Complementary Design Studies for baseline and possible alternative IR magnet designs for 14mrad IR

Alexander Zlobin

Fermilab

Outline

- Intro and Fermilab’s EOI
- Justification
- Proposed Scope of work
- Resources and Deliverables

BDS SC accelerator magnet

Introduction

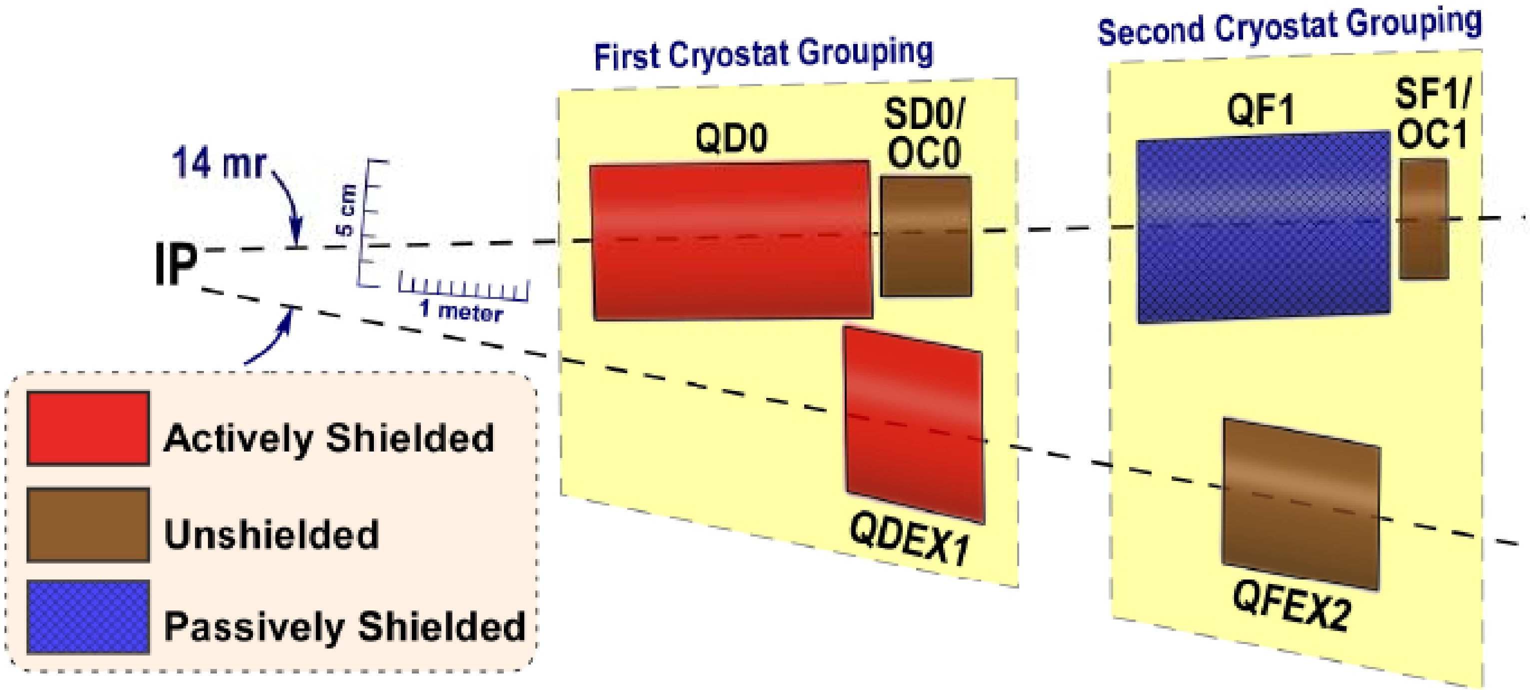
There are four categories of superconducting accelerator magnets in the BDS, three of which are included in the RDR 14 mr baseline and one that was transferred into detector costs.

