CMS EFT efforts

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On behalf of the CMS Collaboration

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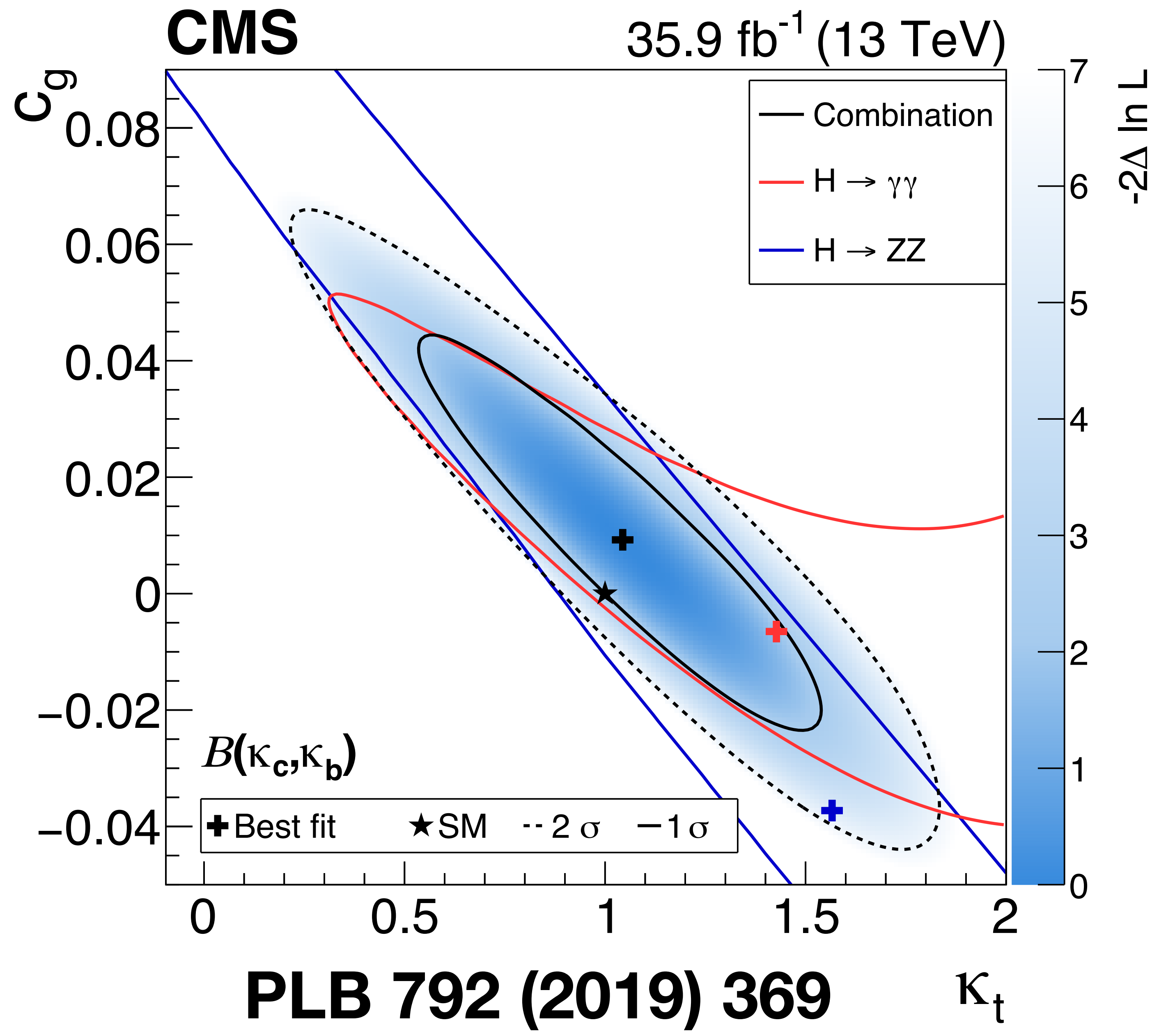
Introduction

- Current CMS EFT efforts summarized by A. Grohsjean in the 1st general meeting: link

