Backgrounds in the planned SuperCDMS SNOLAB dark matter experiment

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SuperCDMS SNOLAB sensitivity reach

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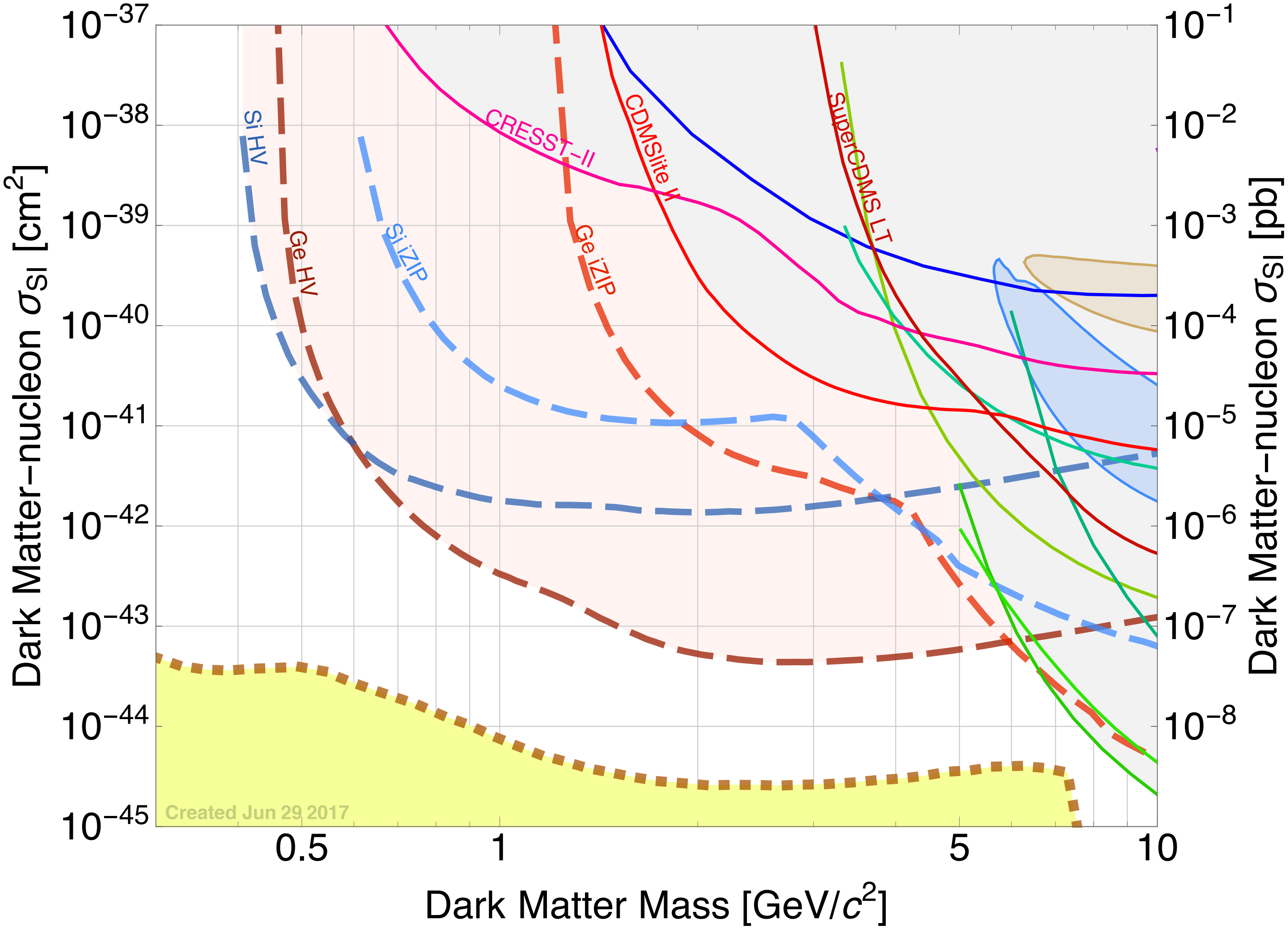
Direct detection dark matter search in the low-mass WIMP regime
→ 0.3 – 10 GeV/c^2 (See "SuperCDMS SNOLAB – Status and Plans" by W. Rau (Tues. 16:00))



SuperCDMS

Anticipated background spectra (Ge HV)

