Low Radon Cleanroom at the University of Alberta

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Introduction

Particle astrophysics requires the development of detectors with extreme levels of purity and careful control of backgrounds. Radon emanation is a large potential source for background radiation. In particular, Radon 222 decays into its daughters such as Polonium 218 and Bismuth 214, emitting many alphas and betas as it does so.
At the University of Alberta, a low radon cleanroom has been built to construct and test equipment used in underground experiments. This cleanroom features a unique radon stripping system, as well as a high precision radon monitoring system. Together these aspects create a one-of-a-kind low radon cleanroom that will lead to revolutionary techniques in low background equipment.

Figure 1. The construction and building process of the DEAP 3600 flow guides inside the cleanroom.

Radon Stripping System

The radon stripping system is designed based on techniques previously used in the Modane Underground Laboratory [1] and in fabricating the nylon vessel for Borexino [2]. The system is designed to allow both cold-column radon adsorption, but can also be run in pressure-swing or vacuum-swing modes. We use an Atlas Copco GA30+ 30kW water cooled compressor that supplies 5m^3/min of compressed air, which is then filtered and dried to -70° C dew point by a desiccant drier. For low temperature adsorption, a custom built 9kW process chiller serves to cool the air to -65° C, which is then passed through carbon columns. The carbon columns are where radon absorption occurs, leaving us with a final rate of approximately 0.02Bq/m^3. There are 5 stainless steel columns, each filled with 200kg of coconut carbon. The air is then warmed up in an air-to-air heat exchanger. This particular heat exchanger will also serve to cool incoming air. The now warm, low radon air is then fed through ducting into the cleanroom [3].

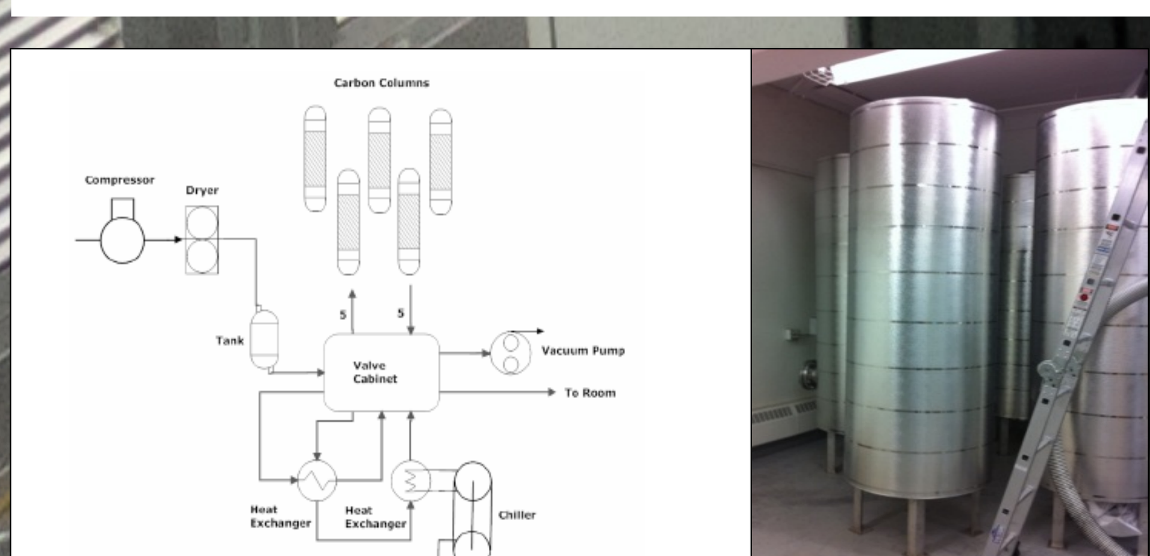


Figure 2. On the left is a schematic of the equipment used to strip radon from the air. The image on the right displays the cylinders used in the radon stripping process.

