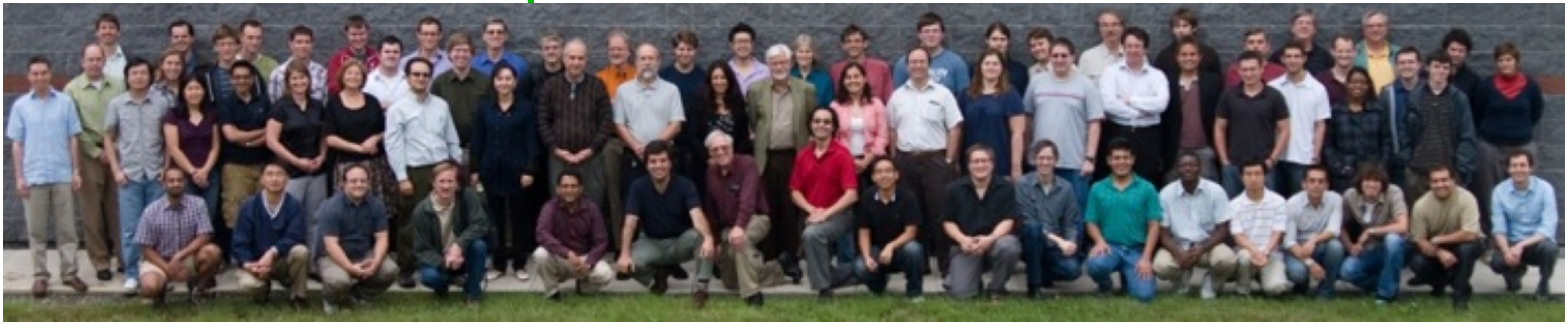
The SuperCDMS Present and Future

Cosmic Frontier Workshop
SLAC National Accelerator Center

March 7, 2013

Blas Cabrera
Spokesperson SuperCDMS
Physics Department, Stanford
KIPAC (Kavli Institute for Particle Astrophysics and Cosmology)
SLAC National Accelerator Center

The SuperCDMS Collaboration

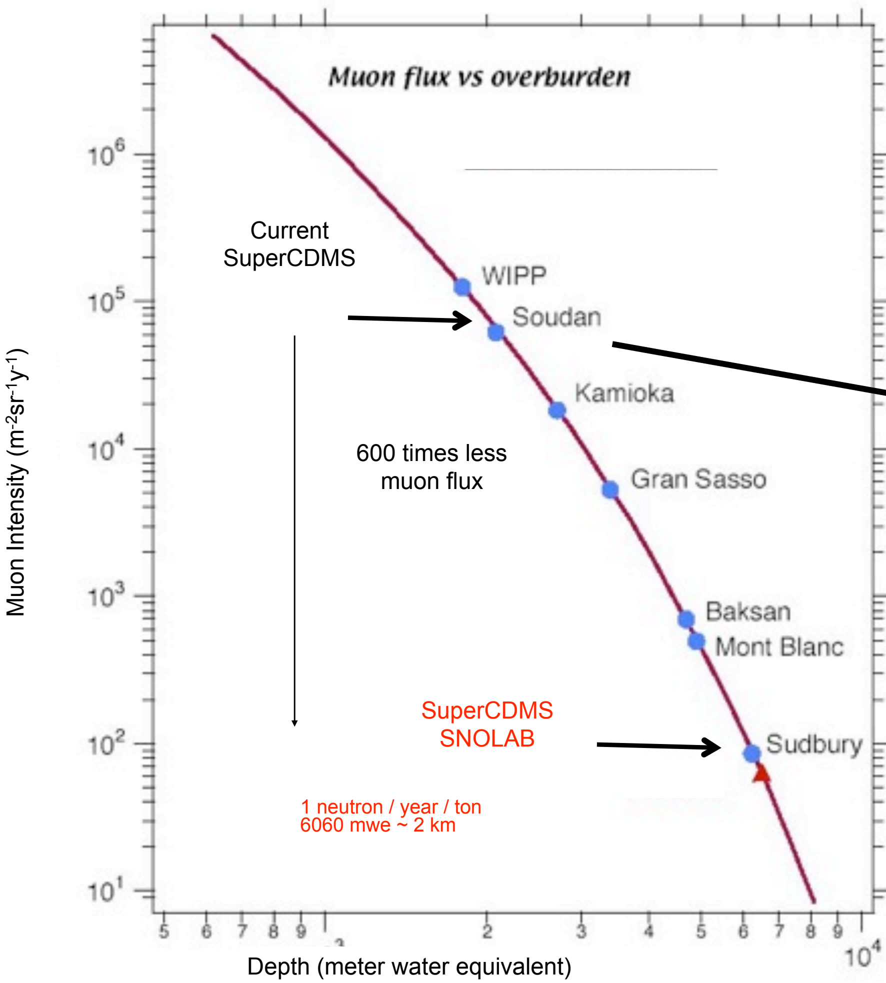


California Institute of Technology	Fermi National Accelerator Laboratory	Massachusetts Institute of Technology
Queen's University	Santa Clara University	SLAC / Kavli Institute for Particle Astrophysics and Cosmology
Southern Methodist University	Stanford University	Syracuse University
Texas A&M University	Universidad Autónoma de Madrid	University of British Columbia
University of California, Berkeley	Pacific Northwest National Laboratory	University of Colorado, Denver
University of Evansville	University of Florida	University of Minnesota

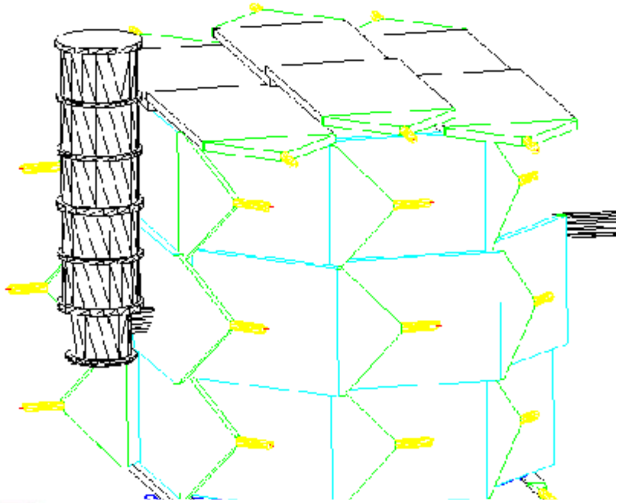
Outline

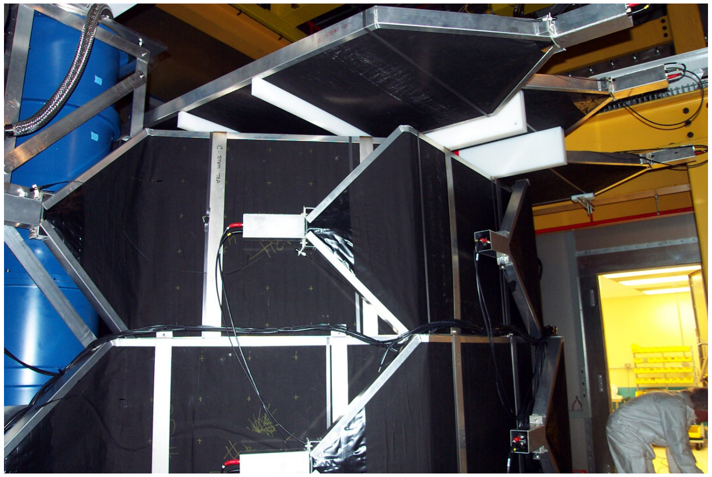
- Now operating 10 kg of Ge iZIPs at Soudan
  - Demonstrated excellent surface event rejection using ^{210}Pb sources at Soudan
  - Complete 2 years of exposure mid 2014
- R&D for 200 kg Ge iZIP at SNOLAB
  - Surface rejection sufficient for 4 yr exposure
  - Begin data taking ~2016
- G2 experiments may detect ^{8}B solar neutrinos
  - look like ~7 GeV/c^2 WIMPs at SI ~5x10^{-9} pb
- G3 R&D possibility of larger mass detectors and pushing thresholds down to a few eVee levels.

