MI-0278

MI8 Transfer Line Lattice Function Measurement

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Abstract

This write-up reports our understanding of the MI8 8-GeV transfer line lattice function, as of April 2000. The beamline optics was examined by analyzing 1-bump orbit data. Our best guess for the actual beamline lattice function is based on the beam emittance fitting using the available profile sigma data and the experimentally verified optics. The projected injection lattice function is included at the end.

Introduction

The data taken for the analysis of the 8 GeV transfer line lattice function consisted of 1-bump data using dipoles MPØ2, HT800, HT802, and VT803. Several different settings for each of the correctors were used. Both BPM data and Multiwire profile data were taken and used for analysis. In addition, by phase-locking BOOSTER RF to that of Main Injector, the beam energy at BOOSTER extraction was varied such that the beamline dispersion function can be studied.

BPM data

At each corrector setting BPM data from multiple beam cycles was collected using console program R99. The calculated mean of position and the RMS variation at each BPM were recorded.

Multiwire profile data

Multiwire profile data was taken for both beam position and profile width information. Off-line Gaussian fit to the profile provides beam centroid information that is used in the orbit analysis. The profile sigma was used for beam width propagation analysis, as well as initial lattice function analysis.

Magnet readings

The MI8 transfer line includes both conventional and permanent magnets. Bulk power supplies are used to power most of the conventional electro-magnets, i.e. major bends and quadrupoles. Current shunts are used to adjust each magnet to it desired current. The reading of both the bulk power supply and the shunts were taken during study and used in the calculation to reproduce the corresponding beam data.

Analysis and results

Calibration of MPØ2 and HT800

MW800 is located before any of the MI8 line quadrupoles. Its position reading can be used to calibrate the kick strength of MPØ2 in the vertical plane. The same works for HT800 in the horizontal plane, except with less accuracy due to much shorter drift distance. Figure 1 showed the vertical position data from MW800 as function of MPØ2 voltages. This implies a local transfer constant of 8.899 gauss/volt. Figure 2 showed a similar plot for HT800 and implies a transfer constant of 31.204 gauss-meter/amp, for a zero-length dipole.

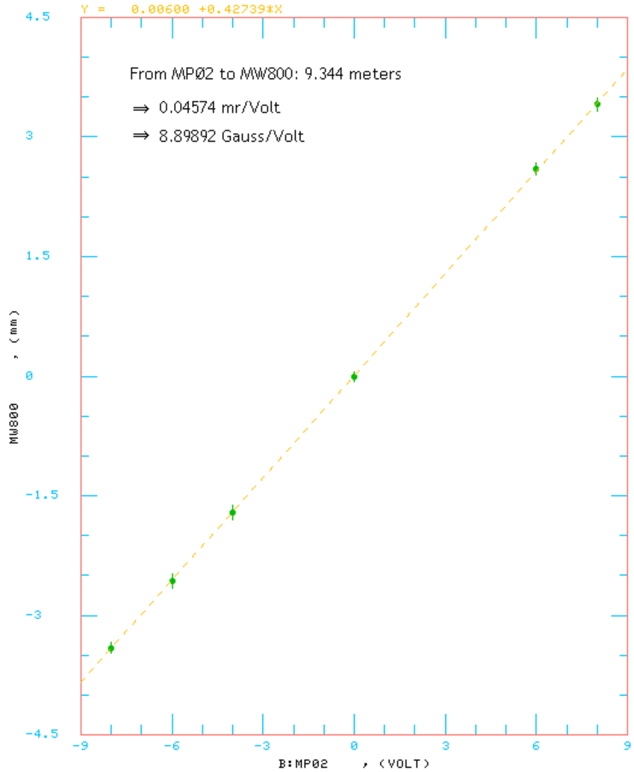

Figure 1. Calculation of transfer constants using vertical plane multiwire profile of MW800. The beam position is plotted as a function of MPØ2 setting.

