Interaction Region Magnets for Future Electron-Ion Collider at Jefferson Lab

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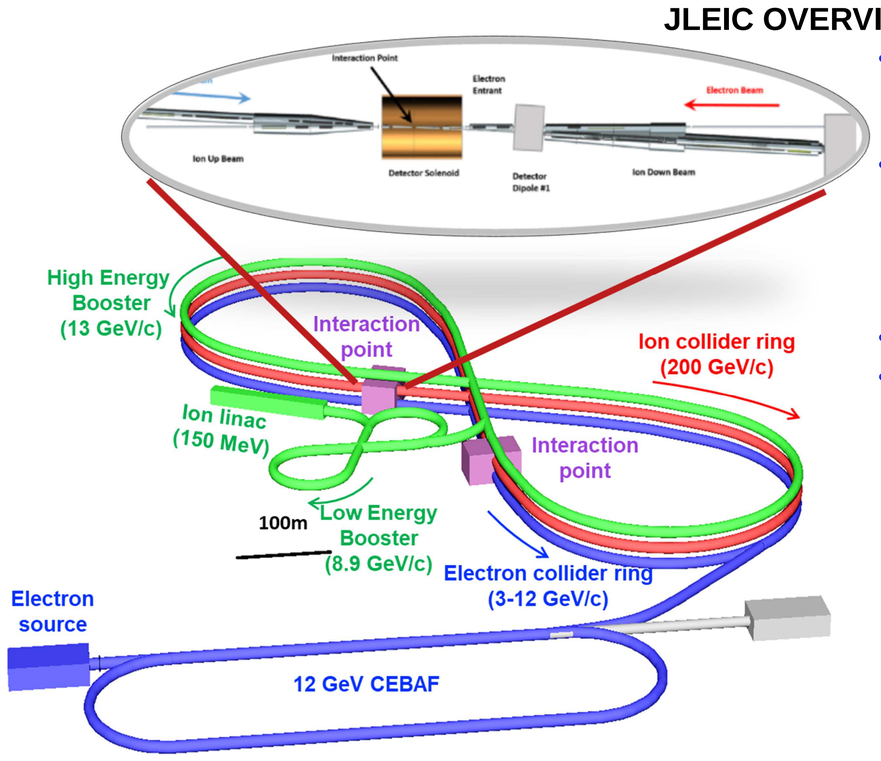
TUPLO13

NAPAC2019 NORTH AMERICAN PARTICLE ACCELERATOR CONFERENCE

Abstract

The Jefferson Lab Electron Ion Collider (JLEIC) is a proposed new machine for nuclear physics research. It uses the existing CEBAF accelerator as a full energy injector to deliver 3 to 12 GeV electrons into a new electron collider ring. An all new ion accelerator and collider complex will deliver up to 200 GeV protons. The machine has luminosity goals of 10^{34} cm^{-2} sec^{-1}. The whole detector region including forward detection covers about 80 meters of the JLEIC complex. The interaction region design has recently been optimized to accommodate 200 GeV proton energy using conventional NbTi superconducting magnet technology. This paper will describe the requirements and preliminary designs for both the ion and electron beam magnets in the most complex 34.5 m long interaction region (IR) around the interaction point (IP). The interaction region has over thirty-four superconducting magnets operating at 4.5K; these include dipoles, quadrupoles, skew-quadrupoles, solenoids, horizontal and vertical correctors and higher order multipole magnets. The paper will also discuss the electromagnetic interaction between these magnets.

JLEIC OVERVIEW

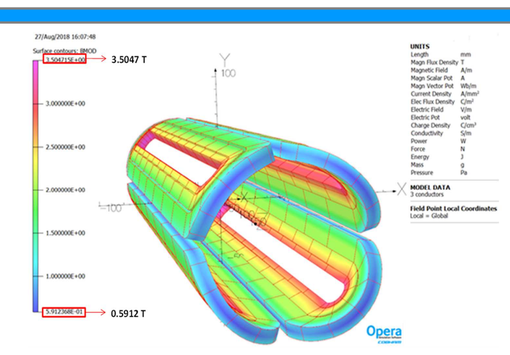


- **Electron complex**
  - CEBAF as a full energy injector
  - Electron collider ring: 3-12 GeV/c
- **Ion complex**
  - Ion source, SRF linac: 150 MeV for protons
  - Low Energy Booster: 8.9 GeV/c
  - High Energy Booster: 13 GeV/c
  - Ion collider ring: 200 GeV/c
- **Up to two detectors** at minimum background locations
- **20-100 GeV CM, Upgradable to 140 GeV CM**

