The PICO Experiment

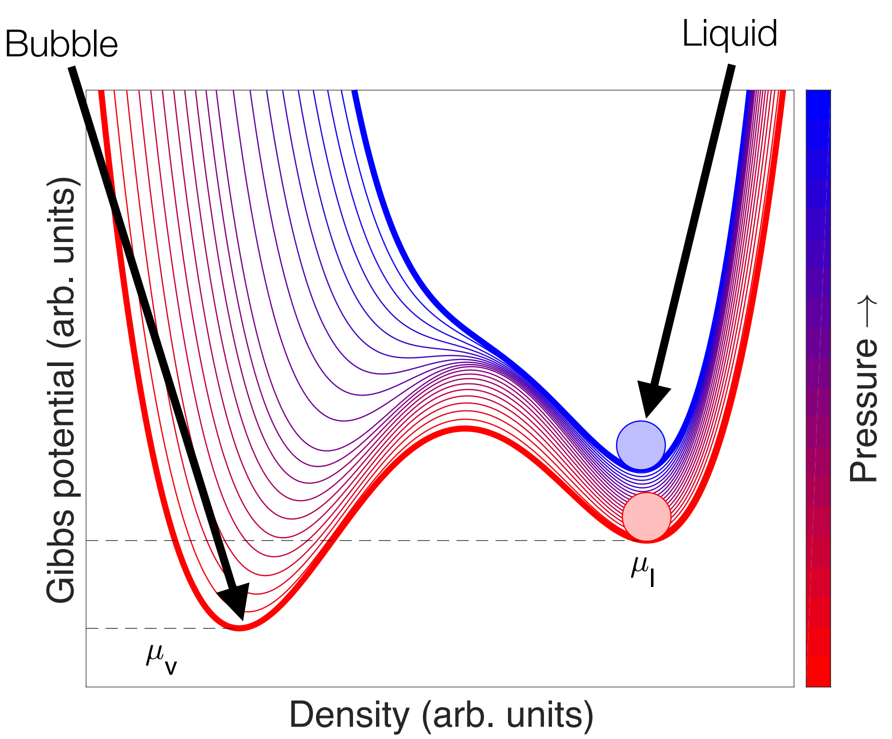
Ken Clark
Queen's University & TRIUMF

TRIUMF

Queen's UNIVERSITY

Basics of PICO

- The PICO collaboration operates bubble chambers for the detection of dark matter
- Target material is a superheated liquid — the metastable state means a small deposit of energy can cause a phase transition

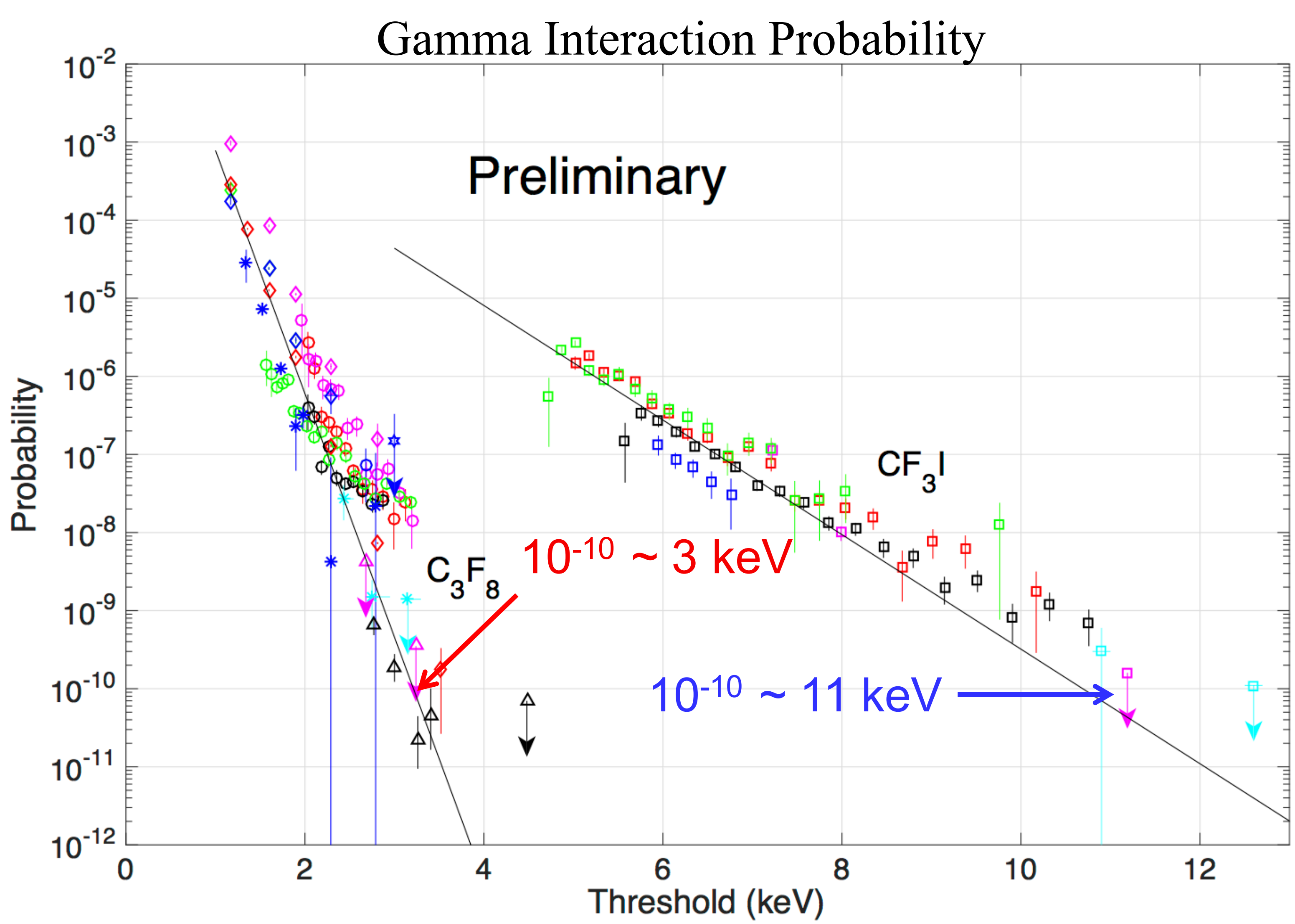


PICO Detectors

- Required:
    - A tank for the target
    - A way to tell that an event has happened
    - A way to recompress the target after an event
- (A little more to it than this, but we can start here)

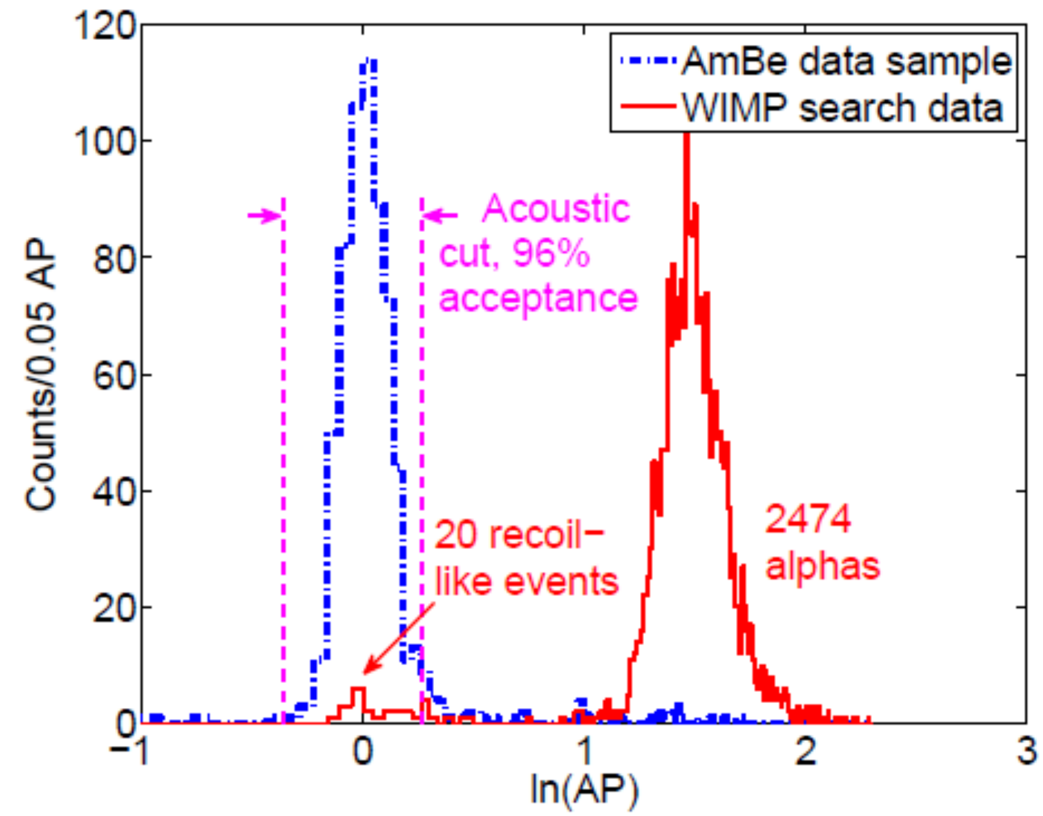
Why use a Bubble Chamber?

