UNIVERSITY OF ALBERTA

Lauréats KILLAM Laureates

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Efficient Radon removal by Silver-Zeolite developed for The NEWS-G Experiment

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SNOLAB

NSERC CRSNG

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Spherical Proportional Counter

- Detector:

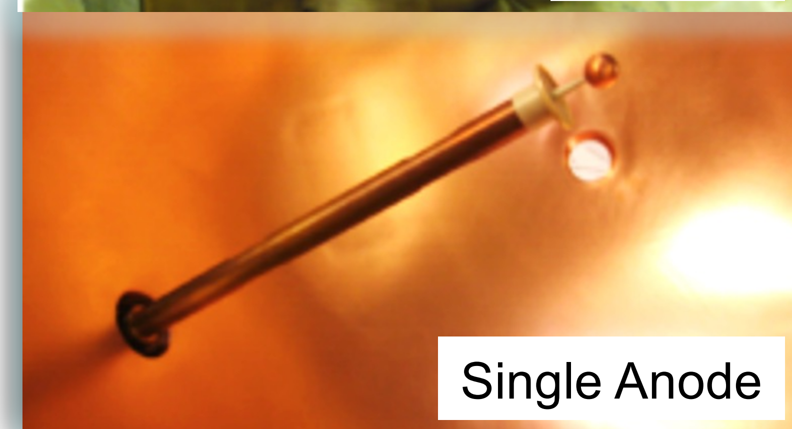
  Spherical copper vessel with a high voltage sensor in its centre.
  → High volume-to-surface ratio

- Active target:

  Gas of neon, hydrogen mixture, helium, argon.
  → Low-A target atoms increase sensitivity to low-mass DM

- Readout:

  Charge-sensitive preamplifier.
  → One or two channels



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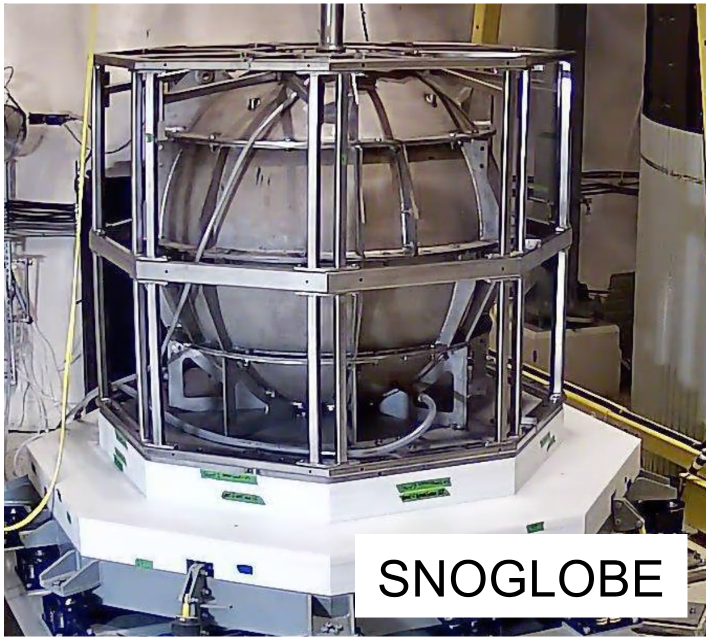
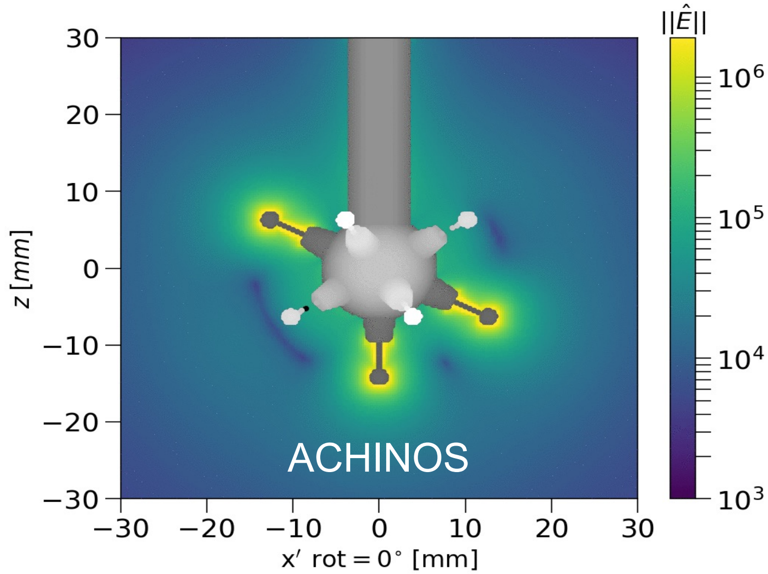
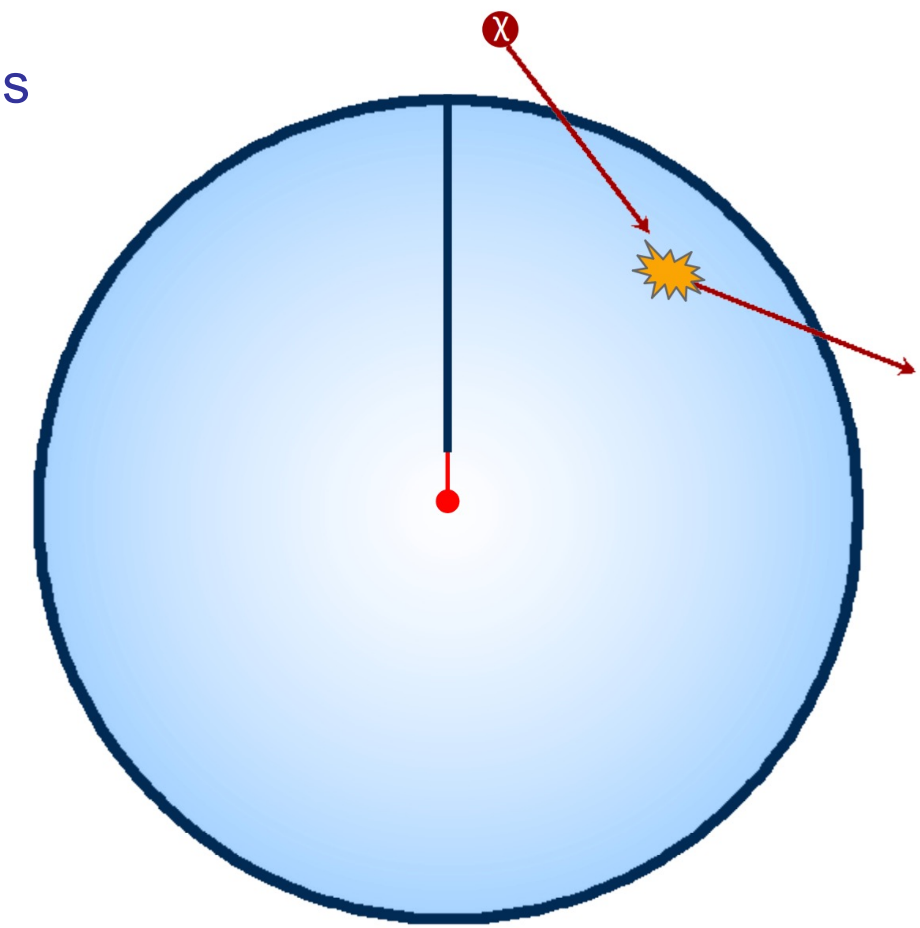




