2009 Linear Collider Workshop of the Americas
28 September - 4 October 2009
Albuquerque, NM, USA

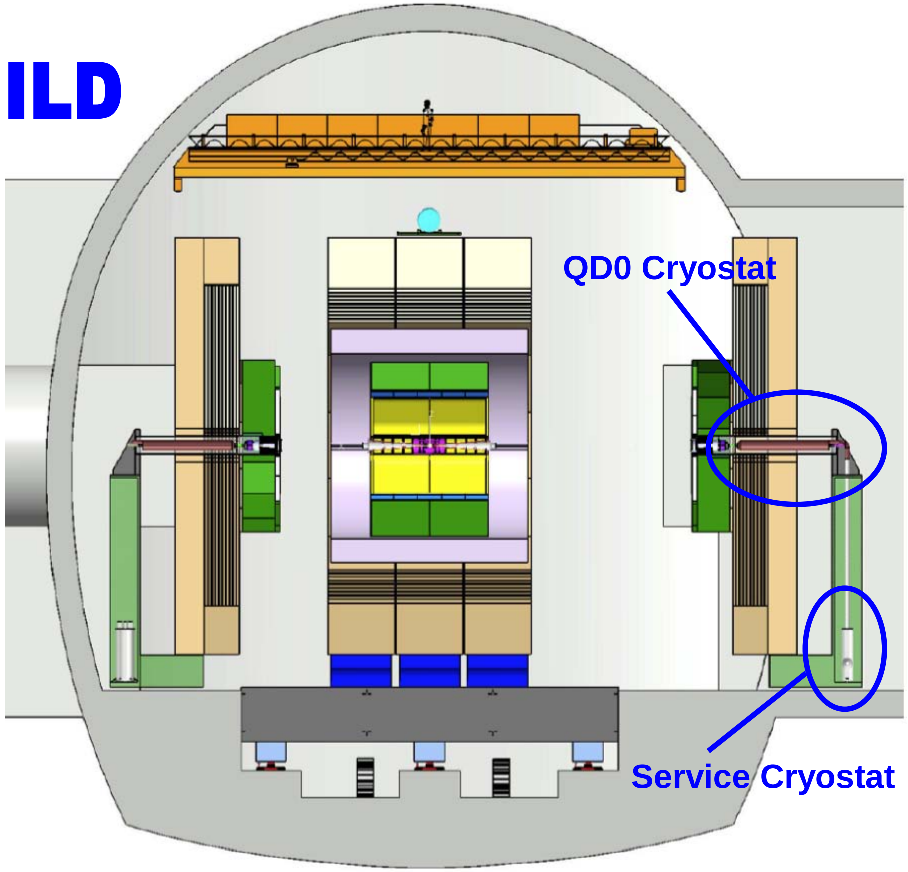
Compact SC Quad Prototype Plans and DID Status

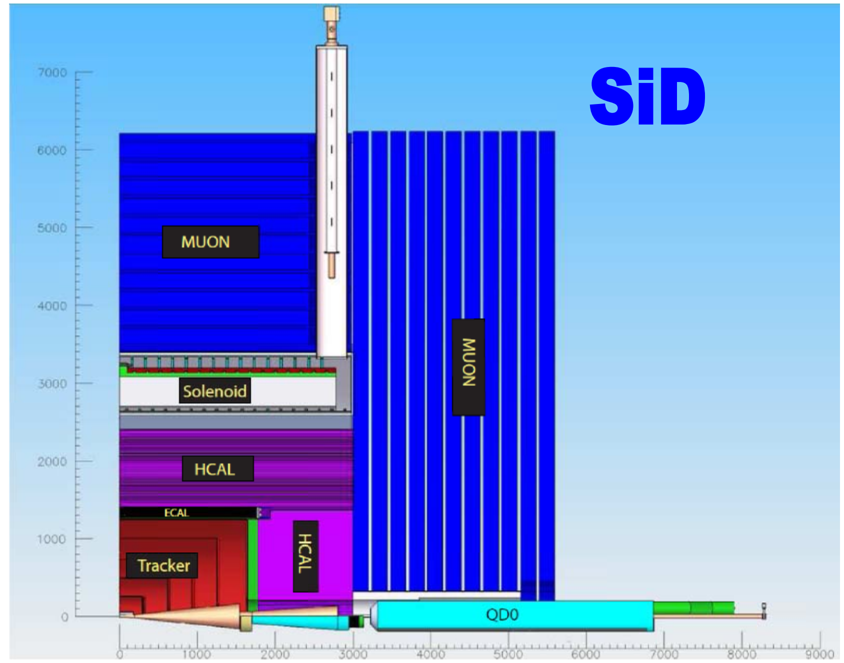
Presented by: Brett Parker (BNL-SMD)

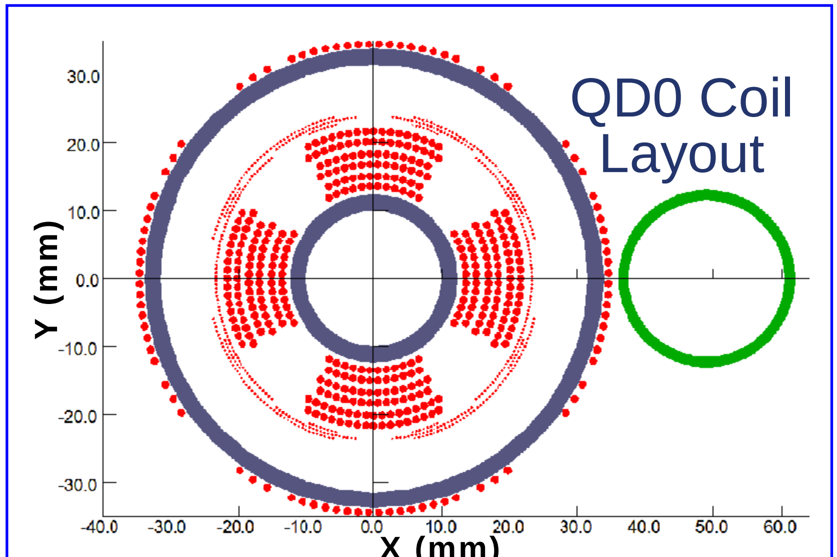
Outline:

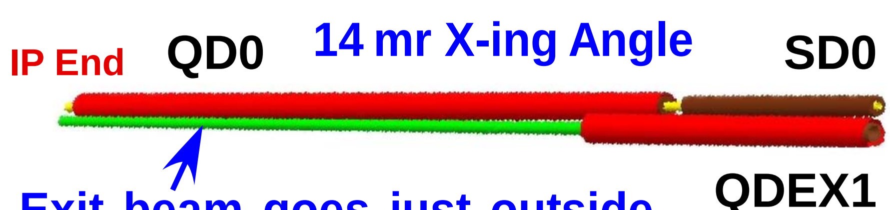
- Review the 14 mr ILC QD0 Baseline Design.
- Review QD0 R&D Prototype & ATF2 SC Q Plans.
- Present some thoughts re. DID coil production.

FF Superconducting Magnets In ILC Detectors.



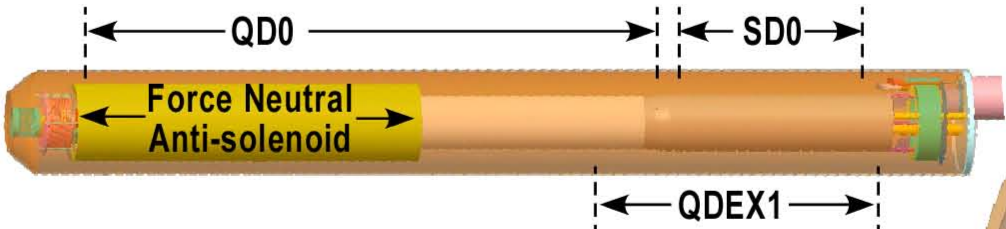




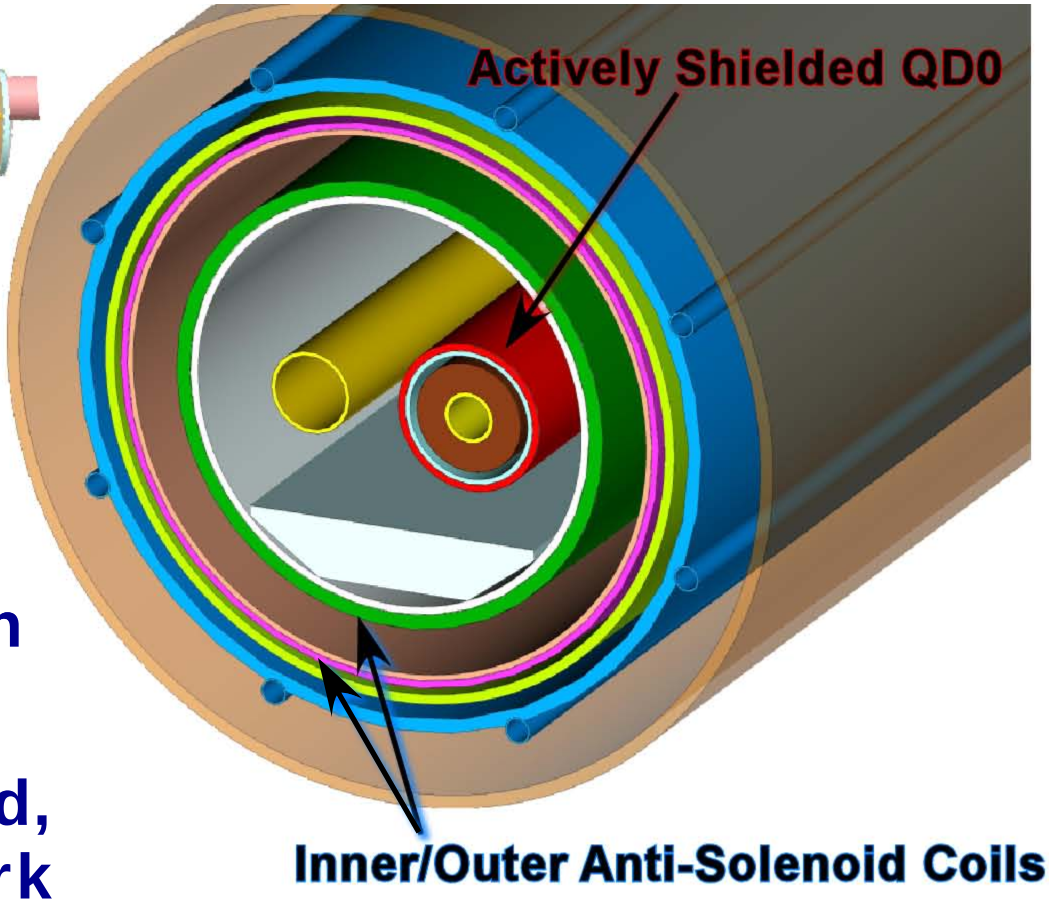


Exit beam goes just outside compact self-shielded coil.