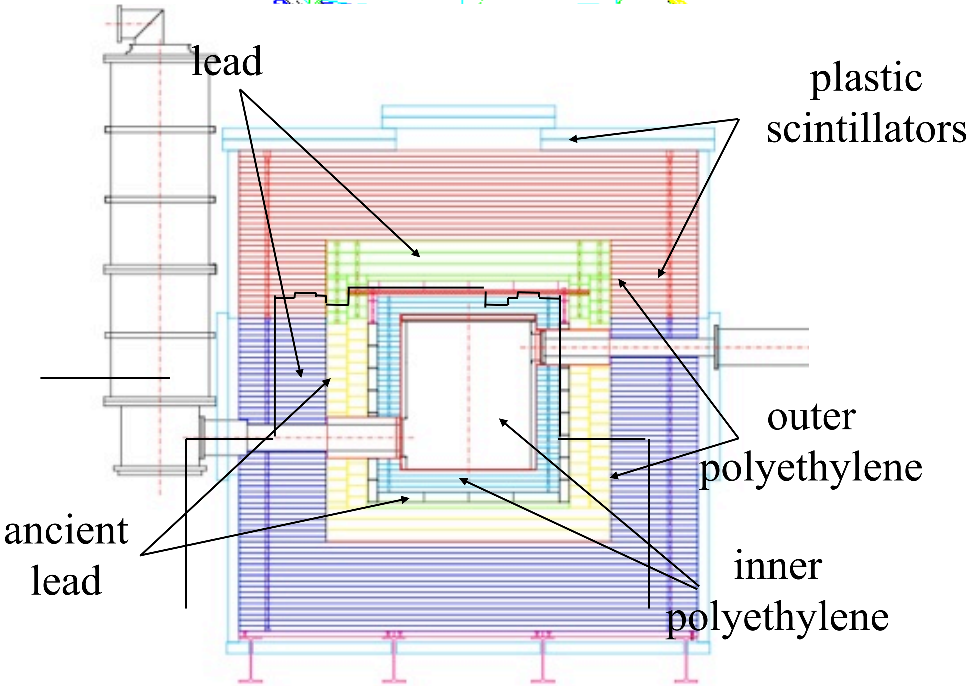
CDMS-II at Soudan (2090 mwe)



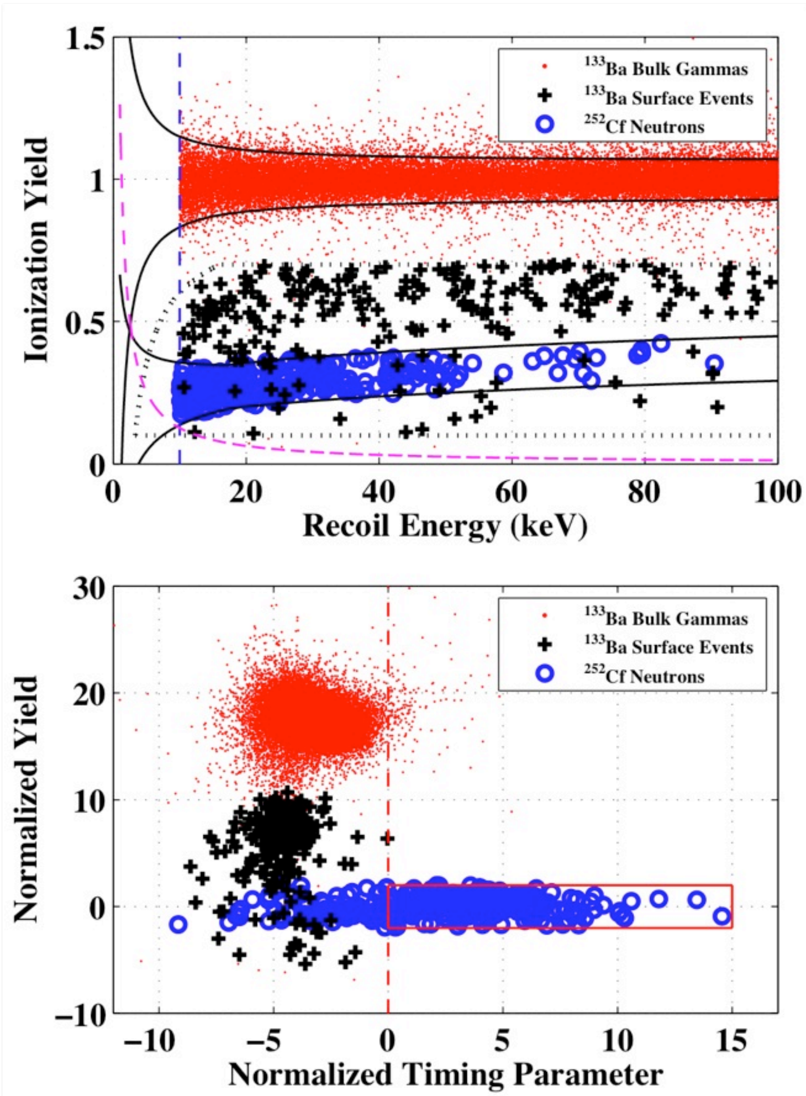
CDMS-II Soudan facility

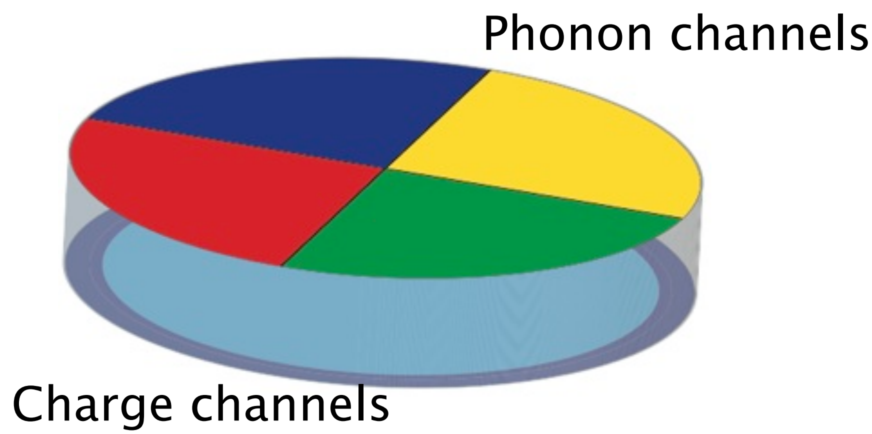






Detector Specifics



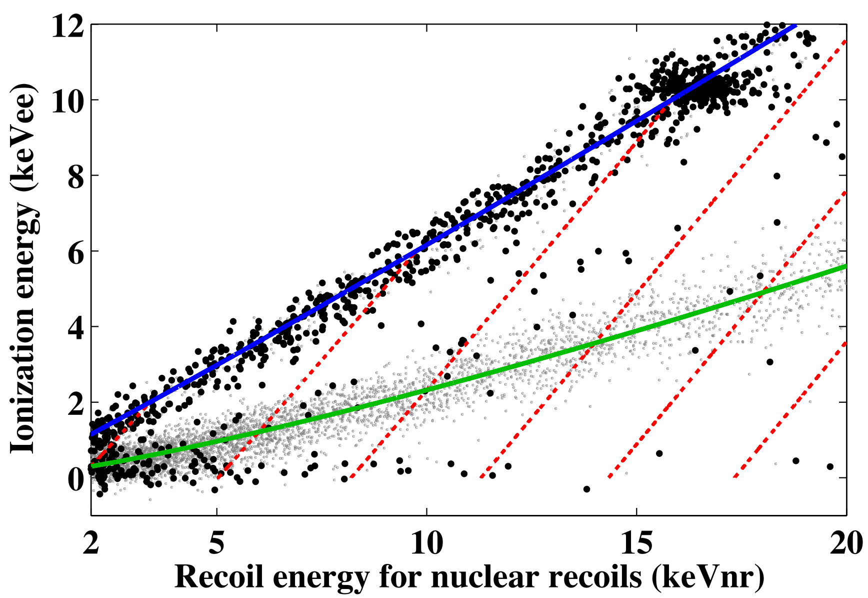


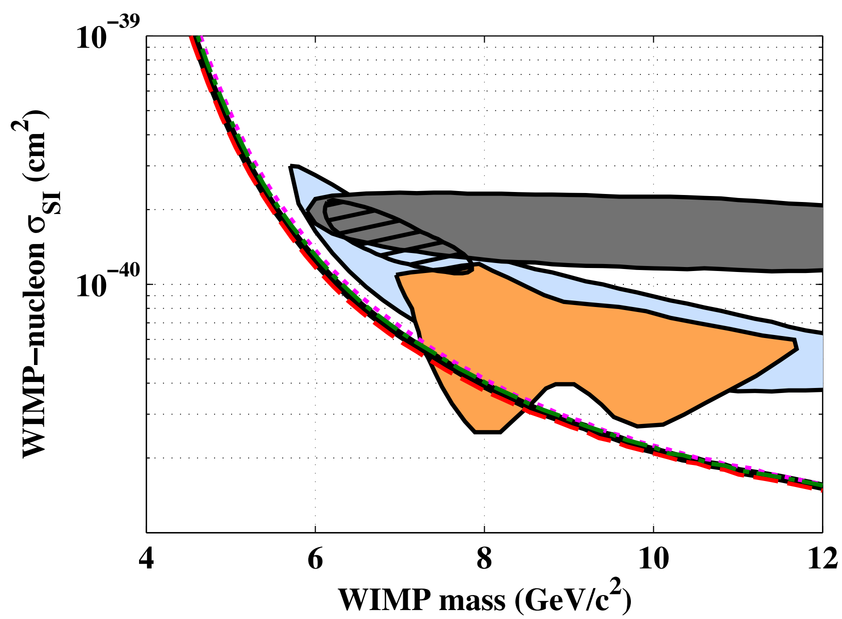
- Phonon and charge channels opposite
- Yield and phonon/charge timing
- Above 10 keV "perfect" ER/NR separation
- Surface events dominate background contribution → need timing cut!

