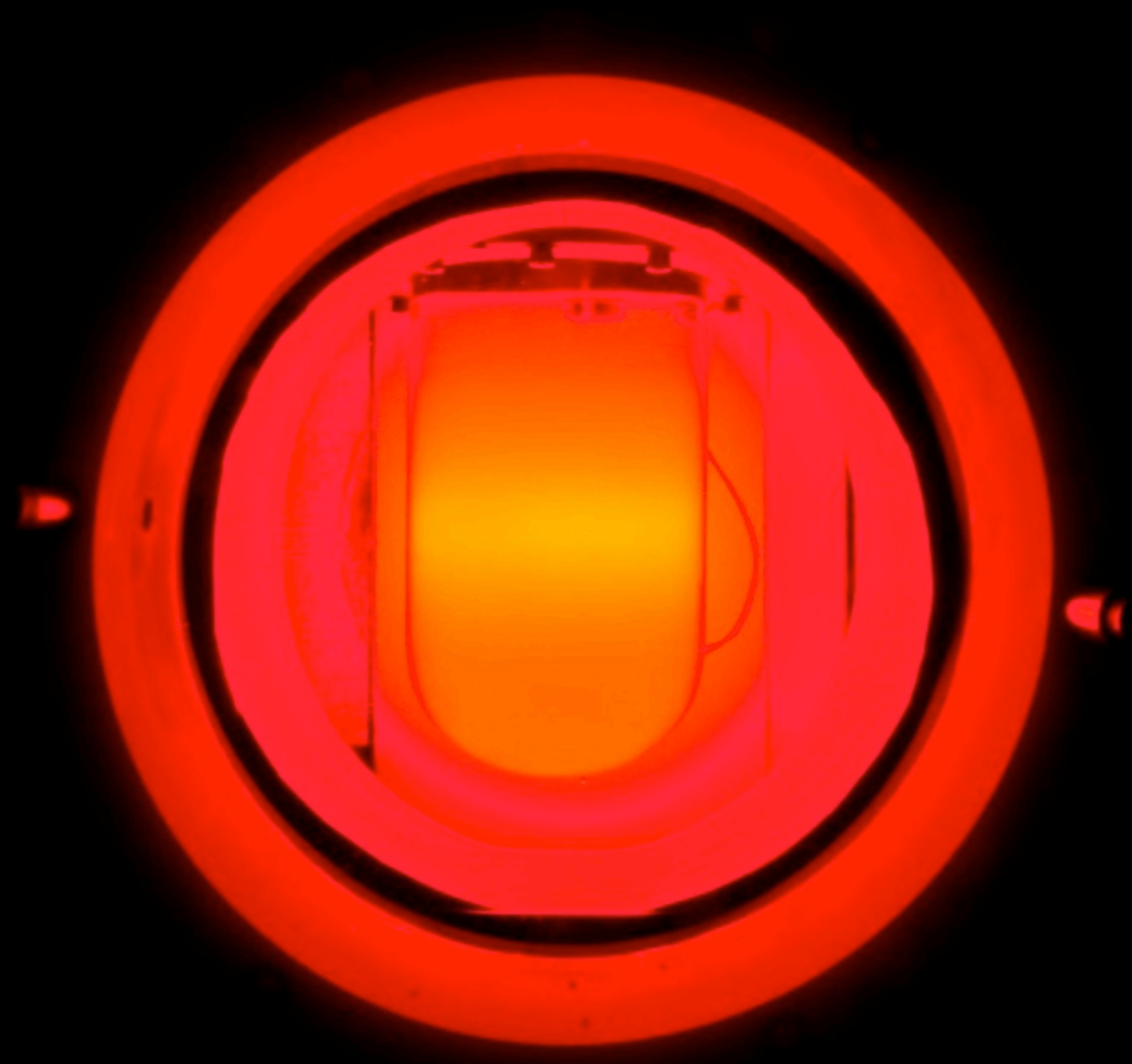
COUPP: an overview



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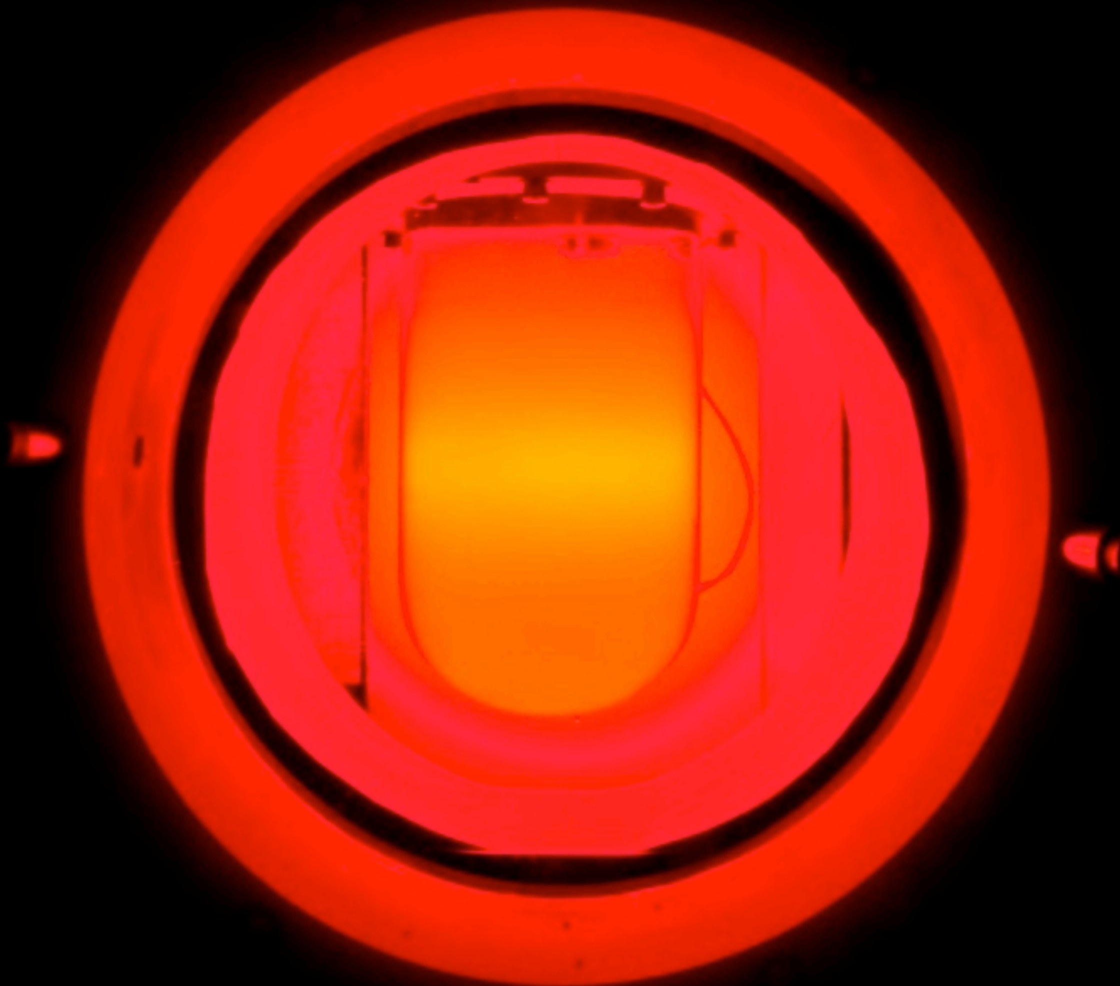

FNAL (DOE):
- 8 scientists
- 2 engineers
- Tech. support

UC (NSF):
- 1 faculty
- 1 KICP fellow
- 2 grad. studs.
- undergrads.

UISB (NSF):
- 1 faculty
- 1 engineer
- undergrads.

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)

