50 Tesla Hybrid Magnet

Feasible now?
R & D recommended?

Superconductor cost?
Power needed by the Bitter coil insert?

Bob Weggel, Particle Beam Lasers

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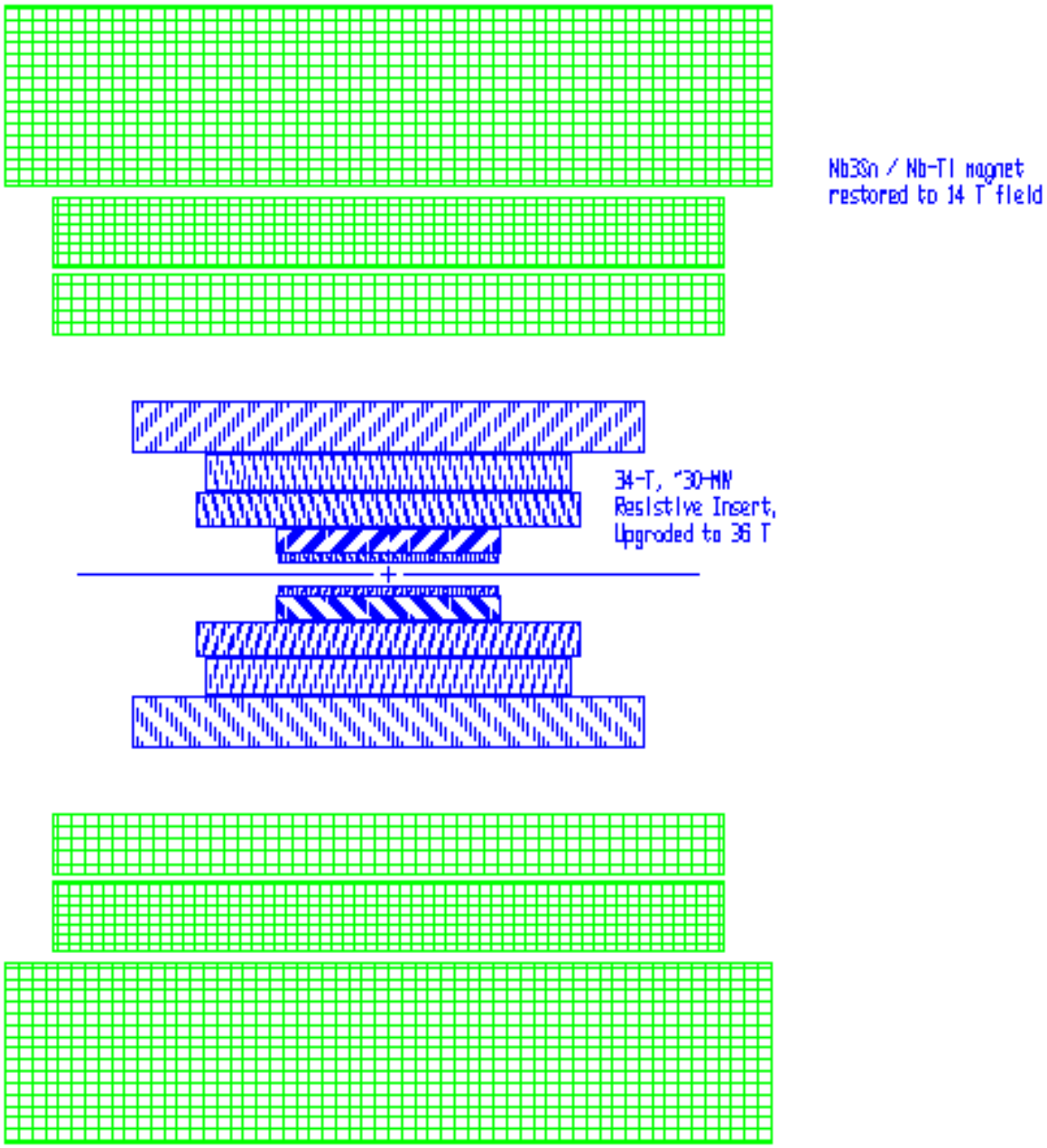
45T NHMFL Hybrid Magnet:

