This document will become the Polarisation Write-Up[1]

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1 Style for sections

Text

1.1 Triple gauge boson couplings

An important feature of the electroweak Standard Model (SM) is the non-Abelian nature of its gauge group, which gives rise to gauge boson self-interactions, in particular to the triple gauge couplings (TGCs) γWW and ZWW. The most general vertices contain altogether 14 complex parameters [1], six of them CP violating. The SM predicts only four CP conserving real couplings to be non-zero at tree level. A precision measurement of the TGCs at high energies will be a crucial test of the validity of the SM, given that a variety of new physics effects can manifest itself by deviations from the SM predictions (for references see e.g. [2]). Though no deviation from the SM has been found for the TGCs from LEP data [3], the bounds obtained are comparatively weak. The tightest bounds on the anomalous couplings, i.e. on the differences between a coupling and its SM value, are of order 0.05 for Δg_1^Z and λ_γ, of order 0.1 for $\Delta\kappa_\gamma$ and of order 0.1 to 0.6 for the real and imaginary parts of C and/or P violating couplings. These numbers correspond to fits where all anomalous couplings except one are set to zero. Moreover, many couplings, e.g. the imaginary parts of C and P conserving couplings, have been excluded from the analyses so far.

At a future linear e^+e^- collider one will be able to study these couplings with unprecedented accuracy. A process particularly suitable for this is W pair production where both the γWW and the ZWW couplings can be measured at the scale given by the c.m. energy $\sqrt{s}$. In two recent papers the prospects to measure the full set of 28 (real) TGCs in this reaction is systematically investigated for unpolarised beams as well as for longitudinal [2] and transverse [4] beam polarisation. In these two studies optimal observables are used, which are constructed to give the smallest possible statistical errors for a given event distribution [5]. In addition, they take advantage of the discrete symmetries of the

[1] For further informations, see `http://www.ippp.dur.ac.uk/~gudrid/powe/` . For questions and comments, please contact `g.a.moortgat-pick@durham.ac.uk` .

Table 1: 1σ statistical errors in units of 10^{-3} on the real parts of CP conserving TGCs in the presence of all anomalous couplings at $\sqrt{s} = 500$ GeV, with unpolarised beams and with different beam polarisations.

	$\mathrm{Re}\,\Delta g_1^\gamma$	$\mathrm{Re}\,\Delta g_1^Z$	$\mathrm{Re}\,\Delta\kappa_\gamma$	$\mathrm{Re}\,\Delta\kappa_Z$	$\mathrm{Re}\,\lambda_\gamma$	$\mathrm{Re}\,\lambda_Z$	$\mathrm{Re}\,g_5^\gamma$	$\mathrm{Re}\,g_5^Z$
no polarisation	6.5	5.2	1.3	1.4	2.3	1.8	4.4	3.3
$(P_l^-, P_l^+) = (\mp 80\%, 0)$	3.2	2.6	0.61	0.58	1.1	0.86	2.2	1.7
$(P_l^-, P_l^+) = (\mp 80\%, \pm 60\%)$	1.9	1.6	0.40	0.36	0.62	0.50	1.4	1.1
$(P_t^-, P_t^+) = (80\%, 60\%)$	2.8	2.4	0.69	0.82	0.69	0.55	2.5	1.9

differential cross section. In W pair production the covariance matrix of these observables consists of four blocks that correspond to CP even or CP odd TGCs and to their real or imaginary parts. Within each block all correlations between couplings are taken into account.

