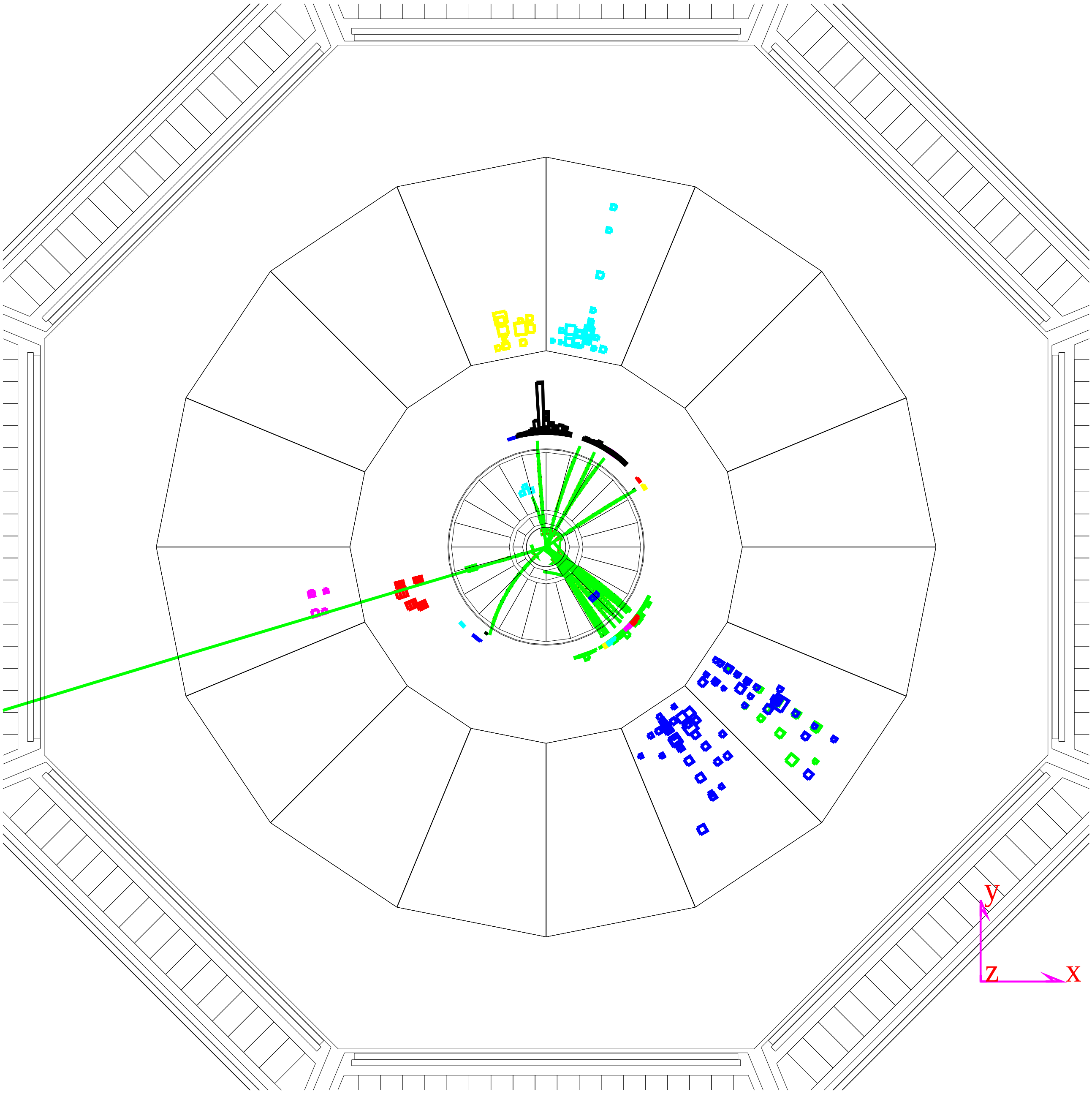
W Boson Production

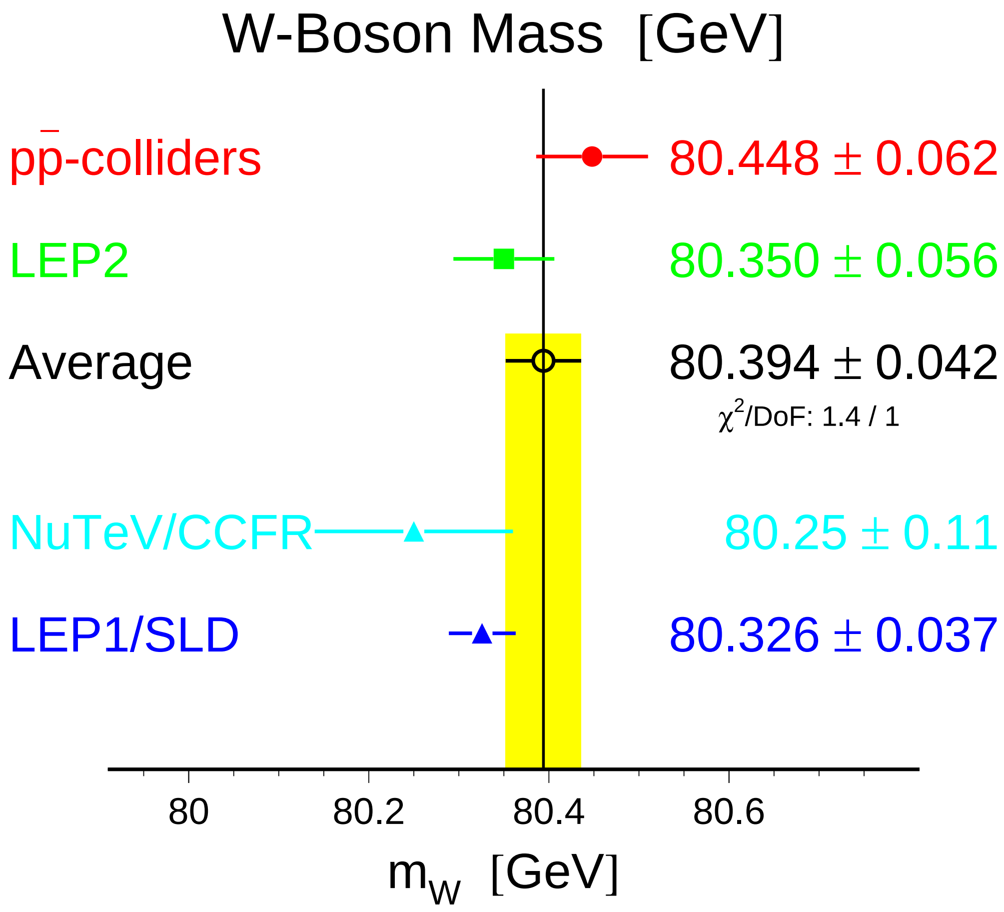
L3



$e^+e^- \rightarrow W^+W^- \rightarrow \mu\bar{\nu}\, q\bar{q}'$ at 172 GeV

Mass of the W Boson

LEP-EWWG 99



NuTeV/CCFR:

$$\frac{\sigma^{\nu}_{NC} - \sigma^{\bar{\nu}}_{NC}}{\sigma^{\nu}_{CC} - \sigma^{\bar{\nu}}_{CC}} = \frac{1}{2} - \sin^2\theta_W$$

