TRANSVERSE OPTICS IMPROVEMENTS FOR RHIC RUN-4*

J. van Zeijts, Collider-Accelerator Department, BNL, Upton, USA

Abstract

The magnetic settings in RHIC are driven by an on-line model, and the quality of the resulting lattice functions depend on the correctness of the settings, and knowledge of the magnet transfer-functions. Here we first present the different inputs into the model, including dipole sextupole components, used to set tunes and chromaticities along the ramp. Based on an analysis of measured tunes along the FY03 polarized proton ramp, we present predictions for quadrupole transfer-function changes which have been implemented for the FY04 Au ramp. We show the improved model agreement for tunes along the ramp, and measured transverse phase-advance at store.

RAMP DESIGN

The RHIC can accelerate species from protons to gold in the two rings (blue and yellow), with optionally different species in each ring. Operating experience includes Au/Au, polarized protons, and deuteron/Au. Constraints include common bending magnets (DX), which introduce crossing angles for unequal species, power-supply limits, and ramp rates, and the nested power-supply scheme (Figure 1).

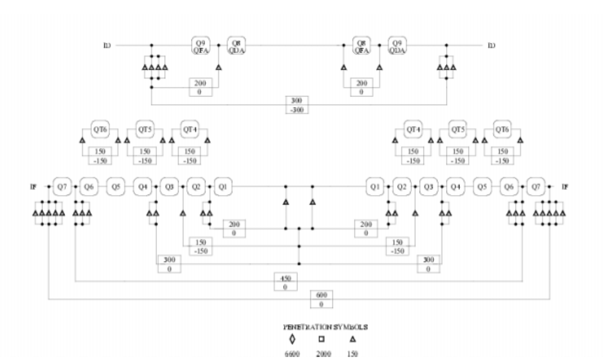

Figure 1: Typical power-supply wire-up for an interaction region in RHIC. Q 4/5/6 magnets have the same current, but not the same strength due to TF differences.

Ramp Construction: The ramp is constructed by defining the magnetic rigidity Bρ for each ring, and the β^* for each interaction-point (IP) as a function of time. Each definition consists of a series of cubic segments with matching first or higher order derivatives. The β^*-squeezing is typically performed during the acceleration part of the ramp to retain, as much as possible, the validity of the measured transfer-functions. Injection is at β^* = 10 m and transition optics is set at β^* = 5 m to achieve the optimal value for momentum compaction during the jump. Limits on insertion power-supply ramp rates further constrain the rate of change of β^*. Figures 2 and 3 show the design configuration for the FY04 Au/Au ramp.

On the ramp, the magnet strengths K are defined at a number of ‘Stepstones’, with spline interpolation in between. To allow control of the slope of the tune and chromaticity we can set the dK/dt for the main-quads, and sextupole circuits at the stones.

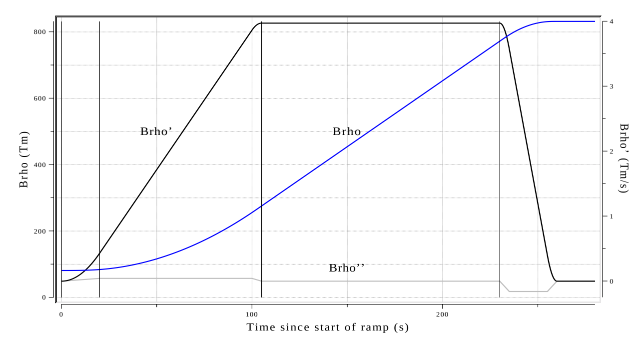

Figure 2: Design $B\rho(t)$ and time derivatives since start of ramp for the Au-Au run. The start of the ramp is slowed down to minimize the effects of power-supply tracking errors.

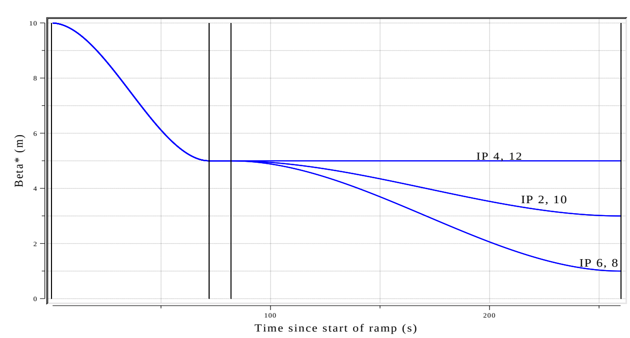

Figure 3: Design β^* per IP vs. time since start of ramp for the Au-Au run.

RAMP OPTICS MODELING

The original MAD calculated magnet strengths are first adjusted to reflect the wire-up constraints. Average transfer-functions are used in calculating currents for all sets of magnets which are logically controlled by a power-supply. In the on-line model the optics is recalculated from power-supply currents using individual magnets transfer-functions. The mismatch of the injection design optics is

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shown in figure 9. There is a strong sextupole component in the dipoles at injection, and for part of the ramp (Figure 4), which, since the main-dipole magnets have been intentionally installed 1.3 mm off-center, have a feed-down effect on the tunes.