(Z. Ahmed et al. (CDMS) Science **327** 1619 (2010))

CDMS-II Low WIMP Mass Results (1)

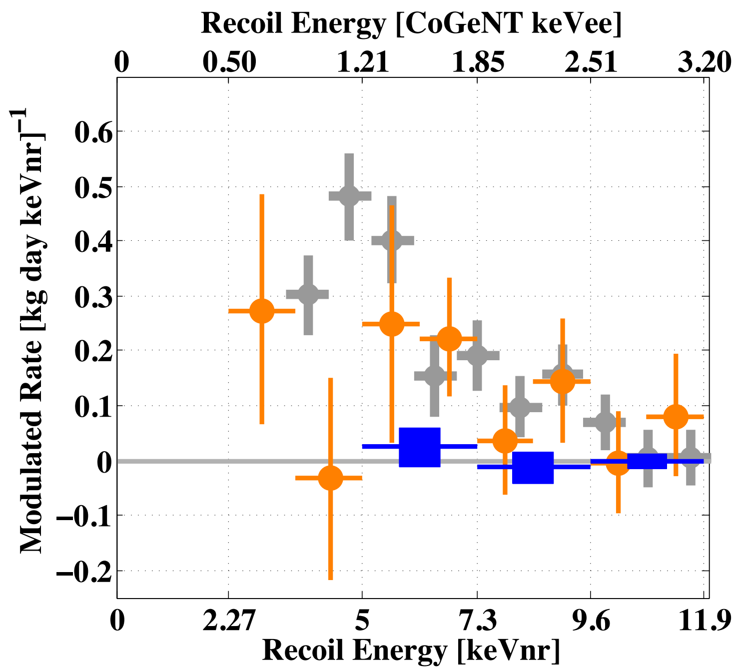
- Results from a Low-Energy Analysis of the CDMS II Germanium Data
  http://arxiv.org/pdf/1011.2482v3.pdf

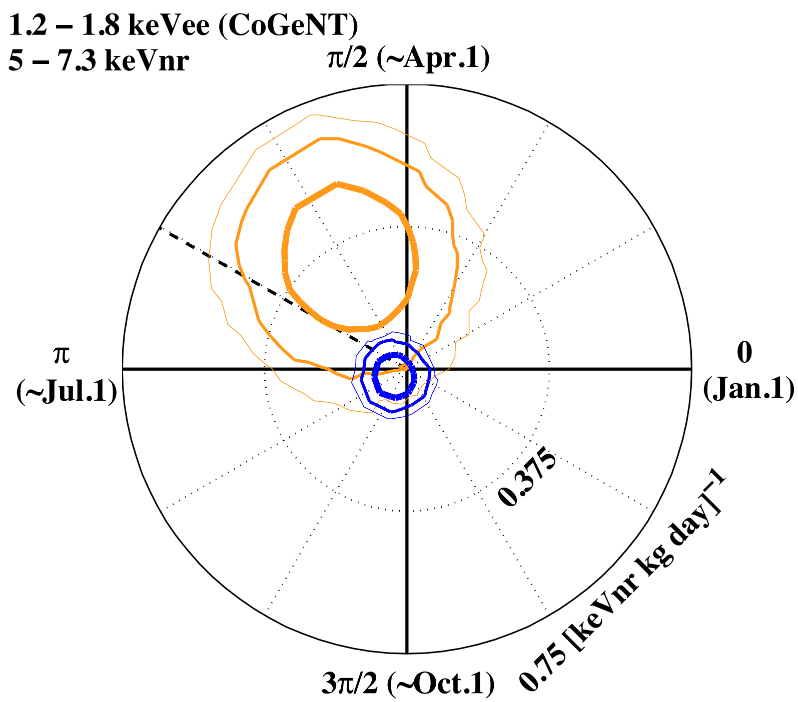




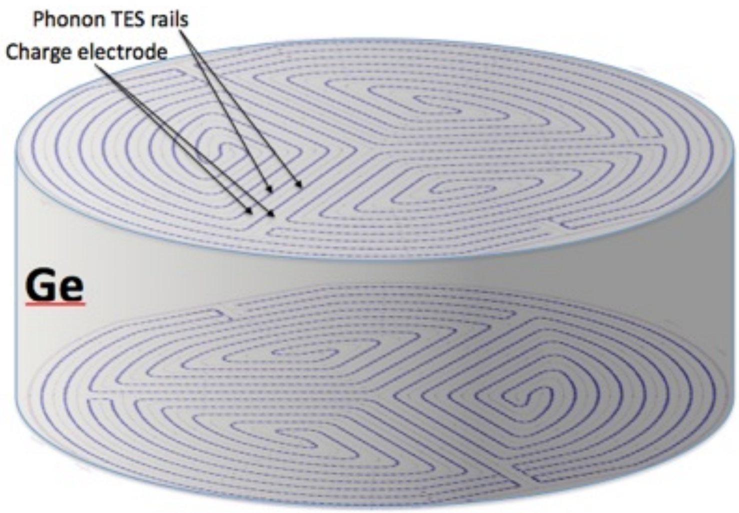
CDMS-II Low WIMP Mass Results (2)

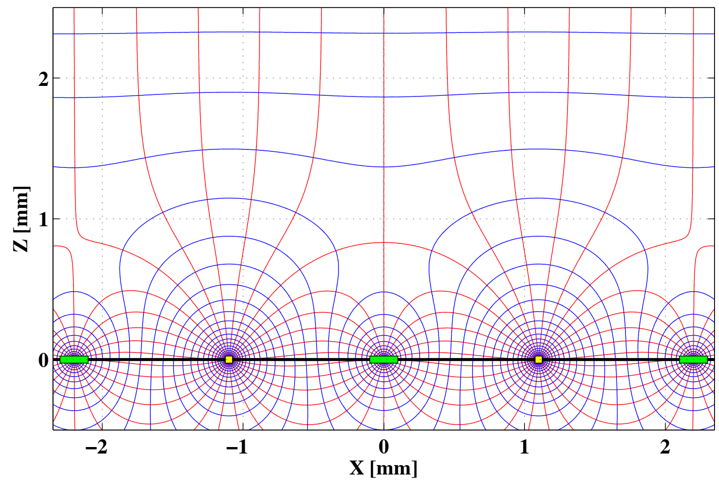
- Search for annual modulation in low-energy CDMS-II data http://arxiv.org/pdf/1203.1309v1.pdf

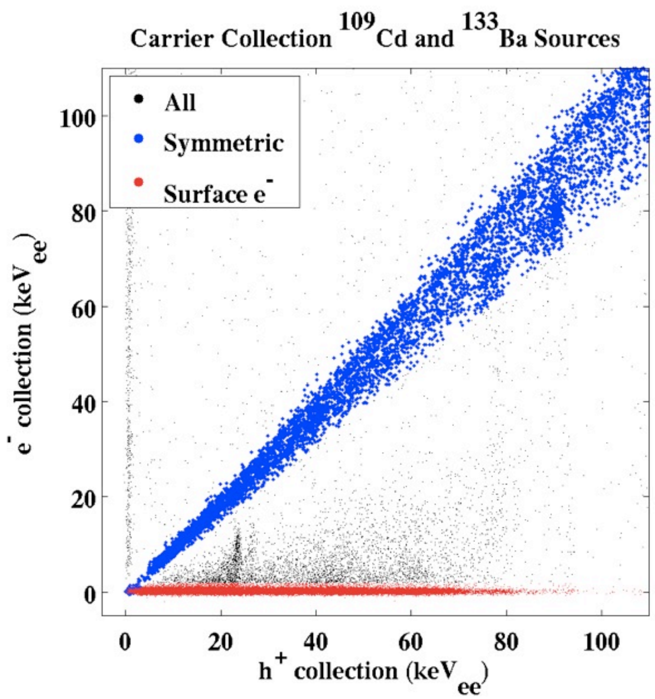


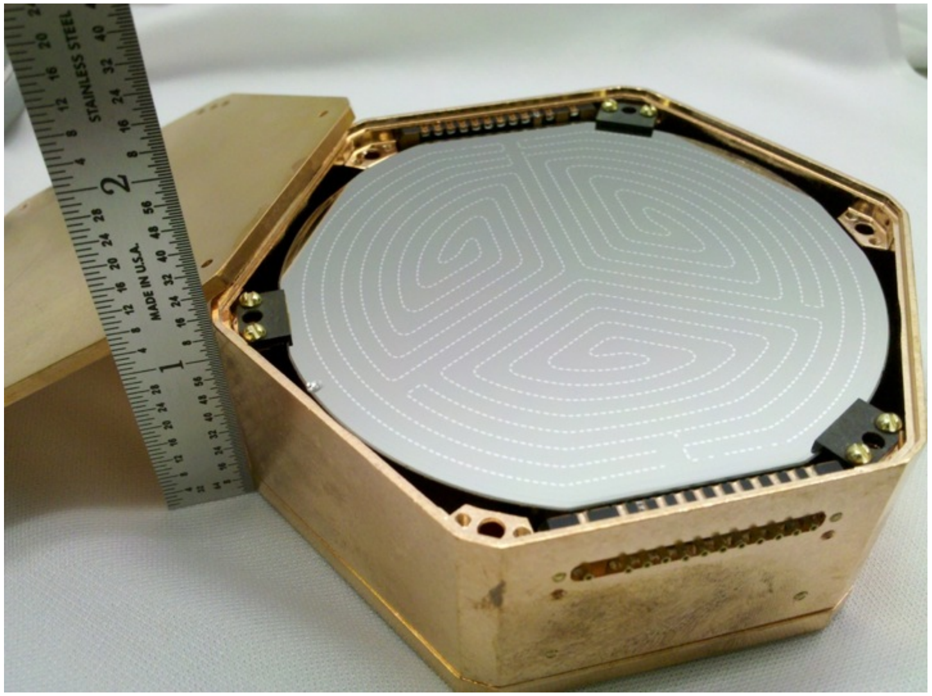


SuperCDMS Soudan IZIP (15 = 9 kg)

