WP7 HFM Status

F. Kircher (CEA Saclay) **and Gijs de Rijk** (CERN)

EuCARD Annual meeting

RAL, 14-16 April 2010

WP7 High field magnets

- Task 1: Coordination and communication
- Task 2: Support studies
- Task 3: High field model
- Task 4: Very high field dipole insert
- Task 5: High Tc superconductor link
- Task 6: Short period helical SC undulator

Task 1: Coordination and communication (1)

After the kick-off in February 2009, 4 collaboration meetings were held (at CEA, CERN and PWR)

Because of LHC machine repair, and of the CEA Nb_3Sn quadrupole program, tasks 3 and 5 officially started on September 1st 2009.

Activities in 1st year:

- Semestriel reports
- Assist the tasks to get started (7.2: 2 WGs, 7.3: 3 WGs)
- Organization of the collaboration meetings
- Collaboration web pages

Task 1: Coordination and communication (3)

Plans for next semester:

- Report on dipole design and layout choice (mid May)
- Detailed design of dipole ➔ external review by end of 2010
- Organize the next collaboration meeting(s) (June, UNIGE; Oct ?)
- Formation of a dipole-insert common design issues working group
- Re-make a full WP schedule for the next 3 years
- Get the working group on common dipole-insert issues started

Task 2: Support studies (1)

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

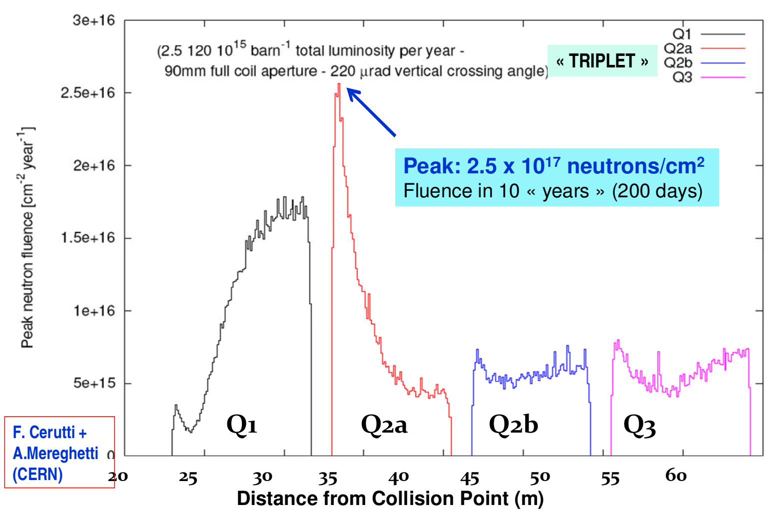
[minor delay, personnel: =, material -]

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 in progress (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)



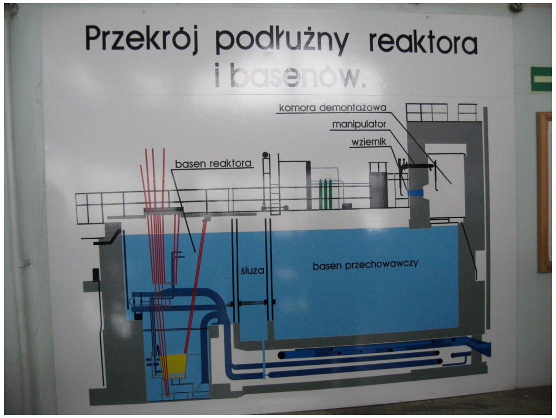
Task 2: Support studies (2)

6) Irradiation sources being surveyed (IJP, Swierk, Po)

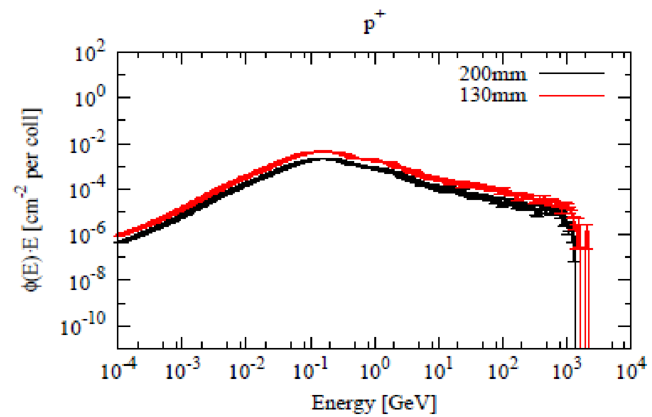
7) Equivalent doses to be calculated on available sources (at CERN)

