Search for a low-mass SM-like Higgs boson in the diphoton final state

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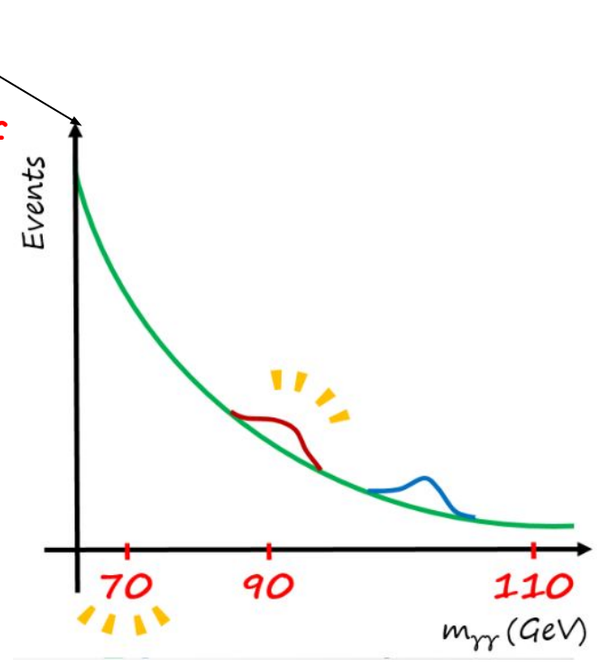
On behalf of CMS Collaboration

Outline

First diphoton resonance search for a **standard model-like Higgs boson** in the mass range between **70 and 110 GeV** with full LHC Run 2 data.

CMS-PAS-HIG-20-002
[https://cms-results.web.cern.ch/cms-results/public-results/preliminary-results/HIG-20-002/]

- Motivation for low mass diphoton resonance searches
- Analysis strategy
- Signal and background modeling
- Full Run2 Results
- Summary
- Acknowledgements



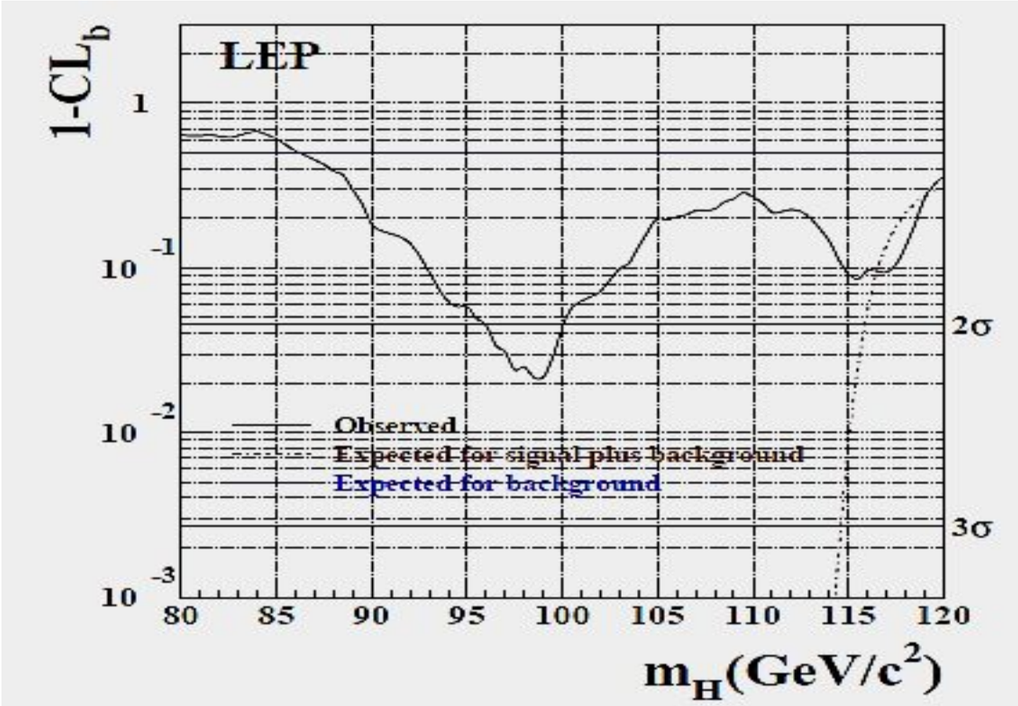
Schematic of low mass diphoton inv. Mass distribution

Motivation for low mass diphoton resonance searches

- **Experimental Motivation :**

Final LEP SM Higgs boson search results : A small excess of events (~2σ) at m_H = 98 GeV w.r.t. background was observed.

LEPHWG, Phys. Lett. B565:61-75,2003



- **Theoretical Motivation :**

Many BSM models allow a low mass resonance with m < 125 GeV coexisting with the Higgs boson discovered in 2012.

J. Fan et al., Chinese Phys. C 38 073101

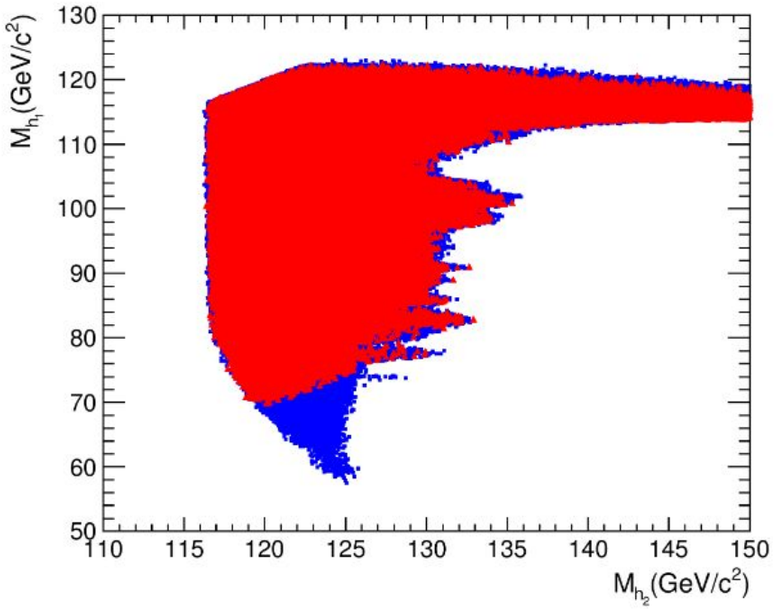


Fig. 1. The NMSSM Higgs boson mass spectrum in the M_{h_1} vs. M_{h_2} plane. Points for case I are represented by blue squares and case II by red triangles.

