FLASH" by M. Scholz, and "Transverse phase space studies with the new CDS booster cavity at PITZ", by G. Vashchenko both from DESY, "Optimization studies and measurements for ultra-low emittance lattices" by S.M. Liuzzo from Rome II University and ESRF, "Study on the Beam Dynamics of the CLIC Main Linac and the Beam Optics of the ILC/CEPC Final Focus System" by Y. Wang from IHEP.

In **Section 6** are announced two interesting beam dynamics events:

- EIC14, International Workshop on Accelerator Science and Technology for Electron-Ion Colliders, that will be held March 17-21, 2014 at Jefferson Lab, Virginia (US),
- Mini-Workshop on "Electromagnetic wake fields in particle accelerators" to be held in April 23-29, 2014 at Erice (Italy).

Finally, we wish to thank the CLIC scientists who took some of their time to review for us the most interesting topics and results of this challenging project, making this Issue a very dense one. In particular, one of the editors (MEB) wish to thank Y. Papaphilippou who did a great work to set up the table of contents and convinced CLIC colleagues to write for us.

The most grateful acknowledgments go of course to Manuela Giabbai (LNF), who assisted us in the editing, getting quite crazy in the effort of harmonize the format of the many, different papers and pictures.

We hope you will enjoy this Newsletter and you will find it useful for your personal knowledge and your activity in the Accelerator Physics and Technology fields.

2 Theme Section: The CLIC Challenge

2.1 The CLIC Project - Status and Prospects

Erik Adli, University of Oslo, Norway
On behalf of the CLIC/CTF3 collaboration
Mail to: Erik.Adli@fys.uio.no

2.1.1 Introduction

The high luminosity of a linear collider, at the lowest power, requires the generation of ultra-low emittance high-intensity bunches, with remarkable stability. Although conventional electron sources and positron production schemes provide beams with the intensity required, the emittances are several orders of magnitude larger than the ones needed. The natural synchrotron radiation damping of the beam when circulating in rings is the cooling mechanism used to reach these small emittances. The CLIC project is a study for a Multi-TeV e+/e-collider, to be built in stages, based on normal-conducting X band technology. A Two-Beam Acceleration scheme is used in order to provide compressed rf pulses for the main accelerating structures with high efficiency. The compressed rf pulses allow the main charge to be accelerated at a very high loaded gradient of 100 MV/m, in short beam pulses of 156 ns. Figure 1 shows the layout for a 3 TeV center of mass machine, illustrating the two-beam acceleration scheme. CLIC completed the CDR in 2012 [1]. The project is currently in a project preparation phase where further optimization, system tests and detailed design of the machine is taking place, in a global collaboration of volunteer institutes. In addition, the CLIC project has started collaborations for the use of CLIC X band technology in compact free electron lasers and medical applications. The CLIC project is linked to the European Strategy Particle Physics priorities related to the Energy Frontier. The LHC may discover Beyond Standard Model physics when operation starts at full energy in 2015 and, depending on the findings, higher-energy hadrons as part of LHC energy upgrades or a high energy e+ e- collider might be the best option to access the new physics. The CLIC work in this period is also integrated in the Linear Collider collaboration, where the ILC technology provides an option for an early exploration of the Higgs sector in particular, while CLIC remains the only option for a Multi-TeV e+ e- collider. Wherever possible, shared activities for ILC and CLIC are being coordinated. This overview article reviews the main conclusions of the Conceptual Design Report and outlines key activities foreseen in the project period from 2012 to 2018, which we will refer to as the "next period"

2.1.2 **Conceptual Design Report**

The CLIC conceptual design report (CDR) was completed in 2012, and documents a proof of principle of all aspects related to the Two-Beam Acceleration scheme, both by comprehensive simulation studies of all parts of the machine and by a detailed experimental program in the CLIC Test Facility 3 at CERN [2]. Figure 2 shows a) the CLIC Test Facility Two-Beam Test Stand and b) data points for the achieved two-beam accelerating gradient as function of input power to the X band accelerating structure. Drive beam generation has been verified and the achieved gradient is up to and beyond the CLIC target of 100 MV/m. Furthermore, ongoing rf based tests of the main linac structure gradient are close to or on target for all parameters (gradient, pulse length and breakdown rate), and Figure 3 shows a summary of the latest results. Uncertainty from beam loading will be tested in the current next period. Studies of the deceleration versus power production show good consistency [3]. Concerning emittance generation, the CLIC damping ring has similar specification to an ambitious light source, and no showstoppers were identified for generation of the ultra low emittances. Concerning emittance preservation, the alignment system principle has been demonstrated, the stabilization system have been developed and benchmarked and integrated simulations of emittance preservation in the main linac meet or exceed the luminosity targets.

