22 February 2005

CARE/JRA4: Status Report of the 4th Quarter of 2004
Title: Next European Dipole (NED)

Coordinator: A. Devred (CEA & CERN), Deputy: A. den Ouden (TEU)

Participating Laboratories and Institutes:

Institute (Participant Number)	Acronym	Country	Coordinator	Scientific Contact	Associated to
CCLRC-RAL (20)	CCLRC	GB	P. Norton	D.E. Baynham	
CEA/DSM/DAPNIA (1)	CEA	F	R. Aleksan	A. Devred	
CERN (17)	CERN	CH	G. Guignard	D. Leroy	
CIEMAT (16)[a)]	CIEMAT	S	A. Faus-Golfe	F. Toral	CSIC
INFN/Milano-LASA (10)	INFN-Mi	I	S. Guiducci	G. Volpini	INFN
INFN/Genova (10)	INFN-Ge	I	S. Guiducci	P. Fabbricatore	INFN
Twente University (11)	TEU	NL	A. den Ouden	A. den Ouden	
Wroclaw University (15)	WUT	PL	M. Chorowski	M. Chorowski	

[a)] **New collaborator with respect to CARE Annex I.**

Main Objectives: Research and Development on high performances Nb_3Sn cables and high field magnets design and manufacturing to push the technology beyond present LHC limits.

Cost:

Total Expected Budget	Allocated EU Funding
2093 k€	980 k€

OUTLINE

1 MANAGMENT

Table 1.a: List of participants and of their implication in the NED Work Packages (**C**: Coordination, X: Participation).
The overall management is carried out by CEA.

Number	Participant	WP1 M&C	WP2 TSQP	WP3 CD	WP4 IDI	WG MDO[a)]
1	**CEA**	**C**	X	X	X	X
10	**INFN**	X	**C**	X		
	INFN-Ge	X		X		
	INFN-Mi	X	**C**	X		
11	**TEU**	X		X		
15	**WUT**	X	X			
16	**CSIC**	X				**C**
	CIEMAT	X				X
17	**CERN**	X		**C**		X
20	**CCLRC**	X	X		**C**	X
	CCLRC-RAL	X	X		**C**	X

[a)] The Working Group on Magnet Design and Optimisation (WGMDO) is an extension of scope with respect to CARE Annex 1.

Table 1b: Calendar of meetings, workshops and events (co)organized by NED or with NED contributions in 2004.

NA/JRA Activity	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**
CARE steering meeting		**23 Paris**				**24-25 Warsaw**					**5 Hamburg**	
NED steering meeting	**8 CERN**		**25 CERN**				**8 CERN**			**28-29 Saclay**		
NED ESAC meeting			**24 CERN**									
HHH network meeting			**22-24 WAMS Archamps**								**8-12 HHH CERN**	
Participation to meetings of other collaborations												
US-LARP						**17-18 LAPAC FNAL**						
Conferences & workshops with activity contrib.												
EPAC'04							**5-9 Lucerne**					
ASC'04										**3-8 Jacksonville**		

Table 1c: List of meetings, workshops and events (co)organized by or pertinent to NED in 2004.

Date	Title /Subject	Location	Main Organizer	Number of Participants	Comments and Web Site
January 8	NED SC	CERN	CEA&CERN	10	http://lt.tnw.utwente.nl/project.php?projectid=9
Mar. 22-24	WAMS	Archamps	CERN	100	http://amt.web.cern.ch/amt/events/workshops/WAMS2004/wams2004_index.htm
March 24	NED ESAC	CERN	CEA&CERN	15	http://lt.tnw.utwente.nl/project.php?projectid=9
March 25	NED SC	CERN	CEA&CERN	12	http://lt.tnw.utwente.nl/project.php?projectid=9
May 19	NED WGCC	CERN	TEU	7	http://lt.tnw.utwente.nl/project.php?projectid=9
May 19	NED WGMDO	CEA	CEA	9	http://lt.tnw.utwente.nl/project.php?projectid=9
July 8	NED SC	CERN	CEA&CERN	15	http://lt.tnw.utwente.nl/project.php?projectid=9
October 28	NED WGCC	CEA	TEU	7	http://lt.tnw.utwente.nl/project.php?projectid=9
October 29	NED SC	CEA	CEA	23	http://lt.tnw.utwente.nl/project.php?projectid=9
Nov. 8-11	CARE-HHH	CERN	CERN	50	http://care-hhh.web.cern.ch/care-hhh/
Dec. 17	NED WGMDO	CIEMAT	CIEMAT	7	http://lt.tnw.utwente.nl/project.php?projectid=9

Table 1c: List of milestones and deliverables due in 2004.

Deliverable Number	Milestone Number	Name	Work Package/Task Number	Delivered by	Planned (in months)	Achieved (in months)	EDMS Number
1		Final Report on Wire and Cable Specifications	CD/3.3	CERN	6	6	475443
	1	Report on Specifications for Conductor Insulation	IDI/4.2	CCLRC	6	7	548037V5
	2	Report on Definition of the Test Programme for Conductor Insulation[a)]	IDI/4.3&4.4	CCLRC&CEA	7	10	548038V2
	3	Status Report on Conductor Development[b)]	CD/3.4	CERN	-	3	Restricted Access
2		Design Report on 15 T Dipole Magnet	CD/3.2	CERN	12	13	555826
	4	Interim Report on Quench Protection	TSQP/2.3	INFN-Mi	12	13	555756

[a)] Scope of report has been extended to include test programme on innovative insulation (Task 4.4).
[b)] The milestone entitled “First Results on Wire Development” that was due on 30 June 2005 has been split into two “Status Reports” due on 15 December 2004 and 15 December 2005.

2 DISSEMINATION

2.1 List of talks

Table 2.1: List of review talks given by NED Collaborators in 2004.

#	2.1.1.1.1.1.1.1 Title	Speaker and lab	Location	Date
1	NED Status Report	A. Devred (CEA&CERN) and T. Taylor (CERN) on behalf of the NED Collaboration	KEK, Tsukuba, Japan	9 March 2004
2	Next European Dipole (NED) Overview	A. Devred (CEA&CERN) on behalf of the NED Collaboration	Journées de l'Association Française de Froid, Belfort, France	25 May 2004
3	Next European Dipole (NED) Overview	A. Devred (CEA&CERN) on Behalf of the NED Collaboration	Department Of Energy (DOE), Washington, DC, USA	16 June 2004
4	Status of the Next European Dipole (NED) Activity of the Coordinated Accelerator Research in Europe (CARE) Project	A. Devred (CEA&CERN) on Behalf of the NED Collaboration	Applied Superconductivity Conference, Jacksonville, FL	6 October 2004

2.2 *List of papers*

Table 2.2: List of papers issued by NED collaborators in 2004.

#	CARE document type and number	Title	Author(s) and Lab(s)	Reference	Date
1	N/A	High field accelerator magnets beyond LHC	A. Devred (CEA&CERN)	*Proceedings of the 2003 IEEE Particle Accelerator Conference*, IEEE Catalogue 03CH37423, pp. 146–150, 2003	2003
2	N/A	High field accelerator magnet R&D in Europe	A. Devred (CEA&CERN), D.E. Baynham (CCLRC), L. Bottura (CERN), M. Chorowski (WUT), P. Fabbricatore (INFN-Ge), D. Leroy (CERN), A. den Ouden (TEU), J. M. Rifflet (CEA), L. Rossi, O. Vincent-Viry (CERN), G.Volpini (INFN-Mi)	*IEEE Trans. Appl. Supercond.*, Vol. 14 No. 2, pp. 339-344, 2004	2004
3	Conf-04-005-HHH	Performance limits and IR design of a possible LHC luminosity upgrade based on NbTi SC magnet technology	F. Ruggiero, O. Brüning, R. Ostojic, L. Rossi, W. Scandale, T. Taylor (CERN), A. Devred (CEA&CERN)	*Proceedings of the 2004 European Particle Accelerator Conference*, pp. 608-610, 2004	2004
4	Conf-04-020-NED	Status of the Next European Dipole (NED) Activity of the Coordinated Accelerator Research in Europe (CARE) Project	A. Devred (CEA&CERN), B. Baudouy (CEA), D.E. Baynham (CCLRC), T. Boutboul (CERN), S. Canfer (CCLRC), M. Chorowski (WUT), P. Fabbricatore, S. Farinon (INFN-Ge), H. Félice (CEA), P. Fessia (CERN), J. Fydrich (WUT), M. Greco (INFN-Ge), J. Greenhalgh (CCLRC), D. Leroy (CERN), P. Loverige (CCLRC), F. Michel (CEA), L. R. Oberli (CERN), A. den Ouden (TEU), D. Pedrini (INFN-Mi, J. Polinski (WUT), V. Previtali (CERN), L. Quettier, J. M. Rifflet (CEA), J. Rochford (CCLRC), F. Rondeaux (CEA), S. Sanz (CIEMAT), S. Sgobba (CERN), M. Sorbi (INFN-Mi), F. Toral-Fernandez (CIEMAT), R. van Weelderen (CERN), P. Védrine (CEA), O. Vincent-Viry (CERN), G. Volpini (INFN-Mi)	To appear in the Proceedings of the Applied Superconductivity Conference, Jacksonville, FL, October 3–8, 2004	2004
5	Conf-04-020-NED	Future accelerator magnet needs	A. Devred (CEA&CERN), S. Gourlay (LBNL), A. Yamamoto (KEK)	To appear in the Proceedings of the Applied Superconductivity Conference, Jacksonville, FL, October 3–8, 2004	2004

3 RESOURCES

3.1 Additional Staff Hiring

Table 3.1: Temporary Staff Hiring.

#	Lab	Job Type	Duration	Work subject	Status
1	INFN-Mi	Fellow	6 months	Quench protection computation (supervisor: G. Volpini)	Hired (251104)
2	WUT	Fellow	7 months	Cryostat design (supervisor: M. Chorowski)	Hired (171104)
3	WUT	Fellow	7 months	Cryostat design (supervisor: M. Chorowski)	Hired (171104)
4	CEA	Postdoc	1 year	Heat transfer measurement (supervisor: B. Baudouy)	Fall 2005

3.2 Budget

Table 3.2a: Estimated budget for the first 18 months (January 1st 2004 to June 30 2005).

JRA4	Participant (cost model)	Permanent Staff including indirect cost (Euros)	Additional Staff including indirect cost (Euros)	Durable Equipment including indirect cost (Euros)	Consumables and Prototyping including indirect cost (Euros)	Travel including indirect cost (Euros)	Expected costs including indirect cost (Euros)	Direct cost	Subcontract	Indirect cost	Requested funding (Euros)
1	CEA (FC)	199,000	5,000	0	65,000	8,000	277,000	179,000	0	98,000	43,000
10	INFN (AC)	0	15,000	0	7,000	11,000	33,000	27,500	0	5,500	22,000
11	TEU (FC)	36,000	0	0	5,000	4,000	45,000	28,000	0	17,000	18,000
15	WUT (AC)	0	8,500	0	39,500	4,000	52,000	47,495	24,968	4,505	52,000
17	CERN (AC)	0	0	0	400,000	0	400,000	400,000	400,000	0	400,000
20	CCLRC (FC)	135,000	138,000	0	40,000	4,000	317,000	167,000	0	150,000	45,000
	Grand total	**370,000**	**166,500**	**0**	**556,500**	**31,000**	**1,124,000**	**848,995**	**424,968**	**275,005**	**580,000**

Table 3.2b: Executed budget for the first 12 months (January 1st 2004 to December 31st 2004).

