Stealth superconducting magnet technology for collider IR and injector requirements

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Background

The intersection regions and the beam injection channels of a high-energy collider require magnets that act strongly upon one beam yet not at all on a closely neighboring beam. Designs are presented for three examples: ; a final-focus quadrupole that must provide high-gradient focusing of electrons with large aperture but pass a close-lying ion beam; a high-gradient quadrupole that must operate in the background field of a spectrometer solenoid; a septum dipole that serves as a forward spectrometer centered on an ion beam exiting collision, which must clear an electron beam leaving the IP nearby. All three designs use to advantage a new superconducting cable-in-conduit that provides for compact winding, robust end geometry, and in-cable flow of liquid helium.

Example application: IR of electron-ion collider (JLEIC)

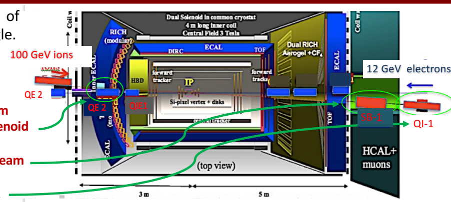
Jlab is developing a design for a collider in which polarized beams of 12 GeV electrons and ions 100 GeV collide with 50 mrad crossing angle.

The closest IR magnets are immersed in the fringe field of the 3 T collider detector solenoid.

Electron beam: QE-2: 58 T/m gradient, 3 cm half-aperture, 10.5 cm from ion beam, immersed in fringe of 3 T detector solenoid

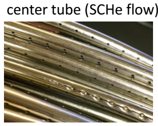
Ion Beam: SB-1: 2 T, 340 mm aperture, 25 cm from the electron beam

QI-1: 90 T/m, 7 cm half-aperture, 36 cm from e-beam



Cable-in-Conduit enabling cable technology for IR magnets

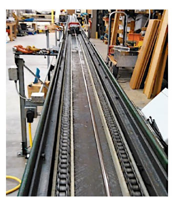
1. Perforated 316L SS center tube (SCHe flow)



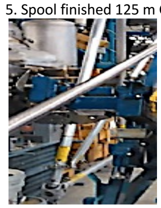
2. Cable single layer of SC strands with twist pitch *L*

3. Over-wrap with SS foil tape (slip surface)

4. Insert in sheath tube, draw to compress strands onto center tube.



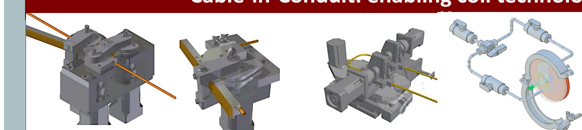
5. Spool finished 125 m CIC



- SCHe flow is contained within cable
- SCHe bathes all strands – stability
- Sheath provides stress management

ATC, HyperTech offer long-length CIC cable as commercial product with NbTi, Nb_3Sn, MgB_2 superconductor.

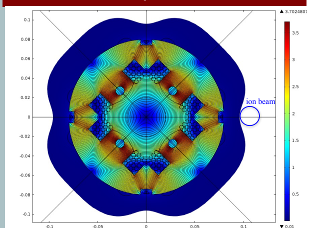
Cable-in-Conduit: enabling coil technology for IR magnets



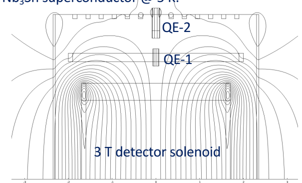
Motorized bend tools form windings in precise contours.
Form racetrack or flared-end windings.
Demonstrated that finished windings have same I_c as wires.

Splice/lead joint is easily mounted/demounted, manifolds SCHe flow

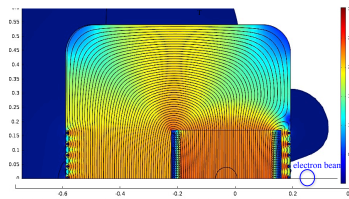
QE-1



90 T/m, 17 cm half-aperture, 36 cm from e-beam.
Nb_3Sn superconductor @ 5 K.

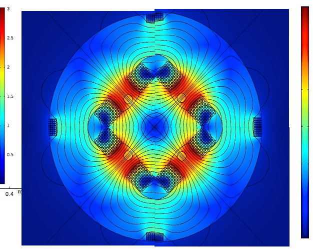


SB-1

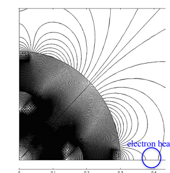


2 T, 340 mm aperture, 25 cm from e-beam.
MgB_2 superconductor @ 10 K.

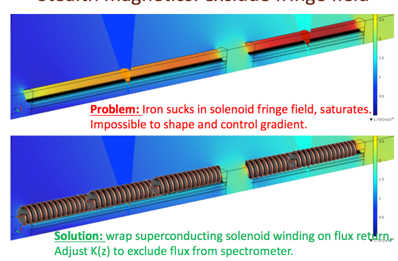
QI-1



58 T/m gradient, 3 cm half-aperture, 10.5 cm from the ion beam.
MgB_2 windings @ 10 K



Stealth magnetics: exclude fringe field



All three designs use reverse-current windings to null out fringe field at the close-by beam location.

All three designs use an anti-solenoid winding on the outside of the flux return to exclude fringe field produced by the 3 T spectrometer solenoid.

Thus 'Stealth Magnetics' makes each magnet disappear to its close neighbors and to the nearby beam.

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Conclusions

- Stealth magnetics can be used to de-couple the magnetic fields of each IR magnet from neighboring magnets and from the close-lying beam.
- Cable-in-conduit conductor makes it possible to integrate the windings of each magnet in a compact package. The close-lying array of magnets in the IR are each independent units with minimum footprint.
- Internal SCHe cooling within the CIC, provides simple cryogenics, stable windings, max heat transfer.