MI8 Line at Recycler Energy

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Abstract

The Recycler Ring (RR) will be re-dedicated as pre-injector for Main Injector (MI) during the NOVA era, with injection coming directly from Booster. The new scenario means that proton beam going through MI8 line will be at energy level dictated by the Recycler Ring, instead of being dictated by Antiproton Ring. To ascertain that MI8 line operates properly with new energy level this study was conducted.

Introduction

The objective of study is to send proton beam through MI8 line to MI with beam energy level consistent with that of Recycler Ring and document the operation of MI8 line. The fact that over two third of MI8 line is consisted of permanent magnet made this study one with priority.

The energy difference between MI and RR has been very well established. Beam transfers to and from RR always include deceleration before, or acceleration after, by the Main Injector. For the study MI injection frequency was set to the 52,809,000 Hz of RR, instead of 52,811,400 Hz. The Booster bend field at extraction was also lowered by 4 amps, from its nominal of 972 Amp. This approximated the energy level being used in MI for transfers to RR.

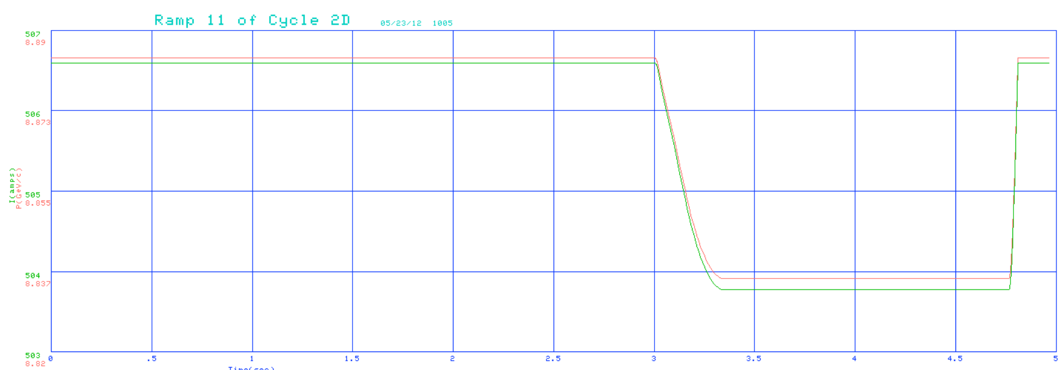

Figure 1. Momentum and bend bus current ramp waveform for MI cycle $2D.

Study setup

Beam cycle $2D for MI to RR proton transfer was used for the study. MI programmed bend bus momentum and current ramp waveforms for the 5-second cycle duration are shown in Fig. 1. The ramp-down at 3.0 second represent the energy matching to RR with beam transfer to RR taking place at 3.4 second.

The study was conducted during normal beam operation. Booster bend bus at extraction was modified only at the beginning of each $2D cycle, and restored right after the injection into MI. Fig. 2 shows the Booster bend bus current devices B:VIMAX being set to 4 Amps lower through the use console program R99. Other devices plotted are: in red trace B:CHG0 showing the time when beam is in Booster, and in cyan trace B:VPLFRQ which is needed for phase locking to MI.

