DYNAMICAL BETA-SQUEEZE FROM 80 TO 40 CM AT RHIC*

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Abstract

Relativistic Heavy Ion Collider (RHIC) has been achieving record luminosities during the last decade. The latest stochastic cooling of the heavy ions, like uranium, achieved the largest luminosity at RHIC during the last heavy ion run. A betatron squeeze method, already used at LHC CERN, where a betatron wave is created through the arc up to the interaction region is applied at RHIC. When the heavy beam size is reduced due to stochastic cooling a dynamical beta squeeze is possible to apply in RHIC where the existing 75 cm value of beta-star could be reduced to 45 cm. This could be achieved by introducing the betatron wave in both planes throughout the arc before and after the interaction region. Higher values of dispersion and betatron functions in the arc, with a 90° degrees phase difference per FODO cell allow easier higher order chromatic corrections.

INTRODUCTION

The RHIC stunning discoveries in quark-gluon plasma in recent years went above any expectations that have captured worldwide attention. First and foremost was the unexpected "perfect"-liquid nature of the 4-trillion-degree quark-gluon plasma that permeated the early universe. RHIC is now closing in on the transition from this hot quark-gluon plasma into ordinary matter made of protons and neutrons—namely everything we see in today's world. This is a report on an attempt to improve on the RHIC existing large luminosity by dynamically squeezing the beam size as the stochastic cooling succeeds in reducing all three emittances. The stochastic cooling has already shown tremendous success during the previous RHIC runs. Under this assumption an additional step might be possible in an attempt to increase further the luminosity by additional beta squeeze at the interaction point (IP). This would be possible as the emittances are reduced and the triplet aperture would not present the aperture limitation anymore – as the beam is getting smaller at the IP the maximum of the betatron functions become larger at the focusing triplet quadrupoles. A complex of the RHIC accelerators used to make the latest achievements is shown in Figure 1.

RHIC 90° Lattice

Advantages of the 90° degrees per cell lattice have been well known [1]. The LHC chromatic and other non-linear compensations [2] were followed for the RHIC lattice chromatic corrections after encouraging results in the eRHIC lattice design.

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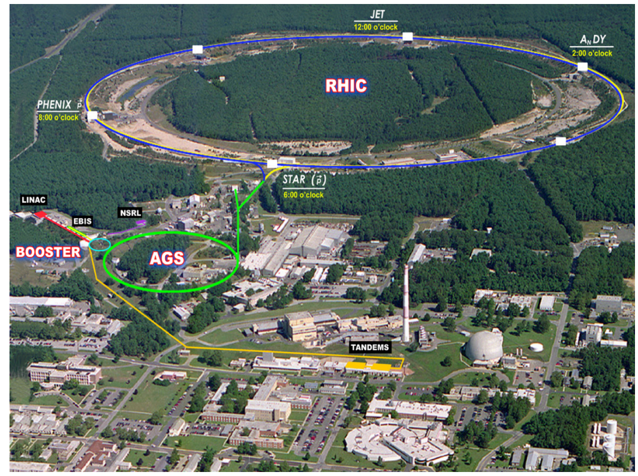

Figure 1: The RHIC accelerator complex shows the major components Linac, Booster, Alternating Gradient Synchrotron (AGS), and RHIC. The Electron Beam Ion Source EBIS is an additional important element.

Major advantage of the 90° lattice is not only reduction in the intra-beam scattering effect but easier linear and non-linear chromatic correction as there are 24 sextupole circuits available in RHIC. The sextupole correction has already shown very impressive results in dynamical aperture improvements during the eRHIC lattice study. The betatron functions of the 90° RHIC lattice with β^*=75 cm is shown in Figure 2.

