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Radon Traps Development at SNOLAB

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UBC Science

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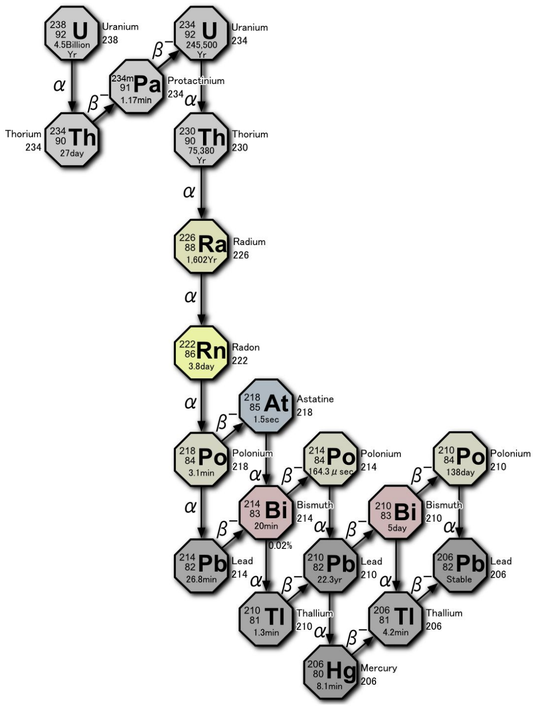
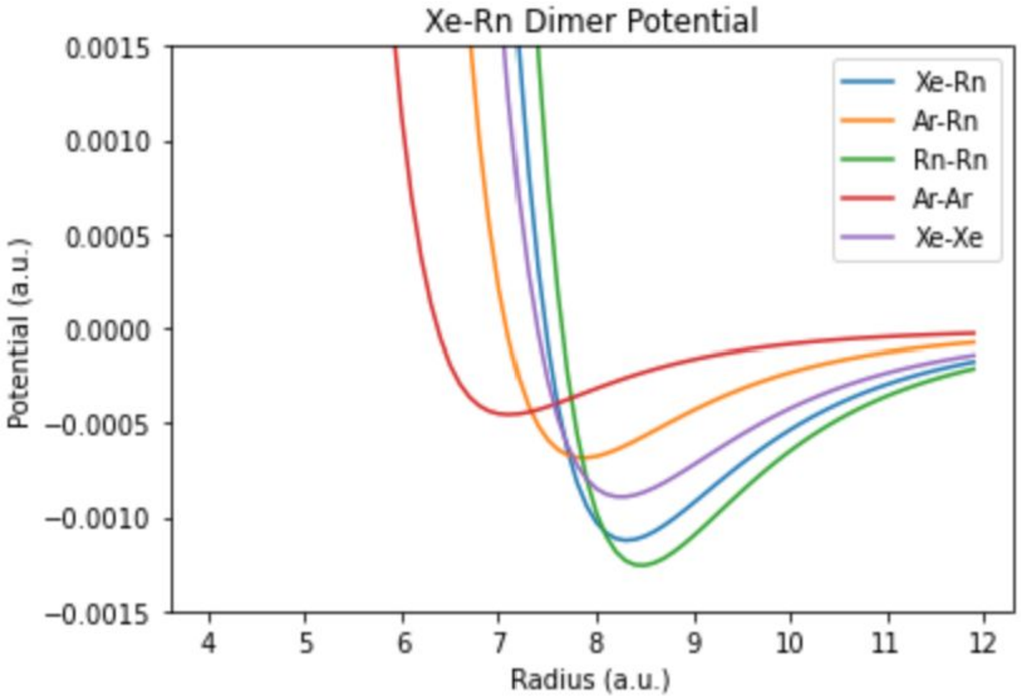
Why are Radon Traps Important?





Bonding and Decay

Radon can emanate from sources such as detector parts or even the rock surrounding the detectors.

