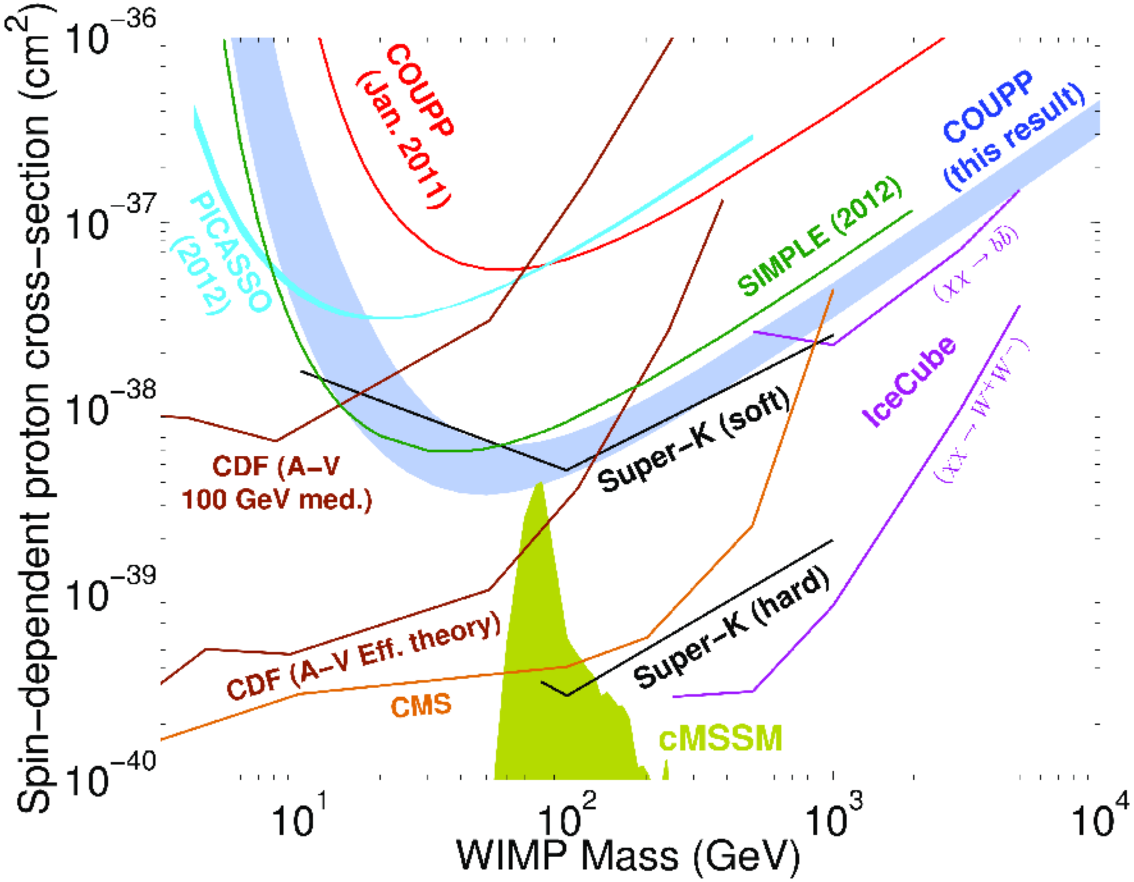
COUPP Carbon and Fluorine Recoil Thresholds



THE UNIVERSITY OF CHICAGO

Alan Robinson

July 26, 2012 IDM 2012, Chicago, IL

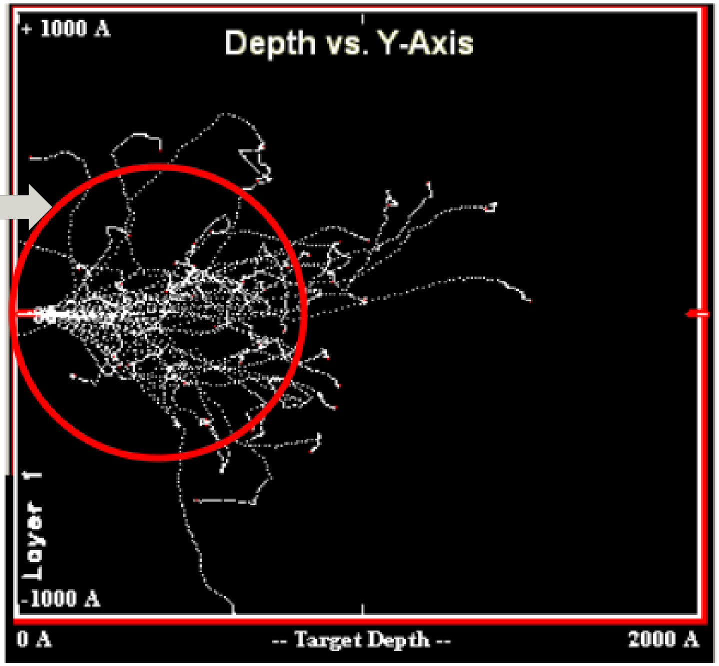
Bubble nucleation efficiency

- Definition:

  The probability for producing an observable bubble from a nuclear recoil.

