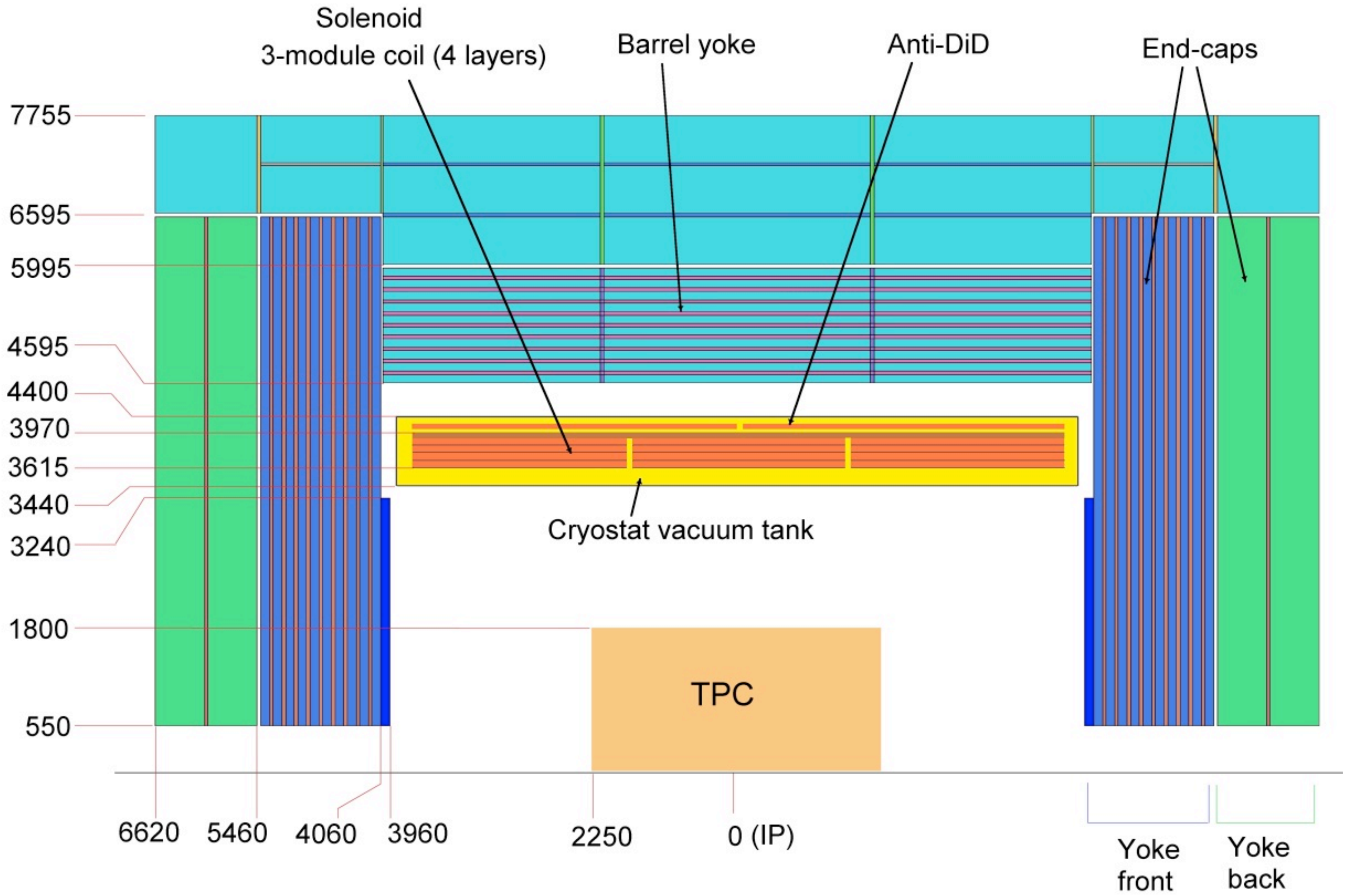
Anti DID Options
Present Status

ILC Mini Workshop, KEK

May, 2017

Uwe Schneekloth, DESY

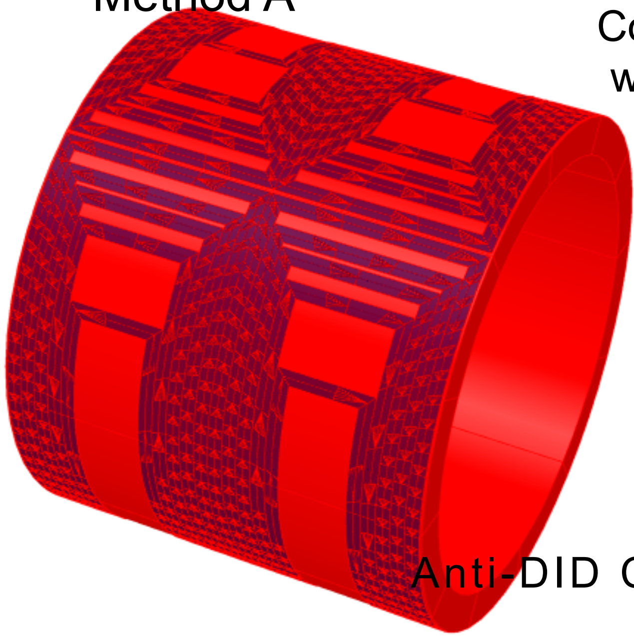
Coil and Yoke Cross-Section ILC TDR/DBD

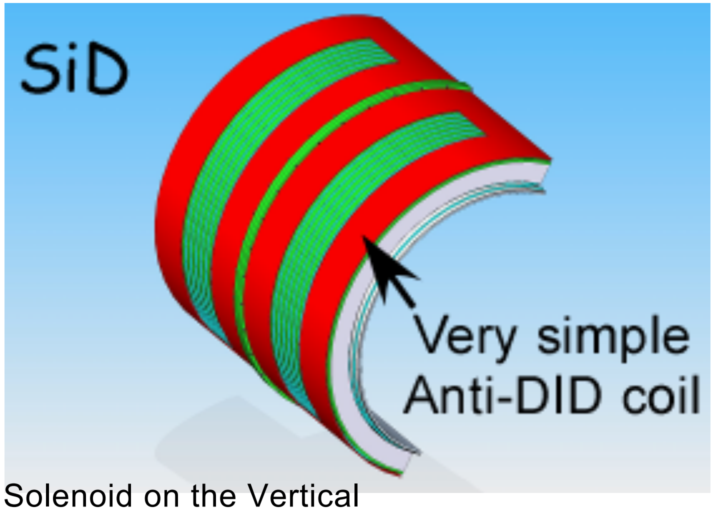


Short Anti-DID Design History Review

- Detector Integrated Dipole (DID) first proposed by A.Seryi & B.Parker† to enable use of large crossing angle needed for ILC Gamma-Gamma IR scheme.
- With present 14 mrad crossing angle, an opposite polarity DID (Anti-DID) can be used to help guide beamstrahlung produced pairs out of detector to reduce background.
- While incorporating DID coils with main detector solenoid avoids introducing material inside detector acceptance (that would adversely impact physics), coming up with practical scheme for implementing anti-DID coils is by no means trivial!
- Directly winding complex coil structure outside detector solenoid is challenging (production infrastructure) and wrapping flat wound anti-DID coil around solenoid is not easy either (anti-DID conductor stress).

Slide B. Parker



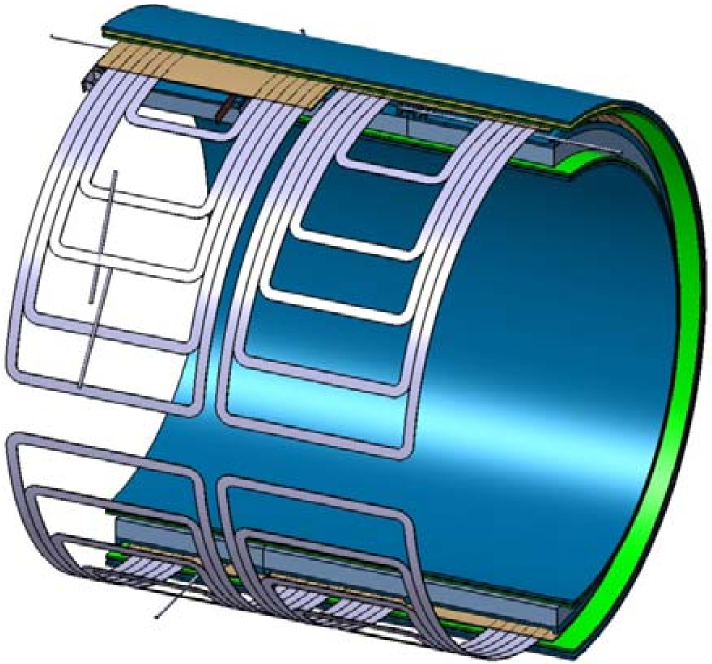


†B. Parker and A. Seryi, "Novel Method of Compensation of the Effects of Detector Solenoid on the Vertical Beam Orbit in a Linear Collider," Rev. Mod. Phys. 2727(84) , April 2005. DOI: 10.1103/PhysRevSTAB.8.041001

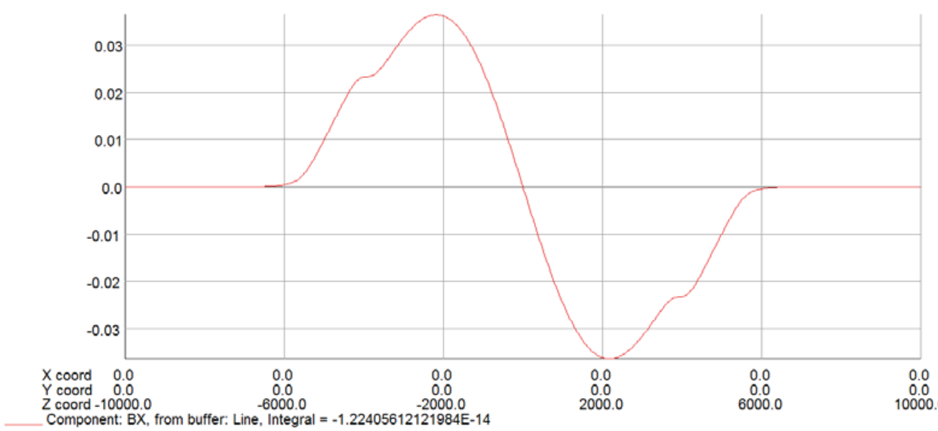
Conceptual Design - BDB Version 1

Requirement:

- Max field Bx 0.035 T at z = 3m



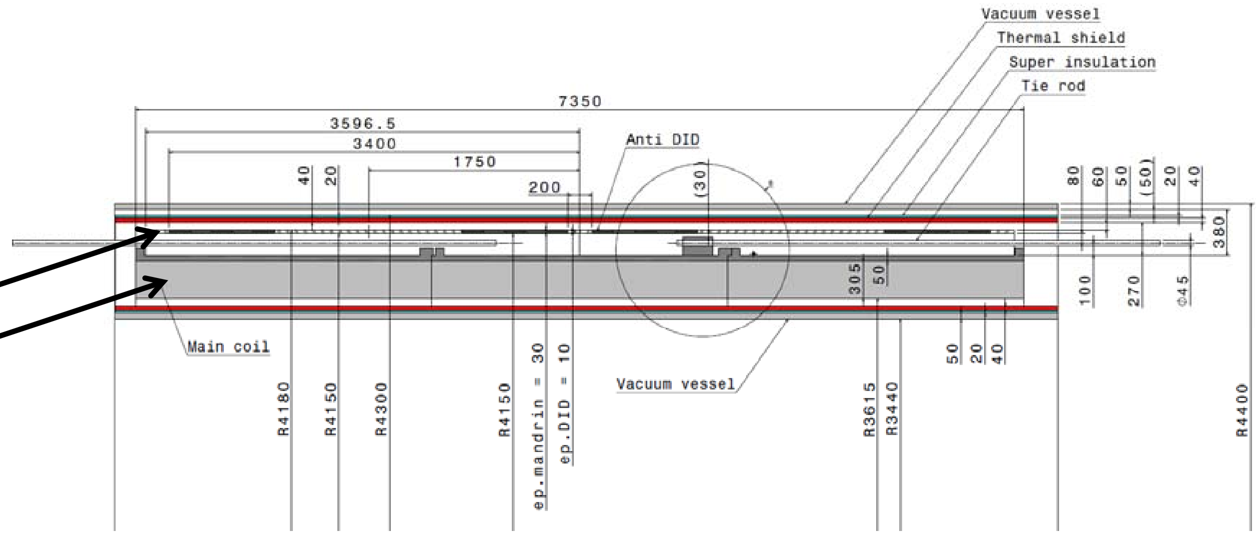
Dipolar Field



Opera

Saclay group
Magnet note
LC-DET-2012-081

Integration in Cold Mass

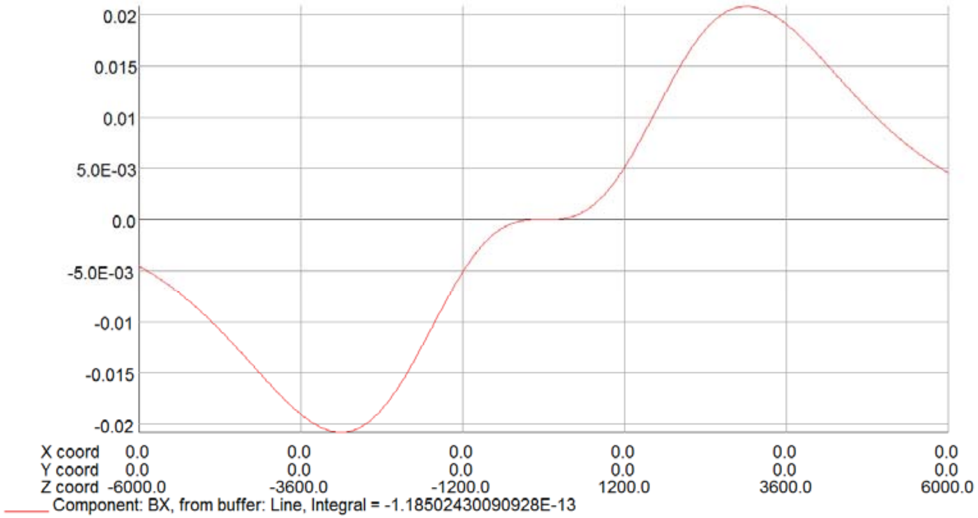


Anti DID
Main Coil

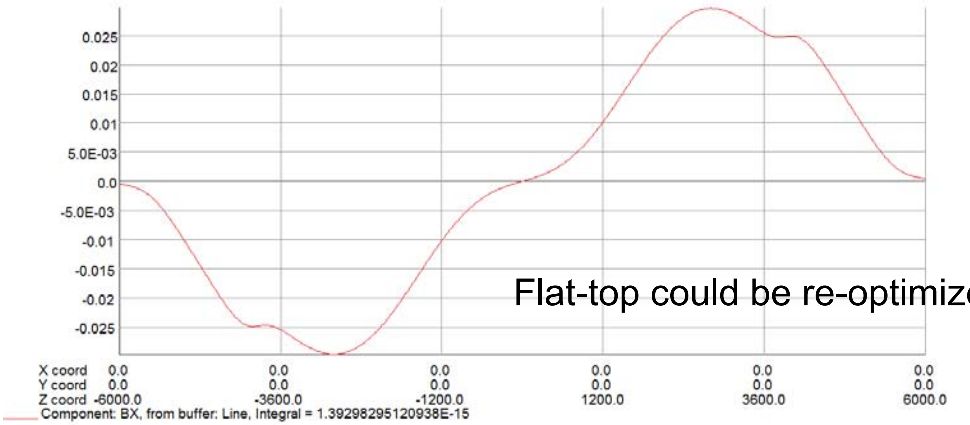
Conceptual Design - DBD Version 2

Saclay group
Magnet note
LC-DET-2012-081

Dipole Field w/o Yoke



Dipole Field with Yoke



Flat-top could be re-optimized

Requirements:

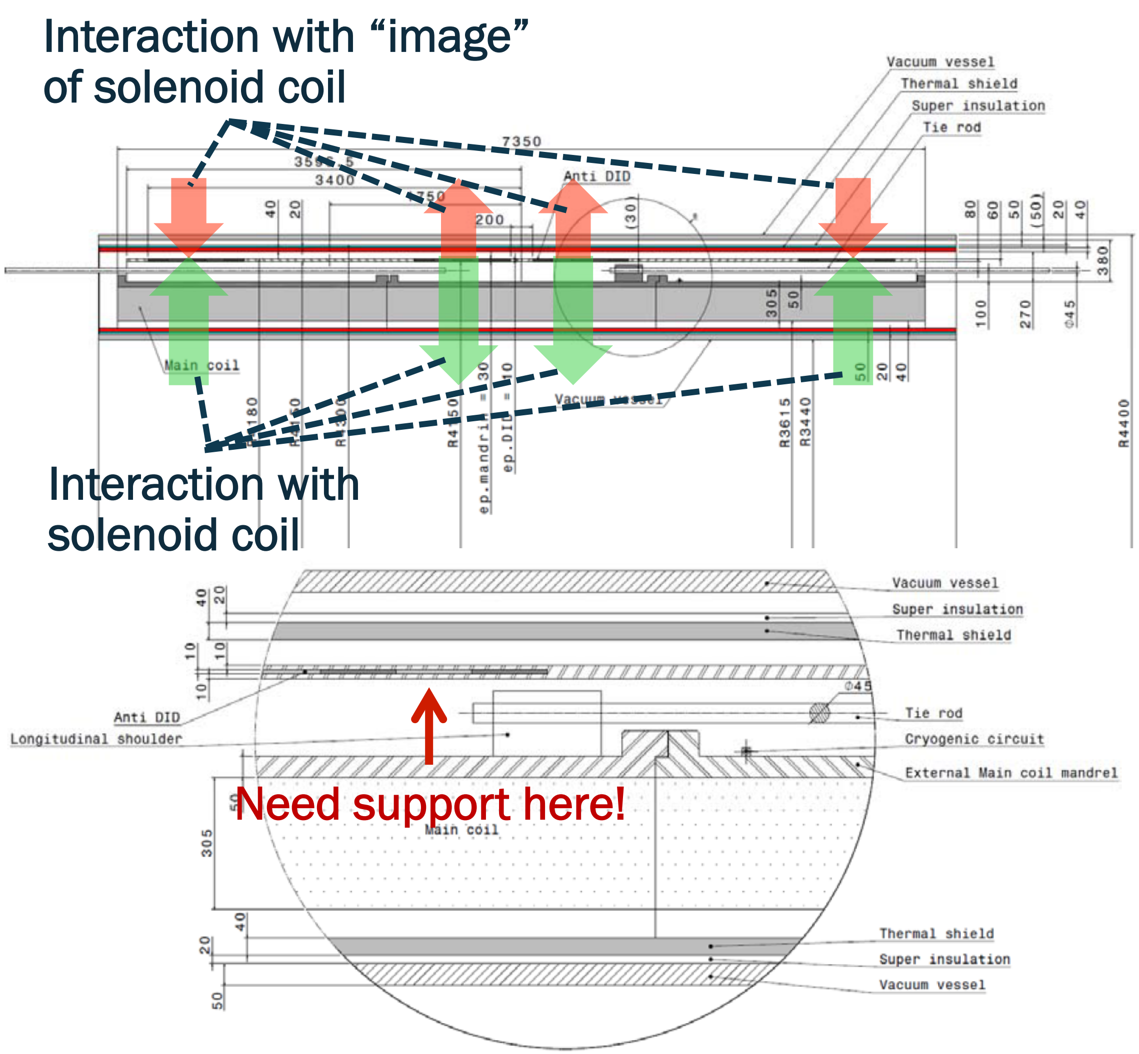
- Max field Bx 0.035 T at z = 3m
- Flat-top zero field ± 0.5m around IP

Coil Design

- Each dipole consists of 2 parts
  - Different, much higher currents
- Coils are complicated
- Should be avoided if not absolutely necessary (B.Parker)

Some AD Construction Considerations

Slide B. Parker



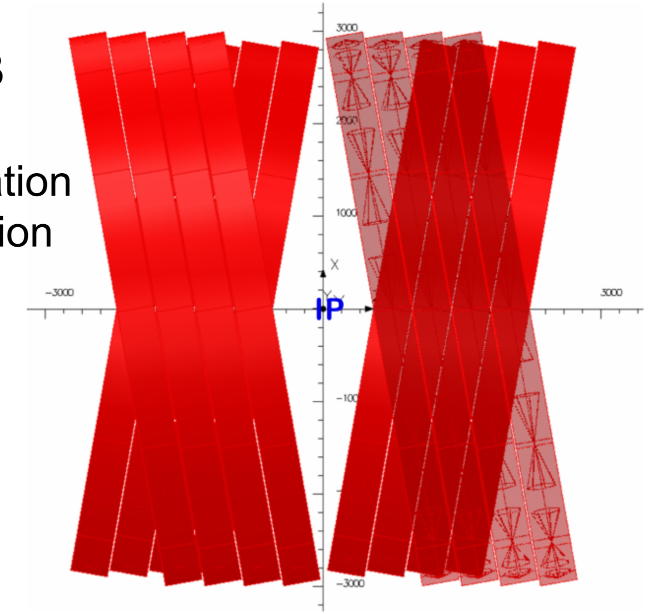
- AD should not experience any net force due to main solenoid but each AD half experiences net torque from forces at ends.
- Torque leads to a bending moment in horizontal plane.
- End turn forces are reduced a bit due to magnetic interaction with yoke (image of main solenoid in the highly saturated yoke).
- Bending forces should be calculated if AD structure is not supported at critical points (structure looks quite thin).
- Method A has pattern gaps to make radial connections to outer cryostat; the Method B coil covers most of the available surface.

