Measurements of the CP Structure of Higgs Boson and Top Quark in ttH Diphoton Channel at CMS

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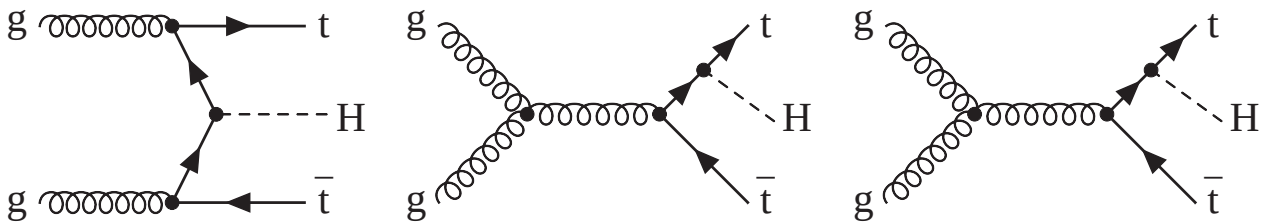
Introduction



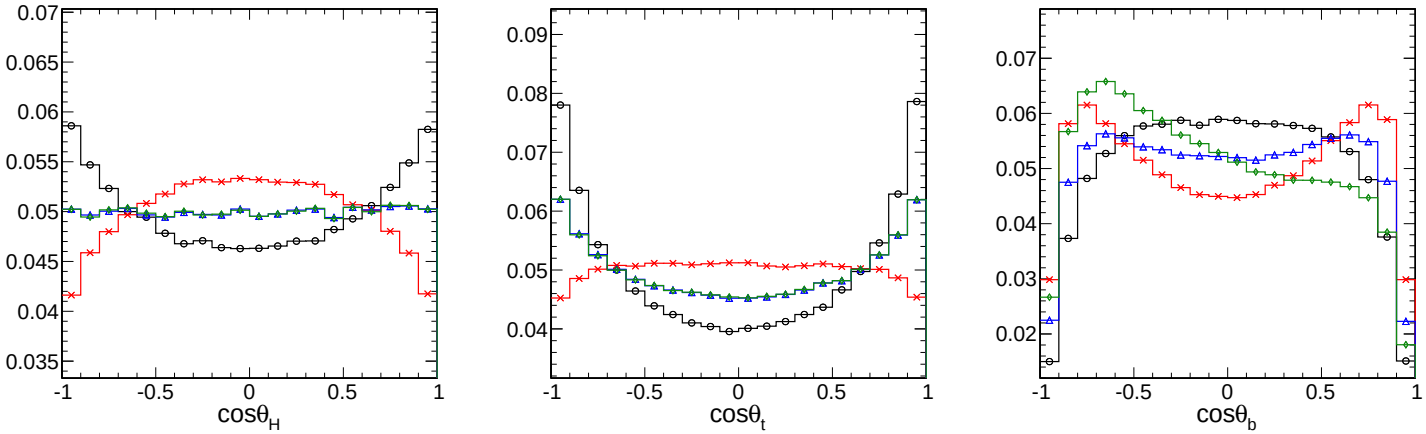
- ttH production observed at LHC
- The CP structure of H-tt has never been measured

$$A(Htt) = -\frac{m_t}{v}\bar{\psi}_t(\kappa + i\tilde{\kappa}\gamma_5)\psi_t$$

- κ: CP-even, $\tilde{\kappa}$: CP-odd; In SM: $\kappa = 1$, $\tilde{\kappa} = 0$
- We measure f_{CP}. if equal cross-section mixture, f_{CP}=0.72

