High Field Magnet programs in Europe

HFM activities in Europe

- NED program : ending
- NED 1.5 Short Model Coil : ongoing
- CERN HFM program : to start Jan 2008
- European FP7, Integrated Activities, Joint Research Activity, HFM : Preparing for proposal

NED

- NED is a Joint Research Activity (JRA) of the Coordinated Accelerator Research in Europe (CARE) project, funded under the auspices of EU- FP6 Research Infrastructures. Launched in January 2004; most tasks were completed by June 2007; total budget of ~2 M€ and an EU grant of 979 k€.

- Three technical Work Packages (WP) are still active
  - WP 2: Thermal Studies and Quench Protection (TSQP),
  - WP 3: Conductor Development (CD),
  - WP 4: Insulation Development and Implementation (IDI),

NED: Insulation and Thermal Studies

Insulation development

- CCRC/RAL has identified a polyimide sized glass fibre tape that is able to sustain the required Nb_3Sn heat treatment without degradation
- CEA is pursuing the development of ceramic He-porous insulation. Encouraging results were obtained for the thermal qualities, more work is needed on the mechanical properties

Thermal Studies

- A He-II double bath cryostat was built and is operational since end 2006 (Univ. of Worclaw and CEA)
- Heat transfer measurements on cable stacks and insulation samples are ongoing at CEA

NED: Conductor Development (1)

- The Conductor Development Work Package is the core of NED(~70% of the EU-allocated funding) and it includes three main Tasks
  - wire development (two industrial contracts under CERN supervision: Alstom/MSA, Fr and SMI, NL/D)
  - wire characterization (CEA, INFN-Ge, INFN-Mi, and TEU)
  - cabling studies (CERN and INFN-Mi)

NED: Conductor Development: SMI

- **Cabling test done at LBNL end of June 2007 with the SMI strand.**
  - **Strand before cabling:**
    - **288 filaments (~ 50 µm)**
    - **D_{strand} = 1.257 mm, Cu/non-Cu ratio of 1.22**
    - **I_c=1397 A @ 12 T, 4.2 K (~ 15 % below spec.), n=80, J_c~ 2500 A/mm² RRR ~ 80**
  - **5 cable sections were manufactured varying the cable compaction by changing mainly the mid-thickness of the cable. Each cable section has a length of ~2 m.**
  - **All sections were characterized by metallographic examination and a first series of critical current measurements was performed by CERN on extracted strands.**
  - **The first results on cabled strands indicate a reasonable degradation between 4 and 8%, which is already a very good result.**
- **The green light was given to SMI-EAS to start the total strand production (12,7 km) (end Febr. 2008)**
- **The cabling will be done under CERN's responsibility (either at LBNL or at CERN).**

NED: Conductor Development: Alstom

- **Has produced strands up to 2100 A/mm^2**
- **New strands expected in November. Expected Jc ~ 2500 A/mm^2**
- **Production of strands expected by mid 2008**

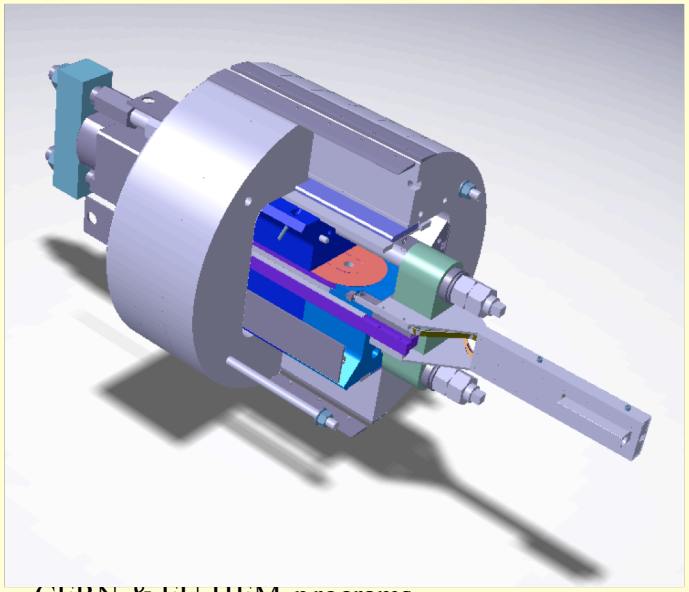
NED 1.5 Short Model Coil

CCLRC-RAL, CERN and CEA have started a program extension (NED phase 1.5) on Short Model Coils

