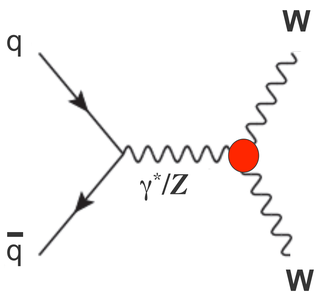
Constraints on Anomalous Gauge Boson Couplings

Kalanand Mishra, Fermi National Accelerator Laboratory

Gauge boson self couplings



✦ Gauge boson trilinear and quartic couplings emerge naturally from the non-abelian gauge symmetry of the standard model (SM).

✦ With $o(10^4)$ WW, $o(10^3)$ WZ, and $o(10^2)$ ZZ events, quickly approaching precision measurement of gauge couplings, already improved over LEP and Tevatron in most cases.

✦ Measure coupling parameters in effective Lagrangian approach. In the case of charged trilinear couplings WWZ and WWγ

$$\mathcal{L}_{anom} = ig_{WWZ}\left[\Delta g_1^Z(W^*_{\mu\nu}W^\mu Z^\nu - W_{\mu\nu}W^{*\mu}Z^\nu) + \Delta\kappa^Z W^*_\mu W_\nu Z^{\mu\nu} + \frac{\lambda^Z}{M_W^2}W^*_{\rho\mu}W^\mu_\nu Z^{\nu\rho}\right] + ig_{WW\gamma}\left[\Delta\kappa^\gamma W^*_\mu W_\nu \gamma^{\mu\nu} + \frac{\lambda^\gamma}{M_W^2}W^*_{\rho\mu}W^\mu_\nu\gamma^{\nu\rho}\right]$$

Five independent parameters: λ_Z, λ_γ, $\Delta\kappa_Z$, $\Delta\kappa_\gamma$, Δg_1^Z. Imposing SU(2) x U(1) gauge invariance reduces the number of independent parameters to three

$\lambda_Z = \lambda_\gamma = \lambda$ (= 0 in SM) $\quad \Delta\kappa_Z = \Delta g_1^Z - \Delta\kappa_\gamma \cdot \tan^2\theta_W$ (= 0 in SM)

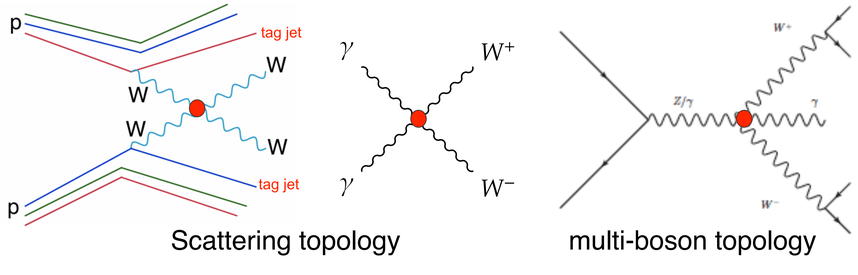
✦ Neutral trilinear gauge couplings ZZγ, Zγγ, ZZZ are forbidden in SM

- Anomalous ZZγ, ZZZ couplings introduced by terms $f_4^{Z/\gamma}$ and $f_5^{Z/\gamma}$ in $\mathcal{L}_{anom}$
- Anomalous Zγγ and ZZγ described by terms $h_3^{Z/\gamma}$ and $h_4^{Z/\gamma}$.

Trilinear couplings are getting highly constrained

Currently constrained within 3–9% for charged and within 1% for neutral aTGC. With 8 TeV data expect further improvement by a factor of few.

