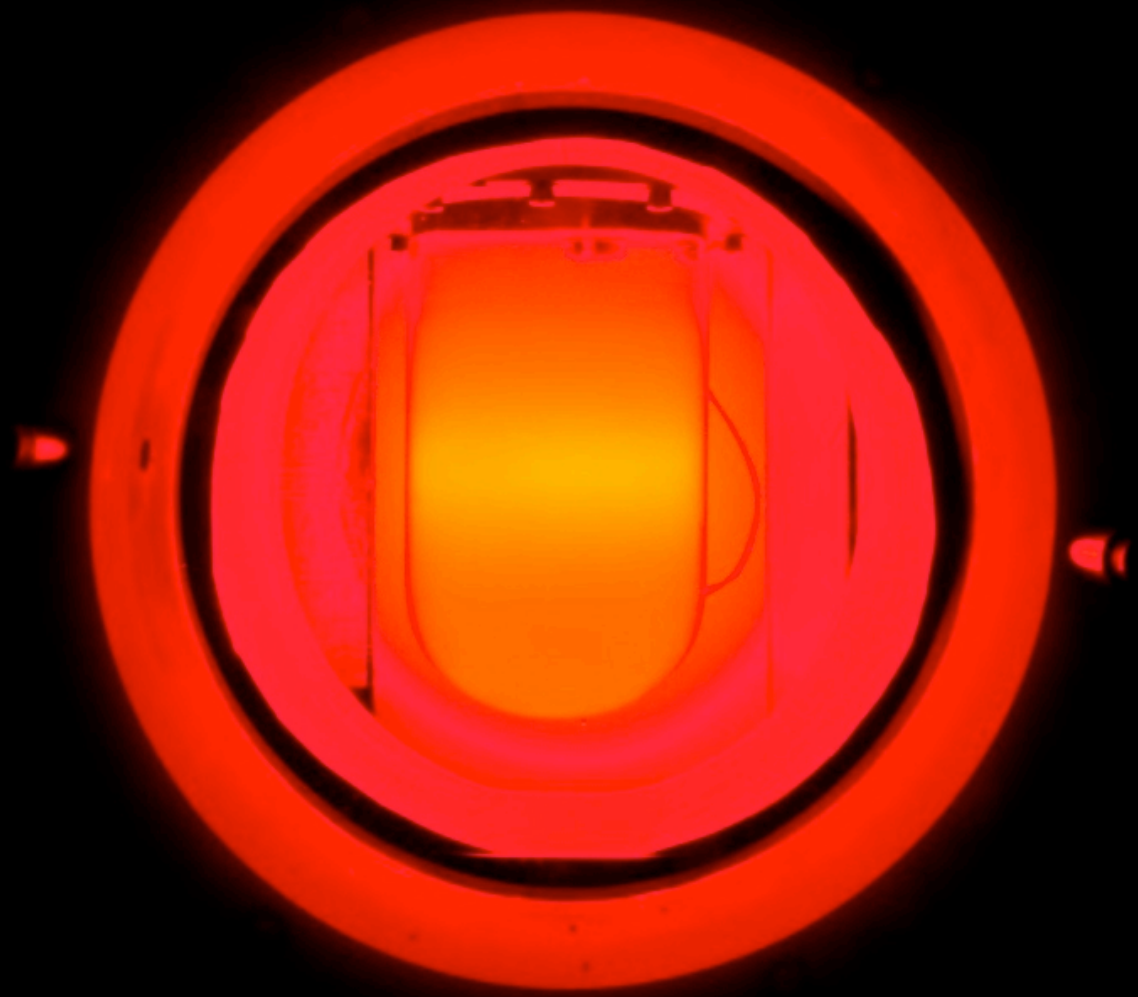
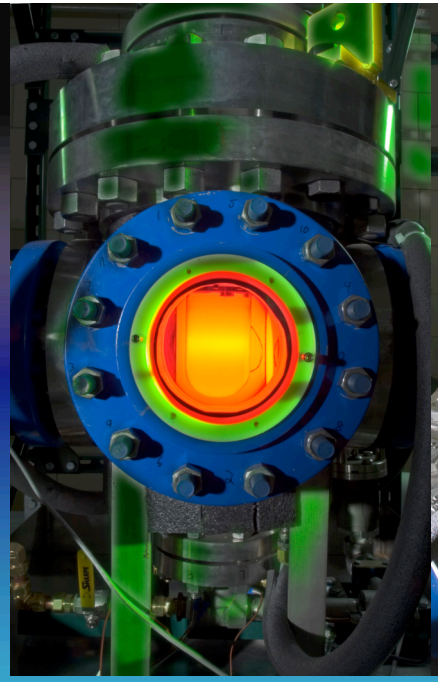
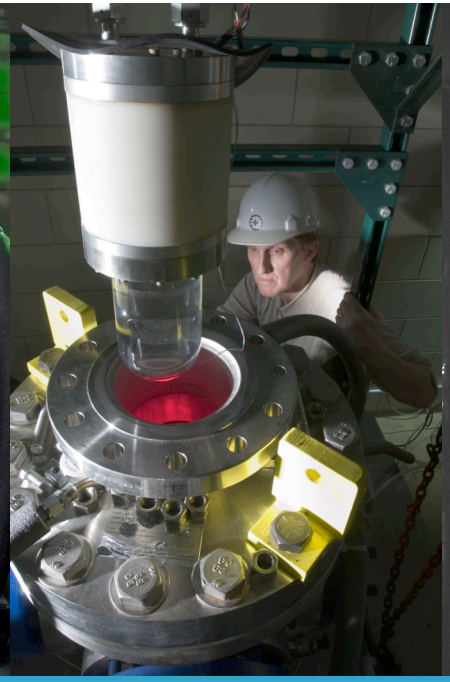
COUPP, CDMS and a brush w/ DAMA

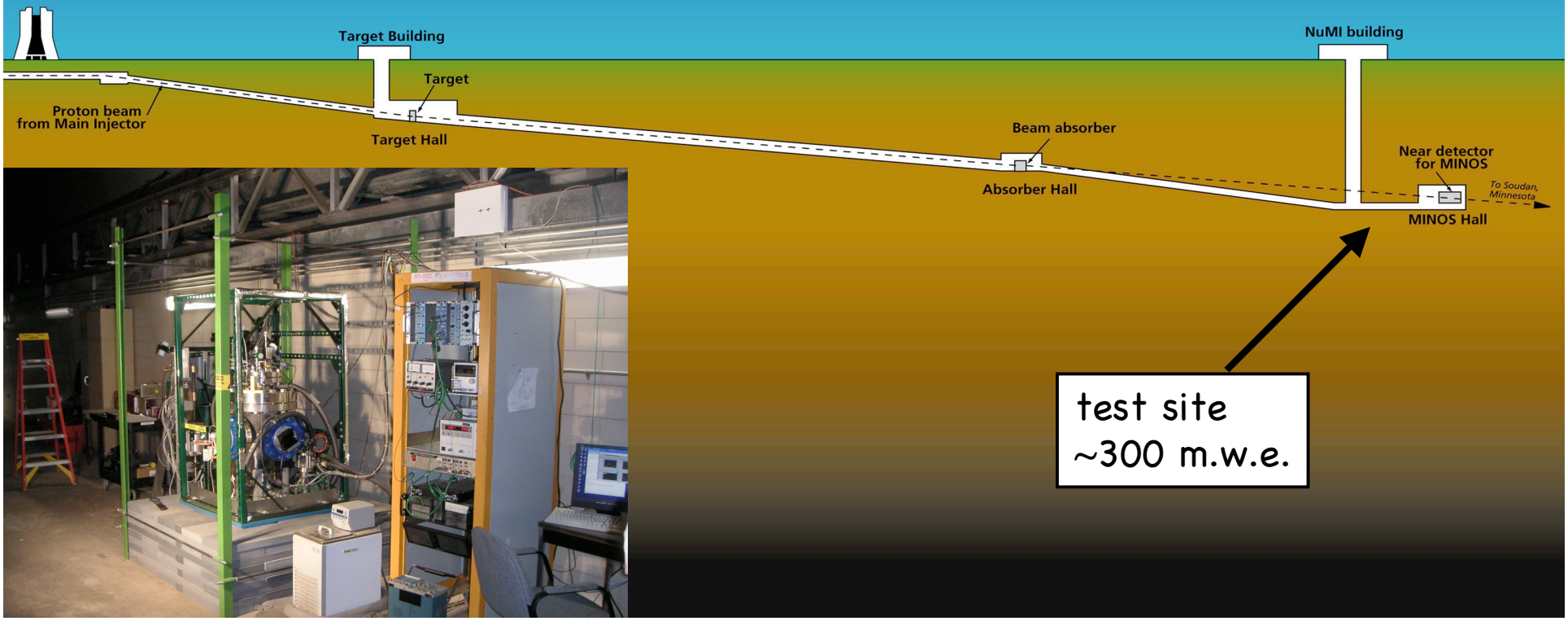


COUPP:
a direct search for Dark Matter using Bubble Chambers

(Fermilab experiment E961, UC,FNAL,IUSB)



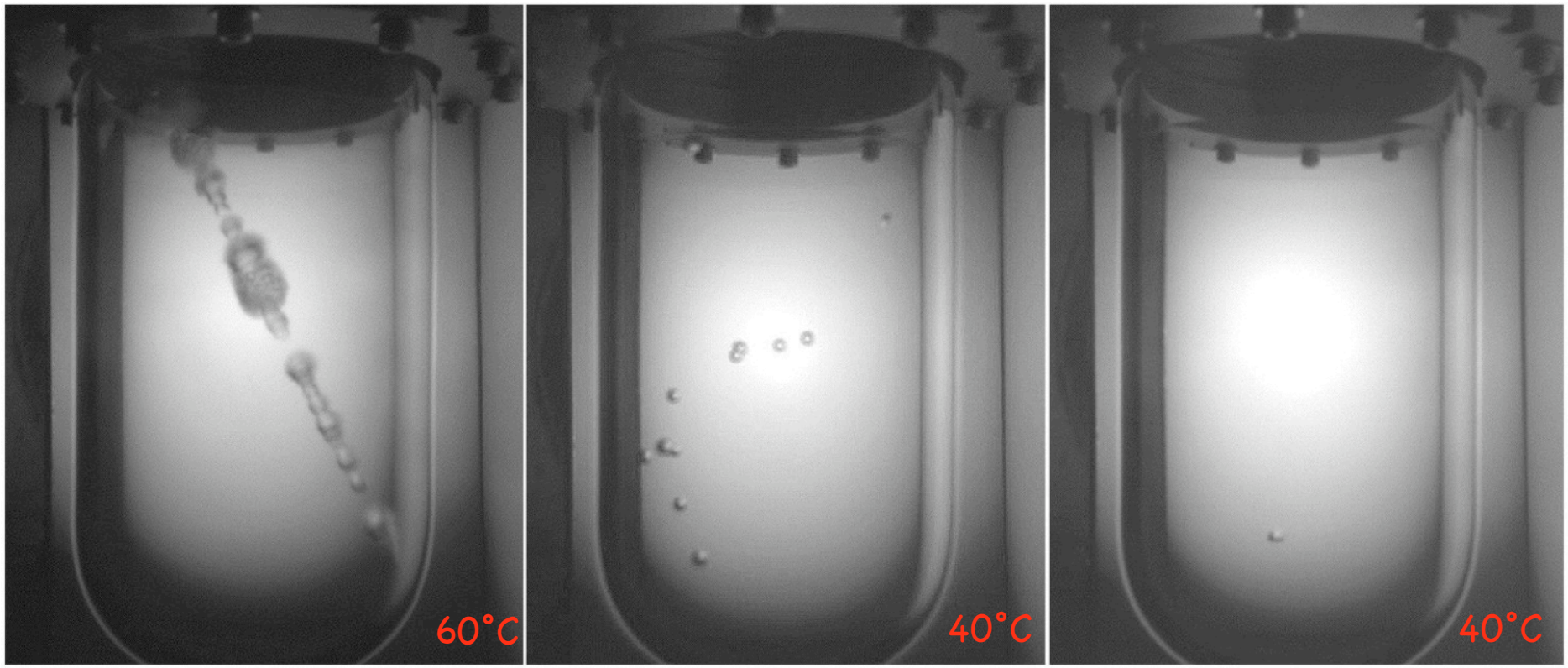




Not your daddy's bubble chamber:

Conventional BC operation
(high superheat, MIP sensitive)

Low degree of superheat, sensitive to nuclear recoils only



muon

Neutron

WIMP

ultra-clean BC: Bolte *et al.*, NIM A577 (2007) 569

COUPP approach to WIMP detection:

- Detection of single bubbles induced by high-dE/dx nuclear recoils in heavy liquid bubble chambers

- $<10^{-10}$ rejection factor for MIPs. *INTRINSIC* (no data cuts)

- Scalability: large masses easily monitored (built-in "amplification"). Choice of three triggers: pressure, acoustic, motion (video))

- Revisit an old detector technology with improvements leading to extended (unlimited?) stability (*ultra-clean* BC)

- Excellent sensitivity to both SD and SI couplings (CF_3I)

- Target fluid can be replaced (e.g., C_3F_8, C_4F_{10}, CF_3Br). Useful for separation between n- and WIMP-recoils and pinpointing WIMP in SUSY parameter space.