IR MAGNET DESIGNS

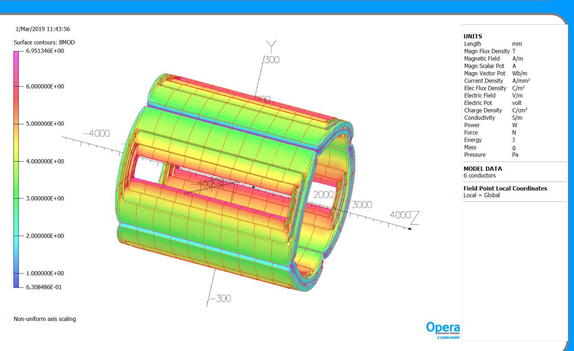
ELECTRON QUADRUPOLES

- 6 electron beam line quadrupoles
- A common coil design is used for all 6 quadrupoles
- Field gradient up to 45 T/m
- The peak field in the coil is 3.6 T
- Coils are keystone Rutherford cable



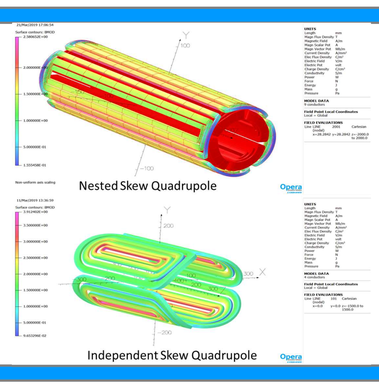
ION QUADRUPOLES

- 6 ion beam line quadrupoles; 3 Rear Side, 3 Forward Side
- The Forward Side quadrupoles have larger bores and are the most challenging
- The peak fields in the ion quadrupole coils are 6.4-7.0 T
- Coils are keystone Rutherford cable



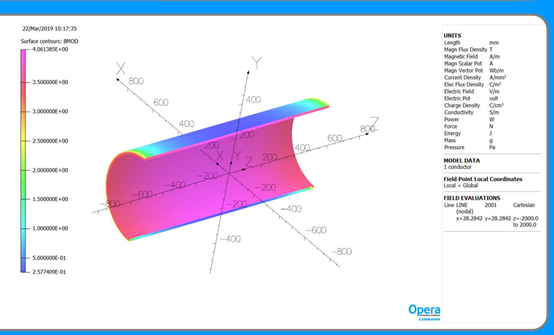
SKEW QUADRUPOLES

- Electron beam line skew quadrupoles are nested around the main quadrupole
- The first ion Rear Side and Forward Side skew quadrupoles are also nested coils
- The other ion beam line skew quadrupoles will be independent due to the gradient
- The coil field in all the skew quadrupoles is relatively low to moderate for NbTi



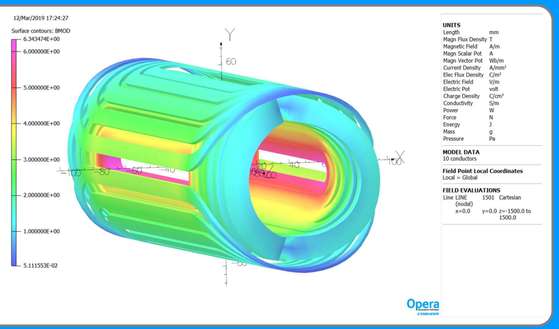
SOLENOIDS

- There are four solenoid magnets in the IR to counteract the effects of the detector solenoid
- The Forward Side ion beam solenoid has a larger bore (19.8 cm radius), coil inner radius (22.5 cm) and it is a 4 T solenoid

