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STATUS OF THE CLIC BEAM DELIVERY SYSTEM*

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Abstract

The CLIC Beam Delivery System (BDS) is experiencing the careful revision from a large number of world wide experts. This was particularly enhanced by the successful CLIC'08 workshop held at CERN. Numerous new ideas, improvements and critical points are arising, establishing the path towards the Conceptual Design Report by 2010.

INTRODUCTION

The recently established CLIC-ILC collaboration has the BDS as a natural common topic thanks to the similarities between the ILC and the CLIC BDS designs. This collaboration materialized in the BDS working group of the CLIC'08 workshop [1]. The working group accomplished very important progress in all areas of the CLIC BDS and summarized it in a CLIC Note [2]. Among the highlights of the results we find:

- The design of the upstream polarimeter [3].
- An exhaustive revision of the collimation section by many experts.
- A proposal to ease the stabilization of the last quadrupole (QD0) by moving it out of the detector to a ground support.

This plus all the progress after CLIC08 is reported below.

THE BDS INSTRUMENTATION

The CLIC BDS emittance measurement and coupling correction section is placed right after the linac. This section is designed to provide an emittance measurement with better than 10% resolution, coupling correction and energy measurement with 0.04% resolution [4, 2]. The emittance measurement has been designed assuming a laser wire technology able to measure beam sizes in the 1 μm level with a resolution better than the 10%. This technology is presently not available but there is on-going research targeting the micron beam sizes [5, 6].

A polarization measurement needs a laser to interact with the beam in the same direction as the e^+e^- IP. A suitable location has been found at s=742m with sufficient free space for the laser crossing as shown in Fig. 1.

The Compton electron detector can be placed at s=907m, 165m from the laser IP containing 12 large aperture dipoles. According to [3], decent polarimetry can be achieved with a standard Q-switched YAG laser (100mJ at 532nm wavelength) with a crossing angle of 10mrad and a laser spot size of 50mm. The relative error in the polarization measurement is expected to be 0.61% and 0.08% for measurement times of 1s and 60s respectively.

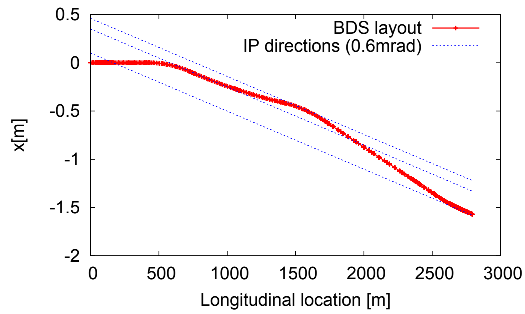

Figure 1: The CLIC BDS layout with parallel lines showing the direction of the beam at the IP. The polarimeter should be placed in a location parallel to the IP.

THE BDS COLLIMATION

The CLIC collimation system consists of two main parts: energy collimation and betatron collimation systems [2]. Different issues of the collimation section have been recently reviewed:

- Spoiler Survivability
- Collimator wakefield effects
- Collimation efficiency and Collimation depths

The energy spoiler was designed with the condition of surviving in case of a deep impact of the entire bunch train. Different energy spoiler designs have been discussed and simulated for fracture and damaged limits [7]. All these studies showed that a spoiler made of Be might be a suitable solution in terms of high robustness and acceptable wakefields [8, 9].

The effect of the CLIC collimator wakefields have been reviewed with the $10\sigma_x$ and $44\sigma_y$ collimator apertures. The full analysis is reported in [2]. A jitter in the vertical beam position of $0.2\sigma_y$ is assumed from considerations upstream. The impact on luminosity is shown in Fig. 2.

The function of the betatron collimators is to clean the transverse beam halo potentially dangerous for the last magnets of the machine and/or the vertex detector. In order to determine the maximum collimation depths with an acceptable cleaning efficiency particles traveling at high transverse amplitudes have been tracked using the code PLACET. The particles positions and angles have been checked at the entrance, in the middle and at the exit of QF1 and QD0. We label particles as bad when either they or their emitted photons impact QF1 or QD0 (with apertures 4.96 mm and 3.83 mm respectively).

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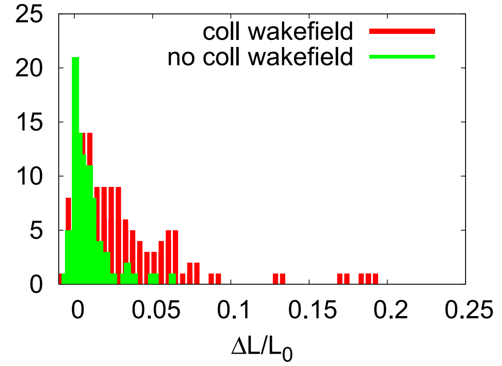

Figure 2: Relative luminosity loss of 100 simulated machines, assuming $0.2\sigma_y$ jitter at the BDS entrance without any feedback. The vertical collimator gaps are set to $44\sigma_y$ (as shown later the new depth is $55\sigma_y$).

