WP7 HFM Status

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

EuCARD 2nd Annual meeting

CNRS, Paris, 11-13 May 2011

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, 7 collaboration meetings were held (at CEA, CERN, PWR, UNIGE and CNRS Grenoble)

Task 1 activities in the last months:

- Semestriel reports
- Organization of the collaboration meetings
- external review 20-21 January 2011

Plans for next semester:

- Organize the next collaboration meetings
- Organize the dipole mini-reviews

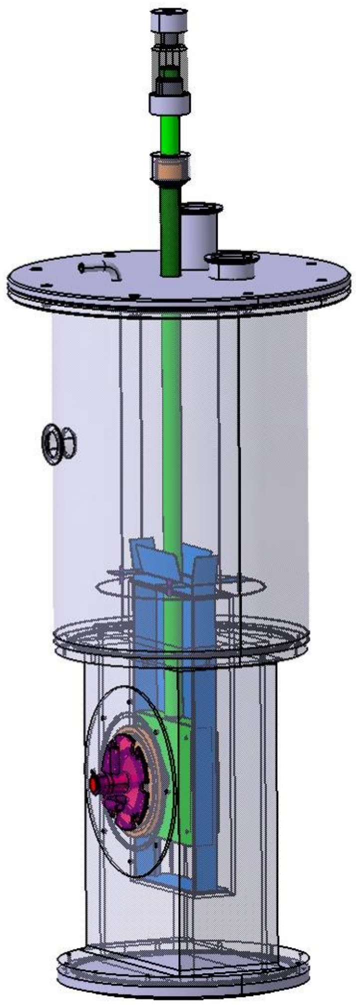
Task 2: Support studies (1)

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

[7.2.1 minor delay, personnel: +, material -]

[7.2.2 task on schedule, personnel: +, material -]

7.2.1 Radiation studies for insulation and impregnation (PWR)



- Future and upgraded accelerators need radiation hard magnets. Insulators in the coil are one of the sensitive components
- LHC inner triplet type dose (total of all types) : 50 MGy, to be done with electron beam of a few MeV
- Test at Soltan have resulted in the feasibility of irradiating with a 6 MeV accelerator structure the thermal and electrical sheets in reasonable time: 12 working days for 11 samples in parallel. It should be possible to irradiate the 52 samples during 3 months.
- For the mechanical samples (6x6x20 mm) it is not possible to do this as the beam spot is too small and the penetration too little: PWR is working on designing smaller samples so that it will fit with the 6 MeV beam

Task 2: Support studies (2)

EuCARD WP 7: HFM Task 2 Start = 01/04/09	1st year				2ed year				3td year				4th	
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14
	3	6	9	12	15	18	21	24	27	30	33	36	39	42
				EuC Rep				EuC Rep				EuC Rep		
Sub-task 2.1: Radiation resistance certification														
Methodology for coil radiation resistance certification								M(24)						D(42)
Determination of radiation types and doses	IM													
Determination of irradiated sample tests scope						IM								
Selection of the Institute capable of the irradiation						IM								
Test samples production														
Irradiated sample test set-ups preparation								IM						
Sample irradiation													IM	
Irradiated sample tests (mech+elec+therm)														IM

Achieved

report from October 2010

SOLTAN Institute Warsaw

remark: not fulfilling all requirements resulting from the report

Conceptual design of irradiation cryostat ready

Studies | Manuf | Tests | **WP** - Work Package Report

M - Mileston | **IM** - Inter. Milestons | **D** - Deliverables | **EuC** - EuCARD Report

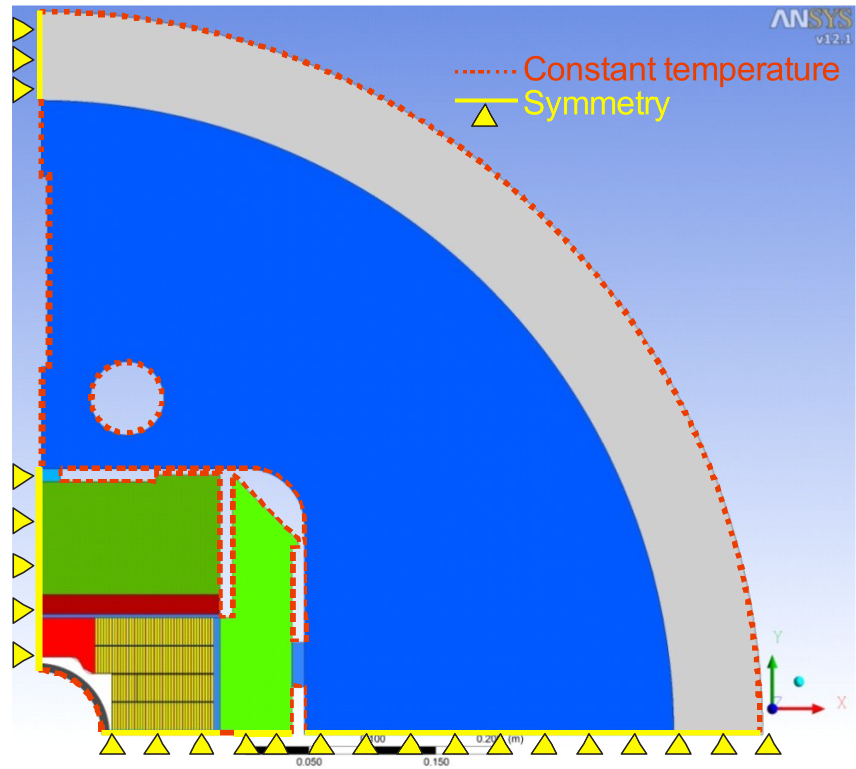
Task 2: Support studies (3)

