Search for Dark Matter with bubble chambers

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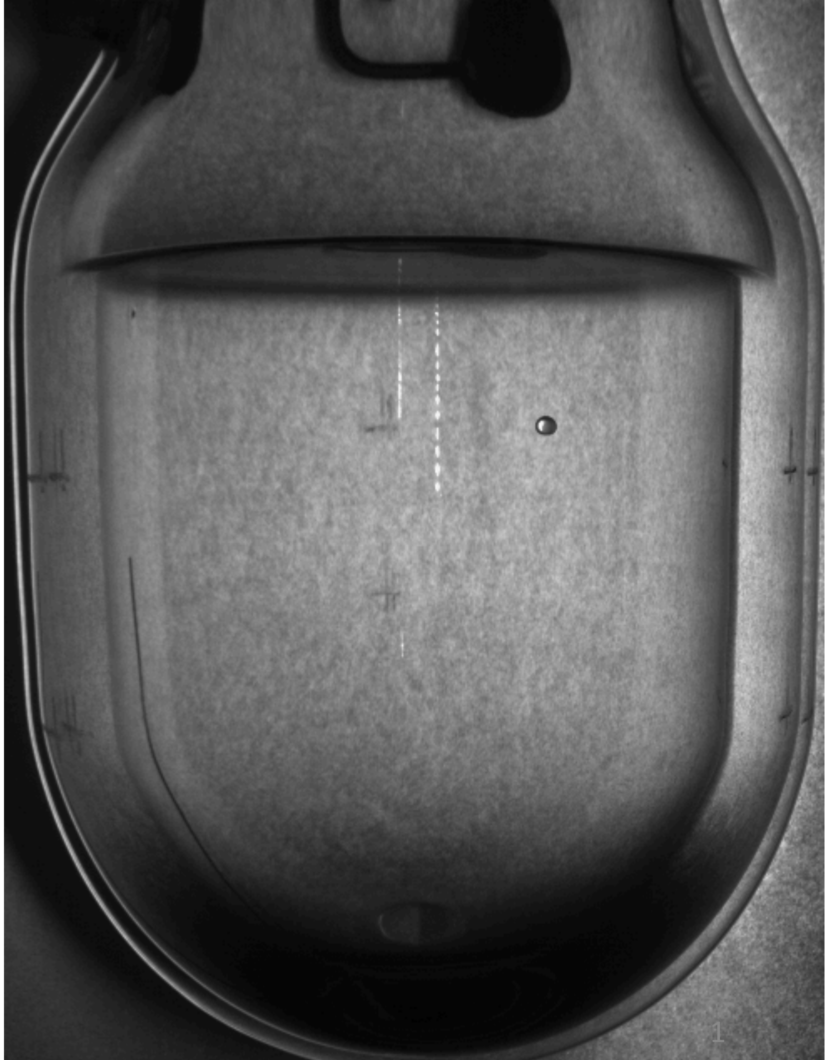
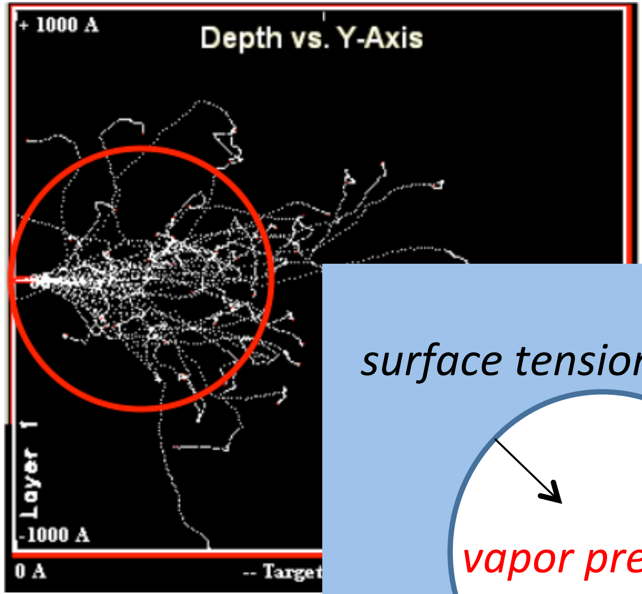
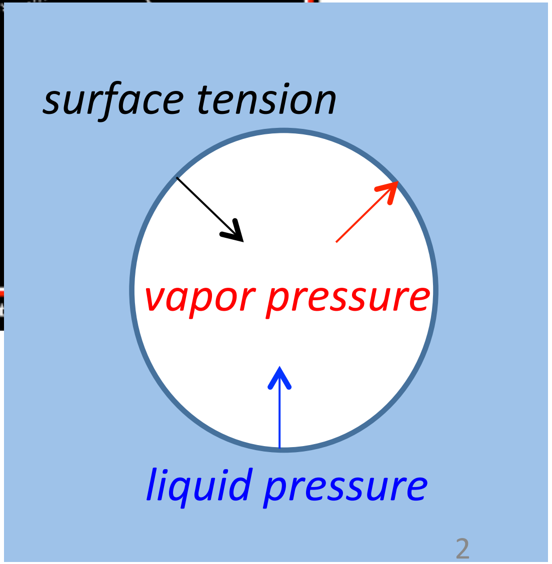
APS DPF 2017



Bubble chamber: theory

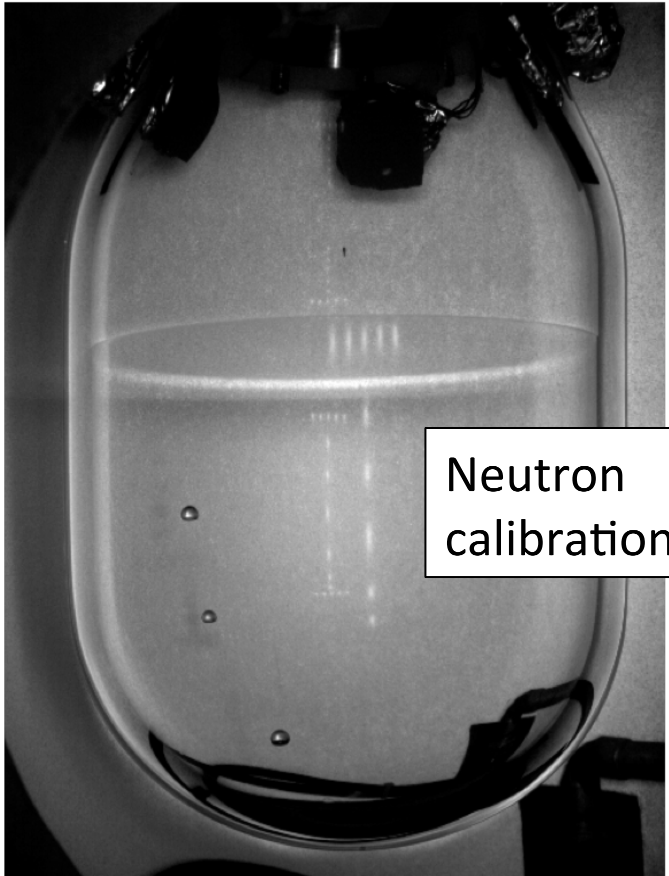
- In a superheated fluid, bubbles will collapse unless they are large enough (r_c) to overcome surface tension: must deposit E_{th} in a radius less than r_c
  → E_{th} & E_{th}/r_c = dE/dx threshold
- Threshold based on theory of Seitz (Phys. of Fluids I, 2 (1958))
  For a given fluid:
  Classical Thermodynamics gives E_{th}, r_c in terms of P, T





