BROOKHAVEN NATIONAL LABORATORY
Superconducting Magnet Division

International Linear Collider Workshop
LCWS08 & ILC08

University of Illinois at Chicago
November 16 - 20, 2008

MDI Review of the ILC 14mr IR Baseline Design

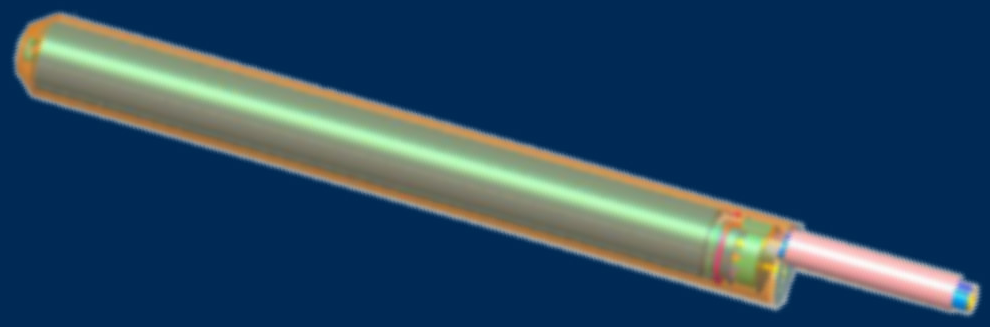
- The Final Focus magnets & Push-Pull
- Anti-Solenoid incorporated with QD0
- (Anti-)DID used to reduce background

and New Prospects for an ATF2 FF Upgrade.

presented by Brett Parker, BNL-SMD

Fermilab · Illinois Institute of Technology · Northern Illinois University · Northwestern University · Argonne National Laboratory · Fermi Research Alliance LLC · Illinois University of Illinois at Urbana-Champaign · The University of Chicago

Section 1



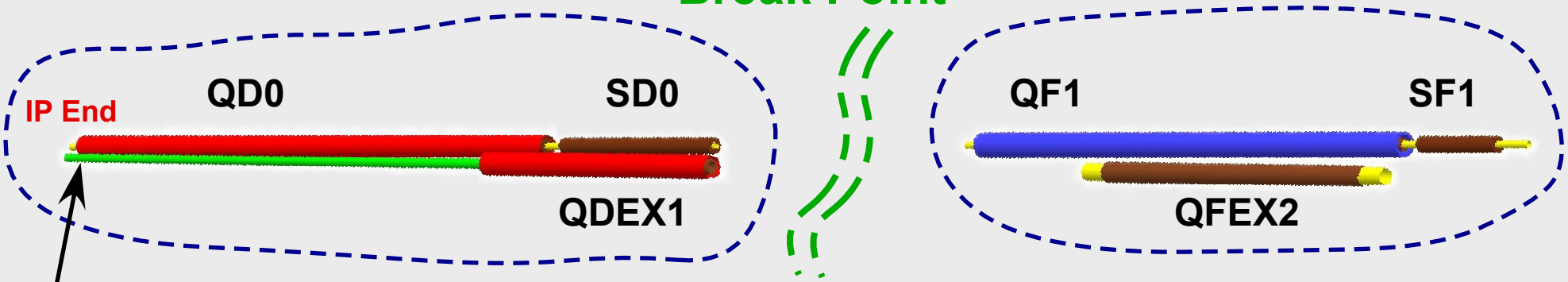
The 14 mr baseline final focus (FF) magnets and some MDI challenges.

Introduction to the ILC 14 mr IR Layout

First magnet grouping is supported by and moves with detector during a swap.

"Push-Pull" Break Point

Second magnet grouping stays fixed in tunnel and is shared by both experiments.



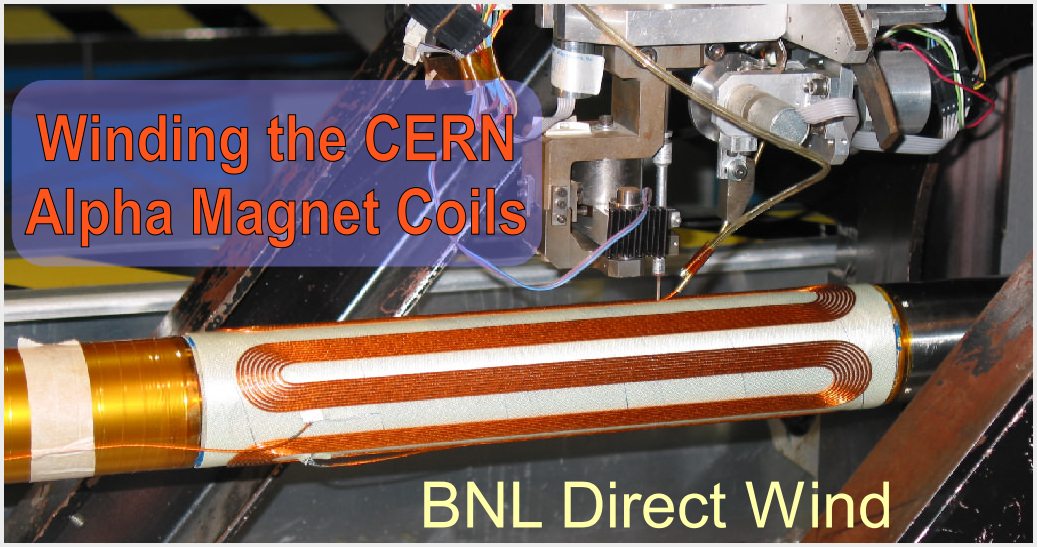
Exit beam goes just outside a compact self-shielded coil.

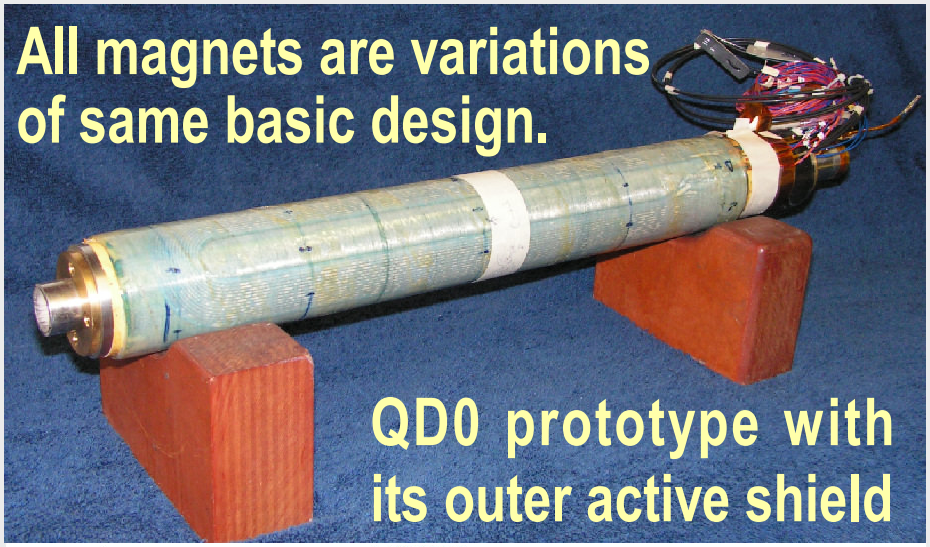
Extraction line magnets send exiting beam to instrumented beamline (focusing & compensate solenoid deflection) with post IP diagnostics before dispatching beam to an absorber.

Flexible setup for IR optics changes & beam energy scans.

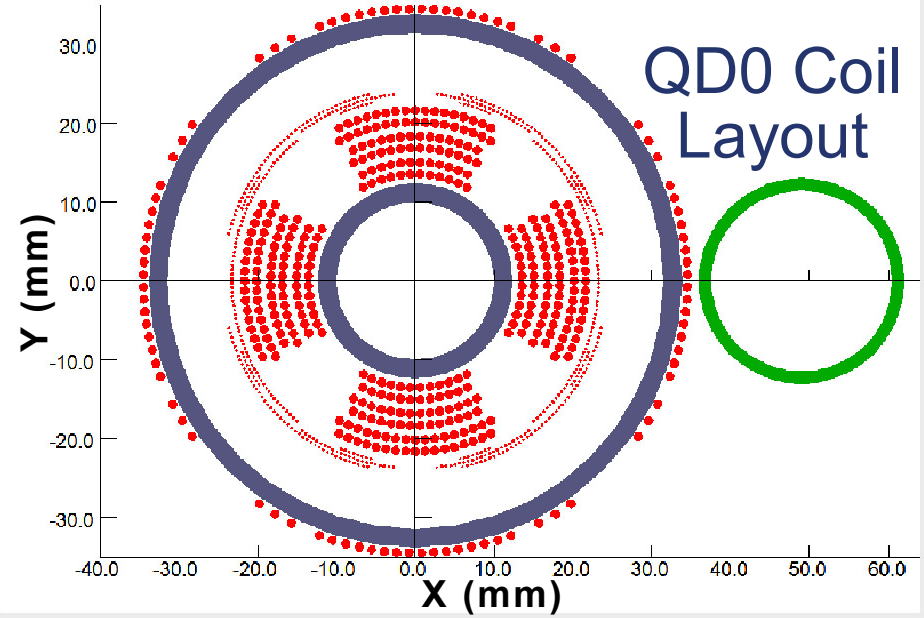
In principle both experiments can have different L.*

Designs for Compact Superconducting Magnets Used in the ILC 14 mr Layout.



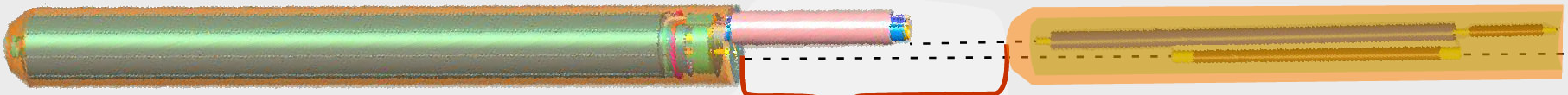


- 14 mr crossing angle via compact self-shielded QD0 coil windings.
- Extracted beam passes just outside coil into separate focusing channel.
- Cryostat to fit within limited space inside detector at L* = 3.5 to 4.5 m.



Extra Material – Background Information

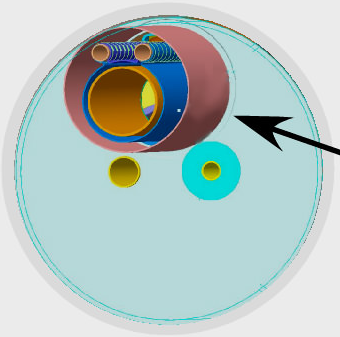
Final Focus Magnet System Components.



QD0 Cryostat Group

QF1 Cryostat Group

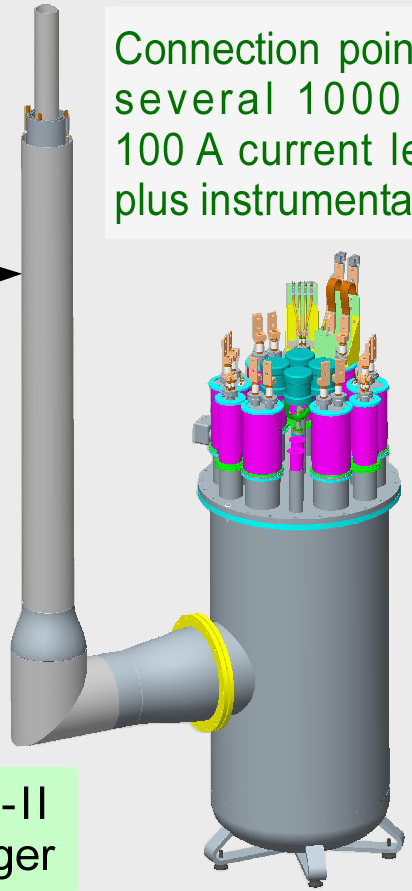
Space for warm kickers, vacuum valves, and pump-out ports.



QD0 Cryostat (End View)

Cryogenic line for connection to the Service Cryostat

Connection point for several 1000 A & 100 A current leads plus instrumentation.



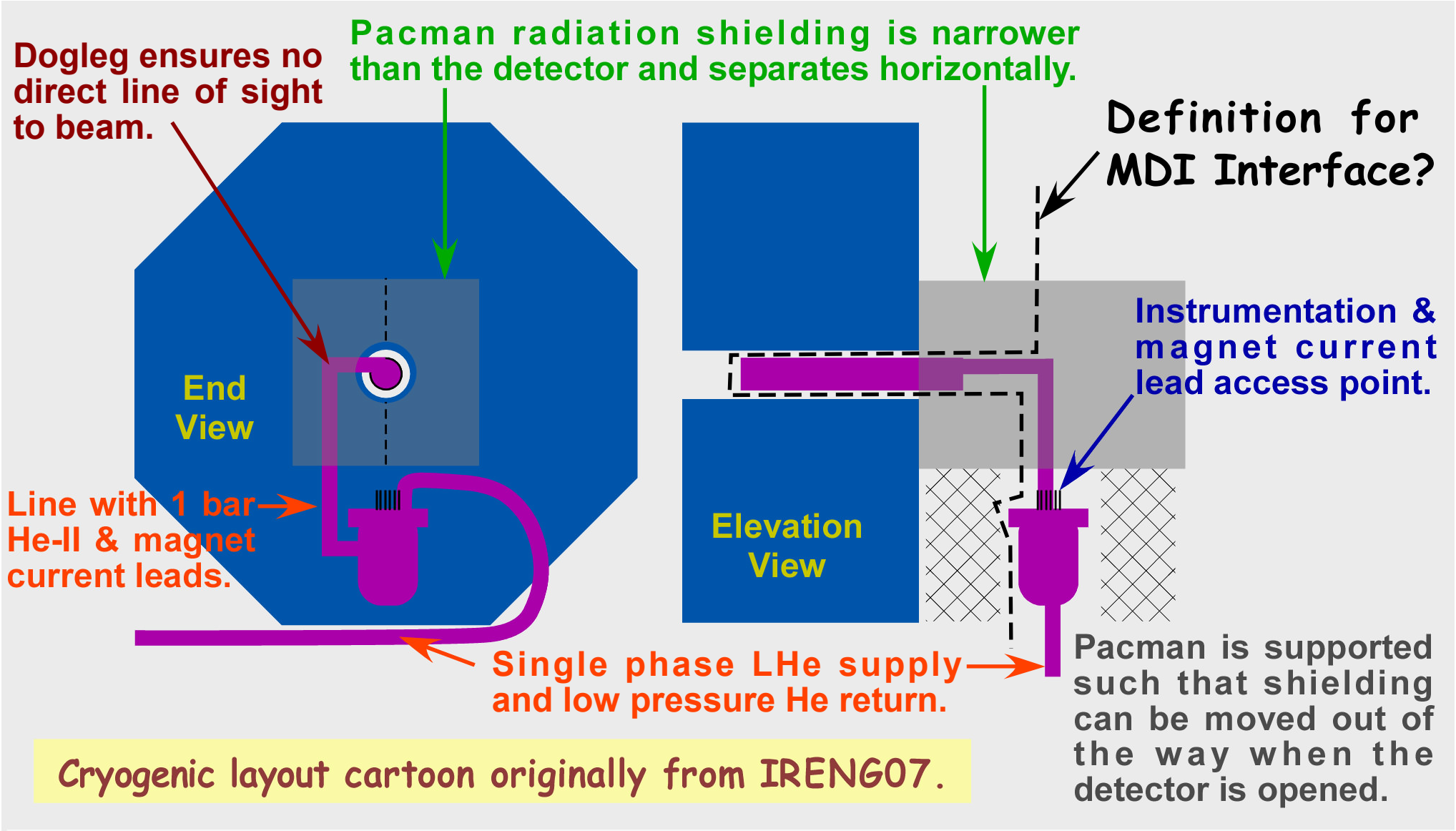
SC has He-II heat exchanger

Service Cryostat

Design uses He-II (superfluid) cooling to avoid "flowing" cryogenics through cold mass; He-II also helps keep QD0 transverse size compact.

