PICO-40, an important step towards a ton-scale spin-dependent dark matter search experiment at SNOLAB

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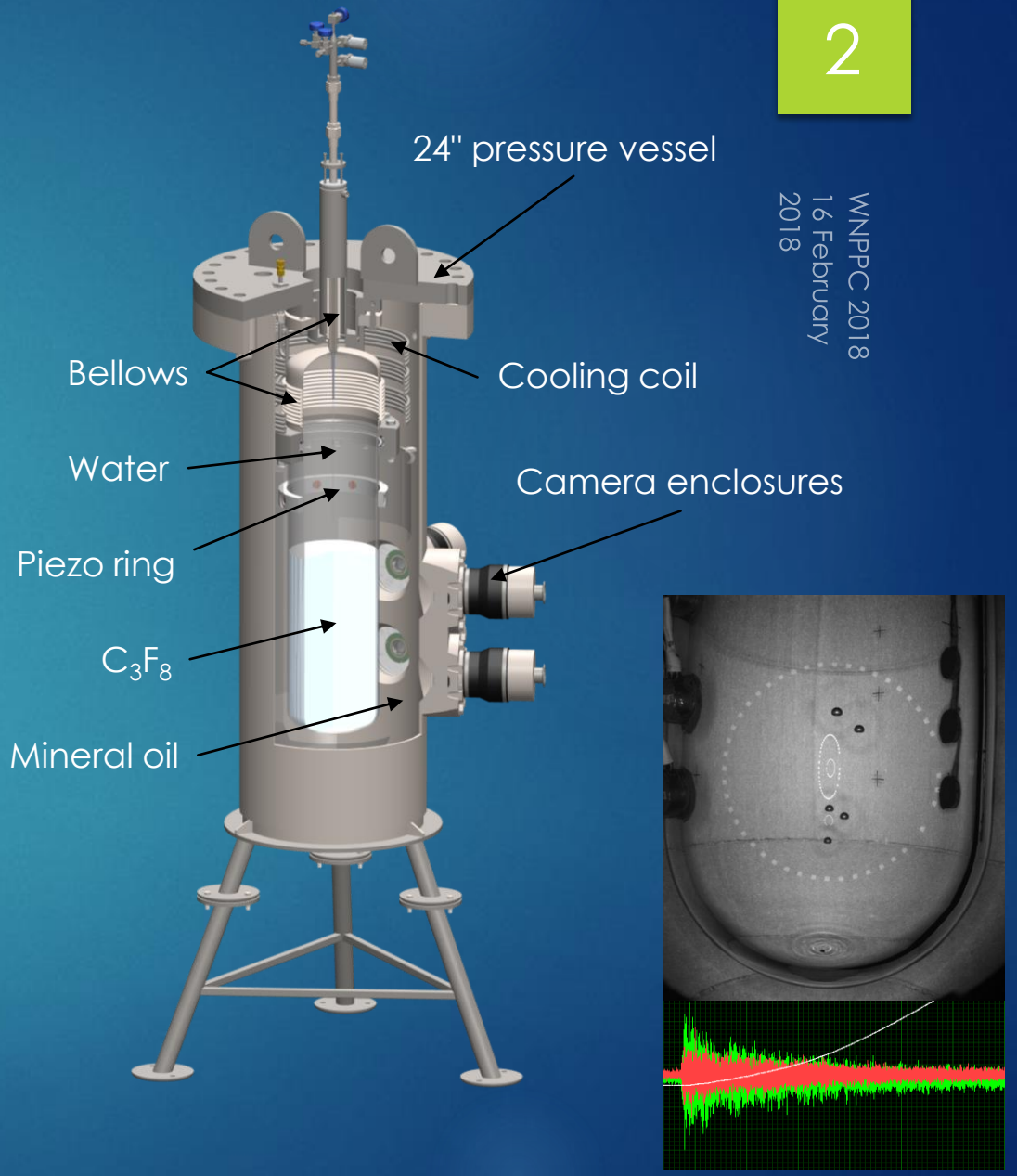
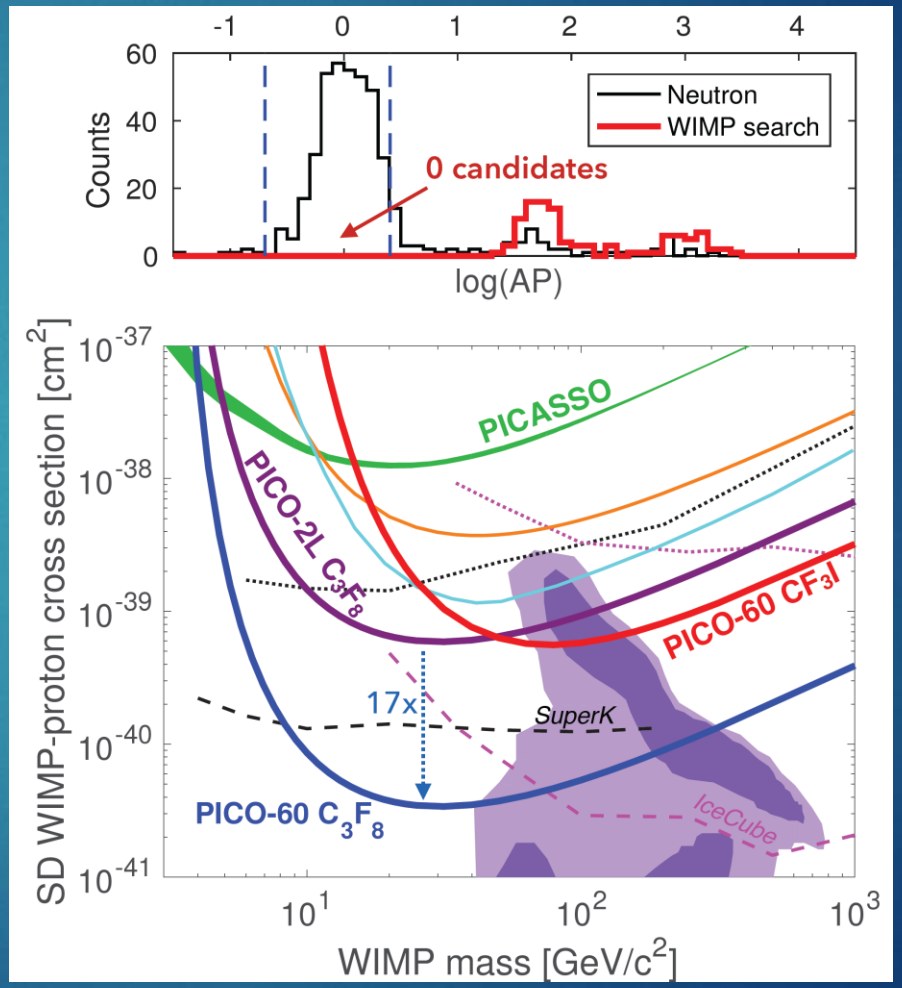
PICO-60: Detector