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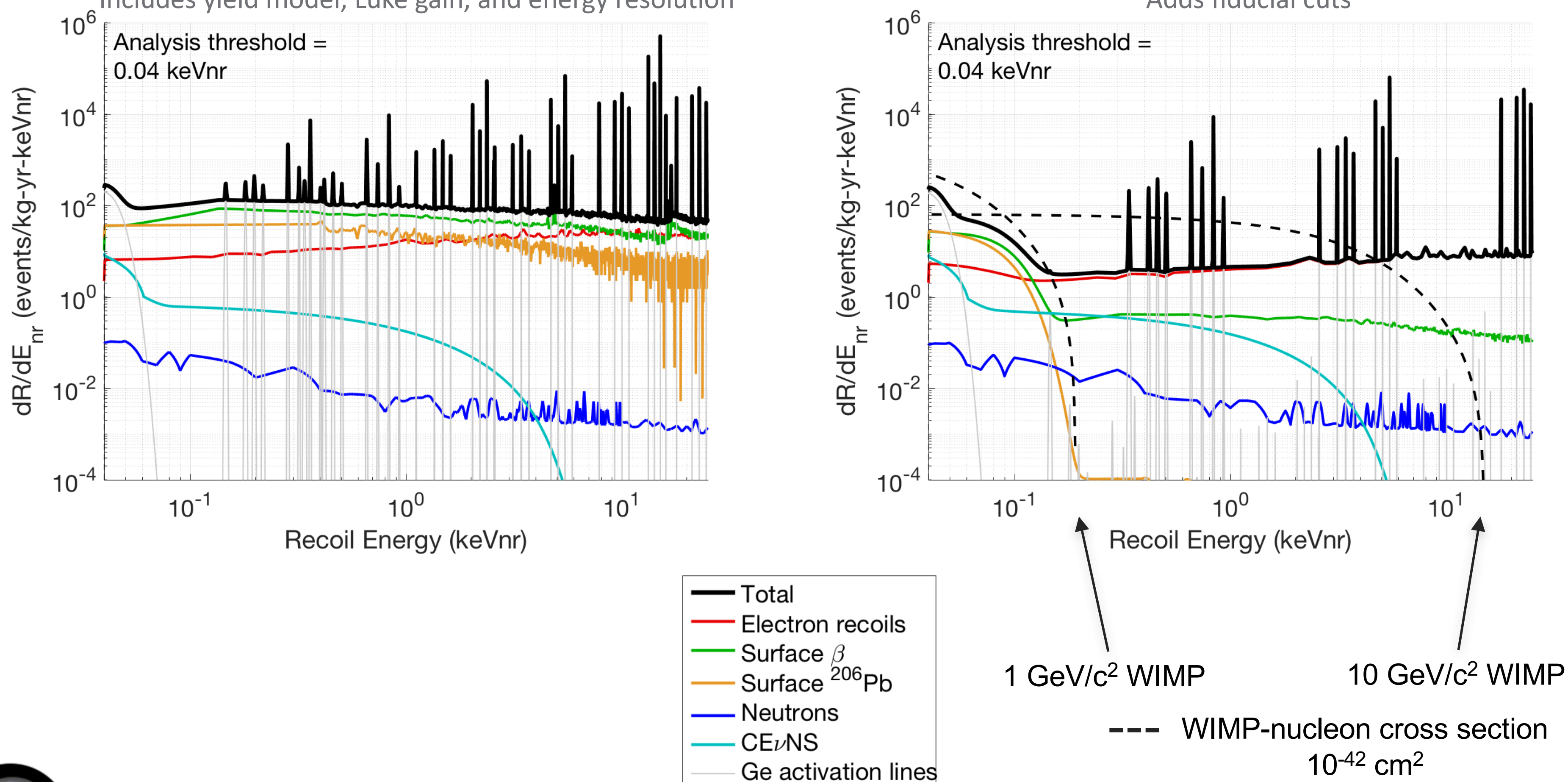
HV detectors – High-voltage assisted phonon measurement of ionization

Raw singles event rates

Includes yield model, Luke gain, and energy resolution

Event rates after response & cuts

Adds fiducial cuts



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Anticipated background spectra (Ge iZIP)

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iZIP detectors – Interleaved *z*-dependent ionization and phonon sensors

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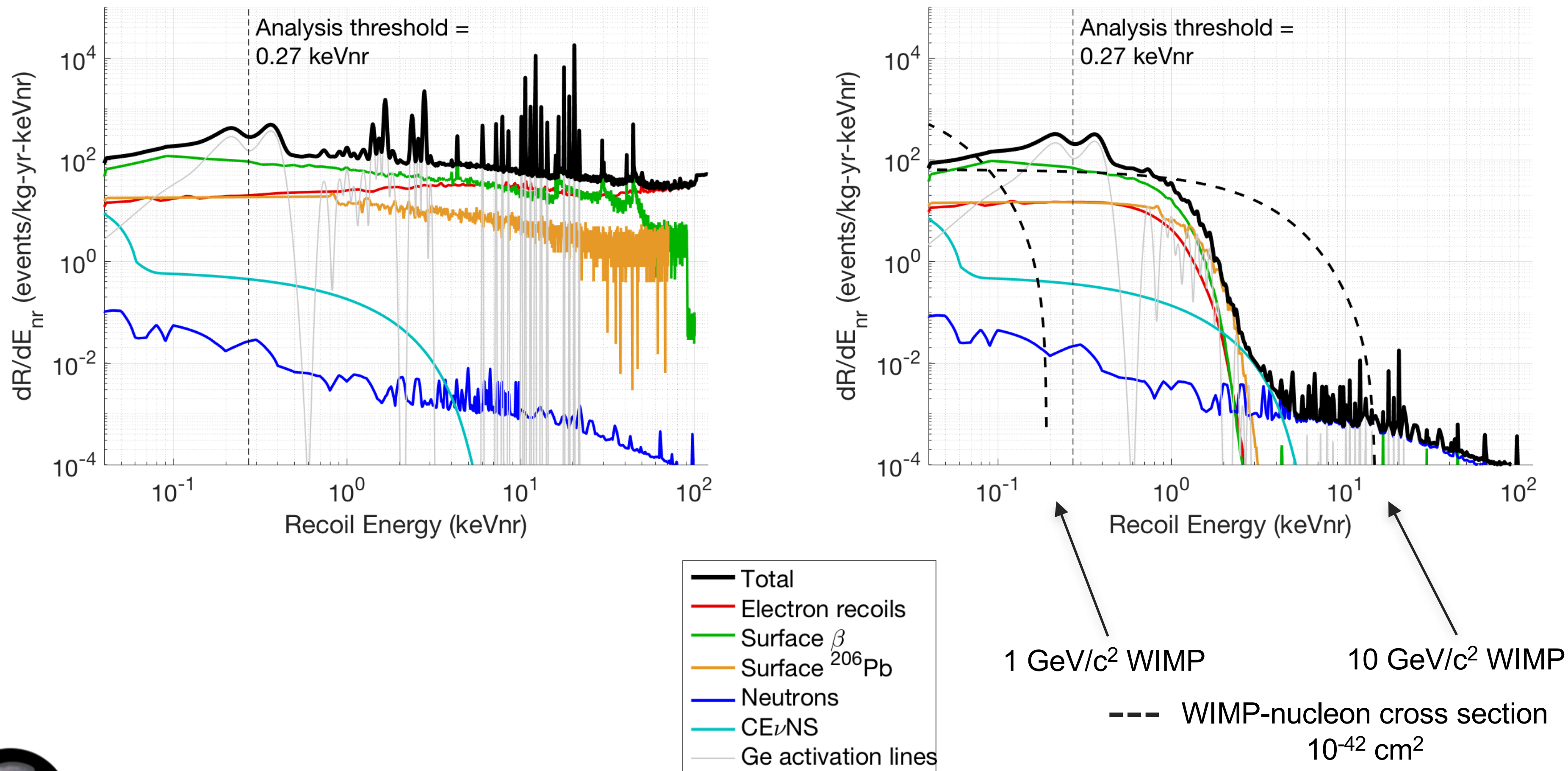

