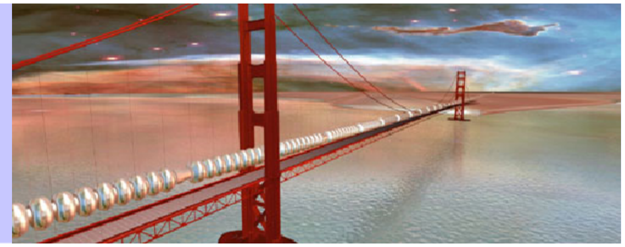

Final Doublet, Anti-Solenoid & Extraction Line Magnets for the ILC

Prepared & Presented by

Brett Parker, BNL

Andrei Seryi, SLAC

Cherrill Spencer, SLAC

Message: A wide variety of superconducting magnets are useful in addressing ILC BDS challenges, but don't forget about warm magnet options.

Outline: Final Doublet, Anti-solenoid & Extraction Line Magnets for the ILC.

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Final Doublet:

- For 20 mr X-ing Scheme we propose that QD0 and first extraction compensator magnet use He-II (1.9°K) cooling for extra compact coils (they start at same L*).
- CAD layout in progress; capture details needed for energy deposition calculations.
- First estimation of cooling capacity; give feedback for E-Dep' and cryostat design.

Anti-Solenoid:

- More details of Anti-Solenoid design have been elaborated and field calculations for practical coils surrounded by laminated yoke (SiD geometry) were completed.
- Preliminary space allocation made; now examine MDI issues (anchor 15 Ton force).

Super Septum:

- The 2 mr X-ing angle extraction line requires a mix of novel superconducting and warm magnets; a particular example is using compact superconducting coils inside iron yokes and cut outs to provide "field free" regions for incoming beam.

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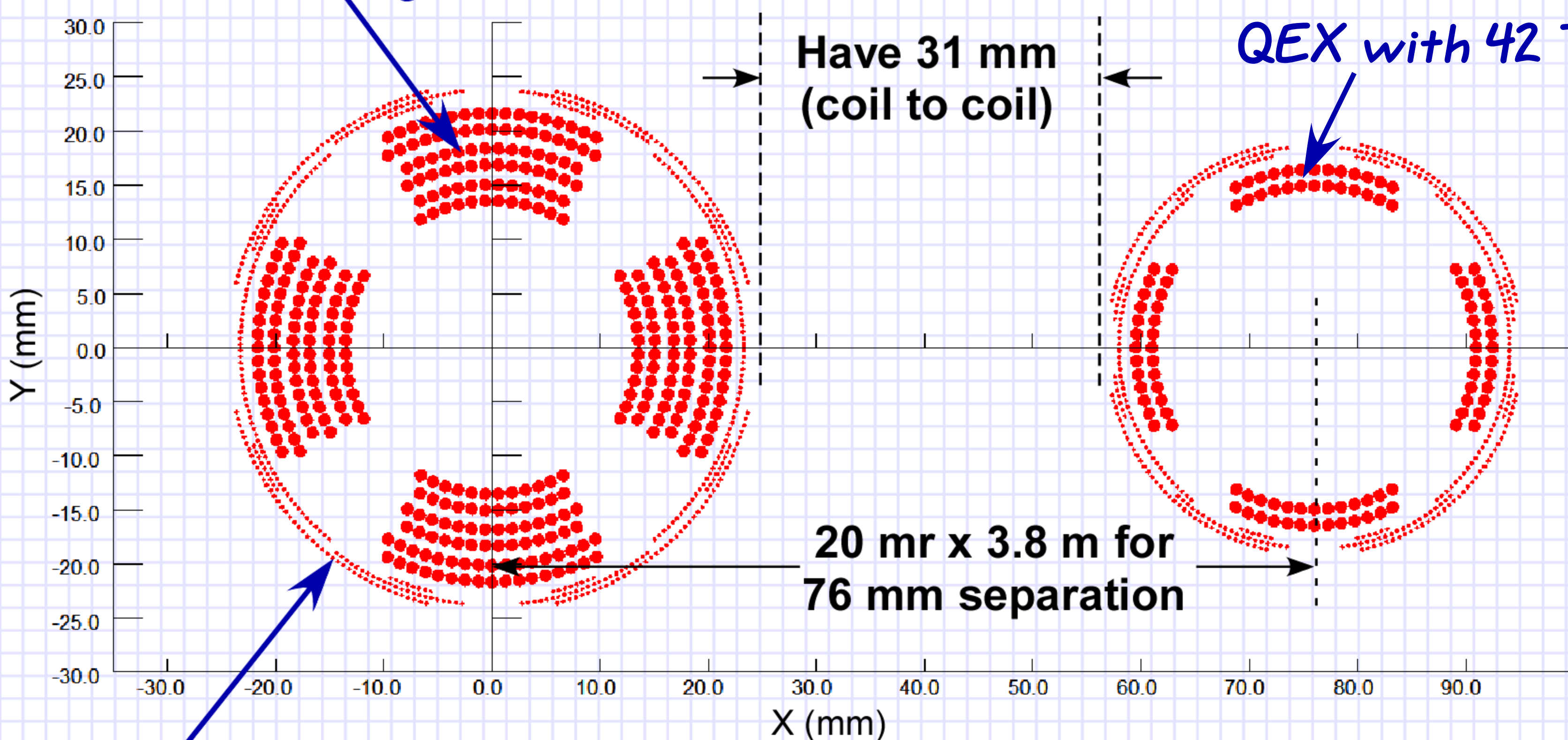
Very compact QD0 and QEX coils side-by-side & both having fringe field compensation.

Need only 6 cable layers to achieve 144 T/m QD0 gradient.

Operate at 1.9°K (pressurized HE-II)

QEX with 42 T/m.



Both magnets have dipole, skew-dipole and skew-quad windings to compensate fringe and detector fields (outbound beam & DID).

Coil Separation @ 3.8 m with 20 mr X-ing angle

But can we direct wind coils with 6-around-1 cable at such a small bend radius?

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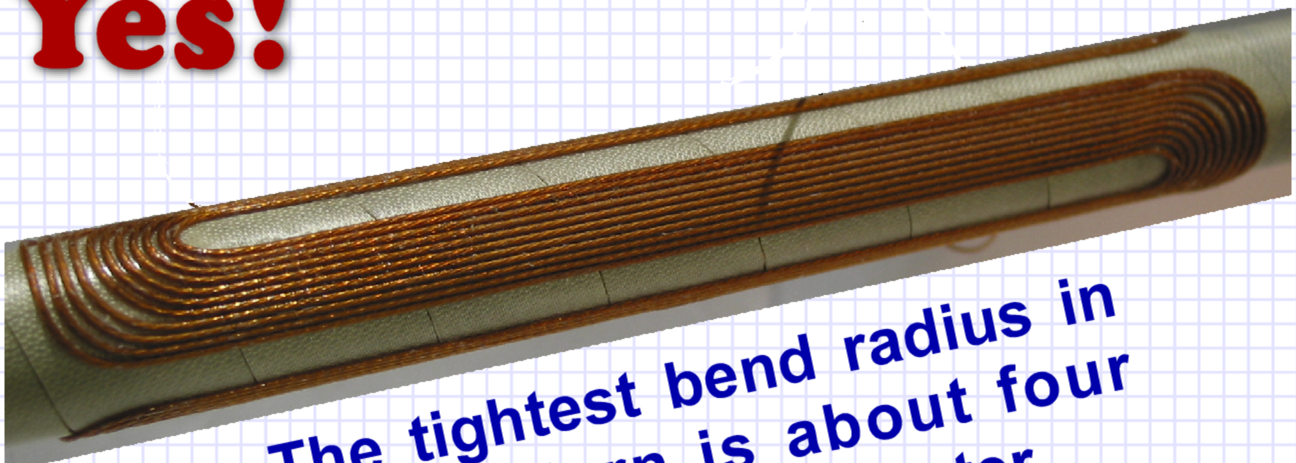
Yes!

Quadrupole pattern with 1 mm cable wound on 25.4 mm diameter tube.



The tightest bend radius in this pattern is about four times the cable diameter.

By the third corner John Escallier had found process parameters that worked for automatic winding of the rest of the coil (two layers were wound).

Idea was to try "semi-automatic" winding with a mechanical assist for the first turn.

