Scintillating Bubble Chamber for WIMP Dark Matter and CEνNS Detection

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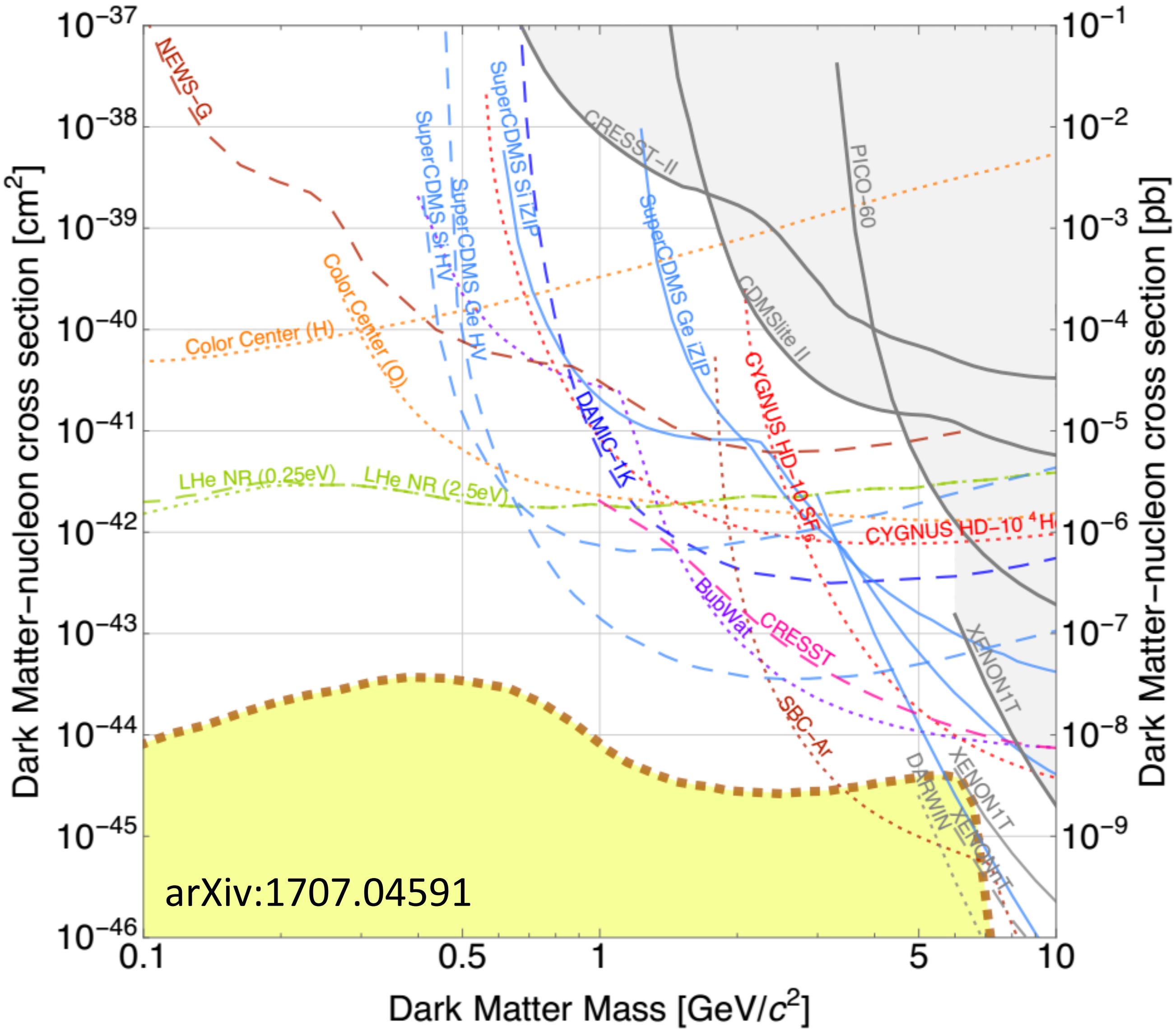
Outline

- Motivation: GeV WIMPs and reactor neutrinos
- The scintillating bubble chamber technique
- Results from a 30-gram xenon prototype
  - arXiv:1702.08861 [PRL **118**, 231301]
- Current status and next steps: lowering thresholds, liquid Argon target

What could you do with a liquid-noble bubble chamber?

