SuperCDMS

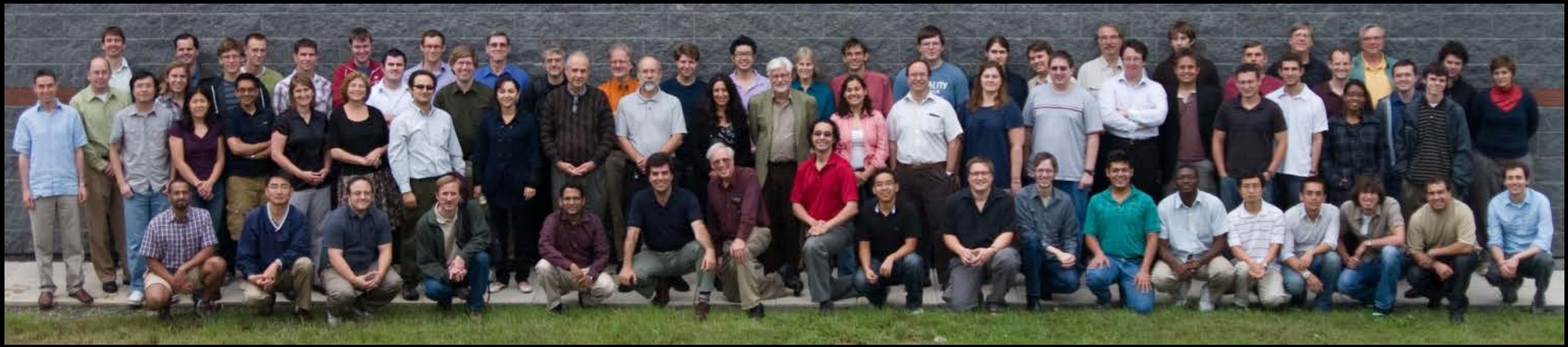
and CUTE

at SNOLAB

Wolfgang Rau
Queen’s University

for the
SuperCDMS Collaboration

SuperCDMS Collaboration



California Institute of Technology **CNRS/LPN** **Durham University**
Fermi National Accelerator Laboratory **NISER** **NIST** **Northwestern University**
PNNL **Queen's University** **Santa Clara University** **SLAC/KIPA**
South Dakota School of Mines & Technology **SNOLAB/Laurentian University**
Southern Methodist University **Stanford University** **Texas A&M**
University of British Columbia/TRIUMF **University of California, Berkeley**
University of Colorado Denver **University of Evansville** **University of Florida**
University of Minnesota **University of South Dakota** **University of Toronto**

SuperCDMS

- Detector technology
- Detector generations
- Experimental Setup
- Goals for SNOLAB
- Status

CUTE

- Motivation
- Design
- Status

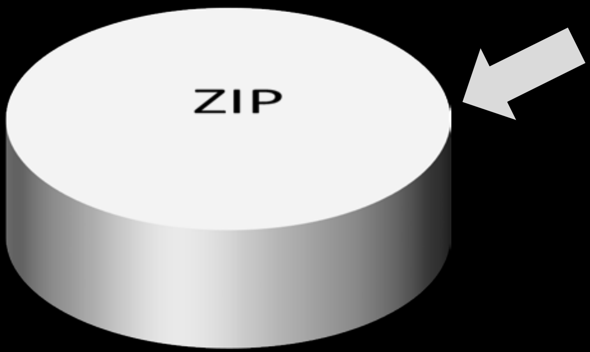
Analysis Projects

- Detector Calibration
- Backgrounds
- Rare interactions
- Dark Matter searches

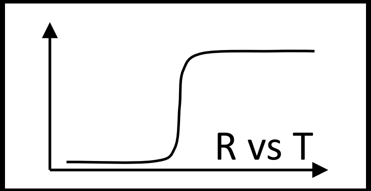
Conclusions

Detectors

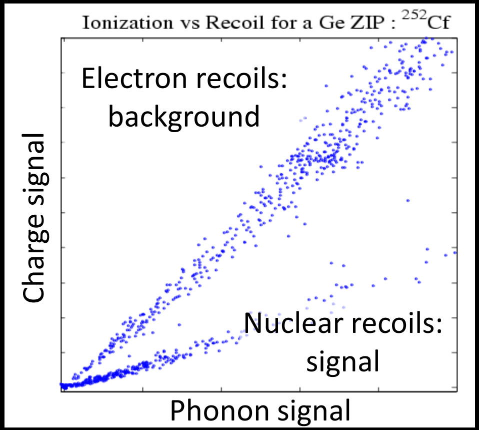
CDMS



Phonon Readout:
Tungsten TES

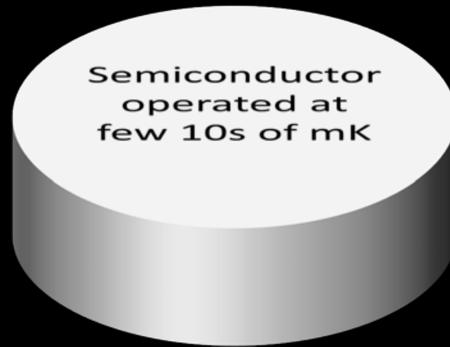


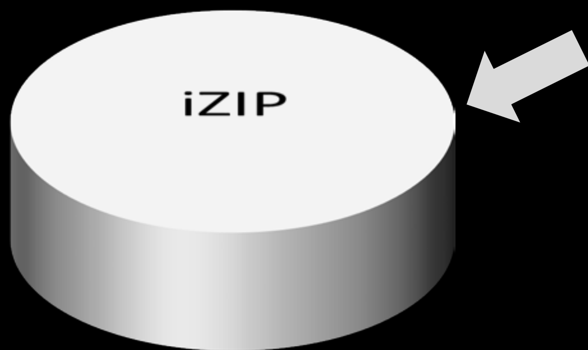
Add: charge readout (few V)
Background discrimination
Threshold < 10 keV

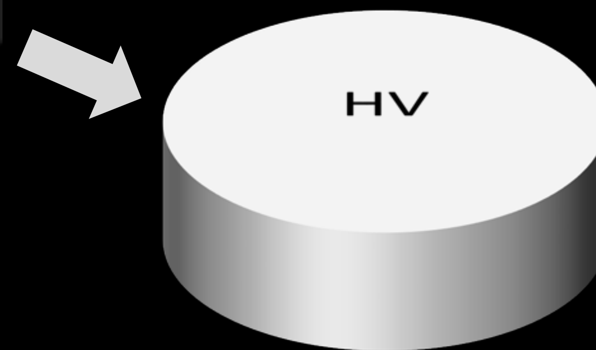


Detectors

SuperCDMS Soudan







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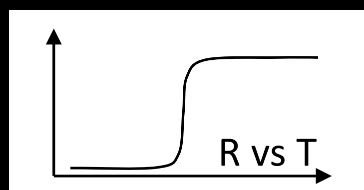
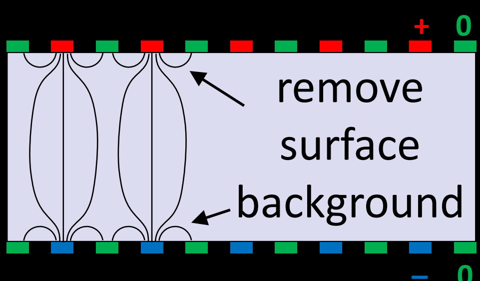
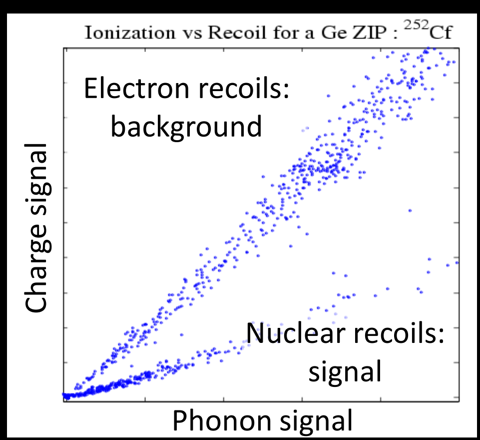
Tungsten TES