a) 14 T SC + 31 T, 24 MW Bitter coil

b) 11 T SC + 34 T, 30 MW Bitter coil



NHMFL 45-tesla hybrid magnet upgraded to 50 T

Superconducting magnet restored

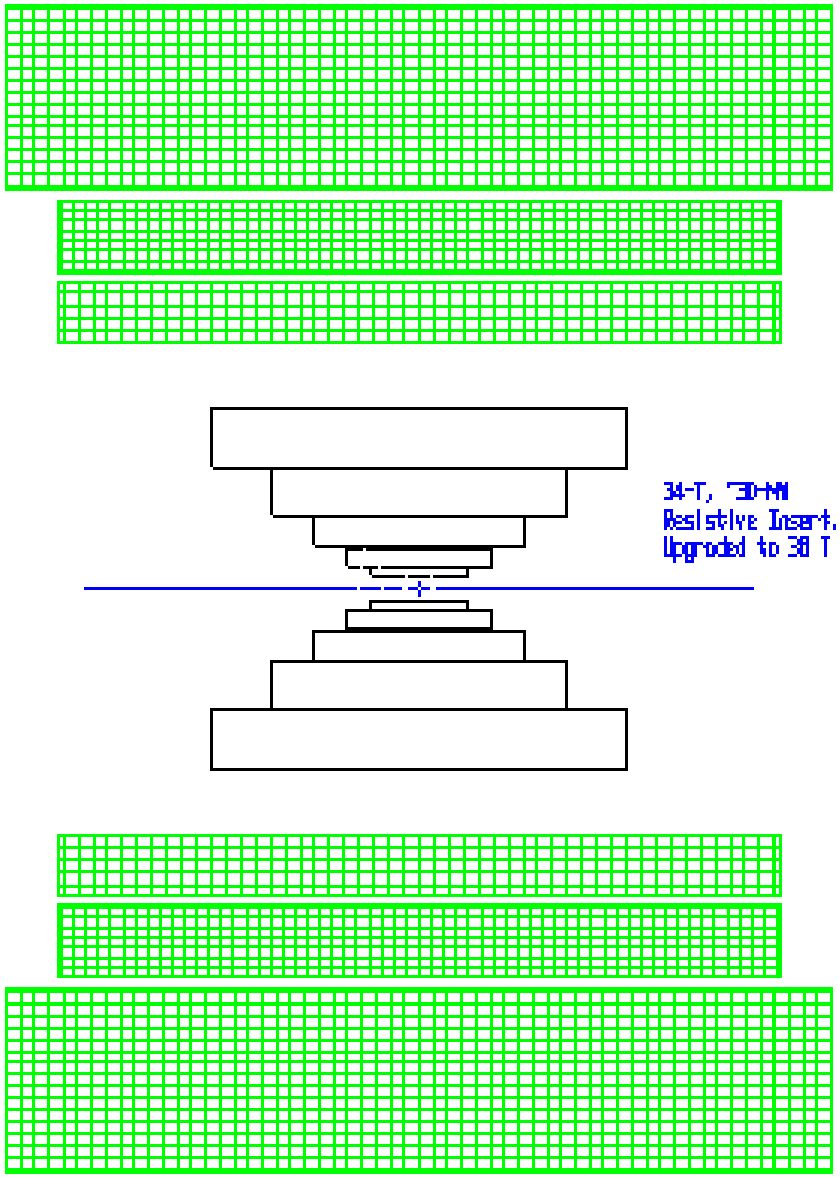
to 14.1 teslas

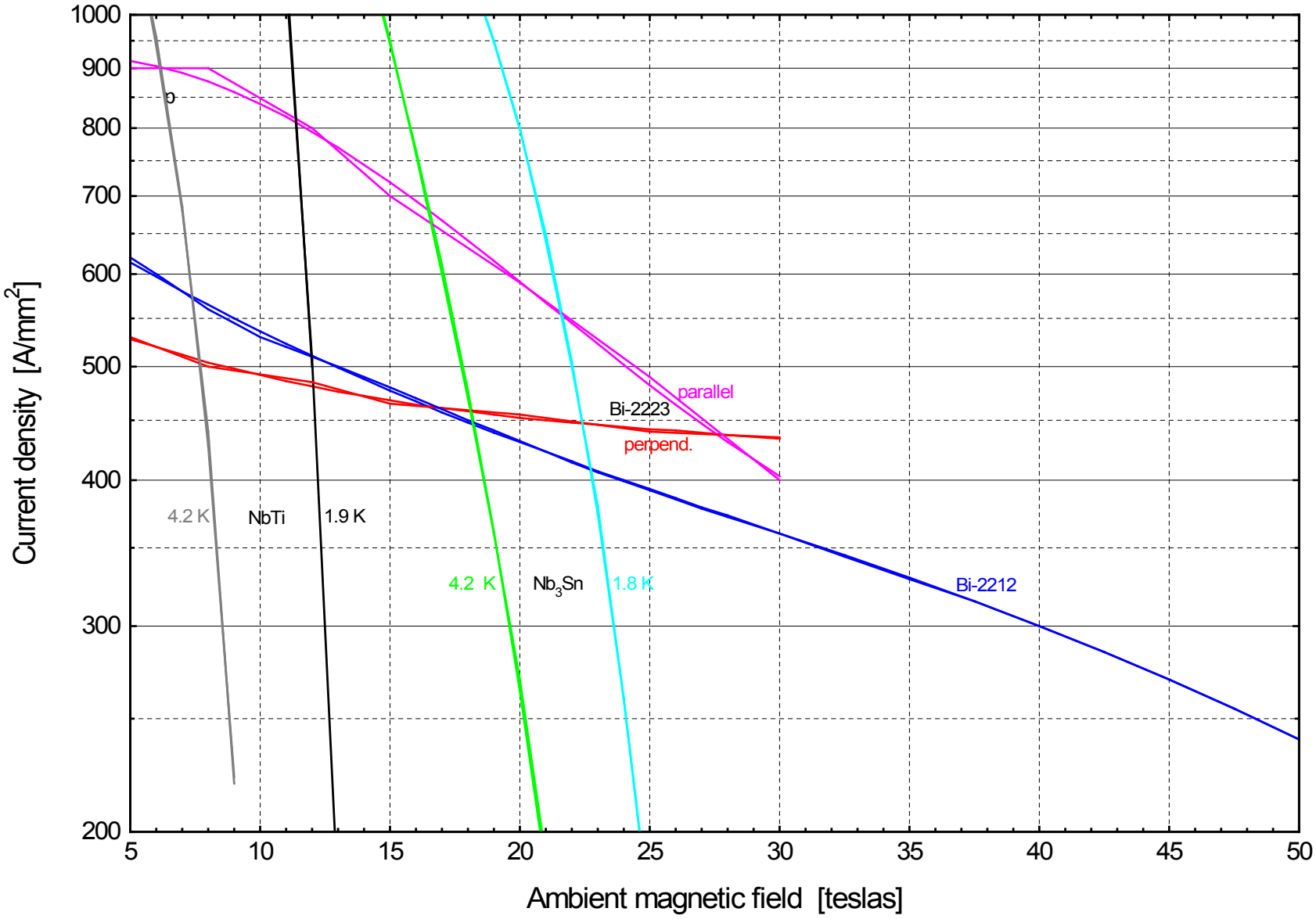
Bitter magnet insert upgraded from

34 T @ 30 MW

to 35.9 T @ 34 MW;

Stretches limits of comfort on heat flux & temperature!