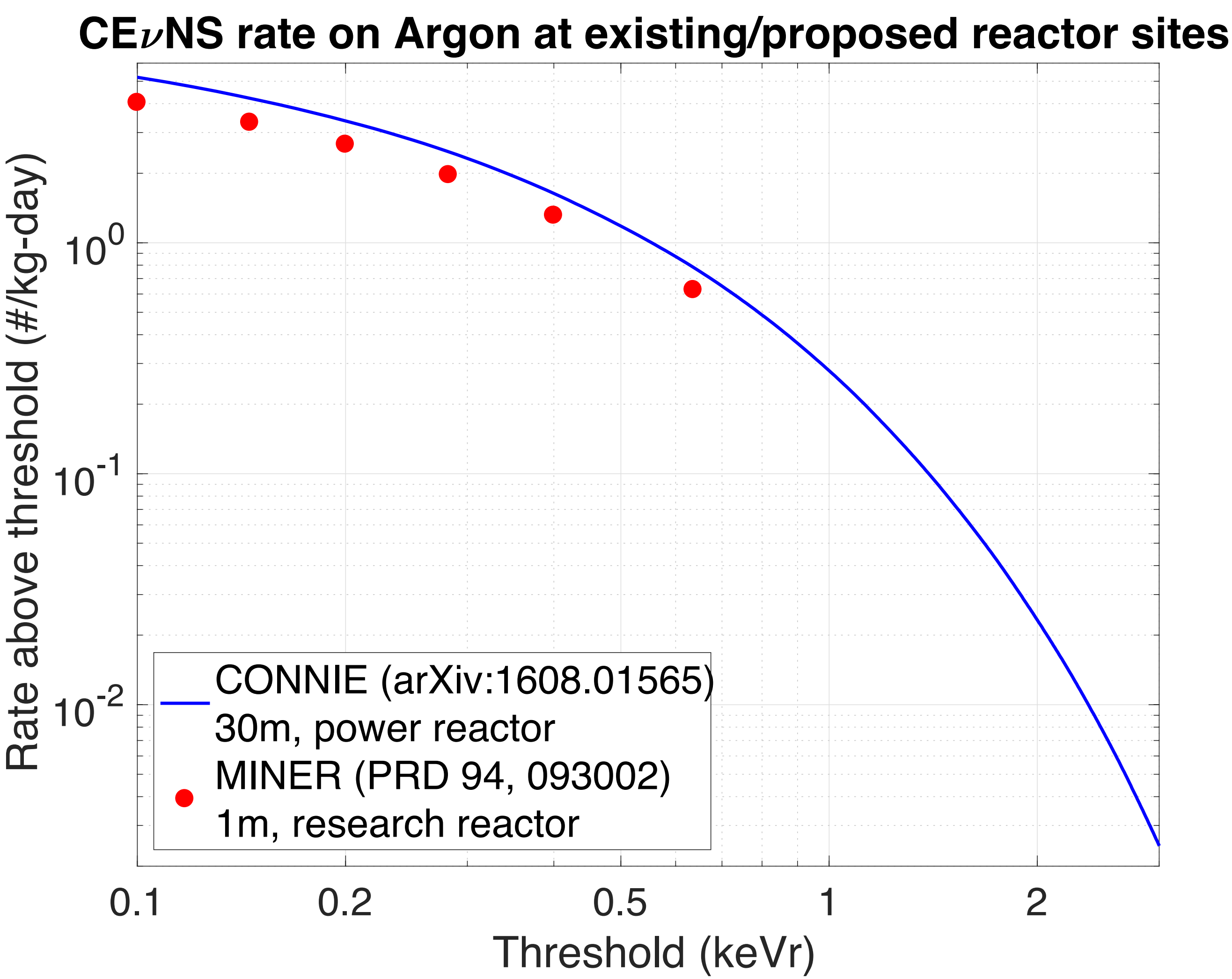
- Discriminating
  - Only sensitive to nuclear recoils (neutrons, neutrinos, and WIMPs), $\sim 10^{10}$ ER discrimination
  - Scintillation channel eliminates bubble-nucleating backgrounds at other energies (e.g. alpha decays, surface wetting phenomena)
- Scalable
  - Largest bubble chamber to date: 35 m^3 (BEBC)
  - Ton-scale low-background bubble chamber in works (PICO)
- Low threshold
  - Sub-keV recoil energy threshold is moving from "plausible" to "realistic"

What could you do with an argon bubble chamber?



1 ton-year at 1-keVr threshold ($76\ ^8B$ neutrino events expected)

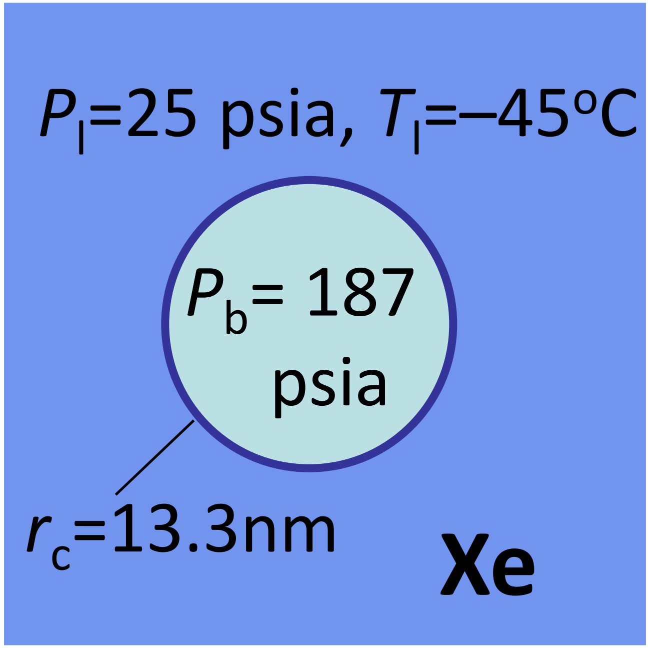
What could you do with an argon bubble chamber?



Up to an event-per-minute in a m^3 target, only background is neutrons

Bubble Chamber Thermodynamics

- What does it take to nucleate a bubble?



