MI-0255

Preliminary Measurement of Airborne Radioactivity in the MI40 Absorber Room and at MI40 Abort Lambertsons

A.F. Leveling

April 7, 1999

NOTE: Conclusions reached in this NOTE regarding MI air activation may need to be revisited. It was discovered during MI Shielding Verification Studies documented in MI NOTE 0298 that activated LCW present in the MI service buildings may cause air monitor response not attributable to activated beam absorber room and tunnel air. – A.F. Leveling 7/23/03

Preliminary Measurement of Airborne Radioactivity in the MI40 Absorber Room and at MI40 Abort Lambertsons

A.F. Leveling
April 7, 1999

A. Introduction

Various measurements of airborne radioactivity have been conducted in the MI40 Absorber Room and in the vicinity of the MI40 Lambertsons at the Main Injector (MI). The need for measurements was anticipated during the Main Injector design phase and they were prescribed in an earlier MI NOTE [1]. Airborne radioactivity is produced when particle beams interact with beam line components or enclosure air. The resulting cascade of secondary particles which travel through beam enclosures cause the air to become activated. The isotopes are short-lived positron emitters and are sources of external radiation exposure, primarily annihilation photons. The common, most abundant isotopes found in measurements at Fermilab are C11, N13, Cl38, Cl39, and Ar41.

B. Measurement

Three paint-can-style stack monitors were installed in the MI40 service building. Air sample hoses for the units were routed from the MI40 service building to the following locations:

1. upstream of the MI40 beam absorber

2. MI40 absorber room exhaust ventilation stack inlet

3. MI40 abort Lambertsons

Small pumps draw air from each of the three locations and are set to a nominal 5 to 10 lpm. A fourth hose was routed from the three monitors in the MI40 service building to return exhaust air from the monitors to the MI tunnel. The output signal was routed from the electrometer to the ACNET controls system via a VME crate. Data from the detectors were logged through the BD controls system program Lumberjack.

Data was collected parasitically in the period January/February 1999 during operation of the MI, primarily during 120 GeV operation to the MI40 beam absorber.

The ventilation exhaust fan for the MI40 absorber room was not operated during these measurements for two reasons. First, since the production rate and release of the isotopes has not been quantified, the intent was to hold the gases within the absorber room for decay. Second, it was considered that if the ventilation fan was permitted to operate, the buildup of radioactive gases might not be sufficient to obtain a non-zero measurement.

C. Discussion

One purpose of these airborne radioactivity measurements is to determine a quantitative relationship between beam energy and intensity transported to the MI40 absorber room and corresponding airborne radioactivity levels in the absorber room. A second purpose is to determine a quantitative relationship between ambient levels of airborne radioactivity produced in the vicinity of the MI40 Lambertsons due to normal beam losses. The goal of all the measurements, as described in Reference 1, is to understand whether airborne radioactivity postings or access delay times are necessary meet the laboratory requirements for radiological work [2].

An observation from measurements performed to date is that beam line tuning has a direct bearing on production of radioisotopes in both the absorber room and in the vicinity of the MI40 Lambertsons. One gross measure of tuning is the relationship of the Scarecrow responses for those instruments installed at the upstream and downstream ends of the MI40 absorber. At 120 GeV, the ratio of the responses for normal operation appears to be approximately 1. Figure 1 shows the paired Scarecrow responses from a period of over 5000 one-minute data points. This relationship should be construed as a figure of merit rather than equivalent detector response because the radiation fields at the extreme ends to the absorber are composed of different radiation types and very likely different quality factors. Where the relative response of the Scarecrows is different than 1 (see region Figure 1, US scarecrow 50,000 to 75,000 mrem/hr), it is thought to be due to mis-tuning as shown in Figure 4.

