20 T Hybrid Nb_3Sn-HTS Block-coil Designs for a Future Particle Collider

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Objectives

- Conceptual design for a **20 T dipole**
- Hybrid magnet = **HTS Bi2212 + Nb_3Sn**
- Feasibility of a **block-coil design**?
- Take the **stress into account**

→ See "Towards 20 T hybrid accelerator dipole magnets", FRI-OR6-101-04

D [mm]	Nstr	Th [mm]	W [mm]	Cu:nCu	J0/JE	J0/Jc
1.2	54	2.46	34.3	1.1	0.724	0.345
1.2	**27**	**2.46**	**17.3**	**1.1**	**0.717**	**0.342**
1.0	32	2.10	17.1	1.1	0.700	0.333
0.85	38	1.83	17.3	1.1	0.683	0.325
0.7	46	1.56	17.2	1.1	0.660	0.314

Considered Cables (bare reacted)

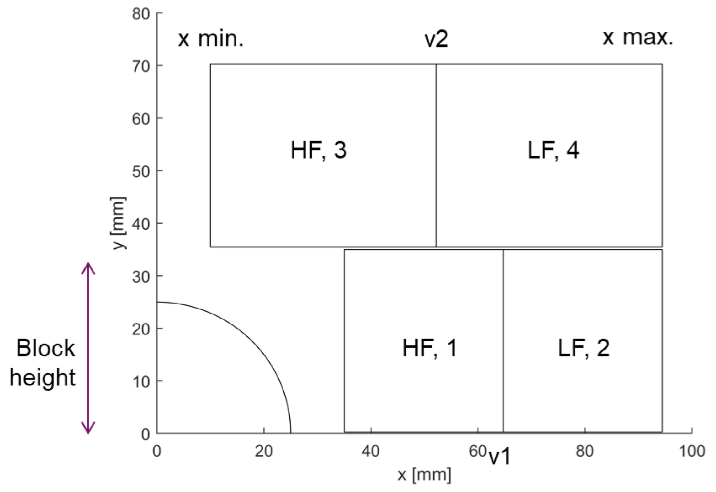
Summary

- parametric analysis to identify the "ideal" X-section
- **Compact design**
- **Stress limitation**

- Exploration of stress-managed layouts
- « hybrid magnet » vs « hybrid coils »
- Hybrid coils → **internal rib**
- **Acceptable stress at nominal**
- **Compact and efficient**
- **Coil fabrication R&D required**

Preliminary Parametric Analysis

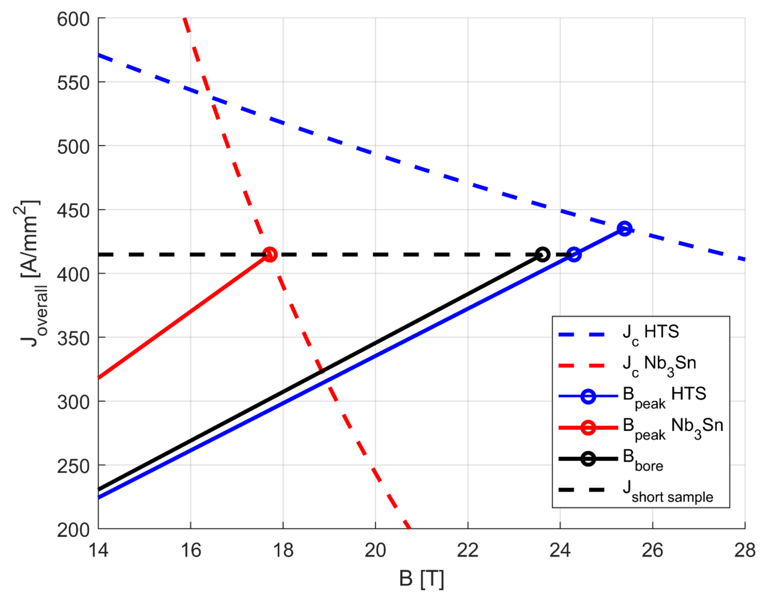
- **Blocks with homogeneous J**
- **Analytical formulas for B and S**
- **Parametric analysis without iron**



