COMPARISON OF ILC FAST BEAM-BEAM FEEDBACK PERFORMANCE IN THE e^-e^- AND e^+e^- MODES OF OPERATION*

M. Alabau Pons, LAL, Orsay and IFIC, Valencia
P. Bambade, LAL, Orsay, A. Faus-Golfe, IFIC, Valencia
A. Latina, D. Schulte, CERN, Geneva

Abstract

Several feedback loops are required in the Beam Delivery System (BDS) of the International Linear Collider (ILC) to preserve the luminosity in the presence of dynamic imperfections. Realistic simulations have been carried out to study the performance of the beam-beam deflection based fast feedback system, for both e^+e^- and e^-e^- modes of operation. The beam-beam effects in the e^-e^- collisions make both the luminosity and the deflections more sensitive to offsets at the interaction point (IP) than in the case of the e^+e^- collisions. This reduces the performance of the feedback system in comparison to the standard e^+e^- collisions, and may require a different beam parameter optimization.

BEAM-BEAM DEFLECTION BASED FEEDBACK SYSTEM

Misalignments in the lattice magnets produced by the ground motion, induce perturbations of the beam trajectory with respect to the ideal trajectory which can increase the transverse beam sizes at the IP and introduce offsets between the beams at the collision point.

Several feedback loops are foreseen in the BDS of the ILC to mitigate these effects and to avoid the resulting degradation of the luminosity [1]. To correct the position and the angle of the beams at the IP, fast feedback systems are applied bunch-to-bunch, while slower feedback systems are required to maintain aligned the lattice magnets and to correct the beam trajectories. The main signal used to maintain the beams aligned within half a nanometre at the IP is the transverse kick that the misaligned beams experience during the collision [2].

Beam-beam Effects for e^+e^- and e^-e^- Collisions

In the case of e^+e^- collisions, a bunch passing close to the axis through the electromagnetic field created by the opposite beam, is strongly focused, which leads to a enhancement of the luminosity. For e^-e^- collisions, on the other hand, repulsion occurs, which enhances the effective transverse sizes at the IP, reducing the peak luminosity to values only typically about 20% of those for e^+e^- . In addition, in e^-e^- collisions the luminosity is much more sensitive to residual offsets at the IP and the deflection curve as a function of the IP offsets is much steeper than for e^+e^- (see Fig. 1), which can impact the feedback performance.

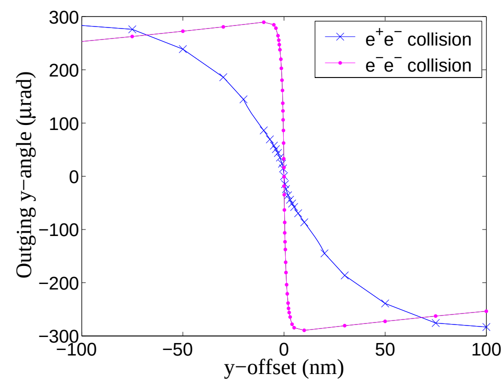

Figure 1: Vertical deflection angle versus vertical half beam-beam offset, for e^+e^- and e^-e^- collisions simulated with GUINEA-PIG [3], using ideal Gaussian beam distributions with ILC nominal parameters at 500 GeV in the center-of-mass [4].

SIMPLIFIED IP POSITION FEEDBACK SIMULATION

A study of the impact of this steeper deflection curve on the performance of the beam-beam deflection based feedback system compared to e^+e^- collisions was carried out in [5]. In this simplified simulation, offsets of the order of hundreds of nanometres were introduced between the trains (which are delivered with a frequency of 5 Hz), as well as a bunch-to-bunch jitter of the order of a fraction of the beam size. The collision was simulated with GUINEA-PIG [3], and the obtained out-going angle was used to predict the offset of the beam, and the correction was carried out bunch-to-bunch. The results indicated that the correction of the position is slower for the e^-e^- collisions due to the steeper deflection curve, but the correction can be done fast enough to recover the average luminosity over a train. On the other hand, the luminosity loss in function of the bunch-to-bunch jitter for the e^-e^- collisions is a factor 2 greater compared to the e^+e^- collisions due to greater sensitivity to the offsets at the IP. Thus, a different beam parameter optimization, reducing the disruption parameter may be required for the case of e^-e^- collisions.