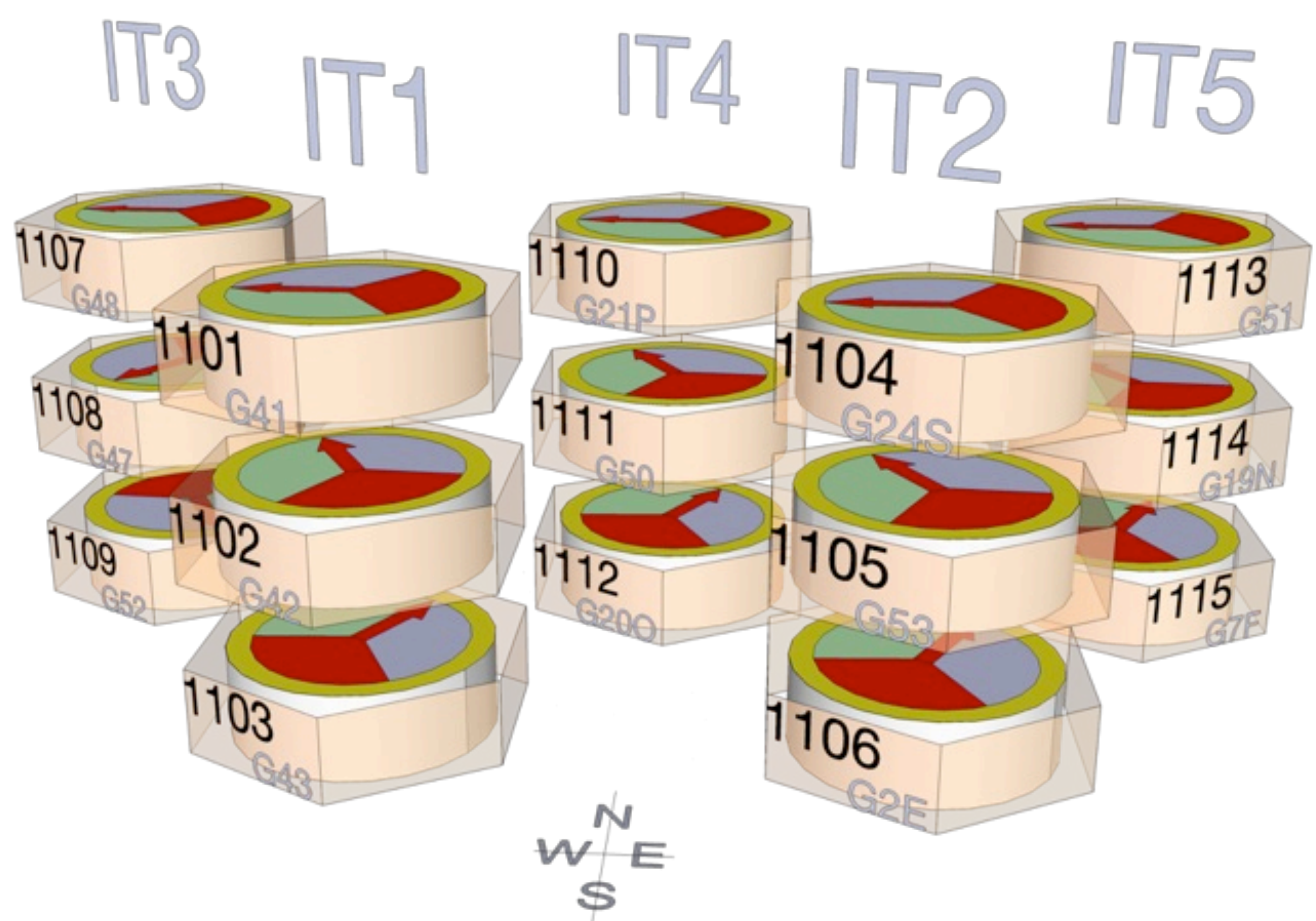






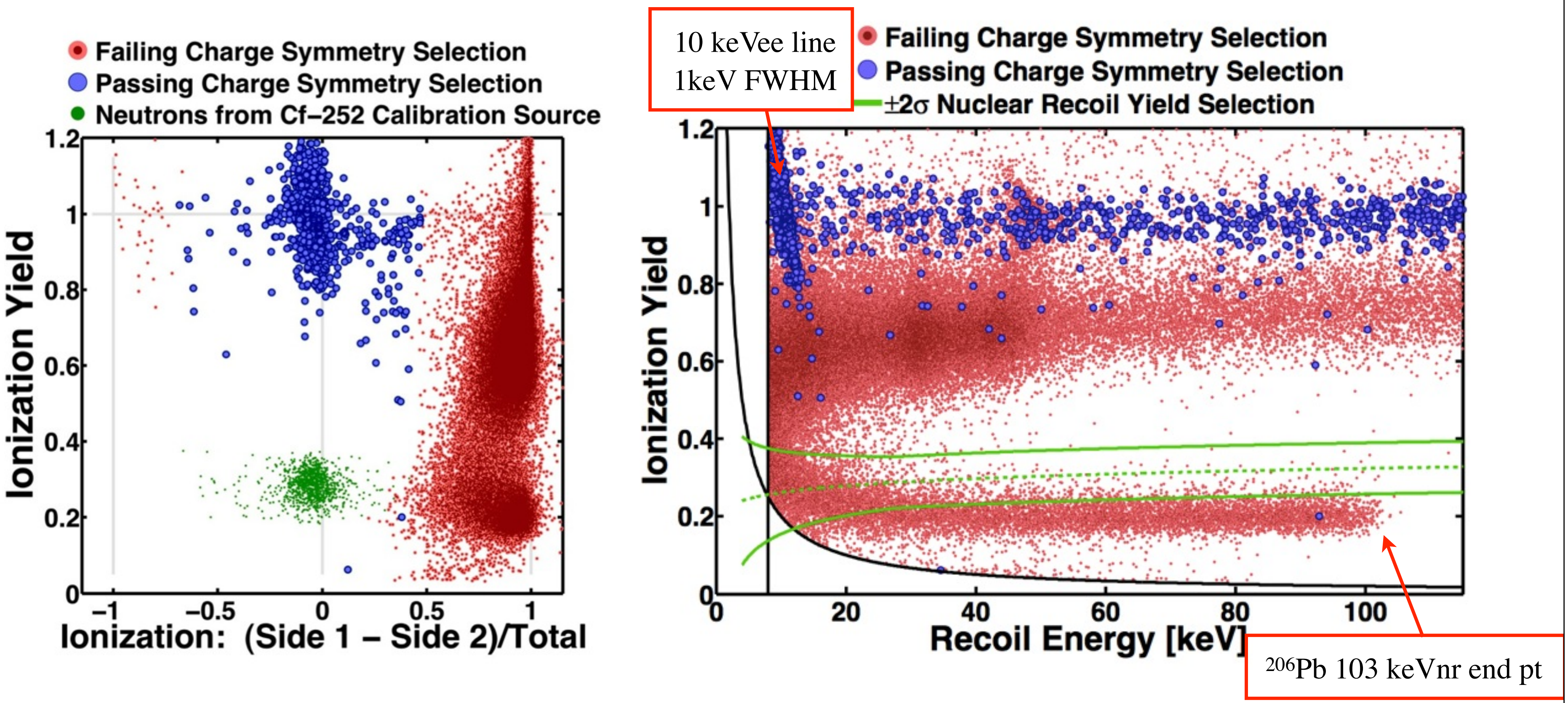


Configuration for up to 3 yr run to Mar 2015



Pb210 Source Data from SuperCDMS Soudan

- Two detectors with one Pb210 decay every min operated for 20 live days corresponds to more than total Pb210 events for SuperCDMS Soudan and even for future 200 kg SuperCDMS SNOLAB



(3) Backgrounds

- SuperCDMS Soudan

Background (10-100 keV)	Total Vol (evt/keV/kg/d)	Fiducial Vol (evt/keV/kg/d)
gamma	NA	3.3E+00
beta + Pb recoils	9.7E-03	<2.8E-07
radiogenic neutrons	NA	2.2E-06
cosmogenic neutrons	NA	1.6E-04

- SuperCDMS SNOLAB

Background (10-100 keV)	Improvement	comment
gamma	2E+02	reducing radioactivity
beta + Pb recoils	1.3E+00	decrease surface/volume ratio
radiogenic neutrons	1E+01	reducing radioactivity
cosmogenic neutrons	6E+02	three times deeper site

(4) Detector Discrimination

- SuperCDMS Soudan

Background	Total	Fiducial	Energy	Comments
gamma	NA	>5(7) sigma	10(100) keVee	ionization yield
beta + Pb recoil	6E-06	2E-01	10-100 keVr	FV + single det hit
radio n's	NA	6E-01	10-100 keVr	single detector hit
cosmo n's	NA	2E-03	10-100 keVr	single det hit + veto

- SuperCDMS SNOLAB

Background (10-100 keV)	Improvement	comment
gamma	NA	no improvement needed
beta + Pb recoils	2E+00	measure existing rejection
radiogenic neutrons	2E+01	singles/multiples + veto
cosmogenic neutrons	NA	no improvement needed at three times deeper site