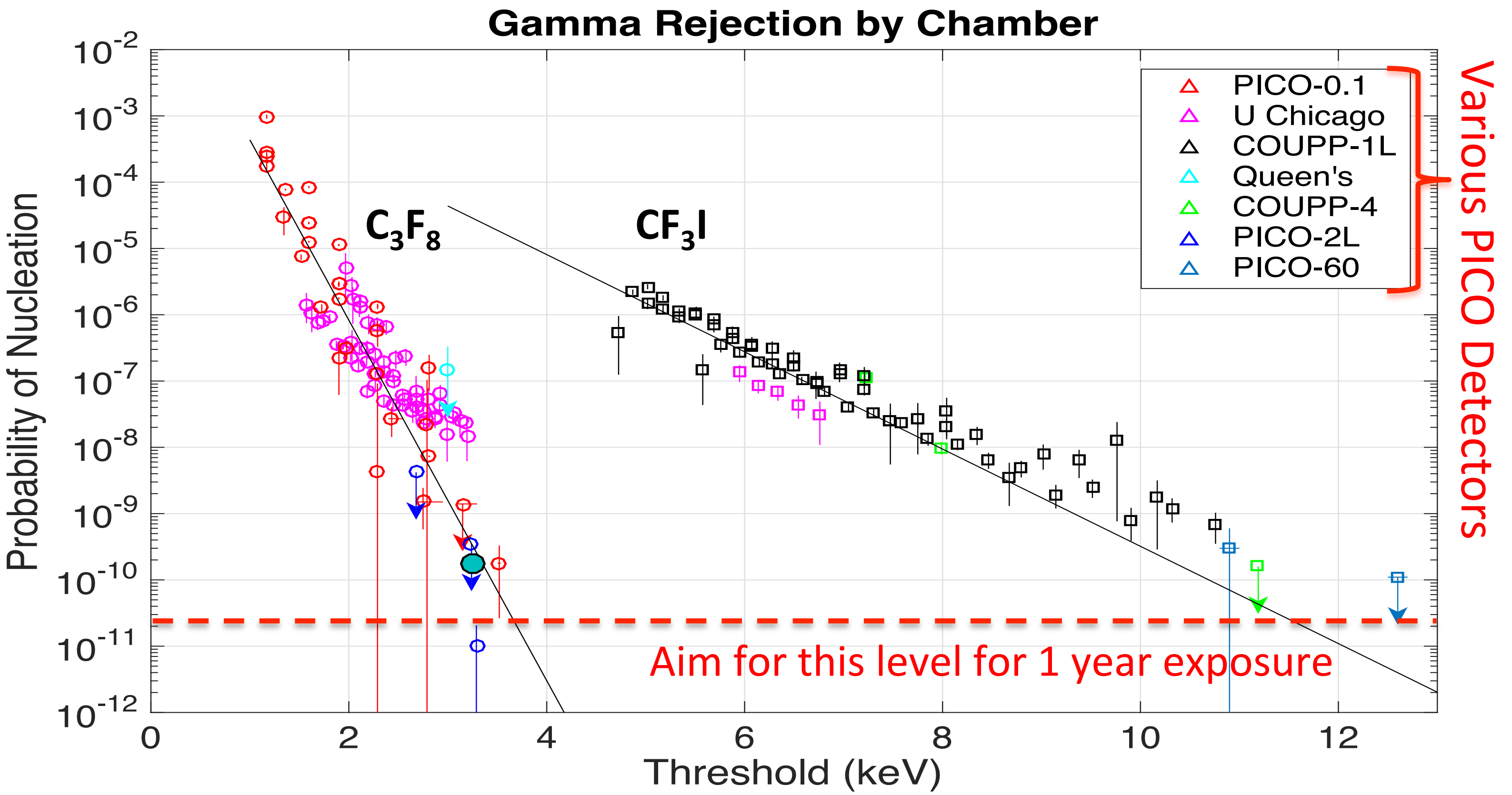
Pressure & temperature → min energy, dE/dx threshold → sensitive to nuclear recoils but not electron recoils

1950s-1970s



Neutron calibration event

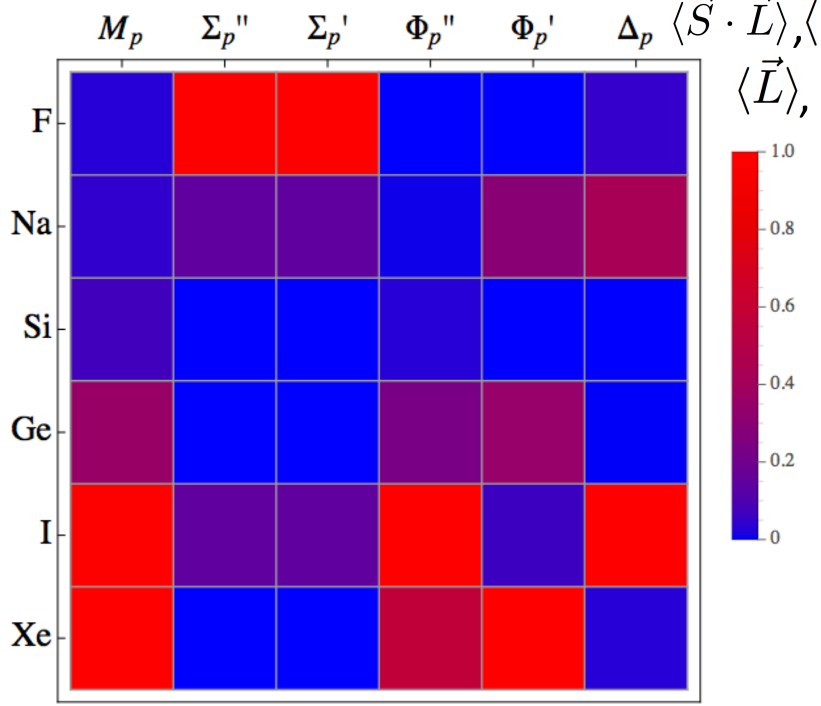
Gamma/Beta Backgrounds



Nuclear target

- Big advantage of bubble chambers is the ease of changing nuclear target (lot's of candidate refrigerants)
- Previously used CF_3I (I for SI sensitivity, F for SD sensitivity), now using C_3F_8 (focusing on SD sensitivity, low mass)

