Low Threshold Operation of the Scintillating Xenon Bubble Chamber

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SBC Collaboration

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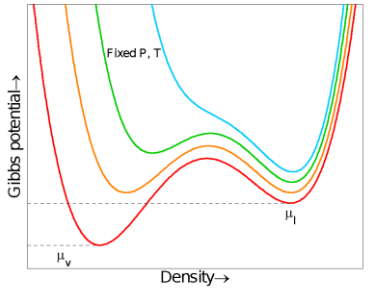
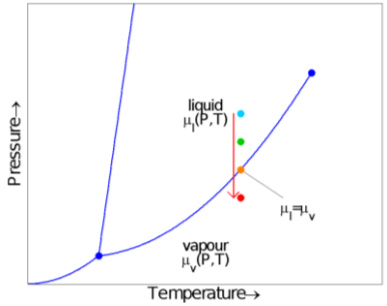
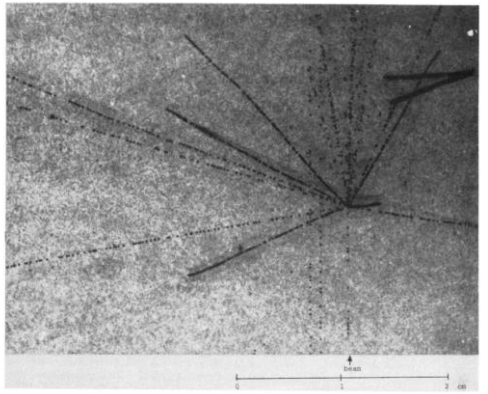
Bubble Chambers (Generally)

- Particle detection by heating in a superheated fluid
- Two "types"
  - Dirty chambers
    - Tracking experiments
    - Short (~milliseconds) superheats
    - Bubble creation threshold generally not of interest
  - Clean chambers
    - NR detection experiments
    - Long (~minutes) superheats
    - Bubble creation (NR detection) threshold very important
      - Q_{Seitz}: function of pressure and temperature





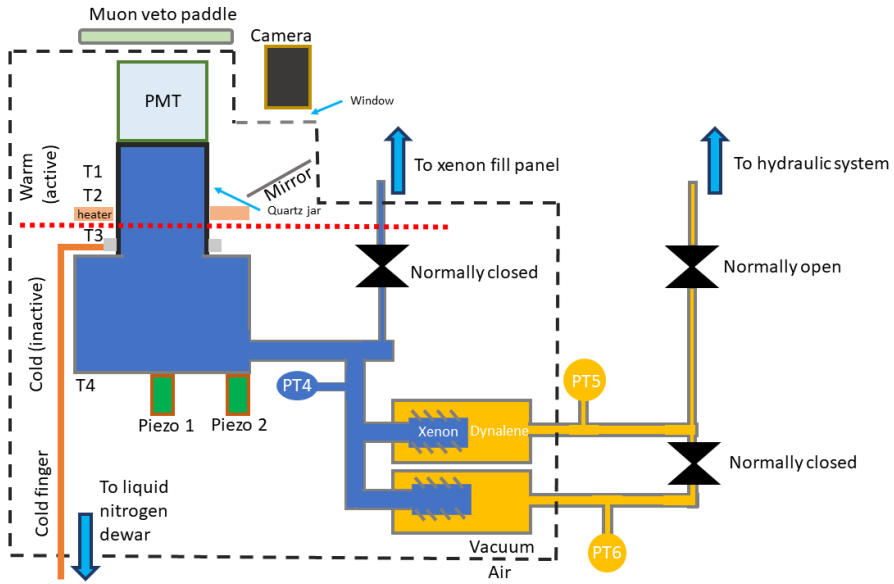


Tracks in a bubble chamber; from *Operation of a bubble chamber filled with argon nitrogen and argon-nitrogen mixtures,* NIM (1981)

Single (left, still) and multiple (right, gif in .pptx presentation) bubble events in a clean bubble chamber;

