U.S. MAGNET DEVELOPMENT PROGRAM

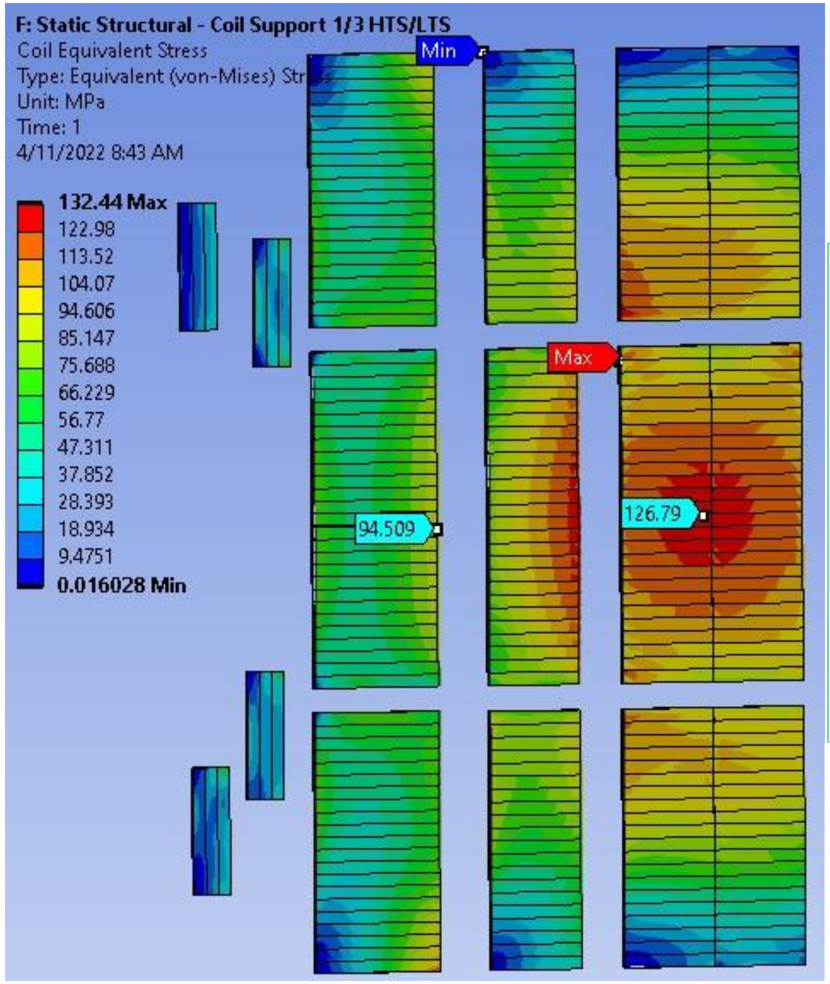
20 T Common Coil Design Iteration

Ramesh Gupta

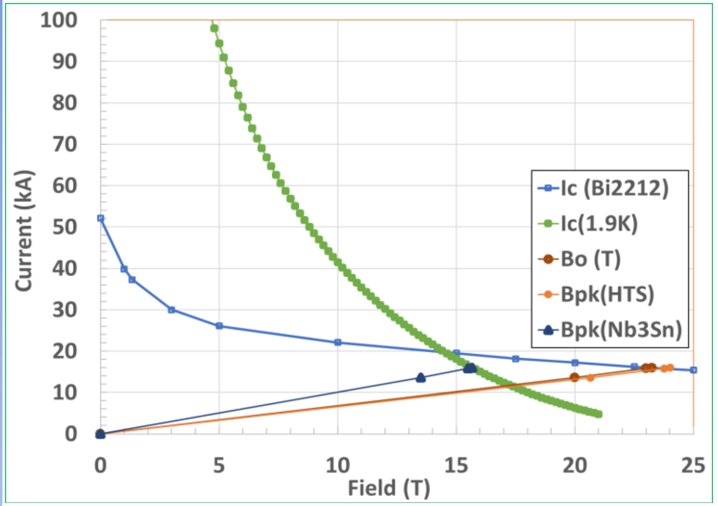
05/31/2022

Previous Mechanical and Magnetic Designs for 20 T Common Coil (similar but not the same)

✓ Acceptable stresses/strain on conductor,15% margin, good field quality



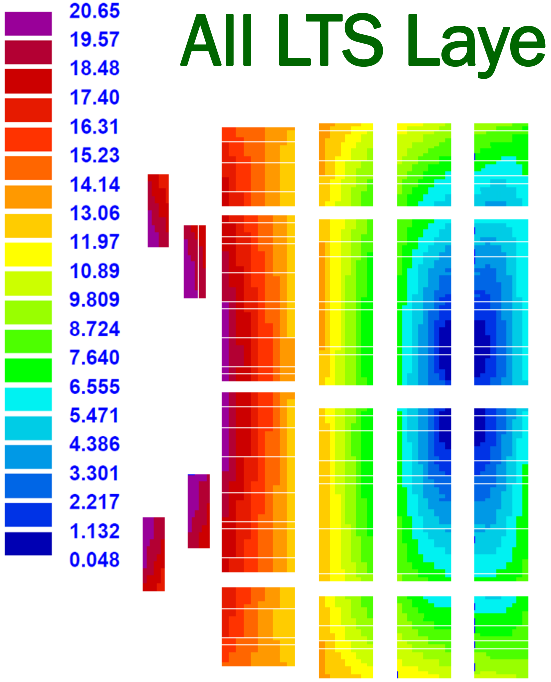
I(kA)	Bo (T)	Bpk(HTS)	Bpk(HTS)	Margins
13.57	**20.00**	20.654	13.503	
15.83	**23.00**	23.757	15.489	
15.83	**23.00**	23.757	15.489	**15.0%**
16.01	**23.25**	24.018	15.659	**16.3%**



SKEW RELATIVE MULTIPOLES (1.D-4):

a 1:	0.00000	a 2:	-0.01890	a 3:	-0.00000
a 4:	0.00591	a 5:	-0.00000	a 6:	0.11424
a 7:	0.00000	a 8:	0.02483	a 9:	-0.00000
a10:	0.14186	a11:	0.00000	a12:	-0.00881
a13:	0.00000	a14:	0.00515	a15:	-0.00000
a16:	0.00259	a17:	0.00000	a18:	0.00066
a19:	-0.00000	a20:	0.00012	a	

All LTS Layers: Identical



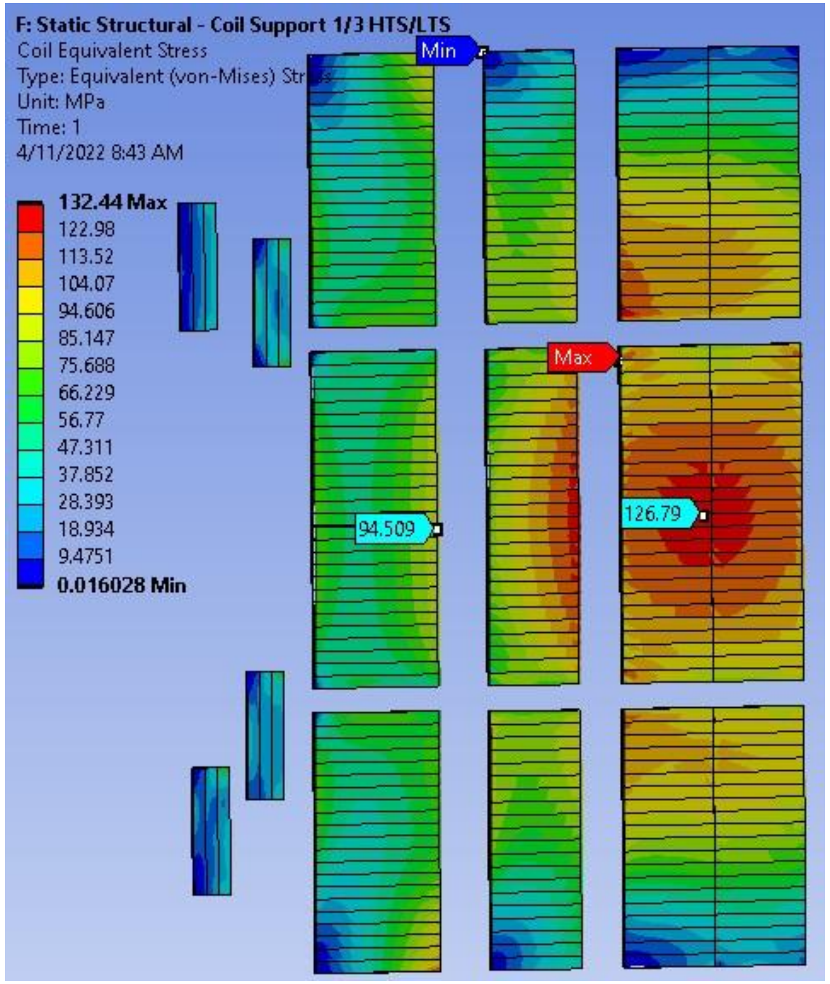
Next Step:
- Same Design
- Structure concept

