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RHIC PROJECT

Brookhaven National Laboratory

The Low β Waist in the Beam Transport Line for the Stripping Foil SA

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For the heaviest ions, it is necessary to pass through a stripping foil SA in the beam transport line to remove the last two electrons in the K–shell before injected into RHIC.[1] At the top energy of AGS the rms scattering angle for a 100 mg/cm^2 copper foil is 0.046 mrad. The corresponding rms emittance growth is $\beta < \theta >^2$ ($\alpha << 1$). So it is desirable to put this foil at a low β waist.

The lattice of the U–line of the beam transport line[2] from AGS to RHIC is modified so as to form a low β waist at a point 1.925 meters upstream of UQ5. Two quadrupoles UQ4' and UQ6' are added in order to form this waist. UQ4' is 6 meters downstream of UQ3 and UQ6' is 10.726 meters upstream of UQ7. The positions of UQ4 and UQ6 are moved upstream 5.413 meters and 3 meters respectively also.

The required parameters of the elements in U–line are shown in Table 1 (input data of MAD). The Twiss parameters and the relative positions of the elements can be found from Table 2 (output of MAD). The stripping foil SA will be put at the end of the 20th element – the second LU100, where $\beta_x = \beta_y = 5$ meters and $\alpha_x = \alpha_y = 0$. The corresponding rms emittance growth is 0.0106π mm·mrad and the relative emittance growth is 8% (the AGS ejected beam rms emittance is 0.13π mm·mrad) which is very small.

Dr. M.J. Rhoades–Brown has studied the energy loss ΔE and the increased energy spread $< \delta E >$ of the gold beam after crossing the foil SA also. ΔE is about 1.7 MeV/u and the beam energy E is 10.4 GeV. So, $\Delta E/E$ is about 1.6×10^{-4}. $< \delta E >$ is about 0.17 MeV/u and the relative energy spread of the AGS beam is 1.02×10^{-3} for gold beam which corresponds to a half width of 10.6 MeV/u.[3] So the relative increase of the bunch area after crossing the foil SA is only 0.15%. It is negligibly small.

Acknowledgment

I am thankful to Dr. M.J. Rhoades–Brown and A.G. Ruggiero for helpful discussions.

[1] Conceptual Design of the Relativistic Heavy Ion Collider, p. 60, BNL 52195, 1989.
[2] J. Claus and H. Foelsche, Beam transfer from AGS to RHIC, AD/RHIC–47, 1988.
[3] Conceptual Design of the Relativistic Heavy Ion Collider, p. 64, BNL 52195, 1989.

TABLE 1

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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
LU4S:DRIFT,L=8.412536
LUS5:DRIFT,L=1.92404
LU56:DRIFT,L=3.933184
LU66':DRIFT,L=6.866622
LU6'7:DRIFT,L=10.000
LU78:DRIFT,L=12.599619
LU891:DRIFT,L=3.534764
LU892:DRIFT,L=0.609600
LU193:DRIFT,L=0.609600
LU293:DRIFT,L=0.609600
LU894:DRIFT,L=0.609600
LU895:DRIFT,L=17.090476
LU910:DRIFT,L=10.695975
LU011:DRIFT,L=1.106874
LU112:DRIFT,L=14.227735
LU100:DRIFT,L=1.000
LU300:DRIFT,L=3.000
LU600:DRIFT,L=6.000

UQ1:QUADRUPOLE,L=0.9525,K1=0.311659
UQ2:QUADRUPOLE,L=0.9525,K1=-0.2896309
UQ3:QUADRUPOLE,L=0.4572,K1=-0.2084732
UQ4:QUADRUPOLE,L=0.72644,K1=-0.261018
UQ5:QUADRUPOLE,L=0.72644,K1=0.1267803
UQ6:QUADRUPOLE,L=0.72644,K1=-0.2049674
UQ7:QUADRUPOLE,L=0.72644,K1=-0.1390189
UQ8:QUADRUPOLE,L=0.72644,K1=0.03686225
UQ9:QUADRUPOLE,L=0.72644,K1=-0.07312521
UQ10:QUADRUPOLE,L=0.72644,K1=0.3673985
UQ11:QUADRUPOLE,L=0.72644,K1=-0.321073
UQ12:QUAD,L=0.72644,K1=0.2145984
UQ4':QUAD,L=0.72644,K1=0.2691402
UQ6':QUAD,L=0.72644,K1=0.1732932

