Beam Transfer Lines for the AGS Booster*

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ABSTRACT

The injection lines for the proton and heavy ion beam injection into the Booster and a beam transfer line from the Booster to the Alternating Gradient Synchrotron (AGS) are described here. The proton injection line is from the 200 MeV linac and the heavy ion injection line is from the present beam transport line of the Tandem Van de Graaff. The beam transfer line is for transporting the accelerated beam from the Booster to the AGS. Also included in the discussion is a method of extraction from the Booster and injection into the AGS.

INTRODUCTION

The AGS Booster will be a multi-purpose machine[1]. This will be a Booster synchrotron to the AGS for the unpolarized protons and heavy ions and will be an accumulator and injector for the polarized protons. This will accelerate protons at 7.5 Hz from 200 MeV to 1.5 GeV, and heavy ions from the BNL Tandem Van de Graaff energy to an energy high enough to completely strip the electrons before injecting them (heavy ions) into the AGS. As shown in the figure 1, there are two injection lines (one for H^- and another for heavy ions) and one beam transfer line from the Booster to the AGS. In this paper we give a description of these beam lines and discuss their optics.

THE PROTON INJECTION LINE

The H^- charge exchange injection method will be used to inject protons in the Booster. The stripper foil is located down stream of an special Booster dipole magnet. As shown in figure 2, a part of the upstream return yoke of this magnet is displaced to accommodate the passage of the incoming H^- ion beam through it. The new beam line starts after the fifth quadrupole in the present beam transport line which goes from the linac to the AGS. A 7.5° kicker magnet will be installed in the present line to deflect the H^- beam towards the new injection line. This would thus preserve, for the time being, the present direct injection system to the AGS. There will be nine dipoles in the new beam line (eight 60cm long giving a deflection of 14.4° each and one 45cm long giving a deflection of 10.6°) to provide the necessary bending to get to the injection point. The beam will get