JRA4	Participant (cost model)	Permanent Staff including indirect cost (Euros)	Additional Staff including indirect cost (Euros)	Durable Equipment including indirect cost (Euros)	Consumables and Prototyping including indirect cost (Euros)	Travel including indirect cost (Euros)	Expected costs including indirect cost (Euros)	Direct cost	Subcontract	Indirect cost	First received payment (Euros)
1	CEA (FC)	157,537			19,724	10,063	187,324	118,745	0	68,579	32,250
10	INFN (AC)	0	2,784	0	5,258	3,203	11,245	9,370	0	1,874	16,500
11	TEU (FC)	27,578	0	0	1,553	2,093	31,224	17,739	0	13,485	12,490
15	WUT (AC)	0	2,191.58	0	26,655.81	1,416.05	30,263.44	29,548	25,968	716	38,994
17	CERN (AC)	0	0	0	91,906	0	91,906	91,906	91,906	0	300,000
20	CCLRC (FC)	71,151	0	0	11,026	8,130	90,307	48,802	0	41,505	33,750
	Grand total	**256,262**	**4,975**	**0**	**156,123**	**24,905**	**442,265**	**316,106**	**117,874**	**126,159**	**433,984**

Table 3.2c: Requested budget for the next 18 months (January 1st 2005 to June 30 2006).

JRA4	**Participant (cost model)**	**Permanent Staff including indirect cost (Euros)**	**Additional Staff including indirect cost (Euros)**	**Durable Equipment including indirect cost (Euros)**	**Consumables and Prototyping including indirect cost (Euros)**	**Travel including indirect cost (Euros)**	**Expected costs including indirect cost (Euros)**	**Direct cost**	**Subcontract**	**Indirect cost**	**Requested funding (Euros)**
1	CEA (FC)	358,116	41,667	0	92,500	24,000	516,283	0	0	516,283	45,000
10	INFN (AC)	0	15,000	0	25,750	7,000	47,750	39,792	0	7,958	47,750
11	TEU (FC)	139,334	0	0	30,000	4,500	173,834	105,693	0	68,141	69,534
15	WUT (AC)	0	6,308	0	12,844	2,584	21,736	18,113	0	3,623	21,736
17	CERN (AC)	0	0	0	350,000	0	350,000	350,000	350,000	0	350,000
20	CCLRC (FC)	274,000	0	0	33,300	16,500	323,800	163,967	0	159,833	26,250
	Grand total	**771,450**	**62,975**	**0**	**544,394**	**54,584**	**1,433,403**	**677,565**	**350,000**	**755,838**	**560,270**

4 STATUS OF THE WORK

4.1 Work Package 1: Management and Communication (M&C)

2004 Summary

The NED Steering Committee (SC) has met four times (8 January, 25 March, 8 July and 29 October), while the NED External Scientific Advisory Committee (ESAC) has met once (24 March) and has produced a report.

The NED work breakdown structure has been implemented by E. Deluncige (CERN) into the CERN Engineering Data and Management Service (EDMS):
https://edms.cern.ch
under CERN/AT Department/CARE. This service is used to release, circulate, track and store documents. Access is restricted to members of the NED collaboration (as identified in EDMS 547908).

A dedicated web page has been set up by A. den Ouden (TEU):
http://lt.tnw.utwente.nl/project.php?projectid=9
The webpage is updated regularly with all information pertinent to the NED JRA and is accessible by the general public.

Detailed implementation plans of the three technical Work Packages (Thermal Studies and Quench Protection or TSQP, Conductor Development or CD, and Insulation Development and Implementation or IDI) have been established and launched and all collaborators have started their activities. In addition, the Activity scope has been extended, thanks to the setting up of a Working Group on Magnet Design and Optimization (WGMDO), supported by CCLRC and by additional resources from CEA, CERN and CIEMAT, a CARE Associated Laboratory who has decided to join the NED collaboration.

Two intermediate status reports have been produced

- 2nd quarter of 2004: EDMS 548027
- 3rd quarter of 2004: EDMS 548028

4.1.1 Activity Coordination

The NED JRA is coordinated by A. Devred (CEA&CERN), helped by A. den Ouden (TEU).

The following actions have been carried out and/or are foreseen

- ✓ 19–21 November 2003: participation of A. Devred (CEA&CERN) and A. den Ouden (TEU) to CARE Kick Off meeting at CERN
- ✓ 13 January 2004: visit of A. Devred (CEA&CERN) to INFN-Ge
- ✓ 16 January 2004: visit of P. Védrine (CEA) and A. Devred (CEA&CERN) to CIEMAT
- ✓ 27 January 2004: visit of A. Devred (CEA&CERN) to TEU
- ✓ 13 February 2004: A. Devred (CEA&CERN), P. Lebrun and L. Rossi (CERN) to INFN-Mi

- ✓ 23–24 February 2004: participation of A. Devred (CEA&CERN) to 1st CARE Steering Committee and Dissemination Board meetings in Paris, France
- ✓ 19 March 2004: visit of F. Rondeaux and P. Védrine (CEA), A. Devred (CEA&CERN) to CCLRC
- ✓ 22–24 March 2004: participation to Workshop on Accelerator Magnets Superconductor (WAMS) organized within the framework of AMT Work Package of HHH Network Activity
- ✓ 13 April 2004: visit of A. Devred (CEA&CERN) and M. Pojer (CERN) to INFN-Ge
- ✓ 2–3 June 2004: visit of B. Baudouy and F. Michel (CEA), A. Devred (CEA&CERN), R. Van Weelderen (CERN) to WUT
- ✓ 24–25 June 2004: participation of A. Devred (CEA&CERN) and A.den Ouden (TEU) to 2nd CARE Steering Committee and Dissemination Board meetings in Warsaw, Poland
- ✓ 24 August 2004: visit of M. Chorowski (WUT) to CEA/Saclay
- ✓ 2–5 November 2004: participation of A. Devred (CEA&CERN) to 1st CARE general meeting at DESY
- ✓ 11-12 November 2004: participation of a number of NED collaborators to the HHH/AMT network meeting organised at CERN.

4.1.2 Meetings

4.1.2.1 Steering Committee Meetings

The oversight of the NED JRA is ensured by a Steering Committee (SC) made up of

- E. Baynham (CCLRC)
- A. Devred (CEA&CERN), Chairman
- D. Leroy (CERN)
- J.M. Rifflet (CEA)
- G. Volpini (INFN-Mi)
- A. den Ouden (TEU), Secretary

SC meetings are held every three months. Available copies of the presentations and minutes of the meetings have been loaded into EDMS and are posted on the NED website.

The following actions have been carried out and/or are foreseen

- ✓ 8 January 2004: meeting at CERN
  participants: E. Baynham (CCLRC), A. Devred (CEA&CERN), D. Leroy, L. Oberli and O. Vincent-Viry (CERN), P. Fabbricatore (INFN-Ge), G. Volpini (INFN-Mi), A. den Ouden (TEU)
  special guests: L. Rossi (CERN), H. ten Kate (CERN&TEU)
  agenda+talks: EDMS 548032; also available on NED website
- ✓ 25 March 2004: meeting at CERN
  participants: B. Baudouy and J.M. Rifflet (CEA), A. Devred (CEA&CERN), D. Leroy and R. van Weldeeren (CERN), F. Toral (CIEMAT), G. Volpini (INFN-Mi), E. Baynham and S. Canfer (CCLRC), A. den Ouden (TEU)
  special guests: A. Yamamoto (KEK), S. Gourlay (LBNL)

agenda+talks: EDMS 548033; also available on NED website

- ✓ 8 July 2004: meeting at CERN
  participants: E. Baynham and S. Canfer (CCLRC), A. Devred (CEA&CERN), F. Rondeaux and P. Védrine (CEA), T. Boutboul, D. Leroy, L. Oberli, V. Previtali, O. Vincent-Viry, R. van Weldeeren (CERN), P. Fabbricatore and S. Farinon (INFN-Ge), M. Sorbi (INFN-Mi), A. den Ouden (TEU)
  special guests: –
  agenda+talks: EDMS 548034; also available on NED website
- ✓ 29 October 2004: meeting at CEA/Saclay
  participants: S. Canfer (CCLRC), A. Devred (CEA&CERN), H. Felice, L. Quettier, J.M. Rifflet, F. Rondeaux, P. Védrine (CEA), T. Boutboul, D. Leroy, L. Oberli, V. Previtali, R. van Weldeeren (CERN), M. Greco (INFN-Ge), D. Pedrini, M. Sorbi, G. Volpini (INFN-Mi), A. den Ouden (TEU), M. Chorowski, J. Polinski (WUT)
  special guests: R. Aleksan (CPPM), P. Debu, M. Durante (CEA), B. Adamowicz (Kryosystem)
  agenda+talks: 548035; also available on NED website
- next meetings: 20 January and 14 April 2005 at CERN

4.1.2.2 External Scientific Advisory Committee Meetings

The NED JRA Coordinator is assisted by an External Scientific Advisory Committee (ESAC). The charges and composition of the committee are defined in EDMS 548039. The committee is made up of

- J.L. Duchateau (CEA)
- P. Lebrun (CERN)
- L. Rossi (CERN)
- R.M. Scanlan (formerly LBNL, retired)
- J.B. Strait (FNAL), Chairman
- H.H.J. ten Kate (CERN&TEU)

The following actions have been carried out and/or are foreseen

- ✓ 24 March 2004: first meeting at CERN
  agenda: EDMS 548039; presentations available on NED website
- ✓ 29 March 2004: first ESAC report (EDMS 548041)
  agenda+talks: 548035; also available on NED website
- next meeting; fall of 2005

4.2 Work Package 2: Thermal Studies and Quench Protection (TSQP)

2004 Summary

The fabrications of the cryostat and of the cryogenic modules of the Heat Transfer Facility are proceeding as planned under the supervision of WUT and the hardware is expected to be delivered to CEA in January/February 2005.

After completing a literature survey of relevant material properties (EDMS 555753), INFN-Mi has carried out detailed quench computations based on the 88-mm-aperture, cos□-layer design chosen as a reference for NED in conclusion of Task 3.2. The computations, summarized is an interim report (EDMS 555756), deal with two magnet lengths (1 m and 5 m) and include the effect of quench protection heaters.

4.2.1 TSQP WP coordination

The TSQP Work Package is articulated around two main tasks: Heat Transfer Measurements (2.2) and Quench Computation (2.3). Task 2.2 is coordinated by B. Baudouy (CEA), while Taks 2.3 is coordinated by G. Volpini (INFN-Mi). The Task Leaders report to the NED Steering Committee and, ultimately, to the NED/JRA Coordinator.

