SC magnet developments at CEA/Saclay

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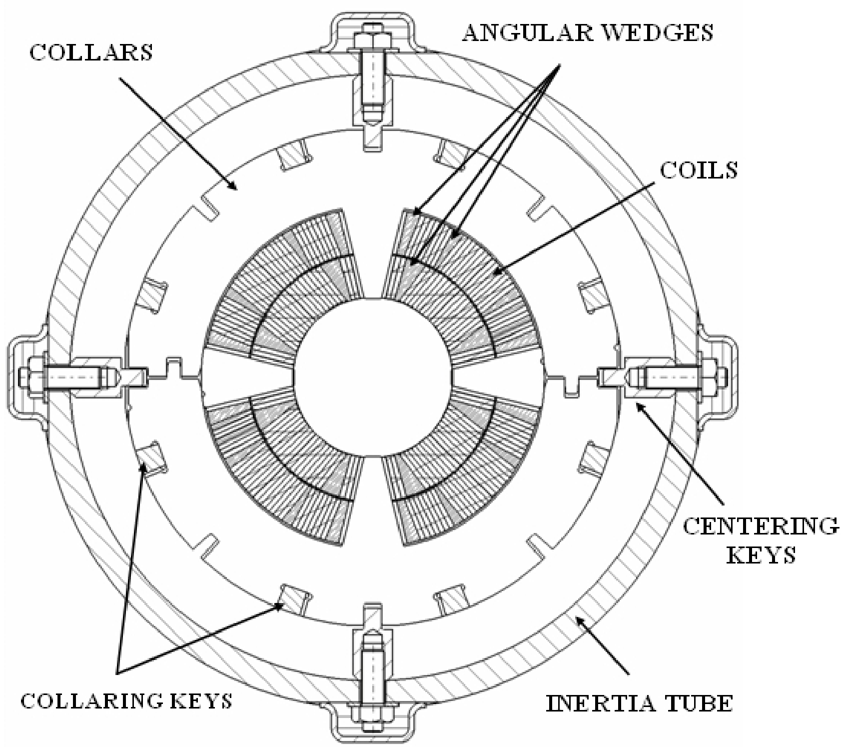
Plan

- Nb_3Sn quadrupole magnet model – M. Durante
- Dipole design studies – H. Felice
- Subscale Dipole – H. Felice

Nb_3Sn Quadrupole Program Main Goals

- Get an experience in the Nb_3Sn technology keeping in mind the industrialization process
- Build a 1-m-long quadrupole magnet model, 56-mm single aperture, with no magnetic yoke
- Model design based on the design of LHC arc quadrupole magnets

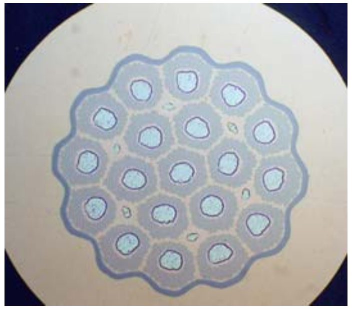
Gradient	211 T/m
Current	11870 A
B_{peak}	8.3 T
Lenght	1 m



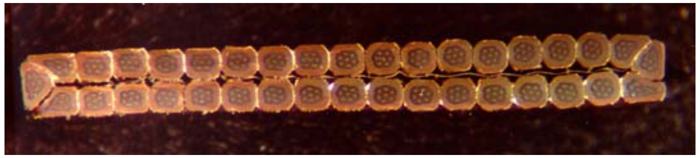
Cross sectional view of the assembly

Pole components

- Rutherford-type cable developed in collaboration with ALSTOM MSA
- Relying on available Nb_3Sn wires



• 36 strands • a 25-µm-thick stainless steel core



• Width : 15.1-mm
• Mid-thickness : 1.48 mm
• Keystone angle : 0.9°

• Strand Ø : 0.825 mm
• Jc (4.2K, 12T) : 750 A/mm2
• Effective filament Ø : 19 µm

Actual collaboration with ALSTOM MSA
Jc (4.2K, 12T) : 2000 A/mm2

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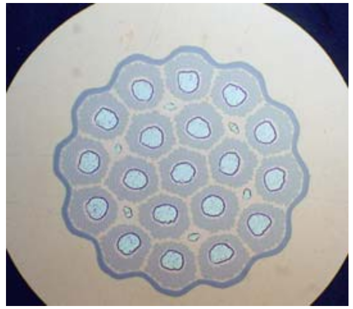

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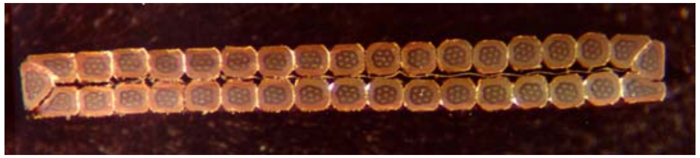

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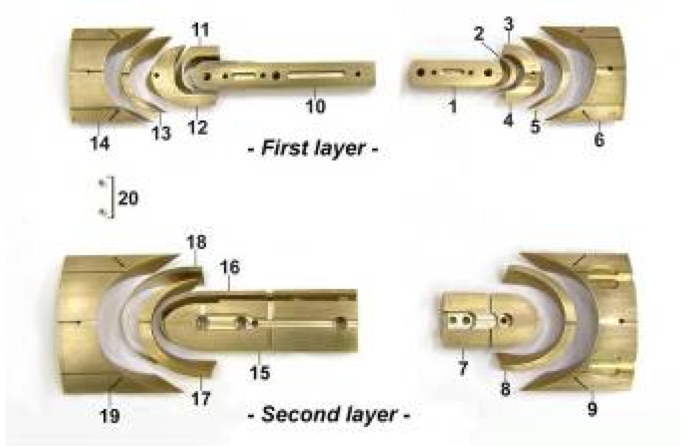
- Cable insulation relying on S2-glass fiber tape

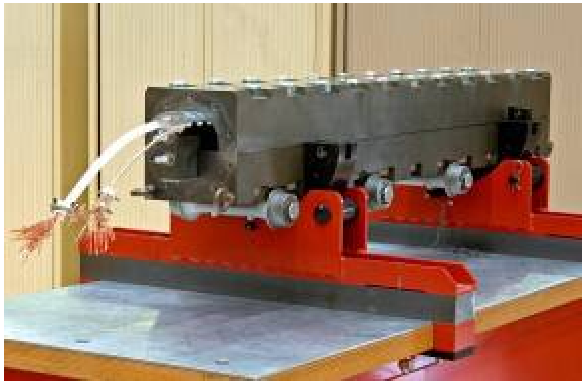
- Angular and End wedges realized in Al-80%wt Cu

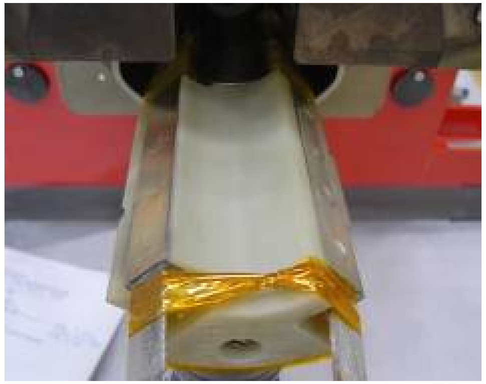
- End wedges insulation and inter-turn insulation made up of 0.1 - mm - thick mica foils



Coil manufacturing

- Nb_3Sn coils will be fabricated by the « Wind, react & impregnate » technique :

