LARP

HQS Progress Report
High Field Nb_3Sn Quadrupole Magnet

Shlomo Caspi

LBNL

Collaboration Meeting – CM11
FNAL
October 27-28, 2008

Introduction

- large bore (120mm)
  - high field (15.2T) (3000 A/mm2, 4.2K, 12T)
    - Gradient 219 T/m at 1.9 K
      - Accelerator quality

Collaboration :

- BNL – reaction and potting tooling
- FNAL – magnetic design, Islands, wedges, “end” spacers
- LBNL – cable, winding & curing tooling, mechanical design, magnet assembly.

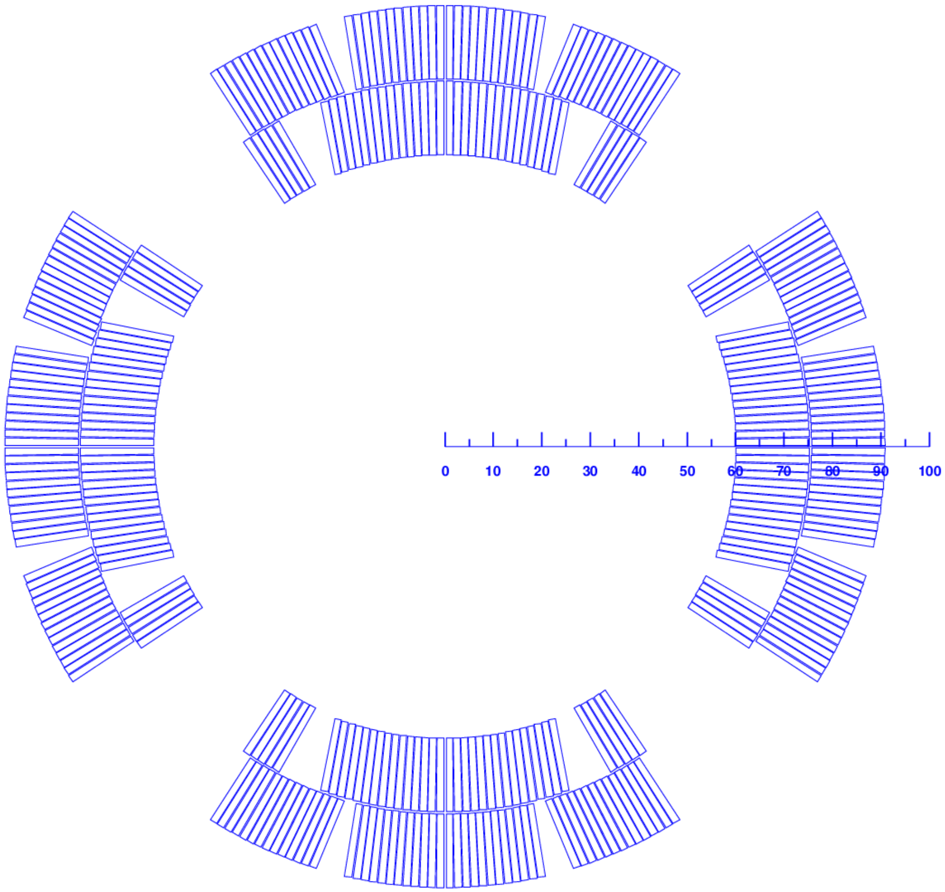
Outline :

- Magnetic design
- Mechanical design
- Tooling design.

Magnetics

Coil cross-section and parameters

Courtesy of V. Kashikhin

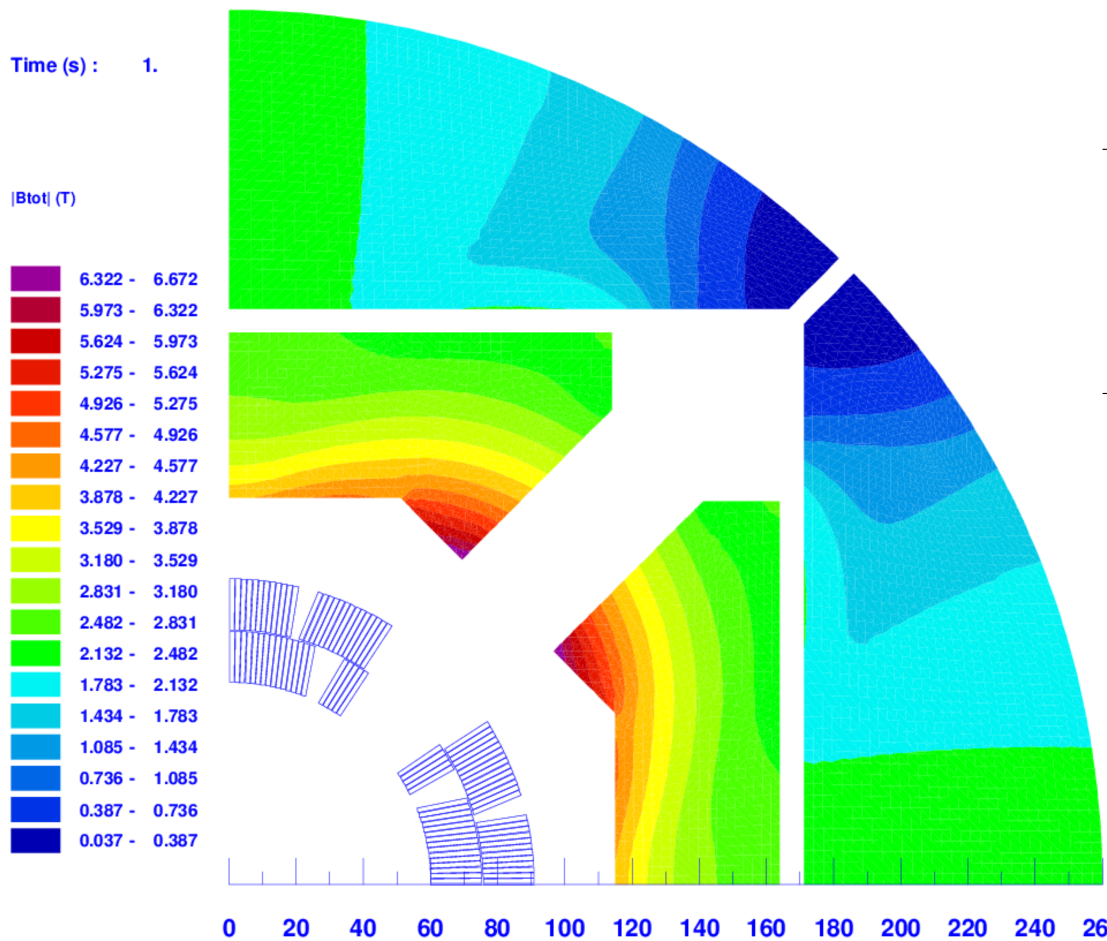


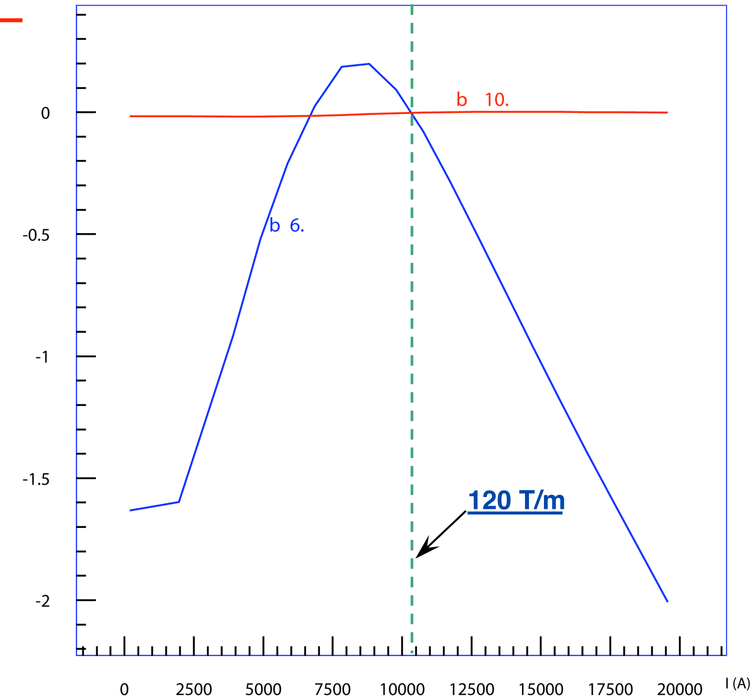
Coil aperture		mm	120
Yoke OR		mm	260
Cable reference name		-	HQ-KC2
Bare cable width		mm	15.150
Bare cable mid-thickness		mm	1.437
Cable keystoning angle		deg	0.750
Cable insulation thickness		mm	0.100
Turns per quadrant IL/OL		-	20/26
Minimum pole width		mm	23.82
Midplane shim per octant		mm	0.140
Quench* gradient @ 1.9K		T/m	219.78
Quench* peak field @ 1.9K		T	15.29
Quench* current @ 1.9K		kA	19.57
Inductance @ quench*		mH/m	7.71
Stored energy @ quench*		MJ/m	1.48
Octant forces @ quench	F_x total	MN/m	3.38
	F_y total	MN/m	-5.03
	F_θ IL/OL	MN/m	2.63/3.15

