Charged Triple Gauge Coupling at LEP

$WW\gamma$ – WWZ and W polarisation

S. Jézéquel
LAPP-Annecy
IN^2P^3/CNRS-Université de Savoie

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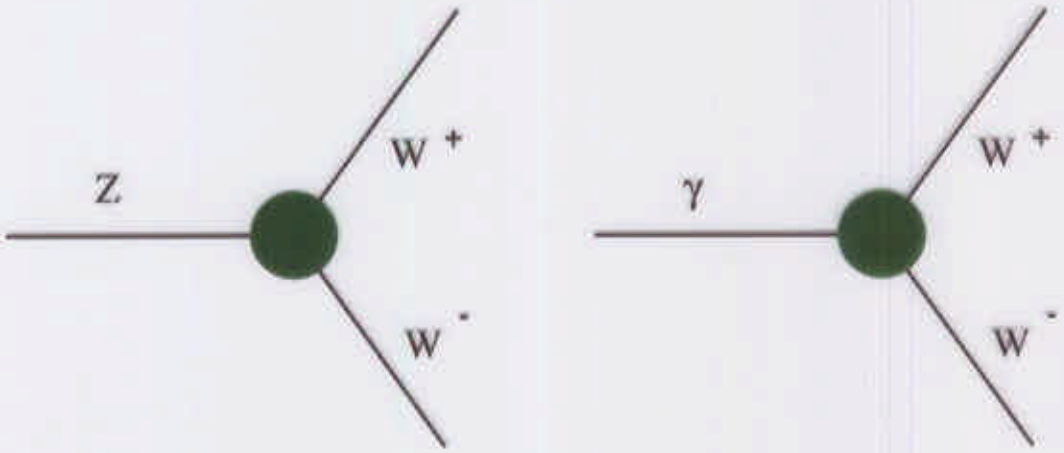
Outline

- Bases on Charged bosons Triple Gauge Couplings ($WW\gamma$ and WWZ)
- Standard analysis
  - W^+W^- channel
  - Single W channel
- Combinations of TGC results (LEP=ADLO)
- W polarisation
- Conclusion

Properties of Triple gauge couplings



- Due to the non-abelian nature of the $SU(2)_L \times U(1)_Y$
- The most general Lagrangian of interactions between WWV (V=Z or γ) contains 2×7 terms

$$\frac{i\mathcal{L}_{eff}^{WWV}}{g_{WWV}} = \left[\begin{array}{lll}
g_V^1 & V^\mu(W^-_{\mu\nu}W^{+\nu} - W^+_{\mu\nu}W^{-\nu}) + & C,P \\
\kappa_V & W^+_\mu W^-_\nu V^{\mu\nu} + & C,P \\
\lambda_V & \frac{1}{M_W^2} V^{\mu\nu} W^{+\rho}_\nu W^-_{\rho\mu} + & C,P \\
ig_V^5 & \epsilon_{\mu\nu\rho\sigma}((\partial^\rho W^{-\mu})W^{+\nu} - W^{-\mu}(\partial^\rho W^{-\nu}))V^\sigma + & \not{C},\not{P} \\
ig_V^4 & W^-_\mu W^+_\nu(\partial^\mu V^\nu + \partial^\nu V^\mu) - & \not{C}\not{P} \\
\tilde{\kappa}_V & \frac{1}{2} W^-_\mu W^+_\nu \epsilon^{\mu\nu\rho\sigma} V_{\rho\sigma} - & \not{C}\not{P} \\
\tilde{\lambda}_V & \frac{1}{2M_W^2} W^-_{\rho\mu} W^{+\mu}_\nu \epsilon\nu\rho\alpha\beta V_{\alpha\beta} & \not{C}\not{P}
\end{array}\right]$$

- Most constrained analysis (C,P and CP conservation , $U(1)_{em}$, $SU(2)_L \times U(1)_Y$) $\Rightarrow$ 3 terms :

$$\boxed{\Delta g_1^Z = g_1^Z - 1 \qquad \Delta\kappa_\gamma = \kappa_\gamma - 1 \qquad \lambda_\gamma}$$

Equal to zero in the S.M.