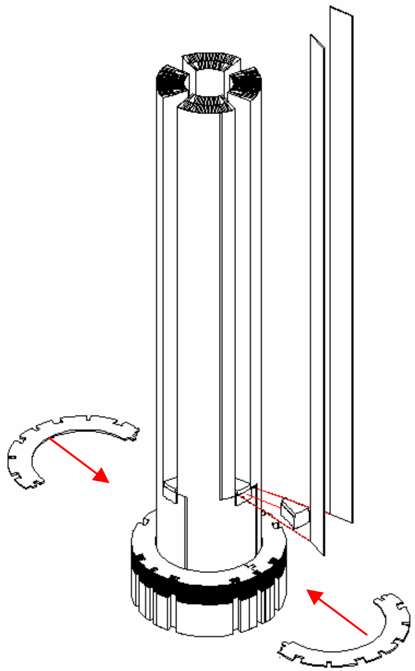



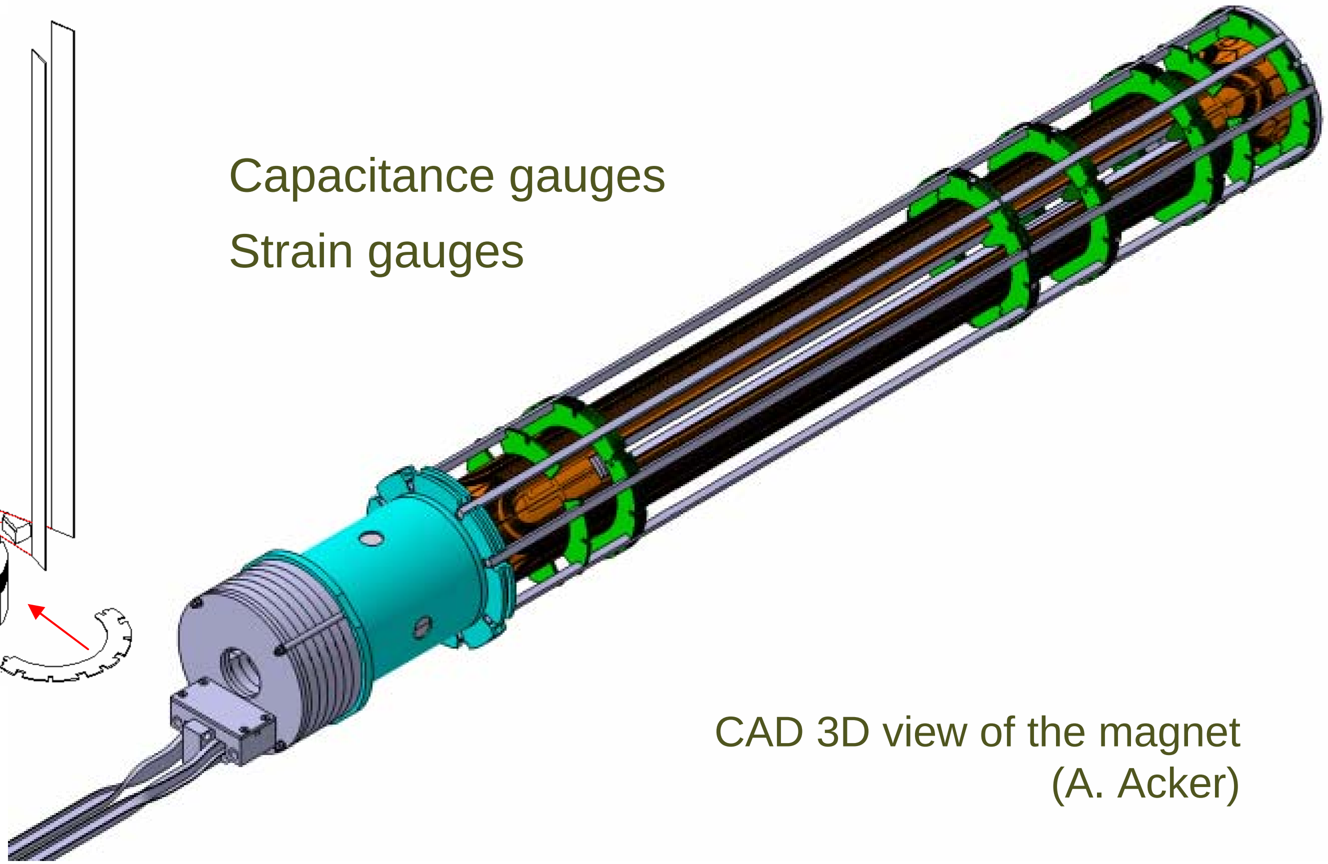
- Each coil is equipped with 13 voltage taps (9 in the end parts, 4 in splice region)

- The fabrication of one coil takes about 2 months

Magnet assembling

- Magnet assembling process is similar the one for the apertures of LHC quadrupole magnets.