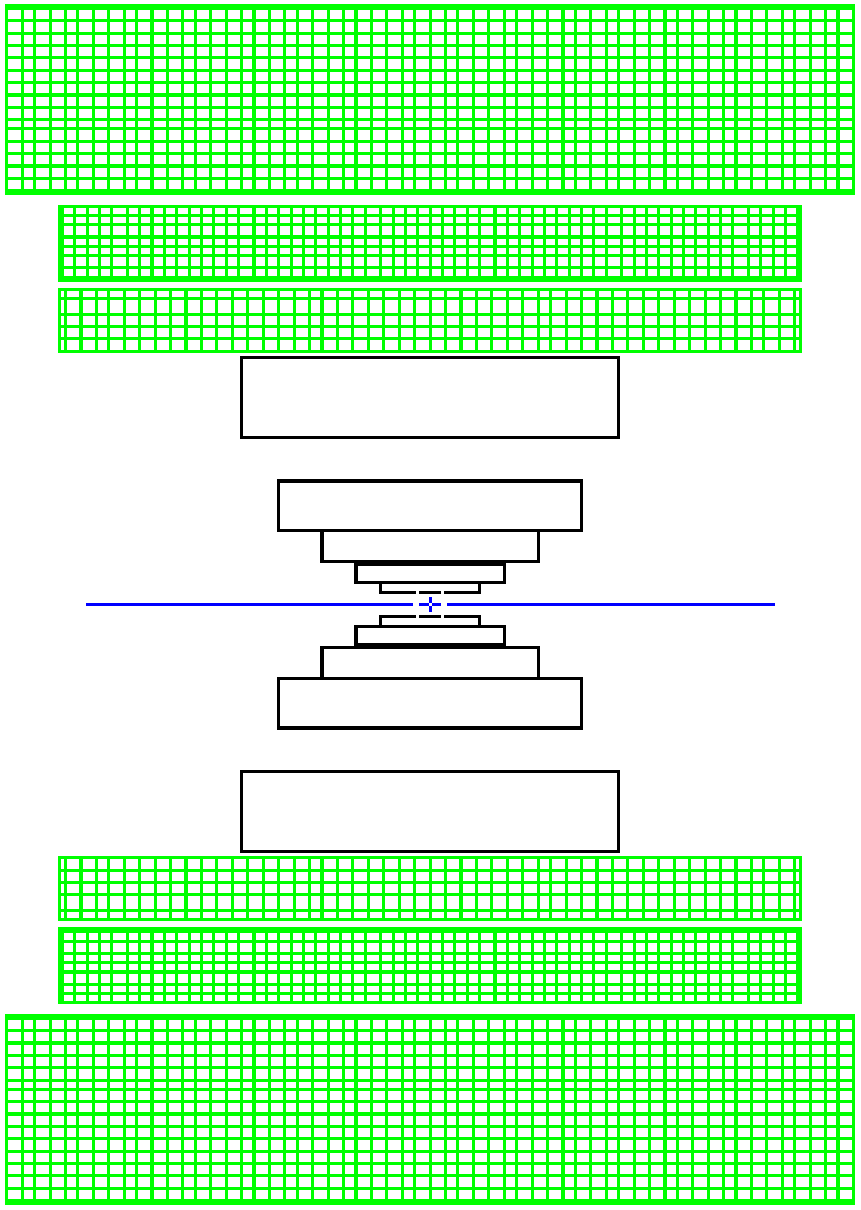


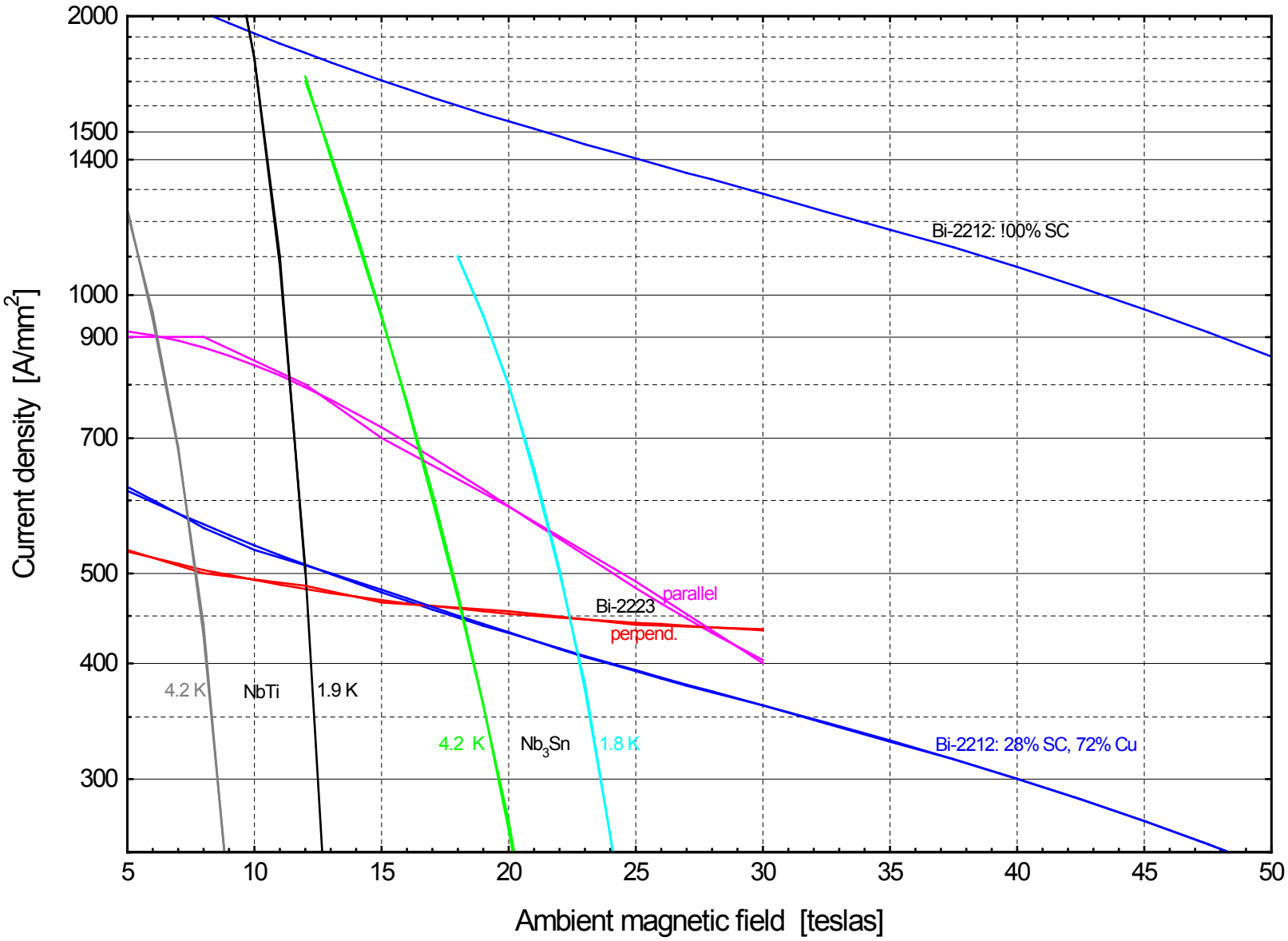

J_e of NbTi, Nb_3Sn, Bi-2212 Wire & Bi-2223 Tape: Measured and Curve-Fit
Current density [A/mm^2]
Ambient magnetic field [teslas]
1000
900
800
700
600
500