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

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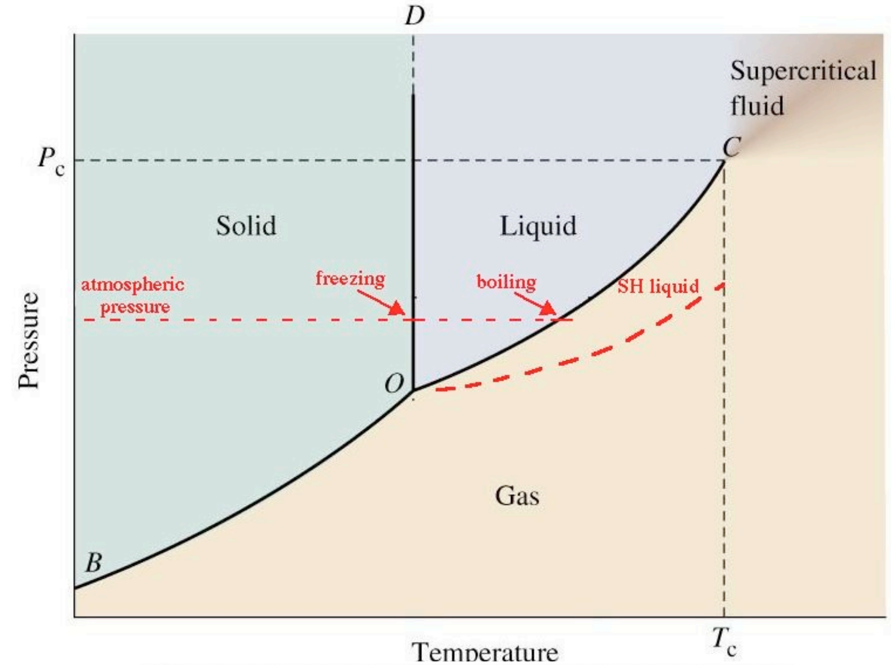
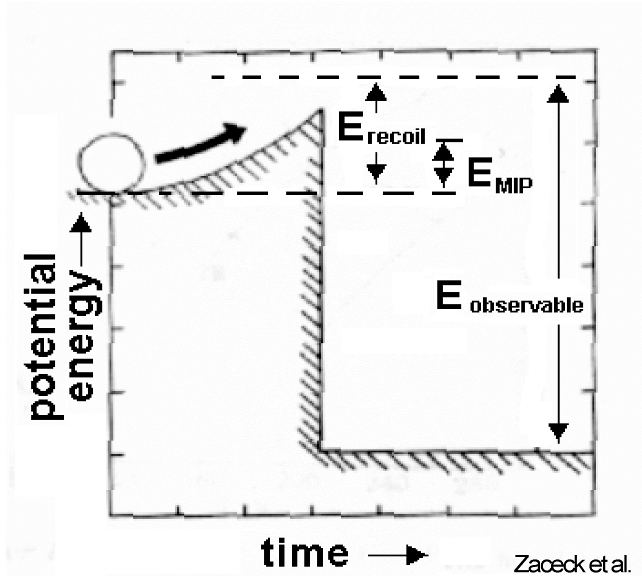
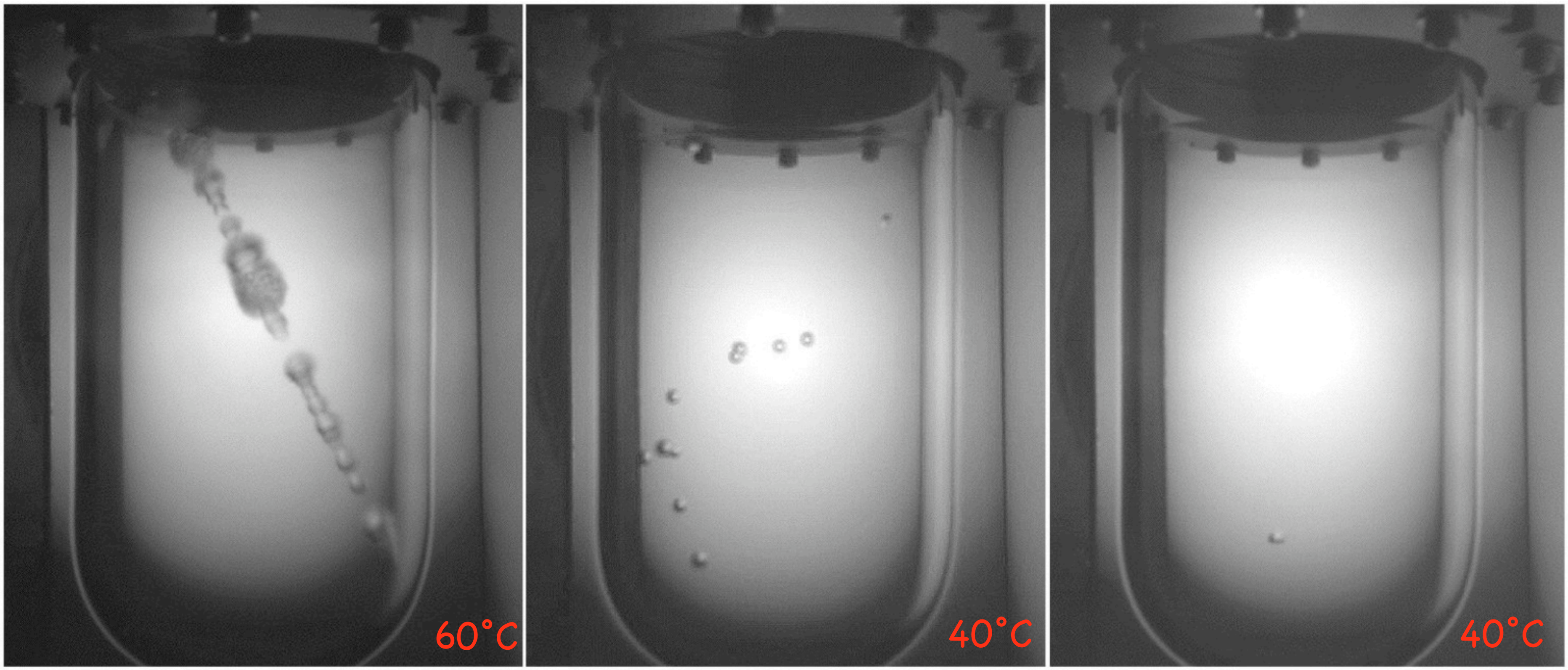




Not your daddy's bubble chamber:

Conventional BC operation
(high superheat, MIP sensitive)

Low degree of superheat, <u>sensitive to nuclear recoils only</u>



muon | Neutron | WIMP

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

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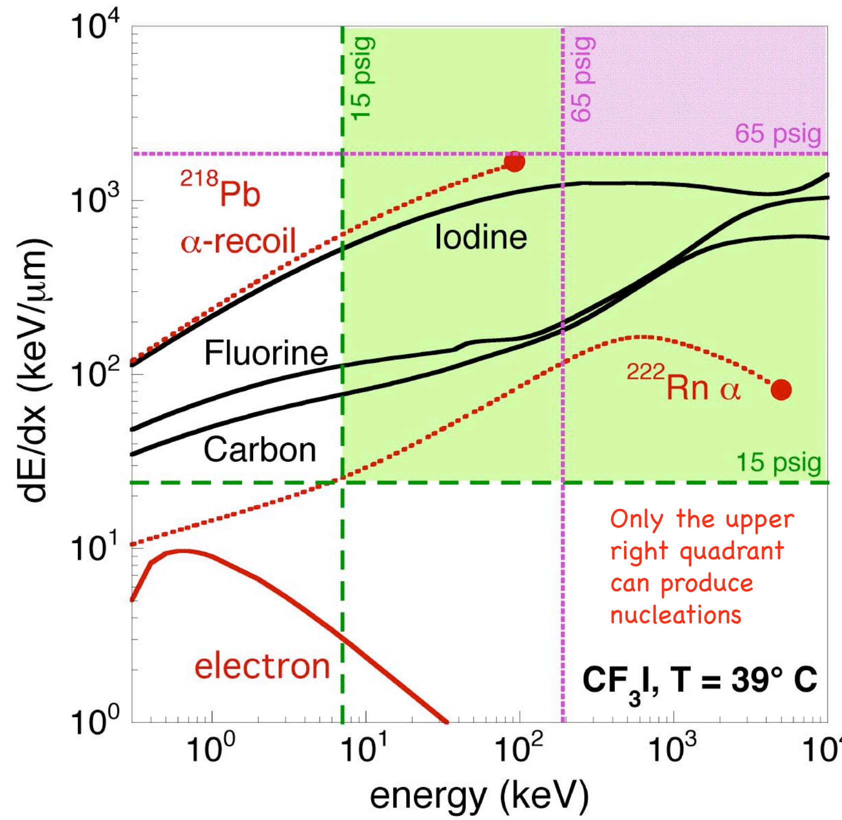
Seitz model of bubble nucleation (classical BC theory):

Threshold in deposited energy

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

$$dE/dx > E_c/(a r_c)$$

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



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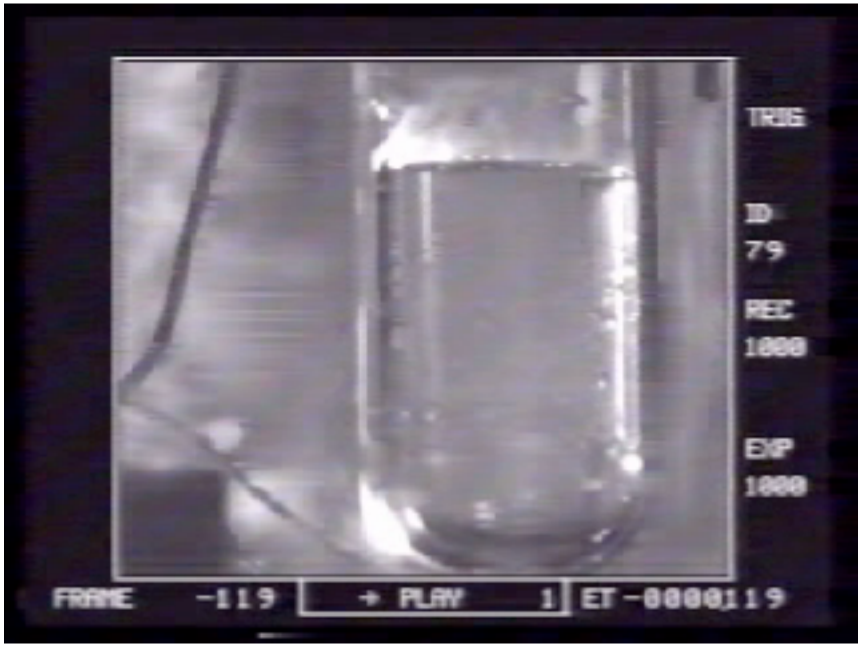
neutron-induced nucleation in 20 c.c. CF_3Br (0.1 s real-time span)
Movie available from http://cfcp.uchicago.edu/~collar/bubble.mov



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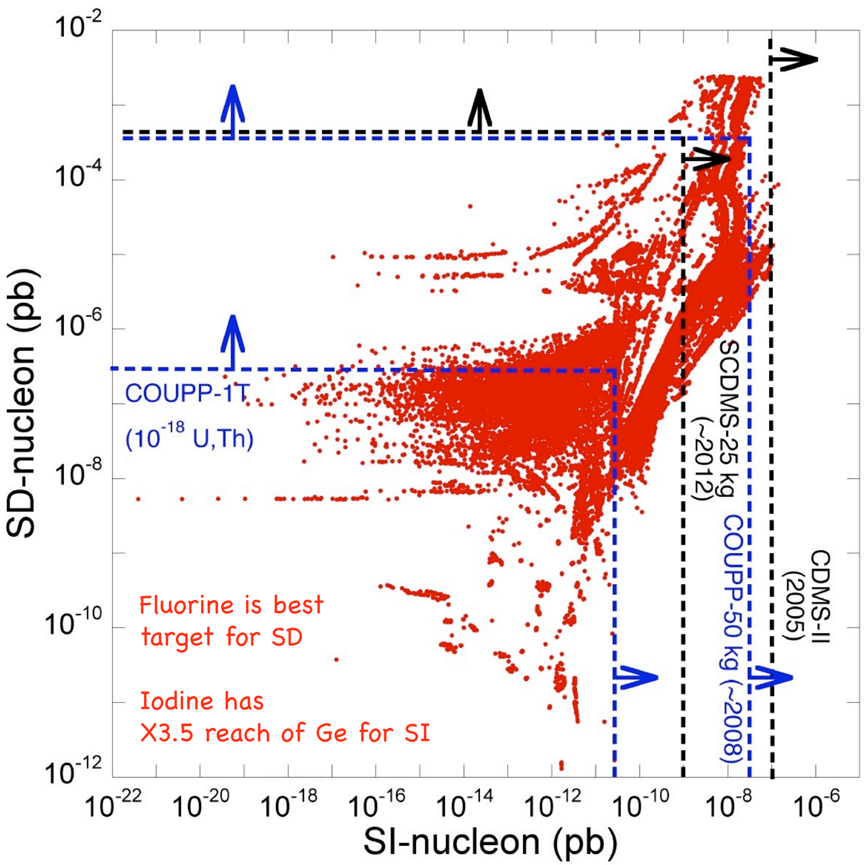
An old precept: attack on both fronts