Anticipated dominant backgrounds

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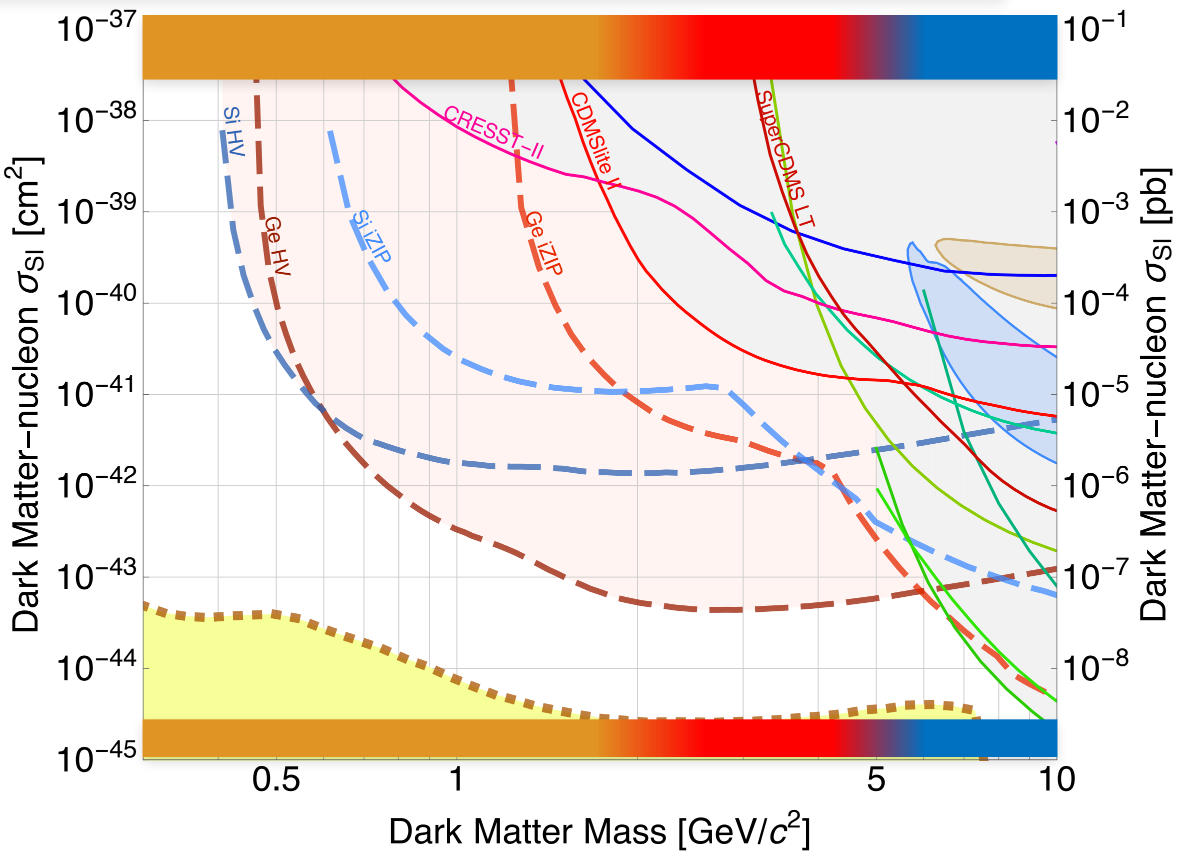
Evaluation of background spectra on prior slides (and in backup) reveals the following anticipated primary background sources…

- In lowest WIMP mass range (~1 GeV/c^2):
  - Line-of-sight surface emissions on HV detectors:
    - ^{210}Pb daughters on surfaces → Low-energy surface-event fiducial-cut leakage
- In middle WIMP mass range (~2 to ~5 GeV/c^2):
  - Electron recoil backgrounds in HV detectors:
    - Cosmogenic tritium (^{3}H) → β-decay electron recoil
    - Naturally occurring ^{32}Si → β-decay electron recoil
    - U & Th daughters in materials → γ-ray Compton scattering electron recoils
- In higher WIMP mass range (~5 to ~10 GeV/c^2):
  - Nuclear recoil backgrounds are identifiable with iZIPs:
    - Solar neutrinos → Coherent neutrino-nucleus scattering
    - Muon produced neutrons → Neutron nuclear recoil background
  - *These backgrounds not discussed in detail in this presentation*

Backgrounds vs. WIMP mass

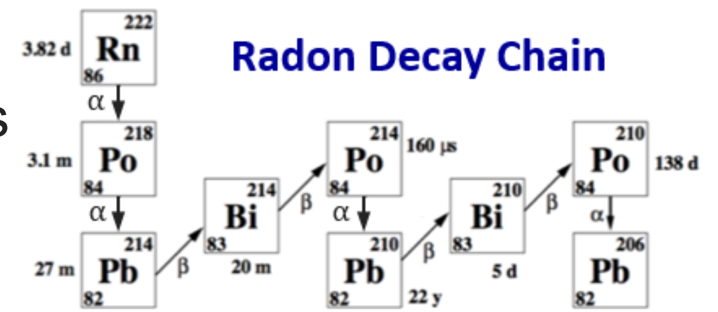
Search for dark matter induced nuclear recoils (NR) limited by:

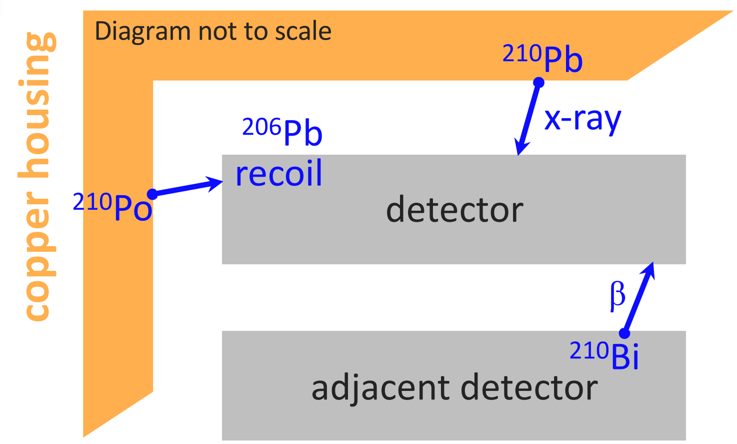
- Surface emission background sources
- Electron recoil (ER) background sources
- iZIP detectors discriminate ER vs. NR backgrounds



Surface emission background sources

- Emission of β-ray, *x*-ray, or nuclei from surfaces *with line-of-sight to detectors* can produce background events

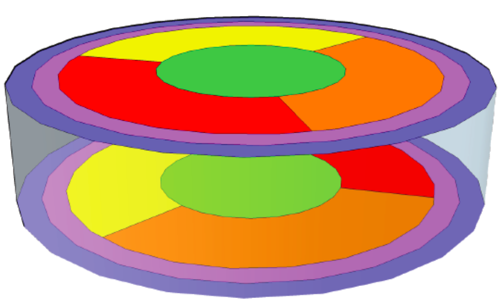




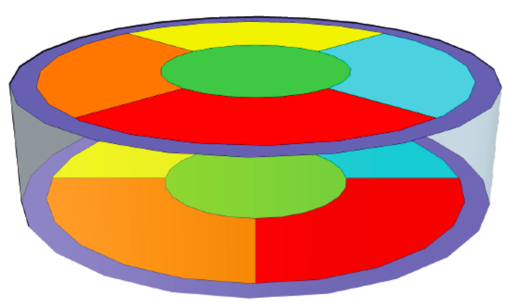
Non-penetrating radiation from ^{210}Pb decay chain

- Sensor layout enables fiducialization away from surfaces to reject line-of-sight events

HV detector sensor layout



iZIP detector sensor layout



- High-radius event rejection relies on discerning partition of energy between inner & outer sensors… (model described on next slide)

Model for rejecting surface backgrounds

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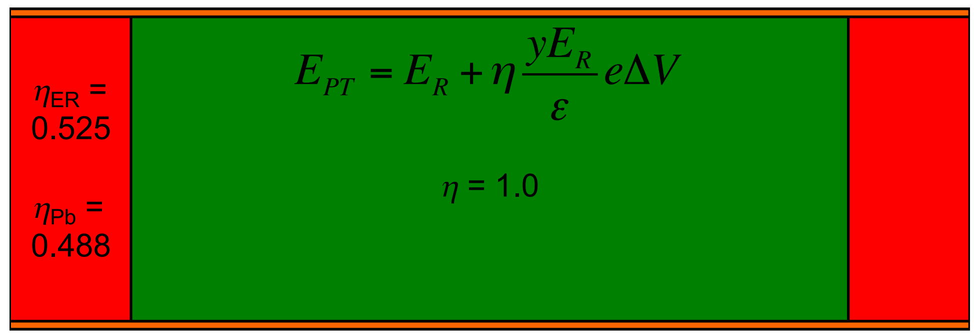
- Fiducialization relies on sufficient energy above signal noise levels, position reconstruction capability is suppressed for small recoil energies

	Volume Fraction		
	ER		NR
Volume Type	Ge	Si	Ge & Si
Bulk Events	0.50	0.675	0.85
Events near the top/bottom faces	0.056	0.075	0.05
Events near the cylindrical sidewalls	0.444	0.25	0.10

	η	
Event Location and Type	Ge	Si
Bulk Events	1.0	1.0
Events near the top/bottom faces	1.0	1.0
Events near the cylindrical sidewalls	0.75	0.90
ERs on the top/bottom faces	0.70	0.65
ERs on the cylindrical sidewalls	0.525	0.585
^{206}Pb recoils on the top/bottom faces	0.65	0.65
^{206}Pb recoils on the cylindrical sidewalls	0.488	0.585

Simple fiducialization model



η_{ER} = 0.70 $\quad$ η_{Pb} = 0.65

E_{PT} = Total phonon energy

E_R = Recoil energy

η = Charge collection fraction

y = yield (quenching)

ε_{Ge} = 2.96 eV ; ε_{Si} = 3.82 eV

e = Charge of electron

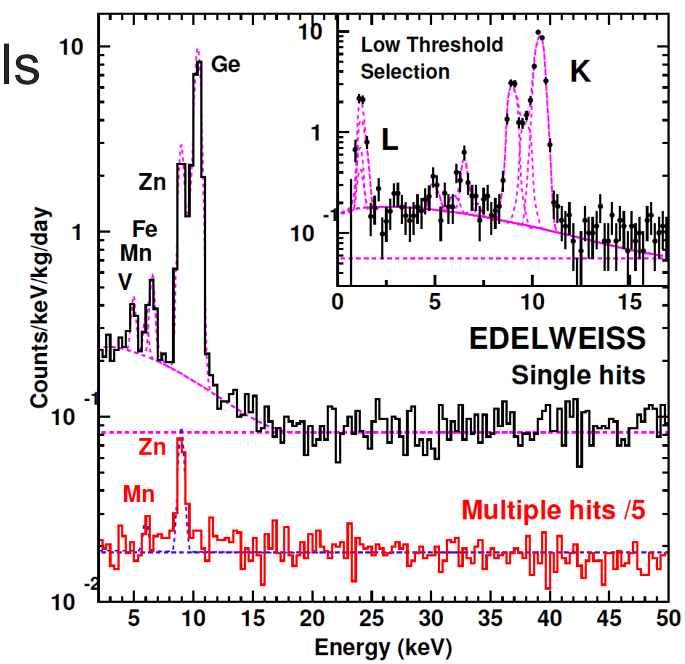
ΔV = Voltage across crystal

- See “SuperCDMS & Radon” by R. Bunker (Wed. 14:30)
  - More detailed surface emission rate evaluations and studies
  - Predictions for sensitivity reach vs. achieved surface background levels

