Search for Dark Matter with the PICO-500 Experiment

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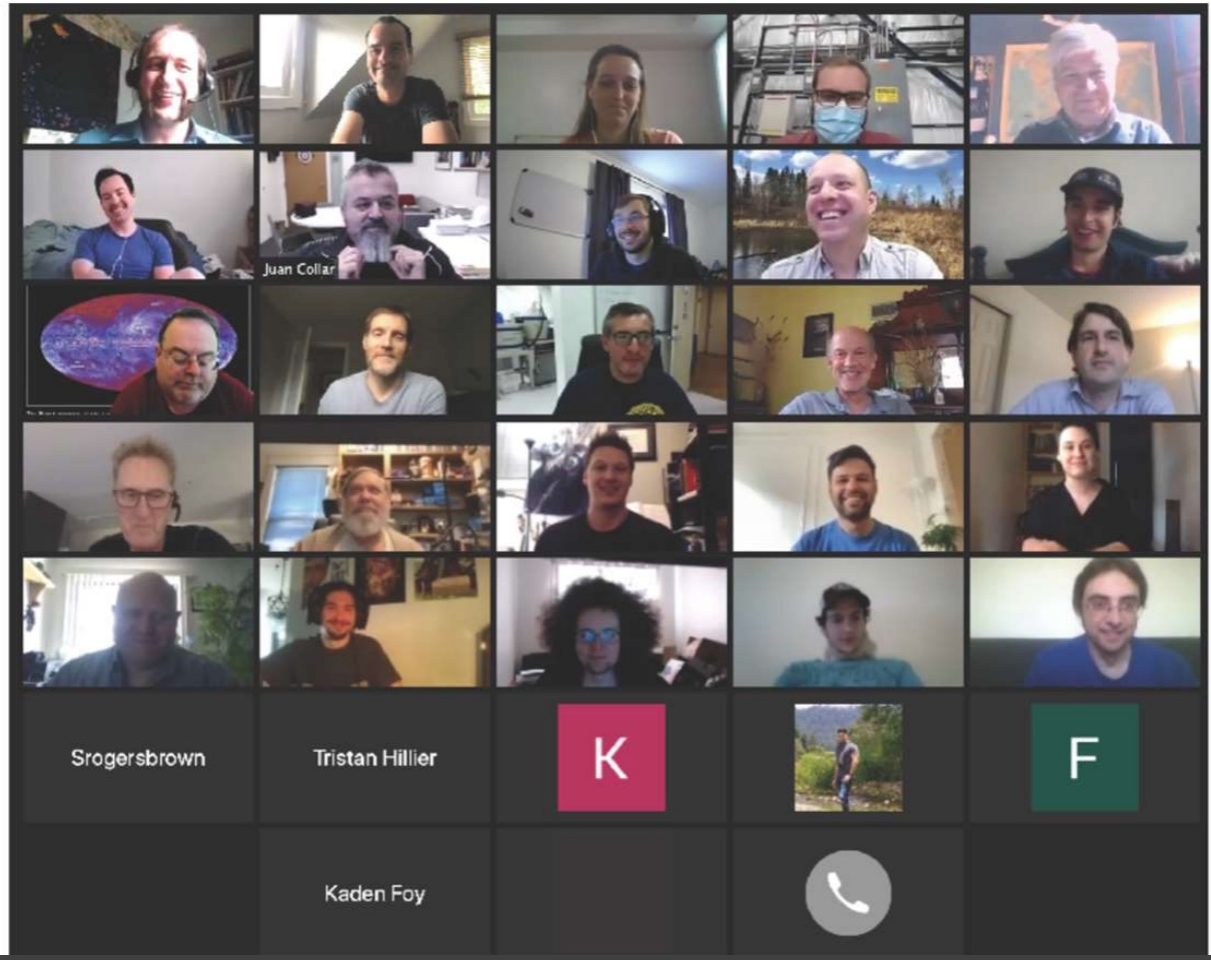
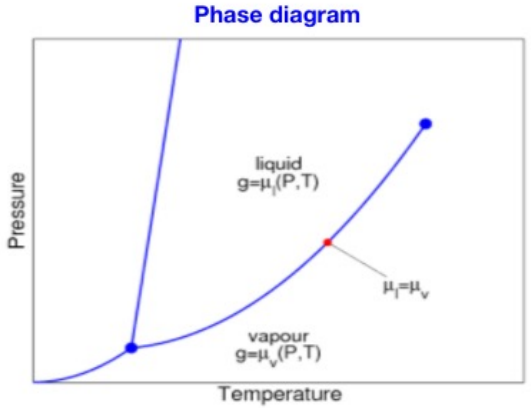
IPP 50th Anniversary Symposium

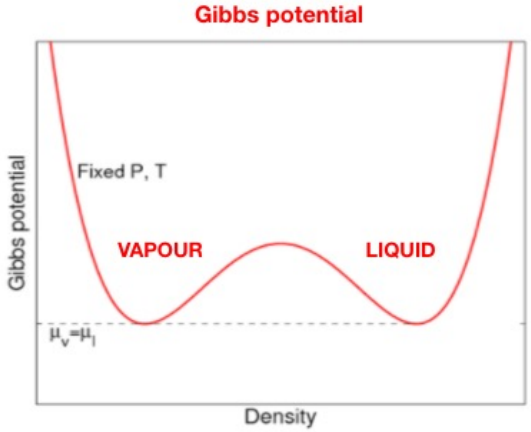


15 Institutions (4 in Canada) and 66 collaboration members

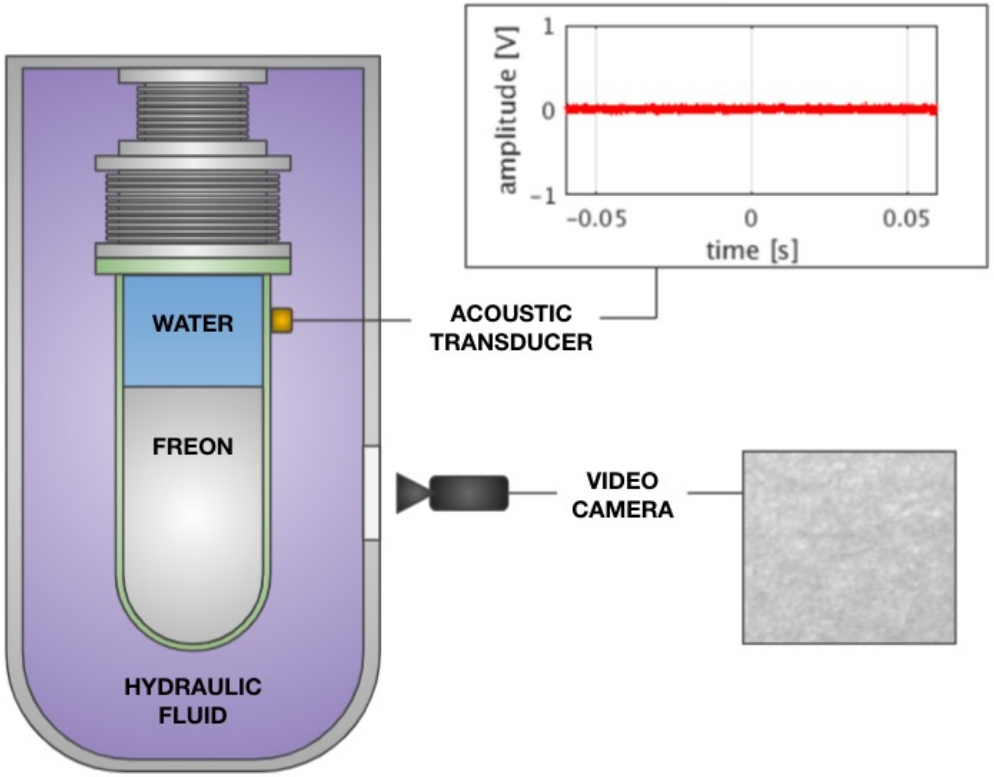
The PICO Bubble Chamber



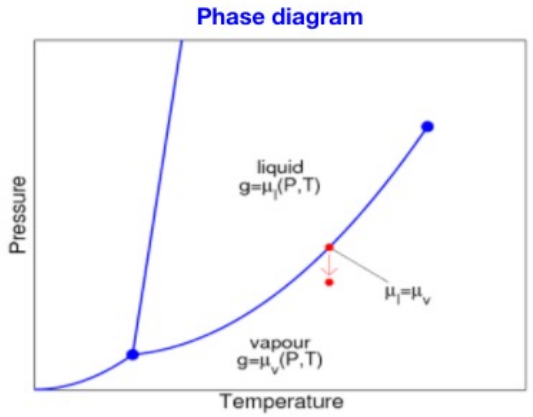
On the saturation curve, two minima exist in the Gibbs potential