400
300
200
5
10
15
20
25
30
35
40
45
50
parallel
Bi-2223
perpend.
4.2 K
NbTi
1.9 K
4.2 K
Nb_3Sn
1.8 K
Bi-2212

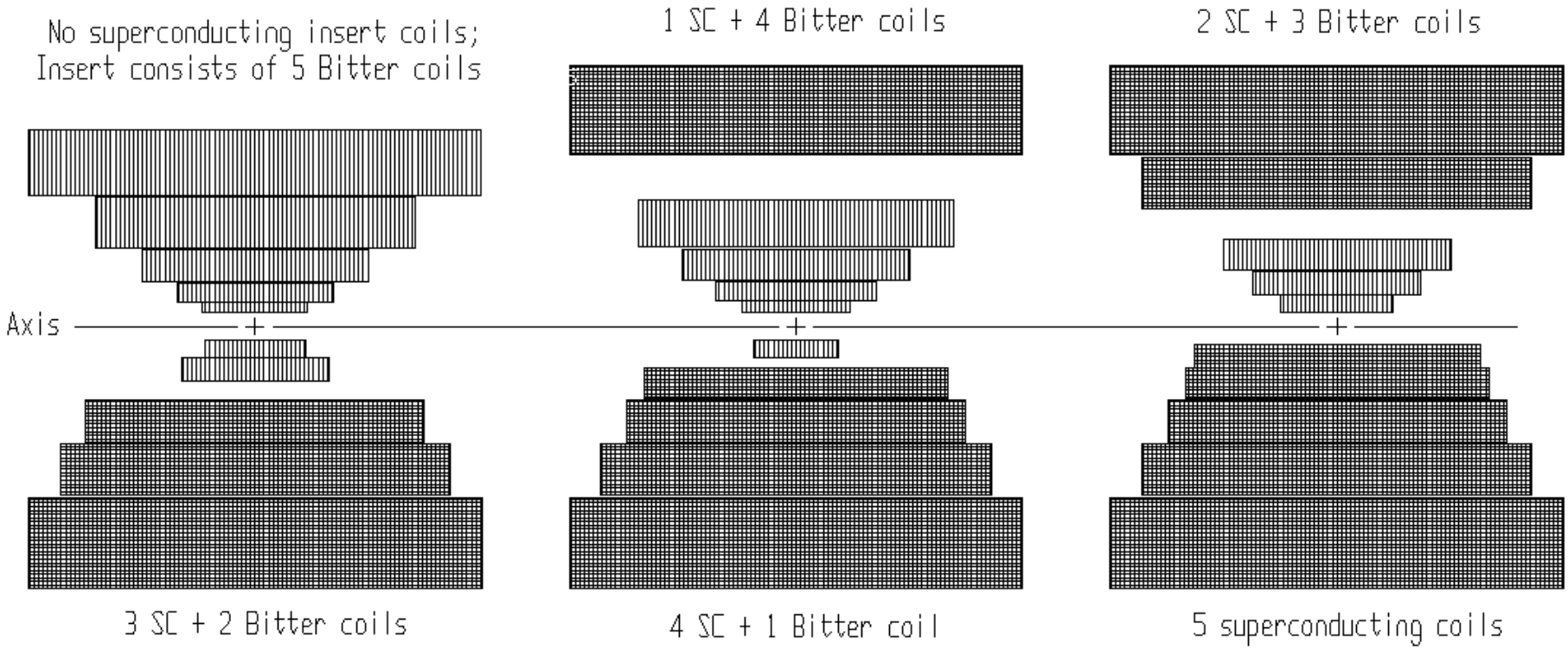
50 tesla hybrid magnet with outermost Bitter coil replaced by Nb_3Sn superconducting coil