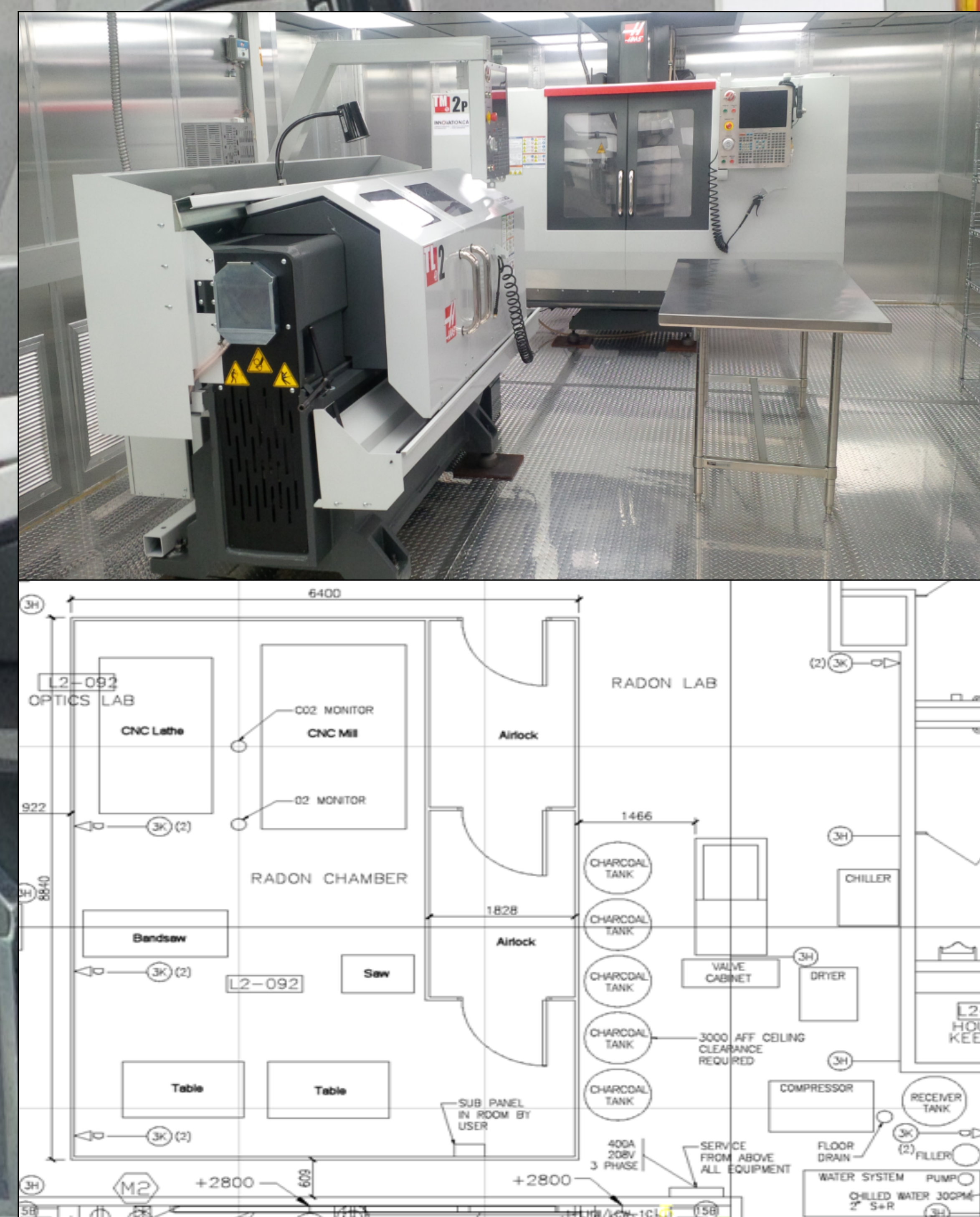


Figure 3. Above is a view of the CNC mill and lathe inside the cleanroom and below is a schematic of the low radon cleanroom. This particular schematic was drawn in 2010 as a concept of the cleanroom. It contains the pertinent information in regards to the layout of the cleanroom but does not reflect the details of the current layout.

