THE AGS-BOOSTER LATTICE*

Y. Y. Lee, D. S. Barton, J. Claus, J. G. Cottingham, E. D. Courant, G. T. Danby, G. F. Dell, E. B. Forsyth, R. C. Gupta, J. Kats, S. Y. Lee, A. J. McNerney, G. H. Morgan, Z. Parsa, G. Parzen, E. C. Raka, S. Tepikian, R. A. Thomas, W. T. Weng, S. P. Yamin, and X. F. Zhao

Accelerator Development Department, Brookhaven National Laboratory
Upton, New York 11973

Introduction

The interests of both particle and nuclear physicists are converging on the AGS; this machine is almost ideally and uniquely suited to perform a new class of frontier experiments. Particle physicists would like to study the extremely heavy (multi-TeV) particles posited by new theories by searching for rare K-decays. Nuclear physicists want to create the extremely dense form of nuclear matter which exists within neutron stars by studying heavy ion collisions. Particle physicists interested in spin physics would like to study polarized proton scattering in the very high momentum transfer region, which requires a higher intensity polarized proton flux. The ability of the AGS to simultaneously fulfill all these requirements can be addressed by the construction of a Booster synchrotron(1). With the addition of the Booster, the enhanced AGS will possess capabilities not available anywhere else in the world.

The AGS Booster has three objectives. They are to increase the space charge limit of the AGS, to increase the intensity of the polarized proton beam by accumulating many linac pulses (since the intensity is limited by the polarized ion source), and to reaccelerate heavy ions from the BNL Tandem Van de Graaff before injection into the AGS. The machine is capable of accelerating protons at 7.5 Hertz from 200 MeV to 1.5 GeV or to lower final energies at faster repetition rates. The machine will also be able to accelerate heavy ions from as low as 1 MeV/nucleon to a magnetic rigidity as high as 17.6 Tesla-meters with a one second repetition rate. As an accumulator for polarized protons, the Booster should be able to store the protons at 200 MeV for several seconds.

We expect that the Booster will increase the AGS proton intensity by a factor of four, polarized proton intensity by a factor of twenty to thirty, and will also enable the AGS to accelerate all species of heavy ions (at present the AGS heavy ion program is limited to the elements lighter than sulfur because it can only accelerate fully stripped ions).

The construction project started in FY 1985 and is expected to be completed in 1989. The purpose of this paper is to provide a future reference for the AGS Booster.

The Lattice

The circumference of the Booster (201.78 m) is chosen to be ¼ of the AGS circumference which will allow efficient synchronous bucket to bucket transfer of the beam from the Booster to the AGS. We have chosen to use a very simple lattice for both operational simplicity and economics. Several lattices, including ones using combined function magnets to gain longer straight sections and higher superperiods, and ones with larger circumference for higher final energy, have been extensively studied. It would be possible to design a structure with long straight-section insertions, but this would involve a greater number of more different types of magnets and would be more expensive, as well as operationally more complex. The lattice chosen is a FODO arrangement with bending dipoles missing from half of the cells. Since the study has not shown any advantage to having a combined function, or a hybrid of a combined and separate function lattice, with respect to the lattice function or its stop-band properties, the Booster magnets are separated function for ease of construction and operational flexibility. The dipoles and the horizontally and vertically focusing quadrupoles will be independently powered to allow maximum versatility in the tune of the machine. The orbit deformations needed for the injection and ejection are accomplished by extra windings in the dipoles. The dipoles have an aperture of 3.25" x 10" with a field of 1.6 kG(0.7 kG for heavy ions) at injection. The magnetic field cycle requirements are 5.46 kG at 7.5 Hz rate for 1.5 GeV protons and 12.8 kG at 1 Hz rate for heavy ions. The heavy ion acceleration aspect is the determining constraint on the magnet design. The power supply requirements for both cases are almost identical except for rearrangement of the modules. The range of fields, appreciably below saturation levels, makes design of magnets of storage-ring quality straightforward. The tune and aperture of the ring are chosen to avoid important systematic orbital resonances and depolarizing resonances for polarized protons, to match the admittance of the AGS and to be flexible enough to accommodate research and development of devices and techniques for the acceleration and storage of polarized protons.

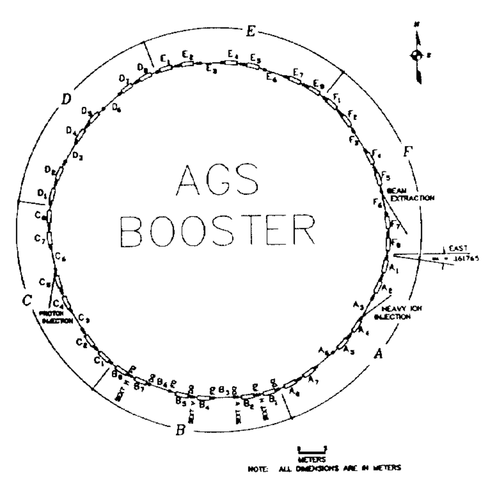

Figure 1. - Booster Layout

* Work performed under the auspices of the U.S. Department of Energy.

