CLIC - A 3 TeV Linear Collider Study

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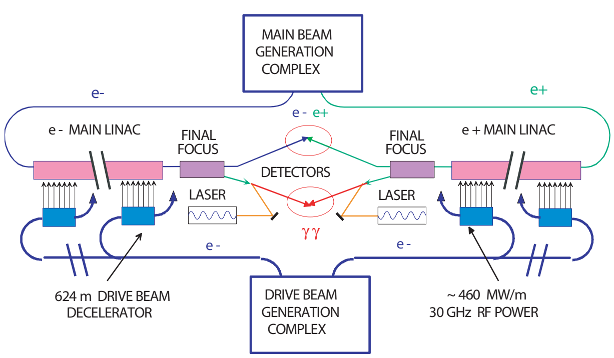
1. General Description

The Compact Linear Collider (CLIC) study aims at centre-of-mass energies for $e^{\pm}$ collisions in the multi- TeV range and it has been optimised for a nominal energy of 3 TeV with a luminosity of 10^{35} $cm^{-2}s^{-1}$ [1]. Its design is however such that its construction could be staged without major modifications (Fig.1, left). The lower energy phases will depend on the existence or not of other accelerator facilities, but the first stage could cover energies between ≈ 0.1 and 0.5 TeV with L= 10^{33}-10^{34} $cm^{-2}s^{-1}$, where interesting physics and overlap with LHC are expected. This stage would be extended to 1 TeV with L above 10^{34} $cm^{-2}s^{-1}$. Next would come the desirable $e^{\pm}$ collisions at 3 TeV which should break new physics ground, while the final stage might be 5 TeV. Fig.1 (left) shows an overall layout of the complex which points out the existence of linear decelerator units running parallel to the main beam [2]. Each unit is 625 m long and decelerates a low-energy high-intensity e^{-} beam (so-called drive-beam) which provides the RF power for each corresponding unit of the main linac through energy-extracting RF structures. With a gradient of 150 MV/m, the main beam is accelerated by ≈ 70 GeV in each unit.

Consequently, the lowest colliding beam energy in the centre of mass E_{cm} is ≈ 140 GeV (1 unit on either side), even less with some adjustment of the drive-beam intensity. Then, E_{cm} can in principle be increased step by step, modulo ≈ 140 GeV, by adding one unit on either side of the interaction point (IP). The nominal energy of 3 TeV requires 2x22 units (linac length of ≈ 14 km). This modularity is possible since the complexes for the generation of all the beams and the IP are both in a central position. The main tunnel, of constant straight section, houses both linacs, the various beam transfer lines and, in its downstream part, the beam delivery system (BDS). The fact that there is such a single tunnel results in a simple and easily extendable arrangement. Fig 1 (right) gives examples of estimated tunnel lengths for various energies in the centre-of-mass.



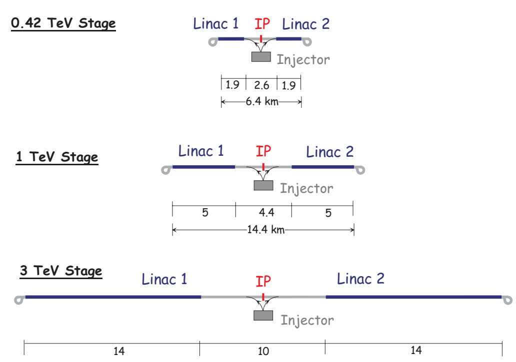


Figure 1: The left side shows the overall layout of the CLIC complex and the right side shows the tunnel lengths (km) for the linacs and the BDS on each side of the IP, at various cm energies.