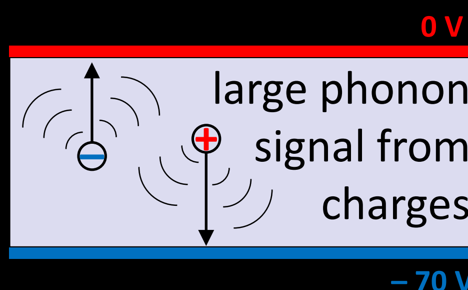
Add: charge readout (few V)
Background discrimination
Threshold < 10 keV



< 1 background event for whole exposure



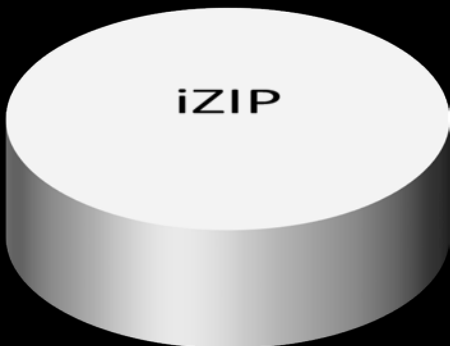
Add: high voltage (~70 V)
Phonons from drifting charges
Threshold < 0.1 keV (phonon)

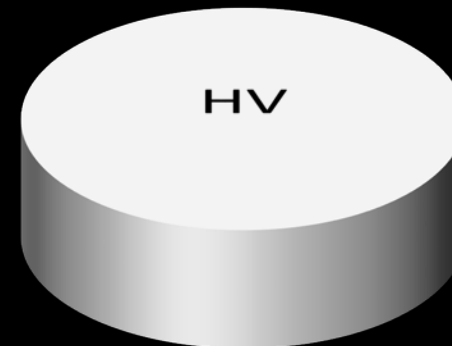


effective threshold:
few hundred eV (NR)

Detectors

SuperCDMS
SNOLAB





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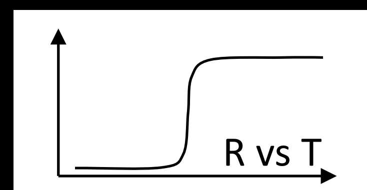
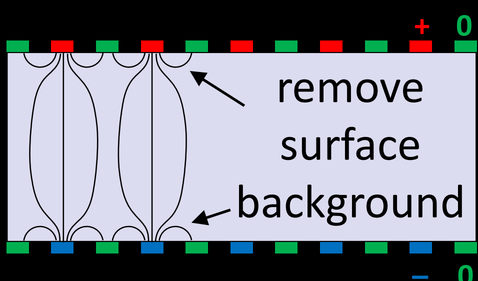
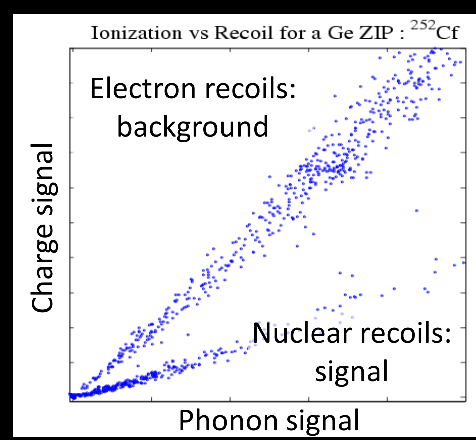


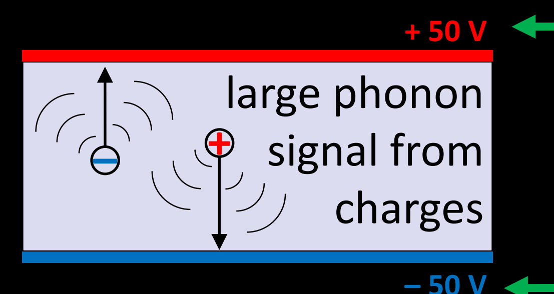
Add: charge readout (few V)
Background discrimination
Threshold < 1 keV



< 1 background event for whole exposure

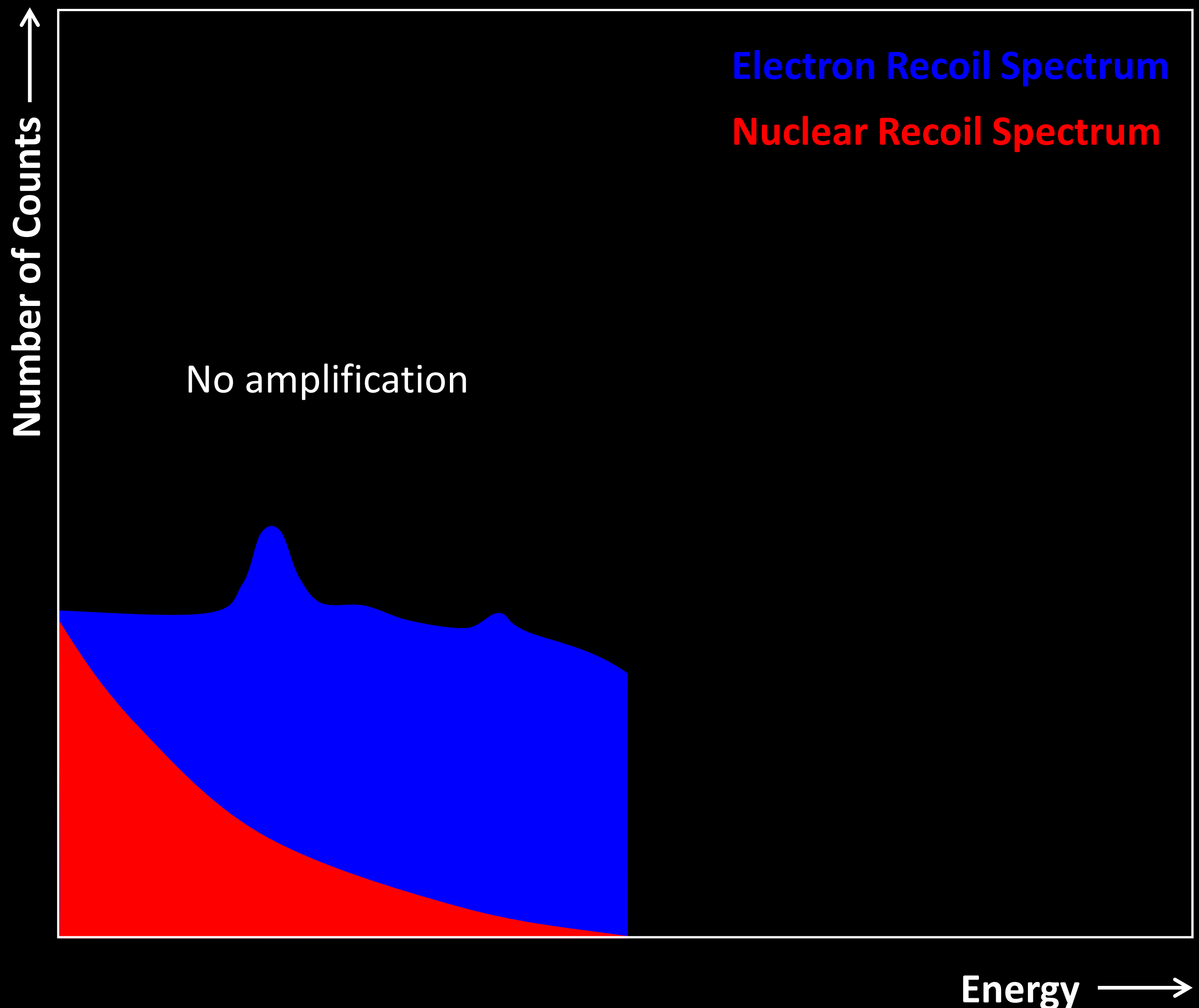


Add: high voltage (~100 V)
Phonons from drifting charges
Threshold < 0.1 keV (phonon)

