Survey of cost reduction R&D for ILC BDS section

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special thanks to B. Parker, BNL

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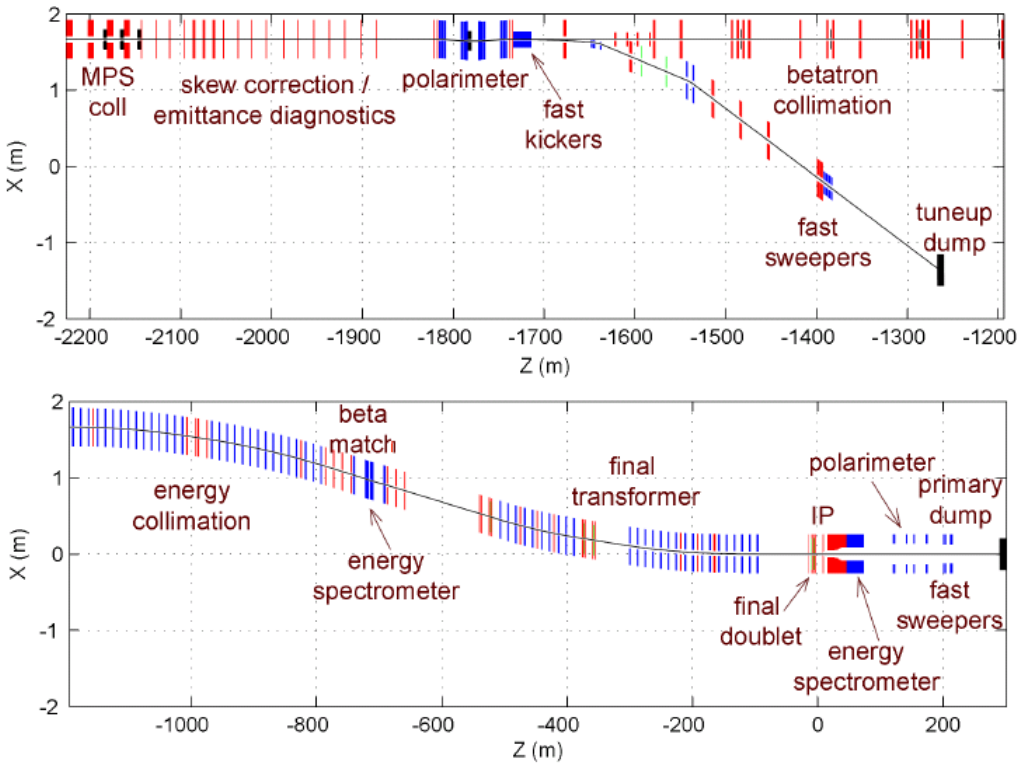
The most of BDS beamline consists of conventional technologies.

- Normal conducting magnets

- beam instrumentation devices (BPM, laserwires etc.)

They are not significant for cost reduction.



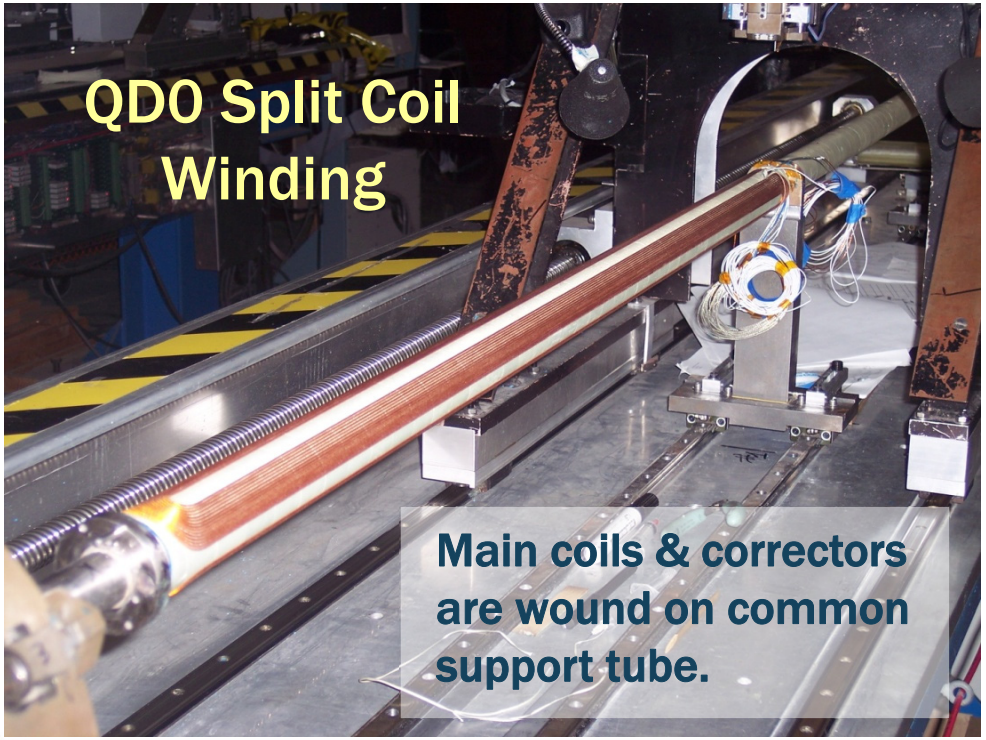
ILC Final Doublet is a complex SC system, and there are on-going R&D items.