8) When data from 3-7 are combined a decision can be taken which irradiations to do on which insulators and a procedure can then be written (program for year 2)

9) Manufacture of test plates to start soon common with the sub-task)

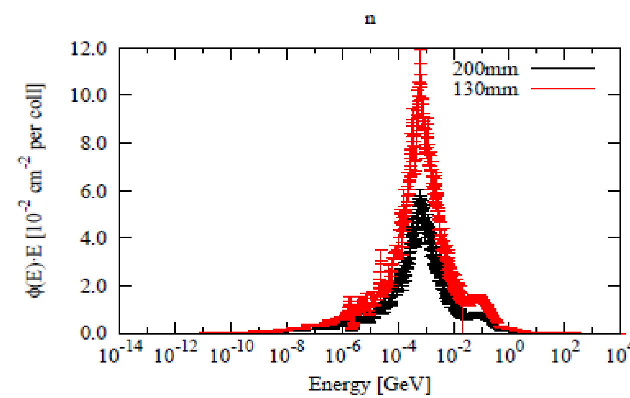


Protons spectrum in the inner coil of Q2a at peak location)



Courtesy F. Cerutti et al.

Neutron spectrum in the inner coil of Q2a at peak location



Task 2: Support studies (3)

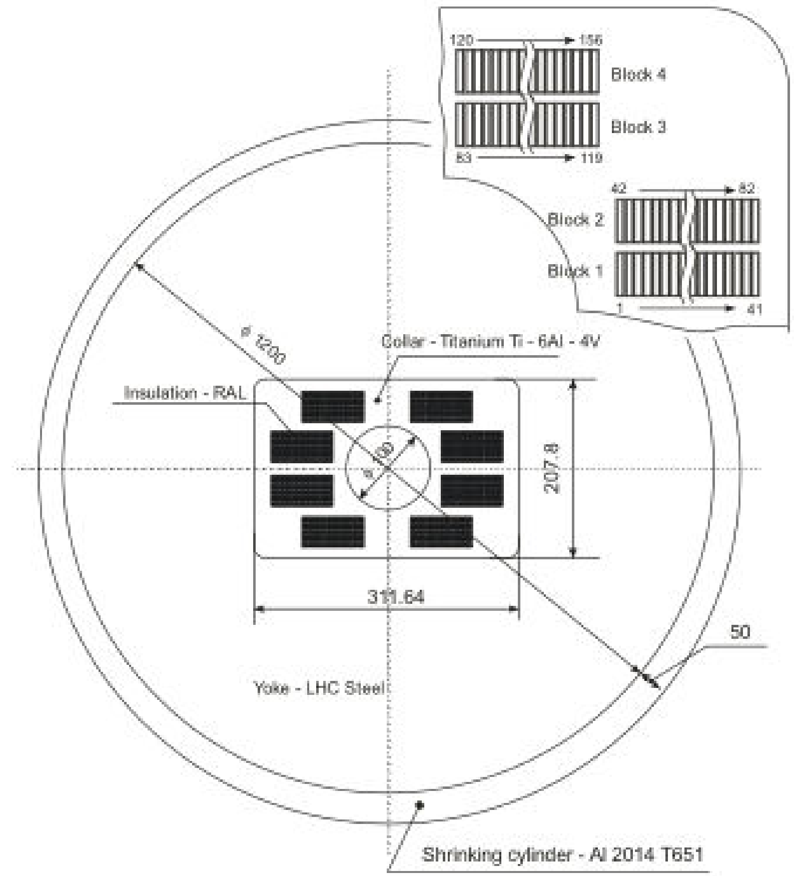
- 7.2.2 Thermal models and design

  – Working group active since Sept. 09 (Workshop at CERN)

  – A very preliminary magnet structure was made by task 3 for input to the modelling

