Superconducting BDS Magnets: RDR Completeness Summary

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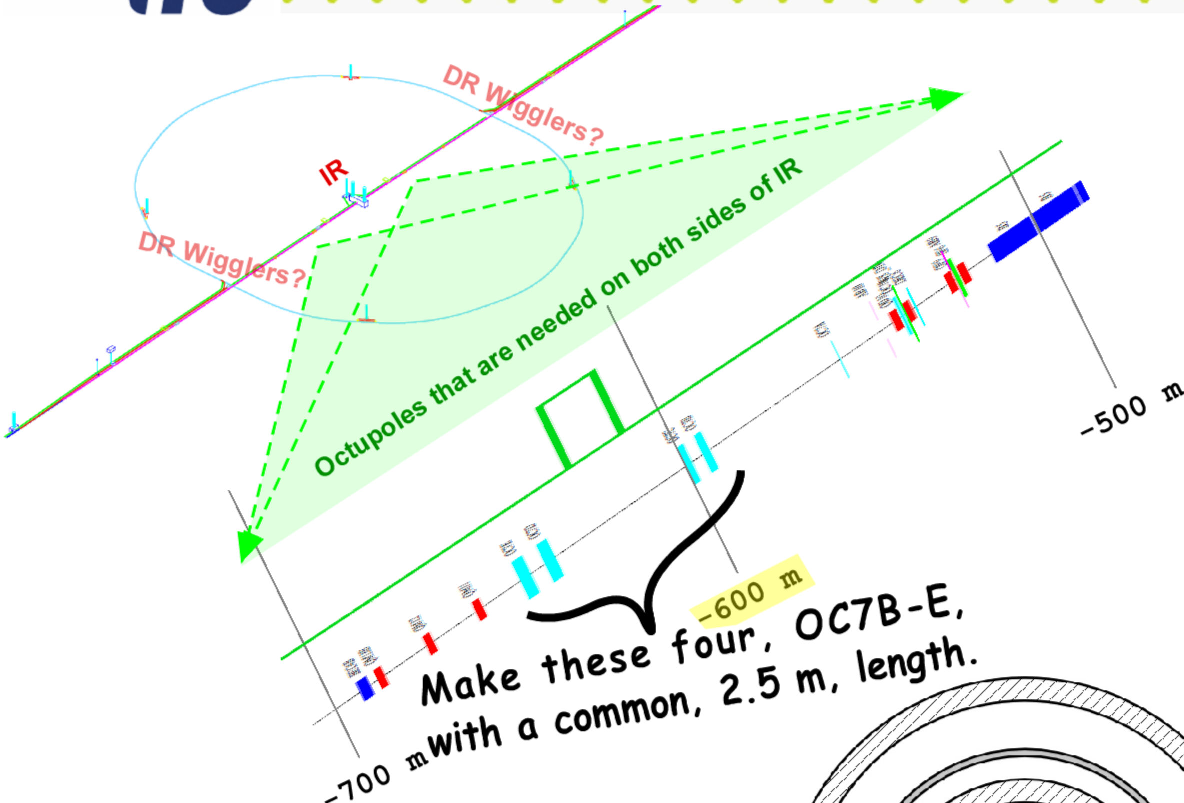
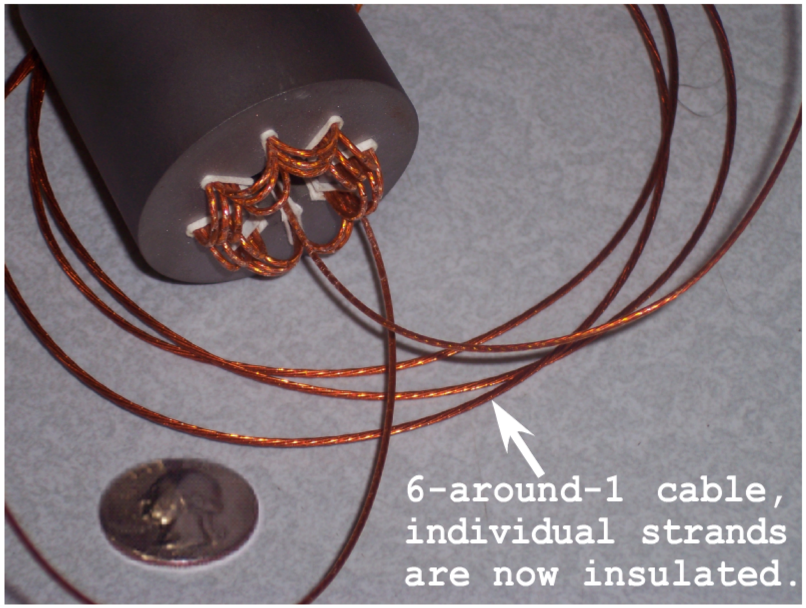
Introduction

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.

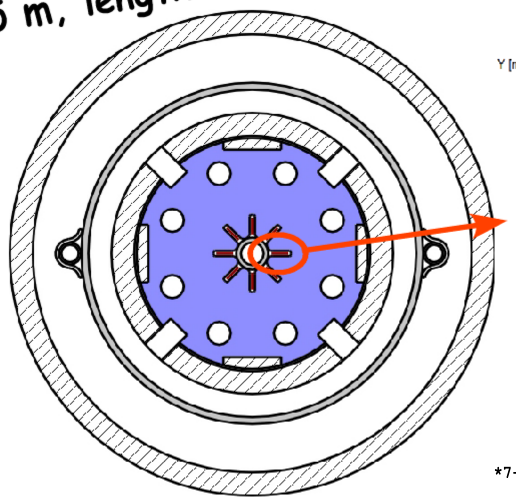
Low-Current Design for Tail-Folding Octupoles Housed in Cryostats Cooled Via Cryocoolers