NORMAL RELATIVE MULTIPOLES (1.D-4):

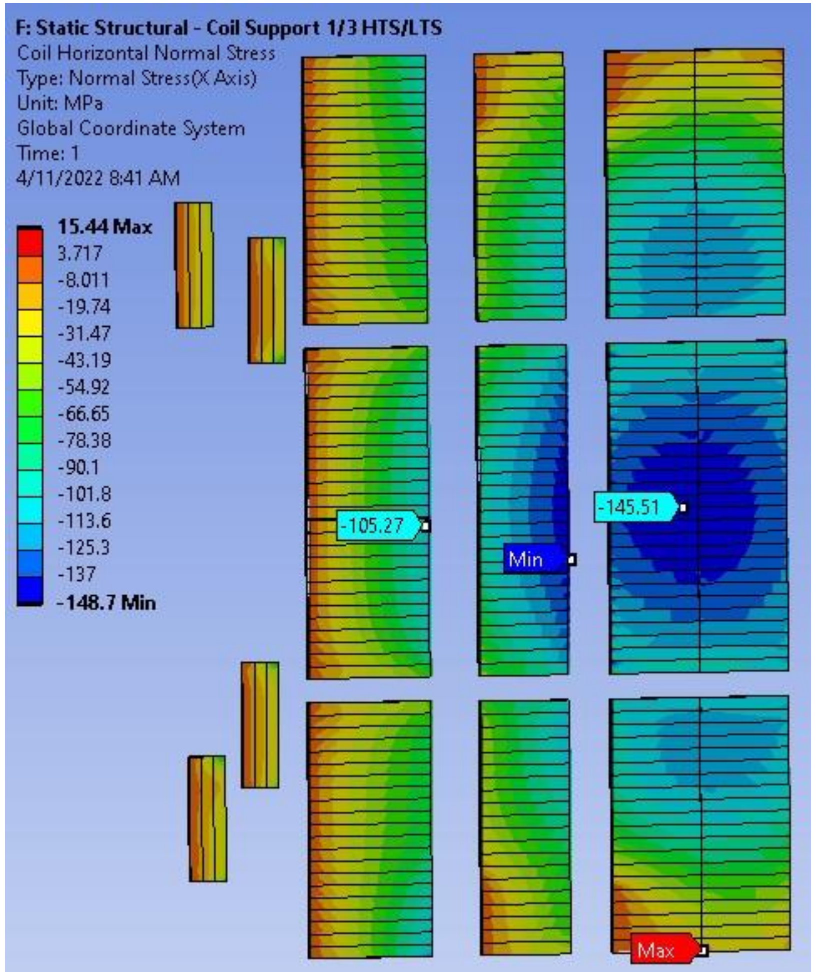
b 1:	10000.00000	b 2:	0.00000	b 3:	0.00537
b 4:	-0.00000	b 5:	0.02576	b 6:	0.00000
b 7:	-0.07742	b 8:	-0.00000	b 9:	-0.41532
b10:	0.00000	b11:	-0.26062	b12:	-0.00000
b13:	-0.00646	b14:	-0.00000	b15:	-0.00448
b16:	0.00000	b17:	-0.00436	b18:	0.00000
b19:	-0.00092	b20:	-0.00000	b	

Distribution of Stresses (@19 T)

