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UC Dark Matter Initiative

Results and Prospects from the Cryogenic Dark Matter Search

CDMS

Low temperature (≈50mK) athermal phonons + ionization
CDMSII 4kg Ge => Recall: Science article March 2010

Low Mass WIMPs

Incompatible with COGeNT claims
Robust result

The future of CDMS

Interleaved ionization read out
SuperCDMS Soudan (10kg)->100kg at SNOLAB-> 1.5 tonne

DUSEL, Homestake (not CDMS)

Marx Committee report, perspectives

Exit 1 minute

The SuperCDMS Collaboration

about 100 collaborators

California Institute of Technology
Z. Ahmed, J. Filippini, S.R. Golwala, D. Moore

Fermi National Accelerator Laboratory
D. A. Bauer, F. DeJongh, J. Hall, D. Holmgren, L. Hsu, E. Ramberg, R.L. Schmitt, J. Yoo

Massachusetts Institute of Technology
E. Figueroa-Feliciano, S. Hertel, S.W. Leman, K.A. McCarthy, P. Wikus

NIST
K. Irwin

Queen's University
C. Crewdon*, P. Di Stefano *, J. Fox *, S. Liu *, C. Martinez*, P. Nadeau *, W. Rau

Saint Olaf College
A. Reisetter

Santa Clara University
B. A. Young

SLAC National Accelerator Laboratory/KIPAC *
M. Asai, A. Borgland, D. Brandt, W. Craddock, E. do Couto e Silva, .G. Godfrey, J. Hasi, M. Kelsey, C. J. Kenney, P. C. Kim, R. Partridge, R. Resch, D. Wright

** new collaborators or new institutions in SuperCDMS*

NSF DOE

Southern Methodist University
J. Cooley, B. Karabuga, H. Qiu

Stanford University
P.L. Brink, B. Cabrera, M. Cherry, L. Novak, R.W. Ogburn, M. Pyle, M. Razeti *, B. Shank*, A. Tomada, S. Yellin, J. Yen*

Syracuse University
M. Kos, M. Kiveni, R. W. Schnee

Texas A&M
K. Koch*, R. Mahapatra, M. Platt *, K. Prasad *, J. Sander

University of California, Berkeley
M. Daal,T. Doughty, N. Mirabolfathi, A. Phipps, B. Sadoulet, D. Seitz, B. Serfass, D. Speller, K.M. Sundqvist

University of California, Santa Barbara
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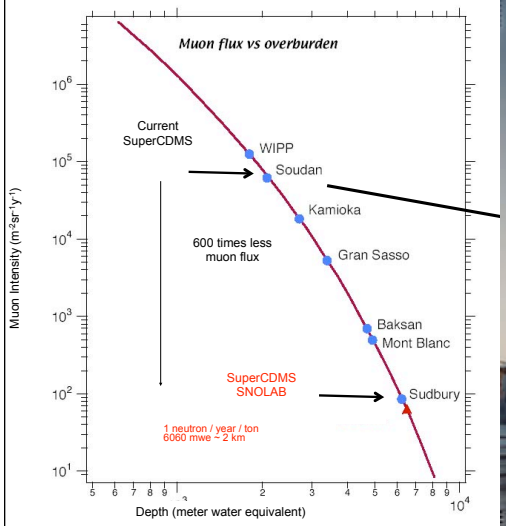
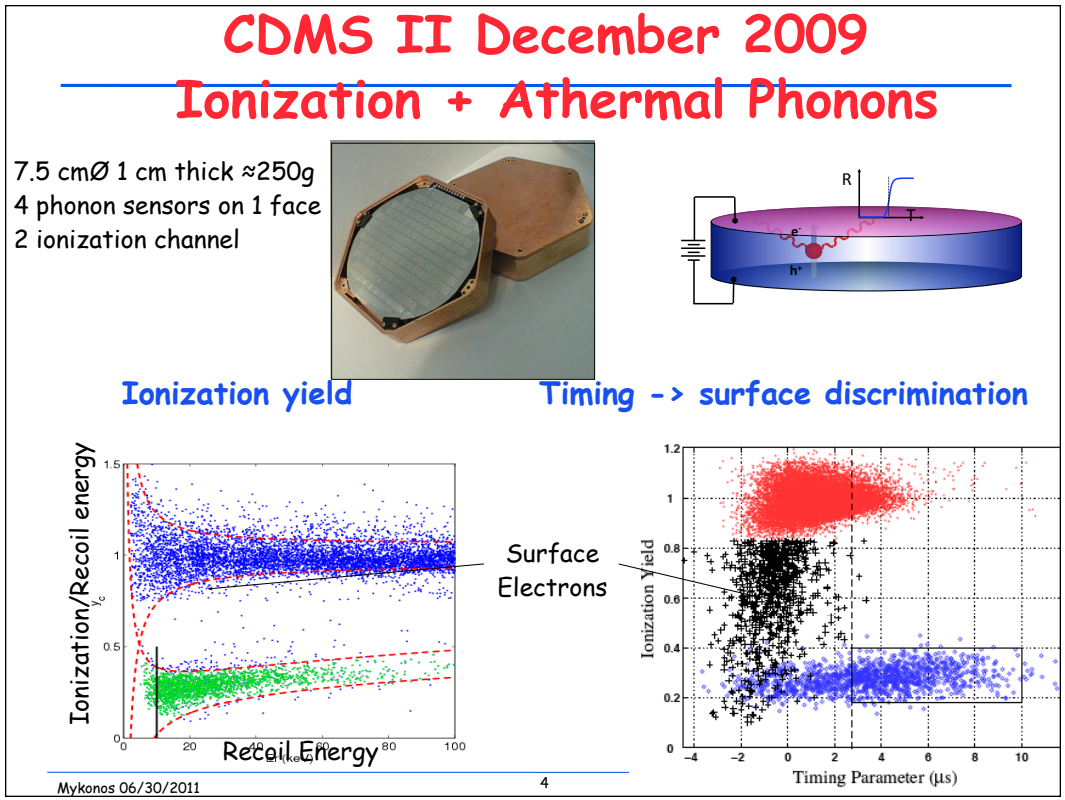
University of Colorado Denver
B.A. Hines, M.E. Huber