UD1:RBEND,L=2.080006,ANGLE=24.725E-3
UD2:RBEND,L=2.080006,ANGLE=24.725E-3
UD3:RBEND,L=2.080006,ANGLE=24.725E-3
U4F:RBEND,L=3.657600,ANGLE=34.906E-3,K1=0.018823143
U5D:RBEND,L=3.657600,ANGLE=34.906E-3,K1=-0.018823143
U6D:RBEND,L=3.657600,ANGLE=34.906E-3,K1=-0.018823143
U7F:RBEND,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,LU600,UQ4',LU300,UQ4,LU4S,2*LU100,LUS5,UQ5,LU56,&
    UQ6,LU66',UQ6',LU6'7,UQ7,LU78,UQ8,LU891)
U2:LINE=(U4F,LU892,U5D,LU193,LU293,U6D,LU894,U7F,LU895,UQ9,&
    LU910,UQ10,LU011,UQ11,LU112,UQ12)
U:LINE=(U1,U2)
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TABLE 2

ELEMENT SEQUENCE POS. NO.	ELEMENT NAME	OCC. NO.	DIST [M]	HORIZONTAL BETAX [M]	ALFAX [1]	MUX [2PI]	X(CO) [MM]	PX(CO) [.001]	DX [M]	DPX [1]	VERTICAL BETAY [M]	ALFAY [1]	MUY [2PI]	Y(CO) [MM]	PY(CO) [.001]	DY [M]	DPY [1]
BEGIN	U	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
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	93.016	21.694	0.015	0.000	0.000	-4.186	1.032	6.704	-2.405	0.213	0.000	0.000	0.000	0.000
4	LU12	1	6.822	72.769	19.183	0.016	0.000	0.000	-3.674	1.032	9.334	-2.906	0.223	0.000	0.000	0.000	0.000
5	UQ2	1	7.774	55.353	0.676	0.018	0.000	0.000	-3.141	0.112	12.545	-0.164	0.237	0.000	0.000	0.000	0.000
6	LU231	1	8.252	54.714	0.664	0.020	0.000	0.000	-3.087	0.112	12.720	-0.203	0.243	0.000	0.000	0.000	0.000
7	UD1	1	10.332	52.068	0.609	0.026	0.000	0.000	-2.828	0.137	13.912	-0.370	0.268	0.000	0.000	0.000	0.000
8	LU232	1	10.792	51.513	0.597	0.027	0.000	0.000	-2.765	0.137	14.270	-0.407	0.273	0.000	0.000	0.000	0.000
9	UD2	1	12.872	49.145	0.542	0.034	0.000	0.000	-2.454	0.162	16.308	-0.572	0.294	0.000	0.000	0.000	0.000
10	LU233	1	13.332	48.652	0.530	0.035	0.000	0.000	-2.380	0.162	16.852	-0.610	0.299	0.000	0.000	0.000	0.000
11	UD3	1	15.412	46.562	0.475	0.042	0.000	0.000	-2.017	0.187	19.731	-0.774	0.317	0.000	0.000	0.000	0.000
12	LU234	1	15.667	46.321	0.468	0.043	0.000	0.000	-1.970	0.187	20.131	-0.794	0.319	0.000	0.000	0.000	0.000
13	UQ3	1	16.124	47.934	-4.047	0.045	0.000	0.000	-1.927	0.001	19.988	1.102	0.323	0.000	0.000	0.000	0.000
14	LU600	1	22.124	109.552	-6.222	0.058	0.000	0.000	-1.918	0.001	10.756	0.437	0.390	0.000	0.000	0.000	0.000
15	UQ4'	1	22.851	103.106	14.672	0.059	0.000	0.000	-1.782	0.368	11.722	-1.829	0.400	0.000	0.000	0.000	0.000
16	LU300	1	25.851	33.953	8.379	0.067	0.000	0.000	-0.680	0.368	26.030	-2.941	0.428	0.000	0.000	0.000	0.000
17	UQ4	1	26.577	26.684	2.083	0.071	0.000	0.000	-0.454	0.261	26.684	2.082	0.432	0.000	0.000	0.000	0.000
18	LU4S	1	34.990	5.800	0.400	0.189	0.000	0.000	1.745	0.261	5.800	0.400	0.550	0.000	0.000	0.000	0.000
19	LU100	1	35.990	5.200	0.200	0.218	0.000	0.000	2.006	0.261	5.200	0.200	0.579	0.000	0.000	0.000	0.000
20	LU100	2	36.990	5.000	0.000	0.250	0.000	0.000	2.267	0.261	5.000	0.000	0.611	0.000	0.000	0.000	0.000
SA 21	LUS5	1	38.914	5.740	-0.385	0.308	0.000	0.000	2.770	0.261	5.740	-0.385	0.669	0.000	0.000	0.000	0.000
22	UQ5	1	39.640	6.002	0.032	0.328	0.000	0.000	2.866	0.000	6.825	-1.142	0.688	0.000	0.000	0.000	0.000