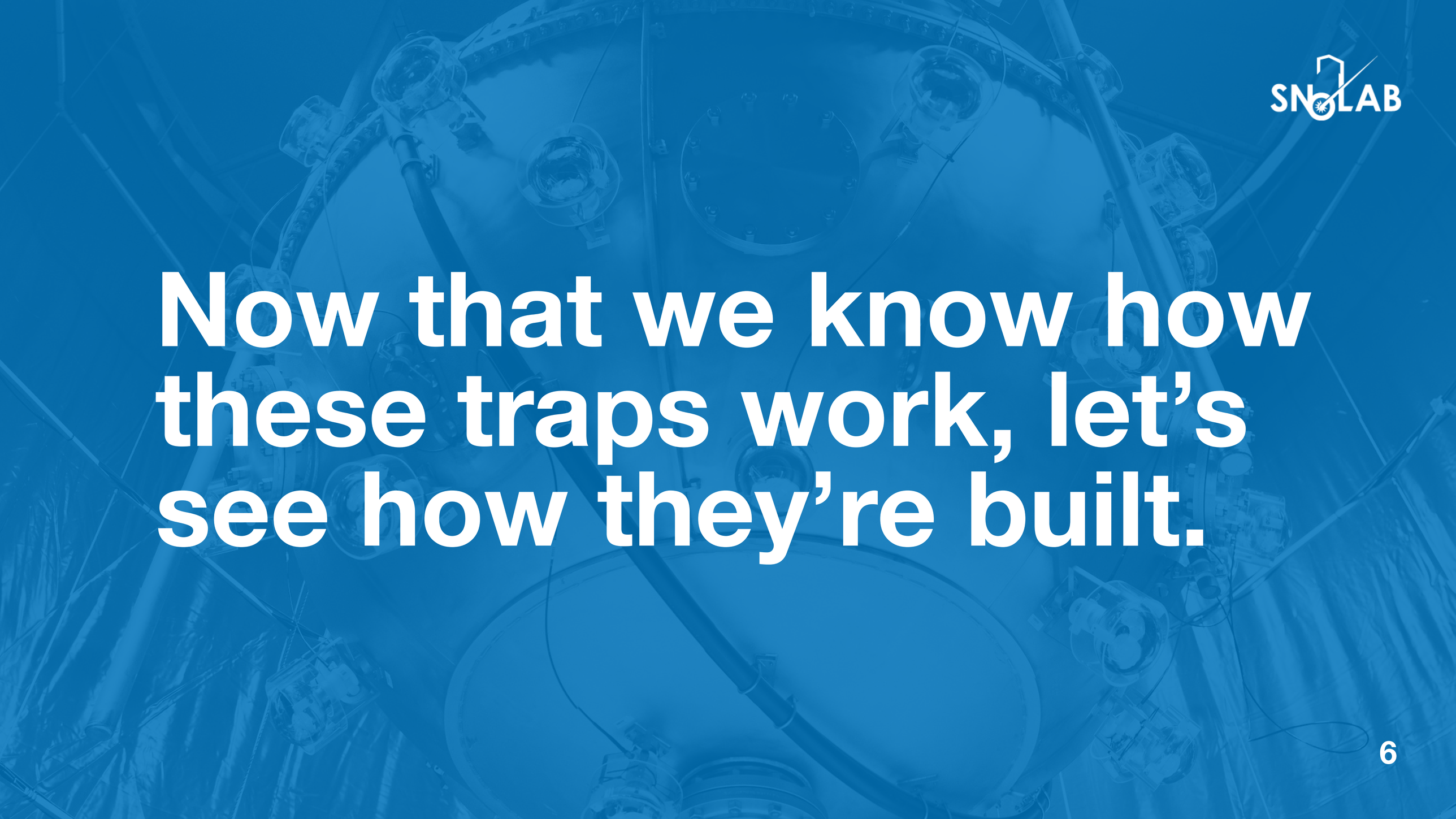
Radon bonds with noble gases through van der waal bonding, creating mixed dimers. Argon and Xenon in specific are used in novel particle detectors.

If radon can get into the gas handling system from emanantion, this can cause the detection medium to be contaminated.

Contaminated medium can decay inside the detector, causing misscounts.

