

FOCUSING AND MATCHING PROPERTIES OF THE ATR TRANSFER LINE*

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Abstract

The AGS to RHIC (AtR) beam transfer line[1] has been constructed and will be used to transfer beam bunches from the AGS machine into the RHIC machine which is presently under construction at BNL. The original design of the AtR line[1] has been modified. This article will present the optics of the various sections of the existing AtR beam line, as well as the matching capabilities of the AtR line to the RHIC machine.

1 THE ATR LINE

The AtR beam transfer line, has been constructed and commissioned[2],[3],[4],[5] by extracting ^{+77}Au beam bunches of momentum 11.2 GeV/c per nucleon, injected from the AGS machine. A schematic layout of the accelerator complex at BNL is shown in Fig. 1. A more detailed diagram of the AtR line is shown in Fig. 2. The AtR line is purposely partitioned into four main sections: U-line, W-line, X- and Y-lines, and the injection sections, one following the X-line and the other the Y-line. This partition facilitates the optical design of the AtR, because each section can be studied independently. A description and the beam optics of each section of the AtR will be discussed next.

1.1 The U-line

The U-line is the first section of the AtR beam line (Fig. 2) which starts at the AGS Fast Extraction Beam (FEB) point[6] H13 and terminates at the entrance of the first magnetic element of the W-line. The U-line has two right bends, one 4.25° made of two A-type dipole magnets[7] modified from a 29 mm gap to 39.6 mm gap, and the other 8° of four C-type combined function magnets[7] (placed in a FDDF arrangement), and thirteen quadrupoles. The U-line has the following functions:

- Match the Twiss parameters at the AGS extraction point[6] H13 (Fig.1) and create an achromatic beam ($\eta_x=0, \eta'_x=0$) at the exit of the 8° bend
- Create a beam waist with low beta function values at the location of a thin gold foil which is placed just upstream of the quadrupole Q6 of the U-line. The gold foil, strips[8] the two K-shell electrons from the ^{+77}Au ions, and other heavier ions.
- Match the Twiss parameters of the line to the ones at the origin of the W-line

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- Maintain a reasonable upper limit of the beta functions along the line, so that beam with 95% normalized emittance $\pi\epsilon = 20\pi \text{ (mm.mrad)}$ will not extend more than half of the available beam tube radius

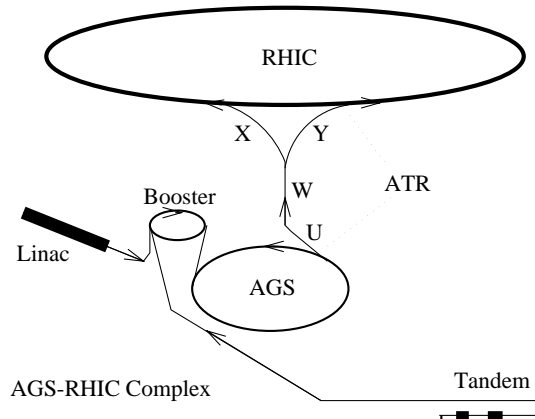


Fig. 1. Layout of the AGS-RHIC complex with the AtR transfer line.

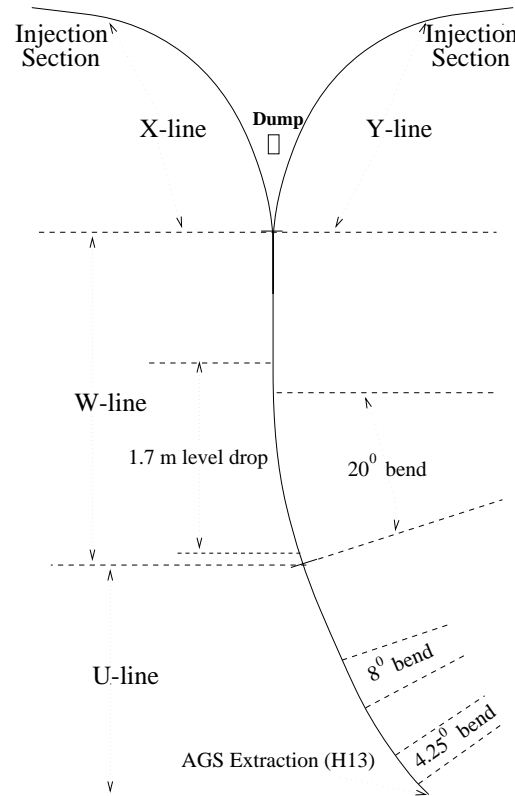


Fig. 2. Layout of the AtR transfer line with the U,W,X,Y lines and Injection sections.