In order to verify that the assumptions on the ground motion amplitudes considered in the simplified simulation of the feedback system are acceptable, a more realistic sim-

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ulation has been carried out, including dynamic imperfections in the BDS magnets, and is presented here.

GROUND MOTION EFFECT

An important source of magnet displacements is ground motion, which is transmitted to the lattice elements by their support structures. Several ground motion models have been built, based on the results of measurements in different sites, with different levels of noise. These models include ATL diffusive motion, slow systematic motion, natural micro-seismic motion, and fast cultural noise [6].

For the feedback simulation, the elements of both BDS lines have been misaligned applying the intermediate noisy level model B [6]. The time interval used to sample the ground motion was 0.2 s, corresponding to the frequency at which trains are delivered. This simulation has been done with the tracking code PLACET [7].

To check the misalignments produced by this model along the lattice as function of time, the r.m.s. displacements for 50 seeds of the generator were calculated. Fig. 2 shows the difference of the vertical misalignments produced at each element in the electron line with respect to the same element in the positron one, for successive time intervals.

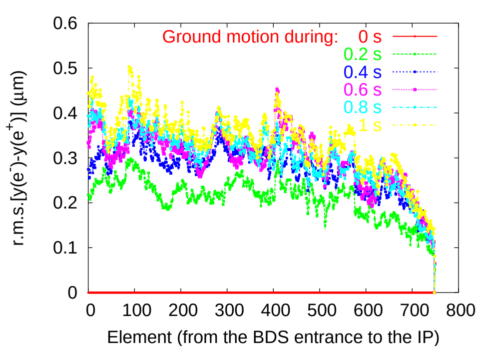

Figure 2: Difference in misalignment of each BDS element in the e^- line with respect to the same element in the e^+ one. Ground motion model B was applied at successive time intervals. The results are the $r.m.s.$ of 50 seeds.

Due to the fact that there is certain spatial coherence in the ground vibration, the sum of the misalignments is bigger than the difference between corresponding elements of the e^- and e^+ lines. The simulation of the beam-based IP position feedback system, is only sensitive to the difference between the beams at the IP. Other deviations of the trajectory with respect to the ideal one, should be corrected upstream, with a slower feedback which maintains the magnets correctly positioned along the beam lines, or through appropriately placed magnetic correctors. Such corrections, while not essential to keep the beam in collision at the IP, are needed to maintain the optical quality of the beam spot, and hence the luminosity.

BEAM-BASED IP POSITION FEEDBACK SIMULATION

For the simulation of the IP position feedback system, after tracking the beams through the BDS lattices misaligned by the ground motion with the code PLACET [7], the beam-beam collision is simulated with the code GUINEA-PIG [3] to obtain the outgoing angle that will serve to compute the correction. The beam position of the next bunch is corrected with a kicker located upstream of the IP close to the final doublet (FD). The operation is repeated bunch-to-bunch.

Fig. 3 illustrates the feedback response for ground motion applied during successive time intervals, for e^+e^- collisions. The average luminosity performance as a function of time is obtained with 50 seeds. The larger a ground motion is applied, the more important are the misalignments in the lattice, and the smaller is the final luminosity which can be recovered with the beam-beam deflection based IP position feedback. Although 70 or 80$\%$ of the luminosity can be recovere after 1 s, the deterioration of the beam sizes due to the optical effects caused by upstream misalignments makes it impossible to recover more than $\sim$30 or 40% of the luminosity after *e.g.* 300 s, and other feedback loops are required.

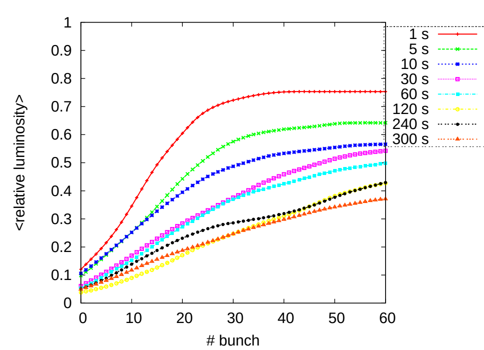

Figure 3: Beam-based IP postition feedback simulation for the e^+e^- collision with ground motion model B applied during different times along the BDS. The average relative luminosity is calculated over 50 seeds.

FEEDBACK SIMULATION INCLUDING IP ANGLE CORRECTION

The IP angle correction has been included in the simulation in order to correct the position of the beams along the Final Focus System (FFS), and thus mitigate the beam size increase produced by passing off-axis through the sextupoles, in order to check if the nominal luminosity can be recovered after the correction of the beam offsets at the IP, at least under the effect of the misalignments produced by the ground motion applied during some seconds or minutes.

