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ELECTRON-ION COLLIDER (EIC) HADRON STORAGE RING (HSR) INJECTION TRANSPORT BEAMLINE (Y-LINE EXT.) LATTICE DESIGN AND MAGNET PARAMETERS

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ELECTRON-ION COLLIDER (EIC) HADRON STORAGE RING (HSR) INJECTION TRANSPORT BEAMLINE (Y-LINE EXT.) LATTICE DESIGN AND MAGNET PARAMETERS

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Abstract

The preliminary design of the Electron-Ion Collider (EIC) Hadron Storage Ring (HSR) Normal Conducting Injection Beamline (*Y-Line Ext.*) lattice is discussed. The preliminary design includes the periodic cells, matching sections, state of the art Twiss parameters at the HSR injection, the magnet parameters and first order instrumentation placement. Furthermore, the beamline parameters, element coordinates, and other information are discussed. The names of the HSR Injection Beamline elements used in this technical report (*i.e. HD1, HQ1*) are preliminary and not the official site wide names.

HSR INJECTION BEAMLINE LAYOUT

The lattice herein described is the new part of the AGS to HSR transport beamline, also known as the *"Warm Injection Beamline"*, or the *"Y-Line Ext."*, is defined from the end of YD27 bending magnet to the end of the HSR Injection Septum system (end of the HSR Injection Induction Septum). The complete injection transport from AGS to HSR will include the currently existing transport beamline segments: AGS to RHIC (AtR) U-Line, W-Line, and the Y-Arc (the arc leading to the RHIC Yellow injection point), up to the end of YD27. The AtR X-Arc (the arc leading to the RHIC Blue injection point) will be removed.

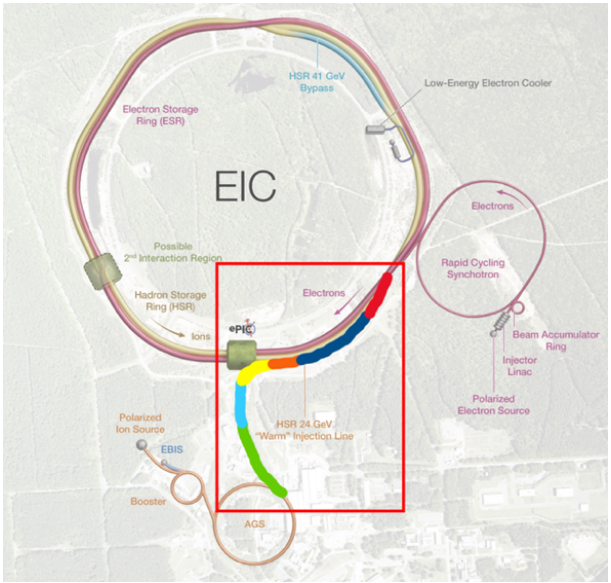

Figure 1: EIC HSR Injection Beamline Layout. (1) Green: AtR U-Line (U-Up and U-Down), (2) Blue: AtR W-Line, (3) Yellow: AtR Y-Arc (up to the end of YD27), (4) Orange: Upstream Matching Section, (5) Dark Blue: Y-Line Ext. Periodic Cells, and (6) Red: Downstream Matching Section.

HSR INJECTION BEAMLINE LATTICE

The HSR Injection Beamline consists of three major segments; Upstream Matching Section, Sector-4 Arc Cell, and Downstream Matching Section (Fig. 1). The bending elements to be used in the HSR Injection Line are mostly the AtR X-Arc Combined Function (CF) magnets. The combined function magnets provide a fixed bend angle with a quadrupole component. Two types of combined function magnets exist in the AtR beamline; the 3.6579 m magnetic length model and the 2.9465 m magnetic length model. While the bend angles are different, the quadrupole strengths for either types are the same (0.038082 m^{-2}). A total of 31 combined function magnets are available in AtR X-Arc, and 25 magnets (L_{mag}=3.6579 m) will be reused for the HSR Injection Beamline to extend the transfer line to the HSR injection point (See Table 1 and 2). The complete list of the combined function magnets is shown in Appendix I. The engineering drawing of a 3.6579 m combined function magnet is shown in Appendix II.

Table 1. RHIC X-Arc L_{mag}=3.6579 m CF Magnets

3.6579 m CF Magnet	**Parameter**
Magnet Length L_{mag}	3.6579 m
3.6579 m Bend Angle	2.7591 deg
	48.155 mrad
Quadrupole Strength k	0.038082 m^{-2}
Integrated Strength kL_{mag}	0.1393 m^{-1}
Focusing Qty	12
Defocusing Qty	13

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Table 2. RHIC X-Arc L_{mag}=2.9465 m CF Magnets

2.9465 m CF Magnet	**Parameter**
Magnet Length L_{mag}	2.9465 m
2.9465 m Bend Angle	2.2224 deg
	38.788 mrad
Quadrupole Strength k	0.038079 m^{-2}
Integrated Strength kL_{mag}	0.1122 m^{-1}
2.9465 CF Focus Qty	4
2.9465 CF Defocus Qty	2

HSR INJECTION PERIODIC CELL

The arc section of the HSR Injection Line, the Sector-4 Arc of the HSR, consists of periodic cells. The preliminary design report of the HSR Injection Periodic Cell is available in BNL-225059-2023-TECH, also published as EIC-ADD-TN-079 [1]. The HSR Injection Periodic Cell consists of nine repetitive optical structures. Each structure consists of two combined fucntion magnets (L_{mag} of 3.6579 m) and two quadrupole magnets.

The Twiss plot of beta functions and dispersions is shown for a single cell (Fig. 2), and for the nine combined structure (Fig. 3). The magnets and instruments used in the HSR Injection Periodic Cell is summarized in Table 3. For the single cell, two 3.6579 m CF magnet are located on each end with 0.5 m drift spacing. Two quadrupole magnets are placed in the middle. Correctors and BPMs are not shown in Figure 2. The nine periodic cells span over the Sector-4 Arc. The beginning of the first cell starts near the Q4 magnet of HSR. Correctors and BPMs are not shown in Figure 3 either. The maximum beta functions are β_x=35.22 m and β_y=35.46 m. Note the correctors and BPMs are placed at every high beam size location and at the entrance and the exit of every combined function magnet. The placement is subject to change upon simulation results.

Table 3. HSR Injection Periodic Cell Magnets and BPMs

Periodic Cell Magnets and Inst.	**Qty**
3.6579 m CF Focusing Magnet	9
3.6579 m CF Defocusing Magnet	9
Quadrupole Magnet	18
Dual Plane Corrector	18
Dual Plane BPM	27

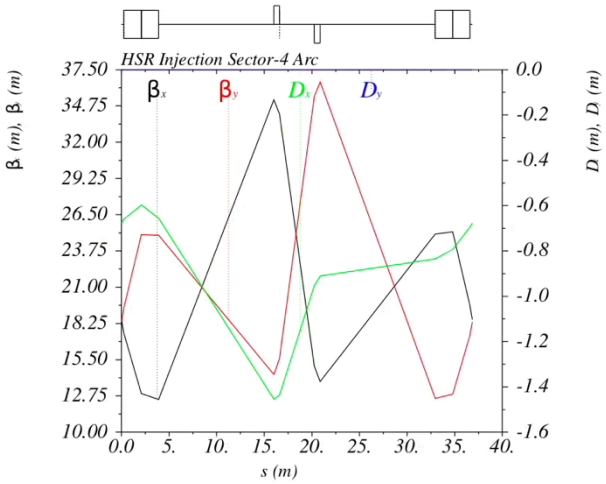


Figure 2: Twiss Plot of a Single Cell. The CF magnets are split into two halves in MAD-X simulation.

