Status of CTF3 at the end 2004, beam commissioning results and plans for the future

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Abstract

A collaboration meeting of the CLIC Test Facility, CTF3, took place at CERN on 23-25 November 2004. The present summary of the CTF3 status, results obtained in 2004 and plans for the coming year 2005 is based on presentations given during this meeting.

1. Project and collaborations

During 2004 the principal goals of CTF3 have been consolidated in order to include the conclusions of the International Linear collider technical review Committee (*SLAC-R-606)* .
The programme has been adapted to answer the highest ranking questions R1.1 to R2.2 as defined by the before mentioned review up to 2009.
In summary these are:

R1.1 demonstration of a CLIC accelerating structure, damped, at design gradient and pulse length
Therefore CTF3 has to operate as 30 GHz RF power source as early as possible and a 30 GHz test stand, well instrumented, will be required for extended exploitation, such as to allow an aggressive CLIC accelerating structure development
R1.2 Demonstrate the feasibility of the CLIC drive beam scheme with a fully loaded linac
Fully loaded linac operation has already been demonstrated.
R1.3 Power-Extraction Structure (PETS) with on/off capability, damped
This requires the availability of the full drive beam with the correct time structure.
R2.1 Validation of beam stability and losses in the drive beam decelerator and design of a machine protection system
This requires the design of bench marking experiments in the 35 A Test Beam Line (TBL) which has been added to the programme
R2.2 Test of a relevant linac sub-unit with beam
This requires a second beam (probe beam), representing the CLIC main beam, which will be accelerated with 30 GHz CLIC-type structures.

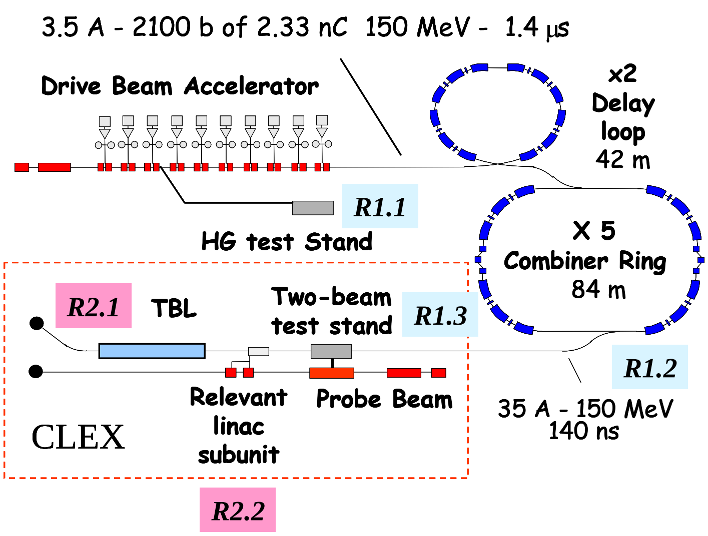

Fig 1: Layout of CTF3 with the main building blocks

The minimum installation required to answer the above questions is indicated in the schematic view of CTF3 shown in Fig 1.

The CTF3 base line plan has changed very little, only the CLEX area has been better defined.
Since the beginning, CTF3 has been conceived as an international collaboration and quite a number of institutions are already participating. On the 19th of May 2004, a meeting was

organised at CERN with the aim to strengthen the collaboration, such that the rather ambitious time schedule can be met. Some of the declarations of the delegations have evolved meanwhile either to a collaboration or to concrete proposals to the respective funding agencies, with approval still pending in most cases. Representatives of most of these institutes participated in the collaboration meeting. The status of these new potential collaborations is described in the following list:

LNF contribution (beyond the Delay Loop DL): *Waiting for approval*
Optics design for Combiner Ring (CR) and Transfer Lines (TL1 and TL2) going on between CERN, LNF,
Path length wigglers for CR
Vacuum chambers for CR and TLs, incl. beam diagnostics (without electronics)
Sweden *Waiting for approval*
TL2 incl. bunch compressor and Two Beam Test Stand: optics design, missing magnetic elements (6 dipoles) and power converters, beam diagnostic equipment,
Two Beam Test stand: optics, magnets, vacuum, diagnostics (spectrometers, optical screens, BPMs, WCMs, for Probe Beam and Drive beam)
RF diagnostics and data handling.
Spain:
Ciemat is building corrector magnets (independent of approval of the rest of the programme)
Waiting for approval:
2 double septum magnets for CR, based on scaled DaFne design.
Ejection kicker for CR
TBL quadrupoles with precision movers
RF structure work
Finland: *Waiting for approval*
power converters for the CR and technology for accelerating structure.
France: *Waiting for proposal and approval*
Probe Beam linac (CEA Saclay, LAL)
Lure magnets
Northwestern (NW) University Illinois *Decision depending on US commitment*
beam diagnostics for TBL,
Turkey
Ankara University proposes to send 4 physicists to participate in CTF3, mainly in operation.
BINP
quadrupoles and sextupoles for CR have being ordered from BINP.

All this is in addition to the already established collaborations:
Finnish Industry: One person for CLIC/CTF3
INFN/LNF: chicane, DL, optics for CR,Operations support, RF deflectors 3 GHz
LAL: Gun electronics and HV, pre-bunchers
Northwestern University Illinois: Drive Beam accelerator, Beam loss monitoring
RAL: Laser development
SLAC: RF gun, Injector design and commissioning
University Lausanne: PhD student
Uppsala University: Operations support, Phase monitor
Many **CERN** groups

In addition work which is partly funded by the European Union within the programme FP6 on the Photo Injector is going on in collaboration between three laboratories:
LAL: RF gun
RAL: Laser
CERN: Photo cathodes

2. Status of the accelerator

Fig. 2 shows the present status of the accelerator. So far the machine has been commissioned with beam up to the end of the linac including the chicane installed by INFN for bunch length manipulations. However, eight accelerating structures fed by four klystrons are still missing and were replaced by simple vacuum chambers, but all focusing magnets are already in place.

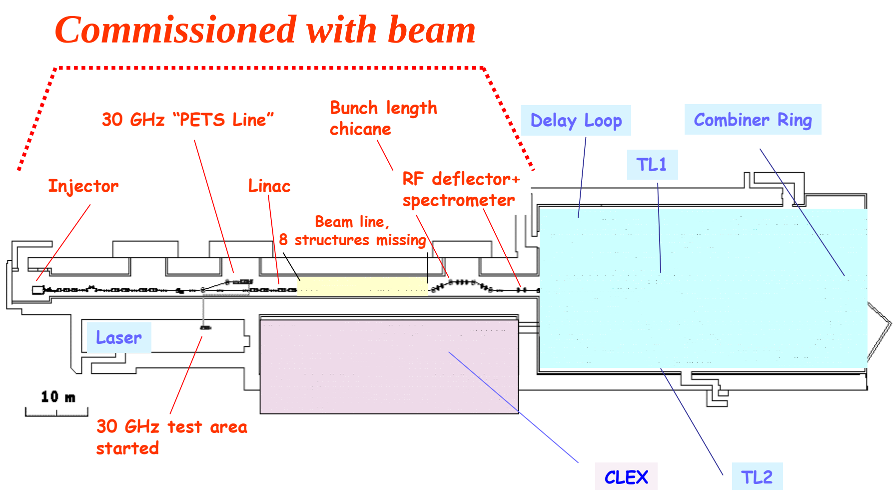

Fig 2: Status of CTF3 installation

At the end of the linac, a 3 GHz RF deflector has been installed. This allows - together with the beam diagnostic and a spectrometer behind it - a measurement of the longitudinal beam parameters. This installation was not initially foreseen, but could be done since we already have an RF deflector (foreseen for the Delay Loop) and a klystron, not used yet in the linac, available. Interesting first measurements were done, reported during the CTF3 Collaboration meeting.

A new beam line, branching off nearly half way along the main linac was installed and commissioned, the "PETS line". Here in a special PETS (Power Extraction and Transfer Structure) RF power at 30 GHz is extracted from the beam and transported via a newly installed waveguide over about 17 m to the test area in another part of the building where CLIC components like for example accelerating structures can be tested with high power RF. This circular, over-moded waveguide with extremely low RF losses is a remarkable development achieved by IAP Nizhny Novgorod. The installation is shown in Fig 3.