- Deployed in SNOLab at 2 km underground
- 52 kg of C_3F_8 target
- UPW as buffer fluid
- Dual bellow system to cycle between stable and superheated state
- 4x camera + LED rings to monitor bubble formation
- 8x piezoelectric transducers to monitor sound of nucleation
- 1x cooling coil for temperature control

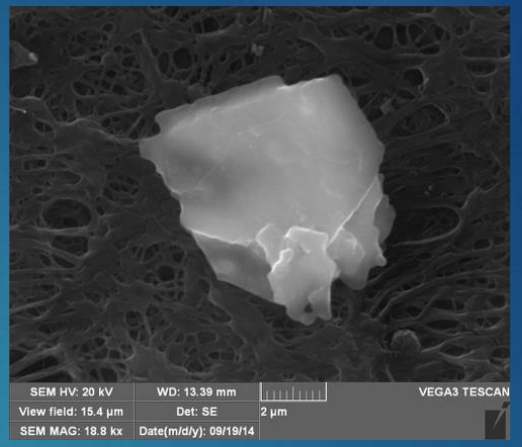


PICO-60: Results

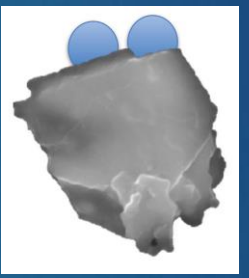
- 30 live-days run at 3,3 keV threshold published (Phys. Rev. Lett. 118, 251301)
- 1167 kg-day WIMP-search exposure
- Additional data at lower threshold still being analysed
- Best limit in the spin-dependant sector to date
- Detector decommissioned since more data acquisition would be expected to be neutron background limited

