EuCARD magnet development

Gijs de Rijk

CERN

EUCARD - HE-LHC'10 ACCNET MINI-WORKSHOP
ON A “HIGH-ENERGY LHC”

Malta, 14-16 October 2010

EuCARD WP7 High Field Magnets

HFM: Superconducting High Field Magnets for higher luminosities and energies,

13 partner collaboration,

CEA, CERN, CNRS-Grenoble, Columbus, BHTS, INFN-LASA, KIT, PWR, SOTON, STFC-D, TUT, UNIGE

5 R&D tasks:

2. Support studies, thermal studies and insulation radiation hardness
3. High field model: 13 T, 100 mm bore (Nb_3Sn)
4. Very high field dipole insert (in HTS, up to ΔB=6 T)
5. High Tc superconducting link (powering links for the LHC
6. Short period helical superconducting undulator (ILC e^+ source)

Duration: April 2009 – April 2013

Budget 6.4 M€ total, 2.0 M€ EC contribution

Task 3: High field model (1)

Jean-Michel Rifflet (CEA) CEA, CERN, PWR

- Objective:

  Design, build and test a 1.5 m long, 100 mm aperture dipole with a design field of 13 T, using Nb_3Sn high current Rutherford cables.

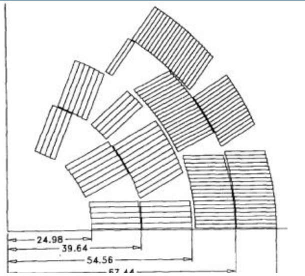
The key component in a SC magnet is the conductor. In order to develop high field magnets it is essential to have a facility to tests the cables (not 'just' the strands) up to the maximum field.

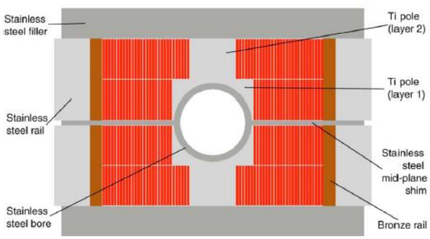
This magnet is intended to replace the present 10 T magnet in the Fresca cable test station at CERN.

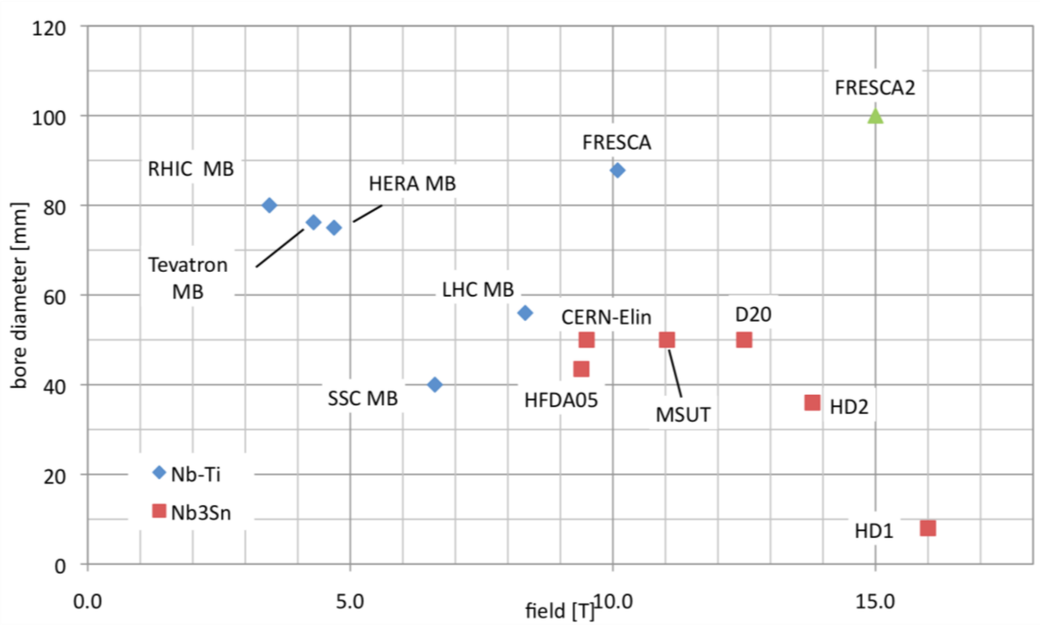
The target field for EuCARD is B=13 T but the real target is B_{max}=15 T.

