Snowmass2020 Letter of Intent: Interplay of beam polarisation and systematic effects in cTGC measurements

Jakob Beyer[1,2] and Jenny List[1]

[1] *Deutsches Elektronen-Synchroton (DESY), Hamburg, Germany*
[2] *Universität Hamburg, Hamburg, Germany*

August 28, 2020

Abstract

Beam polarisation may provide a simple and direct handle on both physical and systematic effects for any future analysis at high-energy e^+e^- colliders. It is known to help analyses by enhancing the signal and suppressing the background cross sections and to provide access to the chiral structure of any process under study.. Additionally, it is expected to help by isolating polarisation-independent systematic effects. The latter may allow more precise measurements at future colliders by minimizing the systematic uncertainties. This study will look at the impact that beam polarisation has on both physical and systematic effects on the parallel extraction of charged triple gauge couplings, beam polarisations and 2-fermion EW observables in 4-fermion and 2-fermion final states.

Charged triple gauge couplings (cTGCs) are sensitive to BSM physics and a vital input to Higgs coupling fits at future e^+e^- colliders [1]. They can be extracted from fits to differential distributions of four-fermion final states [2].
This study aims to investigate two open question for future high-energy e^+e^- colliders within the context of a cTGC analysis.

1. To which extent do systematic effects impact the extraction of physical parameters?
2. How does the impact of systematic effects change with different beam polarisation setups?

Systematic effects are known to limit the precision of measurements with small statistical uncertainties. Future e^+e^- colliders are planning measurements below the permille level [3–6]. It is vital to such analyses to have systematic influences under control within similar or better precision.
Operation with different polarisation signs can provide redundancy, especially if both beams are polarised [7, 8]. Current collider designs allow the polarisation sign to be flipped on time scales much shorter than changes of typical experimental systematics (e.g. detector alignment, calibration constants, ...) [9]. With such a setup, all data sets taken during the same macroscopic running period are expected to see the same systematic effects. A combined interpretation of data sets with different polarisation sign combinations may then reduce the impact of systematic uncertainties.
To study this effect for the first time in a quantitative way, we consider the extraction of cTGCs and beam polarisation values from four-fermion and two-fermion final states. The relevant physics changes significantly with the incoming particle chirality. Polarisation-independent systematic effects should be especially easy to isolate from polarisation-dependent physical effects if at least one of the beams is polarised. This will be investigated in a likelihood-based fit to differential distributions of four-fermion (WW production, single-W production) and two-fermion ($\mu\mu, \tau\tau, qq(uds, c, b)$) final states.
Some aspects which are planned to be studied are:

- the relevance of systematic effects at different luminosities,
- whether systematic uncertainties are reduced by polarising the beams,
- if there is a dependence of the systematic uncertainties on the absolute beam polarisation amplitudes,
- and how potential biases from external constraints propagate for different beam polarisation setups.

This study will give qualitatively new input to the question of the importance of beam polarisation, and to the impact of systematic uncertainties at linear and circular colliders.

References

[1] Philip Bambade et al. "The International Linear Collider: A Global Project". In: (2019). arXiv: 1903.01629 [hep-ex].

[2] K. Hagiwara et al. "Probing the weak boson sector in e+eW+W". In: *Nuclear Physics B* 282 (1987), pp. 253–307. ISSN: 0550-3213. DOI: https://doi.org/10.1016/0550-3213(87)90685-7. URL: http://www.sciencedirect.com/science/article/pii/0550321387906857.

[3] Aura Rosca. "Measurement of the charged triple gauge boson couplings at the ILC". In: *Nuclear and Particle Physics Proceedings* 273-275 (2016). 37th International Conference on High Energy Physics (ICHEP), pp. 2226–2231. ISSN: 2405-6014. DOI: https://doi.org/10.1016/j.nuclphysbps.2015.09.362. URL: http://www.sciencedirect.com/science/article/pii/S2405601415008512.

[4] Ivan Marchesini. "Triple gauge couplings and polarization at the ILC and leakage in a highly granular calorimeter". PhD thesis. Hamburg U., 2011. URL: http://www-library.desy.de/cgi-bin/showprep.pl?thesis11-044.

[5] Robert Karl. "From the Machine-Detector Interface to Electroweak Precision Measurements at the ILC Beam-Gas Background, Beam Polarization and Triple Gauge Couplings". Dissertation, Universität Hamburg, 2019. Dissertation. Hamburg: Universität Hamburg, 2019, p. 330. DOI: 10.3204/PUBDB-2019-03013. URL: https://bib-pubdb1.desy.de/record/424633.

[6] Jakob Beyer, Robert Karl, and Jenny List. "Precision measurements of Triple Gauge Couplings at future electron-positron colliders". In: *International Workshop on Future Linear Colliders*. Feb. 2020. arXiv: 2002.02777 [hep-ex].

[7] G. Moortgat-Pick et al. "The Role of polarized positrons and electrons in revealing fundamental interactions at the linear collider". In: *Phys. Rept.* 460 (2008), pp. 131–243. DOI: 10.1016/j.physrep.2007.12.003. arXiv: hep-ph/0507011.

[8] Keisuke Fujii et al. "The role of positron polarization for the inital 250 GeV stage of the International Linear Collider". In: (2018). arXiv: 1801.02840 [hep-ph].

[9] L.I. Malysheva et al. "THE SPIN-ROTATOR WITH A POSSIBILITY OF HELICITY SWITCHING FOR POLARIZED POSITRON AT THE ILC *". In: *3rd Linear Collider Forum*. Hamburg: DESY, 2013, pp. 570–576.