Another Phase I SBIR/STTR Proposal using the Direct Wind Technology

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Introduction

- SBIR/STTR program allows us to explore different/new ideas.
- SBIR/STTR is not supposed to support what national labs are doing as a part of their main programs - not intended to be an additional supplement funding source.
- This proposal is for a tapered quadrupole based on the optimum integral design. Direct Wind technology makes building a magnet based on the proposed design practical.
- This will be an alternate concept to the double helix design. It works for dipole, etc. also.
- Since this is not part of the EIC baseline design, it qualifies for a BNL based SBIR/STTR.
- This will be in continuation of the ongoing PBL/BNL STTR. Therefore, PBL should be in a better position as compared to last time. We got good feedback from the program manager.
- This will continue to expand the applications of the "Direct Wind Technology". Current Phase I is going well. Both layers wound. New staff is having fun + getting good hands-on training.
- This proposal, if funded, will also bring $200k to the program in Phase I ($60k to $115k to BNL, depending on whether it is SBIR or STTR) and $1.1M ($500k-$600k) in Phase II.

EIC Baseline Tapered Coil Design – Double Helix (Holger Witte)

Overview Q1ABpF

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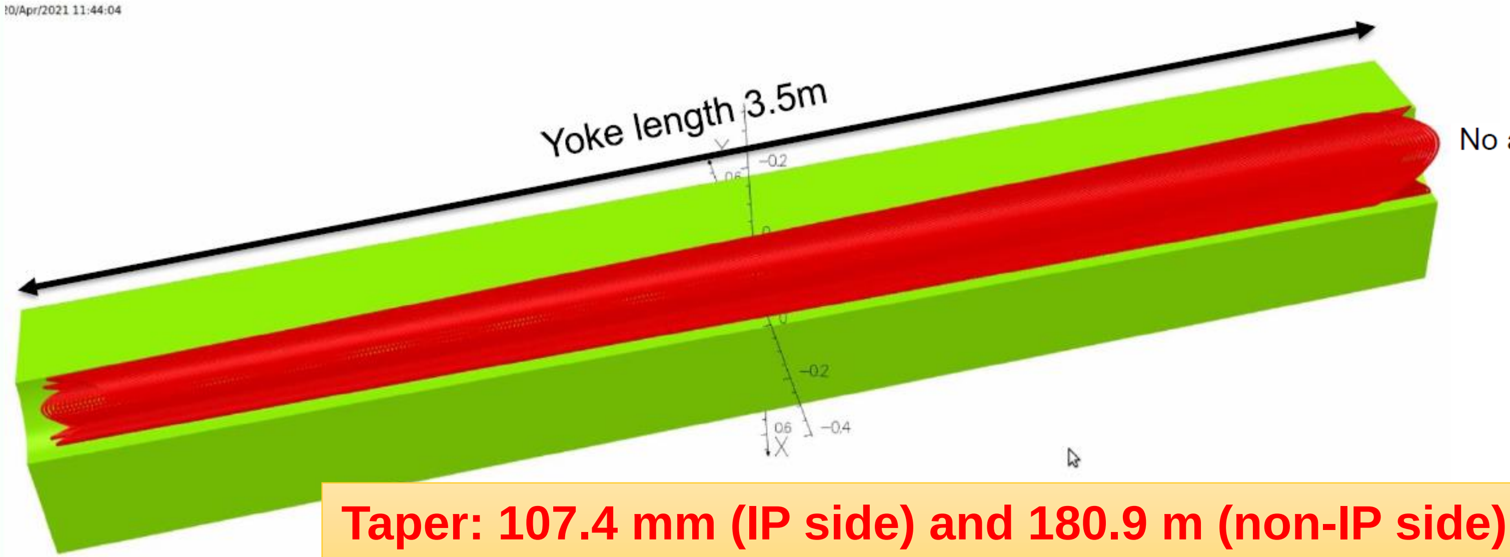
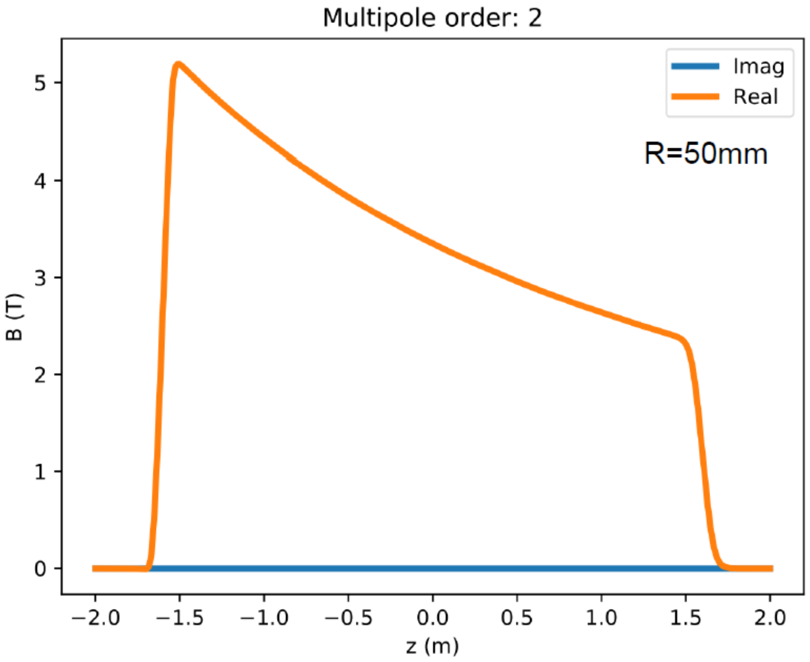
Now updated for higher integral gradient (?)



No adjustment for varying gradient strength (yet)



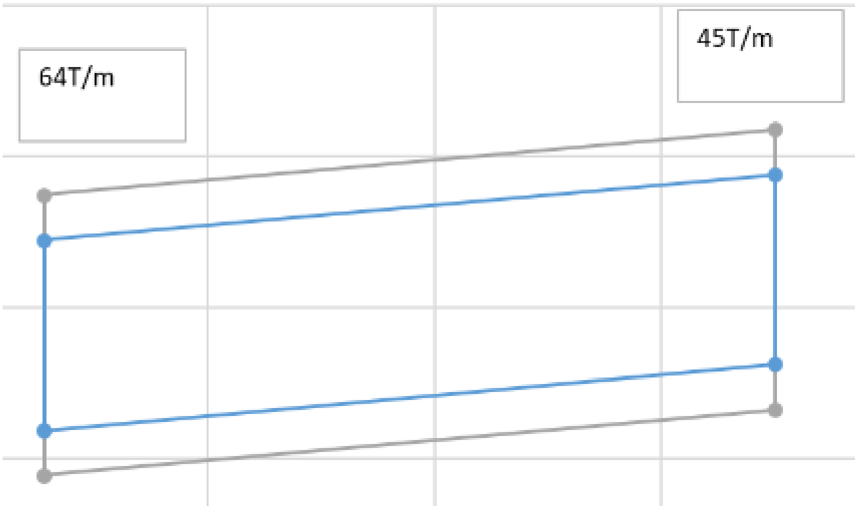
Taper: 107.4 mm (IP side) and 180.9 m (non-IP side) ?

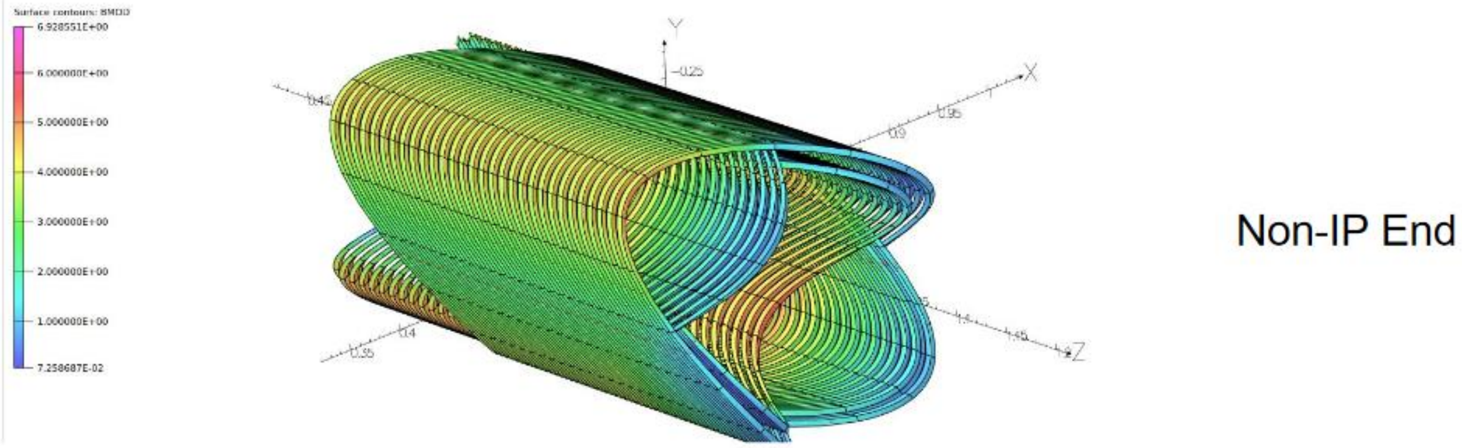
Average gradient: 64T/m
Integrated (3.5m): 224T
(We need: 212T)

