20 Tesla Magnet System for Study II (Hollow-Conductor Option)

Design Concept

Bob Weggel
BNL, Bldg. 901A
Upton, NY 11973
631-344-2428; fax = 3248
weggel@bnl.gov

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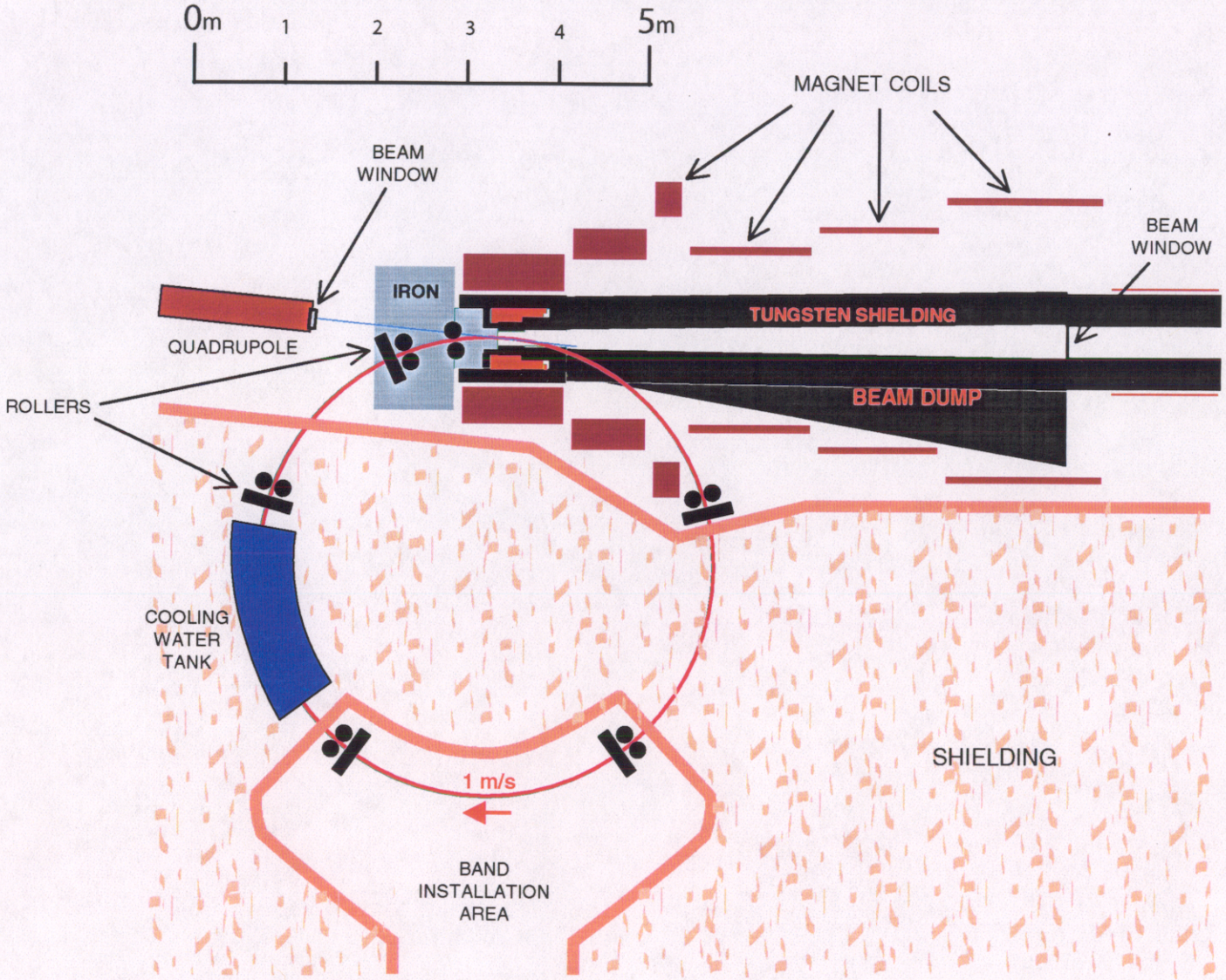
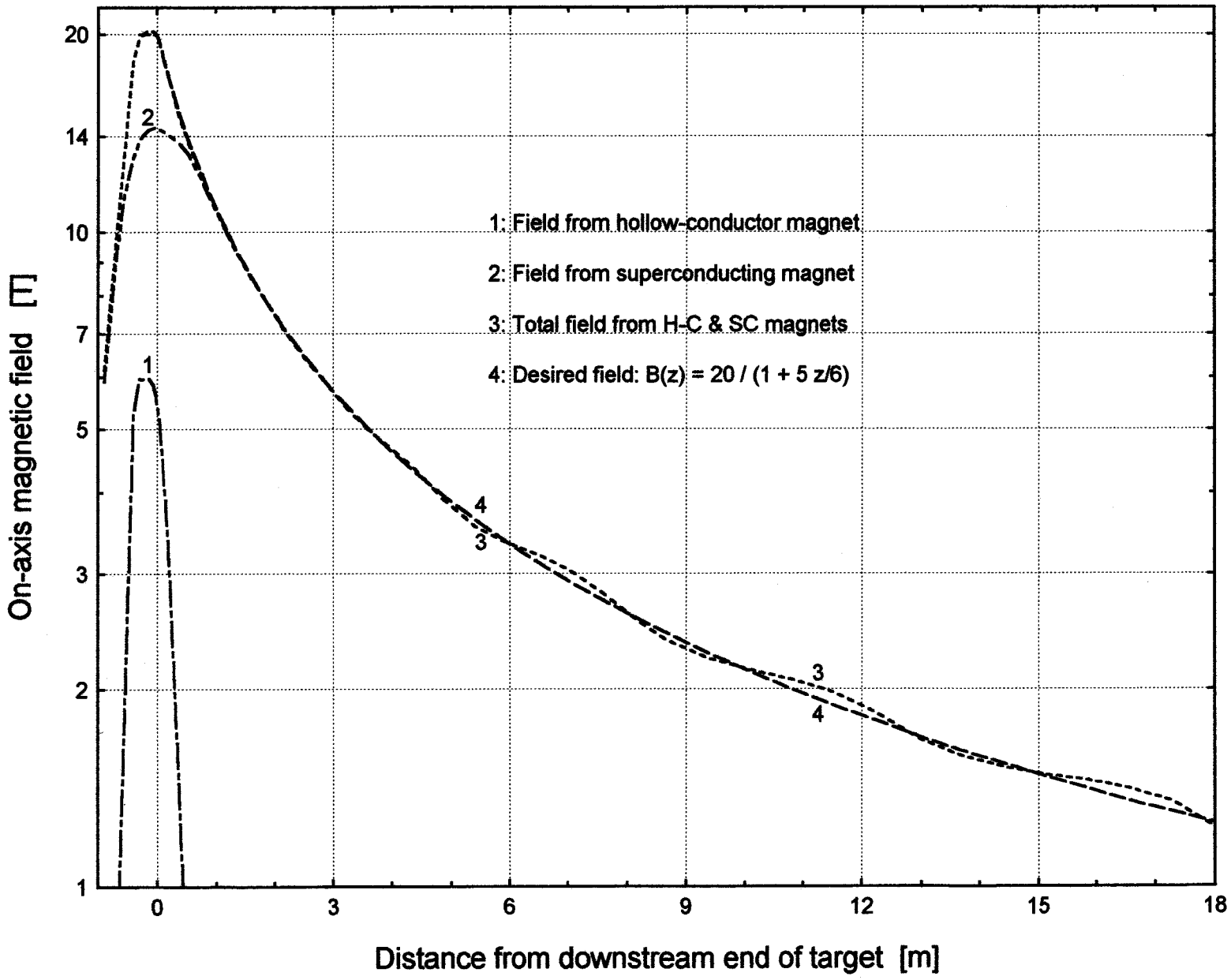
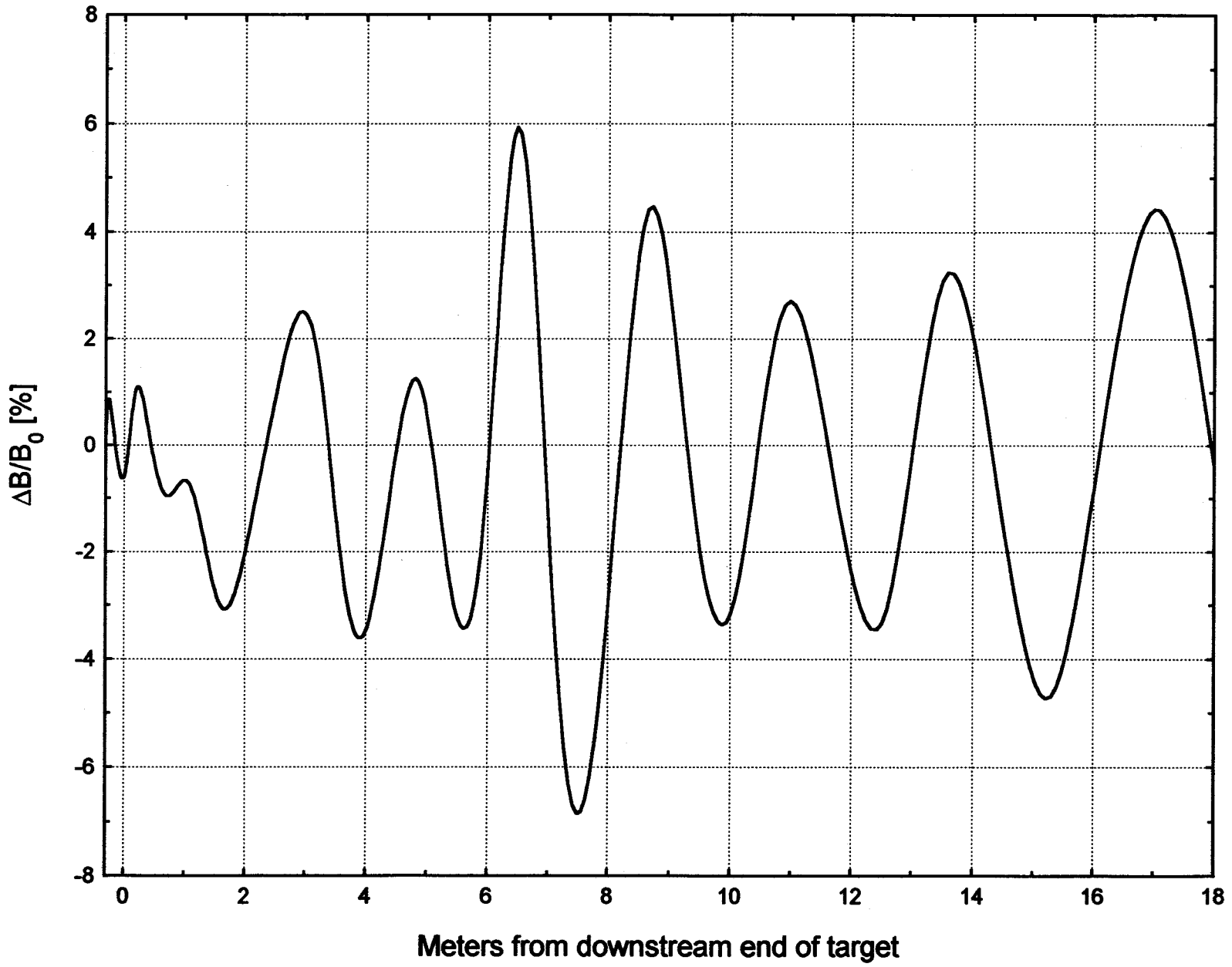
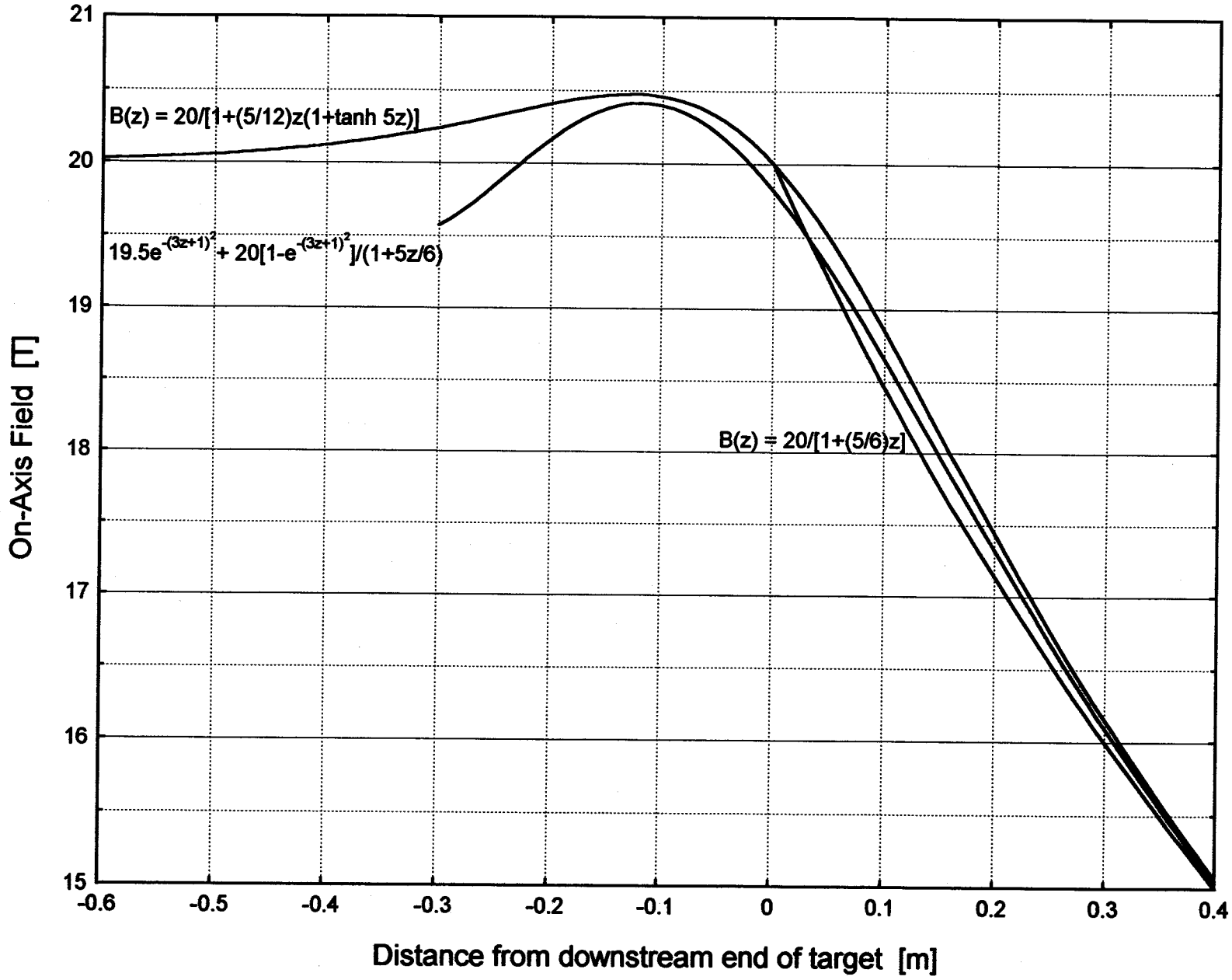
Plan View of Target Layout