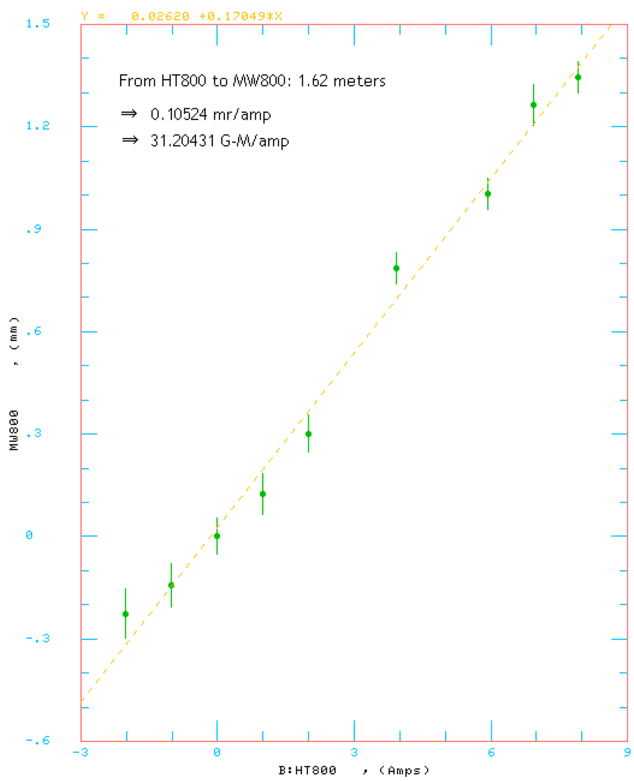

Figure 2. Calculation of transfer constants using horizontal plane multiwire profile of MW800. The beam position is plotted as a function of HT800 setting.

Orbit

The 1-bump orbit data is used to verify the strength of quadrupoles in the beamline. Adjustments to the read magnet current are shown in figure 3. This was found necessary in order for the calculated orbit to match that of the measured data orbit. Shown in Figure 4, 5 , 6 and 7 are the comparisons of calculation with data, using HT800, HT802, MPØ2, and VT803 respectively. Data and calculation as plotted are color coded for each different trim current settings. Circles are from BPM readings and solid dots are from multiwire profile centroids. In all cases the agreements between data and expected orbit excursion are quite good. All the calculations shown were done using one single set of magnet currents which was used for the subsequent lattice function analysis.

		As of...					As used
		4/8/00	4/8/00	3/31/00	2/6/00		by PA1677
DB_name		Setting	Reading	Reading	Reading		Reading
B:MP02	VOLT	1029.59					
MP02	AMPS	1028.994					
Q800	AMP		211.3619	211.9015	211.2415		205.3619
Q801	AMP		184.4019	184.6915	184.5615		184.4019
Q802	AMP		171.7809	171.4155	171.4405		171.7809
Q803	AMPS		89.09375	88.6937	89.3938		99.09375
Q804	Amps		224.6019	225.1415	225.6415		218.6019
Q805	Amps		244.4819	245.0615	244.4815		240.4419
Q806	Amps		161.1009	160.6555	160.8005		167.1009
Q807	Amps		156.0609	155.6955	155.5205		152.0609
Q808	Amps		198.6019	198.8515	198.5615		193.6019
Q809	Amps		204.8419	205.1715	204.8415		207.8419
Q847	Amps		148.695	148.725	148.675		148.695
Q848	Amps		144.83	144.85	144.735		144.83
Q849	Amps		157.575	157.595	157.55		160.575
Q850	Amps		161.215	161.26	161.17		164.215
Q851	Amps		156.915	156.965	156.685		156.915
Q852	Amps		159.425	159.475	159.445		159.425
B:Q800S	Amps	43.74	43.1225	43.0825	43.2425		43.1225
B:Q801S	Amps	31.2	31.0825	31.0425	30.9225		31.0825
B:Q802S	Amps	10.8	11.1225	10.9625	11.0425		11.1225
B:Q804S	Amps	28.86	29.8825	29.8425	28.8425		29.8825
B:Q805S	Amps	10	10.0025	9.9225	10.0025		8.0425
B:Q806S	Amps	21.68	21.8025	21.7225	21.6825		15.8025
B:Q807S	Amps	26.84	26.8425	26.6825	26.9625		30.8425
B:Q808S	Amps	17	16.8825	16.8825	16.9225		21.8825
B:Q809S	Amps	10.6	10.6425	10.5625	10.6425		7.6425
I:Q847S	Amps	16.2	16.18	16.15	16.2		16.18
I:Q848S	Amps	20.1	20.045	20.025	20.14		20.045
I:Q849S	Amps	7.46	7.3	7.28	7.325		4.3
I:Q850S	Amps	3.74	3.66	3.615	3.705		0.66
I:Q851S	Amps	8.1	7.96	7.91	8.19		7.96
I:Q852S	Amps	5.52	5.45	5.4	5.43		5.45
B:Q800	AMP	255.7983	254.4844	254.984	254.484		248.4844
B:Q801	AMP	216.2933	215.4844	215.734	215.484		215.4844
B:Q802	AMP	183.0963	182.9034	182.378	182.483		182.9034
B:Q803	AMPS	96.95435	89.09375	88.6937	89.3938		99.09375
I:Q847	AMP	164.9963	164.875	165.894	164.7		164.875
I:IQD	Amps		201.875				205.926
I:IQF	Amps		206.375				209.436
MI_BEND	Amps	478.19	476.5836				506.403