- The IR magnets proper, i.e. the final focus quadrupoles and sextupoles and the first two extraction line quadrupoles.
  - These magnets are grouped in two independent cryostats, denoted QD0 and QF1.
  - The QD0 cryostats are embedded in and move with a detector; QF1 stays in place.
  - Each main magnet has correction coils; octupole and sextupole coils are combined.
- Large diameter anti-solenoid coils imbedded in detector ends.
  - Coils do not “cancel” detector field but rather “reshape” it to avoid luminosity loss.
  - Baseline configuration gave 62 ton longitudinal force in SiD (independent cryostat!!!).
- Strong tail-folding octupoles about 600 m away from IP.
  - Pairs of octupole doublets affect halo particles but not beam core to relax collimation.
  - Significant pre-engineering performed to reduce costs while retaining functionality.
- Detector Integrated Dipoles (DID) added to detector solenoids.
  - Original DID concept used to avoid luminosity loss for large, 25 mr or greater, x-ing.
  - With 14 mr, DID field reversed (anti-DID) in order to reduce detector backgrounds.

11.10.2007 B. Parker, “Superconducting BDS Magnets: RDR Completeness Summary,” BDS KOM 2

- Fermilab’s EOI is focused on IR magnets

ILC-IR layout



Fermilab's EOI

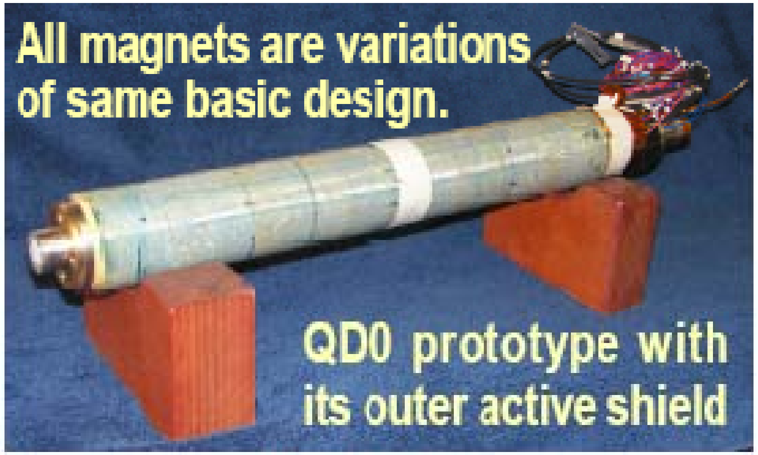
BDS Work Package

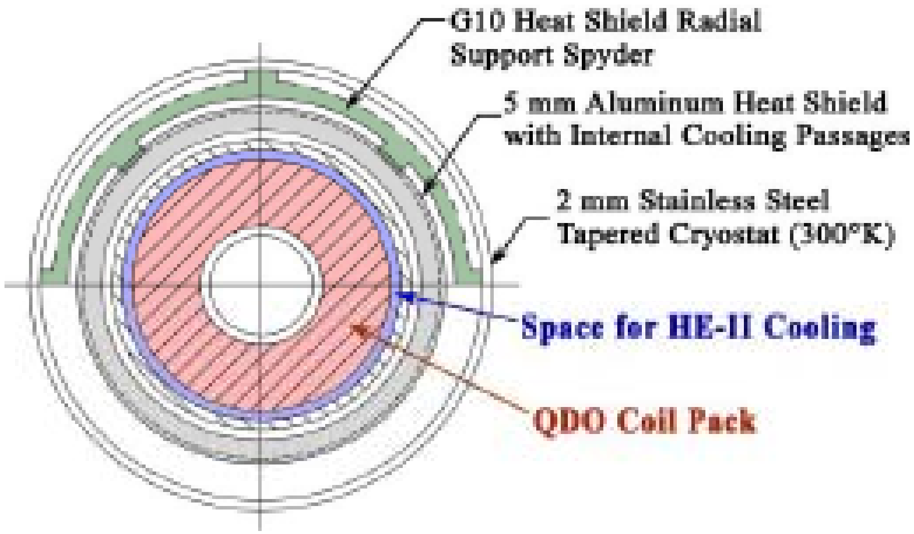
- 4. IR & IR Integration

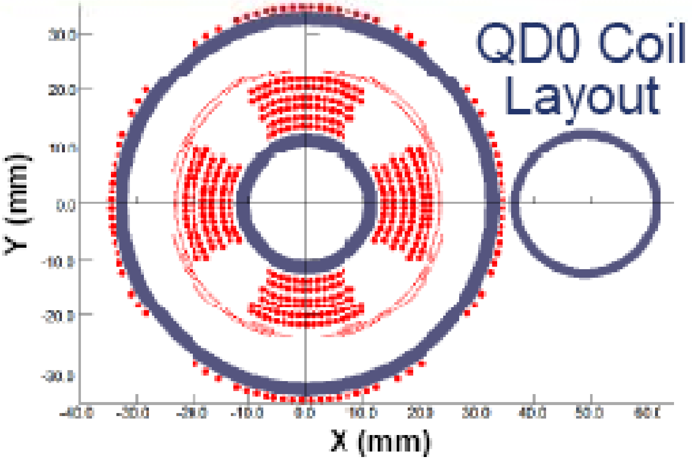
BDS Tasks

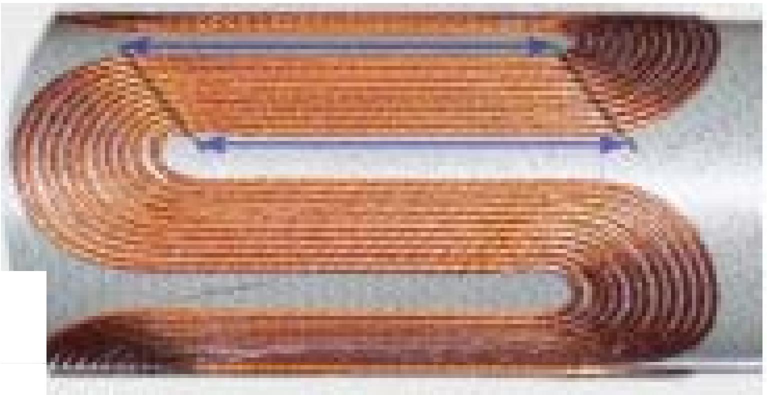
- IR engineering design
  - Complementary FD magnet design and analysis for upcoming and disrupted beams
  - IR shielding design and analysis
- IR hardware options
  - Study Rutherford cable and other options for 14 mrad including IRQ design based on NbTi or Nb3Sn Rutherford cable and standard winding technique

Baseline IRQ design (BNL)



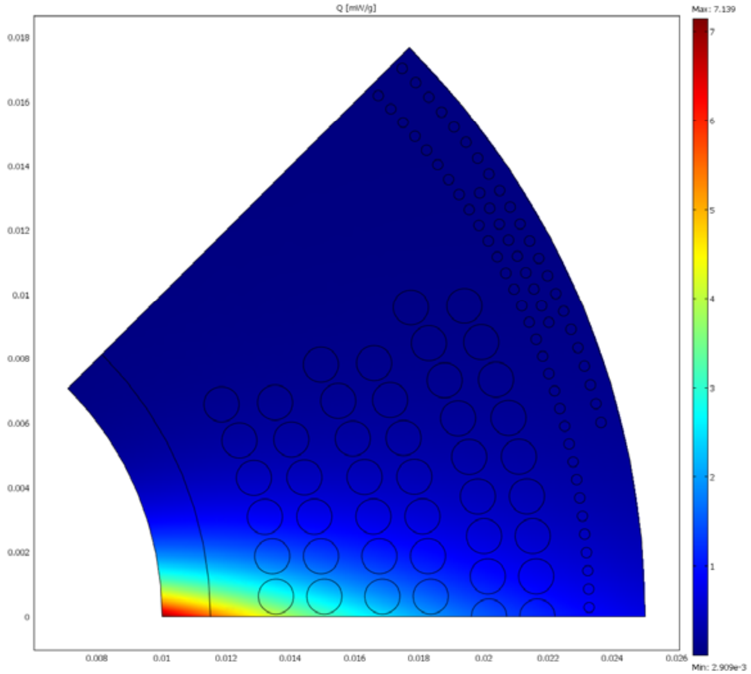






- Well advanced design based on the direct wind technology (BNL).