University of Florida
T. Saab, D. Balakishiyeva, B. Welliver *

University of Minnesota
H. Chagani*, J. Beaty, P. Cushman, S. Fallows, M. Fritts, T Hoffer*, O. Kamaev, V. Mandic, X. Qiu, R. Radpour*, A. Villano*, J. Zhang

CDMS-II at Soudan (2090 mwe)





Entry 17′

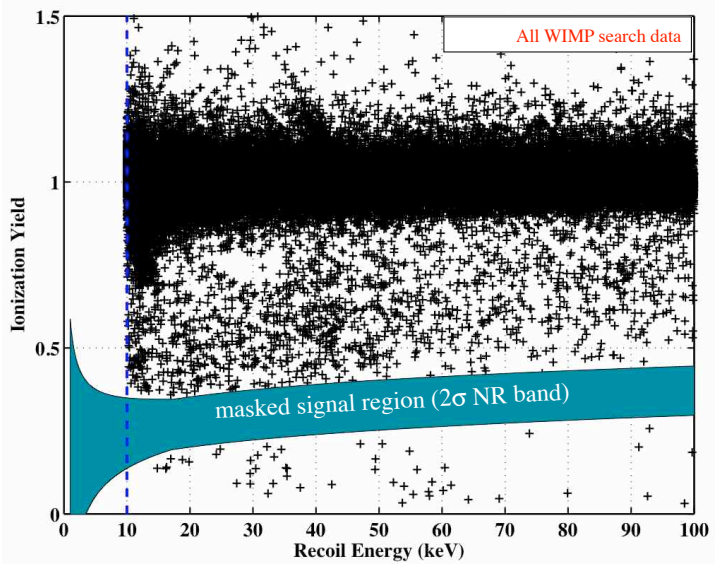
exit 18′

2 levels of discrimination

We set our cuts under a blind analysis using calibration runs with events from a californium neutron source (shown in yellow) and events from a barium photon source (shown in blue). we set our timing cuts so that we expect 0.5 events in the wimps search run in this low-yield region pass the timing cuts. With these stricter cuts, we accept about fifty-three percent of the nuclear recoils.

Exit 14′

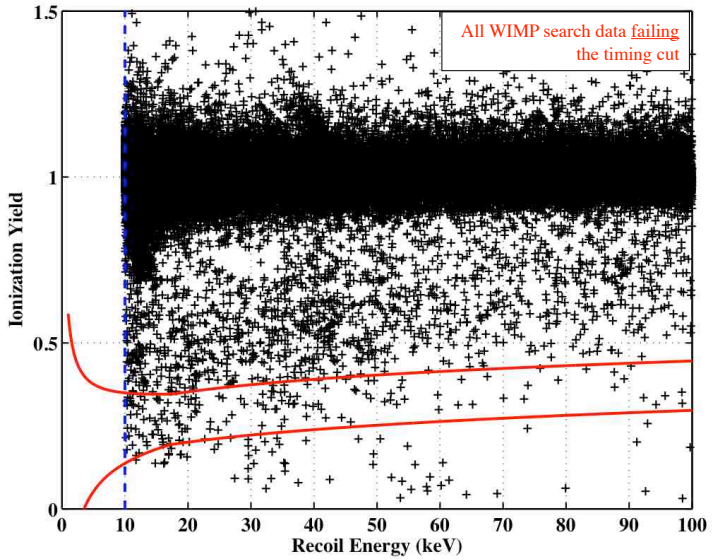
CDMS Blind Analysis



We unblinded the signal region November 5, 2009

Data show all WS data w/ all cuts applied *except* yield and timing (main discrimnation parameters) - explain what ‘all” means!!!