Figure 3. Magnet currents as read and as used by the analysis program.

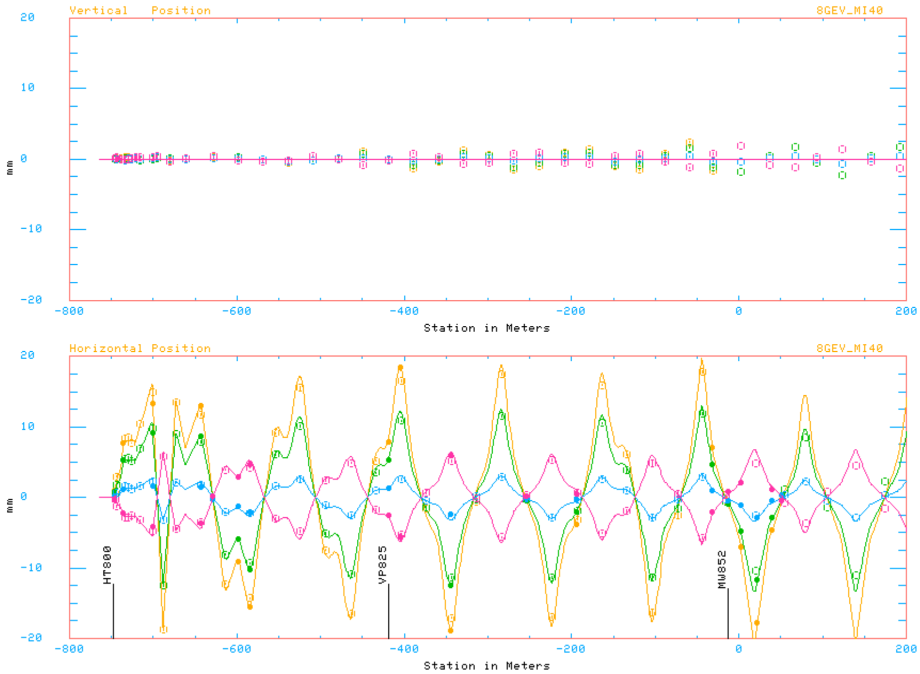

Figure 4. MI8 beamline horizontal plane orbit as result of different HT800 setting.

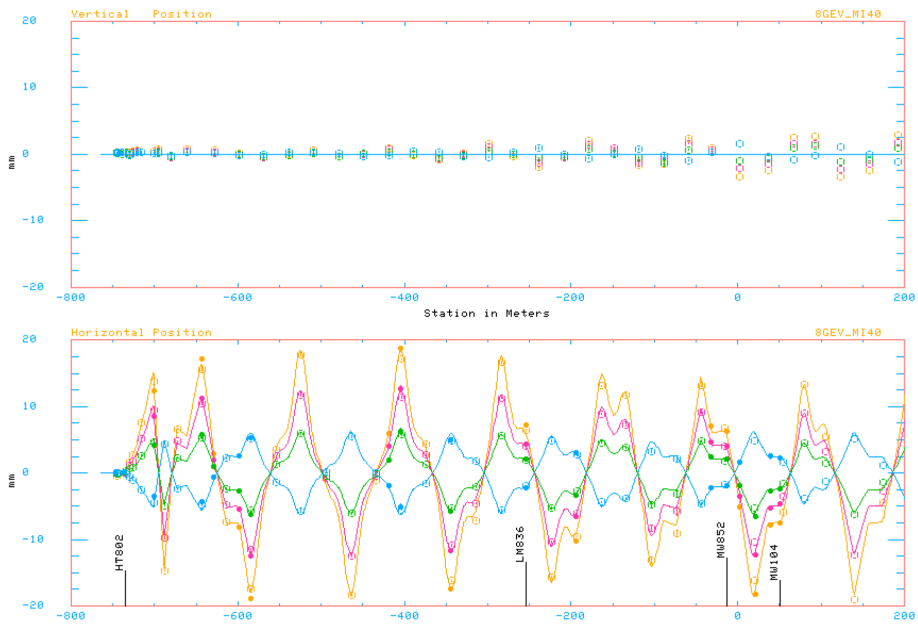

Figure 5. MI8 beamline horizontal plane orbit caused by HT802.

