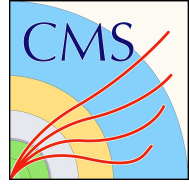
中國科學院高能物理研究所
Institute of High Energy Physics
Chinese Academy of Sciences



Measurements of Higgs boson properties in the γγ decay channel at CMS

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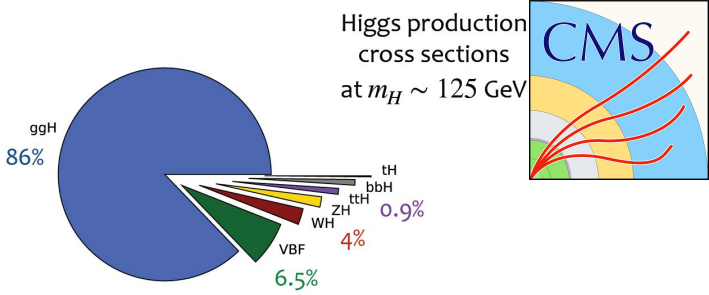
on behalf of the CMS Collaboration

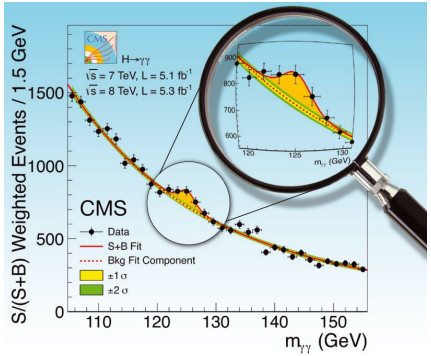
CLHCP – Xinxiang, Henan, October 29 to November 2, 2025

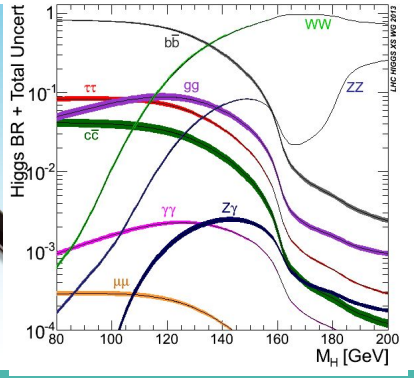
[1] Institute of High Energy Physics (IHEP), Beijing, China

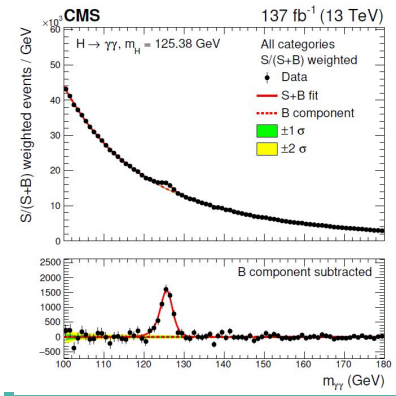
Introduction

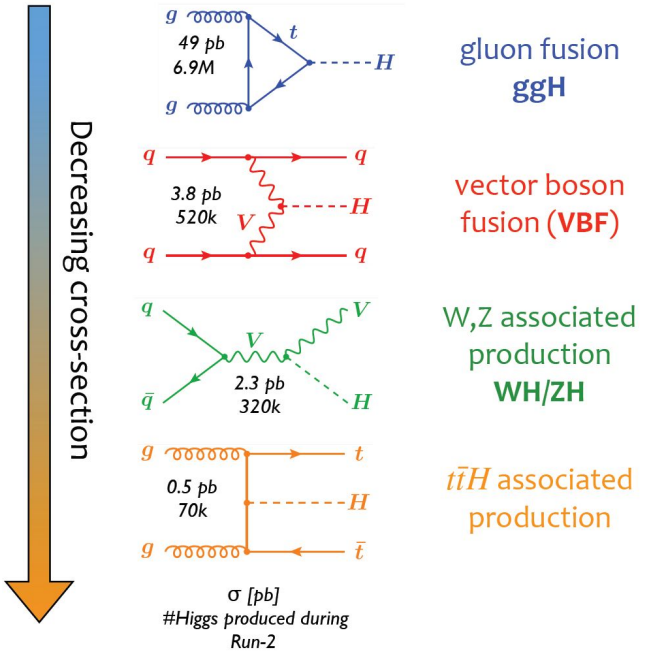
- LHC is a **Higgs factory**: O(8M) Higgs bosons produced in Run2 for each experiment
- **H(yy)** is one of the **golden channels** for discovery, measurements, and searches
  - Relatively clean final state, fully reconstructable
  - Excellent mass resolution, O(1%)
- Branching ratio somewhat small (~0.23%)