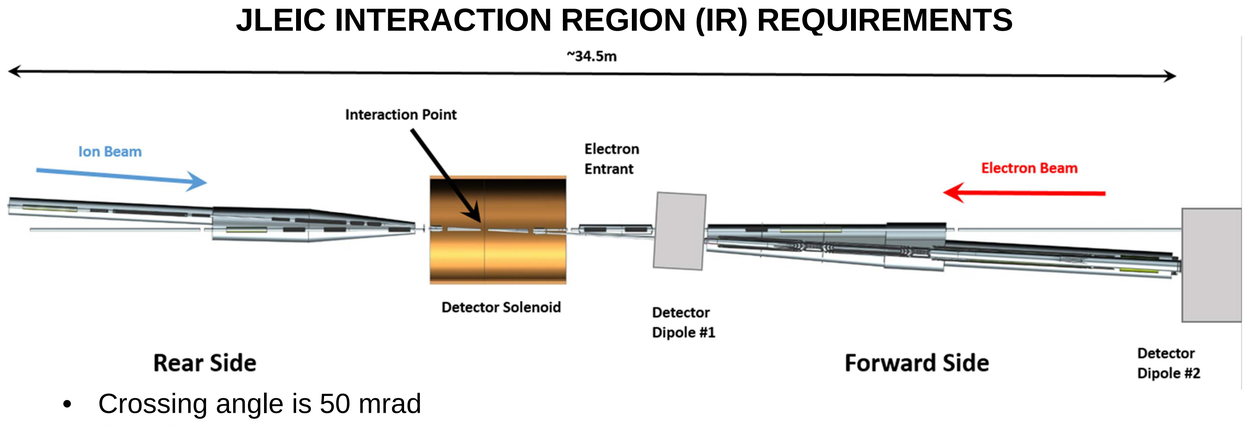


KICKER MAGNET

- The kicker magnets in the ion beamline performs orbit correction
- 2 kicker magnets in the IR with opposite field polarity
- The performance requirements are similar enough that these magnets are the same design



JLEIC INTERACTION REGION (IR) REQUIREMENTS

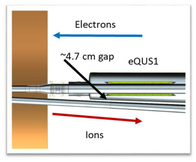


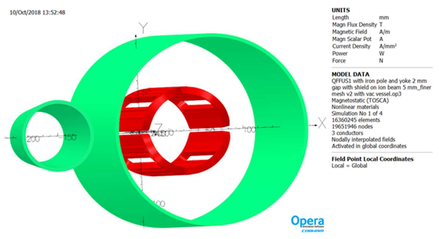
- Crossing angle is 50 mrad
- The IR contains a full acceptance detector built around the detector solenoid
- Forward Side ion magnets have apertures which support ±10 mrad angular acceptance
- All final focus quadrupole magnets use NbTi conductor
- Operating temperature is between 4.5 K and 4.7 K
- All IR magnets are designed as cold bore, to lower the peak field in the coils

