OPERATION AND CALIBRATION PLANS FOR SBC'S FIRST 10 KG ARGON BUBBLE CHAMBER

Matthew Bressler

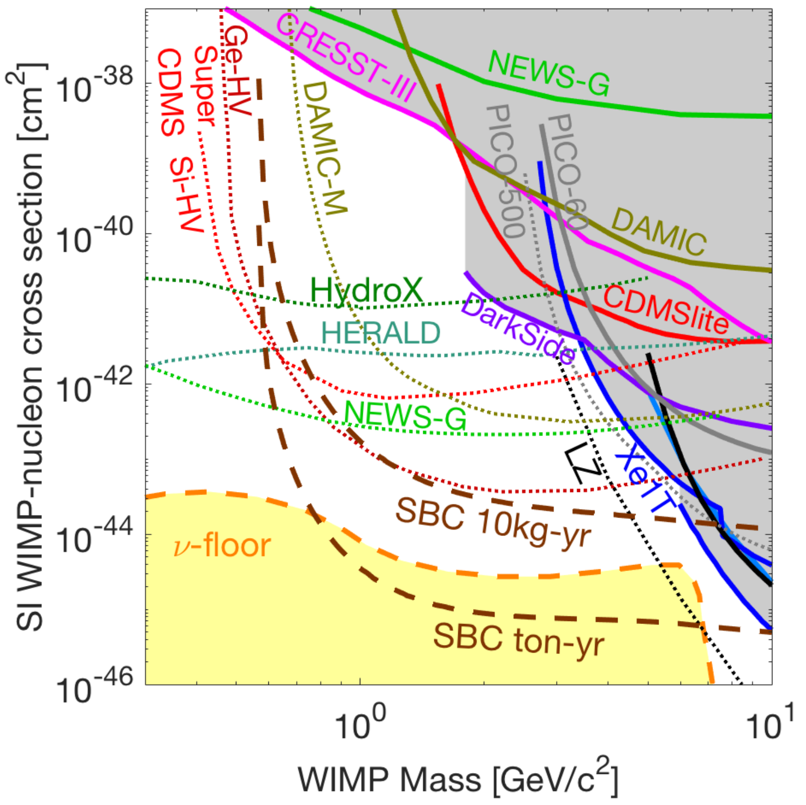
2020 GIRA Recipient

CPAD

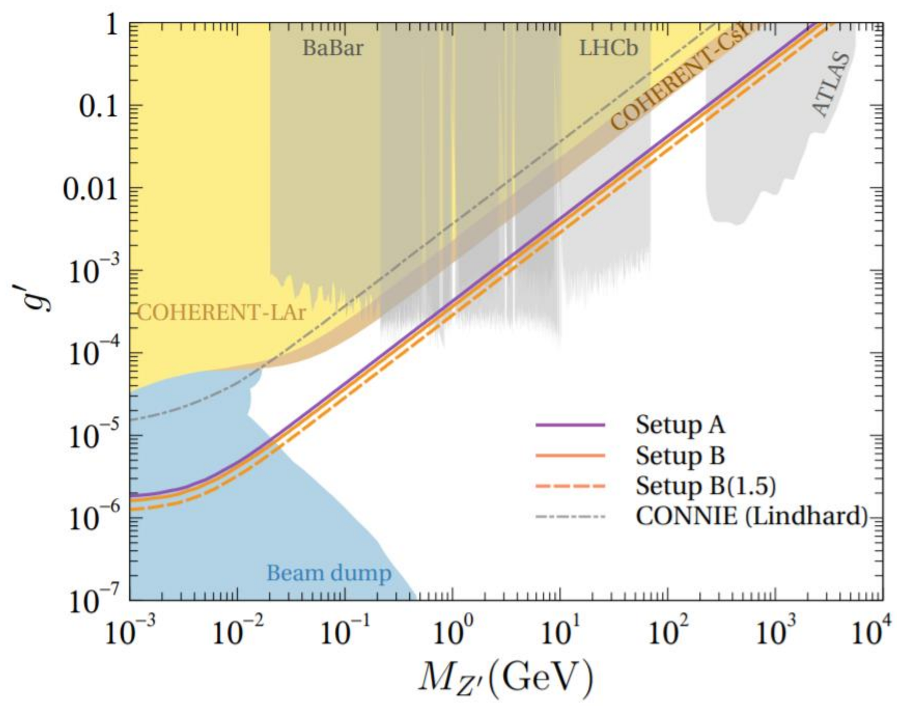
3/22/21

Goals of scintillating bubble chambers

- **Background-free 100 eV nuclear recoil detection** for dark matter and CEvNS experiments