Cleanroom Layout

This modular cleanroom was purchased from CleanAir Solutions, and custom sealed with low radon caulking compounds and tape. The ceiling consists of a top plenum cap 10" high which provides the outer air seal and an 8" suspended inner ceiling holding the lights and 17 HEPA filters. The floor of the cleanroom is sealed with a 1cm thick layer of Precidium 550D, a polyurea industrial floor coating. The cleanroom is unique in that is it designed as a small machine shop. Contained within is a CNC mill and a CNC lathe. It also contains its own water purification system that provides low radon water [3].

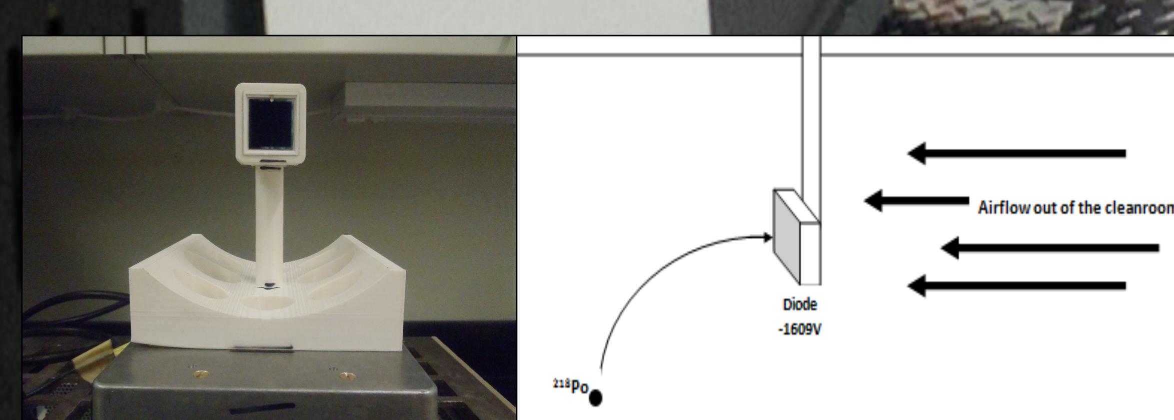


Figure 4. The high sensitivity radon monitor.

Radon Monitoring

All our monitoring systems are based on electrostatic separation and solid state detection. We currently have two silicon photodiodes used to detect alpha particles. These high sensitivity radon detectors are located in the incoming and outgoing airflow vents.
By applying a high voltage of 1.6kV to the diodes, we can produce an electric field in which positively charged radon daughters will be attracted to the diode; the ion velocities are higher than the air-flow velocities. These daughters, particularly Polonium 218 and Polonium 214, are plated onto the diode. Alphas from subsequent decays are measured and identified using their respective energies of 6.00MeV and 7.69MeV.
All data is measured and stored via a DAQ board to Labview software (Figure 5).