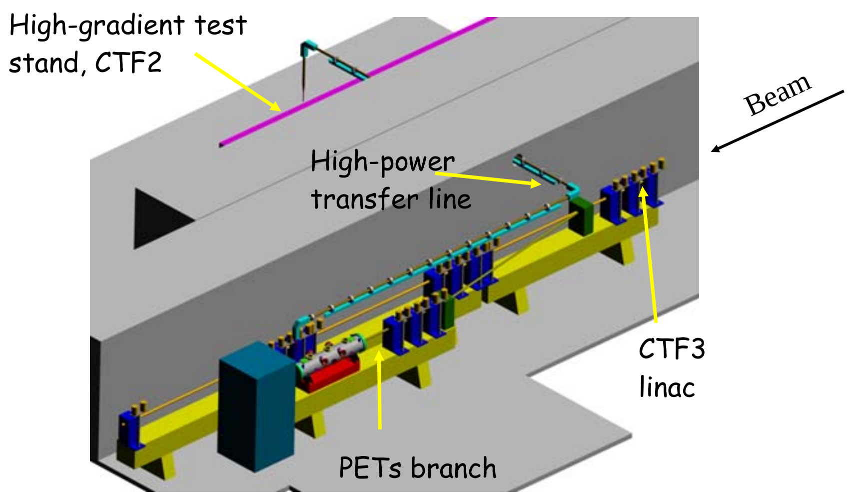

Fig 3: New "PETS Line" installation and 30 GHz RF power transfer line to the test area

3. Operation and performance in 2004

After the first demonstration of the bunch train combination by RF deflector injection in an isochronous ring [1] during 2001-2002 (CTF3 preliminary phase), the exploitation of the new CTF3 installation started in 2003 with the commissioning of the injector and the first full beam loading operation [2].

In 2004, CTF commissioning continued in two runs (7 June-18July and 13 Sept-15 Nov) for a total of 14 weeks of operation with beam. The remaining time was dedicated to installation and maintenance work. In spite of appreciable help in operation from collaborating institutes (especially INFN-Frascati during the 2nd run), the number of operators was not large enough to allow for round-the-clock operation. Therefore beam was up mainly during normal working hours. A few week-ends dedicated operation for 30 GHz RF conditioning could be organized.

The main points of the 1st run experimental program were the commissioning of new linac modules (including four accelerating structures) and the first 30 GHz power production tests, with a short Power Extraction and Transfer Structure (PETS) installed. In the 2nd run, the commissioning of the rest of the linac was carried out, including the magnetic chicane built by INFN. The experiments on 30 GHz RF power production continued, now with a full length PETS and the high-power low-loss
RF line used to transport 30 GHz power to the test area (Figs 3 and 4).

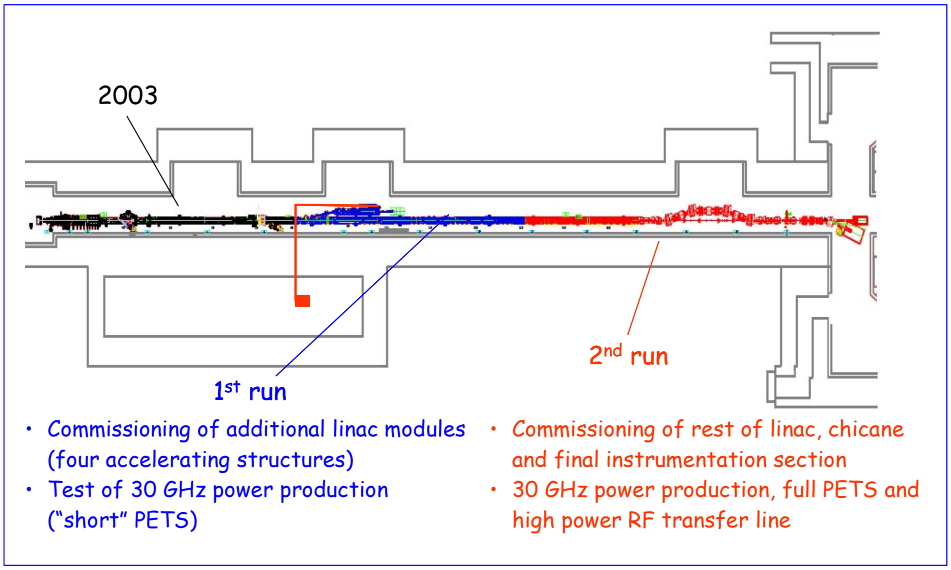

Fig 4: Layout of the CTF3 linac, describing beam operation in 2003 and 2004.

