Simplified EFT example

presented by Adam Falkowski (LPT Orsay)

for LHC XS WG2 meeting

5 Sep 2014

Intro

Alonso et al 1312.2014

- General EFT has many parameters (e.g. 2499 non-redundant parameters at dimension-6 level)
- In practice, we need a simplified procedure to reduce the number of parameters
- Typically, flavor symmetries reduces the number of relevant parameters for a given process to a few/dozen
- That may still be too many parameters to simultaneously constrain by experiment

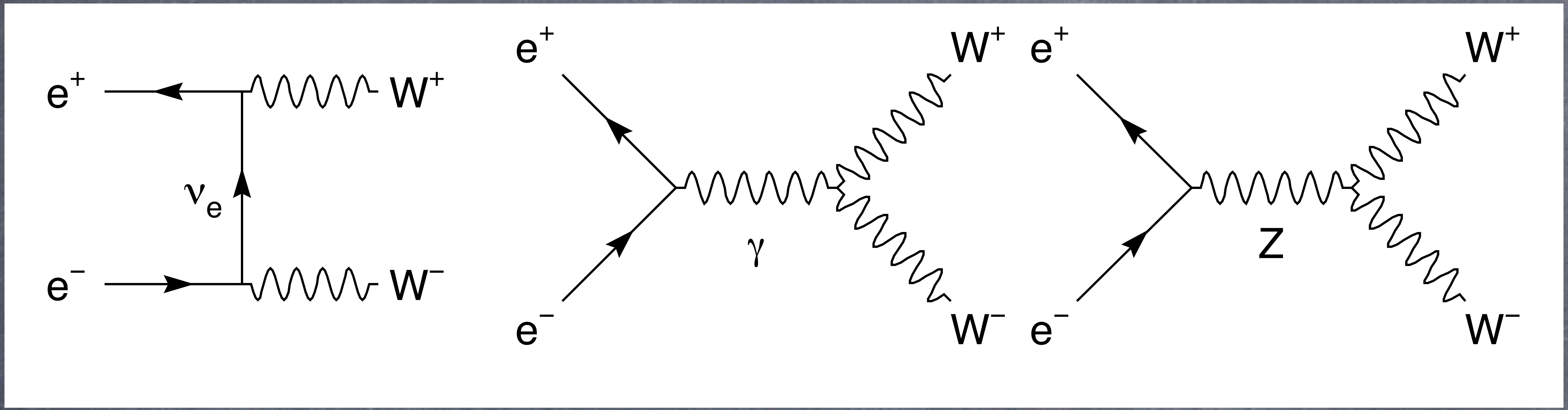
Simplified EFT

- In some cases, constraints on certain EFT parameters from other precision experiments are strong enough that this parameter cannot be really probed at the LHC

- In that case, one can resort to simplified EFT where that parameter is suppressed

Example of VV production

WW production at LEP and LHC



- Depends on triple gauge couplings
- Also depends on electron/quark couplings to W and Z bosons and on operators modifying EW gauge boson propagators
- Indirectly, depends on operators shifting the SM reference parameters (GF, α, mZ)

WW production in effective theory

$$\mathcal{L}_{\rm eff} = \mathcal{L}_{\rm SM} + \frac{1}{v}\mathcal{L}^{D=5} + \frac{1}{v^2}\mathcal{L}^{D=6} + \ldots$$

Using Warsaw basis. Showing only operators affecting WW cross section at linear level. For simplicity, assuming flavor blind couplings.

- 2 (in this basis) operators affecting TGCs

$$\mathcal{L}^{D=6}_{\rm TGC} = c_{WB} B_{\mu\nu} W^i_{\mu\nu} H^\dagger \sigma^i H + c_{3W}\ \epsilon^{ijk} W^{i\,\nu}_{\mu} W^{j\,\rho}_{\nu} W^{k\,\mu}_{\rho}$$

- 7 (in this basis) operators affecting electron/quark couplings to W and Z

$$\begin{aligned}\mathcal{L}^{D=6}_{\rm vertex} =& i c'_{HQ} \bar{q}\sigma^i \bar{\sigma}_\mu q H^\dagger \sigma^i \overleftrightarrow{D_\mu} H + i c_{HQ} \bar{q}\bar{\sigma}_\mu q H^\dagger \overleftrightarrow{D_\mu} H \\ &+ i c_{HU} u^c \sigma_\mu \bar{u}^c H^\dagger \overleftrightarrow{D_\mu} H + i c_{HD} d^c \sigma_\mu \bar{d}^c H^\dagger \overleftrightarrow{D_\mu} H \\ &+ i c'_{HL} \bar{\ell}\sigma^i \bar{\sigma}_\mu l H^\dagger \sigma^i \overleftrightarrow{D_\mu} H + i c_{HL} \bar{\ell}\bar{\sigma}_\mu l H^\dagger \overleftrightarrow{D_\mu} H \\ &+ i c_{HE} e^c \sigma_\mu \bar{e}^c H^\dagger \overleftrightarrow{D_\mu} H.\end{aligned}$$