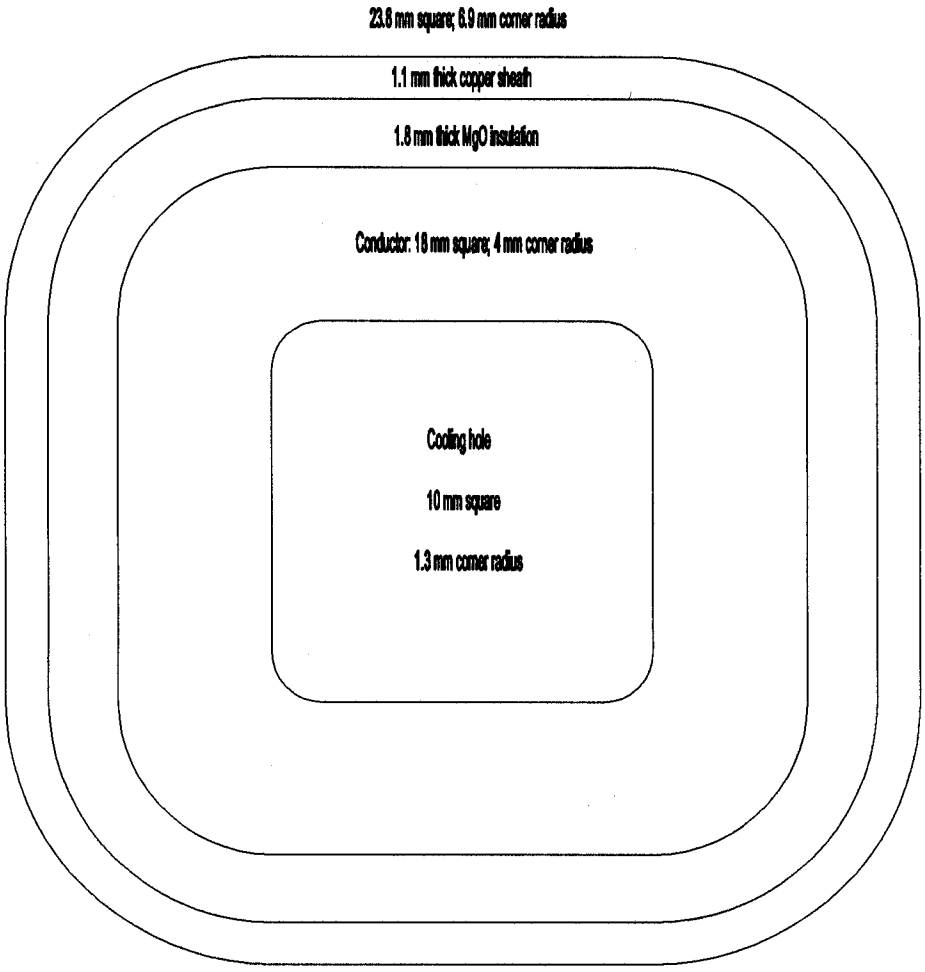
Desired and Actual Field Profile that Falls from 20 T to 1.25 T over 18 meters