4.2.2 Heat Transfer Measurements

The following actions have been carried out and/or are foreseen

4.2.2.1 Drafting of Test Facility Specifications

- ✓ 28 January 2004: preparatory meeting at CEA/Saclay
  participants: B. Baudouy, P. Chesny, B. Hervieu, F. Michel and J.M. Rifflet (CEA), A. Devred (CEA&CERN)
- ✓ 27 February 2004: programme proposal issued by B. Baudouy (CEA; EDMS 548123)
- ✓ March 2004: review of programme proposal by P. Lebrun and D. Leroy (CERN) and approbation by SC meeting
- ✓ 4 May 2004: cryostat specification issued by B. Baudouy, B. Hervieu and F. Michel (CEA; EDMS 548129V1)
- ✓ May 2004: specification submitted for review to P. Lebrun and R. Van Weelderen (CERN) and M. Chorowski (WUT)
- ✓ 8 June 2004: final cryostat specification issued by B. Baudouy, B. Hervieu and F. Michel (CEA; EDMS 548129V2)

Sub-Task completed

4.2.2.2 Cryostat Design and Fabrication

- ✓ 3 June 2004: preparatory visit to Kryosystem (Poland)
  participants: B. Baudouy, F. Michel (CEA), A. Devred (CEA&CERN) R. van Weelderen (CERN), M. Chorowski, J. Fydrych and J. Polinski (WUT), B. Adamowicz, G. Michalski and G. Strychalski (Kryosystem)
- ✓ July 2004: start of technical design at WUT
- ✓ July 2004: start of tendering procedure
- ✓ 10 August 2004: redefinition of WUT budget allocation
- ✓ August 2004: contract attribution to Kryosystem
- ✓ 29 Ooctober 2004: Production Readiness Review at CEA Saclay

- ✓ participants: B. Baudouy, F. Michel (CEA), R. van Weelderen (CERN), M. Chorowski, J. Polinski (WUT), B. Adamowicz (Kryosystem) report: EDMS 548154)
- ✓ 17 November 2004: hiring of Grzegorz Michalski and Maciej Matkowski at WUT (additional staff; till 30 June 2005)
- □ Mid February 2005: completion of manufacturing
- □ Late February 2005: reception test at WUT
- □ Late February 2005: shipment to CEA/Saclay

4.2.2.3 Cryogenic Module Design and Fabrication

- ✓ 22 June 2004: design specifications issued by B. Baudouy and F. Michel (CEA; EDMS 548139, based on design study reviewed in EDMS 548137)
- ✓ 1st July 2004: call for tender issued by F. Michel (CEA)
- ✓ 15 July 2004: reception of answers to call for tender
- ✓ 17 September 2004: purchase requisition to be issued by F. Michel (CEA)
- ✓ 10 October 2004: contract awarded to Kryosystem.
- □ Mid February 2005: completion of manufacturing

4.2.2.4 Facility Integration and Qualification

Not started

4.2.2.5 Measurements and Analyses

Not started

4.2.3 Quench Protection Computation

The following actions have been carried out and/or are foreseen

- ✓ 5 March 2004: draft computation programme issued by M. Sorbi and G. Volpini (INFN-Mi; EDMS 555747)
- ✓ March 2004 SC meeting: discussion of computation programme
- ✓ April–June 2004: compilation of material properties (EDMS 555753)
- ✓ June-October 2004: first computation on baseline (88-mm-aperture, cos□, layer design) magnetic configuration
- ✓ November-December 2004: extended computation on baseline magnetic configuration
- ✓ 25 November 2004: hiring of Valeria Granata by INFN-Mi (additional staff for 6 months)
- □ Early February 2005: interim report (INFN-Mi; EDMS 555756); EU milestone
- □ December 2004-April 2005: cross-calibration of computation codes
- □ January-June 2005: computation on other magnetic configurations
- □ 30 June 2005: final report (INFN-Mi); EU deliverable

Table 4.2a: Status of the lowest Sub-Tasks level in the TSQP WP (as of 31 December 2004).

WBS #	Title	Original begin date (Annex 1)	Original end date (Annex 1)	Estimated Status	Revised end date
2.1	TSQP WP Coordination				
2.2	Heat Transfer Measurements				
2.2.1	Drafting of Test Facility Specifications	1 January 2004	31 March 2004	Completed	8 June 2004
2.2.2	Cryostat Design and Fabrication	1 April 2004	31 Dec. 2004	40%	February 2005
2.2.3	Cryogenic Module Design and Fabrication	1 April 2004	31 Dec. 2004	40%	February 2005
2.2.4	Facility Integration and Qualification	1 January 2005	31 March 2005	Not started	-
2.2.5	Measurements and Analyses	1 April 2005	31 Dec. 2006	Not started	-
2.3	Quench Protection Computation	1 April 2004	30 June 2005	30 %	On time

Table 4.2b: Status with respect to the milestones and deliverables due in the TSQP WP (as of 31 December 2004).

WBS #	Title	Responsible Lab(s)	Due date in Annex 1	Status	Revised delivery date
2.2.4	Report on Heat Transfer Facility Commissioning (deliverable)	CEA and WUT	1 April 2005	Not started	-
2.2.5	Interim Report on Heat Transfer Measurements (milestone)	CEA	31 December 2005	Not started	-
2.2.5	Final Report on Heat Transfer Measurements (deliverable)	CEA	31 December 2006	Not started	-
2.3	Interim Report on Quench Protection (milestone)	INFN-Mi	31 December 2004	90%	January 2005
2.3	Final Report on Quench Protection (deliverable)	INFN-Mi	30 June 2005	Not started	-

4.3 Work Package 3: Conductor Development (CD)

2004 Summary

CERN has investigated two different magnetic designs, referred to as cosθ layer design and cosθ block design and has considered 3 apertures: 88 mm, 130 mm and 160 mm. These investigations, described in a report (EDMS 555826), led to the definition of wire and cable parameters used as a basis for conductor specifications. The 88-mm-aperture, cosθ layer design has been chosen as a baseline for NED (EDMS 555825).

After writing comprehensive wire and cable specifications and a detailed technical questionnaire (EDMS 475443), CERN has carried out a call for tender and has selected Alstom/MSA, in France, and ShapeMetal Innovation (SMI), in the Netherlands, to be the main wire and cable contractors. The two companies have established a development plan, which has been agreed upon by CERN, and have started the procurements of raw materials.

A Working Group on Conductor Characterization (WGCC) made up of representatives from CEA, CERN, INFN-Mi, INFN-Ge and chaired by A. den Ouden (TEU) has been set to oversee the wire I_C and magnetization measurements. The Working Group has initiated a cross-calibration of the various test facilities that will be used to perform these measurements.

4.3.1 CD WP coordination

The CD Work Package is articulated around three main poles: conductor development (encompassing Tasks 3.2, 3.3, 3.4 and 3.6), conductor characterization (encompassing Tasks 3.5 and 3.7), and mechanical studies (extension of scope with respect to CARE Annex I, initiated by INFN-Ge and partially supported by CERN).

The conductor development pole is coordinated by D. Leroy (CERN). A working Group on Conductor Characterization (WGCC), chaired by A. den Ouden (TEU) has been set up to coordinate the conductor characterization efforts, while S. Farinon (INFN-Ge) is the principal investigator on the mechanical model. The Pole Coordinators report to the NED Steering Committee and, ultimately, to the NED/JRA Coordinator.

4.3.2 Design of a 15 T Dipole Magnet

The following actions have been carried out

- ✓ September 2003–July 2004: preliminary design computations carried out by O. Vincent-Viry (CERN) under D. Leroy supervision (CERN)
- ✓ November 2003: report on 2D magnetic induction analytical calculation issued by O. Vincent-Viry (CERN; EDMS 431540)
- ✓ January 2004 SC meeting: first presentation of preliminary design computations by O. Vincent-Viry (CERN)
- ✓ 4 May 2004: meeting at CEA to review magnetic configurations and choice of 88-mm-aperture, cosθ layer, baseline design (EDMS 555825) participants: H. Félice, L. Quettier, J.M. Riflet, P. Védrine (CEA), A. Devred (CEA&CERN), D. Leroy and O. Vincent-Viry (CERN)
- ✓ 2 August 2004: seminar at CERN by O. Vincent-Viry (CERN) on preliminary magnet designs

- Early February 2005: final report (CERN; 555826); EU deliverable

Sub-Task near completion

4.3.3 Specifications on Wire and Cable

The following actions have been carried out

- ✓ 11 May 2004: first draft specification issued by D. Leroy (CERN) and communicated to A. Devred (CEA&CERN)
- ✓ 14 May 2004: first draft reviewed by A. Devred (CEA&CERN)
- ✓ 18 May 2004: second draft specification issued by D. Leroy and communicated to A. Devred (CEA&CERN) and A. den Ouden (TEU)
- ✓ 1 June 2004: third draft specification issued by D. Leroy and communicated to NED SC
- ✓ 4 June 2004: Specification Committee Meeting at CERN participants: T. Boutboul, P. Bryant (Chairman), P. Lebrun, D. Leroy, L. Oberli, L. Rossi (CERN), H.H.J. ten Kate (CERN&TEU)]
- ✓ 18 June 2004: final specification and technical questionnaire issued by D. Leroy (CERN; EDMS 475443); EU deliverable

Sub-Task completed

4.3.4 Wire Development

The following actions have been carried out and/or are foreseen

- ✓ 12 December 2003: preparatory visit to Alstom/MSA, France participants: A. Devred (CEA&CERN), D. Leroy, T. Boutboul and L. Oberli (CERN)]
- ✓ 15 December 2003: preparatory visit to European Advanced Superconductors (EAS, Germany)
  participants: A. Devred (CEA&CERN), D. Leroy and L. Oberli (CERN) + SMI representative
- ✓ 27 January 2004: preparatory visit to ShapeMetal Innovation (SMI, The Netherlands)
  participants: A. Devred (CEA&CERN), D. Leroy, T. Boutboul, L. Oberli and A. Unervick (CERN) + EAS representatives
- ✓ 21 June 2004: call for tender issued to Alstom/MSA, EAS, Outokumpu Copper (OK Cu, Finland), Outokumpu SI (OKSI, Italy) and SMI
- ✓ 20 August 2004: meeting at CERN with SMI and EAS to prepare answer to call for tender
- ✓ 23 August 2004: meeting at CERN with OK to prepare answer to call for tender
- ✓ 24 August 2004: meeting at CERN with Alstom to prepare answer to call for tender
- ✓ 6 September 2004: tenders' opening at CERN; selection of Alstom/MSA and SMI
- ✓ 24 September 2004: sending of orders to CERN Finance Division
- ✓ 15 November 2004: contracts' signature by Alstom/MSA and SMI
- ✓ 15 December 2004: first progress reports issued by Alstom/MSA and SMI (restricted access)

- 15 December 2005: second progress reports issued by Alstom/MSA and SMI
- 30 September 2006: final wire production; EU deliverable

4.3.5 Wire Characterization

The following actions have been carried out and/or are foreseen

4.3.5.1 Definition of Measurement Procedures

- ✓ March 2004: setting up of Working Group on Conductor Characterization (WGCC), chaired by A. den Ouden (TEU)
  WGCC charges and composition: EDMS 548084
- ✓ 19 May 2004: first Working Group meeting at CERN
  participants: L. Quettier (CEA), V. Previtali (CERN), P. Fabbricatore and M. Greco (INFN-Ge), D. Pedrini, G. Volpini (INFN-Mi), A. den Ouden (TEU)
- ✓ June 2004-October 2004: first round of test wires for cross-calibration purposes
- ✓ 28 October 2004: second Working Group meeting at CEA
  participants: L. Quettier (CEA), V. Previtali, T. Boutboul (CERN), M. Greco (INFN-Ge), D. Pedrini, G. Volpini (INFN-Mi), A. den Ouden (TEU)
- November 2004-January 2005: second round of test wires for cross-calibration purposes
- next Working Group meeting: 4 February 2005 at INFN-Mi
- 30 June 2005: end of cross-calibration program
- 31 December 2004: first interim report on wire characterization; EU milestone
- 31 December 2005: second interim report on wire characterization; EU milestone
- 31 October 2006: final report on wire characterization; EU deliverable

4.3.5.2 Wire I_C Measurements

4.3.5.2.1 Wire I_C Measurements at CEA

- June 2004-June 2005: cross-calibration program

4.3.5.2.2 Wire I_C Measurements at INFN-Mi

- June 2004-June 2005: cross-calibration program

4.3.5.2.3 Wire I_C Measurements at TEU

- June 2004-June 2005: cross-calibration program

4.3.5.3 Wire Magnetization Measurements at INFN-Ge

- ✓ 21 January 2004: preparatory meeting at CERN
  participants: A. Devred (CEA&CERN), D. Leroy (CERN) and P. Fabbricatore (INFN-Ge]
- ✓ 23 March 2004: first report on preliminary measurements issued by P. Fabbricatore and M. Greco (INFN-Ge)
- ✓ 23 March 2004–13 April 2004: review of preliminary measurements by A. Devred (CEA&CERN) and D. Leroy (CERN)
- June 2004-June 2005: participation to cross-calibration program defined by WGCC

4.3.6 Cable development and manufacturing

Not started

4.3.7 Cable Characterization
Not started

4.3.8 Mechanical Studies

These studies are an extension of scope with respect to CARE Annex I and are supported by additional resources provided by INFN-Mi and CERN.

