BOOSTER

PARAMETER

LIST

BEAM
EXTRACTION

HEAVY ION
INJECTION

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BOOSTER PARAMETER LIST

1. Introduction

The AGS Booster is designed to be an intermediate synchrotron injector for the AGS, capable of accelerating protons from 200 MeV, the linac operating energy, to 1.5 GeV, (with the possibility of an upgrade to 2.5 GeV), at a repetition rate of 7.5 Hz, and capable of accelerating heavy ions to a magnetic rigidity equal to 17.52 Tesla-meters at a 1 Hz repetition rate.

As presently designed, the Booster will have: A circumference equal to one quarter that of AGS; with six identical superperiods. It will have a FODO lattice with bending magnets missing in some cells in order to accommodate the space needed for RF acceleration, injection, ejection and abort system without otherwise interrupting the periodicity. The dipoles of the proposed lattice have an aperture of 3.25" x 10" and an injection field of about 1.6 kG (0.7 kG for heavy ions).

In total, the Booster will have 36 dipoles, each of 2.4 meter magnetic length, and 48 quadrupoles which have 0.50375 meter magnetic length. We have chosen a "separated function" structure with quadrupoles and zero-gradient dipoles. Furthermore, for maximum tuning versatility the dipoles and the quadrupoles will be independently powered.

This note describes the parameter list of the AGS-Booster. The chromaticity correction sextupole configuration is 1,2,4,7 and the eddy current sextupole strengths are taken to be 0.12 Tesla per meter square [4]. A schematic layout of the Booster lattice and its superperiods are also included [1,6,17]. The present values of the Booster parameters are tabulated below. (Note that, the values listed are for theoretical calculations.)

This new expanded format of the parameter list includes items (more detailed) that were not present in the previous lists. Some of these items will be completed as the information become available. For convenience, we have included additional Figures describing many aspects of the AGS - Booster. This updates the Booster Parameter List. Furthermore, these changes will be reflected in the Booster Design Manual [II].

A brief overview of the parameters is given in the AGS-Booster Parameter List Table (next page).

**QUICK REFERENCE
AGS BOOSTER PARAMETER LIST**

	Protons	Polarized Protons	Heavy Ions
Energy			
Injection	200 MeV	200 MeV	$> 1 \text{ MeV/nucleon}$
Ejection	1.5 GeV	1.5 GeV	$p = 5.25 \text{ } Q/A \text{ (GeV/c)/nucleon}$
No. of Particles/Pulse	$\sim 10^{12}$	$1.5 - 3 \times 10^{13}$	$15 \times 10^9 \text{ (S)}, 3 \times 10^9 \text{ (Au)}$
Lattice			
Circumference		201.78 m (1/4 AGS)	
Magnetic bend radius		13.75099 m	
Periodicity		6	
Number of cells		24 FODO	
Cell length		8.4075 m	
Phase advance/cell		$72.3^\circ / 72.45^\circ$	
ν_x/ν_y (nominal)		4.82/4.83	
β_y max/min		13.6/3.7 m	
x_p max		2.95 m	
transition γ		4.88	
RF System			
Number of stations	2	2	2
Harmonic number	3	3	3
Frequency range (MHz)	2.5 — 4.11	2.5 — 4.11	0.200 — 2.5
Peak RF voltage	90	90	17
Acceleration time (ms)	62	62	500
Repetition rate	7.5 Hz (4/AGS pulse)	1 Hz (1/AGS)	1 Hz (1/AGS)
Dipoles			
Number		36	
Length (magnetic)		2.4 m	
Gap		82.55 mm	
Vacuum chamber aperture		66 mm	
Good field region ($< 10^{-4}$)		$16 \times 6.6 \text{ cm}$	
Injection field (kG)	1.56	1.56	$0.108 \text{ } A/Q$
Ejection field	5.46	5.46	12.74
Quadrupoles			
Number		48	
Length (magnetic)		50.375 cm	
Aperture		16.5 cm	
Vacuum chamber aperture		15.25 cm	
Injection pole tip field (kG)	1.02	1.02	$0.068 \text{ } A/Q$
Ejection pole tip field (kG)	3.6	3.6	8.3
Field Quality 6/2		0.0	
All other harmonics		$< 10^{-4}$	
Chromaticity Sextupoles			
Number		2×12	
Length (magnetic)		10 cm	
Max. pole tip field (kG)		3.0	
Max. Vacuum Pressure		$3 \times 10^{-11} \text{ torr}$	

