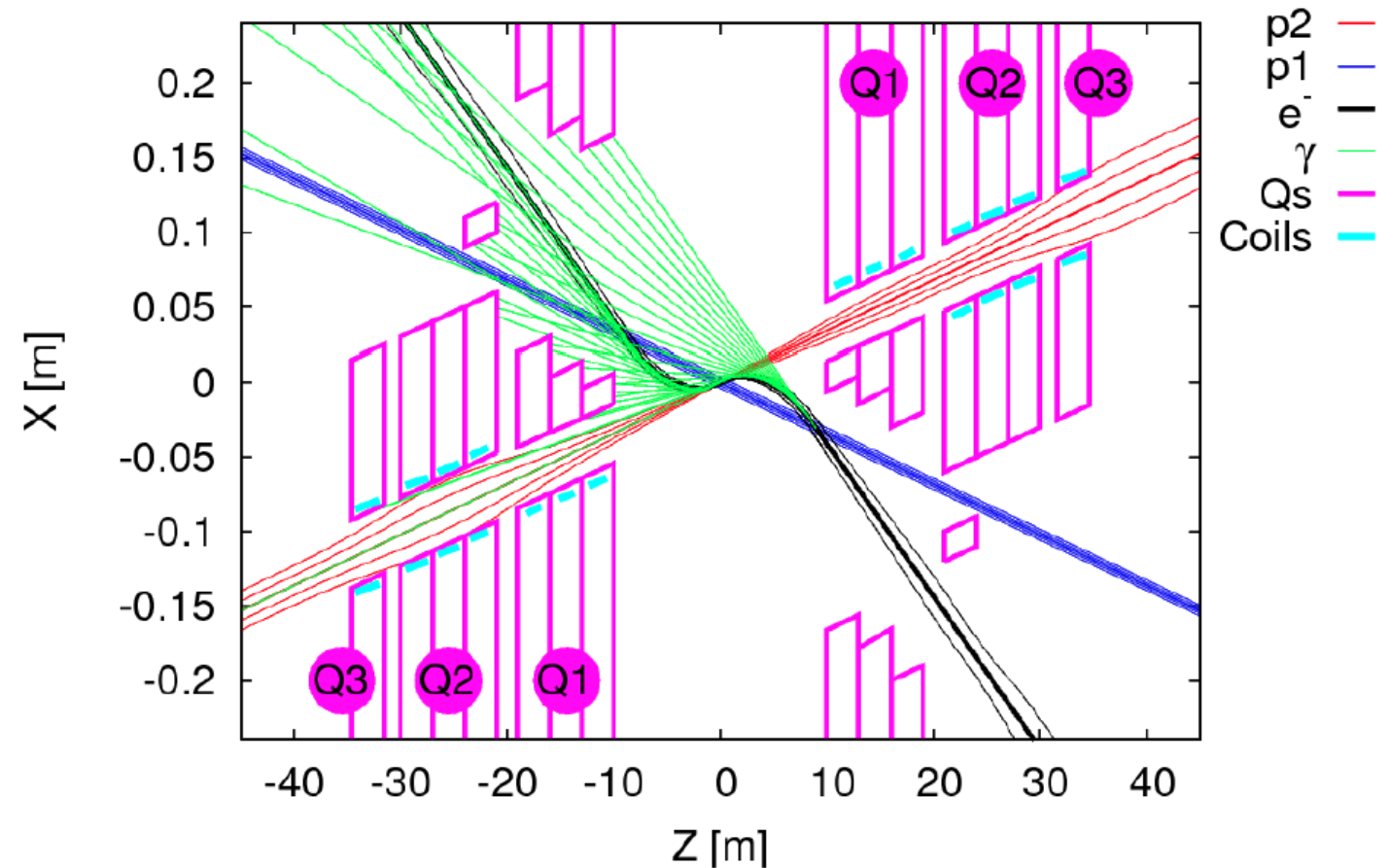
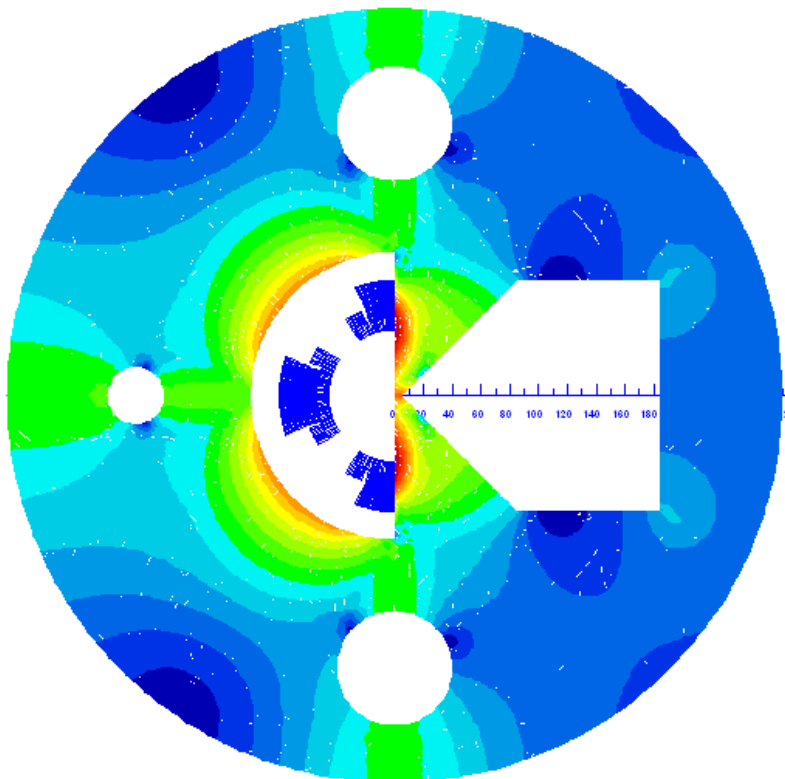


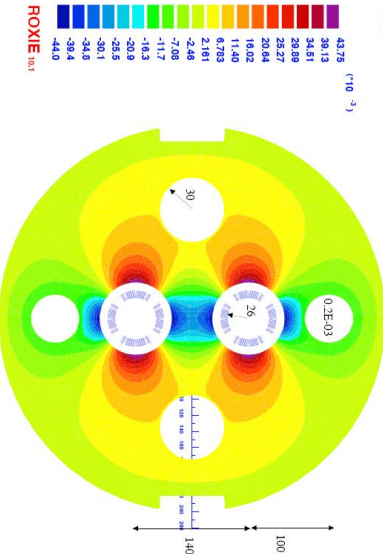
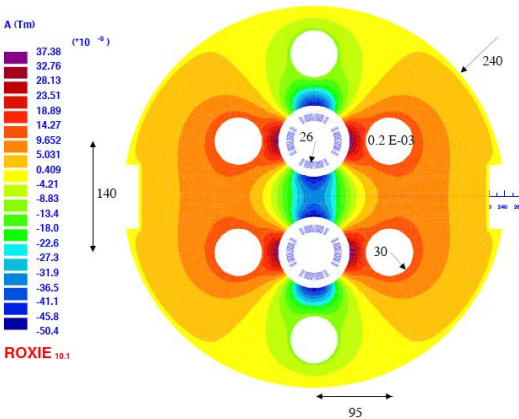
# Superconducting Linac-Ring IR Magnet Design and Prototyping Challenges

