COUPP

Jeter Hall

Fermi National Accelerator Laboratory
COUPP Bubble Chamber Program

- Take long runs with smaller chambers to understand backgrounds, operations, and for research and development, while developing and commissioning a larger chamber.

Test tube (U Chicago)  
COUPP 2kg  
COUPP 4kg  
COUPP 60kg

PRL 106 021303 (2011)  
New results from SNOLAB

Now moving to SNOLAB

Ton Scale?
The Chicagoland Observatory for Underground Particle Physics

University of Chicago
Juan Collar (PI, spokesperson), C. Eric Dahl, Drew Fustin, Alan Robinson, Matthew Szydagis

Indiana University South Bend
Ed Behnke, Joshua Behnke, Tonya Benjamin, Austin Conner, Emily Grace, Adam Grandison, Cale Harnish, Ilan Levine (PI), Thomas Nania, Tim Raymond

Fermilab
Steve Brice, Dan Broemmelsiek, Peter Cooper, Mike Crisler, Jeter Hall, Martin Hu, Hugh Lippincott, Erik Ramberg, Andrew Sonnenschein, Fermilab Engineers and Technicians

SNOLAB
Eric Vazquez Jauregui
Continuously Sensitive Bubble Chambers

- Superheated CF$_3$I target
- Depositions of enough energy ($> E_T$) in a small enough volume ($< R_c$) create bubbles
  - F. Seitz, Phys. Fluids 1, 2 (1958)
- Cameras watch and issue a trigger
- Re-liquefy the target with 60 second compression
COUPP 4 at SNOLAB

- 2009 results obtained in the MINOS near detector tunnel at FNAL (300 mwe) limited by backgrounds from cosmic radiation
- In 2010 we initiated a move of our 2 liter bubble chamber to SNOLAB (6000 mwe)
COUPP 4 at SNOLAB

Physics Operations
Nov 3, 2010
COUPP2L SNOLAB Exposure

- 17.4, 21.9, 97.3 live-days at 8, 10, 15 keV thresholds finished Summer 2011
- 4.048 kg CF$_3$I, 79% efficiency for nuclear recoils
  - 90% quality cuts, 92% fiducial volume, 96% acoustic cut
COUPP2L SNOLAB Results

- >99.3% alpha rejection (15 keV threshold)
- 20 WIMP candidates
  - (0.11, 0.09, 0.03) ev/kg/day above (8, 11, 16) keV
  - Expect ~0.01 ev/kg/day from identified neutron sources

- AP is a measure of acoustic energy
- A(T) temperature correction
- G_j gain correction for j^{th} acoustic sensor
- C_n(x) position correction for n^{th} frequency range
- psd power spectral density with bin center frequency f

\[ AP = A(T) \sum_j G_j \sum_n C_n(x) \sum_f f \times psd_j^f \]
COUPP2L SNOLAB Results

- **20 WIMP candidates**
  - (0.11, 0.09, 0.03) ev/kg/day above (8, 11, 16) keV
  - Expect ~0.01 ev/kg/day from identified neutron sources

- **Are these WIMPs?**
  - Events at 8 keV threshold indicate that this is unlikely
    - Events are not consistent with the neutron AP distribution
    - If we include higher AP events, see clustering in time (3 in 3 hour period, 4 in 9 hour period in a ~1 month exposure with 6+4 events total)
    - Events are correlated with events at the CF$_3$I, H$_2$O, SiO$_2$ boundary

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COUPP2L SNOLAB Results

Spin-dependent proton cross-section (cm$^2$)

WIMP Mass (GeV)

PRELIMINARY
COUPP Thresholds

- Width in limit plots indicates two efficiency models for C,F to characterize our threshold systematics
  - Flat 100% efficiency used for iodine
- Both models fit our calibration data
  - Neutron count rates ~50% of those predicted by simulations
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![Graph showing count rate vs. time between bulk singles.](image)
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COUPP2L SNOLAB Results

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PRELIMINARY

3/5/2012  Jeter Hall - COUPP Results - Moriond EW 2012
COUPP2L SNOLAB Results

COUPP (Jan. 2011)

CDMS (SUF)

COUPP (this result)

XENON10

XENON100

PRELIMINARY

Spin-independent nucleon cross-section (cm$^2$)

WIMP Mass (GeV)
COUPP Thresholds – CIRTE at FNAL

- Better threshold and efficiency measurements are needed for COUPP chambers
- **COUPP Iodine Recoil Threshold Experiment** pion scattering in the Fermilab test beam has been initiated

π
silicon pixel telescope

10 mm CF3I bubble chamber

3/5/2012
Jeter Hall - COUPP Results - Moriond EW 2012
COUPP Thresholds – CIRTE at FNAL

- Better threshold and efficiency measurements are needed for COUPP chambers
- **COUPP Iodine Recoil Threshold Experiment** pion scattering in the Fermilab test beam has been initiated
- Initial 2 days of data with full silicon pixel telescope and 10 mm bubble chamber in 12 GeV pion beam
- 2 weeks beam time scheduled for March 14-27, 2012
COUPP Future

• The 4 kg vessel is being refurbished
• Known neutron sources removed
  – New piezos
  – New viewport
• CF$_3$I purity improved
• Run planned to start April 2012
COUPP60 Status

- 2 runs at shallow MINOS site at FNAL (300 mwe)
- System understood and shipping to SNOLAB
- Lessons learned from COUPP4 impacting the pressure vessel, acoustic sensors, and viewports
- Installation planned for Summer 2012
The End
Acoustic Discrimination

- Alpha/Nuclear recoil discrimination based on acoustic power demonstrated at 10:1 level in 2011

 Observable bubble ~\( \text{mm} \)

~40 \( \mu \text{m} \)

\~50 \( \text{nm} \)

Daughter heavy nucleus (~100 keV)

Helium nucleus (~5 MeV)
COUPP Thresholds

- Track lengths for C,F are significantly larger than the critical radius for bubble nucleation in CF₃I
- I, Po in CF₃I have track lengths smaller than the critical radius
- F in C₄F₁₀ also have track lengths shorter than the critical radius
COUPP60 Darkening

- Optical photons can destroy the C-I bond leading to a red solute in COUPP chambers
- We observed no significant darkening in a two month run of COUPP60