

Search for **additional Higgs bosons decaying to a pair of tau leptons** with **CMS**

Young Scientists Forum (YSF) Talk — Higgs Hunting 2026

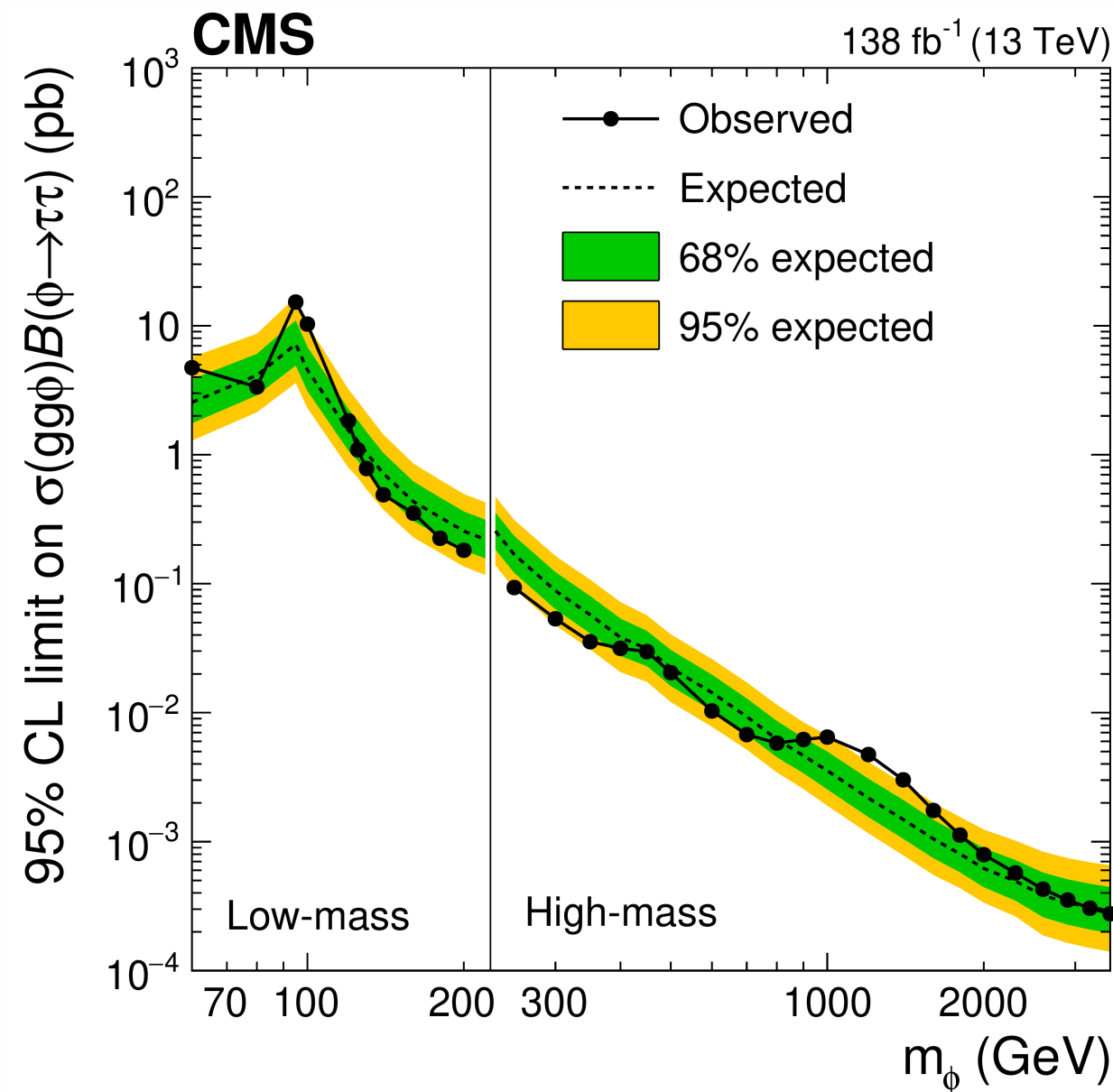
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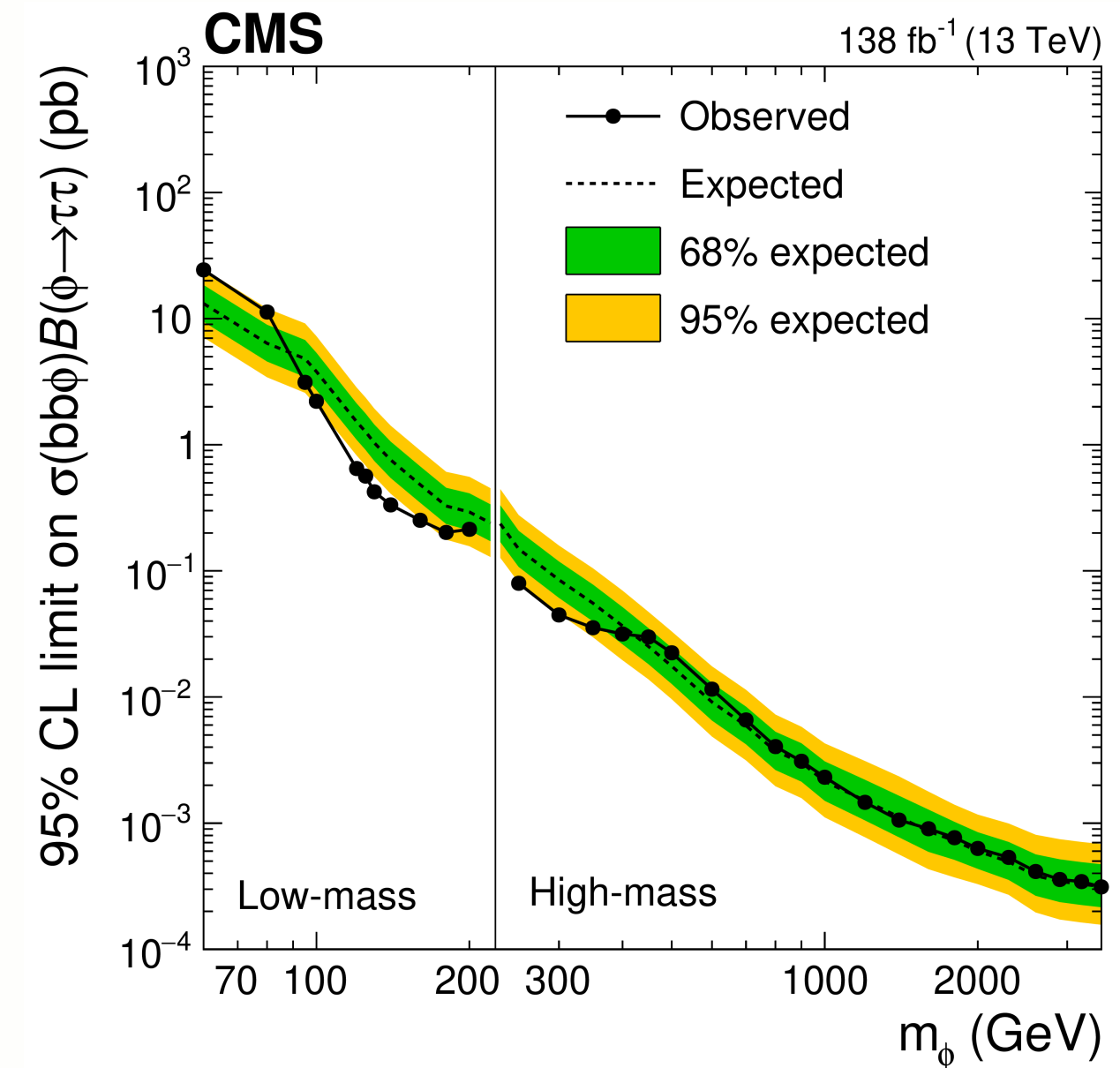
Sep 17th, 2026