NEWS-G: Detector principle

NEWS-G EXPERIMENT:

- Incident particle scatters on target gas
  → Primary ionization



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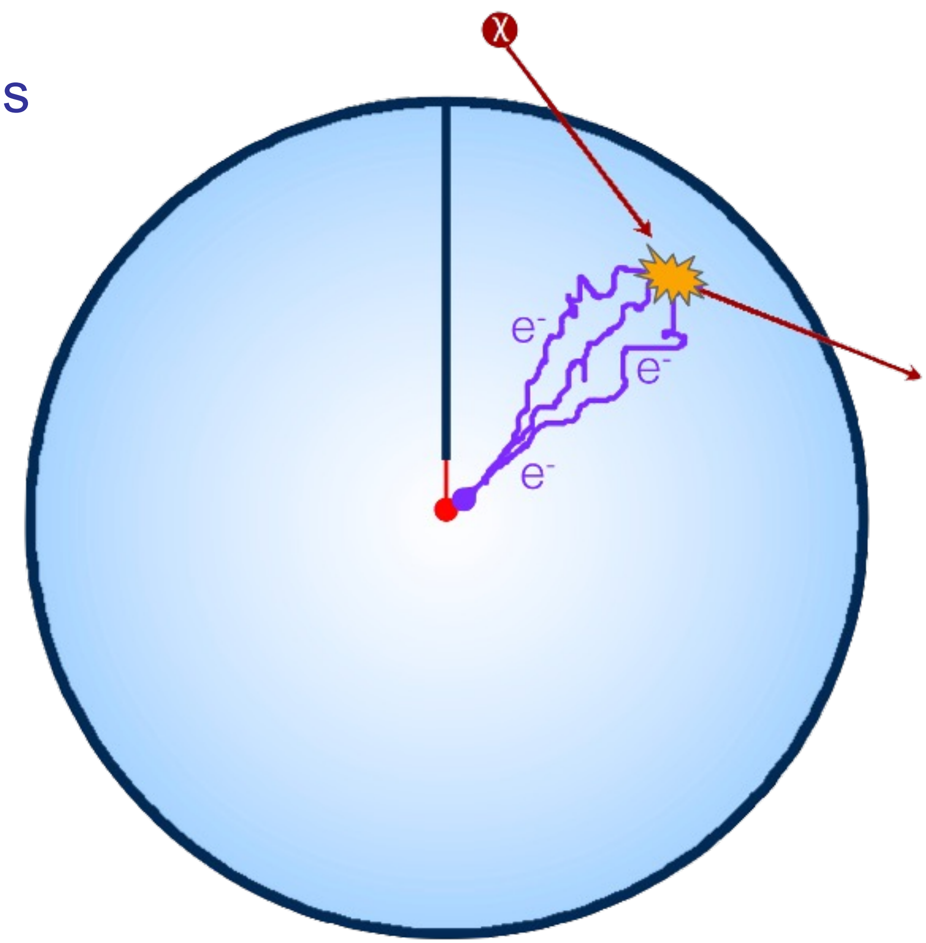
- Drift of primary e^- towards sensor
  → Varies with detector size



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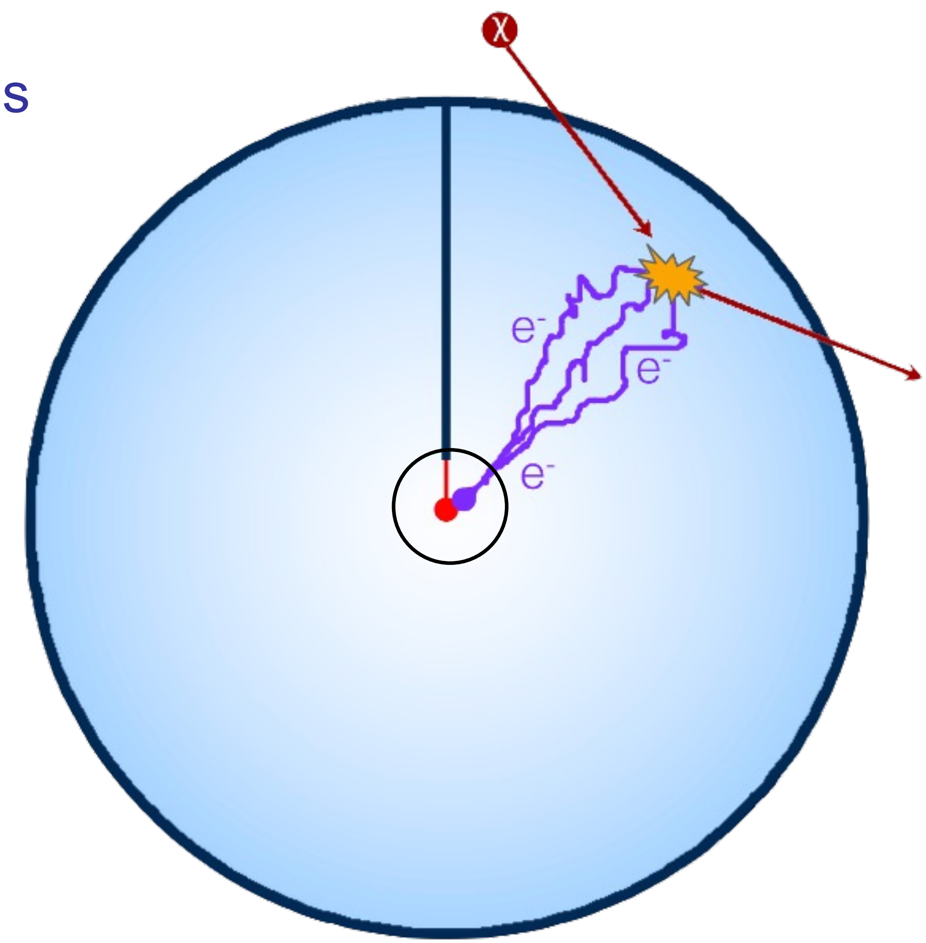
  → Amplification of signal through Townsend avalanche.



