Universität Zürich[UZH]

Anomalous Higgs and Triple Gauge Couplings in the Effective Field Theory Approach

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Based on:

Phys. Rev. Lett. 116, no. 1, 011801 (2016)
arXiv: 1608.xxxxx

In collaboration with:
Adam Falkowski, Martin Gonzalez-Alonso, David Marzocca, and *Minho Son*

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EFT for SM: Motivation

- SM particle content completed
- No evidence for BSM so far; strong direct search limits at LHC
- Scale separation?
- Vanilla BSM is wrong?

Given many possible forms BSM could take, it is important to pursue a **bottom-up approach** in which as few assumptions as possible about the BSM sector are made.

EFT for SM: Introduction

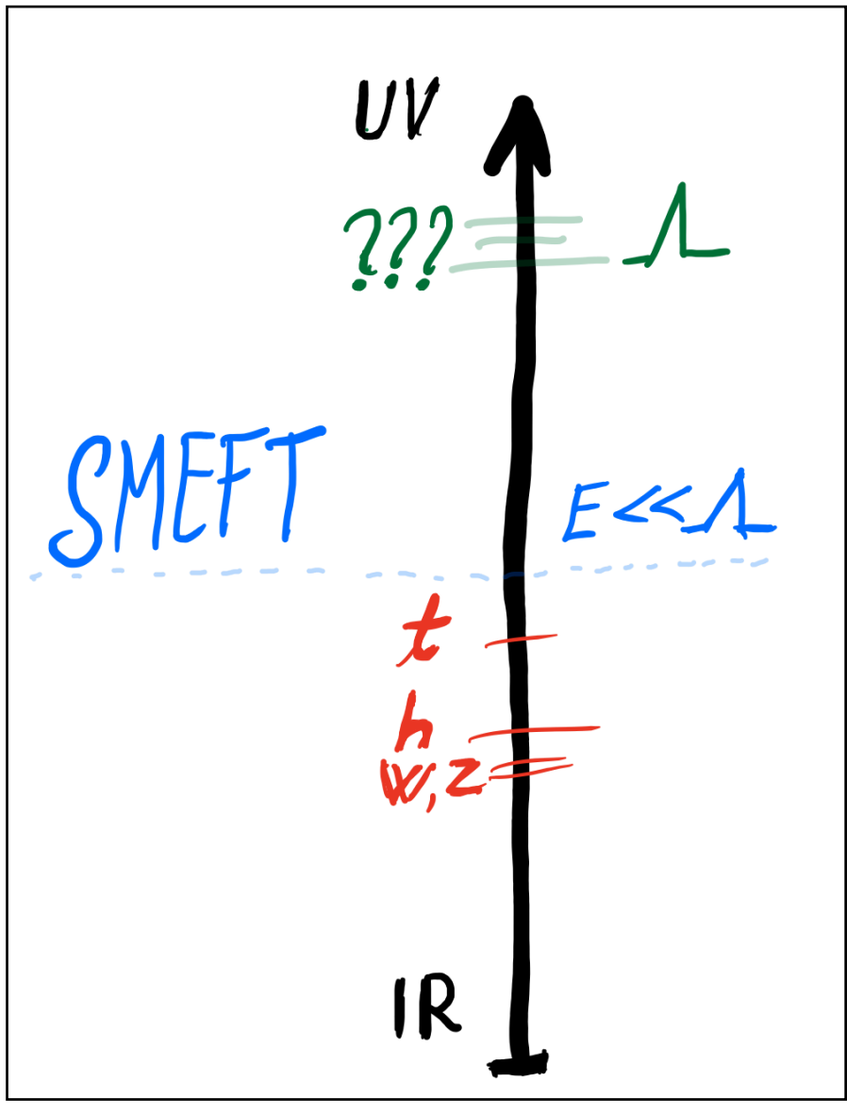
SMEFT:

(a) SM gauge symmetry & dynamical degrees of freedom

(b) Linear realization of EWSB (Higgs is an SU(2) doublet)

(c) SM supplemented with higher dimensional operators with $D > 4$

(d) Scale separation, systematic expansion in D



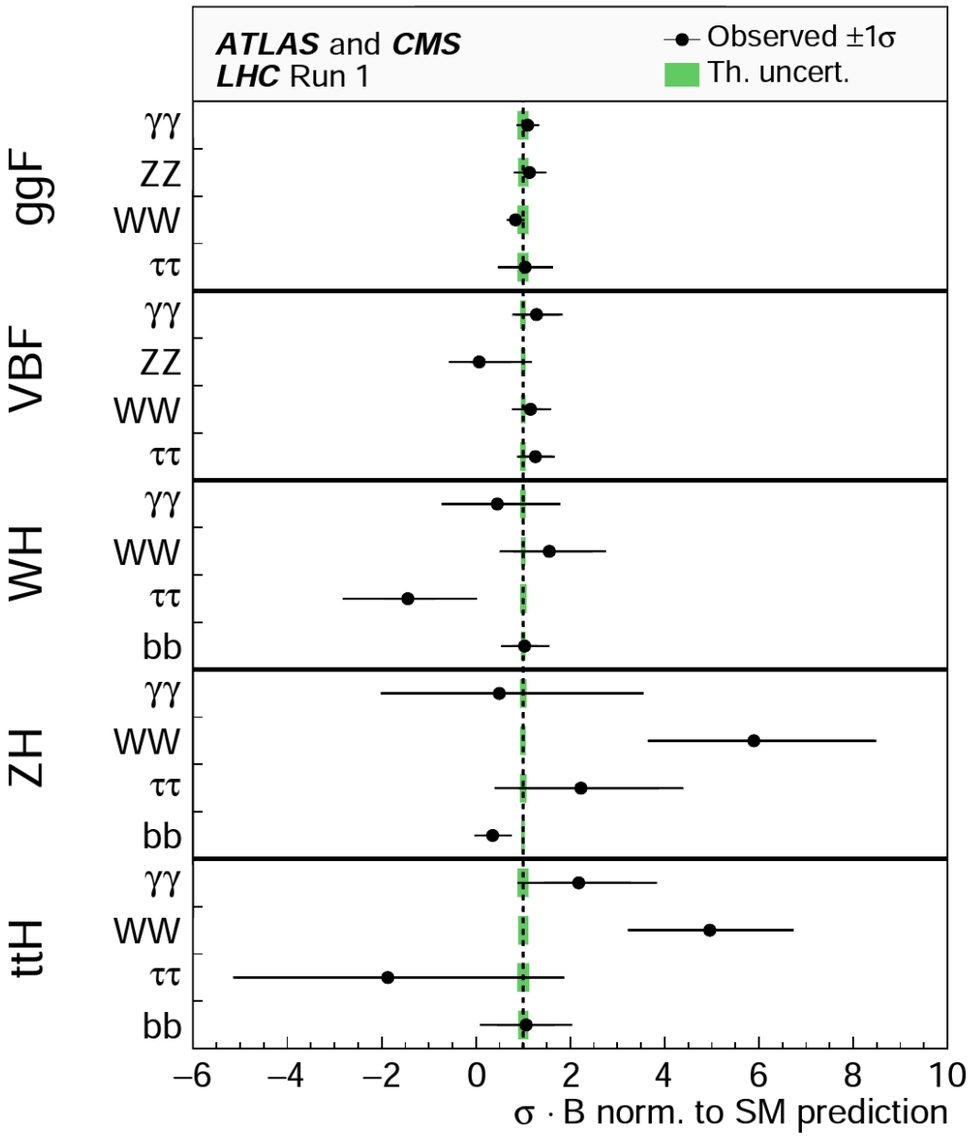
$$\mathcal{L}_{\text{eff}} = \mathcal{L}_{\text{SM}} + \sum_i \frac{c_i^{(5)}}{\Lambda} \mathcal{O}_i^{(5)} + \sum_i \frac{c_i^{(6)}}{\Lambda^2} \mathcal{O}_i^{(6)} + \sum_i \frac{c_i^{(7)}}{\Lambda^3} \mathcal{O}_i^{(7)} + \sum_i \frac{c_i^{(8)}}{\Lambda^4} \mathcal{O}_i^{(8)} + \cdots$$