Task 3: High field model (2)

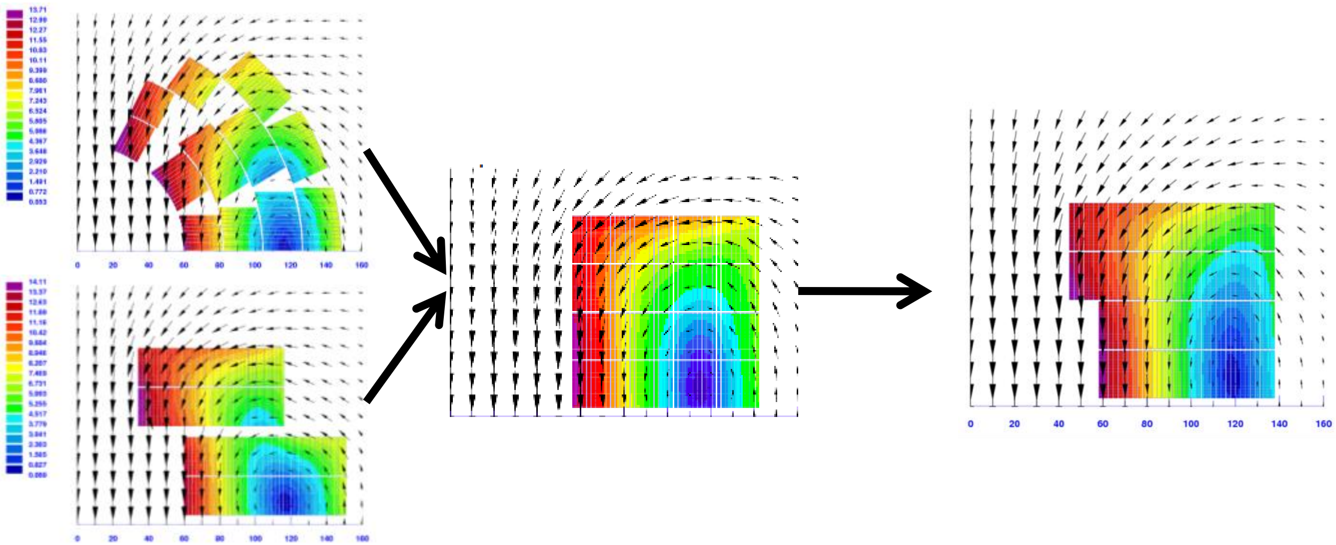
- A 15 T magnet with a 100 mm bore is a challenge.
- It is important to learn from existing HFM projects
- 2 approaches:
  - Classical: scale up from magnets with a cosΘ coil
  - Innovative: design a block coil (working models exist)
- Issues:
  - Conductor (quality and availability)
  - B_{max} on coil
  - Forces and stresses
  - Stored energy
  - Quench protection
  - “makebility”







Task 3: High field model: coil design

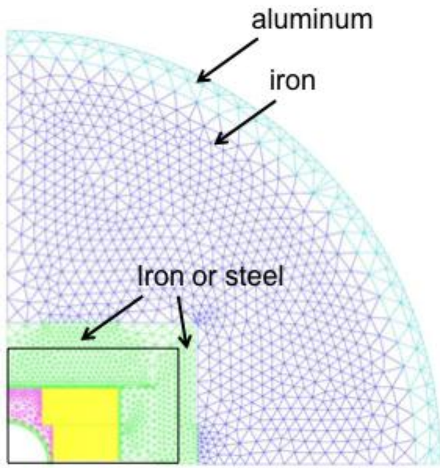


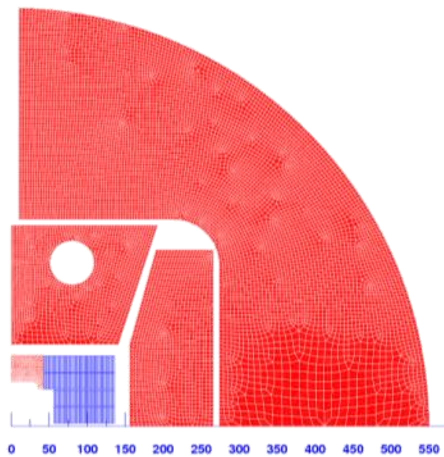
Design version sequence for the coil

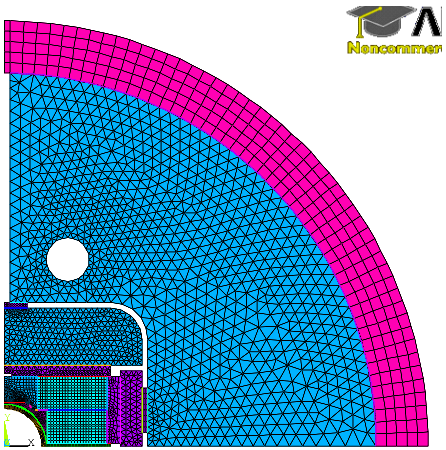
1. → June 2010: CosΘ vs Block coil (156 turns per pole, 2 double layers)
    1. CosΘ 28-37-43-48 turns, first cable at 60 mm
    2. Block coil 41-41-37-37 turns, first cable at 60 mm

