RADON MITIGATION TECHNIQUE FOR PICO-500 ASSEMBLY

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Abstract

Modern bubble chambers offer a unique opportunity to probe the dark matter parameter space through the use of superheated C3F8 as the target material. PICO-500 is the next generation of bubble chamber detector made by the PICO collaboration. It will be located at the underground research facility SNOLAB in Sudbury, Canada. Backed by the operational experience of previous detectors, PICO-500 will be an improvement over previous detectors on many fronts including size and design. Bubble nucleation requires highly localized energy deposition, making PICO-500 insensitive to electrons at the operated energy threshold. This leaves the focus on background rates to alpha and neutron particles. Background rates were among the limiting factors of previous detectors. New mitigation techniques are going to be used in the assembly of PICO-500, most notably for radon mitigation. Limiting this background is difficult due to the high radon concentration in the underground lab. During the assembly of the detector, nylon bags flushed with nitrogen will be used to limit the deposition of radon on the surfaces of the bubble chambers active region.

Background in PICO detectors

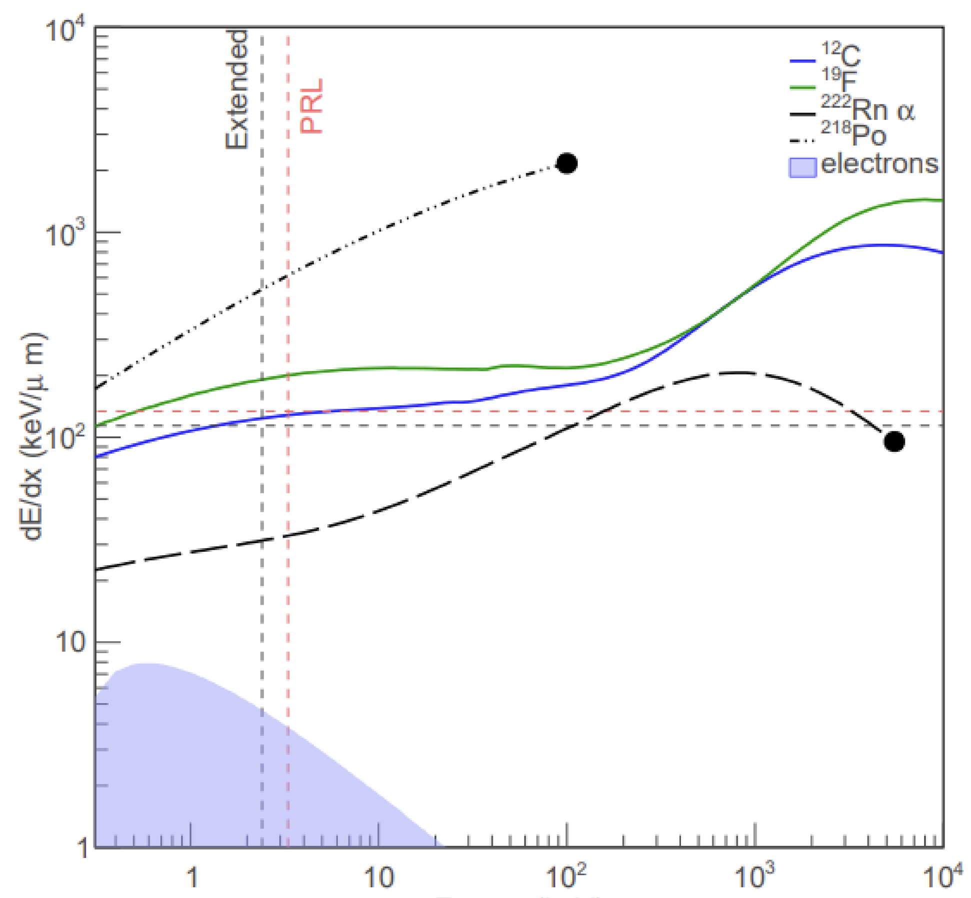


Figure taken from [1]

By carefully choosing the operating threshold, we can suppress bubble nucleation from electron recoil, as electrons deposit their energy in larger area.

