Four-fermion background in luminosity measurement at CLIC

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Impact of four-lepton processes misidentified in luminosity measurement as Bhabha has been studied at CLIC energies. Testing different selection cuts on Bhabha spectrum and physics background, error on luminosity as well as selection efficiencies are estimated for the CLIC01_ILD detector model.

Keywords: Luminosity measurement, four-fermion background, CLIC

I. INTRODUCTION

Four-fermion production via Neutral Current is known to have a large cross-section with maxima at low polar angles. It is dominated by the multiperipheral Feynman diagram (Fig.1) where two virtual photons are exchanged between electron spectators. Spectators remain at high energy, with approximately four of five of them carrying more than 80% of the beam energy. However, about 0.34% of spectators hits the luminosity calorimeter and manifests as a background for Bhabha events. It is interesting to note that the number of spectators is about three times smaller than in the luminometer at ILD [1,2] due to the different position of luminosity detector at CLIC shifted towards higher polar angles in the current geometry CLIC01_ILD [3].

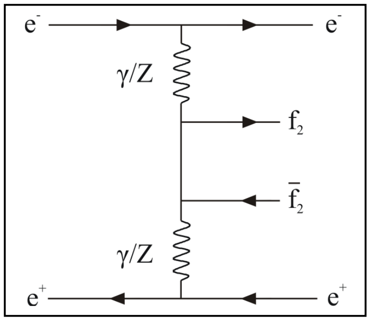

Figure 1. Dominant Feynman diagram for the four-fermion production.

Different event selections have been tested in terms of a physics background rejection power as a possible setup for luminosity measurement.

II. METHOD OF LUMINOSITY MEASUREMENT

At future linear collider, integrated luminosity will be determined from the counted number of Bhabha events reconstructed in the detector fiducial volume N_{exp}, corrected for the number of miss-counted events due to various systematic effects. As shown in (1), the measured luminosity will also depend on the selection efficiency ε and the theoretical cross-section for Bhabha scattering σ_B.

$$L_{\text{int}} = \frac{N_{\text{exp}} - \sum_i N_i^{cor}}{\varepsilon \cdot \sigma_B} \tag{1}$$

Relative uncertainty of the correction N^{cor} will be directly transferred into relative systematic error of luminosity. Since NLO corrections for four-fermion processes are not known at CLIC energies, it can be conservatively assumed that they are of the same order as at LEP [4].

A. Event Selection

In order to exploit the characteristic topology of Bhabha events with two back-to-back showers deposited almost full beam energy in forward and backward arms of the end of the detector, several criteria can be employed:

(a1, a2) Acollinearity of two tracks should be less than (0.1, 0.5) degree in polar angle;

(b.) Acoplanarity of two tracks should be less than 10 degrees in azimuthal angle;

(c.) The total energy deposited in the luminometer must be more than 80% of the center-of-mass energy set at 3 TeV.

(d.) At the same time, in order to minimize the suppression of the Bhabha cross-section due to beam-beam effects, the following empirical selection is applied [5]: the polar angle of the reconstructed shower must be within the detector fiducial volume [θ_{min}, θ_{max}] at one side and within [θ_{min}+4 mrad, θ_{max}-7mrad] at the other. This criterion is subsequently applied at the forward and backward sides of the detector in order to avoid systematic bias from the longitudinal position of the interaction point.

WHIZARD V 1.4 [6] tree-level event generator is used to obtain sample of background events for final states with leptons in the inner legs. Event generator is tuned to reproduce LEP data for charm production in two-photon processes [4] by adjusting the minimal exchanged momentum of the photon to 10^{-4} GeV/c. Background event sample of 0.57 fb^{-1} has been generated in the full physical range, with the cross-section of ($167.8\pm0.7_{stat}$) pb. No PDFs are assumed in the photon description.

Using BHWIDE [7] event generator Bhabha sample of 0.18 fb^{-1} has been generated with the cross-section of ($55.1\pm0.4_{stat}$) pb in the detector geometrical acceptance. Both s and t channel of Bhabha scattering are taken into account, as well as Z^0 exchange.

III. LUMINOMETER AT CLIC

Luminosity calorimeter at CLIC in the geometry model CLIC01_ILD [3] is foreseen as a sampling silicon/tungsten calorimeter consisting of 30 layers of 3.5 mm thick absorber planes followed by 0.3 mm thick segmented silicon sensor planes. To keep the Moliere radius small, 0.1 (0.6) mm gaps are provided for electronics and ceramic support, respectively. Detector is positioned 2.27 m from the interaction point, with the radial aperture [10,35] cm, corresponding to the detector geometrical acceptance of [2.58, 7.73] degrees. Detector fiducial volume determined by the full containment of a shower is covering [2.86,7.45] degrees.

IV. RESULTS

Background suppression as well as signal selection efficiencies are given for different possible event selections (Table 1.). As can be seen, leptonic background at CLIC can be suppressed with respect to the signal at the permile level. This is comparable to the luminosity uncertainty originating from impact of a cell size to the polar angle reconstruction [8]. Signal selection efficiency exhibits somewhat higher values than at ILC [9] due to the fact that luminometer at CLIC is positioned at different slope of Bhabha differential cross-section ($d\sigma_{Bh}/d\theta$). Statistical uncertainties of background to signal ratio are of order of 20%.

V. SUMMARY

Simulation of leptonic sample of four-fermion processes produced at 3 TeV center of mass energy has shown that physics background in luminosity measurement at CLIC can be suppressed with respect to the signal to the permile level. This study should be complemented for the corresponding hadronic processes. As well, effects of luminosity spectrum should be considered.

TABLE I. SIGNAL EFFICIENCY AND BACKGROUND TO SIGNAL RATES FOR DIFFERENT EVENT SELECTIONS

	(c)+(d)	**(b)+(c)**	**(b)+(c)+(d)**	**(a1)+(b)+(c)**	**(a2)+(b)+(c)**
B/S ($x10^{-3}$)	**2.9±0.6**	**2.6±0.5**	**2.7±0.5**	**2.0±0.4**	**2.1±0.4**
Signal efficiency (%)	**75.7**	**91.4**	**75.4**	**71.8**	**84.0**

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