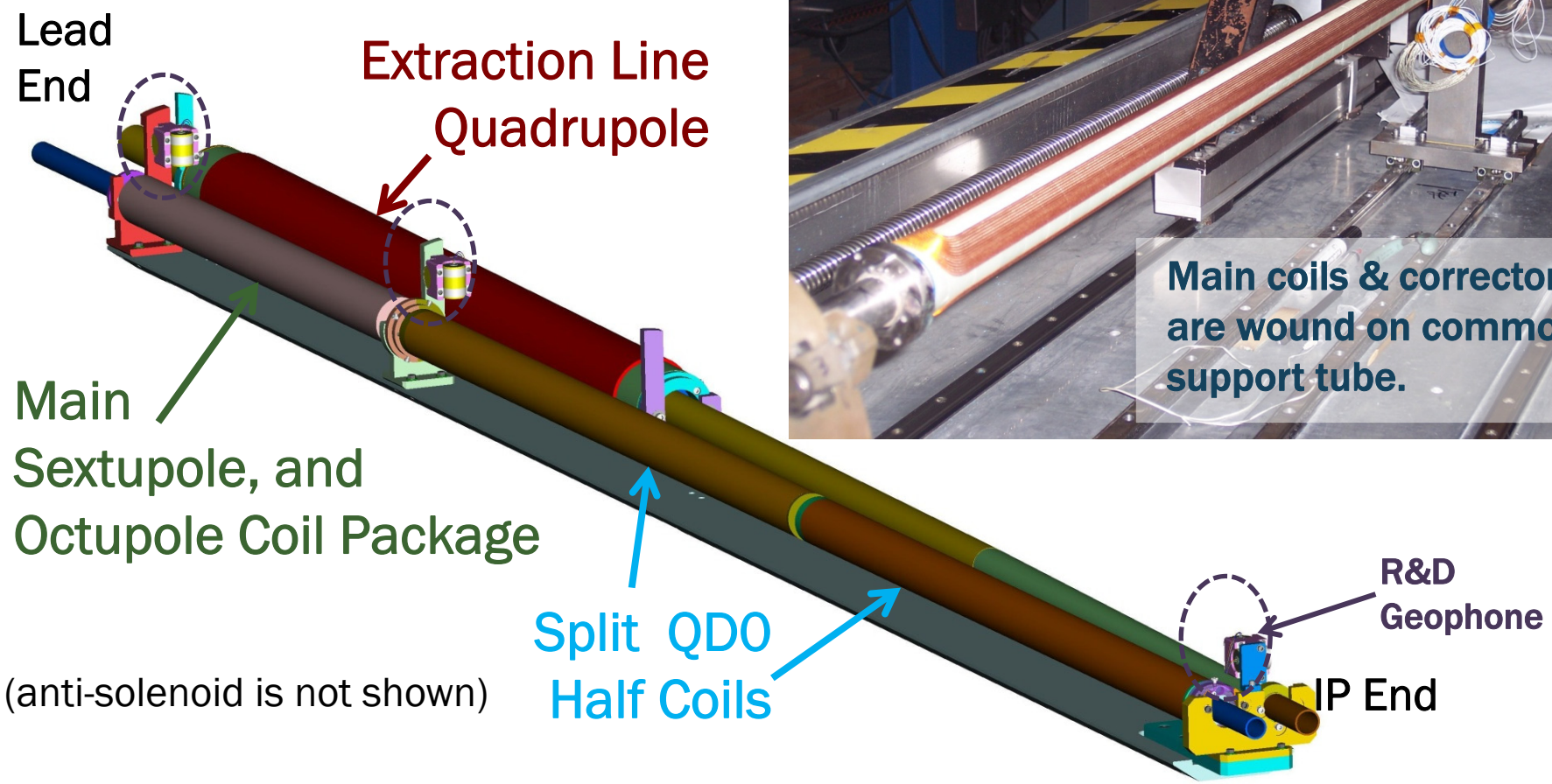
1) *Compact anti-solenoid*
2) *Helium temperature issue of final doublet*

In this presentation, I will introduce the R&D items, which related to ILC FD.
Then, I will evaluate the effect of cost reduction for the R&Ds.

QD0 Magnet Cryostat

The magnets will be packaged to QD0 cryostat for ILC.





(anti-solenoid is not shown)

1. Anti-solenoid R&D

After TDR, Brett Parker investigated the design of anti-solenoid magnets, which is based on the idea of ***sweet spot coils****.*

- *help to increase the quadrupole field, and shorten QD0 magnets*
- *reduce the size of cryomodule.*

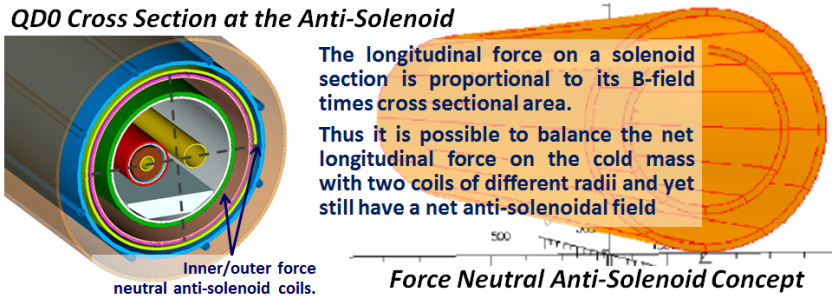
A Short Anti-Solenoid Design History Review

presented by Brett Parker, BNL-SMD

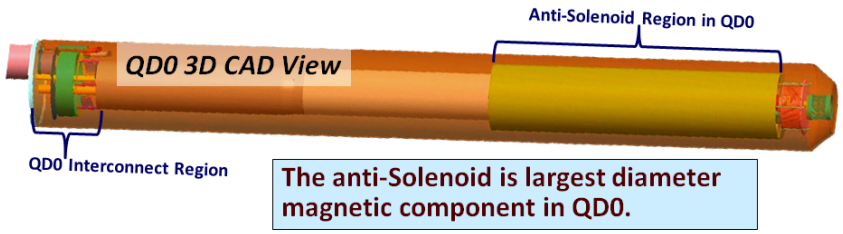
Huge repulsive coil force!
Huge impact on detector!

The accelerator physics formalism and first ILC specific designs for the anti-solenoid (AS) were presented by Y. Nosochkov & A. Seryi†.

But a **62 ton AS longitudinal coil force** can not reasonably be accommodated in the QD0 cryostat; the AS had to be integrated with the detector (i.e. major field and design impacts).



For the ILC RDR/TDR we developed **a force neutral AS** concept where two solenoids of different radii but opposite polarity are used to largely cancel the longitudinal force yet maintain a net field at the beam position.

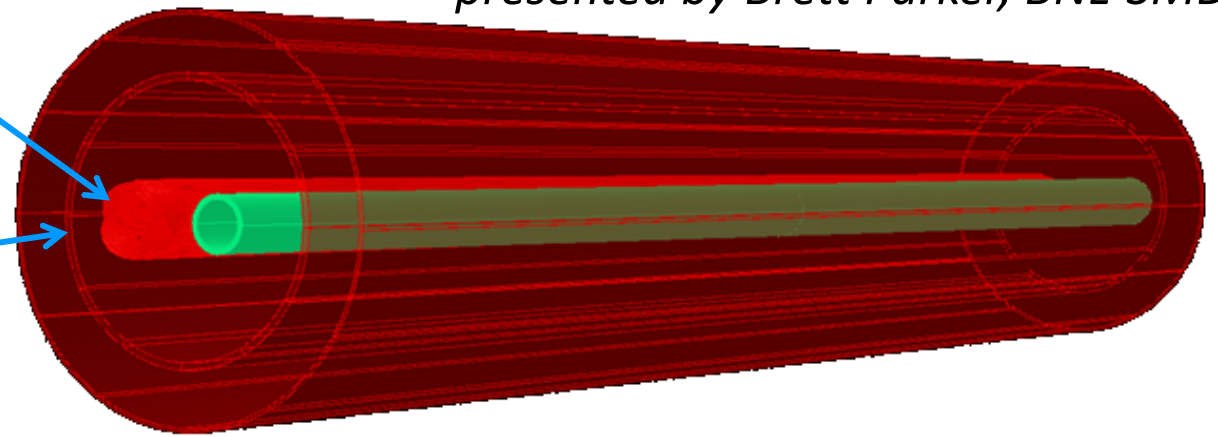


The efficiency of the two coil, force neutral AS configuration improves as the radial separation between the inner and outer coils increases. The size of the outer AS coil then becomes the determining factor (followed by the QD0 interconnect size) for setting the QD0 cryostat radial envelope.

