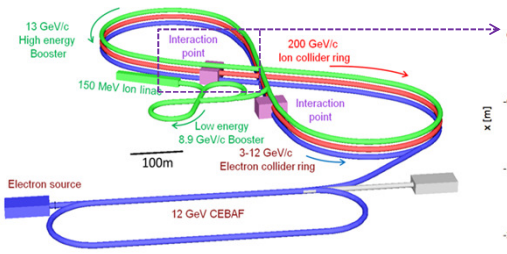
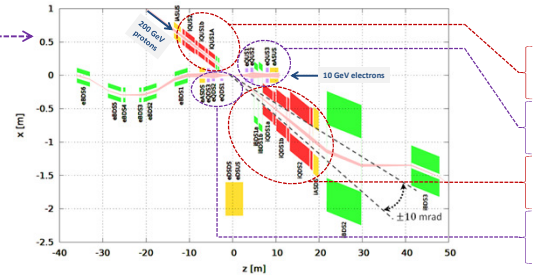
FIELD QUALITY ANALYSIS OF INTERACTION REGION QUADRUPOLES FOR JLEIC

G. Sabbi, LBNL, Berkeley, CA, USA
B.R.P. Gamage, T. Michalski, V.S. Morozov, R. Rajput-Ghoshal, M. Wiseman, Jefferson Lab, Newport News, VA, USA
Y. Nosochkov, M. Sullivan, SLAC, Menlo Park, CA, USA

Jefferson Lab Electron-Ion Collider



IR Layout



IR Quadrupole Parameters

Element name	L_{mag} [m]	R_{bore} [cm]	R_{field} [cm]	R_{out} [cm]	G_{normal} [T/m]	G_{skew} [T/m]
iQUS1a	1.45	3.0	2.0	10.0	-97.88	-3.08
iQUS1b	1.45	3.0	2.0	10.0	-97.88	-
iQUS2	2.10	4.0	3.0	12.0	94.07	-
eQUS1	0.6	4.5	2.0	10.0	-36.94	8.10
eQUS2	0.6	4.5	3.2	11.0	33.66	-7.38
eQUS3	0.6	4.5	1.5	11.0	-20.80	4.56
iQDS1a	2.25	9.2	4.0	23.1	-37.23	-1.23
iQDS1b	2.25	12.3	4.0	31.0	-37.23	-
iQDS2	4.50	17.7	4.0	44.4	25.96	-
eQDS1	0.6	4.5	1.7	8.0	-33.75	-4.89
eQDS2	0.6	4.5	2.8	8.5	36.22	5.25
eQDS3	0.6	4.5	2.4	10.0	-18.72	-2.71

Magnet Requirements

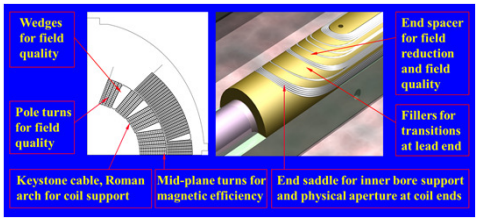
Experimental:

- **Very large aperture for acceptance** of charged and neutral particles in the hadron beam forward side
- Limit **background and detector damage from e-beam synchrotron radiation**
- **Integrate detector elements** (e.g. spectrometers) in IR layout
- Operate under **high heat load from IP** (cooling, radiation lifetime)

Accelerator:

- **Large focusing strength** for small beam size at the IP and high luminosity
- Operate in a **wide range of beam energy/current with good field quality**
- **Compact designs** and/or **interleaved electron and ion magnets** in order to minimize **crossing angle** and **crab cavity system** requirements
- **Control magnet fringe fields** to minimize perturbations on adjacent beam optics

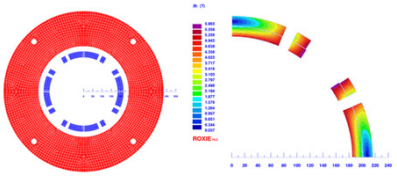
Magnet Design: NbTi, cos2θ, Rutherford cable, collar-based mechanical structure