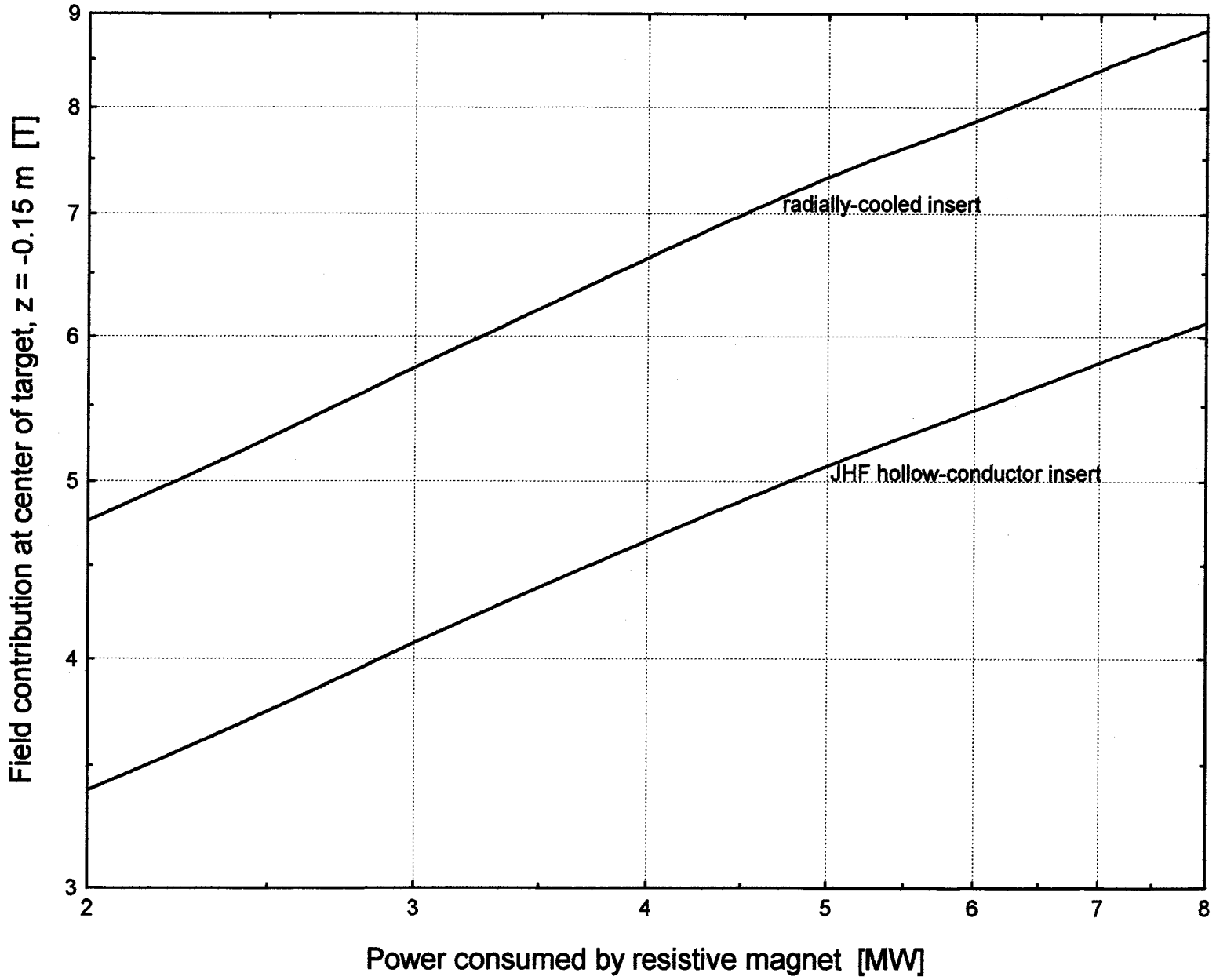

% Error in On-axis Field in Magnet System Band_JHF of 12/11/00
ΔB/B0 [%]
8
6
4
2
0
-2
-4
-6
-8
0
2
4
6
8
10
12
14
16
18
Meters from downstream end of target