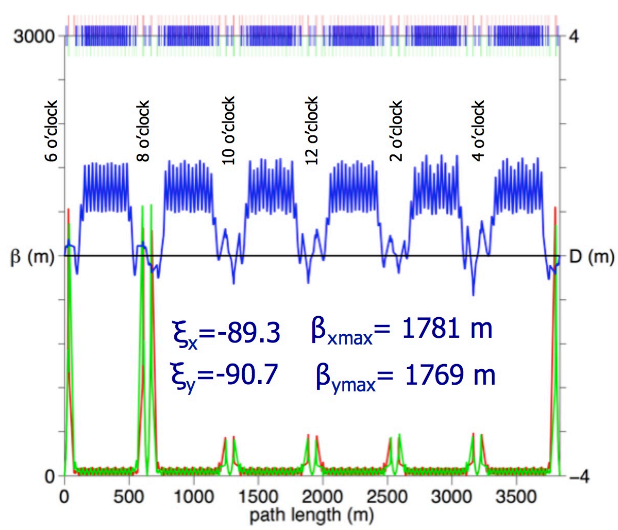

Figure 2: Betatron functions of the RHIC 90° degrees lattice with the β^*=80 cm. Two interaction regions at 6 and 8 o'clock have the same beam size.

Details of the lattice functions around one of interaction regions are shown in Figure 3. The maximum of the dispersion function is D_{max}=1.78 m. The lattice parameters in both cases with the β^*=75 cm and β^*=45 cm are shown in Table 1.

Table 1. Betatron Functions for β^*=75 and 45 cm

β^*(cm)	β_{xmax}(m)	β_{ymax}(m)	ξ_x	ξ_y	D_{xmax}	D_{xmin}
75	1781	1769	-89	-91	1.76	-0.6
40	2985	3317	-108	-119	2.52	-2.6

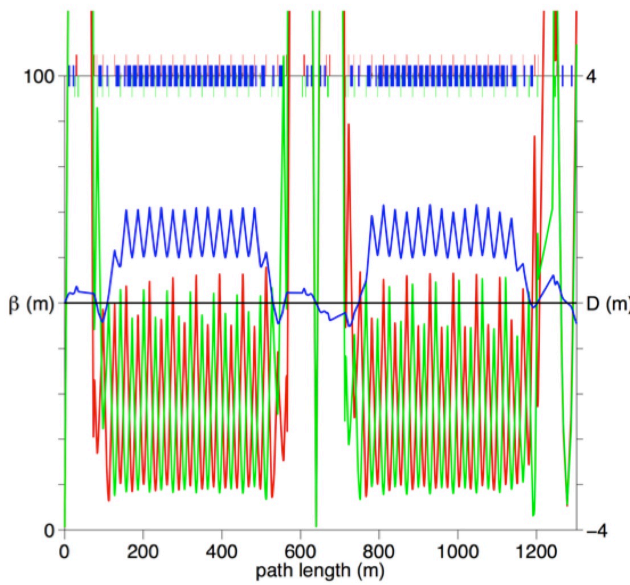

Figure 3: Details of the betatron functions around the IP for the β^*=75 cm.

The RHIC 24 sextupole circuits are shown in Figure 4.

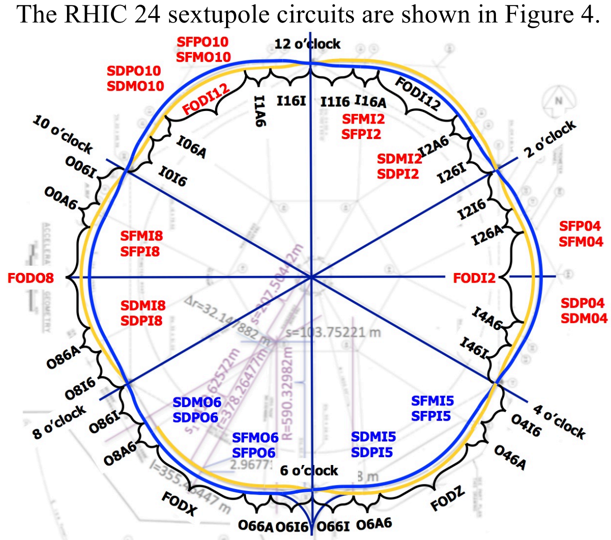

Figure 4: RHIC 24-sextupole circuits schematic.

Two pairs of quadrupoles are used around on each side of the interaction point IP-6 to induce the betatron wave through the IP6. At the end of the arc after the IP-6 there are two additional pairs in both horizontal and vertical plane used to cancel the wave, placed at correct betatron phase. A schematic presentation of the quadrupole pairs used in beta squeeze is shown in Figure 5. The quadrupoles in the pair are 90° degrees apart. The first quadrupole of the pair has a decrease in the gradient of ΔG=-7% while the second one has an increase of ΔG=+7%. The opposite is valid for the other plane at the beginning of the arc before the IP.

