



# Search for nonresonant Higgs boson pair production in final states with a pair of b -quarks and a pair of photons in $\sqrt{s} = 13$ TeV pp collisions data at CMS experiment

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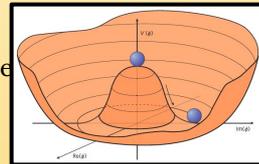
Soumya Mukherjee, TIFR

On behalf of CMS Collaboration



## Introduction

- Shape of the Higgs potential depends on **(trilinear Higgs coupling)**  $\lambda_{HHH}$ ,  $m_H$  (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:  $31.05 \text{ fb}^{-1}$
- VBF cross-section:  $1.73 \text{ fb}^{-1}$
- BR ( $HH \rightarrow 2b2\gamma$ ): 0.26 %
- Despite of small BR,

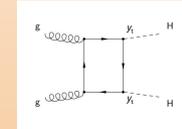
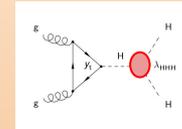
**$H \rightarrow \gamma\gamma$  good mass resolution → CMS ECAL**  
**Easy to detect over continuum backgrounds**

In SM :  $\lambda_{HHH} = \lambda_{HHHH} = \frac{m_H^2}{2v^2} = 0.13$

- Contribution backgrounds
  - Non-resonant backgrounds:  $\gamma\gamma + \text{jets}$ ,  $\gamma + \text{jets}$ ,  $tt + X$
  - Resonant backgrounds: single  $H \rightarrow \gamma\gamma$   
Among the H production modes ( $ttH$ ) has the largest contributions

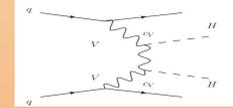
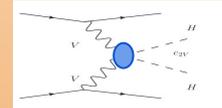
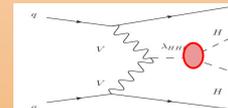
## Feynman diagrams

### Gluon-Gluon Fusion (GGF)



**Destructive Interference**

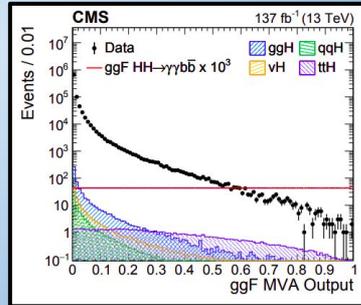
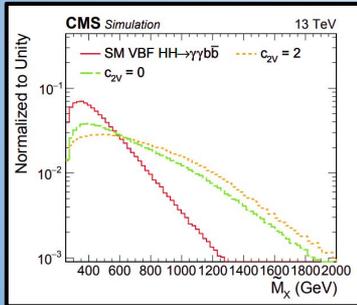
### Vector Boson Fusion (VBF)



- VBF  $HH \rightarrow$  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

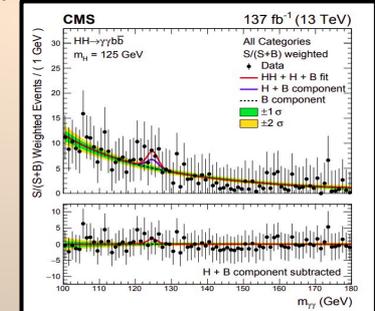
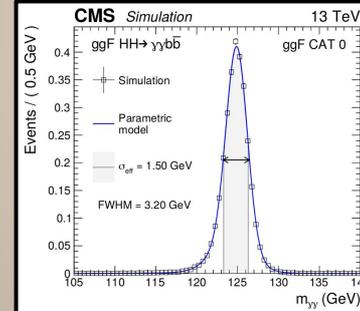
- ❑ Mutually exclusive event selections for VBF HH and GGF HH
- ❑ **Multivariate analysis (MVA) techniques** used to separate background contamination
- ❑ Further categorization based on  $MX (M_{\gamma\gamma bb} - M_{\gamma\gamma} - M_{bb} + 250 \text{ GeV})$  and MVA output score



- ❑  $MX \sim$  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

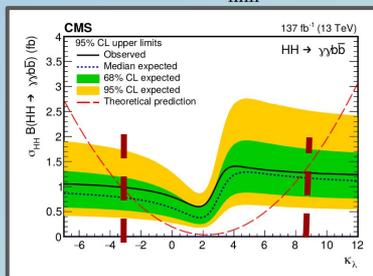
Observed	7.7
Expected	5.2

Best-to-date in CMS

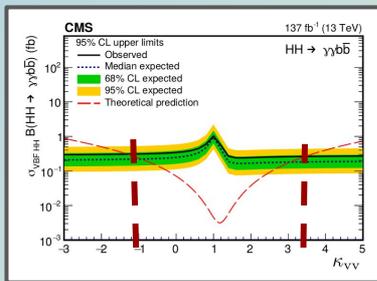
$$\kappa_\lambda = \frac{\lambda_{HHH}^{\text{obs}}}{\lambda_{HHH}^{\text{SM}}}$$

$$\kappa_{VV} = \frac{C_{2V}^{\text{obs}}}{C_{2V}^{\text{SM}}}$$

First from CMS



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



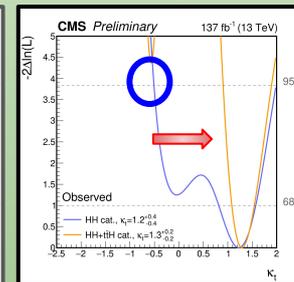
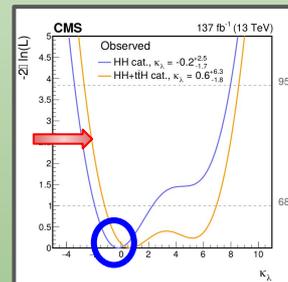
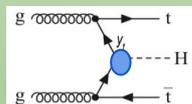
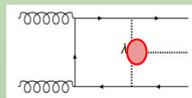
Observed:  $-1.3 < \kappa_{VV} < 3.5$   
Expected:  $-0.9 < \kappa_{VV} < 3.0$

## 1D Likelihood scan

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

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

$$\kappa_t = \frac{y_t^{\text{obs}}}{y_t^{\text{SM}}}$$



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