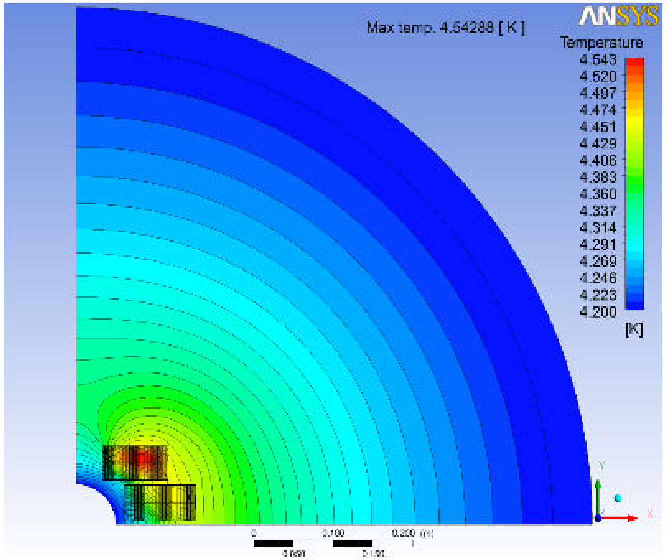
  – A Eddy-current loss map was made for the block coil (CUDI model, CERN & TU Twente)

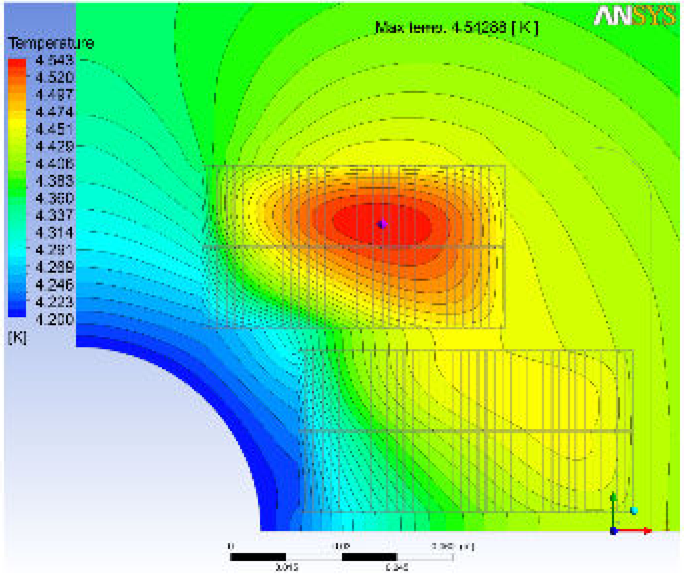
  – Two models now exist (in ANSYS and COMSOL) predicting the temperature profile in the magnet in 2 cooling schemes (1.9 K and 4.2 K) (Milestone 7.2.2) (CEA)



Task 2: Support studies (4)

– A more detailed model is being studied (PWR, CEA and CERN)
– A number of insulation plates (from the 7 candidates from task 7.2.1) will be tested by the "Drum method" (see NED) for thermal conductivity and Kapitza resistance measurements CEA and PWR).
– Some iterations will be needed between the magnet design people and the thermal modelling people to arrive at a cooling layout.





Task 3: High field model (1)

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

[task on schedule, personnel: =, material -]

- 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.

3 working groups:

- cable design WG:

  cable and strand specification made

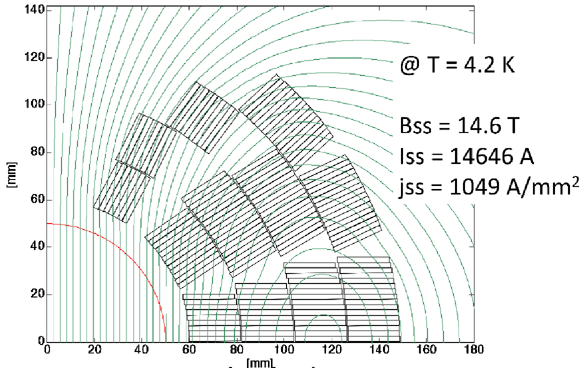
- Specification WG:

  magnet functional specification made

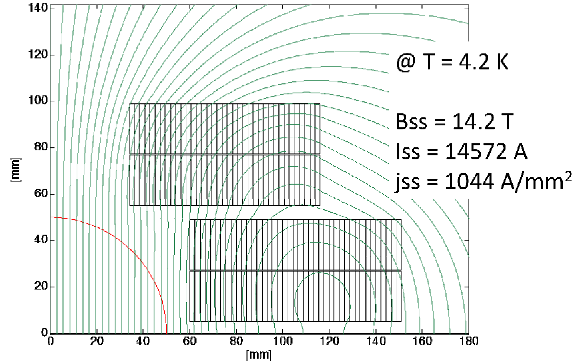
- Magnet pre-design WG

  Working on a pre-design: choice between a block-coil or cosΘ coil ➔ block coil

Cos-theta layout



Blocks layout



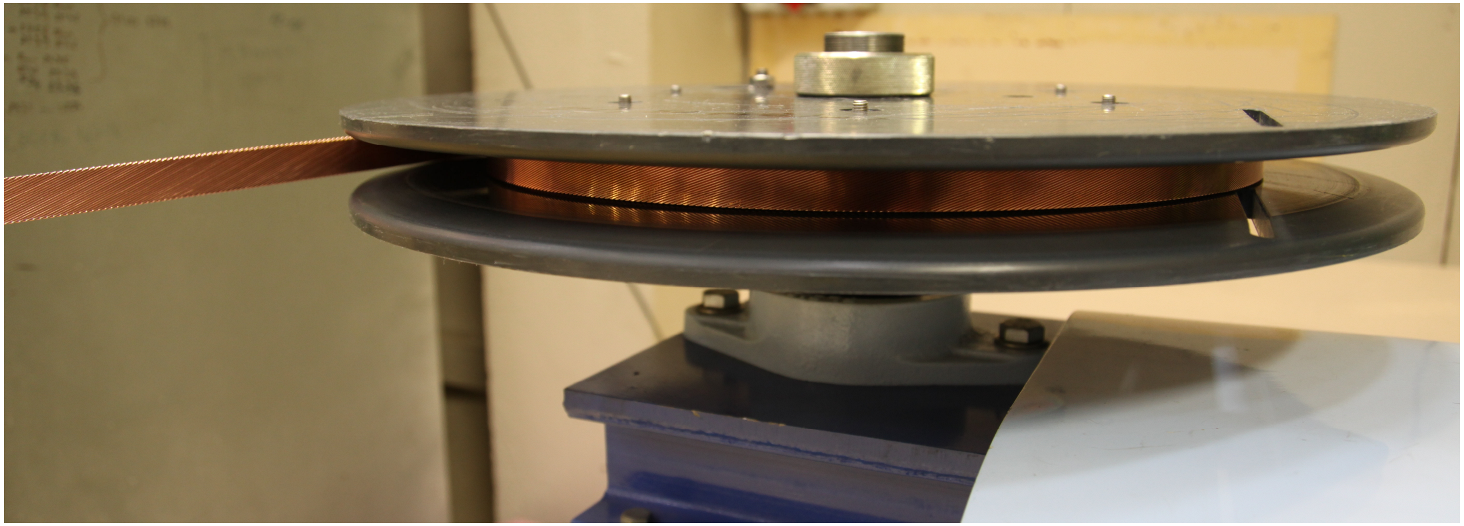
Task 3: High field model (2)

cable design WG; Conductor status:

- Specification written:
    - 1mm diameter strand with J_c=1250 A/mm^2 @ 15 T
    - Rutherford cable with 40 strand
- Procurement procedures launched (CEA & CERN)

  1) qualification: 10 km strand from 2 suppliers each (end 2010)

  2) 45 km strand for 1 set of coils (1 supplier) (June-Aug 2011)



Task 3: High field model (3)