General analysis strategy: per object

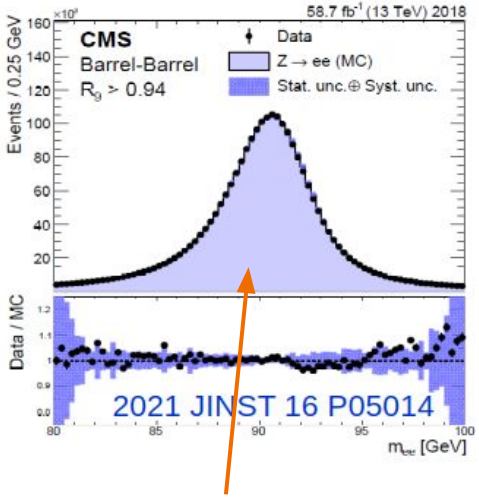
Events

Trigger (Data-only)

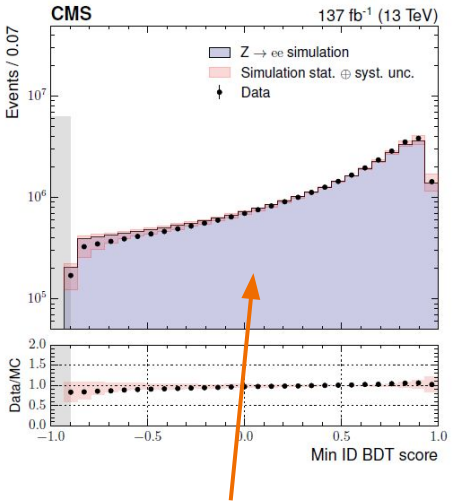
- **Diphoton HLT**
- Single electron HTL for T&P
- Double Muon HLT for Z→μμγ

Correction & Weighting

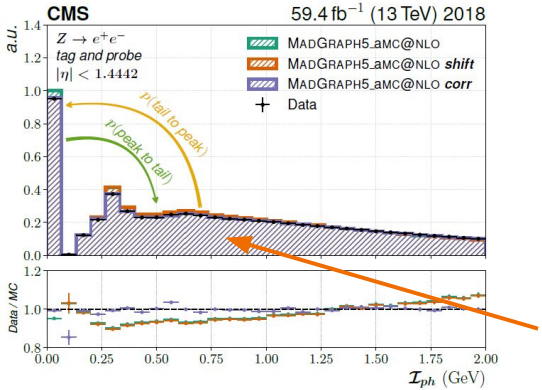
- Energy scaling and smearing (S+S) corrections
- MC corrections (Run2 CQR, Run3 NF)
- Photon MVA ID



Photon energy scale and smearing corrections



PhotonID MVA to separate prompt photons from fakes



Chain Quantile regression corrections to improve data/MC agreement

General strategy: per event

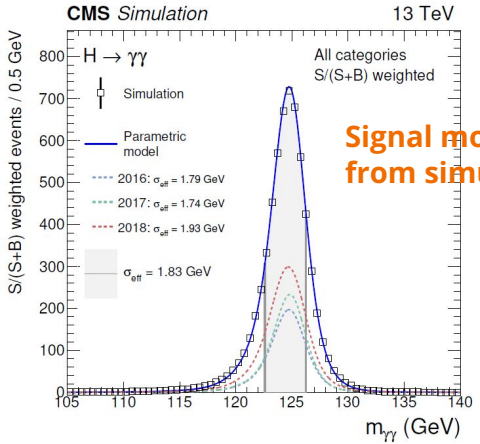
Events

Trigger (Data-only)
- **Diphoton HLT**
- Single electron HTL for T&P
- Double Muon HLT for Z→μμγ

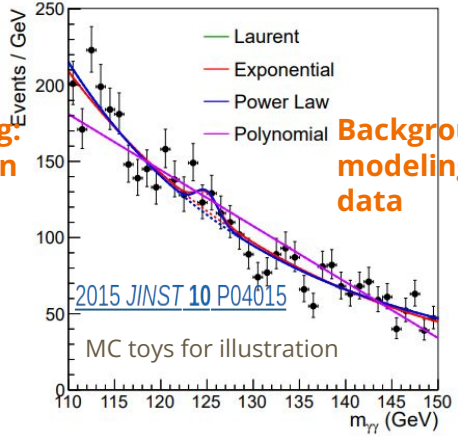
Correction & Weighting
- Energy scaling and smearing (S+S) corrections
- MC corrections (Run2 CQR, Run3 NF)
- Photon MVA ID