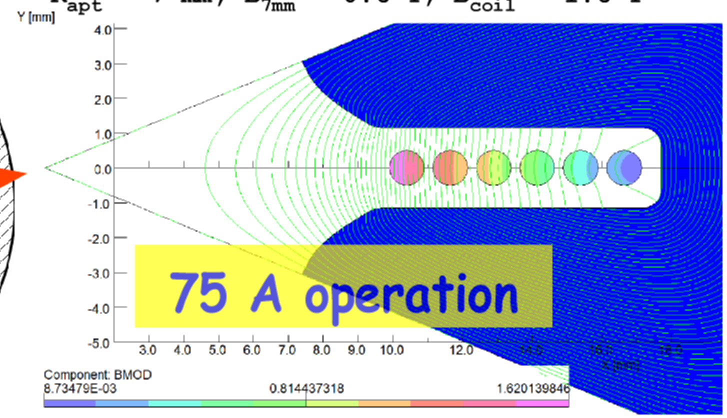
Not located at a convenient point for cryogenics.

See pages 5-7 of "BDS Superconducting Magnets Update," presented by B. Parker at Valencia Cost Review: Magnets & PS, November 9, 2006, Valencia, Spain.



R_{pole} = 8 mm, B_{pole} = 0.9 T at 75 A excitation*

R_{apt} = 7 mm, B_{7mm} = 0.6 T, B_{coil} = 1.6 T



*7-Strand Conductor; Six-Around-One; Each strand is individually insulated.

Tail-Folding Octupoles: Current Status

While the proposed construction technique is quite novel, it is not very "high tech." Thus for costing purposes Mike Anerella assumed that BNL could work with an outside vender to produce parts and develop the coil winding technology & tooling for the first production unit (it is a prototype). BNL would then monitor vender production especially via warm magnetic measurements and cold testing at BNL.

George Ganetis has also suggested that we should look into whether or not the coils can be conduction cooled, say via cryocoolers at each end. Not having to make the cold mass containment a pressure vessel and eliminating other valves and cold plumbing could lead to significant additional savings; winding the coil is a small part of the cost compared to preparing the cryogenic system. His idea needs more study than was possible before coming to Valencia.

"BDS Superconducting Magnets Update," presented by B. Parker at Valencia Cost Review: Magnets & PS, November 9, 2006, Valencia, Spain.

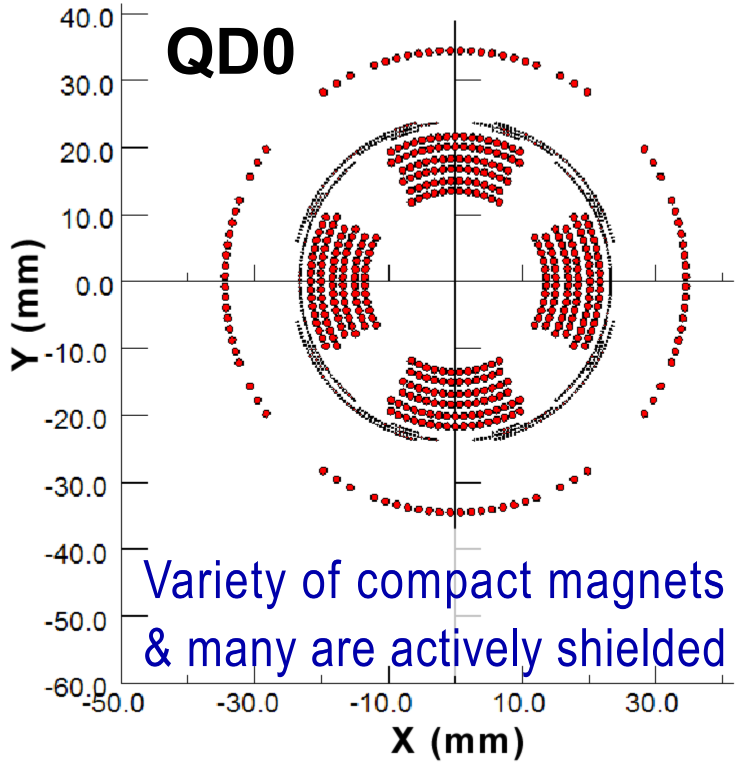
IR magnet work has taken priority so no new development since Valencia on tail-folding octupoles.

Revisit the design during EDR phase in light of comments shown to the left .

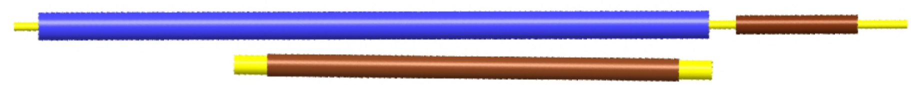
Need some R&D but no prototypes called for in EDR(?).

- Since Valencia, issue raised by Arup Ghosh of performance of "formvar coated conductors."
- Present design has a lot of margin, but is there need for feedback from an early prototype?

14 mr RDR IR Magnets Baseline



QD0 grouping with actively shielded quadrupole coils on incoming and extraction lines and dipole, skew-dipole, skew-quadrupole, sextupole, skew-sextupole and octupole correction capabilities.

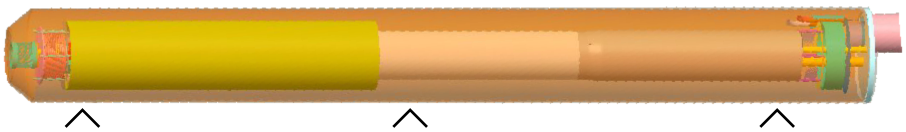


QF1 grouping with a similar set of coils but quite different aperture and strength requirements. QF1 is outside detector field and has a thin magnetic yoke.