BOOSTER PARAMETER SUMMARY

type of machine	synchrotron for protons and heavy ions polarized proton accumulator						
beam energy, max	p	d	C	S	Cu	I	Au
	1.50	1.93	11.60	30.95	53.81	74.62	68.95
	1.500	0.963	0.967	0.967	0.854	0.588	0.350
							GeV
							GeV/nucleon
circumference	201.78 m (1/4 AGS)						
straight-section use	RF, h=3, A6 and E6 RF, h=1, B3 and B6 heavy ion inj. kickers, A5 and F8 heavy ion inj. septum, A3 ejection kicker, F3 ejection septum, F6 absorber blocks, D3						
bunch separation, no. of bunches							
no. of particles/pulse	protons, $1 - 3 \times 10^{13}$ polarized protons, $\sim 10^{12}$						
		C	S	Cu	I	Au	
		54	~15	~10	~6.6	~3.2	$\times 10^9$ ions
beam current	p	p↑	d	C	S	Cu	I Au
							mA pk mA avg
beam energy, max	p	p↑	d	C	S	Cu	I Au
							kJ
transverse emittance, inj., (90% area/ π)	50 mm-mrad						
rms fractional energy spread, inj - ejec	bunched to 1.5 eV-s, protons bunched to 0.05 eV-s/nucleon, heavy ions						
longitudinal emittance, inj - ejec (rms area/ π)							
lattice, total no. of cells	FODO, 8.4075-m cells, 24						
betatron tune, x,y	4.82, 4.83						
β_x max, min	13.865/3.5754 m						

β_y max, min	13.644/3.7033 m							
horizontal dispersion, max, min	2.9515/0.5400 m							
magnet type	iron-dominated, Cu conductor							
magnetic field, dipole, ejec.	protons, 0.546 T; heavy ions, 1.274 T, max							
magnetic radius of curvature	13.75099 m							
magnetic gradient, quad, ejec.	Gf: protons, 1.20 T/m							
	heavy ions, T/m							
	Gd: protons -1.24 T/m							
	heavy ions, T/m							
dipole length (magnetic/physical)	2.4/2.34 m, excl. coils							
quad length (magnetic/physical)	0.50375/0.472 m, excl. coils							
number of dipole and quadrupole magnets	36 dipoles, 48 quads							
dipole excitation current, max	protons, 2220 A							
	heavy ions A							
quad excitation current, max	protons, 2220							
	heavy ions A							
vacuum chamber, dimen.	70 × 152 mm, dipoles							
	152.4 mm (circular), quads							
RF: harmonic number	3							
RF: frequency								
		p	d	C	S	Cu	I	Au
inj.	2.523	0.788	0.562	0.446	0.349	0.265	0.213	MHz
ejec.	4.114	3.877	3.884	3.885	3.804	3.522	3.061	MHz
acceleration period	62 ms, protons; 500 ms (max), heavy ions							
energy gain per turn								
		p	d	C	S	Cu	I	Au
								kV
peak RF voltage, total RF power								
		p	d	C	S	Cu	I	Au
								kV
								kW
RF system length, per cavity system								
rms bunch length, inj - ejec								
		p	d	C	S	Cu	I	Au
inj.								cm
ejec.								cm

synchrotron period, inj - ejec

	p	d	C	S	Cu	I	Au	
inj.								ms
ejec.								ms

Injector system

200 MeV linac, protons
Tandem Van de Graaff, heavy ions

TABLE 1. Isotopes, Charge States, and Ionic Masses.

	Q	Z	A	Ionic Rest Mass (u)	Ionic Rest Mass Energy (GeV/nucleon)
p	+1	1	1	1.00728	0.93828
d	+1	1	2	2.01355	0.93781
C	+6	6	12	11.99671	0.93125
S	+14	16	32	31.96439	0.93047
Cu	+21	29	63	62.91808	0.93029
I	+29	53	127	126.88857	0.93068
Au	+33	79	197	196.94846	0.93126

TABLE 2. Injection Energies and Fields

	v/c	f (MHz)	p (GeV/c)	E_{inj}		B_{inj} (kG)
				(MeV)	(MeV/nucleon)	
p	0.5662	2.5235	0.6444	200.0	200.000	1.563
d	0.1767	0.7878	0.3368	30.0	15.000	0.817
C	0.1262	0.5623	1.4211	90.0	7.500	0.575
S	0.1000	0.4457	2.9925	150.0	4.688	0.519
Cu	0.0782	0.3485	4.5969	180.0	2.857	0.531
I	0.0595	0.2653	7.0489	210.0	1.654	0.590
Au	0.0478	0.2131	8.7805	210.0	1.066	0.645