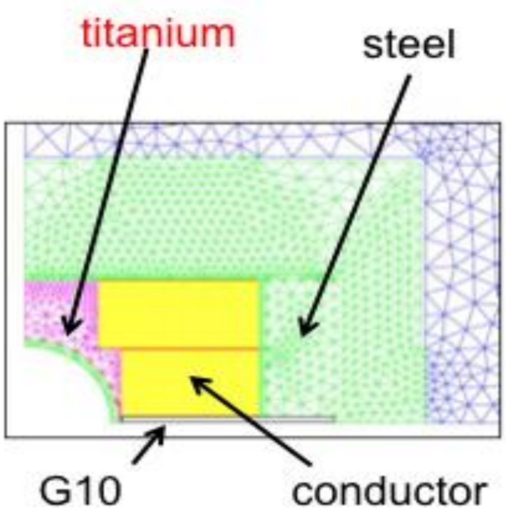
    choice based on winding tests
2. Summer 2010: Block coil 156 turns : 39-39-39-39, 56 mm
3. October 2010: Block coil 156 turns : 36-36-42-42, 58 mm

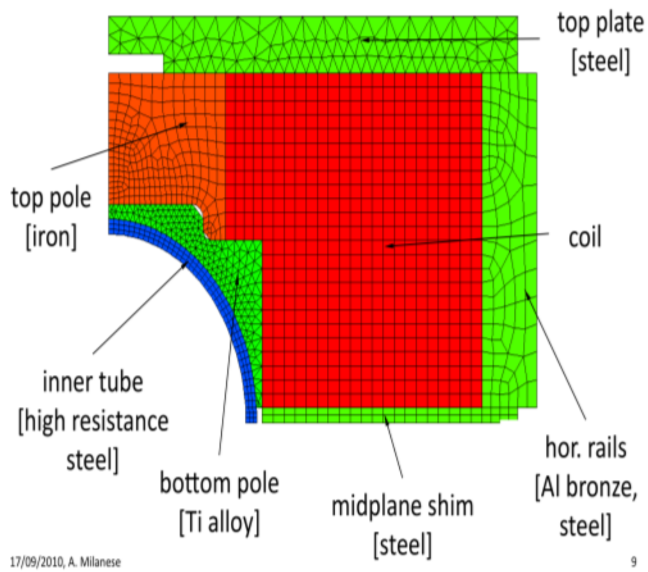
High field model: Structure design

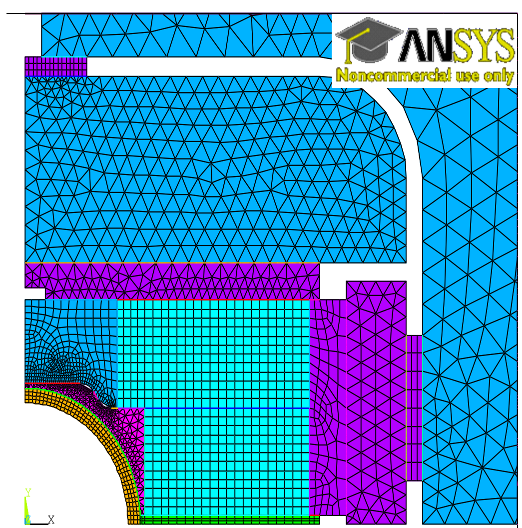






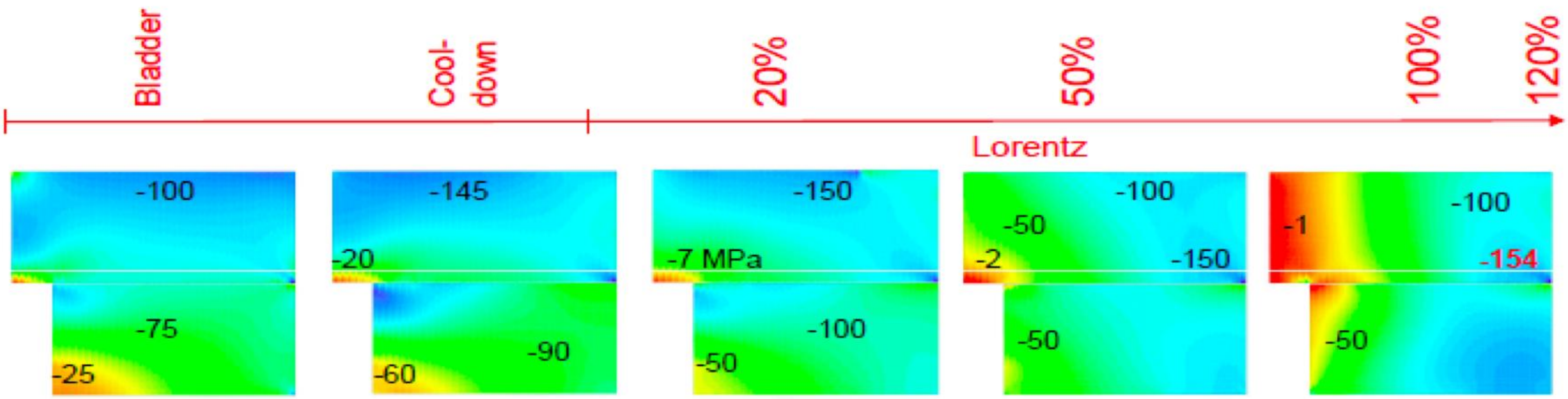






High field model: 2D stress analysis

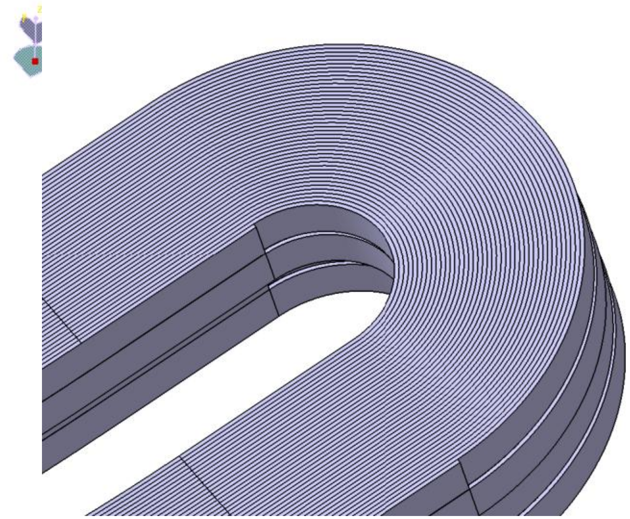
- Global study at CEA
- Details (of components) at CERN
- Stress in coil and structure in the lifecycle:
  - Room temp. with prestress (bladder and keys),
  - at 4.2 K,
  - at 2.6 T, 6.5 T and 13 T

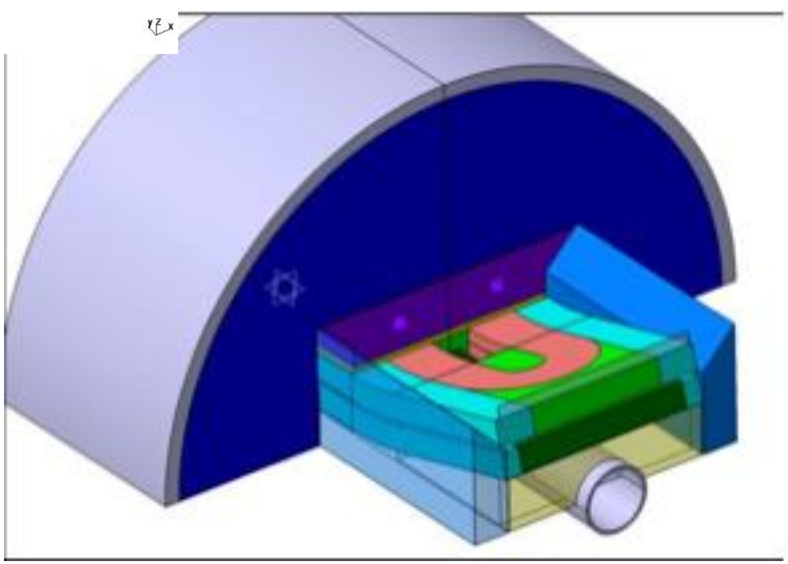


Layout 2: Horizontal stresses σ_{xx} (MPa)

Parameters: i_x=1200µm, i_y = 0, t_{shell} = 50 mm

High field model: 3D design





- Making a detailed 3D model is important: the devil is in the detail
- 3D turn by turn model

Task 3: High field model: planning

- 2010: detailed magnet design (20-21 Jan 2011 design review)
- Structure ready by 30 April 2011, LN2 test with dummy coil April-June 2011
- Components and tooling design: Nov 2010 - March 2011
- Conductor procurement ongoing (2 vendors)