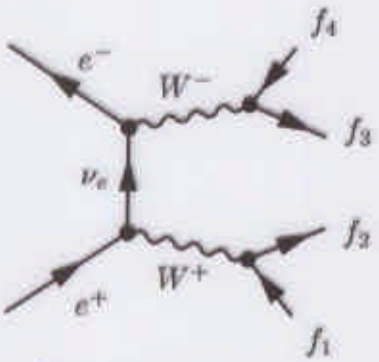
- All other couplings are fixed to S.M. except the 2 constrained ones (assuming $SU(2)_L \times U(1)_Y$ gauge symmetry) :

$$\Delta\kappa_Z = \Delta g_1^Z + \Delta\kappa_\gamma \tan^2\theta_w \quad ; \quad \lambda_Z = \lambda_\gamma$$

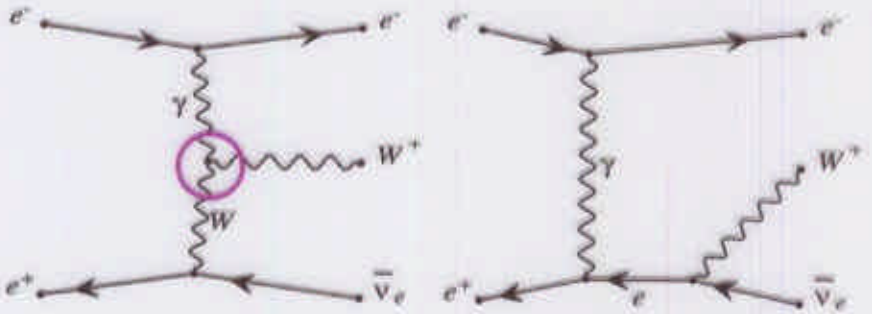
Properties of triple gauge couplings of W (2)

TGCs can be measured through the following processes :

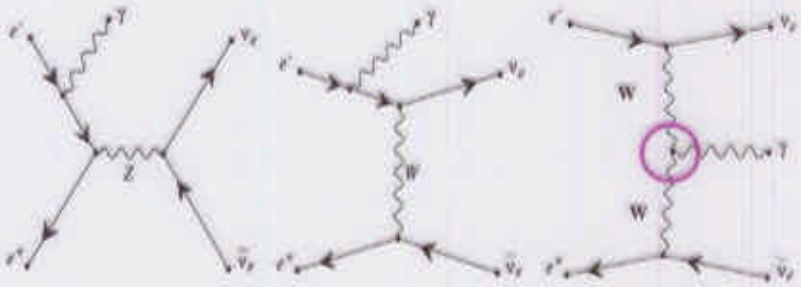
- $e^+e^- \to W^+W^- \to 4$ fermions (Δg_1^Z, $\Delta\kappa_\gamma$ and λ_γ)



- $e^+e^- \to We\nu_e$ ($WW\gamma$ alone : $\Delta\kappa_\gamma$, λ_γ)