The angle at the IP is corrected with a kicker located at the entrance of the FFS, at nπ phase-advance from the

IP. The angle is corrected by zeroing the signal in a BPM located at a phase $\pi/2$ downstream from the kicker [1].

Figs. 4 and 5 illustrates the feedback responses for ground motion applied during successive time intervals, for e^+e^- and e^-e^- collisions respectively, including the IP position and angle correction. The average relative luminosity is also calculated over 50 seeds.

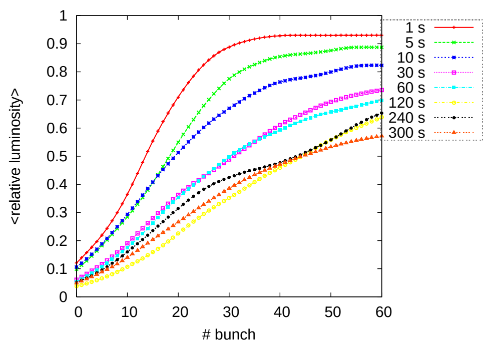

Figure 4: Beam-based IP position and IP angle feedback simulation for the e^+e^- collision with ground motion model B applied during different times along the BDS. The average relative luminosity is calculated over 50 seeds.

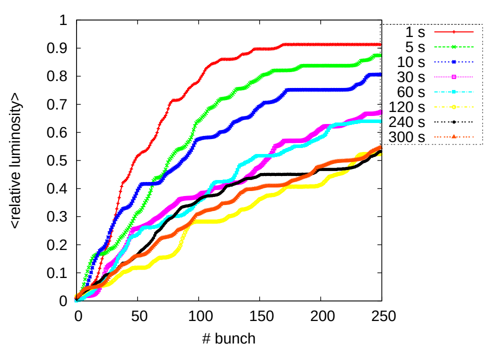

Figure 5: Beam-based IP position and IP angle feedback simulation for the e^-e^- collision with ground motion model B applied during different times along the BDS. The average relative luminosity is calculated over 50 seeds.

The results indicate that about 20 % more of luminosity can be achieved by correcting the IP angle compared to the case where only the IP position was considered (see Figs. 3 and 4). But, on the other hand, the luminosity cannot be recovered until 100% of the nominal value, due to optical effects along the FFS, responsible of the increase of the beam size at the IP. The correlation between the vertical beam size at the IP and the luminosity is shown in Fig. 6. The luminosity loss is directly related to the increased beam size since there is not significant residual offset between the beams at the IP, and they are not correlated with the luminosity.

The correction for the e^-e^- collisions is slower compared with the e^+e^- ones (see Figs. 4 and 5) as the slope relating the outgoing angle with the IP offsets for the e^-e^- case is ∼8 times the one for e^+e^- , which is needed to avoid noise amplification. This is a consequence of the steeper deflection curve for the e^-e^- collisions.

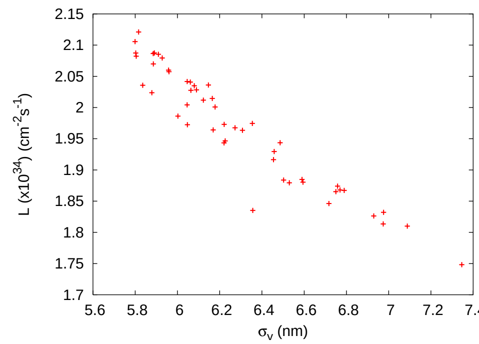

Figure 6: Luminosity versus the combined vertical beam size of both e^- and e^+ beams at the IP. Feedback simulation carried out for e^+e^- collisions under the effect of the missalignments produced by the ground motion after 1 s.

CONCLUSIONS

The results of the IP position and angle feedback simulation including dynamic imperfections in the BDS lattice show that about 10% of the luminosity cannot be recovered due to optical effects that increase the beam size at the IP. A luminosity feedback system or other loops to correct the beam trajectory along the FFS would be required, even under the magnet misalignments produced by the ground motion during a few seconds.

The feedback correction for the e^-e^- collisions has to be done slower compared to the e^+e^- case, due to the steeper deflection curve, but it can be done fast enough to recover the average luminosity over a train.

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