Vapour and liquid phase coexist

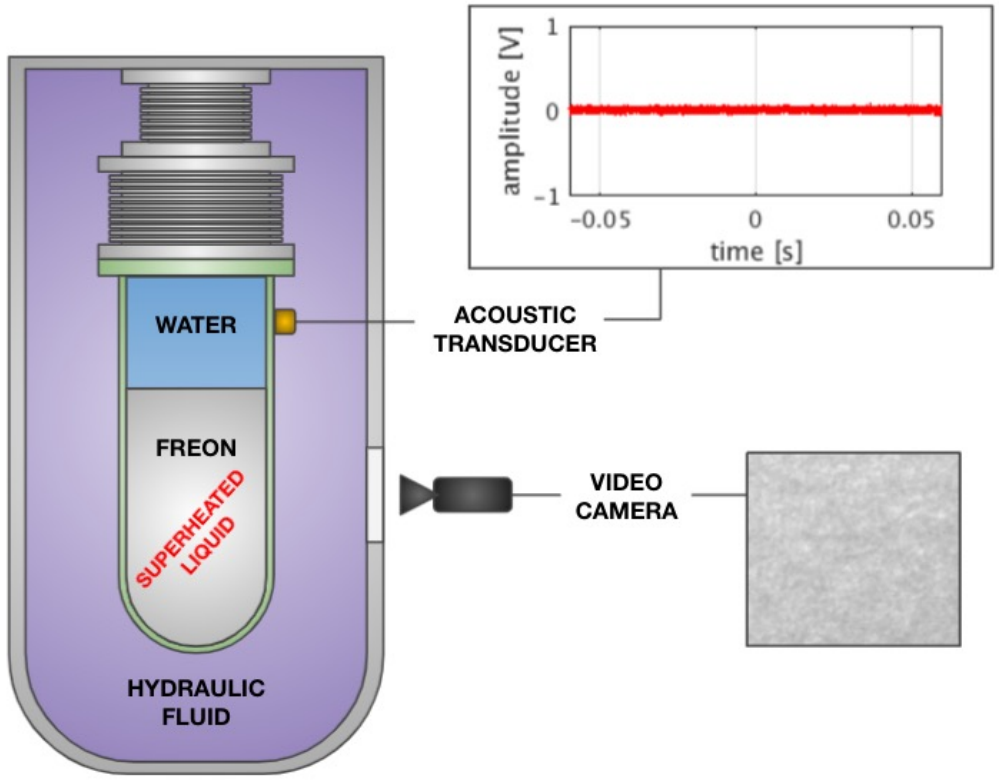


The PICO Bubble Chamber

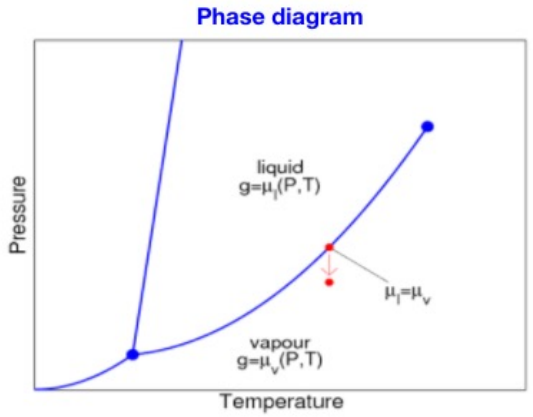


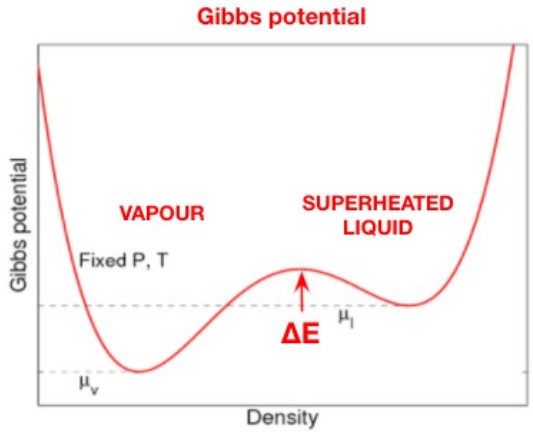
If the pressure is lowered, the Gibbs potential is modified

Still two minima, but one is a metastable state: **superheated liquid**



The PICO Bubble Chamber





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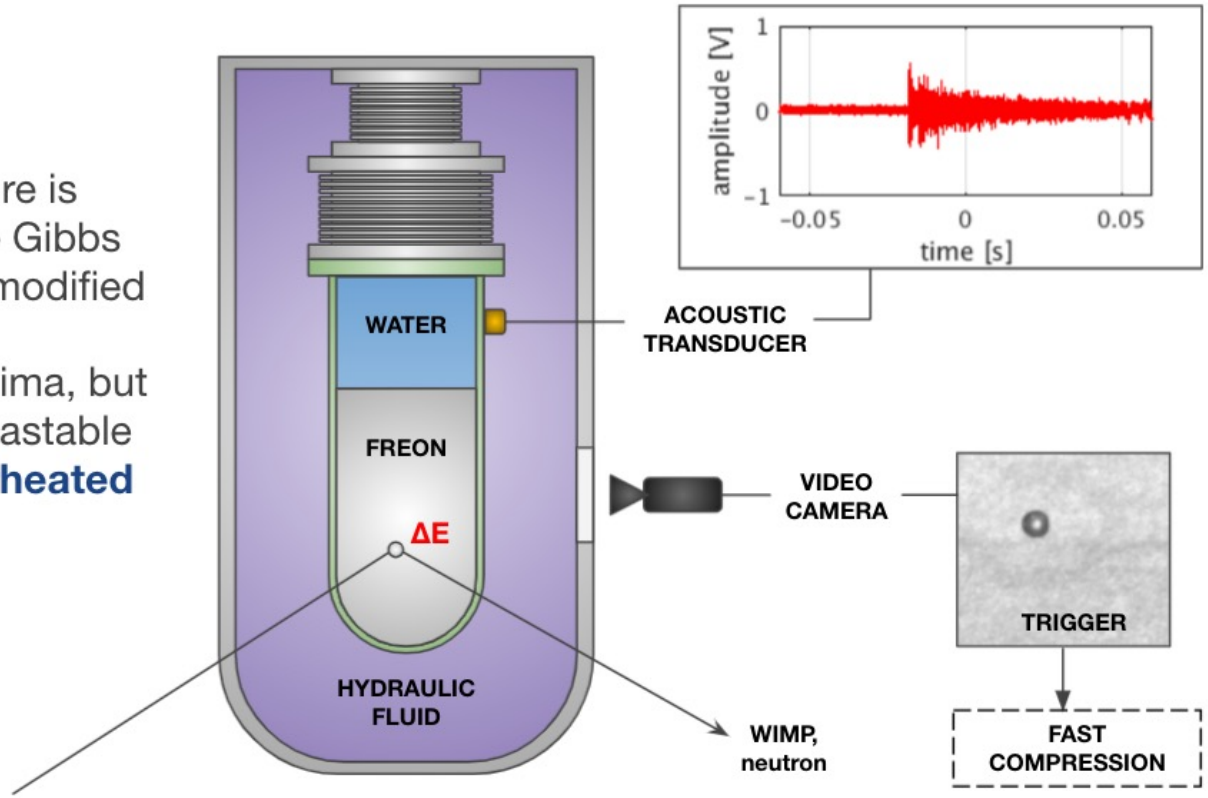
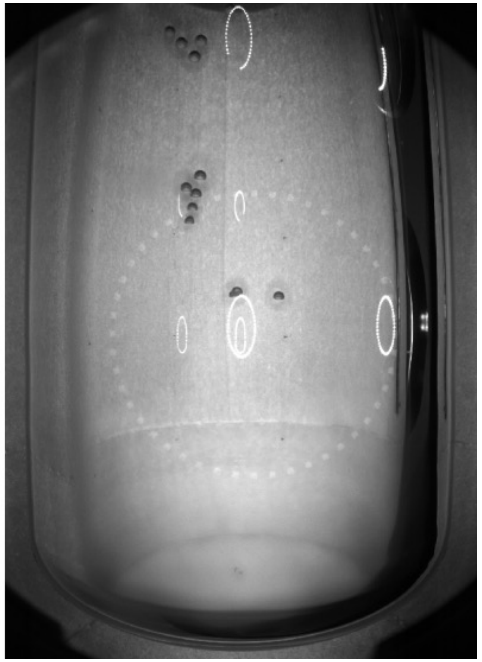