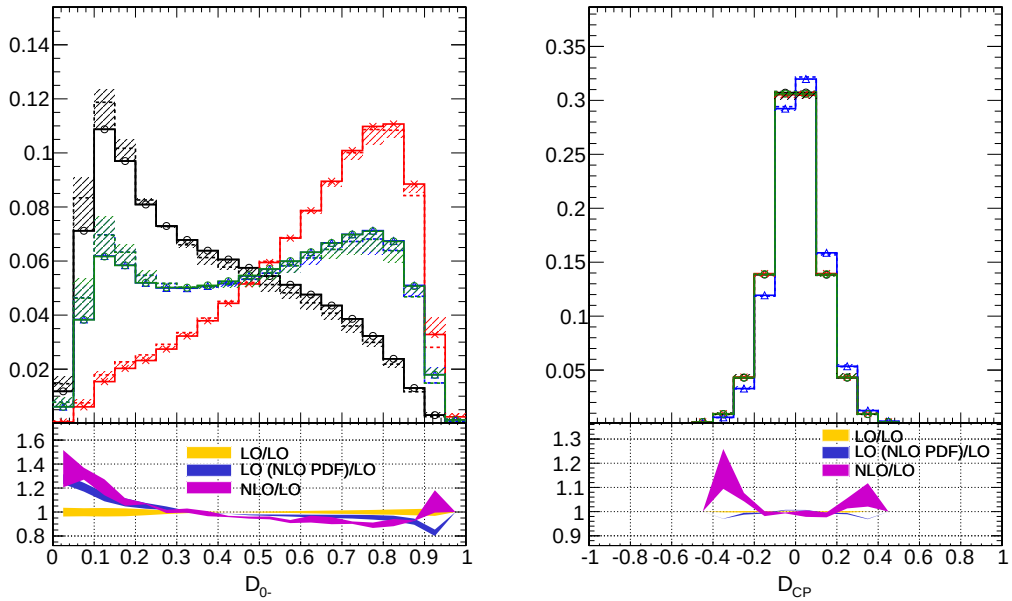
$$f_{CP} = \frac{|\tilde{\kappa}|^2}{|\kappa|^2+|\tilde{\kappa}|^2}\ ,\ \phi_{CP} = arg\left(\frac{\tilde{\kappa}}{\kappa}\right)$$

Angle Correlation



- Correlational angles carry CP information
- Angle definitions and more details: (arxiv: 1606.03107)

Matrix Element



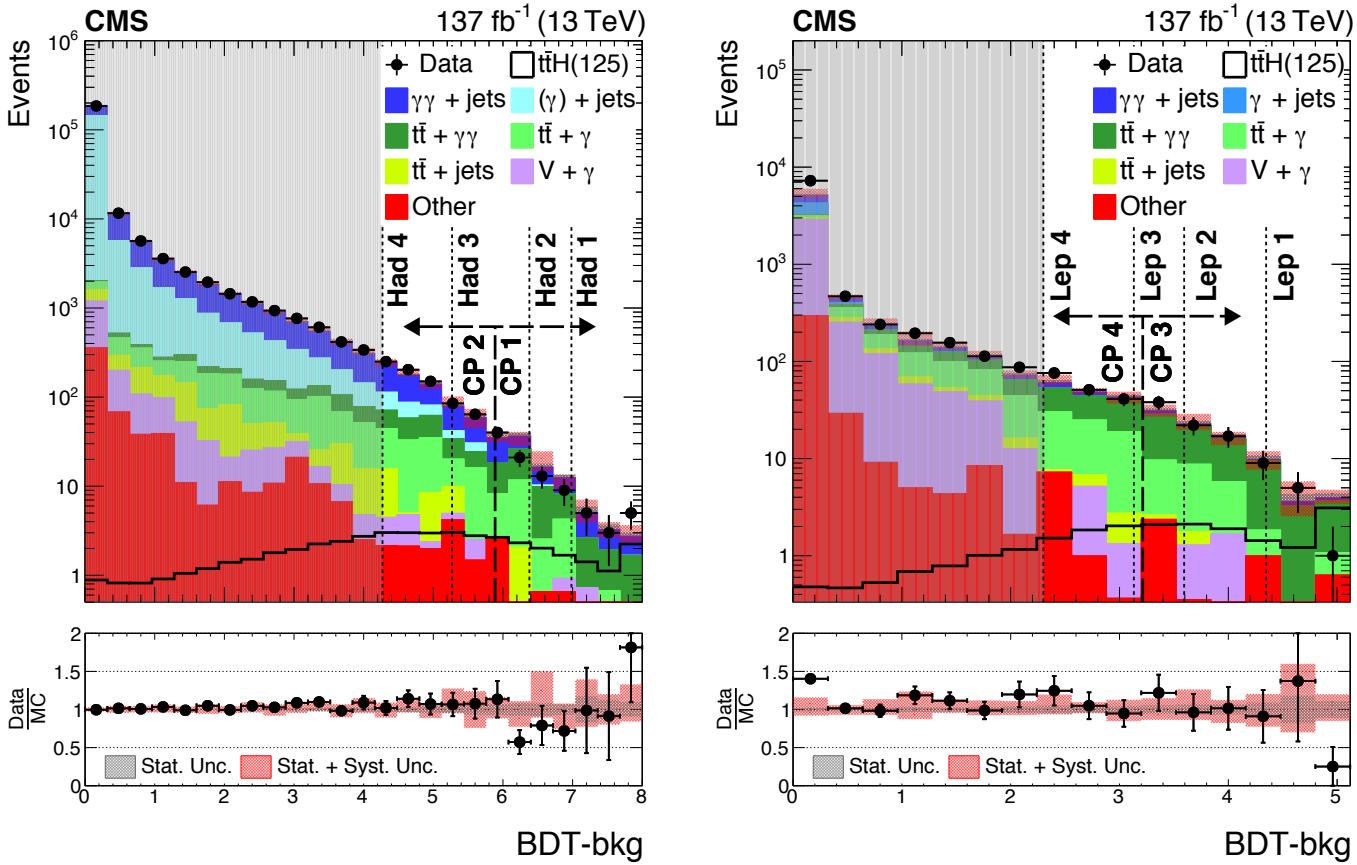
$$\mathcal{D}_{0^-}(\mathbf{\Omega}) = \frac{\mathcal{P}_{0^-}(\mathbf{\Omega})}{\mathcal{P}_{0^+}(\mathbf{\Omega}) + \mathcal{P}_{0^-}(\mathbf{\Omega})}, \quad \mathcal{D}_{\mathrm{CP}}(\mathbf{\Omega}) = \frac{\mathcal{P}_{\mathrm{int}}(\mathbf{\Omega})}{2\sqrt{\mathcal{P}_{0^+}(\mathbf{\Omega})\ \mathcal{P}_{0^-}(\mathbf{\Omega})}}$$

