PBL
Particle Beam Lasers

Brookhaven National Laboratory

U.S. DEPARTMENT OF ENERGY

Optimum Integral Dipole STTR for EIC

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Content

- **Introduction to the Optimum Integral Design – why and what?**
- **Application of the Optimum Integral Design to EIC**
- **Status of the Program**
- **Work/Tasks Remaining and Major Technical Challenges**
- ***Impact on and Possible Application to other EIC Magnets***
- ***Summary***

Work Focused with the Direct Wind Technology

Background material taken from these two presentations - Excellent and complete set of slides on the "Direct Wind" Technology and on the Serpentine Design.

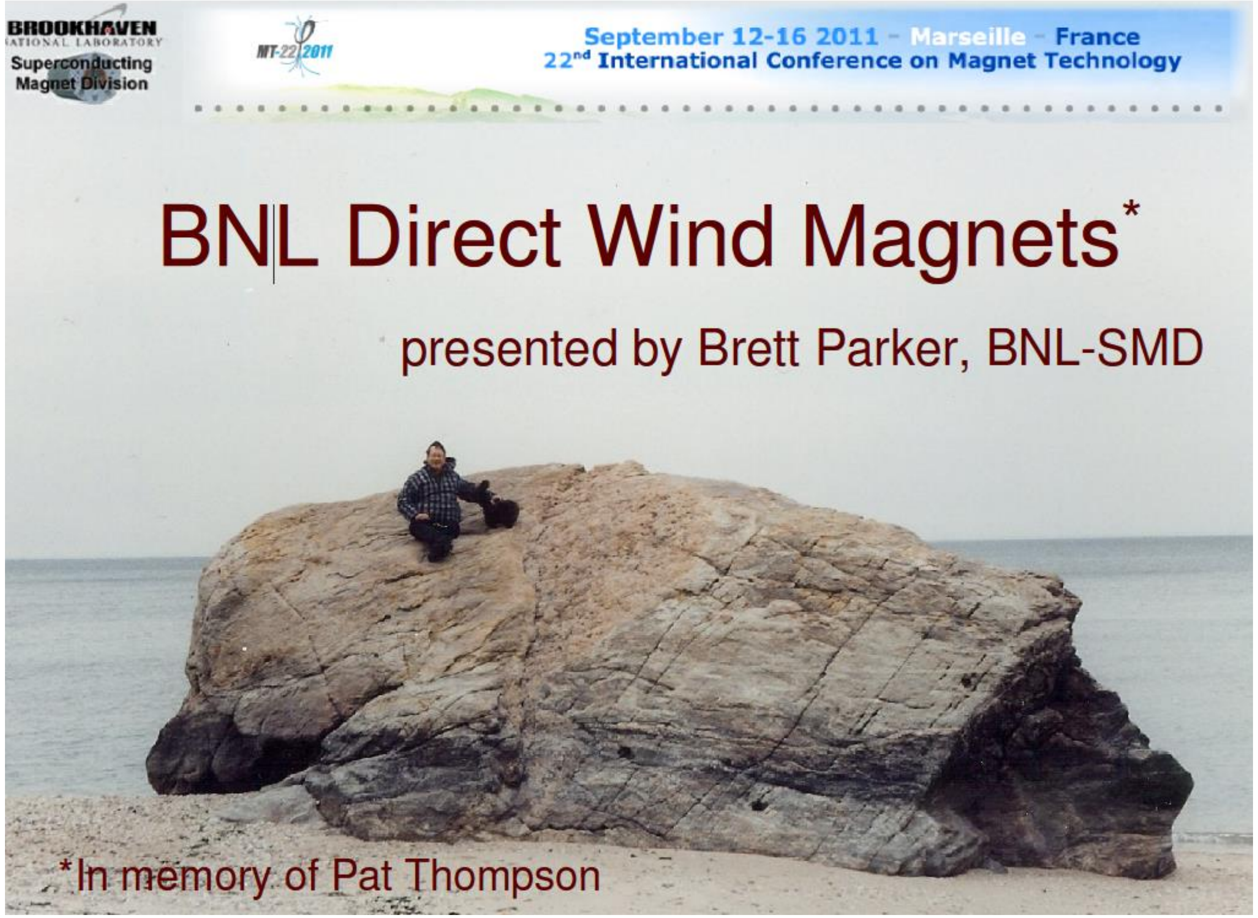
National Synchrotron Light Source II

Direct Wind Magnet Technology

John Escallier

U.S. DEPARTMENT OF ENERGY | Office of Science

BROOKHAVEN NATIONAL LABORATORY



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Superconducting Magnet Division

MT-22 2011

September 12-16 2011 - Marseille - France
22nd International Conference on Magnet Technology

BNL Direct Wind Magnets*

presented by Brett Parker, BNL-SMD

*In memory of Pat Thompson

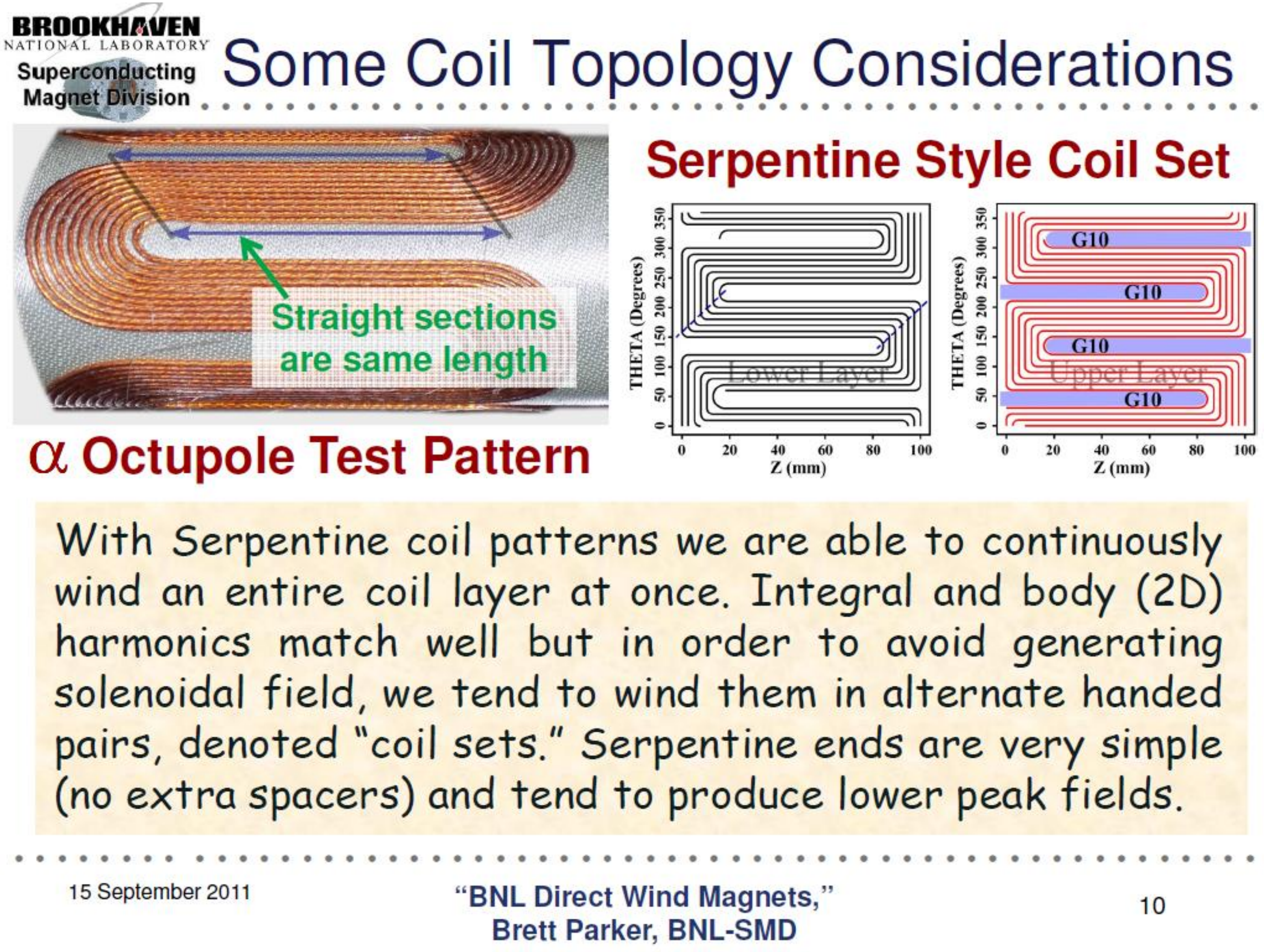
Though the general concept of optimum could be applicable more widely, this work is focused on the designs with the direct wind technology only

Serpentine Design – Workhorse of the Direct Wind

✓ **Design thanks to Brett Parker**

Major Advantages:

- **Continuous winding of the multipole coils (no interruption, no splice)**
- **Easy optimization: 3-d harmonics same as the 2-d harmonics (minor correction for finite bending radii in ends)**
- **Easy to bring out Leads**



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Some Coil Topology Considerations

Serpentine Style Coil Set

α Octupole Test Pattern

With Serpentine coil patterns we are able to continuously wind an entire coil layer at once. Integral and body (2D) harmonics match well but in order to avoid generating solenoidal field, we tend to wind them in alternate handed pairs, denoted “coil sets.” Serpentine ends are very simple (no extra spacers) and tend to produce lower peak fields.

15 September 2011

“BNL Direct Wind Magnets,”
Brett Parker, BNL-SMD

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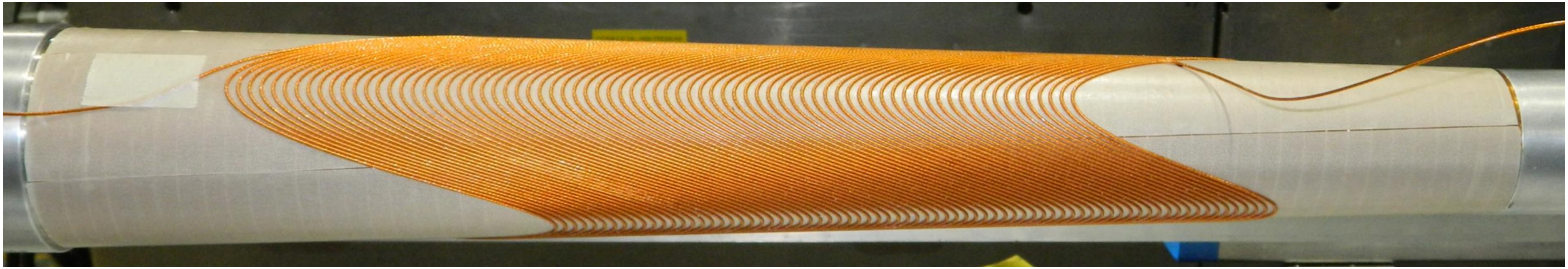
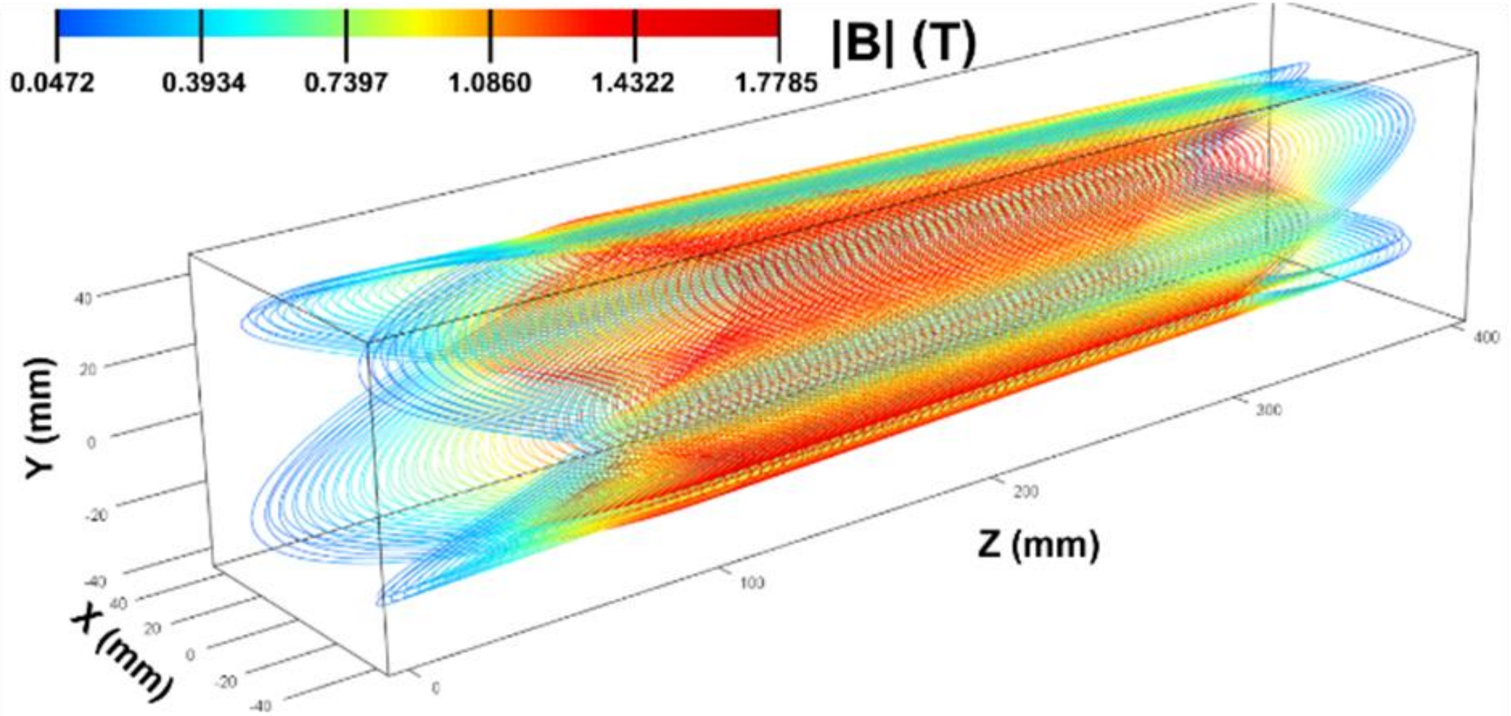
Double Helix



- **Being pursued on LDRD**

Major Advantages:

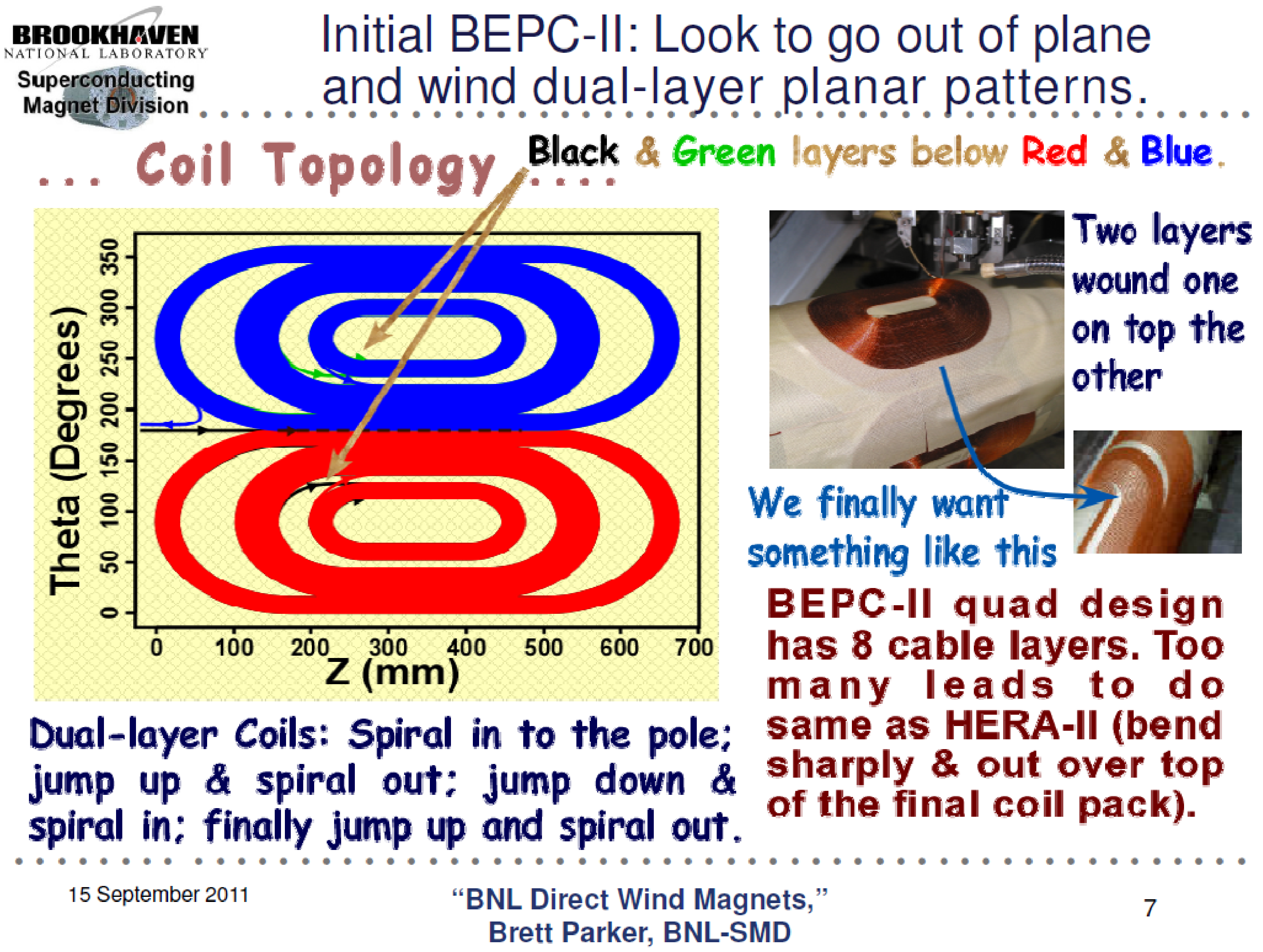
- **Easily adaptable to a tapered geometry**
- **Easy optimization**
- **Easy Leads out**



Cosine Theta Geometry: Used in Earlier Direct Wind Magnets

- X-section and ends must be optimized
- Leads at the pole (need extra radial space for lead out)

Note that the lead comes out at the pole



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Magnet Division

Initial BEPC-II: Look to go out of plane and wind dual-layer planar patterns.

... Coil Topology .... Black & Green layers below Red & Blue.

Two layers wound one on top the other

We finally want something like this

Dual-layer Coils: Spiral in to the pole; jump up & spiral out; jump down & spiral in; finally jump up and spiral out.

BEPC-II quad design has 8 cable layers. Too many leads to do same as HERA-II (bend sharply & out over top of the final coil pack).

15 September 2011

"BNL Direct Wind Magnets,"
Brett Parker, BNL-SMD

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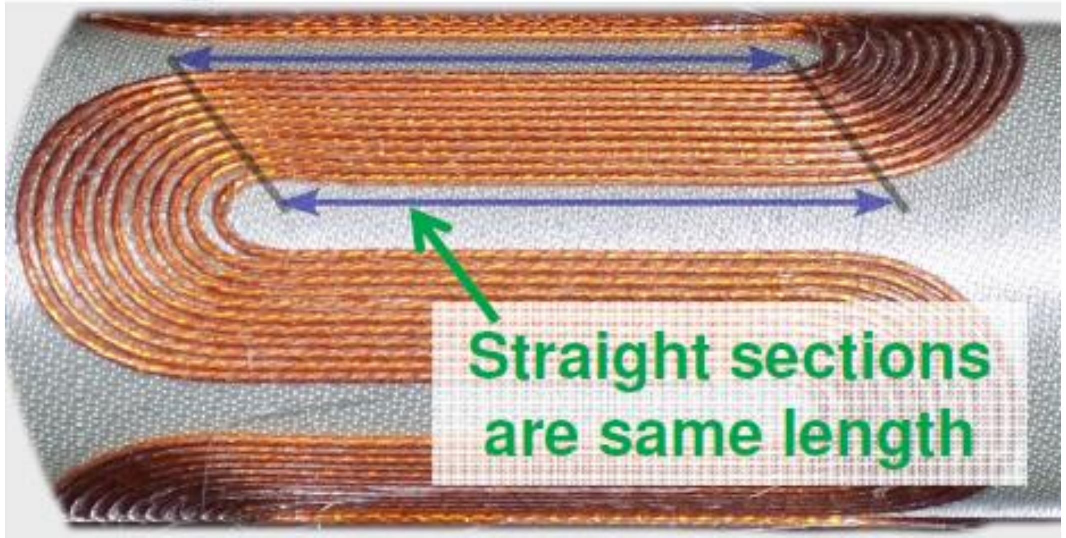
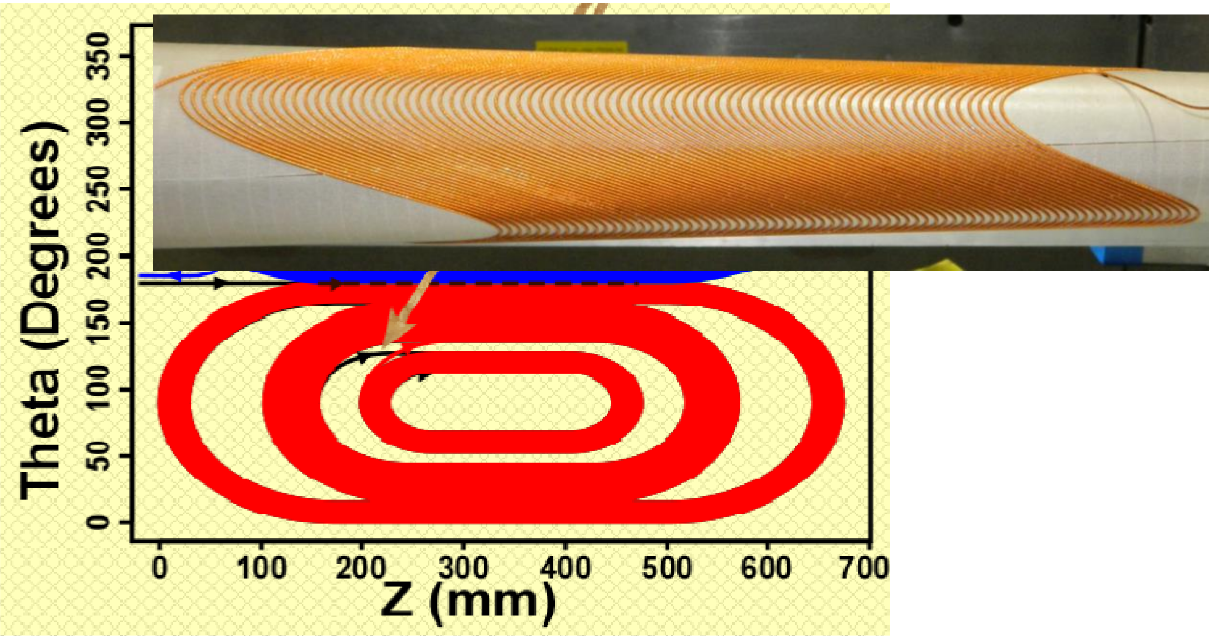
Unique Requirements of AGS Superconducting Corrector Dipole

Superconducting corrector dipole for AGS helical magnet had a tight space requirement (coil length smaller than two coil diameter)

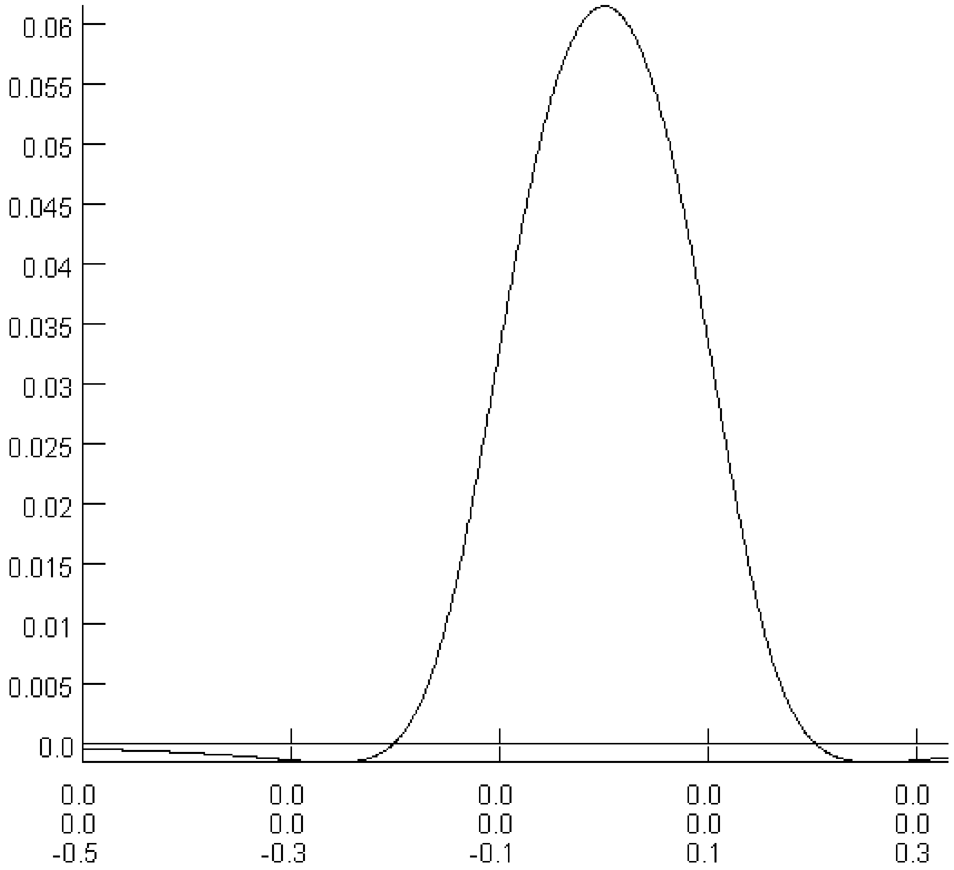
- ➢ *L=300mm for d=182.8 (2d=365.6)*
- *Space for turns in the Ends must be at least as much as that used in the arc of the straight section*
- *Means Straight section will have ~1/3 of the length even in a very tightly designed serpentine or double-helix or cos theta dipole*