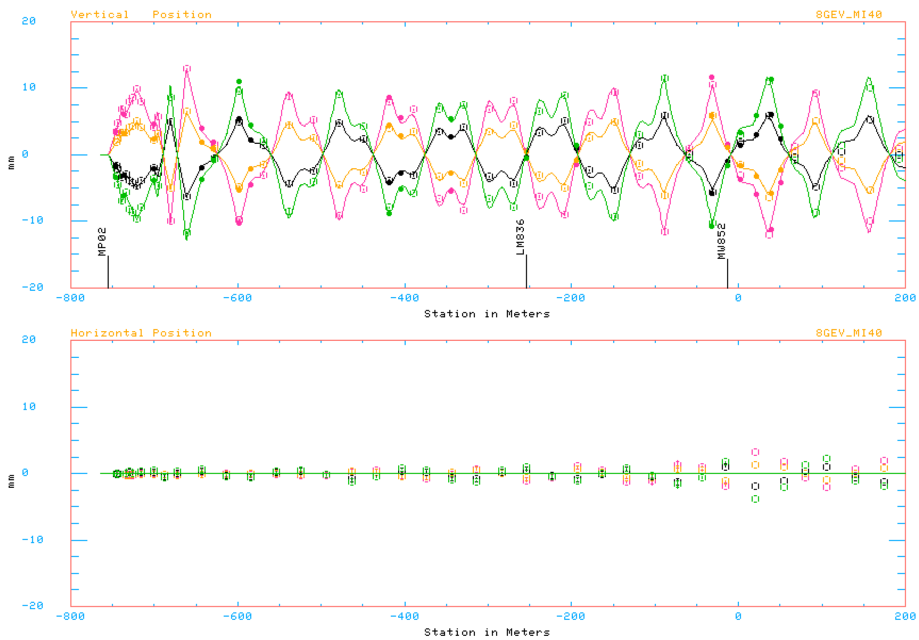

Figure 6. MI8 beamline vertical plane orbit as caused by MPØ2.

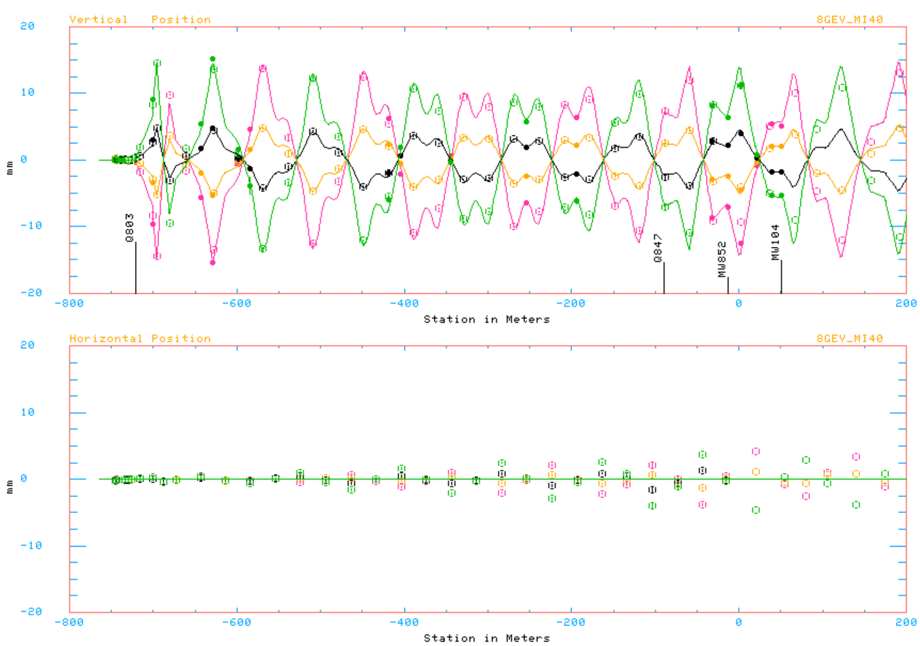

Figure 7. MI8 beamline vertical plane orbit caused by VT803.

