Coherent elastic neutrino nucleus scattering experiments

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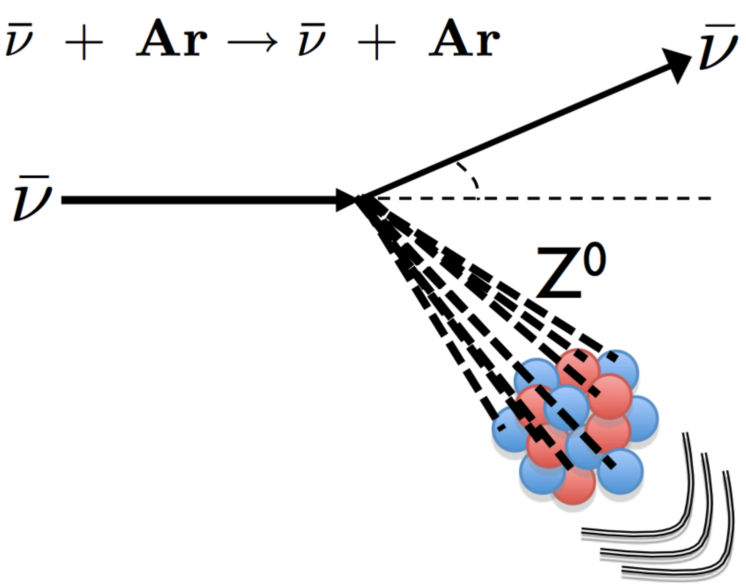
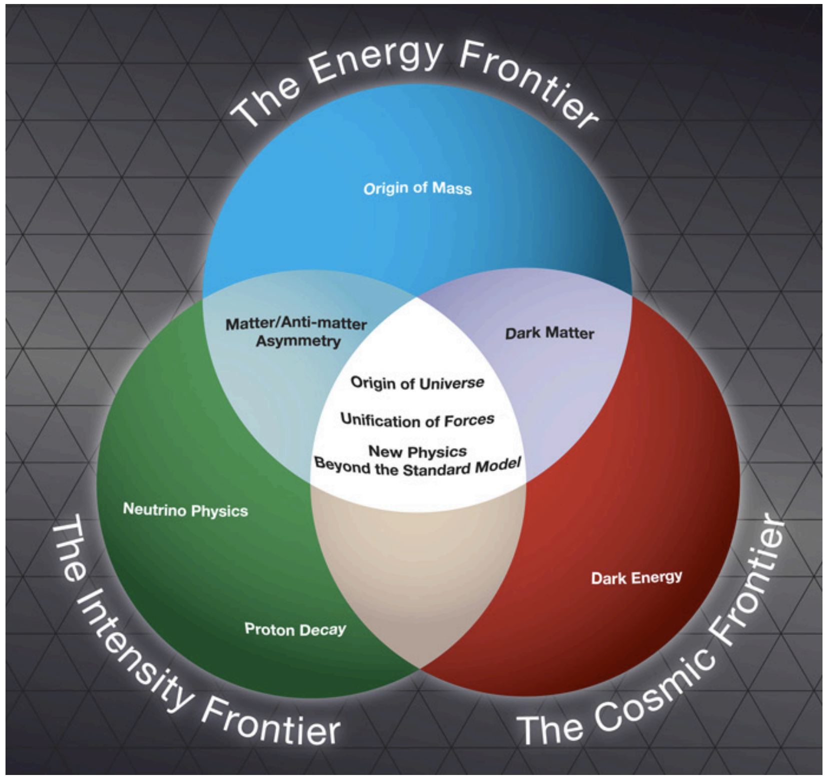
What is CENNS?
- standard model prediction
- mediated by Z0 (flavor blind)
- $\sim N^2$, for $E_\nu \leq 50$ MeV
- see also: Sangiorgio talk (this workshop)
- see also: Barbeau talk (this workshop)



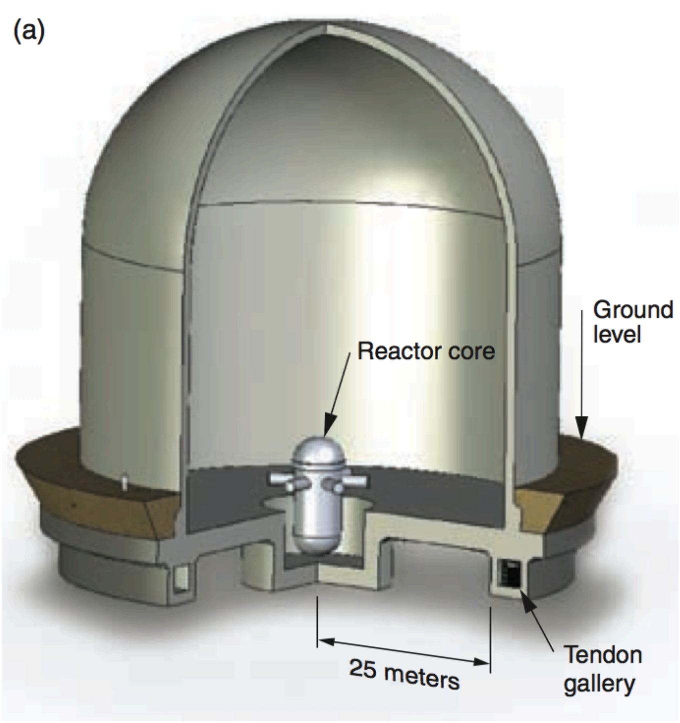
Who is building experiments to detect CENNS?
- lots of groups!
- CoGeNT (coherent germanium neutrino technology)
- LLNL + Liverpool
- RED
- MIT
- ULGEN (UCB + Sandia)
- TEXONO
- others! (apologies if I did not list your work)

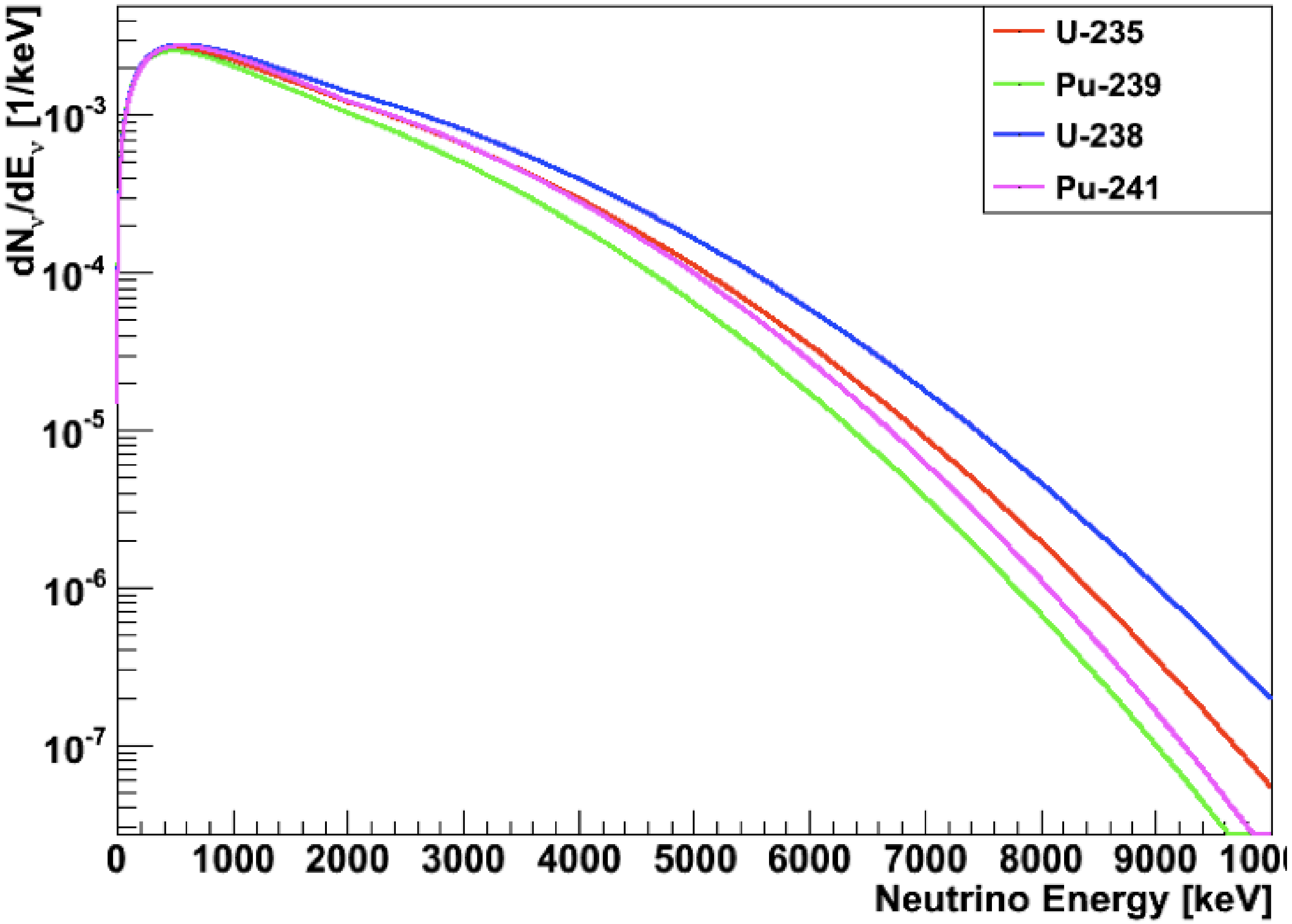


Why..?
- potential tool for cooperative nuclear reactor monitoring
- NSI, e.g. deviations from SM prediction could point to a sterile ν   Phys Rev D **86** 013004 (2012)
- precision measurements, e.g. probe of neutron density distribution   Phys Rev C **86** 024612 (2012)
- technology overlap with direct detection of dark matter