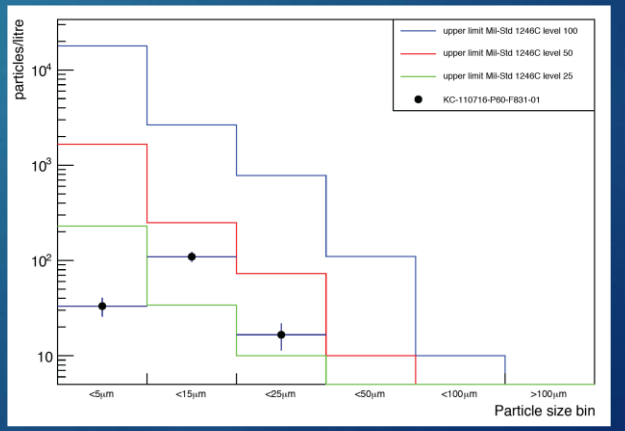


PICO-60: Limitations



- Run 1
  - High background
  - Steel and silica particulate found in the freon
  - Not radioactive enough to explain background BUT,
  - Buffer micro-droplets merging on particulates could explain background
    - Merging water droplets release O(keV) surface tension energy
    - Detector threshold is a few keV
    - Droplets could be attached to particulates and walls
- Run 2
  - Extensive cleaning (MIL-STD1246C level 50)
  - Background free! but neutron limited… (detector materials)



