

PICO

Bubble Chambers for Dark Matter

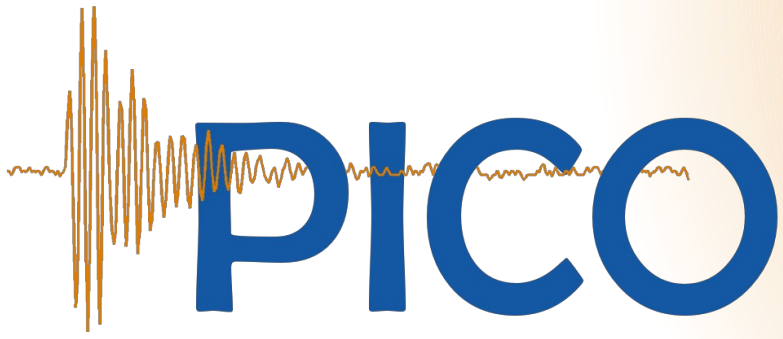
Alan Robinson
PICO Collaboration

CAP Congress Jun 18, 2014



THE UNIVERSITY OF
CHICAGO





PICO



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I. Stekl

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Fermilab

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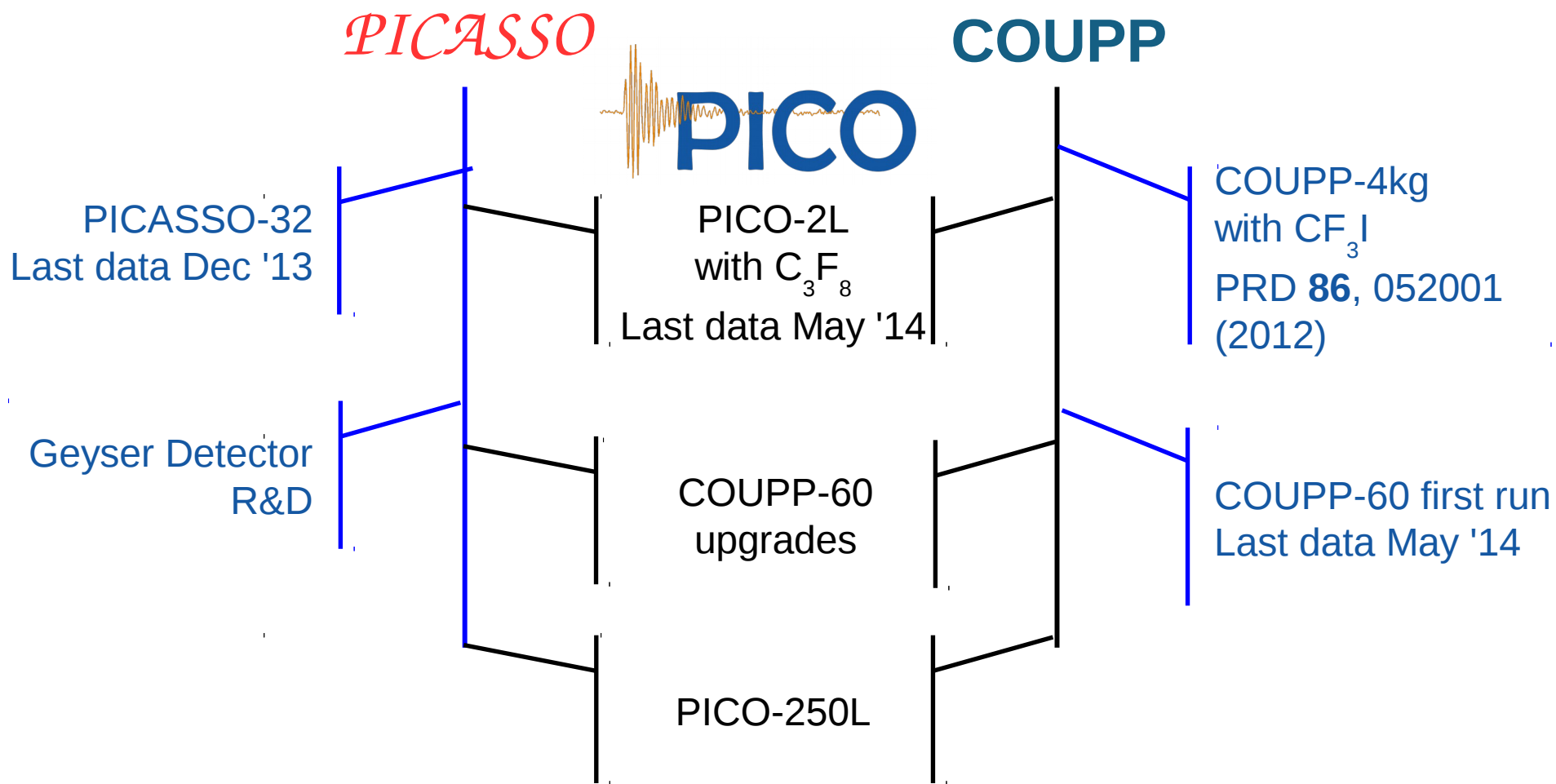