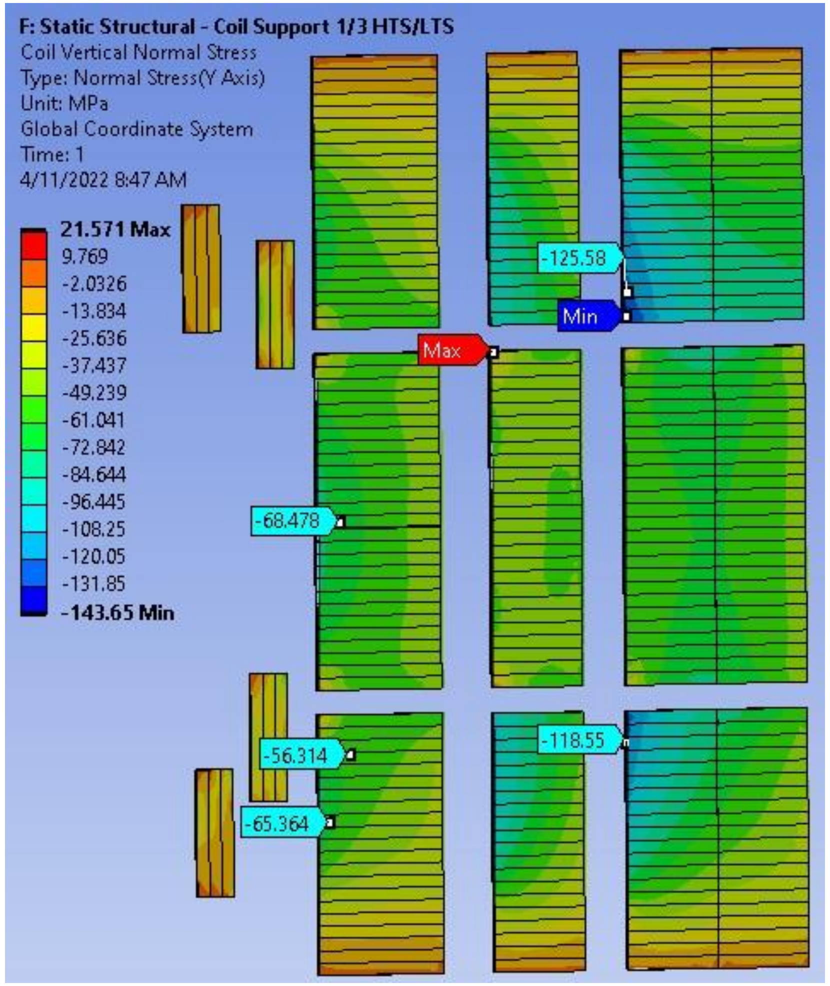
Von Mises



Horizontal

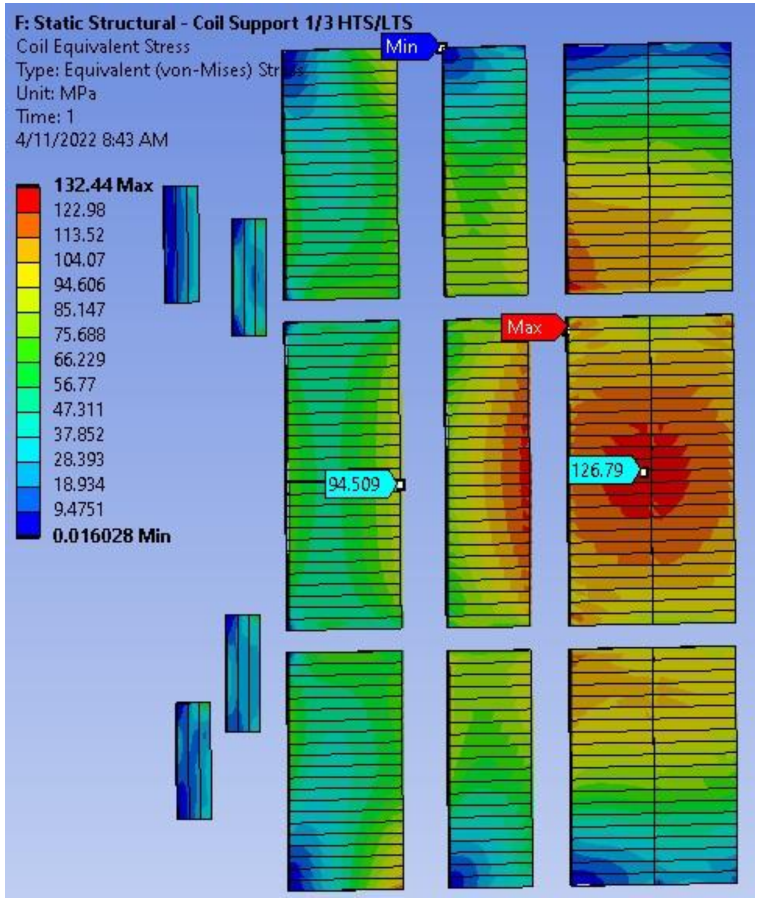


Vertical

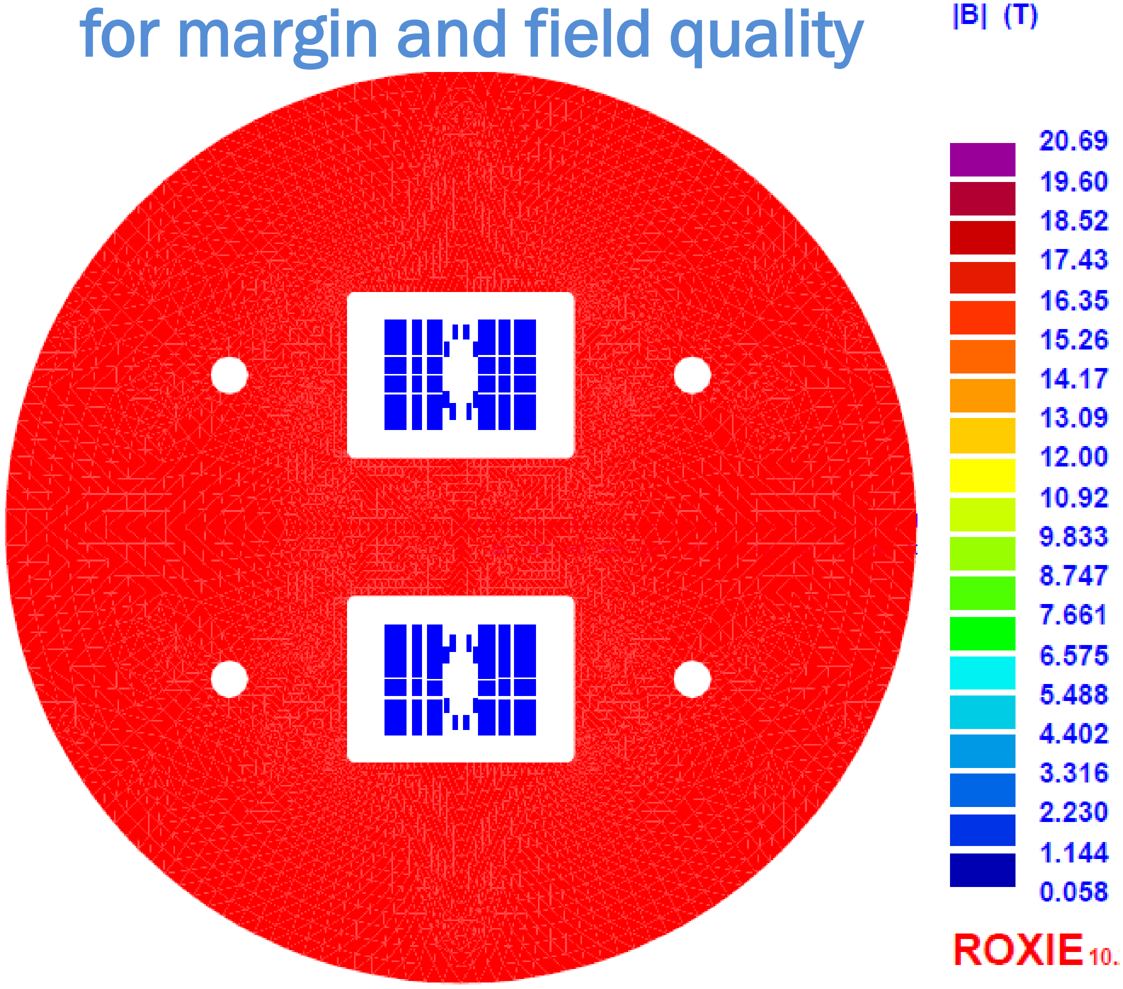


New 20 T HTS/LTS Hybrid Design (May 2022) (spacers in magnetic design takes input from mechanical)

