Progress on Issues of Linear collider Normal Conducting Technology (LTECNC)

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Abstract

ELAN is the European Linear Accelerators Network of the project ‘CARE’ which concerns the “Coordinated Accelerator Research in Europe”. One of the ELAN activities concerns the normal conducting technology dealt with in the work-package LTECNC. The recent progress made in this field which includes topics on injection systems and alignment and vibration was subject of a report at the ELAN meeting of June 21, at RHUL, UK. This document gives a summary of this reporting and is written in the name of all the participants in the various activities concerned.

1. Introduction

The work-package LTECNC is concerned by the activities on high-gradient, normal-conducting accelerating structures, RF power sources, precision alignment, particle sources and components of the injection system, for linear colliders. In addition, LTECNC is also concerned by the improvement of the large-scale accelerator test facility at CERN (CTF) used for beam manipulation in this context. This document summarizes the recent progress made and achievements obtained in these activities and within the CTF collaboration as well as the plans for the next steps and developments foreseen.

2. CTF3 Test Facility collaboration

So far the Drive Beam Linac including a magnetic chicane for varying the bunch length, are completed. Presently installation of the Delay Loop is under way, to be commissioned with beam in fall 2005. It will allow testing the first stage of multiplication of the bunch repetition frequency and beam current compression by a factor of two. In 2006, the Combiner Ring will be installed and commissioned, giving another factor of five. The length of the bunch train is reduced from 1400 ns to 140 ns and the peak beam current is increased from 3.5 A in the linac to 35 A.

In its first phase, operationally now, the Drive Beam Injector of the CTF3 consists of a thermionic gun with a bunching system. In 2007 it is foreseen to replace it with the RF photo injector developed within PHIN.

In order to advance testing of CLIC 30 GHz equipment with high power RF, a separate beam line (High Gradient Test Stand) at intermediate beam energy has been installed in 2004. Here the beam with 30 GHz bunch repetition rate and short bunches can be used to generate 30 GHz RF power by sending it through a special RF structure called PETS (Power Extraction and Transfer Structure).

In 2007, it is foreseen to start equipping the CLEX (CLIC Experimental Area). Various experimental facilities will be set up in this area. A Two-Beam Test Stand will be installed to extract 30 GHz RF power from the Drive Beam with the nominal CLIC parameters. This power will be fed into a CLIC accelerating structure, which will accelerate a low-current beam, the Probe Beam, to demonstrate the full CLIC two-beam accelerating system at its nominal RF power and accelerating gradients. In its present design the Probe Beam will also use an RF photo injector, however with much less severe parameters than the Drive Beam injector.

The plan of activities in CTF3 is given in Fig.1.

Experimental results

Until August 2005, the beam has been accelerated and transported up to the end of the Drive Beam Accelerator.

The efficiency of converting the wall-plug power into 30 GHz RF-power is extremely important for CLIC. This is the reason, why the Drive Beam Linac accelerating-structures are operated under full beam-loading condition. This means that more than 95 % of the RF power injected into the 3 GHz structures is converted to beam power. Stable operation under these conditions has already been demonstrated successfully.

In 2004, the 30 GHz RF power production was put into operation, the results being in good agreement with the expectations. A power in excess of 50 MW in the PETS and pulse duration above 70 ns was produced in a load using a beam current of about 6 A. In 2005, this RF power was use to test a CLIC accelerating structure. So far a gradient of 120 MV/m and a pulse length of about 25 ns have been achieved. Conditioning of the accelerating structure is still in progress.