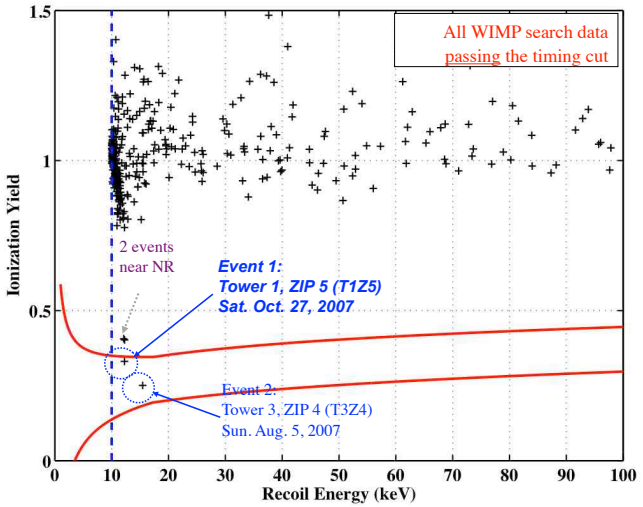
Unblind Events Failing Timing Cut



150 events in the NR band fail the timing cut, consistency checks deemed ok

report number of events in the NR band failing timing cuts

Unblind Events Passing Timing Cut



2 events in the NR band pass the timing cut!

Background 0.8 ± 0.1 (stat) ± 0.2 (syst) surface events

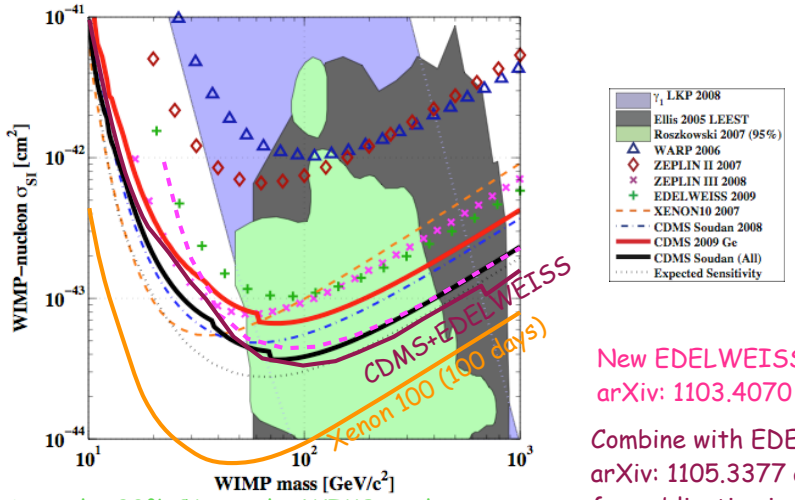
+ 0.1 ± 0.05 (syst) neutron => 23% Probability

click and pause! - especially after event 2 and before event 1

state that the “near miss” are on different detecctors and towers!

90% C.L. Spin-Independent Limit

Science 12 February 2010



New EDELWEISS limit
arXiv: 1103.4070 Johann Gironnet

Combine with EDELWEISS
arXiv: 1105.3377 accepted for publication in PRD

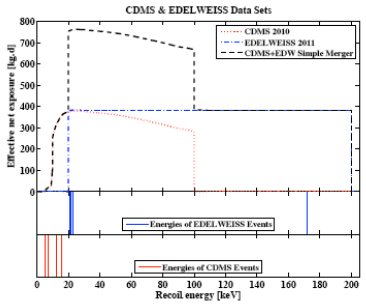
Upper limit at the 90% C.L. on the WIMP-nucleon cross section :3.8×10^{-44} cm^2 for a WIMP of mass 70 GeV/c^2

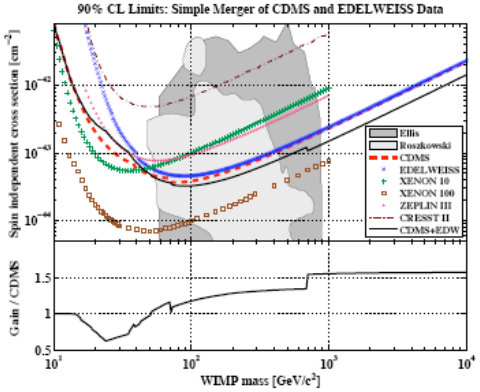
Surpassed of course by Xenon 100 (100 days)
but likelihood profile: some background subtraction

CDMS + Edelweiss

Edelweiss 384kg-days ≈ CDMS 379kg

as good as CDMS at high WIMP mass
obviously combine => increase of sensitivity by 60%
Events from EDELWEISS appear to be background





10’