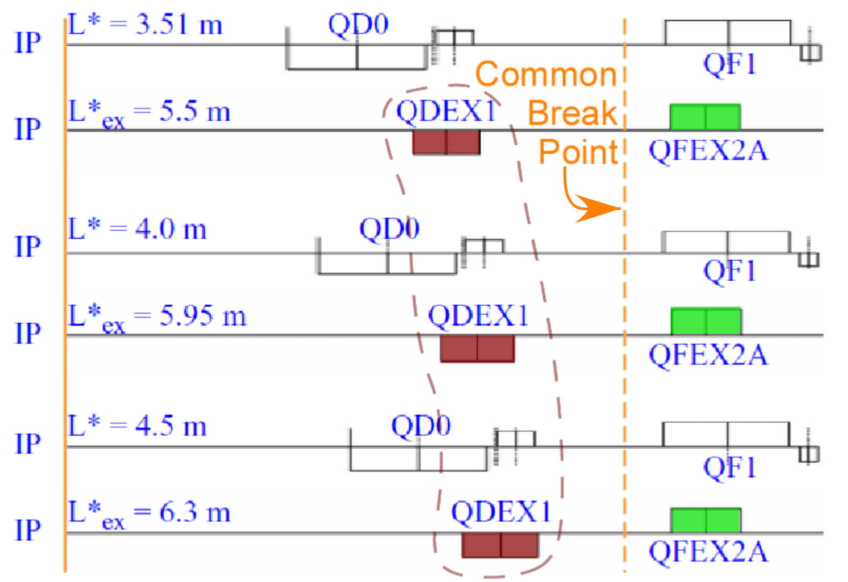
- Present coil layout attempts to minimize fields seen by incoming & outgoing beams (max. magnetic lengths for lower gradients & take account of 3D shielding effects at coil ends).
- Inside cryostat there are several coils & it is not practical to mechanically shift magnets independently; so we use coil integrated correction coils to electrically shift effective centers. This also avoids large field spikes at beam center with lumped dipole correctors.

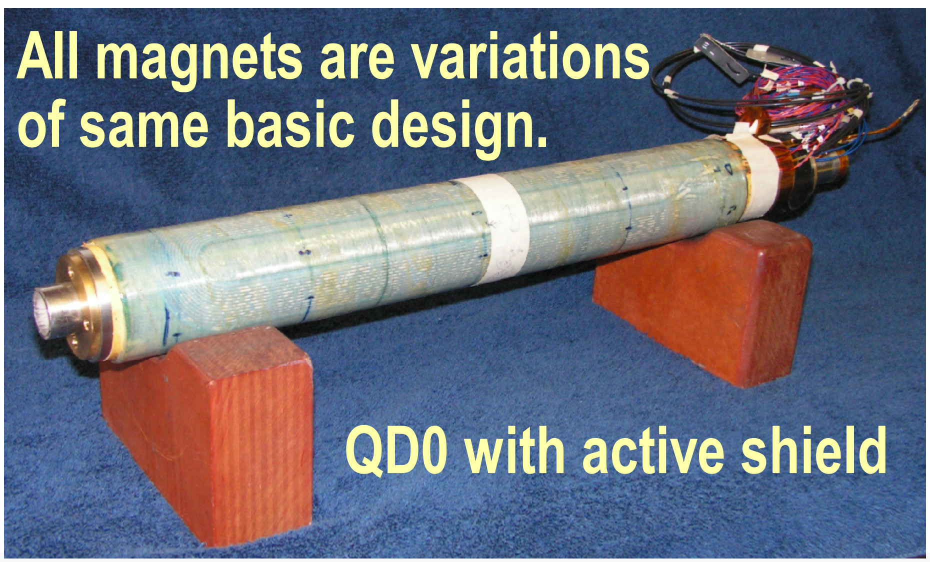
RDR IR Magnet Work & Push-Pull

QD0 Cryostat design for L* = 4.5 m worst case.



There are many magnet designs to keep track of especially as we may end up with different L*s in different experiments.