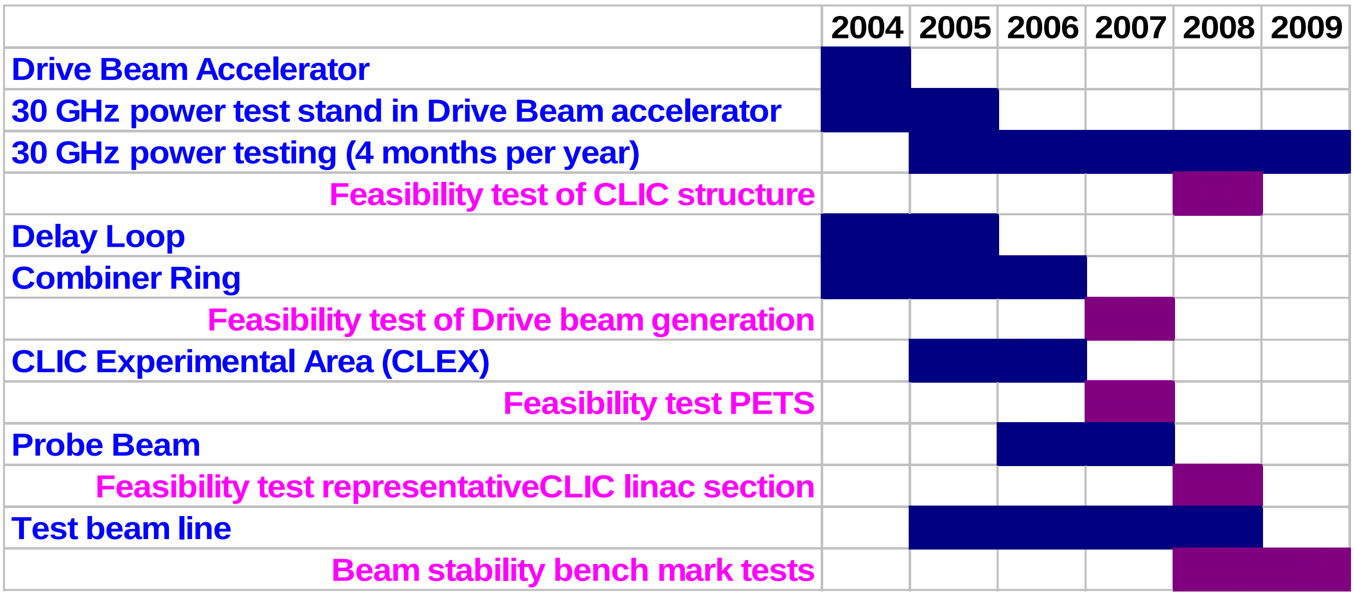

Fig.1 CTF3 activity schedule

3. 30 GHz structure development

This development work includes:
Test of damped accelerating structure at design gradient and pulse length
Design and test of damped ON/OFF power extraction structure
Developments of structures with hard-breaking materials (W, Mo…)

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- Design and test of damped ON/OFF power extraction structure
- Developments of structures with hard-breaking materials (W, Mo…)

Accelerating Structure development

Achieved accelerating fields with molybdenum, tungsten and copper are summarized in Fig.2. The high gradient tests of new structures with molybdenum irises reached 190 MV/m. The peak accelerating gradient without any damage was well above the nominal CLIC accelerating field of 150 MV/m but with an RF pulse length of 16 ns only (nominal 70 ns)

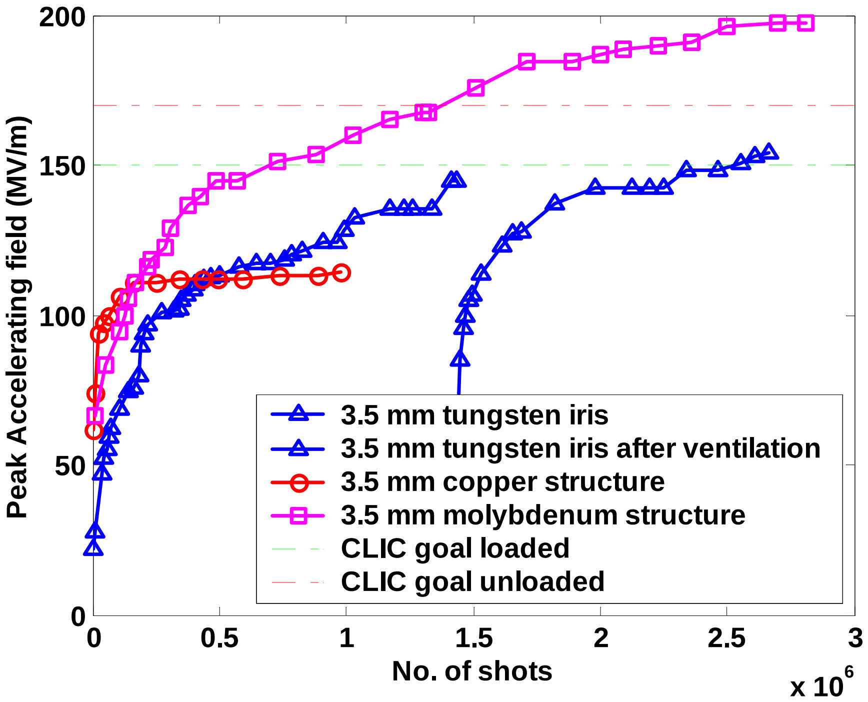


Fig.2 Achieved accelerating fields at 30 GHz.