Some ILC FF Magnet Design Challenges.



QD0 Cryostat Design for L* = 4.5 m.

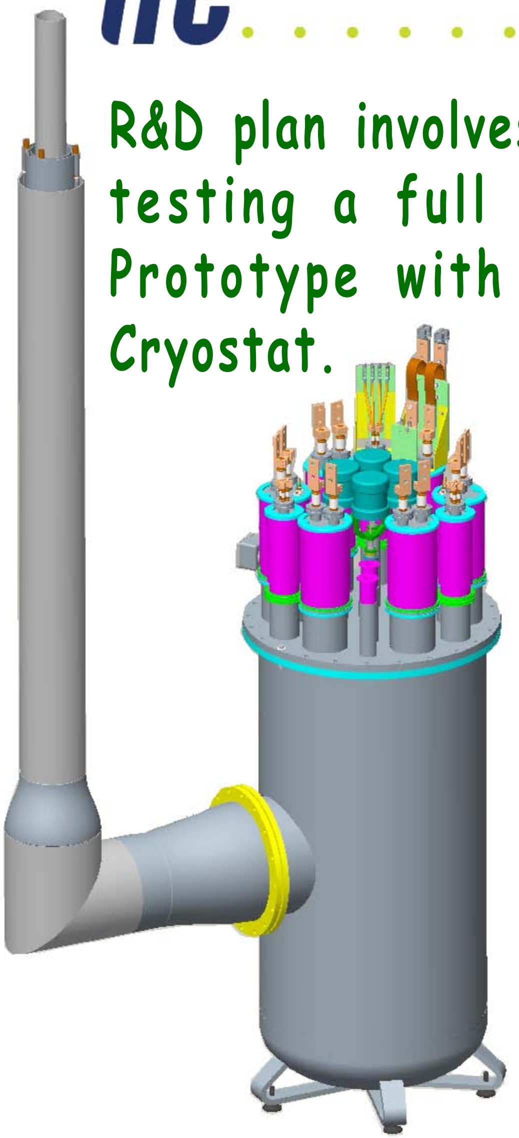


- Space is very tight inside the detector solenoid.
- Magnets must perform in ≈3T background field.
- For the active, beam based, feedback system to work need roughly 50 nm stability.

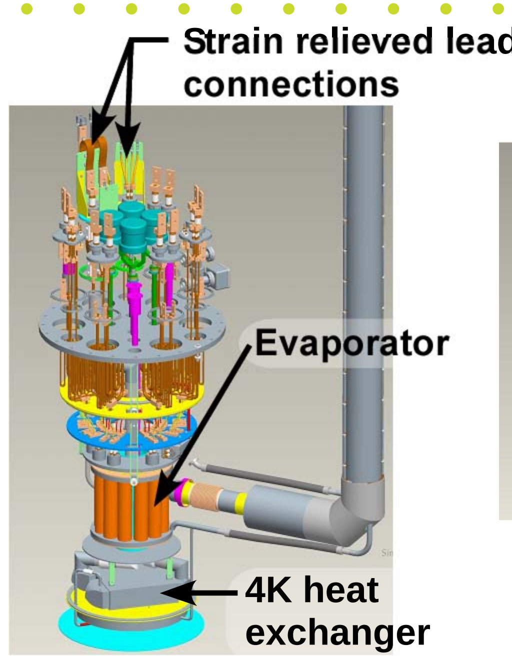
Present design avoids "flowing" helium; concept will be tested with QD0 R&D Prototype.

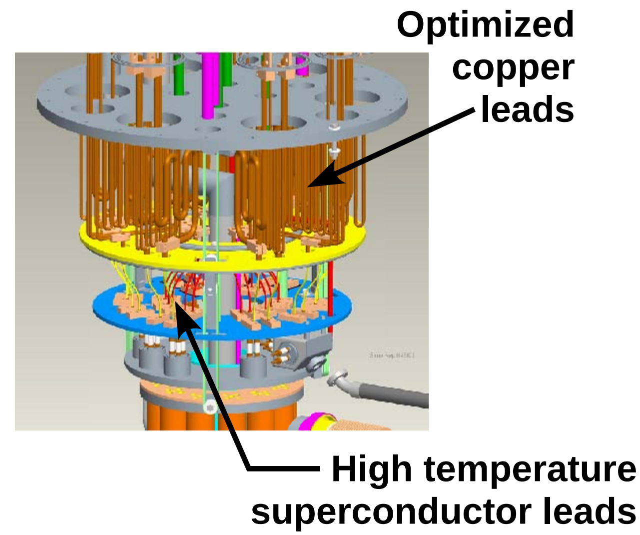
Some ILC FF Component Design Details.

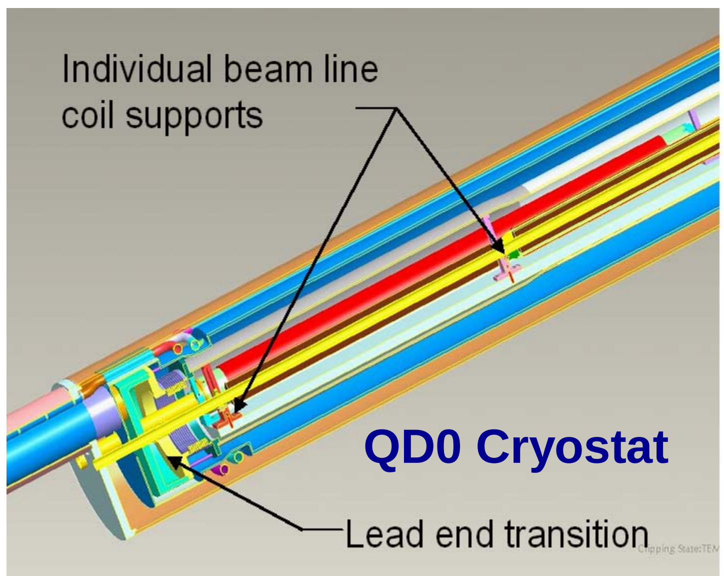
R&D plan involves making and testing a full length QD0 Prototype with its Service Cryostat.

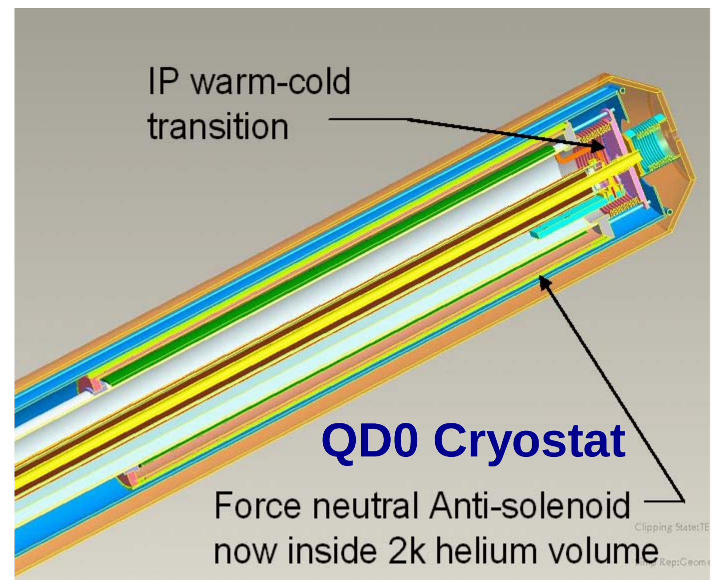


Service Cryostat



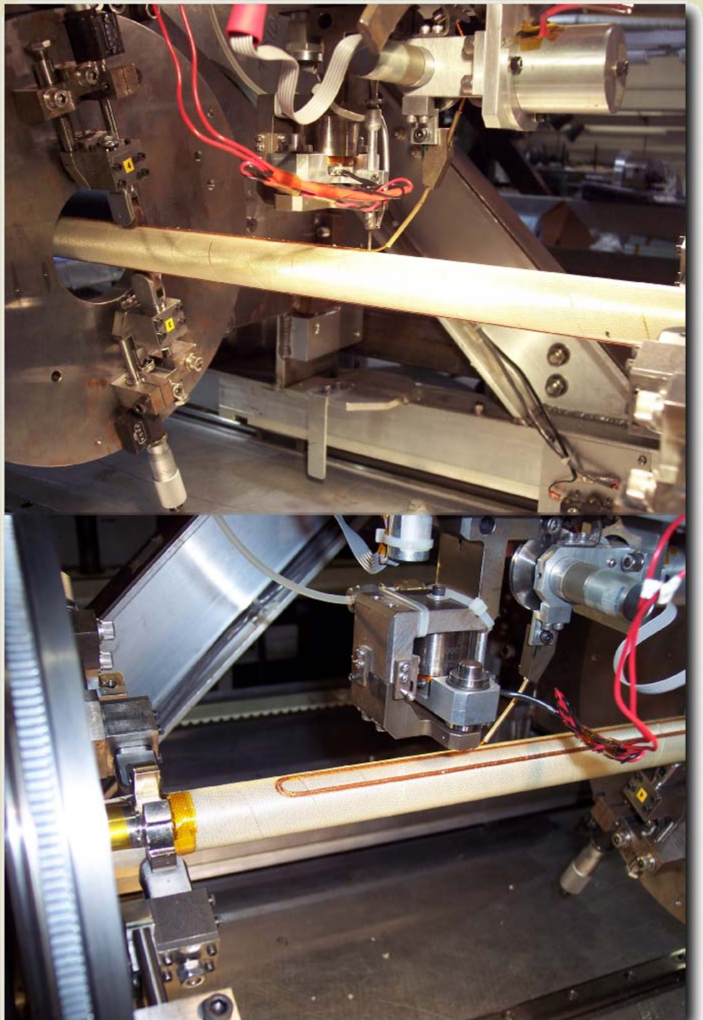






QD0 R&D Prototype and ATF2 Superconducting Upgrade Magnet Status

QD0 Full Length R&D Prototype Magnet.