Pre-selection & γ-ID MVA cut & electron-veto

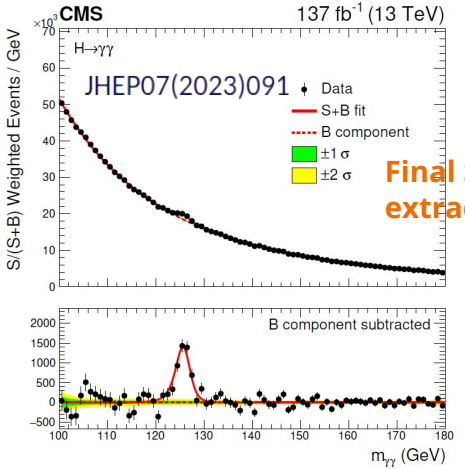
Event classifiers → Event categorizations → Signal/Background modeling → Statistical analysis: Results



Signal modeling: from simulation



Background modeling: from data

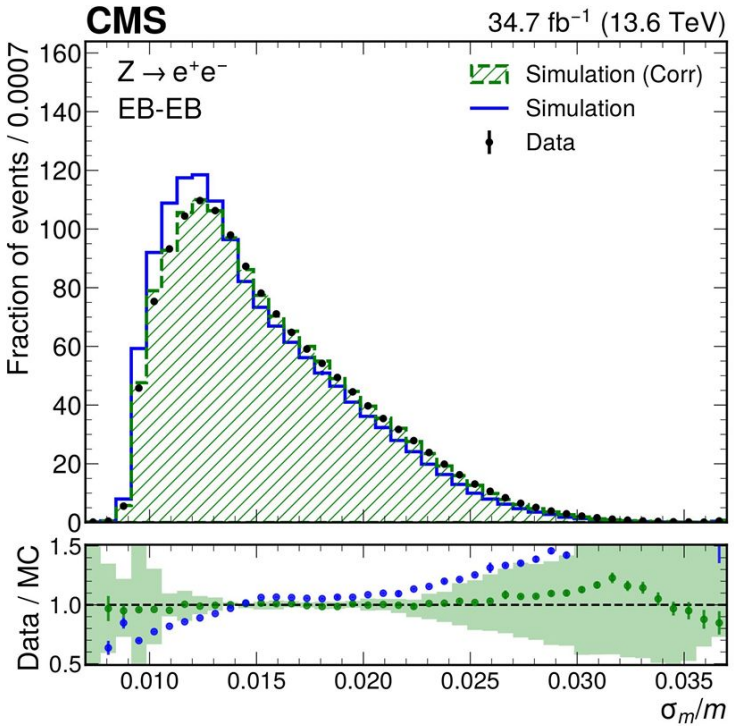


Final S+B fit to extract the signal

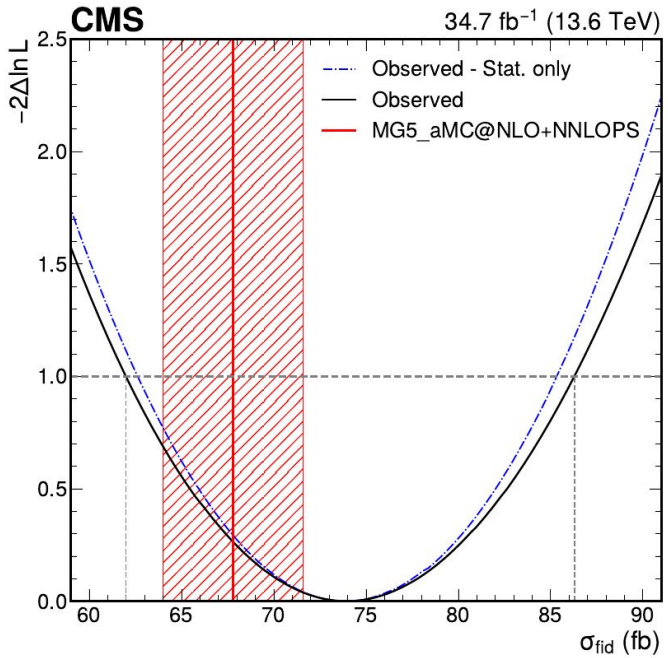
Fiducial cross section with 13.6 TeV data [JHEP09(2025)070]

