Brookhaven National Laboratory
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Electron Ion Collider Parameter Lists

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UNDER CONSTRUCTION
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Contents

Chapter 1

Introduction (S. Nagaitsev)

The EIC collides polarized electrons in an Electron Storage Ring (ESR) with ions in a Hadron Storage Ring (HSR), with species that range from polarized protons and deuterons to unpolarized heavy ions. Figure 1.1 shows the scope of the EIC project.

Electron injector complex. A new electron injector complex delivers full-energy electron bunches to the ESR. It comprises a high-intensity preinjector (a polarized electron source and a linac), a Beam Accumulator Ring (BAR), and a Rapid Cycling Synchrotron (RCS). Each ESR electron bunch is replaced every few minutes, in order to maintain the required average ESR beam polarization. To do this the electron injector provides a new electron bunch at a rate of at least 1 Hz.

Preinjector. The polarized electron source is a polarized, room temperature photo-cathode electron gun. The subsequent copper S-band linac is installed in a new enclosure, connected to the RCS ring enclosure.

Beam Accumulator Ring. The new BAR ring is installed between the S-band linac and the RCS, with a circumference of about 40 m. It accumulates highly-polarized electron bunches from the preinjector before transportation to the RCS.

Rapid Cycling Synchrotron. The RCS is installed in a new enclosure near RHIC Insertion Region 4 (IR4), with a circumference of 1,421 m. It accelerates highly-polarized electron bunches to the ESR collision energy after extraction from the BAR, using normal conducting magnets and superconducting RF cavities.

Electron Storage Ring. The ESR is a new ring installed in the RHIC tunnel, with a circumference close to that of the HSR. The HSR and ESR revolution frequencies are locked when injection is complete, synchronizing bunch collisions. The ESR is comprised of room temperature magnets, superconducting RF systems, and a vacuum system that can absorb up to 10 MW of synchrotron radiation.

Hadron Storage Ring. The HSR is a modified version of the existing RHIC yellow ring; the RHIC blue ring will be removed. Several HSR modifications and upgrades are necessary to support HSR beam parameters, including removal of DX magnets to enhance the