Response functions

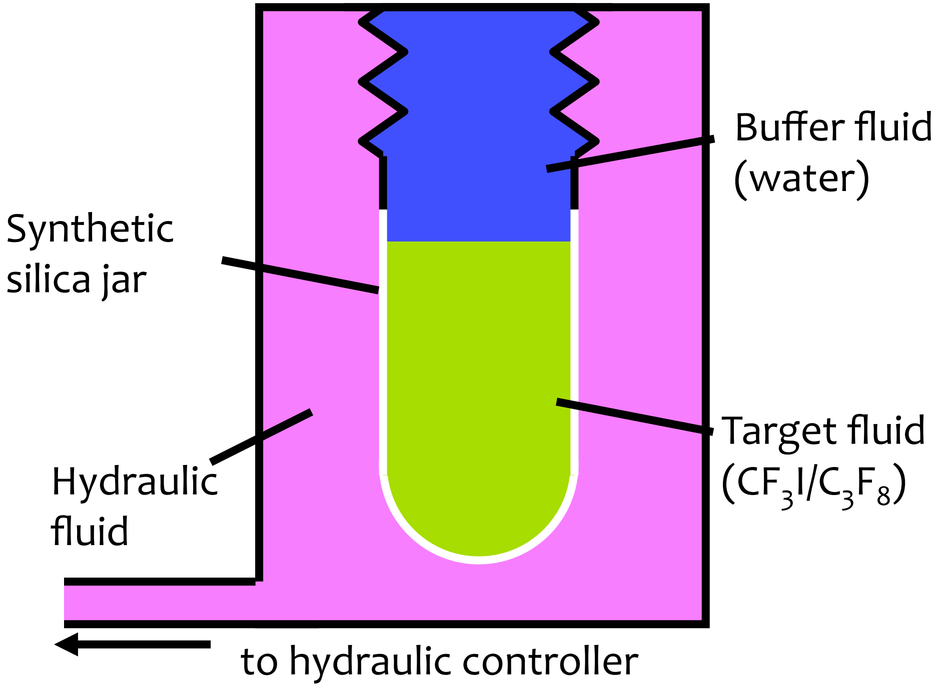


$\langle \vec{S} \cdot \vec{L} \rangle$, $\langle \vec{S} \rangle$, $\langle \vec{L} \rangle$, etc

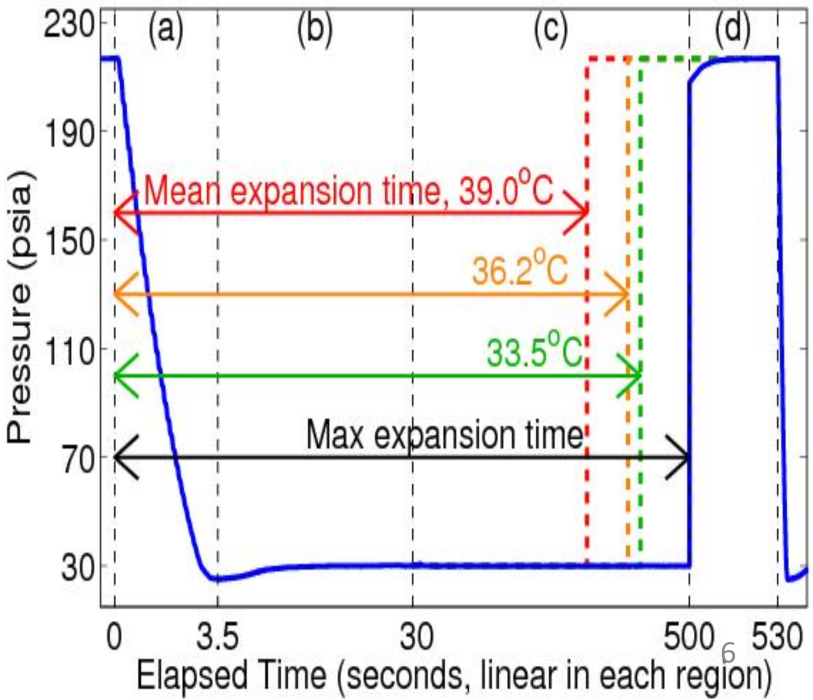
A. L. Fitzpatrick, see also: 0908.2991, 1203.3542, 1211.2818, 1308.6288

PICO Bubble chamber operation

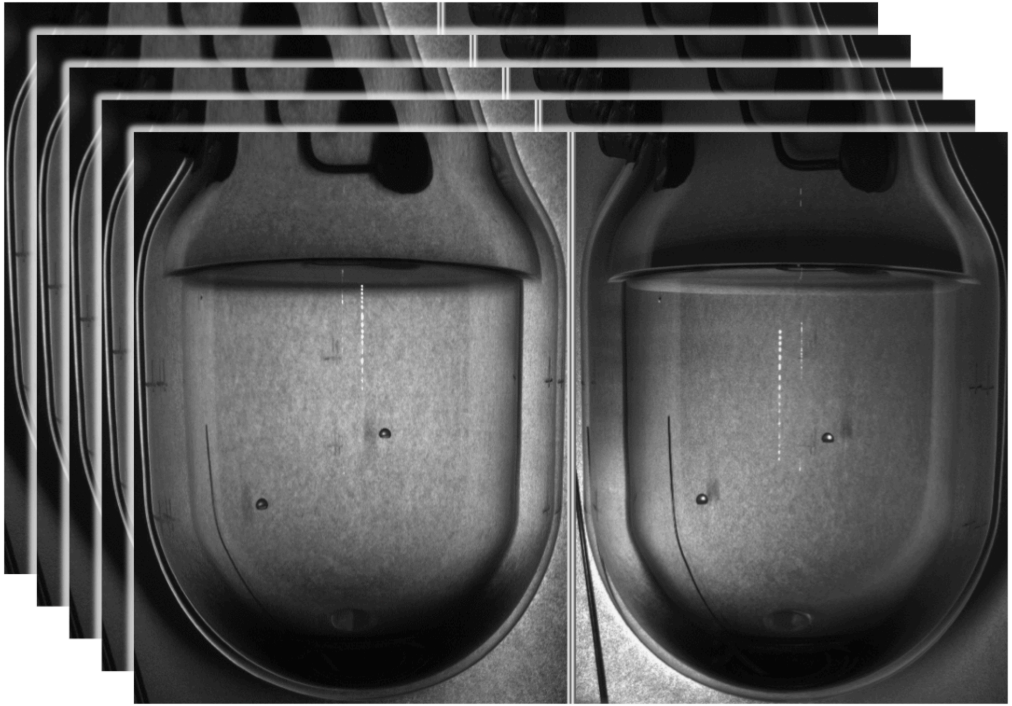
Pressure expansion puts target fluid in superheated state