QD0 Long Coil Winding

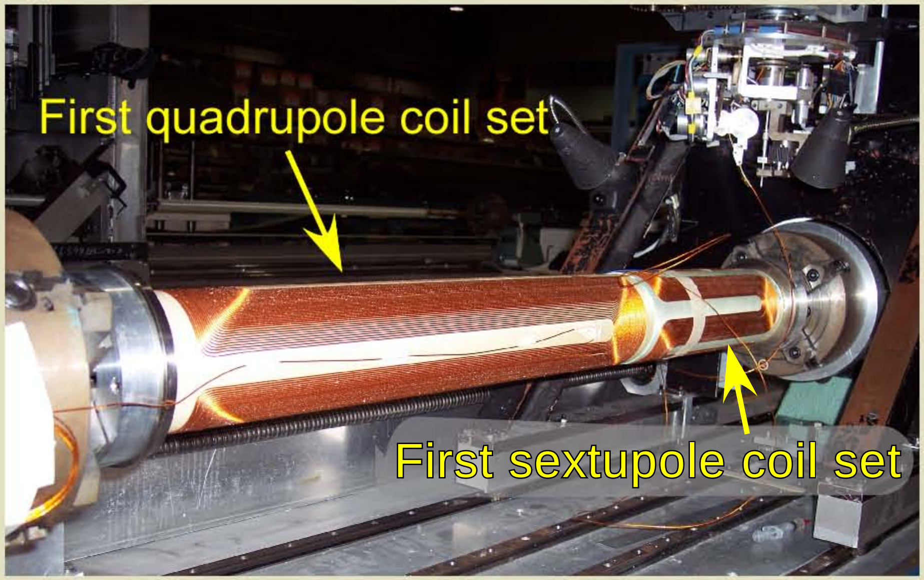
First step was to learn how to control support tube bowing during long coil winding. For this we had to modify the winding machine with extra rolling supports (show at the left).

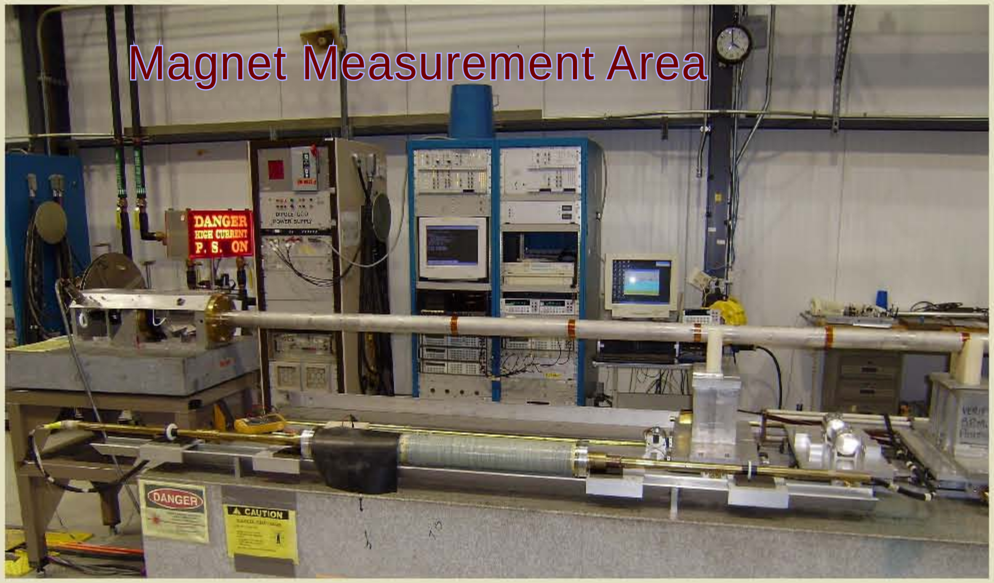
Full length magnet cryostat production and system testing is deferred in favor of earlier ATF2 superconducting magnet production.

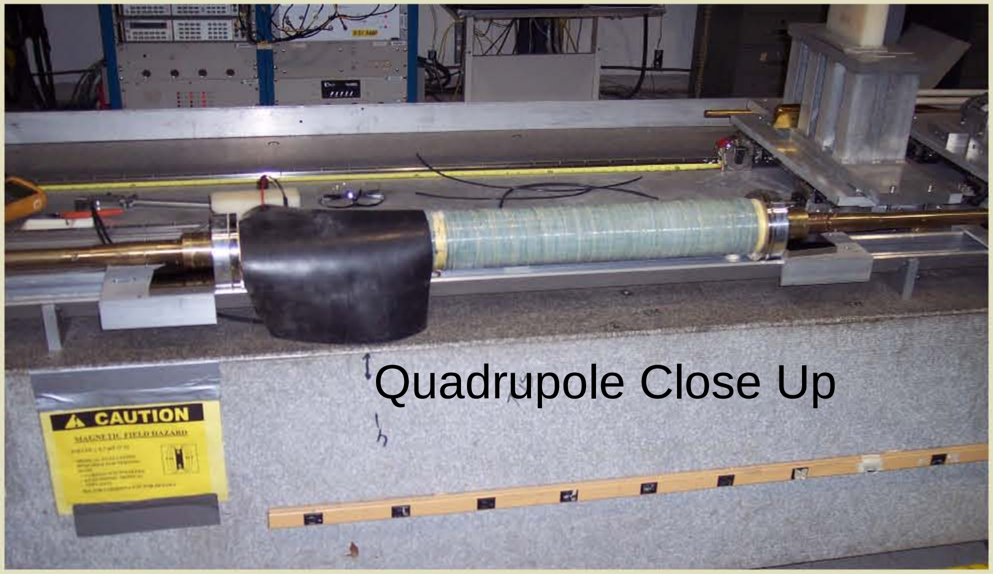
Fortunately we can gain early experience with ILC-like service cryostat and He-II operation by testing ATF2 magnet at BNL before the magnet is sent to KEK.

The ATF2 magnet and QD0 R&D prototype are complimentary in that ATF2 gives experience operating such a magnet at an accelerator FF and the full length R&D prototype allows us to verify performance of a system as similar as possible to an ILC FF magnet (50nm vibration budget etc.).

Start of ATF2 Coil Production & Measurement.

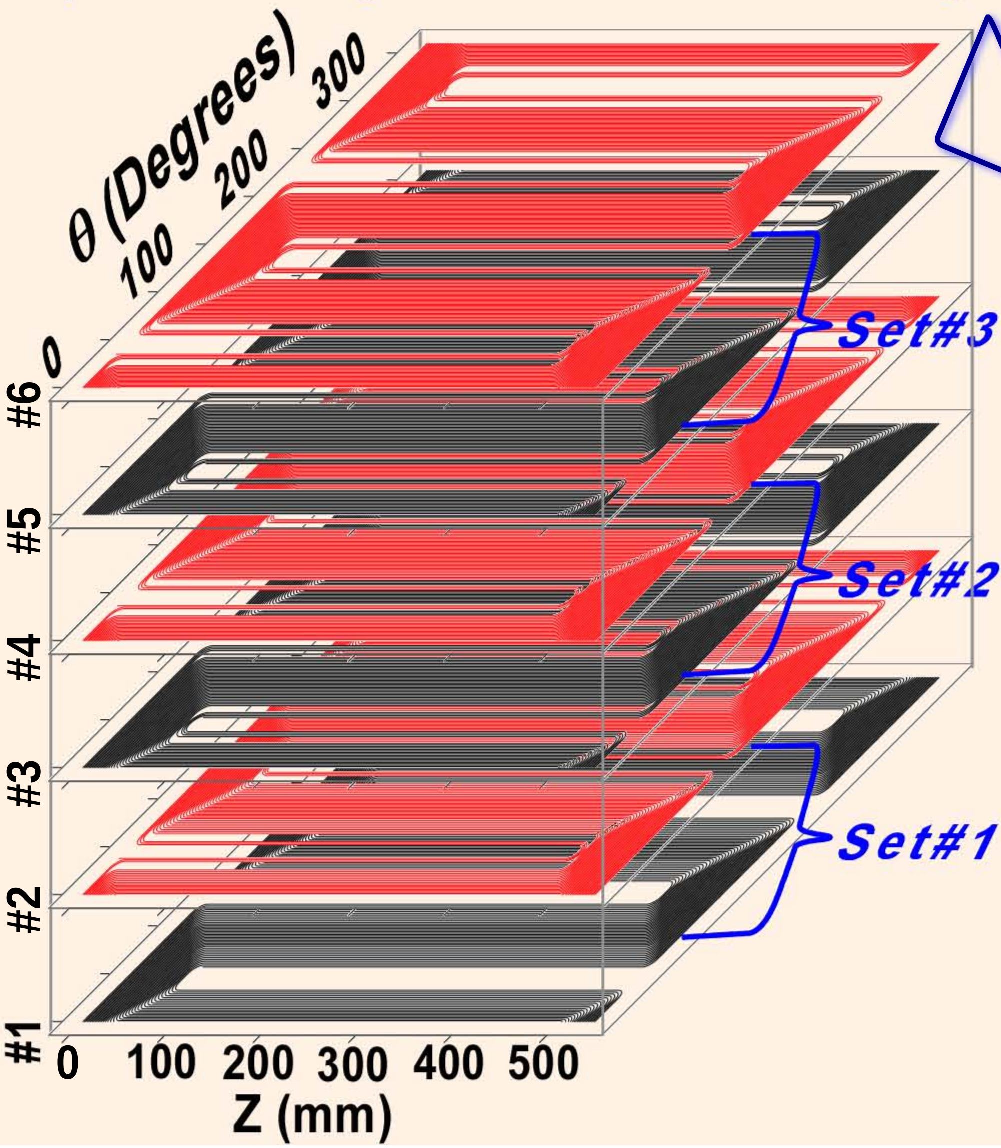






ATF2 Upgrade Superconducting Coil Design.

