CORRECTION OF THE CHROMATICITY UP TO SECOND ORDER FOR MEIC

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Abstract

The proposed electron collider lattice exhibits low β-functions at the Interaction Point (IP) ($\beta_x^* \, 100\,mm$ – $\beta_y^* \, 20\,mm$) and rather large equilibrium momentum spread of the collider ring ($\delta p/p = 0.00158$). Both features make the chromatic corrections of paramount importance. Here the chromatic effects of the final focus quadruples are corrected both locally and globally. Local correction features symmetric sextupole families around the IP, the betatron phase advances from the IP to the sextupoles are chosen to eliminate the second order chromatic aberration. Global interleaved families of sextupoles are placed in the figure-8 arc sections, and non-interleaved families at straight section making use of the freely propagated dispersion wave from the arcs. This strategy minimizes the required sextupole strength and eventually leads to larger dynamic aperture of the collider. The resulting spherical aberrations induced by the sextupoles are mitigated by design; the straight and arc sections optics features an inverse identity transformation between sextupoles in each pair.

INTRODUCTION

Medium Energy Electron Ion Collider (MEIC) complex consists of two separate figure-8 rings: 9 GeV electrons and 60 GeV ions rings. The electron ring parameters are given in table (1). More detailed description of the overall MEIC collider complex is described in [3]. The design requirement for MEIC with high luminosity mandates reducing the beam sizes at the interaction point to micron size level. The required strong focusing generates quite substantial chromaticity due to the combination of strong final focus quadrupoles and expanded β-functions at the final focus quadrupoles. This will pose a challenging requirement for the beam lifetime which calls for a substantial correction scheme taking into account the second order chromaticity and momentum acceptance. In this paper we present a correction scheme based on a mix of two common schemes, which have been utilized in the past [1] , [2]. A detailed description of both schemes will be presented followed by conclusions

INTERACTION REGION

Fig. 1 shows layout and optics of interaction region based on a two doublets with the first final focus quadrupole at 3.5 m from IP limiting maximum values of $\beta_{x,y}$ to 650 m. An antisymmetric dispersion pattern through the IP is assumed. This balanced IR optics, requiring quadrupole strength of less than 50 T/m, results in modest values of chromaticity (less than hundred units). The β and dispersion functions of the whole lattice is shown in Fig. 3

Table 1: MEIC lattice parameters

Quantity	Unit	Value
Beam Energy	GeV	9
Equilibrium relative $\Delta p/p$		1.59×10^{-3}
Equilib. hor. emittance	m	6.8×10^{-8}
Vert. emittance	m	1.37×10^{-8}
Tune $\nu_x(\nu_y)$		36.506(31.531)
$\beta_x(\beta_y)$ at IP	cm	10(2)
Bunch length	m	5×10^{-3}
Initial number of particles		3.1×10^{10}

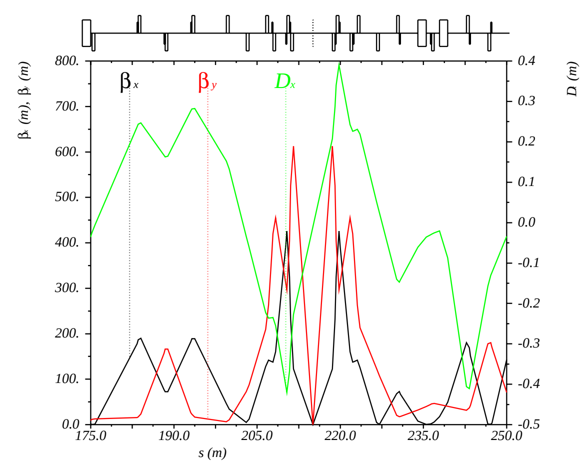

Figure 1: MEIC Interaction Region

LOCAL CORRECTION

Local chromaticity correction for low β insertion was first adopted by linear colliders, where the major concern was to reduce smearing of the beam cross section at IP [2]. In MEIC case it is invaluable to correct the chromaticity locally, in the immediate vicinity of the IP in order for it not to propagate to the rest of the lattice and simultaneously to reduce the effect of smearing of the beam cross section at the IP.

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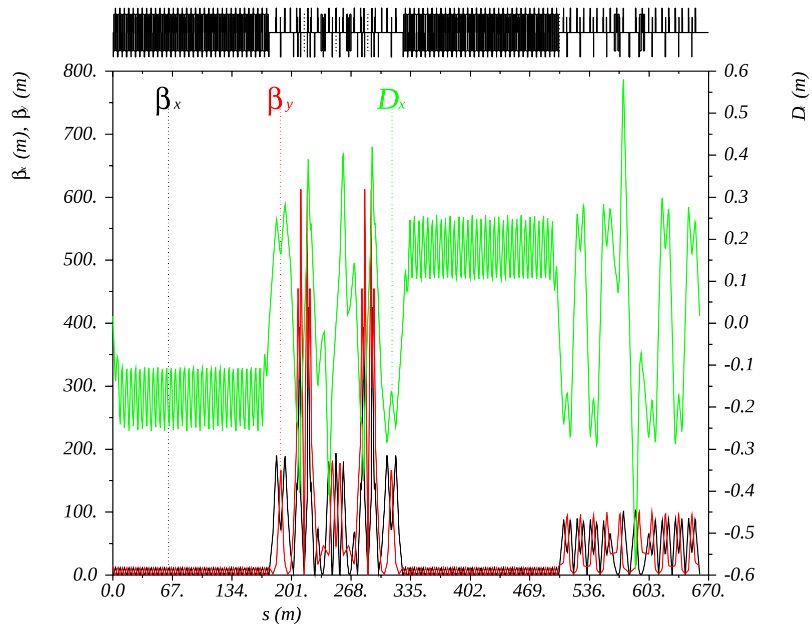