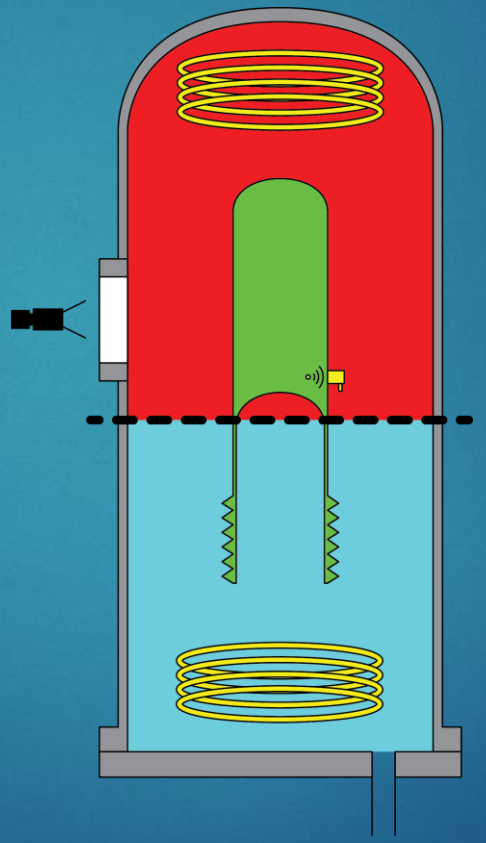


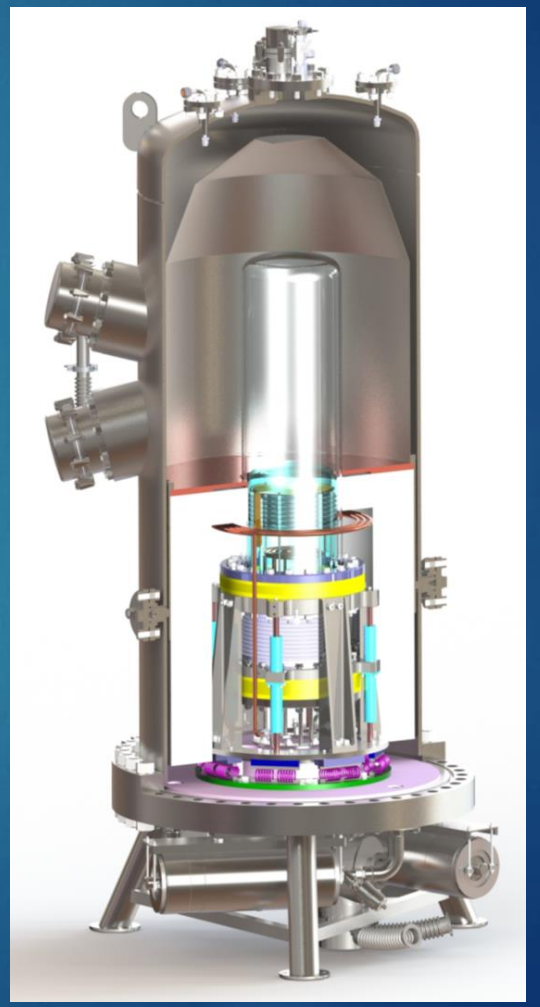
PICO-40: Requirements

- Remove buffer fluid
  - Prevents nucleation from merging buffer droplets
- Reduce number of particulates
  - Prevents nucleation from particulate radioactivity
  - Remove nucleation sites on particulates
- Use less radioactive parts
- Other minor improvements
- Right side-up design!

PICO-40: Design

- Inverted chamber with freon on top
- Second quartz jar as piston
  - No buffer fluid
- Temperature gradient to prevent nucleation in the bellows
- Bigger pressure vessel
  - Reduce neutron background (distance)
- Better material screening
- Several auxiliary systems improvements