LNV

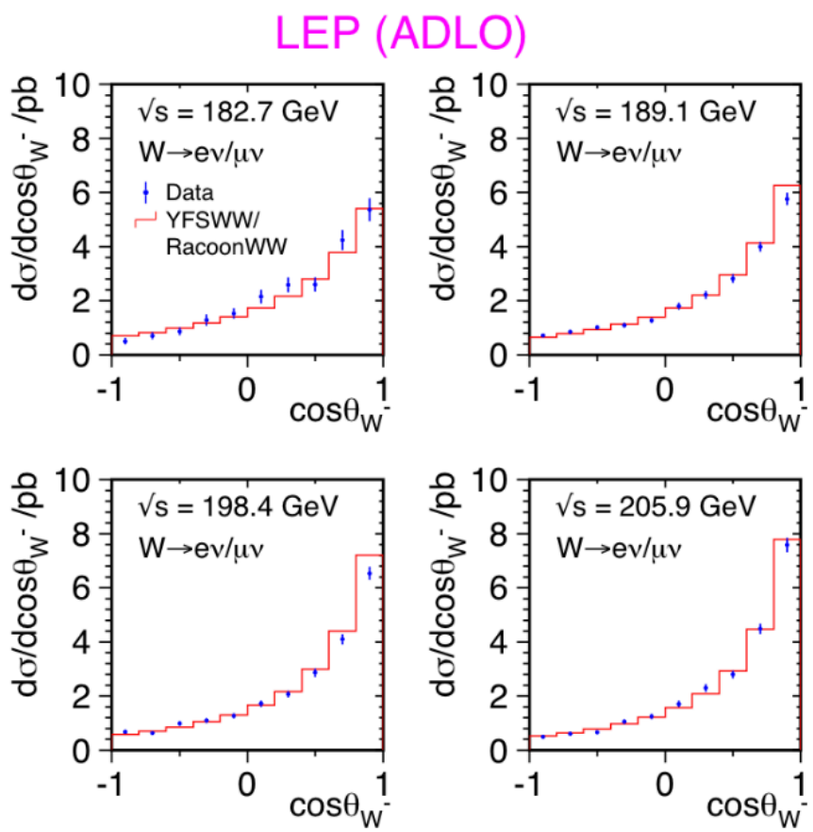
Leading effect

LNV

Global fit: Experimental input



Higgs signal strengths



LEP-2 WW production

For details see:

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EFT for SM: Observables

- A generic EFT contribution to a physical observable:

$$\sigma = \sigma^{\rm SM} + \sum_i \left(\frac{c_i^{(6)}}{\Lambda^2} \sigma_i^{(6\times {\rm SM})} + {\rm h.c.} \right) + \sum_{ij} \frac{c_i^{(6)} c_j^{(6)*}}{\Lambda^4} \sigma_{ij}^{(6\times 6)} + \sum_j \left(\frac{c_j^{(8)}}{\Lambda^4} \sigma_j^{(8\times {\rm SM})} + {\rm h.c.} \right) + \dots$$

Dim-6 interference with the SM

Dim-6 squared & Dim-8 interference with the SM, formally of the same order

- Goal: ***Global fit while keeping only the leading term in the cutoff expansion***

- *Dim-6 squared* terms represent partial next-to-leading corrections; unknown *dim-8* terms required for full consistency

See also:
arXiv:1505.00046,
JHEP 1502 (2015) 039

Anomalous **Triple Gauge** & **Higgs** Couplings in SMEFT

We restrict to the 10-dimensional sub-space of the Wilson coefficients that affects *Higgs* and *WW* observables (assuming MFV), but in which the *LEP-1 Z-pole observables*, constrained at the permil level, are not affected.