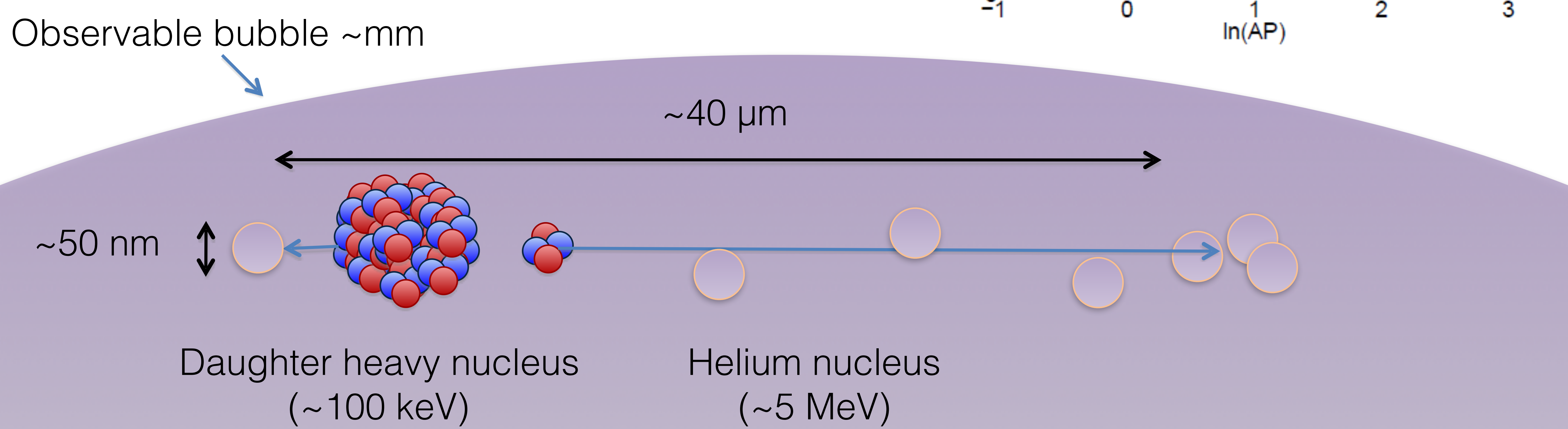
- There are some unique aspects of the bubble chamber that make it attractive
  - Discrimination is one big one



Acoustic Discrimination

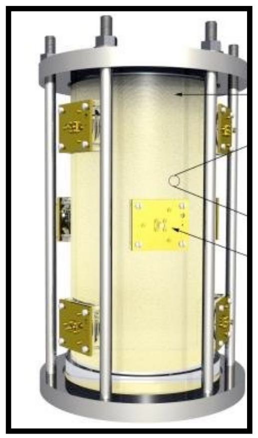
- Alphas deposit their energy over tens of microns
- Nuclear recoils deposit theirs over tens of nanometers



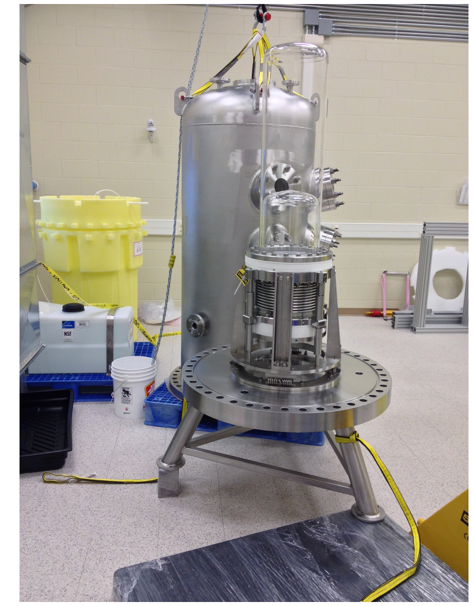


PICO Timeline

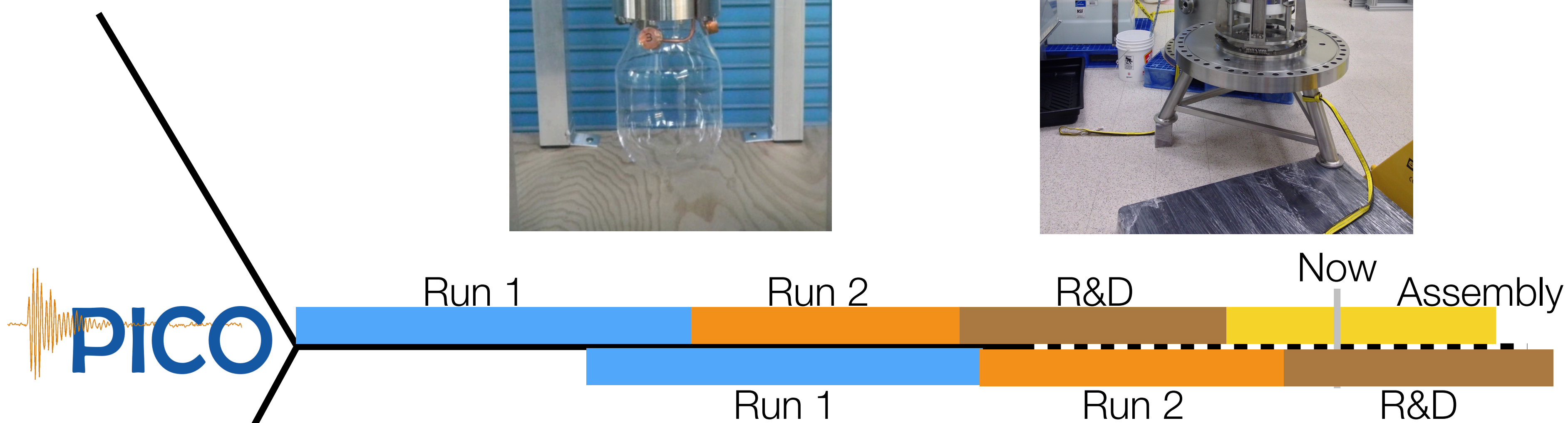
PICASSO

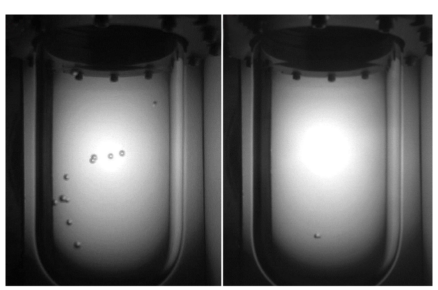


PICO-2L



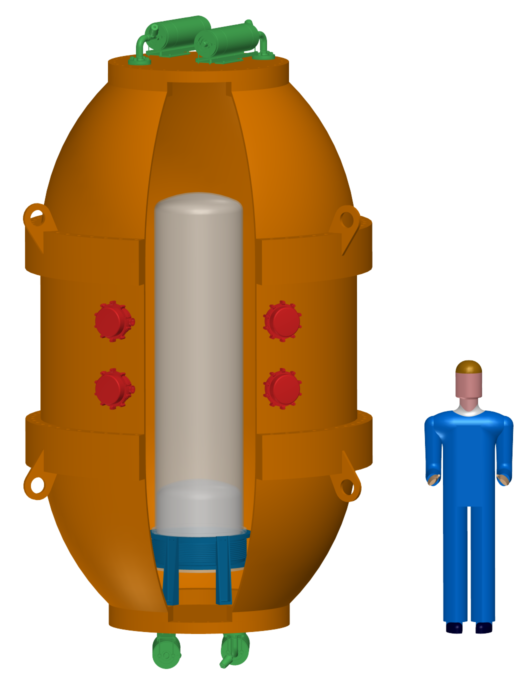
PICO-40L





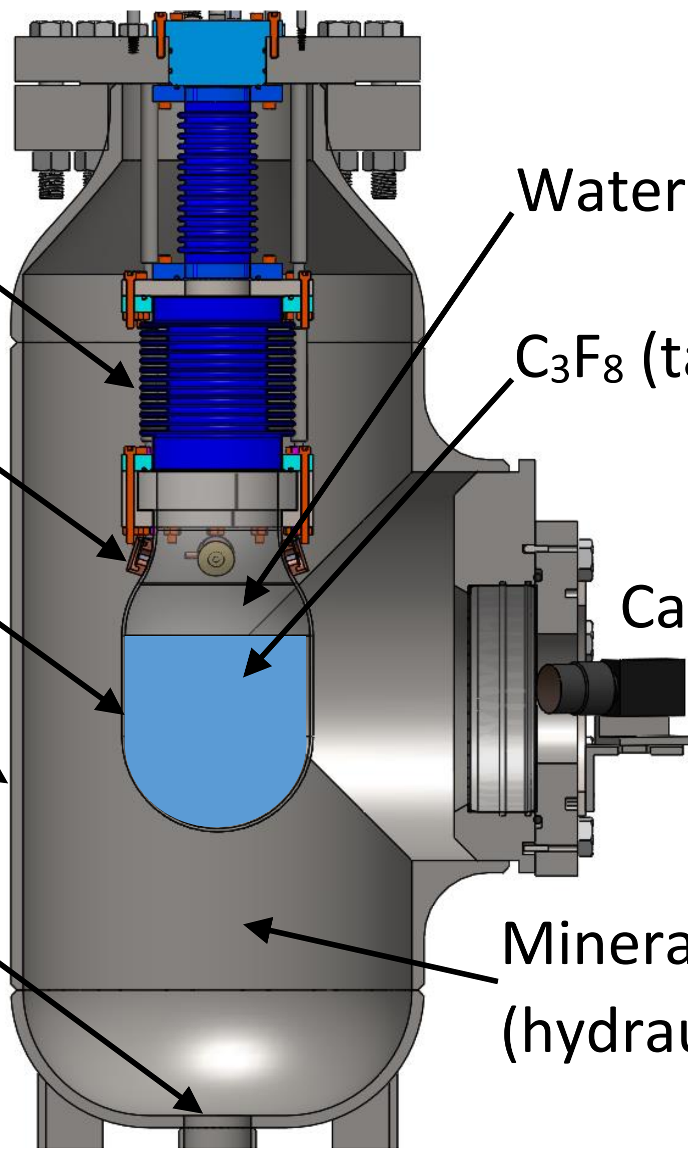
COUPP

PICO-60



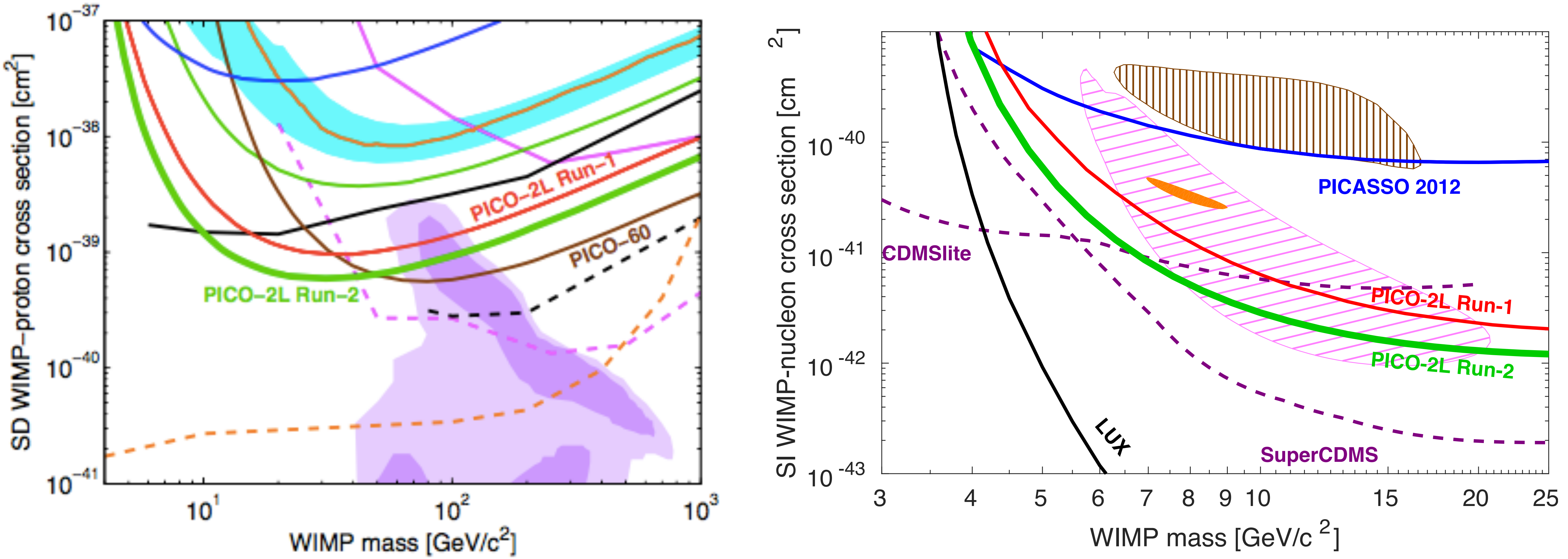
PICO-500

The Distant Past: PICO-2L



- 2L (2.9kg) active mass of C_3F_8
- Change from CF_3I gives better gamma rejection, more active mass for proton-interaction search