NEWS-G: Detector principle

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- Incident particle scatters on target gas
  → Primary ionization
- Drift of primary e⁻ towards sensor
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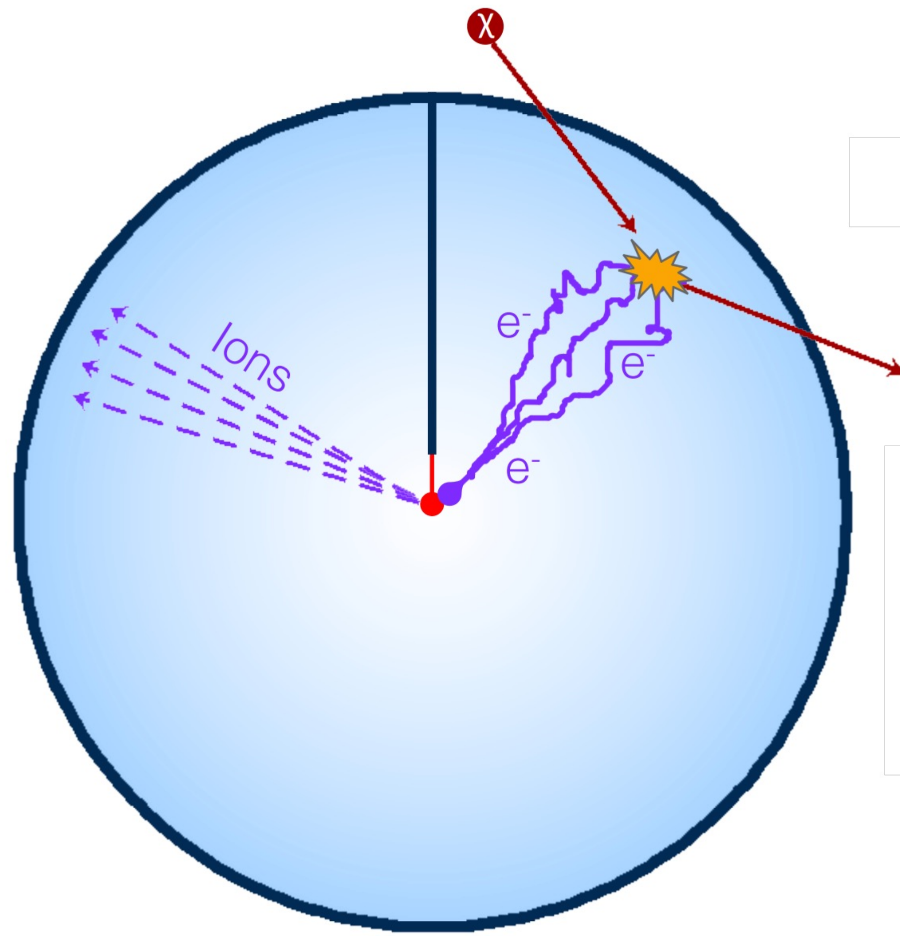
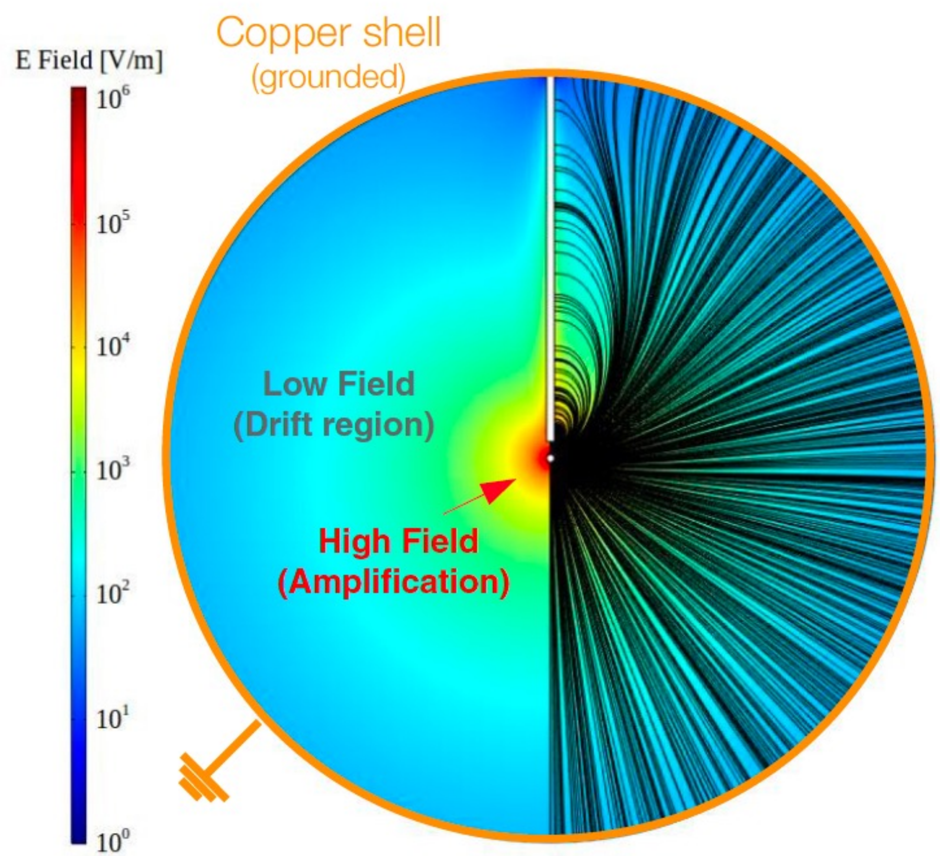
- Avalanche of secondary e-/ion pairs
  → Amplification of signal through Townsend avalanche.
- Signal formation
  → Current induced by the secondary ions drifting away from anode



Advantages of SPC

- Detector:
  High amplification gain
  Energy linearity
  Radiopure construction
- Active target:
  Choices of gas target and pressure
- Signal information:
  Volume fidualisation
  Single or few channel readout
- Low capacitance:
  Independent of detector size
  → Single-electron detection

Radial electric field that scales as $1/r^2$
→ "drift" and "amplification" regions



Toward improving the gas purity

PTEP

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Demonstration of Efficient Radon Removal by Silver-Zeolite in a Dark Matter Detector

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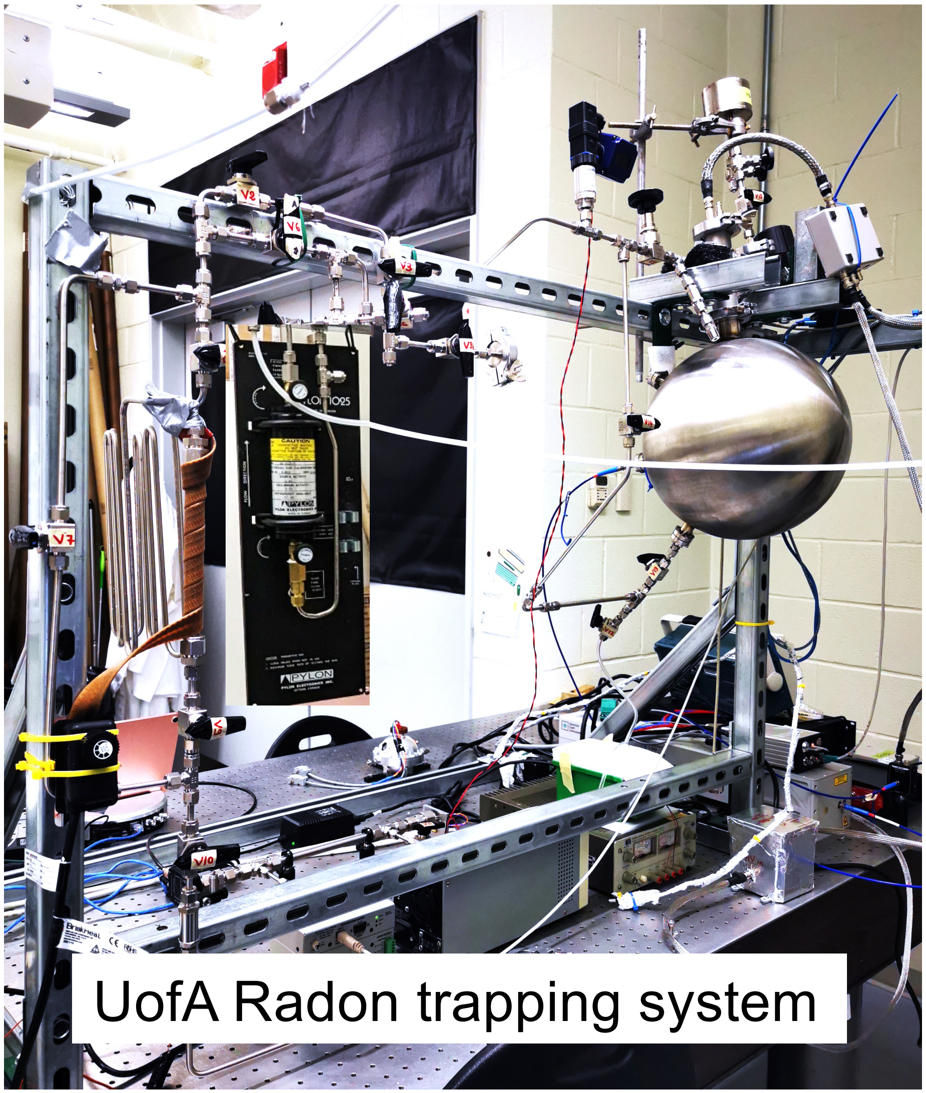
Toward improving the gas purity


