LARGE-APERTURE HIGH-FIELD Nb_3SN MAGNETS FOR THE 2ND EIC INTERACTION REGION*

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Introduction

The design concept of the Electron Ion Collider (EIC), which is under construction at BNL, considers adding a 2nd Interaction Region (IR) and detector to the machine after completion of the baseline EIC project. They are to be installed in IR8 region of the RHIC SC ring and will be used to cross-check the measurements and expand the EIC physics range. To achieve these goals and provide enhanced performance and additional flexibility for the IR optics, the parameters of key IR magnets go beyond the capabilities of traditional Nb-Ti magnets being used in the 1st IR. Recent progress with the Nb_3Sn accelerator magnets including the development of large-aperture high-field Nb_3Sn magnets for the HL-LHC makes this technology interesting for use in the 2nd EIC IR. This paper summarizes the results of feasibility studies of the most challenging large-aperture high-field Nb_3Sn dipoles and quadrupoles for the 2nd EIC IR. The studies included the aperture and field ranges, operation margins, and stress management in brittle Nb_3Sn coils.

2ND IR LAYOUT AND MAGNET PARAMETERS

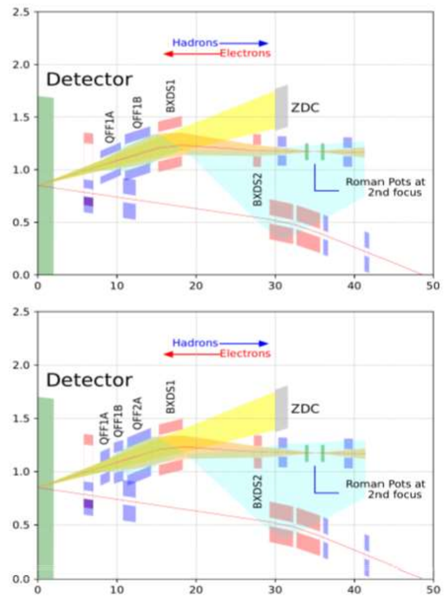

Figure 1: IR8 forward with Nb_3Sn magnets option 1(top) and option 2 (bottom) [5].

Table 1. Nb_3Sn magnet parameters for IR option 1 and 2

Magnet	Length [m]	Aperture [mm]	Field G [T/m]	B field [T]
QFF1A	2.6*/1.2**	173*/119**	-106.4*/155**	-
QFF2A	3.2*/1.2**	256*/190**	71.9*/-65.6**	-
QFF2B	3**	258**	71.6**	-
BXDS1	3	300*/280**	-	8.6
BXDS2	1	110	-	-3.7

* - option 1; ** - option 2.

IR MAGNET DESIGNS AND PARAMETERS

Figure 2: Cross-sections of Nb_3Sn strands and cables used in this study.

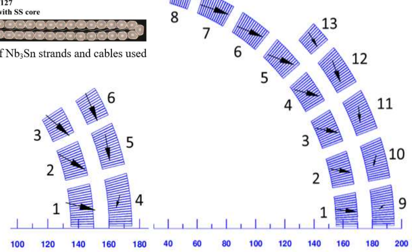

Figure 3: Cross-sections of one octant of IR qudrupole (left) and one quadrant of IR dipole (right) coil with block numbering and Lorentz force vectors in coil blocks.

Table 2. IR magnet parameters

Parameter	IRQ	IRD
Coil ID, mm	270	310
Iron yoke ID, mm	360	400
Coil current, kA	12.5	12.5
Coil field, T	12.55	12.52
Bore field/Field gradient, T/T/m	77.96	10.50
Margin wrt nominal value, %	8.4	22.1

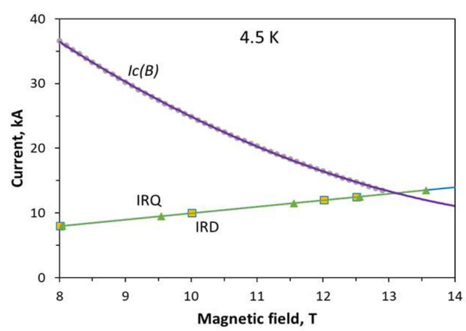

Figure 5: $I_c(B)$ curves for the 40-strand Nb_3Sn cable measured at 4.5 K and IR quadrupole QFFDS01B and dipole BXDS01A load lines.

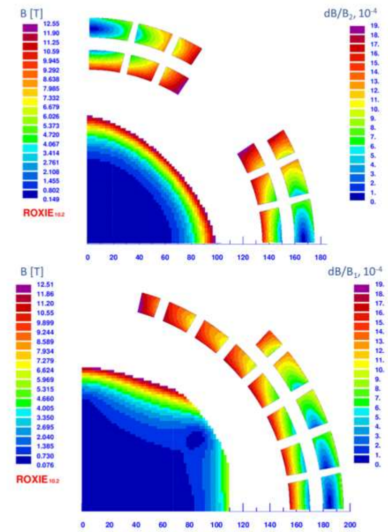

Figure 4: The field quality diagram in the aperture and the field distribution in the quadrupole (top) and dipole (bottom) coil blocks at 12.5 kA current.

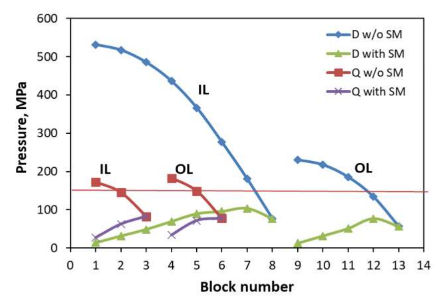

Figure 6: Variation of block average azimuthal stress in dipole and quadrupole coils without and with stress management. Block numbering is shown in Figure 3.

Conclusion

Preliminary analysis shows that the nominal values of field and field gradient with margins are achievable for the expected apertures in 2nd IR using two-layer shell-type coil designs, the state-of-the-art Nb_3Sn technology and operation at 4.5 K. Further magnet design optimization, including field quality and operation margins, is possible and will be done during the engineering design phase.

Due to the large apertures and high fields in the coil, the stress due to Lorentz forces in both magnets is rather large. It significantly exceeds the stress level suitable for the brittle Nb_3Sn superconductor. The reduction of the coil stress to the acceptable level can be achieved by splitting magnet coils into blocks and winding them into special strong stress management coil structures. The practical development and demonstration of the stress management technology for the shell-type coils is in progress at Fermilab in the framework of the US Magnet Development Program. The first experimental results are expected this year. The design, material and parameters of stress management structure for the 2nd IR magnets will be selected and optimized during the magnet engineering design phase.

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