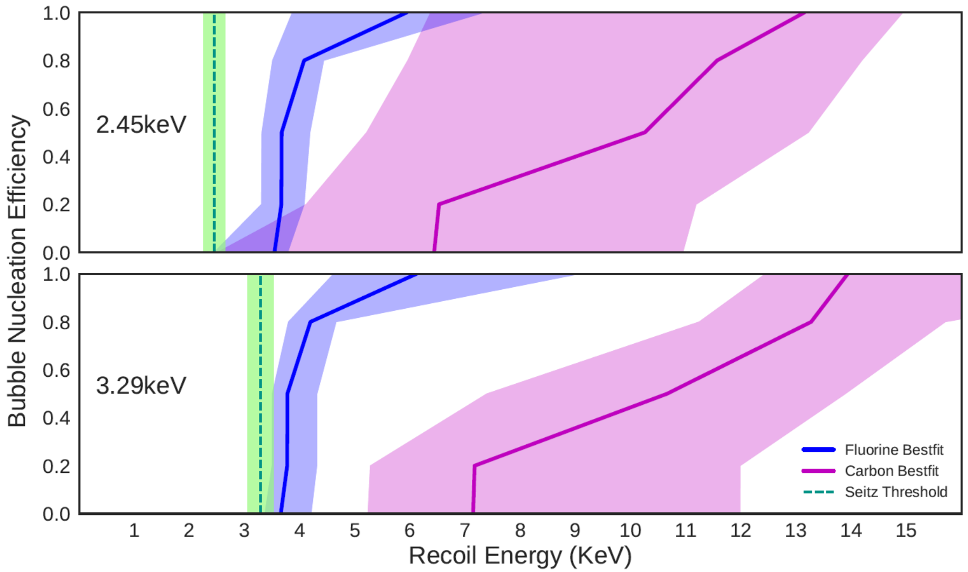


See R. Coppejans talk at the next session, *Designing and building a pair of scintillating bubble chambers for WIMPs and reactor CEvNS*



A note about thresholds

- We calculate the thermodynamic threshold $\boldsymbol{Q_{Seitz}}$: the amount of heat energy required to create a detectable bubble
- The truth is that NR detection efficiency is not a step function at Q_{Seitz}
- Finding the true efficiency curve is what we mean when we say "NR calibrations"