Stephan Russenschuck, CERN TE-MSC

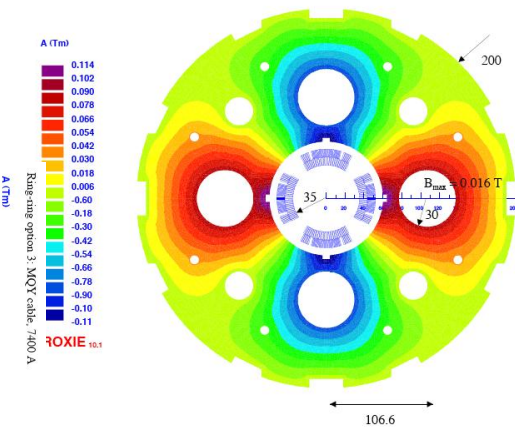


# Conceptual Design Options (for Ring-Ring) using Nb-Ti

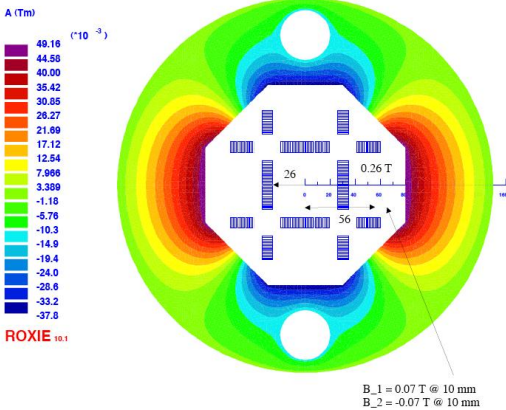
Ring-Ring option2, double aperture, MQY cable, 7400 A



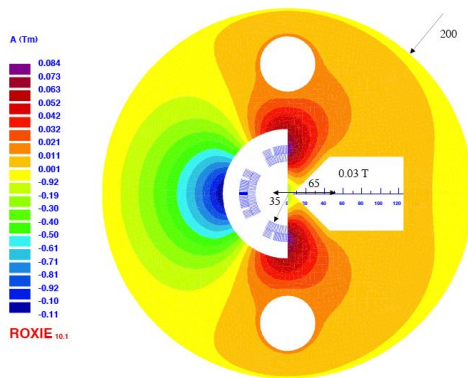
Ring-Ring option. Single aperture magnet for two proton beams, 127 T/m, 4600 A, MQY cable



Ring-ring option with racetrack coils, MQY non-keystoned cable, 5400 A



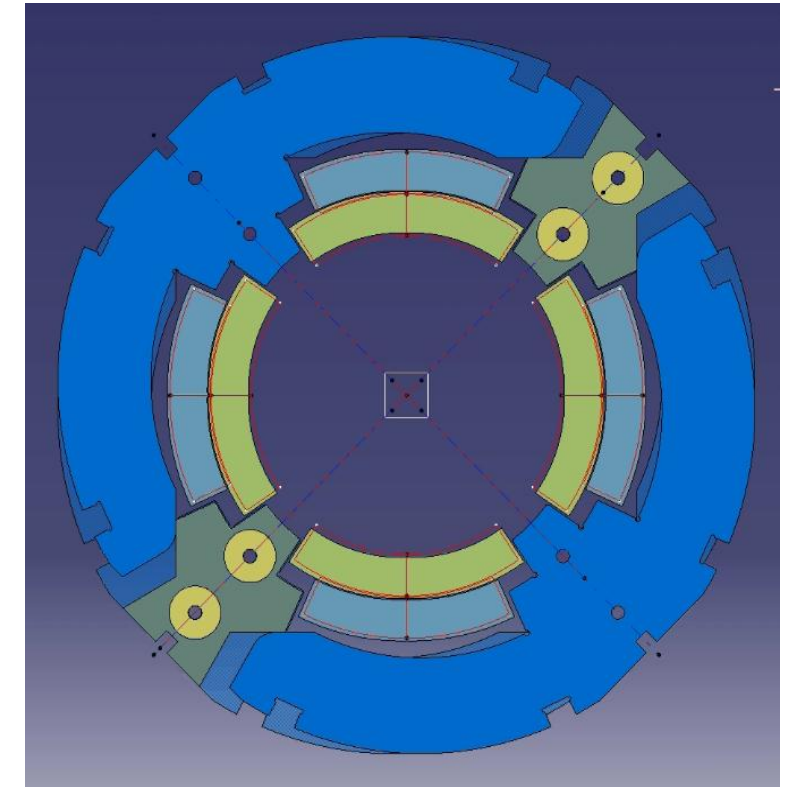
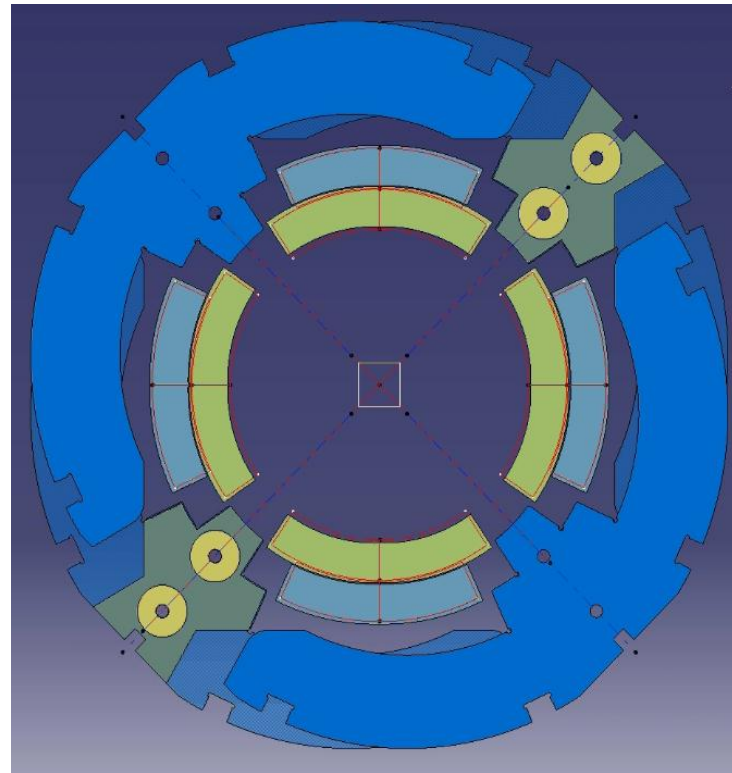
Ring-ring option half-quadrupole, 4900 A, Gradient 137 T/m, + 2.5 T dipole field from feeddown



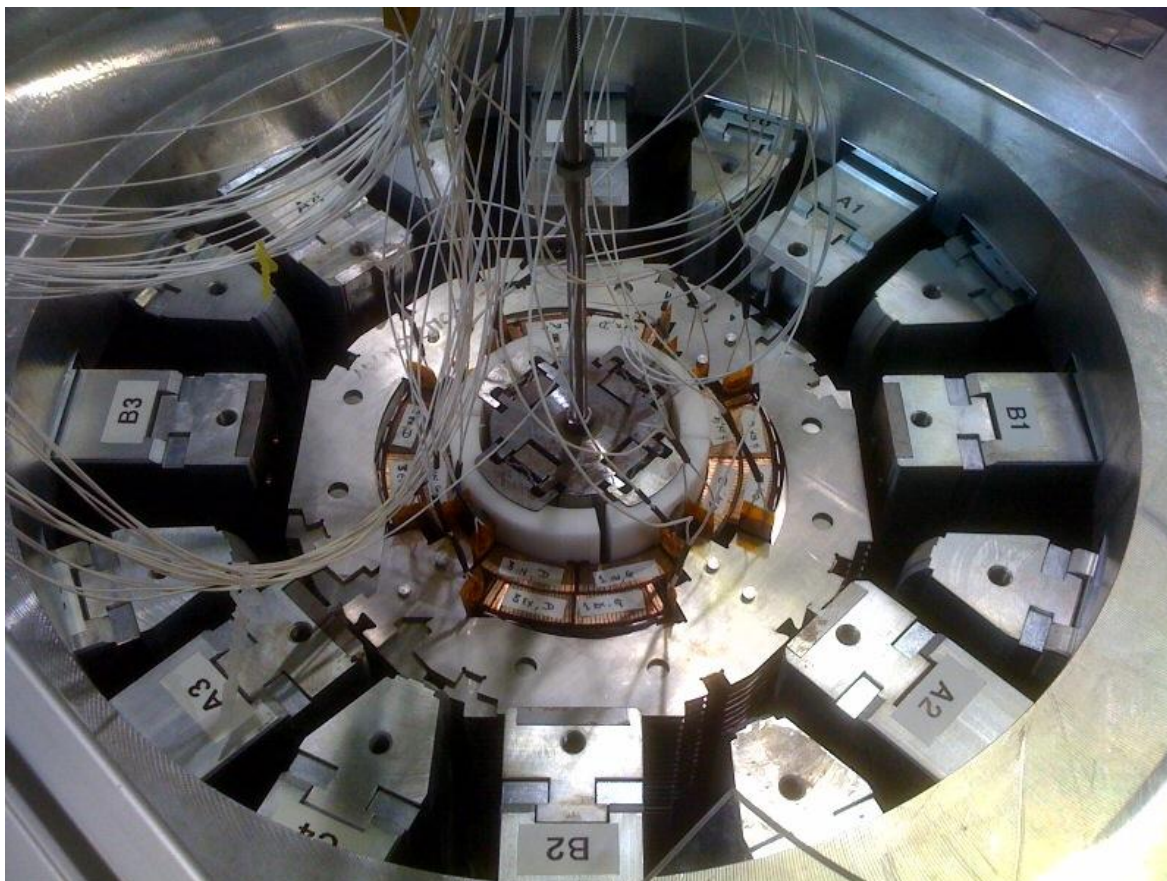
Double aperture (vertical)	Double aperture (horizontal)	Single aperture (for two beams)	Block coil	Mirror
7400 A MQY cable	7400 A MQY cable	4600 A MQY cables	4600 A MQY (non-keyst.)	4900 A MQY cables
95 mm	100 mm	107 mm	56 mm	65 mm
0.2 E -3 T	0.2 E -3 T	0.016 T	0.07 T + quad comp.	0.03 T

