Silicon, Iron, and Copper Ions for RHIC

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1 Review Au and d Setup

Figures 1, 2, 3, 4, 5, 6, 7, 8

2 Silicon, Iron, Nickel, and Copper Parameters

Tables 1, 2, 3, 4, 5, 6

References

[1] C.J. Gardner, et al, “Status and Recent Performance of the Accelerators that Serve as Gold Injector for RHIC”, PAC01, Chicago (2001) 3326–3328.

[2] L. A. Ahrens, et al, “The RHIC Injector Accelerator Configurations and Performance for the RHIC 2003 Au-d Physics Run”, PAC03, Portland, Oregon (2003) 1715–1717.

[3] C.J. Gardner, “Booster, AGS, and RHIC Parameters for the 2003–2004 RHIC Run”, August 26, 2003.

3 Intensities

Currents of Si^{5+} as high as 230 μA have been observed in the TTB line with the Si^{-} source running “flat out”, but typically the current is between 50 and 100 μA. For Si^{5+} ions with 63.8 MeV kinetic energy at Booster injection, the revolution period is 9.63 μs. Since experience has shown that no more than 45 turns can fit into the Booster acceptance, the maximum pulse width that can be accepted by Booster is then 433 μs. Assuming a pulsed current of 100 μA in the TTB line, one then has 54×10^9 silicon ions available per Tandem pulse at Booster injection. Booster output/input is typically 50% or less. The maximum intensity available per Booster cycle would then be $\underline{27 \times 10^9 \text{ silicon ions}}$.

Currents of Fe^{10+} in the TTB line are also typically between 50 and 100 μA. These ions are transported down the TTB line at the same rigidity as Si^{5+}, and, since the charge-to-mass ratios of the two ions are nearly identical, the velocities are nearly identical. Assuming a pulsed current of 100 μA and the same pulse width as for silicon, one then has 27×10^9 iron ions available per Tandem pulse at Booster injection. With Booster output/input at 50%, a maximum of $\underline{13.5 \times 10^9 \text{ iron ions}}$ are available per Booster cycle.

Currents of Cu^{11+} in the TTB line are also expected to be between 50 and 100 μA. The revolution period of these ions in Booster is 9.22 μs which for 45 turns gives a pulse width of 415 μs. At a current of 100 μA one then has 24×10^9 copper ions available per Tandem pulse at Booster injection. The maximum intensity available at extraction per Booster cycle would then be $\underline{12 \times 10^9 \text{ copper ions}}$.

With the acceleration scheme used for the past several years, one Booster load ends up in one RHIC bunch and (RHIC Input)/(Booster Output) is typically at least 50%.