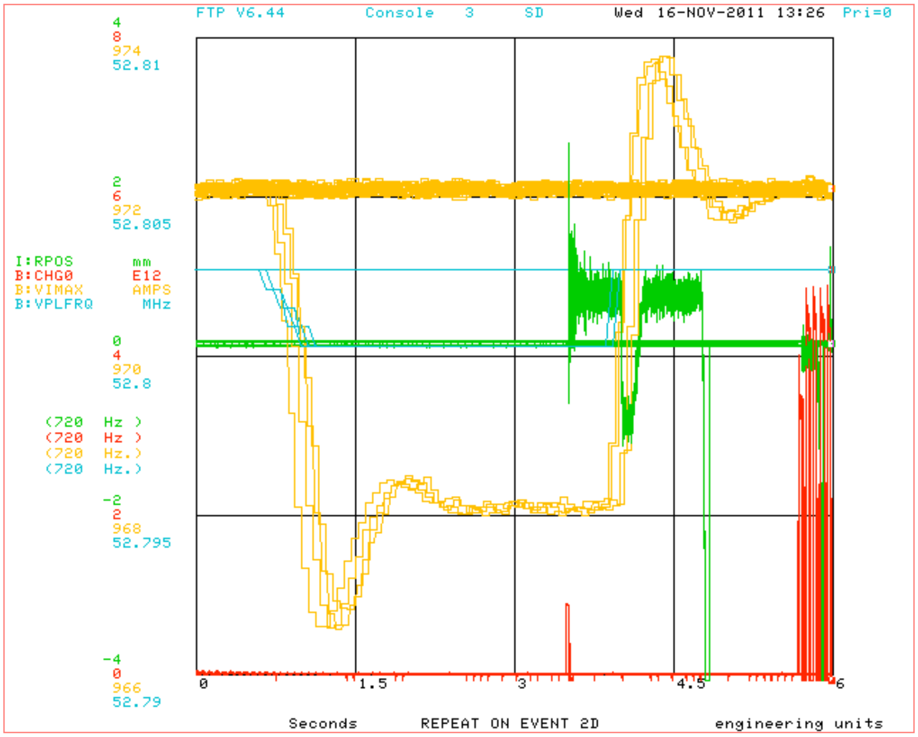

Figure 2. Plot of Booster bend bus current during the $2D cycle.

For all beam cycles g-tables of C453 cards are used to generate reference signals for all MI8 line trim dipoles, cycle used in this study included. The h-tables of C453 cards were used to provide orbit control during study cycle that was independent of normal operation. Figure 3 shows h-table settings used in the second round of study.

-I:HT800H	HT800 H(i) Ordinate Tbl		0		Amps	
-I:HT802H	HT802 H(i) Ordinate	0	-4		Amps	
-I:HT804H	HT804 H(i) Ordinate	0	-1.5		Amps	
-I:HT806H	HT806 H(i) Ordinate Tbl		0		Amps	
-I:HT808H	HT808 H(i) Ordinate	0	-.3		Amps	
-I:HT810H	HT810 H(i) Ordinate	0	-.7		Amps	
-I:HT812H	HT812 H(i) Ordinate	0	-1.5		Amps	
-I:HT814H	HT814 H(i) Ordinate	0	-.2		Amps	
-I:HT816H	HT816 H(i) Ordinate	0	1.5		Amps	
-I:HT818H	HT818 H(i) Ordinate	0	2.3		Amps	
-I:HT820H	HT820 H(i) Ordinate	0	3.8		Amps	
-I:HT822H	HT822 H(i) Ordinate	0	2.3		Amps	
-I:HT824H	HT824 H(i) Ordinate	0	1.3		Amps	
-I:HT826H	HT826 H(i) Ordinate	0	1.6		Amps	
-I:HT828H	HT828 H(i) Ordinate	0	1.6		Amps	
-I:HT830H	HT830 H(i) Ordinate	0	2.8		Amps	
-I:HT832H	HT832 H(i) Ordinate	0	4		Amps	
-I:HT834H	HT834 H(i) Ordinate	0	4		Amps	
-I:HT836H	HT836 H(i) Ordinate	0	3		Amps	
-I:HT838H	HT838 H(i) Ordinate Tbl		0		Amps	
-I:HT840H	HT840 H(i) Ordinate Tbl		0		Amps	
-I:HT842H	HT842 H(i) Ordinate Tbl		0		Amps	
-I:HT844H	HT844 H(i) Ordinate	0	1		Amps	
-I:HT846H	HT846 H(i) Ordinate	0	3.1		Amps	
-I:HT848H	HT848 H(i) Ordinate	0	2.7		Amps	
-I:HT850D	HT850 Reference - D	-2.022	-1.98	-1.975	Amps	.. .
-I:HT852D	HT852 Reference - D	1.299	1.15	1.155	Amps	.. .