Quartic couplings accessible in two topologies



Scattering topology multi-boson topology

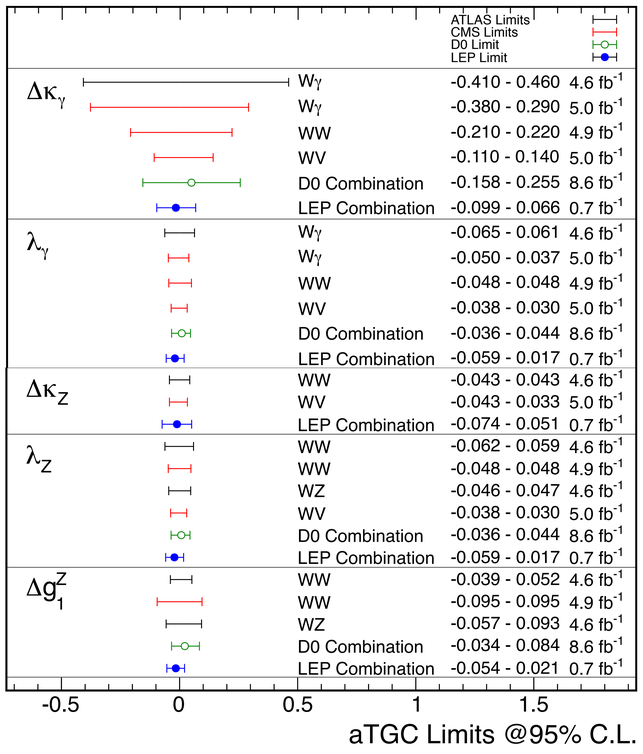
Example of effective Lagrangian (in "dimension 6 realization"):

$$L^0 = -\frac{e^2}{8}\frac{a_0^W}{\Lambda^2}F_{\mu\nu}F^{\mu\nu}W^{+\alpha}W^-_\alpha - \frac{e^2}{16\,c_W^2}\frac{a_0^Z}{\Lambda^2}F_{\mu\nu}F^{\mu\nu}Z^\alpha Z_\alpha$$

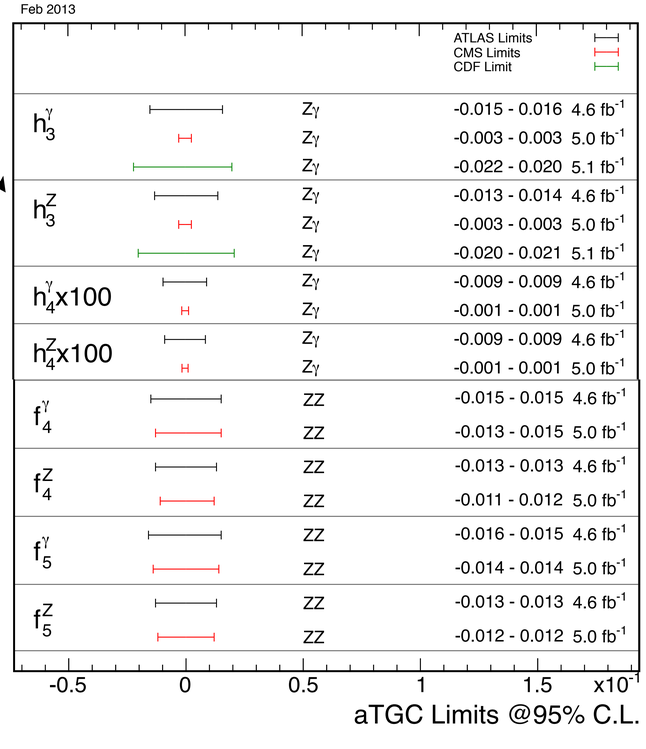
$$L^C = -\frac{e^2}{16}\frac{a_C^W}{\Lambda^2}F_{\mu\alpha}F^{\mu\beta}(W^{+\alpha}W^-_\beta - W^{-\alpha}W^+_\beta) - \frac{e^2}{16\,c_W^2}\frac{a_C^Z}{\Lambda^2}F_{\mu\alpha}F^{\mu\beta}Z^\alpha Z_\beta$$

Measure the coefficients a_0 and a_c from experimental data.