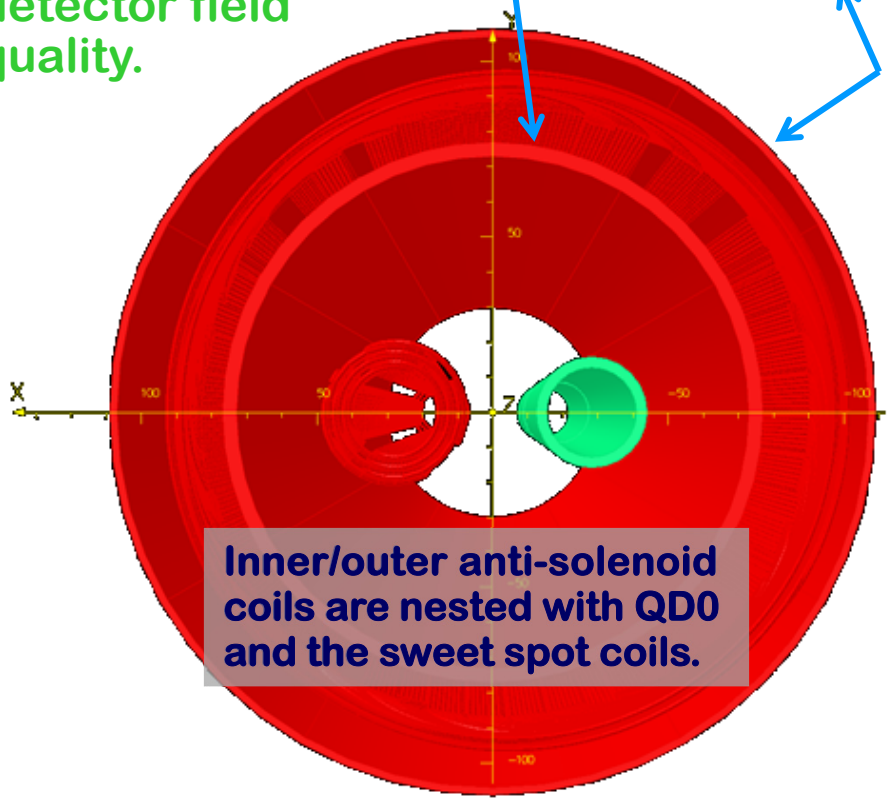
†Yuri Nosochkov and Andrei Seryi, "Compensation of detector solenoid effects on the beam size in a linear collider," Rev. Mod. Phys. 8(2) , February 2005.

A Compact Anti-Solenoid Concept for QD0

presented by Brett Parker, BNL-SMD



New anti-solenoid has little impact on detector field quality.



Outer anti-solenoid coil for use in ILD

We look to reduce the anti-solenoid diameter via this new coil geometry (with the old QD0 layout the active shield coil was in the way).

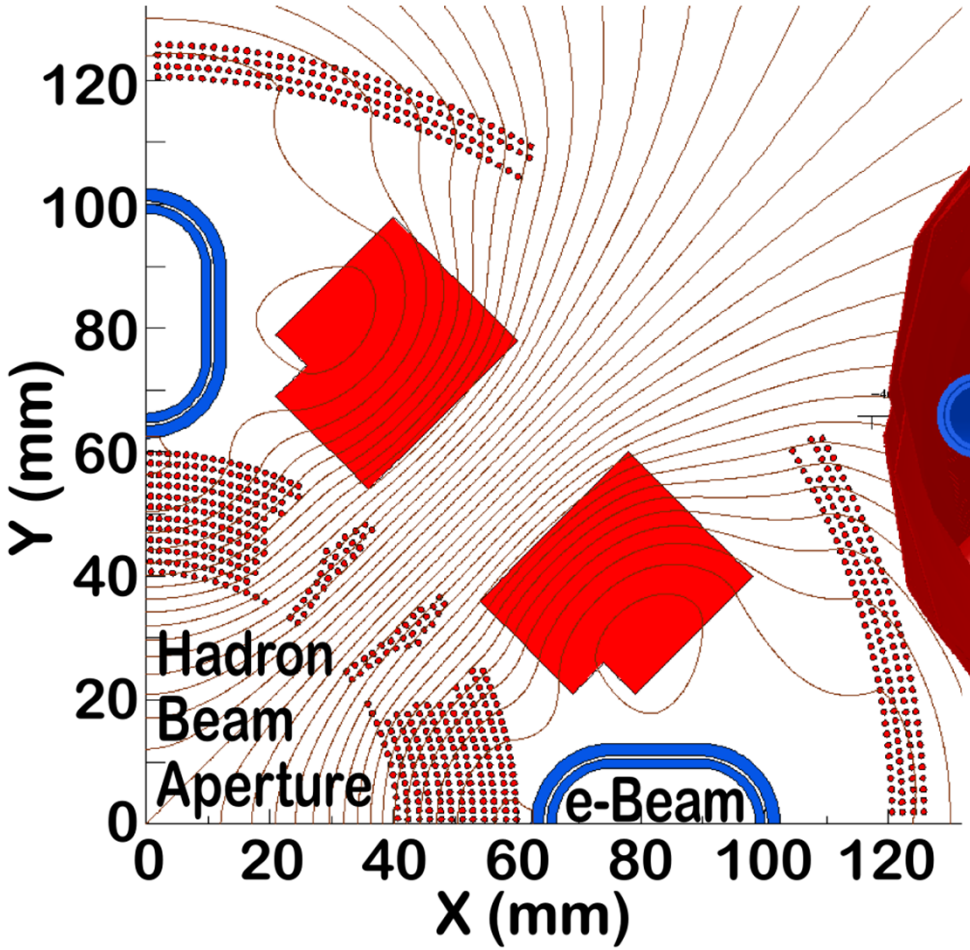
We can roughly balance repulsion between the anti- and detector solenoids via a second opposite polarity coil powered in a **2:1 ratio**.

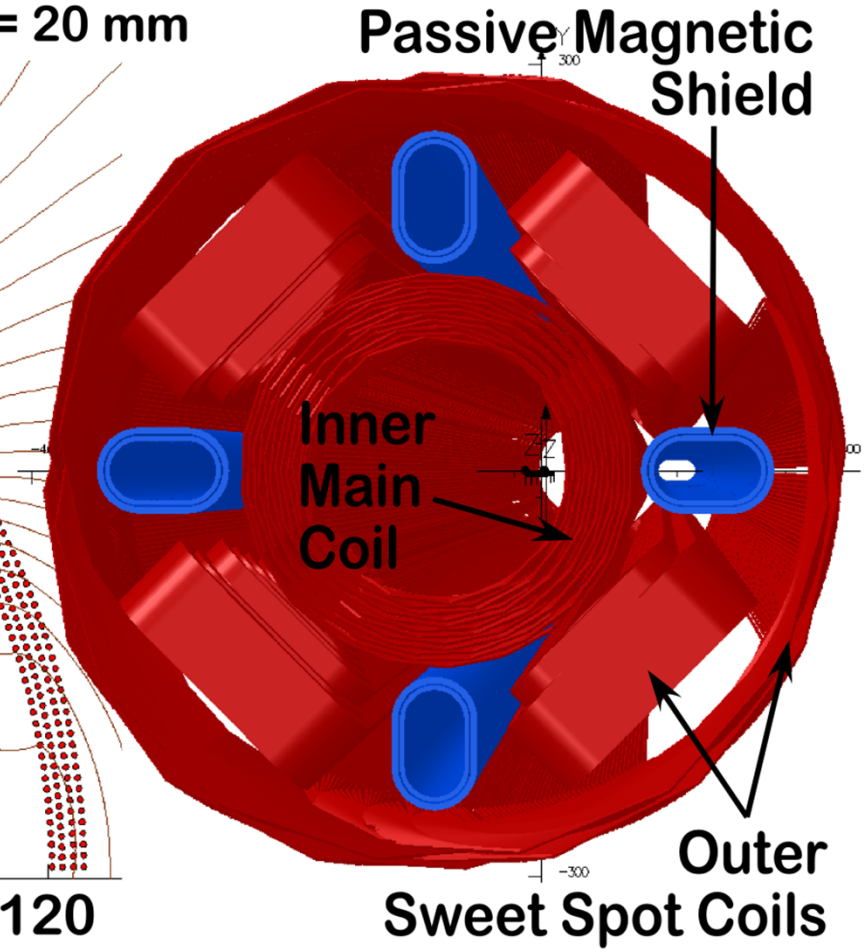
Thus we can use the net anti-solenoidal field for optics compensation without then having to pass any large longitudinal force from the cold mass out to the warm support structure.