Analysis Strategy : Event selection

- **Strategy:** Extract signal events through fit to the smoothly falling background diphoton invariant mass distribution.

- **Background components :**
  1) irreducible direct QCD YY production, reducible Y + jet process and jet + jet processes

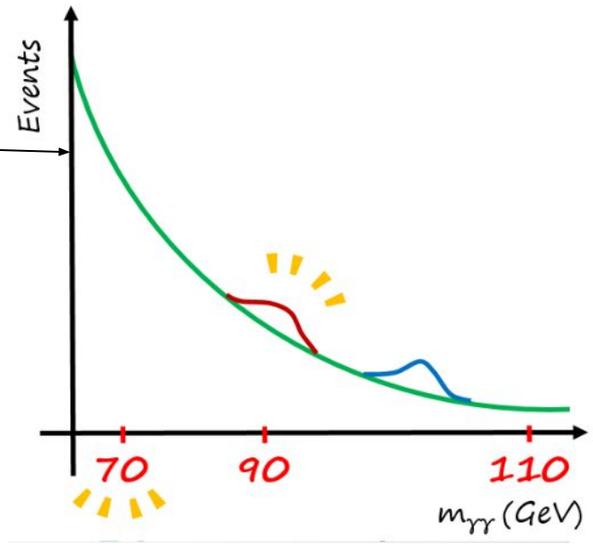
  2) reducible Drell-Yan **Z→ee** events

- **Dedicated low mass trigger algorithms, preselections and acceptance requirements**

- **Many studies in this analysis [Vertex identification, photon identification, event classification] are performed by Multivariate techniques**

- **Major systematic uncertainties :**

1) per-photon energy resolution < 20%,
2) renormalization and factorization scales < 14%,
3) UE modeling <27%, PS < 16%, JES corrections (VBF class) < 16%.



Schematic of low mass diphoton inv. Mass distribution

Analysis Strategy: Major changes w.r.t. previous published results [PLB 793 (2019) 320) (2012+2016 data)]

- **Kinematic event selection BDT classifier** reoptimized in the low mass phase space.
- **Drell-Yan Z→ee suppression strategy :**

  (1) **Electron/relic Z→ee veto**

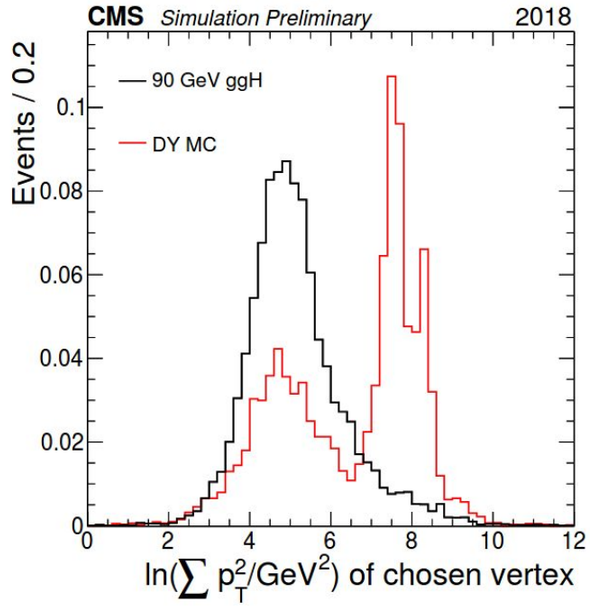
  (based on pixel detector hits)

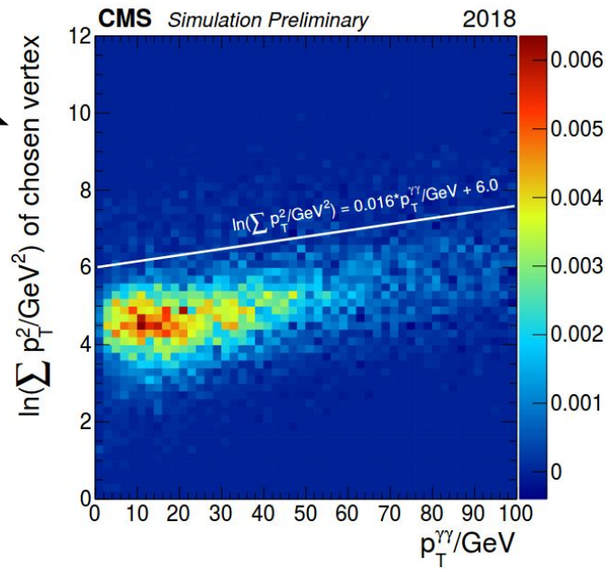
  (2) **$\log(\Sigma p_T^2) <= 0.016 * p_T^{\gamma\gamma} + 6.0$** :

  Maximum value of $\log(\Sigma p_T^2/\mathrm{GeV}^2)$ as a function of $p_T^{\gamma\gamma}$

  (3) **$N_{\mathrm{matchedElectron}} = 0$** :Rejection of photon candidates also reconstructed as electrons