The 30 GHz power produced was in both runs in good agreement with the expectations. In the 2nd run pulses with power in excess of 50 MW and pulse duration above 70 ns were produced using a beam current of about 6 A (Fig. 5). Such power level and pulse length will allow next year test of accelerating structures with gradients up to the CLIC nominal gradient of 150 MV/m. Especially for the higher power range, electron beam transport through the PETS was never 100%, with best results at about 90%, for 3 A beam current. We expect better performances next year, due to an increase in beam energy at the PETS and other hardware improvements.

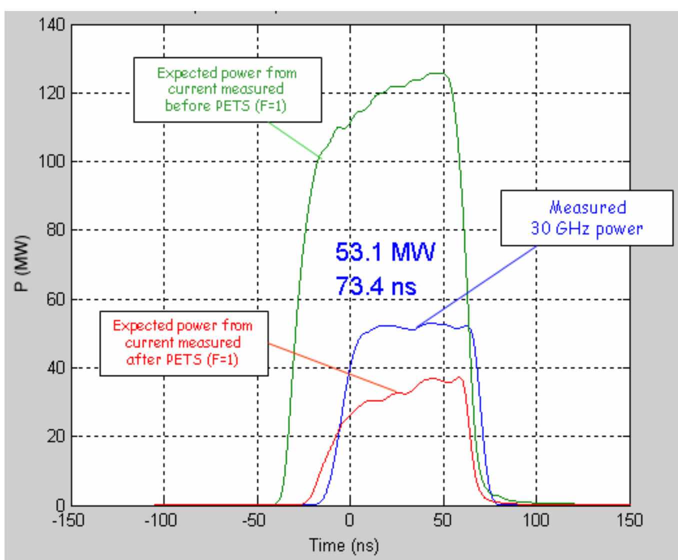

Fig 5: Results of power production test.

A good beam transmission was obtained rapidly through the linac and the INFN chicane (Fig. 6). Several optics measurements were performed. In particular emittance and Twiss parameters were measured at the beginning of the linac and after the chicane. A comparison

with the MAD model showed a good agreement. Dispersion measurements were also performed in the chicane for different optics. The chicane is indeed built in such a way that its momentum compaction (matrix element R_{56}) can be easily changed, obtaining both positive and negative values. Such feature allows to increase or decrease the length of the electron bunches as desired. A vertically deflecting RF structure is used after the chicane to perform a bunch length measurement.
Initial measurements showed bunch compression to less than 0.5 mm rms for an initial bunch length of 2 mm, again in good agreement with the expectations (Fig. 7).

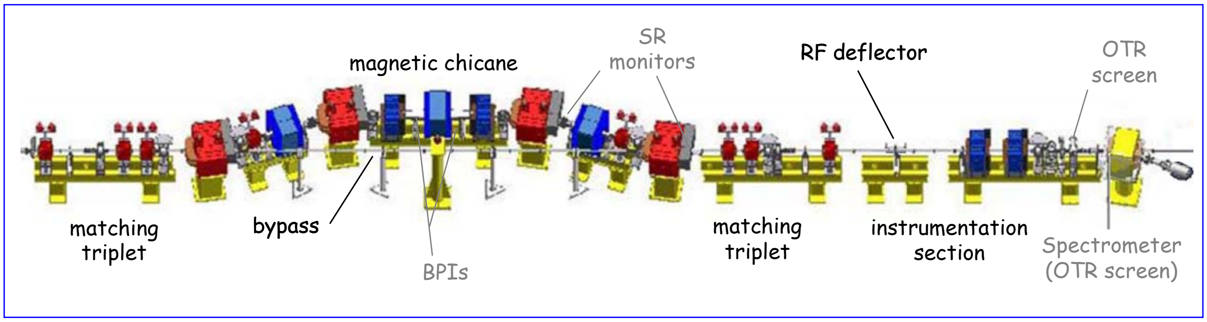

Fig 6: The INFN chicane and the end-of-linac instrumentation region.