7.2.2 Thermal models and design (CEA, CERN, PWR)

At CEA and CERN models have been build to simulate the thermal behaviour of the Fresca2 magnet (task 3 dipole). This has been used to calculate 2 cases:

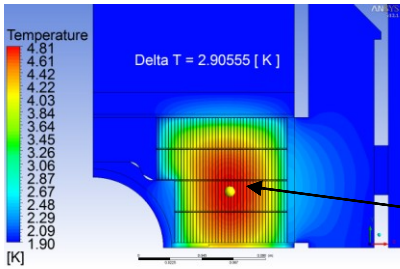
- Steady state losses at 1.9 K and 4.2 K
- Cool down scenarios

A milestone report has just been finished, it will be released in the next 2 weeks

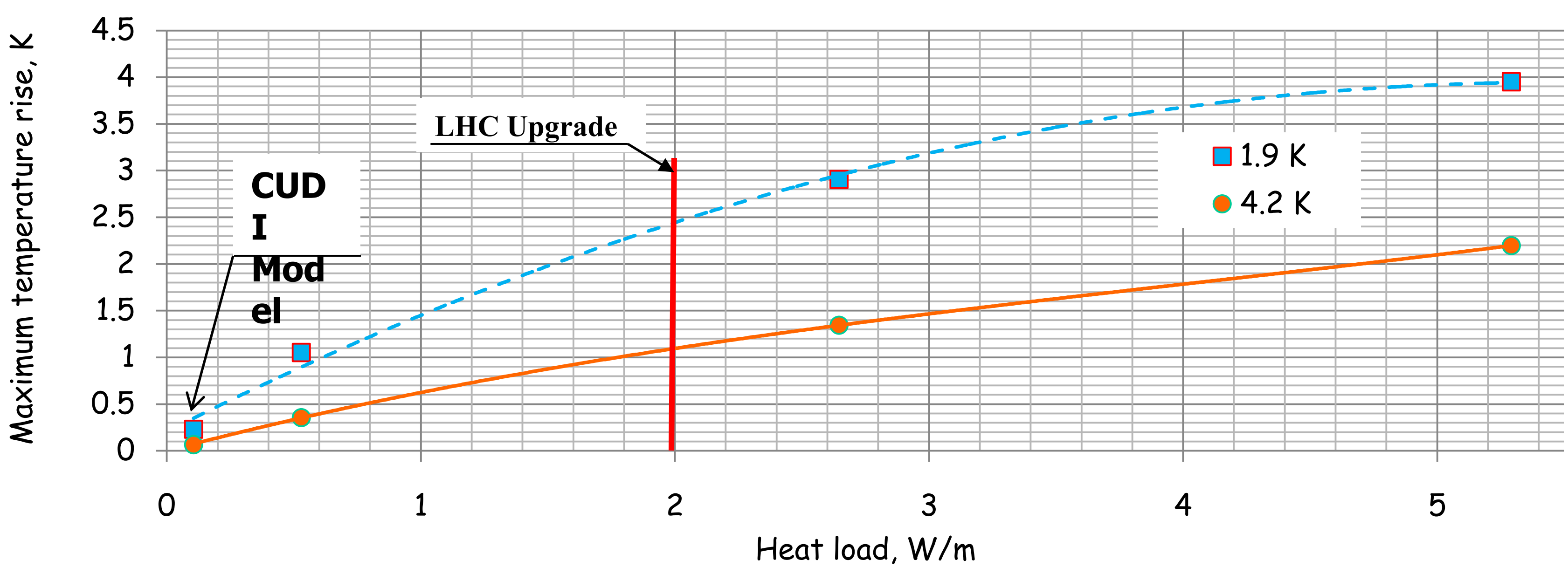


Task 2: Support studies (4), Modeling of thermal process in the magnet during ramp rate – 2 D steady state model

Maximum temperature difference in magnet at different bath temperature and heat load