The New accelerating structure concept HDS is based on

- Damping waveguides + slotted iris for improved wake-field damping
- An optimized geometry to reduce surface electric and magnetic fields

Field calculation indicates that the wake-field induced by a single bunch is reduced by a factor 100 at the position of the next bunch (Fig.3).

A picture of the model of the HDS (Fig.4) gives indications about its design and dimensions.

First high power test are foreseen autumn 2005.

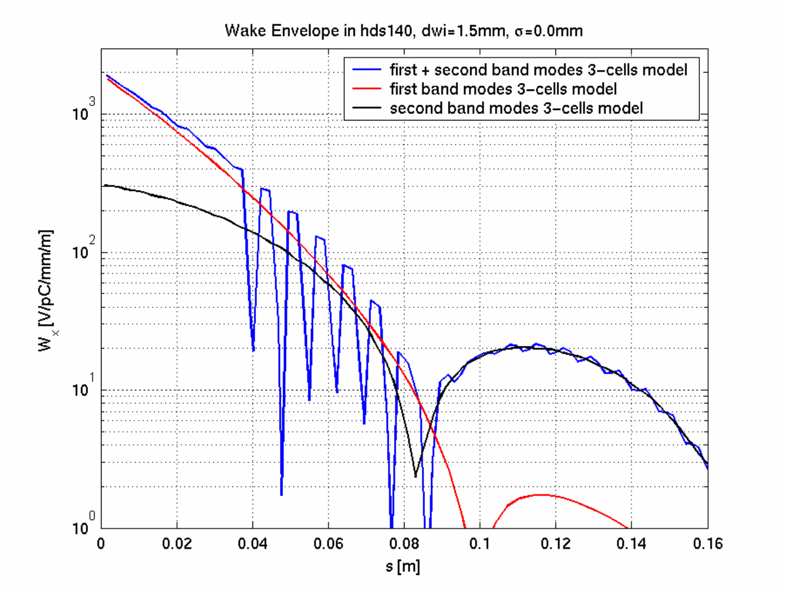


Fig3. Calculated wake-field envelope, for the HDS structure.