PICO (2019) PRD 100:022001

Scintillating bubble chamber signals

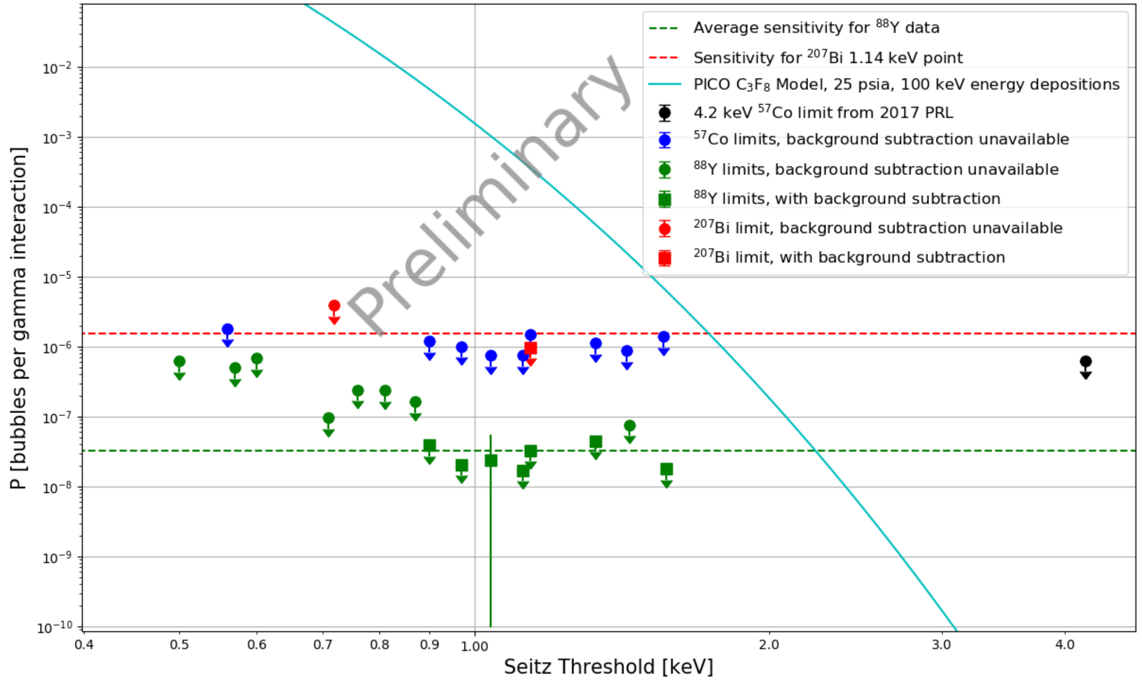
- Detector control and state monitoring:
  - Pressure transducers
  - Thermometry (PT100 RTDs)
  - Bellows position
- Particle detection response:
  - Microphonics (piezoelectric transducers)
  - Camera imaging
  - Photonics (PMT or SiPMs)

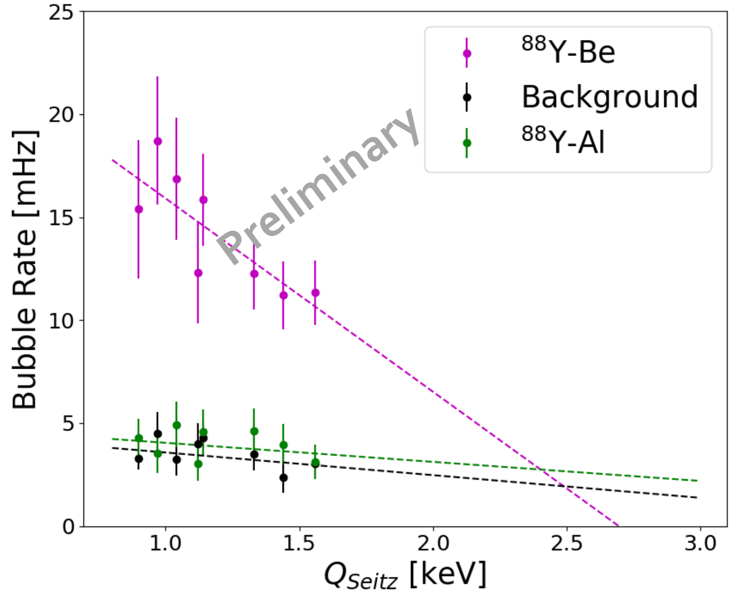
(Pressure transducers and Thermometry:) Q_{Seitz} calculation

(All except Photonics:) Common with non-scintillating bubble chambers

Calibrations in xenon

- We've operated a xenon bubble chamber at $Q_{Seitz} > \sim 0.5\ keV$
  - ER calibrations at 0.5 keV and above
    - ^{57}Co, ^{207}Bi, ^{88}Y
    - No confirmed gamma-induced nucleation; 90% C.L. upper limits $O(10^{-8})$
  - NR calibrations at 0.9 keV and above
    - ^{252}Cf, $^{207}Bi/Be$, $^{88}Y/Be$
- >80% background reduction via the scintillation channel in a surface lab compared to raw rate of bubbles
  - With << 1% LCE!