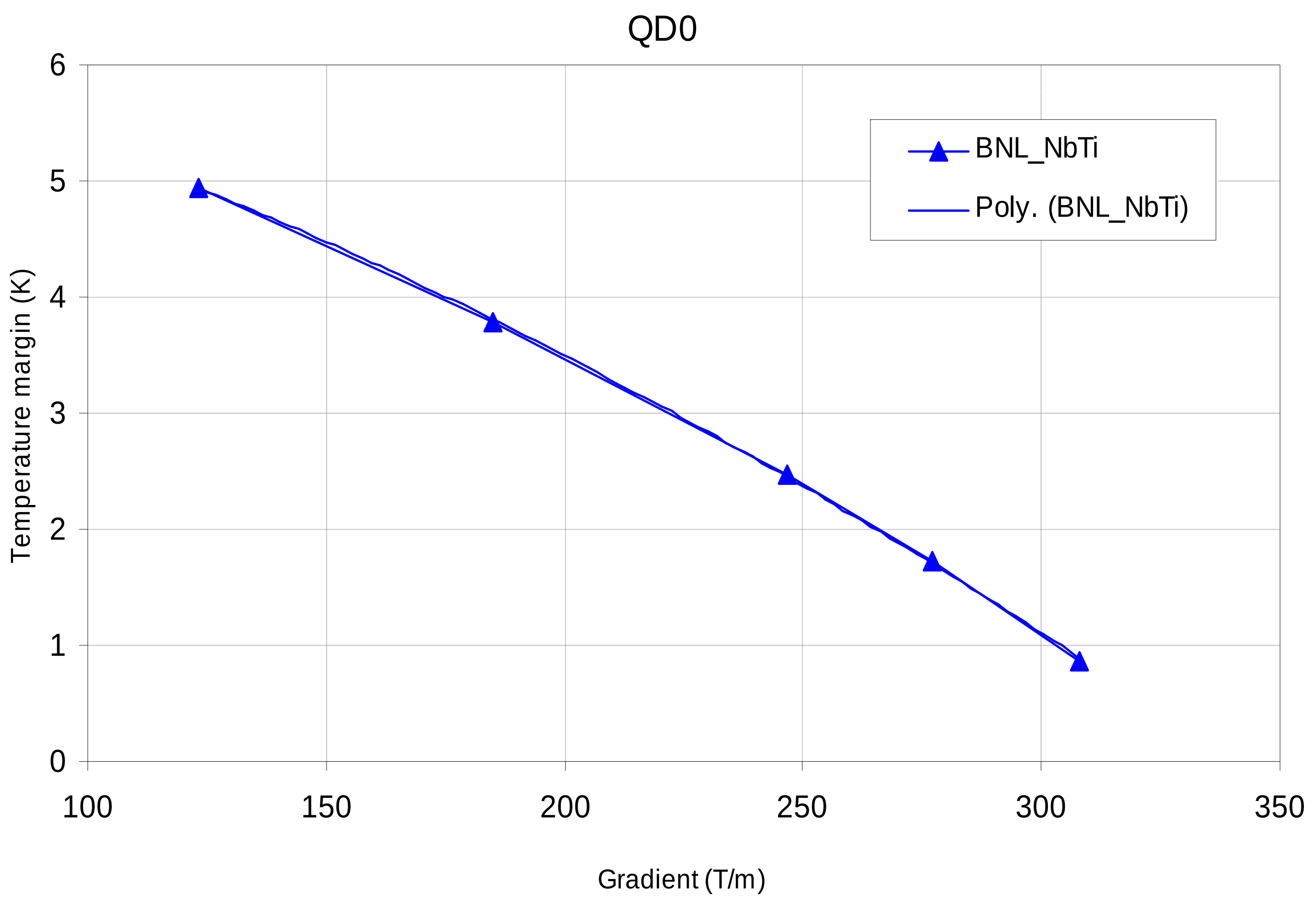
Post RDR Studies



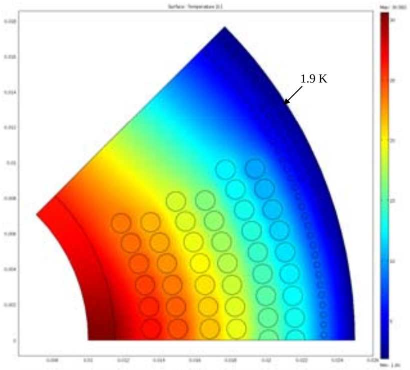
N. Mokhov - **20-mrad IP Extraction Direction**

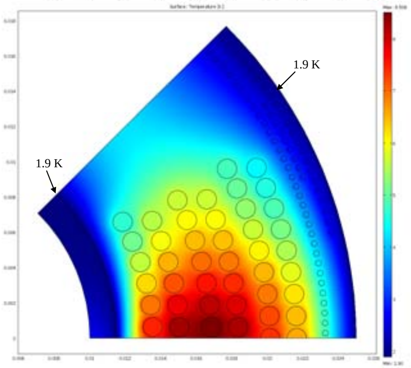
- Power density in SC coils peaks in horizontal plane of non-IP end of the last SC quad QFEX2A
- Peak is 13.6 mW/g without vertical displacement, and 9 mW/g with 120-nm VD
- This is above the quench limit for conventional Nb_3Sn magnets, but there is an evidence that the limit is higher for BNL design; 0.2 s between trains also helps, but one should consider ED per train which is ~3mJ/g to be compared to fast quench limits (0.5 mJ/g in Tevatron dipoles)
- Heat load and peak dose in QFEX2A: 8.2 W/m and 272 MGy/yr, respectively
- Corresponding values in QDEX1C are 3 times lower; much lower in first quads