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)

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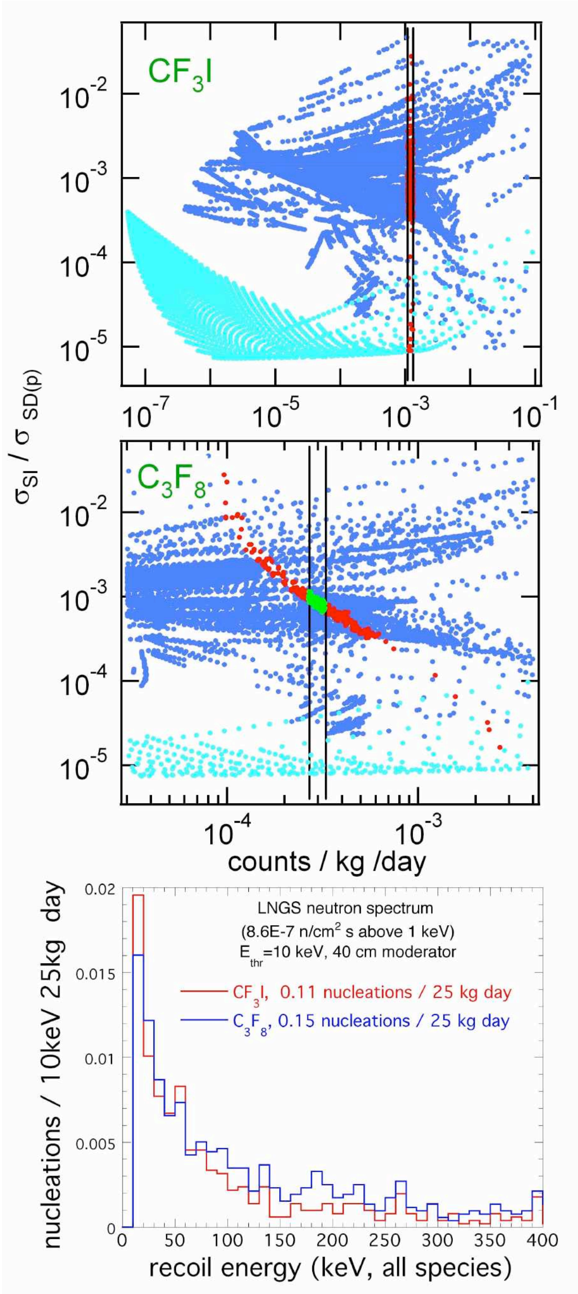

Bertone, Cerdeno, Collar and Odom (Phys. Rev. Lett. 99(2007)151301)

Rate measured in CF_3I and C_3F_8 (vertical bands) tightly constrains responsible SUSY parameter space and type of WIMP (LSP vs LKKP)

Neutrons on the other hand produce essentially the same rates in both (σ_n for F and I are very similar)

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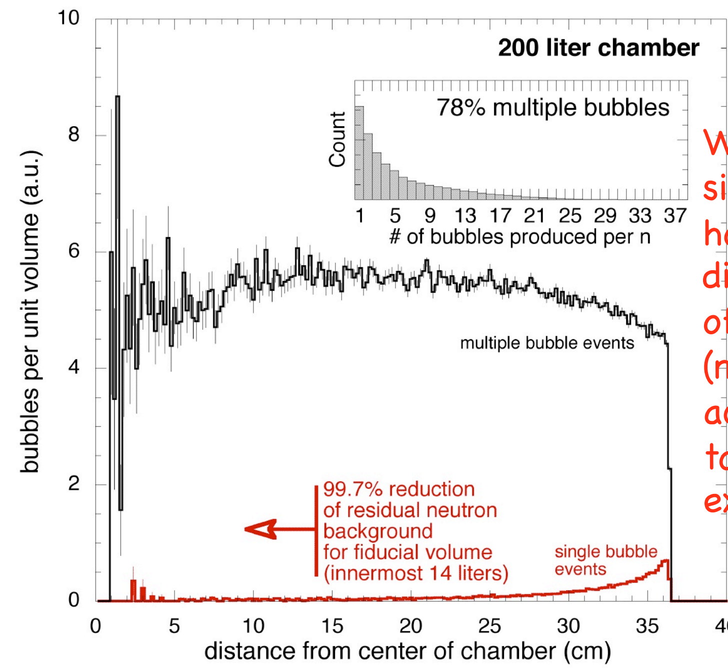
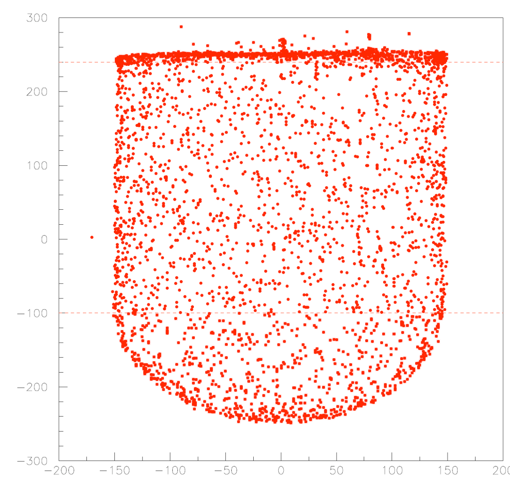
Larger chambers will be "self-shielding"



WIMP signature: homogeneous distribution of singles (n-induced accumulate towards the exterior)



Spatial distribution of bubbles (~1 mm resol.)

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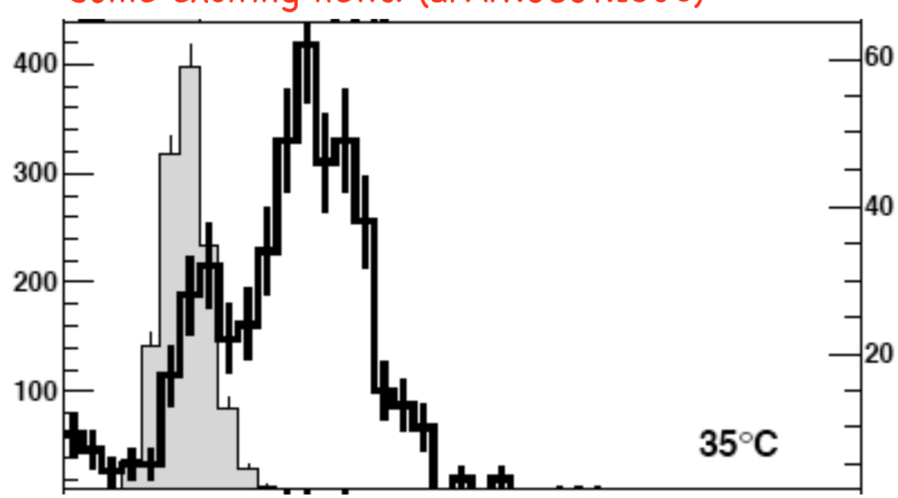
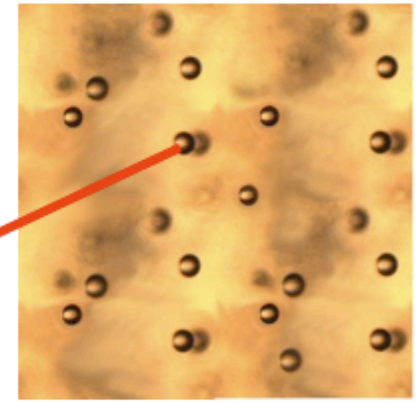
Some exciting news! (arXiv:0807.1536)



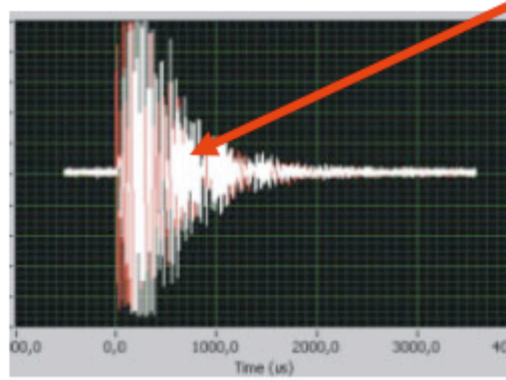
Acoustic alpha/neutron discrimination in SDDs (we believe the effect should be much larger in bulk superheated liquids)

α-neutron discrimination with acoustics

- The Picasso collaboration uses superheated droplets in gel for dark matter search.
- Have recently observed discrimination power in the acoustic signal between alpha interactions and neutron interactions
- Conceivably could give bubble chambers extremely powerful background rejection ability.
- We will have many such sensors on the chamber.