  - deliveries: Sept10, Dec 10, March 10, July11 (2x15 km) , Nov11 (40 km)
  - This is the critical path for the project
- First double pancake coil (½ pole) : end March 2012
- Assembly first full coil set in magnet: end Febr 2013
- First full test: April 2013

Task 4: Very high field dipole insert (1)

Pascal Tixador (CNRS Grenoble-INPG)

CNRS, CEA, KIT, INFN, TUT, UNIGE,PWR

- Objective:
  Design and realization of a high temperature superconductor (HTS) very high field dipole insert (6-7 T), which can be installed inside the 13 T Nb_3Sn dipole of task 3

This is a very first attempt to approach 20 T in a dipole geometry.
(13 T + 6 T or 15 T + 6 T)
Very challenging
Issues:

- I_c of the HTS conductor: need an averaged J_c of ~300A/mm^2
- HTS coil fabrication
- Forces (~1000 t/m)
- Fixing into dipole
- Coupling, quenching

First make small solenoids and only then a dipole

Task 4: Very high field dipole insert (2)

	Bi-2212	YBaCuO
	High current cable (Rutherford cable)	Performances (Jc & stress) *Mat. of the future…*
	Critical Heat treatment Limited Mechanical perf. Long length without defect ?	High current cable ? Coil ends ! Length more than ~ 100 m ?