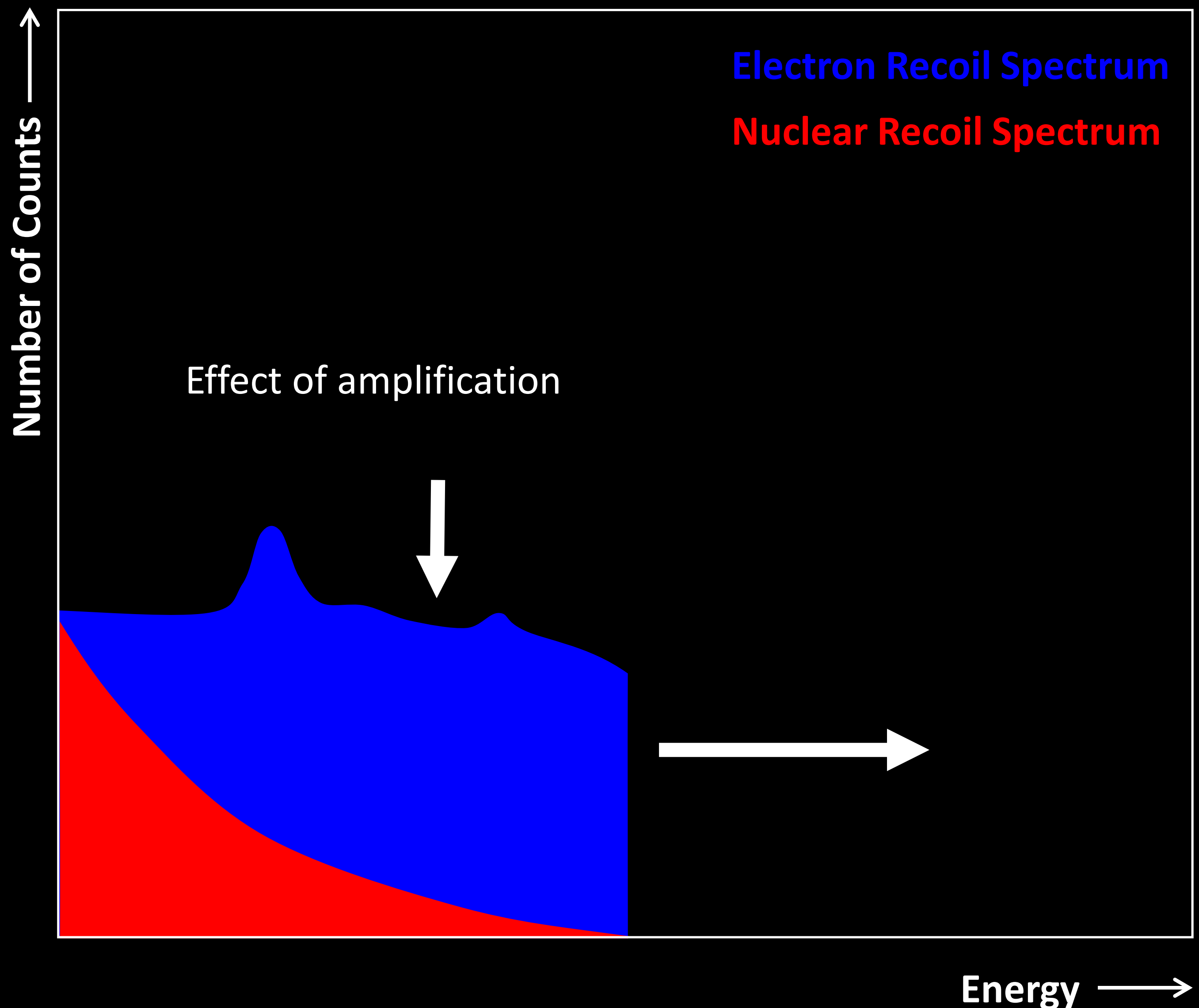


effective threshold: one (or few) electron-hole pairs

Background dilution with Luke Effect



Background dilution with Luke Effect



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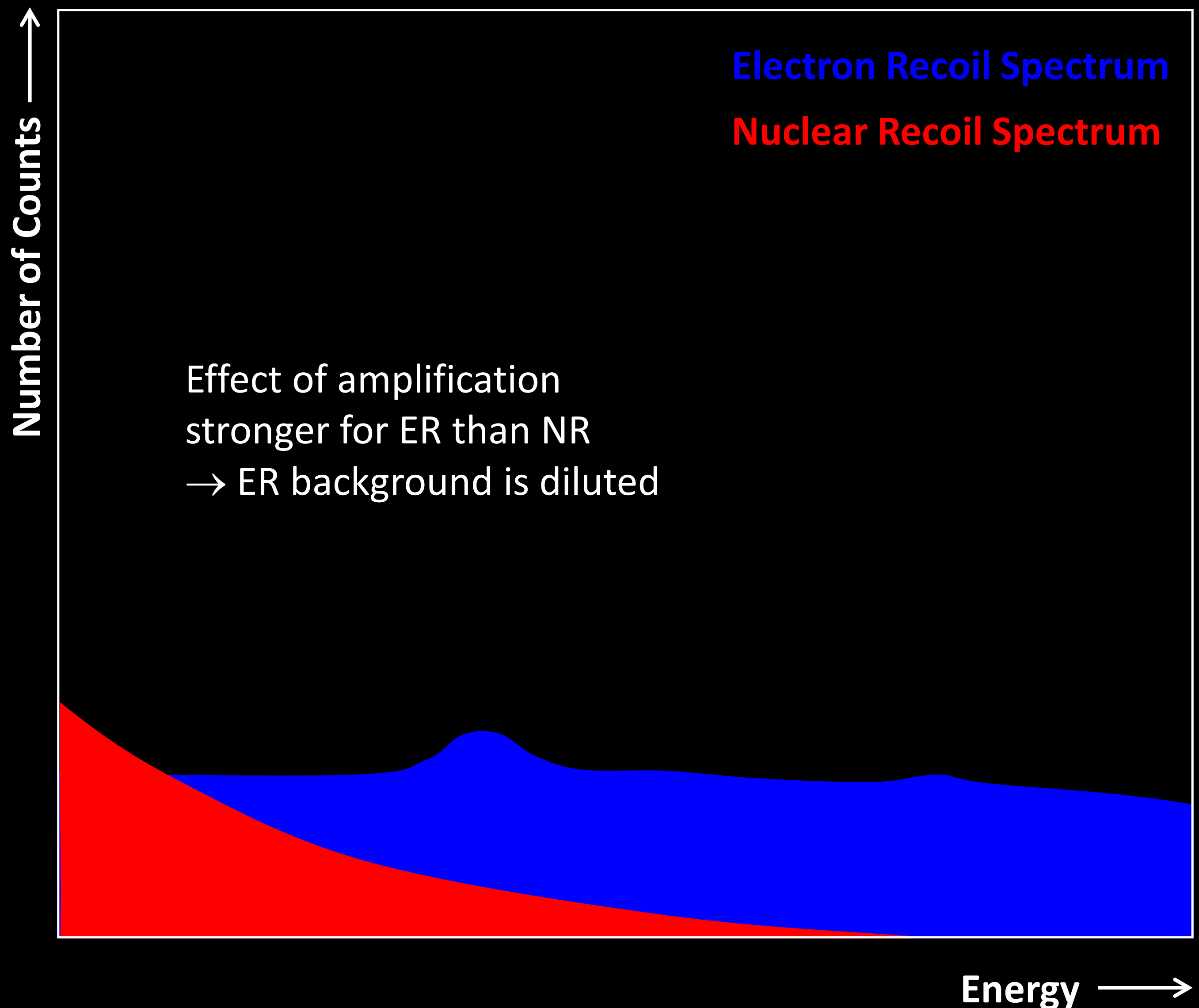


CDMS History

1998 - 2002

CDMS @ SUF
6 detectors
1 kg Ge (30 kgd)
σ < 3.5e-42 cm²

SUF, 10 mwe

CDMS II @ Soudan
30 detectors
~4 kg Ge (1.1 kgy)
σ < 2e-44 cm²

2003 - 2009

2009 - 2014

Soudan, 2000 mwe

SuperCDMS @ Soudan
15 (bigger) detectors
~9 kg Ge (~6.5 kgy)
σ < 3e-45 cm²

exposures are after all cuts!