- $\mathcal{D}_{0^-}$: distinguish CP-odd from CP-even
- $\mathcal{D}_{\mathrm{CP}}$: measure the interference term
- Asymmetry of D_{CP} is not strong; disappear without decay information

Analysis Approach

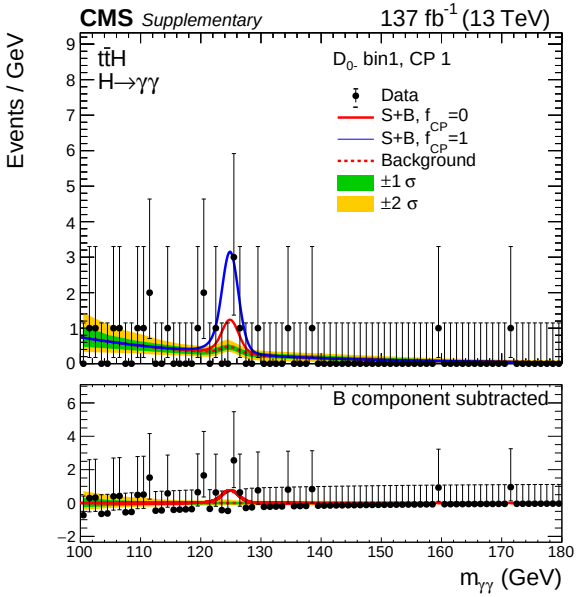
- Two discriminants
  - D_{0^-}: separate CP-even from CP-odd
  - D_{bkg}: separate signal from bkg
- use BDT output instead of matrix element technique
- Categorization: $2(D_{bkg}) \times 3(D_{0^-}) \times 2$(final state)=12 categories
- Fit $m_{\gamma\gamma}$ to extract CP-even, CP-odd signals and bkg
- Data: collected at CMS with luminosity of $137.1 fb^{-1}$