Dispersion function

With Booster phase lock on the beam energy into the MI8 line was controlled by changing the Main Injector RF frequency at injection. During study the Booster flat-top beam energy was changed by about ±0.5E-3. In Figure 8 the measured dispersion function is plotted along with the calculation in connected line. The agreement is quite good except in the vertical plane. A more detailed study needs to be made to certify the vertical dispersion function.

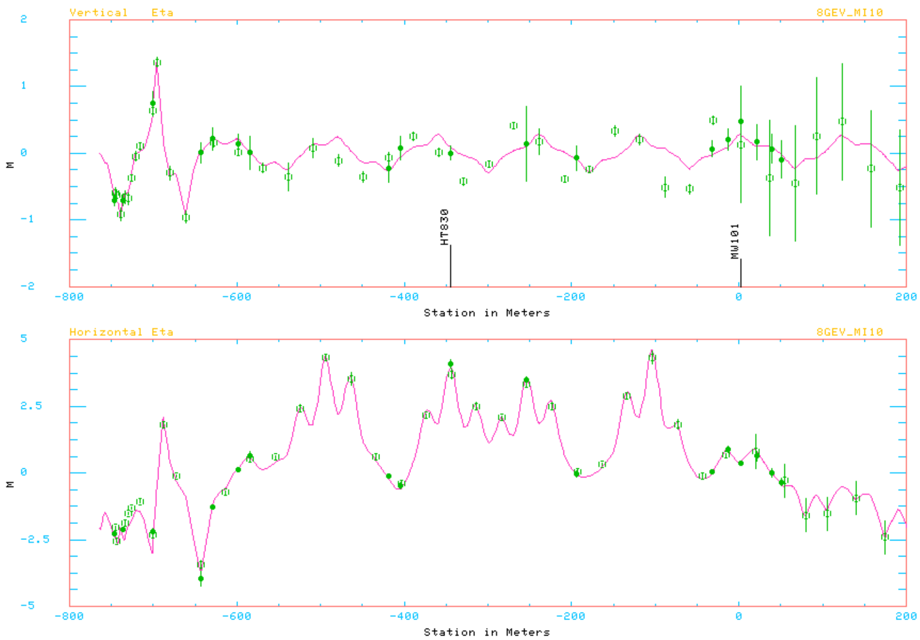

Figure 8. The horizontal and vertical plane dispersion function, measured BPM position data and as calculated. The connected line represents the calculation using the Δp/p calculated according to the measured RF frequency of the Main Injector the design phase slip factor at 8-GeV.

Profile sigma

The beam emittance and σ_p/p were fitted based on the above verified beam optics which includes the dispersion function. Shown in Figure 9 and 10 are the profile data and the corresponding calculation, using the fitted initial lattice function. Shown in figure 11 are horizontal and vertical sigma from profile data taken in multiple beam transfers. With no more than four multiwires in the beam during each transfer the down-stream profiles are expected to be less contaminated by the effect of multiple scattering.

