C1 and K_{EW} factors parametrization in STXS bins for constraining the Higgs boson self-coupling

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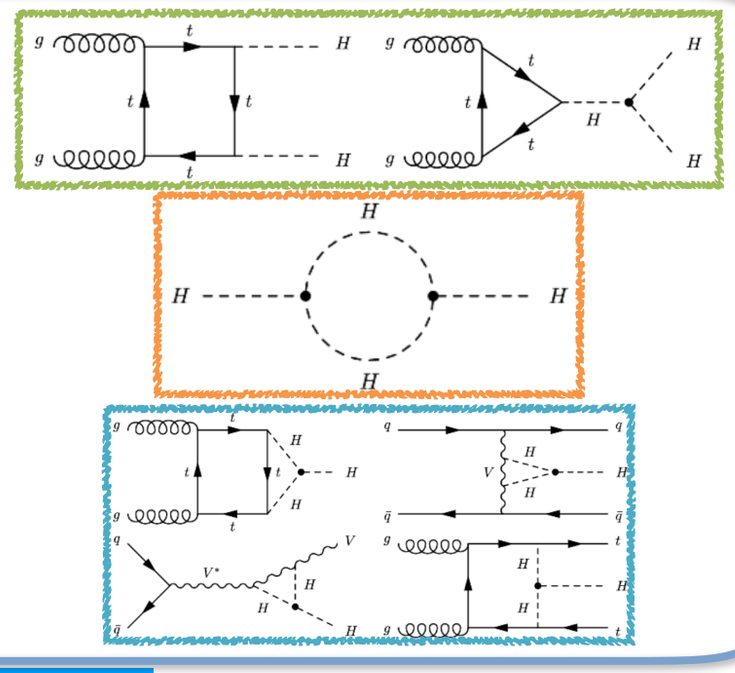
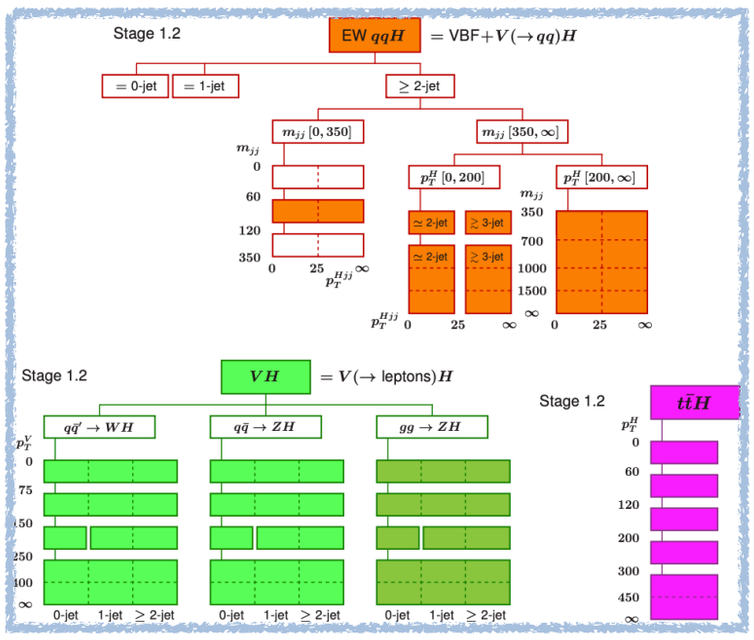
Higgs boson self-coupling (κ_λ) measurements: overview

- **Measurements of the Higgs trilinear self-coupling ($\kappa_\lambda = \lambda_3/\lambda_{SM}$) can be performed through:**
  - **DiHiggs (HH) processes: direct searches**
    HH cross sections depend directly on κ_λ at LO
  - **Single H processes: indirect constraints**
    - **no direct dependency on κ_λ at LO**
    - **sensitivity through NLO EW corrections to the single H processes:**
      - **universal $O(\lambda_3^2)$ correction due to Higgs wave-function renormalization**
      - **linear $O(\lambda_3)$ correction depending on production mode, decay channel and kinematics**



Single Higgs cross sections as a function of κ_λ

- **A parametrization of the single-Higgs cross sections in terms of the κ_λ in regions defined by STXS 1.2 is performed**
  - **Simplified Template Cross Sections (STXS): mutually exclusive regions of the phase space (highest granularity used is 1.2)**