The following actions have been carried out and/or are foreseen

- ✓ 28 January 2004: parameters of mechanical model for 19-subelement, internal tin wire issued by A. Devred (CEA&CERN; EDMS 548087)
- ✓ 30 January 2004: mesh proposal issued by S. Farinon (INFN-Ge)
- ✓ Early February 2004: review of mesh proposal by A. Devred (CEA&CERN), D. Leroy (CERN) and C. Verwaerde (Alstom/MSA)
- ✓ February 2004–present: review of material properties
- ✓ 25 March 2004: informal discussion of preliminary computation results participants: A. Devred (CEA), D. Leroy (CERN), S. Farinon (INFN-Ge), C. Verwaerde and P. Mocaer (Alstom/MSA)]
- ✓ 9 June 2004: meeting at CERN to review material properties and discuss computation results
  participants: A. Devred (CEA&CERN), T. Boutboul, P. Fessia, D. Leroy and S. Sgobba (CERN), S. Farinon and R. Musenich (INFN-Ge), P. Loverage (CCLRC)
- ✓ 7 July 2004: meeting at CERN to review material properties and discuss computation results
  participants: A. Devred (CEA&CERN), T. Boutboul, P. Fessia, L. Oberli M. Pojer and S. Sgobba (CERN), P. Fabbricatore and S. Farinon (INFN-Ge)
- ✓ September 2004: contract issued to EIAJ to perform nano-indentation measurements on an un-reacted, internal-tin wire cross-section
- ✓ 14 October 2004: visit to EIAJ, Le Locle (CH)
  participants: T. Boutboul, C. Scheuerlein, S. Sgobba (CERN)
  trip report: EDMS 520095
- ✓ 29 October 2004: first report issued by EIAJ on nano-indentation measurements (EDMS 548100)
- ✓ 11 November 2004: meeting at CERN to review nano-indentation measurements performed at EIAJ
  participants: A. Devred (CEA&CERN), T. Boutboul, P. Fessia, D. Leroy, L. Oberli, V. Previtali, D. Richter and S. Sgobba (CERN), P. Fabbricatore and S. Farinon (INFN-Ge)
- ✓ 11 November 2004: first report issued by C. Scheuerlein (CERN) on micro-hardness measurements at CERN (EDMS 548116)
- ✓ 22 November 2004: meeting at CERN to review micro-hardness measurements
  participants: A. Devred (CEA&CERN), T. Boutboul, C. Scheuerlein, S. Sgobba and W. Scandale (CERN)
- next discussion: at the January 05 Steering Committee meeting

Table 4.3a: Status of the lowest Sub-Tasks level in the CD WP (as of 31 December 2004).

WBS #	Title	Original begin date (Annex 1)	Original end date (Annex 1)	Estimated Status	Revised end date
3.1	CD WP Coordination				
3.2	Design of a 15 T Dipole Magnet	1 January 2004	31 Dec. 2004	95%	January 2005
3.3	Specifications on Wire and Cable	1 April 2004	30 June 2004	Completed	On time
3.4	Wire Development	1 July 2004	30 June 2006	Started	30 September 2006
3.5	Wire Characterization				
3.5.1	Definition of Measuring Procedures	1 January 2005	30 June 2005	33%	On time
3.5.2	Ic measurements at CEA	1 July 2005	30 June 2006	Started	31 October 2006
3.5.3	Ic measurements at INFN-Mi	1 July 2005	30 June 2006	Started	31 October 2006
3.5.4	Ic measurements at TEU	1 July 2005	30 June 2006	Started	31 October 2006
3.5.5	Wire Magnetization Measurements	1 July 2005	30 June 2006	Started	31 October 2006
3.6	Cable Development	1 July 2005	31 Dec. 2006	Not started	15 December 2006
3.7	Cable Characterization	1 October 2005	31 Dec. 2006	Not started	-
3.8	Mechanical Studies[a)]	1 January 2004	31 Dec. 2005	25%	-

[a)] Extension of scope with respect to CARE Annex I.

Table 4.3b: Status with respect to the milestones and deliverables due in the CD WP (as of 31 December 2004).

WBS #	Title	Responsible Lab(s)	Due date in Annex 1	Status	Revised delivery date
3.2	Design Report (deliverable)	CERN	31 December 2004	95%	January 2005
3.3	Final Report on Wire and Cable Specifications (deliverable)	CERN	30 June 2004	Completed	On time
3.4	Progress Report on Wire Development (milestone)	CERN	30 June 2005[a)]	Completed Not started	15 December 2004 15 December 2005
3.4	Production of Final Wire (deliverable)	CERN	30 June 2006	Not started	30 September 2006
3.5	Intermediate Results on Wire Characterization (milestone)	CEA, INFN-Ge, INFN-Mi, TEU	31 December 2005	Started	-
3.5	Final Report on Wire Characterization (deliverable)	CEA, INFN-Ge, INFN-Mi, TEU	30 June 2006	Not started	31 October 2006
3.6	Production of Final Cable (deliverable)	CERN	31 December 2006	Not started	15 December 2006
3.7	Final Report on Cable Performances (deliverable)	TEU	31 December 2006	Not started	-

[a)] The CARE Annex I milestone entitled “First Results on Wire Development” that was due on 30 June 2005 has been split into two “Status Reports” due on 15 December 2004 and 15 December 2005.

4.4 Work Package 4: Insulation Development & Implementation (IDI)

2004 Summary

CCLRC and CEA have written an engineering specification for the NED conductor insulation (EDMS 548037) and a coordinated Test Programme for the conventional and innovative insulations (EDMS 548038).

CCLRC has started investigations on glass fiber sizings and epoxy resin fillers and is developing an experimental set up to perform fracture tests.

The start of the work on Innovative Insulation at CEA (Task 4.4) has been delayed, pending the hiring of a permanent staff to support the activity of the chemistry laboratory.

4.4.1 IDI WP Coordination

The IDI Work Package is coordinated by E. Baynham (CCLRC). The conventional Insulation Task (4.3) is headed by S. Canfer (CCLRC) while the Innovative Insulation Task (4.4) is headed by F. Rondeaux (CEA). The Work package and Task Leaders report to the NED Steering Committee and, ultimately, to the NED/JRA Coordinator.

4.4.2 Specifications' Drafting

The following actions have been carried out

- ✓ 6 May 2004: draft specifications issued by S. Canfer (CCLRC)
- ✓ 11 May 2004: conference call on insulation specifications
- ✓ participants: S. Canfer and J. Greenhalgh (CCLRC), F. Rondeaux (CEA), A. Devred (CEA&CERN), A. den Ouden (TEU)
- ✓ 11 May 2004: Version 2 of specifications issued by S. Canfer (CCLRC; EDMS 548037V1)
- ✓ 25 May 2004: Version 2.2 of specifications issued by S. Canfer (CCLRC; EDMS 548037V2)
- ✓ 1 June 2004: Version 2.3 of specifications issued by S. Canfer (CCLRC; EDMS 548037V3)
- ✓ 23 June 2004: Version 2.3b of specifications issued by S. Canfer (CCLRC; EDMS 548037V4)
- ✓ 16 July 2004: final specifications (EDMS 548037V5); EU milestone

Sub-Task completed

4.4.3 Conventional Insulation

The following actions have been carried out and/or are foreseen

- ✓ 27 July 2004: first draft of conventional insulation Test Programme (EDMS 548038V1)
- ✓ 12 August 2004: second draft of conventional insulation Test Programme

- ✓ 27 October 2004: final insulation Test Programme (including Test Programme for innovative insulation; EDMS 548038V2); EU milestone
- ✓ 30 September 2004: completion of Literature Survey (Sub-Task 4.3.1)
- ✓ 30 November 2004: completion of Tooling Preparation (Sub-Task 4.3.2)
- ✓ 31 December 2004): completion of Component Supply (Sub-Task 4.3.3)
- 1 January 2005 – 30 September 2005: Iterative Tests (Sub-Task 4.3.4)
- 1 October 2005 – 31 December 2005: Data Analysis (Sub-Task 4.3.5)
- 1 July 2005 – 30 June 2006: Irradiation Tests (extension of scope with respect to CARE Annex I)
- 30 June 2006: final report on conventional insulation; EU deliverable

4.4.4 Innovative Insulation

The following actions have been carried out and/or are foreseen

- ✓ 6 May 2004: preparatory meeting at CEA
- ✓ participants: J.M. Rifflet, F. Rondeaux and P. Védrine (CEA), A. Devred (CEA&CERN); conclusions of this meeting are reported above
- ✓ 30 August 2004: first draft of innovative insulation Test Programme
- ✓ September 2004: final innovative insulation Test Programme (added to EU milestone on conventional insulation Test Programme)
- 1 January 2005 – 31 December 2005: Tape Weaving Trial (Sub-Task 4.4.1)
- 1 January 2005 – 30 June 2006: Characterization Tests (Sub-Task 4.4.2; scope has been modified with respect to CARE Annex I)
- 30 June 2006: final report on innovative insulation; EU deliverable

Table 4.4a: Status of the lowest Sub-Tasks level in the IDI WP (as of 31 December 2004).

WBS #	Title	Original begin date (Annex 1)	Original end date (Annex 1)	Estimated Status	Revised end date
4.1	IDI WP Coordination				
4.2	Specifications' Drafting	1 April 2004	30 June 2004	Completed	22 July 2004
4.3	Conventional Insulation				
4.3.1	Literature Survey	1 July 2004	30 Sept. 2004	Completed	On time
4.3.2	Tooling Preparation	1 October 2004	30 October 2004	Completed	31 Dec. 2005
4.3.3	Component Supply	1 October 2004	31 Dec. 2004	Completed	On time
4.3.4	Iterative Tests	1 January 2005	30 Sept. 2005	10%	-
4.3.5	Data Analysis	1 October 2005	31 Dec. 2005	Not started	-
4.3.6	Irradiation tests[a)]	1 July 2005	30 June 2006	Not started	-
4.4	Innovative Insulation				
4.4.1	Tape Weaving Trial	1 July 2004	31 Dec. 2004	Not started	31 Dec. 2005
4.4.2	Characterization Tests[b)]	1 July 2004	30 June 2005	Not started	30 June 2006

[a)] Extension of scope with respect to CARE Annex I.
[b)] Modification of scope with respect to CARE Annex I.

Table 4.4b: Status with respect to the milestones and deliverables due in the IDI WP (as of 31 December 2004).

WBS #	Title	Responsible Lab(s)	Due date in Annex 1	Status	Revised delivery date
4.2	Report on Specifications for Conductor Insulation (milestone)	CCLRC	30 June 2004	Completed	22 July 2004
4.3&4.4	Report on Definition of the Test Programme (milestone)[a)]	CCLRC&CEA	31 July 2004	Completed	27 October 2004
4.3	Report on Conventional Insulation (deliverable)	CCLRC	31 December 2005	Not started	30 June 2006
4.4	Report on Innovative Insulation (deliverable)	CEA	30 June 2005	Not started	30 June 2006

[a)] Scope of report has been extended to include test programme on innovative insulation (Task 4.4).