Bubble Chamber Thermodynamics

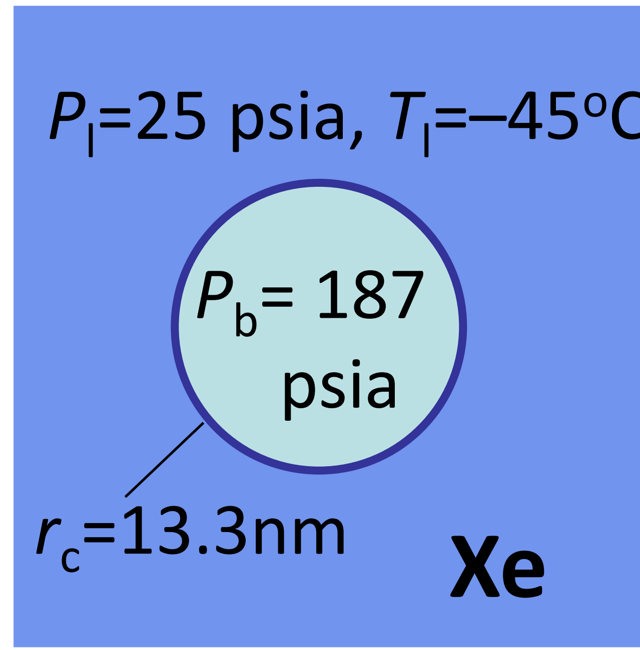
- What does it take to nucleate a bubble?

$$E_T = 4\pi r_c^2 \left(\sigma - T \left(\frac{\partial \sigma}{\partial T} \right)_\mu \right)$$ 0.55 keV

$$+ \frac{4\pi}{3} r_c^3 \rho_b \left(h_b - h_l \right)$$ 0.61 keV

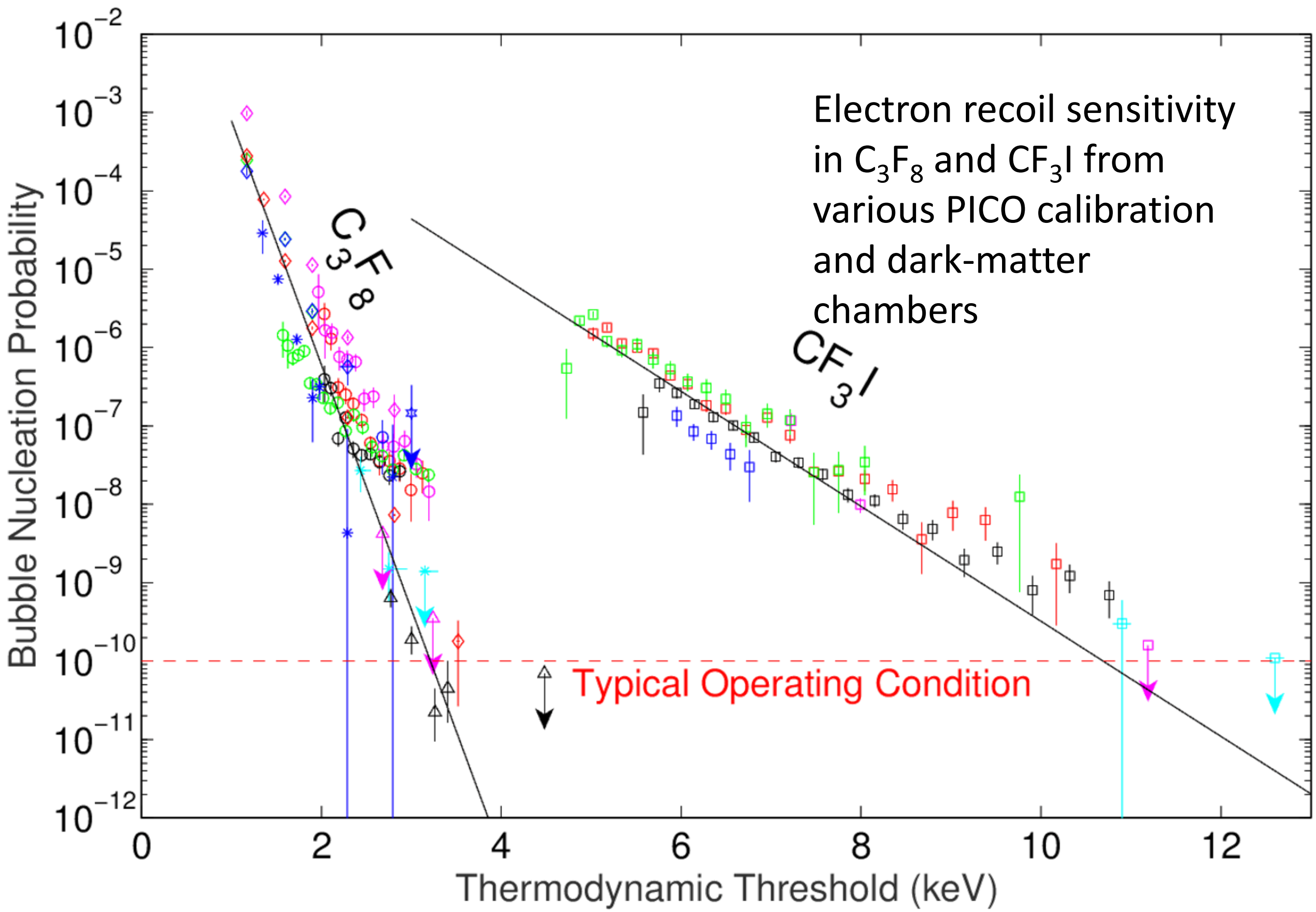
$$- \frac{4\pi}{3} r_c^3 \left(P_b - P_l \right)$$ -0.07 keV

