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Al Tag Radiation Studies for Instrumentation in the Main Injector

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Abstract

Radiation damage to electronics in accelerator tunnels may require using long cable runs to locations where radiation is sufficiently reduced. When constraints such as cable capacitance, high voltages, and/or frequency response suggest having electronics in the tunnel, a study of the radiation loss environment may help identify suitable locations. Using Al Tag activation techniques, we measure the fluence of hadrons in regions of interest in the MI600 - MI100 tunnel locations. We also have placed Al Tags adjacent to three gas ionization beam loss monitors which allows us a new calibration of their response.

1 Introduction

Using Aluminum Tags provided by Gary Lauten, Jim Zagel identified thirteen locations in the MI600 or MI100 sectors for their placement. Three of these were immediately adjacent to loss monitors while the remainder were selected for their relation to beam instrumentation or beam instrumentation electronics needs.

2 Installing Monitoring

On 16 Oct 2014, thirteen locations were selected for placing Al Tags with two tags at nearby locations (some use the same name while some are adjacent but with different names). By removing some tags soon and leaving some in place we gained insight early while getting a better measure by leaving some until much later. Tags were removed on 1/22/2015, 7/8/2015, 4/18/2017, 10/20/2017, and 10/24/2017 and promptly delivered to the Radiation Analysis Facility (RAF) for measurement. Table 1 provides a description of the locations and summarizes the measurements. Tables 3 and 4 provide pictures of the placements for many of these tags.

3 Al Tag Results

When tags are removed from the tunnel, they are delivered to the Radiation Analysis Facility (RAF) where a HPGe detector detects gammas from the decay of Na-22. The activity is determined and corrected for the time from the removal from the tunnel until the end of the measurement. Using the formula for a decay correction assuming uniform radiation from Eq. 10 in Beams-doc-4046 [1], we correct for the exposure (see column Corr), convert to hadron fluence[1] and divide by the exposure time in years to obtain our results as radiation exposure per year for each tag. The table is organized in pairs of tags which were at the same or nearby locations. We do not correct for the detailed time history. We have noticed that the activation in 2014 was at a higher rate than in later periods so there is some systematic bias to these results but we believe that the differences from various tag pairs reflect the uncertainty of this measurement. These results provide guidance for activation levels at these locations. The analysis spreadsheet, a time line for MI Tunnel Activities and the reports from the Radiation Analysis Facility are included in this document.

[1] Al Tag activation is sensitive to the fluence of hadrons above a threshold of 20 Mev. In Eq. 36 of Beams-doc-3980 [2], it is shown that a Rad will produce about 623 pCi/gm in Al. Gary Lauten has used 1000 Rad per pCi/gm and we employ that for our calculation.

Table 1: Aluminum Tag Data

Label	Tag #	Activity	Error	Days	Corr	Exposure	Exp/yr
		pCi/gm	pCi/gm			Rads	kRads/yr
LM102A	6030	25	4	280	1.22	30662.51	39.97
LM102A-LT	6077	80	13	1107	2.24	179326.31	59.13
LM102B	6080	15	3	280	1.22	18397.51	23.98
LM102B-LT	6081	66	11	1107	2.24	147944.20	48.78
Minor Alcove	6082	7	2	280	1.22	8585.50	11.19
Minor Alcove-LT	6084	22.3	3.9	1107	2.24	49987.21	16.48
R3VIPM Magnet	6089	10	2	110	1.08	10835.12	35.95
R3VIPM Pre-Amp-LT	6090	11	2	281	1.22	13501.35	17.54
M3VIPM Magnet	6251	3	1	111	1.08	3252.91	10.70
M3VIPM Magnet-LT	6252	11	2	281	1.22	13501.35	17.54
M3VIPM Floor	6254	1.5	0.9	112	1.08	1627.64	5.30
M3VIPM Floor-LT	6270	2	1	281	1.22	2454.79	3.19
R4HIPM Magnet	6403	18	3	284	1.23	22141.49	28.46
R4HIPM Magnet-LT	6405	4	1	285	1.23	4923.92	6.31
LM104	6433	5	1	285	1.23	6154.90	7.88
LM104-LT	6442	8.2	2	1110	2.24	18421.20	6.06
M4HIPM	6444	4	1	286	1.23	4927.51	6.29
M4HIPM-LT	6446	15.7	2.9	1110	2.24	35269.86	11.60
MI-62 E-Gun	6555	3.2	0.9	287	1.23	3944.89	5.02
MI-62 E-Gun-LT	6707	8	2	925	1.96	15703.99	6.20
MI-62 Aisle	6710	2	0.8	286	1.23	2463.76	3.14
MI-62 Aisle-LT	6725	6	2	925	1.96	11777.99	4.65
MI-62 HV-Box	6731	1.3	0.9	286	1.23	1601.44	2.04
MI-62 HV-Box-LT	6744	9.6	2.2	1111	2.24	21582.01	7.09
MI-62 Video Controller	6750	1.3	0.7	287	1.23	1602.61	2. 04
MI-62 Video Controller LT	6763	1.6	0.5	1103	2.23	3576.08	1.18

