SuperCDMS SNOLAB: Goals, Design, and Status

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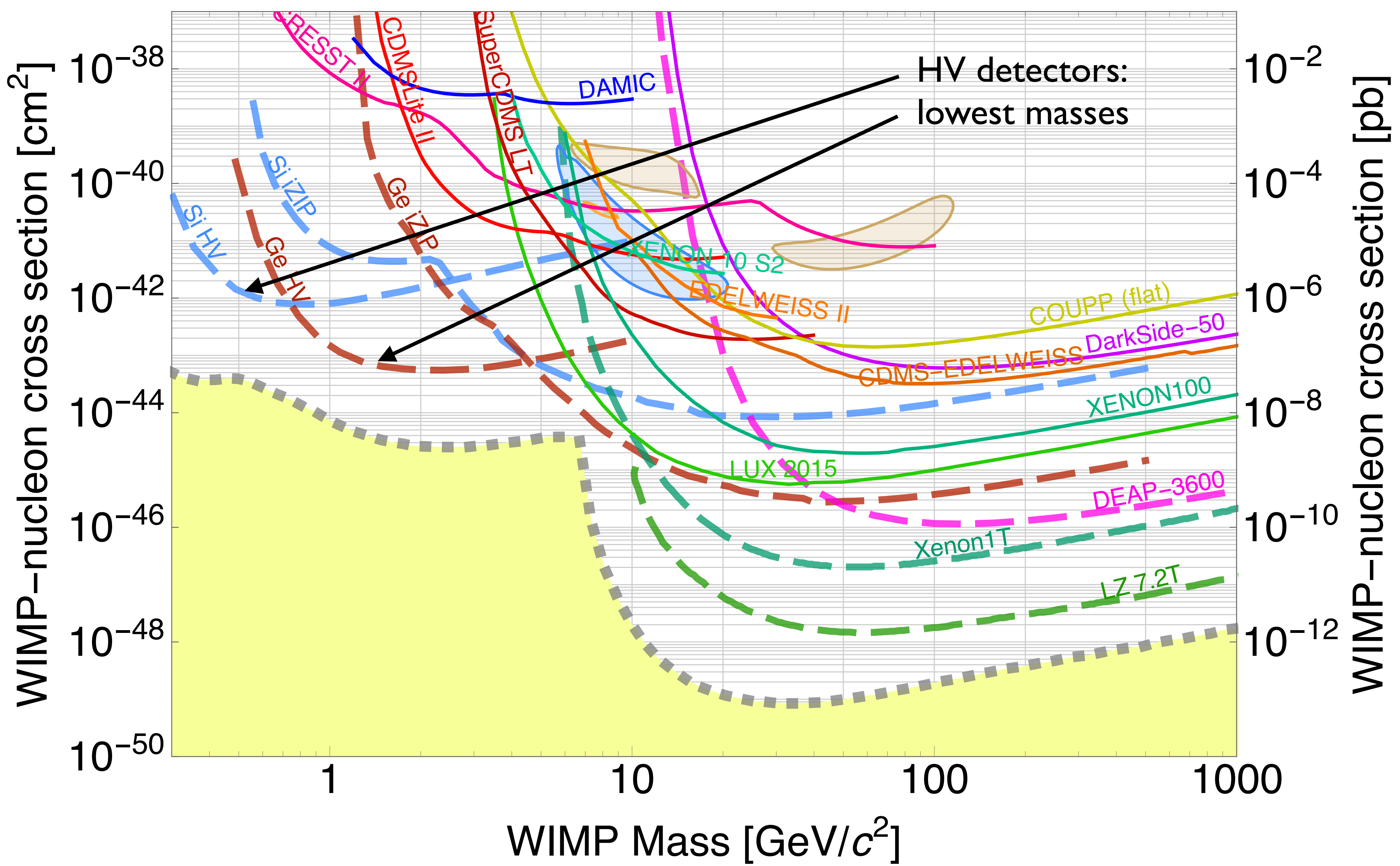
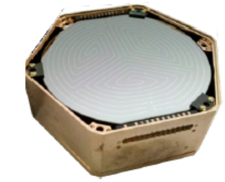
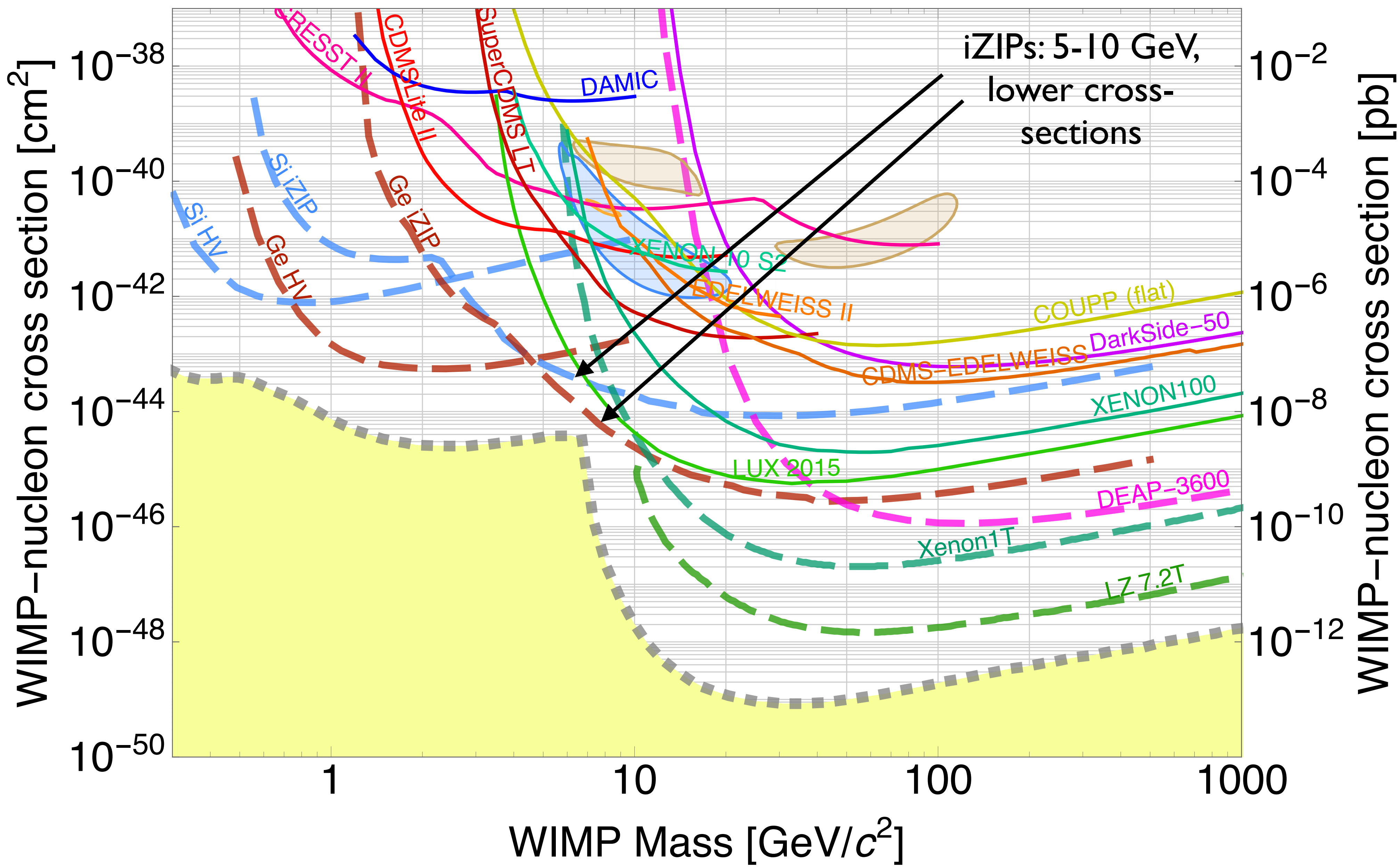
SuperCDMS SNOLAB Science Goals