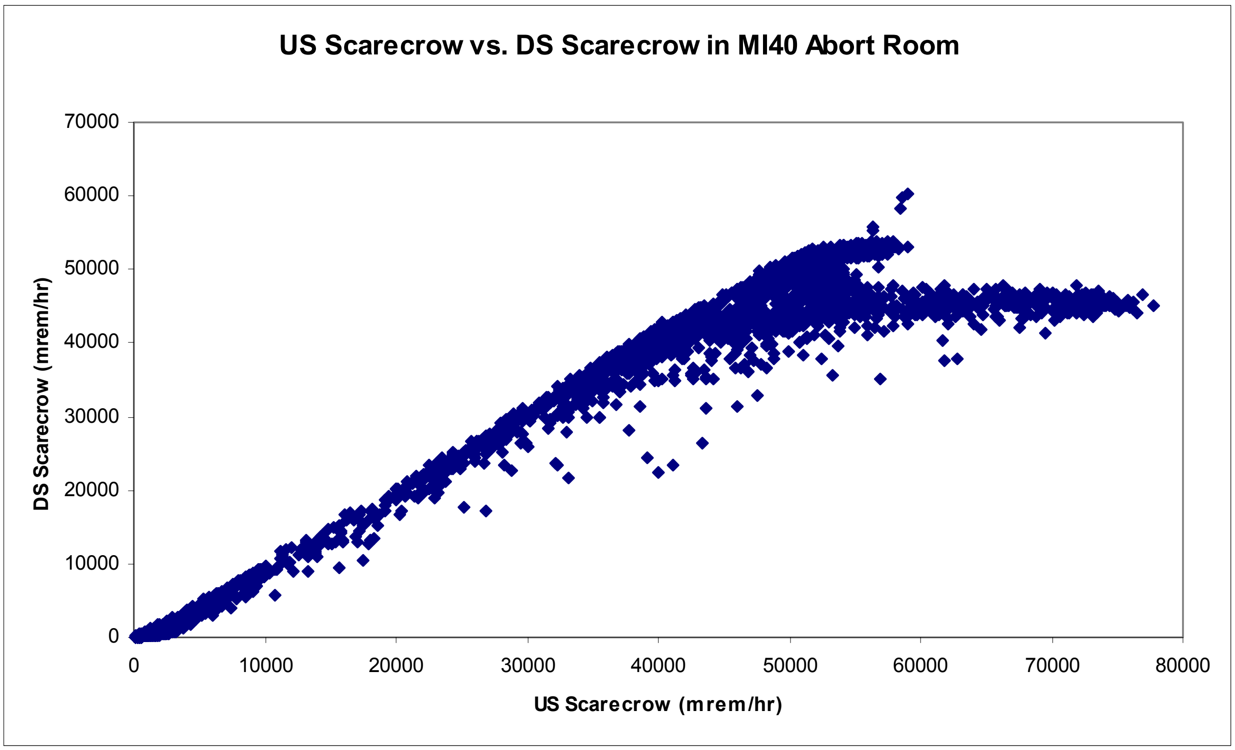

Figure 1 Response of Upstream and Downstream Scarecrows in MI40 Absorber Room over the period 0600 on 2/2/99 to 2100 on 2/5/99.

Figure 2 shows the relationship between Scarecrow response and the MI40 abort line torroid (I:TOR003). The Scarecrow data points are hourly dose rates averaged over 15 minutes while the torroid is the integral of beam intensity over a 15 minute period and normalized to one hour. The relationship is reasonably linear. The slope of the line, based on an average of plotted points, is 3.5E-12 mrem/proton.

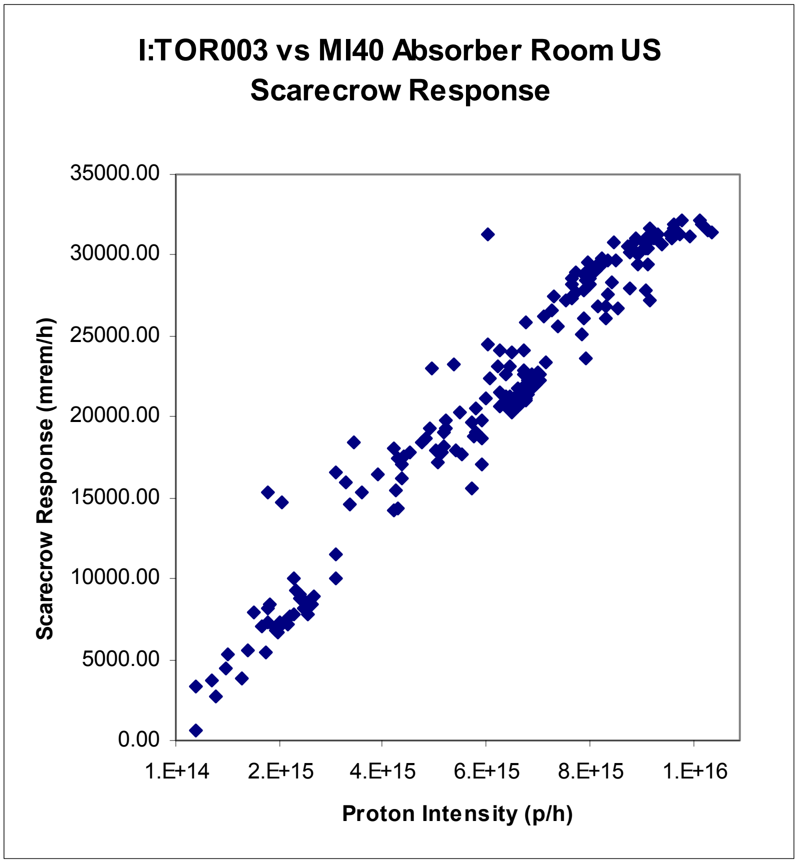

Figure 2 Scarecrow vs. torroid response over period 1/5/99 at 1630 to 1/8/99 at 1045