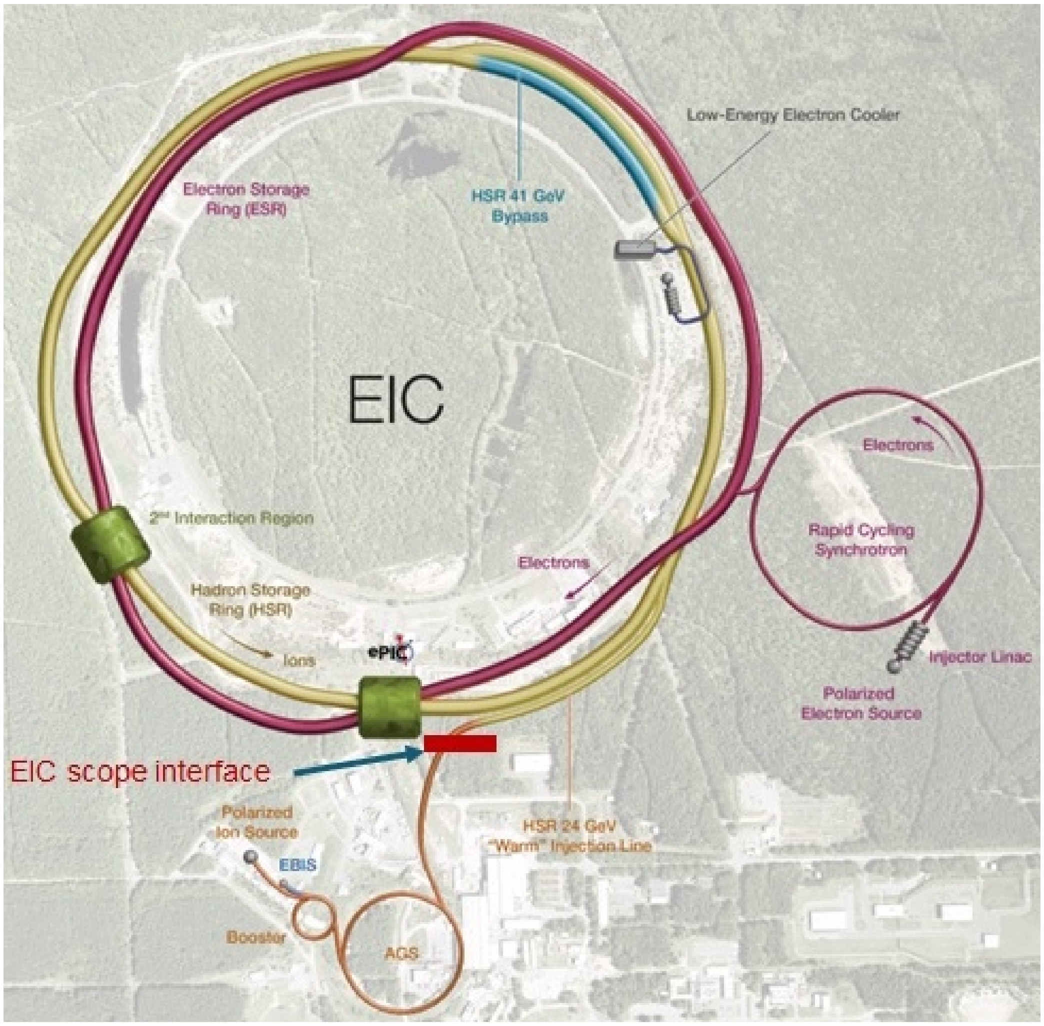

Figure 1.1: The EIC scope starts downstream of the "YD26" dipole in the last section of the AGS-to-RHIC transfer line. For the EIC, the warm transfer line is extended to the IR4 HSR area, where the beam is injected into the cold HSR. Apart from this transfer line extension, the EIC scope does not include any other modifications to the existing Hadron Injector.

maximum hadron energy, addition of a superconducting RF system, and a revised AGS-to-RHIC (AtR) injection beamline. The HSR beampipe vacuum chamber, bellows, and diagnostics are modified and updated. The existing RHIC superconducting hadron spin rotators are upgraded and relocated to support high beam polarization.

Cryogenic systems. The Collider-Accelerator Department (C-AD) upgrades the RHIC Liquid Helium (LHe) central refrigerator plant to improve efficiency, reduce helium loss, and meet the EIC cryogenic load requirements. The EIC project provides 2 K helium to the SRF cavities and the new superconducting magnets near the interaction pont, using three new satellite plants that draw 4.6 K liquid helium from the central cryogenic plant.

1.0.1 Full Capability proton collisions

Collisions			
Proton energy	GeV	275	275
Electron energy	GeV	10	18
Luminosity L	$10^{33}\text{cm}^{-2}\text{s}^{-1}$	10.0	1.54
Hourglass factor H		0.94	0.91
No. of bunches M		1160	290
RMS beam size σ_H	µm	95	119
σ_V	µm	8.5	11.0
$K_x \equiv \sigma_H/\sigma_V$		11.1	11.1
Protons			
Bunch intensity	10^{10}	6.9	19.1
Beam current	A	1.00	0.69
RMS normalized emittance H	µm	3.3	5.2
V	µm	0.30	0.47
RMS emittance H	nm	11.3	18.0
V	nm	1.0	1.6
Collision β^* H	m	0.80	0.80
V	m	0.072	0.071
RMS beam angle H	µrad	119	150
V	µrad	119	150
Beam-beam parameter ξ H		0.012	0.003
V		0.012	0.003
RMS longitudinal emittance	eV.s	0.036	0.036
RMS bunch length	mm	60	60
RMS $\Delta p/p$	10^{-3}	0.68	0.68
Maximum space charge ΔQ		0.004	0.007
Piwinski angle	rad	7.9	6.3
IBS growth time L	h	2.9	2.0
H	h	2.0	2.0
V	h	67	82
Electrons			
Bunch intensity	10^{10}	17.2	6.2
Beam current	A	2.5	0.227
RMS normalized emittance H	µm	391	845
V	µm	26	71
RMS emittance H	nm	20	24
V	nm	1.3	2.0
Collision β^* H	m	0.45	0.59
V	m	0.056	0.057
RMS beam angle H	µrad	211	202
V	µrad	152	187
Beam-beam parameter ξ H		0.072	0.093
V		0.100	0.100
RMS bunch length	mm	7	9
RMS $\Delta p/p$	10^{-3}	0.58	1.09
Piwinski angle	rad	2.4	2.1

Chapter 2

Electron Injector (Q. Wu)

The **Electron Injector** complex generates, accumulates, accelerates, and injects up to two 28 nC polarized electron bunches per second into the Electron Storage Ring. The complex minimizes intensity and polarization loss, and ensures reliable operation.