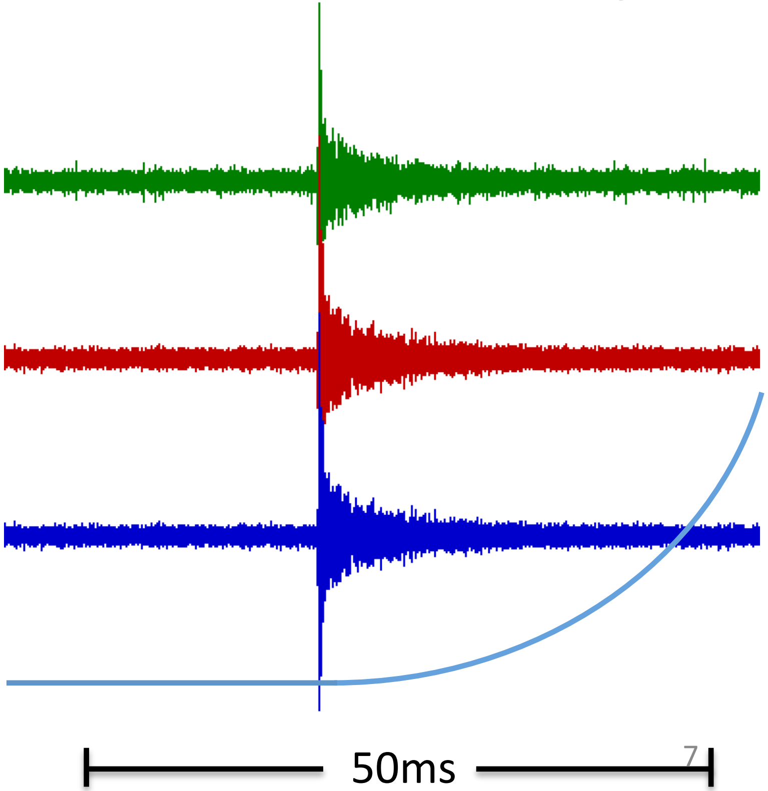
Wait for particle interaction to nucleate a bubble, recompress



Cameras capture stereoscopic bubble images @ 100 fps (primary trigger)

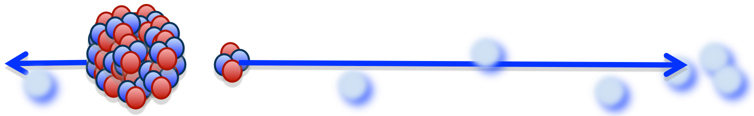


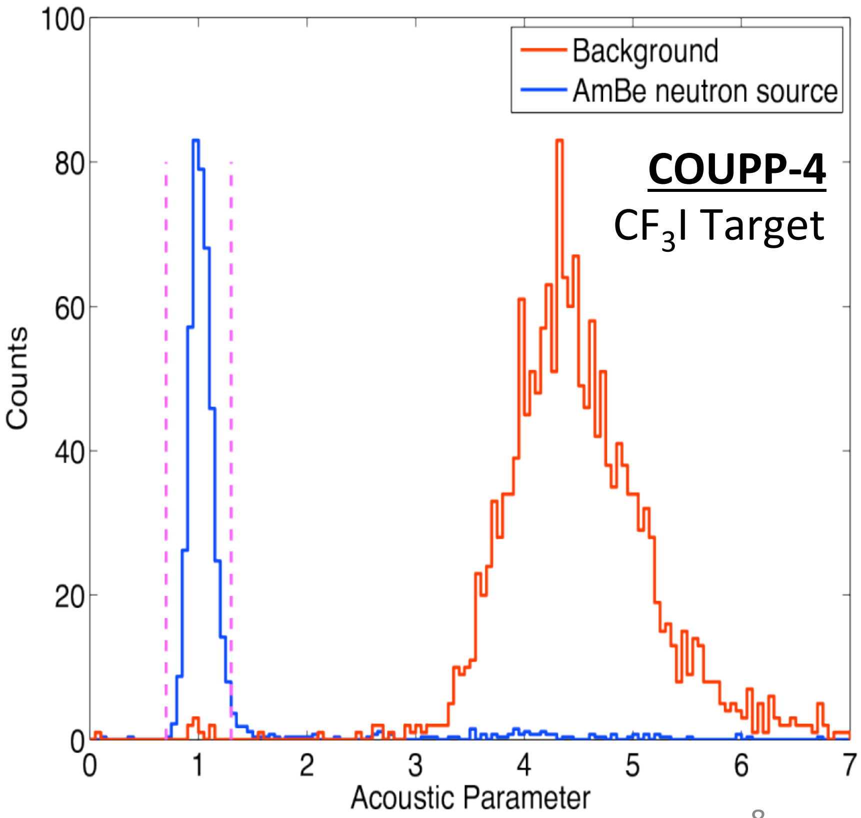
Acoustic sensors & fast pressure transducer capture sound & pressure rise from bubble growth



Acoustic discrimination of α's

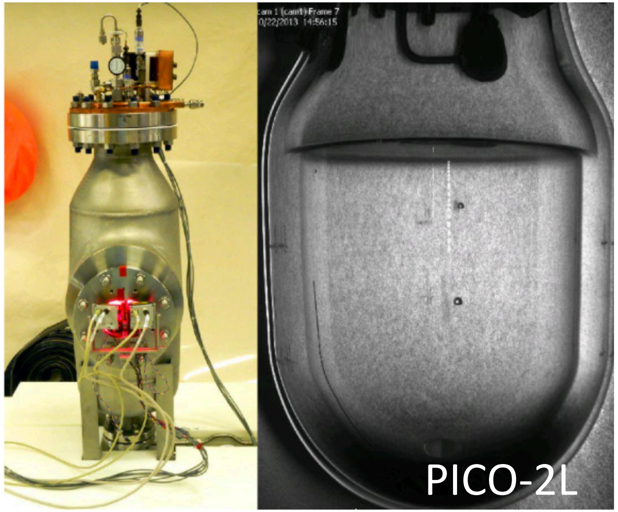
- Clear acoustic signature of single nuclear recoil (track < ~µm)
- Sound emission peaks at $r_{bubble} \approx 10\ \mu m$
- α track much larger (~40 µm)
  → separate nucleation sites
  → <u>α's several times louder</u>