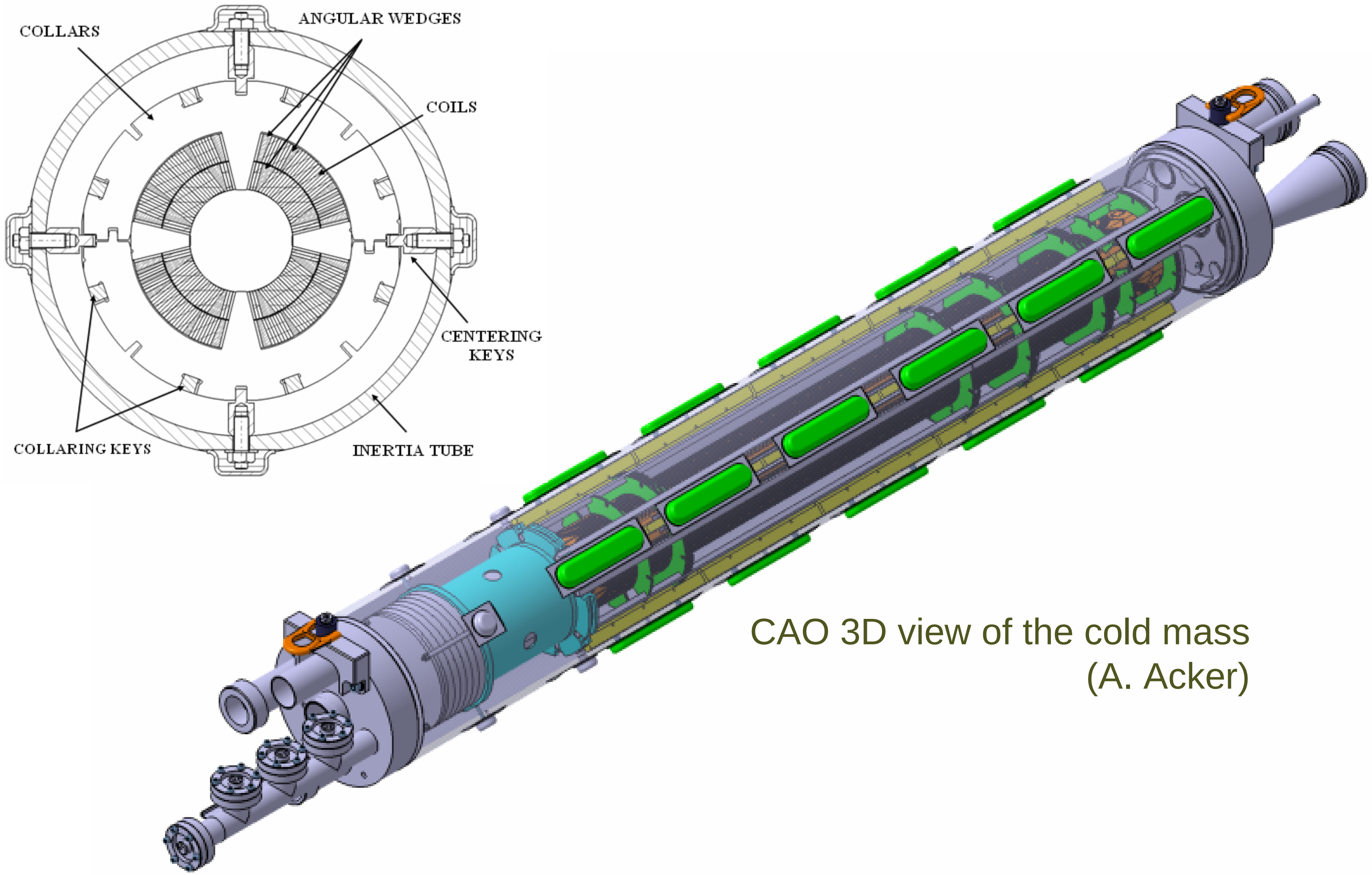


CAD 3D view of the magnet
(A. Acker)

- Collaring will be realized at ACCEL, the German company charged of the manufacturing of the LHC quadrupole magnets

Cold mass assembling

- Cold mass assembling will be realized at Saclay



CAO 3D view of the cold mass
(A. Acker)

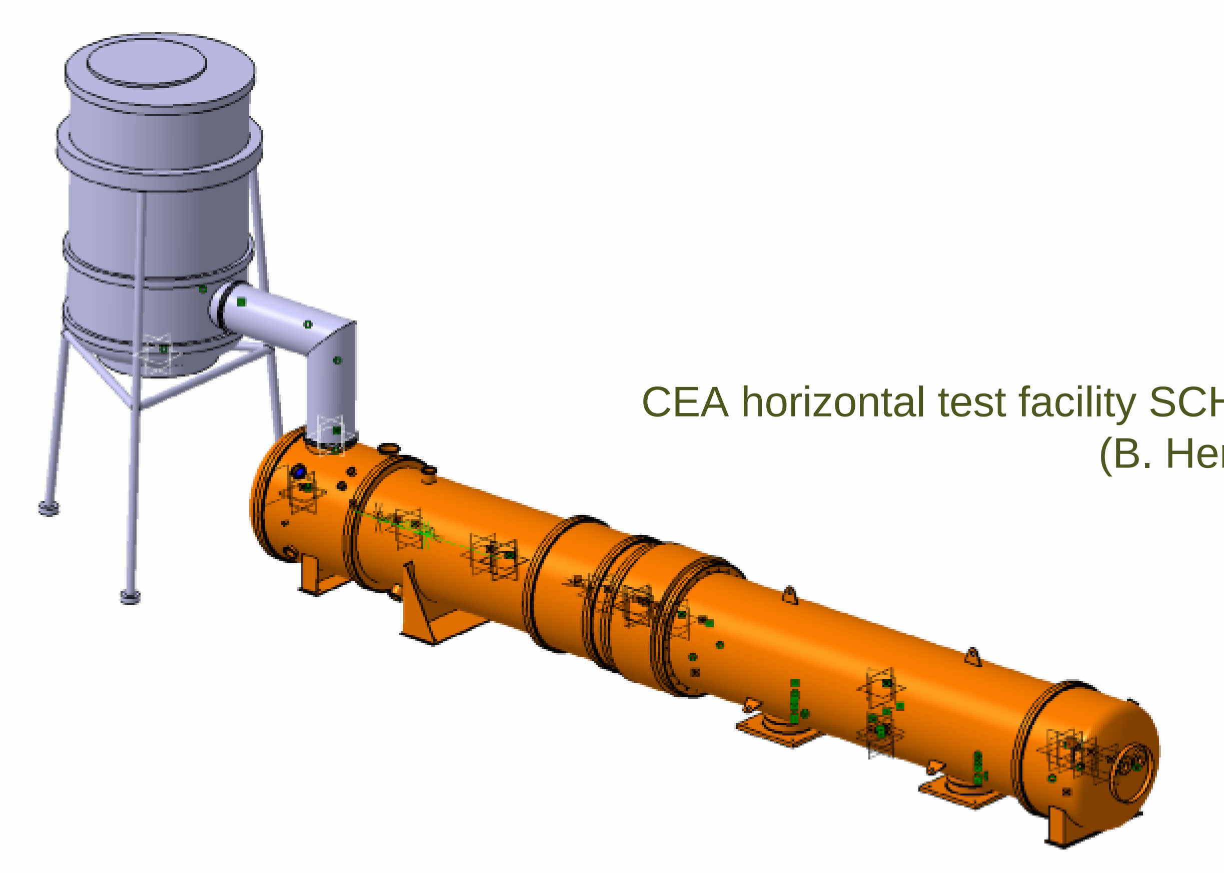
Magnet manufacturing schedule

- 2 dummy coils have been manufactured to validate coil fabrication procedures
- These coils have been used to make collaring tests to validate magnet assembling procedure
- 4 coils relying on certificate cable have been manufactured
- A fifth coil is actually under winding
- If necessary we have components for a further coil

- Magnet assembling is foreseen for January 2007
- Cold mass assembling is foreseen for March 2007

Cold tests - Phase I

- The magnet model will be tested in an horizontal cryostat at CEA



CEA horizontal test facility SCHEMa
(B. Hervieu)