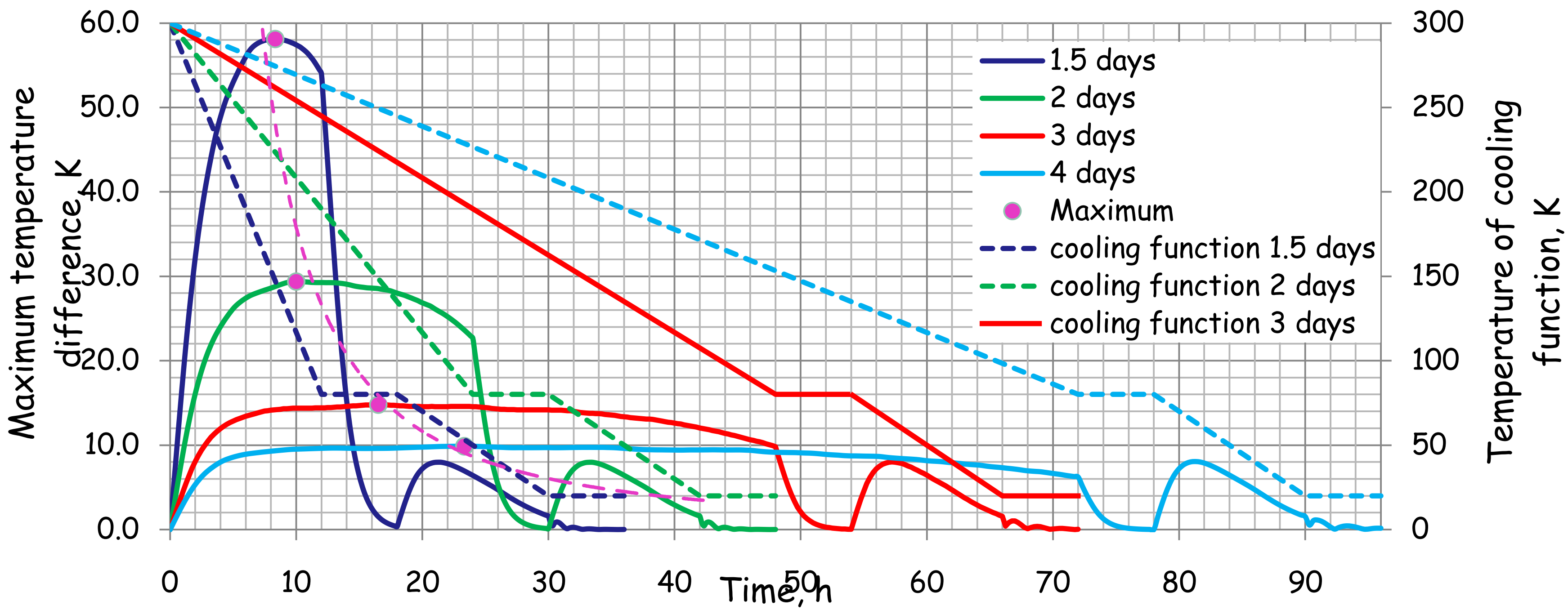
	Name	Unit	Value				Critical temperature rise
Heat load	Total	*W*	0,2	1,0	5,0	10,0	
	Unit	*W/m*	0,1	0,5	2,6	5,3	
	Volumetric	*W/m³*	4,3	21,8	108,9	217,7	
Maximum temperature rise	@ 1,9	*K*	0,231	1,053	2,906	3,951	**6,1**
	@ 4,2	*K*	0,066	0,354	1,344	2,197	**3,8**
			CUDI Model	Homogenous model			



Temperature rise in the magnet as a function of heat load

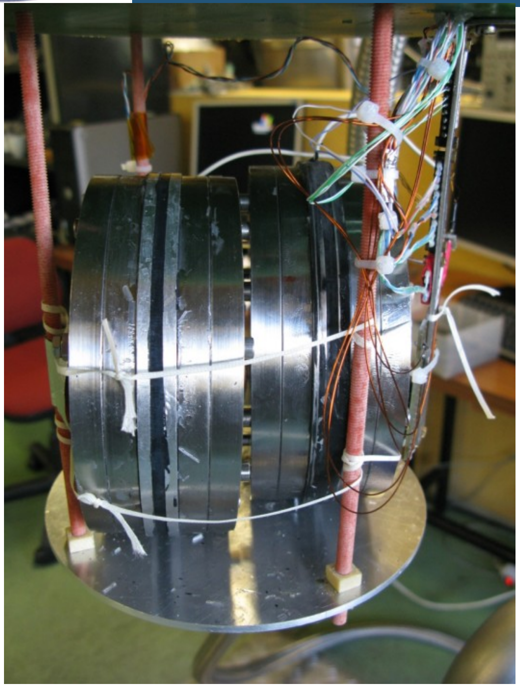
Task 2: Support studies (5), Modeling of cool-down process – 2 D transient model -

- Temperature differences in the magnet should be minimized to avoid peak stresses (< 20 K)
- Cool-down from 300 K => 80 K with 16 bar He gas in tube in contact with outer cylinder
- Cool-down from 80 K => 4.2 K with He gas injected in the cryostat
- A 4 day cool-down from 300 K => 4.2 K looks preferable