Will make & test QD0/Service Cryostat Prototype at BNL

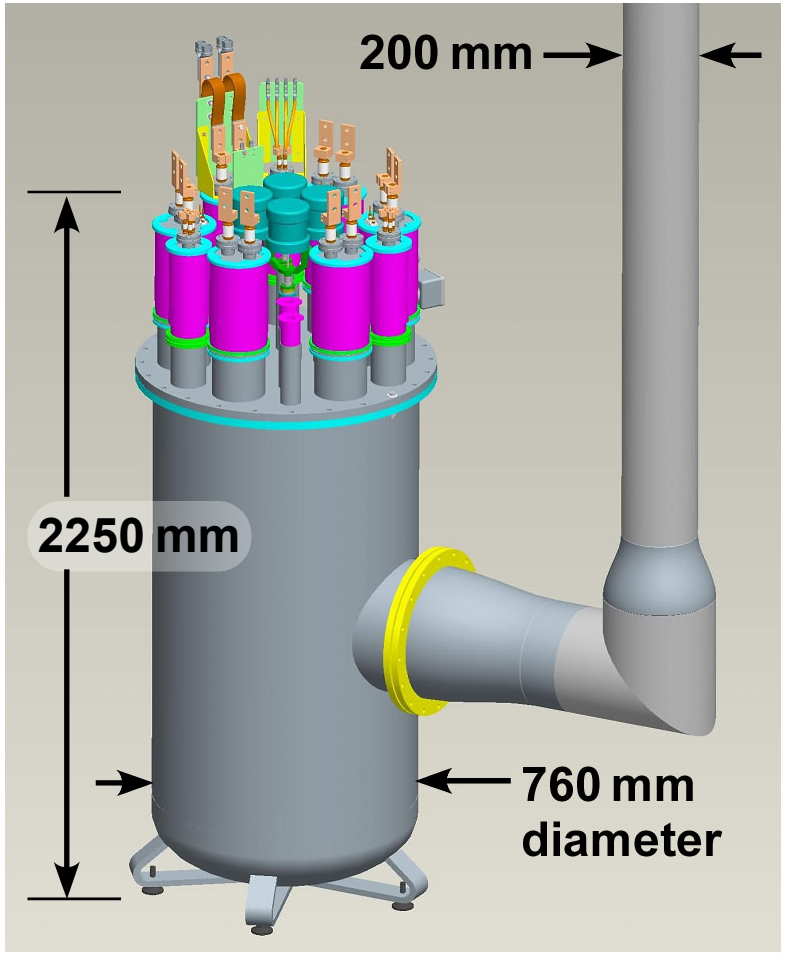
Cryogenic "Straw Man" Configuration.



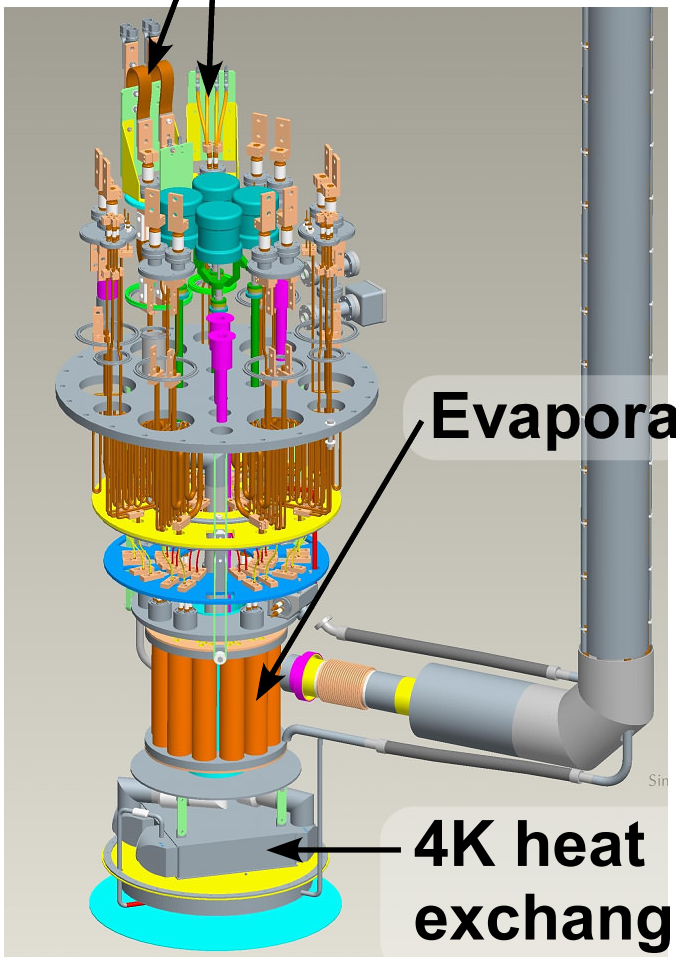
Cryogenic layout cartoon originally from IRENG07.

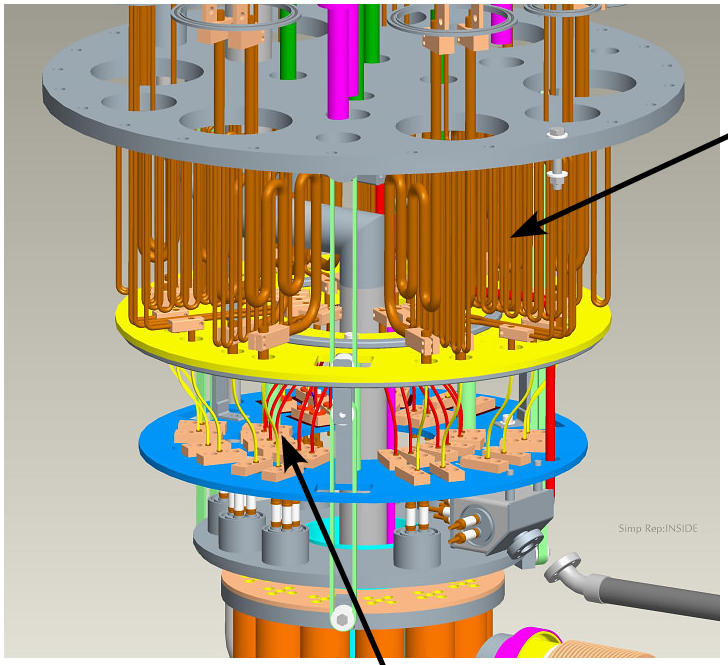
Service Cryostat Design Status.

- Basic design is now completed.
- Possible revision of evaporator & heat exchanger (could lower overall height).
- Transfer line requires more work.



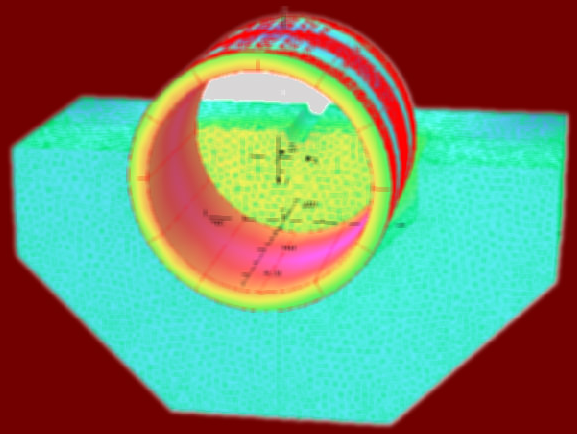
Service Cryostat Inner Construction.





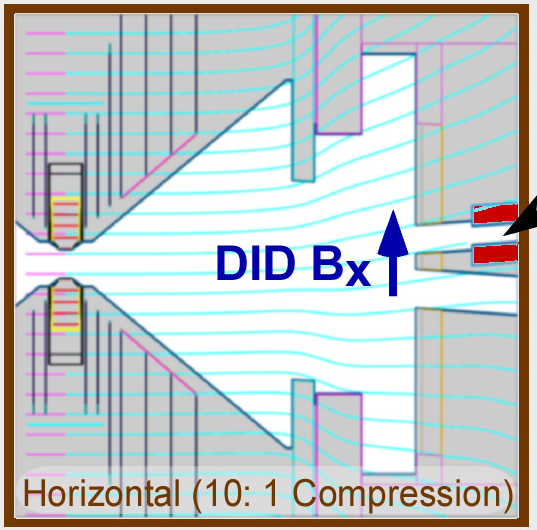
Extra Material – Background Information

Section 2

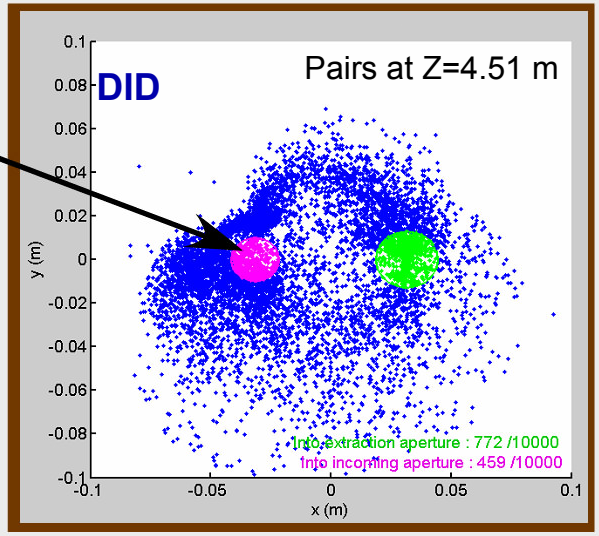


Status of the Detector Integrated Dipole (Anti-DID) design. Anti-DIDs are used by the experiments to reduce experimental background.

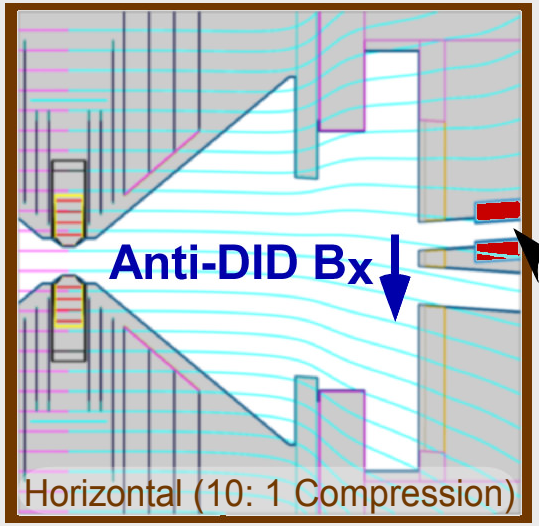
Detector Integrated Dipole (DID) Concept.



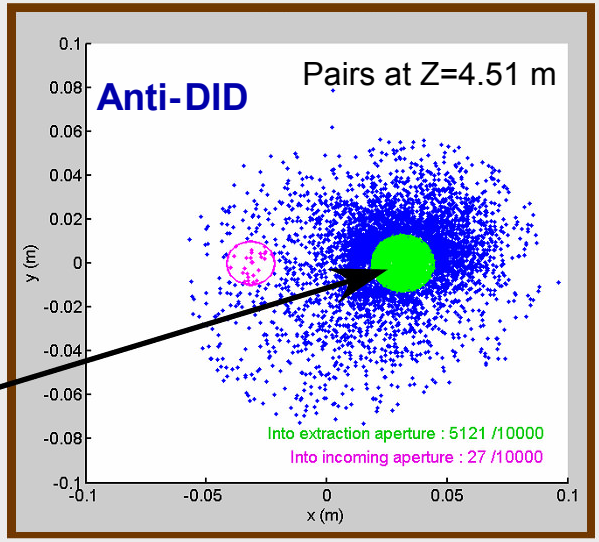
DID directs pairs back into incoming beam pipe.



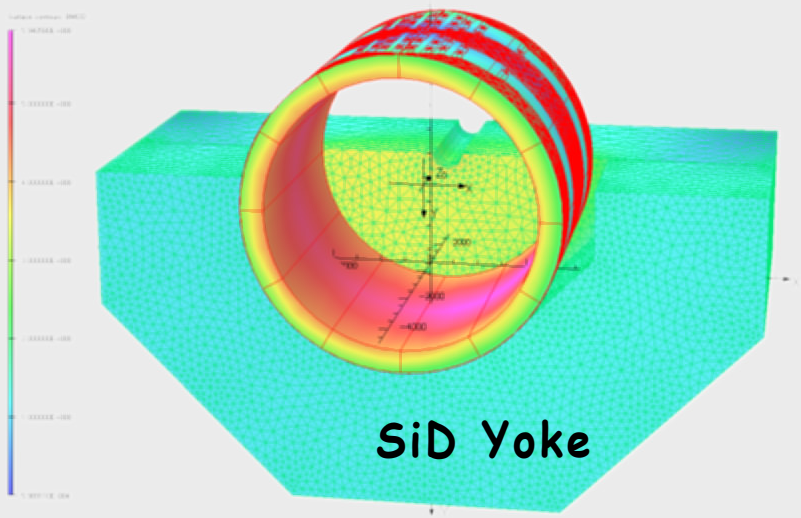
Without DID, the pairs spiral along the detector axis and hit between the two apertures.

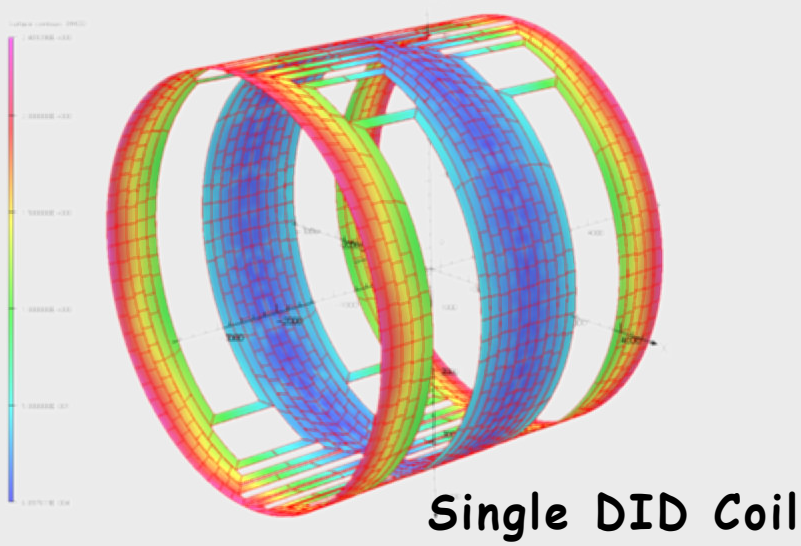


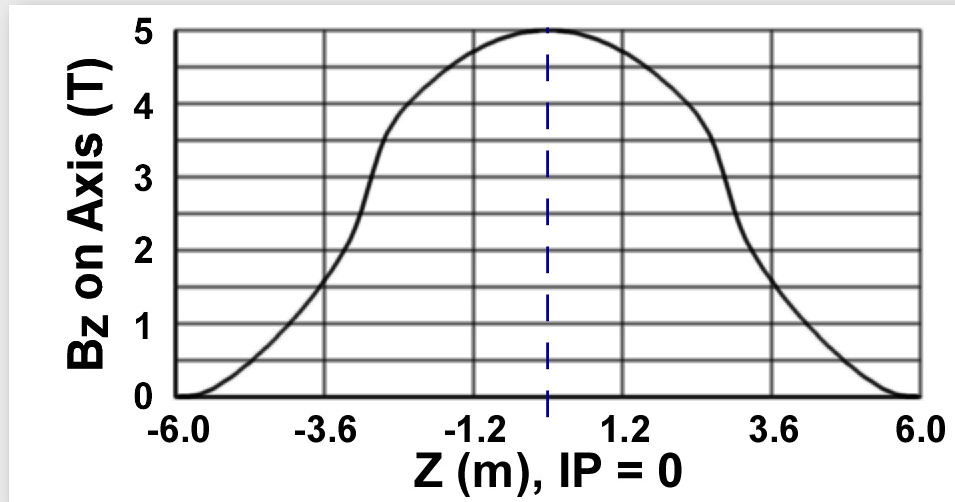
Anti-DID sends pairs into outgoing beam pipe.