The PICO Bubble Chamber

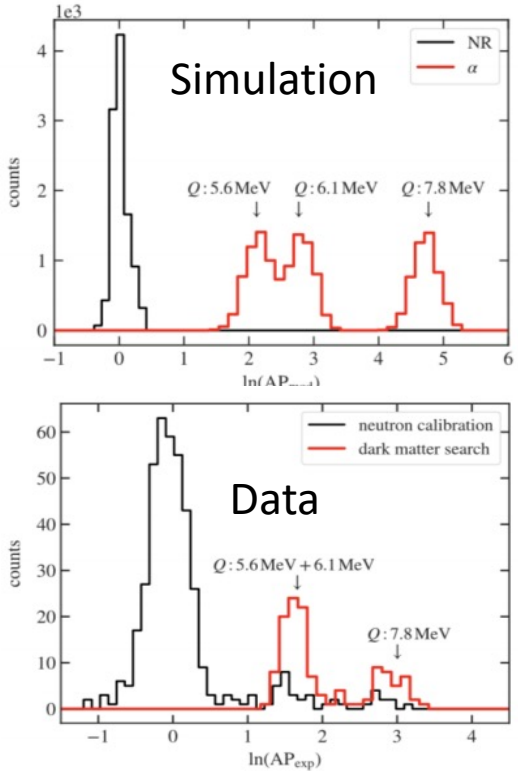
- **Filled with fluorine rich targets WIMP-proton SD cross-section is enhanced**
- **Low threshold (~1 keV)**
- **Background Control**
  - Nucleation from electron-recoil suppressed (~10^{-9} at 3 KeV_{nr} threshold)
  - Acoustic discrimination of alpha decays
  - Fast neutron scattering largely vetoed thanks to multiple site nucleation

Neutron multiple scatter



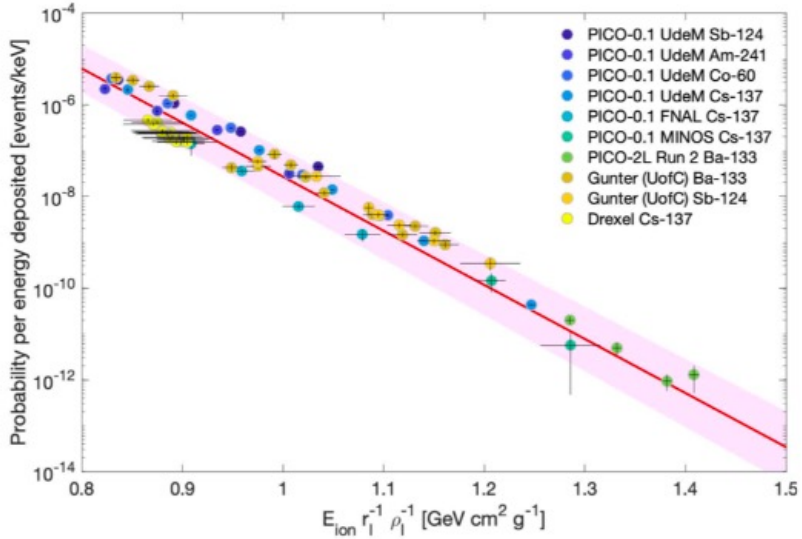
Alpha/recoil acoustic discrimination

Phys. Rev. D **100**, 052001 (2019)