# Collaring Procedure (Free Standing) MQXC Quadrupole

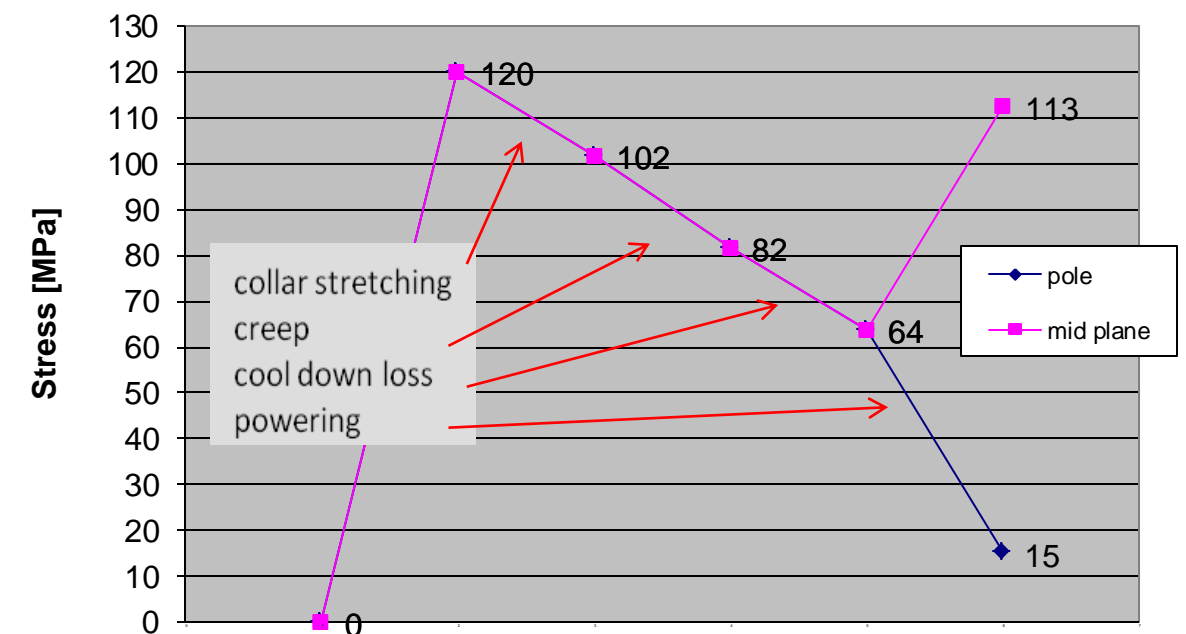
Self-locking collars