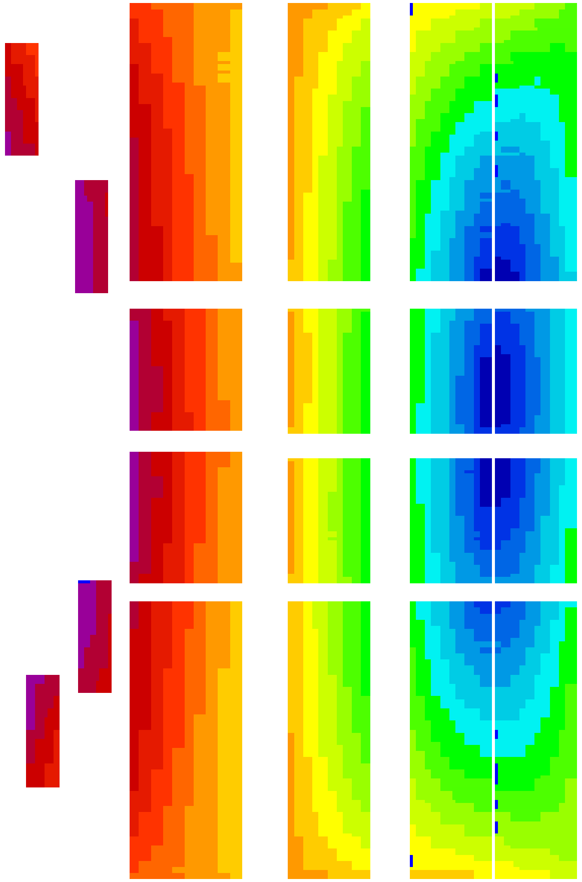
Previous design analyzed with ANSYS



New Magnetic design optimized for margin and field quality



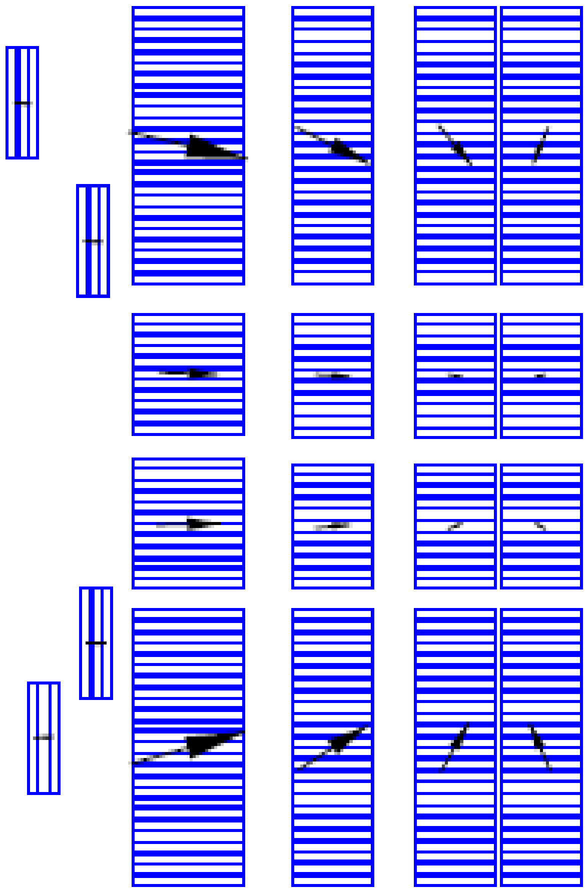
25 mm clear bore + > 3mm for structure

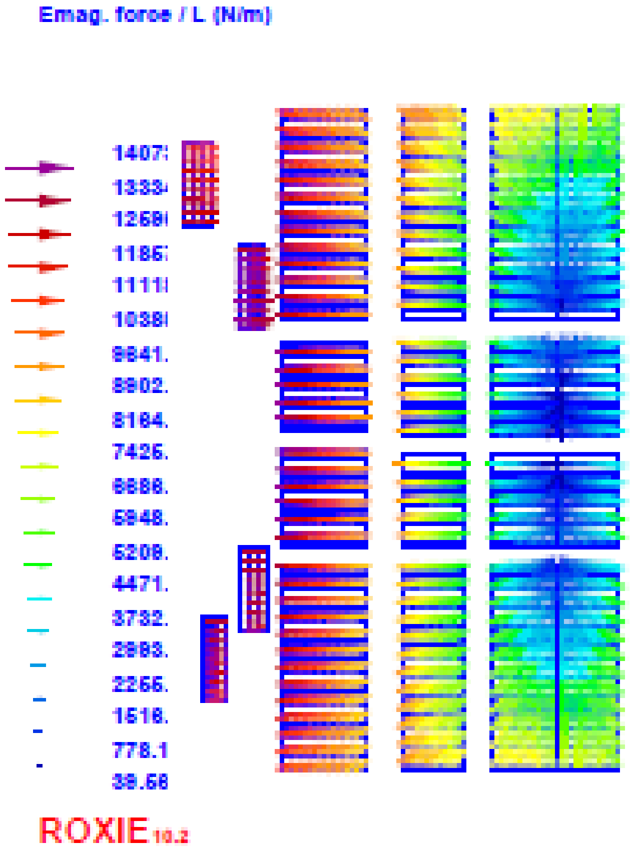


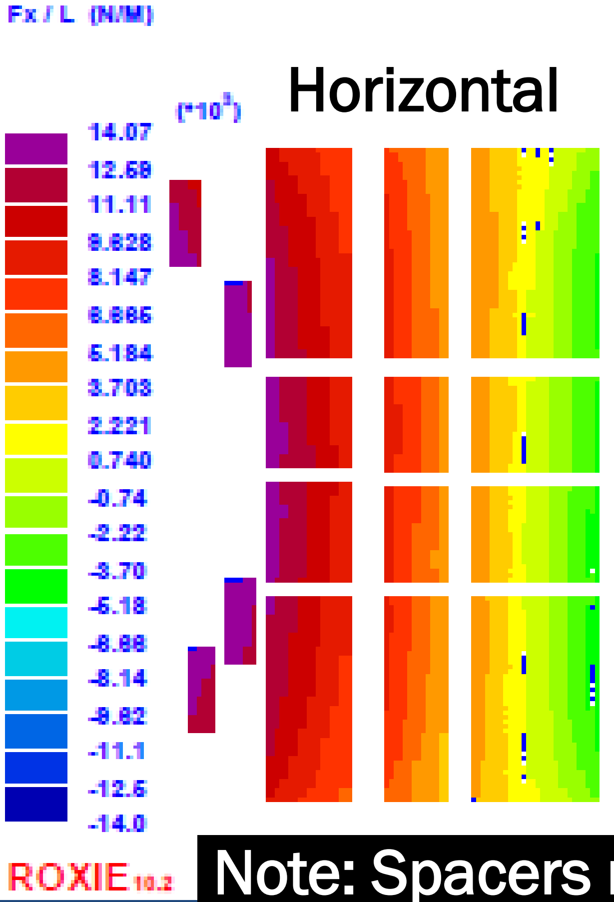
Strategy Behind the Mechanical Structure (taking advantage of the force distribution)

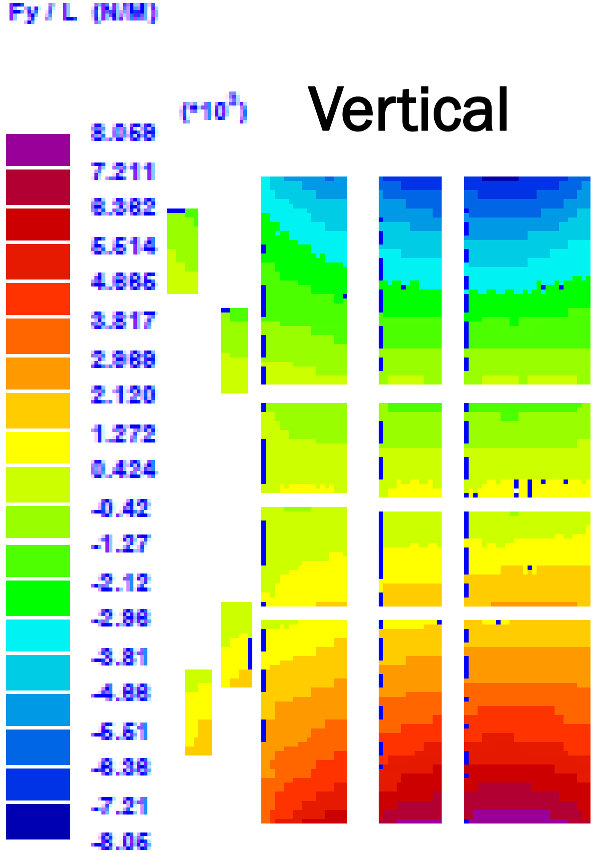
Key Components of Structure: Vertical Plates, Spacers (sliding surface), Springs, Collars

New Design: Forces @20 T, Note: additional spacers at midplane









Note: Spacers not yet fully optimized.