Orsay and Paris, France 

- **Comprehensive CMS Run 2 Search:** Analyzed 138 fb^{-1} of pp collisions at $\sqrt{s} = 13 \text{ TeV}$ across four $\tau\tau$ decay channels: $\mu\tau_h, e\tau_h, \tau_h\tau_h, e\mu$.
- **Broad Resonance Coverage:** Probes narrow neutral scalar states over the wide mass range $60 \leq m_\phi \leq 3500 \text{ GeV}$.
- **Model-Independent Baseline:** 95% CL upper limits on $\sigma \times \mathcal{B}(\phi \rightarrow \tau\tau)$ established separately for $gg\phi$ and $bb\phi$ (profiling the other POI).



(a) 95% CL upper limit for $gg\phi$ ($bb\phi$ profiled) [[JHEP 07 \(2023\) 073](#)]

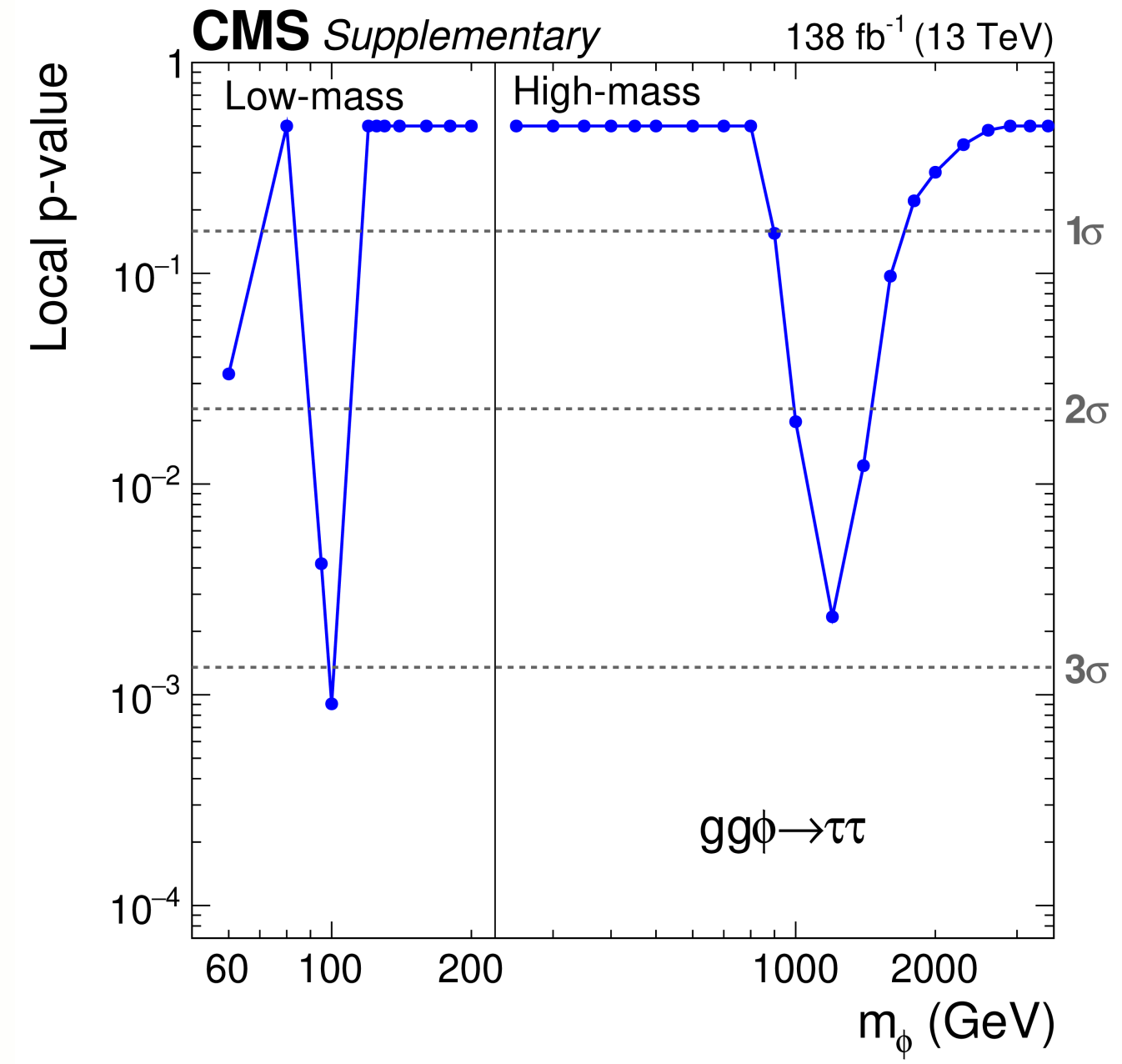


(b) 95% CL upper limit for $bb\phi$ ($gg\phi$ profiled) [[JHEP 07 \(2023\) 073](#)]