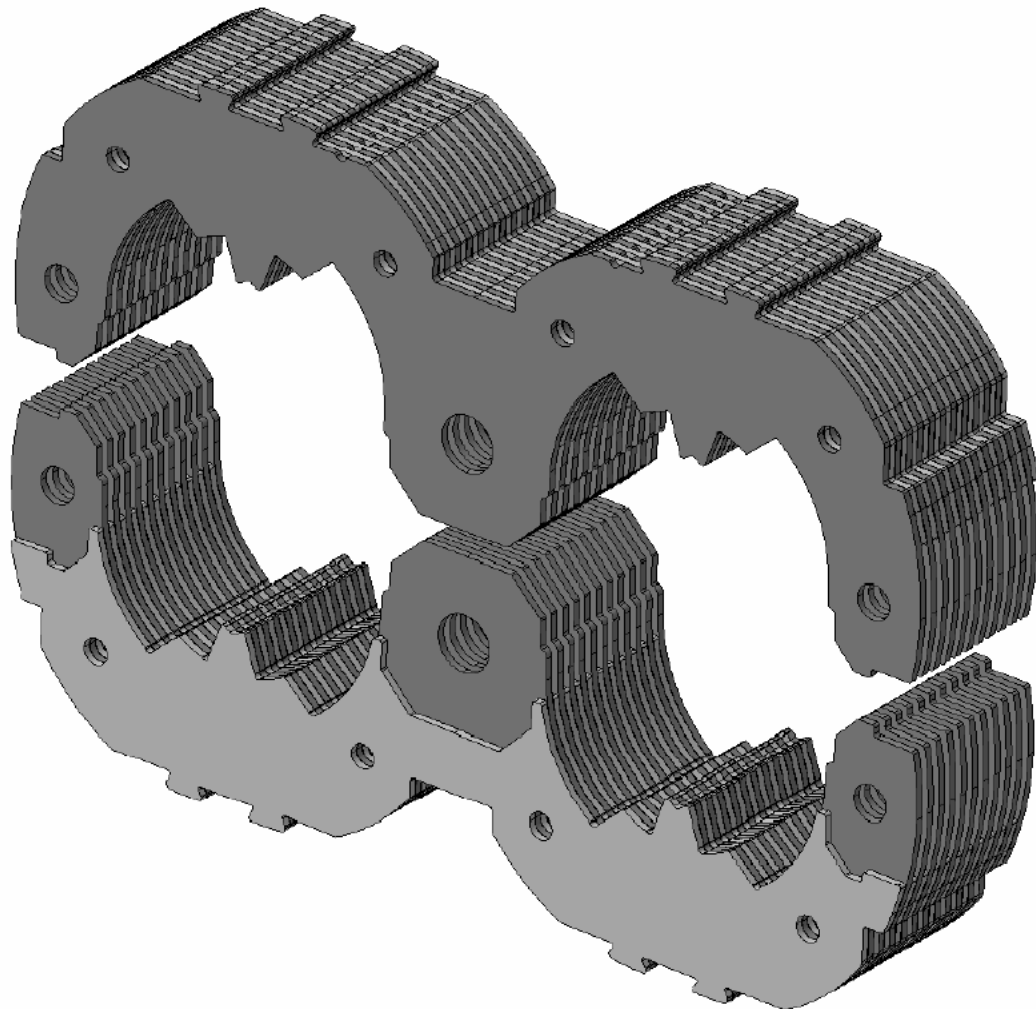
Collaring Press

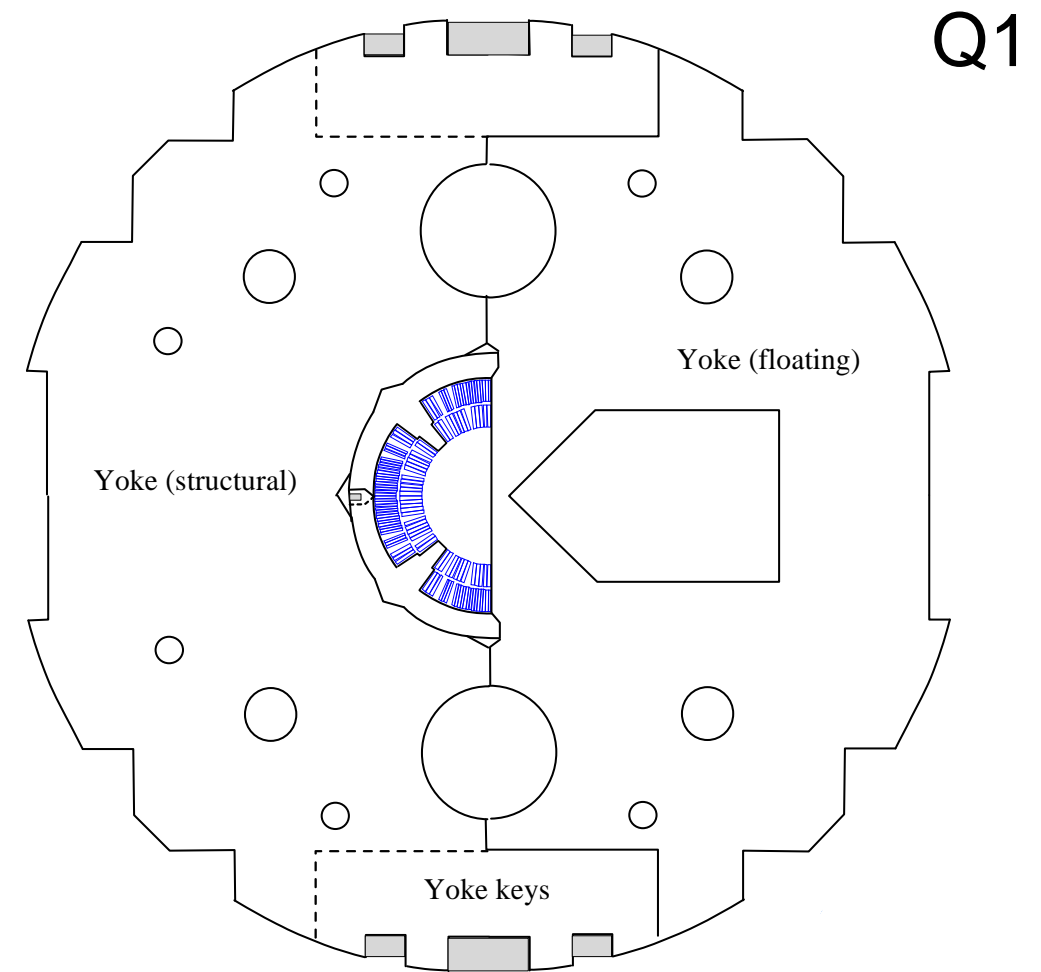
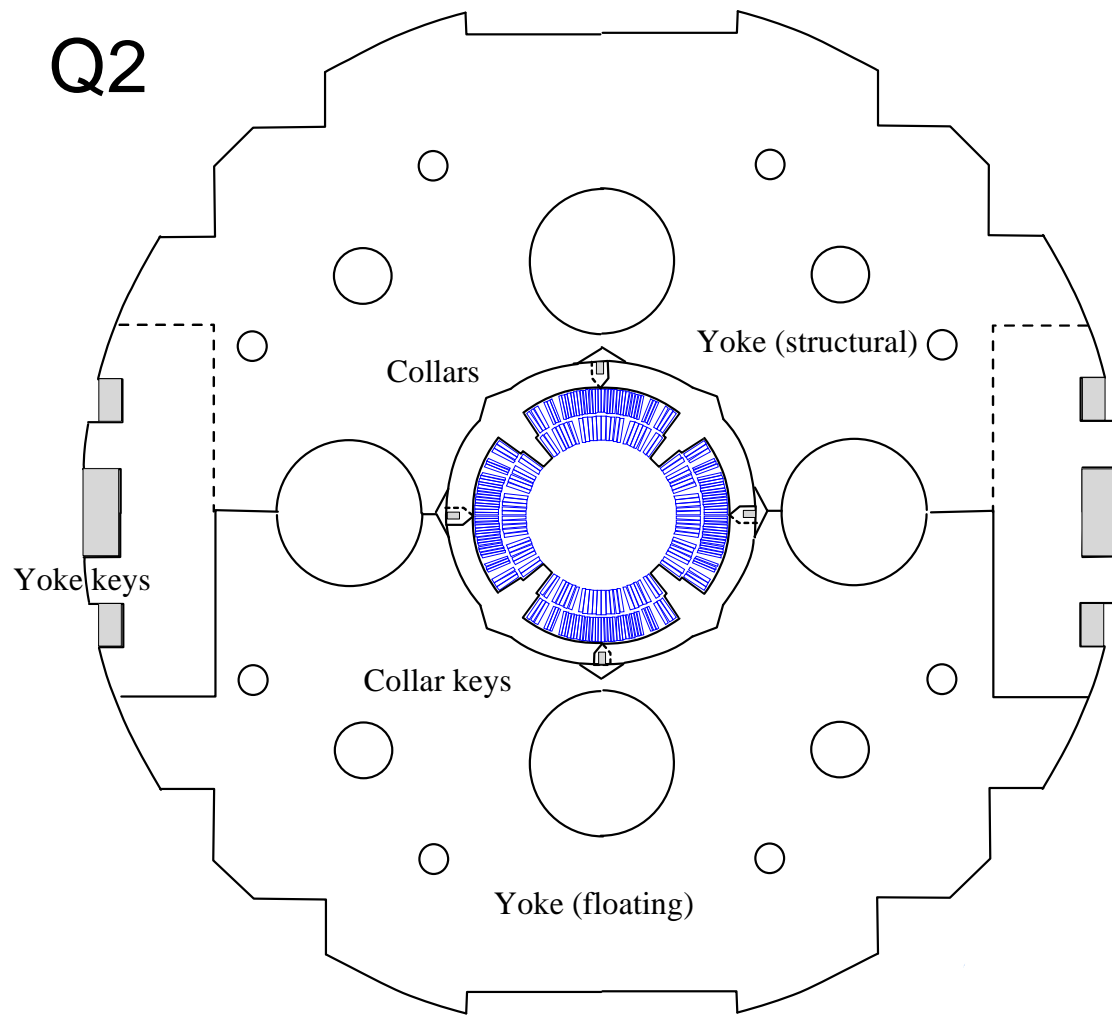