Conductor procured for characterization (CERN & CNRS)

- Bi-2212 round wire, 37 x 16 filaments (25 %) OST (300 + 200 m) Nov. 09
- YBCO coated conductors

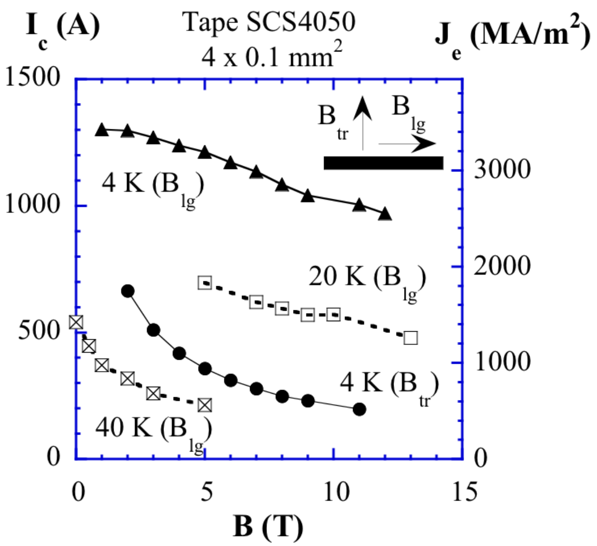
  SuperPower (3 x 100 m) February 2010

  AMSC (2 x 38 m) Dec 2009 (CNRS order)

Task 4: Very high field dipole insert (3)

Characterization:

- Measurements at the various labs
- Cross calibrations in progress
- Understand differences between vendor and user measurements



Critical characteristics of SuperPower tape
4.2 K: CERN, T > 4.2 K: CEA

Quench modelling:

- TUT and INFN have each a model: Benchmarking on a Nb-Ti solenoid
- Insert quench (T hot spot) studies (depends on conductor used and properties data)
- outsert quench interference on insert: study in progress
- First result: Insert will fully quench and thus be autoprotected

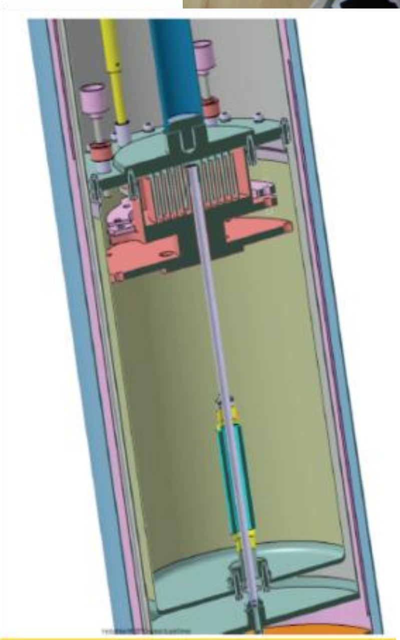
Task 4: Very high field dipole insert (3)

- Test of solenoid inserts under high B
- New Large” Variable temperature cryostat in 20 T, 160 mm high field magnet @ LNCMI Grenoble
  - 20 T High field magnet, $Ø_{bore}$=160 mm
  - Variable temperature (4.2 K - 80 K)
  - Gas and conduction cooling
  - Outer cold Ø ~ 130 mm

- First YBCO test solenoid was made

  (Øi = 22 mm, Øe = 52 mm, h = 37 mm) with

  3 double pancakes and 2 end pancakes
  - some issues with local damages
  - Connections to be improved

