Measurement of Trilinear Gauge Couplings of the W Boson at LEP

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on behalf of the

L3 Collaboration

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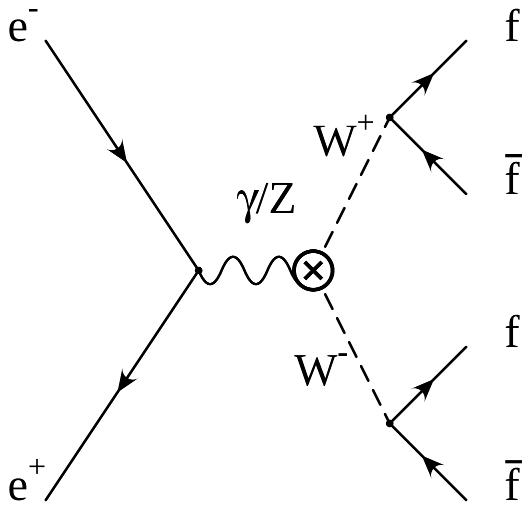
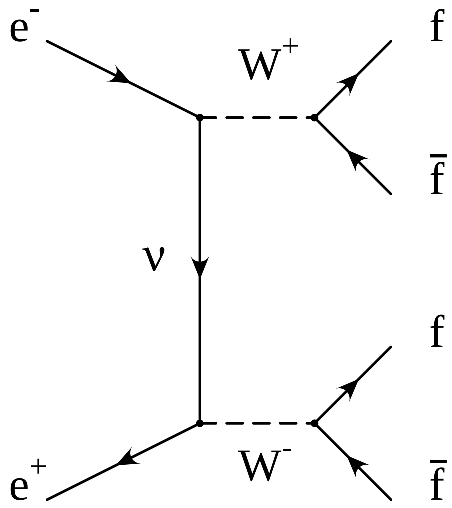
$$ee \rightarrow WW \rightarrow ffff$$

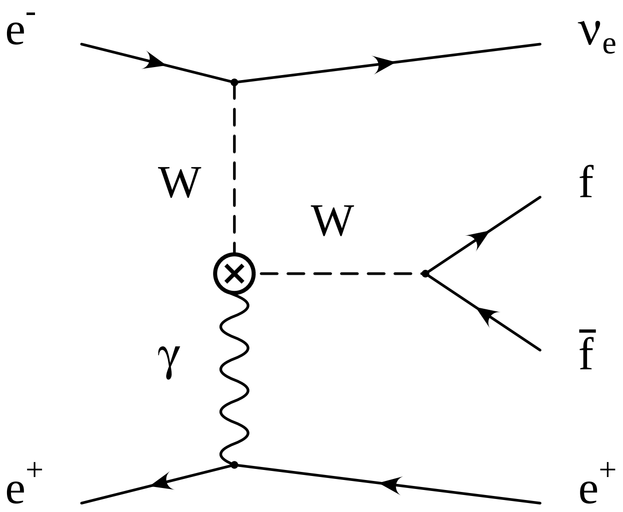




final states: $qqqq,\ qql\nu,\ l\nu l\nu$

events: $\sim 3500\ (\sqrt{s} = 161 - 189\ \mathrm{GeV}\ )$

$$ee \rightarrow We\nu \rightarrow e\nu ff$$



final states: $(e\nu)qq,\ (e\nu)l\nu$

events: $\sim 100\ (\sqrt{s} = 130 - 189\ \mathrm{GeV}\ )$

Triple Gauge Boson Couplings

General effective Lagrangian ($V = \gamma, Z$):

$$
\begin{aligned}
i\mathcal{L}_{eff}^{WWV} = g_{WWV}[\\
& g_1^V V^\mu (W_{\mu\nu}^- W^{+\nu} - W_{\mu\nu}^+ W^{-\nu}) + \\
& \kappa_V W_\mu^+ W_\nu^- V^{\mu\nu} + \\
& \frac{\lambda_V}{m_W^2} V^{\mu\nu} W_\nu^{+\rho} W_{\rho\mu}^-]
\end{aligned}
$$

with $g_{WW\gamma} = e$, $g_{WWZ} = e \cot\theta_W$

- C, P violating terms not considered
- SM: $g_1^Z = g_1^\gamma = \kappa_Z = \kappa_\gamma = 1$, all other vanish
- electromagnetic gauge invariance: $g_1^\gamma = 1$
- $SU(2) \times U(1)$ gauge invariance: $\Delta\kappa_Z = \Delta g_1^Z - \Delta\kappa_\gamma \tan^2\theta_W$
  $\lambda_Z = \lambda_\gamma$
- convenient to introduce

$$
\begin{aligned}
\Delta g_1^Z &\equiv (g_1^Z - 1) \\
\Delta\kappa_\gamma &\equiv (\kappa_\gamma - 1) \\
\lambda_\gamma &\equiv \lambda_\gamma
\end{aligned}
$$

- Total cross section is coupling Ψ dependent

  $\Rightarrow$ log likelihood fit:

$$\ln \mathcal{L} = \sum_{channels} \ln \left(\frac{\mu_i(\Psi)^{N_i^{data}} e^{-\mu_i(\Psi)}}{N_i^{data}!} \right)$$

  with the expected number of events μ_i.