The **Preinjector** produces bunches with a charge as large as 1 nC at a rate of 30 Hz, and accelerates them to 750 MeV. Many bunches are accumulated into a single bunch with an intensity as large as 28 nC in the Beam Accumulator Ring, before being transferred to the Rapid Cycling Synchrotron, where they are further accelerated to a final energy in the range from 5 to 18 GeV. Beam is then extracted from the RCS and transported to the constant-energy Electron Storage Ring. The Preinjector consists of a High Voltage Direct Current (HVDC) polarized electron gun, a spin rotator, a ballistic bunching section employing a buncher and drift, a capture cavity, and a Traveling Wave (TW) linear accelerator. It includes a gun diagnostics beamline, a spin diagnostics beamline with Mott polarimetry, and energy spectrum diagnostics.

The **Beam Accumulator Ring** is a constant-energy storage ring dedicated to accumulating a single full intensity bunch from many electron linac bunches. Single bunches from BAR are injected into the RCS.

The **Rapid Cycling Synchrotron** accepts vertically polarized electron bunches from the Beam Accumulator Ring, or directly from the Preinjector, and accelerates them for delivery to the RCS-to-ESR transport line and the Electron Storage Ring.

2.0.1 Preinjector

General		
Beam extraction energy	MeV	750
Beam repetition rate	Hz	30
Energy spread at end of linac	%	0.25
Normalized RMS horizontal emittance	μm	60
Normalized RMS vertical emittance	μm	40
Bunch charge	nC	1
Spin direction		vertical
Polarization	%	$\geq$86
RMS bunch length	mm	0.75
Electron Gun		
Gun voltage	kV	310
Bunch length	ps	300
Laser pulse energy	μJ	up to 6
Low Energy RF		
Buncher frequency	MHz	197
Buncher voltage	kV	500
Capture cavities frequency	MHz	1300
Capture cavity 1 voltage	MV	5
Capture cavity 2 voltage	MV	10
Electron Linac		
Number of TW accelerating units		14
Linac frequency	MHz	2856
Linac voltage	MV	60

2.0.2 Beam Accumulator Ring

General		
Number of bunches		1
Bunch length	mm	43
Injection		
Energy	MeV	750
Bunch charge	nC	1
Repetition rate	Hz	30
Horizontal RMS emittance (norm)	µm	$\sim$30
Vertical RMS emittance (norm)	µm	$\sim$50
RMS energy spread		0.0045
Extraction		
Energy	MeV	750
Bunch charge	nC	28
Repetition rate	Hz	1
Horizontal RMS emittance (geom)	nm	124
Horizontal RMS emittance (norm)	µm	182
Vertical RMS emittance (geom, 3% coupling)	nm	4
Vertical RMS emittance (norm, 3% coupling)	µm	5.9
RMS energy spread	10^{-3}	0.47
RF		
Frequency	MHz	52.88
Voltage	kV	100
Magnet		
Main dipole number		8
Main dipole effective length	m	1.5
Main dipole field	T	1.3099
Quad number		24
Quad effective length	m	0.3
Quad field gradient	T/m	4.6/-2.9/4.7