CH2387-9/87/0000-0865 $1.00 © IEEE
PAC 1987

There are 24 cells in the Booster, and a superperiod consists of four cells or 8 half cells. The superperiods are named A to F and within each superperiod the half cells are numbered 1 to 6. There are no dipoles in half cells 3 and 6, and they are used as straight sections. Figure 1 shows the magnet arrangement for the ring.

At straight sections 6, the horizontal beta function is large at the upstream end and they are suitable for extraction septums. On the other hand, the horizontal beta function is large at the downstream end of straight sections 3, and these are suitable for injection. The magnetic length of the dipole is 2.4 m and that of the quadrupole is 0.50375 m nominally. The dipoles are located asymmetrically between the quadrupoles; the spaces between quadrupole and dipole are 0.3 m upstream and 1 m downstream which is where correction coils and vacuum equipment will be located. Because of the rapid cycling nature of the Booster, we expect significant eddy-current induced sextupoles in the vacuum chambers which will require large chromaticity corrections. The chromaticity sextupoles are located at the downstream spaces of half cells 1 and 7 for horizontal and 2 and 4 for vertical sets. The locations of the chromaticity sextupoles are constrained by the location of other essential equipment. Figure 2 shows the beta functions and the dispersion function for the lattice; the parameters are listed in the Table.

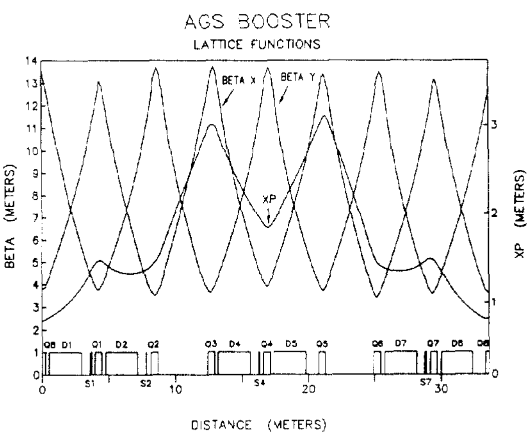

Figure 2. - Lattice Functions

TABLE
AGS BOOSTER PARAMETER LIST

	PROTON	POL PROTON	HEAVY ION
ENERGY			
INJECTION	200 MeV	200 MeV	1 MeV/nuc.
EJECTION	1.5 GeV	1.5 GeV	P=5.27 Q/A GeV/nuc
LATTICE			
CIRCUMFERENCE		201.78 m(1/4 AGS)	
PERIODICITY		6	
NUMBER OF CELLS		24 FODO (SEPARATE FUNCTION 12 MISSING DIPOLES)	
CELL LENGTH		8.4075 m	
PHASE ADVANCE/CELL		72.3/72.45 DEGREE	
Q_x/Q_y (NOMINAL)		4.82/4.83	
BETA MAX/MIN		13.9/3.7 m	
Xp MAX		2.9m	
TRANSITION GAMMA		4.85	
RF SYSTEM			
NUMBER OF STATIONS	2	2	2
HARMONIC NUMBER	3	3	3
FREQUENCY RANGE (MHz)	2.5--4.07		.178--2.5
PEAK RF VOLTAGE (KV)	90	90	17
ACCELERATION TIME (m-SEC)	75	75	500
REPITITION RATE	7.5 Hz(4/AGS PULSE)		1 Hz(1/AGS)
DIPOLES (dipoles are curved and wedged for normal entrance)			
NUMBER		36	
LENGTH \MAGNETIC}		2.4 m	
GAP		82.55 mm	
VACUUM CHAMBER APPERTURE		66 mm	
GOOD FIELD REGION ([10**-4)		16 x 6.6 cm	
INJECTION FIELD \KG}	1.56	1.56	.105 A/Z
EJECTION FIELD	5.46	5.46	12.79
QUADRUPOLES			
NUMBER		48	
LENGTH \MAGNETIC}		.50375 m	
APPERTURE		16.5 cm	
VACUUM CHAMBER APP.		15.5 cm	
INJECTION POLE TIP FIELD \KG}	1.02	1.02	.068 A/Z
EJECTION POLE TIP FIELD \KG}	3.7	3.7	8.4
FIELD QUALITY 6/2		0.0 (SHAPE POLE TIP TO ELIMINATE)	
ALL OTHER HARMONICS		[10**-4	
CHROMATICITY SEXTUPOLES			
NUMBER		2 x 12	
LENGTH \MAGNETIC}		18. cm	
MAX. POLE TIP FIELD \KG}		3.	
MAX. VACUUM PRESSURE		3 x 10**-11 TORR	

Air core correction packages for vertical and horizontal dipoles, normal and skew quadrupoles, and normal and skew sextupoles are located at every half cell except at 6 locations where no physical space is available. The strength of the correction package is such that they should be able to correct all of the random error harmonics including half integer ones at Q=4.5. There are several structure resonances near the nominal working point(Qx=4.82, Qy=4.83). They are 3Q=12, 4Q=18, and 2Qx+2Qy=18. Tracking studies including eddy current effects have been carried out, and it has been concluded that 4th order resonances are negligibly small and the 3rd order resonances are far enough away to be manageable. The coupling resonances of Qx-Qy=0 and 2Qx-2Qy=0 have been studied, and one can cope with them by choosing a suitable correction and a suitable chromaticity value and tune split Qx-Qy.

References

(1) Brookhaven National Laboratory Informal Report 34989R, 1985