BNL-99206-2013-TECH
C-A/AP/53;BNL-99206-2013-IR

RHIC Optics for Transition Jump

J. Kewisch

May 2001

Collider Accelerator Department
Brookhaven National Laboratory

U.S. Department of Energy
USDOE Office of Science (SC)

DISCLAIMER

C-A/AP/53
May 2001

RHIC Optics for Transition Jump

J. Kewisch, C. Tang

Collider-Accelerator Department
Brookhaven National Laboratory
Upton, NY 11973

May 14, 2001

RHIC Optics for Transition Jump

Jörg Kewisch, Cunmei Tang

1 Introduction

RHIC has 8 quadrupoles per arc for transition jumping. They are arranged in 3 groups as shown in Fig. 1 One group with 4 quadrupoles (called gt-quadrupoles) is located in the middle of the arc where they change the dispersion function, the two other groups (called qt-quadrupoles) are used to keep the tunes constant.

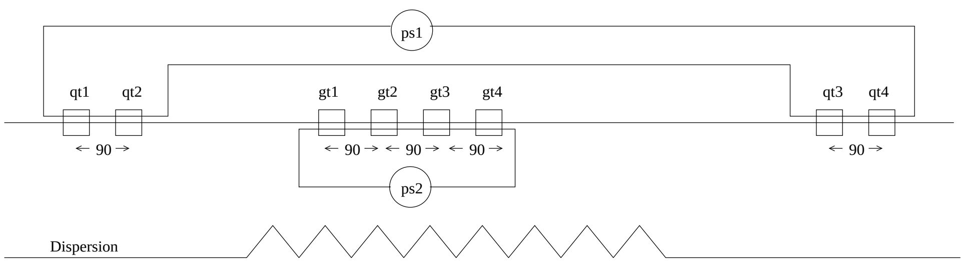

Figure 1: Arrangement of quadrupoles for transition jump

In the ideal case the beta function in each quadrupole is the same, the dispersion function in the gt-quadrupoles is the same and the dispersion in the qt-quadrupoles is zero. The quadrupoles in each group have a phase advance of 90 degrees in both horizontal and vertical direction.

In this configuration the quadrupoles pairs gt1-gt3 and gt2-gt4 build two 180 degree dispersion bumps. The tunes are unchanged if the qt quadrupoles are powered with the opposite current. Finally, the beta functions are not changed outside the quadrupole groups since the beta beat is driven with twice the phase advance so that adjacent quadrupoles cancel each other.

Unfortunately, the RHIC optics is less than ideal. Most important, the phase advance between quadrupoles is only 75 degrees. This causes a significant beta beat and therefore a significant quadratic component in the tune vs. quadrupole strength function. The effect of this mismatch is investigated in this report.

2 Magnet families

Since the beta function in the qt-quadrupoles is not exactly the same as the beta function in the gt quadrupoles two magnet families are necessary to minimize the horizontal tune change. The vertical tune change is neglectable since the vertical beta function in these quuadrupoles is small. There are two power supplies per arc. The current I_{qt} in the qt quadrupole family is between 80% and 90% of the gt quadrupole family current I_{gt}. The power supplies must supply ± 35 Ampere for a $\Delta\gamma$ of ± 0.5.

The original plan called for one power supply feeding the gt-quadrupoles and one of the qt-quadrupole groups. The second power supply feeds the remaining two qt power supplies. This arrangement minimizes the cable length.

However, it has become clear that the tracking of the two currents during the jump is important.

The tune change caused by the qt quadrupoles is 0.01 per ampere. The set point for the qt quadrupoles is a function of the I_{gt} current. The power supply must follow this set point at all times during the jump, so that the tune does not move into the bordering resonances.

This tracking can be accomplished much easier if the load (inductance and resistance) for both power supplies is the same. The quadrupoles will therefore be wired as shown in Fig. 1. The four gt quadrupoles are feed by one power supply and the qt quadrupoles by the other power supply.

3 Tune variation during the jump

Fig. 2 shows the difference of the strength of the two quadrupole families if the tunes are compensated. The strength of the gt quadrupoles is used as x axis. In the ideal case the function should be a straight line. As mentioned above, the quadratic term comes from the phase mismatch and the resulting beta beat around the machine.

The power supplies cannot follow that function. The change in the current is essentially linear during the jump. Also shown in the figure are therefore the two fitted straight lines: the "fit 1" line is the best fit for the whole range ($\Delta\gamma = \pm 0.75$), "fit 2" is for the range $\Delta\gamma = \pm 0.5$.

This straight lines do not go through the (0,0) point. In order to realize such current function it is necessary to vary the timing and the duration of the jump for the qt power supplies.

The expected tune shift is proportional to the difference between the two curves. Fig. 3 shows the tunes for the two fits. The parabolas are the horizontal tunes for fit 1 and fit 2. The straight lines are the vertical tunes. The dashed horizontal lines enclose the tune shift for a $\Delta\gamma$ of ± 0.5.