Pacific Northwest
NATIONAL LABORATORY

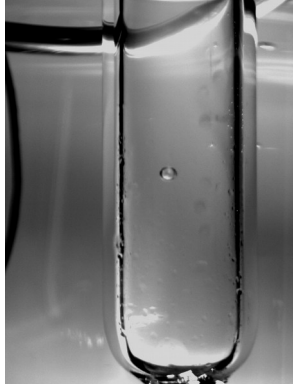
D.M. Asner, J. Hall

**UNIVERSITY OF
ALBERTA**

S. Gagnebin, C. Krauss,
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They're Scalable



2007
1-L bubble chamber



2010
COUPP-4kg at SNOLAB
COUPP-60 at FNAL

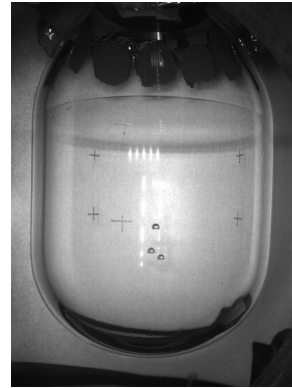


2016
PICO-250 ?

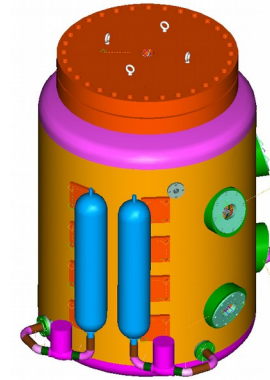
2005
First COUPP prototype



2009
COUPP-4kg at FNAL
Acoustic Discrimination

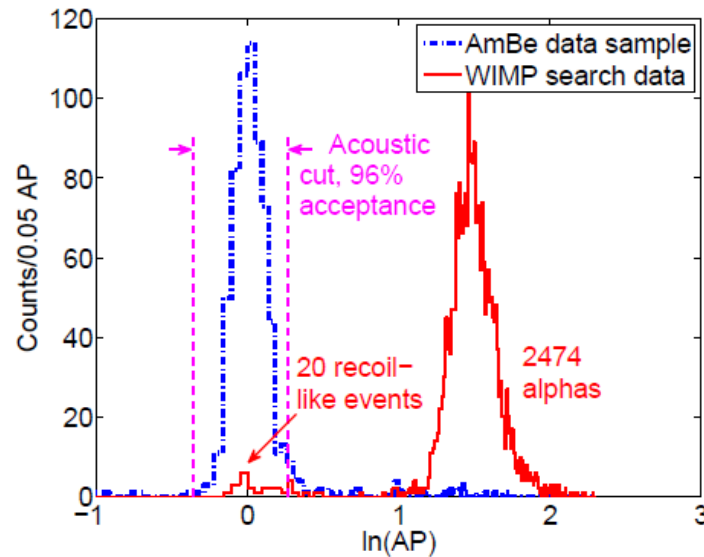


2013
COUPP-60 at SNOLAB
PICO-2L

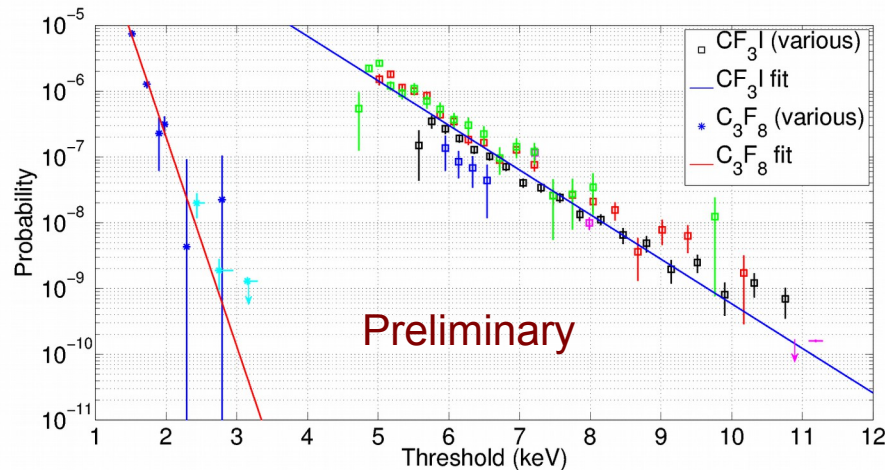


Impressive Background Rejection

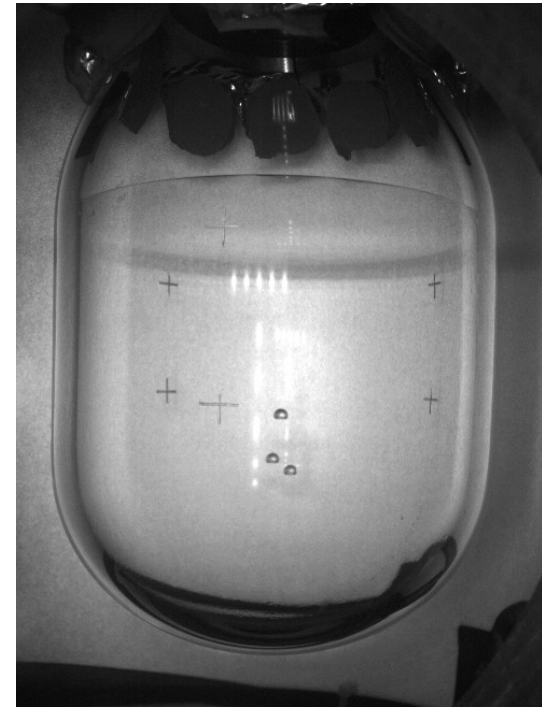
Acoustic Alpha
Discrimination



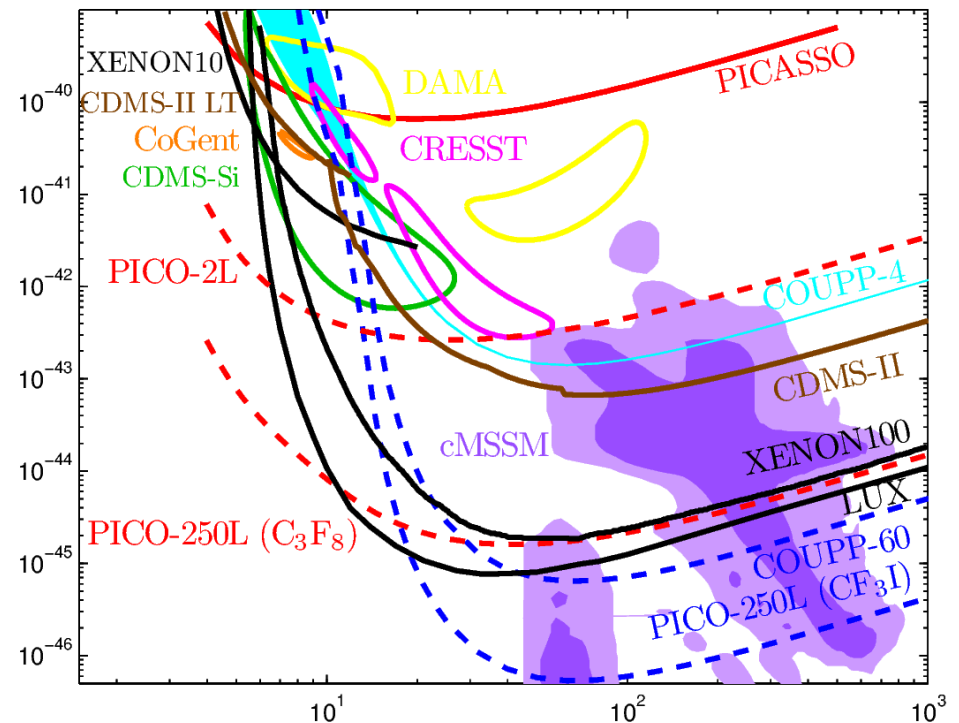
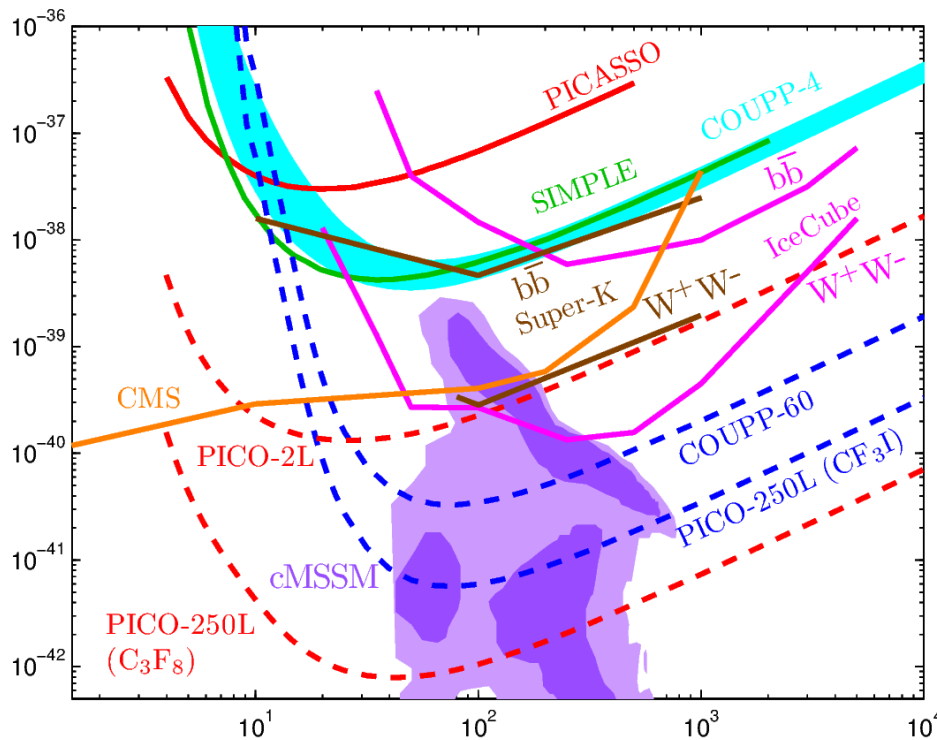
Gamma
Interaction
Insensitivity