- SMC program aim is to test cable in a coil without the complications of a CosQ geometry and to get experience with coil fabrication

  (420 mm x 190 mm x 10 mm, peak field 13 T)

- First model manufacturing to start in spring 2008



CERN High field magnet program

- CERN is starting a High Field Magnet R&D activity
- Aim: prepare for LHC interaction region upgrade to increase luminosity and possible longer term programs
- Using Nb_3Sn technology
- Complementary to existing programs (NED, LARP, Japan)
  - Avoid effort duplication
  - Get CERN up to date in the HFM technologies
- Timescale:
  - Part of the 'white paper' package approved by the CERN council in June 2007
  - To run in 2008-2011
  - In autumn 2007 a budget will be attributed

R&D on Nb_3Sn: magnets needed

- New magnets are needed for the LHC phase 2 upgrade in about 10 years
  - Quadrupoles for the low-beta insertions
  - Corrector magnets for the low-beta insertions

  and possibly
  - Dogleg dipoles for the cleaning insertions
  - Q6 for cleaning insertions
  - 10 m dipoles for the dispersion suppressors
  - Early separation dipole (D0)

- New magnet types needed for a neutrino factory
  - Open midplane dipole for a muon decay ring
  - Open midplane dipole for a beta beam decay ring

Summary: requirements

	Field	Aperture (mm)	Rad. load	e.m. Forces	Peak field	Radiation Hardness	Heat removal	Temp. margin
Low-beta insertion quadrupoles	>140 T/m	>130	high	large	>9 T	increased	very good	large
Early separation dipole in front of TAS	8 T	70	high	large	>9 T	increased	very good	large
Dipole corrector in front of Q1	4 T -6 T	>130	high	as lhc	9 T	increased	very good	large
Dogleg dipole	5 T	>56	high	as lhc	9 T	increased	very good	large
Dispersion suppressor dipole	12 T	>56	high	large	>12 T	increased	very good	large
Multipole correctors	Moderate	>130	High	as lhc	9 T	increased	very good	large
Beta beam decay ring*	4-8 T	large	high	?	9 T	increased	very good	large
Muon decay ring	4-8 T	large	high	?	9 T	increased	very good	large

Also for Phase I

Phase II

Common points:

All magnets need radiation hardness, good heat removal and a large temperature margin

and

The Low-beta quad, dispersion suppressor dipole and early separation dipole need the Nb_3Sn high Jc at 12 T

R&D Chapters (HFM-CERN)

- **Conductor**
  - Develop the conductor and the cable (in continuation of NED)
- **Enabling technologies**
  - Study the possible coil types for the dipoles, quadrupoles etc.
  - Study mechanical magnet structures
  - Develop porous insulator including the coil gluing
  - Develop radiation resistant impregnation
  - Study thermal properties and radiation resistance of components and coils
  - Build model racetrack coils
  - Prospect HTS possibilities
- **Model magnet**
  - Design build and tests 1 m models (dipole, quad and corrector)
- **Prototype magnet**
  - Design build and test 4 m prototype (dipole or quad)

Conductor Work Packages

Nb3Sn R&D

WP	WP title	deliverables	Material (MCHF)	FTE cat2	FTE cat3-4	begin	end
Total			**20.5**	**38.8**	**36.7**	**01-Jan-08**	**31-Dec-11**
Conductor			**5.6**	**11.2**	**8.8**	**01-Jan-08**	**31-Dec-11**
WPA1	Strand development	1000 m of strand lengths qualified for 3000 A/mm2 at 12 T, filaments <0.05 mm				01-Jan-08	31-Dec-10
WPA2	Cable development	100 m of cable with WPA1 strands for each cable type (for dipole, quadrupole and corrector models and prototypes)				01-Jan-08	31-Dec-10
WPA3	Cable production	Cable for 4 short model coils, 1 m (1.5 m) dipole, quadrupole and corrector models, and an 8 m long quadrupole prototype.				01-Jul-08	31-Dec-11