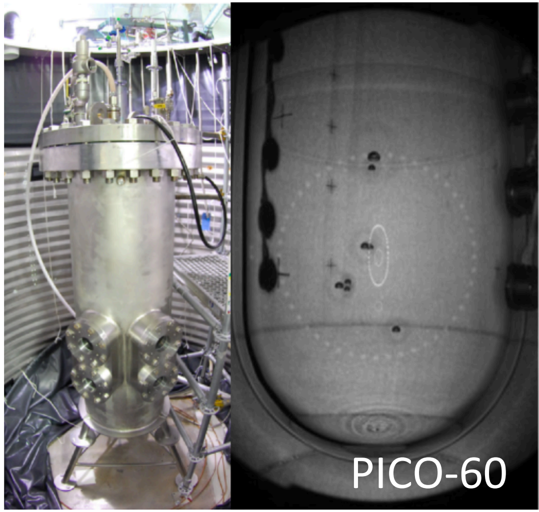


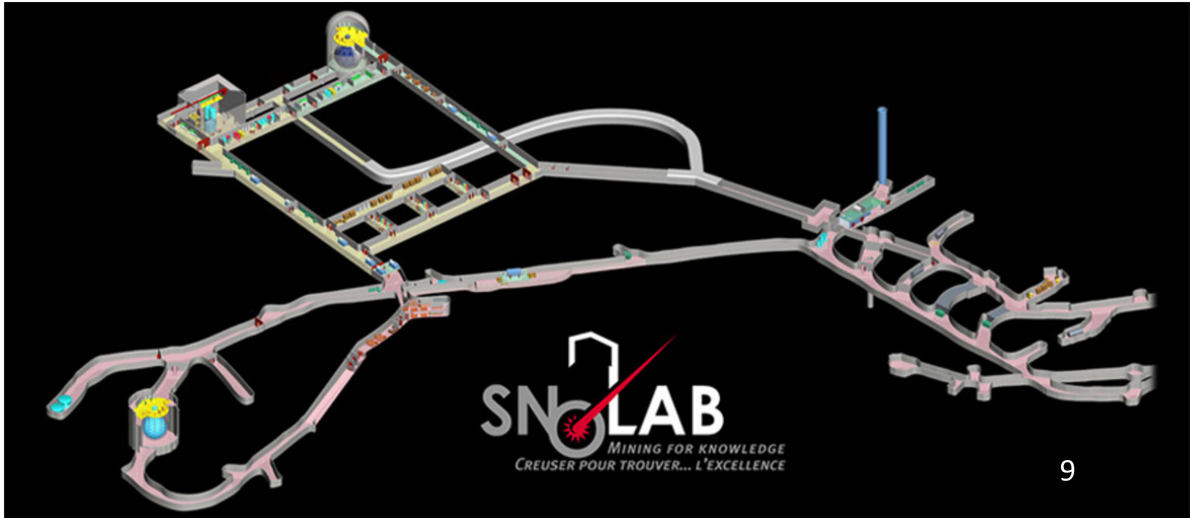


The PICO program

- PICO: merger of **PI**CASSO and **CO**UPP collaborations
- PICO-2L C_3F_8 (2014-17)
  - C. Amole *et al.*,
    Phys. Rev. Lett. **114**, 231302 **(2015)**
  - Phys. Rev. D **93**, 061101 **(2016)**
- PICO-60 CF_3I (2013)
  - Phys. Rev. D **93**, 061101 **(2016)**
- PICO-60 C_3F_8 (2016-17)
  - Phys. Rev. Lett. **118**, 251301 **(2017)**
- PICO-40L (2017-18)
- PICO-500 (future)

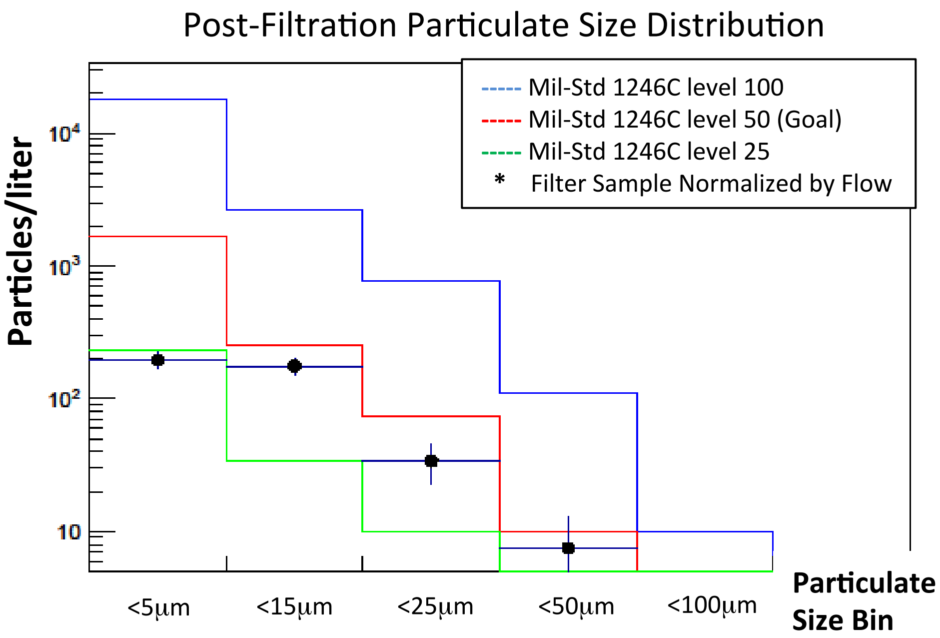






PICO-60 Cleaning

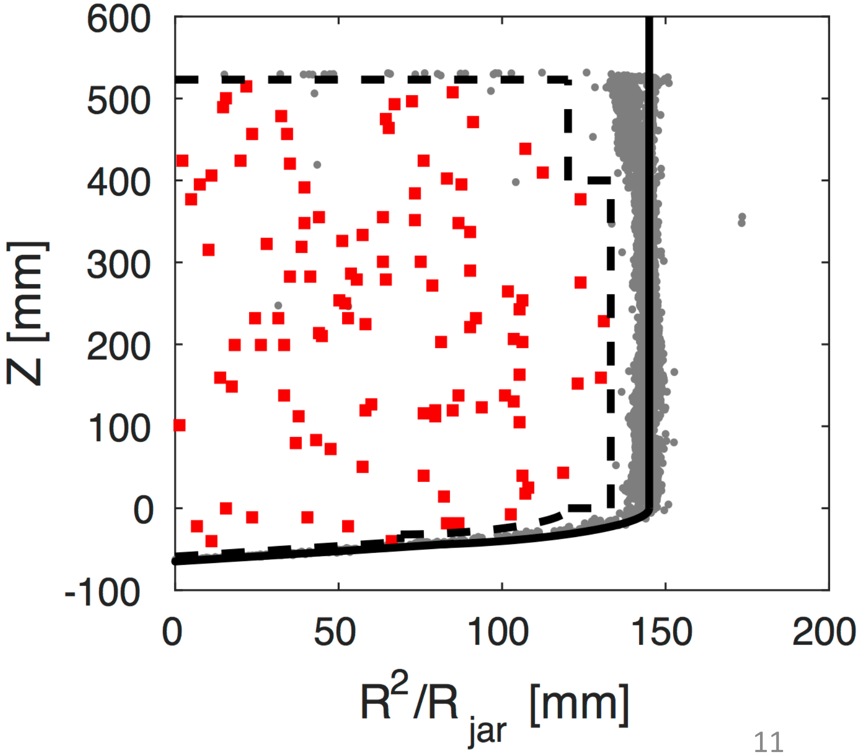
- Every component touching the inner volume was cleaned against MIL-STD-1246C level 50