Radiative corrections small

Couplings-mass-relation confirmed

Target accuracy of M_W measurement: 30 MeV, 300 ppm

Run LC at M_Z and/or M_W?

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GigaZ running:

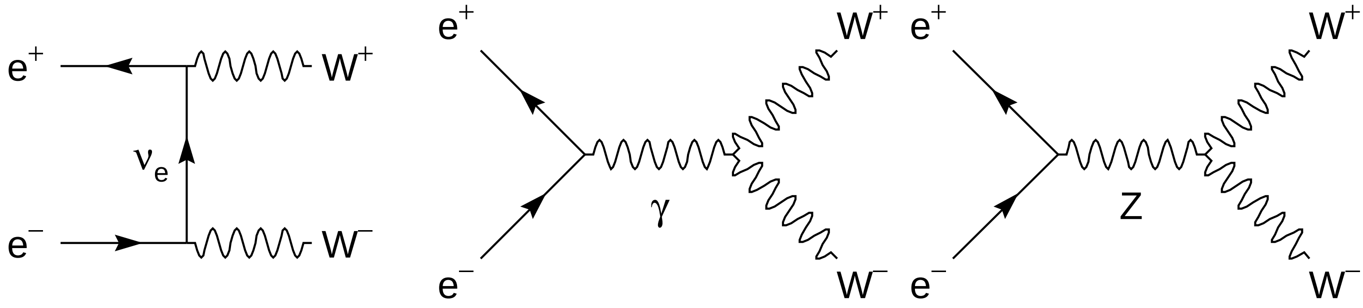
- 10^9 Z with polarised e^- (and e^+?)
- Improve Γ_Z-related quantities by factor 2
- Improve $\delta \sin^2 \theta_{eff}$ by factor 10