- This talk focus on the convention/basis choices and related questions

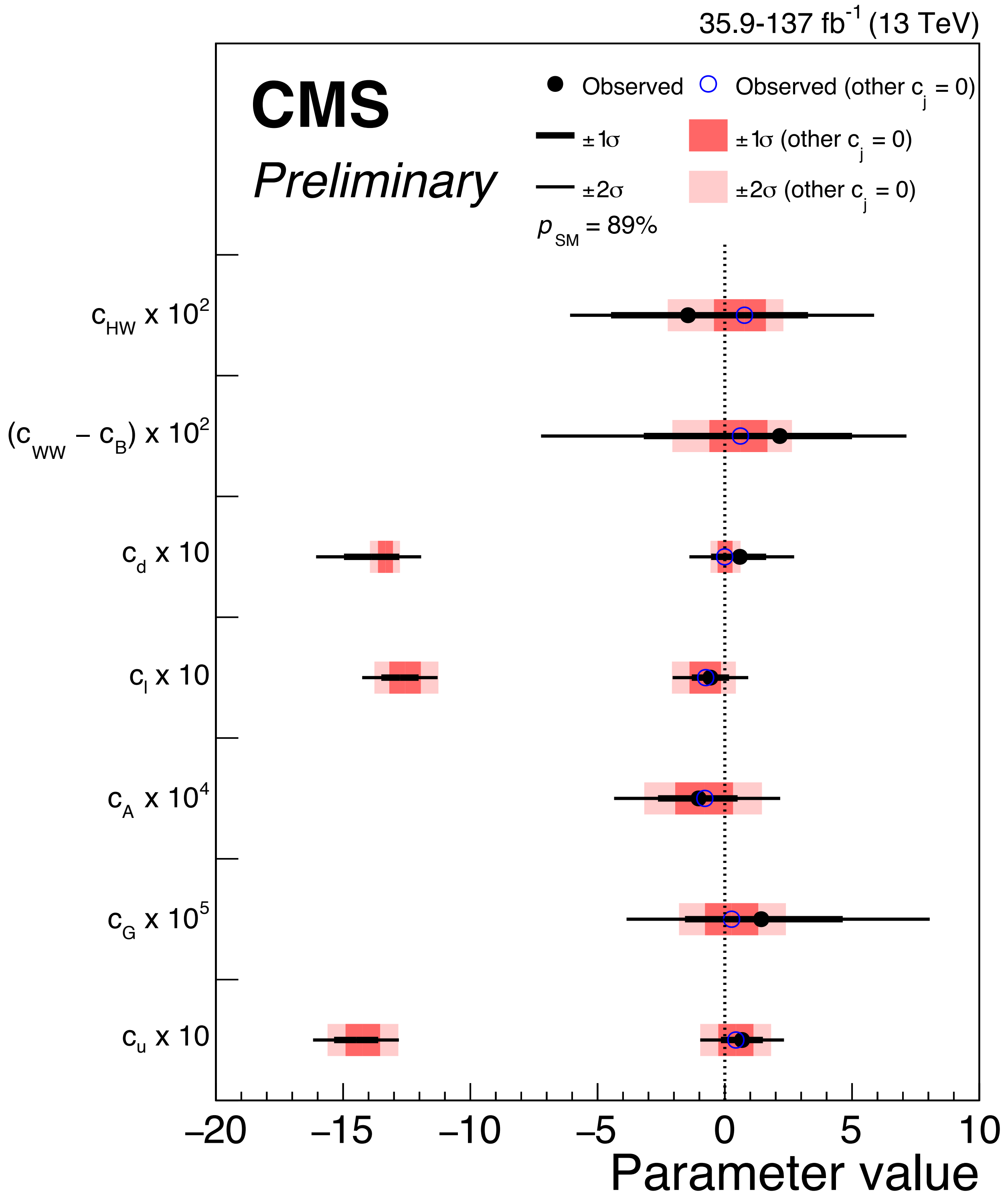
  - TOP, EW and Higgs all have ongoing analyses, questions in common, though most examples given in Higgs

EFT parameters: general approach



PLB 792 (2019) 369

- Higgs differential distributions
  - Parameterization on SILH basis
  - Xsec: linear and quadratic terms
- Multi-dimensional cross section extractions: STXS
  - Parameterization on SILH basis
  - Xsec: linear and quadratic terms



