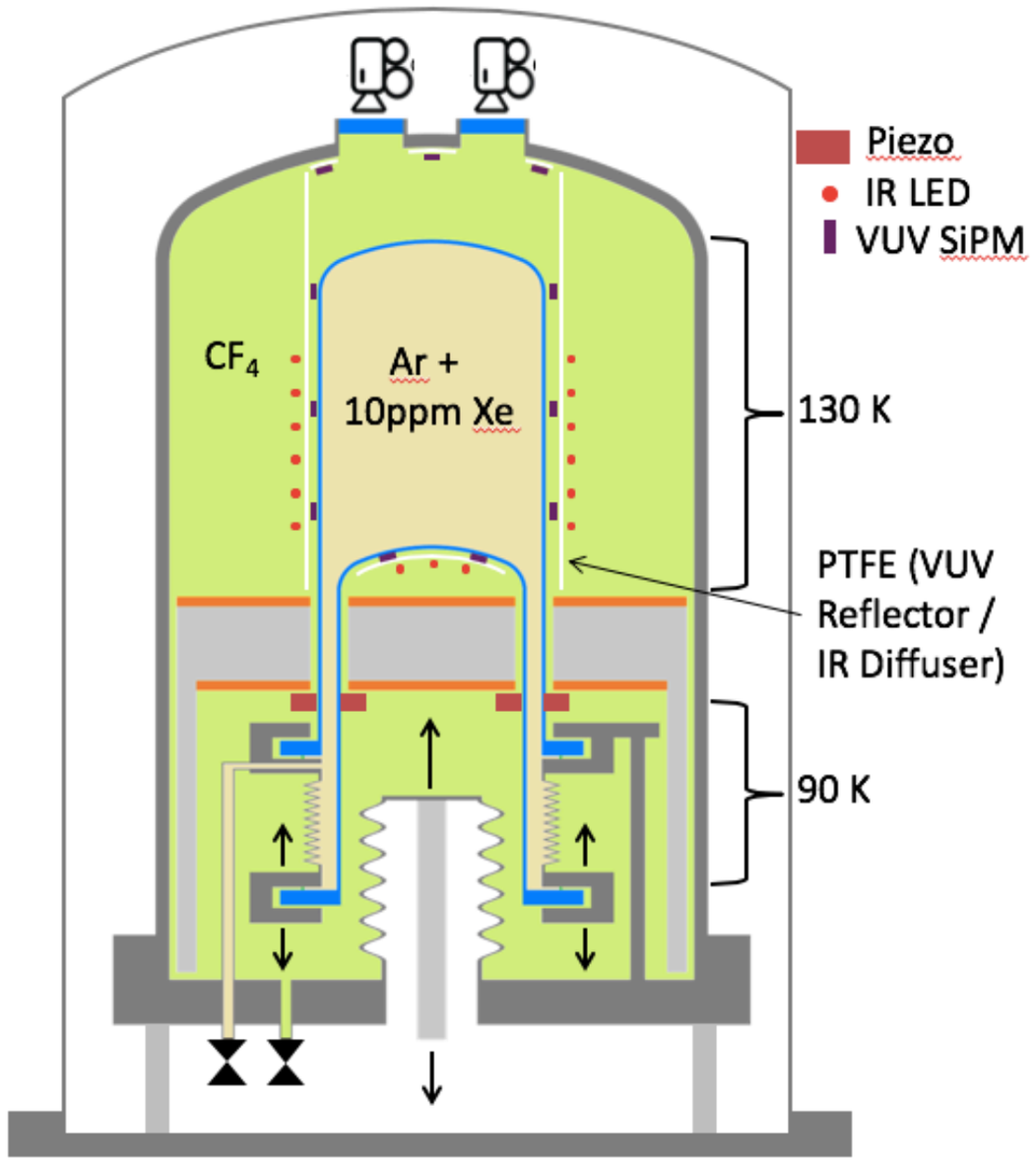
Scintillating Bubble Chamber



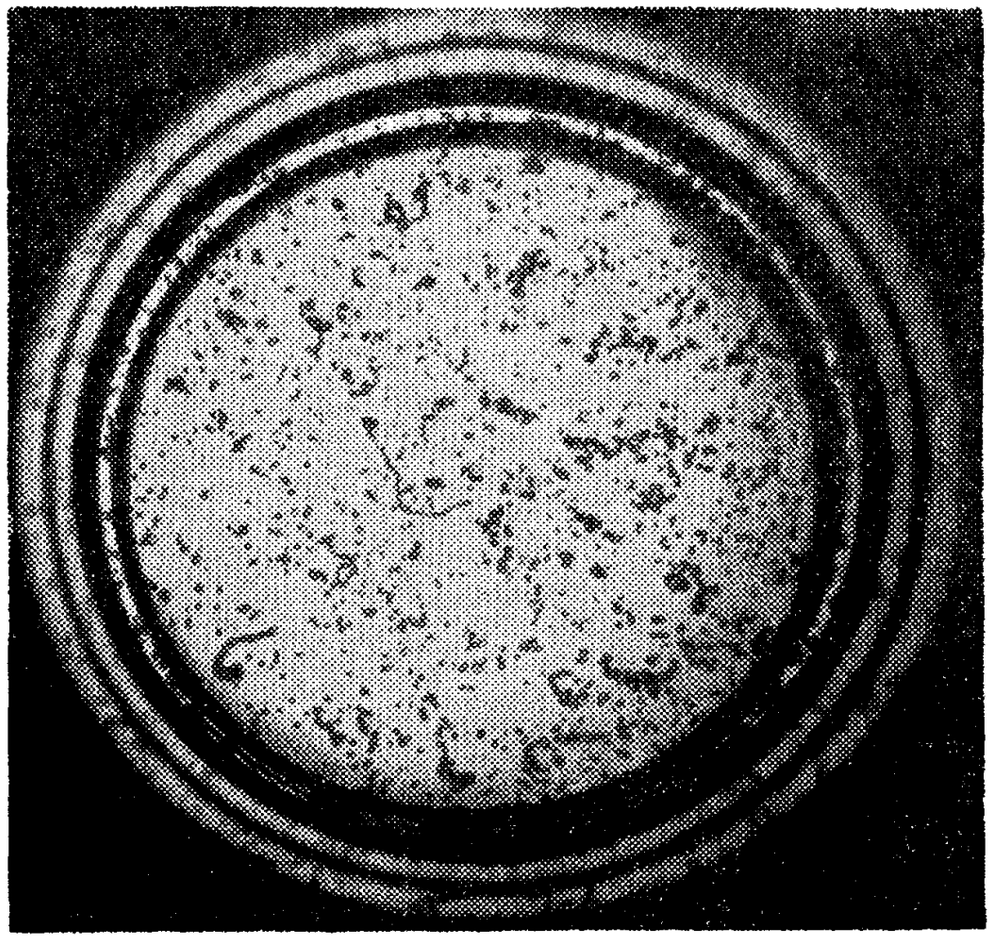
Ken Clark
Queen's, TRIUMF, McDonald Institute