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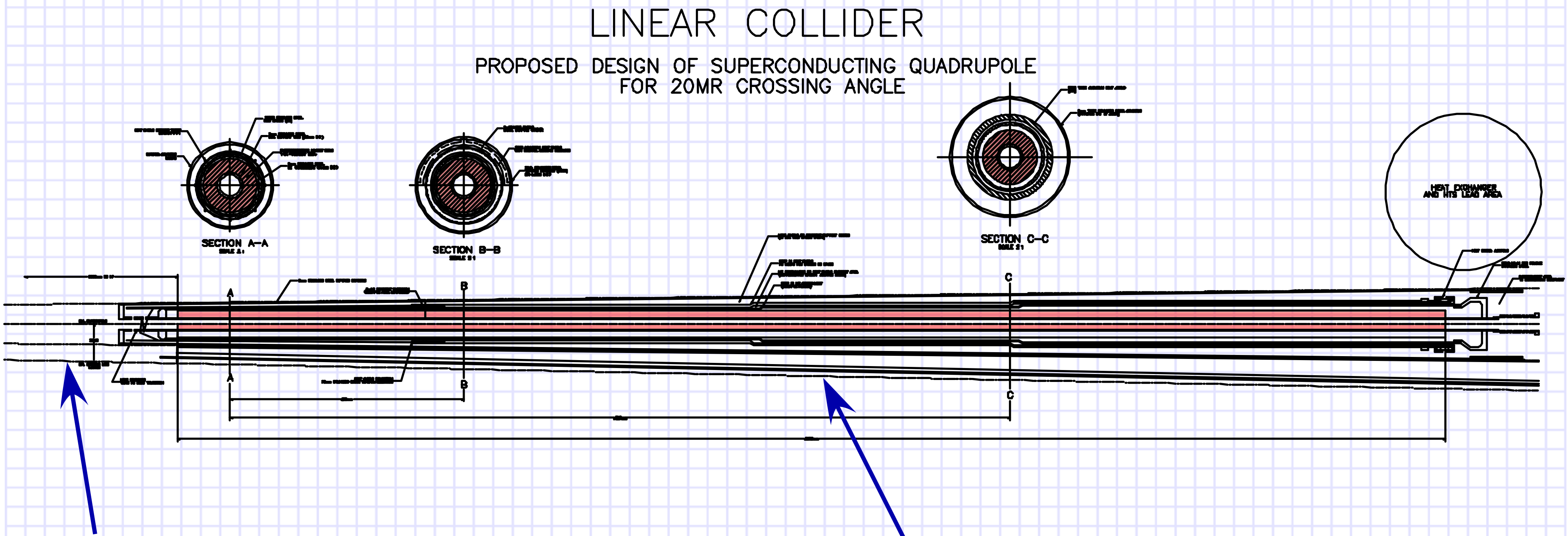
Overview of QD0 Design for 20 mr X-ing.

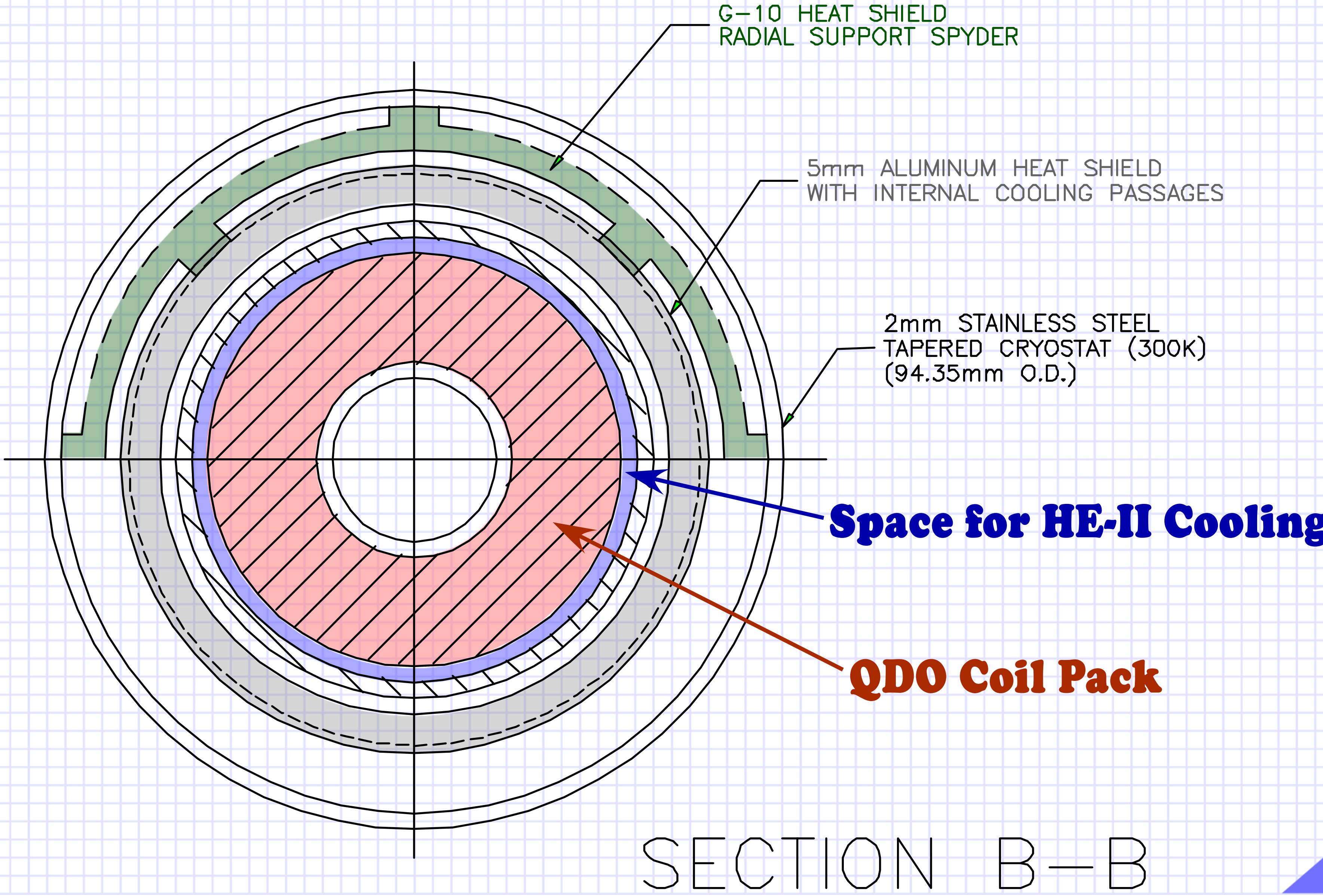


Lines of sight to IP with 20 mm crossing angle as indicated.

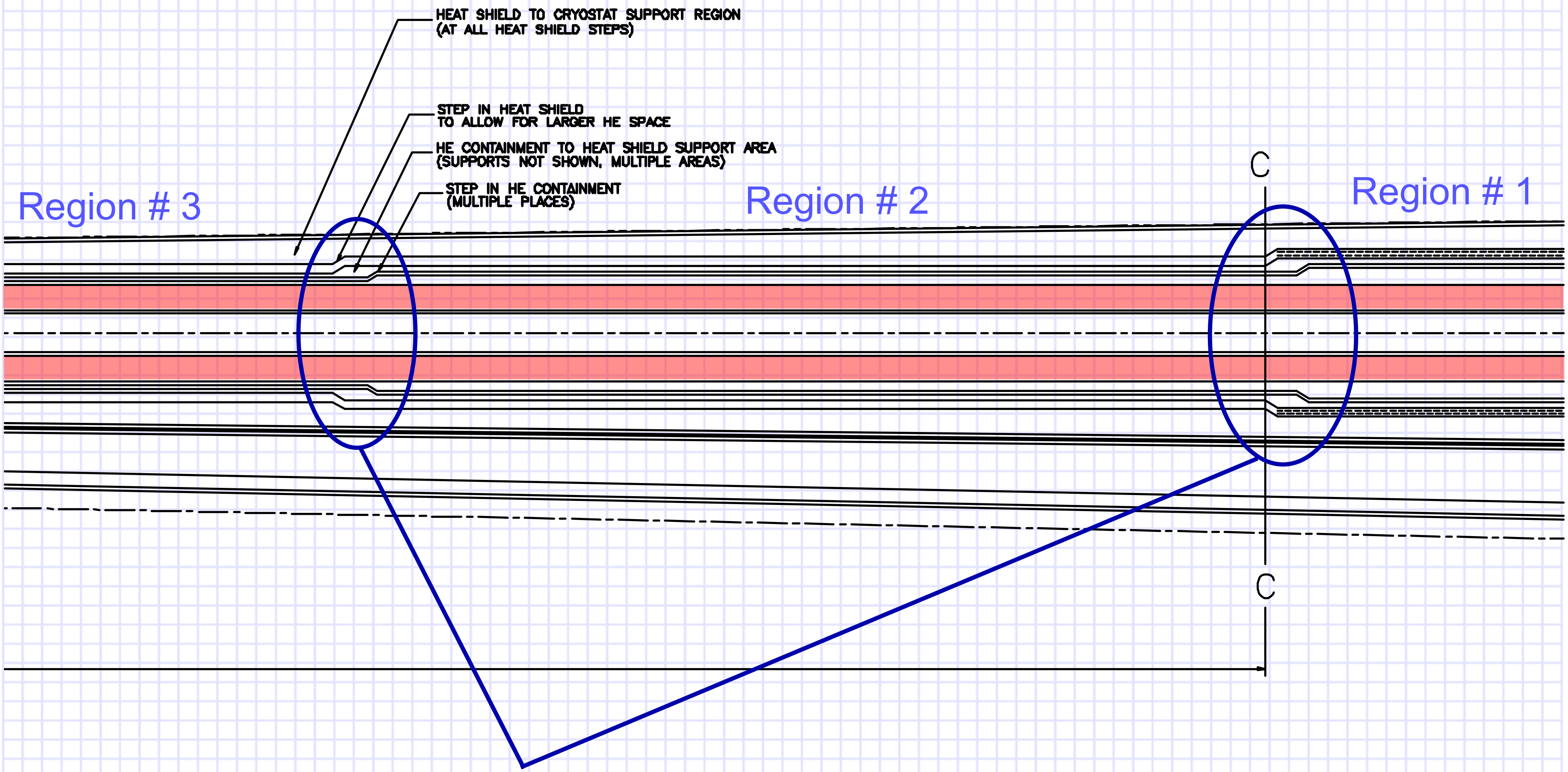
Edge of extraction line magnet.