TABLE 3. Ejection Energies and Fields — $B_{max} = 12.74$ kG

	v/c	f (MHz)	p (GeV/c)	E_{ejec}		B_{ejec} (kG)
				(GeV)	(GeV/nucleon)	
p	0.9230	4.114	2.251	1.500	1.5000	5.459
d	0.8699	3.877	3.308	1.927	0.9635	8.024
C	0.8714	3.884	19.847	11.602	0.9668	8.024
S	0.8716	3.885	52.926	30.952	0.9672	9.170
Cu	0.8534	3.804	95.932	53.810	0.8541	11.081
I	0.7900	3.522	152.345	74.623	0.5880	12.743
Au	0.6868	3.061	173.358	68.950	0.3500	12.743

2. Beam and Operational Parameters

injected particles	protons, polarized protons, heavy ions (through gold)							
injection momenta								
	p	d	C	S	Cu	I	Au	
	0.6444	0.3368	1.4211	2.9925	4.5969	7.0489	8.7805	
$B\rho$, at injection							GeV/ c	
	p	d	C	S	Cu	I	Au	
	2.1496	1.1235	0.7901	0.7130	0.7302	0.8108	0.8875	
$B\rho$, at ejection							T-m	
output momenta								
	p	d	C	S	Cu	I	Au	
	2.251	3.308	19.847	52.926	95.932	152.345	173.358	
$B\rho$, at ejection							GeV/ c	
	p	d	C	S	Cu	I	Au	
	7.507	11.034	11.034	12.610	15.238	17.523	17.523	
$B\rho$, at ejection							T-m	
output kinetic energy								
	p	d	C	S	Cu	I	Au	
	1.500	1.927	11.602	30.952	53.810	74.623	68.950	
	1.5000	0.9635	0.9668	0.9672	0.8541	0.5876	0.3500	
							GeV	
							GeV/nucleon	
radio frequency								
		p	d	C	S	Cu	I	Au
	inj.	2.523	0.788	0.562	0.446	0.349	0.265	0.213
	ejec.	4.114	3.877	3.884	3.885	3.804	3.522	3.061
								MHz
								MHz
bunch spacing								
center to center								
free, between bunches								
avg. beam current (at max energy)								
no. of particles/pulse								
								protons, $1 - 3 \times 10^{13}$
								polarized protons, $\sim 10^{12}$
		C	S	Cu	I	Au		
		54	~ 15	~ 10	~ 6.6	~ 3.2	$\times 10^9$ ions	
bunches per pulse								
rms bunch length, ejec.								
beam energy								

space-charge tune shift, inj.	~.7							
acceleration time	62 ms, protons & polarized protons 500 ms (max.) heavy ions							
repetition rate	7.5 Hz (4 pulses/AGS pulse), protons 1 Hz (1 pulse/AGS pulse), polarized protons 1 Hz (1 pulse/AGS pulse), heavy ions							
peak RF voltage	90 kV, protons & polarized protons 17 kV, heavy ions							
synchronous phase angle	30°, average							
circumference	201.78 m (1/4 AGS)							
avg. radius	32.114 m							
magnetic bend radius	13.75099							
magnetic field, dipole								
	p	d	C	S	Cu	I	Au	
inj.	0.1563	0.0817	0.0575	0.0519	0.0531	0.0590	0.0645	T
ejec.	0.5459	0.8024	0.8024	0.9170	1.1081	1.2743	1.2743	T
horiz. tune	4.82							
vert. tune	4.83							
transition γ	4.8812							
natural chromaticity, horiz.	-4.92970							
natural chromaticity, vert.	-5.26488							
space-charge tune shift								
lattice type	separated function, FODO							
superperiodicity	6							
max β	14 m							
max dispersion	3 m							
no. of dipoles	36							
dipole length	2.4 m (magnetic)							
dipole field, max	1.2743 T							
full good-field aperture, horiz.	152.4 mm							
no. of standard quads	48							
standard quad length	0.50375 m (magnetic)							
standard quad strength, max	1.24 T/m							
full good-field aperture	152.4 mm							
no. of sextupoles	24 (12 SF + 12 SD)							
no. of families	2							
location	1,7 (SF), 2,4 (SD)							
sextupole strength ($B''L$)								

rms fractional energy spread, inj
rms fract. energy spread, ejec
long. emittance, inj., rms
long. emittance, ejec., rms

Note 1: rms longitudinal emittance = $\sigma_E \sigma_t$

3.