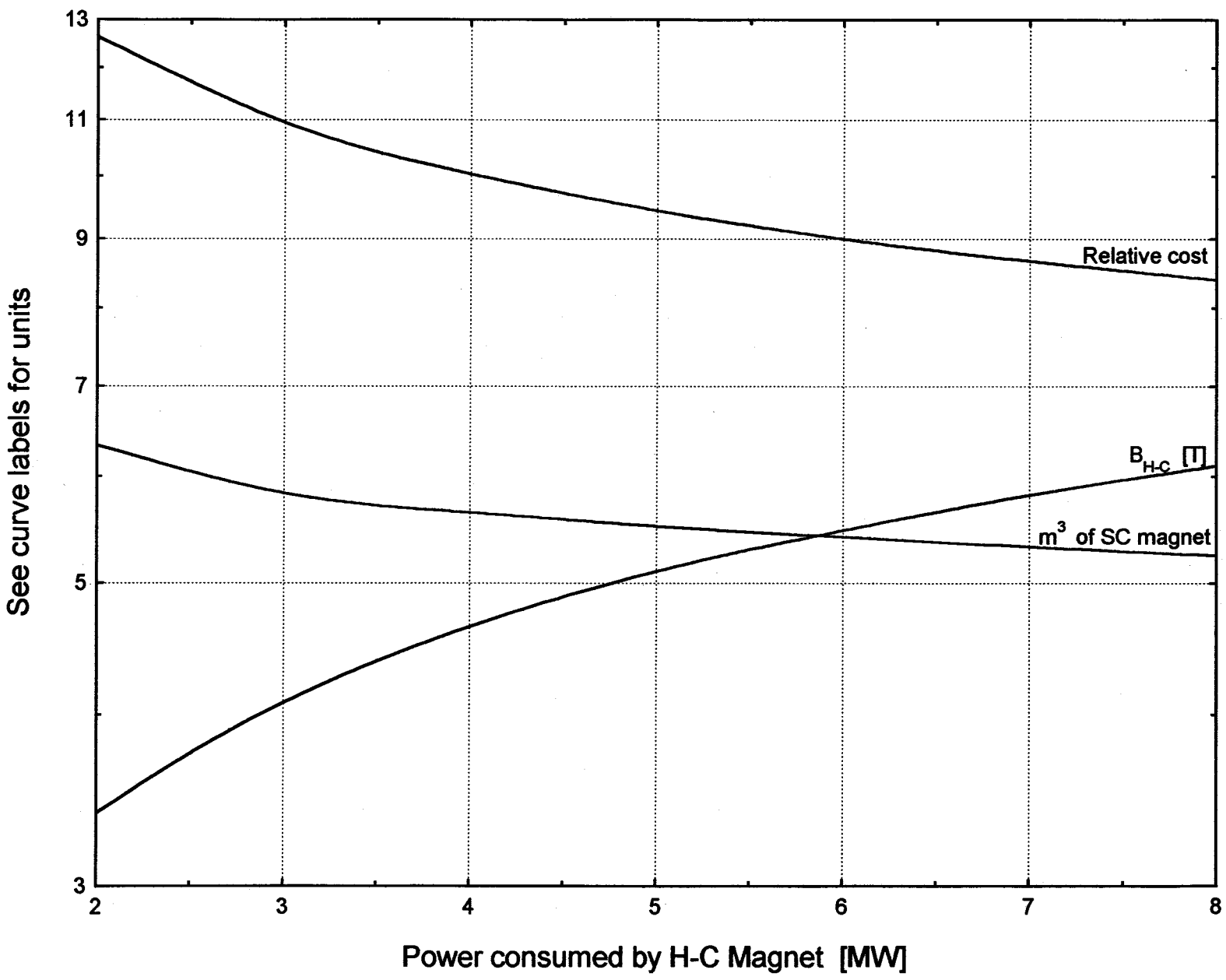

Smooth Approximation to Desired On-Axis Field Profile 20 / (1 + 5 z/6)
B(z) = 20/[1+(5/12)z(1+tanh 5z)]
19.5e^-(3z+1)^2 + 20[1-e^-(3z+1)^2]/(1+5z/6)
B(z) = 20/[1+(5/6)z]
On-Axis Field [T]
21
20
19
18
17
16
15
-0.6
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
Distance from downstream end of target [m]

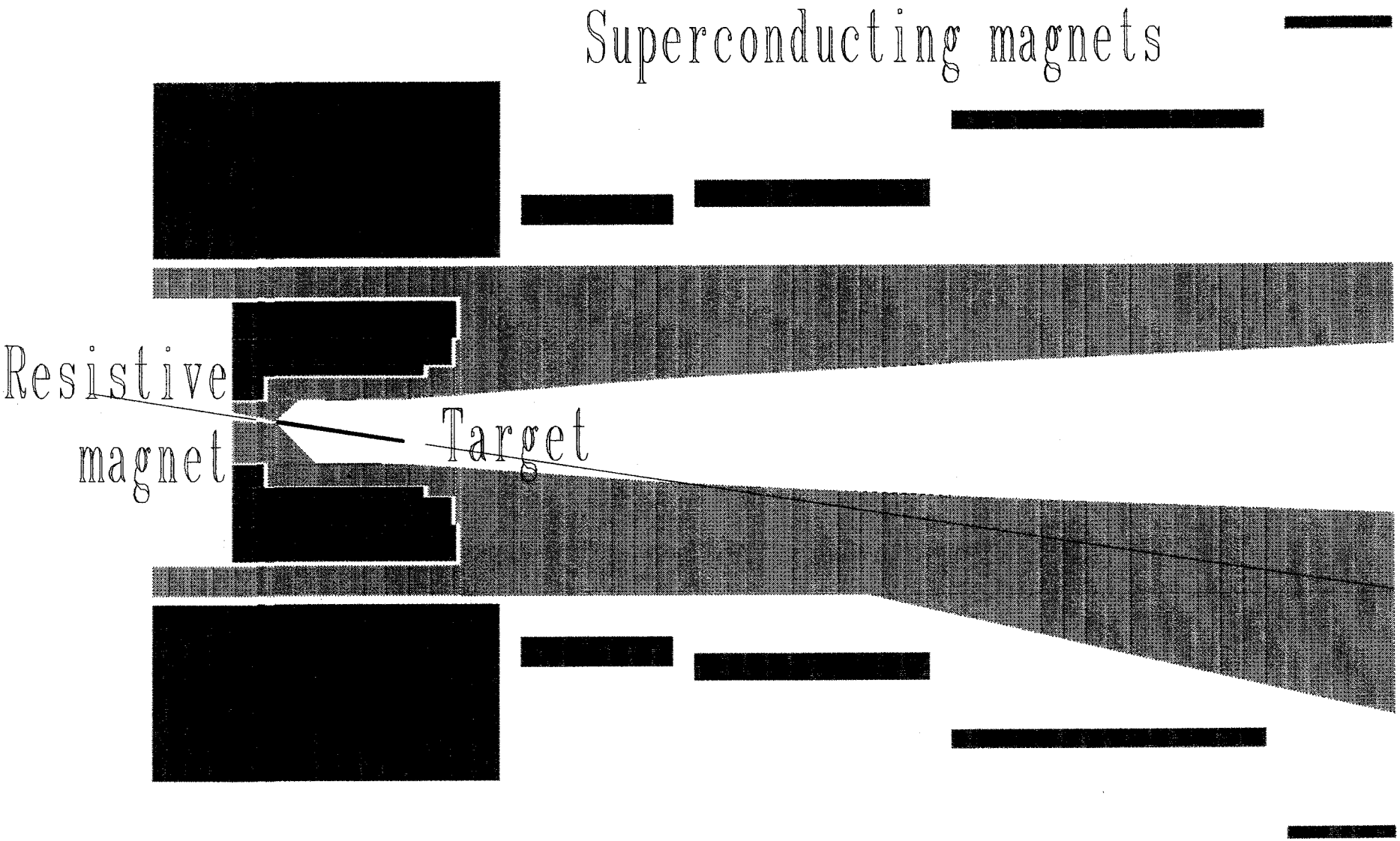
Japan Hadron Facility Hollow Conductor Insulated with MgO