2.0.3 Rapid Cycling Synchrotron

General		
Repetition rate	Hz	1
Acceleration time	ms, turns	100, 21000
Number of bunches		1
Bunch charge	nC	1–28
Circumference	m	1421.257
Betatron tunes $Q_{x,y}$		41.195, 58.128
Max beta functions (x,y)	m	30.48, 35.73
Max dispersion (x)	m	0.5882
Momentum compaction	10^{-4}	6.48
Injection		
Energy	MeV	750
RMS emittance (norm; x,y)	µm	<180
RMS energy spread	10^{-3}	<0.5
RMS bunch length	mm, ps	<12, <40
Extraction		
Energy	GeV	5–18
RMS emittance (norm; x,y)	µm	196–845, 18–113
RMS energy spread	10^{-3}	0.58–1.09
RMS bunch length	mm, ps	7–9, 23–30
Energy radiated per electron (18 GeV)	MeV/turn	101.3
Horizontal damping time (18 GeV)	ms	2.75
RF		
Frequency	MHz	591.039
Voltage	MV	130
Magnet/Vacuum		
Main dipole number		320
Main dipole effective length	m	1.8
Main dipole bend angle	mrad	19.635
Main dipole field (max)	T	0.65
Quad number		352
Quad effective length	m	0.6
Quad strength K_1 (max)	m^{-2}	0.785
Sext number		640
Sext effective length	m	0.2
Sext strength K_2 (max)	m^{-3}	27.5
Beam pipe ID, thickness	mm	36.32, 0.89

Chapter 3

Electron Storage Ring (C. Montag)

The ESR is installed in the existing RHIC tunnel, where it intersects with the HSR in IR6 and IR8. IR6 is equipped with spin rotators, crab cavities, and dedicated low-β magnets, while IR8 contains only a simple cross-over section with the future potential to host a second detector. The circumference ensures that that the electron revolution frequency matches that of 133 GeV on-axis proton beams.

The ESR plane is tilted by 200 μrad with respect to the HSR, about an axis through IP6 and IP8. This results in elevation differences of 104 mm and 208 mm at IP4 and IP12, facilitating the accelerator cross-overs there.

Arc magnets are arranged in a FODO cell pattern. Each half-cell contains two 2.73 m long D13 dipoles and a single 0.89 m D2 dipole, in a "super-bend" structure. All three dipoles are powered uniformly at energies of 10 GeV and above, minimizing synchrotron radiation losses. The D2 dipoles are powered with reverse polarity below 10 GeV, increasing the equilibrium emittance to about 20 nm and increasing radiation damping in order to support a large beam-beam tune shift parameter even at low energy. Arc sextupoles are powered to maximize the dynamic aperture, in family structures that depend on the betatron phase advance in the arc FODO cells, which in turn is chosen depending on the beam energy.

3.0.1 Top level

Top level				
Beam energy	GeV	5	10	18
Maximum circulating current	mA	2500	2500	230
Bunch count		1160	1160	290
Maximum bunch charge	nC	28	28	11
Harmonic number		7560	7560	7560
Natural unnormalized RMS emittance	nm	20	20	30
RMS fractional momentum spread	10^{-3}	0.48	0.54	0.97
RMS bunch length	mm	7	7	9
Sokolov-Ternov time constant	min	1124	679	33.4
Equilibrium polarization	%	16.0	47.4	33.9
Bunch replacement time, spin up	min	149	451	10.1
spin down	min	231	98.6	3.75
Filling rate	bunches/s	1	1	1
Filling time	min	20	20	5
Beam stored energy	kJ	162	325	57.4

3.0.2 Lattice and orbit

Lattice and orbit				
Beam energy	GeV	5	10	18
Circumference	m	3834.0002	3834.0042	3834.0042
Revolution frequency	kHz	78.1931257	78.1930444	78.1930445
Radio frequency	MHz	591	591	591
Harmonic number		7560	7560	7560
Energy loss per turn	MeV	1.15	3.71	40
Momentum compaction factor	10^{-3}	0.60	1.19	0.60
RF Voltage	MV	5.0	22.5	56.0
Number of FODO cells per arc		16	16	16
Phase advance per arc FODO cell	deg.	60	60	90
Average arc bending radius	m	380	380	380
Arc dipole bending radius, D13	m	-52.44	262.26	262.26
D2	m	132.37	262.26	262.26
Arc dipole field, D13	T	-0.32	0.12	0.23
D2	T	0.13	0.12	0.23
Arc quadrupole gradient	T/m	3.74	7.22	18.56
Number of sextupole families per arc		6	6	4

Chapter 4

Hadron Storage Ring (V. Ptitsyn)

The HSR, based on the Yellow ring, inherits RHIC's versatility to collide a large range of ion species over a wide energy range. It operates with three times more hadron beam current, a larger number of bunches, and a 10% larger maximum beam energy. Copper and amorphous carbon coated beam screens are installed in the vacuum chamber to mitigate resistive wall heating and electron cloud effects. The proton beam circumference is varied by changing the radial orbit, in order to synchronize collisions with the electron beam over an energy range from 100 to 275 GeV. Proton collisions at 41 GeV energy are realized by using an inner arc bypass in the sextant from IP12 to IP2. The warm AtR injection line is considerably extended, bringing hadron beams to IR4 before injection into cold HSR magnets.