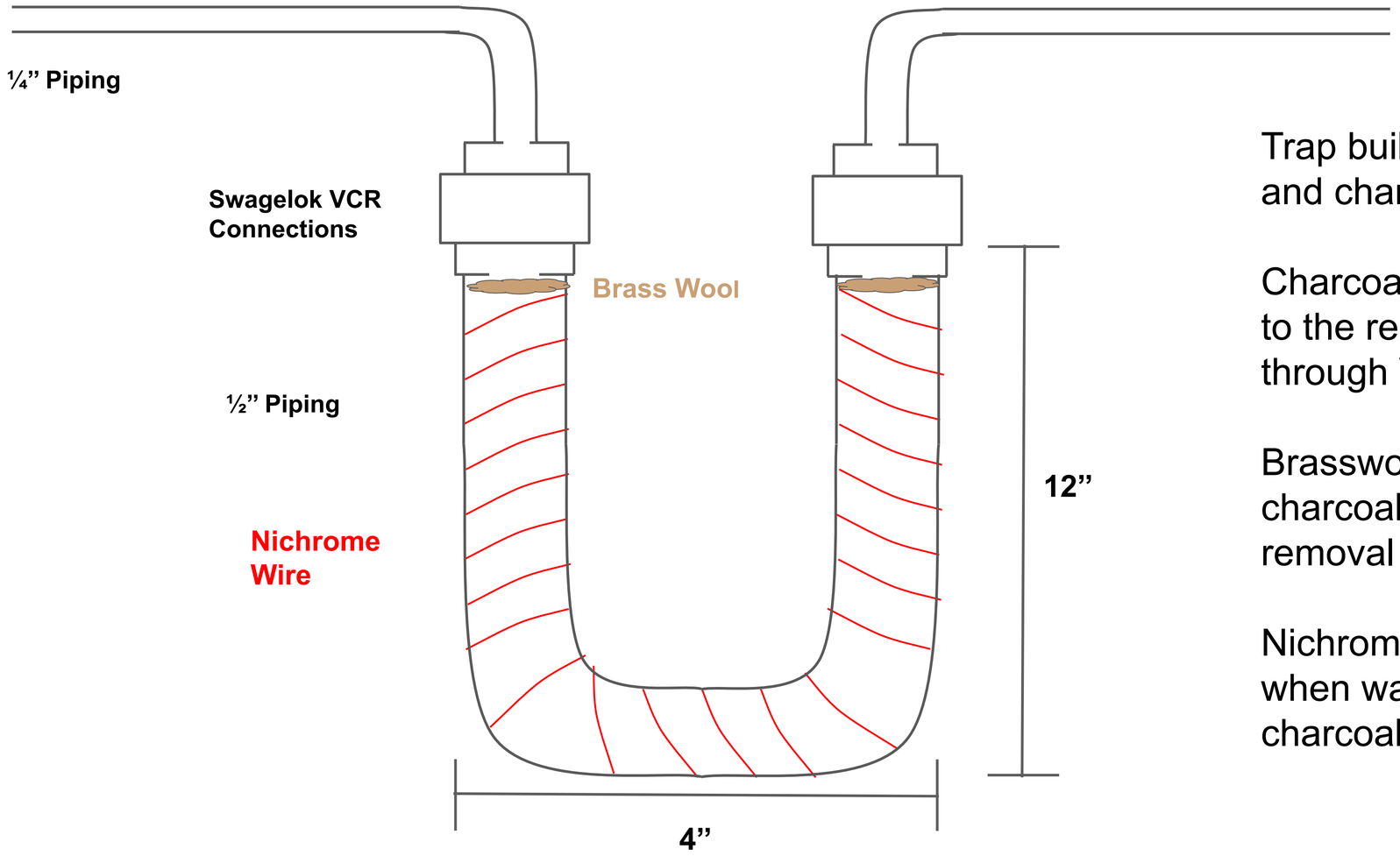
Activated Charcoal

Studies have shown activated charcoal to be an effective adsorbent for radon. The free radon adsorbs to the surface of the charcoal, like an adhesion, creating a sort of film of radon around the charcoal.



Now that we know how these traps work, let’s see how they’re built.

The P2011 LNGCF Radon Trap



Trap built for noble gas flow of 3 slpm and charcoal mass of 30g.

