Modification of the U-Line of the RHIC Injection Line

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RHIC PROJECT

Brookhaven National Laboratory
Associated Universities, Inc.
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The parameters of the U-line of the RHIC injection line with low β waist are described in Reference 1. In that lattice, the location of SA is not dispersion free and 14 quadrupoles are needed. This line has been modified to move SA to a dispersion free region (after the 8-degree bend), the length and maximum gradient of quadrupoles have been adjusted to fit the existing quadrupole parameters and the number of quadrupoles is reduced to 12.

The Effect of Dispersion Functions at SA

According to Reference 2, the energy loss of 10.4 GeV/u Au ion after passing Au foil ($\sim$ 40 mg/cm^2) is 0.65 MeV/u and the additional rms energy spread is 0.065 MeV/u. In the lattice of reference 1, at SA $\eta_x = 3.816$ m, $\eta_x' = -0.019$, $\eta_y = 0$, $\eta_y' = 0$. After passing foil SA, the additional rms Δx and $\Delta x'$ due to additional energy spread are

$$\Delta x_{rms} = 0.02 \text{ mm}$$

$$\Delta x'_{rms} = 1.2 \times 10^{-4} \text{ mrad}$$

The induced rms beam emittance growth is about 6.25×10^{-5} mm·mrad. The injection beam rms emittance is 0.13 mm·mrad. So, the relative emittance growth is only 4.8×10^{-4} which is negligible small.

After passing foil SA, the change of the closed orbit due to energy loss are

$$\Delta x_{co} = 0.2 \text{ mm}$$

$$\Delta x'_{co} = 1.2 \times 10^{-3} \text{ mrad.}$$

This change of closed orbit after the foil SA should be corrected by proper dipole correctors otherwise this closed orbit shift will introduce a shift of beam center. In order to avoid this problem in the modified U-line, foil SA is moved to a dispersion free region.

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The Parameters of the Modified U-Line

The parameters of the modified U-line are shown in Table 1, which is the output of MAD program. The β value at SA is 6 meters and the maximum β value in quadrupoles is 208 meters which is larger than 117 meters in the lattice of reference 1. But considering that, the aperture of the quadrupoles in the U-line is 100 mm, the maximum half beam height is 25.8 mm even when taking 3.2 mm·mrad as the beam emittance. This maximum beam height is less than 60% of the quadrupole aperture and the actual beam emittance is only 0.8 mm·mrad. So, there is enough safety margin.

The maximum beam cross section is smaller if β at SA is larger. The corresponding maximum β values for different β values at SA are shown in Table 2. The maximum beam cross section may be reduced further if we add some extra quadrupole to strengthen the focusing status if this is necessary.

Table 2:

β at SA	6.0	6.1	6.2	6.4	6.6
$\beta_{x,max}$	195.6	199	192.2	191.5	189.9
$\beta_{y,max}$	207.9	199	202.2	194.4	189.3

The parameters of the existing quadrupoles for U-line are shown in Table 3. The parameters of the quadrupoles of this modified lattice are all fit to these existing quadrupoles.

Table 3:

Length (m)	Maximum Gradient (T/M)
0.72	15.5
0.74	17.5
1.0	17.5

References

1. The Effect of the Stripping Foil SA on the Injection Beam of RHIC, Jianming Xu, AD/RHIC/RD-18, 1990.

2. The Heavy Ion Stripping Foil Requirements between AGS and RHIC, M.J. Rhoades- Brown, AD/RHIC-68, 1990.

Table 1

RHIC U-LINE

```
          LUKS:DRIFT,L=5.00000
          LU01:DRIFT,L=0.374005
          LU12:DRIFT,L=0.495300
          LU231:DRIFT,L=0.477256
          LU232:DRIFT,L=0.459994
          LU233:DRIFT,L=0.459994
          LU234:DRIFT,L=0.255379
          LU34:DRIFT,L=15.139416
          LU45:DRIFT,L=13.534843-LU56
          LU56:DRIFT,L=6.775303
          LU67:DRIFT,L=14.622923
          LU78:DRIFT,L=15.89473
          LU891:DRIFT,L=16.153343-LU78
          LU892:DRIFT,L=0.609600
          LU193:DRIFT,L=0.609600
          LU293:DRIFT,L=0.609600
          LU894:DRIFT,L=0.609600
          LU895:DRIFT,L=3.864866
          LU910:DRIFT,L=10.14717
          LU011:DRIFT,L=1.06847
          LU112:DRIFT,L=32.131006-LU910
          LU10:DRIFT,L=.10
          LX:DRIFT,L=3.310474

          UQ1:QUADRUPOLE,TYPE=MQ,L=0.9525,K1=0.3428809
          UQ2:QUADRUPOLE,TYPE=MQ,L=0.9525,K1=-0.3444411
          UQ3:QUADRUPOLE,TYPE=MQ,L=0.4572,K1=.1065712
          UQ4:QUADRUPOLE,TYPE=MQ,L=0.72644,K1=-.08625500
          UQ5:QUADRUPOLE,TYPE=MQ,L=1.0,K1=0.1292571
          UQ6:QUADRUPOLE,TYPE=MQ,L=0.72644,K1=-.08182768
          UQ7:QUADRUPOLE,TYPE=MQ,L=0.72644,K1=-0.04932067
          UQ8:QUADRUPOLE,TYPE=MQ,L=0.72644,K1=0.074032067
          UQ9:QUADRUPOLE,TYPE=MQ,L=0.72644,K1=-0.05987292
          UQ10:QUADRUPOLE,TYPE=MQ,L=1.0,K1=0.1227592
          UQ11:QUADRUPOLE,TYPE=MQ,L=1.0,K1=-.1074035
          UQ12:QUAD,TYPE=MQ,L=0.72644,K1=.1126315
          SA:MONITOR,L=0.0


          UD1:RBEND,TYPE=UD,L=2.080006,ANGLE=24.725E-3
          UD2:RBEND,TYPE=UD,L=2.080006,ANGLE=24.725E-3
          UD3:RBEND,TYPE=UD,L=2.080006,ANGLE=24.725E-3

          U4F:RBEND,TYPE=UD8F,L=3.657600,ANGLE=34.906E-3,K1=0.018823143
          U5D:RBEND,TYPE=UD8D,L=3.657600,ANGLE=34.906E-3,K1=-0.018823143
          U6D:RBEND,TYPE=UD8D,L=3.657600,ANGLE=34.906E-3,K1=-0.018823143
          U7F:RBEND,TYPE=UD8F,L=3.657600,ANGLE=34.906E-3,K1=0.018823143


          U1:LINE=(LUKS,LU01,UQ1,LU12,UQ2,LU231,UD1,LU232,UD2,LU233,UD3,&
              LU234,UQ3,LU34,UQ4,LU45,UQ5,LU56,&
            UQ6,LU67,UQ7,LU78,UQ8,LU891,U4F,LU892,U5D,LU193,LU293,U6D,LU894,U7F,&
            LU895,UQ9,LX,SA,LU910,UQ10,LU10,UQ10,LU011,UQ11,LU10,UQ11,LU112,UQ12)


TWISS,DELTAP=0E-3,BETX=37.59,BETY=8.05,ALFX=-4.778,ALFY=1.053,DX=-2.96,&
          dPX=-0.295,DY=0,DPY=0,X=0E-4,Y=0E-4,PX=0E-4,PY=0E-4
```

