Journal logo

The CARE Project (Coordinated Accelerator Research in Europe)

Olivier Napoly*

CEA/Saclay, DSM/DAPNIA/SACM, Gif-sur-Yvette, 91191, France

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Abstract

CARE, an ambitious and coordinated project of accelerator research and developments oriented towards High Energy Physics projects, has been launched in January 2004 by the main European laboratories and the European Commission with the 6th Framework Programme. This project aims at improving existing infrastructures dedicated to future projects such as linear colliders, upgrades of hadron colliders and high intensity proton drivers An important part of this programme is devoted to advancing the performance of the superconducting technology, both in the fields of RF cavities for electron and proton acceleration and of high field magnets, as well as to developing high intensity electron and proton injectors. We describe the plans of the four main Joint Research Activities and report on the results and progress obtained so far. The CARE project also includes three adjacent Networking Activities whose main goal is to organize a forum of discussions and to provide the strategic plans in the fields of the Linear Collider, intense Neutrino Beams, and future Hadron Colliders.

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1. The CARE project

The CARE project is an Integrated Infrastructure Initiative supported by the European Commission (EC) within the 6th Framework Programme (FP6). Over the years 2004-2008, it aims at improving existing accelerator infra-structures such as those listed in Table 1. Twenty two contracting laboratories and a large number of associated institutes and industrial partners participate in this integrating effort. The CARE general organisation and participation are available on the CARE web site [1] together with the detailed description of work [2].

The EC financial support to the CARE project of about 15 M€ over 5 years is supplemented by contractor financial and manpower internal resources.

* Corresponding author. Tel.: +33 1 69 08 84 52; fax: +33 1 69 08 64 42; e-mail: olivier.napoly@cea.fr.

2. The CARE objectives

The main objective of the CARE project is to generate a structured and integrated European area in the field of accelerator research and related R&D. The programme includes the most advanced scientific and technological developments relevant to accelerator research for Particle Physics. It is articulated around 3 Networking Activities that provide the long-term scientific vision, and 4 Joint Research Activities which integrate scientific and technical developments over several laboratories. The organisation of these activities in work packages is described in separate web sites accessible from the CARE web site [1].

2.1. Networking Activities

The aim of the Networking Activities is to foster and strengthen European knowledge to evaluate and develop efficient methods to produce intense and high-energy electron, proton, muon and neutrino beams as recommended by the European Committee for Future Accelerators (ECFA). They will establish collaborative and prioritised R&D programs aimed at establishing roadmaps toward the longer-term construction of new facilities of worldwide interest.

Three Networking Activities span the full duration of the project:

- ELAN (Electron Linear Accelerator Network) for electron accelerators and linear colliders;
- BENE (Beams in Europe for Neutrino Experiments) for neutrino and muon beams;
- HHH (High energy High intensity Hadron beams) for hadrons rings and colliders.

2.2. Joint Research Activities

Four Joint Research Activities aim at developing critical and/or beyond the actual state-of-the-art components and systems to upgrade the infrastructures:

- SRF (Superconducting RF): the development of the 1.3 GHz superconducting cavity technology for the acceleration of electrons with gradient exceeding 35MV/m and the development of the necessary RF technology and diagnostics;
- PHIN (Charge production with Photo-injectors): the improvement of the technology of photo-injectors, in particular to match the severe requirements necessary for demonstrating the two-beam acceleration concepts;
- HIPPI (High Intensity Pulsed Proton Injector): the developments of normal and superconducting structures for the acceleration of very high-intensity proton beams as well as challenging beam chopping magnets;
- NED (Next European Dipole): the development and mastering of the Nb3Sn technology for reaching very high magnetic fields (>15T) and high current densities (>1500A/mm2).

The SRF and PHIN activities are foreseen to end in 2007, HIPPI in 2008, and NED in 2006.