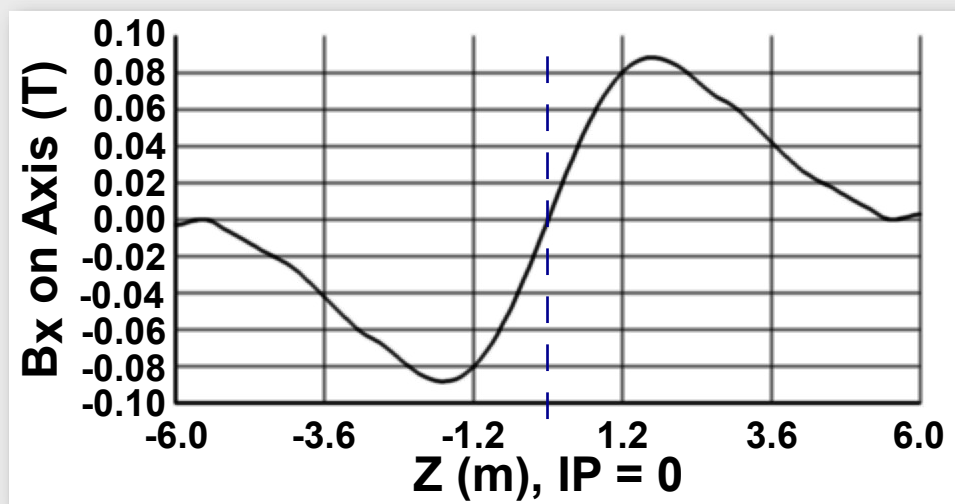


“Simple” Original DID Concept for SiD.



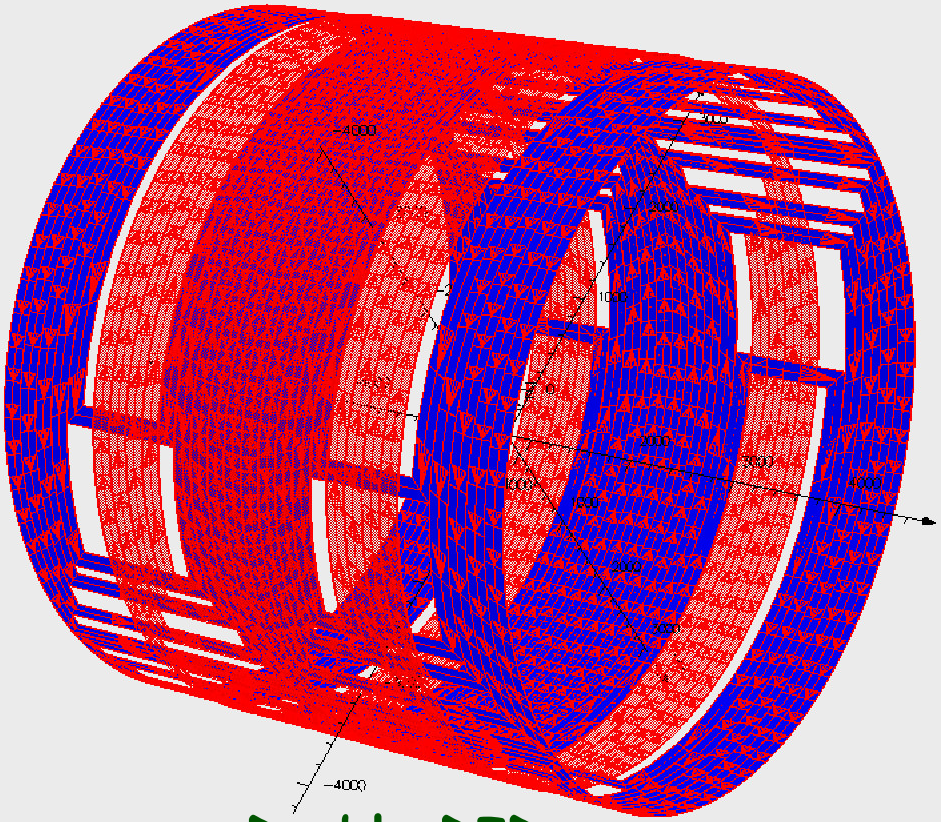




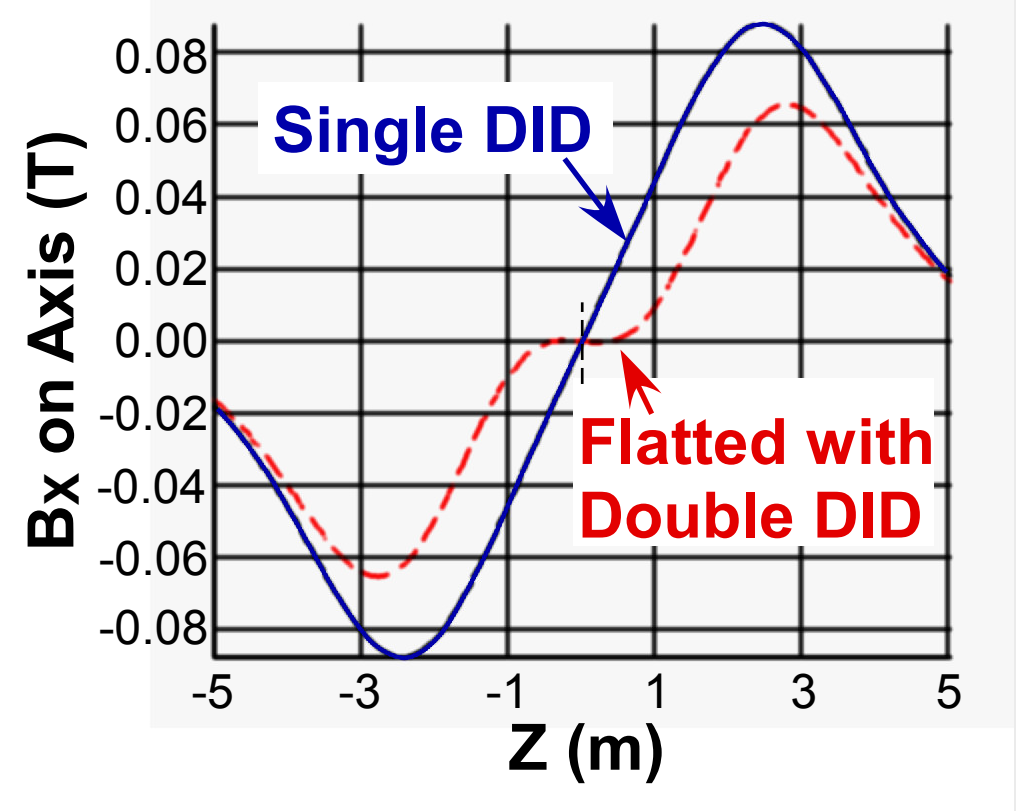


What about central field uniformity?

Scheme to reduce the DID field near the IP (needed for TPC?)



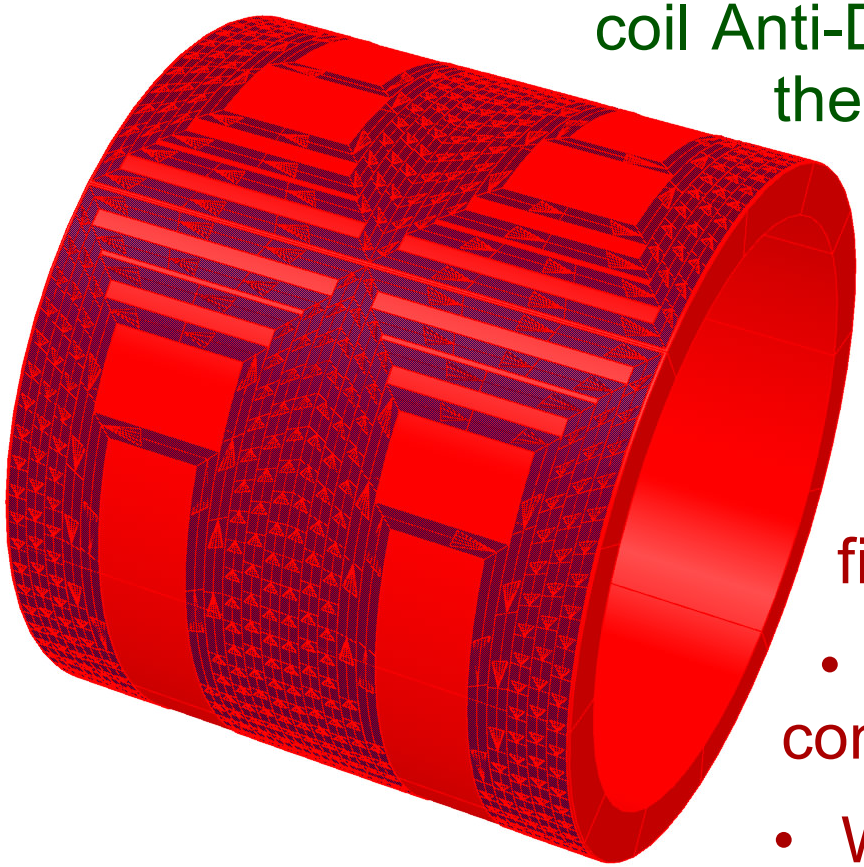
Double DID



Inner/Outer DID coils with different lengths & opposite polarity.

Some Anti-DID Observations & Questions.

Compared to a double Anti-DID solution, a single coil Anti-DID is simpler to make and operate. At the ILD Cambridge ’08 meeting there was discussion whether a single coil Anti-DID solution might be sufficient if the Anti-DID + solenoid field is carefully measured. Has this been resolved?



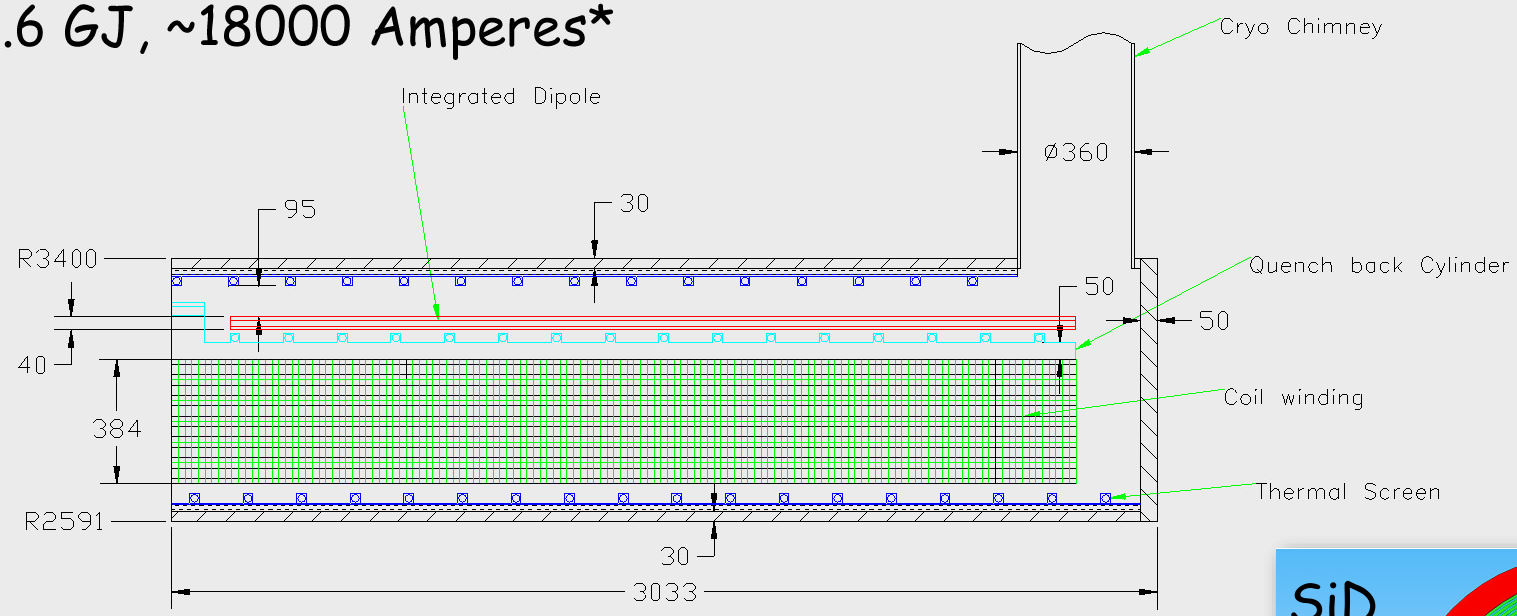
Simple Single DID

- Wind DID atop solenoid (lower coil field and to secure against local forces)?
- But could this be tricky if solenoid is constructed in multiple segments?
- Will 4'th detector require a DID?
- Since Anti-DID fixes field shape, its setting is energy independent; so “set and forget?”*

*DID for low energy precision studies?

Engineering the Anti-DID: SiD Example.

SiD Baseline design: 6 layers CMS conductor
1.6 GJ, ~18000 Amperes*



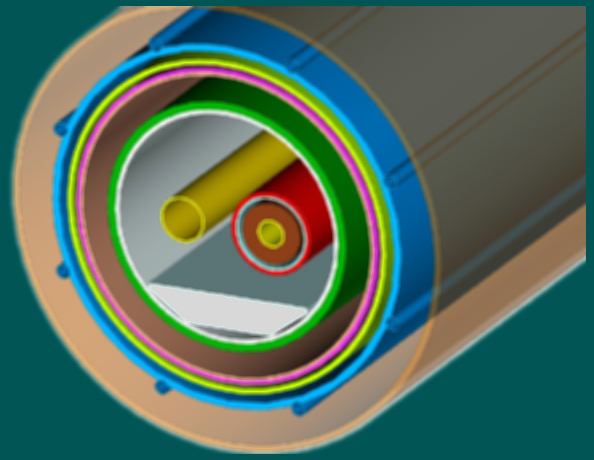
From all the experiments, this is the only Anti-DID coil drawing I have seen to date. B.P.

*SiD Status presented by M. Breidenbach

Note Re. DID Modes and Operation.

- The Anti-DID is mostly useful for high energy operation to redirrect Beamstrahlung pairs.
- Since the Anti-DID makes a geometric change to field shape, it does not need to be changed with energy changes. Expect that except for some minor initial tuning, it is "fix and forget."
- Double-coil configuration to improve central field uniformity is certainly more complicated; hope to use simple coil & carefully measure B.
- Beamstrahlung pairs not an issue for low-energy running, so for high-precision, GigaZ, probably want "DID" (flatten angle, to measure polarization).