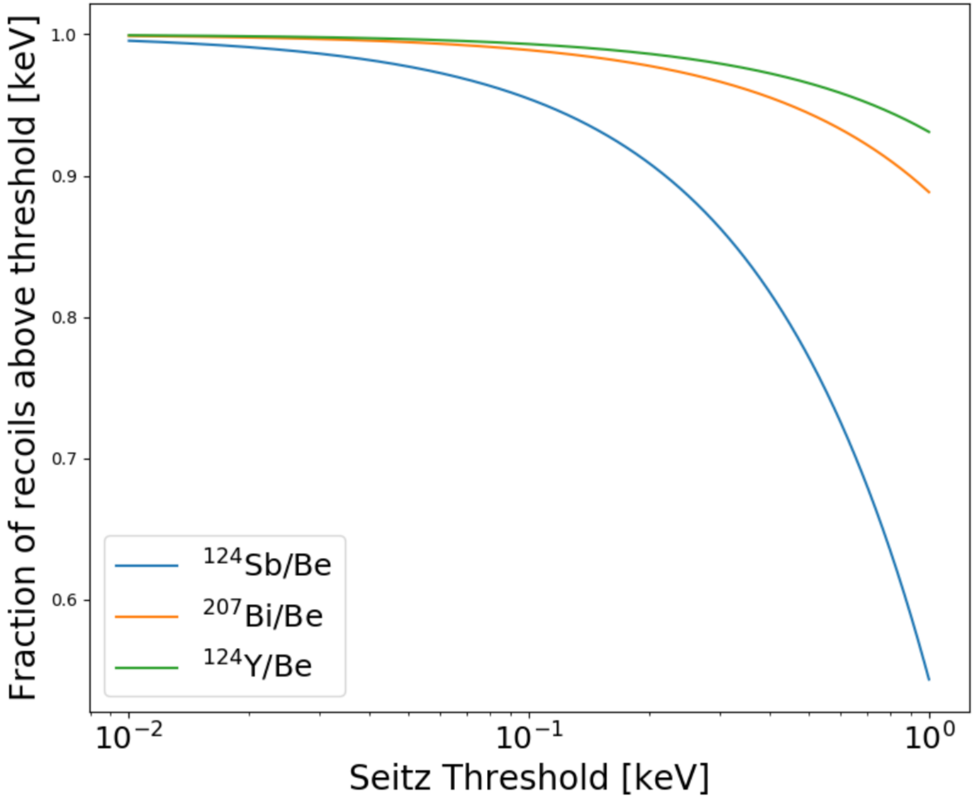


Calibration needs in argon (with ~ppk xenon)

- Design (P,T) = (25 psia, 130K) for $Q_{Seitz} = 0.043\ keV$ (1 bubble per ton-year thermodynamic fluctuation limit)
  - Want to calibrate scintillation of NRs > ~5 keV
    - Spontaneous fission sources
    - (α, n) sources
    - Inelastic scattering
  - Need to calibrate NR bubble formation in the tens-hundreds of eV range
    - Photoneutron sources
    - Thomson scattering
    - Thermal neutron capture
  - Need to check for bubble nucleation from ER events
    - Ordinary gamma and x-ray sources
    - Effect of an electric field O(100 V/cm)

Photoneutron calibrations

- Photoneutrons can provide ~keV nuclear recoils on argon
  - ~monoenergetic neutrons -> simple recoil spectrum
- ^{124}Sb/Be:
  - 23 keV neutrons
  - $E_r < 2.2\ keV$
  - Expect no detected scintillation
- ^{207}Bi/Be:
  - 94 keV neutrons
  - $E_r < 9\ keV$
  - Expect detectable scintillation from ~half of the recoils
- ^{88}Y/Be:
  - Primarily 152 keV neutrons
  - $E_r < 14.5\ keV$
  - Expect detectable scintillation from >half of the recoils