= 1.09 keV total



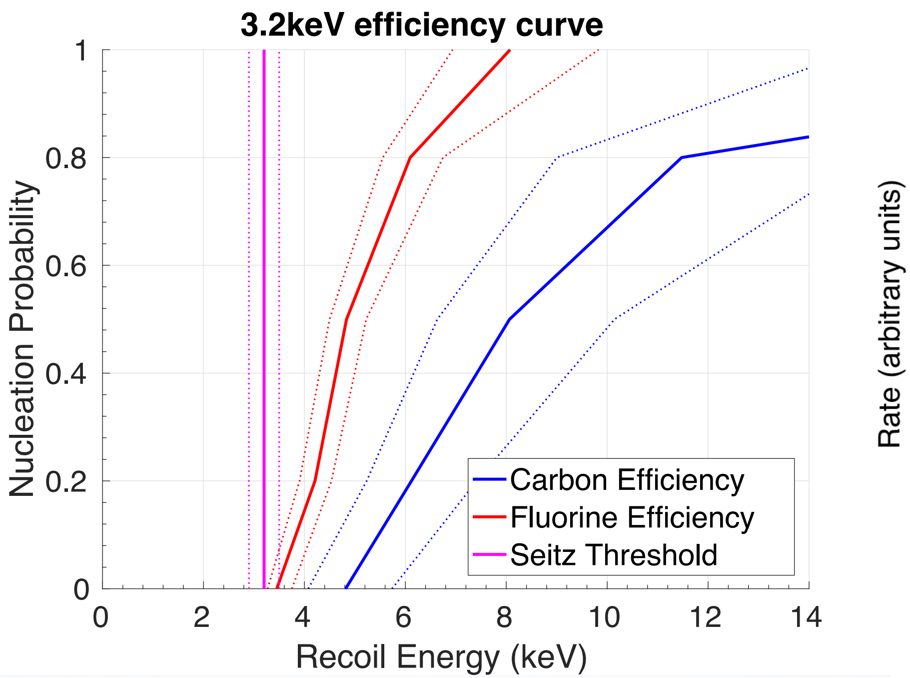
Surface energy, Bulk energy, Reversible Work