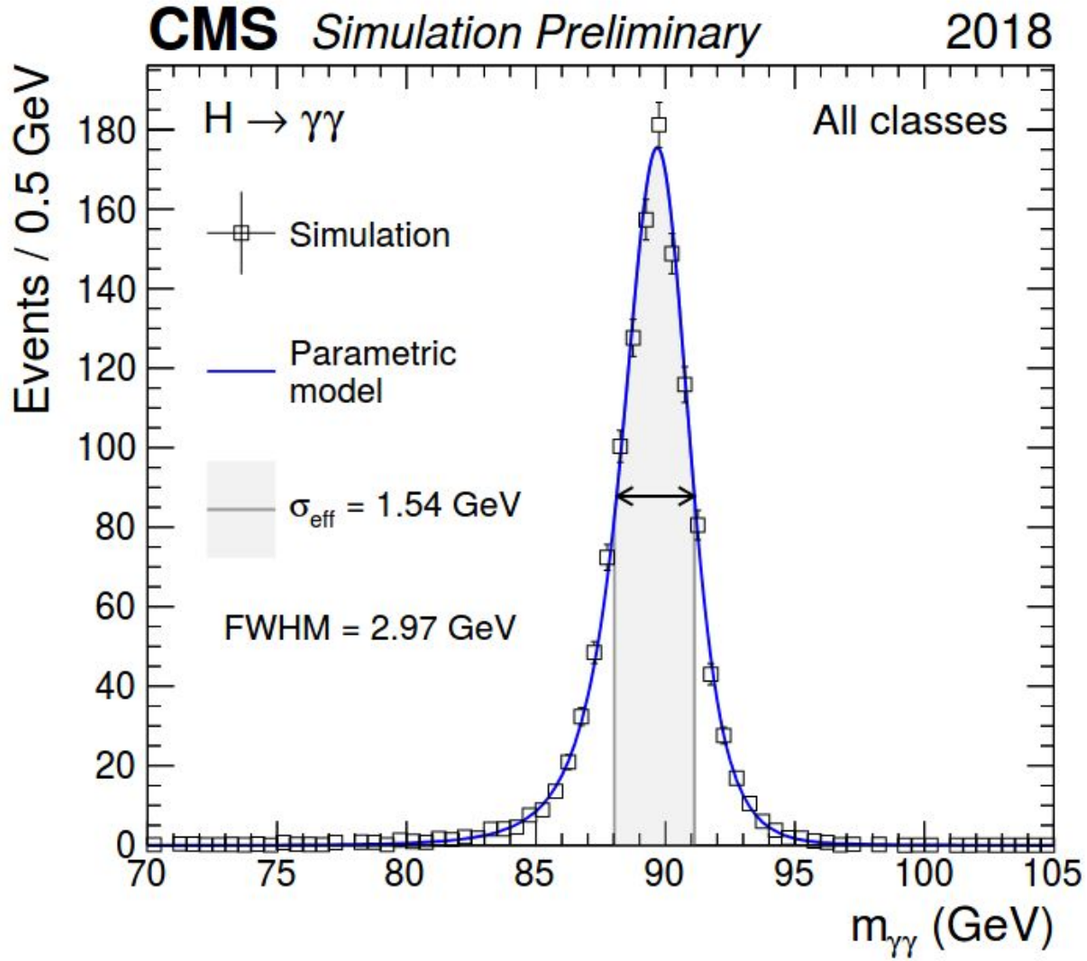
- **2017/18:** Additional VBF event class.
- **2016:** data reanalyzed with improved calibration





Signal modeling

- A parametric model (sum of Gaussian functions) is used to describe the shape of the signal in each event class.
- All production modes (ggH, VBF, WH, ZH, ttH) from 70 GeV to 110 GeV with a 5 GeV granularity are used.
- Different production modes weighted by SM-like Higgs boson cross sections evaluated at $70 < m_H < 110$ GeV



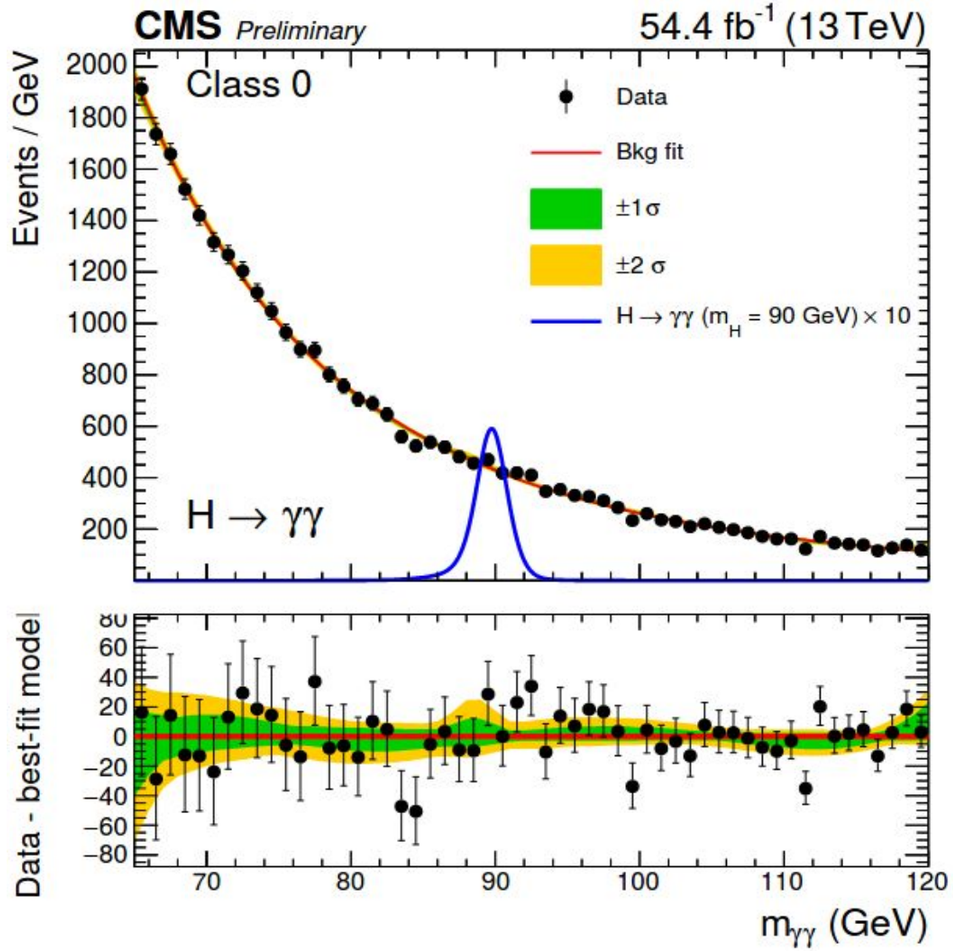
Fully parametrized signal shape in simulated signal events with m_H = 90 GeV for 2018