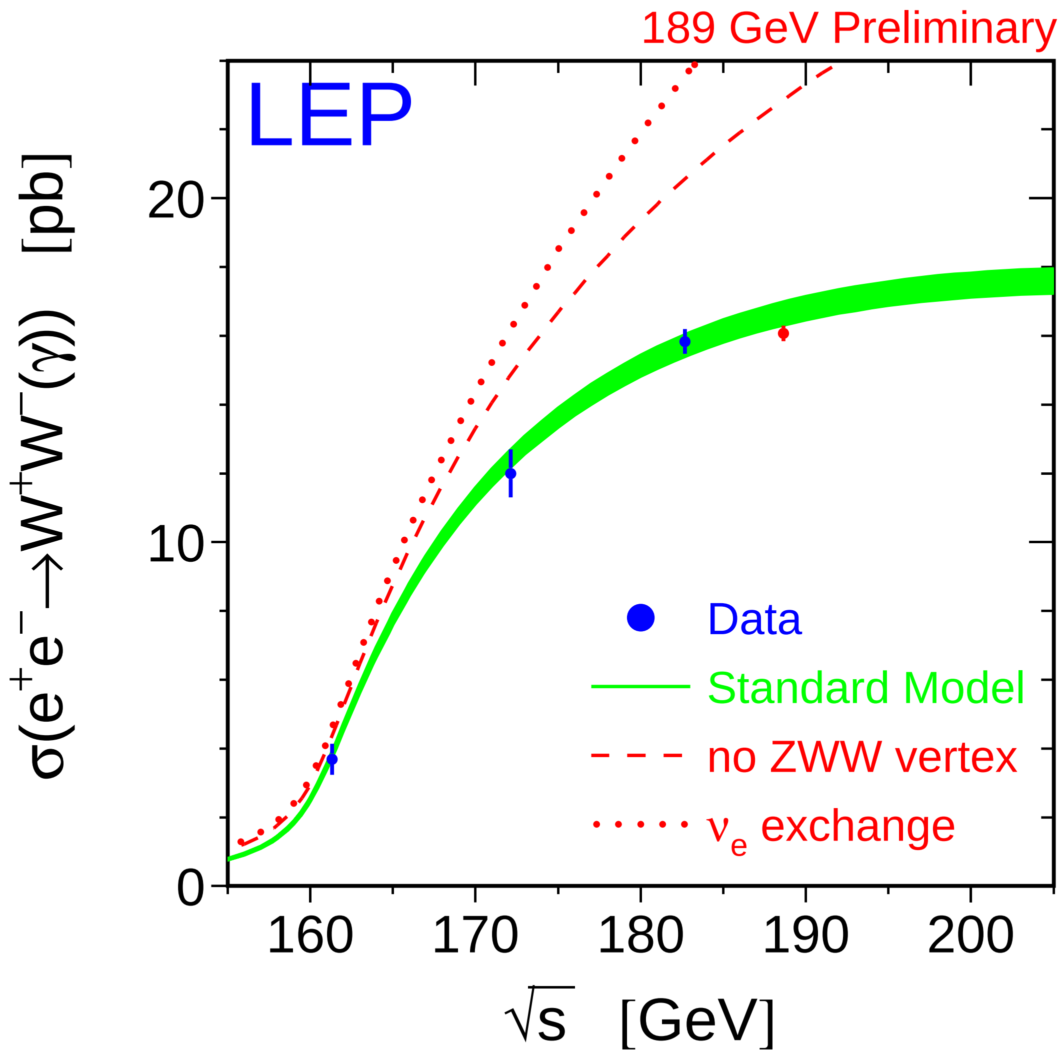
W running:

- High energy running already gives $\delta M_W \simeq 15$ MeV, comparable to LHC precision
- One year at $\sqrt{s} \simeq 2M_W$ gives $\delta M_W \simeq 6$ MeV, comparable to couplings measurement