- High spatial granularity = additional n rejection mechanism

- Low cost, room temperature operation, safe chemistry (fire-extinguishing industrial refrigerants), moderate pressures (<200 psig)

- Single concentration: reducing α-emitters in fluids to levels already achieved elsewhere ($\sim 10^{-17}$) will lead to complete probing of SUSY models

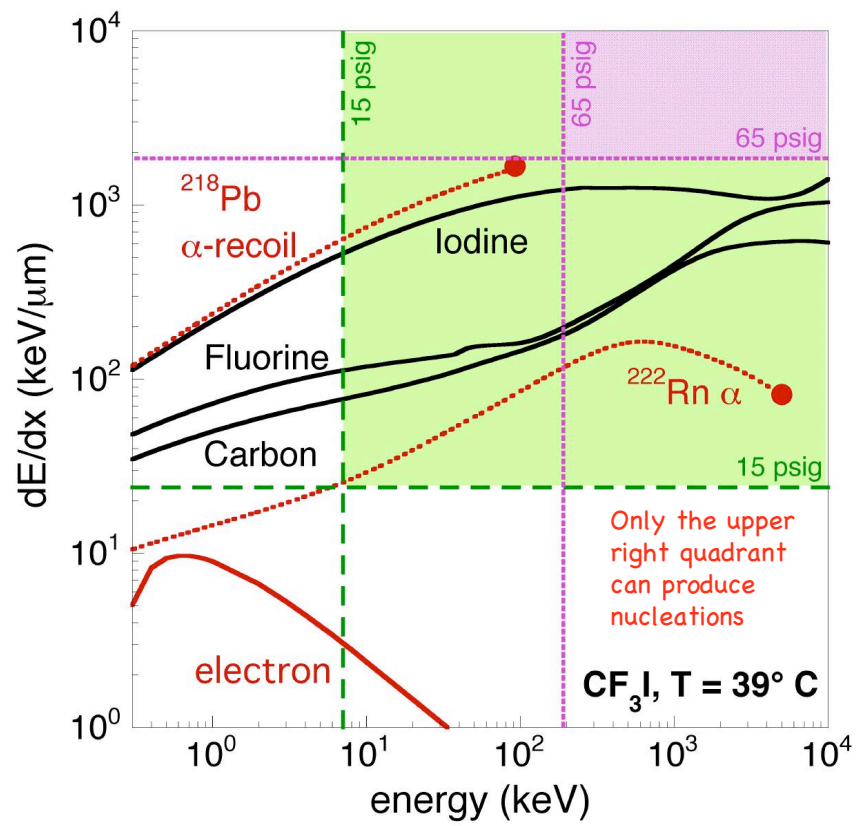
Seitz model of bubble nucleation (classical BC theory):

Threshold in deposited energy

$$E > E_c = 4\pi r_c^2 \left(\gamma - T\frac{\partial\gamma}{\partial T}\right) + \frac{4}{3}\pi r_c^3 \rho_v \frac{h_{fg}}{M} + \frac{4}{3}\pi r_c^3 P \ , \quad r_c = 2\gamma/\Delta P$$

$$\mathrm{d}E/\mathrm{d}x > E_c/(a r_c)$$

Threshold also in stopping power, allows for efficient INTRINSIC MIP background rejection



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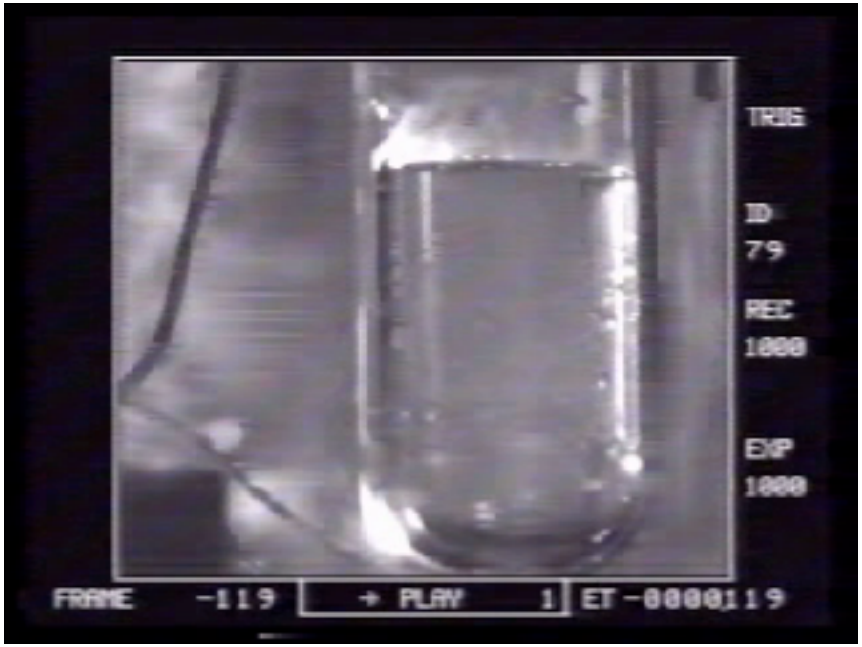
neutron-induced nucleation in 20 c.c. CF_3Br (0.1 s real-time span)
Movie available from http://cfcp.uchicago.edu/~collar/bubble.mov



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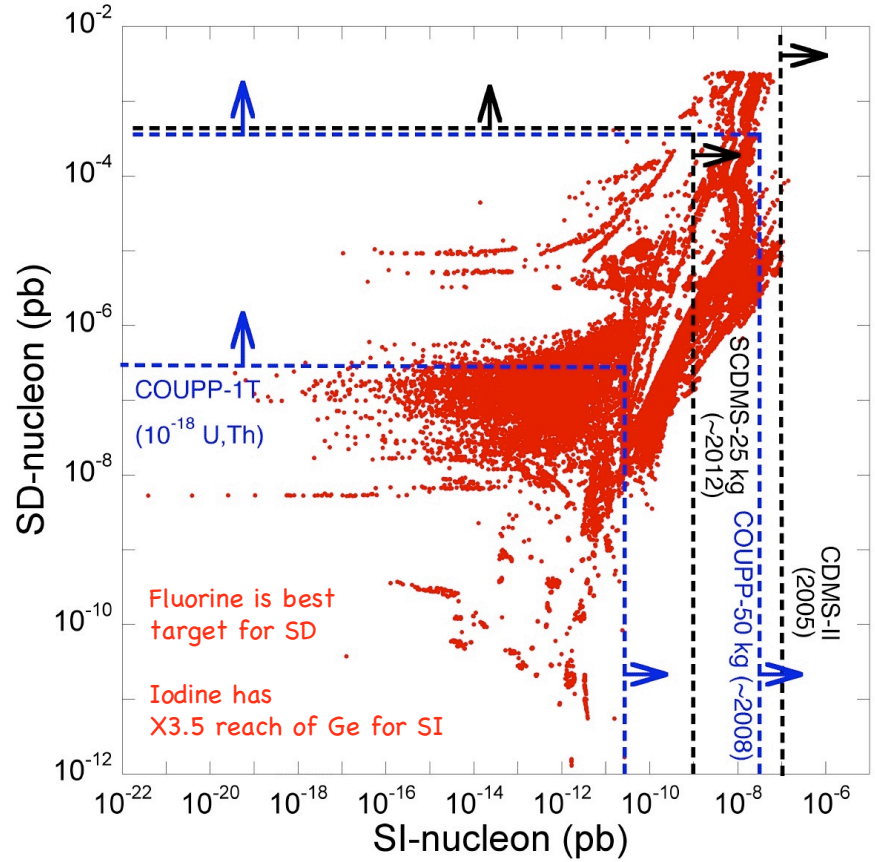
An old precept: attack on both fronts

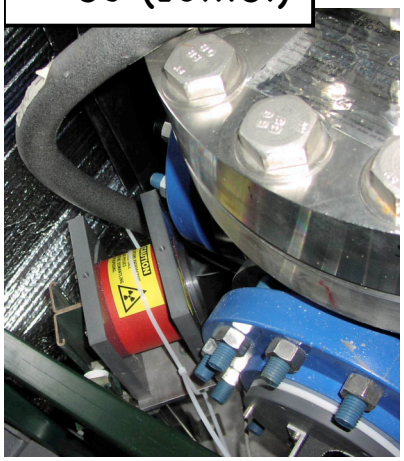


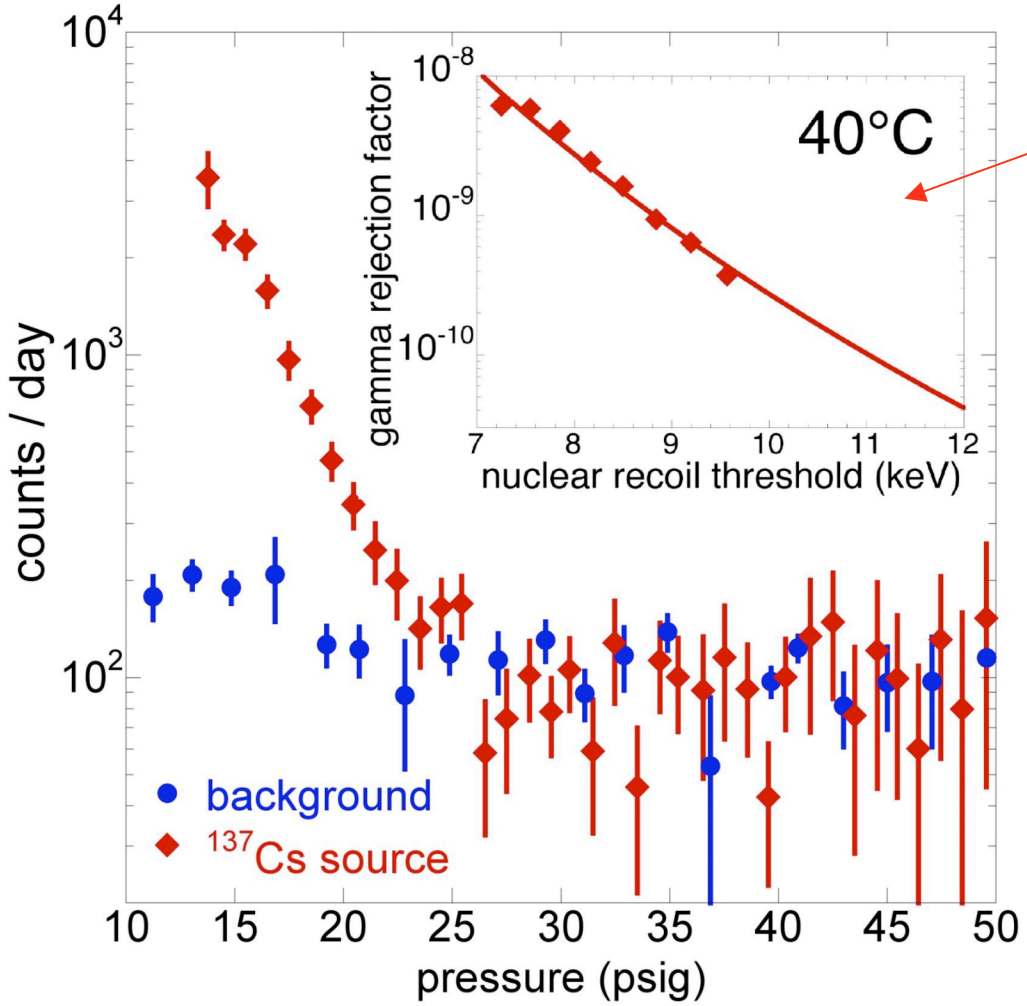
Baltz & Gondolo, JHEP 0410:052,2004. (WMAP-II update)

SD SUSY space harder to get to, but more robust predictions (astro-ph/0001511, 0509269, and refs. therein)

Gamma and neutron calibrations *in situ:*

^{137}Cs (13mCi)





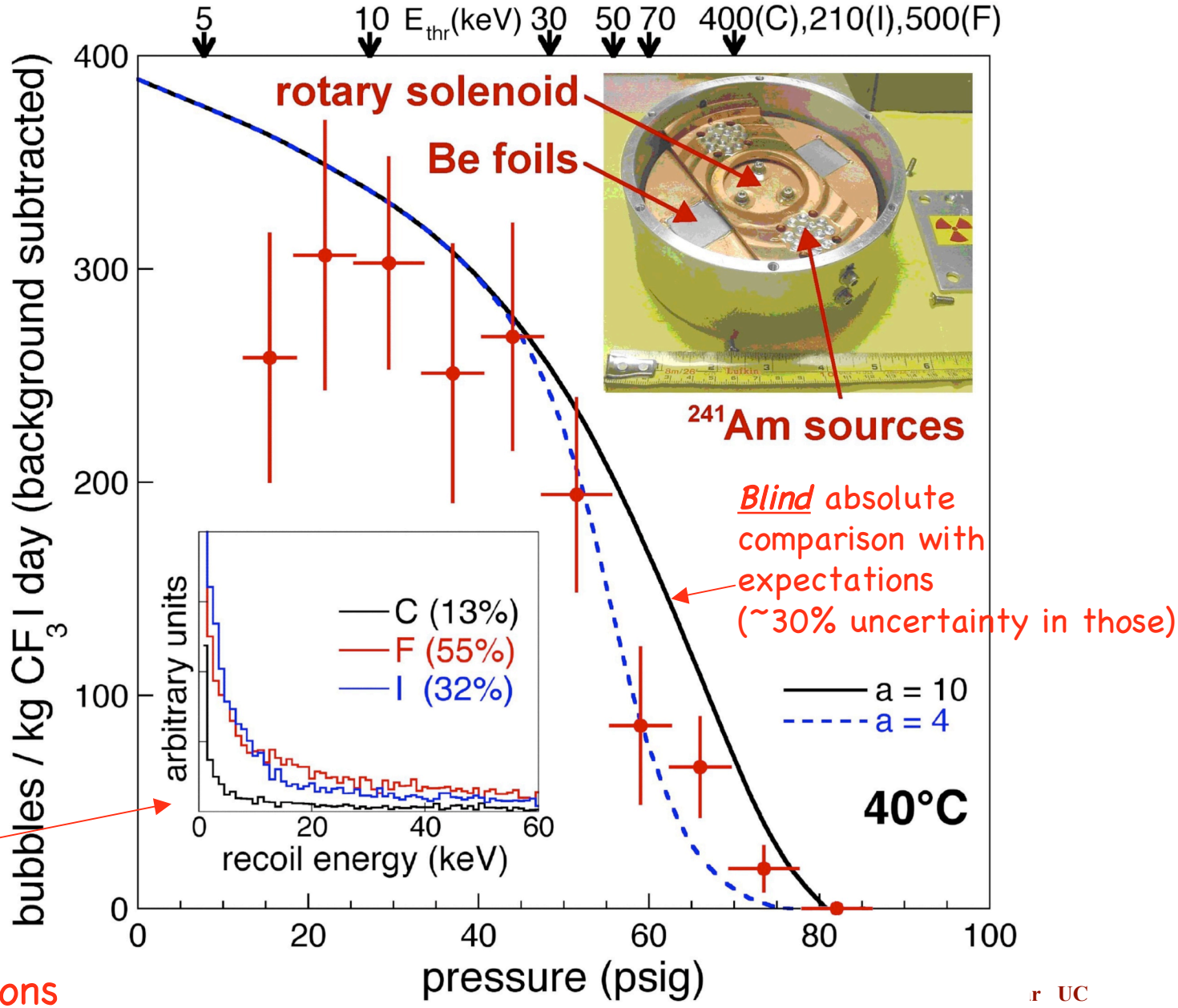
Best MIP rejection factor measured anywhere ($<10^{-10}$ INTRINSIC, no data cuts)

Other experiments as a reference:
XENON ~10^{-2}
CDMS 10^{-4}–10^{-5}
WARP ~10^{-7}–10^{-8}

^{14}C betas not an Issue for COUPP (typical O(100)/kg-day)
No need for high-Z shield nor attention to chamber material selection