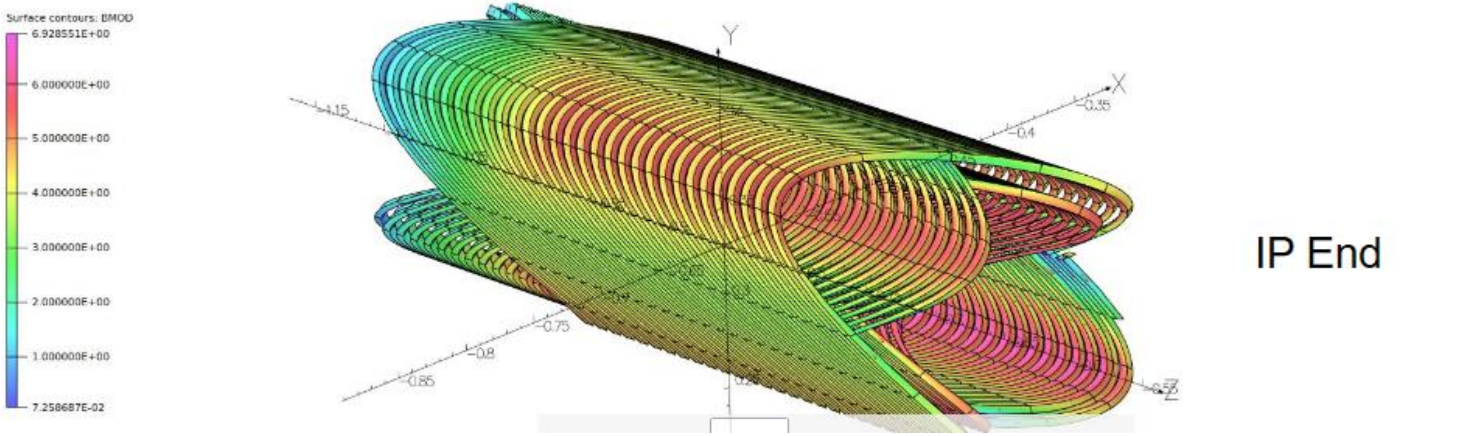
Using macroscopic conductor
Radial thickness: 20mm
Long. Packing fraction: 50%

20 April 2021

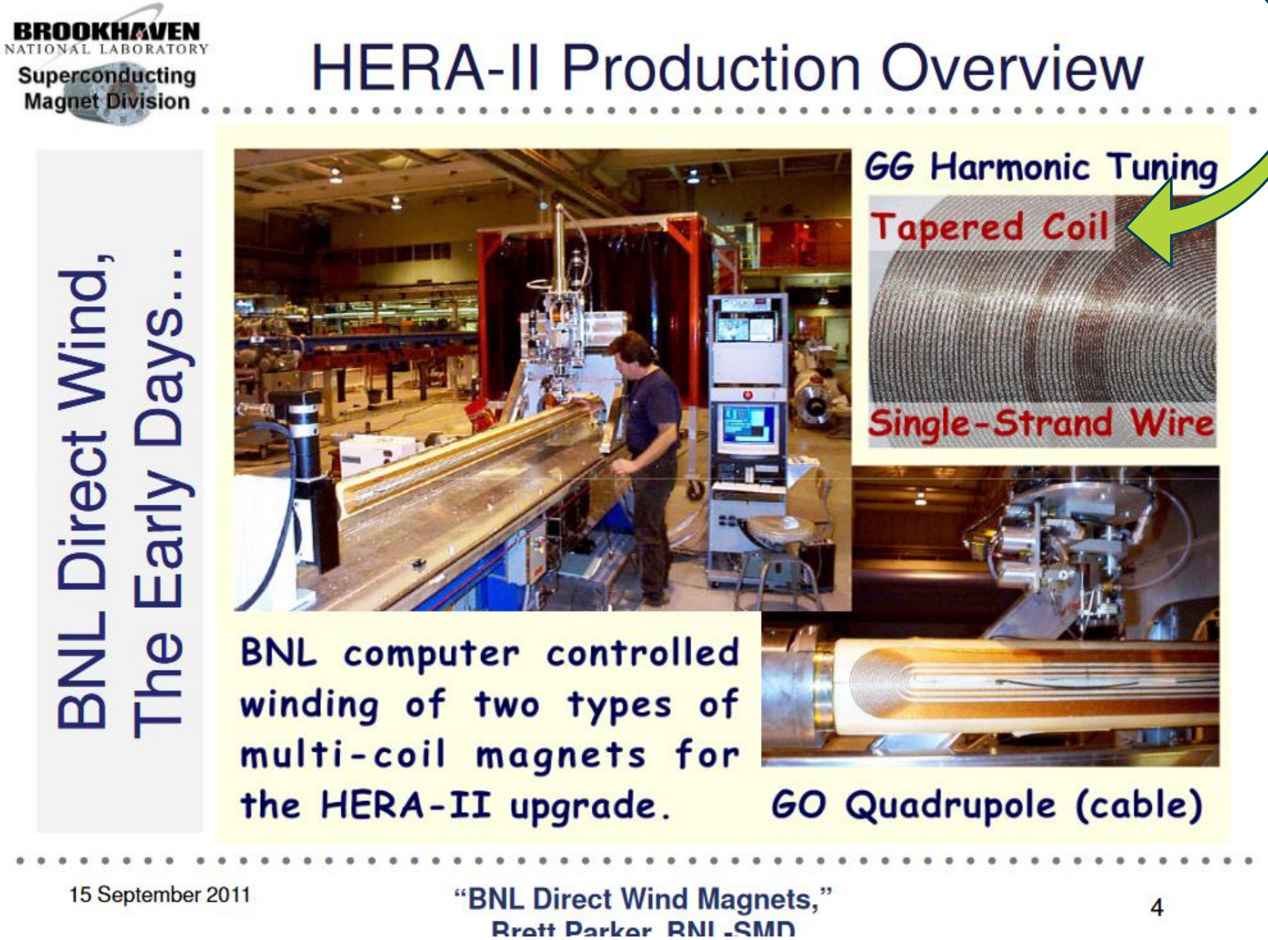
Baseline Tapered Coil – Double Helix (2)







Earlier Tapered Coil Design at BNL- (Brett Parker)



GG Harmonics at R=45 mm, Centered

Tapered Magnet, Quad Inner Radius = 65 to 70 mm

	Quadrupole	Dipole	Skew Dipole	Skew Quad.	Sextupole
I.T.F.	9.423	1.1593	1.0398	15.307	162.51
Fld. Ang.	0.0	-0.4	-2.3	0.0	-1.2
Leff(m)	Not meas.	Not meas.	Not meas.	Not meas.	Not meas.
b1	0.00	10000.00	0.00	0.00	-8.57
b2	10000.00	-2.23	-1.99	0.00	0.00
b3	-2.23	-0.04	0.21	-1.09	10000.00
b4	1.49	-0.07	-0.31	-1.01	-1.95
b5	-1.10	-0.12	-0.58	1.31	-3.27
b6	1.11	0.03	0.43	0.45	0.72
b7	-1.48	0.33	-0.38	0.53	-2.22
b8	0.73	-0.11	-0.34	0.51	0.73
b9	-0.34	0.09	0.04	0.08	-1.57
b10	0.63	-0.03	0.00	0.10	-0.28
b11	-0.08	0.06	0.05	-0.13	-1.19
b12	0.13	0.01	-0.06	-0.17	-0.08
b13	-0.07	-0.04	0.00	0.04	-0.63
b14	0.02	0.06	0.10	0.09	0.04
b15	0.01	-0.08	0.04	0.06	-0.25
a1	0.00	0.00	10000.00	0.00	13.99
a2	0.00	-3.02	5.22	10000.00	0.00
a3	-1.51	0.08	2.95	-3.53	0.00
a4	1.18	-0.43	0.09	5.12	-0.93
a5	1.81	-0.31	-3.25	-0.53	0.55
a6	-0.64	-0.18	-0.37	0.10	-1.61
a7	-0.96	-0.36	0.13	0.51	0.70
a8	0.52	0.14	0.07	0.65	0.44
a9	-0.45	-0.05	0.08	0.12	0.12
a10	-0.11	0.03	-0.11	-0.17	0.32
a11	0.23	0.02	-0.22	0.32	0.42
a12	0.12	-0.02	-0.06	0.02	0.49
a13	-0.03	-0.01	-0.14	-0.08	0.09
a14	0.13	0.00	0.04	-0.16	-0.43
a15	0.02	0.07	0.19	0.02	-0.18