Boson Self Coupling

$e^+e^- \rightarrow W^+W^- \rightarrow ffff$





Three-boson vertices exist, non-Abelian gauge theory

Three-Boson Couplings

General Lagrangian for VWW-coupling
($V = \gamma, Z$, with C- and P-invariance):

$$\frac{i\mathcal{L}_{eff}}{g_{VWW}} = g_1^V V^\mu (W^-_{\mu\nu} W^{+\nu} - W^+_{\mu\nu} W^{-\nu})$$

$$\kappa_V W^+_\mu W^-_\nu V^{\mu\nu} + \frac{\lambda_V}{M_W^2} V^{\mu\nu} W^{+\rho}_\nu W^-_{\rho\mu}$$

Normalisation: $g_{\gamma WW} = -e$; $g_{ZWW} = -e \cot\theta_W$

Static properties of W:
Electric charge:

$$q_W = e g_1^\gamma$$

Magnetic dipole moment:

$$\mu_W = \frac{e}{2M_W}(g_1^\gamma + \kappa_\gamma + \lambda_\gamma)$$

Electric quadrupole moment:

$$Q_W = -\frac{e}{M_W^2}(\kappa_\gamma - \lambda_\gamma)$$

E.m. gauge invariance:

$$g_1^\gamma = 1$$

$SU(2) \otimes U(1)$ gauge invariance:

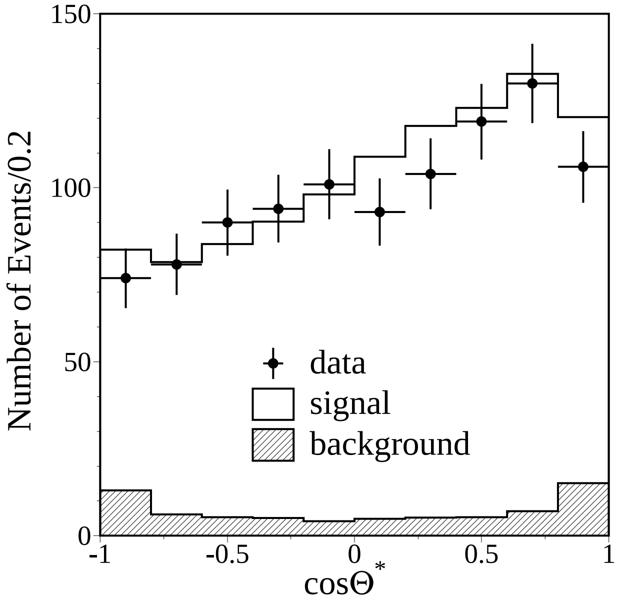
$$\Delta\kappa_Z = \Delta g_1^Z - \Delta\kappa_\gamma \tan^2\theta_W$$

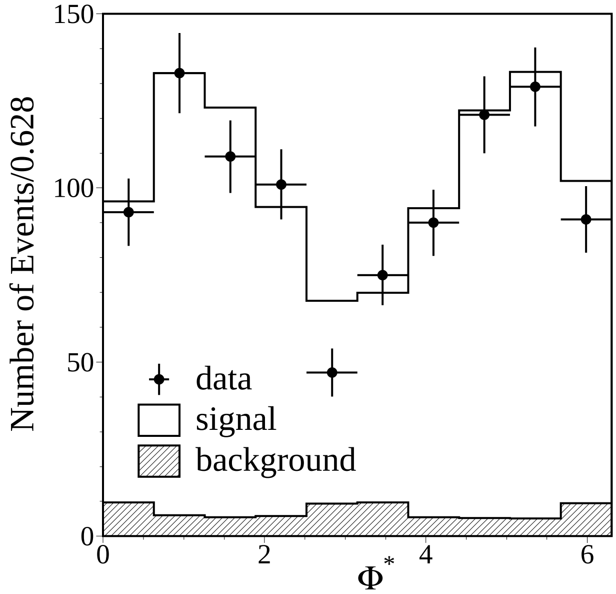
$$\lambda_Z = \lambda_\gamma$$

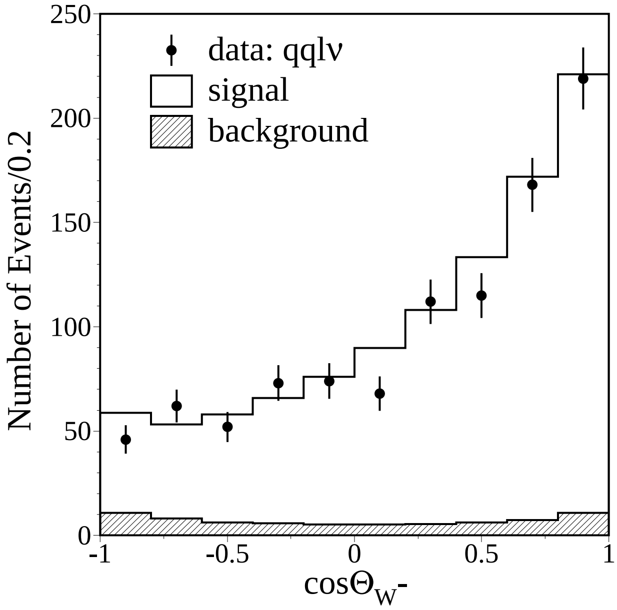
Scattering and Decay Angles

Angular distribution and W-polarisation:

L3 189 GeV preliminary







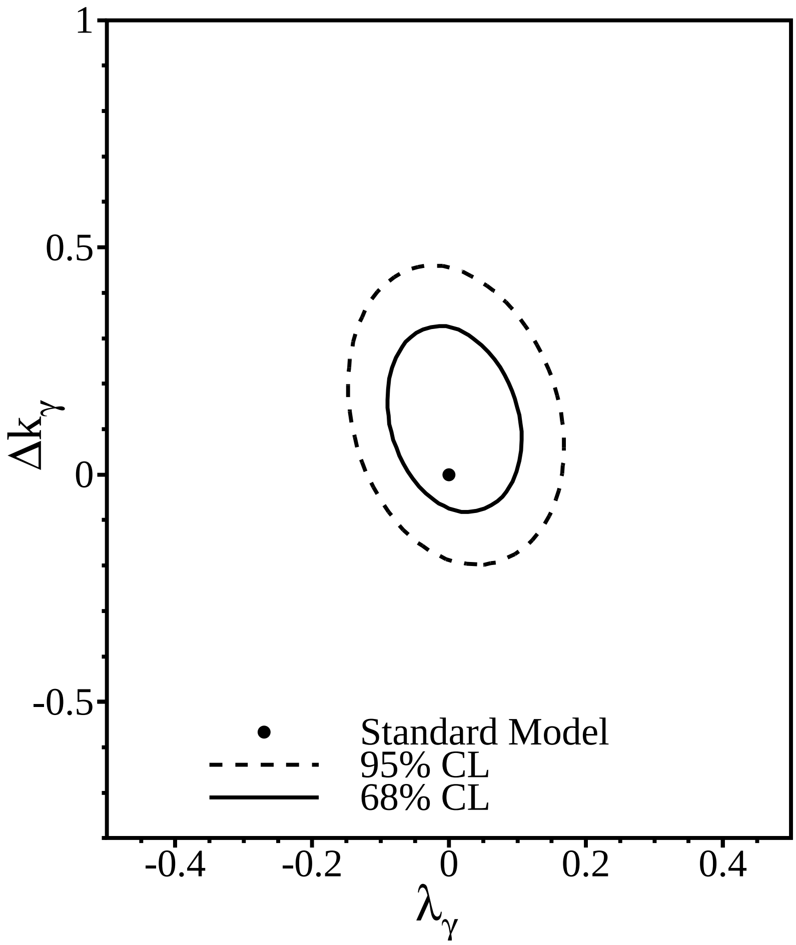
$ee \rightarrow WW \rightarrow qq\ell\nu$:
Production angle Θ_W
Decay angles Θ_l, Φ_l

Three-Boson Couplings

One parameter fit: L3 preliminary

$$\Delta g_Z^1 = -0.03 \pm 0.06$$
$$\Delta\kappa_\gamma = 0.12 \pm 0.13$$
$$\lambda_\gamma = 0.02 \pm 0.06$$

