Nb3Sn Final Focus Magnets

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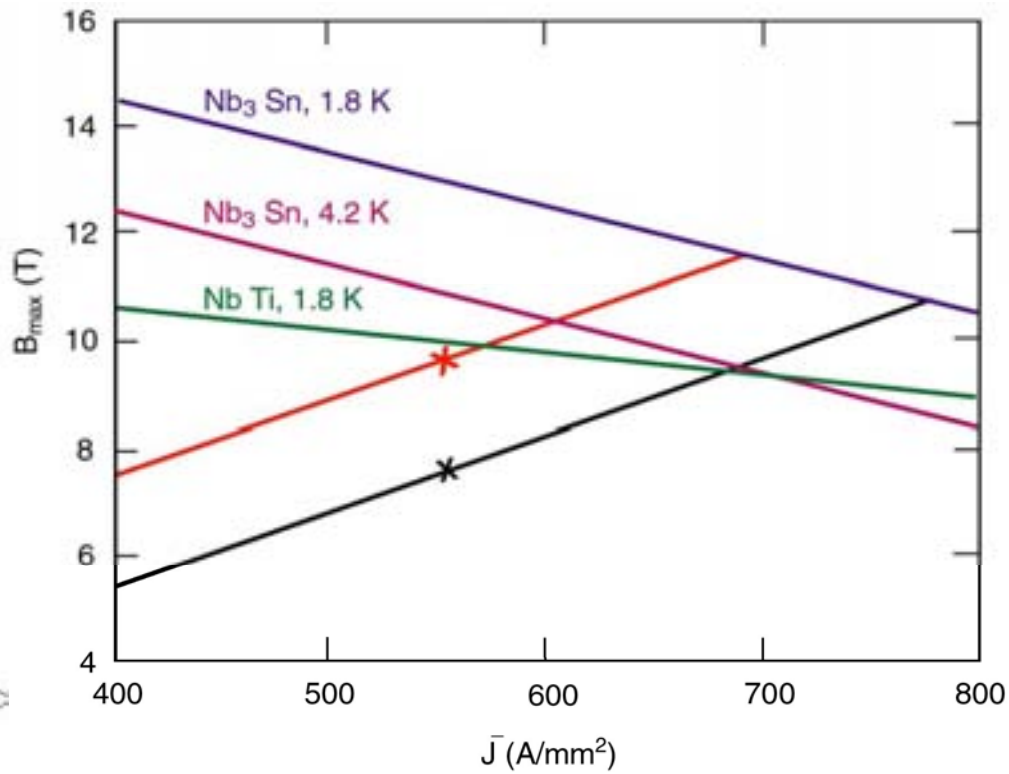
Content

- Introduction
- The Nb3Sn Quadripole Prototype Project (EUROTeV)
- Design of a 70 mm diameter aperture quadrupole
- Shorter 4 T solenoid design
- Sextupoles (nothing done up to now)

Nb_3Sn Quadrupole Program Main Goals

- Motivation for Nb3Sn technology : external 4T solenoid field (TESLA TDR)
- Nb3Sn Dipoles shoot for 15 T field (cf. CARE/NED)



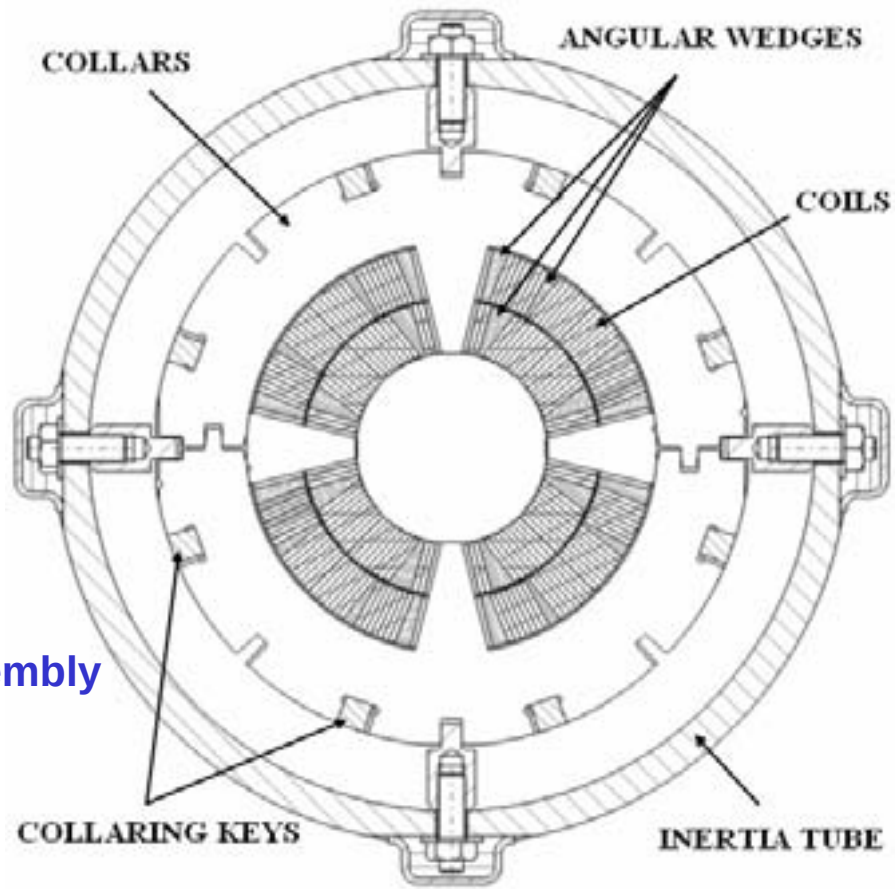
TESLA quadrupole inside the solenoid
$B_{max} = f(J_c)$

X Quadrupole alone (Ø 56 mm, G = 250 T/m)
X Quad + 4T solenoid

Nb_3Sn Quadrupole Program Main Goals

- Build a 1-m-long 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

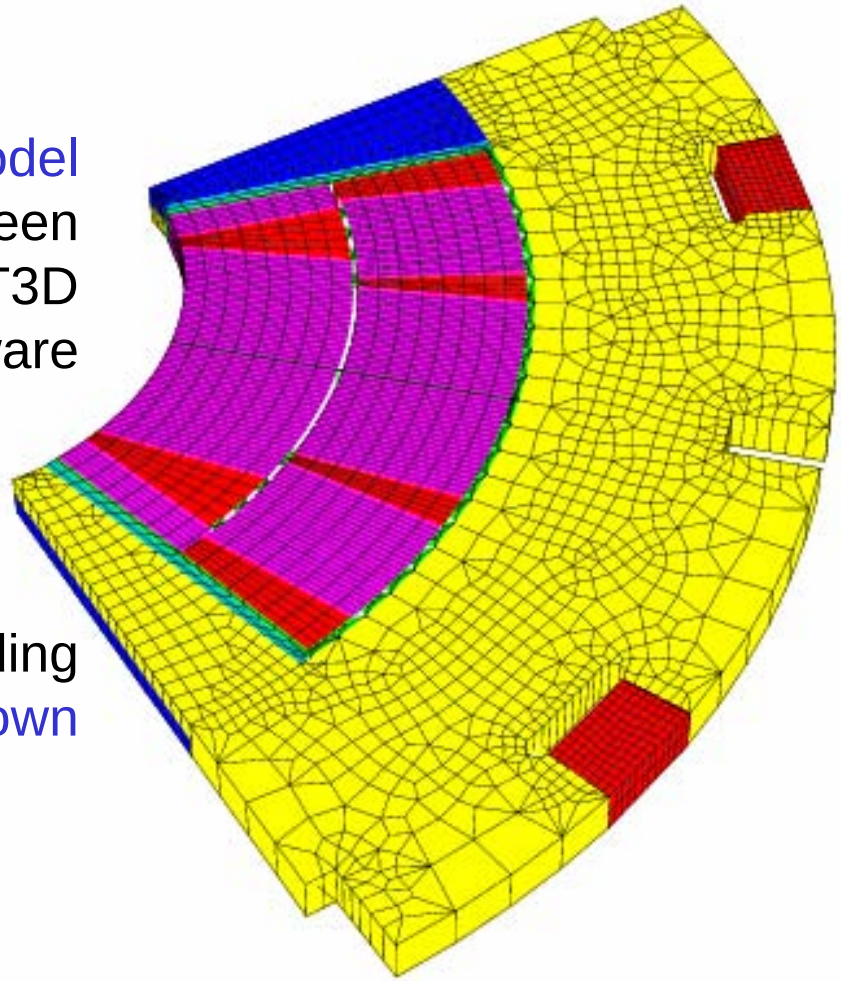


Cross sectional view of the assembly

Mechanical Design

Electromagnetic and mechanical design is similar to the design of the LHC arc quadrupole magnets.