TRIUMF

Queen's UNIVERSITY

Arthur B. McDonald
Canadian Astroparticle Physics Research Institute

Revisit a bit of history

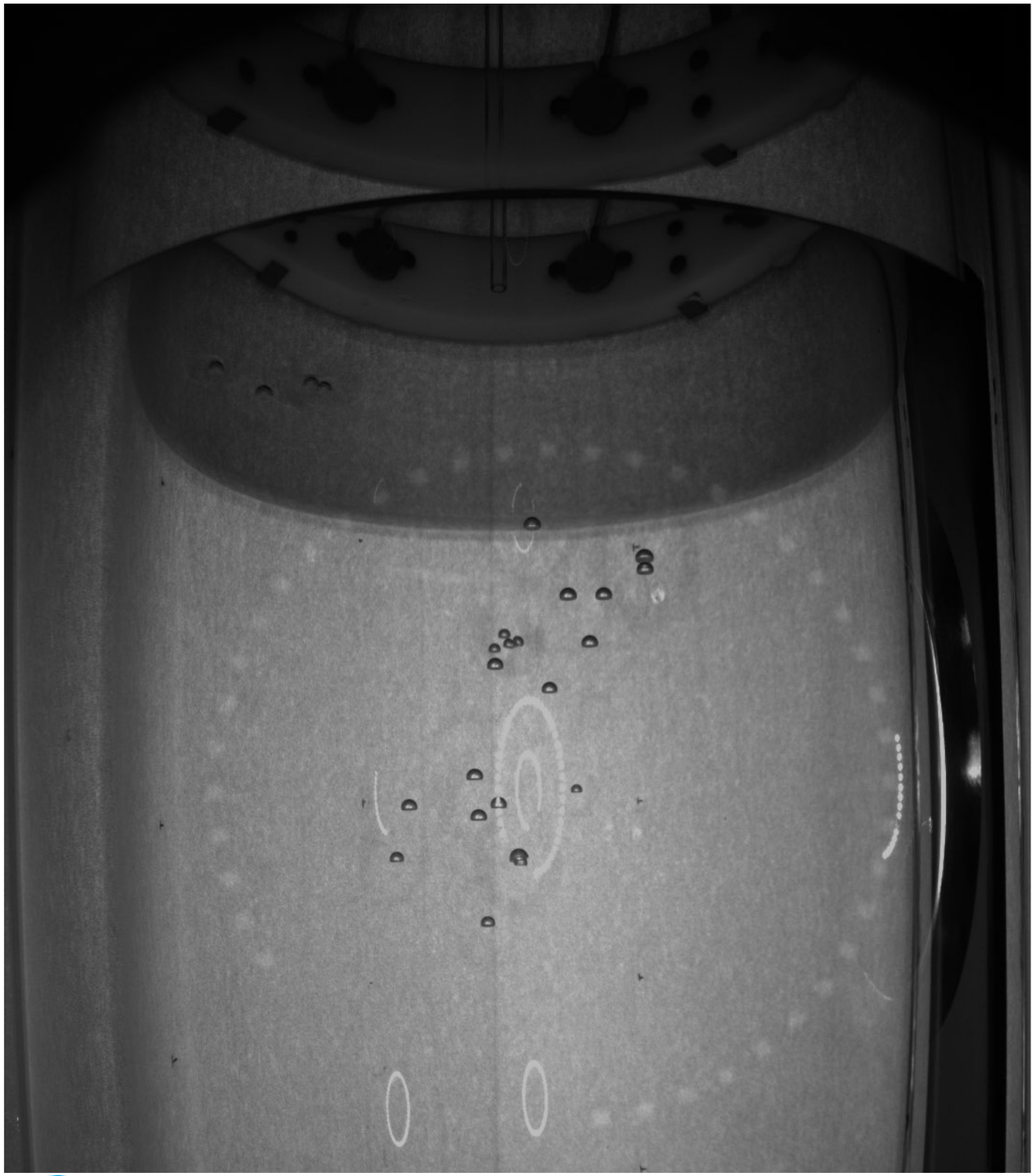


Phys. Rev. 102, 586 (1956)

- In 1956, Glaser made a xenon bubble chamber
  - No bubbles in pure xenon even at 1keV threshold with gamma source
  - Normal production in 98% xenon + 2% ethylene (scintillation completely quenched)
- Scintillation suppresses bubble nucleation (?)

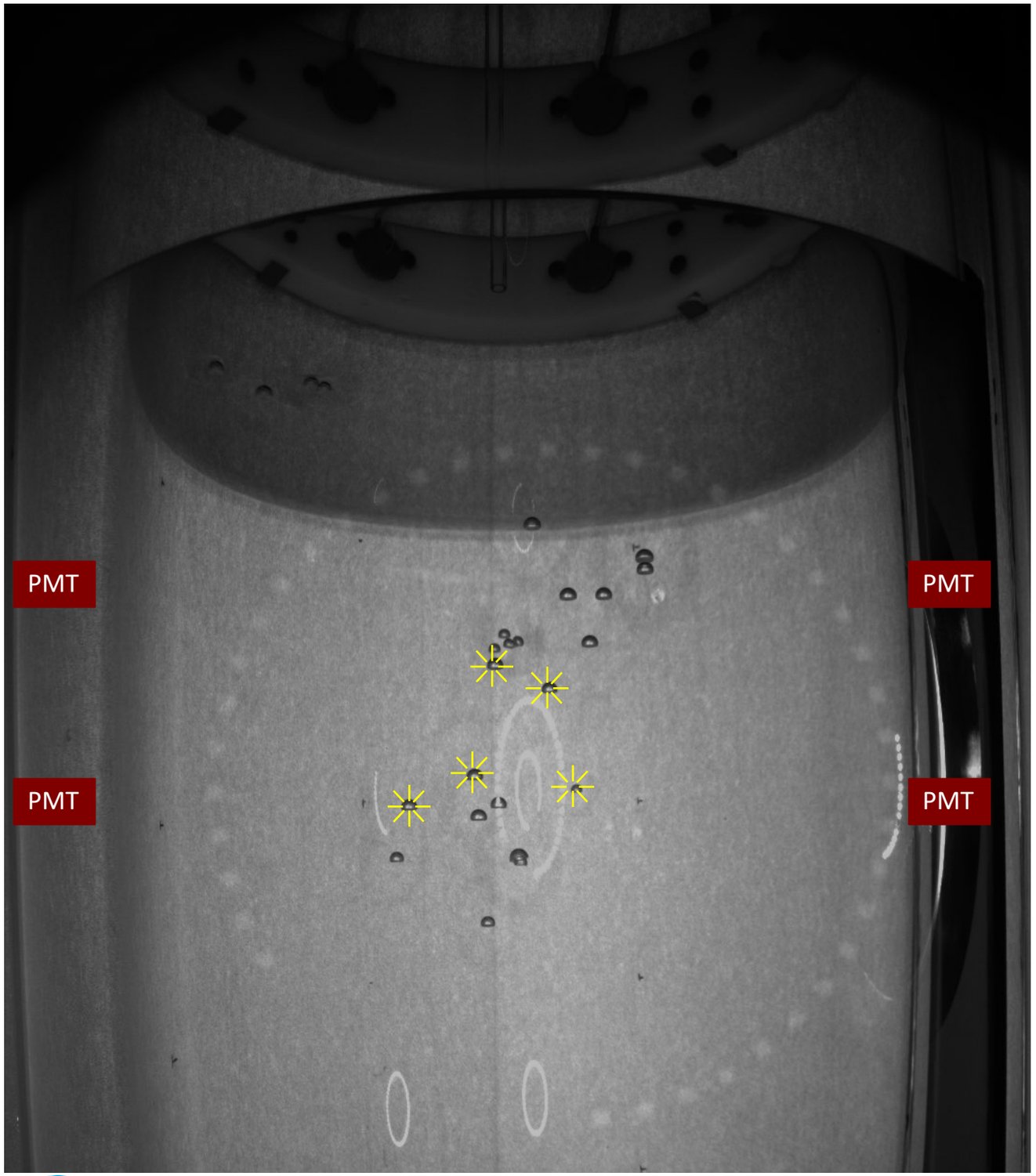
The “traditional” bubble chamber

- Superheated target (C_3F_8, CF_3I…)
- Particle interactions nucleate bubbles
- Cameras and acoustic sensors capture signals
- Chamber recompresses after each event



The “Scintillating” bubble chamber

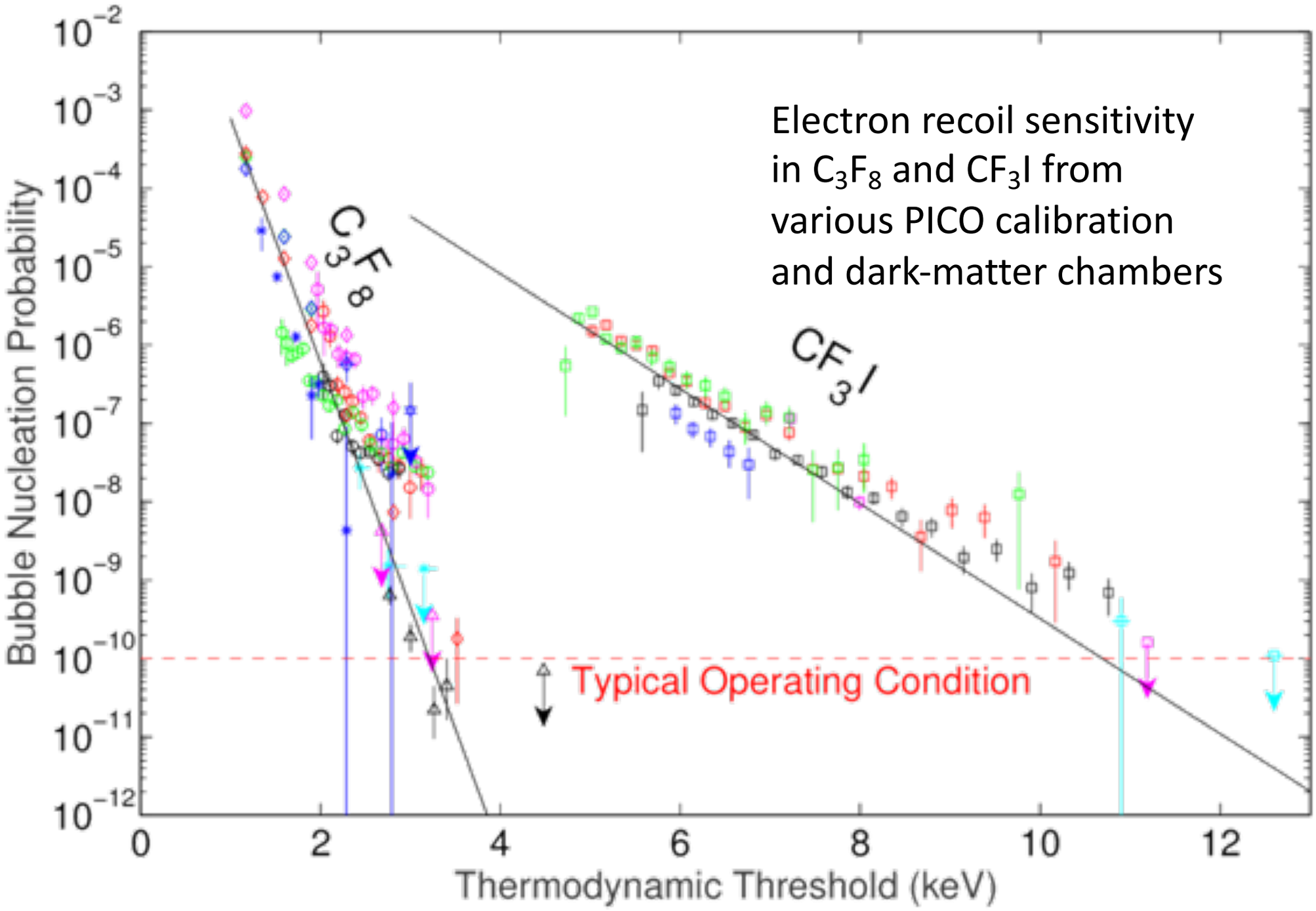
- Superheated scintillator (Xe, Ar…)
- Particle interactions nucleate bubbles and cause scintillation
- Cameras and acoustic sensors capture signals, photodetectors collect scintillation light
- Chamber recompresses after each event