- **Prominent Low-Mass Excess in Run 2:**
 - Largest local deviation observed at $m_\phi = 100$ GeV: **3.1σ local** (2.7σ global).
 - At $m_\phi = 95$ GeV, local significance reaches **2.6σ local** (2.3σ global).
- **Best-Fit Signal Strength at 100 GeV:**

$$\sigma(gg\phi)\widehat{\mathcal{B}}(\phi \rightarrow \tau\tau) = 5.8^{+2.5}_{-2.0} \text{ pb} \quad (m_\phi = 100 \text{ GeV})$$
- **Broad Mass Resolution ($\sim 10\text{--}25\%$):**
 - Undetected neutrinos from τ decays broaden $m_{\tau\tau}$; a few-GeV difference between 95 and 100 GeV is fully consistent with a common hypothesis.
- **High-Mass Fluctuation at 1.2 TeV:**

A secondary deviation of **2.8σ local** (2.2σ global, $\hat{\sigma} = 3.1^{+1.0}_{-1.1}$ fb) is seen in $gg\phi$.



Observed local p -value scan for $gg\phi$ ($bb\phi$ profiled) [CMS HIG-21-001, Additional Fig. 31]

• Synergy Across Multiple Decay Modes:

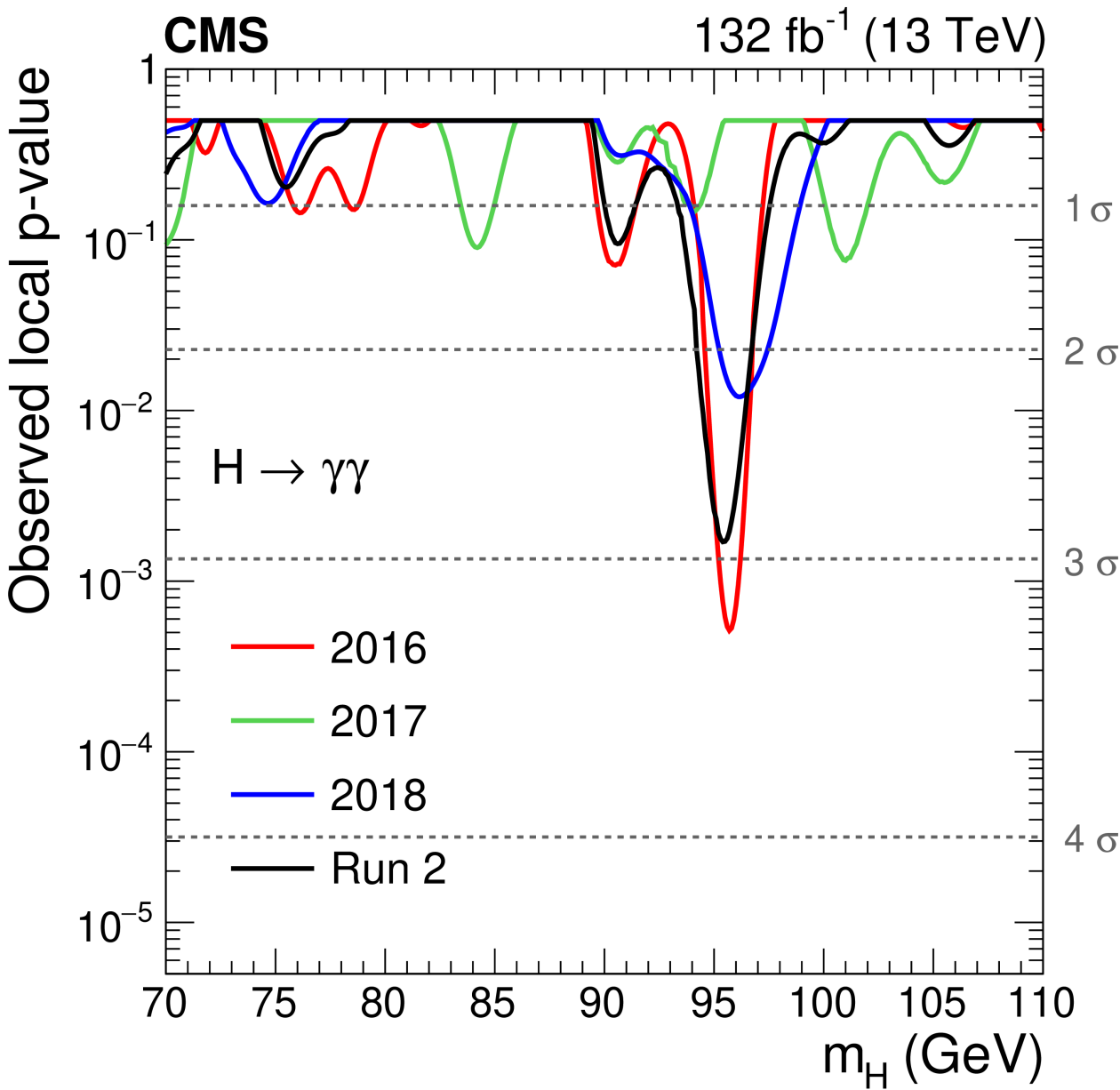
- $\tau\tau$ and $\gamma\gamma$ probe complementary Yukawa and loop couplings with very different mass resolutions.
- High mass-resolution diphoton channel pins down the resonance position to ~ 95.4 GeV.

• Historical LEP Independent Motivation:

- LEP Higgsstrahlung ($e^+e^- \rightarrow Zb\bar{b}$) reported a 2.3σ local excess near $m \approx 98$ GeV.