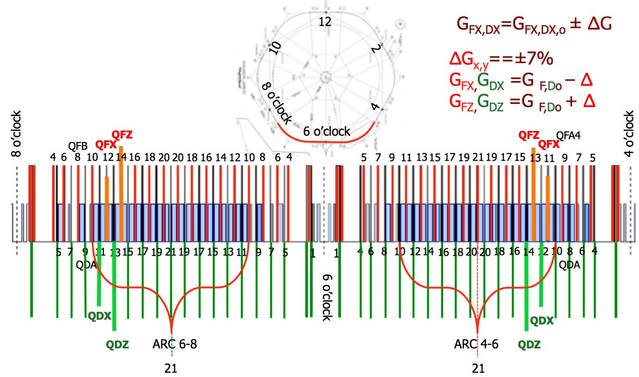

Figure 5: The quadrupole pairs to induce the beta wave are labeled QFX and QFZ, and QDX and QDZ at the beginning and end of the arcs.

The betatron functions in RHIC after introduction of the beta wave and beta squeeze is shown in Figure 6.

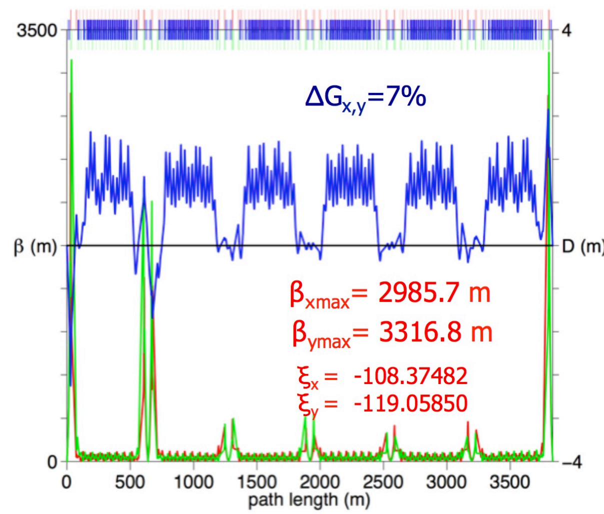

Figure 6: Betatron functions after the betatron wave is created through the IP 6.

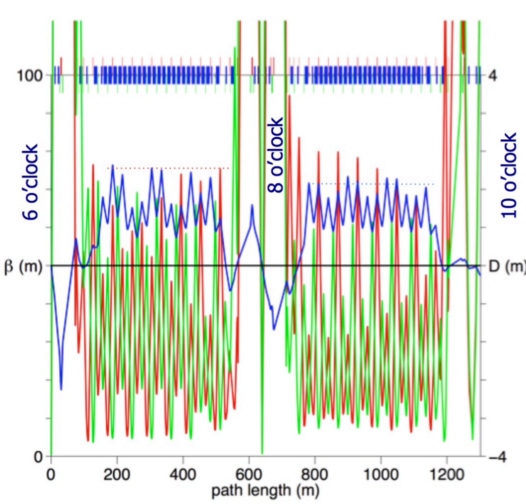

Figure 7: Details of the beta squeeze.

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Details of the beta squeeze from β^*=75 cm to β^*= 45 cm in two arcs around the IP-6 are shown in Figure 7.

SUMMARY

The stochastic cooling in RHIC has showed incredible success getting to the point that almost all beam loss comes from collisions with other beam. As the cooling reduces emittances in all three dimensions it would be possible to gain more in luminosity by dynamically squeezing the size at the collisions as the beam gets cooled, as the maximum of the betatron functions at the triplets are not a limitation any more. This is a study with the lattice design trying to double the luminosity. The LHC [2] method was followed. A betatron wave through the interaction point IP-6 succeeded in reducing the β^* from β^*= 75 cm to β^*= 45 cm with the beta wave creation through the two neighboring arcs. The larger betatron functions and dispersion in the arcs will allow easier chromatic correction as the correction is given by $\sim K_2\,\beta\,D_x$. The dynamical aperture study in this case is in progress.

REFERENCES

[1] B. Autin, NIM, A 298 (1990) 85.
[2] S. Fartoukh, LHC Project Report 278, CERN.