-I:HT800	MI-8 Horz Trim @ 800		-1.608	-1.595	Amps	.. .
-I:HT802	MI-8 Horz Trim @ 802		1.569	-2.42	Amps	.T .
-I:HT804	MI-8 Horz Trim @ 804		4.252	2.765	Amps	.T .
-I:HT806	MI-8 Horz Trim @ 806		.403	.42	Amps	.. .
-I:HT808	MI-8 Horz Trim @ 808		-.478	-.765	Amps	.. .
-I:HT810	MI-8 Horz Trim @ 810		.36	-.33	Amps	.T .
-I:HT812	MI-8 Horz Trim @ 812		1.516	.02	Amps	.T .
-I:HT814	MI-8 Horz Trim @ 814		-.107	-.306	Amps	.T .
-I:HT816	MI-8 Horz Trim @ 816		-1.668	-.165	Amps	.T .
-I:HT818	MI-8 Horz Trim @ 818		-3.611	-1.311	Amps	.T .
-I:HT820	MI-8 Horz Trim @ 820		-4.308	-.51	Amps	.T .
-I:HT822	MI-8 Horz Trim @ 822		-1.879	.413	Amps	.T .
-I:HT824	MI-8 Horz Trim @ 824		-1.566	-.27	Amps	.T .
-I:HT826	MI-8 Horz Trim @ 826		-.499	1.093	Amps	.T .
-I:HT828	MI-8 Horz Trim @ 828		-1.993	-.395	Amps	.T .
-I:HT830	MI-8 Horz Trim @ 83	-3.082	-2.838	-.031	Amps	.T .
-I:HT832	MI-8 Horz Trim @ 83	-2.863	-3.011	.985	Amps	.T .
-I:HT834	MI-8 Horz Trim @ 83	-2.292	-2.205	1.799	Amps	.T .
-I:HT836	MI-8 Horz Trim @ 83	.097	.11	3.11	Amps	.T .
-I:HT838	MI-8 Horz Trim @ 83	-.493	-.458	-.45	Amps	.. .
-I:HT840	MI-8 Horz Trim @ 84	-.861	-.851	-.845	Amps	.. .
-I:HT842	MI-8 Horz Trim @ 842		-.107	-.11	Amps	.. .
-I:HT844	MI-8 Horz Trim @ 844		-.923	.08	Amps	.T .
-I:HT846	MI-8 Horz Trim @ 846		-4.852	-1.75	Amps	.T .
-I:HT848	MI-8 Horz Trim @ 848		-2.112	.585	Amps	.T .
-I:HT850D	HT850 Reference - D	-2.022	-1.98	-1.975	Amps	.. .
-I:HT852D	HT852 Reference - D	1.299	1.15	1.155	Amps	.. .

Figure 3. Listing of settings and readings. On the left is for h-table settings used in second study. On the right is the nominal g-table settings in blue and the actual trim dipole readings in green.

Result

First round of study

During the first study proton beam was extracted successfully from Booster with frequency and B:VIMAX set to values as planned. However, due to large horizontal orbit excursion the proton beam was lost at MI8 line collimator. The plot of this orbit is shown in the first picture of Figure 4, with no beam data beyond 836 location.