CMS-PAS-HIG-19-005

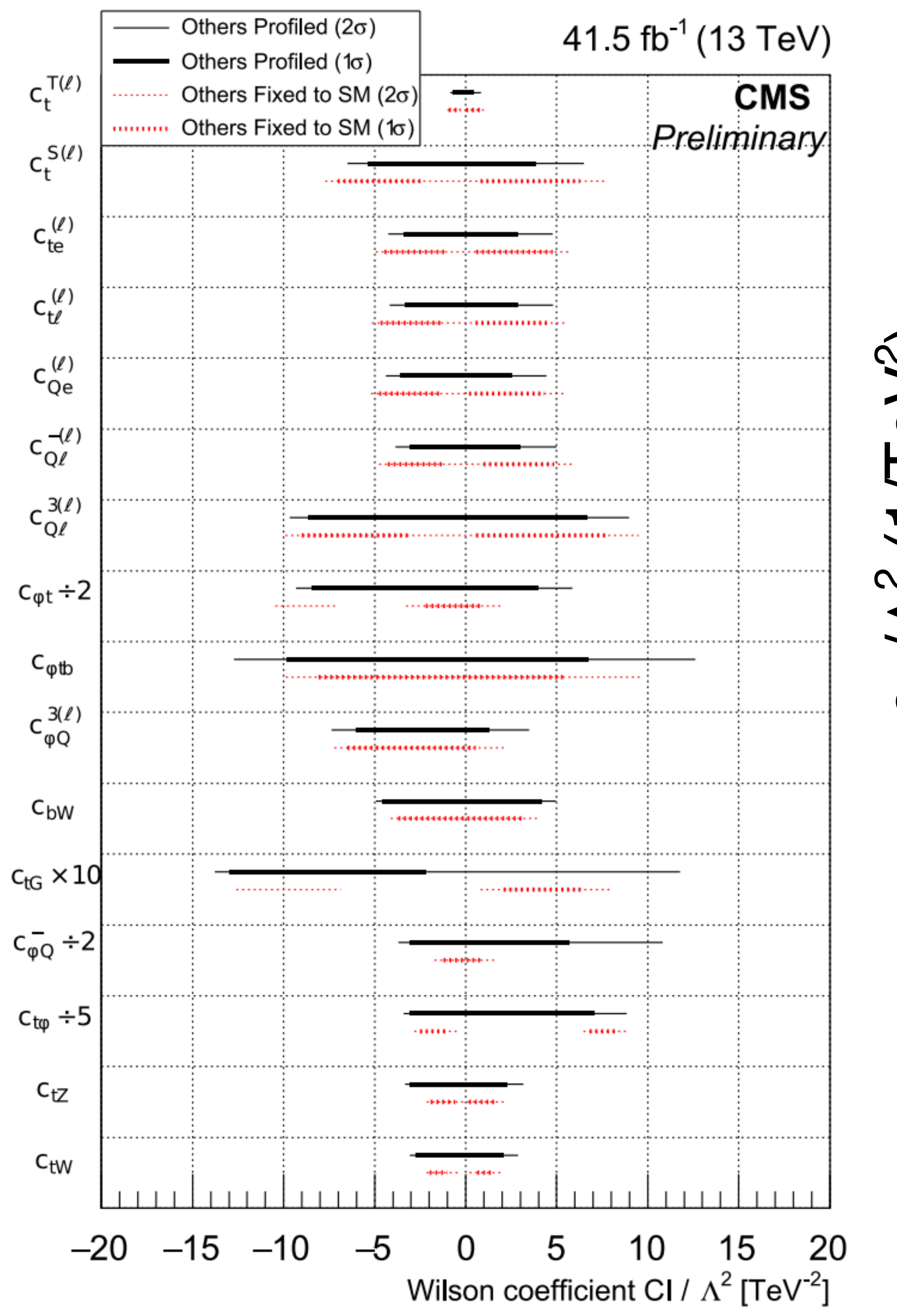
EFT parameters: general approach

- Top process xsec
  - ttlv,ttll,tllq,ttH, and tHq, leptonic final state
  - Warsaw basis, LO (dim6TopEFT model)
  - Linear and quadratic terms

$$w_i(\vec{c}) = s_{0i} + \sum_j s_{1ij}\frac{c_j}{\Lambda^2} + \sum_j s_{2ij}\frac{c_j^2}{\Lambda^4} + \sum_{j,k} s_{3ijk}\frac{c_j}{\Lambda^2}\frac{c_k}{\Lambda^2}$$

Linear Interference **Quadratic** **Quadratic Interference**

- Top differential measurement
  - ttZ differential pt(Z) and cos(θ_Z*)
  - Warsaw basis, LO (dim6TopEFT model)
  - Linear and quadratic terms