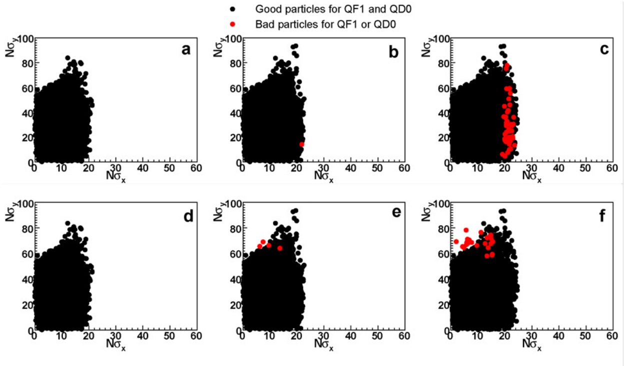

Figure 3: Good (black) and bad (red) particles at BDS entrance with different collimator apertures. The axes show the position of the particles in number of sigma in the x-x' and y-y' planes. In the following the corresponding horizontal and vertical apertures $a_{x,y}$ are given:
a) a_x=0.11mm ($13.7\sigma_x$), a_y=0.08mm ($44\sigma_y$); b) a_x=0.12mm ($15\sigma_x$), a_y=0.08mm; c) a_x=0.13mm ($16.2\sigma_x$), a_y=0.08mm; d) a_x=0.08mm ($10\sigma_x$), a_y=0.09mm ($49.5\sigma_y$); e) a_x=0.08mm, a_y=0.10mm ($55\sigma_y$); f) a_x=0.08mm, a_y=0.11mm ($60.5\sigma_y$).

Figure 3 shows the bad particles (in red) at the BDS entrance for different collimation apertures. All the bad particles are efficiently removed for a collimator aperture $<15\sigma_x$ in the horizontal plane and $<55\sigma_y$ in the vertical plane.

We define $15\sigma_x$ and $55\sigma_y$ as the new collimation depths. Since these apertures are larger than those used in Fig. 2 an improvement of the performance is expected.

THE FINAL FOCUS SYSTEM

The CLIC Final Focus System (FFS) is based on the local chromaticity correction scheme presented in [10] which uses strong sextupoles near the final doublet quadrupoles for the chromatic correction. Extra non-linear elements have been added to the CLIC FFS to cancel residual aberrations of octupolar and decapolar order [11, 12]. The experimental verification of this type of FFS is presently being investigated in the KEK ATF2 facility. The ATF2 optics has been scaled from the ILC FFS, therefore having the same chromaticity. However the CLIC FFS is about 4 times more chromatic than ILC and ATF2. In order to also prove CLIC chromaticity levels in ATF2 an R&D proposal has been made [13] to reduce the ATF2 IP vertical beta function by a factor of 4. The current status of this study can be found in [14].

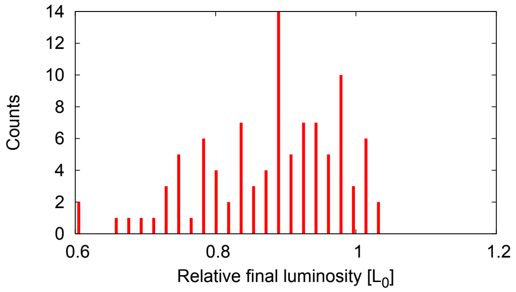

Figure 4: Histograms of number of relative final luminosities after a maximum of 18000 tuning iterations of the CLIC FFS. 80% of the seeds reach 80% of the luminosity with a prealignmenet tolerance of 10μm.

Reducing the IP vertical beta function in ATF2 will not only allow to experimentally demonstrate the CLIC chromaticity but also will serve to investigate the difficulty of tuning the FFS for different beta-functions. By tuning we understand the process of bringing the system to its ideal performance by varying the available parameters in presence of imperfections. Simulations show that tuning difficulty increases for smaller IP beam sizes [14]. CLIC aims to focus the vertical size to about 1nm which is still far from the 20nm that the ATF2 could ideally reach [13]. This is why it will be crucial to experiment with the tuning process versus IP beam size and try to extrapolate the results to the CLIC and ILC lattices.

The CLIC FFS tuning has not yet been fully demonstrated in simulations. We assume a pre-alignment tolerance of 10μm for all the magnets in the FFS. This is an extrapolation of the technology used in the LHC. As tuning algorithm we use the Simplex with the total luminosity as a figure of merit with a relative measurement error of 5%. Realistic simulations taking into account synchrotron radiation show that 80% of the simulated machines reach 80% of the design luminosity in 18000 iterations, see Fig. 4. The target is to get to 90% of the cases reaching 90% of the luminosity. New tuning algorithms will be investigated including using linear and non-linear knobs and starting the tuning at larger a IP betas with a subsequent beta squeeze.