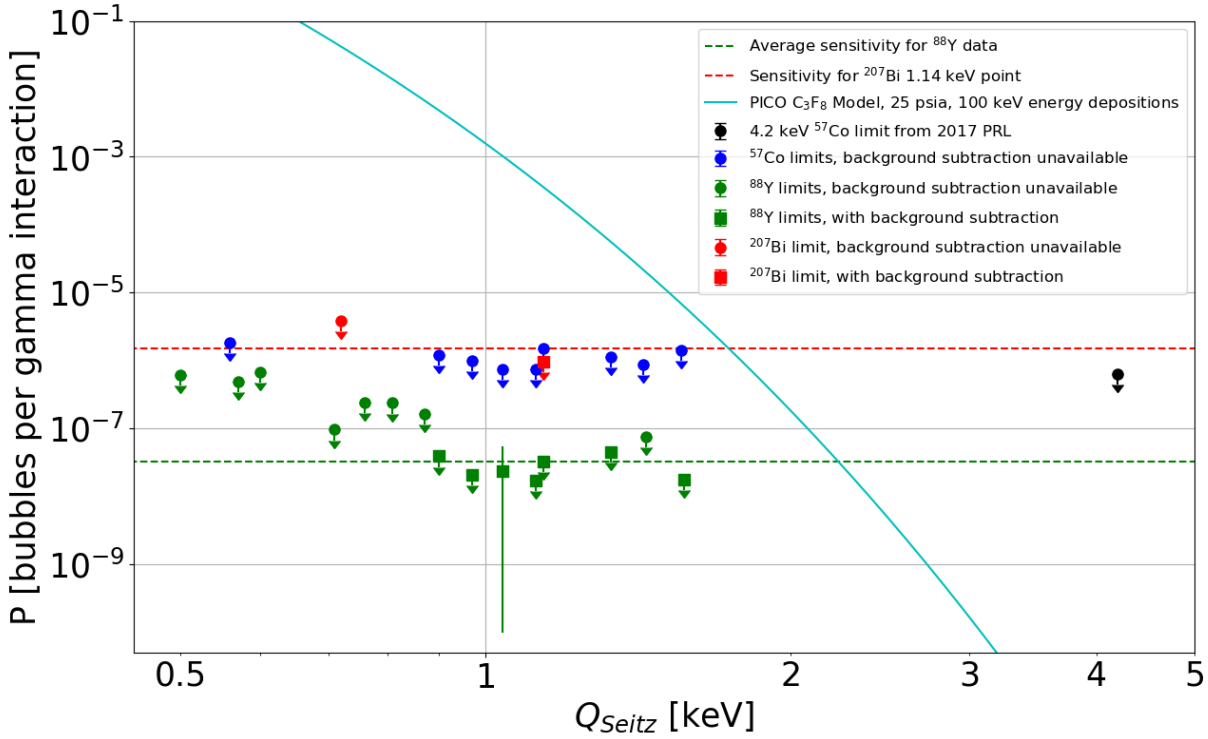
The Xenon Bubble Chamber

- Target region contains about 30 grams of liquid xenon
- Operated at warm region temperatures between -60C and -38C
- First publication in PRL (2017)
  - *First Demonstration of a Scintillating Xenon Bubble Chamber for Detecting Dark Matter and Coherent Elastic Neutrino-Nucleus Scattering* 10.1103/PhysRevLett.118.231301
  - Best estimate of NR detection threshold 19 ± 6 keV at 8.3 keV Seitz threshold
- New data collected after the initial publication
  - Seitz thresholds as low as 0.5 keV
  - Evidence of nucleation by NRs below 5 keV
  - No sign of ER nucleation at any threshold