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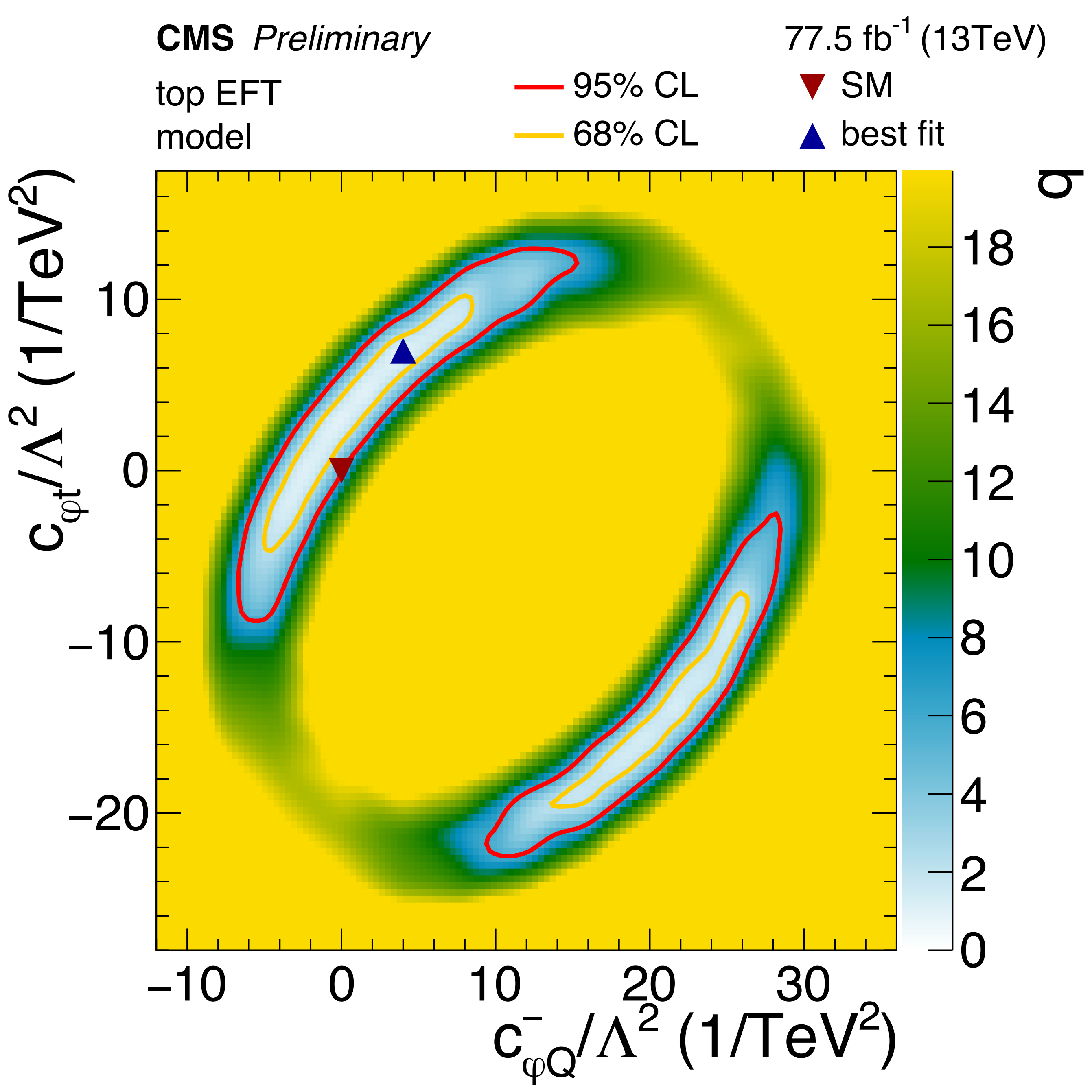
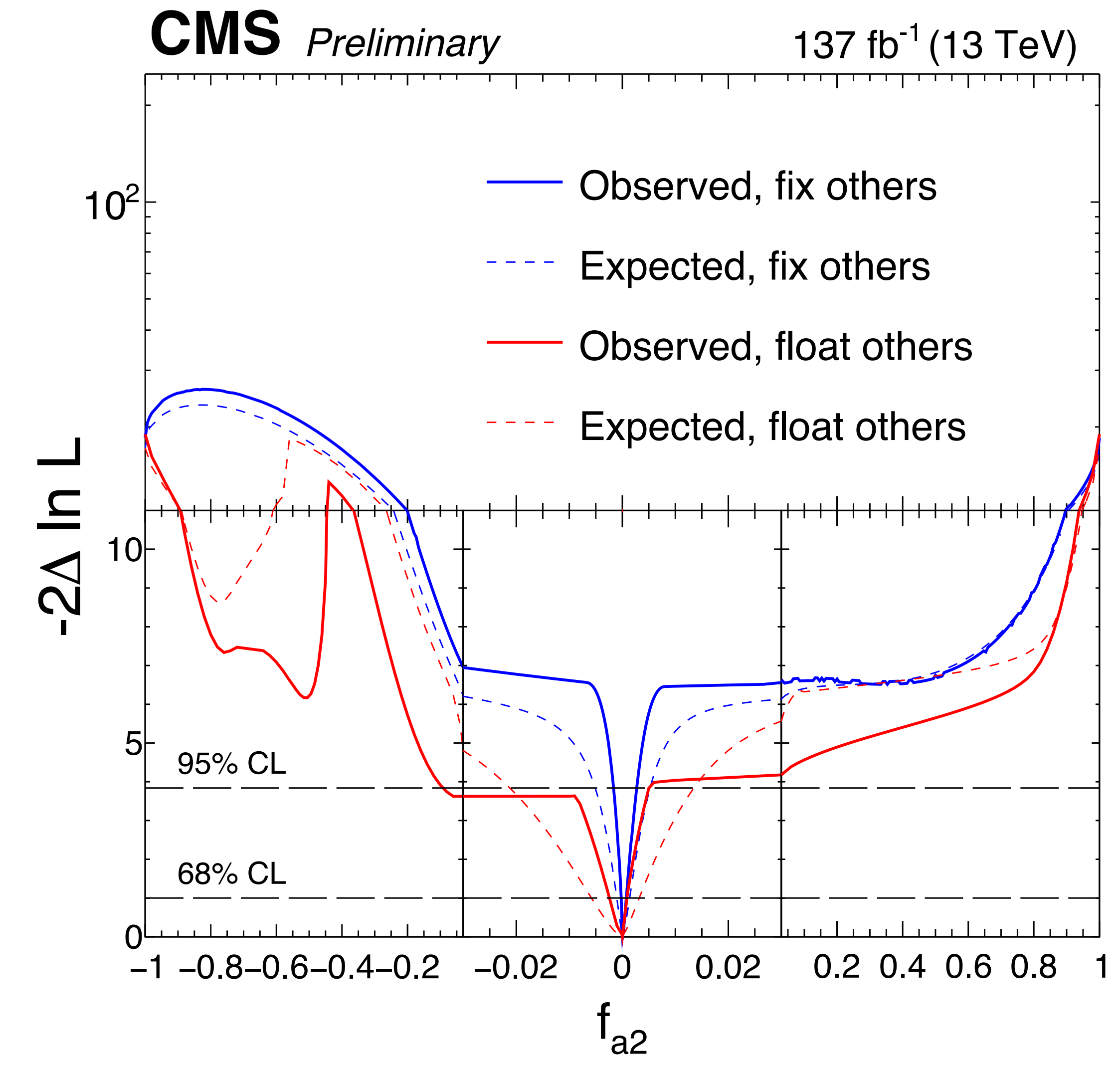


