Triple Gauge Couplings at TESLA

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- TGC's at 500 GeV
- TGC's at 1000 GeV
- Polarised Electrons/Positrons

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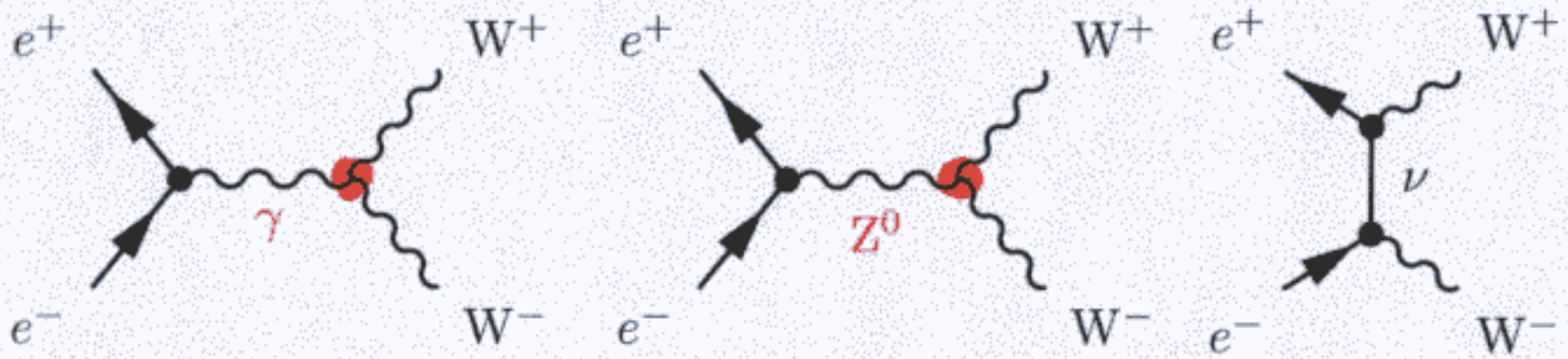
Theory



W-pair production (CC03 diagramms)

$$\frac{\mathcal{L}^{WWV}}{g_{WWV}} =$$

$$ig_1^V V^\mu \left(W^-_{\mu\nu} W^{+\nu} - W^+_{\mu\nu} W^{-\nu}\right) + i\kappa_V W^-_\mu W^+_\nu V^{\mu\nu} + i\frac{\lambda_V}{M_W^2} V^{\mu\nu} W^{+\rho}_\mu W^-_{\rho\nu}$$

$$+ g_5^V \varepsilon^{\mu\nu\rho\sigma} \left[(\partial^\rho W^-_\mu) W^+_\nu - W^-_\mu (\partial^\rho W^+_\nu)\right] V_\sigma$$

$$- g_4^V W^-_\mu W^+_\nu (\partial^\mu V^\nu + \partial^\nu V^\mu) + i\left[\frac{\tilde{\kappa}_V}{2} W^-_\mu W^+_\nu \varepsilon^{\mu\nu\rho\sigma} V_{\rho\sigma} + \frac{\tilde{\lambda}_V}{2M_W^2} W^-_{\rho\mu} W^{+\mu}{}_\nu \varepsilon^{\nu\rho\alpha\beta} V_{\alpha\beta}\right]$$

Couplings

14 couplings in total (7 WWγ, 7 WWZ)