PICO-60 run with blinded acoustics

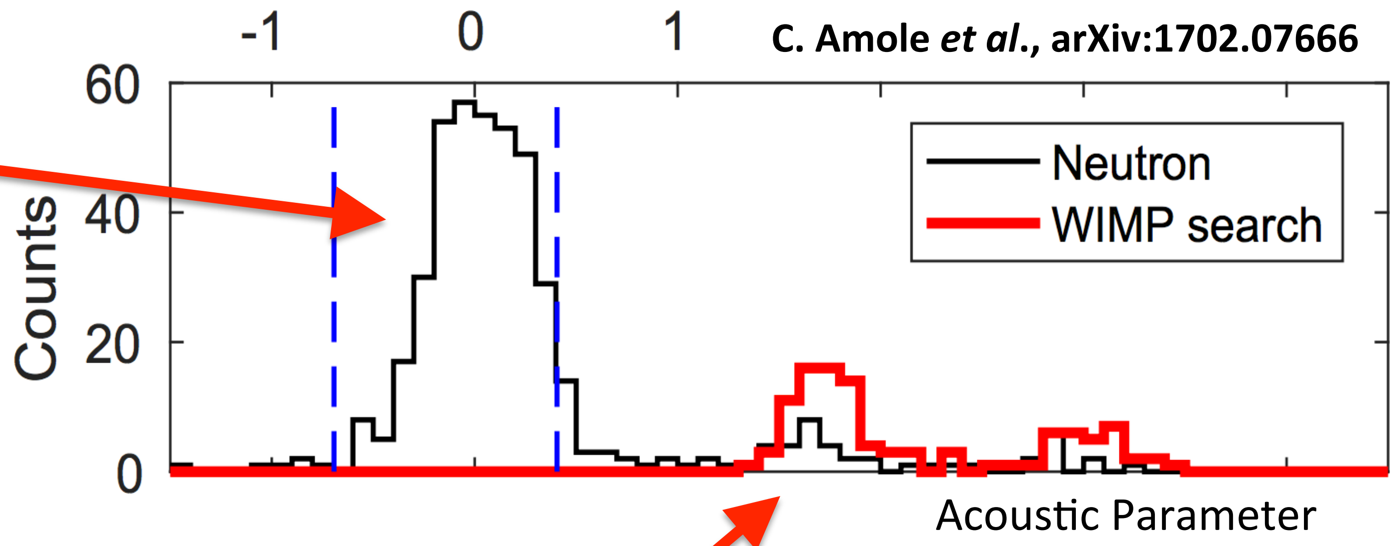
- Filled with 52 kg C_3F_8 in June, 2016
  - Blind analysis on data from November 2016 and January 2017 1167-kg-days at 3.3 keV threshold
- 106 bulk singles in WIMP search dataset
  - Consistent with ^{222}Rn decay rate
- Expected Neutron Background
  - 3 multiple bubbles in the physics data
  - 3:1 multiples to singles ratio from calibration and simulation
  - **0-3 bulk singles would be consistent with neutrons and no anomalous background**

C. Amole *et al.*, arXiv:1702.07666



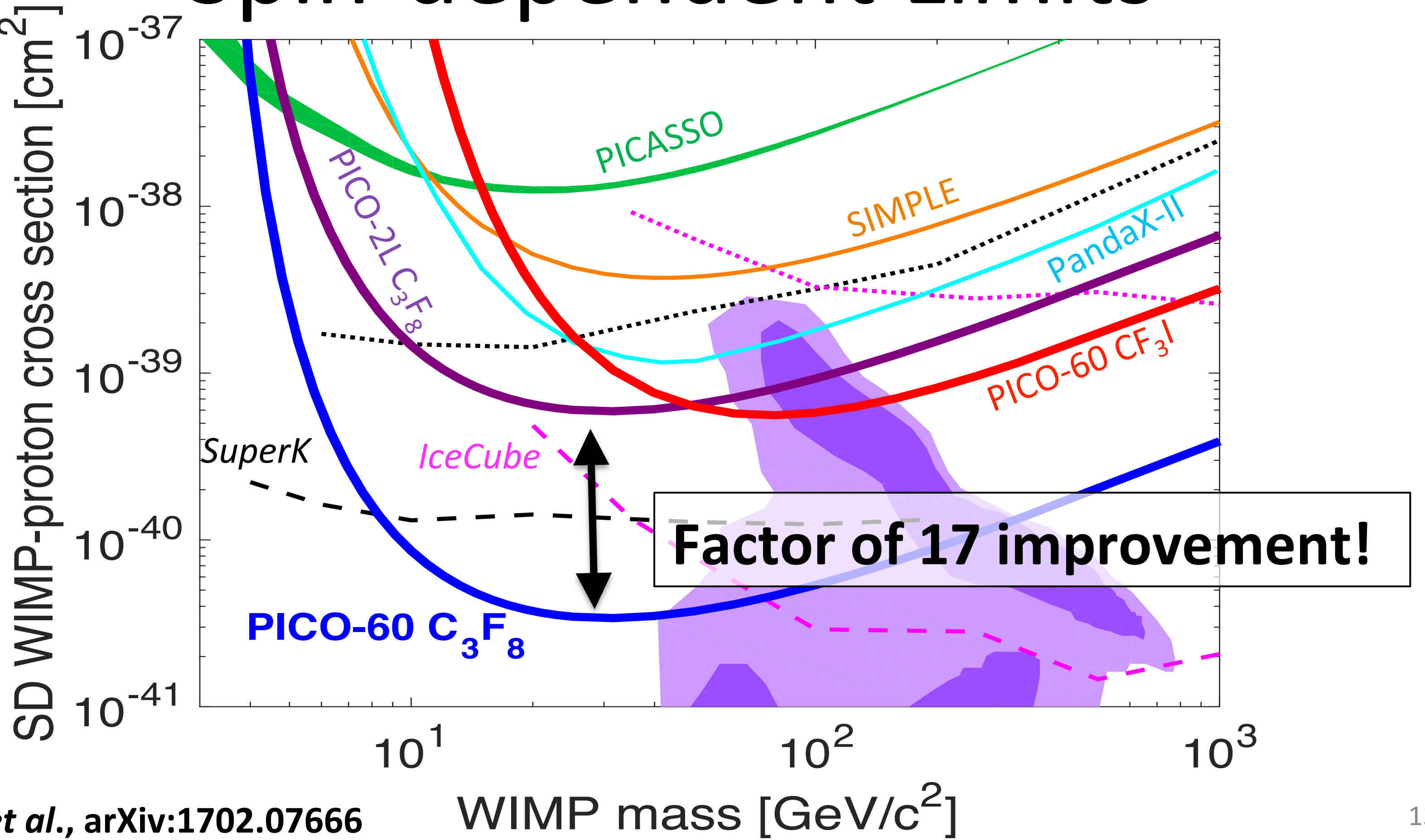
After Opening the Box

No events in signal region!