LHCHXSWG-INT-2015-001

Higgs basis: $\delta c_z,\ c_{zz},\ c_{z\Box},\ \ c_{\gamma\gamma},\ c_{z\gamma},\ c_{gg},\ \delta y_u,\ \delta y_d,\ \delta y_e,\ \lambda_z.$

aHC (***9 parameters***)

aTGC (***3 parameters***)

See also:
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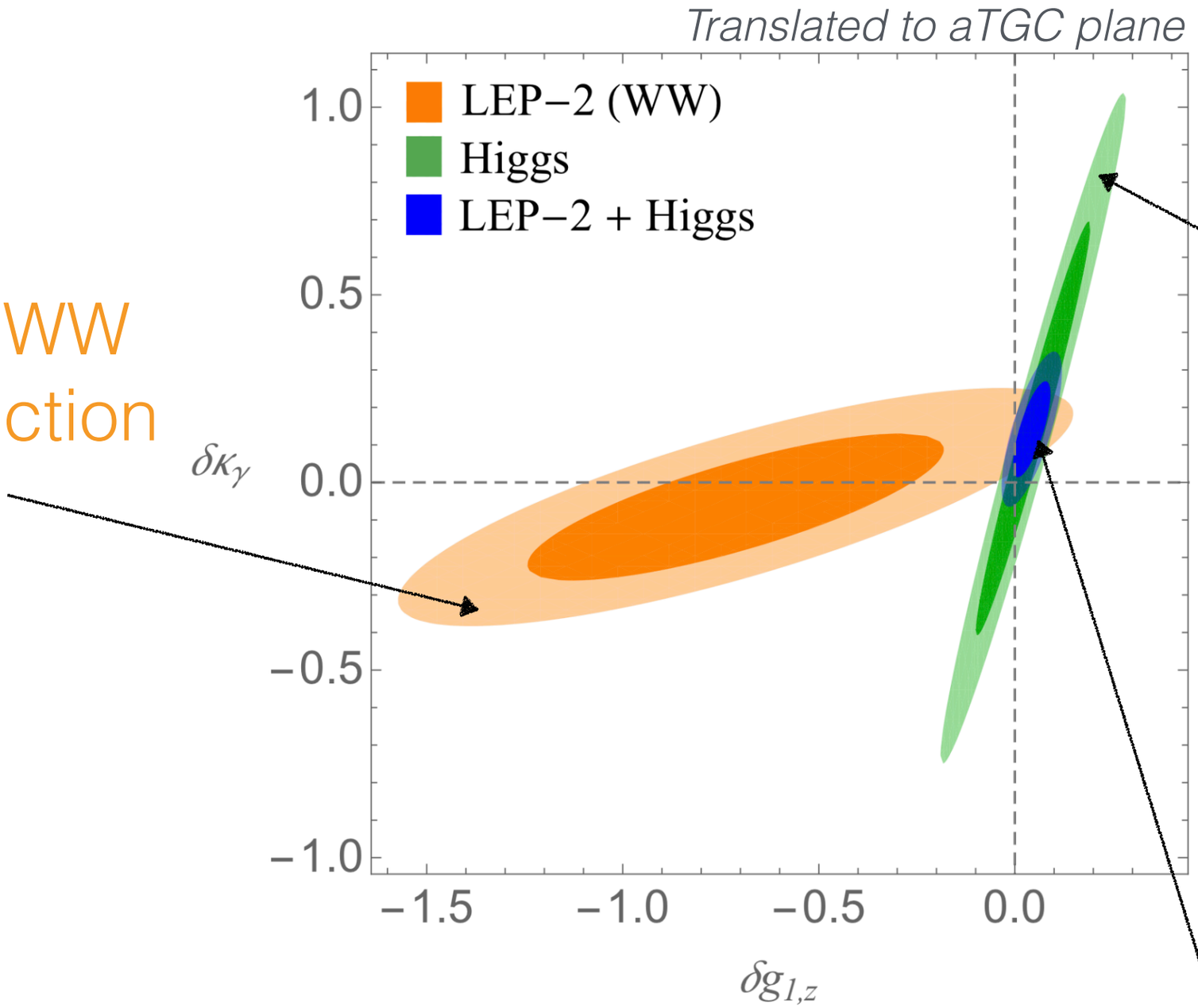
JHEP 1502 (2015) 039