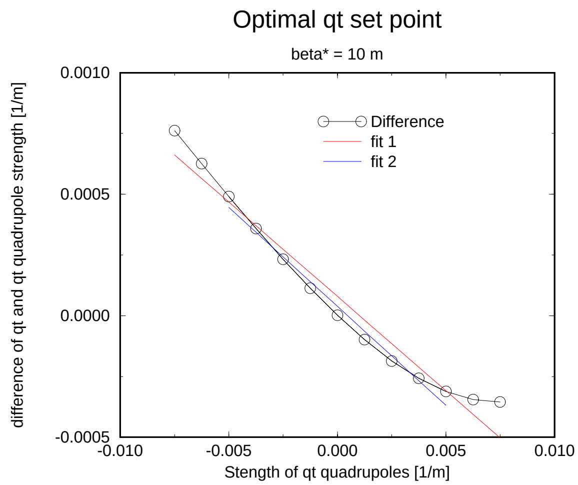

Figure 2: Required difference in quadrupole strength for optimal tune compensation for beta* = 10 m

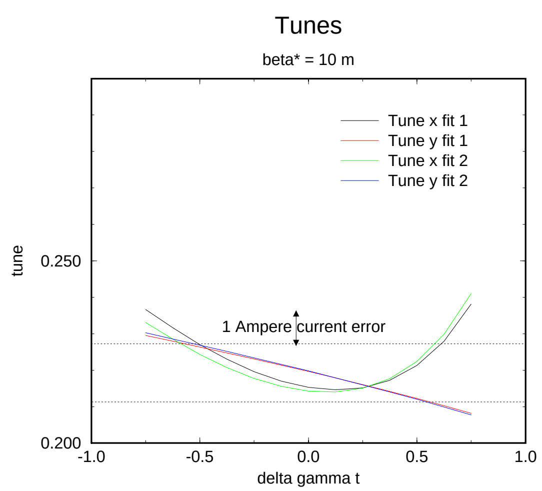

Figure 3: Tunes during the jump for beta* = 10 m

4 Selection of RHIC optics

There are several different optics sets for RHIC. All of them have nearly identical arcs but differ in the interaction regions to produce different beta functions in the interaction points (beta*). The optics are characterized by this beta*.

The original design of RHIC calls for an injection and energy ramp at a beta* of 10 m, followed by a "beta squeeze" at top energy.

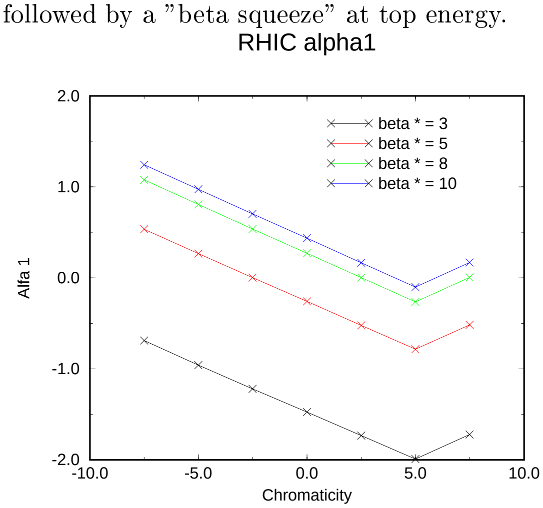

Figure 4: Alpha 1 parameter for different beta* vs. chromaticity

It was discussed to perform the whole ramp with an optics that has a beta* of 3 m instead of 10 m. The advantage is that many power supplies will not be used for this ramp. Also, the alpha1 parameter is -1.5 for beta* = 3 m and theory predicts that this value is favorable for the transition jump. Fig. 4 shows the alpha1 parameter as a function of chromaticity (equal in horizontal and vertical direction) for different beta* parameters.

The disadvantage is a larger maximum beta function which amplifies the nonlinear tune dependence. Fig 5 shows the strength difference and fig. 6 shows the tune variation for beta* of 3 m. The variation in tune leaves no margin for currents and field errors. A transition jump at beta* = 3 m will most likely result in substantial beam loss.

Fig. 7 and 8 show the tune variation for beta* of 8 m and 5 m, respectively. It shows that both optics have less tune variation than the 3 m and 10 m optics. It was therefore investigated if an optics in this range is feasible for the transition jump.