150μm droplets of C4F10 dispersed in polymerised gel



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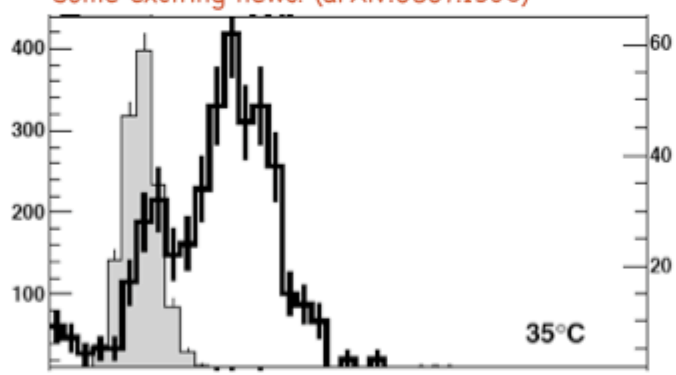

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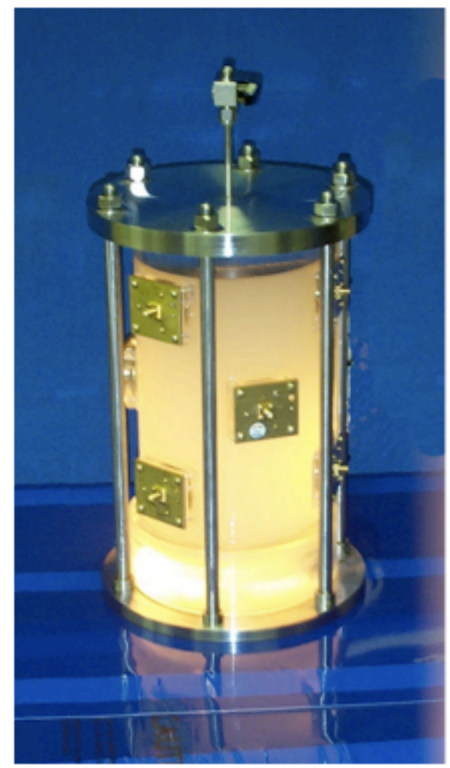
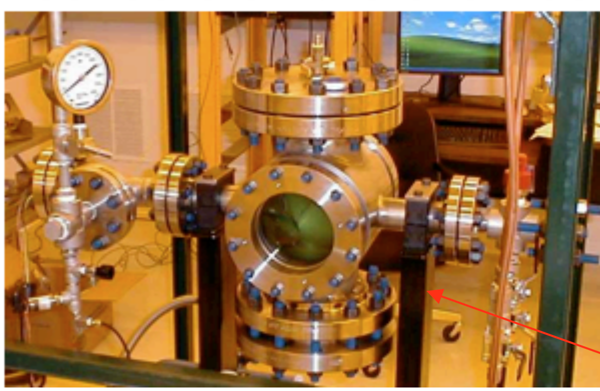
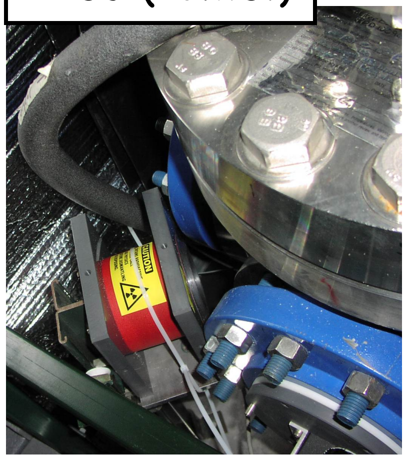
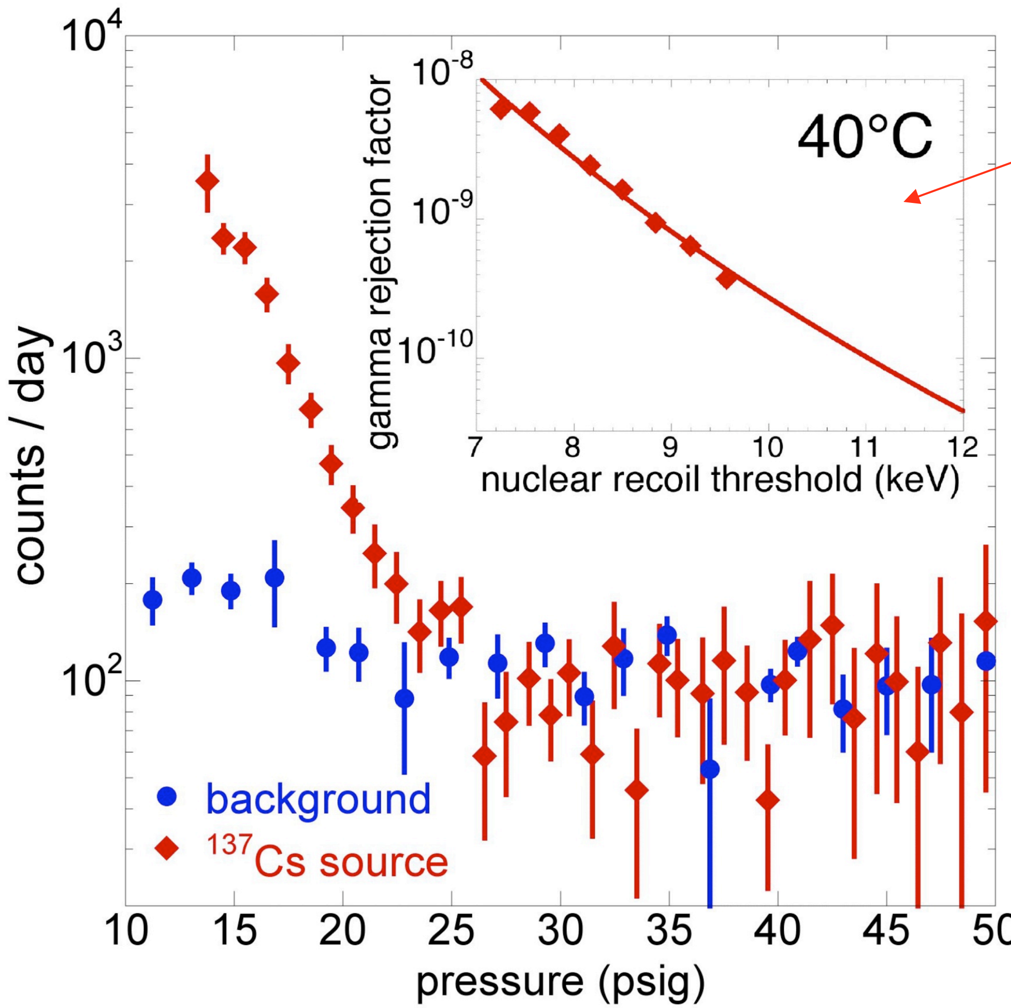




dedicated chamber



Gamma and neutron calibrations *in situ:*



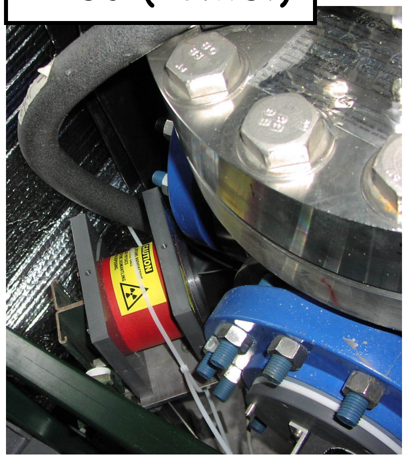
Best MIP rejection factor measured anywhere ($<10^{-10}$ INTRINSIC, no data cuts)

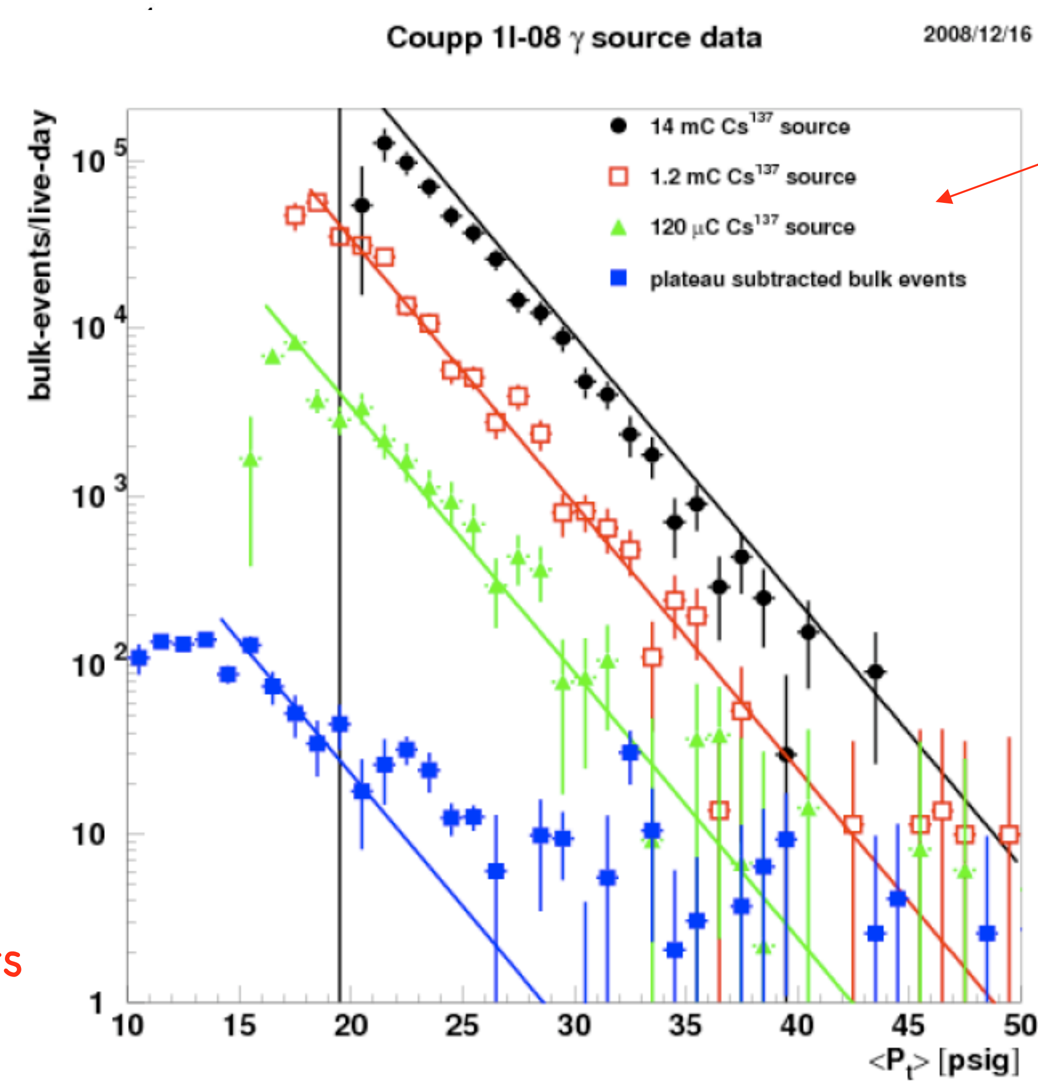
Other experiments as a reference:
XENON ~10^{-2}
CDMS 10^{-4}–10^{-5}
WARP ~10^{-7}-10^{-8}

