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Modification of the U-Line of the RHIC Injection Line

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September 1991

RHIC PROJECT

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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.

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 NAME	OCC. NO.	DIST [M]	BETAX [M]	ALFAX [1]	MUX [2PI]	X(CO) [MM]	PX(CO) [.001]	DX [M]	DPX [1]	BETAY [M]	ALFAY [1]	MUY [2PI]	Y(CO) [MM]	PY(CO) [.001]	DY [M]	DPY [1]
	ELEMENT SEQUENCE		I	HORIZONTAL						I	VERTICAL						
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