UofA Radon trapping system

Adsorbents (10 g):

- Silver-zeolite (Ag-ETS-10)
- Activated charcoal

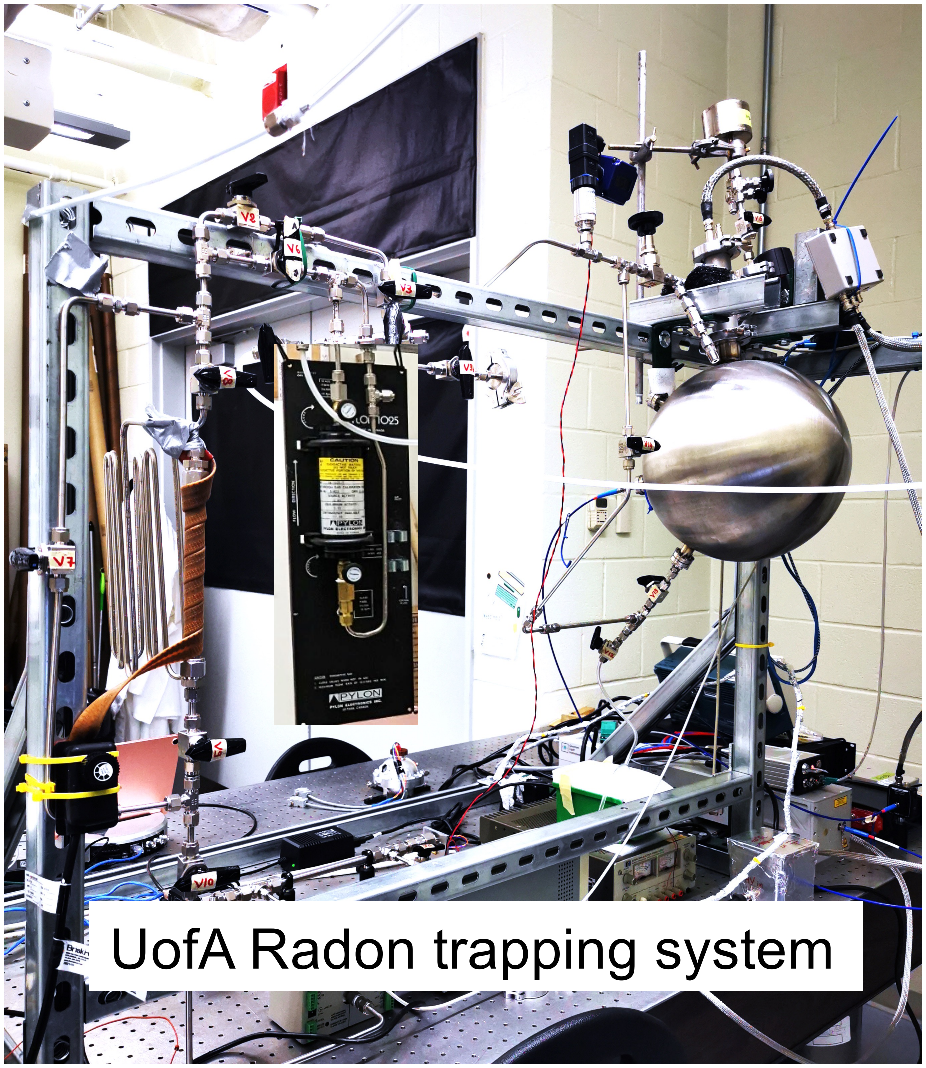
Detector conditions:

- 30 cm ø sphere
- 97% Argon and 3% methane
- 500 mbar
- 1180 V

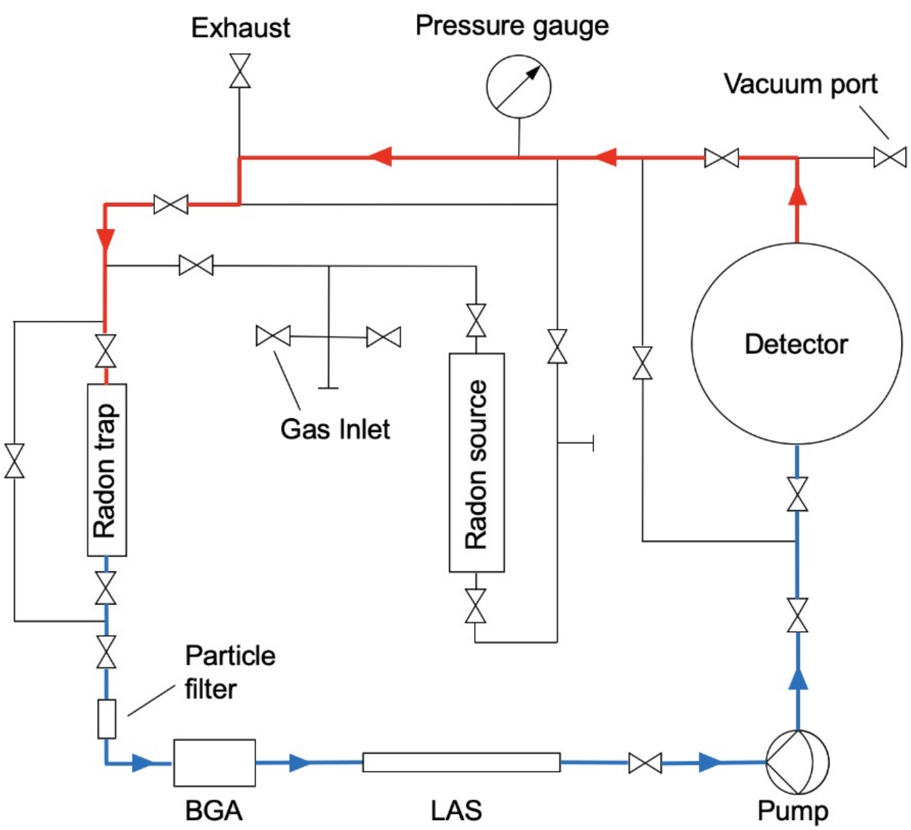
Radon source:

- Pylon 1025 with dry ^{226}Ra
- Activity of 0.93 kBq
- Continuous rate of 117.49 mBq/s