Enabling Technologies Work Packages

Accelerator Technology Department

Nb3Sn R&D

	WP title	deliverables	Material (MCHF)	FTE cat2	FTE cat3-4	begin	end
Total			**20.5**	**38.8**	**36.7**	**01-Jan-08**	**31-Dec-11**
Enabling Technologies			**4.54**	**8.95**	**8.4**	**01-Jan-08**	**31-Dec-11**
WPB1	Coil concept study for dipole	Proposals for dipole coil concepts				01-Jan-08	30-Sep-08
WPB2	Coil concept study for quadrupole	Proposal for a quadrupole coil concept				01-Jan-08	30-Sep-08
WPB3	Coil concept study for open mid plane dipole	Proposals for a muon ring dipole coil concept				01-Jan-09	30-Jun-09
WPB4	Coil concept study for correcor magnets	Proposal for a corrector coil concept for quadrupole, sextupole, octupole and decapole magnets				01-Jan-09	30-Jun-09
WPB5	Ceramic insulation development	Insulation for racetrack coil, mechanical, electrical and radiation qualification				01-Jan-08	31-Dec-09
WPB6	Glass fibre insulation development	Insulation for racetrack coil, mechanical, electrical and radiation qualification				01-Jan-08	31-Dec-09
WPB7	Impregnation development	Porous impregnated coils				01-Jan-08	31-Dec-09
WPB8	Thermal design of coil	Thermaly qualifying coil concepts for heat from interaction debris				01-Jan-08	31-Dec-10
WPB9	Racetrack test coil design and construction	Test coils for two insulation concepts				01-Jan-08	30-Jun-09
WPB10	Racetrack test coil cold tests	test report				########	31-Dec-09
WPB11	Thermal tests	report on the measurements on conductor stacks of the two insulation concepts				01-Jan-08	31-Dec-09
WPB12	Mechanical tests on coil samples and models	report on the measurements on mechanical models				01-Jan-08	31-Dec-10
WPB13	Radiation qualification of coil	report on irradiation tests on coil segments with all types of insulation				01-Jan-08	31-Dec-11
WPB14	Quench protection and trigger R&D	Quench protection concept				01-Jul-08	31-Dec-11
WPB15	Special instrumentation for constr and test of SC magnets	Instrumentation design, assembled instrumentation				01-Jan-08	01-Jan-11
WPB16	Very High field HTC dipole insert	dipole insert for 100 mm bore				01-Jun-10	31-Dec-11

Model Magnet Work Packages

Nb3Sn R&D

	WP title	deliverables	Material (MCHF)	FTE cat2	FTE cat3-4	begin	end
		Total	**20.5**	**38.8**	**36.7**	**01-Jan-08**	**31-Dec-11**
Model Magnet			**4.25**	**11.95**	**12.6**	**01-Jan-08**	**31-Dec-11**
WPC1	Electro-magnetic design of the dipole model	Report for electro-magnetic design of the dipole model				01-Oct-08	31-Dec-09
WPC2	Design of the dipole model magnet	Design report of the dipole model magnet, functional test specification.				01-Nov-08	31-Dec-09
WPC3	Electro-magnetic design of quadrupole model	Report for electro-magnetic design of quadrupole model				01-Oct-08	31-Dec-09
WPC4	Design of the quadrupole model magnet	Design report of the quadrupole model magnet, functional test specification				01-Jan-09	31-Mar-10
WPC5	Prepare short model test station	Test startion ready for the tests				01-Jan-09	31-Mar-11
WPC6	1.5 m tooling design and construction	Complete set of 1.5 m tooling for dipole, quadrupole and corrector model magnets.				01-Jan-08	31-Aug-09
WPC7	Components design for Nb3Sn magnets	Prototype components				01-Jul-08	31-Mar-10
WPC8	Construct coils for quadrupole model	Quadrupole model coils				01-Apr-09	31-Mar-10
WPC9	Construct quadrupole model cold mass	complete quadrupole model magnet				01-Nov-09	31-Jul-10
WPC10	Test quadrupole model magnet	test report quadrupole model magnet				01-Aug-10	31-Dec-10
WPC11	Construct coils for dipole model	dipole model coils				01-Jan-10	31-Dec-10
WPC12	Construct dipole model cold mass	complete dipole model magnet				01-Jan-11	30-Jun-11
WPC13	Test dipole model magnet	test report dipole model magnet with quench position, hot spot temperature, quench cause, multipole description of the field				01-Jul-11	30-Sep-11
WPC14	design feedback from cold tests	updated design report				01-Aug-10	31-Dec-11
WPC15	Design of the corrector model	Report for design of the demonstrator corrector model.				01-Jan-09	30-Jun-10
WPC16	Corrector magnet model construction	demonstrator model of a (sextupole, octupole or decapole) corrector magnet				01-Jan-10	31-Dec-11