Average Coil stress during collaring, cool down and powering



# Collaring Procedure for (two-in-one) Dipole

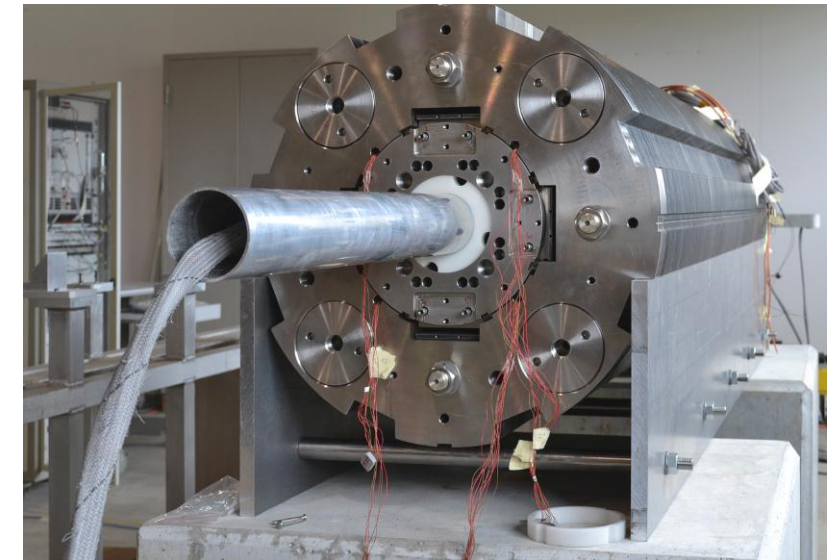
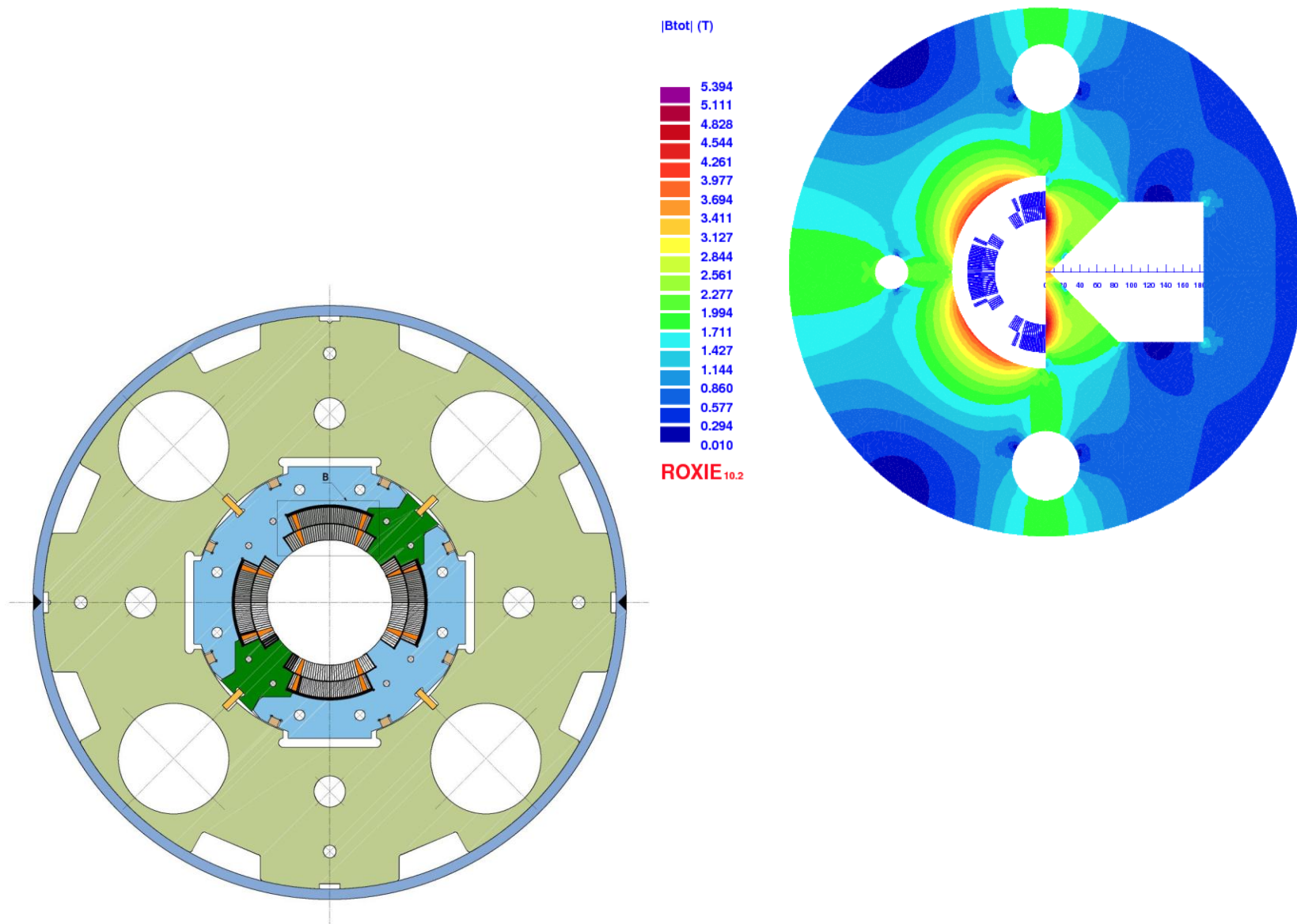




Mechanical structure not trivial: Coil pre-stress must be exerted by the split-yoke structure  
 Creates non-allowed multipoles  
 Loss of pre-stress due to the contraction of coil and yoke (open mid gap at room temperature?)

Use of vertical dipole-type press

# Model Magnet with MQXC (LHC Upgrade Option)

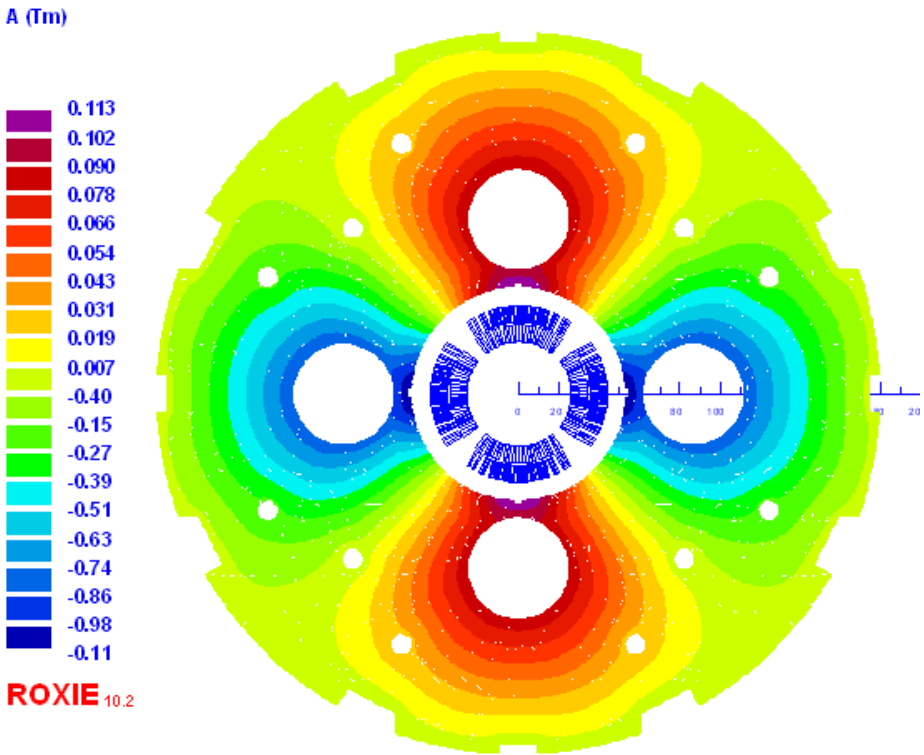


Gradient of 97 T/m and 2.7 T dipole field compared to 120 T/m achieved with MQXC (full) quadrupole but

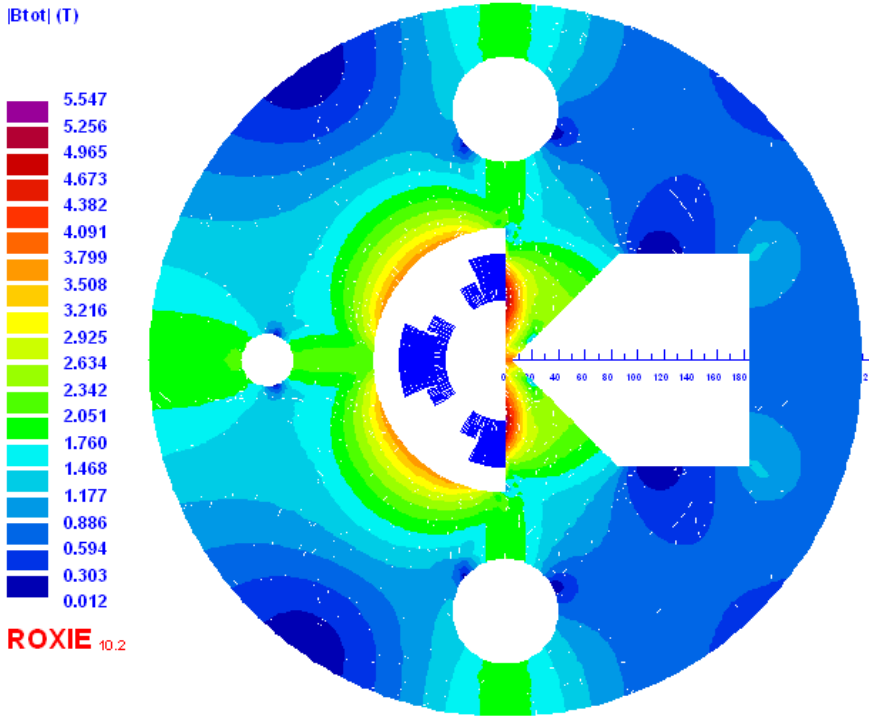
Not so far from the conceptual design using MQY cable (110 T/m)