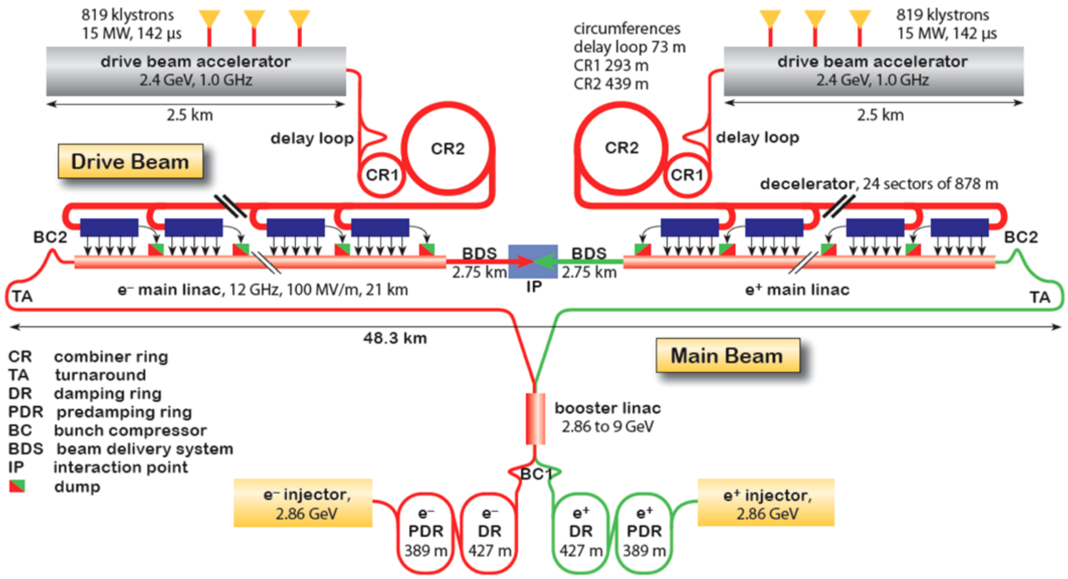

Figure 1: The layout of the 3 TeV CLIC accelerator complex. The main beams are generated and pre-accelerated in the injector linacs and then enter the damping rings for emittance reduction (lower part of the figure). The normalized beam emittances are 500 nm and 5 nm in the horizontal and vertical planes respectively at the exit of the injector complex. The small emittance beams are further accelerated in a common linac before being transported through the main tunnel to the turnarounds. After the turnarounds the beams are accelerated in the main linac with an accelerating gradient of 100 MV/m. The 12 GHz rf power for the accelerating structures are generated by extracting the energy of electron drive beams in decelerator, running in parallel with the main linac accelerators. The top part of the figure shows the Drive Beam generation and the successive time compression of the drive beam pulses in the delay loops and combiner rings (CR1 and CR2). The time-compressed drive beam reaches a current of 100 A at a beam energy of 2.4 GeV. The compressed drive beam is transported through the main linac tunnel. The beams collide after a long beam delivery section (BDS) in one interaction point (IP) in the centre of the complex, where two detectors share the beam-time in a push-pull detector configuration.