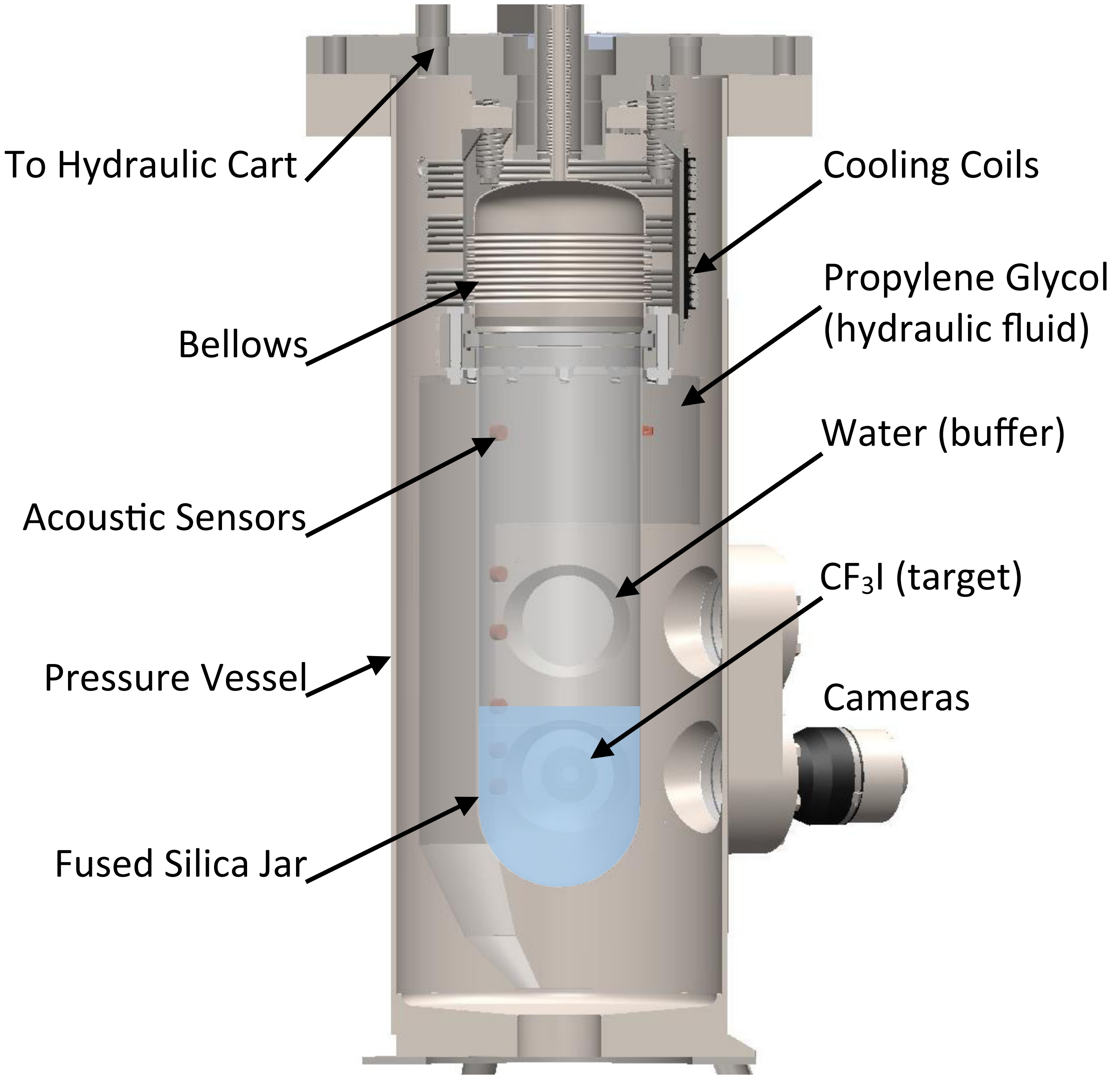
PICO-2L Results



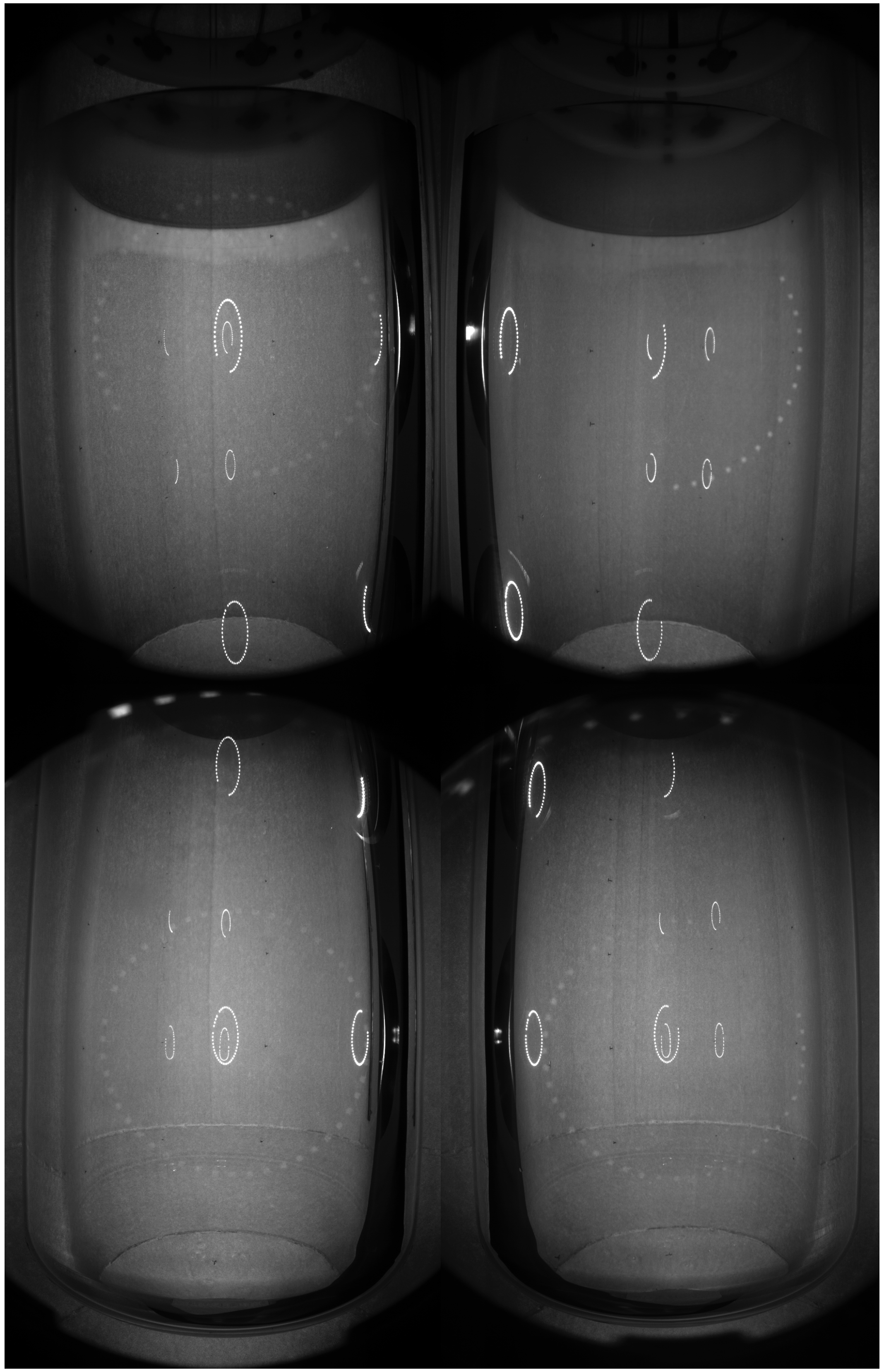
Run 1: Phys. Rev. Lett. 114, 231302 (2015)
Run 2: Phys. Rev. D 93, 061101 (2016)

The Past: PICO-60

- Active material: 36.8kg of C_3FI
- Completed one run with C_3FI, moved on to a second run with a few modifications