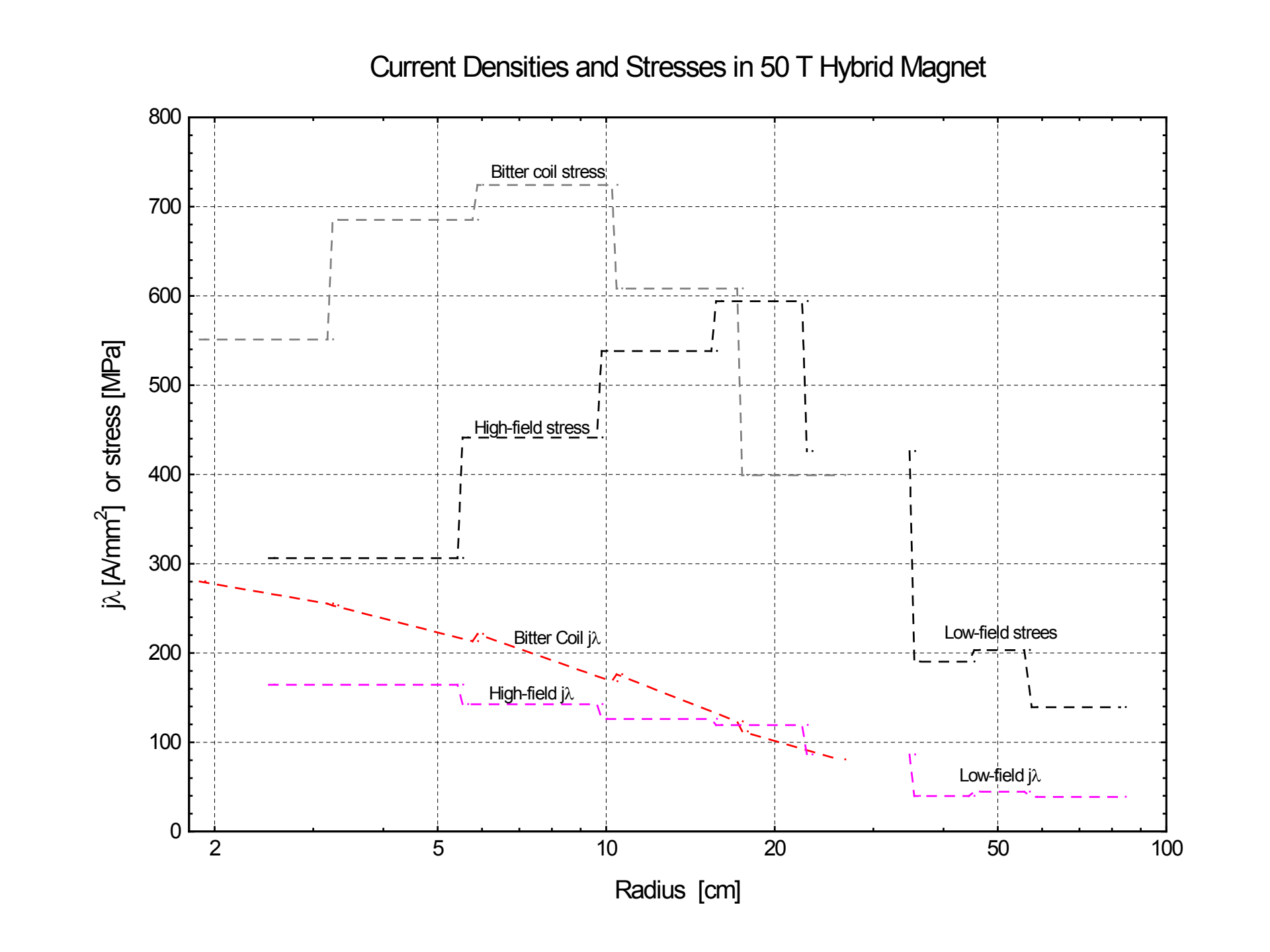
Saves 11.2 MW (33 %)