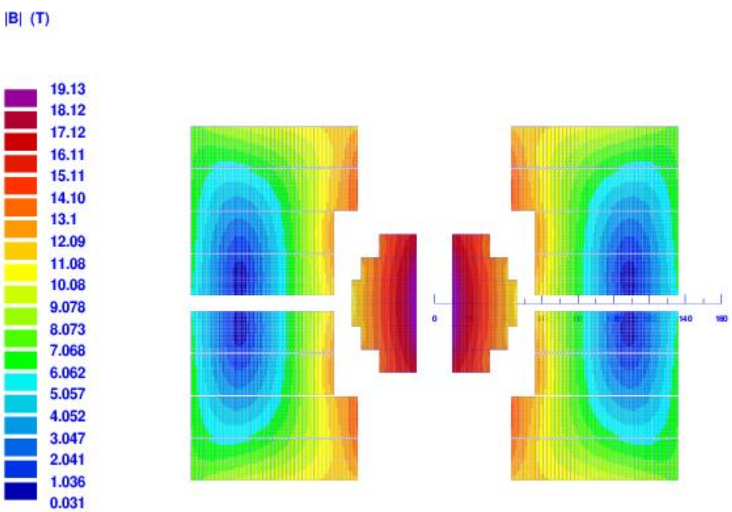


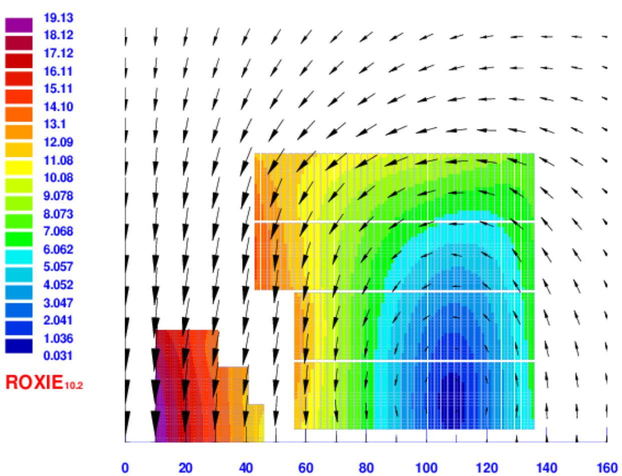
Task 4: Very high field dipole insert (4)

Dipole insert Magnet design: Various options being studied: prospecting as nobody did this before !

A design was made using uses 12 mm wide YBCO coated conductor

- The 6 T central field can be reached with 250 MA/m^2 as overall current density.
- The internal aperture is 20 mm in diameter. The current in a 12 mm tape is 610 A
- The HTS dipole in inside a 3 mm thick steel tube to contain the Lorentz forces (1.4 - 1.6 MN/m) (in B=13 T from the outer dipole)





Task 2: Support studies (1)

Macej Chorowski & Jarek Polinski (PWR) PWR, CEA, CERN

sub-tasks:

- 7.2.1 Radiation studies for insulation and impregnation

1) Workshop on insulator irradiation 4th Dec 2009 at CERN
2) Radiation Working Group created
3) List of 7 candidate insulators (impregnation schemes) established for possible usage in accelerator magnets
4) Literature search for insulator irradiation tests done (PWR)
5) Dose spectra for LHC upgrade situations made available

1) RAL mix 71 ; DGEBA epoxy + D400 hardener
2) Epoxy TGPAP-DDS(2002)
3) LARP insulation; CTD101K + filler ceramic
4) Cyanite ester (pure) AroCy L10
5) Cyanite ester epoxy mix T2 (40% AroCy L10)
6) Cyanite ester epoxy mix T8 (30% AroCy L10)
7) Cyanite ester epoxy mix T10 (20% AroCy L10)

Task 2: Support studies (2)

6) Irradiation sources selected (IJP, Swierk, Po)

7) Equivalent doses known (50 MGy) (CERN simulations Cerutti at al.)

8) Irradiation program established (samples sizes, sample materials)

9) Test cryostat for mechanical and electrical tests designed

10) Manufacture of test plates started (RAL, S. Canfer et al) (in common with the thermal sub-task)

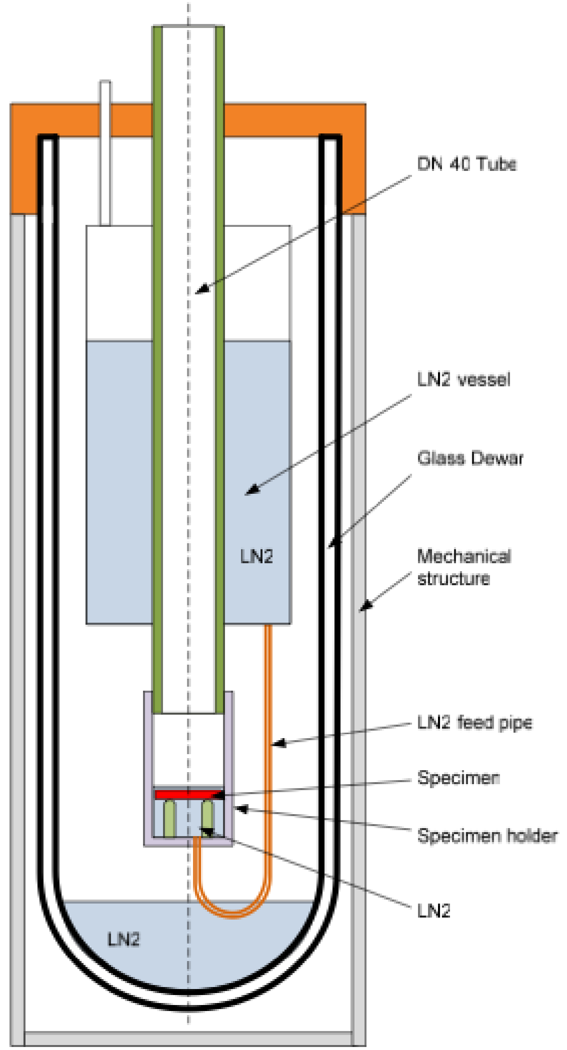


Figure 3. Cryostat for mechanical certification scheme

Task 2: Support studies (3)