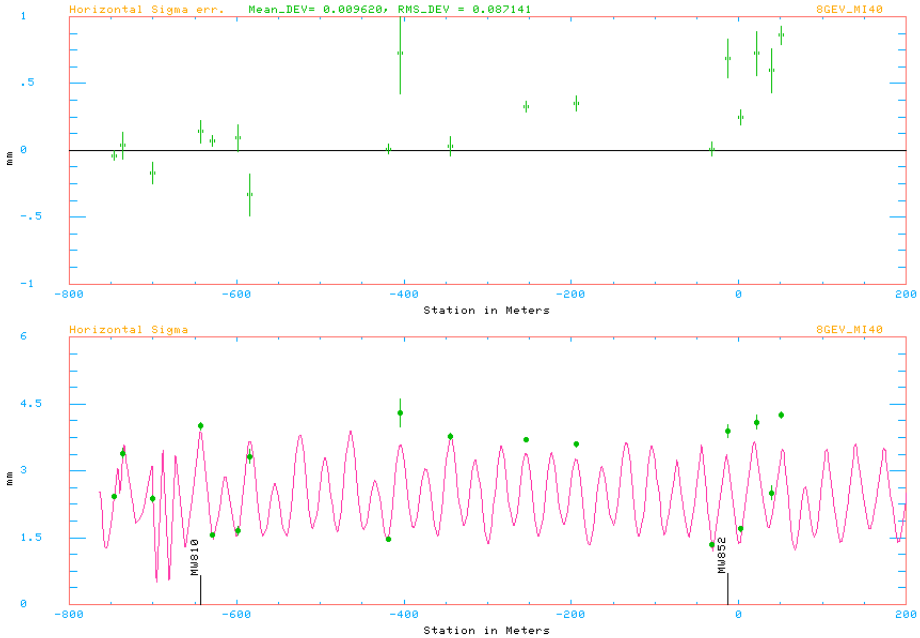

Figure 9. Horizontal plane profile sigma as plotted against the calculation. The top plot shows the difference.

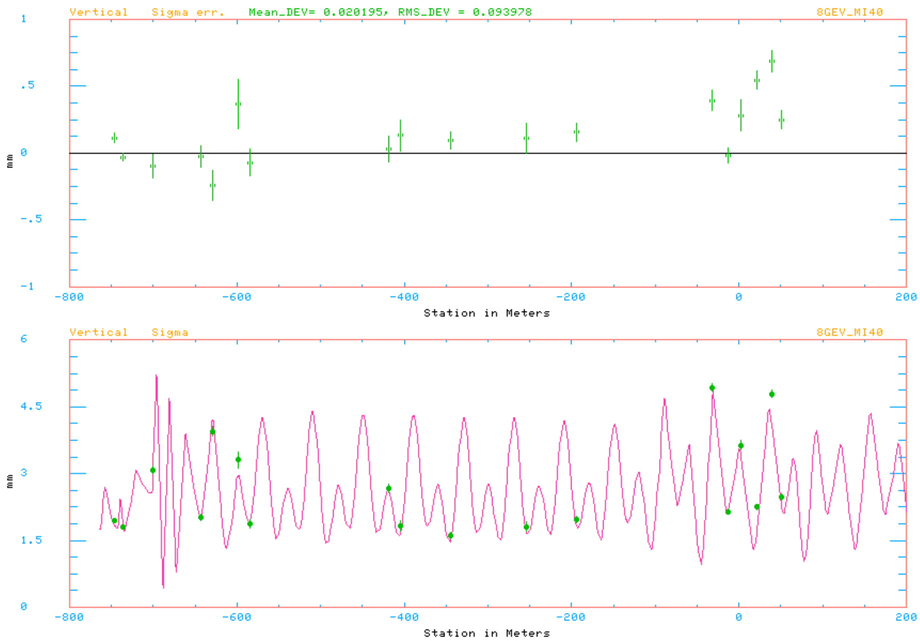

Figure 10. Vertical plane profile sigma plot. Bottom plot shows the data as compared to the calculated sigma and the top plot shows the differences.

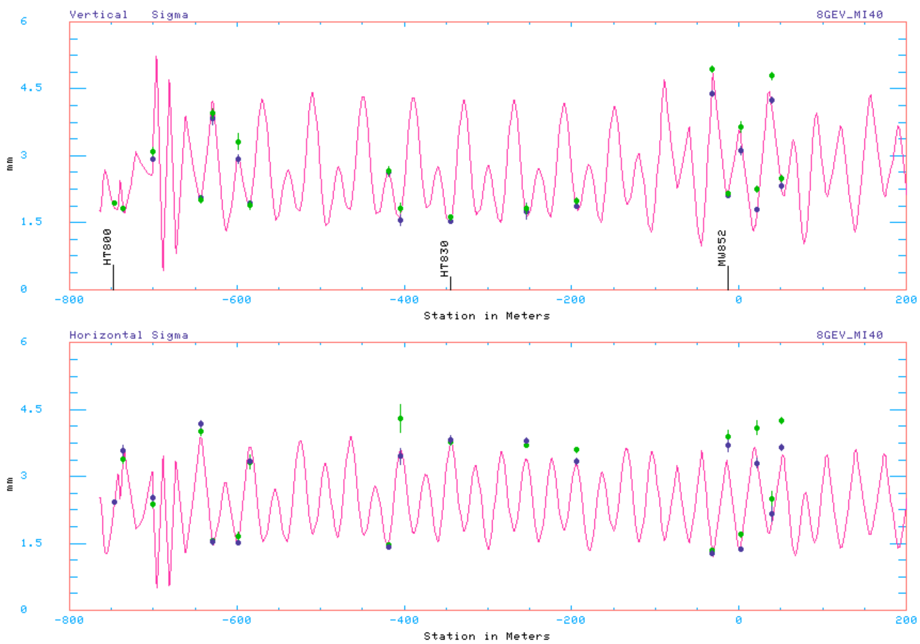

Figure 11. Sigma plot of both horizontal and vertical plane. Green dots are data taken with all MI8 line multiwires in and blue dots are data taken with 4 multiwires in, at a time.