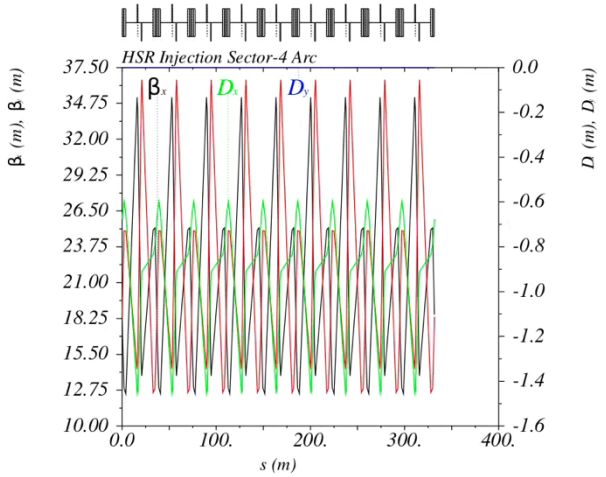


Figure 3: Twiss Plot of the Nine Periodic Cells

UPSTREAM MATCHING SECTION

The HSR Injection Beamline Upstream Matching Section is located between the end of the Y-Arc (rear end of YD27) and the beginning of the Periodic Cell. This section terminates the Y-Arc superbend and establishes a straight section to guide the beam into the Periodic Cell. The beamline consists of some remaining X-Arc CF magnets. This section is also responsible for the elevation adjustment from 0.047669 m (front end of YD26) to 0 m (HSR elevation). Two pitching magnets from X-Arc (XP1) and Y-Arc (YP1) will be reused to accomplish the elevation adjustment. The beta function and dispersion plot are shown in Figure 4. The magnets and instruments used in this beamline is summarized in Table 4. Note the correctors and BPMs are placed at every high beam size location and at the entrance and the exit of every combined function magnet. The placement is subject to change upon simulation results. The pitching magnets are located near s=34 m and s=64 m. s=0 m in the plot is the front end of the Y-Arc YD26 combined function magnet. The maximum beta functions in this section are β_x=60.00 m and β_y=65.00 m.

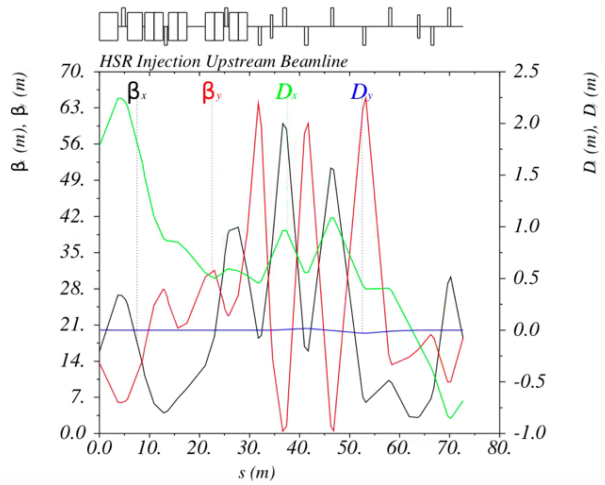


Figure 4: Twiss Plot of the Upstream Matching Section

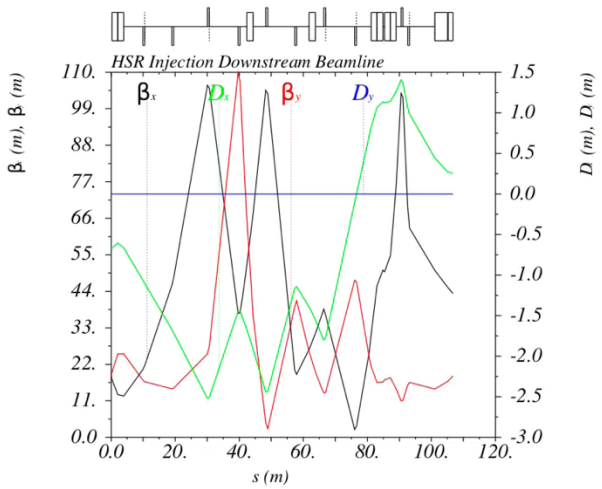


Figure 5: Twiss Plot of the Downstream Matching Section

Table 4. HSR Injection Upstream Magnets and BPMs

HSR Injection Upstream Magnets	Qty
3.6579 m CF Focusing Magnet	2
3.6579 m CF Defocusing Magnet	2
Quadrupole Magnet	10
Pitching Dipoles *(XP1, YP1)*	2
Dual Plane Corrector	5
Dual Plane BPM	5

DOWNSTREAM MATCHING SECTION

The HSR Injection Downstream Matching Section is located between the end of the Periodic Cell and the injection point of HSR. This beamline is responsible for matching the optics for the injection into HSR. The beamline will use three of the remaining X-Arc CF magnets from the inventory. In addition, there will be two horizontal dipoles (*Warm D0 equivalent*) located in the middle of this beamline. These new magnets are required due to the special bending angle requirements, which the existing combined function magnets will not fulfill the requirement. A total of ten quadrupole magnets will be used in this beamline. See Figure 5 for the beta function and dispersion plot. The magnets and instruments used in this beamline is summarized in Table 5. Note the correctors and BPMs are placed at every high beam size location and at the entrance and the exit of every combined function magnet. The placement is subject to change upon simulation results. The maximum beta functions in this section are β_x=106.05 m and β_y=109.99 m. Furthermore, three beam profile flags will be installed in this beamline for beam phase space characterization. Exact locations are yet to be determined.

Table 5. HSR Injection Downstream Magnets and BPMs

HSR Injection Downstream Magnets	Qty
3.6579 m CF Focusing Magnet	1
3.6579 m CF Defocusing Magnet	2
Quadrupole Magnet	10
Horizontal Dipoles (Warm D0 Equivalent)	2
Dual Plane Corrector	7
Dual Plane BPM	7
Current Septum	1
Induction Septum	1
Beam Profile Flag	3

HSR INJECTION BEAMLINE MAGNETS

The complete list of the HSR Injection Beamline magnets can be found in Appendix III. The list describes the proposed site wide name for each magnet, their type, the proposed operating field, location, and their inventory status whether they currently exist. What's been considered for most of the quadrupole magnets in the HSR Injection Beamline are APS (Advanced Photon Source) designs: Q2, Q5, and Q134. Whether APS quads will be used in the HSR Injection Beamline depends on the availability and their quality after refurbishment. The general parameters of these three quadrupole magnet types are shown in Appendix IV. It has been identified that several quadrupoles in the HSR Injection Beamline will be unable to adopt APS quadrupoles due to their limited integrated strength, or limited aperture. A brand new quadrupole magnet design with larger aperture and higher strength is underway. For the quadrupole magnets of strength constraints, two APS quadrupoles or new quadrupoles could be placed in series to accommodate the integrated strength. This information will be identified in Appendix III.