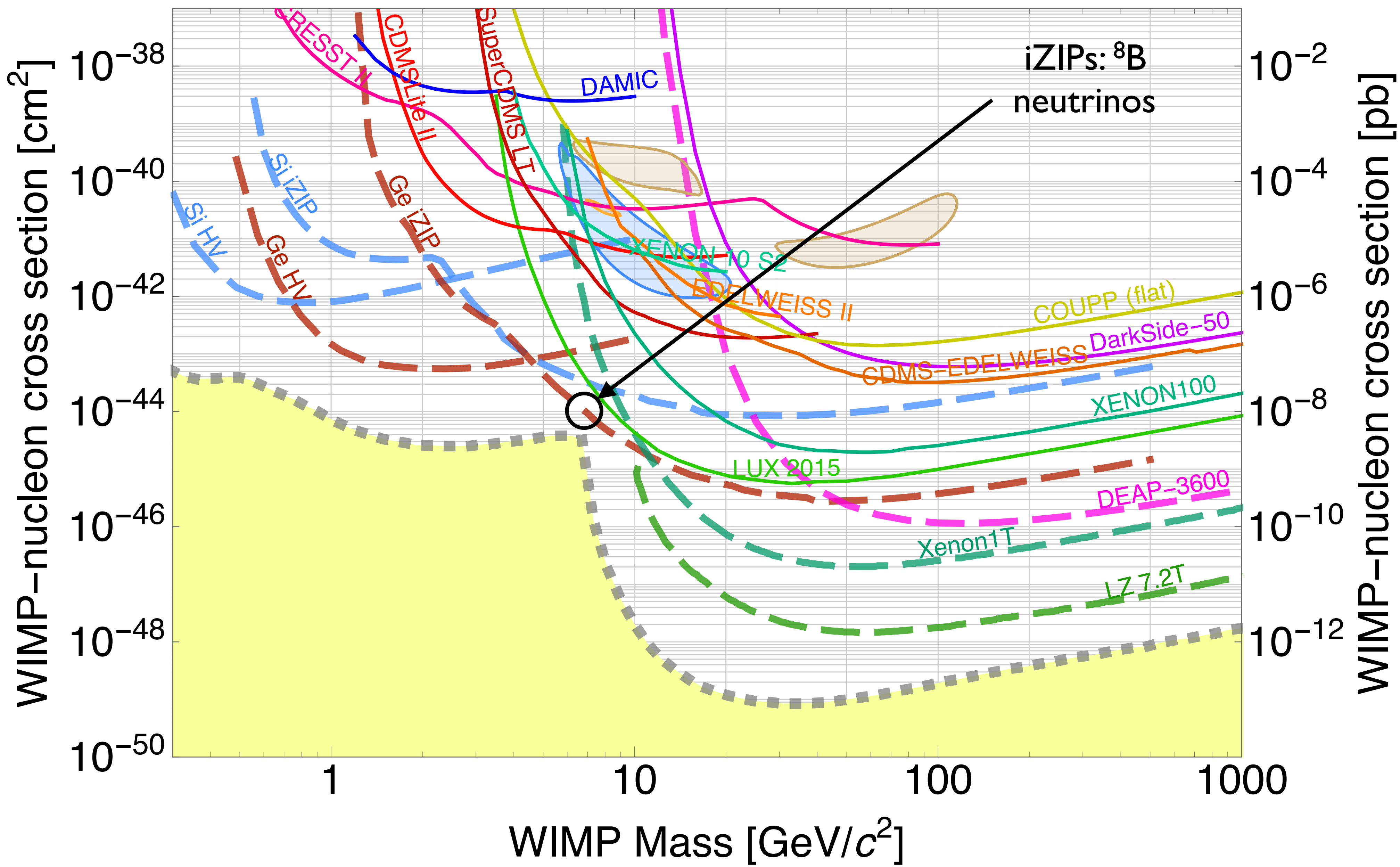


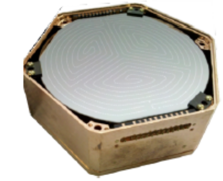
SuperCDMS SNOLAB Science Goals





SuperCDMS SNOLAB Science Goals





Outline

Detector technologies: HV and iZIPs

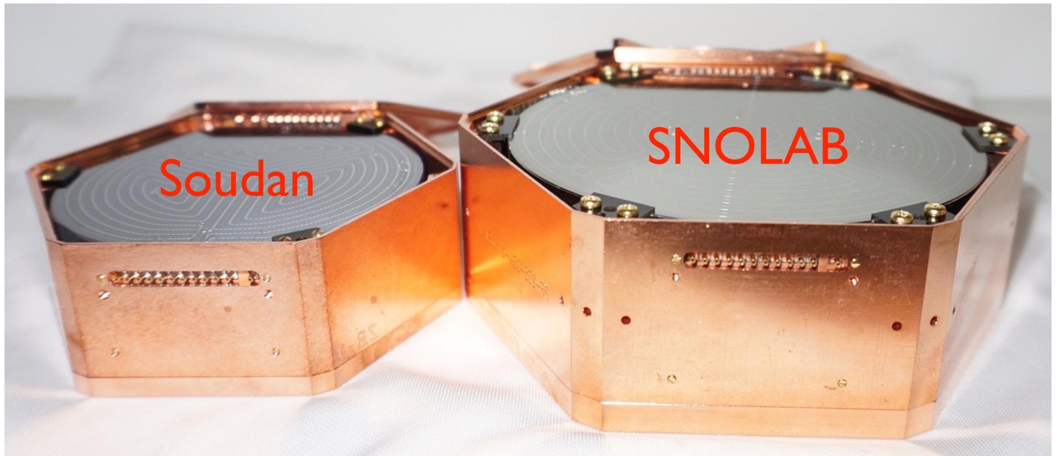
Background sources, expectations, and design

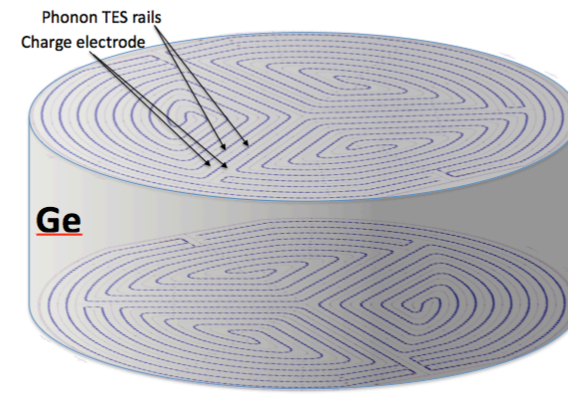
Sensitivity reach including complementary science

Schedule

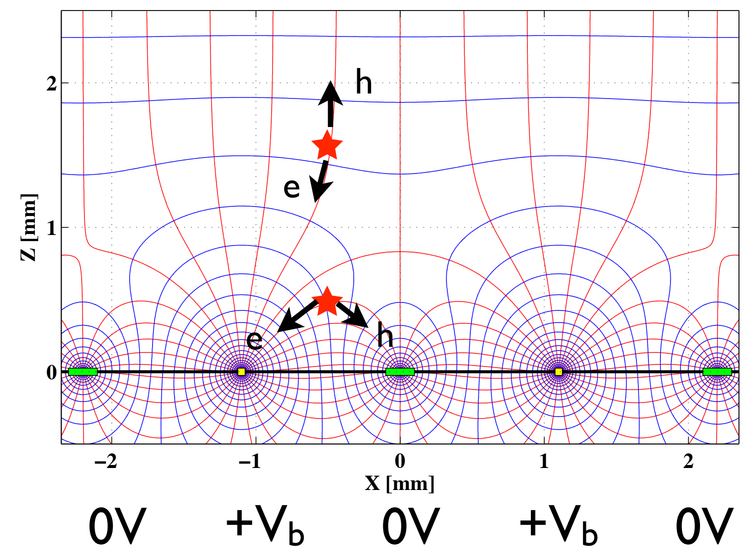
Beyond SuperCDMS SNOLAB

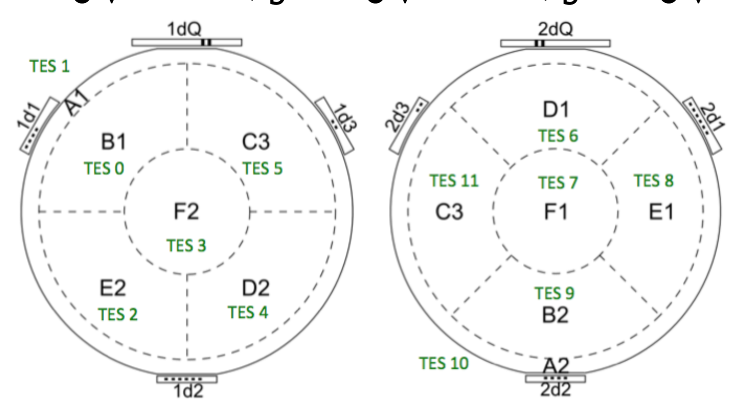
SuperCDMS SNOLAB iZIP Detectors





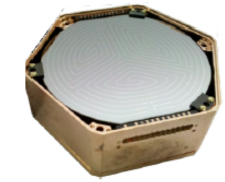
iZIP phonon sensor unit cell (thin to enable interleaving with ionization electrodes)





iZIP: interdigitated Z-sensitive Ionization and Phonon-mediated detectors

- 100 mm x 33 mm versions of Soudan detectors
- 8 → 12 phonon sensors per detector
- σ = 100 eV_t → 50 eV_t phonons via lower T_c
- σ = 300 eV_{ee} → 100 eV_{ee} ionization via improved readout using low-noise HEMTs

