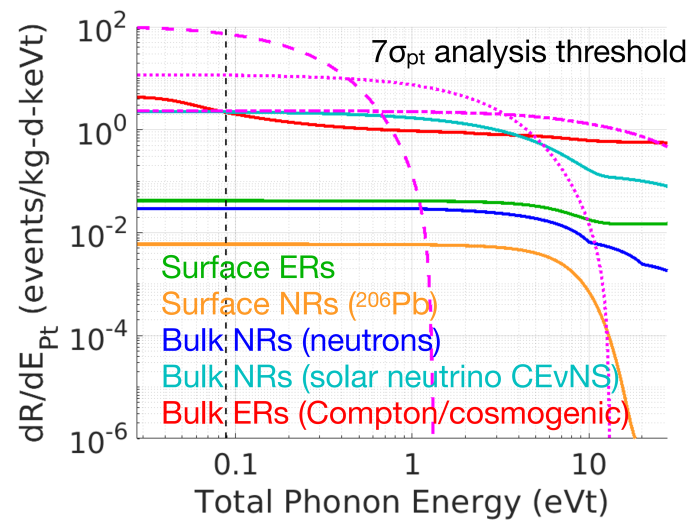
DM Interaction Types

- Nucleon couplings of 0.05-5 GeV DM (NRDM)
- e$^-$ couplings of kinetically-mixed 1-100eV dark photon DM (DP DM)
- e$^-$ couplings of 1-100eV axion-like-particle DM (ALP DM)
- Dark photon-mediated couplings of 1-100MeV light DM (LDM)

Forecasting Method

Forecasts are calculated with two sets of codes, one treating ionization production as continuous (for 0V and iZIP/piZIP), and the other as discrete (for HV).

Background and signal spectra are calculated. Random experiments are drawn from the background spectra and a profile likelihood method is used to calculate the upper 90% CL limit.