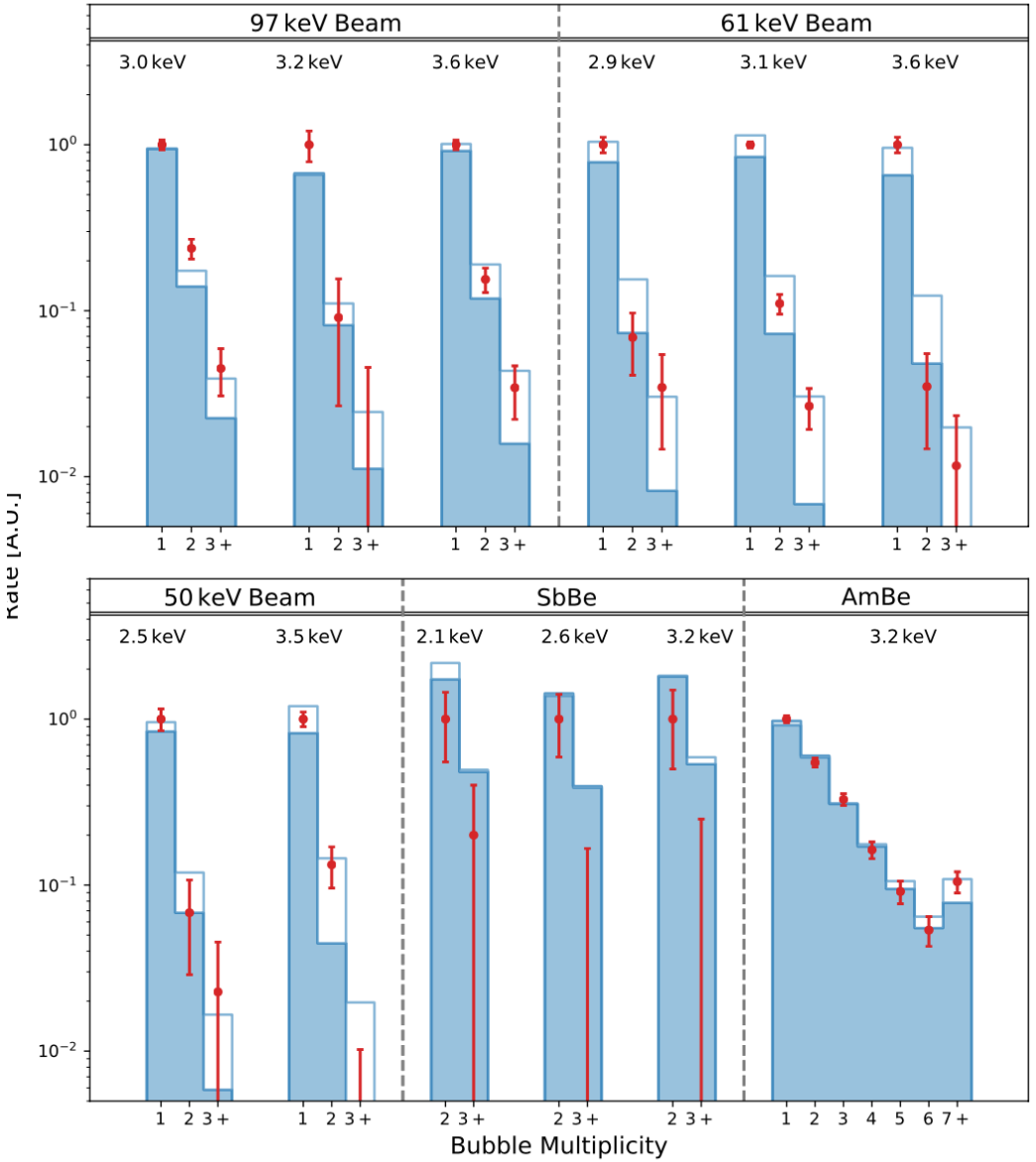
Electron recoil nucleation probability

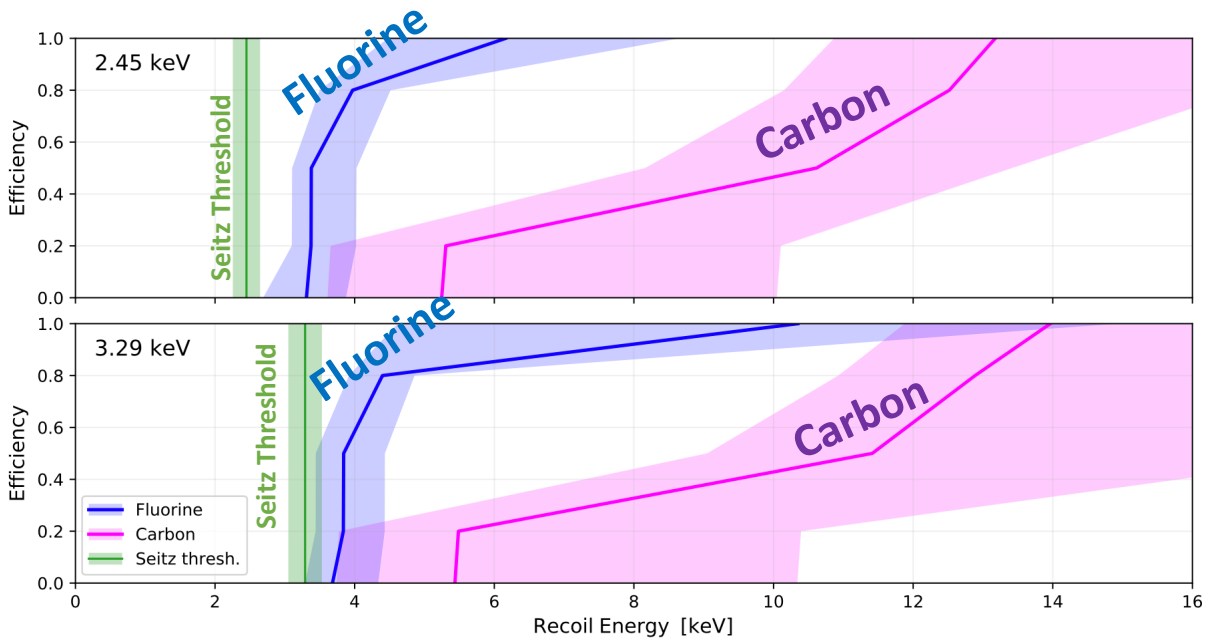
Phys. Rev. D **100**, 082006 (2019)



Nuclear recoil nucleation efficiency

arXiv:2205.05771 **[physics.ins-det]**

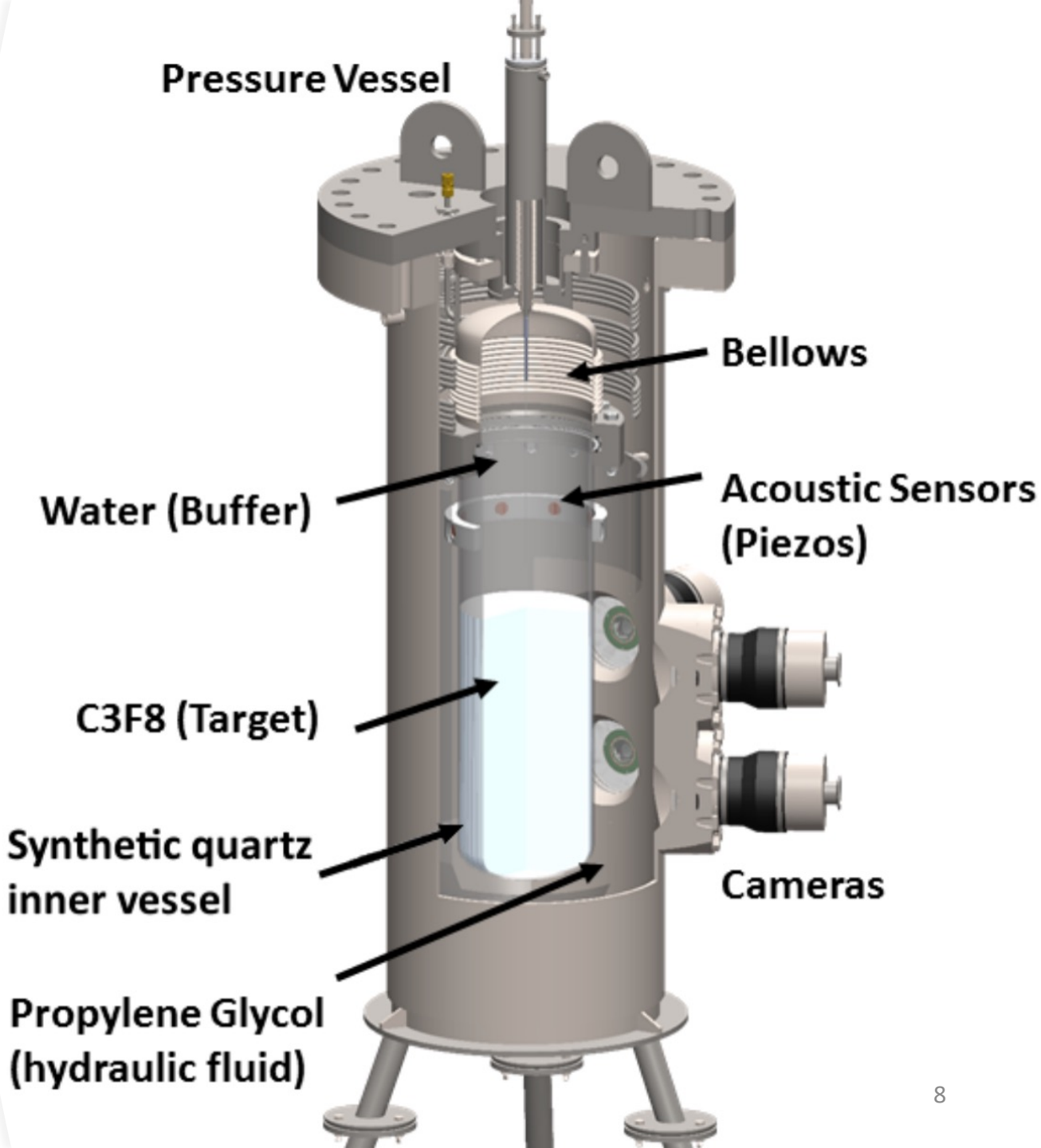




- Multiple neutron calibrations:
  - AmBe at SNOLAB
  - SbBe with small detector
  - Quasi-monoenergetic neutron beam at U of Montreal
- Nuclear recoil (carbon and fluorine) nucleation efficiency model globally fitted with Markov-Chain-Monte-Carlo (MCMC)