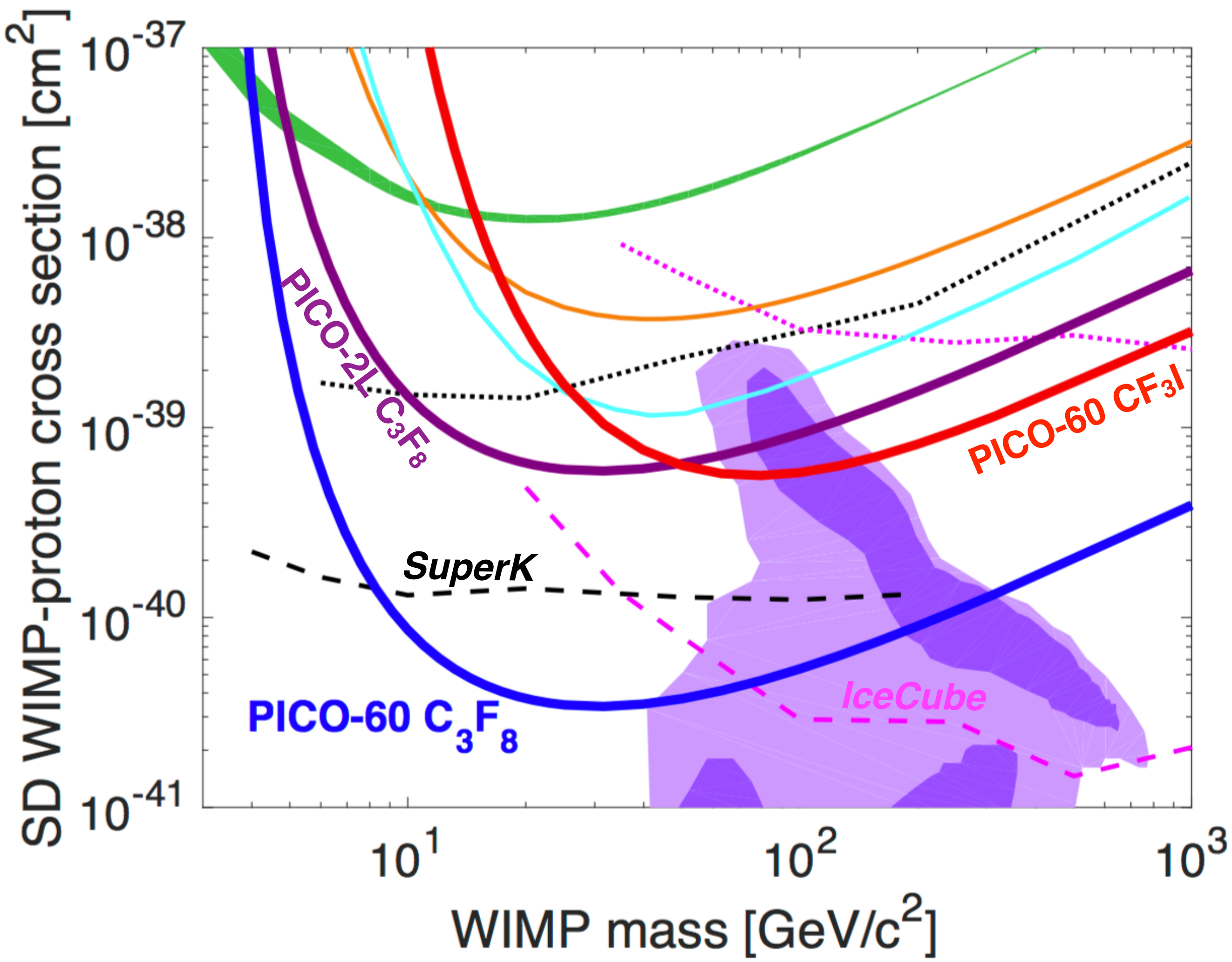


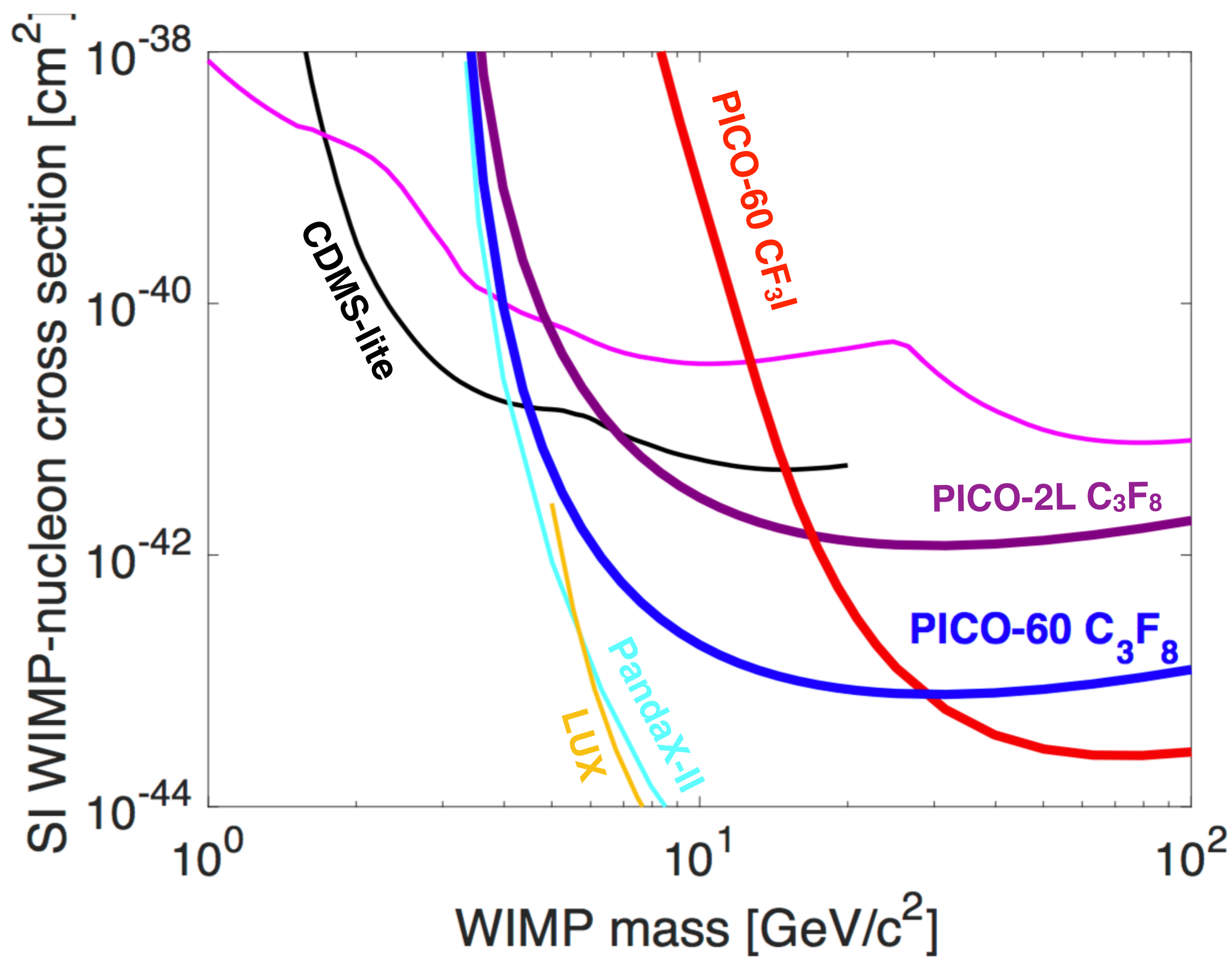
PICO-60 C_3F_8



- Double the number of cameras (from 2 to 4)
    - Doubles the active mass viewed
- Increase the rate to 340 frames per second
- Started taking data August 2016, ended July 2017

PICO-60 Results

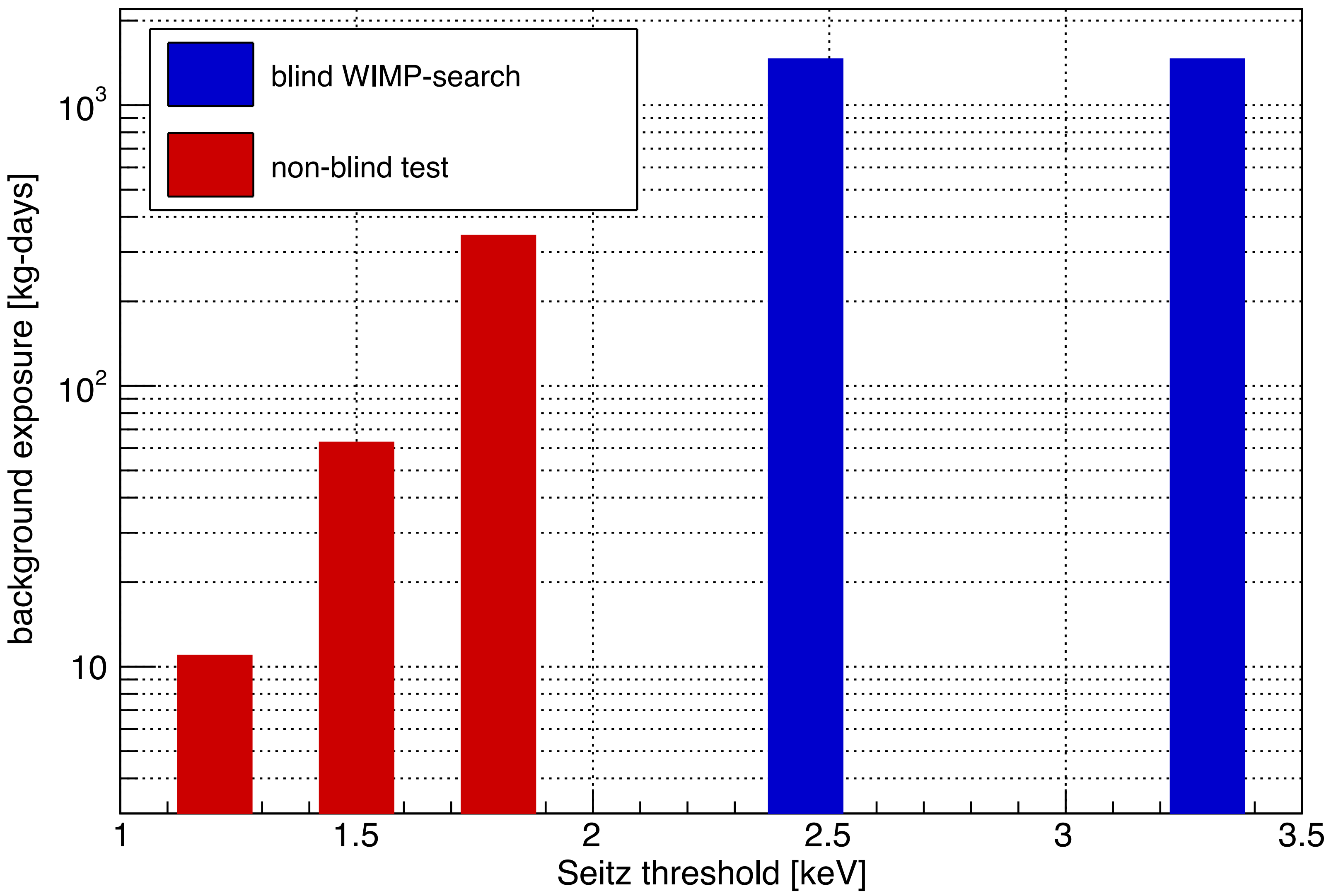




Phys. Rev. Lett. **118**, 251301 (2017)