In Figure 3, data is presented in which nominal tuning and airborne activity production is thought to exist. The ratio of upstream and downstream Scarecrows is very close to 1. The buildup and decay of radioactive gases tracks Scarecrow response to some extent but the response is not completely predictable. For example, the sudden rise in Absorber Room Vent Inlet activity at minute 600 is not consistent with or explained by Scarecrow response. Possible explanations for this behavior would include consideration of air-flow dynamics for which instrumentation and data does not currently exist. Note that air monitor response at the MI40 Lambertsons is consistently less than the response of the Absorber Room Vent Inlet and is thought to be representative of nominal MI40 abort line tuning.

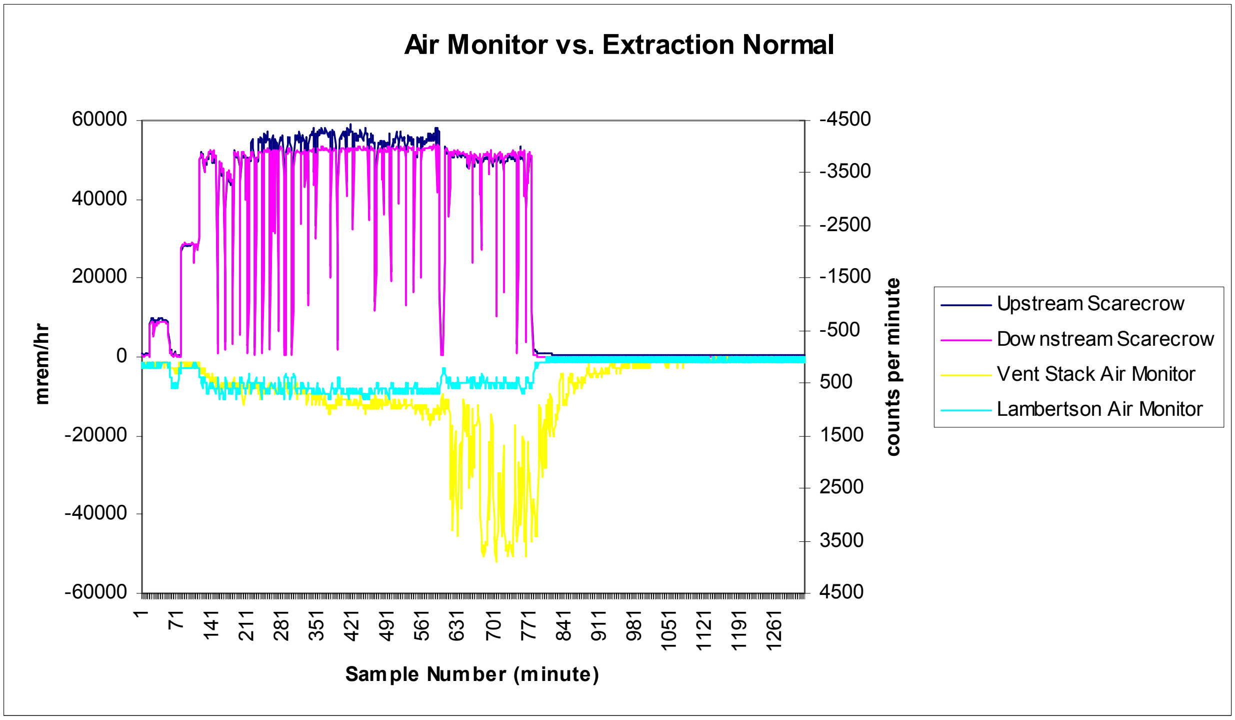

Figure 3 Scarecrow and Air Monitor response during extraction over the period 2/4/99 at 2300 to 2/5/99 at 2100 – nominal tuning

Figure 4 is similar to Figure 3 except that the Upstream Scarecrow response is significantly greater than the Downstream Scarecrow response. In addition, Lambertson Air Monitor response is generally greater than the Vent Stack Air Monitor response except in periods similar to those depicted in Figure 3. In this case, one could conclude that the higher rates at the Upstream Scarecrow compared with downstream rates may be due to less than perfect steering through the beam tube leading to the absorber.