Updated Design for ATF2 QD0 Winding



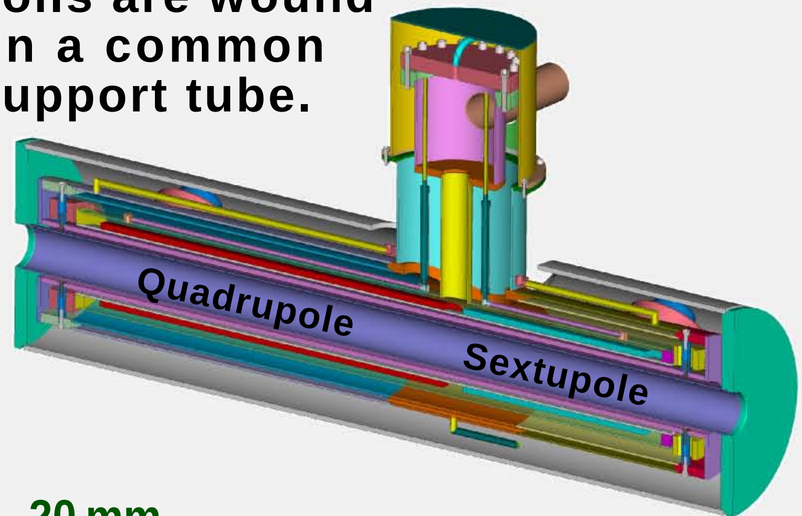
Will keep winding to add two more layers (one coil set) to original coil pattern.

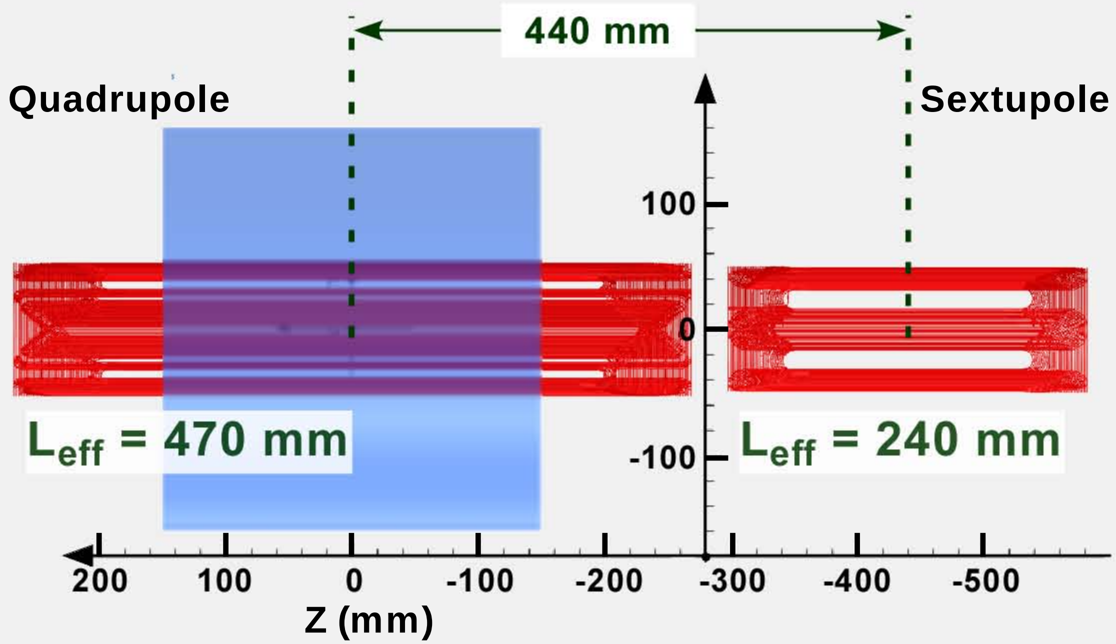
Even though it adds more work (cost) to the ATF2 coil production now in progress, we committed to adding two more cable layers to the quadrupole and sextupole coils in order to bring maximum operating currents to below 300 A.

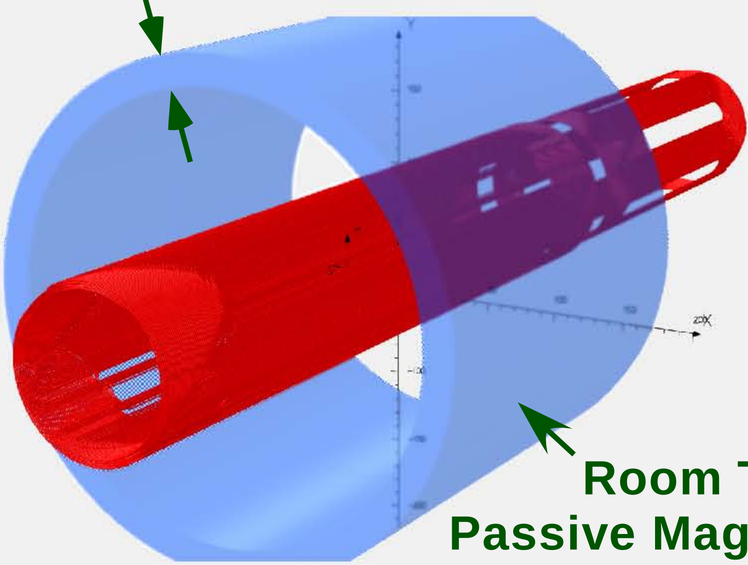
Wind ~~two~~ three quadrupole coil sets (six layers) with a 536 mm pattern length and ~~one~~ two 284 mm sextupole coil sets.

ATF2 Upgrade Superconducting Coil Design.

ATF2 Quadrupole and Sextupole coils are wound on a common support tube.