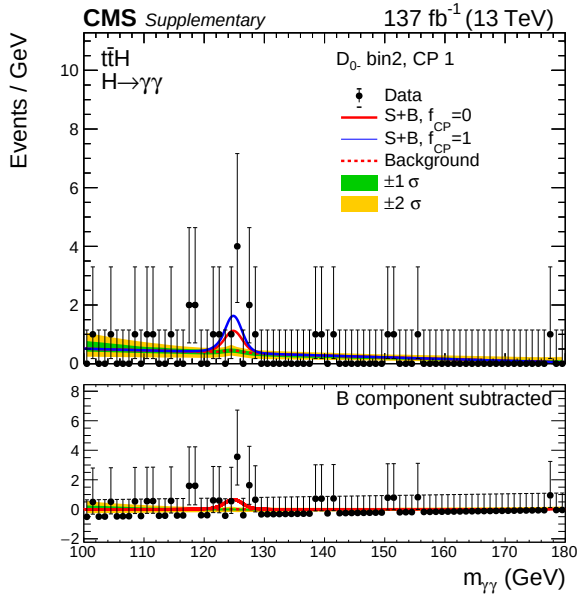
Divide Categories

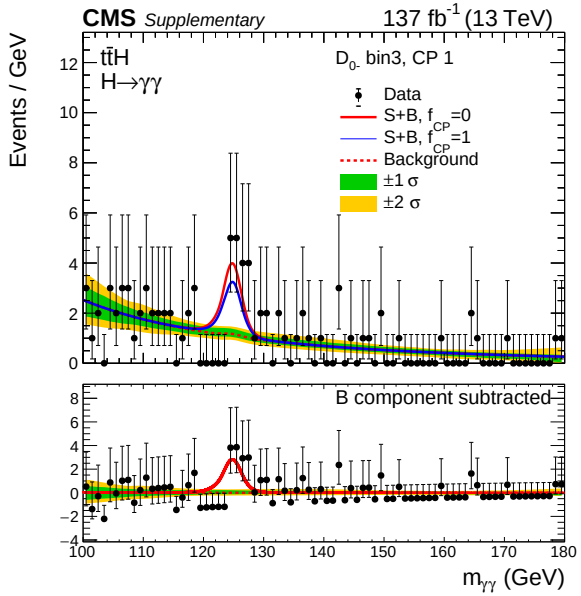


Distribution of the BDT-bkg output used for event categorization

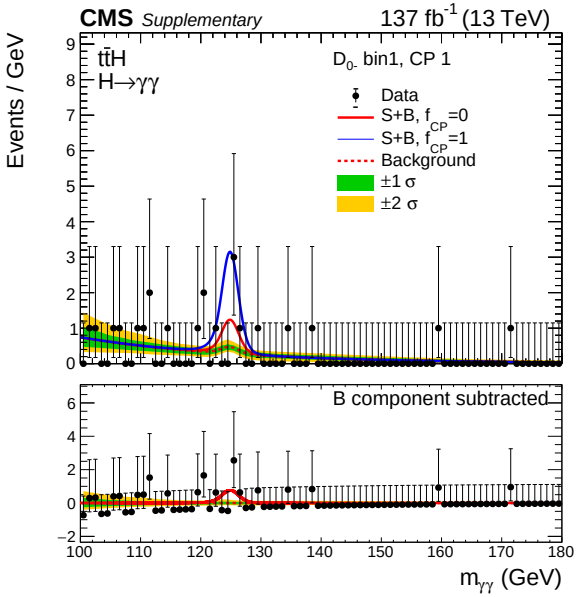
Data distribution

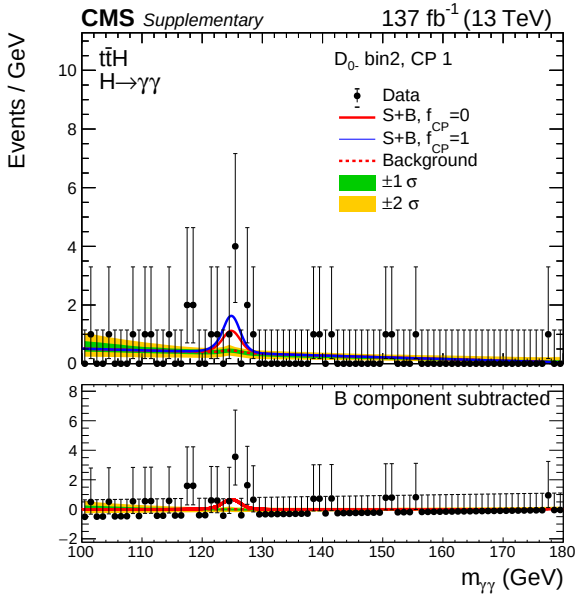


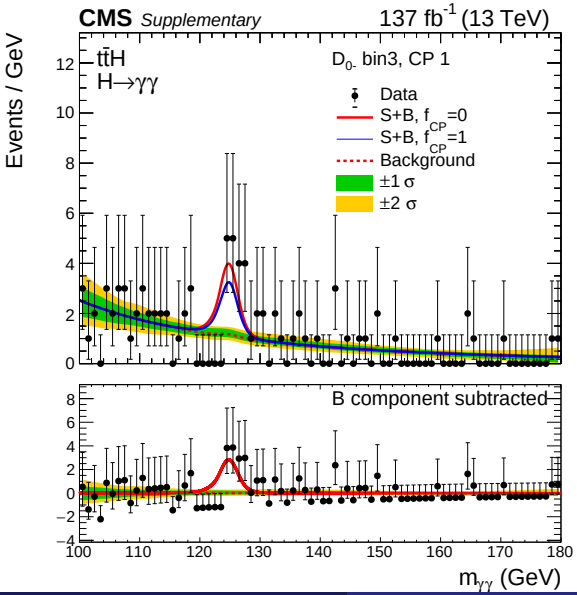


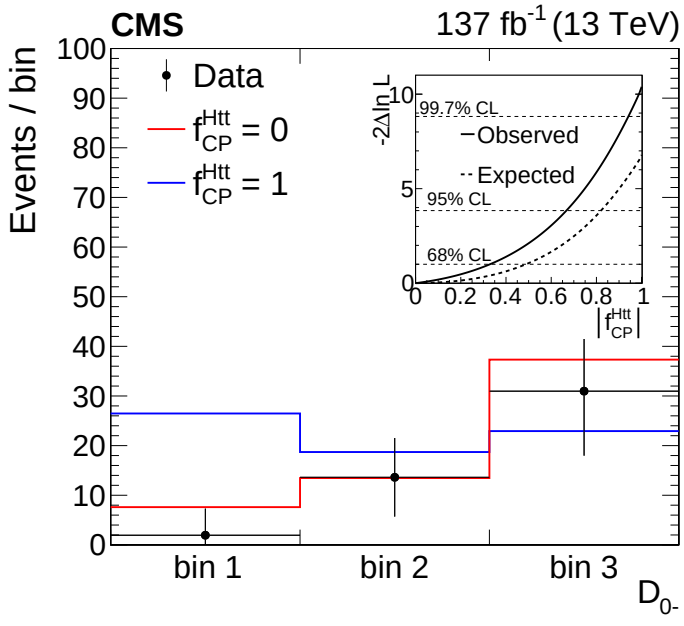


Data distribution

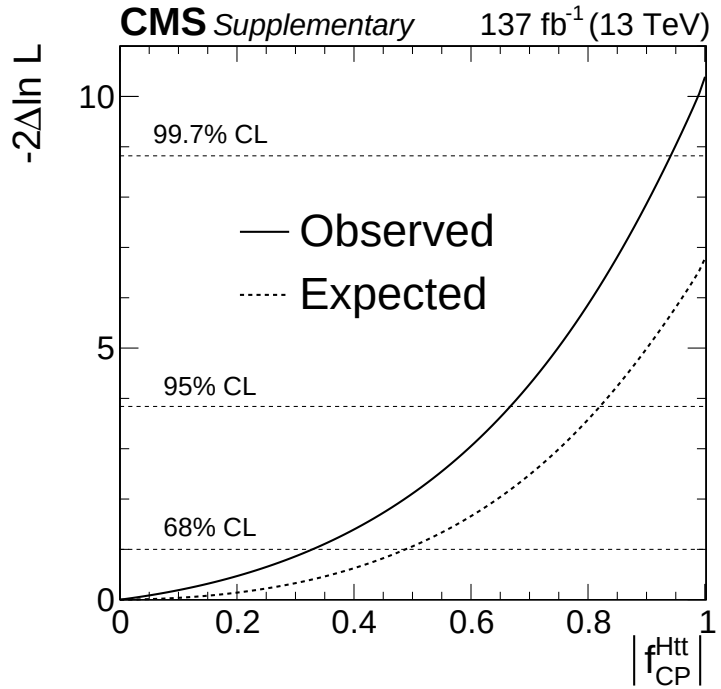








Results



Phys.Rev.Lett.125.061801(CMS-HIG-19-013)

- Extract f_{CP} by fitting $m_{\gamma\gamma}$
- Data consistent with pure CP-even model
- obs(exp) f_{cp} <0.61(0.83) at 95% C.L.
- Pure CP-odd(pseudoscalar) excluded at 3.2 σ

Summary

- The first CP structure measurement of H-tt coupling
- Decay products of top carry CP sensitive information
- Fraction of CP-odd term is measured to be
$$f_{CP} = 0.00 \pm 0.33$$
- Higgs Boson being pseudoscalar excluded at 3.2σ