# CLIC TWO-BEAM MODULE FOR THE CLIC CONCEPTUAL DESIGN AND RELATED EXPERIMENTAL PROGRAM*

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*Abstract*

The CLIC (Compact LInear Collider) study is a site independent study exploring technological developments to extend linear colliders into the Multi-TeV colliding beam energy range. The two-beam linear accelerator being studied at CERN involves the design and integration of many different technical systems, tightly bound and influencing each other. For the construction of two linacs it has been decided to proceed with a modular design, and repetitive two-beam modules of a few types were defined. The modules consist of micron-level precision components operating under ultra-high vacuum as required by the beam physics. For the CLIC Conceptual Design Report, the development and system integration is mainly focused on the most complex module type containing the highest number of components and technical systems. For proving the proper functioning of the needed technical systems and confirming their feasibility it has been decided to build four prototype modules and test them without beam. In addition, three modules have to be produced in parallel for tests with beam in the CLIC Experimental Area. This paper is focused on the design of the different technical systems and integration issues of the two-beam module. The experimental program for the prototype modules is also recalled.

## INTRODUCTION

CLIC is based on the two-beam acceleration method in which the RF power for sections of the main linac is extracted from a second, low-energy, high-intensity electron beam running parallel to the main linac (drive beam) [1, 2]. The drive-beam regularly powers two Accelerating Structures (AS) from one Power Extraction and Transfer Structure (PETS). Due to repetition of the components it has been decided to combine them into units with universal length. Each module might contain up to four PETS, feeding two AS each, and two drive-beam quadrupoles, as a very dense lattice is required for the low-energy drive beam. Consequently the module length for the Conceptual Design Report (CDR) was fixed to 2010 mm. Space for quadrupoles in the main linac is made available by leaving out two, four, six or eight AS and suppressing the corresponding PETS. Therefore five main types of module are needed. Module type 0 contains only AS and module types 1 to 4 contain the main beam quadrupole of variable length, replacing thus from 2 to 8 AS respectively [3]. The experimental program is focused on types 0, 1 and 4 as most critical cases.

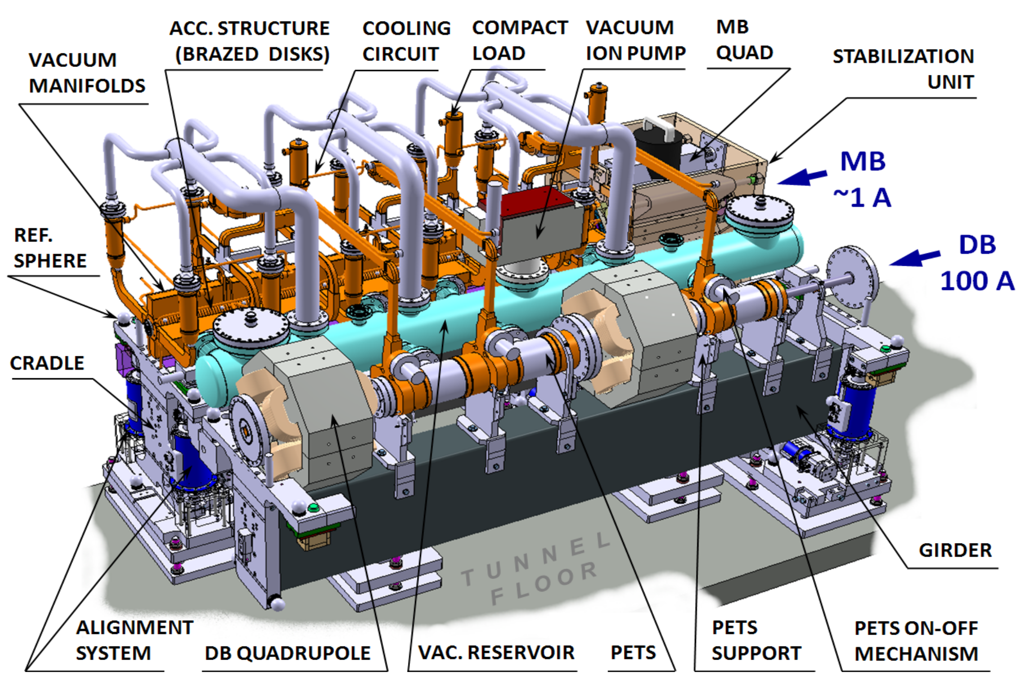


Figure 1: CLIC Module Type 1 integration layout.