Radon chain alphas

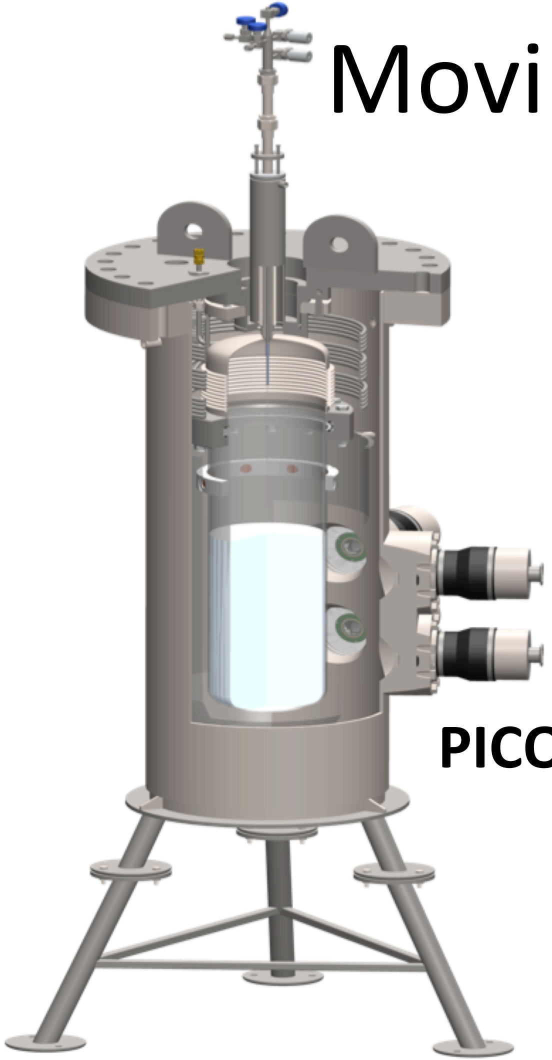
Spin-dependent Limits



C. Amole *et al.*, arXiv:1702.07666

Moving forward: PICO-40L

Eliminate buffer fluid

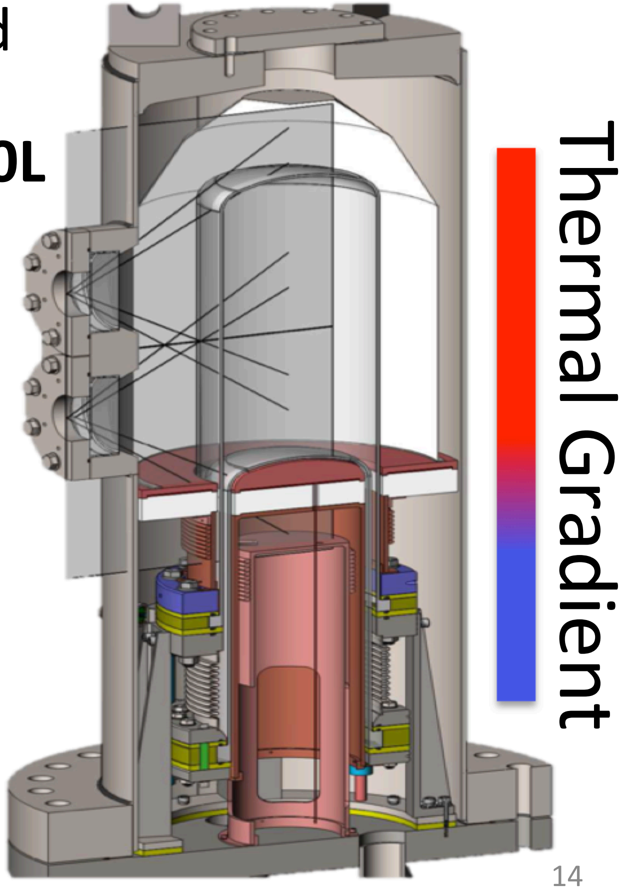


PICO-60

Purpose of buffer liquid is to isolate the active liquid from the stainless parts

PICO-40L

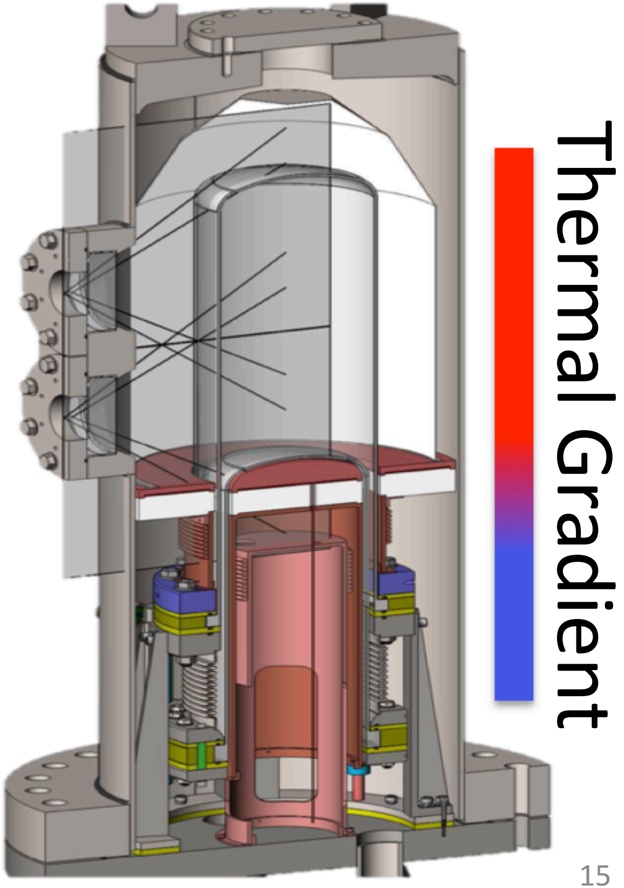
Thermal gradient can ensure that target fluid near stainless parts is not active



Summary

- PICO bubble chambers at the 40L scale are background-free
- PICO dominates the search for spin-dependent WIMP-proton coupling
- PICO-40L: Design changes expected to further improve bubble chamber stability and lower neutron background, deployment this year
- Ton-scale PICO-500 in engineering stage, goal: data taking in 2019

