THE LUMINOSITY FOR THE ILC TRAVELLING FOCUS REGIME WITH OFFSETS AND ANGULAR SCANS*

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Abstract

One of the crucial challenges of a future linear collider is to provide the planned luminosity of order of 10^{34} [cm^{-2} s^{-1}]. This level should be maintained even in the case of the new parameter sets for reduced beam power. The use of the "travelling focus" scheme [1] could provide an additional 30% luminosity. Nevertheless the study of the luminosity stability for various ILC parameters sets suggests that, in comparison with other parameter sets, the "travelling focus" regime is highly sensitive to beam-beam transverse and angular offsets at the collision point. In addition, the distortion in the bunch shape due to short-range wakefields, so-called "banana" effect, can also lead to the significant (10%-15%) luminosity loss even for perfectly aligned bunches. The results obtained suggest that so far this effect was underestimated for the ILC parameter sets.

INTRODUCTION

The luminosity is a measure of the interaction probability of the colliding beams. Therefore the luminosity achieved at the interaction point is one of the key issues for the success of any collider project. In the current ILC design a luminosity of 2x10^{34} [cm^{-2} s^{-1}] is foreseen. The luminosity depends on the machine parameters, bunch characteristics and can be enhanced or reduced by the beam-beam effects at the interaction point.A previous study of beam-beam effects on luminosity for some sets of the International Linear Collider parameters is presented in [2]. Since recently some new sets of parameter are under discussion [3]. The comparison of these new parameter sets with former RDR parameter set is given in Table 1. All three new sets -"SB2009", "Low Charge" and "New Low Charge"- are designed to reduce the bunch charge and consequently the cost of the machine. This reduction of beam power a should be done without compromising nominal luminosity. Therefore it will require a tighter focusing at the collision point. For shorter bunches it can lead to a luminosity loss via hour-glass effect. One of the possibility to enhance the luminosity is to apply the "travelling focus" scheme. This regime might overcome hour-glass effect by arranging for a head and a tail of the bunches to be focused at a proportionally displaced longitudinal position. The effect is further enhanced by strong beam-beam interactions which continuously focused bunches during the collision. The travelling focus could provide an additional 30% luminosity. The alternative Low Charge (LC) and new Low Charge (J. Gao) parameter sets based on the reduction of the number of particle per bunch, could also provide the luminosity of 2×10^{34} [cm^{-2} s^{-1}].

STUDY OF THE DIFFERENT PARAMETER SETS

Orbital and Angular Offsets

The nominal luminosity values given in Table 1 for the four sets of the ILC parameters was calculated with guineapig++ simulation code [4] which is C++ version of GUINEA-PIG [5]. This value is very sensitive to orbital and angular offsets of the interacting bunches. In Fig. 1 the results of simulations are presented. The value of luminosity for the different orbital and angular offset was calculated and normalised with respect to nominal luminosity. An orbital offset scan is presented Fig. 1a. The relative luminosity loss is plotted as the function of the relative vertical orbital offset $\Delta y/\sigma_y$.

Table 1: The ILC Parameter Sets

	RDR	SB2009	Low Charge	New Low Charge
$N_{particles}$	2x10^{10}	2x10^{10}	1x10^{10}	1x10^{10}
$N_{bunches}$	2625	1320	5640	2625
β_x/β_y $[mm]$	20/0.4	11/0.2	12/0.2	8/0.166
$\gamma\epsilon_x$ $[\mu m]$	10	10	10	10
$\gamma\epsilon_y$ $[\mu m]$	40	36	30	10
$\sigma_x[nm]$	639	474	495	404
$\sigma_y[nm]$	5.7	3.8	3.5	2.0
$\sigma_z[\mu m]$	300	300	150	166
D_y	19.0	38.4	10.0	24.0
Lumi.$\times 10^{34}$ $[cm^{-2}s^{-1}]$	1.97	1.96	1.96	2.12

As expected the travelling focus (TF) regime has proved to be more sensitive to the orbital offsets compared to other sets of parameters. The values for RDR parameter set are very close to thouse of the New Low Charge (J. Gao) set,