Straight sections are same length



Trigger to the Integral Design Concept

- **In dipoles with length less than two coil diameter, there is no flat-top (or body of the magnet) in the axial field profile**
- **We typically design "body" of conventional or serpentine dipoles with cos(θ) type distribution of current**
- **Then we design "ends" for low harmonics and low peak fields**
- **Since field profile is not going to see "body" and "ends" separately, why not design two together in an integral sense**

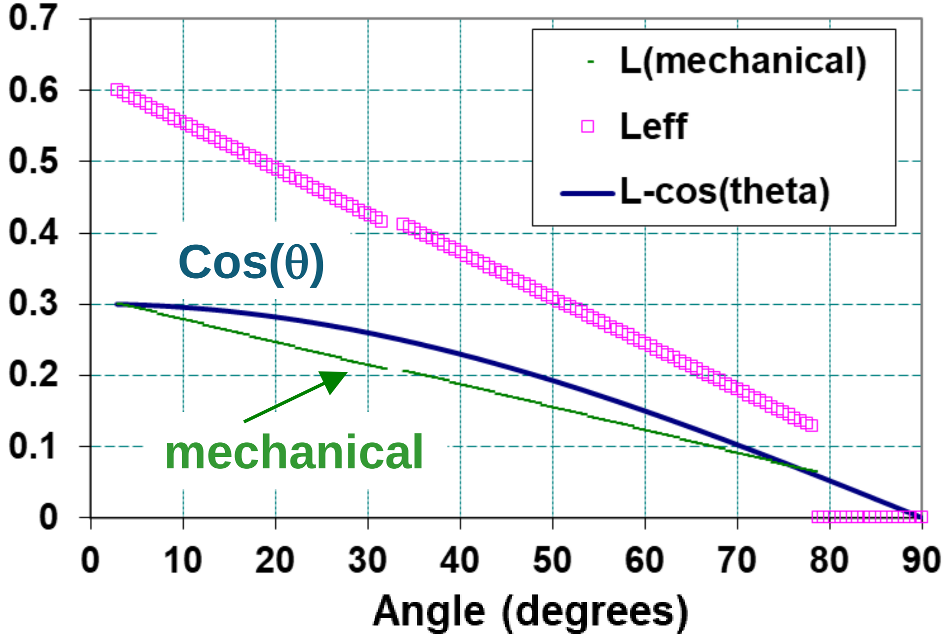


Basic Principle of the Optimum Integral Design

In conventional designs, all turns of the straight section have the same length and the fill factor is approximated azimuthally as:

$$I(\theta) = I_o \cdot \cos(n\theta)$$

...and then ends are optimized separately. Note: turns near midplane, which contribute most to field don't extend full length (a significant loss in field produced)

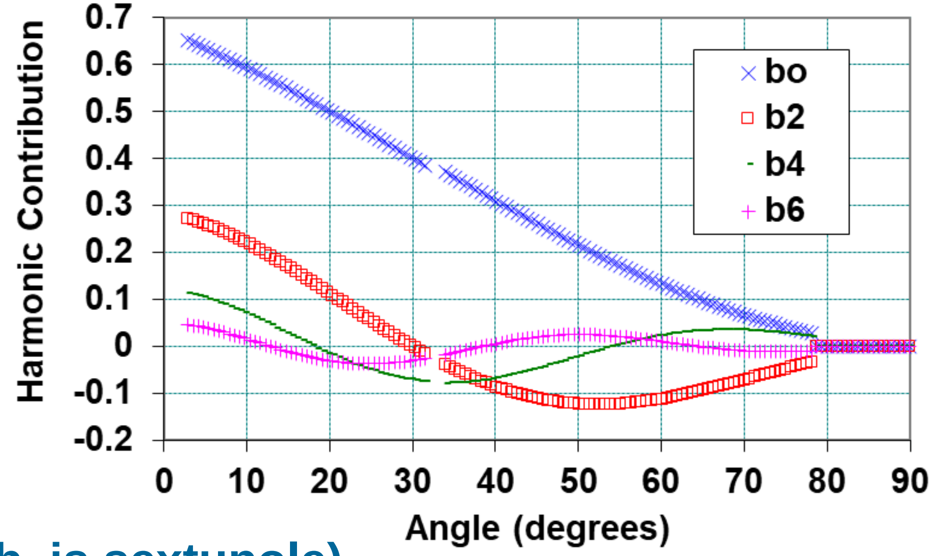


In the optimum integral design, midplane turns extend full coil length and contribute maximum to the field.

The cosine theta azimuthal distribution is obtained in an integral sense, i.e., not in "$I(\theta)$", but in "$I(\theta) \cdot L(\theta)$":

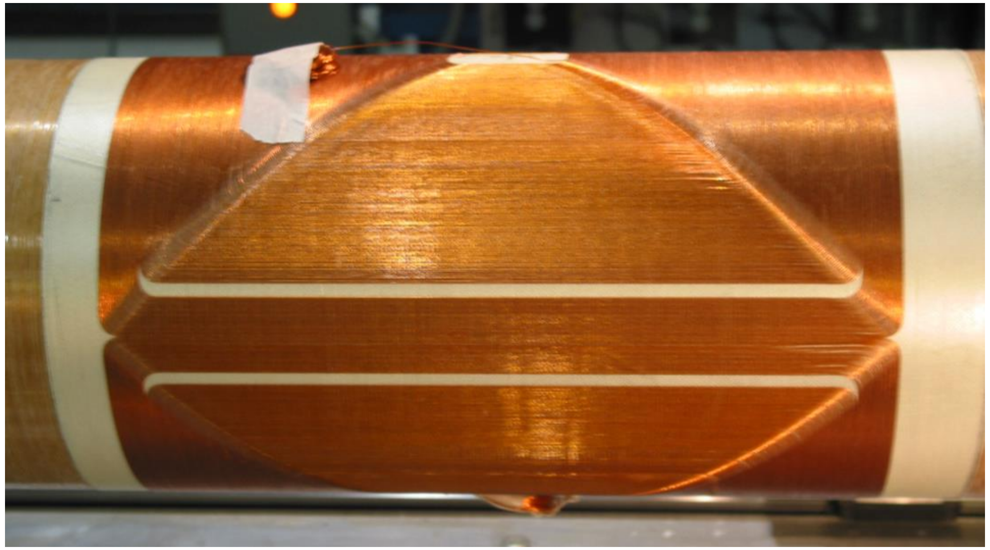
$$I(\theta) \cdot L(\theta) = I_o \cdot L_i(\theta) \propto I_o \cdot L_o \cdot \cos(n\theta)$$

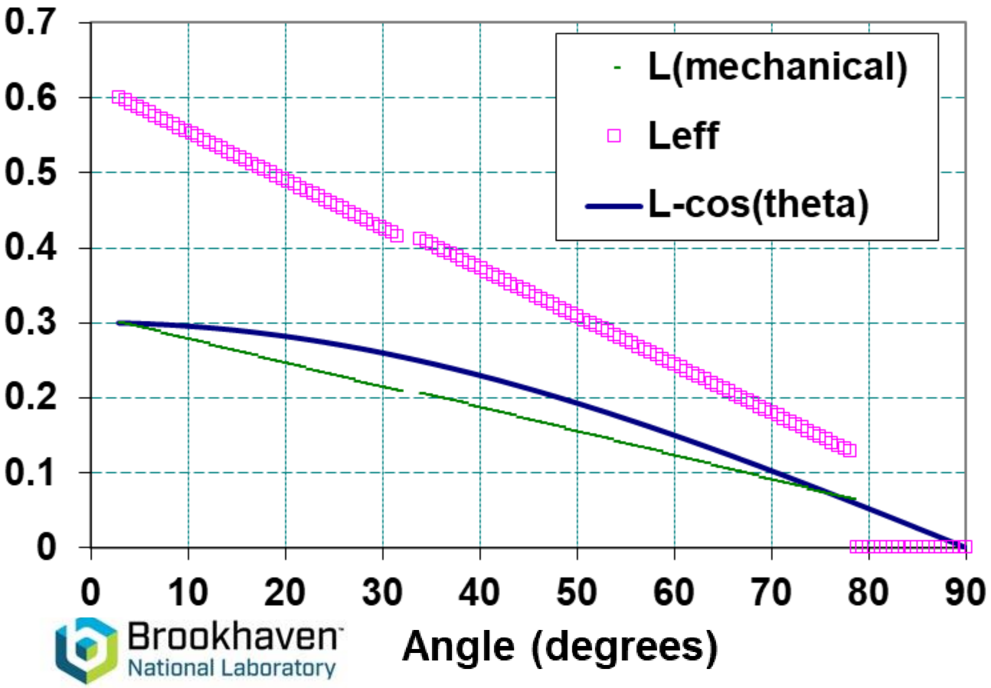
Plus, packing can be increased in the body of the magnet



(b_2 is sextupole)

Computation and Optimization of Integral Field and Field harmonics

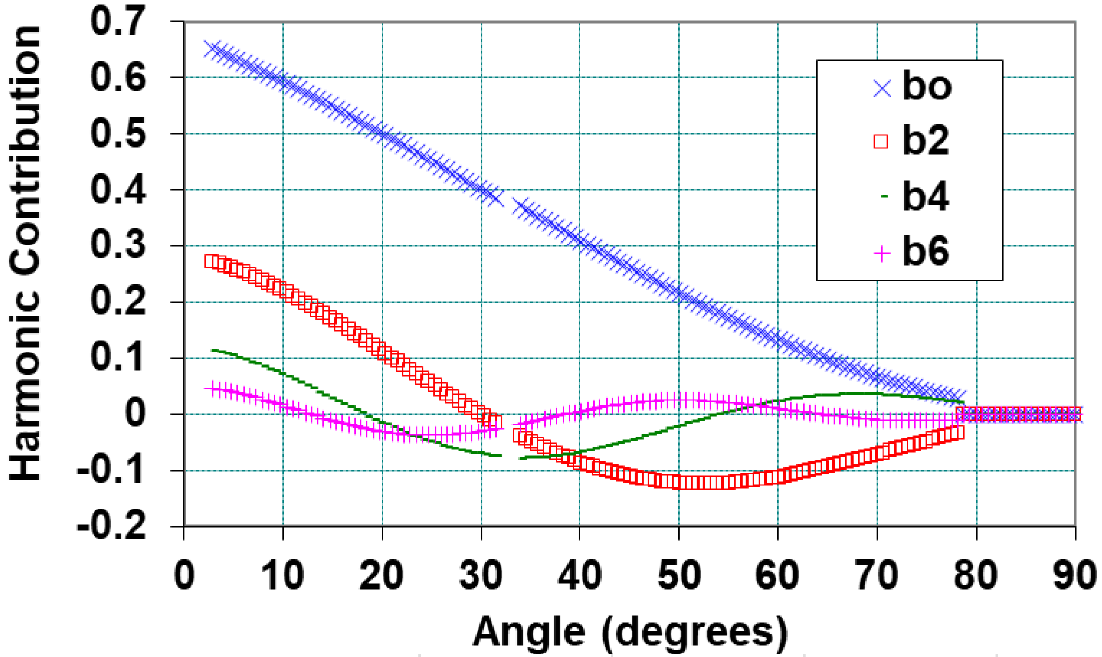




for a line current located at (a, ϕ)

$$b_n = 10^4 \left(\frac{R_0}{a}\right)^n \quad cos\left[(n+1)\,\phi\right]$$

reference radius R_0



US definition (b_2 is sextupole)

Bo (T.meter), bn (10^4)

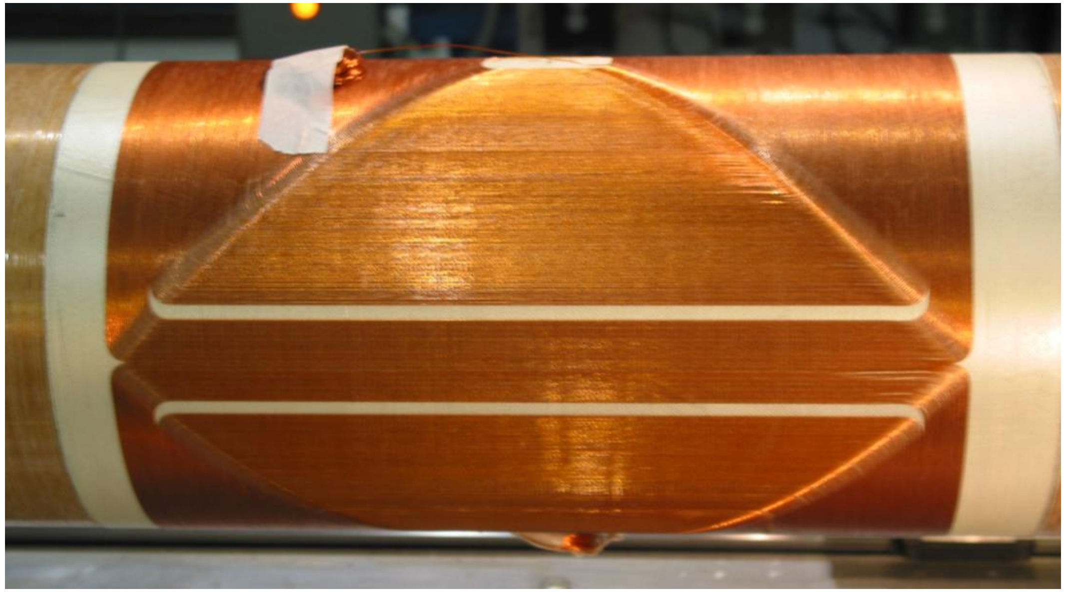
0.014939	-0.09299	-2.89085	-12.1232	-29.3454
37.3473	**-0.00035**	**-0.0108**	**-0.04528**	**-0.1096**
bo	**b2**	**b4**	**b6**	**b8**

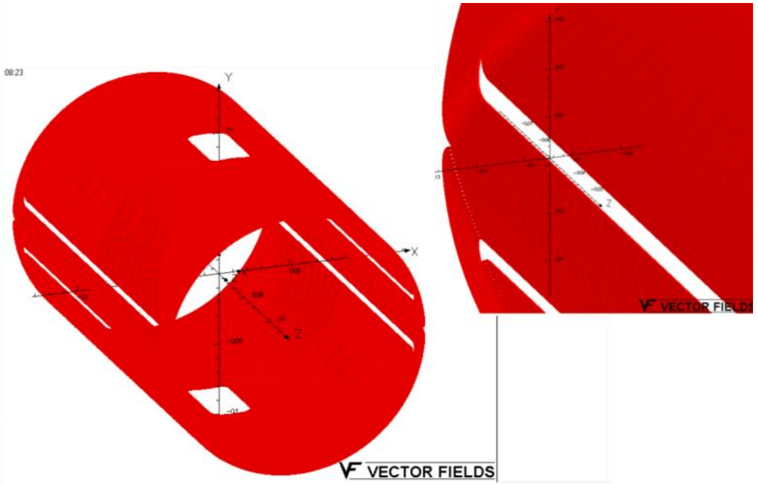
First Use of the Optimum Integral Design: AGS Corrector Dipoles

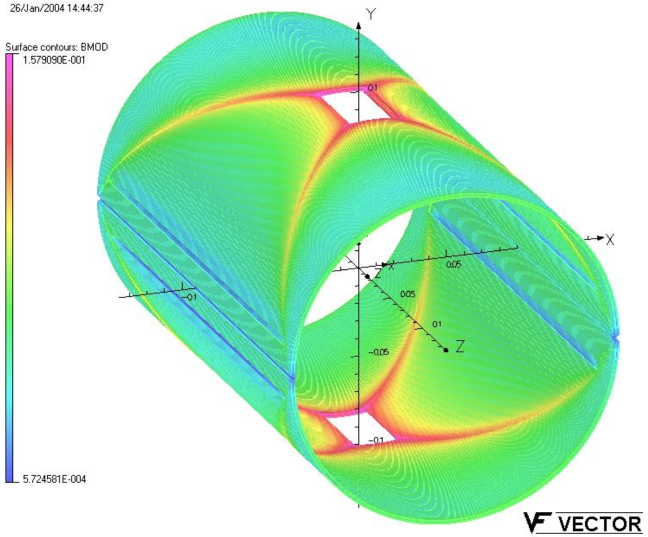
- **Note: Almost the full use of available azimuthal and axial space by the conductor (very high fill factor).**
- **Some space is needed for the leads at the pole. That, and a small azimuthal spacer was sufficient to modulate a natural variation in length for $I_o.L.\cos(\theta)$ to obtain field quality needed in corrector magnets**

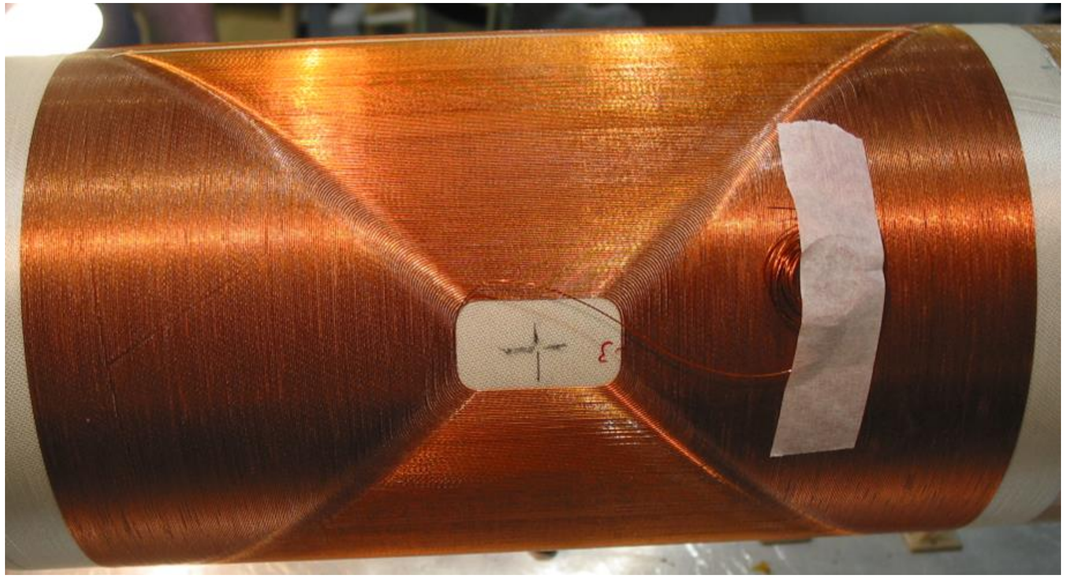
Computed Integral Field Harmonics in the AGS Corrector Dipole Design at a Reference radius of 60 mm. The Coil Radius is 90.8 mm. Note b_2 is sextupole mutliplied by 10^4 (US conventions).

Integral Field (T.m)	b_2	b_4	b_6	b_8	b_{10}	b_{12}
0.0082 @ 25 A	0.4	0.8	-4.7	4.1	5.3	2.4



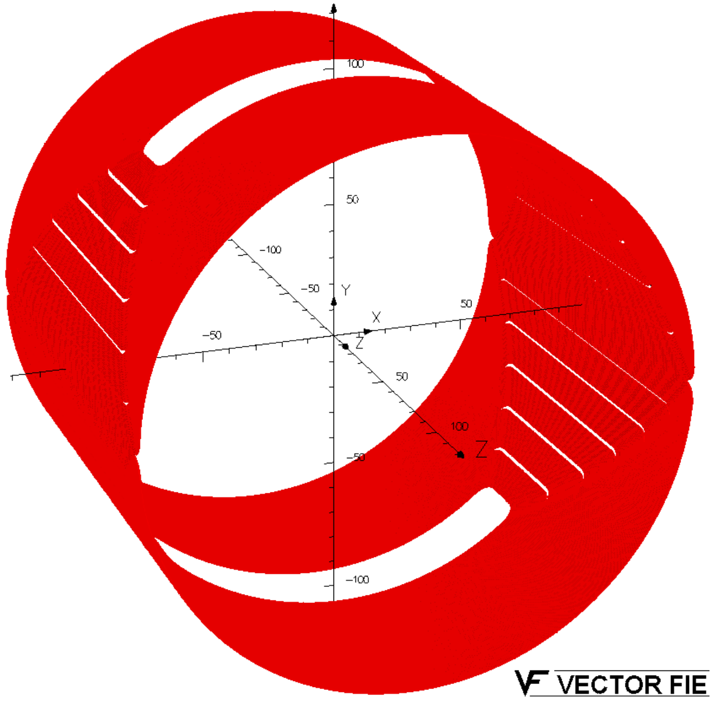






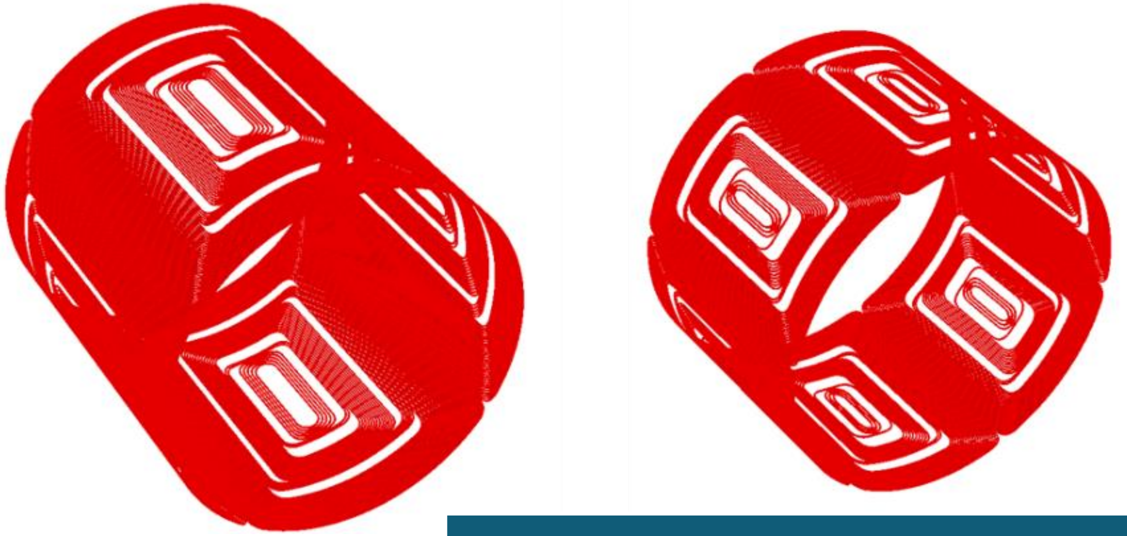
Opening A New Parameter Space with the Optimum Integral Design
(not considered practical for superconducting magnets before)

- **High field quality dipoles with coil length less than the coil diameter**
- **Quadrupole magnets with coil length less than the coil radius**
- **Sextupole magnets with coil length less than 2/3 of the coil radius**



Model of a short length dipole based on the Optimum Integral Design.

Coil length 175 mm; coil diameter 200 mm.



COMPUTED INTEGRAL FIELD HARMONICS FOR A SHORT DIPOLE (COIL LENGTH < DIAMETER) AT A RADIUS OF 66.6 MM. THE COIL RADIUS IS 100 MM. NOTE b_2 IS SEXTUPOLE MUTLIPLIED BY 10^4 (US CONVENTIONS).

