# COUPP, the "Chicagoland Observatory for Underground Particle Physics"

## Status and Plans


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

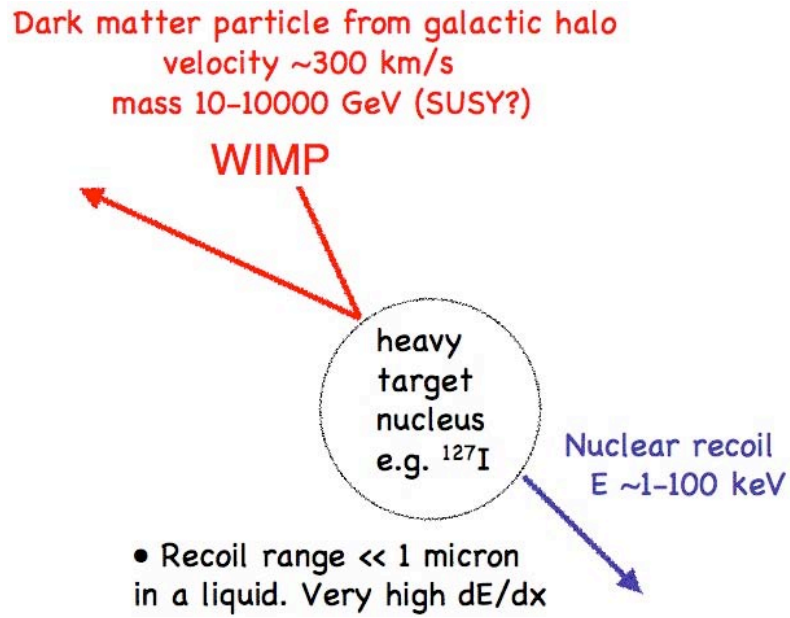
- Excellent sensitivity to both SD and SI couplings ($CF_3I$)

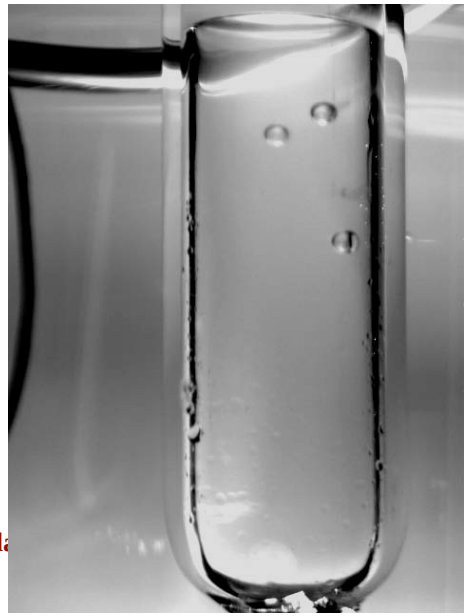
- Target fluid can be replaced (e.g., $C_3F_8$, $C_4F_{10}$, $CF_3Br$). Useful for separation between n- and WIMP-recoils and pinpointing WIMP in SUSY parameter space.

- 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 $\alpha$-emitters in fluids to levels already achieved elsewhere ($\sim 10^{-17}$) will lead to complete probing of SUSY models.



Signal is single bubble corresponding to point-like WIMP recoil (not tracks as in conventional BC)

<- neutron-induced event (multiple scattering)

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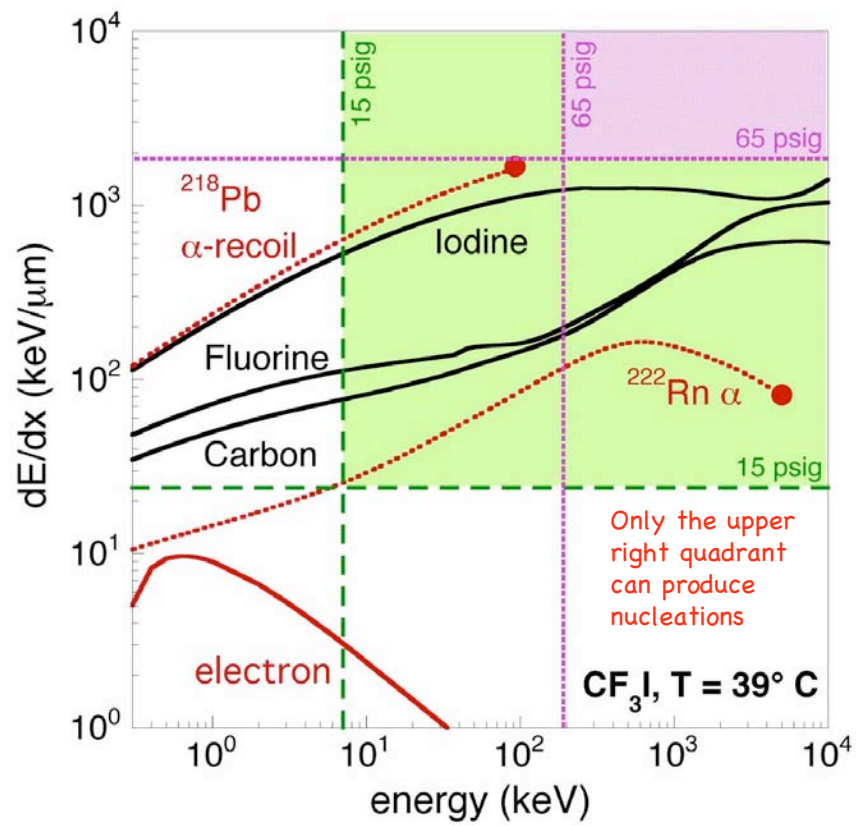
Seitz model of bubble nucleation (classical BC theory):