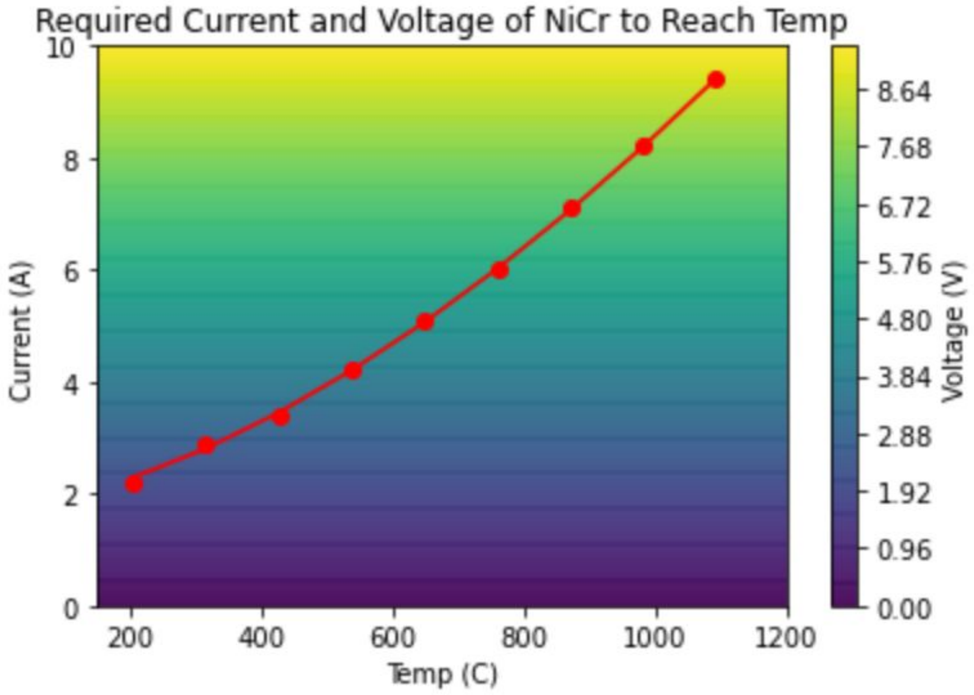
Charcoal placed in ½” piping connected to the rest of the gas handling system through VCR connections.

Brasswool put at end of trap to keep charcoal in trap and also add to radon removal efficiency.

Nichrome wire is used to heat up trap when wanting to remove radon from charcoal.

Trap Heating System

- 1m of Nichrome 60 wire (24 gauge) is wrapped around the trap
- From the data sheet provided for the wire, fitted a parabolic function to estimate the current required to heat the wire to certain temperatures. Fit has chi^2 of 0.007.
- From this can get temperature required for baking (50℃-150℃) with no more than 2V.

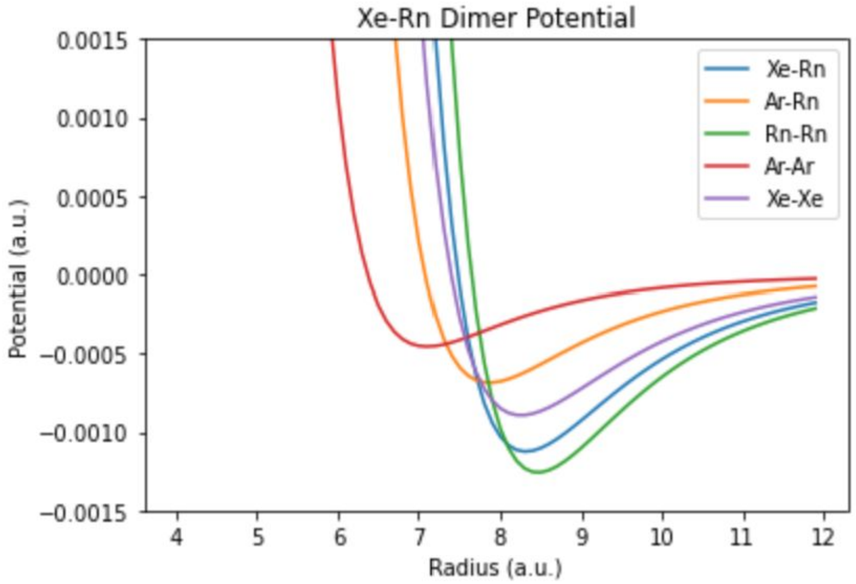


Trap Cooling System

There are several ways to cool radon traps to the desired temperature when they're operating, with lower temperatures leading to higher efficiency.