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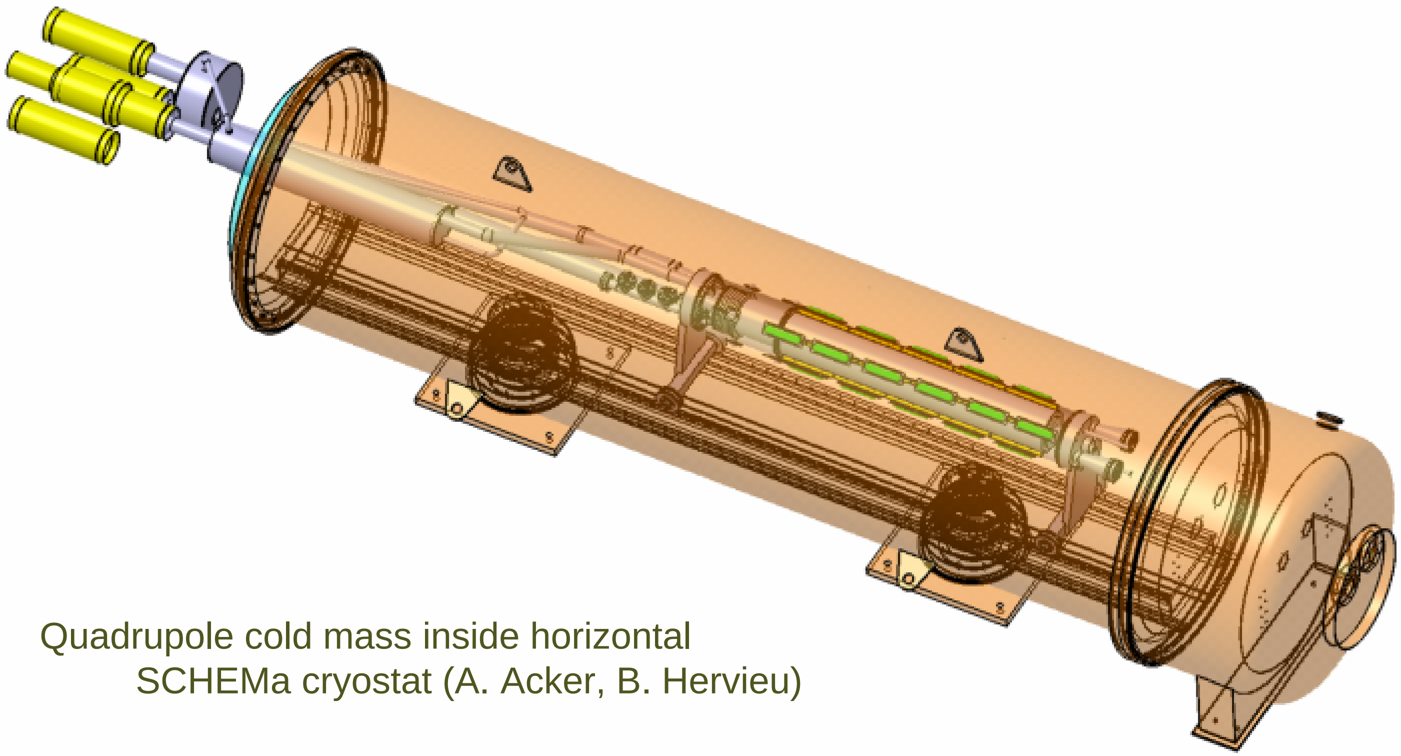
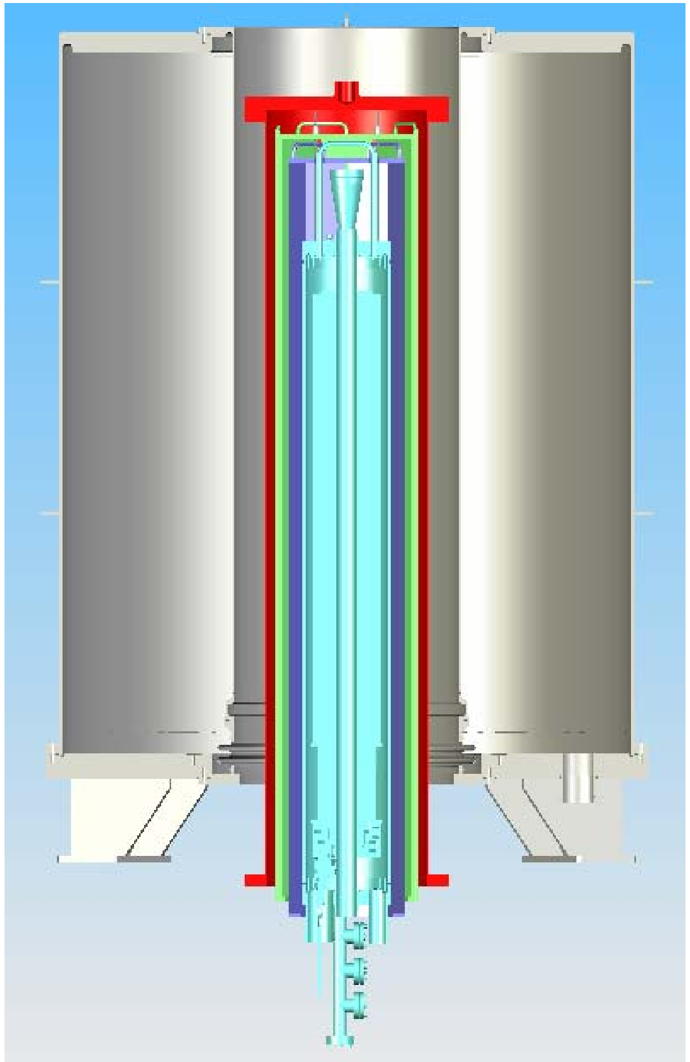


Quadrupole cold mass inside horizontal SCHEMa cryostat (A. Acker, B. Hervieu)

- Cold tests of the magnet are foreseen for June – September 2007

Cold tests – Phase II

- In a second phase, the magnet will be tested in an external solenoidal field
- This part of studies and tests are carried out within the framework of the EUROTeV Design Study
- The return end of the quadrupole will be in the central field of the solenoid (4 T)
- The lead end of the quadrupole will be in the fringe field of the solenoid
- The studies for the vertical cryostat should start at the beginning of 2007



Quadrupole cold mass inside SEHT cryostat (B. Hervieu)

Context of the study

General context : - need of large aperture (above 88 mm) and high field (13-15T) superconducting magnets for LHC luminosity upgrade

- preparation of the next step with aperture above 130 mm

What the state of the art shows :

-NbTi has reached its limit with the LHC use of Nb_3Sn

-Nb_3Sn is stress sensitive (limit around 150 Mpa)

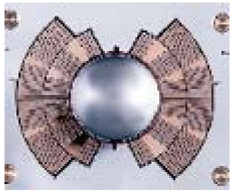
-Cosθ design produces large stresses on coil mid plane for high field and large aperture dipoles

Consequences :

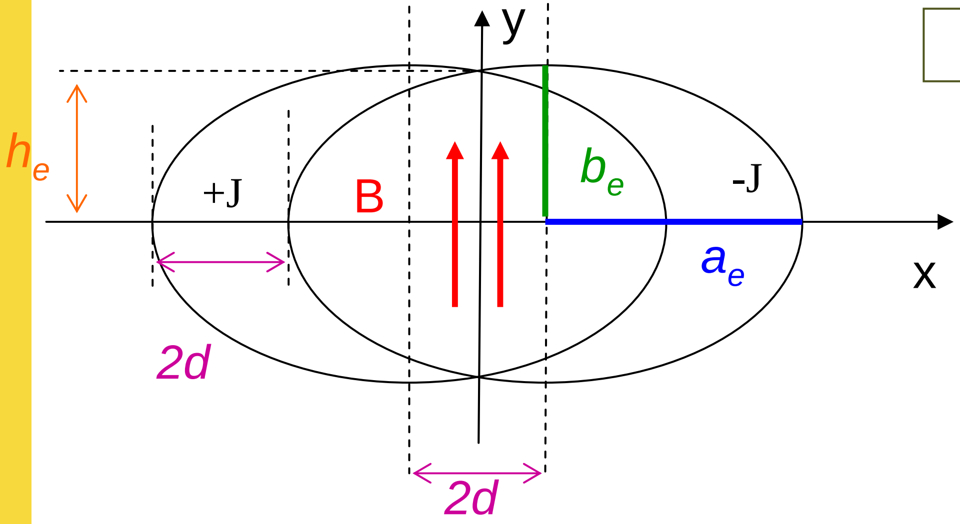
Need to explore new dipole designs to reach high field in large aperture