Conductor, end-spacers, winding and curing tooling available

Q2



Q1



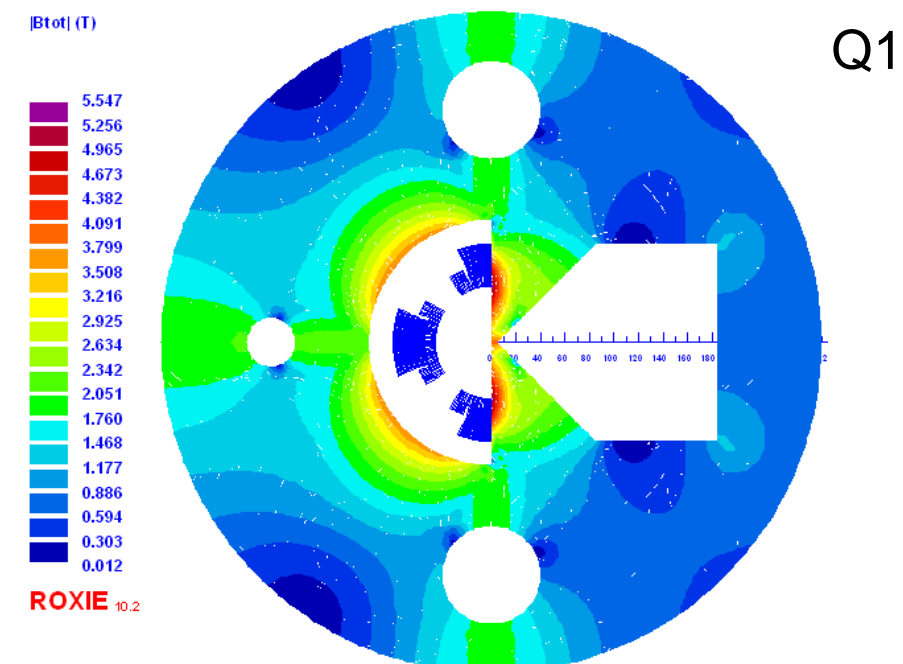
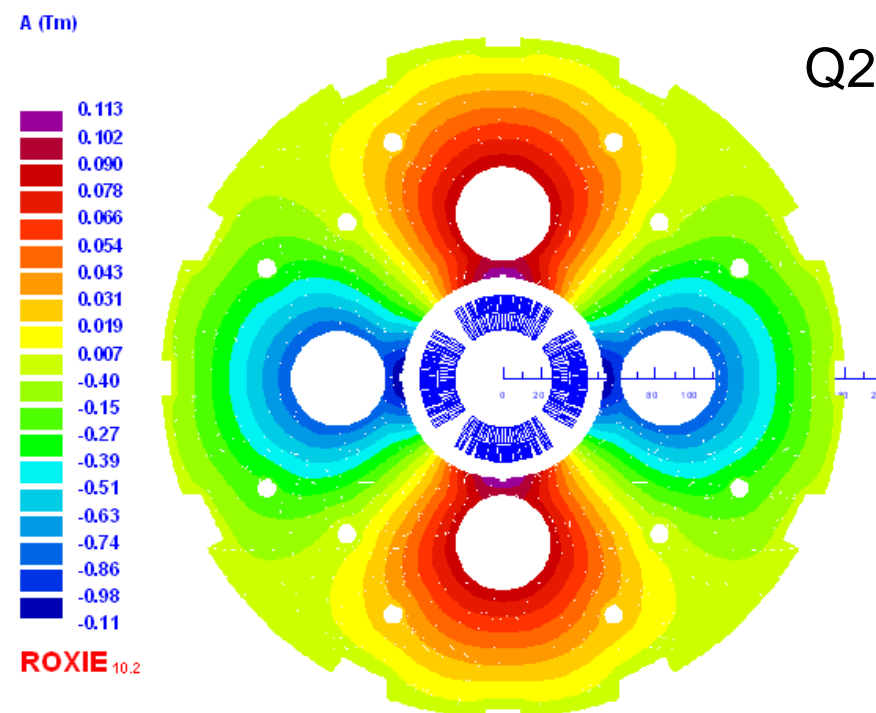
6090 A, 225 T/m at 80% on load-line	4140 A, 133 T/m, 3.3 T at 80%
23 mm aperture 87 mm beam separation	46 mm (half) aperture 57 mm beam separation
0.027 T, 3.2 T/m in p1/e-beam pipe	0.34 T, 16.5 T/m in p1/e-beam pipe

Nb<sub>3</sub>Sn properties in simulations are in accordance with measurements on single strands for CLIC wiggler development (HFM46) and specifications of cables for HL-LHC Inner-triplet upgrade, 11 T dipoles etc.

(2400 A/mm<sup>2</sup>) at 12 T and 4.5 K. **Possibly, operation at 1.9 K (2940 A/mm<sup>2</sup> at 12 )** Operation at about 80% on the load-line.

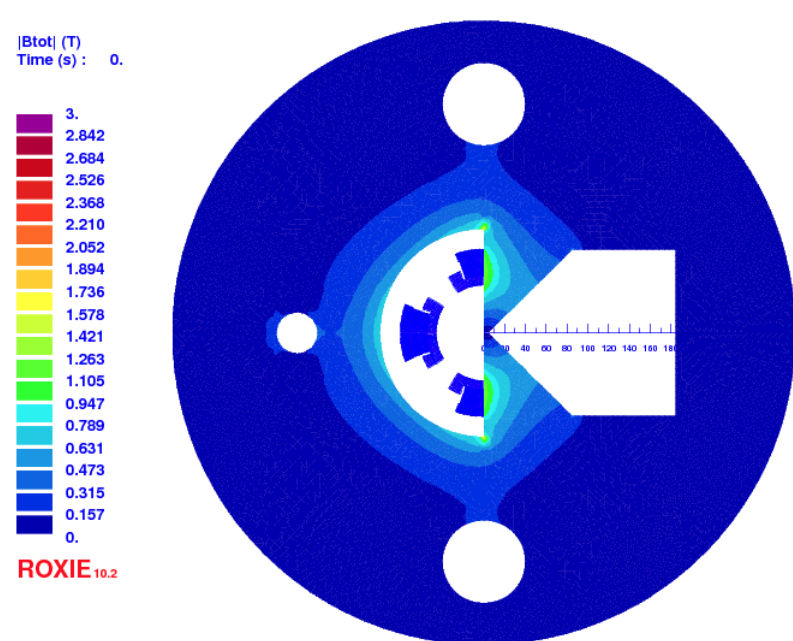
Setting errors (large persistent current, **is this important?**)  
Lengths issues (curing, unit lengths of cables)

