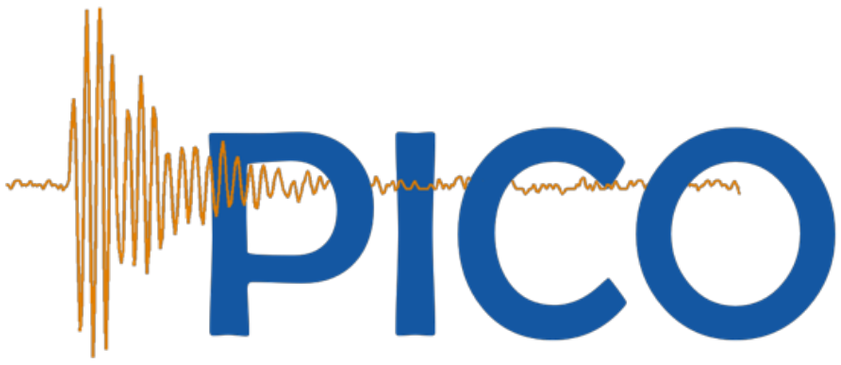
Latest Results From PICO-2L

Scott Fallows, University of Alberta
on behalf of the PICO Collaboration

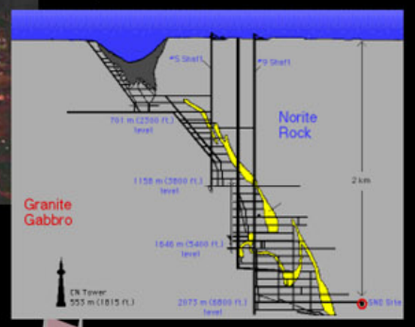
February 10, 2016 – Lake Louise Winter Institute

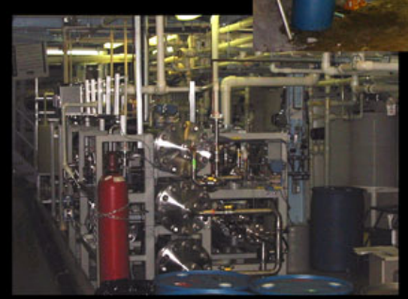


PICO-2L

PICO-60

Inco Ltd.
Creighton No.9 Shaft





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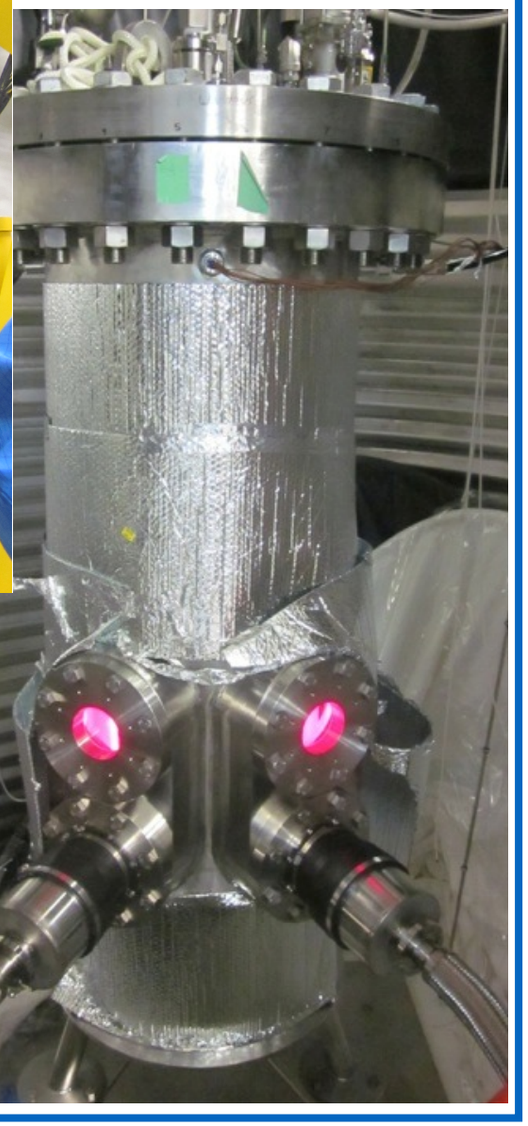
PICO-2L and PICO-60

Run-1 C_3F_8:
PRL 114, 231302 (2015)
arXiv:1503.00008

Run-2 C_3F_8:
arXiv:1601.03729
(this talk)