10.1007/JHEP03(2020)056

EFT parameters: dedicated approach

$$A(\mathrm{HVV}) = \frac{1}{v}\left[a_1^{\mathrm{VV}} + \frac{\kappa_1^{\mathrm{VV}} q_{\mathrm{V1}}^2 + \kappa_2^{\mathrm{VV}} q_{\mathrm{V2}}^2}{\left(\Lambda_1^{\mathrm{VV}}\right)^2} + \frac{\kappa_3^{\mathrm{VV}} (q_{\mathrm{V1}} + q_{\mathrm{V2}})^2}{\left(\Lambda_Q^{\mathrm{VV}}\right)^2}\right] m_{\mathrm{V1}}^2 \epsilon_{\mathrm{V1}}^* \epsilon_{\mathrm{V2}}^* + \frac{1}{v} a_2^{\mathrm{VV}} f_{\mu\nu}^{*(1)} f^{*(2),\mu\nu} + \frac{1}{v} a_3^{\mathrm{VV}} f_{\mu\nu}^{*(1)} \tilde{f}^{*(2),\mu\nu},$$



- HVV anomalous coupling measurements
  - Designed observables sensitive to each anomalous coupling
  - General EFT mass-eigenstate basis
  - SMEFT with SU(2)xU(1) symmetry -> map to Higgs parameterization
  - Linear + quadratic terms