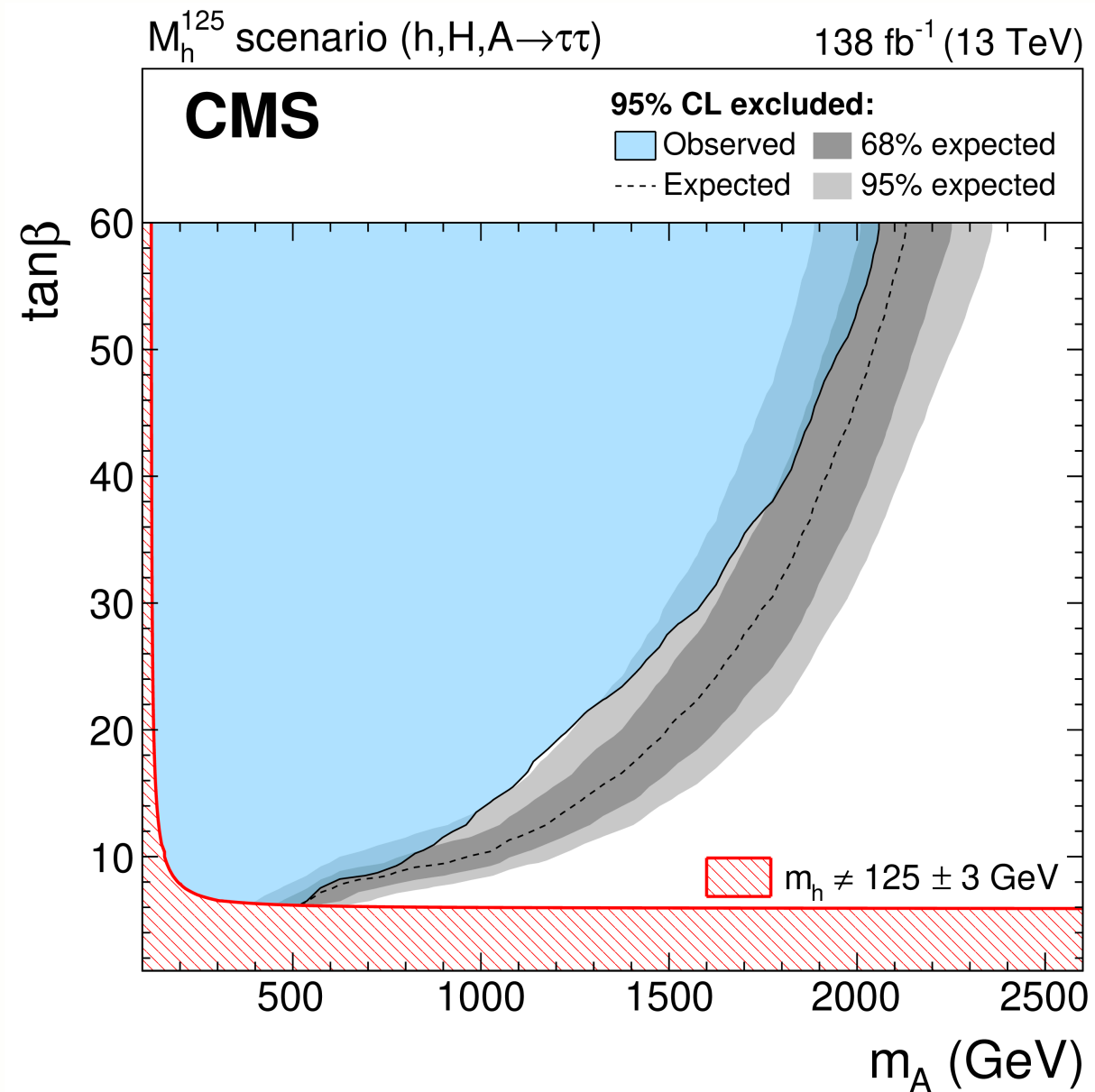
Channel / Experiment	Mass Hypothesis	Observed Excess	Reference
CMS $H \rightarrow \tau\tau$	100 GeV (95 GeV)	3.1σ local (2.6σ)	JHEP 07 (2023) 073
CMS $H \rightarrow \gamma\gamma$	95.4 GeV	2.9σ local (1.3σ global)	PLB 860 (2025) 139067
LEP $e^+e^- \rightarrow Z(b\bar{b})$	≈ 98 GeV	2.3σ local ($1 - \text{CL}_b$)	PLB 565 (2003) 61

Notice: These observations motivate an independent test with new Run 3 collision data; they do not represent a combined discovery claim.