Need to understand the influence of the prestress on Nb_3Sn magnet training

Need to better know the mechanical stress above it the Nb_3Sn is degraded



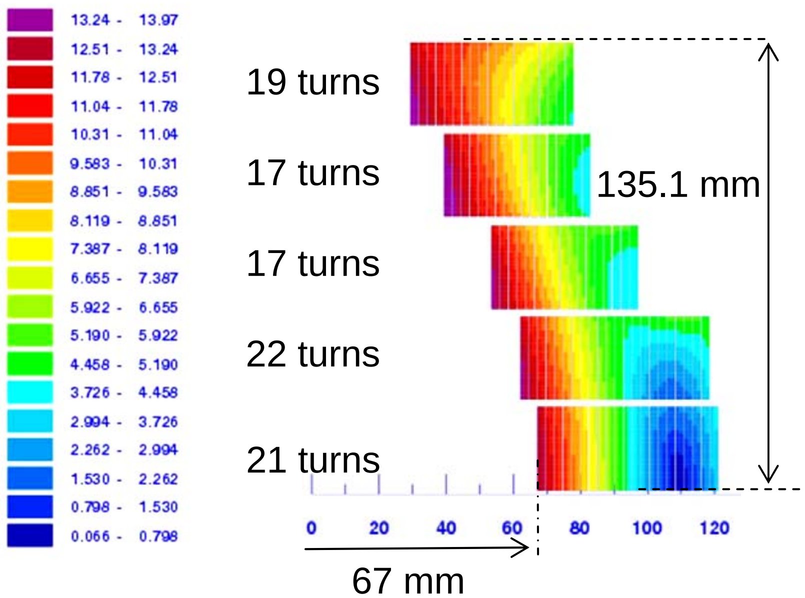
Dipole design study



Magnetic flux density

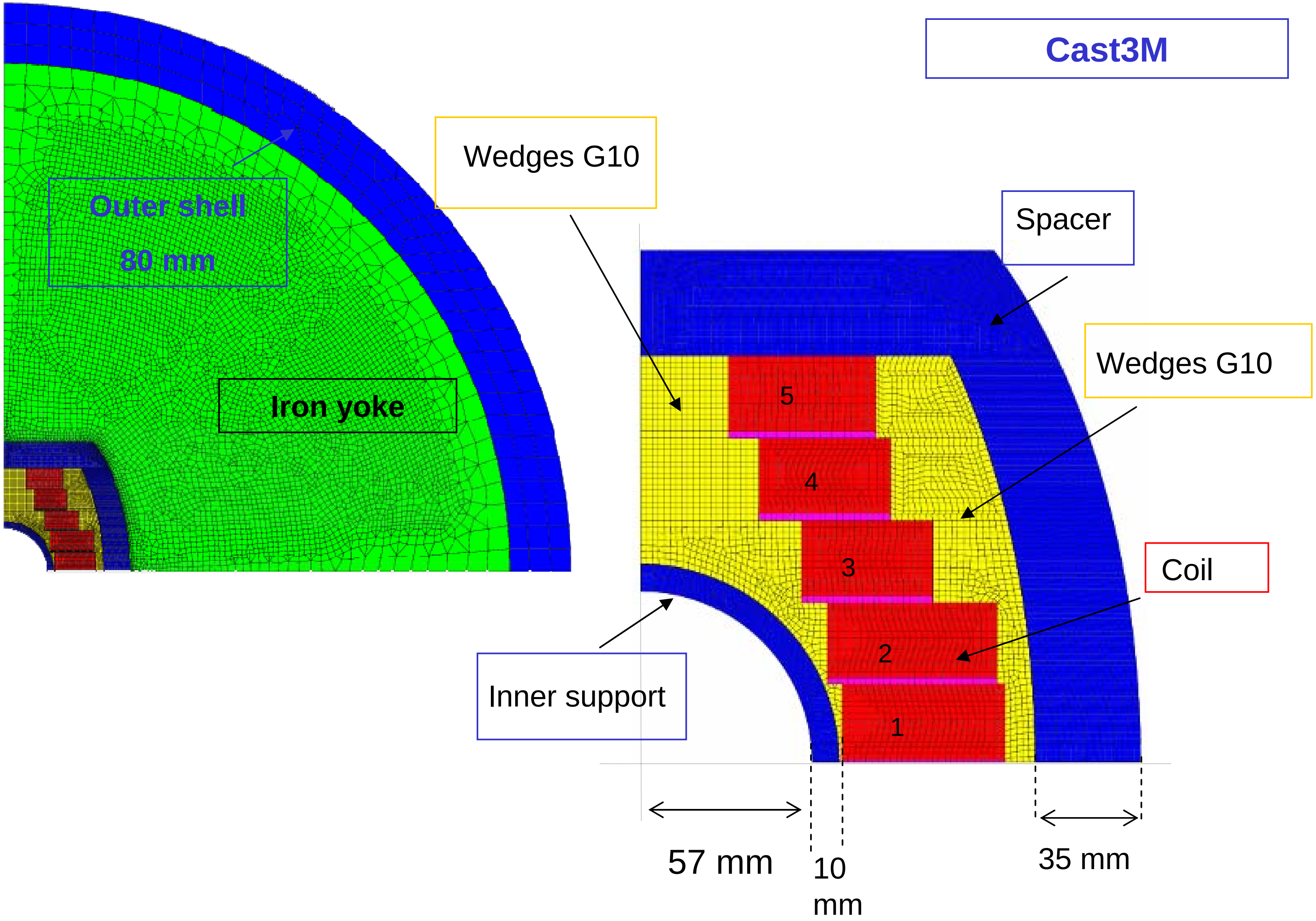
$$B_{ellips} = \mu_0 \frac{J b_e}{a_e + b_e} 2d$$

ROXIE



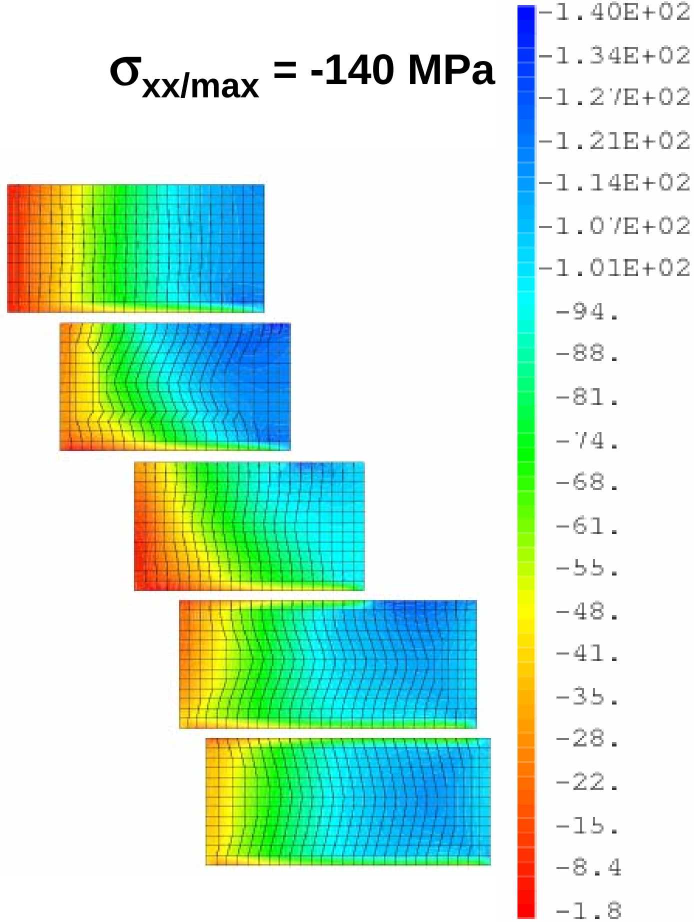
Ouverture	B_0	B_{max}
88 mm	13.54 T	13.97 T
130 mm	13.32 T	13.98 T
160 mm	13.37 T	14.03 T