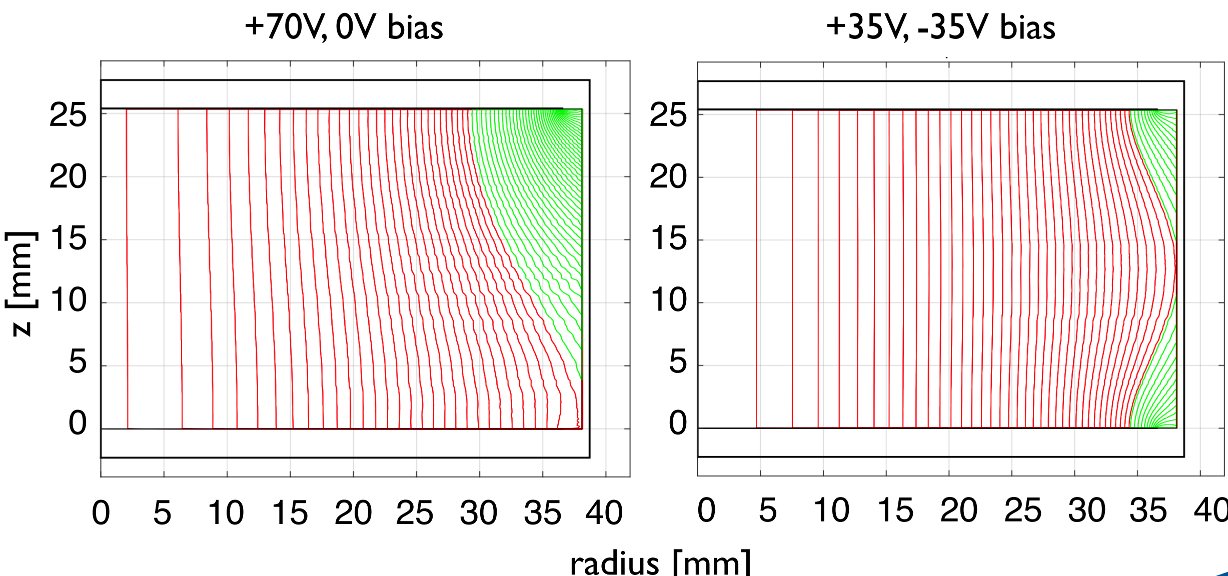


SuperCDMS SNOLAB HV Detectors

(aka CDMSlite)

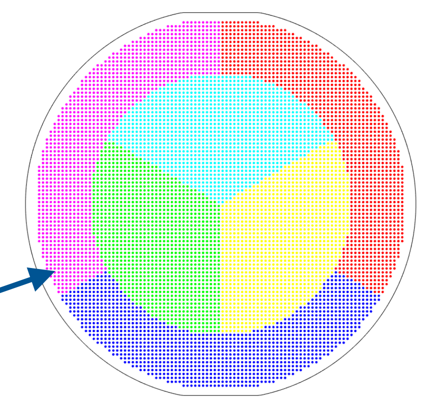
- 100 mm x 33 mm crystals, operated at 100V (goal); 69V demonstrated at Soudan
- Ionization sensed via Luke-Neganov phonon production; no direct ionization readout
- Optimize phonon sensor for energy resolution, fiducial volume: σ = 10 eV_t goal

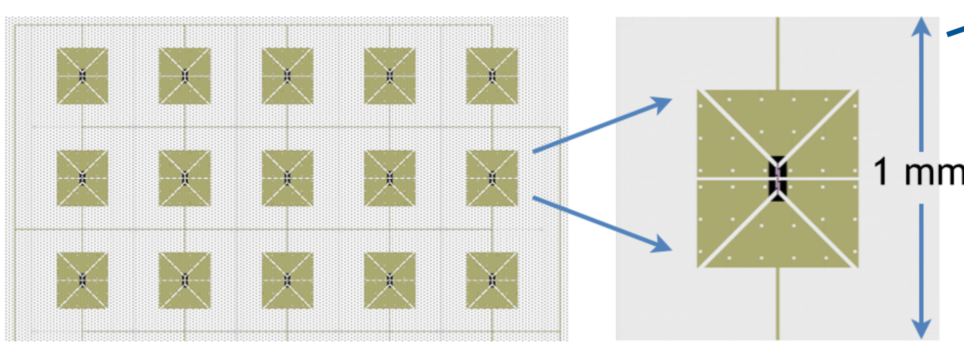
Soudan: asymmetric vs. symmetric bias



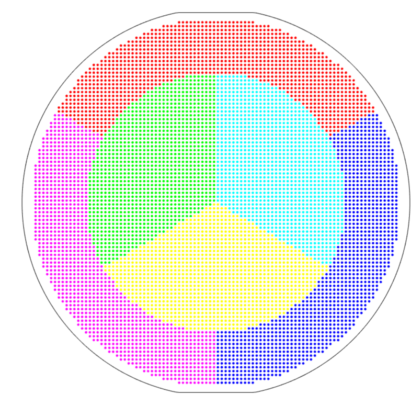
Symmetric HV bias at +/- 50V to maximize fiducial volume

maximize phonon radial position reconstruction information





Uniform coverage phonon sensors to maximize energy collection



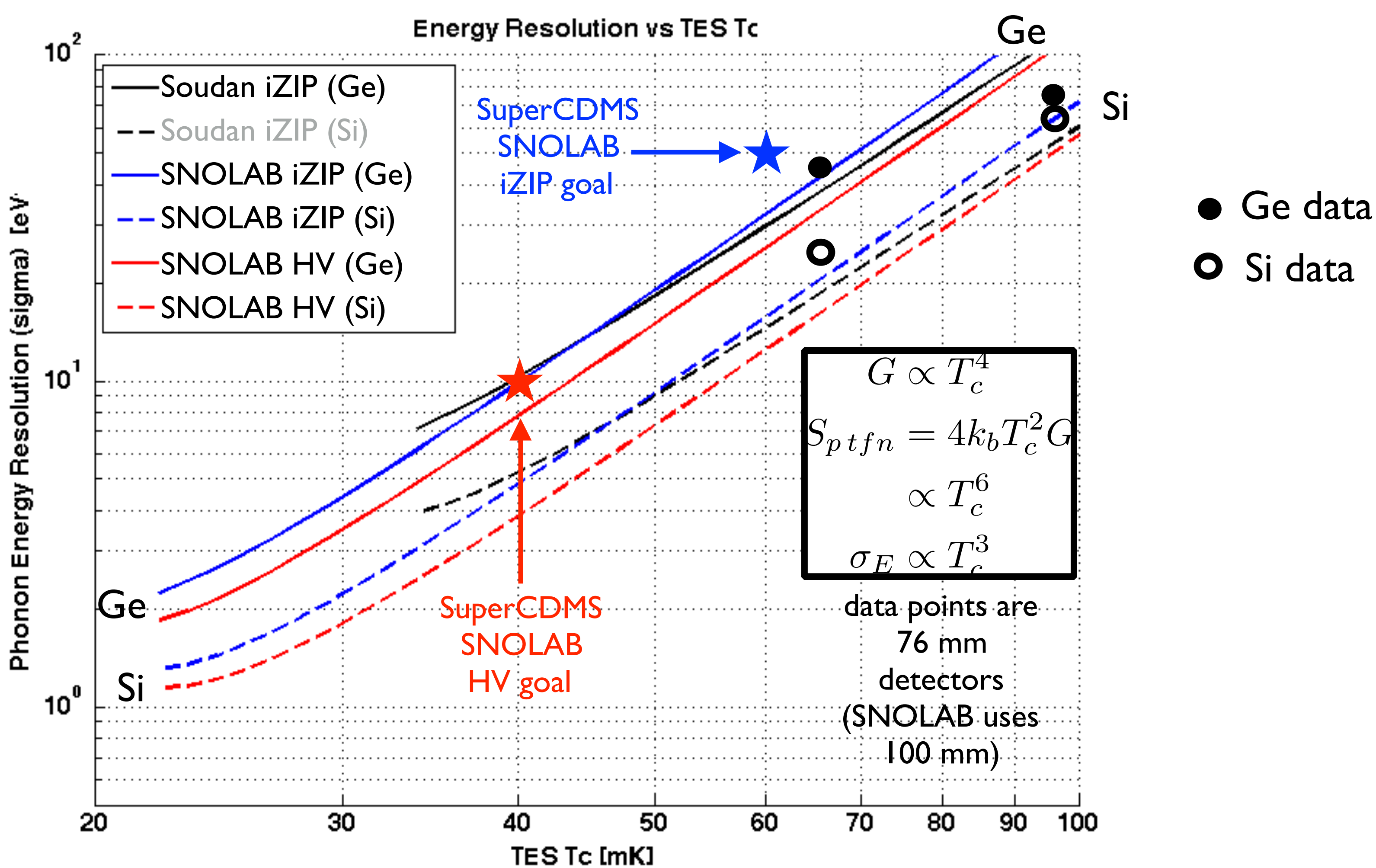
Phonon Resolution is Critical!