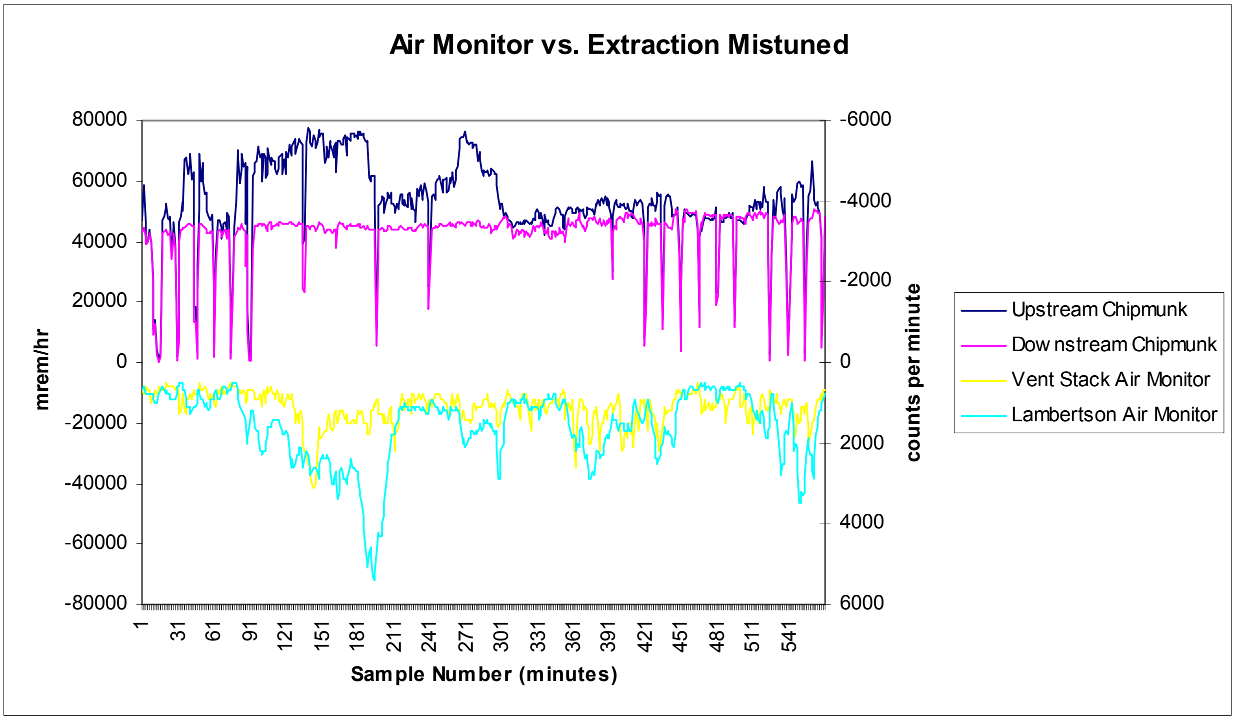

Figure 4 Scarecrow and Air Monitor response during extraction over the period 2/4/99 from 0500 to 1430 – some abort line mis-tuning

The data in Figure 5 is taken from February 7, 1999 when the proton beam was lost in a C-magnet just downstream of the MI40 Lambertsons. During this period, one of the power supplies for the Lambertson magnets was malfunctioning, and as a consequence, beam was kicked out of the MI orbit through the Lambertsons but the beam was not fully bent into the abort line extraction channel. Instead, it was deposited in a C magnet just downstream of the MI40 Lambertsons. Neither the upstream nor downstream scarecrows responded significantly during this period. Figure 5 indicates that the Lambertson Air Monitor response was significant and is a positive indication of significant beam loss. Note, however, the difference in response from minute 100 to 200 and the response from minute 200 to minute 460. The Vent Stack Air Monitor response starting around minute 200 is thought to be due to radioactive gases in the Lambertson Air Monitor paint can.