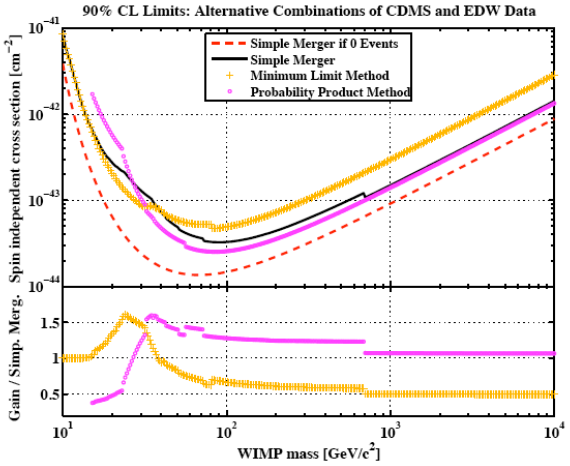
CDMS + Edelweiss (2)

Dependence on statistical method

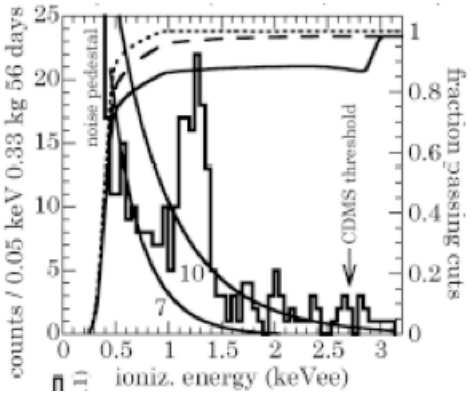
Yellin type methods: optimal interval

(no background subtraction- apply statistical penalty)

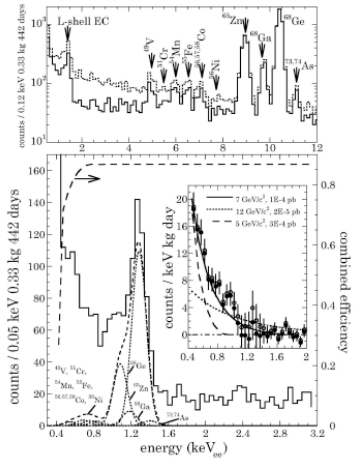
No a priori best method, optimal whatever backgrounds are!



A 7 GeV/c^2 WIMP?



Aalseth et al. ArXiv: 11060650



CoGeNT 440g Ge

Evidence for a signal ?

Detailed shape of the background: very weak!

CRESST?

Raimund Strauss

Hooper, Collar, Hall, McKinsey arXiv 1007.1005

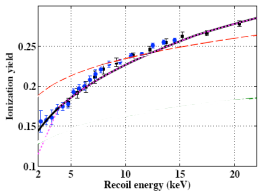
A 7 GeV/c^2 WIMP could explain CoGeNT,DAMA and CRESST!

Start 10’

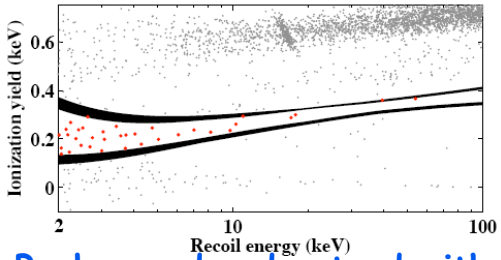
Low threshold CDMS spectra

Method

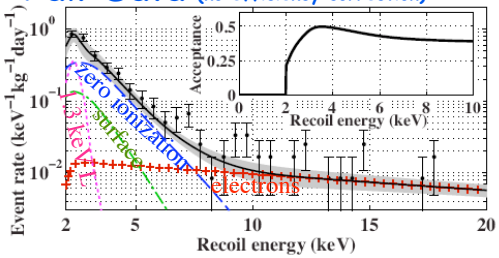
Ionization measurement not good below 5keV
=> Use phonon energy measurement
and correct for extrapolated yield
=> Neganov Luke corrected recoil energy
=> Ionization energy



Nuclear recoil selection



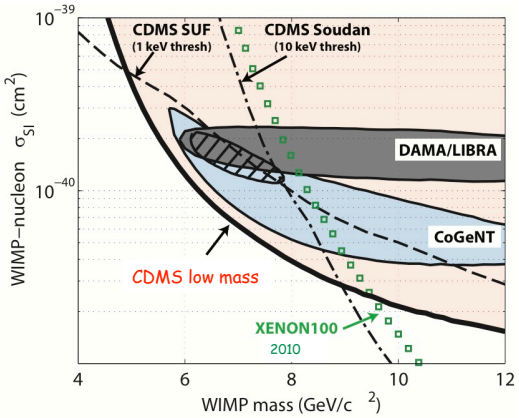
Raw Data (no efficiency correction)



Background understood with 1/4 data

But no subtraction

Alas!



