A CLIC DUAL BEAM DELIVERY SYSTEM FOR TWO INTERACTION REGIONS

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Abstract

The Compact Linear Collider (CLIC) could provide e+ e− collisions in two detectors simultaneously possibly at a linac repetition frequency twice the design value. In this paper, a novel dual Beam Delivery System (BDS) design is presented including optics designs and the evaluation of luminosity performance with synchrotron radiation (SR) and solenoid effects for both energy stages of CLIC, 380 GeV and 3 TeV. In order to develop the novel optics design, parameters such as the longitudinal and the transverse detector separations were optimized. The luminosity performance of the novel CLIC scheme was evaluated by comparing the different BDS designs for both energy stages of CLIC. The dual CLIC BDS design provides a good luminosity and proves to be a viable candidate for future linear collider projects.

INTRODUCTION

A lepton linear collider is considered as one of the candidates to continue the high precision particle physics research. One of the main candidates is the Compact Linear Collider (CLIC) [1], starting from a baseline design with an initial c.o.m. energy of 380 GeV and reaching 3 TeV. The BDS [2] provides the nanometer-level beam sizes at the Interaction Point (IP) required to reach total luminosities of 1.5 × 1×10^{34} cm^{-2s} for CLIC 380 GeV and 5.9 × 1×10^{34} cm^{-2s} for CLIC 3 TeV [3,4]. This paper presents a novel dual BDS system scheme in order to allocate two detectors and make CLIC more competitive with other future collider projects. The paper will describe the main features of the BDS layout for CLIC 380 GeV and for CLIC 3 TeV. In the first section a detailed description of the construction of the dual BDS will be presented, such as the type of dispersion suppressors chosen and the longitudinal and transverse separation displacements needed in order to fit the two detectors. In the second section, the beam dynamics simulation results will be presented. One of the main challenges is represented by the luminosity loss due to synchrotron radiation (SR) coming from the bending magnets added in the diagnostics section (DS). This effect can be considered negligible for the CLIC 380 GeV but it starts to be significant in the CLIC 3 TeV case, since the contribution to the IP beam size scales with the fifth power of energy [5,6]. This limitation drives the BDS design for the energy upgrade case to be considerably longer in order to have acceptable luminosity loss at the IRs. Another important aspect is given by the crossing angles. Both the energy options of the dual BDS CLIC designs have in common the possibility for the second IR, called IR2, to be compatible with gamma-gamma collisions. A crossing angle of 25 mrad can be considered optimal for this type of collisions [7]. In the last section the detector solenoid effects will be taken into account in order to give the real luminosity potential of the CLIC dual BDS.

BEAM DELIVERY SYSTEM LAYOUT

The baseline design was the 380 GeV CLIC with the $L^* = 6$ m, defined as the distance between the final quadrupole and the IR, optimized in [3]. The optics design of the second BDS was done with MAD-X [8] modifying the DS of the baseline BDS by adding 8 more FODO cells with a phase advance of $\mu = 45°$, with an additional total length of 300 m. Furthermore, three dipoles of differing strengths are added in the FODO cells to separate the two BDS while also acting as dispersion suppressors.

The strengths of the two dipoles acting as dispersion suppressors is evaluated as $\theta_1 = (L/\rho_0)/\sqrt{2}$, where $L/\rho_0 = \theta_0$ is the angular kick of each normal dipole in the DS and L is the length of the single dipole [9]. We define as θ the total strength of the dipoles inserted in the DS, given as $\theta = 2\theta_1 + \theta_0$. The total strength θ= 4.83 mrad in the DS has been chosen to provide the desired transverse separation of 10 m, since $\theta * \Lambda \approx 10$ m, where Λ is the BDS length. The transverse separation length was chosen to be about 10 m because of the experimental cavern size. The Twiss function and all the other parameters have been matched to the design values and then the new DS has been connected to the rest of the BDS in order to get the beam to two different IRs. The new layout involves four different beam lines, designed with different lengths to provide the desired longitudinal and transverse separation. The longitudinal separation was chosen to be about 40 m (that corresponds to a FODO cell in the DS), even if it introduces issues with train synchronizations, it is necessary in order to minimize the transverse separation space to allocate the two detectors. The two crossing angles are respectively 16.5 mrad for IR1 and 26 mrad for IR2 (compatible with gamma-gamma collisions). The layout of the new double BDS is shown in Fig. 1 while a zoom in the IRs is shown in Fig. 2.