4.5 Working Group on Magnet Design and Optimization (WGMDO)

CCLRC, CEA, CERN and CIEMAT have decided to join forces in order to create an informal Working Group on Magnet Design and Optimization (WGMDO), whose charges and composition are defined in EDMS 547882.

The Working Group is made up of

- H. Félice (CEA)
- P. Fessia (CERN)
- P. Loveridge (CCLRC)
- J. Rochford (CCLRC)
- S. Sanz (CIEMAT)
- F. Toral-Fernandez (CIEMAT), Technical Secretary
- P. Védrine (CEA), Chairman

This Working Group is an extension of scope with respect to CARE Annex 1. It is supported by CCLRC (whose contribution foreseen to Task 3.2 has been shifted to this end) and by additional resources from CEA, CERN and CIEMAT.

The following actions have been carried and/or are foreseen

✓ 19 May 2004: brainstorming session at CEA/Saclay
participants: H. Felice, L. Quettier and P. Védrine (CEA), A. Devred, (CEA&CERN), P. Fessia (CERN), S. Sanz and F. Toral (CIEMAT), P. Loveridge and J. Rochford (CCLRC)
preparatory document: EDMS 547883
minutes: EDMS 547884

✓ 23 November 2004: meeting at CERN to discuss CCLRC computations on NED baseline (88-mm-aperture, cosθ, layer) design
participants: D.E. Baynham and P. Loveridge (CCLRC), A. Devred, (CEA&CERN), D. Leroy (CERN)

✓ 17 December 2004: meeting at CIEMAT to review 2-D magnetic designs
participants: P. Loveridge, J. Rochford (CCLRC), H. Felice, P. Védrine (CEA), A. Devred (CEA&CERN), S. Sanz, F. Toral (CIEMAT)
minutes: EDMS 547885

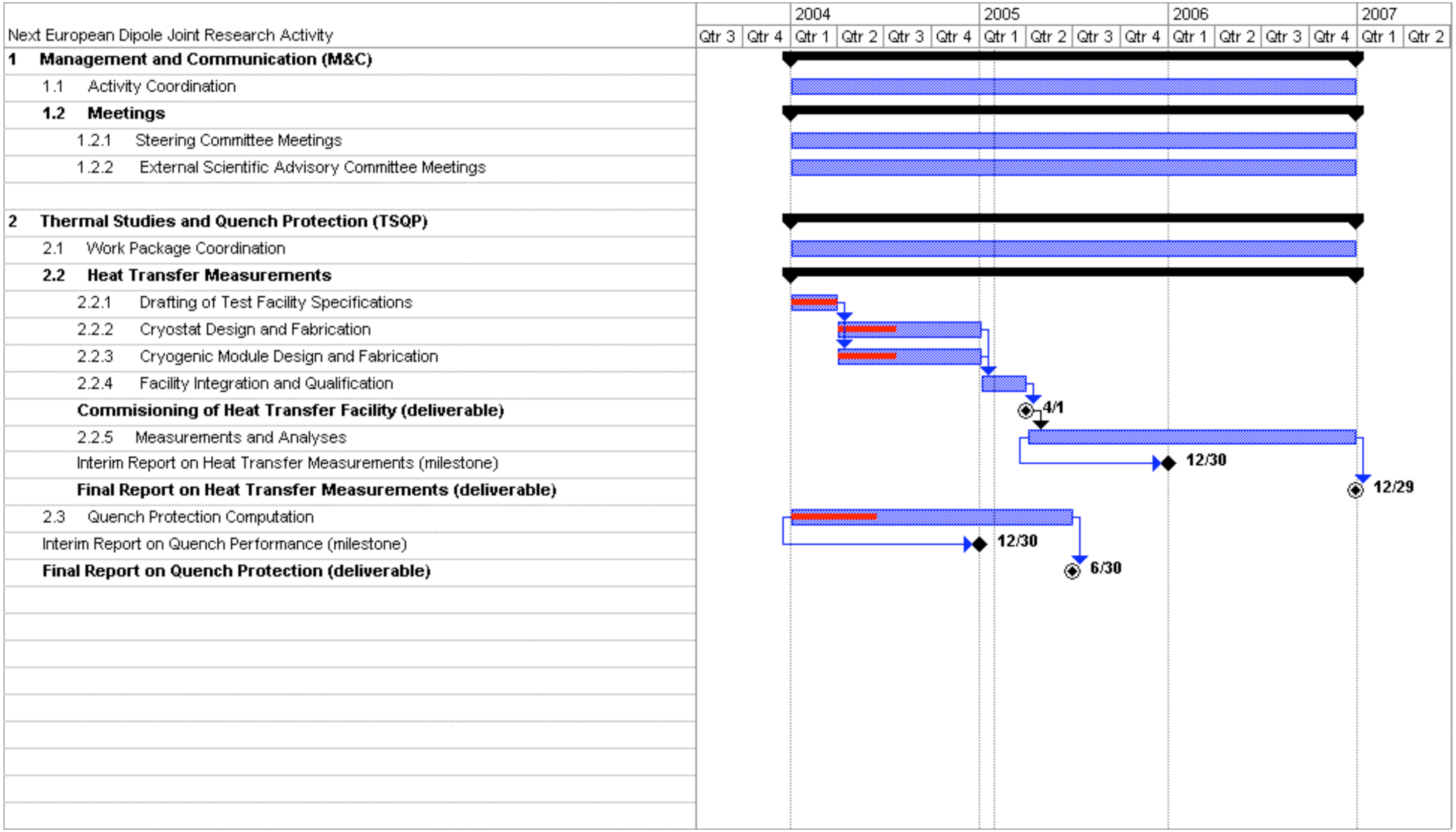
☐ 27 January 2005: visit of P. Loveridge (CCLRC) to CEA

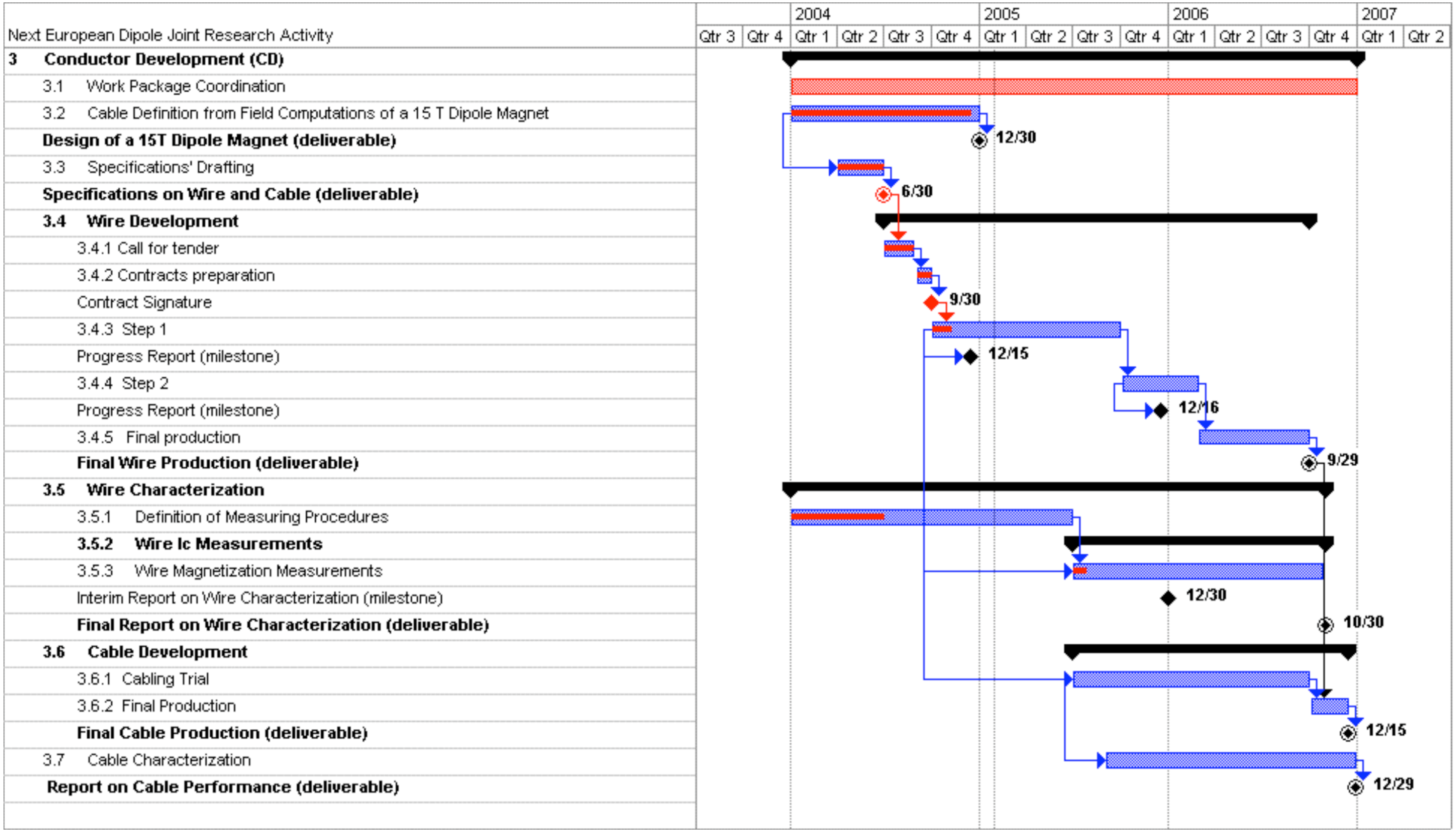
☐ 13 April 2005: interim meeting at CERN

☐ 14 June 2005: meeting at CCLRC to review 2-D mechanical designs

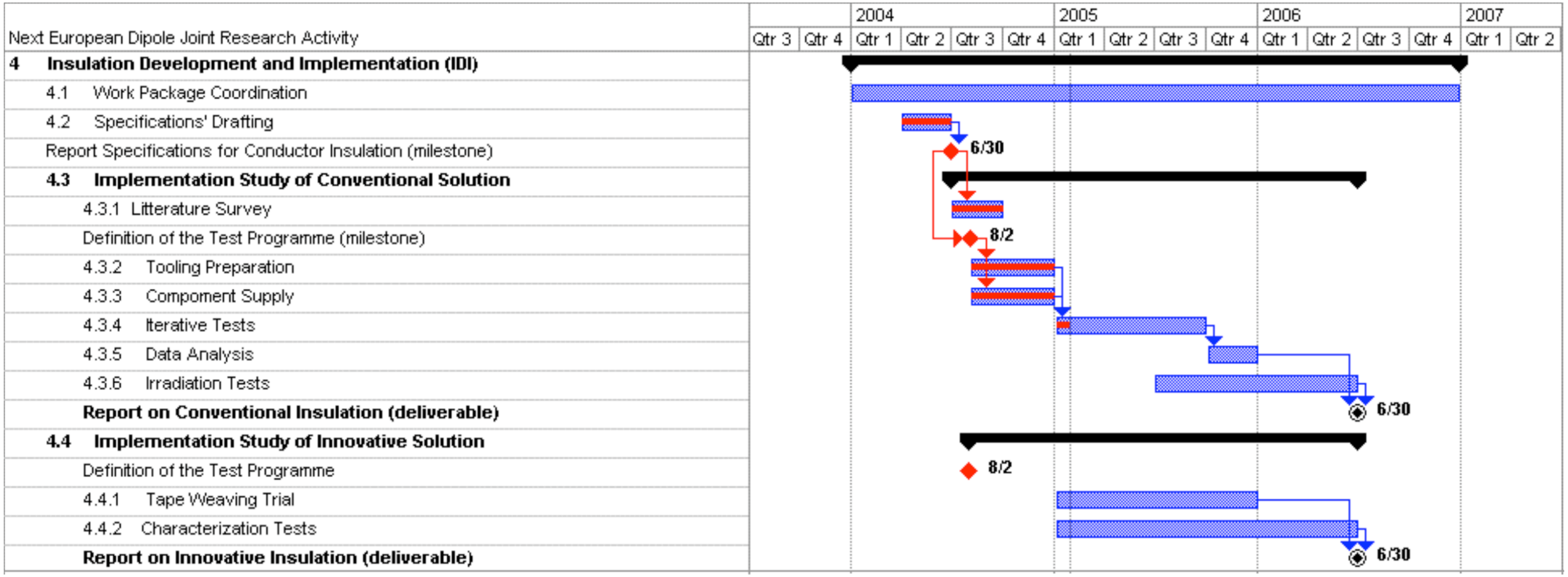
☐ 28 December 2005: review of 3-D configurations

5 APPENDIX 1: UPDATED IMPLEMENTATION PLAN (GANTT CHART) FOR THE NED/JRA AS DESCRIBED IN THE TECHNICAL ANNEX OF CARE CONTRACT (EDMS 548031)





NB: the CARE Annex I milestone entitled "First Results on Wire Development" that was due on 30 June 2005 has been split into two "Status Reports" due on 15 December 2004 and 15 December 2005.