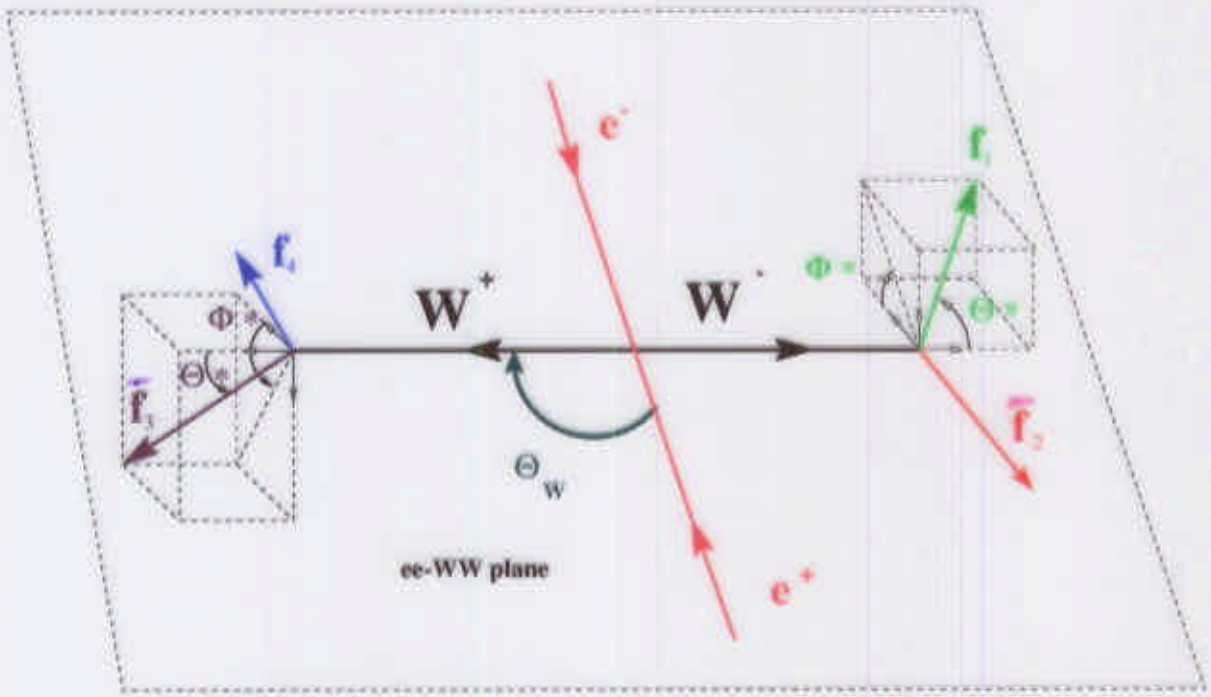


- $e^+e^- \to \nu_e\bar{\nu}_e\gamma$ ($WW\gamma$ alone : $\Delta\kappa_\gamma$, λ_γ)



- WW Selection : Same as cross section restricted to well measured four fermion events