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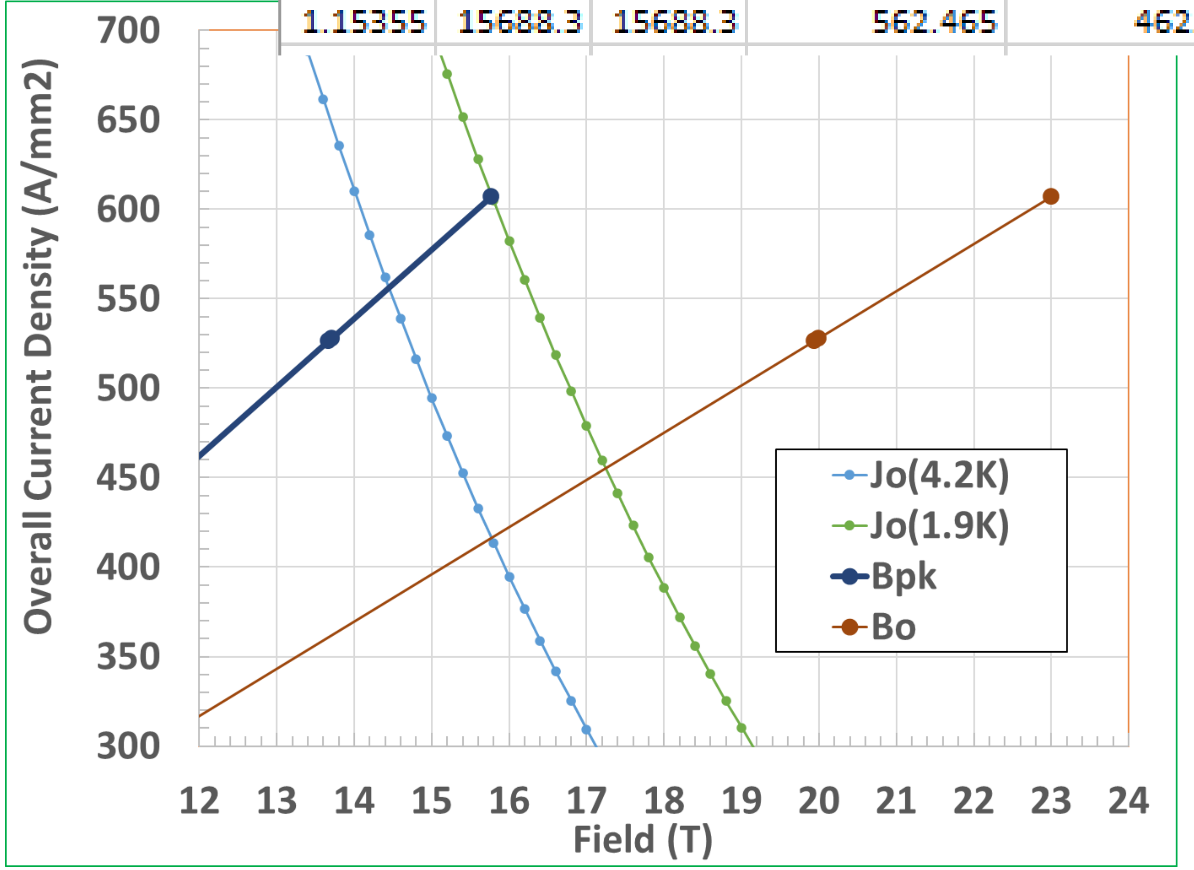
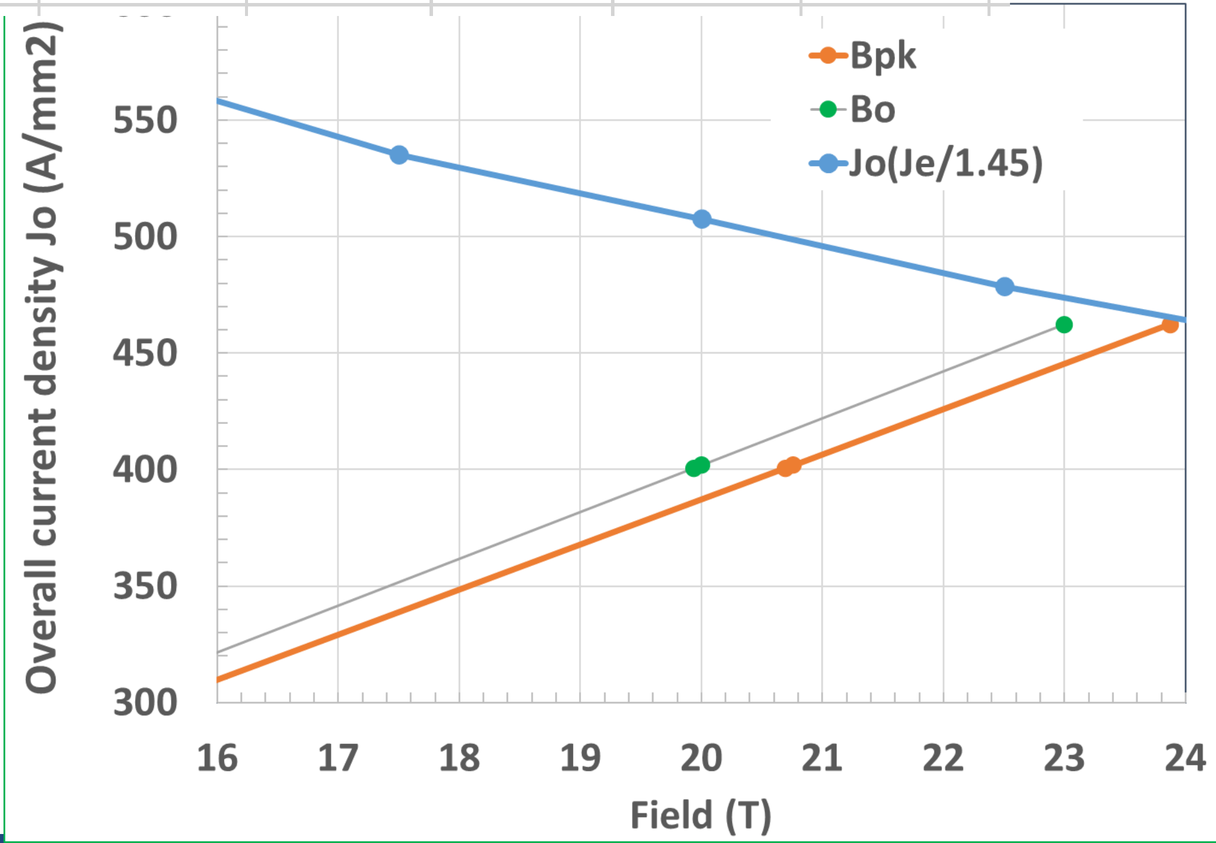
Magnetic Design (May 2022) with 15% Margin

	I(HTS), A	I(Nb3Sn)	Je(HTS), A/mm^2	Jo(HTS), A/mm^2	Je(Nb3Sn)	Jo(Nb3Sn)	Bo (T)	Bpk(HTS), T	Bpk(Nb3Sn)
	0	0	0	0	0	0	0	0	0
	13600	13600	487.60	400.672	639.10	526.316	19.938	20.695	13.670
1.0031	13642.2	13642.2	489.107	401.914	641.079	527.947	20.000	20.759	13.712
1.15355	15688.3	15688.3	562.465	462.195	737.231	607.132	23.000	23.873	15.769