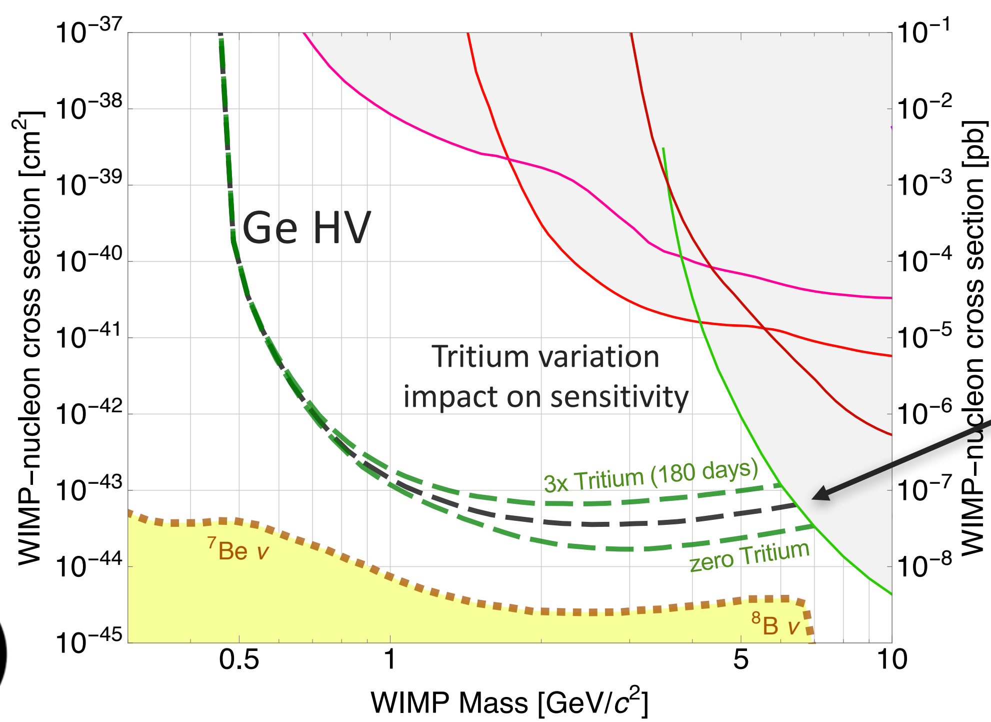
Electron recoil background sources

- ^3H produced through nuclear spallation in crystals by cosmic-ray secondary particles (p, n, μ) during detector production & fabrication
  - Reported by EDELWEISS-III

EDELWEISS-III – arXiv:1607.04560



- SuperCDMS SNOLAB target: 60 days exposure



Bottom-up SuperCDMS detector fabrication & testing estimate suggests less than 40 days sea level equivalent exposure is achievable

Poster by E. Fascione (Tues. 7-9 pm)
CDMSlite measurement of tritium production rate

Electron recoil background sources

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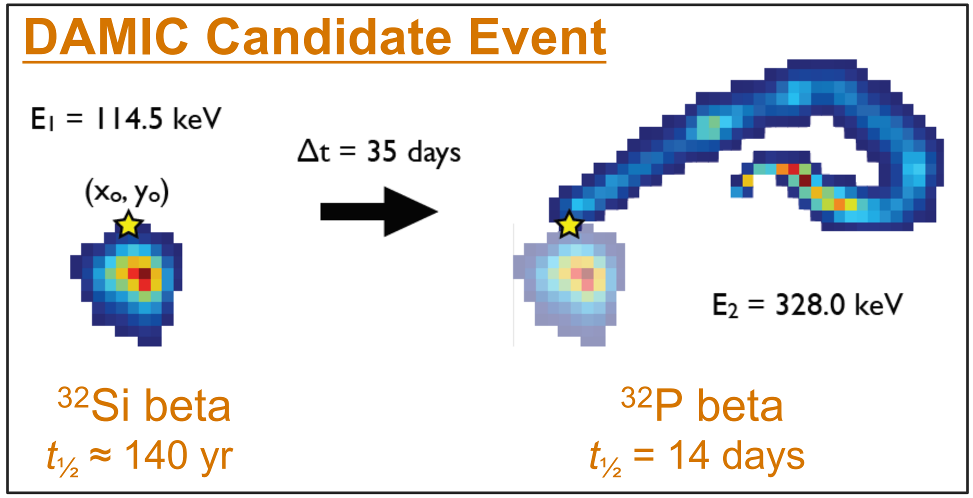
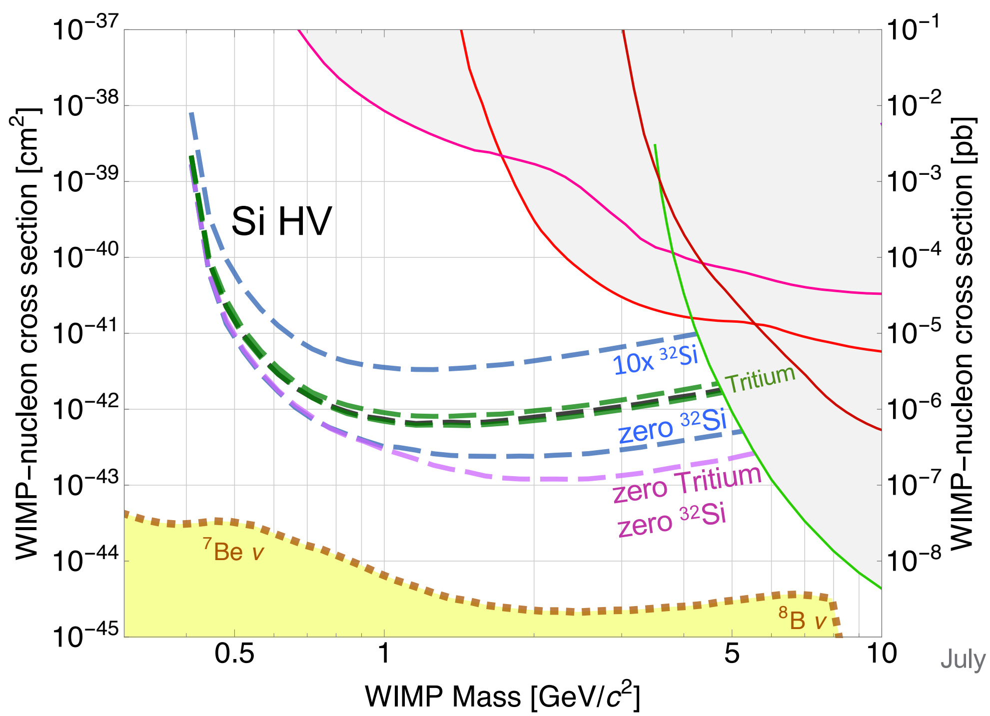
- Naturally occurring ^{32}Si is a nuclear spallation product from cosmic ray interactions with atmospheric ^{40}Ar
  - Reported by DAMIC →
- ^{32}Si levels in silicon "ore" may vary due to local geology & precipitation
- SuperCDMS SNOLAB projections for ^{32}Si based on DAMIC levels