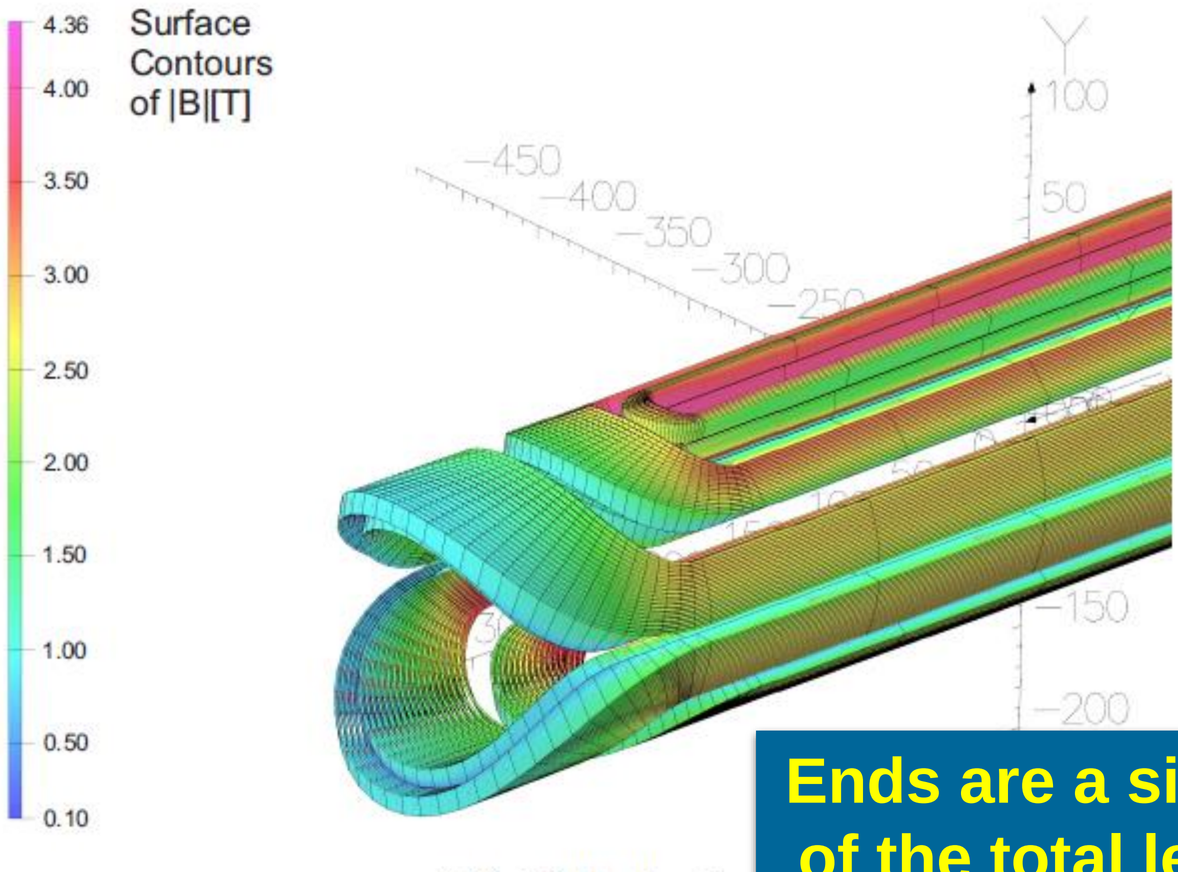
Integral Field (T.m)	b_2	b_4	b_6	b_8	b_{10}	b_{12}
0.00273 @ 25 A	0.0	0.0	0.0	0.0	0.0	0.0

Can the optimum integral design be useful in EIC?

PBL/BNL STTR on EIC for Optimum Integral Design of B0apF

B0apF (as in pCDR) and Motivation for SBIR/STTR

A short dipole (600 mm) based on the conventional cosine (θ) design: x-section and ends optimized separately



(a) Peak Field on the wire

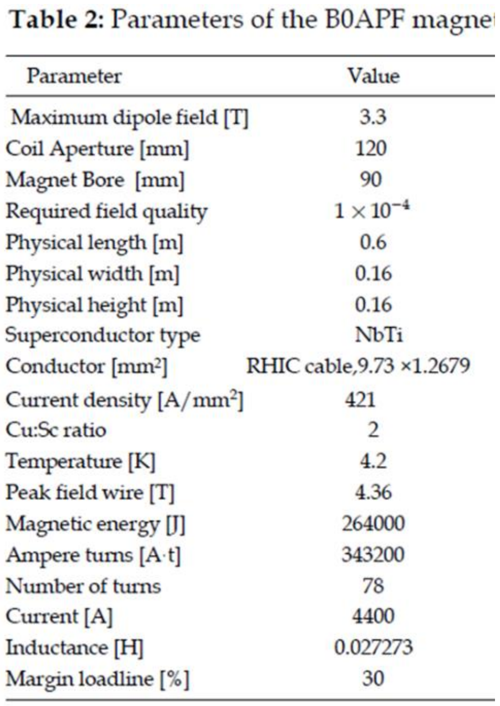
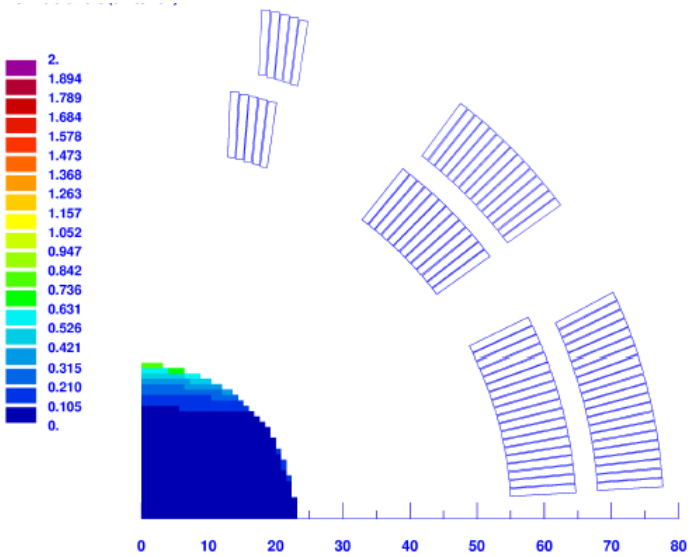
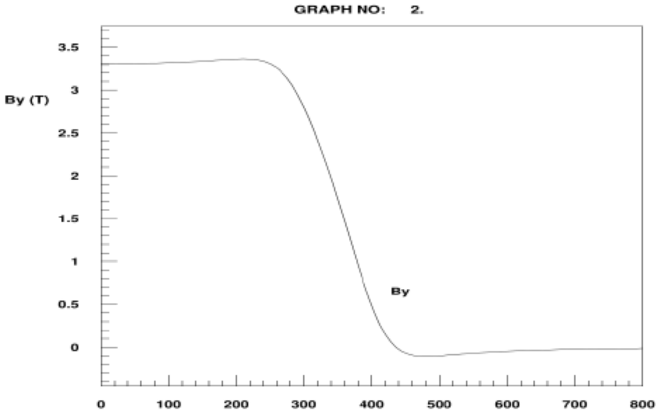


Table 2: Parameters of the B0APF magne

Parameter	Value
Maximum dipole field [T]	3.3
Coil Aperture [mm]	120
Magnet Bore [mm]	90
Required field quality	1×10^{-4}
Physical length [m]	0.6
Physical width [m]	0.16
Physical height [m]	0.16
Superconductor type	NbTi
Conductor [mm²]	RHIC cable,9.73 ×1.2679
Current density [A/mm²]	421
Cu:Sc ratio	2
Temperature [K]	4.2
Peak field wire [T]	4.36
Magnetic energy [J]	264000
Ampere turns [A·t]	343200
Number of turns	78
Current [A]	4400
Inductance [H]	0.027273
Margin loadline [%]	30



(a) Good field region

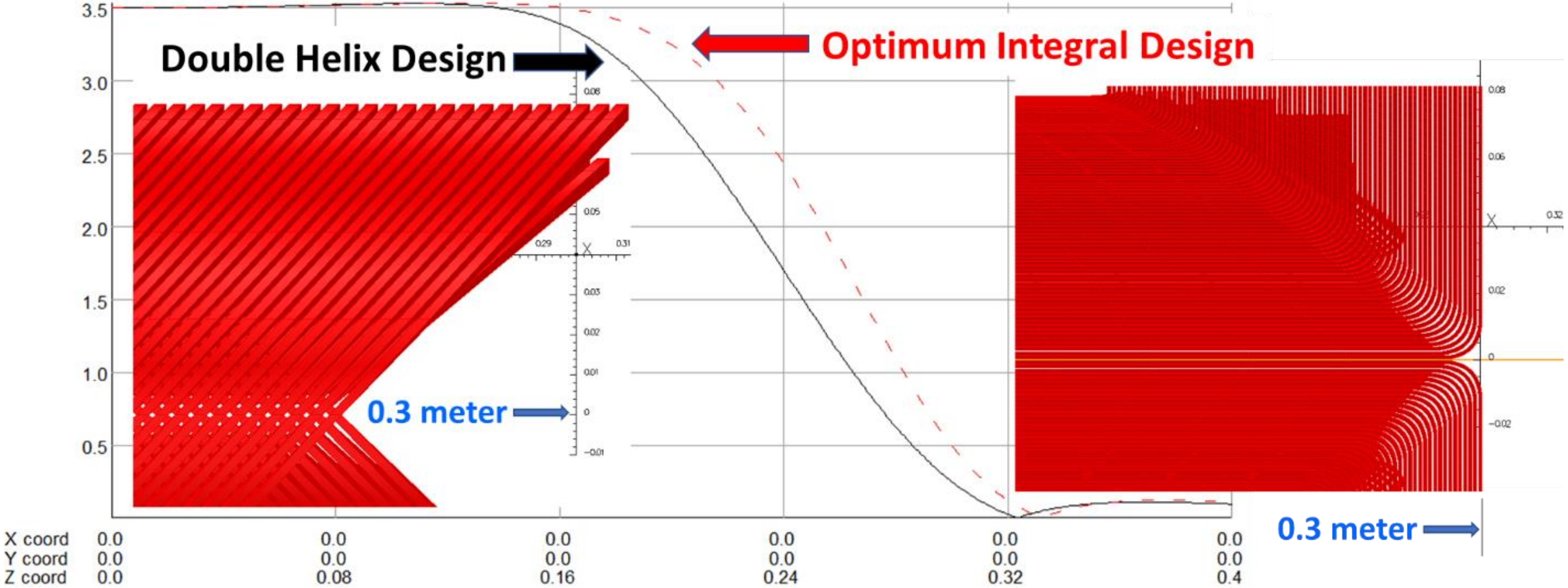


(b) Vertical magnetic field (Tesla) along the length of the magnet (mm)

Ends are a significant fraction of the total length and loss in integrated field is significant

A Comparison between the Alternate Double Helix Design and the Optimum Integral Design as in the STTR Proposal

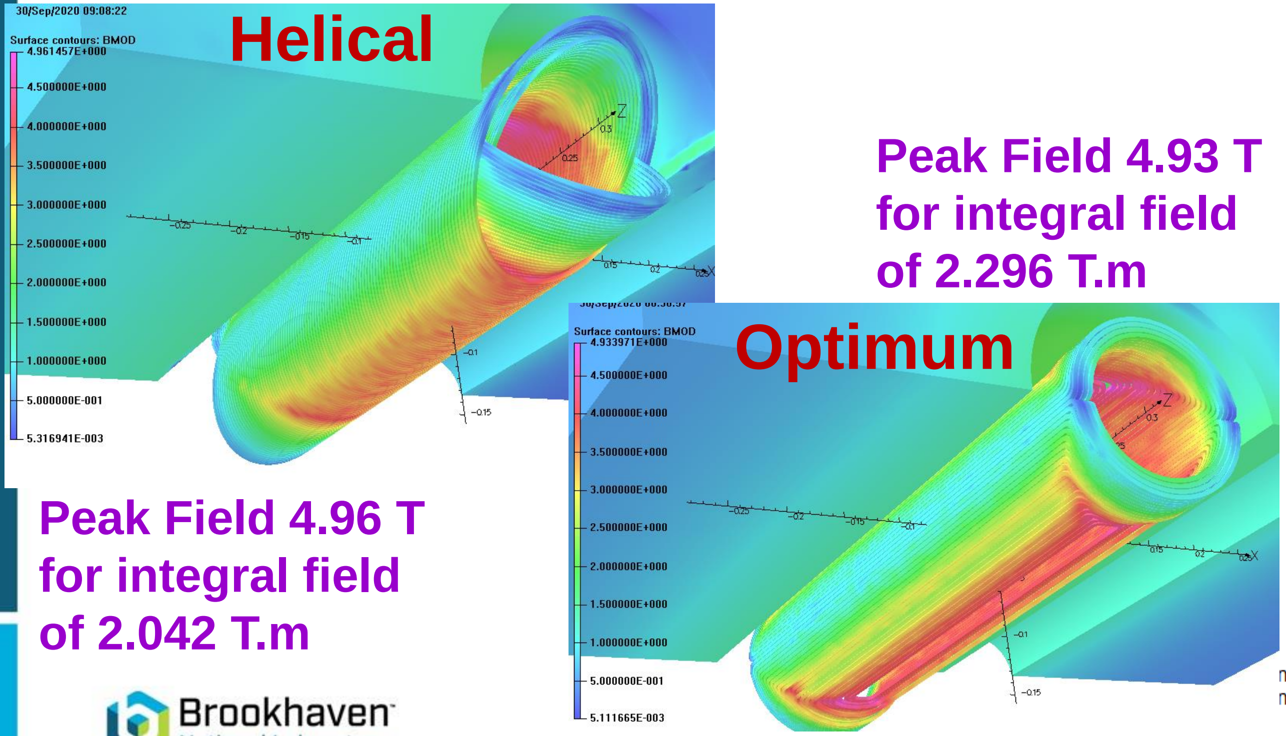
Optimum integral design extends the magnetic length for the same coil length



Phase I & Phase II funded for the demonstration of B0aPF

Argument Made for Optimum Integral Design B0apF STTR

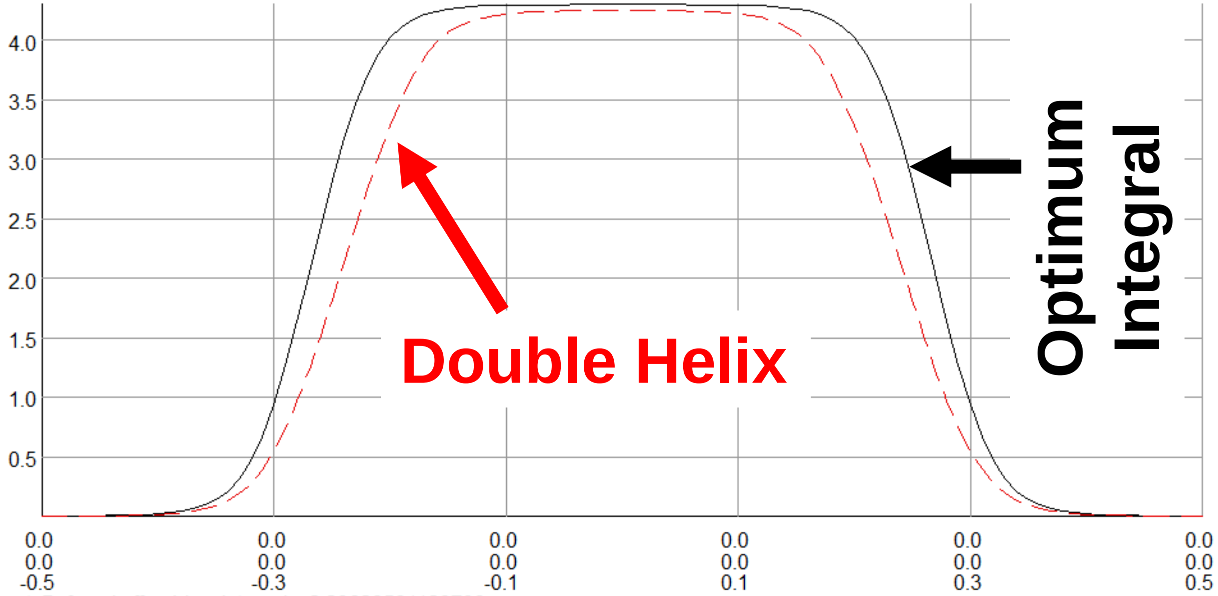
- **Optimum integral design reduces the maximum field by 10-20%. Lorentz forces, stored energy and stresses goes as square of the field. The design is not part of the baseline design of EIC and therefore it can be for SBIR/STTR. Once proven, can be used in EIC.**
- **B0Apf dipole for EIC has an aperture of 120 mm and a total length of 600 mm. The design field is ~3.3 T. This is ideally suited for a potential high impact SBIR/STTR proposal.**



Peak Field 4.96 T for integral field of 2.042 T.m

Peak Field 4.93 T for integral field of 2.296 T.m

~12% gain in integral field for the same peak field



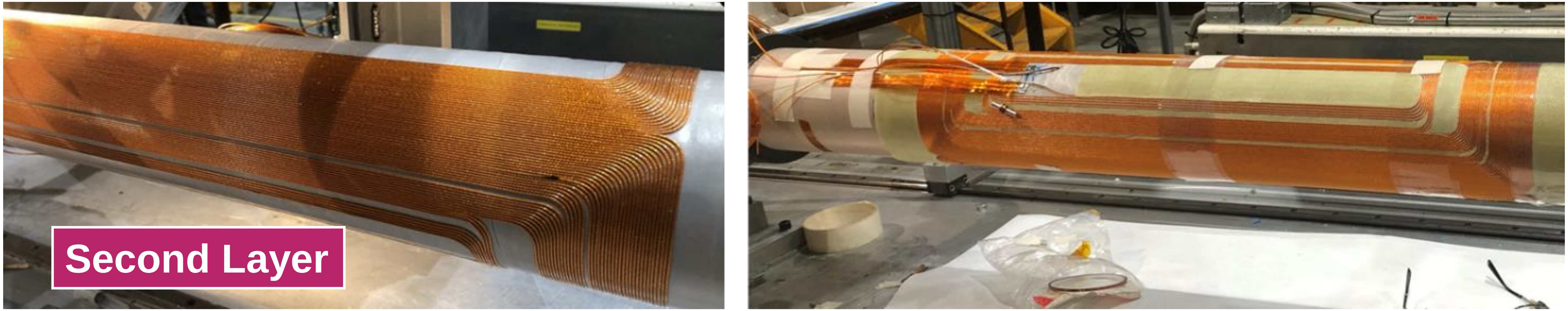
nent: B, from buffer: Line, Integral = 2.29628581129738
nent: B, from buffer: Line, Integral = 2.04202410348335

What was Demonstrated in Phase I

Optimum Integral Dipole - Phase I Coil (double layer)

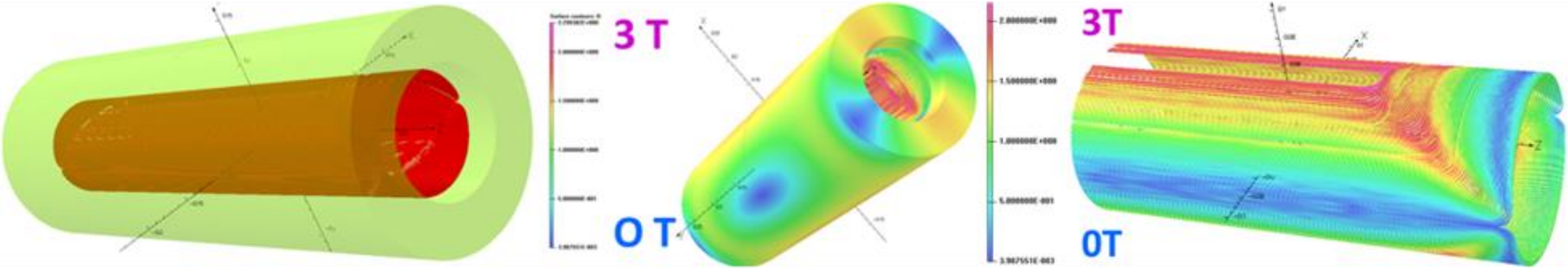
Midplane turns extended full length

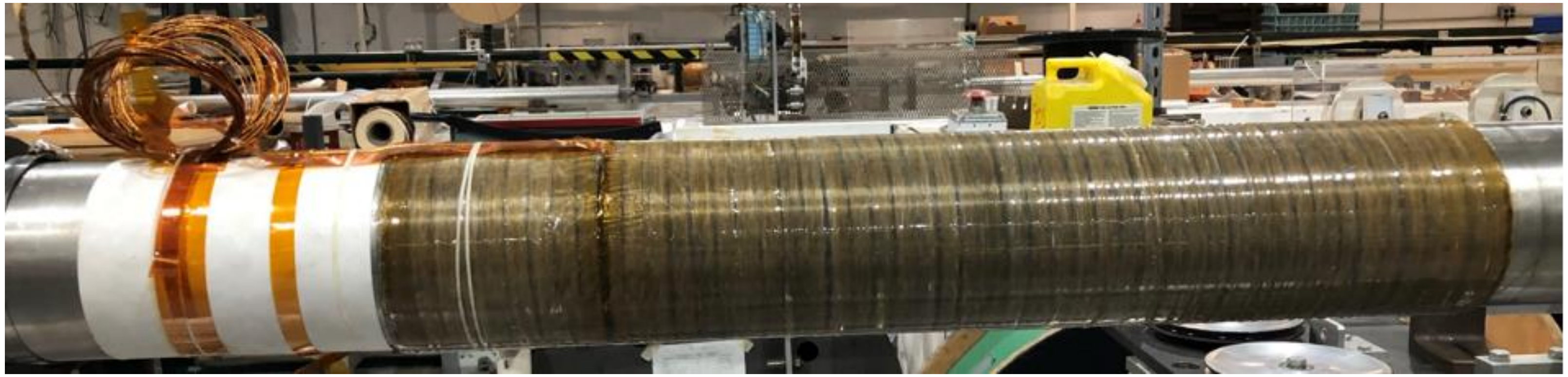
First Layer



Second Layer

Phase I Optimum Integral Dipole
(As Designed and As Built)

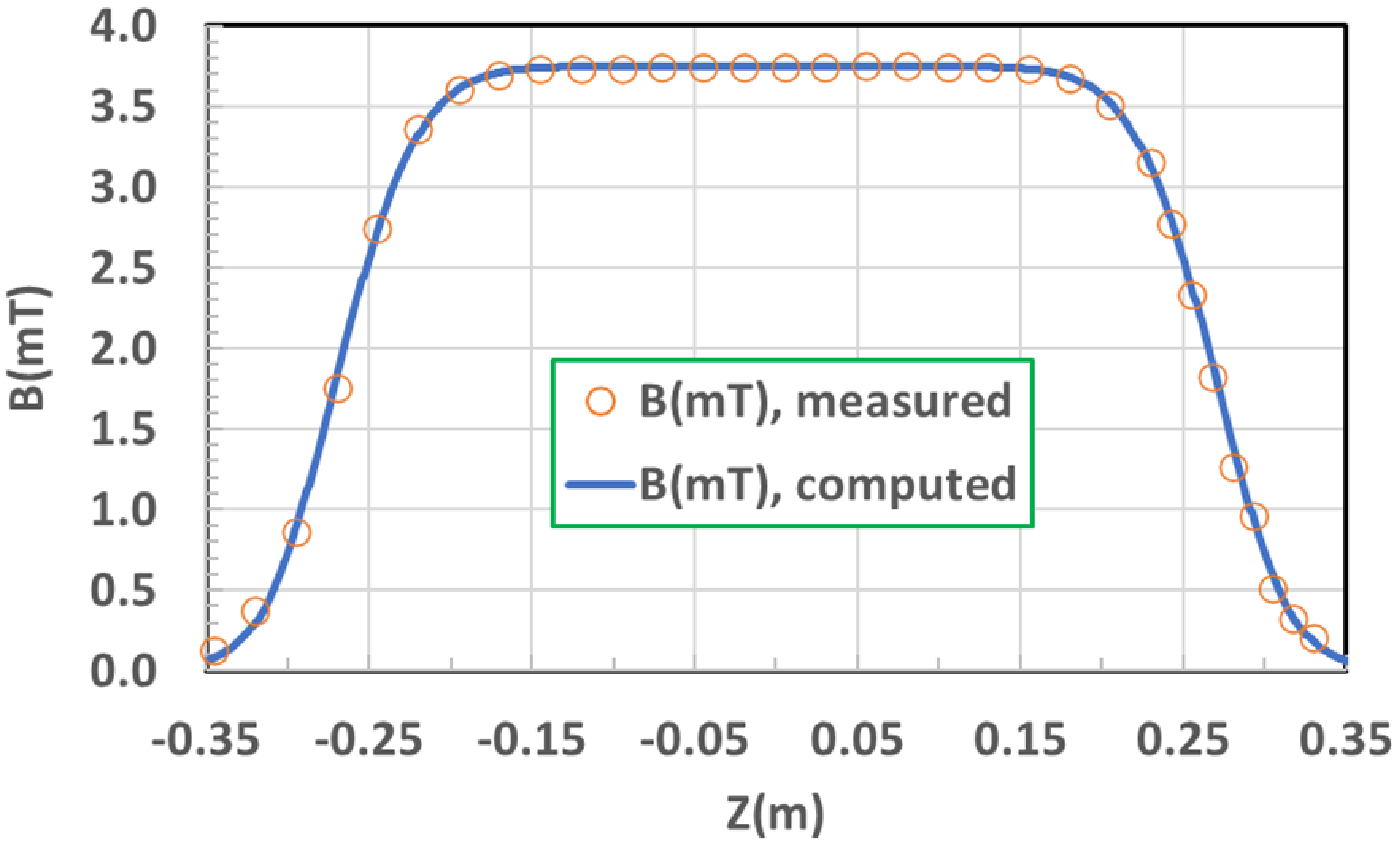




Question: Will optimum integral design extend the magnetic length?