Radon Trapping System



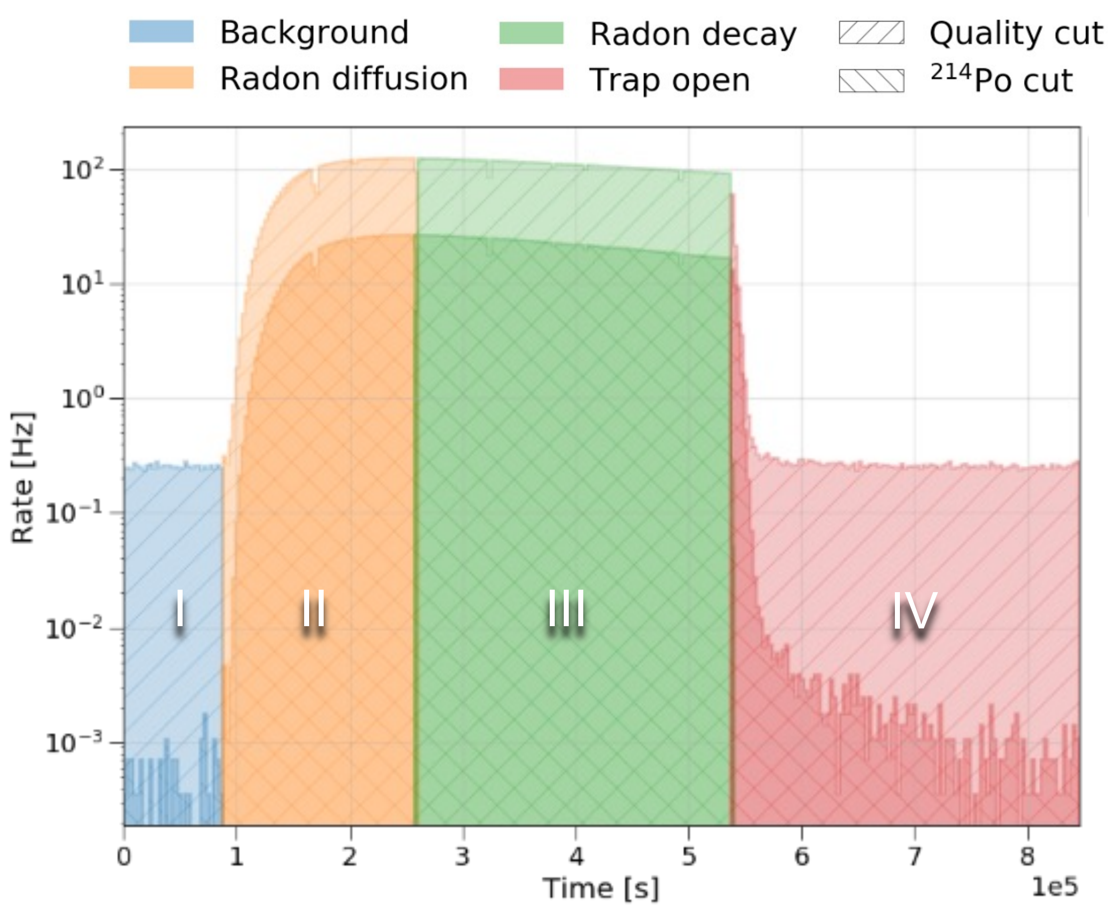
Closed-loop circulation system with a flow of 1L/min



Radon Trapping System

Three campaigns performed with 4 distinguished phases

- Phase I: Background run (~ 24 hrs)
- Phase II: Radon diffusion (until raw rate ~ 75 Hz)
- Phase III: Radon decay (exponential over 2 days)
- Phase IV: Trap open (closed-loop circulation)



Two cuts applied: Quality cut and ^{214}Po cut

Expected decay rate

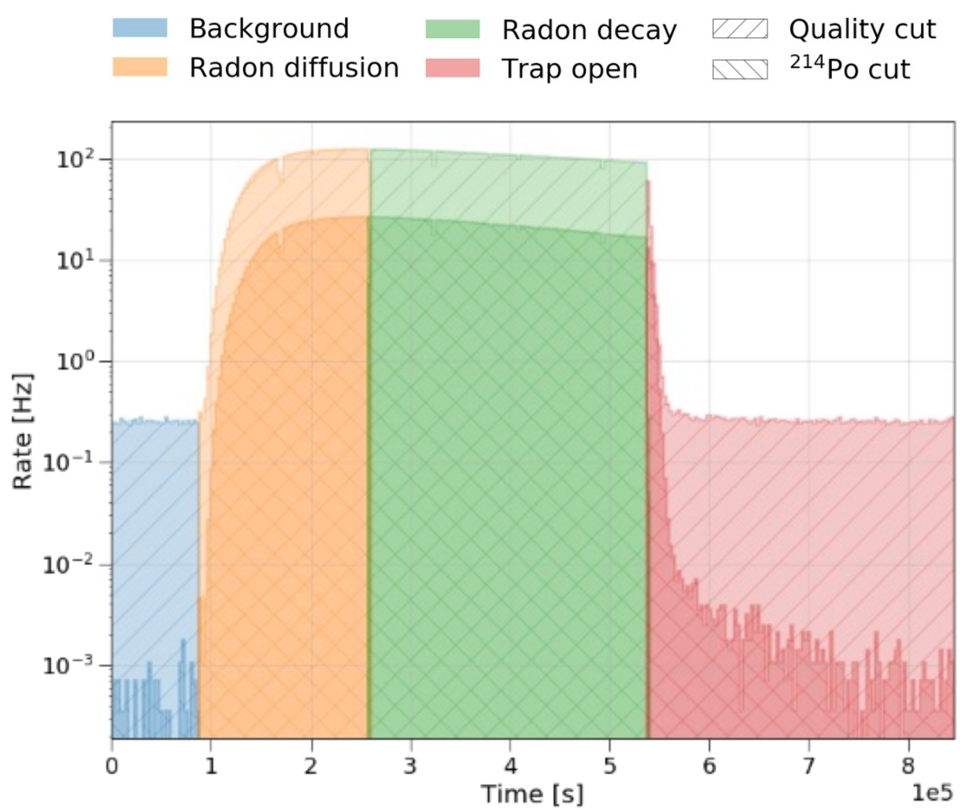
- Determined using the phase III (radon decay) data of each campaign

Phase III

Event rate near 100 Hz with 2 ms event acquisition time window

- introduces significant probability of coincidental events and pileup
- causes deadtime losses due to the DAQ limitations

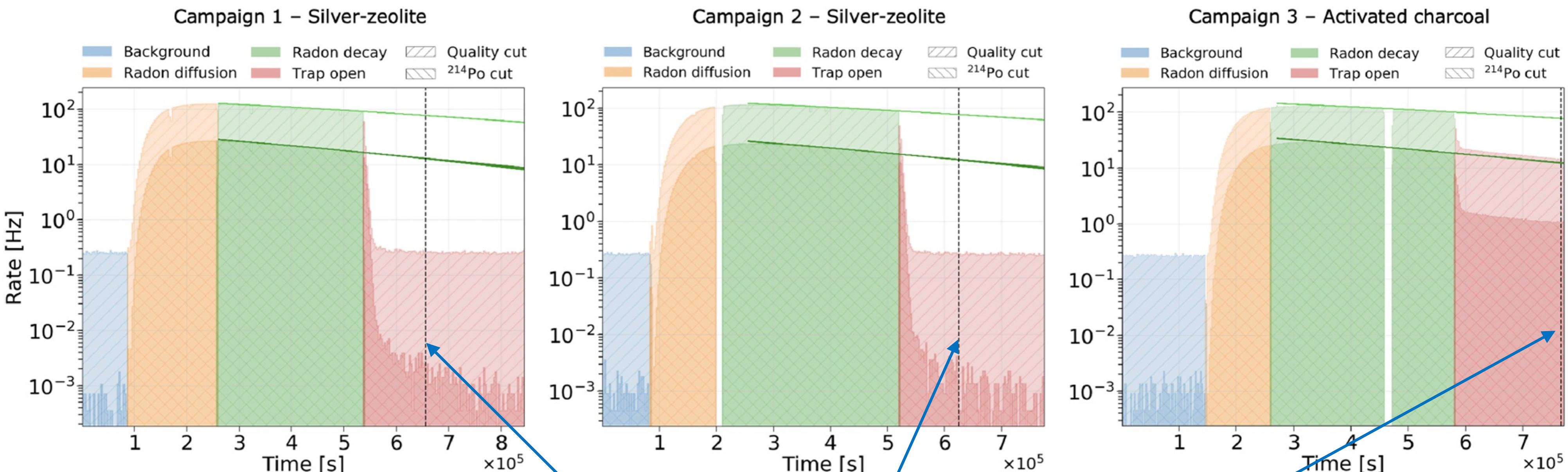
→ Reduce the observed decay rate compared to the true rate



- To take this into account → Pileup Simulation & MCMC Fitting

Results

- Three campaigns performed with silver-zeolite and activated charcoal adsorbent at room temperature.