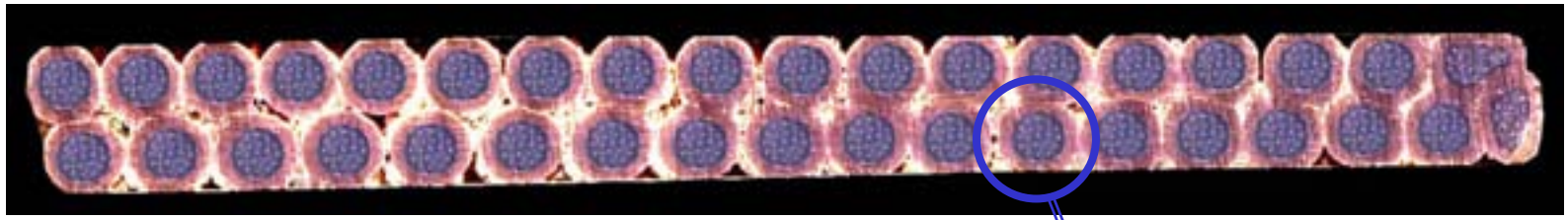
A 3D contact finite-element model of the structure has been developed using the COFAST3D module with CASTEM software package



All successive steps of loading history, from collaring to cool-down and to excitation are described.

Pole components

- Rutherford-type cable developed by ALSTOM MSA

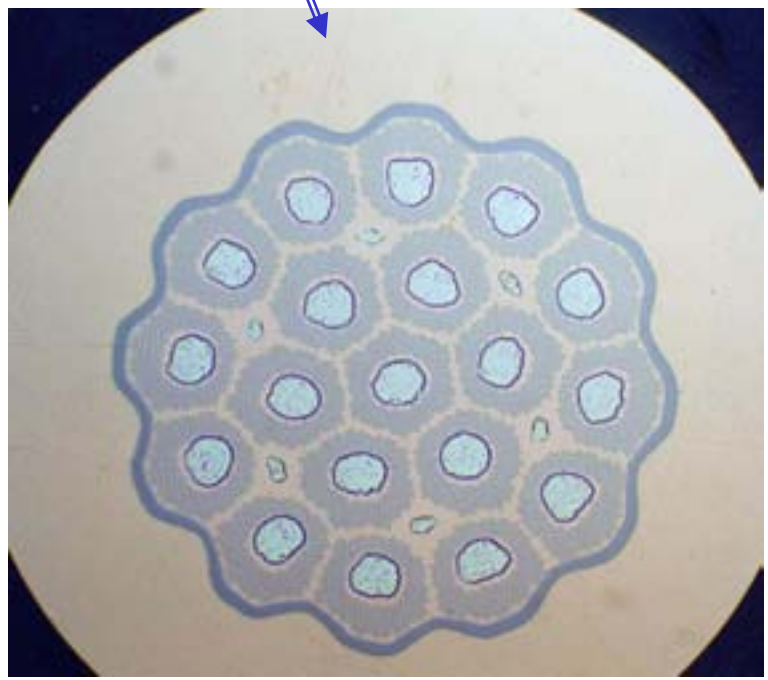


36 strands
25-µm-thick stainless steel core

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

Strand Design is based on Internal Tin process

Strand Ø : 0.825 mm
Jc (4.2K, 7T) : 1850 A/mm^2
Effective filament Ø : 19 µm

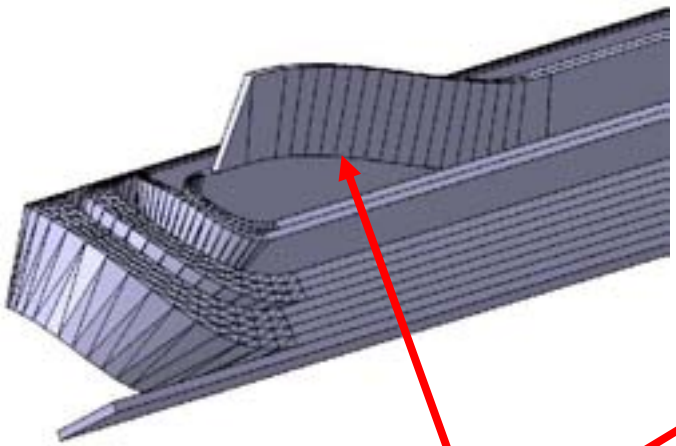


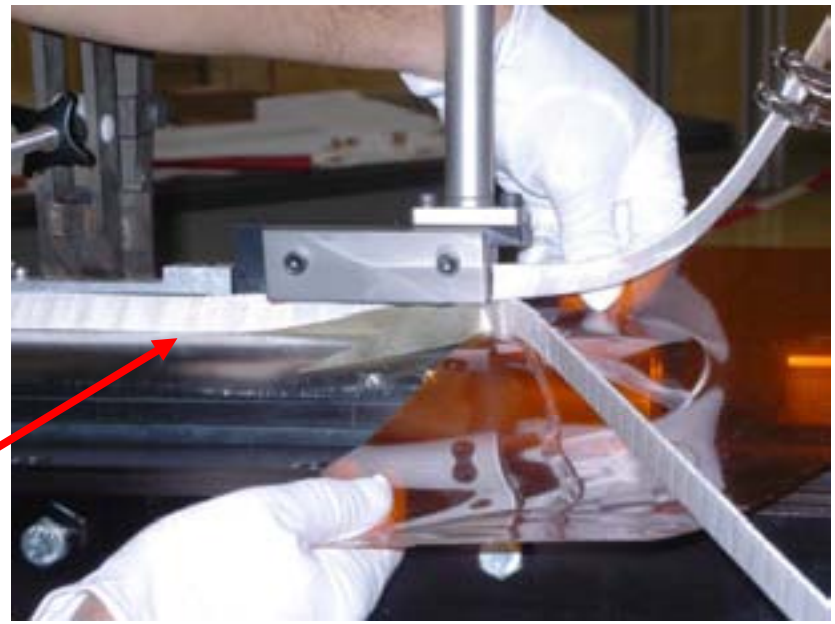
Fabrication process

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

- Coil winding

In one go, with no internal splice





First to second layer transition

Fabrication process

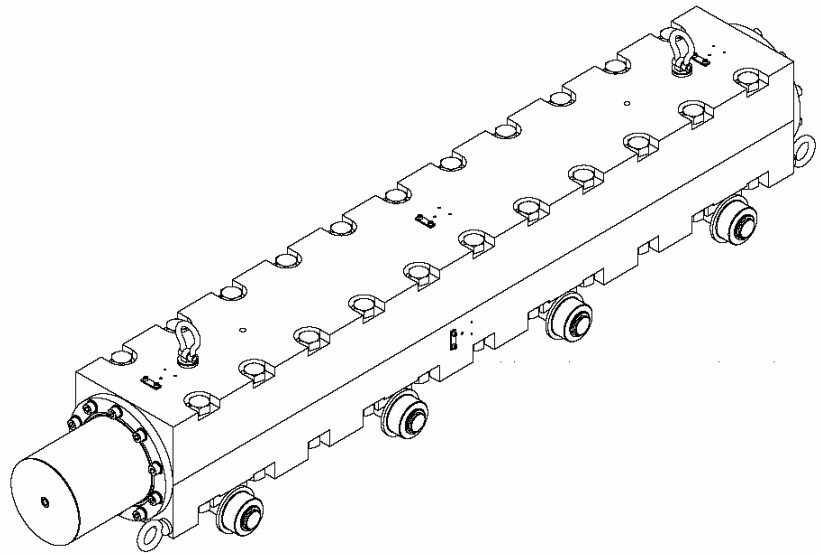
Nb_3Sn coils will be fabricated by the « Wind, react & impregnate » technique :