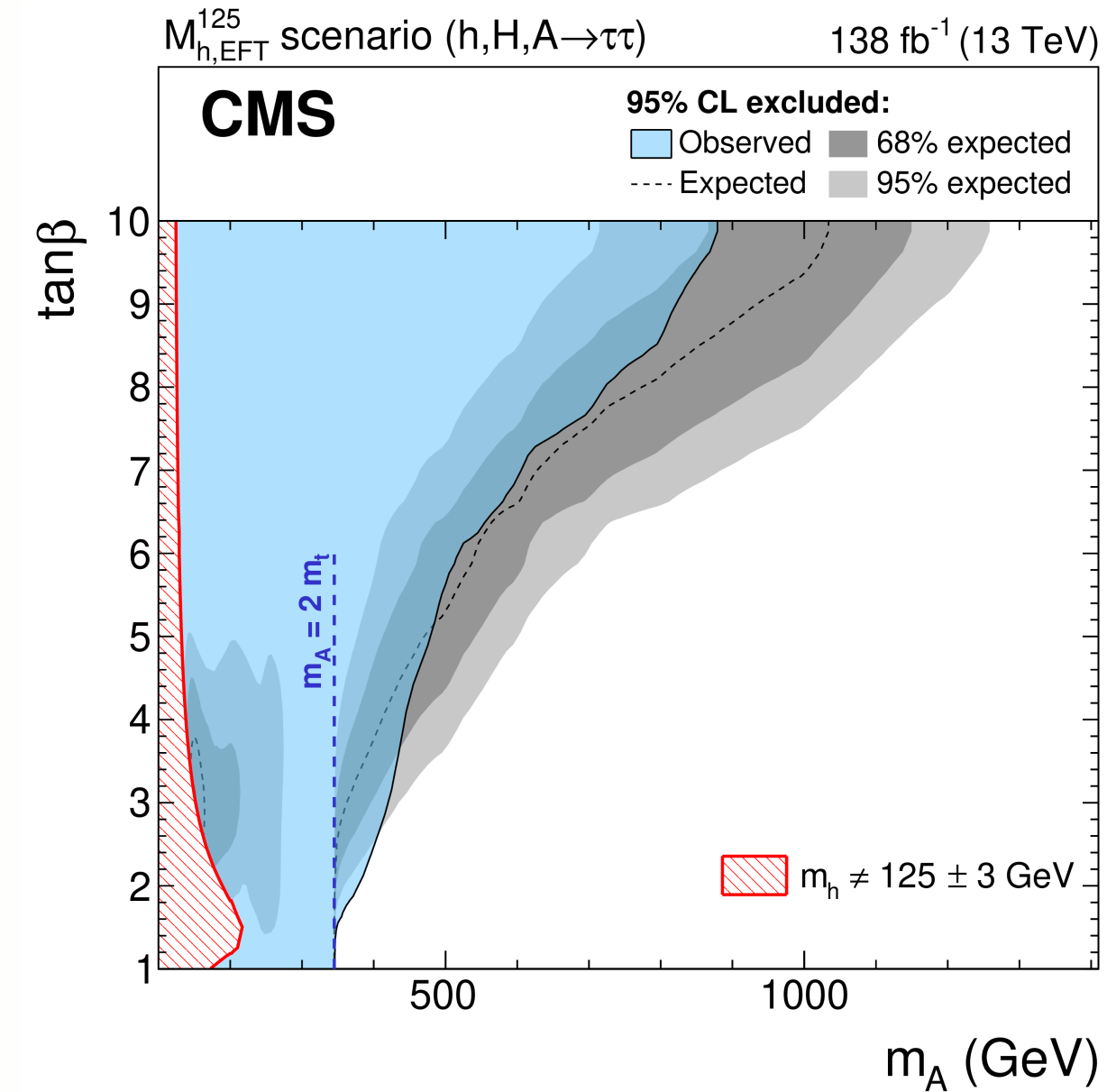


CMS $H \rightarrow \gamma\gamma$ local p -value scan (132.2 fb^{-1}) [HIG-20-002, Fig. 7]

- **Benchmark Interpretations:** Combine predicted contributions from the three neutral bosons (h, H, A) in type-II 2HDM / MSSM.
- **Stringent Bounds on Parameter Space:** Run 2 excludes substantial regions in the $(m_A, \tan \beta)$ plane; masses below $m_A \lesssim 350$ GeV are largely excluded at 95% CL in M_h^{125} and $M_{h,EFT}^{125}$.
- **Motivating Run 3:** Exploring unconstrained parameter space and resolving low-mass hints requires higher collision energy ($\sqrt{s} = 13.6$ TeV) and updated analysis techniques!



(a) M_h^{125} benchmark scenario [JHEP 07 (2023) 073, Fig. 13]



(b) $M_{h,EFT}^{125}$ benchmark scenario [JHEP 07 (2023) 073, Fig. 13]

- **Published CMS Run 2 Legacy [[JHEP 07 \(2023\) 073](#)]:**

- Analyzed full Run 2 dataset (138 fb^{-1} at $\sqrt{s} = 13 \text{ TeV}$) across $\mu\tau_h, e\tau_h, \tau_h\tau_h, e\mu$ final states.
- Established comprehensive model-independent upper limits from 60 GeV to 3.5 TeV for both $gg\phi$ and $bb\phi$ production.
- Observed intriguing **local excesses**:
 - Low mass: **3.1σ local** at 100 GeV in $\tau\tau$, aligned with CMS $\gamma\gamma$ (2.9σ at 95.4 GeV) and LEP hints.
 - High mass: **2.8σ local** at 1.2 TeV in $gg\phi$.
- Extensive exclusion of MSSM benchmark parameter space ($M_h^{125}, M_{h,\text{EFT}}^{125}, \text{hMSSM}$), pushing m_A bounds above 350 GeV.

- **Outlook for LHC Run 3 & Future Prospects:**

- LHC Run 3 operations at $\sqrt{s} = 13.6 \text{ TeV}$ bring higher center-of-mass energy and substantial dataset growth.
- Advances in reconstruction and object identification (DeepTau v2.5, ParticleNet b -tagging, PUPPI pileup mitigation) enhance di- τ sensitivity and background suppression.
- Forthcoming Run 3 analyses will provide critical sensitivity to confirm or rule out the Run 2 excesses across the scalar mass spectrum.

 **Reference: CMS Collaboration, JHEP 07 (2023) 073**

Search for additional neutral Higgs bosons decaying to a pair of tau leptons in pp collisions at $\sqrt{s} = 13 \text{ TeV}$

Stay tuned for Run 3 results! 



Backup Slides

- **Signal Model:**

- Narrow-width scalar resonance decaying to $\tau\tau$; natural width assumed negligible compared to experimental resolution.
- SM Higgs boson $H(125)$ is treated as part of the background with Standard Model couplings and cross sections.

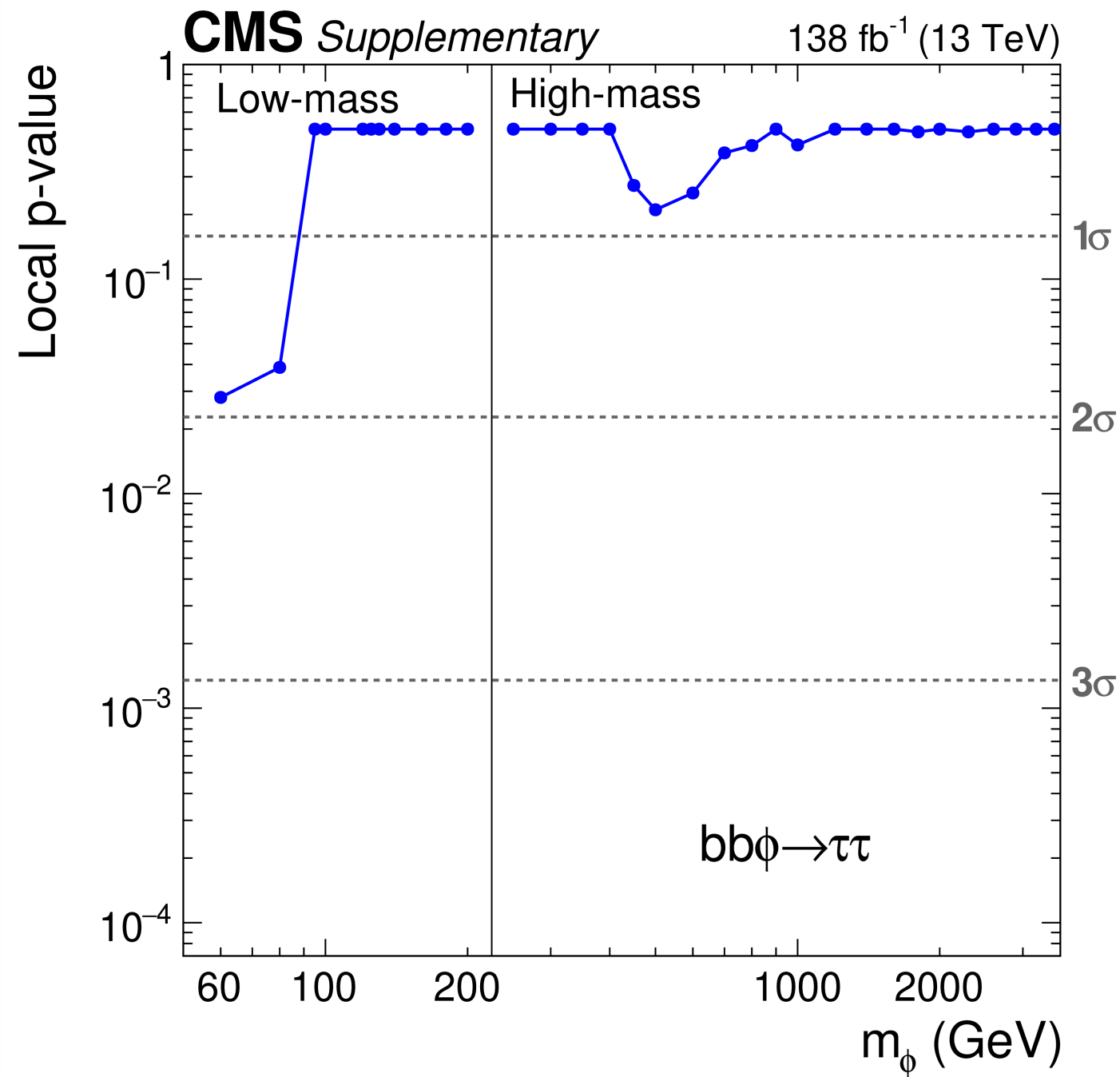
- **Statistical Profiling of Alternate Production Mode:**