Lattice Parameters

circumference	201.78 m (1/4 AGS)							
revolution time								
	p	d	C	S	Cu	I	Au	
inj.	1.1888	3.8032	5.3353	6.7307	8.6076	11.3061	14.0791	μs
ejec.	0.7292	0.7737	0.7724	0.7723	0.7887	0.8519	0.9800	μs
straight-sections (8 total)	RF, h=3, A6 and E6 RF, h=1, B3 and B6 heavy ion inj. kickers, A5 and F8 heavy ion inj. septum, A3 ejection kicker, F3 ejection septum, F6 absorber blocks, D3							
ring	6 superperiods, 4 cells/superperiod							
	cell lattice							
	B CT SF QF B CT SD QD n CT QF B CT SD QD B CT QF n CT QD B CT SF QF B CT QD							
B	dipole bend magnets, horiz., 1.2743 T							
CT	correction and trim coil assembly							
SF, SD	sextupoles							
QF, QD	quads							
magnetic rigidity, ejec	7.507 T-m, protons & polarized protons							
	17.523 T-m (max), heavy ions							
magnetic radius	13.75099 m							
lengths:								
superperiod	33.63 m							
cell	8.4075 m							
B	240 cm (magnetic)							
CT	10 cm (magnetic)							
SF, SD	10 cm (magnetic)							
QF, QD	50.375 cm (magnetic)							

Note 1: Component sequences are listed in the clockwise (CW) direction as seen from above.

Lattice Optics

phase shift per cell, x,y	72.3, 72.45 degrees
betatron tune, x,y	4.82, 4.83
tuning range, x,y	± 1
transition γ	4.8812

natural chromaticity, x,y -4.9297, -5.2649

zero-chrom. sext. $B''L/B\rho$, F,D: F = 0.13607, D = -0.81060 m⁻²
 with eddy currents

4.1.

Ring Dipole Magnets

number of horiz. bends	36
magnetic field	1.2743 T, max
length, magnetic	2.40 m
length, plate to plate	2.34 m (center arc)
length, coil-end to coil-end	2.66 m (center arc)
gap	82.55 mm
inductance	3.2 mH
transfer function	0.2436 T/kA, injection 0.2320 T/kA, ejection
current at ejection	2240 A, protons 5490 A, heavy ions
mass	
aperture	152×70 mm
coil dimensions, pancake	$266.1 \times 26.8 \times 9.46$ cm
turns per pole	8 (4×2 pancakes)
conductor dimensions	25.4×50.8 mm
conductor length	
insulation thickness	
iron lamination dimensions	76.2×59.7 cm
lamination material	
lamination thickness	0.6 mm — 1.0 mm
weight of iron	

4.2.

Ring Quadrupole Magnets

number of quads	48							
B'	+1.2000 T/m, focusing -1.2369 T/m, defocusing							
$B' B\rho$								
length, magnetic	50.375 cm							
length, plate to plate	47.2 cm							
length, coil end to coil end	66.1 cm							
inductance	350 μ H							
transfer function	T/m per kA, inj. T/m per kA, ejec.							
current at ejec	2240 A, protons 5490 A, heavy ions							
mass								
aperture	152.4 mm (circular)							
pole tip radius	82.55 mm							
pole tip field								
	p d C S Cu I Au T							
inj., f	0.0990							T
inj., d	0.1020							T
ejec., f	0.3457					0.8071	0.8701	T
ejec., d	0.3564					0.8308	0.8308	T
coil dimensions	26.76 $\times$ 66.07 $\times$ 9.46 cm							
turns per pole	5							
conductor length								
conductor mass								
maximum field								
conductor dimensions	31.75 $\times$ 31.75 cm							
quadrupole width, max	59.1 cm							
iron lamination dimensions								
lamination material								
lamination thickness	0.6 — 1.0 mm							
iron weight								

4.3.

Ring Sextupole Magnets

number of sextupoles	24 (12 SF + 12 SD)					
number of families	2					
location	1,7 (SF), 2,4 (SD)					
sextupole strength ($B''L$)						
B''	+ T/m ² , focusing - T/m ² , defocusing					
$B''B$						
length, magnetic	cm					
length, plate to plate	10.0 cm					
length, coil end to coil end	~ 20 cm					
inductance	μ H					
transfer function, at inj	T/m ² -kA					
current at ejec	A, protons A, heavy ions					
mass						
aperture	152.4 mm (circular)					
pole tip radius	mm					
pole tip field , mag.	3.0 kG					
	p d C S Cu I Au					
inj., f	0.04576	T				
inj., d		T				
ejec., f		T				
ejec., d		T				
coil dimensions		×		×		cm
turns per pole						
conductor length						
conductor mass						
maximum field						
inter-coil insulation thickness						
conductor dimensions				×		cm
sextupole width, max						
iron lamination dimensions						
lamination material						
lamination thickness				0.6 — 1.0 mm		
iron weight						

4.4.