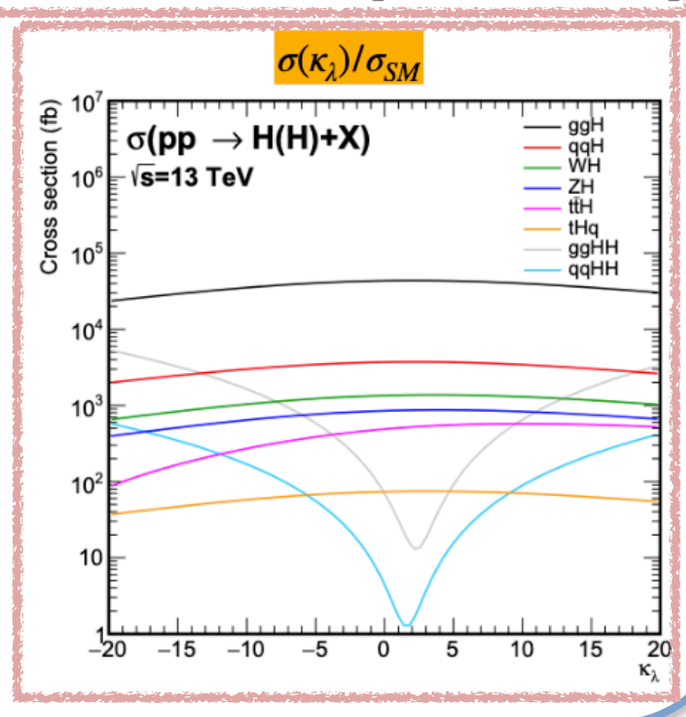
- C_1 are the process and kinematic-dependent coefficients which encodes the magnitude of the κ_λ-dependent corrections (***linear correction***)
- Z_H^{BSM} is the wave function renormalization (***from universal correction***)
- K_{EW} factors represent the full set of NLO EW corrections

Fabio Maltoni et al [1]

$$\mu_i(\kappa_\lambda, \kappa_i) = \frac{\sigma^{\mathrm{BSM}}}{\sigma^{\mathrm{SM}}} = Z_H^{\mathrm{BSM}}(\kappa_\lambda)\left[\kappa_i^2 + \frac{(\kappa_\lambda - 1)C_1^i}{K_{\mathrm{EW}}^i}\right]$$

Fabio Maltoni et al [1]

$$Z_H^{\mathrm{BSM}}(\kappa_\lambda) = \frac{1}{1 - (\kappa_\lambda^2 - 1)\delta Z_H}, \text{with } \delta Z_H = -1.536 \times 10^{-3}.$$

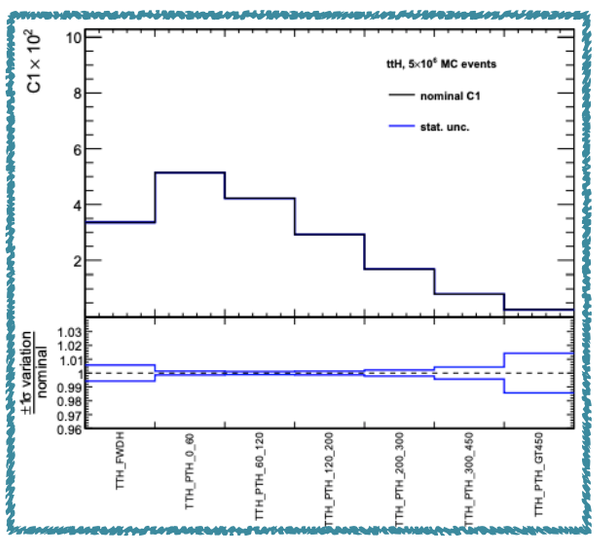


Recipe for C1 and k-factor determination

- **C1 coefficients are obtained separately for the $t\bar{t}H$, $W(l\nu)H$, $Z(ll)H$, and $H(jj)$ processes:**
  - **5M of events are generated for each process using Madgraph5_aMC@NLO (v 2.5.5)using PDFset PDF4LHC15_nlo_mc**
  - **For each event, the weight representing LO cross section (w_{LO}) and the weight corrected by κ_λ-effects are computed (w_{NLO})**
  - **Events are further classified in STXS 1.2 bins using Rivet toolkit routine and C1 for a given STXS 1.2 bin is computed as:**