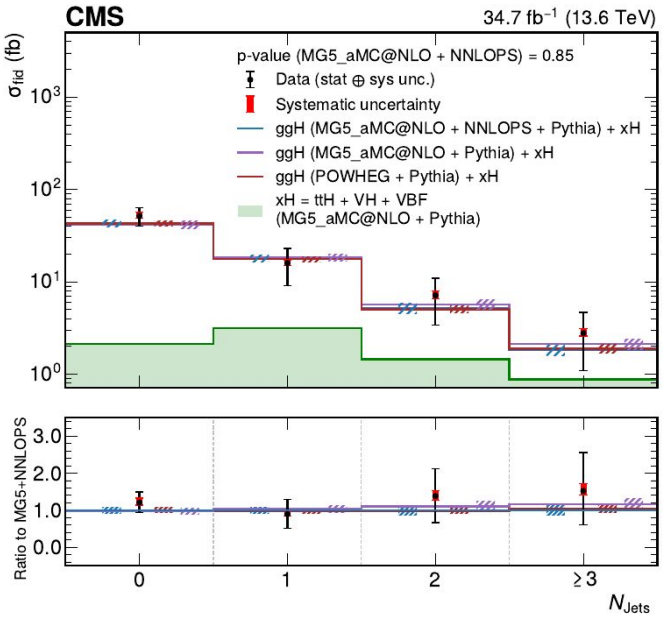
Fiducial cross section with 2022 data

- **First H(yy) analysis with CMS Run3 data**
- Measurement of inclusive and differential cross sections
  - Provide model independent results
- Several **novel techniques** are used
  - NN to improve photon energy resolution
  - Data/MC corrections for shower-shape variables obtained with normalizing flows → reduction of uncertainties
- Categorize based on σ_m/m to improve sensitivity
  - 3 categories; high, medium, low resolution



Fiducial cross section with 2022 data



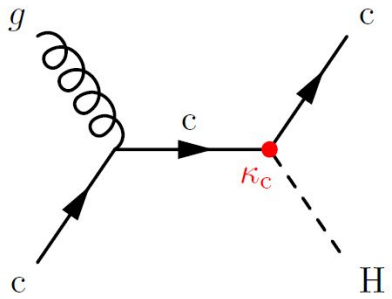


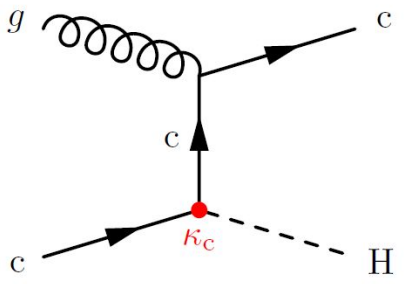
- Both the inclusive and differential results are found to be in **agreement with the SM predictions**

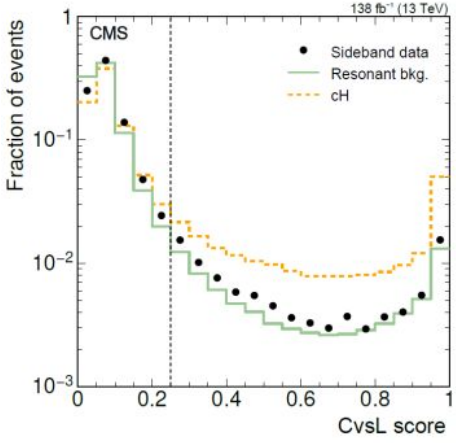
First search for cH associated production [accepted by JHEP]

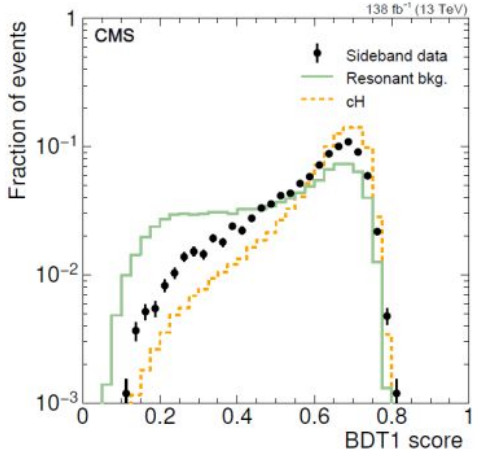
First search for cH associated production