NB:

- Task 4.3.6 is an extension of scope with respect to CARE Annex I,
- The scope of Task 4.4.2 has been modified with respect to CARE Annex I.

6 APPENDIX 2: STATUS REPORT PRESENTED AT THE APPLIED SUPERCONDUCTIVITY CONFERENCE (JACKSONVILLE, FL, OCTOBER 3-8, 2004).

Status of the Next European Dipole (NED) Activity of the Collaborated Accelerator Research in Europe (CARE) Project

A. Devred, B. Baudouy, D. E. Baynham, T. Boutboul, S. Canfer, M. Chorowski, P. Fabbricatore, S. Farinon, H. Félice, P. Fessia, J. Fydrych, M. Greco, J. Greenhalgh, D. Leroy, P. Loverige, F. Michel, L. R. Oberli, A. den Ouden, D. Pedrini, J. Polinski, V. Previtali, L. Quettier, J. M. Rifflet, J. Rochford, F. Rondeaux, S. Sanz, S. Sgobba, M. Sorbi, F. Toral-Fernandez, R. van Weelderen, P. Védrine, O. Vincent-Viry and G. Volpini

Abstract—**Plans for LHC upgrade and for the final focalization of linear colliders call for large aperture and/or high-performance dipole and quadrupole magnets that may be beyond the reach of conventional NbTi magnet technology. The Next European Dipole (NED) activity was launched on January 1st, 2004 to promote the development of high-performance, Nb_3Sn wires in collaboration with European industry (aiming at a non-copper critical current density of 1500 A/mm^2 at 4.2 K and 15 T) and to assess the suitability of Nb_3Sn technology to the next generation of accelerator magnets (aiming at an aperture of 88 mm and a conductor peak field of 15 T). It is integrated within the Collaborated Accelerator Research in Europe (CARE) project, involves seven collaborators, and is partly funded by the European Union. We present here an overview of the NED activity and we report on the status of the various work packages it encompasses.**

Index Terms—**Accelerator magnet, high magnetic field, LHC upgrade, Nb_3Sn superconductor.**

Introduction

In 2003, the European Union approved, after peer review and amendment, the Collaborated Accelerator Research in Europe (CARE) project of Integrated Activities (IA) submitted by the European Steering Group for Accelerator R&D (ESGARD) within the 6th Framework Program [1]. CARE integrates High-Energy-Physics-related accelerator R&D in Europe and involves more than 100 institutes. It includes three Network Activities (NA): linear colliders, neutrino beams and hadron beams, and four Joint Research Activities (JRA): radio-frequency cavities, photo injector, high intensity pulsed proton injector and high field magnets.

The high-field-magnet JRA, nicknamed Next European Dipole (NED), is aimed at the development of a large-

Manuscript received October 5, 2004. This work was supported in part by the European Community–Research Infrastructure Activity under the FP6 "Structuring the European Research Area" program (CARE, contract number RII3-CT-2003-506395).

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B. Baudouy, F. Michel, H. Félice, L. Quettier, F. Rondeaux, J. M. Rifflet, and P. Védrine are with CEA/DSM/DAPNIA/SACM.

D. E. Baynham, S. Canfer, J. Greenhalgh, P. Loveridge, and J. Rochford are with the Engineering Department, CCLRC-RAL, Chilton, Didcot, Oxon, UK, OX11 0QX.

T. Boutboul, D. Leroy, P. Fessia, L. R. Oberli, V. Previtali, and O. Vincent-Viry are with CERN/AT/MAS, R. van Weelderen is with CERN/AT/ACR, and S. Sgobba is with CERN/TS/MME.

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aperture, high-field (up to 15 T conductor peak field) superconducting dipole magnet relying on Nb_3Sn conductors. Such magnet will serve as a technology test bed for LHC luminosity upgrade [2-4]. It can be used also to upgrade an existing superconducting cable test facility at CERN, presently limited to a 10-T background field [5]. The NED activity is also meant to complement the vigorous efforts on Nb_3Sn accelerator magnet technology carried out in the USA within the framework of the US-LHC Accelerator Research Program (LARP) [6] or as part independently-funded base programs at Lawrence Berkeley National Laboratory [7] and Fermi National Accelerator Laboratory [8].

The NED program is divided up into two phases. The first phase, fully funded through CARE, encompasses three main work packages: Thermal Studies and Quench Protection (TSQP), Conductor Development (CD) and Insulation Development & Implementation (IDI). It also includes a working group on Magnet Design and Optimization (MDO). The Nb_3Sn conductor development will be carried through industrial sub-contracts, with financial contributions from some of the industrial partners and is aimed at a non-copper critical current density of 1500 A/mm^2 at 4.2 K and 15 T. The second phase of the NED program, for which funding is not yet secured, groups together all the tasks related to the detailed design, manufacturing and test of the model magnet.

Eight institutes are presently collaborating to NED: CCLRC/RAL, United Kingdom (IDI and MDO), CEA/DSM/DAPNIA, France (TSQP, CD, IDI and MDO), CERN, International (CD and MDO), CIEMAT, Spain (MDO), INFN/Genova, Italy (CD), INFN/Milano-LASA, Italy (TSQP and CD), Twente University, The Netherlands (CD) and Wroclaw University of Technology, Poland (TSQP).

Let us now review in detail the various work packages and report on their status.

Thermal Studies and Quench Protection

The TSQP work package includes two main tasks: heat transfer measurements and quench protection computations.

Heat Transfer Measurements

A key issue in the operation of superconducting accelerator magnets is the power deposited by beam losses on the magnet coils. This power determines the coil temperature margin and must be evacuated through the conductor insulation and absorbed by the cryogenics system [9-11]. The problem can only get worse for LHC luminosity upgrade and for Nb_3Sn magnet technology, in particular in the case of the conventional “wind, react & impregnate” where the magnet coils are fully potted with epoxy resin [12].

As detailed in Section IV.D, engineers are now developing new insulation based on ceramic materials [13-14]. Ceramic insulation with good wrapping capability and excellent thermal resistance during heat treatment would eliminate complex coil fabrication, lower costs and reduce fabrication time. For magnets cooled by superfluid helium, the thermal resistance created by the conventional electrical insulation of the cables forms the main thermal resistance to He II cooling [15]. Ceramic materials can have porosities much lower than those of conventional electrical insulation, which would reduce even more cooling efficiency with helium. Therefore, the NED activity includes a task to study the thermal behavior of this new ceramic insulation, as well as that of traditional polyimide and impregnated glass fiber back-up solutions.

Heat transfer measurements will be performed in superfluid helium (He II) and in normal helium (He I). The investigations will be focused mainly on two configurations. The first one, called the stack experiment, models the coil configurations reproducing the heat transfer through the insulation under mechanical and geometrical constraints [15-16]. The second one, called the drum experiment, creates a 1-D transverse heat transfer through the insulation [17]. This program should be held in the period 2005 to 2006 with 5 to 10 tests for each configuration.

In order to carry out this program, the NED collaboration is manufacturing a pressurized, He-II, double-bath cryostat (relying on the Claudet-bath principle) at Wroclaw University of Technology. As illustrated in Fig. 1, the double-bath cryostat has a classical design with the heat exchanger and the Joule Thomson valve located outside of the pressurized He II bath [18]. The cryostat is expected to be delivered in the first quarter of 2005 to CEA/Saclay where the facility will be implemented an operated.

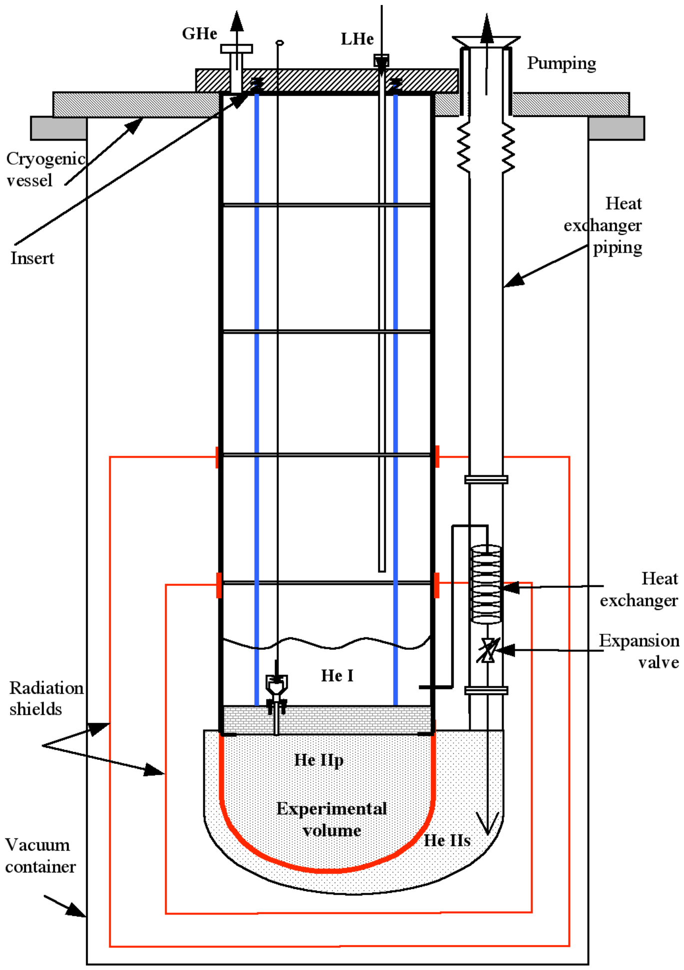

Fig. 1. Schematic of double-bath cryostat for heat-transfer measurements.

Quench Protection Computations

The main purposes of this task is:

1. to study the transition from the superconducting to the normal state of NED magnet model,
2. to design the protection system of the magnet (dumping resistors, diodes, heaters, etc.),
3. to study the extension of the protection system scheme to longer length of magnets.

The quench study will be performed by INFN/Milano-LASA using mainly the numerical code QLASA [19], cross-checked with analytical calculation. We also consider the possibility of making a comparison with other tools devoted to this purpose, like the QUABER code at CERN [20].