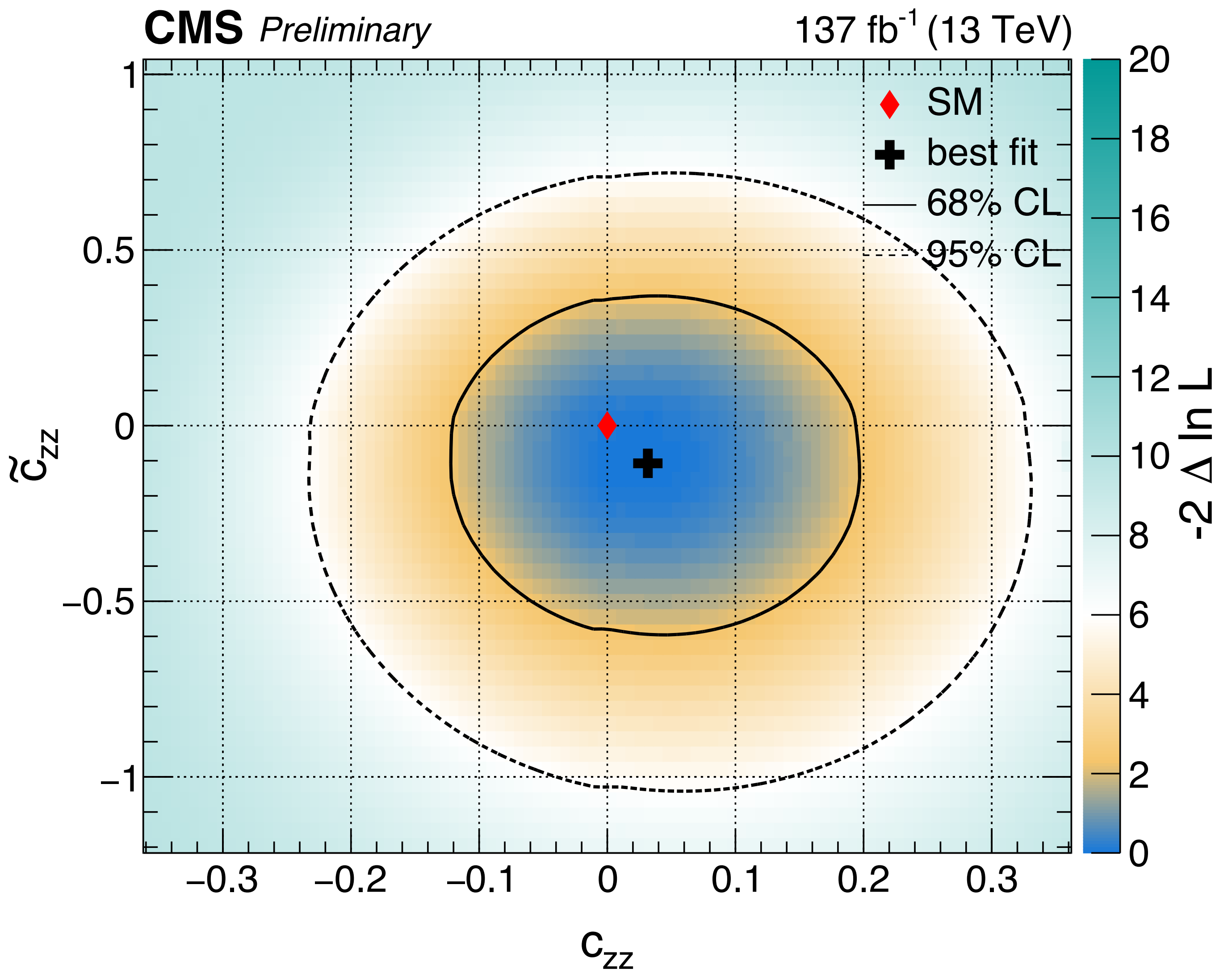
CMS-PAS-HIG-19-009

$$\delta c_z = \frac{1}{2} a_1 - 1\,,$$

$$c_{z\Box} = \frac{m_Z^2 s_w^2}{e^2} \frac{\kappa_1}{(\Lambda_1)^2}\,,$$

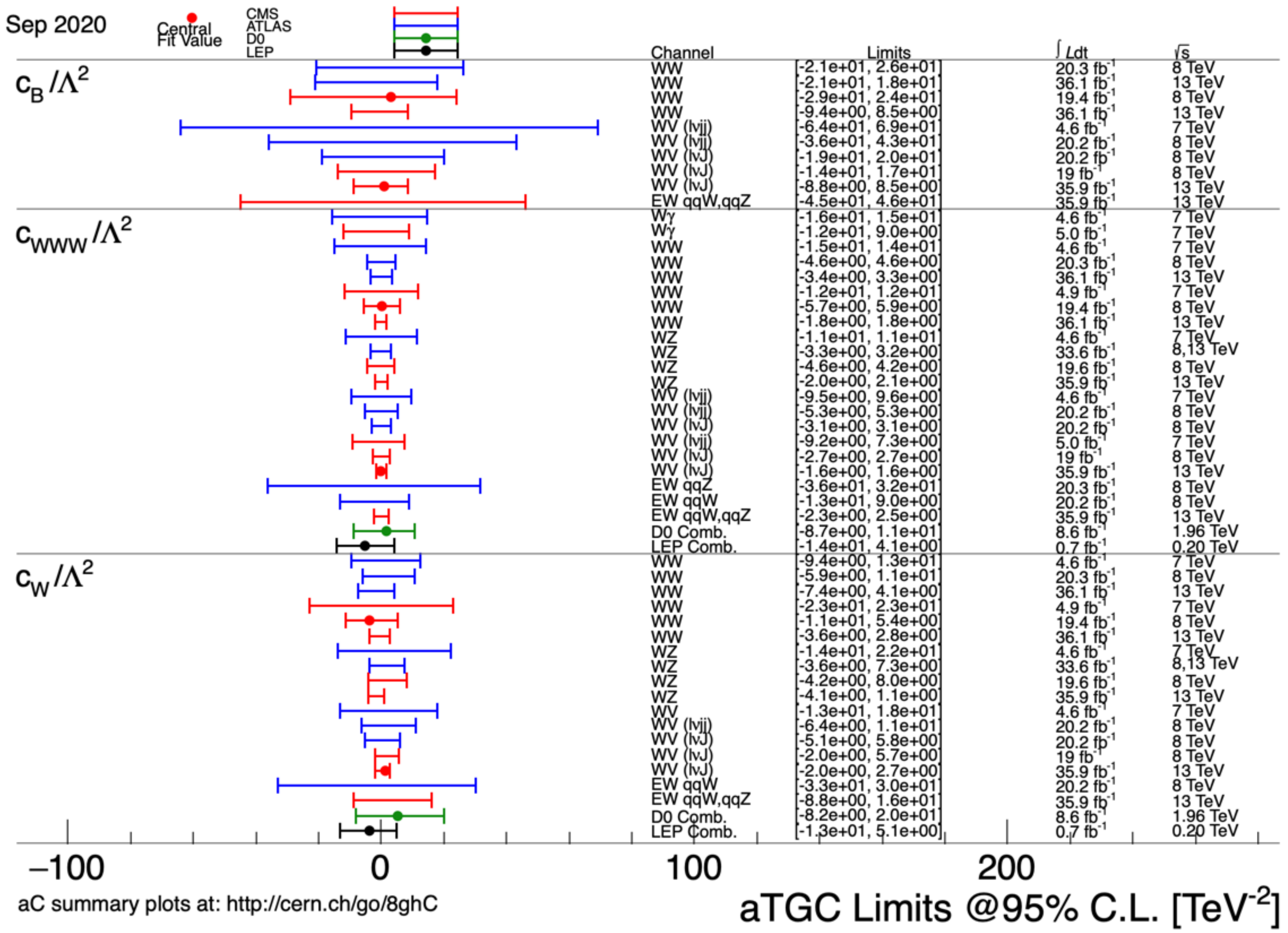
$$c_{zz} = -\frac{2 s_w^2 c_w^2}{e^2} a_2\,,$$

$$\tilde{c}_{zz} = -\frac{2 s_w^2 c_w^2}{e^2} a_3\,.$$



EFT parameters: dedicated approach

- Anomalous triple and quartic gauge couplings
  - Dedicated final states, sensitive to different aTGC and aQGC
  - Conversion to EFT, HISZ basis



Choice of model /basis

- Current choices of models/basis are quite diverse
  - transparent expressions of analysis observables
    - aTGC/aQGC in HISZ, anomalous HVV and Hff couplings map to Higgs parameterization
  - Availability of the tools
  - Direct comparison to previous results
- For grand combination across LHC, easier to use the same language
  - given the correct tool, most analyses could be related in different bases
  - HIG STXS combination plans to move to Warsaw basis: public tool "EFT2Obs" by A.Gilbert and CMS HIG Combination experts
  - Dedicated AC: mass eigenstates to perform analysis and report results, map to any basis rotation in combination
  - Top: SMEFT Warsaw basis
  - EW: mainly in HISZ, for combination could be rotated