Phonon resolution strong function of T_c with demonstrated scaling

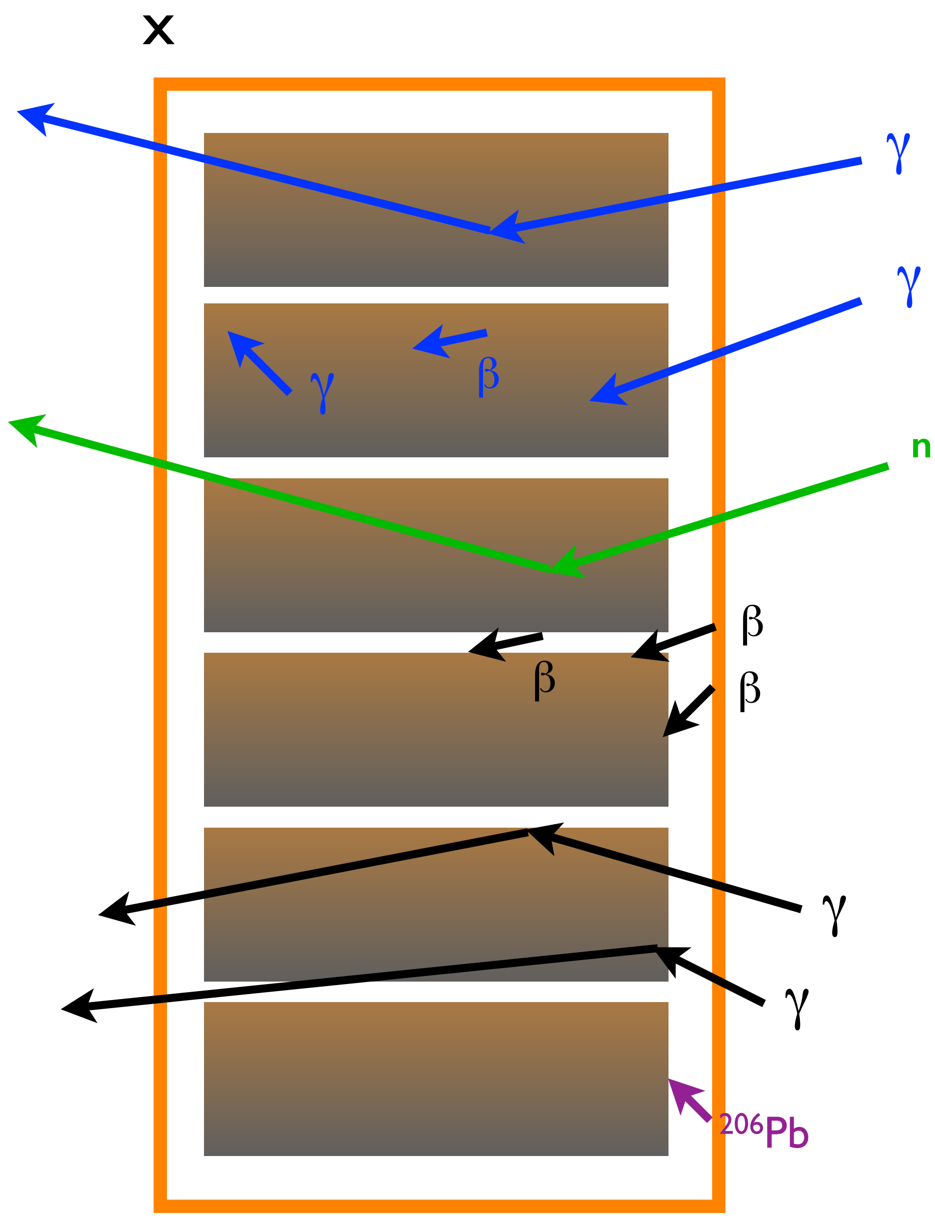
Resolution goals drive T_c goals:

HV: σ = 10 eV_t; T_c ~ 40 mK

iZIP: σ = 50 eV_t; T_c ~ 60 mK



Backgrounds in SuperCDMS SNOLAB



Bulk Electron Recoils (γ or β)

- primarily Compton scattering of broad spectrum up to 2.5 MeV
- small amount of photoelectric effect from low energy gammas
- electron capture photons from decays of cosmogenically activated isotopes
- betas from internal decays (^{3}H, ^{32}Si)

Neutrons (n)

- radiogenic: arising from fission and (α,n) reactions in surrounding materials (cryostat, shield, cavern)
- cosmogenic: created by spallation of nuclei in surrounding materials by high-energy cosmic ray muons

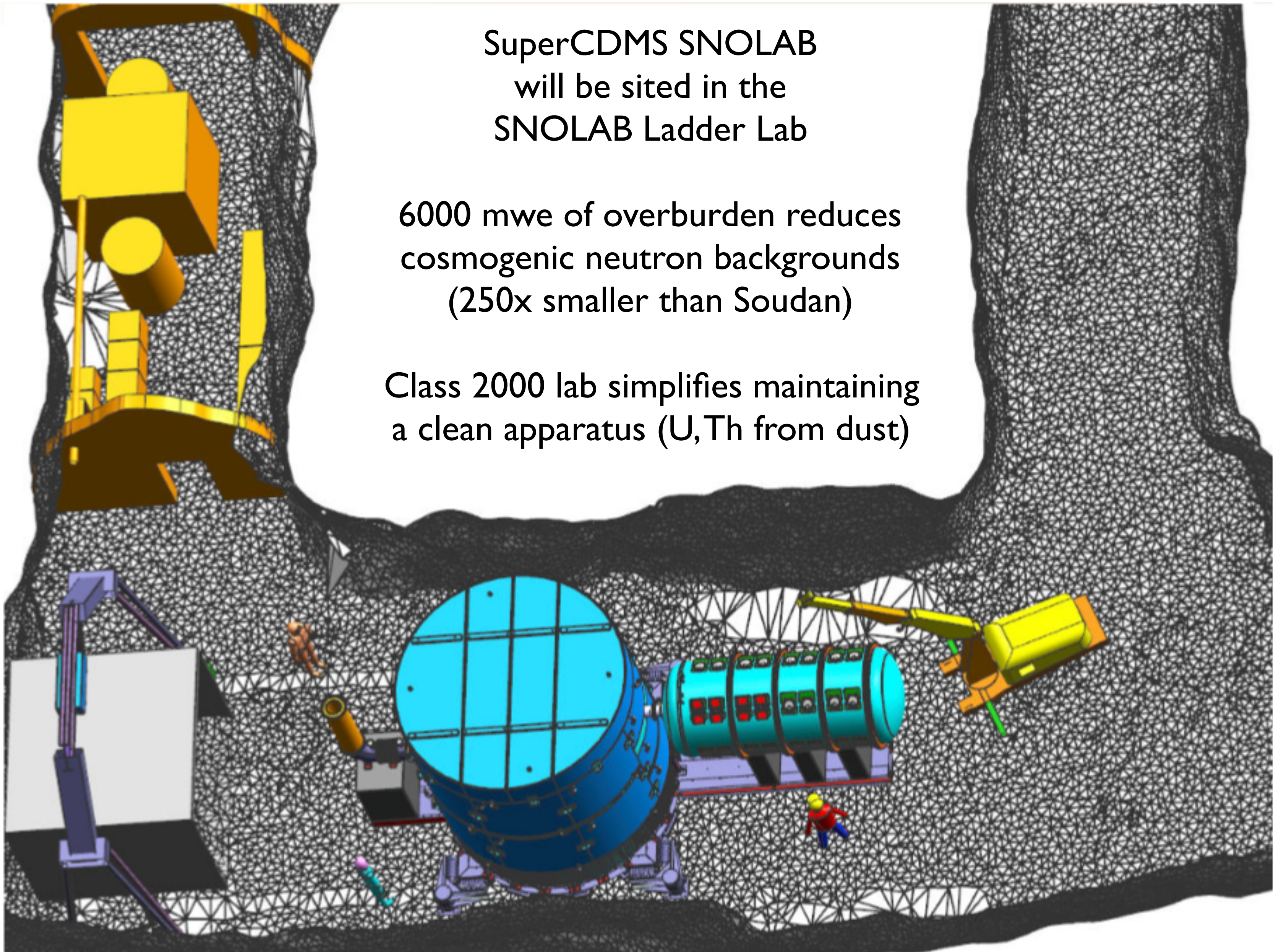
ERs with reduced ionization collection (β or γ)

