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OPTIMIZATION OF CHROMATIC OPTICS NEAR THE HALF INTEGER IN PEP-II*

G. Yocky[#], Y. Cai, F-J. Decker, Y. Nosochkov, U. Wienands, SLAC, Menlo Park, CA 94025, USA; P. Raimondi, INFN/LNF, Frascati, Italy

Abstract

The PEP-II collider has benefited greatly from the correction of the chromatic functions. By optimizing sextupole family strengths, it is possible to correct the non-linear chromaticity, the chromatic beta, and the second order dispersion in both the LER and HER. Having implemented some of these corrections, luminosity was improved in PEP-II by almost 10%.

INTRODUCTION

Whilst investigating parameter space for potential luminosity gains and prospective difficulties in tune-space during PEP-II Run 5, the beta-function response to energy change was measured in both the HER and LER. Initially done as an investigation into large chromatic beta functions in the RF accelerating cavities in the straights as a source of strong synchro-betatron coupling, a method has been developed to address the global chromatic betatron functions as well as the interaction point bandwidth.

In order to measure the chromatic beta function, the SLAC Control Program (SCP) built-in phase-advance measurement package is used to measure the beta functions at several energies. The data then needs to be shipped to another computer for offline analysis in the Matlab programming environment.

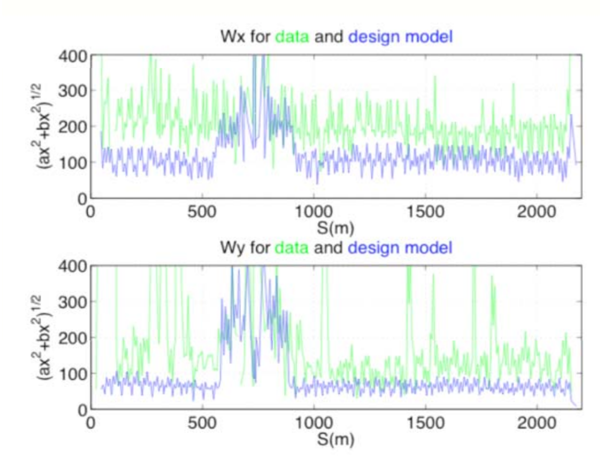

Figure 1: HER chromatic beta function in both the horizontal and the vertical planes for measured (green) and design (blue) lattices.

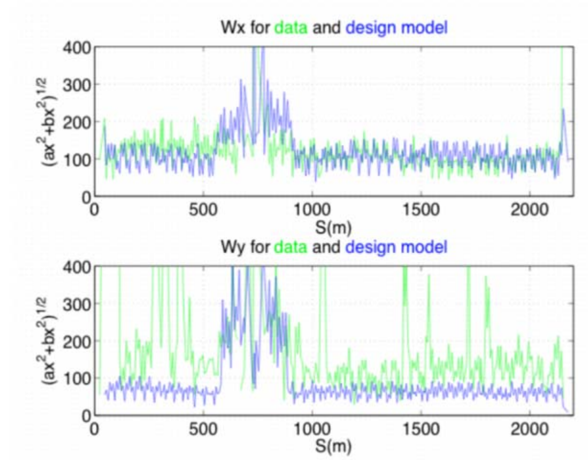

Figure 2: HER chromatic beta function in both the horizontal and the vertical planes for measured (green) and design (blue) lattices following correction.

CHROMATIC FUNCTIONS

Measurement of the W function

The chromatic beta function, or W function, can be calculated from the beta functions provided by the SCP phase advance package and the alphas which require some estimation. The W function is defined thusly:

$$W_x = \sqrt{a_x^2 + b_x^2} \text{ , where}$$

$$a_x = \frac{\frac{\delta\beta_x}{\beta_x}}{\frac{\delta p}{p}}, b_x = \frac{\delta\alpha_x}{\frac{\delta p}{p}} - \alpha_x * \frac{\frac{\delta\beta_x}{\beta_x}}{\frac{\delta p}{p}}$$

and similarly for the vertical plane. Since the SCP online packages do not provide for a direct measurement of alpha, the “pseudo-alpha” is calculated:

$$\alpha = -\frac{1}{2} * \frac{\beta_{n+1} - \beta_{n-1}}{Z_{n+1} - Z_{n-1}}$$

where Z is the location in meters and β is the beta function at the BPM.