Prototype Magnet Work Packages

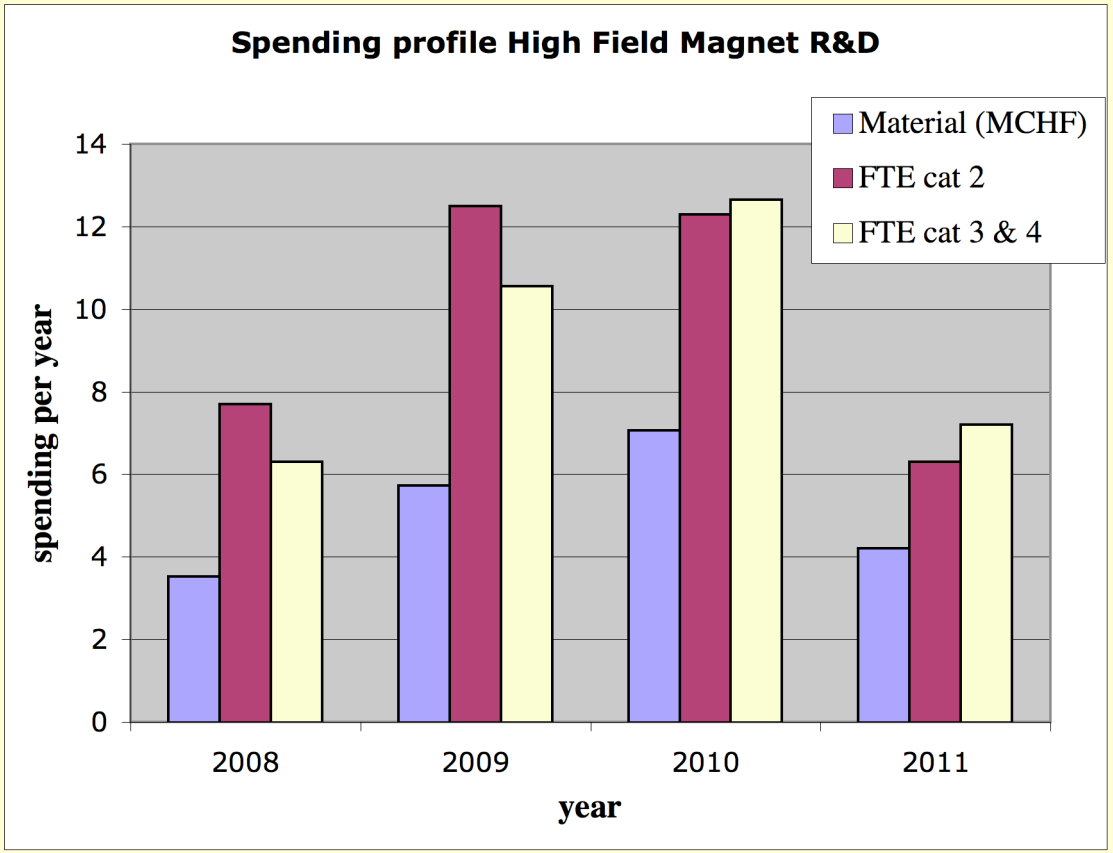
Accelerator Technology Department

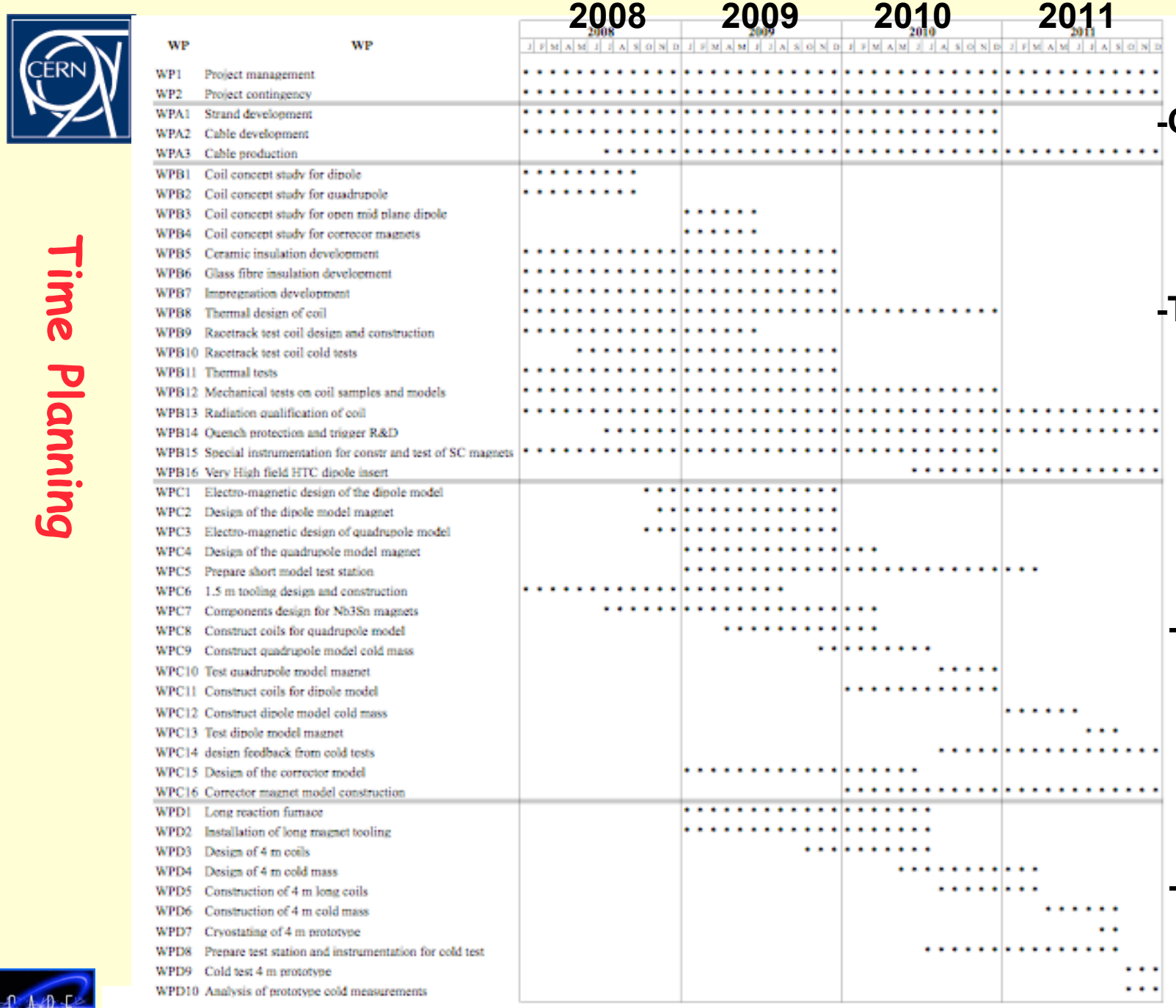
Nb3Sn R&D

	WP title	deliverables	Material (MCHF)	FTE cat2	FTE cat3-4	begin	end
Total			**20.5**	**38.8**	**36.7**	**01-Jan-08**	**31-Dec-11**
Prototype Magnet			**4.85**	**5.5**	**6.9**	**01-Jan-09**	**31-Dec-11**
WPD1	Long reaction furnace	10 m reaction furnace installed and commissioned				01-Jan-09	31-Jul-10
WPD2	Installation of long magnet tooling	full magnet workshop installed				01-Jan-09	31-Jul-10
WPD3	Design of 4 m coils	Design of 8 m quadrupole coils				01-Oct-09	31-Jul-10
WPD4	Design of 4 m cold mass	cold mass design report, functional test specification				01-May-10	01-Apr-11
WPD5	Construction of 4 m long coils	collared coils passing warm electrical tests				01-Aug-10	31-Mar-11
WPD6	Construction of 4 m cold mass	cold mass passing warm electrical and magnetic tests				01-Apr-11	30-Sep-11
WPD7	Cryostating of 4 m prototype	prototype ready for cold test				01-Aug-11	01-Oct-11
WPD8	Prepare test station and instrumentation for cold test	Test station ready for cold test				01-Jul-10	30-Sep-11
WPD9	Cold test 4 m prototype	Report on cold test				01-Oct-11	31-Dec-11