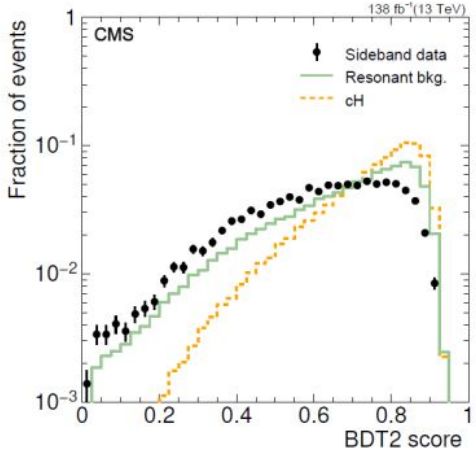
- Unique opportunity to **study charm coupling in production**
- Pt-leading jet must be c-tagged
- Two BDT classifiers
  - BDT1: cH vs ggH
  - BDT2: cH vs continuum background







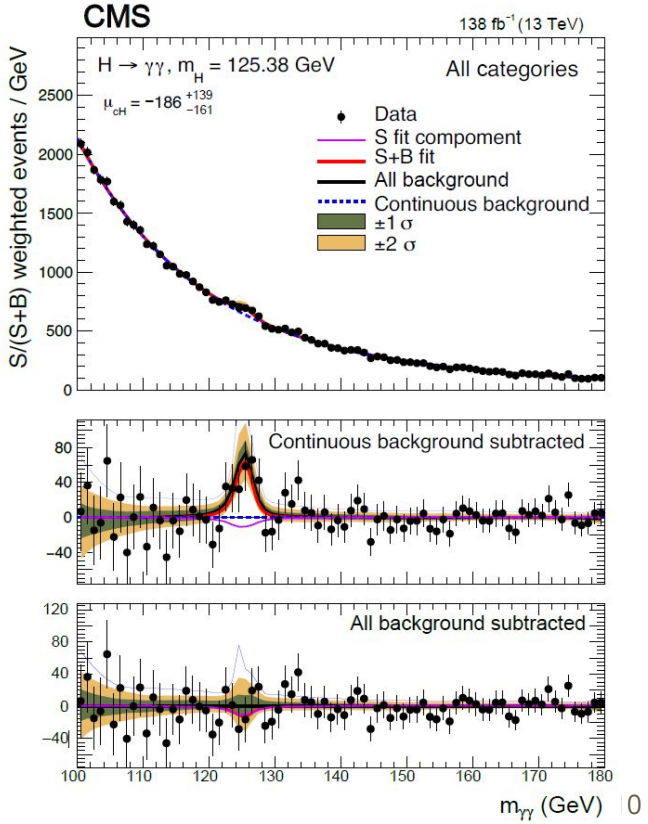




- 9 categories cutting on BDT1 and BDT2 scores

First search for cH associated production

- Upper limit on **cH signal strength < 243** (355) x σ_{SM} obs. (exp.) at 95% CL
- Constraints on c-H coupling strength modifier $|\kappa_c|$ **< 38.1** (72.5) obs. (exp.) at 95% CL
- **Dominated by statistical uncertainty**; most important systematic is theory uncertainties on cH and continuum background



Search for anomalous couplings [CMS-PAS-HIG-24-006]