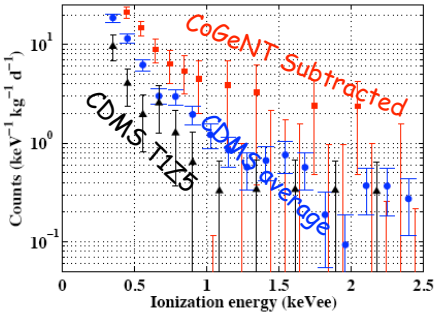
Ahmed et al ArXiv:1011.2482
PRL 2011

Xenon 100 (100d)?
Aaron Manalaysay

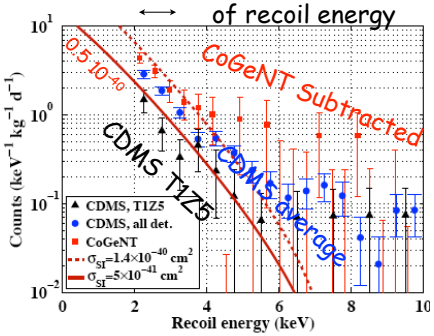
Compatibility with CoGeNT

More exactly:

interpretation by Collar et al.



Would need a 50% underestimate of recoil energy

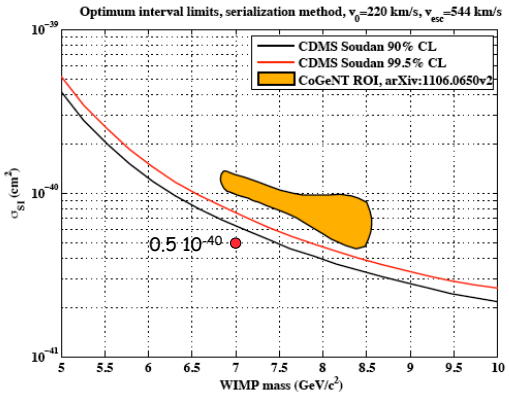


Our best detector is not compatible with CoGeNT

interpretation as a signal (even subtracted)

Same material => a number of possible systematics vanish

Compatibility with CoGeNT (2)



Dominated by 1 detector (T1Z5)

Proper statistical method ("serialized optimal interval" —Yellin) adapted to different backgrounds

Much more powerful than average spectrum where marginally compatible!

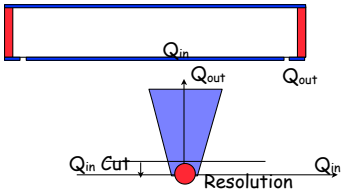
"Zero Ionization Energy" Events

Origin

Bad collection in outer part of detector

Oblique propagation + charging of surfaces

Schematically: created by Q_{in} cut!

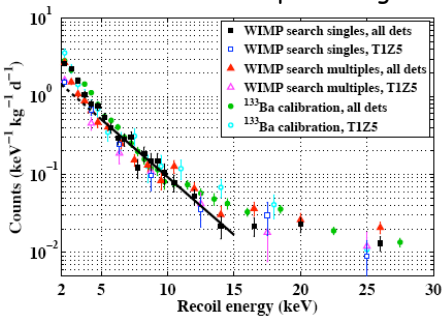


Expect to increase dramatically at low energy

It does!

Cannot be only nuclear recoil ...

Same behavior with multiples and gamma Ba calibration source!

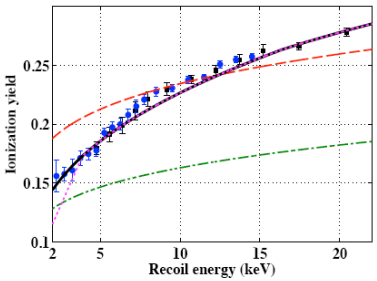


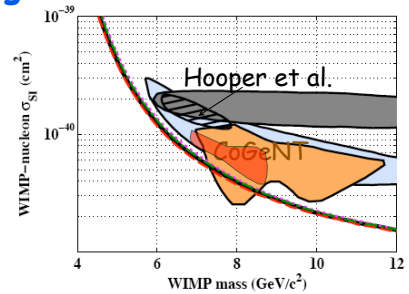
Unlikely: if anything too many evts!

Need more quantitative assessment

Yield and energy

Yield uncertainties are negligible





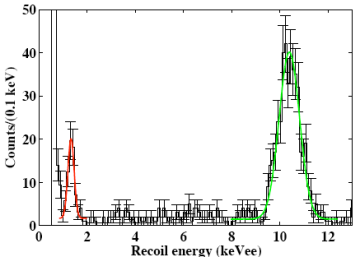
Energy scale for neutrons?

Phonon calibration for electromagnetic recoils <= L+K calibration: Good!

Can nuclear energy be very different?