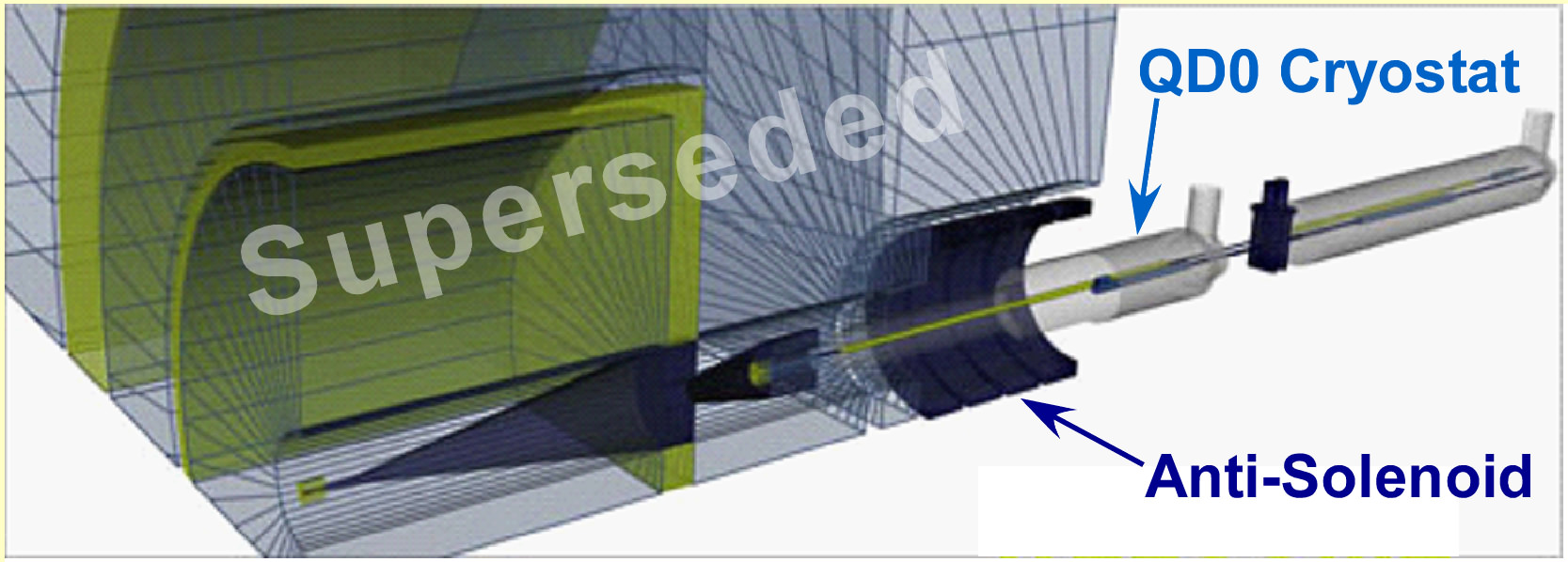
Section 3



A force neutral Anti-Solenoid is now incorporated into the QD0 cryostat.

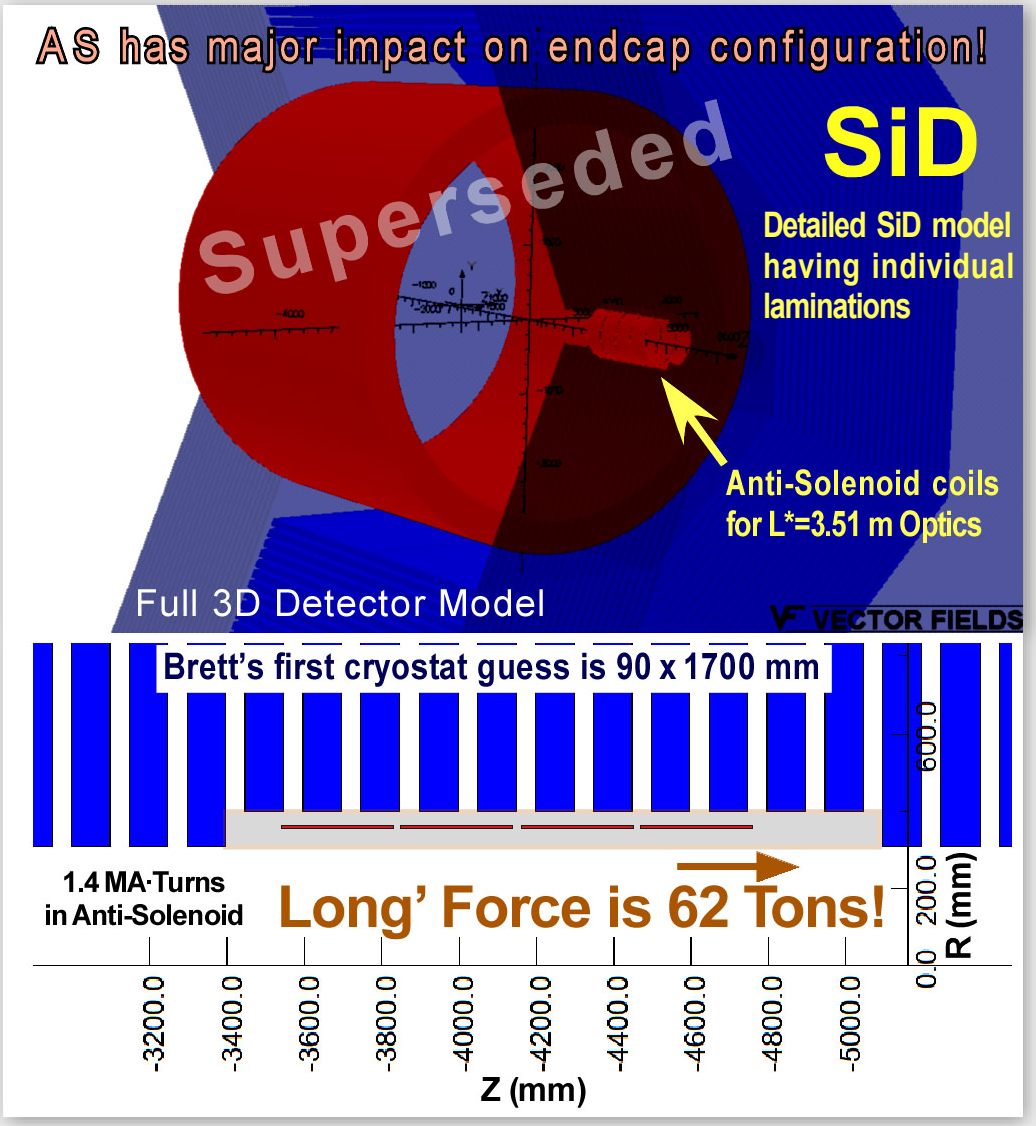
Original large diameter anti-solenoid attached to detector endcap (not QD0).

Generic Detector Scematic from IRENG'07 Workshop at SLAC



- Original anti-solenoid coils experienced a large, multi-ton repulsive force force due to interaction with the detector solenoid (AS could not reasonably be combined with QD0).
- Such a large anti-solenoid would have had a significant impact on the experimental detector design.

First (Obsolete) Large Diameter AS Concept.

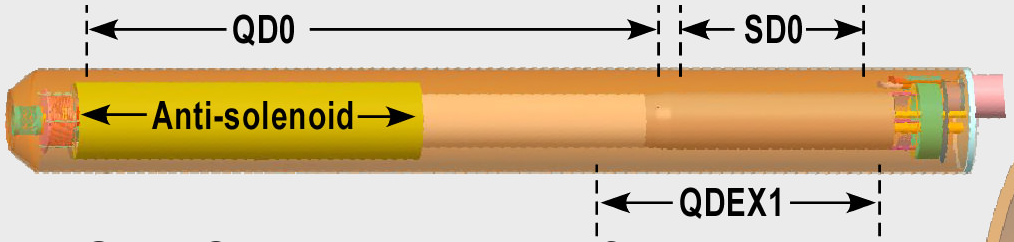


Use SiD as an example...

Because we expected a large longitudinal repulsion acting on AS due to detector field, we first considered making it independent of QD0 by using a second AS cryostat attached directly to the SiD endcap; with large coils the forces were of course quite large. Such a large AS represented a major design perturbation for SiD and would have been even more so for the other detectors.

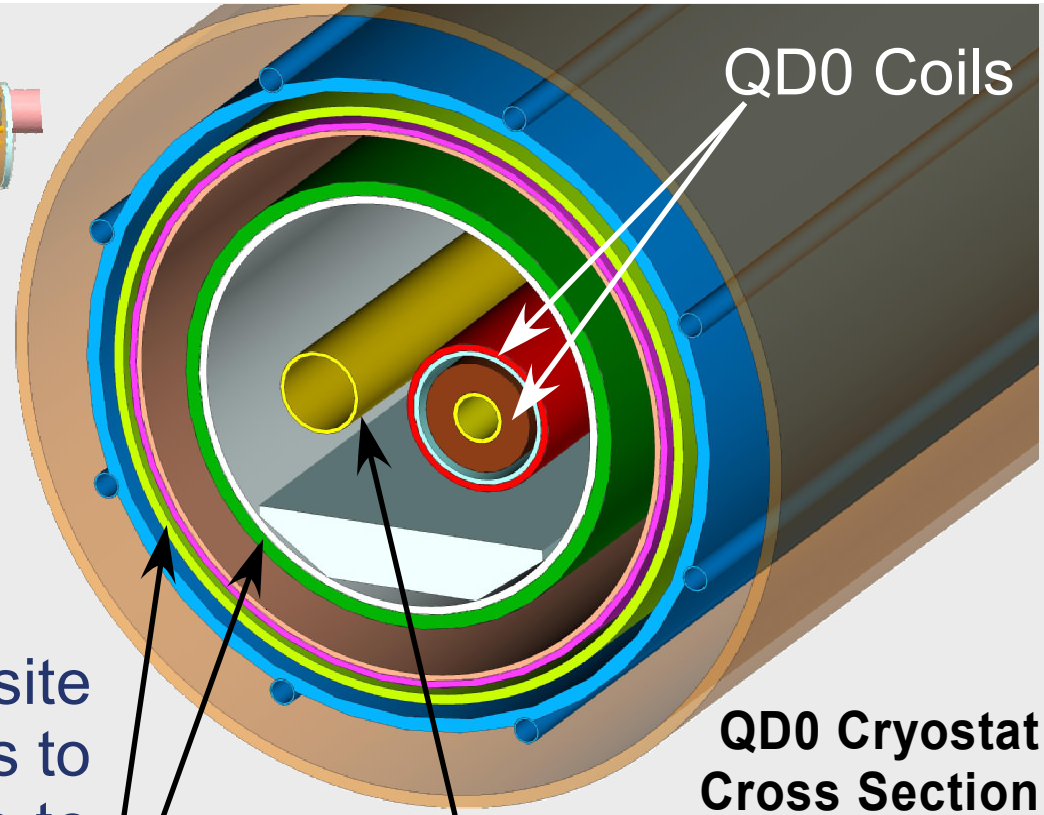
Extra Material – Background Information

QD0 and the Force Neutral Anti-Solenoid



QD0 Cryostat Design for L* = 4.5 m.

- An anti-solenoid, that partially overlaps QD0, is provided to make optics corrections; but it does not “zero” detector field.
- Anti-solenoid design has opposite polarity inner and outer coil sets to balance longitudinal force due to interaction with detector solenoid.



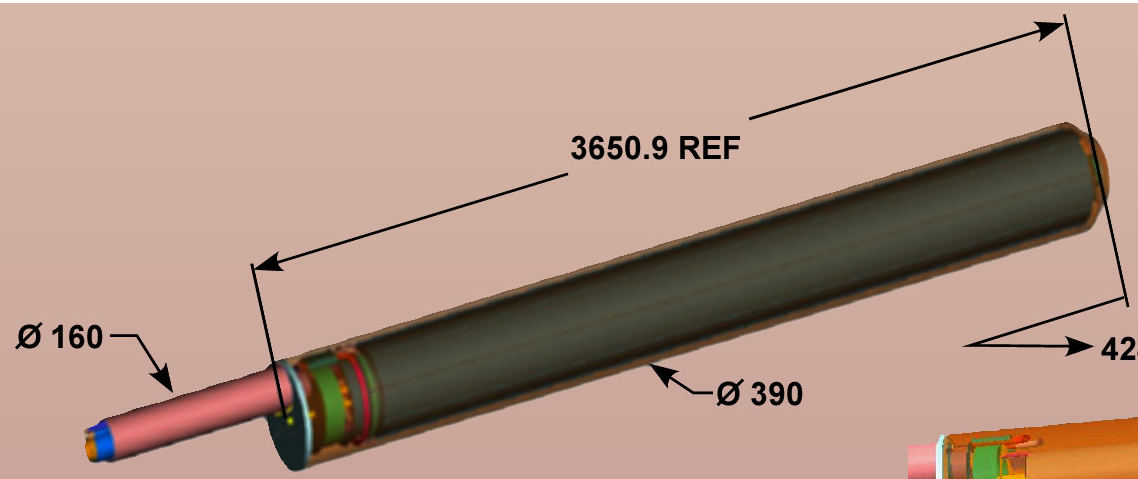
QD0 Cryostat Cross Section

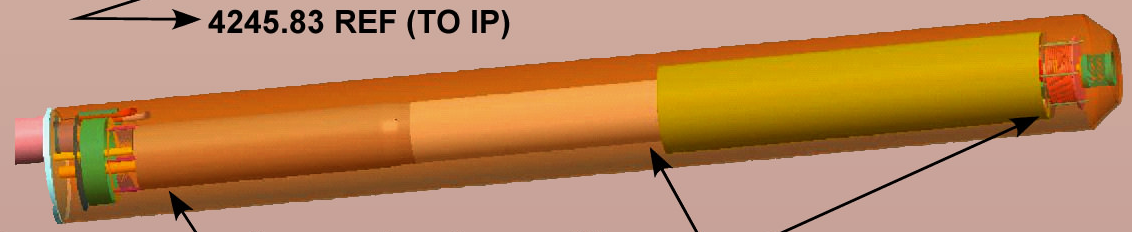
Extraction Line Beam Pipe

Force Neutral Anti-Solenoid Coils
(no net long’ force on cold mass)

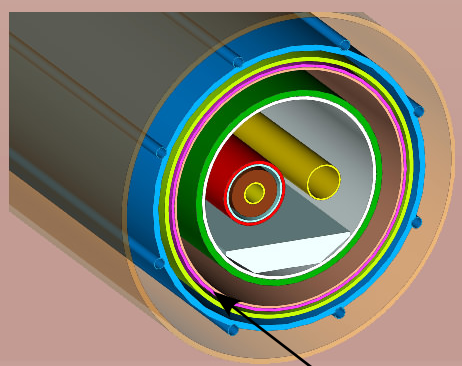
QD0 Cryostat Information, L* = 4.5 m.

- Overall dimensions of QD0 cryostat.
- Sized and shown for L*= 4500 mm.
- For L*= 3500 mm distance to IP would be 3245mm, all other dims. remain constant.

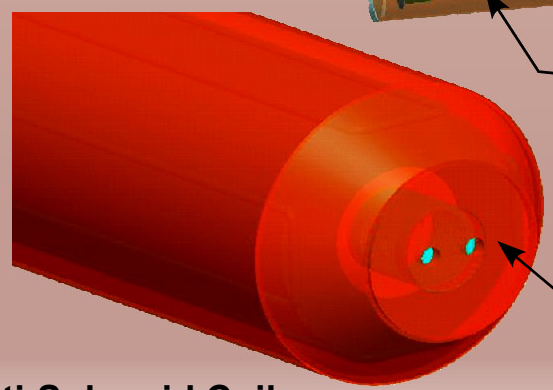




Approximate positions of load transfer points.



