

TECHNICAL SPECIFICATION FOR THE CLIC TWO-BEAM MODULE

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Abstract

A high-energy (0.5–3 TeV centre-of-mass), high-luminosity Compact Linear Collider (CLIC) is being studied at CERN [1]. The CLIC main linacs, 21-km long each, are composed of 2-m long two beam modules. This paper presents their current layout, the main requirements for the different sub-systems (alignment, supporting, stabilization, cooling and vacuum) as well as the status of their integration.

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]. For a 3 TeV collider, there are 24 such drive-beams, each providing enough power to accelerate the main beam. The stagger between the two linacs is made to give the correct relative RF to beam timing. Each main linac contains more than 10000 “repeated” modules. The drive-beam, running parallel to the main linac, regularly powers two ACcelerating Structures (ACS) from one Power Extraction and Transfer Structures (PETS). The main-linac module defines the length of one drive linac module, which is about 2 m long. The drive-linac module comprises then four PETS and two quadrupoles forming a FODO cell, as a very dense lattice is required for the low-energy drive beam. The main parameters for PETS and ACS are given in Table 1. In the standard modules, the main linac contains only accelerating structures (about 80% of the modules). In the quadrupole-type modules, pairs of accelerating structures are removed at regular intervals to liberate space for a quadrupole of a FODO lattice.

Table 1: Main parameters for PETS and ACS

	Length [mm]	Aperture [ϕ , mm]	Gradient [MV/m]	Power [MW]
PETS	308	23	6.5	136
ACS	230	5	100	64

MODULE DESCRIPTION

The present layout of the standard and a typical quadrupole type module is shown in Figure 1. The main and drive linacs are mounted on separate support girders installed on micro-movers which lie on concrete blocks. Eight accelerating structures, fixed to the girder via V-supports, are mounted on each girder. This arrangement defines the 2.01 m long basic module of the main linac. Four types of quadrupole modules can be defined

depending on the length of the main quadrupole which can vary from 450 to 1900 mm as a function of the pairs of accelerating structures to be replaced (e.g. quadrupole type 4 has no accelerating structures). At the end of each 870 m drive beam sector, 4 modules are needed for the drive beam injection and extraction. In this region, the drive beam lattice is not regular and the main beam contains no accelerating structures, but only quadrupoles.

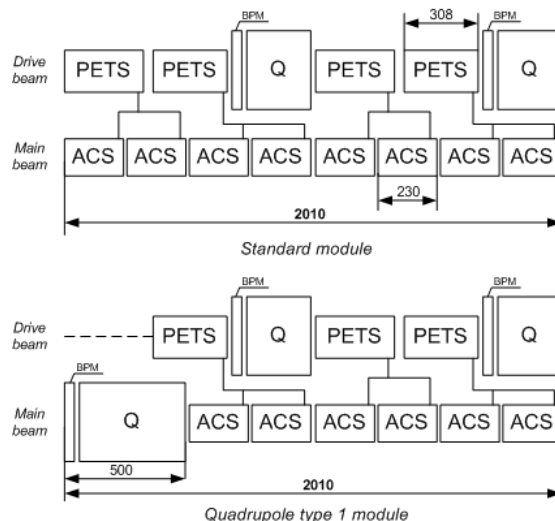


Figure 1: Module schematic layout.

The main beam quadrupoles are supported independently of the string of girders and their positions are optimized by using the signals from the beam-position monitors. For this reason mechanical flexibility shall be assured for the connection between the quadrupoles and the adjacent accelerating structure. Rigid connections are foreseen for components installed on the same girder. The microwave power produced in the PETS is collected at the downstream end of the structure by means of couplers and conveyed to the main linac accelerating structures by means of rectangular waveguides. Dedicated RF components, such as choke mode flanges and splitters will assure the routing between the PETS and ACS and the required mechanical flexibility.

MODULE MAIN REQUIREMENTS

Supporting system

The supporting system of a module takes account of four main components: ACS, PETS, main beam as well as drive beam quadrupoles. In addition, a module houses other components and systems such as loads for ACS, RF system, vacuum system, alignment system, stabilization system and cooling system. The mechanical design of the

supporting system shall be compatible with alignment and stabilization as well as with transport and installation constraints. Alignment has been divided in two stages: pre- and beam-based alignment. High precision pre-alignment (PA) guarantees that the first beams injected will not be too far from the design trajectory and making thus initial operation possible. The first beams will be then detected by the BPM in order to implement the beam based alignment (BBA) system during nominal operation (see Table 2). The stabilization system is required for the main beam quadrupoles only. The requirement is not to exceed 1 nm in the vertical plane and 5 nm in the horizontal plane (for frequencies higher than 5 Hz).