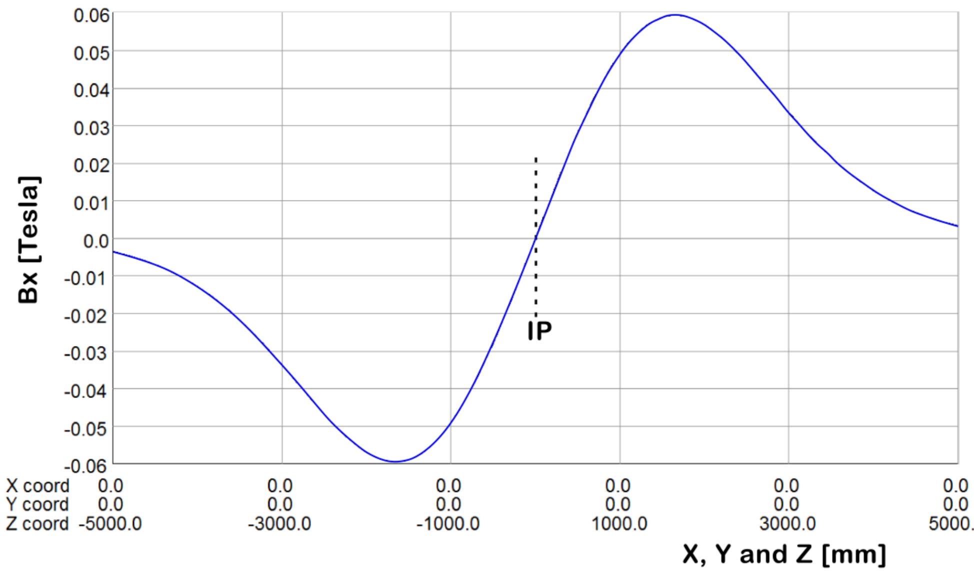
Different Anti-DID Production Geometry

Slide B. Parker

Method B

Approximation for simulation





- Consider using helical coil† (also know as canted coil) winding technique to produce anti-DID; setup makes transverse field but does not couple to main solenoid.
- Scheme is schematically illustrated above where we have tilted the solenoidal turns in two different radial layers in opposite directions and given them opposite currents.
- The longitudinal field, B_z, from the two layers cancels the transverse field component, B_x, adds constructively to give the field profile shown (“air coil” example).
- Should consider winding such “solenoid like” coils on separate structure. Could be integrated with main solenoid cold mass and independently powered.

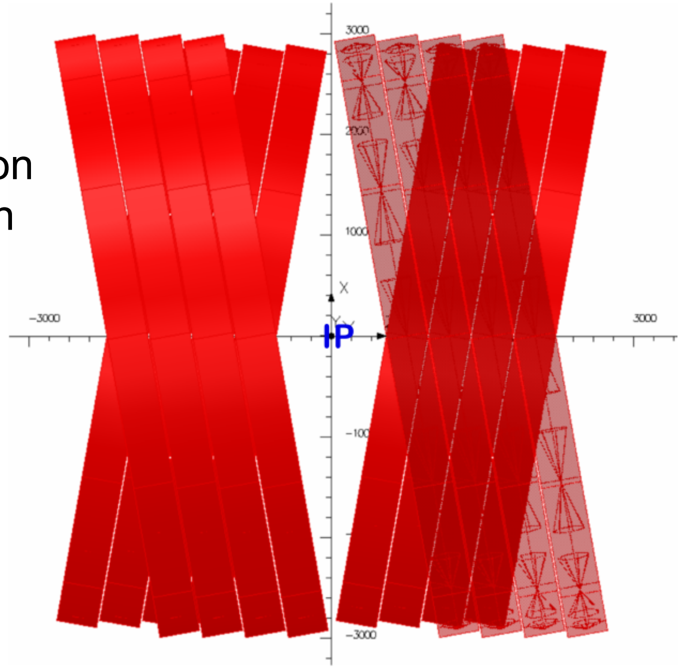
†H. Witte, et.al., "The Advantages and Challenges of Helical Coils for Small Accelerators—A Case Study," IEEE TRANSACTIONS ON APPLIED SUPERCONDUCTIVITY, VOL. 22, NO. 2, APRIL 2012.

