e^-e^- AS A PROBE FOR ANOMALOUS COUPLINGS OF GAUGE BOSONS

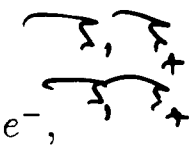


Table 2: A sampling of processes and associated gauge boson couplings measurable at e^-e^-, $\gamma\gamma$, and $e^-\gamma$ colliders.

Process	Couplings probed
$e^-e^- \to e^-\nu W^-$	$WW\gamma$, WWZ
$e^-e^- \to e^-e^-Z$	$ZZ\gamma$, $Z\gamma\gamma$
$e^-e^- \to e^-\nu W^-\gamma$	$WW\gamma$, WWZ
$e^-e^- \to \nu\nu W^-W^-$	$WWWW$
$e^-e^- \to e^-\nu W^-Z$	$WWZZ$
$e^-e^- \to e^-e^-ZZ$	$ZZZZ$
$\gamma\gamma \to W^+W^-$	$WW\gamma$
$\gamma\gamma \to W^+W^-Z$	WWZ, $WW\gamma$
$\gamma\gamma \to ZZ$	$ZZ\gamma$, $Z\gamma\gamma$
$\gamma\gamma \to W^+W^-W^+W^-$	$WWWW$
$\gamma\gamma \to W^+W^-ZZ$	$WWZZ$
$e^-\gamma \to W^-\nu$	$WW\gamma$
$e^-\gamma \to e^-Z$	$ZZ\gamma$, $Z\gamma\gamma$
$e^-\gamma \to W^+W^-e^-$	WWZ, $WW\gamma$, $WWZ\gamma$
$e^-\gamma \to W^-Z\nu$	WWZ, $WW\gamma$, $WWZ\gamma$

THE HIGHER THE ENERGY,
THE FURTHER THE REACH
OF THIS SEARCH

S.M: $g_\gamma = e \quad g_Z = e \cot \theta_W \quad g_1^\gamma = 1$

and we have the tree-level Standard Model values

$$\boxed{\begin{aligned} g_1^Z &= \kappa_\gamma = \kappa_Z = 1, \\ \lambda_\gamma &= \lambda_Z = 0. \end{aligned}} \tag{3.7}$$

The Standard-Model-prescribed values for the κ and λ parameters are best probed in an ensemble of different interactions; a recent study by Choudhury and Cuypers[12] illustrates how the $\gamma(Z)WW$ vertex in the lowest-order graphs (Fig. 5) for the experimentally distinctive process

$$e^-e^- \to e^-\nu_e W^- \tag{3.8}$$

shows sensitivity to changes in the 5-dimensional space spanned by potentially anomalous values of the parameters defined in eq. (3.5). A combined study of results obtained with incoming electron beams of equal and of opposite helicity tests the parameter ranges given in Table 1: in a comparison with other such determinations, it is seen that an NLC e^-e^- collider carries great promise for this mapping of the gauge sector of the Standard Model.