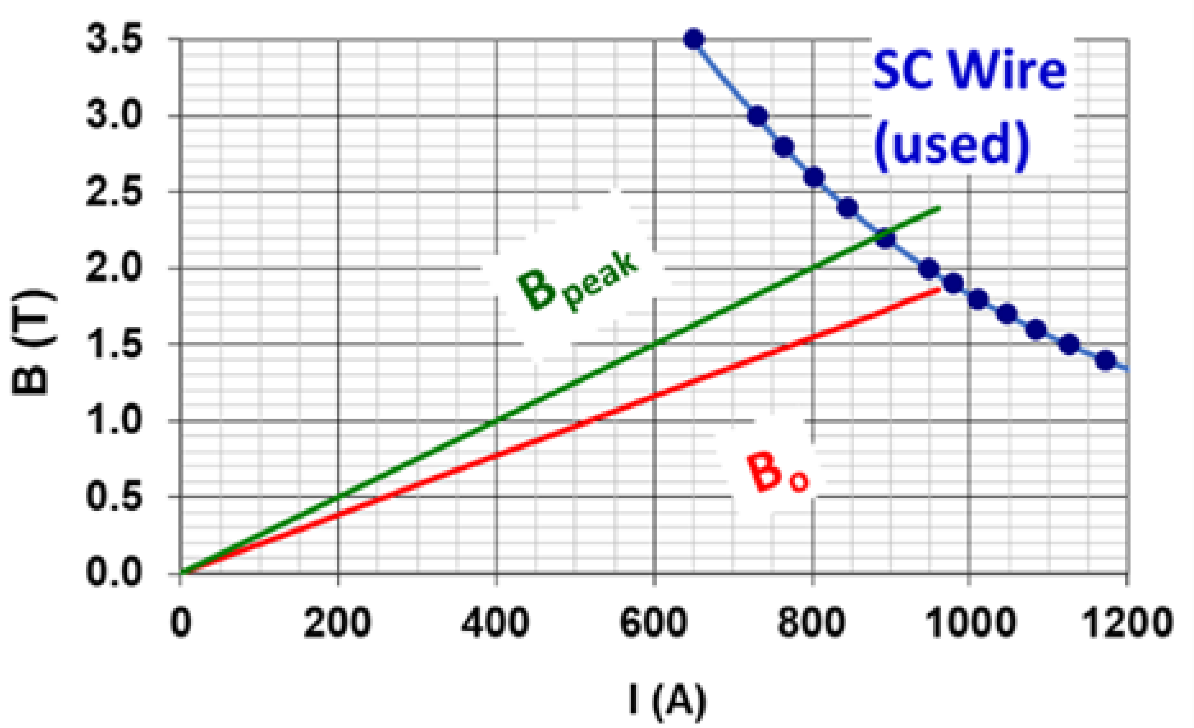
Answer: Measurements show a good agreement with the calculations

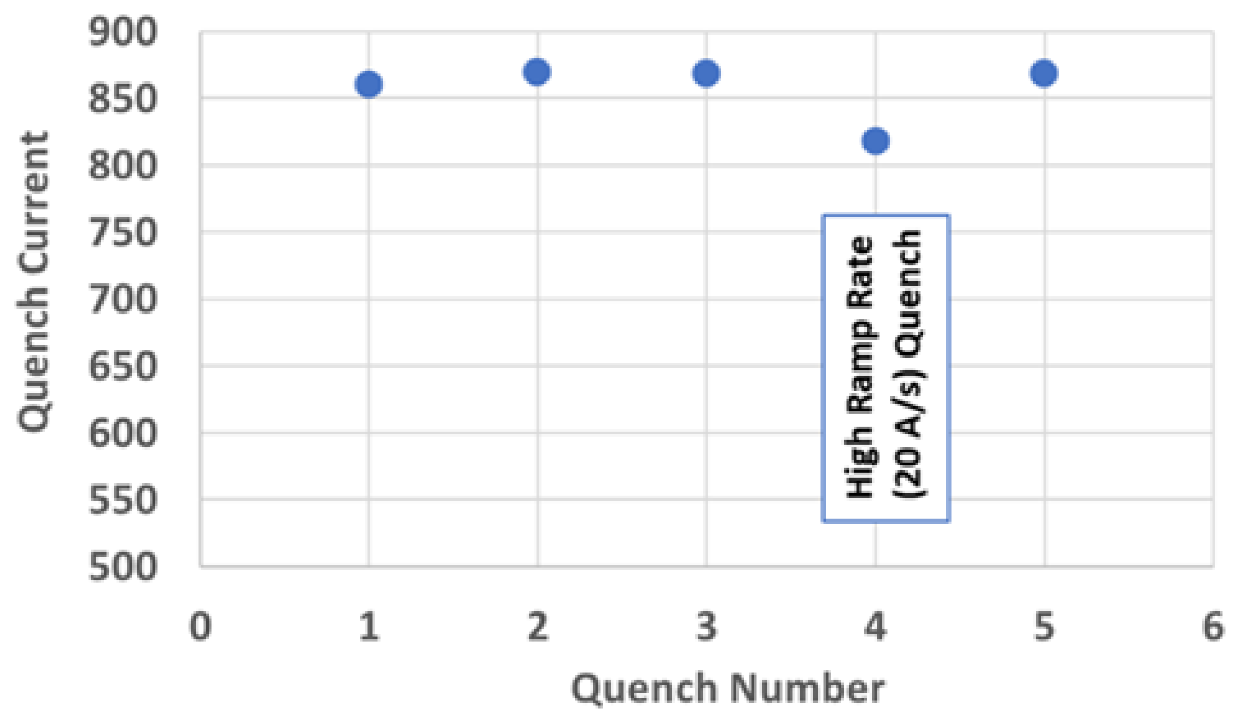
Major motivation of the optimum integral design demonstrated



Question: Will the direct wind coil based on the optimum integral will have good quench performance?

Answer: Quench performance remains excellent (meets computed SS with no quench), at least in the parameter range examined so far





These are significant demonstration for a Phase I SBIR/STTR

Phase II STTR

Tasks and Challenges

(apart from the optimum integral design itself, this will be a significant demonstration of the direct wind technology)

***Computed short sample (4.3 T) is similar to that in RHIC 80 mm arc dipole and 100 mm insertion dipole, but in a larger 114 mm aperture**

Specific Tasks for Year 1 and Year 2

Year 1

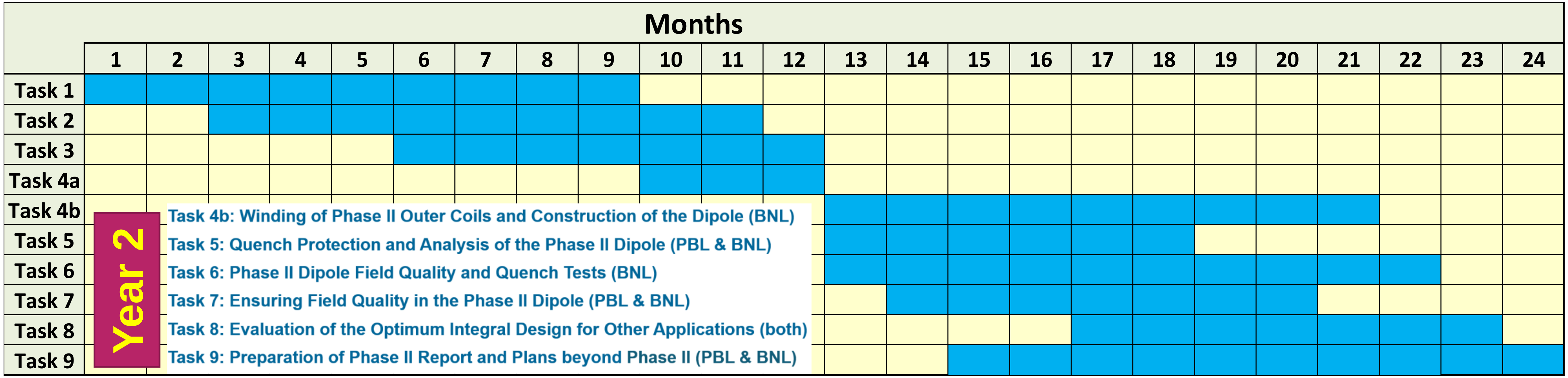
Task 1: Enhancement of Code to Optimize the Phase II Design (mostly PBL)

Task 2: Magnetic Design & Analysis of the Phase II Dipole B0Apf (PBL & BNL)

Task 3:* Mechanical Analysis *(mostly PBL) and Structure Design (mostly BNL)

Task 4a: Winding of Phase II Inner Coils (BNL)

- **Milestone for Year 1: Wind and test inner coil**



	Months																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Task 1	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦															
Task 2			🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦													
Task 3						🟦	🟦	🟦	🟦	🟦	🟦	🟦												
Task 4a										🟦	🟦	🟦												
Task 4b													🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦			
Task 5													🟦	🟦	🟦	🟦	🟦	🟦						
Task 6													🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦		
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Task 8																	🟦	🟦	🟦	🟦	🟦	🟦	🟦	
Task 9															🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦

Year 2

Task 4b: Winding of Phase II Outer Coils and Construction of the Dipole (BNL)

Task 5: Quench Protection and Analysis of the Phase II Dipole (PBL & BNL)

Task 6: Phase II Dipole Field Quality and Quench Tests (BNL)

Task 7: Ensuring Field Quality in the Phase II Dipole (PBL & BNL)

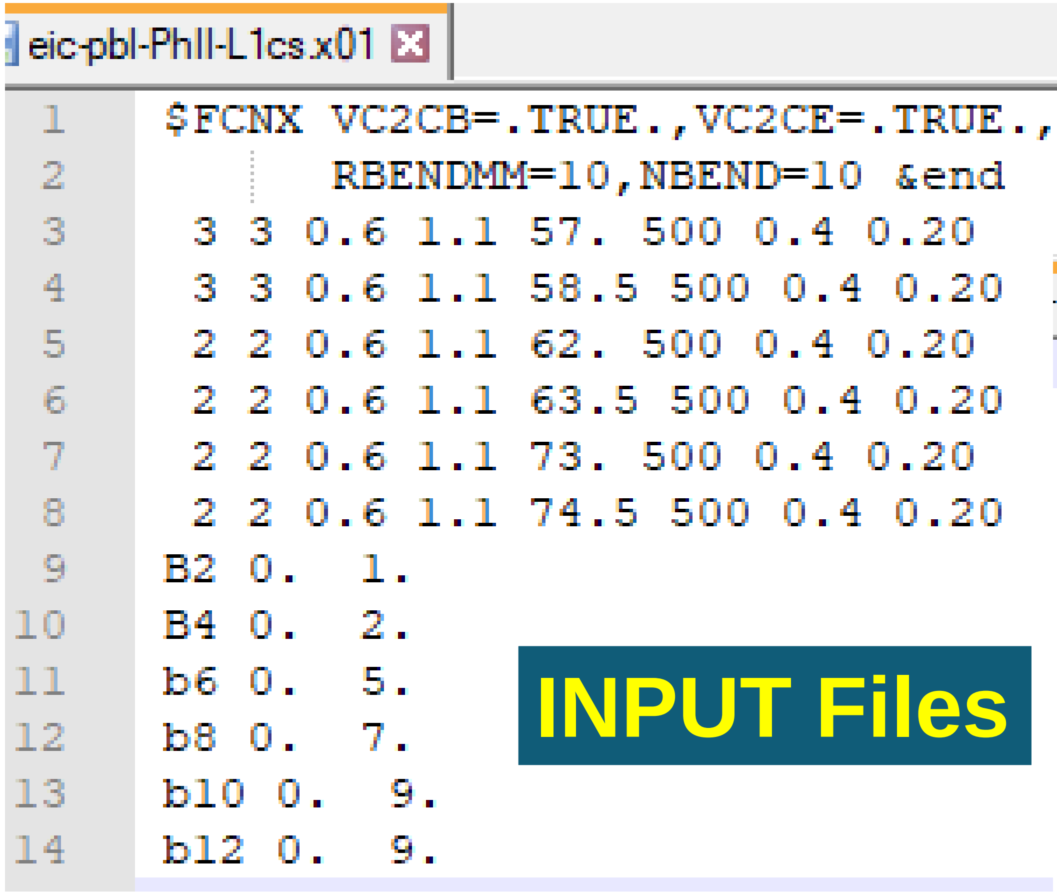
Task 8: Evaluation of the Optimum Integral Design for Other Applications (both)

Task 9: Preparation of Phase II Report and Plans beyond Phase II (PBL & BNL)

We should start Task 5 (Quench Protection and Analysis) now, perform calculations for both the year 1 and the year 2 magnets

Software for the Optimum Integral Design

- **Initially developed for VAX FORTRAN.**
- **It was used to design and optimize optimum integral dipole for AGS**
- **The software has now been ported to PC and is being further upgraded**



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 3 3 0.6 1.1 58.5 500 0.4 0.20
 2 2 0.6 1.1 62. 500 0.4 0.20
 2 2 0.6 1.1 63.5 500 0.4 0.20
 2 2 0.6 1.1 73. 500 0.4 0.20
 2 2 0.6 1.1 74.5 500 0.4 0.20
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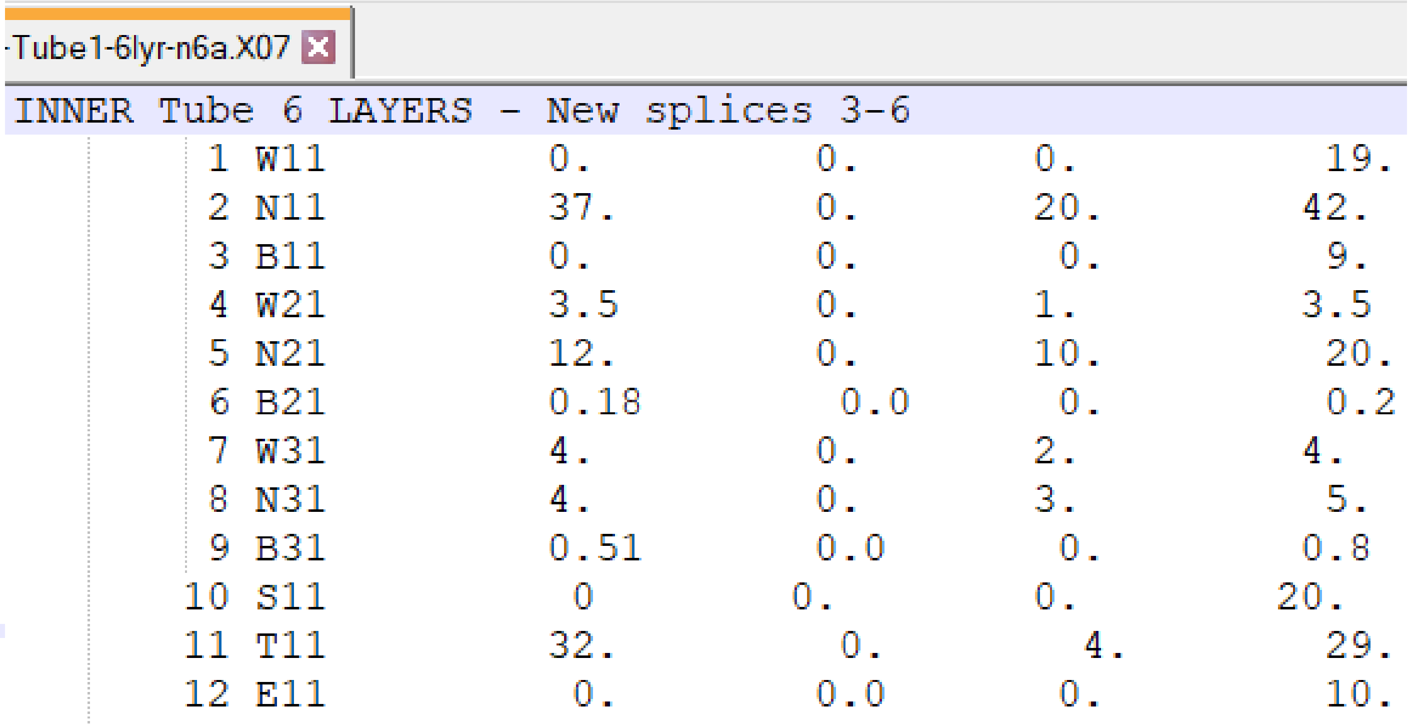
B4 0.  2.
b6 0.  5.
b8 0.  7.
b10 0.  9.
b12 0.  9.
```

INPUT Files



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     4 W21        3.5       0.        1.        3.5
     5 N21        12.       0.        10.       20.
     6 B21        0.18       0.0      0.         0.2
     7 W31        4.        0.        2.        4.
     8 N31        4.        0.        3.         5.
     9 B31        0.51      0.0        0.       0.8
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    11 T11        32.        0.         4.       29.
    12 E11         0.      0.0         0.       10.
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A few of many output files

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    1              3              4       1.00841         0.00000
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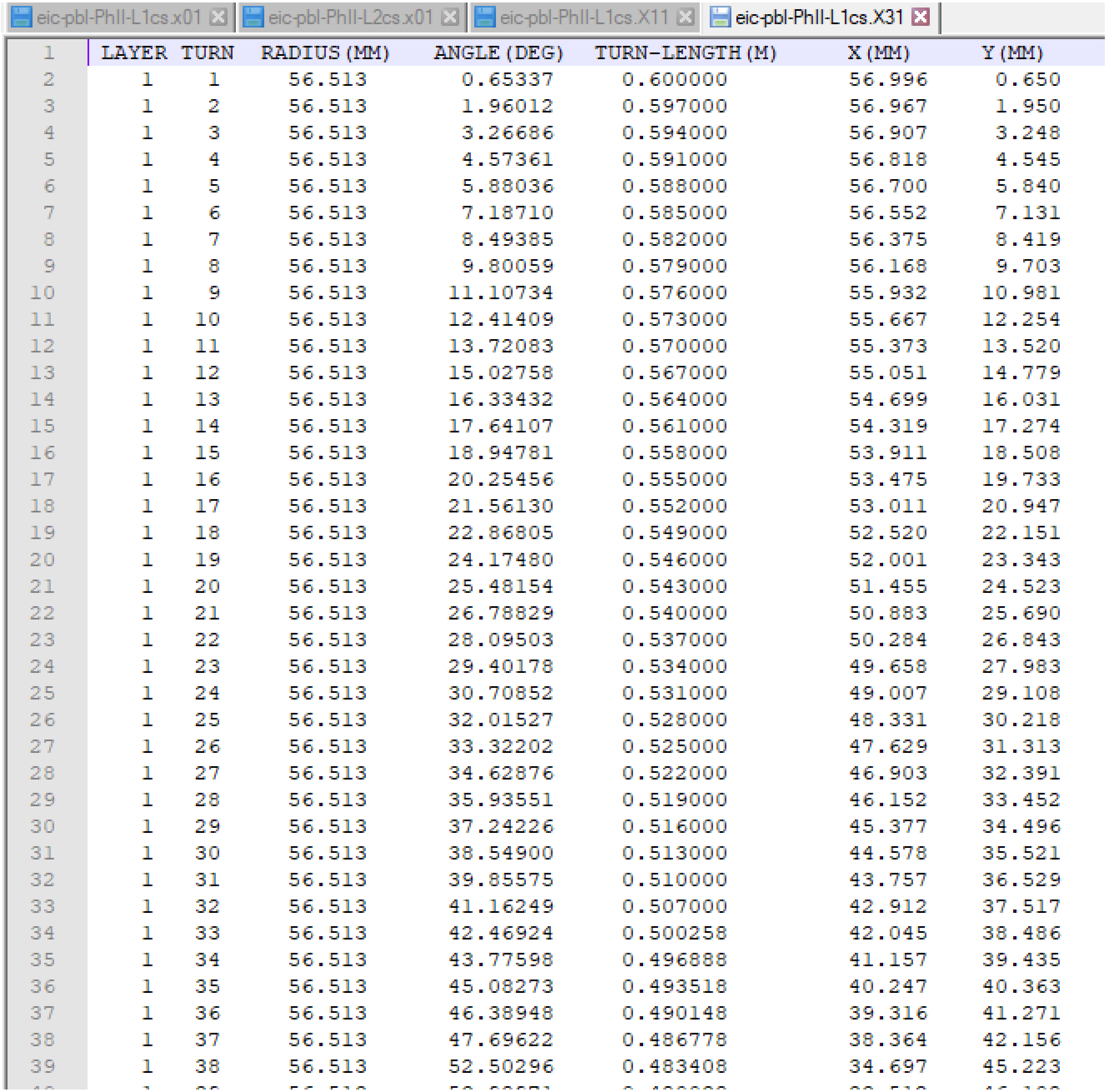
    1              2             22       0.03448         0.00239
    1              3              4       2.00373         0.12796
LAYER NO.      BLOCK NO.      TURN NO.  WEDGE(DEGREE)    C2C-BODY(DEG)
    2              1             47       0.00000         0.00000
    2              2             27       1.00500         0.01948
    2              3              4       4.31012         0.00001
LAYER NO.      BLOCK NO.      TURN NO.  END-SPACER(MM)   C2C-END(MM)
    2              1             52       0.00000         0.00000
    2              2             22       0.00138         0.00125
    2              3              4      11.48548         1.39409
LAYER NO.      BLOCK NO.      TURN NO.  WEDGE(DEGREE)    C2C-BODY(DEG)
    3              1             47       0.00000         0.00000
    3              2             17       2.25399         0.03786
    3              3              9       7.49249         0.01186
LAYER NO.      BLOCK NO.      TURN NO.  END-SPACER(MM)   C2C-END(MM)
    3              1             32       0.00000         0.00000
    3              2             37       0.00180         0.00476
    3              3              4       5.19675         0.20025
LAYER NO.      BLOCK NO.      TURN NO.  WEDGE(DEGREE)    C2C-BODY(DEG)
    4              1             52       0.00000         0.00000
    4              2             22       3.23338         0.00920
    4              3              4       1.44408         0.13169
LAYER NO.      BLOCK NO.      TURN NO.  END-SPACER(MM)   C2C-END(MM)
    4              1             22       0.00000         0.00000
    4              2             50       0.00014         0.00000
    4              3              6       2.01384         0.22288
```