* J_c(12T, 4.2K) = 3000A/mm^2, $K_{cu/nonCu}$ = 0.87

Iron saturation & field quality - Roxie

Courtesy of V. Kashikhin

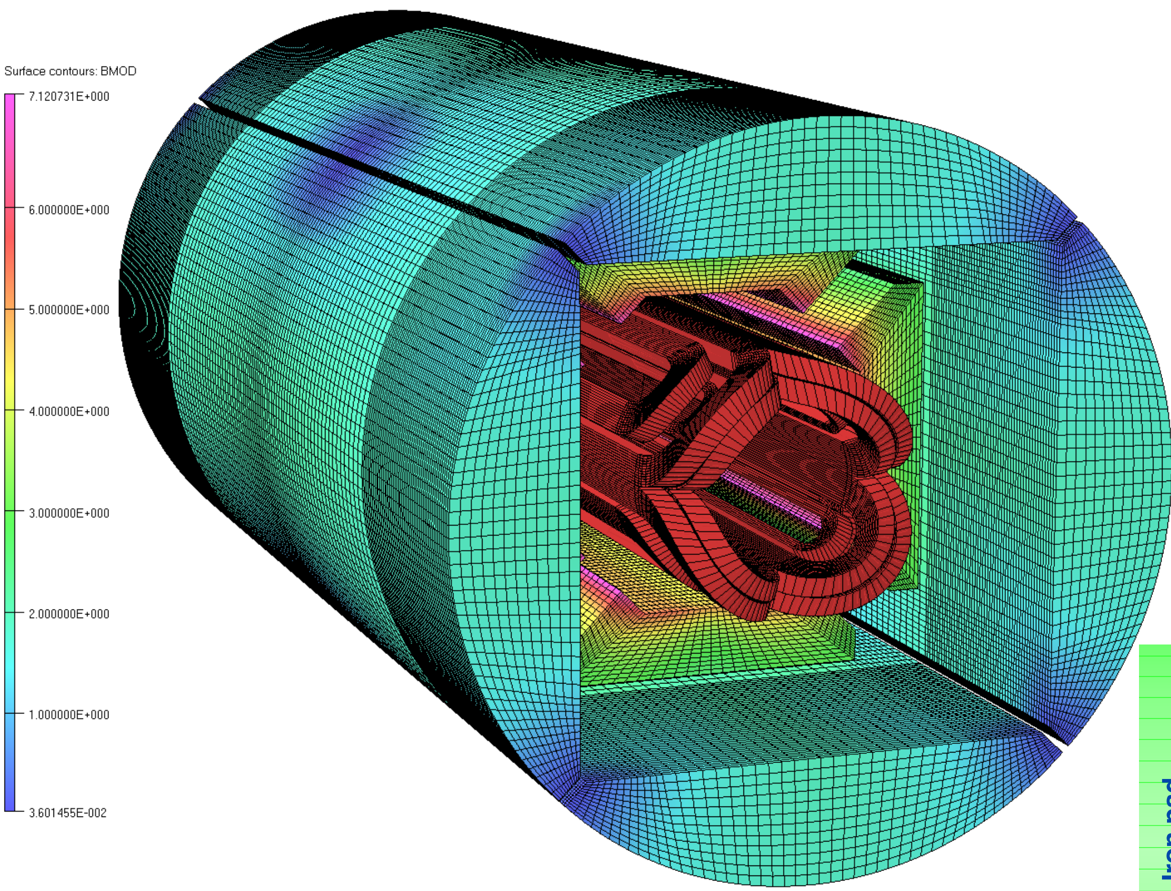


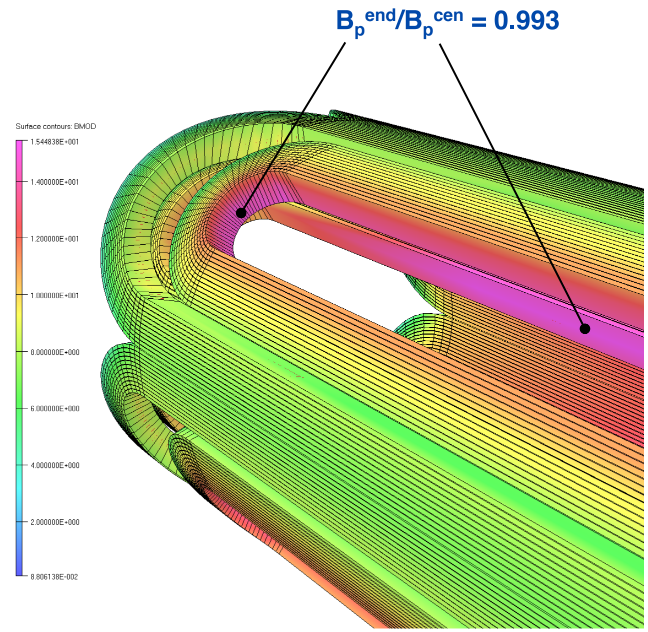


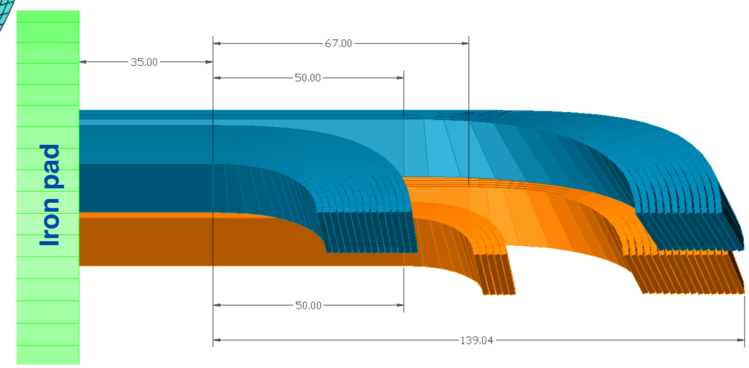
Field reference radius		mm	40
Harmonics @ 10 T/m	b_6	-	-1.6317
	b_{10}	-	-0.0156
	b_{14}	-	-0.0106
	b_{18}	-	-0.3910
Harmonics @ 120 T/m	b_6	-	0.0000
	b_{10}	-	-0.0021
	b_{14}	-	-0.0118
	b_{18}	-	-0.4059