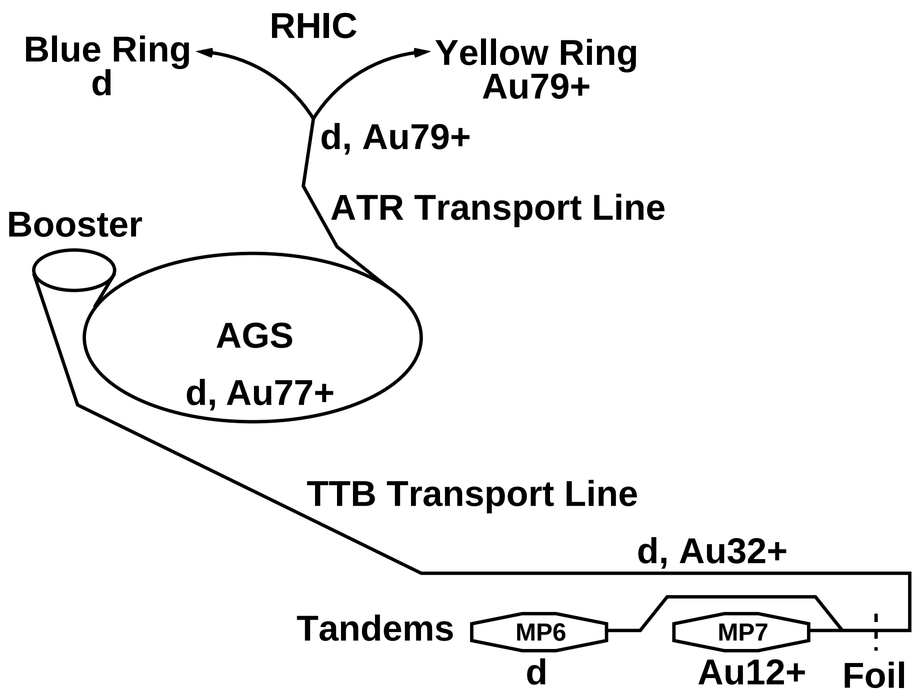

Figure 1: Acceleration of Gold Ions and Deuterons for RHIC

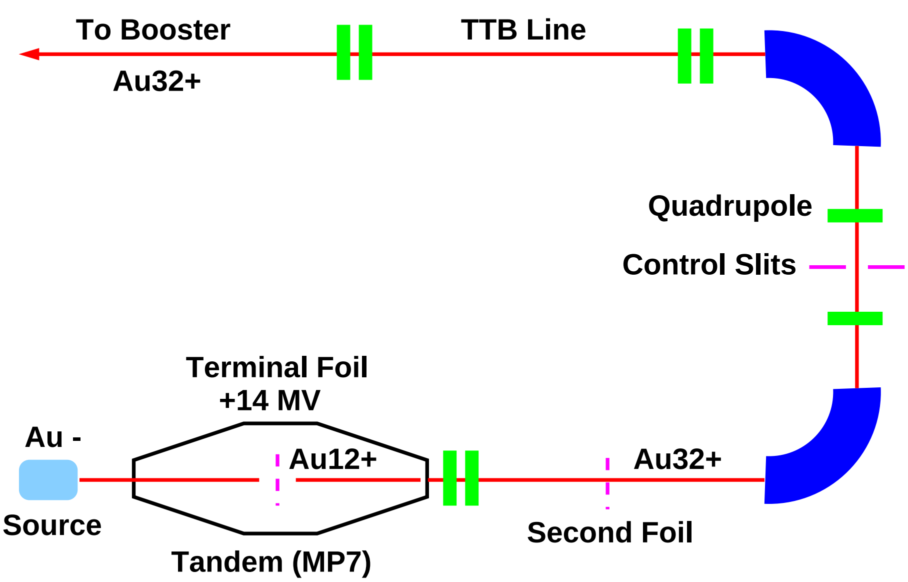

Figure 2: Gold Ions from Source through Tandem to TTB Line

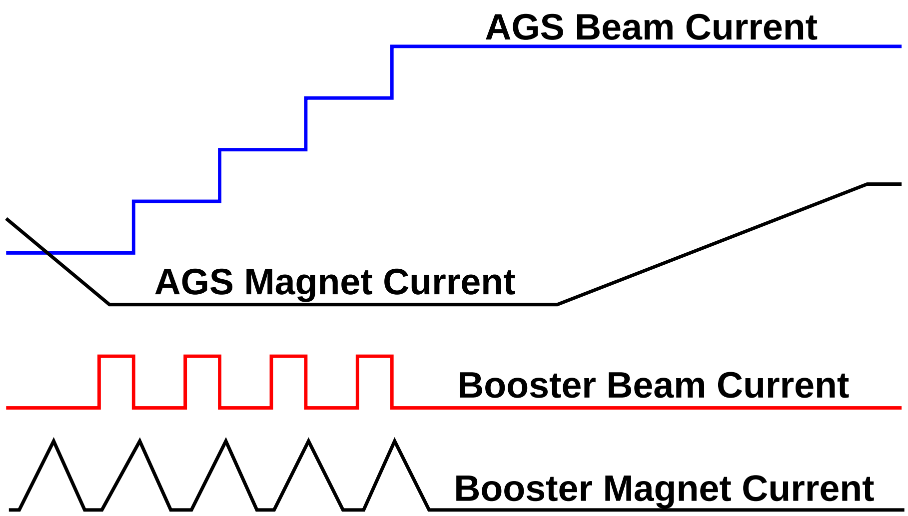

Figure 3: Timing of Booster and AGS Cycles

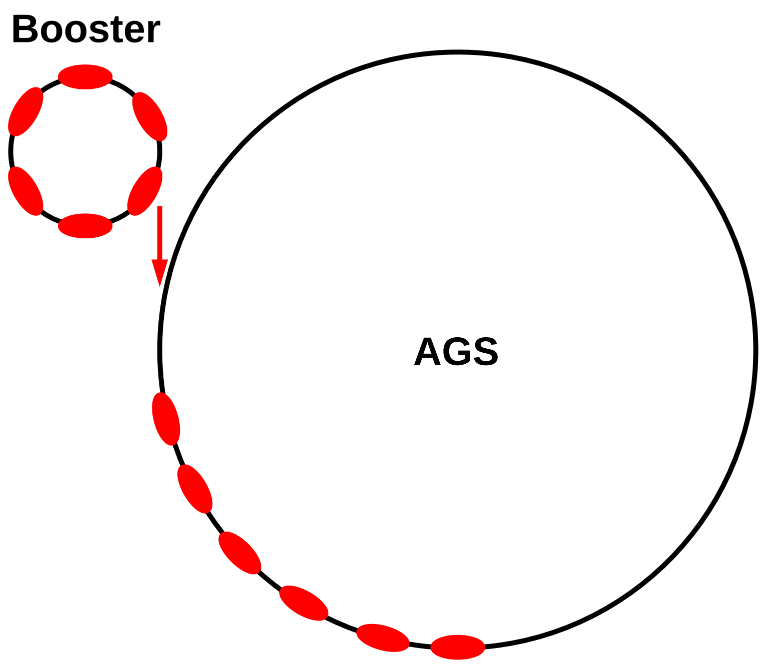

Figure 4: Transfer of One Booster Load to AGS

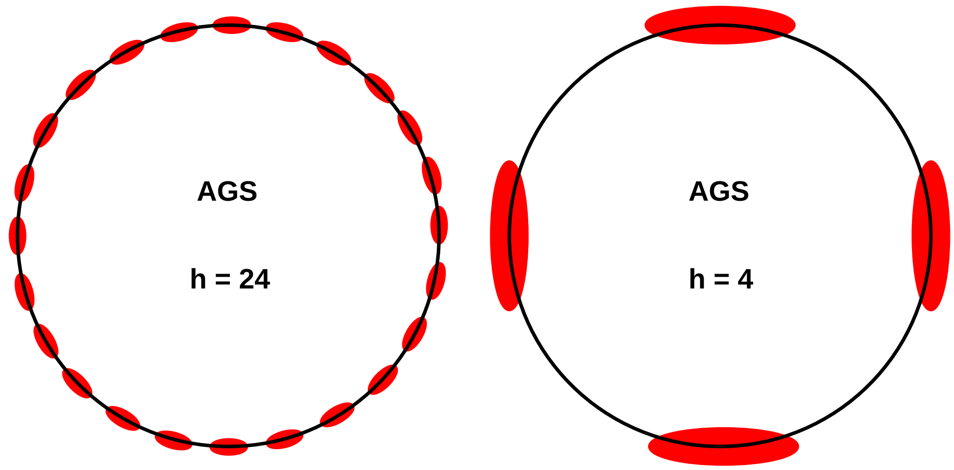

Figure 5: 24 Bunches Rebunched into Four

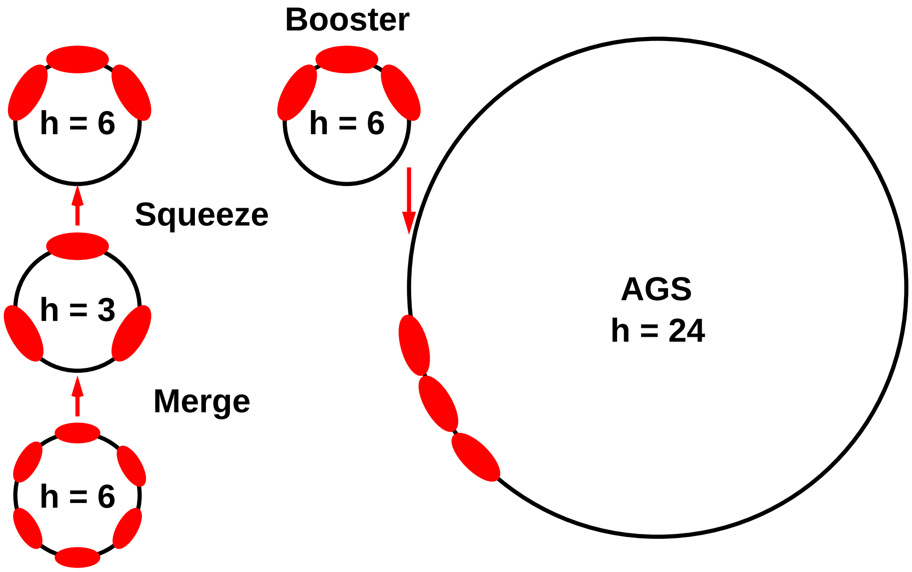

Figure 6: Booster Merge and Squeeze to Double Intensity per Bunch

Table 1: Tandem and Booster Injection Parameters

Ion	Tandem Voltage V_T (MV)	Kinetic Energy W (MeV)	Inflector Voltage V_I (kV)	Magnetic Rigidity $B\rho$ (Tm)	RF Harm h	Injection Frequency hf (kHz)