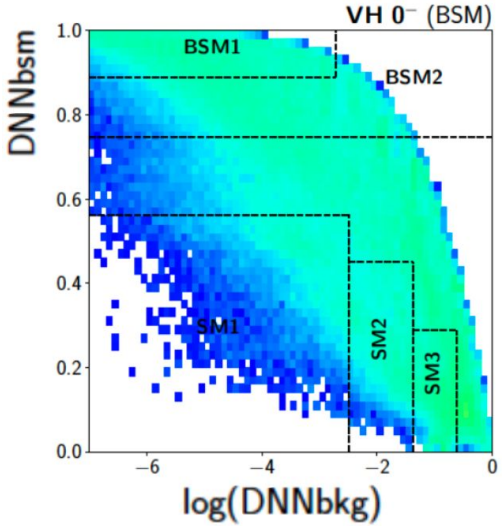
CP properties: anomalous couplings

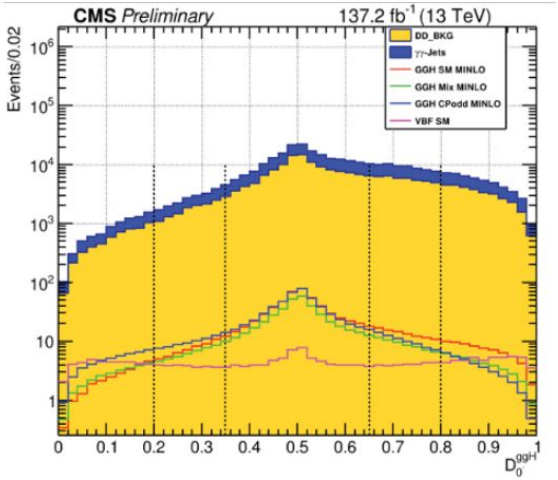
- So far, properties of Higgs boson found to be consistent with SM
- In particular, $J^{CP} = 0^{++}$
- **Limited precision allows for CP-violating anomalous couplings**
  - E.g., CP-odd coupling to top quarks or new BSM interactions would result in CP violation
- Anomalous, CP-violating couplings (ACs) studied in large spectrum of production and decay modes
- Events categorized based on matrix-element discriminants (MELA, [1]) or on advanced Machine Learning techniques
- Results usually expressed in terms of cross-section ratios f_{ai} , depending on ACs a_i

$$f_{ai} = \frac{|a_i|^2 \sigma_i}{\sum_j |a_j|^2 \sigma_j} \operatorname{sign}\left(\frac{a_i}{a_1}\right)$$

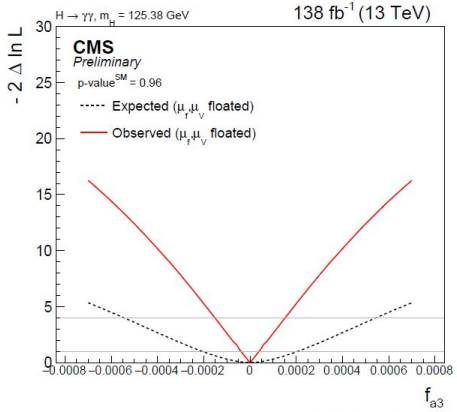
CP-violating ACs

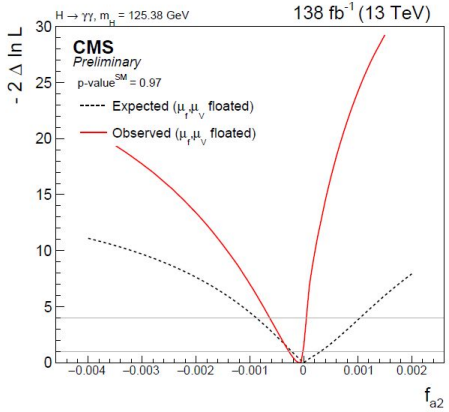
- Determine constraints on ACs **using H(yy) decays**
- Maximize sensitivity to AC **targeting VBF-like kinematics**
- Target **VBF+VH events and ggH+jets events**
- Two analyses produce separate results (don't want to lose ggH sensitivity by requiring orthogonality)
- Selection is based on STXS bins + cuts on MVA and MELA variables