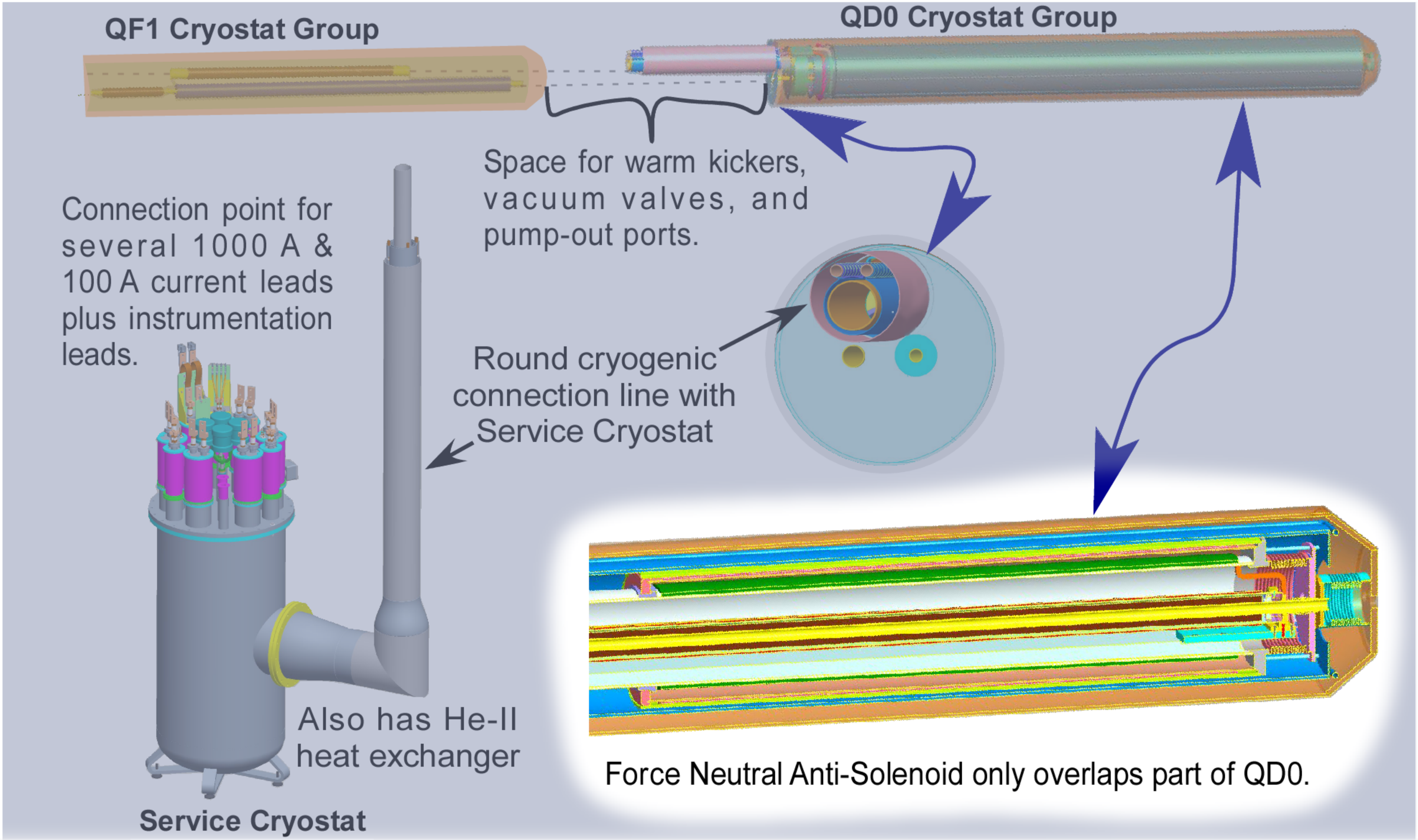




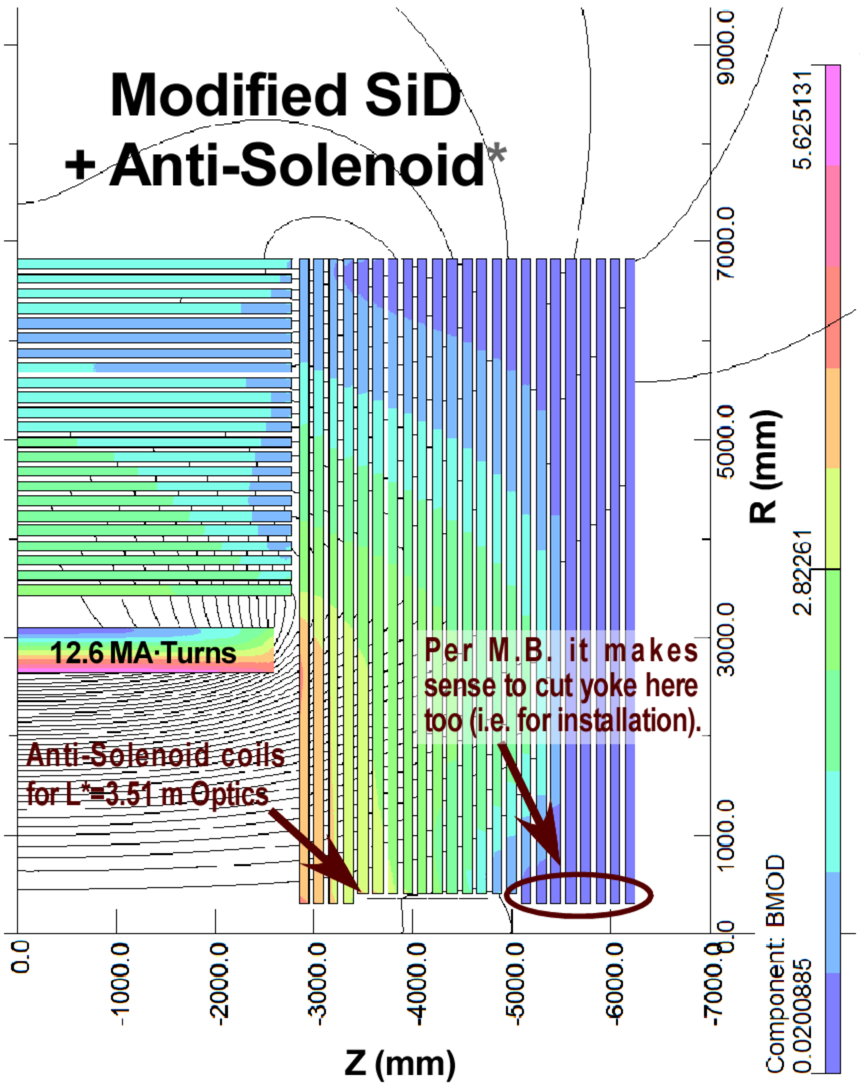
Look for flexible magnet design scheme to accommodate different L*s in each experiment. Incoming beamline magnets are same but first extraction magnet differs.

Optimize anti-solenoid, QDEX1, attachment points/support structure and the cryogenic transfer line routing for each experiment?

