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# Longitudinal Scans of Residual Radiation in MI Collimators C307 and C308

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**Abstract**

The residual radiation profile inside of the Main Injector secondary collimators provides a record of the loss patterns achieved by the Main Injector Collimation system. Scans require the vacuum system to be opened so only two opportunities have been afforded for this information to be acquired for the this system. Data and analysis for profiles inside C307 and C308 are documented here. We also compare the peak residual radiation in a aperture to the measurement at the bar-code location outside the marble shielding on the aisle and find a ratio of about 3000.

# 1 Introduction

The Secondary Collimators for the Main Injector [1] define a $2'' \times 4''$ rectangular vacuum aperture in a $64''$ long stainless steel vacuum box with $1''$ thick walls. The downstream $50''$ has this aperture while the upstream $14''$ tapers from $2.5'' \times 4.5''$ or by $0.25''$ wider aperture for each wall such that the design interaction point occurs $14''$ from the upstream end of the box. The attached measurement is with reference to the upstream flange so that the design impact point (end of the taper) is at about $21.7''$ on the graph. See Ref. [2] and [3] for details of the secondary collimators. A mask downstream of the C307 collimator was added in 2009 with additional shielding added in 2010[4].

By employing this for a primary-secondary collimation system, one should find the interactions take place near the end of that tapered portions so that the residual radiation profile will peak after one interaction length and then fall off with the exponential length characteristic of hadronic showers in stainless steel.

The instrument for these measurements was a Teletector[1]. The Geiger tube is in a $1.5''$ diameter holder so measurements on the 'aisle' side place that device against the wall and one might characterize that transverse position as being $0.75''$ from the aisle side horizontal wall. The 'wall' side measurement is $2.5''$ further outside.

# 2 Longitudinal Scan for C308

The opportunity to measure the longitudinal profile of residual radiation at the C308 collimator occurred during the 2012-3 Fermilab Facility Shutdown. Other work near that collimator including the installation of new kickers and masks left the vacuum system open. [2] This measurement was carried out on August 22, 2013. Collimation tuning for operation (2008 - 2012) placed the beam in the aisle side top corner during collimation. Measurements were taken on the 'aisle' and 'wall' side as described above at $4''$ intervals except near the interaction point where there were some measurements at $1''$ - $2''$ intervals.

Data from this scan are shown in Fig. 1. The lower panel illustrates the inner profile of the collimator. The feature is the same for both the horizontal and vertical profile. The STRUCT simulations used for the design imply that the radial loss is dominant but not overwhelmingly so. The upper panel provides the data for both the 'aisle' and 'wall' side scans. Their ratio is plotted in the middle panel and confirms that the collimator absorbed loss on the 'aisle' side as designed. This is especially pronounced near the interaction point.

[1] This is a Geiger tube mounted with a long pole and provided with a high range readout.

[2] During this time, we were experiencing some concern about Be contamination from exposure of Be-Cu springs which hold bellows shielding when exposed to moist air. Extra precautions for avoiding Be contamination were exercised during this measurement.

The residual radiation peaks a few inches downstream of the interaction point as would be expected for a hadronic shower. The fall off downstream is exponential as would be expected. However, as the downstream end is approached, the fall off is ended and the radiation rises. We interpret this as due to proton losses at the downstream end. To explore this, we characterize the measurement with an exponential rise to the interaction point and a separate exponential fall downstream. For the rising portion we use an exponential fit to the measurements from 8″ to 20″. For the falling portion we fit the measurements from 34″ to 50″. The exponential length is 5.92″ for the rising portion and 20.17″ on the falling portion. We note that the far upstream portion of the data is not well matched to this fit.

To characterize the loss at the downstream end, we assume that it is at a point near the end. We construct a model of the loss for the design interaction point using the two exponentials and matching by eye for two points 2″ apart at the top. We designate this as the fit for the rise and fall (covered by the model of the loss patterned for the rise and early part of the fall). We employ this model by assuming that the interaction is at the downstream end and scaling the rising portion of the fit such that the peak is at that downstream point. We adjust the sum by eye to match the measurements. The results points to a downstream end loss of 30% of the loss at the design interaction point. The attached spreadsheet (C308RadProfileMeas_20130822.xlsx) was employed for this analysis.