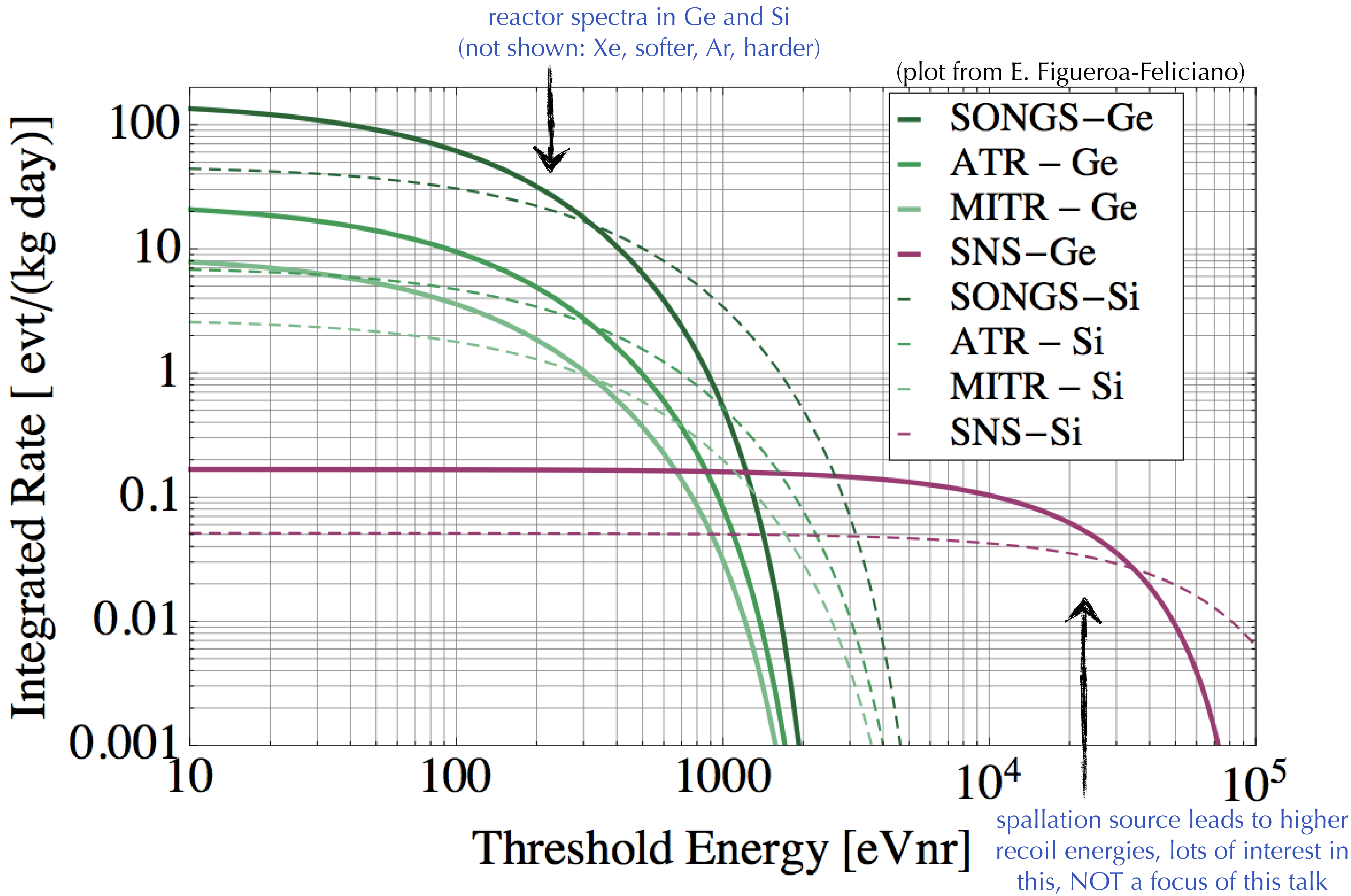
unless noted otherwise, borrowed slides and plots in this talk are from recent LLNL/SNL workshop:
http://neutrinos.llnl.gov/LLNL_CNS.html

~10^{21} ν/s from 3 GWt
spectra depends mildly on isotopic content (burn-up)





Event rate and energy spectra



- Reactors are not the highest priority safeguards problem
- We are introducing a disruptive technology to an agency that demands stability, continuity, and economy
- IAEA sees no <u>immediate</u> utility in antineutrino detection – existing methods have worked, costs are modest, politics of changing are difficult

For coherent scatter detection to be adopted:

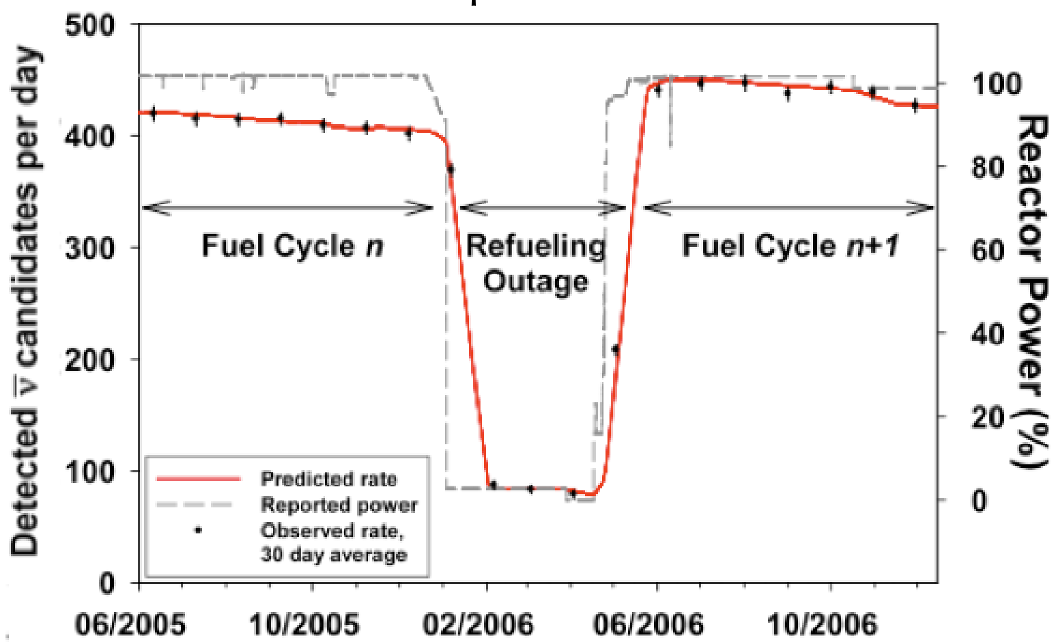
1. **IAEA will have to have seen demonstrations that any kind of antineutrino detector can benefit the safeguards regime**
2. **The CNS community will have to show some advantage compared with the reigning option, inverse beta detection**

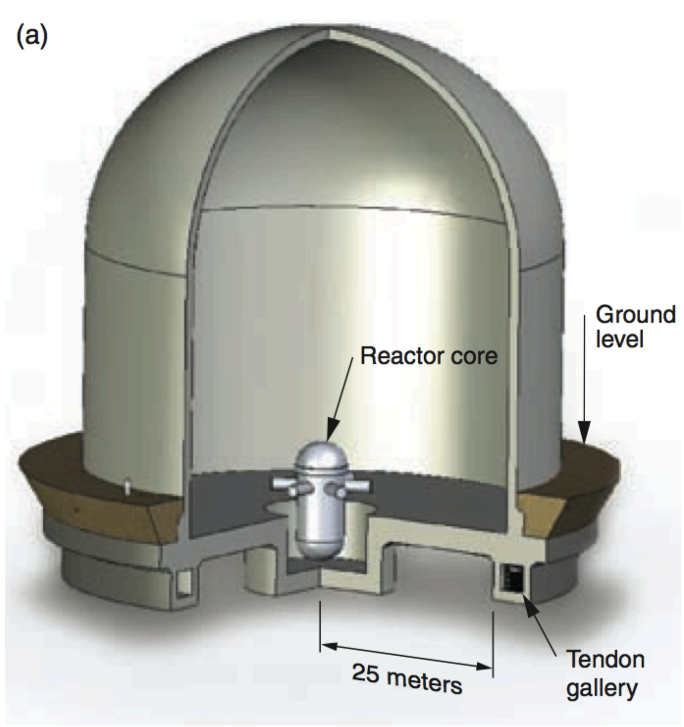
(slide from A. Bernstein)

Utility

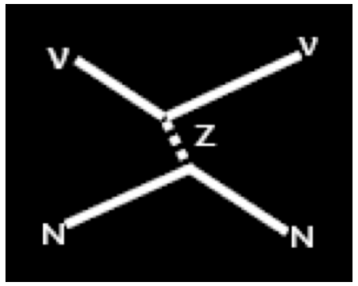
Advantage

(plot from N. Bowden)

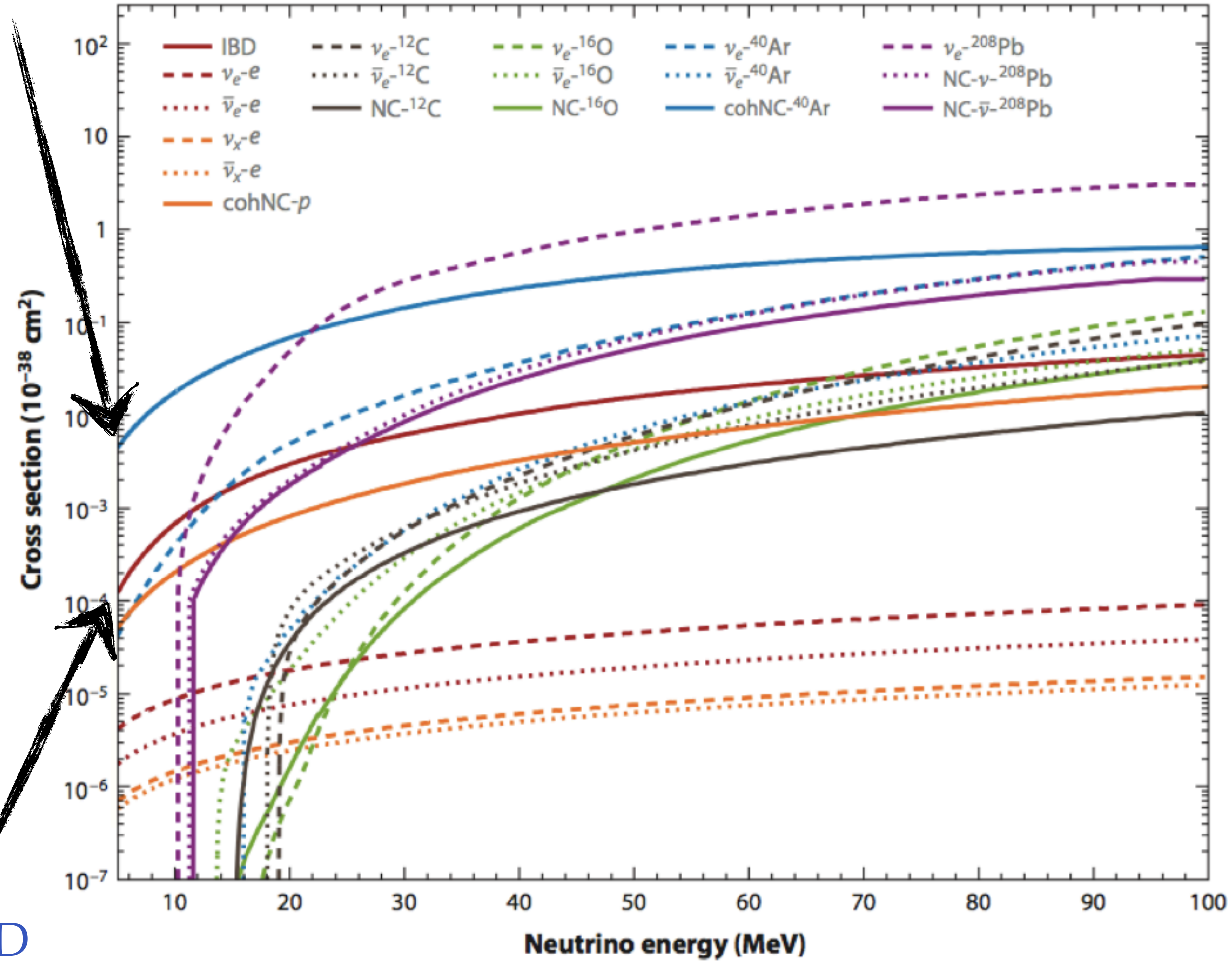




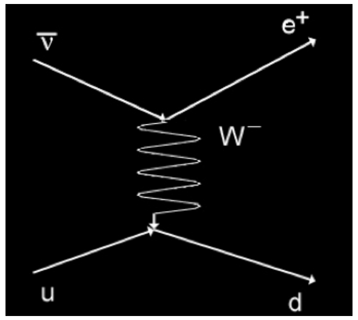
CENNS



(plot from K. Scholberg)