Here the QD0 cryostat is circular in cross section but it is tapered along its length.

Support Location & Heat Shield Detail.



Close Up Near Middle of QD0 Magnet.



Locations where heat shield and cold mass increase in size.

QD0 Cooled with Pressurized He-II.

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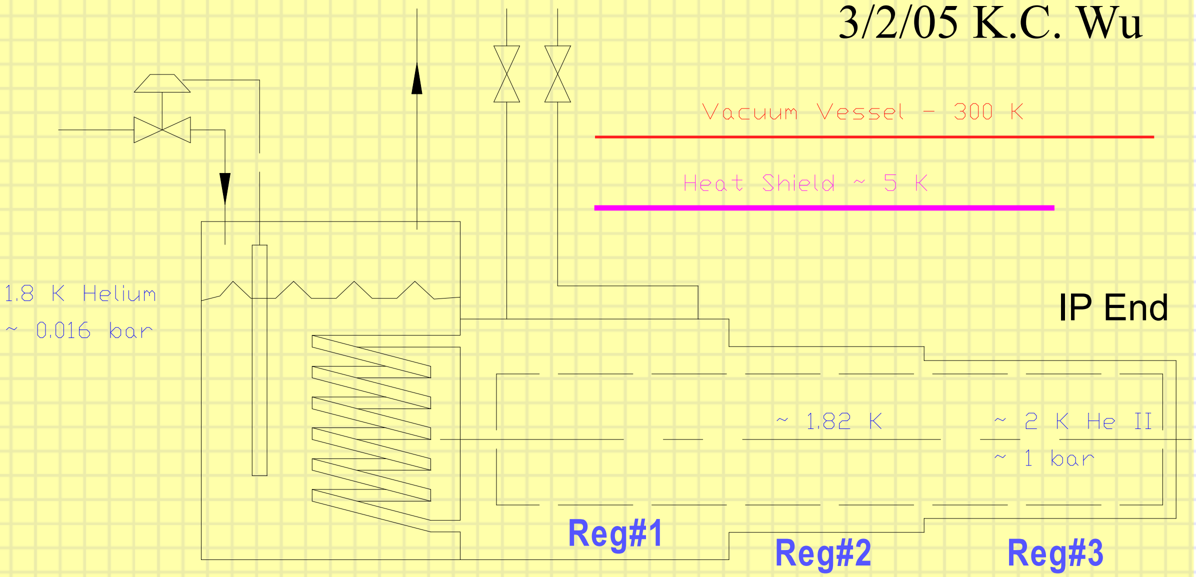
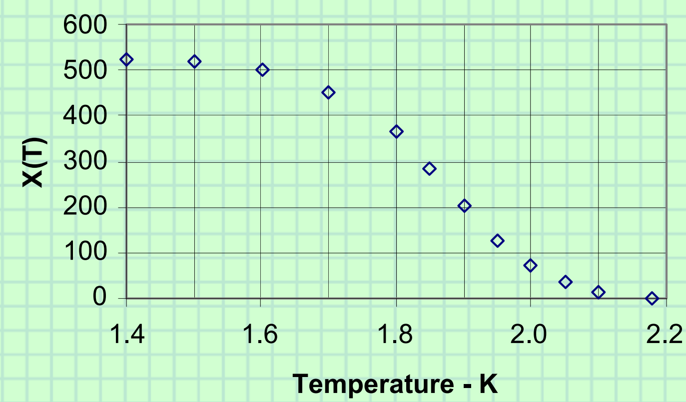
Conceptual Study for Cooling Insertion Magnet of the Linear Collider

3/2/05 K.C. Wu



Temp. profile along a channel filled with He II at 1 atm

$X(T_c) - X(T_w) = q^{3.4} \times L$



Find self consistent T for Reg#1-3.

- *Assuming heat is deposited only at IP end; then can pass about 4 W to heat exchanger (Reg#3 is choke point; Reg#1-2 could pass ~15-20 W).*
- *With uniform heating, can handle ~55% more energy deposition than if solely at IP end.*
- *Must increase Reg#3 area if we want better cooling (elliptical section?); need to know the expected energy deposition in order to make an intelligent choice.*

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Anti-Solenoid Design Developments.