- **Determination of the minimum amount of conductor**:

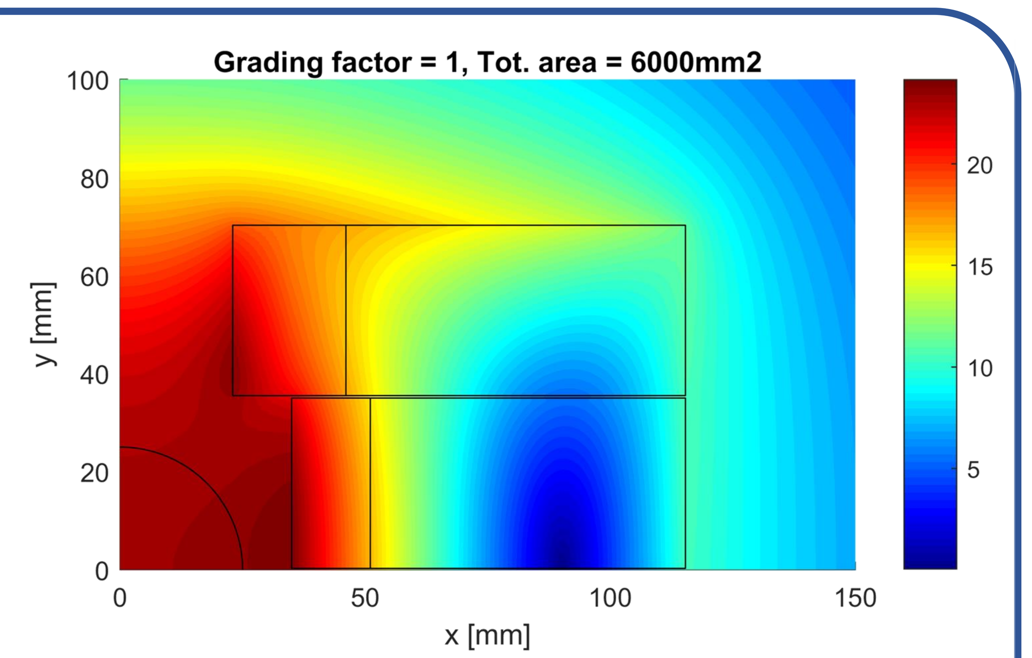
1. given conductor area and minimum radius xmin
2. boundaries v1 and v2 are varied.
3. Max. bore field at short sample is selected.
4. The solution with the min. area of Bi2212 is selected.
5. 1. to 3. repeated, changing area or xmin.
6. A final solution is chosen based on the criteria.

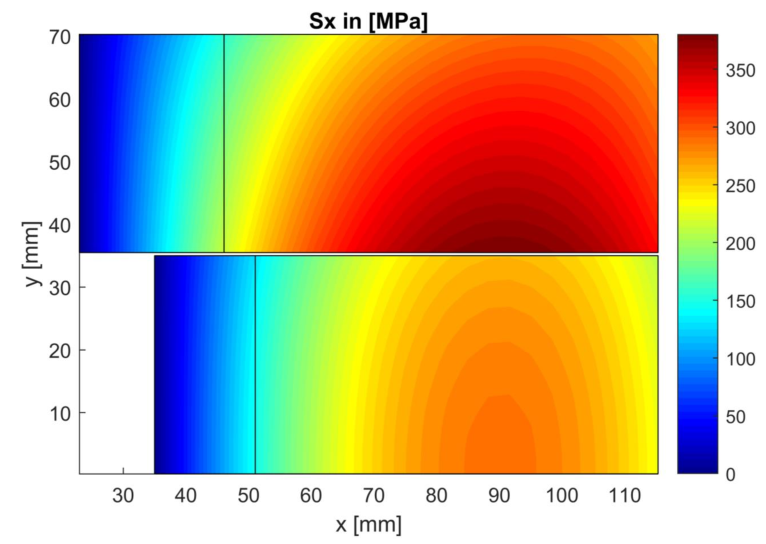
Max. Stress	SS	85% SS
Sx Nb3Sn	380	275
Sy Nb3Sn	151	109
Sx Bi2212	215	155
Sy Bi2212	139	100