Outermost Anti-Solenoid Coil



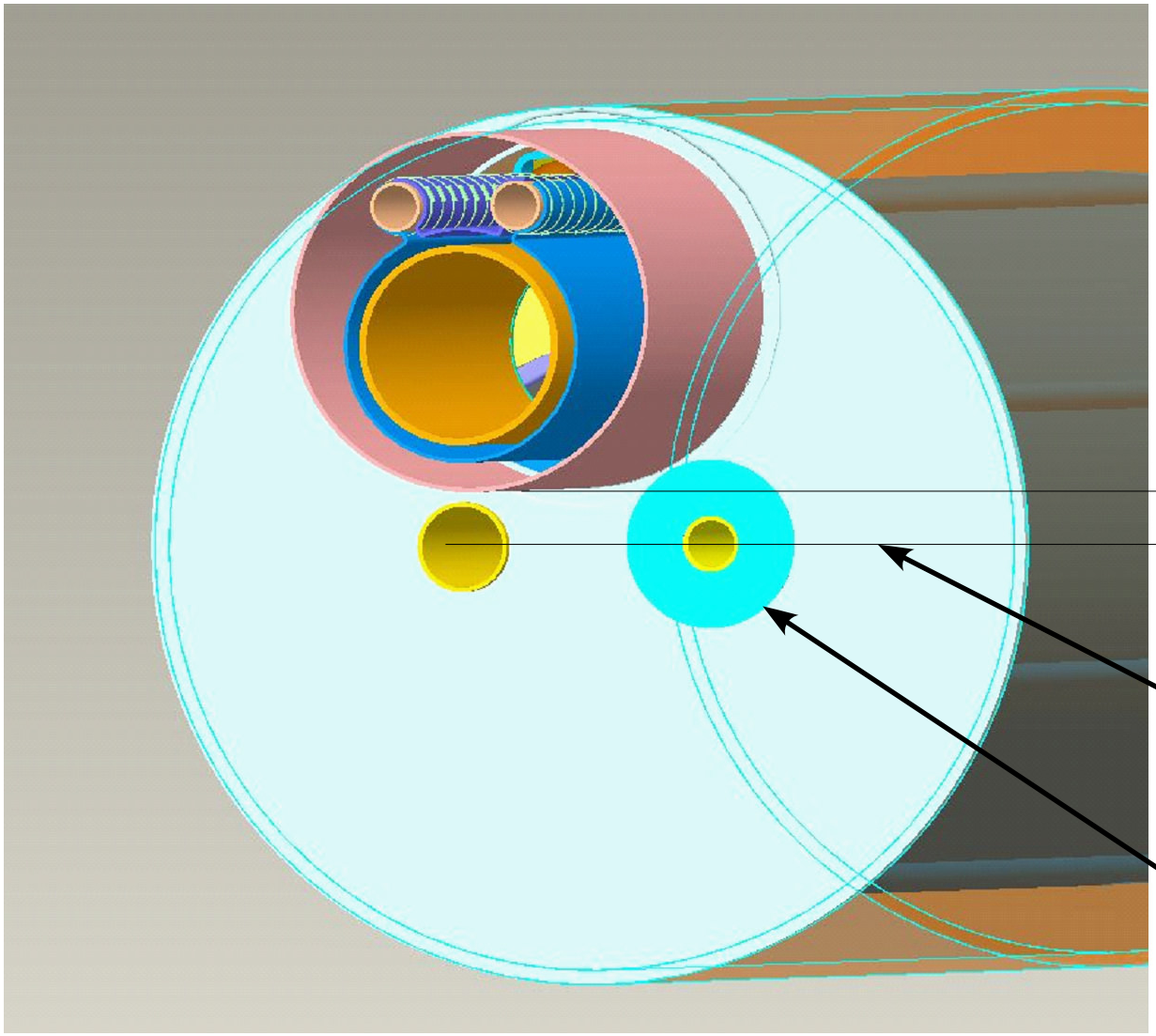
End of cryostat may be adapted to accommodate desired connection type.

Need to define beam tube connection (helico-flex?)

QD0 cryostat OD is set by Anti-Solenoid & cryo-line connection.

Extra Material – Background Information

Lead-End (Non-IP) Beam Tube Connections.



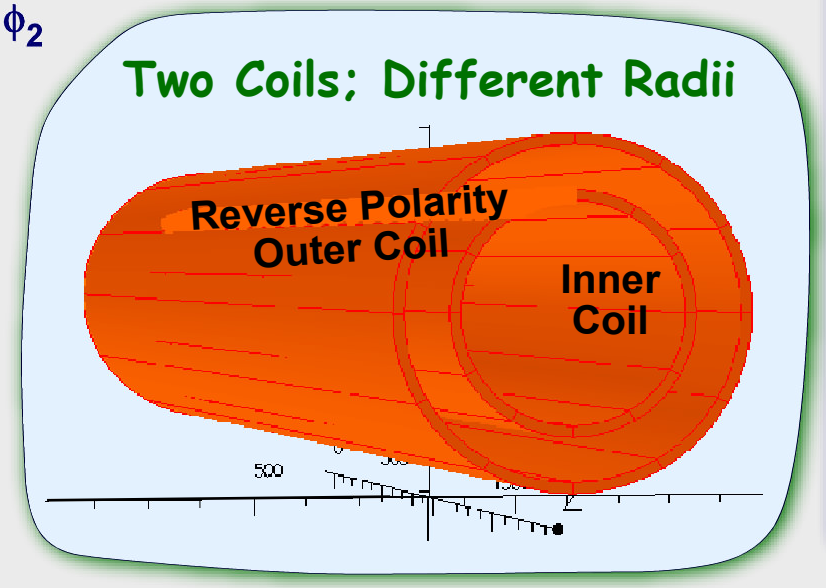
Force Neutral Anti-Solenoid Concept.

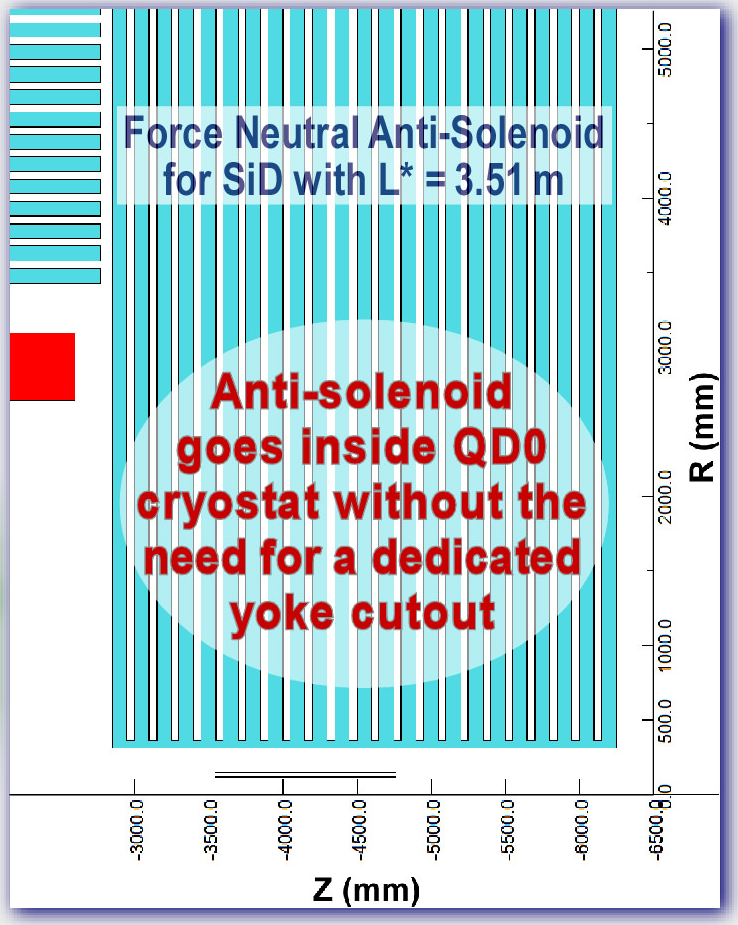
For a loop of circumference C carrying current I the longitudinal force is proportional to Br, thus

We want $$\sum_{j=1}^{N_1} (I_1 C_1 Br_1)_j + \sum_{k=1}^{N_2} (I_2 C_2 Br_2)_k = 0$$

Since $C \propto R$ and $Br \propto R$, so $CBr \propto R^2$ and for $I_1 = -I_2$ we have

$N_1 \overline{A}_1 = N_2 \overline{A}_2$ or $\phi_1 = -\phi_2$





We can arrange for the sum of the forces on the inner and outer coils to fully cancel... but still have a net anti-solenoidal field inside the inner coil.

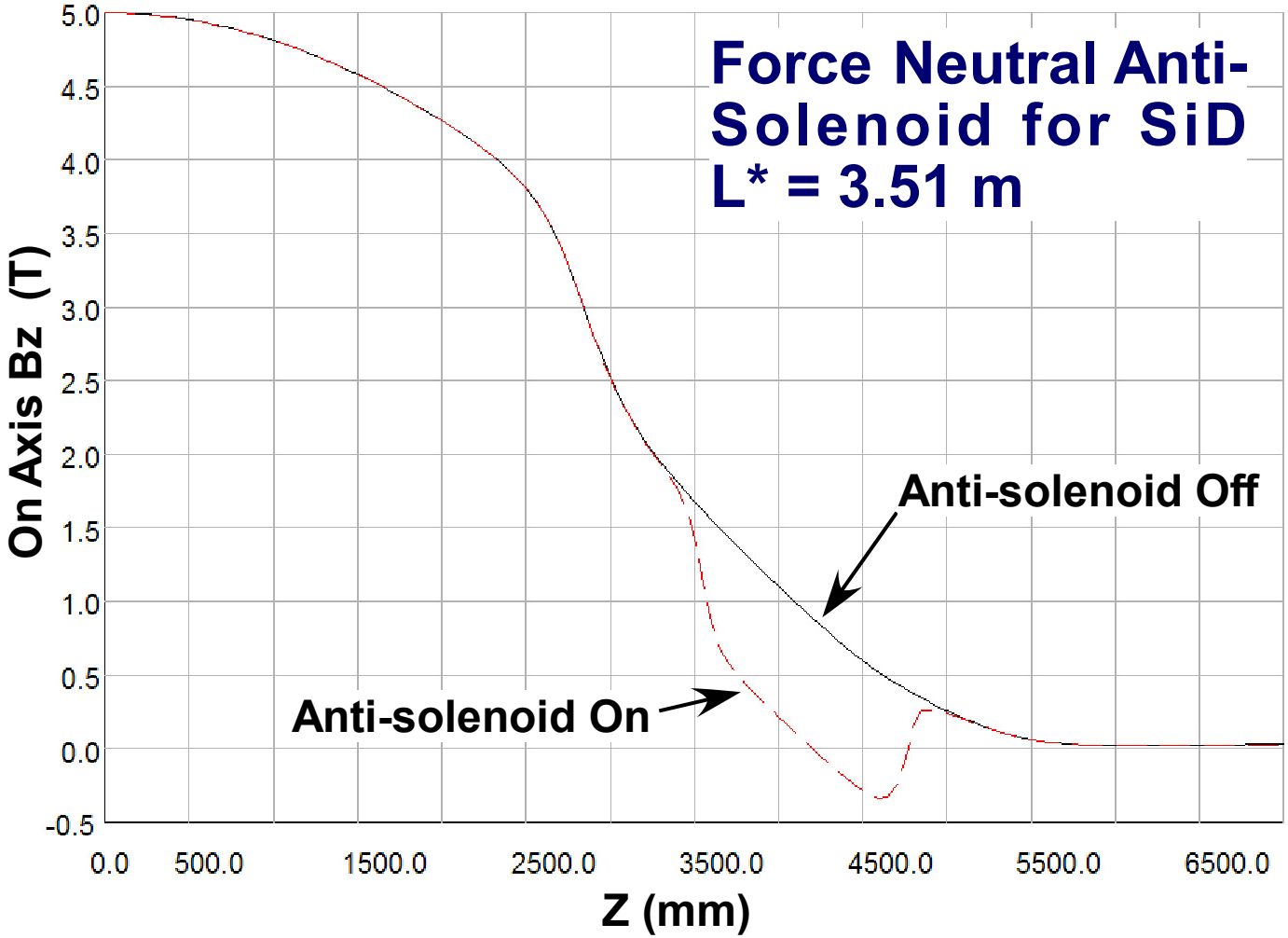
This solution does not require major changes for different detectors or L*.

Example: Force Neutral AS with SiD.

Thanks to cancellation between the external fields of the inner and outer coils, the force neutral anti-solenoid has very little impact on the detector field away from QD0.

Note: we will use trim currents to fine tune the field shape for optics optimization while remaining force neutral.

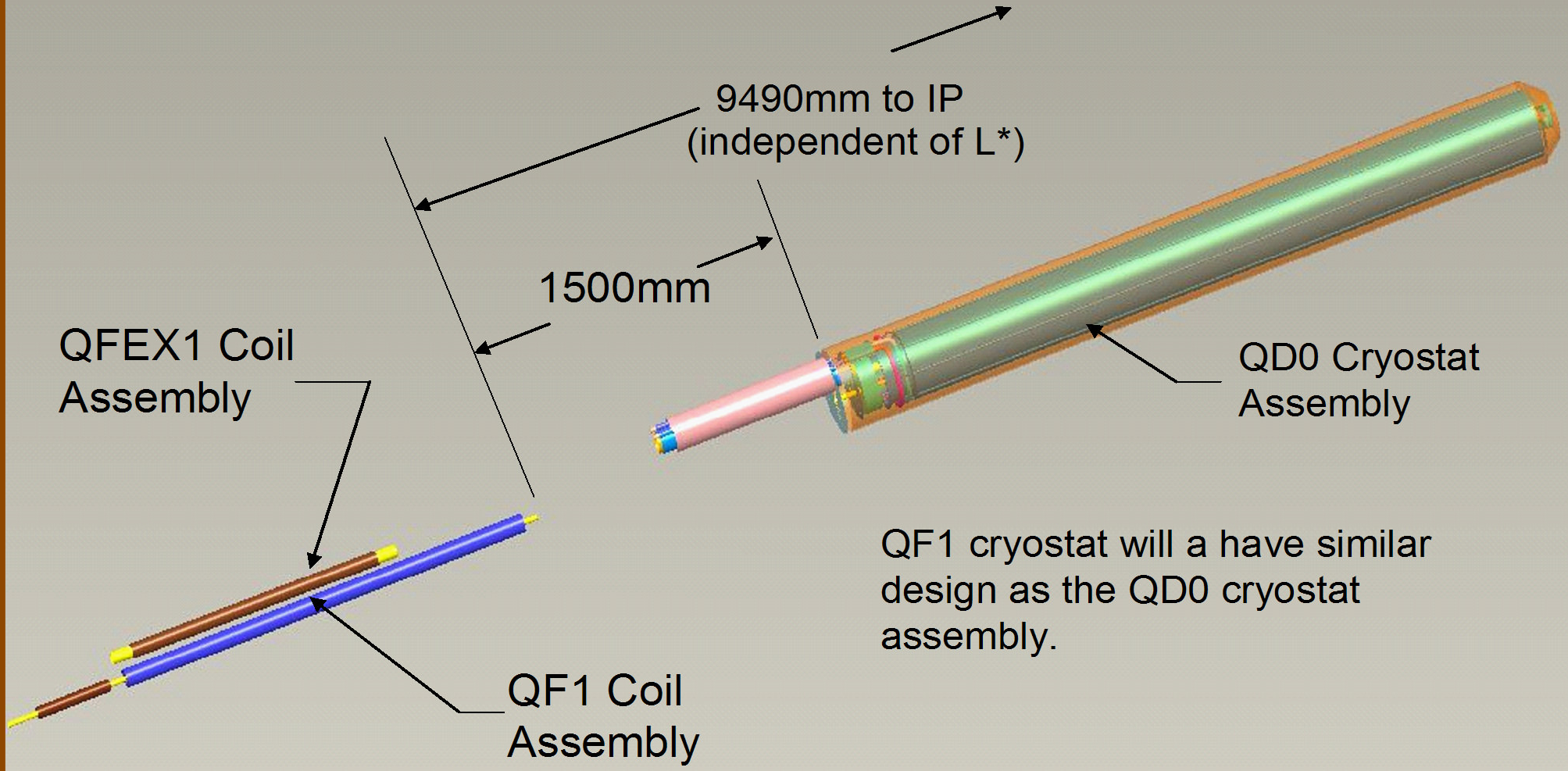
This is a very flexible configuration that can be adapted to various values of L*.