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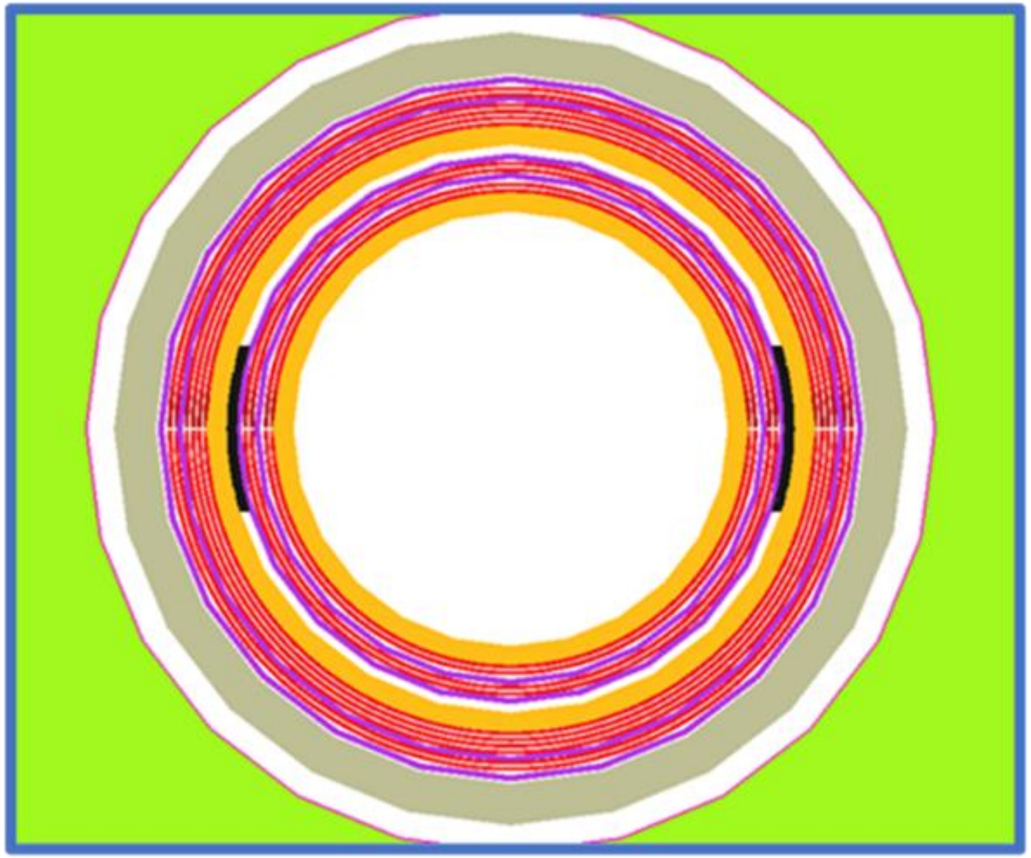
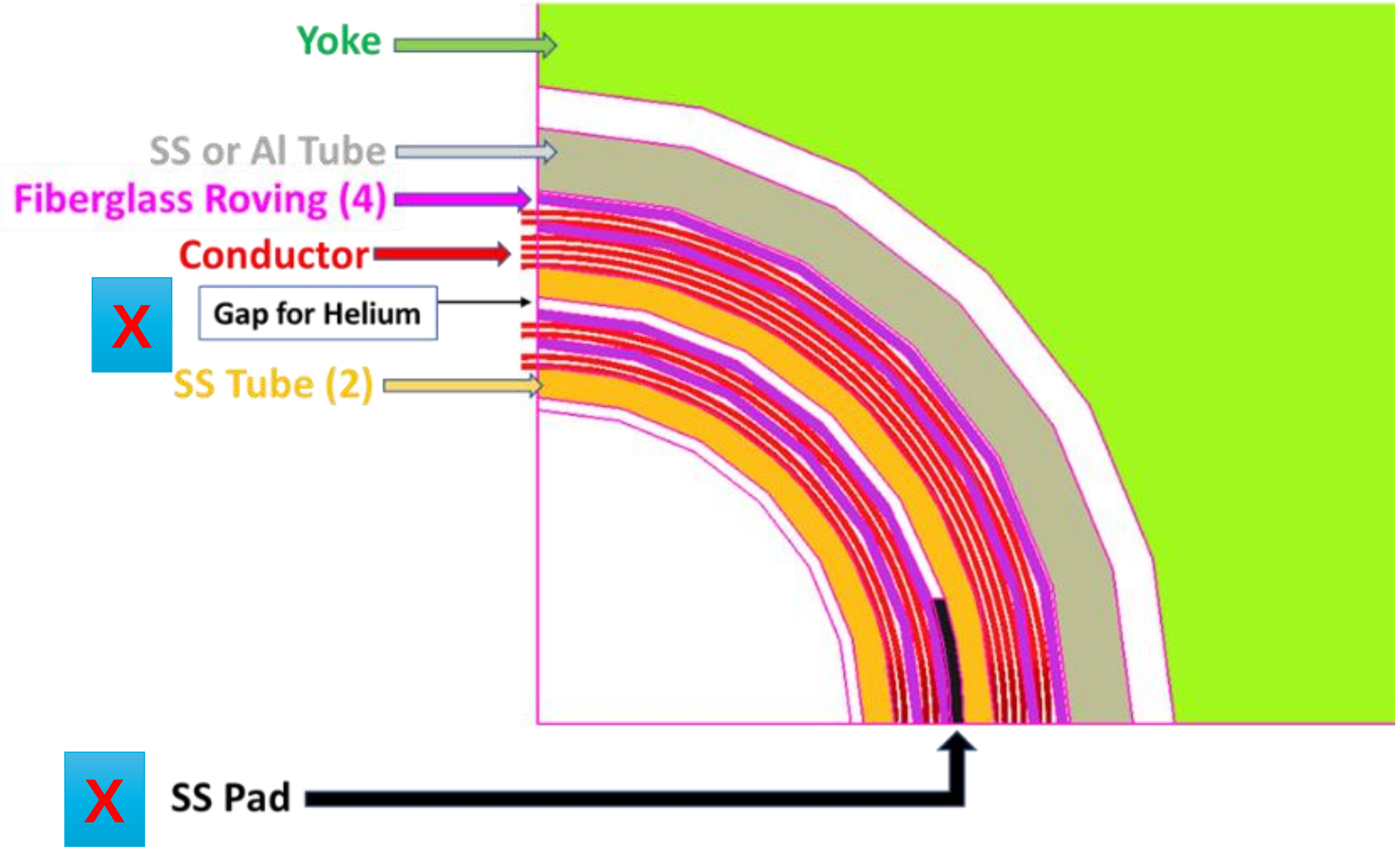
LAYER TURN  RADIUS(MM)   ANGLE(DEG)  TURN-LENGTH(M)    X(MM)     Y(MM)
   1     1    56.513      0.65337     0.600000        56.996     0.650
   1     2    56.513      1.96012     0.597000        56.967     1.950
   1     3    56.513      3.26686     0.594000        56.907     3.248
   1     4    56.513      4.57361     0.591000        56.818     4.545
   1     5    56.513      5.88036     0.588000        56.700     5.840
   1     6    56.513      7.18710     0.585000        56.552     7.131
   1     7    56.513      8.49385     0.582000        56.375     8.419
   1     8    56.513      9.80059     0.579000        56.168     9.703
   1     9    56.513     11.10734     0.576000        55.932    10.981
   1    10    56.513     12.41409     0.573000        55.667    12.254
   1    11    56.513     13.72083     0.570000        55.373    13.520
   1    12    56.513     15.02758     0.567000        55.051    14.779
   1    13    56.513     16.33432     0.564000        54.699    16.031
   1    14    56.513     17.64107     0.561000        54.319    17.274
   1    15    56.513     18.94781     0.558000        53.911    18.508
   1    16    56.513     20.25456     0.555000        53.475    19.733
   1    17    56.513     21.56130     0.552000        53.011    20.947
   1    18    56.513     22.86805     0.549000        52.520    22.151
   1    19    56.513     24.17480     0.546000        52.001    23.343
   1    20    56.513     25.48154     0.543000        51.455    24.523
   1    21    56.513     26.78829     0.540000        50.883    25.690
   1    22    56.513     28.09503     0.537000        50.284    26.843
   1    23    56.513     29.40178     0.534000        49.658    27.983
   1    24    56.513     30.70852     0.531000        49.007    29.108
   1    25    56.513     32.01527     0.528000        48.331    30.218
   1    26    56.513     33.32202     0.525000        47.629    31.313
   1    27    56.513     34.62876     0.522000        46.903    32.391
   1    28    56.513     35.93551     0.519000        46.152    33.452
   1    29    56.513     37.24226     0.516000        45.377    34.496
   1    30    56.513     38.54900     0.513000        44.578    35.521
   1    31    56.513     39.85575     0.510000        43.757    36.529
   1    32    56.513     41.16249     0.507000        42.912    37.517
   1    33    56.513     42.46924     0.500258        42.045    38.486
   1    34    56.513     43.77598     0.496888        41.157    39.435
   1    35    56.513     45.08273     0.493518        40.247    40.363
   1    36    56.513     46.38948     0.490148        39.316    41.271
   1    37    56.513     47.69622     0.486778        38.364    42.156
   1    38    56.513     52.50296     0.483408        34.697    45.223
```

Output files created for OPERA3d, etc.

Phase II Design (as proposed and as updated)

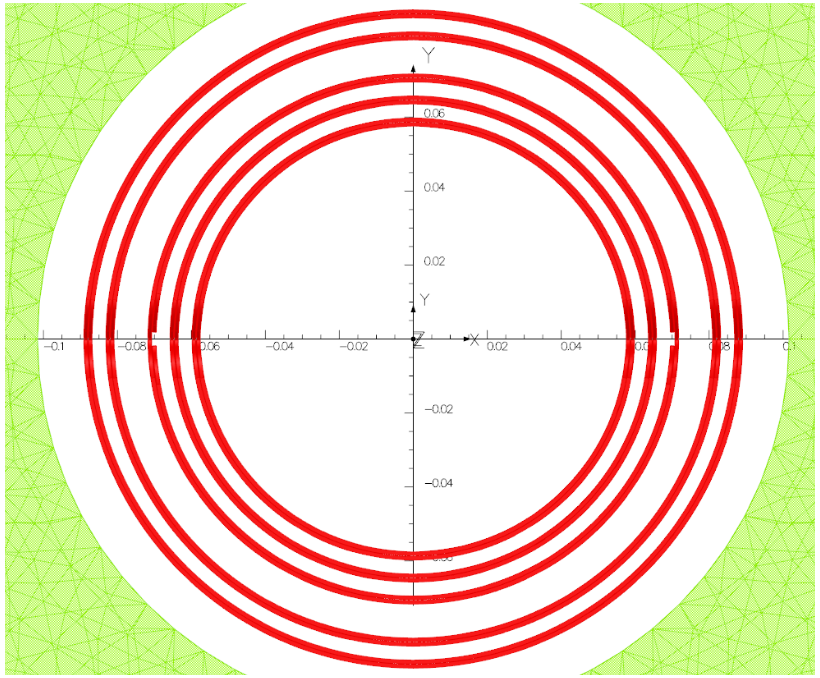


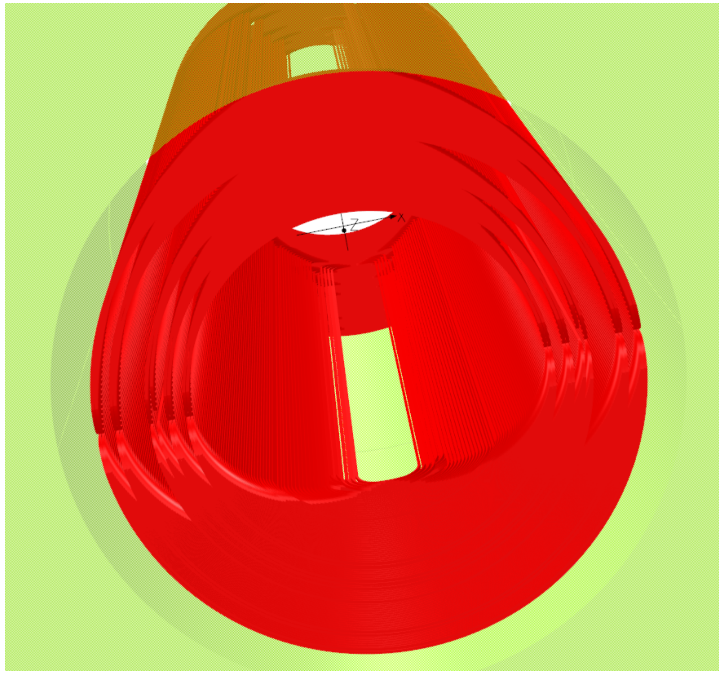


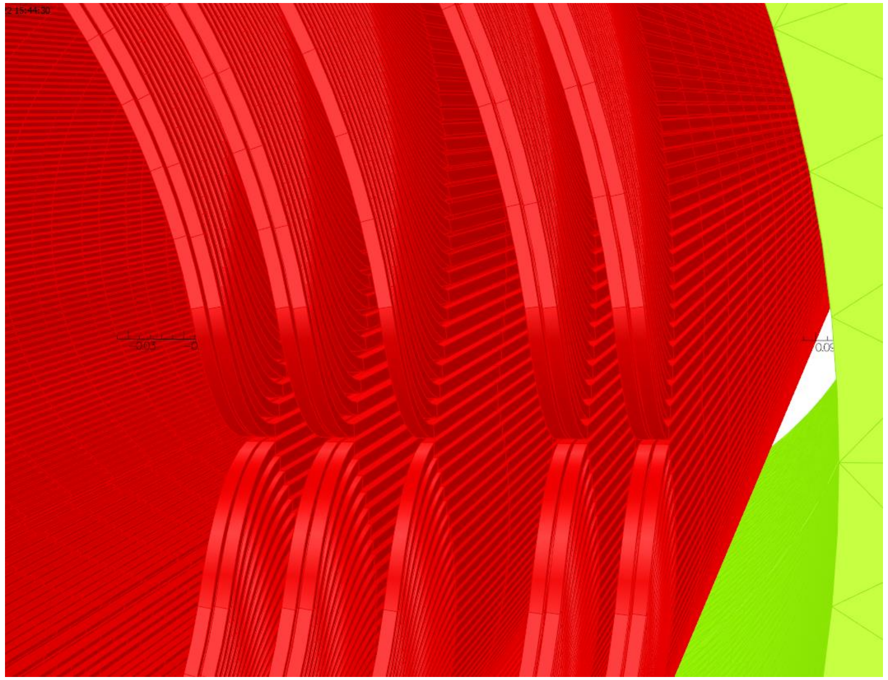
- Present design has no gap for Helium and no SS pad. Also, it has 6 layers in the inner and 4 in the outer. It has three SS tubes (inner, middle and outer)
- For mechanical analysis, we need to include above elements & simplify coils

OPERA3d Models of the Current Design

Three double layers (6 single layers) on inner tube will be built and tested in year 1. Two double layers on outer tube in year 2.



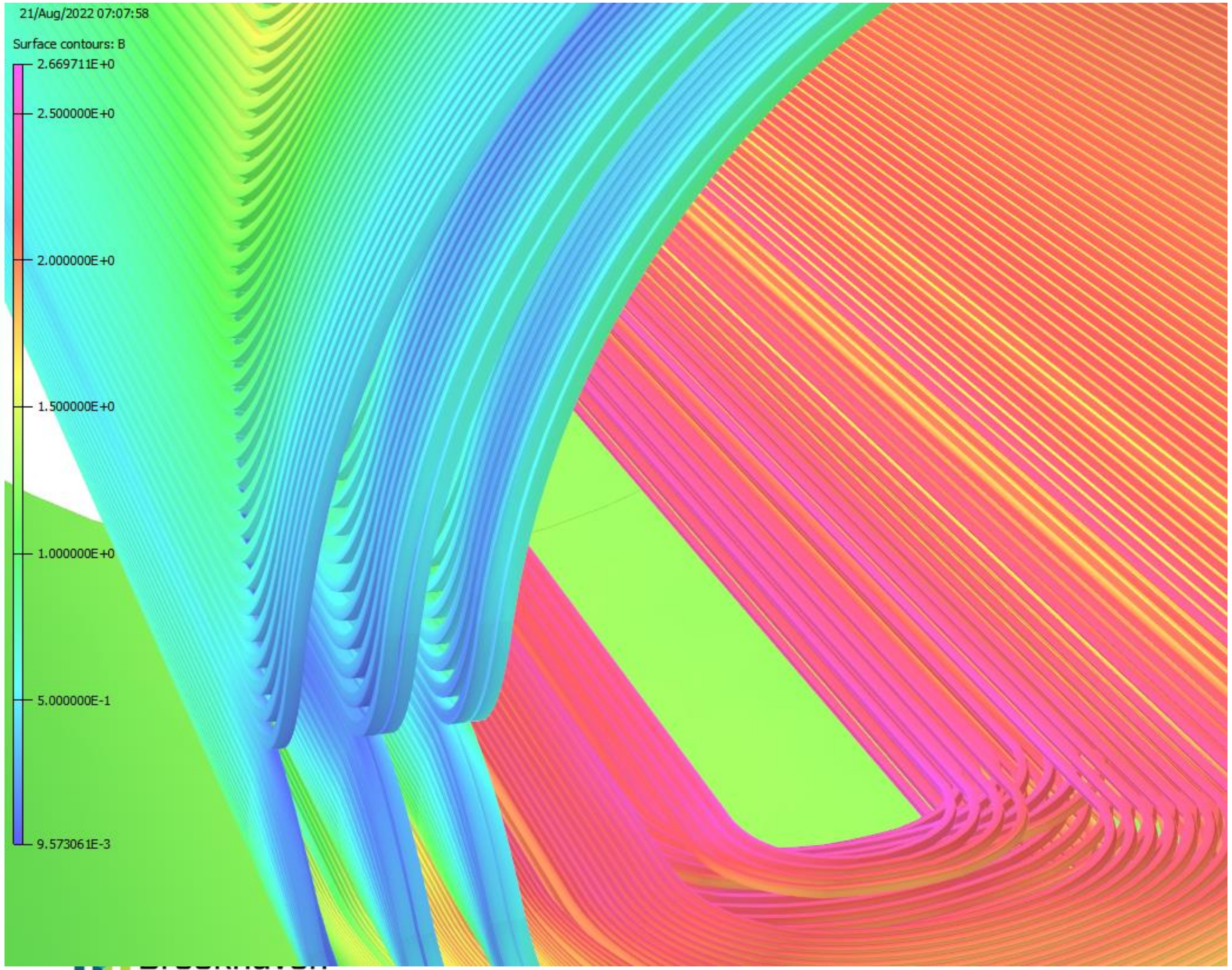


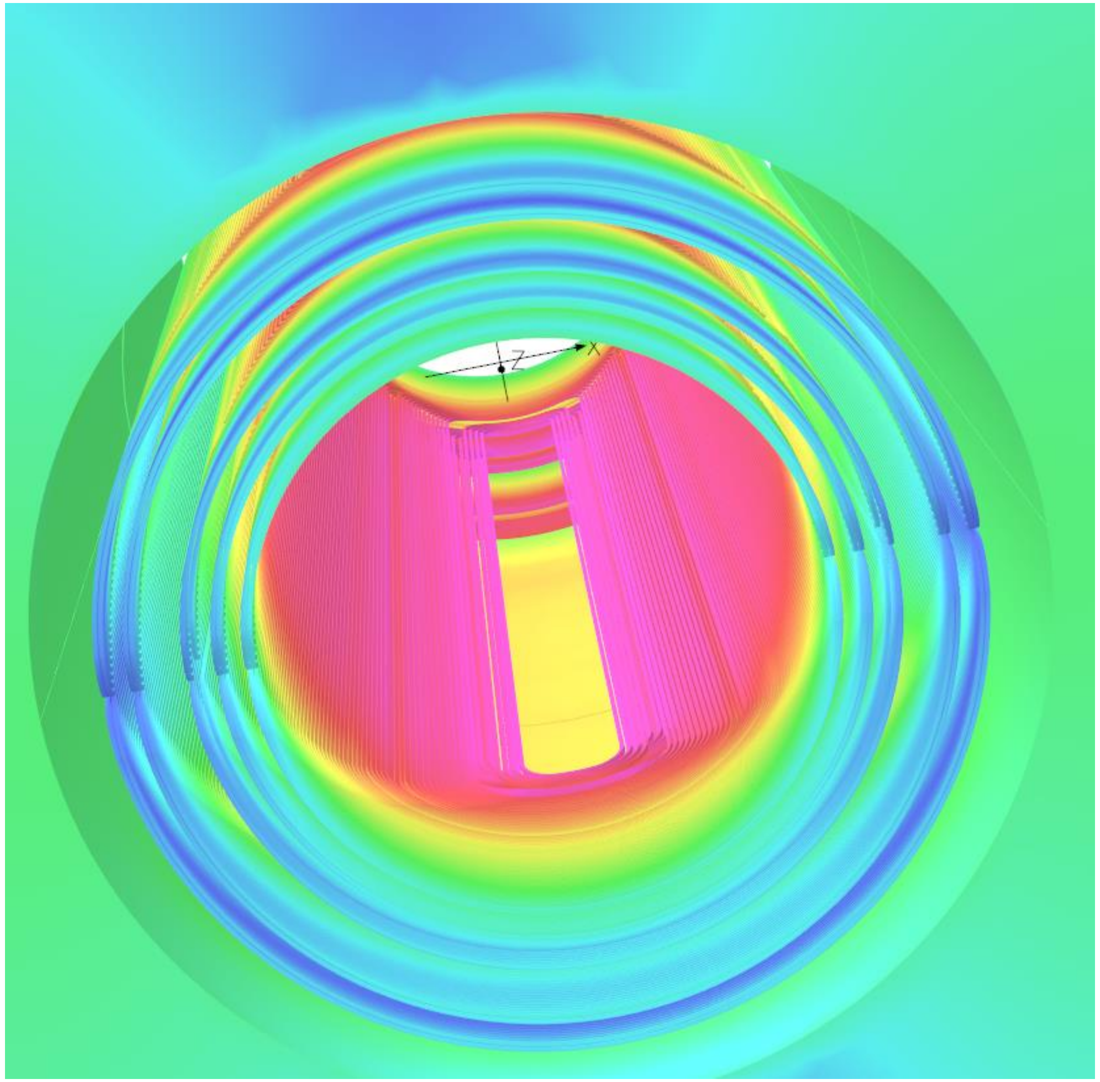


A major task is to do mechanical design and analysis of the 6-layer (year 1) and of the 10-layer (year 2) structures

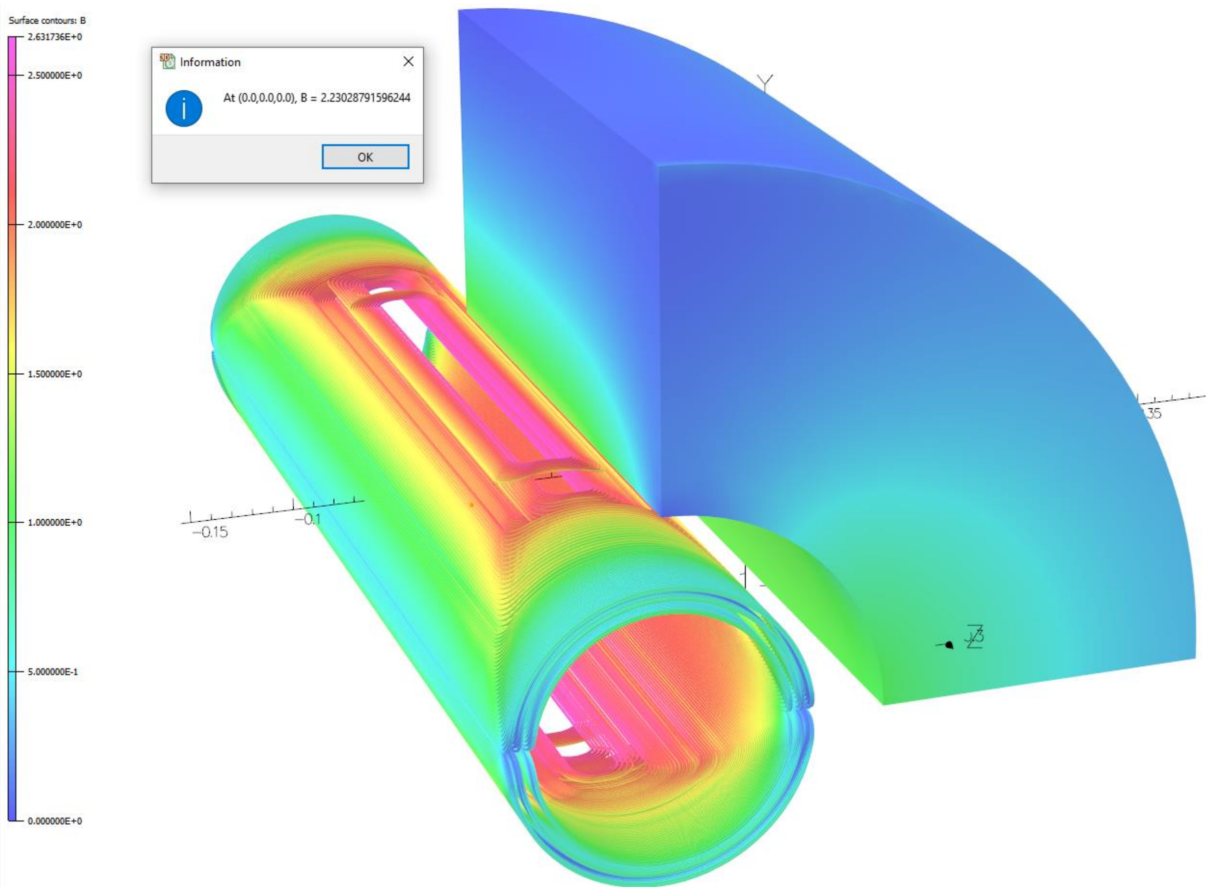
Models of Year 1 and Year 2 Magnets

Ignore curvature at the ends and avoid modelling individual wire. Each coil (or section of coil) becomes a two-part structure – one for the body and another for the end (or a series of them).

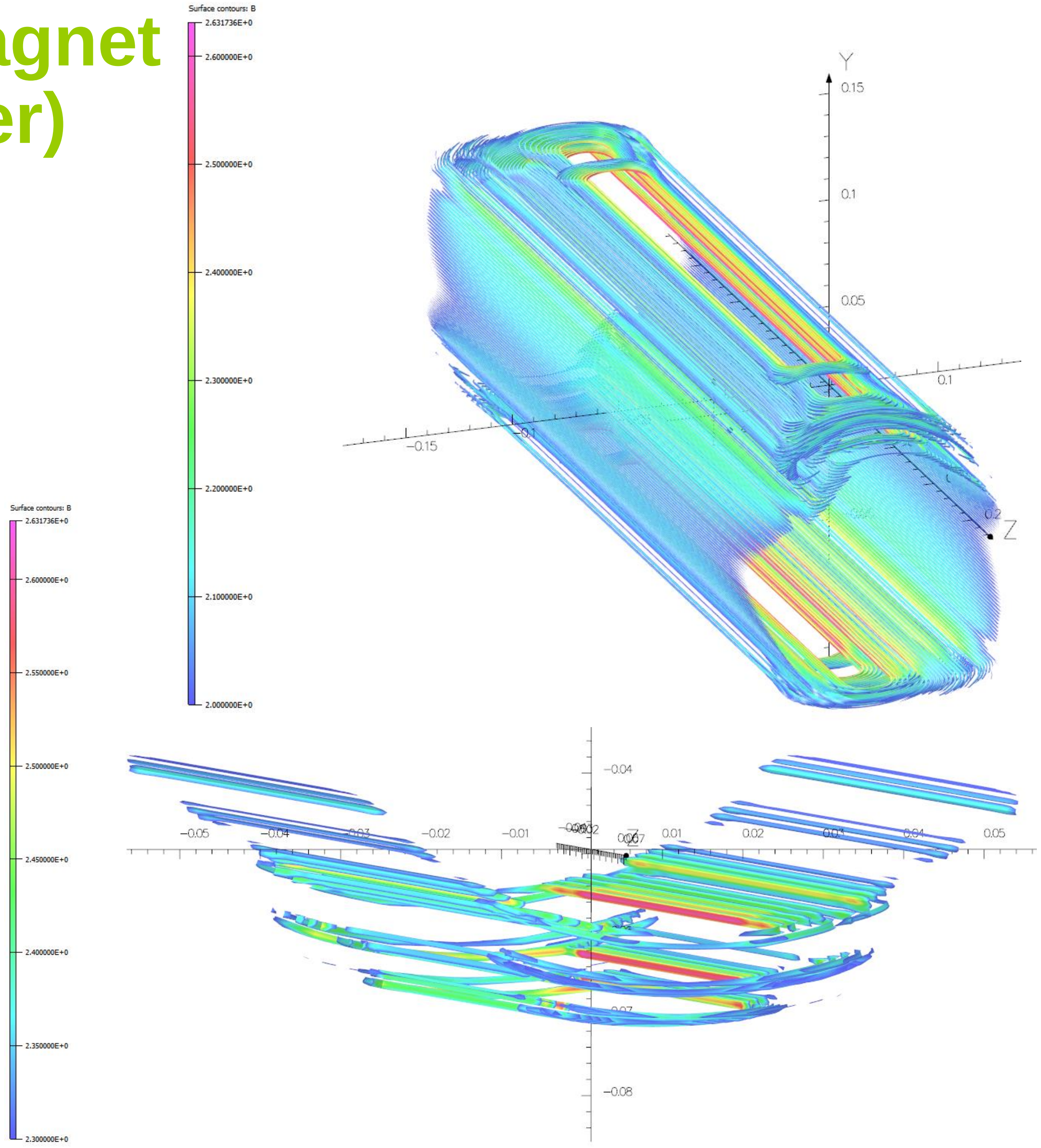




Magnetic Design of Year 1 Magnet (6 single layers, 3 double layer)



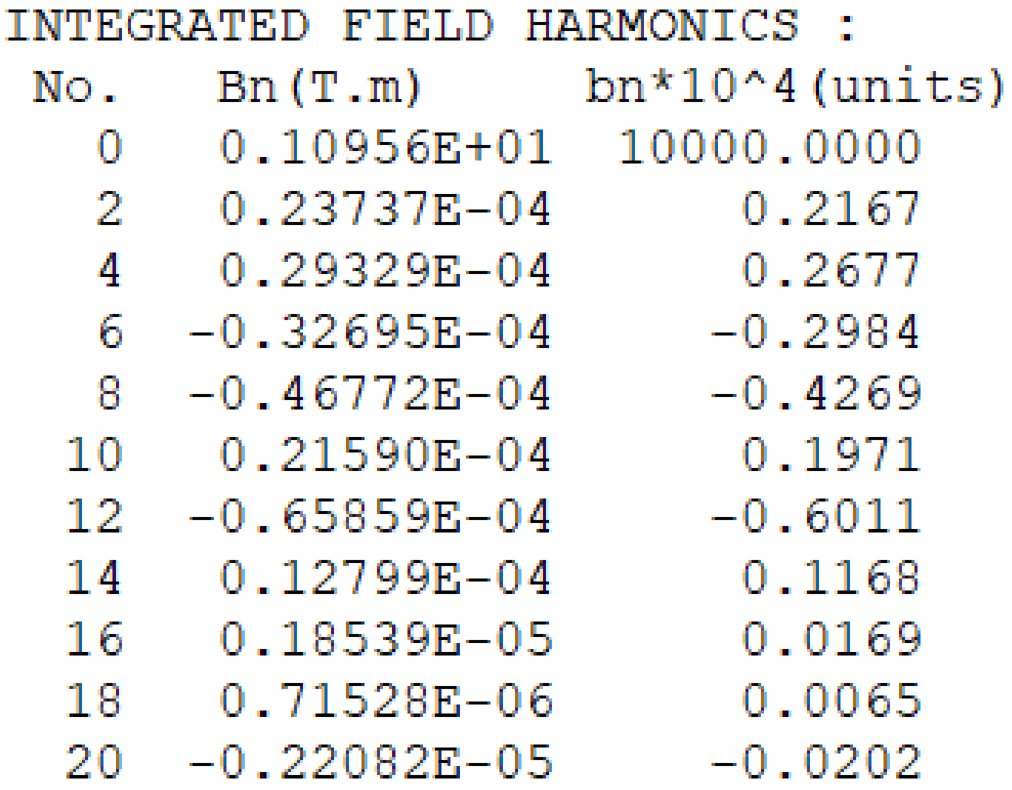
At (0.0,0.0,0.0), B = 2.23028791596244



Peak field is primarily in the body of the magnet (not in the ends)

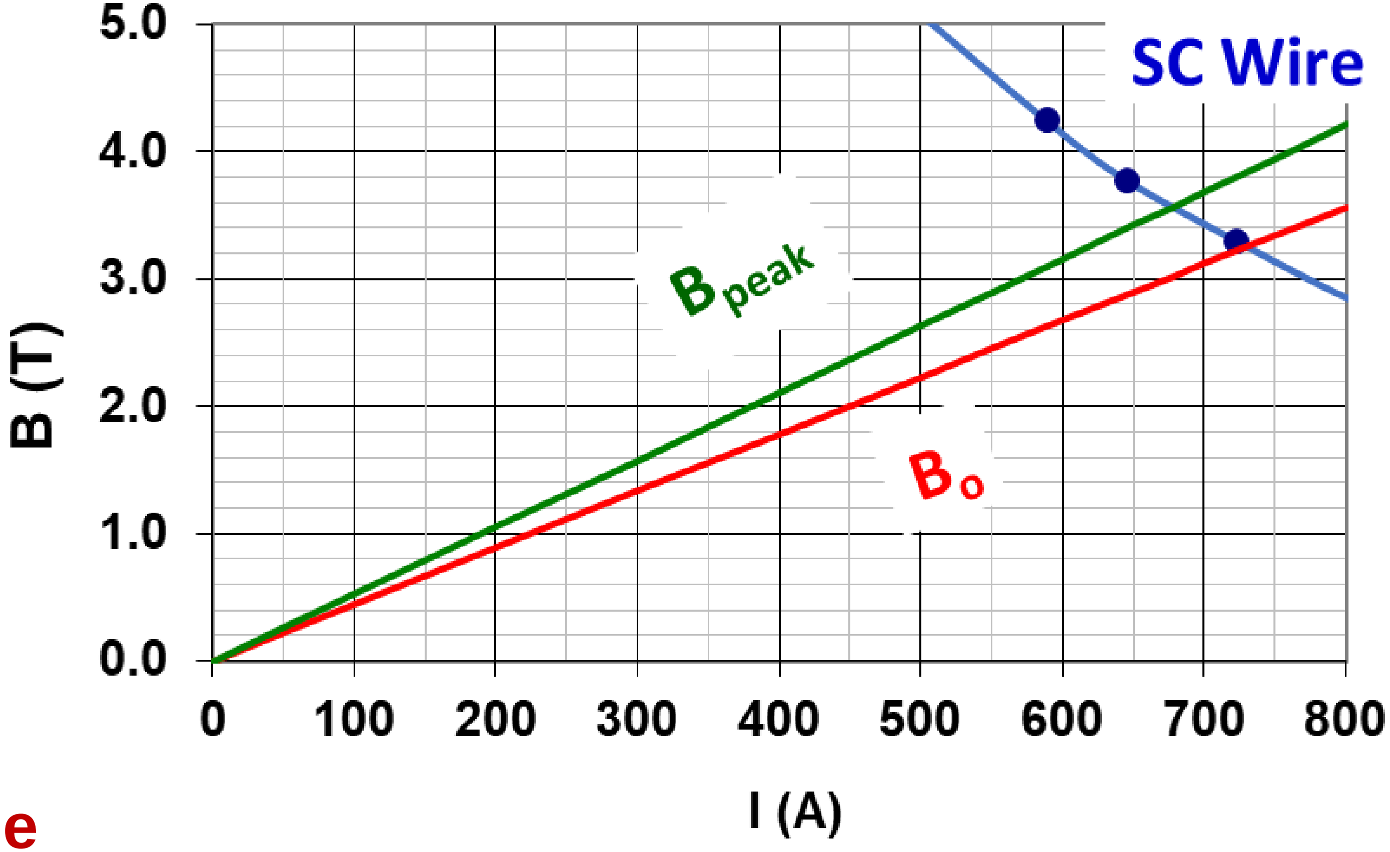
Magnetic Design of Year 1 Magnet (6 layers)

Good field quality (computed)
All harmonics <1 unit @38 mm
Coil inner radius: ~114 mm