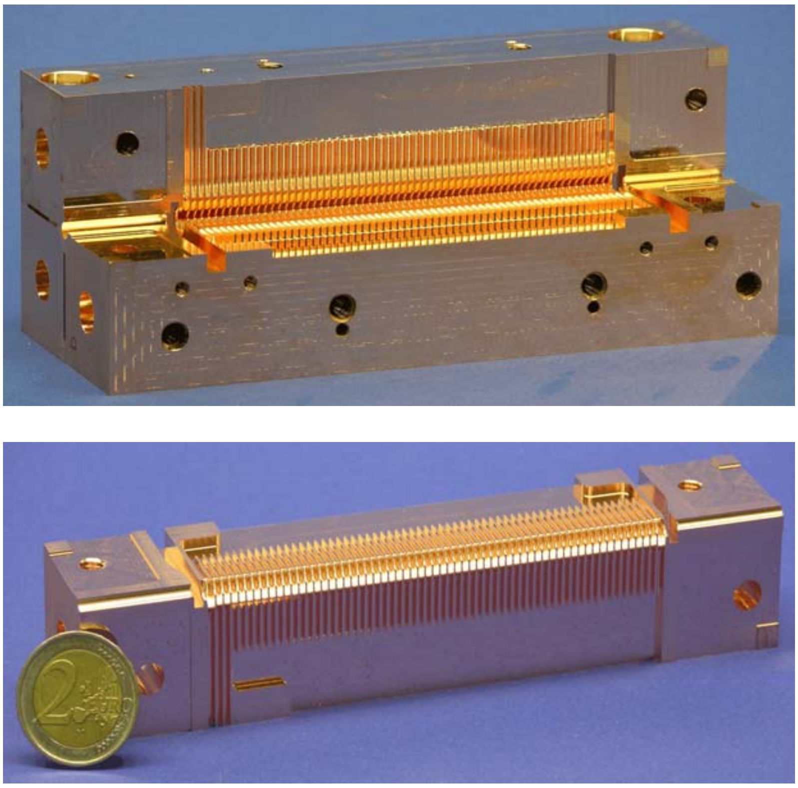


Fig.4 Model of the HDS accelerating structure

Power extraction structure development

Design and test of damped power-extraction structures, whose power generation can be switched ON/OFF are pursued for the drive beam decelerator. Their characteristics are

- Large aperture (25 mm)
- Very shallow sinus-type corrugations
- Eight 1 mm-wide damping slots

By inserting four 1.6 mm thick wedges through the damping slots, sufficient PETS frequency detuning can be achieved and the power extraction is suppressed (Fig.5).
High power tests in CTF3 with beam are foreseen from 2007 onward.

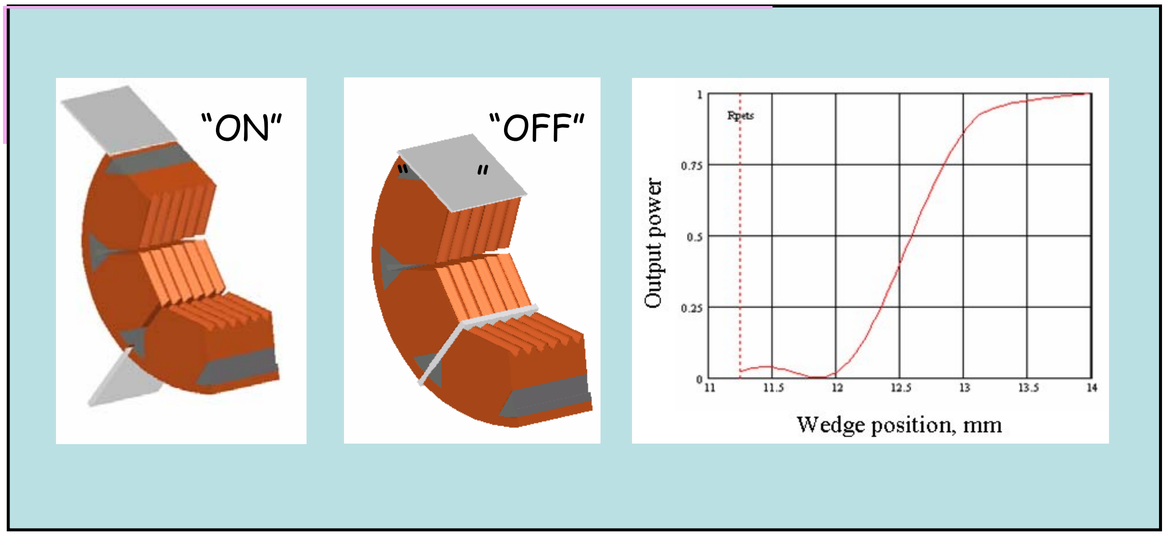


Fig.5 Sketch of the wedge system developed to switch on/off the power generation of a transfer structure.

4. CTF3 Photo-injector in PHIN

One of the main CARE-JRA2-PHIN topics concerns the photo-injector of CTF3. The specifications for this photo-injector, shown in Table 3, are very challenging because of the long train of pulses, the high charge per bunch, the pulse to pulse charge stability, the photocathode lifetime and the temporal structure. The concept of sub-pulse (called “odd” and “even”) inside a long laser pulse in order to perform a frequency multiplication in the Delay Loop via two RF deflectors is a strong constraint which needs carefully study in such photo-injector.