Doubling L^*

The most challenging specification in the CLIC BDS is the stabilization of the QD0 to 0.15nm for frequencies above 4Hz. Although this stability level has been experimentally reached using active isolation and resonance rejection techniques on a simple structure in a quiet area [15], Fig. 5, the challenge remains to prove it in a detector-like environment.

One way to avoid this challenge would be to move QD0 out of the detector [16]. A lattice design proposed by

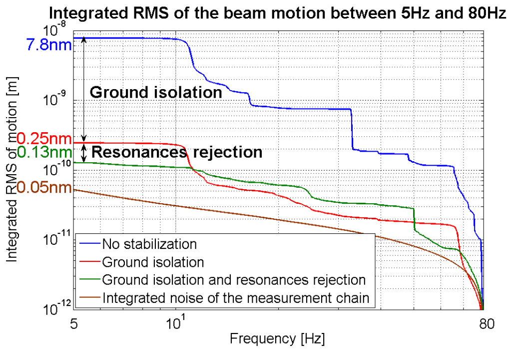

Figure 5: Demonstration of stabilization to the sub-nanometer level via ground isolation and structure resonance rejection in a quiet environment [15].

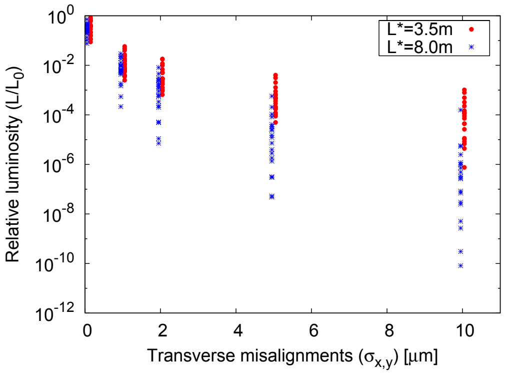

Figure 6: Comparison of luminosity degradation versus random misalignments in the nominal CLIC FFS and the new proposal with L*=8m.

A. Seryi featuring an L* of 8m has been fully studied and compared to the nominal CLIC lattice with L*=3.5m. The FFS with L*=8m has a 28% lower luminosity than the nominal FFS. This is due to the slightly higher IP beta functions and to some residual aberrations. Concerning the impact of transverse misalignments, the L*=8m lattice seems to be between a factor 4 and 5 more sensitive than the nominal, Fig. 6. In order to reach the same tuning performance as the nominal FFS the prealignment tolerance has been tightened from 10μm to 2μm, Fig. 7.

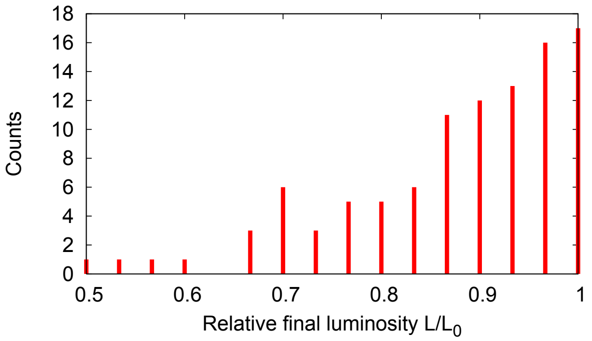

Figure 7: Tuning performance of the new lattice with L*=8m and pre-alignment tolerance of 2μm. 80% of the seeds reach 80% of the luminosity, same performance as the nominal system.

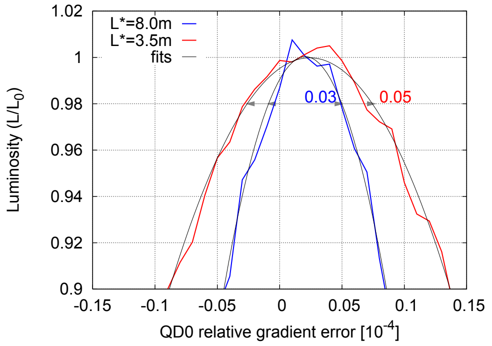

Figure 8: Relative luminosity versus relative QD0 gradient error for the two L* options.

Another challenging tolerance is the field stability of QD0. Figure 8 shows the degradation of the luminosity with the relative deviation of the QD0 gradient for the nominal CLIC FFS and the option with L*=8m.

CONCLUSIONS

The CLIC BDS is in the process of full revision towards the Conceptual Design Report (CDR) by the end of 2010. The next steps are: evaluation of the luminosity performance with the new collimator aperture, improvement of the FFS tuning algorithms, continue with active stabilization studies and the revision of the QD0 design.

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