Electromagnetic properties of the W: L3 preliminary



Accuracy today: $\mathcal{O}(10\%)$

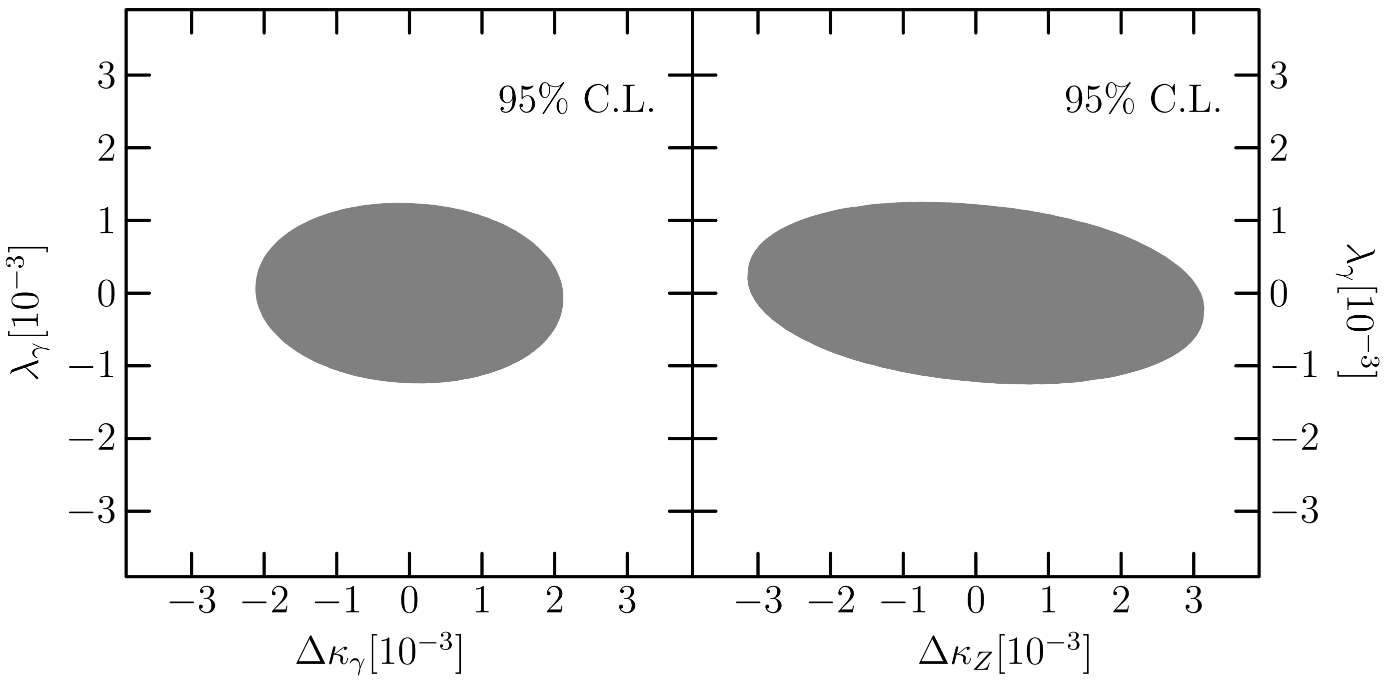
End of LEP 2: Improvement by factor of 2

W Boson Properties

Signature: leptons, jets, missing momentum (ν)

Refine knowledge of SM parameters:

- measure W mass to few MeV accuracy
- measure boson self-couplings to per mil accuracy