2D magnetic conceptual design

Cos θ and block coil layout

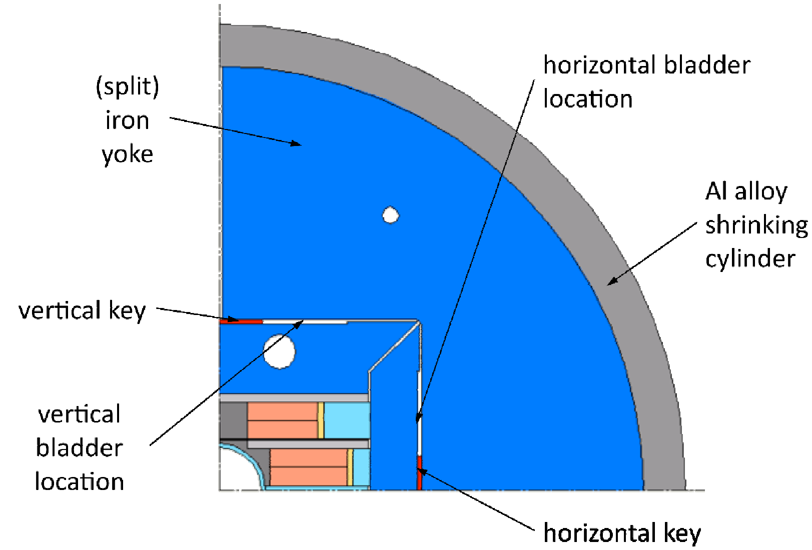
2D concepts for both layouts done.

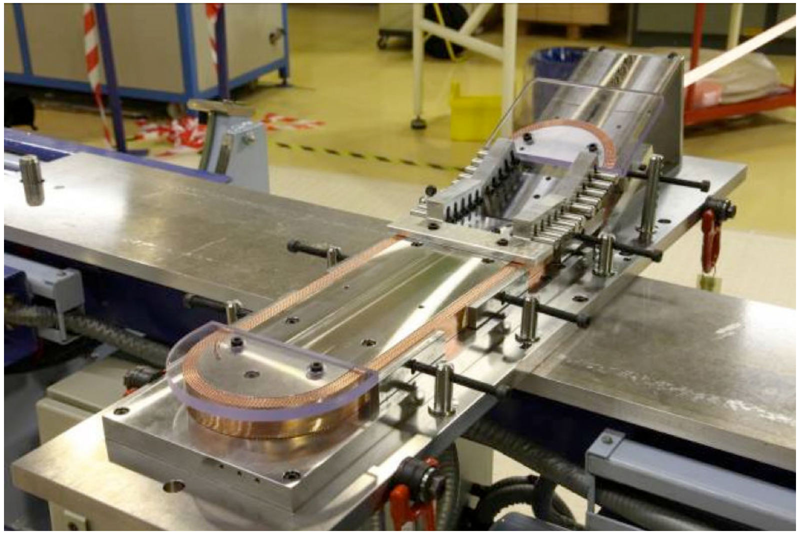
Block coil 3D (ends) design started

Short Model Coil: test the coil manufact.

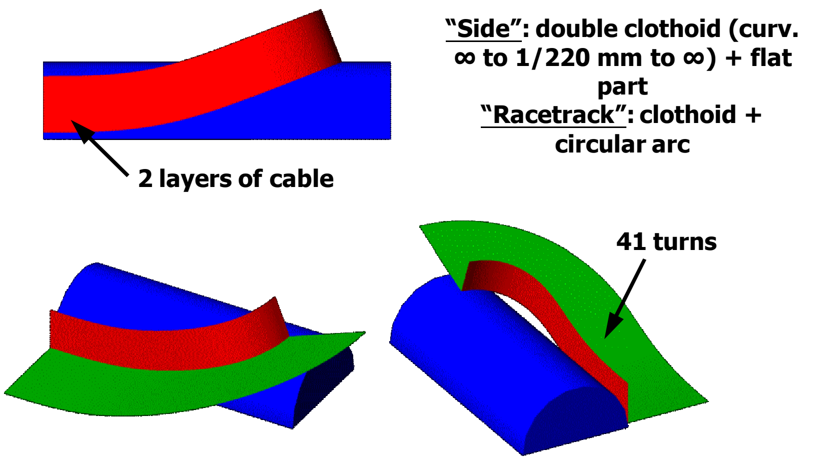
Studies on block coil ends

- special bends (clothoid, super ellips)
- Winding tests at CEA





Blocks layout: ideas for the ends



Task 3: High field model (4)