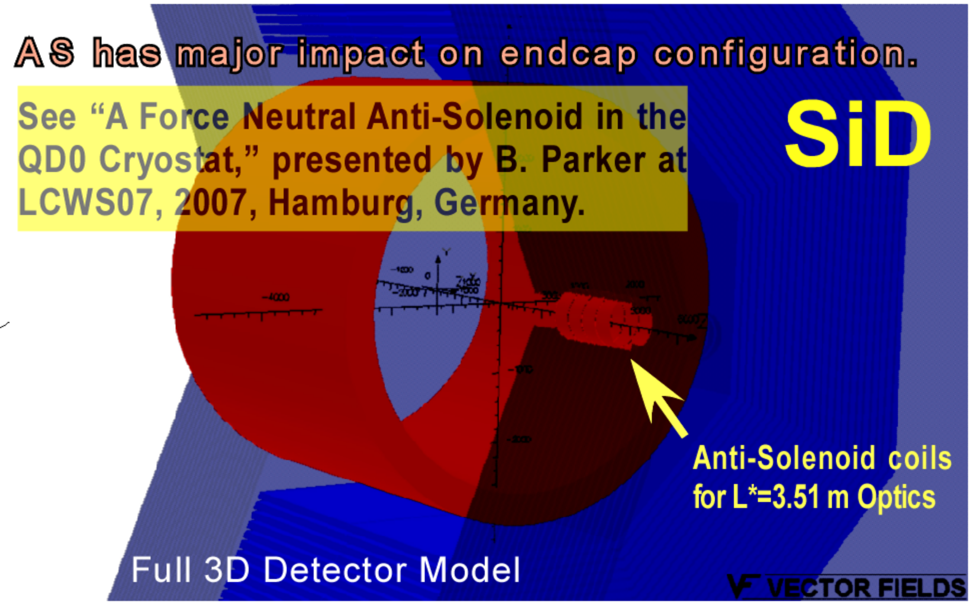
Post-RDR IR Magnet Developments

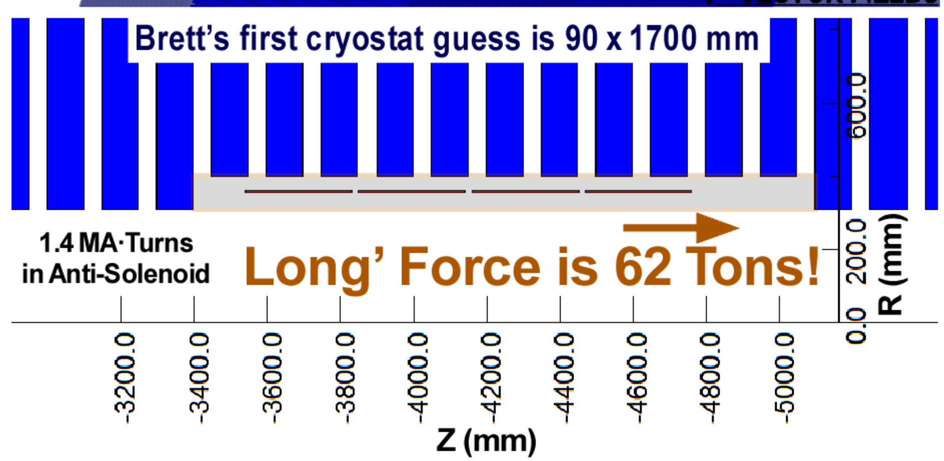


The RDR Anti-Solenoid (SiD Option)



*Anti-solenoid strength must be adjusted to meet optics requirements.