eRHIC "Sweet Spot" IR Quadrupole†

presented by Brett Parker, BNL-SMD

The sweet spot coils contribute 36% of the eRHIC Q1 137 T/m gradient
The e-Beam in the shielded region sees about 1 gauss
Main field quality is 1×10^{-4} at R_{ref} = 20 mm

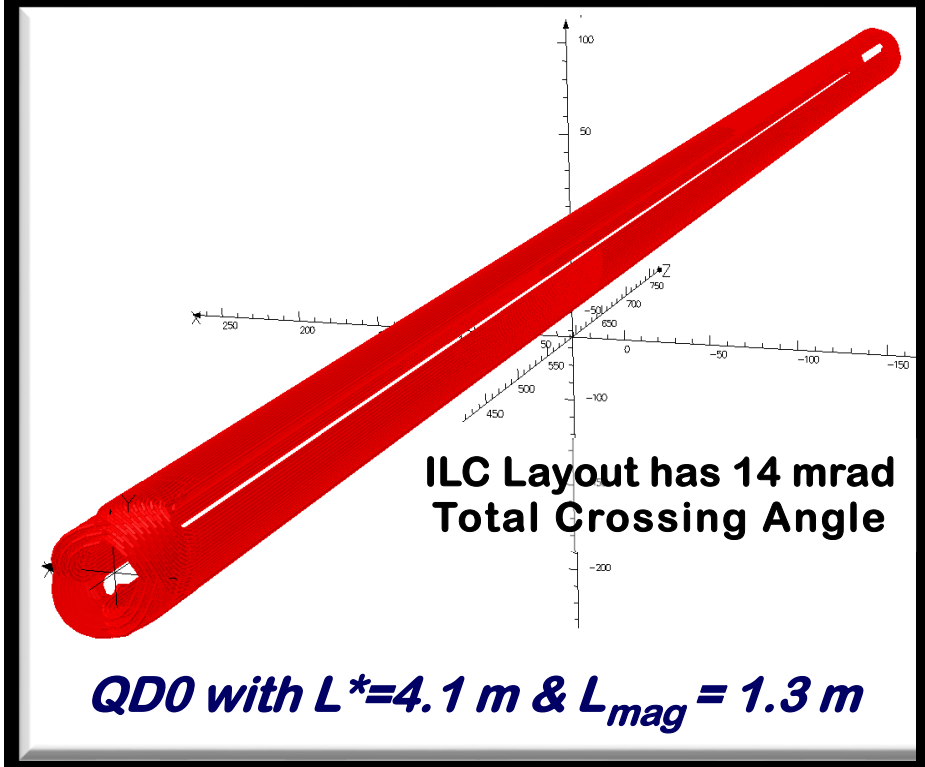


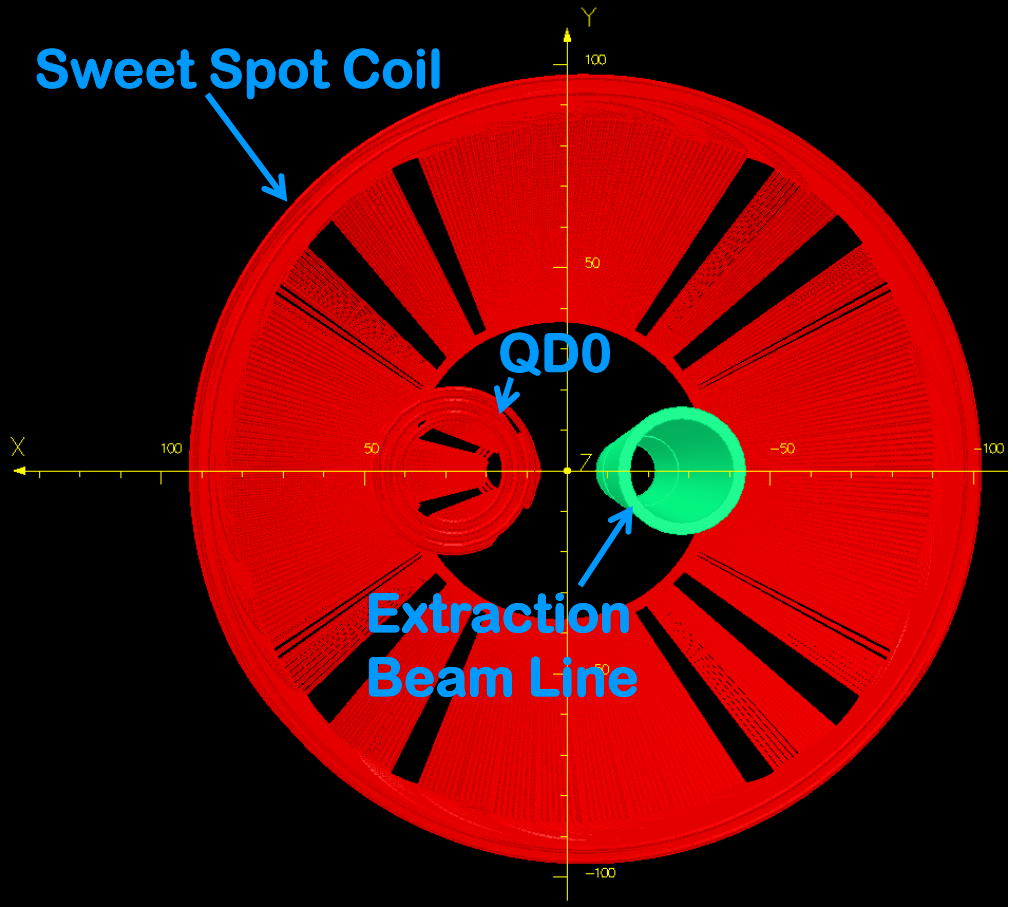


†Brett Parker, "SWEET SPOT DESIGNS FOR INTERACTION REGION SEPTUM MAGNETS," Contribution TUPMB042 to Proceedings of IPAC2016, Busan, Korea, May 2016, pp. 1196-1198.