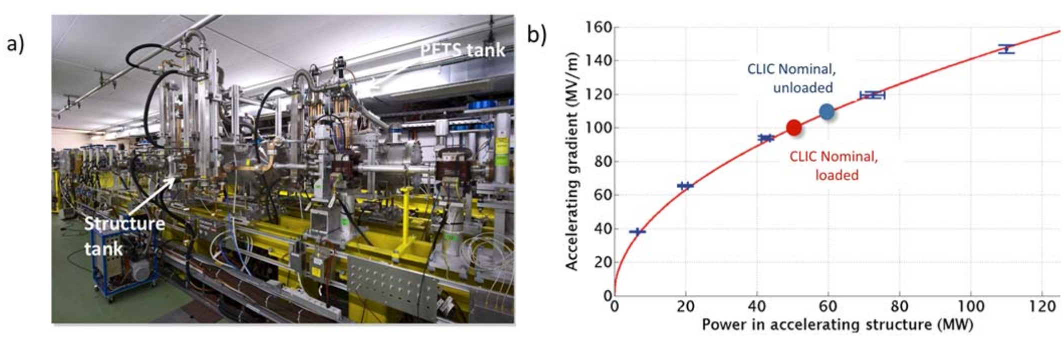

Figure 2: a) The Two-Beam Test Stand at the CLIC Test Facility where 12 GHz rf power is extracted from an up to 28 A drive beam and transferred to structure accelerating a 1 A probe beam. b) Experimental results of two-beam acceleration, up to and beyond the nominal CLIC gradient.

2.1.3 Staging and Optimisation

The Two-Beam Acceleration scheme is particularly suited for energy staging of the machine; once the drive beam complex is constructed, rf power for additional lengths of the main linac can be provided simply by increasing the drive beam length in the drive beam accelerator. No upgrades are needed for the drive beam complex, and once the drive beam complex has been constructed, the addition cost per GeV of center of mass energy is favourable to klystron-based alternatives. Furthermore, lower energy machines can run most of the time during the construction of the next stage. A consistent three-stage implementation scenario has been defined. Schedules, cost and power are being developed, although the energies of the individual stages will be determined by LHC physics results. The minimum center of mass energy being considered is about 375 GeV, which will allow precision studies of the Higgs and the Top quark. Figure 4 illustrates an example of the various stages of a CLIC machine.

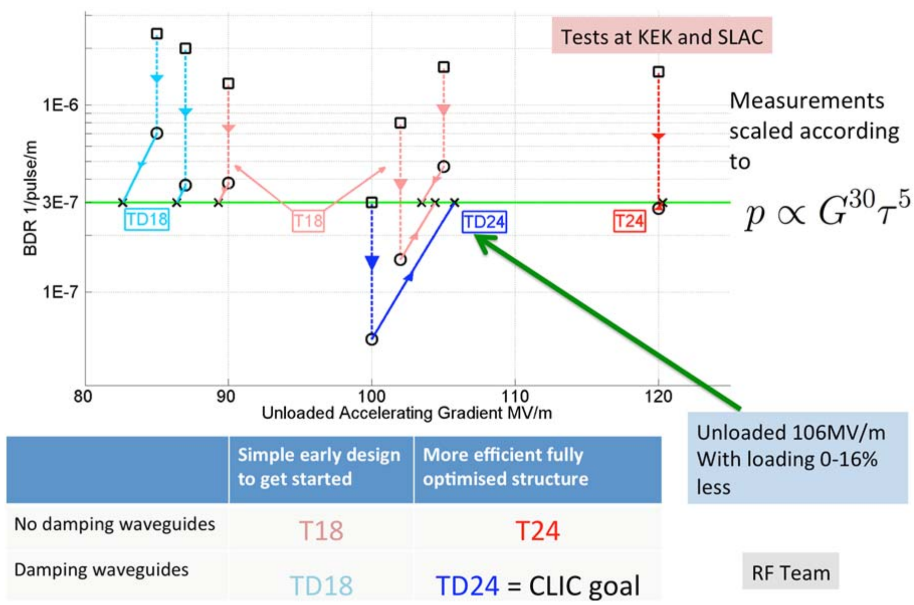

Figure 3: Structure test results, where gradients are scaled to the CLIC allowed breakdown rate of $3x10^{-7}$. A fully optimized CLIC structure with damping waveguides has recently reached an unloaded gradient of 106 MV/m.