Evolution of maximum ΔT within the magnet structure

Task 2: Support studies (6), Thermal test of TGPAP - DETD



Assembled "drum" apparatus in the cryostat

The numbers and thicknesses of tested samples

Sample	D1	D2	D3	D4
	μm	μm	μm	μm
Thickness (average value)	16,0	28,9	40,0	61,1

Sample glued to the holder flange

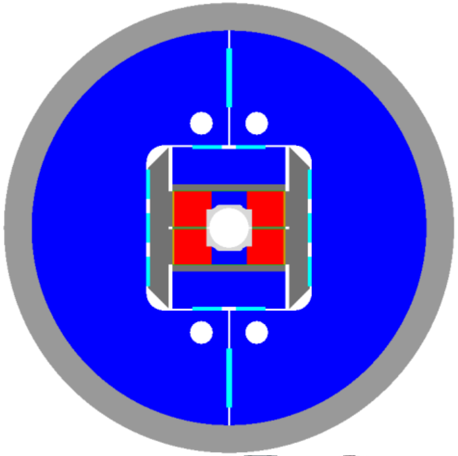
- The heat conduction properties of virgin and irradiated samples of various insulator schemes are to be measured (continuation of NED)
- Work done at CEA with in the NED cryostat and at PWR in a new cryostat
- Measurements have just started

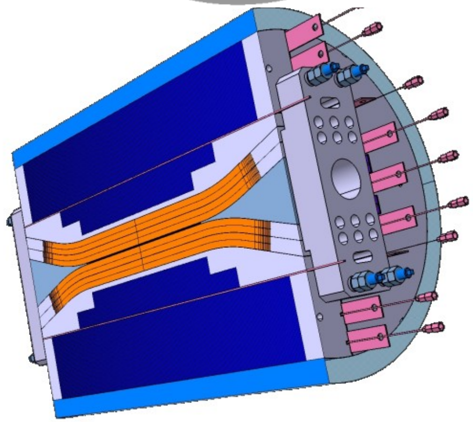
Task 3: High field model (1)

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

[task delayed by 9 months, 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.
  - Magnet design is mostly finalized, only the coil connections are to be designed.
  - Drawing of the structure are ready, procurement of magnet components to start next weeks
  - Tooling tests and design has started winding tests, reaction tests, etc)
  - Strand procurement contracts placed for the pilot production (2 x 15 km, = 2 double pancakes). Full production order to be placed this summer (45 km). Deliveries to be complete by end 2012.
  - Test of the magnet by Dec 2013





Task 3: High field model (2)

- The ESAC high field dipole design review was held at CEA Saclay, on January 20-21, 2011
- Review committee:
    - Giorgio Ambrosio (Fermilab)
    - Shlomo Caspi (LBNL)
    - Pasquale Fabbricatore (INFN Genova)
    - Yukikazu Iwasa (MIT)
    - Tatsushi Nakamoto (KEK)
    - Lucio Rossi (CERN)
- Recommendations (selection only)
    - Wind full-scale dummy (copper) coils to test tooling and procedures
    - Wind full-scale dummy (underperforming) Nb_3Sn coils to check fabrication process and conductor behavior)
    - Take into account all deviations from ideal geometry and imperfection of various systems, to check how much the design is sensitive to tolerance, discrepancies and defects

Task 3: High field model (3)

- Un(der)-addressed issues:
  - Insulation material and thickness;
  - Coil dimensions after winding (ceramic binder);
  - Dimensions of reaction and impregnation cavity (how to accommodate conductor expansion?);
  - Impregnation materials; Splice design;
  - Quench heaters (type, location, power requirement);
  - Instrumentation plan (strain gauges, voltage taps, thermometers, field sensors)
- Schedule
  - The overall schedule is very aggressive and success oriented.
  - additional steps (dummy coils, …) may induce delays, but increase considerably the probability of success
  - Focus on FRESCA2 magnet: (skip time and resources consuming accelerator features)
  - Plan a series of decision points and small readiness reviews
  - Speed up the conductor procurement

Task 3: High field model (4)

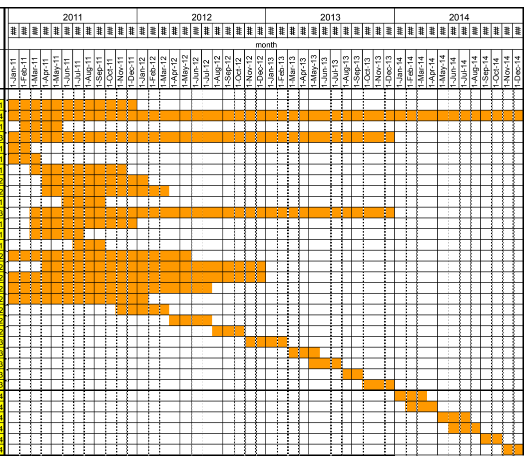
- A resource loaded planning was made including all activities (design, tooling, procurements, tests etc.)