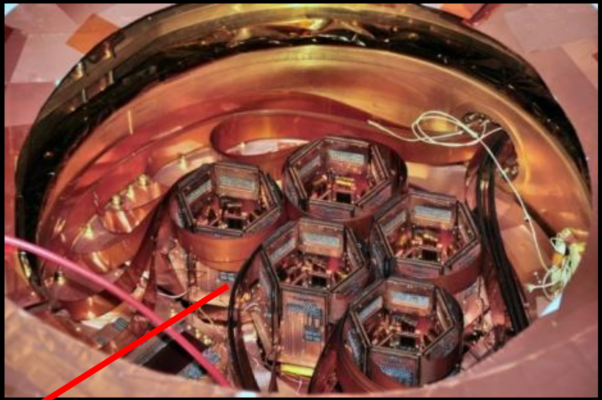
SuperCDMS @ SNOLAB
30-180 detectors
30-200 kg Ge/Si (part HV)
focus on low mass WIMPs
σ < e-43 cm² (1-10 GeV)

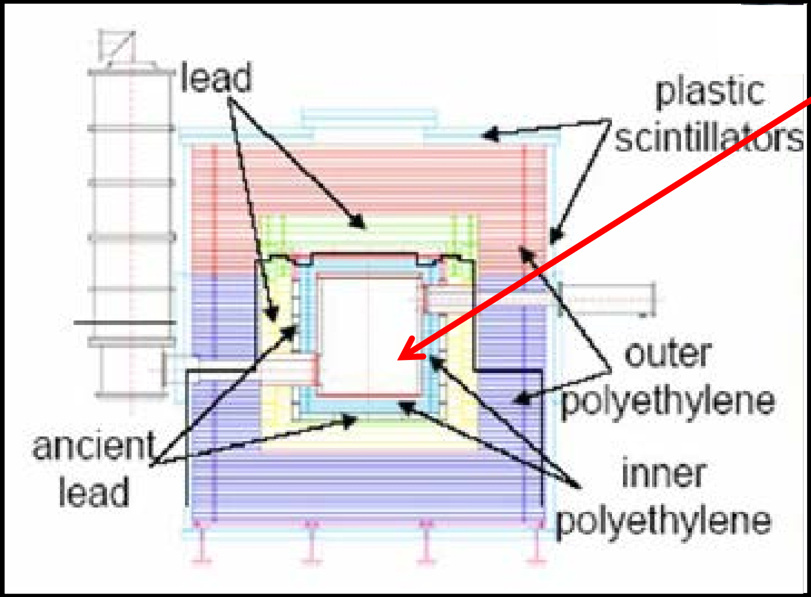
SNOLAB, 6000 mwe

2020

Implementation (Soudan setup)

- Stack detectors (3) to mount (“tower”)
- 5 towers deployed in cryostat (~9 kg Ge)
- Shielded with PE (for neutrons), Pb (gammas) and muon veto (cosmic radiation)
- Located at Soudan Underground Lab (Minnesota) to shield from cosmic radiation (~700 m below ground)





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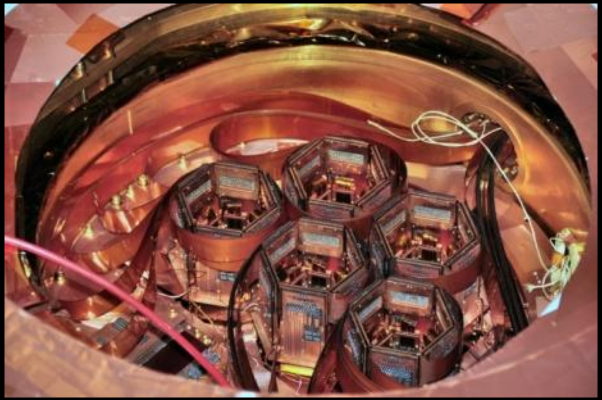
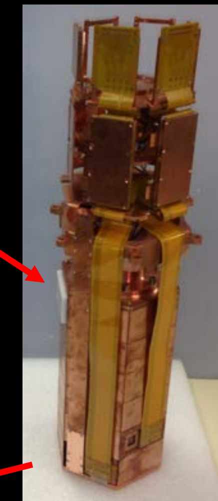


Implementation (SNOLAB setup)

6 detectors
→ 1 tower

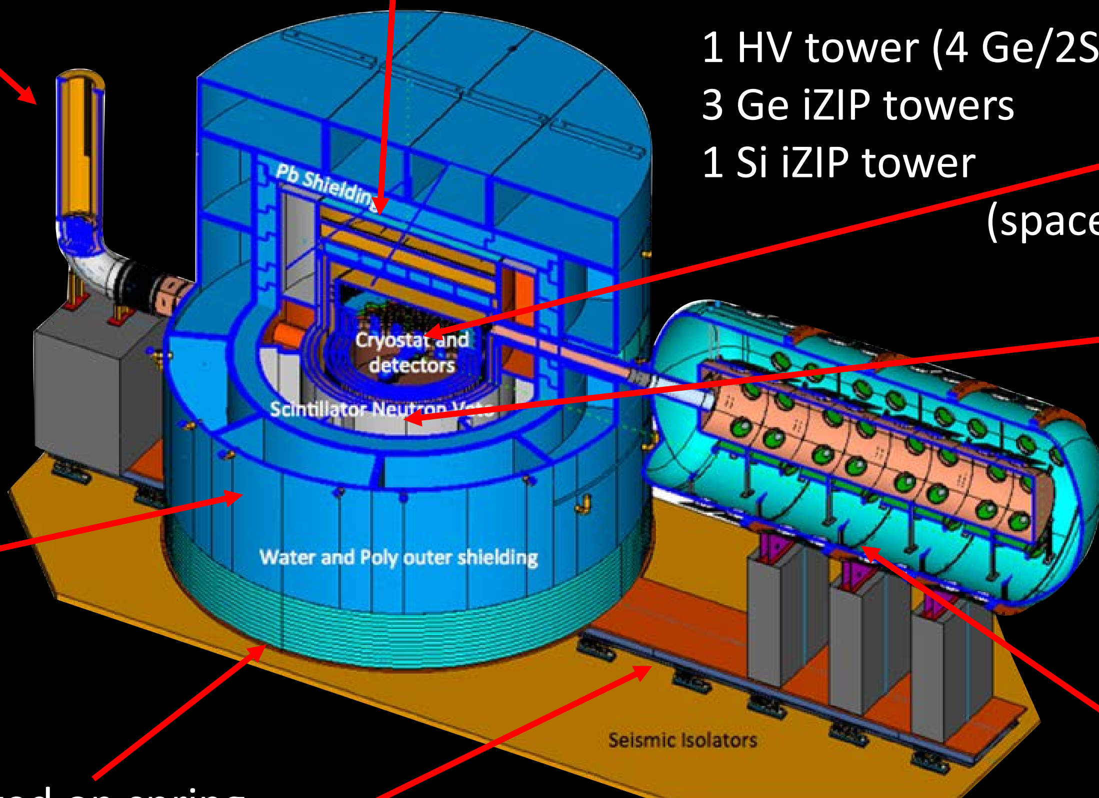


Fridge to provide
<15 mK at the detector

Gamma shield (Pb)

1 HV tower (4 Ge/2Si)
3 Ge iZIP towers
1 Si iZIP tower

(space for up to 31 towers)