$$C_1^i = \sum_j w^j{}_{\mathrm{NLO}} / \sum_j w^j{}_{\mathrm{LO}}$$

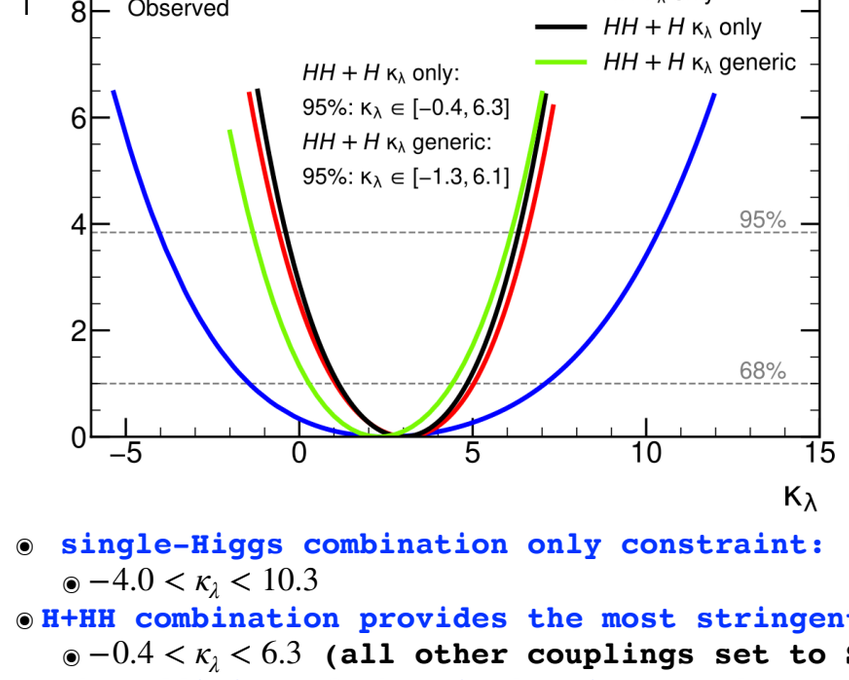
- **C1 coefficients for the $t\bar{t}H$ process show the largest sensitivity to the κ_λ variations:**
  - **large effect for both inclusive/differential cross section**
- **Uncertainties affecting C1 computation evaluated are found to be negligible**



STXS BIN	K_{EW}
TTH_FWDH	1.017
TTH_PTH_0_60	1.041
TTH_PTH_60_120	1.025
TTH_PTH_120_200	1.002
TTH_PTH_200_300	0.978
TTH_PTH_300_450	0.956
TTH_PTH_GT450	0.923

κ_λ constraints from H+HH combination [3]

- **Input channels used in the combination:**
  - **single-Higgs channels (in STXS regions):**
    $\gamma\gamma$, $ZZ^*(4l)$, $\tau^+\tau^-$, $WW(e\nu\mu\nu)$ (ggF, VBF), $b\bar{b}(VH, VBF, t\bar{t}H)$
  - **di-Higgs channels:** $b\bar{b}\gamma\gamma$, $b\bar{b}\tau^+\tau^-$, $b\bar{b}b\bar{b}$



κ_λ profile likelihood ratio

- **single-Higgs combination only constraint:**
  - $-4.0 < \kappa_\lambda < 10.3$
- **H+HH combination provides the most stringent constraints:**
  - $-0.4 < \kappa_\lambda < 6.3$ **(all other couplings set to SM unity)**
- **The addition of the single-Higgs analyses to the combination allow relaxing assumptions on κ_t**
  - $-0.4 < \kappa_\lambda < 6.3$ **(sensitivity on κ_λ is kept)**
- **Generic case where $\kappa_\lambda, \kappa_V, \kappa_t, \kappa_b, \kappa_\tau$ are floated simultaneously in the fit:**
  - $-1.4 < \kappa_\lambda < 6.1$ **(there is still strong constraint on κ_λ)**

For more information:
[1]: Trilinear Higgs coupling determination via single-Higgs differential measurements at the LHC (Eur. Phys. J. C (2017) 77: 887)
[2]: Modeling of the single-Higgs simplified template cross-sections (STXS 1.2) for the determination of the Higgs boson trilinear self-coupling (LHC Higgs Working Group, Public Note) (LHCHWG-2022-002)
[3]: Constraining on the Higgs boson self-coupling from H+HH production with the ATLAS detector using pp collisions at 13 TeV (Phys. Lett. B 843 (2024) 137745)