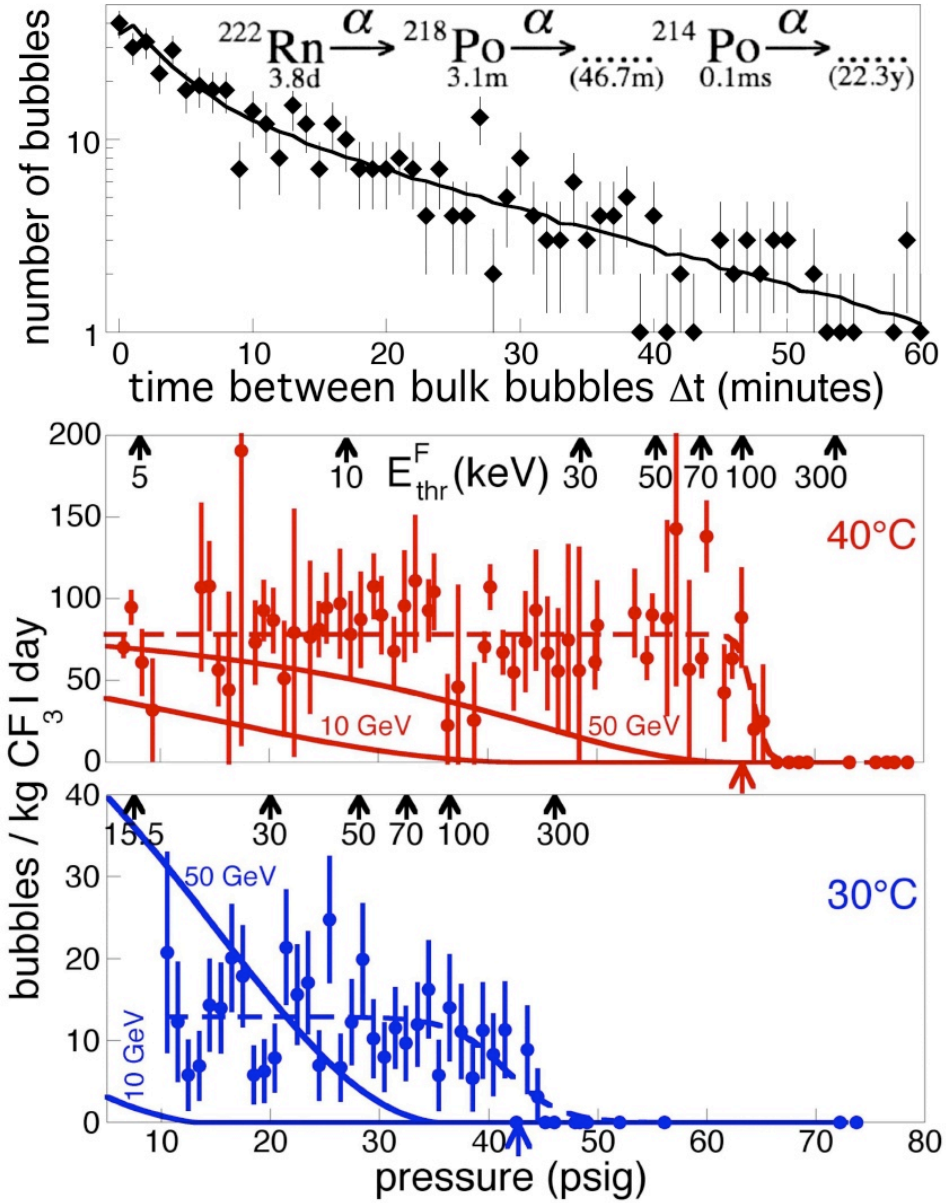
Switchable Am/Be (5 n/s)

Gamma and neutron calibrations *in situ:*



Low-energy WIMP-like recoil energy signal used in these calibrations

A look at the 1st period data: Rn and only Rn



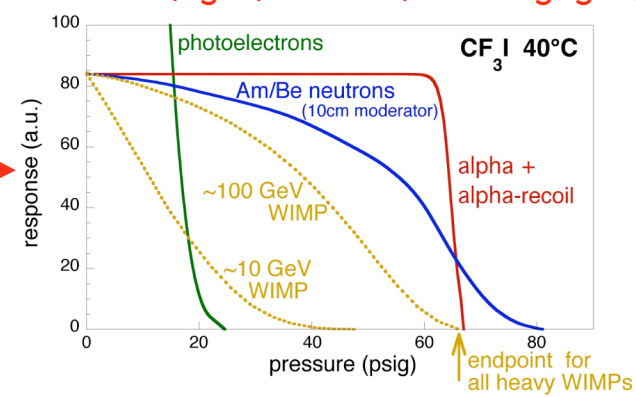
Surface events

- Surface (alpha) rate consistent with measured 50 ppb U and 30 ppb Th in standard quartz
- Tell-tale pressure sensitivity onset (α's)
- Can be rejected, but must be reduced by > 10 to allow >60% live-time in ~50kg chambers
- Addressed via modified etch during vessel manufacture and use of synthetic silica (few ppt)

Bulk events

- Rn sources present: viton o-ring, thoriated weld lines
- Time correlations of bulk events are consistent with 3.1 minute half-life of Po-218. Max. likelihood analysis Favors 100% Rn and 100% efficiency to it.
- Addressed by use of metallic gaskets, lanthanated tips for flange welding, custom-made bellows (electron beam welded) and SNO (light) water (~1E-15 g/g U,Th).

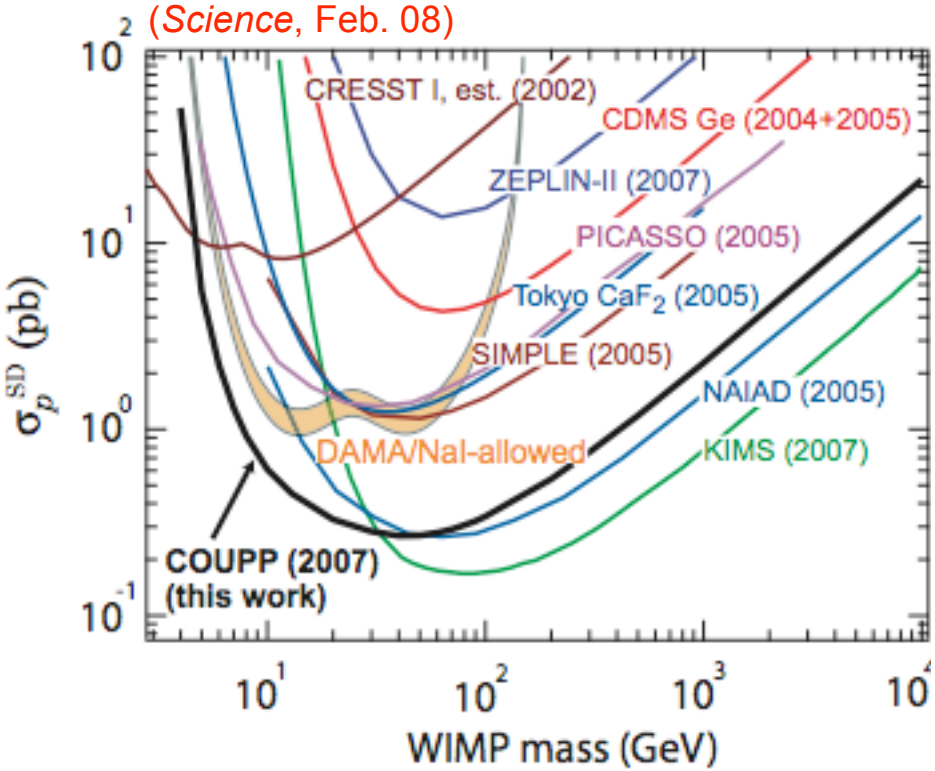
when life gives you lemons… →

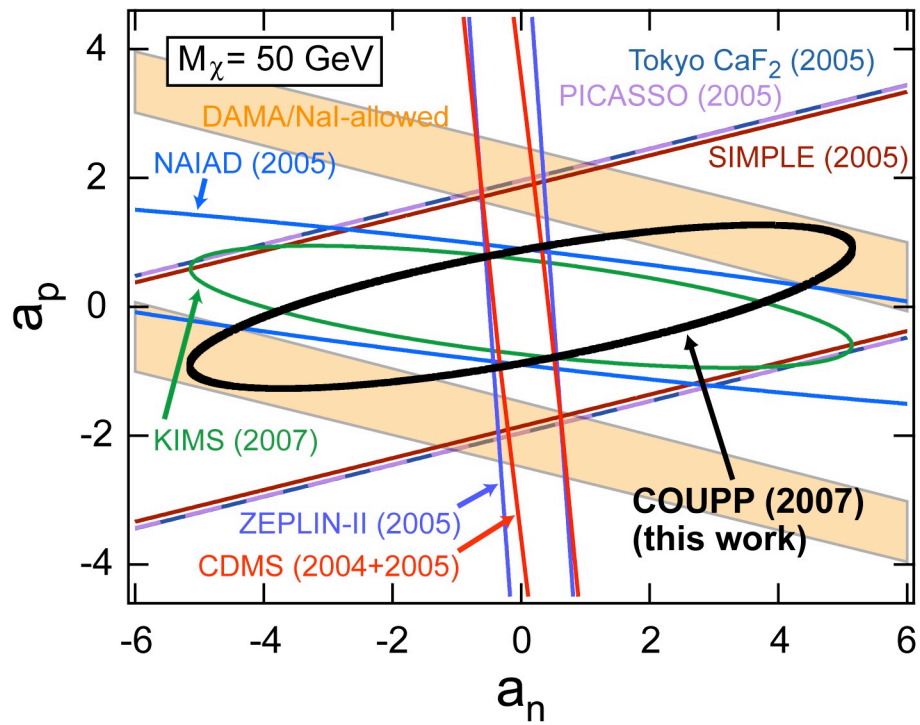


First COUPP results

The bubble chamber is back

Improved SD WIMP sensitivity with 2kg chamber
(*Science*, Feb. 08)





New limits exclude the low-mass region favored by a SD interpretation of the DAMA/NaI signal

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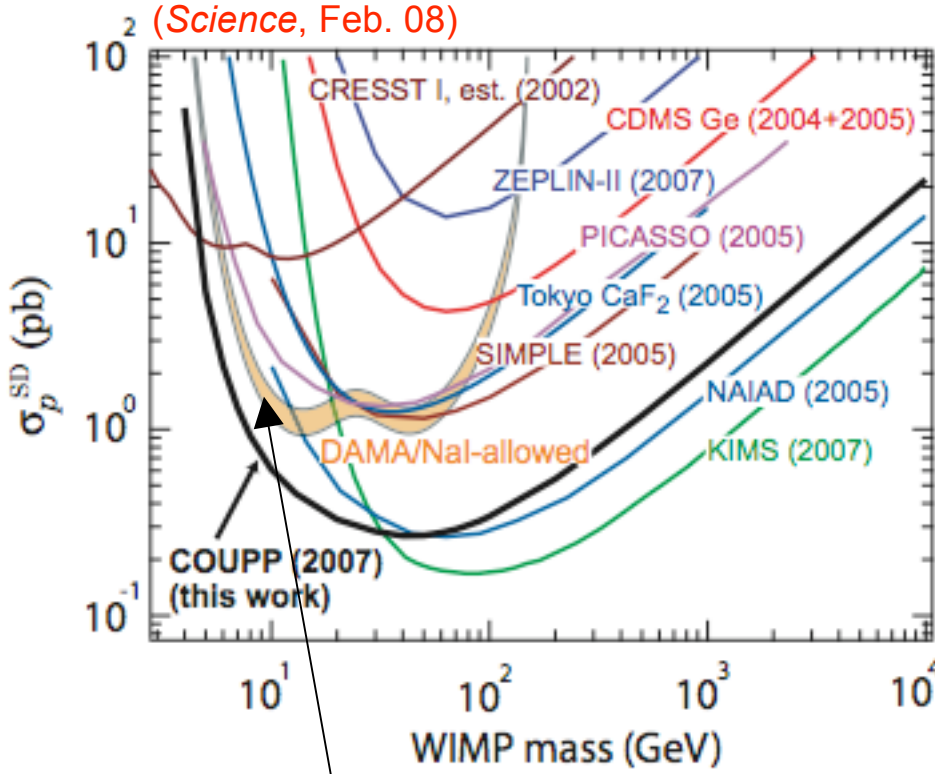
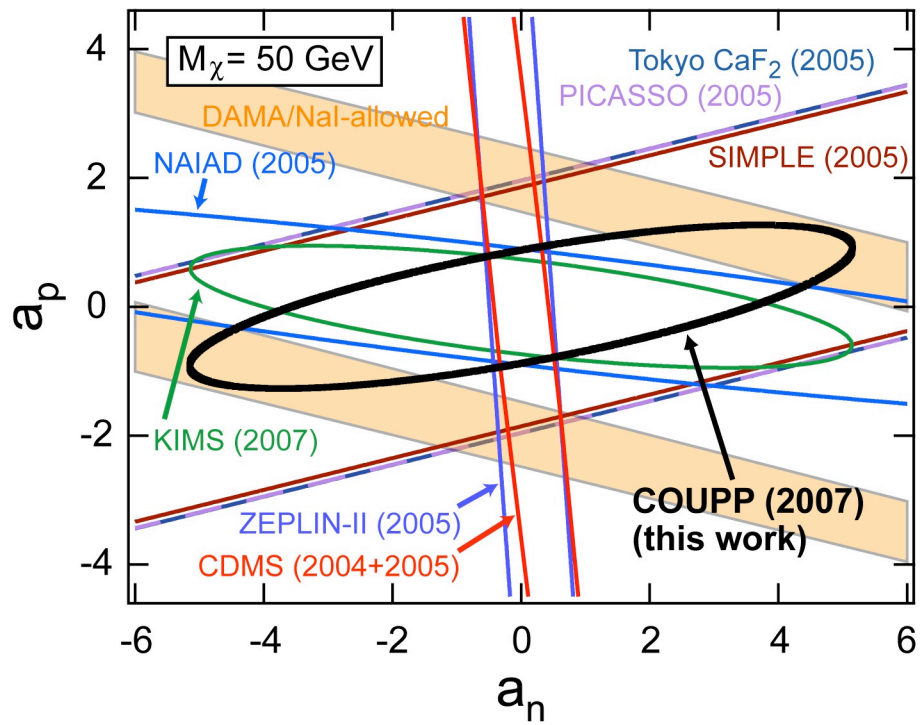
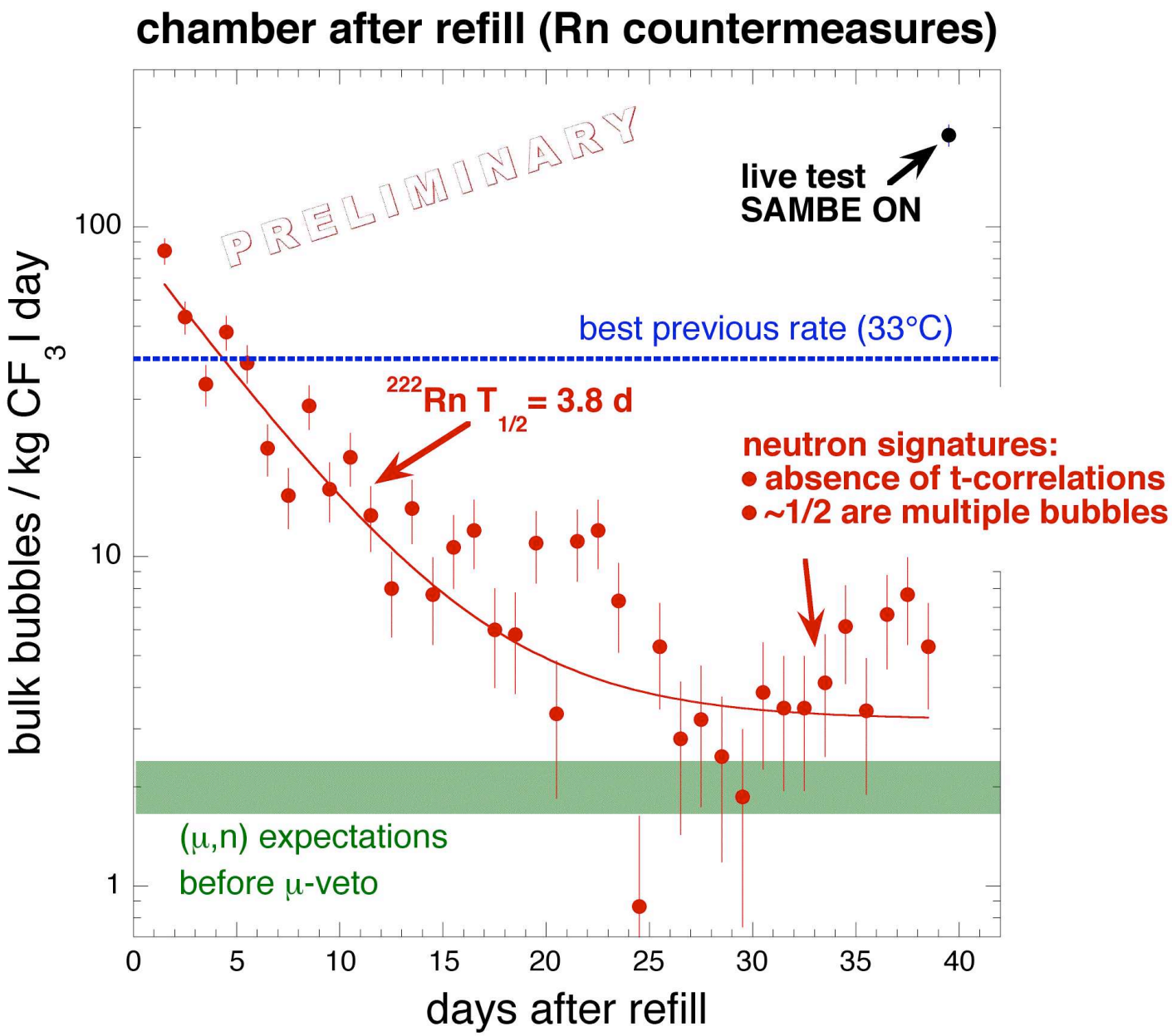