EIC taper is much larger (53.7 mm to 90.45 mm)

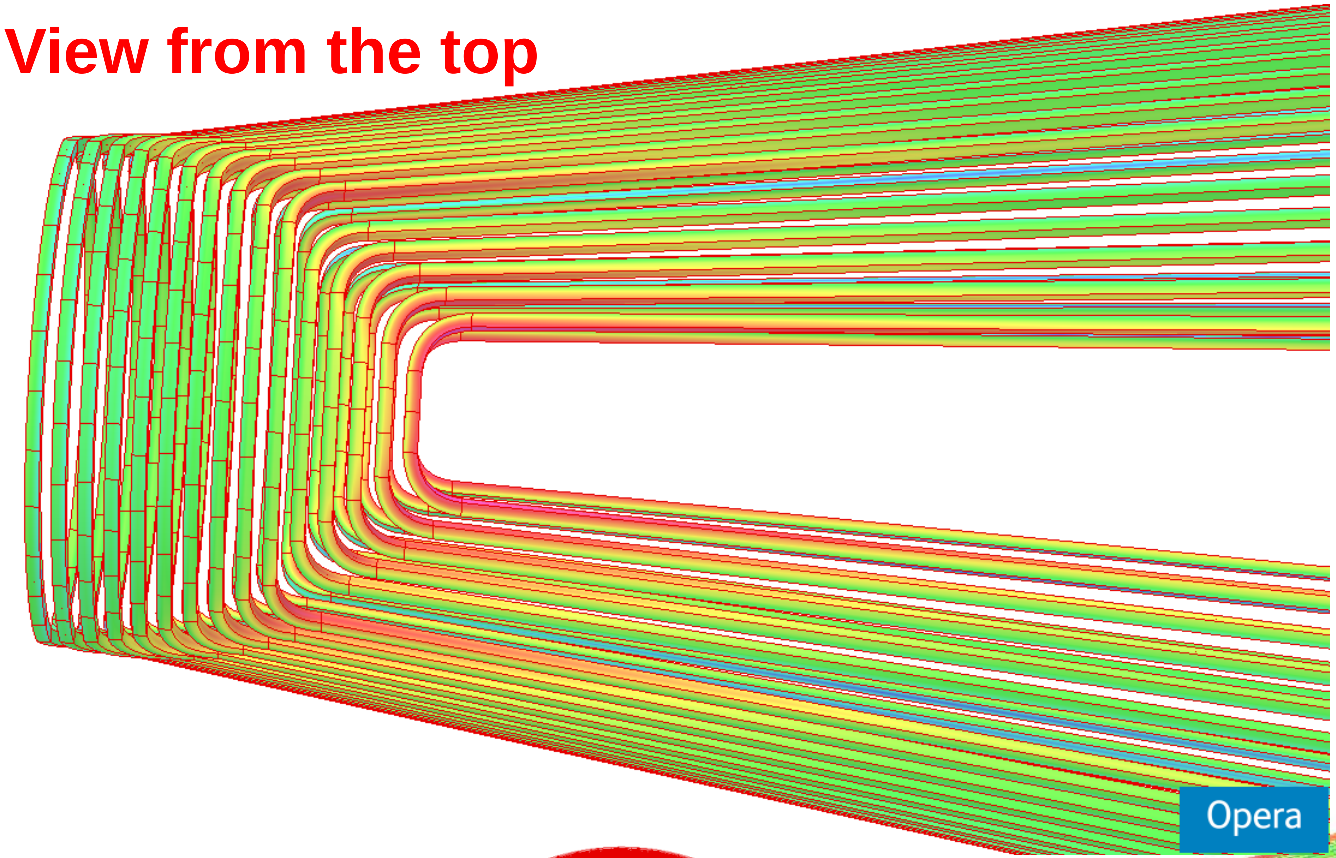
Tapered Cosine Theta Coil Design Principle

- Conventional Design Principle: to assure a good field quality maintain the same angular position of each wire while the coil radius is changing
- Issue: If the taper or the change in radius is large (as is the case in the several EIC magnets), there will be a significant empty space (white space) between the turns causing a large loss in field or field gradient.
- Proposed Principle: A configuration which minimizes the white space between the turns and pack as many turns as possible despite a taper

➢ **Next few slides will explain the proposed concept/principle (illustrated first for the dipole and then for the quadrupole)**

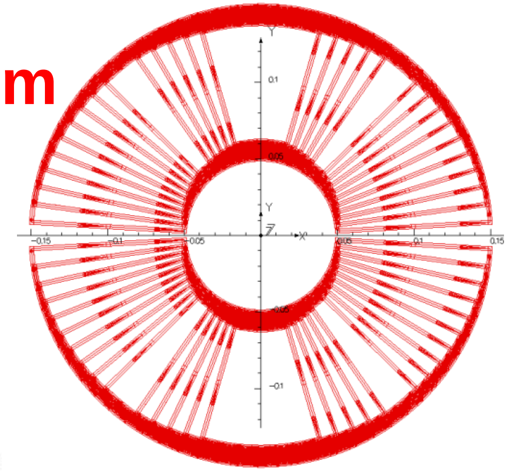
Conventional Design of a Tapered Cosine Theta Dipole