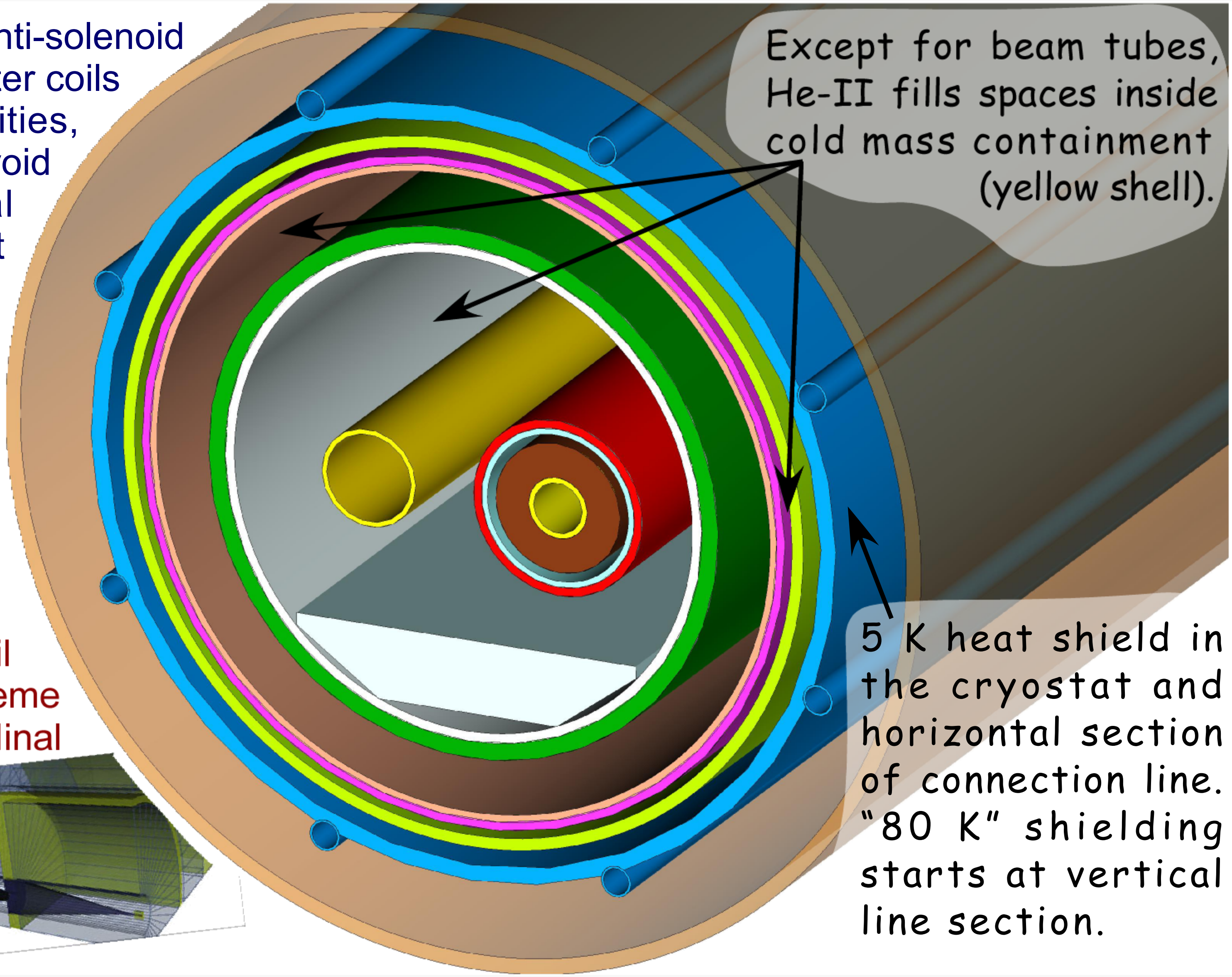




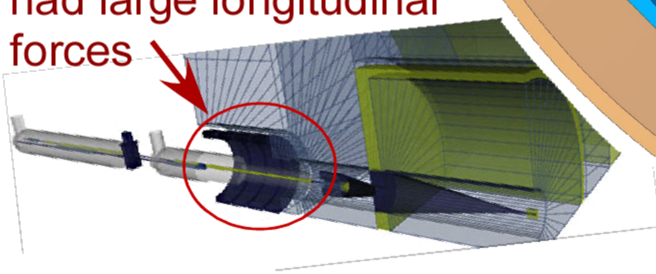
Too much force to share QD0 cryostat!

Force Neutral Anti-Solenoid with QD0

By constructing anti-solenoid with inner and outer coils of opposite polarities, it is possible to avoid large longitudinal net forces so that anti-solenoid can be combined with the other magnet coils inside QD0 cryostat (smaller impact on the detector design).



Previous large coil anti-solenoid scheme had large longitudinal forces



Making the Transition from RDR to EDR: The Force Neutral Anti-Solenoid as a Value Engineering Example

In the RDR a "generic" anti-solenoid was included as a separate WBS item from the other IR superconducting magnets.

- RDR anti-solenoid was missing customizations required for different experiments.
- No (budgeted) R&D plan for developing final solution (cost as NbTi, but thinking HTS).

The force neutral anti-solenoid adds value while reducing cost.

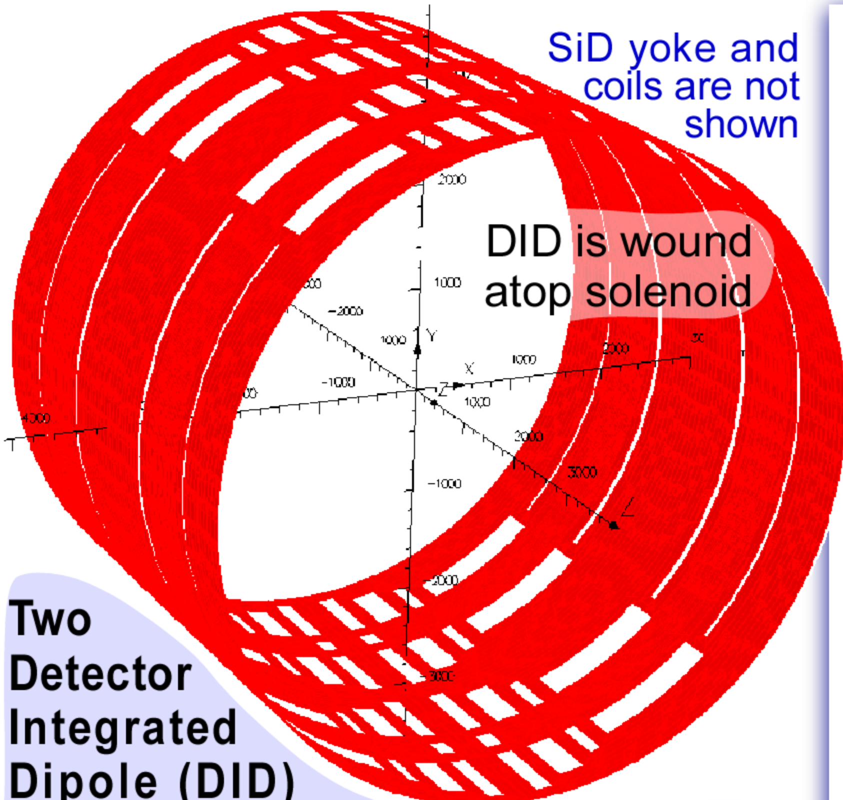
- Does not impact field inside detector even for 4'th detector concept or smallest L*.
- Removes space impact/interference on detector endcap designs for common solution.
- No need for independent cryogenics, service box, R&D plan or production equipment.