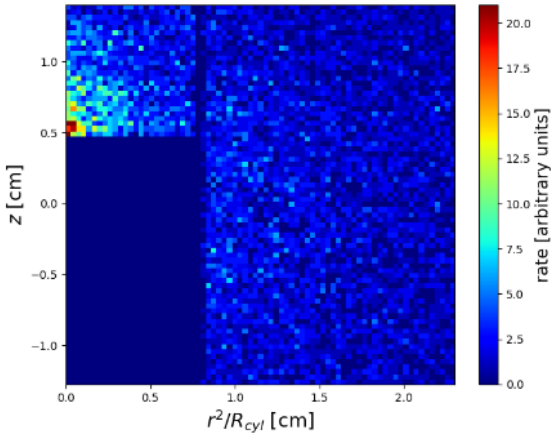
Intrinsic Electron Recoil Insensitivity

- Xenon bubble chambers are remarkably insensitive to electron recoils
  - Glaser was unable to obtain tracks in an early xenon bubble chamber, until the addition of ethylene
- In the NU XeBC, we used 3 gamma sources, the strongest being a ~0.5 mCi ^{88}Y source
- We observe no increased rate of bubble nucleation with these sources
  - 90% C.L. upper limits around 10^{-7} bubbles per gamma interaction

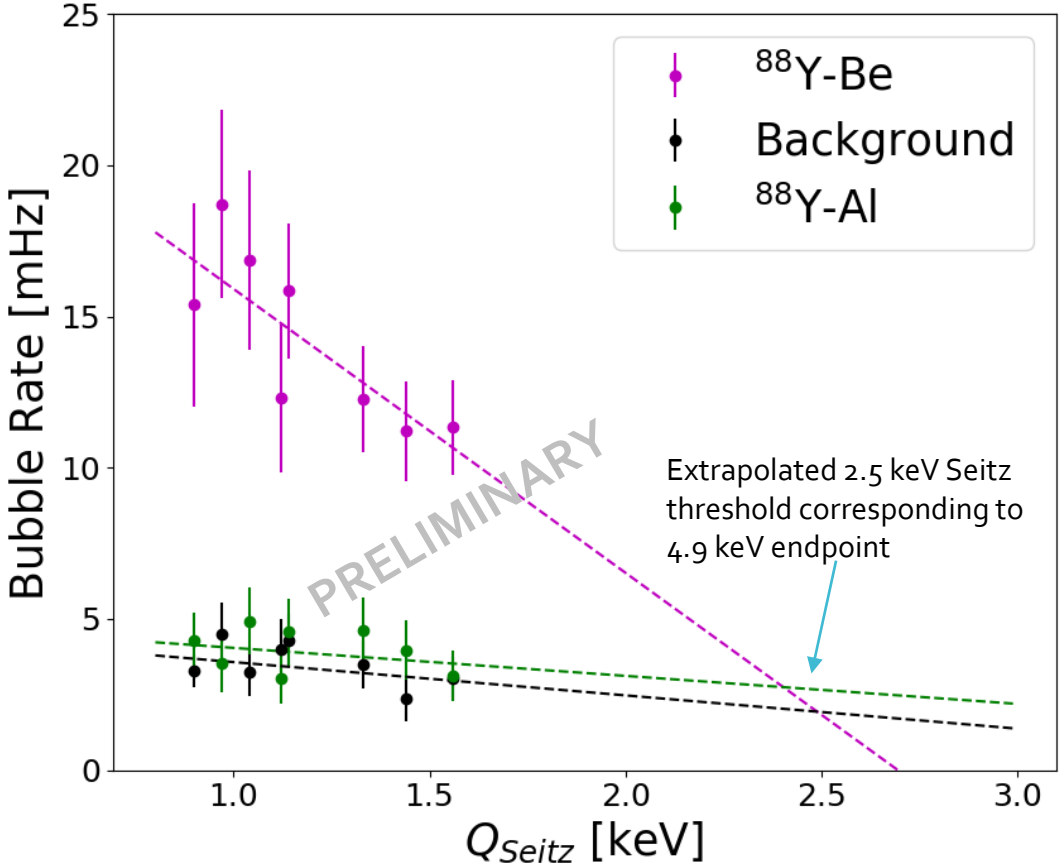


Photoneutron Calibration

- ^{88}Y-BeO source (~850 n/s) produces a rate above background
  - 4.9 keV endpoint for NRs from the dominant ~152 keV neutron
  - *Evidence of true threshold < 5 keV$_{nr}$*
  - Consistent with $E_T \approx 2 \times Q_{Seitz}$