Run-1 CF_3I:
arXiv:1510.07754

Run-2 C_3F_8:
commissioning



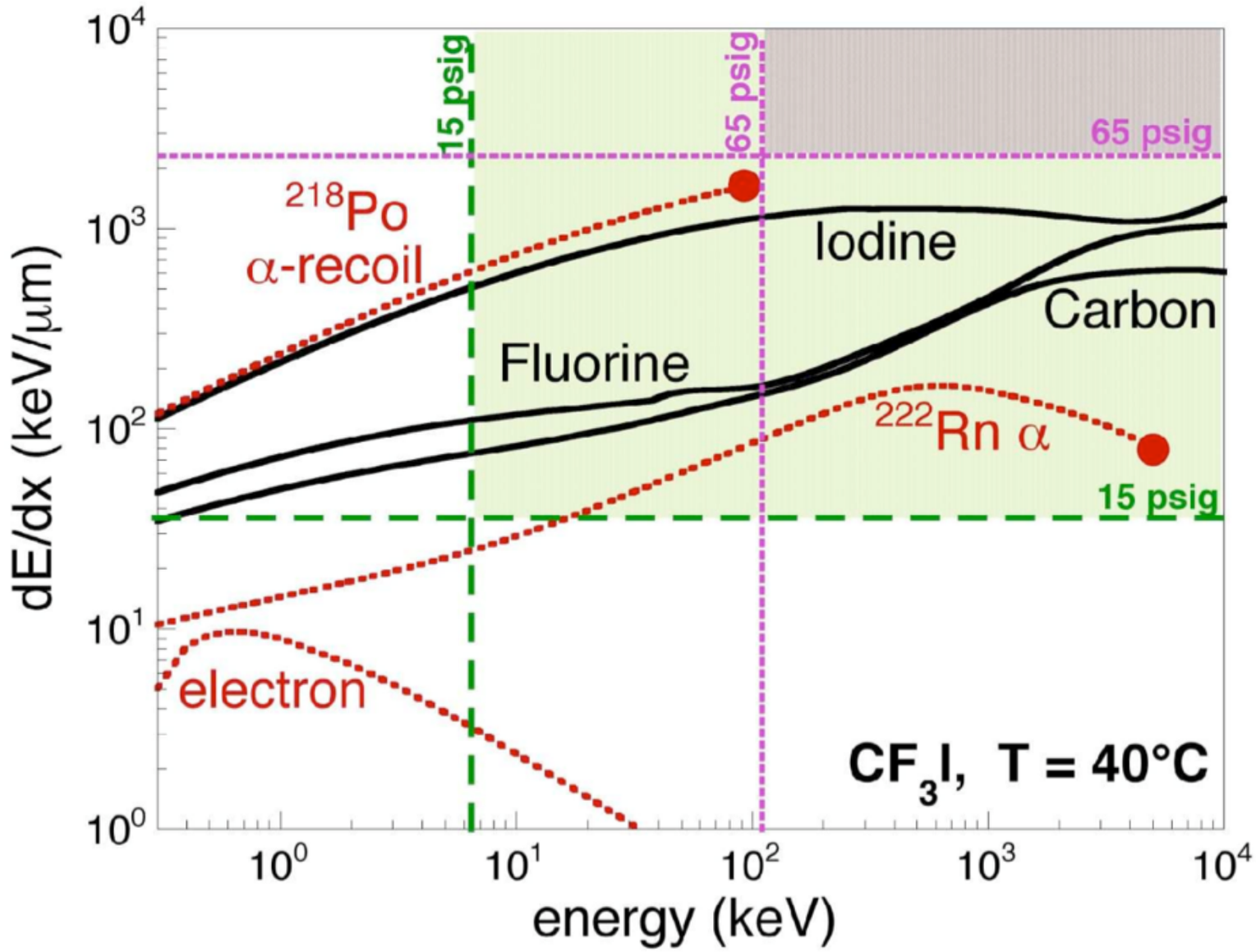
Why bubble chambers?

- Intrinsic rejection of electron recoil backgrounds
- Large target mass (ton-scale, next generation)
- Low energy recoil sensitivity (< 5.5 keV)
- **Multiple target nuclei:** ability to test cross section dependence on atomic number, nuclear spin
- Challenges: image analysis (solved), alpha rejection (largely solved), mechanical stresses (particulates)

Background Rejection

- Gammas – bubble chambers' specialty
- Alphas – acoustic measurements
- Neutrons – minimize with shielding, cleanliness