Table 2: Main alignment requirements in vertical plane

Component	Tolerance (1σ)
ACS	14 μm (PA)
PETS	31 μm (PA)
Main beam quadrupole	17 μm (PA)
BPM for main beam quadrupole	14 μm (PA)
Relative position of quadrupole and BPM	5 μm (BBA)

The module support design is based on a girder concept [3], where the accelerating structures and PETS are actively aligned in batches of eight and four, respectively. To align the components in the tunnel means aligning the girders with respect to some pre-determined accelerator axis. The quadrupoles that are independent from these girders must also be aligned with respect to this axis. Adjacent girders should be mechanically interconnected via a kinematic linkage allowing for movement in three degrees of freedom at each interconnection. The main beam quadrupole should have a separate alignment system allowing for movement in five degrees of freedom and they should be installed along the accelerator following the defined lattice. Furthermore, the design must be compatible with the different types of main beam quadrupoles.

Cooling system

The estimated overall input power of the collider is 322 MW and the wall plug to main beam efficiency is 8.8 % [1]. A large part of the RF input power dissipates into heat in the module structures. The cooling system consists of two 21-km long linear accelerators circuits with more than 10000 modules each. Different module types require different cooling layouts. Apart from the thermal dissipations, requirements for the cooling system are governed by the requirements of vacuum, alignment and mechanical stability. For example, sustaining the required alignment of 14 μm for accelerating structures within 1σ requires a special development of the cooling system under dynamic heat load conditions. Furthermore, vibrations of the lattice elements, if not properly corrected, can result in a loss in performance by creating both unacceptable emittance growth in the linear accelerator and relative beam-beam offsets at the interaction point. The circulating water used to cool the

lattice quadrupoles will increase magnet vibration levels which must remain compatible with the one nanometer stability requirement of the main beam quadrupole. For a module, the thermal dissipations induced in the main components are summarized in Table 3. Considering the tight alignment and stabilization tolerances, the main components in the module are foreseen to be cooled in parallel as shown in Figure 2. The accelerator will be run in several power levels. Therefore, not only the nominal centre-of-mass energy of 3 TeV should be fulfilled by the cooling system but also some other settings such as 0.5 TeV, which may have a higher repetition rate. The total power dissipation for the modules of a 21-km linac is about 70 MW.

Table 3: Power dissipation in a module (quad. type 1)

Component	Unit [No]	Unit power dissipation [W]	Total power dissipation [W]
ACS	6	412	2472
PETS	4	112	448
Main beam quad.	1	500	500
Drive beam quad.	2	148	296
Load	4	712	2848

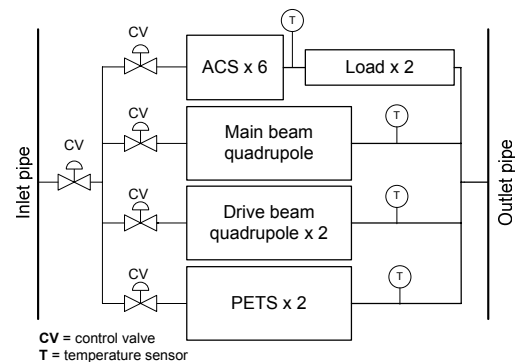


Figure 2: Layout for a module cooling (quad. type 1)

Vacuum system

The main beam and drive beam vacuum must be sufficiently low (10^{-9} to 10^{-10} mbar) in order to prevent an ion trapping instability. Ions are generated from the rest gas by collision and field ionizations. They can be trapped in the beam and spoil the beam performance. The fast beam ion instability is more critical for the main than for the drive beam. Vacuum sectorisation is needed for installation, commissioning and maintenance. In the present baseline, a vacuum sector is approximately 200 m long. The requirements of 10^{-9} mbar can be reached with standard vacuum equipments, such as turbo-molecular stations, sublimation and ion pumps. Lower vacuum requirement would demand a specific study. Conventional techniques, such as bake-out and NEG might not be applicable due to the tight structure tolerances and high-gradient considerations.

RF system

The RF system comprises the connection between the PETS and ACS and then from the ACS to the high power

loads (see Figure 3). Choke mode flanges are used to connect the waveguides between PETS and ACS and allows the power transmission without electrical contact between waveguides. They consist of a transition from rectangular to circular waveguide and have a choke in between, that stops electromagnetic energy to flow outwards. This device should be flexible in order to permit independent alignment of two waveguides. Shifts and twists have been simulated in order to determine the device performance. The dynamic ranges for the accepted performance ($S_{11} < -45$ dB) are ± 0.5 mm for the shifts perpendicular to the electrical field, ± 0.25 for the one parallel to the electrical field and 5° for the twist.