Reference time where the extrapolation reaches 76.5 Hz

- Facilitates comparison between each campaign to obtain rate ratio and radon reduction ratio from expected and observed rates.

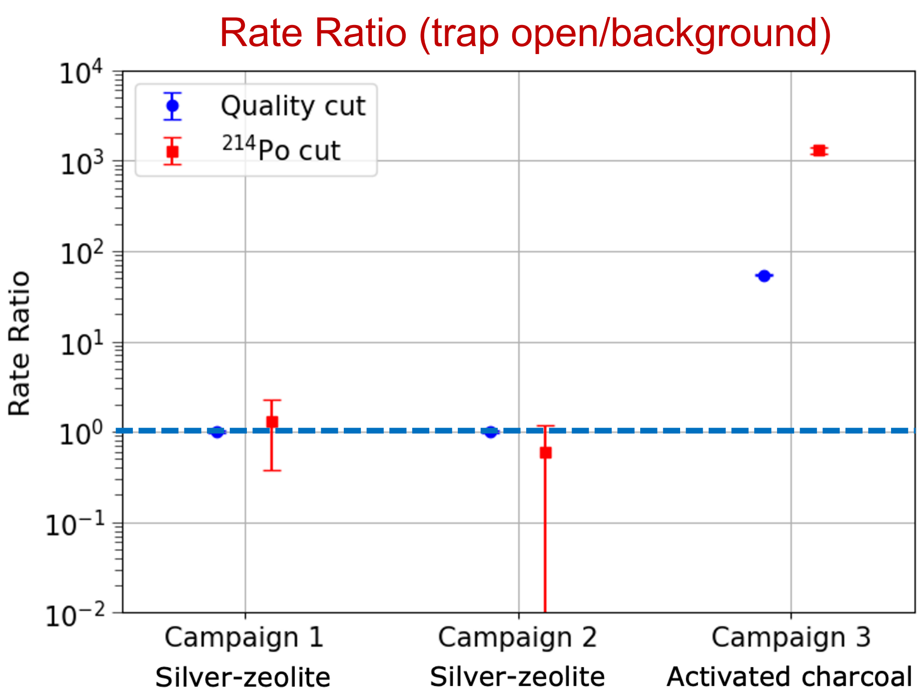
Results at the reference time

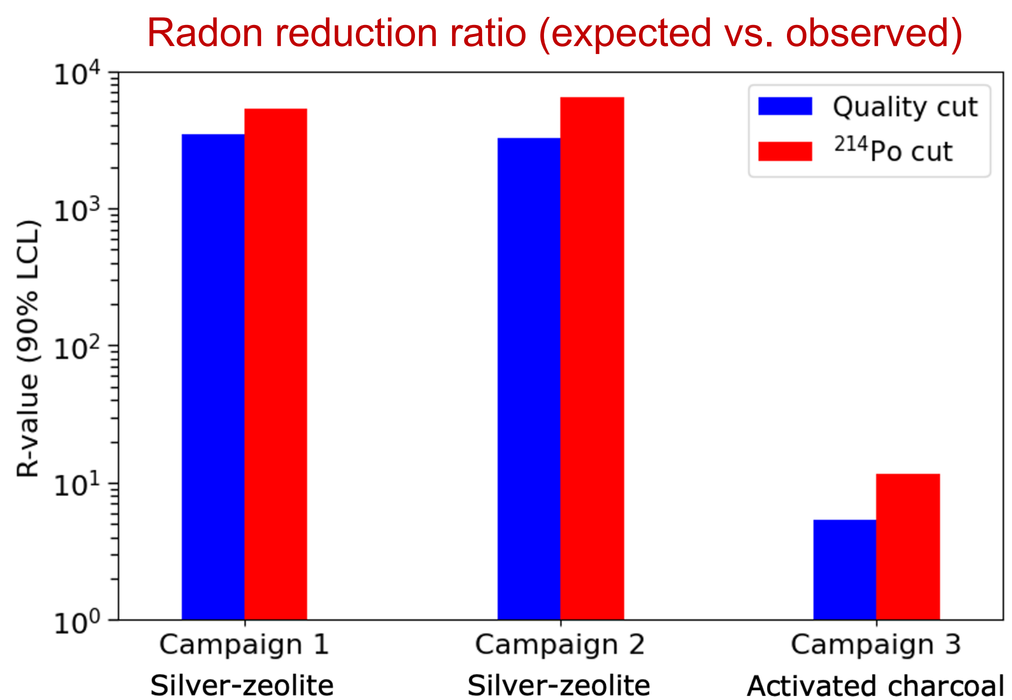
Rate Ratio:

- Silver-zeolite consistently achieves near-complete radon removal

Radon Reduction Ratio:

- Silver-zeolite better by near three orders of magnitude





Current Status

- K-factor estimations *consistent* with standard values in the literature

K-factor [m^3/kg]	Activated charcoal	Silver-zeolite
Our work	6.1720	5323.2–5608.3
In literature for other gas	3–10	> 1400 up to 20,000

- The trap is installed at SNOLAB and data are currently being analyzed
  → Preliminary results show *total removal of the radon* in the volume