Unlike first design, force neutral anti-solenoid has very little external field.

Extra Material – Background Information

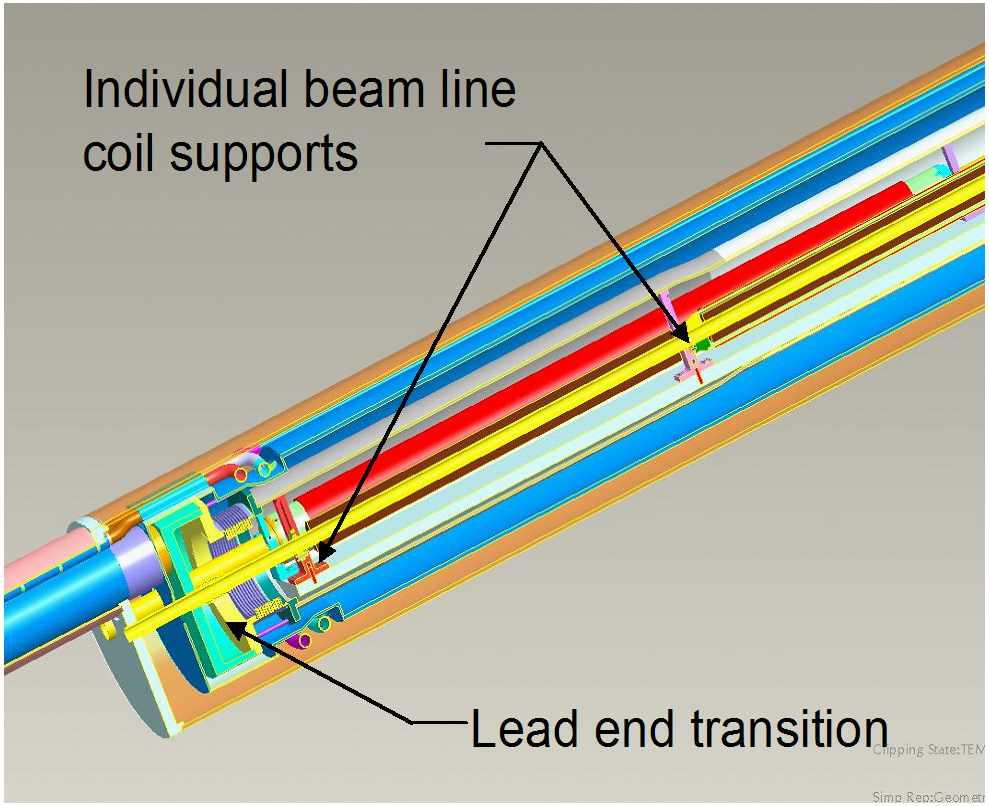
Current Overall Design, L* = 4500 mm.

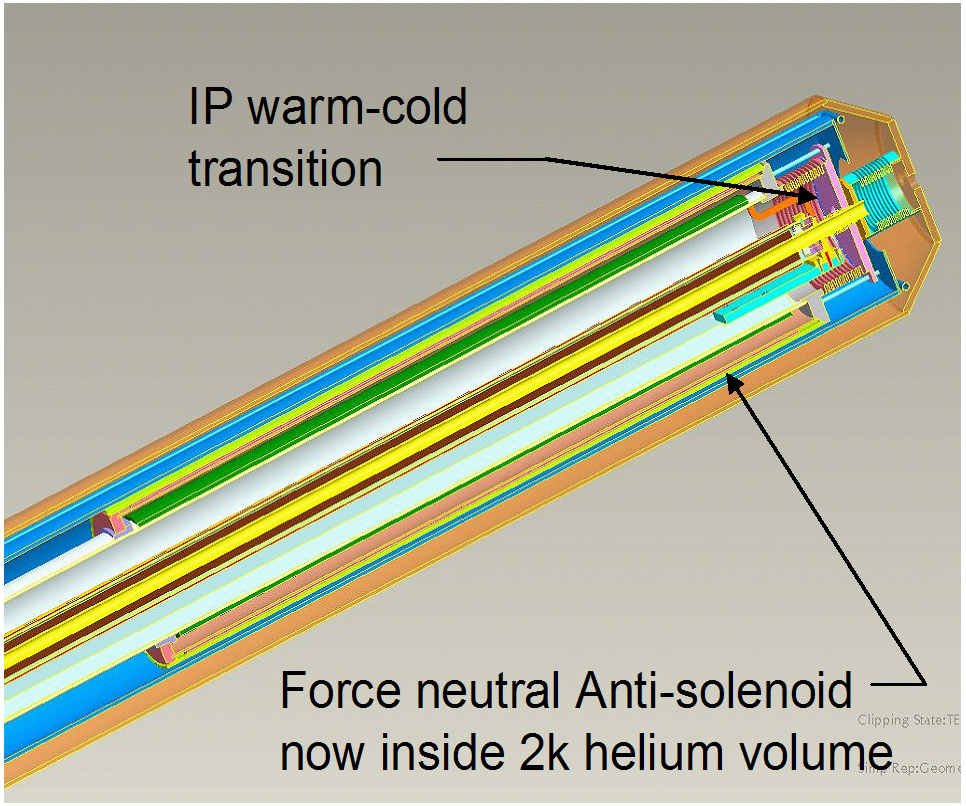


QF1 cryostat will a have similar design as the QD0 cryostat assembly.

Extra Material – Background Information

QD0 Cryostat Design Information.

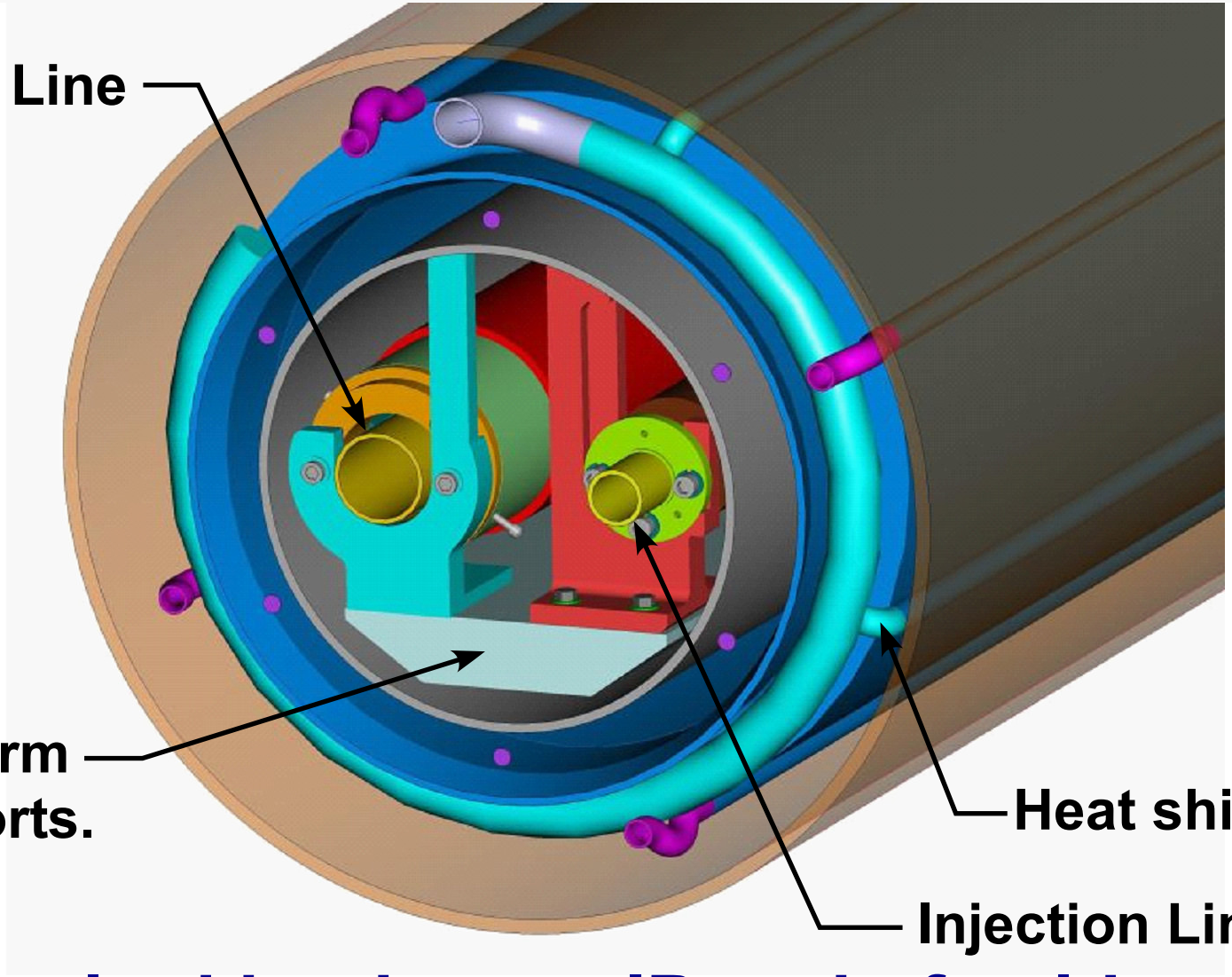




All vessels sized for up to a 4500 mm L*, any larger L* would require an increase in the diameter of each vessel.

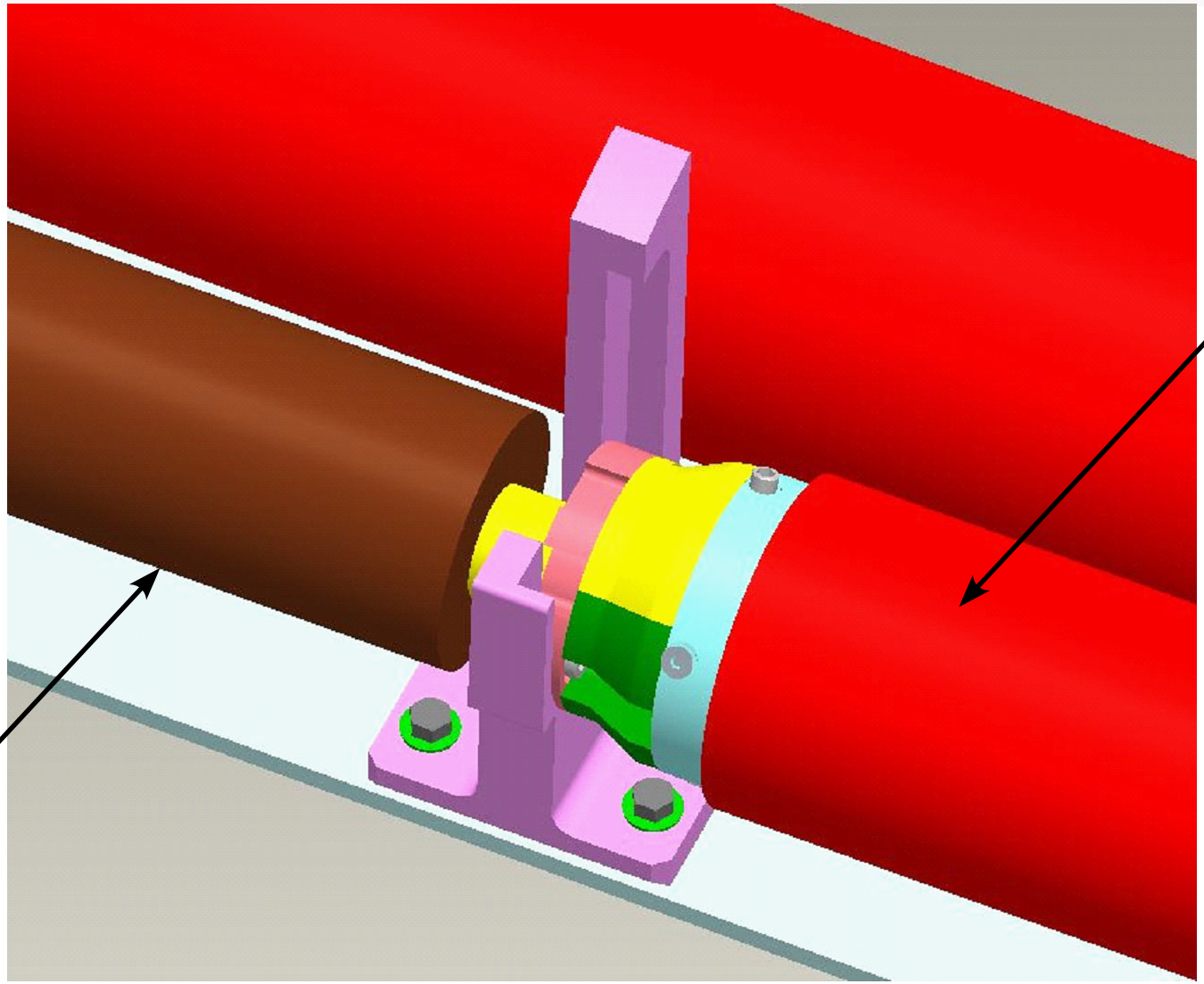
Extra Material – Background Information

QD0 Cryostat Design Information.



View looking in non-IP end of cold mass

QD0 Cryostat Design Information.

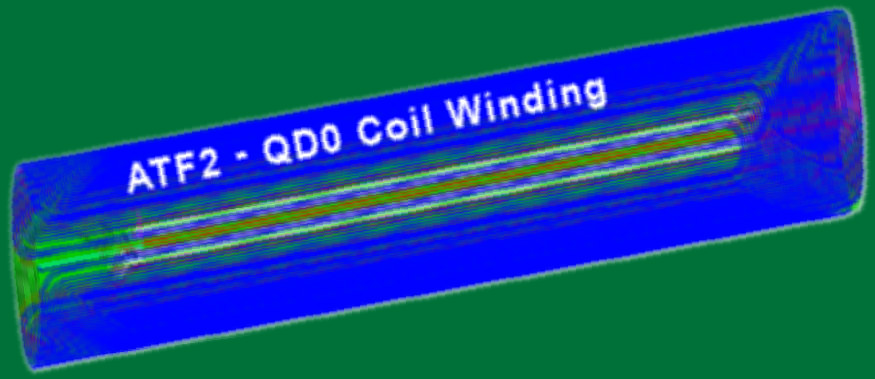


QD0-SD0 Support

Some Remaining Engineering/Design Work.

- Add internal cold mass supports.
- Vibration analysis.
- Lead bus design.
- Detailed transfer line design.
- Interface connection design.
- Cryostat support connection and adjustment design.