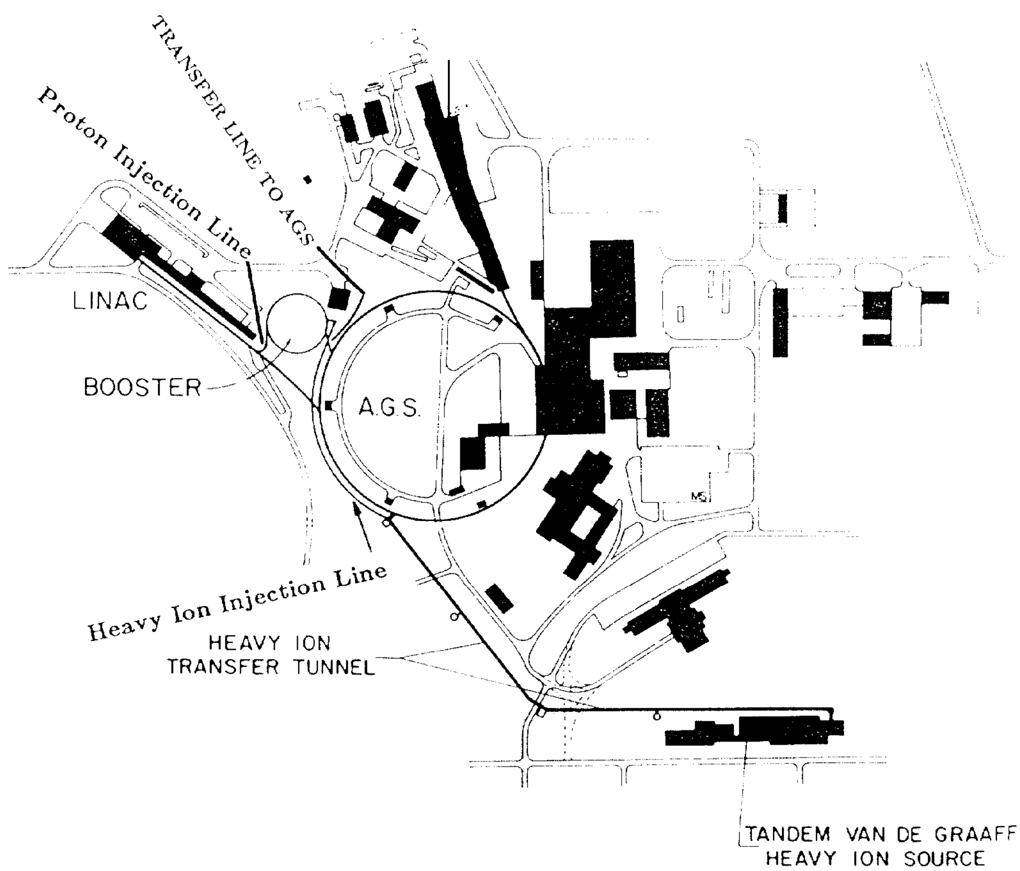

Figure 1 - The Locations of the Beam Transfer Lines

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another bending of 7° inside the special Booster dipole which separates the circulating proton beam from the injected H^- ion beam. Because of a large injection angle (76°), the injected H^- ions will feel a significant horizontal focusing (vertical defocusing) effect at the entrance of this magnet. There are five horizontally focusing and five vertically focusing quadrupoles in this line. They are 30 cm long and have an aperture of 4". The beam optics to shape the phase space ellipse parameters at the stripper foil and to keep the beta functions and the dispersion function reasonable in the transport line is accomplished by using these ten quadrupoles of the new line and five quadrupoles of the present beam line. The five quadrupoles are those which are located between the tank 9 of the linac and the 7.5° kicker. The injection conditions will be experimentally determined to achieve the highest intensity of the accelerated beam. The optimization of these conditions include a possibility of mis-matching the phase space ellipse orientation, however, the dispersion function and its derivative should remain matched. The lattice functions and the position of various components is shown in Fig 3. For the computational purpose, the stripper foil is located at 2 inches from the central orbit, however, the position of it will be emperically determined to optimize the injection and the operation of the Booster.

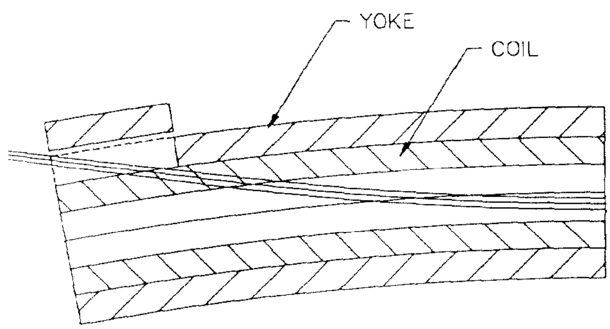

Figure 2 - The Special Magnet for H^- Injection

HEAVY ION INJECTION LINE

The heavy ion beam is presently transported from the BNL Tandem Van de Graaff to the AGS for direct injection. Since the AGS can only accelerate fully stripped ions, it is necessary to pre-accelerate the ions heavier than sulfur to an energy which is high enough to strip them (heavy ions) fully when they pass through a foil. The Booster will accelerate the heavy ions to this energy. The new transport line will be an extension of the present heavy ion line and it will start at the old south west experimental area where the present transfer line has the final bend towards the AGS. It will go through the old south west extraction channel, the AGS tunnel, the old 50 MeV linac conjunction area, the old injection tunnel and the linac tunnel where it will take an almost about turn to inject the heavy ions finally into the Booster. The path, so chosen, does not require any civil construction. The transport line requires 14 horizontal bends. It also requires some vertical bends because of the different elevation of the beam at various places. The beam will be at an elevation of 76.18 feet above the sea level inside the AGS tunnel and remains at that through the linac tunnel. It will then be pitched down to the Booster elevation of 75 feet above the sea level. The pitching will be accomplished by tilting the last two magnets of this beam line; these magnets together give a 160° horizontal bend. In the AGS tunnel, the line will be located a foot inside the outer AGS wall.

The beam line design is conceptually done in three sections. The middle section, which is inside the AGS tunnel, consists of four FODO cells, each of 90° phase advance. It ensures a unit transport matrix for this section and therefore, by definition, transports the beam to the next section with the identical beam properties. The optical elements of the first section consists of an upstream quadrupole doublet in the present beam line. The new line will have two dipoles and ten quadrupoles (five horizontally focusing and five vertically focusing) in the first section. The optics of it is such that the both vertical and horizontal phase space ellipse parameters matches to the lattice parameters of the middle section. A small mismatch can be tolerated in this section if the necessity arises. The last section