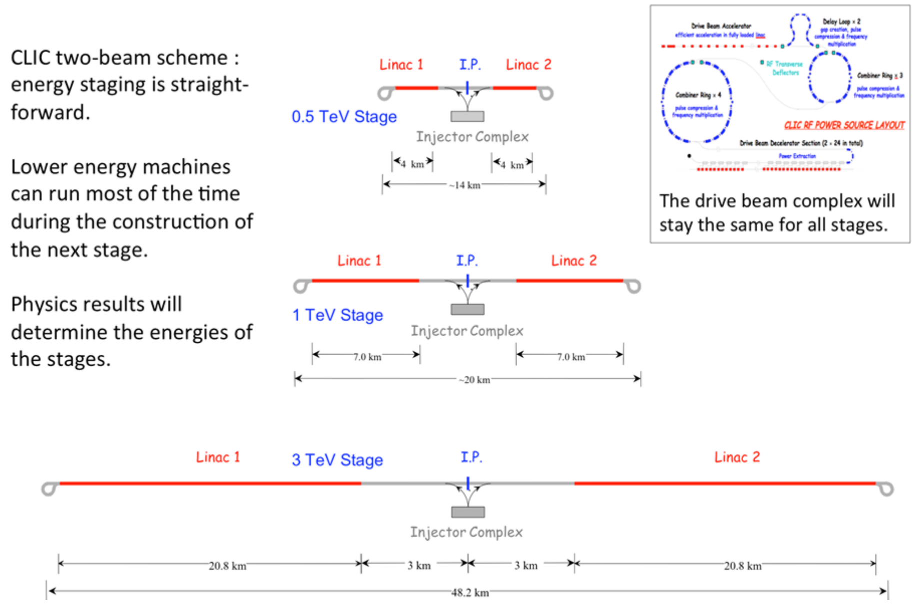

Figure 4: Example of CLIC energy stages. The center of mass energy can be increased without modifications to the drive beam accelerator complex. The actual energy of each stage will be guided by LHC physics results.

The CLIC machine is currently being re-optimized for the lowest energy stage (375 GeV). The optimization includes overall design and system optimization, technical parameters for all systems, cost, power/energy optimization, scheduling and site studies. Examples of areas, which can give increased machine power efficiency, are the use of permanent magnets for the drive beam, and studies of high-efficiency L-band multi-beam klystrons for the drive beam acceleration. The goal is to push the tube efficiency towards 80%, and increase the drive beam klystron power output. Estimates indicate that a reduction in the total machine power consumption of 20%, with respect to CDR figures, can be achieved. As part of the preparation for an optimal implementation strategy, a 500 GeV CLIC where the main linac are powered by klystrons (as opposed to a drive beam) has been studied in detail [4]. 4,400 klystrons would be required for a 500 GeV machine and a simple cost study indicated a cost comparable to a drive beam-based CLIC linac. The luminosity is comparable to that of the drive-beam based design. The pulse length is the same as for the drive-beam design. The drive beam design has the advantage of a comparably lower cost per additional GeV. Figure 5 shows one rf unit for a klystron-based CLIC, where a compressed rf pulse from two 60 MW klystrons powers 8 CLIC accelerating structures.

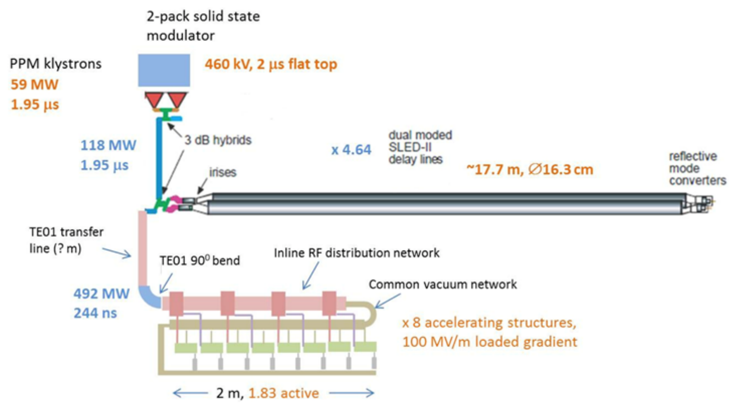

Figure 5: An rf unit for a klystron based CLIC. Two 60 MW klystrons can power 8 CLIC accelerating structures at a gradient of 100 MV/m.

2.1.4 Luminosity and Alignment

In order to reach the target luminosity of $10^{34}/cm^2/s$ CLIC requires a normalized vertical emittance of 20 nm at the interaction point, and a maximum emittance growth of 10 nm in the main linacs. Robust emittance preservation in the main linac will be achieved using beam-based alignment and by integrating wakefield monitors on the structures. In the next period, the two topics will be addressed experimentally. The 2 km FACET linac test facility at SLAC [5] now provides a unique opportunity to test beam-based alignment for linear colliders experimentally, and a proof of principle of the dispersion free correction algorithm as planned for CLIC has recently been demonstrated experimentally [6]. The experiments have shown that an automatic global correction scheme can successfully control the dispersion and reduce the emittance over 500 m of linac. Wakefield monitors are currently being developed, with the aim of providing the required resolution of 3.5 um with a robust and economical design. The monitors will be tested in CTF3 to ensure that the target precision can be reached [8]. Figure 6 illustrates the CLIC alignment techniques and some of the developments foreseen in the next period.