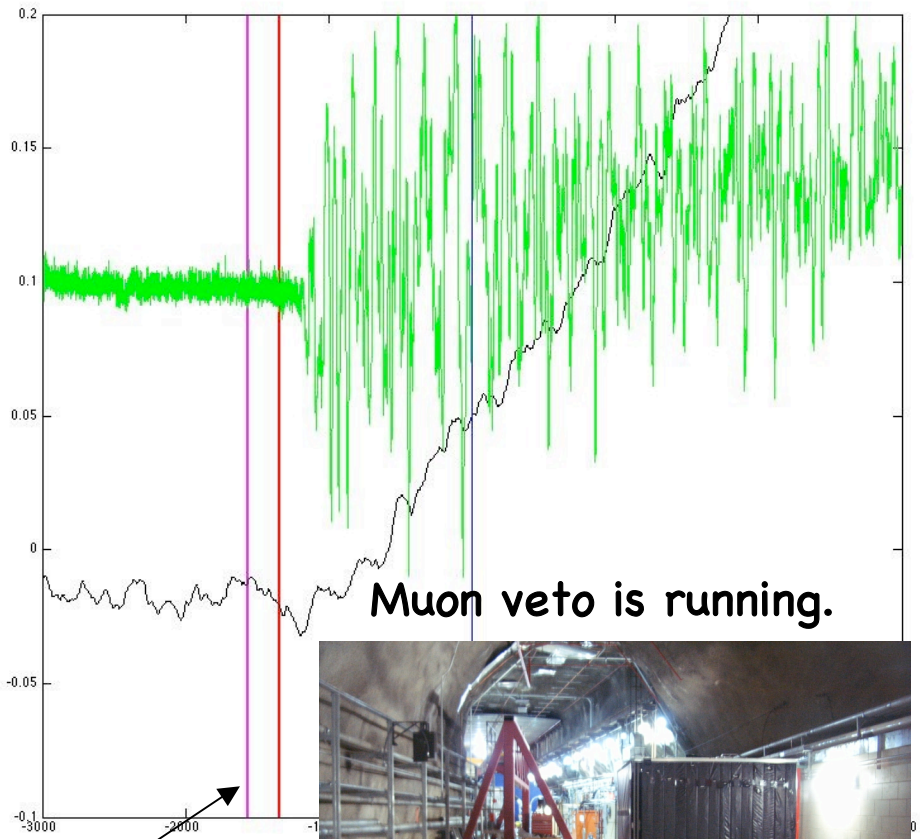
New limits exclude the low-mass region favored by a SD interpretation of the DAMA/NaI signal

A peek at the future (which is here)

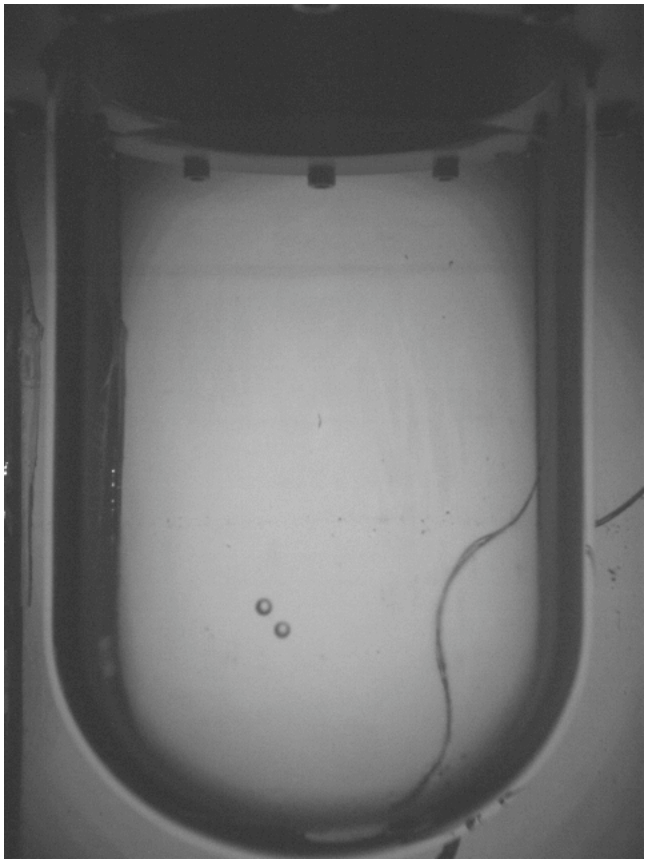


Physics Reach at Fermilab Site

Background goal for E-961: <<1 event per kg per day

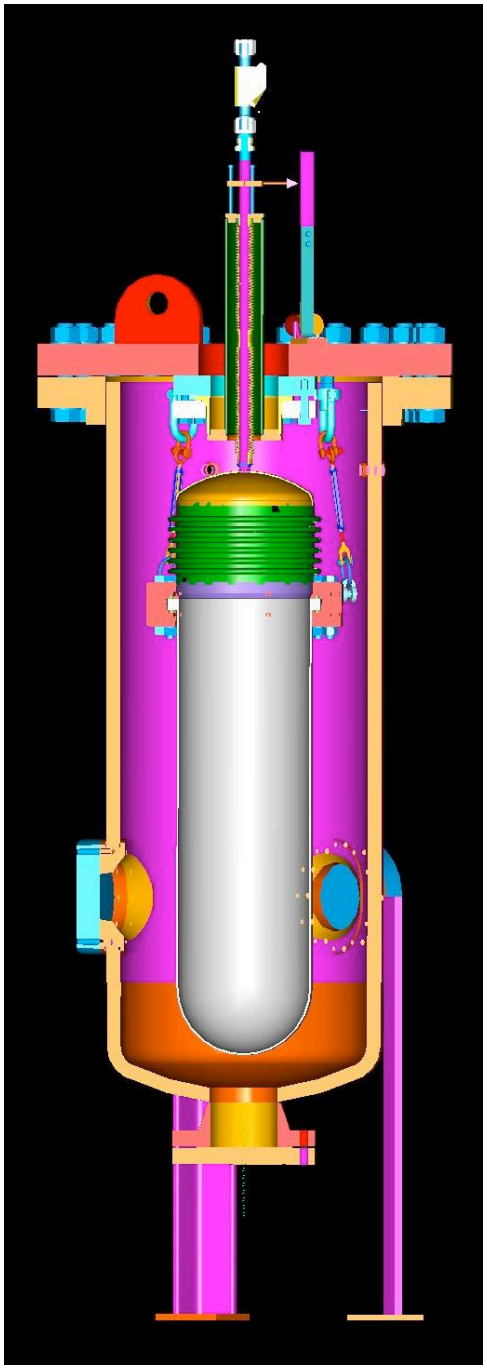


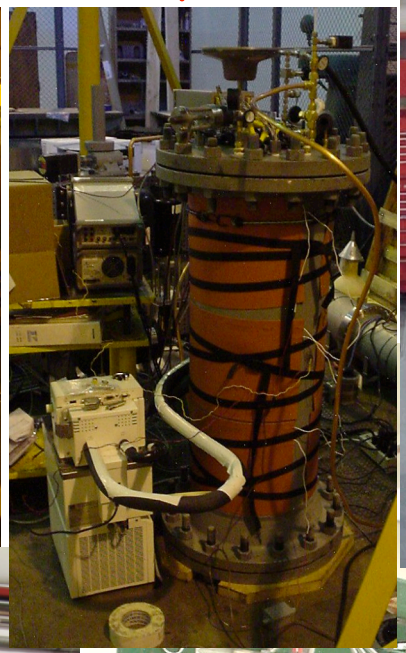
(NuMi signal comes 220 μs before actual spill)



Last refill (~100 d ago, with Rn countermeasures in place) already producing <u>very</u> interesting data.

Next step: 100 kg target mass, deeper site





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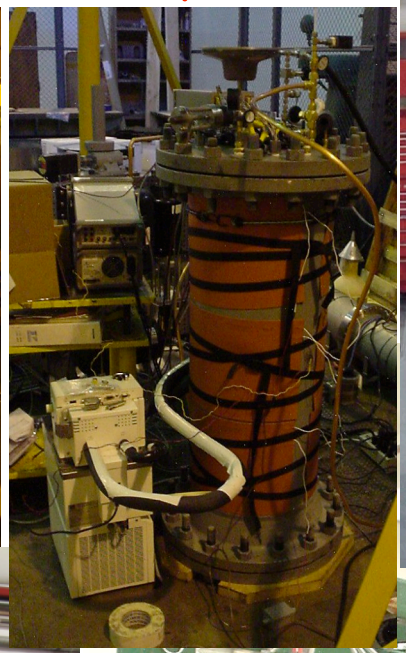

Encouraged by FNAL directorate to start thinking "1 ton"

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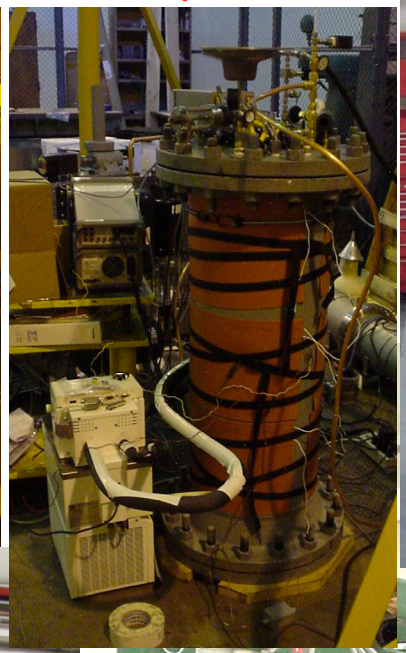

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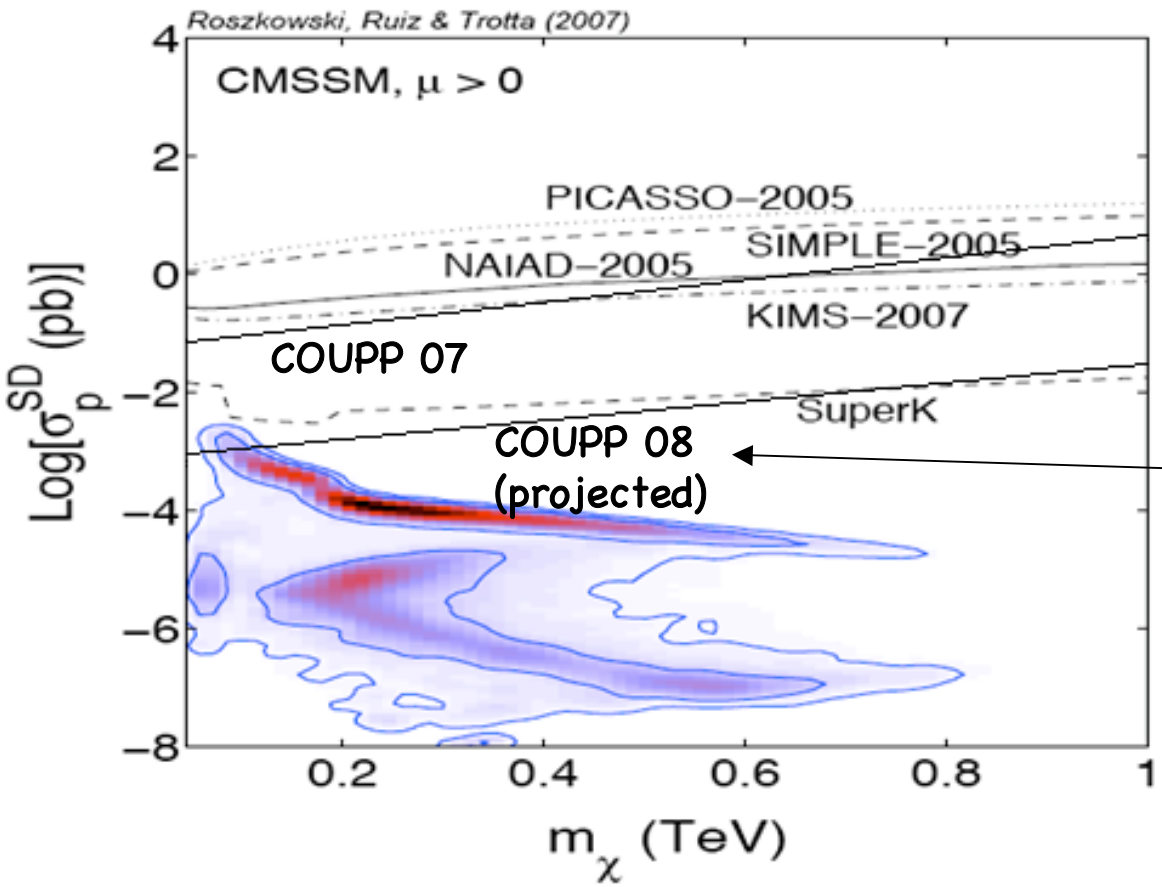
"BIG" chamber first light

http://kicp.uchicago.edu/~collar/fl.gif

Physics Reach at Fermilab Site

Background goal for E-961: <<1 event per kg per day



2008 goals: exploring SD favored region for the first time, competitive SI limits.

