Next European Dipole (NED) Overview & Status

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on behalf of the NED Collaboration

CARE General Meeting
CERN
25 November 2005

NED Collaboration

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NED Program

- The NED JRA is presently articulated around four Work Packages and one Working Group

1 Management & Communication (M&C),

2 Thermal Studies and Quench Protection (TSQP),

3 Conductor Development (CD),

4 Insulation Development and Implementation (IDI),

5 Magnet Design and Optimization (MDO) Working Group.

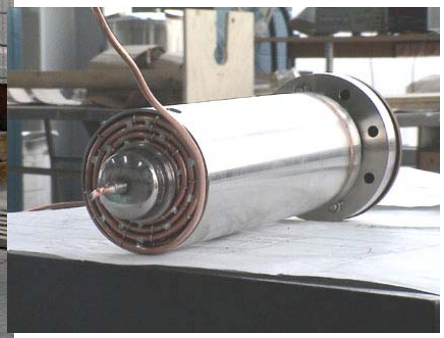
- NED web site

http://lt.tnw.utwente.nl/project.php?projectid=9

TSQP Work Package

- The TSQ Work Package includes two main Tasks
  - development and operation of a test facility to measure heat transfer to helium through Nb_3Sn conductor insulation
    (CEA and WUT; Task Leader: B. Baudouy, CEA),
  - quench protection computation
    (INFN-Mi; Task Leader: G. Volpini).

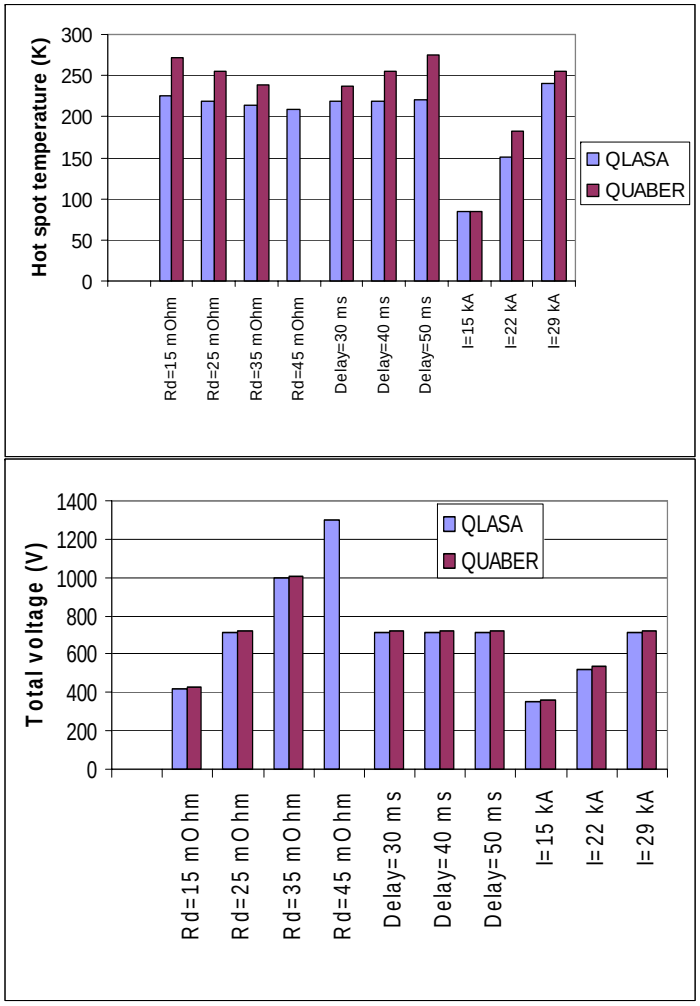
Heat Transfer Measurement Task



Miscellaneous views of NED cryostat (Courtesy M. Chorowski, WUT)

- The first part of the Task was to design and build a new He-II, double-bath cryostat.
- The cryostat was built by Kriosystem in Poland under the supervision of Wroclaw University according to specifications written by CEA.
- The cryostat was delivered to CEA on 20 September 2005 and is being readied for commissioning.
- Measurements are expected to start in January 2006; the CEA team will be strengthened by a WUT postdoc.

Quench Computation



Quench simulations for 10-m-long, 88-mm-aperture, cosθ, layer design (Courtesy M. Sorbi, INFN-Mi)

- INFN-Mi has carried a detailed analysis of the thermal and electrical behaviors of NED-like magnets during a quench.
- The computations were focused on the Reference 88-mm-aperture, cosθ, layer design and show that, magnets up to 10 m long can be operated safely, thereby justifying the choice of conductor parameters made early on.
- The Task is nearly completed and the final report is under peer review.