Although the AGS Twiss parameters at the extraction point H13 depend on the extraction conditions[6], the AtR

line has the capability to satisfy all constraints mentioned above, over the range that these parameters may vary. The $\beta_x, \beta_y, \eta_x, \eta_y$ functions of the U-line are shown in Fig. 3.

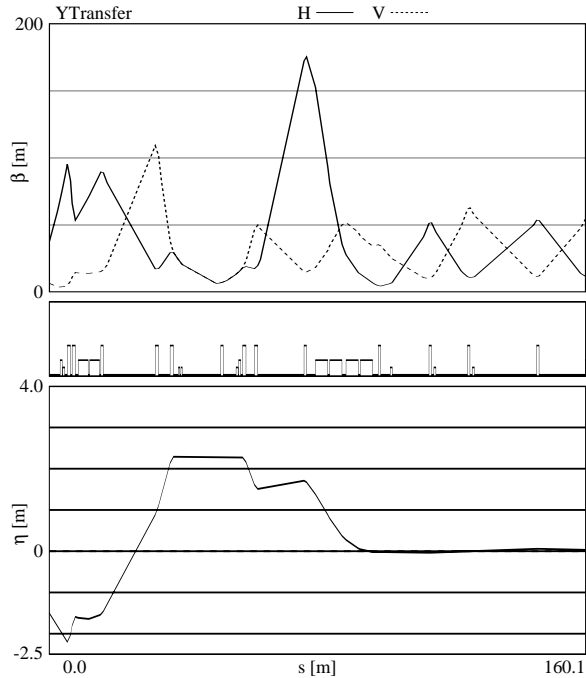


Fig. 3. Beta functions (β_x, β_y), and eta functions (η_x, η_y) of U-line.

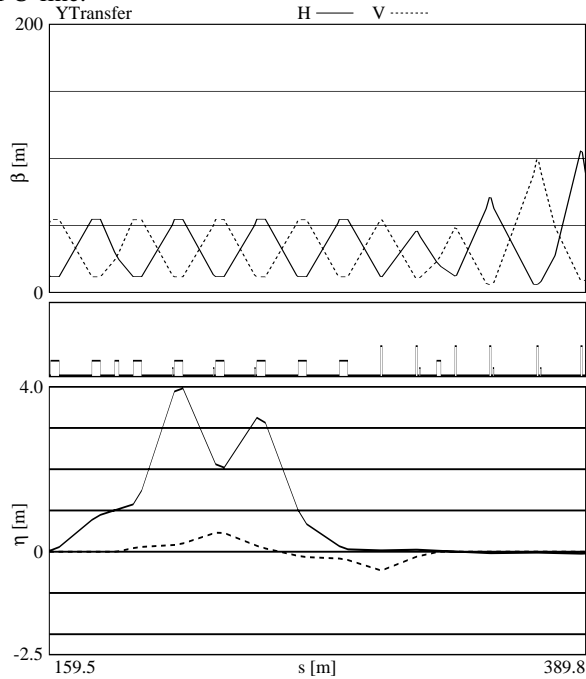


Fig. 4. Beta functions (β_x, β_y), and eta functions (η_x, η_y) of W-line.

1.2 The W-line

The W-line (Fig. 2) consists of eight C-type combined function magnets[7], of 2.5° bend each, followed by six quadrupoles. The eight combined function magnets forming a 20° achromatic horizontal bend are placed in a (F-D)

arrangement to make four cells of 90° phase advance per cell. Part of the W-line lies in an incline of 12.51 mrad which lowers the beam elevation by 1.73 m. This level drop is accomplished by two vertical dipole pitching magnets. One, which bends the beam down, is located between the first and second combined function dipoles of the W-line, and the second, which restores the beam to the horizontal level (bend-up), is located between the second and third quadrupoles of the W-line. The beam section between the two pitching magnets is designed to be non-dispersive in the vertical direction, introducing linear beam-coupling which is not significant as far as the first-order beam transport optics are concerned. However, this simultaneous vertical and horizontal bend of the beam turns out to be a concern when polarized protons are to be transported by the AtR[9]. Finally, the quadrupoles of the W-line are tuned to match the Twiss parameters to the those of the X-line and Y-line, discussed next. The optical functions of the W-line are shown in Fig. 4.