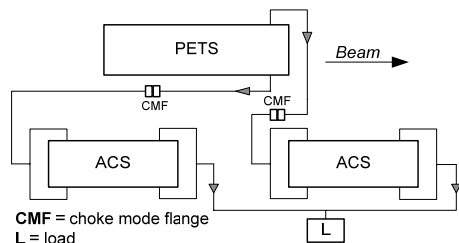
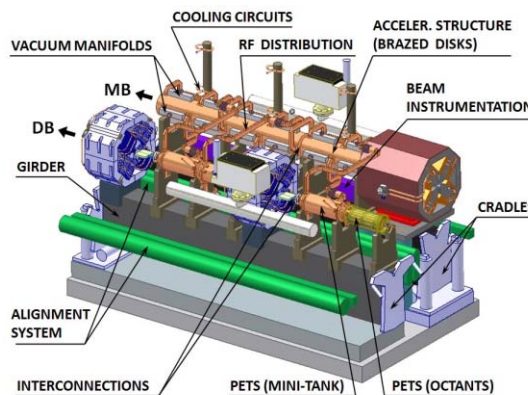


Figure 3: Schematic view of the RF distribution

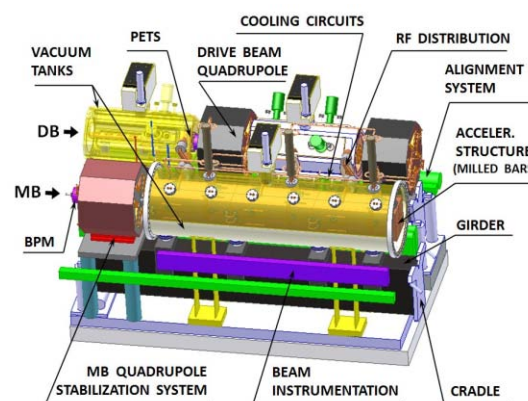
MODULE INTEGRATION

For the module integration several configurations are being studied depending on the RF distribution as well as on the design and manufacturing technology of the PETS and ACS. Figure 4 shows the module according to the two different configurations. In configuration №1, the ACS are made of discs brazed together forming a sealed structure, and the PETS are made of octants and “mini-tanks” around the bars. In configuration №2, the accelerating structures are formed by four high-speed milled bars which are then clamped together, and the PETS bars and couplers are all clamped and housed in a vacuum tank. Potential advantages and drawbacks are being evaluated for each configuration. For example in configuration 1, the saving on the tank would be compensated by additional vacuum manifolds and several connections between them. In configuration №2 the tank support is fully decoupled by the ACS and PETS supports, thus avoiding a high precision manufacturing of the vacuum tanks. For the RF distribution the aim is to avoid bolted flanges, which can be potential sources of leakage. In configuration №1 a probable simplification is the absence of transition pieces between vacuum and atmosphere. In both configurations the ACS and PETS are mounted on about 2-m SiC girders. The extremities of the two adjacent girders rest in the same cradle: the extremity of the first girder being held down rigidly to the cradle, the other part being connected to the cradle by means of small link rods. Space for the alignment system and beam instrumentation has been reserved. Cooling circuits and corresponding interconnections have also been integrated in the module following the scheme shown in Figure 2. Due to the limited available space in order to optimize the accelerator filling factor, the interconnections between components become very

challenging. Technical solutions are being investigated considering as well all constraints linked to the tunnel integration.



a) Configuration №1



b) Configuration №2

Figure 4: Module integration for typical configurations

CONCLUSIONS

The CLIC study is carrying out a number of specialized development programs of subsystems such as high-power RF structure and micron precision alignment, the specification for the CLIC module is being finalized. Based on it different configurations will be fully studied and compared, identifying thus areas needing dedicated study and design. In addition, important aspects of cost will be raised and basic parameters provided for other areas of the study.

REFERENCES

- [1] F. Tecker et al., “CLIC 2008 parameters”, CLIC-Note-764, Geneva, CERN, 17 June 2008.
- [2] I. Syratchev et al., “High RF Power Production for CLIC”, Proceedings of the 2007 Particle Accelerator Conference, Albuquerque, pp. 2194-2196.
- [3] H. Mainaud-Durand, “The CLIC Alignment Studies: Past, Present and Future”, CERN-TS-Note-2005-028; Geneva, CERN, 06 Jan 2006
- [4] D. Schulte, “Beam Dynamics Requirements for Accelerating Structures and PETS”, CLIC-ACE, Geneva CERN, 16 Jan 2008