**3-meter long magnets o.k. and compatible with layout allowing for increased beam-separation distance.**

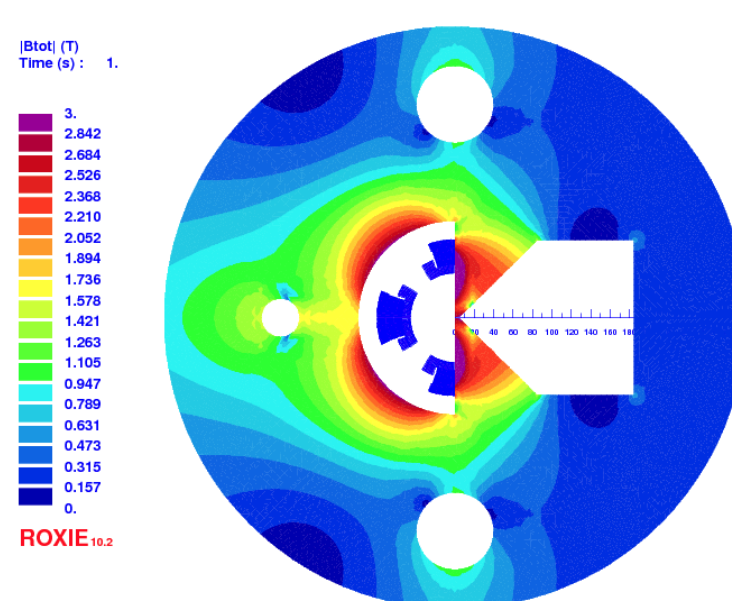
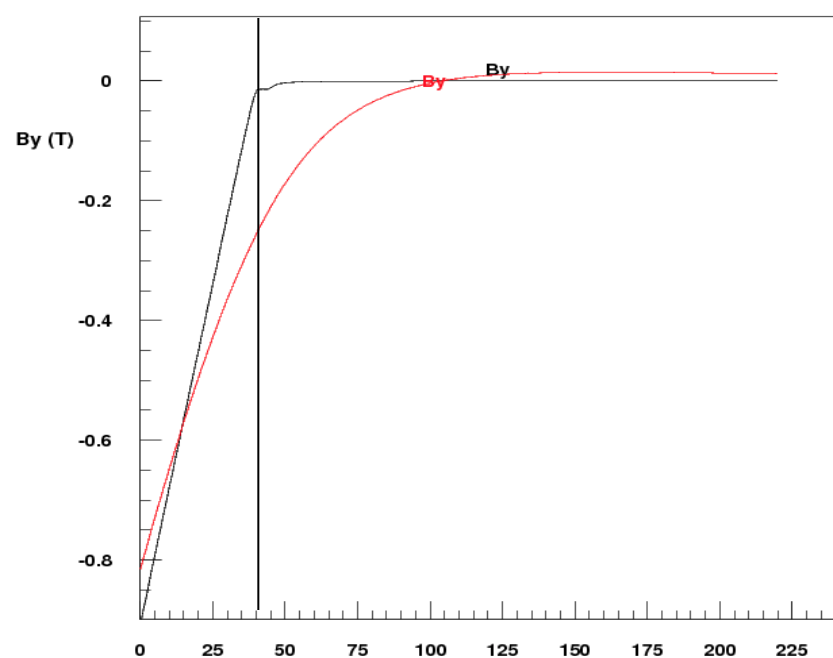


8600 A, 311 T/m, at 78% on load-line	5700 A, 175 T/m, 4.7 T at 79% on LL (4 layers)
23 mm aperture 87 mm beam separation	46 mm (half) aperture 57 mm beam separation
0.09 T, 9 T/m in p1/e-beam pipe	0.5 T, 25 T/m in p1/e-beam pipe

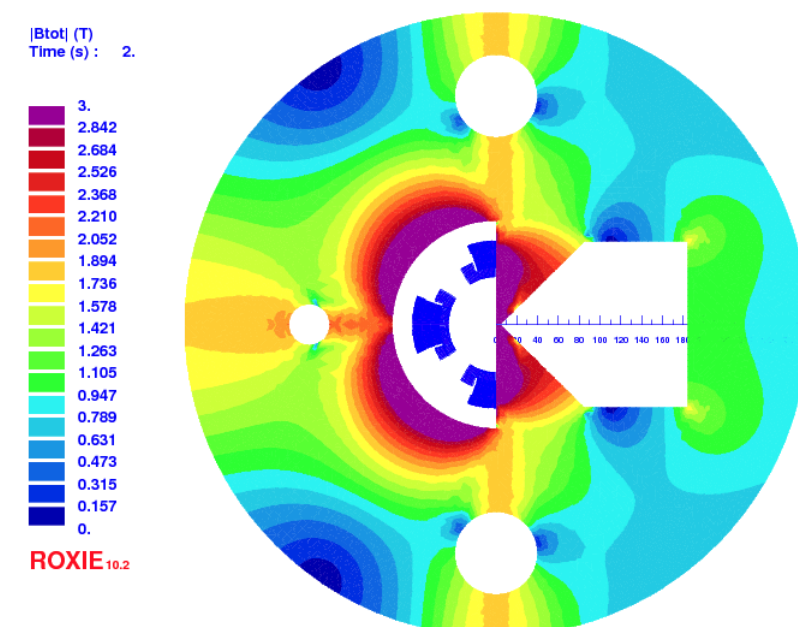
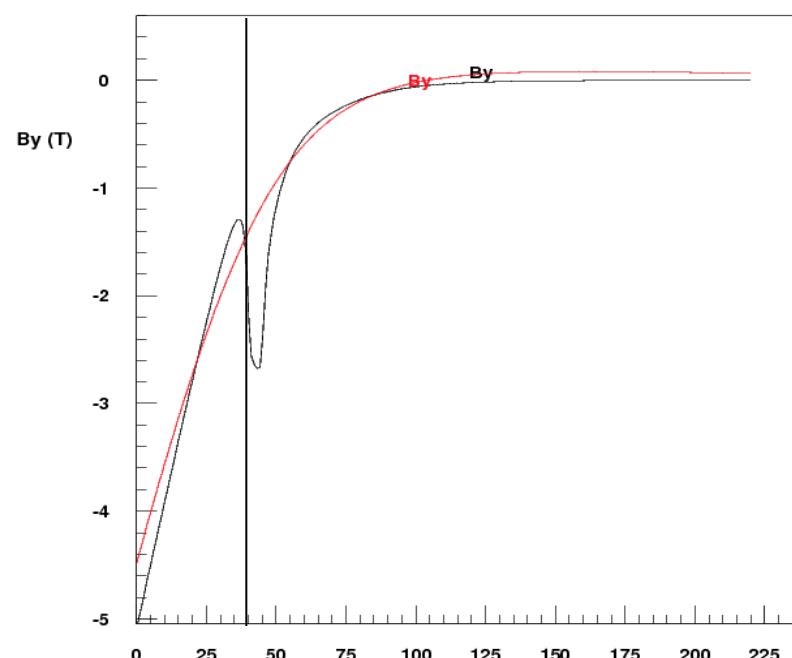
# Saturation of the Mirror