- radiogenic: electrons/photons emitted in low-energy beta decays of ^{210}Pb or other surface contaminants
- photon-induced: interactions of continuum background photons or photo-ejected electrons
- both can interact in thin surface dead layer in z
- both can interact at large radius in region of nonuniform field

Lead nuclei (^{206}Pb)

- From decay of ^{210}Po daughter of ^{210}Pb on detector or housing surfaces; low ionization yield

Low Cosmogenic Activity, Clean Site

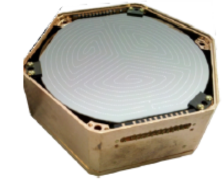


SuperCDMS SNOLAB
will be sited in the
SNOLAB Ladder Lab

6000 mwe of overburden reduces
cosmogenic neutron backgrounds
(250x smaller than Soudan)

Class 2000 lab simplifies maintaining
a clean apparatus (U,Th from dust)

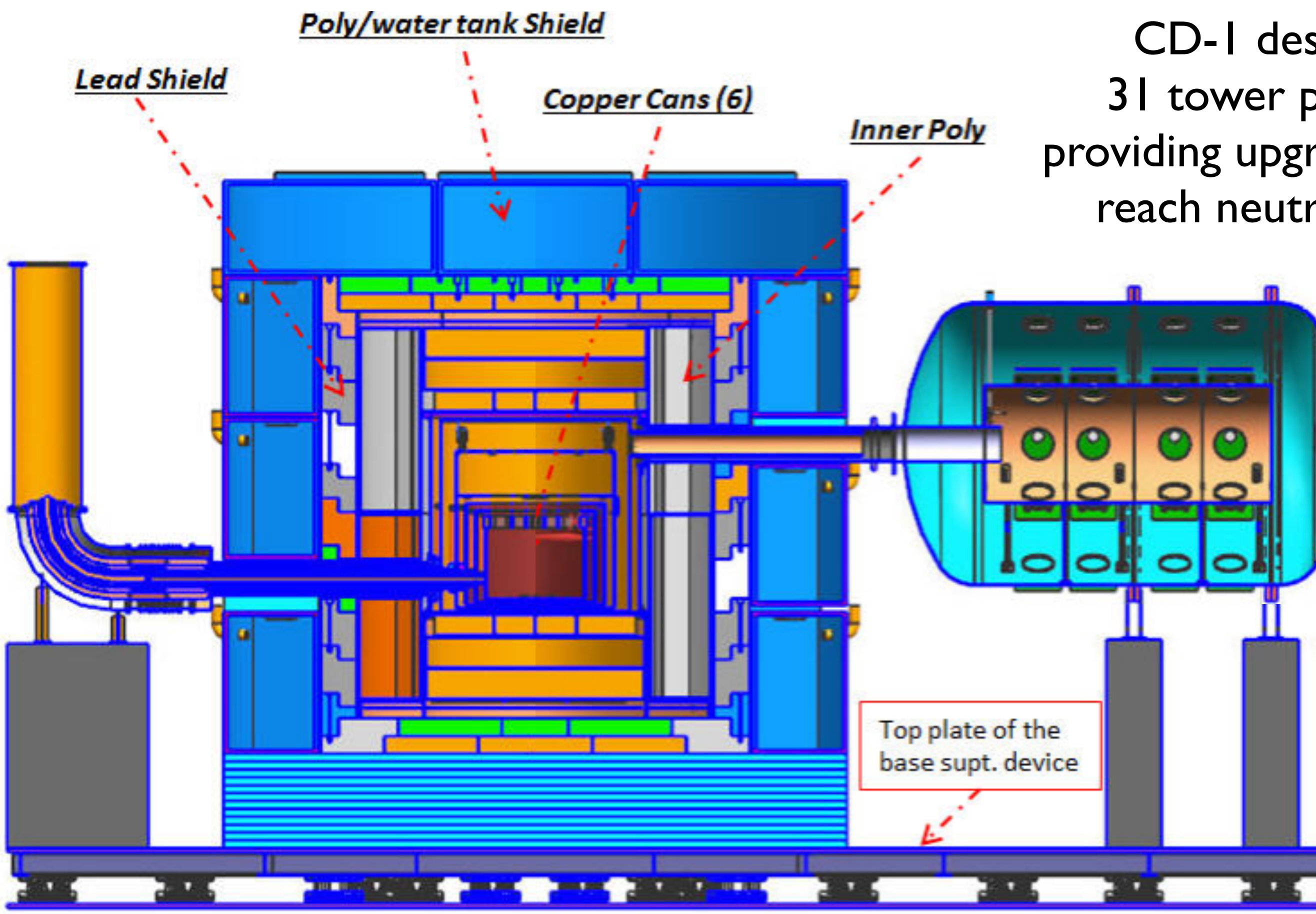
Radiopure Apparatus



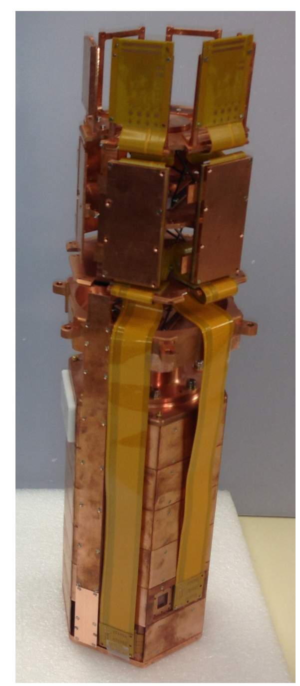
Shield similar to Soudan design (poly/Pb/poly or water), no veto

Cryostat evolved from Soudan design, same basic components

- Like Soudan: dilution refrigerator and other cooling sources are remote, electrical feedthrough tank (though modernized, simpler interfaces)
- Much cleaner cryostat: 200x lower U/Th than Soudan via better materials, cleanliness



CD-1 design has 31 tower positions, providing upgrade path to reach neutrino floor



Detector Payload:

- 3 Ge iZIP towers (50 kg)
- 1 Si iZIP tower (4 kg)
- 1 HV tower:
  - 4 Ge (5.6 kg)
  - 2 Si (1.4 kg)