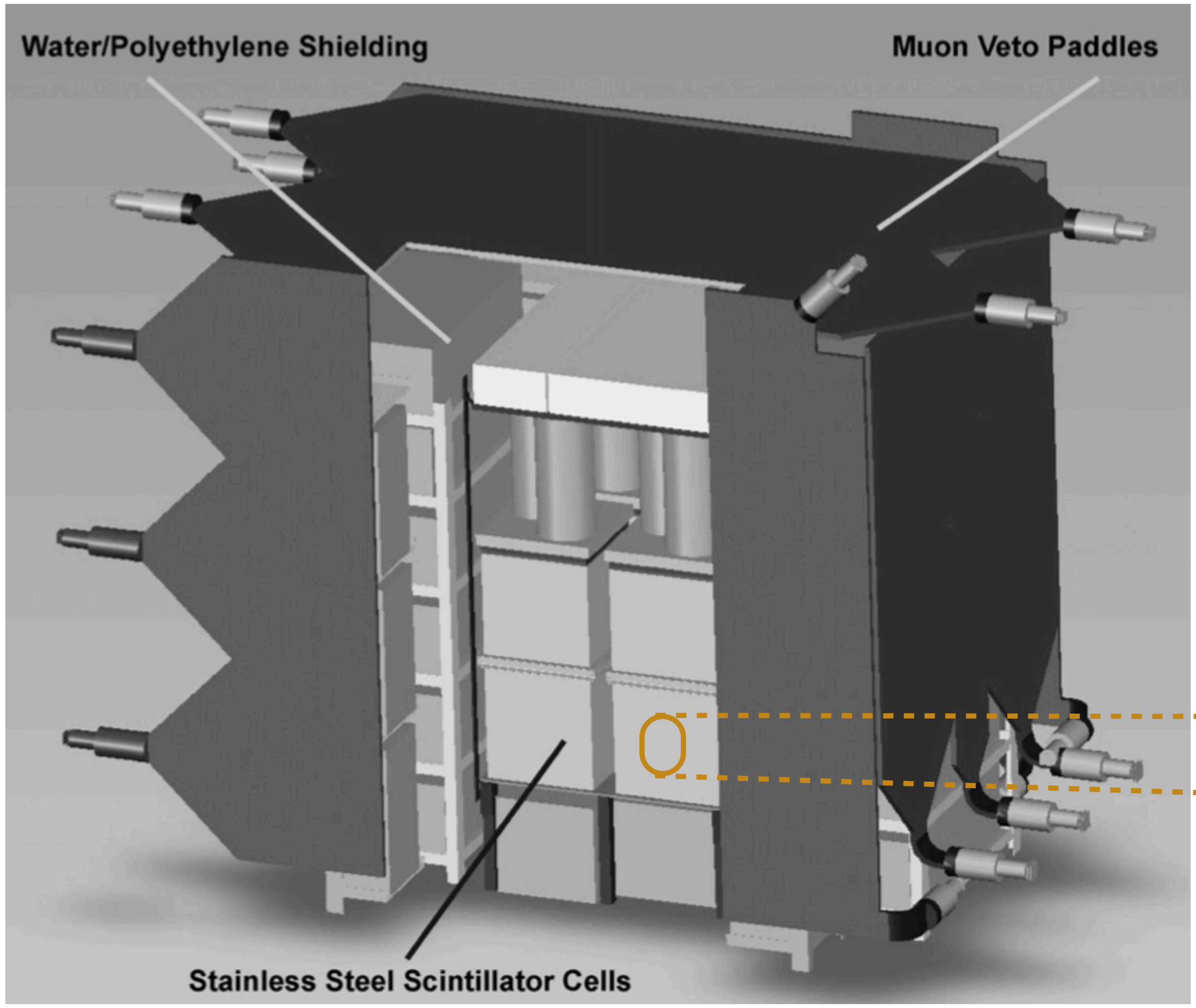


IBD

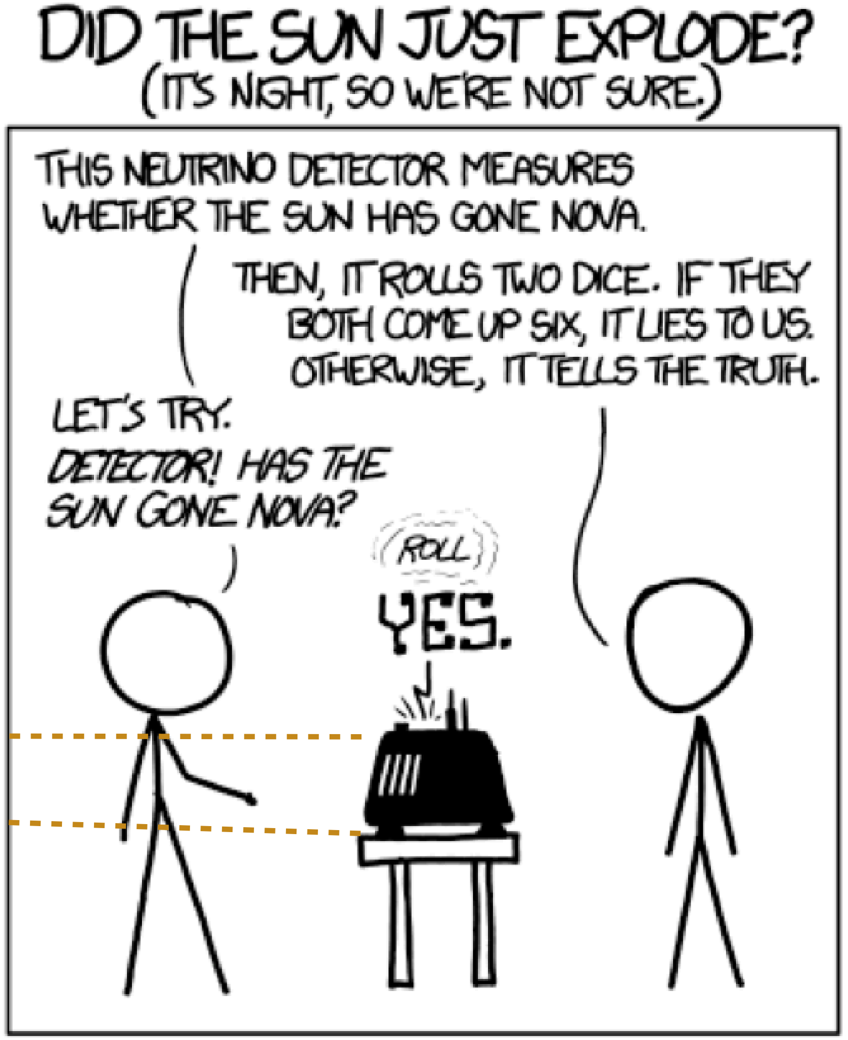


Could it lead to "table-top" neutrino detectors for safeguards?

SONGS1 ~ x0.01 in dimension for same rate → Future CENNS detector



Nucl Instr Meth A **572** 985 (2007)