The study has been performed also for CLIC 3 TeV using as a baseline design the L^*= 6 m optimized in [3,4]. The procedure to make the new beam lines has been the same but in this case the additional length in order to allocate the dipole and the two dispersion suppressors has been of

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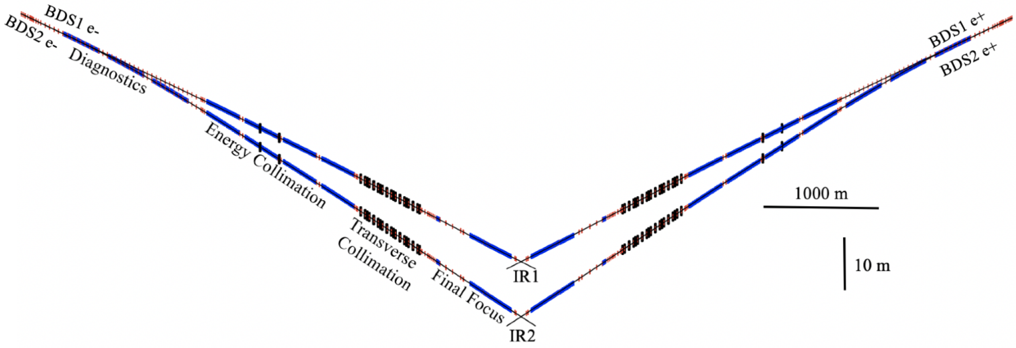

Figure 1: Layout of the new dual CLIC 380 GeV BDS System for two IRs.

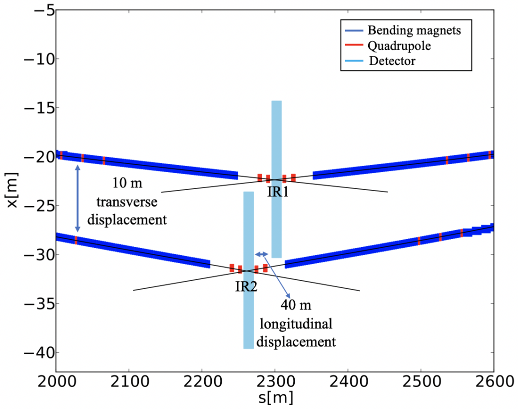

Figure 2: Zoom at the IRs to have a clear visualization on the longitudinal and the transverse separation displacements of about 40 m and 10 m respectively.

about 1 km and a total length of the new DS of about 1.5 km. The deflection angle θ=2.75 mrad provides exactly the same transverse separation of 10 m and the crossing angles are for IR1 and IR2 respectively 20 mrad and 25.5 mrad. The new dual BDS layout design for CLIC 3 TeV option is shown in Fig. 3.

PERFORMANCE RESULTS

The luminosity and beam size simulations have been performed with PLACET [10] and GUINEA-PIG [11]. The tracking and the evaluation of the beam size has been done also in comparison with MAPCLASS [12–14] and PTC [15] codes. The results of these simulations are shown in Figs. 4 and 5, where the beam size is evaluated until the 8th order aberrations. The simulation was done for all the different BDSs, BDS1 and BDS2 e- and e+ and for both energies, 380 GeV and 3 TeV. A further optimization of the 3 TeV cases was needed. This was performed by correcting the aberrations that mostly increase the beam size with a pair of sextupoles in the new DS. The sextupoles were added where there is a peak of dispersion and a high β_x. Thanks to that, a small improvement of the beam size trend for the BDS2 can be seen in Fig. 5. Table 1 shows the beam size performance for the two different IRs for both CLIC energy cases evaluated with PLACET direct tracking procedure (no solenoid), computed for BDS1 e+, e- and BDS2 e+ and e- and the luminosity performance computed with BDS1 tracked bunch against BDS2 evaluated with GUINEA-PIG. From Table 1 and Figs. 4 and 5 we see that the the beam sizes from the different simulation codes show consistency of results for all the cases.

Table 1: Beam Size and Luminosity Performance for the Two IRS for Both CLIC Energy Cases

	CLIC 380 GeV					
	σ_x^* [nm]		σ_y^* [nm]		$\mathscr{L}_{TOT}$ [1×10^{34} cm^{-2s}]	
	ideal	w/ SR	ideal	w/ SR	ideal	w/ SR
IR1	141	144	3.07	3.08	1.515	1.492
IR2	141	144	3.06	3.07	1.491	1.466
	CLIC 3 TeV					
	σ_x^* [nm]		σ_y^* [nm]		$\mathscr{L}_{TOT}$ [1×10^{34} cm^{-2s}]	
	ideal	w/ SR	ideal	w/ SR	ideal	w/ SR
IR1	43.5	51.5	1.02	1.71	9.00	6.30
IR2	44.9	64.8	1.02	1.92	8.33	5.14

Detector Solenoid Effects

The effects of the detector solenoids were simulated with PLACET [10] and GUINEA-PIG [11] using the following tracking procedure [16]: the beam is first tracked forward without SR, and without the solenoid field present. This provides the optimal beam distribution at the IP. The ideal IP beam distribution is tracked backwards through the beam line, with the solenoid field turned on but still without SR. Finally, the SR is turned on, and the beam is tracked forward through the solenoid. In Table 2 we can see the luminosity performance evaluated with both PLACET tracking procedures, the direct (results ideal and w/ SR) and the forward-backward-forward (results ideal, w/sol, w/ sol+SR), for the baseline design and the two different IRs for both CLIC energy stages. The solenoid effects for the dual CLIC BDS are respectively 4% for the baseline design with a L*=6 m, 3.5% for IR1 and 19% for IR2.