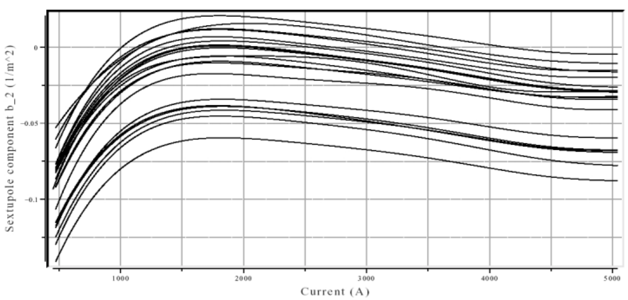

Figure 4: b_2 (sextupole) component vs. dipole current for dipoles in the Blue ring. Most dipoles only have warm measurements available, these are extrapolated using an average warm-cold ratio.

Design and trim models

After the tunes and chromaticity are adjusted to design values the design magnet strengths are loaded into the machine, where we allow the main quadrupole busses to be modified to adjust the measured tunes to the design tunes. The resulting magnet currents are fed back to a 'trim' model, whose deviation wrt. the design model is a metric of our understanding of the machine optics. Figure 5 shows the trim tunes before, and after dipole-b2 feed-down correction.

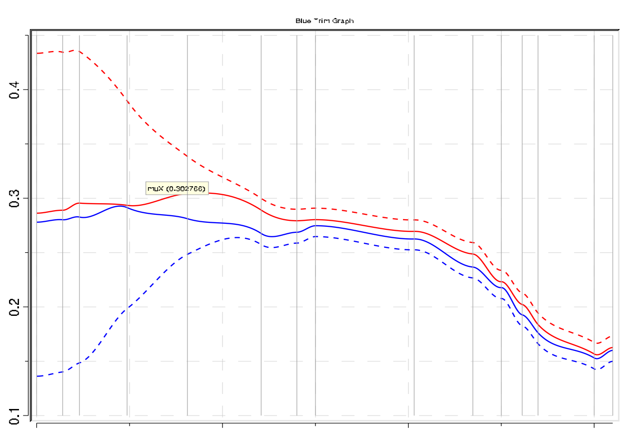

Figure 5: Modeled horizontal (red), and vertical (blue) tune vs. time since start of ramp for the FY03 p-p run. With (solid), and without dipole sextupole feed-down (dashed).

TRANSFER FUNCTION CORRECTIONS

For FY03 the main feature of the trim tune was the large negative swing during the β^*-squeeze (Figure 6). During analysis it was realized this could be explained by assuming a systematic error between 8 and 13cm. measuring coils, which was recently confirmed by cross-calibration measurements[4]. We show the improvement between

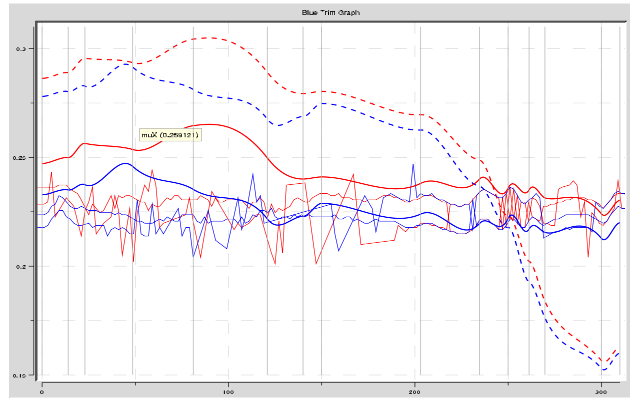

Figure 6: Measured and modeled tune vs. time since start of ramp without (dashed lines), and with corrected transfer-functions (solid lines) since start of ramp for the FY03 p/p run.

measured and trim tunes for the FY04 Au/Au ramps in Figure 7, and for the p/p ramps in Figure 8.

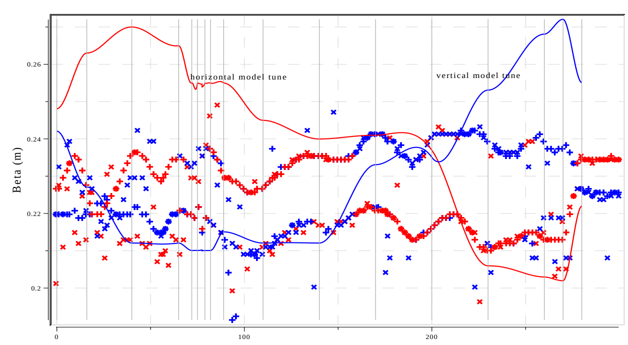

Figure 7: Modeled and measured tune vs. time since start of ramp for the FY04 Au/Au ramp, with -0.28% TF changes for Q 1/2/3, and +0.26% for all other quads.

Lattice function verification

Here we refer to some measurements which confirm the corresponding improvements in lattice functions.

