COUPP

First data from a deep-site bubble chamber
The COUPP Collaboration

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Outline

- Bubble Chamber Review
- COUPP 4kg @ MINOS, results
- COUPP 4kg @ SNOLAB, status and results
- COUPP 60 @ MINOS, status
Review

- Superheated $\text{CF}_3\text{I}$ target
- Particle interactions nucleate bubbles
- Cameras capture bubbles
- Chamber recompresses after each event

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March 18, 2011
Review

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Review

- Only proto-bubbles with $r > r_{\text{crit}}$ grow to be macroscopic.

- Critical proto-bubble requires minimum $\Delta E$ within minimum volume.

- Recoil must be over thresholds in both $E$ and $\Delta E/dx$.

No sensitivity to $\gamma$'s or $\beta$'s, but $\alpha$'s do make bubbles.
3 basic event types

- **alpha-decays**
  - Nuclear recoil + 40 μm alpha track
  - U, Th chain impurities in fluid, especially radon and its daughters

- **neutrons**
  - Nuclear recoils, mean free path ~20 cm
  - Produced by cosmic muons, fission, and (α, n) reactions

- **WIMPs**
  - Single nuclear recoil (mean free path > 10^{12} cm)
Acoustic Discrimination

- Alpha louder when probing length scales <40 µm
- Acoustic emission peaks at ~10 µm

Daughter heavy nucleus (~100 keV)  Helium nucleus (~5 MeV)

Observable bubble ~mm

~40 µm

~50 nm
COUPP 60 @ MINOS

First data, July 28, 2010

- Cosmic-induced neutron (2 bubbles)
COUPP 60 @ MINOS

First data, July 28, 2010

- Cosmic-induced neutron (1 bubble)
COUPP 60
@ MINOS

First data,
July 28, 2010

- Alpha-decay
  (1 bubble)
3 “WIMP candidates” could be:
- alphas
- neutrons
- WIMPs

Note un-vetoed 2-bubble event…

At least 74% alpha discrimination
COUPP 4kg @ MINOS, 2009

Spin–independent nucleon cross-section (cm²)

$10^{-45}$ $10^{-44}$ $10^{-43}$ $10^{-42}$ $10^{-41}$ $10^{-40}$

WIMP Mass (GeV)

$10^1$ $10^2$ $10^3$

COUPP (MINOS 2009)
CDMS (SUF)
XENON10
COUPP (4kg deep*)
COUPP (4kg deep**)
CDMS

* 3 months with zero background
** 1 year with zero background


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6800 Feet Down
COUPP 4kg @ SNOLAB

Installation Begins:
July 27, 2010

July 27, 2010, DAQ and Pressure Control
Move Underground
COUPP 4kg @ SNOLAB

One leaky accumulator, a few leaky plumbing lines, a slightly overstretched bellows, and one unusual occurrence report later…

Installation Ends: Nov 3, 2010

Nov 3, 2010, Shield is completed
Physics data begins!

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COUPP 4kg @ SNOLAB

- 18.1 live-days at 7 keV threshold
- 21.5 live-days at 10 keV threshold
- 3.3 kg fiducial cut (out of 4.0 kg)

Counts

0 1 2 3 4 5 6 7
Acoustic Parameter

Background
AmBe neutron source

130 kg-days

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COUPP 4kg @ SNOLAB

- 5.3 alpha-decays / kg-day
  - 80% $^{222}$Rn, $^{218}$Po, $^{214}$Po triplets
- >98% alpha rejection

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COUPP 4kg @ SNOLAB

- 2 three-bubble events in this dataset!

- Single-bubble background of ~0.05 events/kg-day from neutrons (*big* statistical error bar)

- O(1) event/year expected from cosmogenic and environmental neutrons

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Neutron sources!

- Piezoelectric is the ceramic PZT (Lead zirconate titanate)
- 4.2 ppm $^{238}\text{U}$
- 1.4 ppm $^{232}\text{Th}$
- plus lots of modern lead with $^{210}\text{Pb}$
- Both fission and $(\alpha,n)$ on light elements
- *Preliminary* calculation gives ~1 neutron/day from 8 acoustic sensors
Neutron sources!

- Currently screening alternate piezoelectric materials
- Lower background ceramics are a solution for the 4kg chamber, for 3 months background free
- Plan to refit chamber with low background components this spring
**COUPP 4kg @ SNOLAB**

- Evidence for 2nd, time-varying background
  - Clusters of 3 and 5 events in 3 and 9 hours, respectively at 7 keV threshold
  - Less clustering at 10 keV threshold, but several events are outliers at high AP
- Several plausible sources, still investigating…

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130 kg-days
COUPP 60, milestones

- ~3 weeks successful data taking at MINOS
- Successful commissioning of new pressure control hardware, PLC, DAQ system
- Demonstration of acoustic discrimination in large chamber
COUPP 60, final hurdles

- Chemistry
  - $\text{CF}_3\text{I}$ reacting with impurities or illumination
  - High bubble nucleation rate at $\text{CF}_3\text{I}-\text{H}_2\text{O}$ interface

- Optics, Imaging
  - Higher resolution and frame-rate desired
  - More uniform illumination, lower intensity light source

- Neutron Backgrounds
  - Acoustic sensor replacement needed
  - Screening of other elements ongoing…
Conclusions

- 130 kg-days from a bubble chamber deep underground
- >98% acoustic alpha discrimination, will get better as we eliminate backgrounds
- First direct detection experiment limited by internal neutron background
- Will refit 4kg chamber with low background components this spring
- Progress continues on COUPP 60, with much input from 4kg chamber