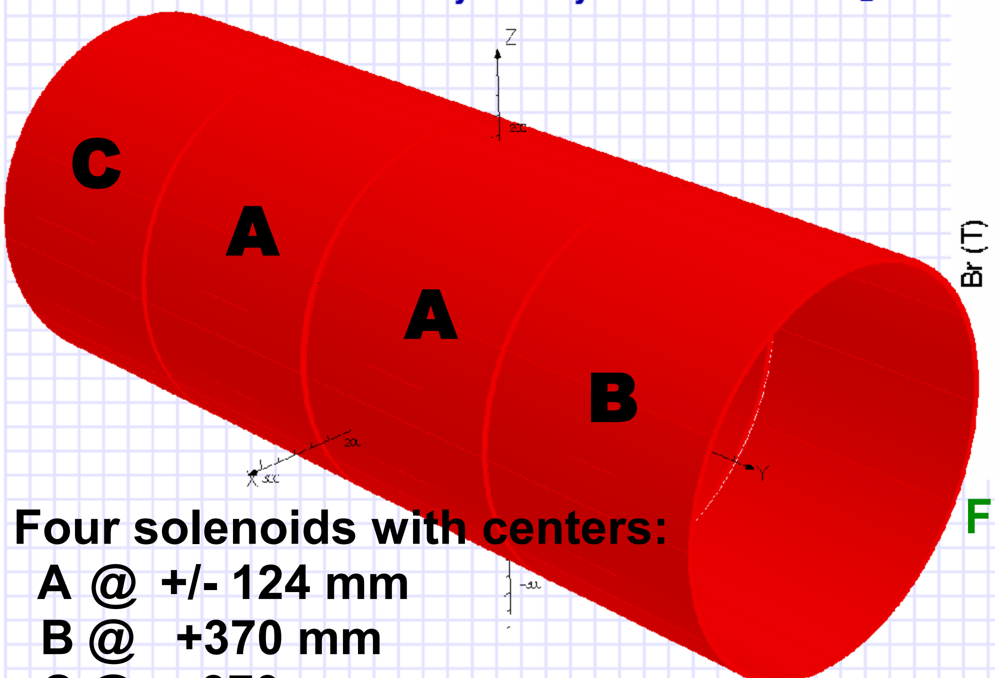
Anti-Solenoid Split Into Four Subcoils

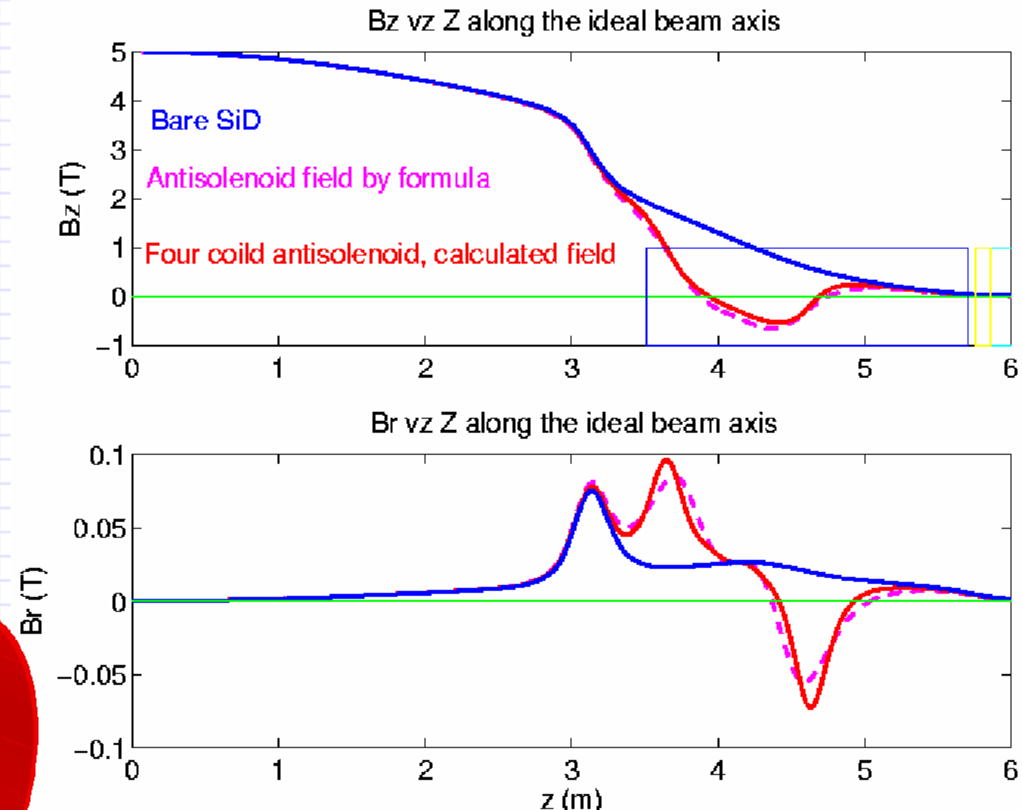
$I_a = I_o + I_1$

$I_b = I_o - I_1 + I_2$

$I_c = I_o - I_1 - I_2$

If each subcoil has the same number of turns, then overall strength is determined by I_o. Modify width via trim I_1 and asymmetry via trim current I_2.





Four solenoids with centers:

- A @ +/- 124 mm
- B @ +370 mm
- C @ - 370 mm

L_s = 240 mm, R_{inner} = 190 mm

Thickness = 6 mm, $\bar{J} \approx -200$ A/mm^2

Field approximation by formula: $\sigma_y/\sigma_{y_o} = 1.38$

Calculated (in air) coils: $\sigma_y/\sigma_{y_o} = 1.45$

(not using the current knobs)

For comparison: without anti-solenoid $\sigma_y/\sigma_{y_o} = 27.6$ for ILC parameters

Anti-Solenoids+DID: Compensate Beam Size, Minimize IP Angle and SR Beam Size Growth.

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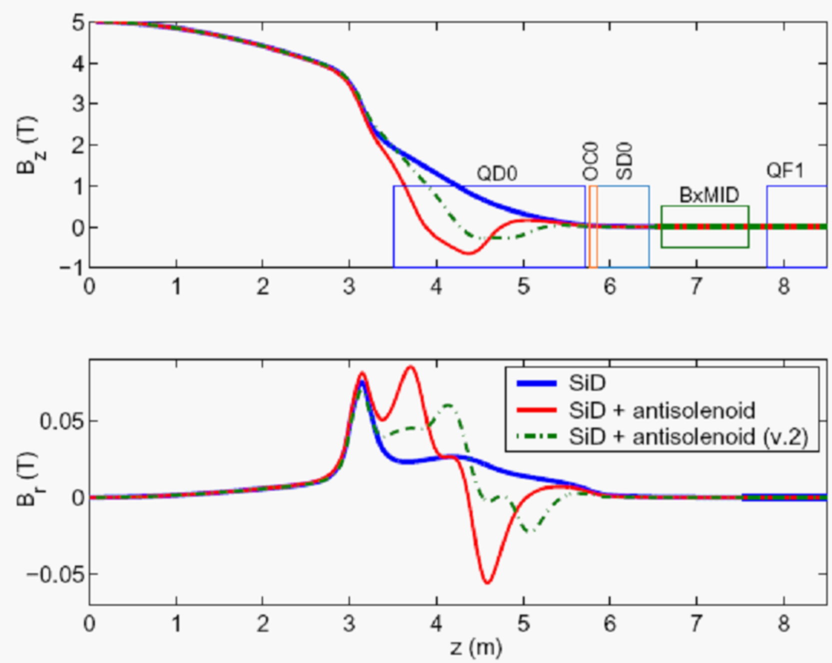

FIG. 3: Longitudinal and radial magnetic field in SiD calculated by ANSYS, without and with the weak antisolenoid which cancels the beam distortions produced by the detector solenoid. The red line shows the field with the antisolenoid parameters suggested in [1], and the green dot-dashed line shows the field with another configuration of the antisolenoids, optimized to reduce SR effects (see text). The radial field is at the nominal beam trajectory with half crossing angle $\theta_c = 10$ mrad. Locations of the Final Doublet elements (quadrupoles QD0 and QF1, sextupole SD0, octupole OC0 and an optional dipole corrector BXMID) are also shown. The IP is at $z = 0$ m.

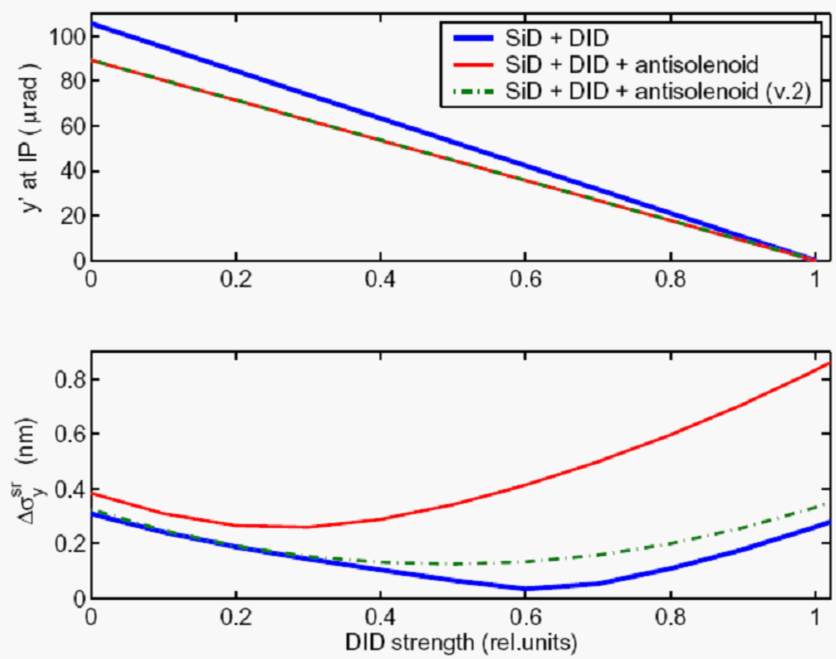

FIG. 9: Vertical angle at the IP (top) and the beam size growth due to synchrotron radiation (bottom), versus strength of the DID corrector, without antisolenoid (thick blue line), with the antisolenoid with parameters suggested in [1] (red line), and with the antisolenoid optimized to reduce the SR effects (green dash-dotted line).

