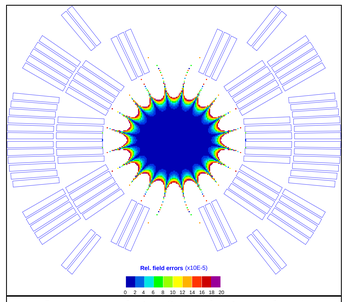
Nb_3Sn superconducting magnet design

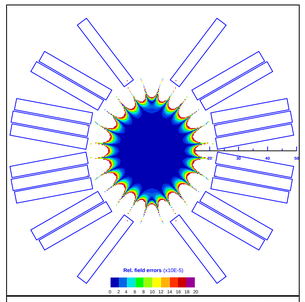
Dipole coil design



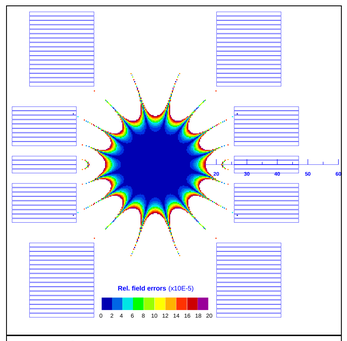
Low-current design (in production and test)

Geometrical and random (+/- 50 μm) harmonics

n	Shell				Block			
	Low current		High current		Low current		High current	
	b_n	$\sigma_{an,bn}$	b_n	$\sigma_{an,bn}$	b_n	$\sigma_{an,bn}$	b_n	$\sigma_{an,bn}$
1	10000	-	10000	-	10000	-	10000	-
2	-	1.20	-	1.02	-	1.04	-	1.07
3	0.000	0.56	-0.0001	0.47	-0.002	0.36	0.0005	0.49
4	-	0.28	-	0.22	-	0.14	-	0.19
5	0.000	0.10	0.0011	0.10	0.000	0.05	0.0003	0.08
6	-	0.05	-	0.04	-	0.02	-	0.03
7	-0.000	0.02	0.0019	0.02	0.014	0.01	0.0005	0.01
8	-	0.01	-	0.01	-	0.00	-	0.00
9	-0.091	0.00	-0.0035	0.00	-0.048	0.00	0.0008	0.00
10	-	0.00	-	0.00	-	0.00	-	0.00
11	0.099	0.00	-0.0219	0.00	0.001	0.00	-0.0013	0.00



High-current design (under consideration)

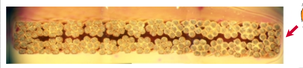


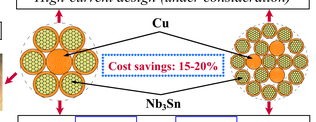
Low-current design (in production)

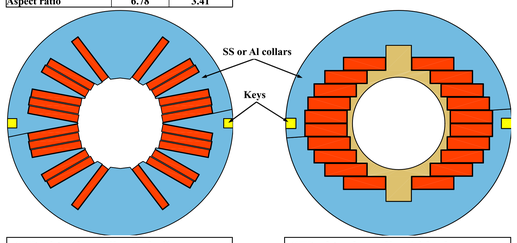
High current cable parameters

Parameter	Shell	Block
Strand diameter, mm	2.200	3.350
Number of strands	24	12
Cable width, mm	26.717	20.233
Cable thickness, mm	3.942	5.935
Aspect ratio	6.78	3.41

Multi-strand cable made at FNAL

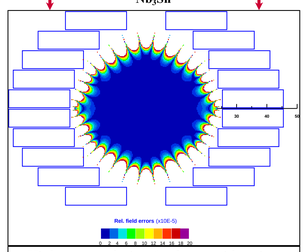






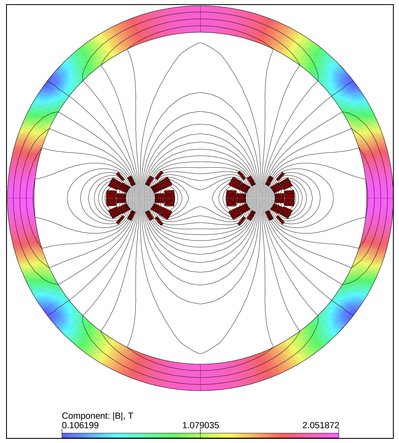
"Wind in the collar" shell structure

"Wind in the collar" block structure



High-current design (under consideration)