Plans:

- Pre-design finished by end of May 2010
- Report end May on coil geometry choice (block coil was chosen)
- Detailed design June 2010 – end 2010
- Detailed design external review Nov-Dec 2010
- Structure design and manufacture : June 2010 – March 2011
- Structure test in LN2 by March 2011
- Conductor for 1 coil set delivery in June – Aug 2011
- Coil manufacturing 2nd half 2011 - first half 2012
- First assembly of coils into the structure by summer 2012
- First test second half 2012
- Meanwhile a second set of coils can be made with a second delivery of conductor (CERN) in second half of 2012
- Deliverable date 1/4/2013

Task 4: Very high field dipole insert (1)

Pascal Tixador (CNRS Grenoble-INPG) CNRS, CEA, KIT, INFN, TUT, UNIGE,PWR

[task on schedule, personnel: =, material -]

- 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

NB: test of the two dipoles together is not part of the present EuCARD contract but will be done nevertheless...

Sub tasks:

7.4.1 Specification, characterization and quench modelling

7.4.2 Design, construction and test of solenoid insert coils

7.4.3 Design, construction and test of dipole insert coils

Task 4: Very high field dipole insert (2)

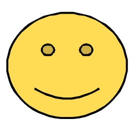
Specification, characterization

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)

	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 ?

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

Quench modelling:

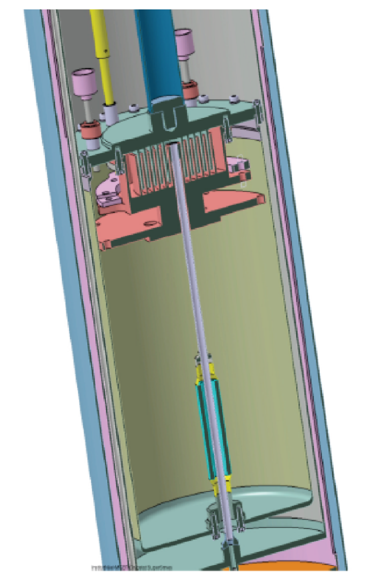
TUT and INFN have each a model:

Benchmarking on a Nb-Ti solenoid

⌘ 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



Task 4: Very high field dipole insert (4)

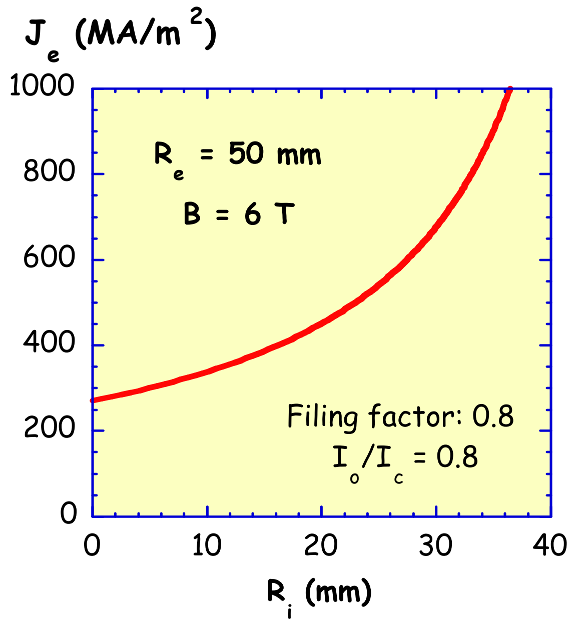
Dipole insert Magnet design:

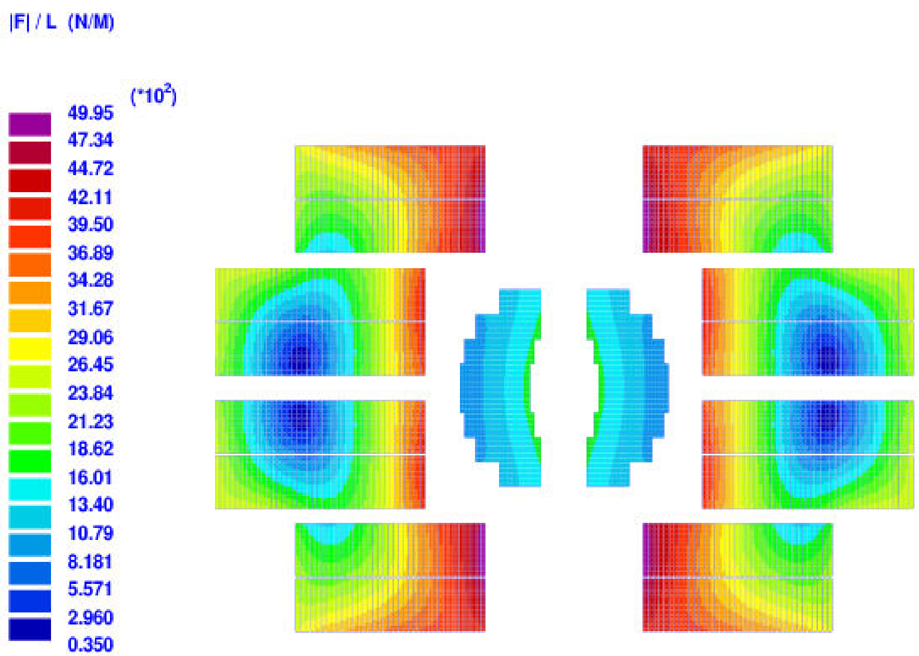
Will need in the coil: J_e > 400 MA/m^2 @ 20T

Various options being studied: prospecting as nobody did this before !

The Jc is not yet available & the forces are enormous (Fx=1000 t/m)

Very challenging, but the vendors are improving each year...





Task 4: Very high field dipole insert (5)

Insert present status:

- High J_e (400 MA/m^2) for 6 T in Ø 100 mm
- Bi-2212 & YBCO are still possible options
- Heat treatment: BSSCO main issue
- Quench code validated for Nb-Ti solenoids

Insert work for the next period:

- Carry on the characterization work
  - Crosschecks for I_c (Nb-Ti & HTS)
  - Mechanical characterization
- Study on Two YBCO tape conductors
- First solenoid realization and tests up to 20 T
- Carry on the two quench models for solenoids

Task 5: High Tc superconducting link

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

[task on schedule, personnel: =, material -]

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 (2)

Link design:

- Conceptual design studies have started at CERN.
- multiple (> 40) cables insulated at V~1.5 kV, cooled by He (5 K to 50 K) operated in quasi-DC mode at I = 60 A to 14 kA and B ≤ 1 T.
- The total length of the links is of up to 500 m.
- Proposed cable geometry: multi-circuit co-axial cable
  - containing electrically insulated annuli of tapes,
  - wound around a former with alternating twist pitch (see Fig. 2).
  - Each annulus contains a number of layers of tapes that depends on the current to be transported and on the operating temperature.
- For the low currents (≤ 600 A), multi-circuits co-axial cables can be arranged in a six-on-one (42 needed at LHC point 3)
- Cryostat, use a semi-flexible pipe of the Nexans type made from concentric corrugated pipes. The envelope contains an actively cooled thermal shield.

Task 5: High Tc superconducting link (3)

Link design:

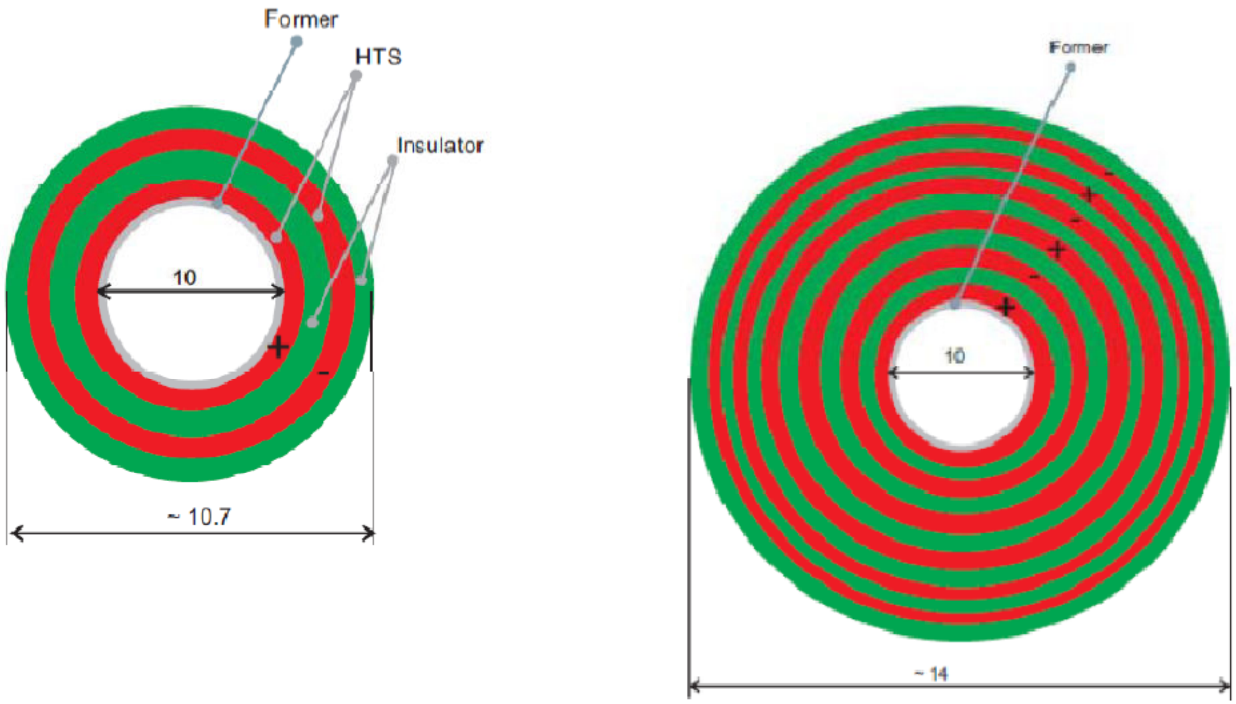


Figure 2. Concentric two-600 A cables and six-600 A cables made from BHTS Bi-2223 reinforced tapes.

Task 5: High Tc superconducting link (4)

Plans in the next months:

•Creation of a database on the properties of conductors (end June 2010)

•Preparation of a functional specification document (CERN) . (end June 2010)

•Definition of procedures for measurement of the Ic for long lengths of MgB_2 conductors (Columbus) (end September 2010)

•Development of splices between tapes and of appropriate procedures. (Columbus and BHTS) (end of September 2010).

•Availability of a set-up for the measurement of strands and cables. (SOTON) (end September 2010)

Task 6: Short period helical superconducting undulator

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

[task on schedule, personnel: =, material -]

aim : fabricate and test a short helical undulator prototype wound with Nb_3Sn wire.

- 11.5 mm period and winding bore of 6.35 mm with much higher fields than possible with Nb-Ti (~1.15 T achieved at the quench limit).
- Primary challenges : the insulation system and its compatibility with heat treatment
- A secondary challenge : make the insulation thin enough to give a current density advantage over Nb-Ti.

The work performed so far: magnetic modelling work, winding and potting trials with a dummy conductor, and trials of a suitable insulation.

- some R&D trials have been carried out on single wire winding into a helical former and the initial results look encouraging.

Task 6: Short period helical superconducting undulator (2)

- Nb_3Sn : small diameter will be used,
  - to keep the I low (<1000A)
  - small winding radius requirements of the undulator.

The 0.5mm diameter appears to offer the best performance compromise between current and operating margin..

Wire Diameter	0.4 mm	0.5 mm	0.6 mm
Winding & $I_{operate}$	39 wires at 452 A	27 wires at 658 A	18 wires at 981 A
Supercon I_c & Margin	547 A (83 %)	855 A (76 %)	1231 A (80 %)

Task 6: Short period helical superconducting undulator (3)

Plans:

- procurement of the 0.5mm diameter wire, insulation specification and trials,
- SC wire winding trials
- short sample tests of the delivered wire at low fields

Conclusions

- All tasks are at work and globally in the planning
- For each task the work to do has been specified
- Technical challenges exist but are being addressed