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CLIC and the studies on the future linear collider

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Summary. — A brief description of the CLIC accelerator and of the International Linear Collider is presented.

PACS `29.20.db` – Storage rings and colliders.
PACS `29.20.Ej` – Linear accelerators.

1. – Introduction

The high energy physicists community agrees that LHC physics results need to be complemented, in the future, by experiments done with a high-energy lepton collider [1]. The centre-of-mass energy will be between few hundreds GeV and few TeV depending on the experimental results from LHC. Linear colliders are the only feasible option since the energy reach of circular storage rings is limited by the emission of synchrotron radiation [2]. For a linear collider with a centre-of-mass energy in the 0.5–3 TeV range one candidate is CLIC (Compact Linear Collider), which aims to reach a peak luminosity in the range of $10^{34}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$ [3]. CLIC is a normal conducting accelerator with X-Band (12 GHz) high gradient (100 MV/m) accelerating cavities that will implement the novel scheme of the two-beam accerelation (TBA) proposed at CERN few years ago. Part of the R&D for CLIC is done in the CLIC Test Facility (CTF3) [4], which is being constructed at CERN by an international collaboration.

If the required centre-of-mass energy is in the 200–500 GeV range, following the recommendation by the ITRP International Panel, the linear collider will be based on the superconducting radio-frequency (SCRF) technology. The project called International Linear Collider (ILC) [5] is now under study by an international collaboration. The ILC aims to reach a peak luminosity of $2\cdot 10^{34}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$ and is based on 1.3 GHz SCRF TESLA type accelerating cavities.

2. – CLIC

CLIC is based on electron/positron beam acceleration with normal conducting copper structures. The optimum operation frequency and acceleration gradient have been found [6] after a systematic scan of accelerating structure parameters. The maximum

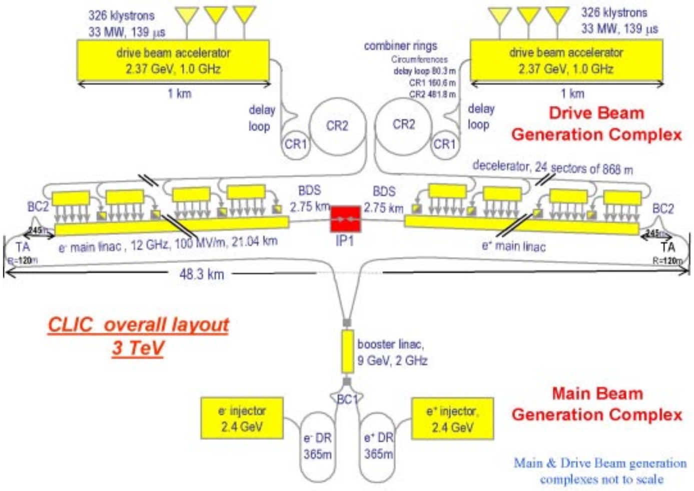

Fig. 1. – CLIC schematic layout.

accelerating field is limited by RF breakdown and fatigue of the copper surface due to pulse power RF heating. The final optimum operating RF frequency is 12 GHz and the accelerating gradient is 100 MV/m. The original old parameters, 30 GHz acceleration frequency and 150 MV/m gradient, were far from this optimum and, at the beginning of 2007, they have been changed. The complete scheme of CLIC is shown in fig. 1. The main CLIC parameters are given in table I.

The RF peak power required to achieve the high accelerating gradient amounts to 68 MW for each accelerating structure. The RF pulse length is 240 ns with a repetition frequency of 50 Hz. In CLIC this high RF peak power is generated from a "Drive Beam" (DB) running parallel to the "Main Beam" (MB). The DB is generated from a long bunch train that is compressed into several short trains, with small bunch spacing and high beam current, in three rings: the "Delay Loop" followed by two "Combiner Rings" [7]. The beam is then decelerated through structures called PETS (Power Extracting and Transfer Structures [8]) that extracts RF power and feed a set of two accelerating structures in the main beam. This scheme is shown in fig. 2.