SRIM calculation of 15 keV fluorine recoils in CF_3I

Length scale
at 15keV threshold



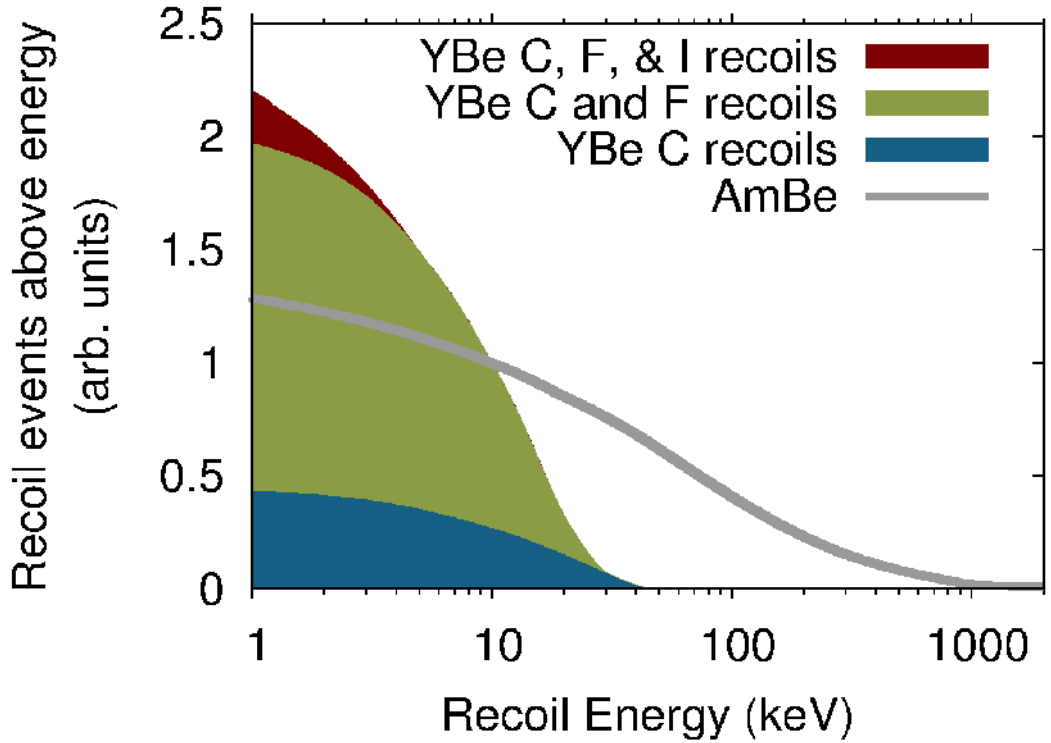
Calibration method

- Produce a spectrum of nuclear recoils.
  - Neutron propagation simulated with MCNP
- Measure a count rate.
- Change the detector's threshold, repeat.

Nuclear recoil spectra

- 152 keV neutrons from ^{88}Y/Be give:
  - Hard upper limit on recoil energy (31 keV on F)
  - Only C & F recoils at >5keV, the ROI.

Integrated nuclear recoil spectra from neutrons in CF_3I



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Carbon and Fluorine Recoil Thresholds

Neutrons from $^{88}Y/Be$

- Method
- Previous calibrations
- This calibration
- Prospects

$$^{9}Be(\gamma, n) \quad Q = 1666\text{keV}$$

TABLE 3. Results of present measurements

E_γ (keV)	$\sigma(E_\gamma)$ (mb)
1674.7	0.88±0.16
1705.2	1.33±0.24
1724.9	1.10±0.20
1778.9	0.73±0.13
$^{88}Y \rightarrow$ 1836.0	0.47±0.09
2167.6	0.18±0.04