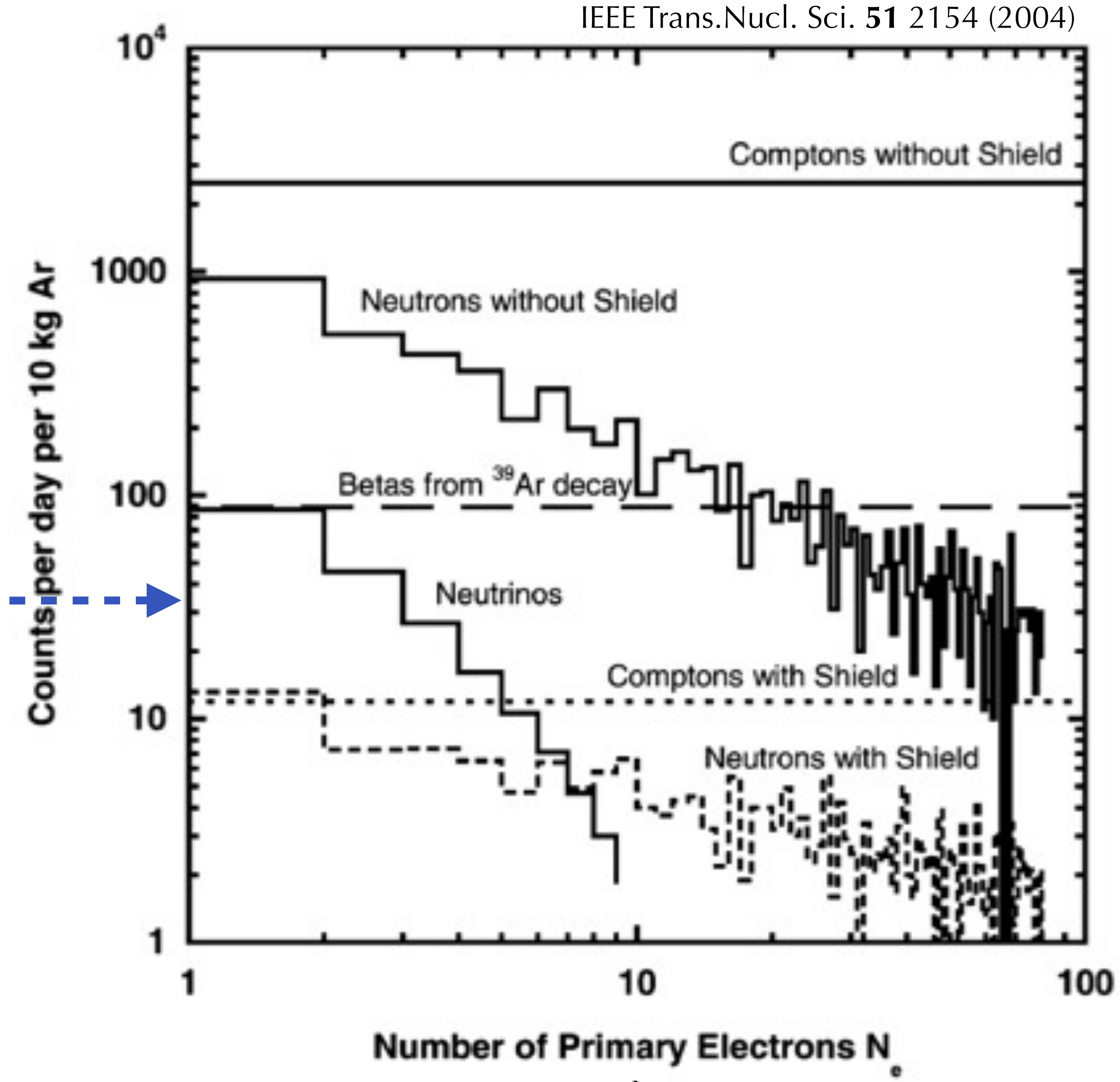
xkcd.com/1132

Maybe. But the prevailing winds seem to be blowing a different direction

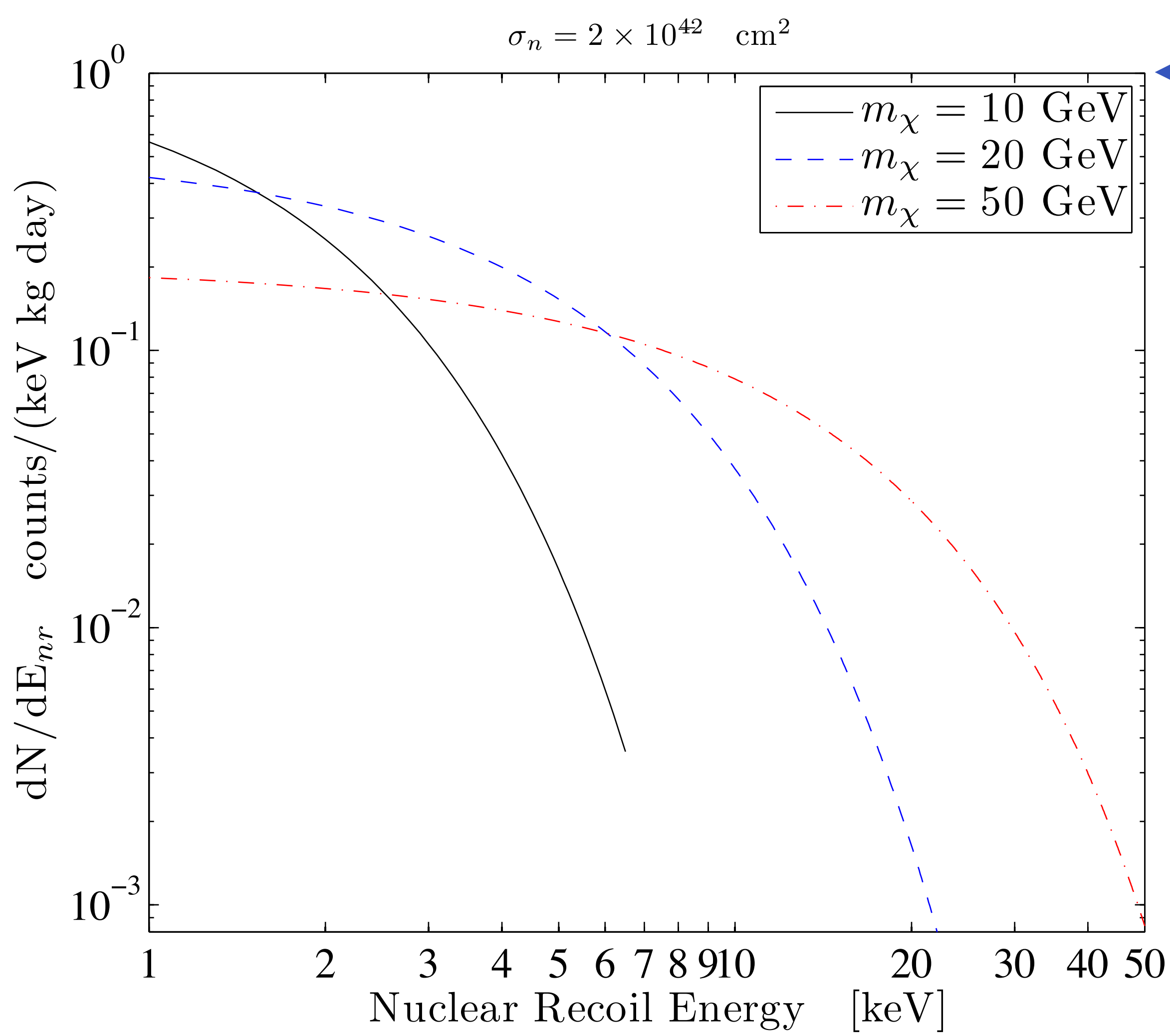
technology, R&D efforts, signal characteristics are similar to those of dark matter direct detection

coherent ν on argon

IEEE Trans.Nucl. Sci. **51** 2154 (2004)

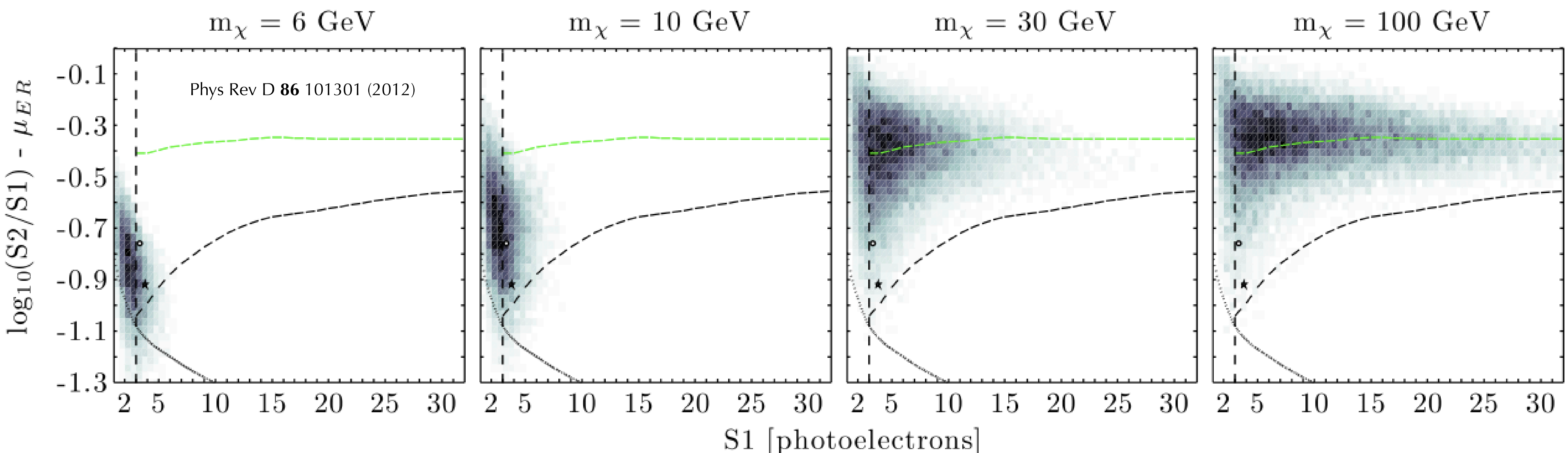


dark matter elastic scatter on xenon



~2 keVnr

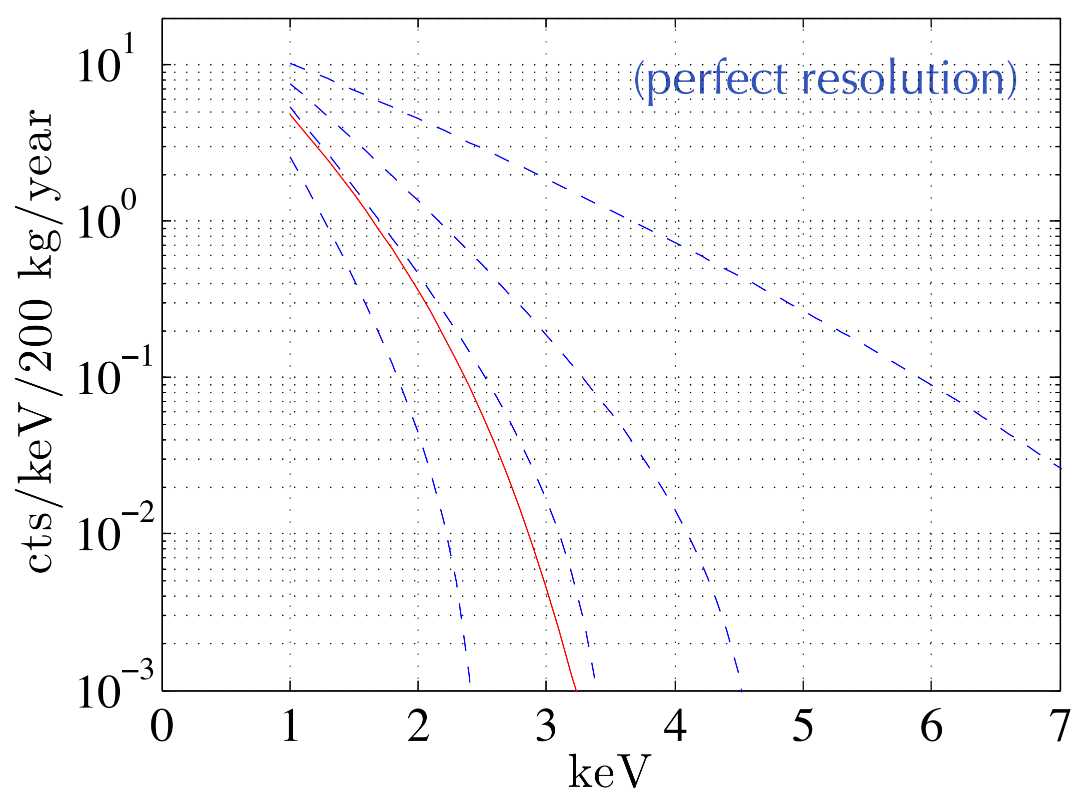
Except that detecting CENNS appears to be technologically more challenging



(above) typical state of the art dark matter sensitivity in e.g. liquid xenon begins to roll off for particle mass ~6 GeV

(right) 6 GeV DM looks similar to expected spectrum for CENNS from 15 MeV endpoint solar neutrinos from ^{8}B (reactor antineutrino endpoint ~ 10 MeV)