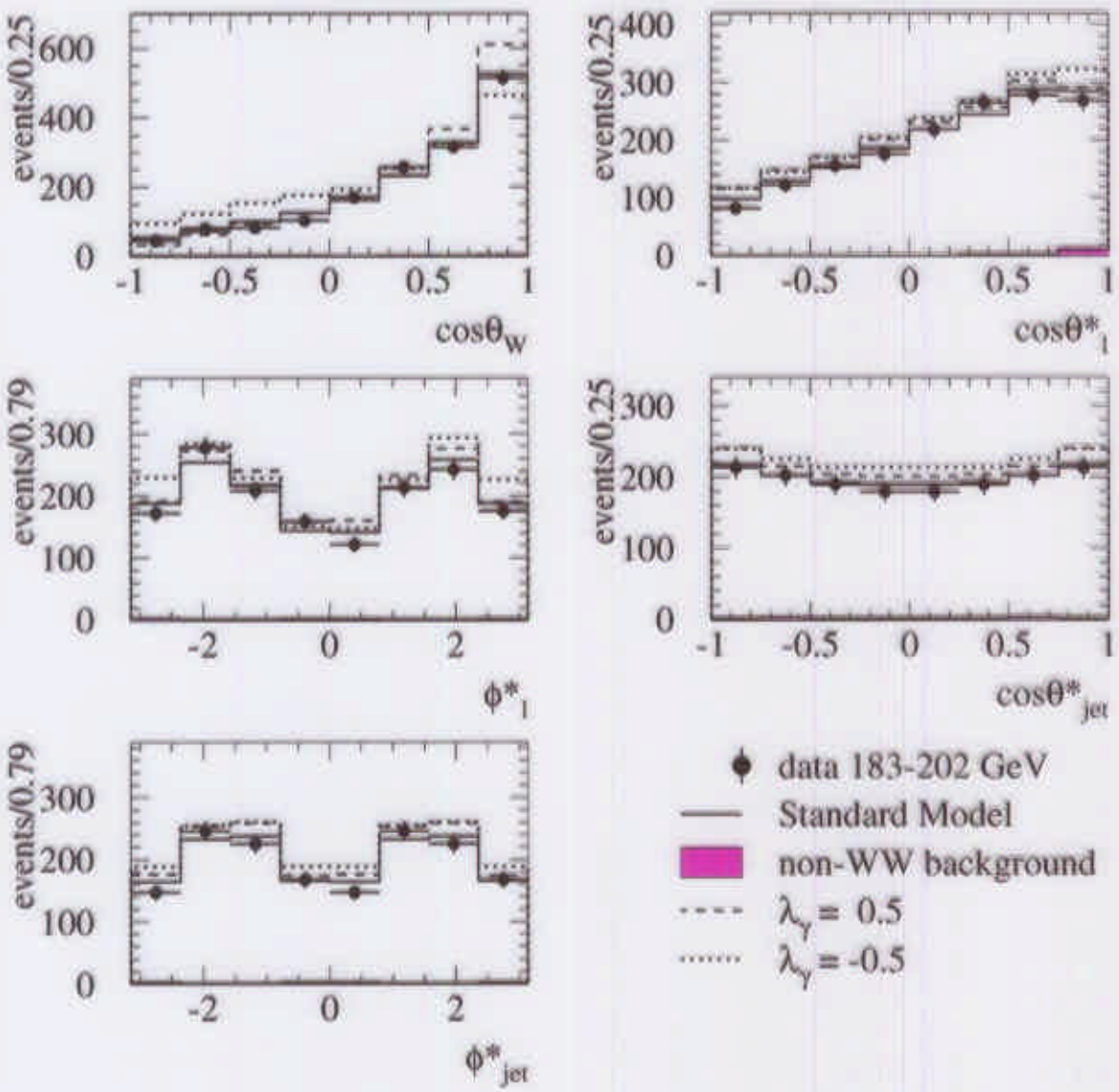
▹Kinematic information



- Electrical charge and flavor of individual jet is unknown ⇒ Folded
- $WW \to l\nu qq$: W_1 axis defined by the dijet axis and W_2 charge defined by lepton charge
- $WW \to qqqq$: Pairing of jets (~ 80% efficiency) ⇒ W_1/W_2 charge estimated from $Q(W_1)$-$Q(W_2)$ (~ 80% efficiency)
- $WW \to l^+\nu l^-\bar{\nu}$: 2 possible solutions for neutrinos (or Ws) which are folded

▹Cross section : Add sensitivity

Triple gauge couplings of WW events : Example of angle distributions



- Angular information

– Problem : Extract the most precise measurement of one/many couplings out of 5 (or less) angles

– Solution 1 : Unbinned likelihood method

▷ALEPH $(e/\mu)\nu qq$: PDF from calculation + detector resolution function

▷L3 : PDF from simulated events

– Solution 2 : Optimal Observables :

Project 5 kinematic variables onto 1 (2) parameter per TGC coupling

$$\mathcal{O}_i^1 = S_i^1(\Omega)/S^0(\Omega) \text{ and } \mathcal{O}_{ij}^2 = S_{ij}^2(\Omega)/S^0(\Omega)$$

with

$$d\sigma(\Omega,\alpha) = S^0(\Omega) + \sum_i \alpha_i . S_i^1(\Omega) + \sum_{ij} \alpha_i \alpha_j S_{ij}^2(\Omega)$$

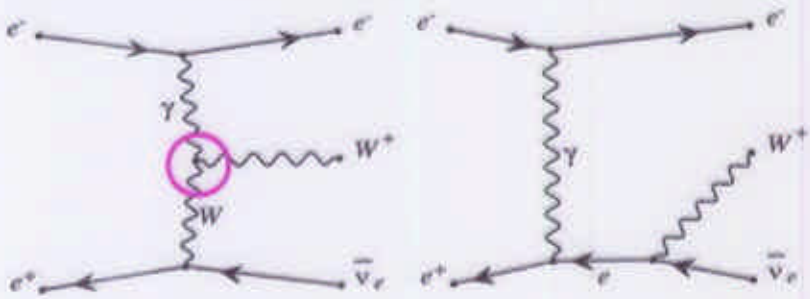
▷Binned maximum likelihood fit to $\mathcal{O}_i^1$ and $\mathcal{O}_{ij}^2$ (DELPHI)