Background modeling

- Continuum background using Envelope method (discrete profiling method) by performing fit with four analytic function families (Power law, Exponential, Laurent, Bernstein)

- Relic Drell-Yan Z→ee contribution fitted by a double-sided Crystal Ball (DCB) function + an exponential

- **Total background model :** continuous functions for continuum background with DCB+exponential (normalization floating) function for Z→ee contribution

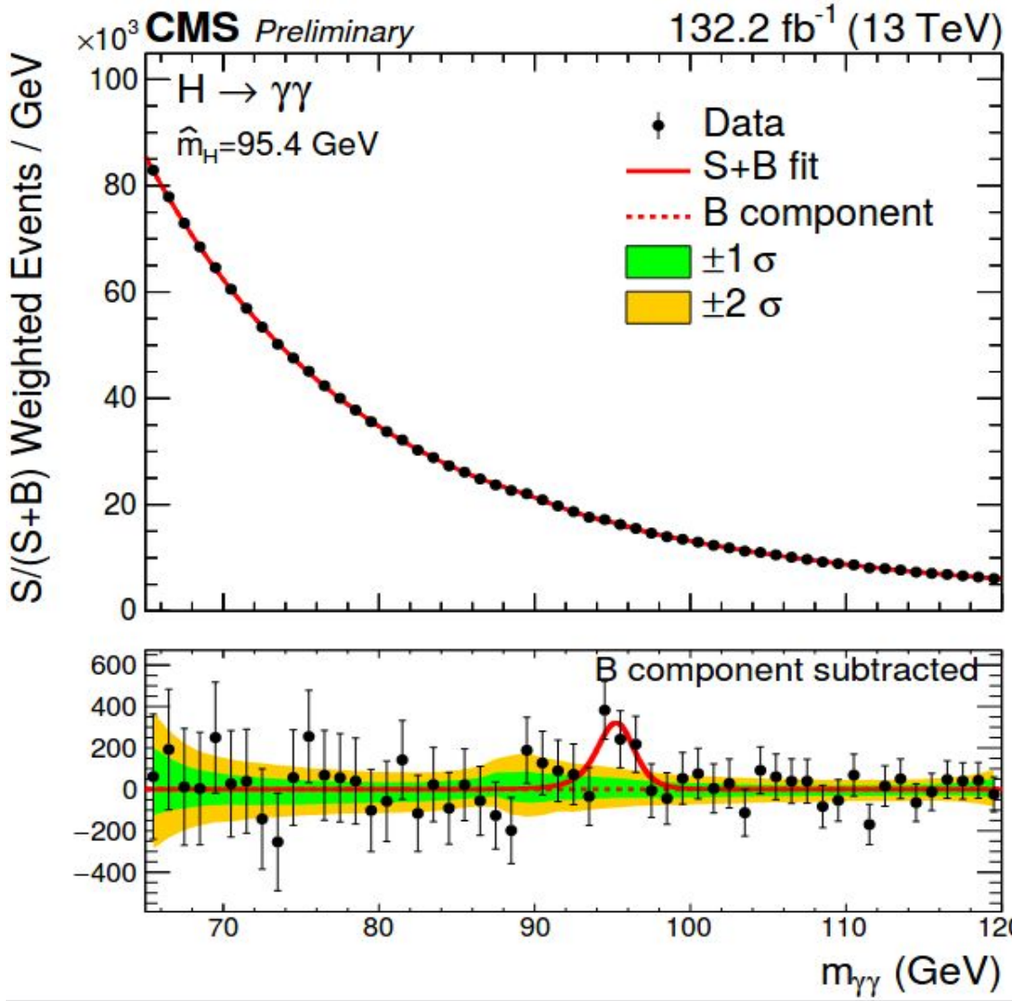


Background model fits using best-fit parametrization to the 2018 data in event class 0., stat.uncertainties only