Mechanical behaviour of the windings

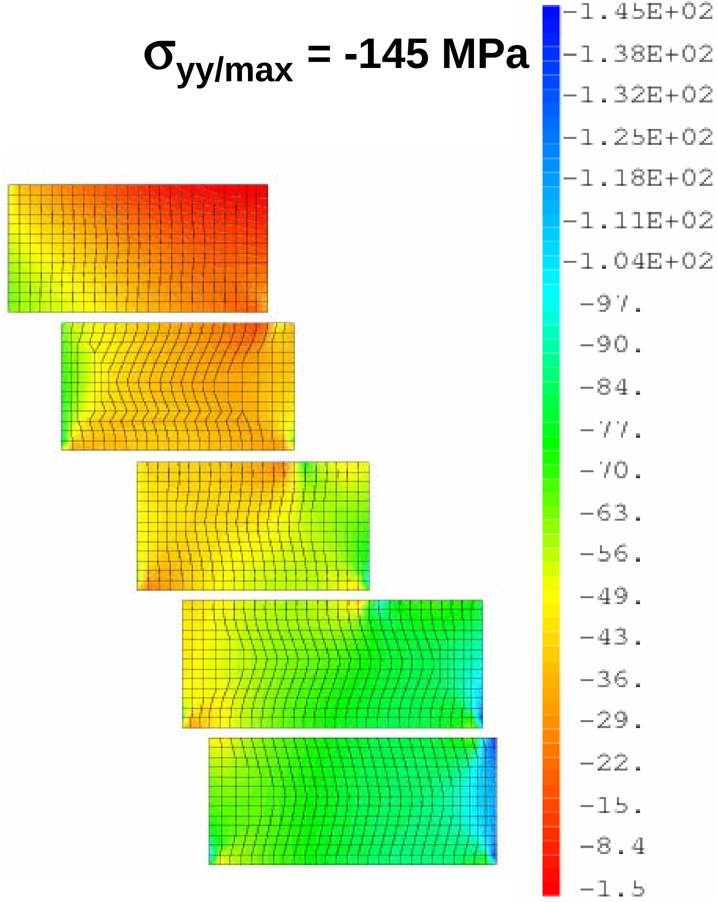


Mechanical behaviour of the windings

σ_{xx} MPa



σ_{yy} MPa



Aperture 130 mm

Subscale Dipole

Motivations and goals

-**Study of the pre-stress influence on Nb_3Sn coil training in a dipole configuration**

- Racetrack coil design from LBNL Subscale Magnet Program

- Mechanical structure (collaboration CEA Saclay / LBNL) to allow variable pre-stress on coil