Multiple Neutron
Scattering

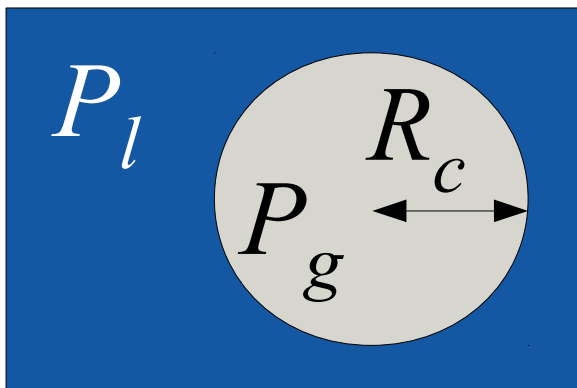


Spin-dependent & Low mass Ability to change target fluid

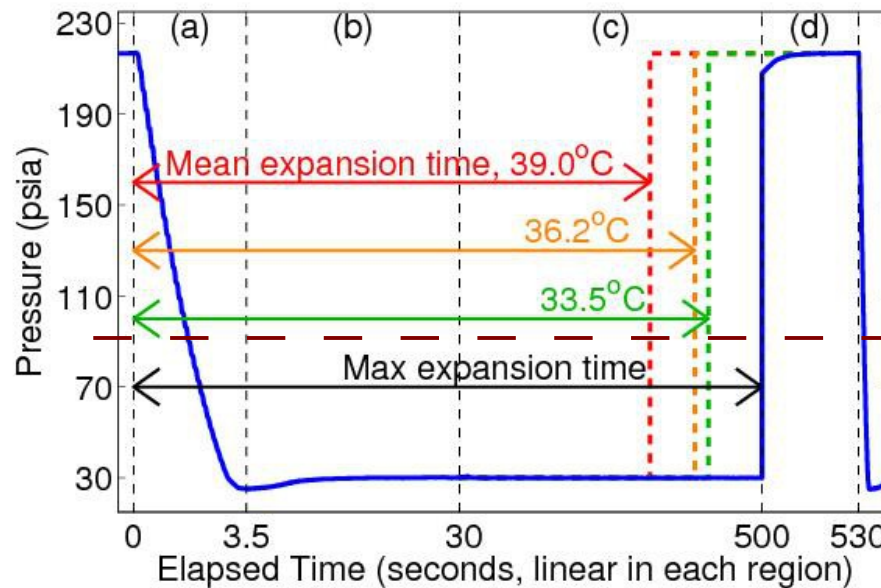


Radiation induced boiling of superheated fluid.

Bubble Chamber operation cycle



$$P_g - P_l = \frac{2\sigma}{R_c}$$



Boiling Point
(33.5°C, 90 psia)

Latent Heat

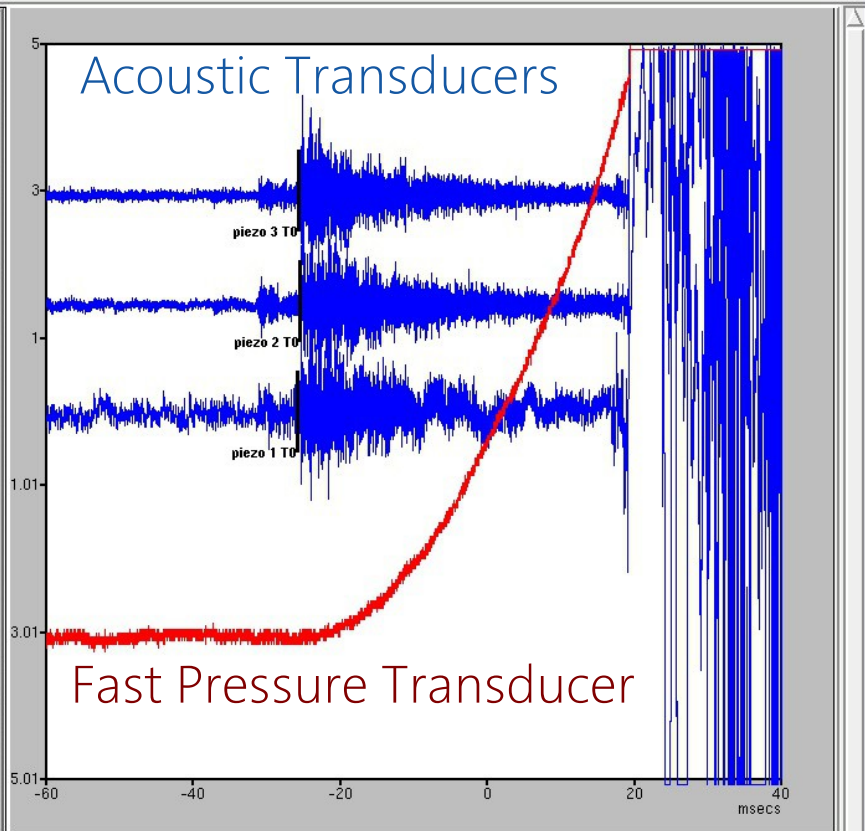
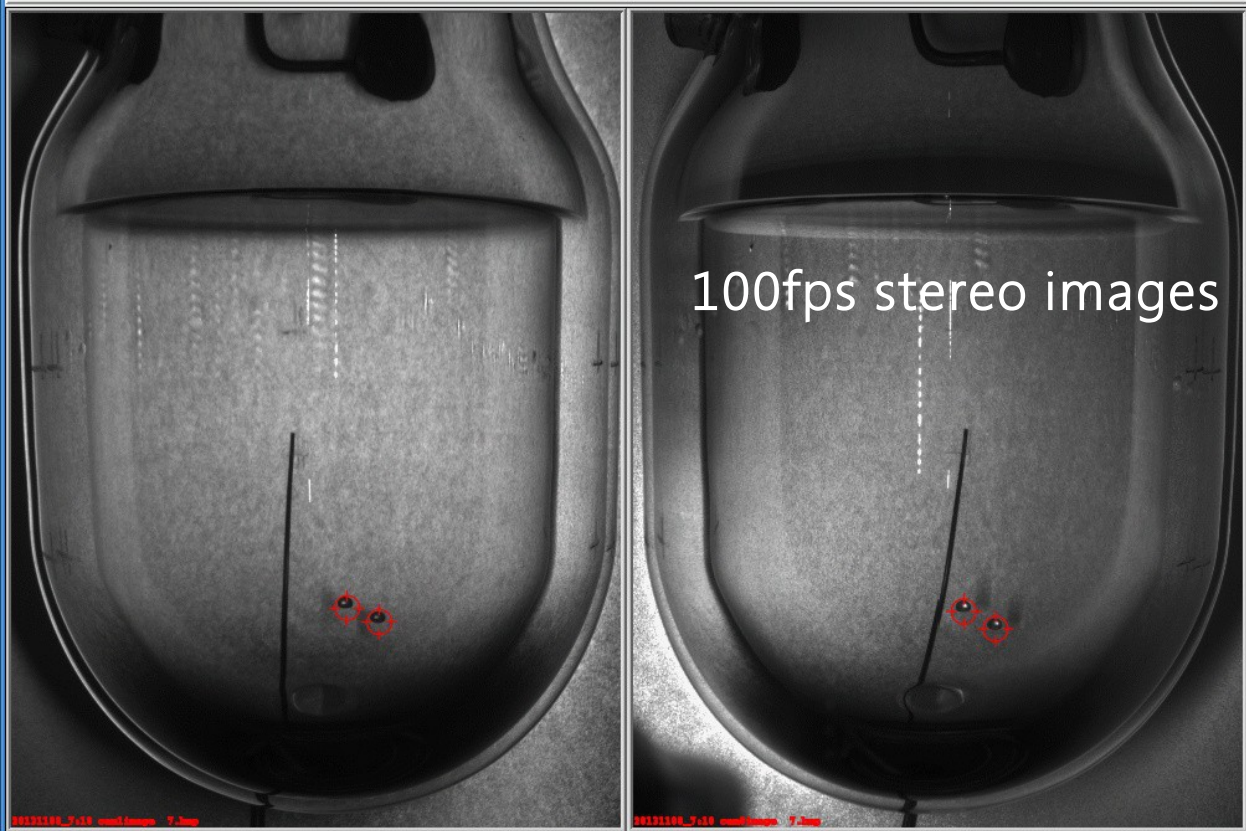
Surface Formation

$$Q = \frac{4\pi}{3} r_c^3 \rho_b (h_b - h_l) + 4\pi r_c^2 \left(\sigma - T \frac{d\sigma}{dT} \right)$$