```
INTEGRATED FIELD HARMONICS :
 No.    Bn(T.m)       bn*10^4(units)
   0    0.10956E+01   10000.0000
   2    0.23737E-04       0.2167
   4    0.29329E-04       0.2677
   6   -0.32695E-04      -0.2984
   8   -0.46772E-04      -0.4269
  10    0.21590E-04       0.1971
  12   -0.65859E-04      -0.6011
  14    0.12799E-04       0.1168
  16    0.18539E-05       0.0169
  18    0.71528E-06       0.0065
  20   -0.22082E-05      -0.0202
```

Computed short sample:
3.02 T @678 A
Peak Field: 3.57 T
Stored Energy: ~31 kJ



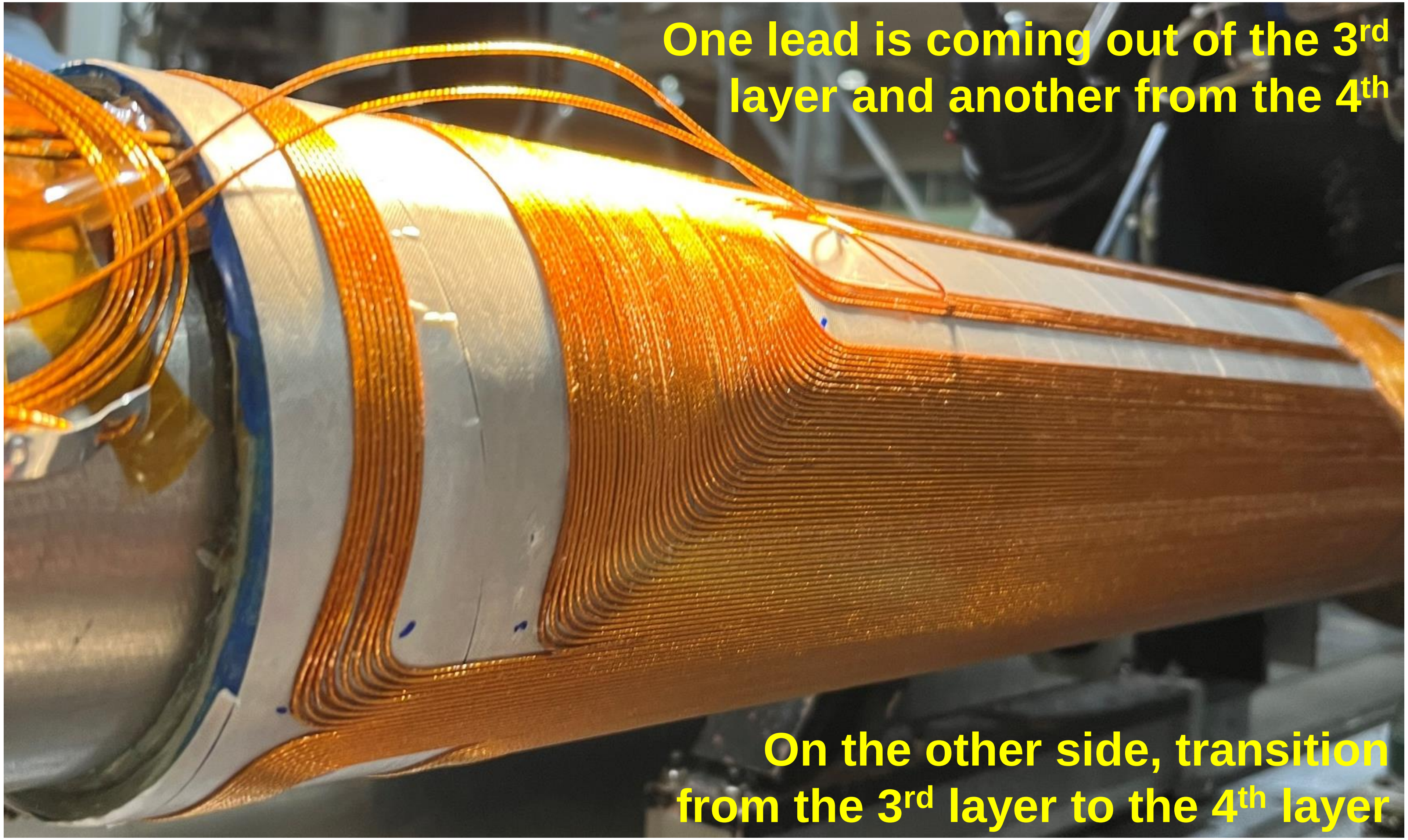
Note: b_2 is sextupole

Status- 4th layer wound (2nd double-layer)

4th layer is visible

3rd layer, wound earlier in Phase II, is hidden underneath

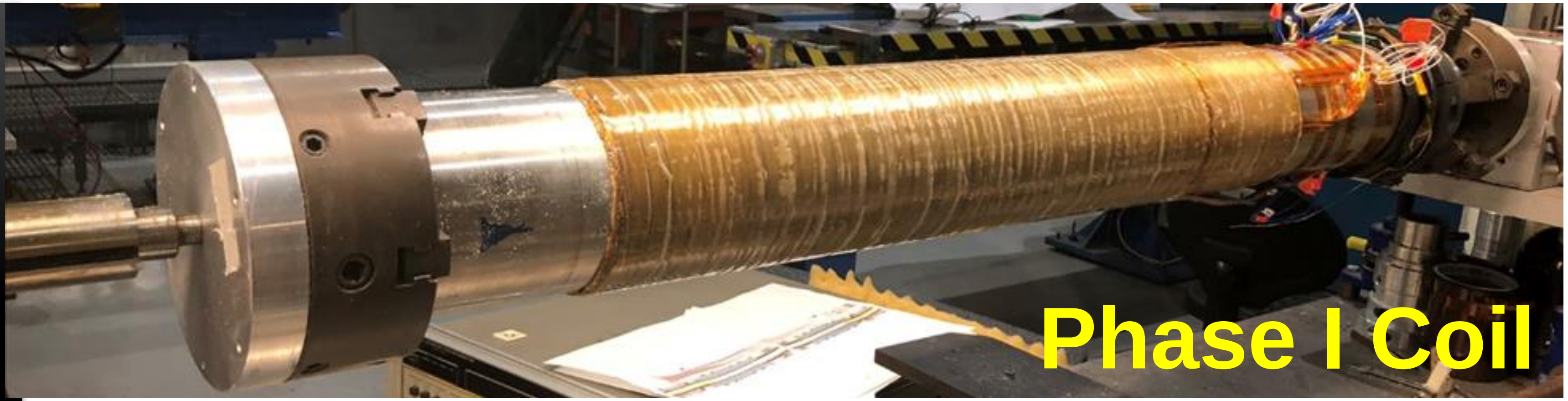
First two layers (1st double-layer) were wound in Phase I. They are hidden further underneath



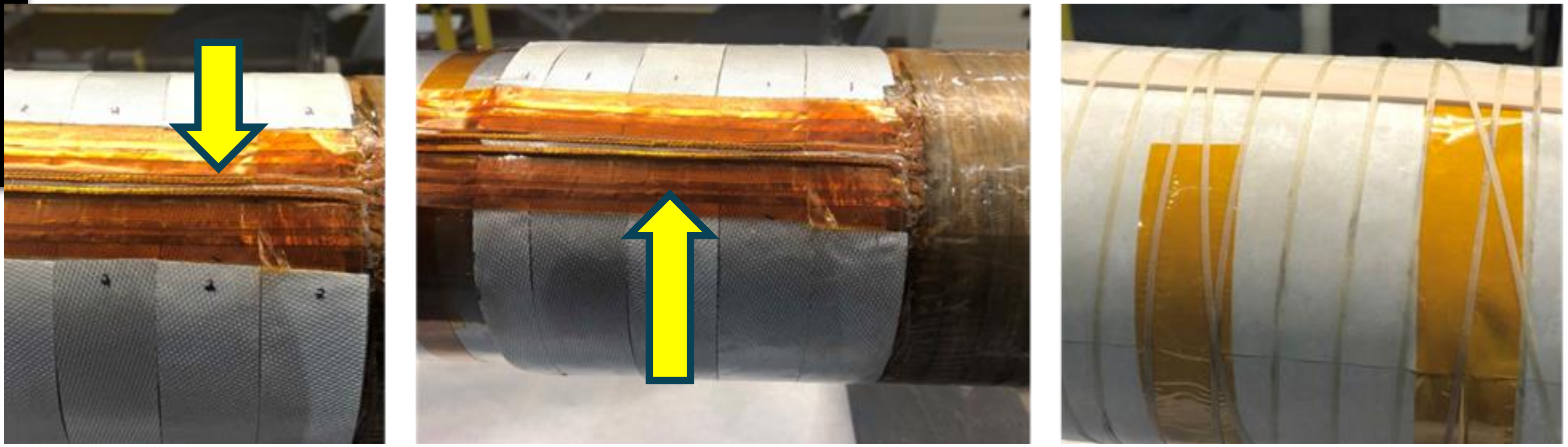
One lead is coming out of the 3rd layer and another from the 4th

On the other side, transition from the 3rd layer to the 4th layer

==> Addressing a significant drawback in the “Optimum Integral Design” as compared to that in the “Serpentine Design” and “Helical Design”



Leads of the double layer of the optimum integral design take extra radial space (see photos on right)



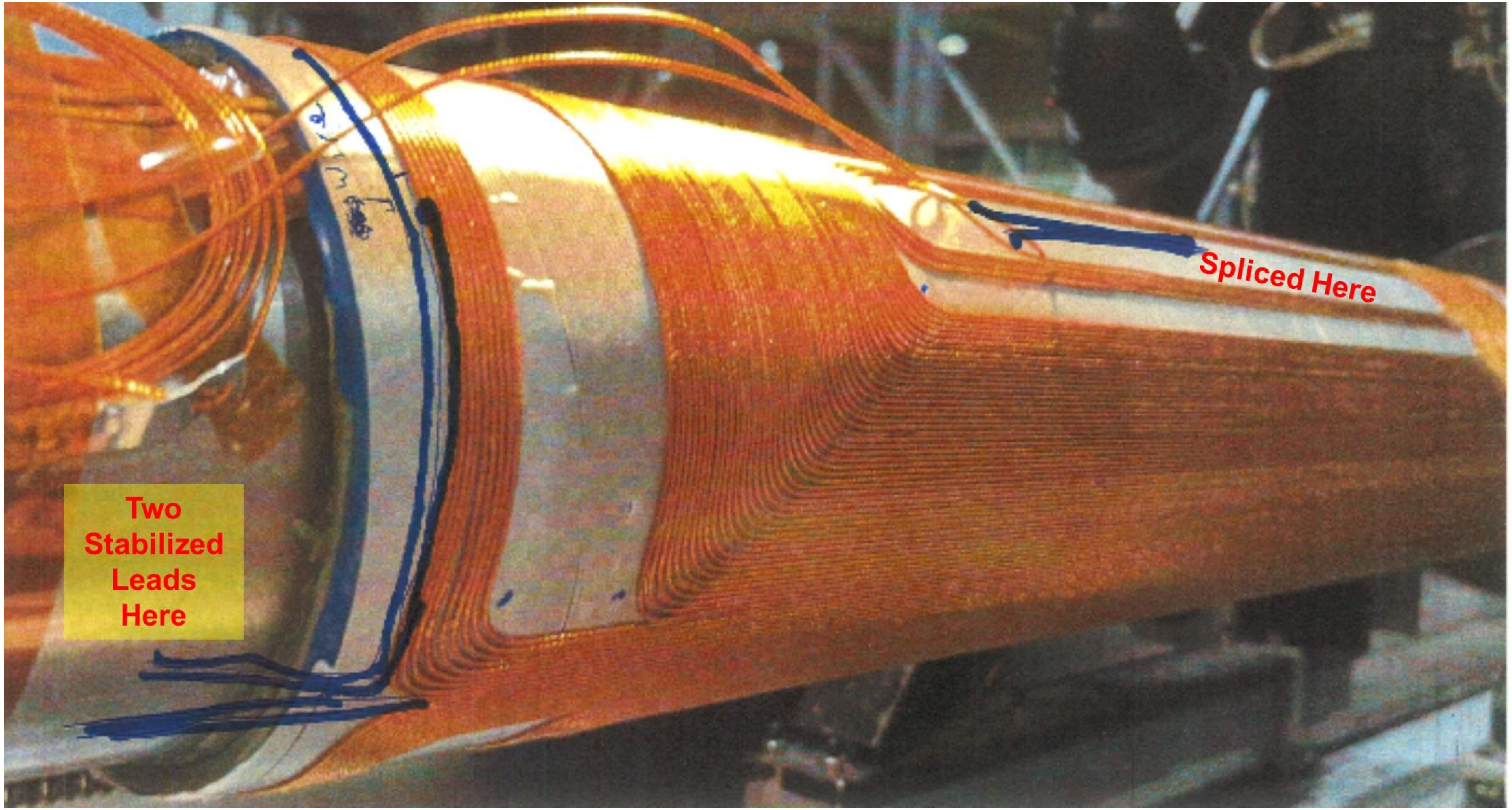
Can it be avoided?

Sketch of the Splices and the Leads for Incorporating it in the coils already wound

(avoiding extra radial space for the leads)

The last turn in one End will be cut and turned in to parts of the two leads.

The last turn will be peeled out, stabilized and put back in.

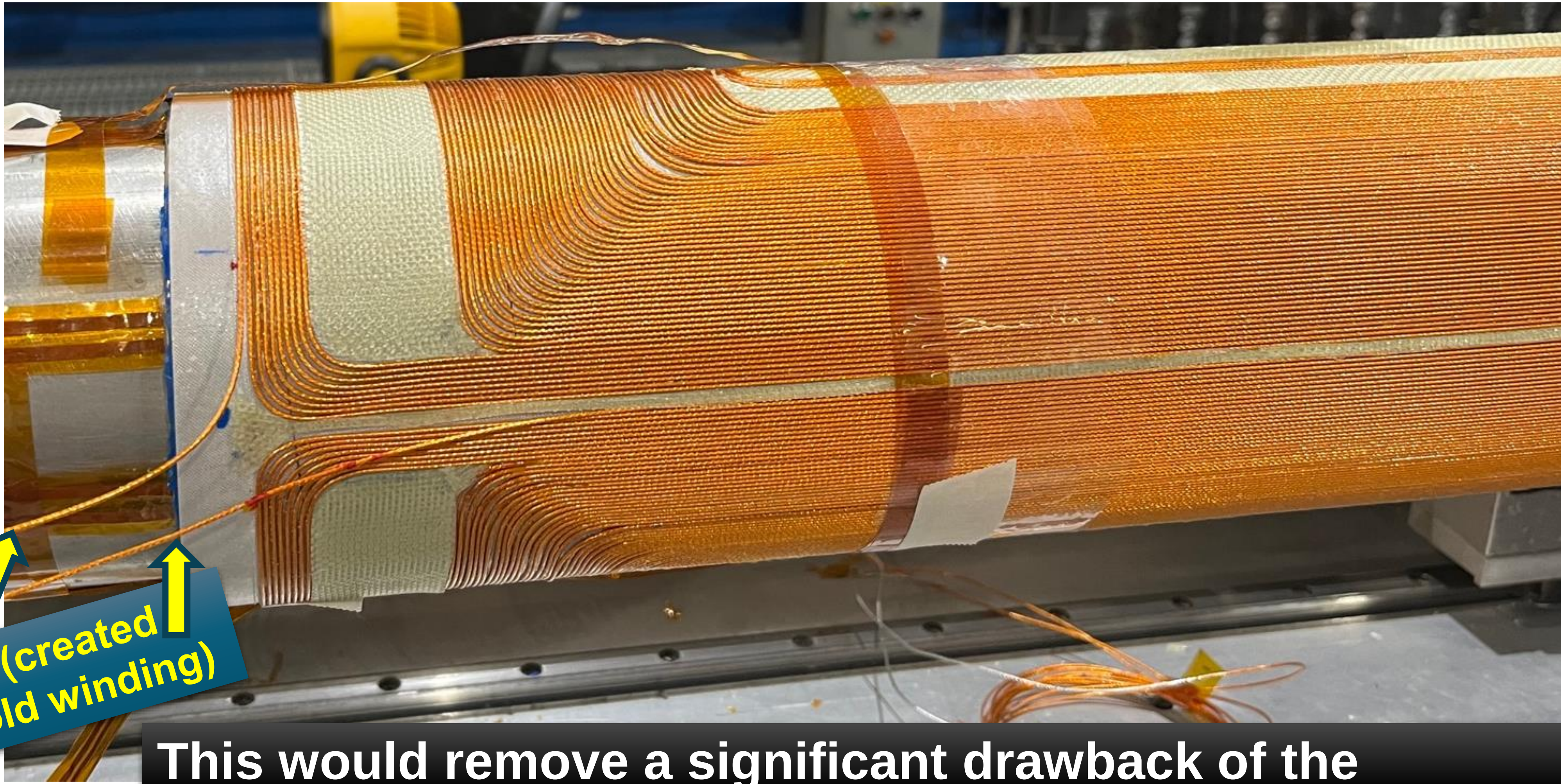


Splices and the Leads as Getting Incorporated Now

(avoiding extra radial space for the leads)

Already getting incorporated in the previously made coil.

Will do even a better and more planned job in the next set of coils.

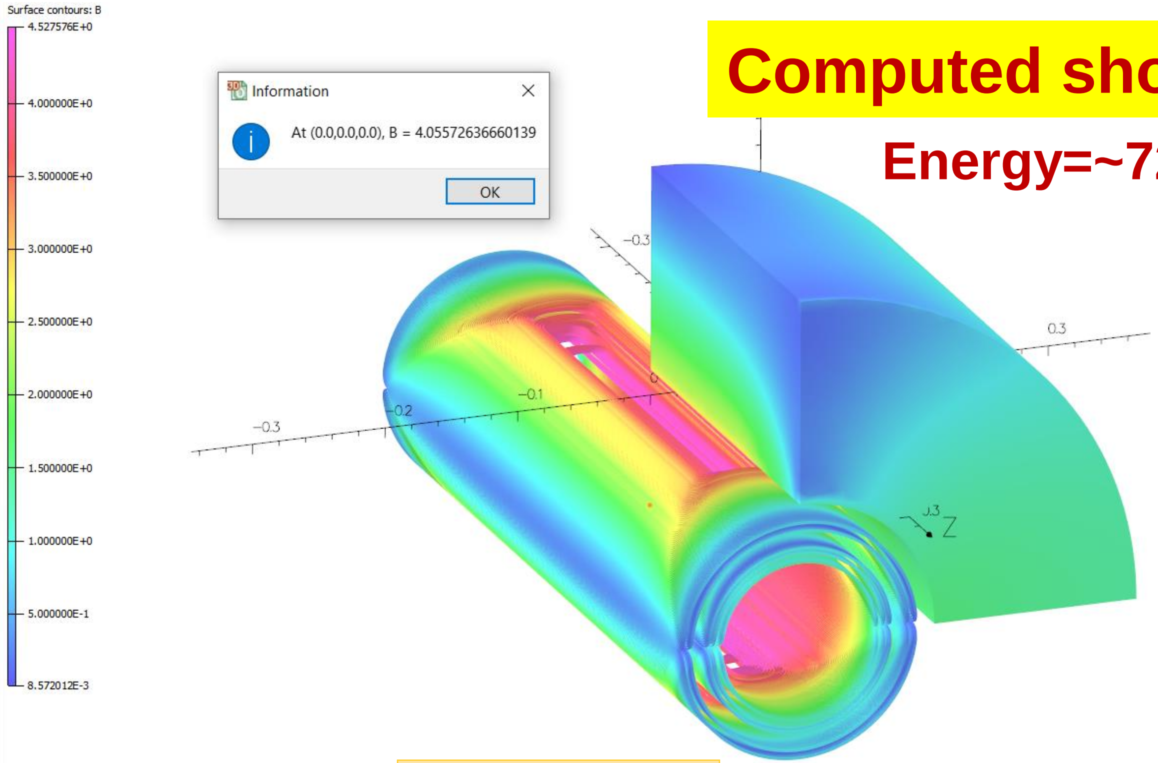


New leads (created from the old winding)

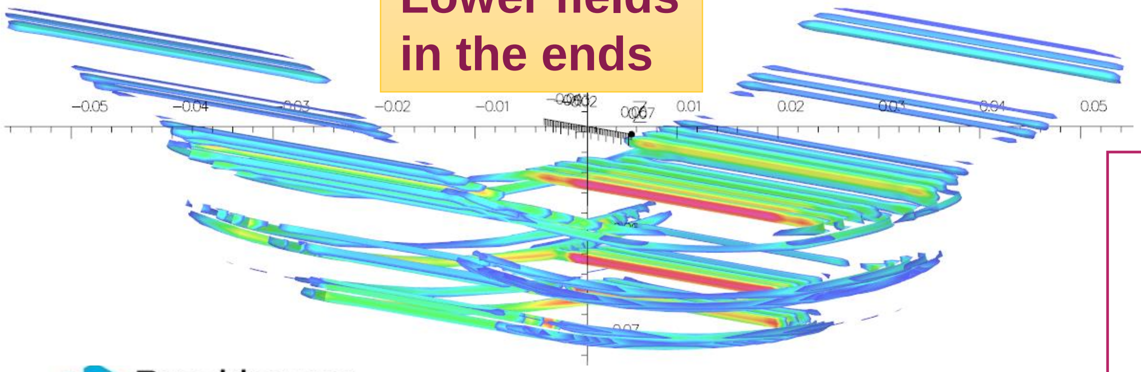
This would remove a significant drawback of the "Optimum Integral Design": extra radial space for leads

Magnetic Design of Year 2 Magnet (10 layers)

Computed short sample: 4.3 T @530 A, Peak Field: 4.8 T

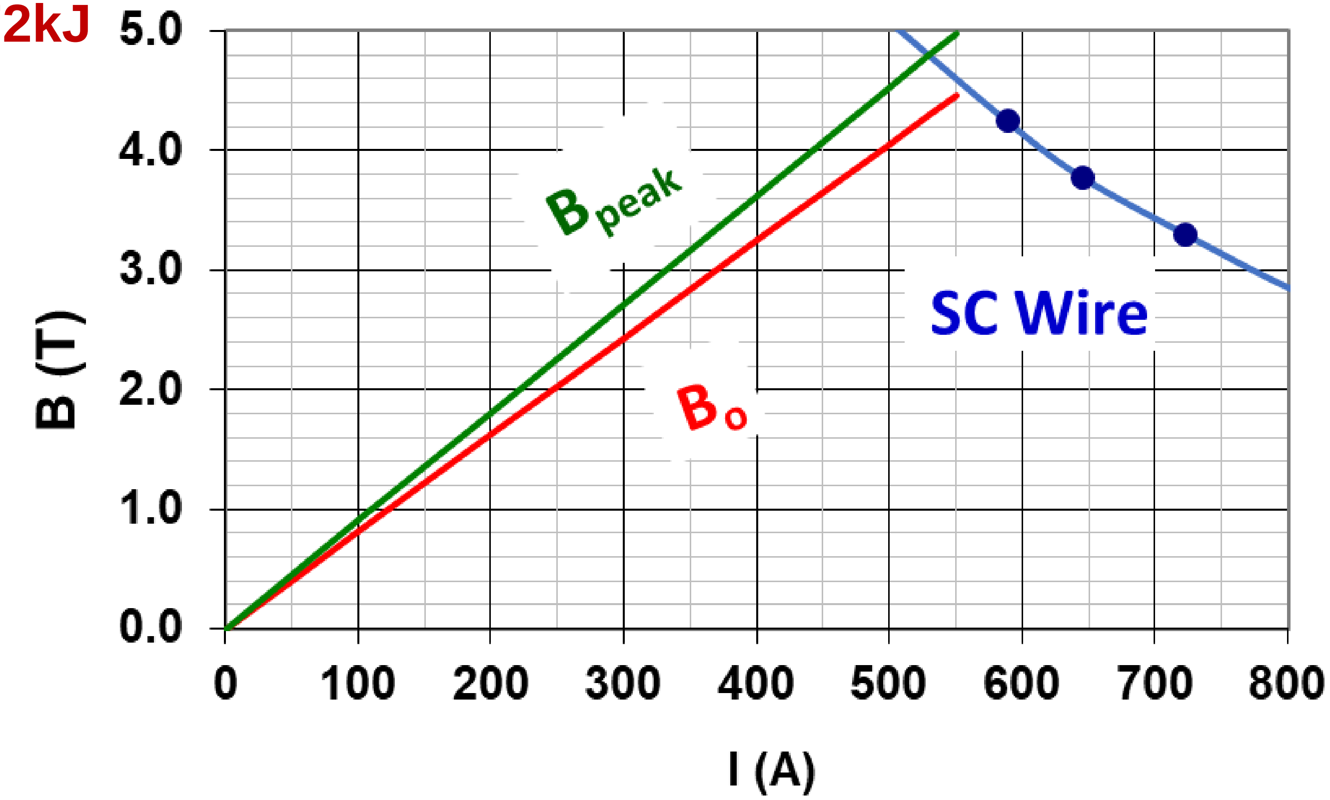


At (0.0,0.0,0.0), B = 4.05572636660139



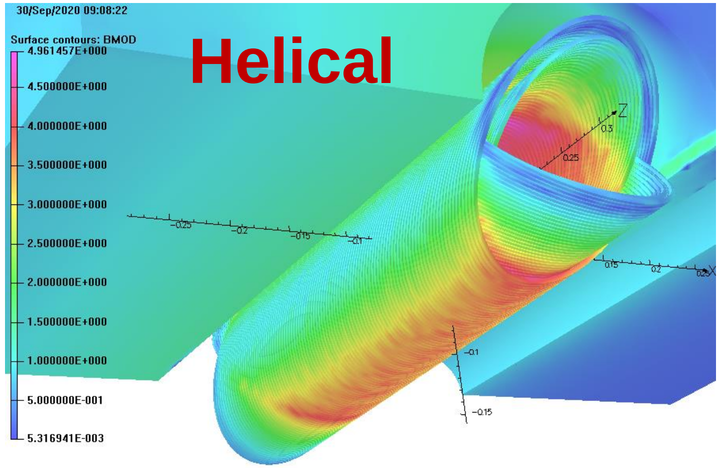
Lower fields in the ends

Energy=~72kJ



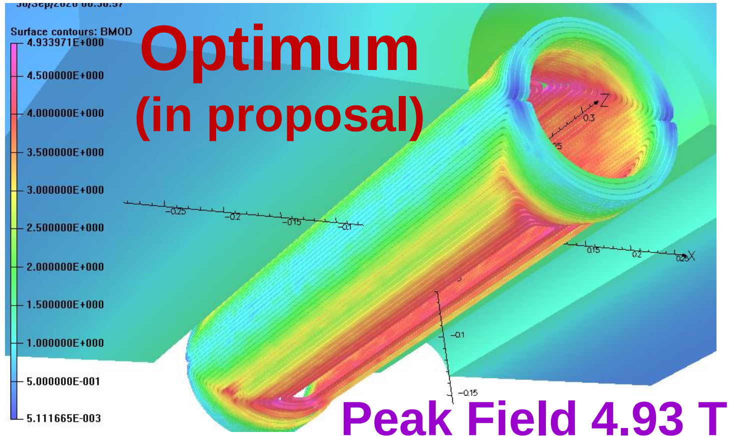
It is easier to obtain lower peak fields in the optimum integral design as compared to that in the double helix or in serpentine

Benefit of Optimum Integral Design
Increase in Integrated Field and Reduction in Peak Field



Helical

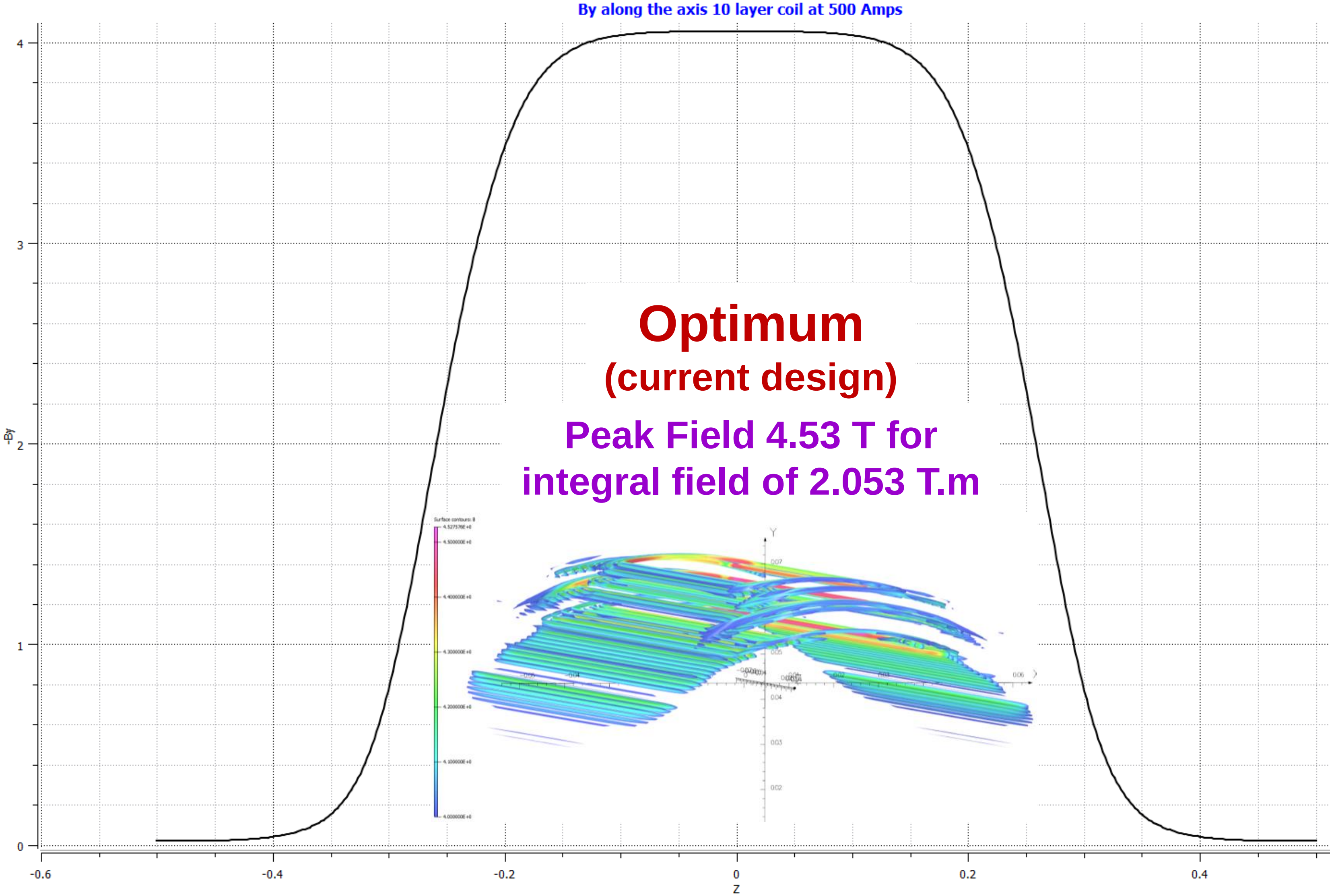
Peak Field 4.96 T for integral field of 2.042 T.m



Optimum

(in proposal)

Peak Field 4.93 T for integral field of 2.296 T.m



Optimum

(current design)

Peak Field 4.53 T for integral field of 2.053 T.m

Major Technical Tasks Remaining and Challenges

Quench Protection

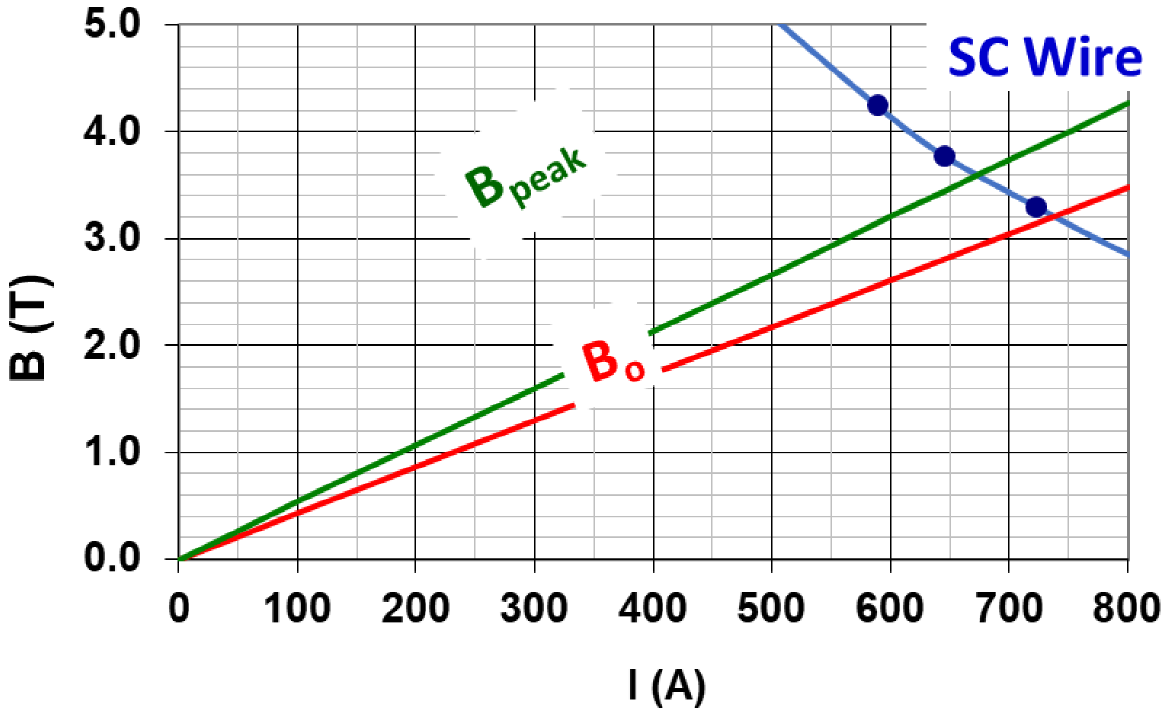
- ***Leads coming out of each double layers. They can be individually protected with diodes and resistors. How much energy can be dumped in the coils inside?***