Threshold in deposited energy

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

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

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



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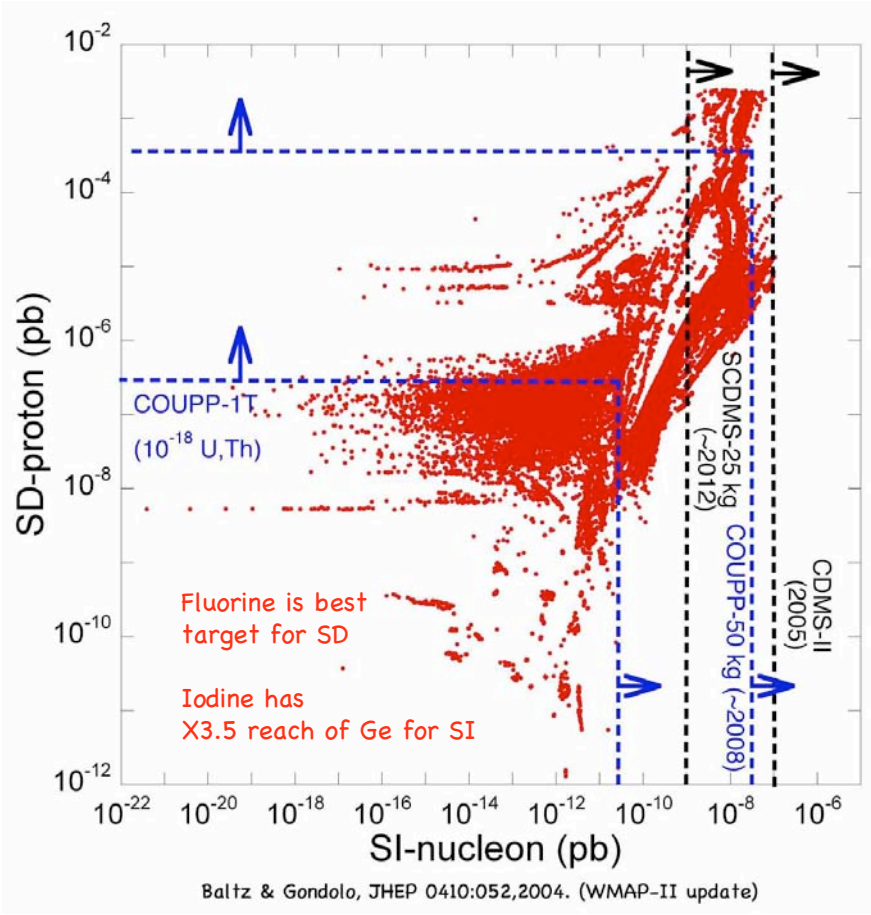
## An old precept: attack on both fronts




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

# COUPP approach to WIMP detection:

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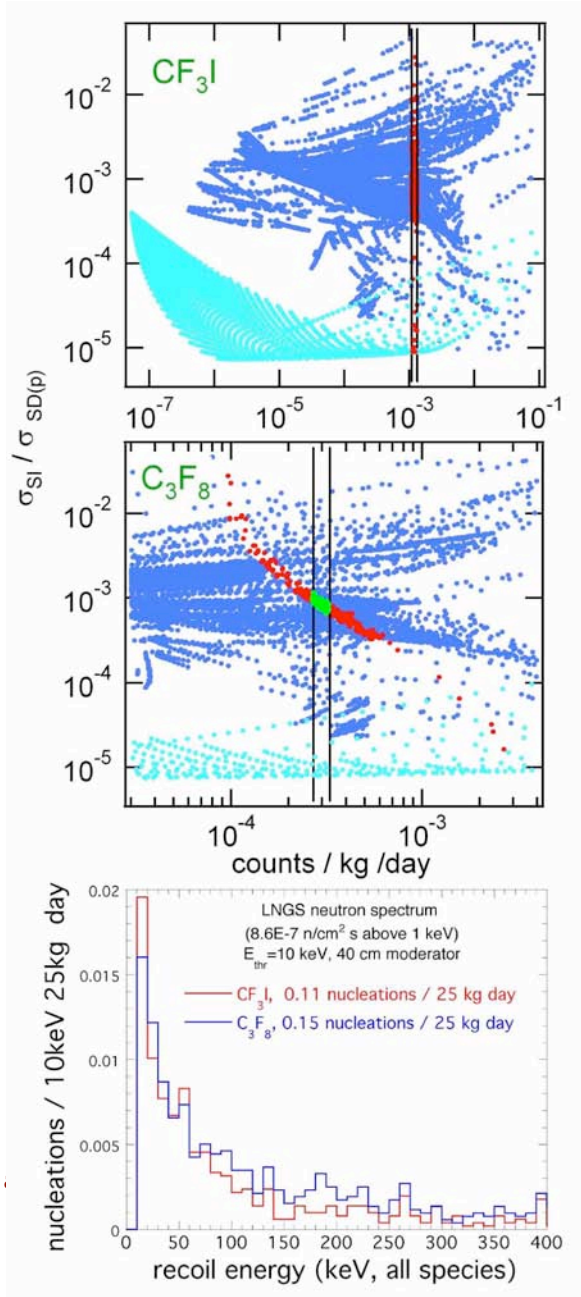