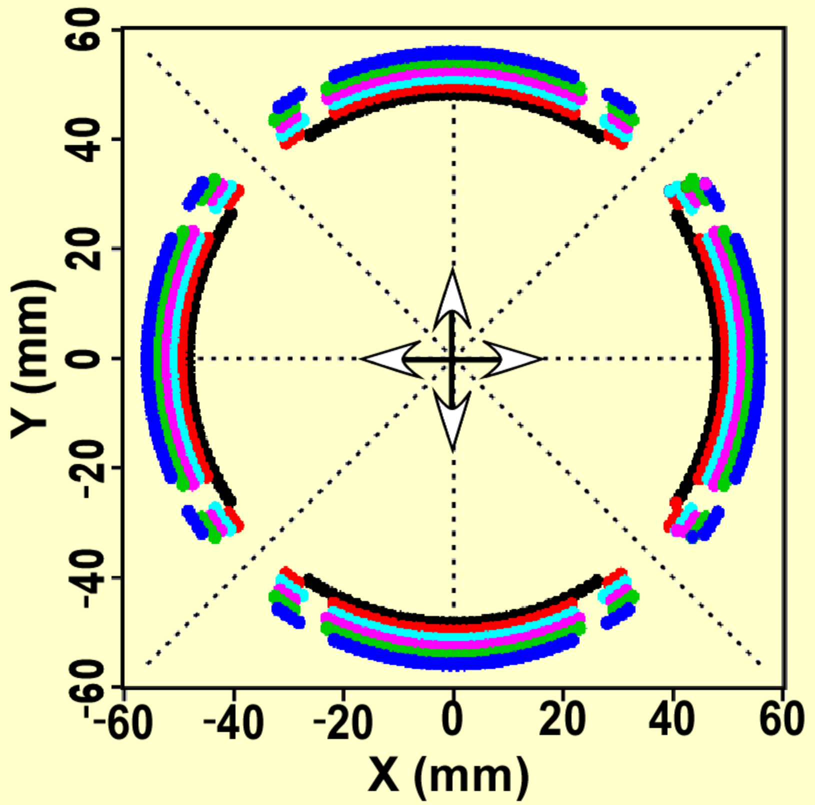




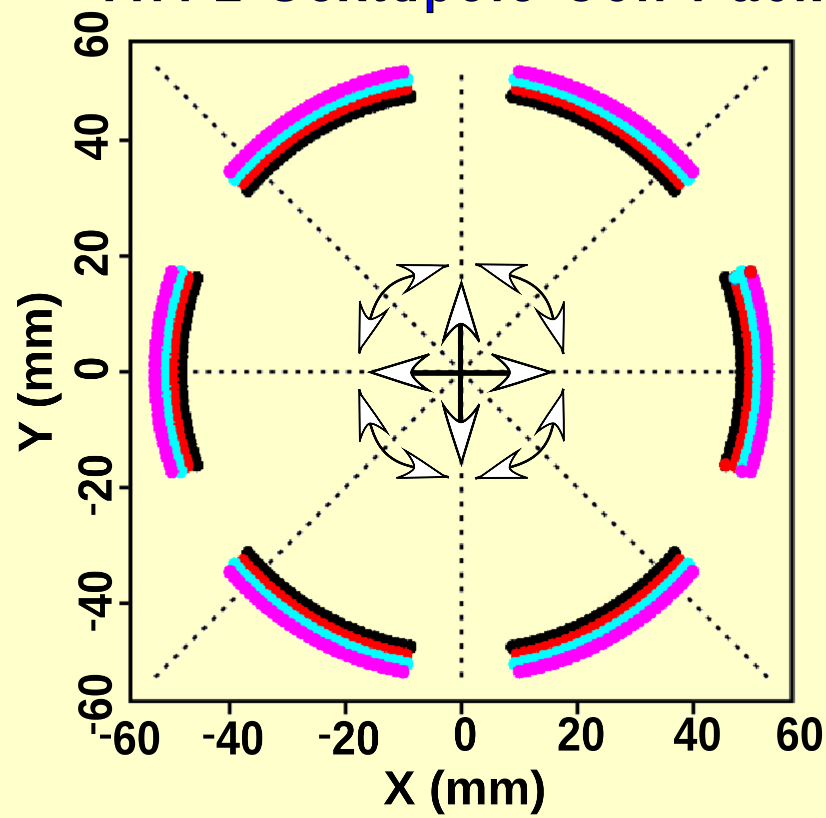
A thin, warm magnetic shell centered on the quadrupole coil, but located outside the cryostat is used to reduces the external fringe field. Note planned ATF2 magnetic lengths & field center separations are as shown above.

ATF2 Upgrade Magnet Coil Scheme*.

ATF2 Quadrupole Coil Pack



ATF2 Sextupole Coil Pack



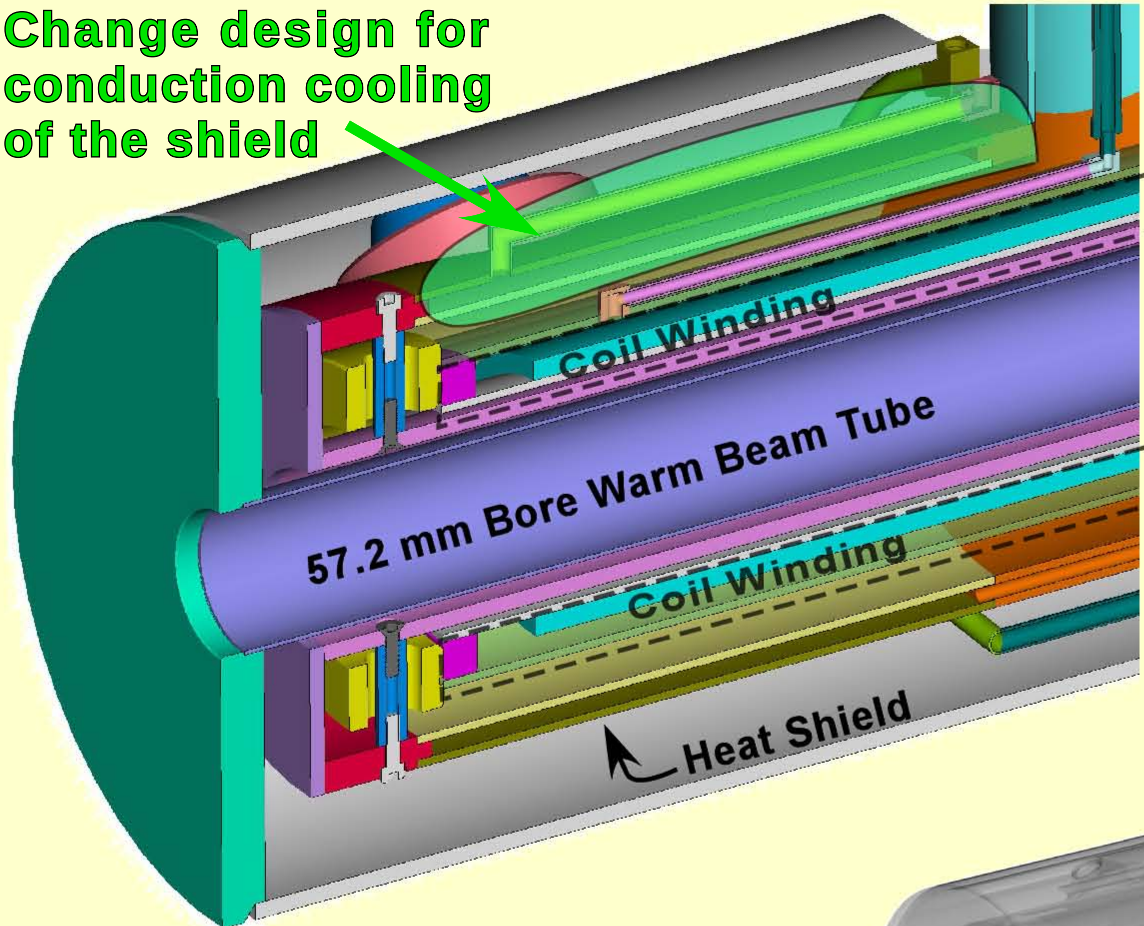
Quadrupole coil pack has normal and skew dipole corrector windings to be able to shift magnetic center.

Sextupole coil pack has normal and skew quadrupole corrector windings as well as skew sextu-pole to be able to shift and rotate the magnetic center.

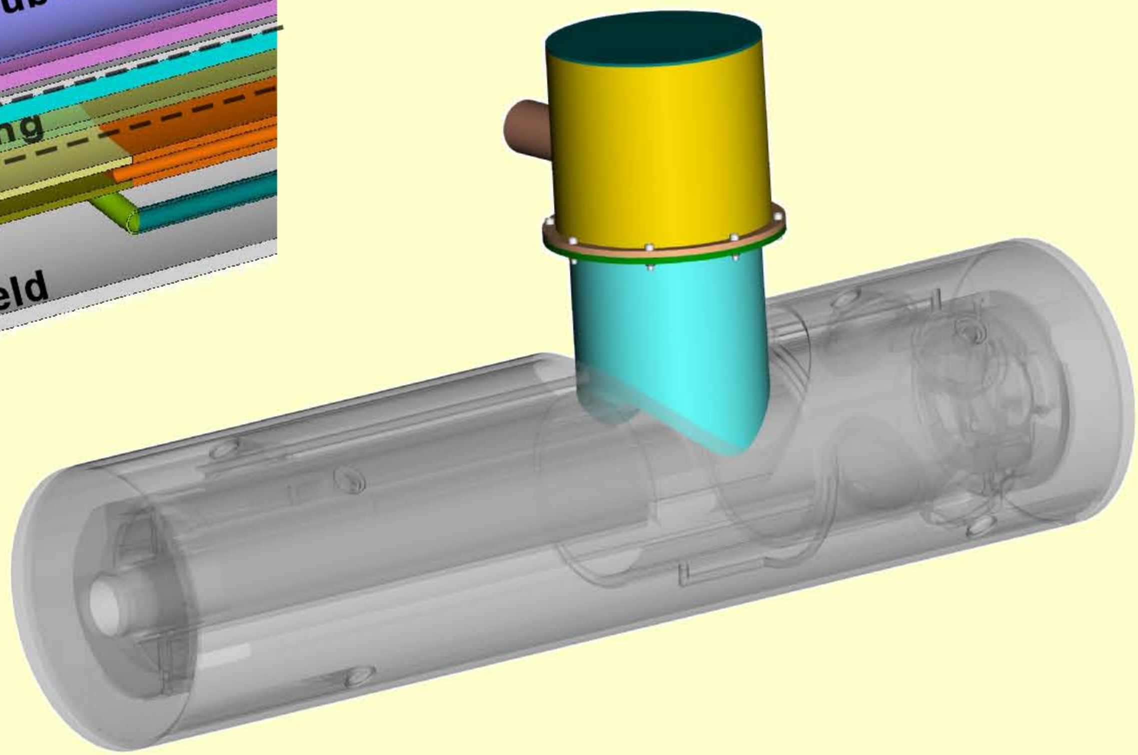
*Has magnetic degrees of freedom similar to ILC QD0.

ATF2 Upgrade Superconducting Coil Design.