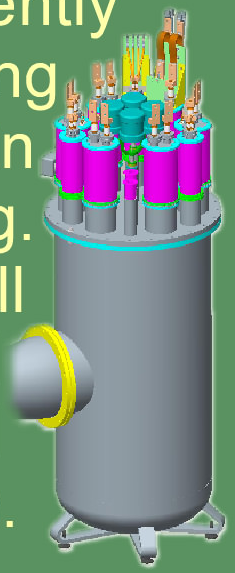
Section 4

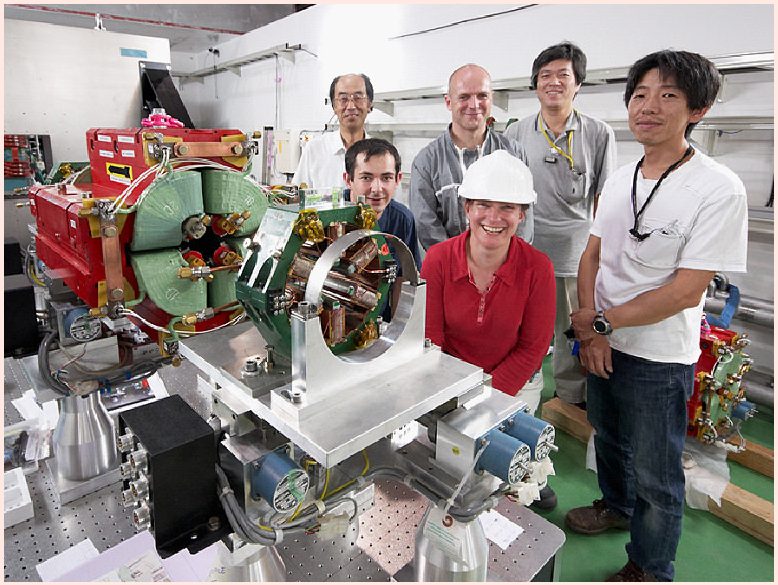


Parameters for a superconducting magnet FF upgrade at ATF2.

ATF2 Upgrade Critical Considerations.

No cryogenic system presently on the floor at ATF2; getting approval for a new setup in Japan could be challenging. Will look to go with a small stand alone system. Critical to minimize heat load (cryostat, current leads etc.).





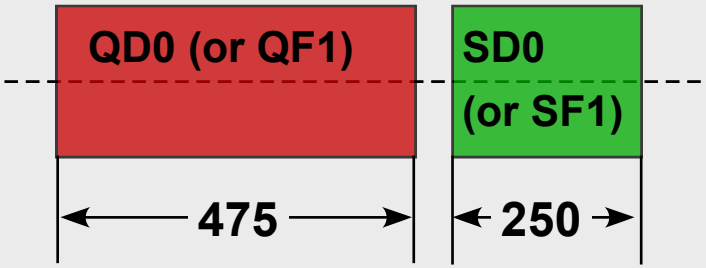
ATF2 Final Focus Magnets

Production & testing of a full length QD0 prototype is underway at BNL. Study begun on how to produce superconducting magnets appropriate for an ATF2 FF upgrade of limited scope (cost & schedule, ongoing discussion during LCWS'08).

Requirements and constraints for ATF2.

... an updated proposal.

Proposed Magnetic Lengths (mm)



50 mm ID Warm Bore

G_{QD0} = 31.4 T/m @ 700 A

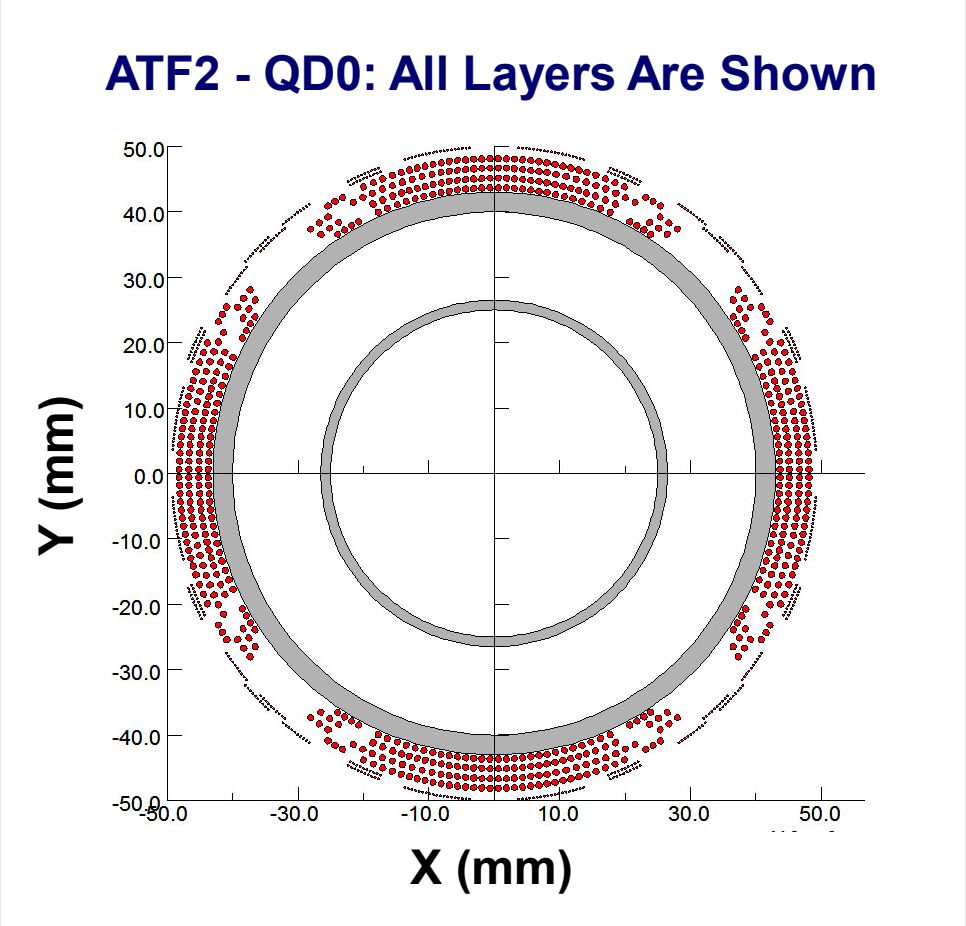
B_{SD0} = 0.234 T @ 700 A and R = 25 mm

QD0 has dipole correctors

SD0 has skew-sextupole, quad and skew-quad

- Only produce one quadrupole/sextupole magnet combination (in common cryostat).
- No self-shielding or anti-solenoid (simple).
- KEK Cryogenic system (major challenge).
- 50 mm aperture but with a warm bore (optimize to reduce cold mass heat leak).
- Minimum degrees of freedom (correctors).
- Found it easy to match all corrector coil magnetic lengths to their main coils.

Proposed ATF2 - QD0 Coil Parameters.



SS warm beam tube 50 mm ID (clear bore) with 1.5 mm wall

SS cold support tube 80 mm ID (clear bore) with 3 mm wall

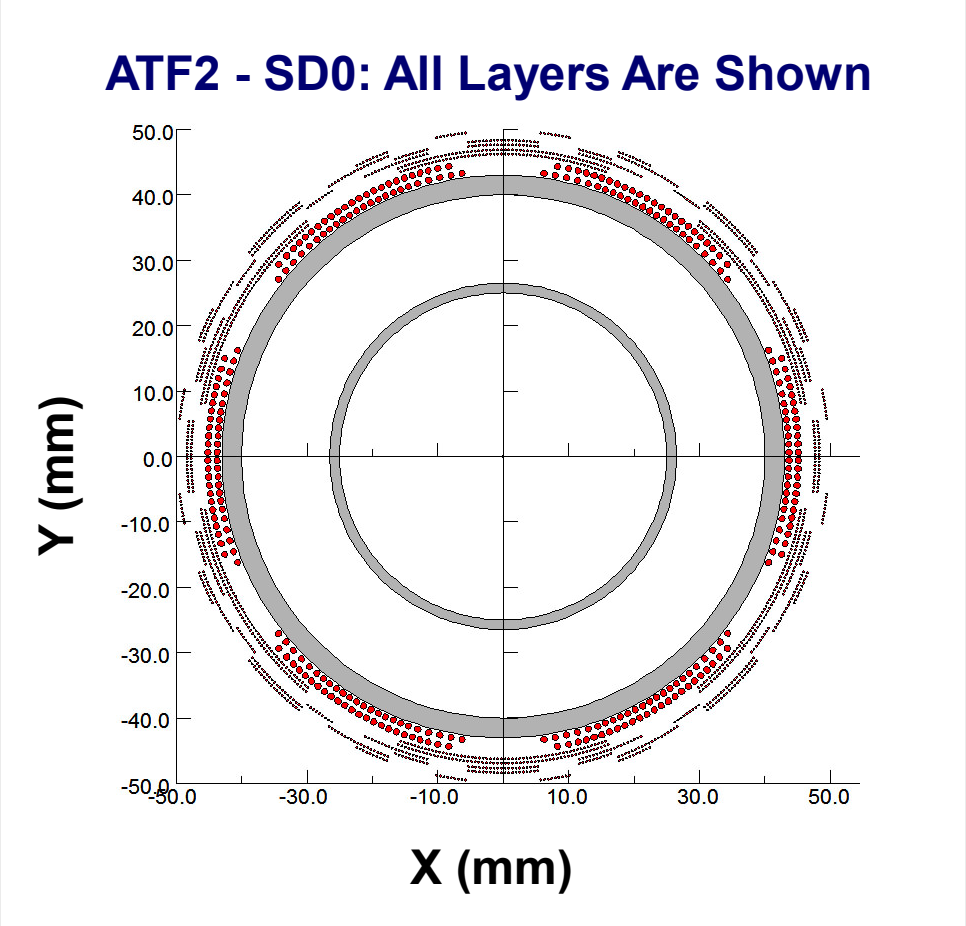
QD0 coils with 7-strand cable four layers with cable centers at R_{cond} = 43.70, 45.15, 46.70, 48.15 mm

Single strand dipole corrector one layer with wire center at R_{cond} = 49.30 mm

Single strand skew-dipole corrector one layer with wire center at R_{cond} = 49.95 mm

Extra Material – Background Information

Proposed ATF2 - SD0 Coil Parameters.



SS warm beam tube 50 mm ID (clear bore) with 1.5 mm wall

SS cold support tube 80 mm ID (clear bore) with 3 mm wall

SD0 coils with 7-strand cable two layers with cable centers at R_{cond} = 43.70, 45.15 mm

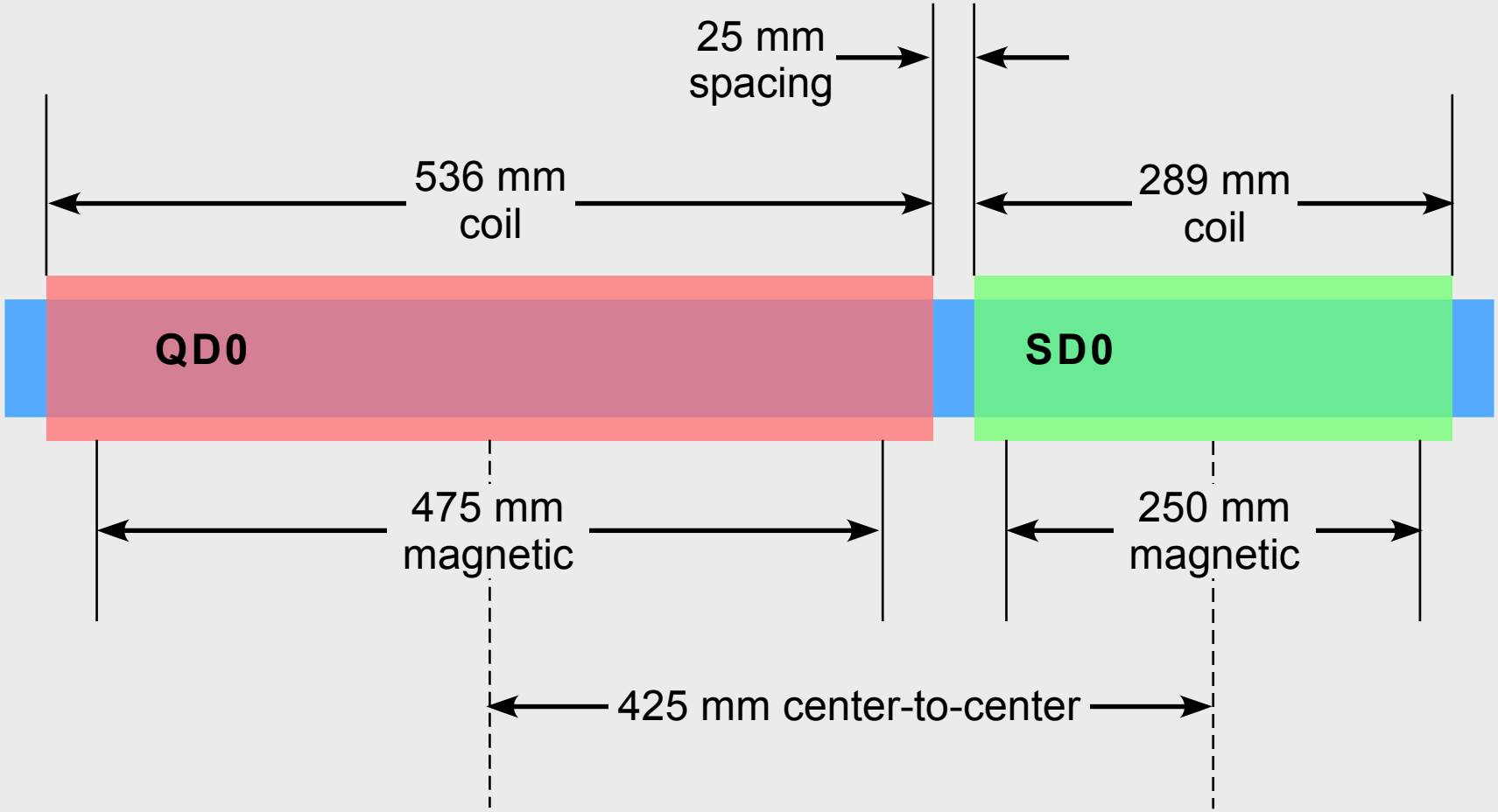
Single strand skew-sextupole corrector two layers with wire centers at R_{cond} = 46.25, 46.90 mm

Single strand quad corrector two layers with wire centers at R_{cond} = 47.70, 48.35 mm

Single strand skew-quad corrector two layers with wire centers at R_{cond} = 49.15, 49.80 mm

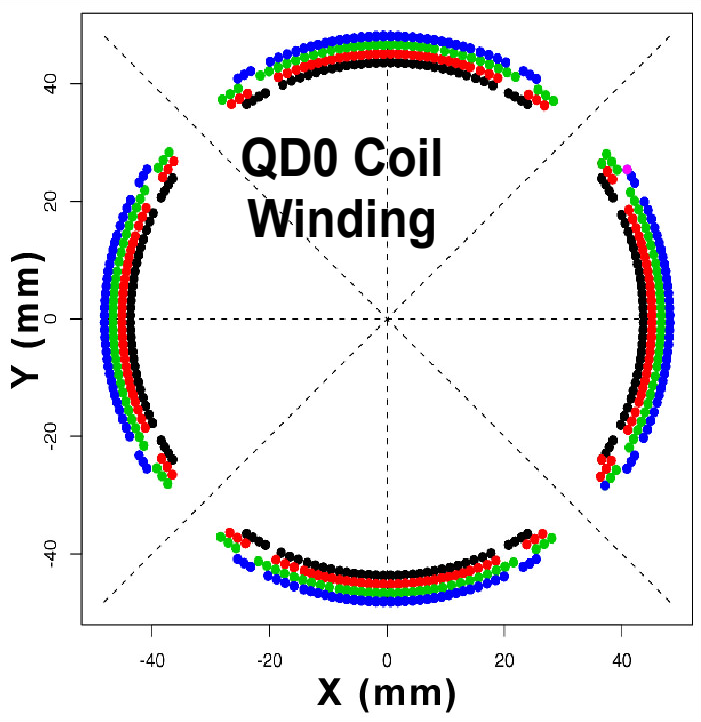
Extra Material – Background Information

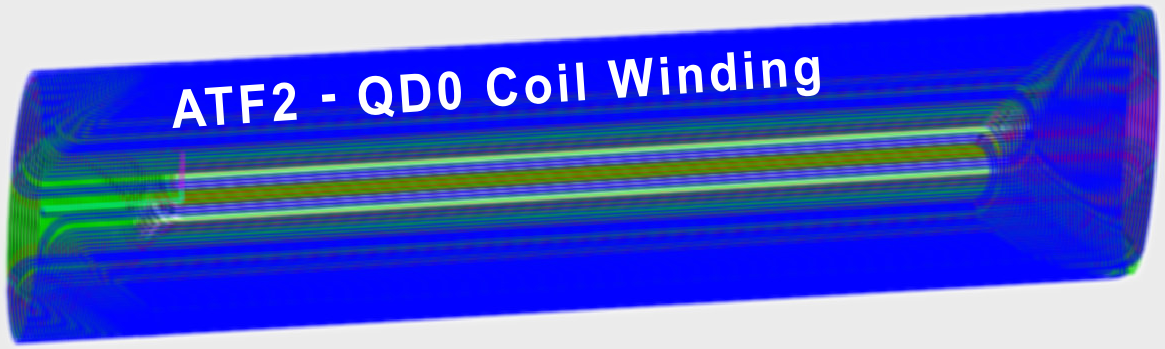
Proposed ATF2 - QD0/SD0 Coil Layout.