Bertone, Cerdeno, Collar and Odom (in preparation)

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 ($\sigma_n$ for F and I are very similar)

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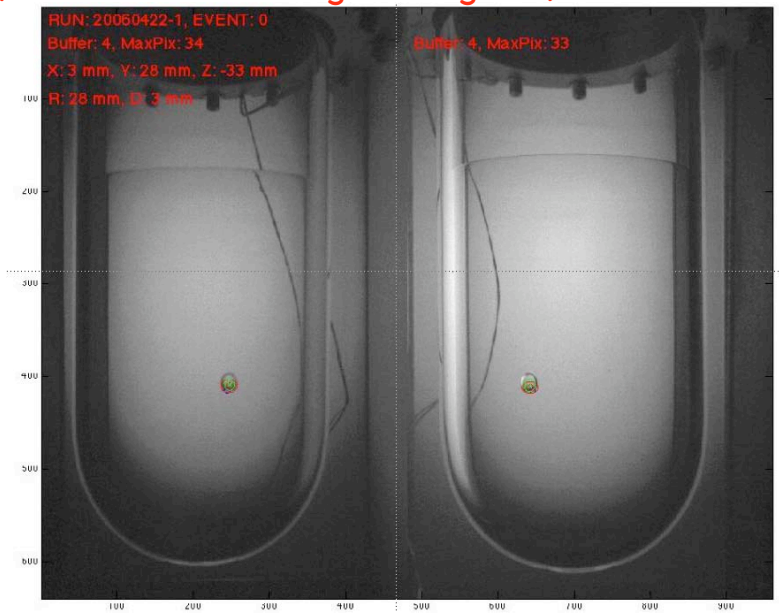
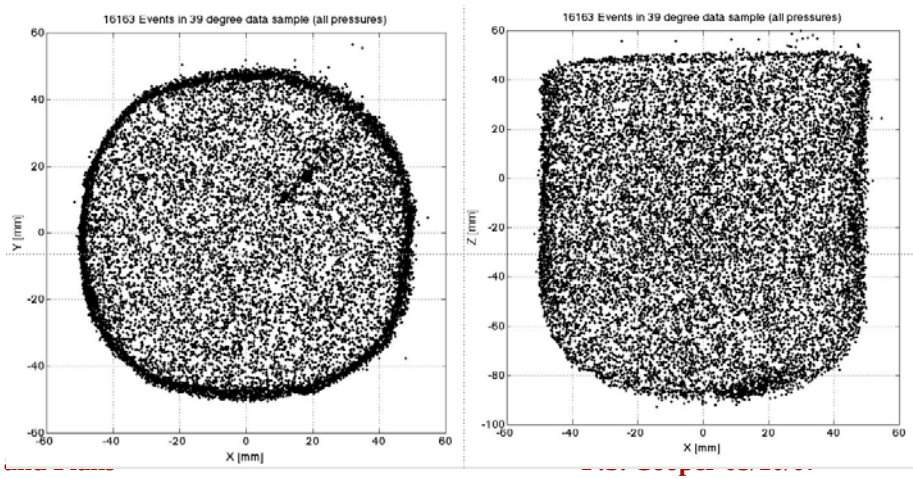
Stereo view of a typical event in 2 kg chamber (data from 2006 engineering run)




Spatial distribution of bubbles (~1 mm resol.)

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**CHEAP**

**Its Plumbing!**

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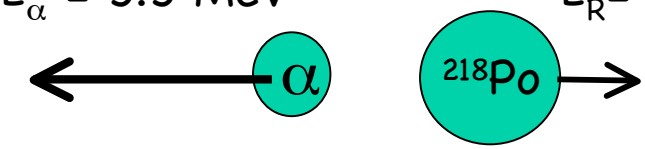
- High spatial granularity = additional n rejection mechanism

- Low cost (<350 USD/kg target mass *all inclusive*), room temperature operation, safe chemistry (fire-extinguishing industrial refrigerants), moderate pressures (<200 psig)

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

Example, consider $^{222}Rn \rightarrow ^{218}Po$:

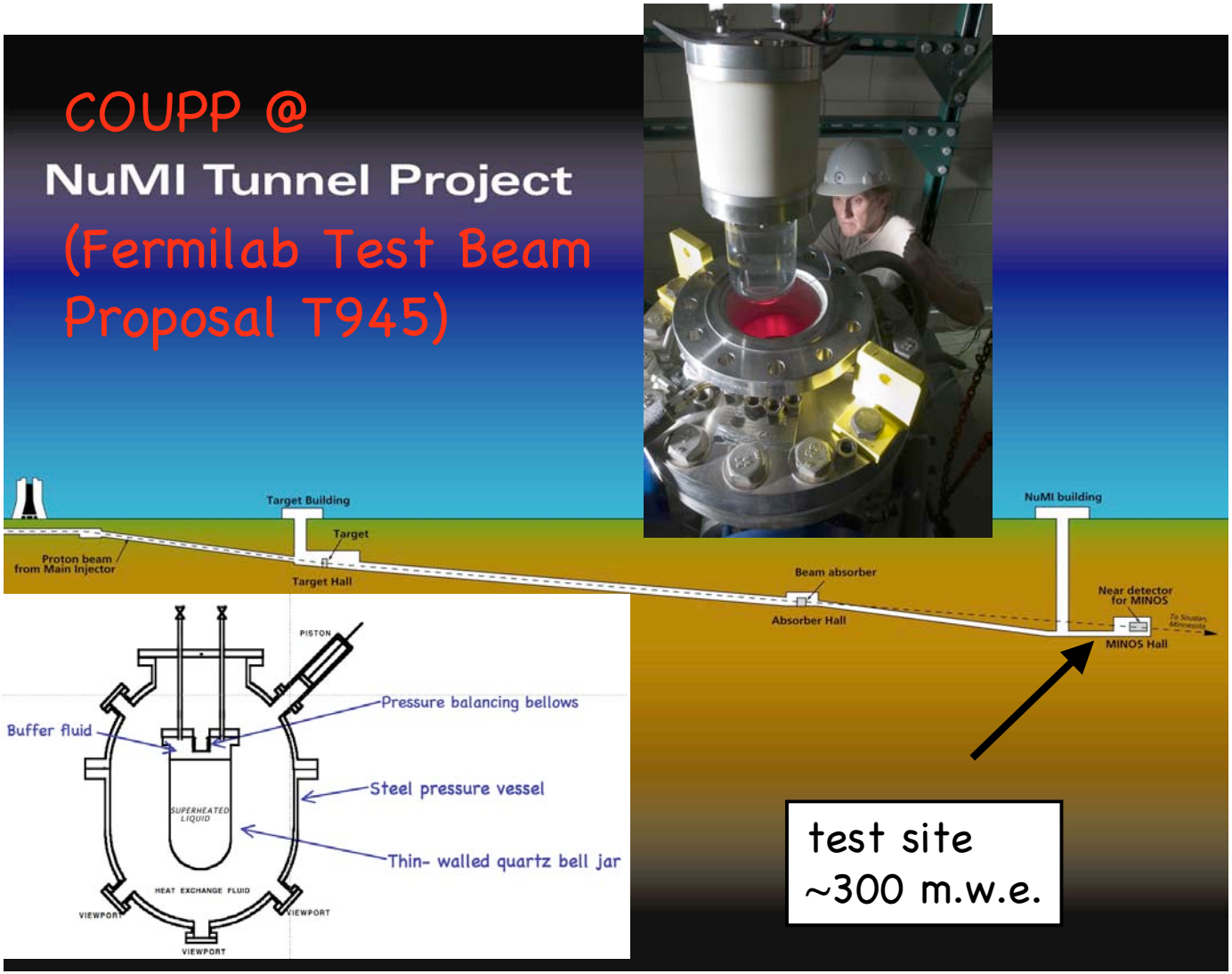
$E_\alpha$ = 5.5 MeV $E_R$= 100 keV



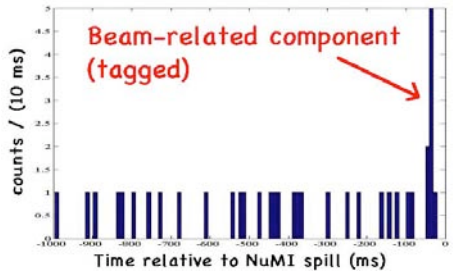

- The recoiling nucleus creates a bubble in a BC sensitive to lower energy WIMP (~10 keV) recoils

- $^{238}U$ and $^{232}Th$ decay series include many $\alpha$ emitters, including Radon ($^{222}Rn$) and its daughters.

# COUPP @ NuMI Tunnel Project (Fermilab Test Beam Proposal T945)



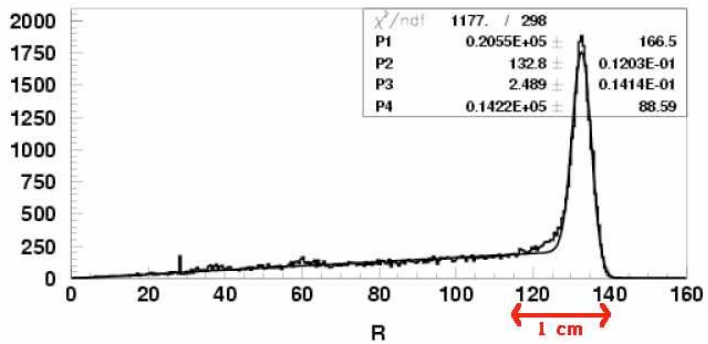

2kg (1l) $CF_3I$ chamber built at UC installed May '05
Data 12/05-12/06




In the FNAL Neutrino Beam!
n flux already dominated by rock radioactivity in a site this deep.