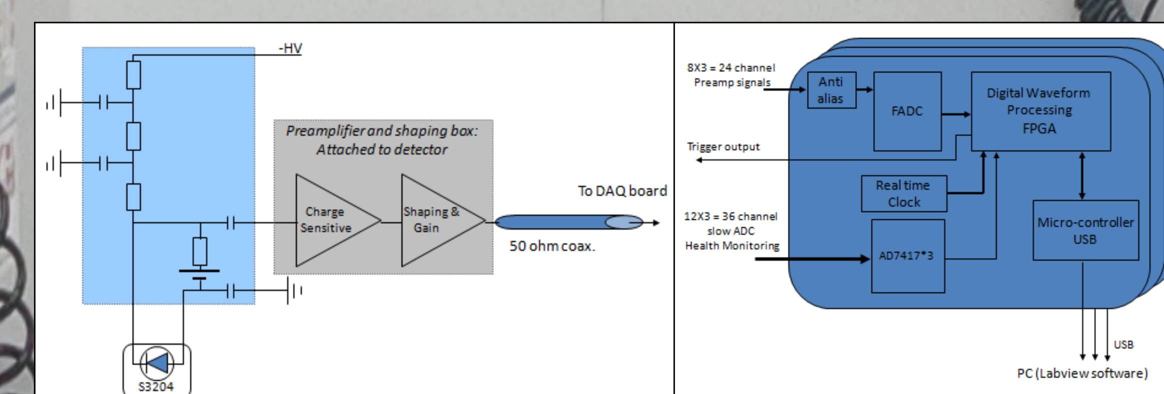


Figure 5. On the left is a circuit diagram for the radon monitor, and the right image shows how data is received and displayed on our computer.

Radon Calibration

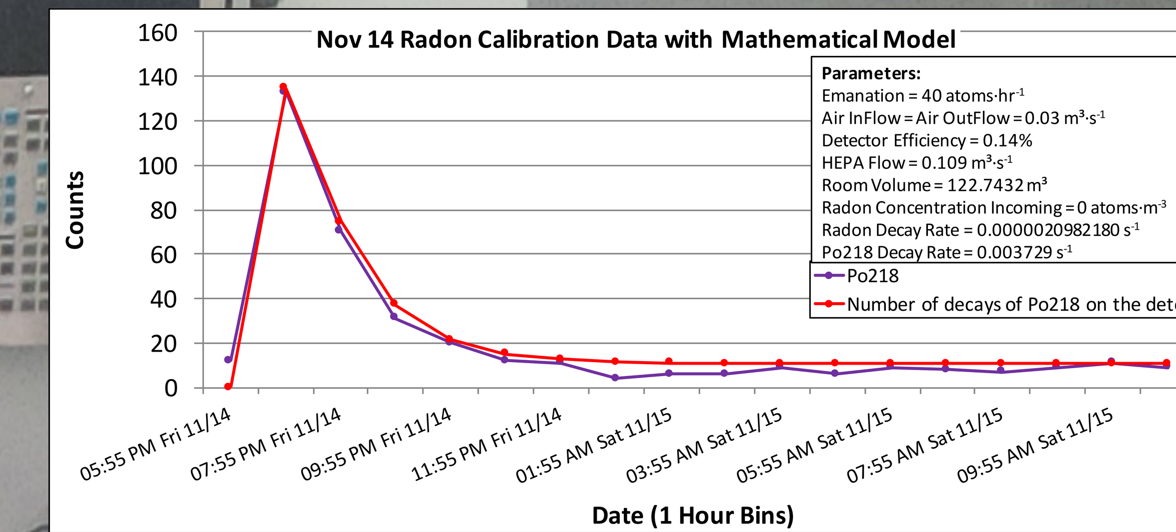
In order to calibrate the data from the monitors, we injected 930Bq of radon from a calibrated source into the room and measured the count rate over a period of several days. The data were then fitted with a mathematical model derived from the following differential equations (Eq 1,2,3) and the data are shown in Graph 1. The number of ^{222}Rn atoms in the room, N_R, is described by equation 1. Equations 2 and 3 then describe the concentration of ^{218}Po atoms in the room, n_{218}, and the number of ^{218}Po atoms on the detector, N'_{218}, respectively. In these equations, E is the radon emanation rate, F_o is the flow of air coming out of the room whereas F_i is the incoming airflow, F_{HEPA} is the airflow from the HEPA filters, ε_{218} is the detector efficiency, V is the volume of the room, and $n_{R,i}$ is the radon concentration going into the room. Finally, λ_R and λ_{218} are the decay rates for ^{222}Rn and ^{218}Po respectively.

$$\frac{dN_R}{dt} = E - \left(\lambda_R + \frac{F_o}{V}\right) N_R + F_i n_{R,i} \qquad (1)$$