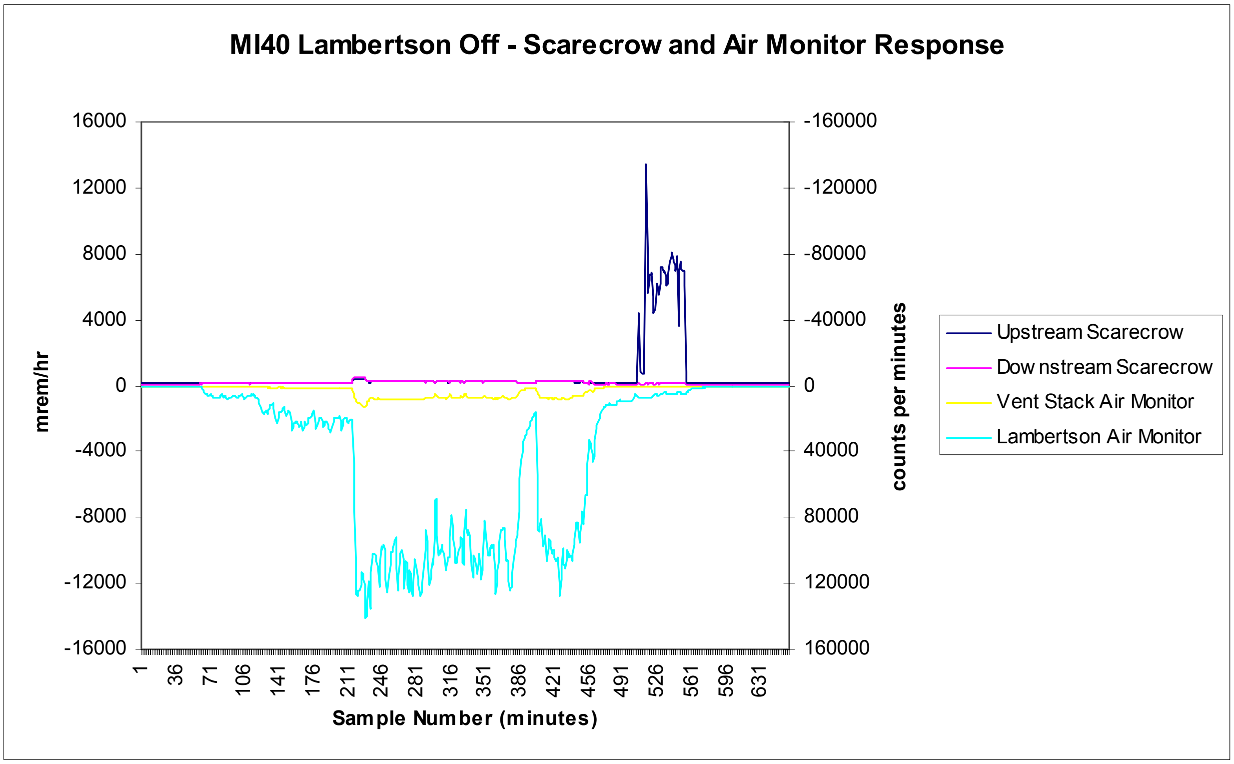

Figure 5 Scarecrow and Air Monitor response during extraction over the period 2/7/99 0700 to 1800 – Lambertsons off

Figure 9 is a plot of beam intensity per pulse over the period on 2/7/99 while the MI40 Lambertsons were turned off. The intensity is measured at TOR800 but a review of the MCR E-log and an interview with the Crew Chief on duty for the shift indicate that this beam was destined to be aborted at MI40. Beam intensity summed over 6 minute periods is also plotted in Figure 8. The smoothness of the data in Figure 9 is belied by that in Figure 8. Figure 9 displays data only during beam-on cycles. The graininess of the data in Figure 8 is attributed to intermittant beam operation, i.e., the beam was not on continuously while the line was being tuned.

A careful comparison of Figures 5 and 9 shows that air monitor response is not consistent with beam intensity. The sudden rise to 120,000 cpm in the Lambertson Air Monitor occurs when Booster beam intensity was reduced from 8 turns to 3 turns and it persists throughout an extended period of lower intensity running. A possible explanation is that the GM tube began to fail spontaneously. However, the response of the Vent Stack Air Monitor at the same time is an indication that a high level of gas activity actually existed in the Lambertson Air Monitor can which was detected by the Vent Stack Air Monitor GM tube

A plausible explanation has been suggested in which the movement of the beam loss point with respect to tunnel air supply could lead to a bimodal response. Figure 6 is a plan view of MI40 region. A supply fan brings air into the tunnel near the MI40 Service Building tunnel entrance. From an inspection in the enclosure on 3/30/99, air flow from the fan can be felt going in the downstream direction. Little if any air flow was noted in the upstream direction. If the beam loss point moves due to tuning attempts as was the case on 2/7/99, it may have been possible to move or partially distribute the loss point downstream of ventilation supply fan in which case the air monitor response could be reduced. Moving the loss point upstream of the ventilation supply fan with little or no air movement could cause a buildup of radioactive gases and a correspondingly higher response.