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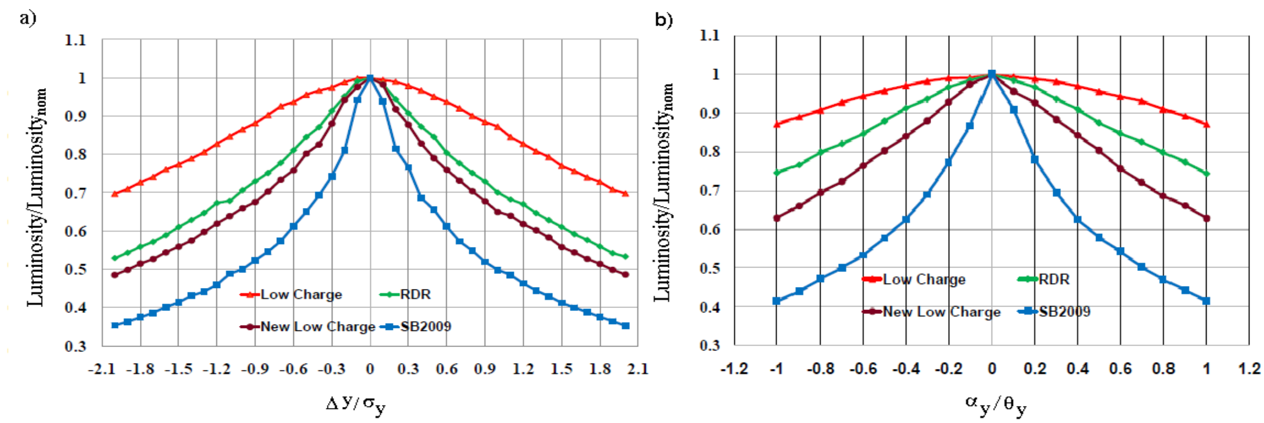

Figure 1: The ILC 500 GeV centre-of-mass energy parameter sets. Scans of effects of orbital a) and angular b) offsets on the normalized luminosity.

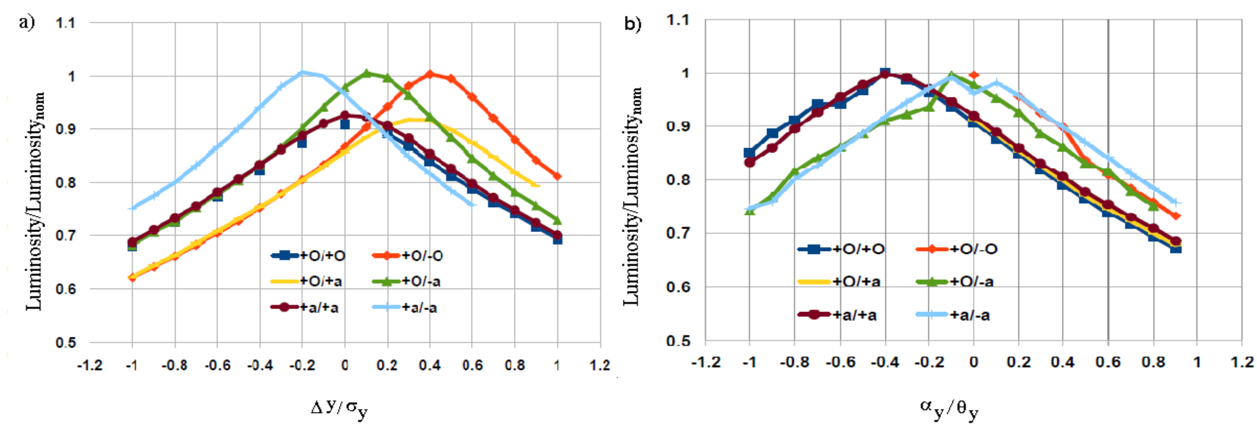

Figure 2: The RDR parameter set scans for different combinations of orbital (O) and angular (a) correlations leading to 1% of emittance growth.

while the Low Charge (LC) parameter set is less sensitive to the bunch displacement at the interaction point.

The study was repeated for the same sets of parameters in the presence of angular offsets. The results are given in Fig. 1b, were the luminosity is plotted as a function of the relative vertical bunch divergence α_y/θ_y where $\theta_y = \sqrt{(\epsilon_y/\beta_y)}$. For the travelling focus regime the relative luminosity loss could be of order of 60%, while for the Low Charge (LC) option a relatively small loss of luminosity $\approx$ 12% is observed. It can be explained by the fact that for the LC set the disruption parameter Dy is nearly 4 times smaller than the Dy parameter for travelling focus regime. New Low Charge regime behavior is again close to RDR parameter set.

"Banana shape" Bunches and the Luminosity

In the presence of wakefields the originally Gaussian bunches are distorted. The influence of so-called "banana" shaped bunches on the luminosity were previously studied in details for the TESLA lattice [6]. Even for a relatively small emittance growth the impact on the luminosity is loss can be significant. Thus for an emittance growth $\approx$ 6% the relative luminosity loss is 30% even without any orbital or angular offsets. This effect can be compensated by very sophisticated feed-back system [7]. For the ILC setting the emittance growth due to "banana" effect is expected approximately 1% or 2%. According to the results reported in [2], where 6% emittance growth was assumed, the relative loss of luminosity was found to be small and a scheme of compensation via subsequent angular scans was suggested. Nevertheless, the new guineapig++ simulations using the linearised model of emittance growth suggest that the luminosity loss can be as significant as 10% even in the case of perfectly aligned bunches for RDR design.