The QLASA code was originally developed for adiabatic multiple solenoids, both in NbTi and Nb_3Sn; it makes assumptions similar to those of the QUENCH code [21] and it can exploit different models for quench velocity calculation. Its modular and flexible structure will allow the implementation of features more suitable to our case, like a geometry and a magnetic field which are not axi-symmetric as for a solenoidal magnet. It will be also necessary to verify the correct implementation of the propagation velocity using experimental data from literature for Nb_3Sn conductors, and consider AC losses in the magnet coils.

In the quench study, a primary role is played by the thermal and electrical properties of materials. Consequently we have compared the properties from a number of material libraries available at LASA [21-28]. The conclusions from this comparison performed between 2 K and 300 K are:

1. for Cu, the sources agree within 25% for all properties,
2. for G10, the differences vary from 50% up to 350% for the specific heat,
3. for Nb3Sn, Ta, Sn and CuSn only one source was available for each property.

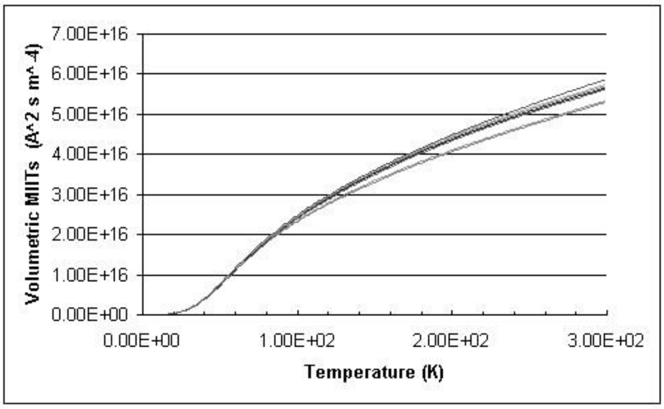

Fig. 2. Comparison of MIITs curve computations relying on different data sources for Cu and G10. The volume fractions of the conductor components are calculated according the NED reference design, *i.e.*: Cu=52%, Nb_3Sn=10%, Ta=4%, Bronze=18%, G10=16%.

For the evaluation of the volumetric MIITs (defined as the integral over time of the overall current density squared) these differences are probably not so significant, as can be appreciated from Fig. 2, while they can be relevant in the case of the quench propagation velocity. As general rule, we have decided to use the data from the Cryocomp library [22] when available (Copper and G10).

A preliminary analysis based on the NED reference design (see Section III.A) is expected in December 2004. The completion of the final parametric study is scheduled for June 2005; this will investigate the impact of the following parameters: wire Cu-to-non-Cu ratio, Cu RRR, magnet length, dumping system, quench heater performance, quench-back inside coils, longitudinal and transverse quench speed.

Conductor Development

The CD work package started with a preliminary magnetic design, aimed at deriving meaningful strand and cable specifications. A working group on conductor characterization has been set up to oversee critical current and magnetization measurements. Also, a numerical model describing the deformation of Nb_3Sn wires under transverse load is being developed so as to simulate the cabling effects.

Preliminary Magnetic Design

Preliminary magnetic designs for large bore and high field dipole magnets have been studied at CERN [29] in order to define the characteristics of Nb_3Sn strands suitable to reach fields in the 13-to-15-T range. Two types of $\cos\theta$ designs have been considered: a layer design and a slot design [30], for three apertures: 88 mm, 130 mm and 160 mm.

Figure 3(a) presents the conductor and electromagnetic force distribution in a quadrant of a 88-mm-aperture, layer-type design. The 26-mm-wide keystone cables are the same in the 2 layers and consist of 40 Nb_3Sn strands of 1.25 mm diameter and a Cu-to-non-Cu ratio of 1.25. The inner yoke radius is 125 mm and its radial thickness is 350 mm. This design has been chosen as reference. Figure 3(b) presents the conductor and electromagnetic force distribution in a quadrant of a 160-mm-aperture, slot-type design. The 20.8-mm-wide rectangular cables consist of 32 Nb_3Sn strands of 1.25 mm diameter and a copper to non-copper ratio of 1.25. The inner yoke radius is 183 mm and its radial thickness is 640 mm.

The preliminary magnetic designs have studied the impact of various parameters like strand diameter, copper-to-non- copper ratio, cable strand number and cable dimensions. The insulation thickness has been kept constant at 0.2 mm on each side of the cable. The study leads to define a strand of 1.25 mm diameter and a copper to non-copper of 1.25 as the most suitable for the development program.

Table I presents a summary of the performance for two dipole designs. The calculations are based on a critical current density of 1500 A/mm^2 at 15 T and 4.2 K in the non-copper part and a cable degradation of 10 %. At 4.2 K, it appears that the bore field B_0 stays around 14 T for a quenching field of ~15 T on the conductor. Hence, the magnet should be operated at 1.9 K to reach bore fields higher than 15 T.

TABLE I. PERFORMANCE SUMMARY FOR 2 DESIGNS

Bore [mm]	Design Type	B_o[T] /I[kA]	Energy [kJ/m]	Max Pres. [MPa]	F_x[a)] [MN/m]	Outer Diam. [mm]
88	Layer	14.42 /28.7	1810	148	15.8	1004
160	Slot	13.87 [illegible]	3959	129	21.48	1734

a) resultant of the horizontal forces for the overall dipole magnet.

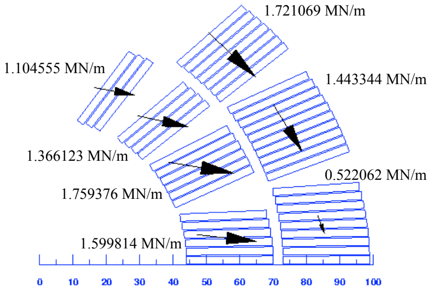

Fig 3(a). Conductors and forces in 88-mm-aperture, layer-type design.

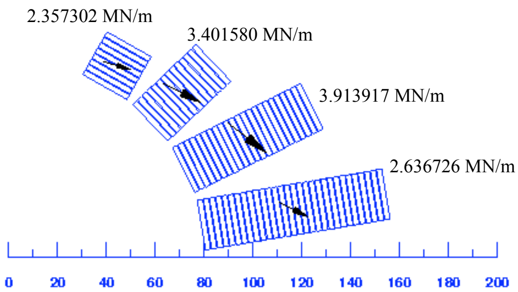

Fig 3(b). Conductors and forces in 160-mm-aperture, slot-type design.

TABLE II. SALIENT STRAND CHARACTERISTICS.

Strand diameter	1.250 mm
Effective Filament diameter	< 50 µm
Cu to non-Cu volume ratio	1.25 ± 0.10
Filament twist pitch	30 mm
Non-Cu J_C at 15 T, 4.2 K	1500 A/mm^2
Minimum critical current, 4.2 K	1636 A at 12 T
	818 A at 15 T
RRR (after full reaction)	> 200
N-value @ 15 T and 4.2 K	> 30

TABLE III. SALIENT CABLE CHARACTERISTICS

Cable width	26 mm
Cable mid-thickness at 50 MPa	2.275 mm
Keystone angle	0.22 degrees
Number of strands	40
Critical current at 4.222 K, with	29440 A at 15 T
field normal to broad face	58880 A at 12 T
Minimum critical current at 4.2 K	736 A at 15 T
of extracted strand	1472 A at 12 T
RRR after reaction	≥ 120
Minimum cable unit length	145 m

Strand and Cable Characteristics

A call for tender to develop high-performance Nb_3Sn strand and cable in collaboration with European industry has been issued by CERN [31]. The aim of the development program is to produce several hundred meter long cables of accelerator magnet quality, characterized by a high critical current density (1500 A/mm^2 at 15 T and 3000 A/mm^2 at 12 T and 4.2 K) in the non-copper part of the strands and a low magnetization at 2 T. For this purpose, an effective filament diameter less than 50 μm will be targeted. The billet weight should be higher than 50 kg.

Table II summarizes the main characteristics of the strand. Although the final cable dimensions will be decided later on, Table III presents the characteristics for the Rutherford cable that could be used in the reference, 88-mm-bore dipole magnet described in Section III.A. The cable critical currents in the table also assume a cabling degradation of 10%.

Working Group on Conductor Characterization

Industrial development of Nb_3Sn conductors exhibiting such unprecedented properties as those listed in Tables II and III is a major ambition of the NED program and calls for reliable, reproducible and unambiguous methods for the measurement of their electromagnetic properties, such as $I_c(B)$, $M(B)$ and RRR(B=0). For this purpose, representatives of the institutes involved (CEA, CERN, INFN/Genova, INFN-Milano and Twente University) have set up a Working Group on Conductor Characterization (WGCC). The WGCC is charged with the definition and development of standardized and certified procedures to measure the mentioned properties of virgin, deformed and extracted strands and the responsibility for certification of the measured data.

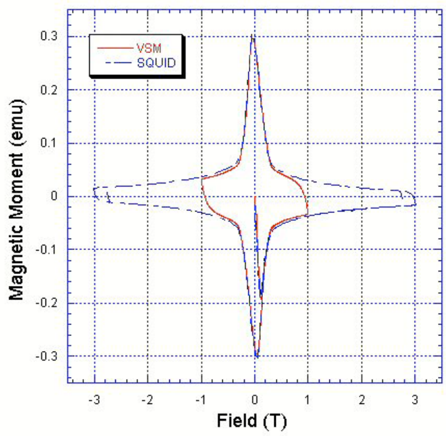

Fig. 4: First magnetization cycle on a 5-mm sample exposed to a transverse field (SQUID measurements are courtesy of C. Ferdeghini, INFM/Genova, while VSM measurements are courtesy of U. Gambardella, INFN/Frascati).

Inspired by the VAMAS program [32] and the successful development of standardized procedures for measuring the critical current of ITER conductors [33], the WGCC has initiated a cross-calibration program between the various test facilities in order to:

1. reveal possible systematic differences of $I_c(B)$ results,
2. get acquainted to preparation and measuring of very high I_c wire samples,
3. bring forward shortcomings or limitations in existing preparation or measuring procedures and agree on a roadmap to improvements,
4. set up procedures for dealing with conflicting results.

As a first step, each laboratory will independently prepare a series of wire samples and measure the $I_c(B)$ and N-value at 4.2 K (10 μV/m criterion) to the extend of their (I,B) capabilities. This first series comprises 2 samples each of: a 1.06 mm LHC NbTi wire, a binary 1.25 mm Nb_3Sn wire, and finally both a virgin and an extracted strand from a Rutherford cable made out of a binary 0.8 mm Nb_3Sn wire. Initially, each laboratory performs heat treatment, sample preparation, measurements and report according to existing procedures. Evaluation of the results of this first round in October 2004 should result in recommendations for adaptations or revisions. After the required revisions, a second round of measurements on different but also highly demanding conductors will start in November and will be evaluated within 3 months. If required, a third iteration will be performed to conclude this cross-calibration program in June 2005.

The aim of the magnetization measurements is to complement the characterization of the electrical transport properties. They will be focused on DC magnetization at low fields (B < 3 T), which can highlight the occurrence of flux jumps. Further information is related to the critical current density and to the filament layout. Though different kinds of samples will be analyzed, the basic measurements will be performed on short (5 mm) straight samples in transverse field, with SQUID Magnetometer and Vibrating Sample Magnetometer (VSM). As an illustration, Fig. 4 shows typical *M*(*B*) curves measured on a Nb_3Sn multi-filament wire with a collective, Nb/Ta anti-diffusion barrier [34].

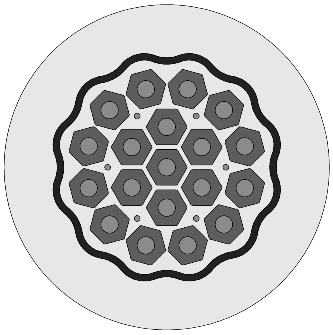

Fig. 5: Example of FE model for mechanical analysis of internal tin wires (Cu is represented in light grey, Ta in black and Sn in medium grey; the multifilament areas surrounding each tin pool, made up of 200 Nb rods in a pure Cu matrix, are represented in dark grey by an average material).