Figure 7 is a sketch of a chipmunk located on the berm at MI40 just downstream of Lambertson #3 and the c-magnet. Figure 8 shows the chipmunk response vs. beam intensity for 2/7/99. Since it is expected that chipmunk response should follow beam intensity for a fixed beam loss scenario, it is clear that the beam loss point was being affected by attempts to tune the beam line. It is possible that subtle changes in tunnel ventilation flow could have led to a variable response. Follow-up air monitoring and tunnel ventilation system monitoring may be necessary to sort out all of the potential confounding effects.

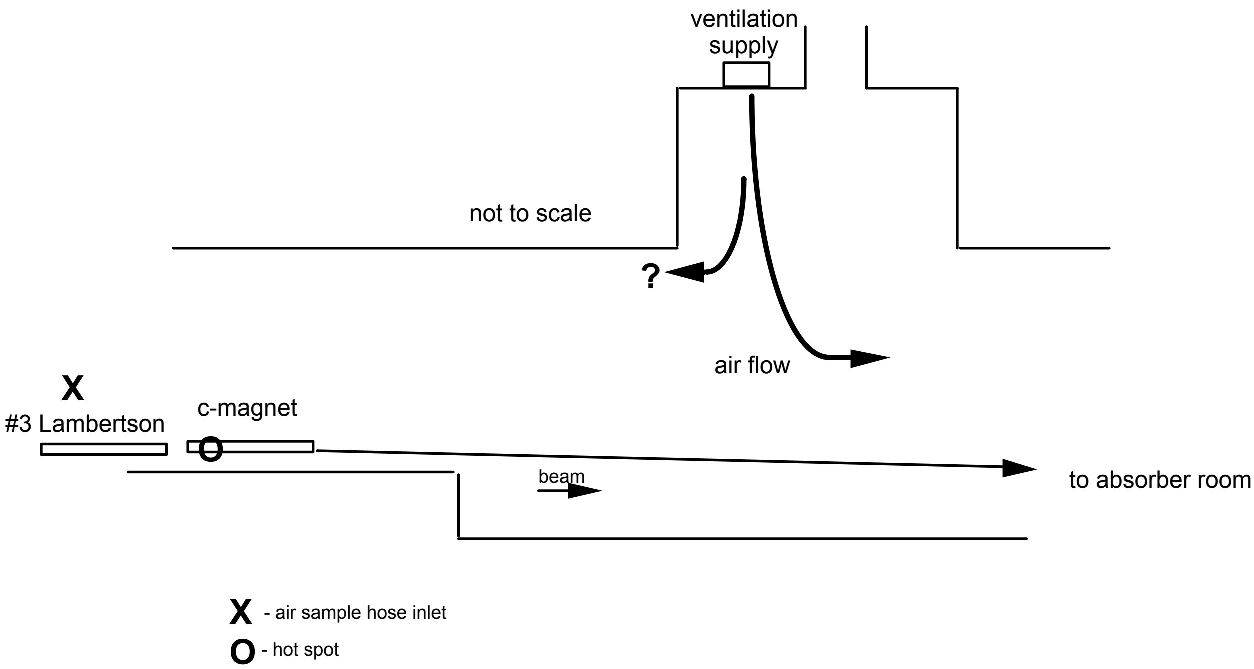

Figure 6 Plan view of MI40 tunnel

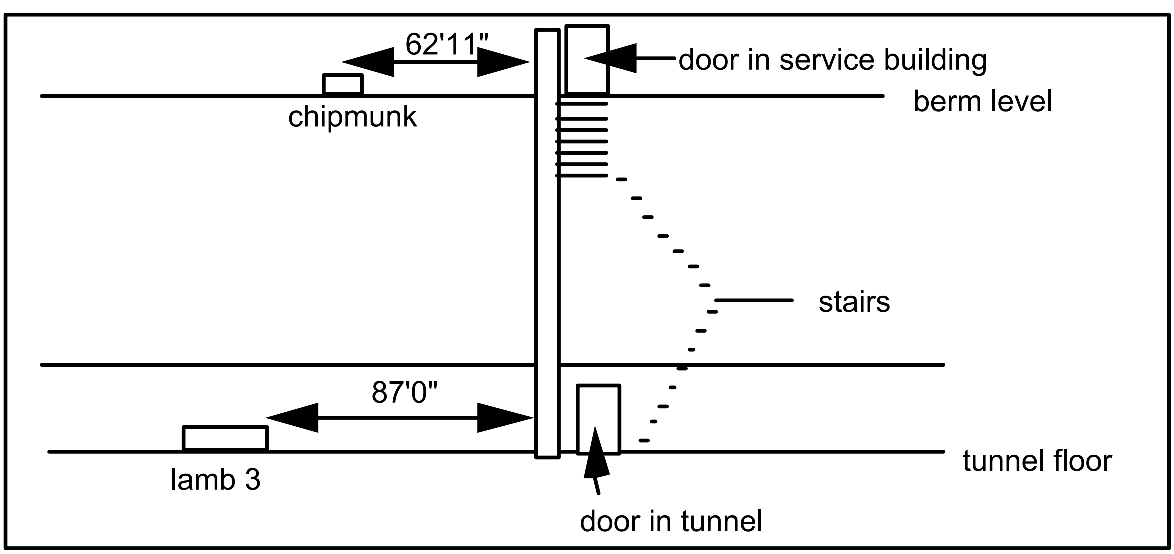

Figure 7 Elevation view of chipmunk on MI40 berm with respect to Lambertson #3 and c-magnet

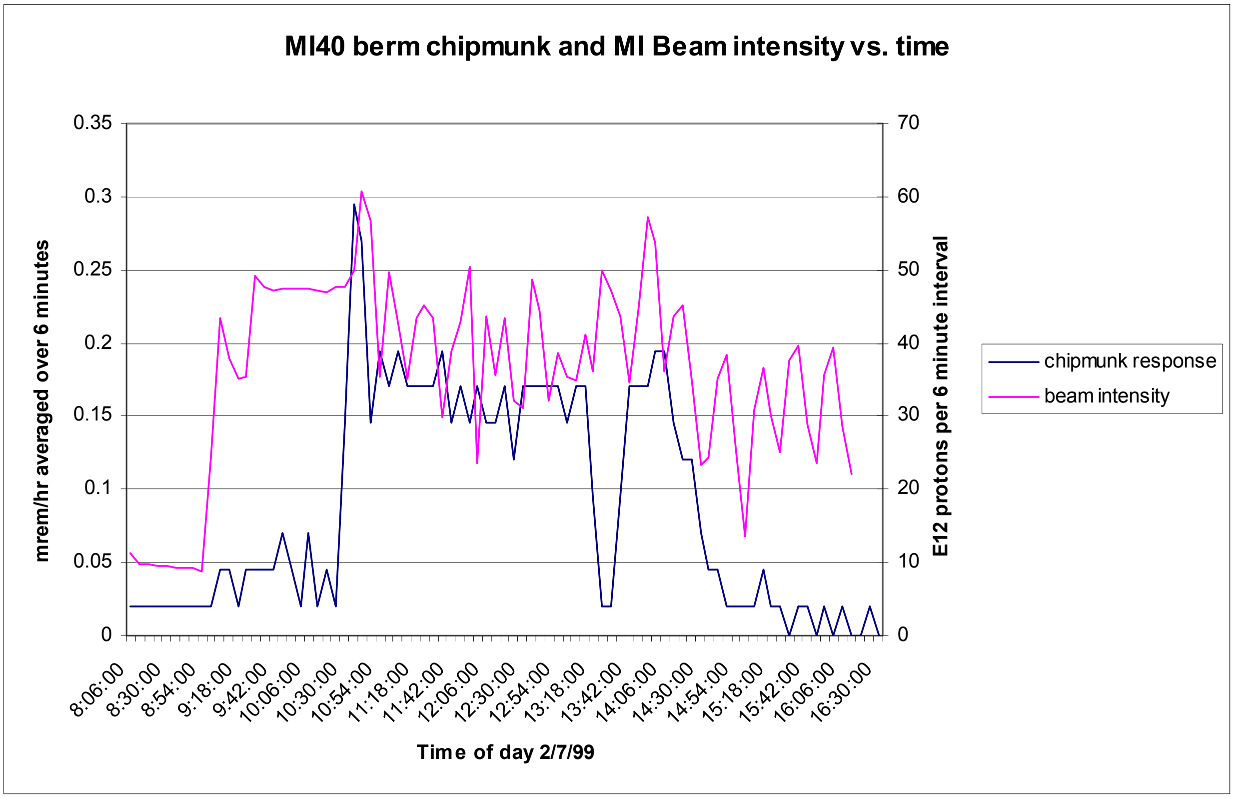

Figure 8 Background corrected chipmunk response vs. beam intensity, both summed over 6 minute intervals.