$\Rightarrow$ C, P, CP: 6

$$g_1^\gamma,\ g_1^Z,\ \kappa_\gamma,\ \kappa_Z,\ \lambda_\gamma,\ \lambda_Z$$

$U(1)_Y$ gauge invariance: 5

$$g_1^Z,\ \kappa_\gamma,\ \kappa_Z,\ \lambda_\gamma,\ \lambda_Z$$

$SU(2) \times U(1)_Y$ gauge invariance: 3

$$g_1^Z,\ \kappa_\gamma,\ \lambda_\gamma$$

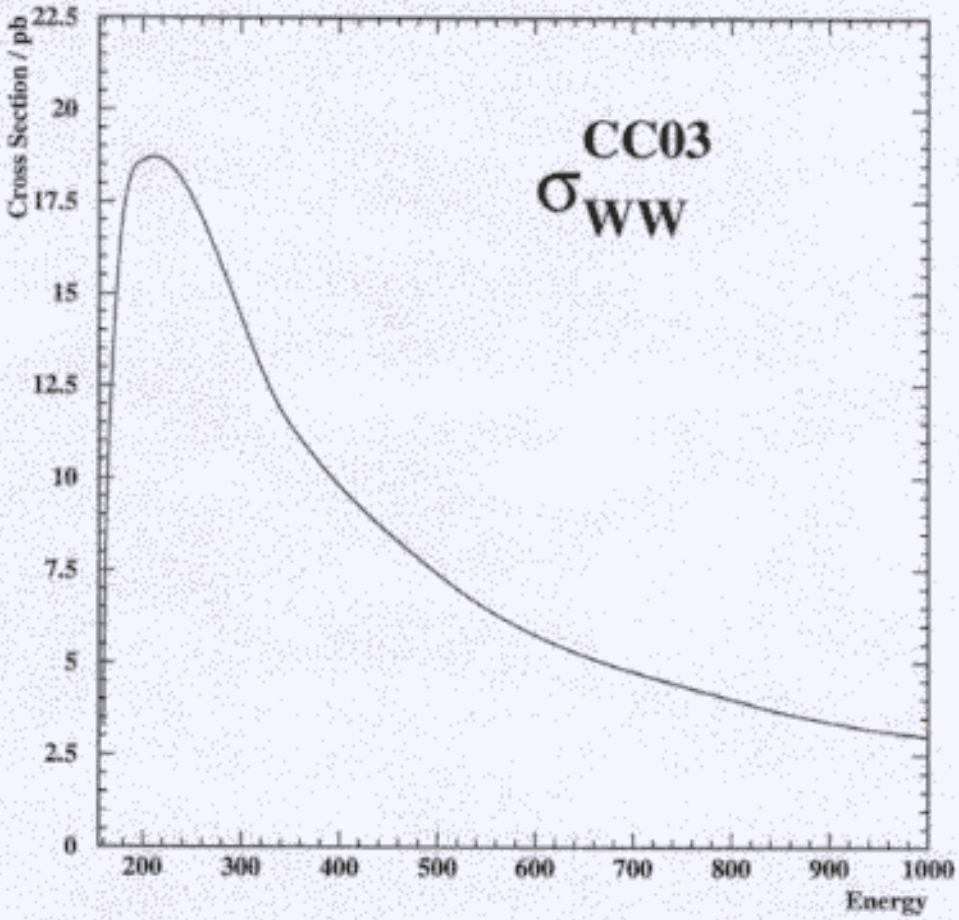
$\Rightarrow$ ~~C~~, ~~P~~, CP: 2

$$g_5^\gamma,\ g_5^Z$$

$\Rightarrow$ ~~CP~~: 6

$$g_4^\gamma,\ g_4^Z,\ \tilde{\kappa}_\gamma,\ \tilde{\kappa}_Z,\ \tilde{\lambda}_\gamma,\ \tilde{\lambda}_Z$$

WW Cross Section

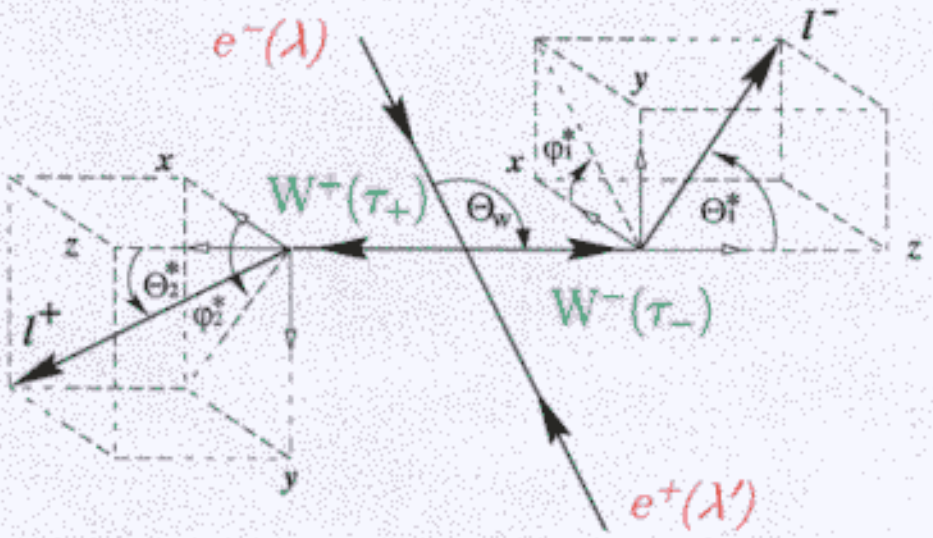


assuming $500\,\mathrm{fb}^{-1}$ we get:

350 GeV	$\approx 11.5\,\mathrm{pb}$	5 750 000 events
500 GeV	$\approx 7.5\,\mathrm{pb}$	3 750 000 events
800 GeV	$\approx 4.0\,\mathrm{pb}$	2 000 000 events
1000 GeV	$\approx 3.0\,\mathrm{pb}$	1 500 000 events

WW Event

Definition of angles:



Event Class:

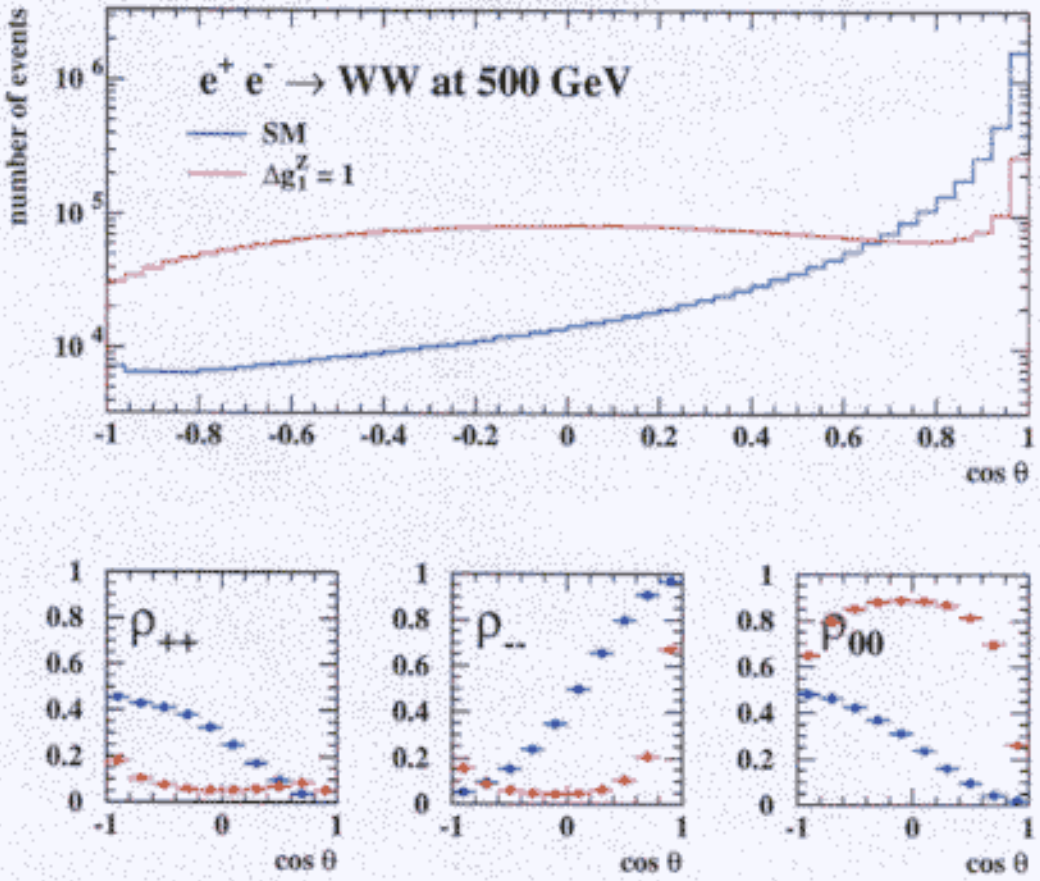
- $q\bar{q}l\bar{\nu}_l$ events (43.4 %, best reconstruction)

Observables:

- $\cos\theta_W$
- decay angles $\cos\theta_l^*, \phi_l^*$, $\cos\theta_j^*, \phi_j^*$

$\Rightarrow$ spin density matrix
(using projection operators)