Complementary TSQP Efforts

- Since the start of NED, two complementary efforts have been launched at CERN
  - – Analysis of available LHC magnet test data at high ramp rate to determine how well the heat-transfer measurements at CEA correlate with actual magnet data,
  - – Review of magnet cooling modes to estimate, on the cryogenics system point of view, what are the limitations on power extraction and to provide guidance on how to improve cooling of magnet coils; preliminary conclusions indicates that NED-like magnets may have to be operated in superfluid helium (work will be pursued within the framework of an existing collaboration between CERN and WUT).

CD Work Package

- The CD Work Package includes three main Tasks
  - – conductor development
    (under CERN supervision; Task Leader: L. Oberli),
  - – conductor characterization
    (CEA, INFN-Ge, INFN-Mi, and TEU; Task Leader: A. den Ouden, TEU),
  - – FE wire model (to simulate cabling effects)
    (CERN and INFN-Mi; Task Leader: S. Farinon, INFN-Mi).
- It is the core of the Program and absorbs about 70% of the EU-allocated funding.

Conductor Development (1/2)

- As a conclusion of preliminary design studies carried out at CERN in 2003 and 2004, the following specifications have been derived for NED Nb_3Sn strands

– **diameter**	**1.250 mm,**
– **eff. filament diameter**	**< 50 μm,**
– Cu-to-non-Cu ratio	1.25 ± 0.10,
– filament twist pitch	30 mm,
– **non-Cu J_C**	**1500 A/mm² @4.2 K & 15 T,**
– **minimum critical current**	**1636 A at 12 T,**
	818 A at 15 T,
– *N*-value	> 30 at 4.2 K and 15 T,
– RRR (after heat treatment)	> 200.

(It is also requested that the billet weight be higher than 50 kg.)

Conductor Development (2/2)

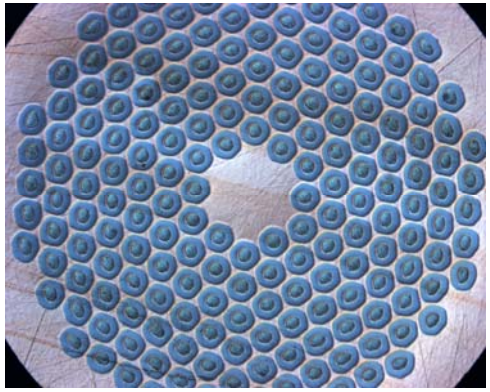
- Based on these specifications, a call for tender was issued by CERN in June 2004 and two contracts were awarded in November to 2004 to
  - Alstom/MSA in France ("Enhanced Internal Tin" process),
  - SMI in The Netherlands ("Powder in Tube" Process).
- After discussion with CERN, the two companies have agreed to work out their development program into two successive RD Steps (referred to as STEP 1 and STEP 2) followed by final cable production.
- A tentative schedule is
  - STEP 1: Fall/Winter 2005,
  - STEP 2: Summer/Fall 2006,
  - Final production: December 2006.

Alstom / MSA Status

- For Alstom/MSA ("Enhanced Internal Tin" process), STEP 1 is devoted to a Taguchi-type plan to study the influence of salient parameters on workability and performances, while STEP 2 will be devoted to a critical current density tuning.
- As part of STEP 1, Alstom/MSA has launched the production of four different types of wires with radically new designs, which can be classified into two main families
  - sub-elements with central tin sources,
  - sub-elements with distributed tin sources.
- The sub-elements with central tin sources have been drawn down to a diameter suitable for restacking, enabling the production of two 20 kg billets; the first of these billets will be assembled and drawn down to final size before the end of the year.

SMI Status

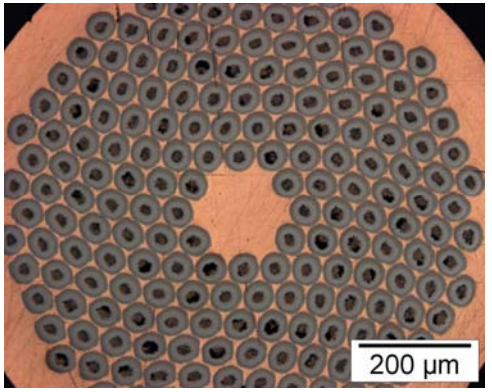
- SMI ("Powder In Tube" Process) has already produced a 1-mm-Ø wire that achieved a non-Cu J_C of ~2500 A/mm^2 at 4.2 K and 12 T (only 17% below the target of 3000 A/mm^2 at 4.2 K and 12 T).
- Based on these promising results, STEP 1 calls for iterations on the existing layout to achieve the desired critical current density while STEP 2 will be devoted to a scale up to larger billet sizes.
- Two 3-kg billets have been drawn down to final size and are under evaluation.