- Differential cross section is coupling Ψ dependent

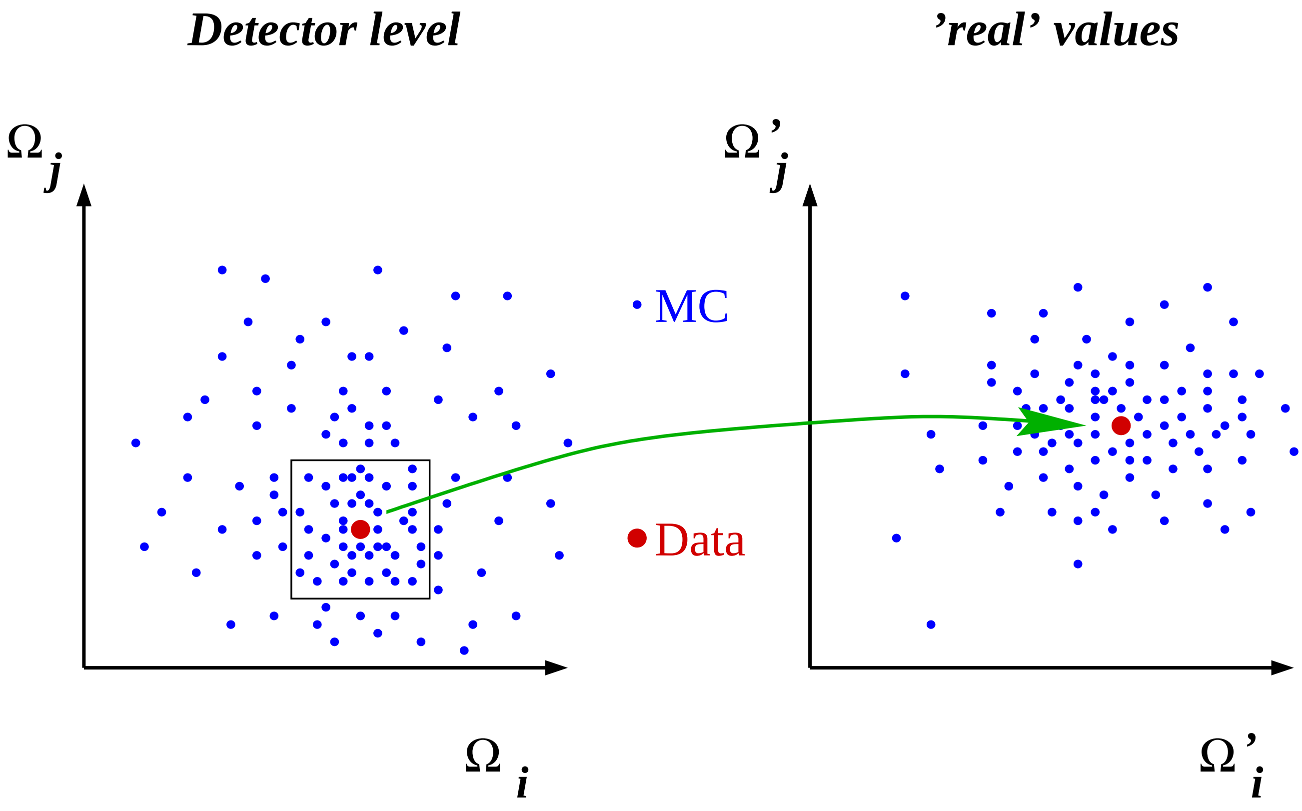
  $\Rightarrow$ unbinned log likelihood fit:

$$\ln \mathcal{L}_{channel} = \sum_{events} \ln \left(\frac{1}{\sigma(\Psi)} \frac{d\sigma(\Omega_i, \Psi)}{d\Omega} \right)$$

  with phase space angles Ω after kinematic fit.

Detector effects ⇒ Box method:

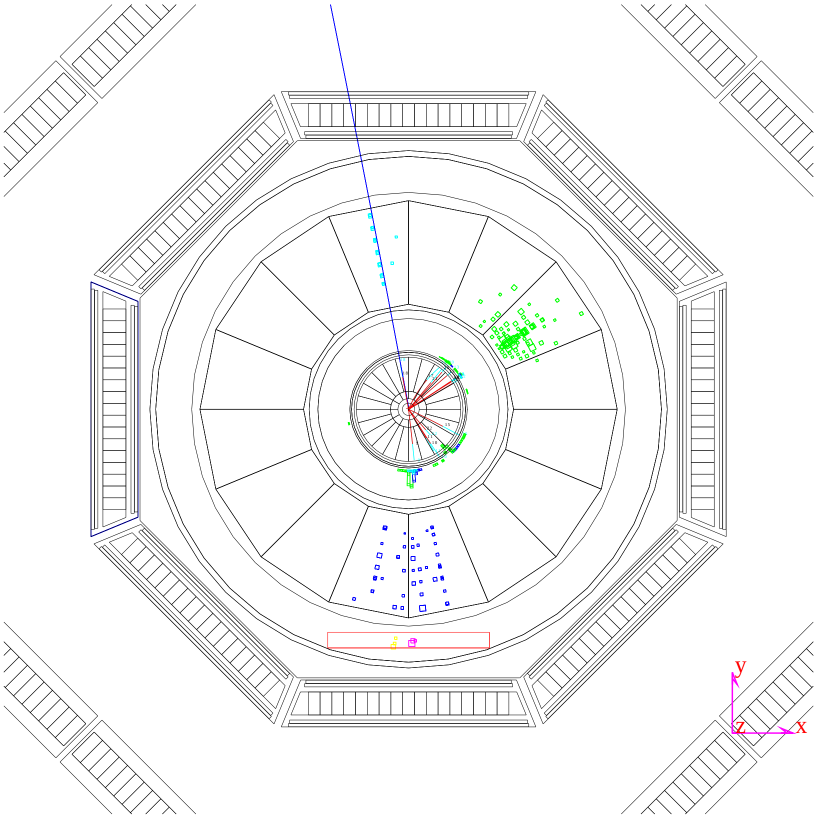
$$\frac{d\sigma(\Omega, \Psi_{fit})}{d\Omega} = \frac{\sigma_{MC}}{N_{MC}} \frac{1}{\Delta\Omega} \sum R_i(\Omega_i, \Psi_{fit}, \Psi_{gen})$$



Reweighting:

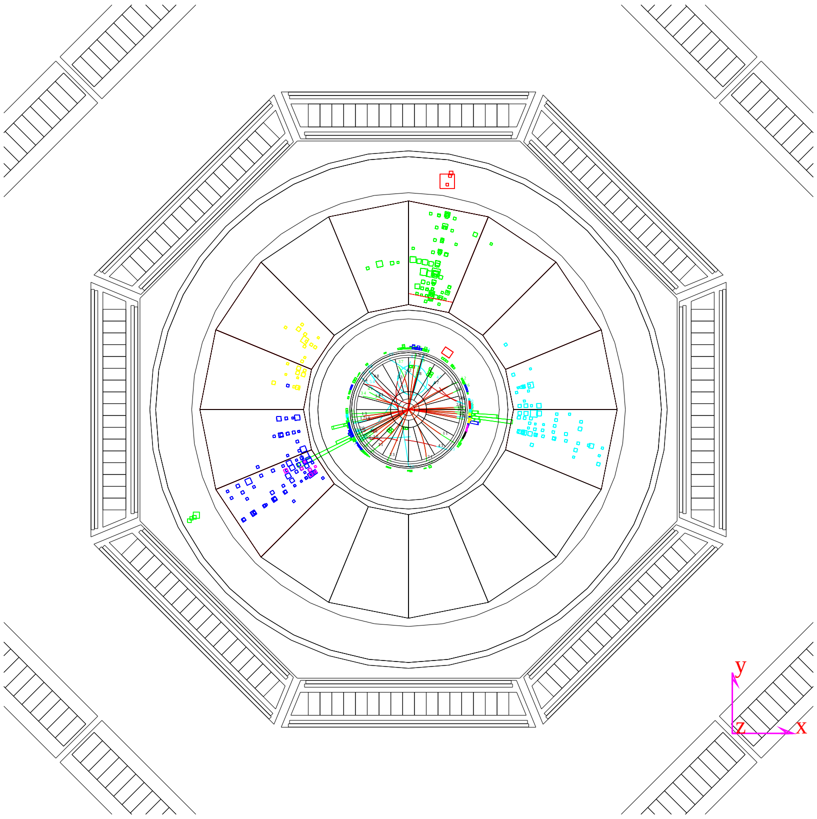
$$R_i(\Omega, \Psi_{fit}, \Psi_{gen}) = \frac{|\mathcal{M}(\Omega, \Psi_{fit})|^2}{|\mathcal{M}(\Omega, \Psi_{gen})|^2}$$