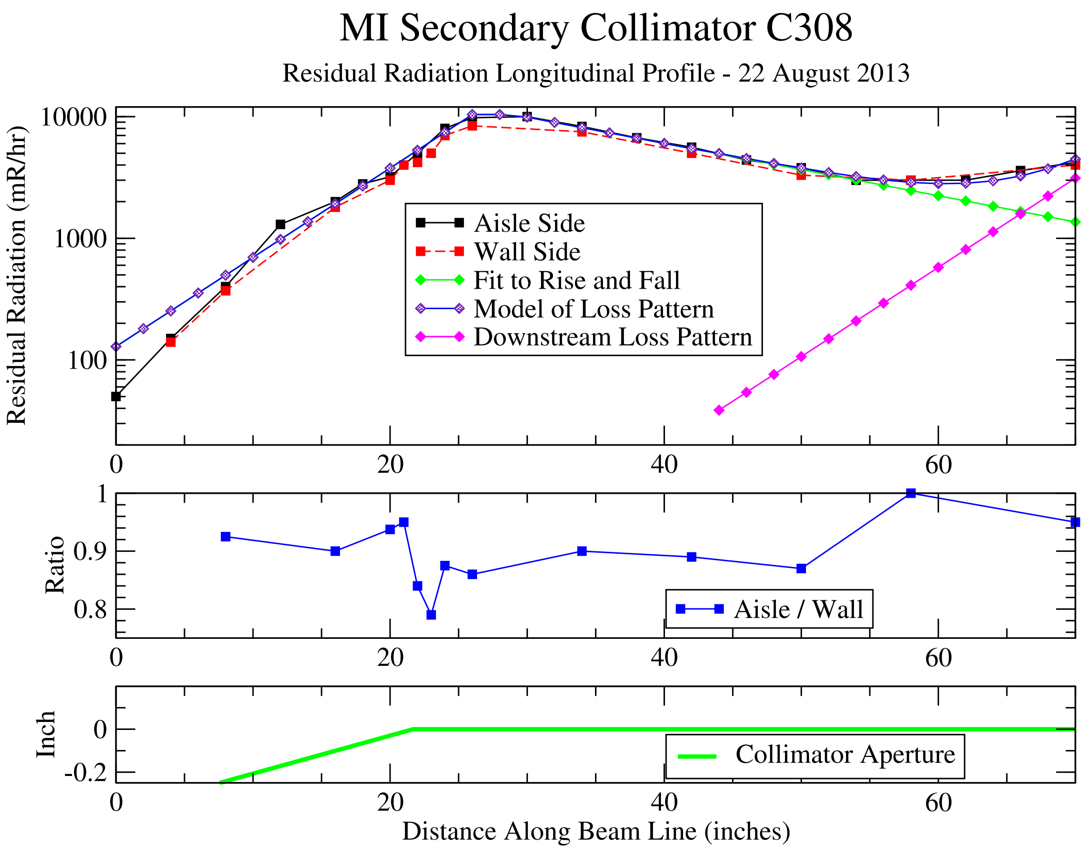


Figure 1: Residual Radiation Scan of C308.

# 3 Longitudinal Scan for C307 and STCM307A

On September 15, 2015 the vacuum system was open and a measurement of the longitudinal profile through C307 as well as STCM307A was carried out. The transverse position was not recorded for this longitudinal scan but since it was not significant for C308, we know it was also not significant here either. The same simple exponential fit to the rising and falling portions of this data was performed with similar exponential lengths recorded. Fig. 2 presents the data for the C307 collimator along with the lines from the exponential fits. Fig. 3 provides the data for the scan through the mask[4].