Technical note:
Higgs basis implemented in UFO via FeynRules, observable dependence on Wilson coefficients found by MC simulations in MadGraph5

Global fit: Results



LEP-2 WW flat direction

Higgs data flat direction

Robust combined fit constraints

*Including dim-6 squared terms does not impact the combined result

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Global fit: Results

Higgs basis

$$\begin{pmatrix} \delta c_z \\ c_{zz} \\ c_{z\Box} \\ c_{\gamma\gamma} \\ c_{z\gamma} \\ c_{gg} \\ \delta y_u \\ \delta y_d \\ \delta y_e \\ \lambda_z \end{pmatrix} = \begin{pmatrix} -0.02 \pm 0.17 \\ 0.69 \pm 0.42 \\ -0.32 \pm 0.19 \\ 0.009 \pm 0.015 \\ 0.002 \pm 0.098 \\ -0.0052 \pm 0.0027 \\ 0.57 \pm 0.30 \\ -0.24 \pm 0.35 \\ -0.12 \pm 0.20 \\ -0.162 \pm 0.073 \end{pmatrix}$$

HISZ basis

$$\begin{pmatrix} f_{H,2} &= 0.03 \pm 0.34 \\ f_W &= 0.64 \pm 0.46 \\ f_B &= 2.11 \pm 1.33 \\ f_{WW} &= -0.37 \pm 0.30 \\ f_{BB} &= 0.36 \pm 0.29 \\ f_{GG} &= 0.41 \pm 0.21 \\ f_u &= -0.83 \pm 0.46 \\ f_d &= 0.32 \pm 0.31 \\ f_e &= 0.14 \pm 0.20 \\ f_{3W} &= -2.53 \pm 1.14 \end{pmatrix}$$

Warsaw basis

$$\begin{pmatrix} c_H &= 0.11 \pm 0.15 \\ c_T &= 0.034 \pm 0.021 \\ c_{WB} &= 0.34 \pm 0.20 \\ c_{WW} &= 0.69 \pm 0.43 \\ c_{BB} &= 0.69 \pm 0.42 \\ c_{GG} &= -0.0052 \pm 0.0027 \\ \hat{c}_u &= 0.65 \pm 0.32 \\ \hat{c}_d &= -0.16 \pm 0.23 \\ \hat{c}_e &= -0.03 \pm 0.13 \\ c_{3W} &= 0.63 \pm 0.29 \end{pmatrix}$$

SILH' basis

$$\begin{pmatrix} s_H &= 0.02 \pm 0.17 \\ \frac{1}{2}(s_W - s_B) &= 0.37 \pm 0.30 \\ s_{HW} &= -0.69 \pm 0.43 \\ s_{HB} &= -0.68 \pm 0.42 \\ s_{BB} &= 0.094 \pm 0.015 \\ s_{GG} &= -0.0052 \pm 0.0027 \\ \hat{s}_u &= 0.59 \pm 0.33 \\ \hat{s}_d &= -0.23 \pm 0.22 \\ \hat{s}_e &= -0.10 \pm 0.15 \\ s_{3W} &= 0.63 \pm 0.29 \end{pmatrix}$$