Magnetic Design (May 2022) Good Field Quality

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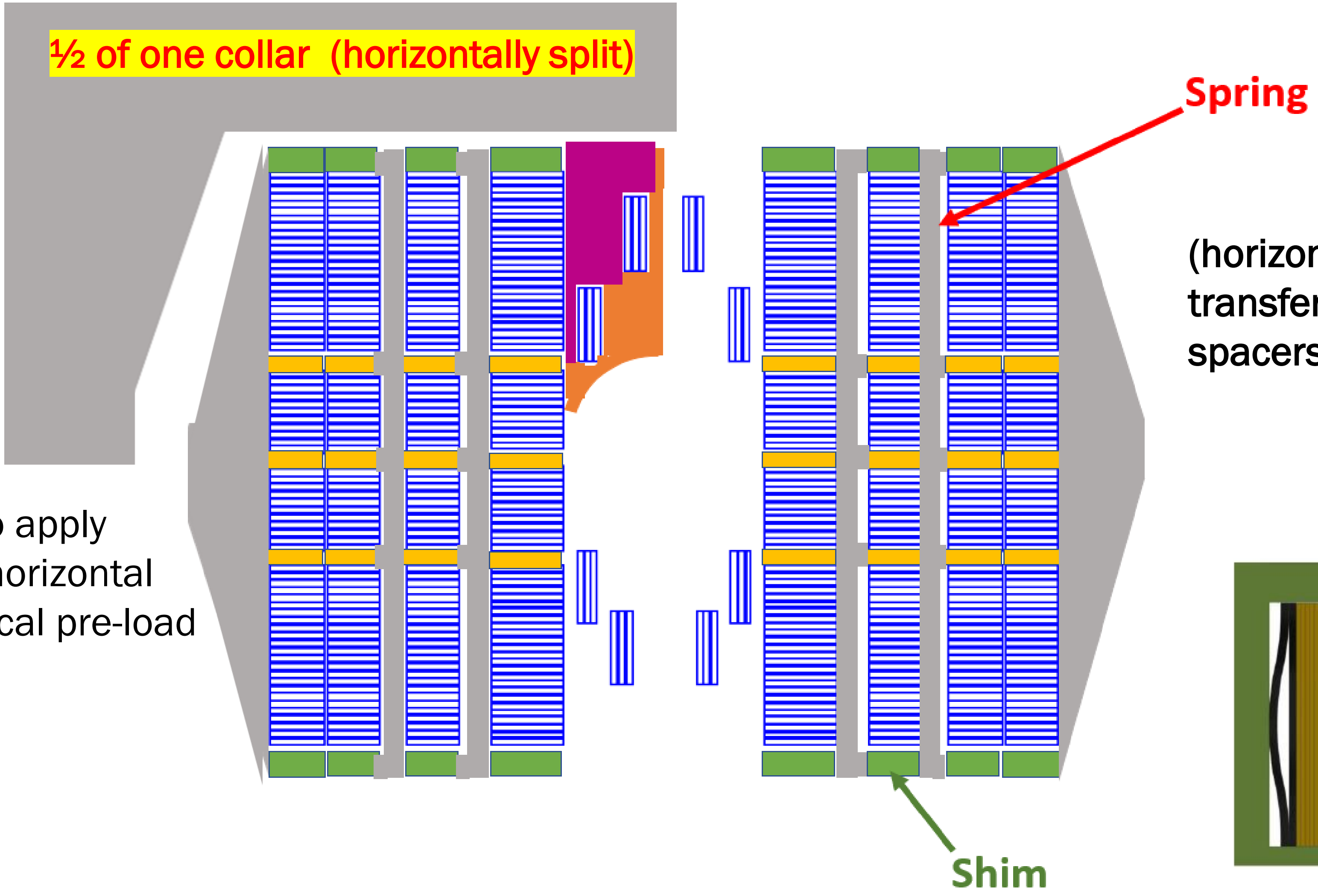
MODEL	mdp_may2022-v2
BI2212R	Bi2212
Bare w	1.52
Bare h	18.35
Insulation	0.15
Ins w	1.82
Ins h	18.65
Ins Area	33.943
Current	13600
Je (A/mm^2)	487.60
Jo (A/mm^2)	400.67
Bpeak (T)	20.6951
MDPH2	Nb_3Sn
Bare w	1.6
Bare h	13.3
Insulation	0.15
Ins w	1.9
Ins h	13.6
Ins Area	25.840
Current	13600
Je (A/mm^2)	639.10
Jo (A/mm^2)	526.32
Bpeak (T)	13.6701
Bo	19.9382

```
NORMAL RELATIVE MULTIPOLES (1.D-4):
b 1:  10000.00000  b 2:     -0.00000  b 3:      0.05059
b 4:     -0.00000  b 5:      0.09440  b 6:      0.00000
b 7:     -0.78244  b 8:      0.00000  b 9:     -0.92602
b10:      0.00000  b11:     -0.18313  b12:     -0.00000
b13:     -0.02800  b14:      0.00000  b15:     -0.01273
b16:      0.00000  b17:     -0.00410  b18:     -0.00000
b19:     -0.00094  b20:      0.00000  b

SKEW RELATIVE MULTIPOLES (1.D-4):
a 1:      0.00000  a 2:     -0.00405  a 3:      0.00000
a 4:     -0.02333  a 5:     -0.00000  a 6:     -0.15914
a 7:      0.00000  a 8:      0.20675  a 9:      0.00000
a10:      0.08678  a11:     -0.00000  a12:      0.00779
a13:      0.00000  a14:      0.00593  a15:     -0.00000
a16:      0.00258  a17:      0.00000  a18:      0.00056
a19:     -0.00000  a20:      0.00019  a
```

Concept for Structure

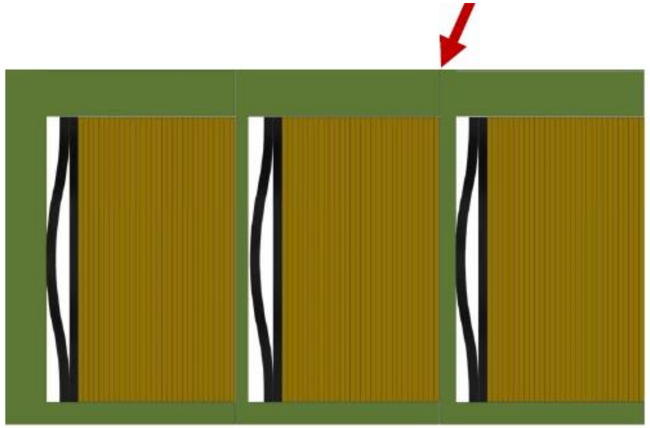


Spacers/Wedges
Sliding contact

(horizontal Lorentz forces are transferred to the collar via the spacers and not through the coils)

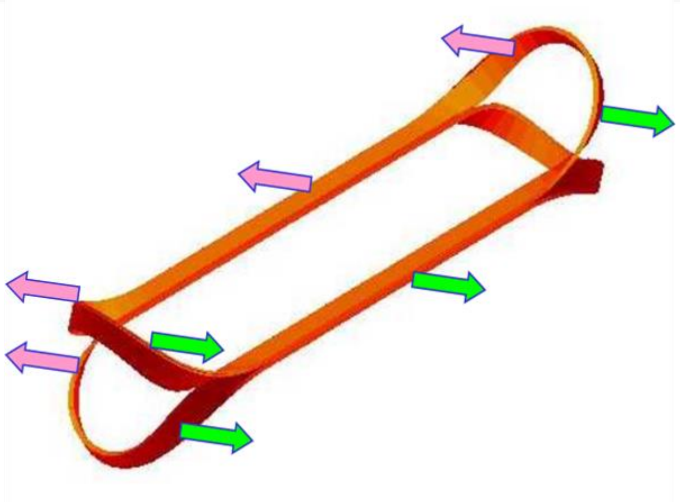
Collars to apply modest horizontal and vertical pre-load