Temperature margin



Temperature Profile





<u>Kapton</u>

Tmax=25K

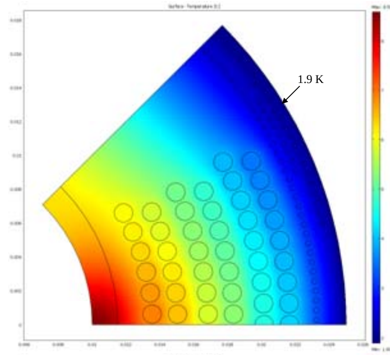
Tmax=8.5K

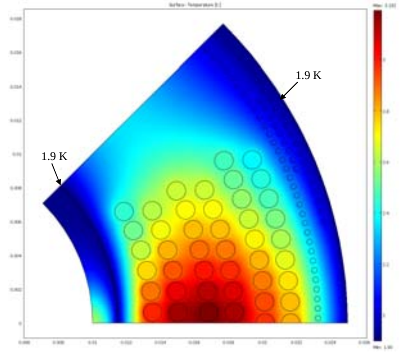
- **Operation margins for QD0 and QF1 are OK**
- **Coil Tmax is too high even for QDEX1**
- **QFEX2 coil Tmax will be even higher**

<u>G-10</u>

Tmax=7K

Tmax=3.2K





$$P(R,\varphi) = P_{ref} \cdot e^{-2(R/R_{ref}-1)} \cdot (e^{-\varphi})^{7}, \ \mathrm{P_{ref} = 4.5 mW/g,\ R_{ref} = 13mm}$$

$$K_{kapton}(T) = (2.28 + 2.4 \cdot T) \cdot 10^{-3}, \ \text{[W/m/K] after B. Baudouy (dapnia-03-303)}$$

$$K_{G10}(T) = \frac{T}{50}\left(1 - \frac{T}{24}\right), \ \text{[W/m/K] after NIST, average}$$

$$K_{SS}(T) = 0.012 \cdot T^{2.4}, \ \text{[W/m/K]}$$

$$K_{Cu}(T) = 51.9 \cdot T, \ \text{[W/m/K] for RRR=100}$$

Contribution to BDS EDR

We need to find solution for this and other possible problems by optimizing the baseline magnet design or developing alternative approaches.

B. Parker (RDR Summary):

> There is a tendency for folks to focus on superconducting magnets as just coils and not as complex interdependent systems with cryostats, support structure, service connections, current leads, power supplies etc.

Fermilab goals:

Contribute to BDS EDR by performing complementary comprehensive design and analysis of all IR magnets for 14mrad IR including:

- Magnetic, mechanical and thermal design and analysis (2D and 3D)
- Magnet power and quench protection
- Radiation dose and shielding
- Superconductor and structural materials
- If necessary develop and study alternative approaches including Rutherford cable and other options integrated with other IR systems
- Provide IR Magnet cost estimates

Scope of Work

- IR engineering design
  - Complementary FD magnet design and analysis for upcoming and disrupted beams for the baseline design
    - magnet design
    - field quality, mechanical, radiation, thermal, and quench protection analysis
  - IR shielding design and analysis
    - Radiation dose and heat deposition analysis
    - Magnet shielding
- IR hardware options
  - Study Rutherford cable and other options for 14 mrad
    - IRQ design based on NbTi or Nb_3Sn Rutherford cable and standard winding technique
    - magnet magnetic, mechanical, radiation, thermal, and quench protection analysis

Duration, FTE, Funding, Deliverables

- Duration: FY08-FY10
- Resources: ~1 FTE per year
- Funding: Fermilab
- Fermilab coordinator: Alexander Zlobin
- Collaborators: BNL
- Deliverables
  - Technical reports
  - Superconductor and structural material specs
  - Magnet cost estimates
  - Model magnet R&D plan

- Fermilab has a qualified team of experts which successfully performed similar studies and developed NbTi IR quadrupoles for present LHC IRs and now is working on the 2nd generation LHC IR optics and Nb3Sn IR magnets for the planned LHC luminosity upgrade