Correlations reported in Appendix:
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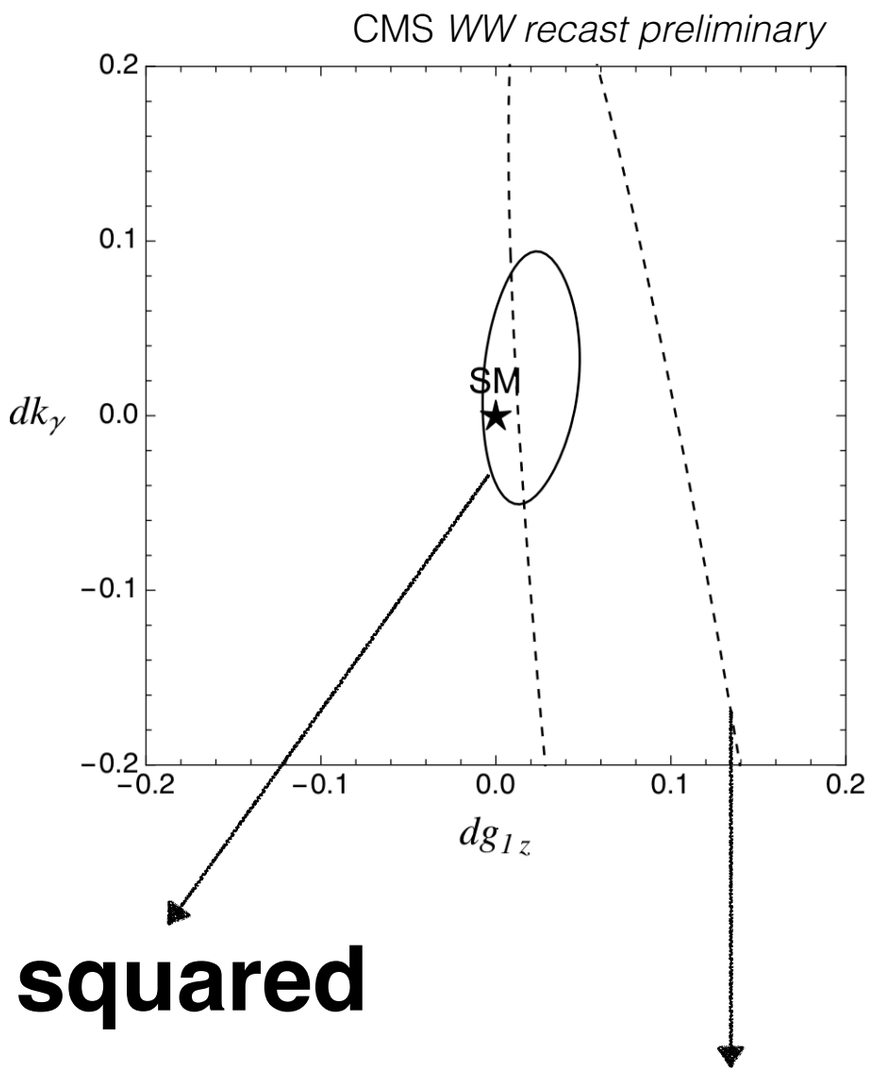
Anomalous Triple Gauge Couplings at LHC

- Recast of the CMS *WW* and ATLAS *WZ* differential distributions as a limit on *aTGC* in the SMEFT