A Sweet Spot Coil Concept for ILC QD0

presented by Brett Parker, BNL-SMD



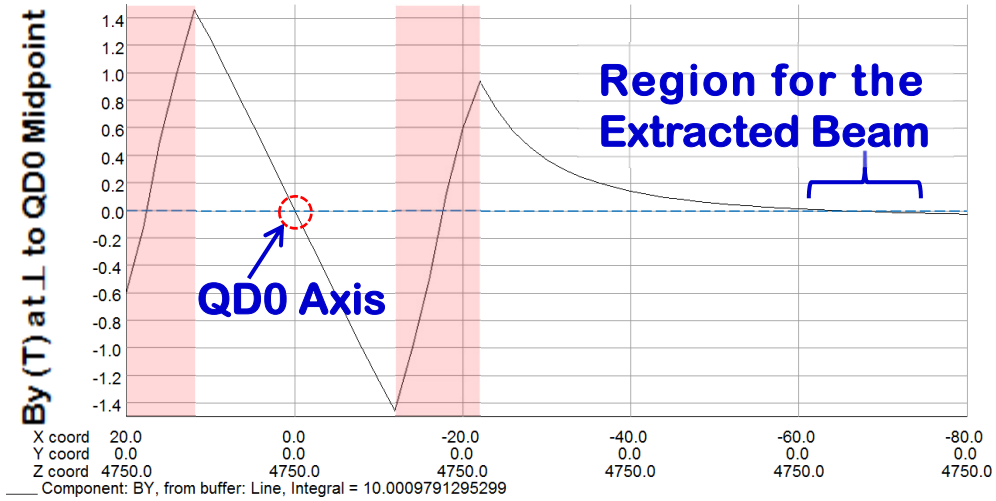


This sweet spot coil has dipole and quad windings, offset but parallel to QD0, that are powered in series such that their fields cancel at QD0 and add at the extraction beam line.

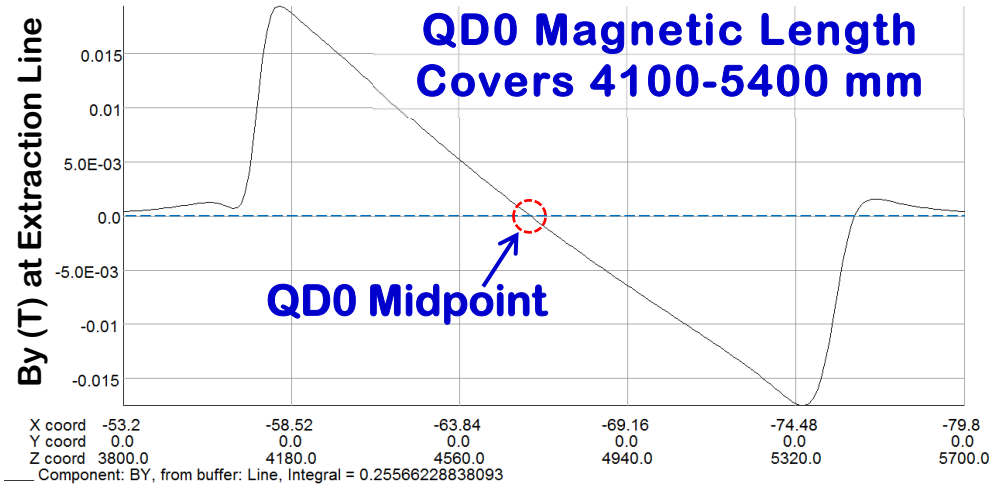
A Sweet Spot Coil Concept for QD0

presented by Brett Parker, BNL-SMD

Combined Field at QD0 Center Projection



Combined Field at Extraction Beam Line



Sweet spot coil is offset -33.05 mm with respect to QD0 which is the place where the dipole and quadrupole fields cancel.

So the sweet spot coil can be adjusted without changing the QD0 field center.

Original QD0 gradient is 124.66 T/m and with sweet spot coil energized, to buck QD0's integrated external field, **the gradient goes up 0.44%** to 125.212 T/m

A simple sweet spot coil, with constant dipole and quad fields, under corrects at QD0's front and over shoots at the end.

It should be possible to tailor the fields shapes, as was done for SuperKEKB, to improve the local field cancellation.

There is small residual weak focusing at the extraction beam line next to QD0 with this sweet spot magnet geometry.

Summary of Anti-solenoid R&D

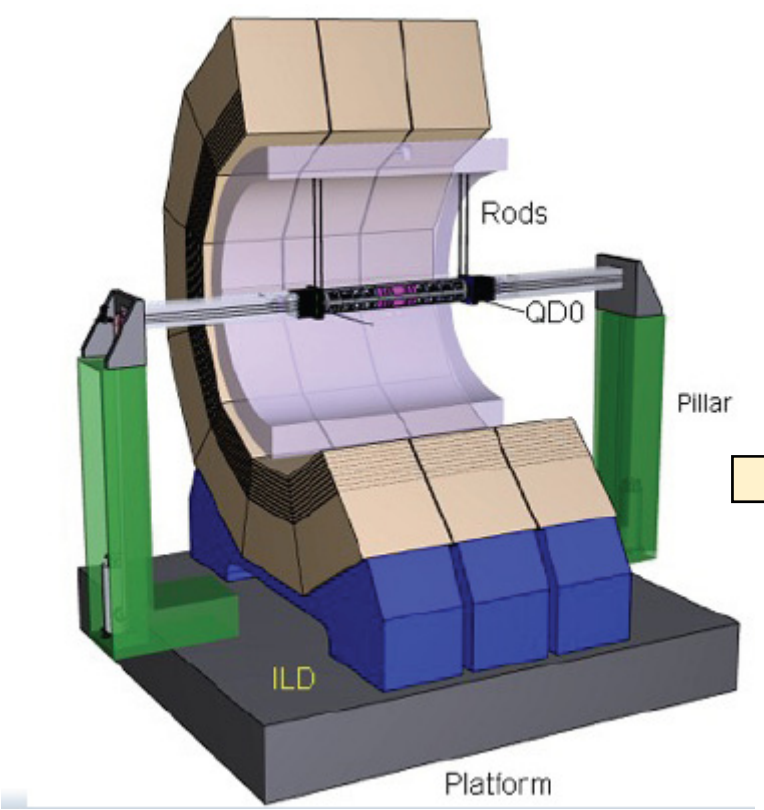
By using the sweet spot coil,
the coil diameter is reduce from 220mmϕ (TDR) to 190mmϕ.
It helps to reduce the detector dead space.
But, since the original size of FD cryomodule in TDR design
is also enough small, the cost impact is not significant.