4.0.1 Proton and gold bunches

		protons	**gold**
Injection energy	GeV or GeV/u	23.8	10.0
Top energy	GeV or GeV/u	275	110
Polarization	%	70	0
Bunch count, injection		290	290
top		1160	1160
Ions per bunch at store		69×10^9	0.5×10^9
Beam current	A	1.0	0.57
Beam stored energy	MJ	3.53	1.97

4.0.2 Layout, lattice, RF voltages

Layout and lattice			
Magnetic rigidity, injection		Tm	79.3
top		Tm	917.3
Arc dipole, bend radius		m	242.78
top field		T	3.804
current		kA	5.602
Arc quadrupole gradient		T/m	75.4
Arc beam screen aperture, H		mm	62.4
V		mm	47.4
RF voltages			
$h = 315$	injection & ramp	MV	0.6
$h = 630$	bunch splitting	MV	0.6
$h = 1260$	bunch splitting	MV	0.6
$h = 2520$	bunch compression	MV	6.0
$h = 7560$	bunch compression	MV	20.0

4.0.3 Radial shift

		protons				gold	
Total energy	GeV or GeV/u	41	100	133	275	40.7	110 .0
Relativistic γ		43.7	106.6	141.8	293.1	43.7	118.1
Circumference shift	mm	-908.7	-73.4	0.0	73.1	-908.7	-42.1
Average radial shift	mm	–	-11.7	0.0	11.6	–	-6.7

4.0.4 Injection line magnets

Magnet style	Count	Length m	Bend angle mrad	Quad strength m^{-2}	Inventory
Combined function	25	3.657	48.15	0.03808	RHIC X-arc recycle
Quadrupole	42	0.6		variable	Build to APS Q5 design
Vertical dipole	2	0.5	1.7		New design
Horizontal dipole	2	2.0	30.2		New design
Current septum	1	3.976	50.11		New design
Induction septum	1	1.5	18.41		New design
Dipole corrector	TBD	TBD	TBD		Existing

4.0.5 Transition crossing

Transition crossing		
Transition energy	GeV	21.407
Transition γ		24.79
RF voltage	kV	200
RF harmonic number		315
Stable phase	rad	0.074
Acceleration rate	γ/s	0.5
Momentum spread max.		0.0055
Nonlinear factor α_1		-1.12$\times 10^{-3}$

Chapter 5

New superconducting magnets (W. Wahl)

Electron and hadron beams collide with a crossing angle of 25 mrad at Interaction Point (IP6). There is a total of 27 new superconducting magnets in Interaction Region 6 (IR6), with a mixture of dipoles, quadruples, correctors, and solenoids. Multiple construction technologies are leveraged, including Direct Wind (DW) and cable. Cable magnets use a Rutherford style cable (Ruth.), while the Direct Wind magnets use a six-around-one conductor (6-R-1). Except for dipoles B2pF and B0pF, the new superconducting dipoles and quadrupoles share interconnected cryostats – four on the hadron-forward side, and three in the hadron-rear. The combined function B0pF magnet resides in a dedicated cryostat that includes Q0eF. Some magnets are tapered, with minimum and maximum coil and beampipe radii.

Spin rotator solenoids. Electron spin rotation is performed by solenoids, with help from neighboring dipoles. There are two sets of solenoids on each side of IP6 – a pair of long solenoids used at 18 GeV, and a pair of short solenoids used at 5 GeV. Both pairs are powered at intermediate energies.