Parameters based upon the 06-Oct-08 ATF2 coil design files.

ATF2 Superconducting Upgrade: QD0.



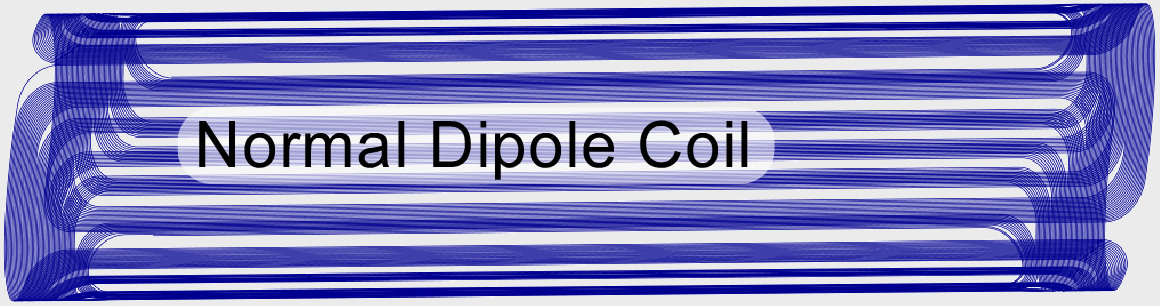


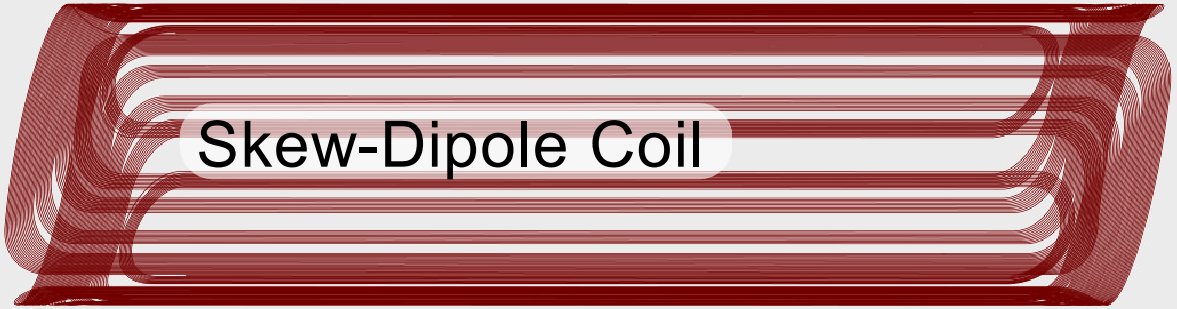
Design has four layers of 6-around-1 cable, in two Serpentine coil sets, with a 536 mm pattern length and 475 mm magnetic length.

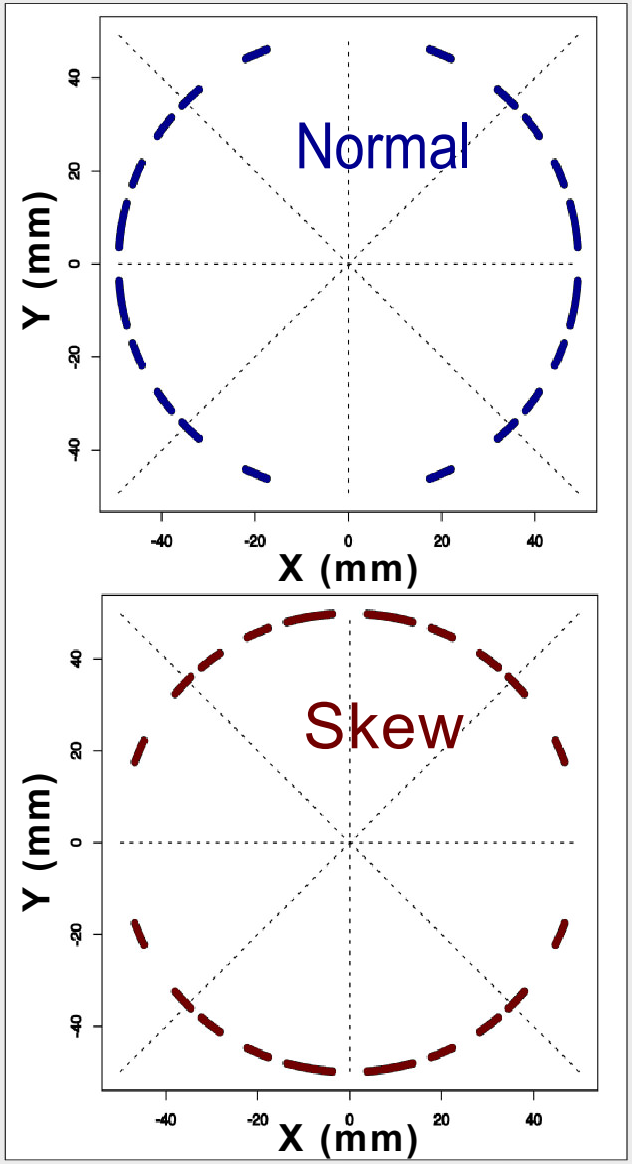
- *Excellent design harmonics out to edge of warm bore, R = 25 mm.*
- *Two coil sets; do field angle/harmonic correction during production.*
- *Space budgeted for heat shield and warm bore, but no design yet.*
- *Next slide for co-wound dipole and skew-dipole correction coil info'.*

Extra Material – Background Information

ATF2 Superconducting Upgrade: QD0.

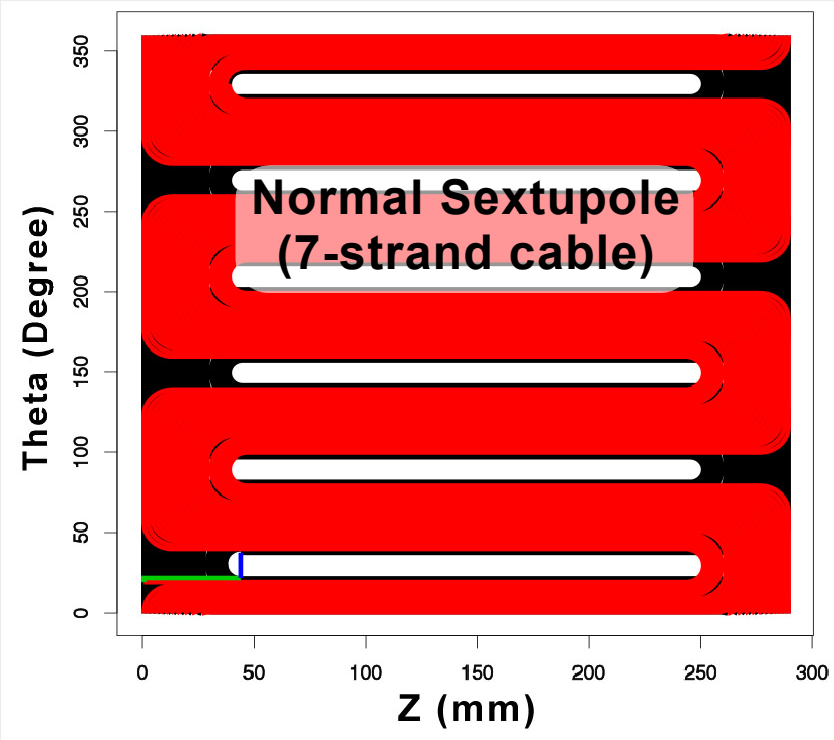


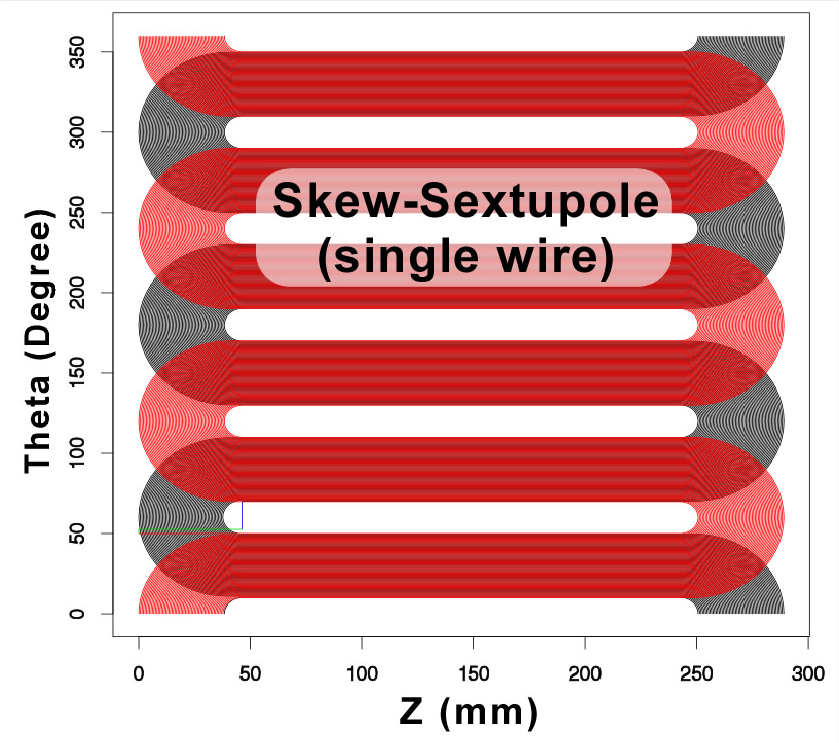




Wind single layer dipole and skew-dipole correction coils atop QD0, using single-strand wire, with parameters carefully matched to QD0's physical & magnetic length.

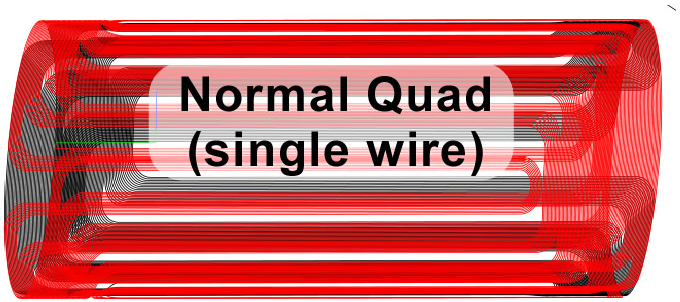
ATF2 Superconducting Upgrade: SD0.

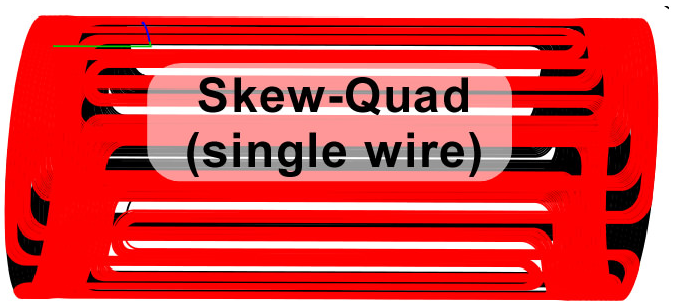




- Single two-layer Serpentine coil sets for normal and skew-sextupole.
- Excellent design harmonics out to edge of warm bore, R = 25 mm.
- Wind sextupole first, before doing QD0, on same tube and measure.
- Next slide for co-wound quad and skew-quad correction coil info'.

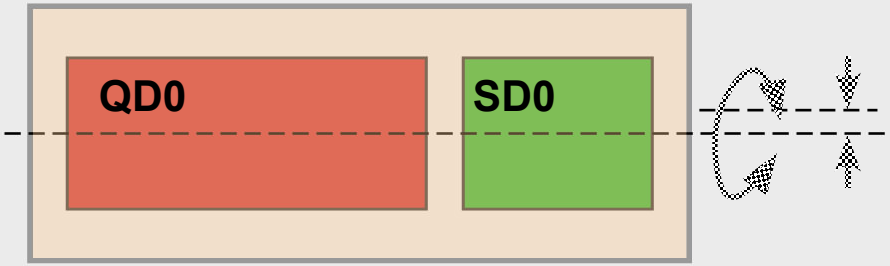
ATF2 Superconducting Upgrade: SD0.





Normal and skew-quadrupole coil windings are matched to the SD0 sextupole total pattern & magnetic lengths.

QD0 and SD0 in a Common Cryostat



Note: With the proposed correction coils, we have magnetic degrees of freedom to both alter their relative offset and give an effective rotation between QD0 and SD0 (inside their common cryostat).

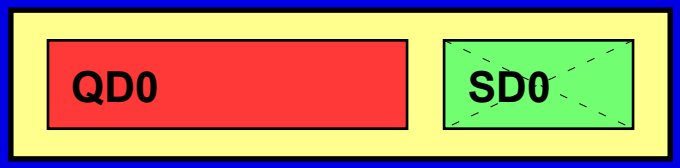
Need to check proposed field strengths against the reduced-beta* scenarios & start engineering design.

ILC/CLIC Commonalties and ATF2?

With adoption of ILC superconducting linac parameters, final focus vibration targets are relaxed (use feedback); however, we can still look to the QD0 prototype for lessons re. "how low can we go."

Experimental data, acquired on such a novel system, are needed to to evaluate real limits; **we don't (yet) know that sub-nm is impossible.**

ATF2 QD0/SD0 in Common Cryostat



With only two magnets, look to keep costs down so we can make progress even with limited funding. Fall back position could be to eliminate SD0 also?

- **With QD0 R&D prototype, characterize system performance at BNL.**
- **With ATF2 QD0, characterize system performance, including the feedback system, at KEK with beam.**
- **Gain experience adjusting "magnetic center" knobs (tuning algorithm).**
- **Integrate superconducting ATF2 QD0 with MONALISA (interferometer)?**

ATF2 Superconducting Upgrade Summary.

- Just getting (re)-started to define scope; no estimate yet for budget or schedule (fix preliminary design/requirements).
- Producing the coils is the easier part; designing/producing cryostat is really the bulk of the work.
- Would plan to make full system test first at BNL before sending to ATF2 by adapting QD0 prototype service cryostat.
- But this service cryostat is then not available for ATF2 usage when we test the QD0 prototype; would KEK make its own ATF2 service cryostat and cryogenic system?

Conclusion

There is plenty of work that needs to be done in the coming year.

Thanks to:

A. Seryi, T. Markiewicz, A. Marone, M. Anerella, A. Jain, K.C. Wu, J. Escallier, P. Wanderer, P. He, W. Morse, T. Tauchi, R. Settles, M. Breidenbach, D. Kaefer, A. Vogel, K. Buesser, T. Peterson, D. Urner, V.Telnov, J. Gronberg, the BDS team and many others.