- In the 1D upper limit on $\sigma(gg\phi)\mathcal{B}(\phi \rightarrow \tau\tau)$, the $bb\phi$ rate is **profiled** (free to float within physical bounds), not fixed to zero.
- Similarly, in the 1D upper limit on $\sigma(bb\phi)\mathcal{B}(\phi \rightarrow \tau\tau)$, the $gg\phi$ rate is profiled.
- Prevents model assumptions about the ratio $\sigma(bb\phi)/\sigma(gg\phi)$ from biasing the upper limits.

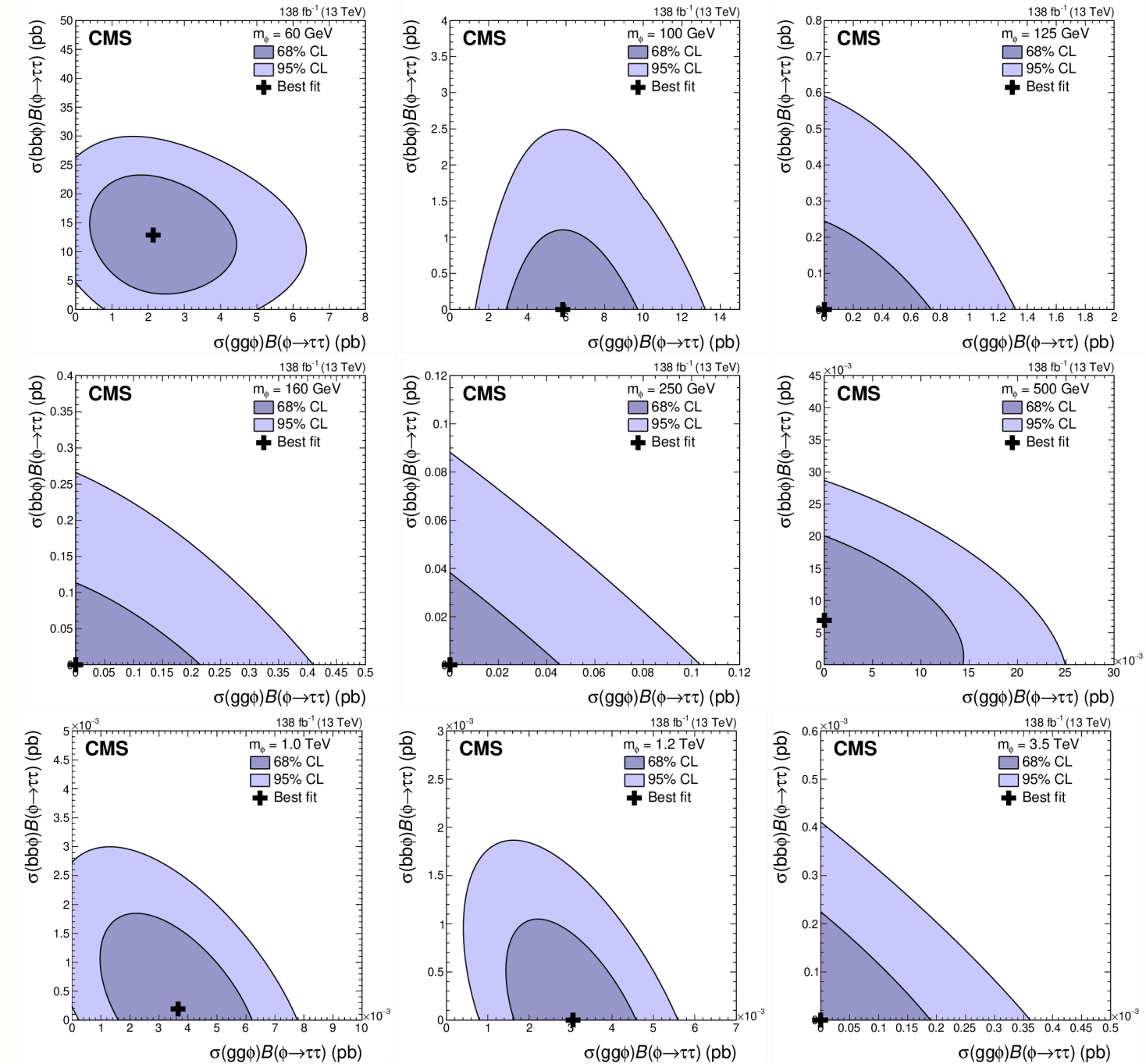
- **Statistical Framework:**

- 95% CL upper limits extracted using the asymptotic CL_s criterion in CMS [Combine](#).
- Systematic uncertainties incorporated as nuisance parameters with Gaussian or log-normal constraints.