(5) Energy Threshold

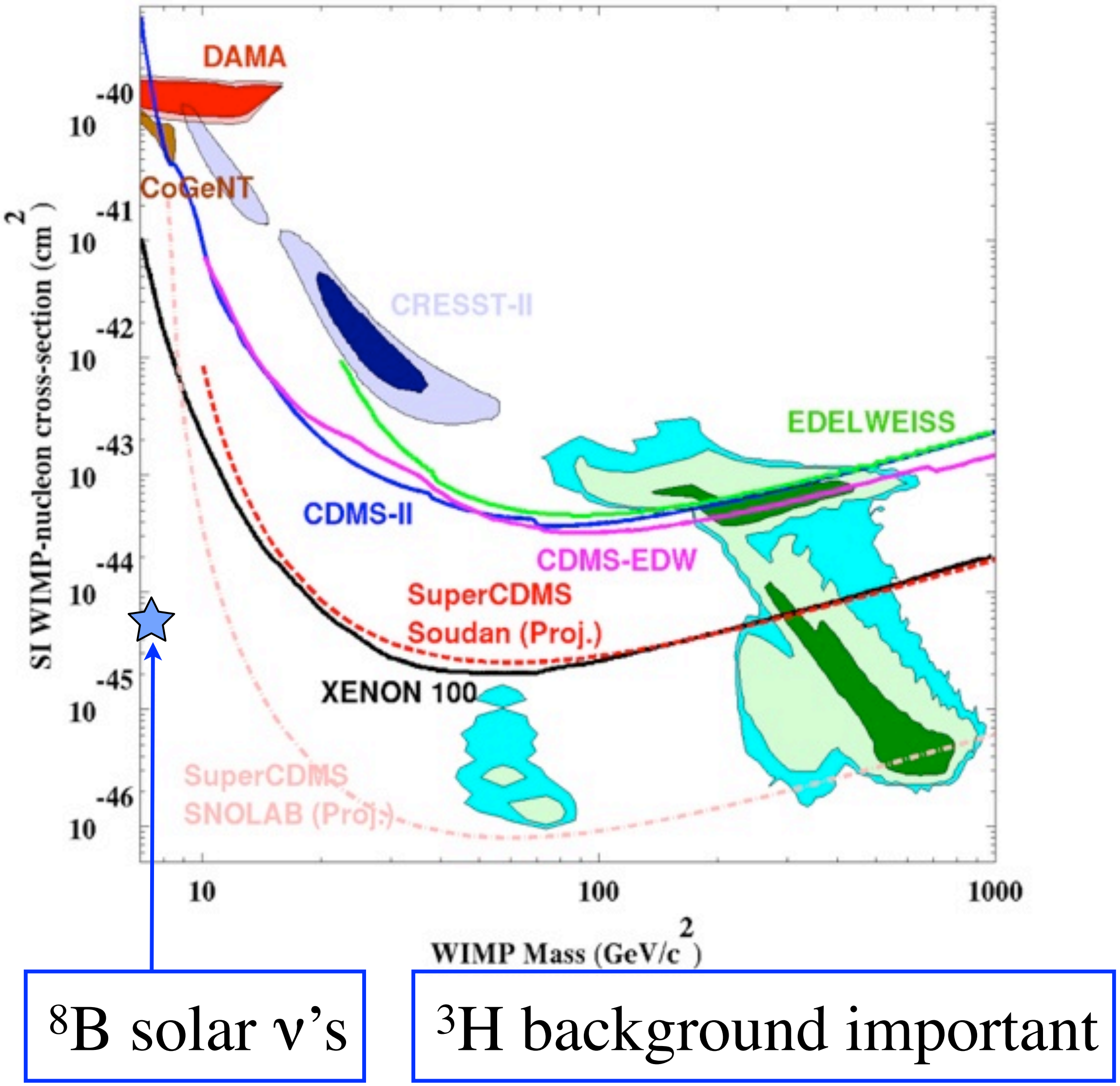
- SuperCDMS Soudan

Energy thresholds	trigger	analysis
electron recoils (standard iZIP)	2 keV (50% efficiency)	6 keVee (>90% efficiency)
nuclear recoils (standard iZIP)	4 keV (50% efficiency)	10 keVnr (>90% efficiency)
nuclear recoils (phonon only iZIP)	2 keV (50% efficiency)	2 keVnr (50% efficiency)
electron recoils (CDMSlite)	0.1 keV (50% efficiency)	in progress
nuclear recoils (CDMSlite)	0.7 keV (50% efficiency)	in progress

- SuperCDMS SNOLAB can use similar threshold specifications but expect improvements

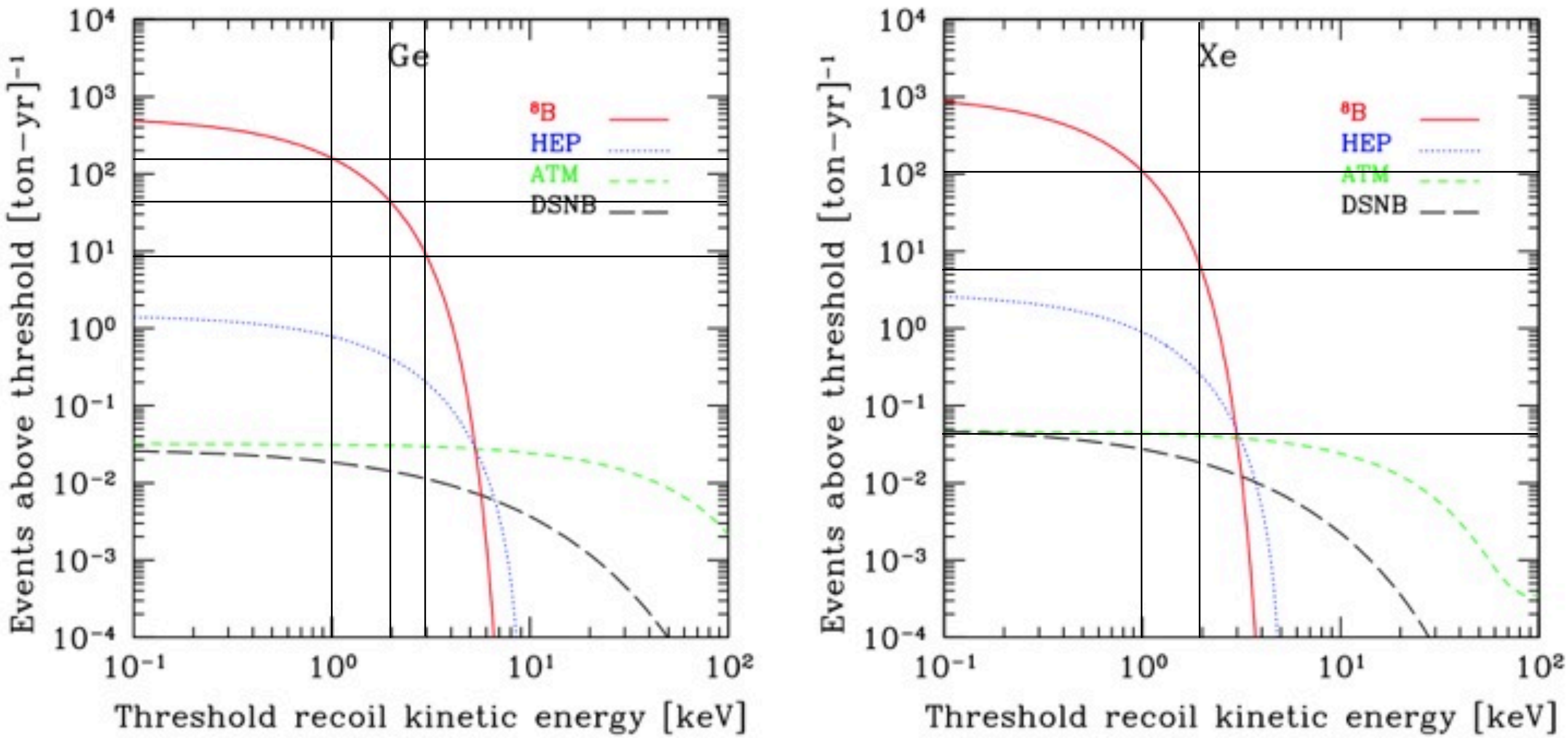
(6) WIMP Sensitivity - experiments & theory

- CDMS II Soudan (blue solid)
- EDELWEISS II (green solid)
- CDMS-EDELWEISS (magenta)
- XENON100 (black solid).
- CRESST II signal: 1-sig (dark purple), 2 sig (light purple).
- DAMA signal: 90% C.L. (red), and 99% C.L. (dark red).
- CoGeNT signal (orange).
- cMSSM regions (with recent LHC and Higgs constraints) at 68%, 95%, and 99% C.L.
- Sensitivities for 3-yr G1 SuperCDMS Soudan (red)
- Proposed 4-yr G2 SuperCDMS SNOLAB 200kg experiment.