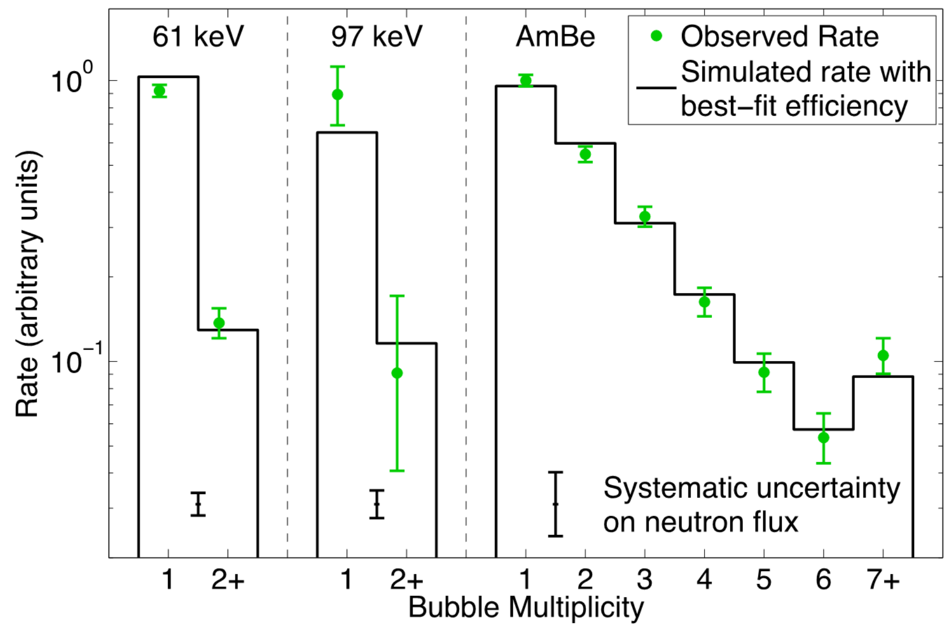
Bubble Chamber Discrimination



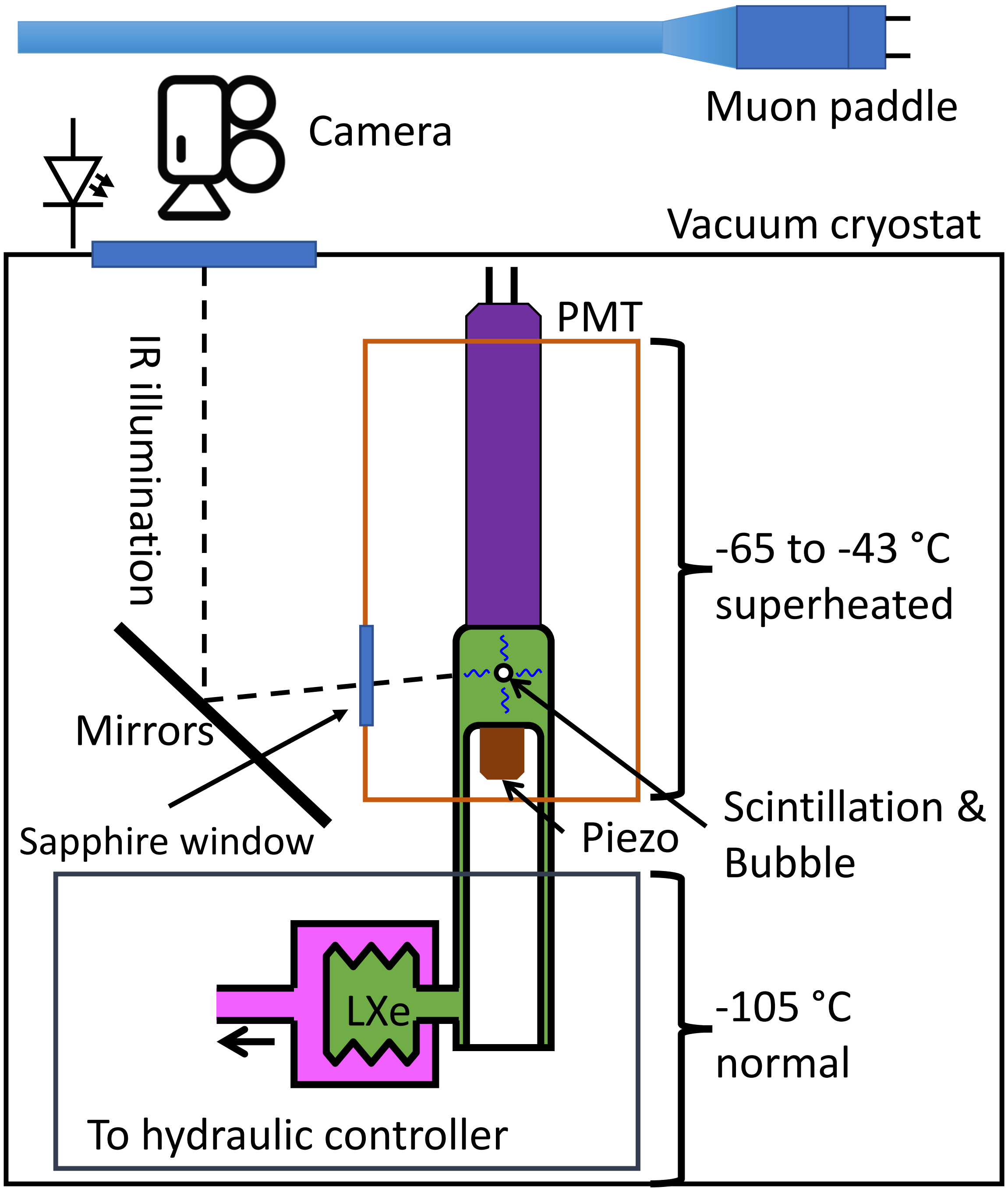
Nuclear Recoil Sensitivity

Neutron Calibrations in C_3F_8 @ E_T = 3.2 keV





NU Xenon Bubble Chamber

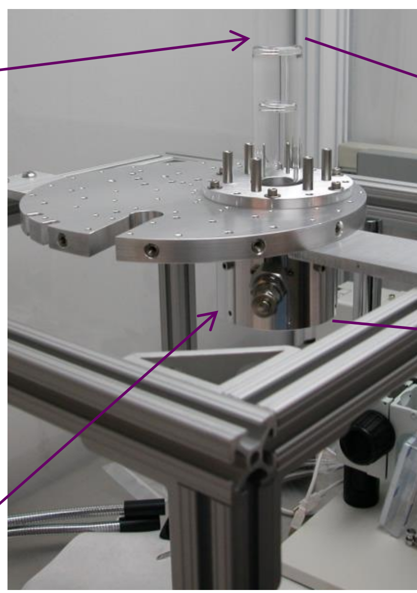