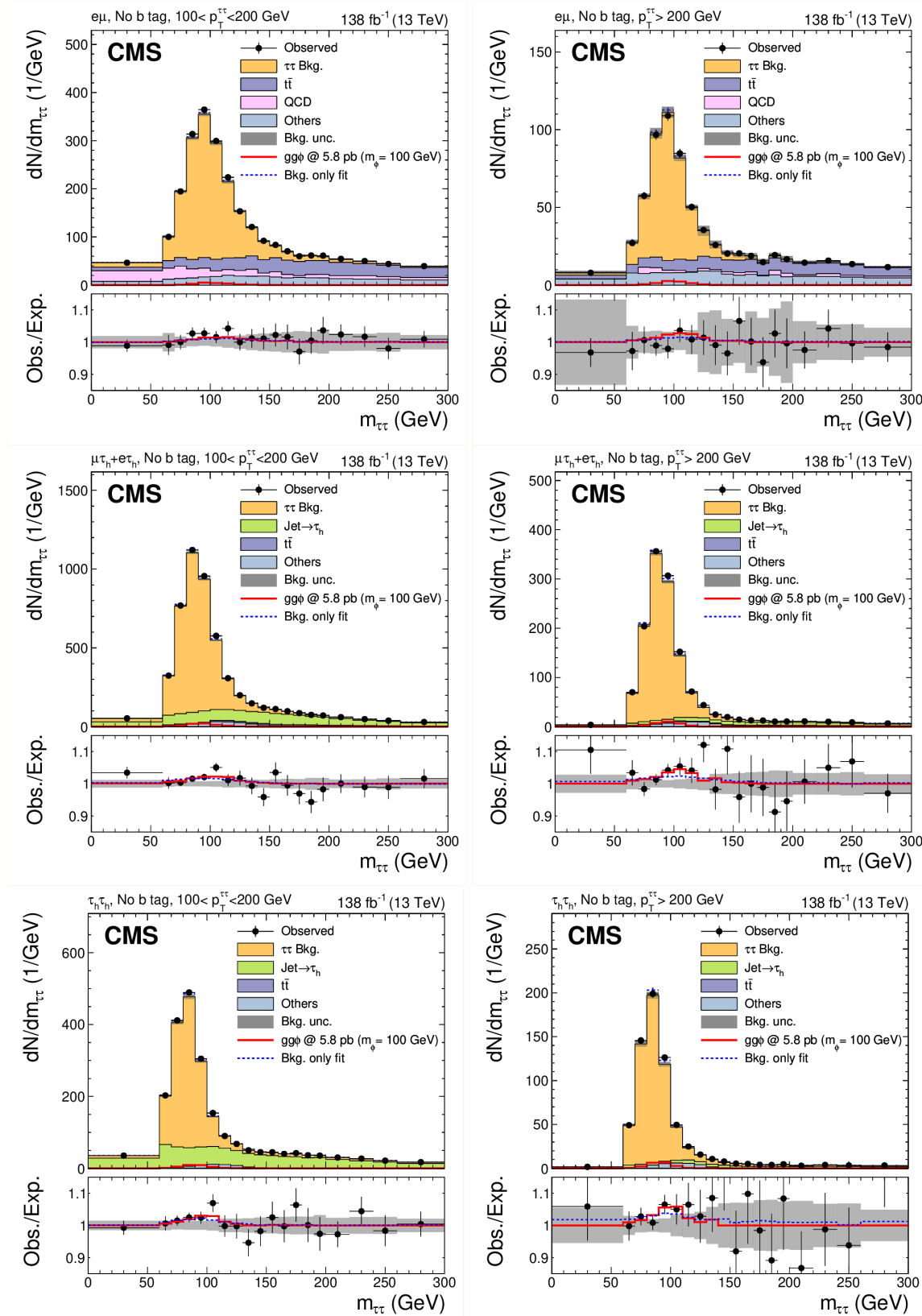
- **Reference:** CMS Collaboration, *Search for additional neutral Higgs bosons decaying to a pair of tau leptons in proton-proton collisions at $\sqrt{s} = 13$ TeV*, [[JHEP 07 \(2023\) 073](#)] [[arXiv:2208.02717](#)].



Observed local p -value scan for $bb\phi$ ($gg\phi$ profiled) [CMS HIG-21-001, Additional Fig. 32]