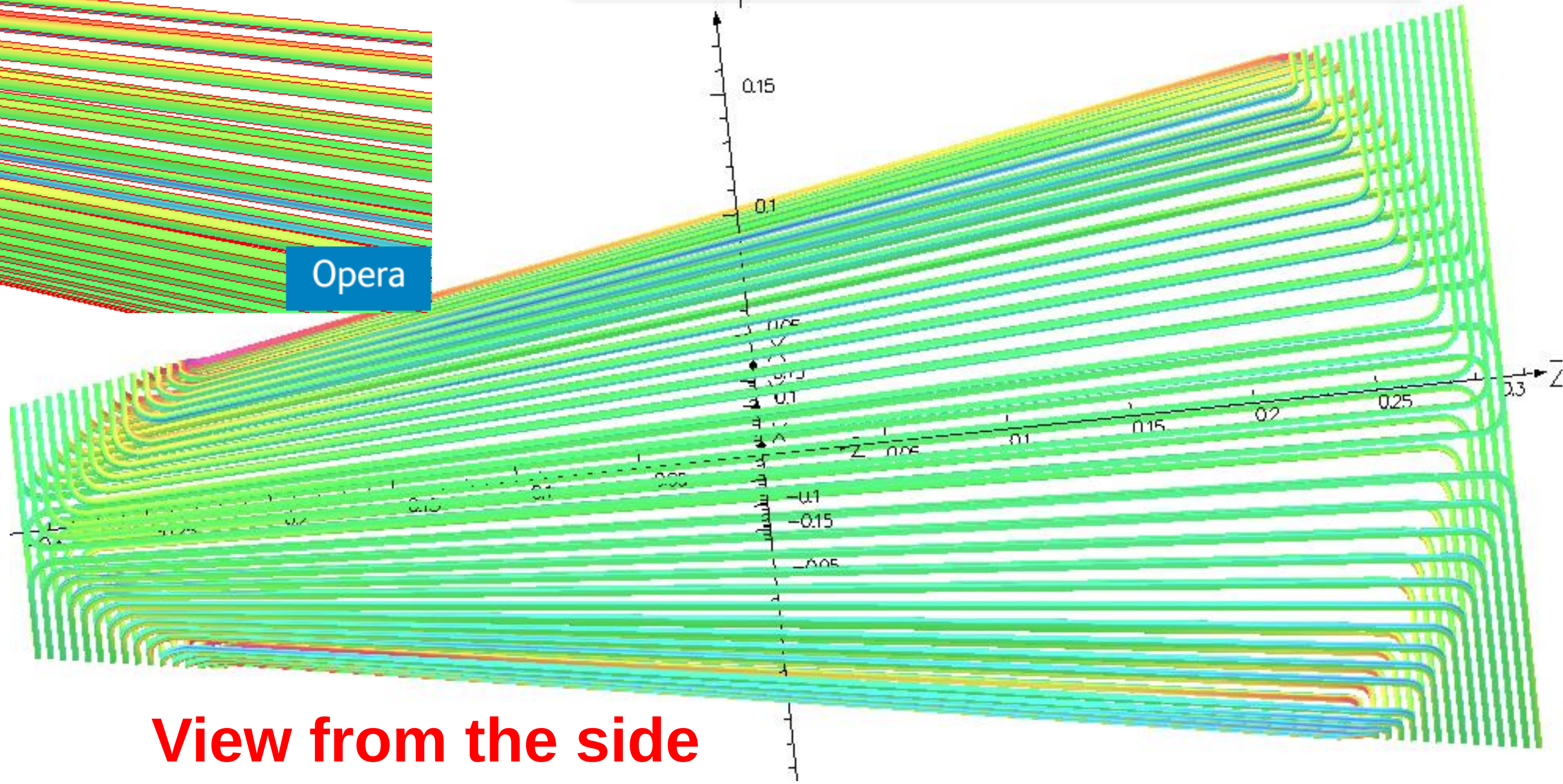
View from the top



Wire maintain their angular position while radii change

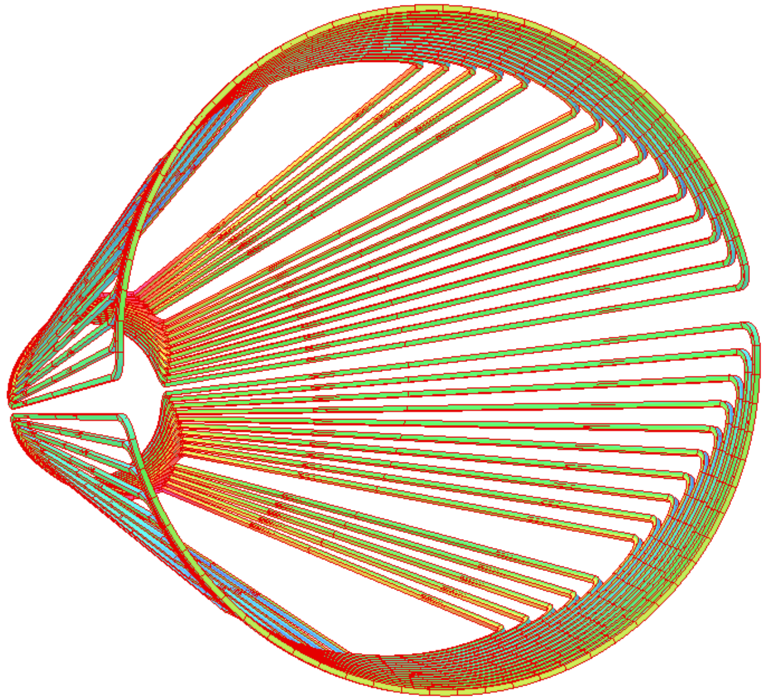
View from the end





View from the side

Positives and Negatives of the Conventional Cosine Theta Tapered Dipole

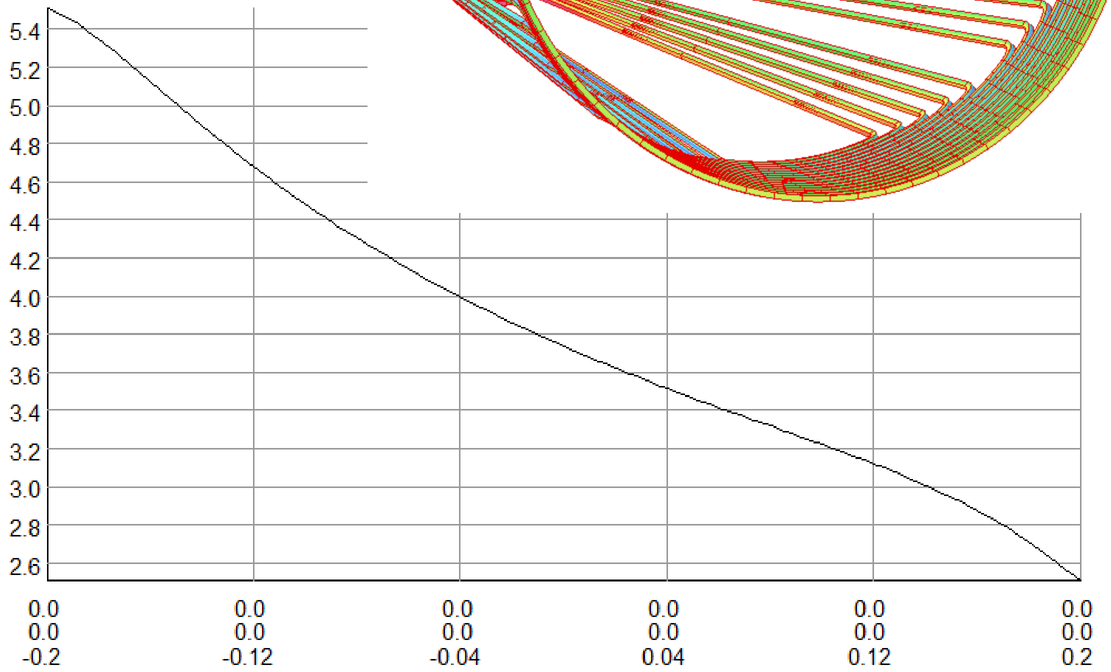


<u>Positives:</u>

- Design is simple to understand
- Good harmonics are assured

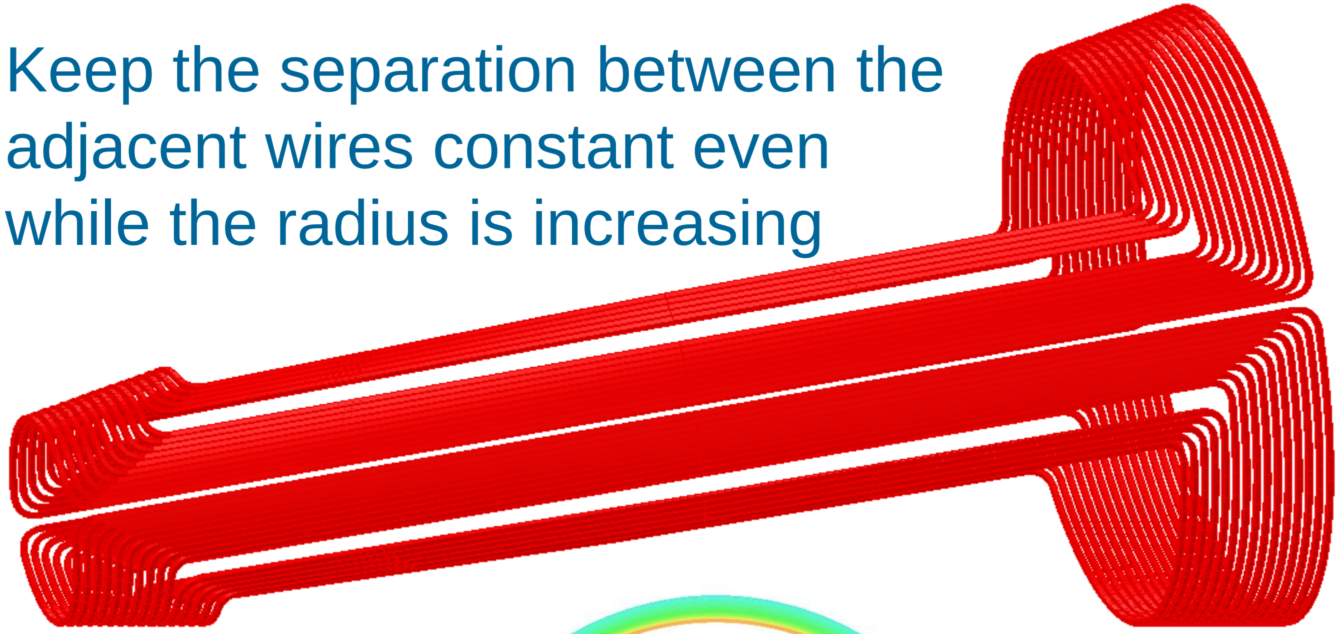
<u>Negatives:</u>

- Number of turns is limited by the side having smaller radius
- Field strength along the axis decreases as the radius increases