Community should promote ^8B signal

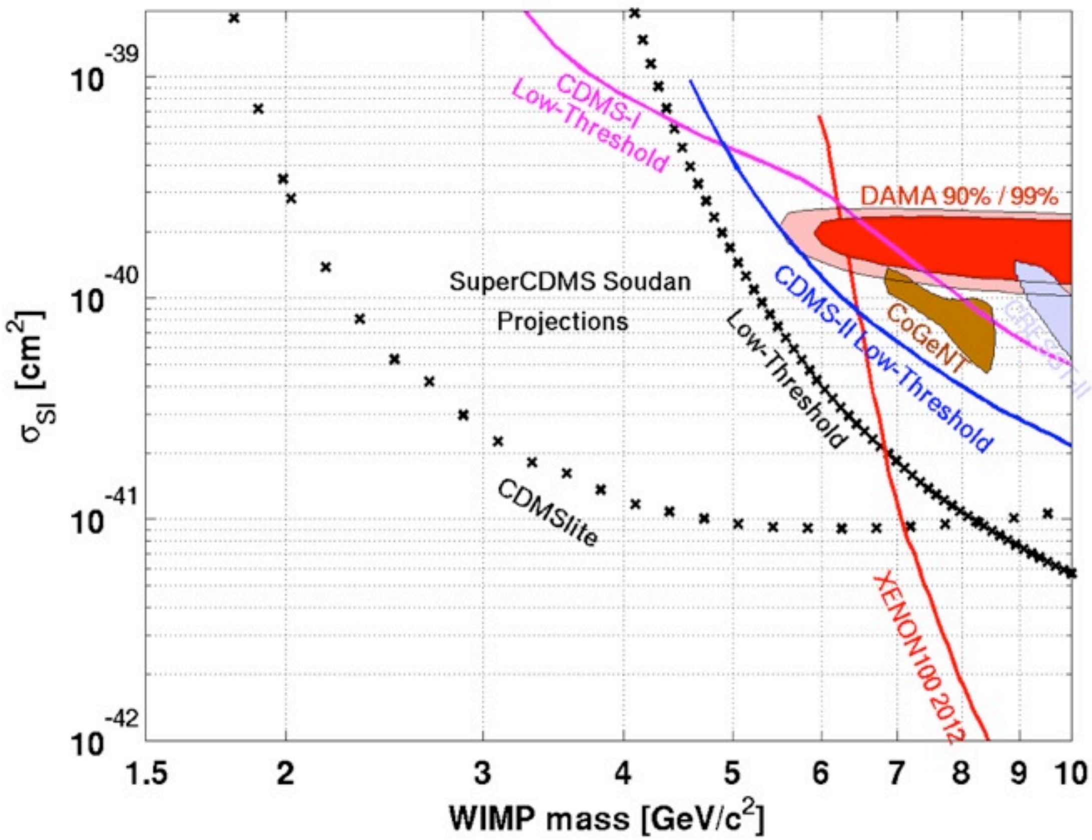
- from Louis Strigari [http://arxiv.org/pdf/0903.3630v2.pdf]



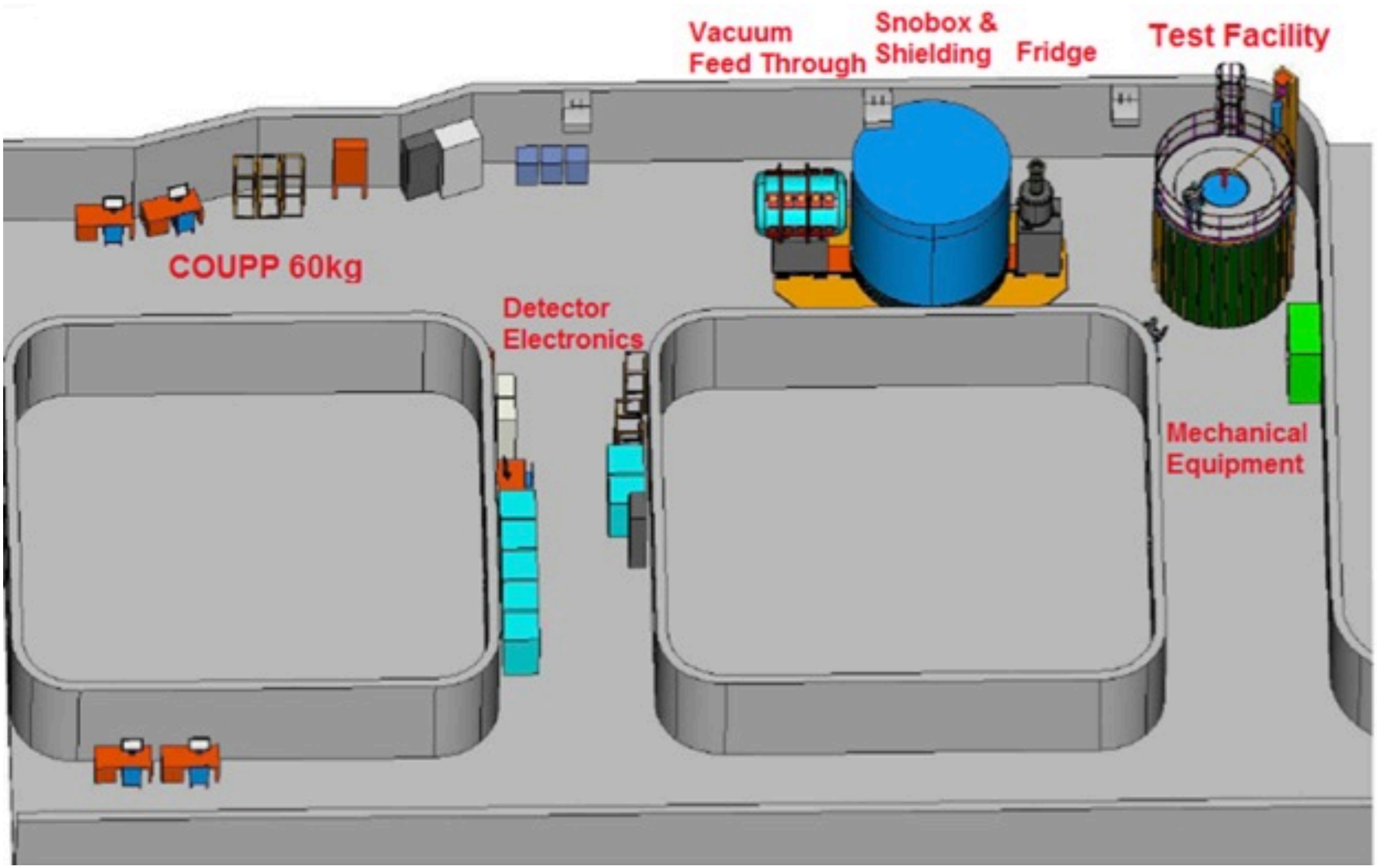
- for 0.3 t-y Ge have 46, 12 & 3 evts above 1, 2 & 3 keVnr

(6) Sensitivity for Low Mass WIMPs

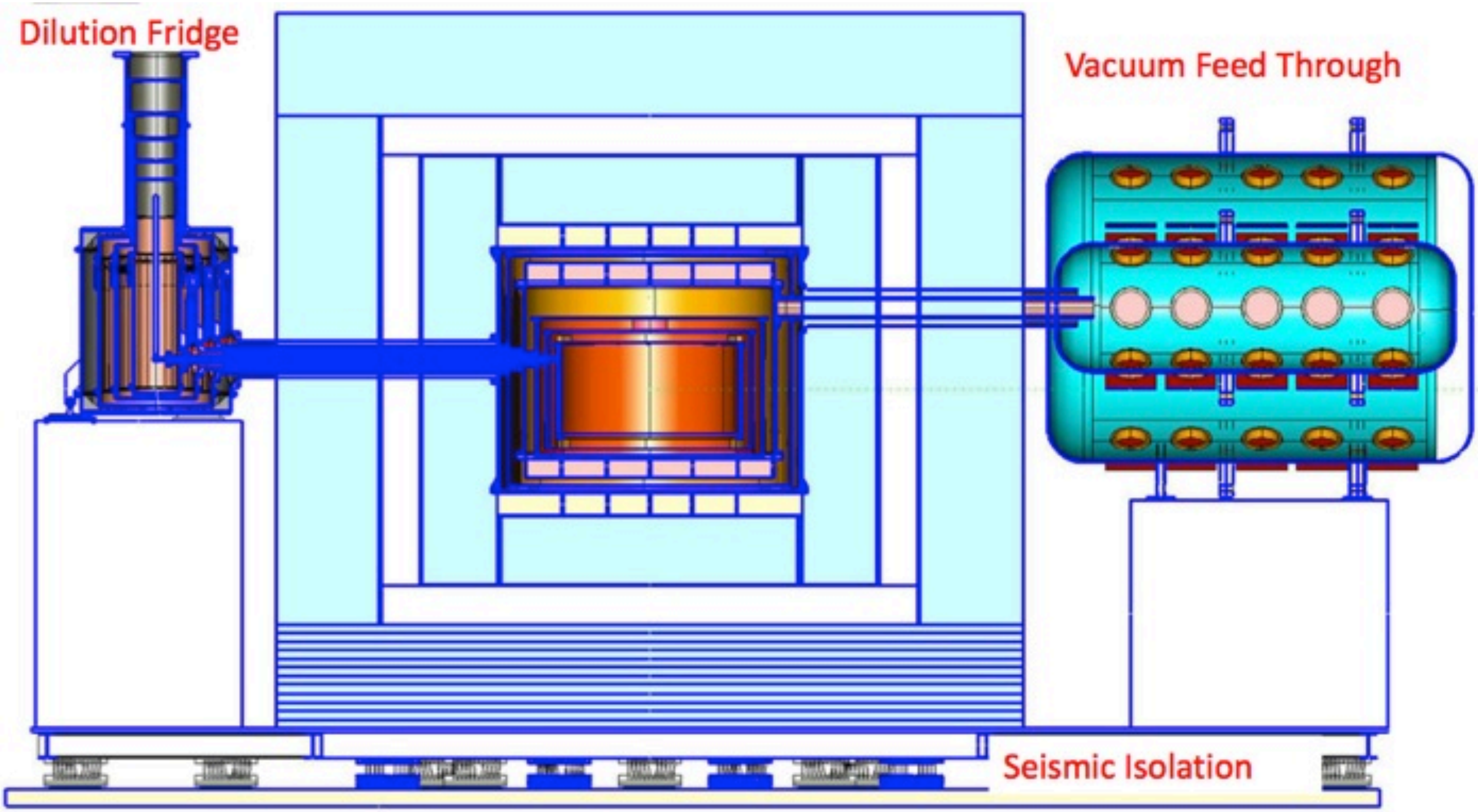
- CDMS I SUF (magenta)
- CDMS II Soudan (blue solid)
- CRESST II signal: 2 sig (light purple).
- DAMA signal: 90% C.L. (red), and 99% C.L. (dark red).
- CoGeNT signal (orange).
- XENON100 2012 (orange)
- Projected sensitivity for phonon only analysis of standard data (black crosses) in SuperCDMS Soudan.
- Projected sensitivity for high voltage operation of CDMSlite (black dashes) in SuperCDMS Soudan.