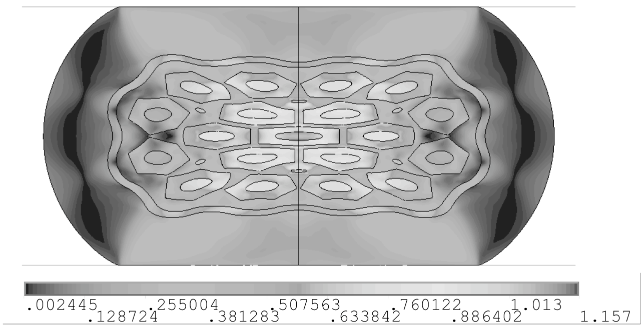

Fig. 6: Von Mises strain due to a diameter reduction of about 40%.

Mechanical FE analysis of Nb_3Sn wires

Independently on the method chosen to manufacture the Nb_3Sn wires (Internal Tin, Powder-In-Tube, and so on), the wires have to undergo a cabling process to form Rutherford cables. During this operation, the wires are largely and permanently deformed, so that possible damages, such as breakages of either filaments or diffusion barriers, may arise.

One way to reduce the risk of damaging the wires during cabling is to optimize their design so as to keep stress and strain within safe limits. The natural approach to this issue is the simulation of the deformation through mechanical Finite Element (FE) analysis. To correctly set up the FE analysis, two aspects have to be deeply investigated: the material properties and the choice of the FE model, which have to be significantly representative of the wires during cabling.

Regarding the material properties, the main difficulty is that we need stress-strain curves for the different phases present in the wires, in the state where they are prior to cabling and for a range extending well beyond the elastic limit. A parallel approach is followed:

1. to find literature data of tensile properties for the metals or alloys constituting the different phases, relative to the level of hardening that the composite wire is supposed to have undergone, based on estimated values of Cu RRR,
2. to experimentally assess, from a wire cross section, the indentation properties of the individual phases at a local scale through nanohardness measurements, thereby allow-ing the determinations of load-displacement curves.

The mechanical FE model, developed by INFN/Genova, is equally important. In Fig. 5., the FE model of a typical, un-reacted, internal tin wire is shown. The simplest deformation which can be applied is an uni-axial compression between two parallel planes. The result is shown in Fig. 6 in terms of Von Mises strain corresponding to a 40% reduction in diameter of the original wire. The maximum strain value, higher than 100%, is in the central tin well, and the tantalum barrier is strained up to 75%; such values demonstrate the importance of optimizing the wire configuration. With this aim, it is important to identify the conditions of the load application which best simulate the wire during cabling. For instance, compressing three adjacent wires would lead for the central one to a different strain map than the one shown in Fig. 6. Finally, we will improve the wire shape keeping, under those conditions, the stress and strain within safe limits

Insulation Development And Implementation

Aim of study

The objective of the Insulation Development Program for NED is to improve insulation techniques in order to improve both industrial manufacture capability and magnet performance. The state of the art insulation processing technology is not sufficiently well developed to enable large-scale production of accelerator magnets by the “wind and react” process [12]. The Rutherford Appleton Laboratory (RAL) is responsible for the development of “conventional,” glass or quartz tape, insulation techniques, while CEA is responsible for the development of an “innovative,” ceramic-based insulation system [14]. It is intended that a direct comparison of conventional insulation with the innovative system will be performed as part of the program.

The program strings will aim to develop manufacturing techniques through improved durability during cable insulation and coil winding and reliability following heat treatment. Magnet performance improvement will target mechanical, radiation and electrical properties of the magnet matrix. In particular, mechanical strength and radiation resistance will need to be advanced in order to meet the high field (15 T) and high radiation environment foreseen for the LHC luminosity upgrade or for future accelerators. These advances will require new processing techniques, new and improved testing procedures and new materials, *e.g.*, the use of cyanate ester matrixes to improve radiation resistance and new fillers to improve mechanical performance at low temperatures.

Engineering specifications

A basic insulation specification for a 15 T dipole has been developed in consultation and is summarized in Table IV [35]. It is not feasible within the scope of the NED activity to explore the whole parameter space within this specification. The goal is therefore to select a small range of process variables and materials and subject these to a full range of tests. As we go along, we aim to define and prove standard test specimens with standard tests and develop new testing techniques for important properties such as work of fracture.

TABLE IV. INSULATION SPECIFICATIONS

GENERAL	Design
Insulation thickness per cable	0.4 mm
Winding compatibility: Capable of being applied to the cable and formed into a dipole winding by a semi-automatic winding system	Minimal fraying or abrasion during winding
Conductor bend radius minimum	20 mm
Compatible with Nb_3Sn heat treatment cycle	Minimal degradation of basic components
Thermal cycles to low temperature: 300K– 4.2K	10
Running cycles: ramp to max compressive stress	100
For conventional organic insulation scheme and innovative scheme if applicable: ability to be impregnated with a liquid of viscosity 200 mPa.s	200 mPa.s

MECHANICAL[1)]	Design
Applied conductor winding load	500 N
Compression during heat treatment	20 MPa
Coil re-shaping after heat treatment before impregnation	20 MPa
Compressive stress after completion of	200 MPa

coil fabrication – at 300K and 4K.	
Shear: Short-beam shear strength at 4K	50 MPa
Tension: Transverse tensile strength of insulation laminate at 4K	25 MPa
Fracture, need to know properties at 300K and 4K, specification to be determined	TBD

[1)] Design stresses are before irradiation.

THERMAL	Design
Transverse thermal contraction (integrated between 300 K and 4K)	0.003 to 0.004
Thermal conductivity at 4.2K	50mW/m/K

ELECTRICAL	Design	Failure
Breakdown voltage inter-turn tested in helium at 300K	1000V 2500V/mm	2000V 5000V/mm

RADIATION	
The failure properties above must be achieved following doses expected during 10 years' running.	
	Range
Dose [36]	50 to 600 Mgy
Fluence >0.1MeV	2.5 to $30x10^{16}cm^{-2}$

Test program for conventional insulation

For magnet manufacture we have identified fiber sizing as a key area for development to improve the viability of industrial Nb_3Sn magnet fabrication. Sizing is applied to glass fibers at the time of fiber manufacture in order to allow industrial fabrication of tape or fabric. Removal of sizing before magnet manufacture to prevent carbonization during Nb_3Sn heat treatment results in substantial degradation of the tape insulating handling properties. Palmitic acid has been used for years at LBNL to act as a lubricant in coil winding [12], As part of the development and test program we propose to study existing sizing chemistry and alternatives, assess and quantify the effect of carbon residue on electrical and mechanical properties. These sizing variants will be subjected to the standard tests.

For magnet performance, material developments which may enhance conductor stability through improved insulation toughness will be studied. This will include radiation hard resin alternatives such as cyanate esters and improved filler materials such as nanoclays and dendritic polymers. The conventional test program will be executed in four phases; development of techniques and tests based on standard specimens; definition of material parameters to be studied; screening tests to determine the potential of materials; comprehensive tests on selected materials.

Test program for innovative insulation

As explained above, the conventional insulation includes vacuum impregnation of glass fibers with an organic material, for instance epoxy, after the heat treatment required to form the Nb_3Sn. This multi-step process is costly and raises the failure risk. As an alternative, CEA/Saclay has been working on an innovative insulation, relying on a pre-impregnated, glass fiber tape, wrapped directly on the un-reacted cable prior to heat treatment, and eliminating the need for a subsequent vacuum impregnation. The feasibility of this insulation has been demonstrated [14]. Developments are now continuing to optimize the mechanical properties of this insulation and to characterize it according to the required specifications [35].

The innovative insulation test program will include two phases. The first one will be devoted to tape weaving trials. During the previous development phase, the nature and weaving of the tape have been found to be critical parameters for the final quality of the insulation. The aim is to find an industrial tape better suited to this application. The thickness, the quality and the reliability of the pre-impregnation, will be some of the qualification parameters.

The second phase will concern characterization tests. Mechanical properties have to be checked, beginning with the properties in compression, which are the most constraining ones for the magnet designs under considerations. In parallel, the electrical properties will also be verified.

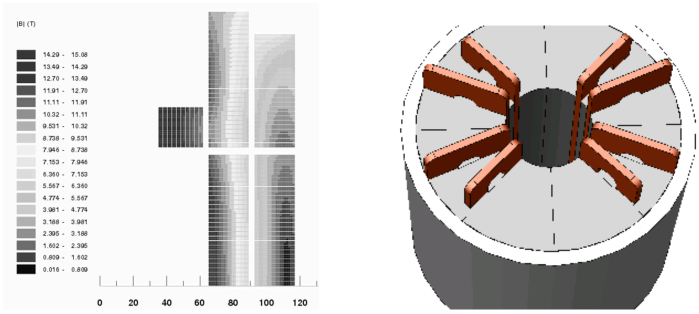

Fig. 7. Two alternative coil arrangements to be optimized and compared: left, window-frame (proposed by CEA/Saclay), and right, motor-type (proposed by CIEMAT).

TABLE V. SALIENT DESIGN PARAMETERS

Peak field on conductor	15	T
Aperture	88-130-160	mm
Superconductor *J*c	3000	A/mm^2 @ 4.2K and 12 T
	1500	A/mm^2 @ 4.2K and 15 T
Cu-to-non-Cu ratio	1÷2	
Operating margin	10÷20	%
Filling factor of cable	87	%
Insulation thickness	0.2	mm per conductor face
Cabling degradation	10	%
X-section multipoles	A few10^{-4}	@ 2/3 x aperture
Overall coil length	1.3	m
Peak stress	150	MPa
Max coil deformation	<0.05	mm (due to Lorentz forces)
Peak temperature	300	K (quench)
Peak voltage to ground	1000	V (quench)
Peak inter-turn voltage	100	V (quench)

Magnet Design and Optimization

The aim of this study is to optimize the design of high-field dipole magnets for particle accelerators, taking into account both technical and economical criteria. For the time being, the focus is on Nb_3Sn technology, but the results may also be useful for other brittle superconductors.

A Working Group on Magnet Design and Optimization (WGMDO) has been established, made up of representatives from CCLRC, CEA, CERN, and CIEMAT. In a brainstorming session held last May, a number of magnet configurations has been selected as candidates, including classical and novel arrangements such as: layer-type and slot-type cos-θ, window-frame, common coil, motor-type, double-helix, slotted dipole and ellipse-type racetrack. Two of the alternative designs under consideration are illustrated in Fig. 7. The WGMDO will also compare the performance of the calculation tools used in magnet design, and contribute to a European material properties database relevant for these computations.

The present plan calls for each institute to completely study one or two solutions based on the design parameters listed in Table V. The terms of comparison between the different solutions have also been established:

1. magnetics: central and peak fields, nominal current, field quality, tunability, magnetic vs. overall length, margin.
2. mechanics: change of pre-stress during cooling down, peak stress, Lorentz forces.
3. quench: self-inductance, stored magnetic energy, peak voltage and temperature.
5. fabrication: sensitivity to manufacturing tolerance, manufacturability, coil end complexity, minimum bending radius (parallel and perpendicular), superconductor volume efficiency, twin/single aperture and minimum distance, number of splices, cost.

Conclusion

The Next European Dipole Activity attempts the integration of high-field accelerator magnet R&D in Europe in preparation for LHC upgrade or a future accelerator. Although not funded through the construction phase, the program is well under way and is triggering the desired synergies.

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