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(Position of antisolenoids was not exactly the same as in latest layout, but very similar)

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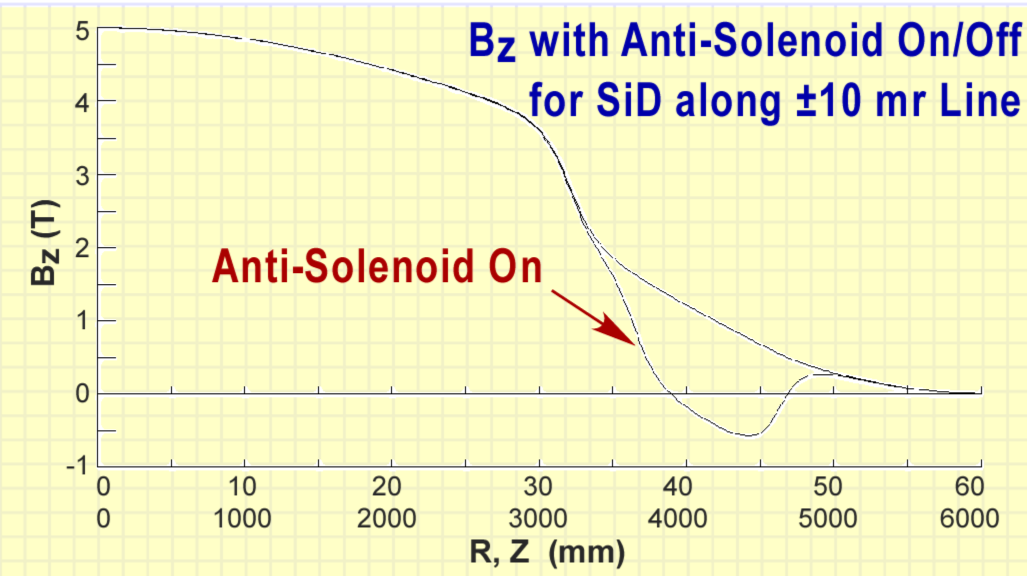
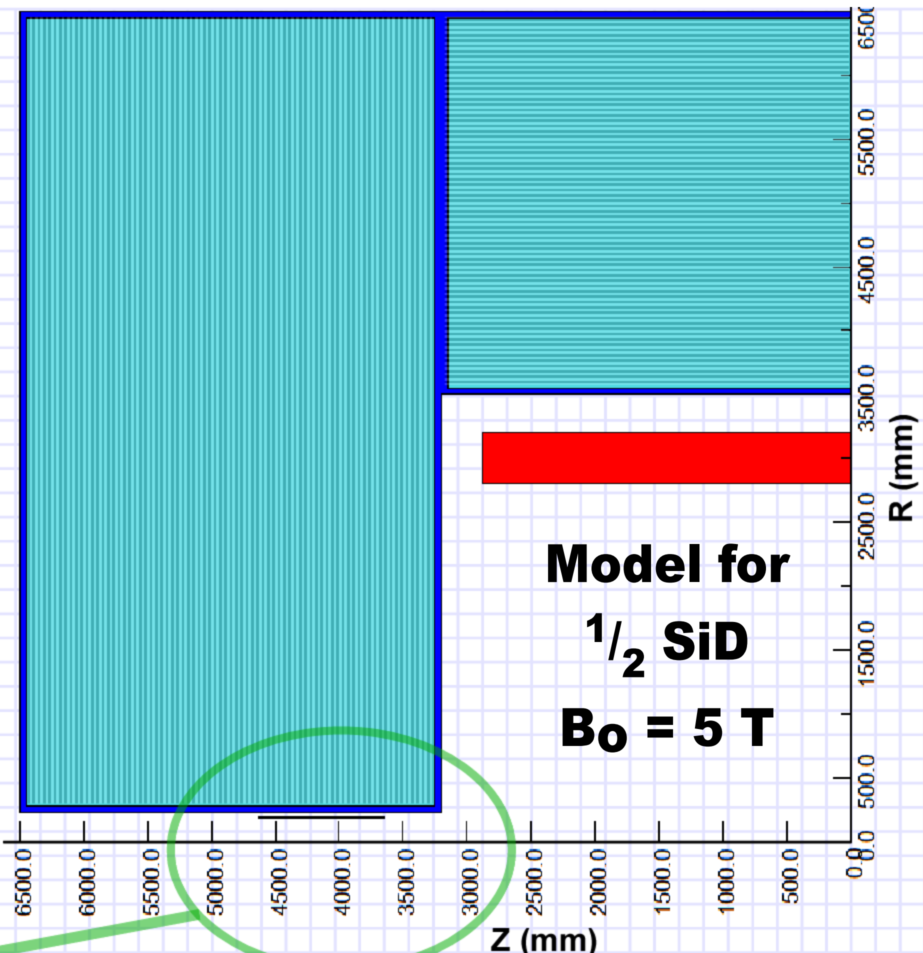
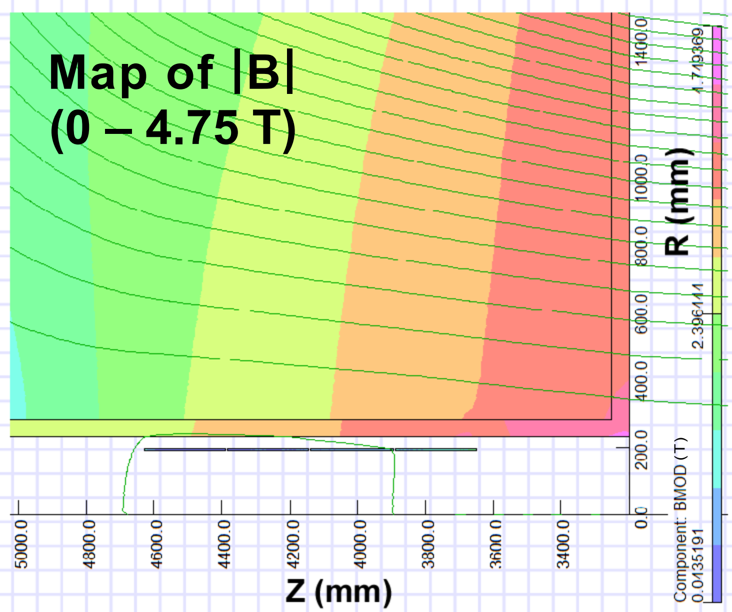
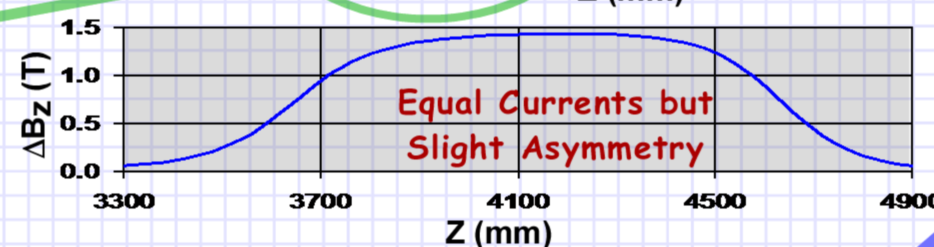
Anti-Solenoid Design Applied To SiD.

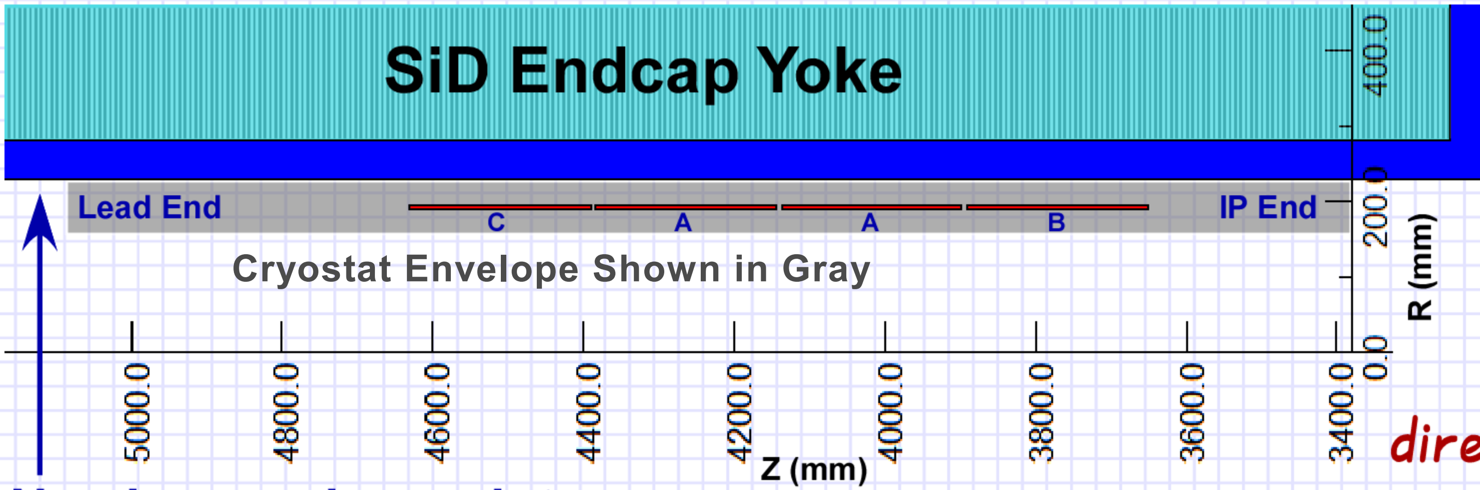






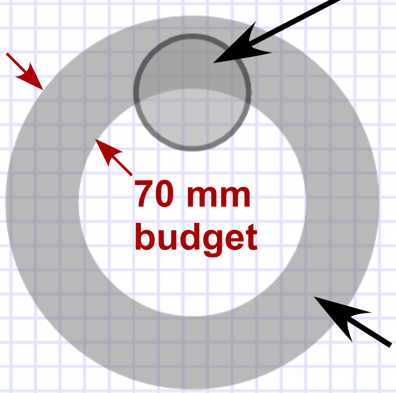


MDI: Anti-Solenoid Design Challenges.