Alphas have high stopping power and will induce bubble nucleation. These alphas will come primarily from radon-222 decay chain. Alphas can also produce neutrons that will mimic dark matter signal.

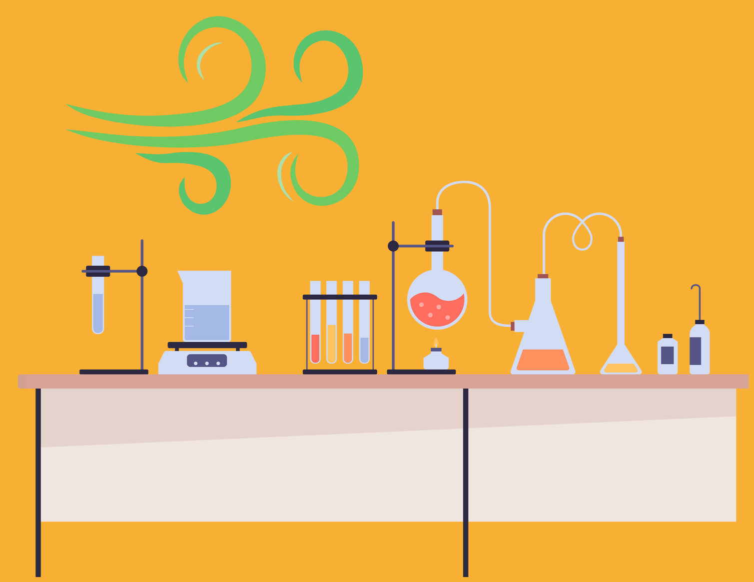
PICO-40L (current generation)

Type	Rate (event/hr)
Wall	11.08 +/- 0.29
Alphas	5.06 +/- 0.21

Where does the radon background come from?