^{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

Gamma and neutron calibrations *in situ:*

^{137}Cs (13mCi)





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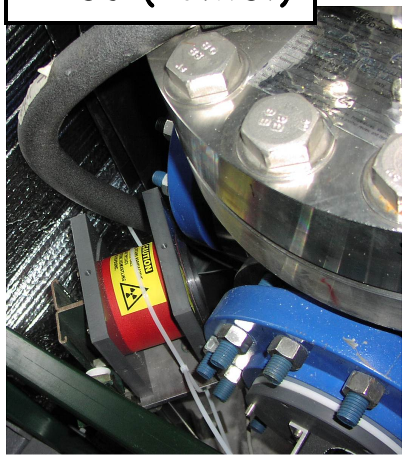

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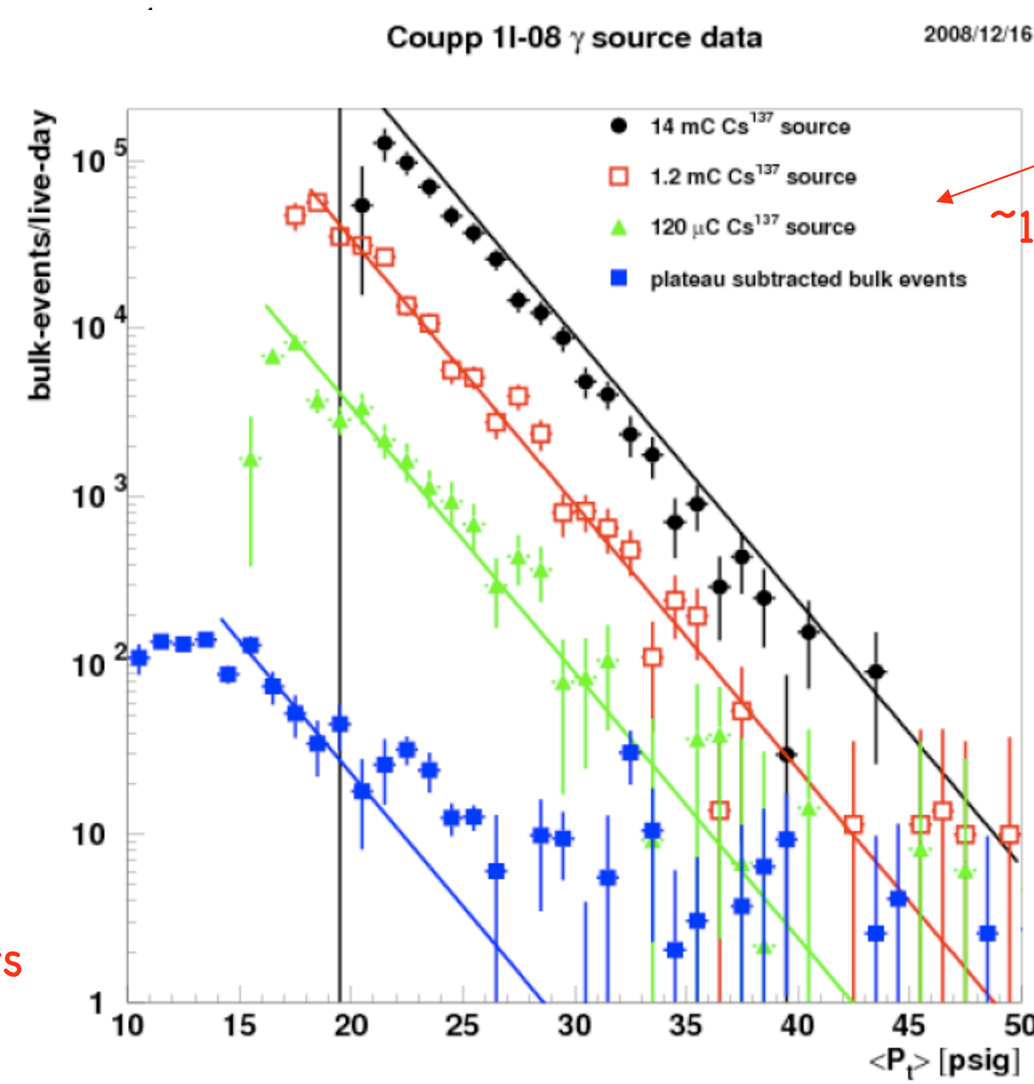

Best MIP rejection factor measured anywhere (~~<10^-10~~ INTRINSIC, no data cuts)

~10^{-13}! (preliminary)

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Switchable Am/Be (5 n/s)

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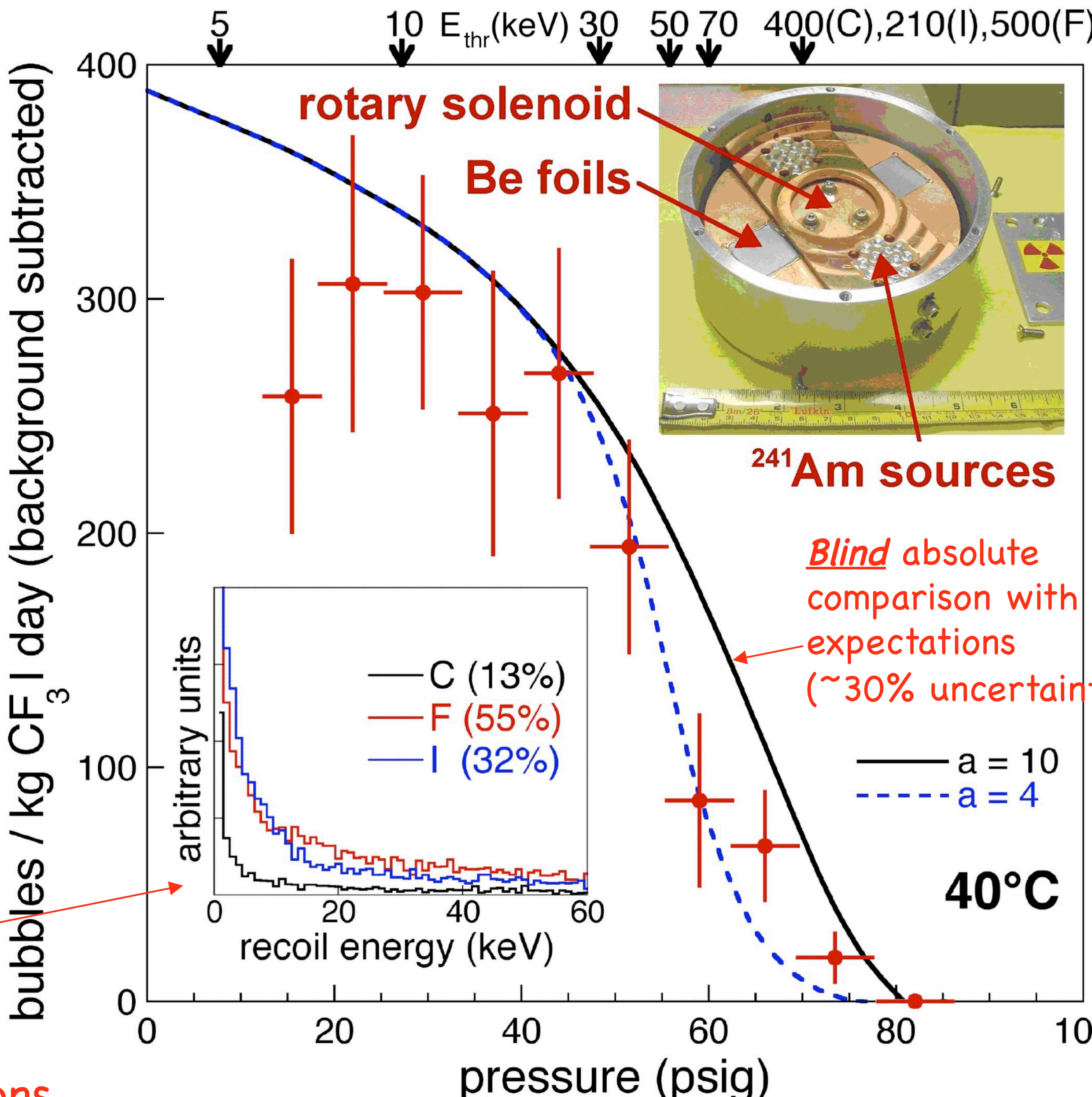
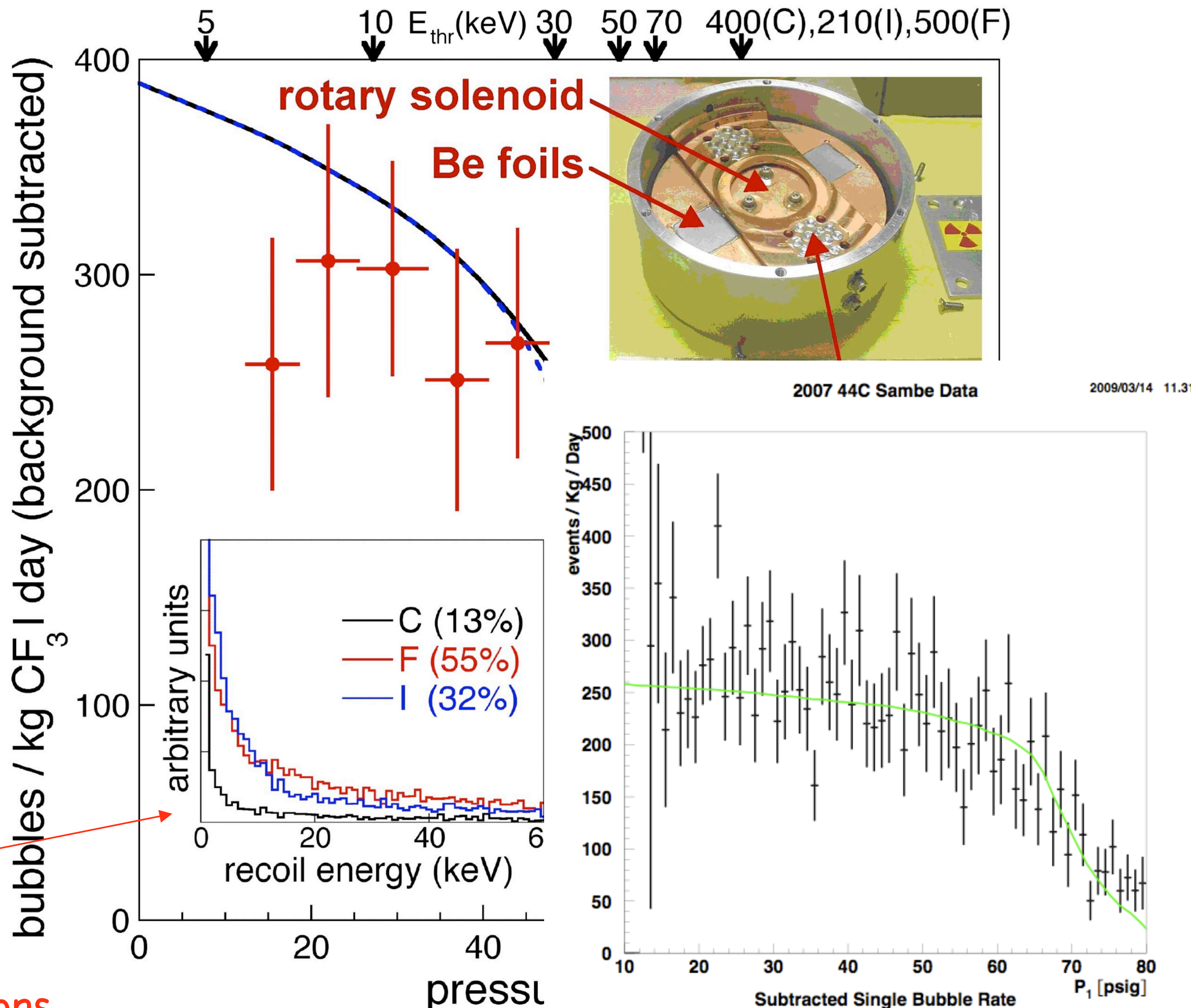