In Fig. 2a the results of orbital offset scans for various combinations of the orbital (y, z) and angular (y , z) correlations leading to 1% emittance growth for RDR parameters are given. The relative luminosity loss is plotted versus the normalized vertical orbital offsets. Surprisingly, the scheme of compensation suggested in [2] still works. The nominal luminosity value can be restored via subsequent

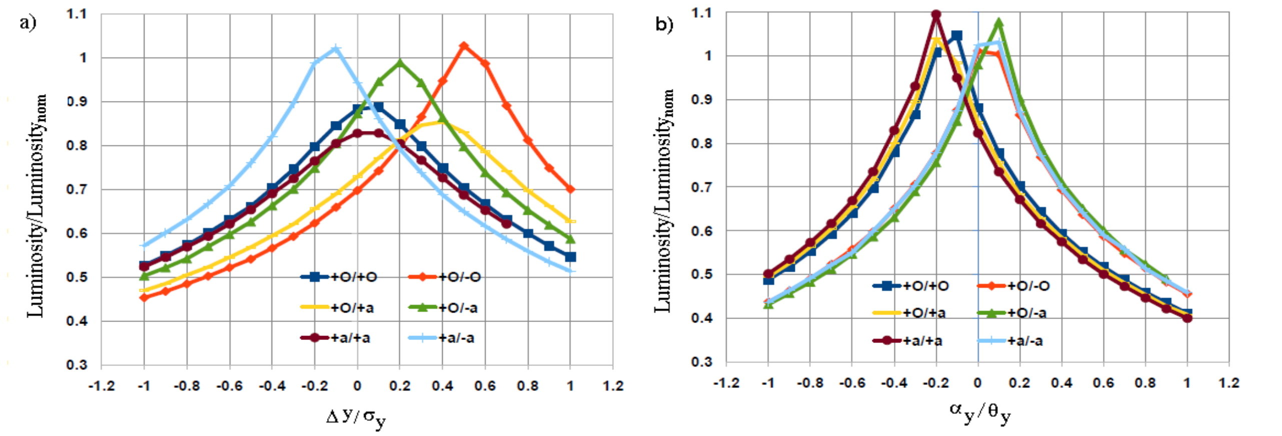

Figure 3: The SB2009 parameter set scans for different combinations of orbital (O) and angular (a) correlations leading to 1% of emittance growth.

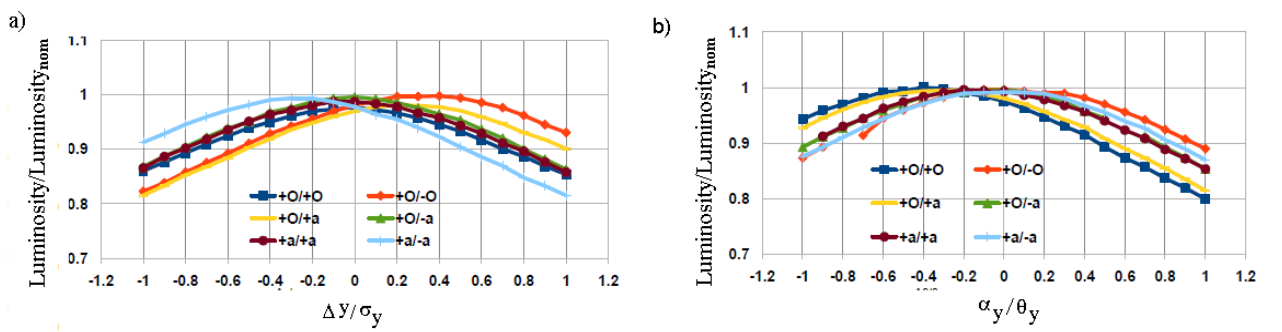

Figure 4: The LC parameter set scans for different combinations of orbital (O) and angular (a) correlations leading to 1% of emittance growth.

angular scan as it seen in Fig. 2b.

The results of orbital/angular scans for travelling focus regime SB2009 are presented in Fig. 3a/3b respectively. The polarisation loss due to "banana shape" bunches is even bigger, but again can be compensated by angular scan. In Fig. 4 the results for the Low Charge parameter set are given. The similar results were obtained for J.Gao set.

CONCLUSIONS

The study of the new parameter sets confirms that the travelling focus regime is very promising but also very sensitive to the bunch-bunch orbital and angular offsets and requires elaborated feed-back system to deliver the required luminosity. It was also found that the "banana" effect may have significant impact on the luminosity. The results of guineapig++ simulations using a linear model make clear that more investigation should be done. An even more realistic representation of "banana" bunches will be obtained by using the simulation package such as Merlin [8], which can model the wakefields in the linac. Using such generated "banana" shape bunches, the luminosity and relative luminosity loss can be calculated by guineapig++.

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