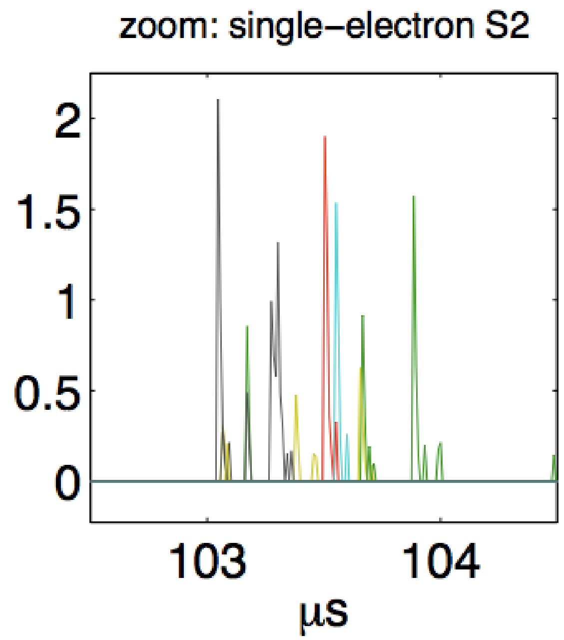
$\sigma_n =$ 5 x 10^{-45} cm^2 (DM)



dashed: DM masses 5, 6, 7 and 10 GeV
solid: ^{8}B coherent neutrinos

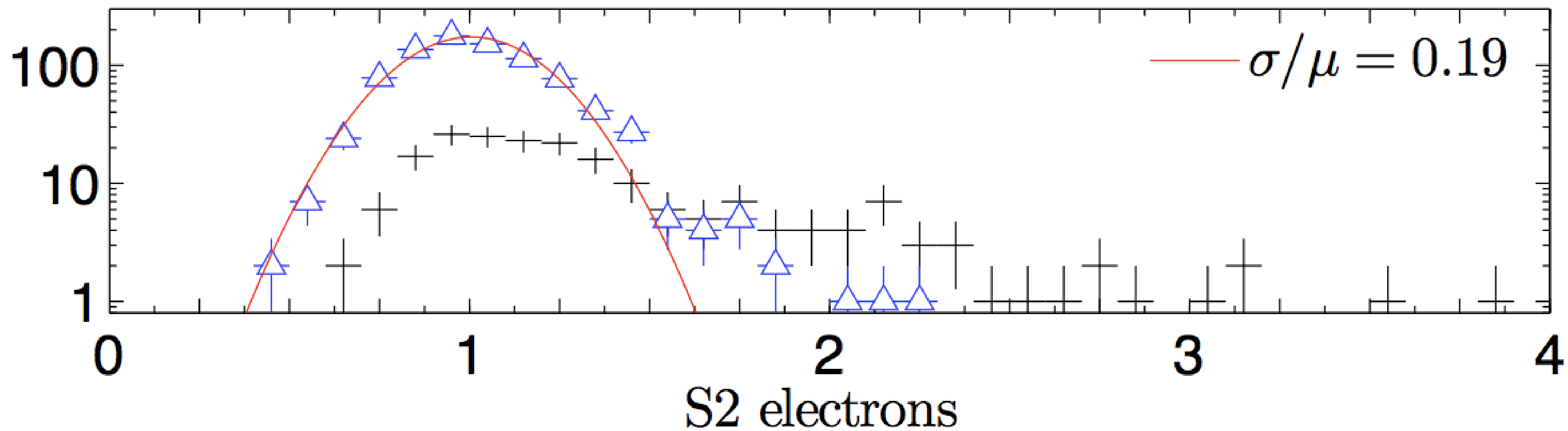
No direct detection of dark matter yet, so technology improvements are welcome

e.g.: proportional scintillation gain in liquid xenon.. leads to single electron sensitivity



typical single e- event in XENON10 (from my thesis)

Phys Rev Lett **107** 051301 (2011)

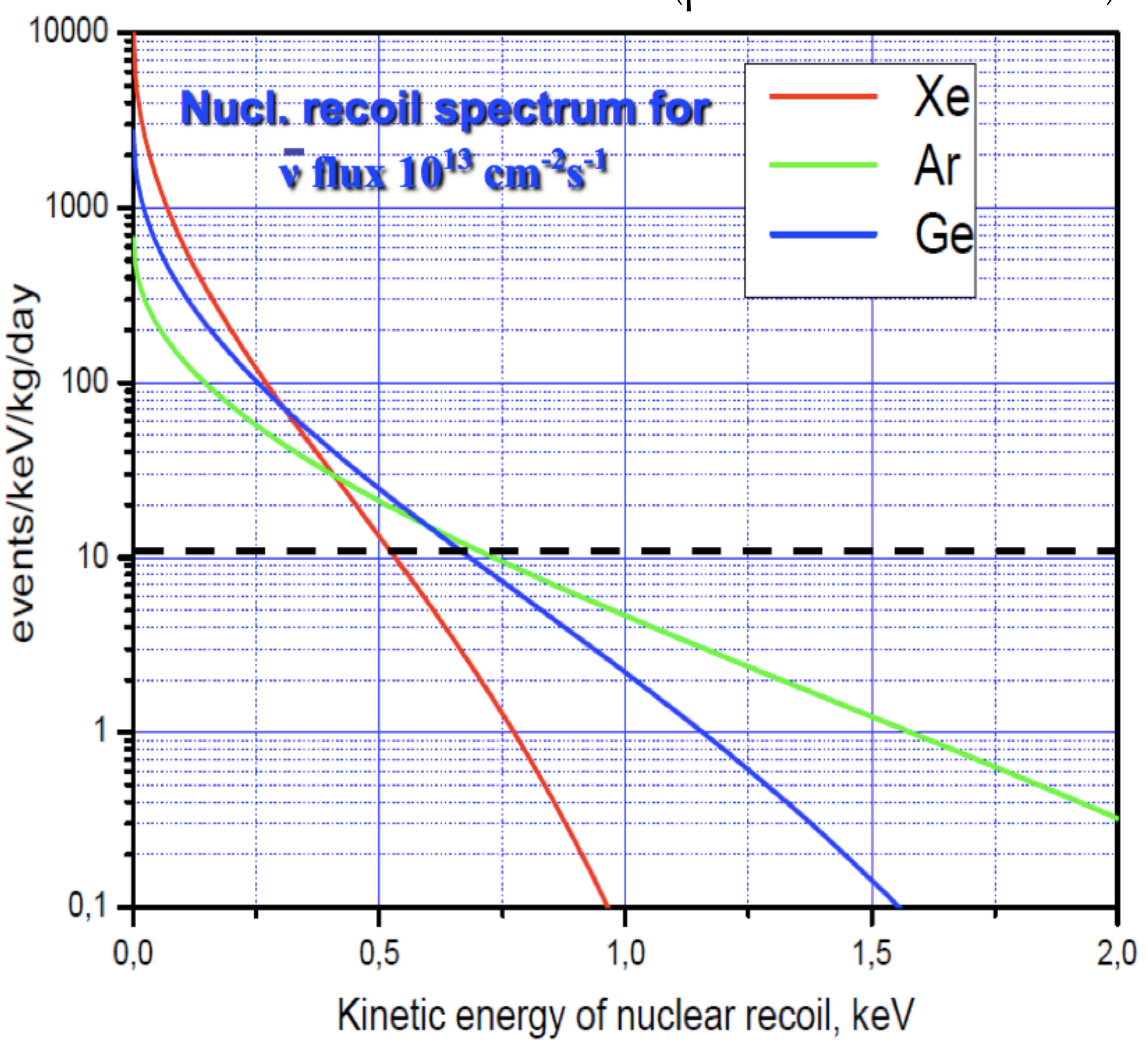


Russian emission detector (RED)

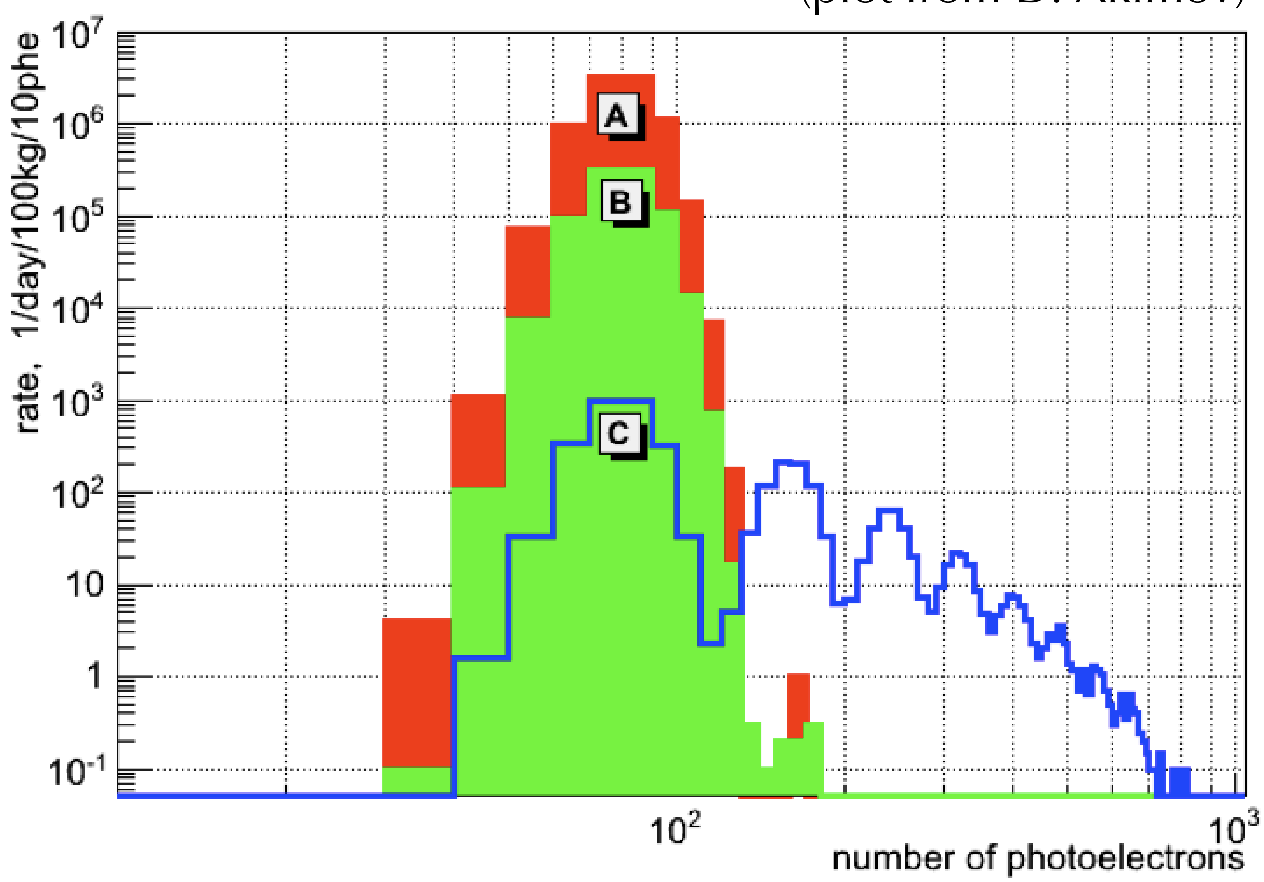
predicted spectrum for key target materials

predicted signal for rosy electron yield assumptions

(plot from D. Akimov)

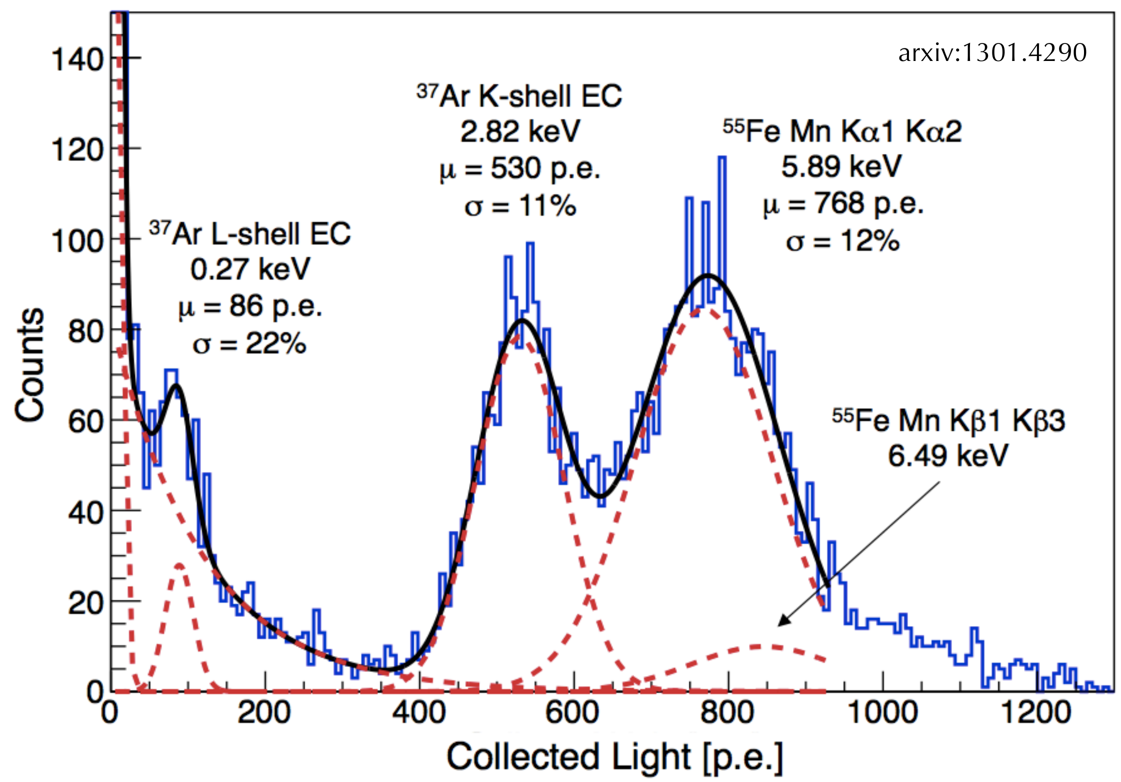


(plot from D. Akimov)



Can this technique be used in liquid argon?