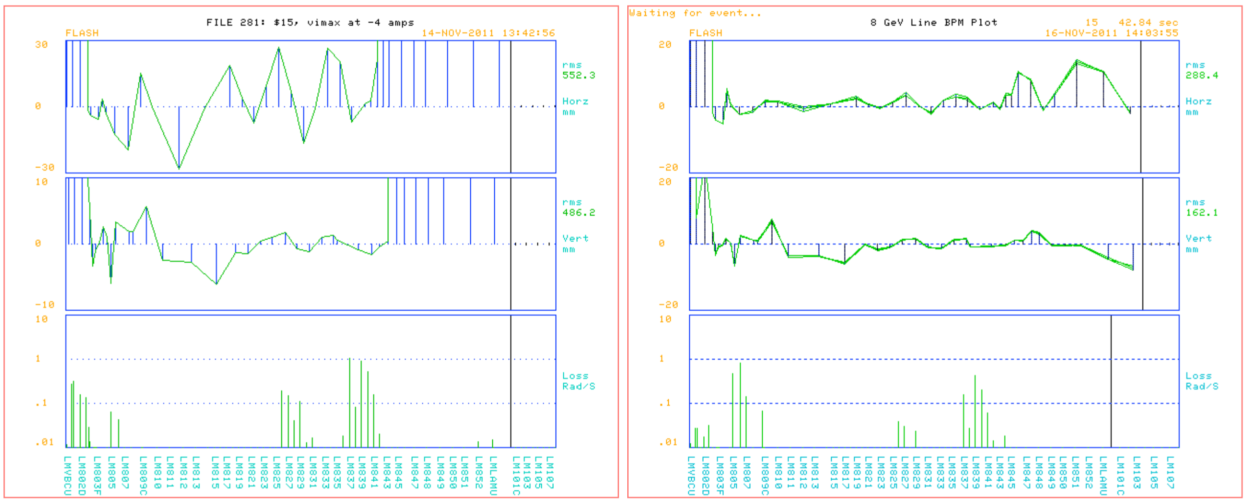

Figure 4. MI8 line BPM orbits. From first study is on the left, with beam position reading up to 836 collimator. On the right is from second study with beam going all the way to Main Injector.

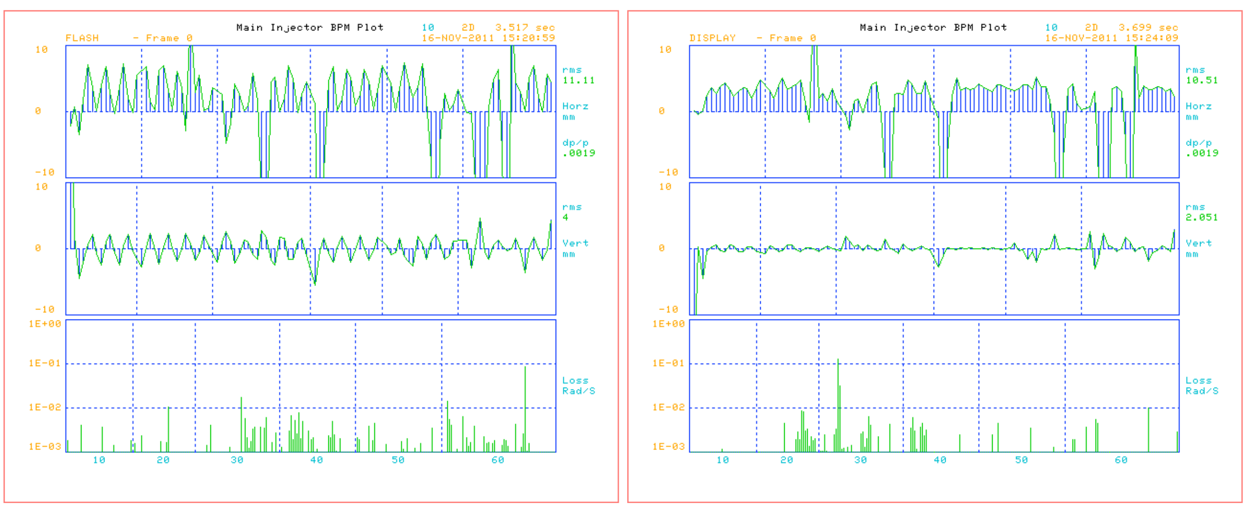

Figure 5. BPM orbit in the Main Injector. The first turn injection orbit is on the left and the circulating beam orbit on the right.