Different Anti-DID Production Geometry

Simple Two Layer Anti-DID Coil, Top View

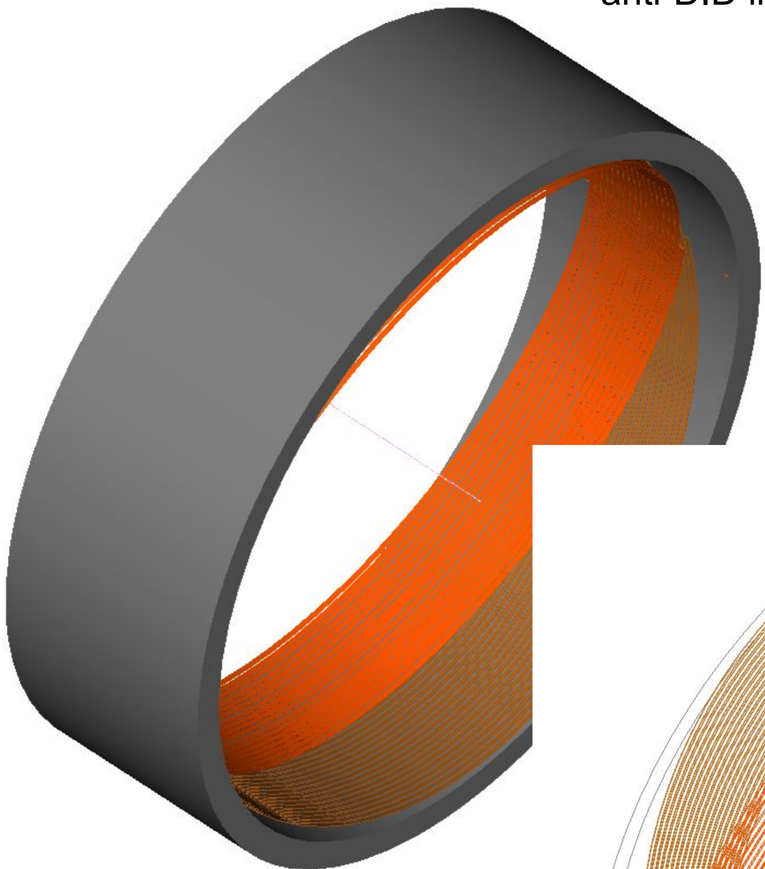
Method B

Approximation for simulation



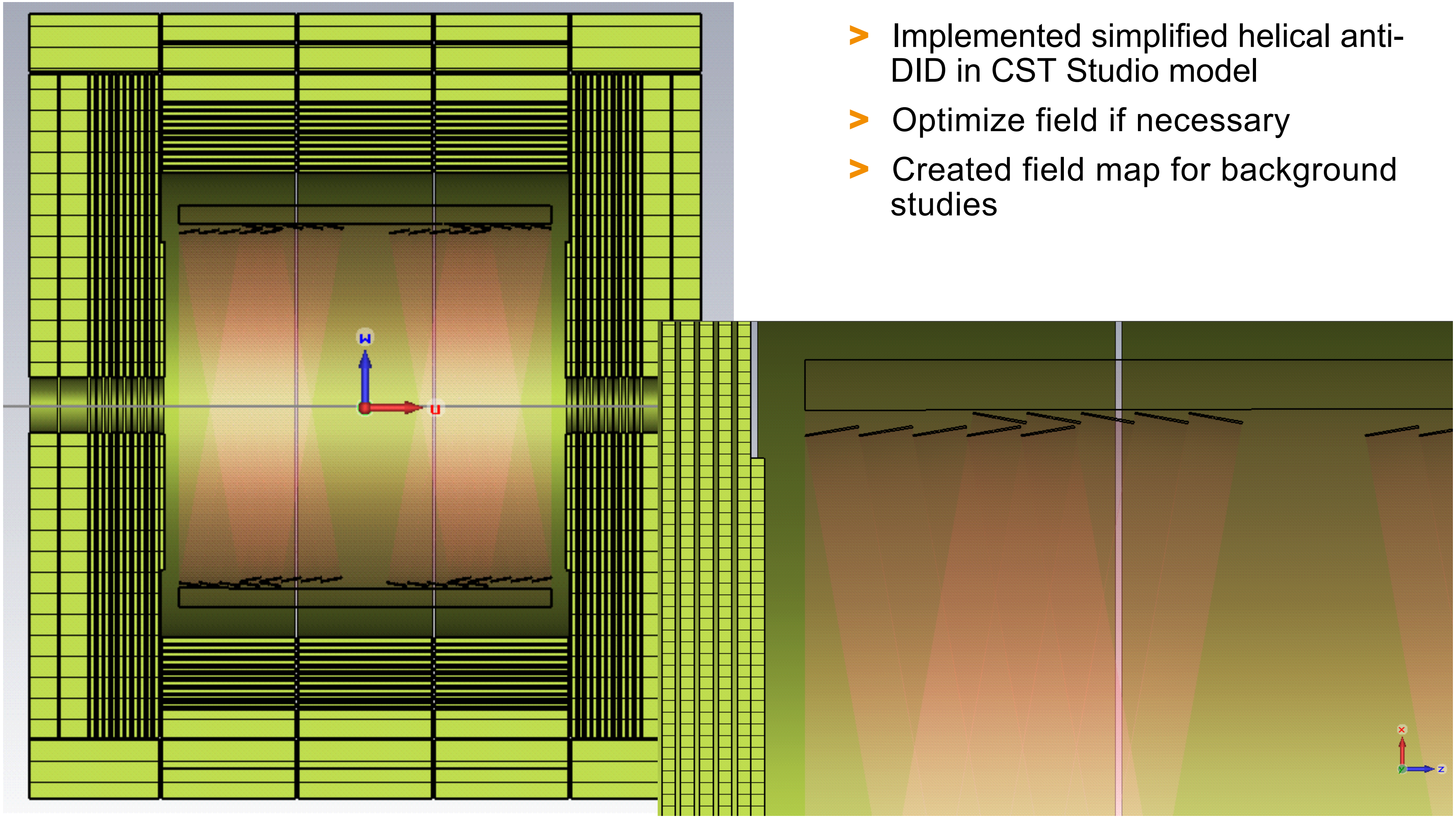
Direct wind scheme

anti-DID inside main solenoid



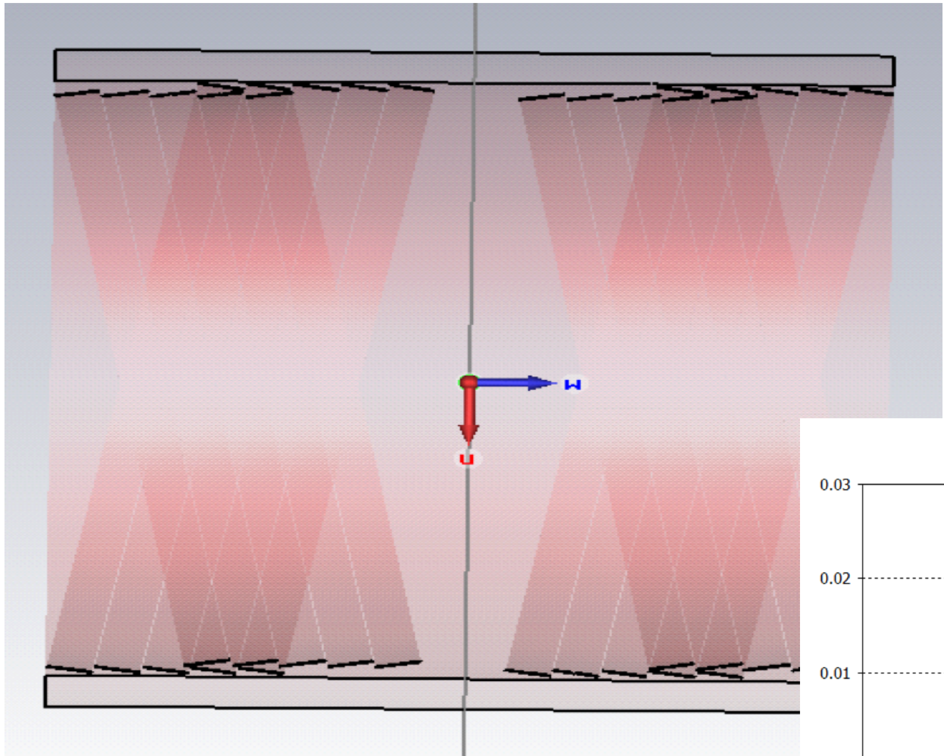
sketch
R.Stromhagen

Field Calculations

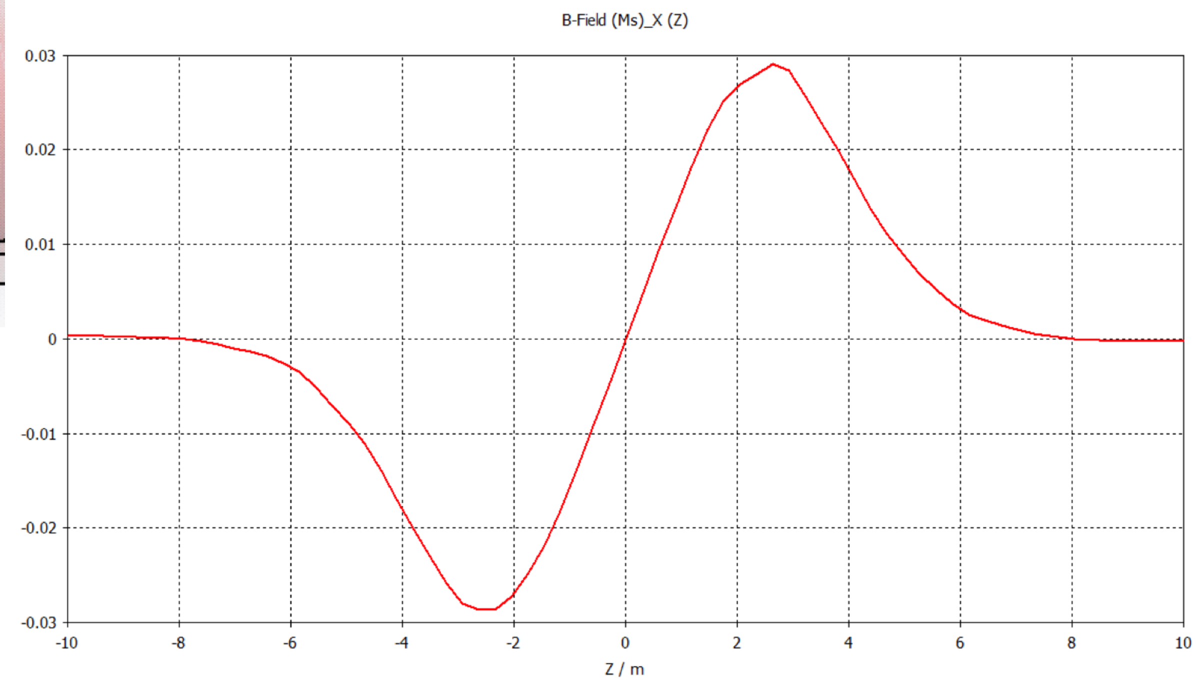


- Implemented simplified helical anti-DID in CST Studio model
- Optimize field if necessary
- Created field map for background studies

Field Calculations



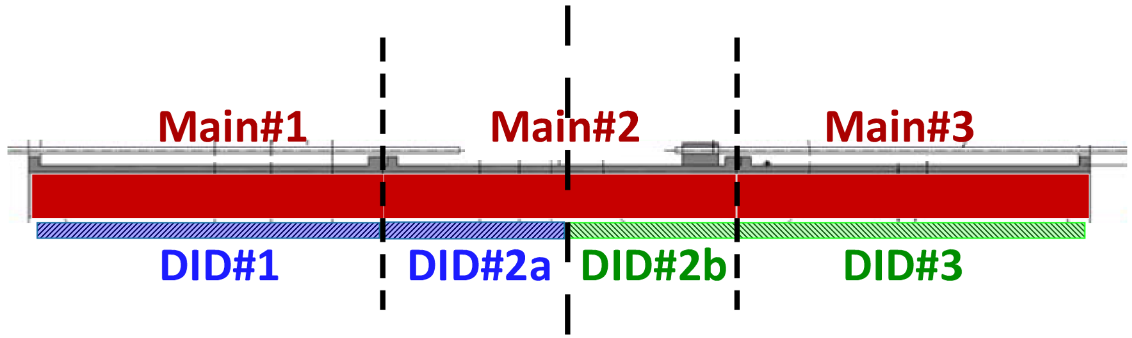
Field with inner two coils off
B_x vs. z



Generated field map used for present background study

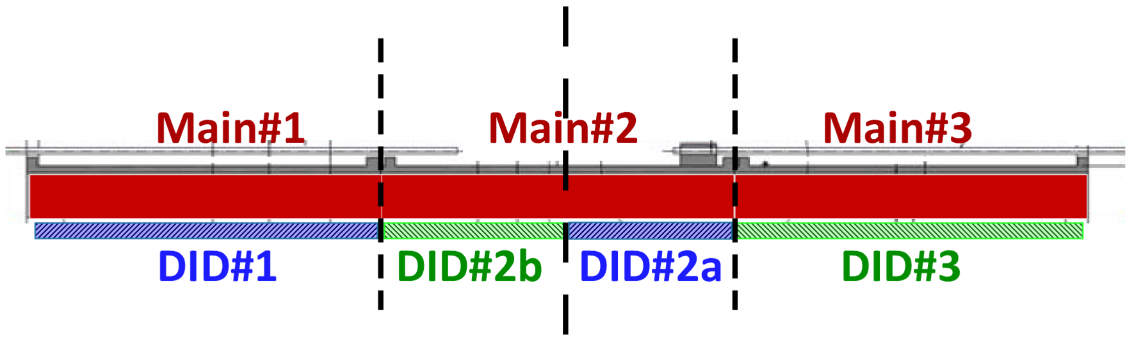
Some AD Construction Considerations

Anti-DID wound with three sections



... and full asymmetry.

Anti-DID wound with three sections



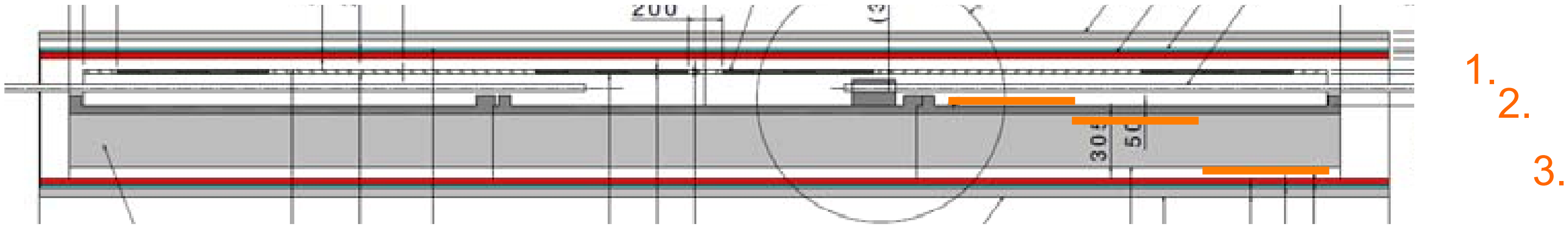
... and reduced central field.

Slide B. Parker

- With main ILD solenoid being wound in three sections, consider also winding helical coil option (Method B) in three independent sections.
- Fundamentally not possible with standard outside surface winding (Method A).
- Note to preserve proper anti-DID symmetry central section must be subdivided into two shorter coils.
- But if there is still a desire to "flatten" the central field region, this could be accomplished by swapping the center section anti-DID polarities.

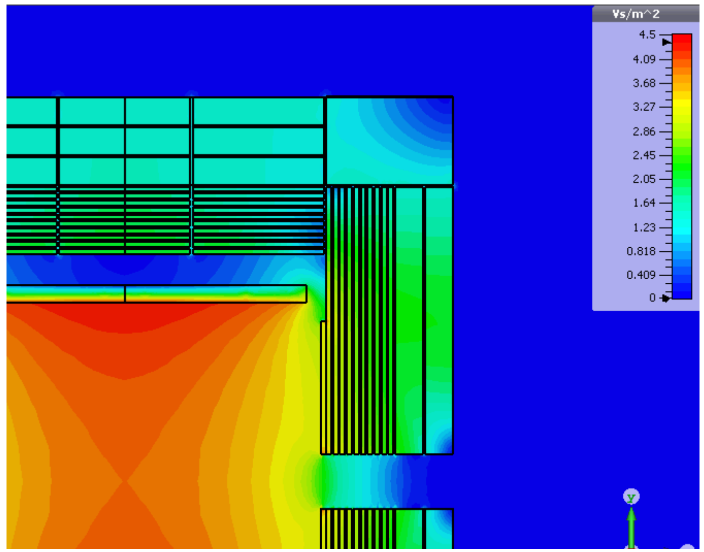
Option to wind anti-DID on one (or two) section(s) and then integrate it with main solenoid by insertion after the three main sections are vertically stacked.