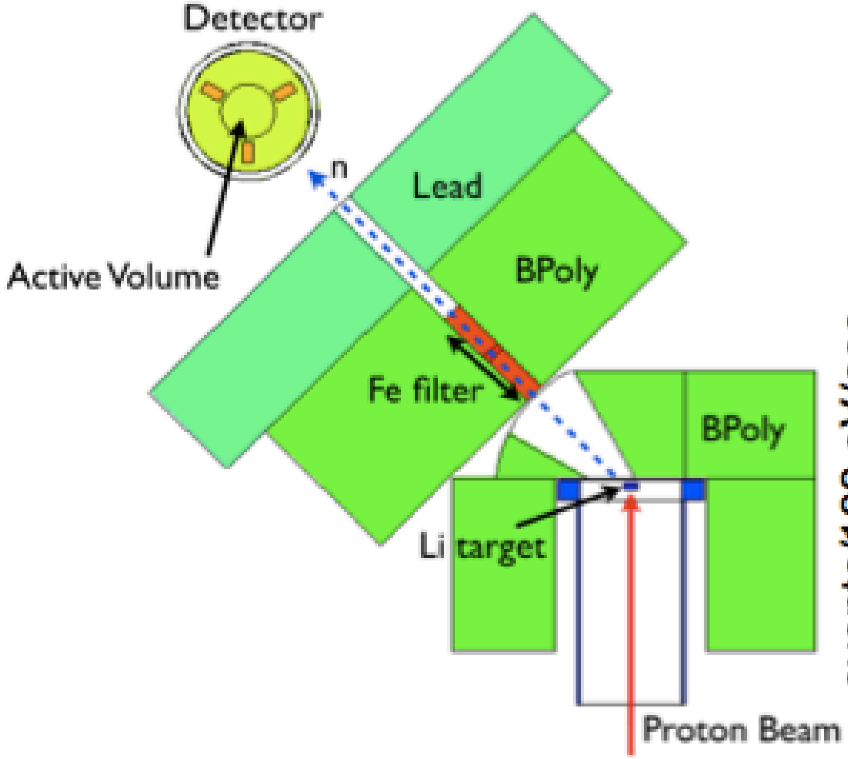
S2-only signal in a dual-phase liquid argon detector

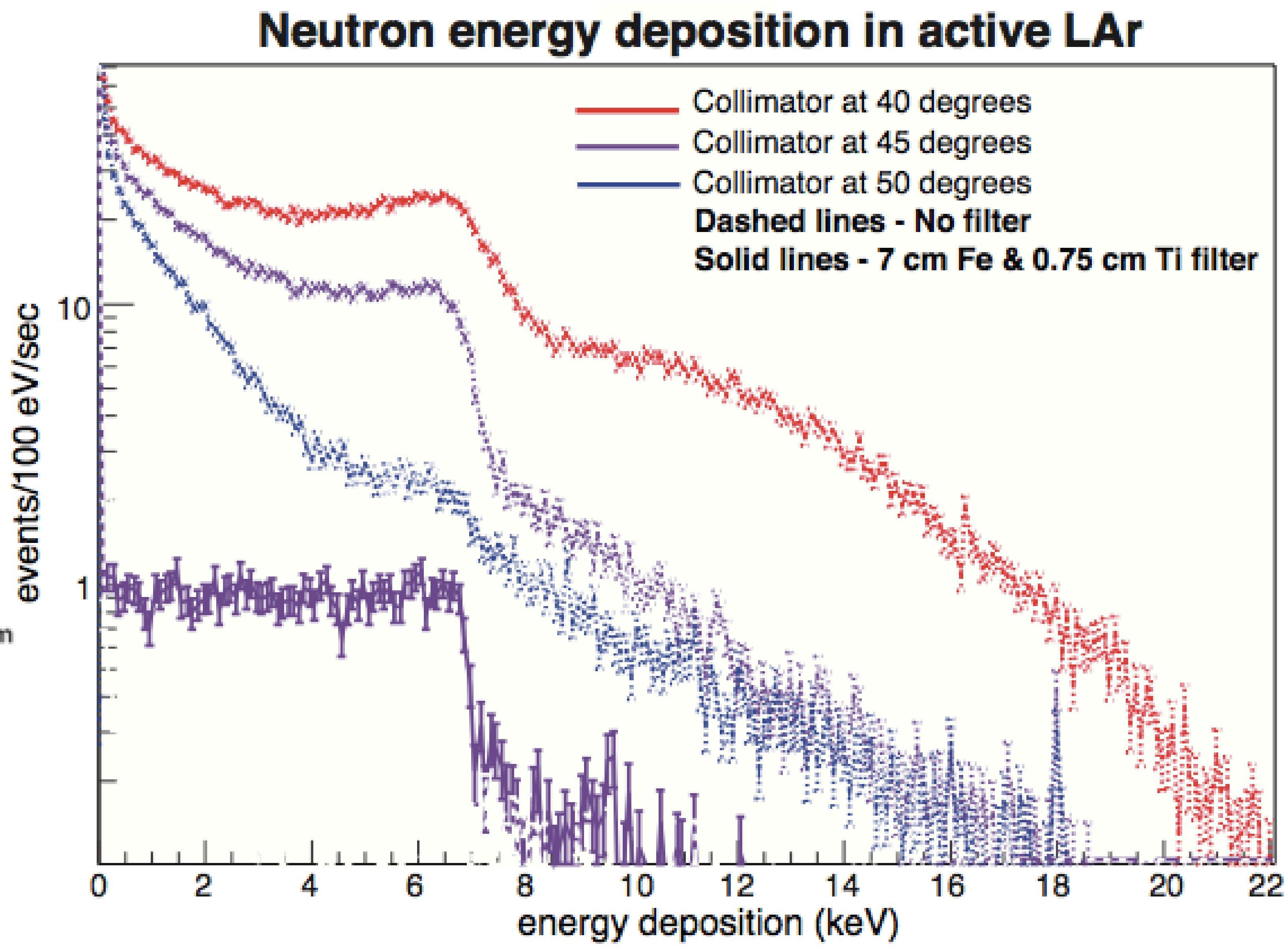


detector developed towards CENNS detection (for non-proliferation)
BUT
complementary to the approach that e.g. the Darkside Collaboration is pursuing for DM

Low-energy nuclear recoil calibration with quasi monochromatic neutrons

we have built a dedicated calibration test bed at the Center for Accelerator Mass Spectrometry (CAMS) at LLNL

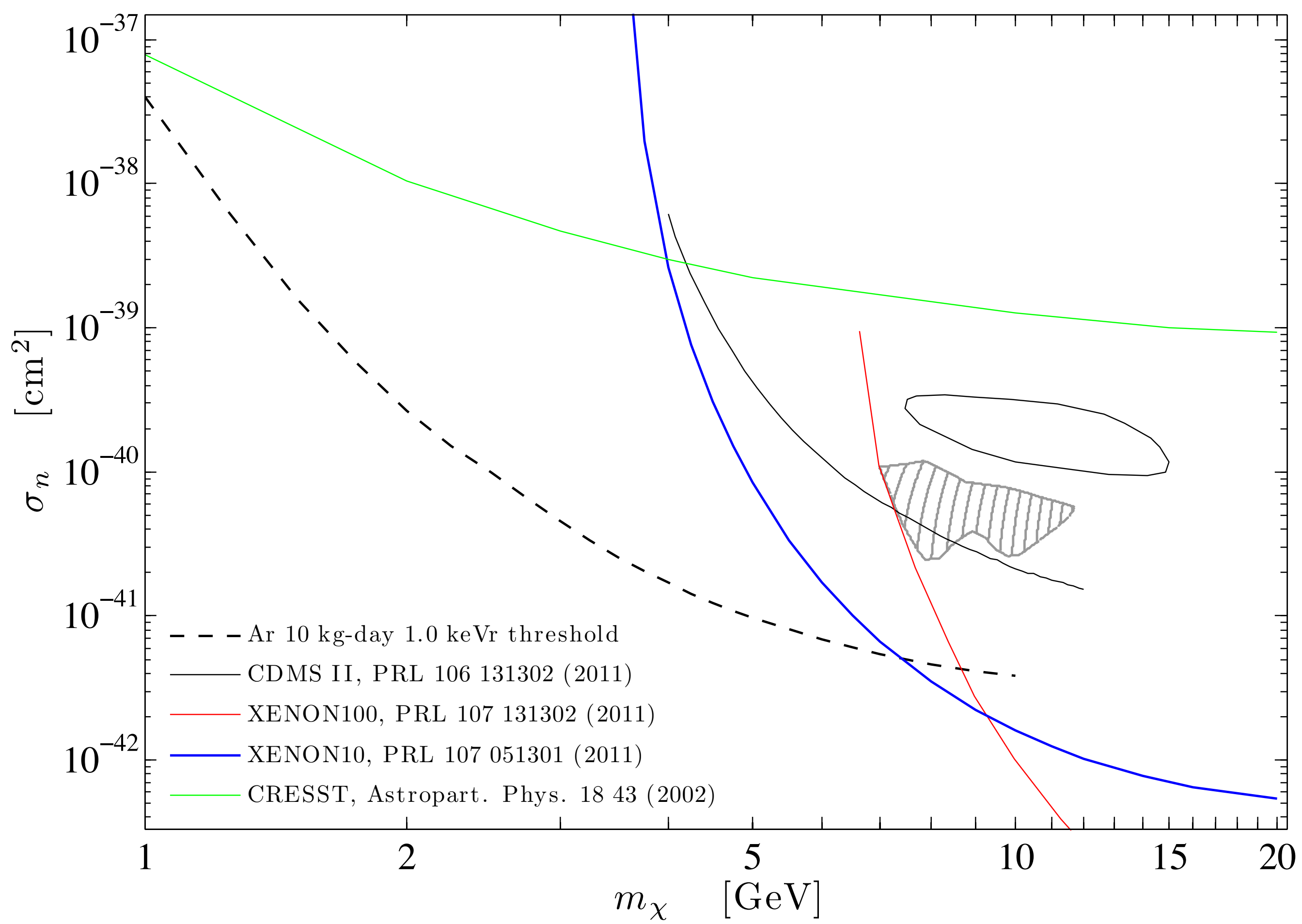




(slide from T. Joshi)