1. Liquid Nitrogen Bath: O(-195.8℃)
2. Alcohol Bath: O(-78℃)
3. Thermoelectric Cooling: O(-40℃)

O = "order of"



Liquid Nitrogen and Alcohol Baths

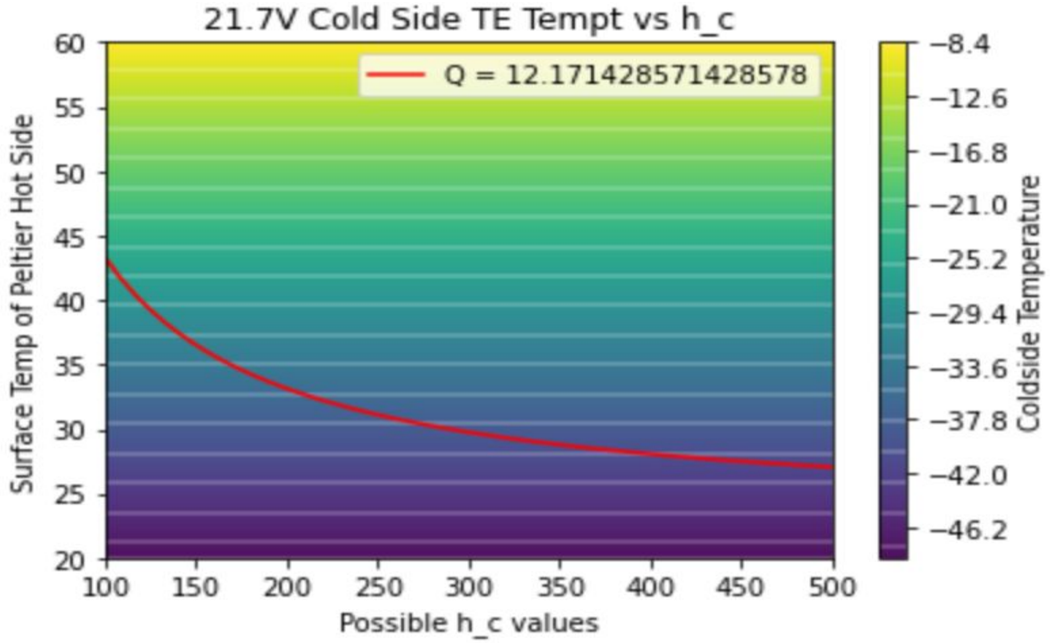
These baths tend to drop traps to low temperatures in the threshold of around -80℃ to -200℃

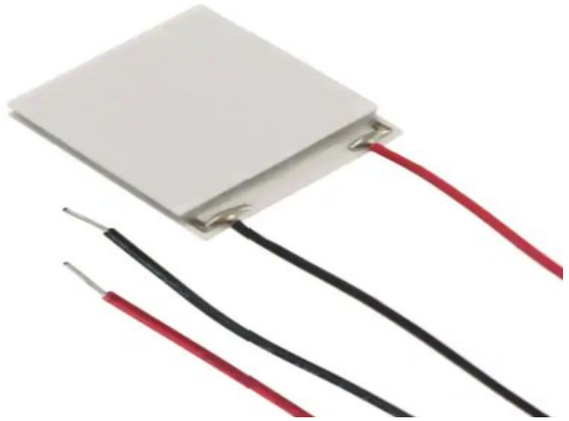
- Because of the traps U-shape, it is fairly easy to to drop it inside of a dewar of either bath.
- These baths are good at getting the trap to a high efficiency rate.
- Can be expensive, and tedious to refill.

Which leads us to the other option...