4 BLM Results

We chose to place tags at three of the gas-filled Beam Loss Monitors (BLM) [3] [4] in the same area of the tunnel. The D44 datalogger provides a summary of the loss recorded by these monitors. The upgraded data acquisition, which allows us to separately monitor the losses while beam is in the Recycler from when the beam is in the Main Injector, is left with an overlap such that using the sum of I:LIxxx and R:LIxxx will overcount the loss. A system which measured the 1 second sum in the device L1xxx was not included in the datalogger during this time. We have examined losses and conclude that losses recorded during I:LIxxx are dominantly in the Recycler so we will normalize to the R:LIxxx sums. The D44 summaries were manually edited to remove spurious sums which characteristically result during shutdown periods, when a single reading is locked into the system. The spreadsheet SummaryResults.xlsx has results for either R: or I: or the sum for the interested reader. The uncertainty is less than $\times$ 2 so it is comparable to other uncertainties in this calibration check. Table 2 shows our results and analysis. Offset values (pedestals) for the BLM data measured each Main Injector cycle are not negligible for these loss monitors and probably explain the low value of activation/BLM for LM104.

Table 2: Activation Calibration at BLM Locations using Al Tags placed on 10/16/2014

Location	Date	Activation	Act/BLM
	Removed	pCi/gm	pCi/gm/kRad
LM102A	7/8/2015	25±4	0.89±0.14
LM102A	10/24/2017	80±13	0.64±0.10
LM102B	1/22/2015	15±3	2.68±0.54
LM102B	10/24/2017	66±11	0.58±0.10
LM104	1/22/2015	5±1	1.93±0.39
LM104	10/24/2017	8.2±2	0.13±0.03

5 Conclusion

We have employed Al Tag activation to document the radiation exposure in locations of the Main Injector tunnel of interest for instrumentation. We find that doses of 1 to 60 kRad/yr are seen at the locations we monitored. This should provide guidance for design of electronic devices which can be placed in these areas.

A confirmation of the relation between Al Tag activation and ionization in the argon gas of standard BLM's has been carried out. Using the 1983 calibration figure for BLM sensitivity and a kRad per pCi/gm for activation of Al to Na-22, we crudely confirm our assumptions.

6 Acknowledgments

We thank Gary Lauten for assistance with procuring the Al Tags and we acknowledge the assistance of Meka Francis and Ian Hoppie of the Radiation Analysis Facility for determination of the activation. We worked with Randy Thurman-Keup to place the detectors in MI62 where electron gun profile monitors are being developed.

References

[1] Bruce C. Brown. Activation of Steel and Copper Samples in the Main Injector Collimator Region. Beams-doc 4046, Fermilab, January 2012.

[2] Bruce C. Brown. Analysis Procedures for Al Activation Studies. Beams-doc 3980, Fermilab, November 2011.