Blind absolute comparison with expectations (~30% uncertainty in those)

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

Switchable Am/Be (5 n/s)

Gamma and neutron calibrations *in situ:*



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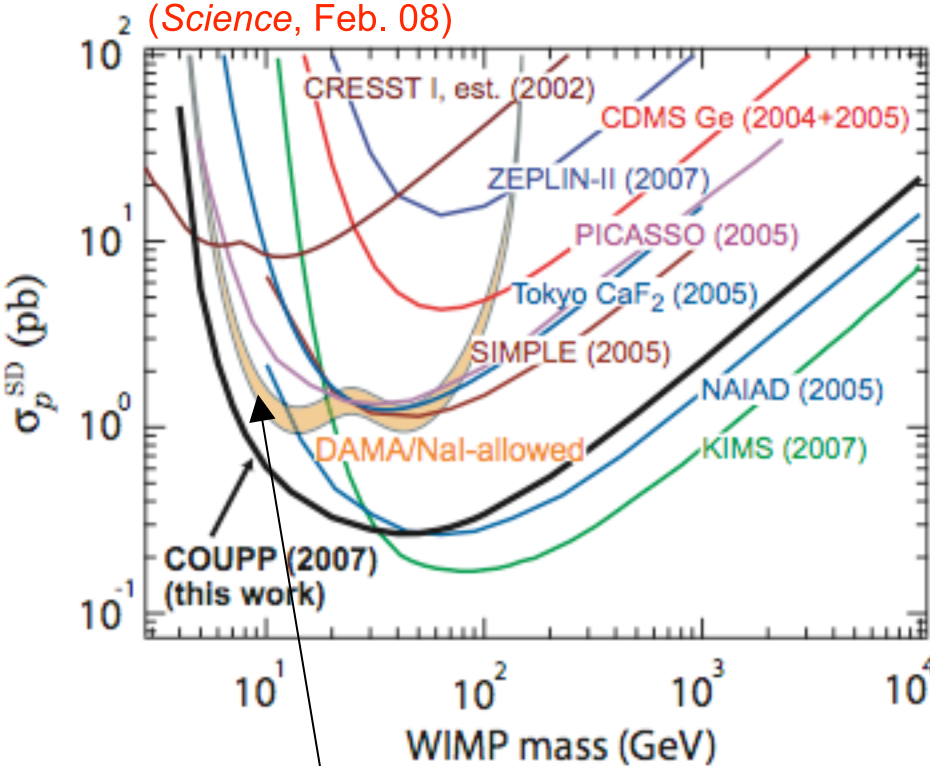
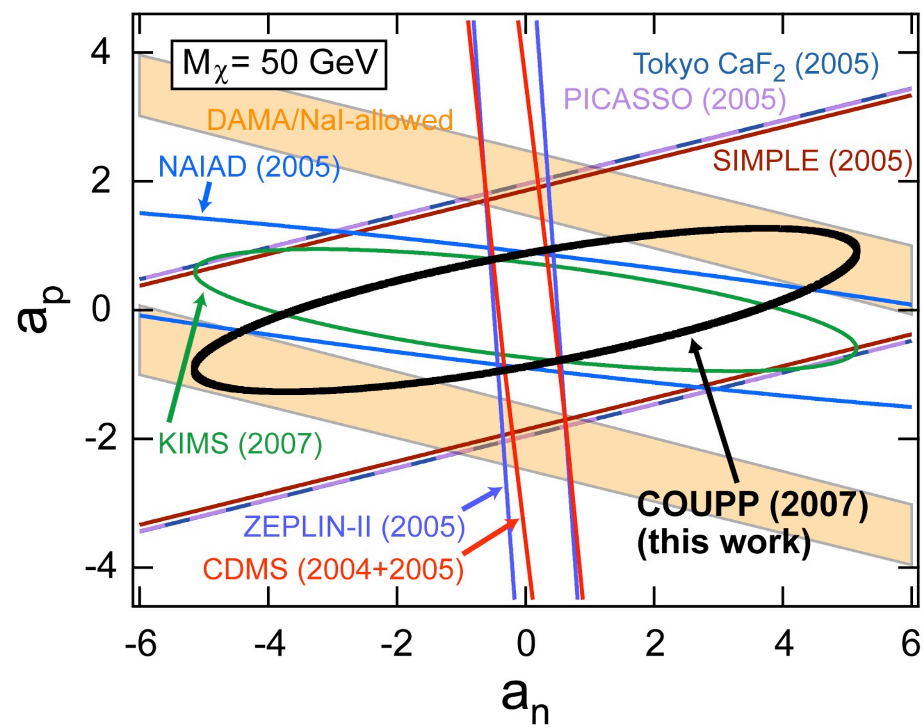
First COUPP results

The bubble chamber is back

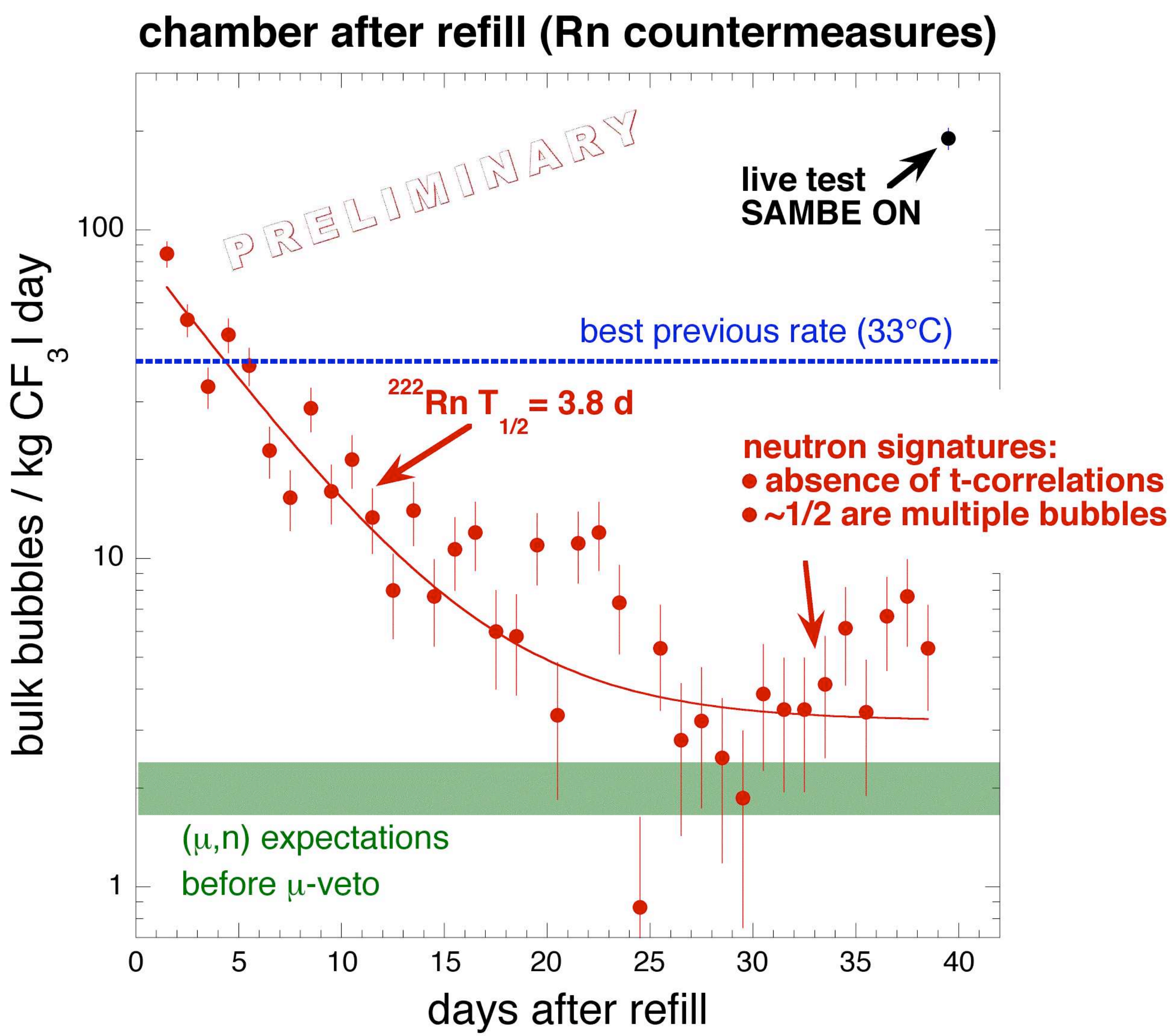
Improved SD WIMP sensitivity with 2kg chamber (*Science*, Feb. 08)