WPD10	Design feedback after prototype cold tests	Reports with design feedback				01-Oct-11	31-Dec-11

Budget

- **Total program (4y) of:**
  - **20.5 MCHF material budget**
  - **75.5 FTE personnel budget**





Time Planning

-Conductor

-Technology

-Models

-Prototype

FP7-IA-HFM

- Coordinated by ESGARD
- In the "High Intensity High Energy Proton Beam" activity (Activity leader: Roland Garoby)
- Joint Research Activity
- 11 European partners
  - CERN
  - CEA-Saclay
  - CIEMAT
  - CNRS-Genoble
  - FZ Karlsruhe
  - INFN Milano LASA
  - STFC-RAL
  - Tampere University of Technology
  - Twente University
  - UNIGE
  - Wroclaw University of Technology

FP7-IA-HFM

Accelerator Technology Department

FP7-IA-HFM

			Material (M€)	Staff (M€)			
		Total	2.56	4.61		01-Jan-09	31-Dec-12
	WP title	deliverables	Material (M€)	FTE cat2	FTE cat3-4	begin	end
Work package			2.56	25.7	19.5	01-Jan-09	31-Dec-12
WP-HFM-1	Management and coordination	Follow -up of the progress in the technical WPs Regular reporting to EU and participants' management (yearly report) Planning Financial follow up (quarterly report)	0.16	1.2	0	01-Jan-09	31-Dec-12