Correction and Trim Magnets

Special Devices/Correction and Trim Coil Assembly

assembly length (CT) 10 cm

Assembly Complements:

Primary Package:

<i>Element</i>	<i>Inner Radius</i>	<i>Outer Radius</i>	<i>Turns/ Pole</i>	<i>Induct.</i>	<i>BL (1 cm) (100 A)</i>
dipole	mm	mm		H	T-m
sextupole					
quadrupole					

In various Secondary Packages:

quadrupole
skew shell
normal shell
sextupole
octupole

Note 1: zero-chromaticity sext. strengths ($B''L/B\rho$) SF, SD = + . / - . m⁻²

4.5.

Injection Magnets

H⁻ Injection Line

External

Injection Dipoles (Horizontal-Bend)

number	8 main bending dipoles
magnetic field	0.901 T (8 main dipoles)
length, magnetic	0.600 m

Injection Trim Magnets

number	2 horiz. trim dipoles 2 vert. trim dipoles
magnetic field	200 G-m
length, magnetic	
length, slot	

Injection Quads

number	6
magnetic field	0.224 T/m, max
length, magnetic	0.30 m

In ring

Injection kicker magnets

type
field strength
magnet gap
eff. length of module
total length of module
bend angle, direction
rise time
flat top
fall time
voltage
current
flat top uniformity
no. of modules

Injection slow orbit-bump magnets

number	3
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Heavy Ion Injection Line

External

Injection Dipoles (Horizontal-Bend)

number	14 main bending dipoles
magnetic field	
length, magnetic	

Injection Pitching and Steering Magnets

number	
number	4 pitching dipoles
	2 steering dipoles
magnetic field	
length, magnetic	

Injection Quads

number	26
magnetic field	
length, magnetic	

In ring

Injection kicker magnets

type
field strength
magnet gap
eff. length of module
total length of module
bend angle, direction
rise time
flat top
fall time
voltage
current
flat top uniformity
no. of modules

Injection slow orbit-bump magnets

number	3
--------	---

4.6.

Ejection Magnets

External

Ejection Dipoles (Horizontal-Bend)

number

3 combined-function dipoles

Ejection Vertical-Bend Magnets

number

magnetic field

length, magnetic

length, slot

Ejection Quads

number

12

magnetic field

length, magnetic

0.50 m

In ring

Ejection kicker magnets

type

field strength

magnet gap

eff. length of module

total length of module

bend angle, direction

rise time

flat top

fall time

voltage

current

flat top uniformity

no. of modules

Ejection septum magnet

Ejection slow orbit-bump magnets

number

4

4.7.

Magnet Errors

DIPOLE ERRORS

a_n and b_n are the skew & regular coefficients of the $2(n+1)$ pole.

Units are 10^{-4} of dipole field at 1 cm.

Calculated Systematic Errors

	b_2	b_4	b_6	b_8	b_{10}	b_{12}	b_{14}
Geometric, at inj							
Geometric, ejec							

Calculated Random Errors

	a_0	a_1	a_2	a_3	a_4	a_5	a_6	a_7	a_8	a_9	a_{10}
rms-geom											
	b_0	b_1	b_2	b_3	b_4	b_5	b_6	b_7	b_8	b_9	b_{10}
rms-geom											

QUADRUPOLE ERRORS

Units are 10^{-4} of the quadrupole field at 1 cm.

Calculated Systematic Errors

	b_5	b_9	b_{13}	b_{17}
geometric				

Calculated Random Errors

	a_1	a_2	a_3	a_4	a_5	a_6
geometric, skew						
	b_1	b_2	b_3	b_4	b_5	b_6
geometric, regular						

Magnet Alignment and Uniformity Tolerances

Dipole

Δx -rms

pitch

roll

Δy -rms

$\Delta \phi$ -rms

$\Delta(BL)/BL$, rms

Quad

Δx -rms

pitch

roll

Δy -rms

$\Delta \phi$ -rms

$\Delta(B' L)/B' L$, rms

Correction and Trim Assembly

Δx -rms

Δy -rms

$\Delta \phi$ -rms

Beam-position monitor relative to quad

Δx -rms

Δy -rms

5.