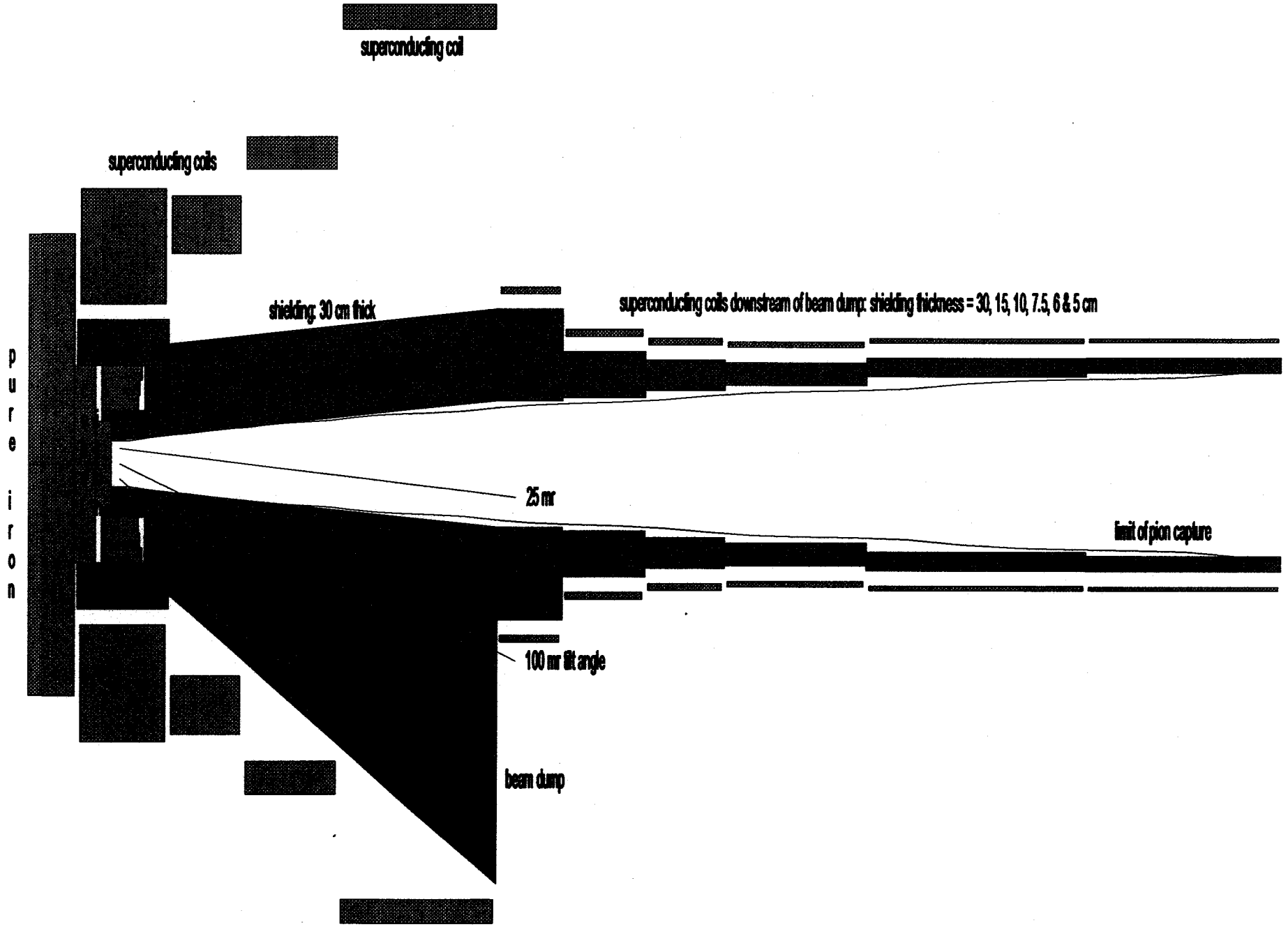
Hybrid Magnets for B(z)=20/(1+5z/6): 1) Radially Cooled; 2) with JHF Hollow Cond.




Hybrid Magnet using JHF MgO-insulated Hollow Conductor: B(z)=20/(1+5z/6)
See curve labels for units
13
11
9
7
5
3
2
3
4
5
6
7
8
Relative cost
B H-C [T]
m3 of SC magnet
Power consumed by H-C Magnet [MW]


Superconducting magnets
Resistive
magnet
Target

Hybrid Magnet using Japan Hadron Facility MgO-insulated Hollow Conductor
z axis foreshortened by factor of 5; on-axis field profile: B(z) = 20 / (1 + 5z/6)



JHF30cm`

S.C. + H.C. + Permendur + Iron: ~20 T from -0.30 to 0 m; B(z>0) ~ 20 /(1+5z/6)

12/14/2000

System parameters:	20.0 teslas flat top			30.0 cm long target			1.724 μΩcm Cu at 20 C			7.0 nΩcm/deg			120 MPa Cu stress			500 MPa Sst stress		
Hydraulic parameters:	30.0 atmospheres ΔP			20.0 m/sec maximum			3 paths in parallel			10.0 °C inlet temperature			60.0 °C max. bulk ΔT			90.0 °C maximum temp.		
Hollow-conductor coils:	10.0 cm shielding			8.00 megawatts			1 paths in parallel			0.17 fract. corner radius			0.11 cm thick sheath			0.18 cm insulation		
Superconducting coils:	30.0 cm typical shielding			100.0 kA/cm² at zero field			20.0 teslas H_{c2}			1.70 nΩ cm base resist.			0.40 nΩcm/T magnetor.			1.00 cm³/W d/w_e		
Coil designation	Units	System	Iron	HC	HC #1	HC #2	HC #3	SC	SC #1	SC #2	SC #3	SC #4	SC #5	SC #6	SC #7	SC #8	SC #9	SC #10
Avg. cur. dens., jλ	kA/cm²		2.40	2.52	**3.42**	**2.48**	**1.98**	3.52	**2.79**	**2.61**	**3.74**	**4.00**	**7.55**	**8.15**	**8.71**	**9.00**	**9.19**	**9.49**
Upstream end	cm	-179.4	**-179.4**	-40.7	**-40.7**	-40.7	-40.7	-70.2	**-70.2**	**61.4**	**197.7**	**341.0**	**599.5**	**696.3**	**837.6**	**1035.9**	**1210.6**	**1563.5**
Downstream end	cm	1859	-80.2	13.96	**-5.0**	**18.9**	**22.9**	1859	51.4	187.7	331.0	589.5	686.3	827.6	1025.9	1200.6	1553.5	**1859.2**
Inner radius	cm	17.50	39.81	17.50	17.50	23.43	28.94	38.32	**56.89**	**69.78**	**85.83**	**94.97**	**54.73**	**51.55**	**38.32**	**48.03**	**39.77**	**39.52**
Min. i.r. or max. o.r.	cm		**17.52**	17.52	*17.52*	*18.01*	*18.11*	38.32	*57.37*	*70.27*	*84.60*	*95.45*	*54.73*	*41.85*	*38.80*	*38.32*	*40.24*	*40.00*
Outer radius	cm	126.0	**92.68**	39.81	23.43	28.94	39.81	126.0	126.03	94.16	100.03	102.66	57.51	54.30	40.29	49.92	41.14	40.65
Dimen. constraints		1.17	0.00	0.22	0.22	0.00	0.00	0.94	0.94	0.94	0.00	0.94	0.93	0.94	0.94	0.94	0.90	0.94
Coil volume [m³]	*19.24*	9.76	2.676	0.230	0.027	0.054	0.149	9.31	4.833	1.585	1.106	1.187	0.085	0.120	0.092	0.096	0.120	0.085
Layers of H.C.; cm of S.C.	--		0.225	8.00	2.00	2.00	4.00	42.85	**69.15**	**24.38**	**14.21**	**7.69**	**2.78**	**2.75**	**1.97**	**1.90**	**1.37**	**1.14**
Est. sst thickness	mm				**5.827**	**3.793**	**3.362**					cm	B_{HC+Fe}	B_{SC}	B_{total}	max. %	7.78	
Radial build of copper	cm			2.38	2.38	2.38	2.38					-90	0.32	7.96	8.28	rms %	1.49	
Axial width	cm			2.38	2.38	2.38	2.38				error B	-60	1.20	11.48	12.68	target	0.01	
Turns per layer	--			23.4	15.0	25.0	26.7				1.49	-45	2.55	13.03	15.58	ΔB/B	ΔB/B	
Conductor length	m			352	38.5	82.4	230.6				B_{wanted}	-36	3.62	13.78	17.40	mT	%	r_{beam}
Loops per layer	--				3.0	3.0	3.0				20.00	-30	5.75	14.19	19.94	-56	-0.28	7.51
Passage length	m			14.15	6.42	13.73	19.22				20.00	-27	5.77	14.37	20.15	147	0.74	7.47
Cooling hole X-sect.	cm²			0.986	0.986	0.986	0.986				20.00	-22.5	5.71	14.61	20.32	322	1.61	7.44
Effective hole diam.	cm			1.12	1.12	1.12	1.12				20.00	-15	5.43	14.91	20.34	344	1.72	7.44
Frict. fact.: ε (mils) =	1.0			0.024	0.024	0.024	0.024				20.00	-7.5	4.93	15.11	20.04	41	0.21	7.49
Water velocity	m/s			14.9	20.3	14.1	12.0				20.00	-3	4.56	15.17	19.73	-275	-1.37	7.55
Water flow	lit/sec			34.6	12.00	8.36	14.20				20.00	0	4.29	15.19	19.48	-522	-2.61	7.60
Corner radius	cm			0.40	0.40	0.40	0.40				19.42	3.6	3.97	15.19	19.16	-261	-1.34	7.66
Conductor spacing	cm			0.58	0.58	0.58	0.58				18.60	9	3.49	15.14	18.63	30	0.16	7.77
Conductor X-section	cm²				2.117	2.117	2.117				17.39	18	2.70	14.96	17.66	269	1.55	7.98
Copper X-section	cm²				3.116	3.116	3.116				16.33	27	1.97	14.64	16.61	280	1.71	8.23
Kg of copper: g/cm³ =	8.96			981	108	230	644				15.38	36	1.38	14.21	15.59	204	1.33	8.50
Current	kA			16.91	24.10	16.26	12.79				13.79	54	0.68	13.15	13.84	43	0.31	9.02
Peak cur. dens.	kA/cm²			7.99	11.38	7.68	6.04				12.50	72	0.38	12.05	12.43	-71	-0.57	9.51
Est. avg. temp.	deg C			59.4	**68.8**	**50.6**	**53.3**				11.43	90	0.24	11.09	11.33	-102	-0.89	9.97
Avg. resistivity	μΩ cm			2.070	2.136	2.071	2.027				10.53	108	0.16	10.31	10.47	-57	-0.55	10.37
Magnet resistance	mΩ			34.0	3.89	8.06	22.1				9.41	135	0.10	9.35	9.45	42	0.44	10.91
Magnet voltage	V				93.7	131.1	282.4				8.51	162	0.07	8.49	8.56	48	0.56	11.47
Magnet power	MW			**8.091**	2.26	2.13	3.61				7.77	189	0.05	7.66	7.71	-56	-0.72	12.08
Max. bulk ΔT	°C			55.6	45.2	61.2	61.0				7.14	216	0.04	7.00	7.03	-109	-1.53	12.65
Heat flux density	W/cm²			87	166	74	44				6.45	252	0.03	6.43	6.46	7	0.11	13.20
Heat transfer coef.	W/cm²C			4.74	5.79	4.69	4.11				5.88	288	0.02	5.96	5.98	99	1.69	13.71
Boundary layer ΔT	°C			17.2	28.7	15.7	10.8				5.41	324	0.01	5.41	5.42	15	0.28	14.41
Power density	W/cm³			144	277	122	74				5.00	360	0.01	4.89	4.90	-97	-1.94	15.15
Δr to hot spot	cm			0.53	0.53	0.53	0.53				4.65	396	0.01	4.56	4.57	-78	-1.67	15.68

