High Beta Insert for MI-like Ring

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Currently, MI-30 straight section, is the prime canidate for the proposed electron cooling system for the recycler ring. The total length of the straight section between Q301 and Q309 is 136 meters. With 90 degree cells, the total phase advance across the nominal straight is 360 degrees. Figure 1 shows the current MI lattice around the MI-30 straight section. Each straight section is bordered by a horizontal dispersion suppression insert.

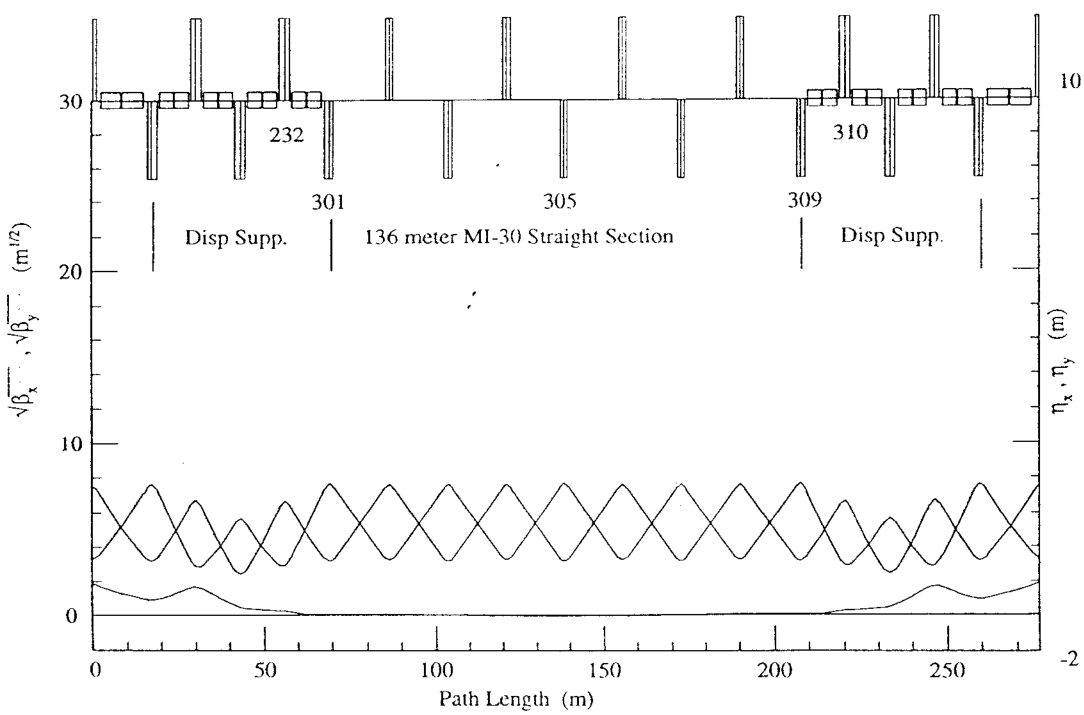

Figure 1: Normal MI-30 Straight Section

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The half-cell between 305 and 306 is currently being reserved for a snake (for polarized beams). This leaves four half-cells ($\approx$ 67m) upstream and three half-cells ($\approx$ 50m) downstream available for a high beta insert for electron cooling. The question is: Can a high beta insert be incorporated into this straight leaving enough room for both the electron cooling and a snake?

The parameters used for the high betas straight are:

- a constant beta function, β within the straight section which implies a symmetric straight,
- $\beta_x = \beta_y$ which implies the use of a triplet should be large, say 200 m. ,
- and near zero dispersion within the straight section which implies triplet should be not be in the dispersion suppression section.

The MI-30 straight section was modified as shown in Figure 2.