3D analysis - Tosca

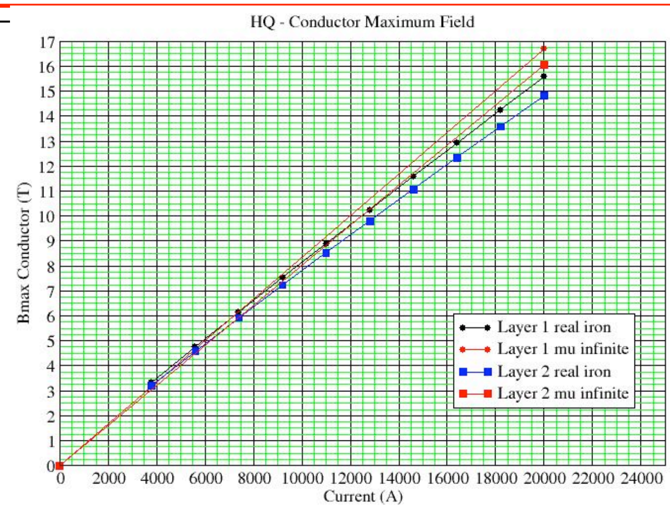
Courtesy of V. Kashikhin

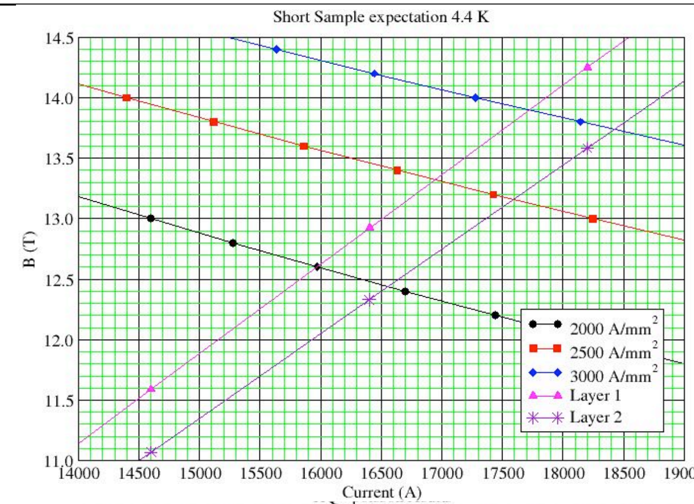


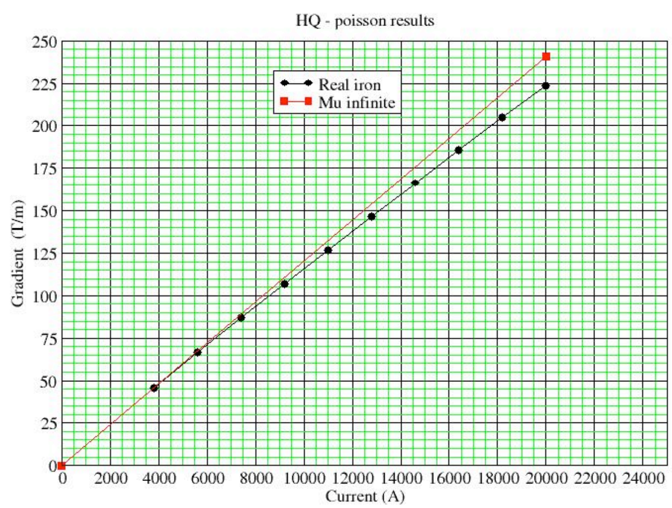


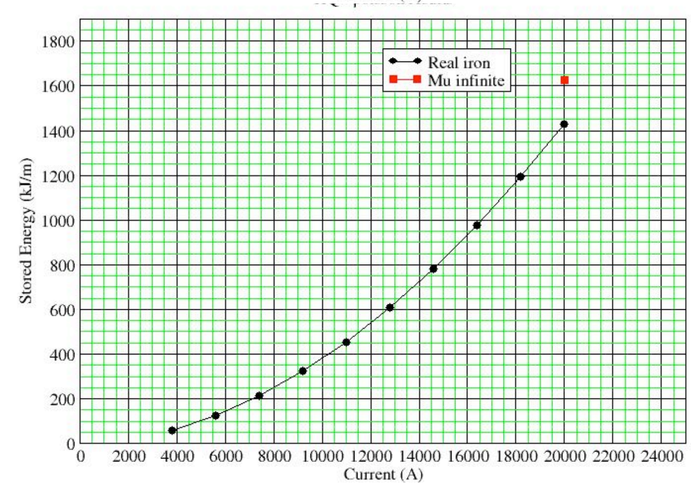


Field, Gradient, Stored-energy - Poisson









Short-sample straight section

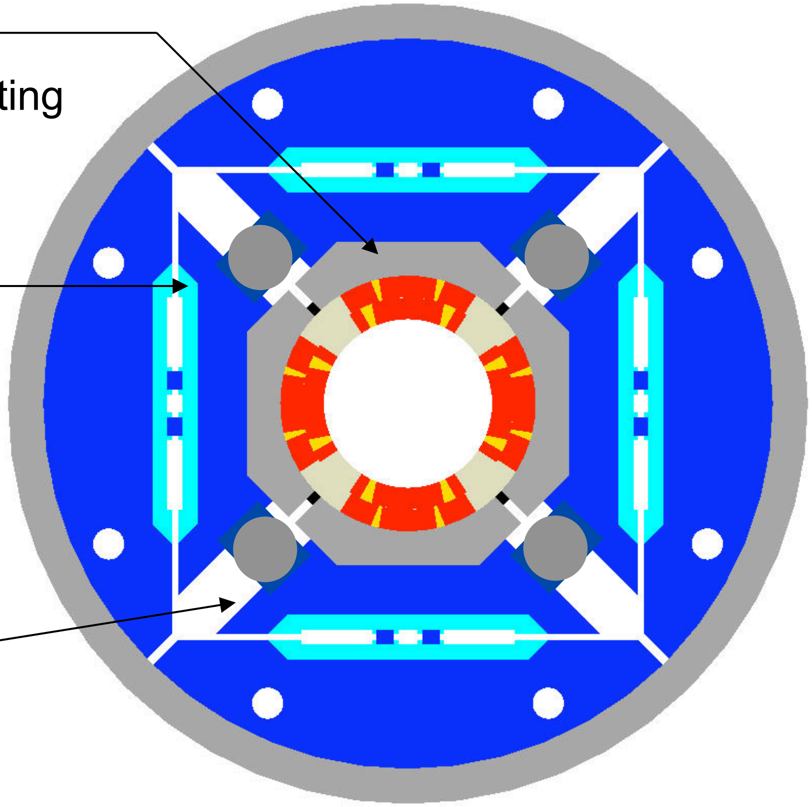
1.9 K / 4.4 K	**Layer 1**			**Layer 2**		
A/mm^2	**2000**	**2500**	**3000**	**2000**	**2500**	**3000**
Imax (kA)	**17.5**/15.98	**18.58**/16.95	**19.45**/17.72	18.14	19.30	20.22
Bmax (T)	**13.72**/12.59	**14.52**/13.3	**15.17**/13.9	13.55	14.34	14.98
Gmax (T/m)	**197**/181	**208**/191	**219**/199			

Mechanics

HQS – Mechanical Shell based Structure

Components

- Aluminum bolted collars => alignment
    - remains in compression from assembly to operating conditions
- Iron pads and yoke
- Iron master key => alignment
- axial rods => axial preload
- 25 mm aluminum shell => azimuthal preload
    - Coil and collar in compression
- Cooling area



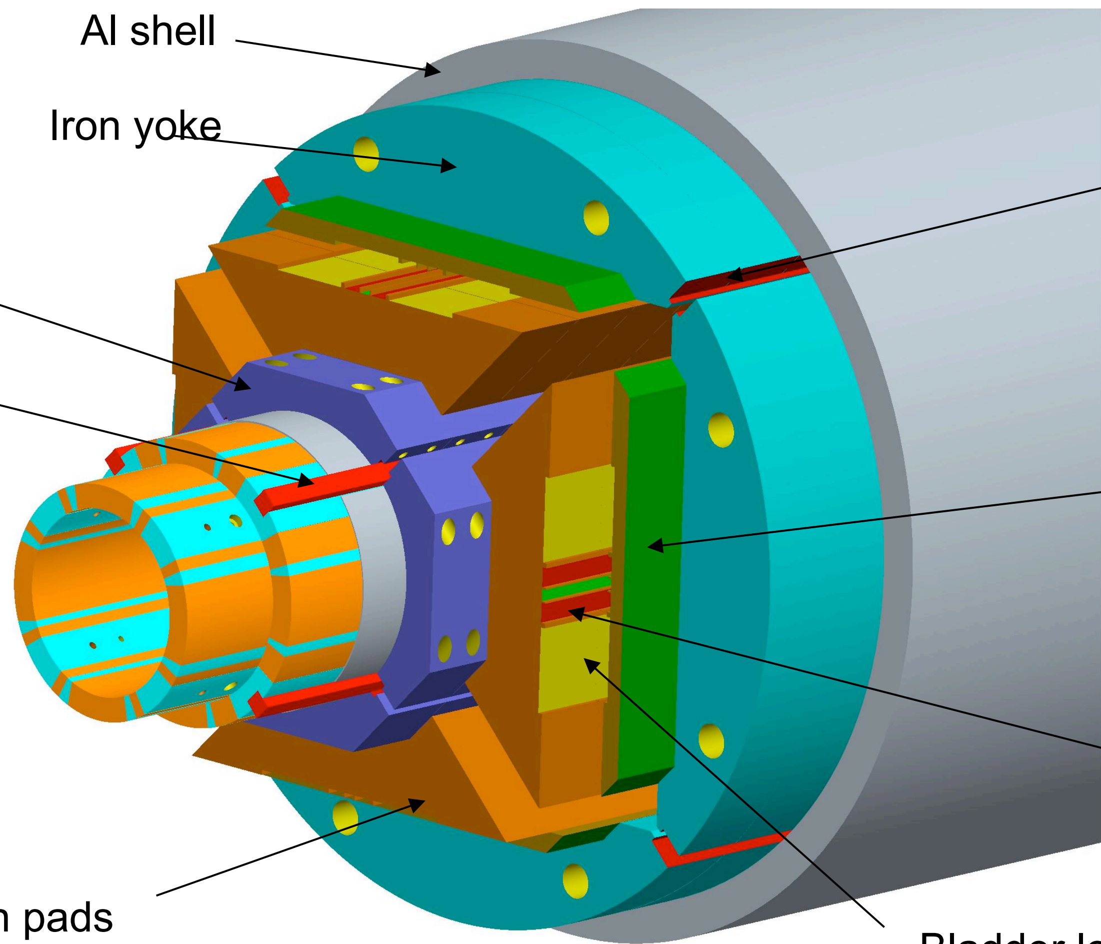
570 mm outer diameter

Assembly

- 60 mm bladders located outside the key span
- 38 MPa pressure (600 + 50 microns clearance for 220 T/m)
- Collars, pads and key locations optimize to minimize stress

HQ – CAD Model

Courtesy of D. Cheng



Design Concept and Guidelines

- Use modified pads and collars for coil alignment
  - Collars for azimuthal alignment (**not for pre-stress**)
  - Bolted pads for coils assembly
  - Keys, bladders and Aluminum shell during final azimuthal assembly
  - Axial rods to control axial forces

- Final pre-stress during cool-down by a shell based Aluminum structure

- Maintain full azimuthal contact between coil-island and island-collar
  - Bladder and key locations optimized

- Structure to maintain pre-stress up to expected “short-sample”

  but coil pre-stress can be reduced if adjusted to the operating point.