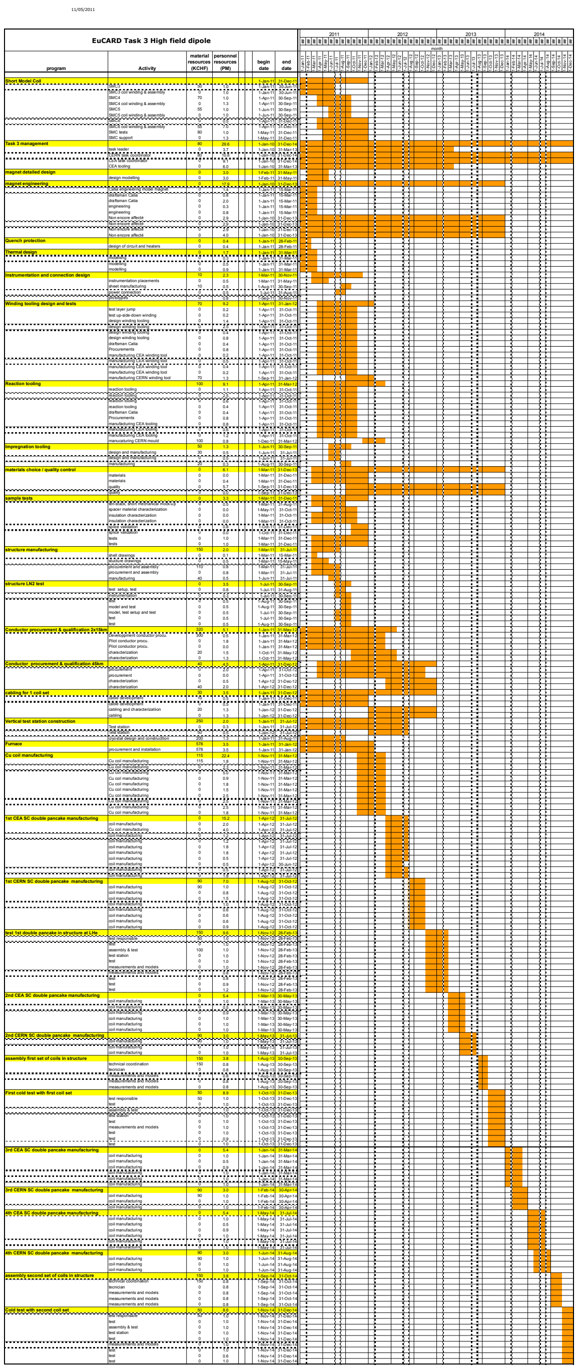
- The first magnet can be tested end 2013

11/05/2011 GdR

EuCARD Task 3 High field dipole

program	Activity	person	code	material resources (KCHF)	personnel resources (PM)			begin date	end date
Short Model Coil		CERN						1-Jan-11	31-Dec-11
Task 3 management		CEA		80	29.6			1-Jan-10	31-Dec-14
magnet detailed design		CERN		0	3.0			1-Feb-11	31-May-11
magnet engineering		CEA		0	17.9			1-Jan-10	31-Dec-13
Quench protection		CEA		0	0.4			1-Jan-11	28-Feb-11
Thermal design		CEA/CERN		0	1.7			1-Jan-11	31-Mar-11
Instrumentation and connection design		CERN		10	2.3			1-Mar-11	30-Nov-11
Winding tooling design and tests		CEA		70	9.2			1-Apr-11	31-Jan-12
Reaction tooling		CEA		100	9.1			1-Apr-11	31-Mar-12
Impregnation tooling		CERN		50	1.3			1-Jun-11	30-Sep-11
materials choice / quality control		CEA/CERN		0	6.1			1-Mar-11	31-Dec-13
sample tests		CEA		0	3.3			1-Mar-11	31-Dec-11
structure manufacturing		CERN		150	2.0			1-Mar-11	31-Jul-11
structure LN2 test		CERN		0	3.5			1-Jul-11	30-Sep-11
Conductor procurement & qualification 2x15km		CEA/CERN		320	5.1			1-Jan-11	31-May-12
Conductor procurement & qualification 45km		CEA		40	4.5			1-Apr-11	31-Dec-12
cabling for 1 coil set		CERN		30	3.5			1-Jan-11	31-Dec-12
Vertical test station construction		CERN		250	2.0			1-Jan-11	31-Jul-12
Furnace		CERN		578	3.5			1-Jan-11	31-Jan-12
Cu coil manufacturing		CEA		115	22.4			1-Nov-11	31-Mar-12
1st CEA SC double pancake manufacturing		CEA		0	15.2			1-Apr-12	31-Jul-12
1st CERN SC double pancake manufacturing		CERN		90	7.0			1-Aug-12	31-Oct-12
test 1st double pancake in structure at LHe		CERN		150	9.6			1-Nov-12	28-Feb-13
2nd CEA SC double pancake manufacturing		CEA		0	5.4			1-Mar-13	30-May-13
2nd CERN SC double pancake manufacturing		CERN		90	3.0			1-May-13	31-Jul-13
assembly first set of coils in structure		CERN		150	3.8			1-Aug-13	30-Sep-13
First cold test with first coil set		CERN		50	8.9			1-Oct-13	31-Dec-13
3rd CEA SC double pancake manufacturing		CEA		0	5.4			1-Jan-14	31-Mar-14
3rd CERN SC double pancake manufacturing		CERN		90	3.0			1-Feb-14	30-Apr-14
4th CEA SC double pancake manufacturing		CEA		0	5.4			1-May-14	31-Jul-14
4th CERN SC double pancake manufacturing		CERN		90	3.0			1-Jun-14	31-Aug-14
assembly second set of coils in structure		CERN		150	3.8			1-Sep-14	31-Oct-14
Cold test with second coil set		CERN		50	8.6			1-Nov-14	31-Dec-14