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[#]yocky@slac.stanford.edu

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Measurement of non-linear dispersion

In addition to measuring the beta functions as a function of the ring energy, we took several measurements of the non-linear dispersion. That is, at several off-energy points, a BPM orbit is saved and the dispersion calculated not just about the nominal running point. The MAD modelling program does give an expectation for how the non-linear dispersion should behave, and tests were run, however no fixes have been implemented as of this writing.

CHROMATIC FIXES

Chromatic Beta Optimization

During the latter part of PEP-II run 5, the first measurements of the W functions were taken. What we saw was that the HER horizontal W function was highly un-optimized (Fig. 1). A hybrid MAD/Matlab program was developed to fix the chromatic response of the beta functions. Since the design lattice is used as a starting point for the optimization due to limitation of properly representing the PEP-II lattices in MAD, there is some uncertainty when implementing these solutions. However, given that only sextupoles are varied for the fixes, hysteresis problems are minimized.

In practice, this amounted to wisely choosing local sextupole families to vary that would both flatten globally the W function and locally narrow the IP bandwidth so that off energy particles would minimally affect the spot size. Constraints on the system, however, make this a non-trivial problem. The beta function and dispersion in the ring must not be disturbed and the tune vs. energy response must either be made less sensitive or untouched.

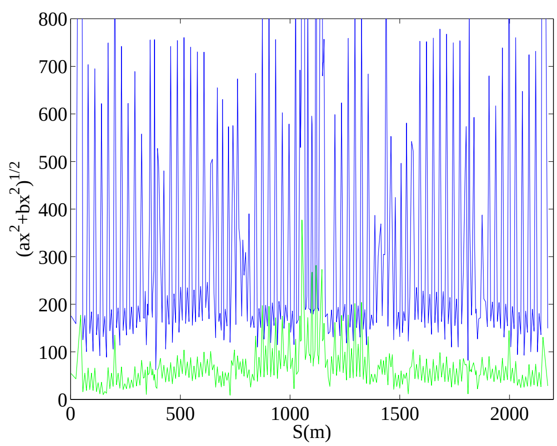

Figure 3: LER horizontal W function for the PSK lattice (blue) and optimized PSK lattice (green).

HER Fix

The first round of fix is seen in Figure 2. The HER horizontal W function has been corrected and the measurement of the lattice confirms this. After re-optimizing the machine via “typical” tuning (ie, operator tune adjustments, skew quadrupole tweaks, and closed orbit bumps in sextupoles), the luminosity was increased by a full 10%.

LER Fix

Following the success in the HER, the LER was tackled in a similar fashion. Given the nature of the LER lattice compared to the HER lattice, however, the solution was longer in coming.

LER PSK Lattice

In Run 6, a new LER lattice was implemented that introduced 12 new skew quadrupoles [1]. The initial measurement shows that the Wx was not addressed sufficiently in the initial design phase and required optimization (Fig 3). In fact, the initial chromatic response of the horizontal beta function was much worse than that of the original LER design lattice in use since commissioning.

By altering the four local horizontal sextupole families any where from 5% to a maximum of 10% (the sextupole power supplies allow for a 50% increase from the nominal design value), the horizontal W function becomes much better behaved (the green trace in Figure 3).

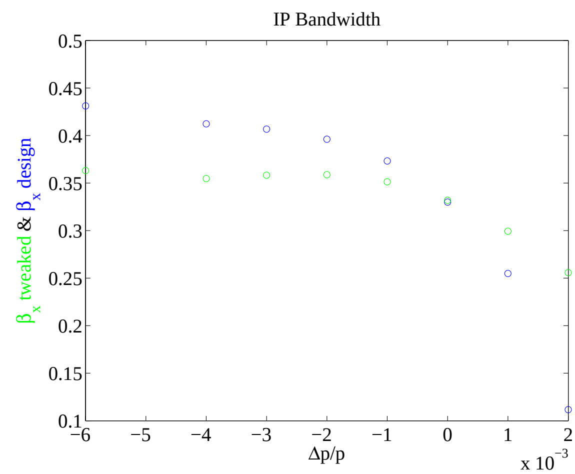

Figure 4: LER horizontal IP bandwidth.