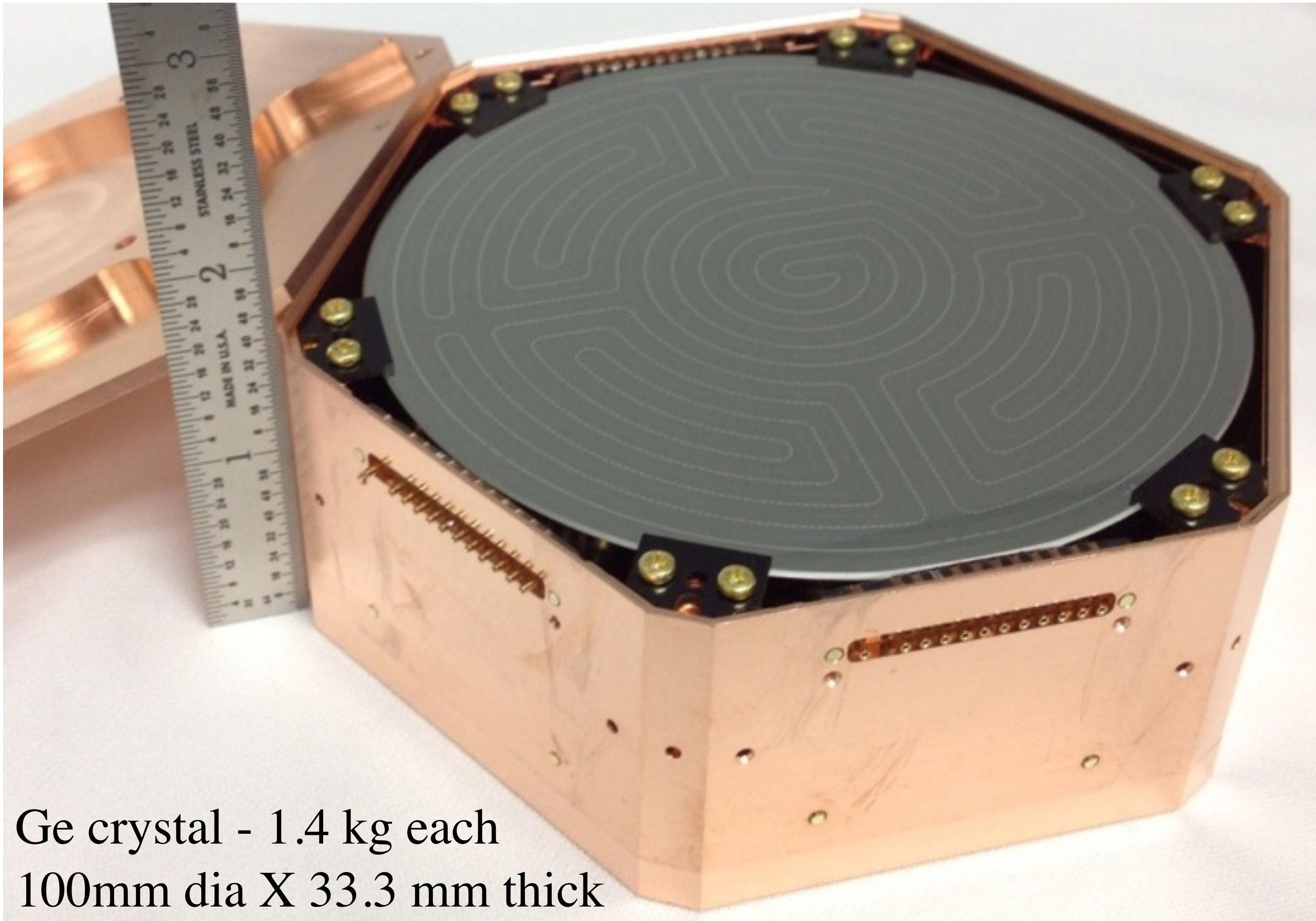
Planned layout for SuperCDMS SNOLAB



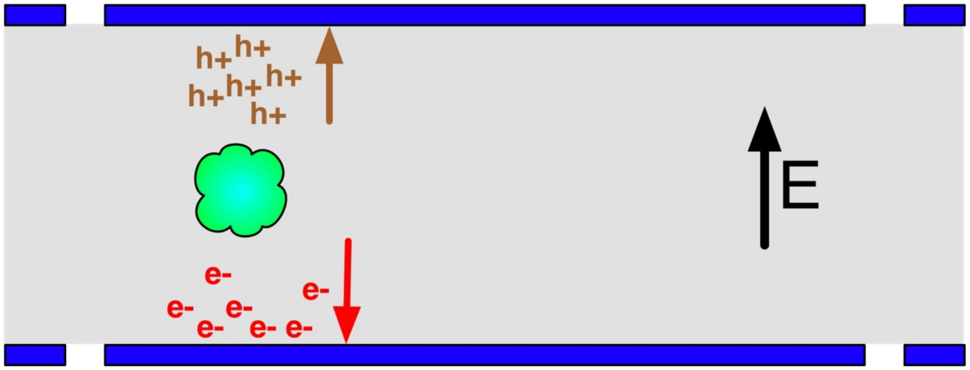
Conceptual Cryo Design



G2 SuperCDMS SNOLAB Detectors



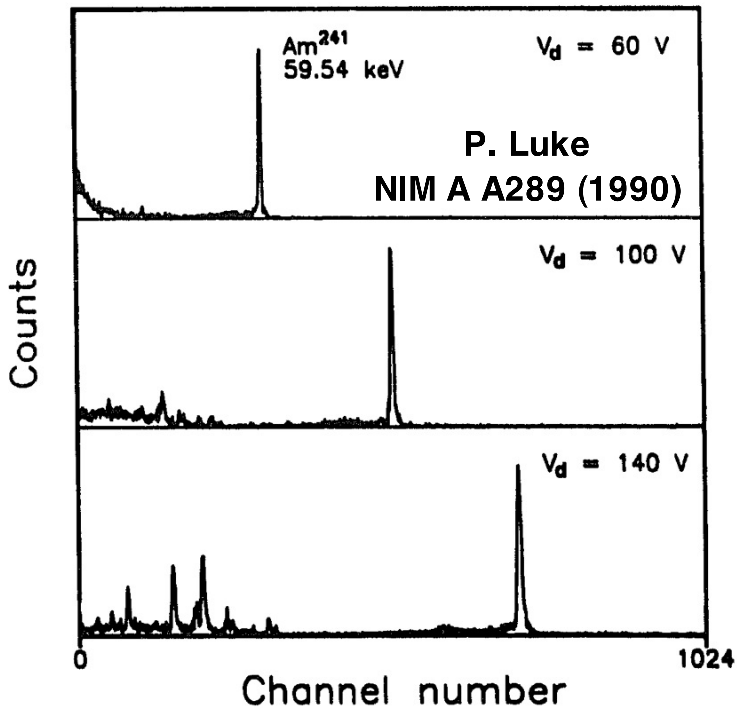
Measure Single Electron-Hole pairs



- **Luke**-Neganov Gain

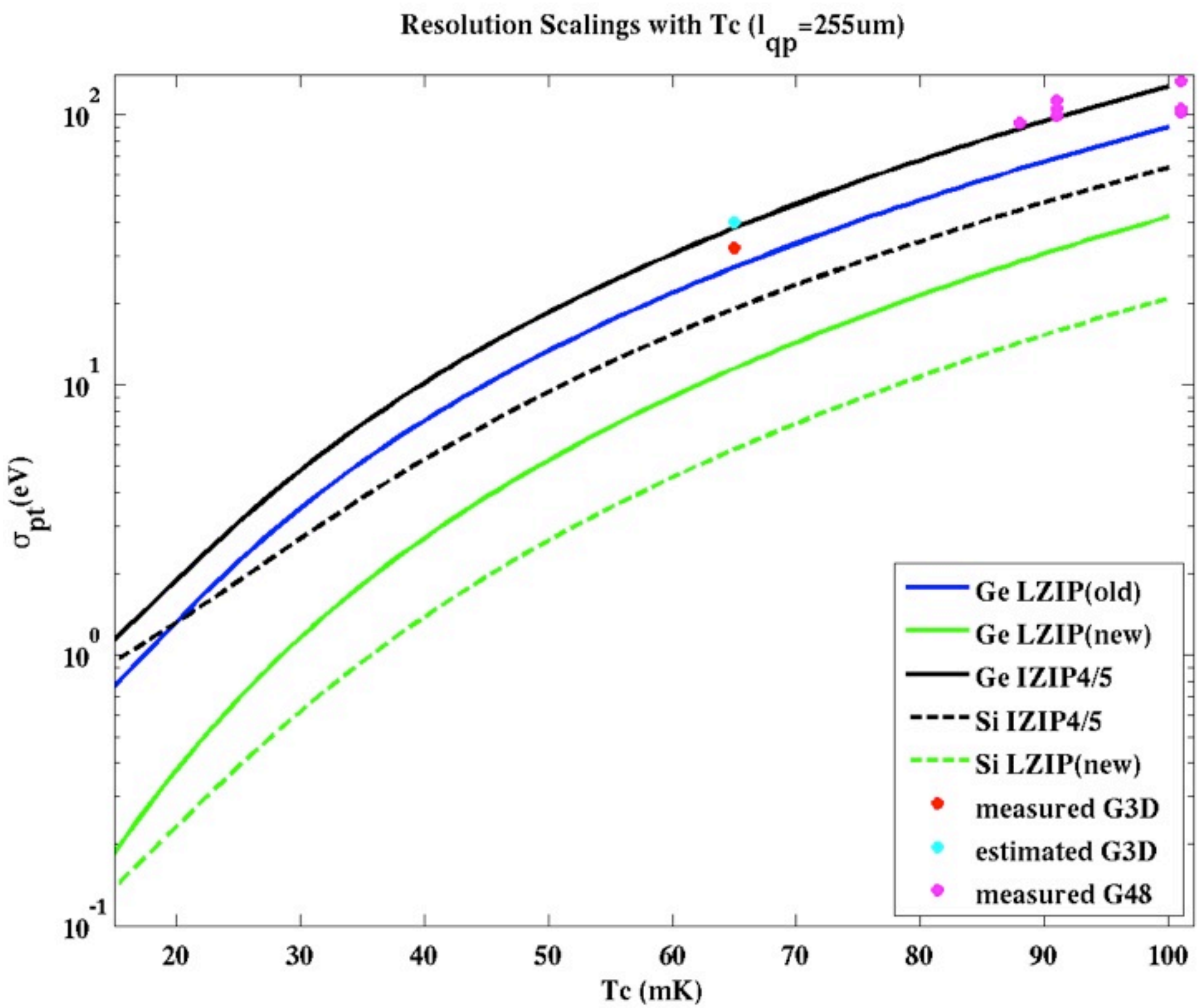
$$
\begin{aligned}
E_{tot} &= E_r + E_{luke} \\
&= E_r + n_{eh} e V_b \\
&= E_r \left(1 + \frac{eV_b}{\epsilon_{eh}}\right)
\end{aligned}
$$