Last refill (~100 d ago, with Rn countermeasures in place) already producing <u>very</u> interesting data.

Physics Reach at Fermilab Site

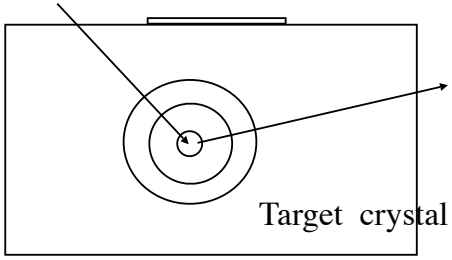
Background goal for E-961: <<1 event per kg per day

...coming up...

First COUPP results...

Last refill (~100 d ago, with Rn countermeasures in place) already producing <u>very</u> interesting data.

Phonon Mediated Detectors



Principle: Detect lower energy excitations

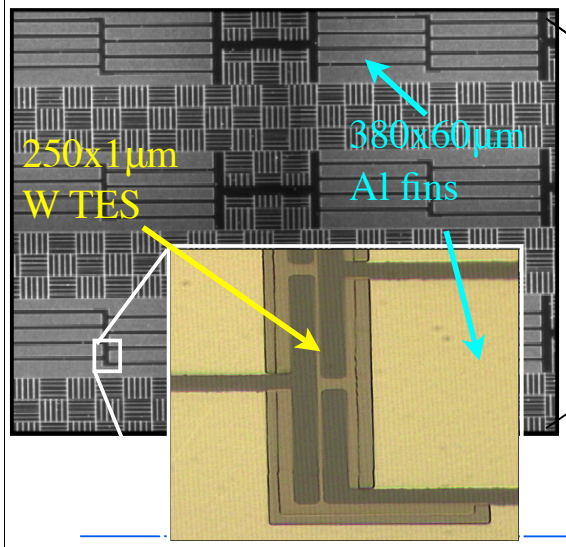
15 keV large by condensed matter physics standards

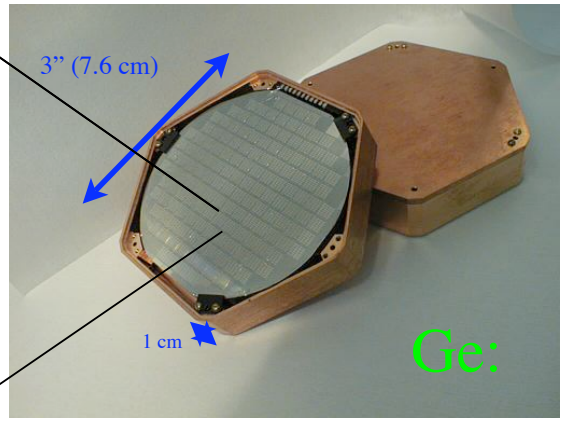
Goals

- Sensitivity down to low energy
  Phonons measure the full energy
- Active rejection of background: recognition of nuclear recoil
  Combine with low field ionization measurement CDMS EDELWEISS
  or scintillation (CRESST II)

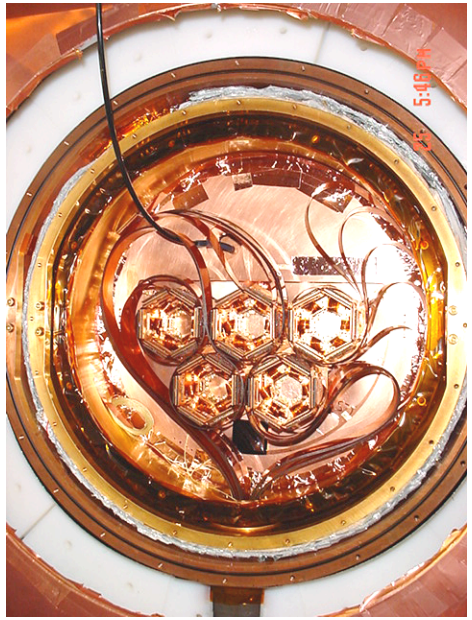
But: operation at very low temperature!

e.g. CDMS II: 40mK





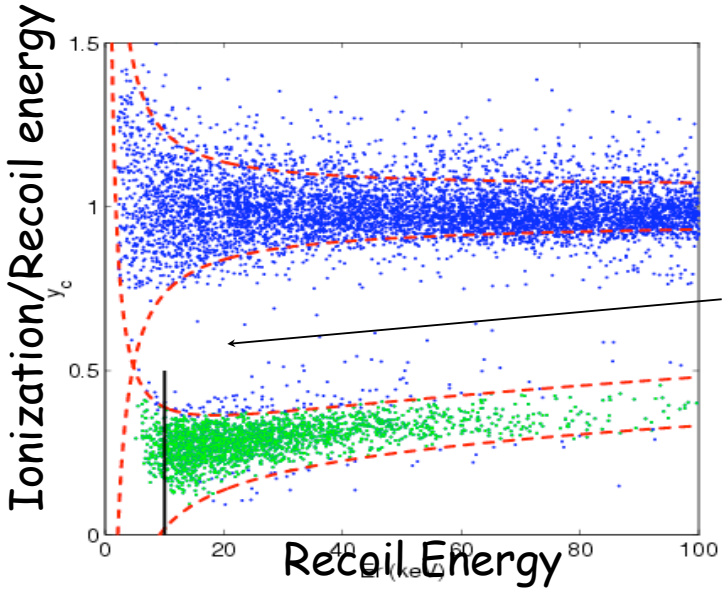
x 30= 5 towers of 6



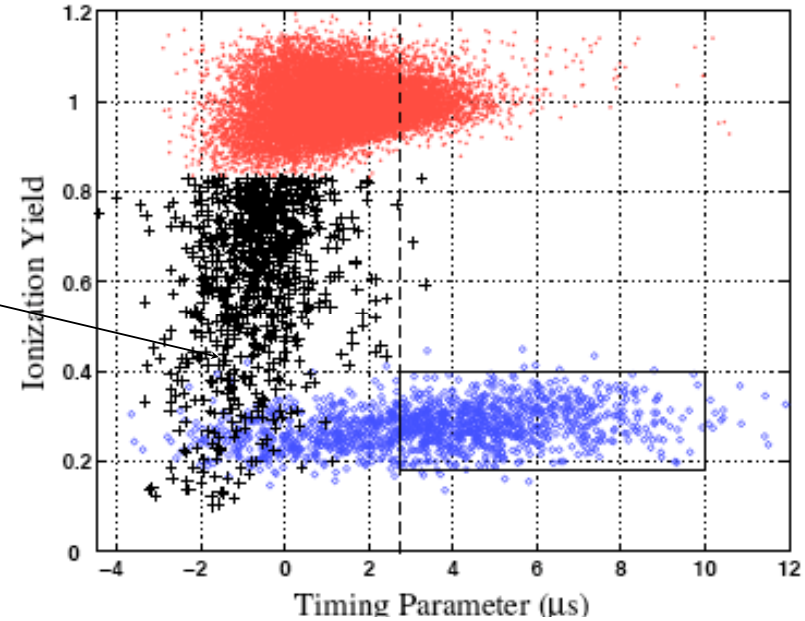
Multidimensional Discrimination

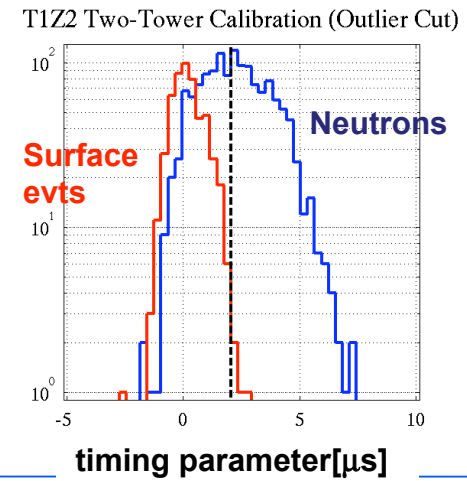
Ionization yield

Timing -> surface discrimination



Surface Electrons





Fix cuts blind (with calibration sources)

to get ≈0.5 events background

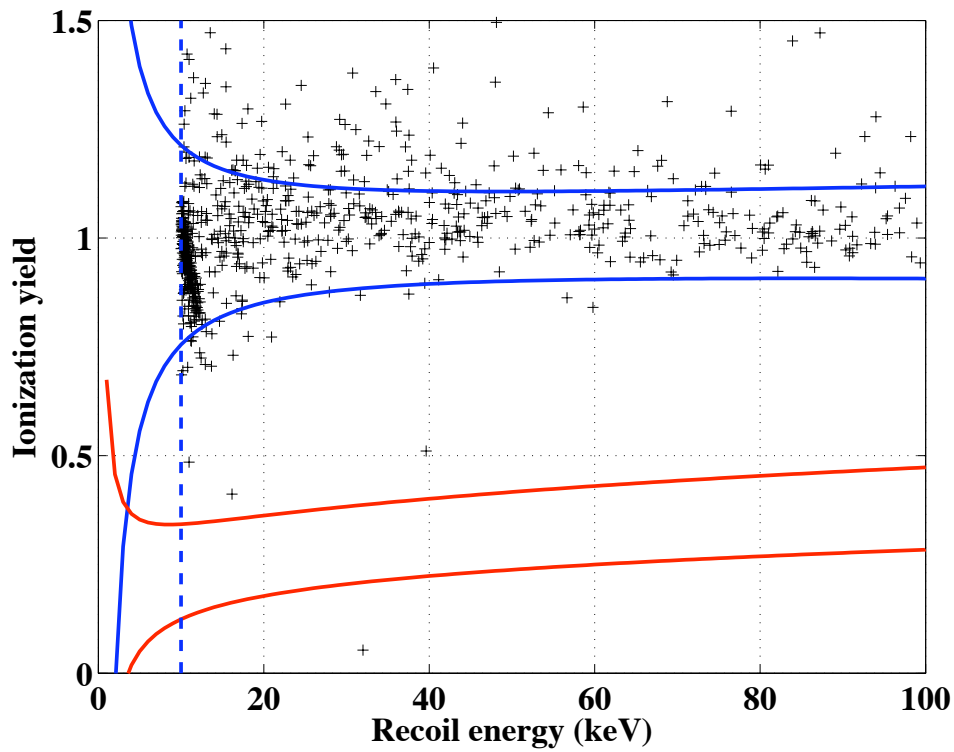
Opening the Box

Box opened Monday, February 4 for 15 Ge ZIPs
Remaining 8 Si and 1 Ge undergoing further leakage characterization

3σ region masked
=> Hide unvetoed singles

Lift the mask, see 97 singles failing timing cut

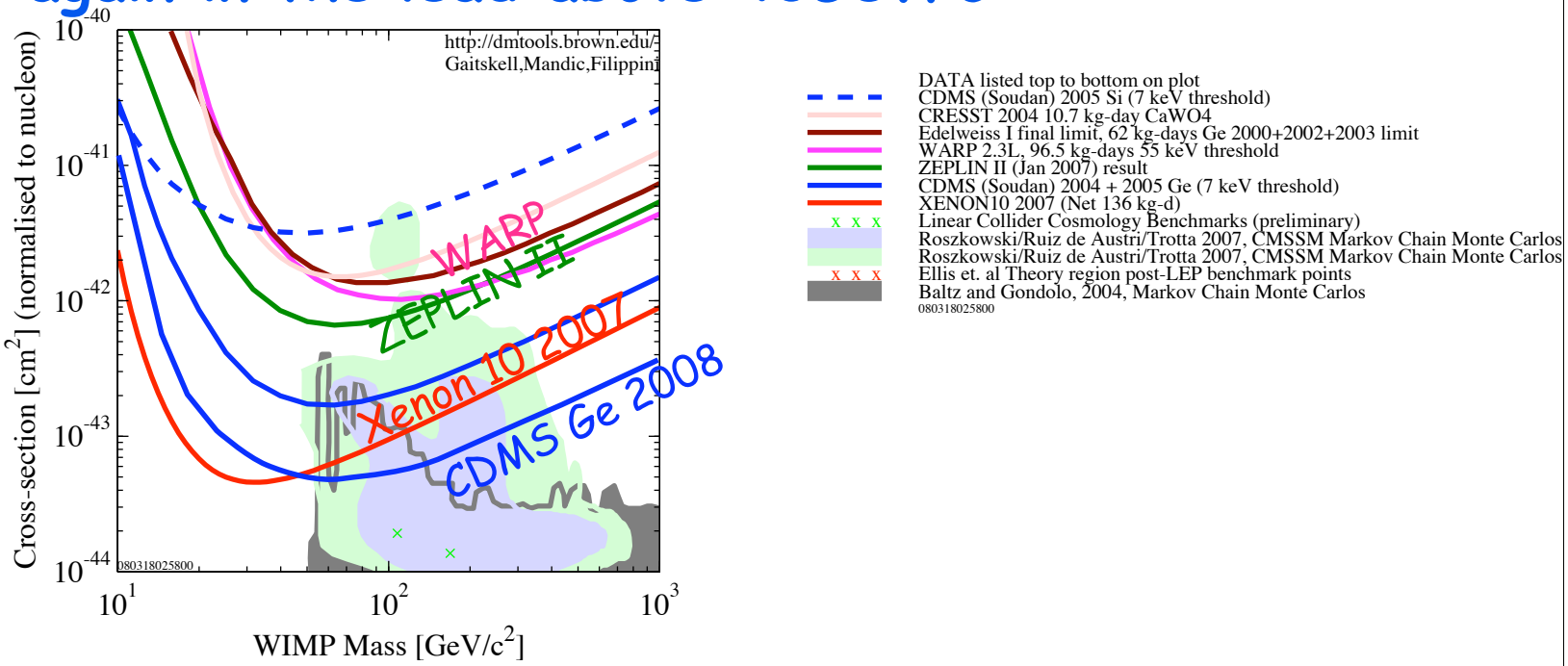
Apply the timing cut, count the ~~candidates~~