As seen in Figure 4, the LER IP beta function variation with energy has been reduced significantly, as well. Before the fix, it can be seen that the IP beta becomes ill behaved with positive off-momentum particles. By reducing the IP bandwidth, less of the tune shift is “lost” to chromatic effects.

The horizontal chromaticity was increased by four units from the fix, thus allowing the global sextupoles to be lowered.

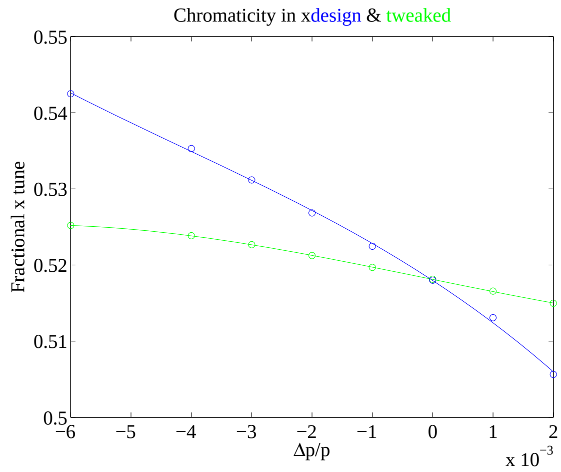

Figure 5: LER chromaticity for PSK lattice (blue) and chromatic-optimized PSK lattice (green).

While a vertical fix has not yet been calculated for the LER PSK lattice, the vertical response to the horizontal fix shows no ill results (Fig 6). In fact, the W functions around the ring have been reduced slightly and only a slight artefact at the interact point has been introduced—a Wy', as it were. Knobs built to specifically vary the W' at the IP have been tested in the machine and seem to show no effect on the luminosity.

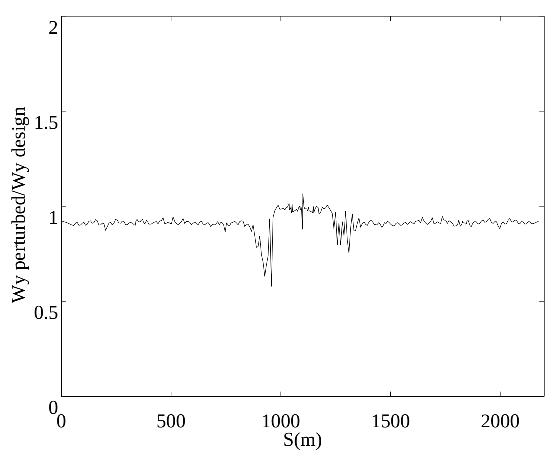

Figure 6: Ratio of perturbed vertical W function over design vertical W function for the LER horizontal W fix.

LIMITATIONS

In order for the W-function fixes to see any kind of significant effect in the machine, the first-order optics need to be squared away. A large beta beat will look like a large W function mismatch, for example. For this reason, the chromatic optics fixes come very late in the running of the collider, unfortunately. After the first-order optics are taken care of, however, significant luminosity improvements can be made with little machine time.

SUMMARY

PEP-II has benefited directly in the form of luminosity increases from the time taken both on the machine for acquisition and offline in the analysis of the data in improved luminosity. The measurement required to calculate the W functions in both the LER and HER takes less than 20 minutes of machine time and the solutions can be dialled in whilst the machine is in production luminosity delivery mode.

The MAD modelling program does have it's limitations in representing the PEP-II lattices as they're operated sufficiently, but the last three rounds of chromatic beta fixes derived from MAD have produced significant luminosity gains.

REFERENCES

[1] F-J Decker, et al., "Lowering the Vertical Emittance in the LER of PEP-II," PAC'07, Albuquerque, June 2007.