- Coil winding

Fabrication process

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

- Coil winding
- Heat treatment



240 hrs at 660°C
in argon flow

Fabrication process

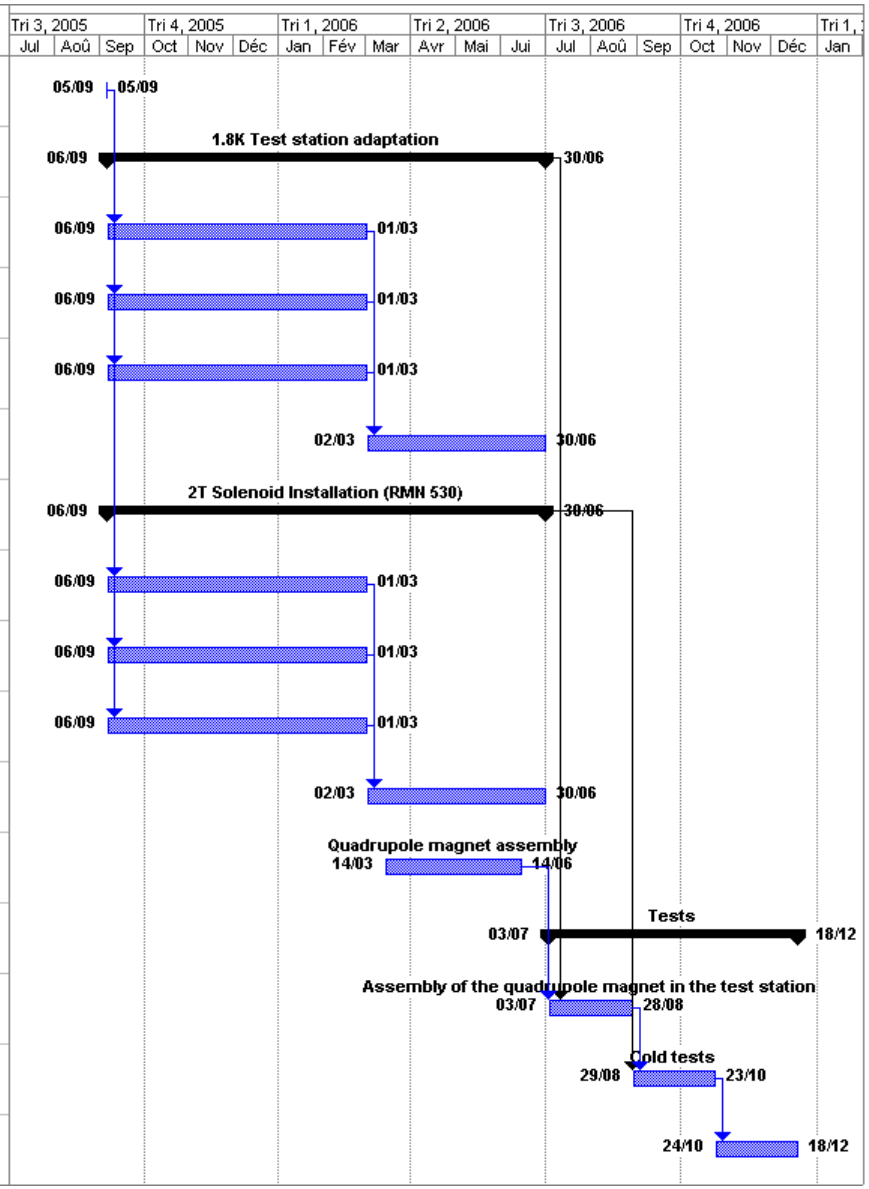
- Continuation of fabrication of the LHC arc quadripoles at ACCEL: tooling will available right after the end of the fabrication early ‘06

7 poles will be fabricated :

- 2 dummy poles
  - → components and procedure validation
  - → collaring tests
- 4 poles for the model
- 1 spare pole

Schedule

N°	Nom de la tâche
1	START of PROGRAM
2	**1.8K Test station adaptation**
3	Cryogenic line manufacturing
4	Electrical connection manufacturing
5	Instrumentation manufacturing
6	Mechanical assembly
7	**2T Solenoid Installation (RMN 530)**
8	RMN 530 Cryogenic line manufacturing
9	RMN 530 Electrical connection manufacturing
10	RMN 530 Instrumentation manufacturing
11	RMN530 Mechanical Assembly
12	**Quadrupole magnet assembly**
13	**Tests**
14	Assembly of the quadrupole magnet in the test station
15	Cold tests
16	Test analysis and report



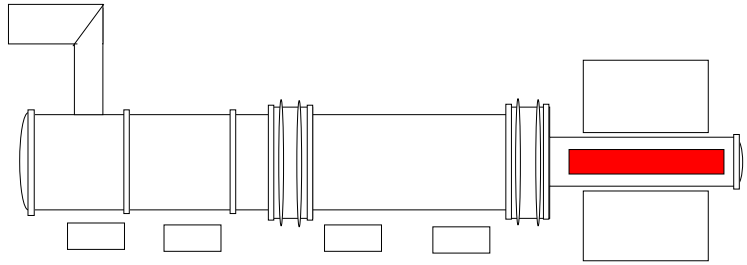
Cold test

RMN 530

* Large superconducting magnet build by CEA for NMR spectroscopy studies on humans at ORSAY hospital - *France*

The cold test will be carried out within the framework of the EUROTeV Design Study.

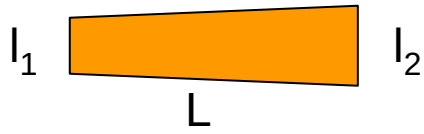
The quadrupole model will be tested at Saclay, alone and in a 2 T sinusoidal background field.

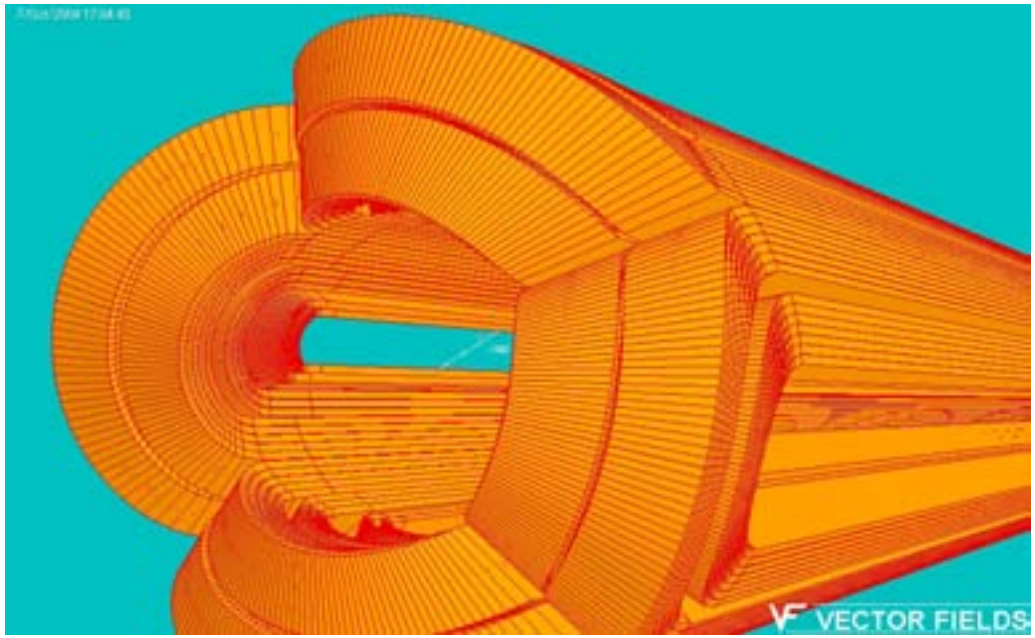


Magnetic Configuration

Study of 1m long LHC-like Nb_3Sn quadrupole (250 $T.m^{-1}$) surrounded by RMN530 solenoid* (2 T)