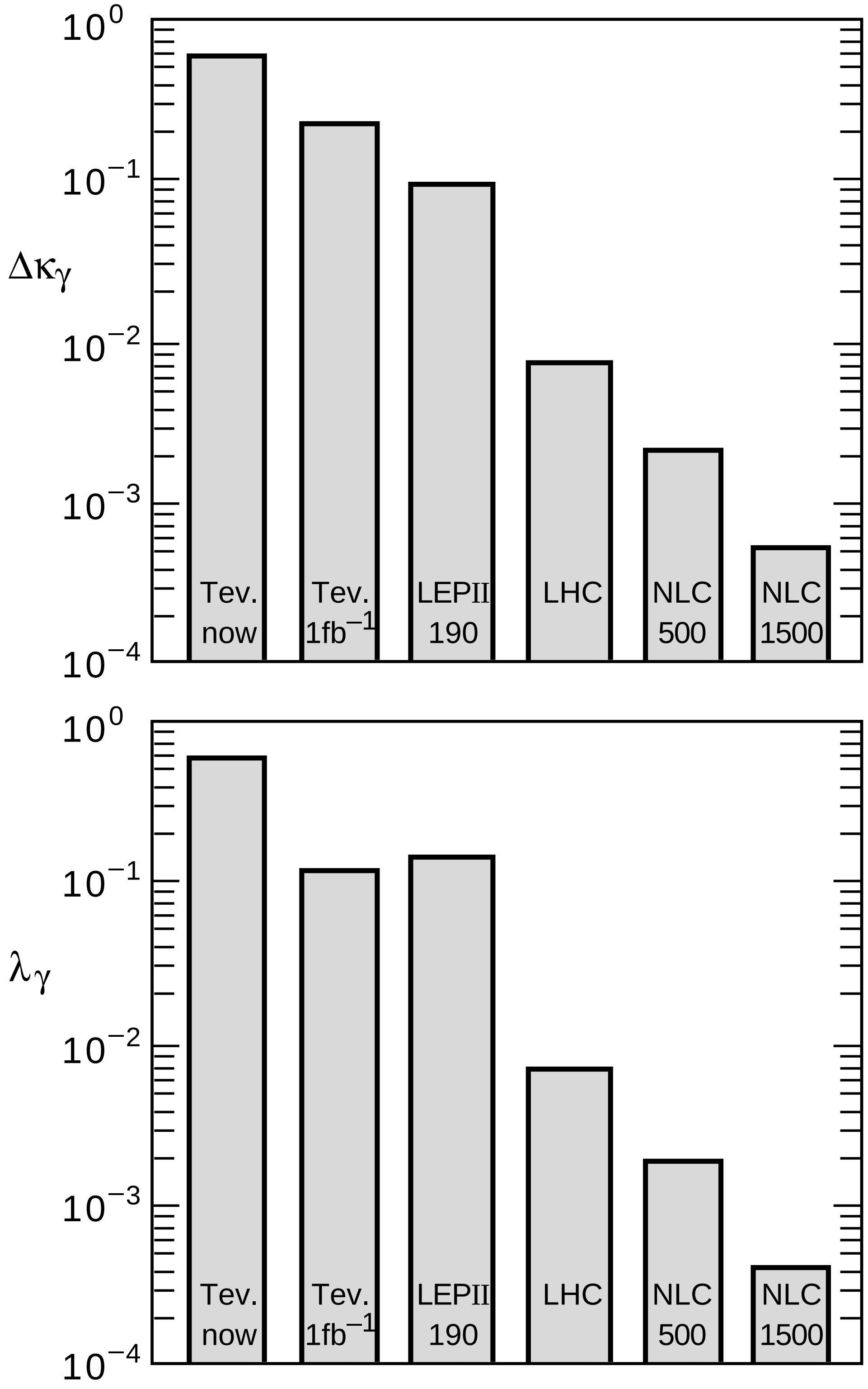


Accuracy TESLA with high luminosity:

$$\Delta\kappa_\gamma \leq 400 \text{ ppm}$$
$$\Delta\kappa_Z \leq 600 \text{ ppm}$$
$$\Delta\lambda_\gamma \leq 200 \text{ ppm}$$