No events observed

Current WIMP Limits

CDMS again in the lead above 40GeV/c^2



Preprint at:
- http://cdms.berkeley.edu
- arXiv:0802.3530

Immediate Future (cryogenic)

CDMS: run till ≈ December 08 ≈2000kg days

sensitivity ≈10^{-44} cm^2/nucleon

stay background free: - new towers 3 lower back grounds
- better discrimination tools

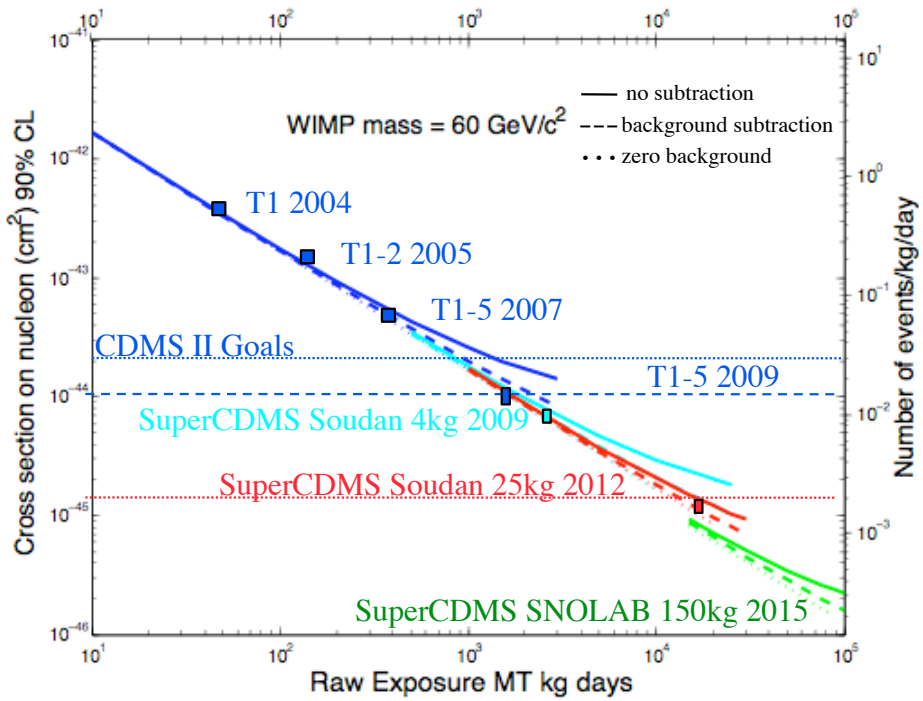
Edelweiss-> 10^{-43} cm

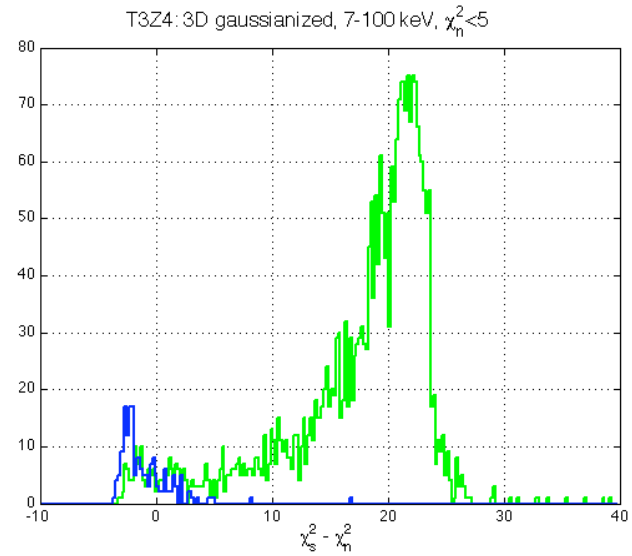
21 330g Ge detectors with NTD
+ 7 400g Nb Si (athermal phonons)
first commissioning run April -May 07
encouraging
no event > 30keV for eight NTD detectors (19 kg day) (cf 3 in EdelI)
first underground test of two 200g Nb Si
Interdigitated detectors

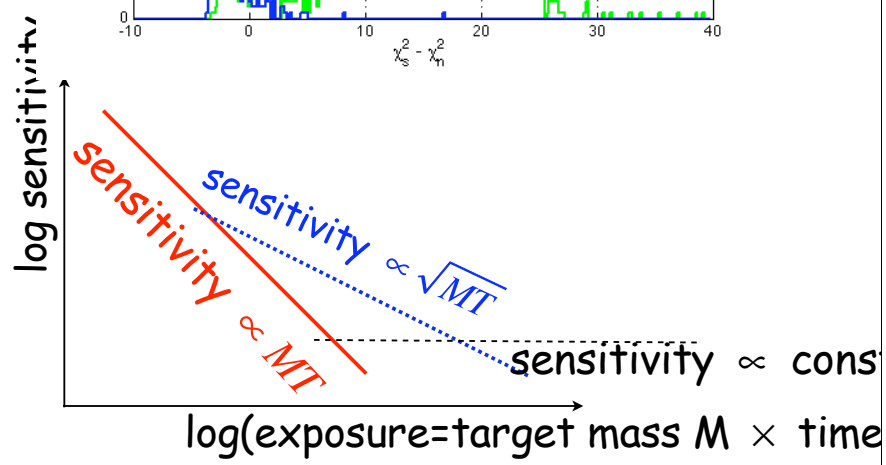
CRESST II-> 10^{-43} cm

Major upgrade 66 SQUIDs for 33 detectors + neutron shield
Three detectors running since 4/07.

Low Temperature Detector Future





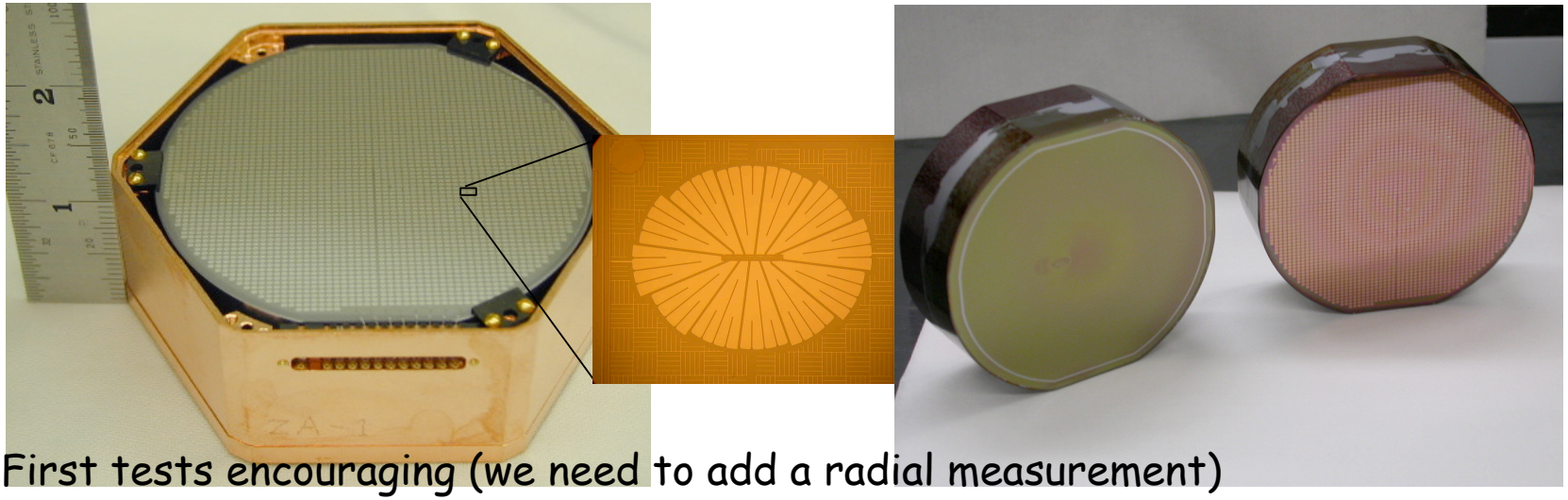


Three General Challenges

- ✓ Understand/Calibrate detectors
- ✓ Be background free
  much more sensitive than background subtraction
  eventually limited by systematics
- ✓ Increase mass while staying background free

Larger Detector Mass

SuperCDMS 25 kg detectors: 1cm-> 1" 250g ->635 g



First tests encouraging (we need to add a radial measurement)

Double face 35% -> 70%?

Much larger detectors -> 1ton expt?

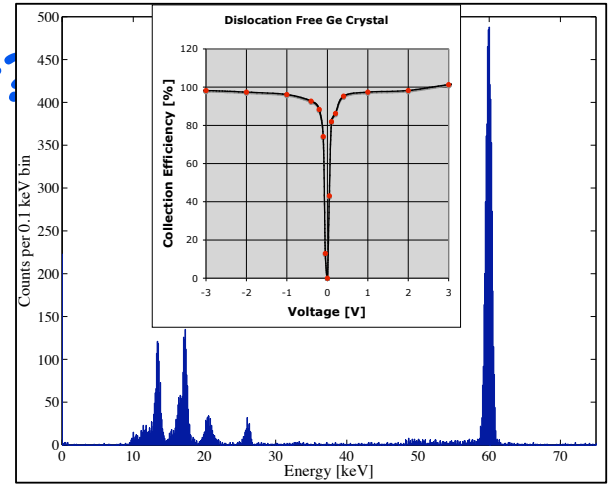
Liquid N2 Ge crystals limited to 3"

≈ 100 dislocation/cm^3

But we showed recently that dislocation free works at low temperature!

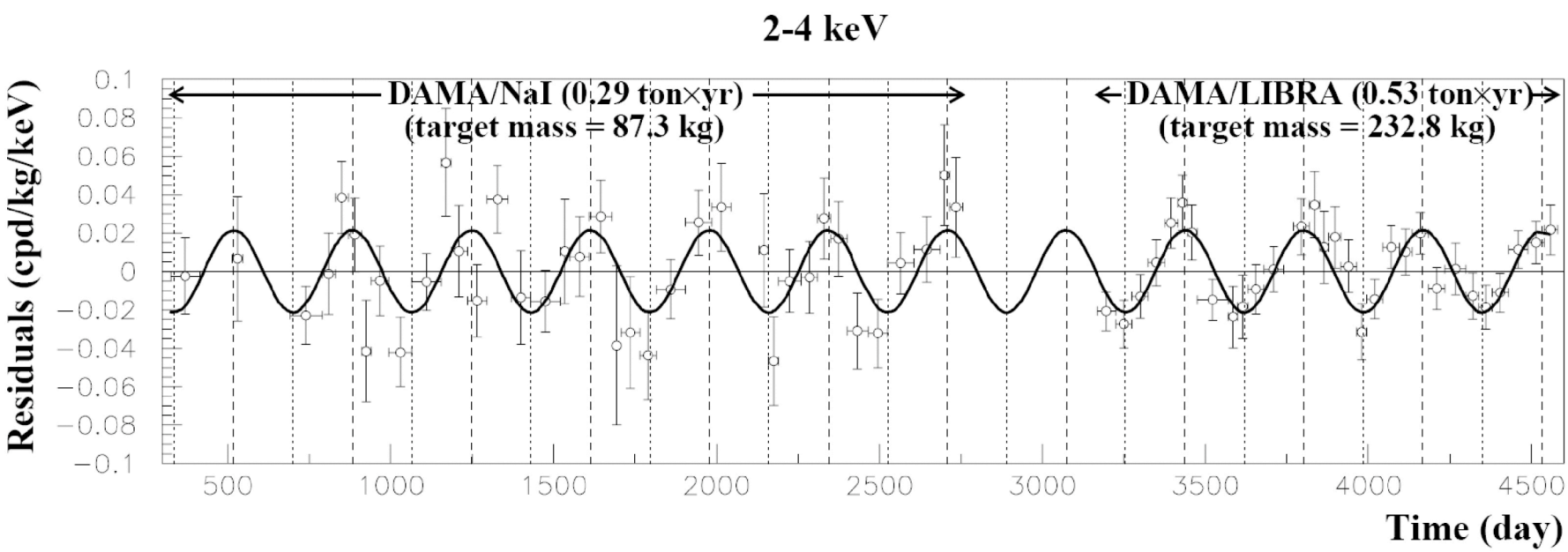
Umicore grows (doped) 8" crystal

6"x2" or 8"x1" ≈ 5kg + Multiplexing



DAMA+DAMA/LIBRA >8σ yearly modulation effect:

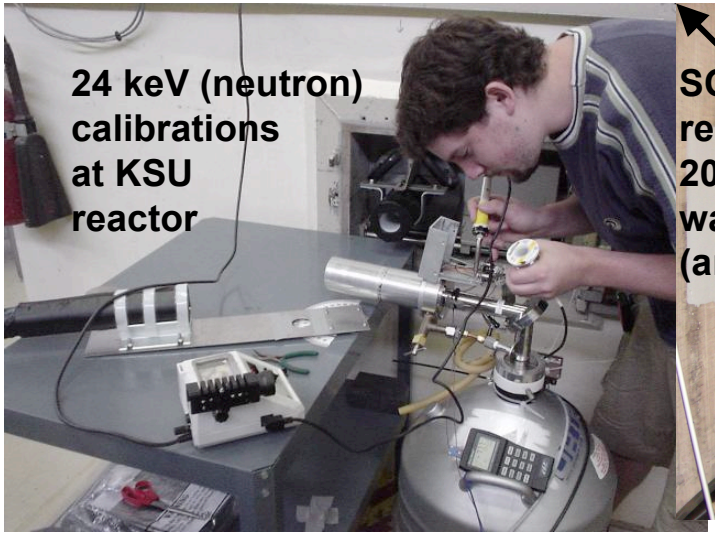
What in god's green Earth is this?