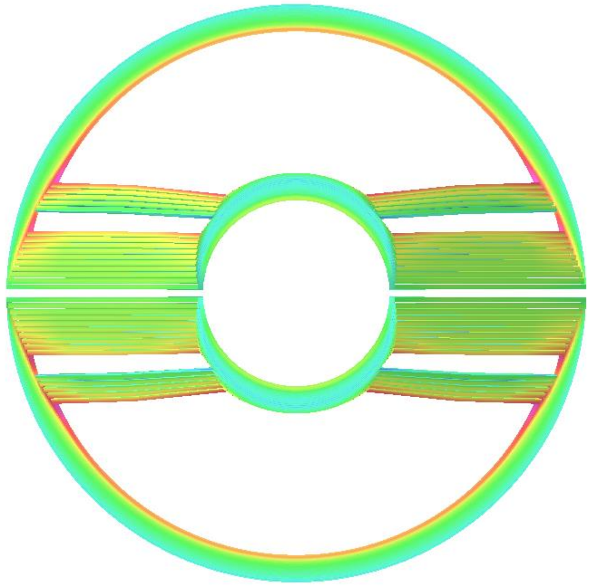


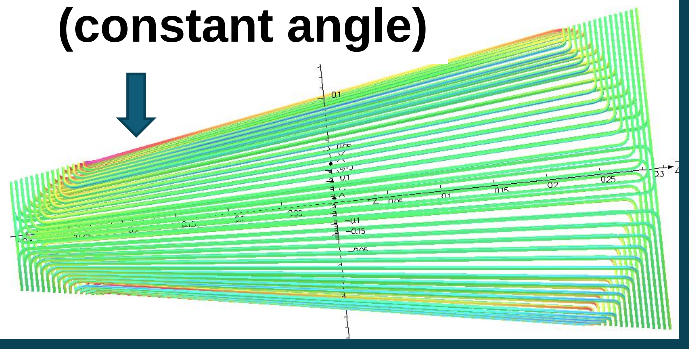
Proposed Design - Step #1

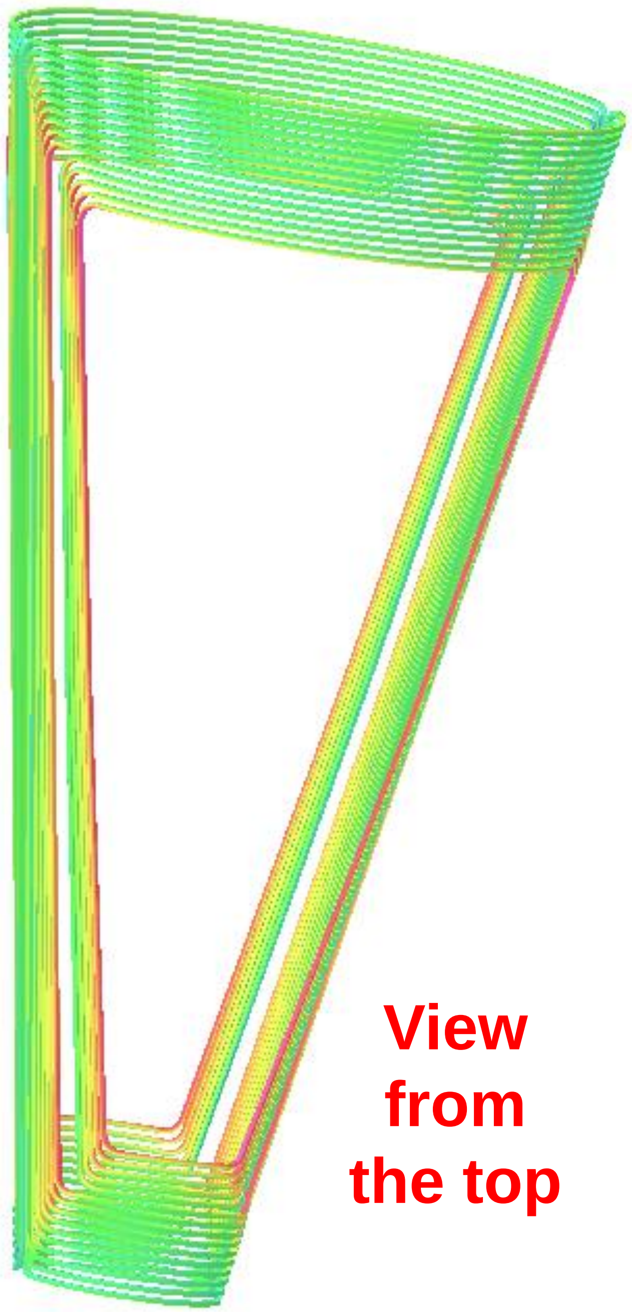
Keep the separation between the adjacent wires constant even while the radius is increasing



