Constraints on λ_3 from single-Higgs precision measurements

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Higgs @ HL/HE-LHC
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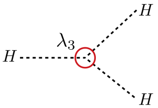
Theoretical motivation

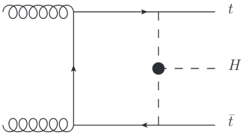
$$\kappa_\lambda = \lambda_3/\lambda_3^{SM}$$

- Even @ HL-LHC: constraints on κ_λ from HH remain limited
  - investigate complimentary means for probing λ_3
- Single H production depends on λ_3 @ NLO EWK
  - non-universal modification of cross sections:

$$\sigma^i/\sigma_{SM} = 1 + (\kappa_\lambda + 1)C_1 + \ldots$$

  - C_1: **production mode + kinematic dependence**
  - Largest for ttH at threshold (low p_T^H)
- Precision measurements of single H (differential) rates provide access to λ_3





$p_T(H)$ [GeV]	$[0,25]$	$[25,50]$	$[50,100]$	$[100,200]$	$[200,500]$	> 500
VBF	0.97	0.88	0.73	0.58	0.45	0.29
ZH	2.00	1.75	1.21	0.51	0.01	−0.10
WH	1.70	1.49	1.04	0.44	0.01	−0.09
$t\bar{t}H$	5.31	5.07	4.38	3.00	1.27	0.17
tHj	1.23	1.18	1.02	0.74	0.33	−0.06

C_1 values (%) for single H production @ 13 TeV

Contribution in YR

3. Di-Higgs production and Higgs self couplings

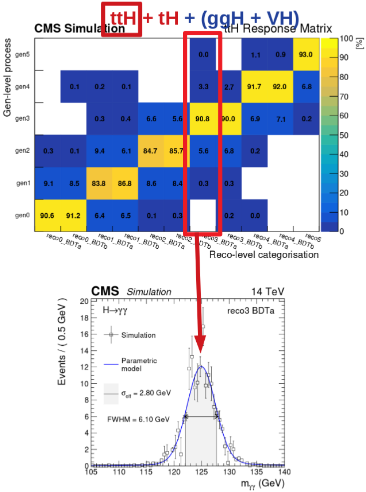
Sub-chapters dedicated to indirect probe...

- g) Indirect probes through single Higgs boson production (theory)
- h) Indirect probes of the trilinear coupling through differential distribution measurements (experimental)
- i) Theory implications: validity of direct and indirect trilinear couplings

Experimental Status: FTR-18-020

- Constraints on κ_λ via $ttH + tH$, $H \to \gamma\gamma$ differential measurements, in p_T^H

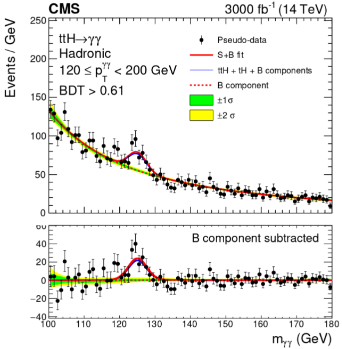
- **Centrally produced Delphes samples**: simulate response of CMS Phase-II detector @HL
- Event selection: isolate $ttH + tH$, $H \to \gamma\gamma$ topology
  - two orthogonal channels: hadronic/leptonic
  - BDT: improve S/B
- Finite detector resolution: $p_T^{\gamma\gamma} \neq p_T^H$
  - gen $\to$ reco-bin migration
  - characterised by response matrices
- Fit sig+bkg model to $m_{\gamma\gamma}$ distribution in bins of $p_T^{\gamma\gamma}$
  - incorporate effect of migration into signal models
  - Bkg model: smoothly falling function to fit bkg MC falling in $p_T^{\gamma\gamma}$ bin

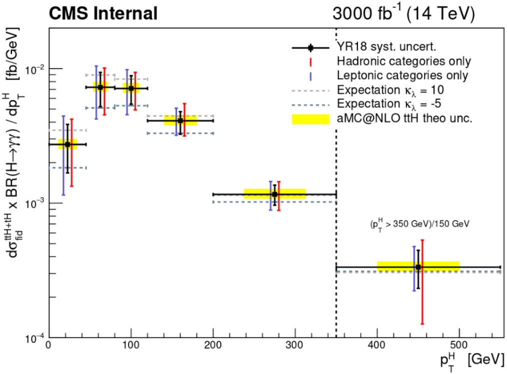


Results: $d\sigma/dp_T^H$

- Predicted sensitivity @ HL-LHC
- Unfold effects of detector: invert response matrix

Hadronic: $p_T^{\gamma\gamma} \in [120,200]$ GeV





Results: κ_λ

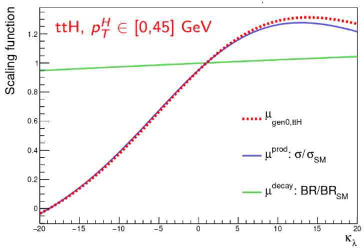
- Derive scaling functions for choice of binning:

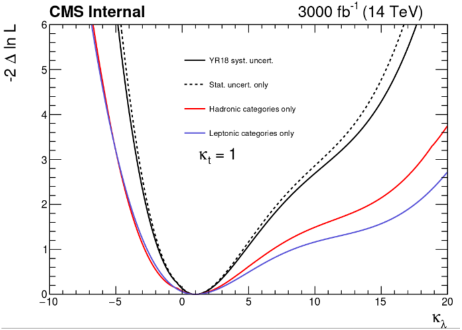
$$\mu_{ij}(\kappa_\lambda) = \frac{[\sigma \times \mathrm{BR}](\kappa_\lambda)}{[\sigma \times \mathrm{BR}]_{\mathrm{SM}}}$$