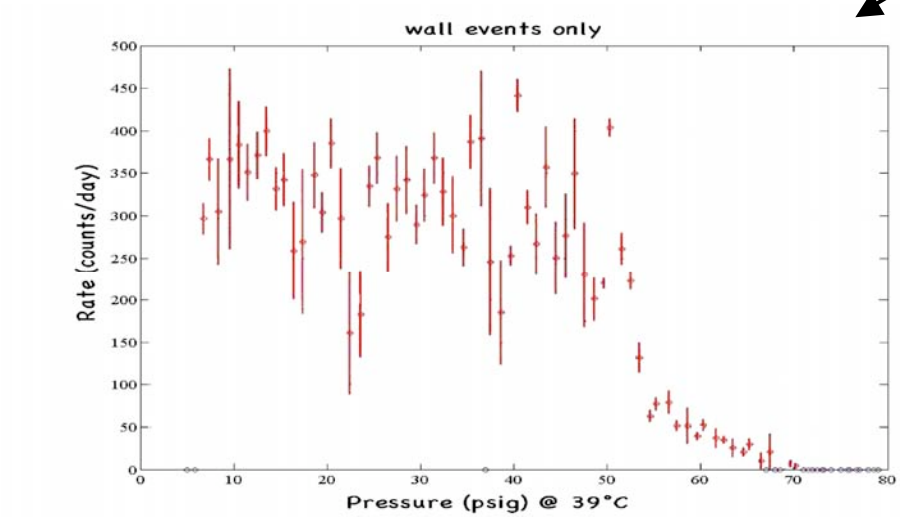
Concept similar to 1st Hydrogen BC

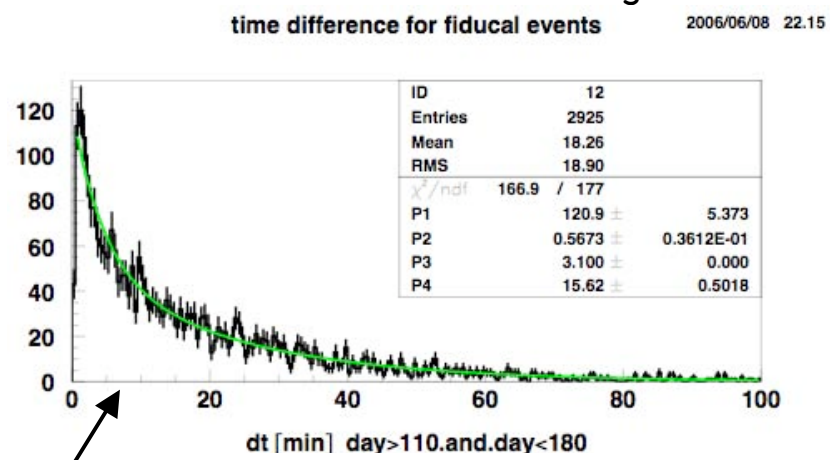
# Two expected backgrounds found and addressed




## 1) Excess surface nucleations from Rn daughter implantation

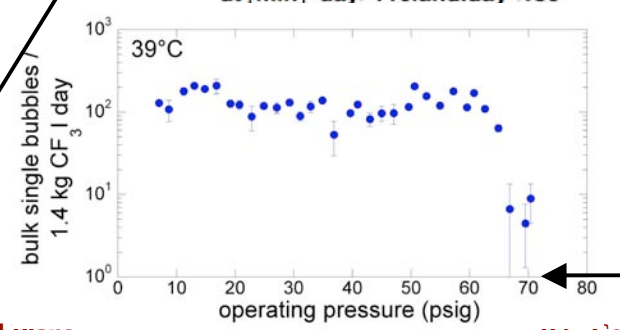
- Rate consistent with ~200 days of quartz exposure to air
- Tell-tale pressure sensitivity onset ($\alpha$'s)
- Can be rejected, but must be reduced by > 10 to allow >60% live-time in ~50kg chambers




## 2) Radon Decays Presently Dominate Bulk Events

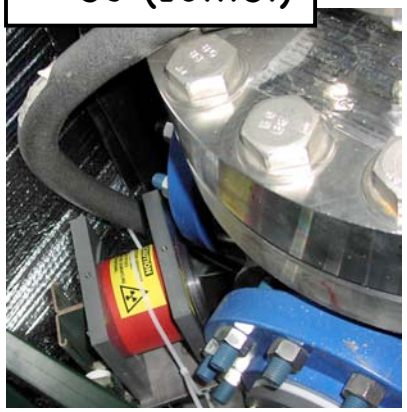
- Rn sources present: viton o-ring, thoriated weld lines.
- Time correlations of bulk events are consistent with 3.1 minute half-life of Po-218 (this provides rejection)



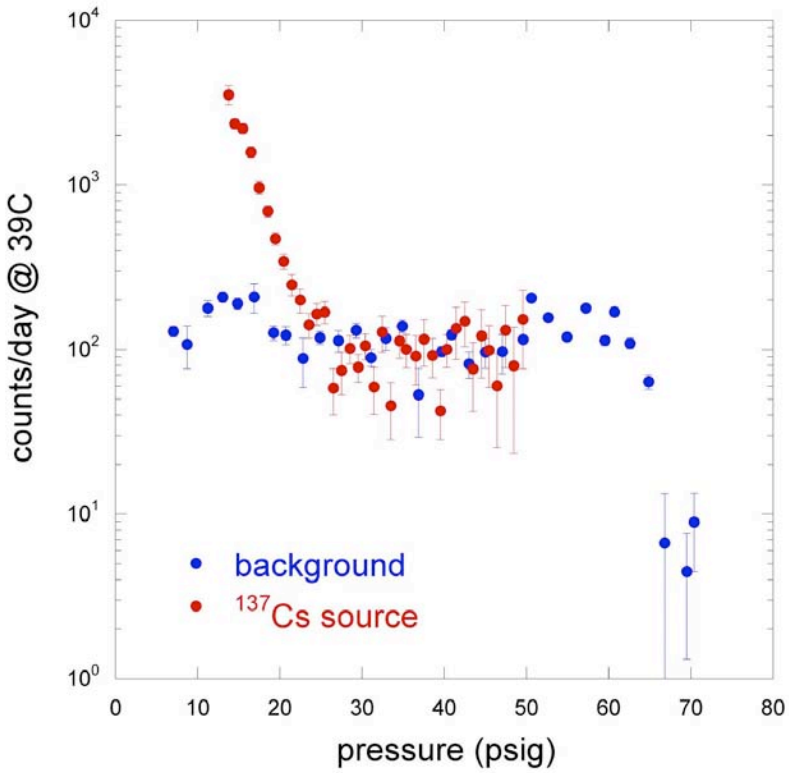

Second signature: P-onset as predicted, flat rate below.