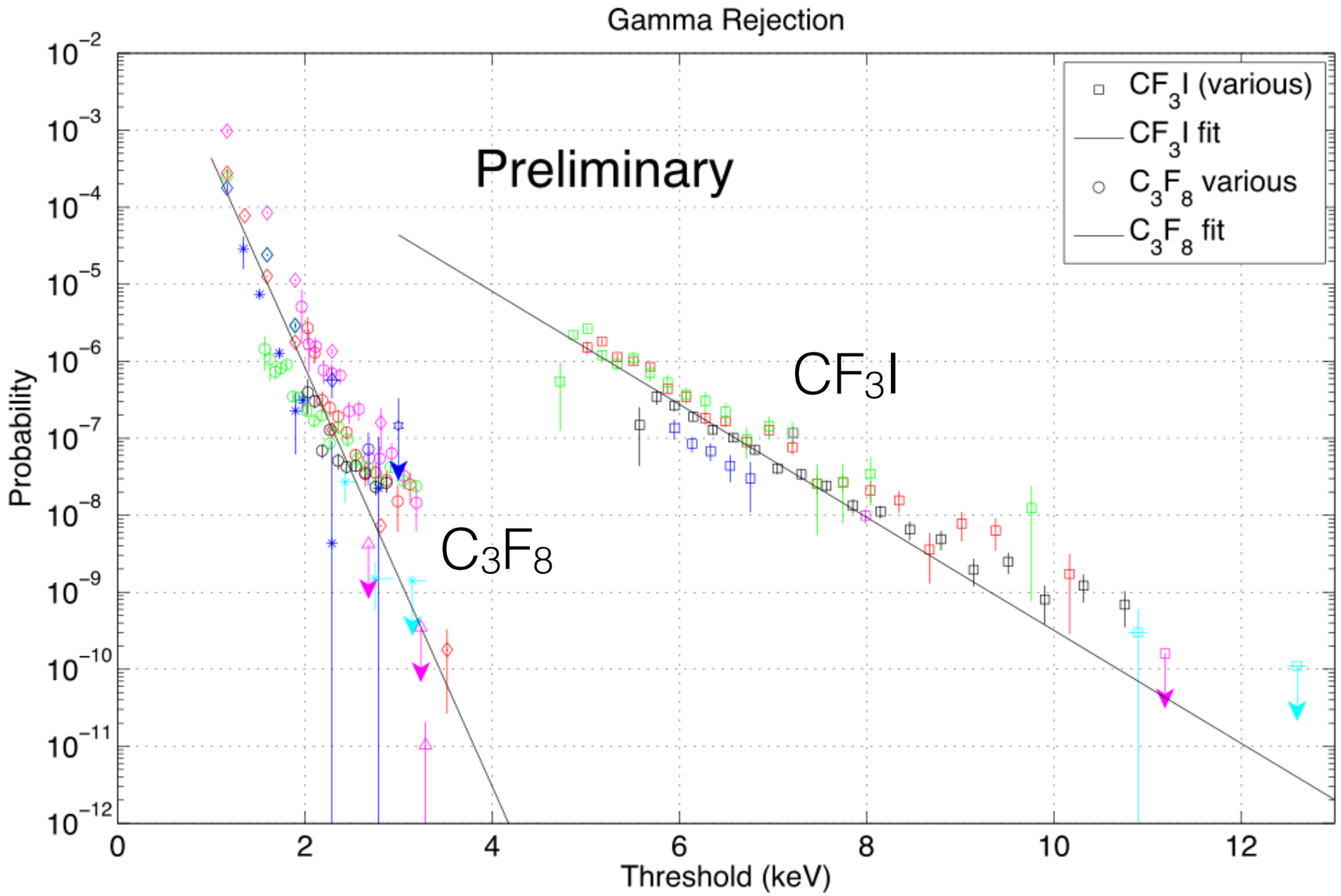
Backgrounds: Gammas



Choose thermodynamic parameters for sensitivity to nuclear recoils, but not electron recoils

Backgrounds: Gammas

Bubble nucleation probability from gamma interactions in C_3F_8 and CF_3I

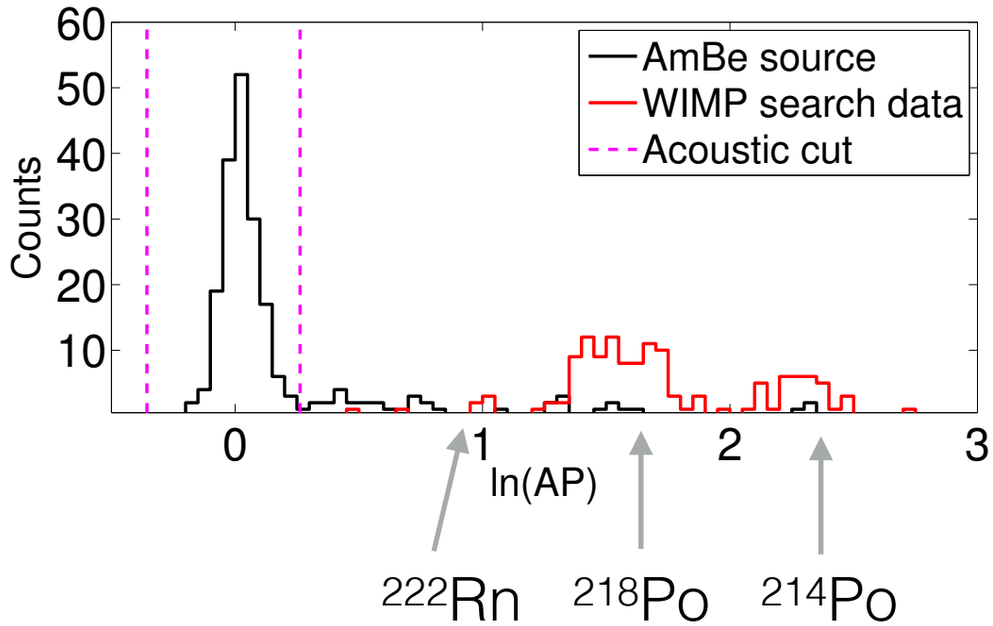


In 12.2 live-days of exposure to a 1 mCi ^{133}Ba gamma source, saw **4 events**

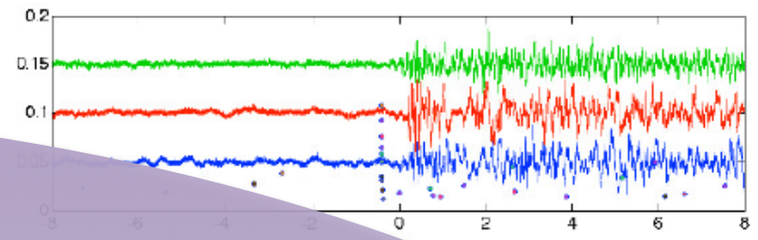
Based on Geant4 MC of local gamma flux, **0.02** electron recoil events in Run-2