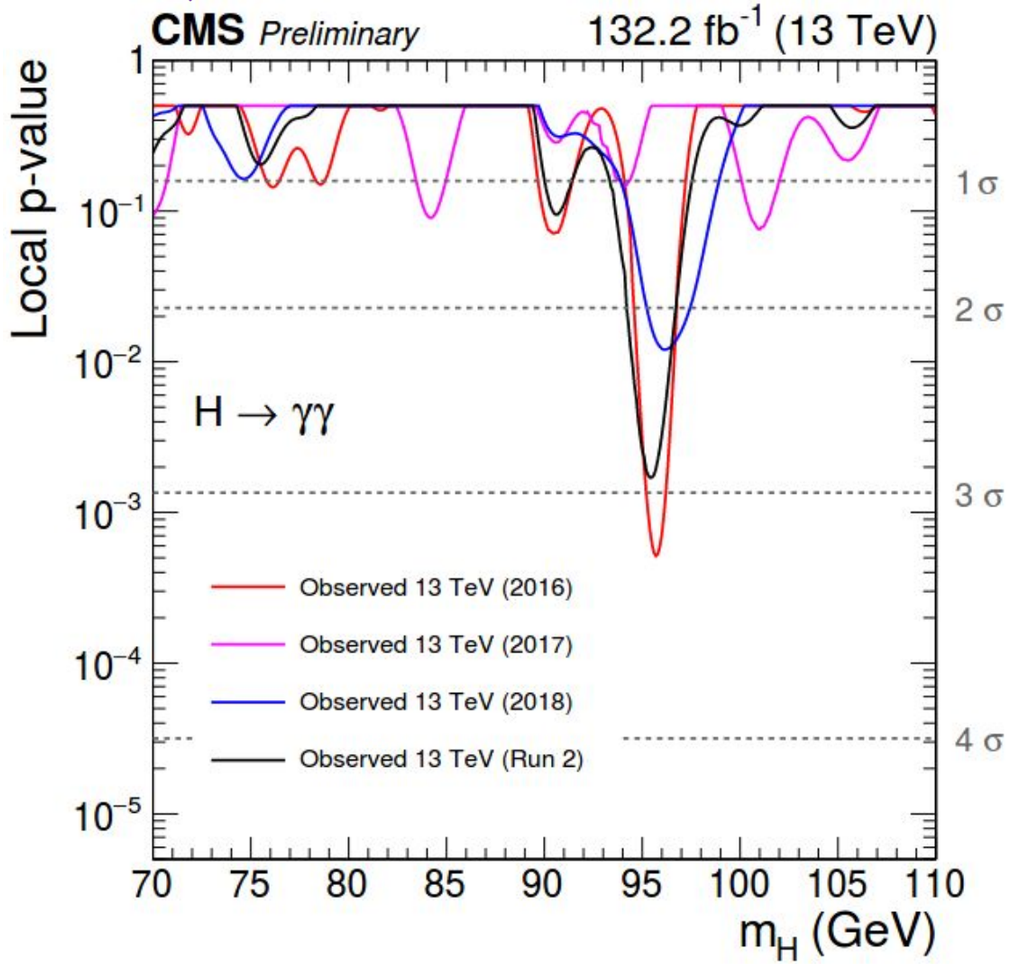
Full Run2 results : Inclusive [p-value & significance]

- **S/(S+B)-weighted $m_{\gamma\gamma}$** distribution with S+B model fit for a mass hypothesis of

$m_{\gamma\gamma}$ = 95.4 GeV



- Observed local p-values for **2016, 2017, 2018** and combination

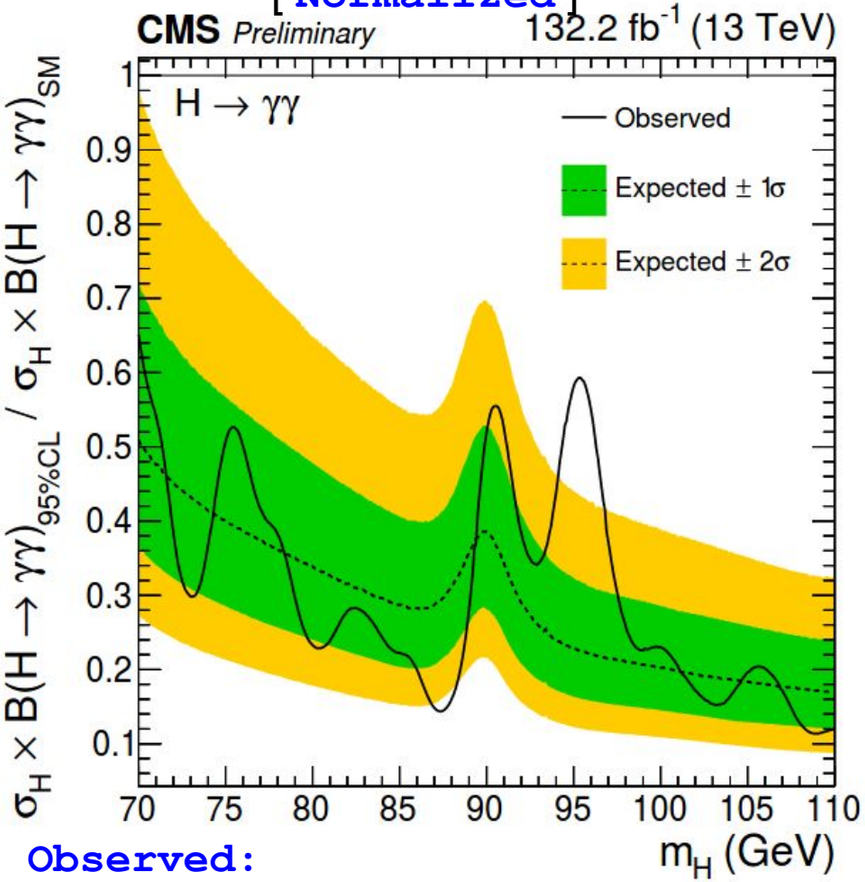


- Modest excess with **~2.9σ local (1.3σ global)** significance at **$m_{\gamma\gamma}$ = 95.4 GeV**, more data needed to conclude!

Full Run2 results : Inclusive [Limits]

- Observed and expected 95% CL UL on σ X Br relative to SM-like expectation (production processes assumed in SM proportions)