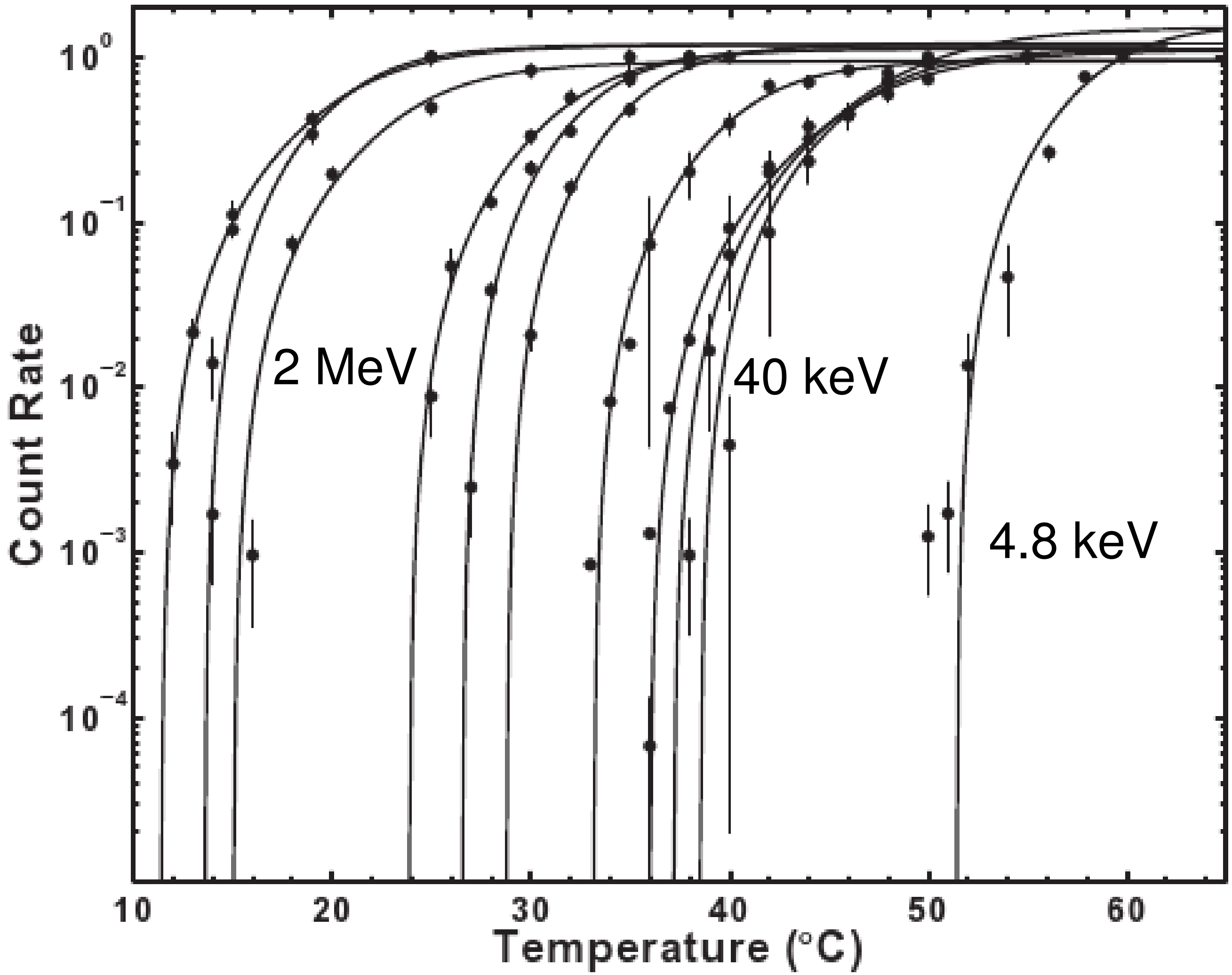
M. Fujishiro et al., Can. J. Phys. **60**, 1672 (1982).

- Mono-energetic 152 keV neutrons.
- 10^5 γ emitted / neutron emitted

PICASSO's calibration

- Method
- Previous calibrations
- This calibration
- Prospects

PICASSO's detector response to monoenergetic neutrons



Archambault et al., New J. Phys. **13**, 043006 (2011).

PICASSO's calibration (con't)

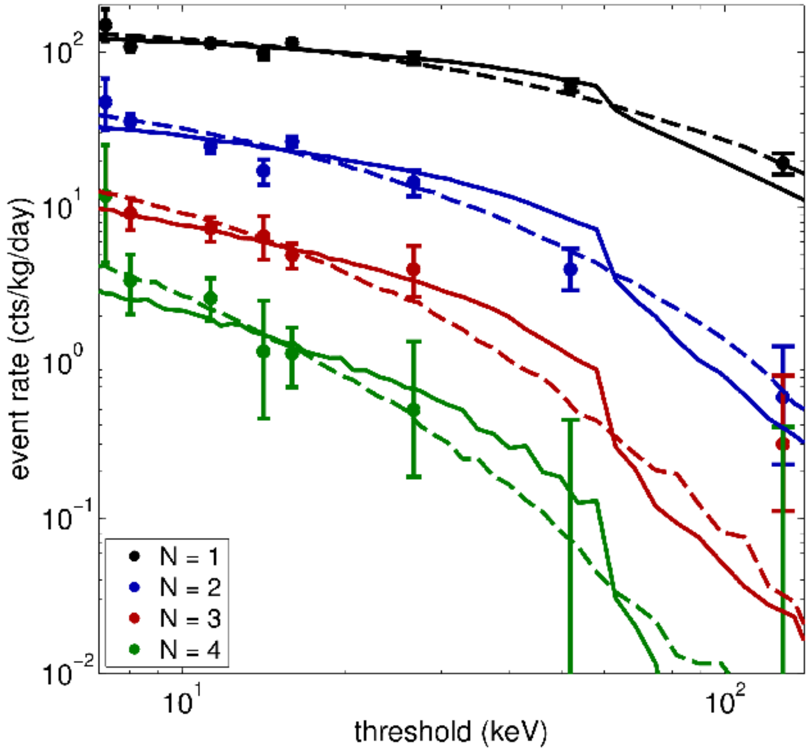
- Fit a functional form:

$$P = 1 - \exp\left\{-\alpha \frac{E_r - E_{thr}}{E_{thr}}\right\}$$

  - P – nucleation efficiency
  - $\alpha = 2.5 \pm 0.5$ – fitted parameter
  - E_{thr} – calculated threshold energy
  - E_r – recoil energy

AmBe calibrations

- Using COUPP-4kg with AmBe neutrons.
  - Fit to
    - PICASSO model, $\alpha = 0.15$ (dashed line) or
    - Step function w/ length scale cutoff, (solid line).



D.A Fustin, Ph.D. Thesis
Univ. of Chicago, 2012.