COUPP Event Display

Windows

Run: 20131108_7 Event: 10 Event Time: Fri Nov 8 14:15:00 2013 Current Time: Tue Jun 10 11:25:53 2014



Time run start: Fri Nov 8 13:49:15 2013 this event: Fri Nov 8 14:15:00 2013 msec time: 3301294483	Pressure [PSIA] PT0: 32.66 PT1: 194.37 PT2: 31.64 PT3: 30.01 PT4: 31.28 setpoint: 30	Pressure Ramp	Temperature [degC] T0: 14.26 T1: 14.4 T2: 12.83 T3: 12.68	Event Timing [s] expanded time: 106 live time: 114.08	Frame Timing [ms] Time between frames [ms] 1-0 2-1 3-2 4-3 5-4 6-5 7-6 8-7 9-8 cam0: 11 10 9 10 11 10 10 9 10 cam1: 11 10 9 10 11 10 10 9 10 cam1 frame0 - cam0 frame0: 0 # skipped frames cam0: 0 cam1: 0	Pixels # hit pixels 0 1 2 3 4 5 6 7 8 9 cam0: 0 0 0 0 25 116 167 236 390 854 cam1: 0 0 0 0 44 158 253 414 523 584	Misc. trigger type: main=0, ctic=12, plc=1, slow=0 run type: 1(neutron calib) data series: 21-13 DAQ version: PICO2L:1.0
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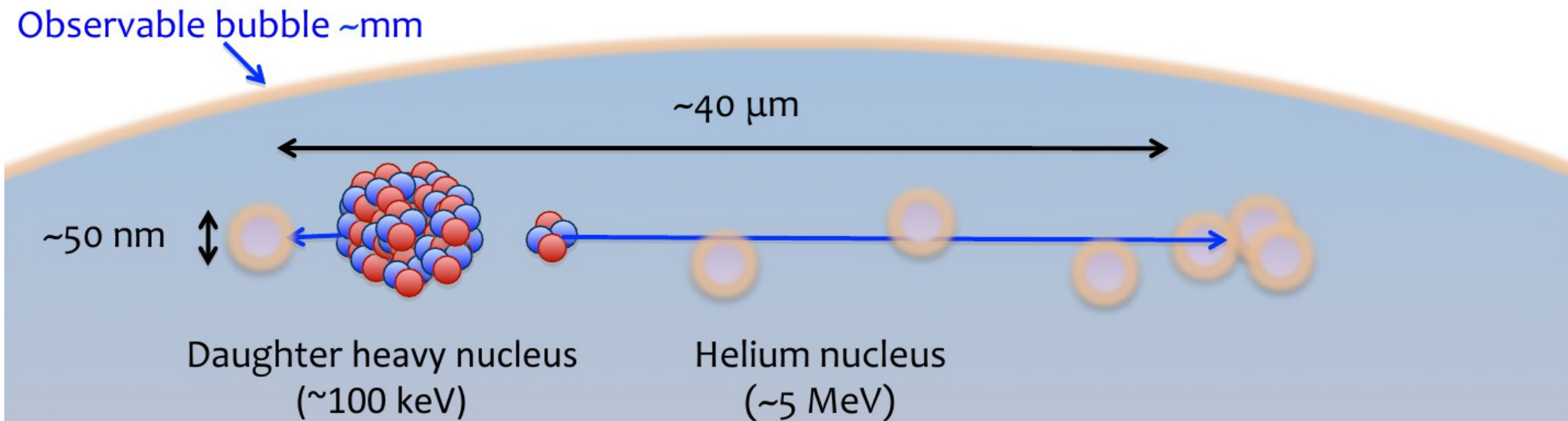
Pressure and Temp monitoring

Bubble Recon Bubble frame (cam0,cam1): (4,4) Bubble count (cam0,cam1): (2,2) Bub 1: (0,0): (290.5, 160.5) _ f(1,j1): (295.1, 166)	Dytran Analysis dytran2_type: 0(wall/other) dytran2_bubnum: 2.38 Quadratic Fit Cubic Fit	Acoustics Acoustic Parameter: 2.480 Acoustic Parameter (3 band): 2.872 Channels Used: 7(1,2,3)	Trigger Times TO Piezo 1: -0.0258744 TO Piezo 2: -0.0255704 TO Piezo 3: -0.0256452	Misc analysis version: R3-13 recon event type: spurious video
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PICO How it works

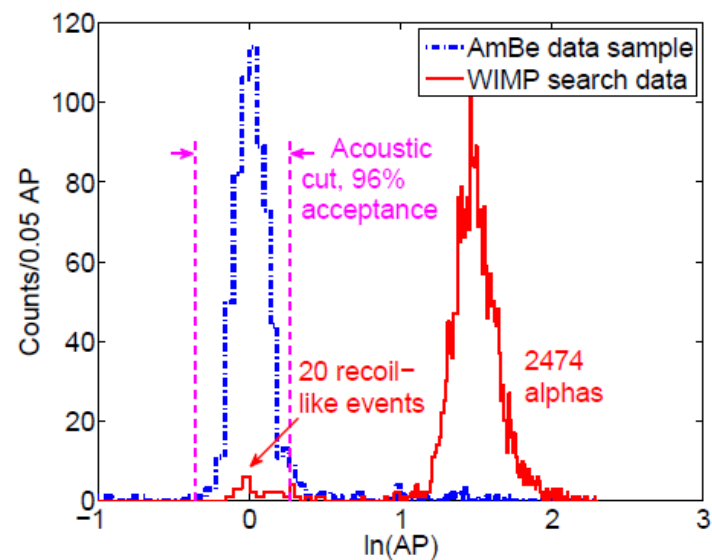
Alphas are ~ 4 times louder than nuclear recoil bubbles.

$>99.4\%$ discrimination against alpha events demonstrated.





- First run deep underground.
- Demonstrated 99.4% alpha discrimination



- Backgrounds

- ▶ (α, n) neutrons from components
- ▶ Time-clustered events.