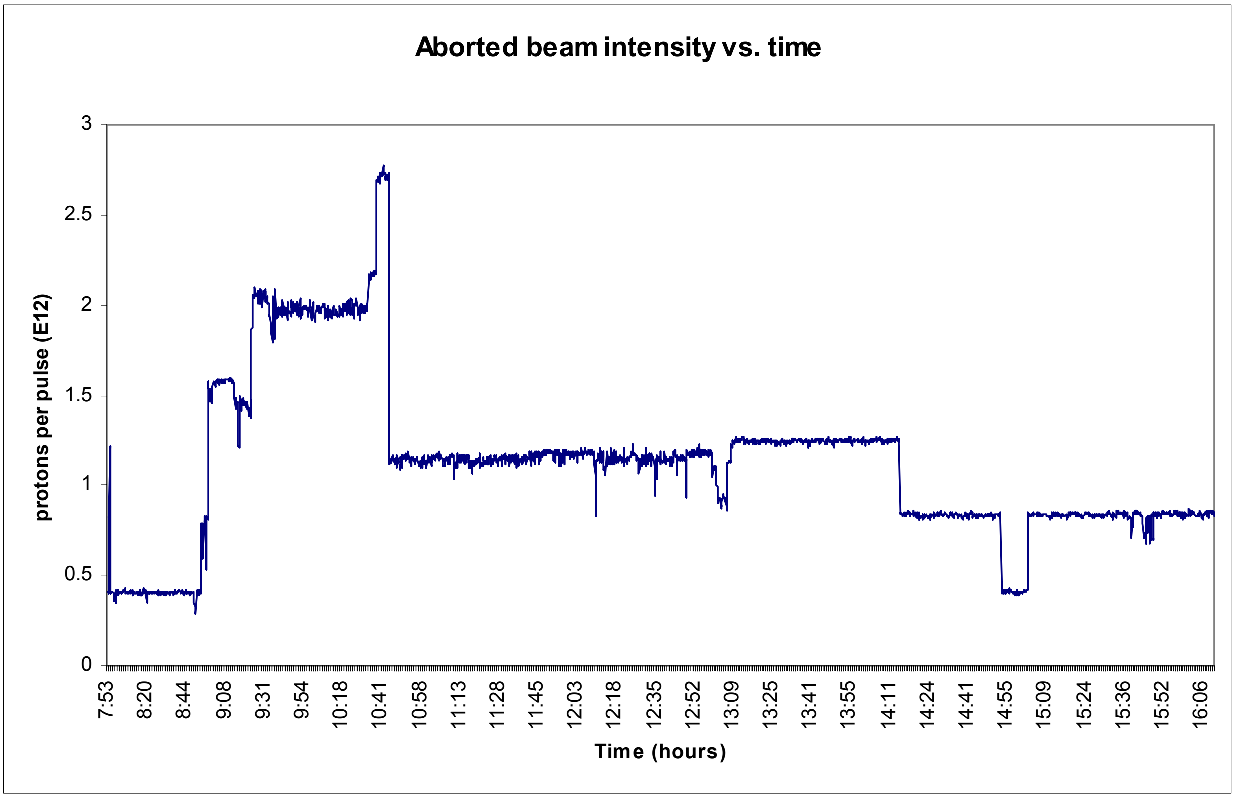

Figure 9 Beam intensity in protons per pulse to MI40 Lambertson from 0758 to 1611 on 2/7/99

D. Conclusions

A fair amount of data has been collected and analyzed to attempt to establish airborne radioactivity levels as a function of beam energy and intensity with mixed results. The upstream scarecrow may be a reliable indicator of aborted beam, at least up to 9 E15 p/h. The ratio of upstream to downstream scarecrow response appears to be approximately 1 for nominal tuning at 120 GeV beam energy. There is indication of appropriate air monitor response at the abort room and at the MI40 Lambertson but a quantitative relationship has not been established. Significant changes in air monitor response are not yet understood, but are thought to be due to tunnel ventilation dynamics. Some data is available to study the efficacy of the MI shielding.

I would like to thank John Larson of the ES&H Section for retrieving the February 7th MUX data making the MI40 berm chipmunk plot possible. I would also like to thank Phil Martin for his discussion, insights, and review of this Note.

References

[1] MI NOTE 0241, Committed Effective Dose Equivalent Calculation for Personnel Exposure to Airborne Radioactivity Produced by Main Injector Beam Loss, A. F. Leveling, July 7, 1998

[2] Fermilab Radiological Control Manual