POS. NO.	ELEMENT SEQUENCE ELEMENT NAME	OCC. NO.	DIST [M]	I I I	BETAX [M]	ALFAX [1]	MUX [2PI]	X(CO) [MM]	PX(CO) [.001]	DX [M]	DPX [1]	I I	BETAY [M]	ALFAY [1]	MUY [2PI]	Y(CO) [MM]	PY(CO) [.001]	DY [M]	DPY [1]
BEGIN U1		1	0.000		37.590	-4.778	0.000	0.000	0.000	-2.960	-0.295		8.050	1.053	0.000	0.000	0.000	0.000	0.000
1	LUKS	1	5.000		101.218	-7.948	0.013	0.000	0.000	-4.435	-0.295		4.069	-0.257	0.169	0.000	0.000	0.000	0.000
2	LU01	1	5.374		107.252	-8.185	0.013	0.000	0.000	-4.545	-0.295		4.298	-0.355	0.183	0.000	0.000	0.000	0.000
3	UQ1	1	6.327		90.279	24.117	0.015	0.000	0.000	-4.123	1.158		6.868	-2.617	0.213	0.000	0.000	0.000	0.000
4	LU12	1	6.822		67.972	20.920	0.016	0.000	0.000	-3.549	1.158		9.741	-3.184	0.223	0.000	0.000	0.000	0.000
5	UQ2	1	7.774		49.319	0.660	0.019	0.000	0.000	-2.957	0.118		12.812	0.302	0.235	0.000	0.000	0.000	0.000
6	LU231	1	8.252		48.696	0.646	0.020	0.000	0.000	-2.900	0.118		12.544	0.261	0.241	0.000	0.000	0.000	0.000
7	UD1	1	10.332		46.133	0.586	0.027	0.000	0.000	-2.629	0.143		11.818	0.088	0.269	0.000	0.000	0.000	0.000
8	LU232	1	10.792		45.600	0.572	0.029	0.000	0.000	-2.563	0.143		11.755	0.048	0.275	0.000	0.000	0.000	0.000
9	UD2	1	12.872		43.345	0.512	0.036	0.000	0.000	-2.241	0.168		11.916	-0.126	0.303	0.000	0.000	0.000	0.000
10	LU233	1	13.332		42.880	0.499	0.038	0.000	0.000	-2.164	0.168		12.049	-0.165	0.309	0.000	0.000	0.000	0.000
11	UD3	1	15.412		40.932	0.438	0.046	0.000	0.000	-1.789	0.192		13.096	-0.338	0.336	0.000	0.000	0.000	0.000
12	LU234	1	15.667		40.710	0.431	0.047	0.000	0.000	-1.740	0.192		13.274	-0.360	0.339	0.000	0.000	0.000	0.000
13	UQ3	1	16.124		39.428	2.353	0.049	0.000	0.000	-1.633	0.275		13.924	-1.072	0.344	0.000	0.000	0.000	0.000
14	LU34	1	31.264		6.181	-0.157	0.259	0.000	0.000	2.524	0.275		81.764	-3.409	0.418	0.000	0.000	0.000	0.000
15	UQ4	1	31.990		6.790	-0.694	0.277	0.000	0.000	2.783	0.440		82.982	1.757	0.420	0.000	0.000	0.000	0.000
16	LU45	1	38.750		26.150	-2.170	0.362	0.000	0.000	5.759	0.440		61.478	1.424	0.435	0.000	0.000	0.000	0.000
17	UQ5	1	39.750		27.097	1.264	0.368	0.000	0.000	5.821	-0.316		66.724	-6.894	0.437	0.000	0.000	0.000	0.000
18	LU56	1	46.525		14.372	0.614	0.424	0.000	0.000	3.678	-0.316		193.535	-11.822	0.447	0.000	0.000	0.000	0.000
19	UQ6	1	47.251		14.135	-0.283	0.432	0.000	0.000	3.526	-0.103		202.362	-0.153	0.447	0.000	0.000	0.000	0.000
20	LU67	1	61.874		38.734	-1.400	0.539	0.000	0.000	2.021	-0.103		207.926	-0.227	0.459	0.000	0.000	0.000	0.000
21	UQ7	1	62.601		41.861	-2.942	0.542	0.000	0.000	1.972	-0.032		202.888	7.102	0.459	0.000	0.000	0.000	0.000
22	LU78	1	78.495		193.635	-6.607	0.571	0.000	0.000	1.471	-0.032		41.172	3.072	0.487	0.000	0.000	0.000	0.000
23	UQ8	1	79.222		195.640	3.884	0.571	0.000	0.000	1.419	-0.110		38.357	0.854	0.490	0.000	0.000	0.000	0.000
24	LU891	1	79.480		193.636	3.863	0.571	0.000	0.000	1.391	-0.110		37.918	0.842	0.491	0.000	0.000	0.000	0.000
25	U4F	1	83.138		126.103	13.028	0.575	0.000	0.000	0.898	-0.154		41.651	-1.947	0.506	0.000	0.000	0.000	0.000