PICO COUPP-60

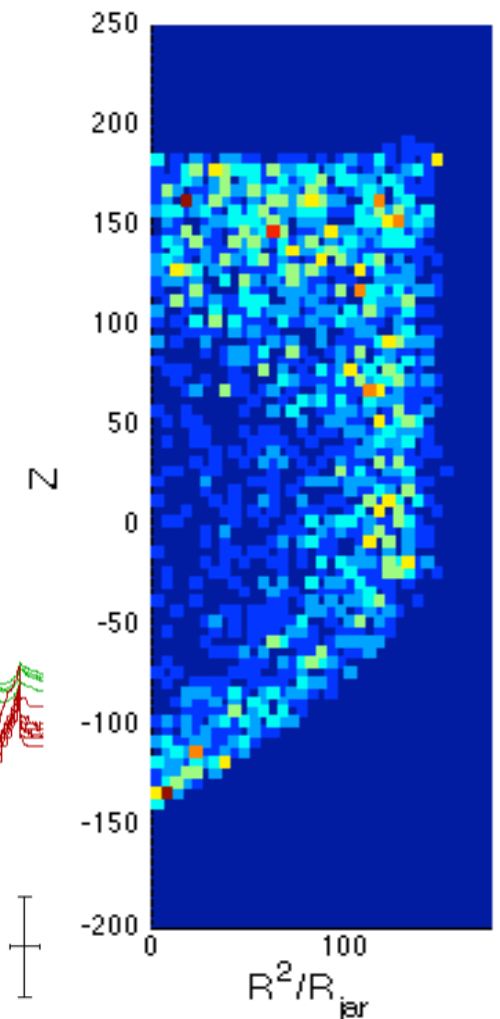
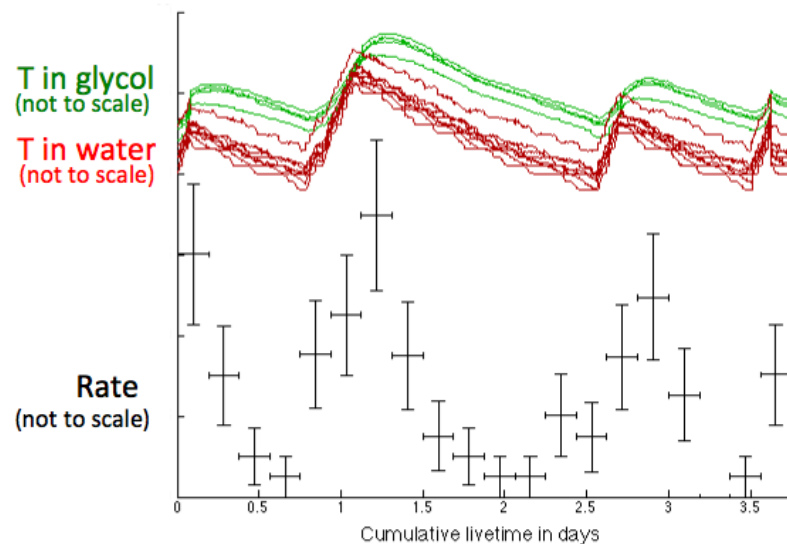
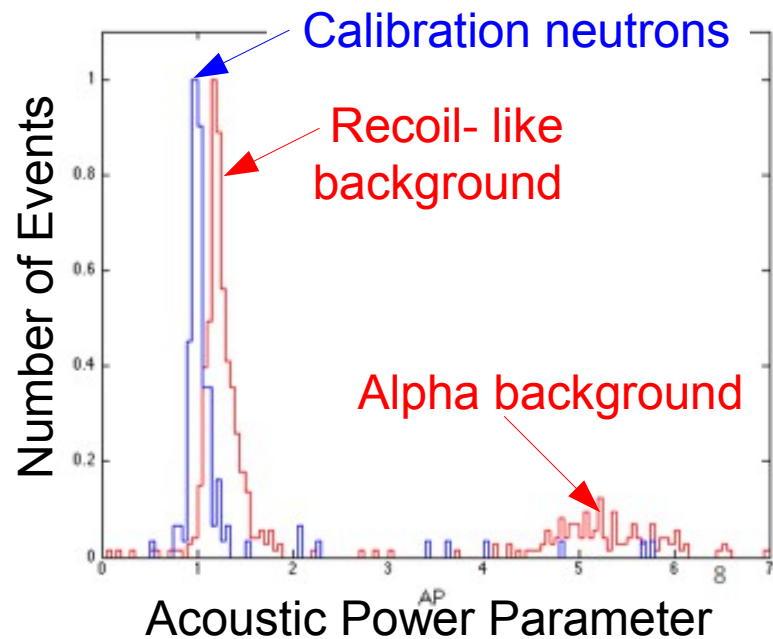


- Operational success:
 - ▶ 10x more massive
 - ▷ (35 kg of CF_3I)
 - ▶ > 80% live fraction
 - ▶ No multiple bubble events from neutrons
 - ▶ Acoustic discrimination confirmed in large chamber
 - ▶ > 3000 kg-days DM search data collected.