Quadrupole field simulation





Cable cross section :

36 x 0.25mm strands
Minor edge l_1=**1.362** mm
Major edge l_2=**1.598** mm
Width L=**15.1** mm

One coil simulation :

2861 8-node BRICKS (OPERA-3D conductors)

- Node coordinates of each cross section are converted into conductor file (*.cond*) by external interface program
- Conductors are loaded by *.comi* files into OPERA-3D

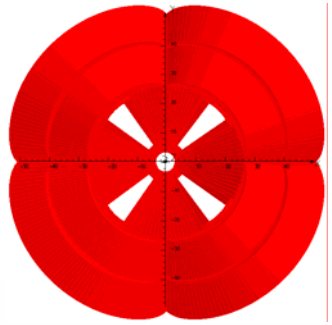
Quadrupole calculation :

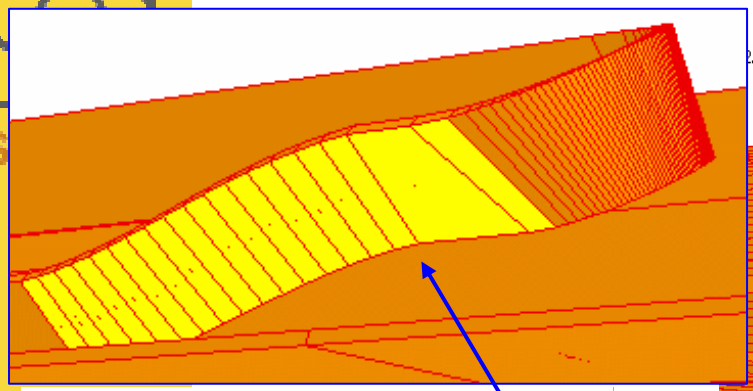
Replication by rotation

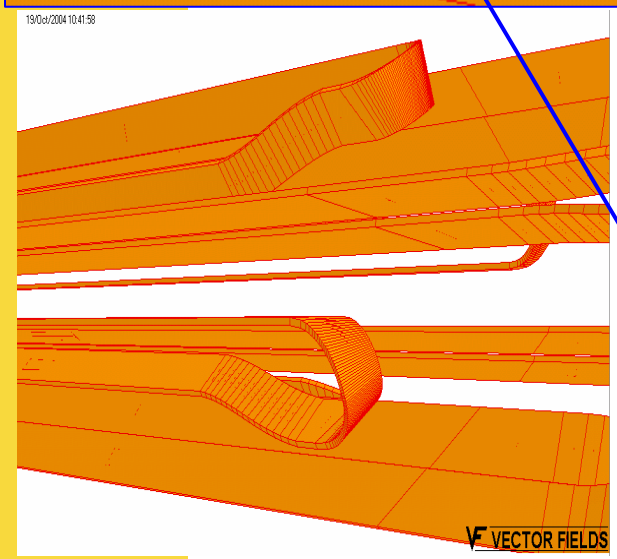
Magnetic Configuration

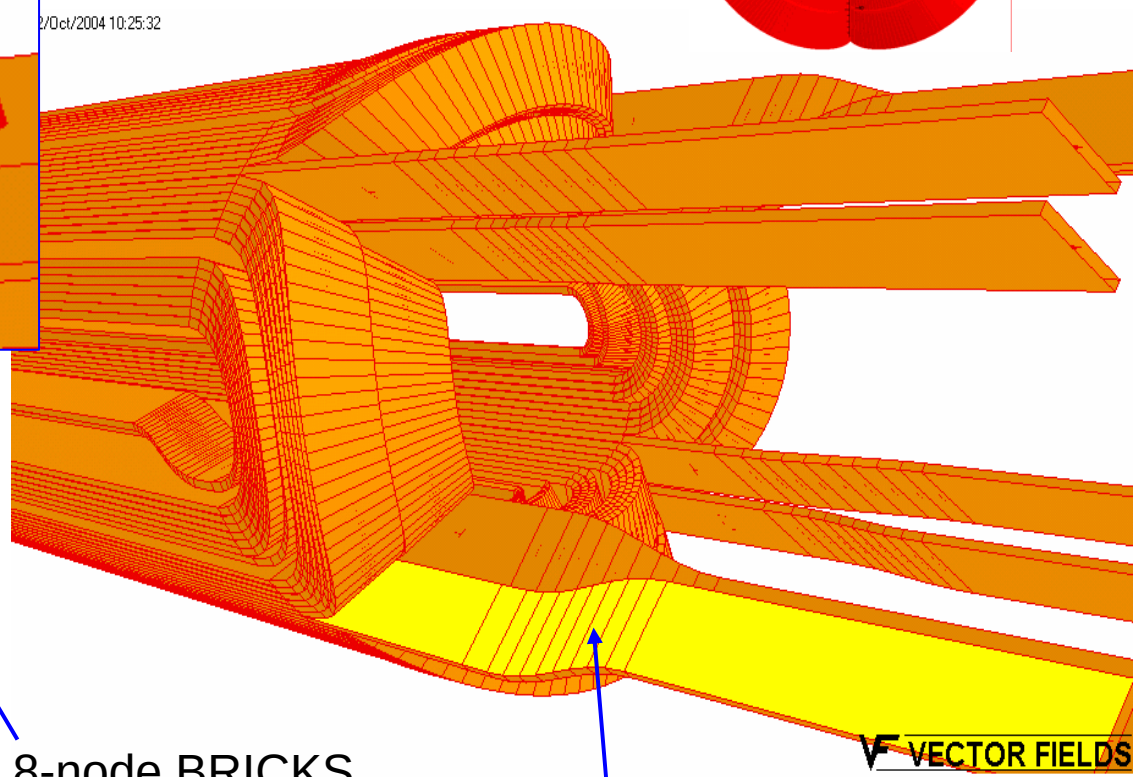
Nb_3Sn quadrupole (250 $T.m^{-1}$)