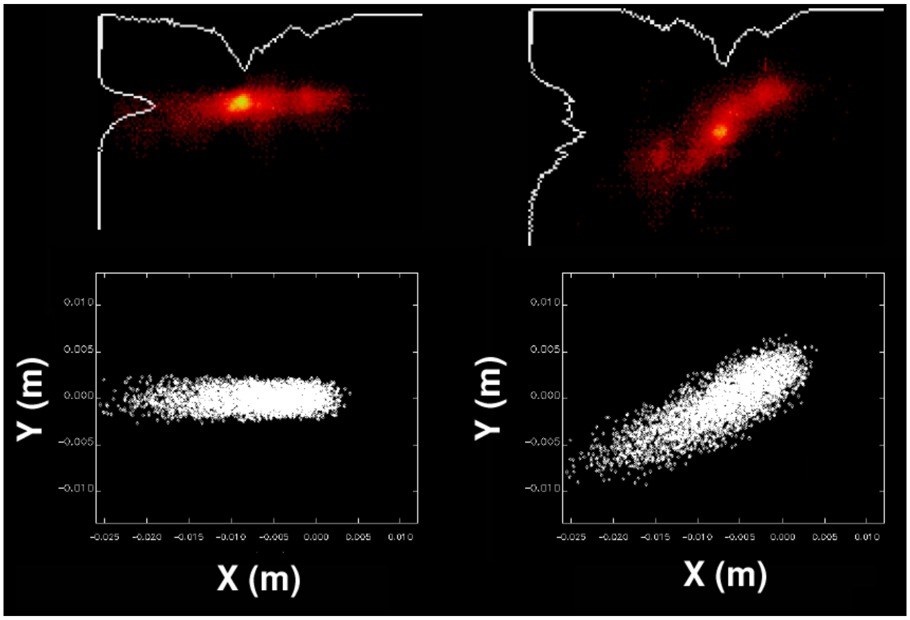

Fig 7: Measured (top) and simulated (bottom) beam transverse beam distributions with the RF deflector off (left) and on (right), for R_{56} = 0.1 m. Horizontal dispersion at the location of the screen is responsible for the correlation visible in the images to the right (from C. Biscari, INFN/LNF).

4. Future Plans

During 2005 a new Sub-harmonic Bunching system will be installed, allowing to produce the 1.5 GHz bunch repetition frequency and the phase coding of the bunches required for operation of the Delay Loop and the Combiner Ring. The originally foreseen design based on a wide band klystron was abandoned for financial reasons in favor of three traveling wave tubes driving three traveling wave bunching structures. All components are on order, the sub-harmonic bunchers will be installed in winter 2004/2005 and commissioned with RF power in summer 2005. Fig. 8 is a layout which summarizes the existing installation together with the new installations in 2005.

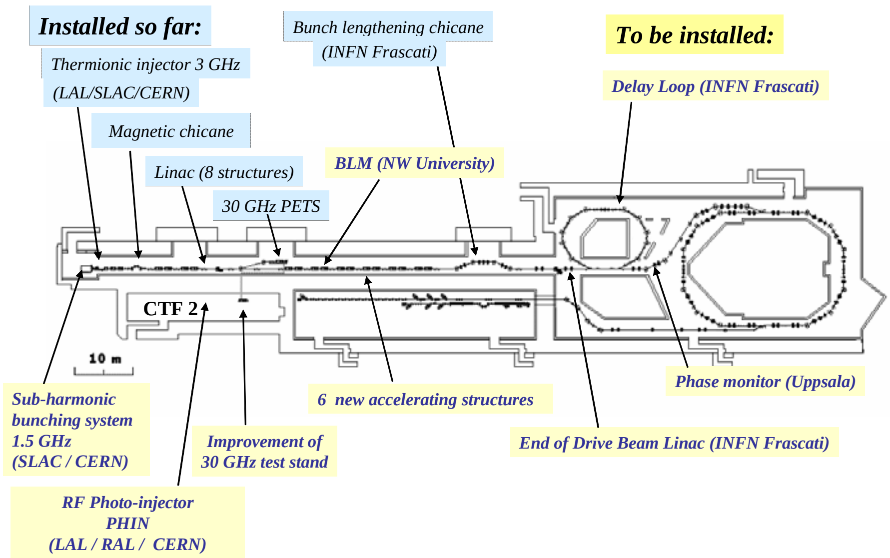

Fig 8: Installation foreseen in 2005

The activity of the JRA2 (Joint Research Activity) PHIN of CARE will be concentrated in the former hall of CTF2 where the test stand for the photo-injector will be installed.