$ee \rightarrow WW \rightarrow ffff$



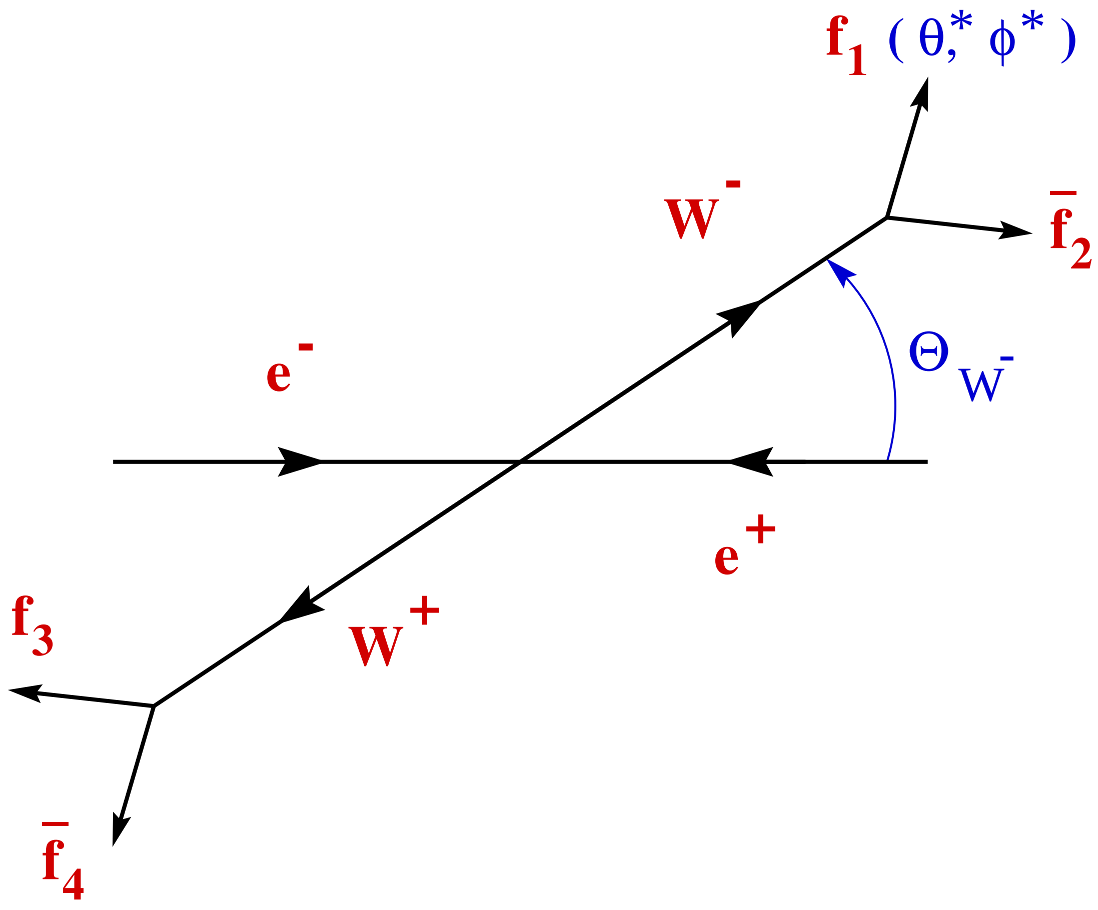
$qq\mu\nu$

$qqqq$

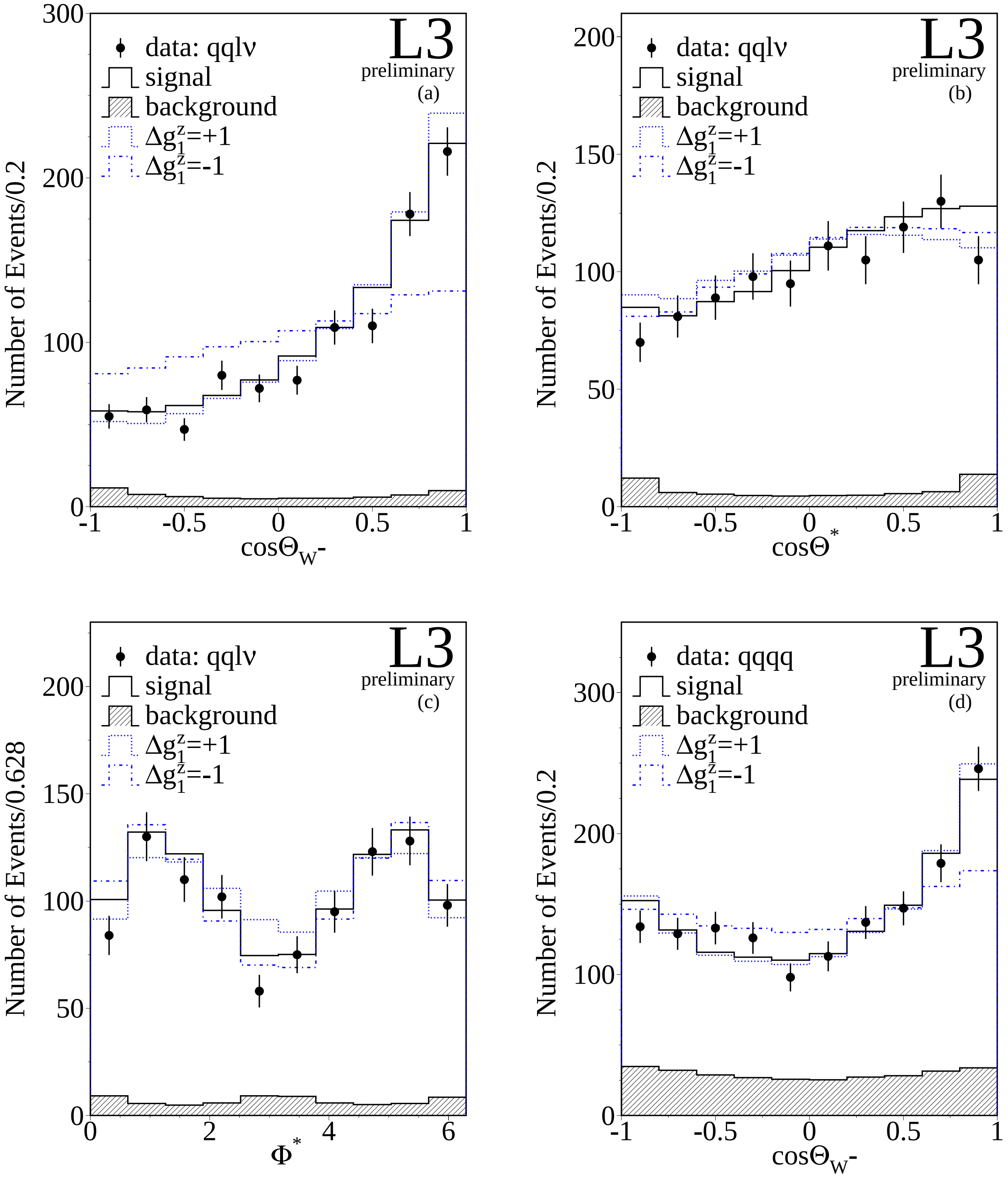


Measured Quantities used

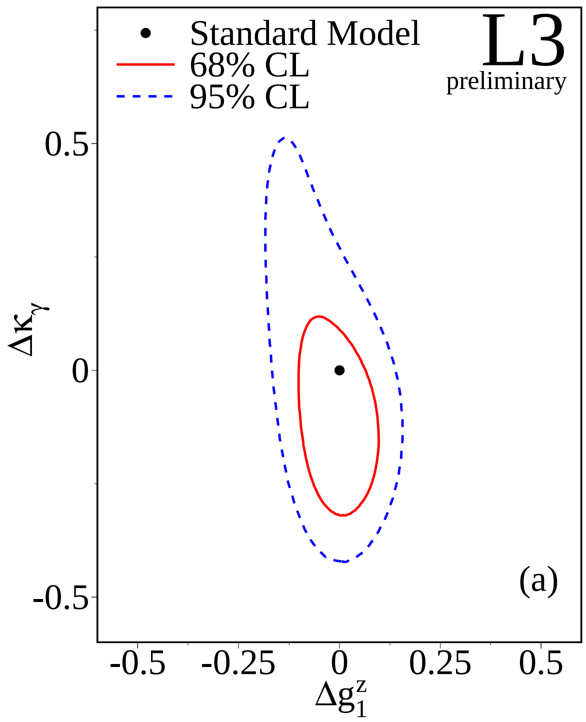
- **Total cross section:** measured number of events in each channel, including $l\nu l\nu$
- **Differential cross section:** angular information
  - $WW \to q\bar{q}q\bar{q}$: $\Omega = \{\cos\theta_{W^-}\}$
  - $WW \to q\bar{q}l\nu$: $\Omega = \{\cos\theta_{W^-},\ \cos\theta_l^*,\ \phi_l^*\}$
  - $WW \to l\nu l\nu$: not used