- Field Emission
  - $E_b < 25$V/cm
  - $V_b < 75$V for 1” **(best measurement)**
- **Requirement: $E_{trigger}$ ~ 50eV**



Phonon Energy Resolution Estimates

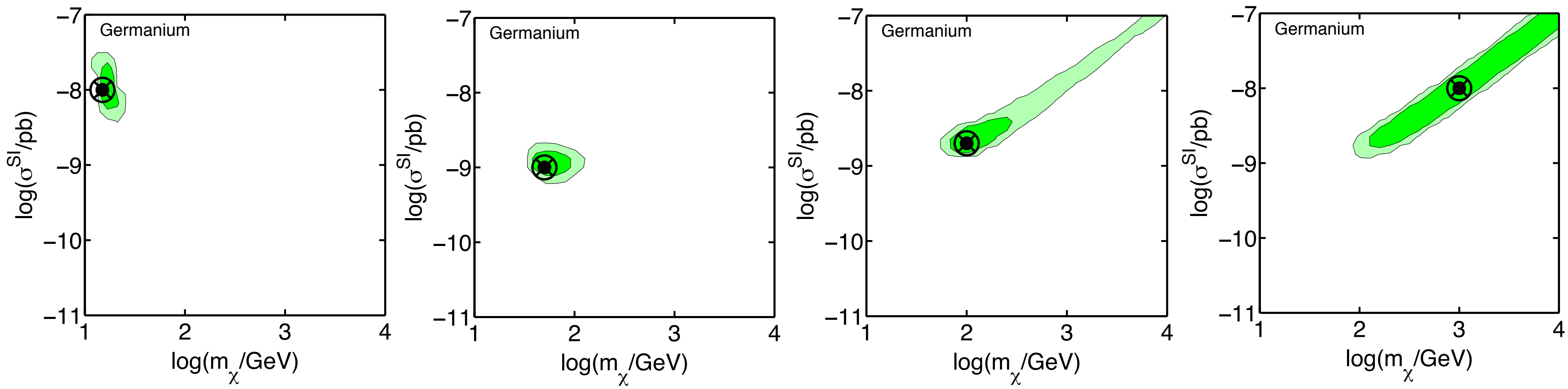
- $\Delta E \propto T_c^3$
- T_c= 20mK: x125 better than CDMS!
- Engineering Hurdles
    - IR loading
    - 20mK W T_c



- Single Excitation Sensitivity Should Be Possible

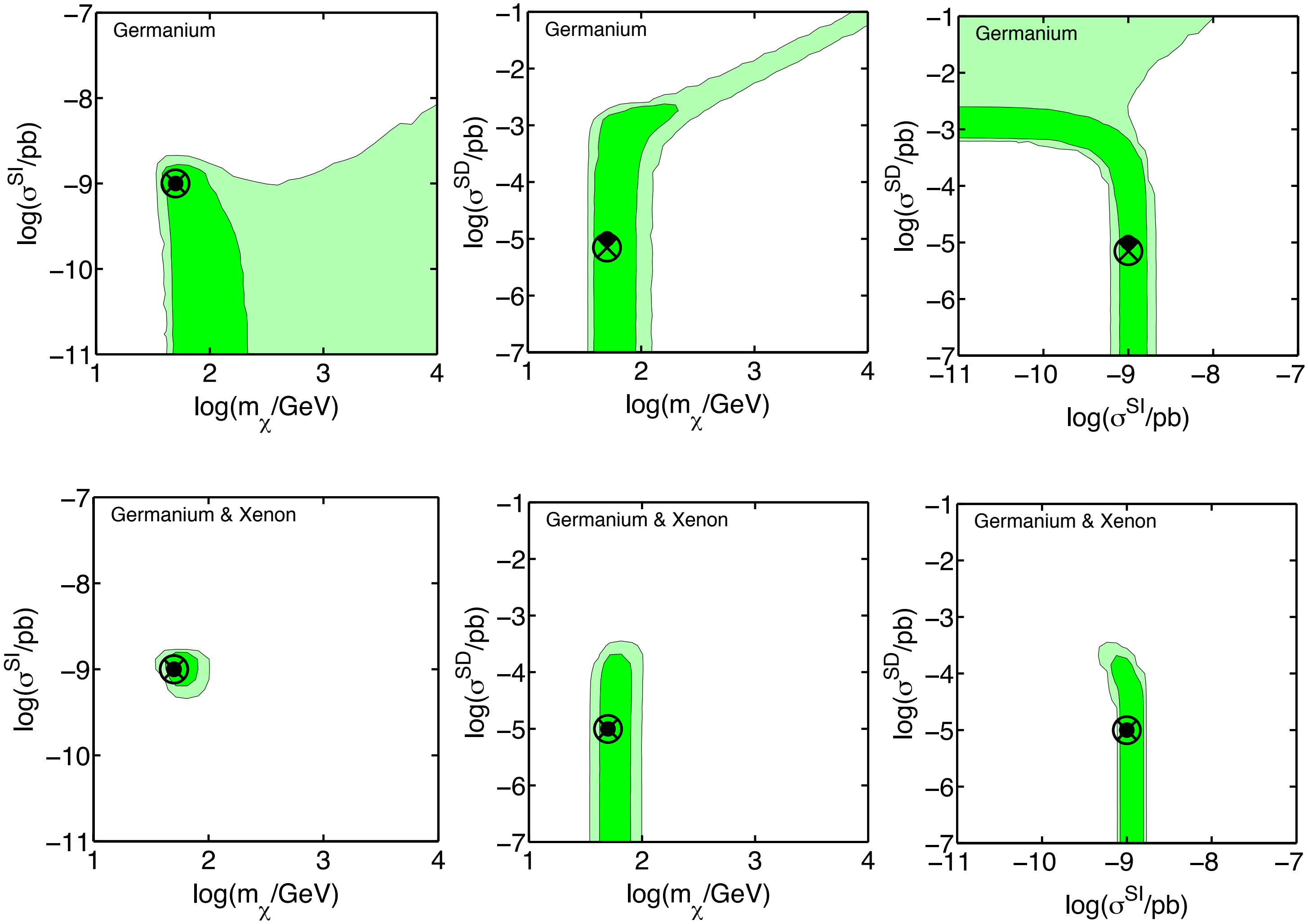
(10) Determine WIMP Parameters

- These four figures show reconstructions for SI interactions of m_W = 15, 50, 100, 1000 GeV/c^2 in a Ge detector with an exposure of 300 kg-yr. The assumed SI cross sections are 10^{-8} pb, 10^{-9} pb, 2×10^{-9} pb, and 10^{-8} pb respectively with the SD=0. Such particles would produce 44, 41, 73, and 54 events respectively. The threshold is 10 keV and include 0.4 event background. The two contours shown are for 69% and 95% C.L., and these plots do not have astrophysical uncertainties included.



Stronger Reconstruction with Ge & Xe

- Benchmark point with m_W = 50 GeV, $\sigma_{SI}=10^{-9}$ pb, $\sigma_{SD}=10^{-5}$ pb, giving 42 evts in Ge and 79 in Xe.



Summary

- The performance of the new iZIP detectors deployed in SuperCDMS Soudan has already proven to be excellent. We expect initial science results in 2013 for light mass WIMPs.
- The science case for WIMP dark matter remains compelling and direct detection experiments are the surest way to establish this case within the Cosmic Frontier community.
- Community should use ^{8}B solar neutrinos as calibration and convincing demonstration of sensitivity for WIMPs with G2.
- The CDMS cryogenic Ge technology has consistently shown low backgrounds, and iZIP detectors ensure that surface electron backgrounds are rejected for SuperCDMS Soudan and for G2 200 kg SuperCDMS SNOLAB experiment.
- Exciting possibilities for much lower phonon thresholds and substantial improvements in charge thresholds with HEMTs.