In the linac we plan to install the missing accelerating structures, with the exception of two structures, since the klystron foreseen for them will still be used for the RF deflector.

The installation of the Delay Loop is foreseen in winter for the first part, the remaining parts being planned in the summer shut-down, such that in the second part of 2005 the commissioning of this ring can begin. Planning for the CLEX building has started ; construction is foreseen in 2005.

The installation steps for the coming years are shown in Fig 9.

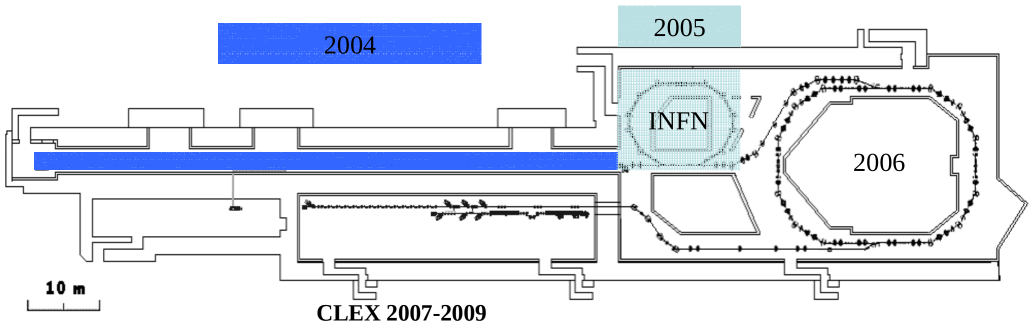

Fig 9: Steps of installation

So far only the Delay Loop foreseen for 2005 is funded. Installation of the Combiner Ring planned in 2006 as well as the CLEX installation and exploitation from 2006 onwards depend on collaboration partners taking over some of the work. Ideas for CLEX are now emerging, in particular about bench marking experiments to provide answers to the drive beam stability in CLIC.

The thermionic injector presently used will eventually be replaced by a Photo Injector. Work on this new facility has started in a very active collaboration within PHIN between LAL, RAL and CERN, with substantial funding from the EU. In 2007, the new injector will be installed in the accelerator, after extensive testing in the ex-CTF2 area.

5. Operational aspects and 2005 schedule

The basic purpose of CTF3 is twofold: a) demonstrate the feasibility of the CLIC 30 GHz power source and b) produce high power RF at 30 GHz for testing CLIC components. Therefore the beam time, already limited because of installations of new equipment, has to be shared between these two activities, to approximately 50 % each.

Fig. 10 shows the CTF3 schedule for 2005 where 2 periods of beam running (in green) are foreseen with periods of installation (in grey).

In the future the demand on 30 GHz power testing will drastically increase, and the machine will become much more complex with the addition of the rings and later of CLEX (CLIC Experimental area). The only way to cope with this is to organize operation on a 24 hour basis, possible seven days a week. This, however, requires much more manpower resources than we have presently available.