23	LU56	1	43.573	8.330	-0.624	0.422	0.000	0.000	2.867	0.000	21.030	-2.470	0.741	0.000	0.000	0.000	0.000
24	UQ6	1	44.300	10.329	-2.226	0.434	0.000	0.000	3.024	0.435	22.343	0.728	0.747	0.000	0.000	0.000	0.000
25	LU66'	1	51.166	68.070	-6.183	0.476	0.000	0.000	6.011	0.435	15.572	0.258	0.807	0.000	0.000	0.000	0.000
26	UQ6'	1	51.893	70.773	2.576	0.478	0.000	0.000	6.049	-0.330	16.680	-1.828	0.814	0.000	0.000	0.000	0.000
27	LU6'7	1	61.893	30.042	1.497	0.513	0.000	0.000	2.750	-0.330	79.289	-4.432	0.858	0.000	0.000	0.000	0.000
28	UQ7	1	62.619	30.076	-1.545	0.516	0.000	0.000	2.609	-0.061	79.876	3.644	0.860	0.000	0.000	0.000	0.000
29	LU78	1	75.219	86.869	-2.963	0.556	0.000	0.000	1.840	-0.061	16.434	1.392	0.916	0.000	0.000	0.000	0.000
30	UQ8	1	75.945	89.498	-0.633	0.557	0.000	0.000	1.778	-0.110	14.802	0.869	0.924	0.000	0.000	0.000	0.000
31	LU891	1	79.480	94.169	-0.688	0.564	0.000	0.000	1.391	-0.110	10.141	0.450	0.970	0.000	0.000	0.000	0.000
END	U1	1	79.480	94.169	-0.688	0.564	0.000	0.000	1.391	-0.110	10.141	0.450	0.970	0.000	0.000	0.000	0.000
BEGIN	U2	1	79.480	94.169	-0.688	0.564	0.000	0.000	1.391	-0.110	10.141	0.450	0.970	0.000	0.000	0.000	0.000
32	U4F	1	83.138	76.803	5.032	0.570	0.000	0.000	0.898	-0.154	10.756	-0.632	1.030	0.000	0.000	0.000	0.000
33	LU892	1	83.747	70.796	4.823	0.571	0.000	0.000	0.804	-0.154	11.575	-0.711	1.038	0.000	0.000	0.000	0.000
34	U5D	1	87.405	53.652	0.252	0.581	0.000	0.000	0.384	-0.080	14.852	-0.108	1.081	0.000	0.000	0.000	0.000
35	LU193	1	88.014	53.352	0.240	0.583	0.000	0.000	0.335	-0.080	15.009	-0.150	1.088	0.000	0.000	0.000	0.000
36	LU293	1	88.624	53.066	0.228	0.585	0.000	0.000	0.286	-0.080	15.217	-0.191	1.094	0.000	0.000	0.000	0.000
37	U6D	1	92.282	65.913	-4.031	0.595	0.000	0.000	0.083	-0.033	13.692	0.572	1.133	0.000	0.000	0.000	0.000
38	LU894	1	92.891	70.925	-4.191	0.597	0.000	0.000	0.063	-0.033	13.030	0.513	1.141	0.000	0.000	0.000	0.000
39	U7F	1	96.549	83.489	1.049	0.604	0.000	0.000	0.000	0.000	13.573	-0.674	1.187	0.000	0.000	0.000	0.000
40	LU895	1	113.639	54.994	0.619	0.644	0.000	0.000	0.000	0.000	67.891	-2.505	1.282	0.000	0.000	0.000	0.000
41	UQ9	1	114.366	56.235	-2.349	0.646	0.000	0.000	0.000	0.000	68.907	1.125	1.284	0.000	0.000	0.000	0.000
42	LU910	1	125.062	119.734	-3.588	0.667	0.000	0.000	0.000	0.000	48.605	0.773	1.313	0.000	0.000	0.000	0.000
43	UQ10	1	125.788	102.604	25.625	0.668	0.000	0.000	0.000	0.000	57.398	-13.649	1.316	0.000	0.000	0.000	0.000
44	LU011	1	126.895	53.730	18.530	0.671	0.000	0.000	0.000	0.000	91.612	-17.262	1.318	0.000	0.000	0.000	0.000
45	UQ11	1	127.621	36.869	5.976	0.673	0.000	0.000	0.000	0.000	100.915	5.188	1.319	0.000	0.000	0.000	0.000
46	LU112	1	141.849	68.398	-8.192	1.128	0.000	0.000	0.000	0.000	9.287	1.252	1.396	0.000	0.000	0.000	0.000
47	UQ12	1	142.576	72.470	2.800	1.129	0.000	0.000	0.000	0.000	8.570	-0.229	1.409	0.000	0.000	0.000	0.000
END	U	1	142.576	72.470	2.800	1.129	0.000	0.000	0.000	0.000	8.570	-0.229	1.409	0.000	0.000	0.000	0.000