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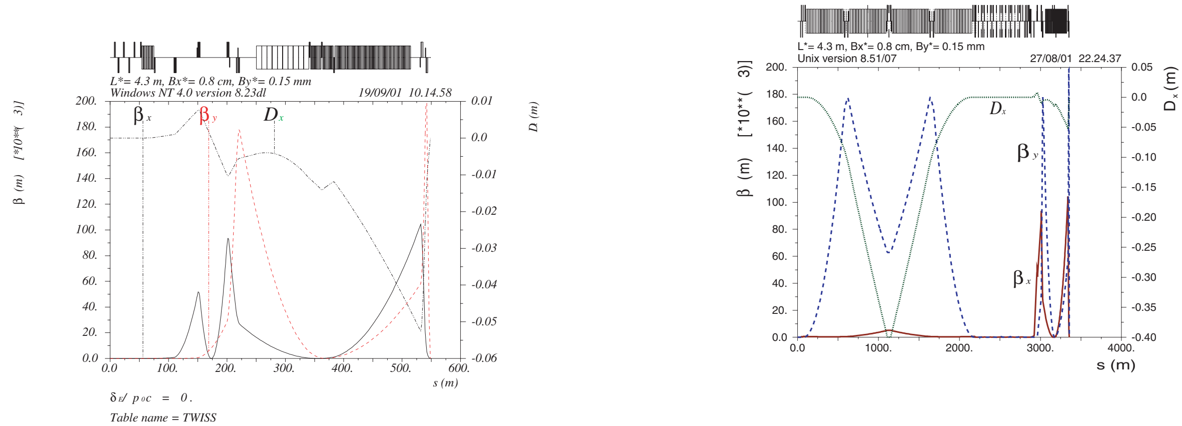

Figure 2: The left side shows the compact final focus optics at 3 TeV and the right side shows the optics of a 3 TeV beam delivery system made of a collimation section and a compact final focus.

The general description of the CLIC two-beam technology, of the main-beam complex and of the RF power source at 30 GHz is given in [1]. It also summarises the main-beam (main-linac) and drive-beam (decelerator and accelerator) parameters at the nominal energy of 3 TeV as well as some main-beam parameters at various other energies.

2. Beam delivery system

The new optics studied for a compact final focus (FF) system [3] derives from the NLC 1-TeV final focus [4] and is only 500 m long (Fig.2, left). To limit the effect of synchrotron radiation, the sextupole strengths are increased by a factor 3.4 from the NLC design and all bending angles are reduced accordingly. The beta functions are matched to the CLIC design values and their peak values are ≈ 200 km. The upstream quadrupoles, sextupoles, and bending angles have been fine-tuned for maximum luminosity, using a Monte-Carlo optimization. The dispersion has a nonzero slope at the collision point (D′ = 1.8 mrad), and is maximum across the final doublet (D = 5 cm). Two chromatic sextupoles are located here and three more are positioned upstream of the main bends in order to cancel the geometric aberrations induced by the first two. The free length between the last quadrupoles and the IP is 4.3 m (2 m for the base line optics [5]), which avoid having the final quadrupoles in the detector solenoid field.

As for the FF, a preliminary design of a collimation optics [6] has been obtained by scaling from NLC [7] to the 3 TeV needs and by omitting the second half of the energy collimation. The two parts of the optics, related to energy and betatron collimation, are shown in Fig.2 (right). The length of the cut-down energy-collimation part is ≈ 4 times larger than in NLC such as to get beam spots that allow the collimators to withstand the impact of a full bunch train of nominal emittance and to limit the effects of the synchrotron radiation on the emittance. Because of the latter, bending angles are reduced by 32. The betatron-collimation part has the same optics as that of NLC, since the collimators here are supposed to be replaceable or renewable. In the energy-collimation part, the rms radial (transverse) beam size defined as $(\sigma_x\sigma_y)^{1/2}$ is 147 μm and 1.862 mm at spoilers and absorbers, respectively. This should be sufficient to guarantee the survival of the spoilers, provided they are made from beryllium, carbon or possibly titanium [8].

3. The new test facility CTF3

CLIC requires a very efficient and reliable RF source, at a frequency well above the usual one of klystrons. This is why a two-beam acceleration scheme is proposed [1] [2]. The drive-beam time structure (bunch spacing of 2 cm) has a strong 30 GHz component, and the RF power is

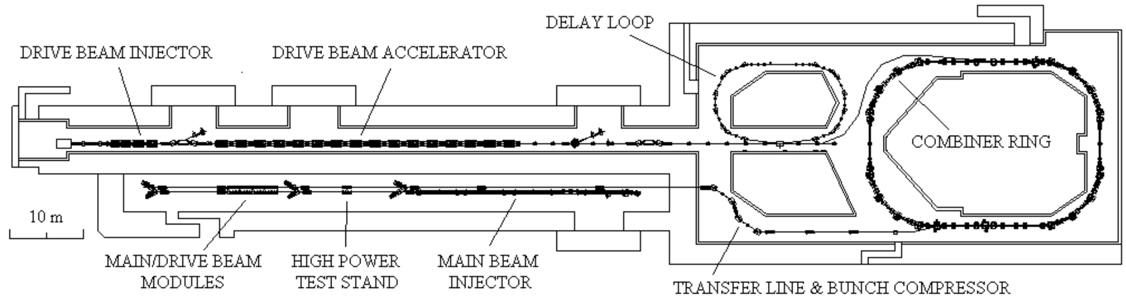

Figure 3: Layout of the final configuration of the test facility CTF3 (nominal phase).