Quadrupole field simulation







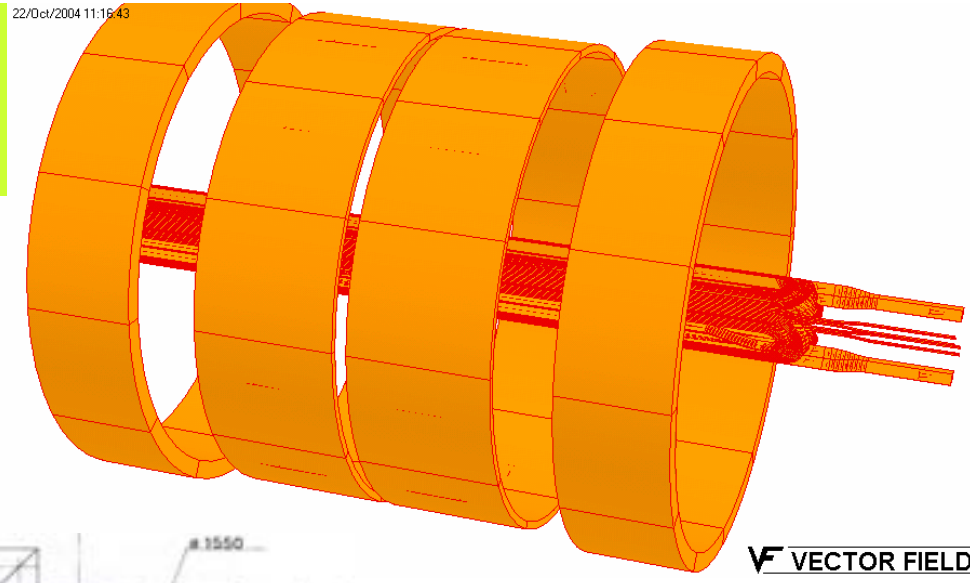


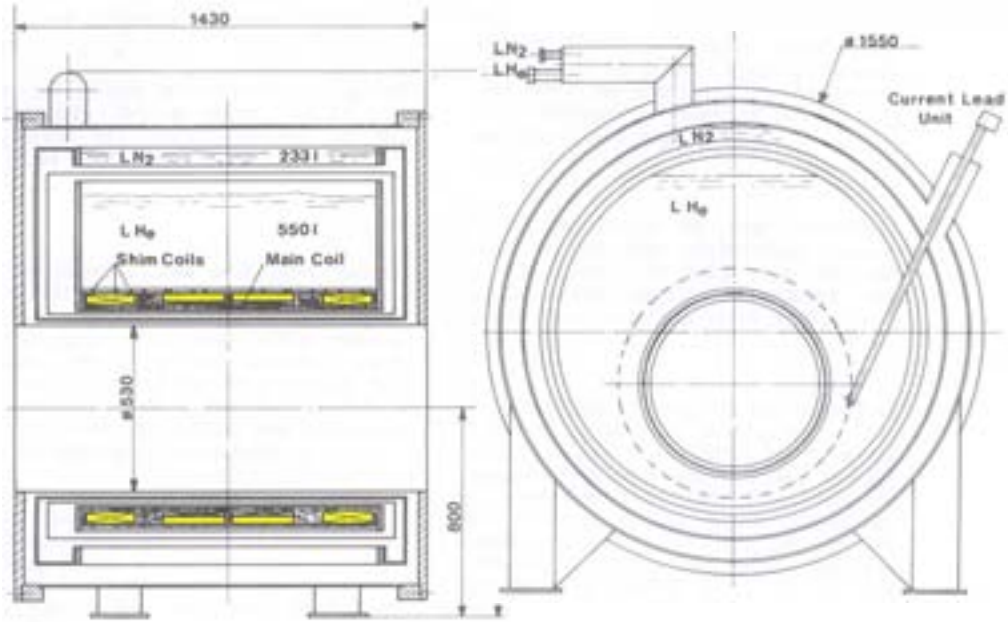
18 8-node BRICKS for the two layers transition

11 8-node BRICKS for connections

Magnetic Configuration

RMN530
Solenoid
(2 T)





RNM530 solenoid with
Nb_3Sn quadrupole inside

- Main coil parameters

SECTIONS :	central	lateral
Winding diameter mm	670	670
Axial length mm	200	155
Center position mm	110	377
Turn number	1904	3570