Table 1: The main existing infrastructures

Laboratory	Accelerator	Description
CCLRC-RAL	ISIS	Accelerator complex for the neutron and muon facility
CEA	IPHI CryHoLab	High intensity proton injector Hor.[tal] cryogenic test stand
CERN	PS, SPS,LHC CNGS CTF3	Proton accelerator complex Neutrino beam Electron two-beam linac test facility
CNRS-Orsay	NEPAL	Test stand with photo injector Coupler test laboratory
DESY	PETRA, HERA TTF	Electron and proton accelerator complex Electron superconducting linac test facility and FEL
FZR	ELBE	Electron linear accelerator
GSI	SIS, ESR	Heavy-ion accelerator complex
INFN-LNF	DAPHNE	Electron-positron collider
PSI	SINQ	Accelerator complex for the neutron and muon facility

3. Highlights of the CARE project

In this section, we highlight some of the progress obtained in the years 2004-2005. A complete review of the first year activity was made at the CARE'04 annual meeting [3] held in November'04 at DESY, and is documented in the CARE Annual Reports [4]. A review of activity over the first half of the year 2005 is documented in the CARE First 2005 Intermediate Reports [4]

3.1. Networking Activities

Each Networking Activity has organized several internal meetings and broader workshops where the scientific case and the strategy of the field have been discussed. Highlighting a few such events per activity:

- ELAN organized in November'04 at DESY a meeting [3] where the European contributions to the International Linear Collider (ILC) project, in preparation of the first ILC workshop at KEK, were assembled. Topical ILC related workshops have been further organized in 2005, for instance on "Wiggler Optimization for Emittance Control" in Frascati [5]. The first International Workshop on "High Energy Electron using Plasmas" has been organized in Paris [6] in June'05.
- BENE co-organized in May'04 at CERN the workshop "Physics at a Multi MegaWatt Proton Source" [7] which reviewed the parameters of a proton driver for a future neutrino facility.
- HHH organized in November'04 at CERN the workshop "Beam Dynamics in Future Hadron Colliders and Rapidly Cycling High-Intensity Synchrotrons" [8] which reviewed the critical items and possible scenarios for CERN-LHC and GSI-SIS upgrades. LHC upgrade issues have been extensively discussed within the HHH network and topical workshops organized like on "Beam Generated Heat Deposition and Quench Levels for LHC Magnets" [9], or on "Crystal Collimation in Hadron Storage Rings" [10].

In addition, the Networking Activities are setting up very complete and informative web sites which include accelerator databases, simulation code repositories, future meetings announcements, and passed meeting proceedings. To be of efficient and wide use, these web sites are regularly updated.

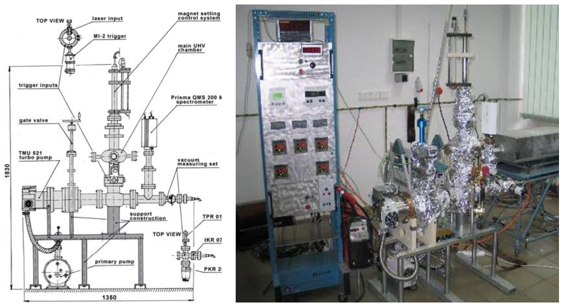

Figure 1: UHV linear-cathode arc stand at IPJ, Swierk

*3.2. The **SRF** Joint Research Activity*

- Scientific investigations on coated Niobium films by the vacuum arc method at IPJ-Swierk (see Fig.1) and INFN-Roma have shown that the superconducting properties, i.e. J_c and T_c, are the same as in bulk Niobium
- The progress with the preparation of cavities by electropolishing (see Fig.2) and moderate bake out give hope that this method results in 1.3 GHz cavities with accelerating gradients above 30 MV/m and quality factors above 10^{10}.
- RF studies at CNRS-Orsay of two alternative couplers design are complete (see Fig.3). Prototypes will be built in industry and RF tests are foreseen in spring of 2006.
- The progress in the design of two piezo-tuners, lateral at CEA or axial at INFN-Milano (see Fig.4), will allow the fabrication and RF-tests of tuner prototypes in 2005.