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## CLIC MODULE REQUIREMENTS

The two-beam module design has to take into consideration the requirements for the different technical systems. Fig. 1 illustrates the overall layout of the CLIC Module (Type 1) as a result of the current integration. The main RF system components are the AS (active length 229 mm) and PETS (active length 213 mm). The AS and PETS are installed on the V-shaped supports of the supporting girders. To fulfill the beam physics requirements, the RF cavities of these components need ultra-high precision and therefore their manufacturing and assembly have to be optimized to reduce the cost. In addition, proper pre- and alignment techniques must be used. The pre-alignment system is needed for making possible the "first" beams pass through the linac. Then the beam-based alignment will take over this function. Hence to fulfill the requirements, the CLIC Module components must be aligned within a transversal and vertical tolerance of 10 μm along a 200 m sliding window [4]. The overlapping wires stretched between two beams are used to form a straight reference line all along the linac. The determination of the position of the components will be performed thanks to the alignment system and the associated sensors. Fiducialisation, allowing for defining the beam axis with regard to the external alignment points, will be performed to align components precisely on the supports [4]. Position re-adjustments will be carried out by actuators. In addition, for stability reason, the MB quadrupoles must stay independent of other components and such require self-governing supports, which should combine both, alignment and stabilization functions. The BPMs are required for the measurement of the beam trajectory. The time resolution was set to less than 10 ns and the spatial one to 50 nm for the MB. The corresponding accuracy must be better than 5 μm. A precision of 20 μm and resolution of about 2 μm are necessary for the DB. The residual gases in the vacuum volume of RF structure will be ionized by the beam. Therefore, ions can accumulate around the beam. A large concentration of them can induce a transverse beam instability. A low pressure level, set to $10^{-9}$ mbar, is needed for keeping the good beam quality [4].

## TEST PROGRAM WITHOUT BEAM

The program foresees the construction of four prototype modules assembled together with the following sequence of types: 1-0-0-4. The aim is to show the feasibility of the proposed solutions for the RF, supporting, pre-alignment, stabilization and vacuum systems. The cooling system will be built and tested on one of the modules type 0. A transport test representing the real transport in the tunnel will be also carried out. These tests started in 2010 and will continue until 2012.

### *RF-structures and Components*

The present test requires mock-ups of RF-structures and components without internal RF geometry, but with real mechanical interfaces to demonstrate manufacturing and assembly procedures. At the same time they have real reference surfaces for positioning and alignment, therefore the same accuracy.

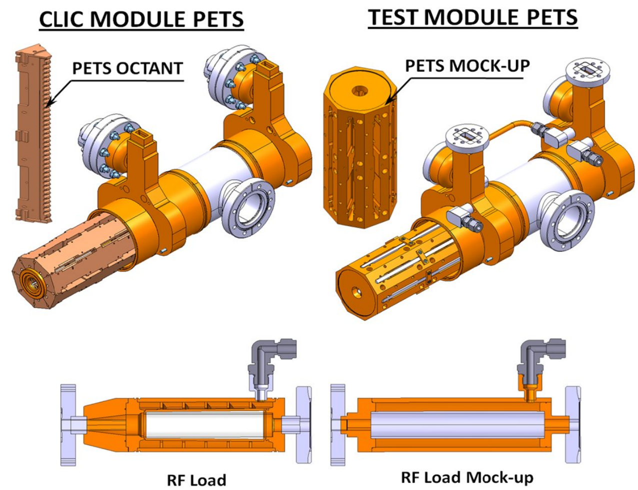


Figure 2: CLIC RF components and mock-ups.

For the reliable test of the vacuum system, the surface area of the internal volume representing RF cavity on the mock-up coincides with the surface area of the RF volume of the real structures. Fig. 2 shows the difference between real RF structures and their mock-ups.

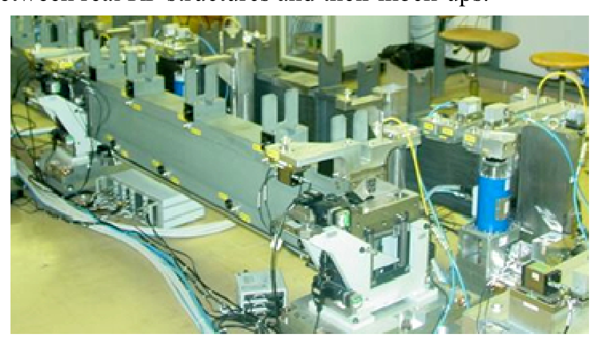

Figure 3: Supporting and pre-alignment system for two test modules type 0 in the laboratory.

The design of the mock-ups aims at reducing the cost of the components while keeping the necessary functionality for the tests.