Photo-cathodes activities

- Rejuvenation of the preparation chamber and the transport carrier is done.
- Re-alignment of the measurement line – DC gun – preparation chamber and transport carrier is done.
- Improvement of Cs-Te cathode production
- Rest gas analysis by mass spectrum analyzer DONE
- Co-evaporation : thickness calibration ➔ evaporation rate control ➔ ratio control
- R&D for using 2nd harmonic of Nd-crystals (green)

RF Gun status

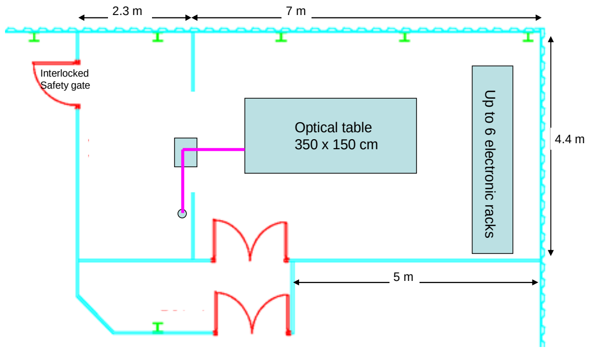
- Design is completed, based on :
  - Over-coupled: to match intense beam (3.5 A) in long pulse (1.5 ms)
  - Beam loading fully compensated
  - Emittance growth by space charge compensated with coils
  - Transverse kicks compensated with symmetric couplers
  - Vacuum improved with high temperature bake-out and NEG coating close to the cells
- Latest news:
  - Cold model constructed for RF tests, delivered in June
  - Final Gun: ordered in July, available at CERN towards the end of 2005.

Laser status

- Oscillator at 1.5 GHz frequency for controlling pulse-to-pulse jitter, and amplitude stability: Tested < 0.25 %
- Oscillator box at RAL for integration in the system Acceptance: tests done with success
- Diode Stacks and Nd:Ylf rod for 1st amplifier is ordered (available this summer).
- Price Enquiry for Diode Stacks of 2nd amplifier is out (Diodes available in the fall)
- Mechanical design for amplifier is done.
- Pockels cell driver to be found for a switch of 5kV in 333 ps
- Stable driver (<1%) for pumping diodes is being built for 100 Amps. New design is needed for 120 Amps.
- Studies on stabilization feedback and phase coding started at RAL.

2005 – 2006 Photo-injector installation and commissioning	From 2007 After commissioning
• **Photo-injector installed in the former CTF2** • **Laser-room in the former CTF2 laser-room**	• **Photo-injector installed in the CTF3** • **Laser-room in the former CTF2**

Fig.6 indicates where these systems are or will be installed.



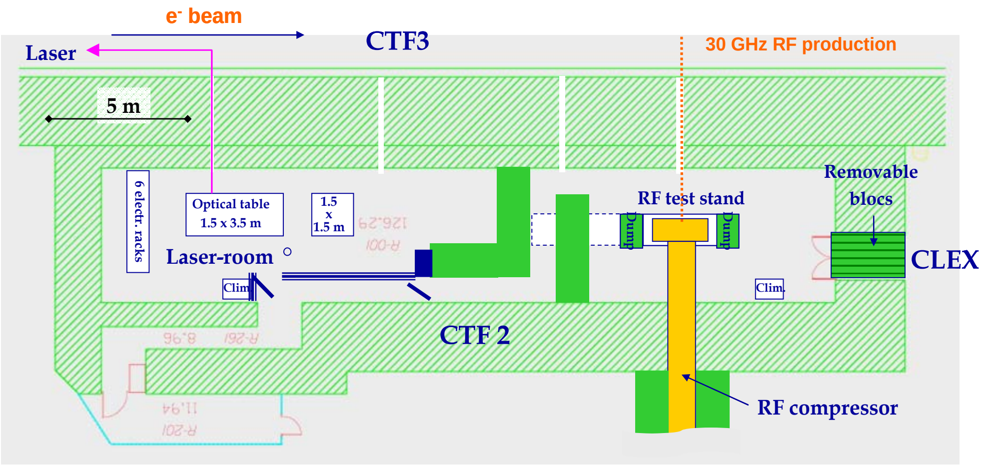


Fig6. Laser room in 2005-2006 (up) and from 207 onwards (down)

5. WIGGLE05 workshop on wigglers

The workshop was held at the INFN Institute, Frascati, Italy, in February 2005.

Wiggler design for the damping ring (DR) is critical. Work in this field will take advantage from the operating experience gained in different machines or Colliders, CESR, DAPHNE and the ATF Ring, as well as from the Synchrotron Light Sources SPRING8, BESSY, ANKA.