Potential Benefits

- Extra information for background rejection compared to PICO
    - Improve on 10^{10} gamma rejection
    - Better rejection than usual xenon detectors
    - Good position reconstruction from cameras

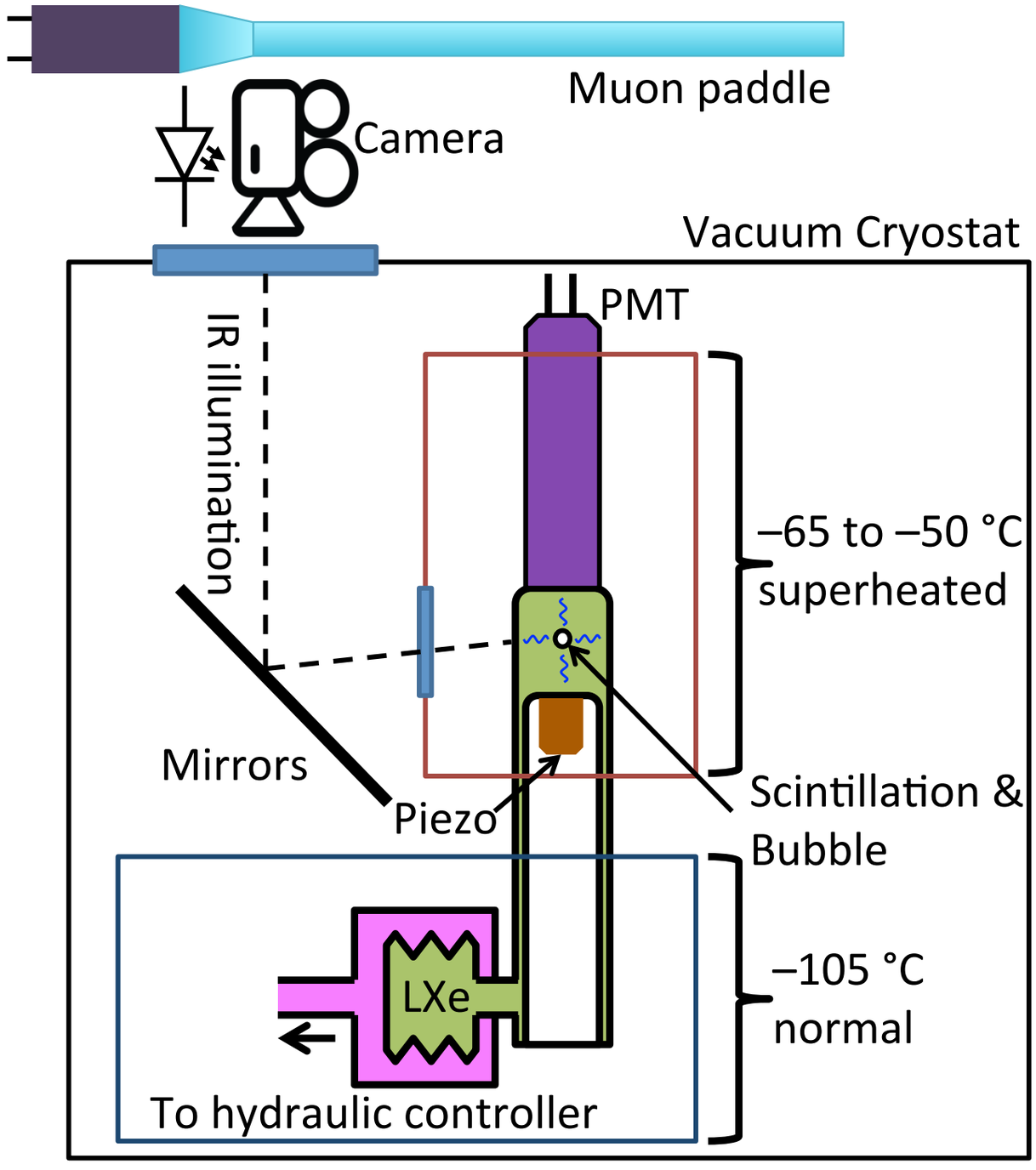
Electron recoil sensitivity



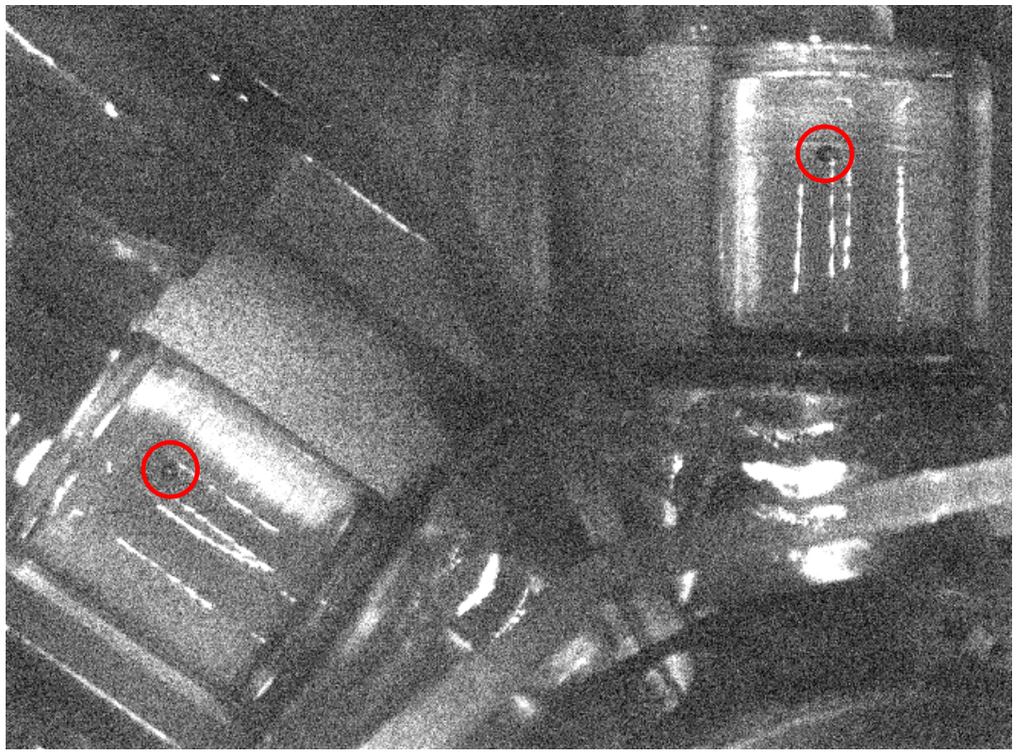
Electron recoil sensitivity in C_3F_8 and CF_3I from various PICO calibration and dark-matter chambers