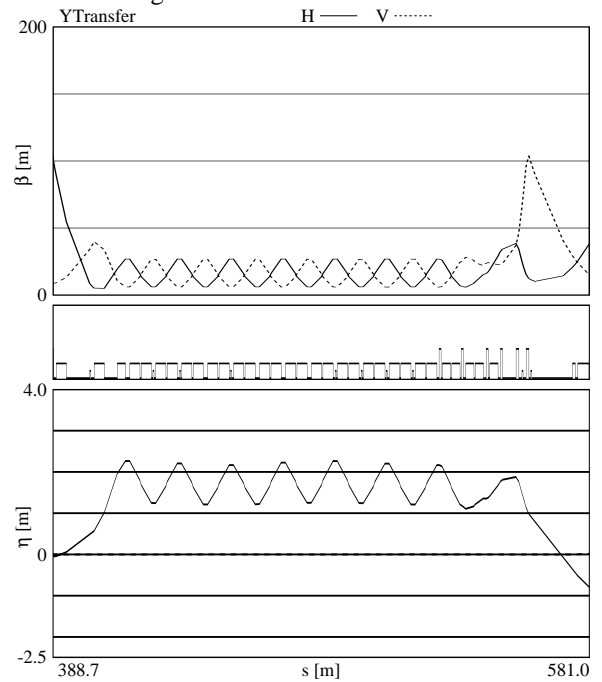


Fig. 5. Beta functions (β_x, β_y), and eta functions (η_x, η_y) of Y-line.

1.3 The X- and Y-lines

At the end of the W-line the AtR line branches into two separate lines, the X-line and the Y-line which transport the beam to the injection point of the Blue (clockwise circulating beam) and Yellow (clockwise circulating beam) ring respectively. The layout of the magnets of the X-line is identical to that of the Y-line apart from the bending direction of the beam due to the dipoles of each line. The first magnet, common to both lines, is a switching magnet which directs the beam to the X or Y line. This is followed by an array of twenty six B-type combined function magnets[7] providing a total beam-bending angle of 74° . All of the combined function magnets are identical in cross-section and length

except, the second magnet, which is shorter. The next 24 magnets are arranged in a regular lattice of six cells. Each cell has four magnets (FFDD) with 90° phase advance per cell. The last part of the (X,Y) line is the Injection section which is discussed next. The optical functions of the line are shown in Fig. 5.

2 THE INJECTION SECTION AND MATCHING WITH RHIC

This section of the AtR at the end of the (X,Y)-lines consists of four short C-type combined function magnets[7], a single A-type dipole magnet[7] six quadrupoles, a vertical pitching magnet of 3 mrad bend, followed by a Lambertson septum magnet[10] of 38 mrad horizontal bend. The total beam-bend of the dipoles is 13.5° . The main function of the injection section is to match the beam parameters of the injected beam to the those of the RHIC lattice, which depend on the cell phase advance. Although the original design value of the phase advance per cell for the RHIC machine is 89.3° , a different phase advance per cell may be required when the value of β^* at injection is different from that of the design. For this reason, a study of the matching ability of the injection section, was made over a range of RHIC Twiss parameters corresponding to different phase advances per cell. It was found that, within the range of the strength of the last six quadrupoles, the AtR Twiss parameters can match those of the RHIC lattice from 70° to 130° phase advance per cell. Figure 6 shows the optical functions of the Injection line and part of the RHIC lattice when the phase advance per cell is 100° . Beam emittance growth due to optical mismatch of the AtR line with RHIC has already been simulated[11].

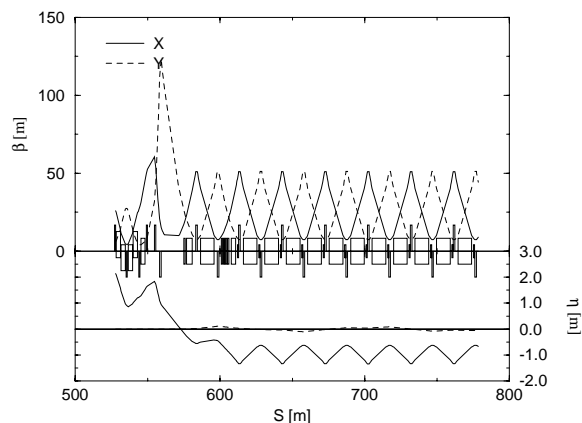


Fig. 6. Beta functions (β_x , β_y), and eta functions (η_x , η_y) of Injection-line and a section of RHIC. The phase advance per cell in RHIC is 100°

3 CONCLUSIONS

The theoretical predictions of the AtR optics and its matching properties to RHIC were presented. Experimental tests[2],[4],[5] performed on the AtR optics showed good

agreement with theory. The matching properties of the AtR line were also tested[2][3] and found to agree well with the theoretical predictions.

4 REFERENCES

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