Different Anti-DID Production Geometry



Location of direct wind anti-DID conductor

1. Outside solenoid support cylinder
   - In conflict with cooling tubes, current leads and tie-rods
   - Low magnetic field, low forces
   - Would require new, additional winding machine
2. Between support cylinder and solenoid
   - Reduced cooling contact between solenoid conductor and support
   - Transfer of forces during quench
   - Still low magnetic field and forces
   - Could use modified main winding machine
3. Between support cylinder and solenoid
   - Still low magnetic field and forces
   - Could use modified main winding machine



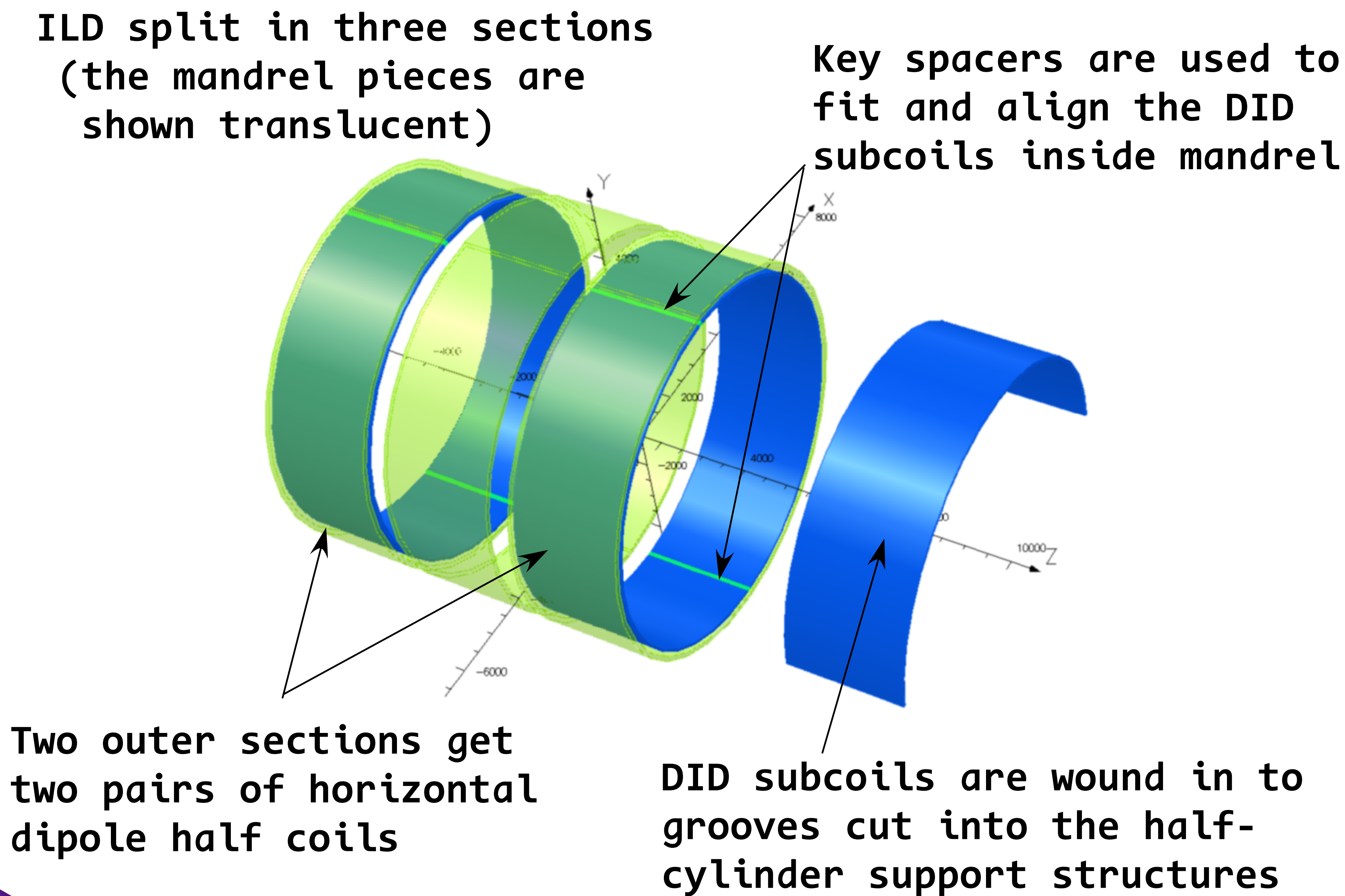
Meeting at CERN with CMS magnet experts
(B.Parker. H.Gerwig, B.Cure   Dec. 2016)

Propose

> Anti-DID between solenoid and support (2.)
> Conductor in grooves cut into support cylinder
> Use dipole winding

New Concept – B.Parker

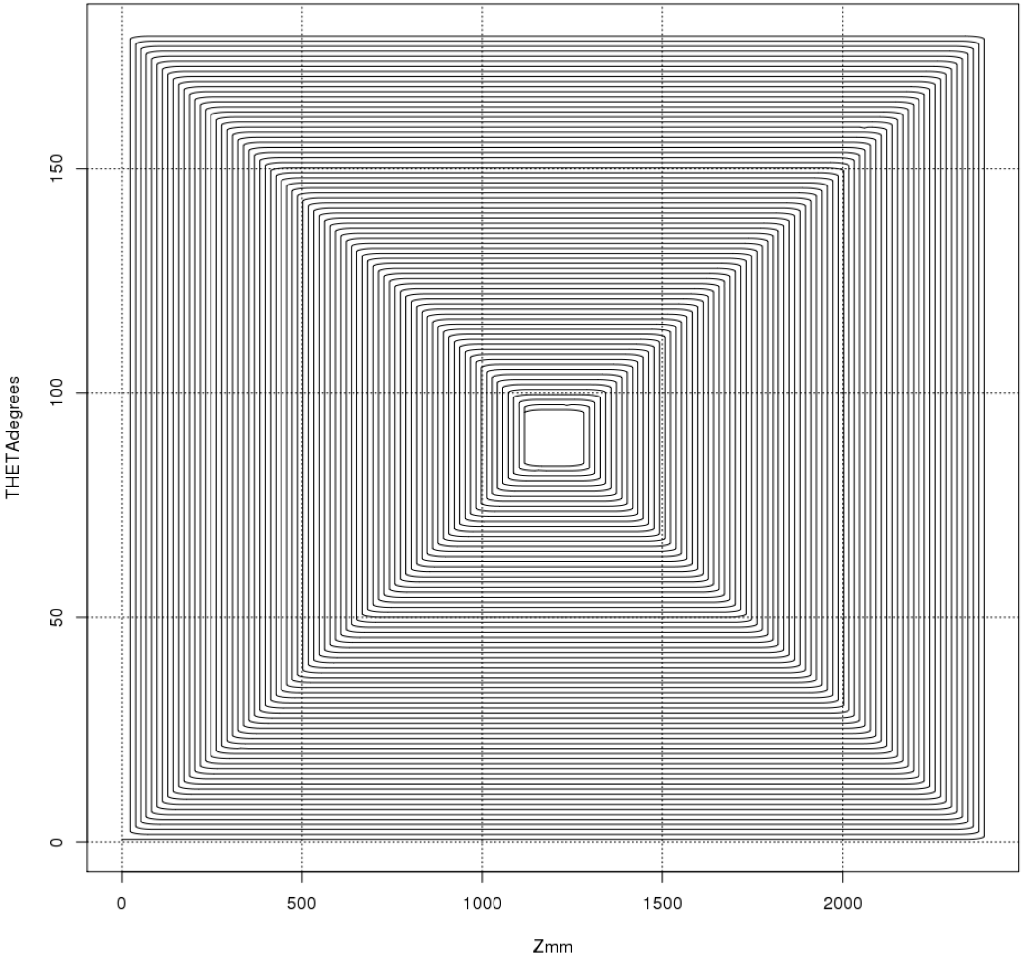
Slide B. Parker



New Concept – B.Parker

Slide B. Parker

Z-Theta Projected View of Subcoil Pattern



Note:

- Uniform z-spacing.
- Uniform angular spacing.
- Nearly uniform* bend radius at the corners for each turn.

*As shown on the next slide one set of the four corners must be different due to the need to connect turn N to turn N+1.

Comment on inner part of winding (U.S.):

- Not important for B-field
- Main reason transfer of forces and heat due to spacing to conductor