▷χ^2 fit to $\mathcal{O}_i^1$ and $\mathcal{O}_{ij}^2$ averages (OPAL)

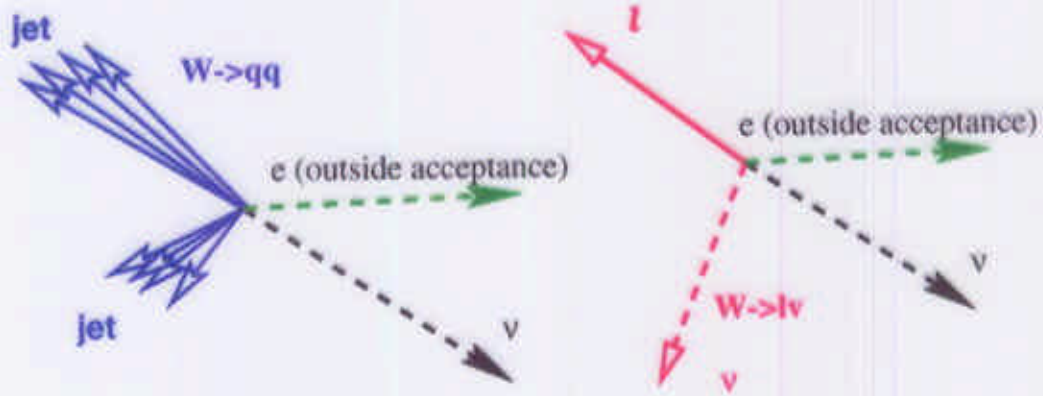
▷χ^2 fit to $\mathcal{O}_i^1$ and $\mathcal{O}_{ij}^2$ averages (ALEPH)

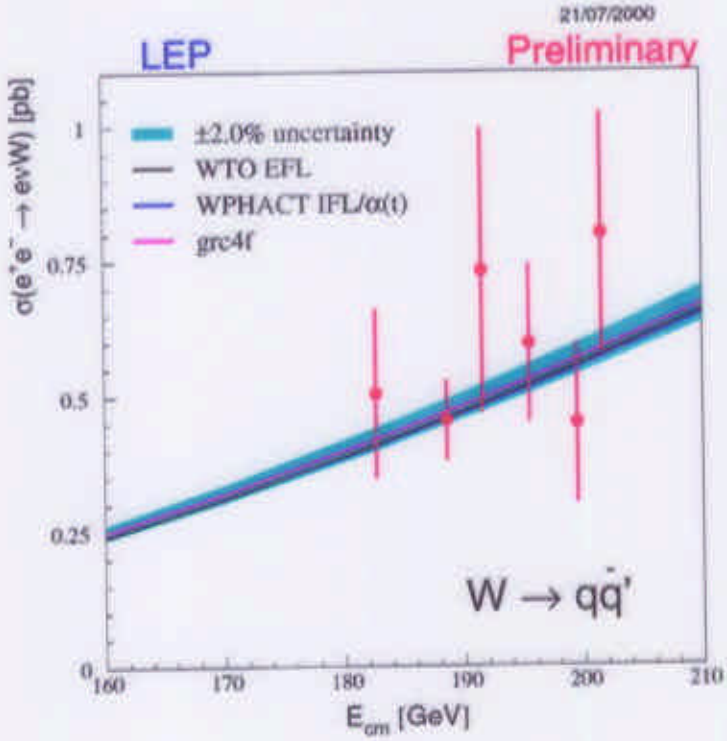
- Cross Section : Adjust expected cross section from simulation to the number of observed data

Cross-Section of single W events (Wev)