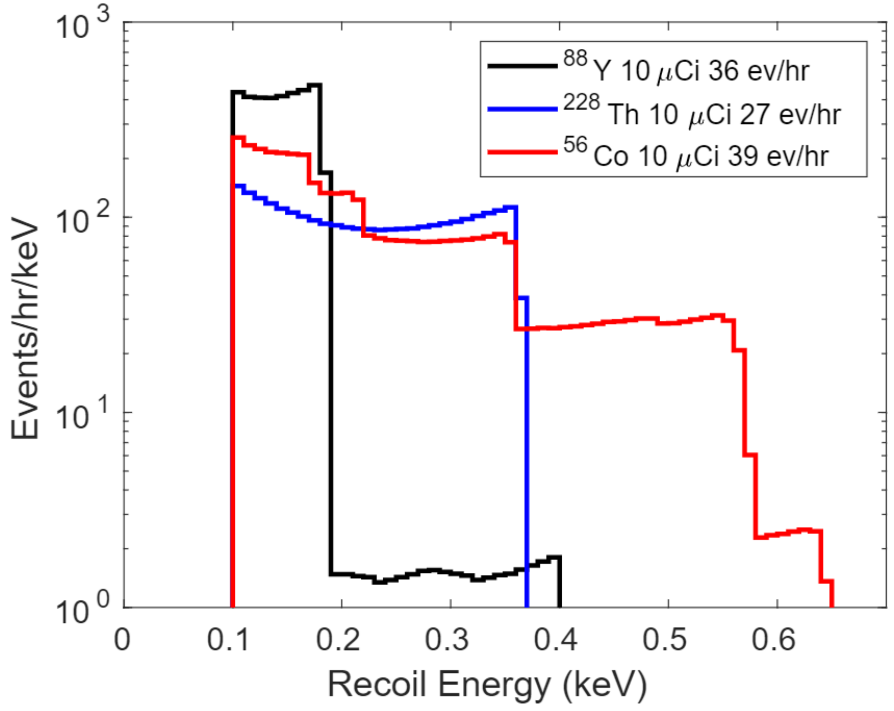


Thomson scattering

- Elastic gamma-nucleus scattering
- Tens to hundreds of eV recoils from high energy (>MeV) gammas
- 100 eV is our goal

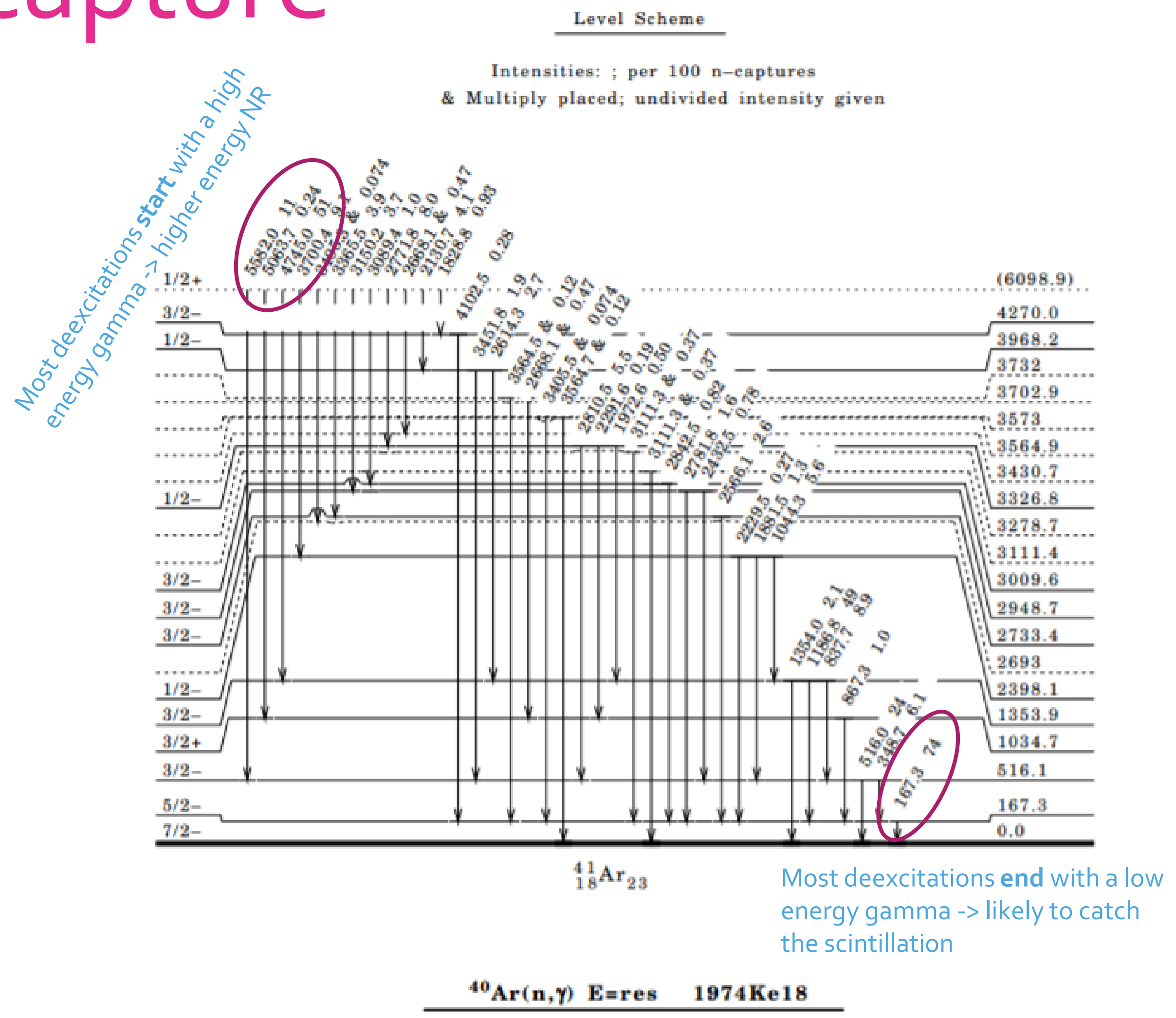
Source	Gamma energy [MeV]	Maximum argon recoil energy [eV]
^{60}Co	1.33	95
^{152}Eu	1.41	107
^{40}K	1.46	115
^{208}Tl	2.6	362