Using the computer code TIBETAN [[1]] the particle loss through transition was calculated for different alpha1. With a jump time of 40 msec no loss was observed for any alpha1. The losses were then calculated for a jump time of 200

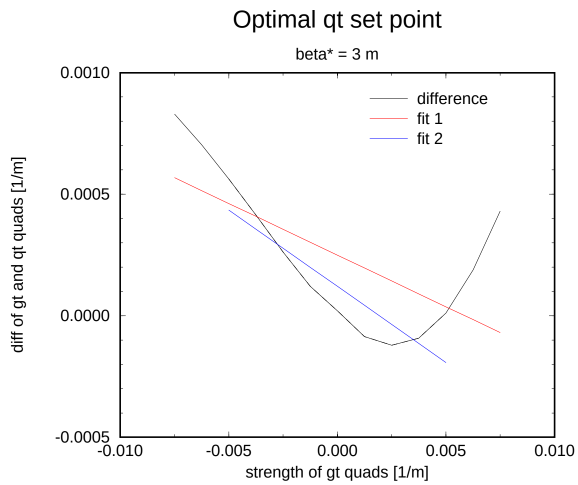

Figure 5: Required difference in quadrupole strength for optimal tune compensation for beta* = 3 m

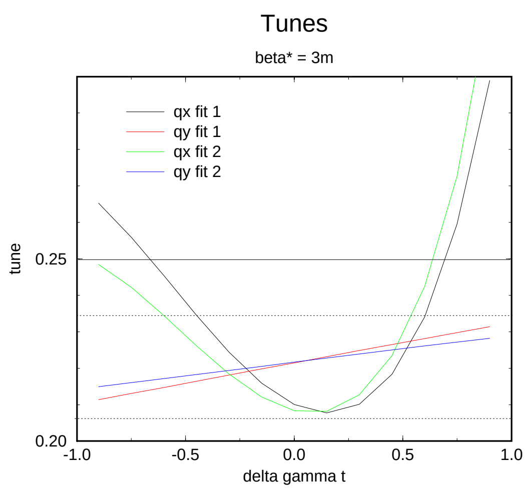

Figure 6: Tunes during the jump for beta* = 3 m

Beta*	Alpha 1	Loss t=40msec	Loss t=200msec
10 m	1.5	0 %	10 %
8 m	0.5	0 %	2 %
5 m	0.0	0 %	0 %
3 m	-1.5	0 %	0 %

Table 1: Beam loss during transition as a function of alpha1.

msec. The results are given in table 1.

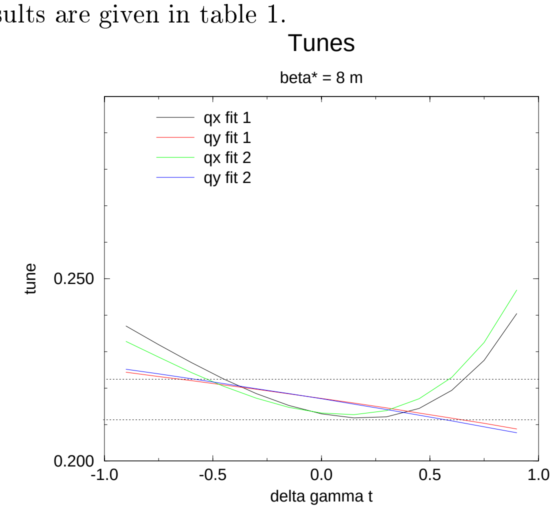

Figure 7: Tunes during the jump for beta* = 8 m

5 Conclusion

The beta* = 3 m optics have a large tune variation during the jump and do not allow for additional errors of the power supplies currents nor magnet field transfer functions. Therefore, a different optics must be used. It is necessary that all interaction region power supplies are operational.

The beta* = 5m optics fulfills both the requirement for small tune variation and small beam loss caused by the alpha1 parameter. With this optics systematic power supply current errors of up to 2 ampere can be tolerated.

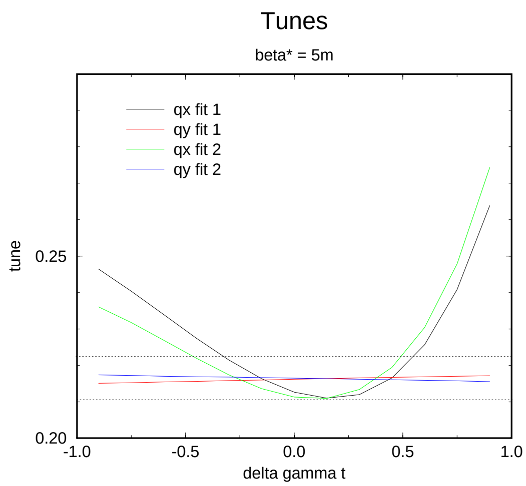

Figure 8: Tunes during the jump for beta* = 5 m

It is proposed that the beta squeeze is performed of the fly, i.e. injection at beta*=10m, squeeze down to 5 m while accelerating to the transition energy and squeeze to the final beta* while accelerating to the top energy. The advantage of such squeezing on the fly is that all magnet currents (with exception of the tq quadrupoles) increase during the ramp. A separate beta squeeze ramp at top energy would require to lower some of the magnet currents and invite problems with the magnet hysteresis.

References

[1] Jie Wei, "Longitudinal Dynamics of the Non-Adiabatic Regime on Alternating-Gradient Synchrotrons", PhD dissertation, State University of New York at Stony Brook, 1990.