View from the end



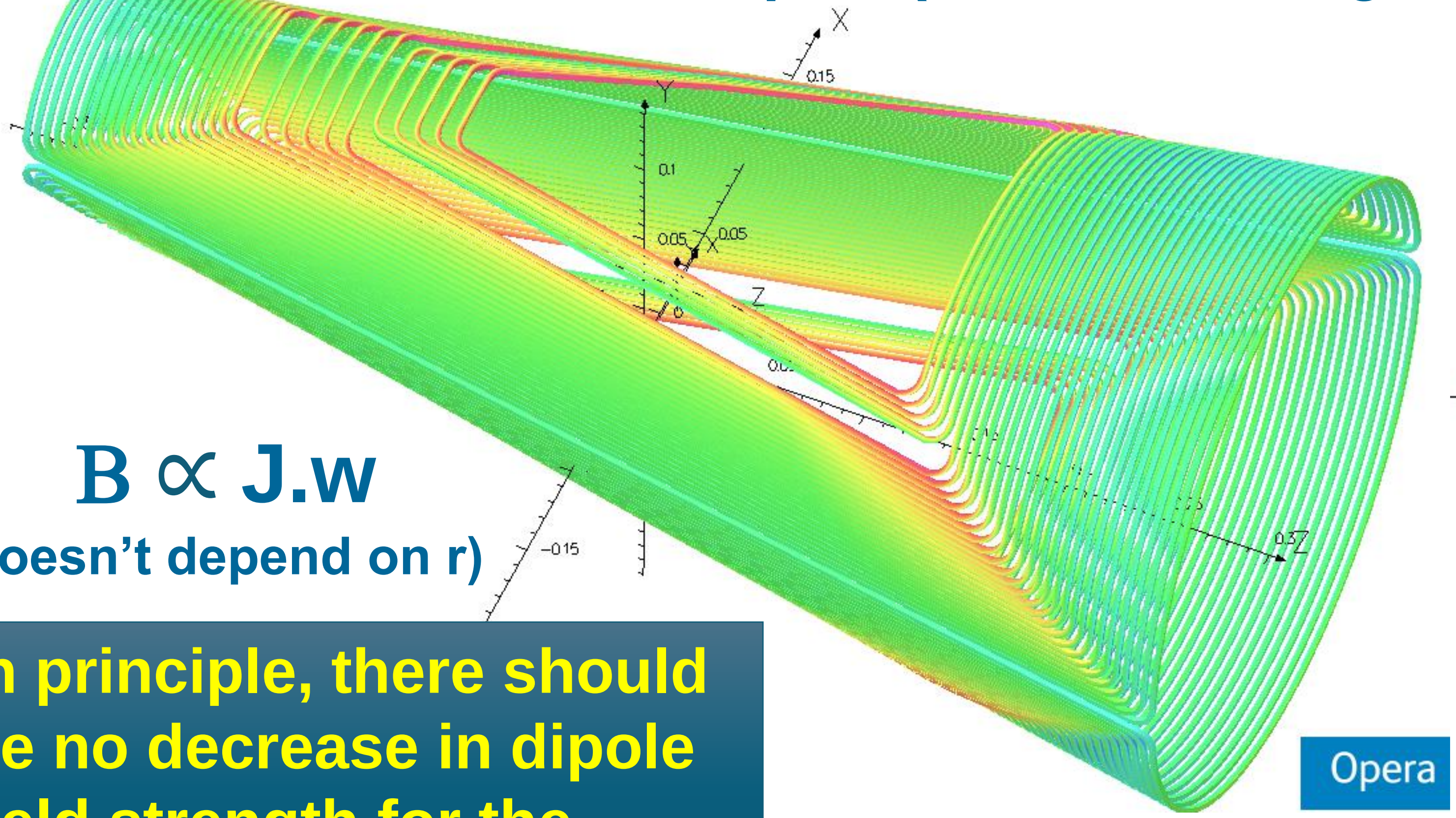




View from the top

Proposed Design - Step #2

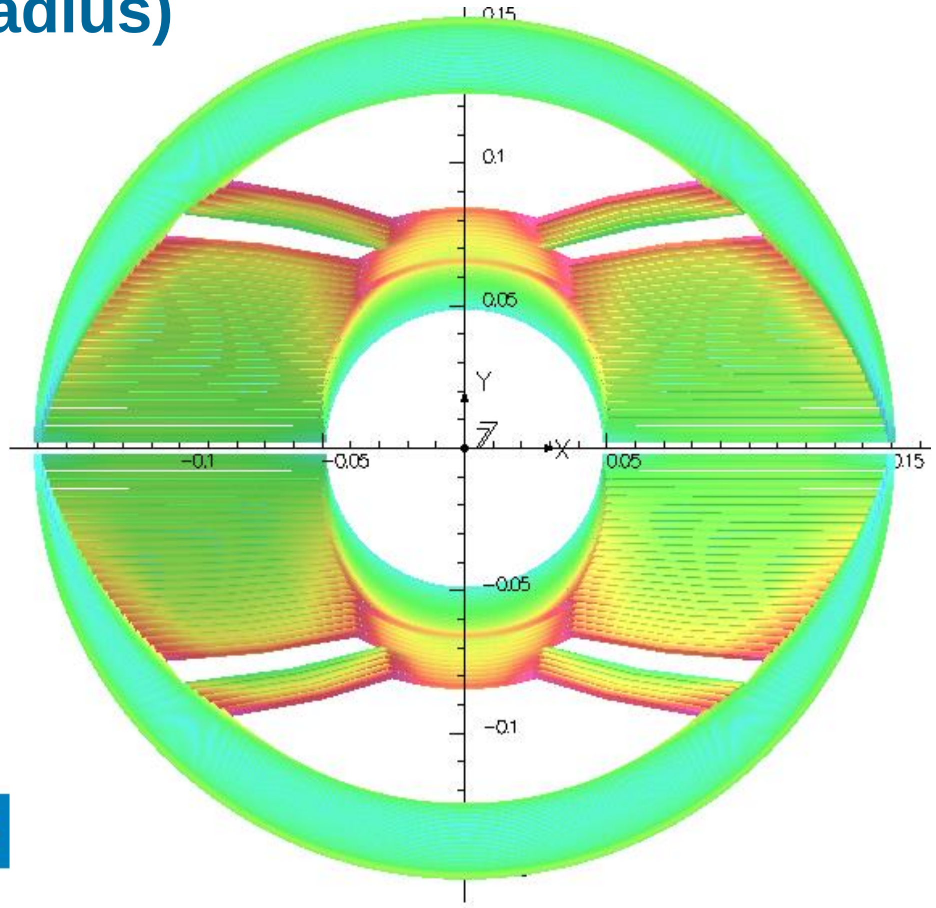
- Add more turns in the longitudinal space created in step #1 (with increasing radius)



$B \propto J.w$

(doesn't depend on r)

In principle, there should be no decrease in dipole field strength for the same conductor width



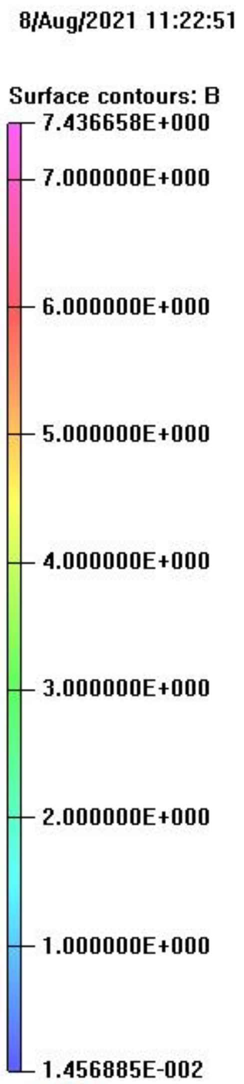
View from the end

EIC Magnet to be evaluated for SBIR: Q1AB

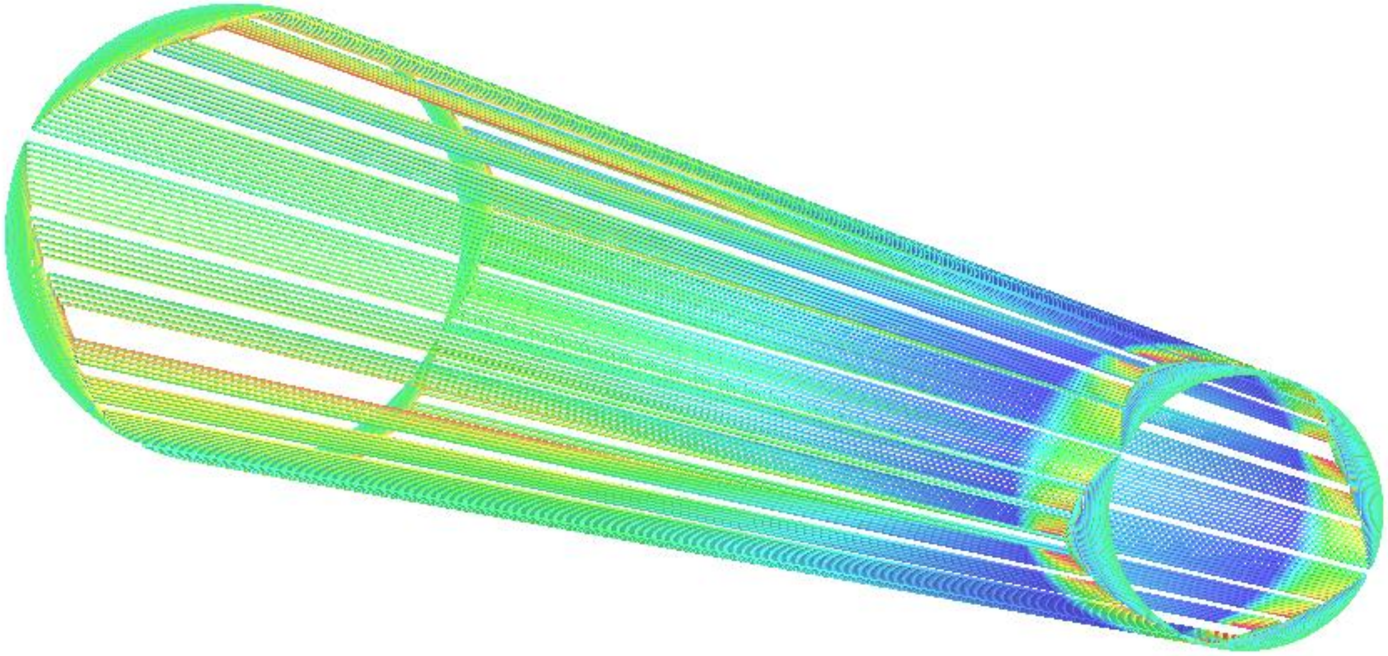
(to see if there is any real advantage of this approach)

Parameters of the current design will be used

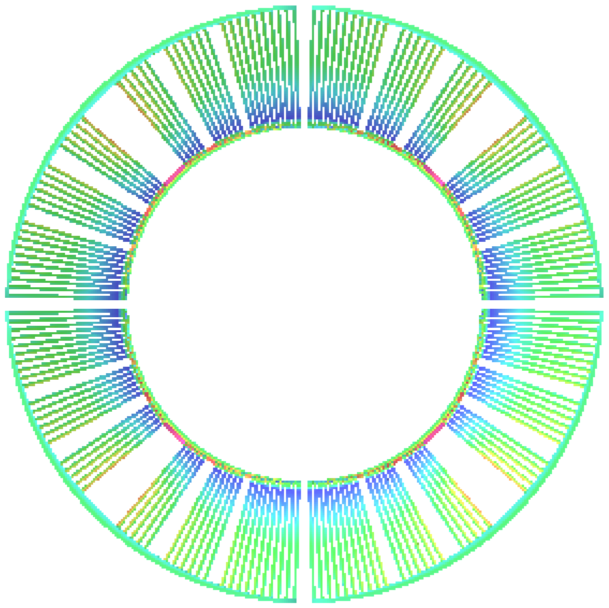
EIC Cosine Theta Tapered Quad Q1AB (conventional design)