Au^{32+}	14.058	182.879	22.218	0.854085	6	397.740
d	8.636	17.3965	67.355	0.854085	2	401.922
Si^{5+}	10.616	63.822	49.588	1.217428	6	622.770
Fe^{10+}	11.838	127.687	49.604	1.217428	6	622.980
Ni^{10+}	11.196	123.288	47.899	1.217428	6	601.567
Cu^{11+}	13.046	156.675	55.327	1.300433	6	650.493

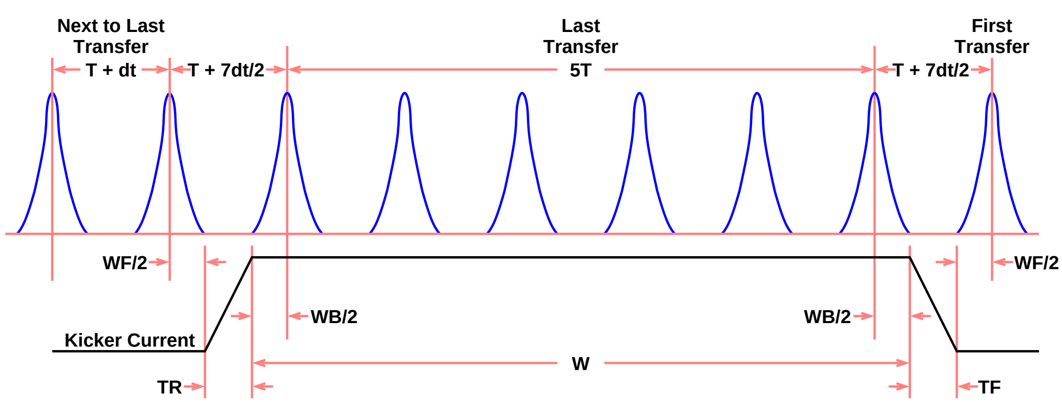

Figure 7: AGS Injection Kicker Timing for Transfer of One Booster Load. The kicker width is fixed; this fixes the Booster extraction frequency.

Table 2: Rigidities and Frequencies

Ion	h	Booster Injection $B\rho$ (Tm)	Booster Injection hf (kHz)	Booster Extraction $B\rho$ (Tm)	Booster Extraction hf (MHz)	AGS Injection $B\rho$ (Tm)
Au	6	0.854085	397.740	9.1360	3.842917	3.7216
d	2	0.854085	401.922	7.3224	2.259236	7.3224
Si^{5+}	6	1.217428	622.770	8.323813	3.850	2.972266
Fe^{10+}	6	1.217428	622.980	8.321000	3.850	3.199882
Ni^{10+}	6	1.217428	601.567	8.618614	3.850	3.077552
Cu^{11+}	6	1.300433	650.493	8.510510	3.850	3.227618

Table 3: Frequencies and Periods

Ion	h	Booster Injection hf (kHz)	Booster Extraction hf (MHz)	Revolution Period $1/f$ (ns)	Bunch Spacing $1/(hf)$ (ns)
Au	6	397.740	3.842917	1561.31	260.219
d	2	401.922	2.259236	885.255	442.627
Si^{5+}	6	622.770	3.850	1558.44	259.740
Fe^{10+}	6	622.980	3.850	1558.44	259.740
Ni^{10+}	6	601.567	3.850	1558.44	259.740
Cu^{11+}	6	650.493	3.850	1558.44	259.740