Table I. – *CLIC and ILC parameters.*

Parameter	CLIC	ILC
Center-of-mass energy (TeV)	3	0.5
Luminosity ($\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$)	$2 \cdot 10^{34}$	$2 \cdot 10^{34}$
Number of particles per bunch	$3.72 \cdot 10^{9}$	$2 \cdot 10^{10}$
Bunch separation (ns)	0.5	370
Number of bunches per train	312	2625
Beam dimension at IP (nm) (y/x plane)	0.7/40	5.7/639
Average accelerating gradient in cavities (MV/m)	100	31.5
Proposed site length (km)	48	35
Repetition rate (Hz)	50	5

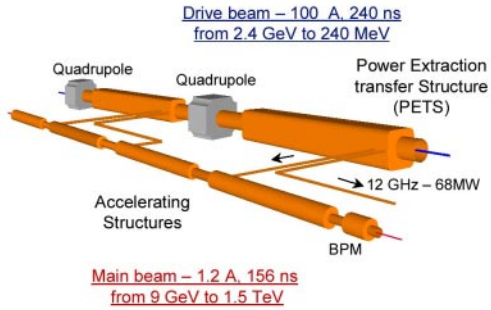

Fig. 2. – CLIC two-beam scheme.

The total length of both linacs including the beam delivery system is 48.2 km. Both the DB and the MB are generated in the central area and are transported to the beginning of the linacs via transfer lines in the accelerator tunnel.

The beam dimensions at the collision point (IP) are 0.7 and 40 nm rms in the vertical and horizontal plane, respectively. A set of two damping rings (DR) allow to obtain this small emittances [9].

CLIC has many novel concepts which have never been used before and some parameters are approaching the limit of available technology. The main R&D effort within the CLIC study is aimed at answering these major feasibility issues. One line of this R&D goes into the development of accelerating structures, the other major programme is the CLIC Test Facility CTF3. The aim is to demonstrate the feasibility of the TBA concept. CTF3 is now under commissiong at CERN [10, 11].

3. – ILC

The ILC schematic layout is shown in fig. 3. The main ILC parameters are given in table I.

The ILC injector provides 5 GeV electrons and positrons that are injected into DR to reduce the transverse emittances and are transferred into the main linacs traveling through bunch length compressor and spin rotator systems.

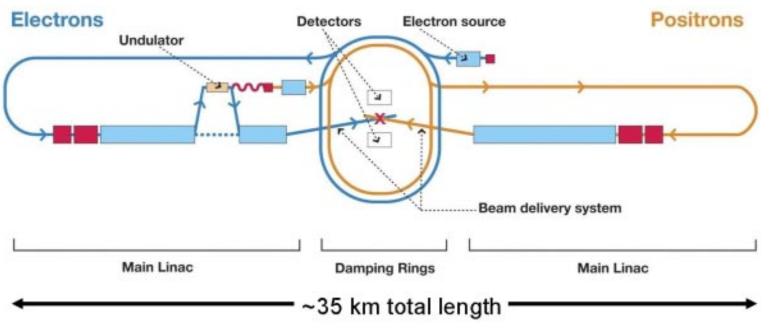

Fig. 3. – ILC schematic layout.

The positron charge needed for ILC is a factor 10^3 larger than that achieved at SLC (Slac Linear Collider) and, for this reason, an undulator-based novel scheme has been proposed for the positron source.

The electron and positron DRs have a circumference of 6.4 km and are located in a shared tunnel around the interaction region. The DRs are needed to accept the large transverse and longitudinal beam emittances produced by the sources and to damp them to the extremely low values required to achieve the design luminosity. In order to get the short damping time required, a high field (1.6 T) wiggler section, nearly 200 m long, is used to increase the radiation damping. The length of the 1 ms linac pulse, corresponding to 300 km, has to be compressed to 6.4 km to be stored in the DR. For this reason fast kickers have to be implemented to inject and extract each bunch individually.

The two main linacs accelerate the electron and positron beams to the final energy of 250 GeV over a combined length of 23 km. They are housed in two tunnels, an accelerator tunnel and a service tunnel, each with a 4.5 meters diameter. The basic element of the accelerating structure technology is a nine-cell 1.3 GHz niobium cavity. The cavities operate at 2 K. Five cryomodules are currently installed in the FLASH linac at DESY, where they are routinely operated. In this framework the X-FEL at DESY, with the construction of the European XFEL facility, with a 20 GeV superconducting linac, will be the most important test for cavity industrialization and mass production.

One of the principal challenges in the beam delivery system are tight tolerances on magnet motion (down to tens of nanometers), which require fast beam-based feedback systems. Tests on the manipulation of extremely small-size beams will be performed by a worldwide collaboration at ATF2 (KEK).

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