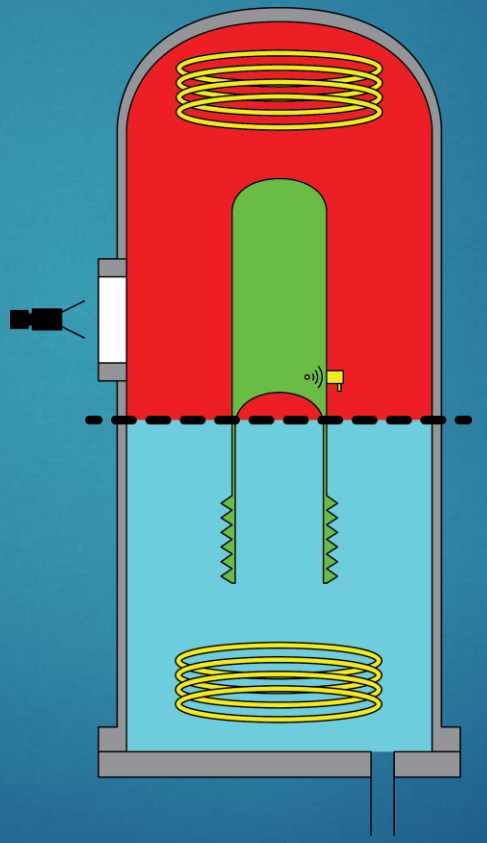


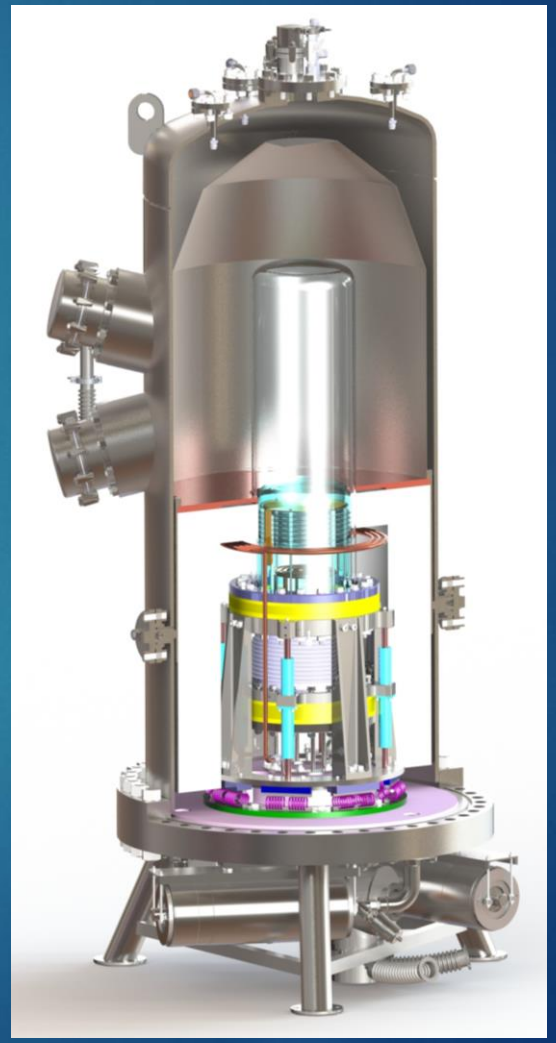
PICO-40: Inner vessels

- 2x synthetic silica jars
  - Piston like assembly
- An electro-polished stainless steel bellow
  - Balance pressure inside and outside the chamber
- Guiding rod assembly
- 2x filling ports
  - Recirculation possible
- Seismic mitigation

PICO-40: Thermal management

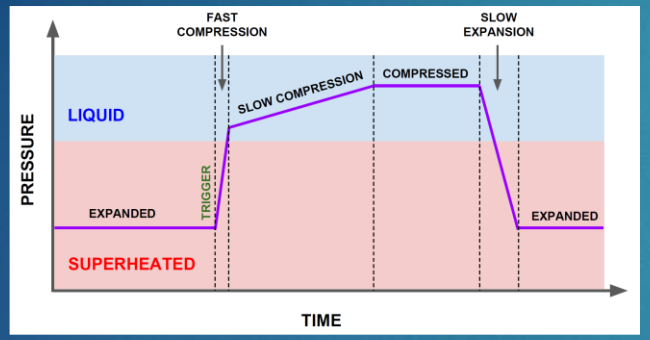
- Hot superheated region ~15 °C
  - Upper cooling coil
  - Inner and outer heating plates
- Cold liquid-state region ~ -25 °C
  - HDPE/oil insulation
  - Bottom inner and outer cooling coils
- Low convection area in the jar annulus
- Localised thermal gradient

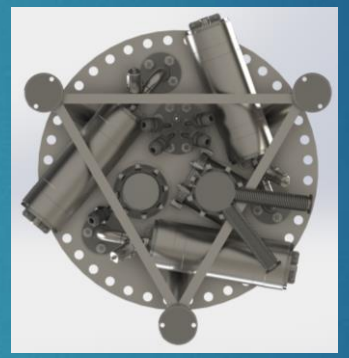




PICO-40: Hydraulic system

- Detector states
  - Expended : 20 to 80 PSIA regulation (control superheat -> threshold)
  - Compressed : 200 PSIA (liquid stable state)