CONCLUSION

The HSR Injection Beamline; consists of the existing AtR U, W, Y-Arc (up to YD27), and the newly designed HSR Injection Beamline, will be responsible for a successful transfer of hadron beam from AGS to the Hadron Storage Ring (see Figure 6). The HSR Injection Beamline is designed in such way it will preserve the spin polarization by avoiding interleaving horizontal and vertical bending. The HSR Injection Beamline lattice design has matured, and engineering efforts are being made for the construction of the beamline. Current efforts include the placement of orbit correction instruments, vacuum elements such as ion pumps, and bellow sections. The design of the current septum and the induction septum are underway. Future studies will include a progression in the new quadrupole designs, AtR magnet removal and refurbishment, and other magnet logistics. The AtR Removal and Repurpose (R&R) effort may be supported by this technical note. In particular, see Appendix V. On the physics side, lattice simulations will continue for spin tracking, and magnet sensitivity and misalignment, based on the field error tolerances defined by the existing AtR magnets and power supplies.

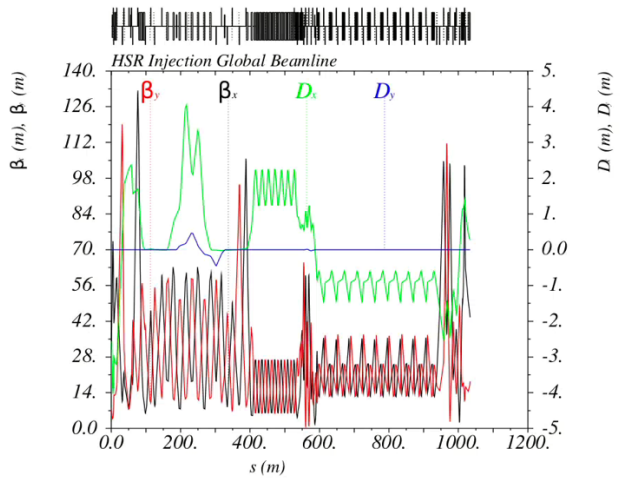


Figure 6. HSR Injection Beamline Twiss Plot (AGS-HSR)

REFERENCES

[1] BNL-225059-2023-TECH (EIC-ADD-TN-079)

APPENDIX I. COMBINED FUNCTION MAGNET INVENTORY

Installation dwg #	Description	FLG to FLG inch/m	Magnet dwg #	Core Length inch/m	Quantity
53020029	Long Defocus	157.39" / 3.997703 m	53020001	144.0" / 3.6576 m	13
53020019	Long Focus				11
53021017	Short Focus	129.3" / 3.286506 m	53021001	116.0" / 2.9464 m	3
53021018	Short Defocus				2
53023004	Short	129.39" / 3.286506 m	53023001	116.0" / 2.9464 m	1
53021019	Long Focus	157.39" / 3.997703m	No Drawing	144.0" / 3.6576m	1

Magnets Selected for HSR Injection	53020029	13
	53020019	11
	53021019	1

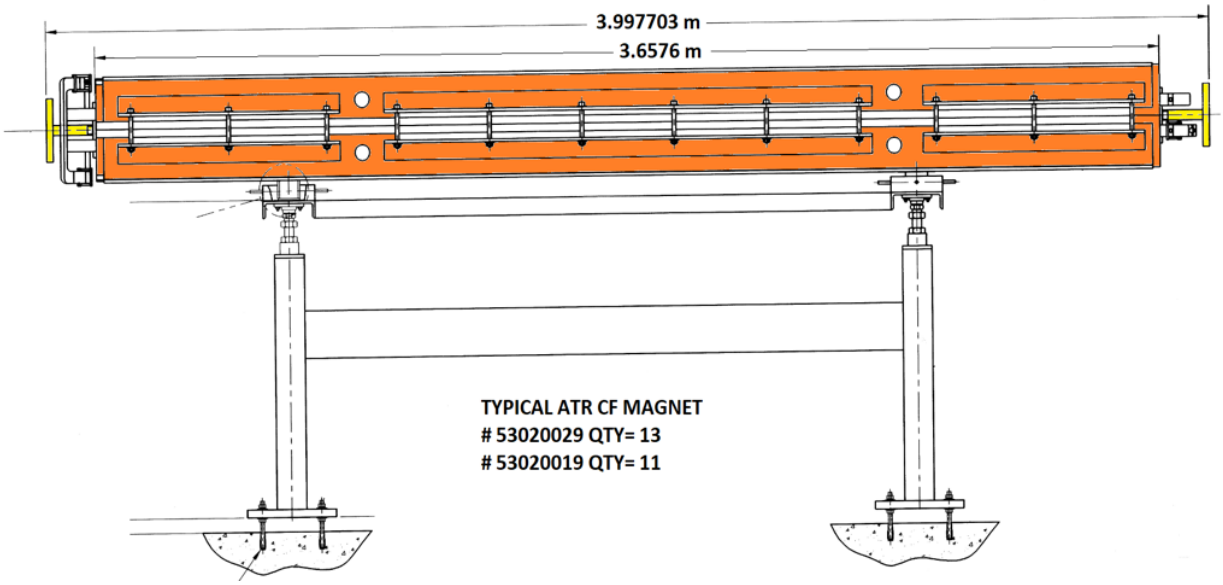
RHIC X-LINE INJECTION DIPOLES 57060001

Beam direction		Assembly dwg	Installlation dwg #		Bend angle [deg]	FOCUS/ DEFOCUS	Note
|	1	57060016					No assy drawing
|	2	57060017	53020029	XD1	2.7589	DEFOCUS	
|	3		53021017	XD2	2.2225	FOCUS	
V	4	57060016	53020019	XD3	2.7589	FOCUS	
	5		53020029	XD4	2.7589	DEFOCUS	
	6		53020029	XD5	2.7589	DEFOCUS	
	7	57060015	53020019	XD6	2.7589	FOCUS	
	8		53020019	XD7	2.7589	FOCUS	
	9	57060014	53020029	XD8	2.7591	DEFOCUS	
	10		53020029	XD9	2.7591	DEFOCUS	
	11	57060013	53020019	XD10	2.7591	FOCUS	
	12		53020019	XD11	2.7591	FOCUS	
	13	57060012	53020029	XD12	2.7591	DEFOCUS	
	14		53020029	XD13	2.7591	DEFOCUS	
	15	57060011	53020019	XD14			No assy drawing
	16		53020019	XD15			
	17	57060010	53020029	XD16	2.7591	DEFOCUS	
	18		53020029	XD17	2.7591	DEFOCUS	
	19	57060009	53020019	XD18	2.7589	FOCUS	
	20		53020019	XD19	2.7589	FOCUS	
	21	57060008	53020029	XD20	2.7591	DEFOCUS	
	22		53020029	XD21	2.7591	DEFOCUS	
	23	57060007	53020019	XD22	2.7591	FOCUS	
	24		53020019	XD23	2.7591	FOCUS	
	25	57060006	53020029	XD24	2.7591	DEFOCUS	
	26		53020029	XD25	2.7591	DEFOCUS	
	27	57060005	53021019	XD26	2.7589	LONG FOCUS	No drawing
	28		53021017	XD27	2.2224	SHORT FOCUS	
	29	57060004	53021018	XD28	2.2226	SHORT DEFOCUS	
	30		53021018	XD29	2.2226	SHORT DEFOCUS	
	31		53021017	XD30	2.2226	SHORT FOCUS	
	32	57060003	53023004	XD31	2.4523	SHORT	
	33	57060002	N/A				