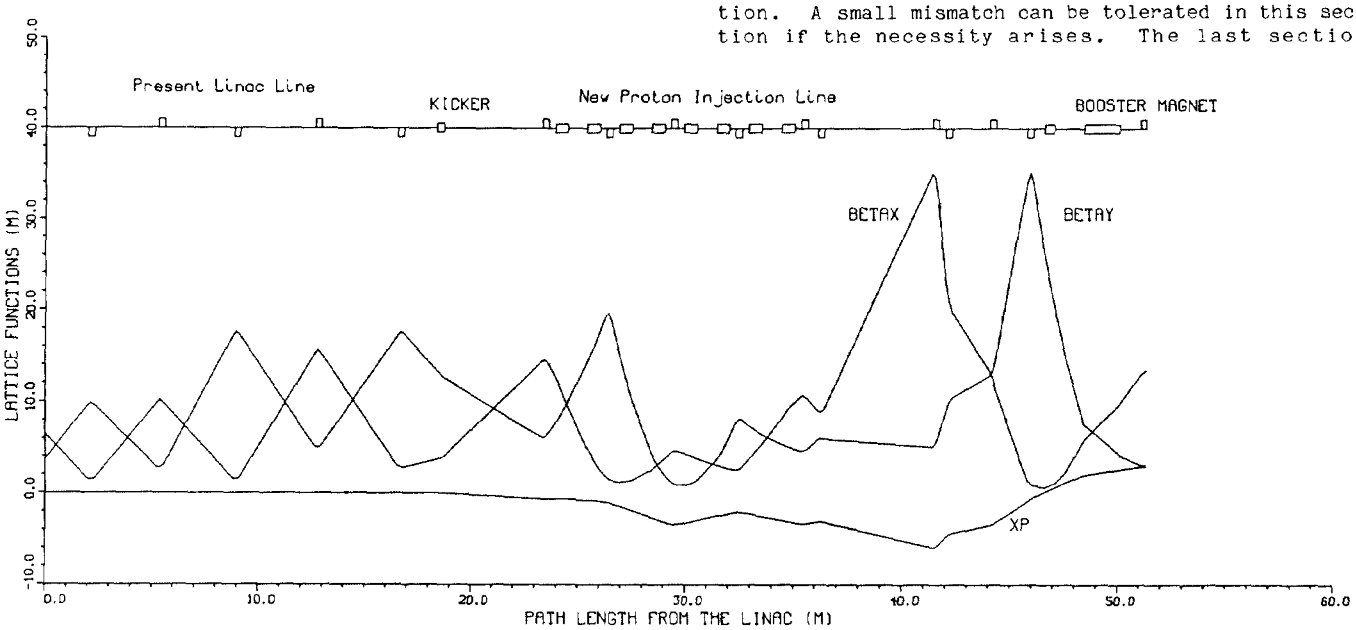

Figure 3 - The Lattice Functions and the Location of Various Components in the Proton Injection Line

consists of one dipole inside the AGS tunnel and two sector magnets and two pairs of trim dipoles in the linac tunnel. There are ten quadrupoles in this section to shape the horizontal and vertical phase ellipses and the dispersion functions of the injected beam. The beam will be stacked multi-turn in the Booster horizontal betatron space.

BEAM TRANSFER LINE FROM THE BOOSTER TO THE AGS

Two straight sections are used for extracting the accelerated beam from the Booster. The bunched beam is kicked at the first straight section and ejected by the septum at the second straight section. The ejected beam is then focused by a quadrupole doublet onto a stripper foil made of 70 mg/cm^2 Cu target. For heavy ions, heavier than Sulfur, this foil produces the fully stripped ions as required for the AGS injection. The fully stripped beam is then deflected 31.7° by a number of dipoles towards the old 50 MeV linac injection line. A set of 5 FODO cells then transport the beam along the old 50 MeV linac line into the main field of the AGS magnet. A kicker at the 10 feet straight section in the AGS, before the AGS magnet, is used to kick the injected beam onto the AGS closed orbit. The AGS closed orbit is distorted by an orbit bump at the time of injection. The beam is injected into the main field of the AGS magnet L20, where the beam optics is matched to the AGS betatron functions. This requires one quadrupole in the beam line at a location equivalent to that of the AGS L17 straight section in the transfer line. This, in turn demands the beam separation at L17 straight section to be 35 cm or more. This requirement gives a relationship between x and x', where x is the orbit bump required for the circulating beam at the center of straight section L20 and x' is the angle between the injected beam with the closed orbit at the the mid-point to the straight section L20. Table 1 lists the distance between the transfer line and the AGS beam line at L17 straight section with various conditions of x and x' for the injected beam. We find that x=25.4 mm would require x' to be 12 mrad. The kicker requirement at the center of the straight section would be 14 mrad. At x=38.1 mm, x'=10 mrad, the kicker requirement becomes 12 mrad. The kicker is used to kick the injected beam onto the bumped AGS closed orbit. To achieve a 25mm orbit bump, we need 3 backleg windings at the 4% of the AGS main dipole field, which is small at the injection where the magnet rigidity is 11 Tesla-meter or less.

Table 1
Parameters at the midpoint of the straight section.

x' / x	9	10	11	12	13	14
25.4	316.	327.	339.	351.	363.	374.
38.1	338.	349.	361.	373.	384.	396.
50.8	359.	371.	383.	395.	406.	418.

The optics is matched by the ten quadrupoles in five FODO cells between the 31.7 degree bend point and the AGS injection section. Detail optics is shown in Fig. 4.

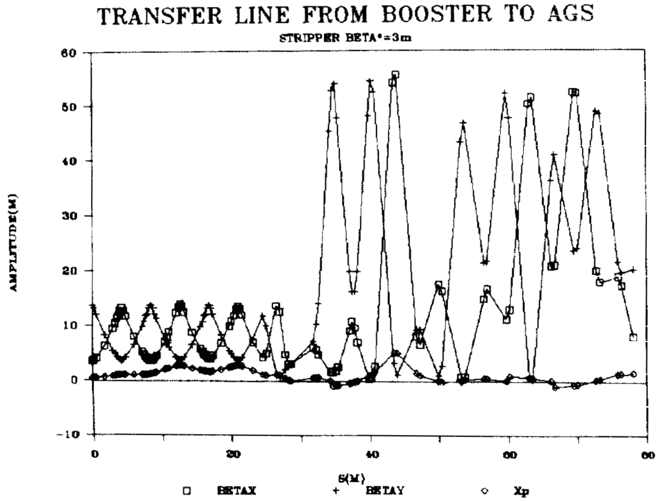

Figure 4 - The Optics for Beam Transfer Line from the Booster to the AGS

REFERENCES

1. E. B. Forsyth, Y. Y. Lee, "Design and Status of the AGS Booster Accelerator", to be published in this conference.