### *Supporting and Pre-alignment System*

The two first modules of the laboratory mock-up have been installed, including girders, linear actuators and associated cradles equipped with WPS sensors and inclinometers to perform the pre-alignment of the girders.

Figure 3 shows the supporting and pre-alignment systems for two test modules type 0 already installed in the laboratory. Girders and other main components have been supplied by three different companies to be able to investigate different fabrication and assembly methods. The dimensional control of all girders was successful and all measured values are within the technical specification. Tests of actuators behaviour are currently under way.

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### *Vacuum System*

Two different configurations of the vacuum system are developed for tests in the laboratory without beam. The first option is based on a central reservoir concept equipped with vacuum pumps. The AS and PETS are linked to it via dedicated side ports through bellows. This option is shown in Fig. 1. In the second configuration all AS and PETS are equipped with their own vacuum pump, therefore the central reservoir is not needed anymore. As the necessity to pump the compact loads placed at the end of each AS remains, a common mini-tank is placed above the AS. This alternative configuration is shown in Fig. 4.

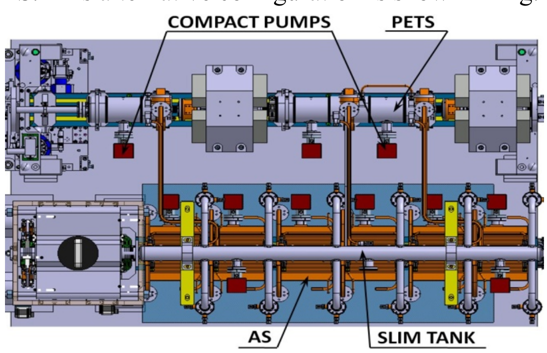


Figure 4: Test module with individual pumps.

### *Module Thermal Tests*

The module cooling system and its influence on the RF structures is also going to be tested in the laboratory. Special heaters will be installed inside the RF structures to simulate the power (about 7 kW per module) dissipated by the main components. The power supply and control equipment are being procured and the corresponding software is under development. Demineralized water will be provided for cooling the components.

### *Module Transport Test*

The accelerator construction foresees the pre-assembly of each module separately on the surface and then lowering them down to the tunnel for installation. Thus a special transport procedure must be developed and taken into account during design and integration at the very early stage. The operational capability and accordance to the strict requirements must be validated through dedicated tests (see also Fig. 5).

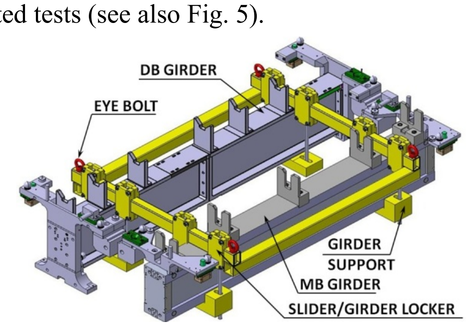


Figure 5: Two beam test module supporting system restrained by recently developed module transport frame.

The transport operation requires special accessories, which allow for keeping all the components mutually fixed and to preserve their integrity and pre-alignment. In addition it must be compact because of the tunnel cross-section limits. A special frame for the test purpose is currently under design. The conceptual idea is shown in Fig. 5. It foresees a spreader beam with adjustable centre of gravity attached to four eye bolts.

## TESTS IN THE CLIC EXPERIMENTAL AREA (CLEX) WITH BEAM

A second generation of three additional modules, taking into account the lessons learnt during the string test study in the laboratory, are being prepared for future test with beam in the CLEX area of CTF3.

The schematic layout of the CLEX Test modules (TM) installation is shown in Fig. 6. Testing of the AS alignment on girder by using probe beam and the wakefield monitors (WFM) in low and high power conditions and after a breakdown is of prime importance. In addition, the breakdown effect on the beam is going to be explored. Besides that, feasibility of alignment and stabilization systems in a dynamic accelerator environment must be confirmed. The RF network phase stability, vacuum system performance with RF and cooling system dynamics due to beam loss and power flow changes also need to be verified.

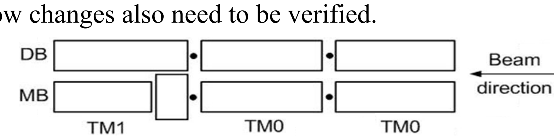


Figure 6: Sequence of CLEX Test Modules installation.

The integration of all these different sub-systems and other aspects, e.g. assembly, transport, activation and maintenance must be demonstrated in the period between 2012 and 2014.

## ACKNOWLEDGMENTS

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