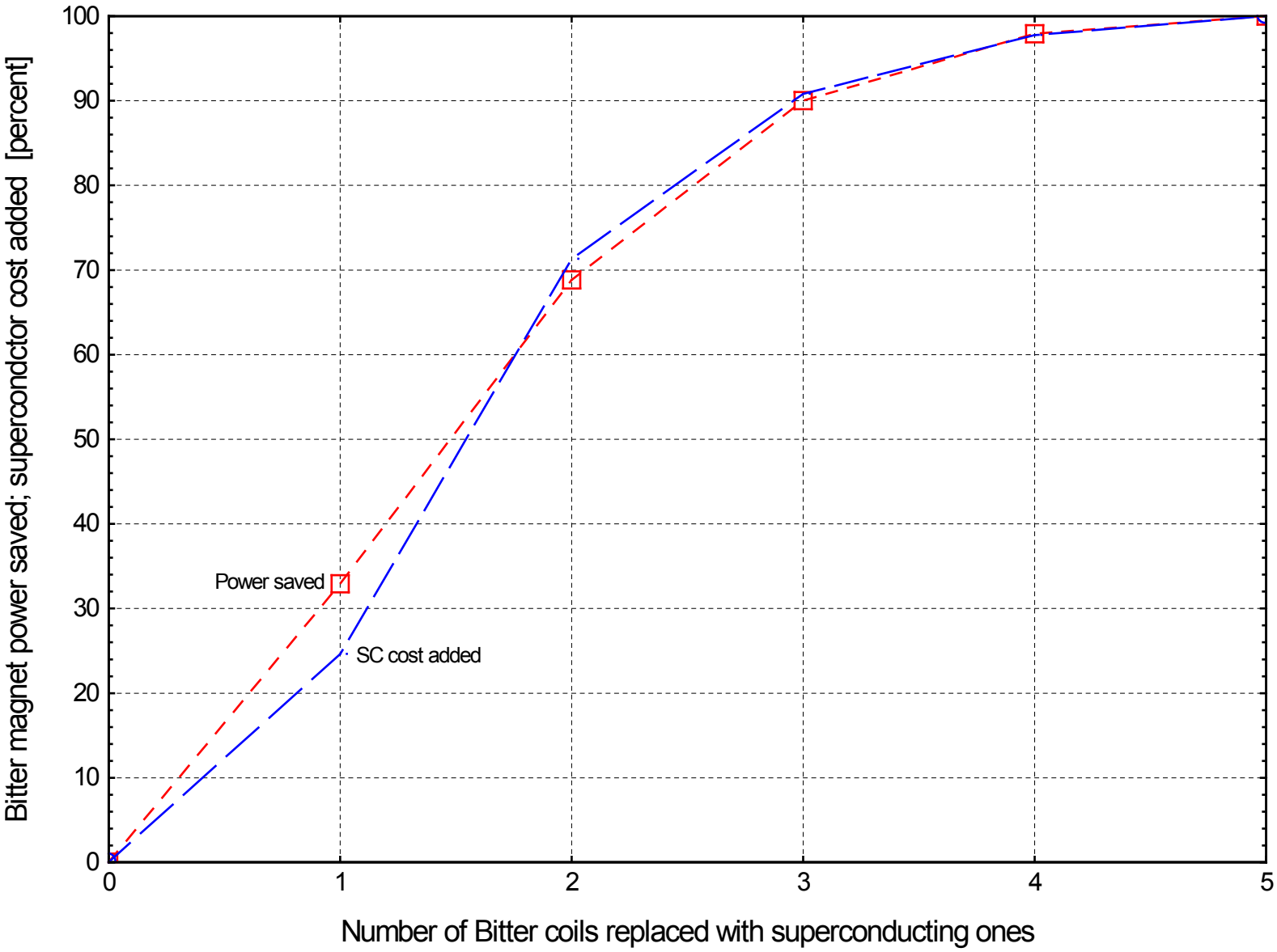
Adds ~32% SC cost

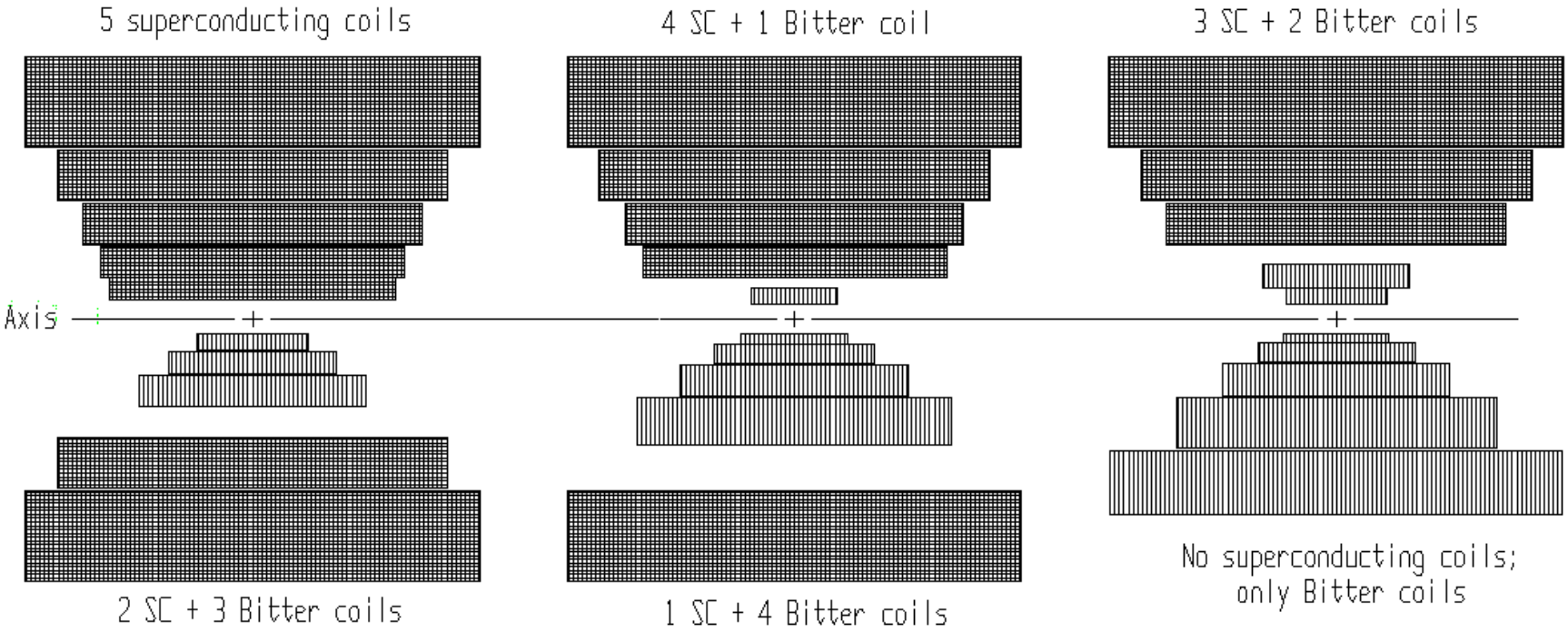


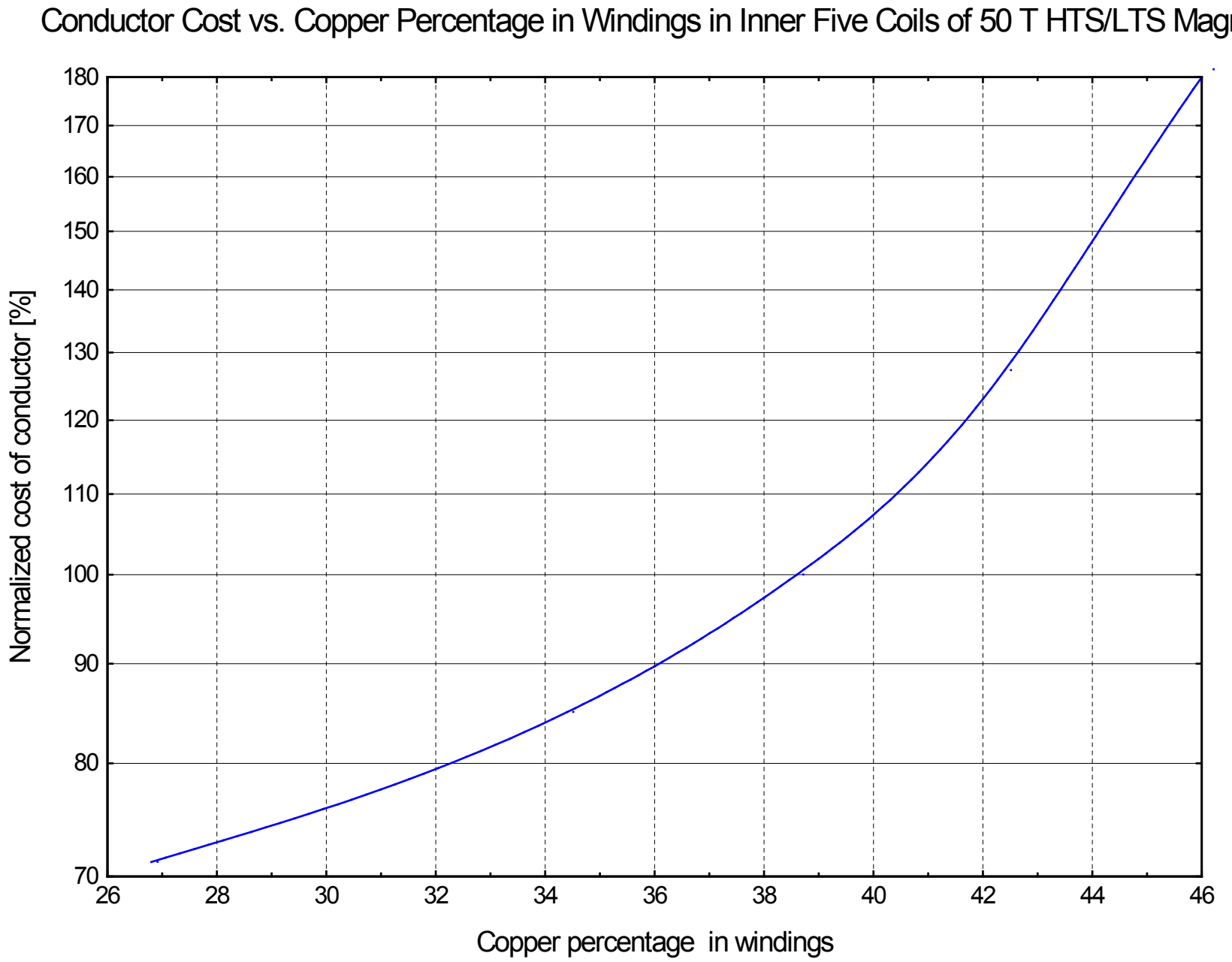

J_e of NbTi, Nb_3Sn, Bi-2212 Wire & Bi-2223 Tape: Measured and Curve-Fit
Current density [A/mm^2]
2000
1500
1400
1000
900
700
500
400
300
5
10
15
20
25
30
35
40
45
50
Ambient magnetic field [teslas]
Bi-2212: !00% SC
parallel
Bi-2223
perpend.
4.2 K
NbTi
1.9 K
4.2 K
Nb_3Sn
1.8 K
Bi-2212: 28% SC, 72% Cu