HQ – Mechanical analysis
Azimuthal stress in the coil

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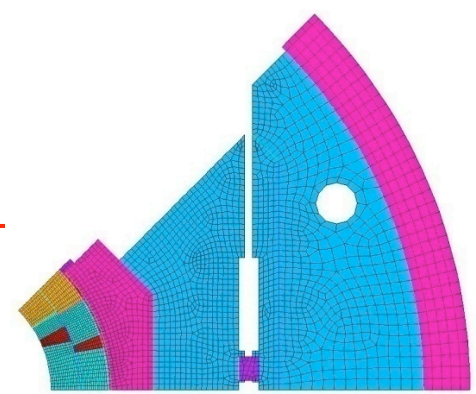
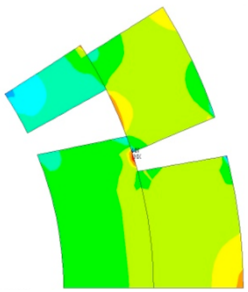
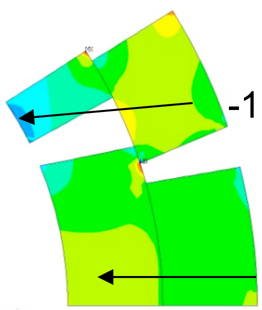


-90 MPa



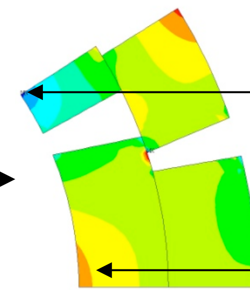
-177 MPa



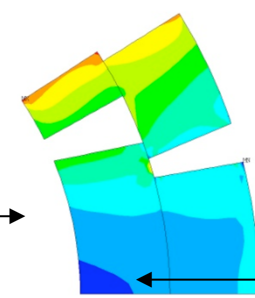
- 80 MPa

	Target 219 T/m
During bladder operation	-90 MPa
With loading key	-82 MPa
At 1.9 K	-177 MPa
With Lorentz forces	-177 / 20 MPa

-82 MPa



- 20 MPa

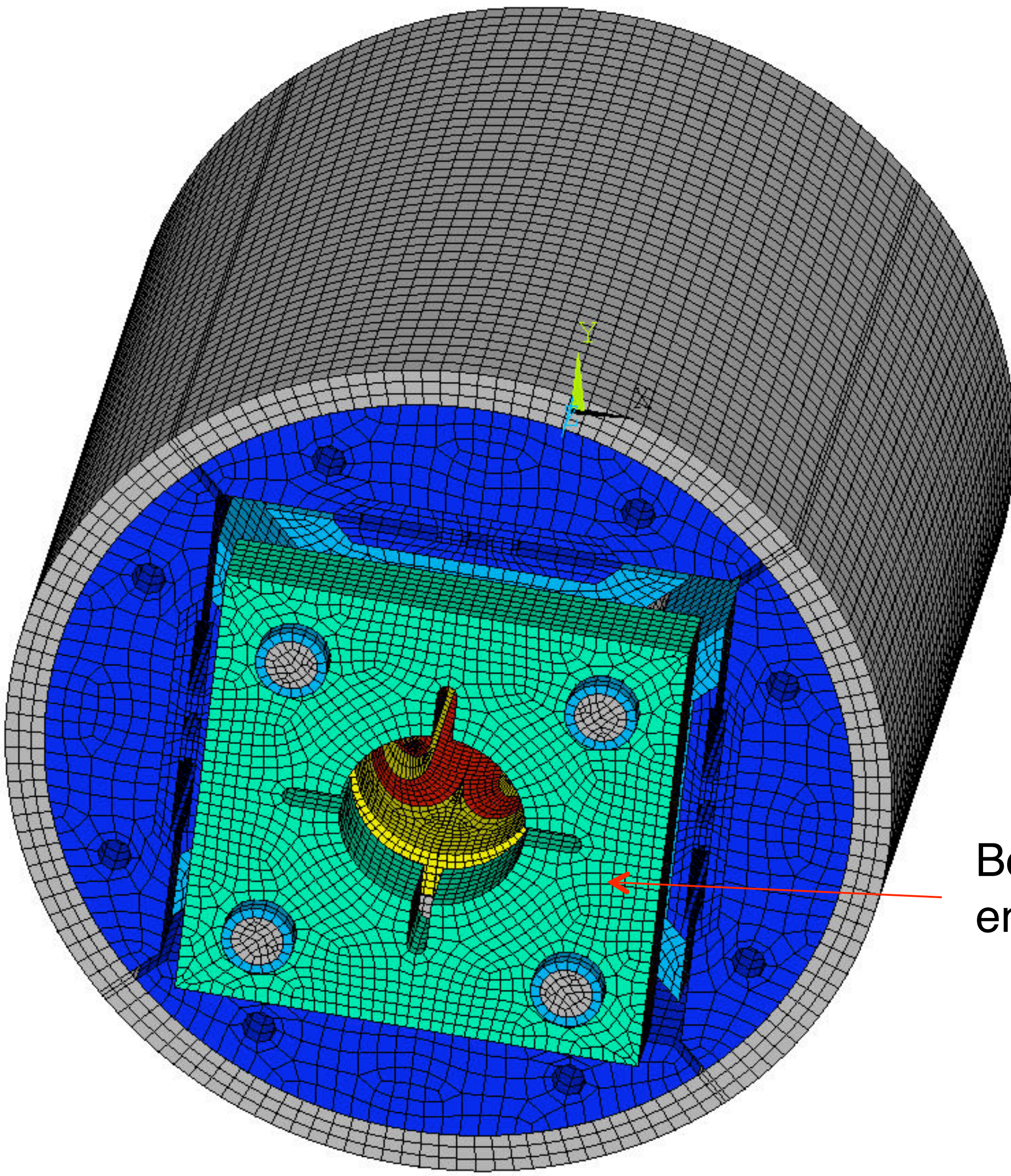


-177 MPa

=> High but acceptable stress at short sample

Courtesy of H. Felice

Axial Aluminum rods



Bolted to a Nitronic endplate

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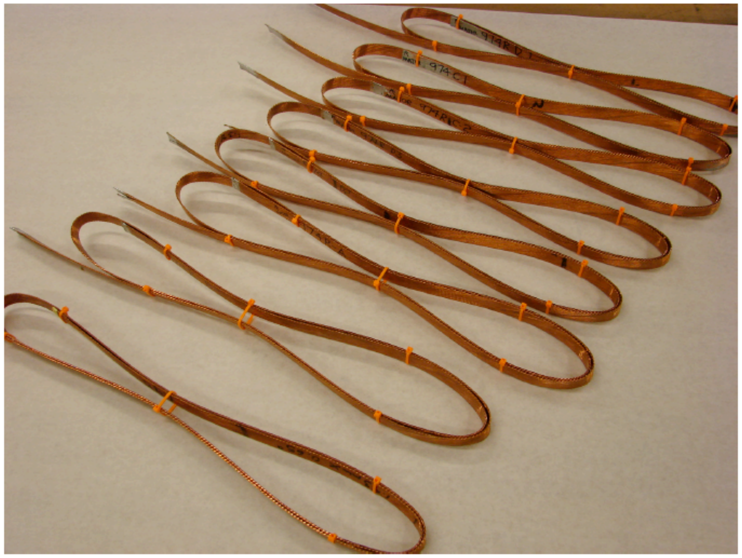
Winding-Curing-Reaction-Potting

HQ – Cable optimization



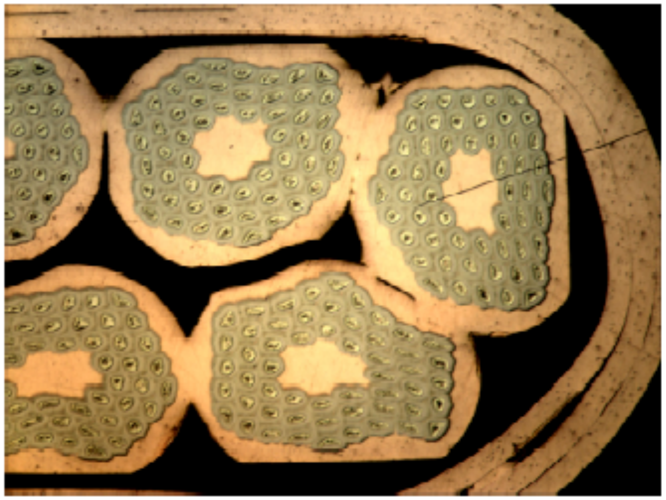
Test winding samples

Variation of the keystone angle, thickness…

Up to now, 8 cables evaluated

Micrographs analyzed for each sample

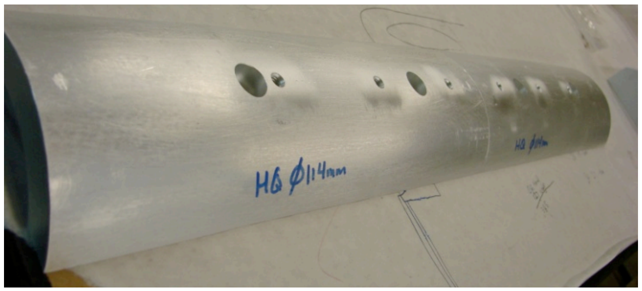
- Edge deformation – strand distortion
- Deformation of the sub-elements
- Barrier
- Size of the facets on the surface of the cable