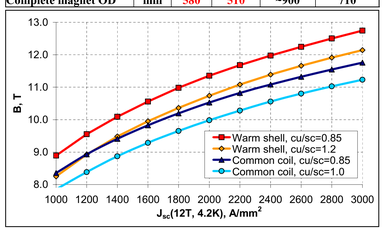
Dipole yoke design



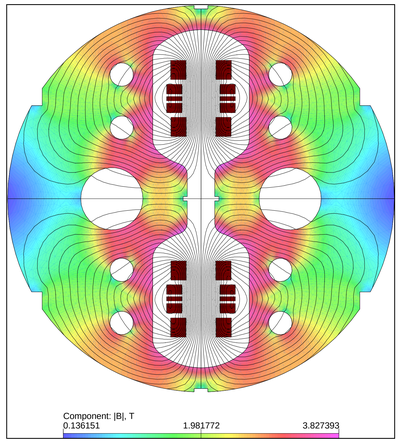
Shell type magnet with "warm" yoke

Magnet parameters

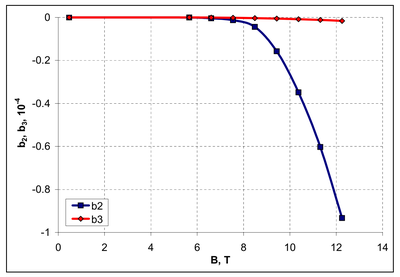
Parameter	Units	Shell		Common coil	
Magnet current option		low	high	low	high
Yoke type		warm	warm	cold	cold/warm
Aperture	mm	43.5	45.0	40.0 (51.6)	45.0
Bore separation	mm	180	120	290	256
Quench field$_{(@2400A/mm^2, Cu/Sc=1.2)}$	T	11.4	11.3	10.6	11.8
Quench current	kA	24.2	111.2	25.2	107.3
Transfer function at 11 T	T/kA	0.47	0.1025	0.42	0.1100
Inductance at 11 T	mH/m	2x1.07	2x0.049	2x1.47	2x0.054
Stored energy at 11 T	kJ/m	2x294	2x282	2x498	2x270
Conductor area	cm^2	2x21.6	2x21.8	2x26.8	2x21.8
"Cold" block OD	mm	380	320	580	480
Complete magnet OD	mm	580	510	~900	710