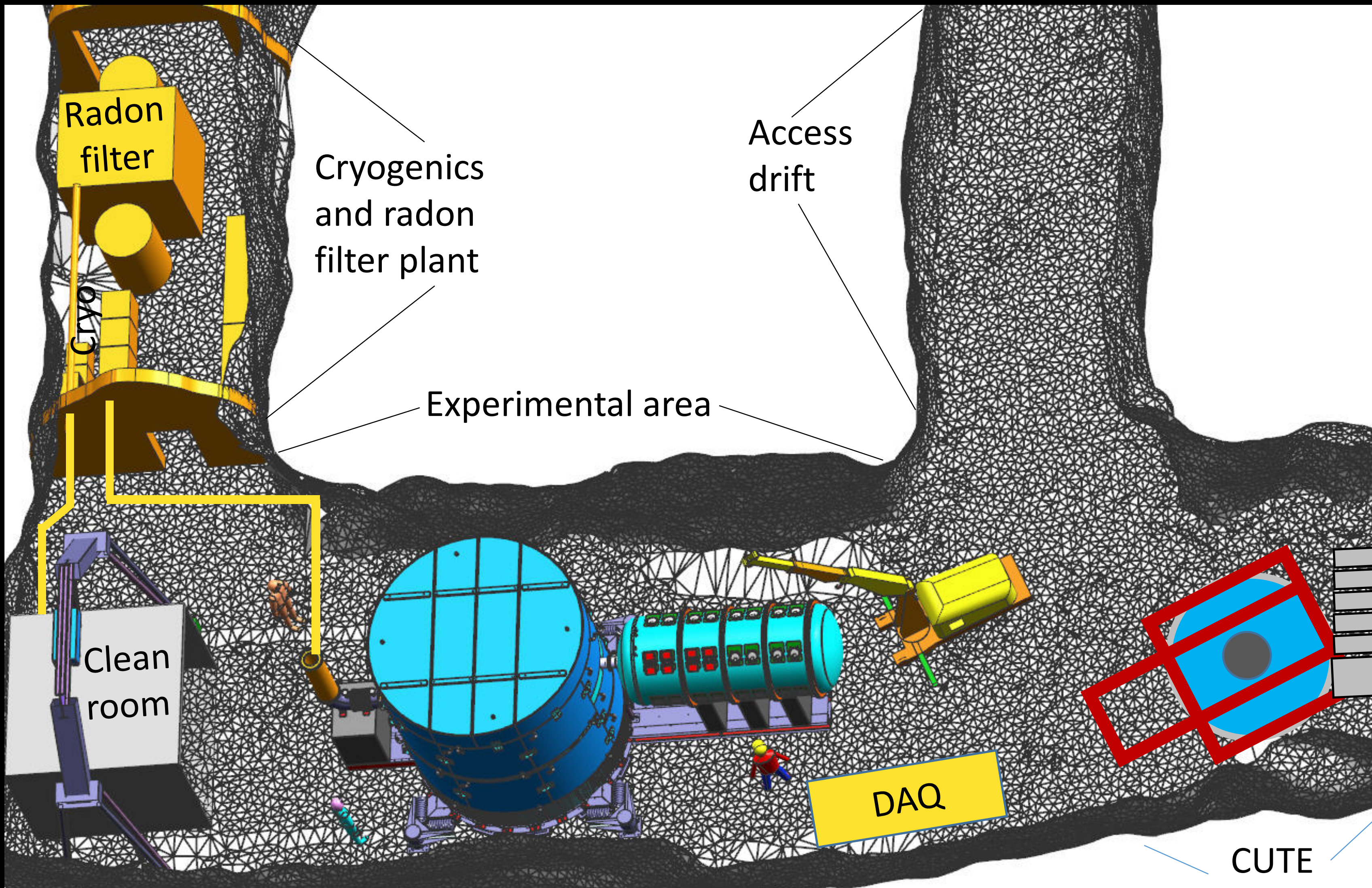
Inner neutron
shield (PE)

Outer
neutron shield
(PE and water)

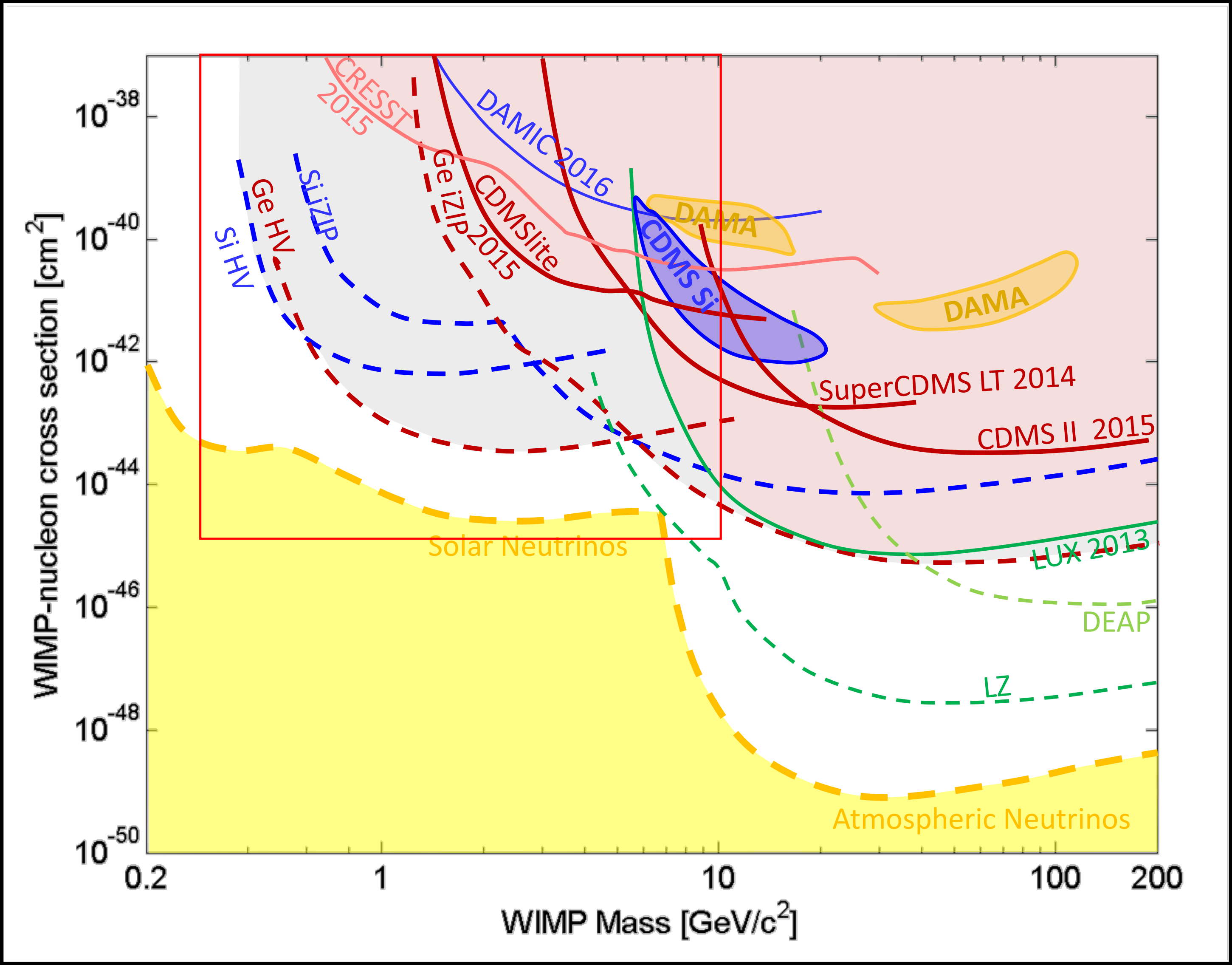
Mounted on spring-
loaded platform
(earthquake)