2) 7.2.2 Thermal studies

1) CEA-Saclay has started the thermal test of unirradiated samples of insulation material candidate RAL mix 237
2) PWR is commissioning a new cryostat for thermal tests
3) CEA Saclay continues developing the thermal model of the magnet coil for steady state conditions (2D conduction model without helium)
3) PWR and CERN are developing the superfluid and helium solvers in OpenFOAM code

Task 5: High Tc superconducting link (1)

Amalia Ballarino (CERN) CERN, COLUMBUS, BHTS, SOTON

DESY has left the task due to lack of interested personnel, the 11 PM were re-distributed over CERN and SOTON

Conductor choice:

- between Y-123, Bi-2223 and MgB_2 all pre-reacted and in the form of tape
- Long lengths (> 1 km) of MgB_2 tape from Columbus and of Bi-2223 tape from BHTS are available.
- Short lengths of Y-123 tape from BHTS are available from stock
- A set-up for the electrical characterization at liquid nitrogen temperature of long lengths of Bi-2223 and Y-123 tapes is available at BHTS

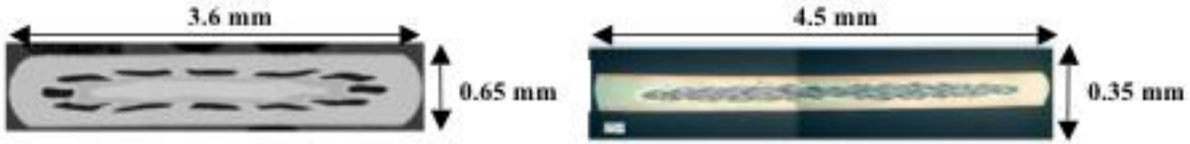
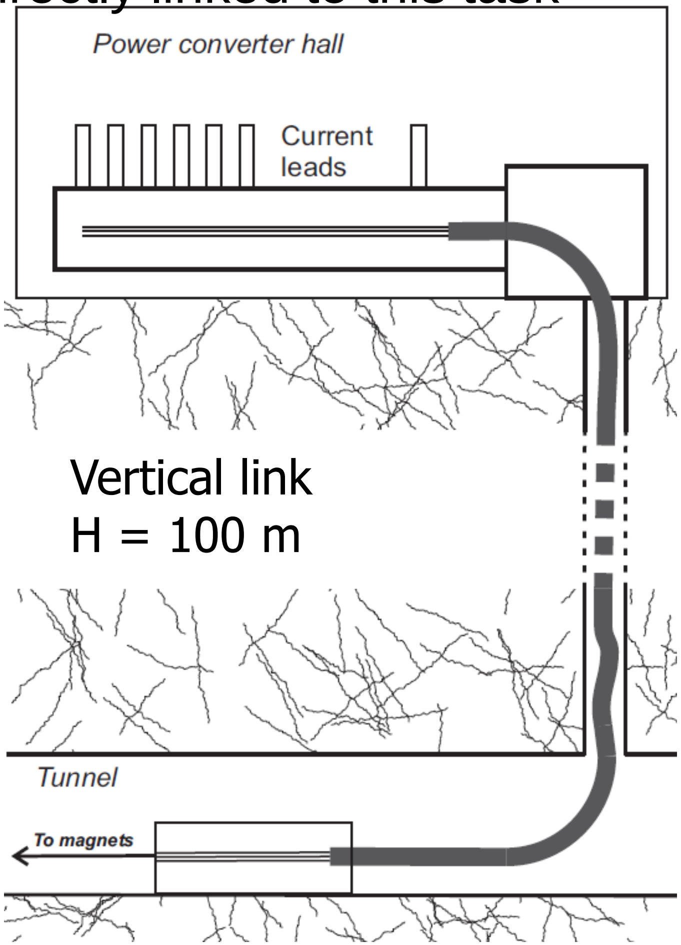
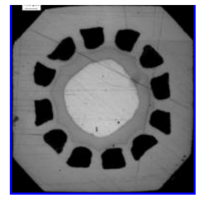


Figure1. MgB_2 tape from Columbus and Bi-2223 laminated tape from BHTS.