Background Expectations

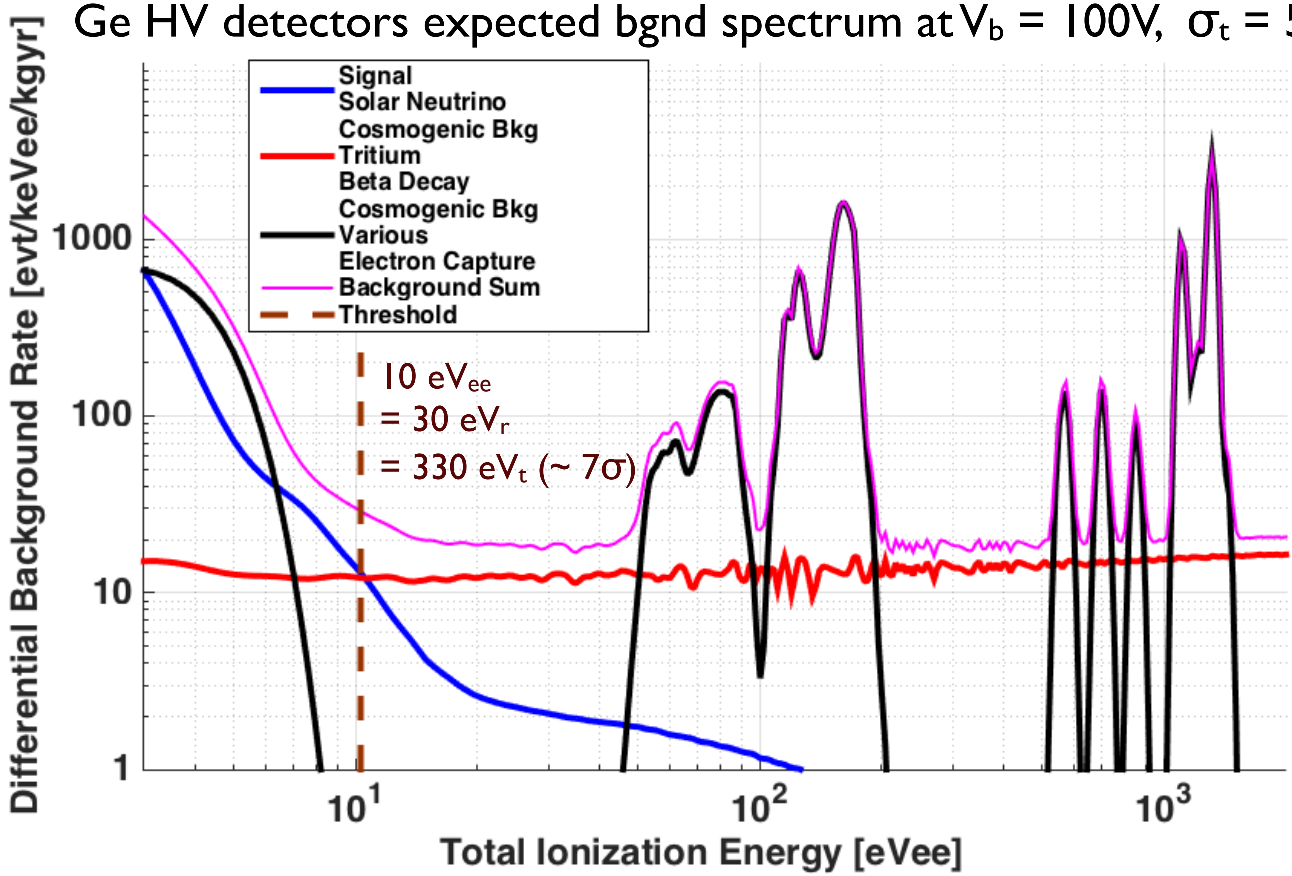
ER background levels 200x lower than Soudan via more exhaustive materials screening and more demanding (though still moderate) req'ts

reduced surface bgnds on Cu via radon tracking (detectors ok already!)

HV detectors require extreme care with cosmogenics

^{3}H by cosmo. spallation of Ge and Si, ^{32}Si from atmosph. Ar (contam. path not clear)

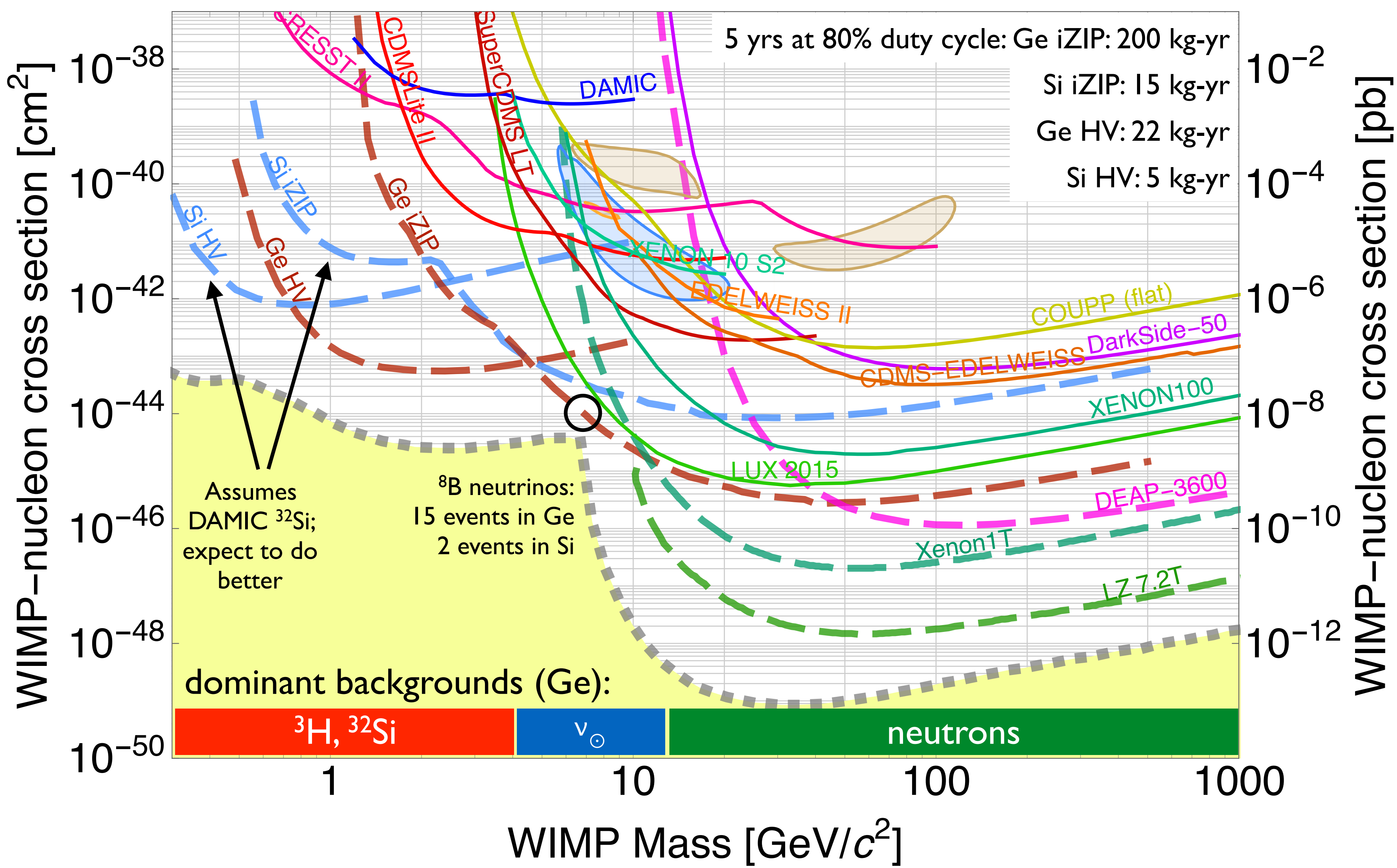
Ge HV detectors expected bgnd spectrum at V_b = 100V, σ_t = 50 eV



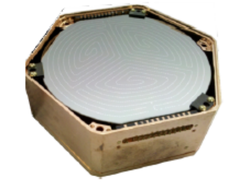
After fiducialization in z and radius, cosmogenics given for low-exposure HV detectors assuming:

	days
detectors (^{3}H)	120
housings/tower (^{60}Co)	90
cryostat (^{60}Co)	180

Expected Sensitivity, Dominant Backgrounds



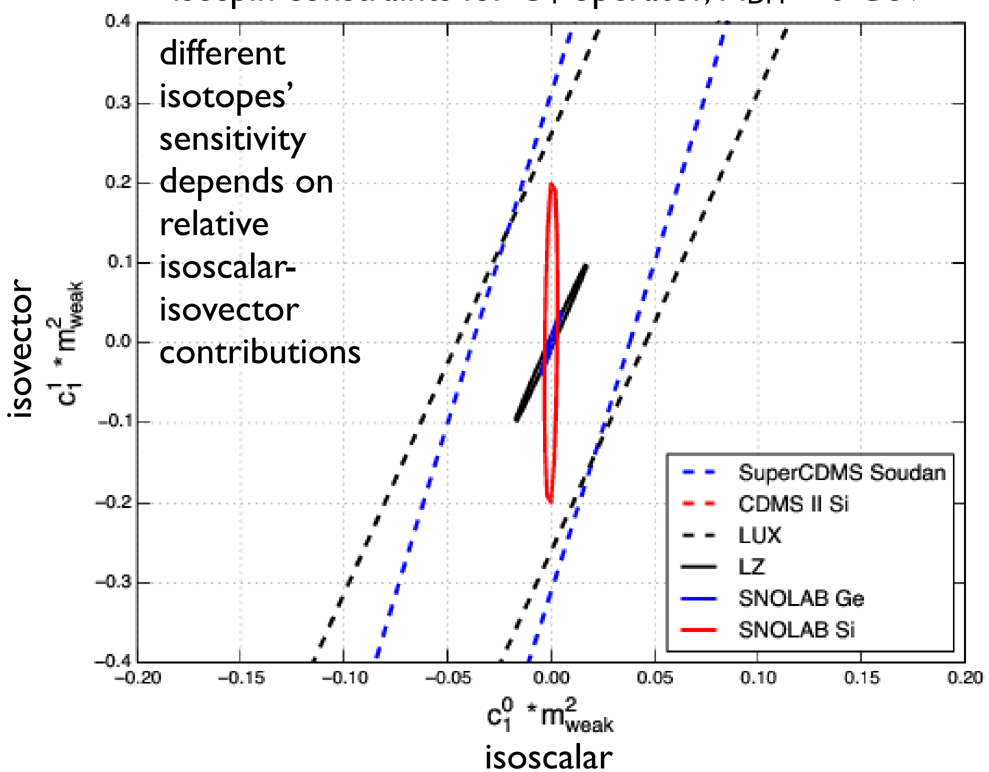
Complementary Science



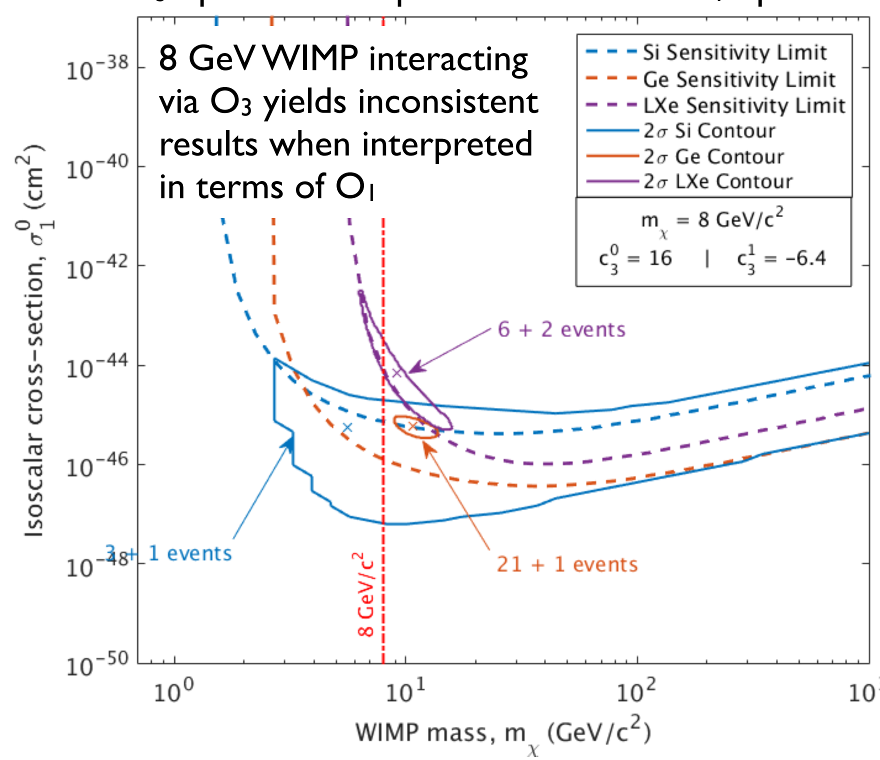
Non-standard WIMP interactions

- If isospin symmetry violated, Si very complementary to Ge, Xe
- Effective Field Theory: Wide range of nuclear interaction operators motivate multiple targets to ensure exclusions are comprehensive (left), results consistent (right)

isospin constraints for O_1 operator, M_{DM} = 6 GeV



O_3 operator interpreted in terms of O_1 operator

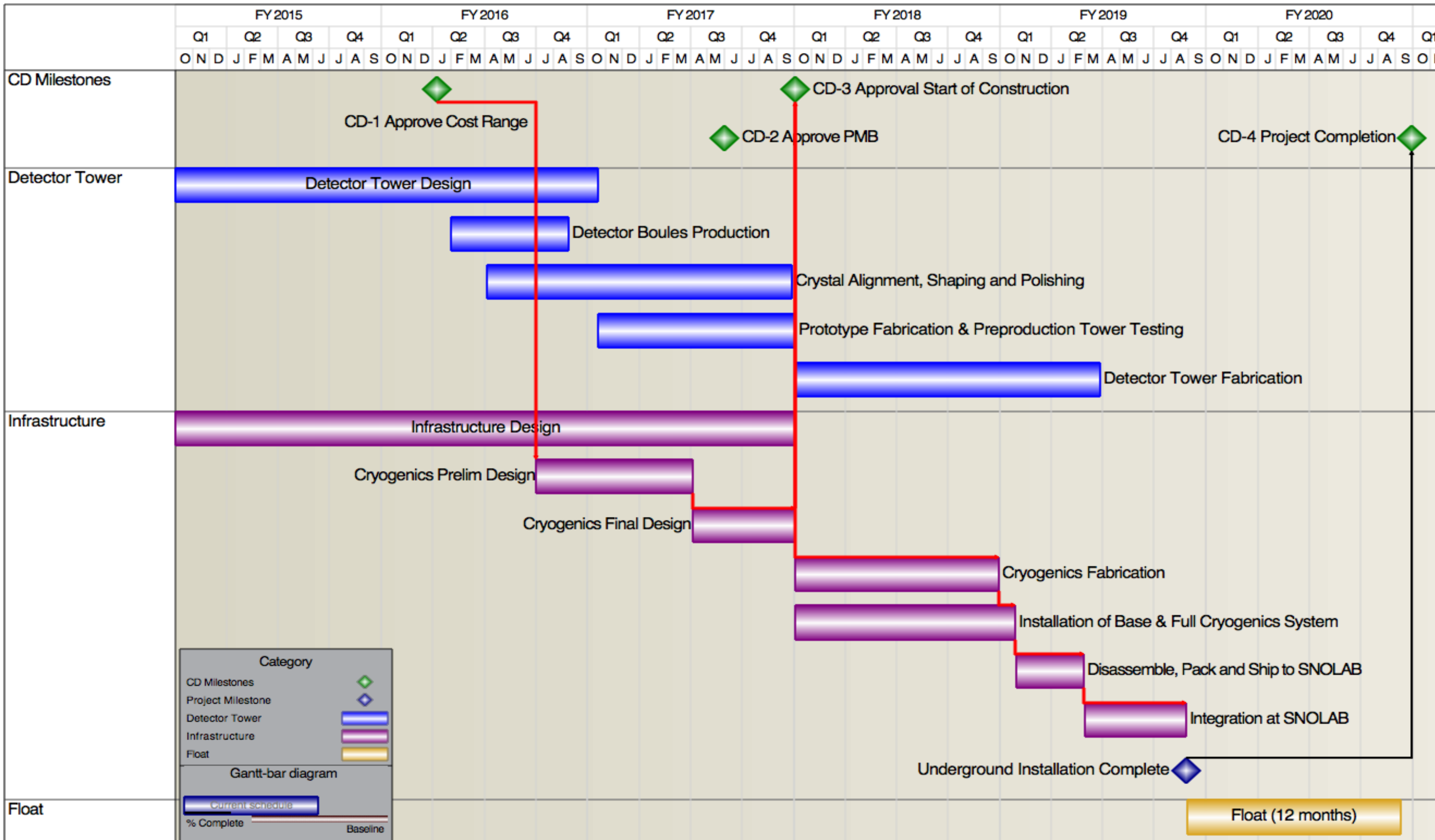


Also searches for solar and galactic axions, lightly ionizing particles

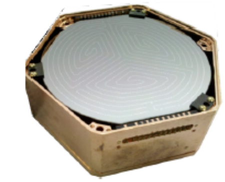
Schedule

CD-1 passed!

CD-2/3 in 2017, construction 2018-2020, data taking begins in 2020.