SuperCDMS

Electron recoil background sources

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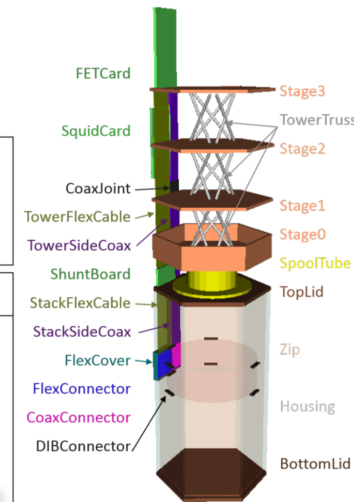
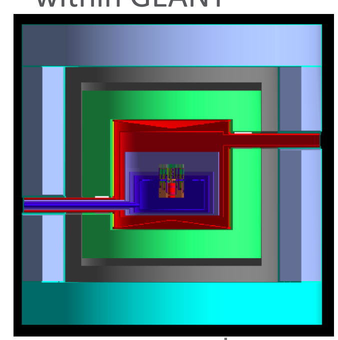
- Comparison background singles event rate in crystal bulk

Energy range used for tabulation →	0.003 – 2 keVee		1 – 50 keVee		1 – 50 keVnr	
Background Category for events in the detector bulk	**Ge HV (ER)**	**Si HV (ER)**	**Ge iZIP (ER)**	**Si iZIP (ER)**	**Ge iZIP (NR) $\times 10^{-6}$**	**Si iZIP (NR) $\times 10^{-6}$**
Total Rate (counts/keV/kg/year)	**43.**	**340.**	**33.**	**350.**	**3400.**	**2800.**
1. Coherent Neutrinos					**2300.**	**1600.**
2. Detector Internal Contamination	**24.**	**280.**	**4.7**	**250.**		
Tritium (^{3}H)	24.	33.	4.7*	6.6		
^{32}Si		250.		250.		
3. Material Internal Contamination	**12.**	**35.**	**18.**	**58.**	**400.**	**440.**
Housing and Towers	2.5	8.3	3.9	13.	39.	48.
SNOBOX Cans	3.9	12.	6.2	21.	120.	76.
Kevlar Ropes	2.1	5.1	2.7	8.3	3.6	4.0
Shield Materials	3.5	10.	5.3	17.	240.	310.
Bulk ^{210}Pb in Lead	0.44	1.8	0.64	1.5		
4. Material Internal Activation	**2.1**	**7.9**	**3.7**	**13.**		
Housing and Towers	0.58	2.3	0.92	3.8		
SNOBOX	1.5	5.6	2.8	8.9		
5. Surfaces (non-line-of-sight)	**1.7**	**5.1**	**3.6**	**12.**	**63.**	**42.**
Dust	1.4	3.8	2.2	6.7	63.	42.
Pb-210 (Radon daughter)	0.33	1.3	1.4	5.1	0.45	0.76
6. Prompt Interstitial Radon	**0.61**	**1.8**	**0.87**	**2.7**		
7. Cavern Environment	**2.3**	**3.5**	**2.0**	**9.6**	**300.**	**350.**
8. Cosmogenic Neutrons					**320.**	**480.**



Material radio-impurity backgrounds (γ-ray Compton) simulated within GEANT



Summary

- SuperCDMS SNOLAB
  - Direct detection search for low-mass WIMP dark matter
  - Anticipate a background-limited search
- Major classes of anticipated background sources:
  - ^{210}Pb daughters → Low-energy surface-event fiducial-cut leakage
  - Cosmogenic tritium (^{3}H) → β-decay electron recoil
  - Naturally occurring ^{32}Si → β-decay electron recoil
  - Material U & Th chains → γ-ray Compton scattering electron recoils
- Total sensitivity reach in WIMP-nucleon cross-section $O(10^{-43}\ \text{cm}^2)$
- Complementary of HV & iZIP detectors with material screening program provides information to constrain and fit anticipated backgrounds

SuperCDMS Collaboration

California Institute of Technology
CNRS/LPN
Fermi National Accelerator Laboratory
NISER
Pacific Northwest National Laboratory
Santa Clara University
South Dakota School of Mines & Technology
SNOLAB
Southern Methodist University
Texas A&M
University of California, Berkeley
University of Colorado Denver
University of Florida
University of South Dakota