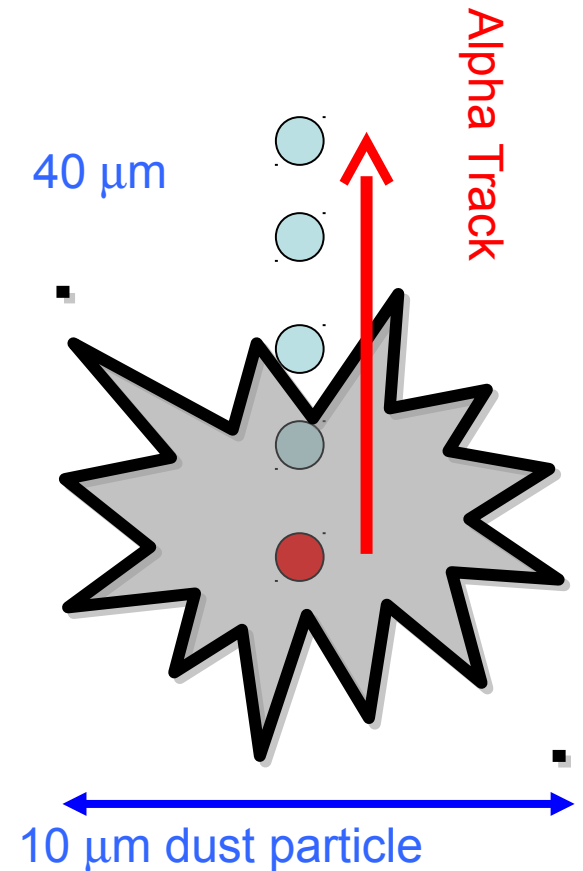
Slide 11/17

CAP 2014
Jun 18, 2014

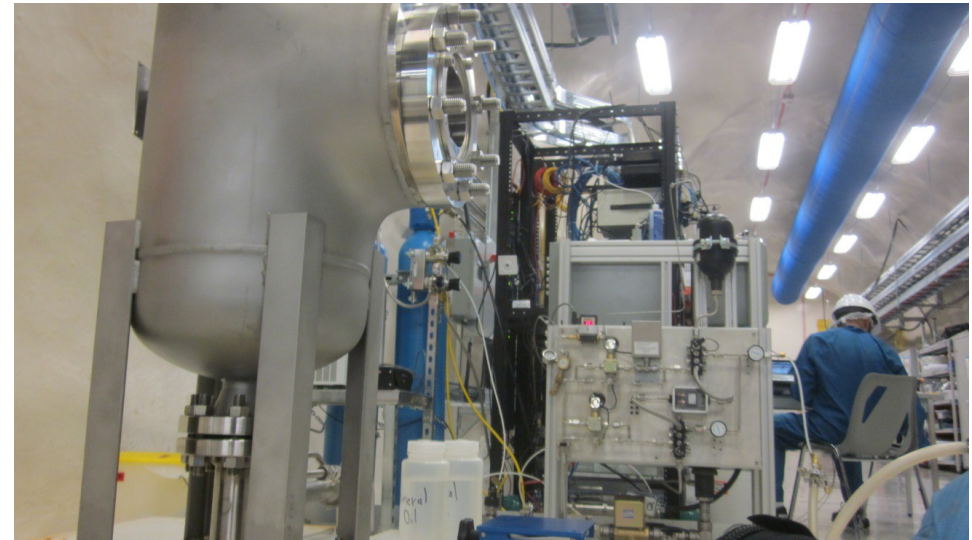
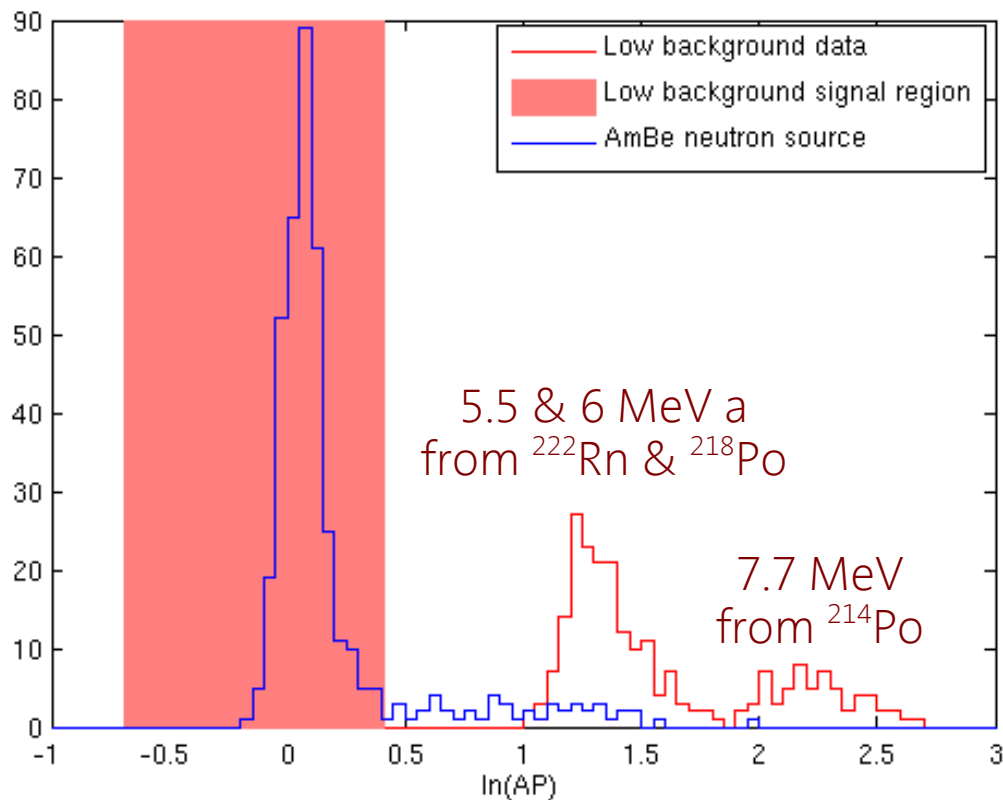
- Time-clustered background:
 - ▶ Correlated with temperature ramp
 - ▶ Spatially clustered around outside of active volume.
 - ▶ Anomalous acoustic power



- Suspect background from dust.
- Next steps:
 - ▶ Assay target fluid for particulates.
 - ▶ Installation of in-situ fluid filtration system.
 - ▶ Elimination of sources of particulate



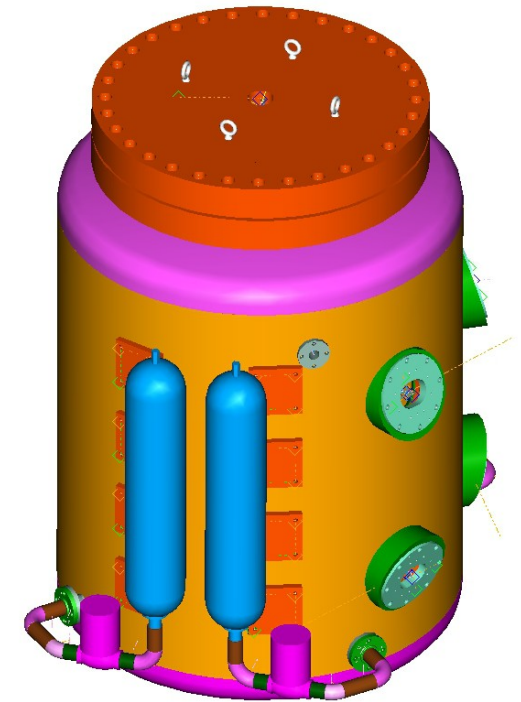
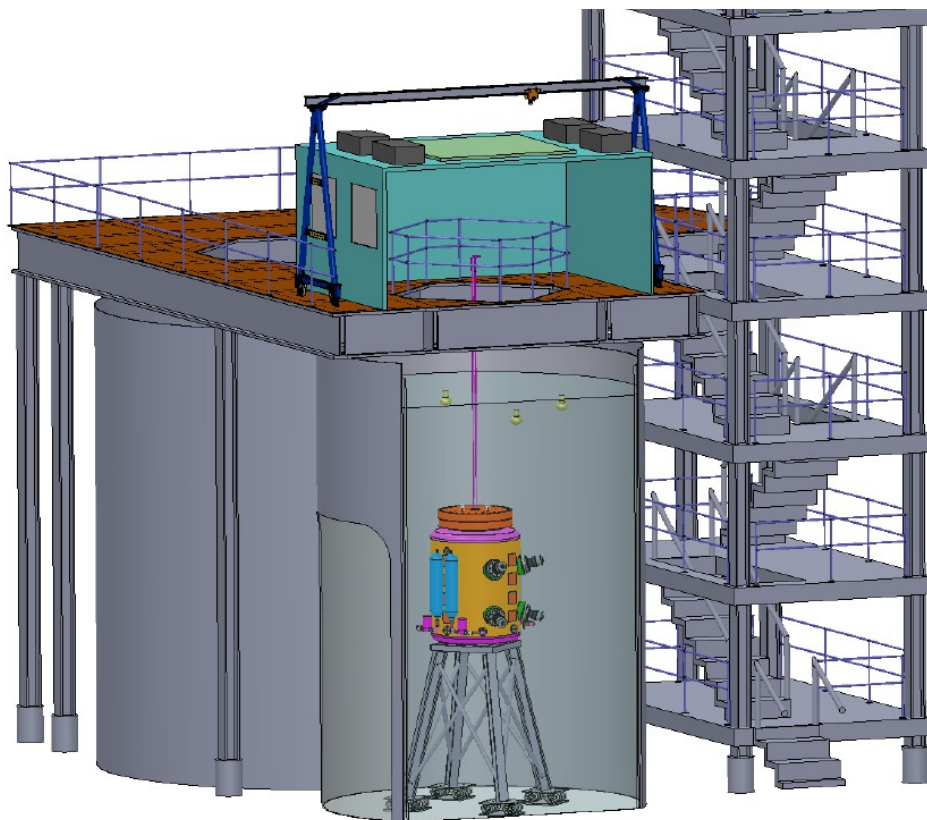
- C_3F_8 filled:
 - ▶ Lower threshold
 - ▶ Spin-dependent sensitivity
 - ▶ Chemically inert