Limits on charged trilinear couplings*

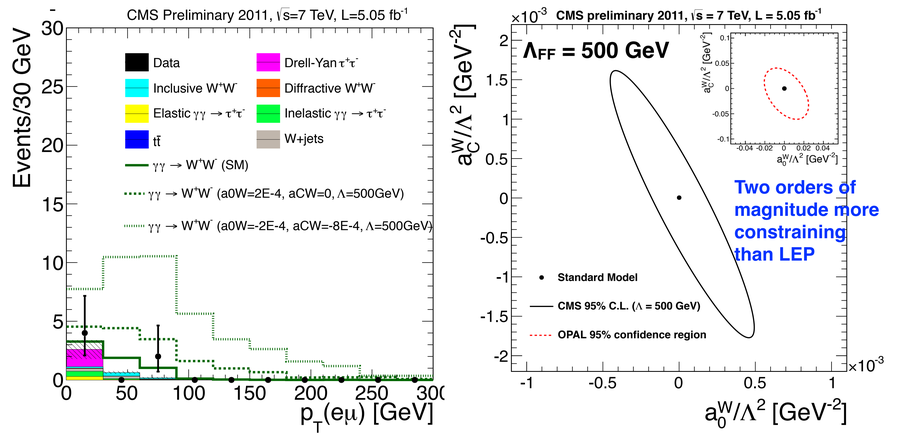


Limits on neutral trilinear couplings*

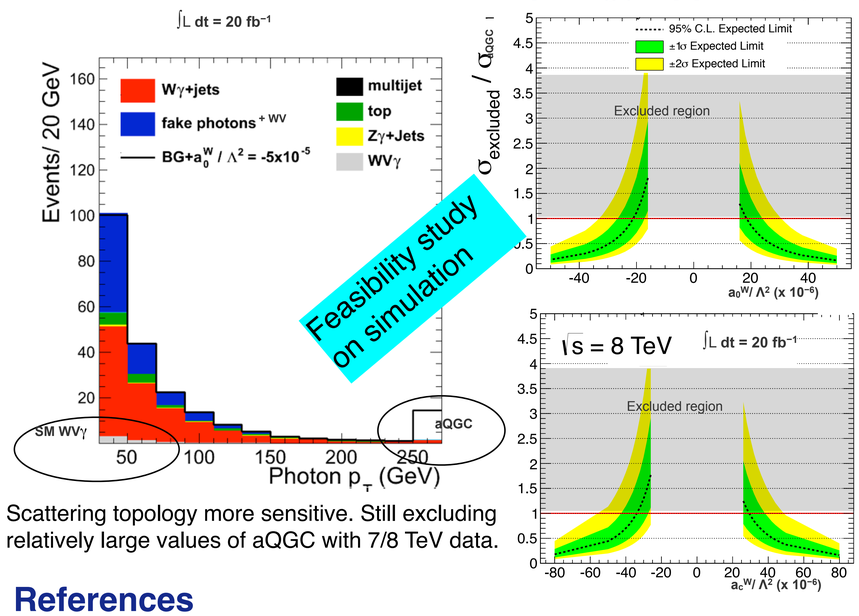


* Some information is repeated twice.

First measurement in scattering topology: γγ→WW



Simulation studies in 3-boson topology: qq→WWγ



Scattering topology more sensitive. Still excluding relatively large values of aQGC with 7/8 TeV data.

References

1. https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSMPaTGC
2. https://twiki.cern.ch/twiki/bin/view/AtlasPublic/StandardModelPublicResults
3. LEP Combination: arXiv:1302.3415, D0 combination: arXiv:1208.5458
4. CMS Collaboration, "Study of exclusive two-photon production of W⁺W⁻ pairs in pp collisions at 7 TeV and constraints on anomalous quartic couplings", CMS arXiv: 1305.5596 (2013).
5. K. Mishra, report in the LHC Electroweak Working Group Meeting (April 16, 2013) https://indico.cern.ch/conferenceOtherViews.py?confId=245037

Summary

✦Study of gauge boson couplings is a rich physics program
- LHC data sufficient for sensitivity to SM and anomalous couplings
- New excitement after the discovery of a light Higgs boson

✦Starting to set serious constraints on gauge boson couplings
- Already broke new ground with 7/8 TeV data by exceeding previous limits, in some cases by orders of magnitude