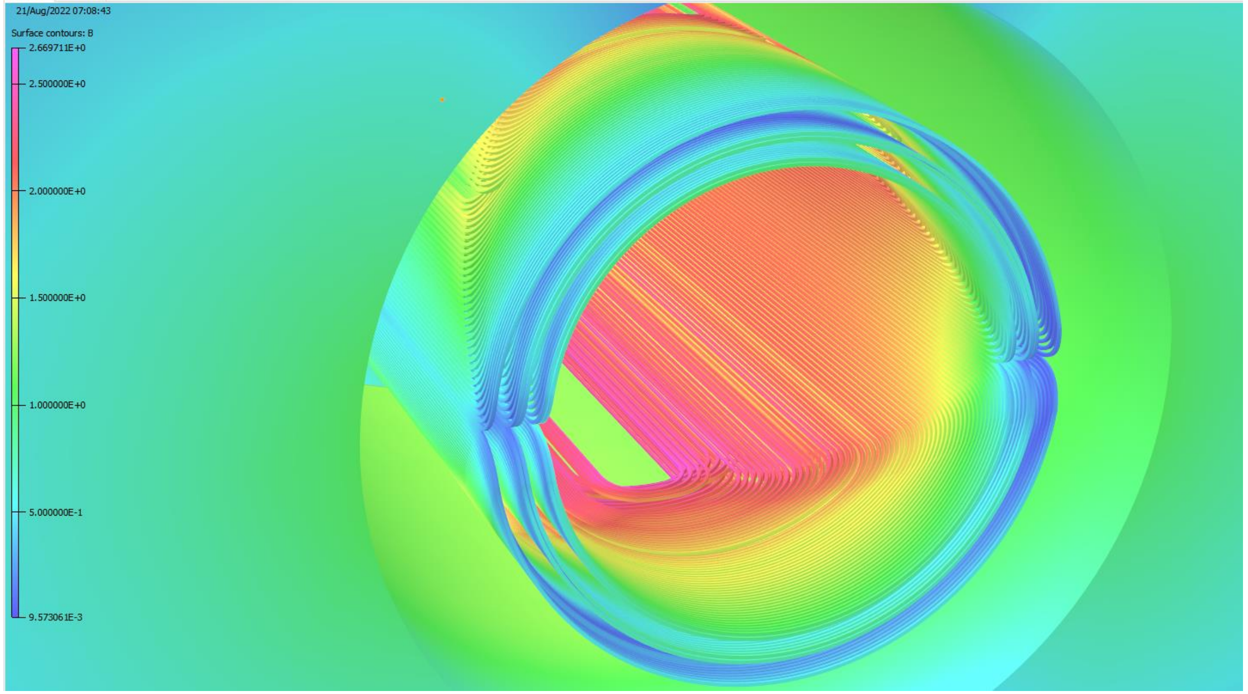
Mechanical Structure

- ***This is a significant field (~4.3 T) in a significant aperture (coil i.d. 114 mm) - beyond what has yet been demonstrated with the direct wind technology. It must be treated with proper care and respect.***

Quench Analysis

- **Year 1 test (with three double-layer coil) is expected to have a short sample field a little under 3 T, peak field of ~3.5 T, and stored energy @quench ~31 kJ**
- **We have 3 pairs of leads coming out (one pair from each double pancake)**
- **Do we need resistors or diodes between resistors and how about outside**
- **What will be the maximum temperature rise in the 6-layer coil dipole?**
- **How about in the final Phase II dipole (year 2) with 10 layers; ~4.3 T, ~72 kJ**





Mechanical Structure Consideration

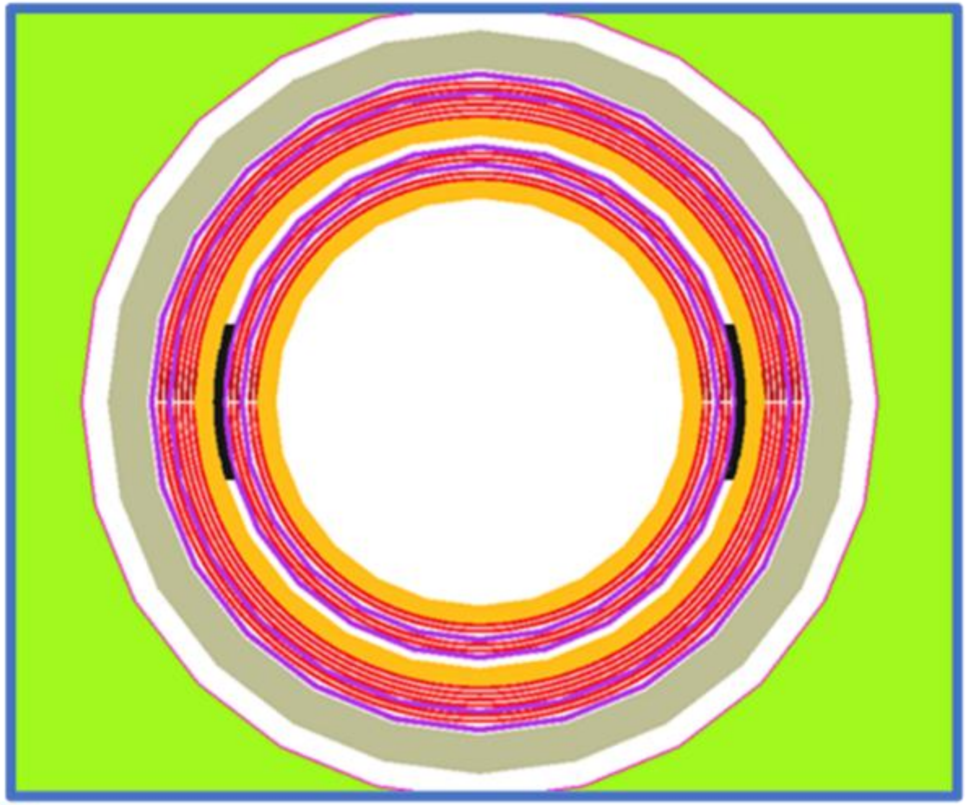
Structure elements available to support the present design:

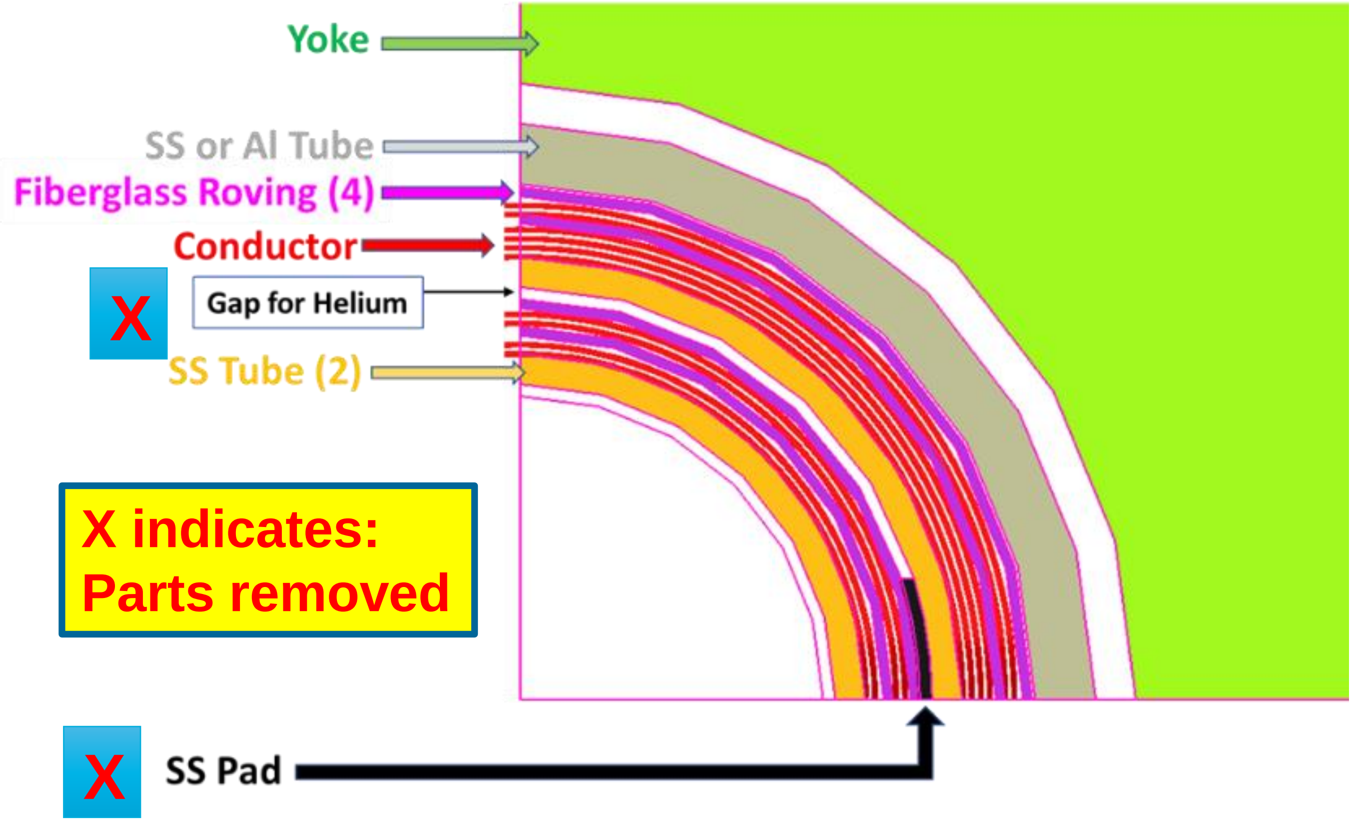
- ➢ ***Three stainless steel tubes and tension roving after each double layer.***

Need to ensure reliable calculations with sufficient margin

- ➢ ***Immediate question: Do we need an outer SS tube for the Year 1 test?***

PBL is supposed to do most of the mechanical analysis, but we need to support and ensure it

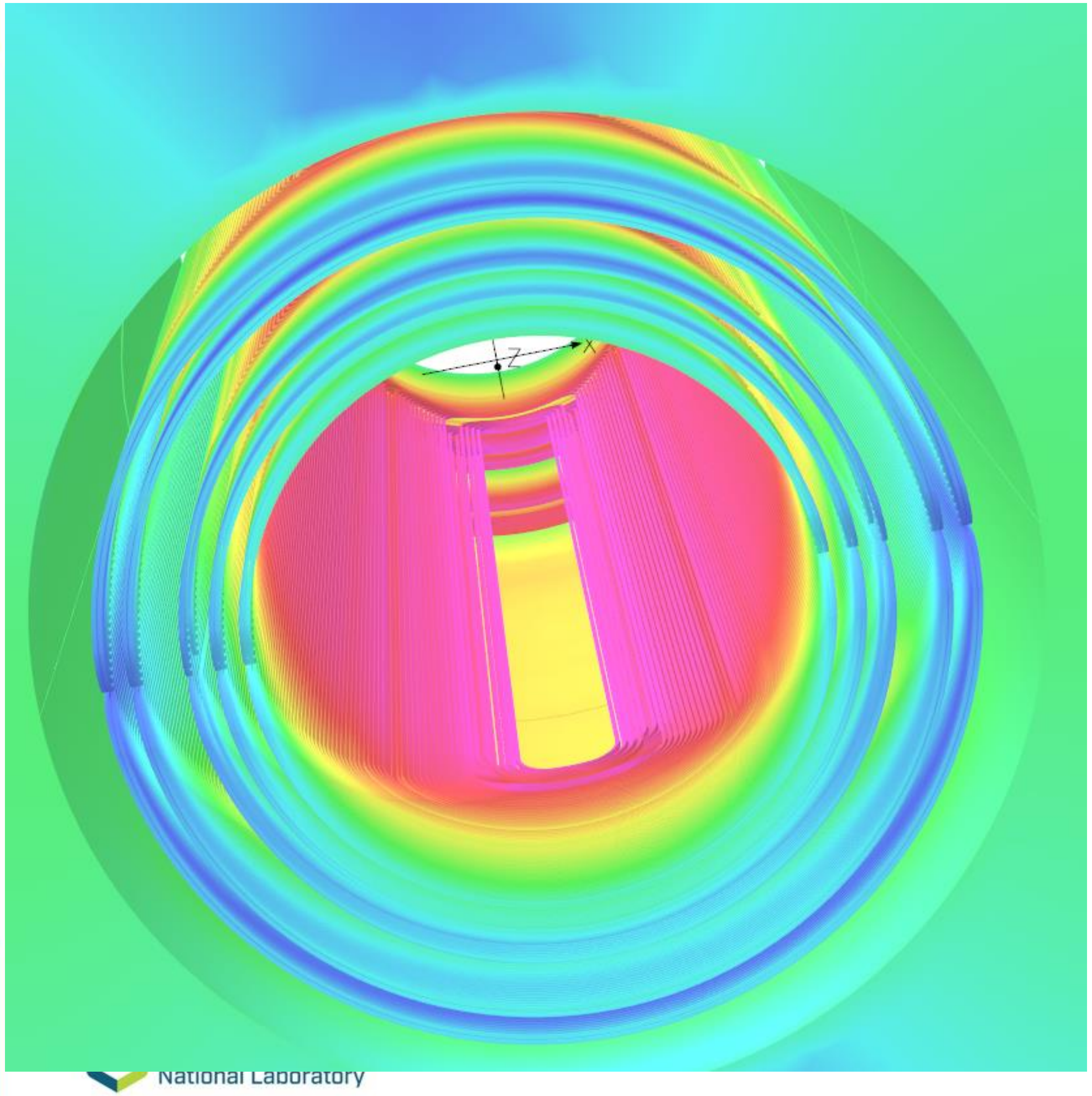


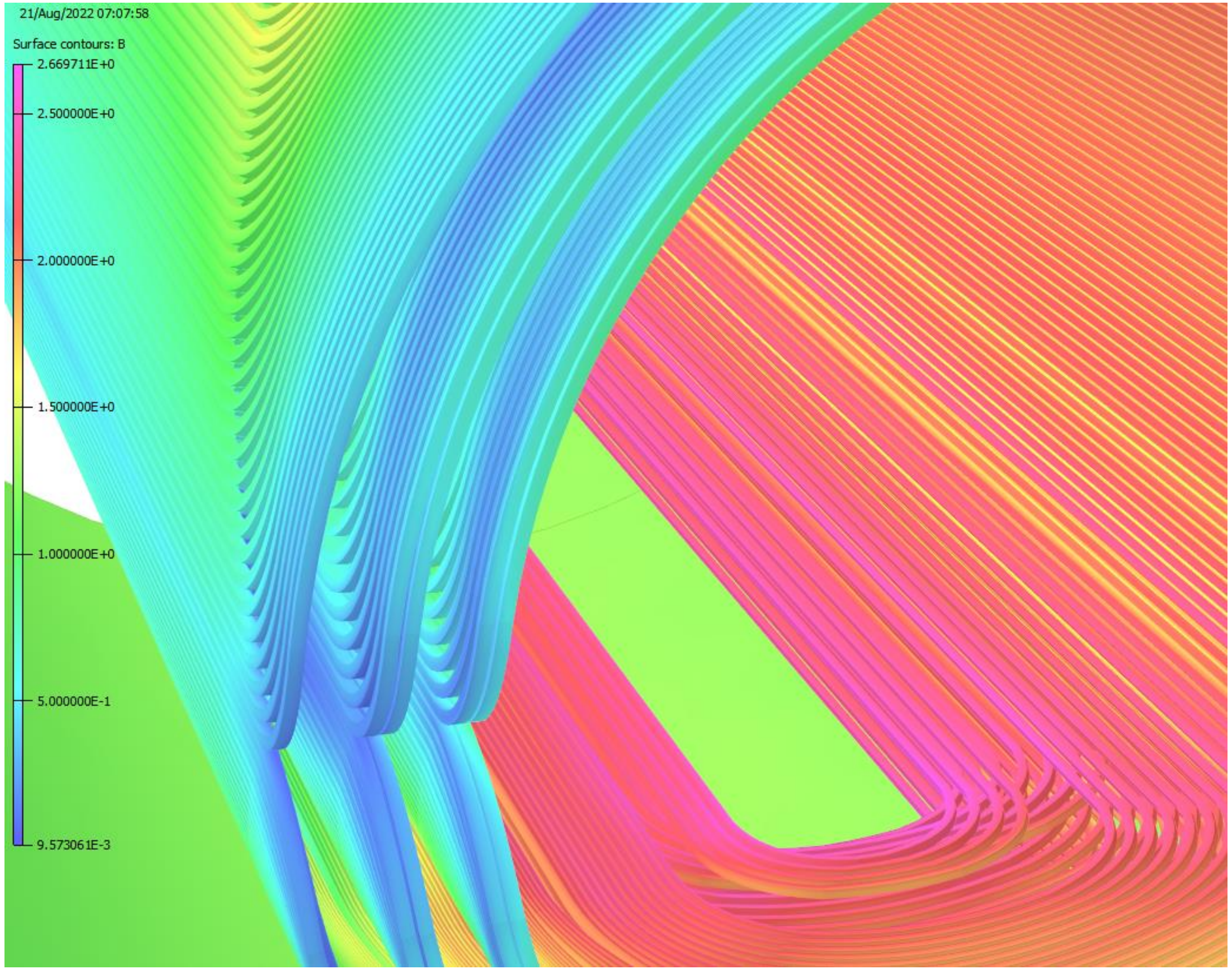


X indicates: Parts removed

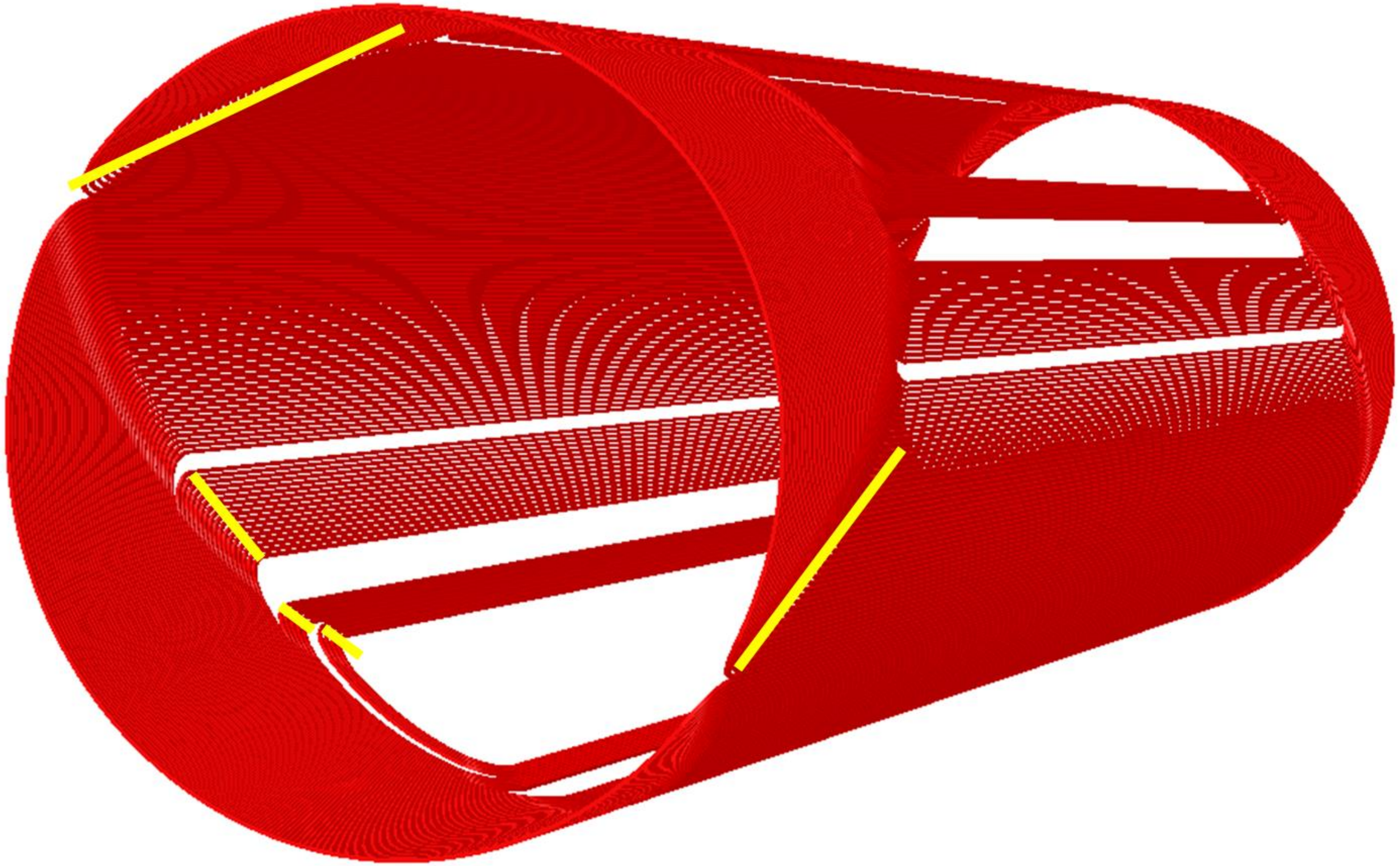
Simplifying Coils for Overall Mechanical Analysis

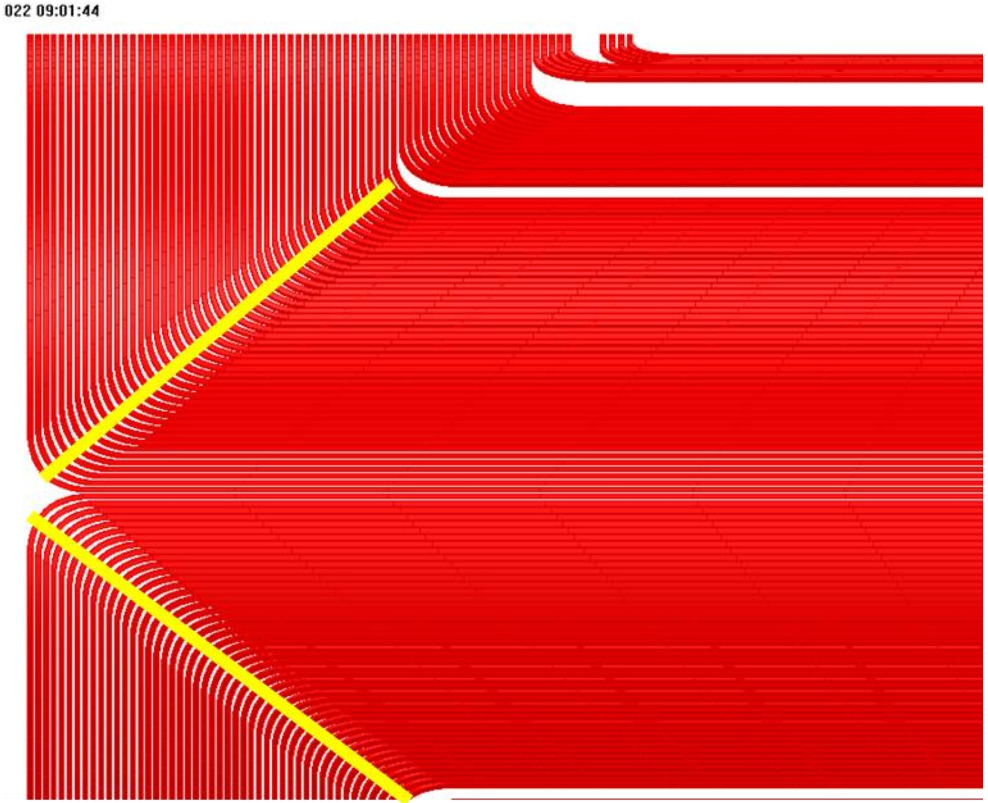
Ignore curvature at the ends and avoid modelling individual wire. Each coil (or section of coil) becomes a two-part structure – one for the body and another for the end (or a series of them).





Dividing Coils for a Simple Model Blocks
(One part for the body and another part for the end)





Recycling Existing Iron for the Phase II Dipole

Ray Ceruti found the existing iron that can be used for this R&D magnet. THANKS

Yoke for year 1 test

8” ID, 14” OD, 26” long

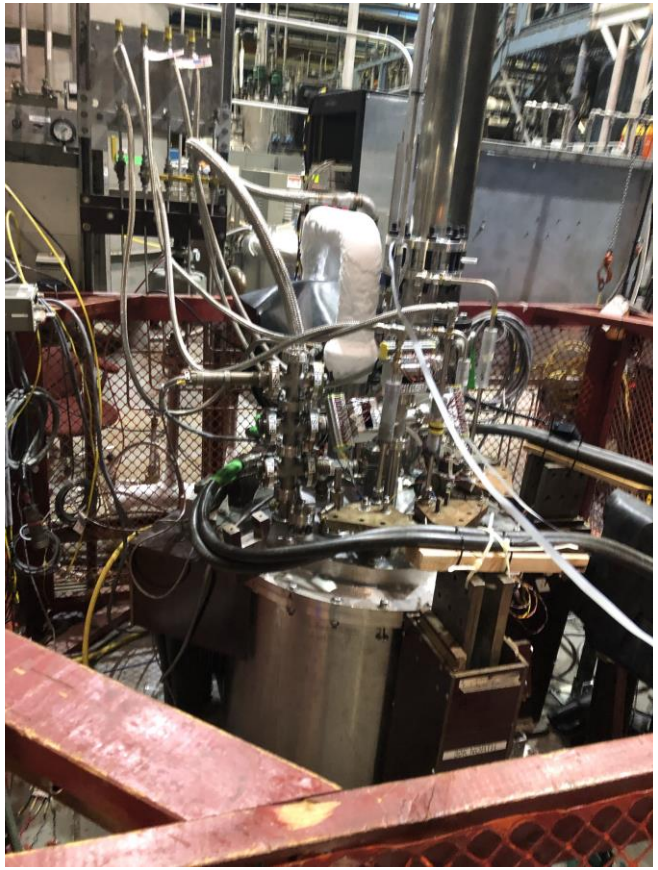
Additional yoke for year 2 test

14” ID, 23” OD, 24” long

(need to do the final check that one can go inside another)

Initial Test Planning for Year 1 and Year 2

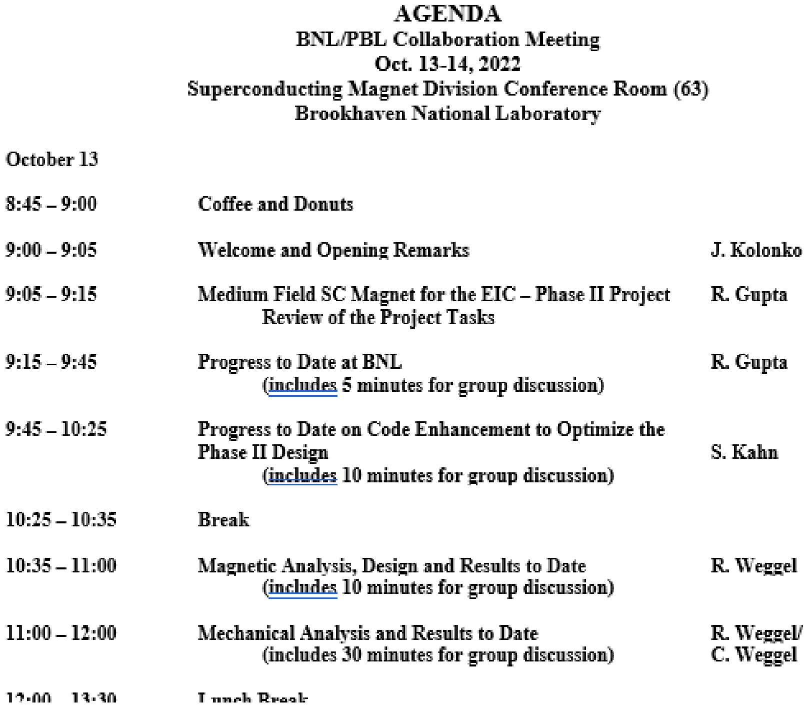
- The overall test setup and most of the plan will be based on the test carried out during Phase I
- Phase I dipole reached ~870 A, year 1 dipole is expected ~680 Amp, and year 2 dipole ~530 A
- Start planning overall test plan and test date once we start winding #5 and #6 layers
- Detailed planning to be carried out with PBL after details are sorted out (~2 months before test)



Impact on and Possible Application to other EIC Magnets

Impact on and Possible Application to other EIC Magnets

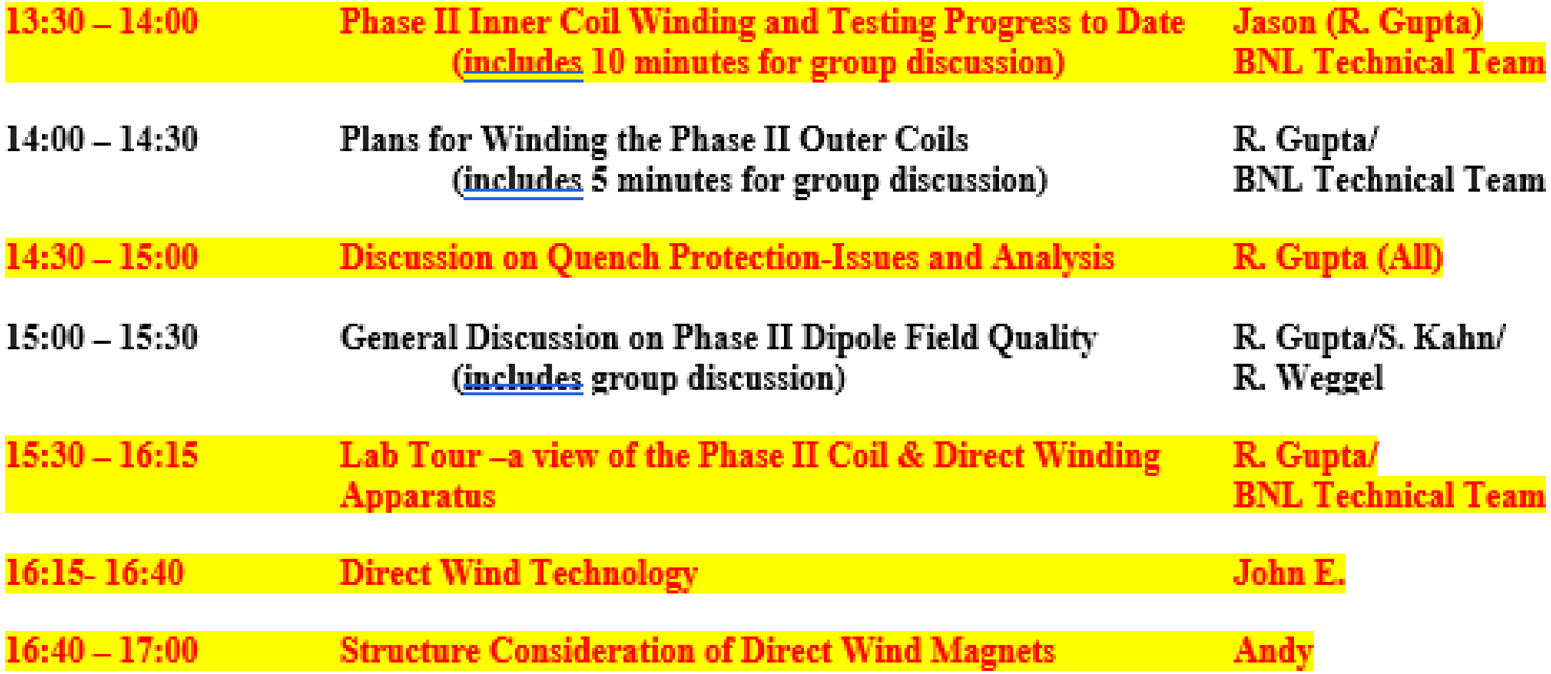
- **Construction and test of 4.3 T, 114 mm aperture dipole should be a significant demonstration of the direct wind technology for EIC.**
- **For comparison, RHIC arc dipole and insertion dipoles operate at ~3.5 T (similar quench field) and have 80 mm and 100 mm aperture.**