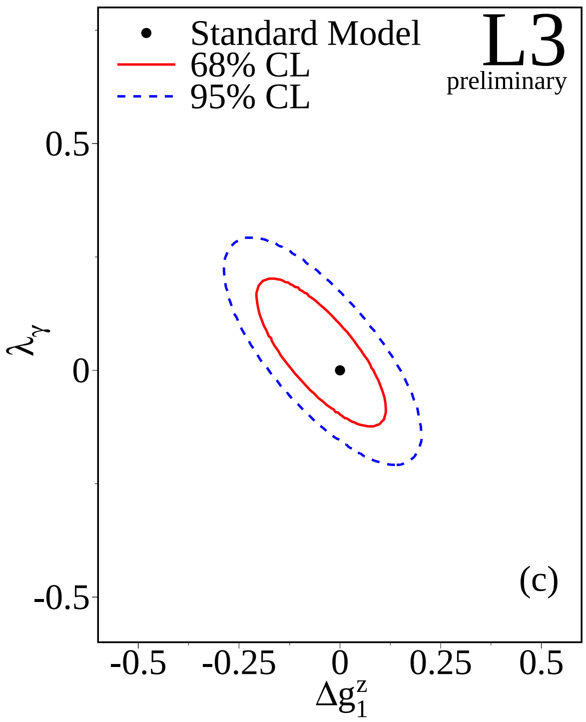


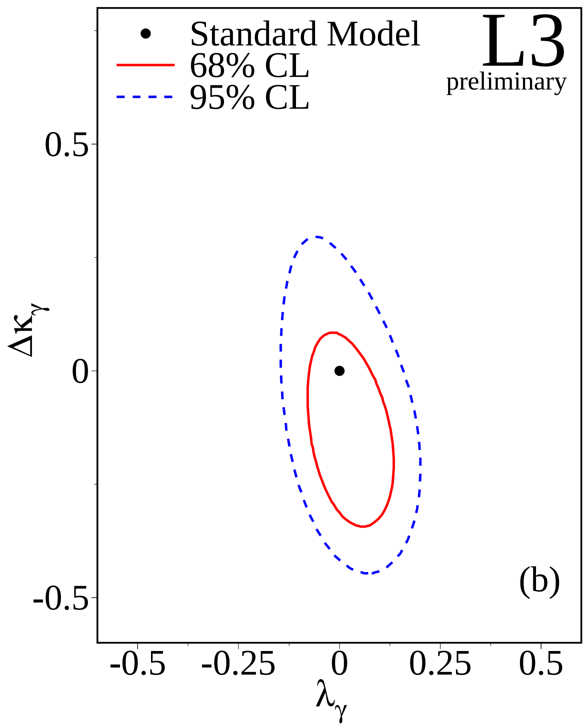
Angular Distributions at $\sqrt{s} = 189$ GeV



Combined WW Results







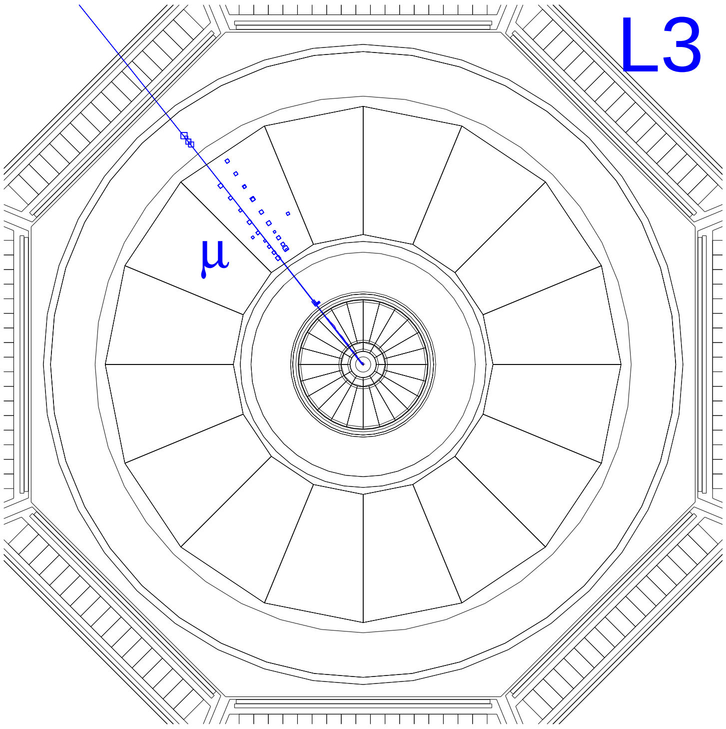
$$\Delta g_1^Z = -0.02^{+0.07}_{-0.07}$$

$$\Delta\kappa_\gamma = -0.12^{+0.14}_{-0.12}$$

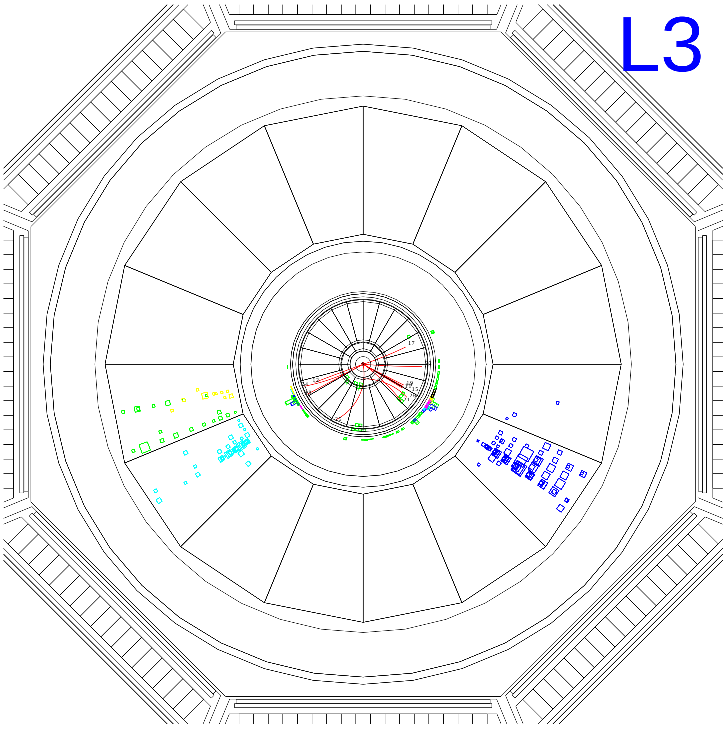
$$\lambda_\gamma = 0.00^{+0.07}_{-0.07}$$