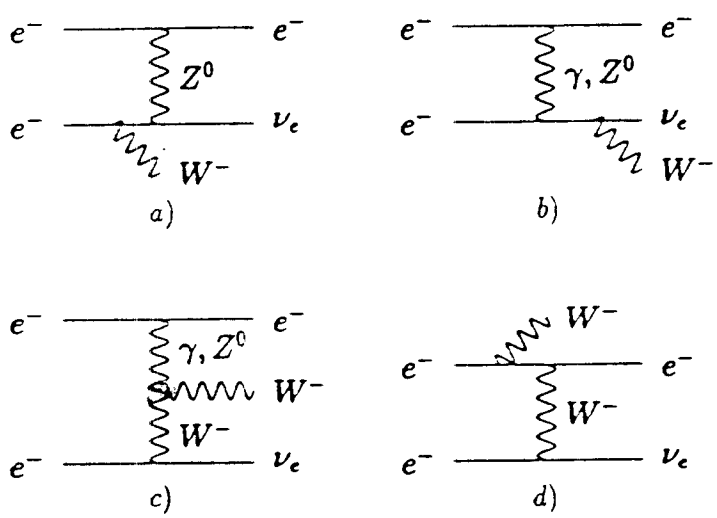


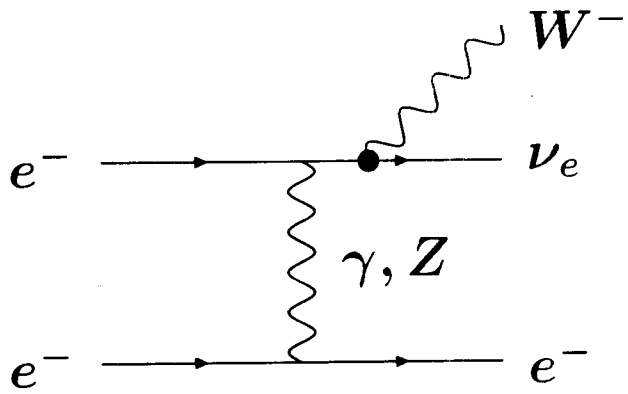
Figure 5: Lowest-order Feynman graphs contributing to the process $e^-e^- \to \nu_e e^- W^-$. Note that only graph c) is sensitive to a potential anomalous boson coupling (from ref. 12).

A subsequent extension of this work to quartic couplings[13] by means of the observation of two-gauge -boson production

$$\begin{aligned} e^-e^- &\to \nu_e\nu_e W^-W^-, \\ &\to e^-e^- ZZ, \\ &\to e^-\nu_e ZW^- \end{aligned} \tag{3.9}$$

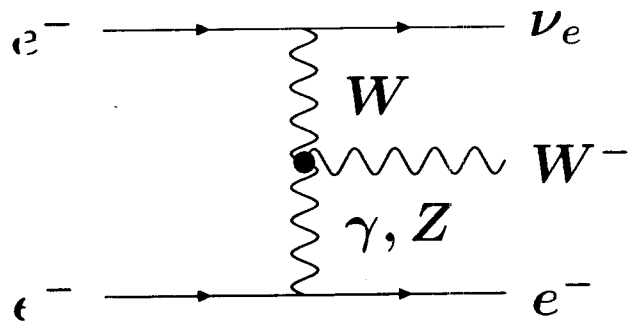
leads to results competitive with e^+e^- NLC capabilities, but does not have the competitive edge of the previous investigation in e^-e^-.

$e^-e^- \to e^-\nu_e W^-$



$+ \cdots$

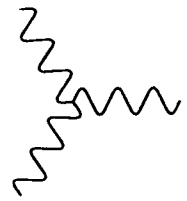
experimentaly well known
from $\mu^- \to e^-\bar{\nu}_e\nu_\mu$



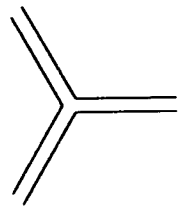
experimentaly unknown

Anomalous couplings:

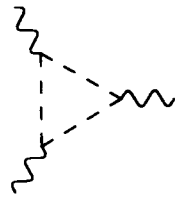
- gauge invariance:



- substructure:



- loops:



COMPLEMENTARITY OF ANOMALOUS GAUGE COUPLING STUDIES

Machine or Experiment	g_Z^1		κ_γ		κ_Z		λ_γ		λ_Z	
	min	max	min	max	min	max	min	max	min	max
UA2			**-3.1**	**4.2**			**-3.6**	**3.5**		
TEVATRON			**-1.3**	**3.2**			**-0.7**	**0.7**		
HERA			0.5	1.5			-2	2		
TEVATRON*			0.5	1.8	0.2		-0.2	0.2	-0.4	0.4
LHC			0.8	1.2	0.8		-0.02	0.02	-0.03	0.03
LEP2			0.86	1.87	0.76		-0.4	0.4	-0.4	0.4
LC500 e^+e^-			0.985	1.14			-0.02	0.04		
LC500 $e\gamma$			0.96	1.04			-0.05	0.05		
LC500 $\gamma\gamma$			0.98	1.015			-0.04	0.065		
LC500 e^-e^-	0.91	1.07	0.985	1.015	0.96	1.04	-0.045	0.075	-0.11	0.06

D. CHOUDHURY