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

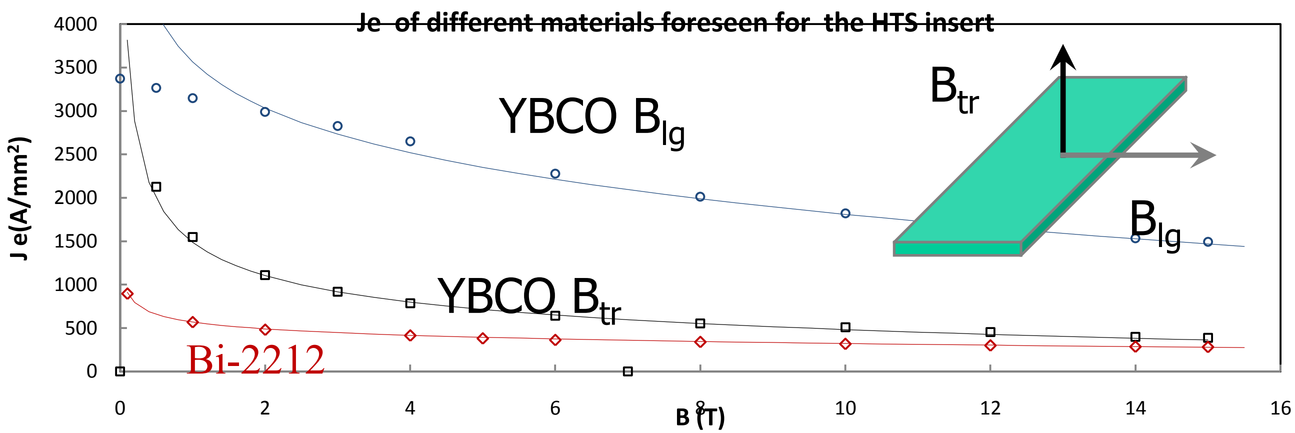
7.4.2 Design, construction and test of solenoid insert coils

7.4.3 Design, construction and test of dipole insert coils

Task 4: Very high field dipole insert (2)

Specification, characterization and quench modeling

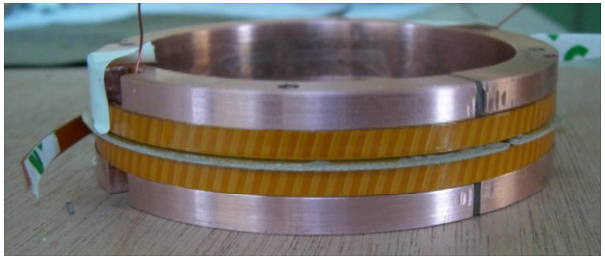
- The conductor has been selected: YCBO 12 mm width
  - The Bi-2212 option is parked for the moment due to Ic performance, the fragile nature of the strands and the additional difficulty of the reaction.
- The conductor characterization is in progress a model for the conductor performance has been made.
- Quench models (TUT and INFN-LASA) have been made and are being used to study the quench development and protection schemes.
- The quench models will be ‘calibrated’ with the solenoid tests coils
- Important subject for quench study is the coupling with the dipole outsert

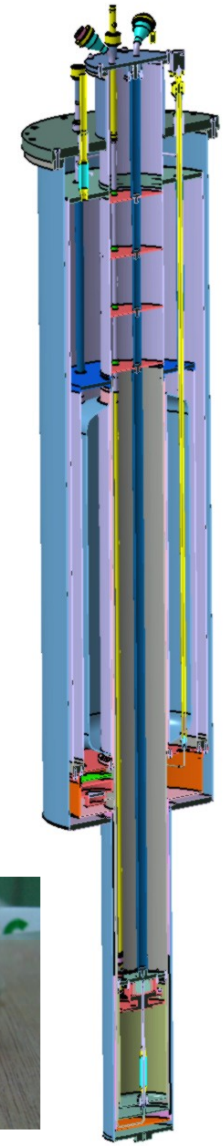


Task 4: Very high field dipole insert (3)