Change design for conduction cooling of the shield

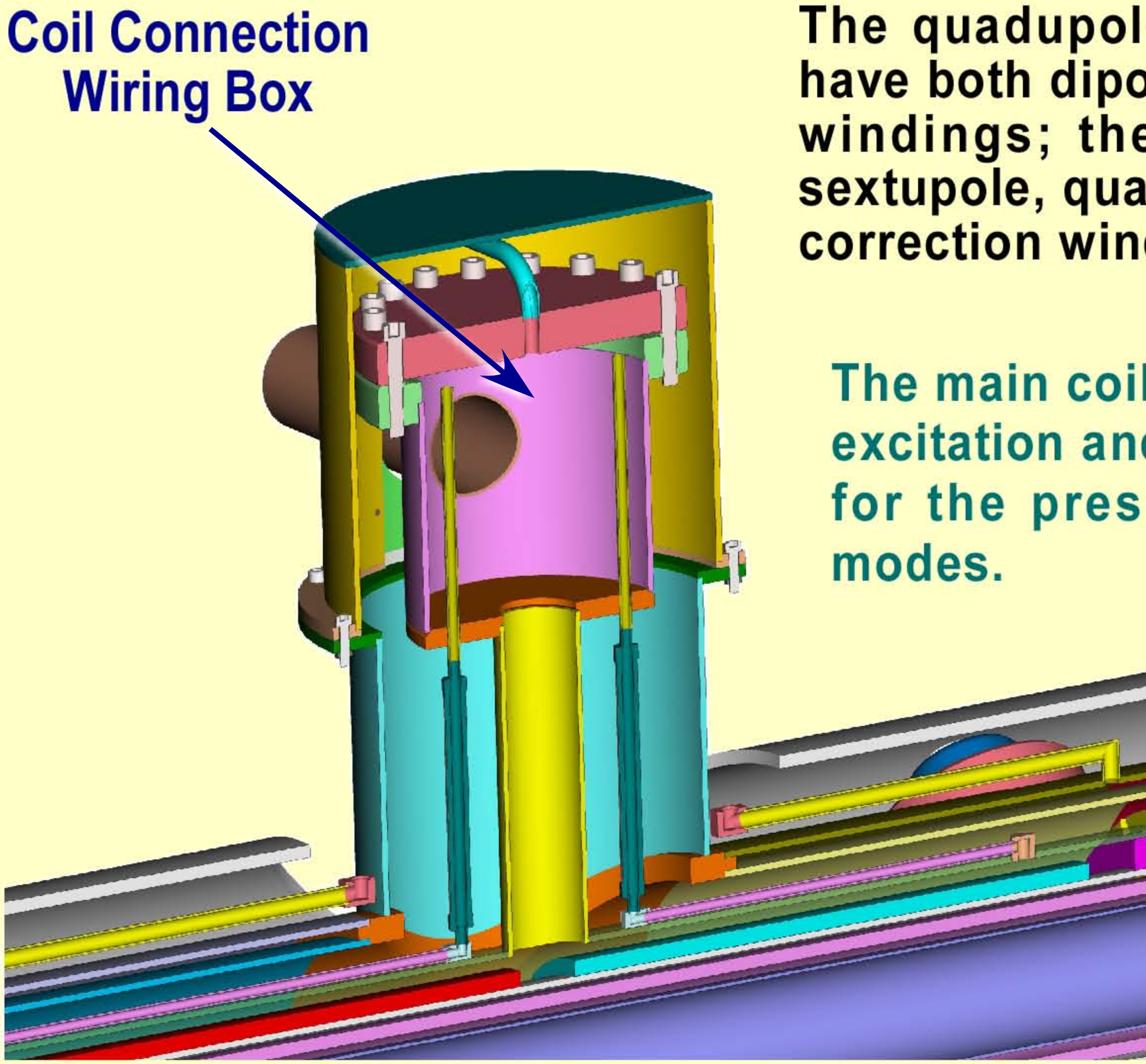


Coil diameters are sized so as to provide a warm beam tube a bit larger than in present magnets.



Accommodate both 1.9k (superfluid) and 4.2k He operation modes.

ATF2 Upgrade Superconducting Coil Design.



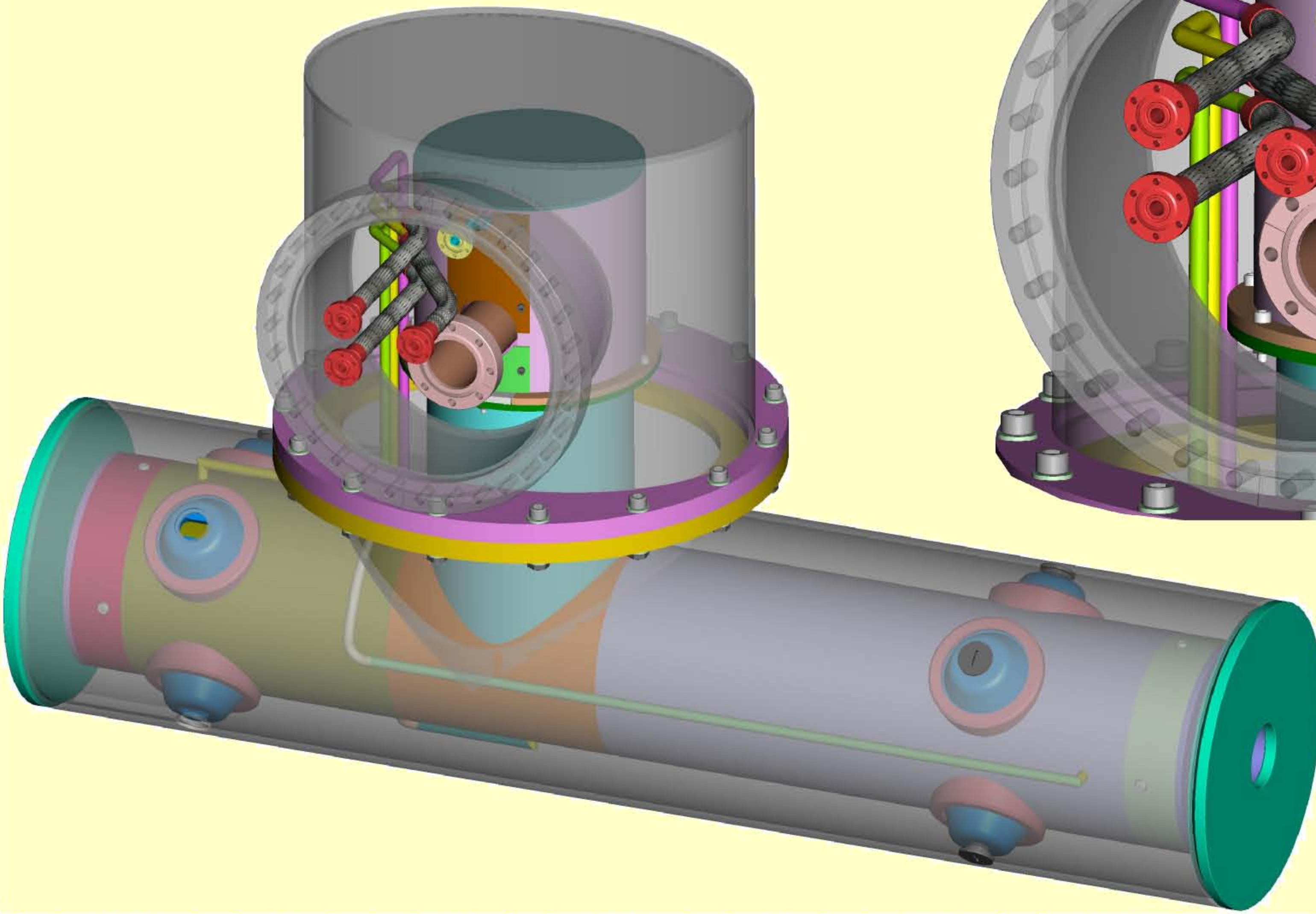
The quadupole coil winding is planned to have both dipole and skew-dipole correction windings; the sextupole coil gets skew-sextupole, quadrupole and skew-quadrupole correction windings.

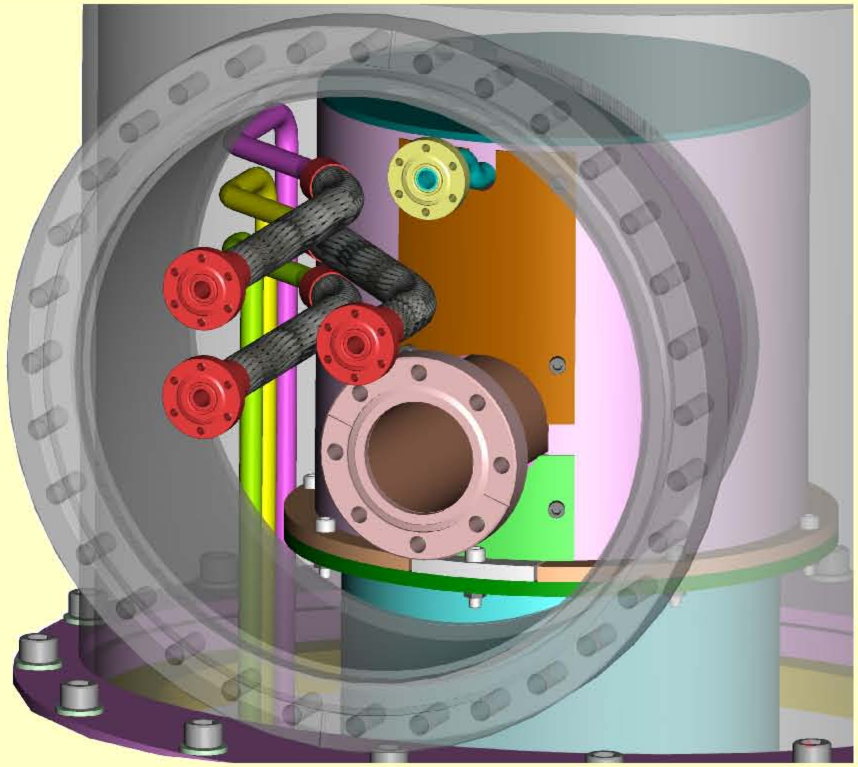
The main coils could be energized to 300 A excitation and the correction coils to 100 A for the presently anticipated operation modes.

So we need four 300A and ten 100A current leads plus a number of instrumentation leads.

ATF2 Upgrade Cryostat Design Parameters.

Cryostat design is now much farther along.





Finally we can pin down cryogenic interface details.