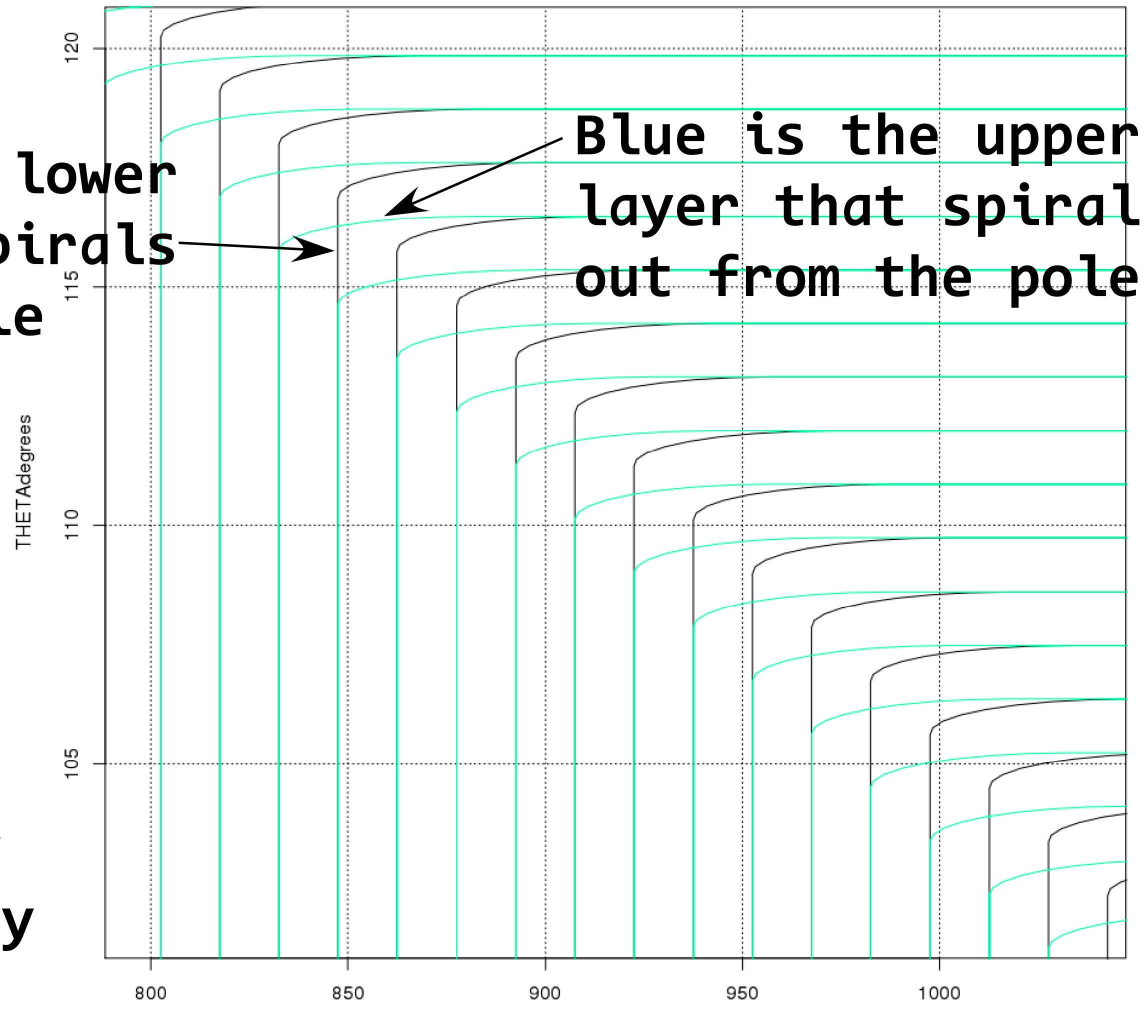
New Concept – B.Parker

Slide B. Parker

Close Up View of Two Layers Wound On Top of Each Other

Black is the lower layer that spirals in to the pole

Blue is the upper layer that spirals out from the pole

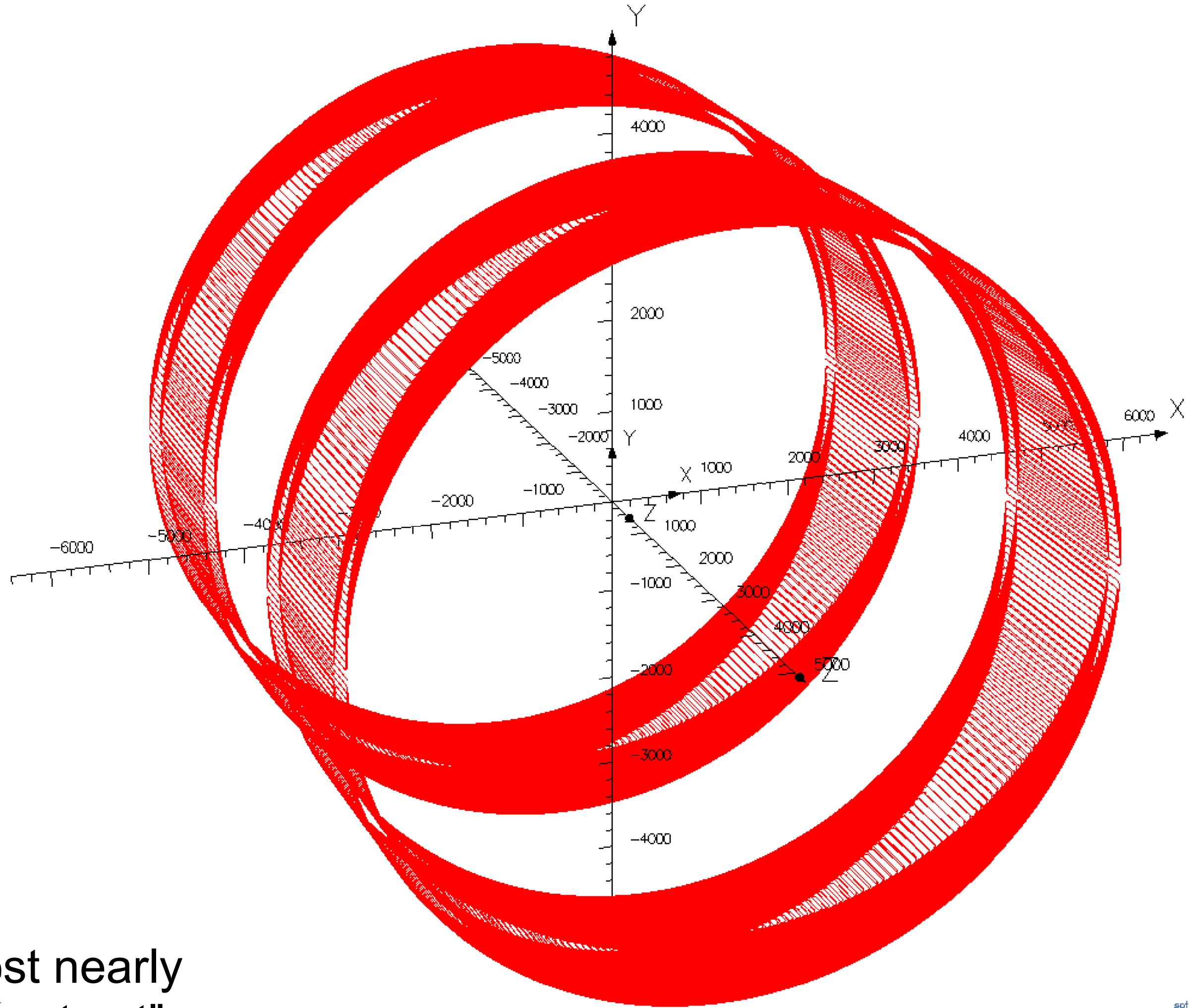


Note that at the other three corners of a given turn, the inner and outer layers are wound directly on top of each other (they share the same groove)

New Concept – B.Parker

Slide B. Parker

ILD anti-DID Coil Using the Two Outer Solenoid Sections

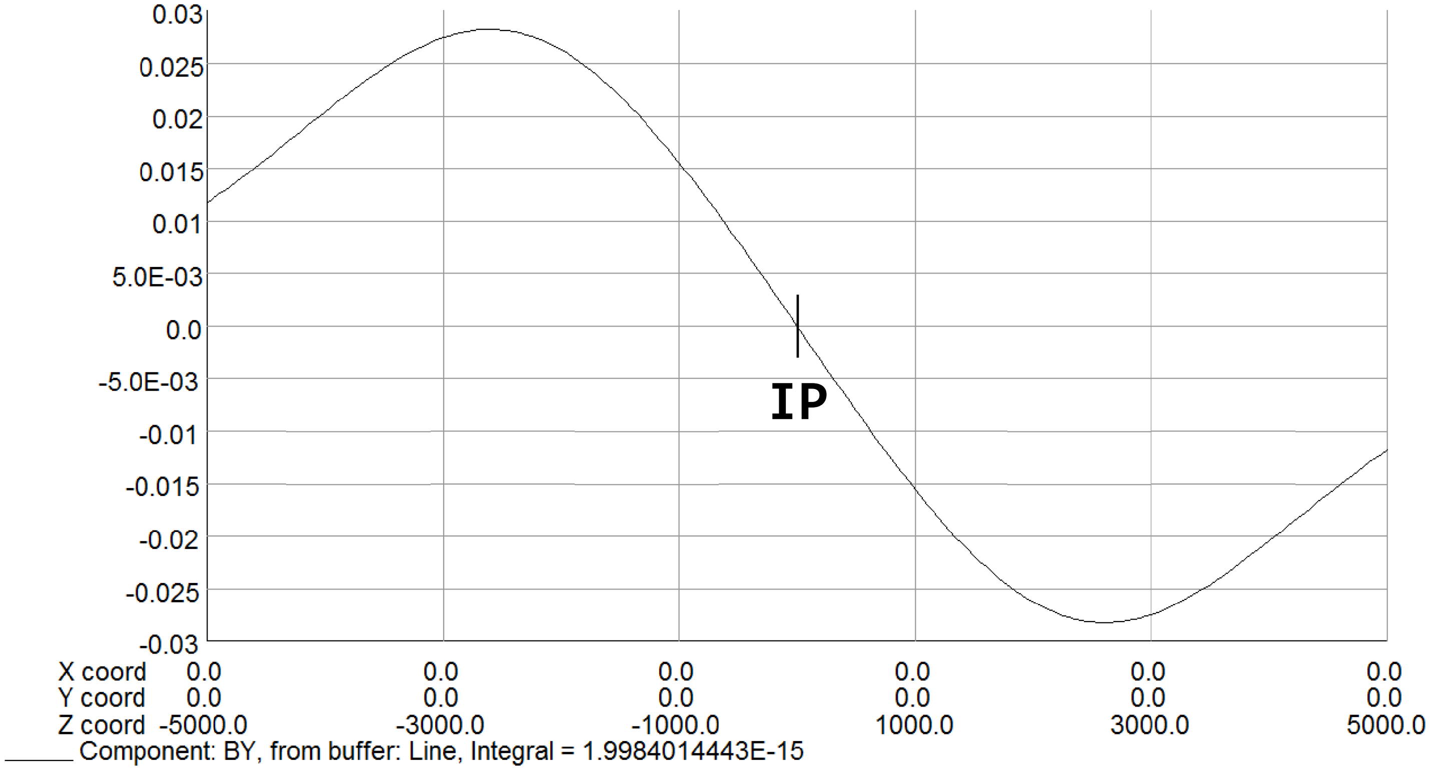


Brett: " the most nearly buildable concept yet"