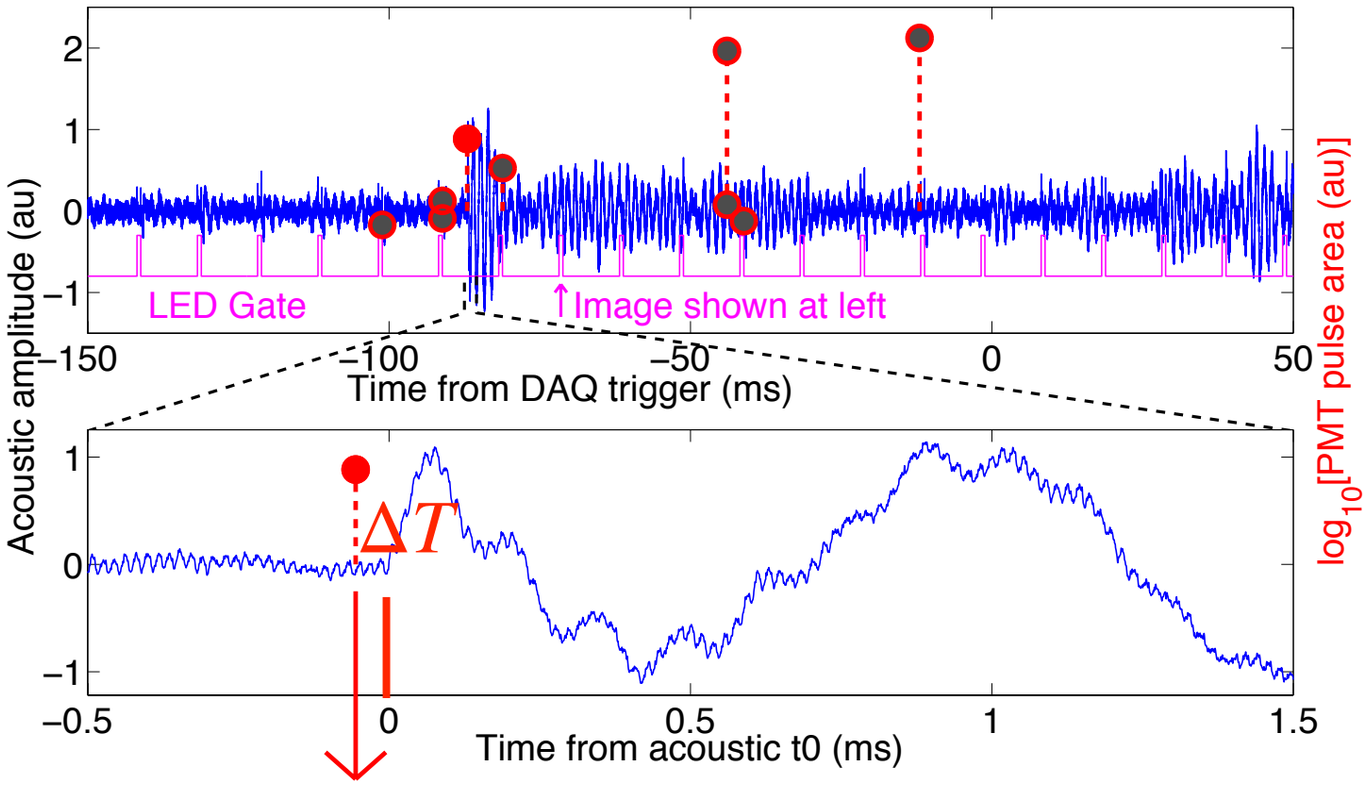
Northwestern Chamber

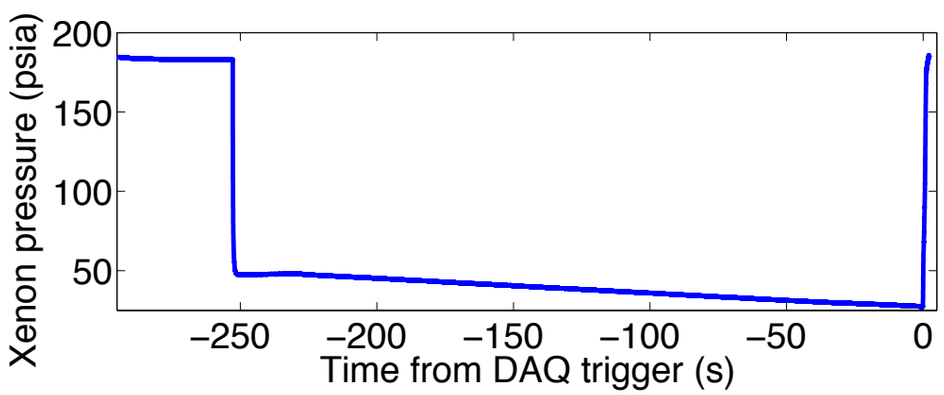
- Operated at 4keV threshold
- Camera ported through sapphire window
- Mirrors allow two angles on the bubble

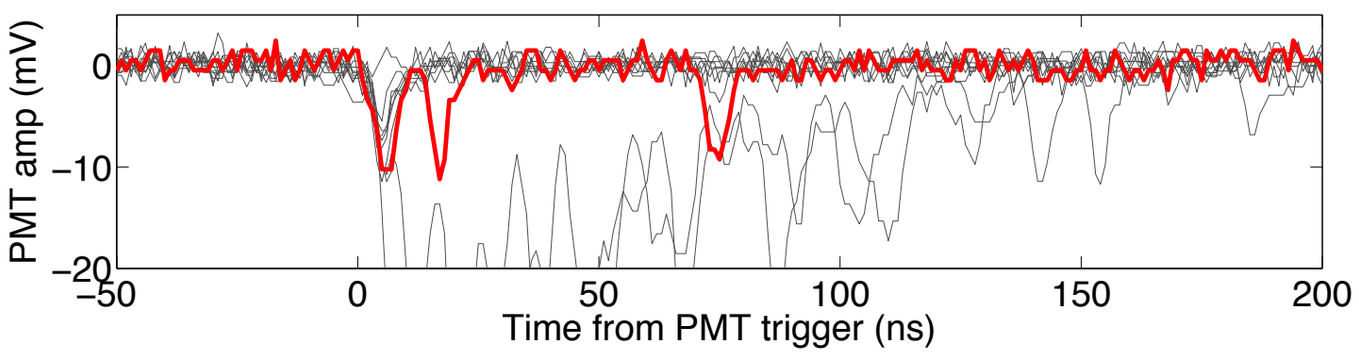


An event

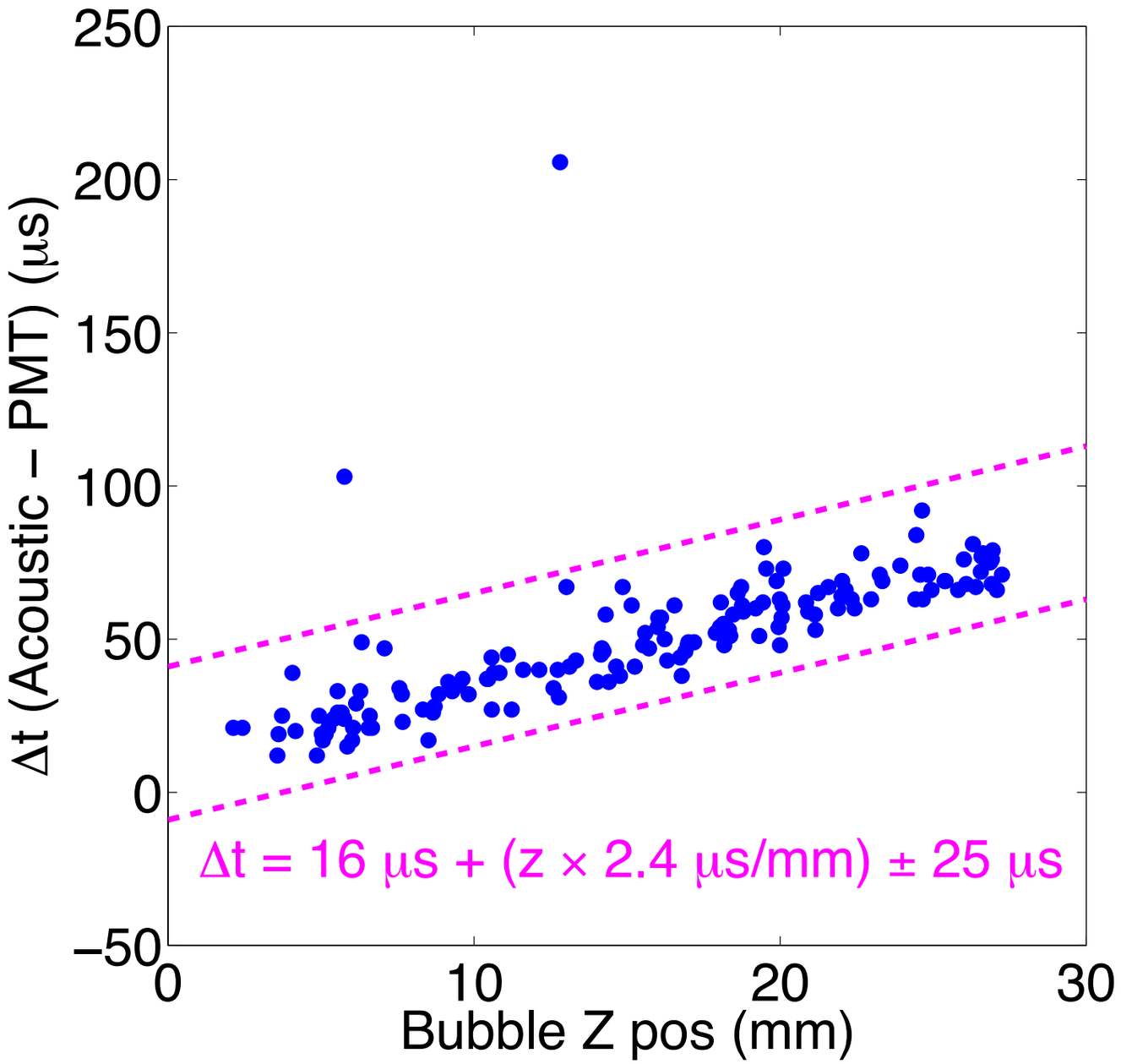



Acoustic amplitude (au)
LED Gate
Image shown at left
Time from DAQ trigger (ms)
ΔT
Time from acoustic t0 (ms)
log10[PMT pulse area (au)]