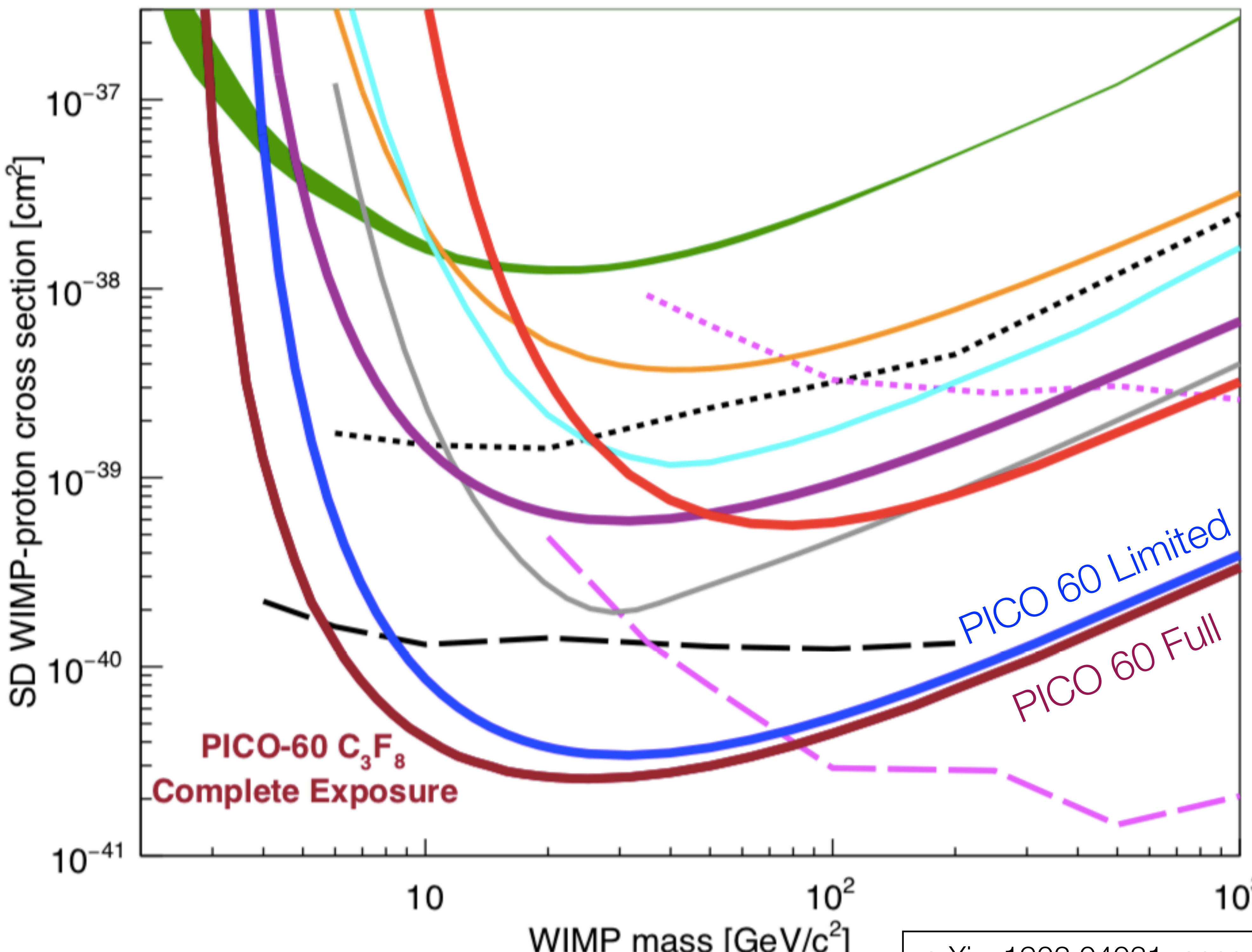
- World leading SD WIMP proton sensitivity for large range of WIMP masses

PICO-60 Lowered Threshold



- Stable operation was achieved at lower thresholds
- Analysis took slightly longer than expected…