Analysis in different base

Whatever basis chosen, analysis will be sensitive to the same physics, just in different combinations of operator

AC **Higgs** **Warsaw basis**

$$-\frac{2s_w^2c_w^2}{e^2}a_2\,,$$

$$c_{zz} = \frac{g^4 c_{WW} + 4g^2 g'^2 c_{WB} + g'^4 c_{BB}}{(g^2+g'^2)^2}\,,$$

$$c_{z\gamma} = \frac{g^2 c_{WW} - 2(g^2 - g'^2) c_{WB} - g'^2 c_{BB}}{g^2+g'^2}\,,$$

$$c_{\gamma\gamma} = c_{WW} + c_{BB} - 4c_{WB}\,,$$

$$c_{w\Box} = \frac{2}{g^2-g'^2}\left[g'^2 c_{WB} - c_T + \delta v\right],$$

$$c_{z\Box} = -\frac{2}{g^2}\left[c_T - \delta v\right],$$

$$c_{\gamma\Box} = \frac{2}{g^2-g'^2}\left[(g^2+g'^2)c_{WB} - 2c_T + 2\delta v\right].$$

HVV **Rosetta, arXiv:1508.05895**

AC **Warsaw basis**

$$g_4^{ZZ} = -2\frac{v^2}{\Lambda^2}\left(s_w^2 w_{\phi\tilde{B}} + c_w^2 w_{\phi\tilde{W}} + s_w c_w w_{\phi B\tilde{W}}\right),$$

$$g_4^{\gamma\gamma} = -2\frac{v^2}{\Lambda^2}\left(c_w^2 w_{\phi\tilde{B}} + s_w^2 w_{\phi\tilde{W}} - s_w c_w w_{\phi B\tilde{W}}\right),$$

$$g_4^{Z\gamma} = -2\frac{v^2}{\Lambda^2}\left(s_w c_w (w_{\phi\tilde{W}} - w_{\phi\tilde{B}}) + \frac{1}{2}(s_w^2 - c_w^2) w_{\phi B\tilde{W}}\right),$$

$$g_4^{gg} = -2\frac{v^2}{\Lambda^2} w_{\phi\tilde{G}}\,.$$

HVV CP-odd **JHUGenLexicon, arXiv:2002.09888**

Questions

- Linear or linear+quadratic terms

$$w_i(\vec{c}) = s_{0i} + \sum_j s_{1ij} \frac{c_j}{\Lambda^2} + \sum_j s_{2ij} \frac{c_j^2}{\Lambda^4} + \sum_{j,k} s_{3ijk} \frac{c_j}{\Lambda^2} \frac{c_k}{\Lambda^2}$$

Linear Interference | **Quadratic** | **Quadratic Interference**

- Most CMS analyses consider linear+quadratic terms
  - positive definite
  - sensitive to operators (e.g CP-odd) does not enter linear terms
  - allow to access EFT validity
- Aware of possible issues
  - D8 operators neglected in both cases
  - dependence on quadratic terms indicates poor sensitive to EFT effects
- Pros usually outweighs cons in experimental analyses

Questions

- Operator double insertion
  - VBF/ZH/WH, H→ ZZ/WW

$$w_i(\vec{c}) = \left(s_{0i} + \sum_j s_{1ij}\frac{c_j}{\Lambda^2} + \sum_j s_{2ij}\frac{c_j^2}{\Lambda^4} + \sum_{j,k} s_{3ijk}\frac{c_j}{\Lambda^2}\frac{c_k}{\Lambda^2}\right) \times \left(s_{0i} + \sum_j s'_{1ij}\frac{c_j}{\Lambda^2} + \sum_j s'_{2ij}\frac{c_j^2}{\Lambda^4} + \sum_{j,k} s'_{3ijk}\frac{c_j}{\Lambda^2}\frac{c_k}{\Lambda^2}\right)$$

Production **Decay**

  - Up to $1/\Lambda^8$
  - What to include in this case? Currently keep all for positive definite

Questions

- CP-odd operators
  - no strict reason why CP-odd should be prohibited
  - so far not many analyses extracting CP-odd WC
  - overall xsec=0 in linear term
  - observables could be designed to be sensitive to the linear term
  - dedicated measurements in combination with general ones

Summary

- As more EFT analyses ongoing, some common questions come up
  - EFT expansions to be used
    - double insertion operators
  - CP-odd operators
- For a grand combination, analyses explore expressing results in different bases