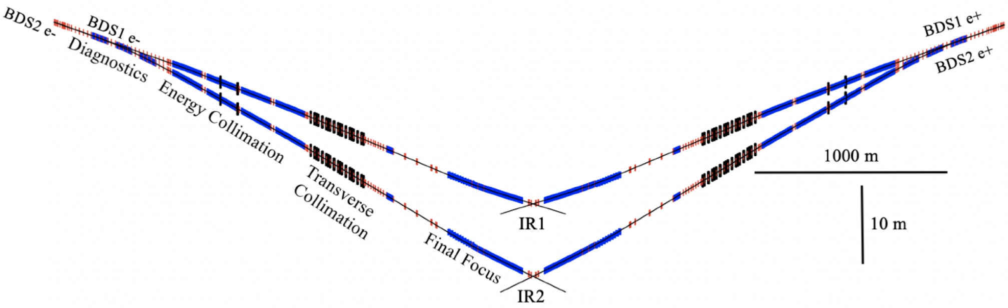

Figure 3: Layout of the new dual CLIC 3 TeV BDS System for two IRs.

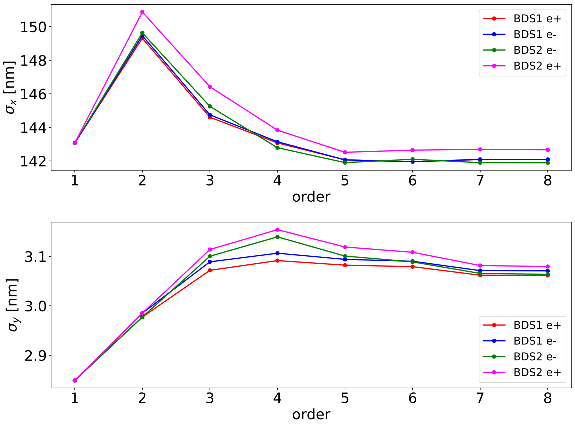

Figure 4: σ_x^* and σ_y^* evaluated with MAPCLASS until the 8^{th} order aberrations for the 380 GeV case.

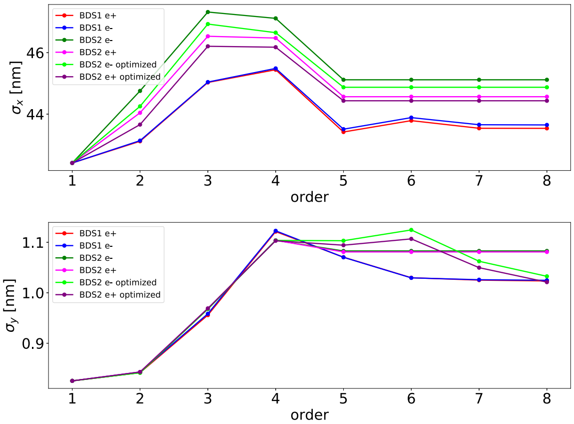

Figure 5: σ_x^* and σ_y^* evaluated with MAPCLASS until the 8^{th} order aberrations for the 3 TeV case.

CONCLUSION

Considering the detector solenoid effects there is a total luminosity performance loss from the baseline design for the 3 TeV CLIC of about 2% at the IR1 and about 33% of luminosity performance loss at the IR2, both with respect to the previous baseline design but including the solenoid, $6.22{\times}10^{34}$ cm^{-2s}. The impact on 380 GeV CLIC is still negligible for the solenoid field effects.

Table 2: Luminosity Performance Evaluated for the Baseline and the Two IRs for Both CLIC Energy Cases

CLIC 380 GeV				
	$\mathscr{L}_{TOT}$ $[1{\times}10^{34}\,\mathrm{cm}^{-2s}]$			
	ideal	w/ sol	w/ SR	w/ sol+SR
IR1	1.515	1.512	1.492	1.412
IR2	1.491	1.475	1.466	1.392
CLIC 3 TeV				
	$\mathscr{L}_{TOT}$ $[1{\times}10^{34}\,\mathrm{cm}^{-2s}]$			
	ideal	w/ sol	w/ SR	w/ sol+SR
baseline	9.40	8.65	6.50	6.22
IR1	9.00	8.21	6.30	6.09
IR2	8.33	7.59	5.14	4.17

This study also leads to another very important result never evaluated before: the impact of the solenoid field on the CLIC baseline design with an L* of 6 m. In fact, the impact on the luminosity performance of CLIC 3 TeV for the detector solenoid field is about 4% for the CLIC current baseline design and is about 3.5% for the dual CLIC BDS1 and about 19% for the dual CLIC BDS2 that could it be partially recovered by adding an antisolenoid. Further improvements can still be performed for the dual BDS layout in order to recover part of the luminosity performance especially for the BDS2 of the CLIC 3 TeV case.

We conclude that the CLIC dual BDS, serving two detectors, is a real candidate for the future linear collider project with a cost of requiring about 2 km longer site at the highest energy.

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