NU Xenon Bubble Chamber

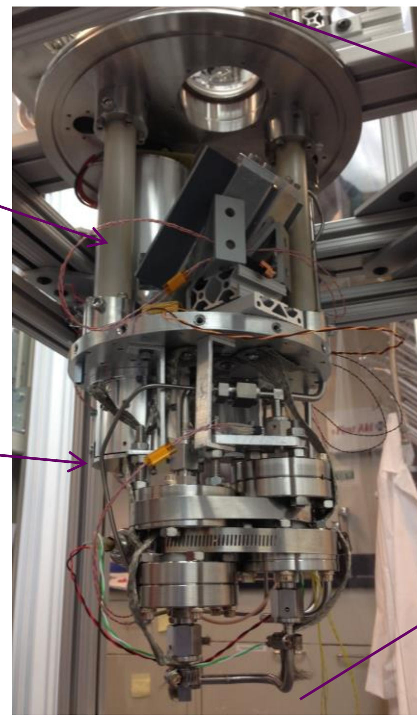
- First Bubbles June 2016

June 2015

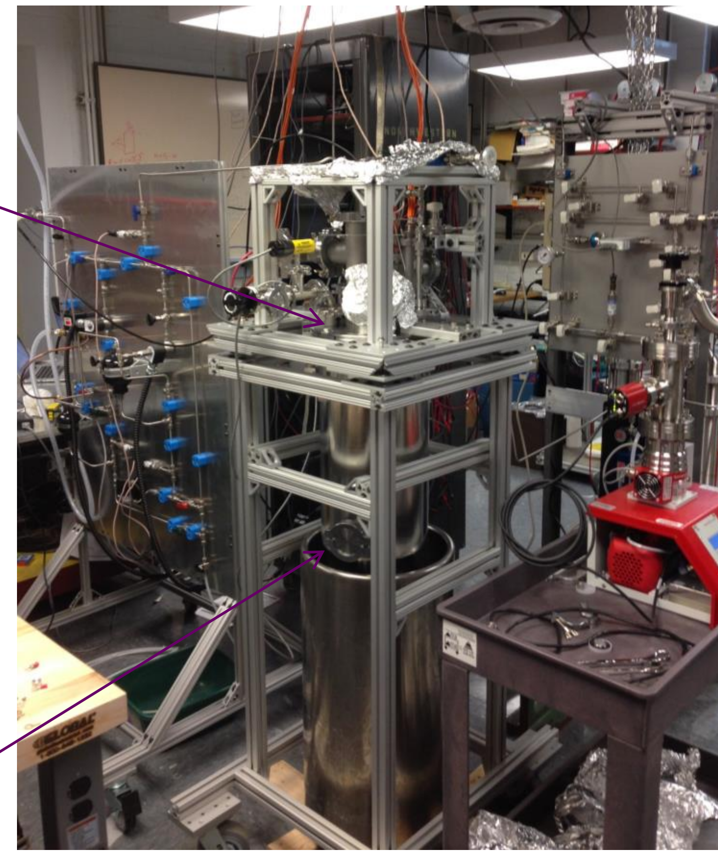
Sept 2015



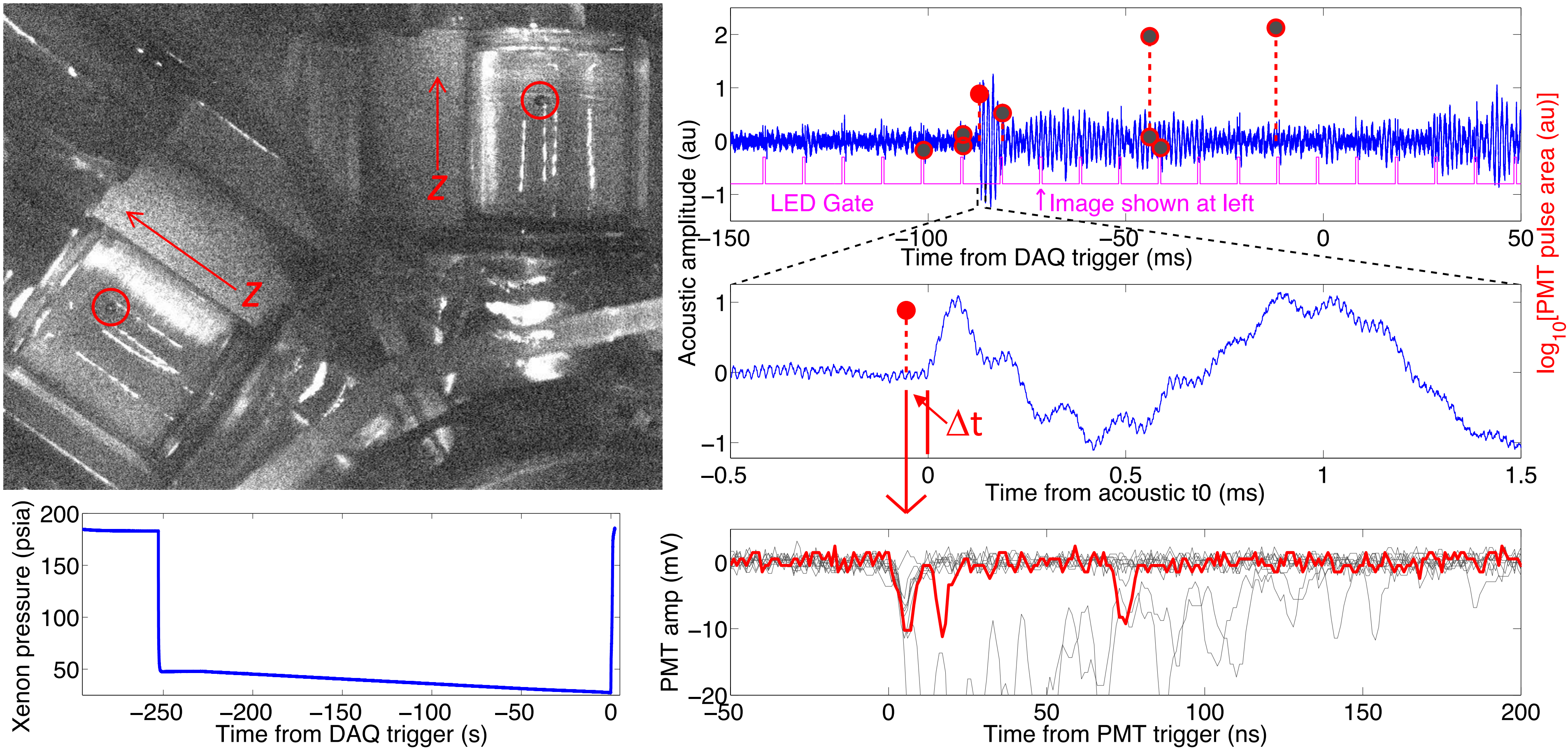
Feb 2016



April 2016