- 2 operators entering indirectly by affecting SM parameters

$$\mathcal{L}^{D=6}_{\rm EWPT} = c_T \left(H^\dagger \overleftrightarrow{D^\mu} H\right)\left(H^\dagger \overleftrightarrow{D}_\mu H\right) + \left[c_{4F} (\bar{e}\sigma_\rho \nu_e)(\bar{\nu}_\mu \sigma_\rho \mu) + \text{h.c.}\right]$$

- In total, 11 dimension-six operators affecting WW production

LEP constraints

- But, most of these 11 parameters are constrained by LEP and Tevatron precision measurements
- Precision of WW measurements is only O(1)% in LEP and O(10%) in LHC, compared with O(0.1%) precision of LEP measurement
- Thus, many BSM directions within EFT are irrelevant for WW measurements, given existing constraints

Simplified EFT for WW production

- One can show that LEP constrains the following 8 combinations of EFT parameters

Gupta et al, 1405.0181

$$
\begin{aligned}
\hat{c}'_{HL} &= c'_{HL} + g_L^2 c_{WB} - \frac{g_L^2}{g_Y^2} c_T, \\
\hat{c}_{HL} &= c_{HL} - c_T, \\
\hat{c}_{HE} &= c_{HE} - 2c_T, \\
\hat{c}'_{HQ} &= c'_{HQ} + g_L^2 c_{WB} - \frac{g_L^2}{g_Y^2} c_T, \\
\hat{c}_{HQ} &= c_{HQ} + \frac{1}{3} c_T, \\
\hat{c}_{HU} &= c_{HU} + \frac{4}{3} c_T, \\
\hat{c}_{HD} &= c_{HD} - \frac{2}{3} c_T,
\end{aligned}
$$

$$c_{4F}$$

- Limits on these combinations are O(0.001), much better than precision of WW cross section measurements

- This leaves only 3 EFT directions that can visibly affect VV production at the linear level

- These 3 directions can be parameterized by cT, cWB, c3W

Simplified EFT for WW production

$$\begin{aligned}\mathcal{L}_{TGC} =& ie\cot\theta_W(1+\delta g_1^Z)\left(W^+_{\mu\nu}W^-_\mu - W^-_{\mu\nu}W^+_\mu\right)Z_\nu \\ &+ie(1+\delta\kappa_\gamma)\,A_{\mu\nu}\,W^+_\mu W^-_\nu + ie\cot\theta_W(1+\delta g_1^Z - \tan^2\theta_W\delta\kappa_Z)\,Z_{\mu\nu}\,W^+_\mu W^-_\nu \\ &+ie\frac{\lambda_\gamma}{m_W^2}W^+_{\mu\nu}W^-_{\nu\rho}A_{\rho\mu} + ie\cot\theta_W\frac{\lambda_\gamma}{m_W^2}W^+_{\mu\nu}W^-_{\nu\rho}Z_{\rho\mu}\end{aligned}$$

- One can prove that these 3 EFT directions are EQUIVALENT to the usual 3 dimensional TGC parameterization
- cT, cWB, c3W can be mapped to g1Z, κγ and λγ
- Constraining these 3 TGCs gives a decent approximation of the constraints on EFT parameters cT, cWB, c3W
- Constraint on vertex corrections can be obtained, again to a decent accuracy, assuming c-hats are zero

$$\begin{aligned}\delta g_{1,Z} &= (g_L^2+g_Y^2)c_{WB} - \frac{g_L^2+g_Y^2}{g_Y^2}c_T, \\ \delta\kappa_\gamma &= g_L^2 c_{WB}, \\ \lambda_\gamma &= -\frac{3}{2}g_L^4 c_{3W}.\end{aligned}$$

Simplified EFT for Higgs searches

- Similar story for $H \to 4l$ (in principle, dependence on many parameters, but given existing constraints one can reduce it to a few) Gino's talk today; Isidori,Trott 1307.4051; Pomarol,Riva, 1308.803
- Presumably, similar story for other Higgs processes as well ($H \to 2l2\nu$, H+V, etc)
- Custodial breaking: can we use simplified EFT where Higgs couplings to W and Z are related? Is this purely data driven or it relies on model dependent assumptions
- Other topics where simplified EFT is applicable?