Second round

Based on orbit errors obtained from the first study necessary dipole corrections were calculated, as shown in the first picture of Figure 3 for h-table settings, and applied during the second study. These settings were good enough to take beam through MI8 line and into MI. After some injection orbit closure adjustment to minimize injection oscillation the efficiency was close to 100%. The second picture in Figure 3 it shows that currents needed in the trim dipoles were actually lower, in absolute value, with beam running at RR energy level. The corresponding MI8 line orbit is shown in the second picture of Fig. 4. First turn orbit and circulating beam orbit in the Main Injector are shown in Figure 5.

Longitudinal matching

Wall Current Monitor data was taken to make sure that beam was matched longitudinally when transferred from Booster to MI. Shown in Figure 6 are plots of longitudinal beam profiles, at the beginning of the injected batch and at the tail end of the batch. Neither showed any appreciable signs of injection phase or energy error. The injection appeared well matched in longitudinal phase space.

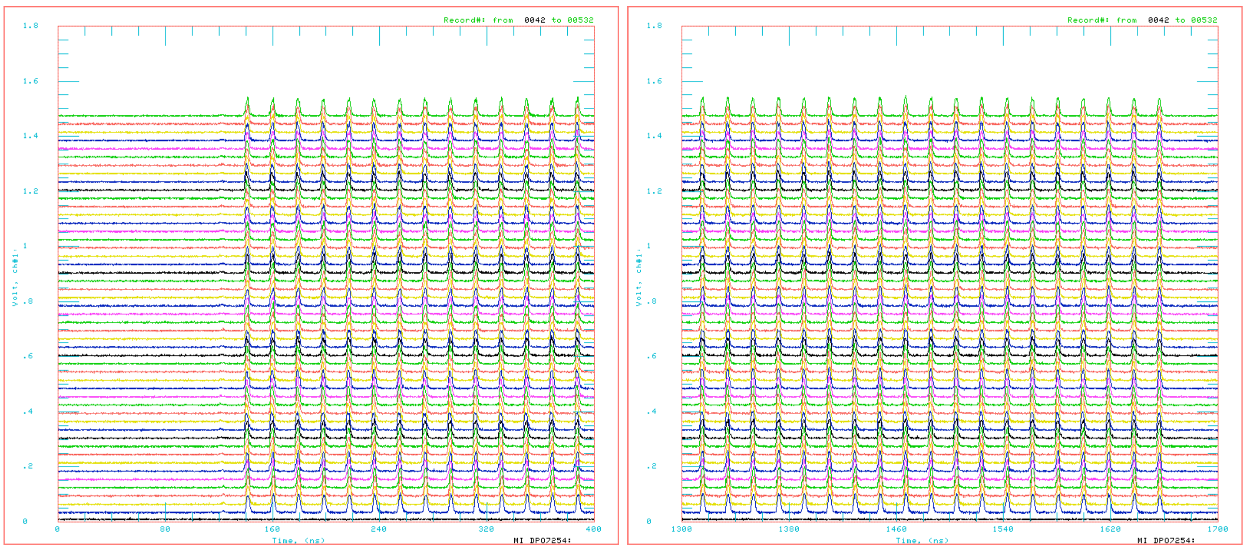

Figure 6. Longitudinal beam profile as seen from Wall Current Monitor in Main Injector. First picture shows the beginning of batch and second shows the end of batch. Data was plotted every 210 turns.

Conclusion

This study confirmed easily that MI8 line will have no trouble handling the new 8-GeV energy level, consistent with expected Recycler Ring requirement. It showed that horizontal correction dipoles, known to be running mostly on positive, had being used mostly to compensate for the lack of bending strengths in the MI8 line. With lower energy beam this requirement can be relaxed. It also provides a measure of how much room there is should the energy level of new Recycler Ring goes down further than expected.