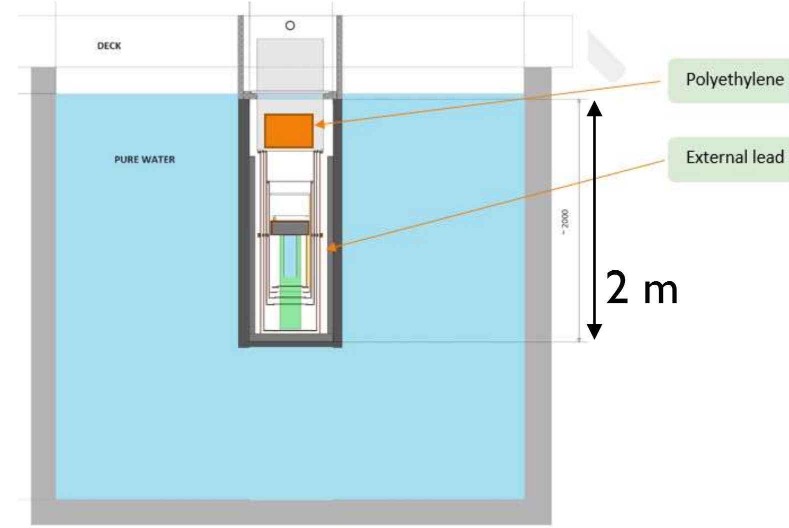


Beyond SuperCDMS SNOLAB



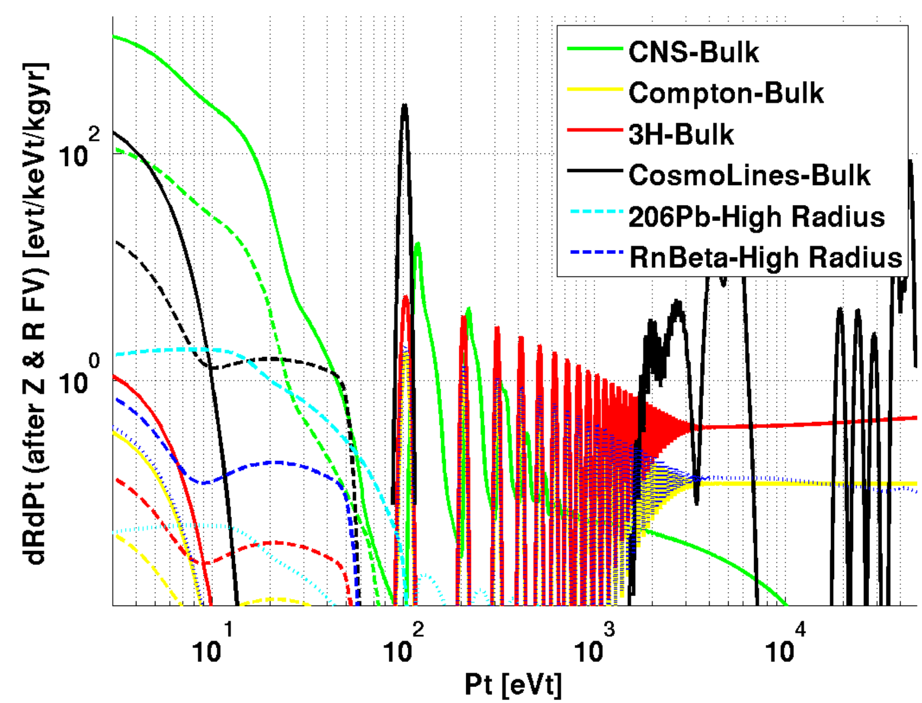
Coordination with EURECA

- SNOLAB cryostat can hold many more towers
- Active work to adapt SuperCDMS tower design and readout to EURECA detectors
  - Primarily EDELWEISS, but CRESST also exploring
- Queen's developing low background underground test facility at SNOLAB (CUTE) to demonstrate operation of EURECA towers with SuperCDMS infrastructure



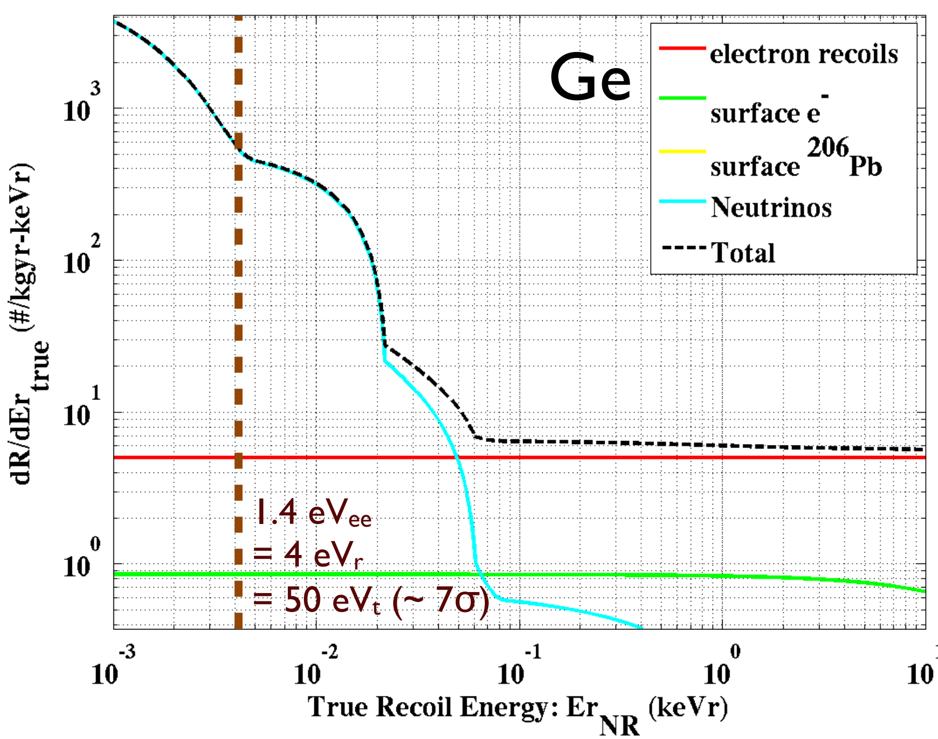
R&D to reach the solar ν floor

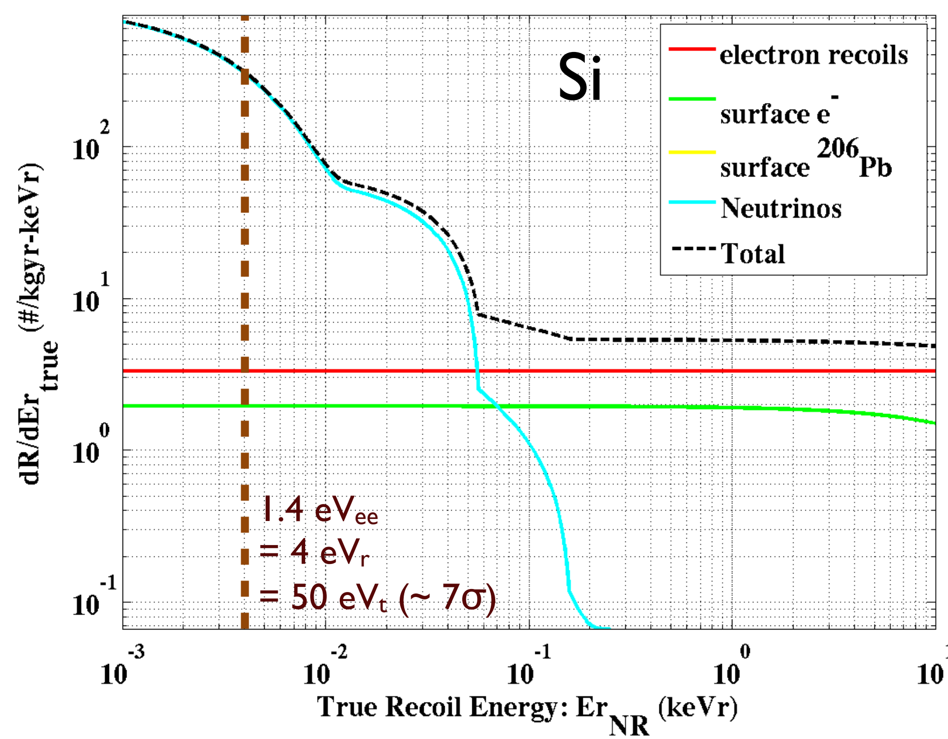
- Improving phonon resolution to $\sigma = 3\mathrm{eV}_t$ in HV mode enables resolution of ER spectrum into peaks for 1, 2, etc. e-h pairs
- NRs would appear in the space between (different phonon production per e-h pair)
- *Recovery of NR rejection in HV mode!*



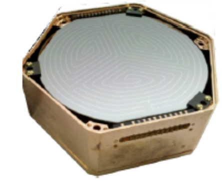
Beyond SuperCDMS SNOLAB

- For resolution below σ = 7 eV_t and for trigger thresholds below 50 eV_t, solar neutrinos become the dominant background
- With an expanded payload of HV detectors (Ge 150 kg-yr; Si 250 kg-yr), many 100s of solar ν events
- Prospects for searching below the ν floor by using 2 targets to calibrate solar ν spectrum





SuperCDMS Collaboration



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* Associate members