JHF30cm`

S.C. + H.C. + Permendur + Iron: ~20 T from -0.30 to 0 m; B(z>0) ~ 20 /(1+5z/6)

12/14/2000

Fraction of circle	--			0.27	0.27	0.27	0.27				4.35	432	0.01	4.36	4.36	15	0.34	16.06
Conduc. eff. i.r.	cm			2.04	2.04	2.04	2.04				3.96	486	0.01	4.06	4.06	100	2.54	16.64
Conduc. eff. o.r.	cm			2.57	2.57	2.57	2.57				3.64	540	0.00	3.61	3.62	-18	-0.48	17.63
ΔT_e °C: W/cm^3 °C =	3.90			5.7	10.9	4.8	2.9				3.36	594	0.00	3.30	3.30	-60	-1.79	18.46
Total hot spot ΔT	°C			78.4	84.8	81.7	74.8				3.13	648	0.00	3.15	3.15	27	0.85	18.89
True avg. total T	°C			58.7	**68.8**	**59.6**	**53.4**				2.86	720	0.00	2.88	2.88	25	0.88	19.76
ΔT constraints	°C			0.43	0.33	0.06	0.04				2.63	792	0.00	2.62	2.62	-11	-0.42	20.72
Field at o.r., z_1	T				16.94	16.15	13.41				2.44	864	0.00	2.40	2.40	-38	-1.54	21.64
Field at o.r., $(z_1+z_2)/2$	T				18.64	17.52	15.08				2.27	936	0.00	2.30	2.30	31	1.36	22.10
Field at o.r., z_2	T				18.77	16.53	14.80				2.13	1008	0.00	2.13	2.13	1	0.03	22.99
Slope of o.r. field					0.92	0.19	0.70				2.00	1080	0.00	2.00	2.01	5	0.25	23.69
Curvature of o.r.field					-0.78	-1.18	-0.98				1.86	1170	0.00	1.88	1.88	19	1.00	24.47
ζ of peak o.r. field	--				0.58	0.08	0.36				1.74	1260	0.00	1.67	1.67	-73	-4.22	25.99
Peak field at o.r.	T				18.91	17.53	15.20		0.00		1.63	1350	0.00	1.62	1.62	-14	-0.88	26.37
Field at i.r., z_1	T				18.04	16.94	14.59		10.30		1.54	1440	0.00	1.59	1.59	55	3.56	26.57
Field at i.r., $(z_1+z_2)/2$	T				20.31	18.81	16.91		15.07		1.45	1530	0.00	1.45	1.45	-9	-0.60	27.90
Field at i.r., z_2	T				19.87	17.32	15.99		13.31		1.38	1620	0.00	1.35	1.35	-31	-2.28	28.89
Slope of i.r. field					0.92	0.19	0.70		1.51		1.31	1710	0.00	1.34	1.34	31	2.33	28.95
Curvature of i.r.field					-1.35	-1.69	-1.62		-3.27		1.25	1800	0.00	1.25	1.25	-3	-0.25	30.04
ζ of peak i.r. field	--				0.34	0.06	0.21		0.23									
Peak field at i.r.	T				20.47	18.82	16.99		15.24	12.69	7.42	5.14	3.30	2.87	2.35	1.93	1.66	1.29
Tension or coil stress				kN	106.7	82.5	77.4	MPa	242	249	238	225	136	120	79	83	61	48
Copper hoop stress	MPa			120.0	120.0	120.0	120.0	frac. SC	0.117	0.077	0.059	0.062	0.090	0.095	0.099	0.100	0.100	0.101
Sst thickness	mm			4.172	**5.827**	**3.793**	**3.362**	frac. Cu	0.152	0.134	0.163	0.199	0.431	0.473	0.501	0.500	0.500	0.499
Dimens. constraints				0.00	0.00	0.00	0.00	frac. Sst	0.331	0.389	0.378	0.340	0.079	0.032	0.000	0.000	0.000	0.000
Structural fraction								0.001	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600
Vol. of supercond.	m^3	0.887						0.867	0.568	0.122	0.066	0.073	0.008	0.011	0.009	0.010	0.012	0.009
Mass of copper	t	15.80		0.981	0.108	0.230	0.644	14.82	6.59	1.90	1.61	2.11	0.33	0.51	0.41	0.43	0.54	0.38
tonnes of reinforcement.	7.8	24.00		0.244	0.042	0.058	0.144	23.76	12.46	4.81	3.26	3.14	0.05	0.03	0.00	0.00	0.00	0.00
	cm	B_{total}	B_{iron}	B_{HC}	B_{HC1}	B_{HC2}	B_{HC3}	B_{SC}	B_{SC1}	B_{SC2}	B_{SC3}	B_{SC4}	B_{SC5}	B_{SC6}	B_{SC7}	B_{SC8}	B_{SC9}	B_{SC10}
	-90	8.28		0.32	0.06	0.08	0.18	7.96	7.50	0.34	0.08	0.03	0.00	0.00	0.00	0.00	0.00	0.00
	-60	12.68		1.20	0.32	0.30	0.58	11.48	10.81	0.52	0.11	0.04	0.00	0.00	0.00	0.00	0.00	0.00
	-45	15.58		2.55	0.87	0.65	1.03	13.03	12.21	0.65	0.12	0.04	0.00	0.00	0.00	0.00	0.00	0.00