Xenon pressure (psia)
Time from DAQ trigger (s)


PMT amp (mV)
Time from PMT trigger (ns)

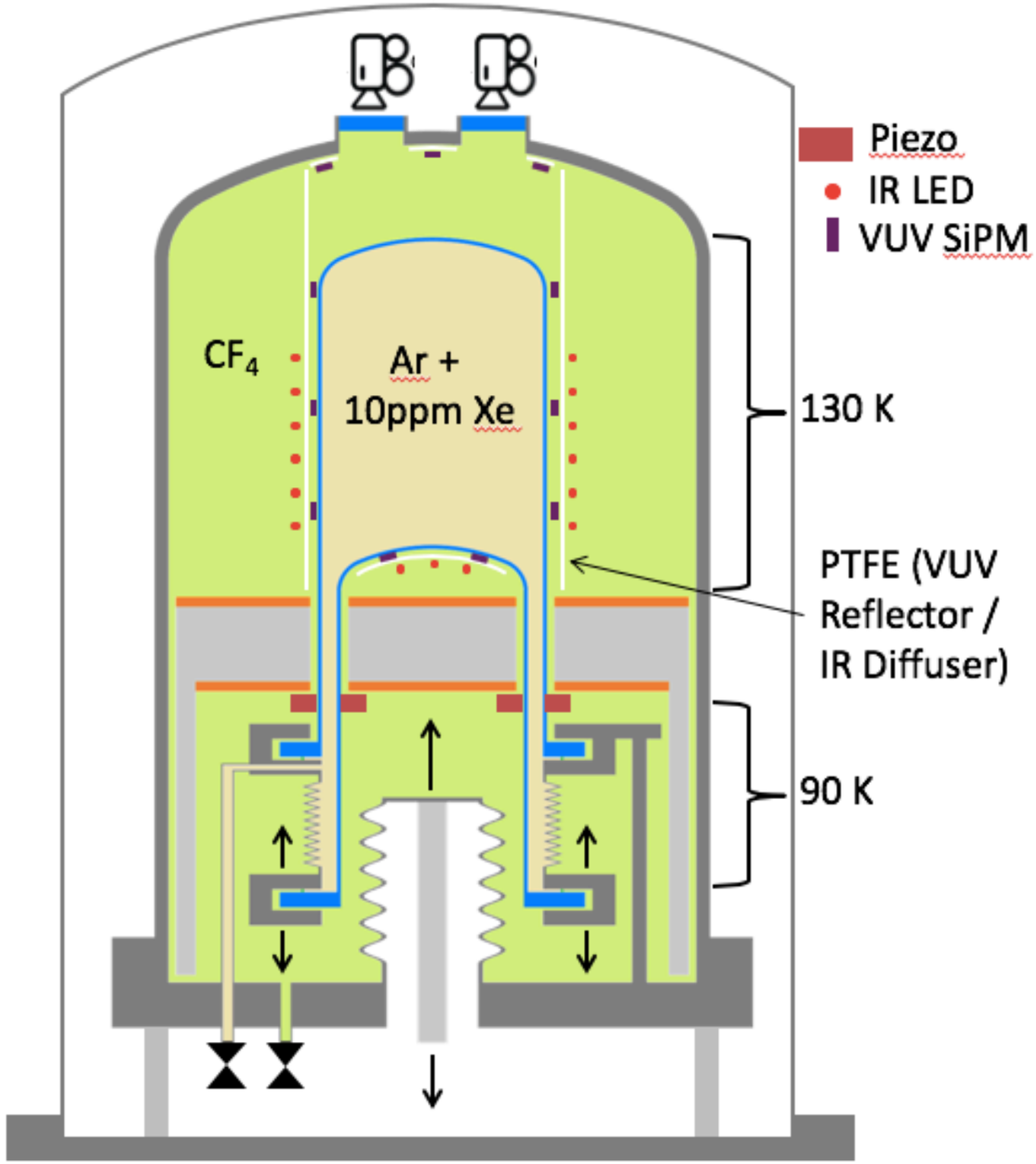
Timing



- Look at the time difference between scintillation and acoustics
- Derive the speed of sound in xenon (to ~20%)

The SBC Detector

- Roughly 10kg of Argon
- SiPMs used for detection
- Much of the internal detail modelled on PICO 500



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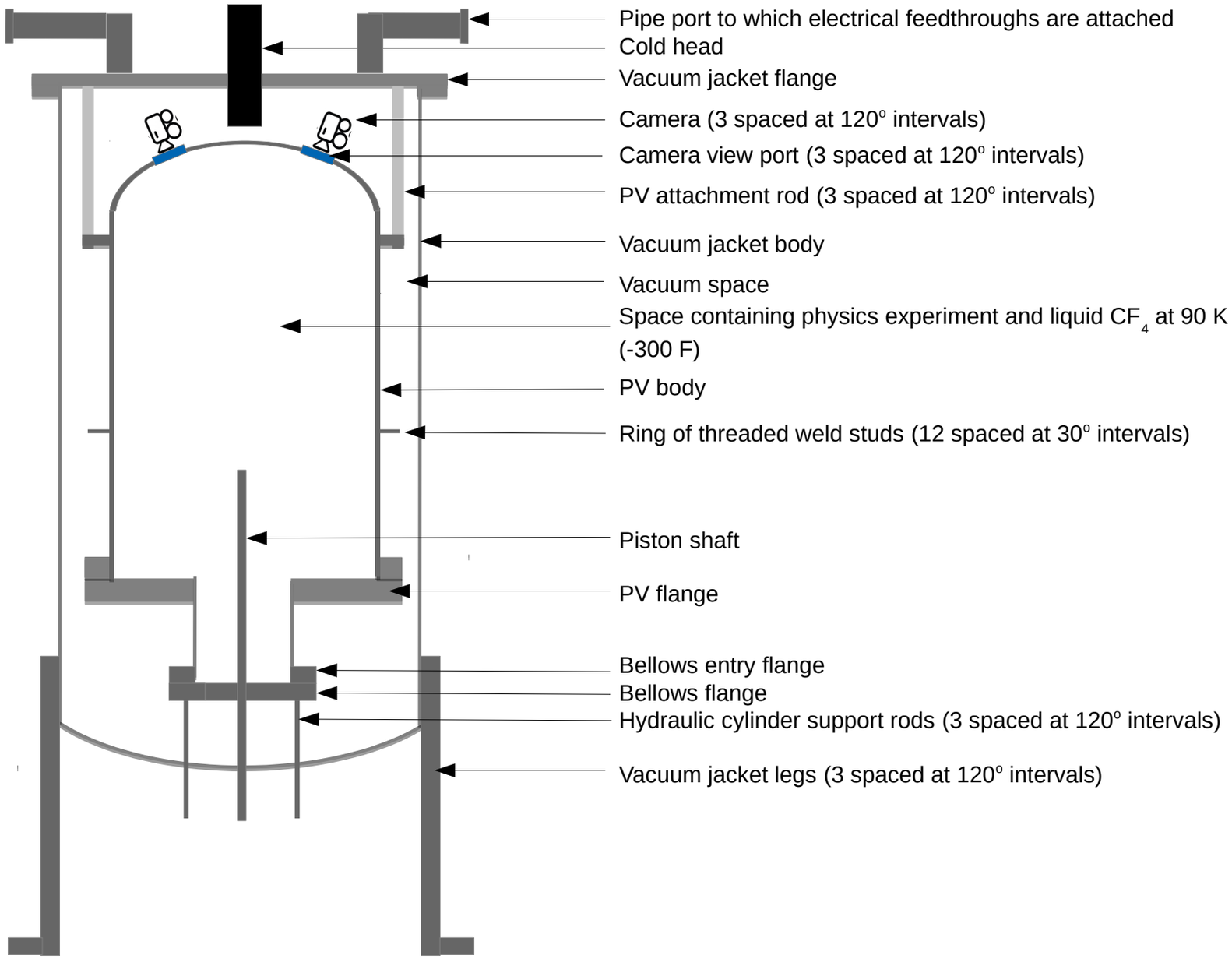

