THE BHABHA SUPPRESSION EFFECT REVISITED

By
Strahinja LUKIĆ

(1) Vinca Institute of Nuclear Sciences, Belgrade, Serbia

The calculations of the Bhabha Suppression Effect (BHSE) in luminosity measurement at the International Linear Collider (ILC) were revisited. Preliminary estimates of the BHSE at the Compact Linear Collider (CLIC) were performed for the first time, as well. The regularities in the largest contribution to the BHSE, the Beamstrahlung, are used to find event selection algorithms that minimize the BHSE at ILC, or reduce the sensitivity of the BHSE on the variations in the beam parameters. At CLIC, the BHSE is much larger, so that the precision of the luminosity measurements critically depends on the precise estimate of the BHSE.

Keywords: linear colliders, luminosity measurement, Bhabha scattering, Beam-beam effects, BHSE, numerical simulations

INTRODUCTION

Precise integral luminosity measurement at ILC will be performed by counting the Bhabha events recorded in the LumiCal detector in the Forward Region. The BHSE induced by the Beamstrahlung before the Bhabha scattering and by the electromagnetic deflection after the scattering represents an important source of systematic uncertainty in this context. As shown by C. Rimbault et al. [1] using the BHLUMI Bhabha event generator [2], together with a modified version of the Guinea-PIG software [3], the BHSE can be reduced by modification of the selection criteria for counting the Bhabha events in LumiCal.

In this work, this study was revisited to exploit the rather regular characteristics of the shift in the polar-angles of the outgoing electron-positron pairs after the Bhabha scattering.

Similar as in ref. [2], a set of 500,000 Bhabha events were produced with the energy in the center of mass (CM) frame $= 500$ GeV using the BHLUMI 4.04 software [3]. These events were then fed to the Guinea-PIG to simulate the Beamstrahlung and the Electromagnetic deflection effects.

POLAR ANGLES OF THE OUTGOING BHABHA PAIRS

As already shown in refs. [2] and [4], at ILC energies, the Beamstrahlung effect can be very well described using the assumption that approximately all radiation emitted by an electron-positron pair prior to the Bhabha scattering is emitted in the same direction along the beam axis. Thus the CM frame of the collision has non-negligible velocity directed, to a good approximation, along the beam axis. As a result, the polar angles of the outgoing particles, which are almost perfectly collinear in the CM frame, are shifted in opposite directions in the laboratory frame. The correlation between the shifts of the two polar angles is shown in
Because of that, the regions of the combined phase space of the two outgoing particles that are the most strongly affected by the BHSE are those where both polar angles are either in the immediate vicinity of the minimum angle $\theta_{\text{min}}$ or in the immediate vicinity of the maximum angle $\theta_{\text{max}}$ of the fiducial volume of the LumiCal (see Fig. 2).

**BHSE REDUCTION AT ILC**

Fig. 2 represents the 2D histogram plot of the polar angles of the outgoing Bhabha positrons versus the electrons. Selection cuts to the fiducial volume were applied before including the Beamstrahlung effect. The angular region enclosed by the thin box from 41 to 67 mrad in both $\theta_e$ and $\theta_p$ corresponds to the fiducial volume of the detector. The events appearing outside the fiducial volume represent the BHSE. The two small thick boxes enclose the areas the most strongly affected by the BHSE.

The BHSE at ILC can be effectively reduced if the regions within $\delta\theta$ from $\theta_{\text{min}}$ and $\theta_{\text{max}}$, respectively, are excluded from the selection cuts. Depending on $\delta\theta$, the BHSE at ILC can be reduced.
to zero, or even made insensitive to variations in the horizontal bunch size $\sigma_x$ (Fig. 3). Assuming ILD geometry and 500 GeV CM energy, for $\delta \theta = 2.8$ mrad, the result of the simulation is BHSE = (0.01±0.06) %. The reduction of the BHSE comes at a moderate cost in efficiency. With $\delta \theta = 2.8$, 31% of all Bhabha events hitting the geometrical volume of the LumiCal are counted towards the luminosity measurement. Compared to that, the number of counts in the entire fiducial volume represents 37% of all events hitting the geometrical volume. Thus a relative loss of statistic of 16% is induced by the modification of the selection criteria in order to suppress the BHSE. The region of low sensitivity to $\sigma_x$ is situated around $\delta \theta = 4.8$, which induces a relative loss of statistic of about 31%. In either case, the relative loss of statistic is not critical, since the relative statistical error of the luminosity measurement when the entire fiducial volume is used is of the order of $0.5 \times 10^{-4}$ [5] on the yearly level.

At 1 TeV in CM, for $\delta \theta = 3.5$ mrad, the result is BHSE = (0.07±0.07) %, with a relative loss of statistic of 21%.

**BHSE AT CLIC**

Due to the intense Beamstrahlung at 3 TeV under the CLIC beam conditions, the BHSE at CLIC is estimated to around 70 %.

Fig. 4 represents a plot of the polar angles of the outgoing electron and positron from the Bhabha scattering at CLIC. The dashed lines represent the points that are directly reached by the Lorentz boost of the points $(\theta_{\min}, \theta_{\max})$ and $(\theta_{\max}, \theta_{\min})$ from the CM frame to the laboratory frame, under assumption that the CM moves along the beam axis. The edges of the distribution lie very close to these lines, indicating that the Beamstrahlung is the dominant effect, and that it is indeed predominantly emitted along the beam axis. The existing small spread of the distribution beyond the dashed lines is due to the electromagnetic deflection after the Bhabha scattering, as well as to the small transversal components of the Beamstrahlung momenta.

Such high BHSE cannot be meaningfully reduced with the selection criteria shown in the previous section. The precision of the luminosity measurement at CLIC thus critically depends on the possibility to precisely simulate and estimate the beam-beam effects. A method of data-driven control of the BHSE is necessary for that. A set of measurable parameters of the distribution needs to be defined that can be cross-checked between the simulation and the measured data. This is the topic of the ongoing work.

![Figure 3: BHSE as a function of $\delta \theta$ for different horizontal bunch sizes $\sigma_x$.](image)
CONCLUSIONS

It was shown that the regular nature of the polar-angle shifts induced by the beam-beam effects at ILC can be used to reduce the BHSE to zero, or to make it insensitive to the horizontal bunch size. Additional studies are necessary in order to propose optimal selection cuts that minimize the overall systematic effects, taking into account imperfections and uncertainties in the bunch shape parameters at the interaction point, the possible misalignment of the beams, uncertainties in the estimate of the BHSE, as well as the physics background.

Preliminary estimates of BHSE at CLIC were performed for the first time. At CLIC, the BHSE is much larger than at ILC, so that the precision of the luminosity measurement critically depends on the precise estimate of the BHSE. Data-driven methods of BHSE correction are necessary for this purpose. This will be the topic of the ongoing work.

REFERENCES