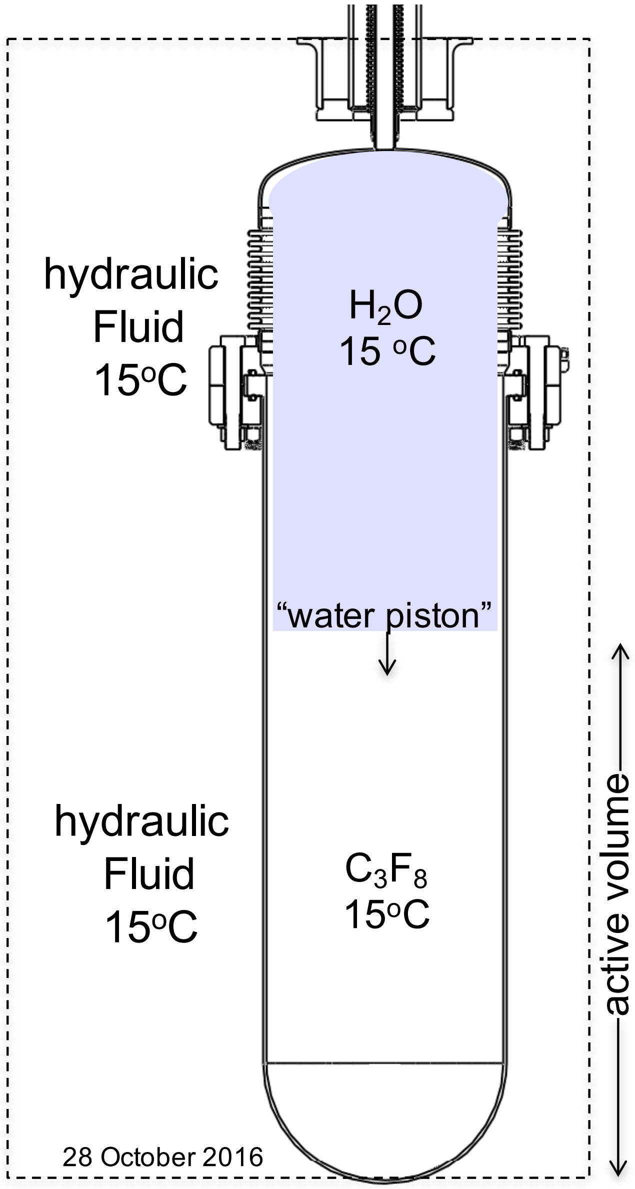
PICO-60 Full Exposure Results



arXiv: 1902.04031, accepted to PRD

The Present

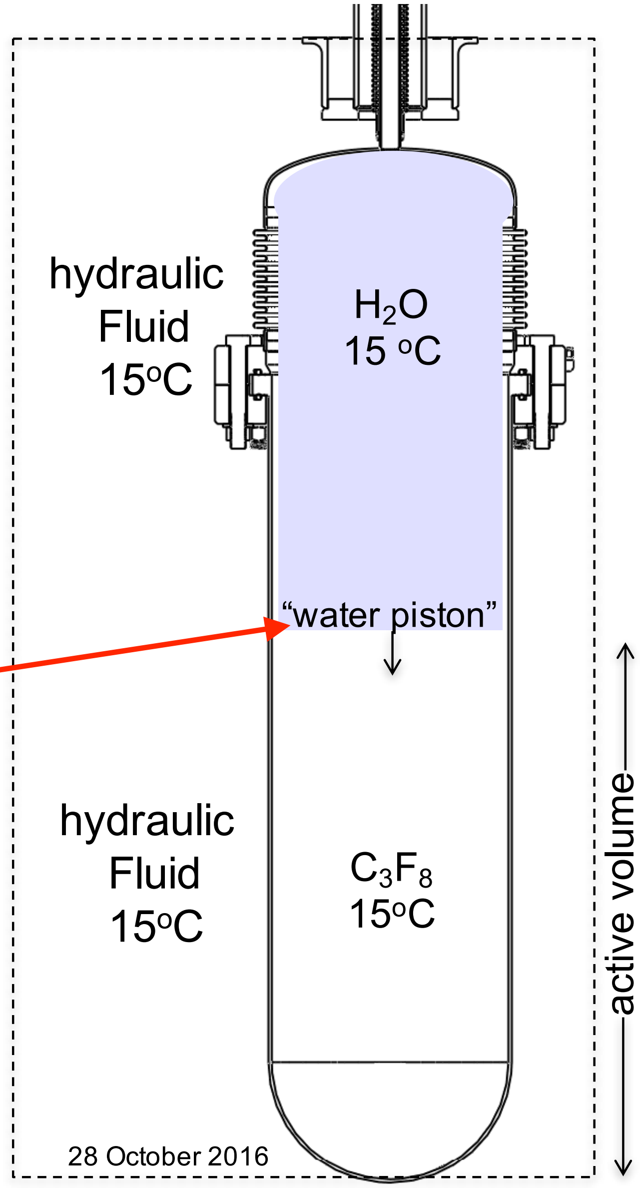
PICO-60



- Many problems seem connected to water/active fluid interface

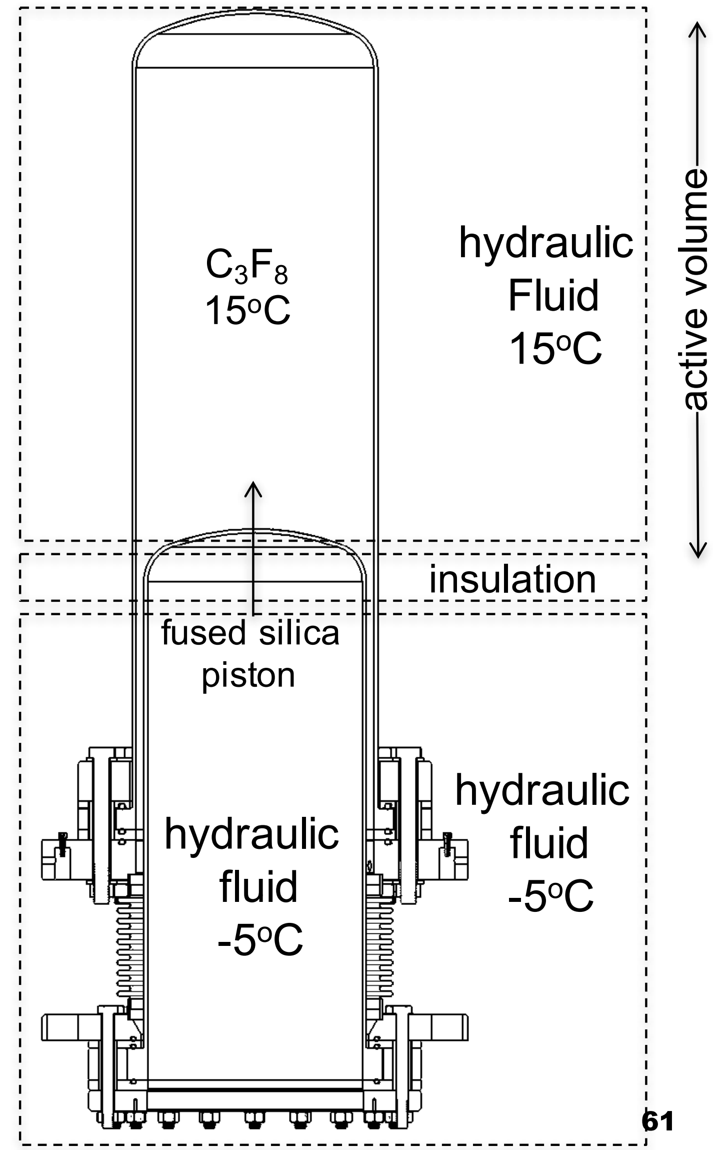
The Present

PICO-60



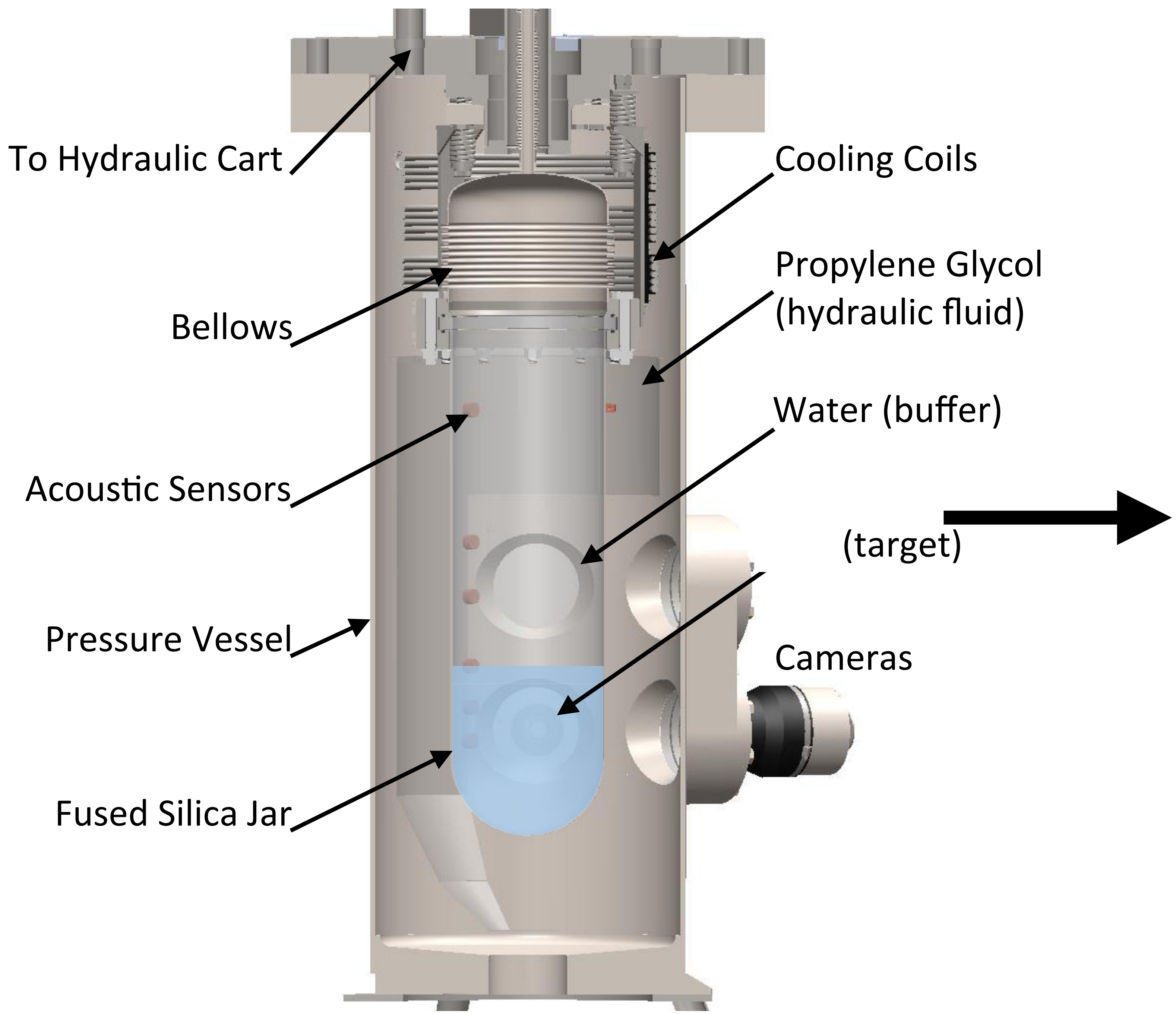
Remove this interface, contact between active fluid H_2O

PICO-40L

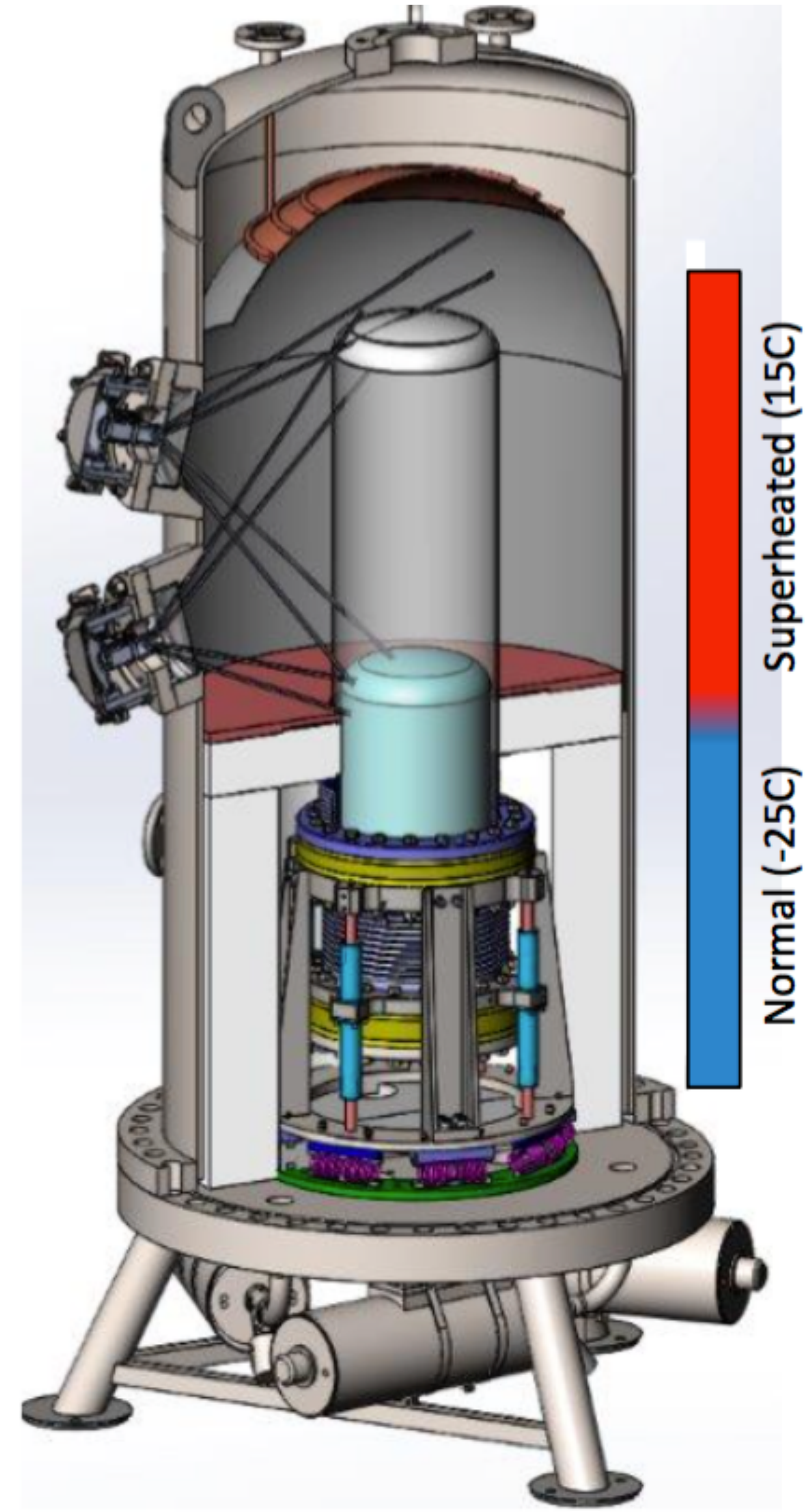


- Many problems seem connected to water/active fluid interface

PICO-40L



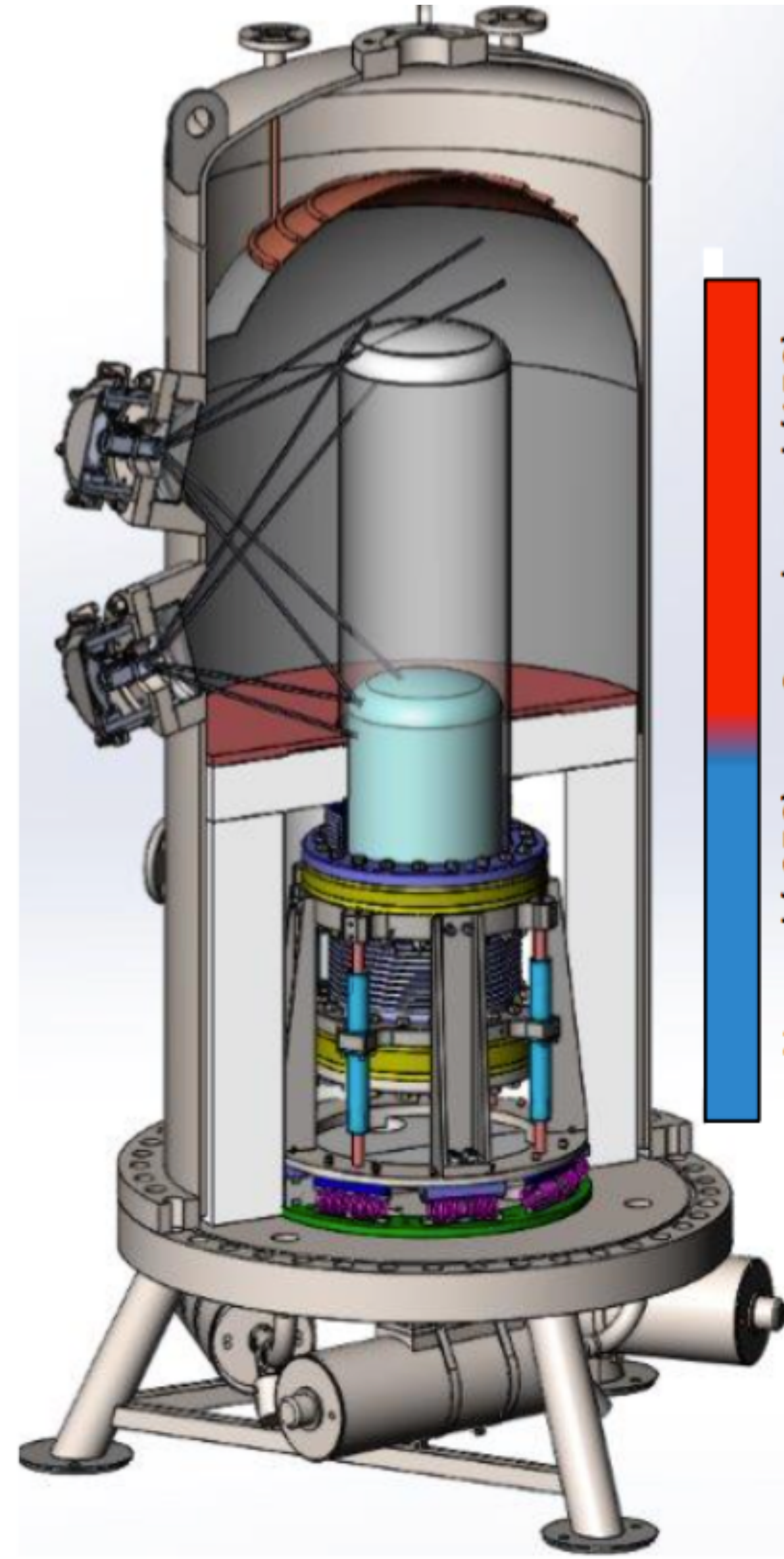
To Hydraulic Cart
Cooling Coils
Propylene Glycol
(hydraulic fluid)
Bellows
Water (buffer)
Acoustic Sensors
(target)
Pressure Vessel
Cameras
Fused Silica Jar