Signal vacuum
feedthroughs

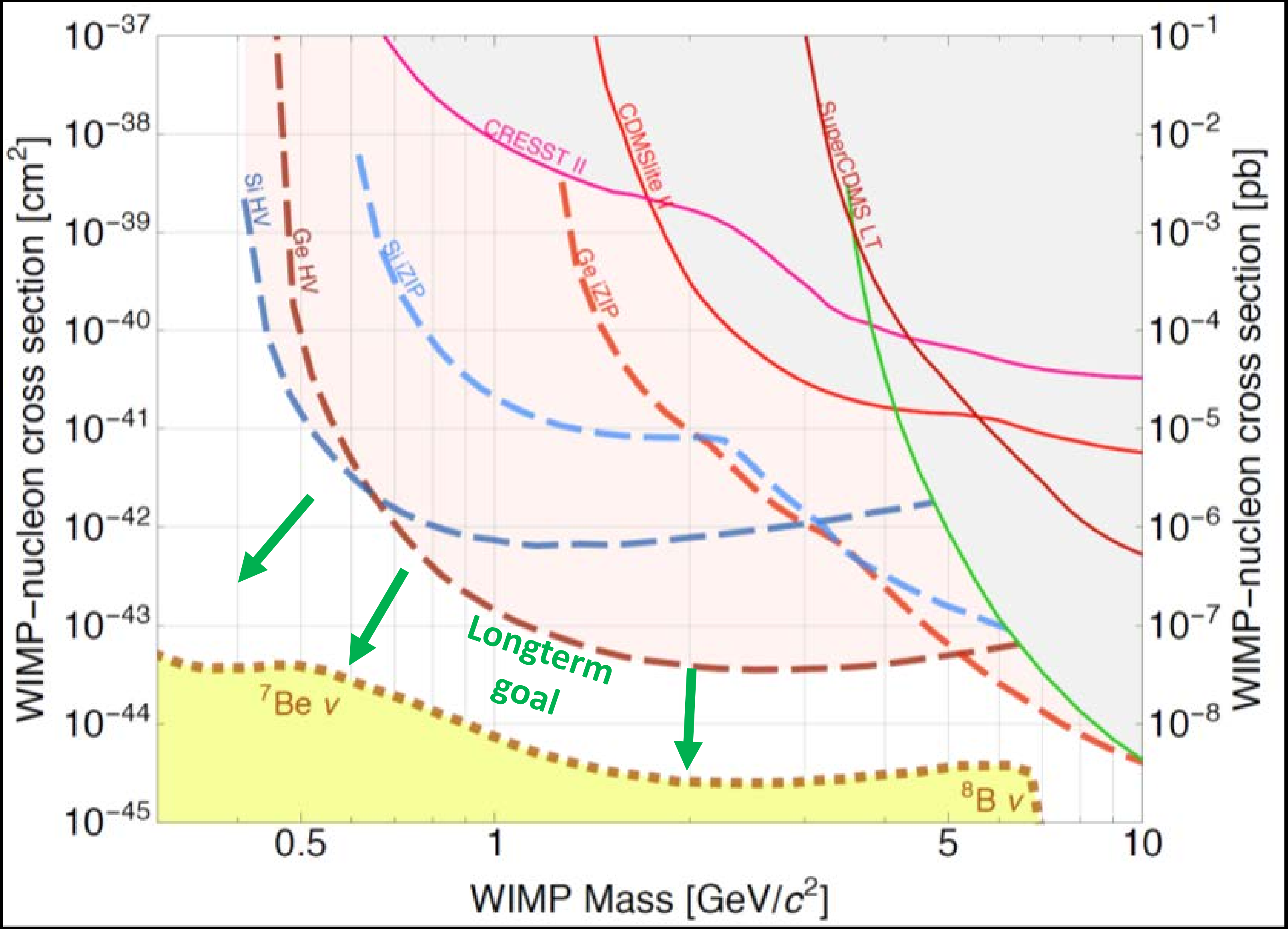
SNOLAB


Radon filter
Cryo
Cryogenics and radon filter plant
Access drift
Experimental area
Clean room
DAQ
CUTE

Goal

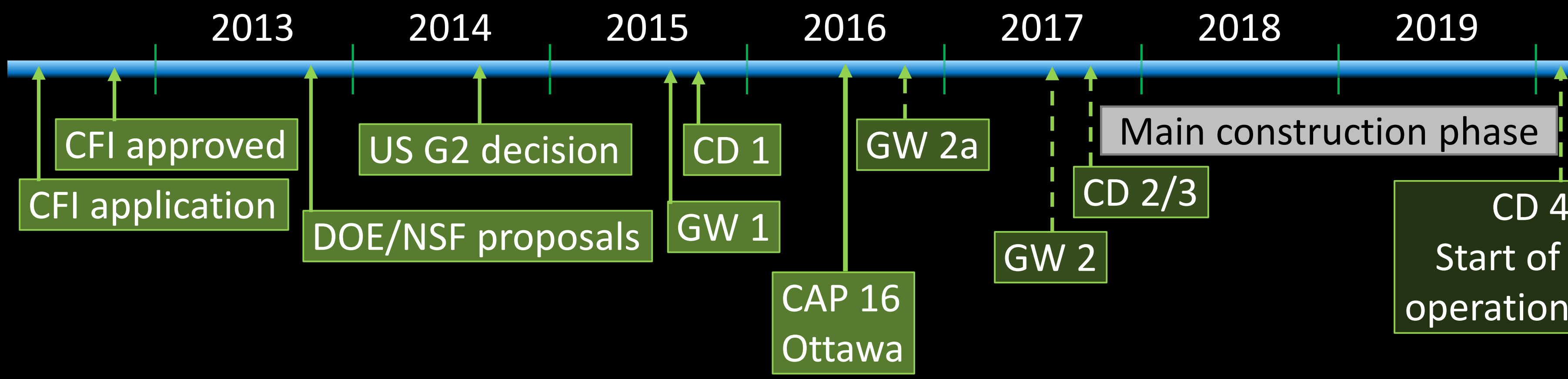

WIMP-nucleon cross section [cm^2]
WIMP Mass [GeV/c^2]
10^{-38}
10^{-40}
10^{-42}
10^{-44}
10^{-46}
10^{-48}
10^{-50}
0.2
1
10
100
200
CRESST 2015
DAMIC 2016
Si iZIP
Ge HV
Si HV
Ge iZIP 2015
CDMSlite
DAMA
CDMS Si
DAMA
SuperCDMS LT 2014
CDMS II 2015
LUX 2013
DEAP
LZ
Solar Neutrinos
Atmospheric Neutrinos

Goal



WIMP–nucleon cross section [cm^2]
WIMP–nucleon cross section [pb]
WIMP Mass [GeV/c^2]
CRESST II
CDMSlite II
SuperCDMS LT
Si HV
Ge HV
Si iZIP
Ge iZIP
Longterm goal
^{7}Be ν
^{8}B ν

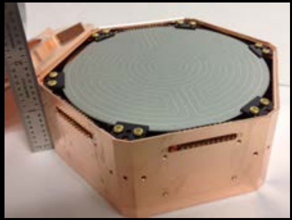
Schedule and Funding



- Funding approved (CFI: 2012, DOE/NSF: 2014)
- DOE/NSF review process:
  First step passed (CD 1: conceptual design review)
  Next step in fall 2017: technical design review/ready for construction (CD 2/3)
- Reviews at SNOLAB:
  passed Gateway 1 (space allocation) in fall 2015;
  GW2a (early construction) in December 2016 / GW2 (construction) summer 2017
- Total project costs ~$30M

Development

- Detectors: larger crystals; iZIP: design ready, prototypes exist and have been tested; HV detectors: first prototypes built; testing has started
- Detector tower (mechanical structure, wiring): design ready, mechanical prototype exists; wiring prototype expected in early 2017
- Readout electronics:
  Preamp: thermal readout design ready; charge readout: circuits are being tested
  "Warm electronics" (outside cryostat): prototype exists, tests underway
- DAQ: MIDAS based, being developed at UBC with help from TRIUMF (version for detector test facilities already in use)
- Cryogenics and shielding: design advanced, but not ready yet
  Procurement of dilution refrigerator under way
- Backgrounds: devised extensive material screening program; tracking and monitoring program being developed; radon filter to be installed for detector assembly cleanroom at SNOLAB.



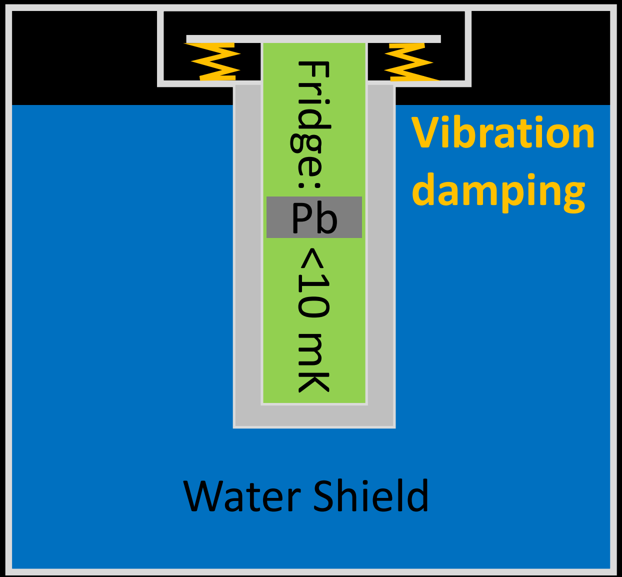
Cryogenic Underground TEst facility (CUTE)

Motivation

- Detector performance:
  Detector integrity after transportation
  Background discrimination
  Noise performance (impact of background)

- Background studies
  Confirm that screening program
  and handling procedures are appropriate
  Study cosmogenic backgrounds (^{3}H, ^{32}Si)

- Test EURECA detectors in a SuperCDMS environment (possibly join forces)