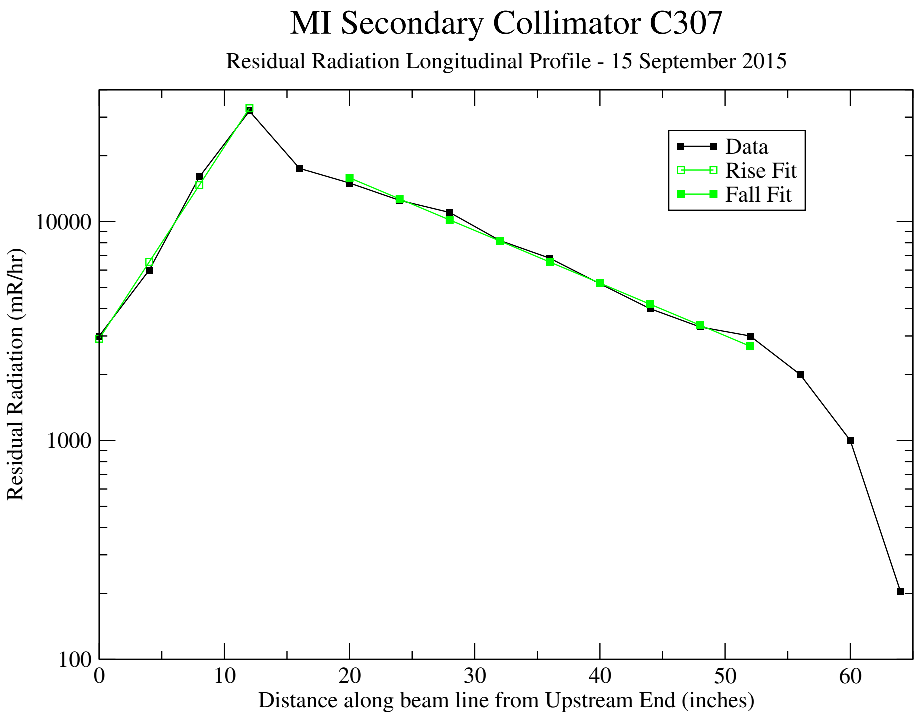


Figure 2: Residual Radiation Scan of C307.

Table 1: Fit Parameters for C307 and C308 Longitudinal Scans

| Location | C307 | C308 |
|---|---|---|
| Rising Exponent | 4.95 in | 5.92 in |
| Falling Exponent | -18.06 in | -20.17 in |

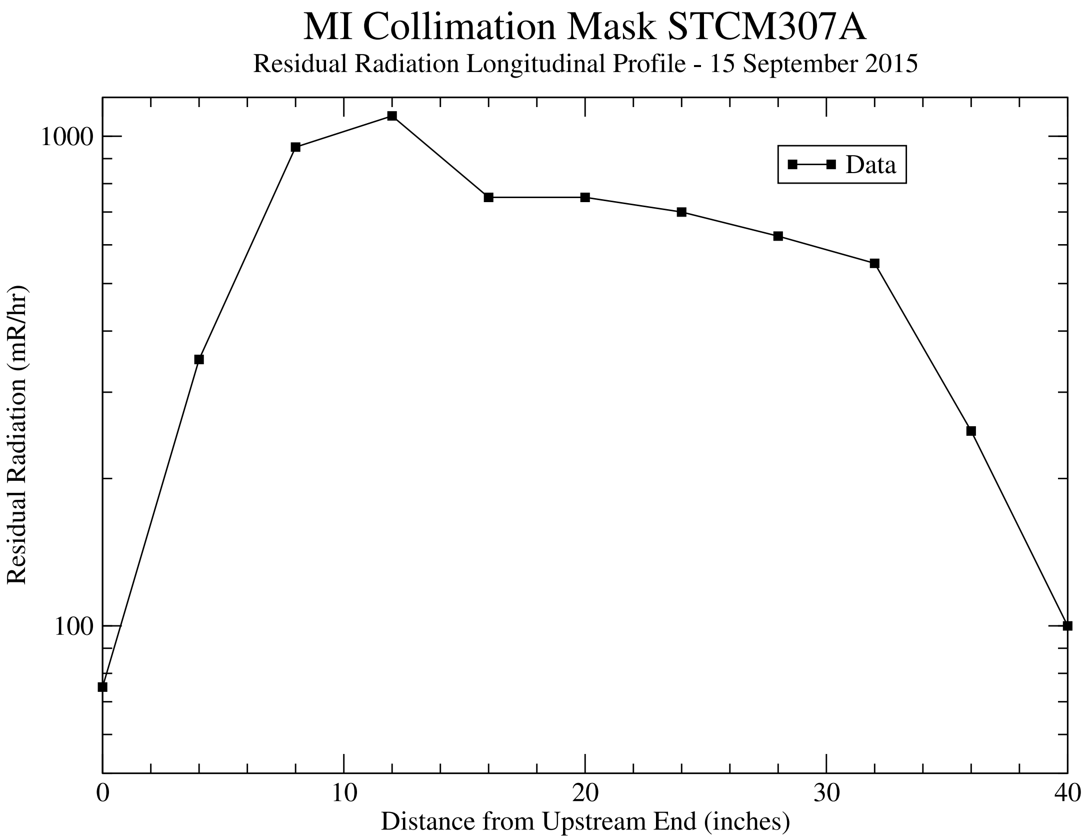


Figure 3: Residual Radiation Scan of STCM307A.