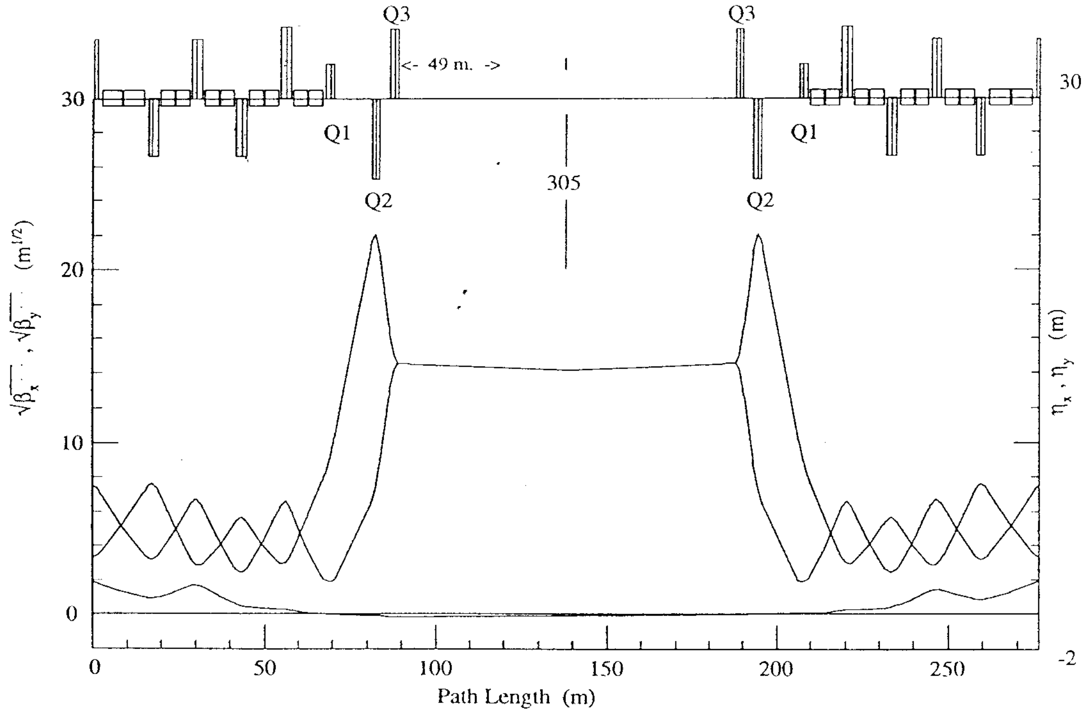

Figure 2: High Beta Insert, Version 1, FDF t

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Here Q232 and Q301 position in the lattice are not changed. An additional quad is inserted 2 meters upstream of Q302 to make the middle quad (Q2) in the triplet. The position of Q303 remains (nearly) unchanged. The triplet is then made up of Q301 (Q1), changed polarity to become a focussing quad, the new quad (Q2) which run as a defocussing quad, and Q303 (Q3) at the same polarity as the normal lattice. The polarity of this triplet is FDF. In this configuration, the gradient of Q232 has to be slightly modified, but this does not greatly impact the dispersion suppression. The nominal quad strengths for the various configurations are shown in Table 1.

Table 1: Quad Values

Quad	length [in]	Nominal Lattice $[m^{-2}]$	Version 1 $[m^{-2}]$	Version 2 $[m^{-2}]$
Q232	116	0.0403538	0.04618951	0.04583040
Q301	100	-0.0394974	Q1 = 0.02330793	-0.04232120
Q302	84	0.0403538	Q2 = -0.05467832	Q1 = 0.04760479
Q303	84	-0.0394974	Q3 = 0.04738560	Q2 = 0.06127740
Q304	84	0.0403538	0.0	Q3 = -0.05277880
Q305	84	-0.0394974	0.0	0.0

It should be noted that the insert is symmetric and extends between Q301 and Q309. This produces an insert with ≈ 50 meters clear real estate on either side of the straight section center. However, this arrangement of quads procudes a β_y max of ≈ 500 meters at the center of Q2. Assuming a 2 inch vertical aperture this reduces the vertical admittance to ≈ 49 mm-mr. Increasing the vertical aperture to 3 inches, increases the admittance to over 100 mm-mr.