RHIC X-line Dipole Inventory available for EIC

Installation dwg #	Description		FLG TO FLG [inch/m]	Magnet dwg #	Core dwg	Core length [inch]	qty
53020029	Dipole Mag Type - B, Long	DEFOCUS	157.39"/3.997703m	53020001	53020002/3	144.0"/3.6576m	13
53020019	Dipole Mag Type - B, Long	FOCUS					11
53021017	Dipole Mag Type - B, short	SHORT FOCUS	129.39"/3.286506m	53021001	53021002/3	116.0"/2.9464m	3
53021018	Dipole Mag Type - B, short	DEFOCUS					2
53021019	Dipole Type B	LONG FOCUS	157.39"/3.997703m			144.0"/3.6576m	1
53023004	Dipole Mag Type - A, short	x	129.39/3.286506m	53023001	53023002	116"/2.9464m	1

APPENDIX II. COMBINED FUNCTION MAGNET DRAWING



APPENDIX III. HSR INJECTION BEAMLINE MAGNETS

Subject	*s* (m)	Length (m)	Strength	Type	Remarks
YB12	*0			Dual Plane BPM	Relocated from Y-Arc
YD26	3.6579	3.6579	0.1393 m^{-1}	Combined Function	Unchanged Y-Arc
**YTH9/YTV10		***0.4069		Dual Plan Corrector	Relocated from Y-Arc
YQ1	5.157	0.726	0.04026 m^{-1}	Quadrupole	Unchanged Y-Arc YQ1
YB13				Dual Plane BPM	Relocated from Y-Arc
YD27	8.5525	2.9465	0.1122 m^{-1}	Combined Function	Unchanged Y-Arc YD27
HD1	12.7112	3.6579	-0.1393 m^{-1}	Combined Function	Refurbished from X-Arc
HQ1	13.5612	0.6	-0.0859 m^{-1}	Quadrupole	APS Q2/Q5/Q134
HD2	17.4692	3.6579	0.1393 m^{-1}	Combined Function	Refurbished from X-Arc
HTH1/HTV1				Dual Plan Corrector	XTV1/XTH3
HB3				Dual Plane BPM	YBV11/XBH4
HD3	24.7994	3.6579	-0.1393 m^{-1}	Combined Function	Refurbished from X-Arc
HQ2	25.6494	0.6	0.1076 m^{-1}	Quadrupole	APS Q2/Q5/Q134
HD4	29.5574	3.6579	0.1393 m^{-1}	Combined Function	Refurbished from X-Arc
HTH2/HTV2				Dual Plan Corrector	XTV2/XTH4
HQ3	32.3574	2.0	-0.3161 m^{-1}	Quadrupole	Two New Quads in Series
HB4				Dual Plane BPM	New Dual Plane BPM
HV1	35.6574	1.0	0.0017 rad	Vertical Dipole	Refurbished from YP1
HQ4	37.3834	1.0	0.2300 m^{-1}	Quadrupole	New Quadrupole Design
HTH3/HTV3				Dual Plan Corrector	XTH5/XTV6
HQ5	41.7234	2.0	-0.4183 m^{-1}	Quadrupole	Two New Quads in Series

HB5				Dual Plane BPM	XBV1/XBH6
HQ6	46.8234	1.0	0.2092 m^{-1}	Quadrupole	New Quadrupole Design
HTH4/HTV4				Dual Plan Corrector	XTH7/XTV8
HQ7	53.2234	2.0	-0.2820 m^{-1}	Quadrupole	Two New Quads in Series
HB6				Dual Plane BPM	XB5
HQ8	58.4112	1.0	0.2405 m^{-1}	Quadrupole	New Quadrupole Design
HV2	64.0782	1.0	-0.00169 rad	Vertical Dipole	Refurbished from XP1
HQ9	66.8452	0.6	-0.1370 m^{-1}	Quadrupole	APS Q2/Q5/Q134
HTH5/HTV5				Dual Plan Corrector	XTH9/XTV10
HQ10	70.1984	1.0	0.2522 m^{-1}	Quadrupole	New Quadrupole Design
HB7				Dual Plane BPM	XBV7/XBH8
HB8 (Cell 1)				Dual Plane BPM	XBV9/XBH10
HD5	76.6008	3.6579	-0.1393 m^{-1}	Combined Function	Refurbished from X-Arc
HTH6/HTV6				Dual Plan Corrector	New Dual Plane Corrector
HQ11	89.2978	0.6	0.1363 m^{-1}	Quadrupole	APS Q2/Q5/Q134
HB9				Dual Plane BPM	XBV11/New BPMH
HTH7/HTV7				Dual Plan Corrector	New Dual Plane Corrector
HQ12	93.5478	0.6	-0.1363 m^{-1}	Quadrupole	APS Q2/Q5/Q134
HB10				Dual Plane BPM	XB12
HD6 (Cell 1)	109.3027	3.6579	0.1393 m^{-1}	Combined Function	Refurbished from X-Arc
HB11 (Cell 2)				Dual Plane BPM	XB13
HD7	113.4607	3.6579	-0.1393 m^{-1}	Combined Function	Refurbished from X-Arc
HTH8/HTV8				Dual Plan Corrector	New Dual Plane Corrector
HQ13	126.1577	0.6	0.1363 m^{-1}	Quadrupole	APS Q2/Q5/Q134
HB12				Dual Plane BPM	XBV2/New BPMH
HTH9/HTV9				Dual Plan Corrector	New Dual Plane Corrector
HQ14	130.4077	0.6	-0.1363 m^{-1}	Quadrupole	APS Q2/Q5/Q134
HB13				Dual Plane BPM	XBV3/New BPMH
HD8 (Cell 2)	146.1627	3.6579	0.1393 m^{-1}	Combined Function	Refurbished from X-Arc
HB14 (Cell 3)				Dual Plane BPM	New Dual Plane BPM
HD9	150.3206	3.6579	-0.1393 m^{-1}	Combined Function	Refurbished from X-Arc
HTH10/HTV10				Dual Plan Corrector	New Dual Plane Corrector
HQ15	163.0176	0.6	0.1363 m^{-1}	Quadrupole	APS Q2/Q5/Q134
HB15				Dual Plane BPM	New Dual Plane BPM
HTH11/HTV11				Dual Plan Corrector	New Dual Plane Corrector
HQ16	167.2676	0.6	-0.1363 m^{-1}	Quadrupole	APS Q2/Q5/Q134
HB16				Dual Plane BPM	New Dual Plane BPM
HD10 (Cell 3)	183.0226	3.6579	0.1393 m^{-1}	Combined Function	Refurbished from X-Arc
HB17 (Cell 4)				Dual Plane BPM	New Dual Plane BPM
HD11	187.1805	3.6579	-0.1393 m^{-1}	Combined Function	Refurbished from X-Arc
HTH12/HTV12				Dual Plan Corrector	New Dual Plane Corrector