[3] R.E. Shafer, R.E. Gerig, A.E. Baumbaugh, and C.R. Wegner. The Tevatron Beam Position and Beam Loss Monitoring Systems. In Francis T. Cole and Rene Donaldson, editors, *Proceedings of the 12th International Conference On High-Energy Accelerators*, pages 609–615. Fermilab, 1983. Also available as FERMILAB-CONF-83-112-E.

[4] A. Baumbaugh, C. Briegel, B. C. Brown, D. Capista, C. Drennan, B. Fellenz, K. Knickerbocker, J. D. Lewis, A. Marchionni, C. Needles, M. Olson, S. Pordes, Z. Shi, D. Still, R. Thurman-Keup, M. Utes, and J. Wu. The upgraded data acquisition system for beam loss monitoring at the Fermilab Tevatron and Main Injector. *JINST*, 6:T11006, 2011. Also available as FERMILAB-PUB-11-618-AD-PPD.

A Images of Al Tag Locations

This Beams Document will have all these pictures included. They are converted from .jpg to .eps for inclusion in the LaTeX document but both versions will be available for the reader's convenience. The file name is provided with each picture in the table.

Table 3: Images of Al Tag Locations

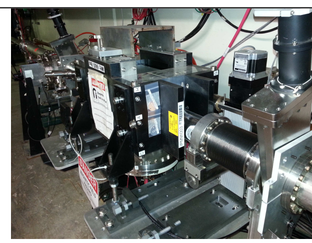
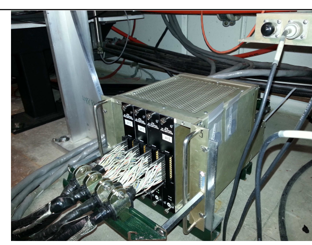
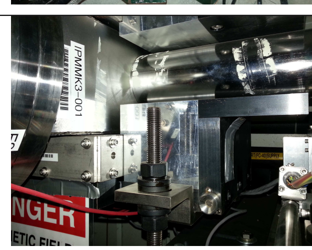
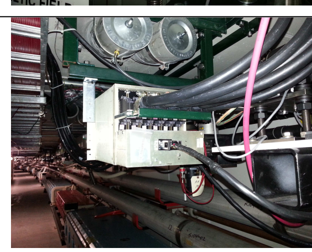
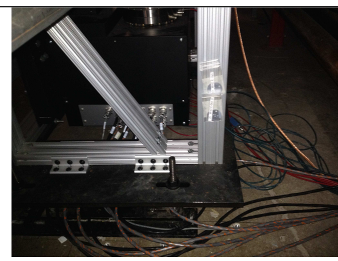
Location	Image
Minor Alcove downstream of MI-10 Stairway 20171024_143038.eps 20141016_111949.eps	
R3VIPM Magnet ST On Magnet 20141016_112005.eps	
R3VIPM Pre-Amp LT On Pre-Amp 20141016_112029.eps	
M3VIPM Magnet On Magnet Upstream Face 20141016_110827.eps	
M3VIPM Floor Pre-Amps on Floor 20141016_110841.eps	
R4HIPM Magnet Upstr Face 20141016_112454.eps	
R4HIPM Magnet LT - Pre-Amp 20141016_112500.eps	

Table 4: More Images of Al Tag Locations

Location	Image
LM104 ST - LCW Support LT - Vert Conduit(shown) 20171024_143258.eps	
M4HIPM Main Injector Horizontal 104 20141016_112314.eps 20171024_143225.eps	
MI-62 E-Gun Near the bottom of the upstream side of the e-gun 80/20 supports. Wall side of ring. IMG_4808.eps	
MI-62 Aisle - across from e-gun IMG_4810.eps	
MI-62 HV-Box Vertical unistrut support just below quad bus. Upstream side of e-gun. IMG_4809.eps	
MI-62 E-Gun video controller Tags on the wall of the mini-alcove. Just upstream of the e-gun. IMG_4807.eps