It was recognized that,

- with a proper optimization of the field quality, harmful effects on Dynamic Aperture (DA) can be avoided.
- Proper tools for wiggler field modeling have been developed
- Different techniques are used for the realization of the wigglers:
  Permanent magnets, SC magnet, electro-magnet, and hybrid
- Technological advances allow to produce wiggler magnets with ambitious parameters for good field quality, high peak field and short period

The following conclusions were reached:

- Proper tools for wiggler field modeling have been developed

- Tools for Wiggler modeling and DA evaluation are available. These tools are used for wigglers in operation and checked in operation.
- Code benchmarking has to be done using field map and same lattice.
- Design is possible for a lattice with required DR emittance and a DA of the order of 10 σx (3 σx is the minimum needed)
- E-cloud effects have to be seriously considered in the wiggler design. Associated single- and multi-bunch instabilities might indeed limit the beam current
- Wiggler field nonlinearities don't sensibly reduce DA. DA is mainly reduced by field non-uniformity in the horizontal plane. Consequently, good field-quality wigglers don't harm the DR performance

Hence, if the tools and the technologies are available to design and build wigglers with the characteristics and the field quality required, the cost remains critical because of the long integrated length of wiggler magnets needed in the DR.

6. Workshop on Positron Sources for the International Linear Collider

The workshop was held at the Daresbury Laboratory, CCLRC, UK, in April 2005

The workshop :

- - discussed all of the possible positron source options for the ILC that are presently being considered,
- - assessed the outstanding R & D issues that will need to be addressed for each of them to become viable,
- - considered how the final selection and design of the ILC positron source should be made.

Beside the plenary session, there were specific sessions about the targets, the positron capture, the positron polarization and the operational aspects. R&D challenges have been addressed in all these technical sessions.

The three basic concepts for e+ production were thoroughly discussed:
1) Conventional (low-energy beam on a target)
2) Undulator-based
3) Laser Compton-based
The choice will depend on the arguments to be specified by the physics community. The latter has also to indicate what emphasis should be put on polarized positrons.
This workshop was an important contribution in view of helping the choice for the baseline configuration of the ILC positron source.

7. Workshop on Metrology and Stabilization for Linear Colliders

The workshop was held at the Laboratoire de Physique d'Annecy le Vieux (LAPP), France, in March 2005

The topics discussed were in relation with the metrology and the stabilization of the components of a linear collider. They concern the alignment and positioning of these components, ground motion measurement campaign and site surveys, stabilization and control of the vibration, modelling of the structures, finite element analysis and possible feedback systems with resonance cancelling.

Ground motion study will continue on measuring correlation measurements, sensor improvement, dependence on the underground depth and magnetic field influence. R&D should be done on inertial sensor small enough to take place in a cryostat and on molecular sensors should be submitted to further tests.

The development of a second generation LiCAS (), smaller and lighter, to be eventually used in the XFEL, will be pursued. The aims of this development will be defined in relation with possible use in existing or developed infrastructures such as XFEL, ATF and CTF3.

On the stabilization topic, major axes of activities have been raised:

- modeling, simulation and theory (LAPP, ESIA, Cracow)
- development of small and well performing sensors in collaboration with industrial companies
- launch work on actuators where development is needed, define where tests could be done, e.g. ATF
- establish contacts with the designers and builders of the final focus quadrupoles and link the actuator work to possible tests.

The idea was raised to make cross-check possible between the LAPP inertial system and the system developed in Oxford, by having a common set-up for tests, for instance with a quadrupole mock-up.

References

1. H.H.Braun for the CLIC team, "CLIC progress towards Multi-TeV Linear Colliders", Part, Accel. Conf. (PAC2005), Knoxville, USA.
2. R.Losito, the PHIN photo-injector for CTF3, http://www.infn.it/phin/talks.html, 2005.
3. M.E.Biagini, Report on WIGGLE2005 mini-workshop on wiggler optimization for emittance control, CARE/ELAN document-2005-013
4. L.Rinolfi, Workshop report on positron sources for linear colliders, CARE document to be published.
5. G.Guignard, A.Jeremie, Y.Karyotakis, Workshop report on Metrology and Stabilization for Linear Colliders, CARE-Note-2005-005-ELAN.

Acknowledgements

We acknowledge the support of the European Community-Research Infrastructure Activity under the FP6 "Structuring the European Research Area" programme (CARE, contract number RII3-CT-2003-506395)