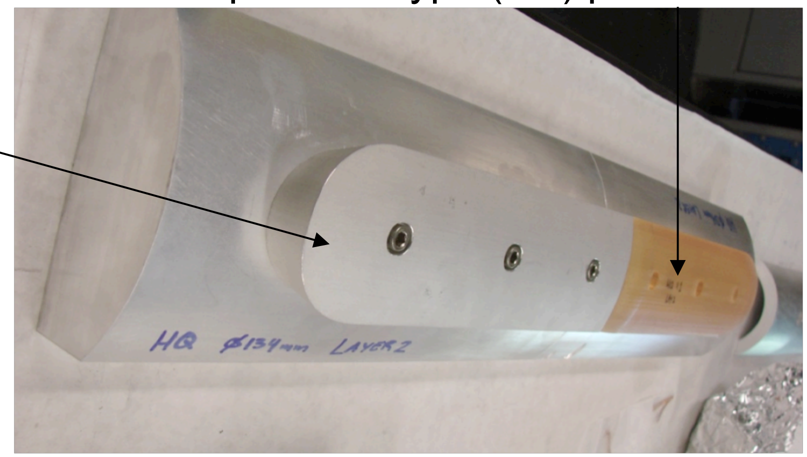


HQ – Winding tests

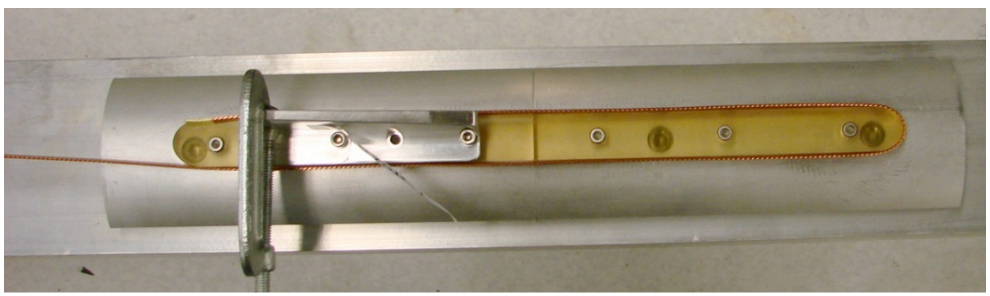
EDM part return end

Rapid Prototype (RP) part lead end





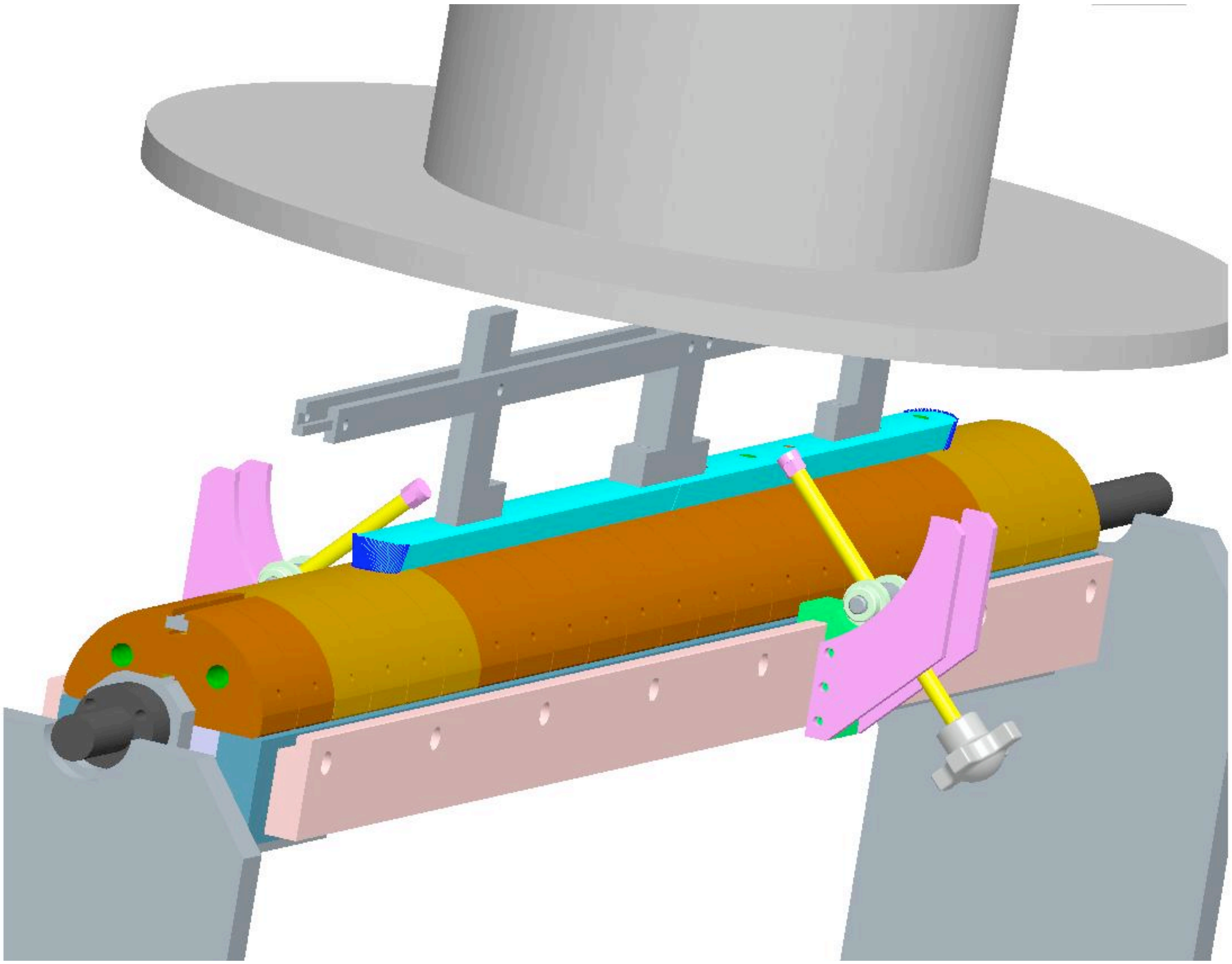
114 mm aperture mandrel



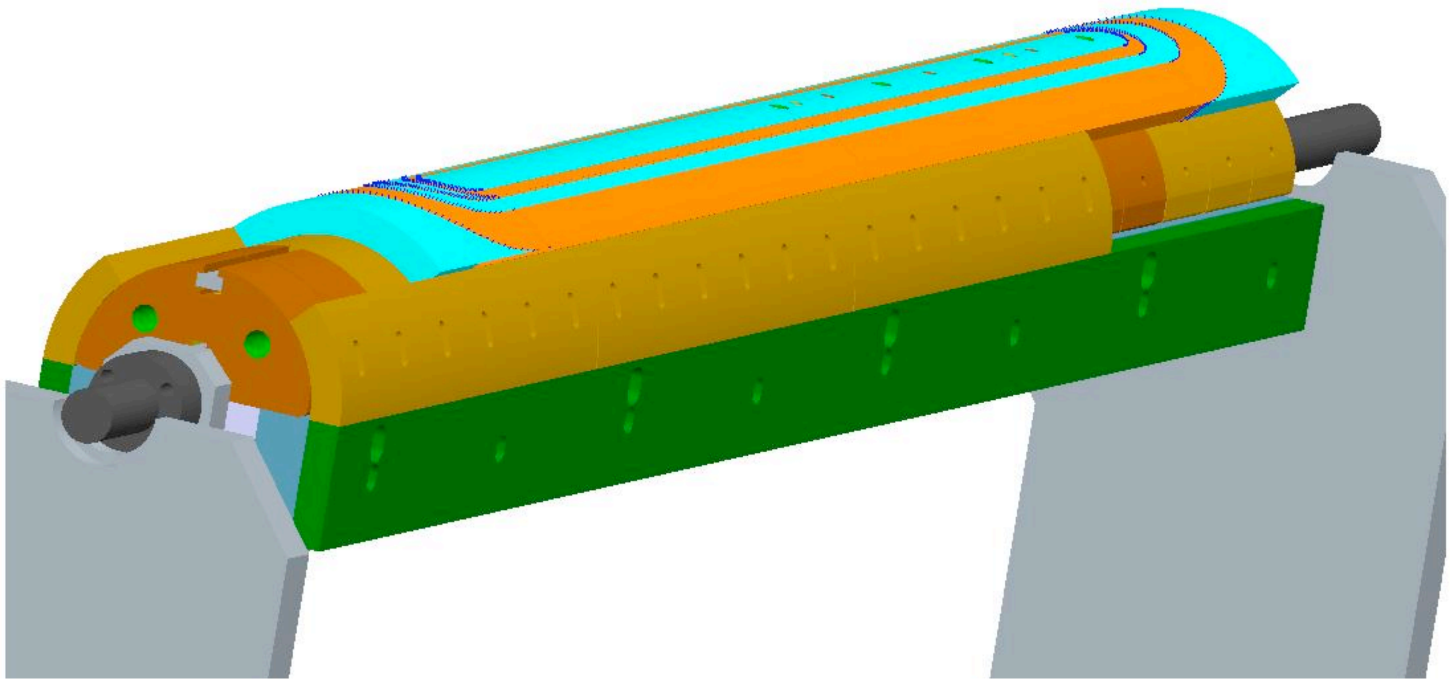
134 mm aperture mandrel