Vacuum System

beam tube lengths

shaped, in dipole

circular

beam-tube material

beam-tube dimensions

shaped, in dipole

circular

beam-tube conductance

pressure required, avg. 3×10^{-11} torr, avg.

normal pumping

ion pumps

isolation valves

roughing

flanges and bellows

pumpdown hand valves

bake-out temperature

beam-tube insulation

pump-down time

6.

Main Power Supply

- current, ejec
- current regulation
- inductance, ring dipoles
- stored energy, ring dipoles
- inductance, ring quadrupoles
- stored energy, ring quadrupoles
- voltage during ramp
- voltage during de-ramp

7.

Tuning and Correction Power Supplies

	$BL (I_{max})$ (T-m, 1 cm)	Range (T-m)	Tolerance (T-m)	No. of Families	No. Elements/ Family
<i>primary package</i>					
dipole, H,V					
quad, QF, QD					
sext, SF,SD					
<i>secondary packages</i>					
quad, Q1,—,Q4					
skew quad, SQ1,—,SQ4					
sextupole, S1,—,S4					
skew sext.,SS1,—,SS4					
octupole, O1,—,O4					
skew octupole, SO1					
tuning power supplies					
<i>correction element supplies</i>					
	$BL (I_{max})$ (T-m, 1 cm)	Range (T-m)	Tolerance (T-m)	No. Families	No. Elements/ Family
<i>primary package</i>					
dipole, H,V					
quad, QF, QD					
sext, SF,SD					
<i>special packages</i>					
dipoles, H					
dipoles, V					
dipoles, H & V					
skew quad, SQ					

8.

Radio Frequency Acceleration System

radio frequency

	p	d	C	S	Cu	I	Au	
inj.	2.523	0.788	0.562	0.446	0.349	0.265	0.213	MHz
ejec.	4.114	3.877	3.884	3.885	3.804	3.522	3.061	MHz

revolution time

	p	d	C	S	Cu	I	Au	
inj.	1.1888	3.8082	5.3353	6.7307	8.6076	11.3061	14.0791	μs
ejec.	0.7292	0.7737	0.7724	0.7723	0.7887	0.8519	0.9800	μs

harmonic

3

acceleration time

62 ms, protons

500 ms, heavy ions

repetition rate

7.5 Hz (4 pulses/AGS pulse), protons

1 Hz (1 pulse/AGS pulse),

polarized protons

1 Hz (1 pulse/AGS pulse), heavy ions

energy gain

no. of stations

4 total

2 for protons

2 for heavy ions

vacuum aperture

	Inj		Ejec		
	protons	hvy ions	protons	hvy ions	
peak voltage	90	17	90	17	kV
synchronous phase					
long. emitt.					eV-s
bucket/bunch area ratio					
bucket half height, $\Delta E/E$					$\times 10^{-4}$
energy spread (σ_E/E)					$\times 10^{-4}$
rms bunch length					cm
synch. tune (f_s/f_o)					$\times 10^{-3}$
total RF power					kW

9. Booster Injection System

Transfer line from linac
length (from ___ to ___)

magnet sequence

dipole parameters
field
bend angle
length, effective
magnet gap
current
resistance
current regulation
number

quadrupole parameters
gradient
length, effective
pole-tip diameter
current
resistance
number

vacuum required

Proton injection fast-kicker magnets
number
type
field strength
magnet gap
eff. length of module
total length of module
bend angle, direction
rise time
flat top
fall time

voltage
current
flat top uniformity

Proton injection slow orbit-bump magnets

number
type
field strength
bend angle, direction
rise time
flat top
fall time
voltage
current
flat top uniformity

Transfer line from tandem

length (from __ to __)

magnet sequence

dipole parameters

field
bend angle
length, effective
magnet gap
current
resistance
current regulation
number

quadrupole parameters

gradient
length, effective
pole-tip diameter
current
resistance
number

vacuum required

Heavy-ion injection fast-kicker magnets

number
type
field strength
magnet gap
eff. length of module
total length of module
bend angle, direction
rise time
flat top
fall time
voltage
current
flat top uniformity

Heavy-ion injection electrostatic septum

number
type
electric field strength
electrostatic gap
eff. length of module
total length of module
deflection angle, direction
rise time
flat top
fall time
voltage
flat top uniformity

Heavy-ion injection slow orbit-bump magnets

number
type
field strength
bend angle, direction
rise time
flat top
fall time
voltage
current
flat top uniformity