← High end of easy-to-get predominant gammas



Thermal neutron capture

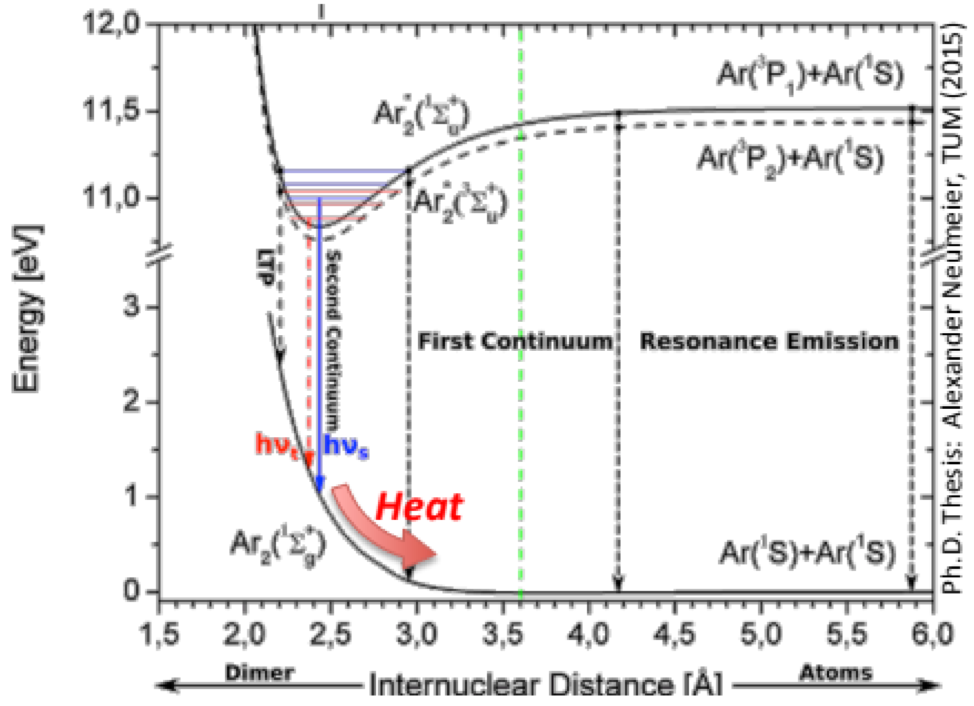
- ^{40}Ar captures thermal neutrons with $\sigma = 673\ mb$
- Capture is followed by a gamma cascade (~ps) resulting in a nuclear recoil of the ^{41}Ar nucleus of ~320 eV
- D-D generator neutrons from neighbors in MINOS area
- Can find full efficiency point with threshold scan



1974Ke18: E_n=15–70 keV and 58 keV produced from ^{7}Li(p,n)^{7}Be reaction. Measured Eγ, Iγ using Ge(Li).