Table 1 shows the errors on the real parts of CP conserving TGCs at $\sqrt{s} = 500$ GeV with unpolarised beams and with different beam polarisations, assuming an integrated luminosity of 500 fb^{-1}. Here, only those events are considered where one W boson decays into a quark-antiquark pair and the other one into $e\nu$ and $\mu\nu$. It is further assumed that the two jets of the hadronic W decay cannot be identified as originating from the up- and down-type (anti)quark. In the case of longitudinal polarisation the luminosity is distributed equally on both directions of the polarisation vectors and the results are then combined. The errors with unpolarised beams are between 10^{-3} and 10^{-2} in the parameterisation using photon and Z couplings. At 800 GeV all errors (with or without polarisation) are smaller, notably for $\mathrm{Re}\,\Delta\kappa_\gamma$. For both c.m. energies the errors on the couplings in the γ-Z-parameterisation decrease by about a factor 2 when going from unpolarised beams to longitudinal e^- polarisation and an unpolarised e^+ beam. Going from unpolarised beams to polarised e^- and e^+ this factor is between 3 and 4 for all couplings, except for $\mathrm{Re}\,\Delta\kappa_Z$ at 800 GeV where it is 4.7. If both beams have transverse polarisation, the errors on most couplings are approximately of the same size as in the situation where only the e^- beam has longitudinal polarisation. Only for $\mathrm{Re}\,\lambda_\gamma$, $\mathrm{Re}\,\lambda_Z$, $\mathrm{Re}\,\tilde{\lambda}_\gamma$ and $\mathrm{Re}\,\tilde{\lambda}_Z$ are they smaller, viz. they are of the same size as with both beams longitudinally polarised. This is true for both energies. If electron as well as positron polarisation is available we thus conclude that, regarding the 1σ-standard deviations on the TGCs (without assuming any coupling to be zero) *longitudinal* polarisation is the preferable choice, apart from one exception (see below). Note that we are better with longitudinal polarisation also for all CP violating couplings.

It has been emphasized [5] that the following linear combinations [1] can be measured with much smaller correlations than the γ-Z couplings:

$$\begin{aligned} g_1^L &= 4\sin^2\theta_W\, g_1^\gamma + (2 - 4\sin^2\theta_W)\,\xi\, g_1^Z, \\ g_1^R &= 4\sin^2\theta_W\, g_1^\gamma - 4\sin^2\theta_W\,\xi\, g_1^Z, \end{aligned} \tag{1}$$

where $\xi = s/(s - m_Z^2)$, and similarly for the other couplings. The L- and R-couplings respectively appear in the amplitudes for left- and right-handed initial e^-. Therefore this parameterisation seems to be more “natural” in the presence of beam polarisation than the conventional one. For detailed plots showing the sensitivity to the TGCs as a function

Table 2: Same as Table 1, but for the imaginary parts and with the L-R-parameterisation.

	$\mathrm{Im}\, g_1^L$	$\mathrm{Im}\, \kappa_L$	$\mathrm{Im}\, \lambda_L$	$\mathrm{Im}\, g_5^L$	$\tilde{h}_-$	$\tilde{h}_+$	$\mathrm{Im}\, \lambda_R$	$\mathrm{Im}\, g_5^R$
no polarisation	2.7	1.7	0.48	2.5	11	—	3.1	17
$(P_l^-, P_l^+) = (\mp 80\%, 0)$	2.6	1.2	0.45	2.0	4.5	—	1.4	4.3
$(P_l^-, P_l^+) = (\mp 80\%, \pm 60\%)$	2.1	0.95	0.37	1.6	2.5	—	0.75	2.3
$(P_t^-, P_t^+) = (80\%, 60\%)$	2.6	1.2	0.46	2.0	3.7	3.2	0.98	4.4

of the degree of longitudinal polarisation we refer to [2]. There an extended optimal-observable method [6] has been used where correlations between TGCs are eliminated through appropriate energy- and polarisation-dependent reparameterisations.

For the imaginary parts of the CP conserving couplings, see Table 2, we further use the linear combinations $\tilde{h}_\pm = \mathrm{Im}(g_1^R \pm \kappa_R)/\sqrt{2}$ instead of $\mathrm{Im}\, g_1^R$ and $\mathrm{Im}\, \kappa_R$. It has been shown in [2] that $\tilde{h}_+$ is not measurable from the normalised event distribution, neither with unpolarised beams nor with longitudinal polarisation. One can however measure this coupling with *transverse* beam polarisation with good sensitivity. In the γ-Z-parameterisation this means that the four couplings $\mathrm{Im}\, g_1^\gamma$, $\mathrm{Im}\, g_1^Z$, $\mathrm{Im}\, \kappa_\gamma$ and $\mathrm{Im}\, \kappa_Z$ are not simultaneously measurable without transverse polarisation.

Although for most couplings longitudinal polarisation of both beams is the advantageous choice, measurement of the full parameter space requires to spend part of the total luminosity of the collider on the transverse polarisation mode.

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