Turns at a "*constant angle*" along the length of the taper



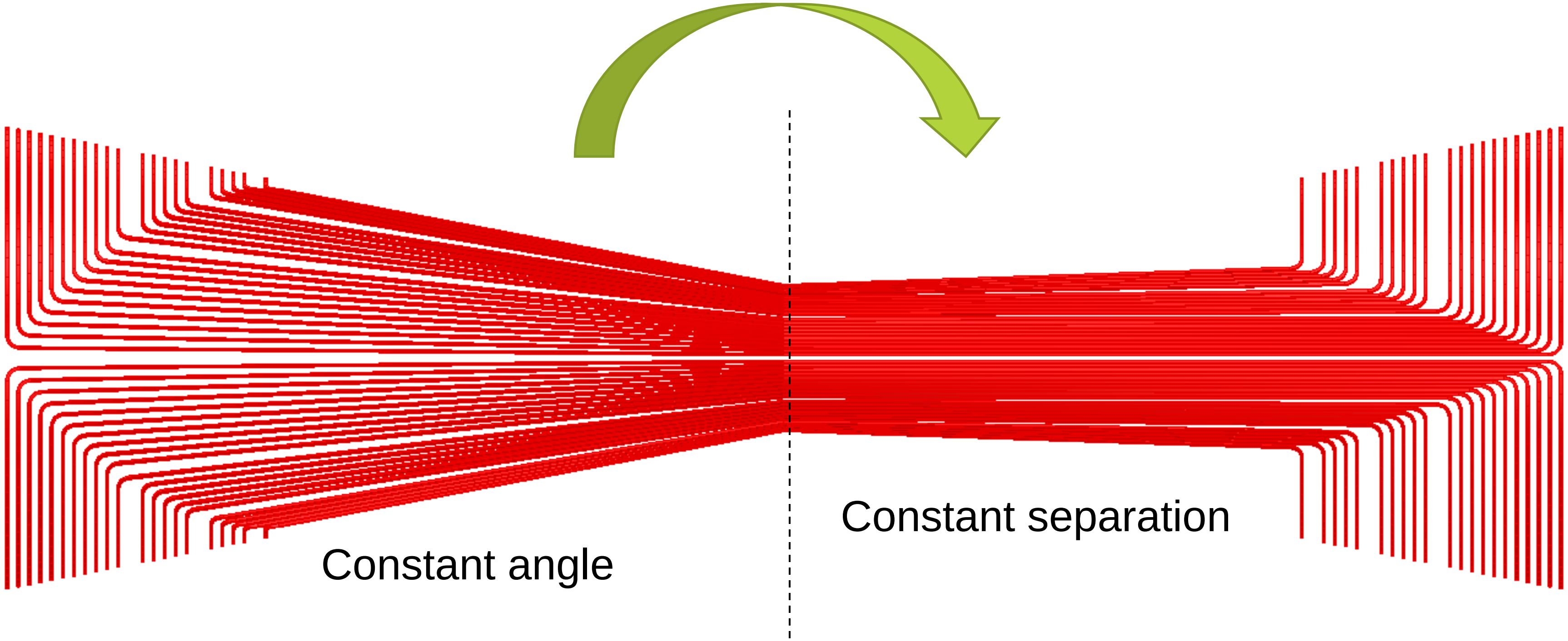
L= 3.5 m, Taper: 107.4 mm (IP) and 180.9 m (non-IP)

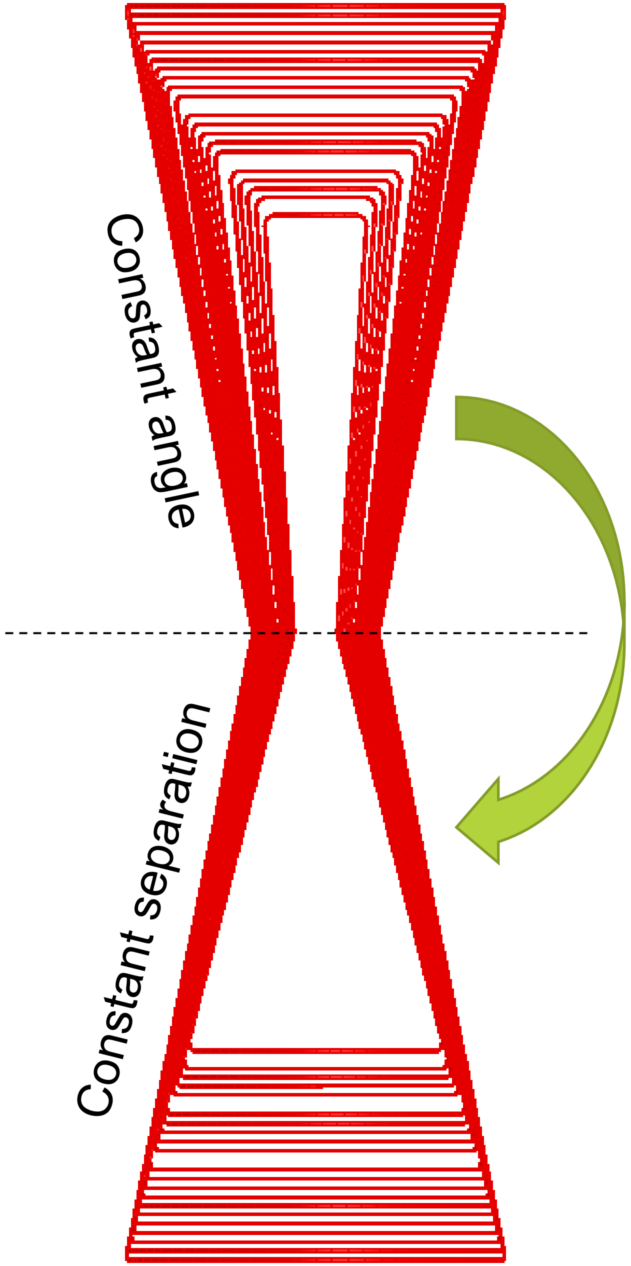


View from the end

Proposed Design – Step 1

Wind pattern with a "*constant separation*"
between the turns along the length of the taper