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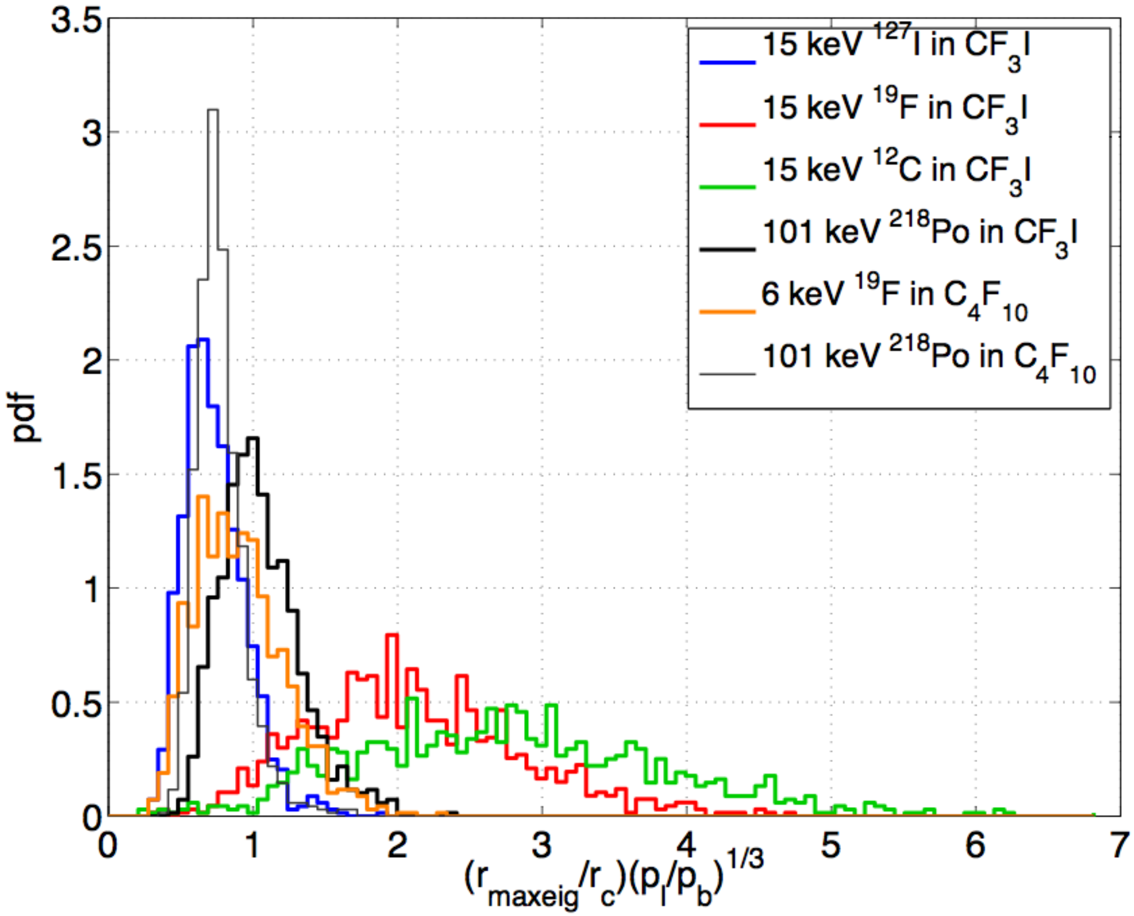
Carbon and Fluorine Recoil Thresholds

Is CF_3I different?

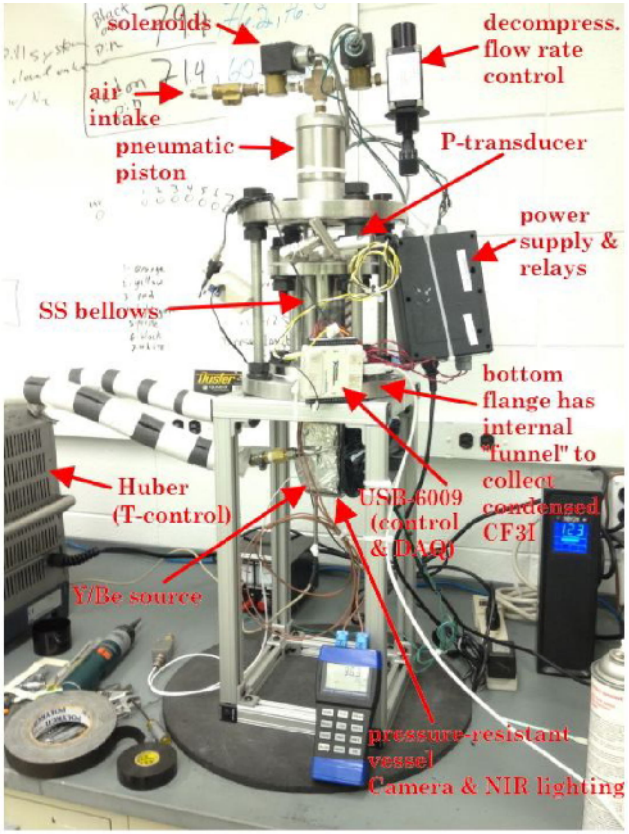
- Method
- Previous calibrations
- This calibration
- Prospects

- Carbon and fluorine recoils produce longer tracks in CF_3I than in C_4F_{10}.