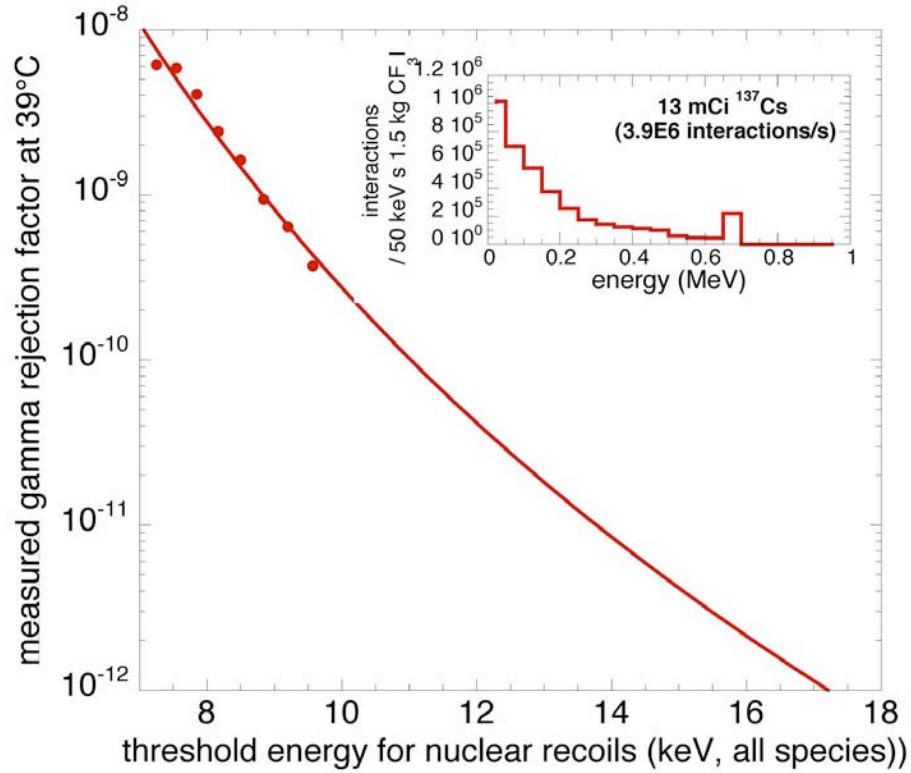
# Gamma calibration *in situ*

$^{137}$Cs (13mCi)



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

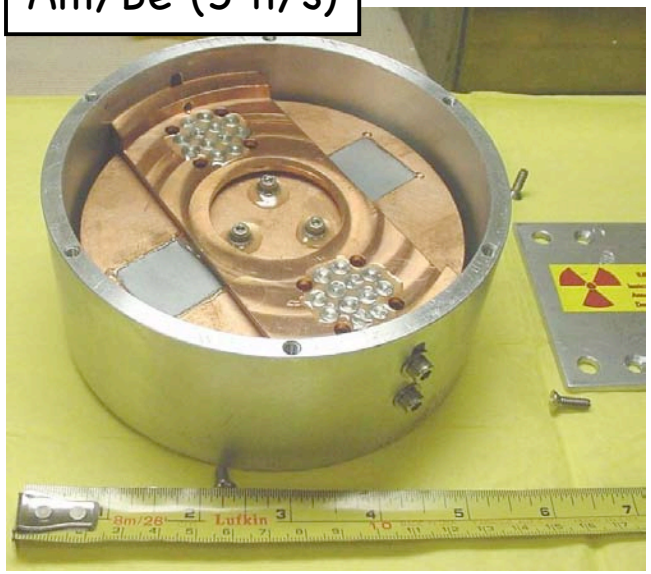


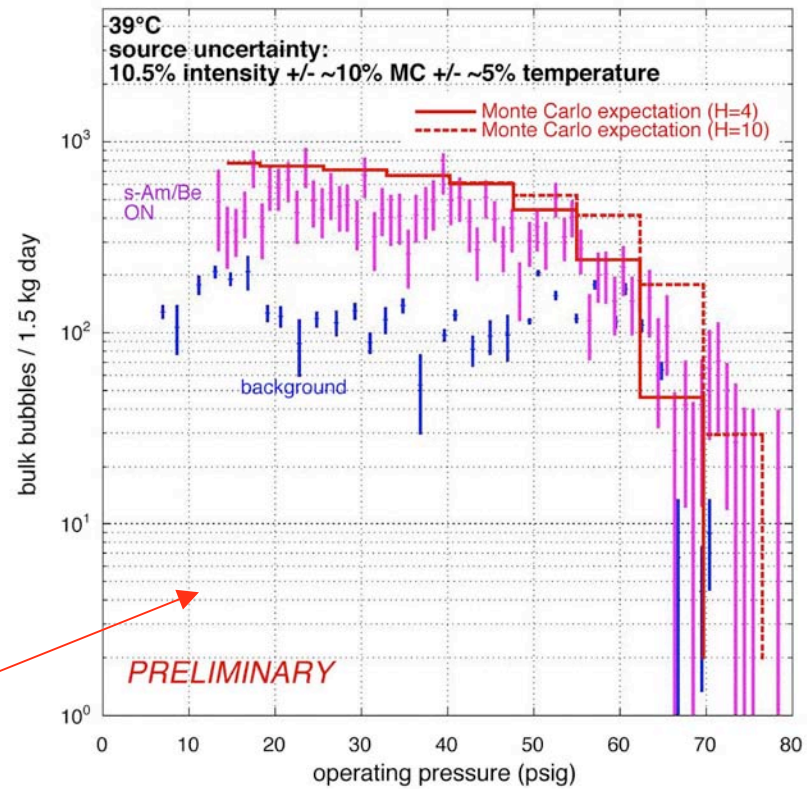

Beta and gamma emitters not an issue for COUPP. Blind to MIPS too.