$ee \to W e\nu \to e\nu f f$

$e\nu\mu\nu$



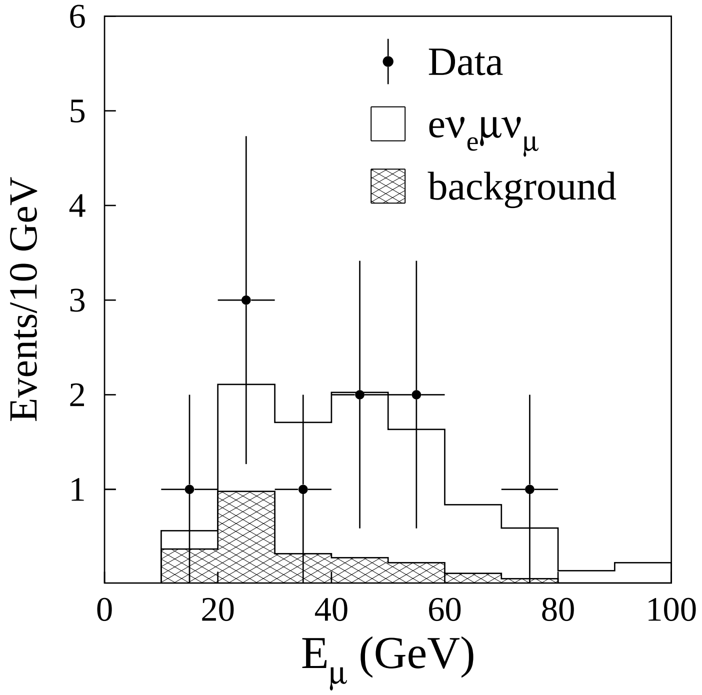
$e\nu qq$

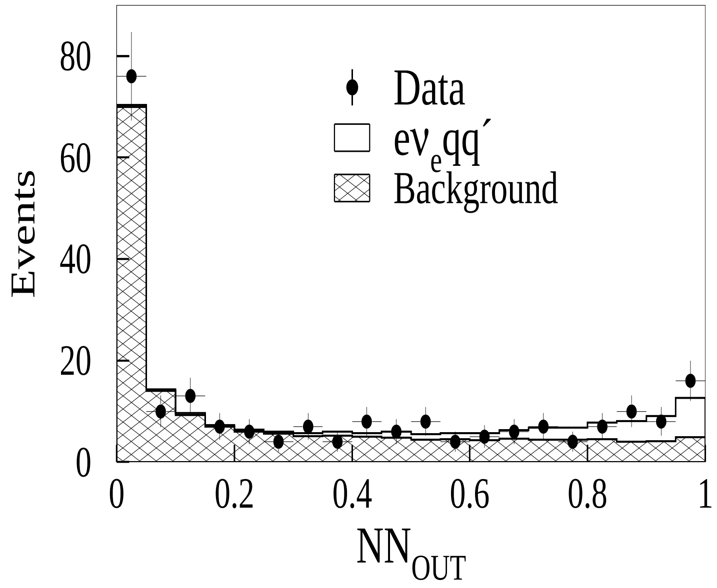


$\Delta\kappa_\gamma$ and λ_γ from binned likelihood fit to

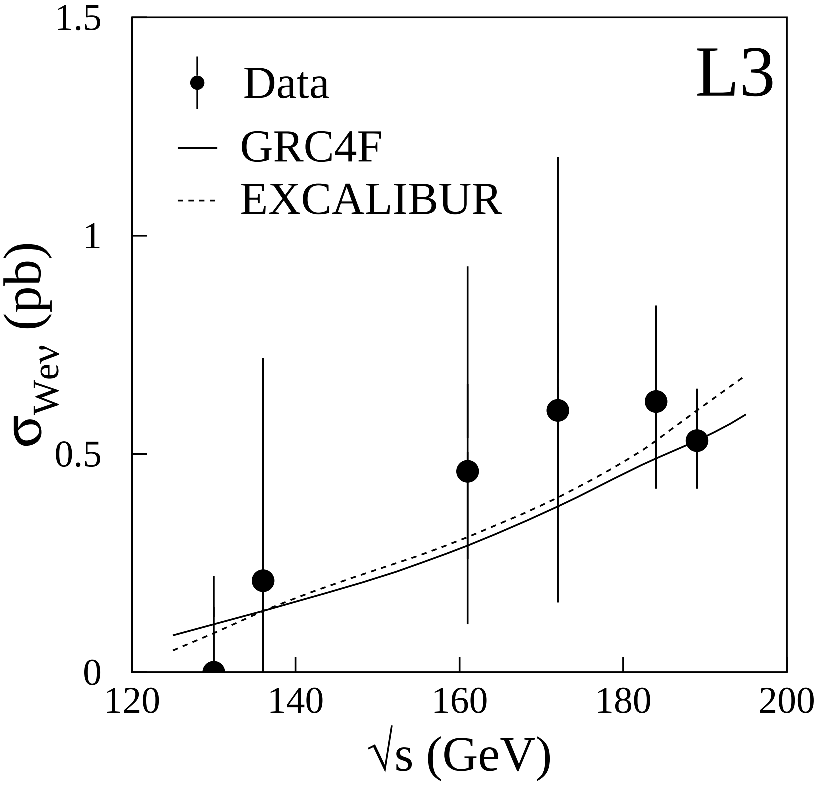
- Neural Net Output in $W \to q\bar{q}$
- Lepton energy spectrum in $W \to l\nu$