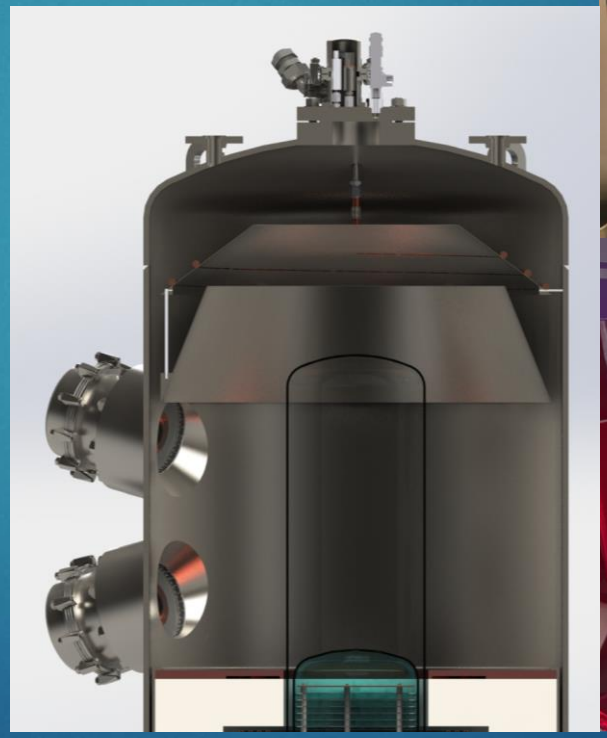


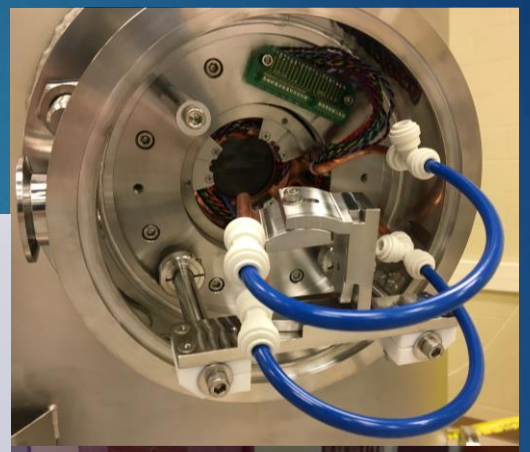


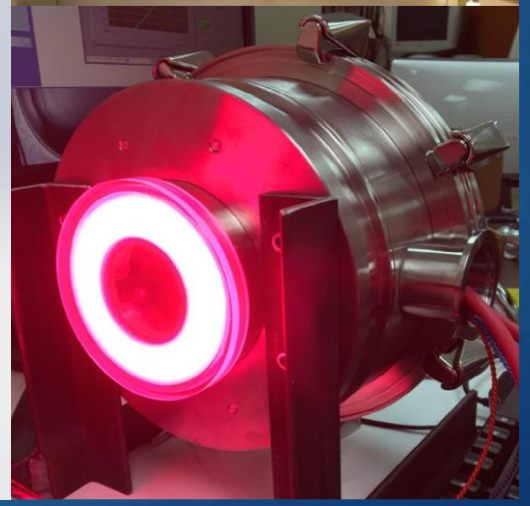
- 3x 10 L pressure accumulators for fast compression
- Several pressure sensors to monitor freon and oil pressures
- Fast pressure sensor to monitor bubble growth
- Remote pressure cart with NI PLC

PICO-40: Optical system

- 4x camera system
  - Triggered LED ring
  - USB3, 164 fps, 1920 x 1200 camera with lens
  - 4x axis camera mount
  - Cooling lines
  - T°, Humidity sensors
  - Defogging N_2 line
- Light retroreflector
- External DAQ