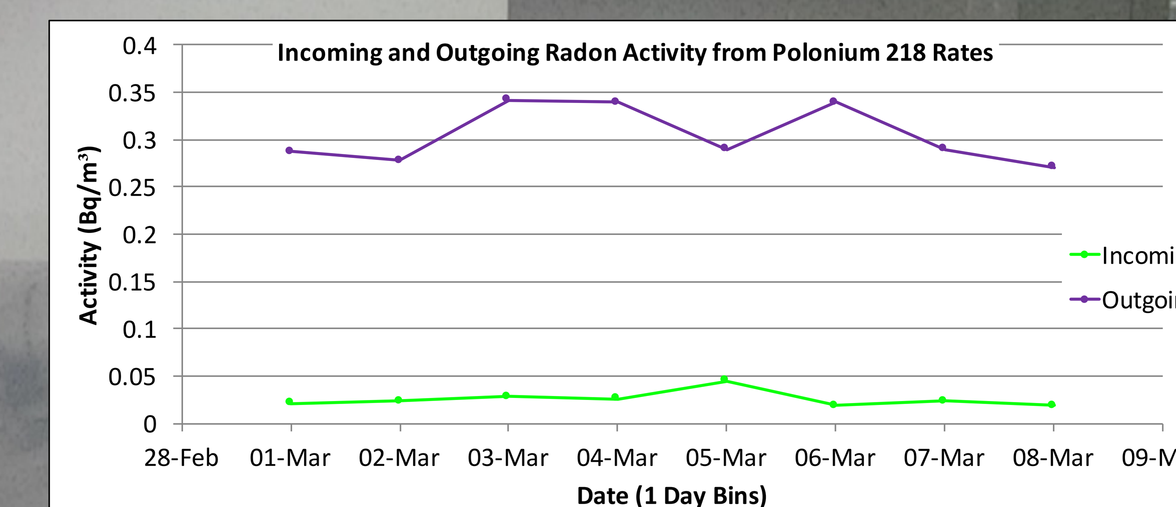
$$\frac{dn_{218}}{dt} = n_R\lambda_R - n_{218}\lambda_{218} - \frac{F_o n_{218}}{V} - \frac{F_{HEPA}\, n_{218}}{V} \qquad (2)$$

$$\frac{dN'_{218}}{dt} = \varepsilon_{218} F_o n_{218} - N'_{218}\lambda_{218} \qquad (3)$$

The resulting detector efficiency of 0.14% is then proportional to the number of ^{218}Po atoms detected on the counter divided by the total number of ^{218}Po atoms. We are also seeing a current radon emanation rate of close to 20 atoms/hr and an activity of 0.3Bq/m^3.



Graph 1. In purple are the counts of Polonium 218 during and after a radon source was introduced in the cleanroom. The red line designates the mathematical fit based on differential equations.



Graph 2. A plot showing the activity of Polonium 218 through the incoming and outgoing channels.

Conclusion

The cleanroom has been functioning and the monitoring systems work well, and we have consistent radon levels of 0.3 Bq/m^3. The dust levels in the room are also low, with measured values typically well below 100 particles/ft^3, in which the particles measure less than 0.5μm.
The radon level is dominated by emanation from components within the room. We have been working to isolate and remove radon sources; which have improved our base radon rate by about a factor of two. We are continuing this program. We have not seen any correlation between radon rates in the room and changes in the exterior building air.
The first project to be completed in the cleanroom was the construction of acrylic flow guides for DEAP 3600, as seen in Figure 1. Future projects will include custom built proportional counters for low background measurements, amongst other low background radiation experiments.

References

[1] P. Loaiza, “Low Radioactivity at the Modane Underground Laboratory”, AIP Conference Proceedings, *Topical Workshop on Low Radioactivity Techniques (LRT 2004)*, p100
[2] A. Pocar, “Low Background Techniques for the Borexino Nylon Vessels”, AIP Conference Proceedings, *Topical Workshop on Low Radioactivity Techniques (LRT 2004)*, p153
[3] Grant D., et. al., “Low Radon Cleanroom at the University of Alberta”, AIP Conference Proceedings, *Topical Workshop on Low Radioactivity Techniques (LRT 2010)* , p161

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