Example of NED/STEP 1 PIT wire with improved powder content produced by SMI (courtesy L. Oberli, CERN)

Before HT

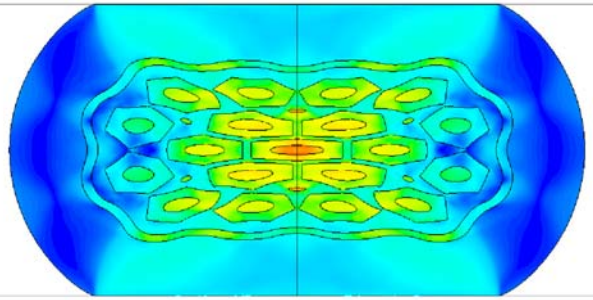
After HT



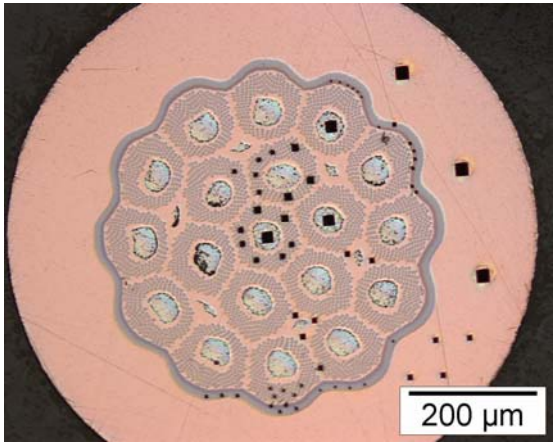
Conductor Characterization

- NED conductors will be characterized by performing critical current and magnetization measurements (⇒ see M. Greco Highlight Talk).
- Critical current measurements represent a real challenge, given the expected performances (*e.g.*, ~1600 A at 4.2 K and 12 T on a 1.25-mm-Ø wire, compared to ~200 A presently achieved on 0.8-mm-Ø ITER wires).
- To validate sample preparation and measurement processes, CEA, INFN and Twente University have launched a cross-calibration program.
- Two of the partners have achieved a good convergence (measured values within 2%), while the third is still in the process of upgrading its test set up; a final round is underway and should be completed before the end of the year.

FE Wire Model



FE model of internal tin wire
(courtesy S. Farinon, INFN-Ge



Micro-hardness measurements
on a X-cut of internal tin wire
(courtesy C. Scheuerlein, CERN)

- INFN-Ge has started to develop a mechanical FE model (based on ANSYS®) to simulate the effects of cabling on un-reacted, Nb-Sn wires.
- To feed the model, CERN has supervised or carried out a series of nano-indentation and micro-hardness measurements aimed at determining the mechanical properties of the materials making up the wire in the cold work stated where they are prior to cabling.

IDI Work Package (1/2)

- The IDI Work Package includes two main Tasks
  - – studies on “conventional” insulation systems relying on ceramic or glass fiber tape and vacuum-impregnation by epoxy resin
    (CCLRC; Task Leader: S. Canfer),
  - – studies on “innovative” insulation systems relying on pre-impregnated fiber tapes and eliminating the need for a vacuum impregnation
    (CEA; Task Leader: F. Rondeaux).

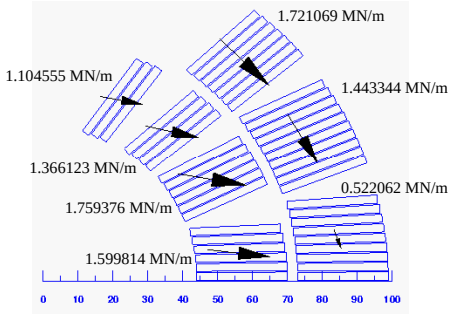
IDI Work Package (2/2)

- Before launching their efforts, CCLRC/RAL and CEA have written an engineering specification for the turn-to-turn insulation of NED-like, "wind & react," Nb_3Sn magnets and have agreed on a coordinated test program for both insulation types.
- As part of its screening tests, CLRC/RAL is evaluating a polyimide-sized glass fiber tape that may be able to sustain the required Nb_3Sn heat treatment without degradation and which seems a promising alternative to conventional insulation ($\Rightarrow$ see S. Canfer Highlight Talk).
- The Innovative Insulation Task is built upon an ongoing R&D program at CEA which has demonstrated the feasibility of such a system, but the work has been put on hold due to a lack of human resources and is expected to restart in January 2006.