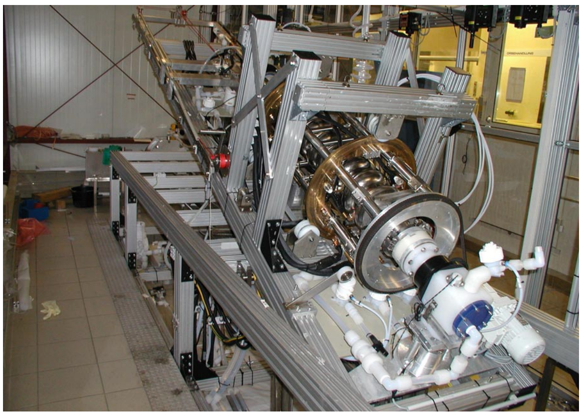

Figure 2: Electropolishing setup at DESY

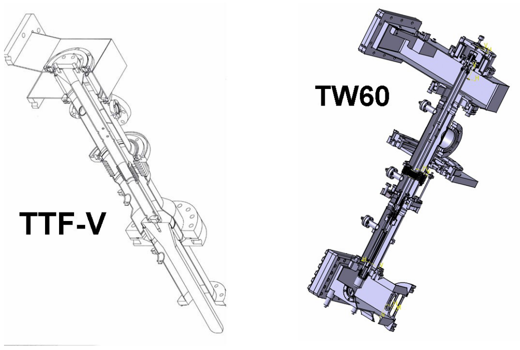

Figure 3: Design of two alternative coupler prototypes

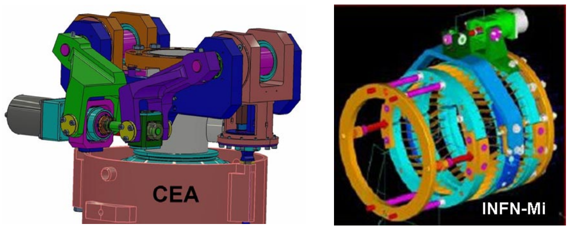

Figure 4: Design of two piezo-electric tuner prototypes

Figure 5: Nine-cell cavity in CryHoLab with high power coupler.

- An inclusive low level RF activity is going on with both software and hardware developments, and measurements on TTF.
- Integrated high power cavity tests are under way at the CryHoLab (IN2P3-CEA) test stand with the first goal of qualifying the cold tuning system prototypes (see Fig. 5).

*3.3. The **PHIN** Joint Research Activity*

- The characteristics of more than 30 photocathodes, (preparation condition, quantum efficiency, laser wave-length, lifetime, vacuum conditions…) have been collected.
- A new superconducting RF gun with 3 ½ cells has been designed at FZR-ELBE (see Fig. 6).
- The demonstration of a high charge (0.5nC) mono-energetic 170 MeV ± 20 MeV electron beam generation in the laser plasma accelerator concept has been achieved at CNRS-LOA (see Fig. 7).
- Experiments on pulse shaping with the acousto-optic modulator (Dazzler) achieved the required square laser pulse characteristics before the amplifier system at INFN (see Fig. 8).

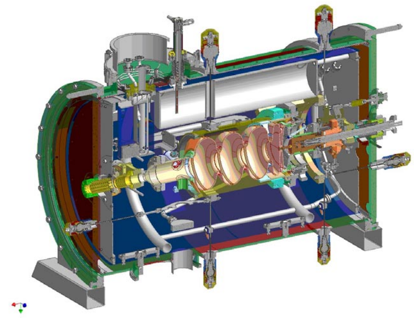

Figure 6: Cryomodule design for the SC-RF gun

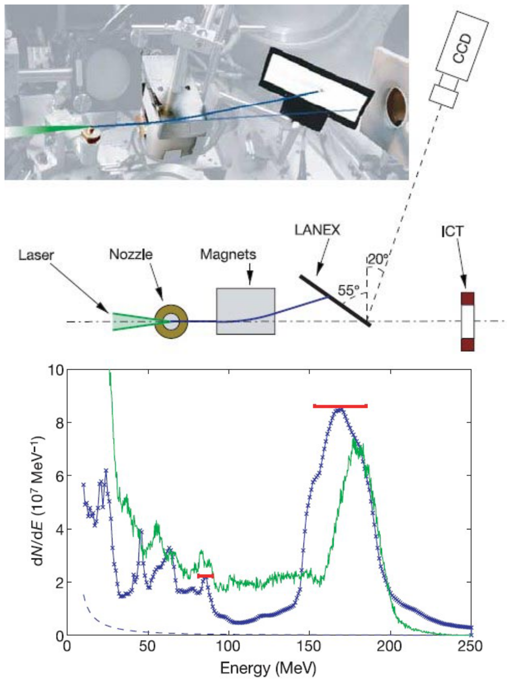

Figure 7: Laser-plasma acceleration: top, experimental setup and, bottom, data (blue) vs. simulation (green) results