Many
s and t channels





WW = Main background

Aleph @ 183-202 GeV

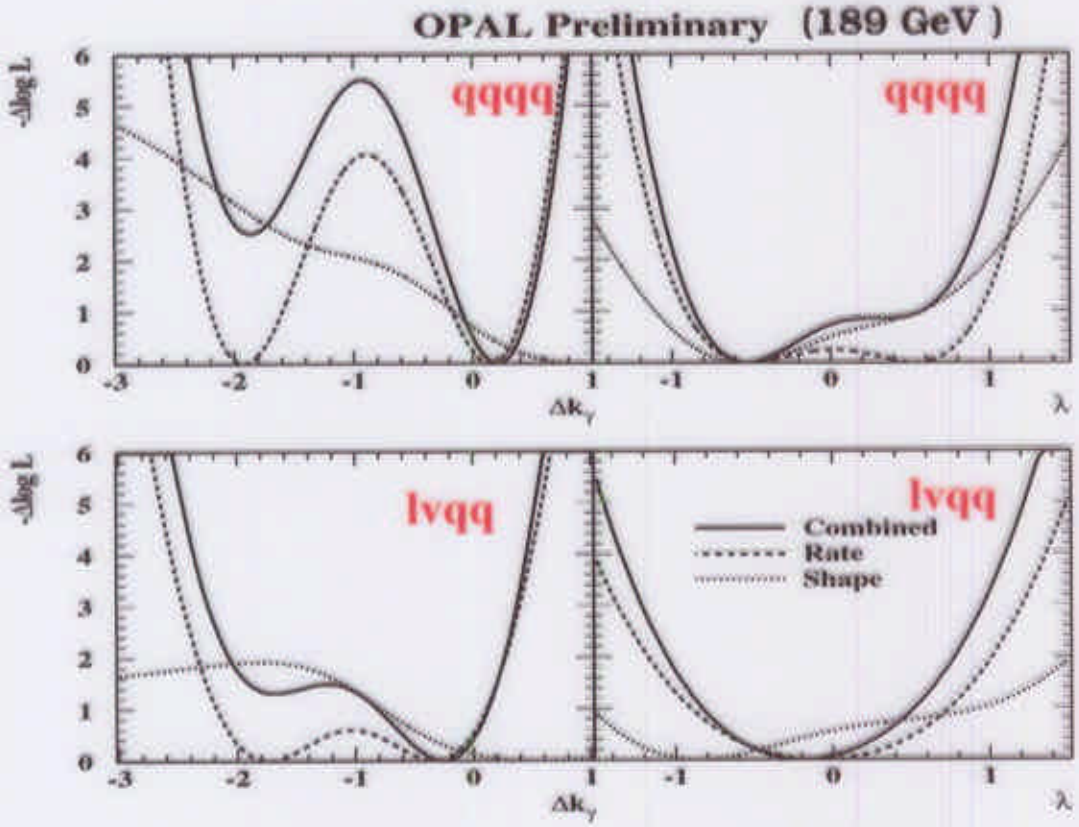
L3 @ 189-202 GeV

Delphi @ 189-202 GeV

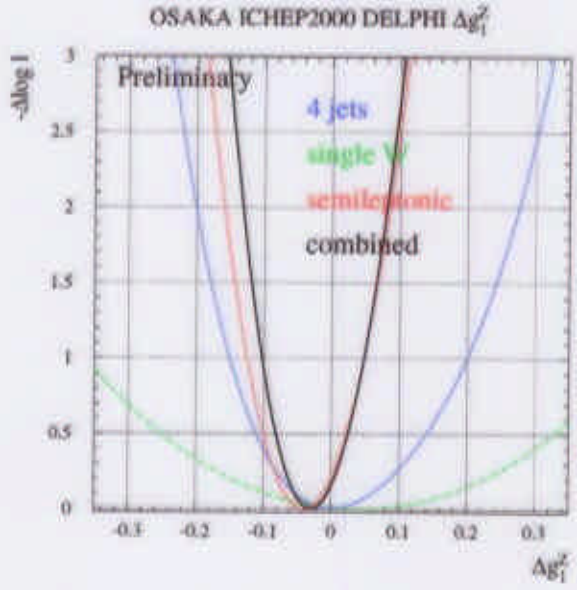
Opal @ 189 GeV

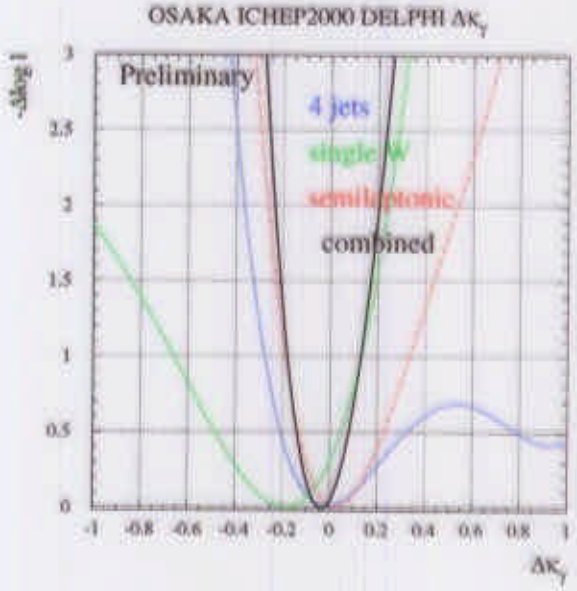
W couplings of single W events

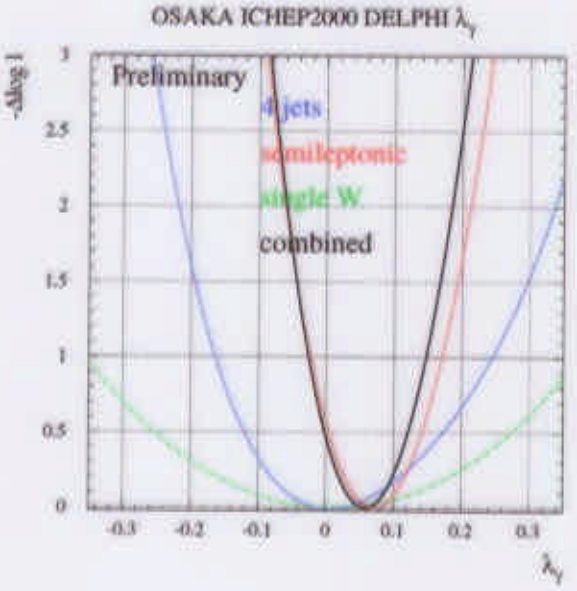
- Sensitivity to $WW\gamma$ alone $\Rightarrow$ Sensitive to $\Delta\kappa_\gamma$ and λ_γ
- Main sensitivity through cross section
- the double minima structure is removed with the kinematic information
  - Pt_W (ALEPH)
  - $(Pt_W, |\cos\theta_{jet1} - \cos\theta_{jet2}|)$ for W$\rightarrow$ 2 jets (OPAL)
  - $(E_l, \cos\theta_l)$ for W$\rightarrow$ $l\nu$ (OPAL)