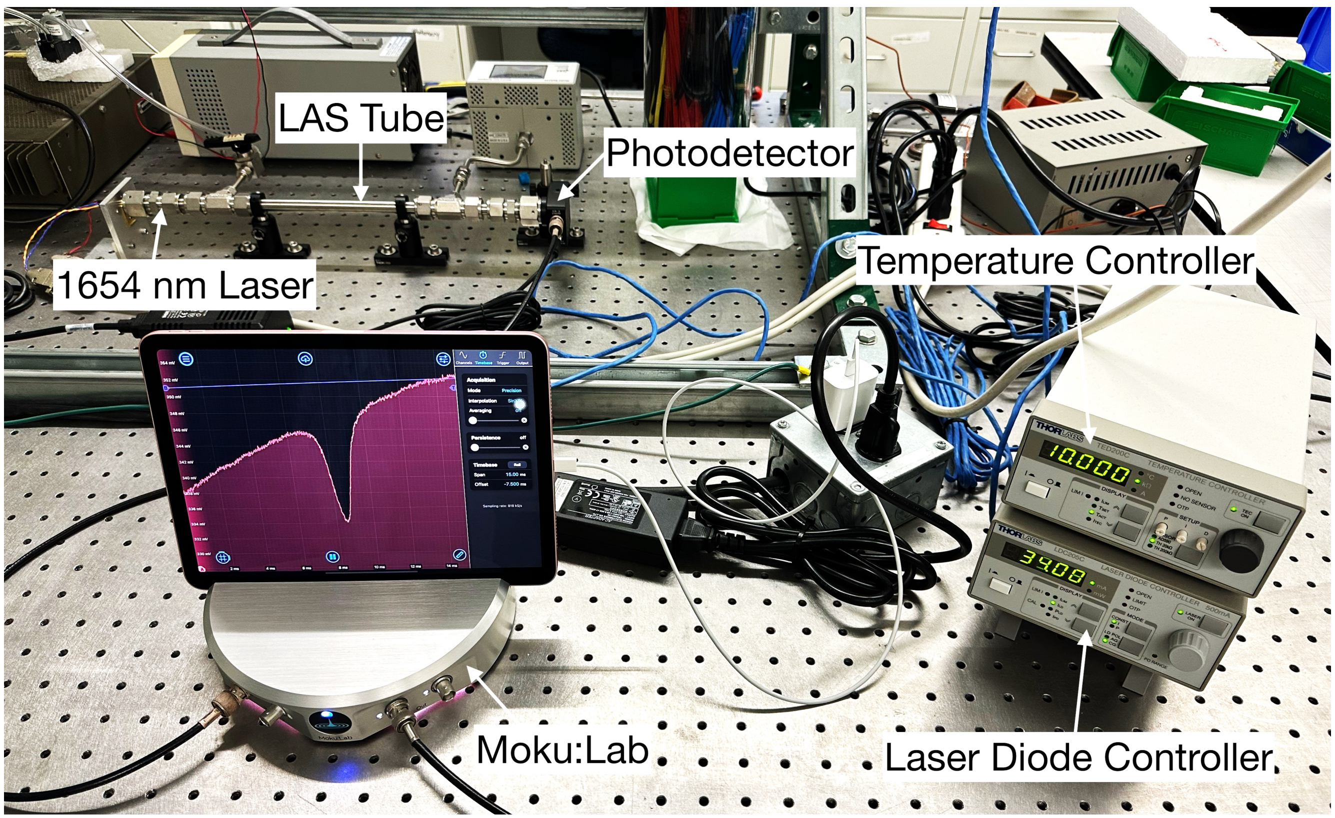
Next campaigns at low temperatures

- Preliminary campaigns show significant decrease of the gain due to the methane adsorption

→ Spike the trap with a known methane concentration

Laser Absorption Spectroscopy (LAS)

- Measure the absolute concentrations of gases with a laser tuned to a wavelength matching the absorption features of the methane gas
- Monitor accurate and absolute methane concentration over time