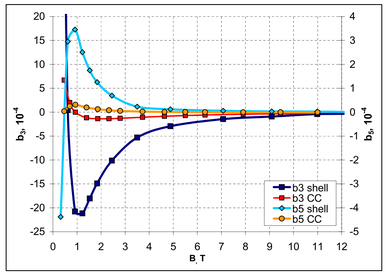
Magnet quench performance



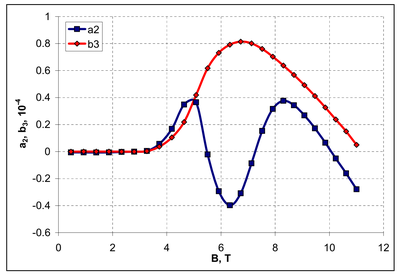
Common-coil magnet with "cold" yoke



Yoke saturation effect

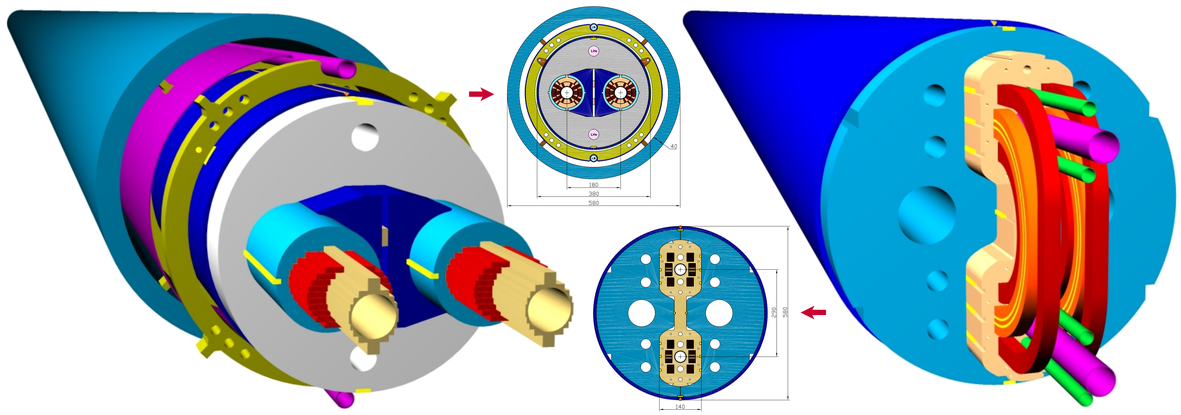


Persistent current effect

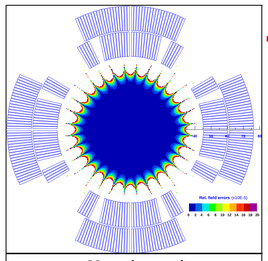


Yoke saturation effect

Dipole magnet mechanics



Quadrupole magnet for LHC IR upgrade

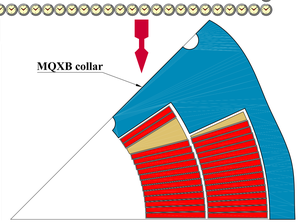


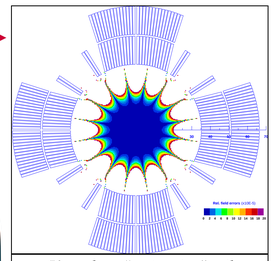
90 mm bore coil

In order to accelerate the short model R&D and save on materials and labor, using of existing MQXB collars is considered. Design based on the same cable as 90 mm coil.

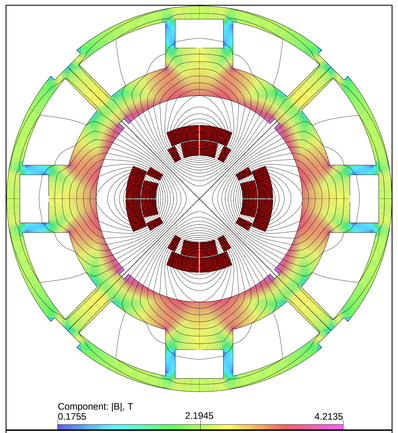
Geometrical and random (+/- 50 μm) harmonics

n	b_n		max(σ_{an},σ_{bn})	
	90 mm	MQXB	90 mm	MQXB
3	-	-	1.114	0.28
4	-	-	0.456	0.37
5	-	-	0.172	0.15
6	0.00018	-0.013	0.069	0.17
7	-	-	0.025	0.03
8	-	-	0.009	0.01
9	-	-	0.003	0.01
10	0.00048	-0.001	0.001	0.01

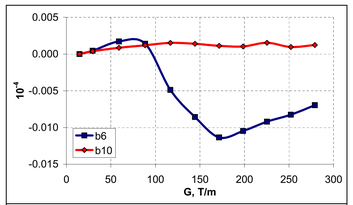




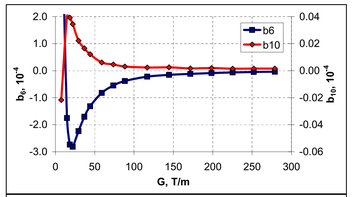
70 mm bore "cost-saving" coil



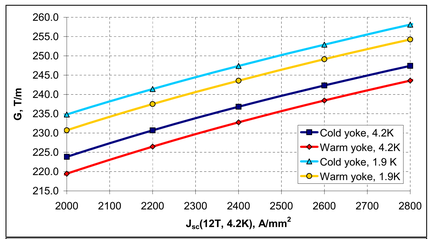
"Cold" yoke with cooling holes in 90 mm design



Yoke saturation effect in 90 mm design



Persistent current effect in 90 mm design

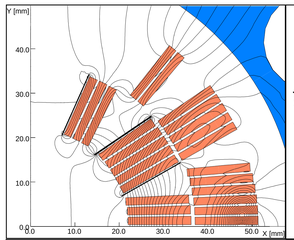


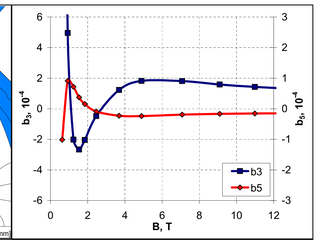
Magnet quench performance

Magnet parameters

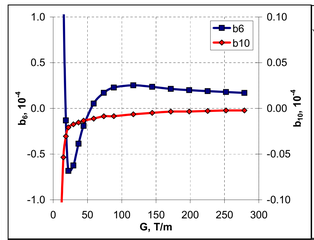
Parameter	90 mm "cold"	70 mm "cold"	MQXB
Aperture, mm	90	70	70
G max$_{(2400A/mm^2, (@4.2K))}$ @1.9K T/m	~245	~315	~245
G nom., T/m	205	265	205
I nom, kA	14.46	14.88	11.33
G/I nom., T/m/kA	14.18	17.80	18.09
L nom., mH/m	4.59	3.07	3.50
W nom., kJ/m	479.9	340.2	224.7
Yoke OR, mm	200	200	200

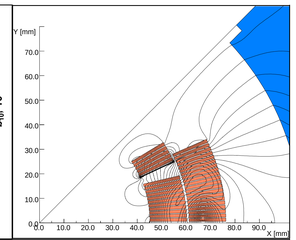
Correction of the persistent current effect





Correction in the shell type dipole magnet





Correction in the quadrupole magnet