HQ17	199.8775	0.6	0.1363 m^{-1}	Quadrupole	APS Q2/Q5/Q134
HB18				Dual Plane BPM	New Dual Plane BPM
HTH13/HTV13				Dual Plan Corrector	New Dual Plane Corrector
HQ18	204.1275	0.6	-0.1363 m^{-1}	Quadrupole	APS Q2/Q5/Q134
HB19				Dual Plane BPM	New Dual Plane BPM
HD12 (Cell 4)	219.8825	3.6579	0.1393 m^{-1}	Combined Function	Refurbished from X-Arc
HB20 (Cell 5)				Dual Plane BPM	New Dual Plane BPM
HD13	224.0404	3.6579	-0.1393 m^{-1}	Combined Function	Refurbished from X-Arc
HTH14/HTV14				Dual Plan Corrector	New Dual Plane Corrector
HQ19	236.7374	0.6	0.1363 m^{-1}	Quadrupole	APS Q2/Q5/Q134
HB21				Dual Plane BPM	New Dual Plane BPM
HTH15/HTV15				Dual Plan Corrector	New Dual Plane Corrector
HQ20	240.9874	0.6	-0.1363 m^{-1}	Quadrupole	APS Q2/Q5/Q134
HB22				Dual Plane BPM	New Dual Plane BPM
HD14 (Cell 5)	256.7424	3.6579	0.1393 m^{-1}	Combined Function	Refurbished from X-Arc
HB23 (Cell 6)				Dual Plane BPM	New Dual Plane BPM
HD15	260.9003	3.6579	-0.1393 m^{-1}	Combined Function	Refurbished from X-Arc
HTH16/HTV16				Dual Plan Corrector	New Dual Plane Corrector
HQ21	273.5973	0.6	0.1363 m^{-1}	Quadrupole	APS Q2/Q5/Q134
HB24				Dual Plane BPM	New Dual Plane BPM
HTH17/HTV17				Dual Plan Corrector	New Dual Plane Corrector
HQ22	277.8473	0.6	-0.1363 m^{-1}	Quadrupole	APS Q2/Q5/Q134
HB25				Dual Plane BPM	New Dual Plane BPM
HD16 (Cell 6)	293.6023	3.6579	0.1393 m^{-1}	Combined Function	Refurbished from X-Arc
HB26 (Cell 7)				Dual Plane BPM	New Dual Plane BPM
HD17	297.7602	3.6579	-0.1393 m^{-1}	Combined Function	Refurbished from X-Arc
HTH18/HTV18				Dual Plan Corrector	New Dual Plane Corrector
HQ23	310.4572	0.6	0.1363 m^{-1}	Quadrupole	APS Q2/Q5/Q134
HB27				Dual Plane BPM	New Dual Plane BPM
HTH19/HTV19				Dual Plan Corrector	New Dual Plane Corrector
HQ24	314.7072	0.6	-0.1363 m^{-1}	Quadrupole	APS Q2/Q5/Q134
HB28				Dual Plane BPM	New Dual Plane BPM
HD18 (Cell 7)	330.4622	3.6579	0.1393 m^{-1}	Combined Function	Refurbished from X-Arc
HB29 (Cell 8)				Dual Plane BPM	New Dual Plane BPM
HD19	334.6201	3.6579	-0.1393 m^{-1}	Combined Function	Refurbished from X-Arc
HTH20/HTV20				Dual Plan Corrector	New Dual Plane Corrector
HQ25	347.3171	0.6	0.1363 m^{-1}	Quadrupole	APS Q2/Q5/Q134
HB30				Dual Plane BPM	New Dual Plane BPM
HTH21/HTV21				Dual Plan Corrector	New Dual Plane Corrector
HQ26	351.5671	0.6	-0.1363 m^{-1}	Quadrupole	APS Q2/Q5/Q134
HB31				Dual Plane BPM	New Dual Plane BPM

HD20 (Cell 8)	367.3221	3.6579	0.1393 m^{-1}	Combined Function	Refurbished from X-Arc
HB32 (Cell 9)				Dual Plane BPM	New Dual Plane BPM
HD21	371.4800	3.6579	-0.1393 m^{-1}	Combined Function	Refurbished from X-Arc
HTH22/HTV22				Dual Plan Corrector	New Dual Plane Corrector
HQ27	384.1770	0.6	0.1363 m^{-1}	Quadrupole	APS Q2/Q5/Q134
HB33				Dual Plane BPM	New Dual Plane BPM
HTH23/HTV23				Dual Plan Corrector	New Dual Plane Corrector
HQ28	388.4270	0.6	-0.1363 m^{-1}	Quadrupole	APS Q2/Q5/Q134
HB34				Dual Plane BPM	New Dual Plane BPM
HD22 (Cell 9)	404.1820	3.6579	0.1393 m^{-1}	Combined Function	Refurbished from X-Arc
HD23	408.3400	3.6579	-0.1393 m^{-1}	Combined Function	Refurbished from X-Arc
HTH24/HTV24				Dual Plan Corrector	New Dual Plane Corrector
HQ29	414.9248	0.6	0.01581 m^{-1}	Quadrupole	APS Q2/Q5/Q134
HB35				Dual Plane BPM	New Dual Plane BPM
HQ30	424.0097	0.6	-0.03029 m^{-1}	Quadrupole	APS Q2/Q5/Q134
HTH25/HTV25				Dual Plan Corrector	New Dual Plane Corrector
HB36				Dual Plane BPM	New Dual Plane BPM
HQ31	435.0945	1.0	0.09169 m^{-1}	Quadrupole	New Quadrupole Design
HTH26/HTV26				Dual Plan Corrector	New Dual Plane Corrector
HQ32	444.6794	1.0	-0.1660 m^{-1}	Quadrupole	New Quadrupole Design
HB37				Dual Plane BPM	New Dual Plane BPM
HH1	448.8340	2.5	-0.03016 rad	Horizontal Dipole	Warm D0 Equivalent
HTH27/HTV27				Dual Plan Corrector	New Dual Plane Corrector
HQ33	453.3340	1.0	0.1296 m^{-1}	Quadrupole	New Quadrupole Design
HB38				Dual Plane BPM	New Dual Plane BPM
HTH28/HTV28				Dual Plan Corrector	New Dual Plane Corrector
HQ34	462.3340	0.6	-0.1760 m^{-1}	Quadrupole	APS Q2/Q5/Q134
HB39				Dual Plane BPM	New Dual Plane BPM
HH2	468.2341	2.5	-0.03016 rad	Horizontal Dipole	Warm D0 Equivalent
HTH29/HTV29				Dual Plan Corrector	New Dual Plane Corrector
HQ35	471.3340	0.6	0.1848 m^{-1}	Quadrupole	APS Q2/Q5/Q134
HB40				Dual Plane BPM	New Dual Plane BPM
HTH30/HTV30				Dual Plan Corrector	New Dual Plane Corrector
HQ36	481.0401	0.6	-0.0906 m^{-1}	Quadrupole	APS Q2/Q5/Q134
HB41				Dual Plane BPM	New Dual Plane BPM
HTH31/HTV31				Dual Plan Corrector	New Dual Plane Corrector
HD24	489.3019	3.6579	0.1393 m^{-1}	Combined Function	Refurbished from X-Arc
HD25	489.8019	3.6579	-0.1393 m^{-1}	Combined Function	Refurbished from X-Arc
HQ37	495.5599	0.6	-0.0711 m^{-1}	Quadrupole	APS Q2/Q5/Q134
HB42				Dual Plane BPM	New Dual Plane BPM
HQ38	497.6599	1.0	0.1306 m^{-1}	Quadrupole	New Quadrupole Design