Superheated (15C)
Normal (-25C)

PICO-40L

- Deployed at same location as PICO-60
- Target ~40L C_3F_8
- Synthetic fused silica piston removes water interface
- Larger stainless steel pressure vessel minimizes backgrounds

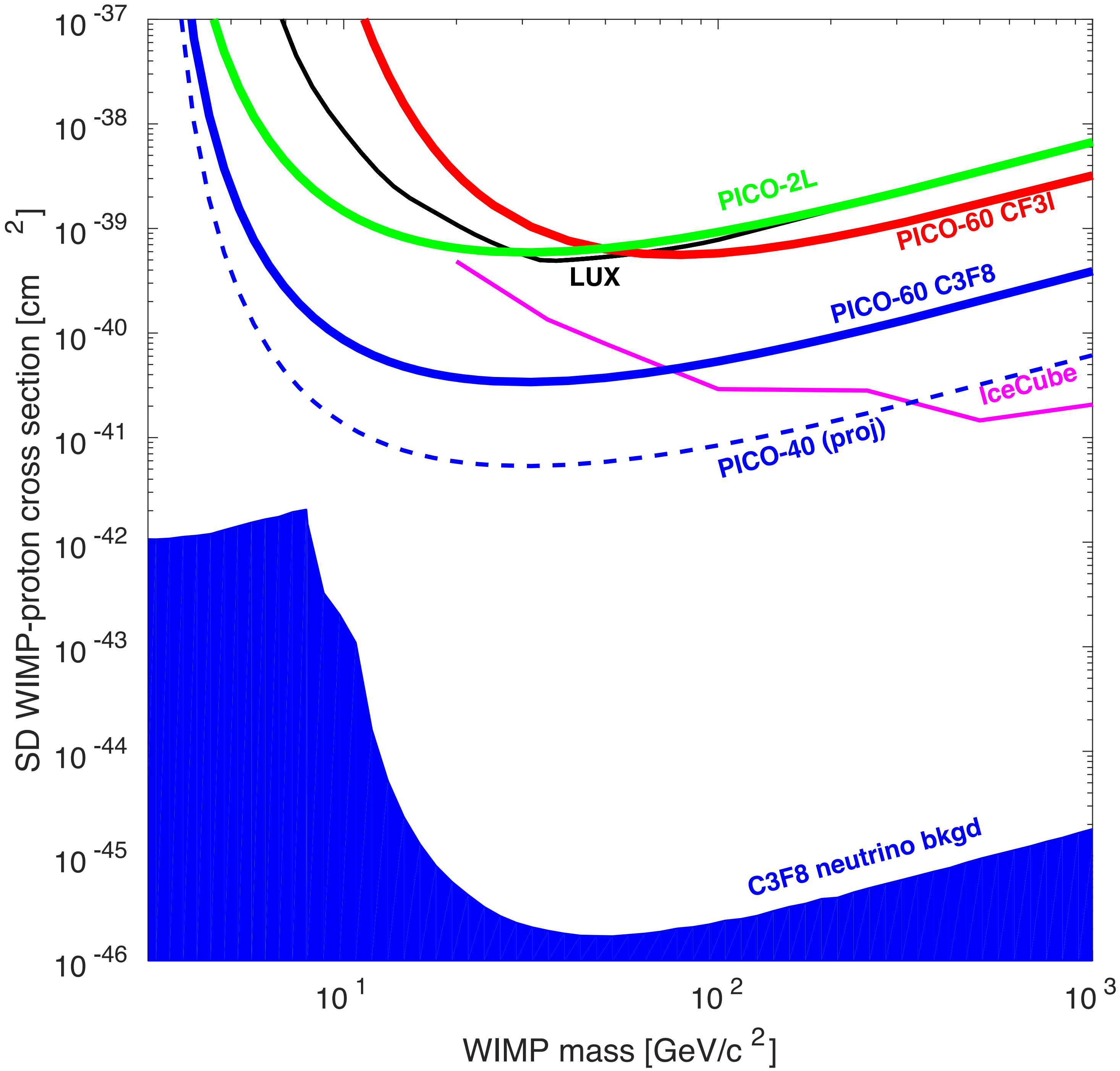


PICO-40L

- Currently commissioning components at SNOLAB
- Completion in July 2019
- Commissioning to extend for a few months
- Data taking for ~a year

PICO-40L Sensitivity

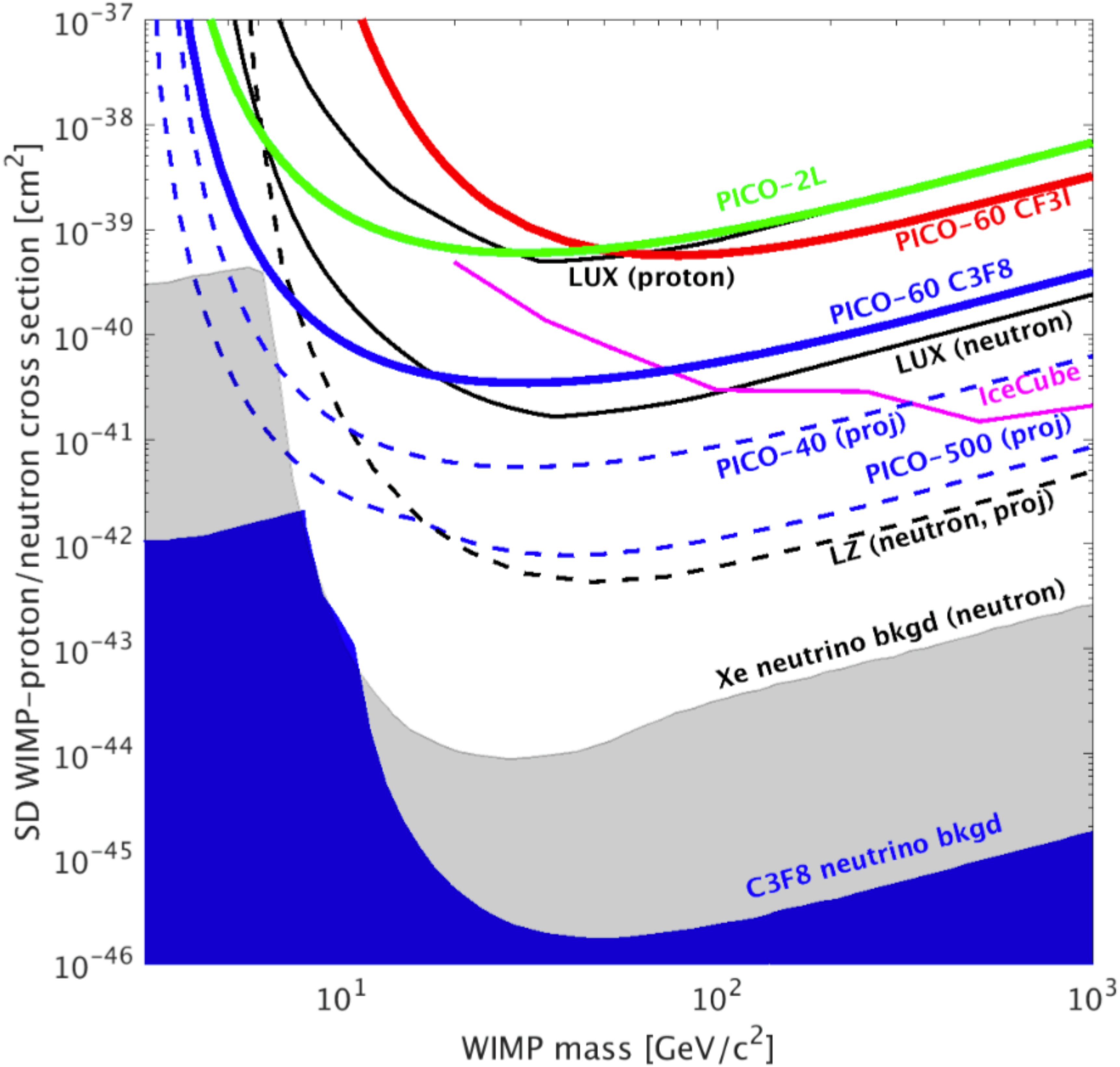
- One year of running with "traditional" threshold of 3.2 keV
- We now think that lower thresholds can be explored with PICO 40L, so this sensitivity limit now appears very conservative



The Future: PICO 500

- Designed to increase sensitivity by an order of magnitude
- Could run C_3F_8 and/or CF_3I or other targets