Central field	2 T
Peak field	3,7 T
Rated current	200 A
Inductance	45 H

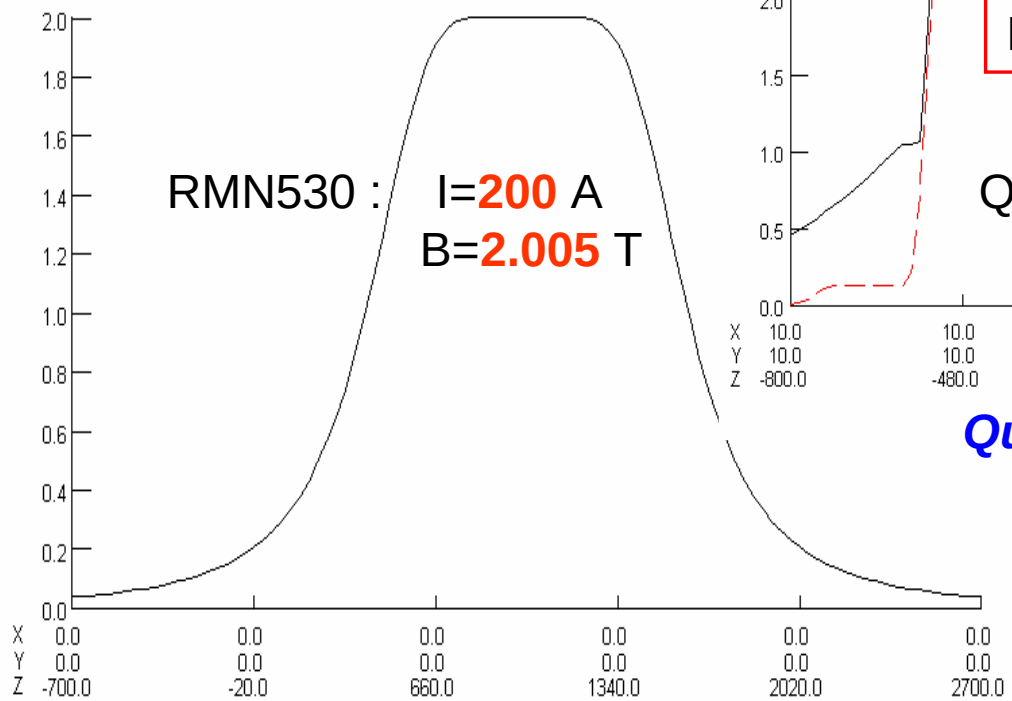
Magnetic Calculations

RMN530 Solenoid + Nb3Sn Quadrupole

Field calculation results

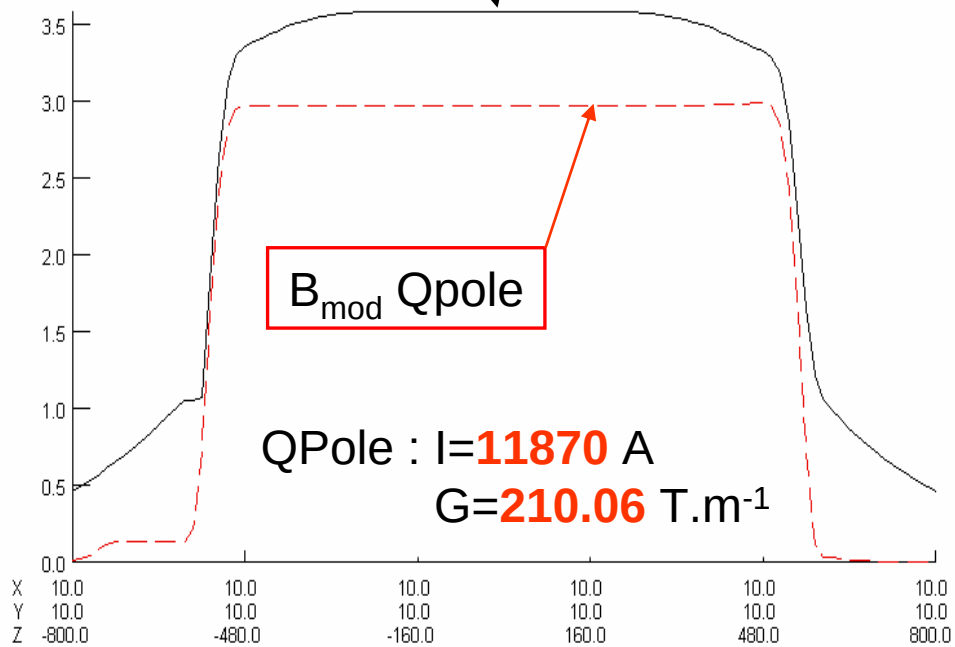
Solenoid simulation

Field B_z on axis



RMN530 : I=**200** A

B=**2.005** T



QPole : I=**11870** A

G=**210.06** T.m^{-1}

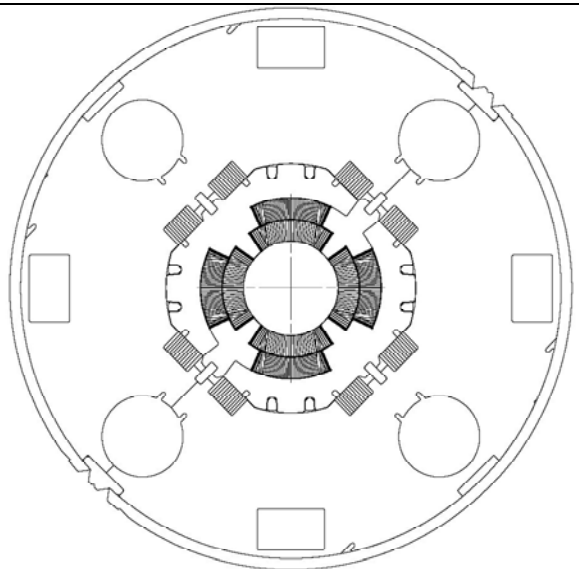
Quadrupole simulation

Field B_{mod} off axis at :

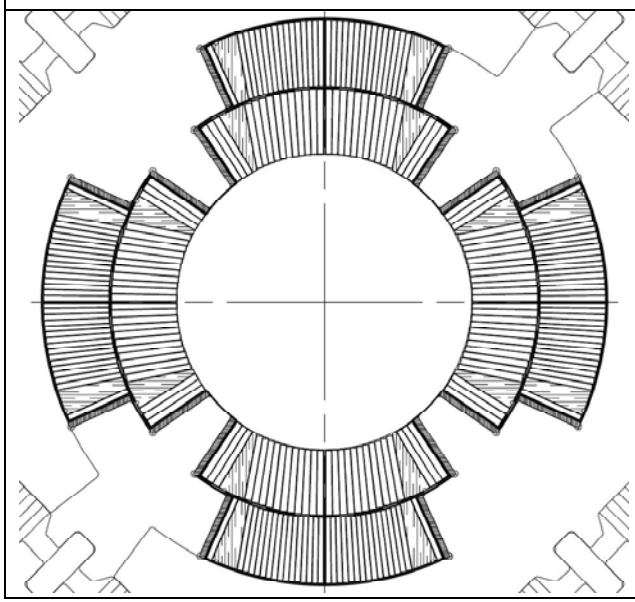
X=10 mm

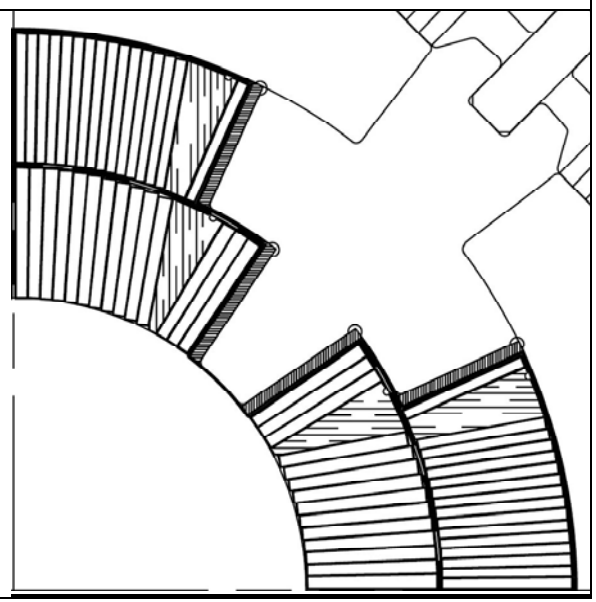
Y=10 mm

A 70 mm Diameter Quadrupole



Rayon	35 mm	
Gradient	210 Tm^{-1}	
Courant	12800 A	
Caractéristiques géométriques conducteur		
Conducteur	interne	externe
Largeur radiale	15.4 mm	15.4 mm
Petit côté	1.326 mm	1.054 mm
Grand côté	1.587 mm	1.238 mm
Nombre de tours	14	16



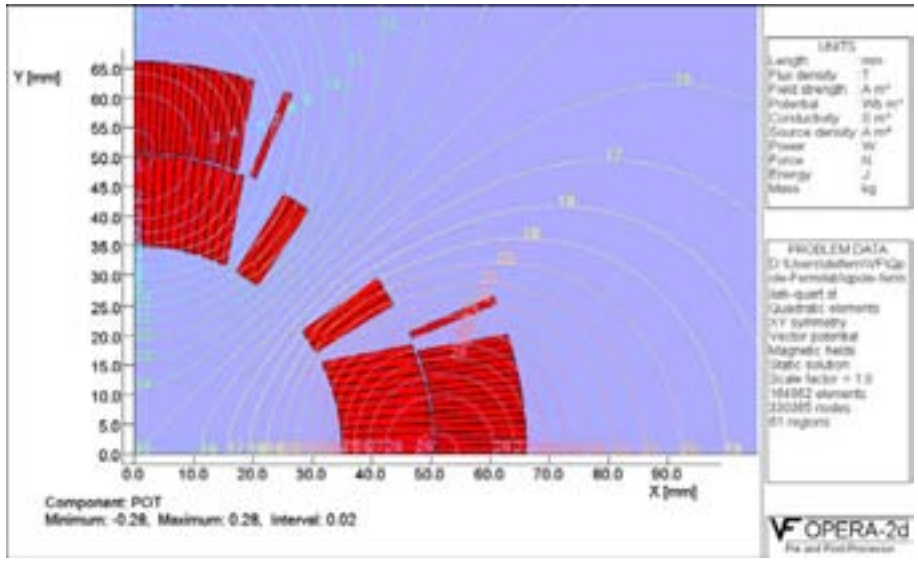


Proposal:
Re-use the cold mass of the low-β LHC quadripole from FNAL design

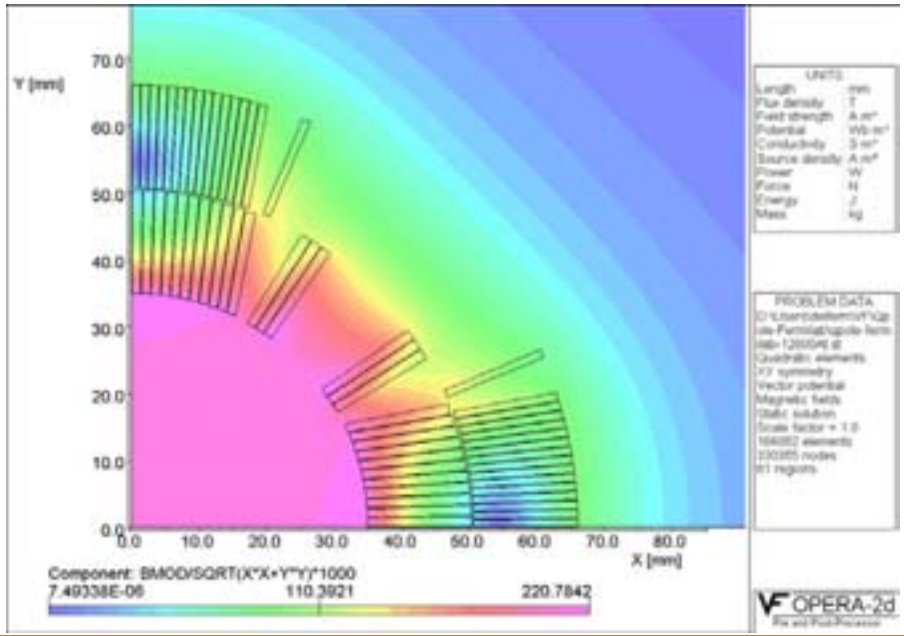
Claim from A. Devred (to be checked with FNAL experts):
1) Can reach 250 T/m with 15000 A Nb3Sn conductor
2) Cold mass mechanics is strong enough

70 mm Diameter Quadrupole : Magnetic calculations

2D section



Gradient



A New Solenoid for the LDC Detector (TESLA)

- Discussions are ongoing for a shorter and cheaper calorimeter and hence a shorter solenoid (~9.5 m down to ~7 m) with a relaxed field homogeneity in the TPC.