Parameter	Unit	eQ	iQDS1a	iQDS1b	iQDS2
Strand diam.	mm	0.735	1.065	1.065	1.065
No. strands		22	28	28	28
Cable width	mm	8.3	15.1	15.1	15.1
R_{coil} (inner)	mm	53	100	131	185
No. layers		1	1	2	2
No. blocks		2	2	4	4
R_{yoke} (inner)	mm	70	135	187	245
R_{yoke} (outer)	mm	95±15	225	302	434
Ref. current	kA	3.15	9.5	7.1	6.5
Ref. grad.	T/m	35.5	38.0	36.7	26.2

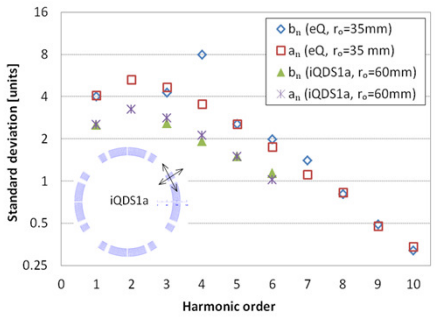
Example: iQDS2:

- Very large aperture: 37 cm coil diameter
- Double-layer coil with 30 mm total width
- LHC dipole inner cable with lower keystone angle
- Magnetic analysis performed with ROXIE



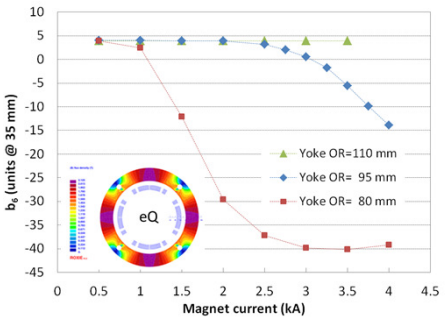
Operating Parameters (2D)	Unit	Value
Current	kA	6.5
Copper current density	kA/mm²	0.42
Field at coil radius (GxR_{in})	T	4.85
Peak (2D) coil field	T	5.86
Lorentz force (F_q 1 octant)	MN/m	1.49

Geometric and random errors



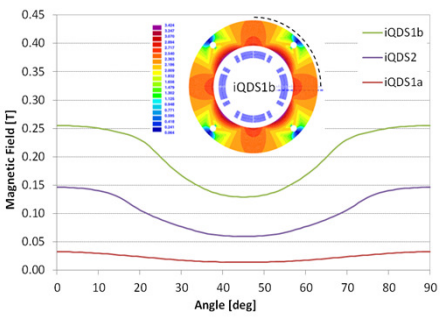
- Block displacements have a flat distribution of ±100 μm in radial and azimuthal direction

Saturation effects



- Saturation curves may be shifted vertically by a fixed amount (by coil cross-section design) to optimize the DA

Fringe Fields

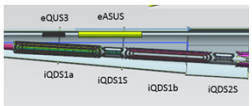


- Main concern is the effect of high field, large bore ion quadrupole fringe fields on the adjacent electron beam

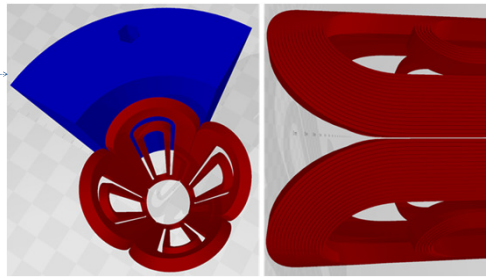
End Field Quality and Magnet Length Optimization

Longitudinal space allocation is very tight:

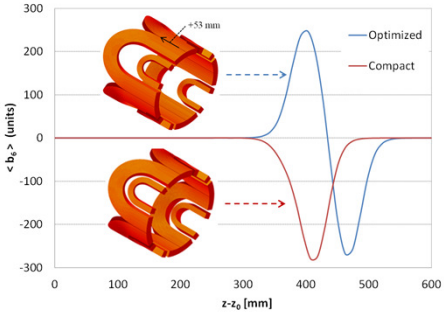
- Coil end geometry has to be optimized for winding
- Spacers to control peak field and field quality make the coil end less compact
- Include space for engineering features: leads, axial force support, cryostat
- Estimate field quality and allocate space for correctors



- Increase operating gradient limited by NbTi properties



- Coil and iron yoke model for end field analysis of iQDS1a
- Local correction of b_6 requires 53 mm shift of lower block



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