Test solenoids in YBCO tape

- Several have been made
- On the learning curve to make coils from YCBO
  - Conductor damage during handling
  - Connections splice problems
- The latest coils was much improved
- About 6 months delay to produce working coils
- Test cryostat existing
  - Tests in 20 T backgound fields at CNRS Grenoble and KIT

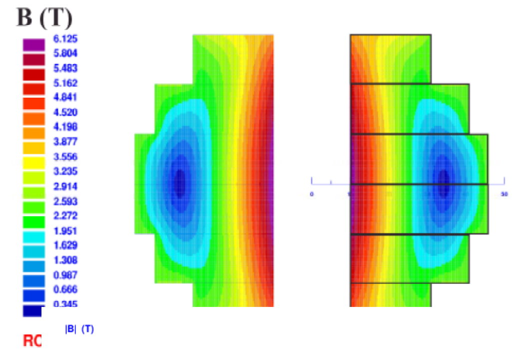


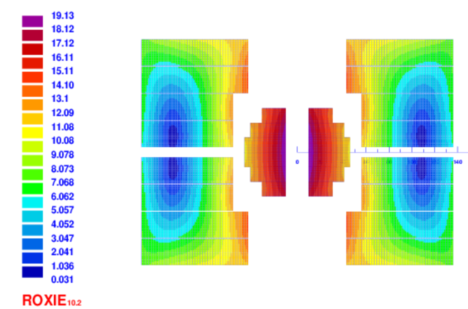


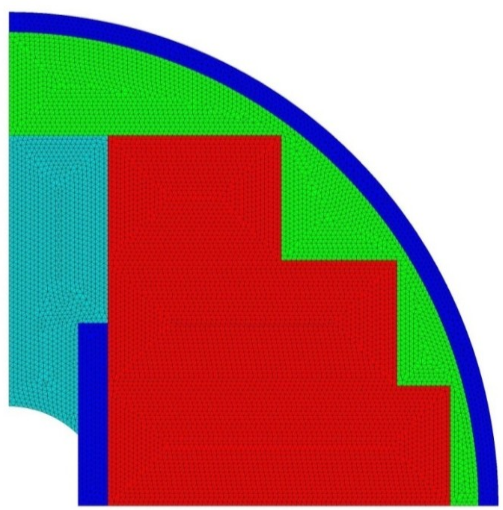
InstitutNéel-MCBT-Cryostat SuperSmes

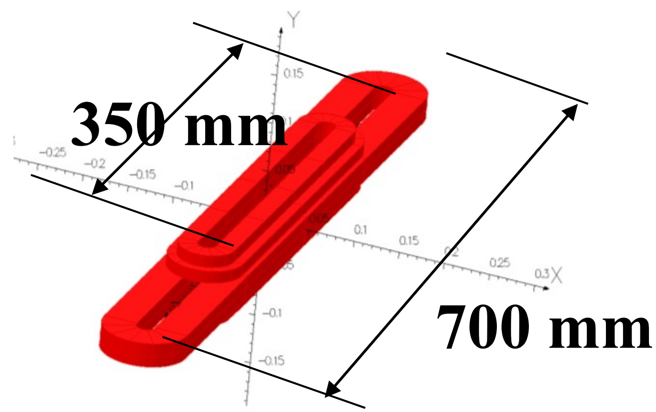
Task 4: Very high field dipole insert (4)

- Conceptual design of the insert done.
- Winding pack in 6 flat pancakes of 12 mm wide YBCO tape using a total length of 1770 m
- Insert will be mechanically independent (outer diameter 99 mm , dipole aperture 100 mm)
- Support tube 3 mm thickness + stainless steel structural part (e beam welded)
- Total Horizontal force ~ 1000 t (at 6 T insert field in 14 T oursert field from the dipole)









3D geometry

Task 5: High Tc superconducting link

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

[task ahead of schedule, personnel: =, material =]

- Conceptual design done of a novel 600 A twisted-pair cable made from different High Temperature Superconducting tapes (MgB_2, Y-123 and Bi-2223)
- assembled prototype cables of about 2 m length successfully tested at CERN at 4.5 K in a straight configuration
- Southampton University has designed and assembled a cryogenic test station to test cables of 2 m length in He gas in a variable temperature range (from 5 K to 70 K). Tests have already been performed on a 600 A twisted pair Y-123 cable
- Columbus has manufactured and delivered to CERN 1200 m of MgB_2 tape, and worked on the optimization of the joints between MgB2 tapes
- CERN is now working on the assembly of a 5 m long prototype link, which is planned to be tested at Southampton University before the end of 2011
- The HTS material needed for the 20 m long prototype has already been procured by CERN. A cabling machine is being designed and assembled at CERN for the production of long twisted pair electrically insulated cables.