  - C_1: extract using EWK reweighting tool
  - $(i,j) = (p_T^H,$ prod. mode$)$

- **1D Likelihood scan**:
  - signal scale according to κ_λ dependence: $\mu_{ij}(\kappa_\lambda)$
  - other couplings fixed to SM

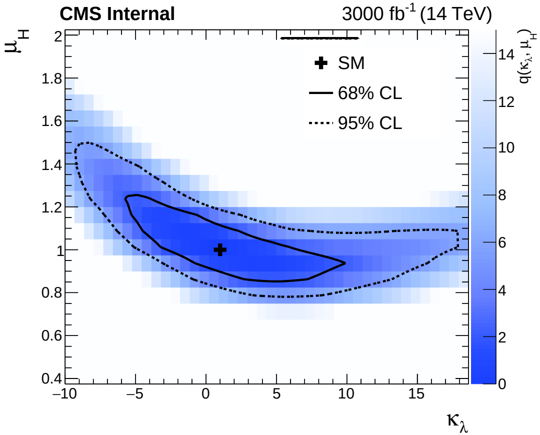
- -3.9 $< \kappa_\lambda <$ 13.9 @ 95% C.L.





Results: μ_H-vs-κ_λ

- **2D likelihood scan:** inc. overall normalisation parameter, μ_H
- other effects e.g. anomalous top-Higgs coupling
- still sensitive to κ_λ: shape differences



- **Unique to differential cross sections**

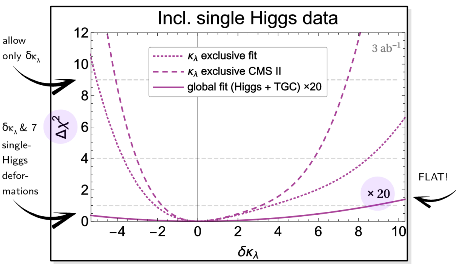
Remarks

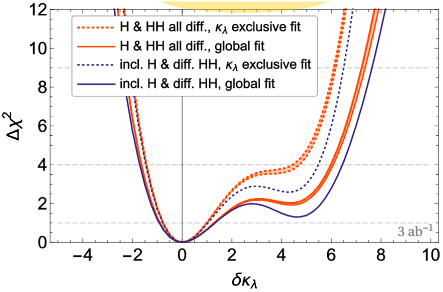
- **Proof of concept: from experimental perspective**
  - additional sensitivity to λ_3 via single H precision measurements
- Within factor ~2-3 of projected HH sensitivity @ HL-LHC
  - See previous talks
- Important to note:
  - only considered ttH (+tH), only considered $H \to \gamma\gamma$
  - extra sensitivity to be gained
- Disentangle λ_3-dependent corrections from other anomalous effects.
  $\Longrightarrow$ Difficult in HH
- Stat limited: scope widens at far future collider

- **Status**:
  - Pre-approved
  - Going through ARC: aiming for approval in next few weeks (deadline Nov 7)
  - Inclusion in YR18

Theory Status: Global fit of λ_3

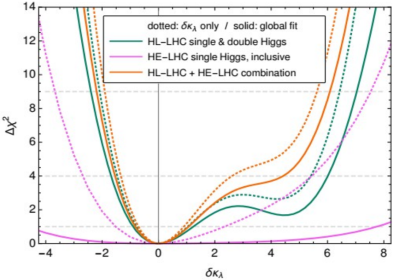
- Single Higgs inclusive: good sensitivity in 16 channels
  $\Longrightarrow$ global H couplings fit
  $\Longrightarrow$ degeneracies prevent robust bounds on κ_λ
- Include HH & single-Higgs (WH,ZH,ttH) differential: [arXiv:1704.01953]
  $\Longrightarrow$ HH drives κ_λ sensitivity
  $\Longrightarrow$ H important for constraining other coefficients which deform HH
- See talk by Stefano Di Vita
- κ_λ: [0.1,2.3] @ 95% C.L.

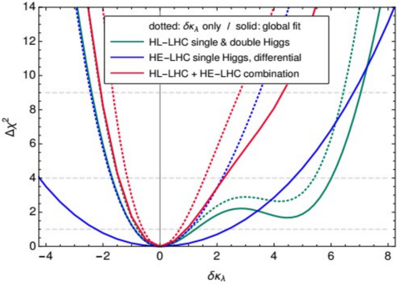




Theory Status: HE-LHC

- Single H constraints also investigated for HE-LHC
  $\Longrightarrow$ 27 TeV, 15 ab^{-1}
  $\Longrightarrow$ different C_1
- HL-LHC: global fit
- Shows importance of single H in determining λ_3
  $\Longrightarrow$ see combination
- Extrapolation based on (old) inclusive single H 13 TeV uncertainties
  $\Longrightarrow$ needs to be co-ordinated with other single H chapter





Summary

- Constraints from HH remain limited
  - important to investigate complimentary avenues for determining λ_3

- Single H depends on λ_3 @ NLO: non-universal modifications to $\sigma \times \mathrm{BR}$
  - parameterised by C_1: production mode + kinematic dependence

- Dedicated sub-chapters in YR:
  - Experimental (FTR-18-020): constraints on λ_3 from $ttH + tH, H \to \gamma\gamma \; d\sigma/dp_T^H$
    $\Longrightarrow$ proof of concept. Pre-approval
  - Theory: global fit, single H + HH
    $\Longrightarrow$ H important for constraining other coefficients which deform HH