Backgrounds: Alphas

- Acoustic discrimination against alphas discovered by PICASSO
  (Aubin et al., New J. Phys.10:103017, 2008)
  - Alphas deposit their energy over tens of μm
  - Nuclear recoils dep. energy over tens of nm
- In PICO, alphas are several times louder
- 90% LL on alpha rejection is 98.2%, based on stats.-limited 4.4 keV data in PICO-2L



First instance of acoustic spectroscopy?



Backgrounds: Neutrons

- Single-scatter neutrons are indistinguishable from WIMPs in these detectors

- Can't discriminate against them, so minimize them

- Two neutron sources for PICO-2L:

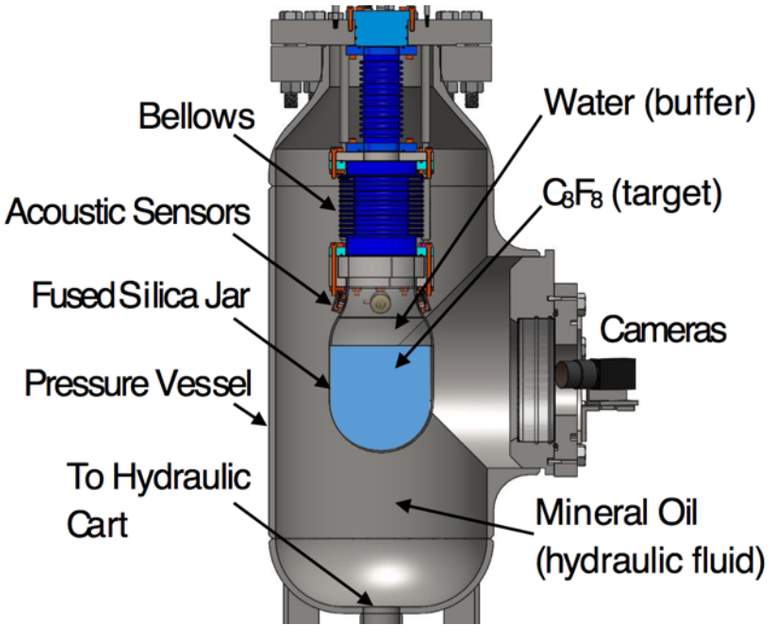
  - **Cosmogenic:** spallation in rock near detector by high energy cosmic ray muons (negligible for PICO-2L; *veto present for PICO-60 Run-2*)

  - **Radiogenic:** natural radioactivity in rock and detector apparatus (alpha-n and spontaneous fission)

- Total neutron background estimate for Run-2:
  1.0 (1.8) single (multiple) bubble events, with 50% overall uncertainty

PICO-2L Run-1

- Successor to *COUPP-4kg: 4 kg of CF_3I*
  - same size silica jar, location, water shield
- Lower radioactivity components
- **Target fluid:** $CF_3I \rightarrow C_3F_8$
  - Focus on sensitivity to spin-dependent couplings
  - Double ^{19}F density, lower energy threshold, improved efficiency, more stable chemistry