5.1 Hadron Storage Ring

5.1.1 Dipoles

		B0pF	B0ApF	B1pF	B1ApF	B2pF
Construction		DW	DW	Cable	Cable	Cable
Coil radius	mm	328	TBD	150	TBD	60
Beampipe radius	mm	TBD	43	135	168	50
Lattice length	m	< 1.2	< 0.6	< 3	< 1.5	2.47
Coil length	m	1.2	0.6	3	1.5	2.85
Reference radius	mm	50	26	45	45	30
Field	T	-1.3	3.3	3.4	2.7	6.28
Layers		2	12	1	1	2
Current	kA	1.2	2	11.9	13.4	8.2
Ramp rate	T/s	-0.0065	0.0165	0.017	0.0135	0.031
Temperature	K	1.9	1.9	1.9	1.9	1.9
Strand diameter	mm	0.473	0.473	1.065	1.065	1.065
Conductor style		6-R-1	6-R-1	Ruth.	Ruth.	Ruth.

5.1.2 Quadrupoles

		Q1ApF	Q1BpF	Q2pF	Q1ApR	Q1BpR	Q2pR
Construction		Cable	Cable	Cable	DW	DW	DW
Focus/Defocus		D	D	F	D	D	F
Gradient max.	T/m	89	56	41	78	78	26
Coil rad. min.	mm	71	93		28.35		
max.	mm				34.65		
Pipe rad. min.	mm	56	78	131	20.0	28	54
max.	mm				25.5		
Lattice length	m	<1.46	<1.61	<3.8	<1.8	<1.4	<4.5
Coil length	m	1.46	1.61	3.8	1.8	1.4	4.5
Ref. radius	mm	45	45	83	17	19	36
Layers		2	1	2	8	8	4
Current	kA	11	16	8.5	0.9	0.89	1.3
Ramp rate	T/ms	-0.44	-0.28	0.21	-0.39	-0.39	0.17
Temperature	K	1.9	1.9	1.9	4.5	4.5	4.5
Strand diam.	mm				0.33	0.33	0.473
Conductor		Ruth.	Ruth.	Ruth.	6-R-1	6-R-1	6-R-1

5.1.3 Correctors

		B0ApF -SkQ	**B0ApF -Vcorr**	**Q1ApR -SkQ**	**Q2pR -Hcorr**	**Q2pR -Vcorr**
Construction		DW	DW	DW	DW	DW
Corrector type		Skew quad	V dipole	Skew quad	H dipole	V dipole
Coil rad. min.	mm	TBD	TBD	28.35		
max	mm			34.65		
Beampipe rad. min.	mm	43.0	43.0	20.0	54	54
max.	mm			25.5		
Lattice length	m	< 0.6	< 0.6	<1.8	<4.5	<4.5
Coil length	m	0.6	0.6	1.8	4.5	4.5
Field	T		0.6		0.6	0.6
Integrated gradient	T	3.0		3.0		
Layers		2	2	2	2	2
Current	kA	TBD	TBD	TBD	TBD	TBD
Temperature	K	1.9	1.9	4.5	4.5	4.5
Strand diam.	mm	0.33	0.33	0.33	0.33	0.33
Conductor		strand	strand	strand	strand	strand

5.2 Electron Storage Ring

5.2.1 Quadrupoles

		Q0eF	Q1eF	Q1eR	Q2eR
Construction		DW	DW	DW	DW
Corrector					
Focus/Defocus		D	F	D	F
Gradient max.	T/m	14	6.3	14	14.1
Coil radius	mm				
Beampipe rad min.	mm	26	64.8	47.6	64.5
max.	mm			55.5	
Lattice length	m	<1.2	<1.61	<1.8	<1.4
Coil length	m	1.2	1.61	1.8	1.4
Reference radius	mm	17	43	TBD	20
Layers		4	2	4	2
Current	kA	0.08	1	1.8	1.8
Temperature	K	4.5	1.9	4.5	4.5
Strand diameter	mm	0.33	1.0	0.33	1.0
Conductor style			6-R-1		6-R-1