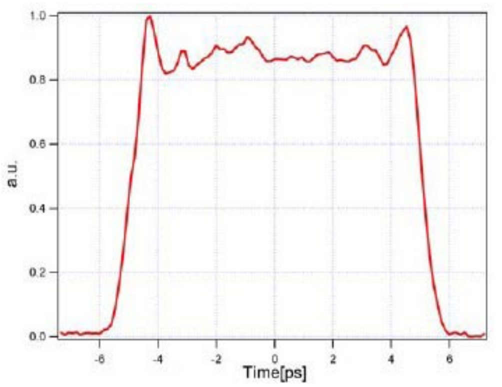

Figure 8: Dazzler pulse shape (10 ps flat top with less than 0.8 ps rise time)

- The development [11] of the RF photo-injector of the CTF3 drive beam is underway with laser design and fabrication at CCLRC-LAL and RF-gun cavity at IN2P3-Orsay.

*3.4. The Joint Research Activity: **HIPPI***

- RF studies have been completed and prototypes are in fabrication for both normal and superconducting low-beta cross-H 352 MHz resonators at IAP-Frankfort (see Fig.9).
- A 352 MHz Cavity Coupled DTL pre-prototype in construction at CERN has been copper plated (see Fig.10) and will undergo high power tests.
- Superconducting spoke resonator prototypes, ranging from β=0.1 to β=0.35 have been designed at FZJ-Jülich at 352 and 760 MHz, and CNRS-Orsay at 352 MHz (see Fig.12). They have been fabricated in industry and RF tests have started.
- A β=0.47 704 MHz elliptical cavity fabricated at INFN-Milano reached 16 MV/m accelerating gradient with $Q_0 = 5.10^9$ during a vertical RF test at CEA-Saclay (see Fig. 11).
- Tuning systems for the elliptical cavities are developed at CEA-Saclay and INFN-Milano in parallel with the piezo-tuners for the 1.3 GHz SRF cavities presented above.
- A multi-laboratory comparison of 3D high intensity linac codes with space charge solvers has been initiated and a benchmarking experiment in the UNILAC DTL at GSI is being prepared.

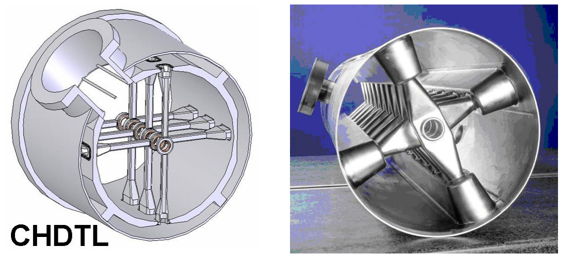

Figure 9: Normal (left) and super (right) conducting cross-H resonators at IAP-Frankfort

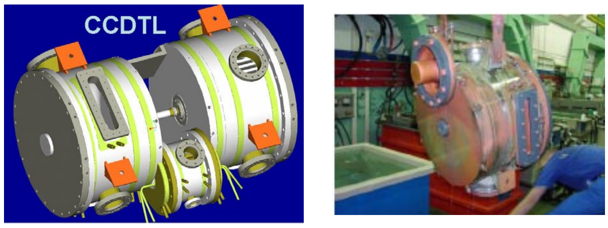

Figure 10: CCDTL design and copper plating at CERN

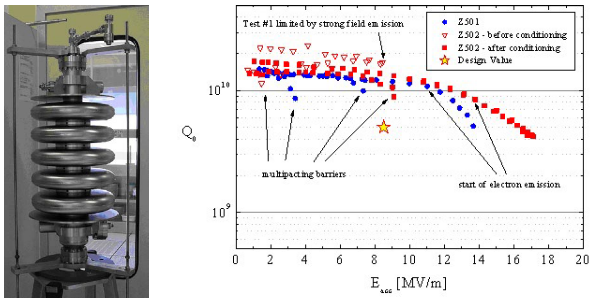

Figure 11: Vertical test of a β=0.47 elliptical cavity.

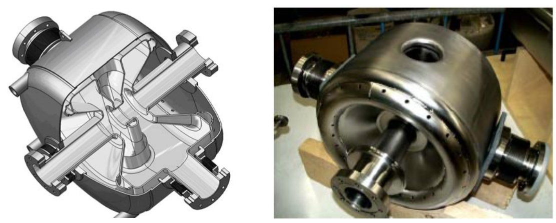

Figure 12: Superconducting spoke resonator at CNRS-Orsay.