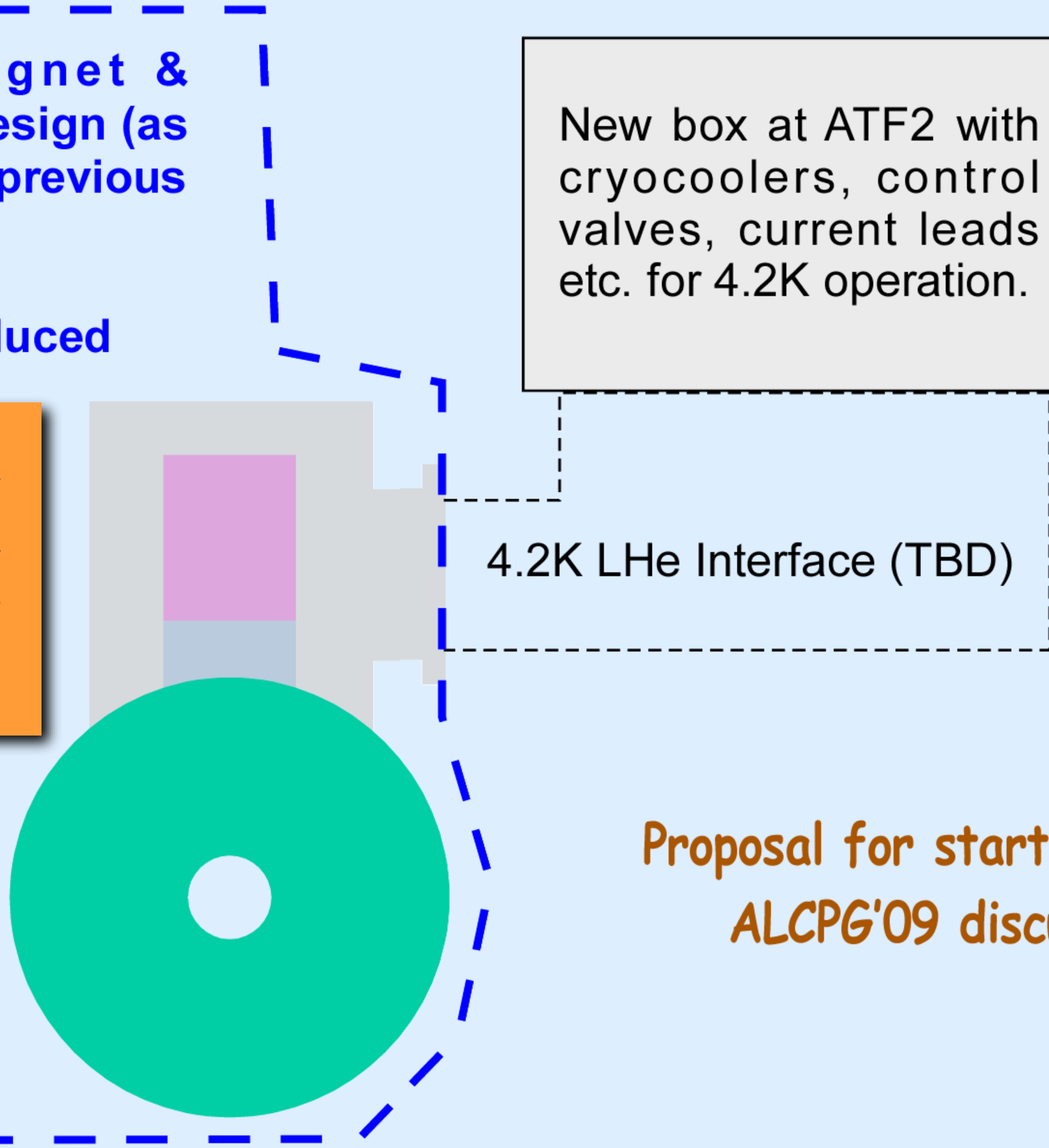
ATF2 Upgrade Cryostat Interface.

ATF2 magnet & cryostat design (as shown on previous pages)

BNL - Produced

New box at ATF2 with cryocoolers, control valves, current leads etc. for 4.2K operation.

Will be discussed further in dedicated ATF2 session later today.



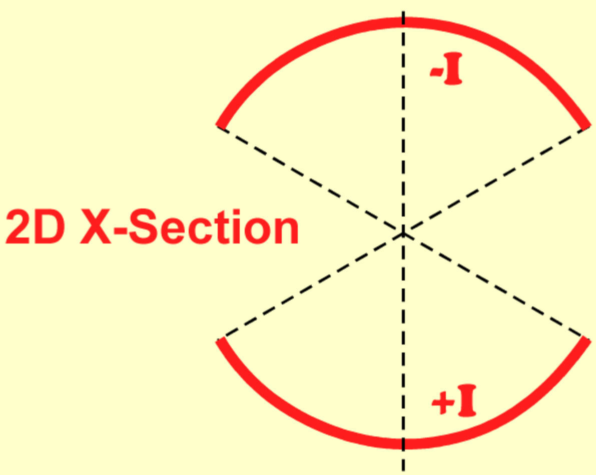
Proposal for starting point of ALCPG'09 discussions.

Some DID Design Considerations

The DID Coil Pattern: Some Observations.

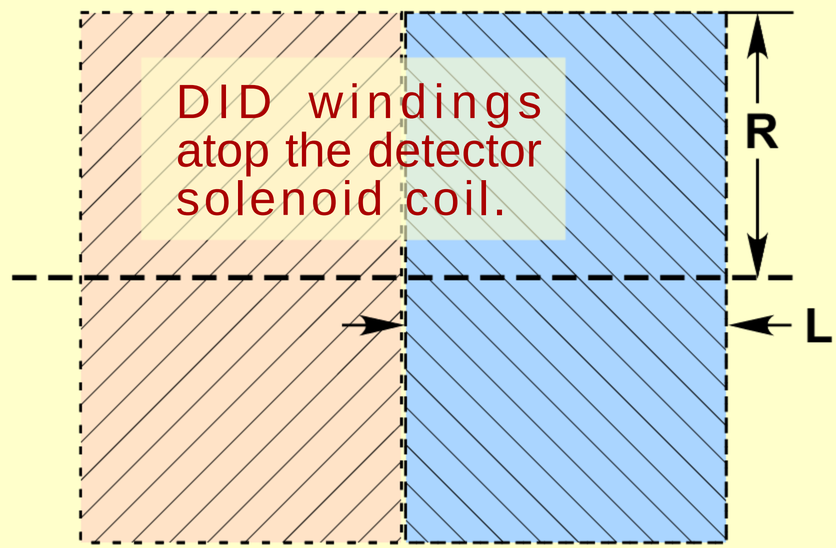
- A single dipole experiences torque from solenoid coil (back reaction to solenoid). DID's two coils give no net torque but is still good idea to support together (minimize coil flexing).
- Background field for DID is lowest outside solenoid coil.

Normally want dipole coil to span ±60° (to eliminate first harmonic)*



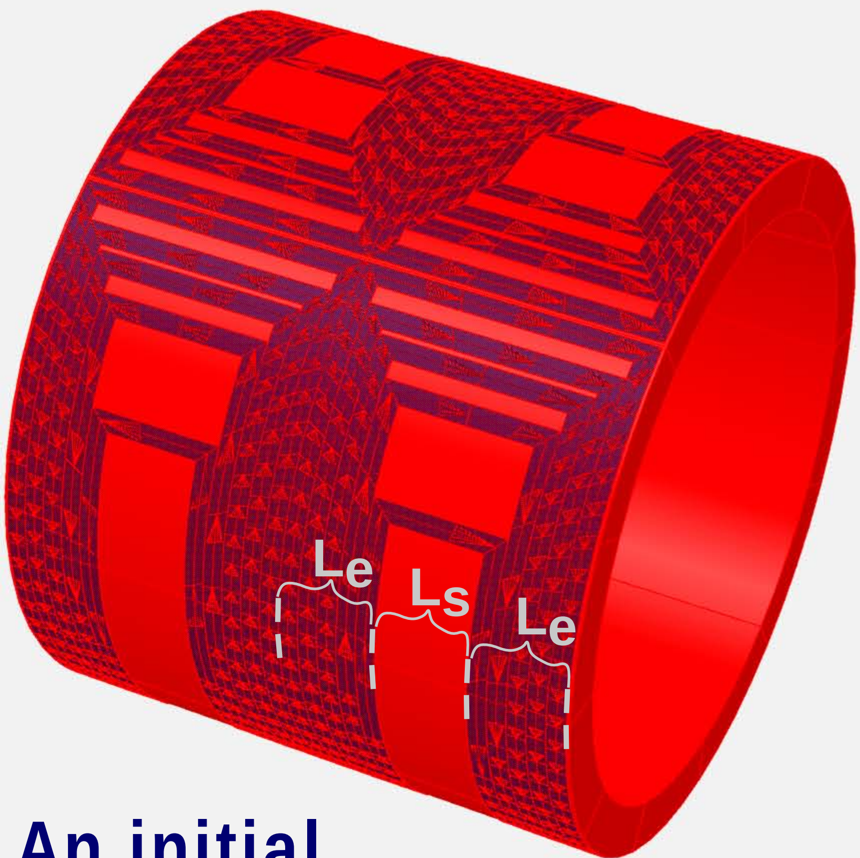
But then even with no straight section and sharp bends, we need $2\cdot(\pi/6)\cdot R \approx 1.05$ R for length.

But we barely have this much space for each coil pattern and a coil without any straight section is very inefficient.



*But 2D result assumes that we can neglect ends; so it breaks down anyway...

(My) Steps for Designing a Short Dipole Coil.