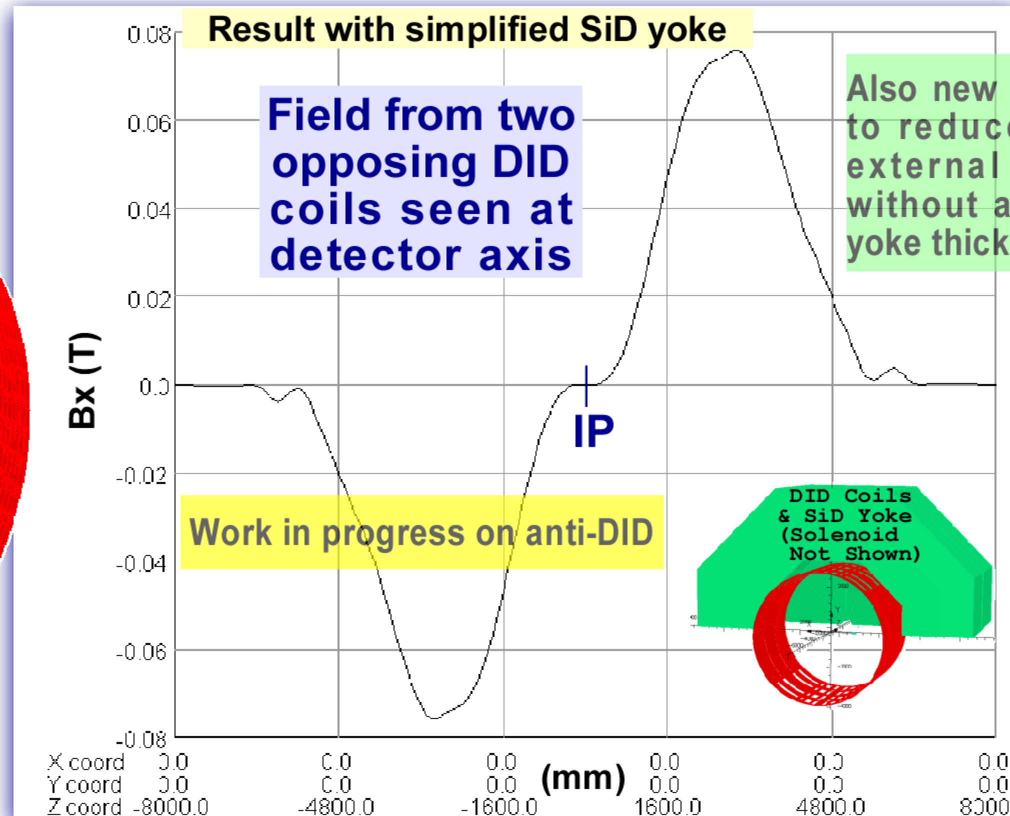
For ERD we still need to iterate accelerator/detector requirements.

What sort of change control (if any?) is needed to implement this?

- Note there is added scope for the QD0 prototype but we do avoid unfunded EDR R&D.