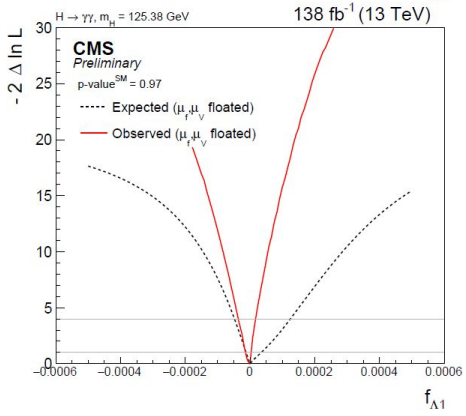


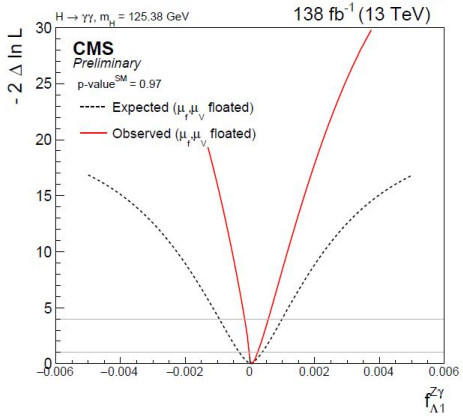


CP-violating ACs: HVV







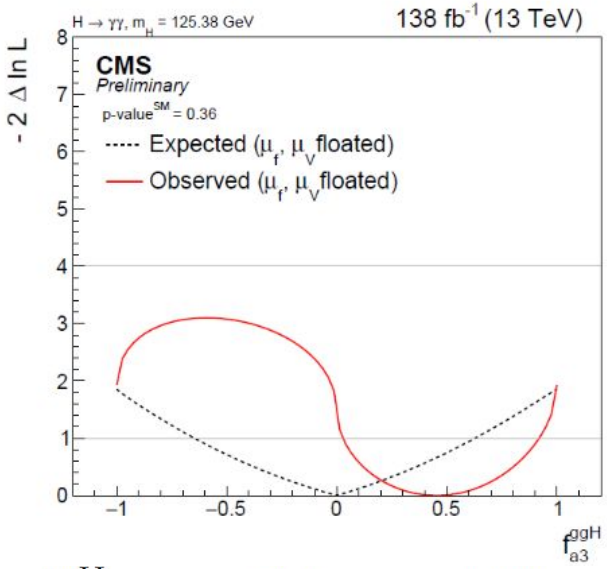


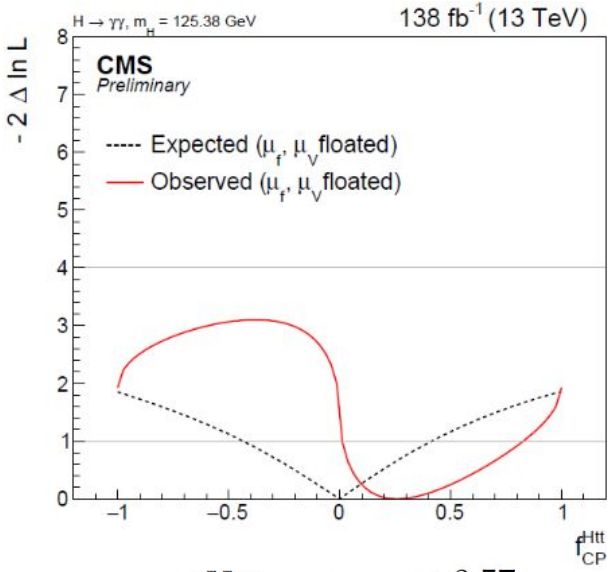
68% CL intervals for ACs

Parameter	Expected/(10^{-4}) $H \to \gamma\gamma$ (68% CL)	Observed/(10^{-4}) $H \to \gamma\gamma$ (68% CL)	Expected/(10^{-4}) $H \to 4\ell + H \to \tau^+\tau^-$ (68% CL)
f_{a3}	$0.0^{+2.1}_{-2.1}$	$0.00^{+0.39}_{-0.39}$	[−0.5,0.5]
f_{a2}	$0.0^{+3.1}_{-2.3}$	$-0.81^{+0.65}_{-2.0}$	[−4,5]
$f_{\Lambda1}$	$0.0^{+0.35}_{-0.12}$	$-0.014^{+0.032}_{-0.14}$	[−0.4,1.1]
$f^{Z\gamma}_{\Lambda1}$	$0.0^{+3.7}_{-3.3}$	$0.83^{+1.5}_{-0.92}$	[−10,10]

- Results are **compatible with SM expectations**: no ACs (f_{ai}=0)
- These are among the most stringent limits to date

CP-violating ACs: ggH





$$f_{a3}^{\mathrm{ggH}} = 0.45^{+0.46}_{-0.42}\ (\mathrm{stat.})\ ^{+0.10}_{-0.08}\ (\mathrm{syst.})$$

$$f_{\mathrm{CP}}^{Htt} = 0.26^{+0.57}_{-0.25}$$

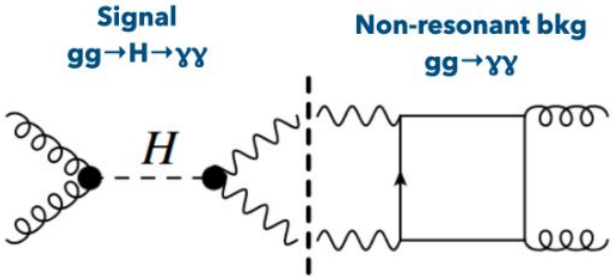
- Results are compatible with the SM

- Uncertainty dominated by statistical component (systematics cancel in ratios)
- **Results expected to improve with more LHC data**