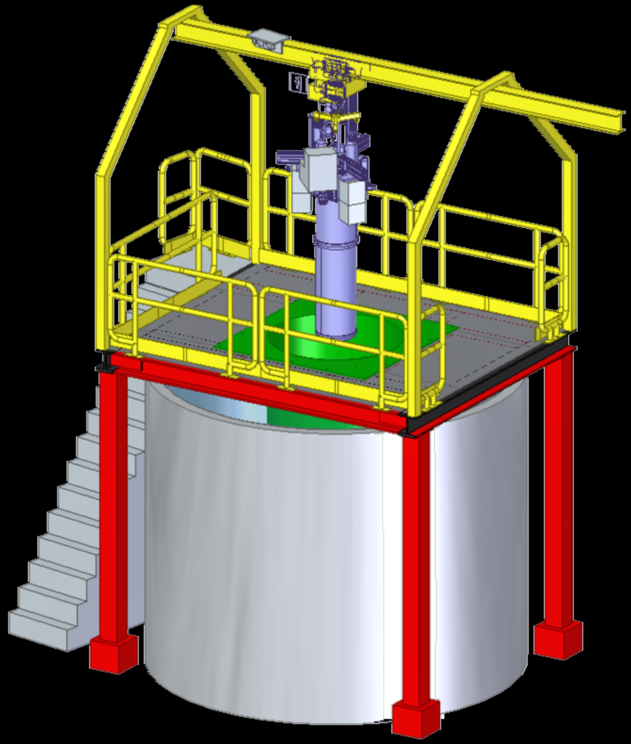


- Opportunity for early science! (BG $\mathcal{O}$ (few evt/keV/kg/d below 100 keV))

Schedule

- Cryostat ordered
- Infrastructure (water tank, cleanroom, services): in early 2017
- May 2017: test at Queen's; summer installation underground
- Commissioning: early fall 2017 (~2-3 years ahead of SuperCDMS)

Cryogenic Underground TEst facility (CUTE)



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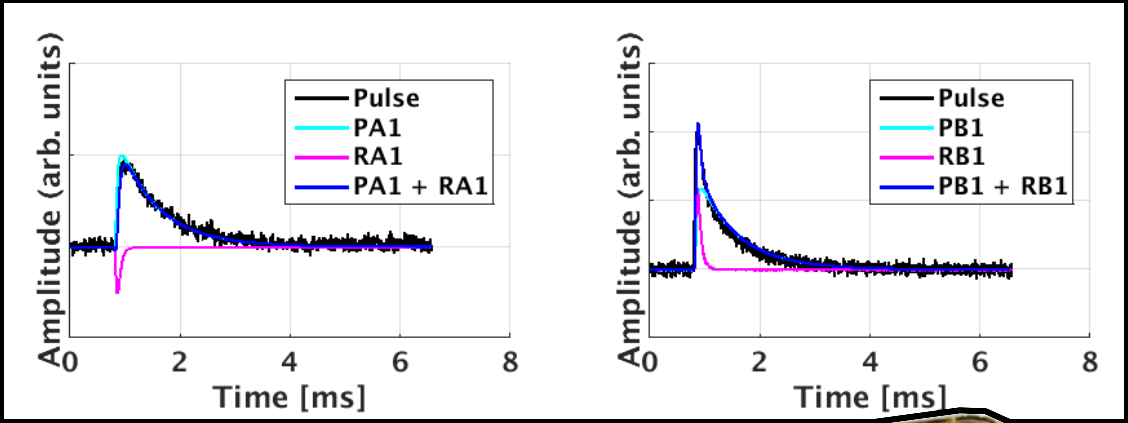
Cryogenic Underground TEst facility

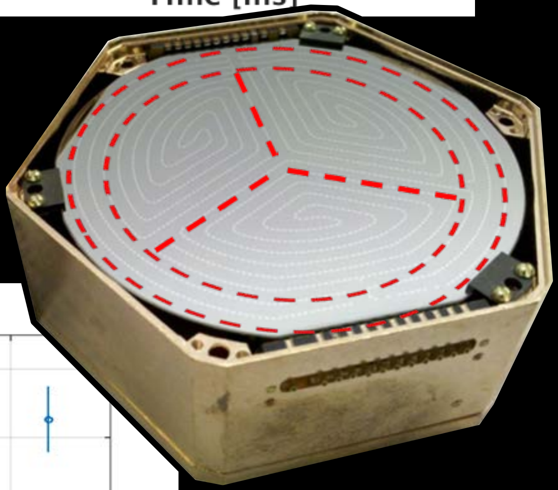
Analysis Projects

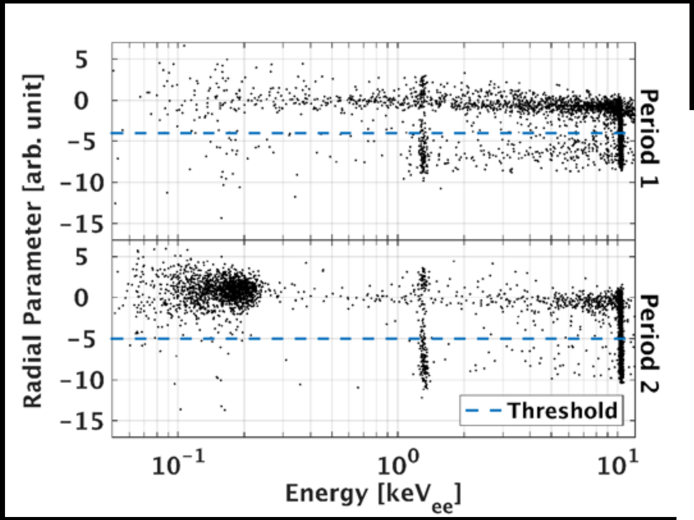
- Photo-Neutron calibration (low-energy nuclear recoil calibration)
  Last “physics” measurement from Soudan (summer/fall 2015)
  Analysis under way, publication ‘sometime next year’
- Backgrounds: Analysis of cosmogenic backgrounds in CDMSlite (^{3}H and others)
  Analysis in good shape; hope to publish early next year
- Backgrounds: radioactivity from the setup/environment – improved MC simulations to inform ongoing anlysis of dark matter data and learn for SNOLAB
- Rare interactions: follow-up of LIPs analysis (can we use CDMSlite data to improve our sensitivity for lower fractional charges?)
- Annual modulation analysis – long time coming; hopefully ready within the next 2-3 months
- Standarad WIMP search from SuperCDMS (full discrimination, intermediate to high mass range): not competitive with Xe for ‘vanilla WIMP’, but still important for non-standard models (EFT …); first half of next year (?)
- Last CDMSlite data set – develop blinding scheme, consider background modeling