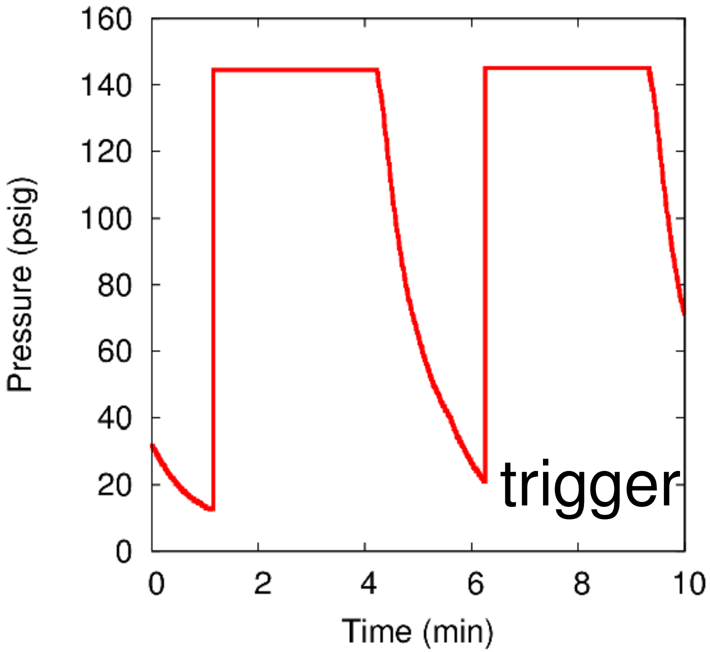


Calibration bubble chambers

- < 2mm moderating material.
- Pressure (threshold) scanning during each expansion.



Sample expansion history

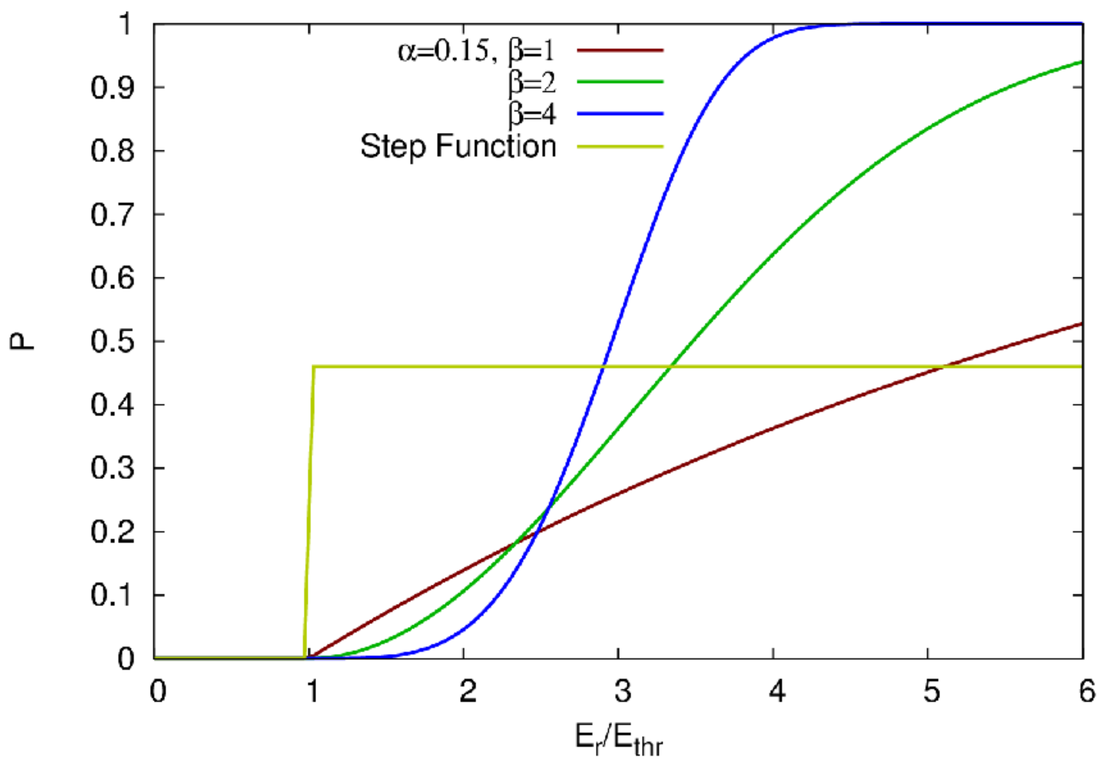


Models

- Use:

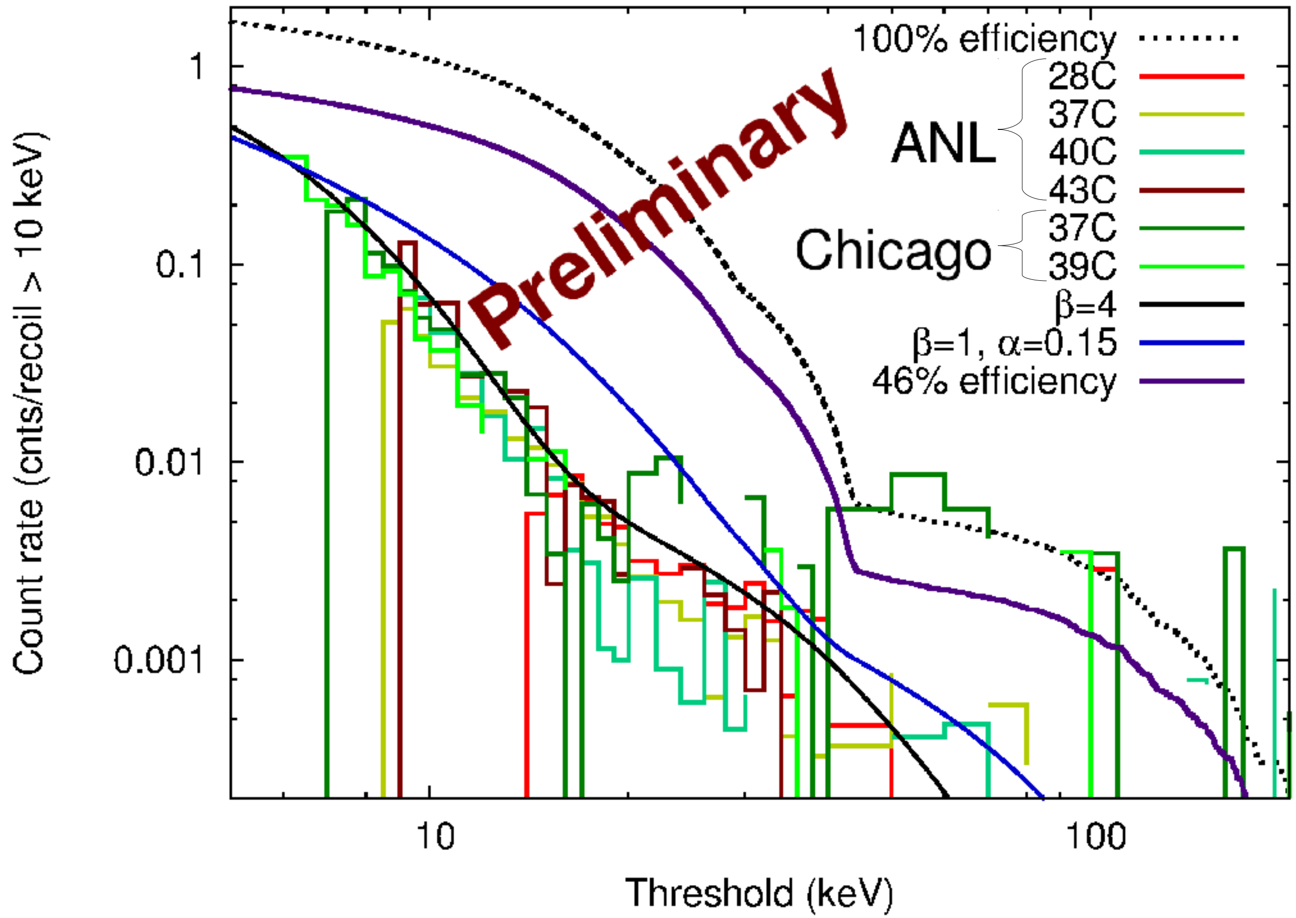
$$P = 1 - \exp\left\{ -\left(\alpha \frac{E_r - E_{thr}}{E_{thr}} \right)^{\beta} \right\}$$

  - $\beta=1$ is the PICASSO model



Count rates

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



Systematics

- 15% uncertainty in recoil rate normalization, mostly from MCNP simulation.
- 0.5°C uncertainty in temperature (8% threshold uncertainty)

Prospects

- Obtain a nucleation efficiency calibration at low energy using a consistent threshold model.
- Use a monoenergetic neutron beam to calibrate at other energies.
- Study the response of other fluids with Y/Be.