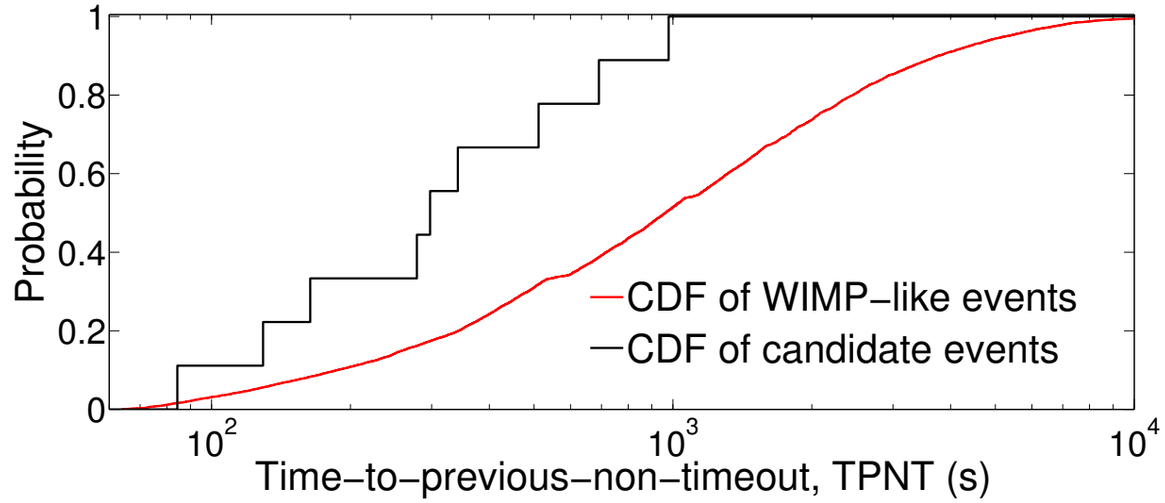
Run-1 Results

T (°C)	P (psia)	Seitz threshold, E_T (keV)	Livetime (d)	WIMP exposure (kg-d)	No. of candidate events
14.2	31.1	$3.2 \pm 0.2(\text{exp}) \pm 0.2(\text{th})$	32.2	74.8	9
12.2	31.1	$4.4 \pm 0.3(\text{exp}) \pm 0.3(\text{th})$	7.5	16.8	0
11.6	36.1	$6.1 \pm 0.3(\text{exp}) \pm 0.3(\text{th})$	39.7	82.2	3
11.6	41.1	$8.1 \pm 0.5(\text{exp}) \pm 0.4(\text{th})$	18.2	37.8	0

- 9 background events seen in signal region after AP cut

- Time correlations with previous expansions: not neutrons, and **not** DM, so what is the source?

- Particulate radioactivity? – Found steel and quartz by SEM/EDX, but not enough U/Th in ICP-MS to fully account for these events



PICO-2L Run-2

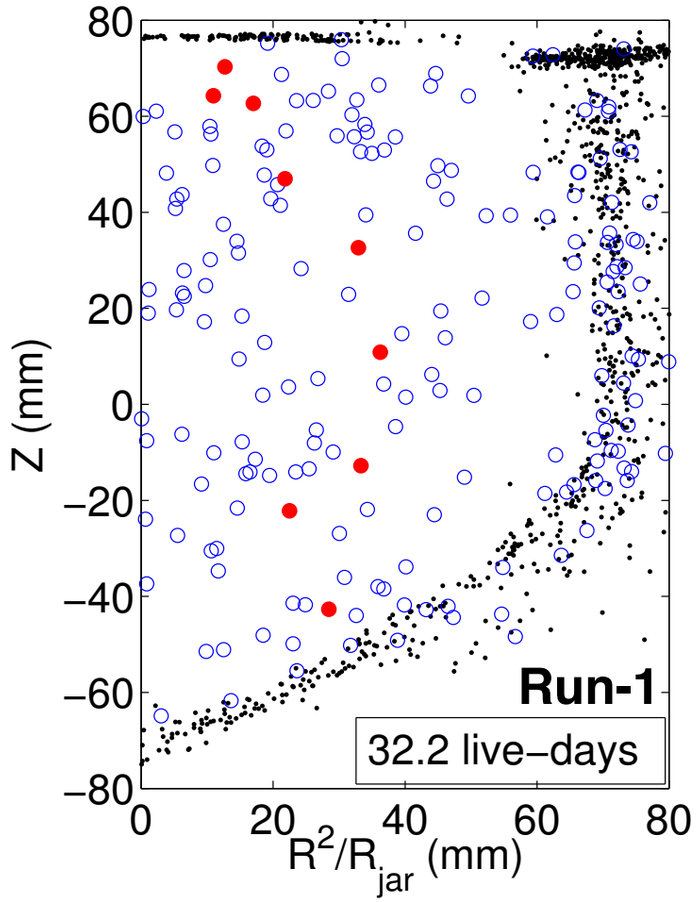
- First bubble: 2015, Feb 27
- Physics run: Jun 12 – Sep 25
  66.3 live-days in total
- Natural quartz inner vessel
  flange replaced with low-radioactivity fused silica
- Focused on minimizing particulate contamination during assembly and filling
- Improved cooling and piezo acoustic sensor reliability

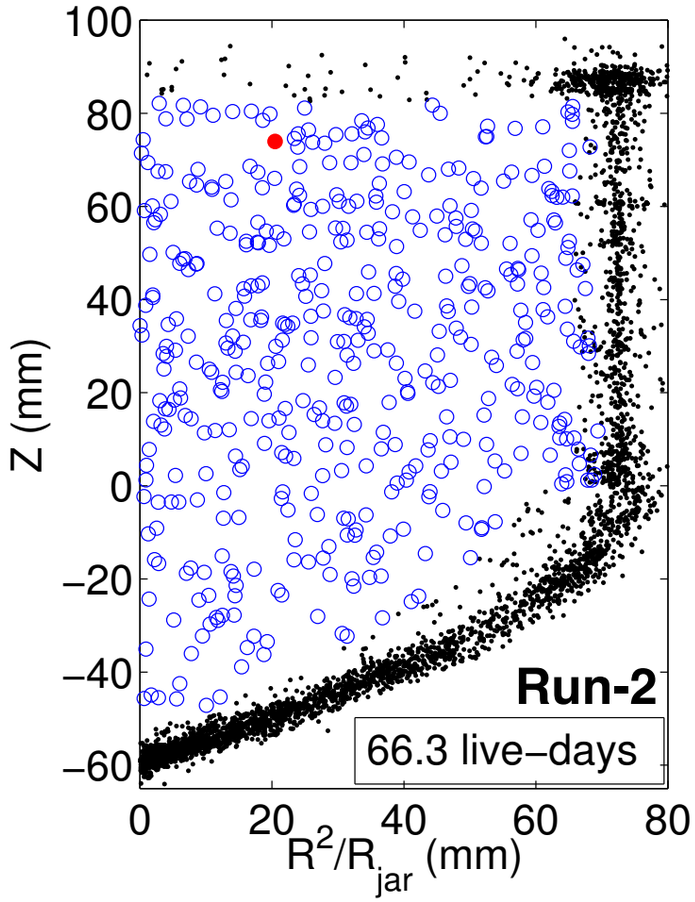
← IV flange:
natural quartz →
synthetic fused silica