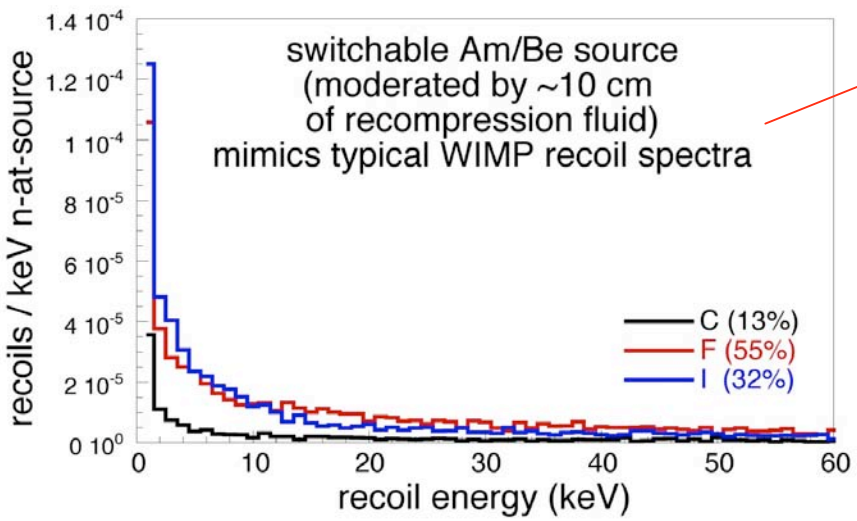
# Neutron calibration *in situ*

Switchable Am/Be (5 n/s)



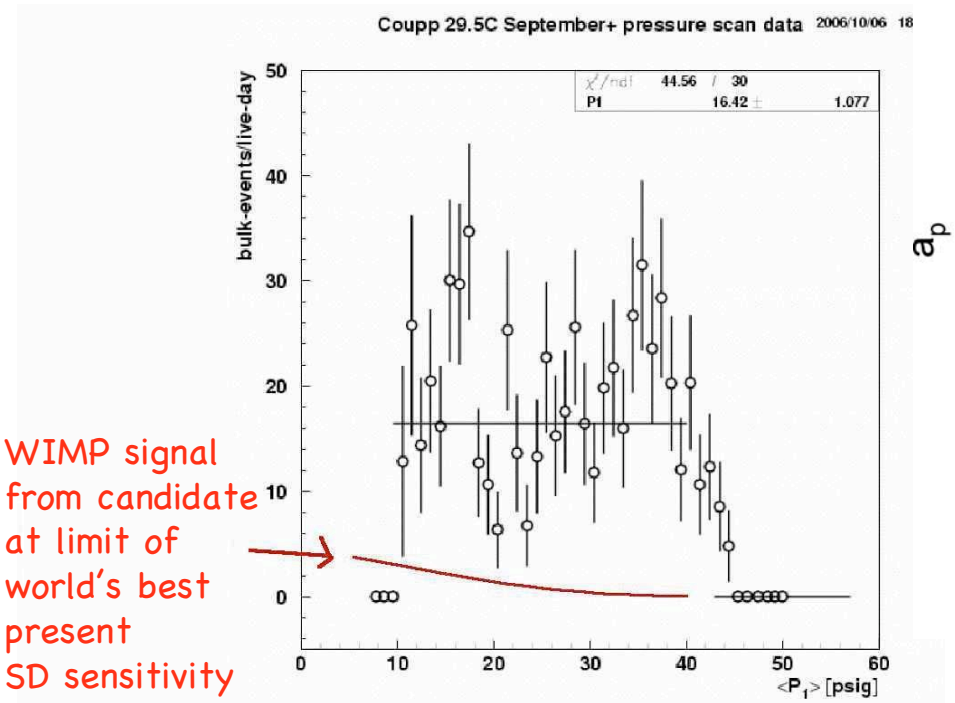
O(0.2) n/day when OFF. Second generation design produces none.



