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INTEGRATION AND TESTING OF 3 CONSECUTIVE CLIC TWO-BEAM MODULES

Alexios Vamvakas[1], Markus Aicheler[2], Steffen Doebert[1], Mathieu Duquenne[1], Helene Mainaud Durand[1], Vivien Rude[,3], Mateusz Sosin[1], Jukka Vainola[2]

[1]CERN, Geneva, Switzerland
[2]Helsinki Institute of Physics, Helsinki, Finland
[3]ESGT-CNAM, Le Mans, France

Abstract

CLIC (Compact LInear Collider) is a study of a 50 km long linear electron-positron collider, consisting of ap-proximately 20,000 repetitive 2 m long modules. Micron level manufacturing and alignment tolerances are re-quired for the RF and magnet components due to the nanometre beam size and luminosity goal. The effect of thermal, vacuum and mechanical loads needs to be as-sessed, both in transient and in steady state conditions. The dynamic behaviour of mock-ups was investigated on the prototype two-beam module. Two additional two-beam modules are installed to further investigate the interconnections between them, in a machine-like environment. The array of three consecutive modules allows for alignment tests of the module sequence, while thermal and vacuum tests can be executed simultaneously. A transportation experiment is foreseen, investigating the feasibility of installing prealigned modules. Finally, new design of components is being tested, based on the expe-rience gathered from the first module and leading to a new generation module.

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Vamvakas, S. Doebert, M. Duquenne, H. Mainaud-Durand, M. Sosin, CERN, Geneva, Switzerland
M. Aicheler, J. Väinölä, Helsinki Institute of Physics, Helsinki, Finland
V. Rude, ESGT-CNAM, Le Mans, France

Abstract

CLIC (Compact LInear Collider) is a study of a 50 km long linear electron-positron collider, consisting of approximately 20,000 repetitive 2 m long modules. Micron level manufacturing and alignment tolerances are required for the RF and magnet components due to the nanometre beam size and luminosity goal. The effect of thermal, vacuum and mechanical loads needs to be assessed, both in transient and in steady state conditions. The dynamic behaviour of mock-ups was investigated on the prototype two-beam module. Two additional two-beam modules are installed to further investigate the interconnections between them, in a machine-like environment. The array of three consecutive modules allows for alignment tests of the module sequence, while thermal and vacuum tests can be executed simultaneously. A transportation experiment is foreseen, investigating the feasibility of installing prealigned modules. Finally, new design of components is being tested, based on the experience gathered from the first module and leading to a new generation module.

INTRODUCTION

CLIC [1] is a multi-TeV normal conducting electron positron collider, whose current design foresees the construction of two meters long repetitive modular units, namely the Two Beam Modules (TBM) for the two 21-km long main linacs, resulting in a total collider length of about 48 km.

In CLIC, the Main Beam (MB) passes through the Accelerating Structures (AS) and is accelerated by the RF power extracted from a low energy and high-intensity Drive Beam (DB). The power, that is drawn using Power Extraction and Transfer Structures (PETS), is transferred from the DB to the MB through a dedicated RF network. During normal operation modes, the estimated power dissipation per module is about 7 kW, thus making the thermomechanical behaviour a major design constraint.

FEA models of the TBM has been developed in the past [2] to predict structural deformations due to gravity, vacuum and thermal loads, affecting the alignment and performance of the various RF components, which need to be aligned to a 10 μm envelope. Re-adjusting is possible, but the understanding of the limitation of this system is also important. One module has already been successfully installed and tested in laboratory environment [3], [4].

After the conclusion of the first testing cycle, the experiment needs to continue with a string of three modules, including different types, allowing for more specific tests, especially for alignment purposes. Aligning three consecutive modules is much more relevant for predictions for a 50km long machine.

EXPERIMENTAL TEST AREA

The thermal test program started in early 2013 with one prototype testing module. The components used where similar to real ones but manufactured to lower tolerances. Those tests were concluded in 2015 [5], [6].

Two more TBM are planned to be installed following the first one. In CLIC there are 5 types of TBM, depending on the presence and size of main beam focusing magnets [1]. For a better understanding of the interconnections between the modules it was decided to install different kinds. The final configuration is T0-T0-T1, which means that a short MB quadrupole of the Type 1 will be integrated at the second interconnection. While the T0-T0 connections has no magnet. The layout is shown in Fig. 1.

The stretched wires that are used as reference for alignment and the extremities stations remained the same, as provisions were made during the first installation. The ventilation system was also calculated to suffice for this second testing phase.