New Concept – B.Parker

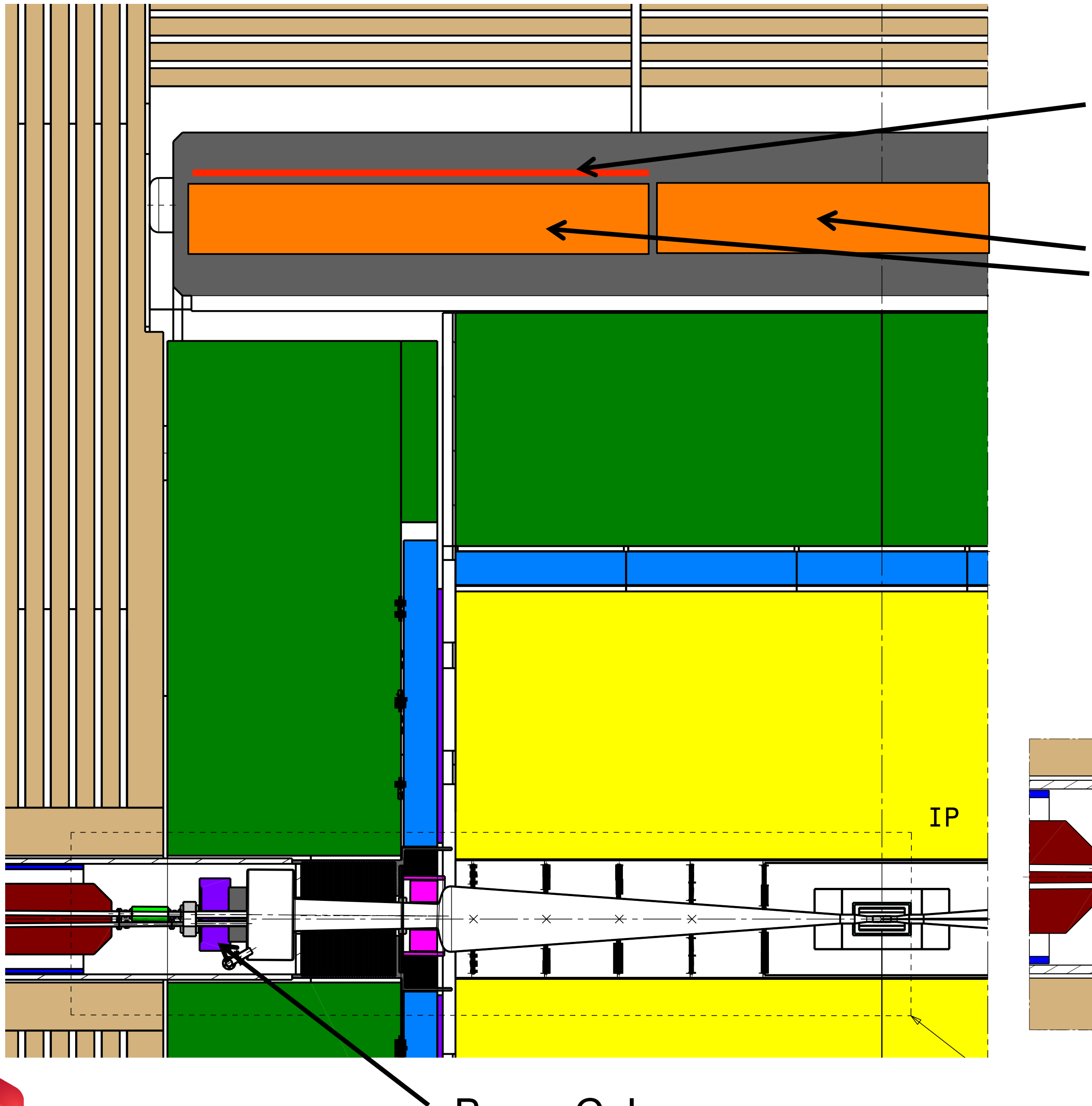
Slide B. Parker

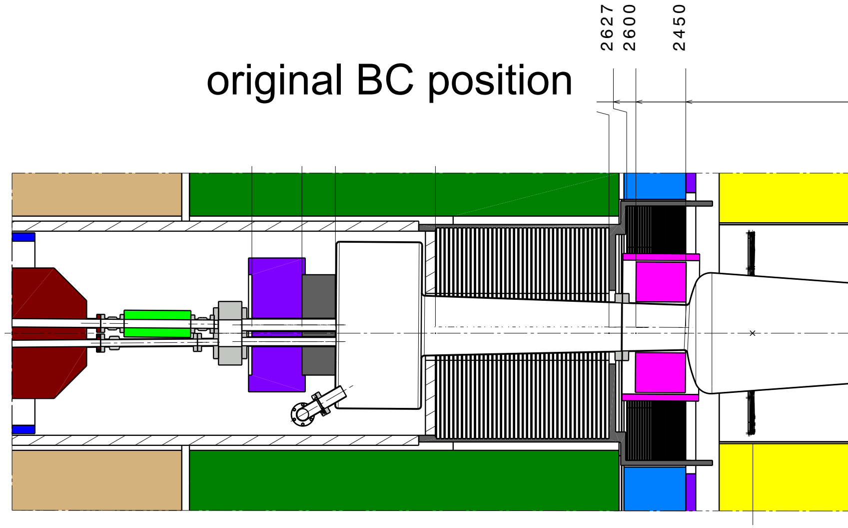
Field Profile From Simple Double Air Coil*



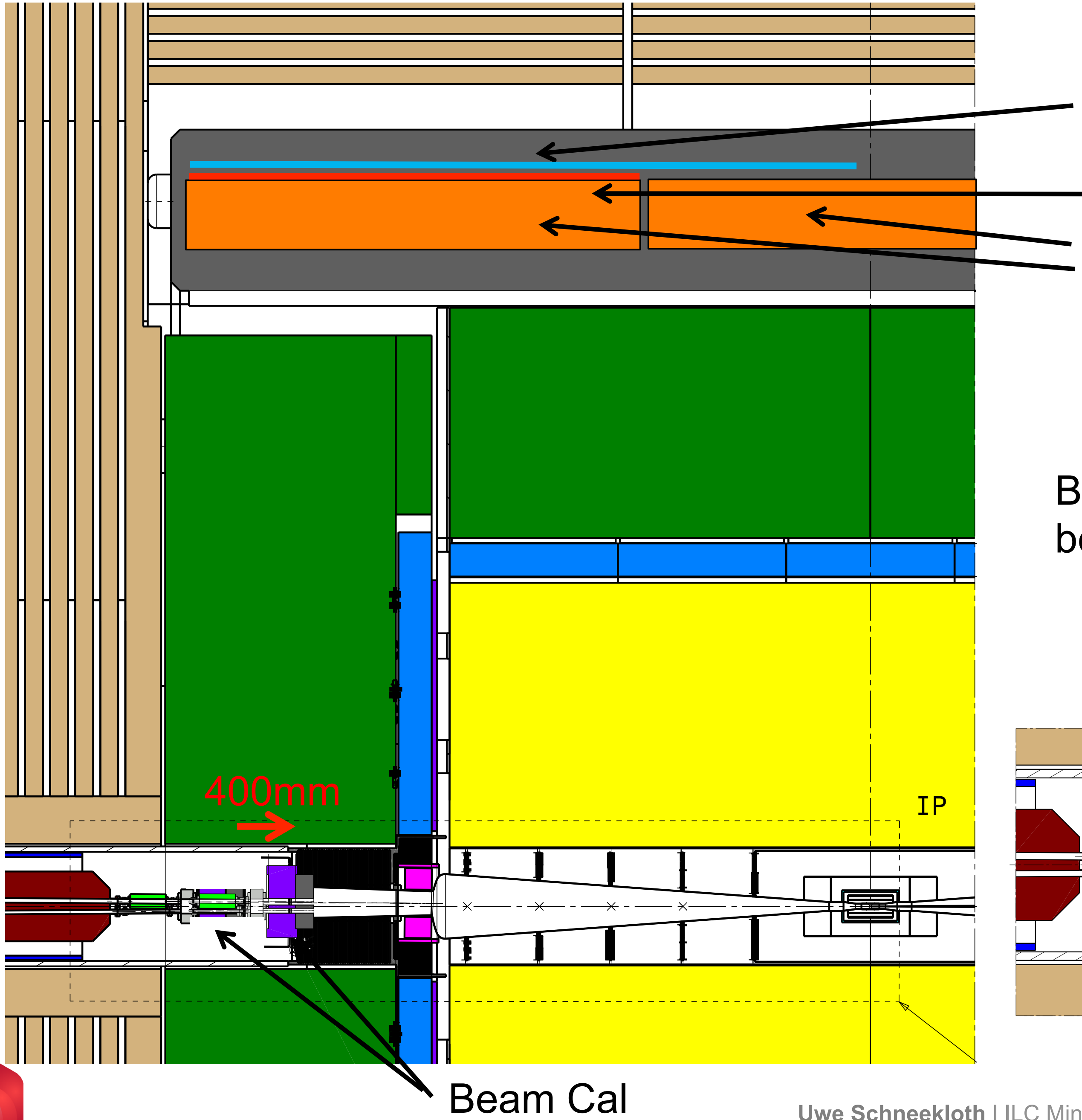
*For ILD this coil needs to be rotated 90 degrees to create horizontal field, Bx, instead of By shown. Also the ILD yoke with enhance the the peak fields shown while truncating the long-range field tails of this air coil at the yoke ends.

Solenoid – Beam Cal

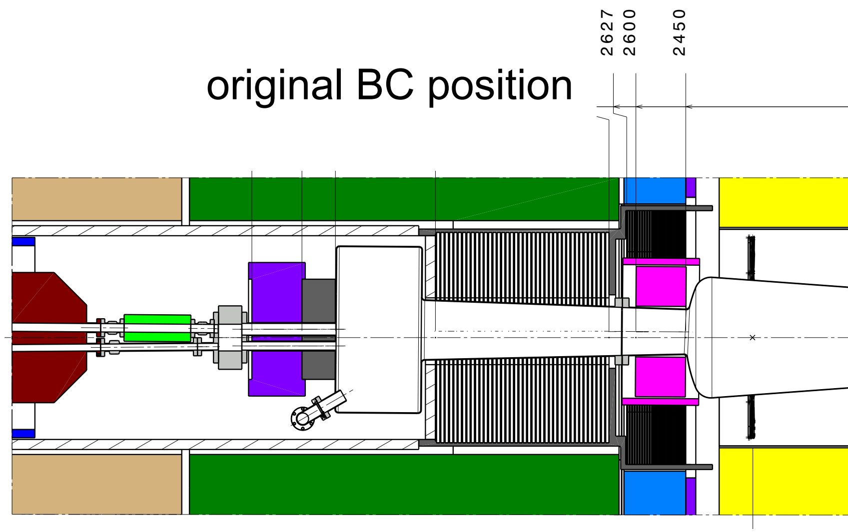




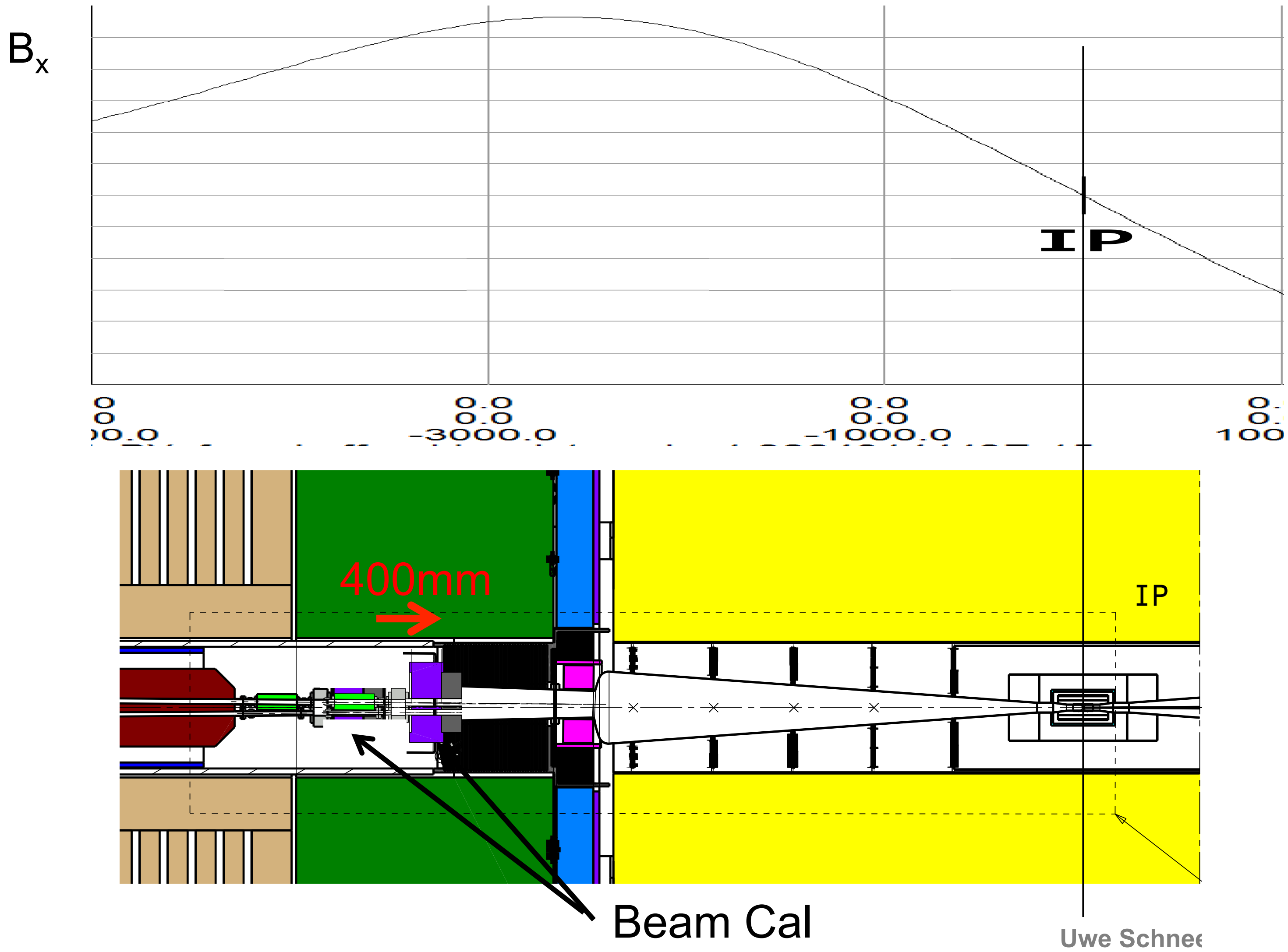
Solenoid – Shifted Beam Cal (l* 4m)