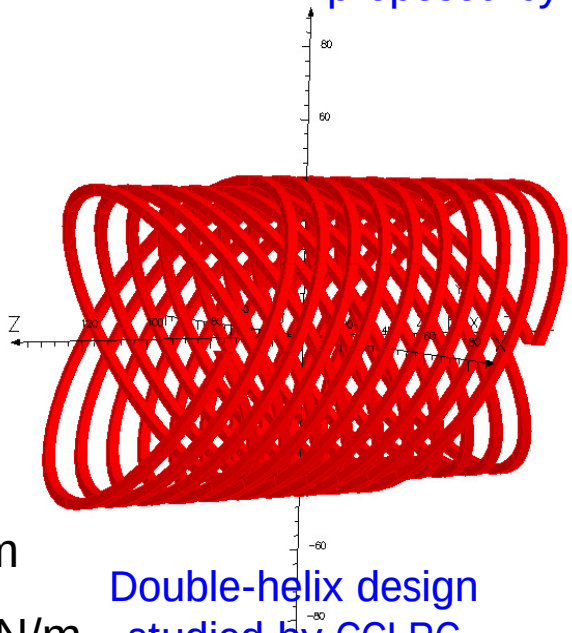
MDO Working Group (1/3)

- The MDO Working Group is made up of representatives from CCLRC, CEA, CERN and CIEMAT
(Chairman: F. Toral, CIEMAT).
- Its main charge is to address the following questions
  - How far can we push the conventional, $\cos\theta$, layer design in the aperture-central-field parameter space (especially when relying on strain-sensitive conductors)?
  - What are the most efficient alternatives, in terms of performance, manufacturability and cost?
- A number of magnetic configurations have been selected and are presently being evaluated.

MDO Working Group (2/3)

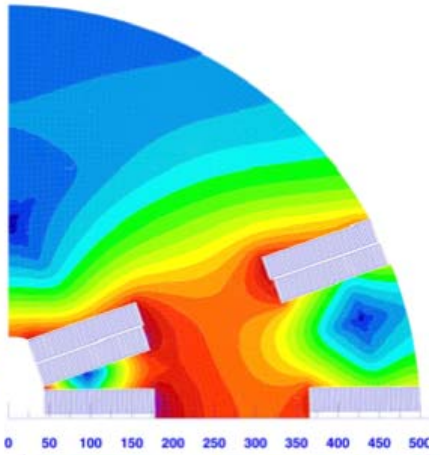


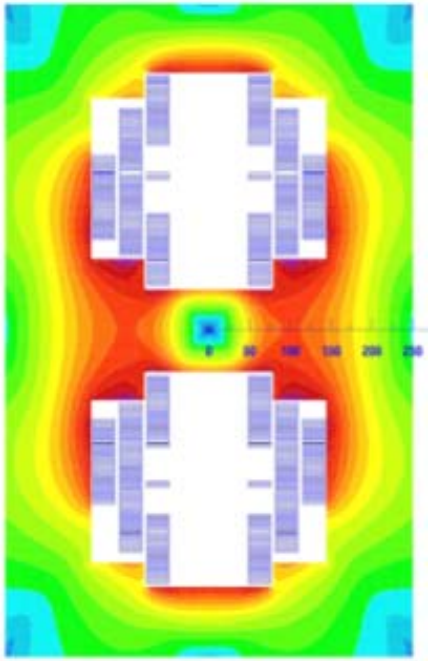
88-mm-aperture, cosθ, layer design studied by CCLRC & CERN