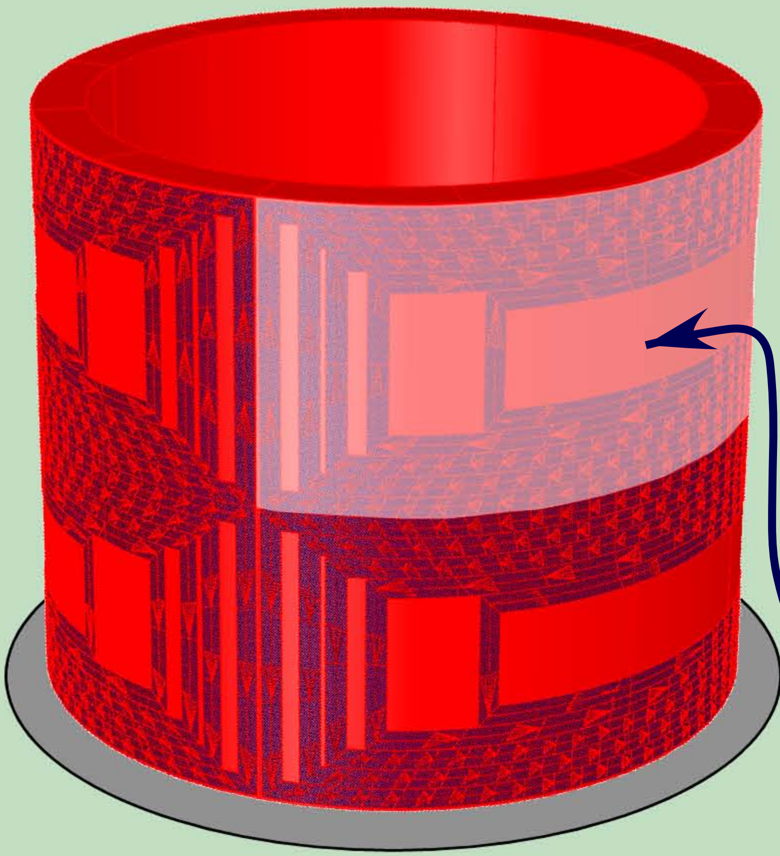


An initial DID coil with sharp corner bends; next step, choose the conductor and make small adjustments to coil pattern.

1. Decide on shortest straight section, L_s, which then fixes length of ends, L_e.
   - Longer L_s increases transfer function.
   - Shorter L_e reduces # turns (raise I_o).
2. Break Le into a small number of blocks.
   - In this example I chose to use 5 blocks.
   - Having blocks equal width is convenient for magnetic modeling (decide I_o later).
3. Use code to reduce integral harmonics for 3D "air coil" and test in full model.
4. Use full model results to feedback into air coil optimization and itterate.
5. Choose conductor size to determine I_o & corner radius (impacts L_s; so iterate).

Some thoughts about DID coil production.*

Assume, like RHIC correctors, entire DID pattern is put down flat on a flexible substrate and then wrapped around the main coil.



During wrapping the difference in length of the inner/outer conductor is then $\Delta C = 2\pi \Delta R$. This is 157 mm for a 25 mm thick conductor. In this case conductor could be stressed and might come off the substrate. Coil pattern handling is tricky and it is not so easy to wrap coil uniformly with no gaps/misalignment.

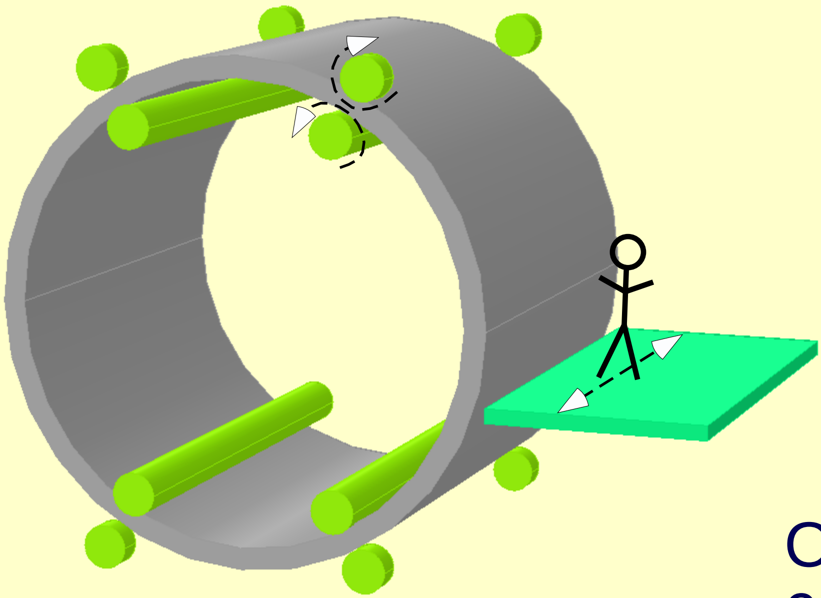
Split into subcoils? (need more splices)

For R = 3.5 m stretch, $\Delta R/R$, is about 4.5%

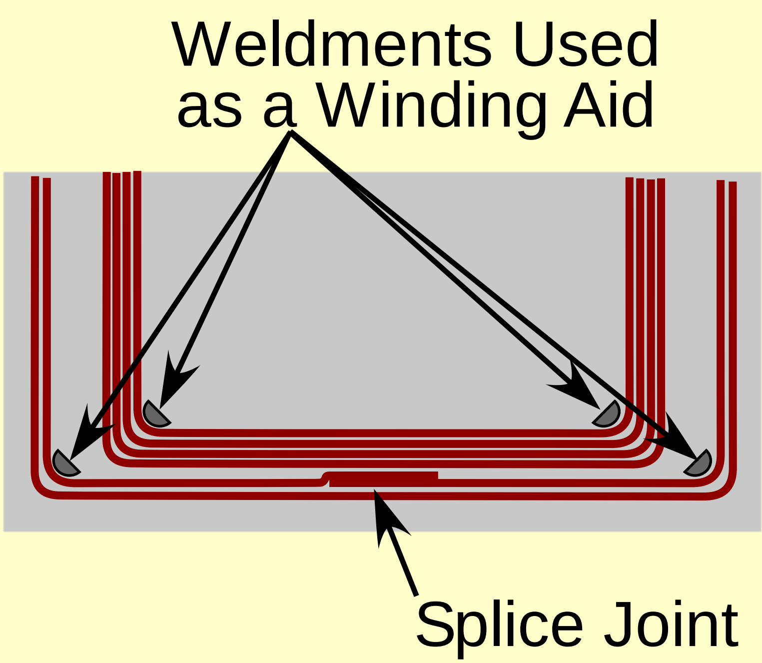
*Summary of a brainstorming session with John Escallier last week.

Some thoughts about DID coil production.*

Direct Wind Approach



Workers on a platform use tooling to temporarily fix insulated conductor in place (use ultrasonics?).



Once full coil pattern is laid down, the conductor blocks can be more firmly strapped in place.

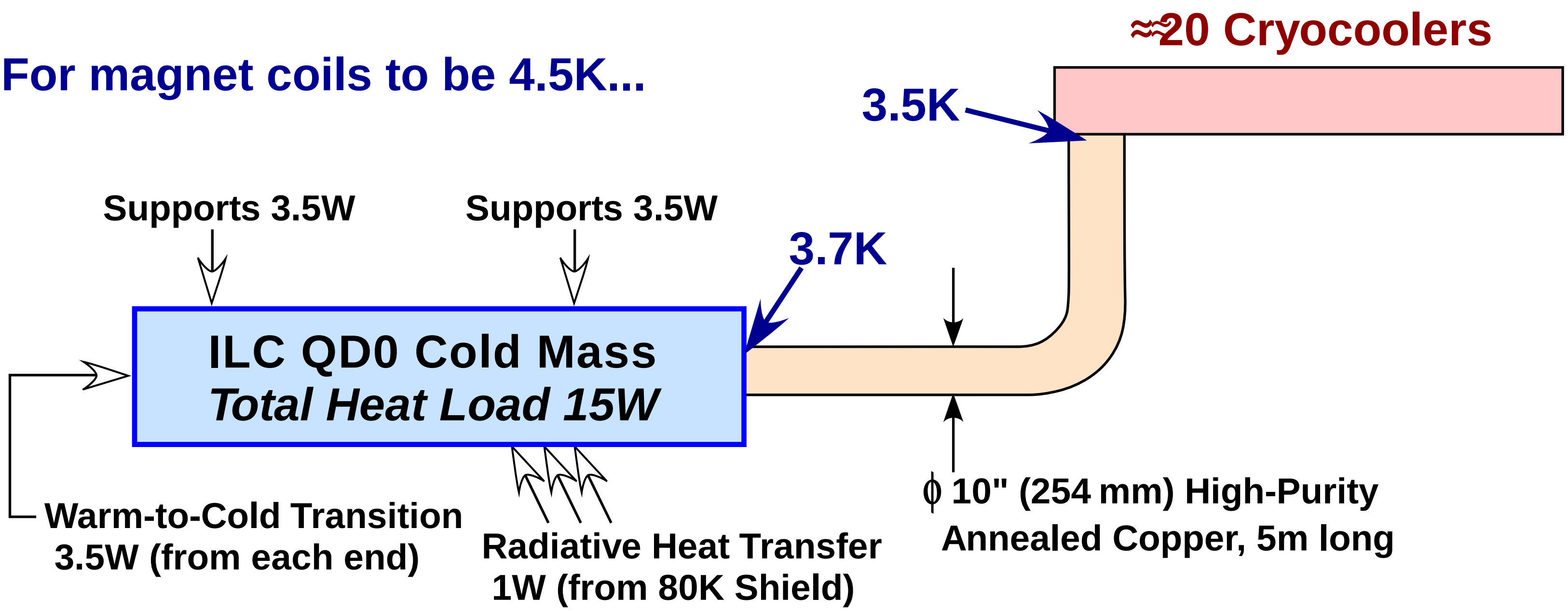
Magnetic measurement of DID field angle?

*Summary of a brainstorming session with John Escallier last week.

Thank you for your attention.

Backup Slides

A Conduction Cooled ILC QD0; Not Practical.



Assumptions for this exercise:

1) Entire cold mass can be held to within 0.75K ΔT (cold mass assembly is extremely complicated).
2) Beam heating is not taken into account.
3) There is no safety margin.
4) Individual cryocooler can handle 0.75W @ 3.5K.