

EIC *Estimated* Energy Usage

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Thanks to C. Folz, R. Srinivasan, and T. Nehring (BNL)

eeFACT'22 Workshop
12-16 September 2022

Electron-Ion Collider

BROOKHAVEN
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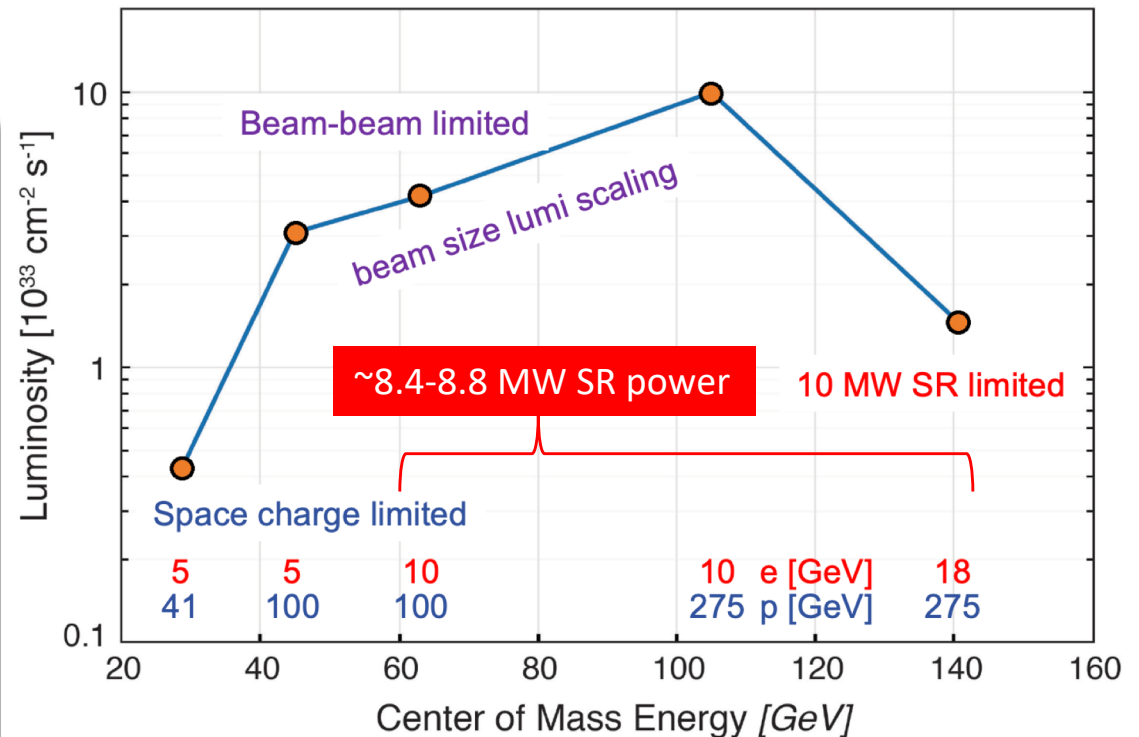
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EIC Luminosity and RF, SR Power

	Electrons	Protons
Beam energies	2.5 - 18 GeV	41- 275 GeV
Center of mass energy range	$E_{cm} = 20\text{-}140$ GeV	
	Electrons	Protons
Beam energies	10 GeV	275 GeV
Center of mass energy	$E_{cm} = 105$ GeV	
number of bunches	nb = 1160	
crossing angle	25 mrad	
Bunch Charge	$1.7 \cdot 10^{11}e$	$0.7 \cdot 10^{11}e$
Total beam current	2.5 A	1 A
Beam emittance, horizontal	20 nm	9.5 nm
Beam emittance, vertical	1.2 nm	1.5 nm
β - function at IP, horizontal	43 cm	90 cm
β - function at IP, vertical	5 cm	4 cm
Beam-beam tunes shift, horizontal	0.073	0.014
Beam-beam tunes shift, vertical	0.1	0.007
Luminosity at $E_{cm} = 105$ GeV	$1 \cdot 10^{34} \text{cm}^{-2} \text{s}^{-1}$	