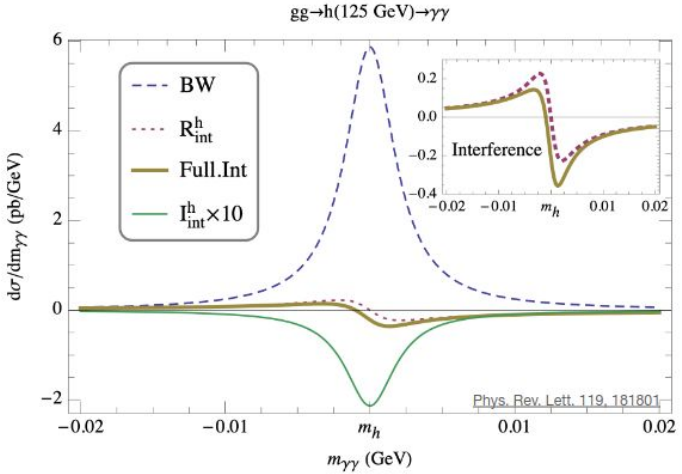
Higgs boson natural width [CMS-PAS-HIG-25-004]

Higgs natural width

- **Complementary to standard approach** using on-shell and off-shell production in H(4L)
- First time at the LHC: use interference between H(γγ) signal and γγ continuum background to measure the Higgs width

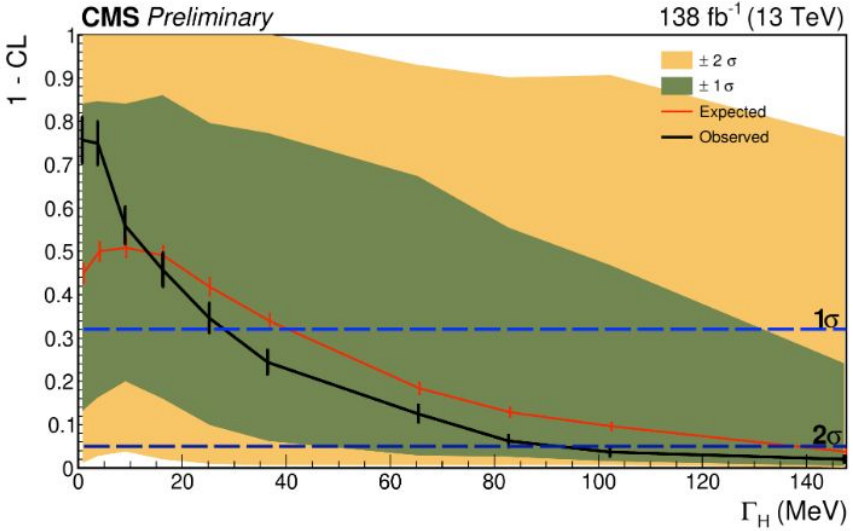


$$|A_S + A_B|^2 = \mu_F S + \sqrt{\mu_F \frac{\Gamma_H}{\Gamma_H^{SM}}} I + B$$



Higgs natural width

- 11 mutually exclusive categories
  - ggH: use diphoton BDT to reject background and $pt_{\gamma\gamma}$ to enhance sensitivity to interference
  - VBF: cut based analysis
- Maximum-likelihood fit to templates
  - S and S+I from MC
  - B from data sidebands
- **Competitive approach**, sensitivity in between direct measurement and off-/on-shell measurement



$\Gamma_H < 91.8\,(138)\,\text{MeV}\ @\ 95\,\%\ \text{CL}$

Conclusions

- Presented **latest results on Higgs properties** with yy decays
  - First xsec measurement with Run3 data
  - First search for cH associated production
  - Search for anomalous couplings
  - Measurement of natural width using sig/bkg interference
- All the results are compatible with the SM
- **More results to come!**
  - Mass & width
  - HHH(4b2γ) Run2
  - STXS with Run3
  - HH(bbγγ) (out already! CMS-PAS-HIG-25-007)
- Please stay tuned

Backup slides