The Future: PICO 500



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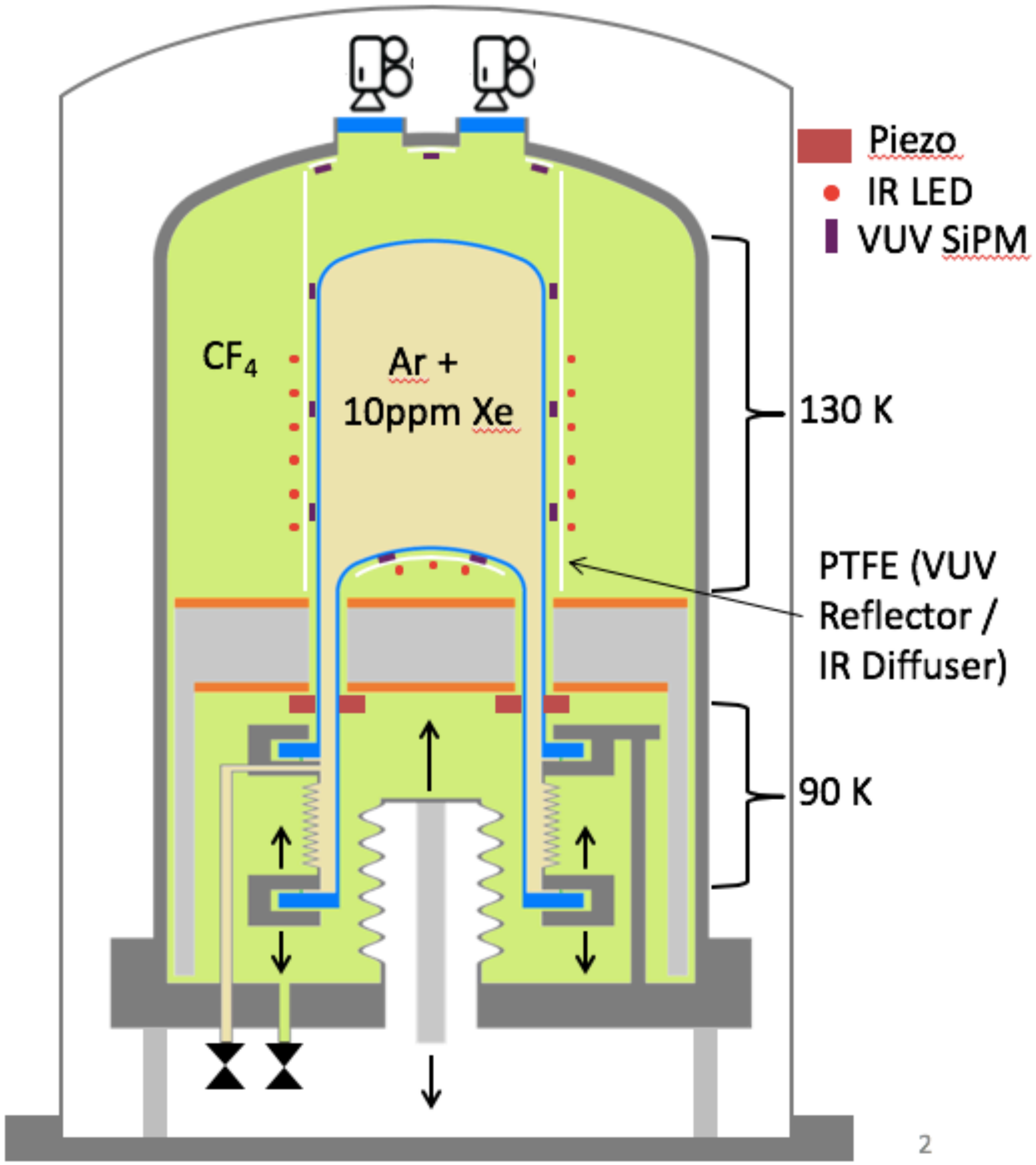
The Further Future



- Identifying a quartz jar manufacturer for PICO 500 was a challenge (although eventually successful)
- New technologies for different materials are being investigated
- A detector using a scintillating target is also being constructed (see poster by Hector Hawley Herrera)

PICO

Northeastern Illinois University
O. Harris

České vysoké učení technické v Praze
R. Filgas, I. Stekl

KICP
Kavli Institute for Cosmological Physics at The University of Chicago
J.I. Collar, A. Ortega

Université de Montréal
S. Chen, M. Laurin, J.-P. Martin, A. Plante, A.E. Robinson, N. Starinski, F. Tardif, D. Tiwari, V. Zacek, C. Wen Chao,

SNOLAB
I. Lawson

Indiana University South Bend
E. Behnke, I. Levine, T. Nania

Universitat Politècnica de València
M. Ardid, M. Bou-Cabo, I. Felis

M. Das, S. Sahoo, S. Seth

Drexel University
M. Bressler, R. Neilson

PennState
D. Maurya, S. Priya, Y. Yan

Fermilab
P.S. Cooper, M. Crisler, W.H. Lippincott, A. Sonnenschein

University of Alberta
C. Coutu, S. Fallows, C. Krauss, M.-C. Piro

Northwestern University
D. Baxter, C.E. Dahl, M. Jin, J. Zhang

iF
E. Vázquez-Jáuregui

Queen's University
B. Broerman, G. Cao, K. Clark, G. Giroux, C. Hardy, C. Moore, A. Noble

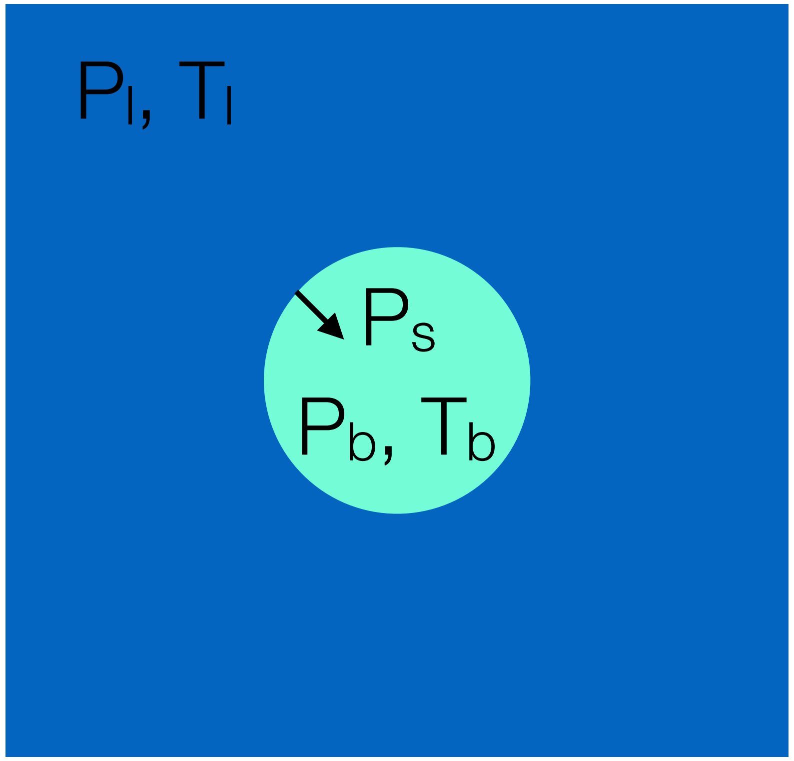
Pacific Northwest National Laboratory
I. Arnquist , C. Cowles, C.M. Jackson, B. Loer, K. Wierman

Laurentian University / Université Laurentienne
J. Farine, A. Le Blanc, C. Licciardi, O. Scallon, U. Wichoski

Queen's University

How does PICO work?

- Start with a bubble in a liquid
- In thermal equilibrium, so $T_l = T_b$
- Also in chemical equilibrium, so $\mu_l = \mu_b$
- P_b is then roughly the vapour pressure at temperature T, and $P_b > P_l$, so the bubble should expand… if there were no surface tension



Calculation of Threshold

- So how is the threshold energy calculated?

$$E_T = 4\pi r_c^2 \left(\sigma - T \left[\frac{d\sigma}{dT} \right]_\mu \right)$$

Surface energy

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

Bulk energy

$$-\frac{4\pi}{3} r_c^3 (P_b - P_l)$$

Reversible work

- Where ρ is the density and *h* the specific enthalpy

Calculation of Threshold

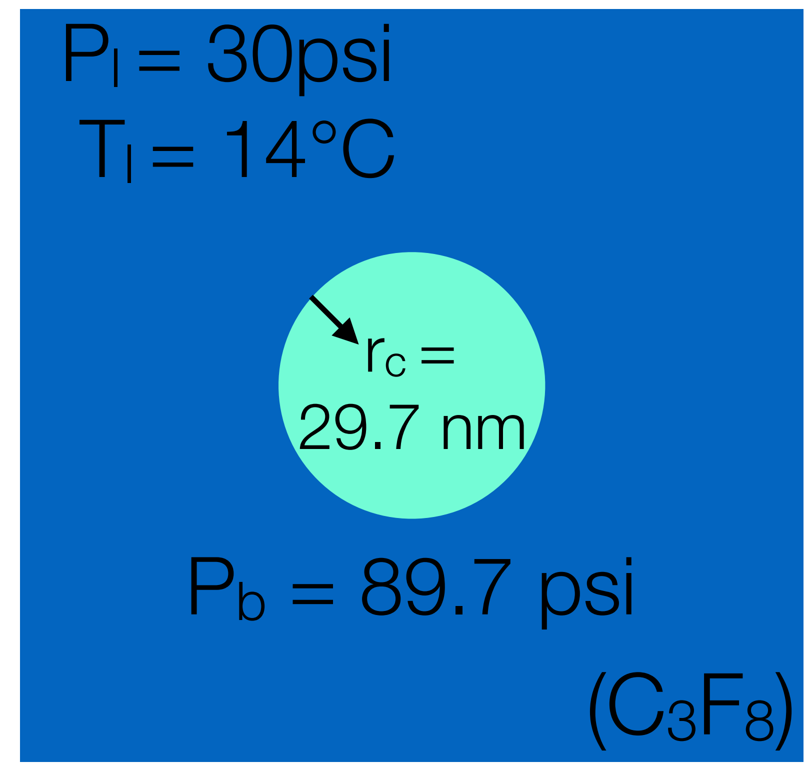
- So how is the threshold energy calculated?

$$E_T = 4\pi r_c^2 \left(\sigma - T \left[\frac{d\sigma}{dT} \right]_\mu \right)$$ 1.53 keV

$$+ \frac{4\pi}{3} r_c^3 \rho_b (h_b - h_l)$$ 1.81 keV

$$- \frac{4\pi}{3} r_c^3 (P_b - P_l)$$ 0.15 keV

3.19 keV



Chamber Operation

- Detector is made sensitive by depressurizing chamber
- Use video for trigger, acoustically monitor as well
- A trigger causes pressurization to force back into liquid state