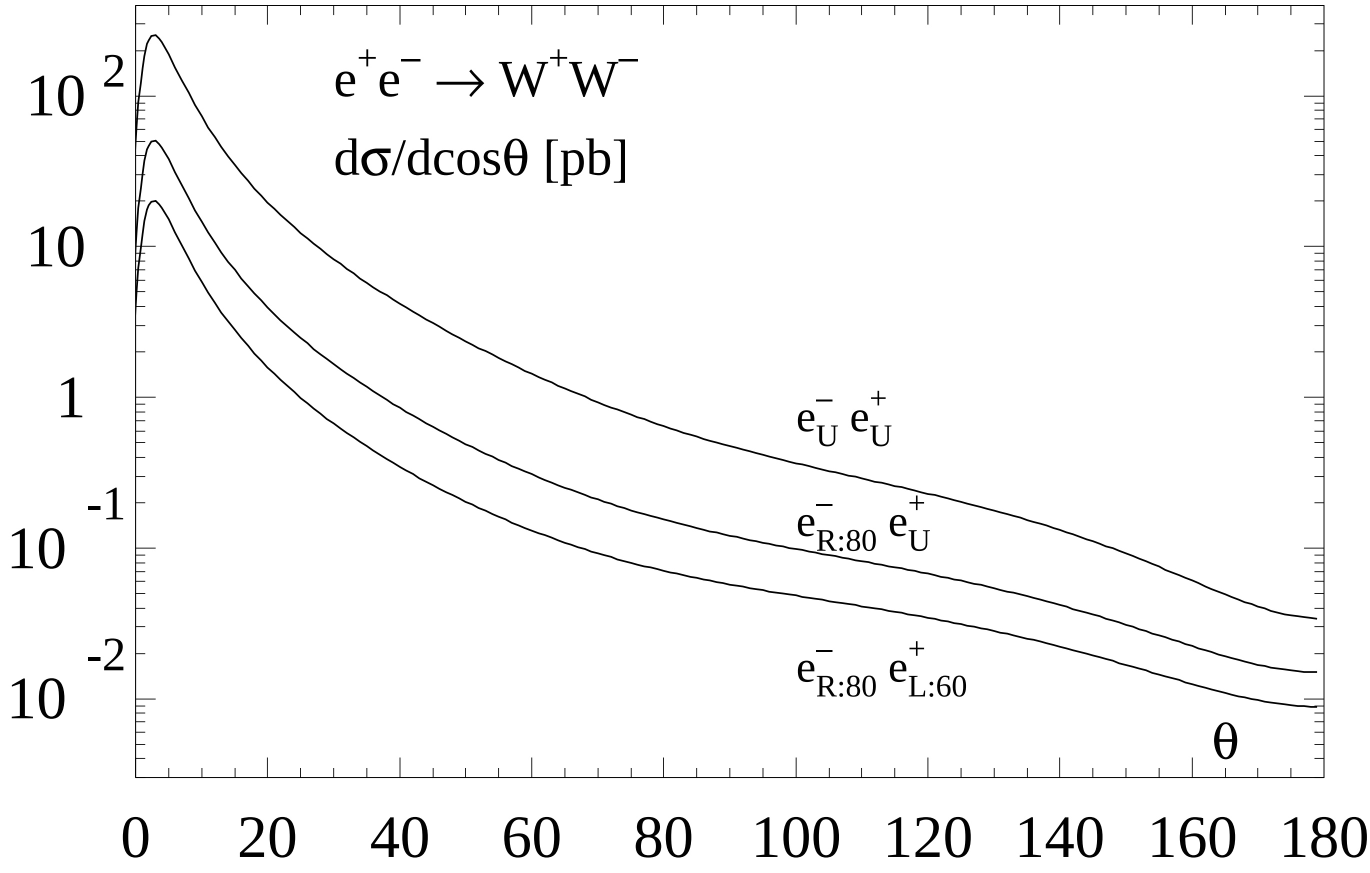
W Boson Properties

T. Barklow et al., Snowmass (1996)



Initial State Polarisation

Initial state polarisation can suppress large parts of W pair production



Select W helicity components by initial state polarisation

Polarisation and VWW Couplings

At $\sqrt{s} - 2M_W >> \Gamma_W$: Structure of $\mathcal{L}$ the same for $WW\gamma$ and WWZ

$\rightarrow$ Couplings hard to disentangle with unpolarised beams

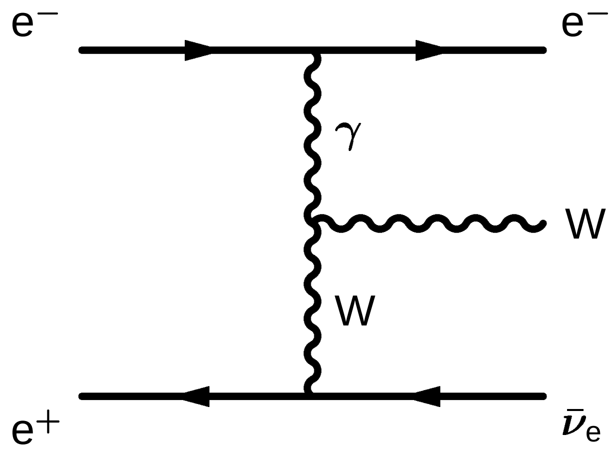
But:

- $e^+e^-\gamma$ couplings are symmetric for $e_L \leftrightarrow e_R$
- e^+e^-Z couplings are anti-symmetric

$\rightarrow$ Initial state polarisation can disentangle $WW\gamma$ and WWZ couplings at high energies

Note:

Also "single W" production singles out the $WW\gamma$ vertex, since t-channel Z exchange is suppressed for $t << M_Z^2$



Expected Results on VWW Couplings

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At $\sqrt{s} = 500$ GeV, $\mathcal{L} = 500$ fb^{-1}, $\mathcal{P}_{e^-} = 0.8$:

Parameter	Statistical Error
CP-conserving	$[\times 10^{-3}]$
$\Delta\kappa_\gamma$	0.48
λ_γ	0.72
Δg_1^Z	2.50
$\Delta\kappa_Z$	0.79
λ_Z	0.65
CP-violating	$[\times 10^{-3}]$
$\Delta\tilde{\kappa}_\gamma$	20
$\tilde{\lambda}_\gamma$	6
$\Delta\tilde{\kappa}_Z$	20
$\tilde{\lambda}_Z$	10

At $\sqrt{s} = 1000$ GeV 20 - 50% better