Radon Emanation

Underground Lab Air



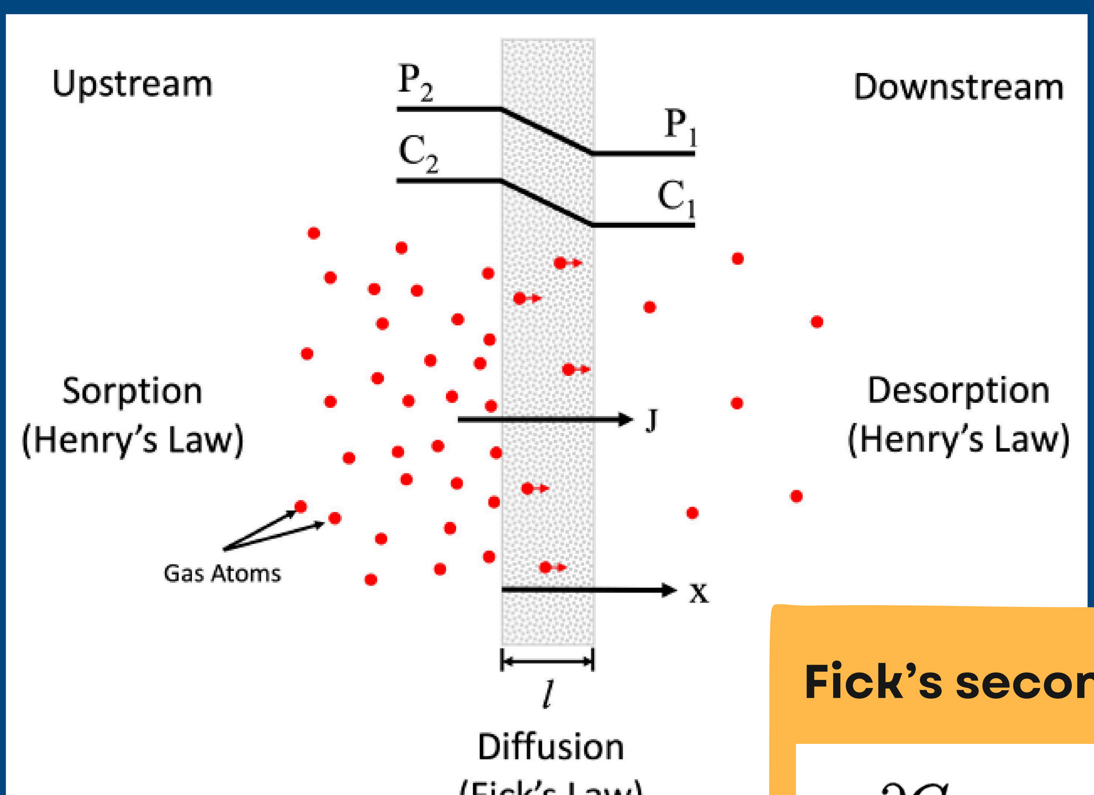


Figure taken from [2]

Fick's second law

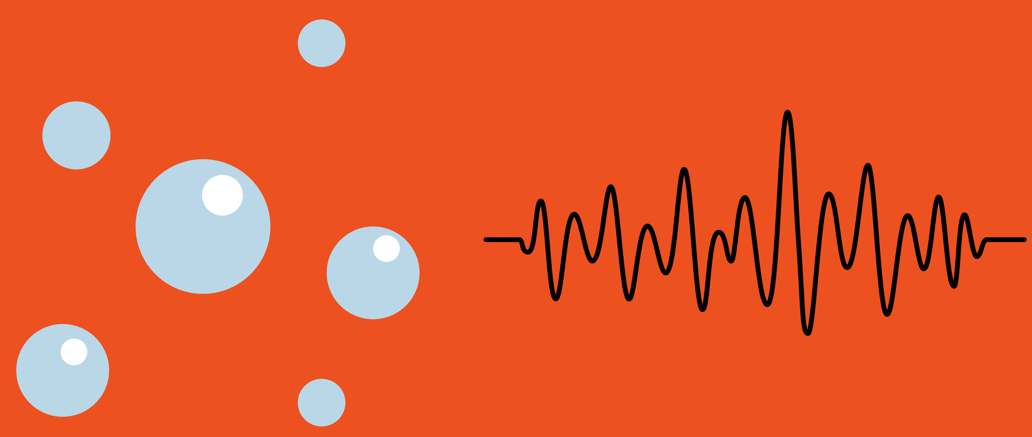
$$V\frac{\partial C}{\partial t} = A\frac{D(C_{out} - C)}{l^2} - JC - \lambda_{R_n} VC$$

Permeation | Nitrogen flush | Radon decay

PICO-500

Bubble chambers work by exploiting the superheated state of a fluid. To undergo phase transition (from liquid to gas), the fluid needs a highly localized energy deposition. The threshold for the phase transition is determined by the operating pressure and temperature and in our case is on the order of a few keV.