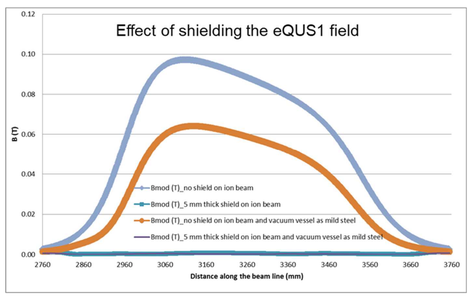
		Specifications									Design			
Element Name	Type	Length [m]	Good Field Radius [cm]	Aperture Inner Radius [cm]	Outer Radius [cm]	Dipole field [T]		Quadrupole field [T/m]		Solenoid [T]	Coil Inner Radius (cm)	Coil Outer Radius (cm)	Coil Width in Radial Direction (mm)	Peak Field in the coil (T)
						Bx	By	Normal	Skew					
Ion Rear Side Elements														
iASUS	SOLENOID	1.6	3.0	4.0	12.0	0	0	0	0	2	6	6.7	7	2.0
iQUS3S	QUADRUPOLE	0.5	3.0	4.0	12.0	0	0	0	3.38	0	4.5	4.7	2	0.3
iQUS2	QUADRUPOLE	2.1	3.0	4.0	12.0	0	0	94.07	0	0	4.5	7.8	33	5.7
iQUS2S	QUADRUPOLE	0.5	2.0	3.0	10.0	0	0	0	-9.26	0	3.5	4	5	0.6
iQUS1b	QUADRUPOLE	1.45	2.0	3.0	10.0	0	0	-97.88	0	0	3.45	4.95	15	5.1
iQUS1S	QUADRUPOLE	0.5	2.0	3.0	10.0	0	0	0	16.42	0	3.5	4.4	9	0.9
iQUS1a	QUADRUPOLE	1.45	2.0	3.0	10.0	0	0	-97.88	-3.08	0	3.45	5.75	23	5.1
iCUS1	KICKER	0.3	2.0	3.0	10.0	-3.90	0.076	0	0	0	3.45	5.25	18	6.3
iCUS2	KICKER	0.3	2.0	3.0	10.0	4.50	-0.019	0	0	0				
Ion Forward Side Elements														
iQDS1a	QUADRUPOLE	2.25	4.0	9.2	23.1	0.0	0	-37.23	-1.23	0	13.0	17.1	41	6.4
iQDS1S	QUADRUPOLE	0.5	4.0	9.9	24.8	0.0	0	0	14.85	0	13.0	14.2	12	3.9
iQDS1b	QUADRUPOLE	2.25	4.0	12.3	31.0	0.0	0	-37.23	0	0	13.0	16.3	33	6.4
iQDS2S	QUADRUPOLE	0.5	4.0	13.0	32.7	0.0	0	0	-7.83	0	13.6	14.5	9	2.3
iQDS2	QUADRUPOLE	4.5	4.0	17.7	44.4	0.0	0	25.96	0	0	18.2	21.5	33	7.0
iQDS3S	QUADRUPOLE	0.5	4.0	18.4	46.2	0.0	0	0	0.63	0	20.0	20.2	2	0.4
iASDS	SOLENOID	1.2	4.0	19.8	49.7	0.0	0	0	0	4	22.5	24.0	15	4.0
Electron Rear Side Elements														
eASDS	SOLENOID	1.2	2.2	4.5	11.0	0	0	0	0	-4	6.5	8.0	15	4.0
eQDS3	QUADRUPOLE	0.6	2.4	4.5	10.0	0	0	-18.72	-2.71	0	4.95	6.5	15.5	3.6
eQDS2	QUADRUPOLE	0.6	2.8	4.5	8.5	0	0	36.22	5.25	0				
eQDS1	QUADRUPOLE	0.6	1.7	4.5	8.0	0	0	-33.75	-4.89	0				
Electron Forward Side Elements														
eQUS1	QUADRUPOLE	0.6	2.0	4.5	10.0	0.0	0.00	-36.94	8.10	0	4.95	6.5	15.5	3.6
eQUS2	QUADRUPOLE	0.6	3.2	4.5	11.0	0.0	0.00	33.66	-7.38	0				
eQUS3	QUADRUPOLE	0.6	1.5	4.5	11.0	0.0	0	-20.80	4.56	0				
eASUS	SOLENOID	1.8	2.2	4.5	11.0	0.0	0	0	0	-4	6.5	8.0	15	4.0

MAGNET-MAGNET INTERACTIONS

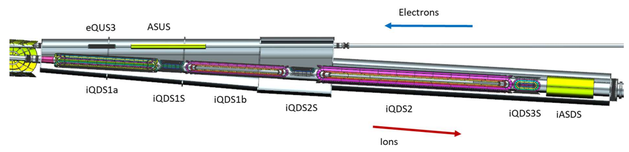
eQUS1 with Ion Beam Line

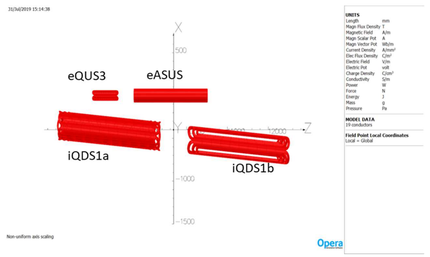


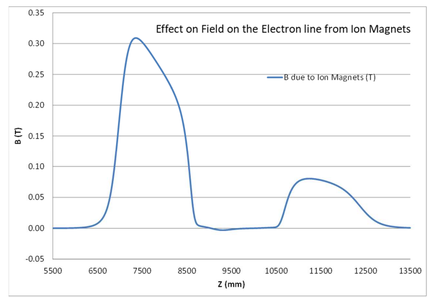




iQDS1a, iQDS1b, eQUS3 and eASUS







Acknowledgements

This material is based upon work supported by the U.S. Department of Energy, Office of Science, and Office of Nuclear Physics under Contracts DE-AC05-06OR23177 and DE-AC02-76SF00515 .

SUMMARY

- All preliminary IR magnet designs are complete
- The peak fields in the coils are less than 7 T
- Acceptable shielding solutions exist for interactions
- Preliminary optimizations have been completed
- Additional optimizations are required for detailed coil design, minimizing coil peak field, and multipoles
- The interaction between the detector magnets and the transport magnets remain to be studied
- The conceptual cryostat designs are in progress