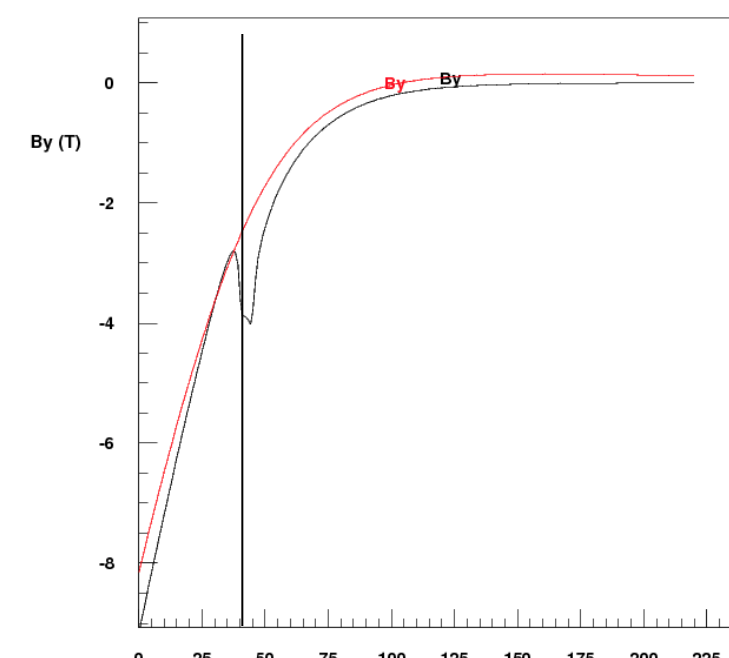
22 T/m



108 T/m

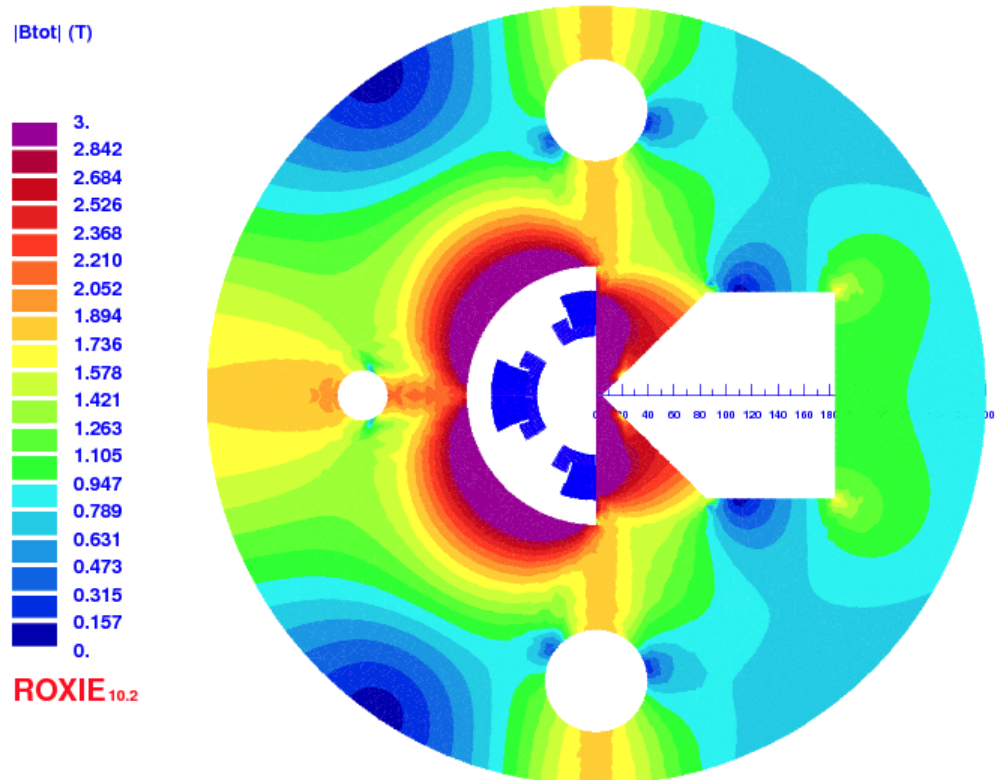


170 T/m



# Multipole Field Errors and Fringe Fields due to Mirror Saturation

172 T/m



NORMAL RELATIVE MULTIPOLES (1.D-4):

b 1: -27908.45654	b 2: 10000.00000	b 3: -543.99569
b 4: -124.23743	b 5: -65.38469	b 6: -34.42817
b 7: -16.66928	b 8: -8.41883	b 9: -4.18402
b10: -2.14435	b11: -1.16740	b12: -0.65666
b13: -0.39151	b14: -0.23111	b15: -0.14666
b16: -0.08633	b17: -0.05492	b18: -0.03319
b19: -0.01811	b20: -0.01411	b

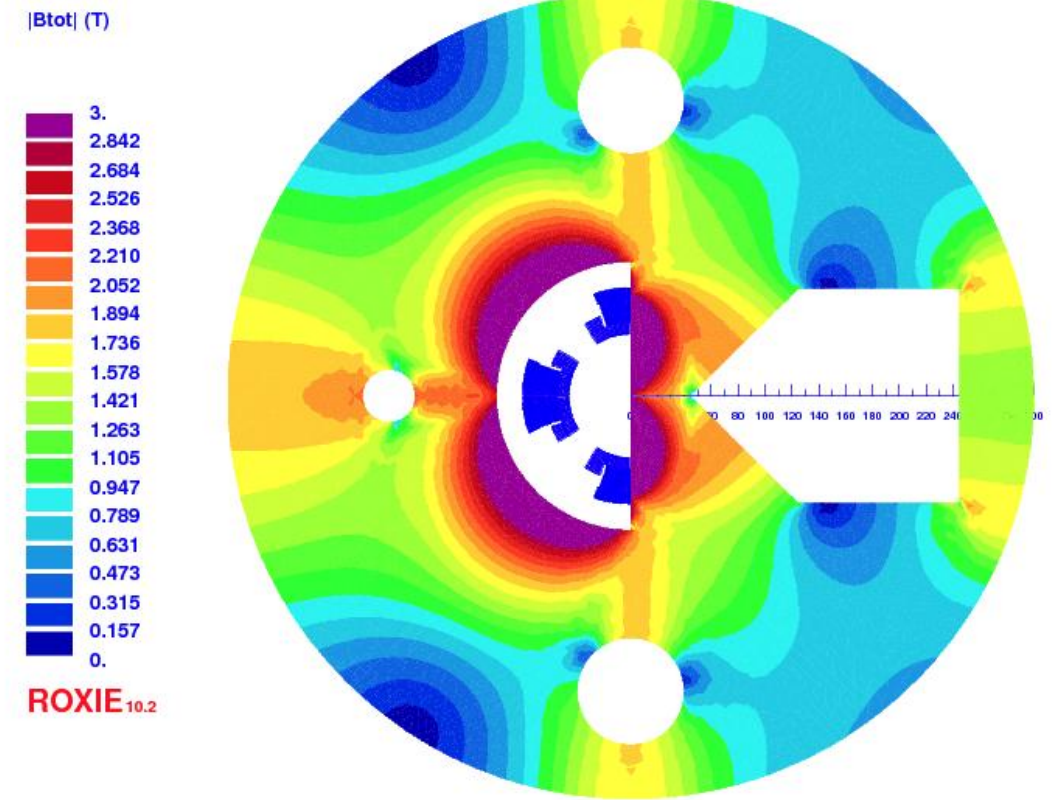
X = - 17 mm

NORMAL FIELD COMPONENTS:

B 1: -0.55146E+00	B 2: 0.25948E+00	B 3: -0.59168E-01
B 4: 0.91483E-02	B 5: -0.14800E-02	B 6: 0.36193E-03
B 7: -0.92051E-04	B 8: 0.14351E-04	B 9: 0.14489E-05
B10: -0.19508E-05	B11: 0.75932E-06	B12: -0.40525E-07
B13: -0.21500E-07	B14: -0.29285E-08	B15: -0.68902E-07
B16: -0.30569E-07	B17: 0.12855E-07	B18: 0.52518E-07
B19: 0.48979E-07	B20: -0.93814E-08	B

X = 40 mm

188 T/m



NORMAL RELATIVE MULTIPOLES (1.D-4):

b 1: -24494.03016	b 2: 10000.00000	b 3: -137.57380
b 4: 48.15985	b 5: 9.58545	b 6: -3.01172
b 7: -4.06281	b 8: -3.50334	b 9: -2.32189
b10: -1.44243	b11: -0.88736	b12: -0.53385
b13: -0.32218	b14: -0.19139	b15: -0.11651
b16: -0.06836	b17: -0.04154	b18: -0.02466
b19: -0.01388	b20: -0.00946	b

X = - 17 mm

NORMAL FIELD COMPONENTS:

B 1: -0.17239E-01	B 2: 0.13364E-01	B 3: -0.42731E-02
B 4: 0.94115E-03	B 5: -0.18657E-03	B 6: 0.45354E-04
B 7: -0.13955E-04	B 8: 0.43292E-05	B 9: -0.13080E-05
B10: 0.35295E-06	B11: -0.47452E-07	B12: 0.87819E-07
B13: 0.66630E-08	B14: -0.31212E-07	B15: -0.54256E-07
B16: -0.31709E-07	B17: 0.13090E-07	B18: 0.51769E-07
B19: 0.46712E-07	B20: -0.63778E-08	B

X = 80 mm

**Ring-ring option:** Nb-Ti magnets can be built with LHC cable (either MQY cable [stock?] or LHC main dipole cable [if not used for the Upgrade Triplets]). Single aperture magnet is a straight-forward engineering design effort, mirror quad requires **validation with a short model**.

Consider building a full-scale model (2-m-long) with MQXC like coils (CEA-Saclay has tooling).

**Linac-ring option:** **Nb3Sn technology requires R&D efforts** (synergies with LHC upgrade, Fresca II, US-LARP). Long lead times for the production of strands and cables, large tooling costs for coil production and curing.

Any decision must be based on outcome of said R&D efforts (milestone 2014-2015).

Consider increasing the beam separation (crossing angle) and lowering the gradient in Q1 (to limit saturation of the mirror). Check collision optics for field errors.

**Serious model magnet (2-m-long) program required.**