Durham University
Northwestern University
Queen's University
SLAC/KIPA
NIST
Laurentian University
Stanford University
University of British Columbia
TRIUMF
University of Evansville
University of Minnesota
University of Toronto

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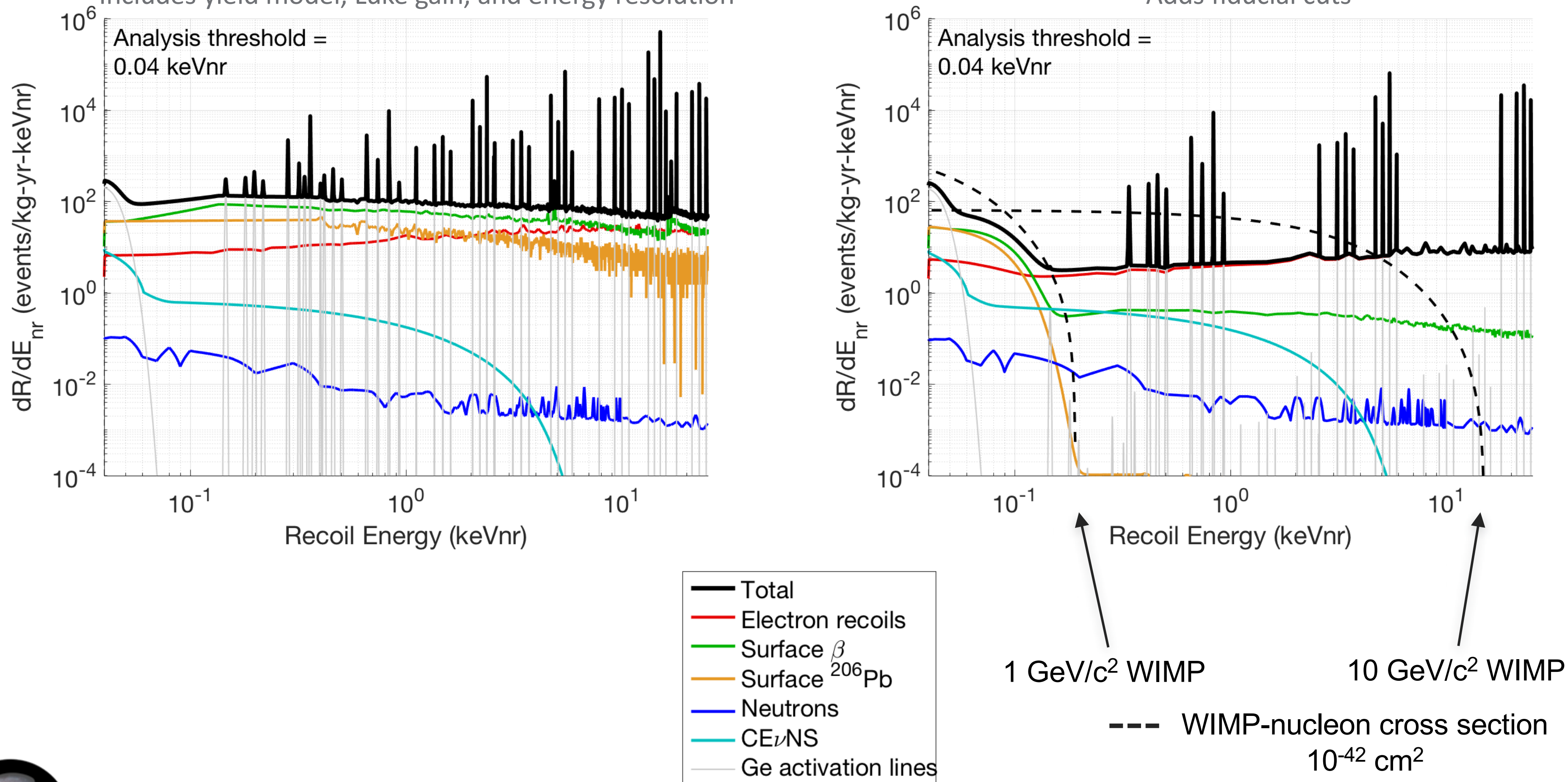

super CDMS

Anticipated background spectra (Si HV)