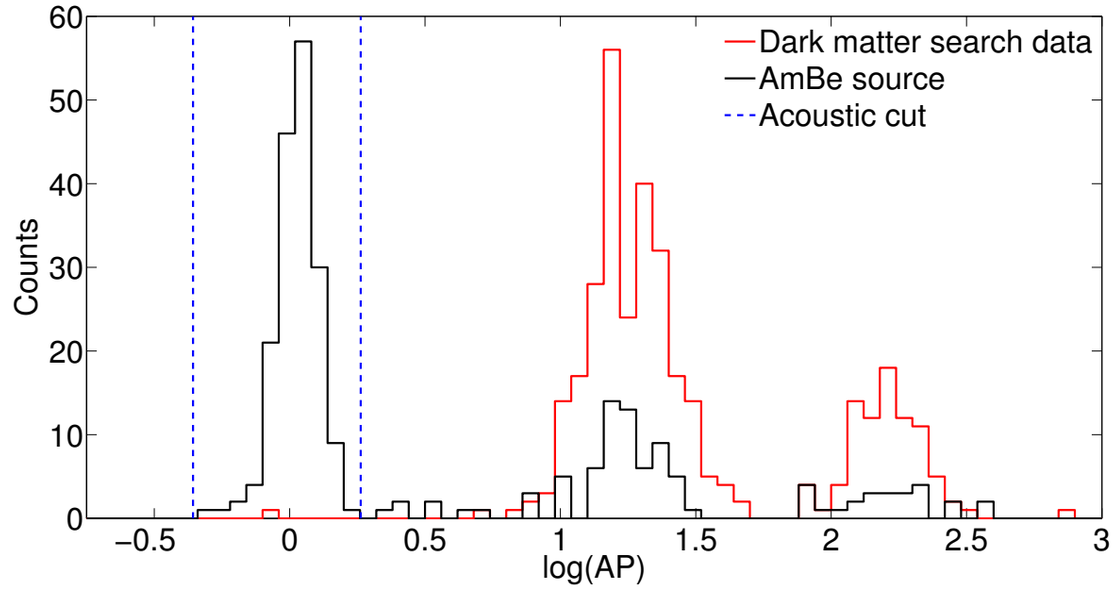
active camera cooling

Run-2 Results

- Anomalous background is no longer present
- Single candidate event, consistent with neutron background estimate
- Improvements made for Run-2 had the intended effect in suppressing background
- Improved limits…