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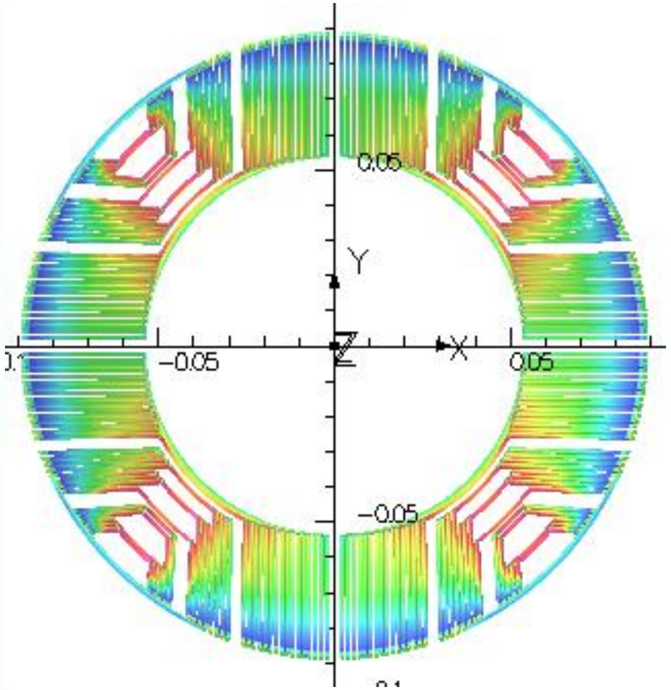
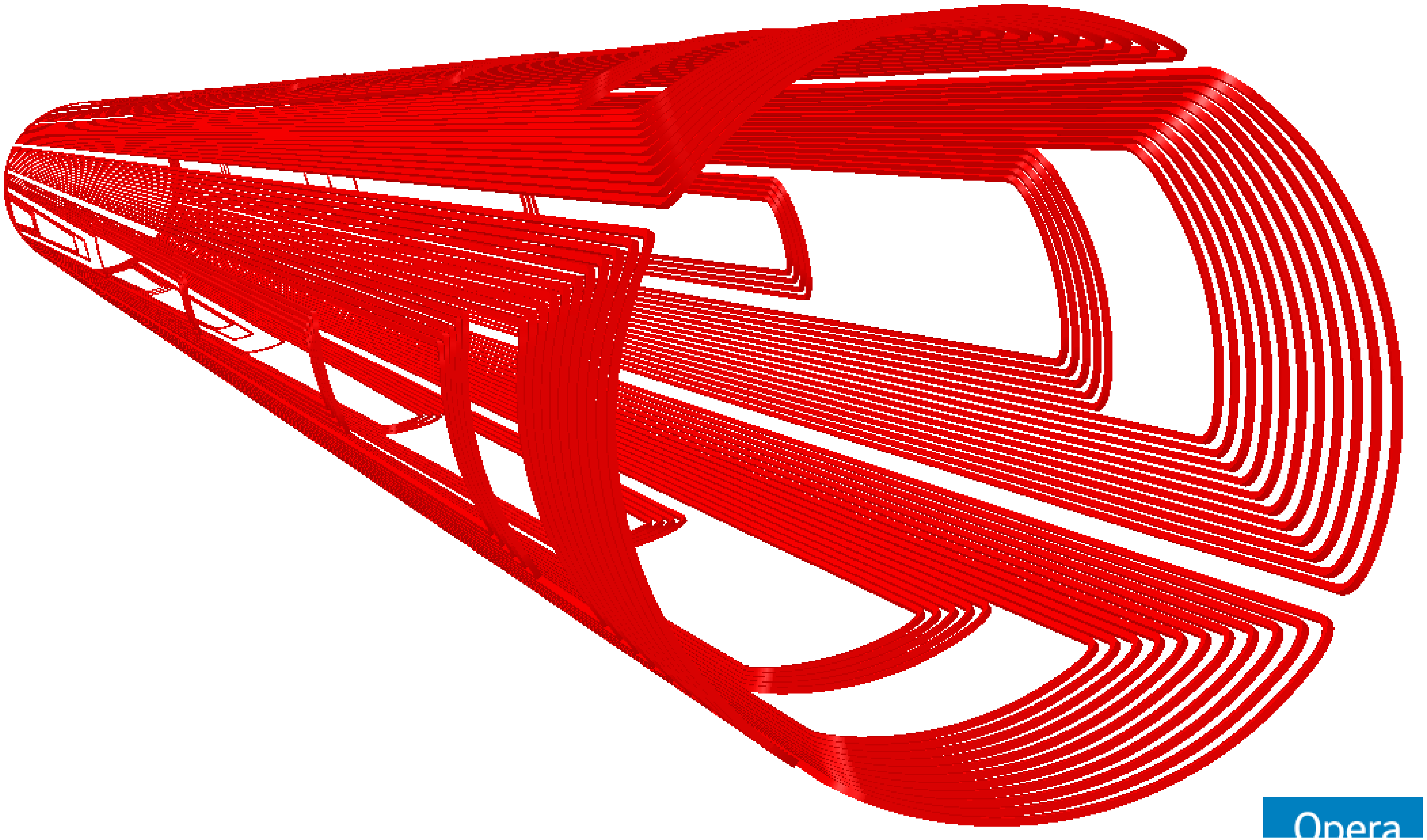
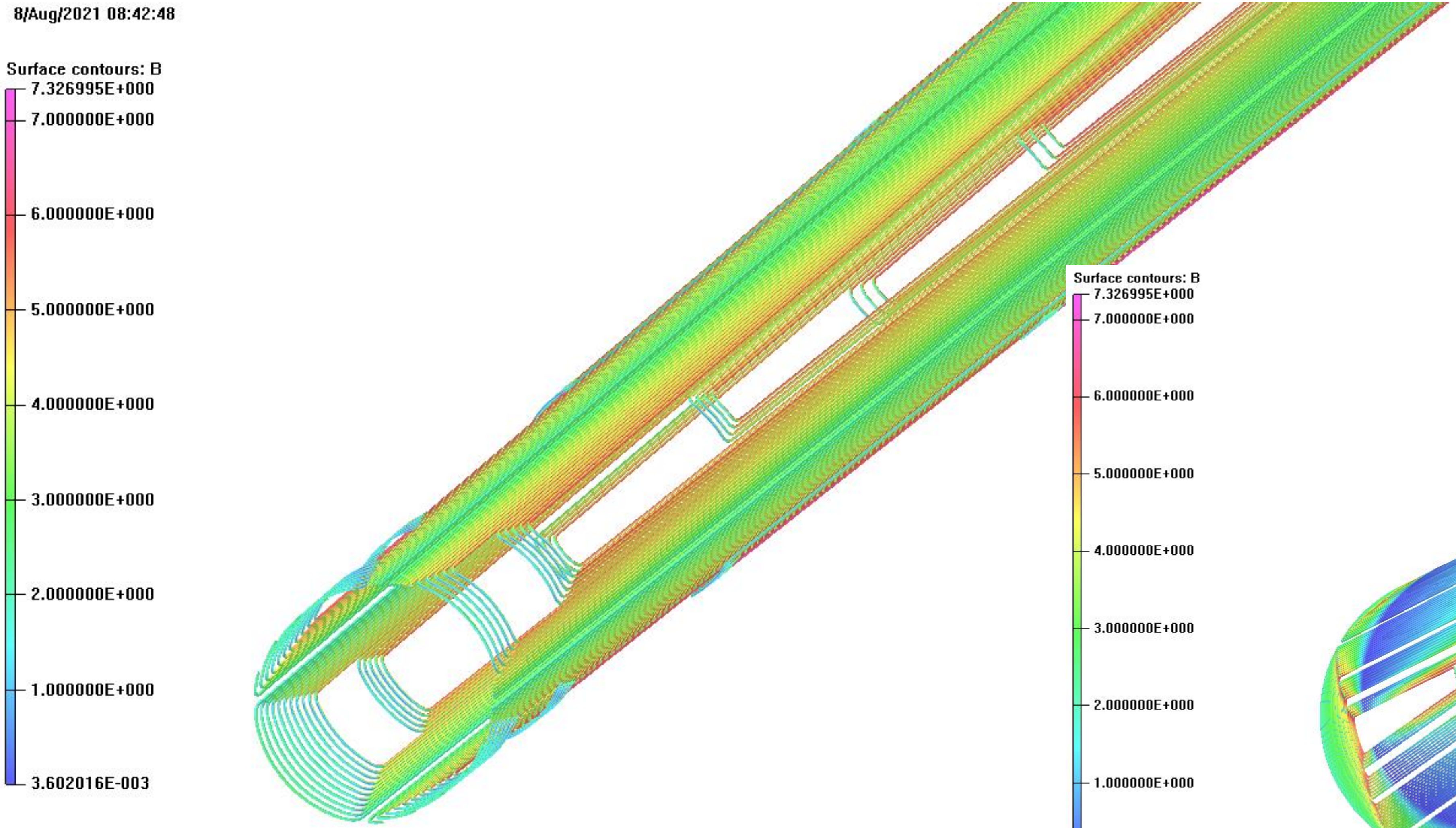


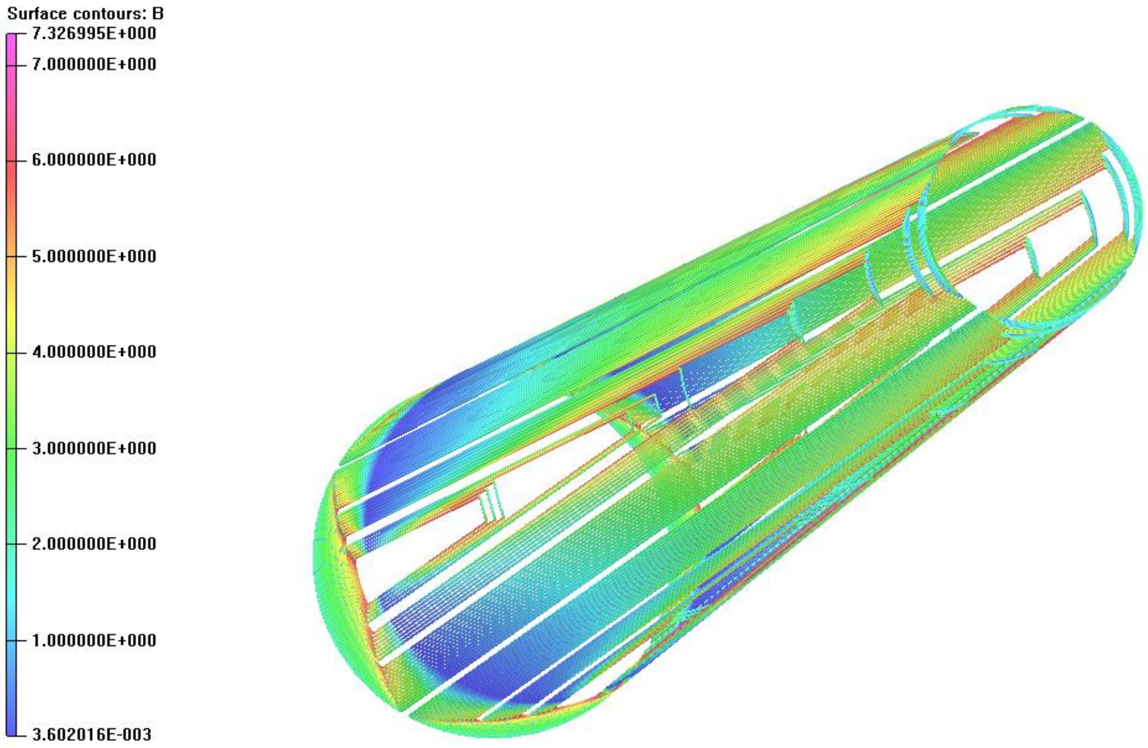


Opera

Proposed Design - Step #2 (cont.)

- Add more turns in longitudinal space created in step #1 (with increasing radius)





Earlier Distributed Windings at BNL

Two Main Tasks of Phase I

- Develop codes and methodology (including a theoretical prescription that can be easily used in optimization).

- Wind a single layer coil and measure field profile/harmonics. These will be warm measurements only. No cold test will be performed in Phase I (budget limitations).

Summary (same as the introduction)

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