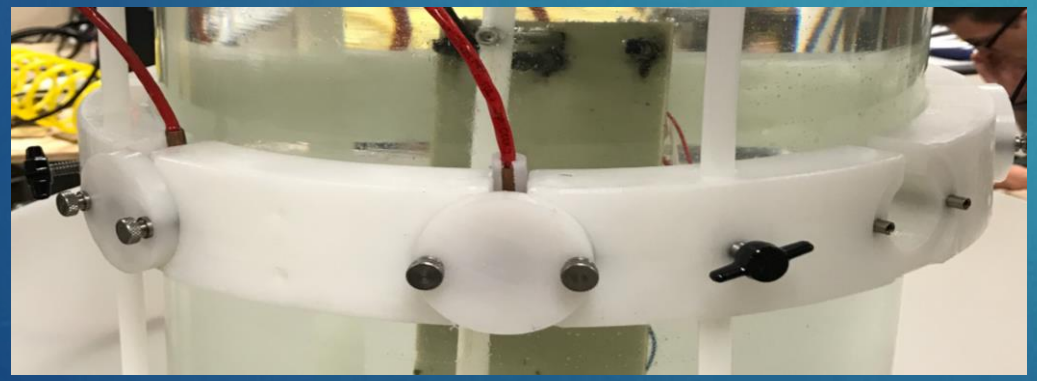


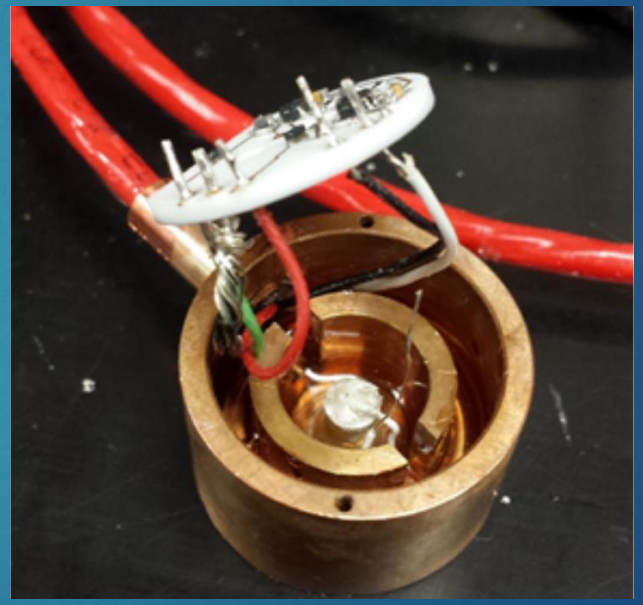




PICO-40: Acoustic system

- 12x piezo elements on 3 holder rings
- Spring loaded against the jar
- Low noise amplifiers
- NI DAQ





PICO-40: Other systems

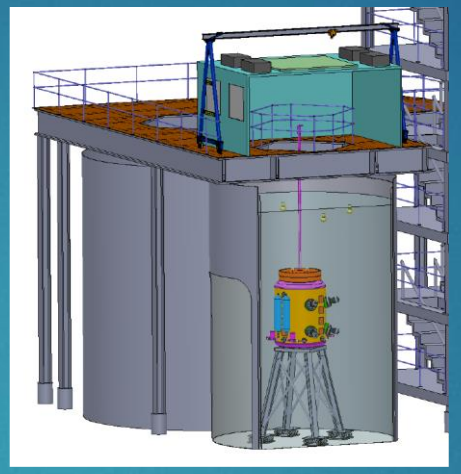
- Water shielding bath
- 2 magnetic position sensors
  - Bellow position
  - Inner vessel position (seismic mitigation springs)
- Muon veto system (future addition)
- Freon filtration/recirculation (optional)