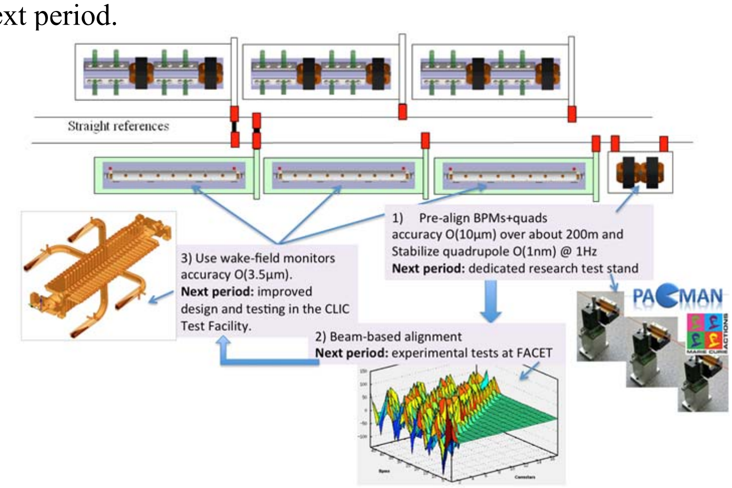

Figure 6: Three areas where alignment and stabilization will be further studied in the next period: 1) development of an automatic alignment and stabilization test stand, 2) experimental tests of beam-based alignment at FACET, 3) experimental tests of wakefield monitors.

Proof of principles of both pre-alignment and stabilization has been demonstrated with the CDR, and in the next period a sizable research project funding ten PhD student grants, "PACMAN", has been approved [7]. The technical goal of the program is to develop very high accuracy metrology and alignment tools and integrate them in a single automatic alignment test stand.

2.1.5 **CLIC Test Facility**

The CLIC Test Facility 3 (CTF3) at CERN is primarily a scaled version of the CLIC drive beam complex shown in Figure 1. CTF3 first accelerates a 4 A beam up to 120 MeV, in a fully loaded linac with more than 95% efficiency. A delay loop and one combiner ring subsequently compress the beam current up 28 A [2]. CTF3 has successfully demonstrated drive beam generation and two-beam acceleration in the CDR period, and will operate up to the end of 2016 to address further system tests and perform more detailed studies. The facility has recently demonstrated drive beam combination by a factor four with the nominal emittance of 150 um in both planes, and the current stability of the drive beam has earlier been demonstrated to better than the CLIC requirements of ΔI/I = 7.5x10-4 [9]. The final step of a full demonstration of the CTF3 drive beam generation is stable factor 8 combination. The progress has been impeded the last year by technical problems with the traveling wave tubes required for the sub-harmonic bunching, required for delay loop operation. A fast phase feed-forward system has been designed to correct the drive beam phase profile and jitter, with the aim of demonstrating the CLIC drive beam phase requirements [10]; the first kickers and amplifiers are to be installed in 2013.