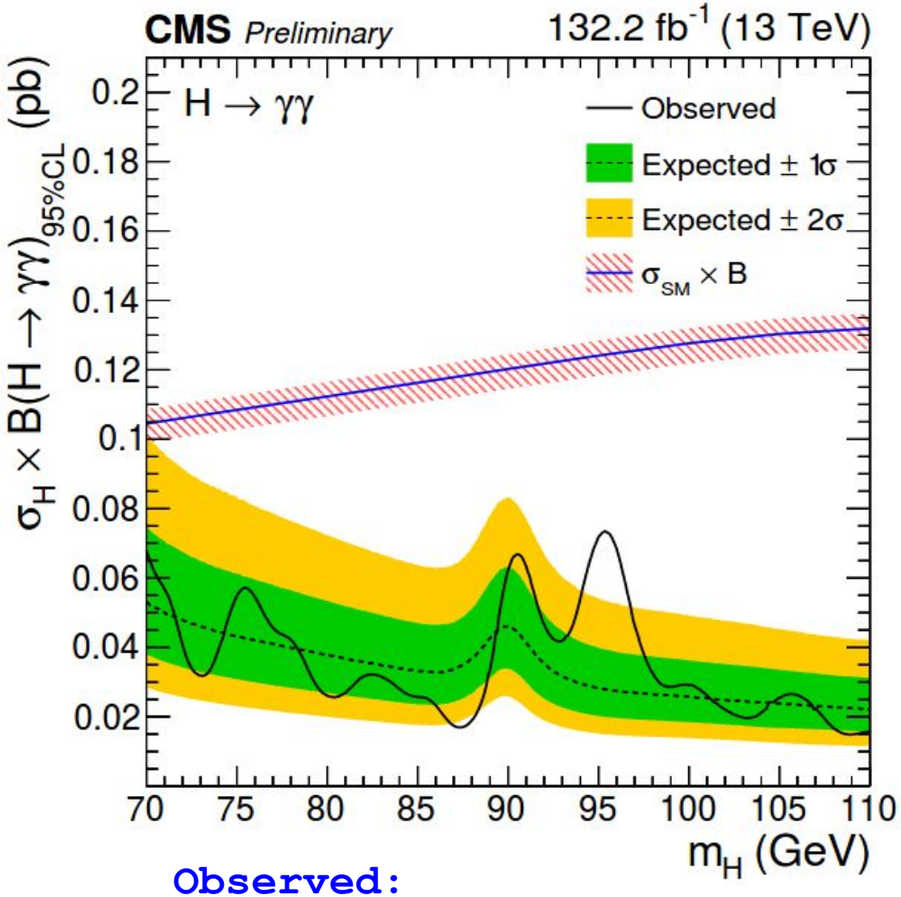
[**Normalized**]



Observed:
Worst: 0.65*SM @70 GeV
Best: 0.11*SM @108.9 GeV

- Observed absolute 95% CL UL on σ X Br between 15-73 fb

[**Absolute**]

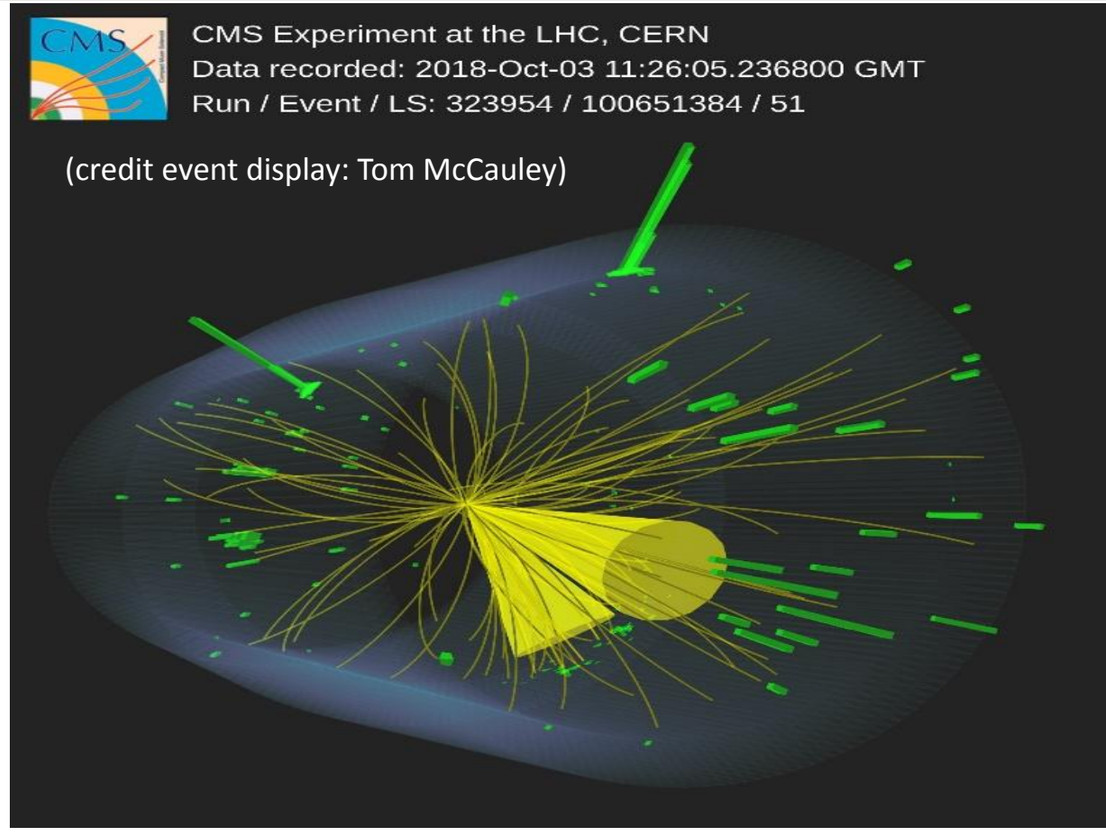


Observed:
Worst: 73 fb @95.4 GeV
Best: 15 fb @108.9 GeV

- Limits also evaluated per production process: see backup

Summary

- Presented new CMS search for additional low-mass SM-like Higgs boson (70 GeV < m_H < 110 GeV) using full LHC Run 2 data: No evidence for the existence of extra Higgs bosons found so far.
- New strategy for suppression of relic Drell-Yan Z→ee background to increase the sensitivity.
- Modest excess at **$m_{\gamma\gamma}$ = 95.4 GeV** with **2.9σ local** (**1.3σ global**) significance.
- First diphoton resonance search in this mass range with full LHC Run 2 data.
- Looking forward to more LHC Run 3 data to conclude on the nature of this excess.