PICO-40L



PICO

SNOLAB – Mining for knowledge / Creuser pour trouver... l'excellence
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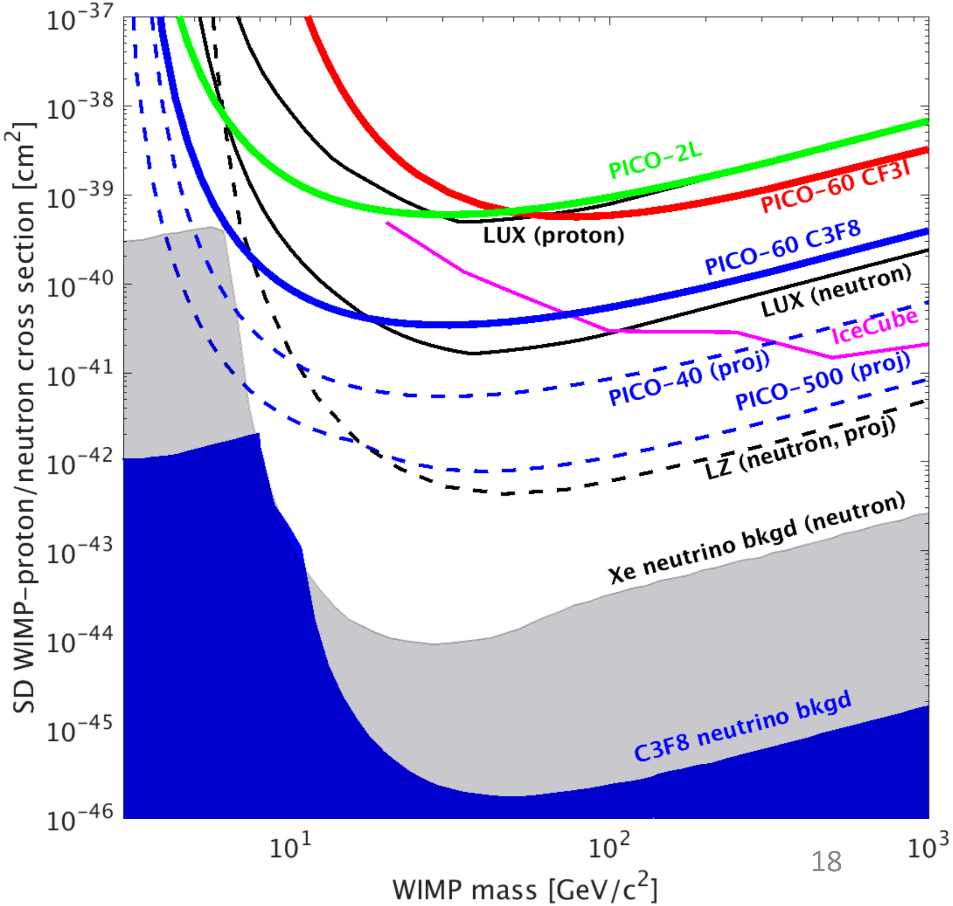
BACKUP

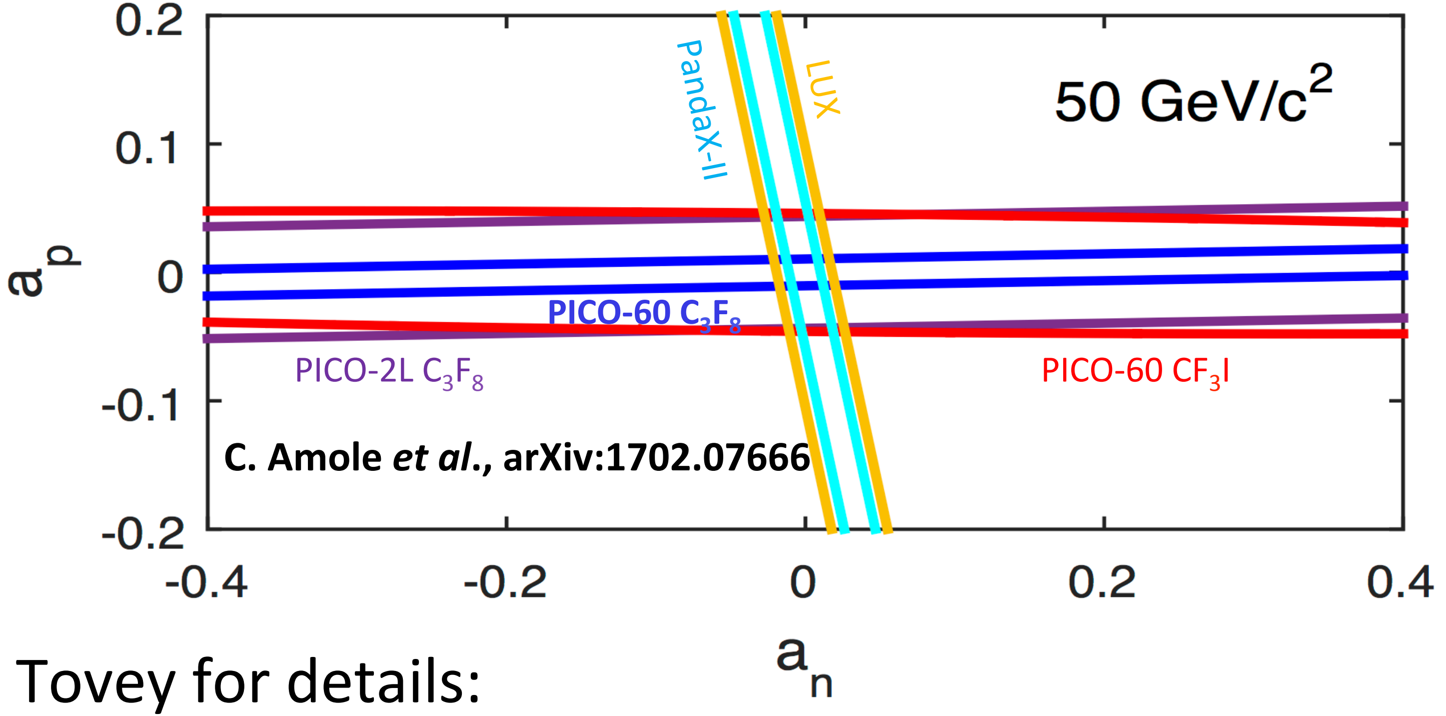
Long term

- Coherent neutrino background much lower for light target compared to Xe



Nucleon Coupling Limits

Limits on neutron vs proton spin-dependent coupling



See Tovey for details:

D.R. Tovey, *et al.*, Phys. Lett. B 488, 17 (2000)

Comparison to Collider