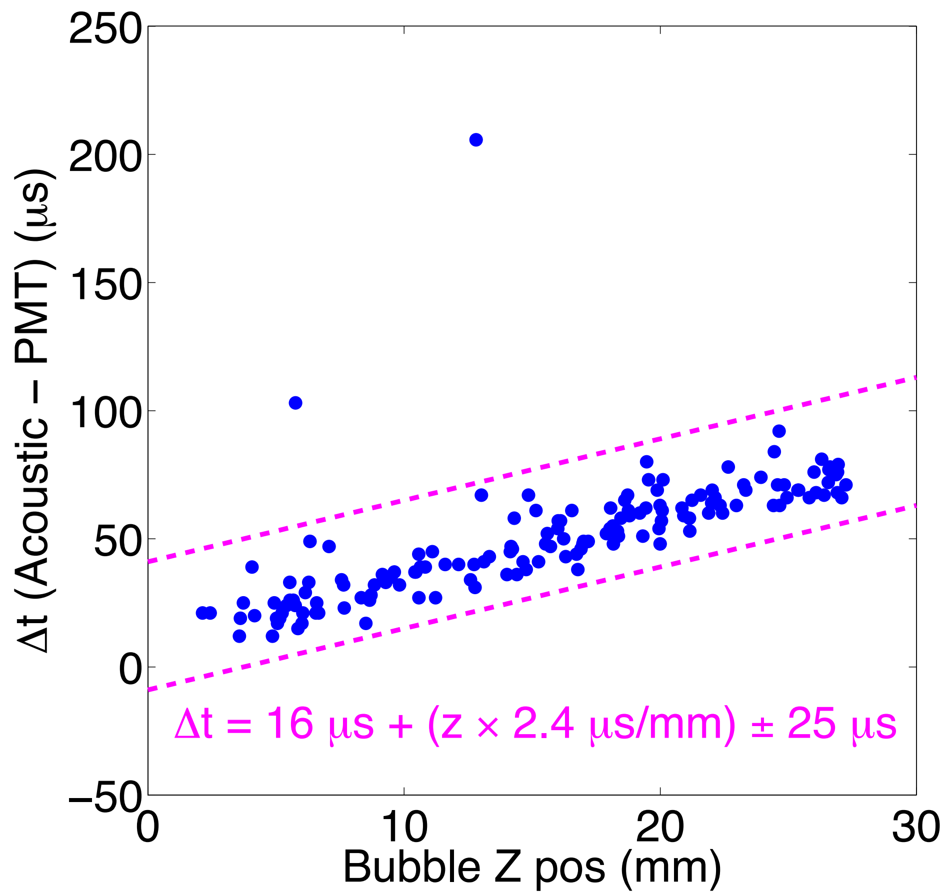


Sample Nuclear Recoil Event

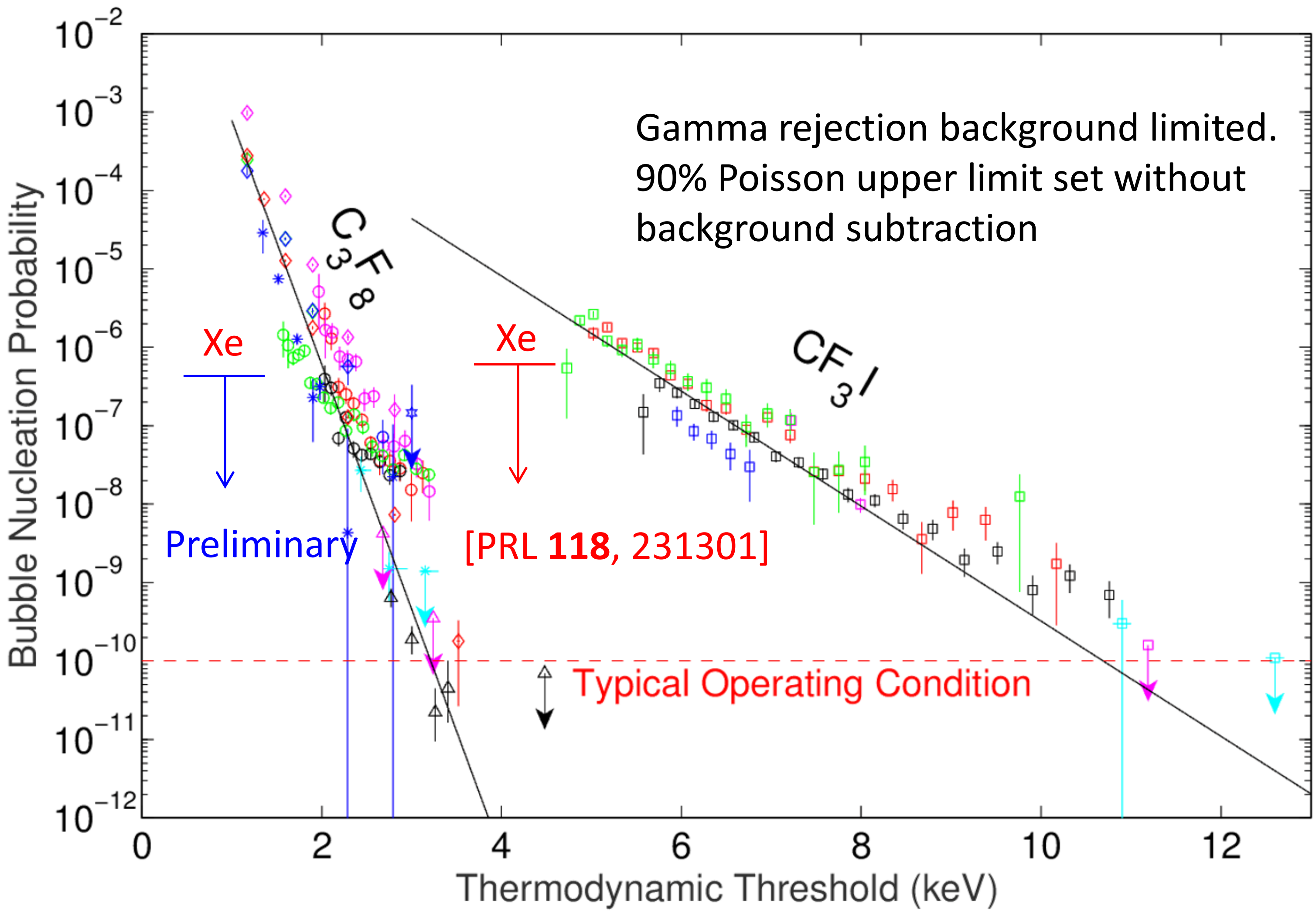


Acoustic – Scintillation Coincidence

- $< 1\%$ accidental coincidence rate in calibration data
- Slope = speed of sound in xenon (to 20%)