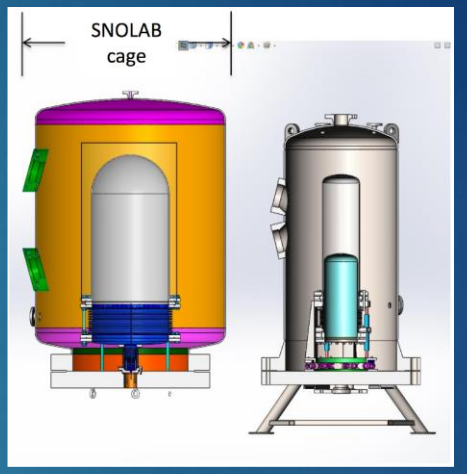
PICO-40: Construction status

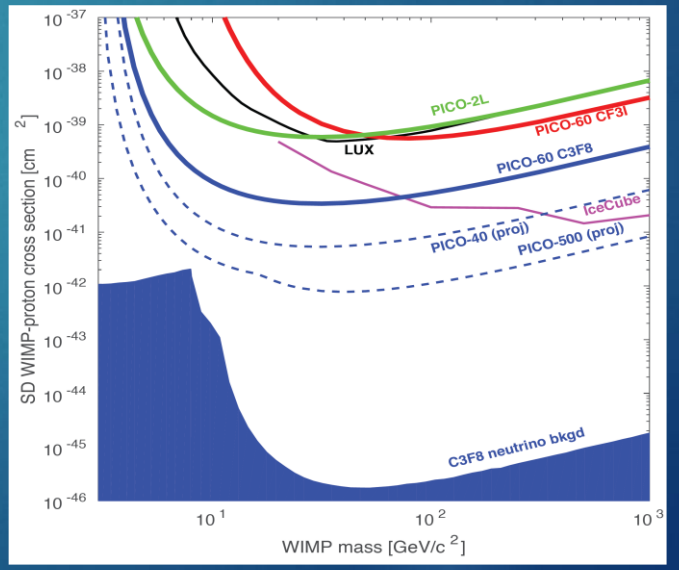
- Construction well underway
  - Inner vessel ready to be assembled next weeks
  - Thermal management being built
  - Hydraulic system almost ready
  - Optical system ready
  - Acoustic system being built
- Assembly at SNOLab surface clean room
- 4 parts will be shipped UG
  - Inner vessel
  - Pressure vessel bell
  - Pressure vessel base flange
  - Insulation
- Final assembly to occur UG
- Data taking this summer!

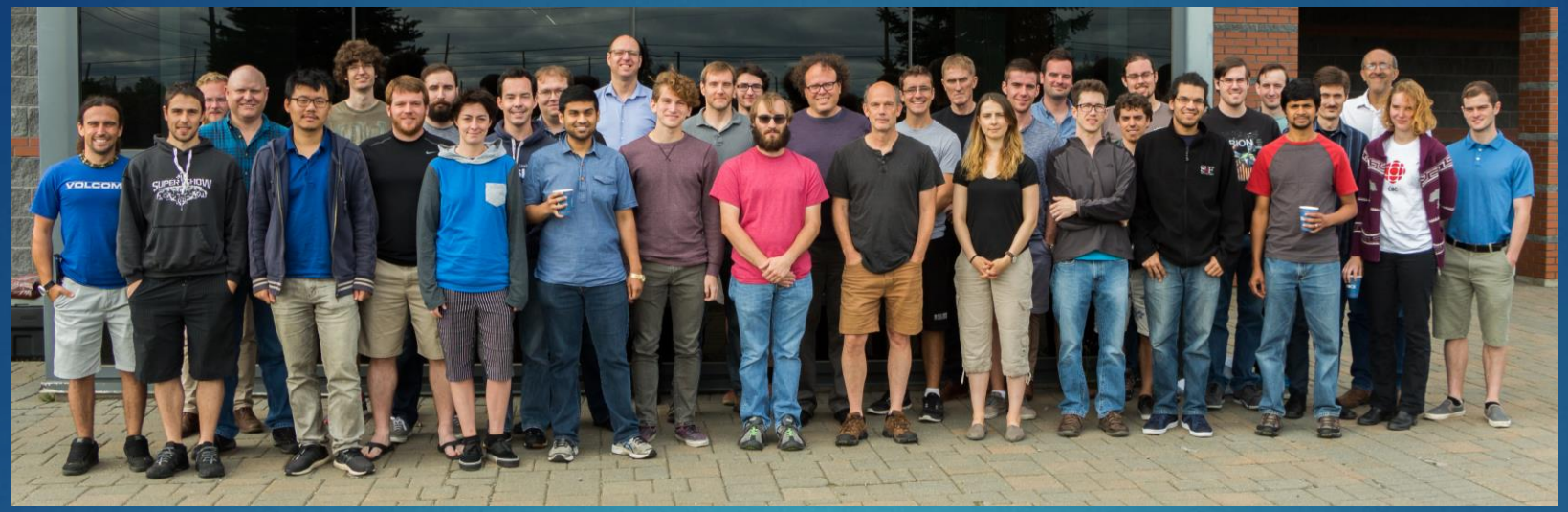
PICO-500: The next detector

- Tonne scale detector
- Scaling of PICO-40
- Design already started
- CFI funded
- Re-use miniCLEAN water tank
- Data taking in 2019
- An order of magnitude better than PICO-40
- Other freon possible (e.g. $C_2H_2F_4$ for low mass WIMP)









- PICO-60 : Best spin-dependant limits
- PICO-40 : Improved design, data taking summer 2018
- PICO-500 : Data taking 2019
- Stay tuned!

Any questions?