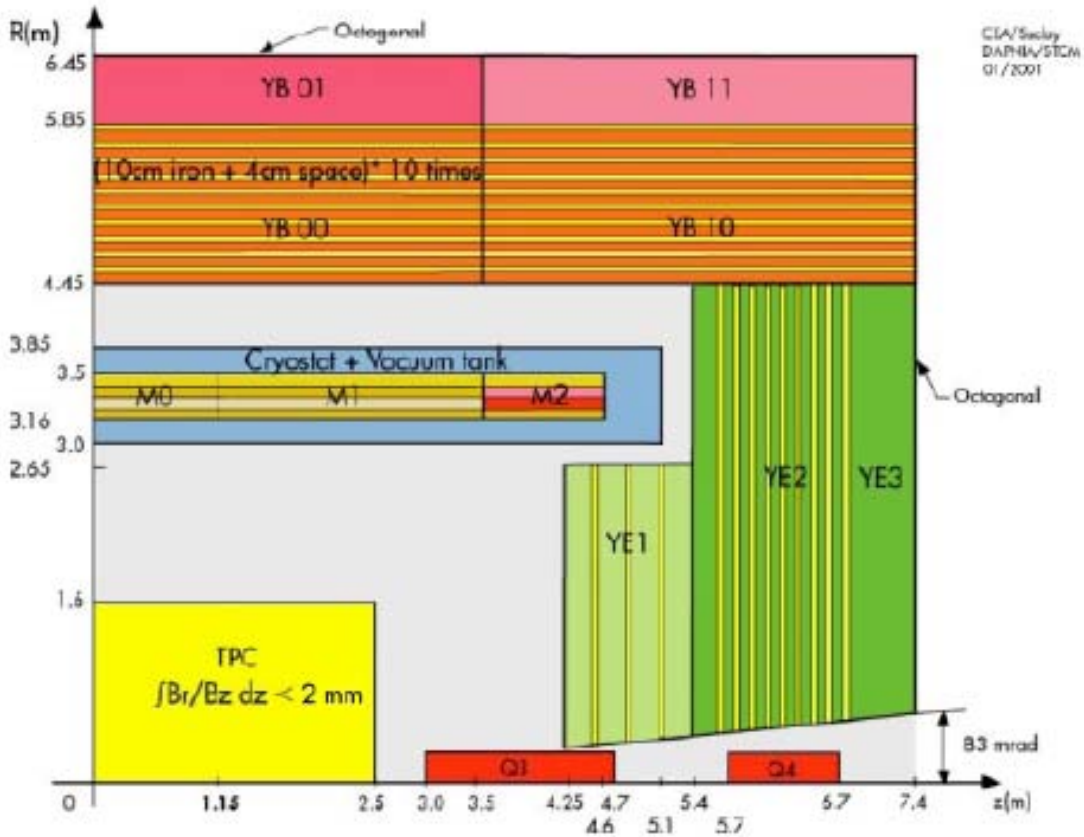
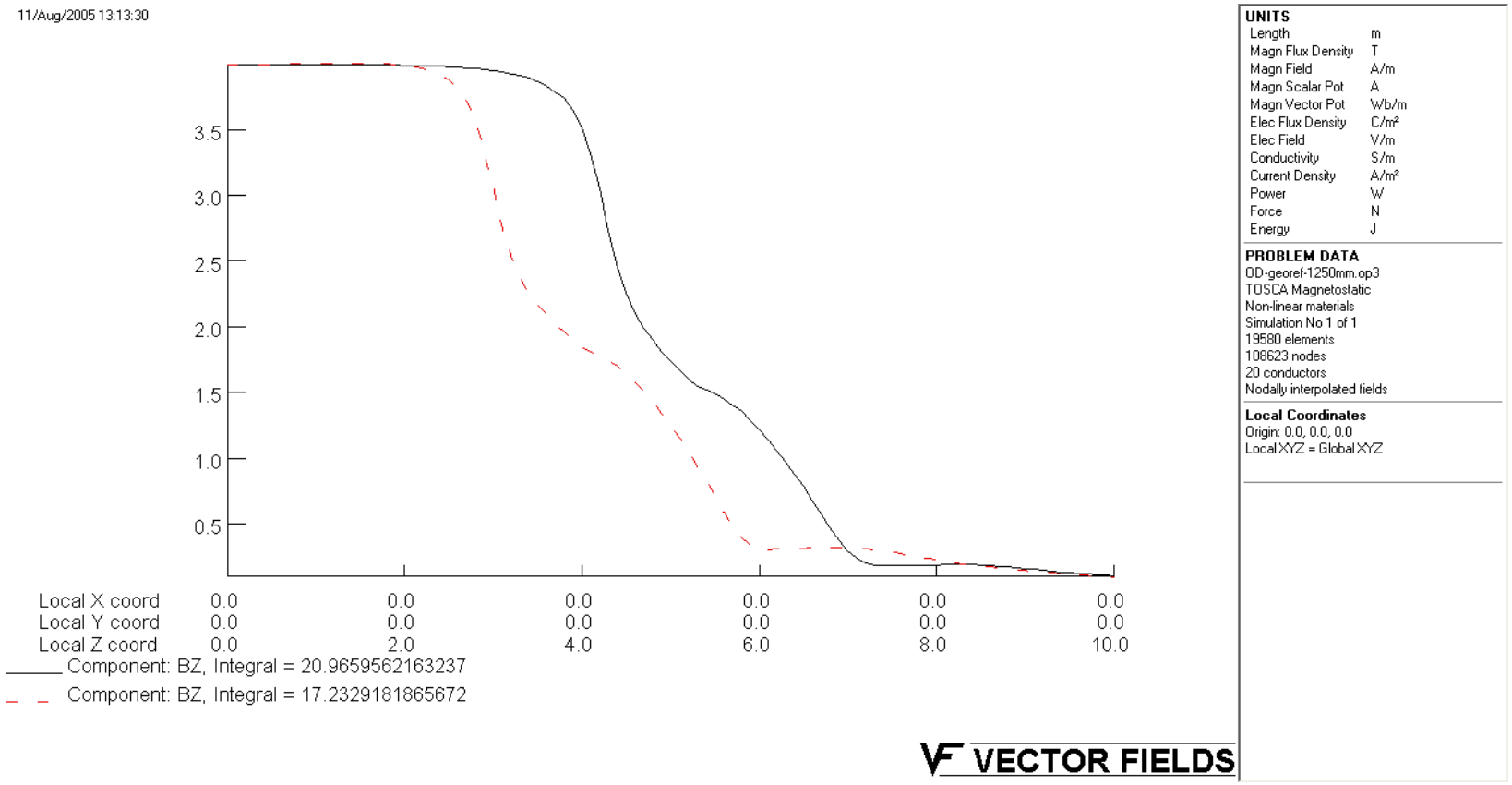