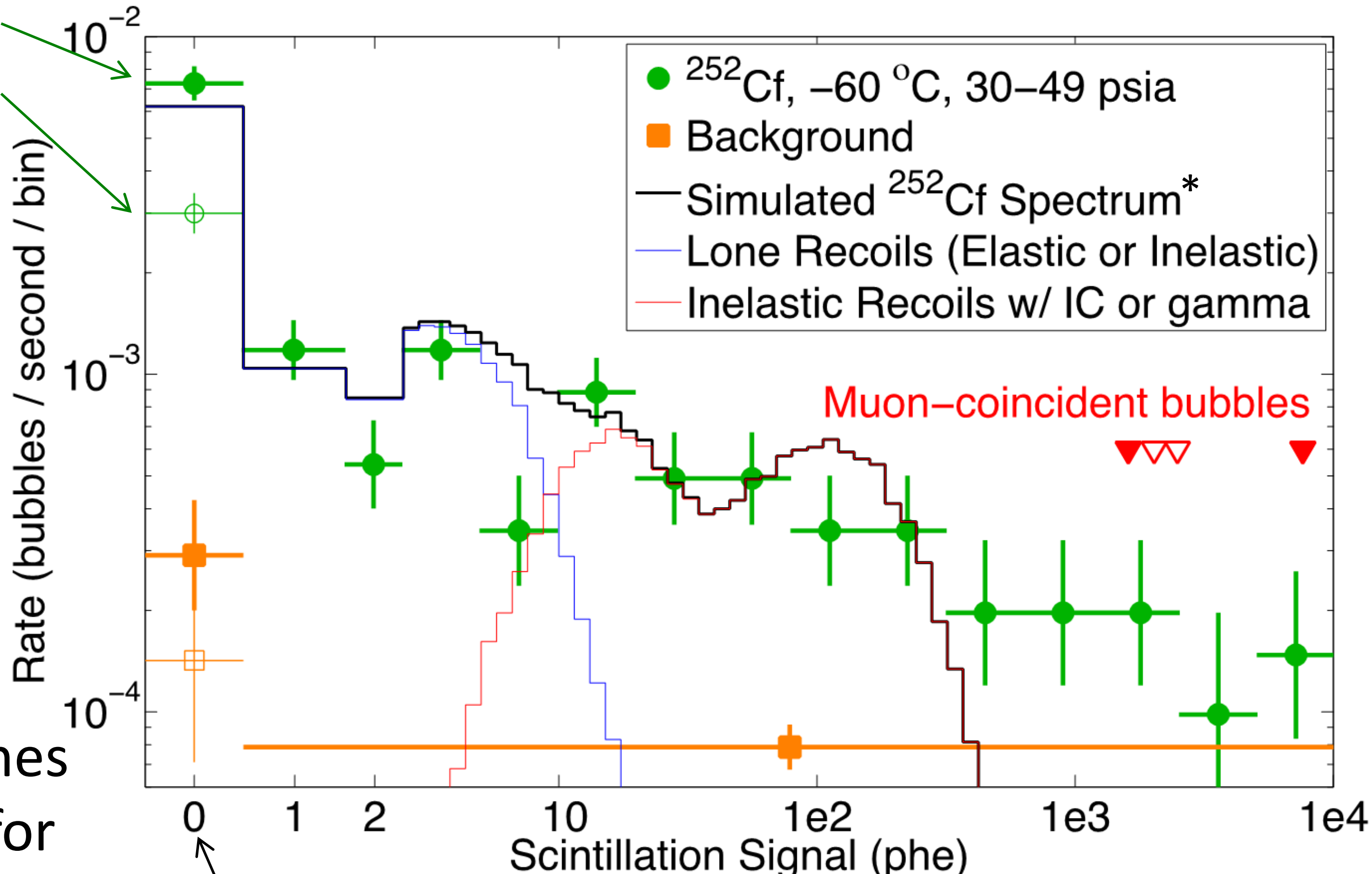
Gamma Rejection



Scintillation Spectrum for Bubble Events

E_T = 8.2 – 8.6 keV
E_T = 8.6 – 15 keV

No E_T dependence observed in other bins



*Simulation assumes 15-keV threshold for bubble nucleation

Bubbles with no PMT Trigger

Based on rate alone, NR threshold is 19 ± 6 keV

Current Status and Next Steps

- Simultaneous bubble nucleation and scintillation for nuclear recoils demonstrated
- Bubble nucleation by gammas $<10^{-6}$ at E_T=1.0 keV
- Nuclear threshold analysis ongoing at E_T=1.0 keV
  - Now calibrating sensitivity to low-energy nuclear recoils using (γ,n) sources
- Reconfiguring the xenon chamber to use liquid Ar as target fluid
- Ready to scale up soon