DAMA+DAMA/LIBRA >8σ yearly modulation effect:

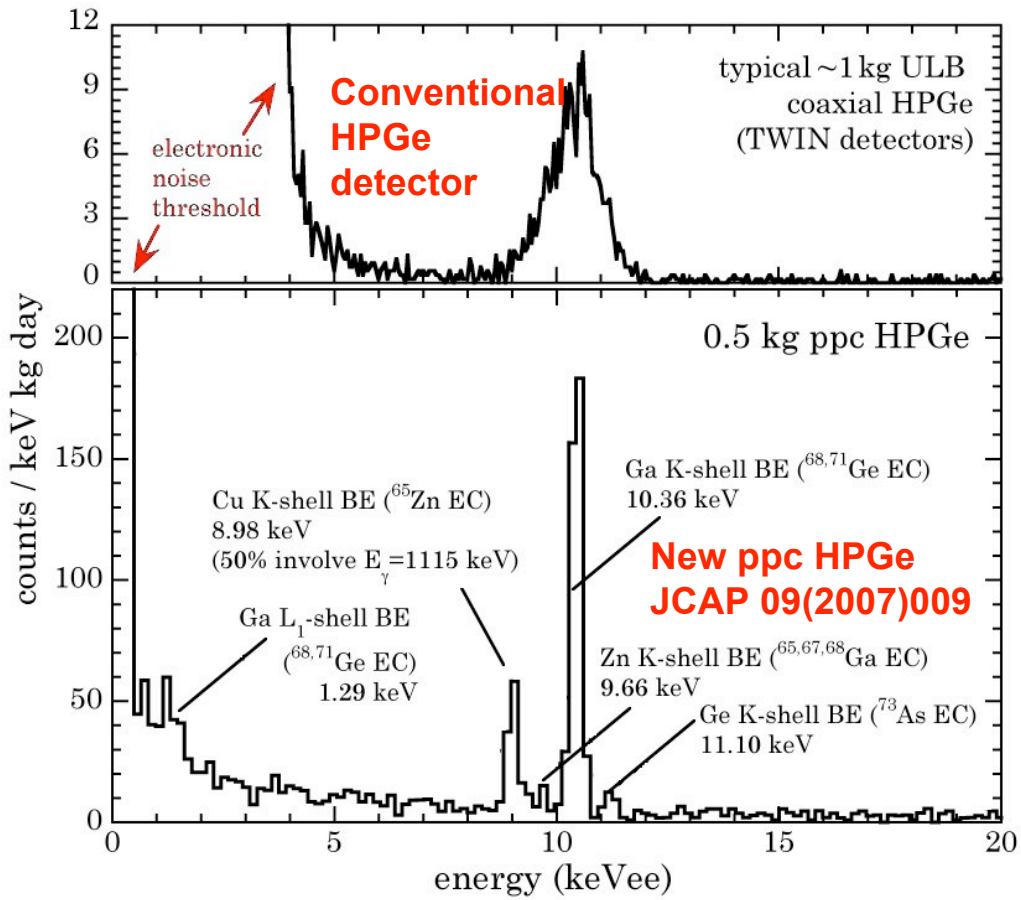
What in god's green Earth is this?

WIMPS it ain't!

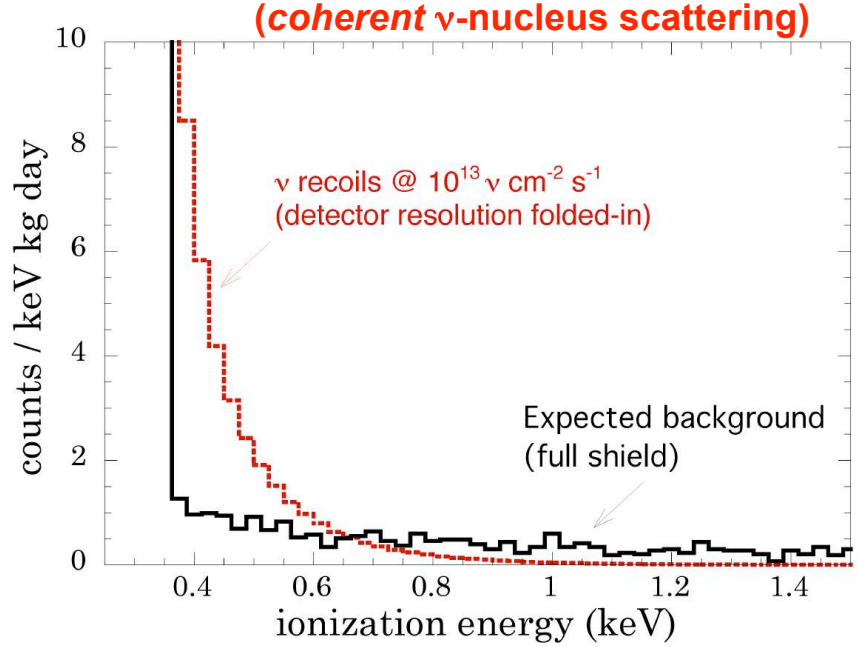


COGENT:
neutrino & astroparticle physics using large-mass, ultra-low noise germanium detectors

(ANL, CANBERRA, LLNL, PNNL, SNL, UC, UW)

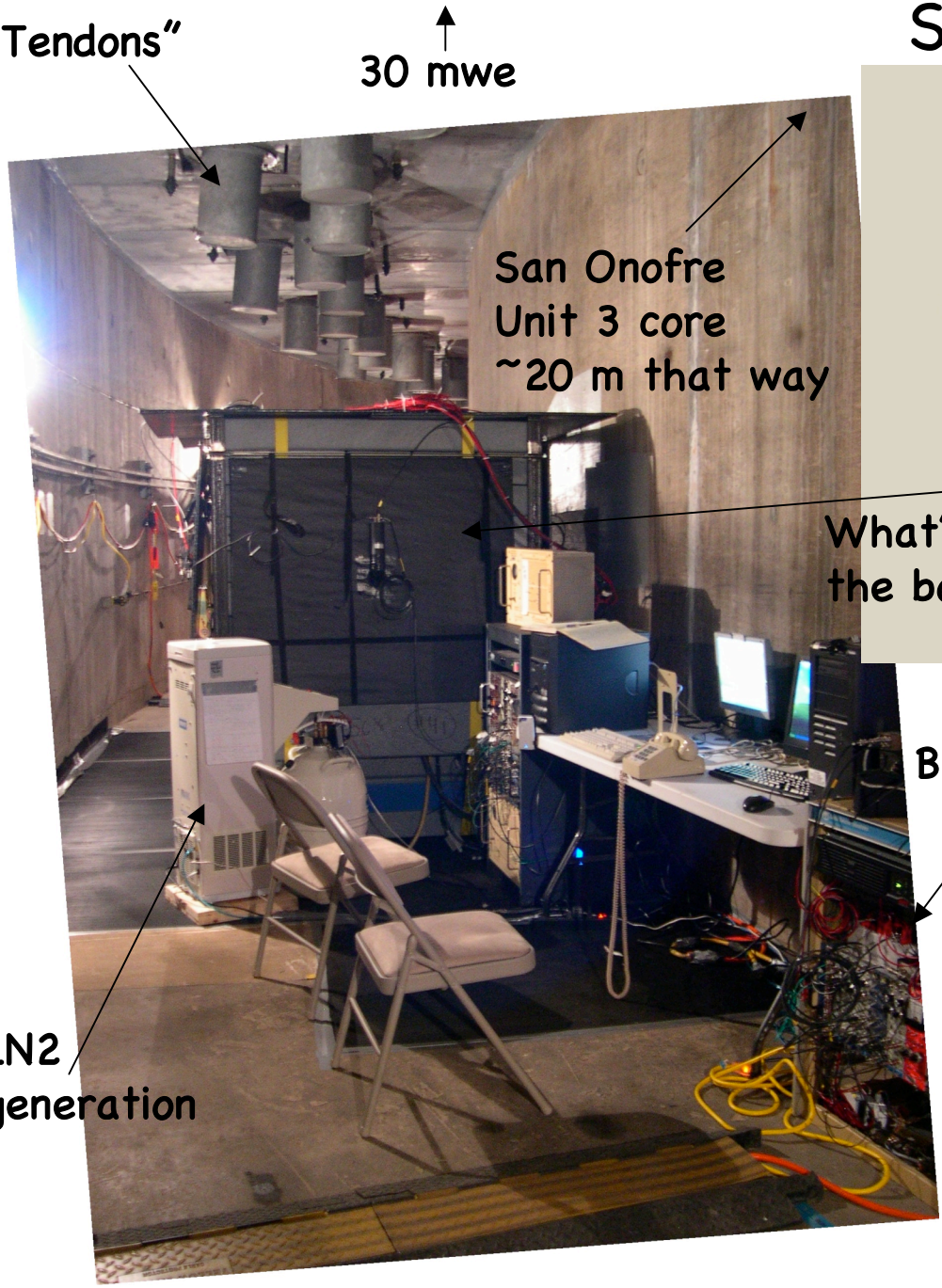


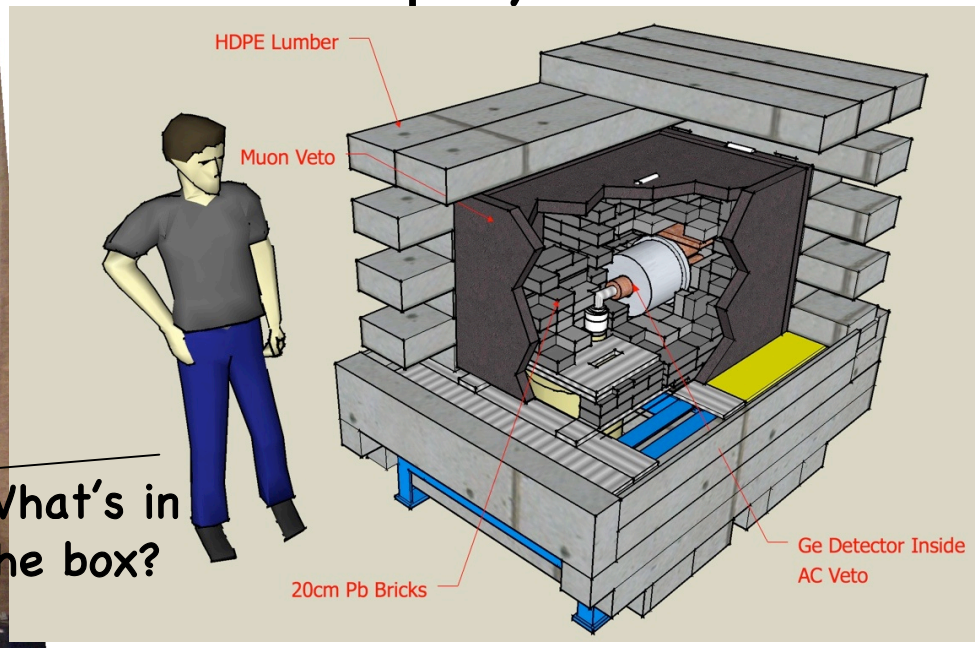
A new (30 year old) path to neutrino detection: (*coherent* ν-nucleus scattering)



Other applications in light WIMP searches, MAJORANA

SONGS deployment



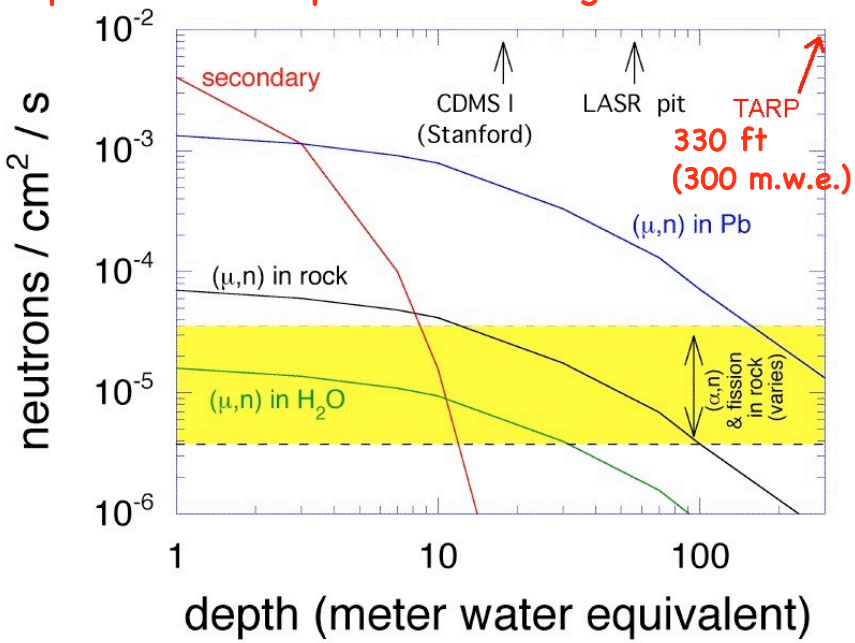


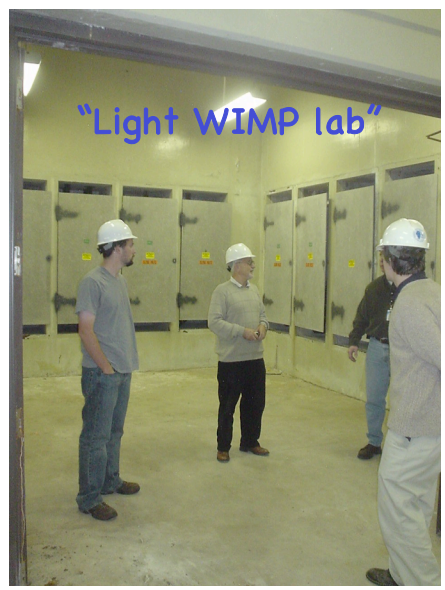
Is this the year for coherent neutrino detection?