=> 120 mm cross-section: minimum pole width 23.8 mm

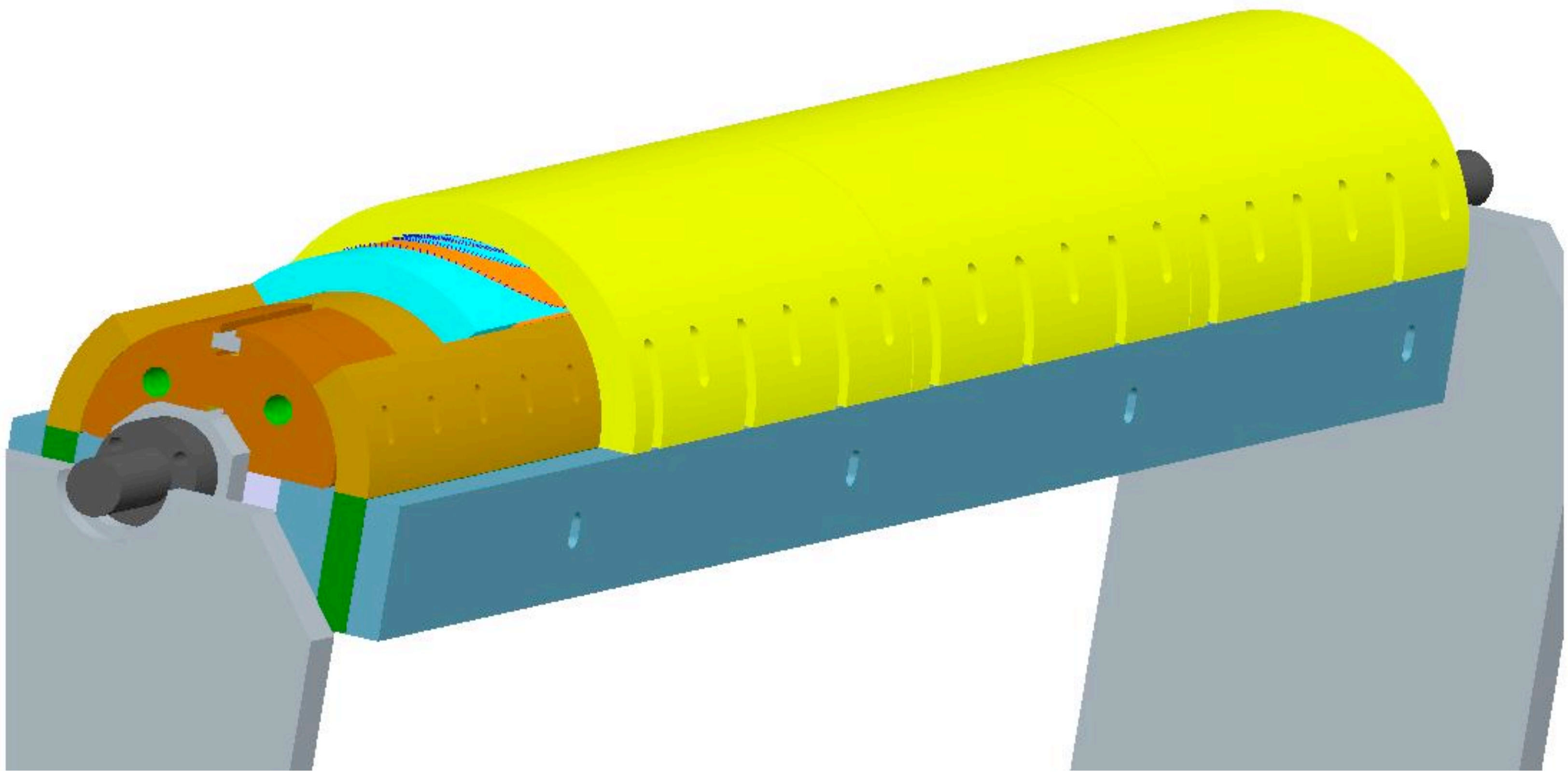
Winding tooling



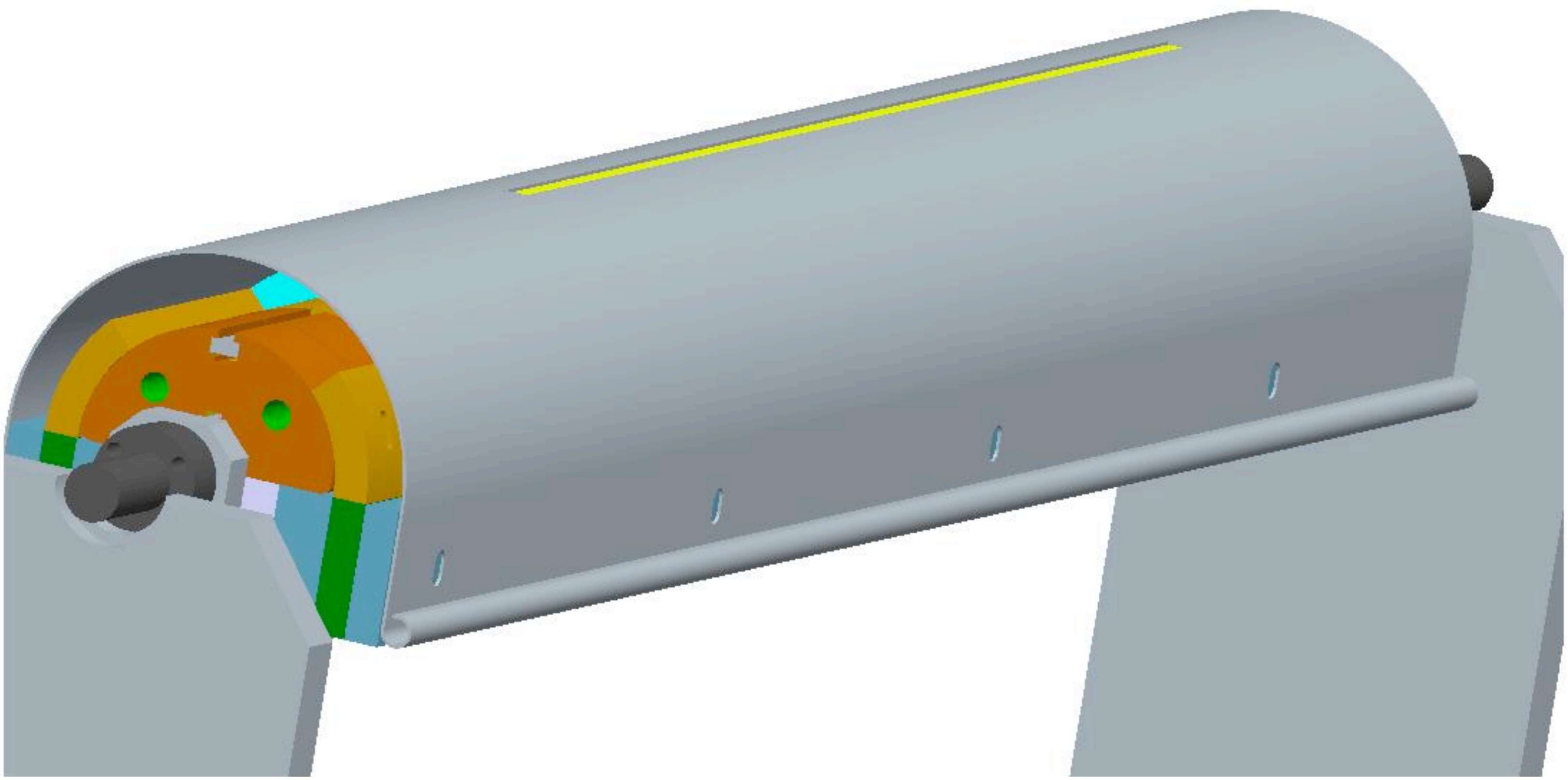
Winding layer 1



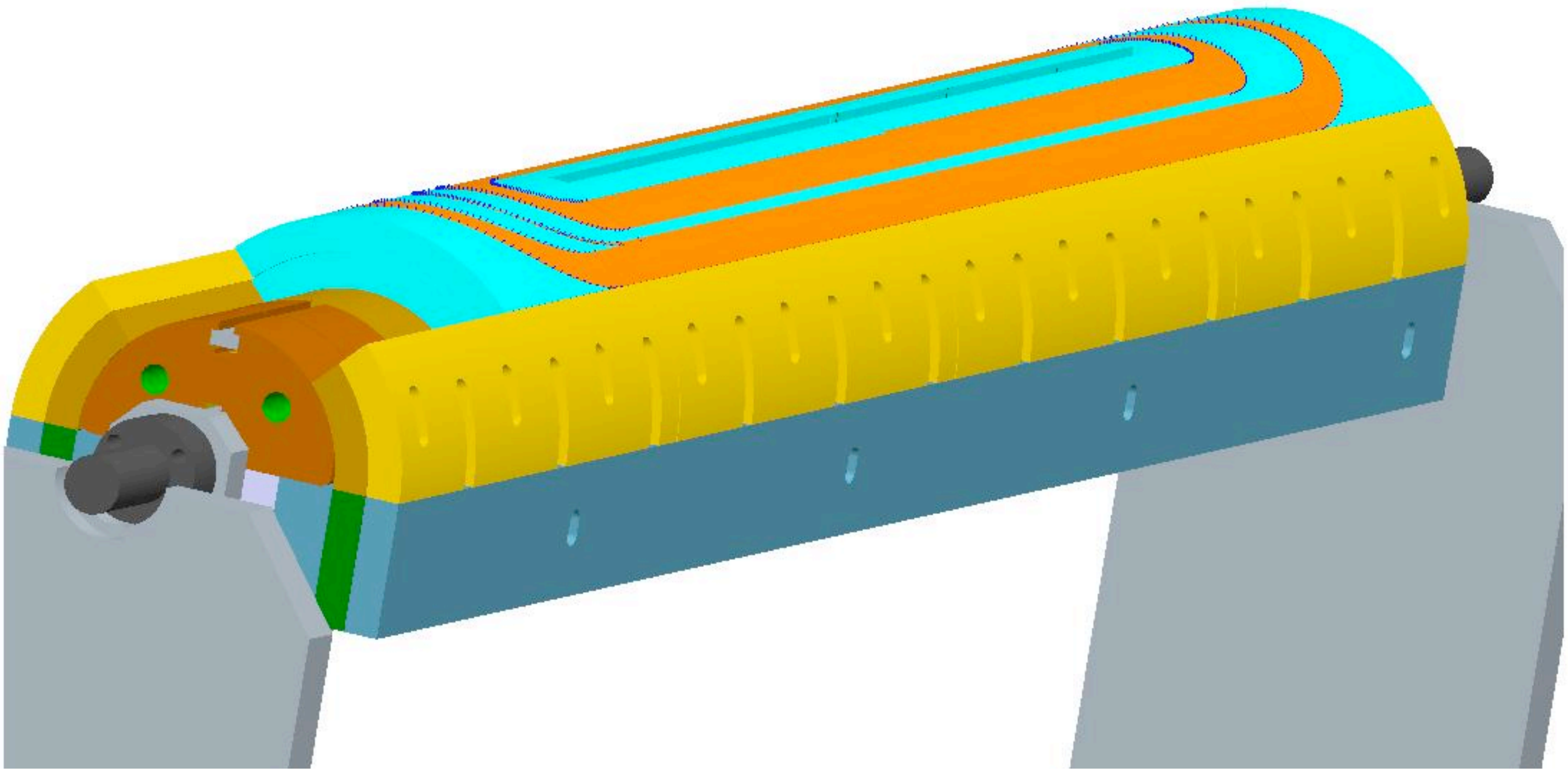
Layer 2 spacer



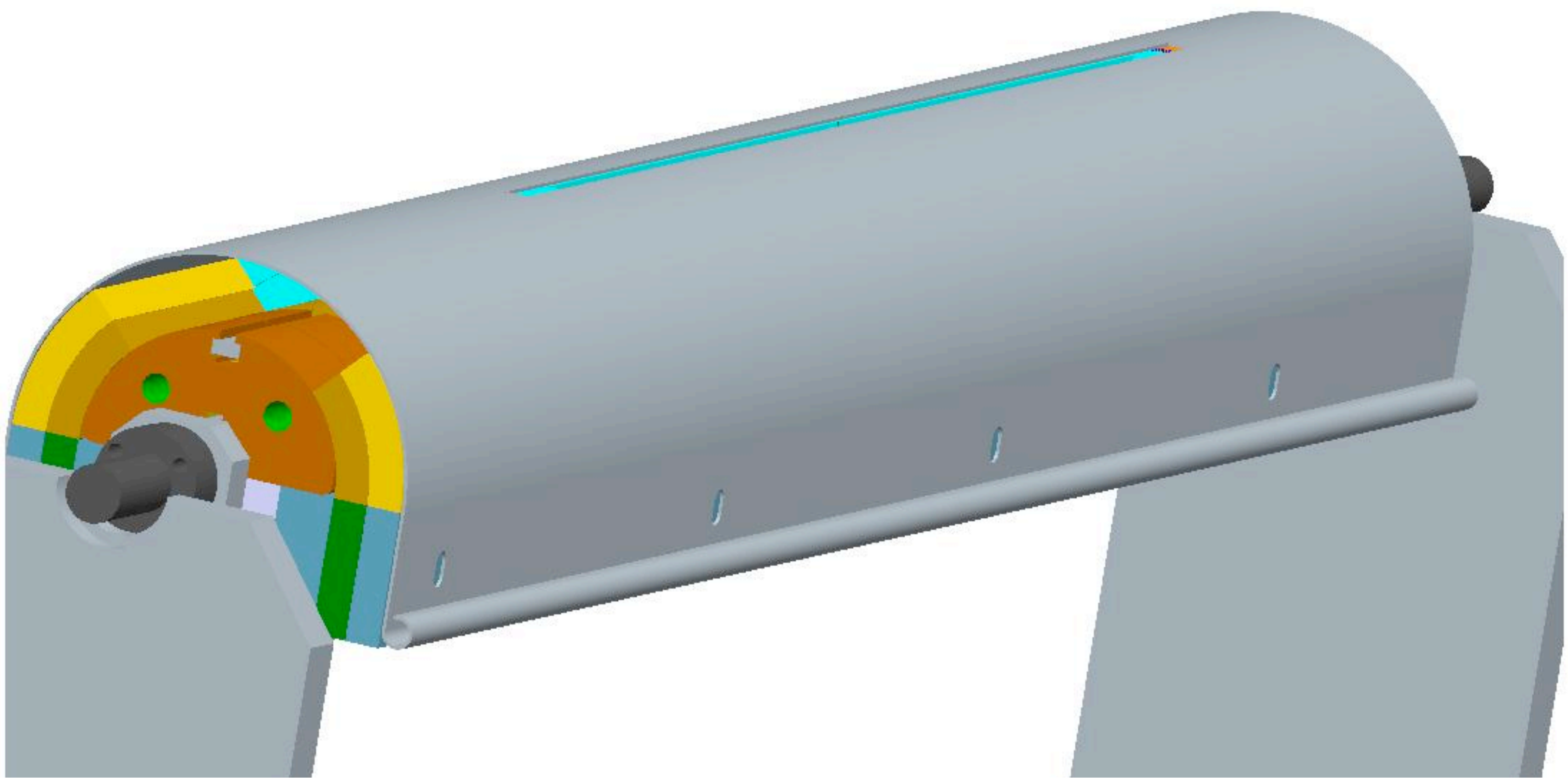
Curing layer 1