Anti-DID Conceptual Development

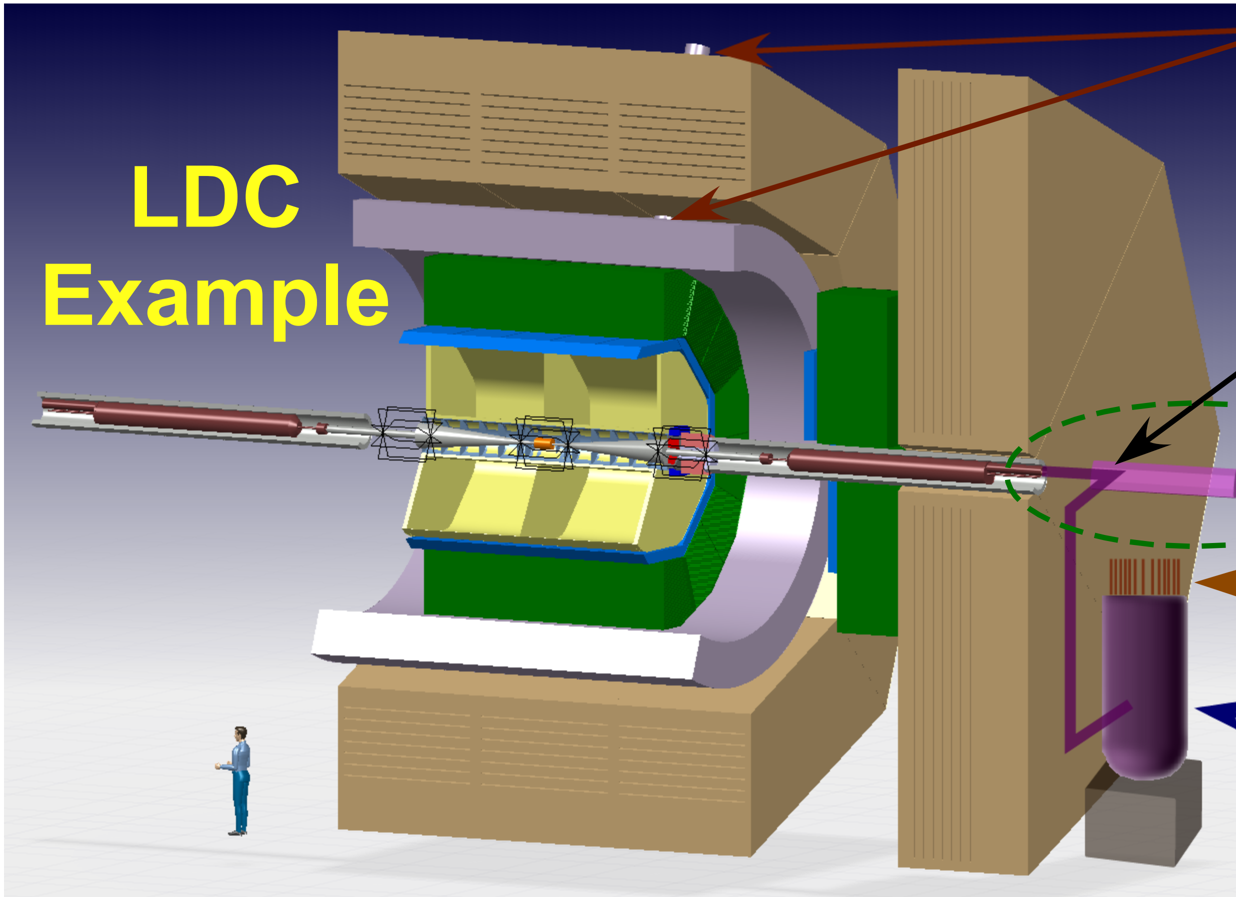




Two Detector Integrated Dipole (DID) coils can be used to improve the field uniformity near the IP (important for TPC based detectors).

- Anti-DID coils are important for 14 mr.
- But design requirements are strongly coupled with detector solenoid design.
- A toy model exists for most difficult (TPC) case.
- Make sure this work does not fall between the cracks; increase collaboration with experiments.

RDR Completeness & Push-Pull



Cryogenic supply requirements for detector solenoid and anti-DID? How does "chimney" affect self-shielding? External field?

Watch for QF1 interference!

Pacman scheme is not shown here.

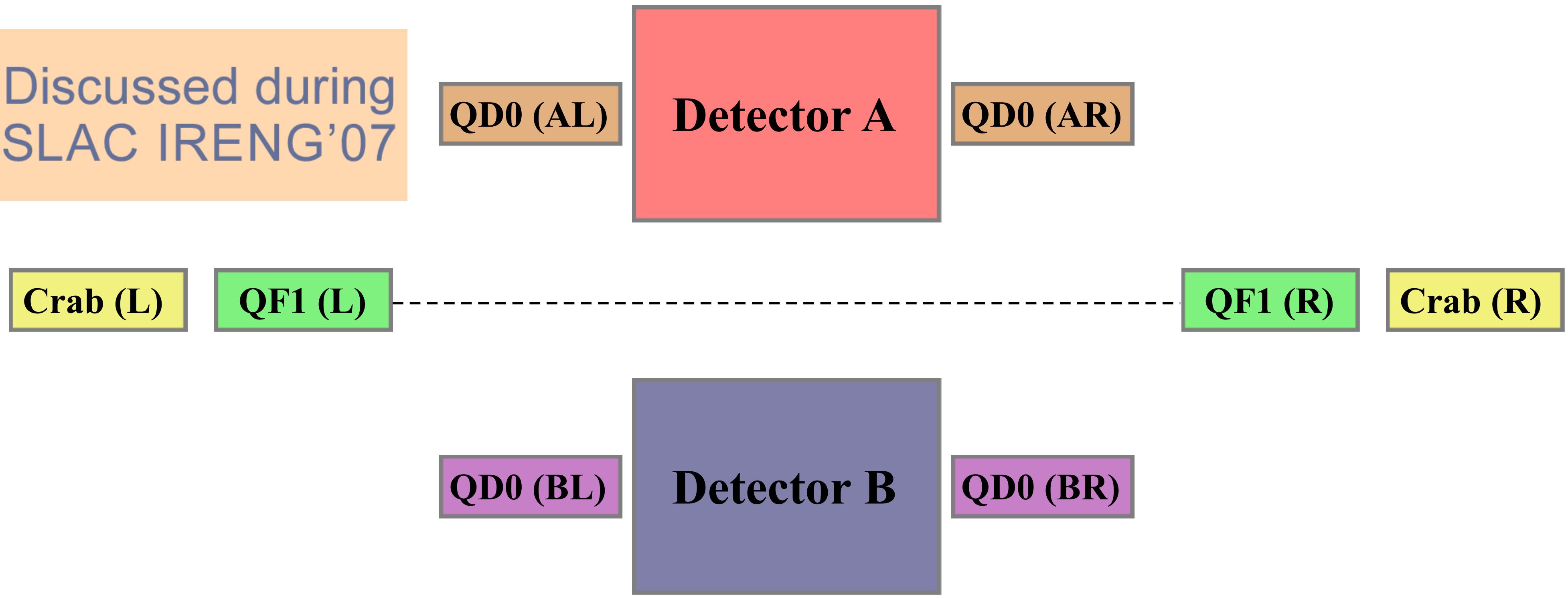
Magnet leads & cryogenic supply need 20 m flexible connections?

Minimize size of Service Cryostat since it (along with QF1) limits how far door can be opened.

- Push-pull drives very complex interface issues which were not dealt with in RDR.
- Find 3D CAD models helpful and effective in identifying and resolving such issues.

Systems coded the same color may be operated in common.

Discussed during SLAC IRENG'07



Systems not the same color must be operated independently*.

*Here independent means a given system can be warmed up/cooled down without impacting another system.

BDS Superconducting Magnets Summary

While developing the RDR 14 mr baseline, the BDS superconducting magnets underwent almost constant evolution and in a controlled way we can expect this process to continue as we undertake more formal Value Engineering during the EDR phase.

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.

Except for the (anti-)DID, we have flexible, proven coil solutions in hand for these magnets and the real engineering challenge, which may not seem as exciting, is to work through these interface issues and then follow through with the required systems engineering.

For example the true value of making the QD0 prototype, vertical transfer line and service cryostat is not to test coils but to be forced to deal with practical, real world issues and obtain engineering feedback from actual magnet systems tests.