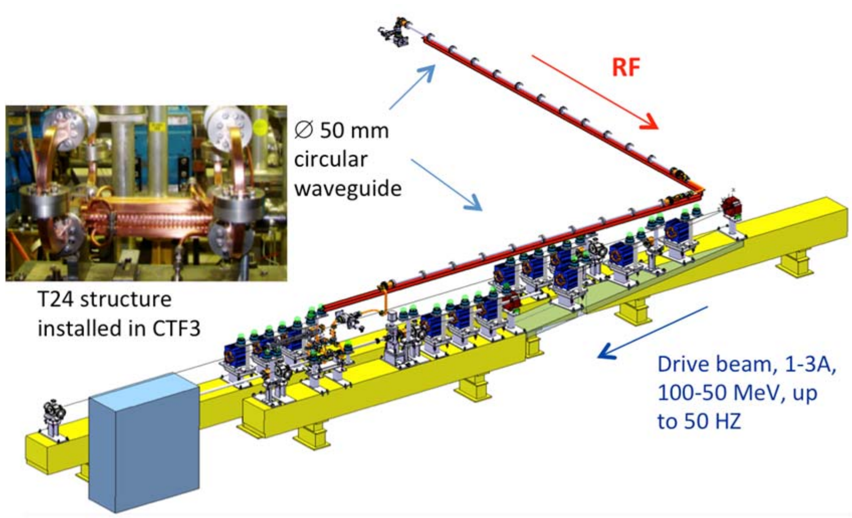

Figure 7: A new beam loading test facility: a 1 A CTF3 beam and X-band rf power will be simultaneously delivered to an accelerating structure.

In the two-beam test stand, new structures will be conditioned with drive beam rf and the breakdown rates measured. Kicks imparted to the beam during breakdown events will be measured and characterized, and the precision of the CLIC wakefield monitors will be measured. A dogleg halfway down the linac allows the drive beam to be directed to a test accelerating structure. Using this to deliver a 1 A beam from the linac, simultaneously as it is filled with the nominal X-band rf power [12], breakdown rates in the accelerating structure can be tested with beam loading and compared to operation without beam loading. Figure 7 shows the sketch of the planned beam loading test facility.

As a prototype of a CLIC injector, a 1 GHz klystron test stand to test a drive beam accelerating structure at full power is planned, including a gun and a sub-harmonic buncher [11]. A 1 GHz multi-beam klystron with high efficiency (>70%) and a 1 GHz modulator is planned to be delivered to and tested at CERN in 2015-2016, and can potentially be the first stage of a larger test-facility followingCTF3. The 1 GHz injector will have the parameters of the full CLIC machine, and the hardware can be reused as the first part of CLIC.

Full prototypes of the CLIC two-beam modules are currently being constructed and tested [13]. Two modules will be build for system integration tests in the laboratory and key objectives are validation of different types of girders and movers, pre-alignment tests, magnet stabilization, identification of vibration sources, measurement of resonant frequencies and simulation of thermal cycles bench-marked with finite element modelling. Figure 8 shows a picture of a completed laboratory module, installed at CERN. The first tests results are promising and in line with simulations [14]. A similar two-beam module is currently under fabrication for installation in CTF3, fully equipped with X-band structures and components. The power extraction structures will provide the nominal power for the accelerating structures, thus giving a complete system test of a full CLIC main linac module with rf and beams.

2.1.6 **X-band Technology**

In the coming project period, the CLIC project will see a significant increase in X-band structure test capacity. One 12 GHz klystron based X-band test stand ("XBOX1") has been operating at CERN for a year [12], allowing 12 GHz structure to be tested at 50 Hz. This test stand uses a scaled version of the XL4 klystron tube developed for the NLC, provided by SLAC. With the use of a SLED1-type pulse compressor output power of up to 100 MW can be provided in pulses of 250 ns, sufficient to power two CLIC accelerating structures at nominal power and pulse length. Two new prototype accelerating structures with damping features are currently under test in XBOX1 and at NEXTEF at KEK. When these tests are completed the reproducibility of the CLIC structure performance will be better quantified.

A second test area ("XBOX2") is under construction and planned to be commissioned by the end of 2014. A SLAC XL5-type tube will be commercially procured from CPI, and will provide XBOX2 similar capabilities as XBOX1. A cluster of four 6 MW tubes from Toshiba ("XBOX3") is planned to be commissioned by the end of 2015 and will give additional test capabilities. In total, we estimate that more than 40 structures will be tested in these facilities by 2017, including structures with SiC damping material and X-band crab cavities. Figure 9 shows the XBOX test facilities.