The PICO-60 Detector

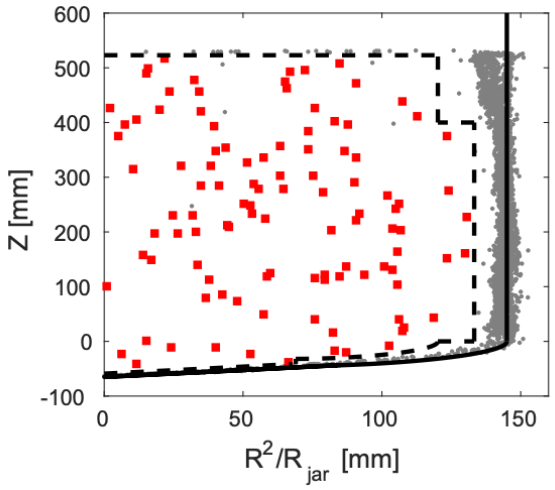
- 52.2 kg C_3F_8 target
- Operated at SNOLAB between 2016 -2017
- 1st run: 3.3 keV_{nr} 1167 kg-day
  - Zero event in ROI
    Phys. Rev. Lett. 118, 251301 (2017)
- 2nd run: 2.45 keV_{nr} 1404 kg-day
  - Phys. Rev. D 100, 022001 (2019)
- Ultimately background limited from single scatter neutron due to the size of the pressure vessel

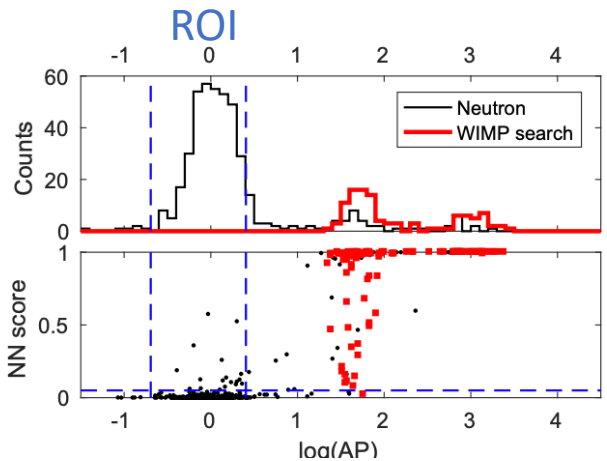


Results from the complete exposure of PICO-60 at SNOLAB

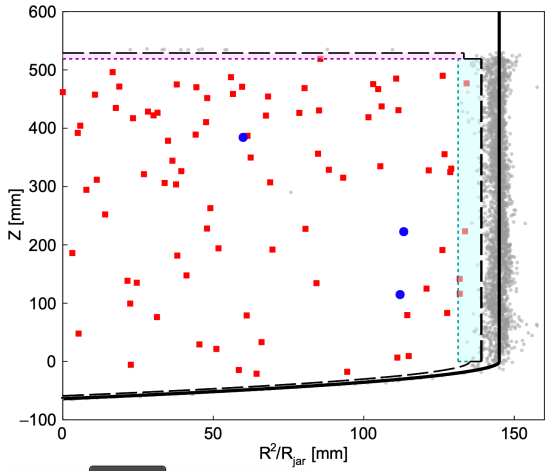
Phys. Rev. D 100, 022001 (2019)

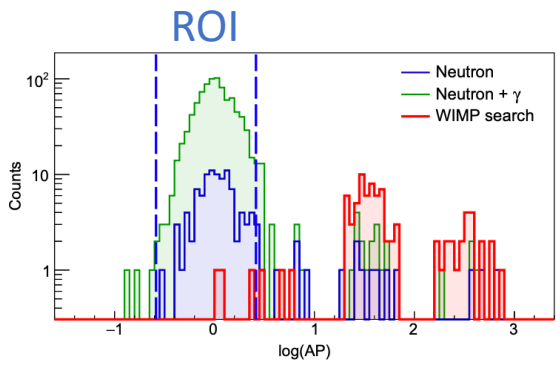
3.3 keV





2.4 keV





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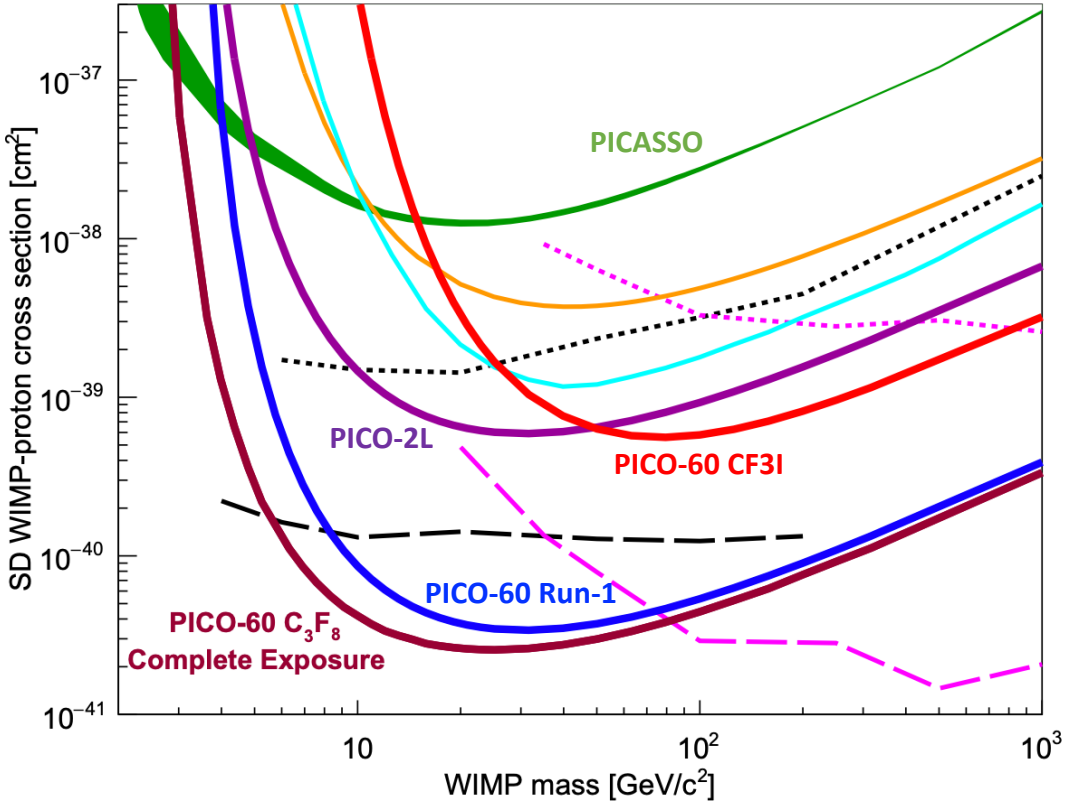
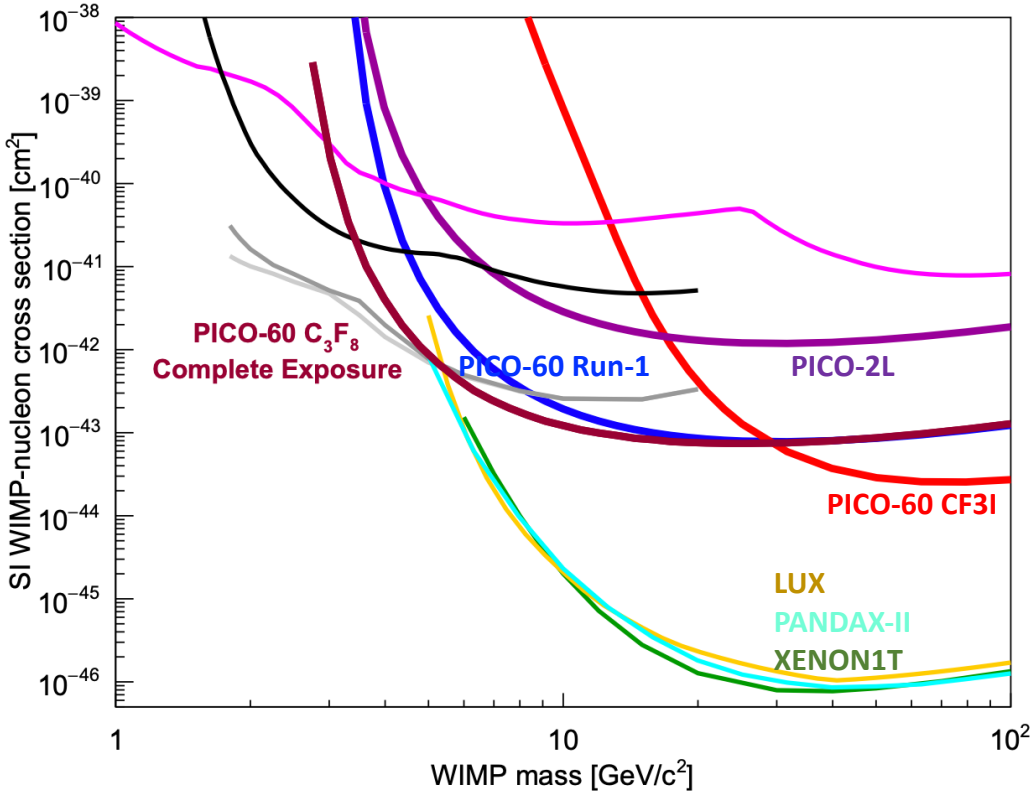
Phys. Rev. D 100, 022001 (2019)