FIGURE 1. One quadrant of the TESLA detector magnet

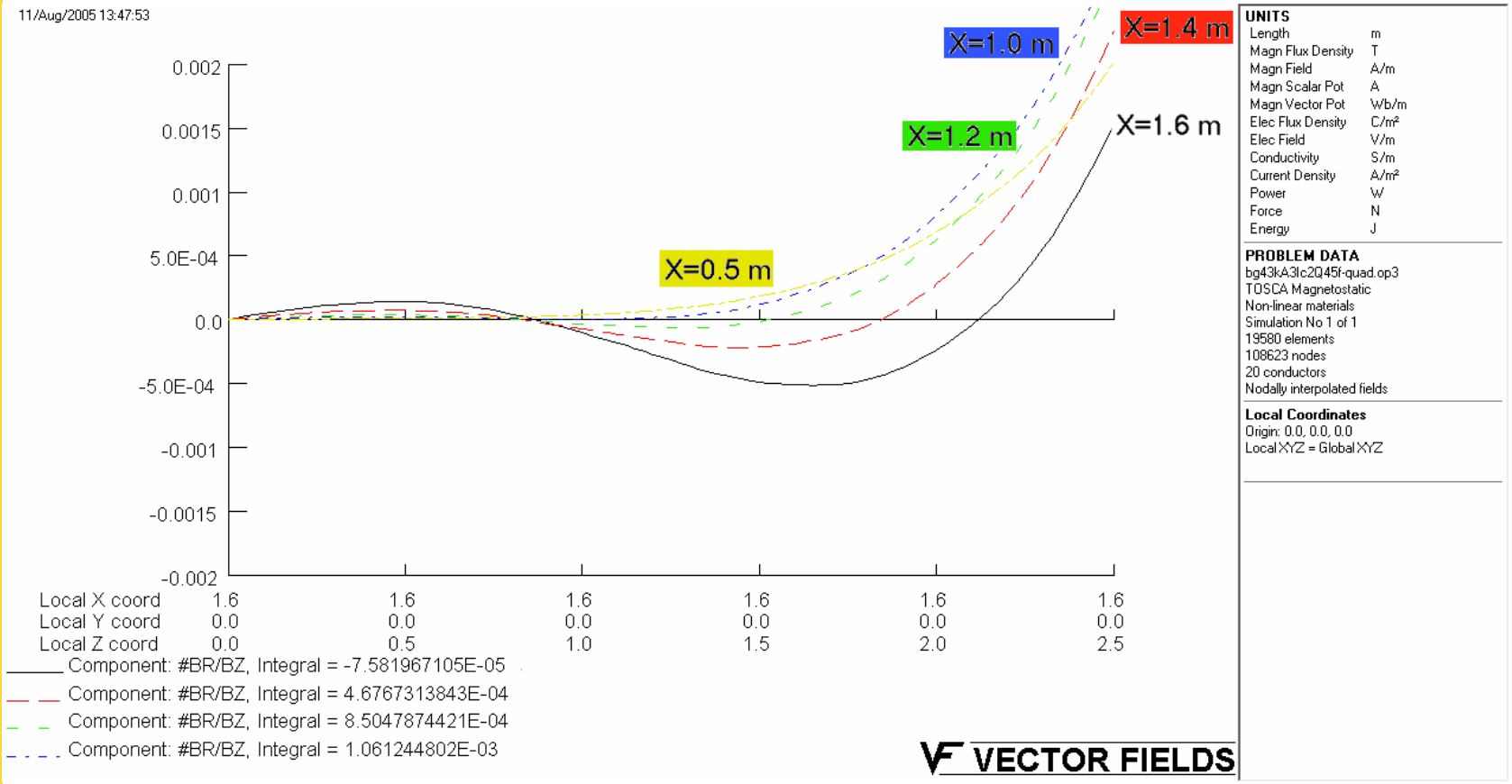
Solenoid Magnetic Calculations

- *Bz* component along the detector axis



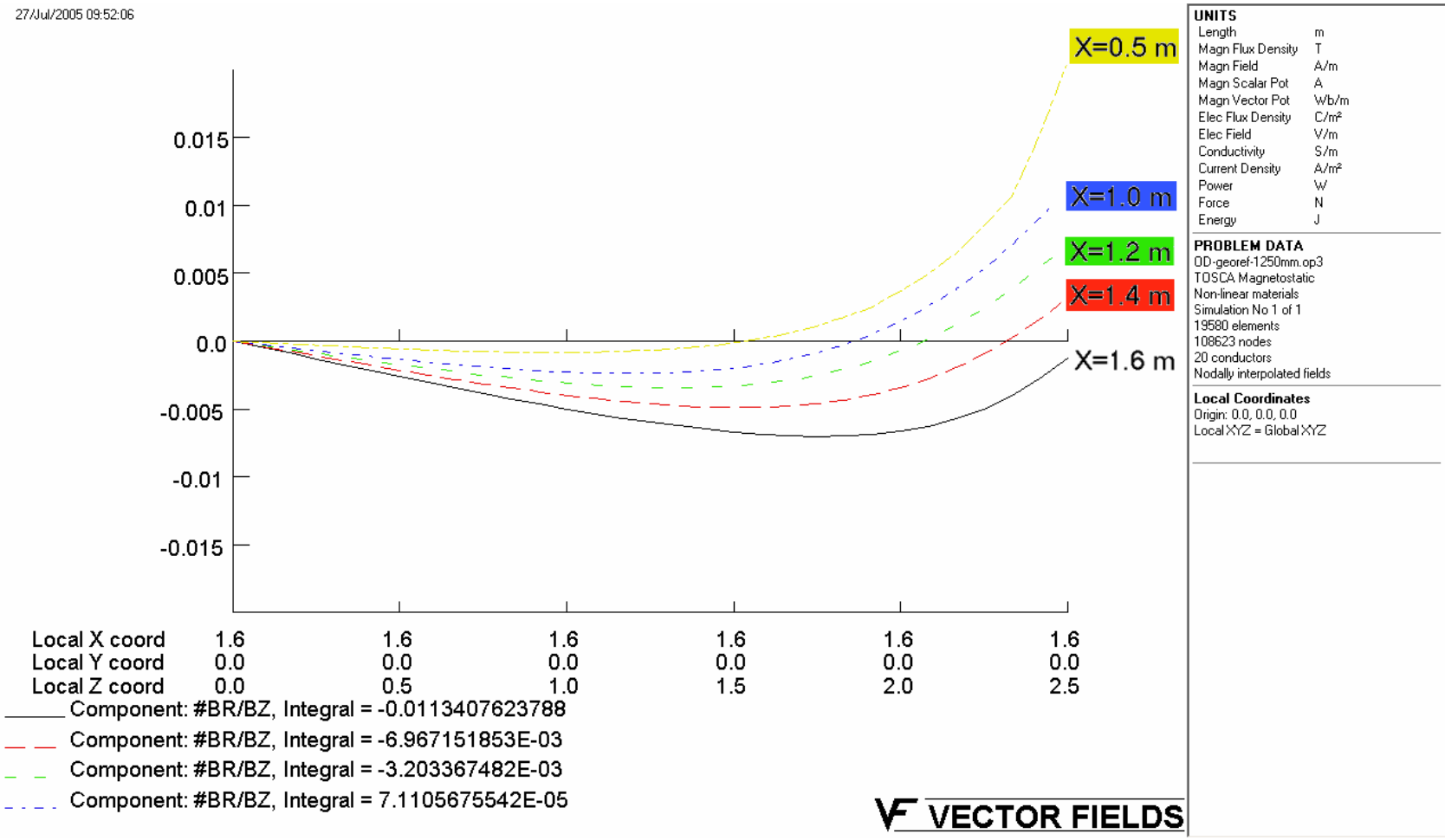
Solenoid Magnetic Calculations

- *Br* / *Bz* along the TPC at different radii *x* : *L* = 9.5 m



Solenoid Magnetic Calculations

- *Br* / *Bz* along the TPC at different radii *x* : *L* = 7 m



Future Work

- Build and test the 1 m long Nb3Sn prototype
- Iterate the 70 mm diameter quadripole design with Fermilab magnet experts
- Complete the calculation of the LCD detector IR magnetic field : 4T Solenoid + 70 mm quadripole.
- Design the SD0 solenoid