Potential dark matter sensitivity of a liquid argon CENNS detector

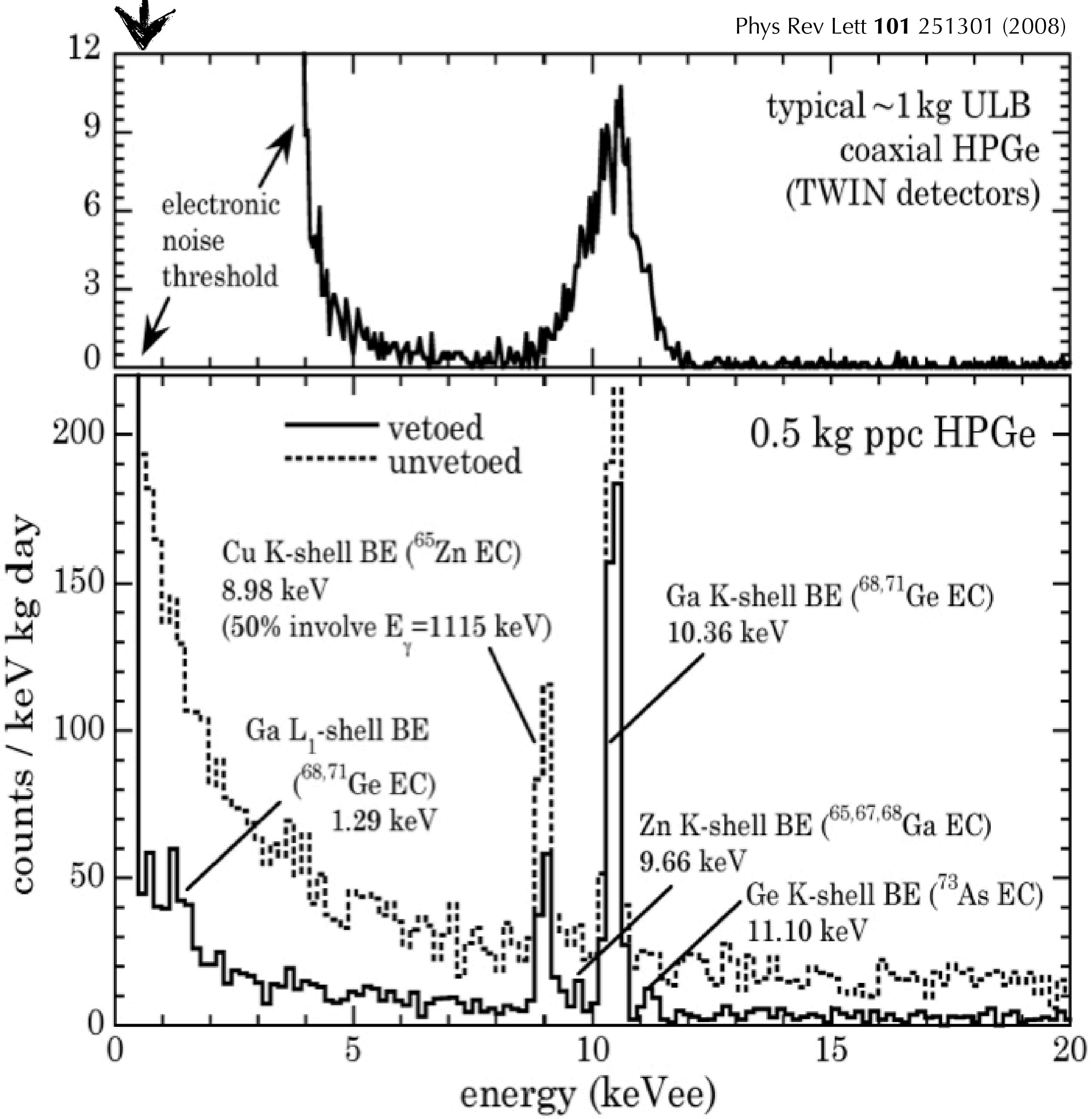
potential DM sensitivity of S2-only in liquid argon



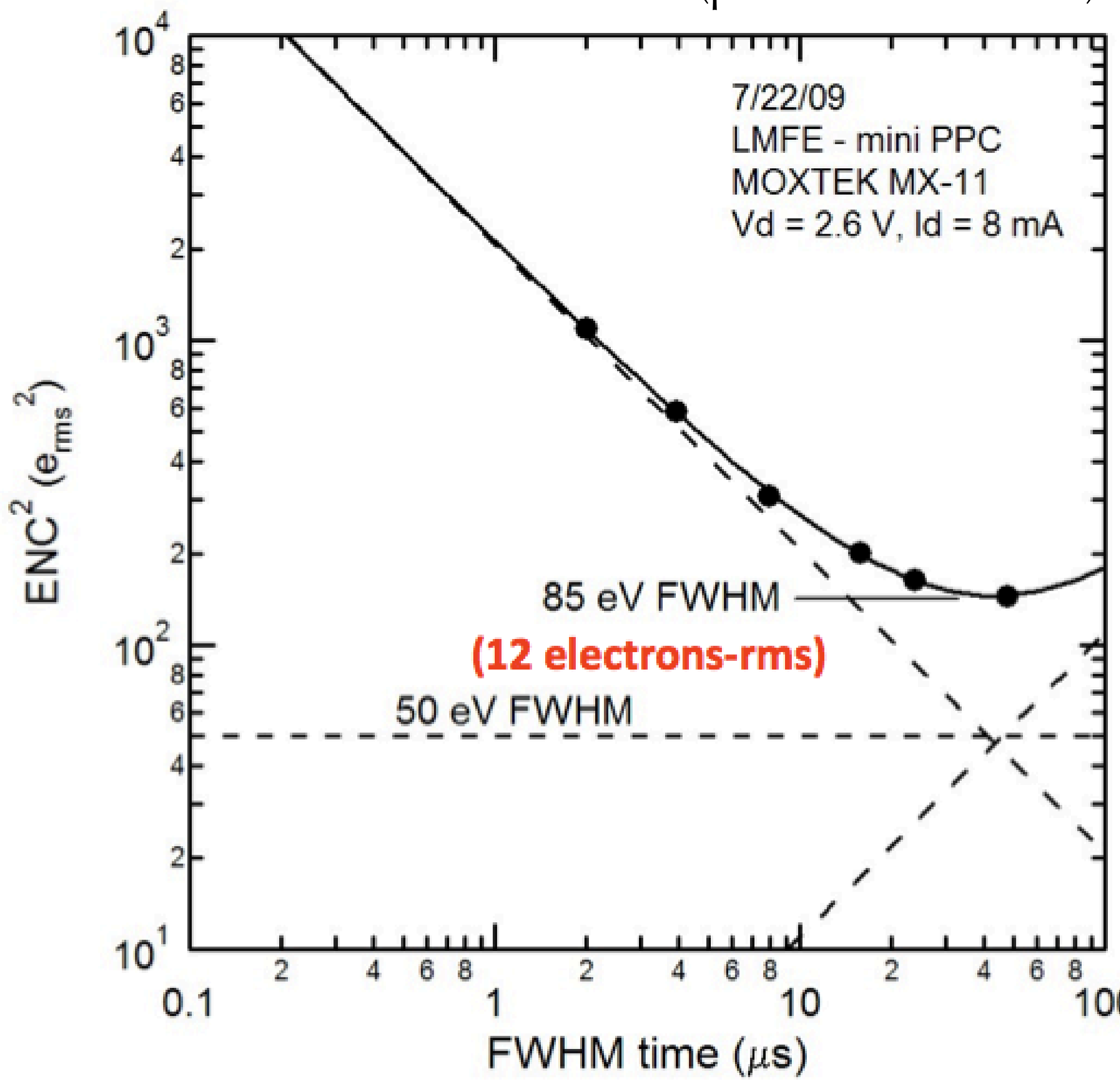
~ 2 keV nuclear recoil

(compare slide 3.. all reactor CENNS events <2 keVnr

Phys Rev Lett **101** 251301 (2008)

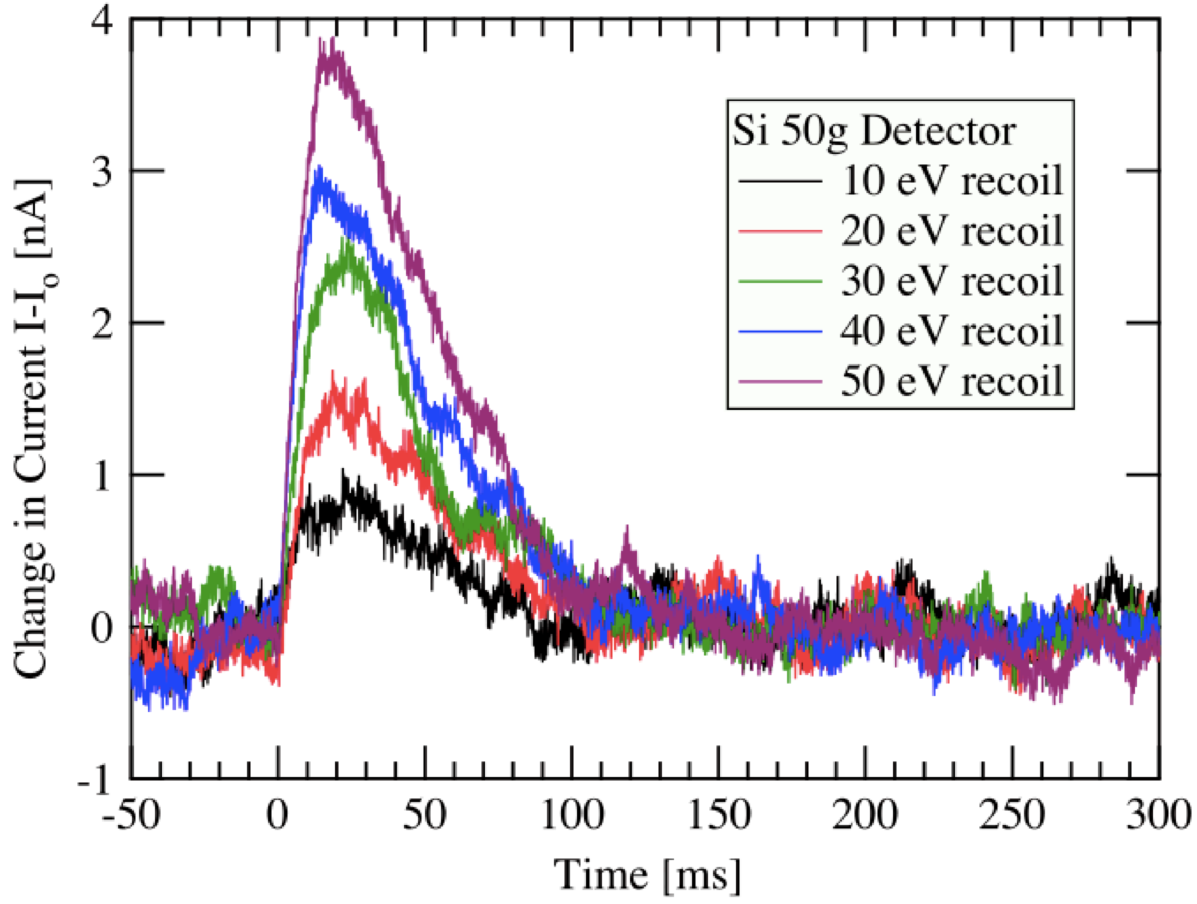


(plot from P. Barton)