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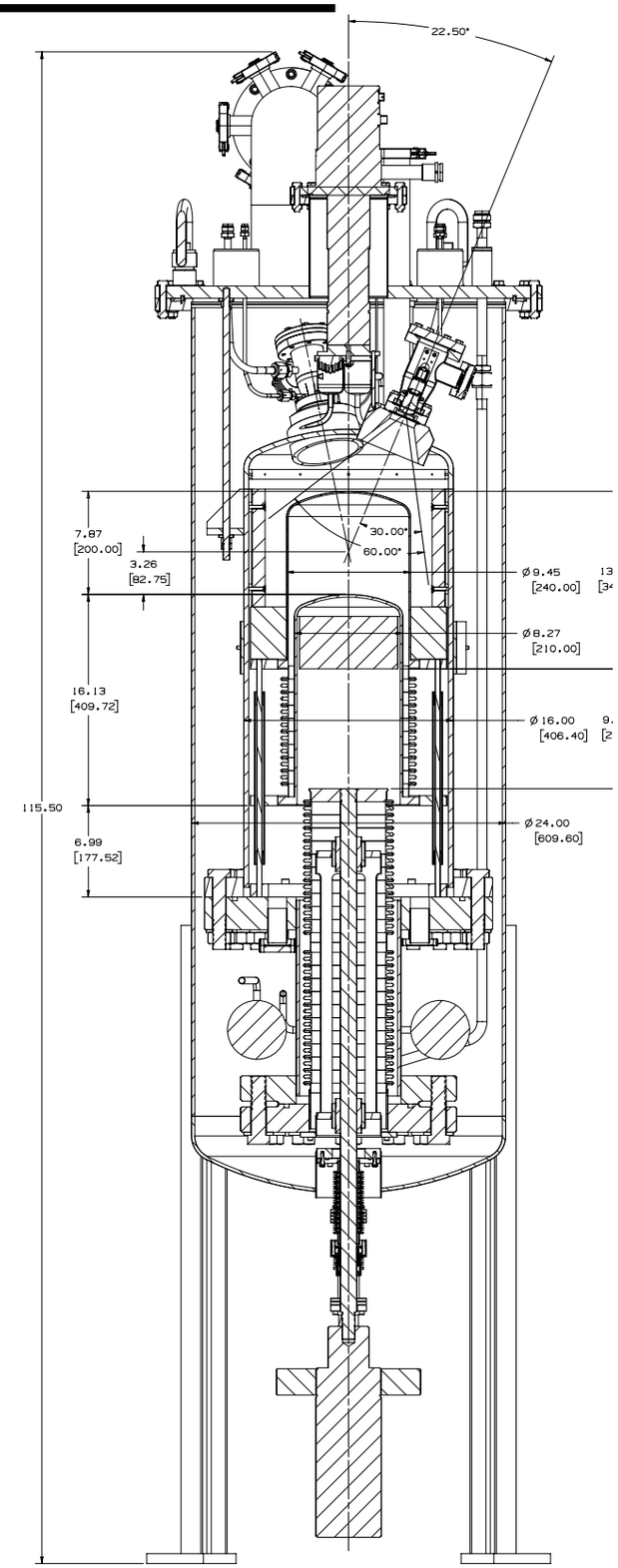

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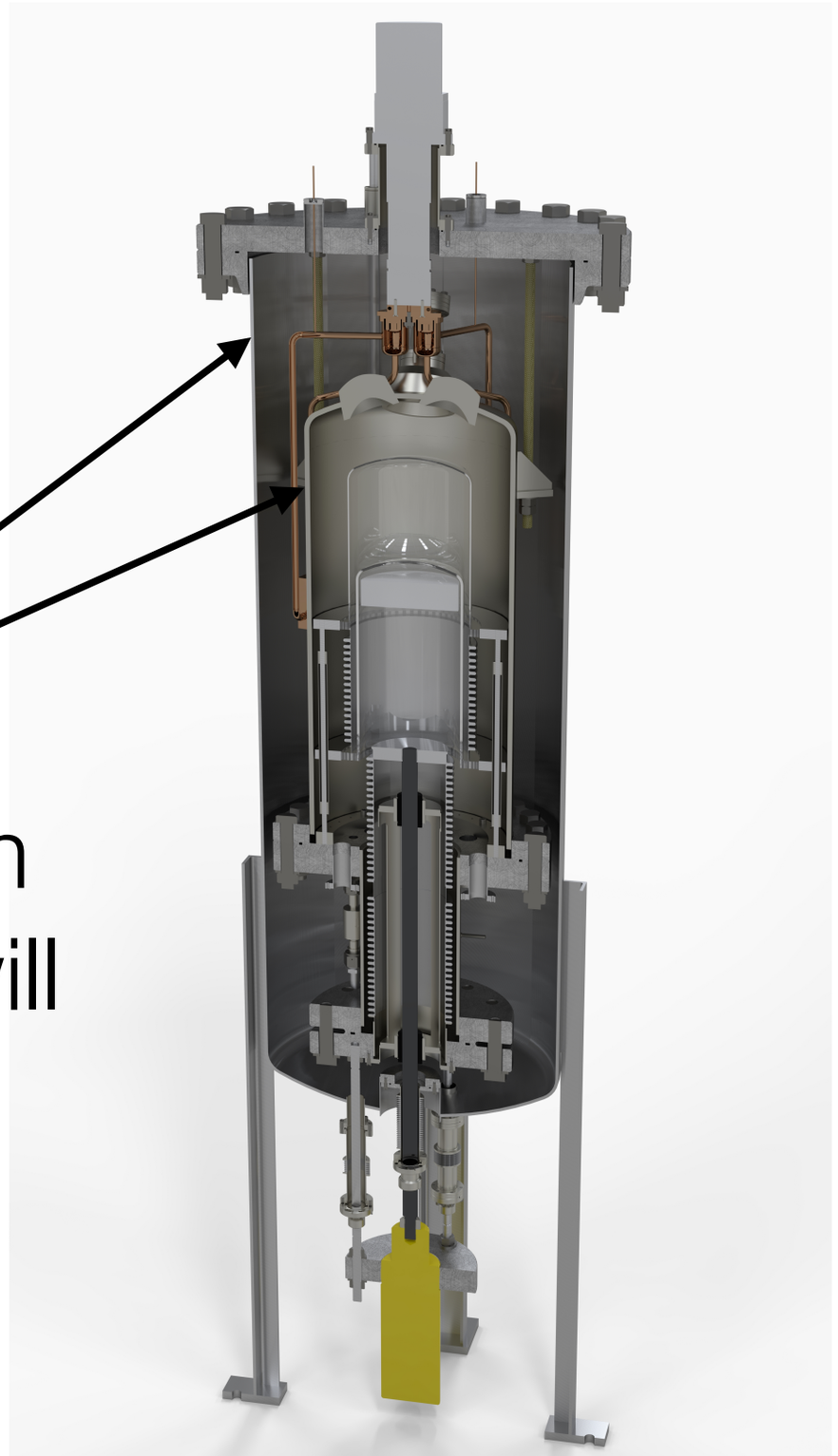
The SBC Detector