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Extra slides

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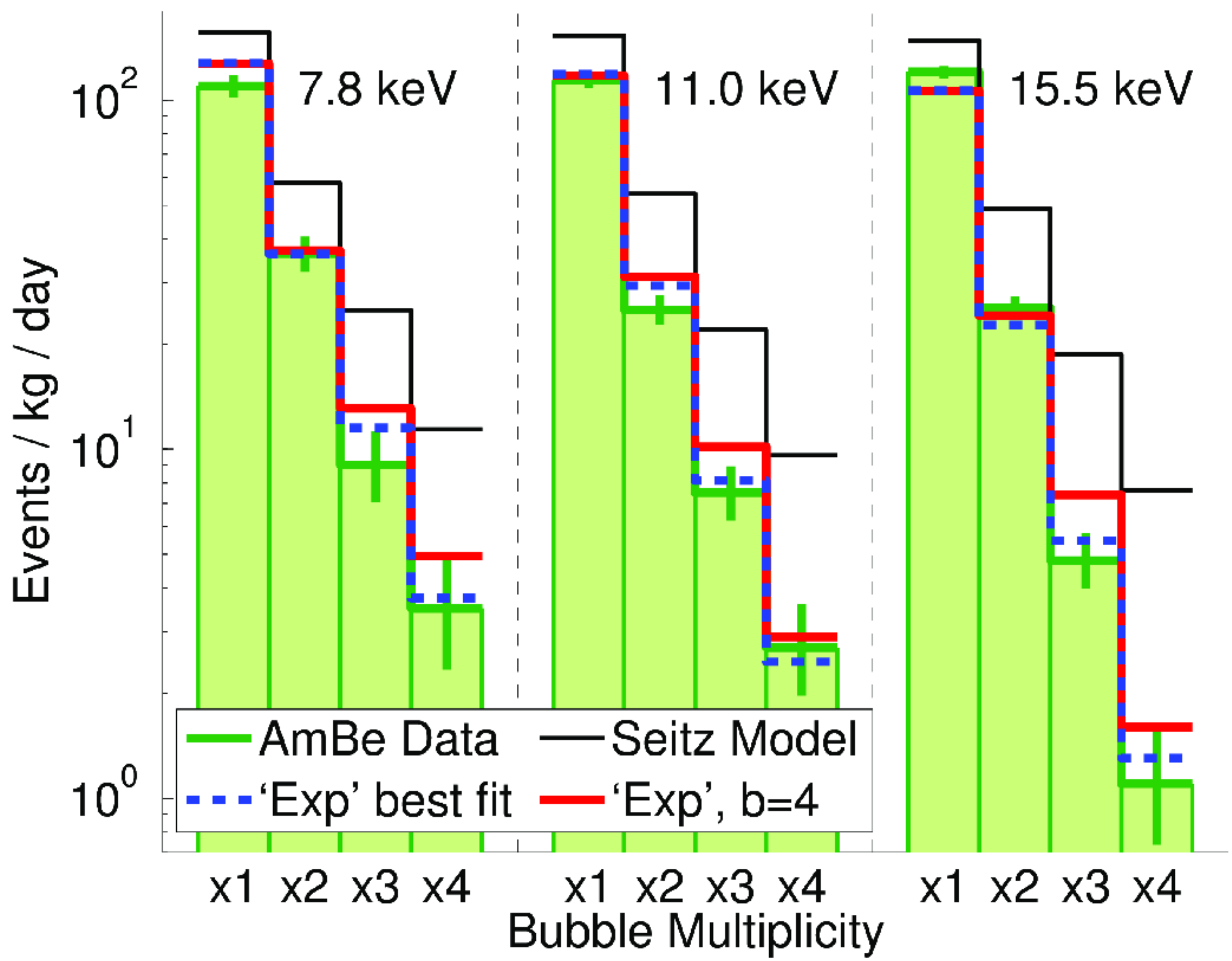
Carbon and Fluorine Recoil Thresholds

Consistency with AmBe and multiples

Extra Slides



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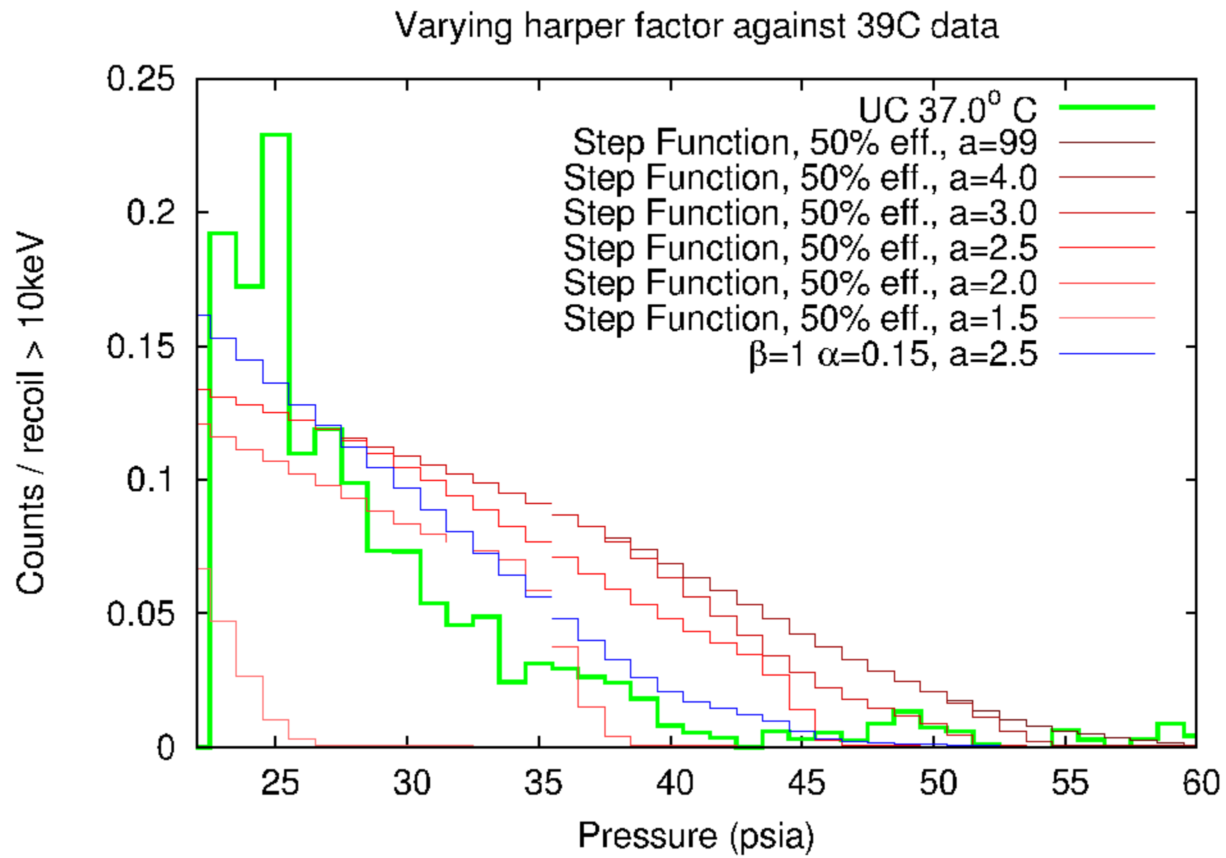
Carbon and Fluorine
Recoil Thresholds