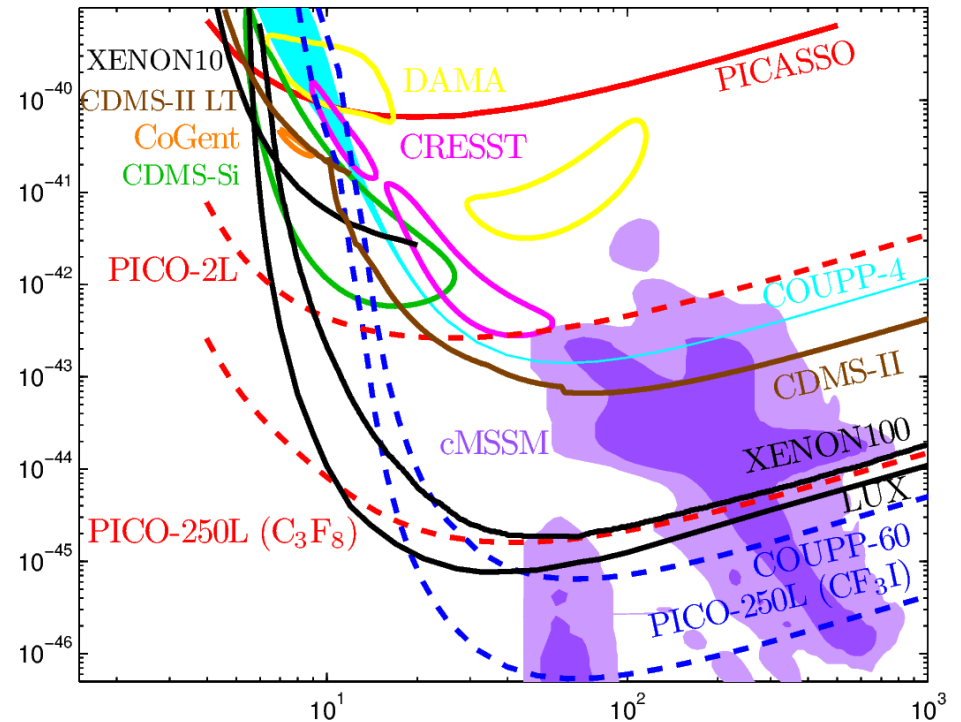
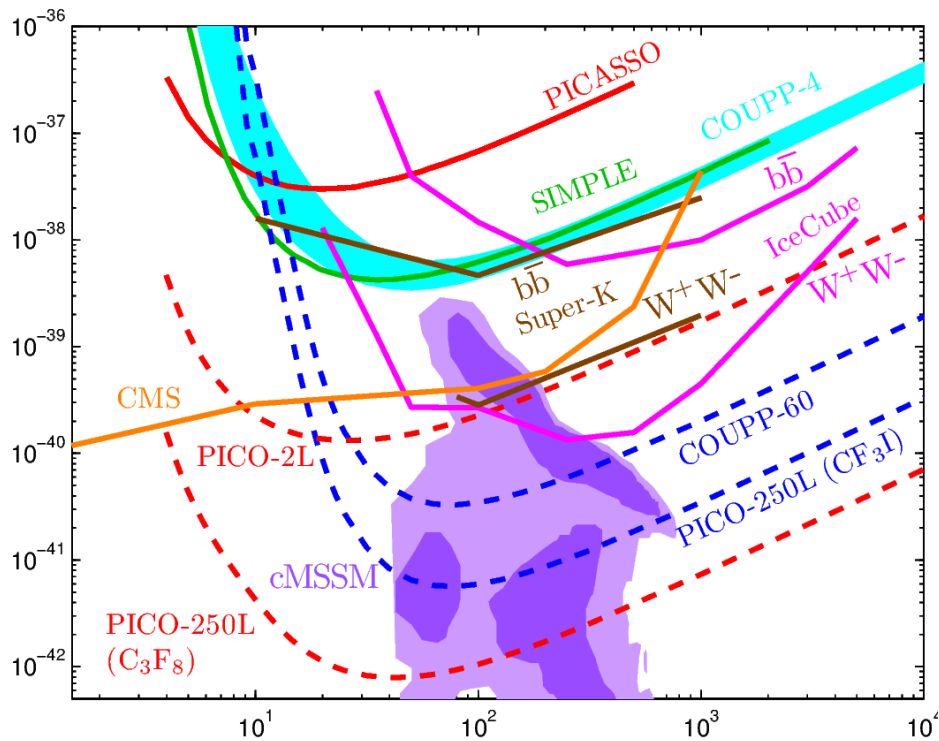


- >300 kg-days exposure.
- Run completed in May.
- Acoustic calorimetry.

PICO PICO-250L

- Designed for 250L of C_3F_8 or CF_3I target fluid
- Awaiting funding decision (DOE G2)
- Engineering of components underway