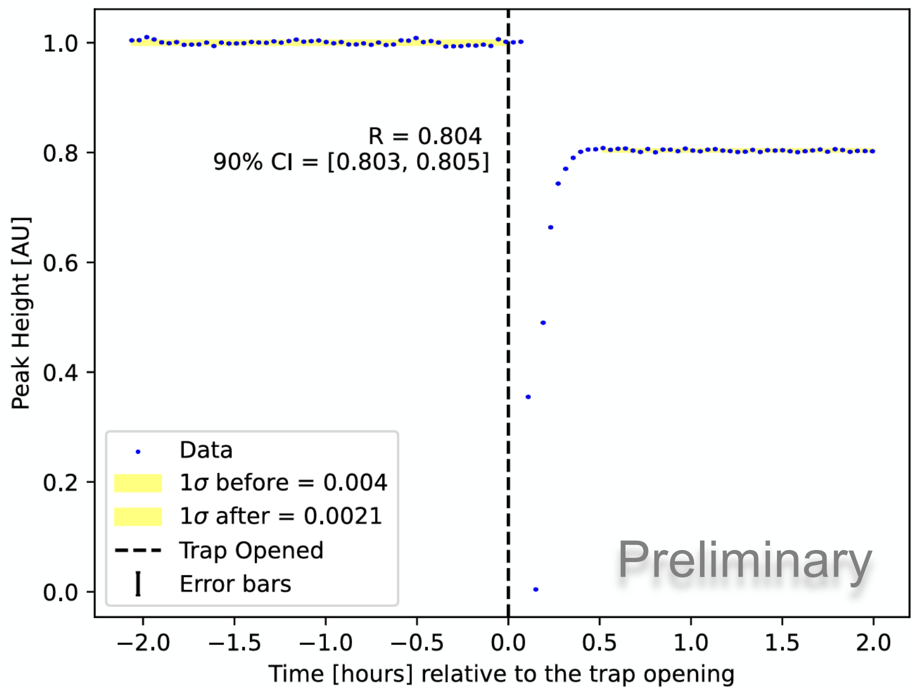


LAS monitoring

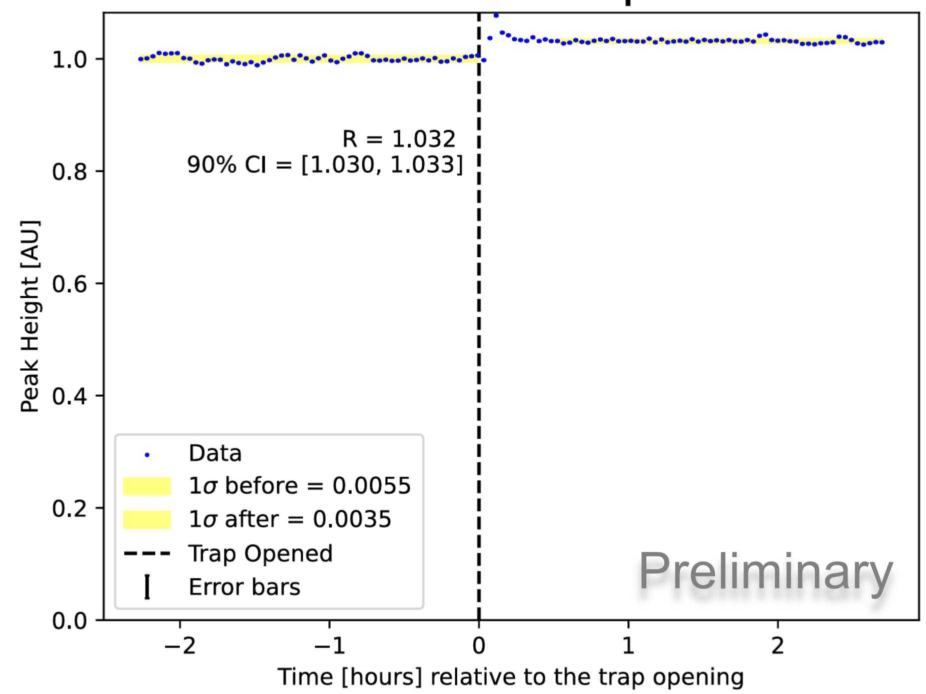
Results at room temperature

Spike the trap with 15 psi of methane to recover the initial concentration

No Methane Added



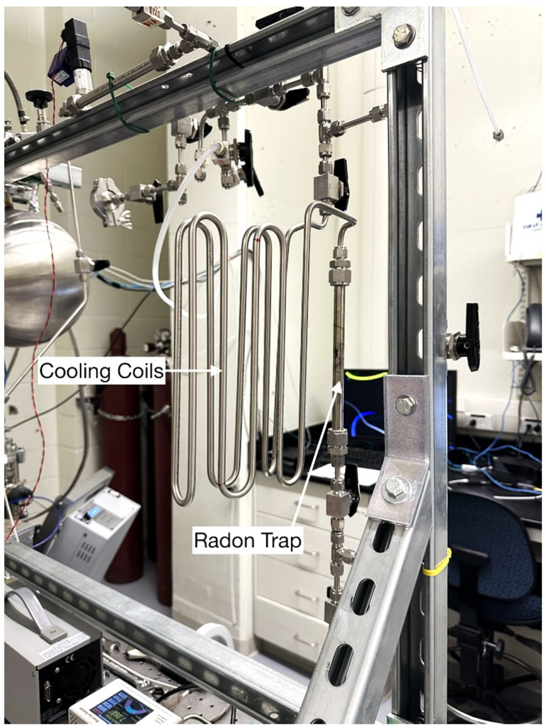
Pre-saturated with 15 psi methane

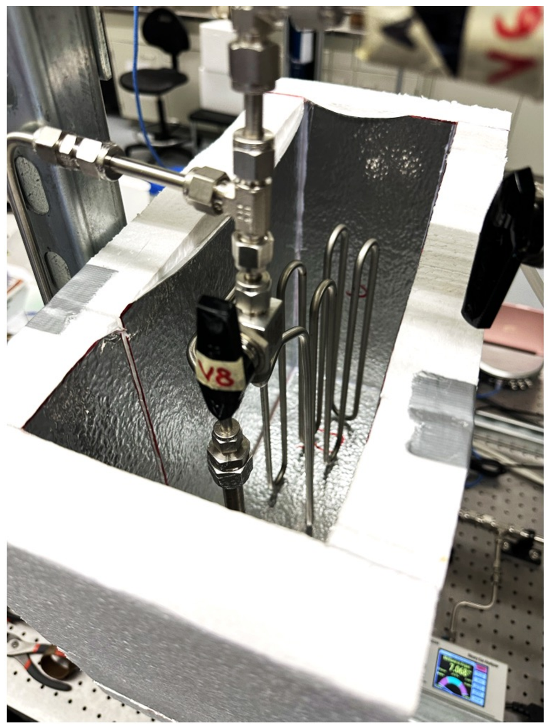


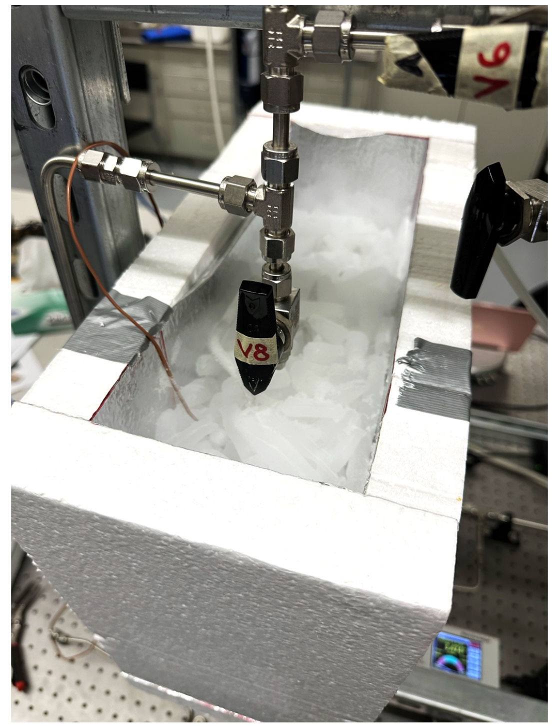
LAS monitoring

Results at dry-ice temperature

Dedicated setup to cool down the trap at ~ – 100ºC



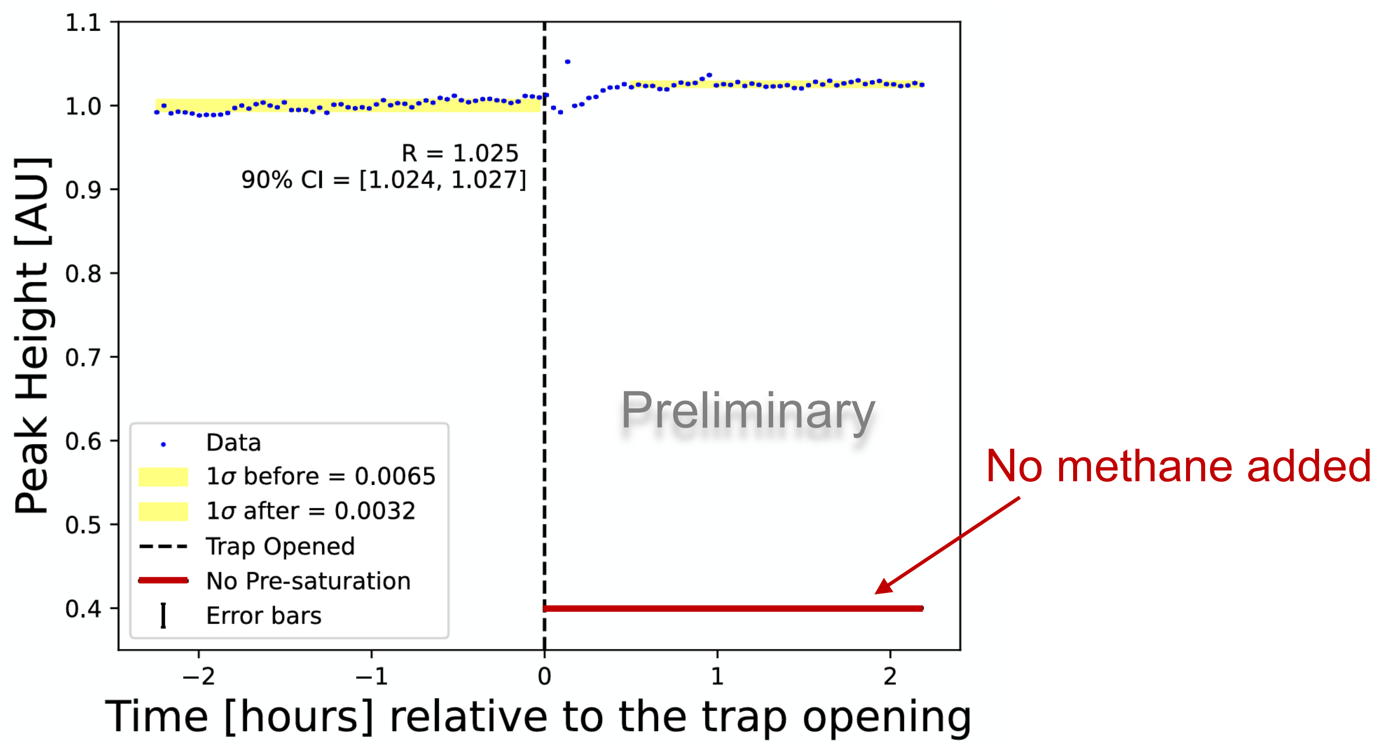




Laser Absorption Spectroscopy (LAS)

Results at dry-ice temperature

Spike the trap with 39.81 psi of methane to recover the initial concentration



Next steps:

- Redo campaigns to confirm the trap remains efficient by being spiked

Summary

We demonstrate that silver-zeolite removes efficiently radon at ambient temperature using an actual dark matter-type detector

- Offers a novel approach beyond previous methods and validated under realistic operating conditions for the first time
- These findings highlight the strong potential of silver-zeolite for ambient-temperature radon reduction systems in rare-event search experiments.
- Could eliminate the need for cryogenic cooling requirements, reducing overall system complexity for future ton-scale detectors and beyond.
- This advancement is particularly important for underground laboratories
- Enable useful applications across multiple sectors, including residential basements, healthcare facilities, and other industrial environments.