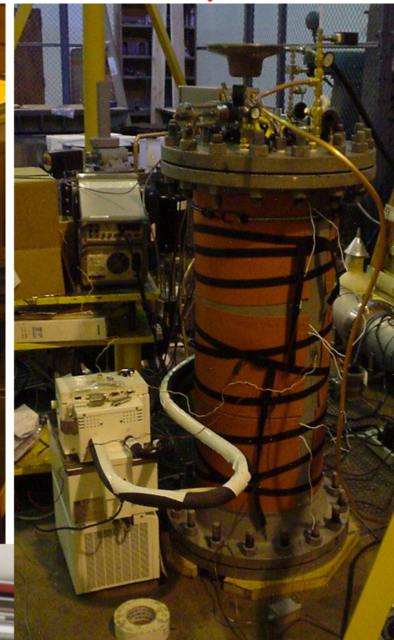
New limits exclude the low-mass region favored by a SD interpretation of the DAMA/NaI signal

A peek at the future (which is here)



Next step: ~100 kg target mass, deeper site



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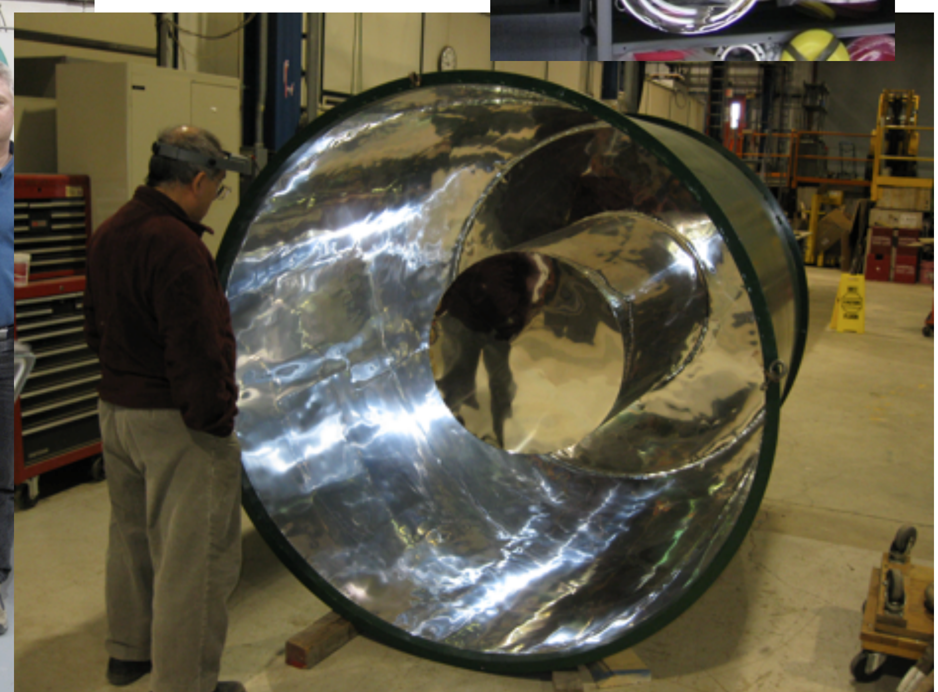
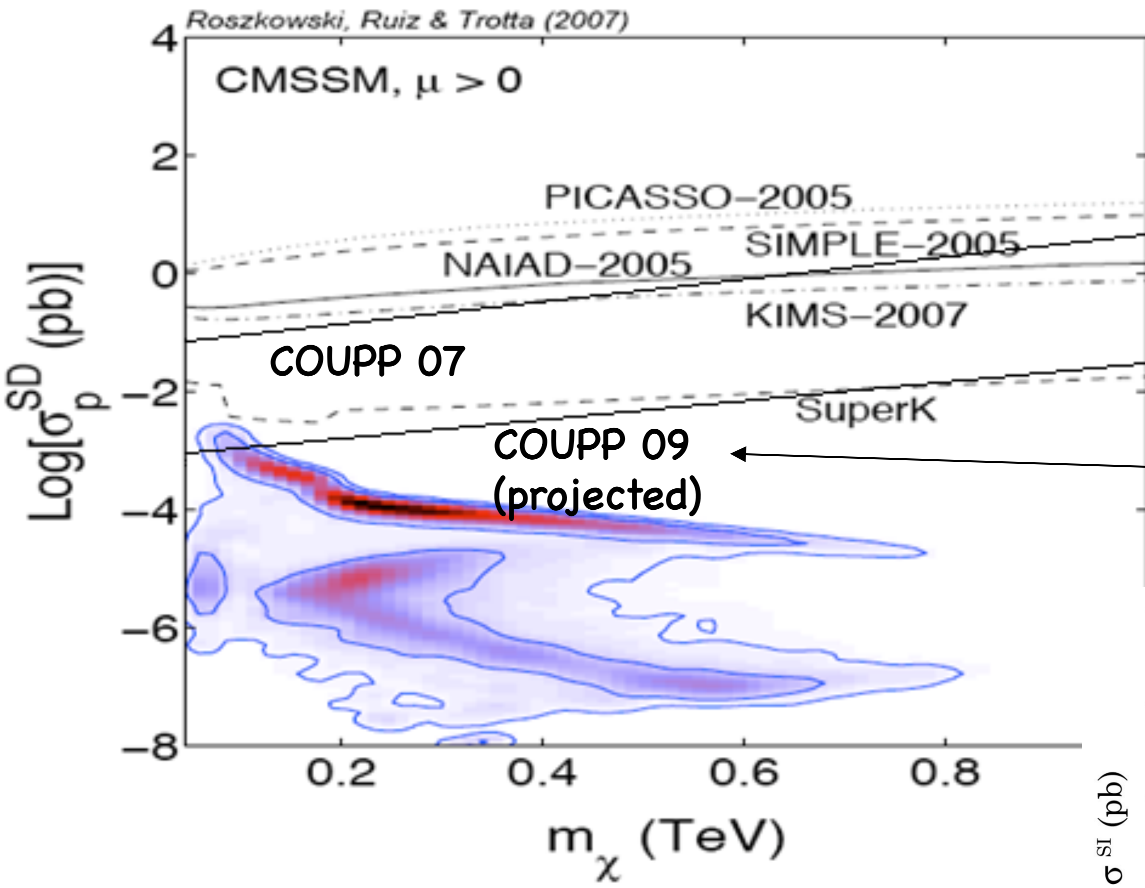
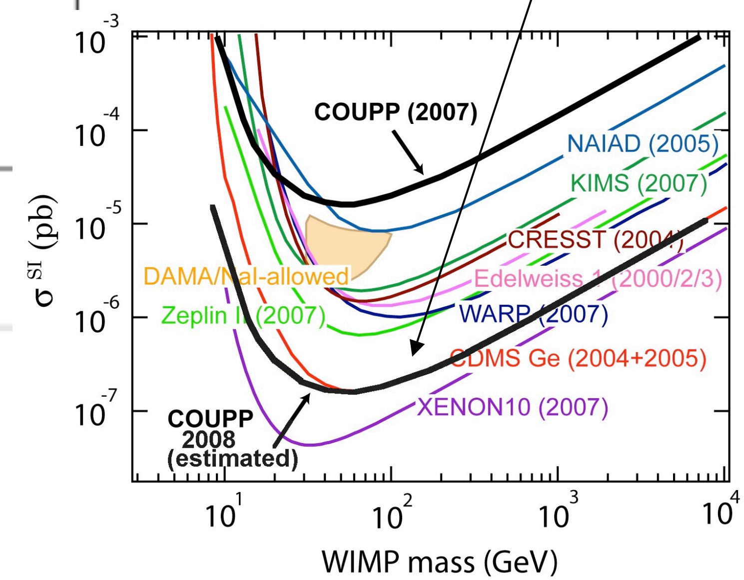


Physics Reach at Fermilab Site

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



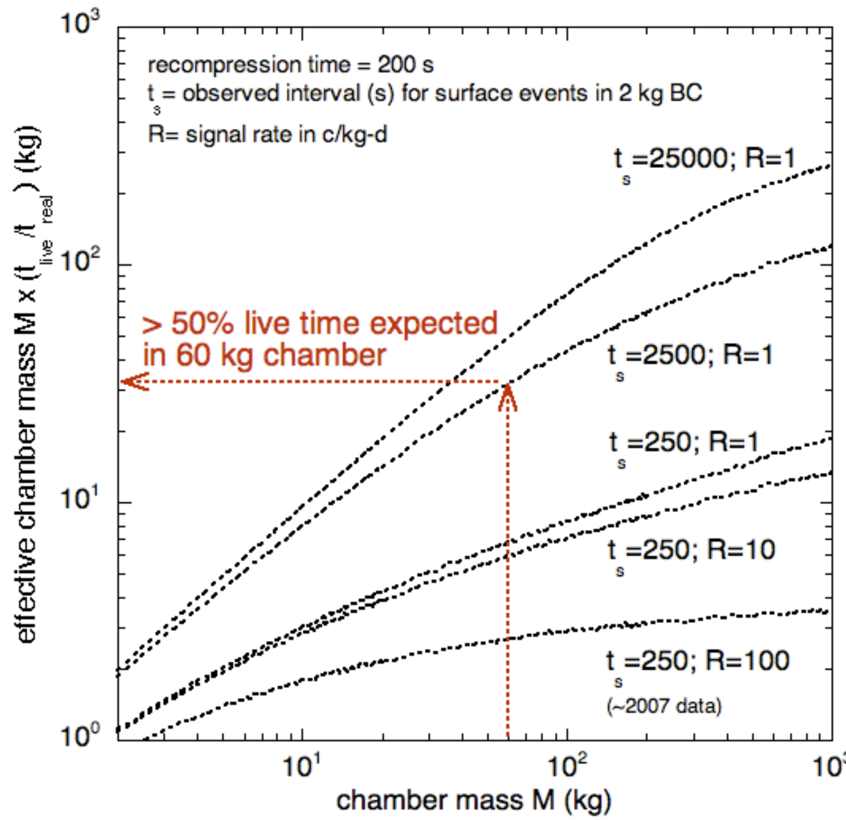
2009 goals: exploring SD favored region for the first time, and competitive SI limits.