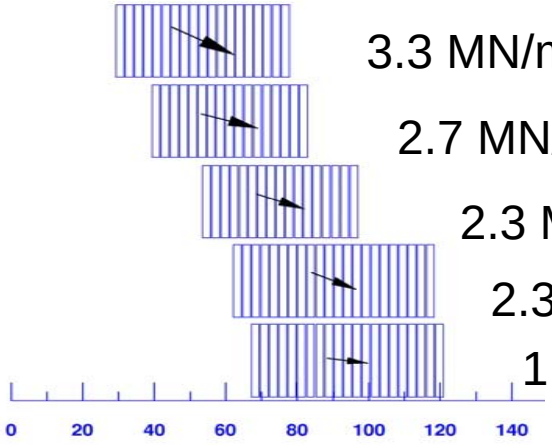
Double-helix design studied by CCLRC

88-mm-aperture, motor-type design proposed by CIEMAT





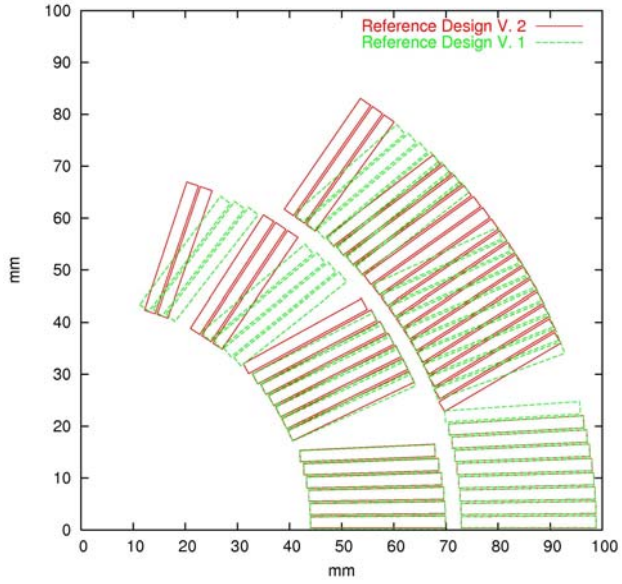
88-mm-aperture, common-coil design studied by CIEMAT

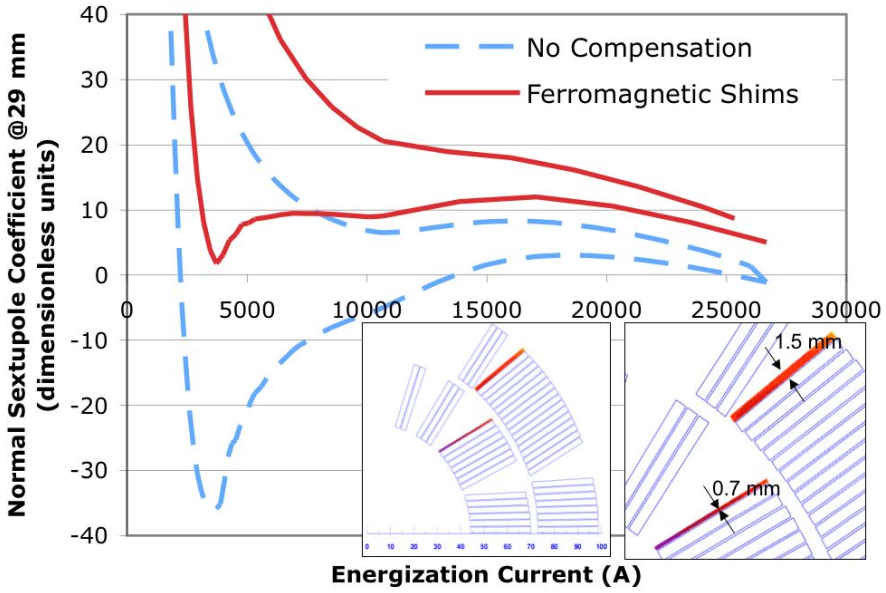


130-mm-aperture, intersecting-ellipse design proposed by CEA

MDO Working Group (3/3)

- CERN has pursued the electromagnetic optimization of the baseline, 88-mm-aperture, cosθ layer design with respect to
  - conductor geometry,
  - iron shape (to reduce saturation effects),
  - ferromagnetic shims (to compensate magnetization effects).





(Courtesy N. Schwerg, CERN)

Conclusion

- Save for the innovative insulation, all the Tasks of the NED program have been launched and are well under way; a three-month delay may be expected.
- The cryostat for heat transfer measurements is completed and has been delivered to CEA.
- The next few months will be critical for the Conductor Development Task with the results of STEP 1 wires.
- Polyimide-sized fiber tapes seem a promising alternative to conventional insulation system.

Perspectives

- At present, the funding provided by CARE does not cover the detailed design, manufacturing and test of the 15-T (conductor peakfield) dipole magnet model that was included in the initial NED proposal (~22 staff.year, material costs: ~1.2 M€).
- As a result of CARE/HHH activities, there are now clear recommendations from the CERN accelerator physics community (see J.P. Koutchouk's highlight talk and F. Ruggiero's talk in the AMT session) to strengthen Nb_3Sn magnet R&D efforts in Europe and complement the ongoing US-LHC Accelerator Research Program in a time frame compatible with LHC luminosity.
- It is now up to the managements of the NED collaborators and to ESGARD to establish a strategy on how to cope with the NED funding issue.