Thermoelectric Cooling

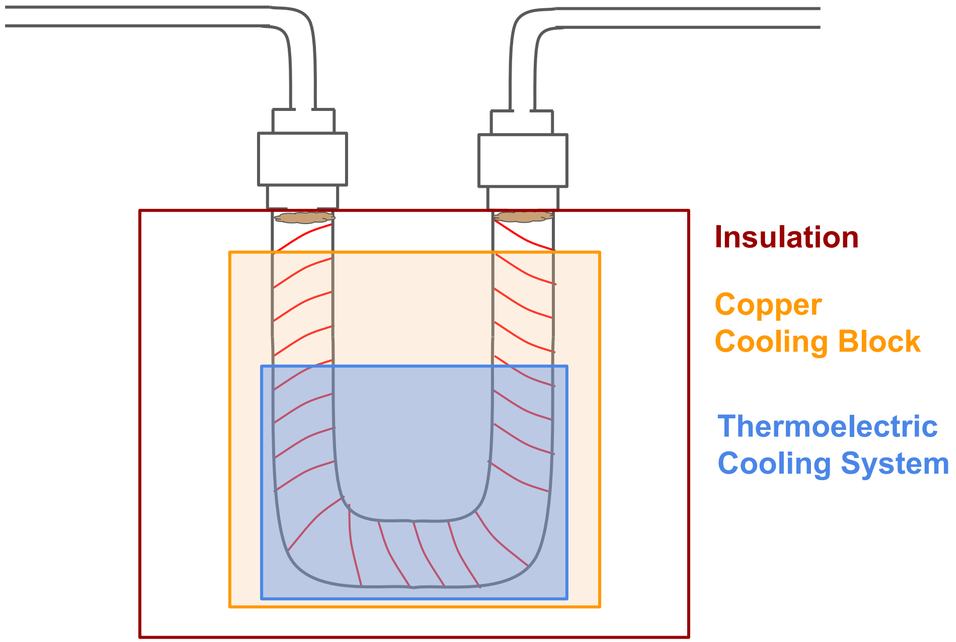
Thermoelectric modules are semiconductor heat pumps, that create a difference in temperature (dT) between a hot side and a cold side.

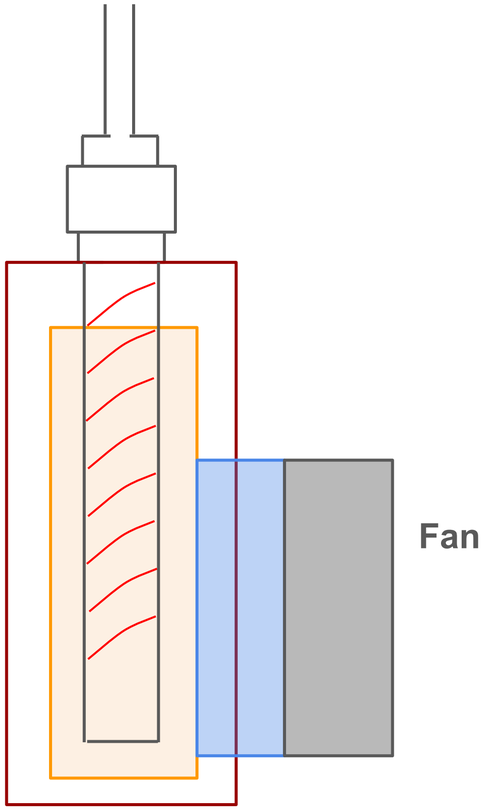




Insulated Copper Cooling Block

The TE Module cold side is then placed of an insulate copper cooling block, which is cut to perfectly fit around the trap. It is possible to have multiple modules placed on block.





What is the Expected Efficiency?