Further to the addition of different modules, certain components were revised according to the feedback from

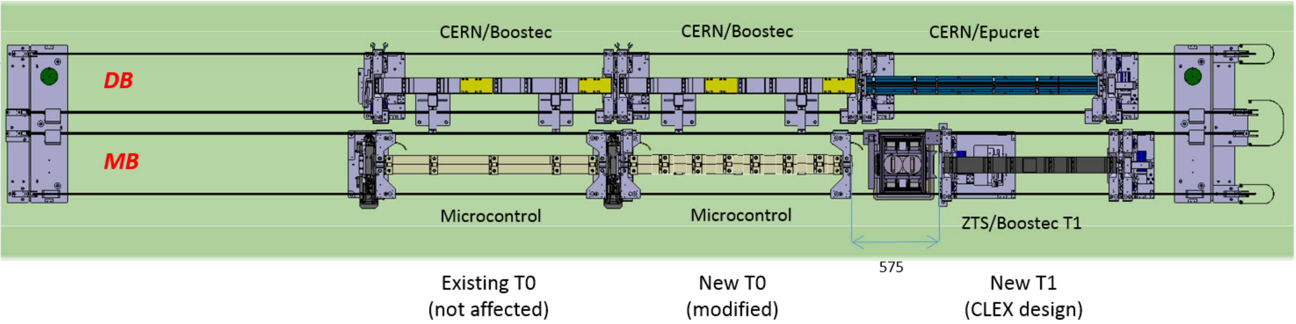

Figure 1: The layout of the new module string.

the test results of the first run. The design differences are explained in the next sections.

Accelerating Structures

The AS is the most central piece of the TBM, as it dominates the tight specifications of the assembly. Due to their complexity, they are represented by mock-up components in this testing environment. The outer dimensions, surface and total mass are kept identical to the real structure, but the tolerances of secondary features are relaxed significantly and the internal geometry and the manufacturing methods are simplified substantially.

A 500mm single piece core is used instead of a bonded disk stack. Moreover, each Super Accelerating Structure, consisting of two AS, is now separated with bellows, allowing independent movements, contrary to the single 2m single-piece of 8 AS used before [2]. Heating is also integrated, with the ability to test each structure separately and study the thermal effect of a breakdown.

Finally, it is the first time that such a complex assembly was ordered as a whole from an industrial partner. In the past only parts or specific operations of similar assemblies were outsourced. This order allowed for a small series production, giving feedback towards industrialisation and mass production (Fig. 2).

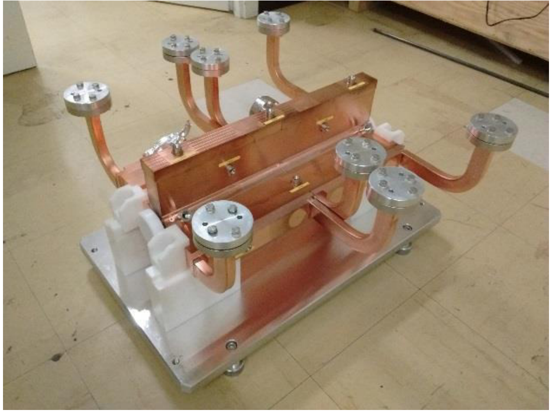

Figure 2: New SAS mock-up, after brazing and fiducialisation.

Vacuum System

The initial design of the vacuum system for the TBM included a central pump operated tank, where all the components were connected. However, it was discovered that this designed introduced constraints and mechanical loads that upset the alignment of critical components. More importantly, they coupled the movement of the two beams, obstructing the precise alignment.

The first step was to fully decouple the two beams, by pumping all the components directly and separately, using multiple compact pumps instead of central one.

Furthermore, the vacuum forces affecting the SAS needed to be mitigated. Due to the micron level tolerances, even relatively low stresses can have an effect on the performance of the RF components. A new design for the manifolds was implemented, including small manifolds separated by bellows. The end pieces are supported externally to cancel the opposite longitudinal forces. The new vacuum system designed is presented in Fig. 3.

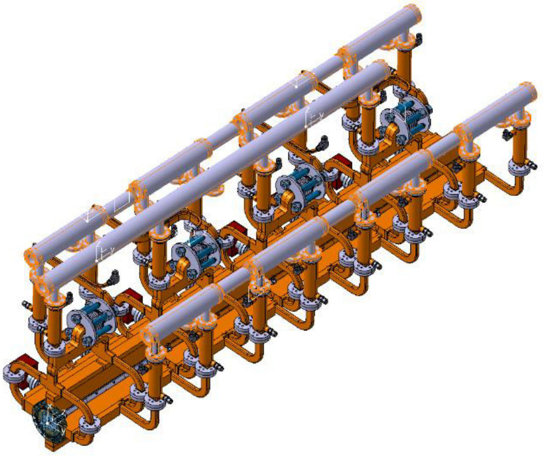

Figure 3: Force cancelling vacuum system on MB.

DB Quadrupoles and Supports

The DB quadrupole magnets are powerful components that have a significant effect on the thermomechanical behaviour of the TBM. In first test module mock-ups were used without external cooling, which distorted the results. It was decided that for the second iteration real magnet with functional cooling should be used, adding confidence to the new tests.