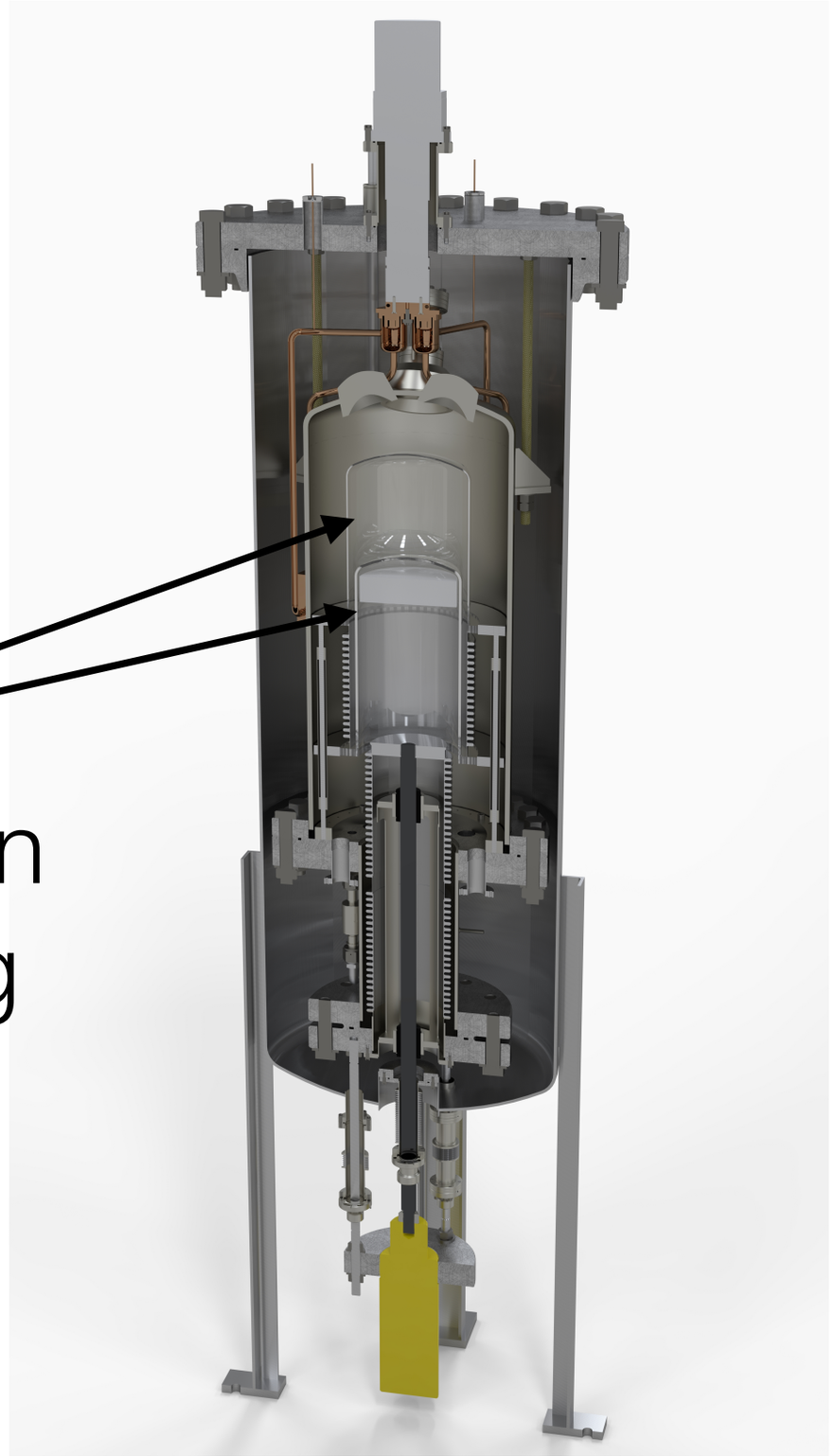
- Focus now is design



Pressure vessel and vacuum jacket bid spec is finished, will go out shortly

The SBC Detector

- Focus now is design

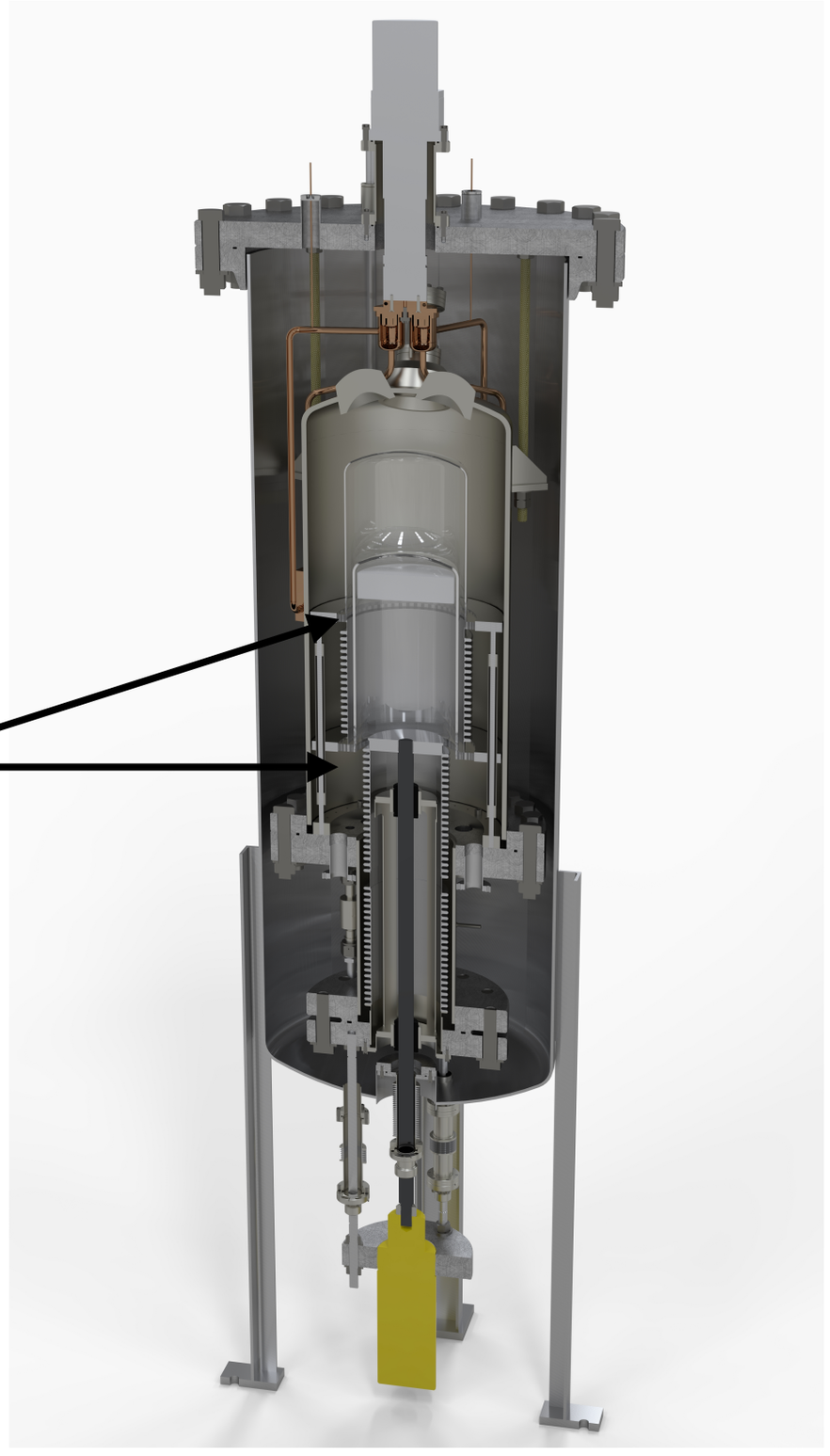


Inner and outer jar have been designed and we are talking to manufacturers

The SBC Detector

- Focus now is design

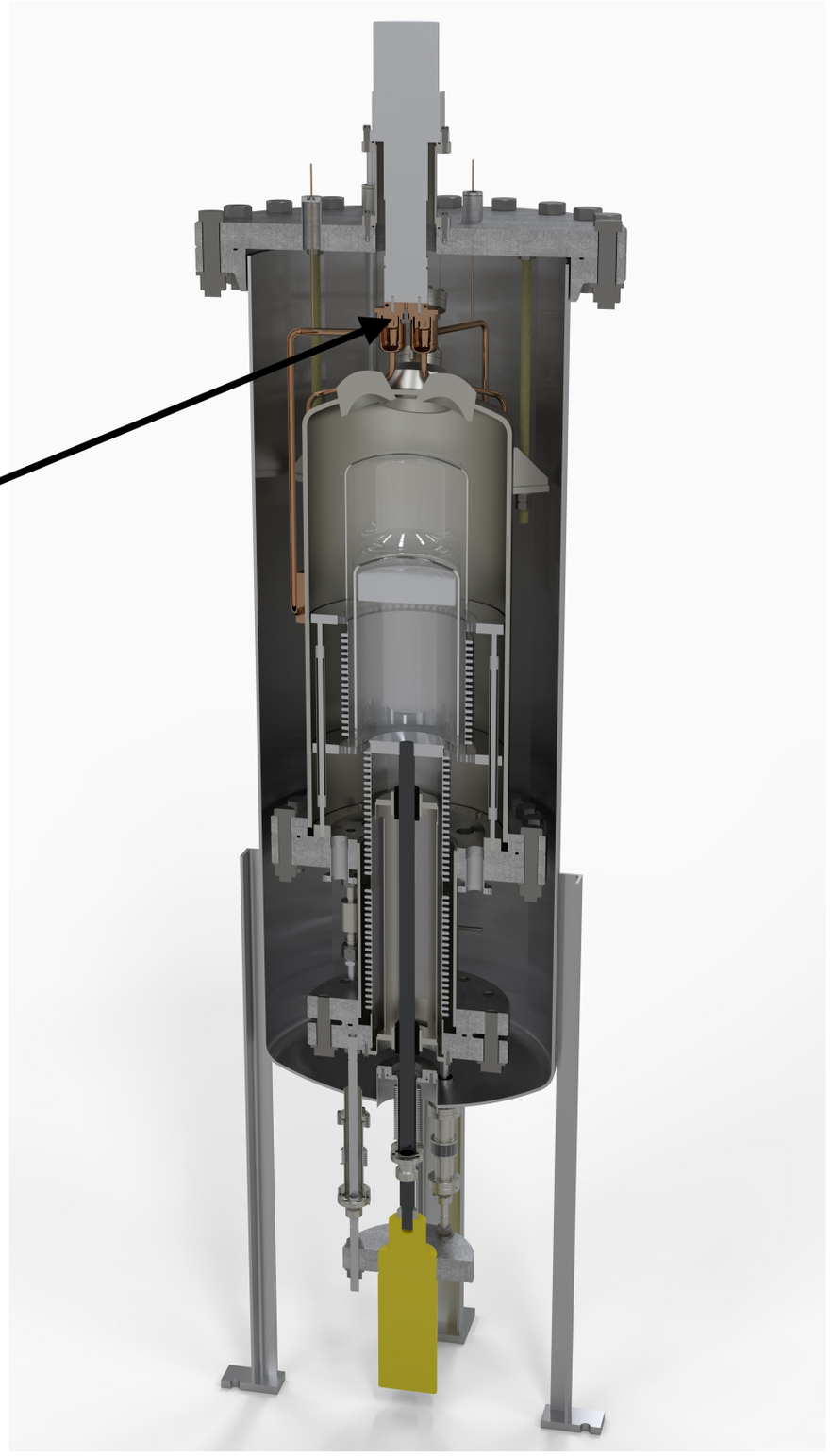
One key component is the quartz-to-metal seals. The technology has been identified and engineers are being consulted.