TARP: 5 minutes from ANL, 20 min from UC

permission to use until (at least) 2012: Big THANKS to Tom Economou

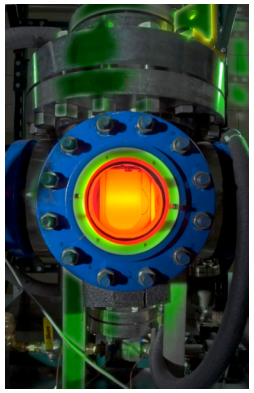
Equivalent of deeper site with a good muon veto



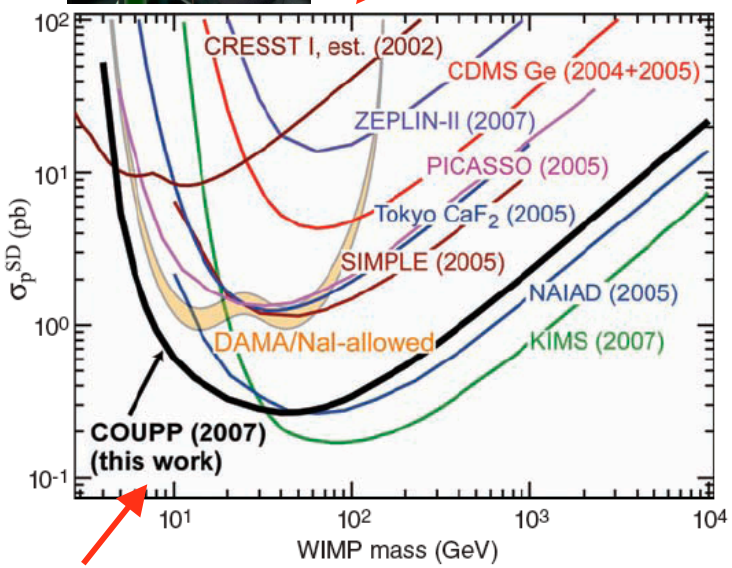


The city of Chicago lending a hand to local Dark Matter hunters…

First physics results from these ppc's…

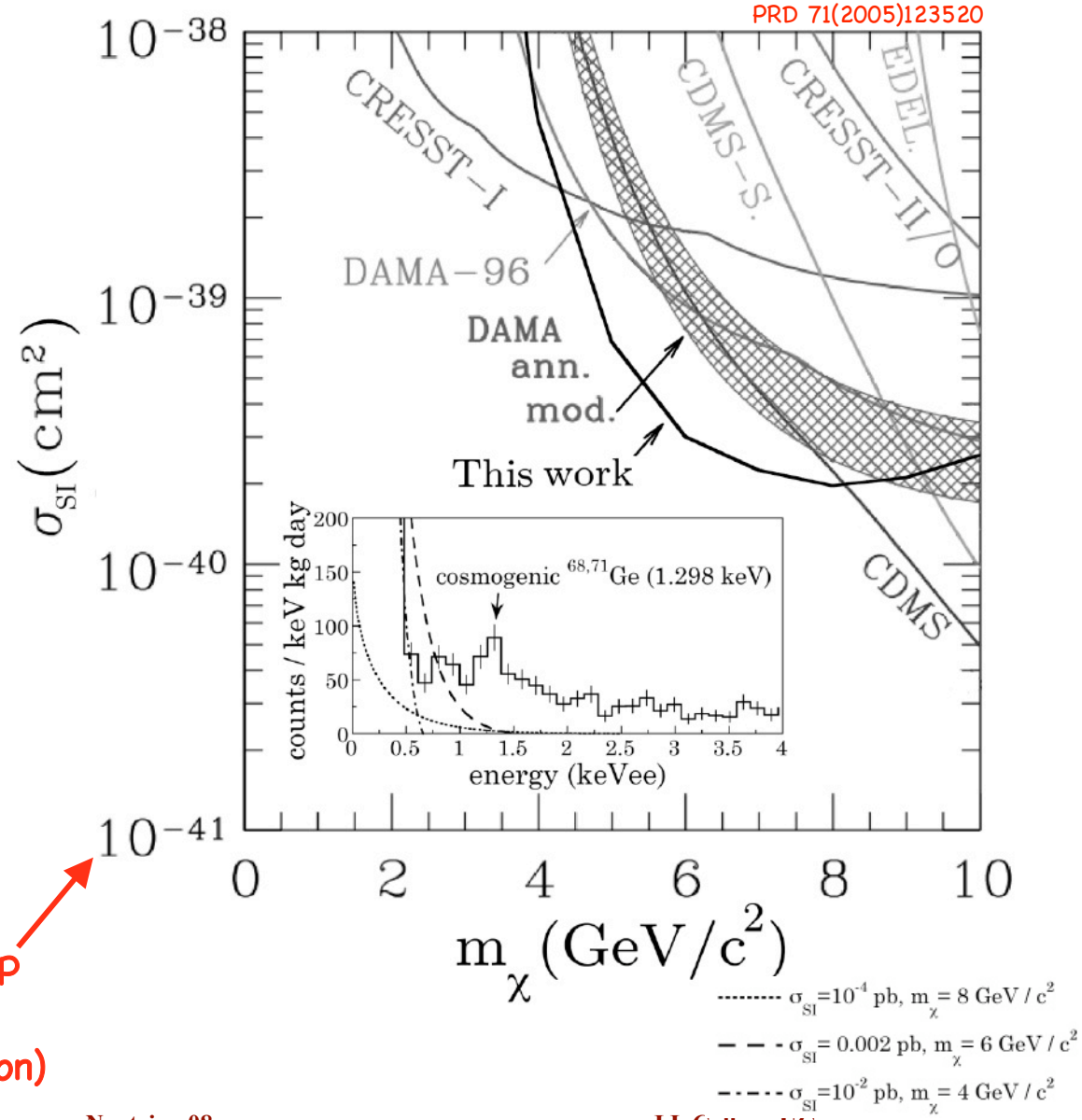


COUPP excludes last SD WIMP possibilities (Science, Feb. 08)



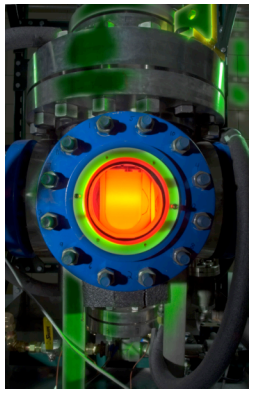
2008 dataset
~ x70 bckg reduction

Gondolo & Gelmini
PRD 71(2005)123520

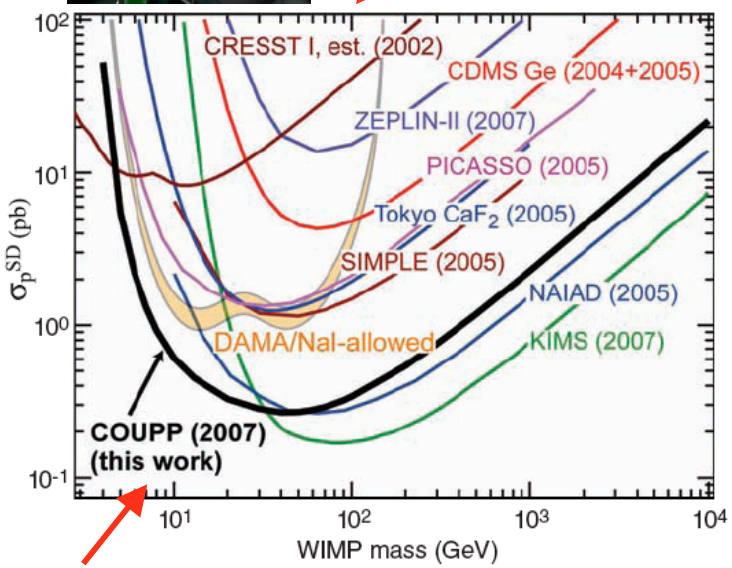


p-pc HPGe excludes last SI WIMP possibility (in preparation)

First physics results from these ppc's…



COUPP excludes last SD WIMP possibilities (Science, Feb. 08)



2008 dataset
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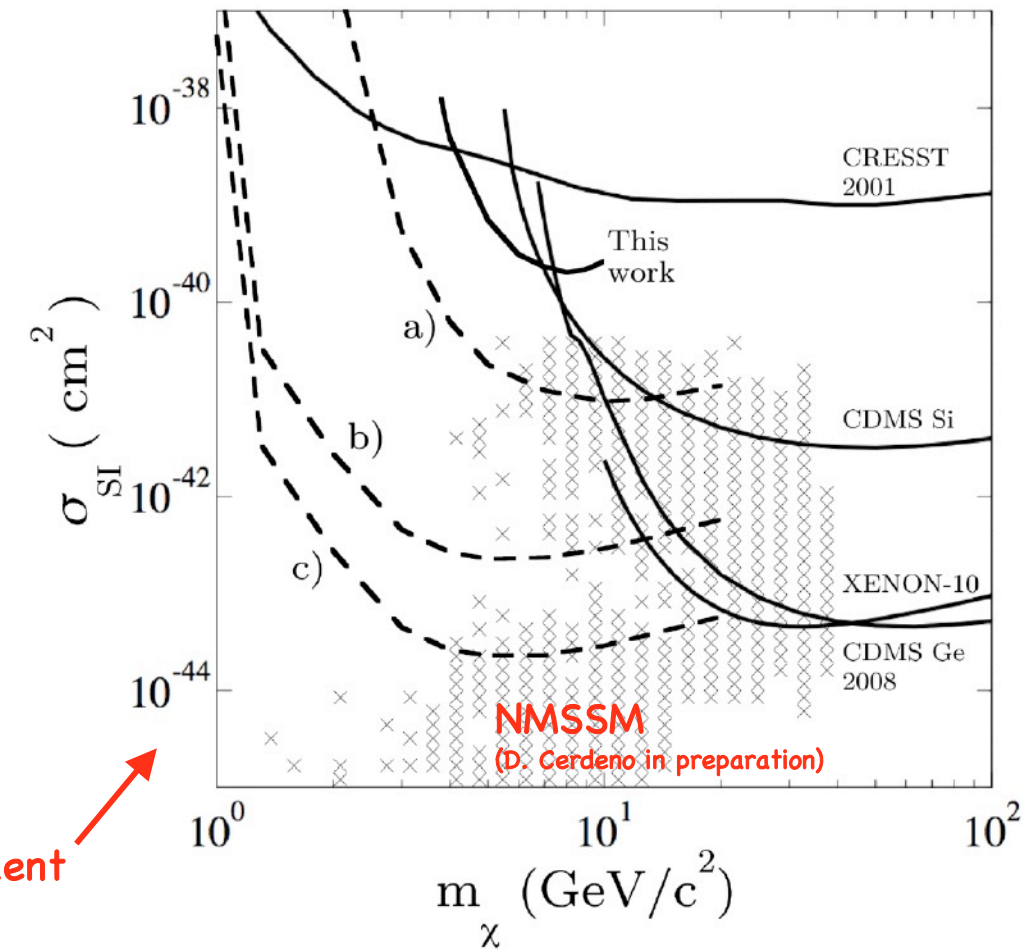
Future PPC spin-independent sensitivity (MAJORANA)



But NEVER surrender!

Classic example of this laudable behavior:
* Monty Python's Black Knight

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More recently:
* Hillary Clinton
* DAMA collaboration

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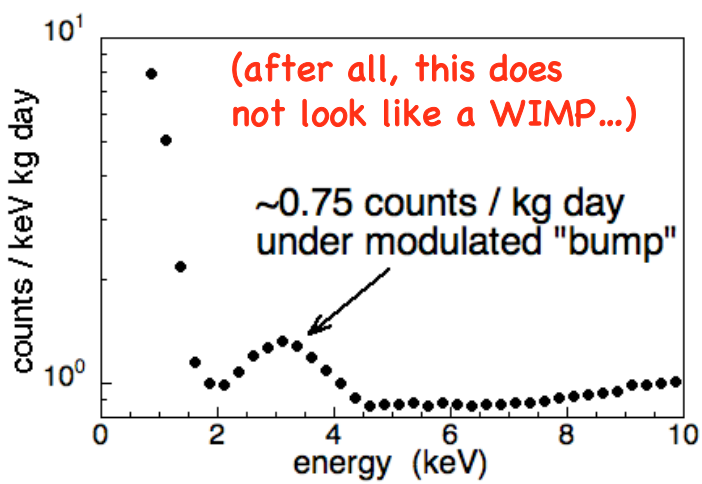
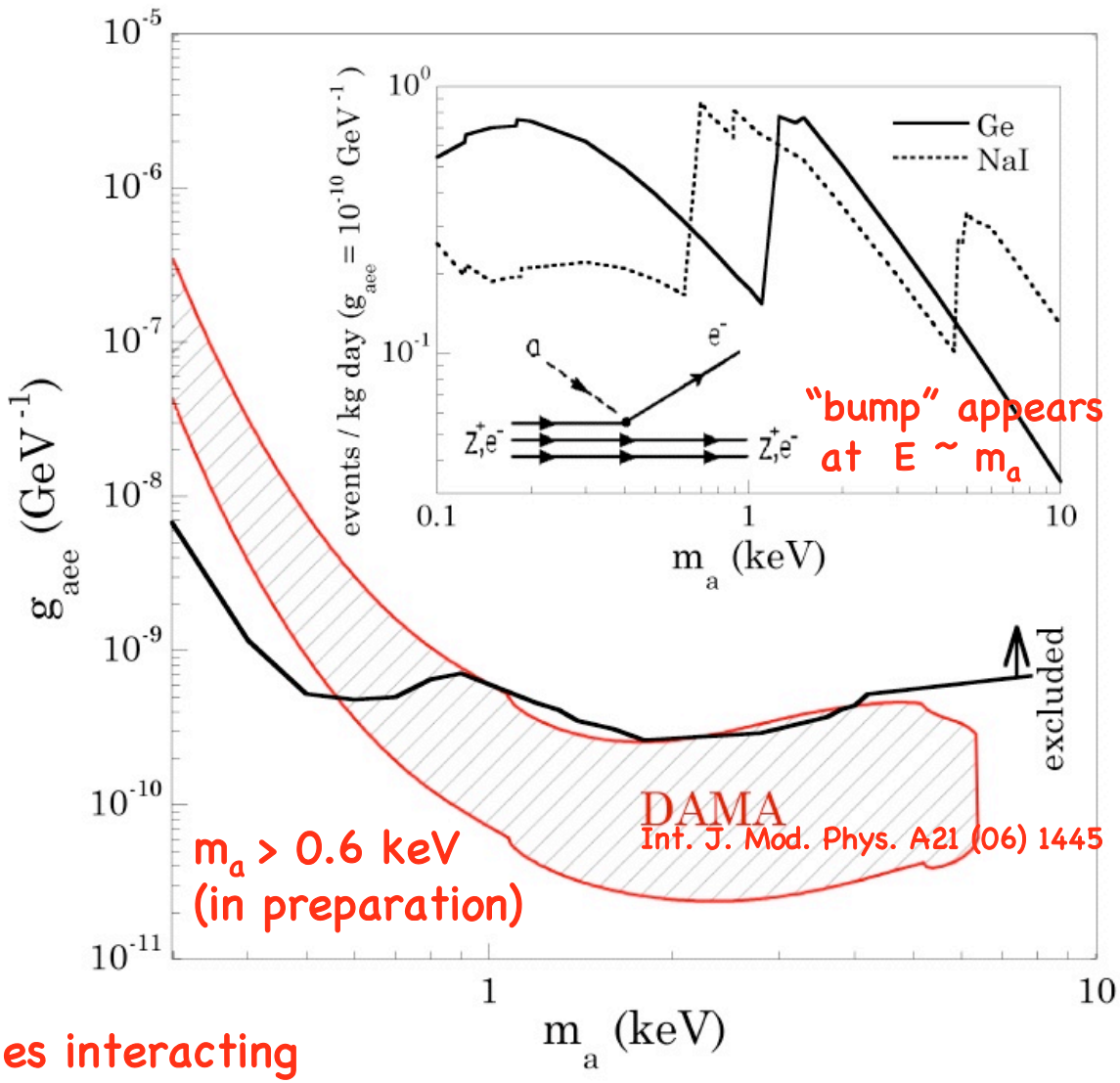


First physics results from these ppc's...



Axion-like particles interacting
via axio-electric effect?...
We are <u>a few weeks</u> from knowing
(after modest internal background and exposure improvements)