ER calibrations

- Easy if superheated Lar(+ppk Xe) is gamma-blind in the bubble nucleation channel, like xenon
  - First calibration will just be exposing the chamber to a variety of strong standard gamma sources
  - If the bubble rate does not increase, we set an upper limit on bubbles/gamma interaction and we're done

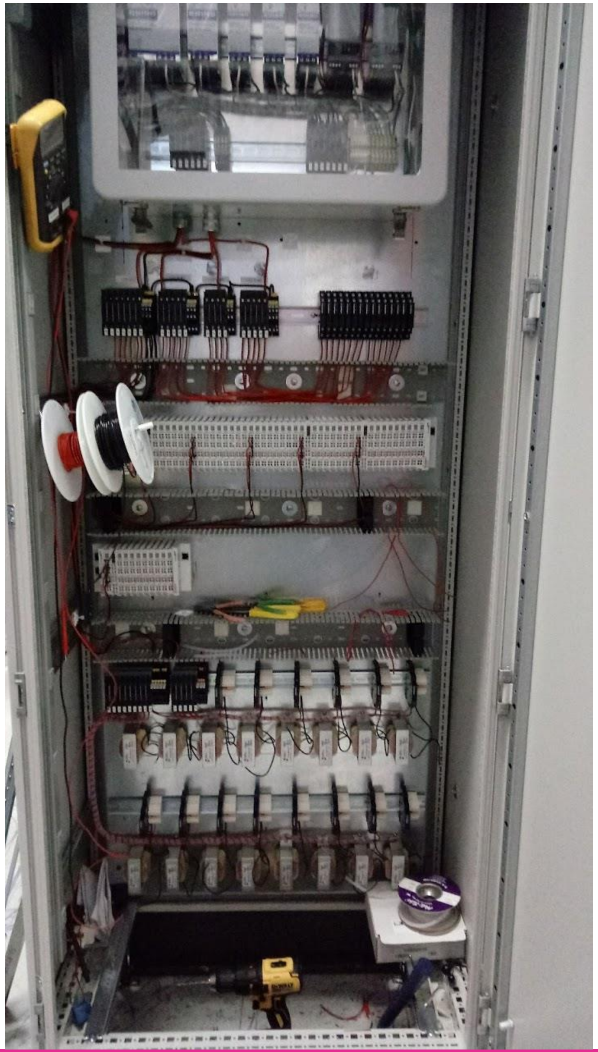


ER calibrations

- If there *is* a rate above background, we have some more work to do
  - HV electrode – does TPC-ish electric field kill the rate by preventing recombination?
  - Fill with pure LAr – is the xenon contamination causing the bubbles?
    - This would destroy our ability to detect scintillation; the fused silica is opaque to the argon scintillation wavelength
    - But, if we need to operate at low thresholds as a more traditional bubble chamber, this would be an option
  - Switch to pure xenon; we have confirmation down to ~500eV that xenon is gamma-blind at better than 10^{-6}
  - Or, adjust pressure and temperature to see what happens
    - We've worked for the past few years to understand ER nucleation in freon bubble chambers, and it turns out to be somewhat tunable, may be similar here