    -Assembly with key and bladders

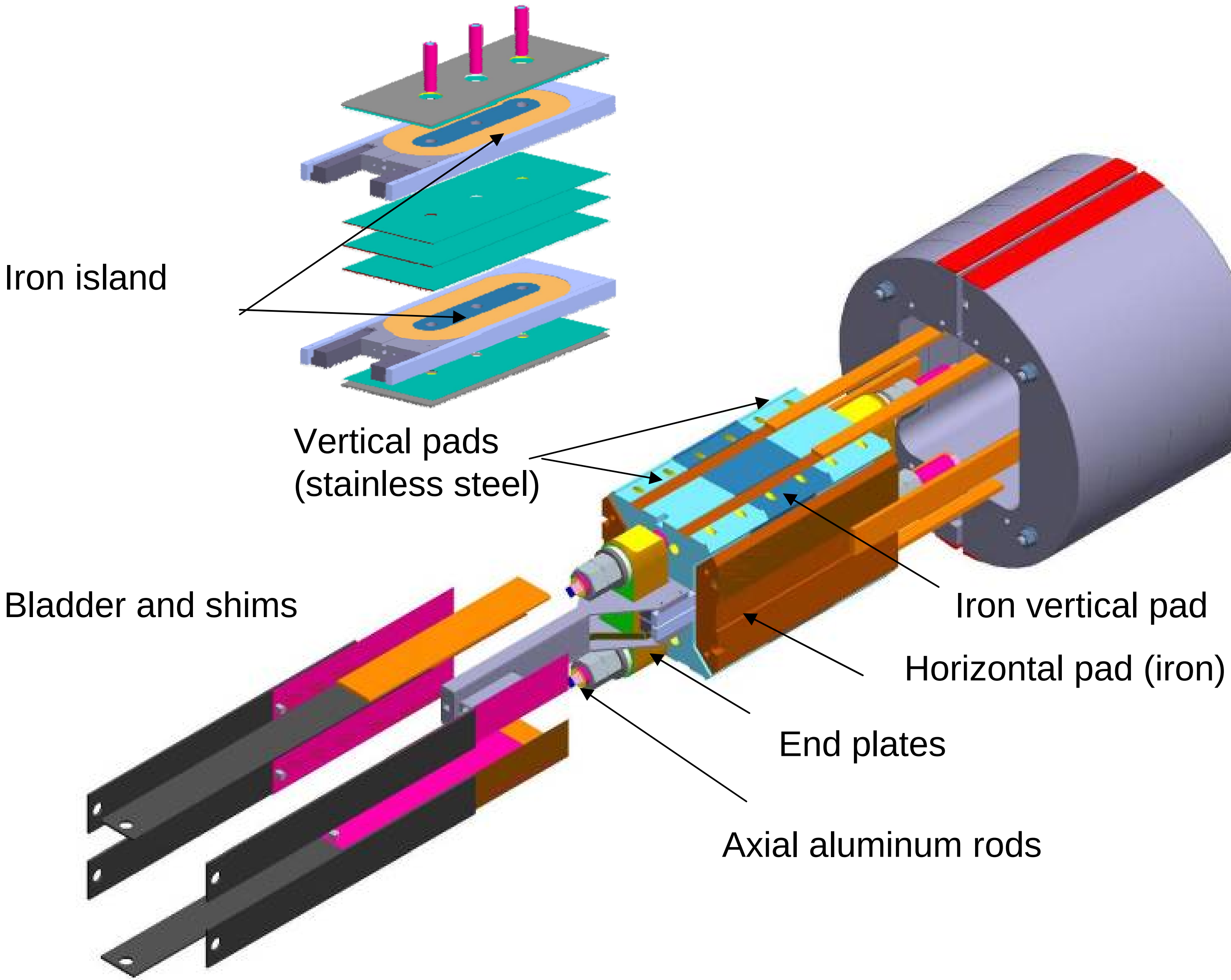
    -Aluminum shell

    - Axial rods

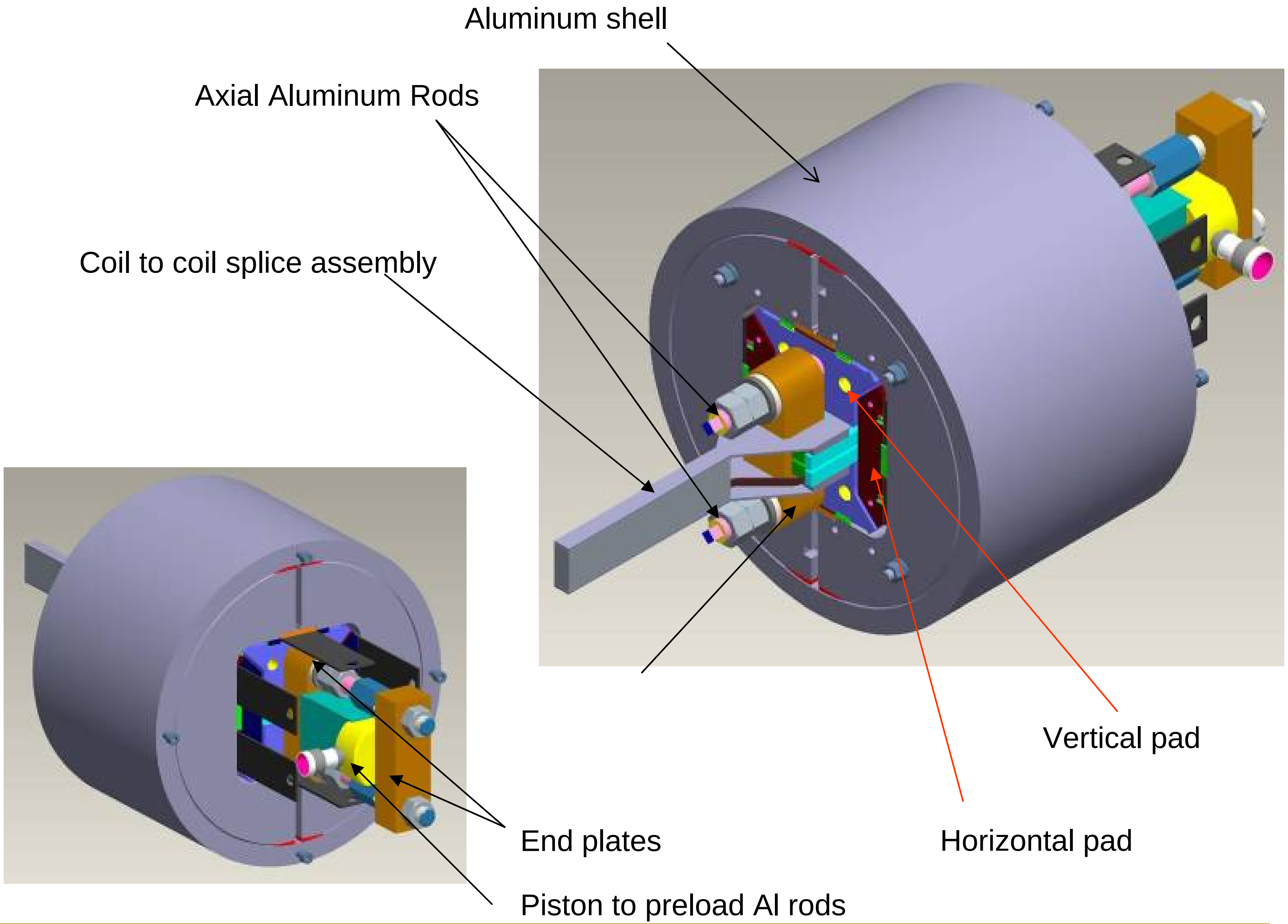
Collaboration with LBNL

- **Racetrack coil delivery**: LBNL (SC01 and SC02 coils)
- **Design of a new external mechanical structure** : collaboration LBNL / Saclay
- **Mechanical Structure Manufacturing**: CEA Saclay
- **Instrumentation and Assembly** : LBNL
- **Tests** : LBNL in June 2006

SD01 3D (I)


Iron island
Vertical pads
(stainless steel)
Bladder and shims
Iron vertical pad
Horizontal pad (iron)
End plates
Axial aluminum rods

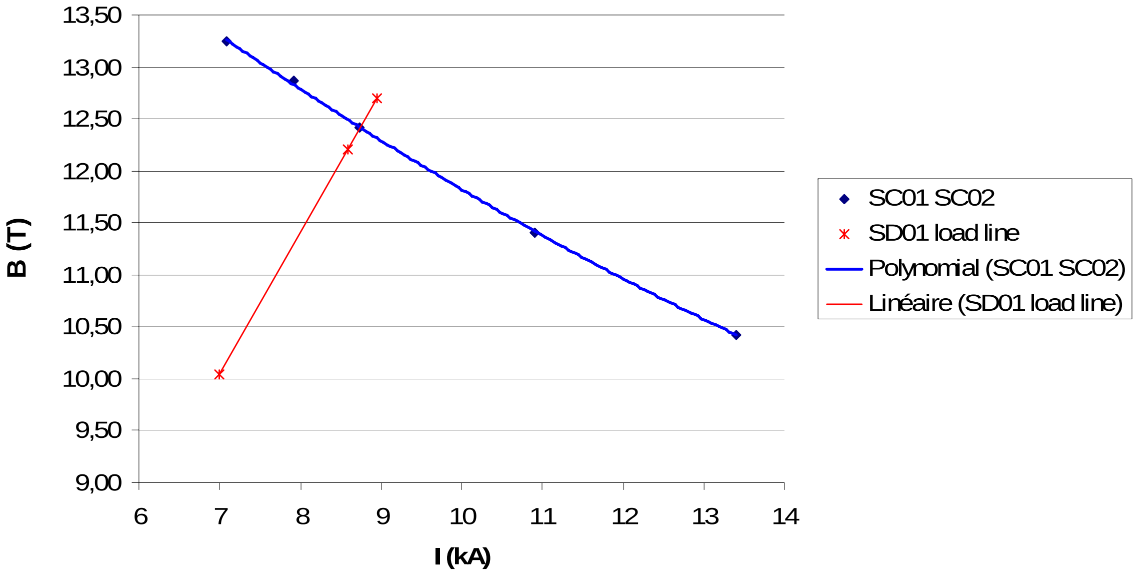
SD01 3D (II)



Aluminum shell
Axial Aluminum Rods
Coil to coil splice assembly
Vertical pad
End plates
Horizontal pad
Piston to preload Al rods