10. Booster Ejection System

Transfer line to AGS

length (from ___ to ___)

magnet sequence

dipole parameters

field

bend angle

length, effective

magnet gap

current

resistance

current regulation

septum thickness, eff.

number

quadrupole parameters

gradient

length, effective

pole-tip diameter

current

resistance

number

stripper

vacuum required

Ejection fast-kicker magnets

number

type

field strength

magnet gap

eff. length of module

total length of module

bend angle, direction

rise time
flat top
fall time
voltage
current
flat top uniformity

Ejection septum magnet

number
type
field strength
magnet gap
eff. length of module
total length of module
bend angle, direction
rise time
flat top
fall time
current
voltage
flat top uniformity

Ejection slow orbit-bump magnets

number
type
field strength
bend angle, direction
rise time
flat top
fall time
voltage
current
flat top uniformity

11. Abort Systems

Absorber Blocks

location

absorber block section

beam energy into absorber blocks

material

dimensions

max temp. rise

Beam Dump System

location

component sequence

kicker magnets

type

field strength

length, effective

no. modules

wave shape

rise time

characteristic period

duration

peak current

voltage

beam dump

beam energy into dump

material

dimensions

max temp. rise

12. Instrumentation

Beam-Monitoring System

beam-position monitors

- resolution at 10^8 protons/bunch
- resolution at 10^8 protons/bunch
- resolution at 10^{10} protons/bunch
- length
- number, x and y
- mechanical position accuracy

beam-loss monitors

- sensitivity
- number

- dynamic range

Schottky pickup station

- beam-motion sensitivity
- number of stations per ring

beam-profile monitors

- wire
- wire speed
- number per ring
- resolution

beam-current monitors

- sensitivity
- resolution
- number per ring

Feedback System

transverse instability damping system

- operating frequency
- length of 50-ohm terminated strip line
- system bandwidth
- total power
- number of systems, per ring

13. Control System

Computer System

host computer characteristics:

CPU's

RAM

disk storage

magnetic tape

high speed bus

communication

no. terminals

floor space

ac power

Booster Ring Communication Links:

cable bandwidth

cable assignments

(Fiber-optic links probably cannot be used in the tunnel because of their vulnerability to radiation damage.)

Control and Monitor Points

beam position monitors

beam loss monitors

beam profile

vacuum pump status and current

vacuum gauge current

gate valves

PS voltage taps

dipole corrector status,

readback, and reference

other correctors

energy dumps

miscellaneous

tunnel environment

totals

14. Conventional Facilities

tunnel	
type	helical (corrugated) steel pipe
length	675 feet
mean radius, from Booster center	107.5 feet
cross-section	diameter, 10 feet
	height from concrete floor, 8 feet at center
shielding	
power supply stations, no.	
area	
RF station alcoves, number	
area	
height

Figure 1. The layout of the Booster.

0 5
METERS
NOTE: ALL DIMENSIONS ARE IN METERS

Figure 2. The booster lattice and components of a superperiod.

- = FOCUSING QUADRUPOLE
- = DEFOCUSING QUADRUPOLE
- = BENDING MAGNET (DIPOLE)
- X = SEXTUPOLE

Figure 3. Amplitude and dispersion functions for the Booster lattice.

Figure 4. Dipole magnet, cross-section.

Figure 6. Quadrupole magnet.

Figure 7. The effect of silicon content on the resistivity of the lamination steel.

Figure 8. Beveled ends to ameliorate end effects.

Figure 9. Iso-field region in a dipole.

Figure 10. Movement of the iso-field boundary for 2-mil error in bump height.

Figure 11. Shrinkage of good field region with increase in B .

Figure 12. Saturation effects on field linearity.

Figure 13. Flux pattern in the region of the coil.

Figure 14. Flux pattern in the quadrupole aperture.

Figure 16. Quadrupole assembly.

TRIAL	INSULATION (W/APPED)	POWER INPUT (WATTS)	TEMP. °F	
			POLE TIP	INSIDE
1	.04 FIBERGLASS TAPE	150	140	251
2	.04" FIBERGLASS + AL KAPTON + .01 FIBERGLASS	150	140	300
3	.05" FIBERGLASS + AL KAPTON	150	130	275
4	.09" FIBERGLASS + 2 AL KAPTON	150	125	303
5	.09" FIBERGLASS + 2 AL KAPTON	250	156	387
6	.120" FIBERGLASS + 3 AL KAPTON	250	160	401

Figure 17. Bake-out experiment with quadrupole.

Figure 18. Relationship between quadrupole at F8 and dipole at A1.

Figure 18 B, The angle α .