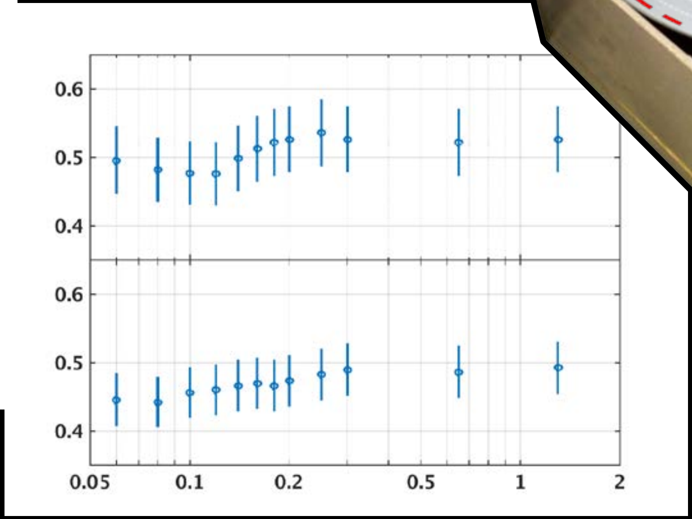
CDMSlite R2

- Reduced threshold
- New pulse fitting
- Improved resolution
- Fiducialization

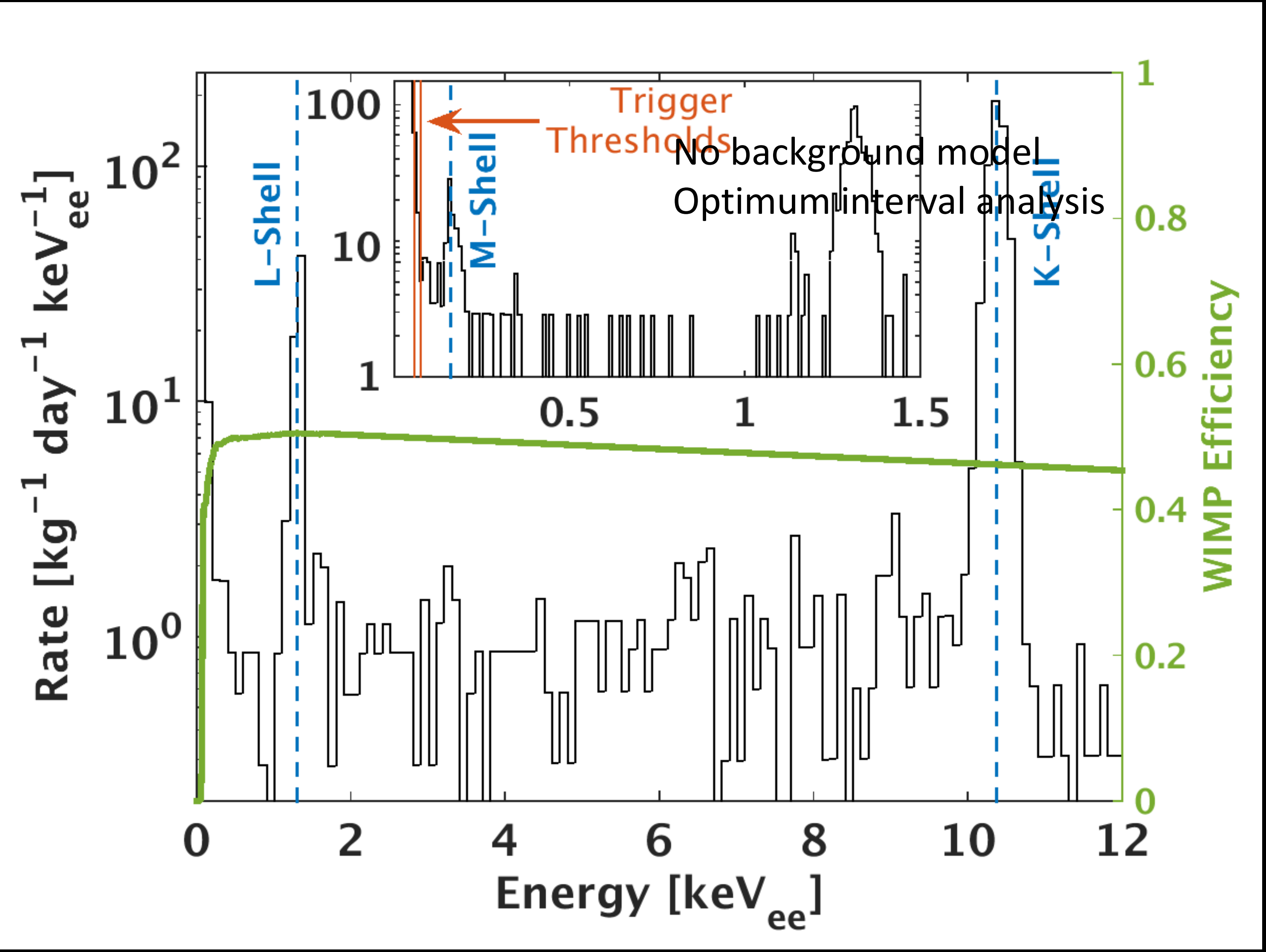




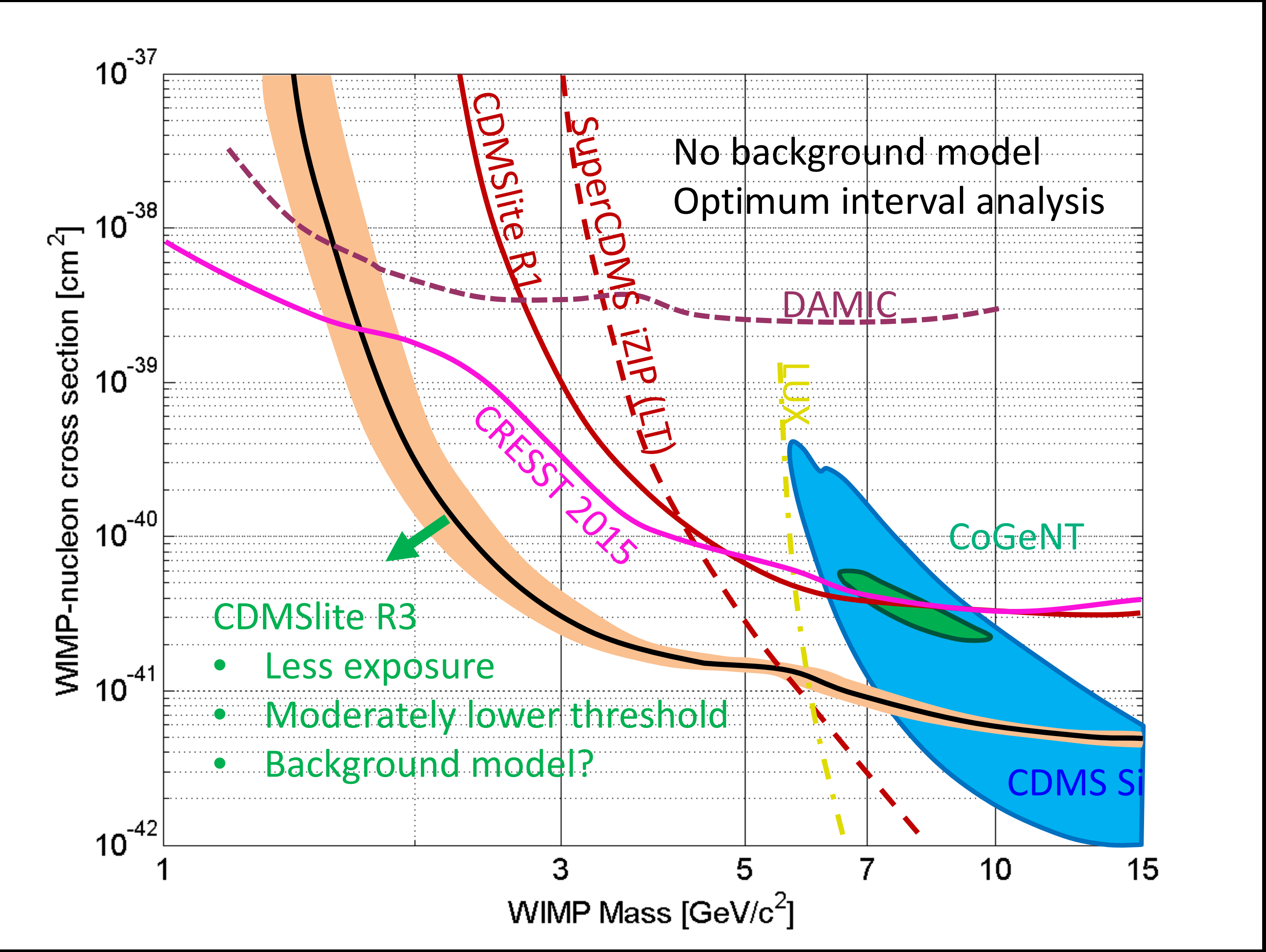




CDMSlite R2


Trigger
Thresholds
No background model
Optimum interval analysis
L–Shell
M–Shell
K–Shell
Rate [kg^{-1} day^{-1} keV$_{ee}^{-1}$]
WIMP Efficiency
Energy [keV$_{ee}$]

CDMSlite R2



No background model
Optimum interval analysis
CDMSlite R1
SuperCDMS iZIP (LT)
DAMIC
LUX
CRESST 2015
CoGeNT
CDMS Si
CDMSlite R3
• Less exposure
• Moderately lower threshold
• Background model?
WIMP-nucleon cross section [cm^2]
WIMP Mass [GeV/c^2]
10^{-37}
10^{-38}
10^{-39}
10^{-40}
10^{-41}
10^{-42}
1
3
5
7
10
15

Conclusions

- SuperCDMS SNOLAB aims at detecting dark matter WIMPs
- Main focus are low-mass WIMPs (< 10 GeV/c^2)
- Project planning well under way
- Main R&D is done, full technical design expected for spring 2017
- Start of operation expected in 2020
- Upgrades (improved HV detectors, EURECA detectors, …) will allow us to reach the neutrino floor at low mass and/or check discovery claims at high mass
- CUTE: Queen's initiative for an underground test facility, operational in about a year (detector performance studies, background checks, early dark matter science)
- Analysis: many updates in the pipeline; small steps until new facilities come online