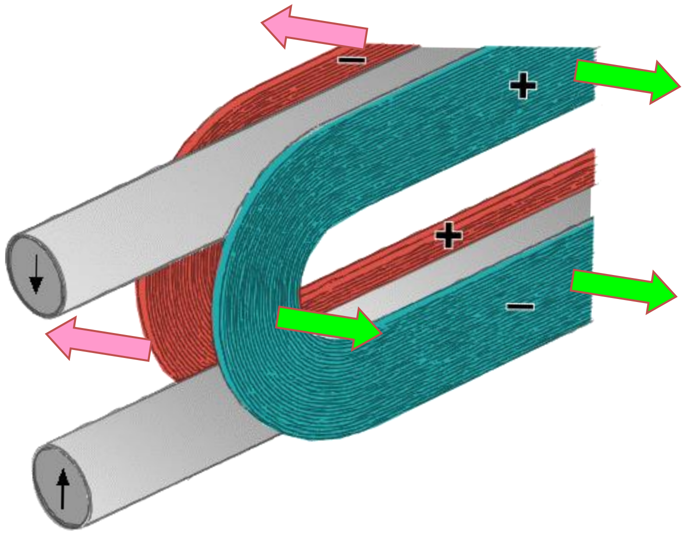
Peter McIntyre Style



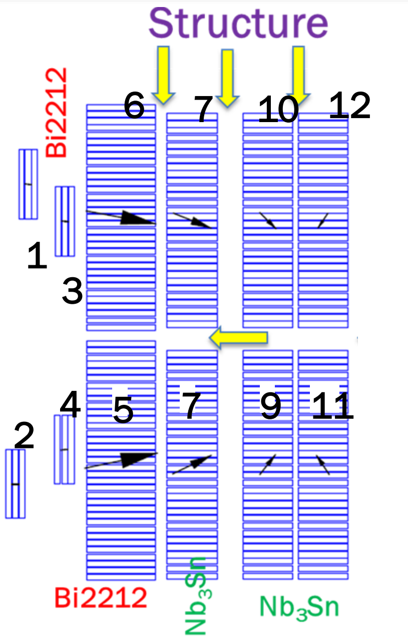
Extra Slides

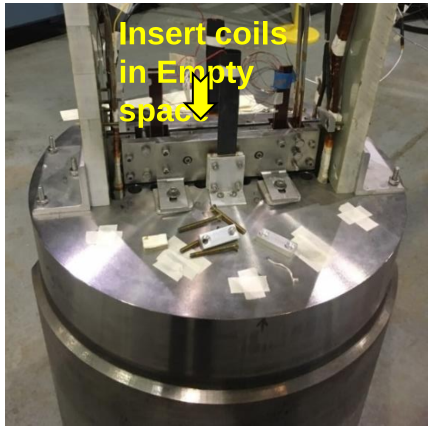
Key Benefits of the Common Coil Design for HTS/LTS High Field Hybrid Dipoles



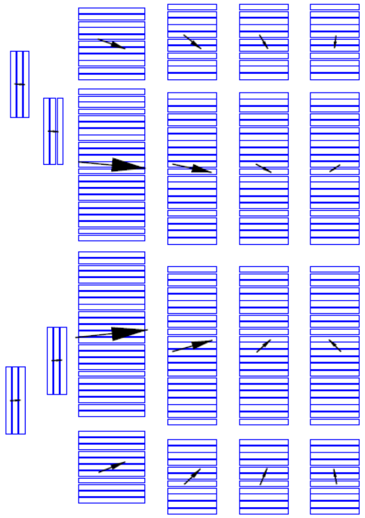


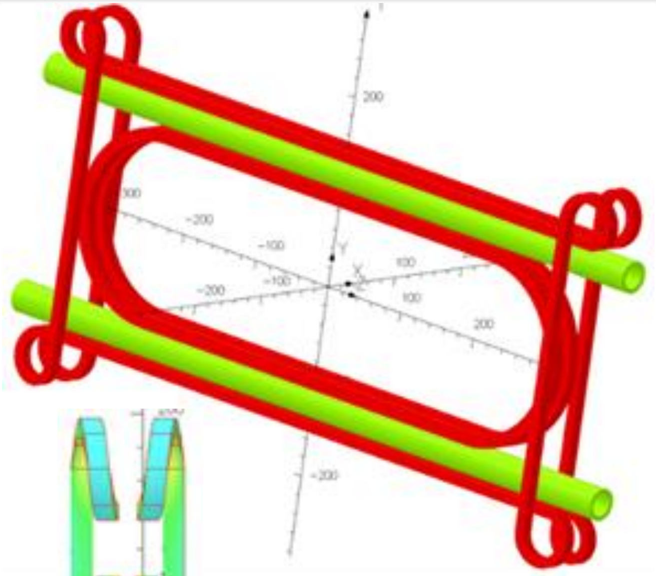
- Coil layers move as a module without causing strain at ends (BNL common coil had 200 μm). This should also save on the structure needed
- Flexible space for stress managed structure
- Natural segmentation between HTS and LTS for efficient optimization of conductor usage
- Simple coil geometry with large bend radii allow more technologies (W&D, R&W), more cables, more materials, etc.
- Modular design for low-cost, fast-turn-around R&D (PoP: 12.3 T MDP HTS/LTS hybrid dipole)



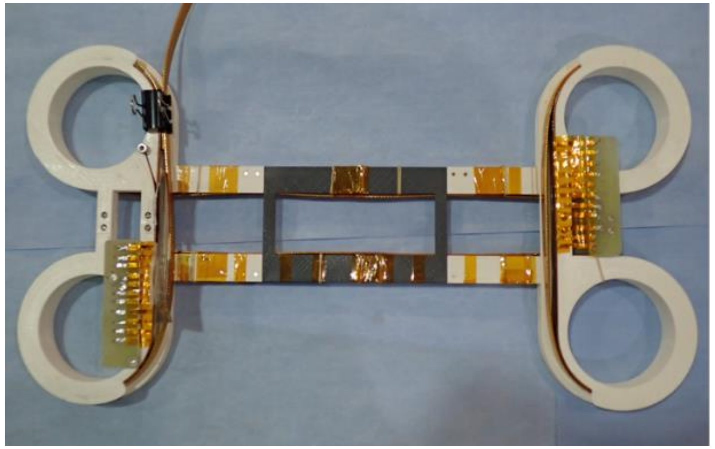


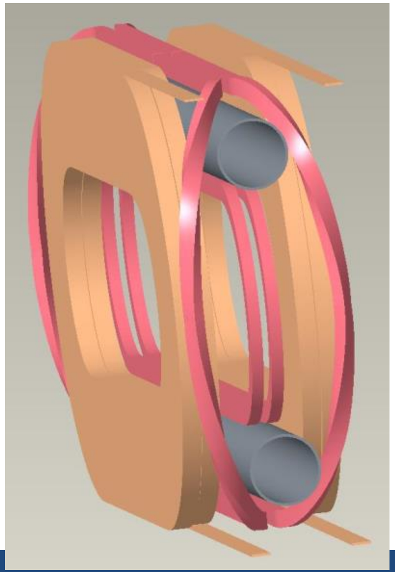
A Few Possible Layouts of Pole Coils Clearing the Bore (other geometries shown elsewhere)

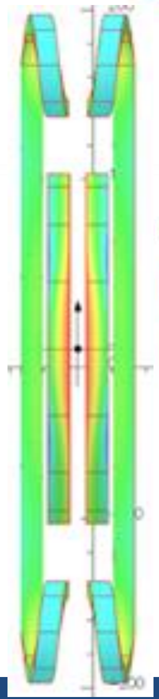


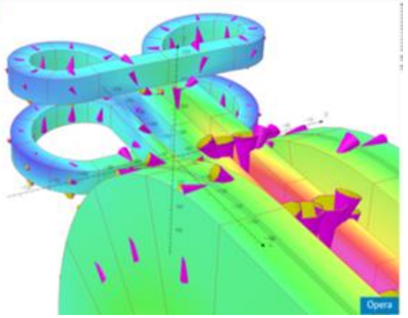


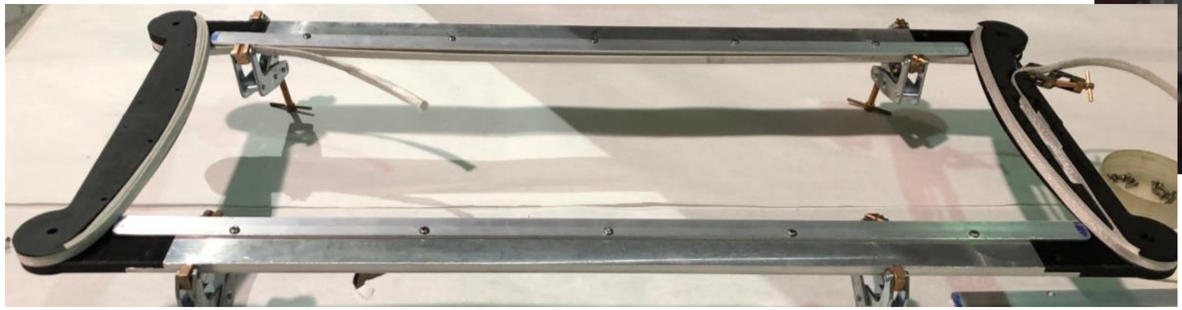
Practice pole coil windings and preliminary designs (performed under three SBIR Phase I; no Phase II).
They can be built and tested under MDP.