JHF45cm

S.C. + H.C. + Permendur + Iron: ~20 T from -0.30 to 0 m; B(z>0) ~ 20 /(1+5z/6)

12/15/2000

System parameters:	20.0 teslas flat top			45.0 cm long target			1.724 μΩcm Cu at 20 C			7.0 nΩcm/deg			120 MPa Cu stress			500 MPa Sst stress		
Hydraulic parameters:	30.0 atmospheres ΔP			20.0 m/sec maximum			3 paths in parallel			10.0 °C inlet temperature			60.0 °C max. bulk ΔT			90.0 °C maximum temp.		
Hollow-conductor coils:	10.0 cm shielding			8.00 megawatts			1 paths in parallel			0.17 fract. corner radius			0.11 cm thick sheath			0.18 cm insulation		
Superconducting coils:	30.0 cm typical shielding			100.0 kA/cm² at zero field			20.0 teslas H_{c2}			1.70 nΩ cm base resist.			0.40 nΩcm/T magnetor.			1.00 cm³/W d/w_s		
Coil designation	Units	System	Iron	HC	HC #1	HC #2	HC #3	SC	SC #1	SC #2	SC #3	SC #4	SC #5	SC #6	SC #7	SC #8	SC #9	SC #10
Avg. cur. dens., jλ	kA/cm²		2.40	2.40	**3.26**	**2.20**	**1.86**	3.45	**2.75**	**2.81**	**3.08**	**4.61**	**7.34**	**8.26**	**8.70**	**9.00**	**9.20**	**9.49**
Upstream end	cm	-183.1	**-183.1**	-51.0	**-51.0**	-51.0	-51.0	-89.7	**-89.7**	**63.0**	**194.5**	**347.1**	**599.7**	**716.7**	**932.0**	**1039.3**	**1267.0**	**1562.4**
Downstream end	cm	1860	-99.7	12.54	**-5.9**	**18.3**	**21.8**	1860	53.0	184.5	337.1	589.7	700.7	822.0	1029.3	1197.0	1552.4	**1860.0**
Inner radius	cm	17.50	39.38	17.50	17.50	23.30	28.68	38.46	**56.70**	**70.31**	**86.90**	**95.83**	**50.96**	**49.52**	**38.46**	**46.13**	**39.82**	**39.61**
Min. i.r. or max. o.r.	cm		**6.50**	17.51	*17.51*	*18.04*	*18.11*	38.31	*57.09*	*70.70*	*85.96*	*96.22*	*54.93*	*41.70*	*38.85*	*38.31*	*40.21*	*40.00*
Outer radius	cm	122.0	**92.78**	39.38	23.30	28.68	39.38	122.0	122.01	95.63	101.11	103.43	62.93	52.24	40.44	48.02	41.20	40.75
Dimen. constraints		0.65	0.00	0.04	0.04	0.00	0.00	0.61	0.60	0.61	0.00	0.61	0.61	0.61	0.61	0.61	0.61	0.60
Coil volume [m³]	*20.00*	10.26	2.256	0.262	0.033	0.062	0.167	9.79	5.233	1.603	1.196	1.154	0.116	0.097	0.097	0.088	0.121	0.085
Layers of H.C.; cm of S.C.	--		0.203	8.00	2.00	2.00	4.00	41.81	**65.31**	**25.31**	**14.21**	**7.00**	**2.98**	**2.72**	**1.98**	**1.80**	**1.38**	**1.14**
Est. sst thickness	mm				**5.177**	**3.121**	**2.957**					cm	B_{HC+Fe}	B_{SC}	B_{total}	max. %	8.56	
Radial build of copper	cm			2.38	2.38	2.38	2.38					-100	0.31	8.79	9.10	rms %	1.53	
Axial width	cm			2.38	2.38	2.38	2.38				error B	-75	0.91	11.72	12.62	target	-0.02	
Turns per layer	--			27.4	18.9	29.5	30.6				1.53	-60	1.94	13.21	15.15	ΔB/B	ΔB/B	
Conductor length	m			406	48.5	96.4	261.5				$B_{standard}$	-51	2.94	13.95	16.88	mT	%	r_{beam}
Loops per layer	--				3.0	3.0	3.0				20.00	-45	5.49	14.36	19.85	-153	-0.76	7.53
Passage length	m			16.09	8.08	16.06	21.79				20.00	-41	5.20	14.63	19.83	-170	-0.85	7.53
Cooling hole X-sect.	cm²			0.986	0.986	0.986	0.986				20.00	-33.8	5.21	14.96	20.18	176	0.88	7.47
Effective hole diam.	cm			1.12	1.12	1.12	1.12				20.00	-23	5.22	15.35	20.58	575	2.88	7.39
Frict. fact.: ε (mils) =	1.0			0.024	0.024	0.024	0.024				20.00	-11.3	4.77	15.54	20.31	308	1.54	7.44
Water velocity	m/s			13.9	18.2	13.1	11.3				20.00	-5	4.28	15.55	19.83	-171	-0.85	7.53
Water flow	lit/sec			31.9	10.77	7.75	13.35				20.00	0	3.91	15.52	19.43	-569	-2.85	7.61
Corner radius	cm			0.40	0.40	0.40	0.40				19.42	3.6	3.61	15.48	19.09	-330	-1.70	7.68
Conductor spacing	cm			0.58	0.58	0.58	0.58				18.60	9	3.17	15.37	18.54	-60	-0.32	7.79
Conductor X-section	cm²				2.117	2.117	2.117				17.39	18	2.45	15.11	17.56	164	0.94	8.01
Copper X-section	cm²				3.116	3.116	3.116				16.33	27	1.77	14.74	16.51	180	1.10	8.26
Kg of copper: g/cm³ =	8.96			1134	135	269	730				15.38	36	1.23	14.28	15.51	122	0.79	8.52
Current	kA			15.86	22.49	14.66	11.84				13.79	54	0.60	13.19	13.79	-1	-0.01	9.03
Peak cur. dens.	kA/cm²			7.49	10.63	6.92	5.59				12.50	72	0.34	12.08	12.41	-89	-0.71	9.52
Est. avg. temp.	deg C			59.4	**70.4**	**57.1**	**52.8**				11.43	90	0.21	11.12	11.33	-99	-0.86	9.96
Avg. resistivity	μΩ cm			2.069	2.147	2.054	2.024				10.53	108	0.14	10.35	10.49	-37	-0.35	10.36
Magnet resistance	mΩ			39.3	4.92	9.35	25.0				9.41	135	0.09	9.40	9.48	71	0.75	10.89
Magnet voltage	V				110.6	137.0	296.0				8.51	162	0.06	8.51	8.57	58	0.68	11.46
Magnet power	MW			**0.691**	2.49	2.01	3.50				7.77	189	0.04	7.66	7.70	-69	-0.89	12.09
Max. bulk ΔT	°C			60.2	55.4	62.2	63.0				7.14	216	0.03	6.98	7.01	-131	-1.83	12.67
Heat flux density	W/cm²			77	146	59	38				6.45	252	0.02	6.42	6.44	-13	-0.20	13.22
Heat transfer coef.	W/cm²C			4.58	5.59	4.43	3.95				5.88	288	0.02	5.97	5.98	99	1.68	13.71
Boundary layer ΔT	°C			15.7	26.1	13.4	9.6				5.41	324	0.01	5.43	5.45	41	0.75	14.37
Power density	W/cm³			128	242	98	63				5.00	360	0.01	4.91	4.92	-79	-1.58	15.12
Δr to hot spot	cm			0.53	0.53	0.53	0.53				4.65	396	0.01	4.56	4.57	-83	-1.79	15.69