AC Dipole measurements: Measurements of the transverse optics at different working points were performed [5], and show good agreement of model vs. measured beta functions, across a large range of tunes.

β^* **perturbation:** During a beam-experiment β^* functions were decreased by linearly perturbing the existing optics [6], the results showed excellent agreement with the model. Decreasing the β^* functions for production stores

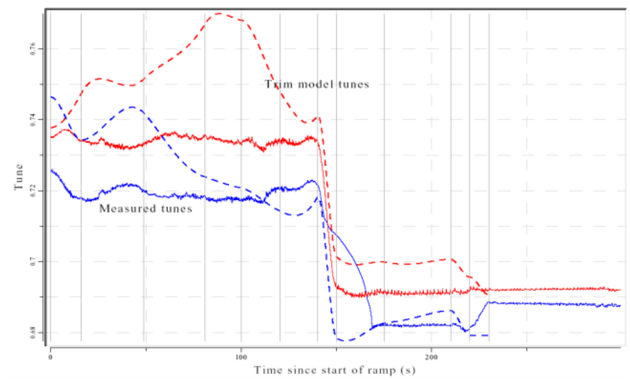

Figure 8: Modeled (dashed) and measured tune vs. time since start of ramp for the FY04 p/p ramp. The tune swing down, during which the PLL tune tracking was not perfect, was implemented to optimize spin lifetime.

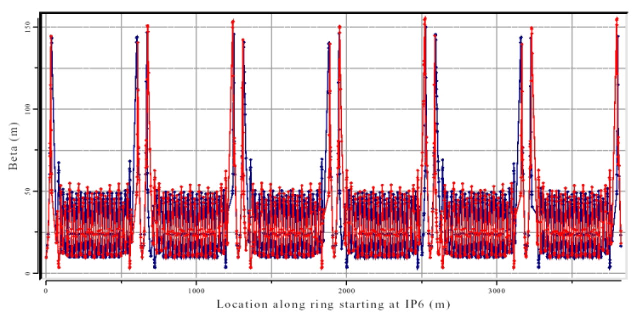

Figure 9: Blue injection model beta functions.

will require non-linear fitting to minimize dispersion effects, and constrain power-supply currents.

CONCLUSIONS AND PLANS FOR FY05

The improved model led directly to more efficient operations, by allowing simultaneous steering of all IR's without cross-talk. We also enabled rapid machine state changes to lower energies, and drastic changes in tune working point. Issues to be addressed include the agreement for chromaticity, and modeling of linear coupling taking into account quad/dipole rotations, skew-quadrupoles, and the effect of experimental magnets. Fitting using the on-line model will

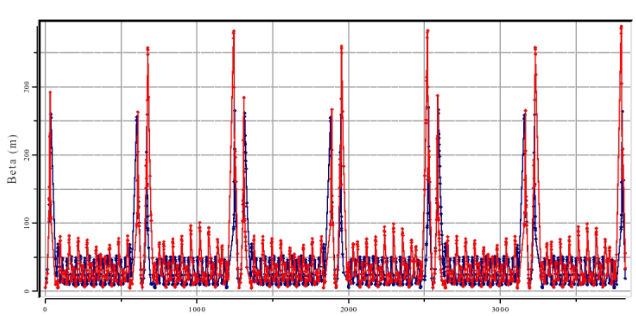

Figure 10: Blue model beta functions before transition.

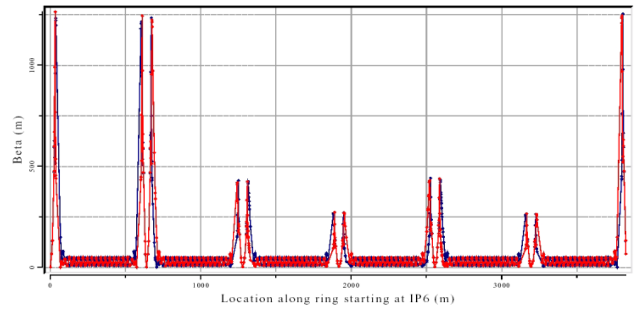

Figure 11: Blue store model beta functions.

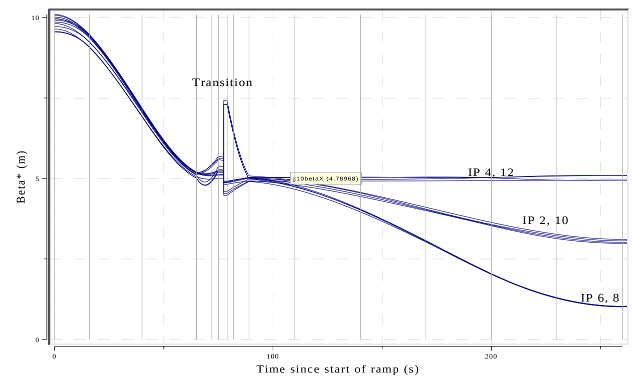

Figure 12: Modeled β^* per IP vs. time since start of ramp for the FY04 Au-Au run

also be implemented for FY05.

ACKNOWLEDGEMENTS

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