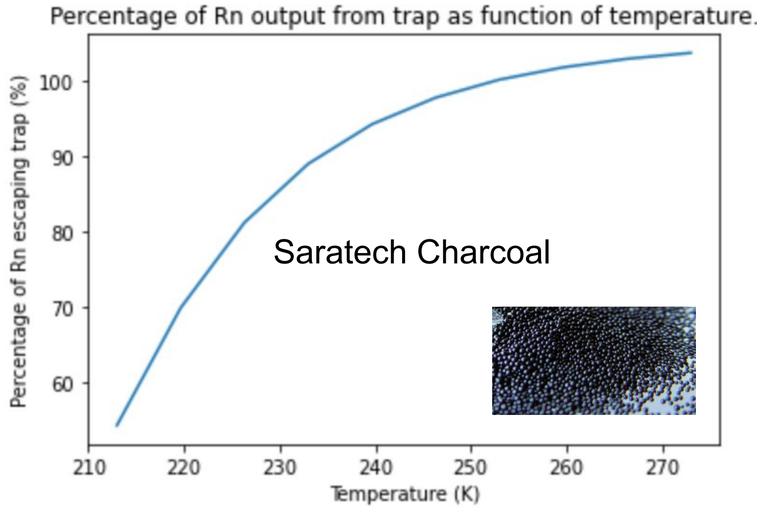
Radon Trap Efficiency Equations

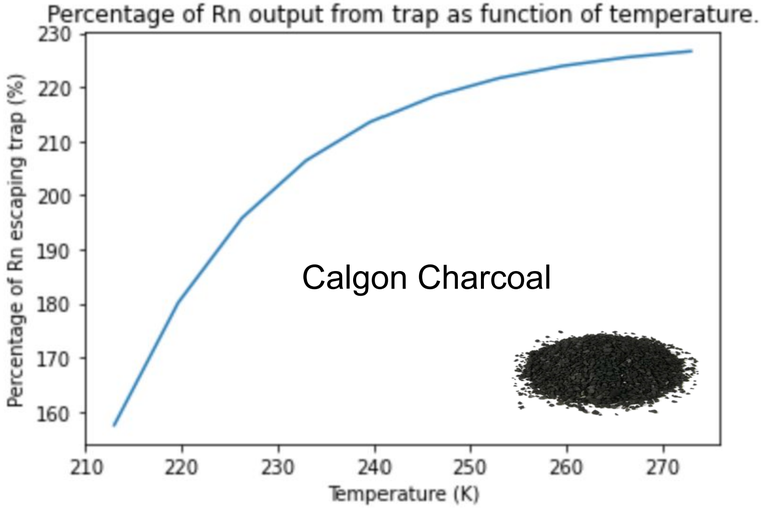
Radon efficiency equations have been done before, but appear to break down at certain temperatures for different charcoal brands. This simulation uses the charcoals adsorption coefficient and specific activity, the traps flow rate and mass, and the average lifetime of radon. The adsorption coefficient itself is fitted with an Arhenius equation. $k_a = k_0 e^{\frac{Q}{RT}}$.

$$N_{out} = N_{in} e^{-\frac{k_a \cdot m}{f \cdot \tau_R}} + s_0 f \frac{\tau_R}{k_a}\left(1 - e^{-\frac{k_a \cdot m}{f \cdot \tau_R}}\right),$$

Adsorption Factor

Emanation Factor





New Efficiency Equation and Testing

Can test traps efficiencies using the SNOLAB radon board.

By using sources with known radon amounts, such as surface air or an emmanation source, can run radon board with the trap, then collect efficiency using a RAD7 Radon Detector, although the RAD7 does come with some measurement uncertainty.

With efficiency measurements, we hope to come up with a model that will effectively predict future radon trap efficiencies dominated by the following values.

- k_A (Adsorption Coefficient)
  - Litres of radon adsorbed per gram of charcoal
- E (Emmanation Rate)
  - Rate at which radon emmantes from charcoal
  - dependent on temperature
- N (Initial Number of Radon passing through trap)

Conclusions and Outlook

- Our goals are to complete the radon trap built for LNGCF project, a new open cryogenic facility, while testing new methods and models.
- Thermoelectric cooling modules paired with CPU heat sinks and copper blocks will be used for first time as a cooling method for trap.
- Efficiency of trap will be measured with RAD7, then paired with a possible model dominated by the adsorption coefficient, emmanation rate.
  - Efficiency for future trap designs will be done as well for new model.
- Trap will be installed in gas handling system for the LNGCF project.

Thank You

Thank you to my supervisor, Pietro Giampa, the LNGCF team, and the Radon Trapping Team.