Spin dependent

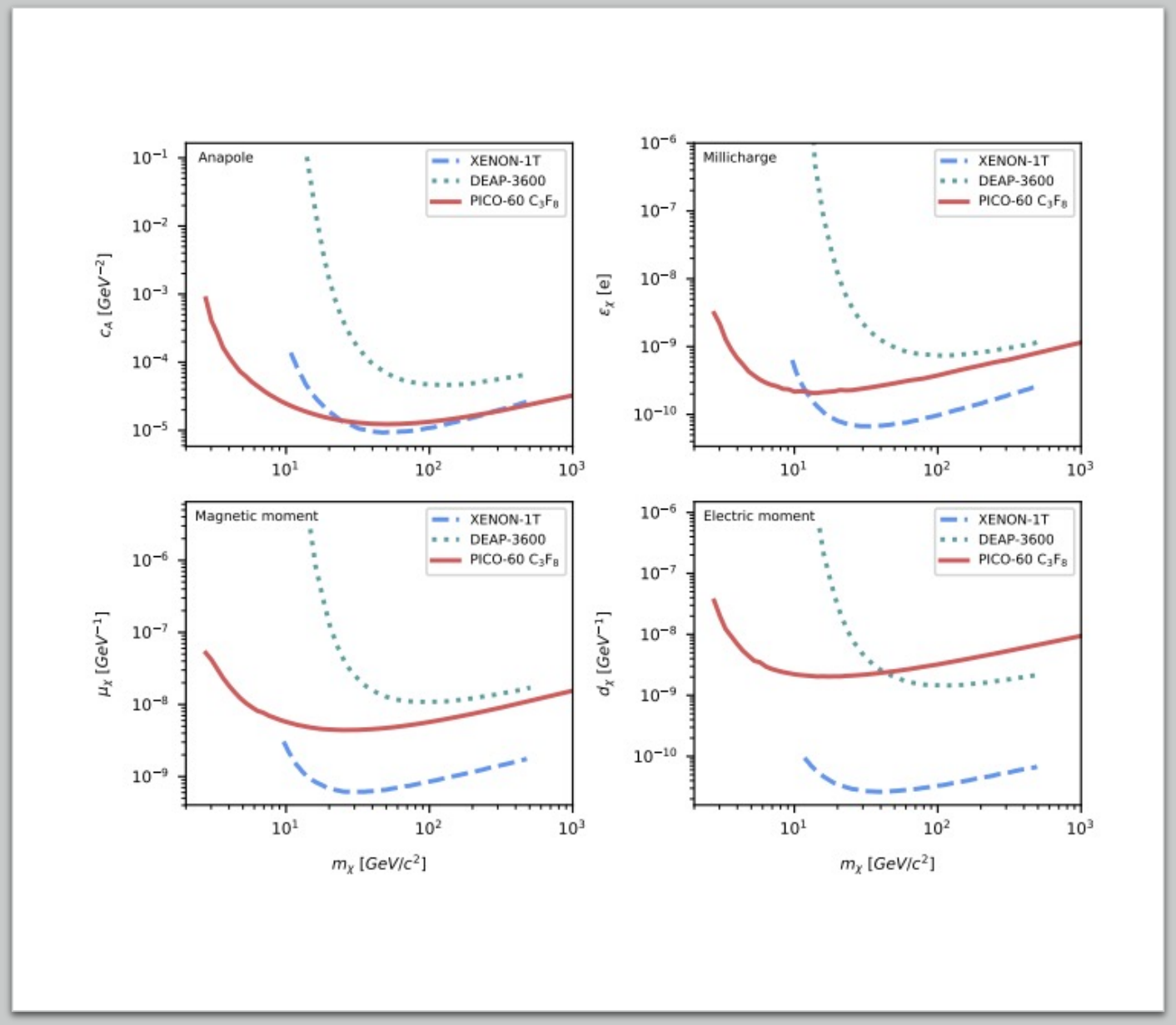


Spin independent

Continued Physics Exploration with PICO-60

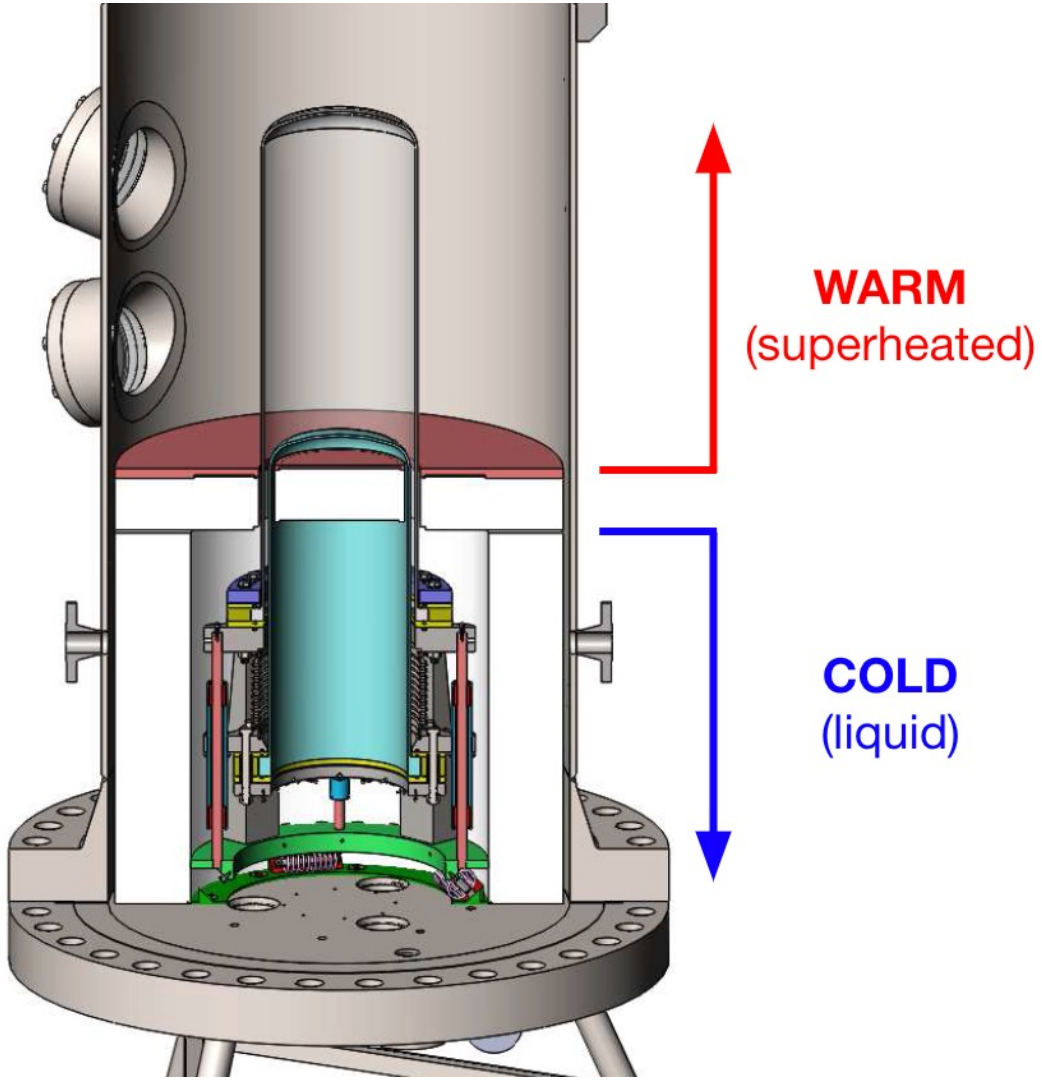
- New results on photon-mediated dark matter-nucleus interactions (anapole, electric and magnetic dipole, millicharged) from the complete exposure of PICO-60: world-leading at low mass (arXiv:2204.10340).