Table 2: Shielding ratios comparing radiation inside collimator to radiation at bar code location on surface of marble shield. Beam was off for long enough that Mn-54 dominates the residual radiation. Ratio in () is corrected for 312 day half life to correct for the different cool down.

| Location | Measure Date | Reading |
|---|---|---|
| C308 Scan Peak | 8/22/2013 | 10000 mR/hr |
| C308 Bar Code | 7/19/2013 | 3.88 mR/hr |
| Ratio | | 2577 (2779) |
| C307 Scan Peak | 9/15/2015 | 17500 mR/hr |
| C307 Bar Code | 9/22/2015 | 4.13 mR/hr |
| Ratio | | 4237 (4172) |

# 4 Discussion

The MI Collimation system primarily removes beam which is not captured in rf buckets by using a primary collimator to scatter those protons when they move to the inside because they fail to be accelerated. These scattered protons have a high probability to strike a secondary collimator at the design interaction point 14″ from the upstream end of the collimator. We see confirmation of this in both the C308 and C307 residual radiation profiles. We comment that for the C308 scan we carefully noted the relation of the Geiger tube so that the distance measurement reflected that. We did not correct for the offset from the collimator face to the measurement reference upstream but simply describe it. The measurement team doing the C307 measurement had different constraints so the relation between the reference position for the scan and the design interaction point were not the same.

The exponential rise and fall as fit provide a good description of the residual radiation profile. Table 1 gives the fit results. The data and the fits are in the attached spreadsheets. To estimate the quantity of beam which strikes the downstream end of C308, we assume that the for an interaction of similar character to that at the design interaction point, we will observe a similar pattern upstream. Using the observed profile from the upstream end, we assign the interaction point to the end of the collimator and adjust the coefficient of the exponential rise to give the observed sum. We know that there is no material for protons to strike downstream of the 64″ collimator body so we place the peak of the interaction there. A match to the sum of the falling exponential plus the rise from interactions at the end gives downstream proton interactions which are 30% of the interactions at the design point. The source of these lost protons is likely due to the anti-damped beams in the gaps between bunches. Anti-damping removes beam using vertical kicks. The vertical beta is growing as the beam approaches the downstream end of C308 so it is reasonable that anti-damped beam of the appropriate phase would strike the vertical collimation aperture at that point.

As we review other residual radiation features, we are now not surprised by higher residual radiation on the C308 Vertical Downstream motor. Details of this sort will allow us to better choose features which merit detailed comparison with MARS results.

# 5 Note on Shielding

The purpose of the collimators was to provide a safe place to have protons die. These measurements provide a very direct measure of the effectiveness of the thick iron absorber and the marble shielding. The monitoring of residual radiation at bar-coded locations[5] includes a measurement on the aisle side of each collimator. Measurements were carried out at a sufficiently nearby date for C308 and on the same day for C307. The comparisons are in Table 2.

## 6 Acknowledgments

The scan of C308 was carried out by Gary Lauten with data recording by Bruce Brown. The scan of C307 was carried out by David Capista and Kyle Hazelwood.

## References

[1] Bruce Brown et al. Fermilab Main Injector Collimation Systems: Design, Commissioning and Operation. In Martin Comyn, editor, *Proceedings of the 23rd Particle Accelerator Conference, 4 - 8 May 2009, Vancouver, British Columbia, Canada*, pages 2841–2843, 2009. Available also as FERMILAB-CONF-09-167-AD.

[2] Bruce C. Brown. Main Injector Collimation System Hardware. Beams-doc 2881 v2, Fermilab, April 2008.

[3] Vladimir Sidorov. MI Secondary Collimator. Engineering Note MDSN-ME-000071, Fermilab Accelerator Division, Mechanical Support Department, 2007.

[4] Bruce C. Brown. A Collimation Mask at MI308 to Protect RR to MI Injection Kickers. Beams-doc 4460, Fermilab, October 2013.

[5] Bruce C. Brown. Residual Radiation Monitoring in the Main Injector with the ROTEM RAM DA3-2000 Radiation Survey Meter. Beams-doc 3523 v1, Fermilab, December 2009.