The unperturbed lattice functions extend between Q232 and Q310 which has a phase advance of 440 degrees. This insert as well as the next iteration retard the phase advance across the straight. The horizontal phase advance is retarded nearly a unit while the vertical changes by 90 degrees in Version 1. The change in phase advance in the second version is nearly a unit in both planes. The phase advances for the unperturbed and the two inserts as well as other parameters are shown in Table 2.

In an effort to reduce the maximum vertical beam size a second polarity triplet was tried, namely a DFD. This polarity triplet increases the horizontal beam size to ≈ 500 m, however the horizontal aperture is likely to be larger. The insertion quads are contained with in the first two half-cells. It produces a slightly shorter real estate, i.e. 36 meters, available for electron cooling. This solution is shown in Figure 3.

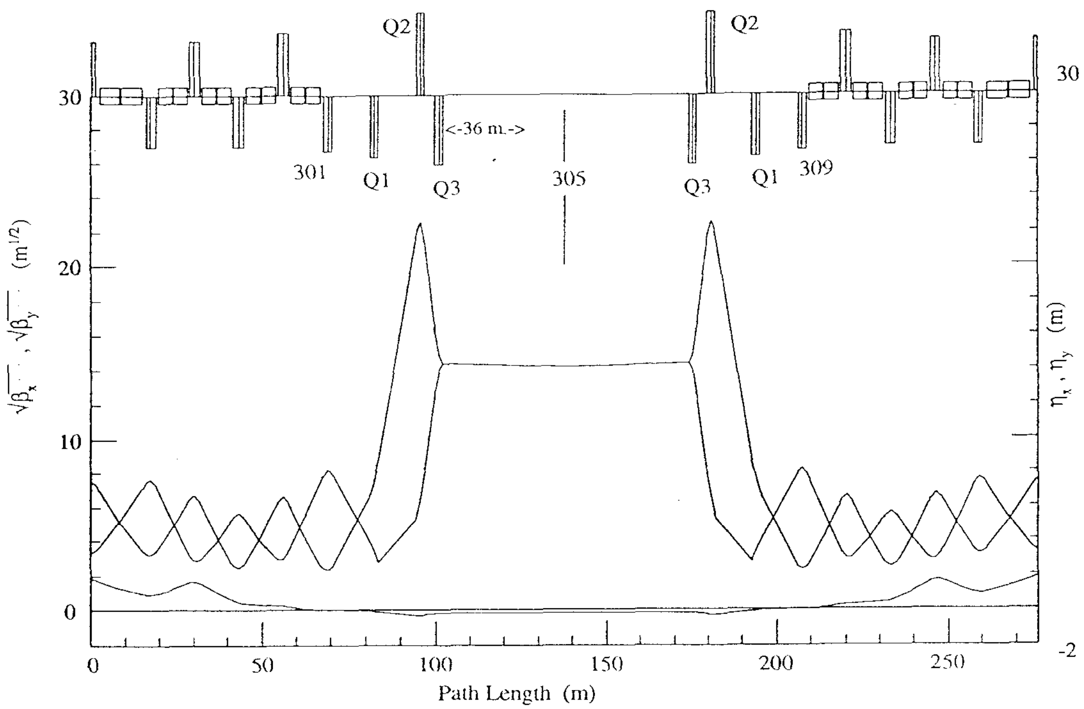

Figure 3: High Beta Insert, Version 2, DFD t

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Conclusion:

This exercise has shown that a symmetric high beta insert with $\beta_x = \beta_y$=200 meters is possible in a MI like lattice without distorting the lattice outside the insert. This same insert could be utilized in a ring with combined function magnets equally as well.

Table 2: Straight section parameters

Parameter	Nominal Lattice	Version 1	Version 2
drift length	136.17 m	$\approx$ 100 m	$\approx$ 72 m
β_x max	57.8 m	213.3 m	505.6 m
β_y max	58.7 m	489.3 m	207.3 m
η_x @ 305	-0.032 m	-0.13 m	-0.204 m
$\Delta\nu_x$	443 deg	360 deg	95 deg
$\Delta\nu_y$	422 deg	100 deg	72 deg