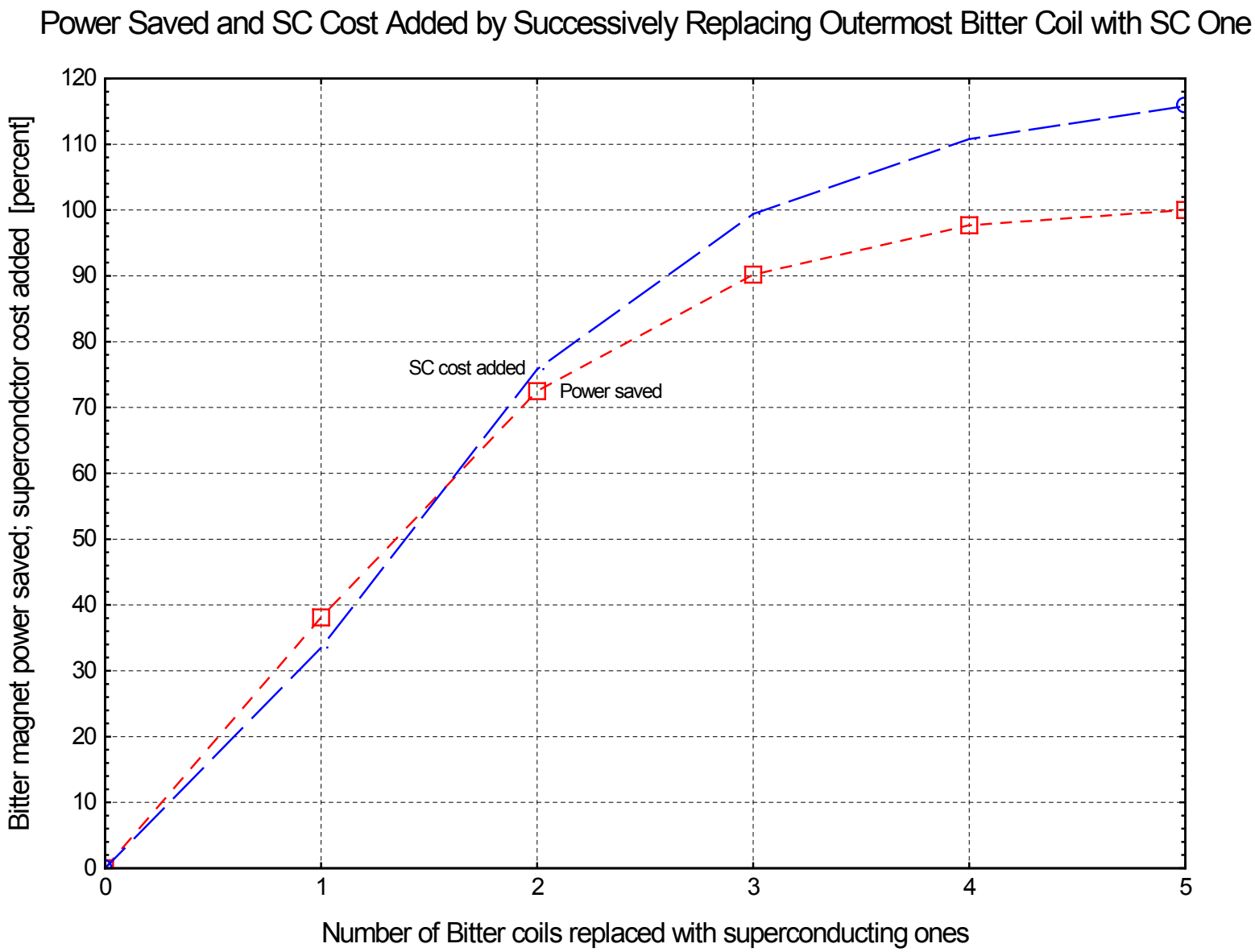

No superconducting insert coils;
Insert consists of 5 Bitter coils
1 SC + 4 Bitter coils
2 SC + 3 Bitter coils
Axis
3 SC + 2 Bitter coils
4 SC + 1 Bitter coil
5 superconducting coils


Current Densities and Stresses in 50 T Hybrid Magnet
Bitter coil stress
High-field stress
Bitter Coil jλ
High-field jλ
Low-field strees
Low-field jλ
jλ [A/mm2] or stress [MPa]
Radius [cm]
800
700
600
500
400
300
200
100
0
2
5
10
20
50
100


Power Saved and SC Cost Added by Successively Replacing Outermost Bitter Coil with SC One
Bitter magnet power saved; superconductor cost added [percent]
100
90
80
70
60
50
40
30
20
10
0
0
1
2
3
4
5
Power saved
SC cost added
Number of Bitter coils replaced with superconducting ones


5 superconducting coils
4 SC + 1 Bitter coil
3 SC + 2 Bitter coils
Axis
2 SC + 3 Bitter coils
1 SC + 4 Bitter coils
No superconducting coils;
only Bitter coils


Conductor Cost vs. Copper Percentage in Windings in Inner Five Coils of 50 T HTS/LTS Magnet
Normalized cost of conductor [%]
180
170
160
150
140
130
120
110
100
90
80
70
26
28
30
32
34
36
38
40
42
44
46
Copper percentage in windings


Power Saved and SC Cost Added by Successively Replacing Outermost Bitter Coil with SC One
Bitter magnet power saved; superconductor cost added [percent]
120
110
100
90
80
70
60
50
40
30
20
10
0
0
1
2
3
4
5
SC cost added
Power saved
Number of Bitter coils replaced with superconducting ones