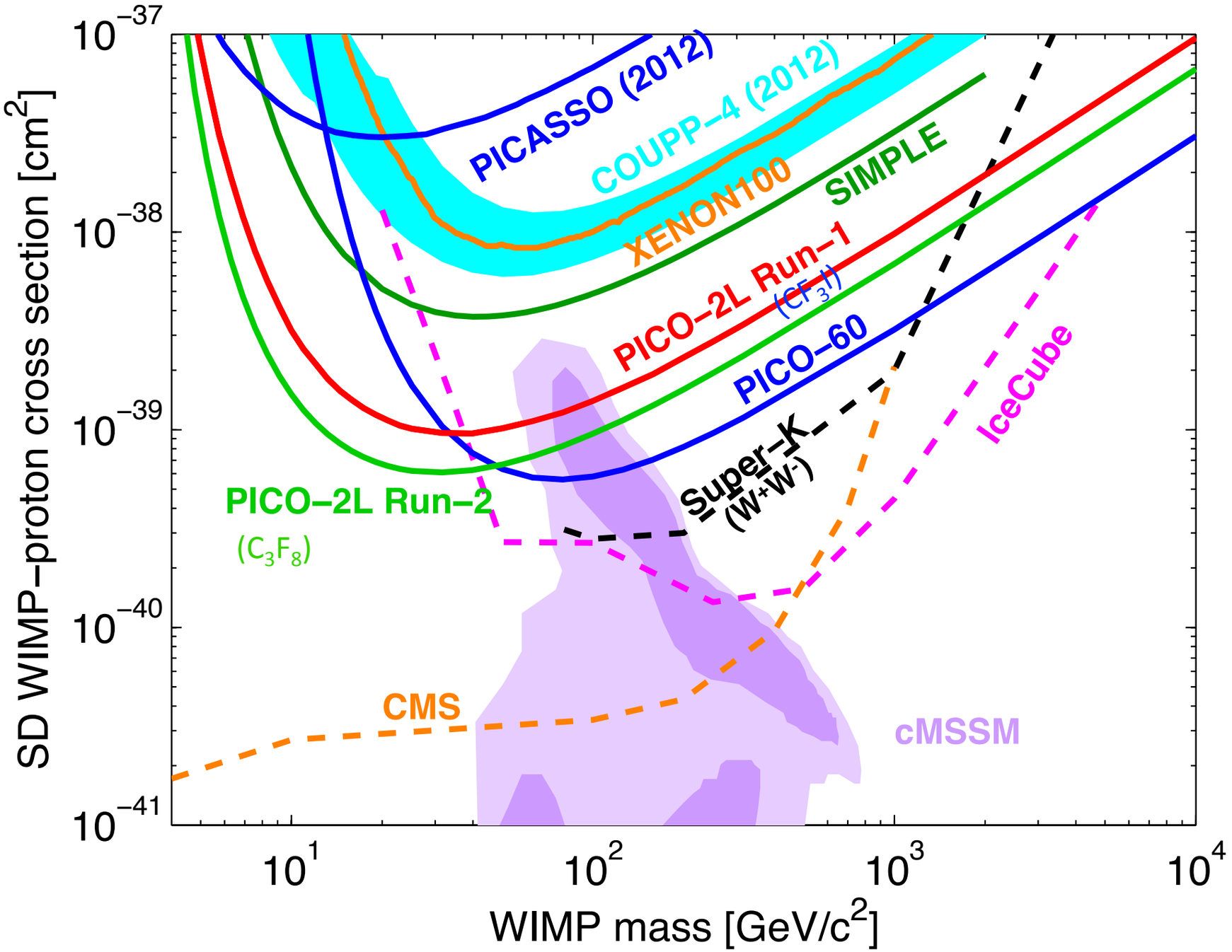






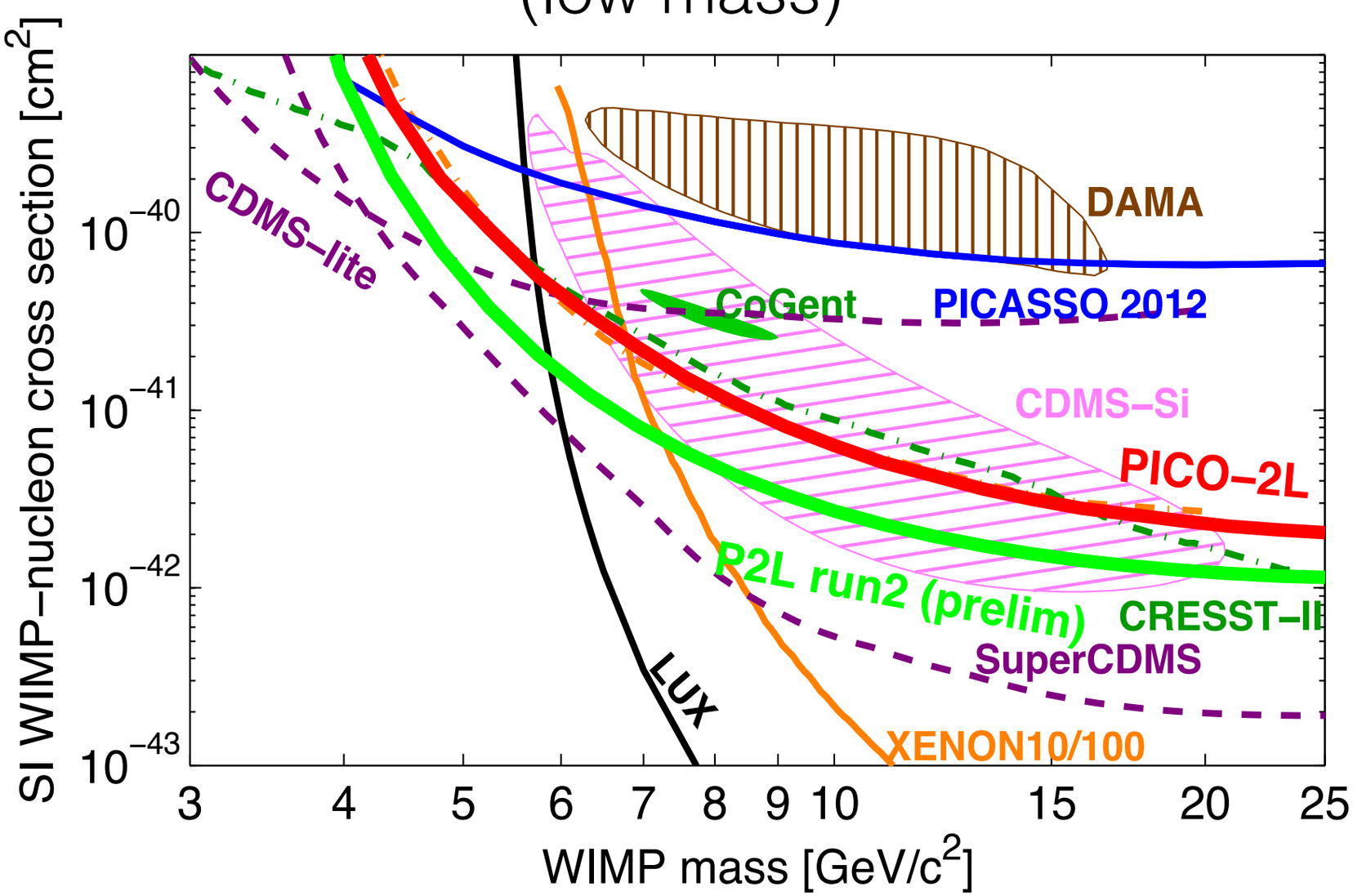
Limits: Spin-Dependent

Improved leading direct detection limits on SD WIMP-proton cross section below 40 GeV