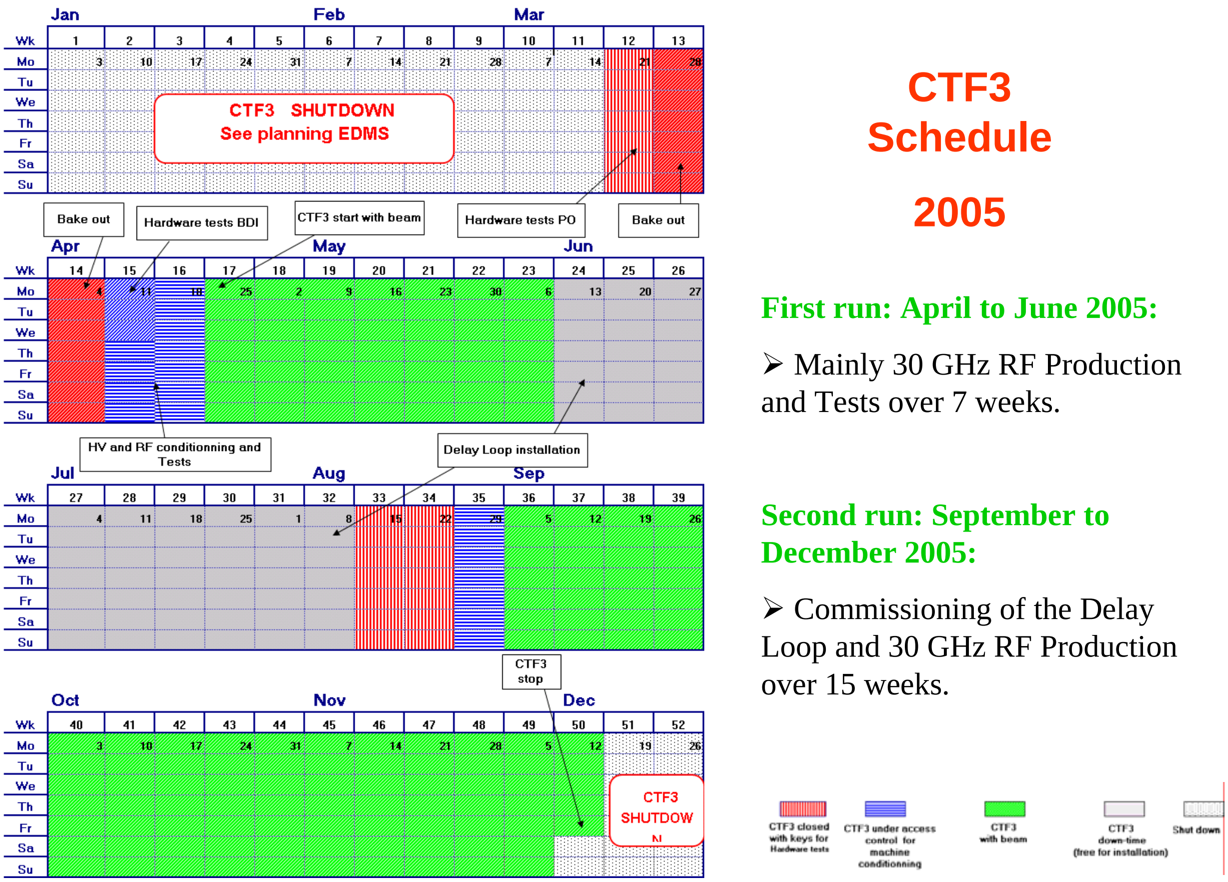

Fig 10: CTF3 Schedule for 2005

Conclusion

CTF3 is a very ambitious project, which can only succeed with collaborations. So far it is assured up to including the Delay Loop. Many questions are still open, in particular concerning benchmarking experiments. The CTF3 team both at CERN and in collaborating institutes is highly motivated and an enormous asset for the success of the project.

The presentations given at the CTF3 collaboration meeting of 2004 are available on a web page [3].

References

[1] R. Corsini, A. Ferrari, L. Rinolfi, P. Royer, F. Tecker, "Experimental results on electron beam combination and bunch frequency multiplication", Phys. Rev. ST Accel. Beams 7, 040101 (2004).

[2] R. Corsini, H. Braun, G. Carron, O. Forstner, G. Geschonke, E. Jensen, L. Rinolfi, D. Schulte, F. Tecker, L. Thorndahl, L. Groening, M. Bernard, G. Bienvenu, T. Garvey, R. Roux, T. Lefevre, R. Koontz, R. Miller, D. Yeremian, R. Ruth, A. Ferrari, "First full beam loading operation with the CTF3 linac", Proc. EPAC 2004, 5-9 July 2004, Lucerne, Switzerland Gyeongju (Kyongju), Korea, CERN/PS 2002-068 (RF) and CLIC Note 538. Proceedings of EPAC2004.

[3] URL address of the 9th CLIC/CTF3 collaboration meeting: http://ctf3.home.cern.ch/ctf3/New_collab_meet.htm

Acknowledgements

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