When energized the anti-solenoid generates ~15 Ton longitudinal force directed away from IP

Need an anchor point



Cryostat Cartoon

Connection to bring leads and cooling in/out.

Place this at top to stay out of the way of QD0 support structure? (cryogenic flow issues?)

Ring cryostat, ID ≈ 316 mm & OD ≈ 456 mm, that is anchored to the solenoid yoke?

Active length = 1220 mm, 1700 mm budget has 150 mm at IP end and 330 mm at lead end. Warm to cold transition at lead end must handle 15 Ton force. Do this with set of 20 mm dia.,160 mm long G10 rods put in compression and uniformly spaced on cold mass end flange.

MDI: Anti-Solenoid Experimental Impact.

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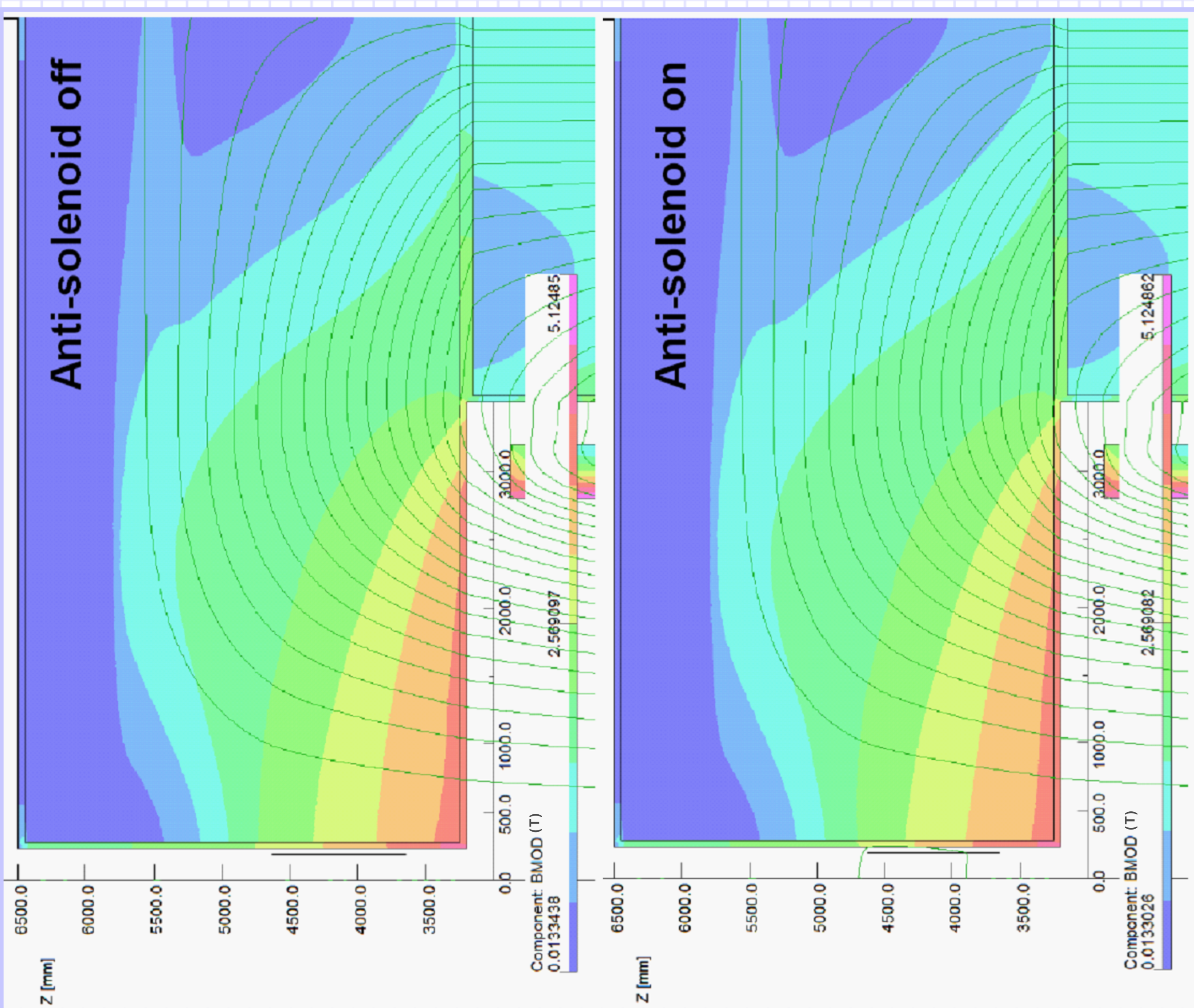
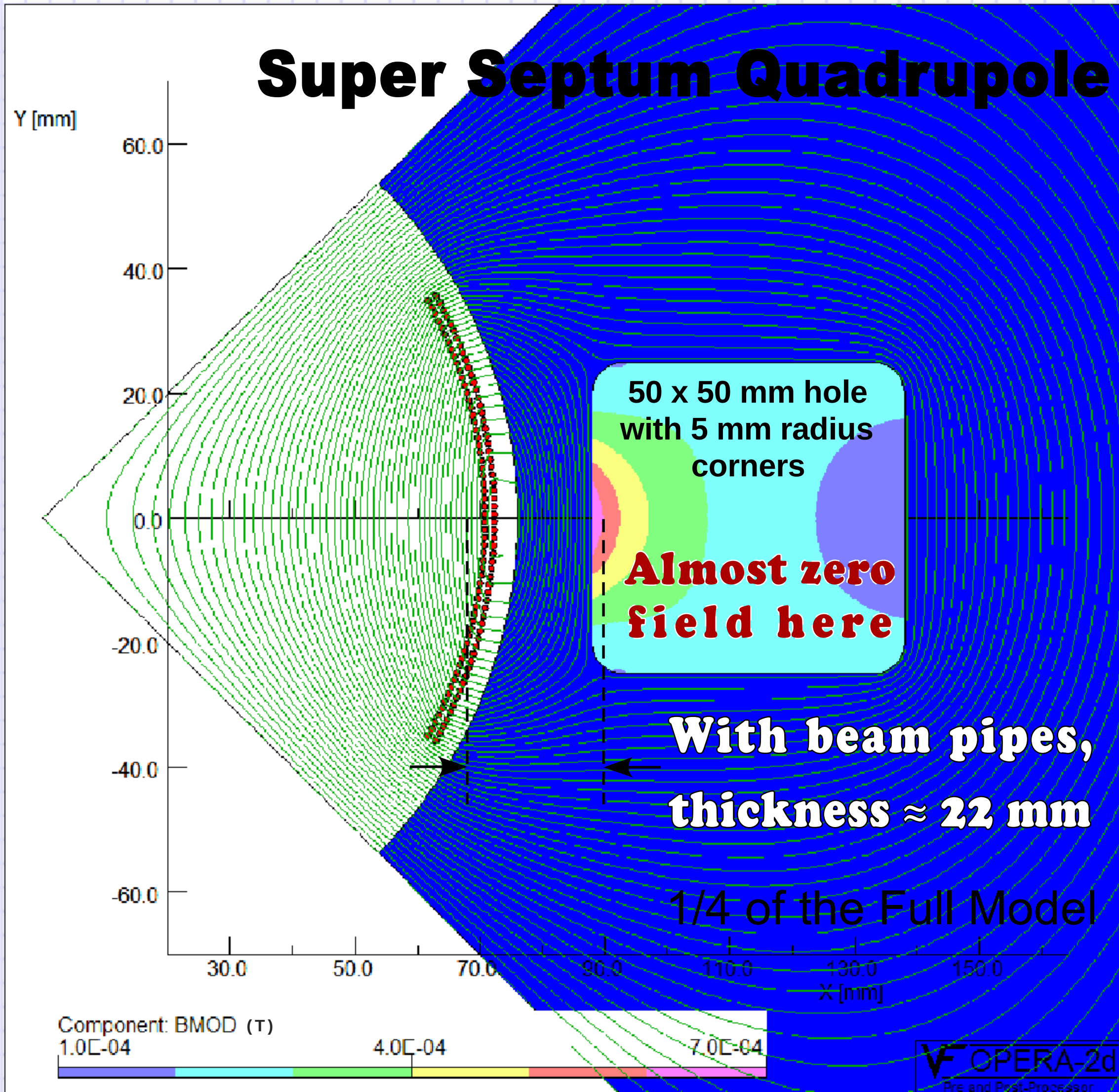


The endcap field is almost unchanged with anti-solenoid ON and OFF.