The SBC Detector

- Focus now is design and construction

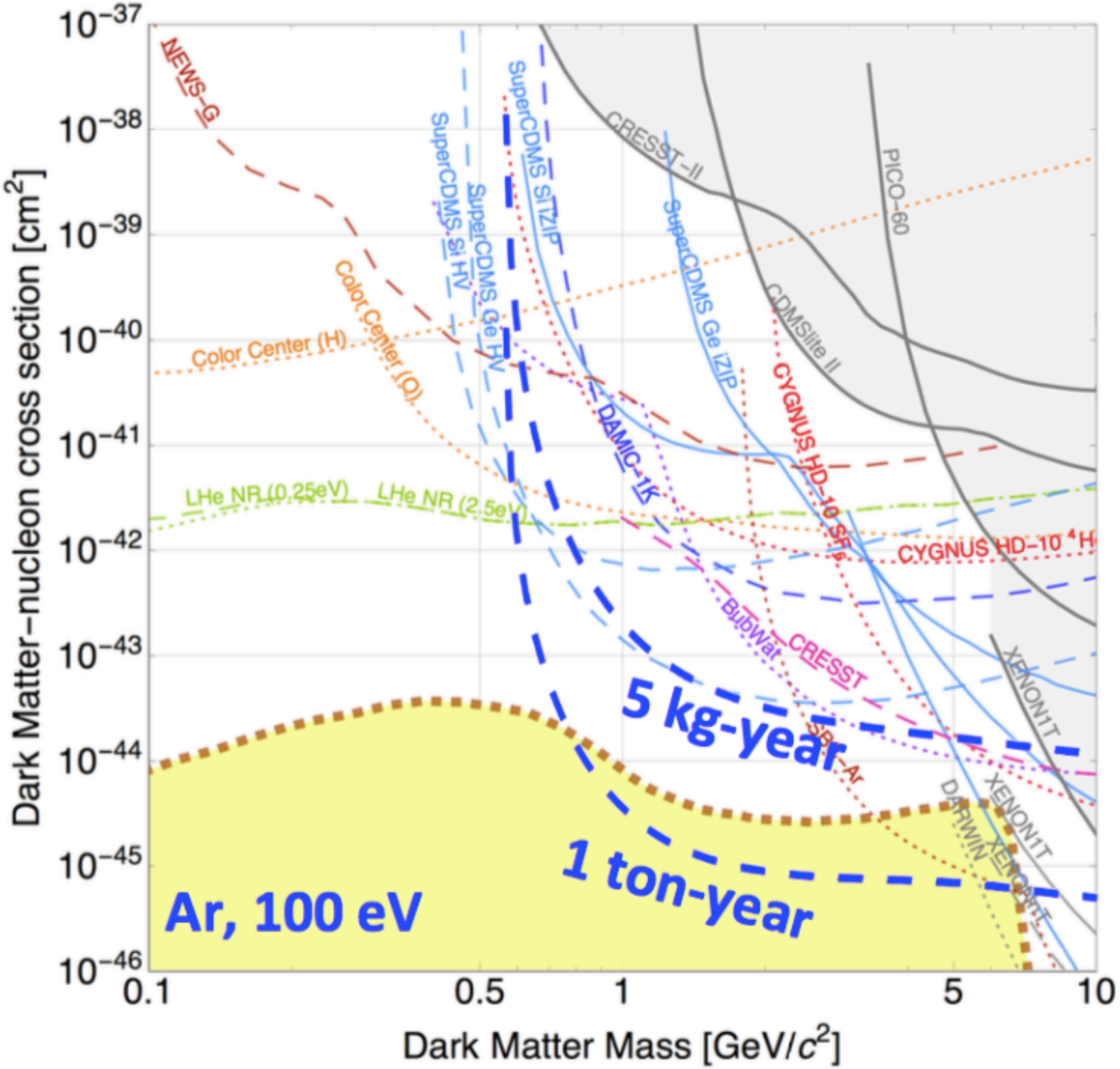
Cryogenic heads already constructed (Queen's purchased, machined at UofA)



Physics Goals

- Building two detectors for two different physics goals
- One for installation at SNOLAB
    - Look into low background response and feasibility for dark matter search
- One for installation at ORNL (?)
    - Look to further study coherent neutrino scattering

Physics Goals



Task Breakdown

Task definition has happened, progress on all fronts

- WBS 1.1 Cryostat and Pressure Vessel (Fermilab / Dahl)
- WBS 1.2 Inner Assembly (Queen's / Clark)
- WBS 1.3 Fluid Systems (Alberta / Piro)
- WBS 1.4 Cryogenics (Fermilab / Lippincott)
- WBS 1.5 Optics and Imaging (Northwestern / Dahl)
- WBS 1.6 Scintillation Detection (TRIUMF / Giampa)
- WBS 1.7 Acoustic Detection (IUSB / Levine)
- WBS 1.8 Shield Systems (UNAM / Vazquez Jauregui)
- WBS 1.9 Calibration (Drexel / Neilson)
- WBS 1.10 Online Computing (Northwestern / Dahl)
- WBS 1.11 Offline Computing (TBD)

Schedule

Completed
Work started

WBS v	Dec-18	Jan-19	Feb-19	Mar-19	Apr-19	May-19	Jun-19	Jul-19	Aug-19	Sep-19	Oct-19
MS									Double-jar leak check		
PV/OV					Out for bids	PO out				PV/OV arrive	
Rocco ->	Piston solution identified	Begin drafting bid package		Bid package review							
Russ->	Piston interface spec	Hangar interface spec	Seals	Bid package review		Hangar tie-rod spec	Piston shaft specs		Safety Documentation		
Bill ->	Piston penetrations	OV flange layout	PV inner wall attachment points	Bid package review							
		OV shell layout, legs, ports									
IV (Jars)											
	Seals fixed	Dimensional contraints fixed	Jar clamp FEA	Jar material assay		Jar procurement					
Alberta Machining (all enough for 2x chambers)	Condenser	Heater block	Evaporators	Titanium rings	Bellows supports	PTFE, HDPE PV parts					
FNAL Facilities											
	Identify space, Tech for surface	assembly		Occupy Space						Identify space UG	
Fluids											
		Fill/Empty / E-recovery plans	TS P&ID	Warm hydraulic P&ID	Pneumatic P&ID	Complete P&ID		Fluids Layout			
Cryo											
	Order cryomech										
	Start condenser fab		Start Evap Fab		Start TS panel fab		Cryo ready to install on OV				
	Complete COMSOL		Start thermal strap fab								
			Spec heater/RTD mounts								
Cameras											
	Design camera back flange	PO -- camera feedthrough		Test cameras cold by now							
	1-mm transmission test	1-mm transmission w/ fluorinert									
SiPMs											
	Test setup @ NU	P-cycle VUV-4 and IR LED		Cold test UV LEDs		Identify SiPMs by now	Buy SiPMS				
		Test setup @ Queens	VUV-4 vs FBK (IR+175)		Electronics tests			Identify SiPM electronics chain by now	Buy SiPM bases, digitizer, DC supplies, amps		
Acoustics											
				First sensors -> NU							
					P-cycle @ NU						
Sensors				Test pressure tansducer	Test bellows postion sensor						
Calibrations											
					Have full G4 model by now					Have calibration plan by now	

Timeline

- Technical design happening now, to be complete by the middle of 2019
- Assembly and commissioning at Fermilab continues into 2020
  - Assembly of second detector may happen elsewhere
- Installation at the earliest early 2021

Conclusion

- This is an exciting experiment that has several applications
- A group of strong, young physicists has been formed to push this forward
- Installation at SNOLAB is the priority of all groups

Questions to be answered

- Can this style detector be operated for a DM search?
- Can the ~1keV threshold be reached in xenon?
- What's the nuclear recoil efficiency at that threshold?
- What is the low threshold behaviour?