Event display : VBF category

Acknowledgements

- I would like to acknowledge CMS Higgs group.

- I would also like to acknowledge CMS conference committe and the HH 2023 organisers for giving me the opportunity to present this talk.

**********THANK YOU**********

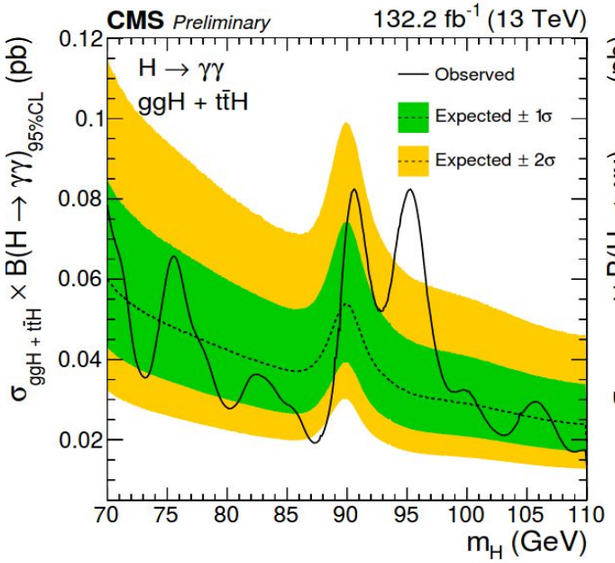
BACKUP

Best-fit background functions with DCB+exponential fractions

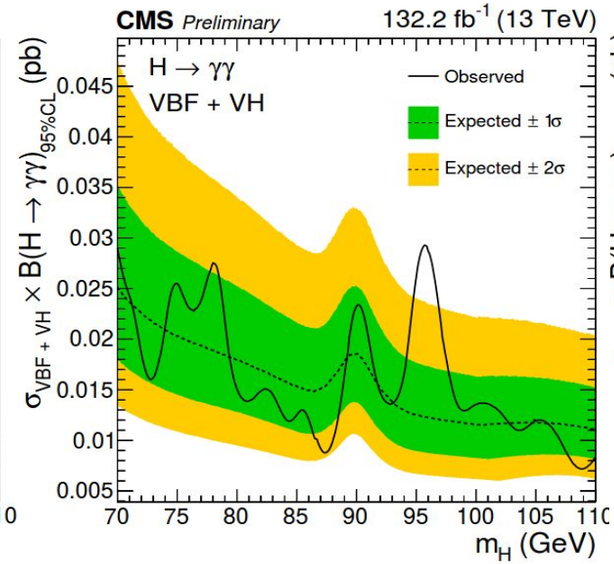
Event class		0	1	2	VBF
2016	Family/Order	Power Law 1	Bernstein 4	Exponential 3	
	DCB + Exp. Fraction (%)	3.0	3.1	3.3	
2017	Family/Order	Bernstein 3	Exponential 3	Bernstein 4	Bernstein 3
	DCB + Exp. Fraction (%)	2.7	1.4	1.9	2.6
2018	Family/Order	Laurent 1	Bernstein 4	Exponential 3	Bernstein 2
	DCB + Exp. Fraction (%)	0.5	4.1	4.8	0.8

Full Run2 results : By production mode [Limits]

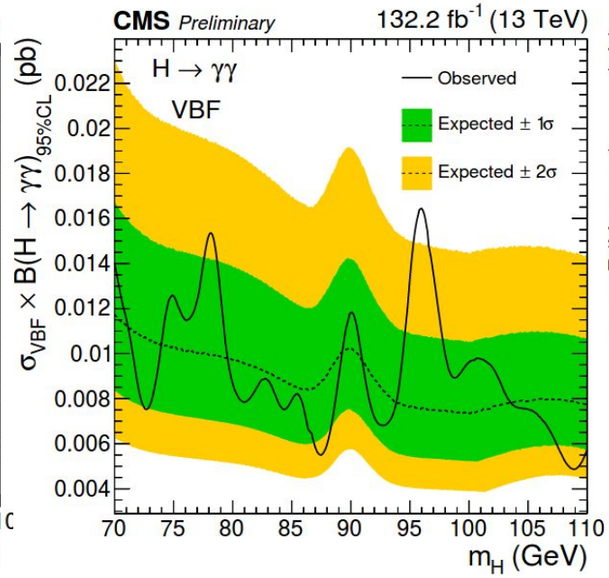
- Observed and expected 95% CL limits on σ X Br by production process (integrated over all event classes)



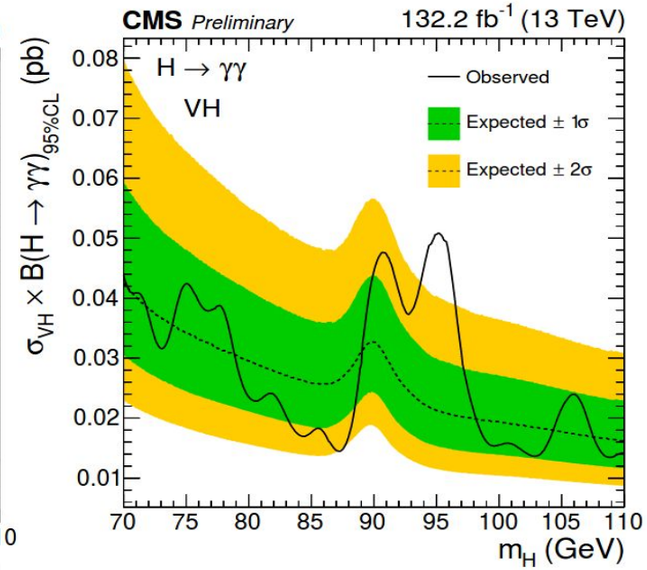
100% production via gluon-induced processes (ggH, ttbarH in SM proportions)



100% production via vector boson coupling (VBF, VH in SM proportions)