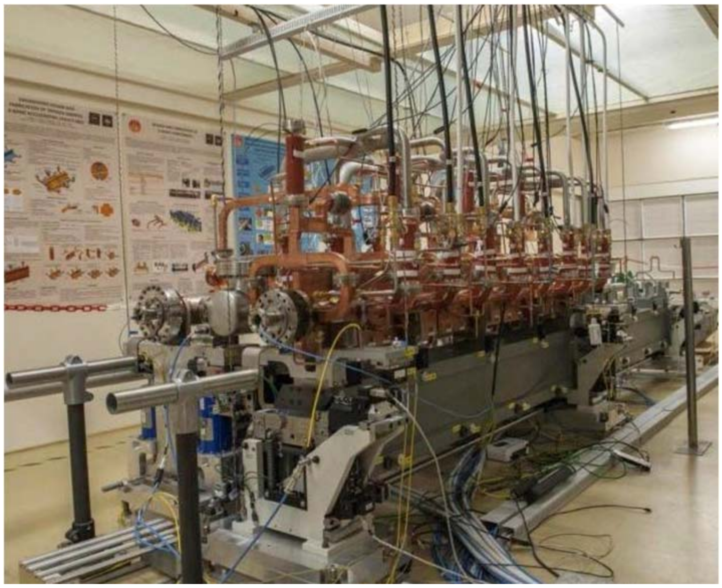

Figure 8: The first prototype of the CLIC two-beam module has been completed, and is undergoing thermo-mechanical validation.

The basic high gradient structure research will continue in the next period, including further development of the understanding of rf breakdown from first principles by theoretical studies, and multi-scale simulation studies. Modeling and simulations efforts for understanding the formation of vacuum arcs in breakdowns are being pursued [15], and the simulation results will be benchmarked against experiments at the DC spark test stand at CERN [16].

Two CLIC X-band technology application projects have recently been started. The first is use of CLIC X-band structures for compact FELs in the few GeV range. An early collaboration with Turkey has been followed by a recent initiative where countries or institutes can collaborate with CLIC on common CDR work for a FEL based on CLIC X-band technology [17]. Institutes from 5 different countries have already shown interest. Example parameters for an X-band FEL are an electron energy of 6 GeV and a charge of 250 pC as proposed in [18], however, collaborating institutes are free pick different parameters. Collaborators may profit from the planned X-band test facilities at CERN, thus reducing the risk of starting a new project. For CLIC, development and eventually operation of GeV level e-linacs with high gradient X-band structures will provide an increased technology maturity for the X-band technology. A second project studies the potential for technology transfer of CLIC high-gradient research to 3 GHz high gradient structures for proton therapy, where a main goal is to increase the effective gradient in proton therapy linac structures to about 50 MV/m (a factor of two with respect to the state of the art).

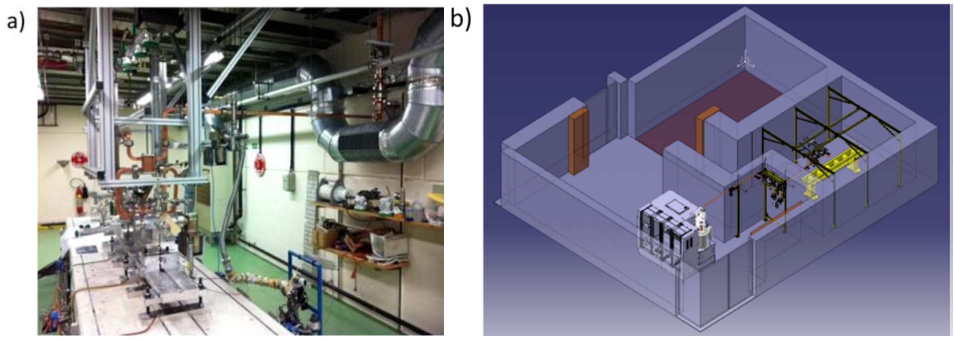

Figure 9: a) The new X-band test facility at CERN, with a SLAC-procured 12 GHz klystron. b) A planned X-band test facilities which will include commercially acquired tubes from CPI and Toshiba. In total these facilities will provide X-band power for testing up to 8 accelerating structures simultaneously.

2.1.7 Conclusions

The CLIC project has demonstrated the two-beam acceleration proof of principle, documented in the comprehensive Conceptual Design Report completed in 2012. In the next period up to 2018, the CLIC study will continue a number of technical studies on power and cost optimization, system tests including full CLIC module tests with rf and beam and experimental verifications of methods to preserve nm emittances. New X-band test facilities are being constructed at CERN and will greatly increase the capacity for 12 GHz rf testing. Systems testing can further profit from strengthening the exploitation of existing facilities worldwide (FACET, ATF2 and CesrTA). Finally, projects for the use of CLIC X-band technology in high-gradient FELs and for medical applications have been initiated with a potential outcome of increased technology maturity of linear collider X-band technology.

2.1.8 References

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