HTH32/HTV32				Dual Plan Corrector	New Dual Plane Corrector
HF1				Flag	XF1 or YF1, Location *TBD*
HF2				Flag	XF2 or YF2, Location *TBD*
HF3				Flag	Location *TBD*
HS1	509.5010	3.9763	0.05011 rad	Current Septum	New Septum
****HS2	511.2011	1.5000	0.01841 rad	Induction Septum	New Septum

**s* = 0 m in this table is defined at the front end of the YD26, along with the drift space that will facilitate the first dual plane BPMs.

**Omitted *s* coordinates found in correctors and BPMs indicate that they are zero length placeholders at this time, and will be located in between the elements on each end.

***Length of a single plane corrector found in X-Arc and Y-Arc are 0.4064 m. If used for dual plane correction purposes, two single plane correctors may be placed in series; the length may double.

****The coordinate at *s* = 511.2011184 m is the HSR Injection (x, y, z) = (31917.465552 m, 0 m, 30697.759056 m).

The number of correctors and BPMs placed in this lattice are subject to change depending on the results of the beamline misalignment and magnet sensitivity simulations.

The name convention of the HSR Injection Beamline elements are only preliminary and not the official site wide names.

List of Available X-Arc and Y-Arc Instrumentation

Y-Arc		**X-Arc**	
Corrector	**BPM/CT**	**Corrector**	**BPM/CT**
YTV1	YBV1	XTV1	XBV1
YTV2	YBV2	XTV2	XBV2
YTH3	YBV3	XTH3	XBV3
YTH4	YBH4	XTH4	XBH4
YTH5	YB5	XTH5	XB5
YTV6	8.5525	XTV6	XBH6
YTH7	YBH6	XTH7	XBV7
*YTV8	YBV7	XTV8	XBH8
YTH9	YBH8	XTH9	XBV9
YTV10	YBV9	XTV10	XBH10
	**YBH10		XBV11
	YBV11		XB12
	YB12		XB13
	YB13		XF1
	YF1		XXF1 (CT)
	YXF1 (CT)		XF
	YF2		

*Last Corrector before YD27

**Last BPM before YD27

APPENDIX IV. ADVANCED PHOTON SOURCE QUADRUPOLES SPECIFICATIONS

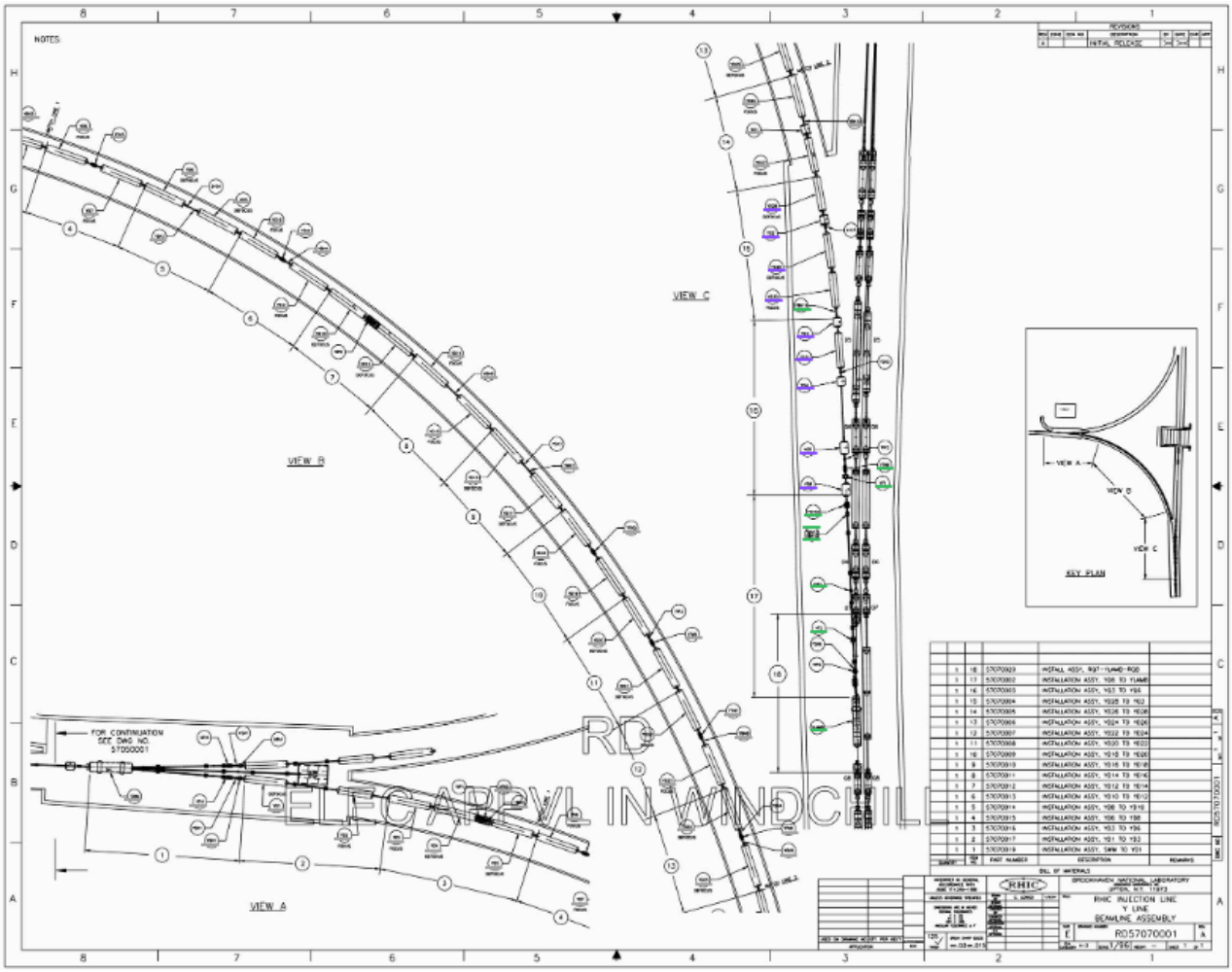
Parameters for the Storage Ring Qudrupole Magnets