- Coming soon: Inelastic dark matter-nucleus interactions from PICO-60 C_3F_8 and CF_3I



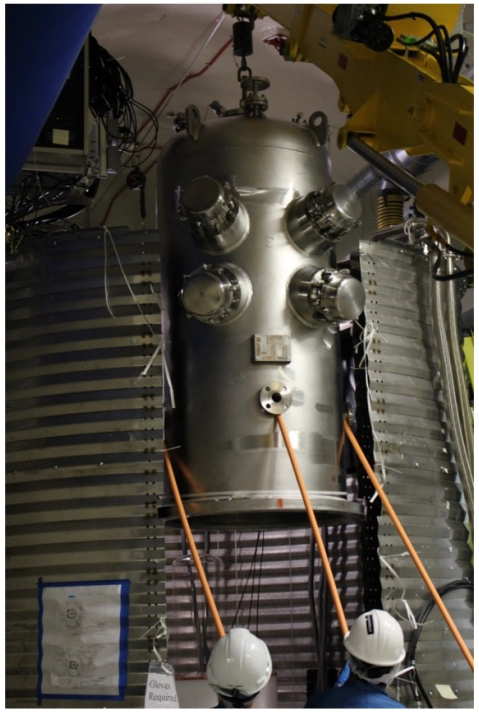
The PICO-40L Detector at SNOLAB

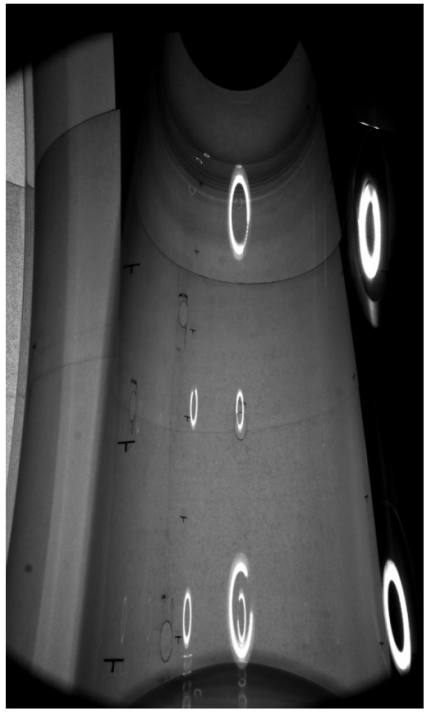
- PICO-40L is a large-scale prototype of the right-side-up design
- The water buffer is replaced by a thermal gradient that renders the C_3F_8 in the stainless-steel bellows inactive
- Water removal helps with detector deadtime (instability at the water/C_3F_8 interface) and particulates control (anomalous backgrounds seen in PICO-2L and PICO-60 CF_3I)
- Comparable active mass as PICO-60, but new physics reach thanks to larger pressure vessel that contributes to lower neutron background



Status of PICO-40L

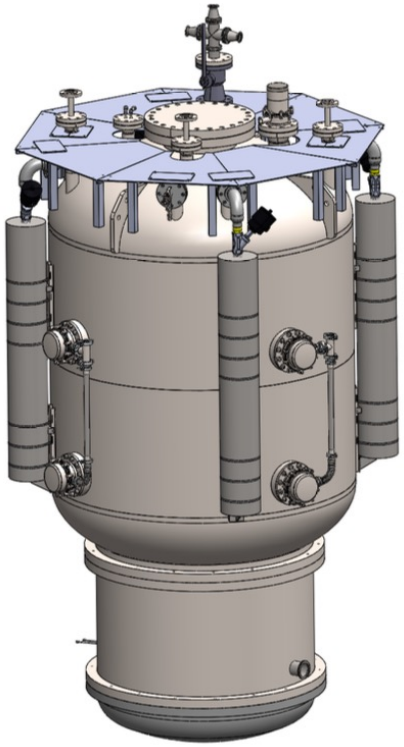
- Installation completed in 2019
- Some commissioning data taken, but delayed by chiller issues
- Shortcomings of the thermal design were identified, while a leak in the cooling coils triggered the interruption of operations.
- PICO-40L is being rebuilt with a revised thermal design and a new quartz jar (updated surface treatment method)
- Running expected during summer 2022

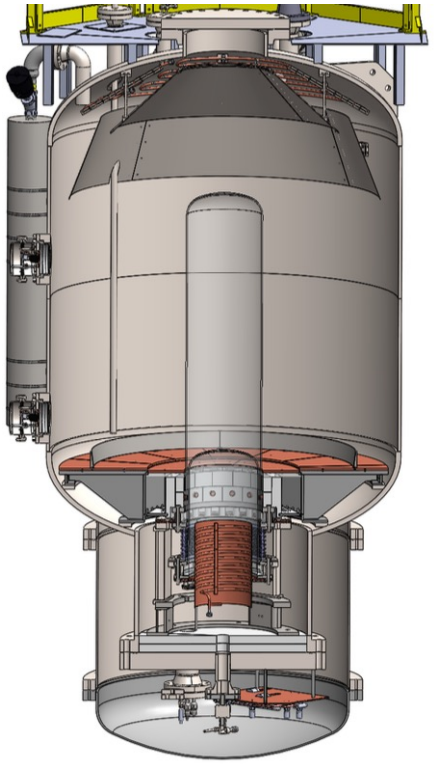


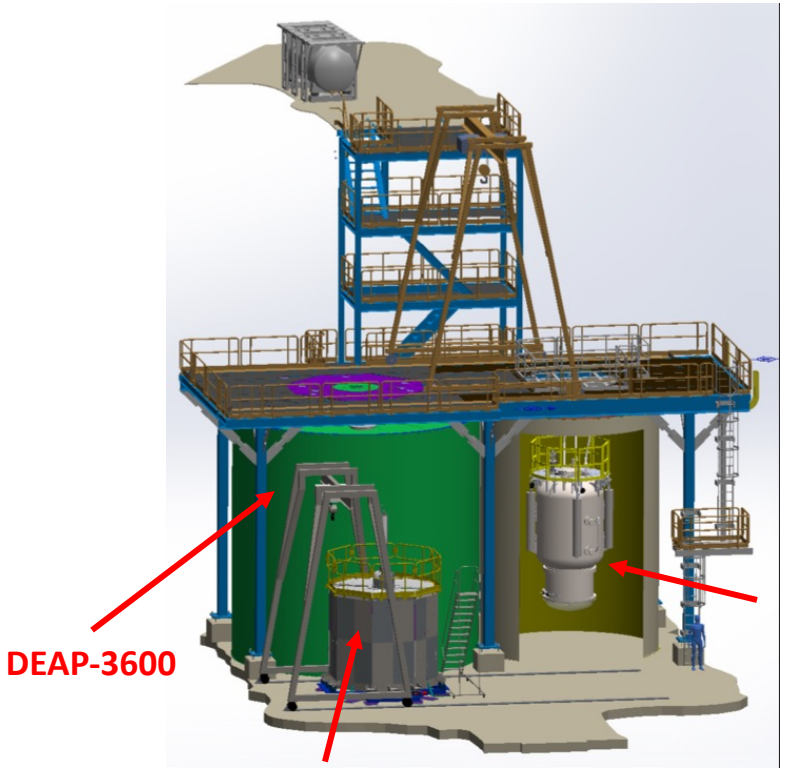


The PICO-500 Detector at SNOLAB

- Next generation PICO detector to be installed in the miniCLEAN water tank in SNOLAB cube hall
- 260L (420 kg C_3F_8) quartz vessel: size limited by fused silica forming methods
- Pressure vessel can hold a 1000 L vessel for future upgrade