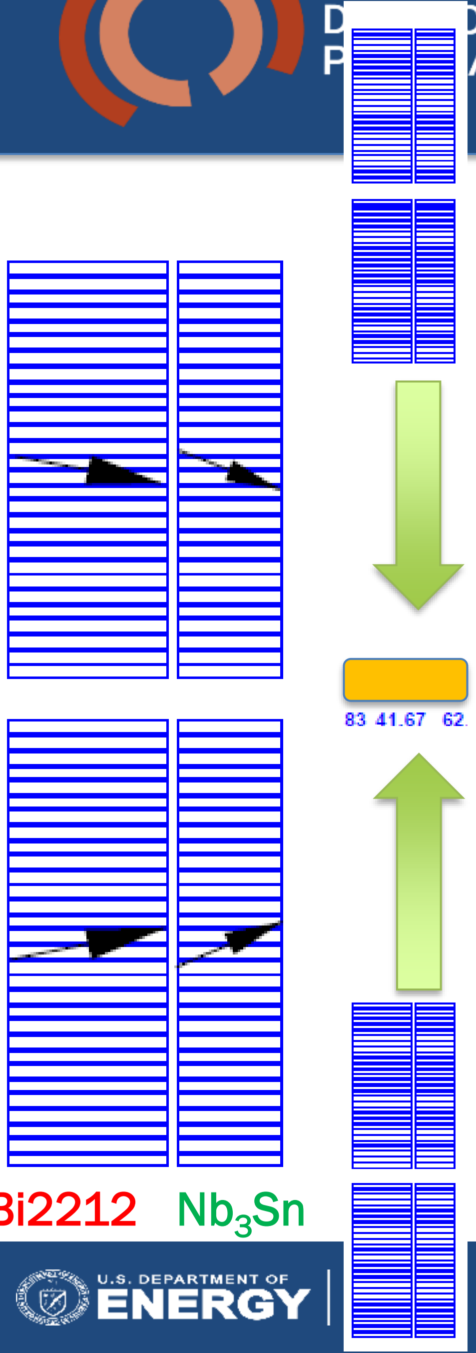




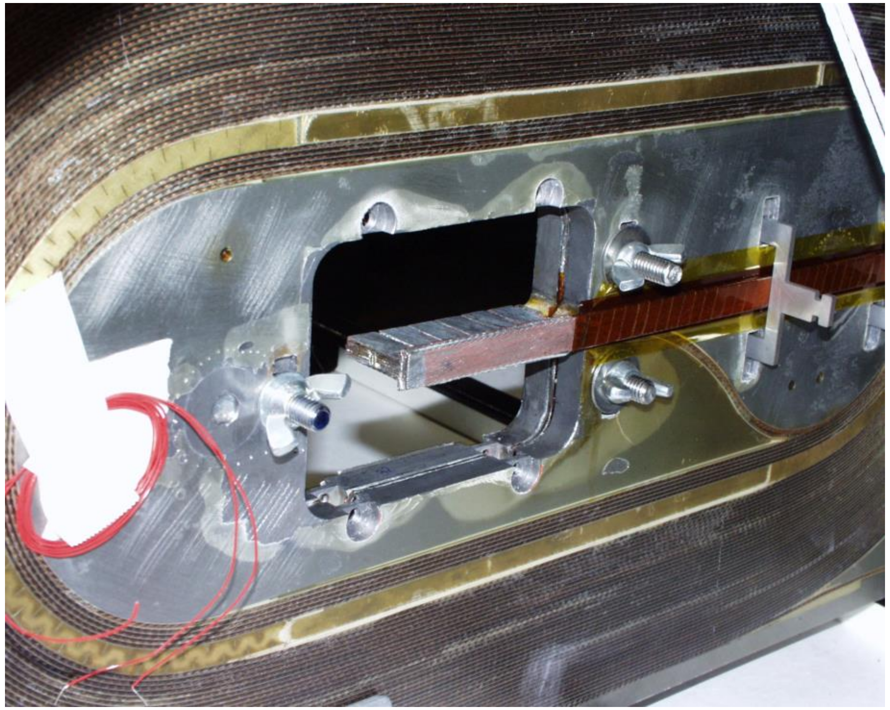


Splices in Common Coil Design (between two single layer coil)

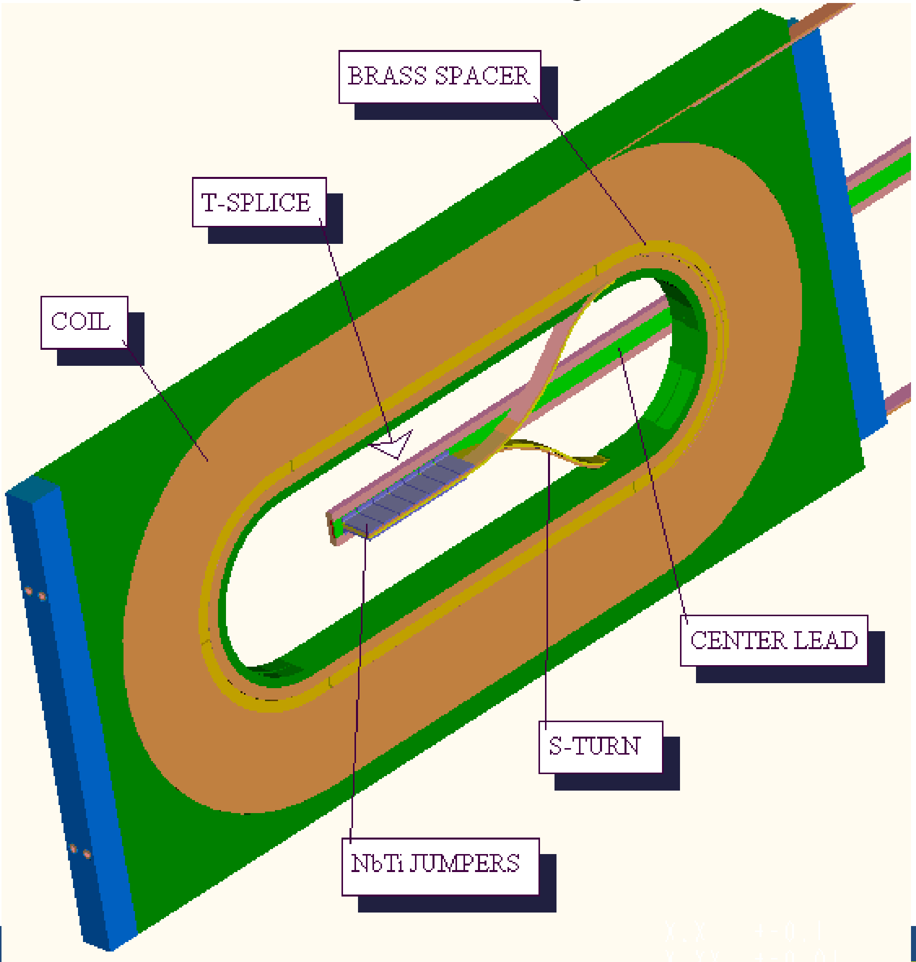
In common coil design, splice (even between two types of coils), can be easily made in the middle of the coil where the field is very low



Bi2212 Nb_3Sn



Perpendicular Nb-Ti splice in the low field region of BNL common coil dipole DCC017



New 20 T HTS/LTS Hybrid Design (May 2022)
(spacers in magnetic design takes input from mechanical)