- **Final solution computed with iron** using FEM

Parameter	Unit	Hybrid			HTS only	LTS only
		SS no iron	83%SS	SS	SS	SS
Area	A/mm2	6000	6000	6000	1360	4740
B0 total HTS+LTS	T	23.3 6.5+16.8	20.0 6.5+13.5	23.7 7.6-16.1	10.4	16.6
Bp HTS	T	24.16	20.6	24.3	12.4	
Bp LTS	T	17.15	15.1	17.2		18.2
J HTS	A/mm^2	447.5	346.1	416.9	593.7	0
J LTS	A/mm^2	447.5	346.1	416.9	0	387.9
Margin HTS	%	0	20.5	4.2	0	-
Margin LTS	%	0.93	17.0	0	-	0



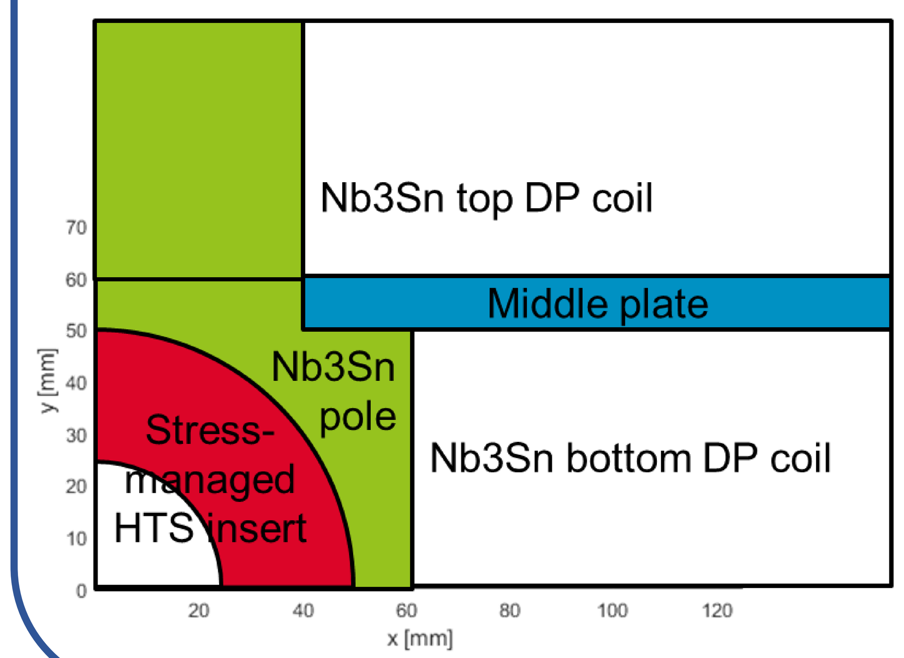


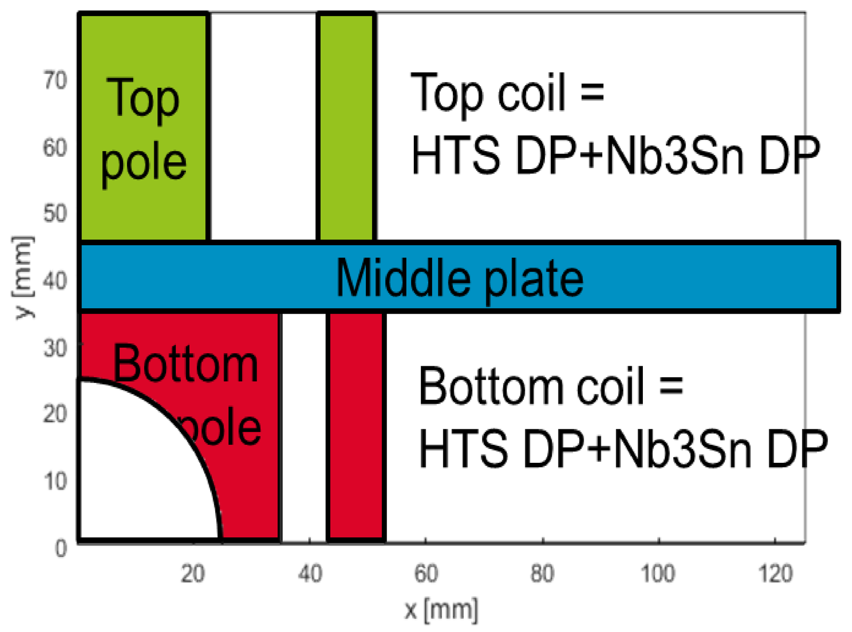
Outlook for Stress-managed Hybrid Designs

"Hybrid magnet" assembly VS "Hybrid coils"

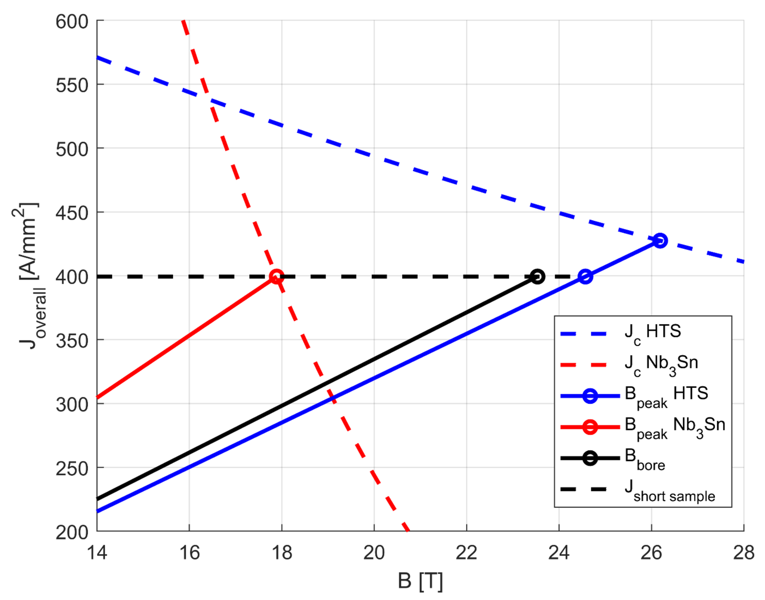
"Hybrid magnet" assembly:
- ✓ **Mechanically decoupled**
- ✓ **Independent R&D Nb_3Sn / Bi2212**
- × **Less degrees of freedom**
- × **Nb_3Sn outsert less compact**

"Hybrid coils":
- × **Separate coil fabrication**
- × **External/internal joints**
- ✓ **Ribs to intercept Sx**
- ✓ **More compact**





Max. Stress	SS	85% SS
Sx Nb3Sn	222	160
Sy Nb3Sn	136	98
Sx Bi2212	193	139
Sy Bi2212	84	61



- **Final solution computed with iron** using FEM

Parameter	Unit	Hybrid			HTS only	LTS only
		SS no iron	83.5%SS	SS	SS	SS
Area	A/mm2	7500	7500	7500	1500	6000
B0 total HTS+LTS	T	23.4 6.5+16.9	20.0 6.3+13.7	23.6 7.4+16.2	10.6	16.2
Bp HTS	T	24.58	20.9	24.7	12.1	
Bp LTS	T	17.57	15.2	18.0		18.5
J HTS	A/mm^2	427.9	334.8	401.0	598.2	0
J LTS	A/mm^2	427.9	334.8	401.0	0	367.3
Margin HTS	%	2.2	21.7	6.2	0	-
Margin LTS	%	0	16.5	0	-	0