Observables at 500 GeV



Fit

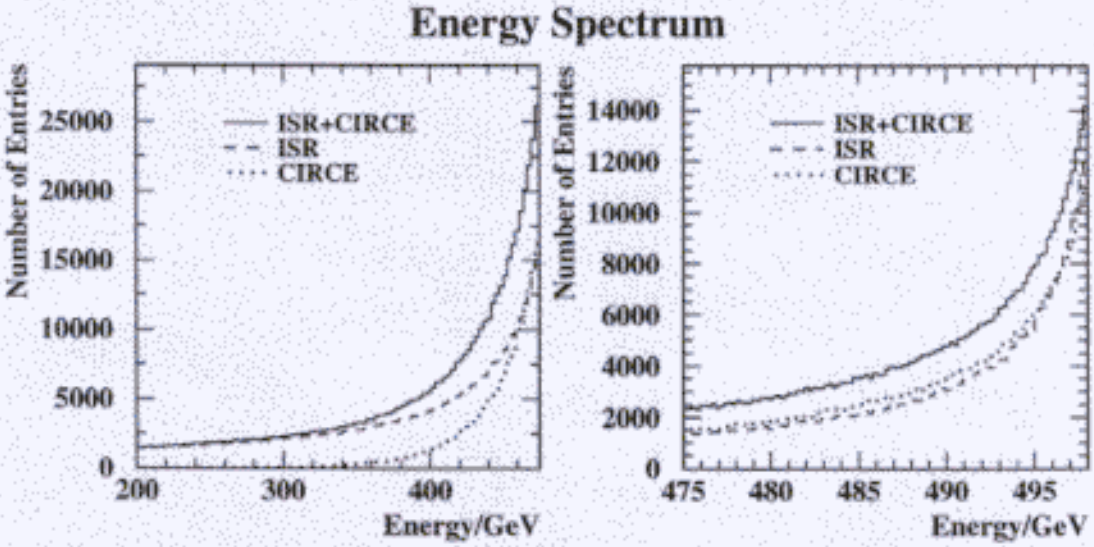
χ^2 fit with MC reweighting

- includes detector effects
- good for 1d, 2d, 3d, ... fits

expected errors (10^{-4}) for 1d fits:

		500 GeV	1000 GeV
$CP(3)$	Δg_1^Z	7.3	6.2
	$\Delta\kappa_\gamma$	5.7	4.2
	λ_γ	6.1	3.4
$CP(5)$	Δg_1^Z	38.1	55.8
	$\Delta\kappa_\gamma$	4.8	3.6
	λ_γ	12.1	6.1
	$\Delta\kappa_Z$	8.7	6.5
	λ_Z	11.5	6.2
~~C,P,CP~~	g_5^Z	27.7	41.4
~~CP~~	g_4^Z	85.8	40.1
	$\tilde{\kappa}_Z$	64.9	30.5
	$\tilde{\lambda}_Z$	11.4	5.3

Systematics
ISR & Beamstrahlung



very simple test:

- switch off ISR in "data", leave reweighting MC unchanged
- switch off beamstrahlung in "data", leave reweighting MC unchanged

ISR:

- 500 GeV: biases of $\mathcal{O}(100 * stat.error)$
- 1000 GeV: biases of $\mathcal{O}(25 * stat.error)$

$\Rightarrow$ need to understand to better than 1 %

Beamstrahlung:

- 500 GeV: biases of $\mathcal{O}(10 * stat.error)$
- 1000 GeV: biases of $\mathcal{O}(5 * stat.error)$

$\Rightarrow$ need to understand to better than 10 %

Systematics
M_W & Beam Energy

- change M_W by $\pm 50\,\text{MeV}$ in "data", leave reweighting MC unchanged
- change E_{beam} by $\pm 2 \times 10^{-4} E_{beam}$ in "data", leave reweighting MC unchanged

systematic error from M_W:

	CP(3)	CP(5)	~~CP~~
500 GeV	14 %	20 %,	10 %
1000 GeV	10 %	8 %,	5 %

systematic error from E_{beam}:

	CP(3)	CP(5)	~~CP~~
500 GeV	12 %	10 %,	6 %
1000 GeV	5 %	3 %,	2 %

Polarisation

Polarised electrons and positrons helps

- to switch off the t-channel ν exchange
- to disentangle the WWZ- and WWγ-vertex

Idea:

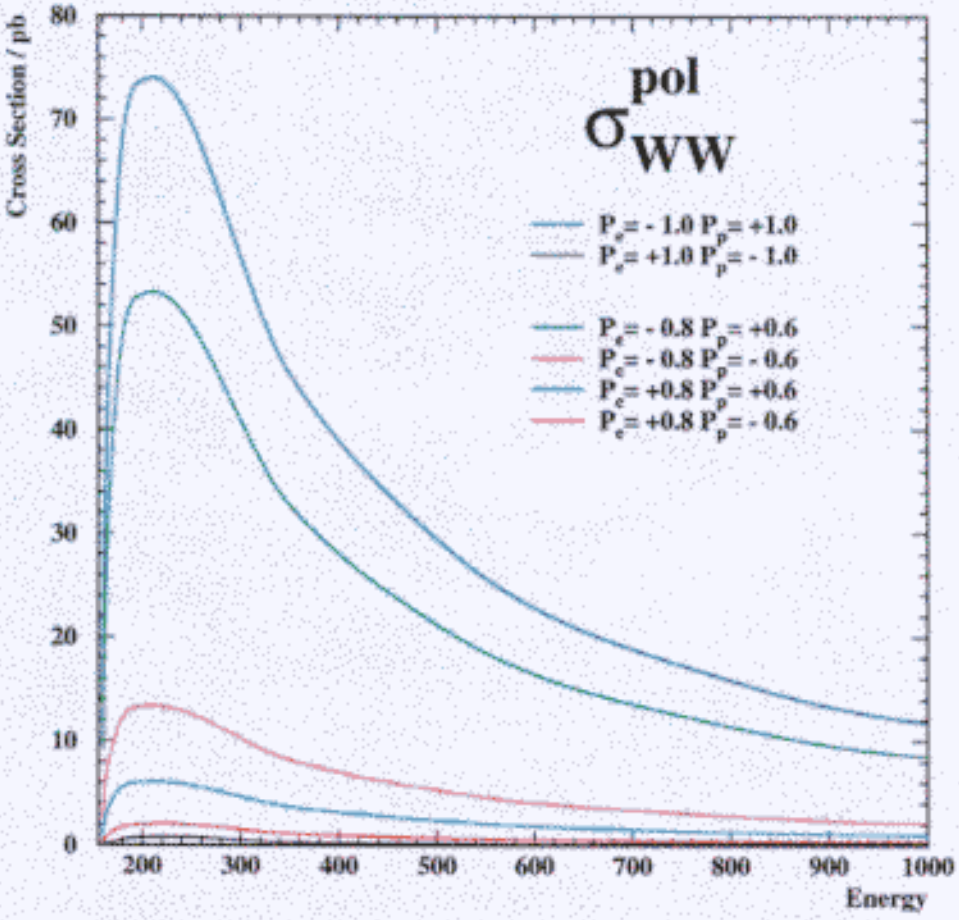
LR:

RL:

Questions:

- how much gain we with $P_{e^-} = 80\,\%$ and $P_{e^+} = 60\,\%$?
- can we fit for 5 parameters simultaneously?

Cross Section



$250\,\mathrm{fb}^{-1}$ at 500 GeV

RL (+1.0/-1.0)	0.2 pb	→	50 000 events
LR (-1.0/+1.0)	32.2 pb	→	8 050 000 events
RL (+0.8/-0.6)	0.8 pb	→	200 000 events
LR (-0.8/+0.6)	23.1 pb	→	5 775 000 events

⇒ increase of statistics

⇒ more WWZ/WWγ vertex

~~Results~~

First look at 500 GeV!

	Δg_1^Z	$\Delta\kappa_\gamma$	λ_γ
$P_{e^-}=0.0$, $P_{e^+}=0.0$ 500 fb^{-1}	7.3	5.7	6.1
$P_{e^-}=0.8$, $P_{e^+}=-0.6$ (RL) 250 fb^{-1}	4.0	3.4	3.4
$P_{e^-}=-0.8$, $P_{e^+}=0.6$ (LR) 250 fb^{-1}	3.7	7.9	4.8
$P_{e^-}=0.8$, $P_{e^+}=-0.6$, 250 fb^{-1} $P_{e^-}=-0.8$, $P_{e^+}=0.6$, 250 fb^{-1}	4.7	4.3	8.6

SU(2)xU(1)

$\times 10^{-4}$

Outlook

We expect errors in the order of 10^{-3} to 10^{-4}!
Systematics look okay!

Some work has still to be done:

- detector simulation
  (previous studies showed no problems)
- selection efficiencies
  (LEP: $80 - 90\,\%$, safety margin through σ)
- Polarisation
- ...