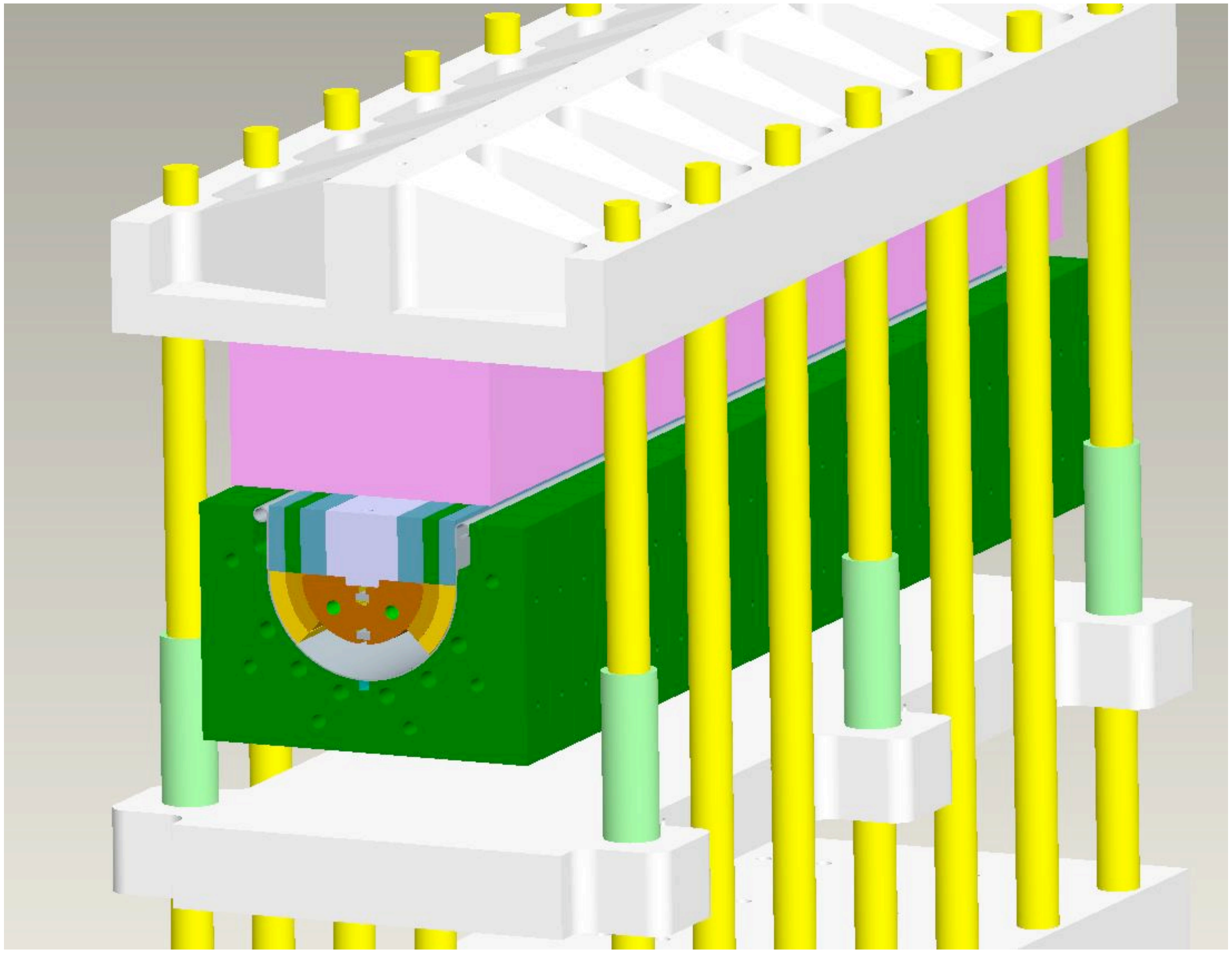


Winding layer 2

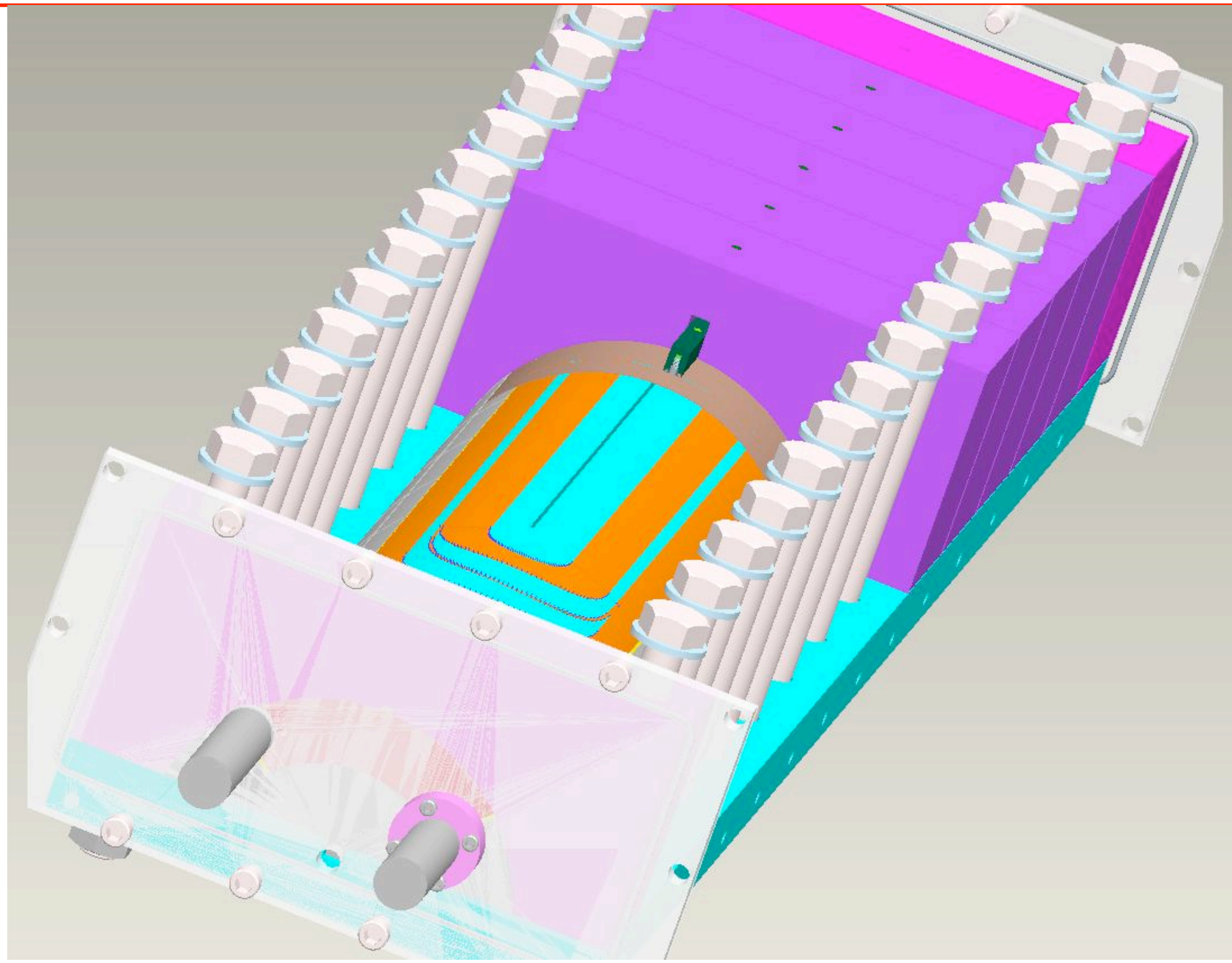


Curing layer 2

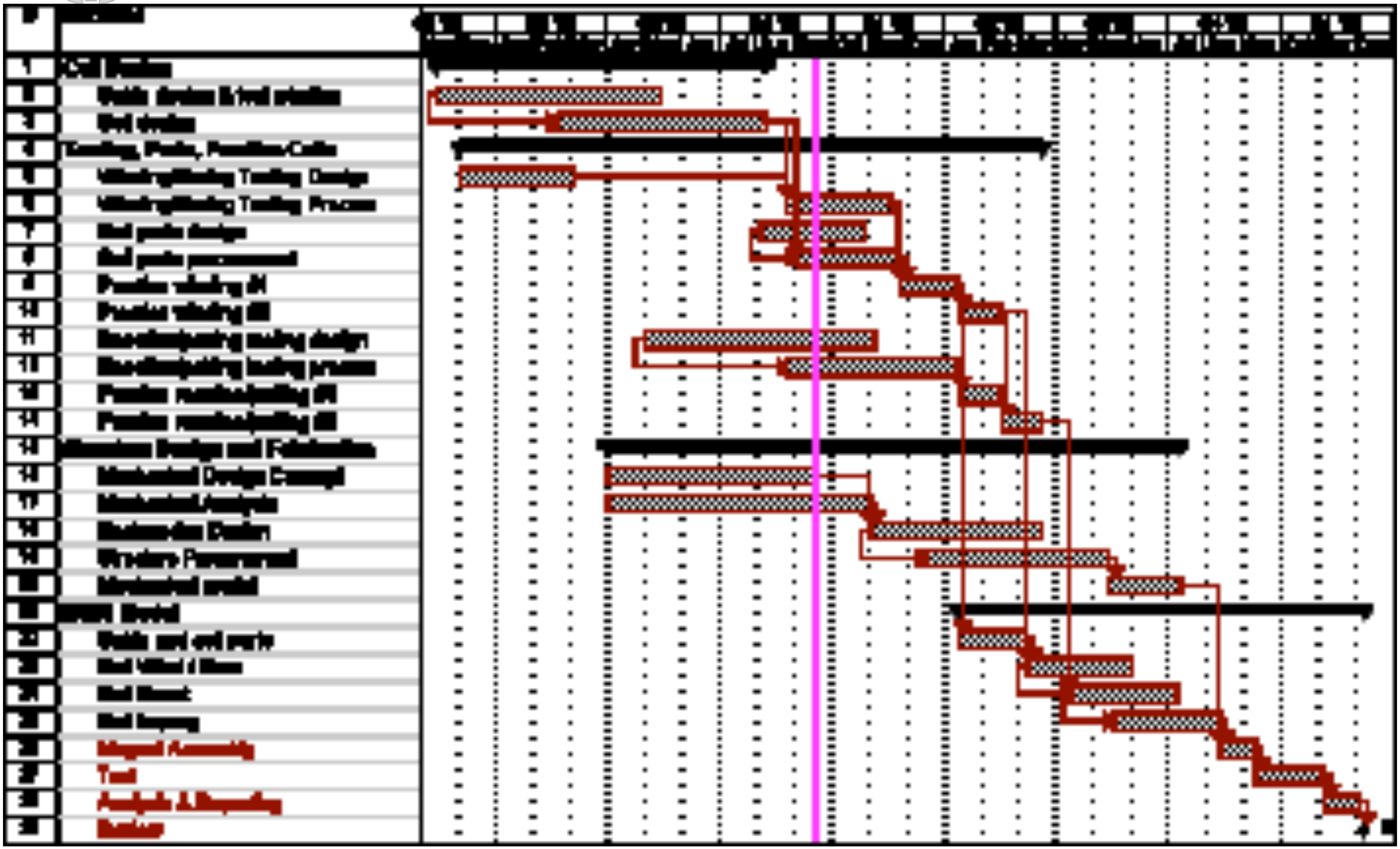




Reaction tooling



HQ Schedule (updated 9/18/08)



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Summary

- We have 90m of cable to wind first practice coil
- Design of coils, spacers, end-shoes, layer-to-layer transition completed.
- Shipment of tooling for winding and curing in the next few weeks
- Reaction and potting tooling in final design stage.
- 3D magnetic design completed.
- 3D analysis of structure and assembly underway.