Moreover, a new DBQ support is going to be tested for the first time. After the experience of magnet installation, the need for adjustment was evident. The new support has 5 degrees of freedom and can position the magnet within a few micrometres [7]. It is based on flexural joints to eliminate any backlash (Fig. 4). A motorised version is also being developed, decreasing the installation time from hours to minutes. If successful, similarly designed supports could be introduced for other components in future design iterations, allowing for relaxation of tolerances, minimising assembling time and therefore reducing the total cost.

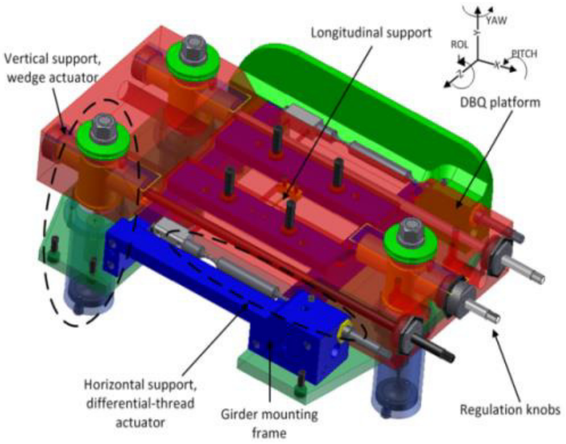

Figure 4: Adjustable magnet support.

TESTING CAPABILITIES

The new experimental configuration allows a variety of tests to be conducted.

Thermal Tests

Complimentary thermal tests will be conducted, with more realistic and relevant results expected in comparison to the first version of the TBM. Also further tuning of the FEM simulator will be possible. More importantly, there is now one TBM fully confined, removing any arbitrary boundary conditions from the system and allowing a better understanding of the tunnel environment. Finally, independent breakdowns will be simulated in each SAS, allowing a better understanding of the transient response during the various operation scenarios of the CLIC machine.

Vacuum Tests

Vacuum will be operational, contrary to the previous module, which never reached an operational level due to manufacturing issues. That will allow a detailed study of the mechanical loads that pumping will induce to the high tolerance structures. A study of the vacuum volume characteristics of the whole module will be also available, determining the outgassing viability of the SiC damping material, as well the performance of the force cancelling design.

Alignment Tests

Alignment tests will be performed during all the testing stages, including a step-by-step monitoring of the installation effects during the assembly. The effect of the thermal and vacuum loads will be measured. Since every module has different design and materials on their supporting systems, a comparison of different solutions will be conducted. Finally, the test set up made of 3 modules makes the alignment more challenging and will give useful insight for the alignment of the long sections of the machine. The modules are interlinked via a new adjustable articulation point, whose different functions will be also tested. The addition of on MB quadruple to the string will also add value to the testing of different module types.

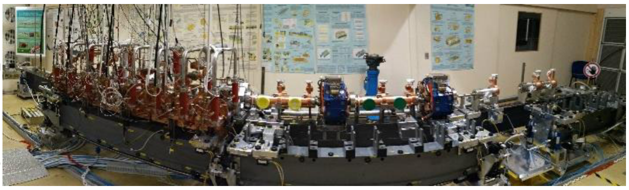

Figure 5: Current status of the installation.

INSTALLATION PROGRESS & PLAN

At the moment the supporting system is fully installed and being tested (Fig. 5). Examination of all the assembling steps is being conducted, to be referenced in new assembling techniques. The rest of the parts are under procurement and the assembly is planned to be finished by the end of May 2016.

Subsequently, the first tests of the supporting system actuators will take place. A first round of thermal tests will be executed, including transient and steady state scenarios. The system will then be pumped to study vacuum related issues. Finally the thermal tests will be repeated under vacuum.

The testing sequence is planned to be completed by the end of 2016. A transportation test is also foreseen once the rest of the tests are over, examining the feasibility of assembling entire modules before transporting them to the tunnel.

CONCLUSION

Stability to the micrometre level in the two-meter repetitive modules in the two main linacs is one of the most important requirements to achieve the luminosity goal for the CLIC collider. Deformations due to gravity, thermal and vacuum loads affect the alignment of the linacs, and therefore their performance, and need to be thoroughly studied.

One TBM has been successfully installed in the past and valuable experience and information was gathered regarding its behaviour in laboratory environment. Two more modules are currently being installed and will be tested in 2016. These modules will allow more relevant tests. New testing modules also contain improved versions of several key components, based on the results from previous tests and analytical models.

Testing of the string of modules will provide insight on areas that have not been previously studied. The results will be compared to similar structures operating under real conditions and feedback needs to be given back to the design. The changes on the design will be tested and validated and a new generation module will be created.

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