26	LU892	1	83.748		110.722	12.203	0.576	0.000	0.000	0.804	-0.154		44.066	-2.017	0.509	0.000	0.000	0.000	0.000
27	U5D	1	87.405		55.697	4.086	0.583	0.000	0.000	0.384	-0.080		47.628	1.127	0.521	0.000	0.000	0.000	0.000
28	LU193	1	88.015		50.833	3.893	0.585	0.000	0.000	0.335	-0.080		46.272	1.098	0.523	0.000	0.000	0.000	0.000
29	LU293	1	88.624		46.205	3.699	0.587	0.000	0.000	0.286	-0.080		44.951	1.069	0.525	0.000	0.000	0.000	0.000
30	U6D	1	92.282		31.639	0.613	0.603	0.000	0.000	0.083	-0.033		28.525	3.036	0.541	0.000	0.000	0.000	0.000
31	LU894	1	92.892		30.908	0.587	0.606	0.000	0.000	0.062	-0.033		24.957	2.818	0.544	0.000	0.000	0.000	0.000
32	U7F	1	96.549		20.686	1.970	0.628	0.000	0.000	0.000	0.000		12.722	0.802	0.579	0.000	0.000	0.000	0.000
33	LU895	1	100.414		8.982	1.058	0.674	0.000	0.000	0.000	0.000		8.455	0.303	0.639	0.000	0.000	0.000	0.000
34	UQ9	1	101.141		7.825	0.552	0.688	0.000	0.000	0.000	0.000		7.827	0.552	0.653	0.000	0.000	0.000	0.000
35	LX	1	104.451		5.999	0.000	0.768	0.000	0.000	0.000	0.000		6.000	0.000	0.734	0.000	0.000	0.000	0.000
36	SA	1	104.451		5.999	0.000	0.768	0.000	0.000	0.000	0.000		6.000	0.000	0.734	0.000	0.000	0.000	0.000
37	LU910	1	114.598		23.166	-1.692	0.933	0.000	0.000	0.000	0.000		23.159	-1.691	0.899	0.000	0.000	0.000	0.000
38	UQ10	1	115.598		23.709	1.170	0.940	0.000	0.000	0.000	0.000		29.959	-5.386	0.905	0.000	0.000	0.000	0.000
39	LU10	1	115.698		23.476	1.160	0.941	0.000	0.000	0.000	0.000		31.046	-5.486	0.905	0.000	0.000	0.000	0.000
40	UQ10	2	116.698		18.671	3.447	0.948	0.000	0.000	0.000	0.000		47.951	-12.105	0.910	0.000	0.000	0.000	0.000
41	LU011	1	117.767		12.093	2.710	0.959	0.000	0.000	0.000	0.000		77.331	-15.392	0.912	0.000	0.000	0.000	0.000
42	UQ11	1	118.767		8.338	1.179	0.976	0.000	0.000	0.000	0.000		100.914	-7.340	0.914	0.000	0.000	0.000	0.000
43	LU10	2	118.867		8.105	1.150	0.977	0.000	0.000	0.000	0.000		102.387	-7.395	0.914	0.000	0.000	0.000	0.000
44	UQ11	2	119.867		6.836	0.164	0.999	0.000	0.000	0.000	0.000		106.056	3.858	0.916	0.000	0.000	0.000	0.000
45	LU112	1	141.850		72.219	-3.138	1.226	0.000	0.000	0.000	0.000		8.810	0.565	1.044	0.000	0.000	0.000	0.000
46	UQ12	1	142.577		72.470	2.800	1.228	0.000	0.000	0.000	0.000		8.570	-0.229	1.057	0.000	0.000	0.000	0.000
END	U1	1	142.577		72.470	2.800	1.228	0.000	0.000	0.000	0.000		8.570	-0.229	1.057	0.000	0.000	0.000	0.000

```
----------------------------------------------------------------------------------------------------
TOTAL LENGTH =        142.576927         MUX        =        1.227746    MUY        =        1.057056
DELTA(S)     =          0.000000 mm      DMUX       =       -4.202104    DMUY       =       -2.489040
                                         BETAX(MAX) =      195.639767    BETAY(MAX) =      207.925719
                                         DX(MAX)    =        5.821198    DY(MAX)    =        0.000000
----------------------------------------------------------------------------------------------------
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