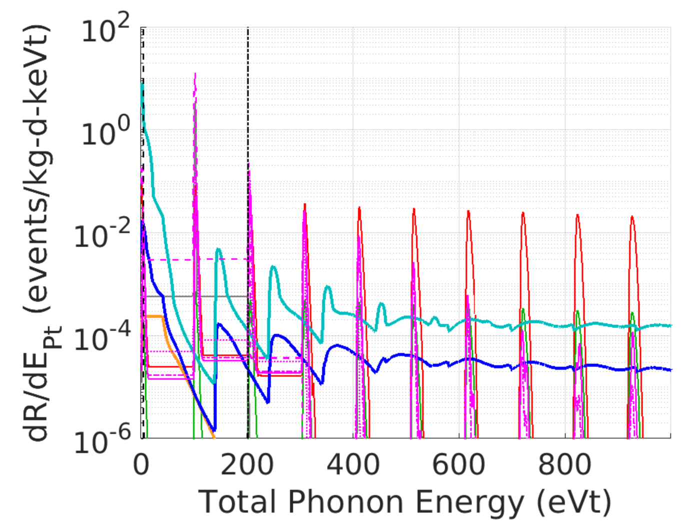


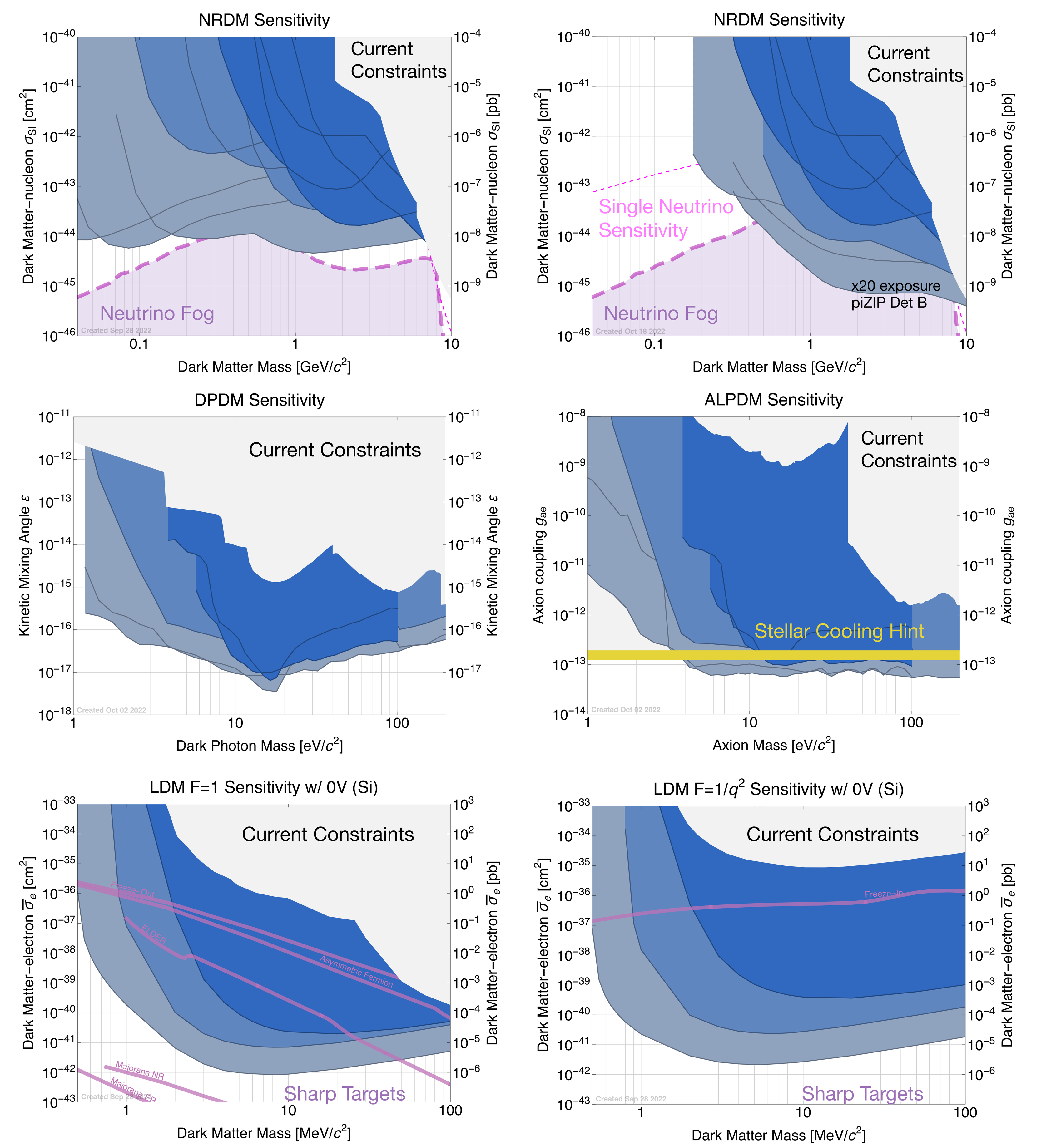
Figure 1 (left): Si 0V 1cm^3 detector backgrounds. Magenta: NRDM signals for DM particle mass of 0.16, 0.5, and 1.6 GeV/c^2.

Figure 2 (right): Ge HV SNOLAB-sized detector backgrounds. Magenta: LDM (light mediator, F(1) = 1) signals for DM particle mass of 1, 3, 10, and 30 MeV/c^2.

Detector Size	Detector Type	Dimensions	Mass [g] Ge	Mass [g] Si	Number of Detectors (for each material)	Raw Exposure [kgyr] Ge	Raw Exposure [kgyr] Si
SNOLAB	HV/iZIP piZIP	⌀10cm × 3.3cm	1400	610	12 6	54 27	23 12
10cm^3	HV iZIP piZIP 0V	3 × 3 × 1.2cm^3	57	25	36 24 12 144	6.6 4.4 2.2 26	2.9 1.9 1.0 12
1cm^3	0V	1 × 1 × 0.4cm^3	21	9.3	144	1.0	0.42

Table 2: Detector sizes and raw exposures (4 years of data taking and 80% duty cycle).

Forecasting Results



Figures 3-8: Summary of sensitivity for different upgrade scenarios: expected reach of SuperCDMS SNOLAB (dark blue), scenarios that could be implemented with in-hand detector performance and background improvements (light blue), scenarios that exploit the full possible reach with current cryostat and facility (grey-blue). For NRDM, the best choice of detector design depends on the DM mass range; (top left) best low-mass sensitivity (0V detectors) and (top right) best sensitivity reachable in the 0.5-5 GeV/c2 mass range (iZIP and piZIP detectors).

Conclusion

With upgrades to the SuperCDMS detector technology we can probe new parameter space for a number of dark matter models including NRDM, DP DM, ALP DM, and LDM. Stronger reach is achieved via improved detector performance without necessitating expensive facility background upgrades.

Discovery, accelerated