extracted in structures and transferred to the accelerating cavities. The drive-beam is initially accelerated at low RF frequency where commercial power sources are available, and in a fully-loaded mode, so that all the RF power is converted into beam energy. The beam is subdivided into 130 ns bunch trains which are interleaved by injection with transverse RF deflectors into isochronous rings, that raises the bunch repetition frequency and the mean current of each train. A new facility (CTF3) [9] is under construction at CERN in collaboration with INFN (Italy), LAL (France) and SLAC (US), for testing the main parts of this power production scheme, namely the fully-loaded accelerator operation and the bunch combination. The drive-beam pulse obtained after combination (140 ns, 35 A) will be sent to special structures to produce 30 GHz RF power at the nominal CLIC parameters, and to test accelerating cavities and waveguide components. To reduce costs, it is based on the use of 3 GHz klystrons and modulators from the LEP Injector Linac (LIL), and of most magnets of the LEP Pre-Injector (LPI). CTF3 will be built in stages over five years. Low current tests of the train combination scheme, will be performed in the Preliminary Phase [10], using the present LIL cavities (start in Autumn 2001). With limited beam current in this first stage, the 30 GHz RF power production and the study of collective effects will only be possible in later phases. The second stage (Initial Phase) is based on a linac rebuilt with specially designed cavities adapted for high current and fully loaded operation [11]. It will allow tests of fully-loaded acceleration and limited production of 30 GHz power. The final configuration of CTF3 will be reached in the third stage (Nominal Phase, see Fig 3), with nominal power production and the capability to study effects associated with high charges.

4. Comments and conclusion

The CLIC two-beam scheme is the most promising technology for extending the energy reach of a future linear collider to the multi-TeV range. This paper focuses on the present status of the design study, the issues associated with the beam delivery system and a summary on how the key-points of the RF power source will be addressed in the new test facility CTF3. However there are many other challenges. Two of them are briefly covered in a companion paper [12]. They concern the accelerating structure technical studies which are mandatory to establish that the needed high gradient can be obtained at 30 GHz for a pulse length of 130 ns and the investigations going on the control of vibration and jitter effects through damping supports and feedbacks. In addition the damping ring design is very demanding. Collective effects have to be included from the beginning. Intra-beam scattering is a major determinant of the emittances, and electron cloud effects can be severe [13]. Another study topic concerns failure modes. Certain modes have been simulated in the context of the performance requirements for the CLIC collimation system and of the collimator survival [14]. Taking up these challenges calls upon an intense research and development program over the next five to six years, before a conceptual design can be delivered.

References

[1] CLIC Study Team , Ed. G.Guignard, CERN 2000-008, 2000.
[2] H.H.Braun, 16 co-authors, Ed. R.Corsini, CERN 99-06, 1999.

[3] F.Zimmermann, 5 co-authors, PAC2001, Chicago, June 2001.
[4] P.Raimondi, A.Seryi, EPAC2000, Vienna, p.492, June 2000.
[5] F.Zimmermann, 5 co-authors, EPAC2000, Vienna, June 2000.
[6] R.Assmann, 8 co-authors, PAC2001, Chicago, June 2001.
[7] P.Tenenbaum, 4 co-authors, LINAC2000, Monterey, US, 2000.
[8] S.Fartoukh, 3 co-authors, CERN-SL-2001-012-AP, 2001.
[9] R.Corsini, for CTF3 Study Team, CERN/PS 2001-30, 2001.
[10] R.Corsini, 6 co-authors, PAC2001, Chicago, June 2001.
[11] E.Jensen, 3 co-authors, PAC2001, Chicago, June2001.
[12] CLIC - Developments on 30 GHz structures and on vibration stabilisation, this conference.
[13] J.Jowett, 4 co-authors, PAC2001, Chicago, June 2001.
[14] D.Schulte, F.Zimmermann, PAC2001, Chicago, June 2001.