Table 4: Emittances assuming aperture filled to 185π at Booster Injection

Ion	h	Booster Injection $\beta_0\gamma_0$	Booster Extraction $\beta\gamma$	Adiabatic Ratio $\beta_0\gamma_0/(\beta\gamma)$	BTA Emittance $\epsilon\pi$	Normalized Emittance $\epsilon_N\pi$
Au	6	0.0447	0.4777	0.0936	17.3π	8.26π
d	2	0.1365	1.1704	0.1166	21.6π	25.3π
Si^{5+}	6	0.0700	0.4788	0.1462	27.2π	13.0π
Fe^{10+}	6	0.0701	0.4788	0.1464	27.2π	13.0π
Ni^{10+}	6	0.0676	0.4788	0.1412	26.1π	12.5π
Cu^{11+}	6	0.0732	0.4788	0.1529	28.3π	13.5π

Table 5: Stationary Bucket Area at End of Capture (assuming 0.5 kV gap voltage at end of capture).

Here $h\frac{A_S}{N} = 8\,\frac{R_s}{c}\left\{\frac{2}{\pi|\eta_s|}\right\}^{1/2}\left\{\frac{E_s}{N}\right\}^{1/2}\left\{\frac{Q}{Nh}\right\}^{1/2}\{eV_g\}^{1/2}$.

Ion	Q	N	h	η_s	E_s/N	$Q/(Nh)$	hA_S/N
Au	32	197	6	-0.955	932.181	0.0271	0.0786
d	1	2	2	-0.938	946.505	0.2500	0.2428
Si^{5+}	5	28	6	-0.952	932.915	0.0298	0.0826
Fe^{10+}	10	56	6	-0.952	932.600	0.0298	0.0826
Ni^{10+}	10	58	6	-0.952	932.493	0.0287	0.0811
Cu^{11+}	11	63	6	-0.951	932.851	0.0291	0.0817

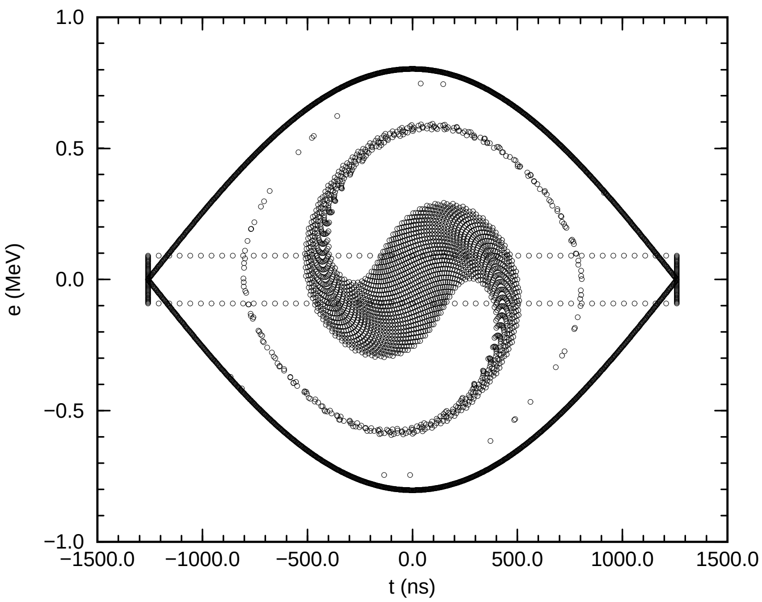

Figure 8: Au^{32+} distribution at end of RF capture in Booster. Here $h = 6$, $V_g = 0.5$ kV. The bucket area gives an upper limit on the longitudinal emittance in Booster.

Table 6: Longitudinal parameters for single bunch of gold ions (measured by J.M. Brennan). Six of these bunches become one RHIC bunch.

Parameter	Booster Extraction	After BTA Foil	After AGS Filamentation	Unit
ϵ	0.045/6	$4 \times 0.045/6$	$6 \times 0.045/6$	eV-s/n
Δt	48	48	76	ns
ΔE	20	76	76	MeV
hf	3.848719	3.848719	3.775458	MHz
$1/(hf)$	259.827	259.827	264.868	ns