- **Optimum integral design extends the integral field for the same coil length and have better handle in reducing the peak enhancement factor.**
- **Latest design eliminates the drawback of optimum dipole leads requiring extra radial space and complications as compared to serpentine and double helix.**
- **Lorentz forces in optimum integral design should be simpler and in more favorable as compared to that in a double helix design.**
- **The relative benefit of the optimum integral design is more in short magnet, but the design will be beneficial to all EIC magnets. So why not consider it?**



AGENDA
BNL/PBL Collaboration Meeting
Oct. 13-14, 2022
Superconducting Magnet Division Conference Room (63)
Brookhaven National Laboratory

October 13

8:45 – 9:00	Coffee and Donuts	
9:00 – 9:05	Welcome and Opening Remarks	J. Kolonko
9:05 – 9:15	Medium Field SC Magnet for the EIC – Phase II Project Review of the Project Tasks	R. Gupta
9:15 – 9:45	Progress to Date at BNL (includes 5 minutes for group discussion)	R. Gupta
9:45 – 10:25	Progress to Date on Code Enhancement to Optimize the Phase II Design (includes 10 minutes for group discussion)	S. Kahn
10:25 – 10:35	Break	
10:35 – 11:00	Magnetic Analysis, Design and Results to Date (includes 10 minutes for group discussion)	R. Weggel
11:00 – 12:00	Mechanical Analysis and Results to Date (includes 30 minutes for group discussion)	R. Weggel/ C. Weggel
12:00 – 13:30	Lunch Break	



13:30 – 14:00	Phase II Inner Coil Winding and Testing Progress to Date (includes 10 minutes for group discussion)	Jason (R. Gupta) BNL Technical Team
14:00 – 14:30	Plans for Winding the Phase II Outer Coils (includes 5 minutes for group discussion)	R. Gupta/ BNL Technical Team
14:30 – 15:00	Discussion on Quench Protection-Issues and Analysis	R. Gupta (All)
15:00 – 15:30	General Discussion on Phase II Dipole Field Quality (includes group discussion)	R. Gupta/S. Kahn/ R. Weggel
15:30 – 16:15	Lab Tour –a view of the Phase II Coil & Direct Winding Apparatus	R. Gupta/ BNL Technical Team
16:15- 16:40	Direct Wind Technology	John E.
16:40 – 17:00	Structure Consideration of Direct Wind Magnets	Andy

Final Comments

- SBIR/STTR programs have allowed us to explore and demonstrate the designs and program that were not yet matured to be pursued with regular funding.
- We must continue to explore and develop new techniques in such R&D program where we have a relatively more flexibility and less visibility
- However, we must look into all aspects in sufficient details (as much as allowed by the budget) and ensure that we are not overlooking any thing.
- Please be as critical and as open as possible. I welcome that. That ensures the success as we don't overlook something that could have been avoided.
- Detailed optimization of the longer magnets based on optimum integral design will be slightly different, but benefits mentioned in the last slide will be there.
- Optimum integral design, in principle, offers several advantage in the tapered magnet as well (topic for another discussion).
- PBL team is visiting next week, please participate in the meeting and help succeed the program.

Questions?