5.2.2 Correctors

		B2eRDrift -Vcorr	Q0eF -Hcorr	Q0eF -shield	Q1eF -Vcorr	Q1eF -SkQ	Q2eR -SkQ
Construction		DW	DW	DW	DW	DW	DW
Corrector type		V dipole	H dipole		V dipole	Skew Q	Skew Q
Coil radius	mm						
Pipe rad min.	mm	50.0	26.0	26.0	64.8	64.8	50.0
Lattice length	m	<5.5	<1.2	<1.2	<1.61	<1.61	<1.54
Coil length	m	TBD	1.2	1.2	1.61	1.61	1.54
Field	T	0.6	0.6	TBD	0.6		
Integ. gradient	T					3.0	3.0
Layers		2	2	2	2	2	2
Current	A	TBD	80	80	1	TBD	TBD
Temperature	K	4.5	4.5	4.5	1.9	1.9	4.5
Strand diameter	mm	0.33	0.33	0.33	0.33	0.33	0.33
Conductor style		strand	strand	strand	strand	strand	strand

5.2.3 Spin rotator solenoids

		Short SSR	**Long LSR**
Coil radius	mm	86.0	86.0
Beampipe radius	mm	50.0	50.0
Lattice length	m	2.5	6.2
Coil length	m	1.874	5.68
Reference radius	mm	33.0	33.0
Integrated field	Tm	15.30	46.75
Layers		33	33
Current	kA	0.866	0.874
Inductance	mH	6.04	18.71
Stored energy	MJ	2.26	7.14
Temperature	K	1.9	1.9
Strand diameter	mm	1.6	1.6
Conductor style		WIC	WIC

Chapter 6

Hadron Cooling (A. Fedotov)

The Low Energy Cooler (LEC) uses electron cooling to decrease the vertical emittance of proton bunches just after they are injected into the Hadron Storage Ring. Electron and proton beams co-move in a common straight section. A second harmonic RF system is used to alleviate space-charge effects during cooling, producing a longitudinally flattened proton bunch distribution with a peak current that is reduced by a factor of two. After cooling the proton bunches are accelerated to the collision energy, and are each split into four bunches. The LEC uses a 12.5 MeV RF electron accelerator to deliver electron bunches for hadron beam cooling.

6.0.1 Proton cooling at injection

Proton cooling at injection		
Relativistic gamma	–	25.4
Proton energy	GeV	23.8
Electron kinetic energy	MeV	12.5
Length of cooling section	m	170
Proton repetition rate	MHz	24.6
Proton bunch length, RMS	m	1.0
Proton beta function in the cooling section	m	150
Electron beta function in the cooling section	m	150
Total electron charge per proton bunch	nC	3
Single electron bunch charge (3 electron bunches)	nC	1
Average electron current	mA	74
Electron emittance in cooling section, normalized RMS	µm	<1.5
Electron angular spread in cooling section, RMS	µrad	25
Electron energy spread in cooling section, RMS	–	4×10^{-4}
Electron bunch length in cooling section, RMS	mm	40

6.0.2 Low Energy Cooler

Low Energy Cooler		
DC gun voltage	kV	400
Final electron kinetic energy	MeV	12.5
Main RF bunch frequency	MHz	197
Number of 197MHz NCRF cavities		17
Voltage per 197MHz RF cavity	kV	850
Energy correction RF frequency	MHz	591
Number of 591MHz NCRF correction cavities		4
Voltage per 591MHz cavity	kV	375
Number of 591MHz deflecting cavities		1
Voltage of deflecting cavity	kV	150
Number of 24.6MHz cavities		1
Voltage of 24.6MHz cavity	kV	10
Bunch train repetition rate	MHz	24.6
Photocathode material		CsK_2Sb
Laser wavelength	nm	532
Electron bunch full length on cathode	ps	400
Average electron current	mA	74
Beam dump power	kW	925

6.0.3 LEC beam diagnostics

Beam diagnostics	**Count**
Faraday cups (FC)	3
DC Current Transformer (DCCT)	2
Fast Current Transformer (FCT)	3
Integrated Current Transformer (ICT)	1
Profile Monitors	13
Beam Position Monitors	44
Loss Monitors (PMTs, fibers, PIN diodes)	32
Temperature sensors	32
Emittance slits	2
Recombination monitor	1
NMR Gaussmeter	1
Ion clearing	2
Gun radiation monitors	2
Remote scopes	2