WP-HFM-2	Support studies	1) radiation resistance of Nb3Sn certified 2) radiation resistent insulation certified 3) rediation resistent impregnation certified 4)Heat deposition and heat removal model with experimental validation. 5)Thermal coil design parameters for dipole and quad	0.8	12.5	7	01-Jan-09	31-Dec-12
WP-HFM-3	High field dipole model	1.5 m long, 13T, 100 mm aperture model dipole magnet	0.9	5	6	01-Jan-09	30-Sep-11
WP-HFM-4	Very High field dipole insert	1 solenoid insert for 100 mm bore 1 dipole insert for 100 mm bore	0.4	5	4	01-Jun-10	31-Dec-12
WP-HFM-5	Corrector model in Nb3Sn	short model of a single conductor wound Nb3Sn corrector	0.3	2	2.5	01-Jun-10	31-Dec-12

Next steps

- **White paper HFM program**
  - Waiting for budget allocation and program comments by the DG
  - Formulate definitive HFM program
  - Selection of WP leaders
  - Form collaborations with other institutes (eg CEA, CIEMAT, INFN, STFC-RAL, UNIGE, Twente, Wroclaw, etc…)
  - Define (hardware) collaboration with LARP
  - Start work on 1/1/2008
- **FP7-IA-HFM**
  - Preparative negotiations until end of year (ESGARD, DG, DL, GLs, activity leaders, potential partners) to get a program proposal
  - Write WPs for the FP7-IA submission (Febr. 08)
  - Wait for EU approval (mid 2008)
  - FP7-IA negotiation phase
  - FP7-IA contract signature (2nd part 2008)
  - Start work in 2009 (mid 2009 ?)