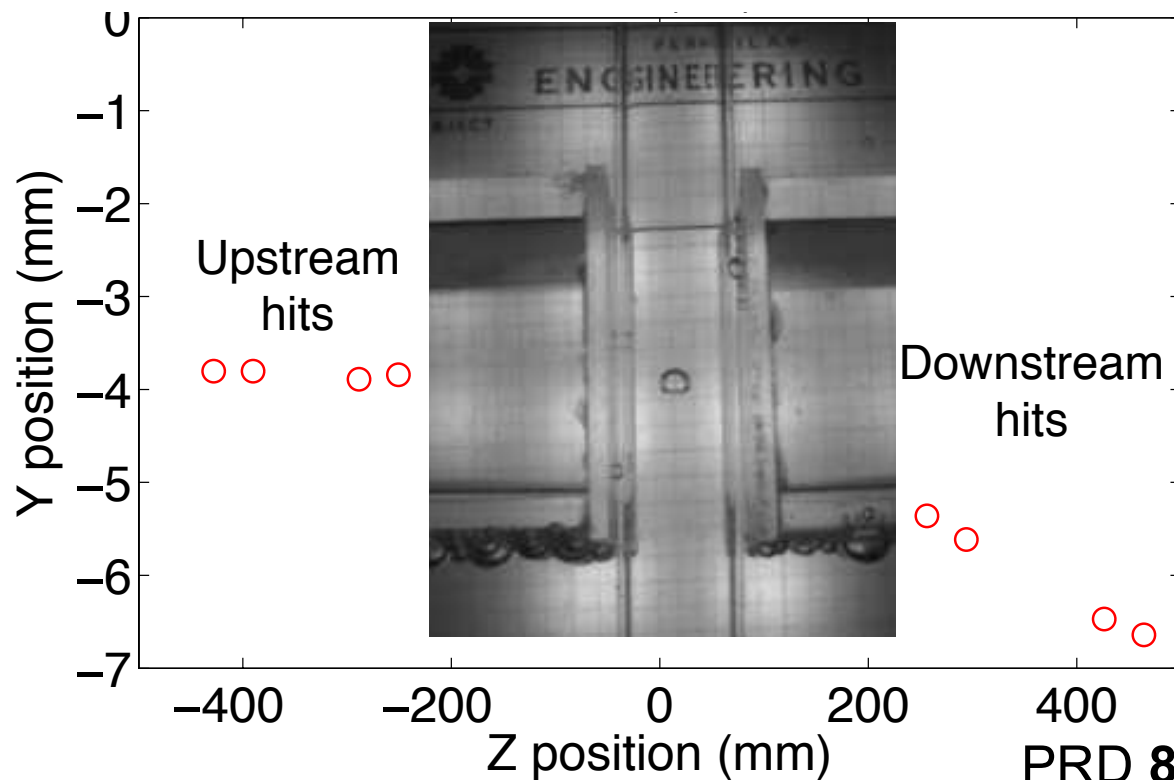




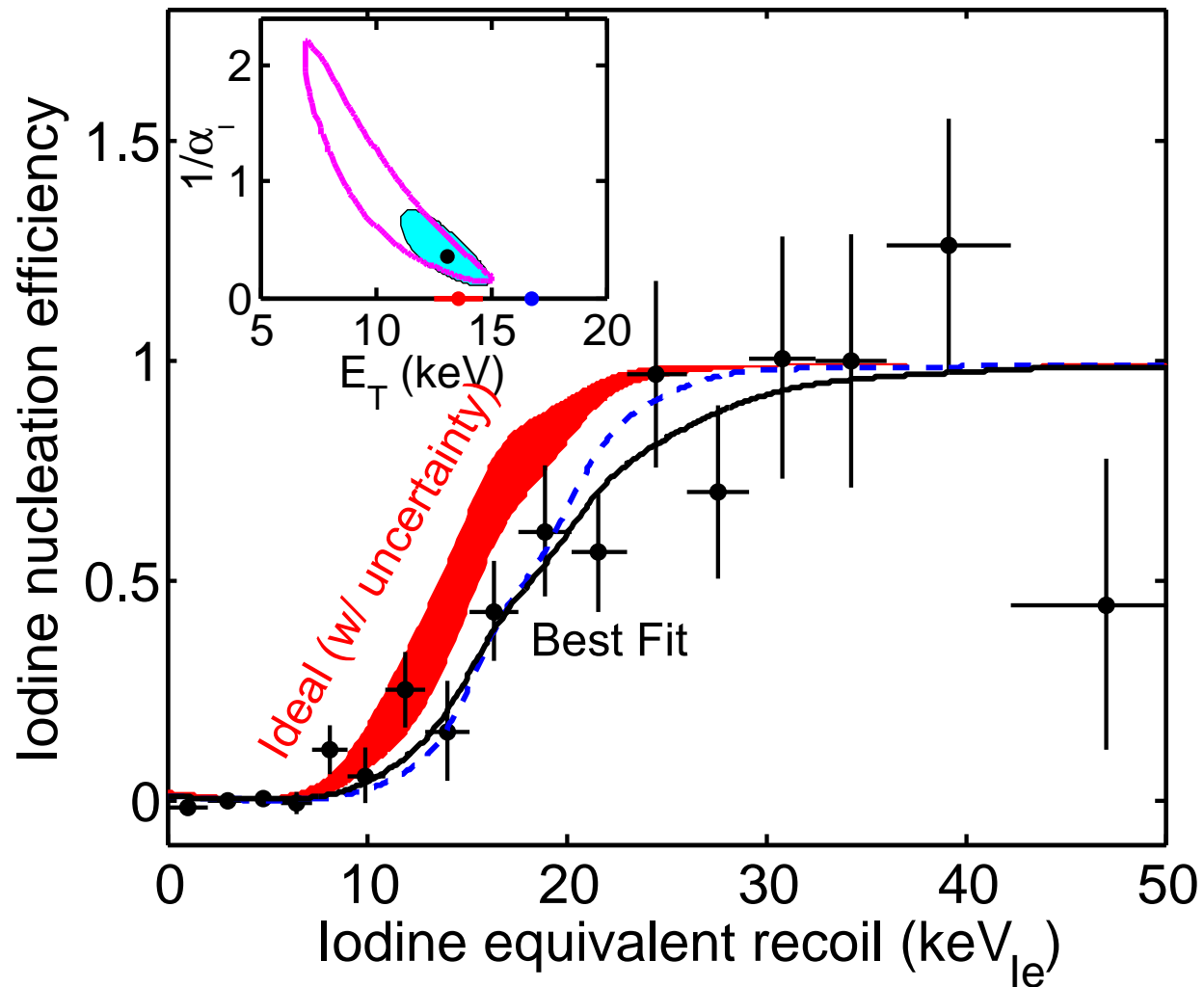
- (R1-9) Dark Matter II – 09h45 tomorrow
 - ▶ Chanpreet Amole – PICO-2L analysis
 - ▶ Ruslan Podvianuk – Acoustic signal conditioning
 - ▶ Pitam Mitra – Geyser detector R&D
- Poster Session – 19h00 today
 - ▶ Matthieu Lafrenière – Geant4 simulations
 - ▶ Arthur Plante – Acoustic Discrimination
- (F1-5) Dark Matter III – 08h45 Friday
 - ▶ Mathieu Laurin – Characterization of detectors using mono-energetic neutrons

Extra slides

- Measure elastic scatters of a 12 GeV π^- beam
 - ▶ Event-by-event recoil energy measurement.
 - ▶ Preferentially scatters on iodine.

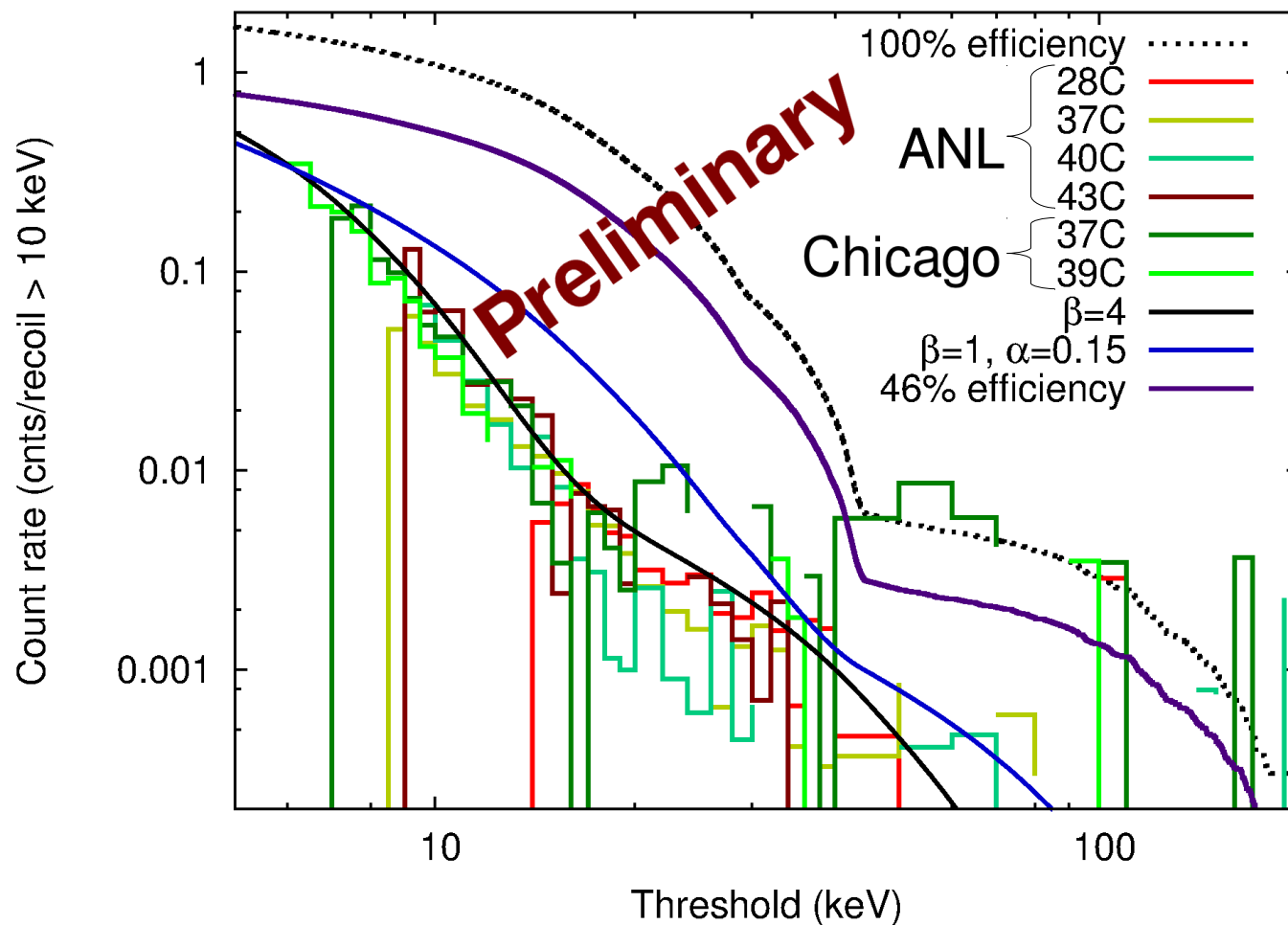


Efficiency calibrations



CF₃I C/F Efficiency

Normalized background subtracted count rate for Y/Be neutrons on CF₃I bubble chambers



Expectation and Fit from Y/Be neutrons on C₃F₈