Length scale threshold

Extra Slides

- A step threshold in length scale make a sharp turnon:
- Y/Be data is insensitive to a > 4.



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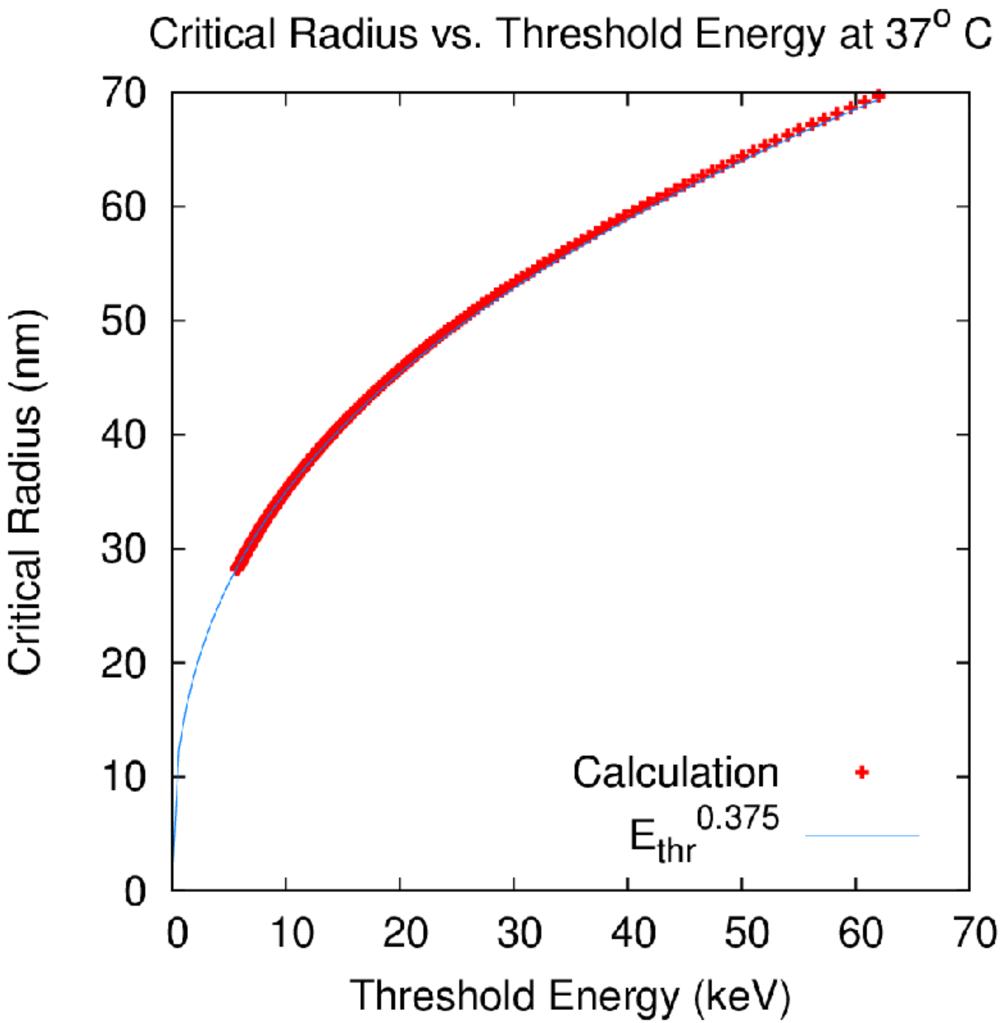
Carbon and Fluorine Recoil Thresholds

Length scale threshold

Extra Slides

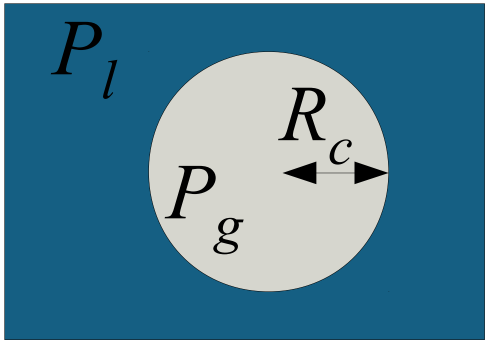


Seitz model calculation

- Two steps:
  - Critical radius of the bubble

    σ – surface tension

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



  - Energy to form critical bubble
    - Surface formation energy - dominant at high threshold.
    - Heat of vaporization

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