SD01 : magnetic model

Opera3D



I_{ss} = 8750 A

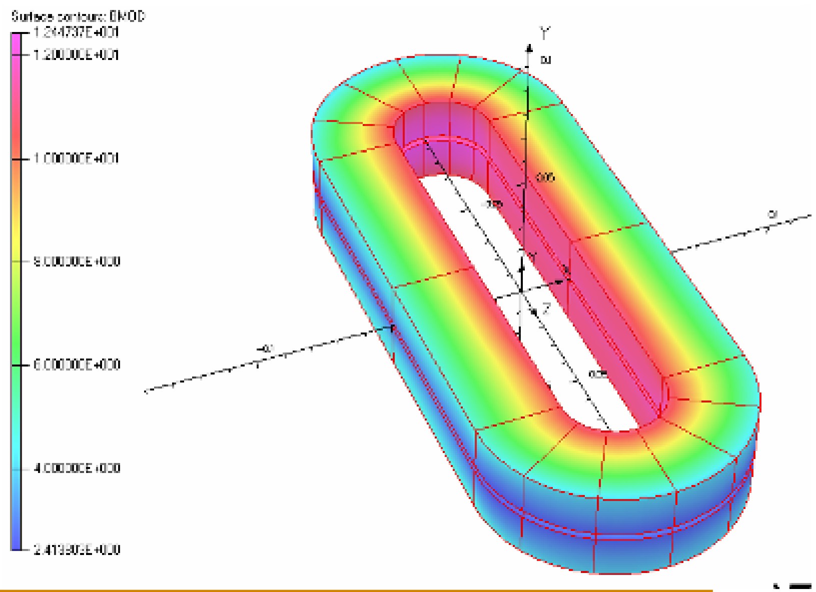
B_0 = 11,68 T

B_{end} = 12,45 T

B_{ss} = 11,45T

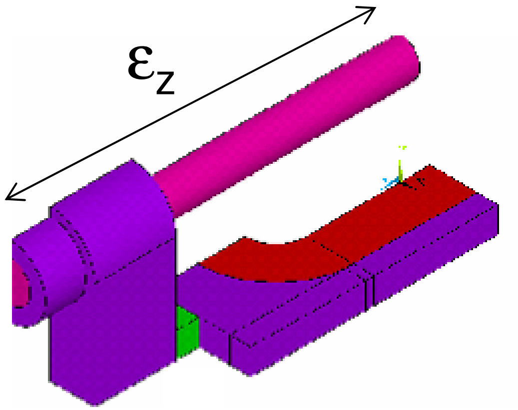
$F_{z/end}$ = 85 kN

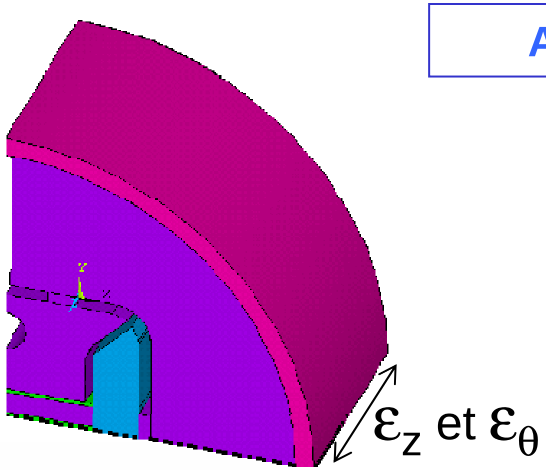
Peak field located in the coil ends

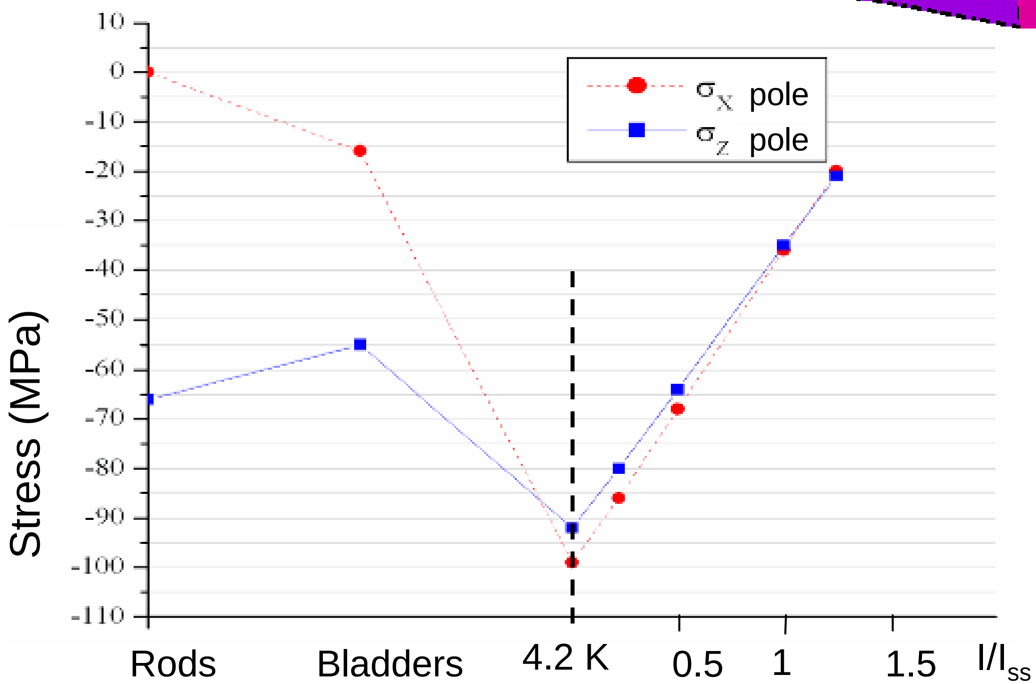


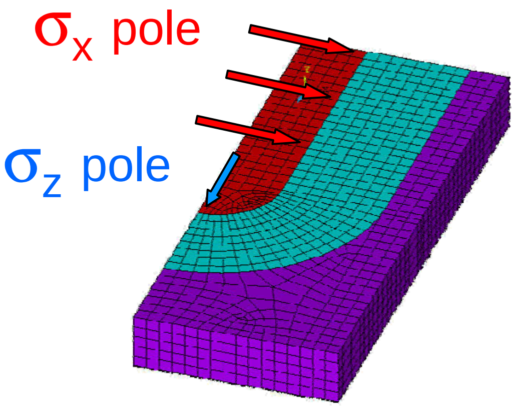
SD01 : mechanical model

Ansys

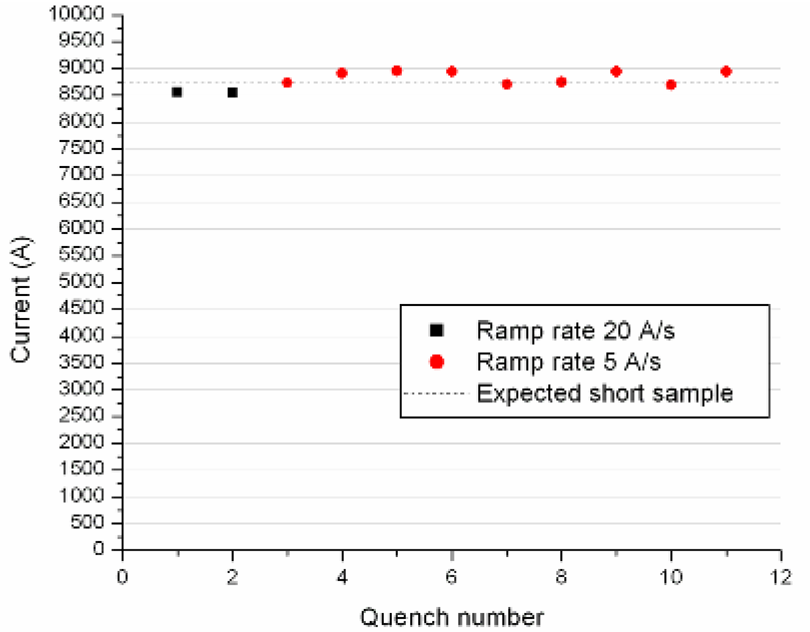




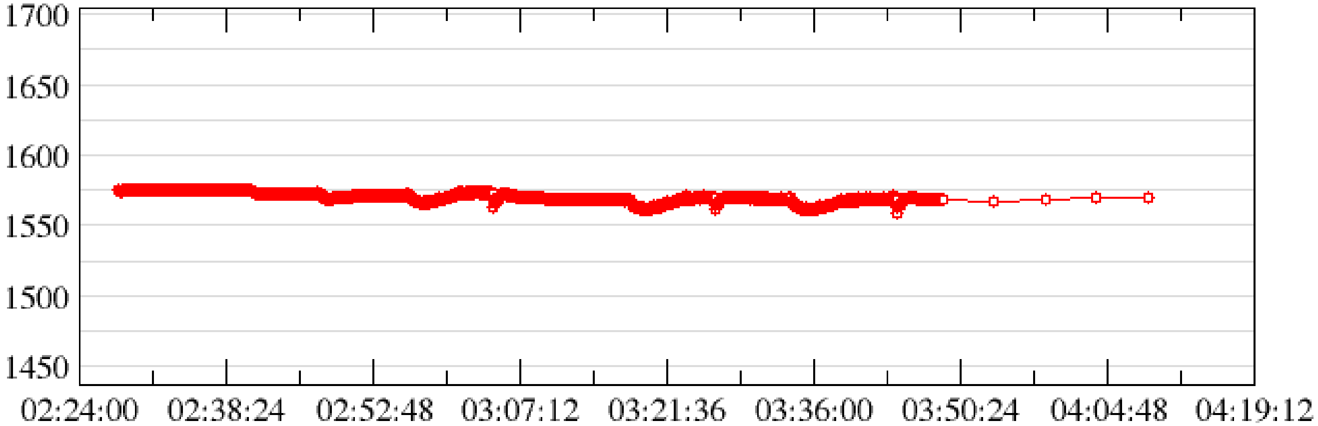




SD01: test result



Shell



Validation of the magnetic and the mechanical model