100% production via VBF

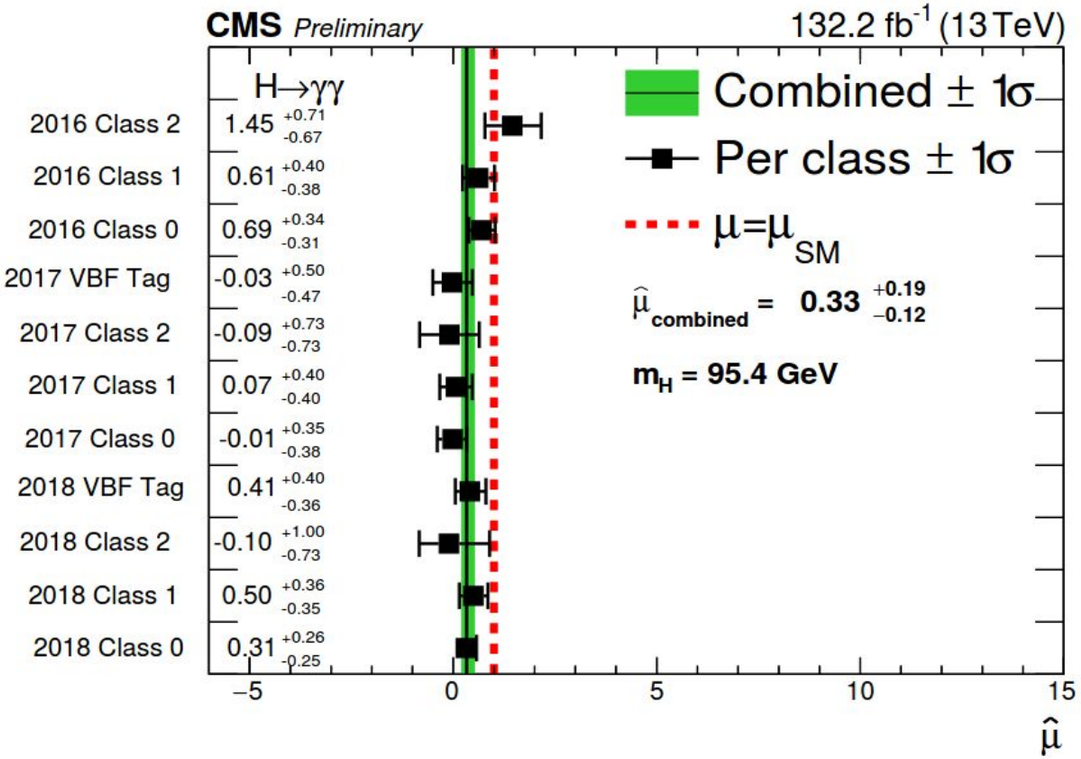


100% production via VH

Full Run2 results : Channel compatibility

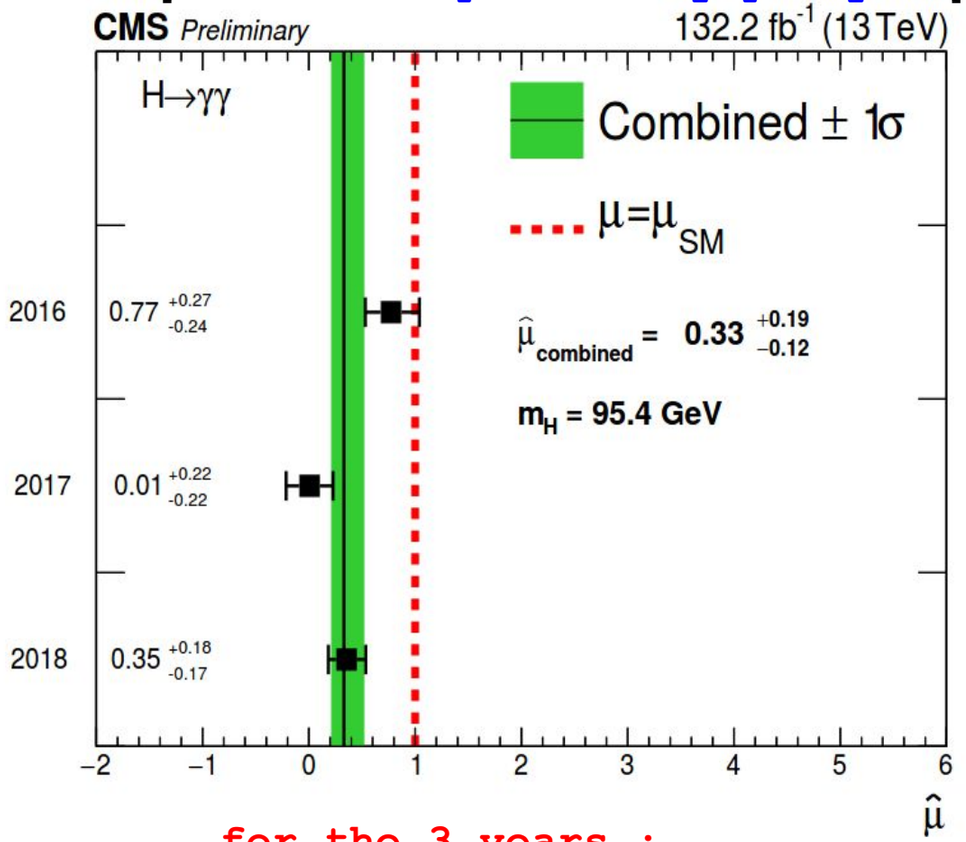
- **Signal strength μ** : m_H fixed to max. significance value of 2016+2017+2018 (95.4GeV)

[Channel compatibility per event class]



for the 11 event classes :
compatibility probability: 68%

[Channel compatibility per year]



for the 3 years :
compatibility probability: 6%

First search for new diphoton resonances in this mass range with full LHC Run 2 data!