Figure 3: MEIC twiss functions

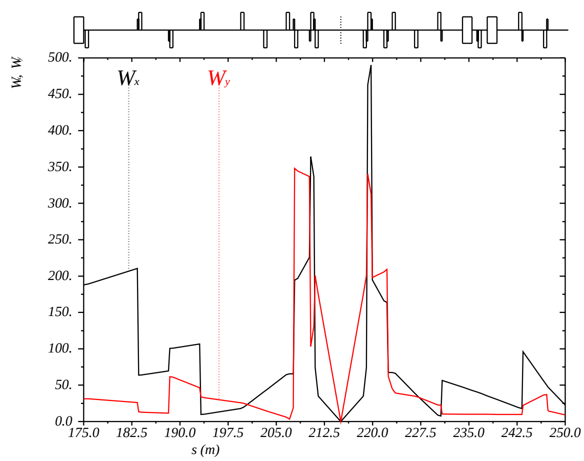


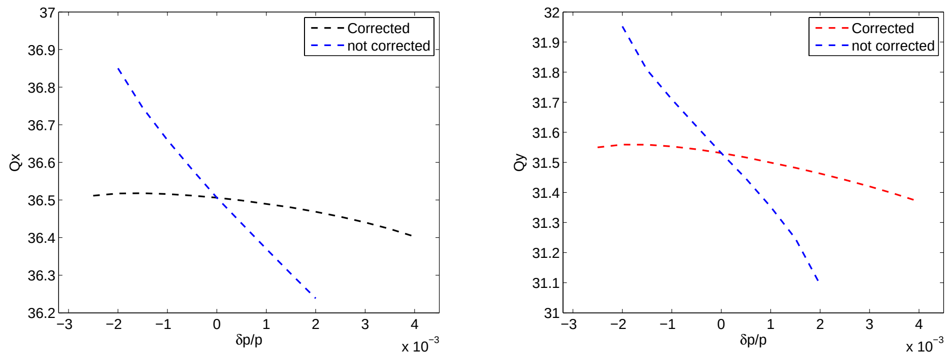
Figure 2: Montague chromatic function at interaction point

The correction was done using a set of sextupoles placed symmetrically around the IP, in places with suitably large values of dispersion and β function in order to reduce the sextupole strength needed for the correction. The dispersion required for the chromatic correction was generated from the arc dipoles and left to propagate through the IR while maintaining dispersion free IPs with antisymmetric dispersion wave around the IPs. This has the advantage of reducing the space occupied by the IR and dispersion suppressors. Montague chromatic functions (W_x, W_y) were used as a measure of β chromaticity at the IP. β correction sextupoles around IP were used to reduce those functions from 10^3 to 10^{-4} range and they are confined to acceptable values for the rest of the ring. Six Sextupole pairs were used in this process; the closest pair to IP was applied to eliminate the $W_{x,y}$ at IP, and the remaining five pairs were invoked to confine chromatic functions within the IR. Fig. 2 shows Montague functions locally around the IP after correction.

Second order chromaticity arising from IRs final focus quadrupoles and correcting sextupoles was mitigated by fixing the phase advance between the two symmetric interaction regions to be $\pi.(1/2 + n)$ (where n is an integer number) [4].

GLOBAL CORRECTION

The residual chromaticity propagated from IR in addition to the natural chromaticity generated by the arc quadrupoles was compensated with families of sextupoles placed in the arcs and in the other straight which has no IP. In the arc case, sets of interleaved sextupoles families were placed in the arc cells adjacent to quadrupoles whose correction being carried on, every family member was placed at (3 π) -I transformation from each other to cancel second order effects from those sextupoles. As for the IP free straight with special symmetric insertion blocks, the sextupoles were placed in a non interleaved families with I transformation apart as well. The main goal of the sextupole families in the arcs and free straight is to reduce the tune variation with momentum deviation (tune chromaticity). A global optimization was launched to reduce it. Fig. 4 shows tune variation with momentum offset after correction.



(a) Q_x Horizontal tune variation with momentum offset (b) Q_y Vertical tune variation with momentum offset

Figure 4: Tune Variation with momentum offset

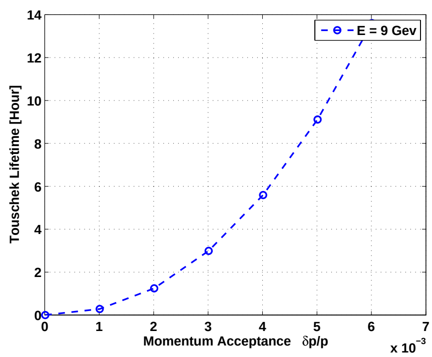


Figure 5: Touschek lifetime for 9 Gev lattice

TOUSCHEK LIFETIME

A Touschek lifetime calculation based on [5] showed that for a the lattice under study one needs at least 0.003 momentum acceptance for the lifetime to reach 3 hours. Fig. 5 shows Touschek lifetime dependance on momentum acceptance. The depolarization time at MEIC is expected to have shorter time scale, hence the electron ring will be refilled before Touschek effect becomes an issue.

CONCLUSION

A chromaticity correction scheme for MEIC is a challenge.We demonstrated a proof of principle study to address this problem. For a complete design of the collider, future studies must include tracking to examine the dynamic aperture of the lattice after sextupole correction.

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