Figure 19. Foil location downstream of dipole.

Figure 20. Bump in the circulating beam at injection.

Figure 21. Linac to Booster Injection Line.

INJECTION TRAJECTORIES (CD5)

Figure 22. Injection trajectory in dipole magnet MDC5.

Figure 23. Populating the phase space with the injected beam.

Figure 24. Location of the bump in the ring lattice.

Figure 25. Injected and circulating polarized proton beams.

Figure 26. Heavy-ion transfer and injection line to the Booster.

Figure 27. Booster ejection line to the AGS.

Half-Cell 1

CT Assembly = Correction and
Trim Assembly

PUE = Pick-Up Electrodes

T = Transition from elliptical
to circular beam pipe

Figure 28. The first half-cell of each superperiod has, in general, a sextupole and a CT assembly in addition to the dipole and quadrupole. This half-cell is identical to half-cells 4 and 7 and differs from half-cell 2 only in its being followed by another dipole instead of being followed by a straight section.

Half-Cell 2

Figure 29. Half-cell 2 is followed by a straight section, thus no transition piece is required for the beam pipe downstream of the quadrupole.

Half-Cell 3

Figure 30. Half-cell 3 is identical to half-cell 6. In superperiod F, the CT Assembly is omitted in half-cell 3.

Half-Cell 5

Figure 32. Half-cell 5, like half-cell 2, is followed by a straight section, but it does not contain a sextupole. In superperiod C, the CT assembly is omitted and a carbon foil is present for H^- stripping. The CT assembly is also eliminated in this half-cell in superperiod A.

Half-Cell 4

Figure 31, Half-cell 4 is identical to half-cell 1.

Half-Cell 6

Figure 33. Half-cell 6 is identical to half-cell 3. In superperiod F, the CT assembly is omitted.

Half-Cell 7

Figure 34. Half-cell 7 is identical to half-cell 1.

Half-Cell 8

Figure 35. Half-cell 8 differs from half-cells 1, 4, and 7 only in its not having a sextupole. The CT assembly is omitted in this half-cell in superperiods C and F.

Figure 36, Commutation overlap.

Figure 37, Injection undershoot process.

Figure 38. Filter designs for the dipole rectifier system.

Figure 39. Dipole field versus time for different accelerating bucket areas.

Figure 40, dB/dt and dipole voltage versus time.

Figure 41, Proton accelerating cycle.

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TABLE
AGS BOOSTER PARAMETER LIST

	Protons	Polarized Protons	Heavy Ions
Energy			
Injection	200 MeV	200 MeV	$> 1 \text{ MeV/nucleon}$
Ejection	1.5 GeV	1.5 GeV	$p = 5.25 \text{ } Q/A \text{ (GeV/c)/nucleon}$
Lattice			
Circumference		201.78 m (1/4 AGS)	
Periodicity		6	
Number of cells		24 FODO	
Cell length		8.4075 m	
Phase advance/cell		$72.3^\circ / 72.45^\circ$	
ν_x / ν_y (nominal)		4.82/4.83	
β_y max/min		13.6/3.7 m	
x_p max		2.95 m	
transition γ		4.88	
RF System			
Number of stations	2	2	2
Harmonic number	3	3	3
Frequency range (MHz)	2.5 — 4.11	2.5 — 4.11	0.200 — 2.5
Peak RF voltage	90	90	17
Acceleration time (ms)	62	62	500
Repetition rate	7.5 Hz (4/AGS pulse)	1 Hz (1/AGS)	1 Hz (1/AGS)
Dipoles			
Number		36	
Length (magnetic)		2.4 m	
Gap		82.55 mm	
Vacuum chamber aperture		66 mm	
Good field region ($< 10^{-4}$)		$16 \times 6.6 \text{ cm}$	
Injection field (kG)	1.56	1.56	$0.108 \text{ } A/Q$
Ejection field	5.46	5.46	12.74
Quadrupoles			
Number		48	
Length (magnetic)		50.375 cm	
Aperture		16.5 cm	
Vacuum chamber aperture		15.25 cm	
Injection pole tip field (kG)	1.02	1.02	$0.068 \text{ } A/Q$
Ejection pole tip field (kG)	3.6	3.6	8.3
Field Quality 6/2		0.0	
All other harmonics		$< 10^{-4}$	
Chromaticity Sextupoles			
Number		2×12	
Length (magnetic)		10 cm	
Max. pole tip field (kG)		3.0	
Max. Vacuum Pressure		$3 \times 10^{-11} \text{ torr}$	