*3.5. The Joint Research Activity: **NED***

- NED and HHH co-organized in March'04 at Archamps the workshop "Accelerator Magnet Superconductors" [12] to review present R&D and define directions of developments in connection with European industries.

- Magnetic designs for large bore and high field dipole magnets have been studied at CERN in order to define the characteristics of Nb_3Sn strands suitable to reach a 15 T field for two different apertures (see Table 2 and Fig.13).
- Two contracts for Nb3Sn conductor development have been awarded to Alstom/MSA (France) and SMI (The Netherlands).

Table 2: Nb3Sn dipole parameters

Bore [mm]	Design Type	B_o [T]	Energy [KJ/M]	Max Pres. [MPa]	Outer Diam. [mm]
88	Layer	14.42	1810	148	1004
160	Slot	13.87	3959	129	1734

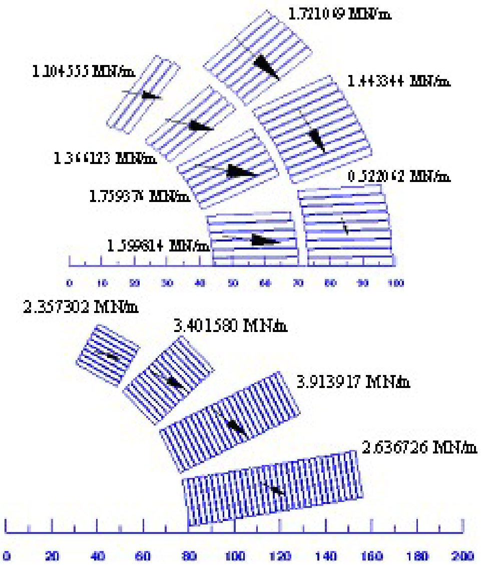

Figure 13: Cross-sections of the large bore Nb3Sn dipole design (top 88 mm, bottom 160 mm bore diameters).

4. Conclusion

The CARE project started successfully a multi-laboratory collaborative effort following the multi-year plan of integrated R&D programmes. Many parts of the programme are synergetic like the tuner and coupler developments between SRF and HIPPI. Driven by particle physics, the CARE project has also strong synergies with other programmes supported by the European Union like EURISOL for nuclear physics, XFEL and EUROFEL for free electron lasers and ITER for fusion research. Dissemination of the acquired knowledge proceeds via the CARE publication repository [13] and the organization of activity workshops and of the CARE annual meeting.

Acknowledgments

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References

[1] http://esgard.lal.in2p3.fr/Project/Activities/Current/
[2] CARE Annex I to the EC Contract http://esgard.lal.in2p3.fr/Project/Activities/Current/Overall/CARE_AnnexI_16Jan04.pdf
[3] CARE'04 Annual Meeting, http://care04.desy.de/
[4] CARE Annual and Intermediate Activity Reports http://dphs10.saclay.cea.fr/Doc/Care/care-rapport-index-2005.php
[5] WIGGLE 2005, http://www.lnf.infn.it/conference/wiggle2005/
[6] HEEAUP'05, http://polywww.in2p3.fr/actualites/congres/heeaup2005/
[7] "Physics with a Multi MW Proton Source" workshop http://physicsatmwatt.web.cern.ch/physicsatmwatt
[8] "Beam Dynamics in Future Hadron Colliders and Rapidly Cycling High-Intensity Synchrotrons" workshop http://care-hhh.web.cern.ch/CARE-HHH/HHH-2004
[9] "Beam Generated Heat Deposition and Quench levels for LHC Magnets" workshop http://indico.cern.ch/conferenceDisplay.py?confId=0516
[10] "Crystal Collimation in Hadron Storage Rings" workshop http://care-hhh.web.cern.ch/care-hhh/CrystalCollimation/default.html
[11] CARE-JRA2 activities on photo-injectors and CLIC Test Facility (CTF3) L. Rinolfi, CERN, Geneva, Switzerland, CARE-Conf-05-010
[12] Workshop on "Accelerator Magnet Superconductors" http://amt.web.cern.ch/amt/events/workshops/WAMS2004/wams2004_index.htm
[13] CARE Publication Repository http://dphs10.saclay.cea.fr/Doc/Care/care_index.php