JHF45cm

S.C. + H.C. + Permendur + Iron: ~20 T from -0.30 to 0 m; B(z>0) ~ 20 /(1+5z/6)

12/15/2000

Fraction of circle	--				0.27	0.27	0.27	0.27					4.35	432	0.01	4.34	4.35	-3	-0.06	16.09			
Conduc. eff. i.r.	cm				2.04	2.04	2.04	2.04					3.96	486	0.00	4.04	4.05	85	2.14	16.68			
Conduc. eff. o.r.	cm				2.57	2.57	2.57	2.57					3.64	540	0.00	3.62	3.63	-8	-0.22	17.61			
ΔT_e °C: W/cm^3 °C =	3.90				5.0	9.5	3.9	2.5					3.36	594	0.00	3.31	3.31	-47	-1.40	18.42			
Total hot spot ΔT	°C				81.0	91.0	79.4	75.1					3.13	648	0.00	3.14	3.15	21	0.66	18.91			
True avg. total T	°C				59.2	***70.4***	***57.1***	***52.9***					2.86	720	0.00	2.86	2.86	5	0.17	19.83			
ΔT constraints	°C				0.60	0.04	0.20	0.36					2.63	792	0.00	2.63	2.63	3	0.11	20.67			
Field at o.r., z_1	T					17.69	16.96	13.95					2.44	864	0.00	2.40	2.40	-38	-1.57	21.65			
Field at o.r., $(z_1+z_2)/2$	T					18.67	17.71	15.50					2.27	936	0.00	2.30	2.30	26	1.14	22.12			
Field at o.r., z_2	T					18.86	16.47	14.97					2.13	1008	0.00	2.14	2.14	9	0.40	22.95			
Slope of o.r. field						0.59	-0.25	0.51					2.00	1080	0.00	2.01	2.01	8	0.41	23.67			
Curvature of o.r.field						-0.40	-1.00	-1.05					1.86	1170	0.00	1.87	1.87	10	0.56	24.52			
ζ of peak o.r. field	--					0.74	-0.12	0.24					1.74	1260	0.00	1.66	1.66	-81	-4.66	26.05			
Peak field at o.r.	T					18.89	17.73	15.57		0.00			1.63	1350	0.00	1.62	1.62	-11	-0.69	26.34			
Field at i.r., z_1	T					18.77	17.69	15.08		10.02			1.54	1440	0.00	1.60	1.60	60	3.90	26.53			
Field at i.r., $(z_1+z_2)/2$	T					20.43	18.96	17.33		15.45			1.45	1530	0.00	1.44	1.44	-10	-0.67	27.90			
Field at i.r., z_2	T					19.95	17.19	16.10		13.25			1.38	1620	0.00	1.35	1.35	-32	-2.32	28.90			
Slope of i.r. field						0.59	-0.25	0.51		1.62			1.31	1710	0.00	1.34	1.34	29	2.24	28.97			
Curvature of i.r.field						-1.08	-1.52	-1.74		-3.81			1.25	1800	0.00	1.25	1.25	-3	-0.20	30.03			
ζ of peak i.r. field	--					0.27	-0.08	0.15		0.21													
Peak field at i.r.	T					20.52	18.97	17.37		15.62	12.62	7.50	5.08	3.30	2.84	2.37	1.93	1.66	1.29				
Tension or coil stress					kN	99.0	74.5	72.6	MPa	243	249	240	225	145	116	79	80	61	48				
Copper hoop stress	MPa				120.0	120.0	120.0	120.0	frac. SC	0.125	0.076	0.059	0.062	0.088	0.096	0.099	0.100	0.100	0.101				
Sst thickness	mm				3.688	***5.177***	***3.121***	***2.957***	frac. Cu	0.150	0.133	0.159	0.198	0.407	0.484	0.501	0.500	0.500	0.499				
Dimens. constraints					0.00	0.00	0.00	0.00	frac. Sst	0.325	0.391	0.382	0.340	0.105	0.020	0.000	0.000	0.000	0.000				
Structural fraction									0.001	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600				
Vol. of supercond.	m^3	0.978							0.978	0.656	0.122	0.070	0.071	0.010	0.009	0.010	0.009	0.012	0.009				
Mass of copper	t	16.43			1.134	0.135	0.269	0.730	15.29	7.03	1.91	1.70	2.05	0.42	0.42	0.44	0.40	0.54	0.38				
tonnes of reinforcement.	7.8	25.14			0.246	0.047	0.056	0.144	24.89	13.27	4.89	3.57	3.06	0.10	0.01	0.00	0.00	0.00	0.00				
	cm	B_{field}	B_{iron}		B_{HC}	B_{HC1}	B_{HC2}	B_{HC3}	B_{SC}	B_{SC1}	B_{SC2}	B_{SC3}	B_{SC4}	B_{SC5}	B_{SC6}	B_{SC7}	B_{SC8}	B_{SC9}	B_{SC10}				
	-100	9.10			0.31	0.06	0.07	0.18	8.79	8.37	0.31	0.08	0.03	0.00	0.00	0.00	0.00	0.00	0.00				
	-75	12.62			0.91	0.23	0.22	0.46	11.72	11.15	0.43	0.10	0.03	0.00	0.00	0.00	0.00	0.00	0.00				
	-60	15.15			1.94	0.63	0.48	0.83	13.21	12.53	0.53	0.12	0.04	0.00	0.00	0.00	0.00	0.00	0.00				
$\Delta B/B$	$B_{nominal}$	z/L [%]	-51	16.88		2.94	1.08	0.72	1.13	13.95	13.18	0.60	0.12	0.04	0.00	0.00	0.00	0.00	0.00	0.00			
-0.76	20.00	100	-45	19.85	1.88	3.61	1.39	0.89	1.33	14.36	13.53	0.66	0.13	0.04	0.00	0.00	0.00	0.00	0.00	0.00			
-0.85	20.00	90	-41	19.83	1.17	4.03	1.57	1.00	1.47	14.63	13.74	0.70	0.14	0.04	0.00	0.00	0.00	0.00	0.00	0.00			
0.88	20.00	75	-33.8	20.18	0.73	4.48	1.72	1.12	1.63	14.96	13.99	0.78	0.15	0.04	0.00	0.00	0.00	0.00	0.00	0.00			
2.88	20.00	50	-23	20.58	0.48	4.74	1.72	1.23	1.80	15.35	14.20	0.94	0.16	0.05	0.00	0.00	0.00	0.00	0.00	0.00			
1.54	20.00	25	-11.3	20.31	0.35	4.42	1.36	1.24	1.82	15.54	14.17	1.13	0.18	0.05	0.00	0.00	0.00	0.00	0.00	0.00			
-0.85	20.00	10	-5	19.83	0.30	3.98	1.00	1.20	1.77	15.55	14.03	1.26	0.20	0.05	0.00	0.00	0.00	0.00	0.00	0.00			
-2.85	20.00	0	0	19.43	0.27	3.64	0.77	1.15	1.72	15.52	13.89	1.37	0.21	0.05	0.00	0.00	0.00	0.00	0.00	0.00			
-1.70	19.42	0.2	3.6	19.09	0.25	3.36	0.61	1.10	1.65	15.46	13.75	1.45	0.21	0.06	0.00	0.00	0.00	0.00	0.00	0.00			
-0.32	18.60	0.5	9.0	18.54	0.23	2.95	0.42	0.99	1.53	15.37	13.49	1.59	0.23	0.06	0.00	0.00	0.00	0.00	0.00	0.00			
0.94	17.39	1.0	18	17.56	0.19	2.26	0.23	0.76	1.26	15.11	12.93	1.86	0.25	0.06	0.00	0.00	0.00	0.00	0.00	0.00			
1.10	16.33	1.5	27	16.51	0.16	1.61	0.14	0.51	0.96	14.74	12.23	2.16	0.28	0.07	0.00	0.00	0.00	0.00	0.00	0.00			