What’s so special about COUPP?
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\(_3\)I)
- Target fluid can be replaced (e.g., \(C_3F_8\), \(C_4F_{10}\), CF\(_3\)Br). 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 (~\(10^{-17}\)) will lead to complete probing of SUSY models
Not your daddy’s bubble chamber:

Conventional BC operation
(high superheat, MIP sensitive)

Low degree of superheat, **sensitive to nuclear recoils only**

Seitz model of bubble nucleation (classical BC theory):

\[ E > E_c = 4\pi r_e^2 \left( \gamma - 1 \frac{\partial \gamma}{\partial T} \right) + \frac{4}{3} \pi r_e^3 \rho_v \frac{h_{\gamma}}{M} + \frac{4}{3} \pi r_e^3 \rho \rho_v \Delta P, \quad r_e = \frac{2\gamma}{\Delta P} \]

d\(E/dx > E_c/(ar_e)\)

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

COUPP approach to WIMP detection:

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neutron-induced nucleation in 20 c.c. CF\(_3\)Br (0.1 s real-time span) Movie available from http://cfcp.uchicago.edu/~collar/bubble.mov
COUPPP 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 ($\text{CF}_3\text{I}$)
- Target fluid can be replaced (e.g., $\text{C}_3\text{F}_8$, $\text{C}_4\text{F}_{10}$, $\text{CF}_3\text{Br}$). 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 ($\sim10^{-17}$) will lead to complete probing of SUSY models

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

- Excellent sensitivity to both SD and SI couplings (**CF$_3$I**)

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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)
Gamma and neutron calibrations *in situ*:

- **$^{137}\text{Cs}$ (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$^{-8}$

$^{14}\text{C}$ 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:

Switchable Am/Be (5 n/s)
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 ($\alpha$'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
A peek at the future (which is here)

chamber after refill (Rn countermeasures)

- Live test
  - SAMBE ON
- Best previous rate (33°C)
- \( ^{222} \text{Rn T}_{1/2} = 3.8 \text{ d} \)

Neutron signatures:
- Absence of \( t \)-correlations
- \(~1/2\) are multiple bubbles

\((\mu, n)\) expectations before \(\mu\)-veto
Next step: ~100 kg target mass, deeper site

Encouraged by FNAL directorate to start thinking “1 ton”
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.

COUPP 07
COUPP 08 (projected)