Comparison of |B| Maps for SiD Yoke and the conductors (0.013 – 5.125 T)

Special Magnets for 2 mr Extraction Line.



There are places where beams are not well separated but we need to focus one and not deflect the other. This happens frequently along the 2 mr X-ing angle extraction beamline.

If the field at the conductor is low enough, then we can consider making a thin superconducting coil via the direct wind technique. Then we surround this coil with a magnetic yoke that has a hole for the "reduced field" region.

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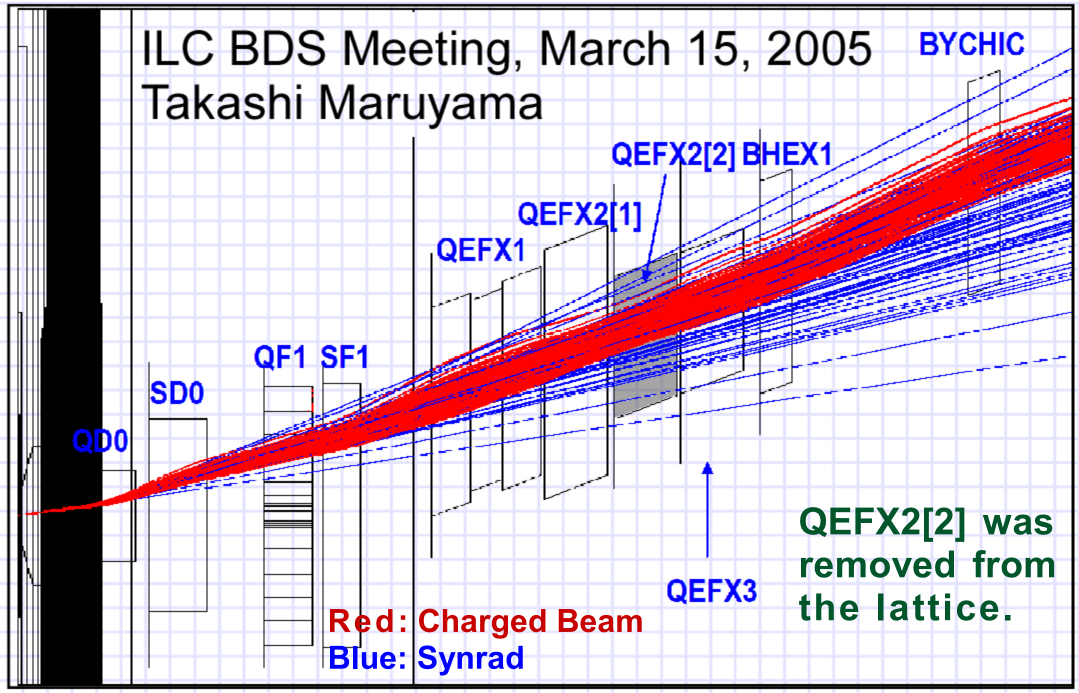
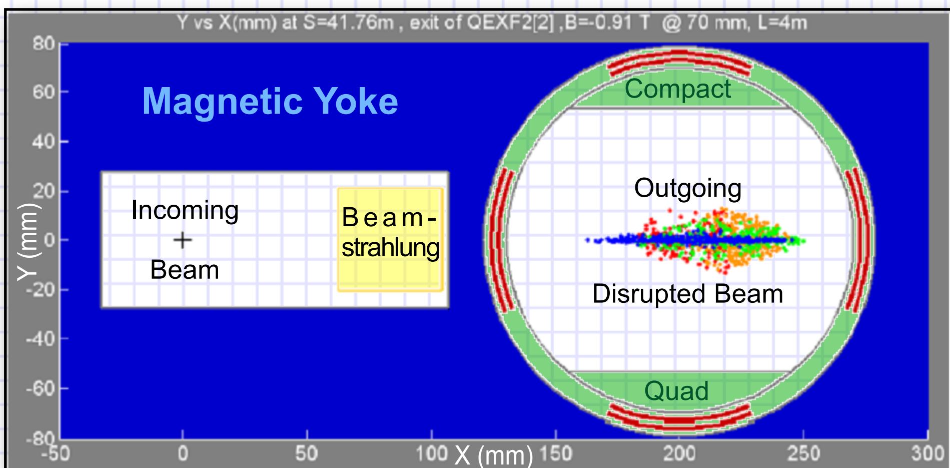
Energy Deposition & Superconducting Coils.

Super Septum Design Challenge

Must be careful with energy deposition in a superconducting magnet. For some cases even a few watts heating can be significant.

For the super septum magnet we need to protect the septum region.