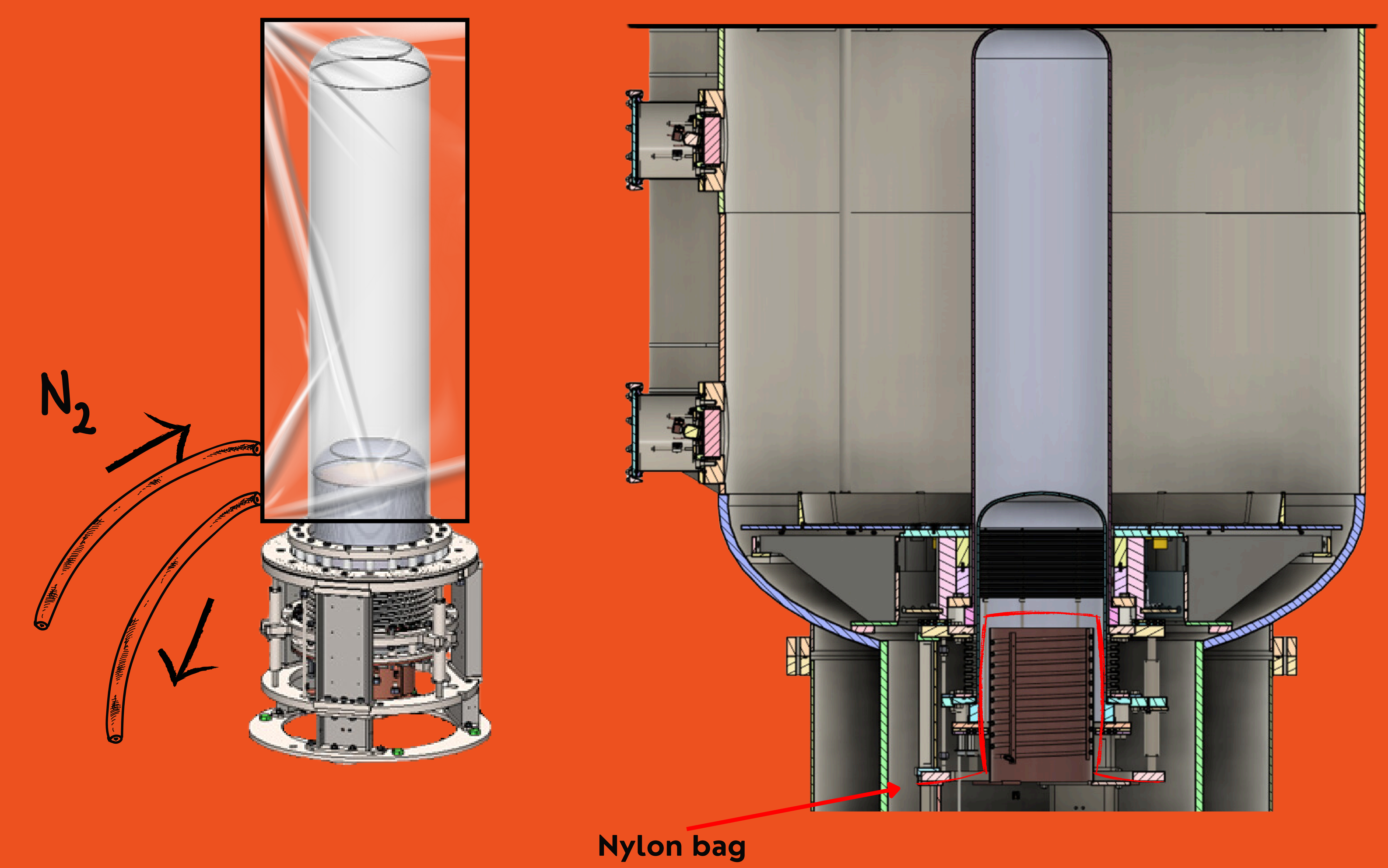
- 250 liters of C3F8
- Excellent spin-dependent reach
- Particle discrimination with acoustics
- Easily interchangeable fluid



Mitigation Technique

By covering the silica jar with nylon bags during the assembly, we can reduce the exposure to radon. These bags will be removed once the assembly is completed.

PICO-500 inner vessel with nylon bags



Nitrogen Flush

The concentration of radon will reach roughly 80% of underground radon concentration in 10 days with purging only. We need a constant flow of nitrogen to help flush radon that permeates through the nylon bags.

Equilibrium concentration, assuming a proper flow through the bagged volume, is 17.06 Bq/m3. This changes our dominant contribution from plate-out to diffusion.

Contribution	Max exposure time (no mitigation)	Max exposure time (with mitigation)
Plate-out	1.05 years	8.00 years
Diffusion	3.38 years	-

References

- [1] Mitra, P. *PICO-60: A Dark Matter Search Experiment with C3F8 in a Bubble Chamber.* PhD Thesis. University of Alberta.
- [2] Miller-Chikowski, S. *Studies on Radioactive Background Mitigation for the PICO-500 Dark Matter Search Experiment.* MSc Thesis. University of Alberta.
- [3] Mamedov, F. et al. *Measurement of the radon diffusion through a nylon foil for different air humidities. AIP Conf. Proc.* 1672. 140007 (2015).
- [4] Cozmuta, I. (2001). *Radon generation and transport: a journey through matter.* s.n.