	Q2	Q5	Q1,Q3,Q4	
Number Required	80	80	240	
Strength at 7.0 GeV	18.9	18.9	18.9	T/m
Effective Length	0.8	0.6	0.5	m
Gap Height or Diameter	80	80	80	mm
Total mass of Magnet	1815	1374	1153	kg
Beam stay clear				
Horizontal	±35.0	±35.0	±35.0	mm
Vertical	±20.0	±20.0	±20.0	mm
Coils per Pole	1	1	1	
Conductor				
Height	11.5	11.5	11.5	mm
Width	11.5	11.5	11.5	mm
Hole Diameter	6.3	6.3	6.3	mm
Number of Turns per Pole	32	32	32	
Total Inductance	27	20	17	mH
Total Resistance	44	35	30	mΩ
Time Constant	614	571	567	ms
Peak Current	412	412	412	A
Current Density in Coil	2.6	2.6	2.6	A/mm^2
Voltage	18.3	14.3	12.3	V
Power	7.5	5.9	5.1	kW
Cooling Water Circuits per Magnet	4	4	4	
Total Water Flow	2.8*	3.2*	3.4*	gpm
Water Pressure Drop	40*	40*	40*	psi
Water Temperature Rise	13*	9*	7*	°C

*Will be redesigned at 80 psi

APPENDIX V. ATR REMOVAL AND REPURPOSE PLAN, AUGUST 1, 2025

ATR Y-ARC

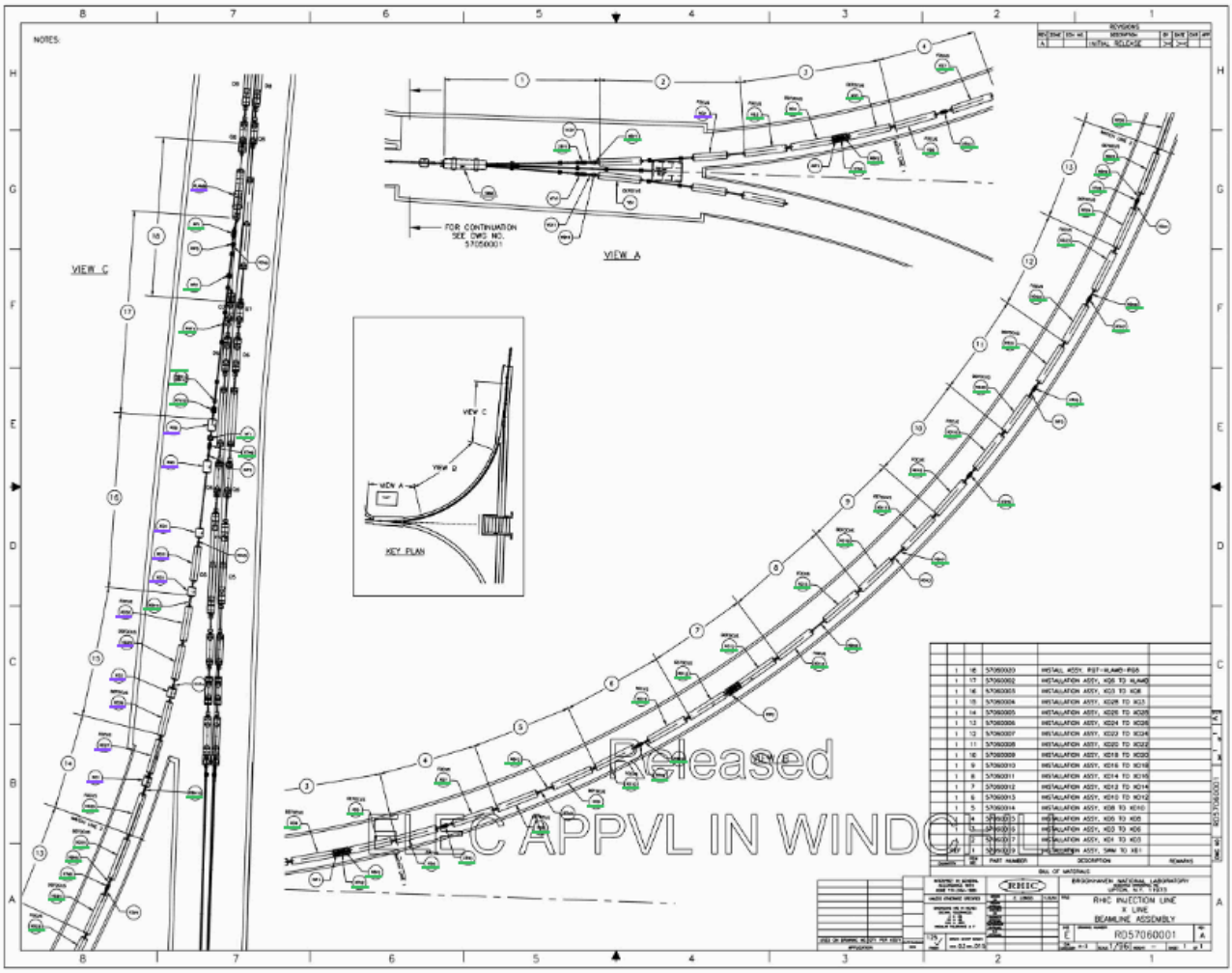


SUBJECT	TYPE	ACTION REQUIRED	RELOCATION/REASSIGNMENT
YSWM	Switching Magnet	OUTSIDE PROJECT SOW	Remain in the W-Line
YTV1	Corrector	OUTSIDE PROJECT SOW	HSR Injection Y-Arc
YBV1	BPM	OUTSIDE PROJECT SOW	HSR Injection Y-Arc
YD1	Combined Function	OUTSIDE PROJECT SOW	HSR Injection Y-Arc
YD2	Combined Function	OUTSIDE PROJECT SOW	HSR Injection Y-Arc
YD3	Combined Function	OUTSIDE PROJECT SOW	HSR Injection Y-Arc
YD4	Combined Function	OUTSIDE PROJECT SOW	HSR Injection Y-Arc
YTV2	Corrector	OUTSIDE PROJECT SOW	HSR Injection Y-Arc
YBV2	BPM	OUTSIDE PROJECT SOW	HSR Injection Y-Arc
YD5	Combined Function	OUTSIDE PROJECT SOW	HSR Injection Y-Arc
YD6	Combined Function	OUTSIDE PROJECT SOW	HSR Injection Y-Arc
YTH3	Corrector	OUTSIDE PROJECT SOW	HSR Injection Y-Arc