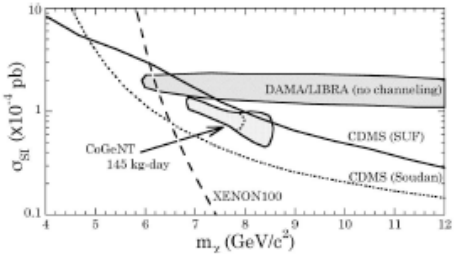
- e.g., pulse shape difference
- No neutron beam calibration!
  - Upper limit from ionization yield comparison: 15% overestimate
  - (e.g., because of pulse shape variation)
  - => would improve our limit
  - Monte Carlo of neutron source spectra: same order of magnitude! << 50% needed

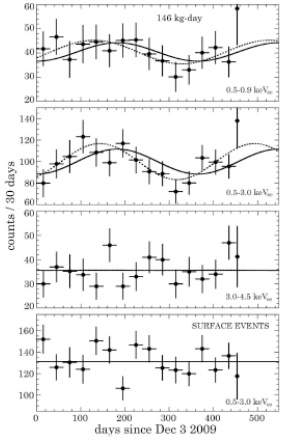
Paper on calibration in preparation



Modulation?

Aalseth et al. ArXiv: 11060650





We (CDMS) are looking!

We believe that our rate result is extremely robust

Stability close to threshold is difficult:

requires stability that we do not readily have: working on it!

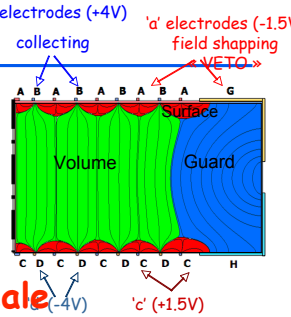
Should not you understand your background before claiming that it modulates?

20’

The future of Ge

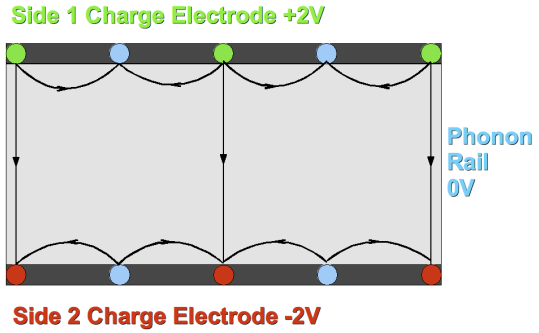
Breakthrough: Interdigitated detectors

Positive and ground electrodes on top side
Negative and ground on negative
=> separate surface (asymmetric) from bulk (symmetric)
CDMS + EDELWEISSS



The surfaces are gone!

Rejection should be good enough-> ton scale



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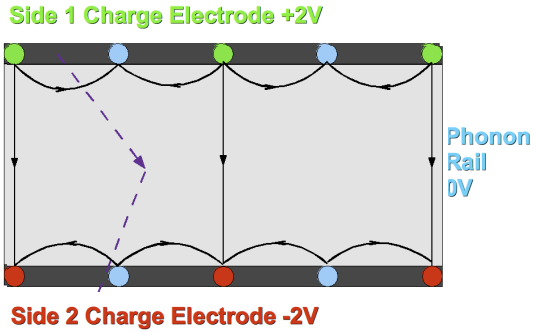
Bulk



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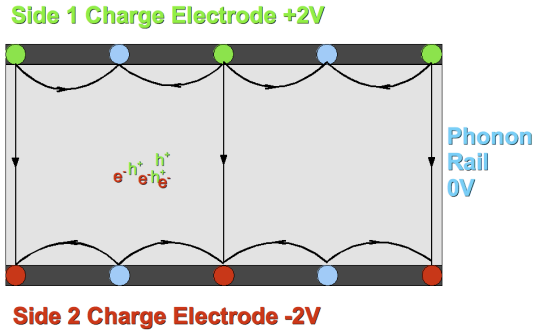

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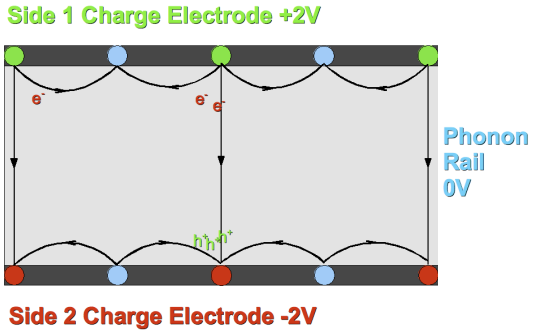

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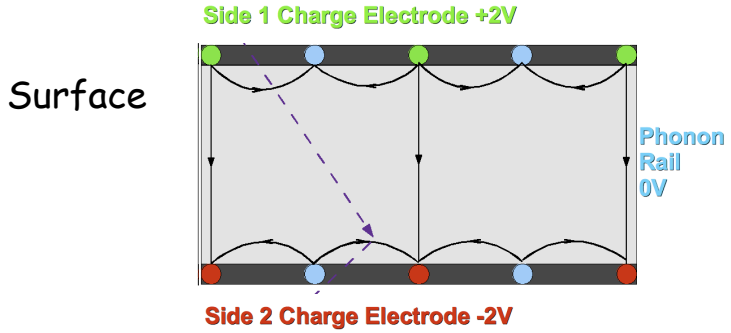