# Physics Reach with Engineering Prototype

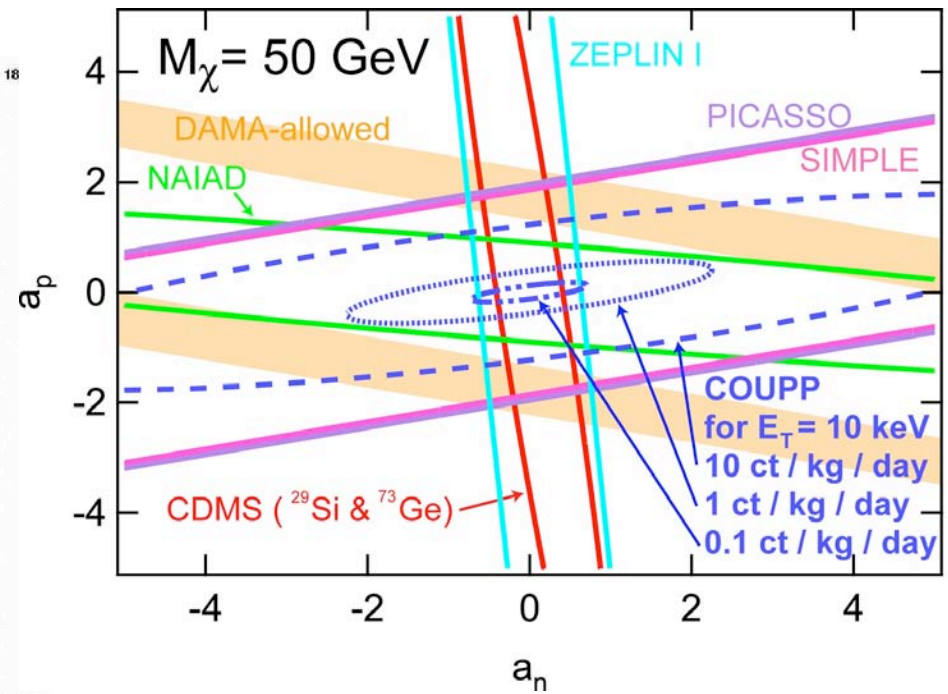
Where exactly are we
in sensitivity as of today




WIMP signal
from candidate
at limit of
world's best
present
SD sensitivity
($m_\chi$=50 GeV/c$^2$,
$\sigma_{Wp}$= 0.3 pb)

Telltale signature:
Response to $\alpha$'s is flat,
not the case for WIMPs
(or neutrons)

e.g. Spin-dependent




Not a limit yet
(trying to include systematics,
increase statistics, reduce threshold)

# Plans

FNAL T945

- Complete analysis and publish results from 2006 engineering run
- Replace inner vessel of 1-liter chamber with measures against Radon and other improvements.
- Commission muon veto system to extend sensitivity at NuMi site.

Goals: Demonstrate reliable operation.

Understand expected backgrounds ($Rn^{222}$, wal $\alpha$'s n's). Calibrate with sources: $\gamma$, n.

Improve understanding of bubble nucleation threshold and efficiency through test beam experiments and neutron experiments.

World's best sensitivity for spin-dependent scattering.

FNAL E961

- Finish design and construction of chamber in the 30-liter 60 kg regime.
- Commission chambers at Fermilab NuMI site. Goals: Further understanding of weaker backgrounds.
- Evaluate deployment of chamber(s) at a deep underground location (Soudan? DUSEL? SNOlab?)

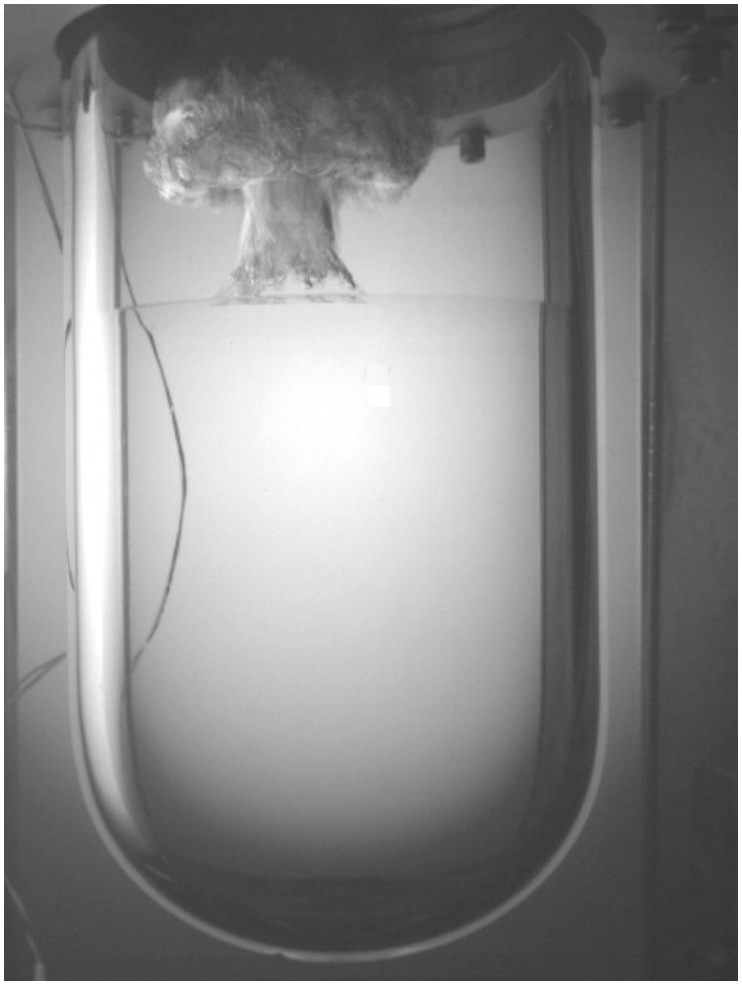
Goals: reduce background to <<1 event per kg per day

maintain good live time (>80%)

Physics (E???)

- Successful runs deep underground with ~60 kg modules may lead to the design of larger (or more) devices. Alpha-emitter radiopurity must also be in place before this.

# Questions ?



Coupp Website:
http://www-coupp-fnal.gov/