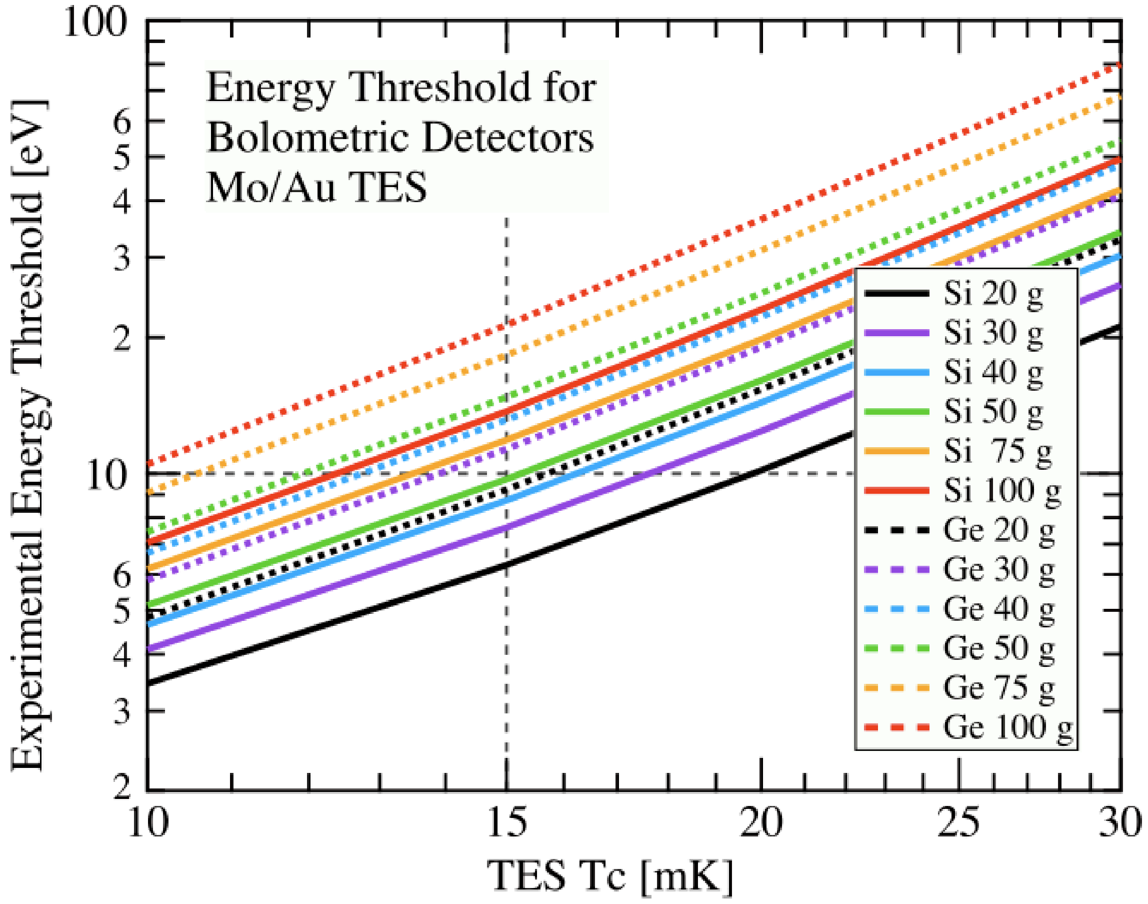


Optimizing Ge and Si bolometers for O(10) eV threshold

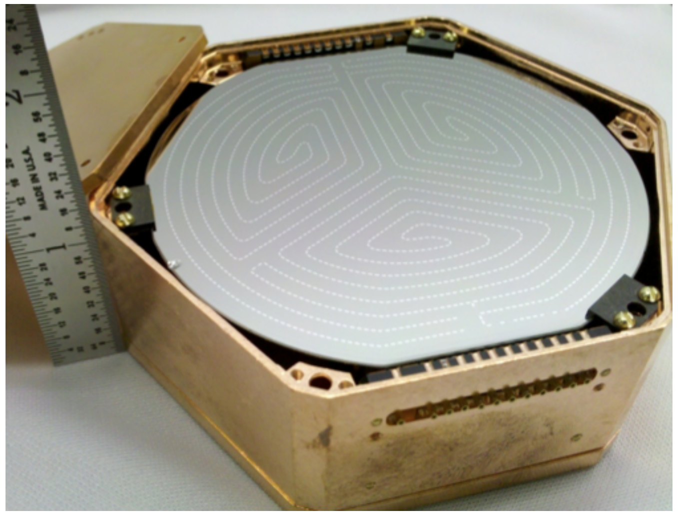
Phys Rev D **85** 013009 (2012)

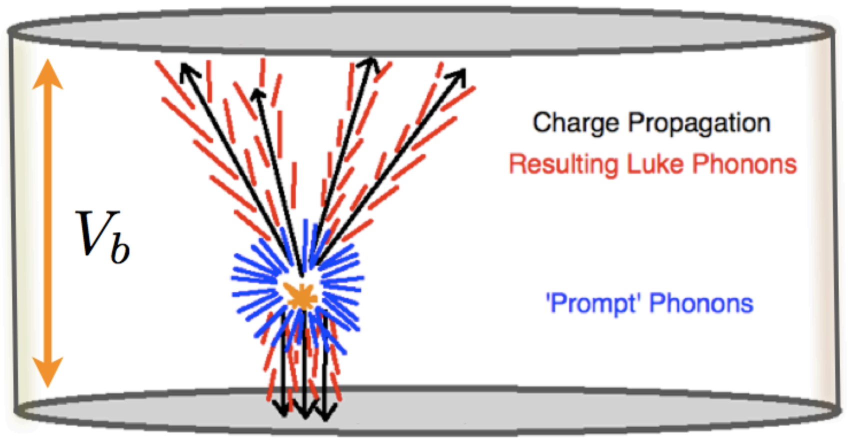


Phys Rev D **85** 013009 (2012)

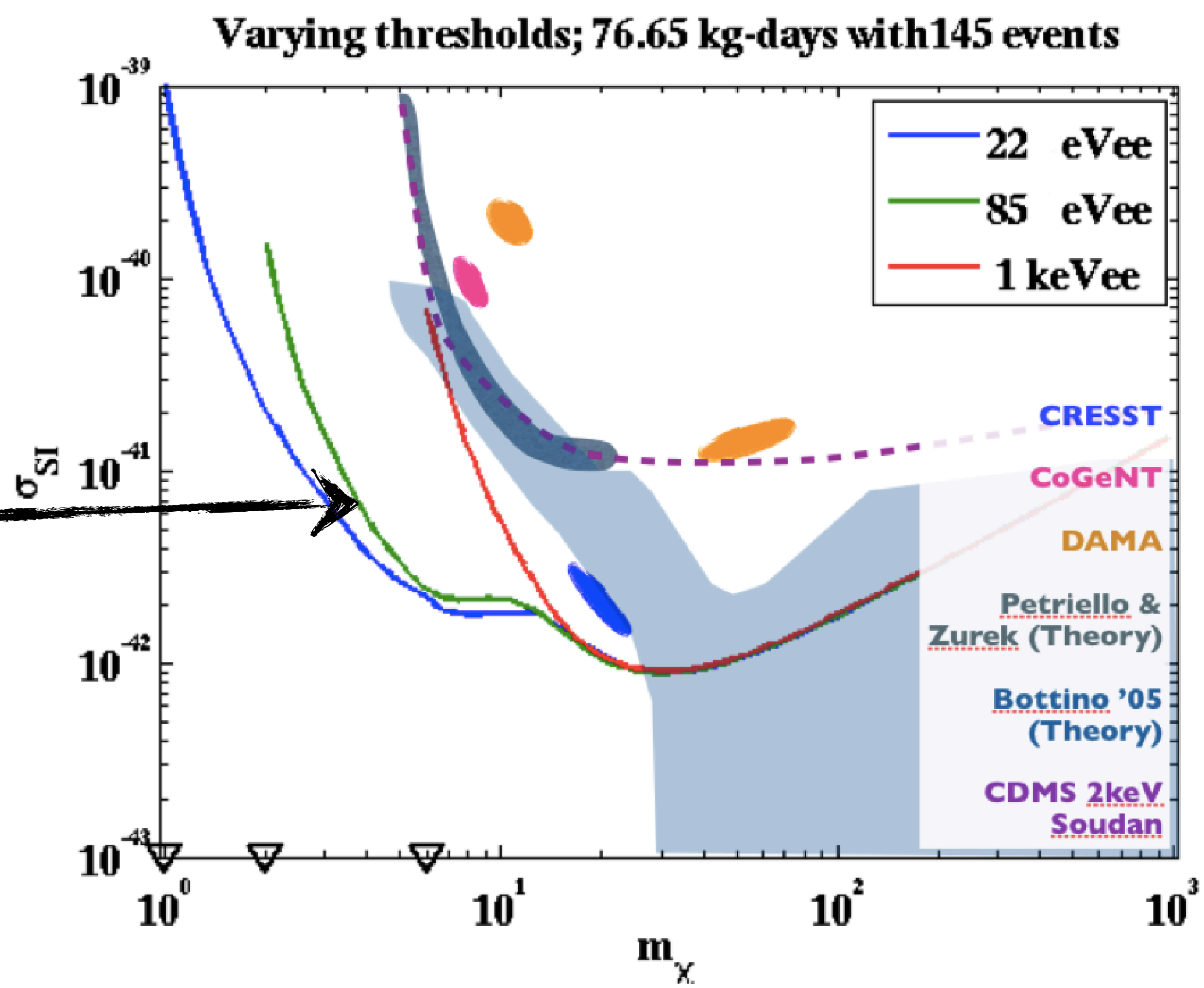


Bolometers with phonon gain! CDMS lite





- looks like ~x24 internal gain possible!
- will lead to a significantly lower NR and ER threshold



graphics selected from R.B. Thakur talk at IDM 2012 (Chicago)

Summary

- CENNS remains an undetected prediction of the Standard Model
- coherent rate enhancement could lead to benefits for nonproliferation, assuming technical challenges (<<1 keV energy threshold) can be surmounted
- numerous groups are pursuing research towards deteection of this process, generally in conjunction with improving sensitivity for dark matter search
- once the process is detected, possibilities for new physics searches and precision measurements arise