Single W Production at $\sqrt{s} = 189$ GeV





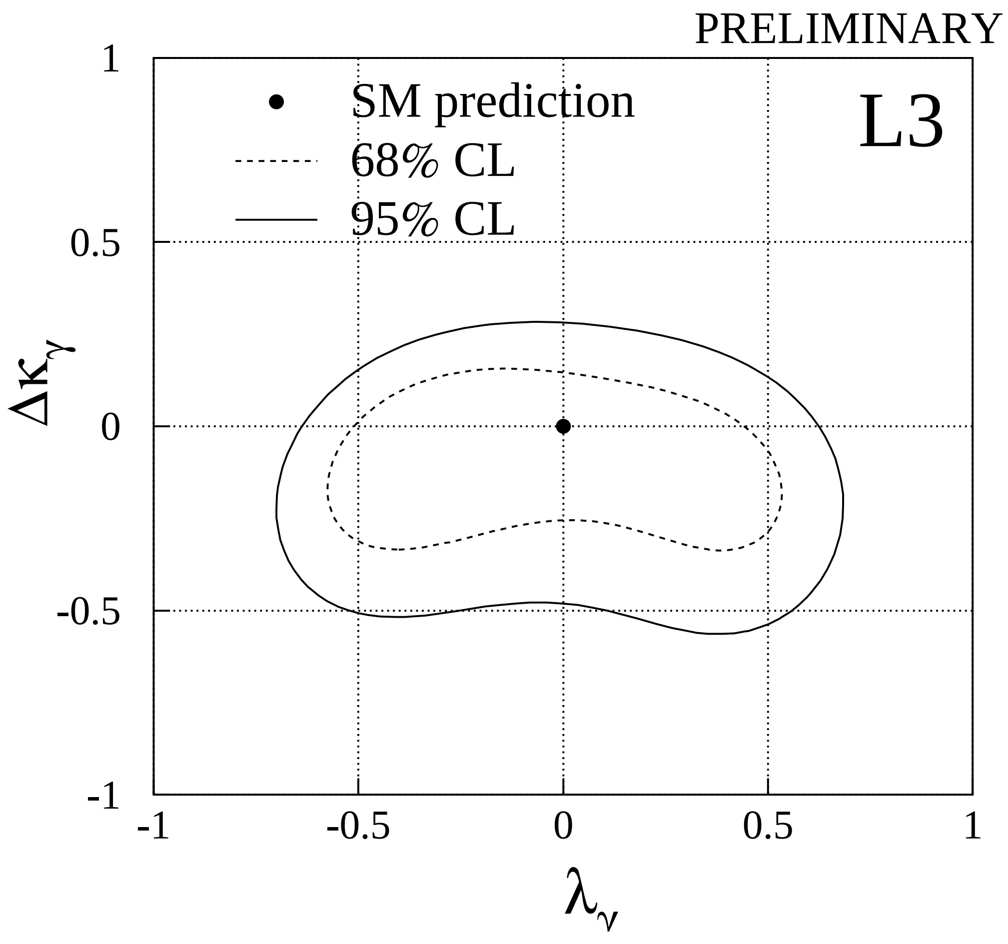
total cross section



Combined Single W Results

95% CL from two parameter fit:

$$-0.42 < \Delta\kappa_\gamma < 0.22$$
$$-0.64 < \lambda_\gamma < 0.61$$



Summary

- **Very successful run at $\sqrt{s} = 189$ GeV**
  - **$3\times$ higher statistics at higher energy**
  - **Significant improvement in limits on anomalous couplings**
- **TGC measurement agrees with SM**
- **Analysis in single W channel yields very important contribution to $\Delta\kappa_\gamma$ measurement**
- **Looking forward to this years run at $\sqrt{s} \longrightarrow 200$ GeV**