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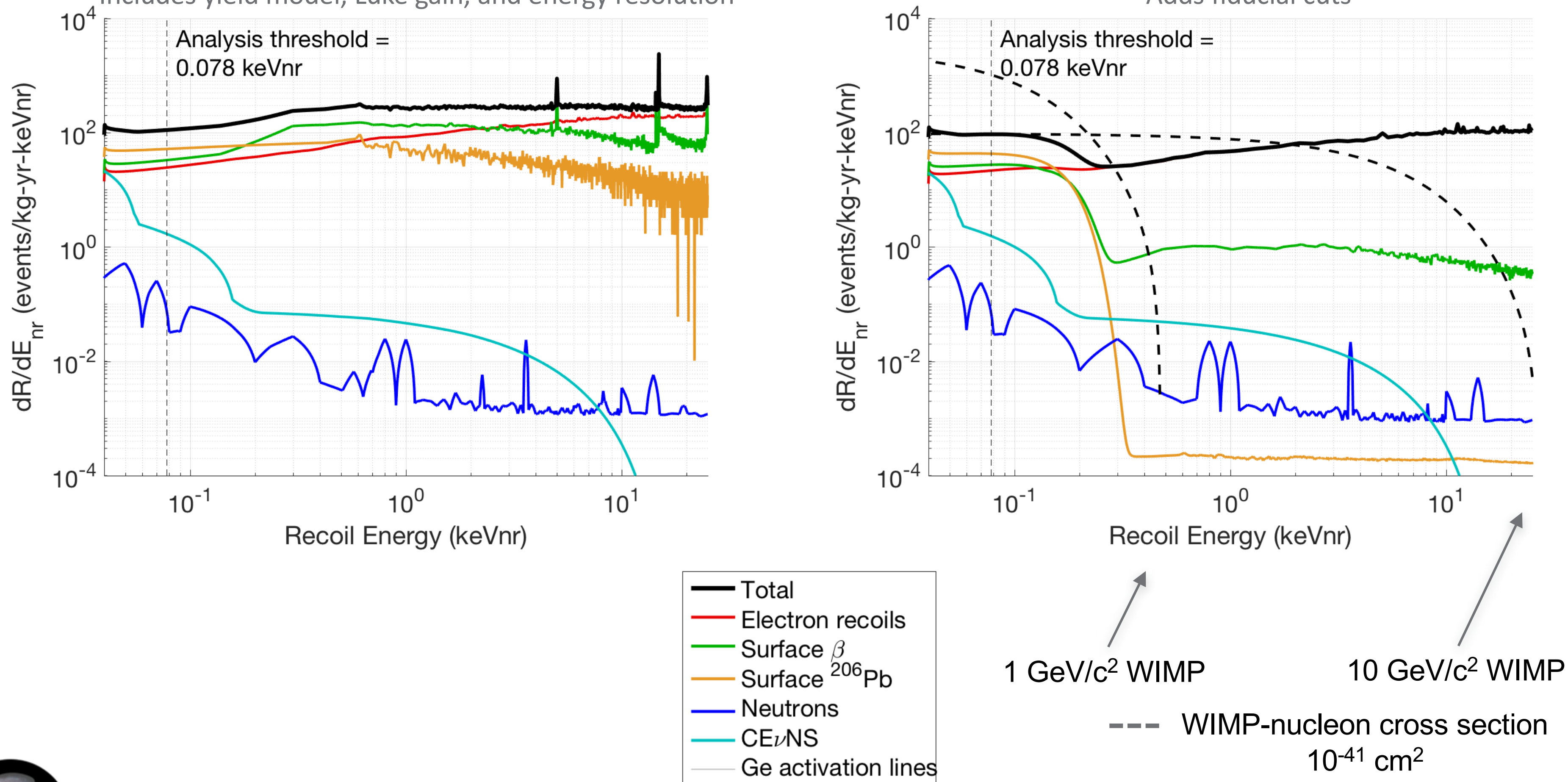

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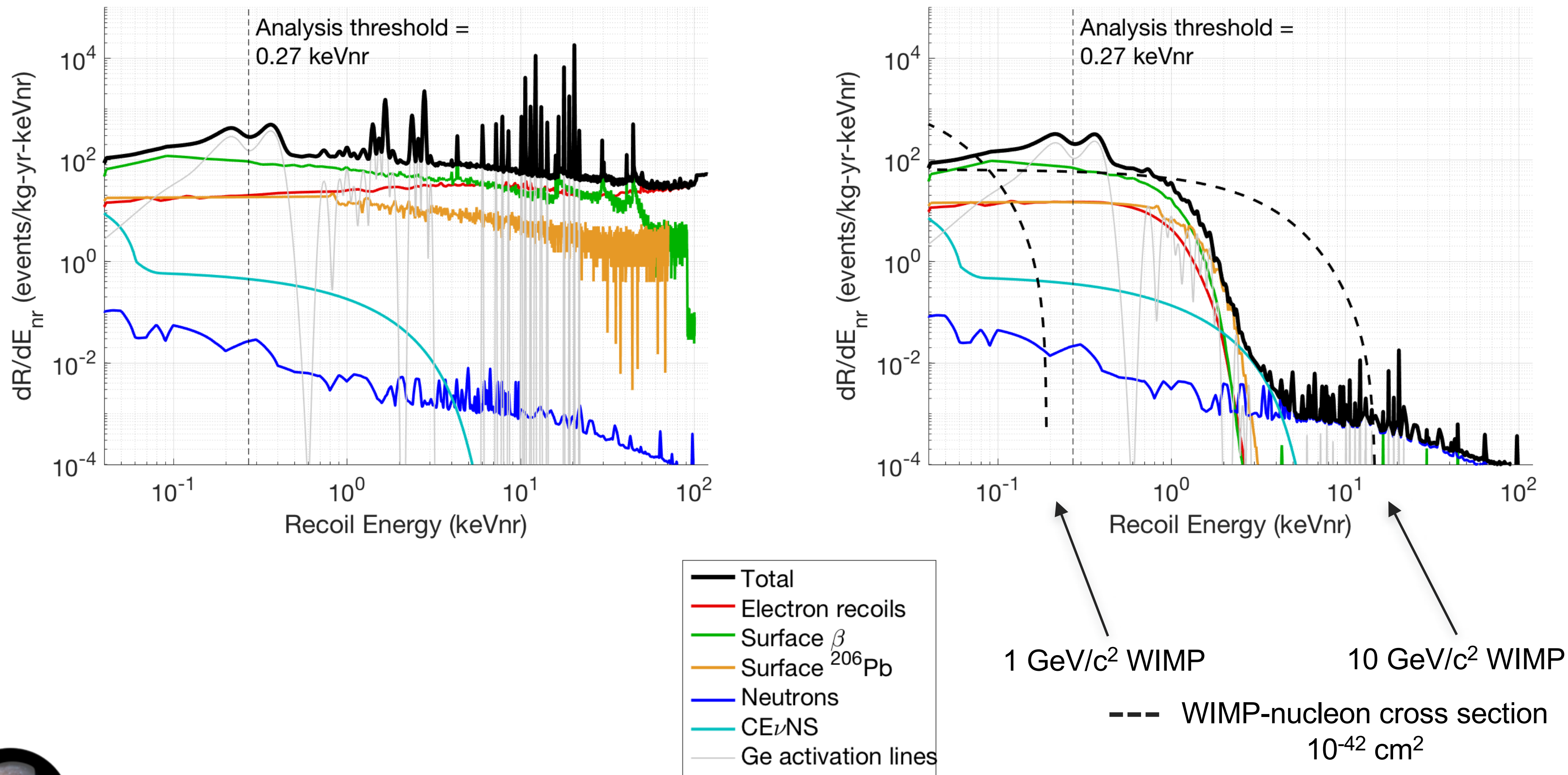

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