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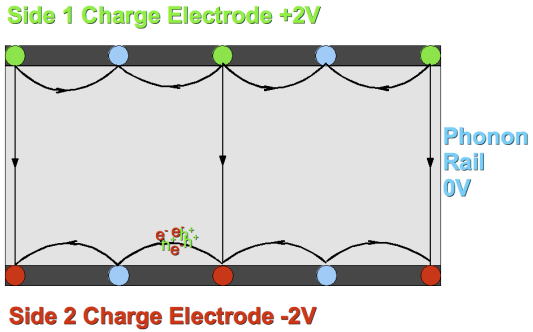
Surface



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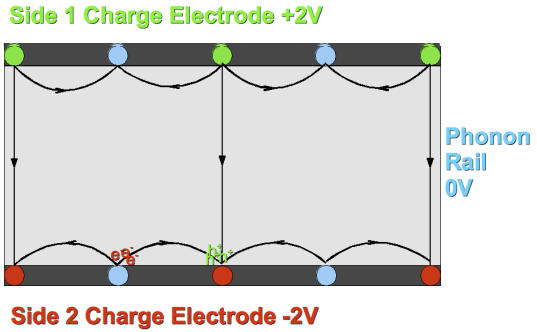


CDMS Plans

SCDMS Soudan 10kg interdigitated

≥15kg previous CDMS

2011-2013->15?: 8-> 5? 10^{-45} cm^2

Depends on neutron background

Similar to current sensitivity of Xenon 100 (100days)

Cross check

+ demonstration of technology for SNOLAB

SCDMS SNOLAB 100kg

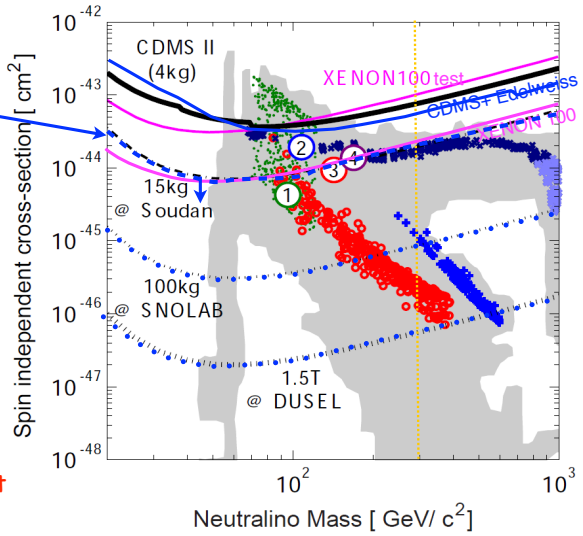
2015-2018 3 10^{-46} cm^2

Part of Generation 2 competition

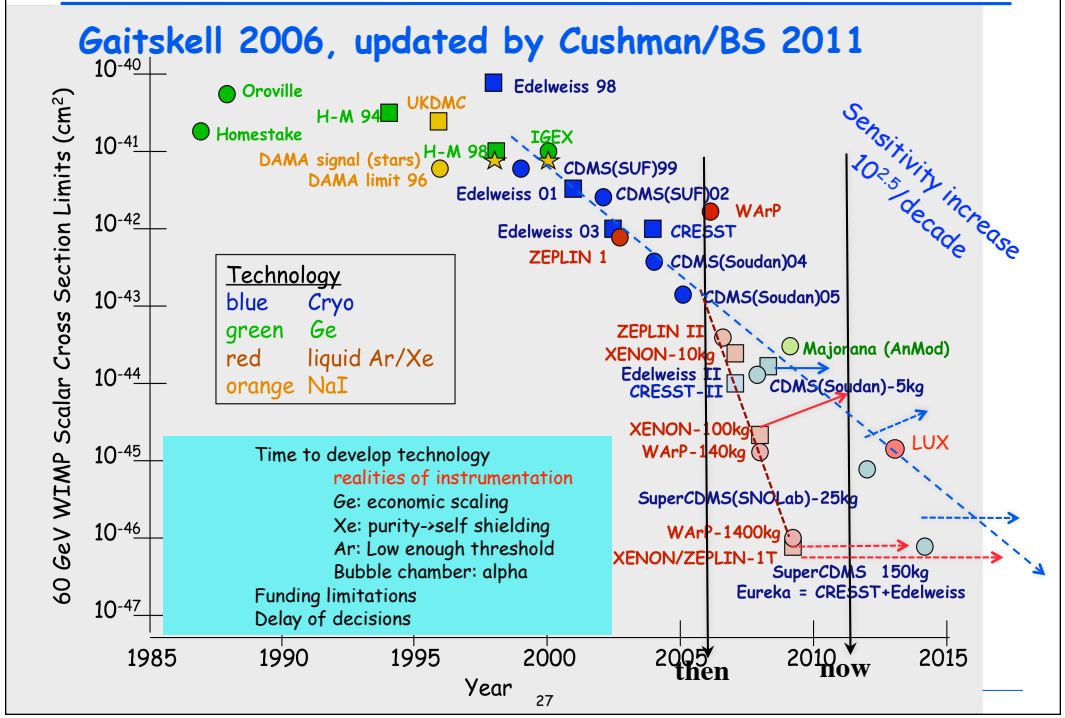
GEODM DUSEL 1.5 tonne

2018?-2022? 2 10^{-47} cm^2

Challenge is to produce detector at low enough cost ($50M + 50% contingency)



Hopes and Progress



Conclusions

Lots of action: nice progress of CDMS, Edelweiss and Xenon 100 (100 days)

But WIMP searches are not yet background free!