Background simulation should be performed with shifted BC



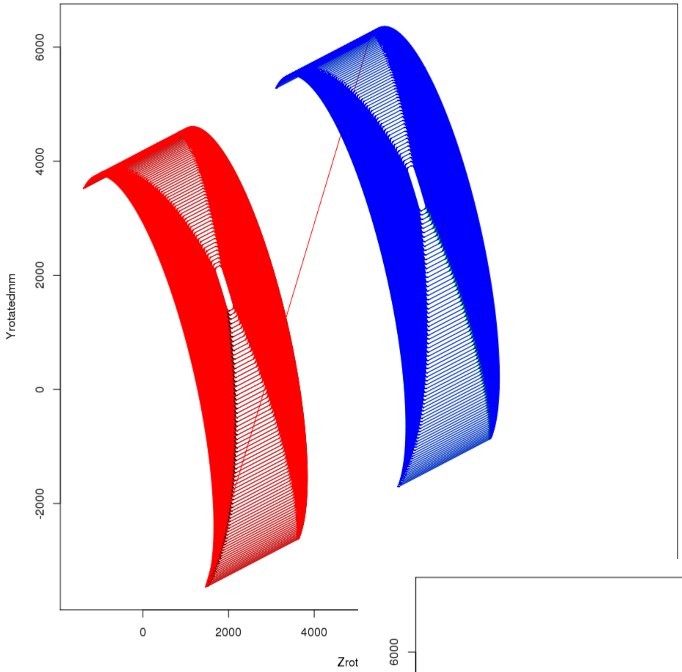
Solenoid – Shifted Beam Cal (l^* 4m)

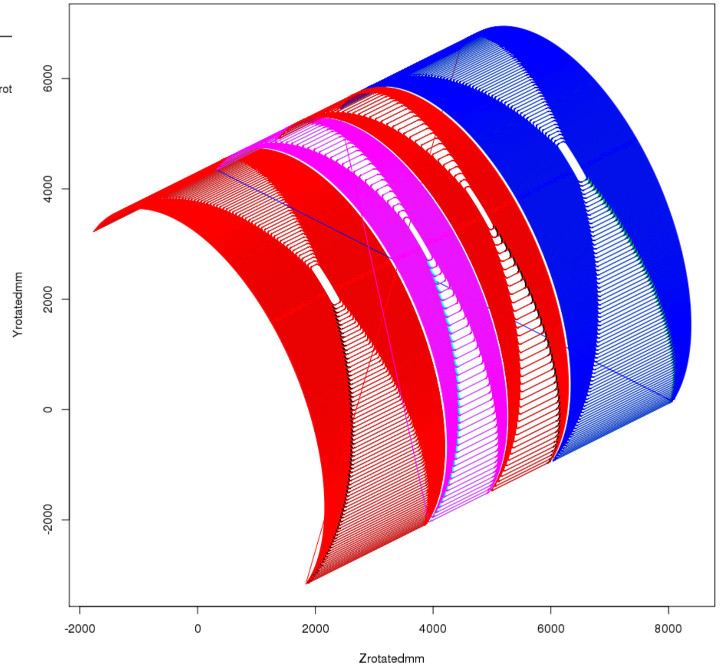


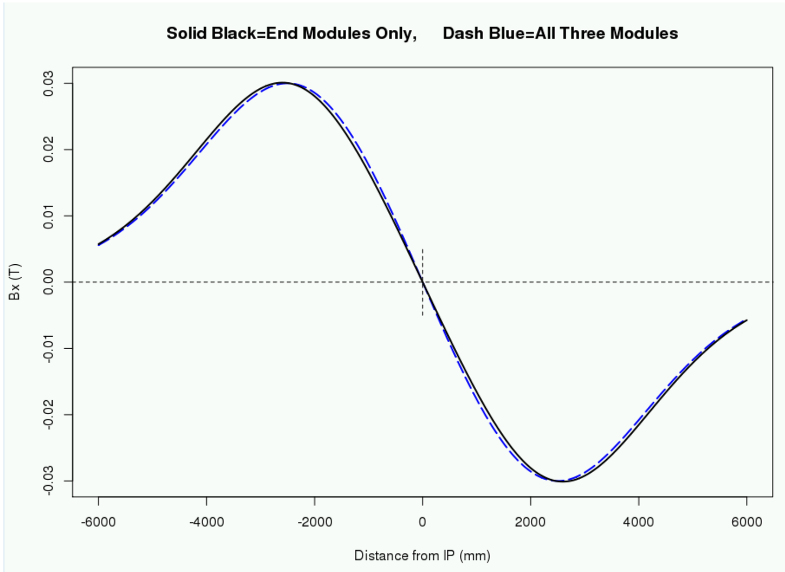
- Field for anti-DID in outer solenoid modules
- Max. field would be shifted towards IP if anti-DID over whole length of solenoid
- Field will be distorted by iron yoke

New Concept – Anti-DID in all Modules

B. Parker



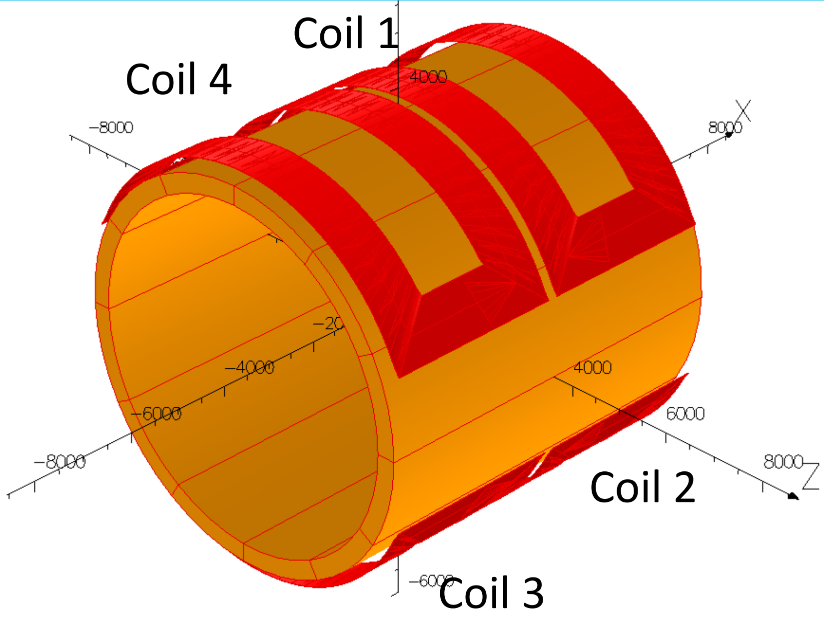


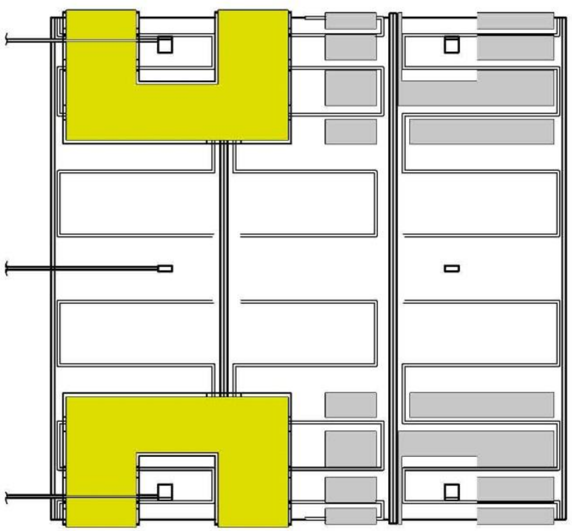


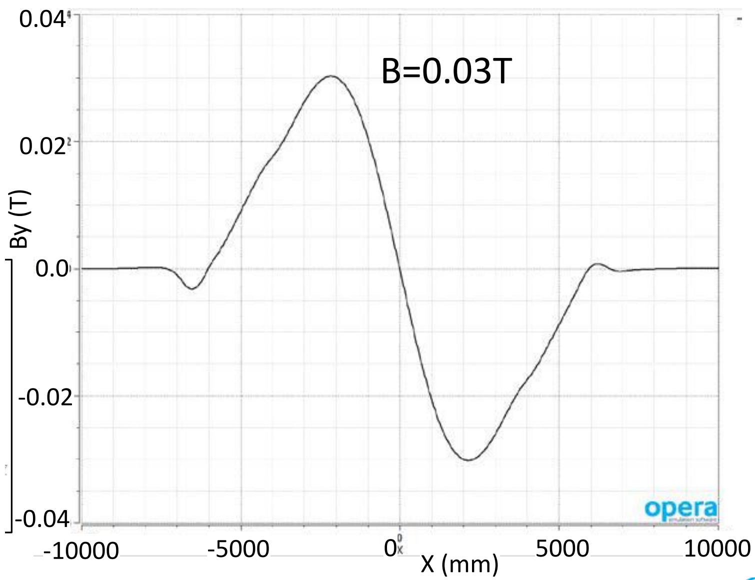
- No significant shift of peak field
  - Could increase current, but more complicated (peak current,…)
  - Not worth the effort
- Only option going back to independent anti-DID

Comments on Toshiba/Hitachi Design

- Peak of B-field again shifted towards IP (+)
- Needs new, additional winding machine (-)
- Divided coil:
  - Additional complication
  - Field even more inhomogeneous
  - Hopefully, not required for transport. Not very large and heavy.
- Have to check machining tolerances of solenoid mandrel, spacers and anti-DID coils







Conclusions

Recent progress

- Independent anti-DID versus integrated into solenoid modules

  Independent anti-DID

  - Issue with support and forces
  - Max. field close to IP

  Integrated into outer solenoid modules

  - Recently, good progress on conceptual design
  - Max. field closer to Beam Cal
  - (Integrating anti-DID into all three modules not worth the effort)
- Back to more traditional like dipole coils
  - Helical/tilted compensating solenoids more difficult to integrate into solenoid modules
- Should compare new B.Parker design with Toshiba/Hitachi design
- Need background simulations (in progress)