Operation plans

- Working hard on assembly now
- Calibrations begin in 2022

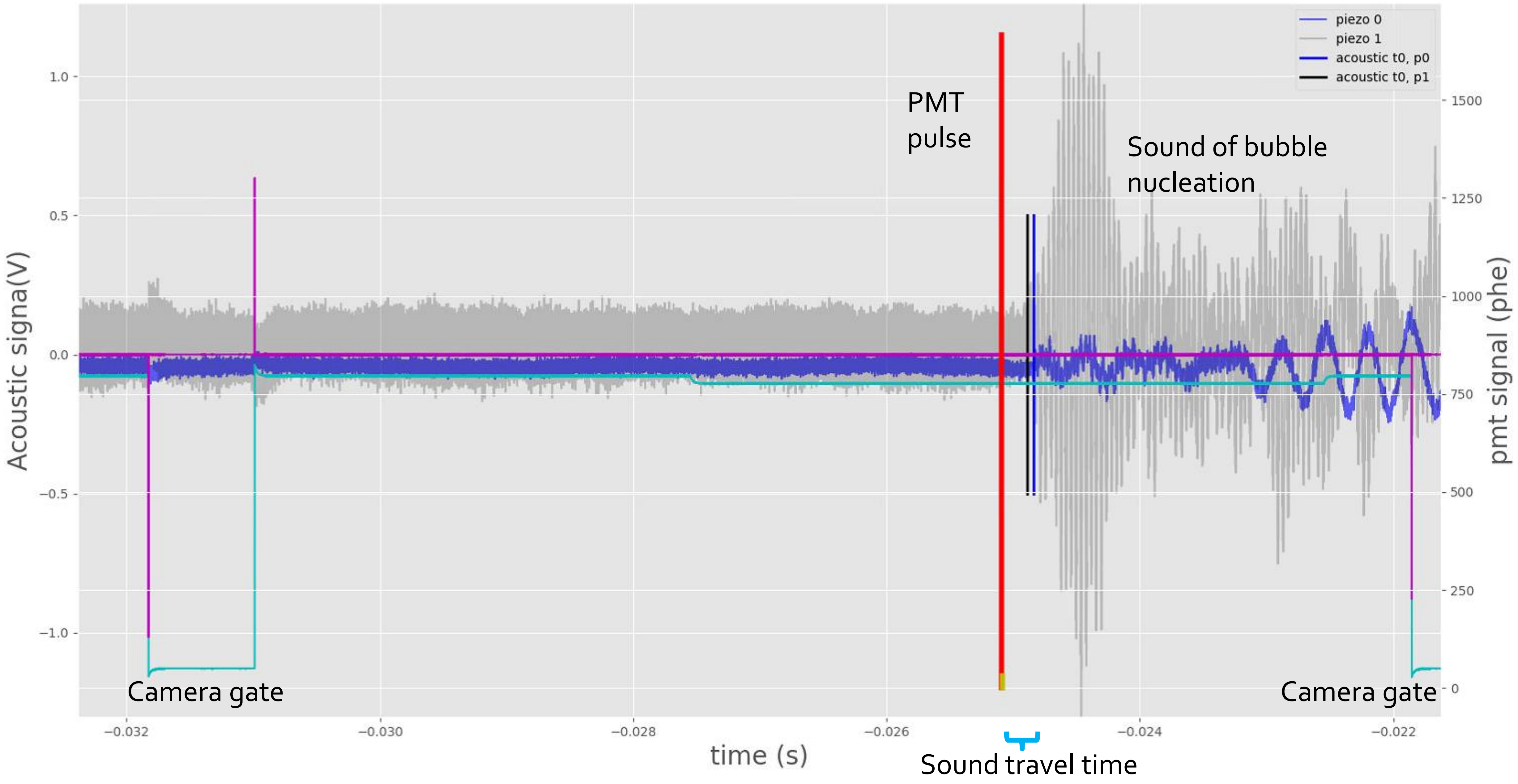


THANK YOU!

Many thanks to the DOE and the GIRA committe,

and to my advisors and mentors at FNAL and Drexel!

BACKUP



piezo 0
piezo 1
acoustic t0, p0
acoustic t0, p1
PMT pulse
Sound of bubble nucleation
Camera gate
Camera gate
Acoustic signa(V)
pmt signal (phe)
time (s)
Sound travel time
1.0
0.5
0.0
−0.5
−1.0
1500
1250
1000
750
500
250
0
−0.032
−0.030
−0.028
−0.026
−0.024
−0.022

Argon Bubble Chamber Concept