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:

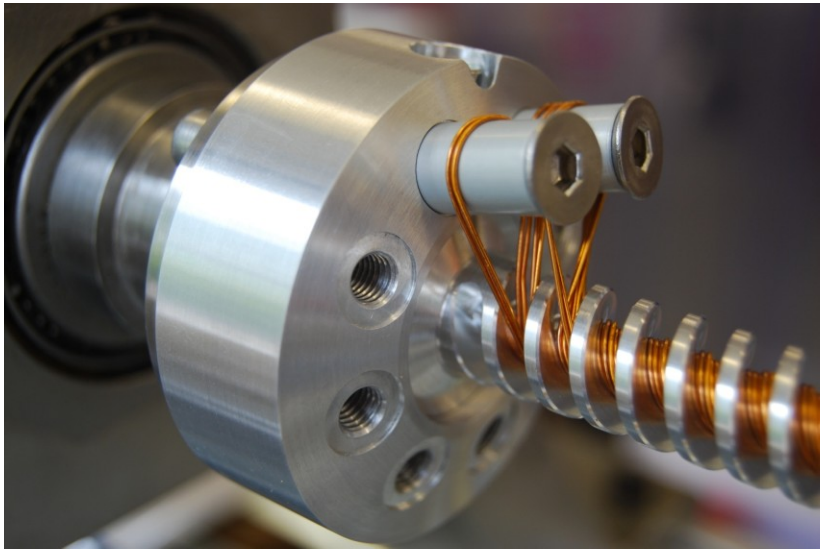
- The Nb_3Sn conductor
- Nb_3Sn insulation system (compatibility with heat treatment at 650C)
- Thin insulation (high current density).

Task 6: Short period helical undulator (2)

- First test winding of wiggler done

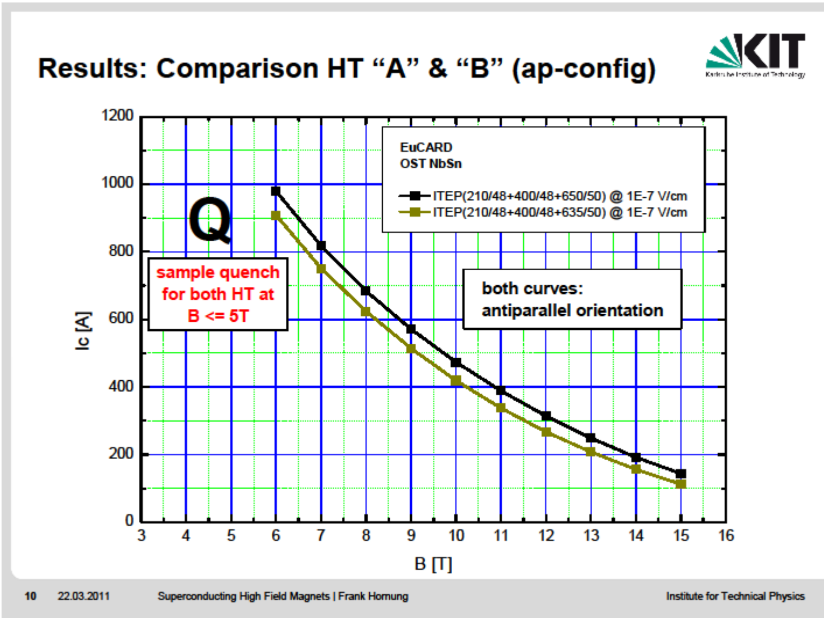
- Small issues seen with the forming of the helical groove in the steel piece: solvable problem

- The conclusion is that with 0.5 mm diameter wire one can wind a helical wiggler with a correct precision and impregnate it



Task 6: Short period helical undulator (3)

- Low field (<5 T) Ic measurements were done at KIT for the selected OST 0.5 mm RRP strand
- The strand shows at low field instabilities
- These instabilities are linked to the high Jc performance of the strand at high field.
- A different strand has to be found: with a lower Jc
- Open question: will a stable Nb_3Sn strand used at these field give a higher field than a NbTi strand ?
- Deliverable date will depend on the strand availability



Deliverables and Conclusions

Mile-stone	Description/title	Nature	Delivery month	Comment
7.1.1	1st annual HFM review meeting	O	M12	
7.1.2	2nd annual HFM review meeting	O	M24	
7.1.3	3rd annual HFM review meeting	O	M36	
7.1.4	Final HFM review meeting	O	M48	
7.2.1	Methodology for the certification of radiation resistance of coil insulation material	R	M24	
7.2.2	Preliminary heat deposition model for a dipole Nb_3Sn model magnet	R	M12	publication on web
7.2.3	Engineering heat deposition model for a dipole Nb_3Sn model magnet	R	M24	publication on web
7.3.1	Dipole Nb_3Sn coils finished	D	M36	2 coils ready for mounting
7.3.2	Dipole Nb_3Sn model magnet finished	D	M42	Ready for cold test
7.4.1	HTS conductor specifications for insert coils	R	M12	
7.4.2	Two HTS solenoid insert coils	D	M24	
7.5.1	Final design report HTS link	R	M34	
7.6.1	Short prototype SC helical undulator fabricated and tested	D	M36	

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