Introduction

- Shape of the Higgs potential depends on \( \lambda_{HHH} \), \( m_H \) (Higgs mass) and \( v \) (vacuum expectation value).
- Measuring \( \lambda \) important because it probes the shape of the Higgs potential.
- \( HH \) production at the LHC provides direct access to \( \lambda \).
- \( GGF \) & \( VBF \) → Leading and sub-leading modes.
  - \( GGF \) cross-section: 31.05 fb\(^{-1} \)
  - \( VBF \) cross-section: 1.73 fb\(^{-1} \)
- \( BR (HH \rightarrow 2b2\gamma) \) : 0.26 %
- Despite of small BR, \( H \rightarrow \gamma\gamma \) good mass resolution → CMS ECAL. Easy to detect over continuum backgrounds.
- Contribution backgrounds
  - Non-resonant backgrounds: \( \gamma\gamma + \text{jets}, \gamma + \text{jets}, \text{tt} + \text{X} \)
  - Resonant backgrounds: single \( H \rightarrow \gamma\gamma \)
- Among the H production modes (ttH) has the largest contributions.

Feynman diagrams

Gluon-Gluon Fusion (GGF)

Vector Boson Fusion (VBF)

- VBF HH → probes the direct coupling between a pair of Higgs boson with a pair of Vector bosons (\( C_{2V} \))
- The coupling parameters are measured in \( K \)- framework.
Analysis Strategy

- Mutually exclusive event selections for VBF HH and GGF HH
- Multivariate analysis (MVA) techniques used to separate background contamination
- Further categorization based on $M_{\gamma\gamma} - M_{\gamma\gamma} - M_{bb} + 250$ GeV and MVA output score

- MX $\sim$ sensitive to probe beyond the standard model (BSM) physics. MVA helps in signal purity

Signal and background modelling

- 2D parametric model of $m_{\gamma\gamma}$ and $m_{bb}$ has been used
- Signal and resonant background modelling:
  - $m_{\gamma\gamma}$: multi Gaussian fit
  - $m_{bb}$: Double Sided Crystal Ball (DSCB) function
- Non-resonant background is directly modelled from Data
  - Discrete profile method used
  - F-Test $\rightarrow$ determines the polynomial function and its order

- Final signal extraction performed by simultaneous fit to all categories
Results

- Upper limit on inclusive HH cross section * BR @ 95% CL in terms of SM predicted value

<table>
<thead>
<tr>
<th>Observed</th>
<th>7.7</th>
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<tbody>
<tr>
<td>Expected</td>
<td>5.2</td>
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Best-to-date in CMS

1D Likelihood scan

- ttH process gives better constraints on $y_t$ and $\lambda_{tHH}$
- Selection of events for ttH process are mutually exclusive to HH categories

$\kappa_\lambda = \frac{\lambda_{obs}^{HHH}}{\lambda_{SM}}$

$\kappa_V = \frac{\gamma_{obs}^{VV}}{\gamma_{SM}}$

→ Inclusion of ttH makes positive $\kappa_\lambda$ preferable rules out negative $\kappa_t$ at 95% CL

Observed: $-3.3 < \kappa_\lambda < 8.5$
Expected: $-2.5 < \kappa_\lambda < 8.2$

Observed: $-1.3 < \kappa_V < 3.5$
Expected: $-0.9 < \kappa_V < 3.0$

Observed: $-2.5 < \kappa_t < 8.2$
Expected: $-0.9 < \kappa_t < 3.0$

First from CMS