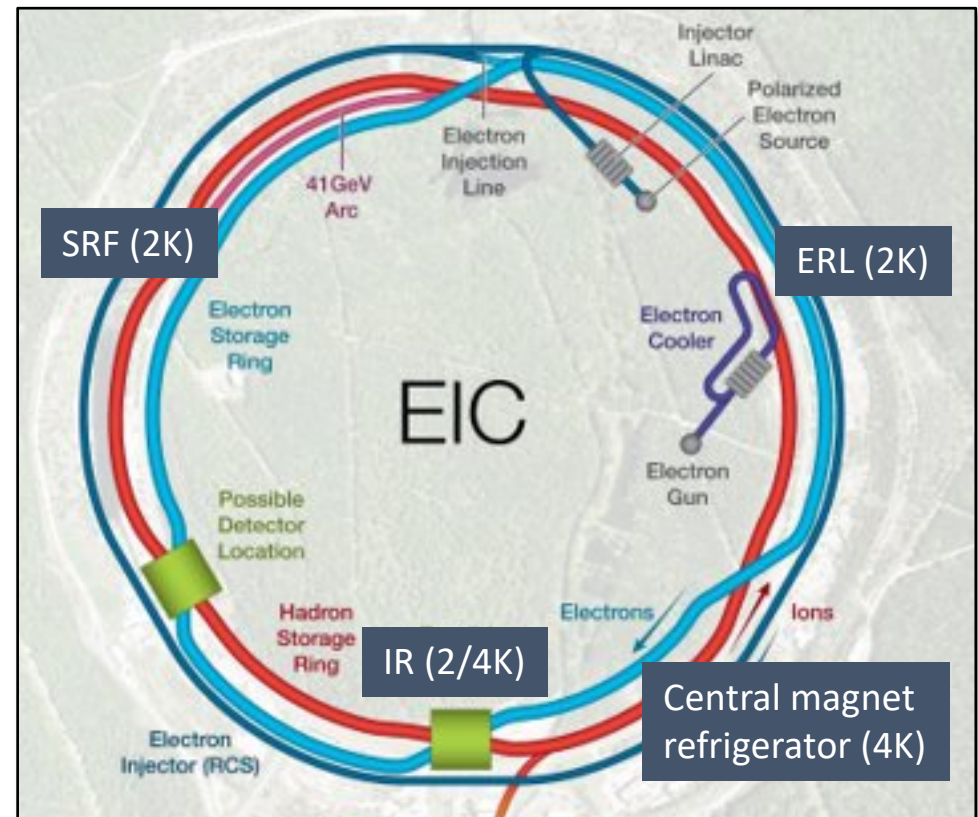


- Facility designed to max 10 MW ESR SR power
 - Vacuum chamber, installed RF power
- ESR: 8-9 MW SR power at most operating points
 - **Installed ESR SRF power 13 MW**
 - 5 MeV 2.5 A beams => 0.5 MW SR power

EIC Cryogenic Power

Location	Power [MW]
Central Plant (4K)	10.9
IR6 (Experiment)	0.32
IR10 (SRF)	0.56
IR2 (ERL cooler)	0.35
Total	12.1

- These are based on CD-1 Conceptual Design Report
- That these numbers will likely change based on design updates to CD-2
 - e.g. ERL injector change to SRF
 - e.g. IR6 magnet modification, spin rotator finalization
- Dominant 4K power well-known from RHIC operations and upgrade experience



Snowmass Spreadsheet

- These are based on CD-1 Conceptual Design Report
 - And engineering input
 - Requirements documents under development
- That these numbers **will** change based on design updates to CD-2 and requirements document development
 - e.g. ERL injector change to SRF
 - e.g. IR6 magnet modification, spin rotator finalization
- Dominant 4K power well-known from RHIC operations and upgrade experience
- Luminosity/MW $\sim 1/80$ is quite small!

Proposal name	EIC	
Beam energy [GeV]	5-18	
Average beam current [A or mA]	0.23-2.5	
SR power [MW]	9	10 or 18 GeV
Collider cryo power [MW]	12	2K, 4K
Collider RF power [MW]	13	Max
Collider magnet power [MW] (RCS, ESR drivers)	25	
Cooling & ventilation power [MW]	5	
General services power [MW]	4	
Injector cryo power [MW]	0	Included in Collider
Injector RF power [MW]	5	
Injector magnet power [MW]	5	
Pre-injector power (where applicable) [MW]	10	
Detector power (if included) [MW]		
Data center power (if included) [MW]		
Total power [MW]	79	
Luminosity [10^{34} /cm ² /s]	1	max
Total integrated luminosity / year [1/fb/yr]	145	max
Effective physics time per year asumed/needed to achieve integrated annual luminosity [10^7 s]	1.45	30 weeks * 80% availability
Energy Consumption / year [TWh]	0.32	
Many numbers based on nameplate estimations at CD-1 time and subject to substantial changes		

Provisional

CDR Parameters: High Divergence e-p

Table 3.3: EIC beam parameters for different center-of-mass energies \sqrt{s} , with strong hadron cooling. High divergence configuration.