YD7	Combined Function	OUTSIDE PROJECT SOW	HSR Injection Y-Arc
YD8	Combined Function	OUTSIDE PROJECT SOW	HSR Injection Y-Arc
YBV3	BPM	OUTSIDE PROJECT SOW	HSR Injection Y-Arc
YD9	Combined Function	OUTSIDE PROJECT SOW	HSR Injection Y-Arc
YD10	Combined Function	OUTSIDE PROJECT SOW	HSR Injection Y-Arc
YTH4	Corrector	OUTSIDE PROJECT SOW	HSR Injection Y-Arc
YBH4	BPM	OUTSIDE PROJECT SOW	HSR Injection Y-Arc
YD11	Combined Function	OUTSIDE PROJECT SOW	HSR Injection Y-Arc
YD12	Combined Function	OUTSIDE PROJECT SOW	HSR Injection Y-Arc
YB5	BPM	OUTSIDE PROJECT SOW	HSR Injection Y-Arc
YD13	Combined Function	OUTSIDE PROJECT SOW	HSR Injection Y-Arc
YD14	Combined Function	OUTSIDE PROJECT SOW	HSR Injection Y-Arc
YBH6	BPM	OUTSIDE PROJECT SOW	HSR Injection Y-Arc
YD15	Combined Function	OUTSIDE PROJECT SOW	HSR Injection Y-Arc
YD16	Combined Function	OUTSIDE PROJECT SOW	HSR Injection Y-Arc
YBV7	BPM	OUTSIDE PROJECT SOW	HSR Injection Y-Arc
YD17	Combined Function	OUTSIDE PROJECT SOW	HSR Injection Y-Arc
YD18	Combined Function	OUTSIDE PROJECT SOW	HSR Injection Y-Arc
YTH5	Corrector	OUTSIDE PROJECT SOW	HSR Injection Y-Arc
YD19	Combined Function	OUTSIDE PROJECT SOW	HSR Injection Y-Arc
YD20	Combined Function	OUTSIDE PROJECT SOW	HSR Injection Y-Arc
YTV6	Corrector	OUTSIDE PROJECT SOW	HSR Injection Y-Arc
YD21	Combined Function	OUTSIDE PROJECT SOW	HSR Injection Y-Arc
YD22	Combined Function	OUTSIDE PROJECT SOW	HSR Injection Y-Arc
YTH7	Corrector	OUTSIDE PROJECT SOW	HSR Injection Y-Arc
YBH8	BPM	OUTSIDE PROJECT SOW	HSR Injection Y-Arc
YD23	Combined Function	OUTSIDE PROJECT SOW	HSR Injection Y-Arc
YD24	Combined Function	OUTSIDE PROJECT SOW	HSR Injection Y-Arc
YTV8	Corrector	OUTSIDE PROJECT SOW	HSR Injection Y-Arc
YBV9	BPM	OUTSIDE PROJECT SOW	HSR Injection Y-Arc
YD25	Combined Function	OUTSIDE PROJECT SOW	HSR Injection Y-Arc
YD26	Combined Function	OUTSIDE PROJECT SOW	HSR Injection Y-Arc
YBH10	BPM	OUTSIDE PROJECT SOW	HSR Injection Y-Arc
YQ1	Quadrupole	OUTSIDE PROJECT SOW	HSR Injection Y-Arc
YD27	Combined Function	OUTSIDE PROJECT SOW	HSR Injection Y-Arc
YD28	Combined Function	RETAIN FOR C-AD	N/A
YQ2	Quadrupole	RETAIN FOR C-AD	N/A
YD29	Combined Function	RETAIN FOR C-AD	N/A
YD30	Combined Function	RETAIN FOR C-AD	N/A
YBV11	BPM	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.
YQ3	Quadrupole	RETAIN FOR C-AD	N/A

YD31	Combined Function	RETAIN FOR C-AD	N/A
YQ4	Quadrupole	RETAIN FOR C-AD	N/A
YQ5	Quadrupole	RETAIN FOR C-AD	N/A
YTH9	Corrector	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.
YF1	Beam Profile Flag	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.
YQ6	Quadrupole	RETAIN FOR C-AD	N/A
YTV10	Corrector	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.
YB12	BPM	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.
YXF1	Current Transformer	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.
YF2	Beam Profile Flag	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.
YCOR1	Dipole Magnet	RETAIN FOR C-AD	N/A
YP1	Pitching Magnet	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.
YLAMB	Lambertson Magnet	REPURPOSE FOR EIC	N/A

ATR X-ARC



SUBJECT	TYPE	ACTION REQUIRED	RELOCATION/REASSIGNMENT
XSWM	Switching Magnet	OUTSIDE PROJECT SOW	Remain in the W-Line
XTV1	Corrector	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.
XBV1	BPM	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.
XD1	Combined Function	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.
XD2	Combined Function	RETAIN FOR C-AD	N/A
XD3	Combined Function	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.
XD4	Combined Function	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.
XTV2	Corrector	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.
XBV2	BPM	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.
XD5	Combined Function	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.
XD6	Combined Function	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.
XTH3	Corrector	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.
XD7	Combined Function	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.
XD8	Combined Function	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.

XBV3	BPM	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.
XD9	Combined Function	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.
XD10	Combined Function	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.
XTH4	Corrector	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.
XBH4	BPM	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.
XD11	Combined Function	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.
XD12	Combined Function	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.
XB5	BPM	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.
XD13	Combined Function	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.
XD14	Combined Function	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.
XBH6	BPM	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.
XD15	Combined Function	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.
XD16	Combined Function	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.
XBV7	BPM	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.
XD17	Combined Function	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.
XD18	Combined Function	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.
XTH5	Corrector	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.
XD19	Combined Function	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.
XD20	Combined Function	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.
XTV6	Corrector	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.
XD21	Combined Function	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.
XD22	Combined Function	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.
XTH7	Corrector	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.
XBH8	BPM	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.
XD23	Combined Function	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.
XD24	Combined Function	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.
XTV8	Corrector	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.
XBV9	BPM	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.
XD25	Combined Function	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.
XD26	Combined Function	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.
XBH10	BPM	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.
XQ1	Quadrupole	RETAIN FOR C-AD	N/A
XD27	Combined Function	RETAIN FOR C-AD	N/A
XD28	Combined Function	RETAIN FOR C-AD	N/A
XQ2	Quadrupole	RETAIN FOR C-AD	N/A
XD29	Combined Function	RETAIN FOR C-AD	N/A
XD30	Combined Function	RETAIN FOR C-AD	N/A
XBV11	BPM	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.
XQ3	Quadrupole	RETAIN FOR C-AD	N/A
XD31	Combined Function	RETAIN FOR C-AD	N/A
XQ4	Quadrupole	RETAIN FOR C-AD	N/A

XQ5	Quadrupole	RETAIN FOR C-AD	N/A
XTH9	Corrector	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.
XF1	Beam Profile Flag	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.
XQ6	Quadrupole	RETAIN FOR C-AD	N/A
XTV10	Corrector	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.
XB12	BPM	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.
XXF1	Current Transformer	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.
XF2	Beam Profile Flag	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.
XB13	BPM	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.
XCOR1	Dipole Magnet	RETAIN FOR C-AD	N/A
XP1	Pitching Magnet	REPURPOSE FOR EIC	HSR Injection Y-Line Ext.
XLAMB	Lambertson Magnet	REPURPOSE FOR EIC	N/A