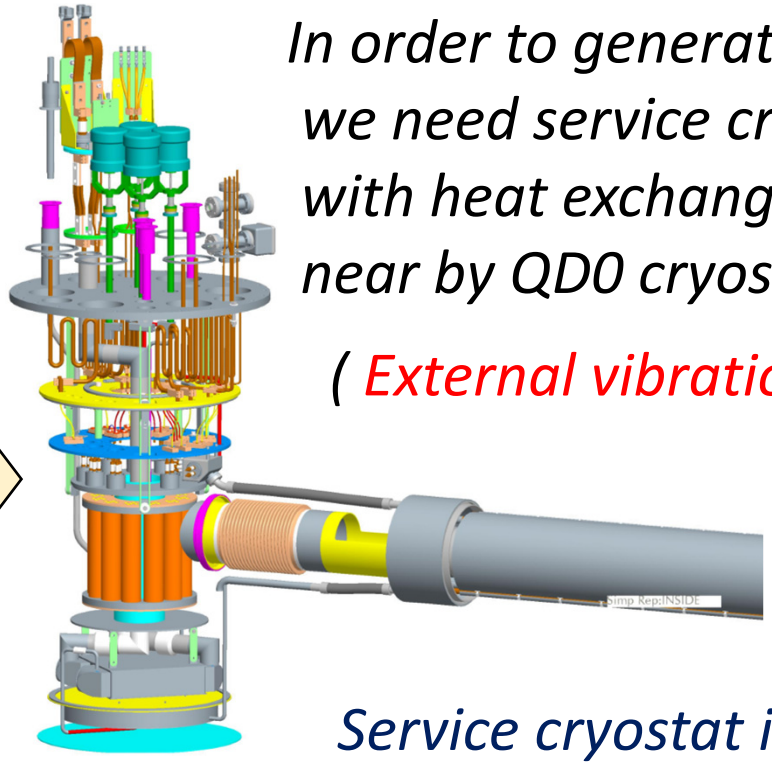
The quadrupole field, which is generated by the sweet spot coils
are small to BNL magnet for their complex package.
Then, it will not help to make the QD0 shorten
and the cost impact is small.

Vibration reduction issue

Vibration Reduction for ILC FD

ILC baseline is designed to utilizing "Superfluid" Helium in order to reduce the vibration of Helium transfer line.





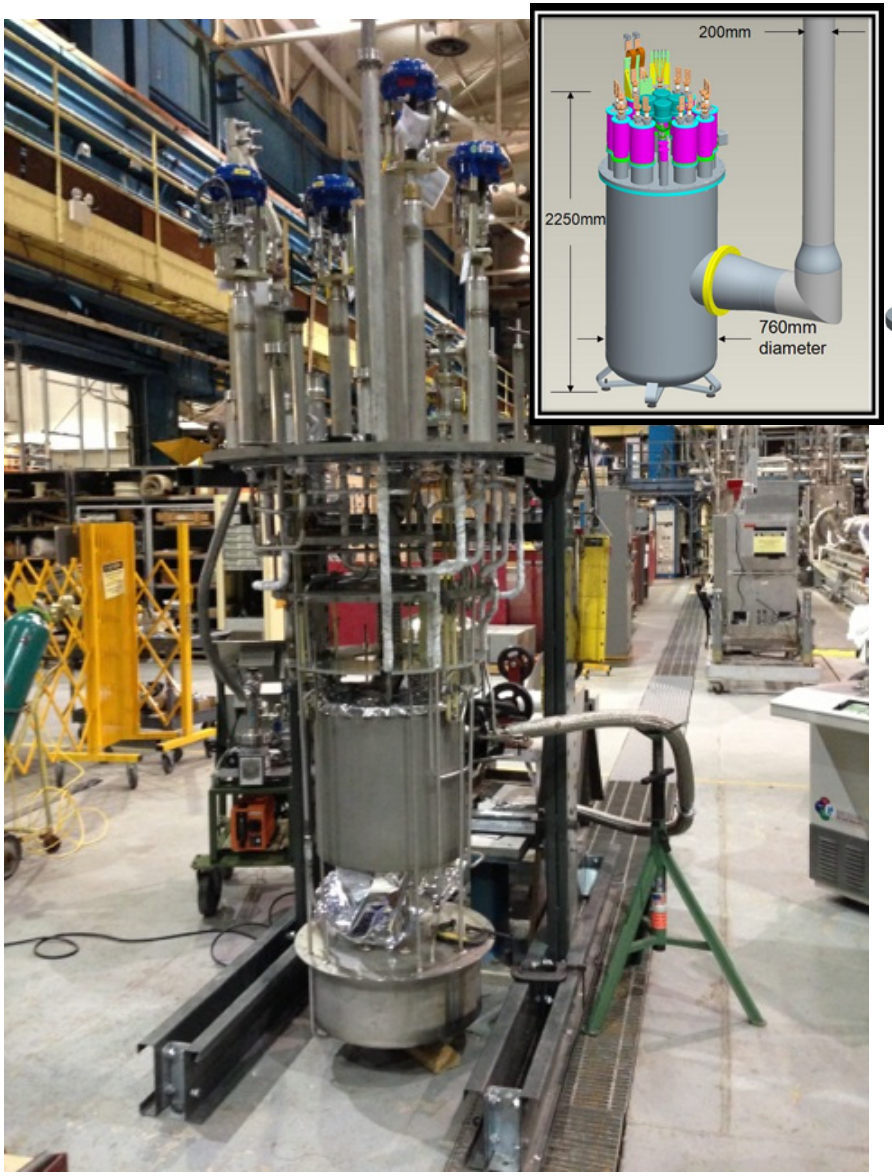
In order to generate 2K Helium, we need service cryostat with heat exchanger (4K→2K) near by QD0 cryostat.

(External vibration source ??)

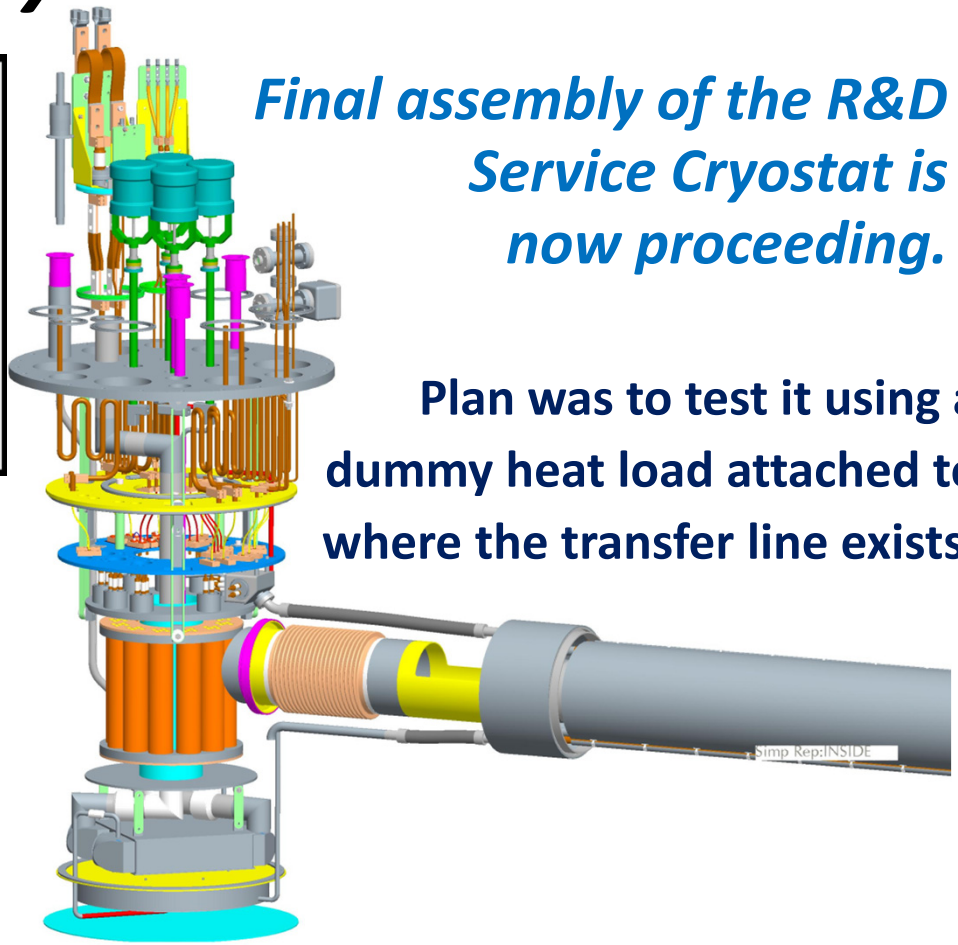
Service cryostat is designed to locate into the pillar.