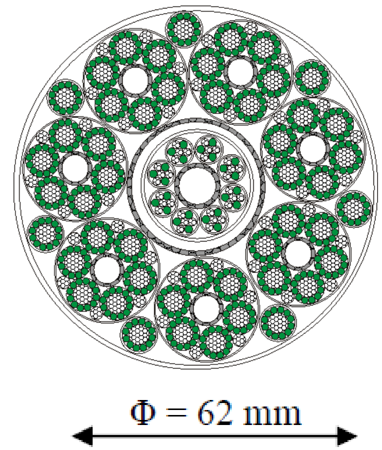
Task 5: High Tc superconducting link (4)

SC links needed for the LHC upgrade:
Directly linked to this task

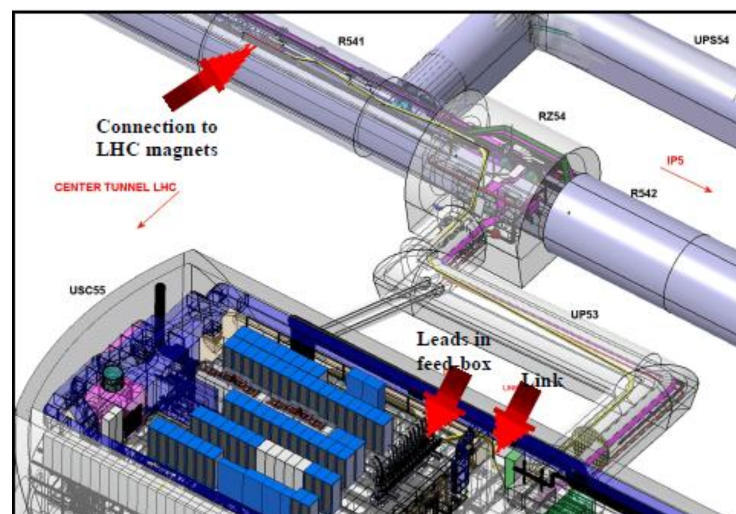




1.1 mm MgB_2 wire



Semi-horizontal link (100-700 m)



Courtesy: A. Ballerino

Task 6: Short period helical undulator (1)

Short period undulator for the ILC positron source

Jim Clarke (STFC-DL) STFC (DL and RAL)

Period 11.5 mm , field >1 T

Aim :

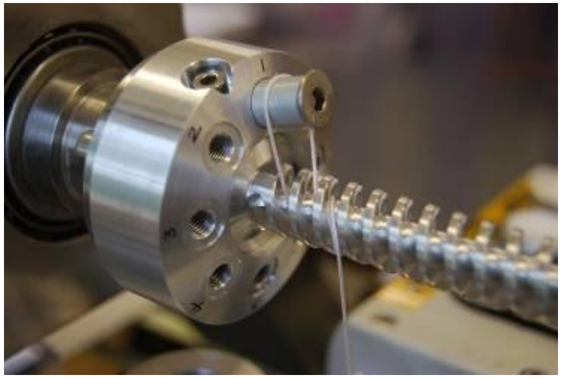
- fabricate and test a short helical undulator prototype using Nb3Sn wire.
- With: 11.5 mm period and winding bore of 6.35 mm.
- Nb_3Sn usage for high current density and large thermal margin to go higher than the 1.15 T achieved for Nb-Ti

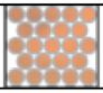
Primary challenges:

- Nb_3Sn insulation system (compatibility with heat treatment at 650C)
- Thin insulation (high current density).

Task 6: Short period helical undulator (2)

- Electromagnetic design done
  - Cu beam pipe
  - Steel helix
  - 27 turns of 0.5 mm strand
  - Field on coil ≅4T
- Conductor selected
- Conductor characterization in progress
- Insulation 0.075 mm braided glass fibre
- Winding tests in progress
- Reaction and impregnation tests soon to follow.



0.5 mm 
27 wires at 658 A
855 A (76 %)

EuCARD-2 ?!

ESGARD request for ideas for an EuCARD successor

FP7 call end of 2011

Probably less budget available than for EuCARD

From: Gijsbert de Rijk <Gijs.de.Rijk@cern.ch>
Subject: **Fwd: call for ideas for R&D areas to be included in the next FP7 IA project "EuCARD2"**
Date: September 14, 2010 16:45:36 CEST
To: Jean Pierre Koutchouk <Jean-Pierre.Koutchouk@cern.ch>
Cc: Rifflet Jean-Michel <jean-michel.rifflet@cea.fr>, gianluca sabbi <GLSabbi@lbl.gov>, Tatsushi Nakamoto <nakamoto@post.kek.jp>, Gijsbert de Rijk <Gijs.de.Rijk@cern.ch>

Dear Jean-Pierre,
I discussed between 4 potential partners and we would like to state the following idea for HFM topics for a EuCARD successor project (see below).
Regards
Gijs

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The partners and the contact persons are:
CERN : G. de Rijk
CEA (F): J-M. Rifflet
LBNL (US): G-L. Sabbi
KEK (J): T. Nakamoto
=====================================
Proposal for High Field magnet development in EuCARD2:
Issued by CERN, CEA, LBNL and KEK as core institutes. In a later stage an enlarged collaboration should be formed.
Following the development of the 13 T wide aperture magnet in EuCARD and the HTS insert and under the condition that these developments are successful, the logical successor project is to prepare for a high field magnet for a collider application.
The project would consist of items:
1) Make a design study for a 20 T magnet for HE-LHC.
2) Construct a technology demonstrator model dipole magnet in the 15 T - 18 T range.
3) Conductor development for the 20 T field range.
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