Preliminary:
synthetic silica does reduce wall nucleation rate by >10

Two consecutive orthogonal views of neutron-induced multiple nucleation in 15 kg synthetic silica test vessel

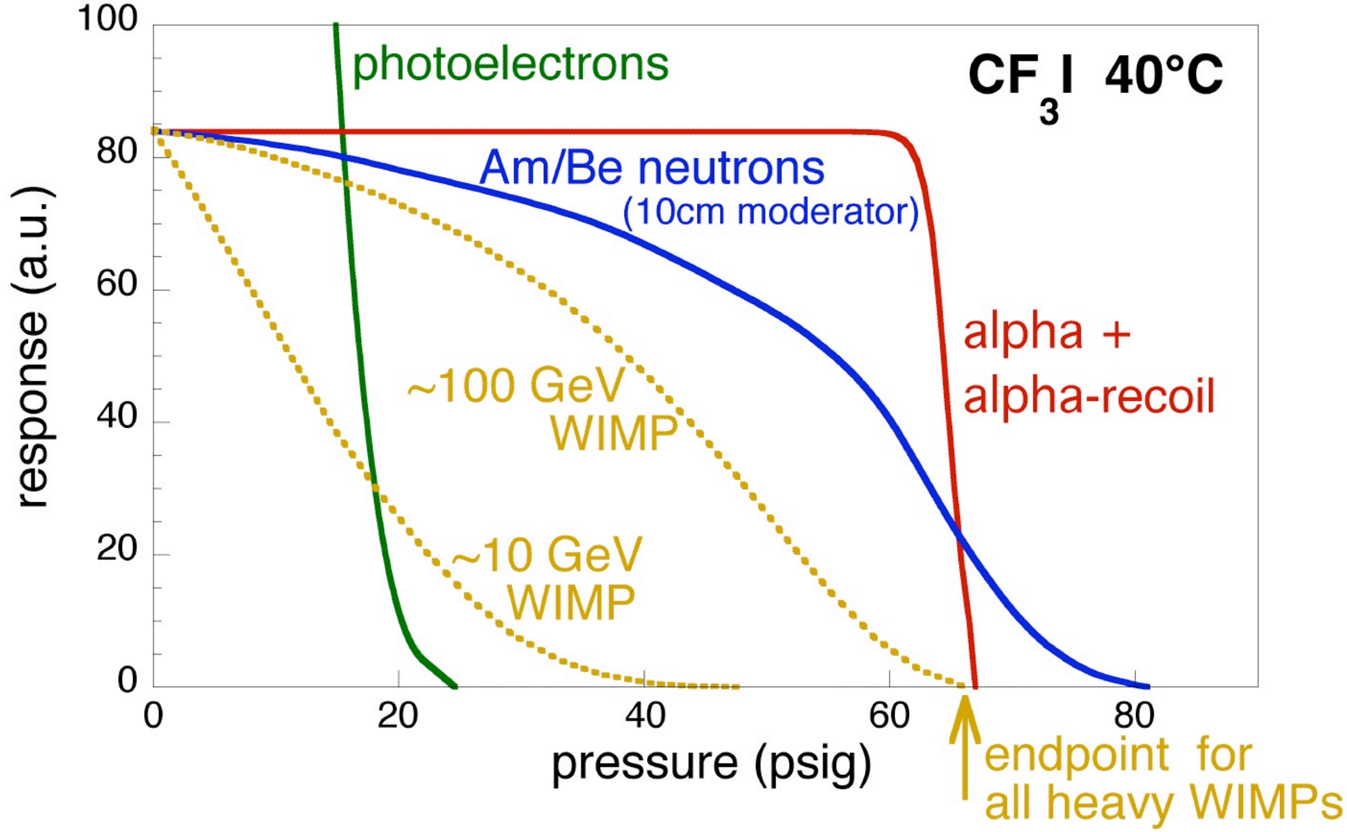
Movie available from http://cfcp.uchicago.edu/~collar/two.mov

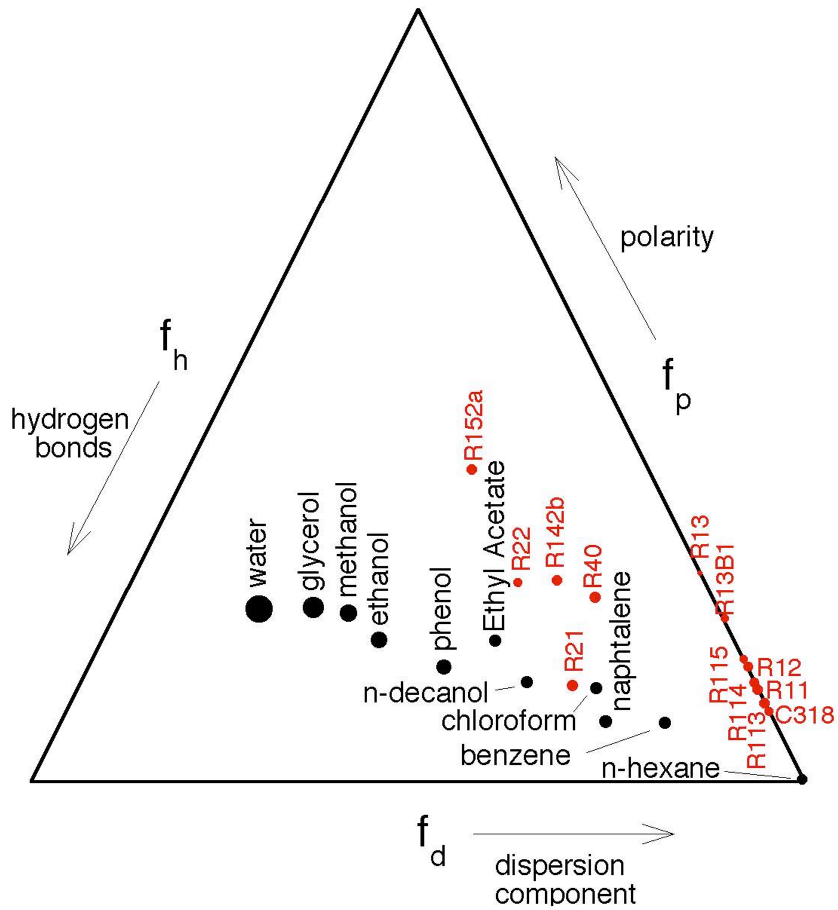


Reserve transparencies

Templates for the future:

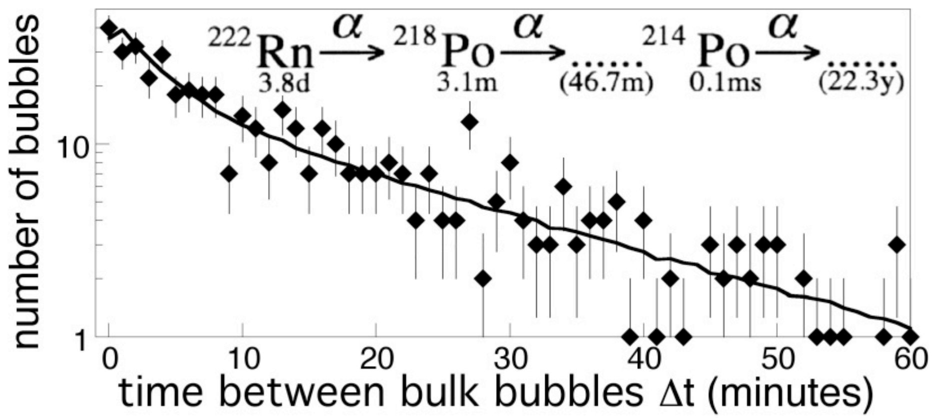
(when life gives you lemons...)

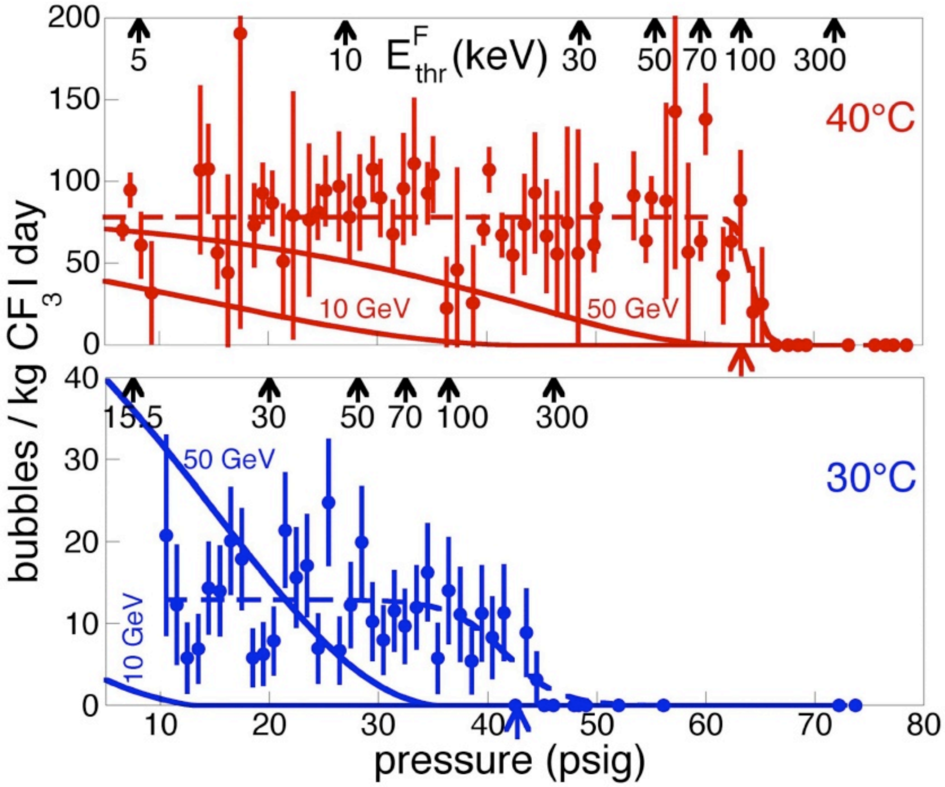




Fractional cohesion parameters
for refrigerants and common solvants
(size of marker ~ δ_t)

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... →