Species	proton	electron	proton	electron	proton	electron	proton	electron	proton	electron
Energy [GeV]	275	18	275	10	100	10	100	5	41	5
CM energy [GeV]	140.7		104.9		63.2		44.7		28.6	
Bunch intensity [10^{10}]	19.1	6.2	6.9	17.2	6.9	17.2	4.8	17.2	2.6	13.3
No. of bunches	290		1160		1160		1160		1160	
Beam current [A]	0.69	0.227	1	2.5	1	2.5	0.69	2.5	0.38	1.93
RMS norm. emit., h/v [μm]	5.2/0.47	845/71	3.3/0.3	391/26	3.2/0.29	391/26	2.7/0.25	196/18	1.9/0.45	196/34
RMS emittance, h/v [nm]	18/1.6	24/2.0	11.3/1.0	20/1.3	30/2.7	20/1.3	26/2.3	20/1.8	44/10	20/3.5
β^* , h/v [cm]	80/7.1	59/5.7	80/7.2	45/5.6	63/5.7	96/12	61/5.5	78/7.1	90/7.1	196/21.0
IP RMS beam size, h/v [μm]	119/11		95/8.5		138/12		125/11		198/27	
K_x	11.1		11.1		11.1		11.1		7.3	
RMS $\Delta\theta$, h/v [μrad]	150/150	202/187	119/119	211/152	220/220	145/105	206/206	160/160	220/380	101/129
BB parameter, h/v [10^{-3}]	3/3	93/100	12/12	72/100	12/12	72/100	14/14	100/100	15/9	53/42
RMS long. emittance [10^{-3} , eV·s]	36		36		21		21		11	
RMS bunch length [cm]	6	0.9	6	0.7	7	0.7	7	0.7	7.5	0.7
RMS $\Delta p/p$ [10^{-4}]	6.8	10.9	6.8	5.8	9.7	5.8	9.7	6.8	10.3	6.8
Max. space charge	0.007	neglig.	0.004	neglig.	0.026	neglig.	0.021	neglig.	0.05	neglig.
Piwinski angle [rad]	6.3	2.1	7.9	2.4	6.3	1.8	7.0	2.0	4.2	1.1
Long. IBS time [h]	2.0		2.9		2.5		3.1		3.8	
Transv. IBS time [h]	2.0		2		2.0/4.0		2.0/4.0		3.4/2.1	
Hourglass factor H	0.91		0.94		0.90		0.88		0.93	
Luminosity [$10^{33}\text{cm}^{-2}\text{s}^{-1}$]	1.54		10.00		4.48		3.68		0.44	

CDR Parameters: High Acceptance e-p

Table 3.4: EIC beam parameters for different center-of-mass energies \sqrt{s} , with strong hadron cooling. High acceptance configuration.

Species	proton	electron	proton	electron	proton	electron	proton	electron	proton	electron
Energy [GeV]	275	18	275	10	100	10	100	5	41	5
CM energy [GeV]	140.7		104.9		63.2		44.7		28.6	
Bunch intensity [10^{10}]	18.9	6.2	6.9	17.2	6.9	17.2	4.8	17.2	2.6	13.3
No. of bunches	290		1160		1160		1160		1160	
Beam current [A]	0.69	0.227	1	2.5	1	2.5	0.69	2.5	0.38	1.93
RMS norm. emit., h/v [μm]	5.2/0.46	845/70	3.3/0.3	391/26	3.2/0.29	391/26	2.7/0.25	196/18	1.9/0.45	196/34
RMS emittance, h/v [nm]	17.6/1.6	24.0/2.0	11/1.0	20/1.3	30/2.7	20/1.3	26/2.3	20/1.8	44/10	20/3.5
β^* , h/v [cm]	417/38	306/30	265/24	149/19	94/8.5	143/18	80/7.2	103/9.2	90/7.1	196/21
IP RMS beam size, h/v [μm]	271/24		172/16		169/15		143/13		198/27	
K_x	11.1		11.1		11.1		11.1		7.3	
RMS $\Delta\theta$, h/v [μrad]	65/65	89/82	65/65	116/84	180/180	118/86	180/180	140/140	220/380	101/129
BB parameter, h/v [10^{-3}]	3/3	92/100	12/12	72/100	12/12	72/100	14/14	100/100	15/9	53/42
RMS long. emittance [10^{-3} , eV·s]	36		36		21		21		11	
RMS bunch length [cm]	6	0.9	6	0.7	7	0.7	7	0.7	7.5	0.7
RMS $\Delta p/p$ [10^{-4}]	6.8	10.9	6.8	5.8	9.7	5.8	9.7	6.8	10.3	6.8
Max. space charge	0.007	neglig.	0.004	neglig.	0.026	neglig.	0.021	neglig.	0.05	neglig.
Piwiński angle [rad]	2.8	0.9	4.3	1.4	5.2	1.5	6.1	1.7	4.2	1.1
Long. IBS time [h]	2.0		3.2		2.5		3.1		3.8	
Transv. IBS time [h]	2.0		2.0		2.0/4.0		2.0/4.0		3.4/2.1	
Hourglass factor H	0.99		0.98		0.94		0.91		0.93	
Luminosity [$10^{33}\text{cm}^{-2}\text{s}^{-1}$]	0.32		3.14		3.14		2.92		0.44	