Very interested in next results of Xenon 100, LUX and XMASS +SuperCDMS Soudan

Interleaved ionization technology

Should totally get rid of surface

SuperCDMS Soudan : important to see the real life limits

7 GeV/c^2 WIMP

We believe that the CDMS result is very robust

- Little dependence on ionization yield
- Would need phonon yield for nuclear recoil wrong by ≈ 50% (compared to electron recoil): unlikely

Even without background subtraction, incompatible with Collar's claim

- >99.5% incompatible with 10^{-40} cm^2 /nucleon (spin independent Ge)

Not ready to comment about modulation: requires stability that we do not readily have: working on it!

Exciting/challenging path ahead

Interesting physics: LHC disfavors in mSUGRA/CSSM bulk region=> high mass WIMP ?

Direct Detection: Perfect our technologies while pushing the physics frontier.

Ge: main challenge is economics and time to go to large mass

However, the challenge for all technologies is to stay on $10^{2.5}$ sensitivity increase per decade! Of course not a law of physics!

DUSEL and Homestake

Deep underground Science and Engineering laboratory
Being studied by NSF since ≈2000

- S1: scientific importance— site independent, multidisciplinary, nation wide study
- S2-S3: => choice of Homestake
- Preparation of MREFC (≈$50M NSF, ≈$110M South Dakota –including private donor)

Dec 2010: Collapse!

- NSF National Science Board expresses reservation with implementation of the project: do not fund bridge funding... Unhappy about:
  - Costs $850M in 2011 dollars
  - Balance:Too much infrastructure, not enough science
  - Stewardship model: NSF building infrastructure

  - But encourages to rethink the project
- NSF/Office Management of Budget decide not to pursue development
  - Presidential budget of 2011

DOE comes to rescue!

Fortunately, the Department of Energy reacted rapidly:

- Formed a committee (the "Marx-Reichanadter Committee"= "Marx Committee") to consider cost effective options for implementing a world class underground science program.

- Funds are being provided by NSF (FY11) and DOE (proposed FY12) to keep the Homestake 4850 ft level dry and safe through September 2012, while decisions are being made.

Marx-Reichanadter Committee

Report at HEPAP Thursday June 23, 2011

The Marx committee strongly endorses the LBNE, Dark Matter and Neutrinoless Double Decay Science.

Deploying stand alone Dark Matter or double beta decay experiments at Homestake 4850 ft (or a fortiori at 7400) would not be not cost effective.

SNOLAB: likely not enough space at it is: would need extension!

However, in spite of a cost differential (estimated at $100M, to be confirmed) in favor of of SNOLAB:

The presence of LBNE at Homestake at 4850ft would make attractive the siting of dark matter and double beta decay experiments at the same level, "if the infrastructure needed can be shared in a cost effective manner".

A common facility is important for the training of the next generations of US scientists and " locating such a facility in the U.S. would help to promote U.S. leadership in these fields for the foreseeable future."

Marx-Reichanadter Committee

LBNE

The Marx Committee favors a location of the LBNE far detector at 4850ft and argues for a fast technology choice process.

It suggests that a two-phase approach with Water Cherenkov in a first phase and liquid argon in a second phase would be attractive, leading to richer physics and possibly lower cost of the first phase.

Fact not known to Marx committee

4850ft location of liquid Ar is comparable in terms of cost to 800ft

better in terms of science and simplify coupling with dark matter and double beta decay

=> drop 800ft option?

Homestake rises from its ashes!

Much scaled down compared to DUSEL

Real interest at OSTP and in Congress

survival of Fermilab

low operation support costs: $20-22M vs $70-80M for DUSEL

NSF now seems ready to play a scientific role

Contribution to experiments

Science MREFC? (e.g. Dark Matter + Double beta)

Personal Opinion

A real chance to get a US underground facility!

But important not to be trapped if LBNE is delayed or cancelled

Reevaluation in 2 years, taking into account:

- Situation of Homestake and LBNE
- Confirmation that operation at 4850 ft is OK in terms of cosmogenic backgrounds for dark matter and double beta.
- Progress of dark matter technologies!

Investigate SNOLAB as a potential back up

Costs on a comparative basis (Fully equipped cavities)

Institutional aspects: a US-Canada partnership in a North American facility
liability issues
relationship with Creighton mine (where SNOLAB is) operator