6.0.4 LEC magnets

Magnet	**Count**	**Field**	**Gradient**	**Effective length**
		T	T/m	m
		Dipoles		
180 degree	2	0.07		2.04
20 degree	2	0.065		0.30
		Solenoids		
Gun area	2	0.04		0.10
Linac area	3	0.08		0.10
Transport	8	0.02		0.30
Cooling section	15	0.02		0.134
Extraction	2	0.01		0.1
		Quadrupoles		
Diagnostics & extraction lines	3		1.0	0.1
U-turn	2		0.1	0.1
		Dipole correctors		
Gun area	2	1×10^{-3}		0.1
Linac and transport	8	1×10^{-3}		0.1
Transport	10	6×10^{-4}		0.1
U-turn	4	1×10^{-3}		0.1
Cooling section	15	1×10^{-4}		0.1
Diagnostics & extraction lines	8	1×10^{-3}		0.1

Chapter 7

Cryogenic Systems (B. Shell)

The Cryogenics Systems consist of the existing Central Plant located near sector 5, and Satellite Plants located near their associated loads. The Central Plant provides 4.5 K cooling to HSR components, interfaces with the Satellite Plants, and processes return gas from the Satellite Plants. Satellite Plants provide 1.92 K and 2 K cooling to components located in IR4, IR6, and IR10 by processing the 4.5 K helium down to 1.92 K for spin rotators, or 2.0 K for other SRF components. They also return helium gas back to the Central Plant.

7.0.1 Central plant

Central Plant		
Refrigeration capacity at 4.5 K	kW	55
Temperature	K	4.5
Pressure	bar	16
Compressor flow at full capacity	g/s	4500
Existing distribution length (RHIC)	km	~ 4
Liquefaction load (4.5 to 300 K)	g/s	45
Re-liquefaction load (4.5 to 4.5 K)	g/s	288
Non-isothermal load (4.5 to 10 K	g/s	282
Non-isothermal load (45 to 80 K)	g/s	102
Valve box count		8
Cryogenic controls I/O channel count		7500

7.0.2 Detector

Detector cryogenics		
Temperature	K	4.6
Cryogenic load at 4.6 K	W	100
Flow rate at 4.6 K load	g/s	6
Load on thermal shield (45 to 80 K)	W	600
Flow rate on thermal shield	g/s	3
Current lead intercepts load (4.5 to 300 K)	W	850
Flow rate on current lead intercepts (4.5 to 80 K)	g/s	0.5
Electrical cryogenic heater count		4
Cryogenic distribution length	m	40
Valve box count		2
Cryogenic valve count		14

7.0.3 Satellite plants

		IR4	**IR6**	**IR10**
Cryogenic load at 2 K	W	500	650	1250
Temperature – main load	K	2	1.92	2
Temperature – SRF cryomodules	K	2	2	2
Flow rate at 2 K load	g/s	24	45	63
Current lead intercepts load (4.5 to 80 K)	W	TBD	6050	2220
Flow rate on current lead intercepts (4.5 to 80 K)	g/s	TBD	17.14	24
Cryogenic distribution length	m	TBD	168	163
Valve box count		8	19	12
Cryogenic valve count		56	95	60
Cryo-Controls				
I/O channel count		1272	1744	1220
Electrical cryogenic heater count		32	76	50

Chapter 8

Glossary

AGS	Alternating Gradient Synchrotron
AtR	AGS-to-RHIC
APS	Argonne Photon Source
BAR	Beam Accumulator Ring
C-AD	Collider-Accelerator Department
D	Defocus
DW	Direct Wind
EIC	Electron-Ion Collider
ESR	Electron Storage Ring
F	Focus
FODO	Focusing-drift-Defocusing-drift
H	Horizontal
HSR	Hadron Storage Ring
HVDC	High Voltage Direct Current
IP	Interaction Point
IR	Insertion Region
LEC	Low Energy Cooler
LHe	Liquid Helium
linac	Linear accelerator
NMR	Nuclear Magnetic Resonance
PMT	Photo-Multiplier Tube
RF	Radio Frequency
RHIC	Relativistic Heavy Ion Collider
RCS	Rapid Cycling Synchrotron
RMS	Root Mean Square
Ruth.	Rutherford cable
SC	SuperConducting
TBD	To Be Determined
TW	Traveling Wave
V	Vertical
WIC	Wire-In-Channel
6-R-1	6 around 1 conductor