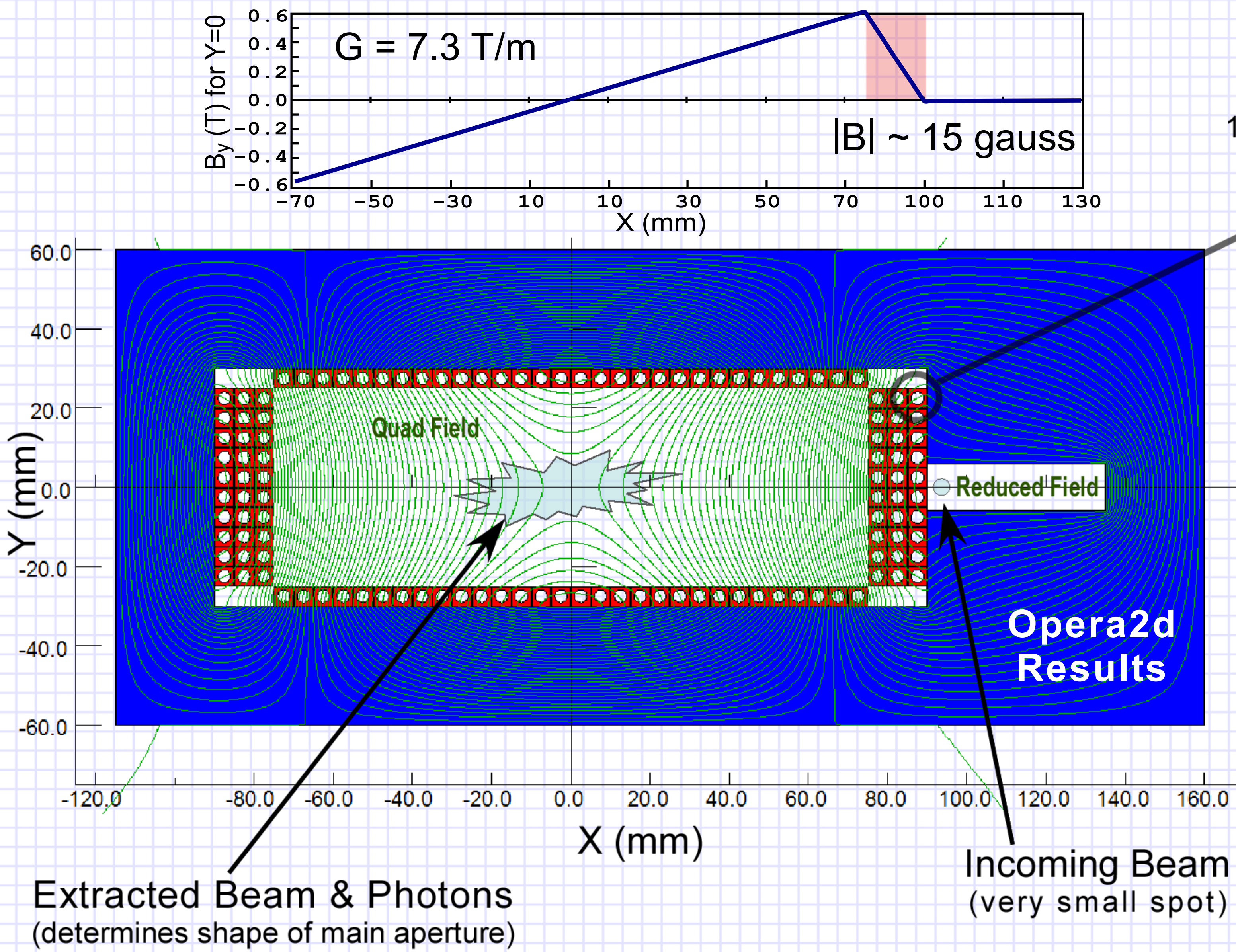


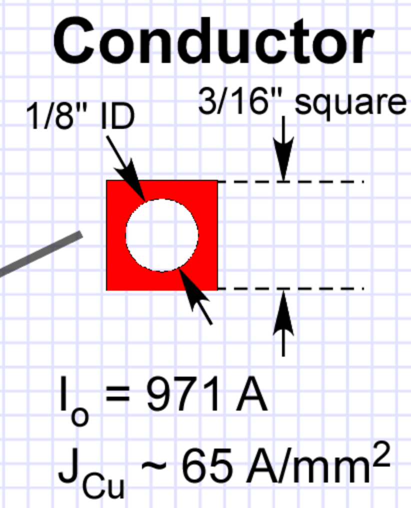


Even if the main part of the disrupted beam and beamstrahlung pass cleanly, there can be synrad hits from upstream magnets.

Advice: Only go with a superconducting magnet when sure that a normal conducting or permanent magnet solution is not practical or not desirable for some reason.

Warm QEXF1 Option: Cherrill Spencer's Panofsky Septum Quadrupole.





Preliminary Model for QEXF1 Magnet (Check feasibility)

Original POISSON Model Was Done By Cherrill Spencer, ILC@SLAC

Basic Design Data for Panofsky Septum Quad for QEXF1, 8th March 2005 version.

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Cherrill Spencer,
ILC@SLAC

- Based on preliminary POISSON model, with no real engineering of the coils
- Panofksy quad uses 4 coils, each coil to pass 14,568 amp·turns
- Small space available for side coils leads to very high current density
- Use 15 turns 0.1875"sq hollow Cu, with 0.125" diam cooling hole, per coil
- So need to pass 971 amps in conductor we typically pass 160 amps max!
- Requested magnet length is 2.5m, -> 2 separate magnets, 1.25m each
- Solution: each turn is a water circuit, then approx 14 ft per circuit
- Need to keep LCW water velocity below ~15 ft per sec to reduce erosion
- Allow LCW temp to increase by 30 °C, then need P ~ 60 PSI and water cooling works in theory
- Need to monitor water flows and voltages interlocked to power supply for fast turnoff
- Engineering issues not tackled yet, e.g. how to fit in all the water fittings? How to shape coils at ends?
  Impact of end fields for reduced field region? (this note added by B. Parker)

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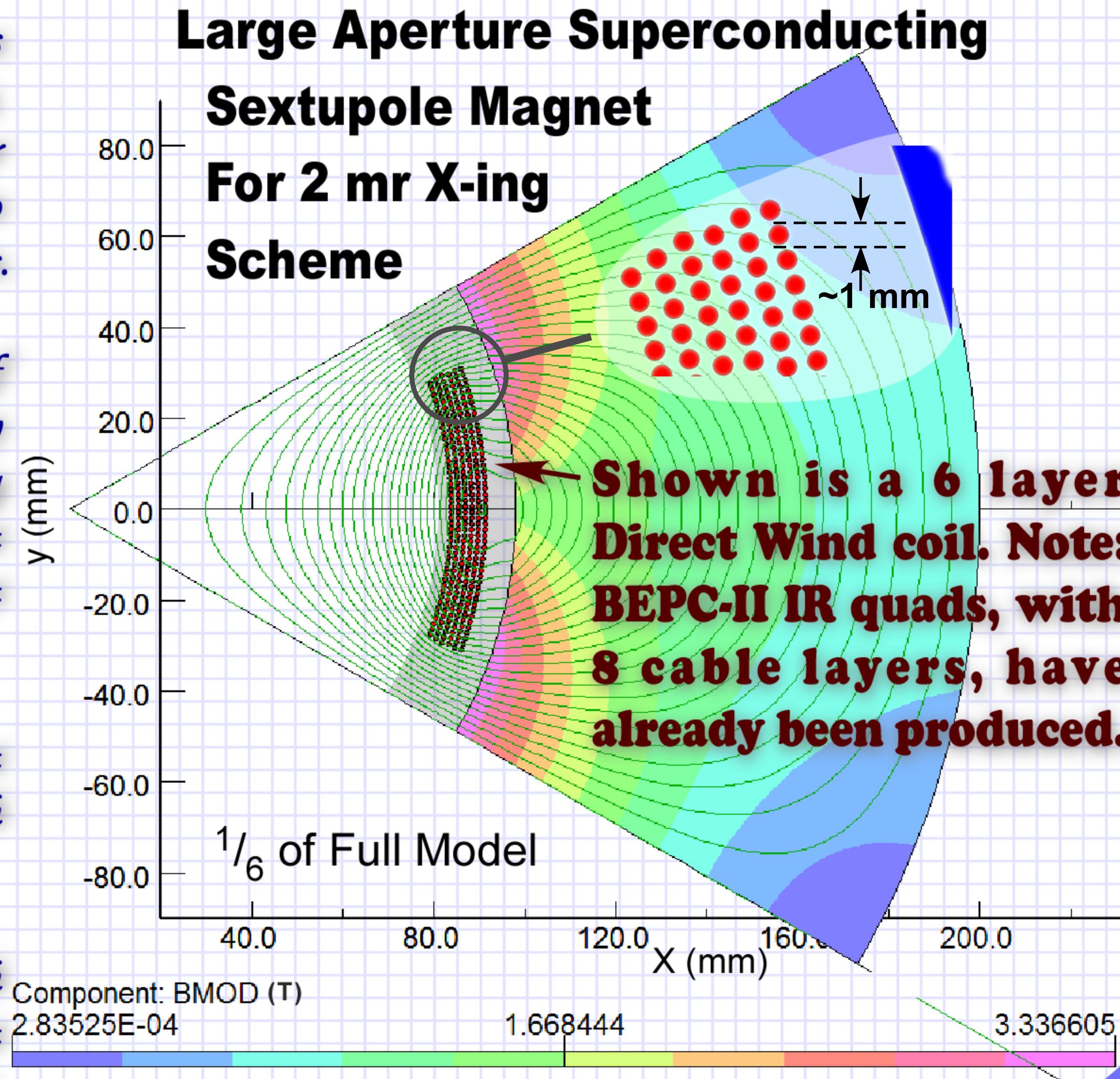
Superconducting Magnets for the ILC.

Both the 20 and 2 mr X-ing angle latices require some magnets that are challenging. either because the pole-tip field is high or the available transverse space is small, to implement as conventional warm magnets.

While Direct Wind enables production of superconducting magnets with a variety of apertures and lengths without having to make new tooling, we should not get "carried away" (new cryostats are not so trivial to design and manufacture).

Also some magnets, like the sextupole at the left, are good "Rutherford cable with collared-yoke" design candidates.

For now we can use a variety of such magnets in our straw designs but must come back later and consider many details.



Presentation Conclusion and Thanks.

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It is clear that superconducting magnet technology can make significant contribution to addressing many of the ILC BDS and MDI design challenges. Some applications discussed in this talk were the final focus and extraction line magnets, the detector integrated dipole and the anti-solenoid. Other magnets not discussed here are the strong tail folding octupoles, the energy spectrometer and diagnostic chicane magnets and of course the main superconducting linac lattice magnets.

BNL Direct Wind technology is relevant to many of the above magnet designs and it has been most interesting to collaborate as part of the early Linear Collider global design effort on the ILC BDS.

I would like to take this opportunity to thank Andrei Seryi for presenting this talk for me to LCWS'05 and Cherrill Spencer for providing me with her design for the Panofsky Septum Quadrupole.

Brett Parker, BNL 18-Mar-2005