Dim-6 squared

Linearized fit - weak limits

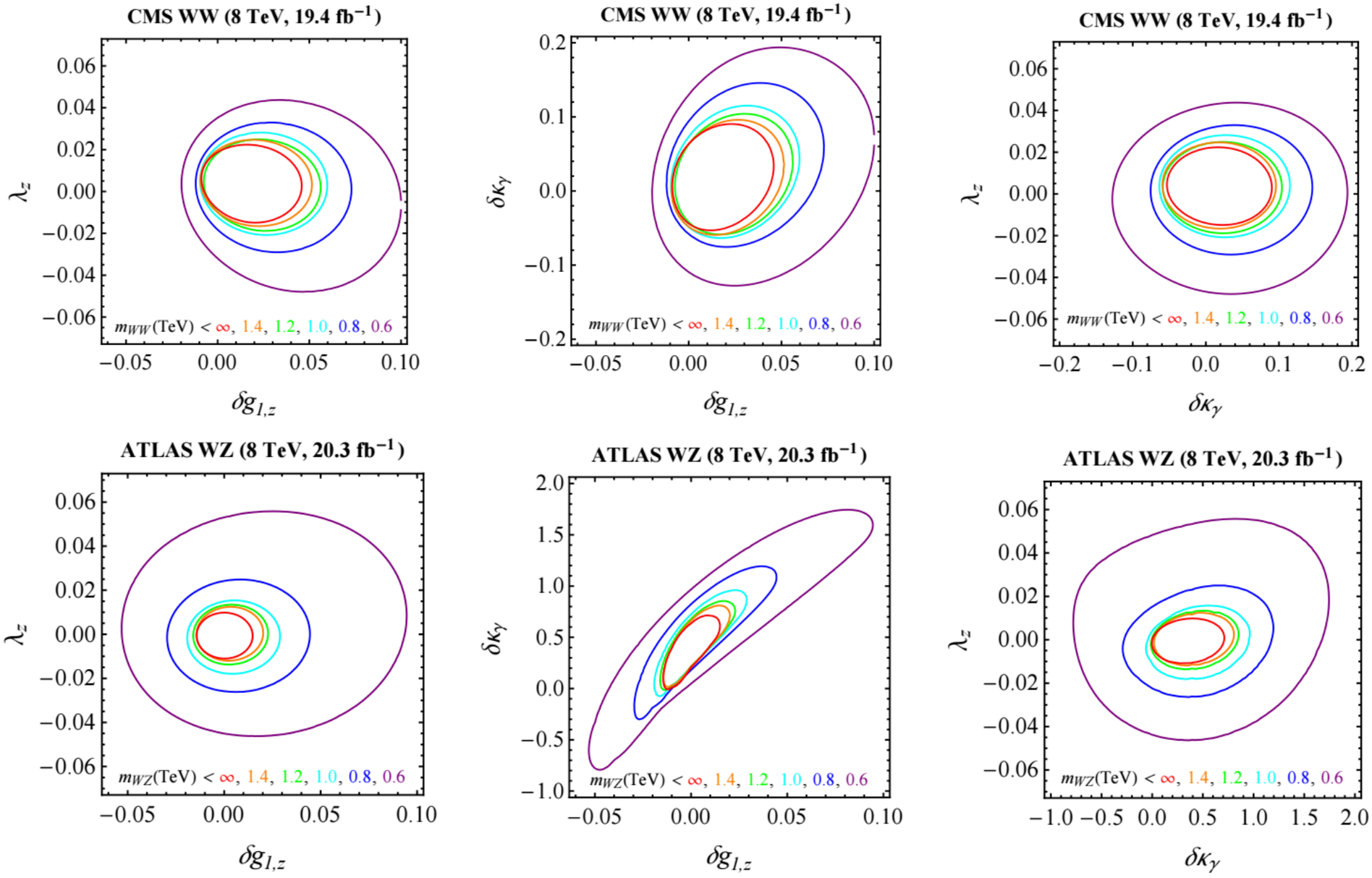
Challenges:

- LHC "scans" over a wide range of energy scales
- Limits as a function of the cut on the EFT validity control variable

Work in progress

Anomalous Triple Gauge Couplings at LHC

Including dim-6 squared terms:



Upper cut on *VV* invariant mass as a control tool, **extended applicability**

Work in progress

Conclusions

- *Global fit* to LEP-2 WW and LHC Higgs data in the **SMEFT**
- *Consistent* analysis at leading order in cutoff expansion
- *Robust limits* obtained ***only after*** combining the two datasets
- LHC aTGC searches to be interpreted *with care* in the EFT approach