Limits: Spin-Independent

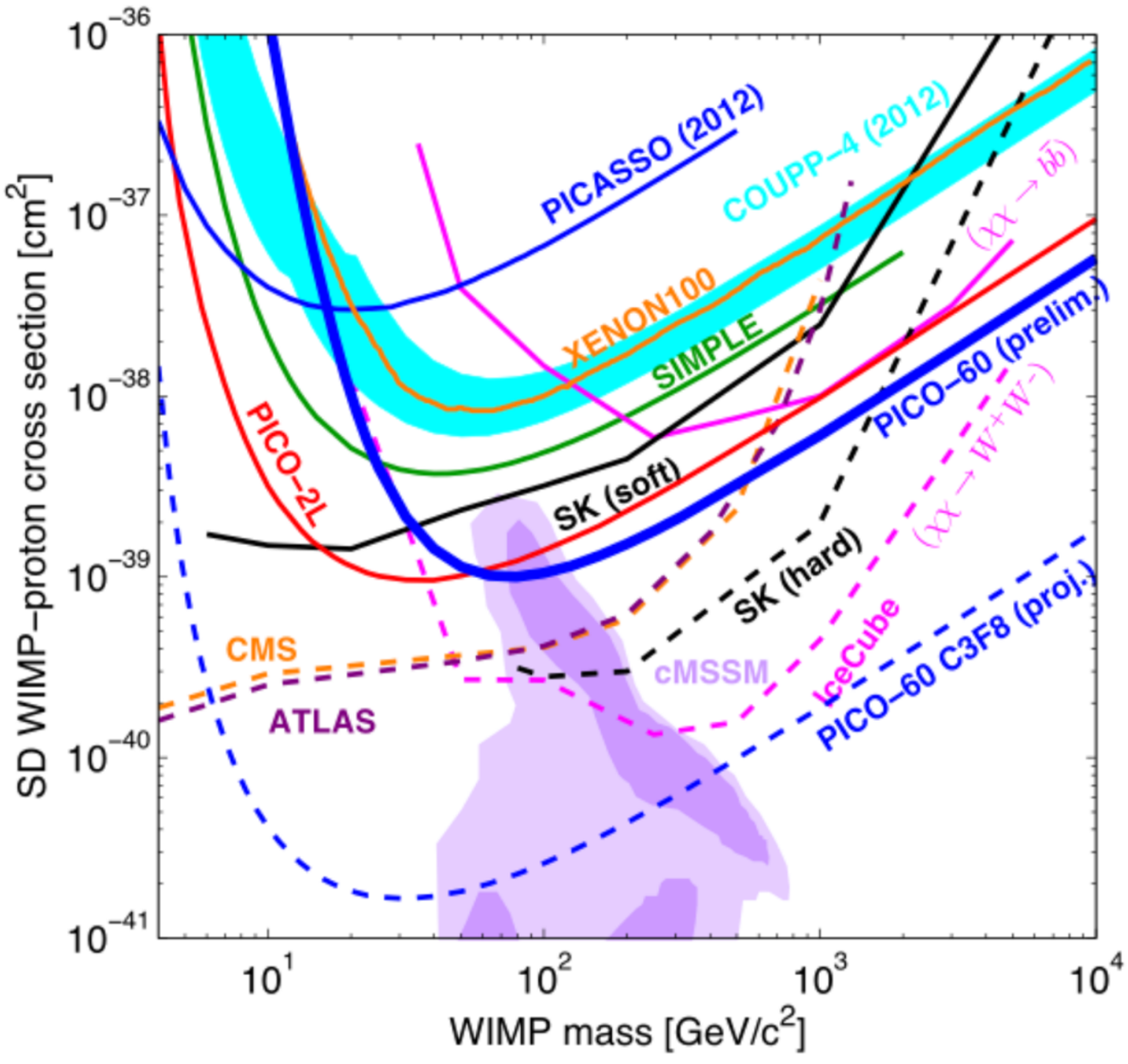
(low mass)



SI is not the design goal, but competitive with Ge and Xe at low mass

Next steps for PICO

- PICO-2L
  - Insufficient shielding for further background-free running
  - Run-2 informs techniques for zero-background running with PICO-60
- PICO-60
  - Run-2 with C_3F_8 target fluid
  - Double volume, 4 cameras @ 300 fps
  - New vessel w/ fused silica flange
  - Coated bellows to eliminate steel
  - Active fluid recirculation with filtering



PICO

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