Low Radon Cleanroom at the University of Alberta

Berta Beltran¹, Paul Davis², Arthur Firmino¹, Darren Grant¹, Aksel Hallin¹, Stephen Hanchurak¹, Carsten Krauss¹, Shengli Liu¹, Ken McFarlane², Richard Soluk³, Pooja Woosaree¹

¹University of Alberta, Edmonton AB Canada T6G 2Z7
²SNOLAB, Sudbury ON Canada P3Y 1N2

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.

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+ 55kW water cooled compressor that supplies 5m³/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/m³.

Radon Monitoring

All our monitoring systems are based on electrostatic separation and solid state detection. We currently have two silicon photodetectors 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 1.6 kV to the diodes, we can produce an electric field in which positively charged radon daughters will be attracted to the diodes, and the ion velocities are higher than the airflow velocities. These daughters, particularly Polonium 218 and Bismuth 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).

Radon Calibration

In order to calibrate the data from the monitors, we injected 900Bq 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 222Rn atoms in the room, N₀, is described by equation 1. Equations 2 and 3 then describe the concentration of 218Po atoms in the room, N₂¹₈, and the number of 218Po atoms on the detector, N₂¹₈', respectively. In these equations, E is the radon emanation rate, F₂¹₈ is the flow of air coming out of the room, whereas F₀ is the incoming airflow, F₂¹₈ is the airflow from the HEPA filters, and F₂¹₈ is the detector efficiency. The number of Po atoms is in the room and the number of Po atoms on the detector is determined by the relationship between the radon concentration going in to the room.

Finally, λ₀ and λ₂¹₈ are the decay rates for 222Rn and 218Po respectively.

\[
\frac{dN}{dt} = \left( -\lambda_0 + \frac{F_0}{V} \right) N_0 + \frac{F_0}{V} N_{218} \quad (1)
\]

\[
\frac{dN_{218}}{dt} = 2 \lambda_0 N_{218} - \frac{F_{218}}{V} N_{218} + \frac{F_{218}}{V} \chi_{218} \quad (2)
\]

\[
\frac{dN_{218}'}{dt} = 2 \lambda_0 N_{218}' - \frac{F_{218}}{V} N_{218} + \frac{F_{218}}{V} \chi_{218} \quad (3)
\]

The resulting detector efficiency of 0.14% is then proportional to the number of 218Po atoms detected on the counter divided by the total number of 218Po atoms. We are also currently a radon emanation rate of close to 20 atoms/hr and an activity of 0.3Bq/m³.

Conclusion

The cleanroom has been functioning and the monitoring systems work well, and we have consistent radon levels of 0.3 Bq/m³. The dust levels in the room are also low, with measured values typically well below 100 particles/cm³, 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