The vibration of FD by the service cryostat have not ever measured.

ILC Service Cryostat R&D



ILC Service Cryostat undergoing final leak testing before assembly with outer vessel.

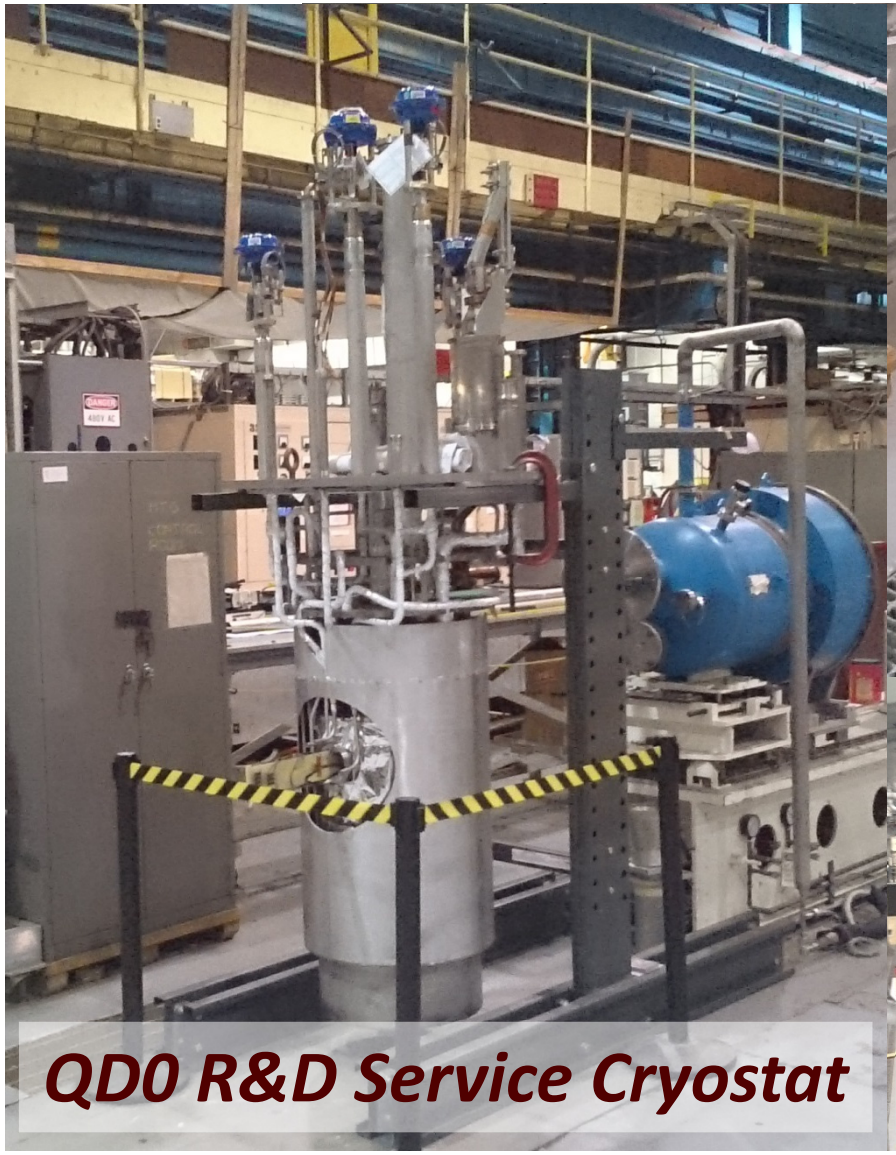


Final assembly of the R&D Service Cryostat is now proceeding.

Plan was to test it using a dummy heat load attached to where the transfer line exists.

Transfer line parts drawings do exist but all work has remained stopped due lack of funds.