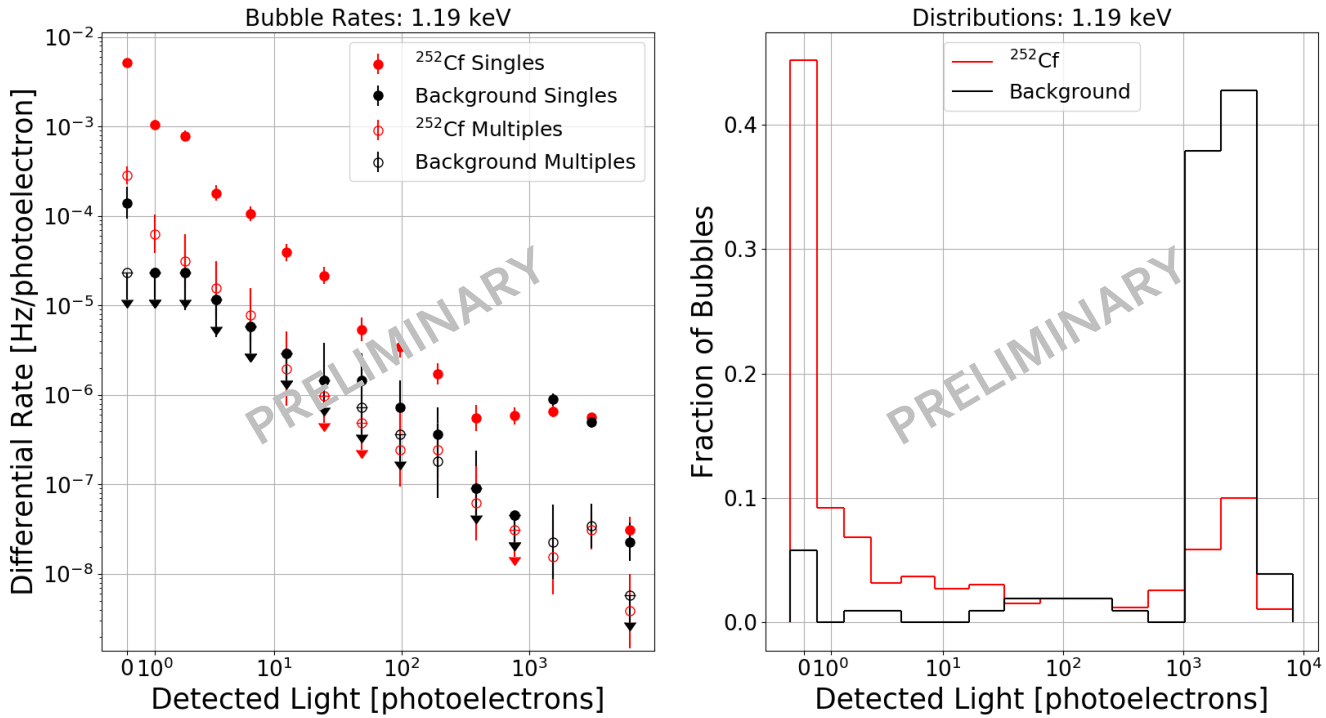


(γ,n) production simulation; further simulations are in progress



Coincident Bubble Nucleation and Scintillation

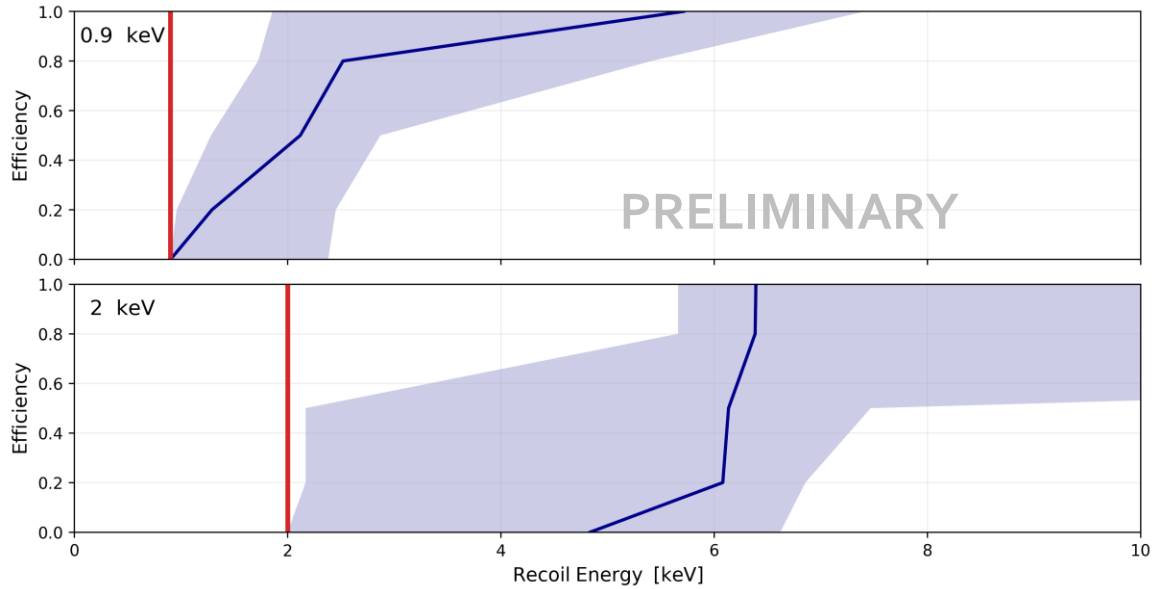
- Main appeal of liquid noble bubble chambers: the spectral information in scintillation
  - In a traditional bubble chamber, we have no information about the energy of the nuclear recoil
  - With a scintillating bubble chamber, high energy recoils can be vetoed from a WIMP or CEvNS signal region by their associated scintillation
- We demonstrate this with a ^{252}Cf source, compared to background events



Nuclear Recoil Efficiency

- With a scintillation-based cut on ^{252}Cf data, we achieve low-background-rate data sets for a first run of a nuclear recoil detection efficiency analysis
  - See Daniel Durnford's talk "Nucleation efficiency of nuclear recoils in bubble chambers" this afternoon
  - Consistent with $E_T \approx 2 \times Q_{Seitz}$
  - Consistent with the qualitative photoneutron constraint, at the ~1 keV Seitz thresholds
- Constraint will improve when we incorporate the photoneutrons into this analysis!

In other words, we've demonstrated sensitivity to ~keV NRs while remaining entirely blind to ERs ($< 10^{-7}$ bubbles per gamma interaction) in xenon



Conclusions, Future Work, and Outlook

- At ~1 keV Seitz thresholds in xenon:
  - We confirm the **insensitivity of xenon bubble chambers to gammas**
  - We confirm that the **Seitz model is a good predictor of nuclear recoil detection**
  - We make use of the **scintillation accompanying bubble nucleation events to veto backgrounds**
- The next step is to incorporate the photoneutron data into the NR analysis
- A paper on these results is in progress
- The next generation scintillating bubble chamber (10 kg of LAr) is being constructed at Fermilab now!
  - See Eric Dahl's talk yesterday "A 10-kg LAr bubble chamber for sub-keV nuclear recoil detection -- Update and Calibration Strategies"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Thank you!