Combination of channels : 1D







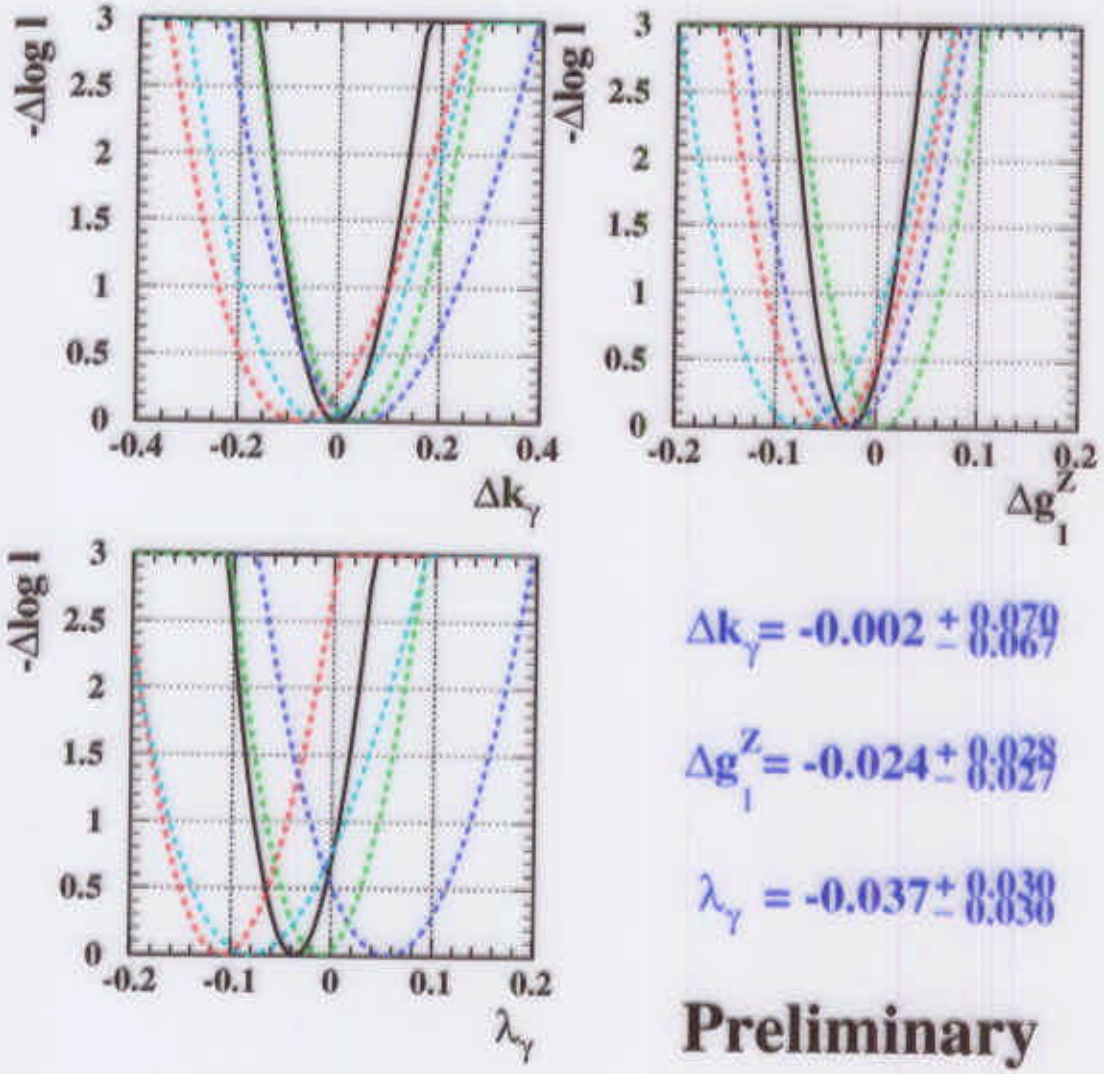
Delphi

192-202 GeV data

▷WW and single W (LEP2 → 202 GeV in 99)

(Except Single-W from OPAL for 192-202 GeV data)

ALEPH + DELPHI + L3 + OPAL



$\Delta k_\gamma = -0.002 \pm 0.079 \pm 0.067$

$\Delta g_1^Z = -0.024 \pm 0.028 \pm 0.027$

$\lambda_\gamma = -0.037 \pm 0.030 \pm 0.030$

Preliminary

Systematic source	Δg_1^Z	$\Delta\kappa_\gamma$	λ_γ
σ (WW) (± 2%)	± 0.012	± 0.055	± 0.014
Fragmentation	± 0.013	± 0.051	± 0.014
Color Reconnection	± 0.003	± 0.012	± 0.005
Bose-Einstein effect	± 0.006	± 0.020	± 0.006
σ (Weν) ± 5%)	-	± 0.049	± 0.067