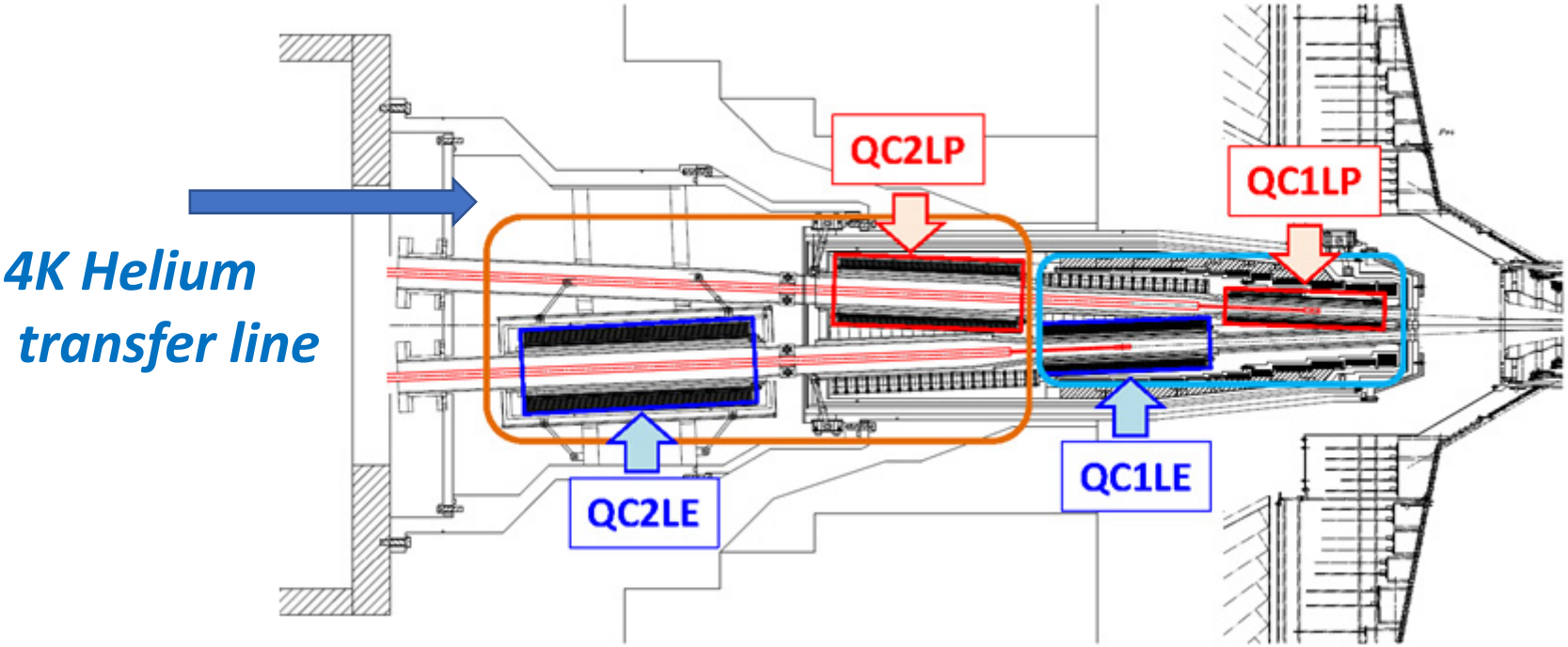
ILC Service Cryostat R&D



These pictures were taken in 2014; no additional work since then.

SuperKEKB FD system

SuperKEKB is designed to use the 4K Helium transfer line.

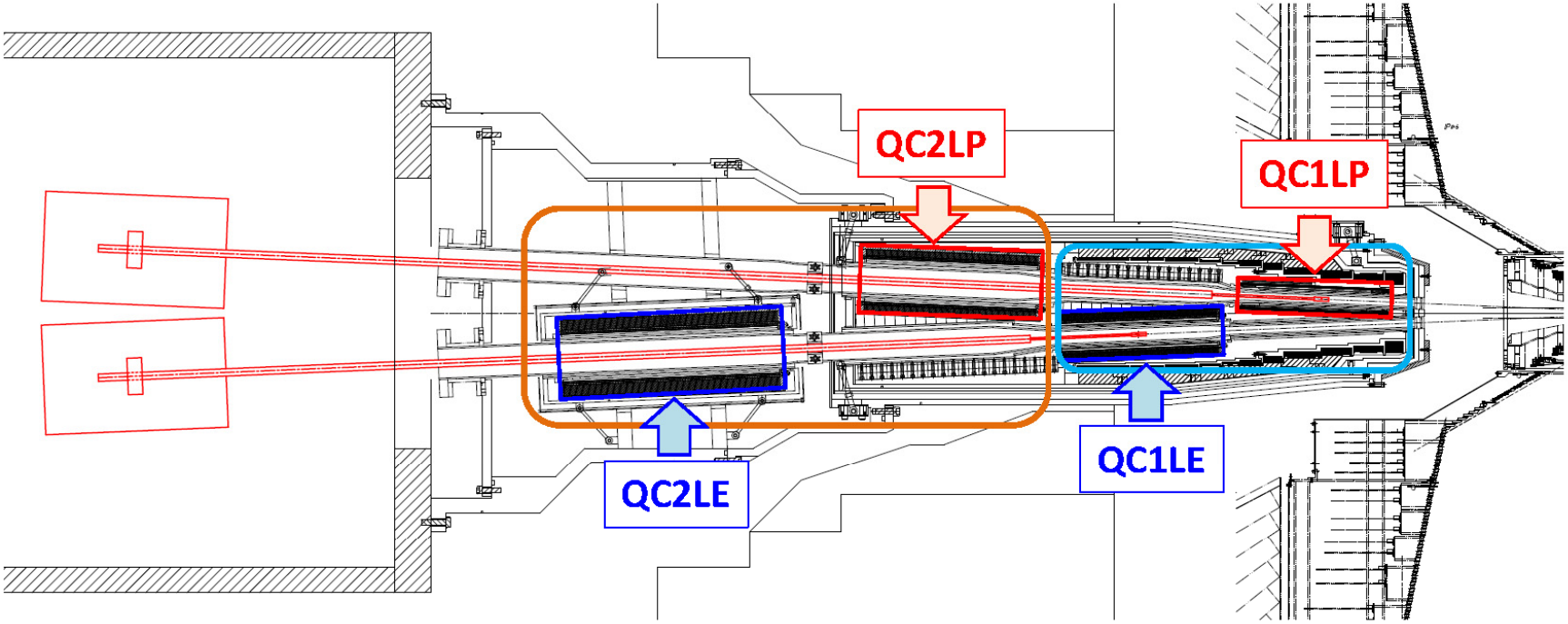


The requirement of the vibration is 25-50nm, which is comparable to ILC FD.

Vibration measurement

- From the beam study, two quadrupole magnets in HER and LER beam lines need to be measured at the same instant.

Magnet-cryostat in the left side of IP



- **Measuring the correlation of vibrations in the two quads to ~ 5nm for f > 5Hz**
  (Vibration resonance of SuperKEKB cryostat = ~ 30 Hz)
- **Two probes need to be installed simultaneously.**

The vibration measurement will be planed at 2018 January.

Some Considerations towards R&D Path Forward

presented by Brett Parker, BNL-SMD

It would be interesting to complete the ILC Service Cryostat and run it closed loop with a dummy heat load and characterize its vibration with Geophones and the Laser Vibrometer (similar technology as ILC and SuperKEKB work).

With the QD0 R&D Cryostat we could do impulse testing, similar to SuperKEKB, to measure response to a driving vibration (e.g. warm and/or cold) and compare to a model.

It would be especially good to leverage SupeKEKB work to compare internal cold mass movement (Geophones) with the cryostat shell (Laser) and the B-field (Pickup Coil).

The vibration test was proposed to US-Japan Funds lase year, but not approved.

Summary of Vibration reduction

We have 2 FD scheme for ILC FD SC system.

1) 2K helium (superfluid) with service cryostat
- *ILC base design*
- *Have not yet measured*
  (not applied by US-Japan Funds lase year).

2) 4K helium transfer line
- *Vibration will be measured at SuperKEKB.*

If the performance is better to use 4K helium transfer line,
we can reduce the costs of 4 service cryostat (2 for 2 detectors).

Then, we can reduce the cost of coupled of MILCU.

Summary

There are on-going R&D items for ILC BDS part.

1) ***Compact anti-solenoid***

By using the sweet spot coil,
the coil diameter is reduce from 220mmϕ (TDR) to 190mmϕ.
It helps to reduce the detector dead space.
But, the cost impact is not significant.

2) ***Helium temperature issue of final doublet***

We have 2 FD scheme for ILC FD SC system.

The vibration evaluation from 4K He transfer line
will be evaluated at SuperKEKB on 2018 January.

If the vibration test from service cryostat (2K helium) will be performed,
and the performance is worse to that from 4K helium transfer line,
we can reduce the costs of 4 service cryostat (2 for 2 detectors).
Then, we can reduce the cost of coupled of MILCU.

The on-going R&Ds can improve the performance of ILC BDS.
However, the cost impact is not significant.