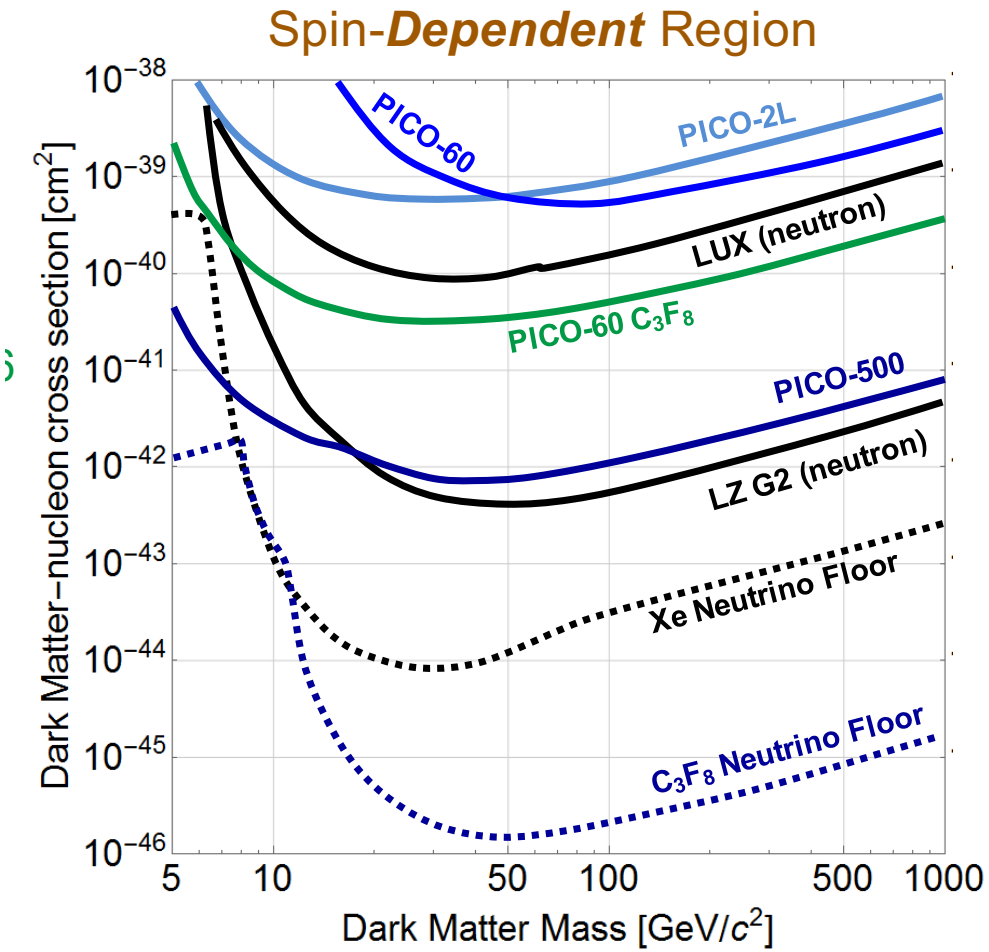






Outlook

- *Technical Design Review* for PICO-500 is planned for June 2022
- Procurement for quartz jars complete, pressure vessel sent for production
- PICO-500 will have a comparable reach in the SD_p as LZ in the SD_n sector
- The neutrino floor for fluorine is far below the neutrino floor for xenon



Thank you!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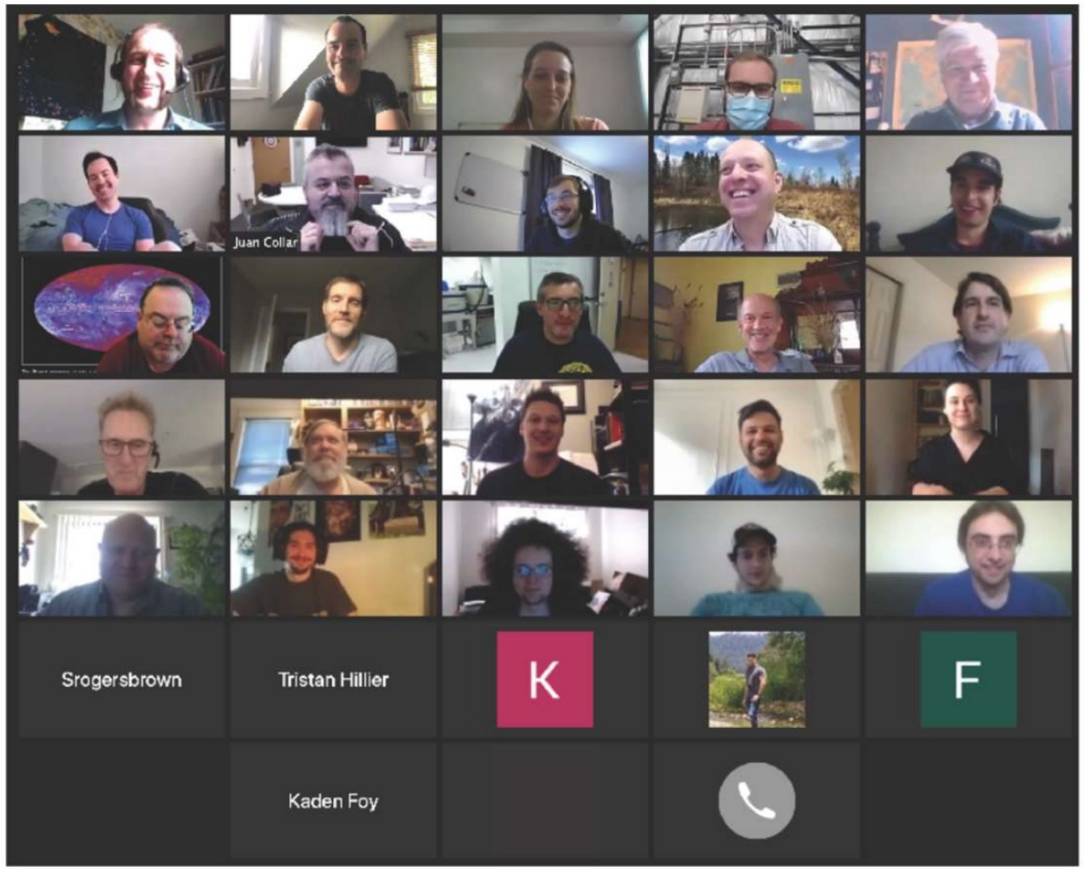
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Extra Slides

Theoretical Motivations arXiv:2104.03245

New theoretical work on pMSSM models that are not excluded by LHC, provide a dark matter candidate and an explanation for the g-2 anomaly, and are minimally fine-tuned.

Direct detection searches are complementary in regions of the MSSM parameter space where the LHC has little sensitivity

Current and future PICO experiments at SNOLAB will be able to test all these models in the Spin-Dependent sector