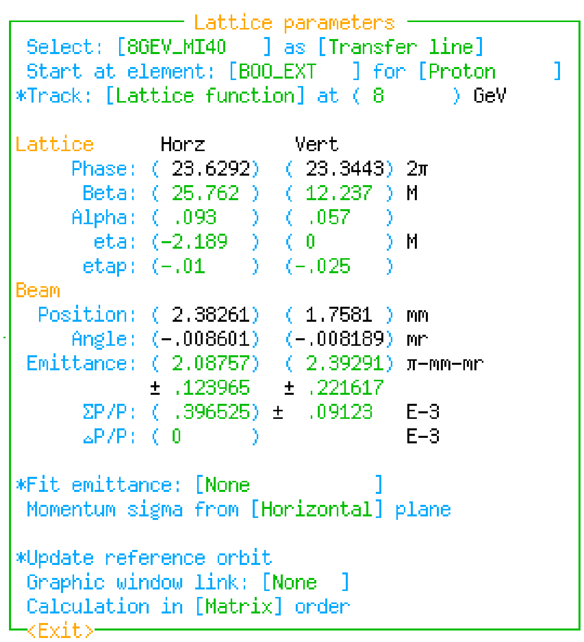

Figure 12. The initial lattice parameters used for calculation as shown in the window named "Lattice Parameters."

Lattice

In order for the profile sigma propagation to fit the data the initial lattice function, starting at Booster, had to be modified. Figure 12 shows the initial lattice parameters used for lattice calculation and the fitted emittances. The use of experimentally determined initial twiss parameters is justified in part because of the optics up-stream of MI8 beamline was not directly verified. This changes the beamline line lattice function substantially. Further effort is needed to justify the initial condition used. The projected injection lattice function into Main Injector is shown in Figure 13 and 14.

Text view

*List [Twiss parameters] of [8GEV_MI40] *Seq# -< >+
*Device: [BPMs] in [Horz plane] *Calc -< >+
From -<HP852 >+ to [HP112]

Name	Station	phase	Beta	Alpha	Eta	Etap
HP852	-15.02	6.7875	49.02	-2.5552	0.8786	0.0475
HP102	19.50	7.0758	59.65	2.3309	0.7091	-0.0391
-	19.62	7.0761	59.08	2.3177	0.7043	-0.0391
HP104	54.47	7.2892	51.59	3.3440	-0.4663	0.0150
HP106	80.40	7.5764	31.27	1.6318	-0.5264	0.0431
HP108	105.93	7.7860	54.46	2.5520	0.4329	-0.0054
HP110	140.52	8.0682	58.27	2.3127	0.7020	-0.0387
HP112	175.10	8.2867	54.29	2.5457	-0.4948	0.0081

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Figure 13. The projected horizontal plane lattice function at injection into Main Injector.

Text view

*List [Twiss parameters] of [8GEV_MI40] *Seq# -< >+
*Device: [BPMs] in [Vert plane] *Calc -< >+
From -<VP847 >+ to [VP107]

Name	Station	phase	Beta	Alpha	Eta	Etap
VP847	-88.87	5.9572	85.22	3.0918	0.1087	-0.0151
VP849	-58.73	6.0909	49.78	3.5610	-0.4841	0.0237
VP851	-30.66	6.4705	90.80	3.3940	-0.0301	0.0120
VP101	2.21	6.6266	47.72	2.5213	0.5808	-0.0220
-	2.33	6.6270	47.11	2.5025	0.5781	-0.0220
VP103	36.79	6.9455	77.57	2.8702	0.1701	-0.0178
VP105	67.43	7.1045	39.45	3.1459	-0.4707	0.0262
VP107	93.37	7.4588	61.77	2.9034	-0.0846	0.0171

<Exit>

Figure 14. The projected horizontal and vertical plane lattice function at injection into Main Injector.

Miscellaneous

Multiwire

MW852 horizontal appears to be inverted in horizontal plane.