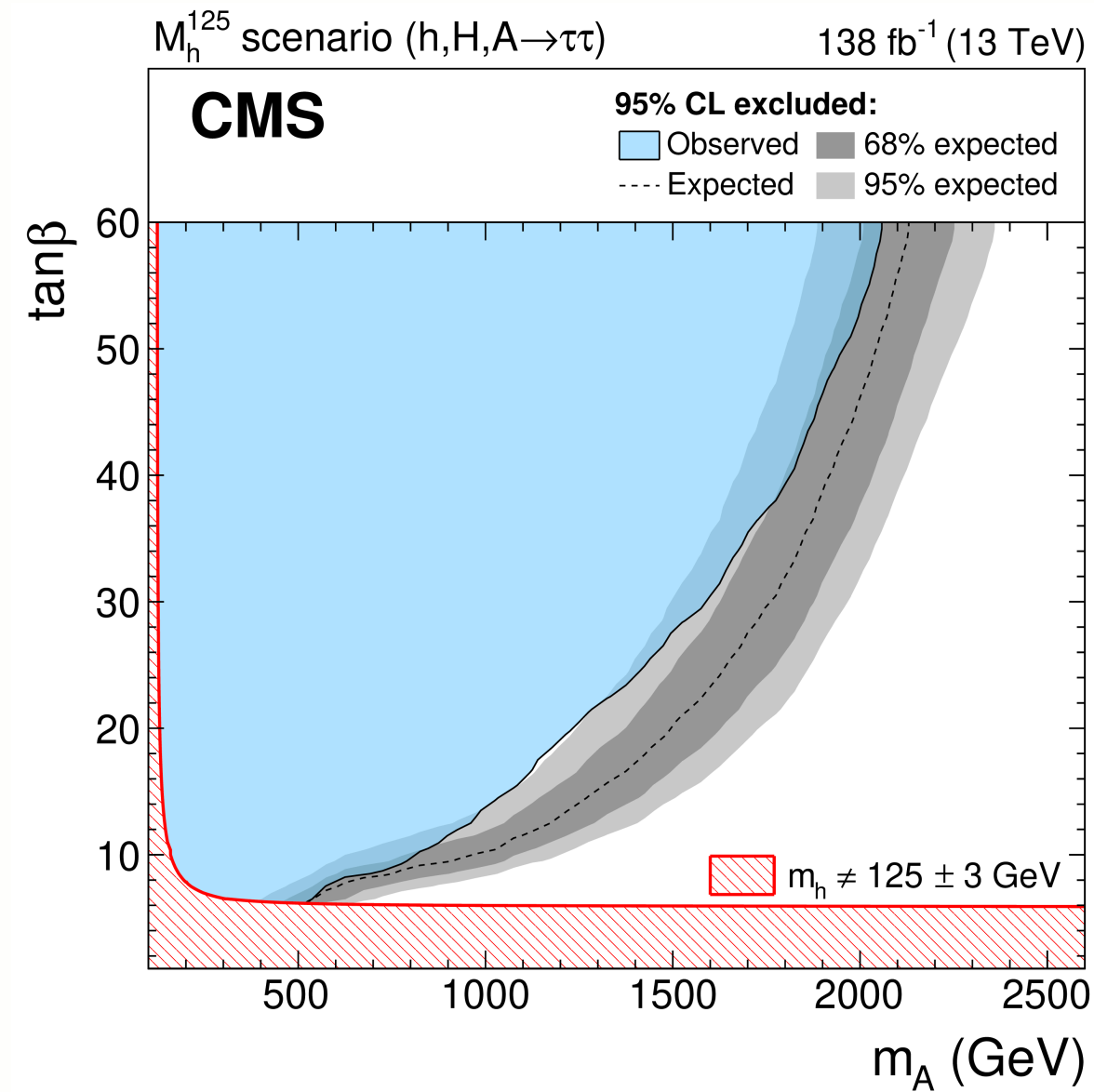


2D likelihood contours in $(\sigma_{gg\phi}, \sigma_{bb\phi})$ at selected masses [JHEP 07 (2023) 073, Fig. 11]

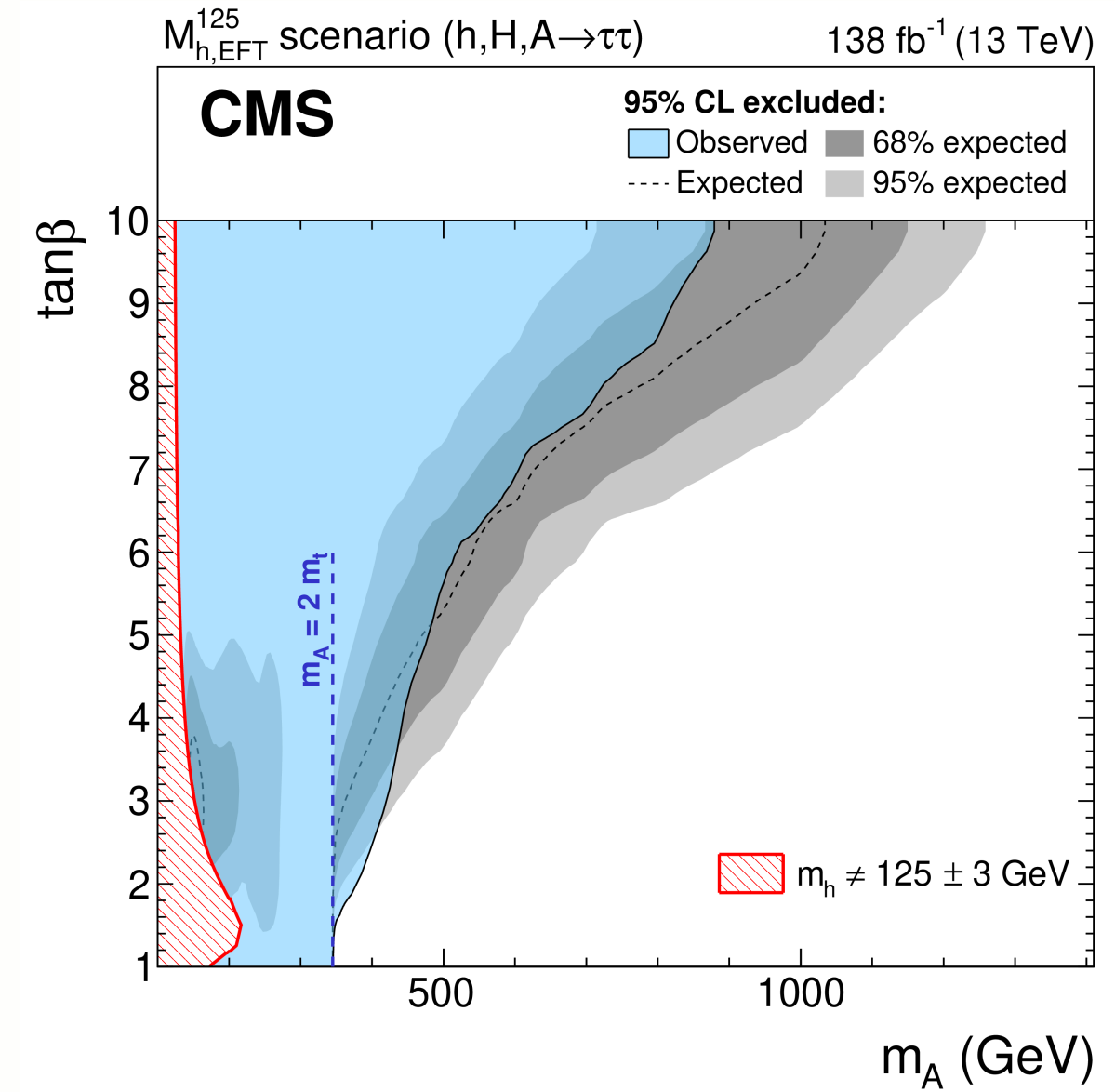


Observed and predicted distributions in the low-mass search under the signal-plus-background fit at $m_\phi = 100$ GeV [JHEP 07 (2023) 073, Fig. 9]

- **Benchmark Interpretations:** Combine predicted contributions from h, H, A in the MSSM ($m_A, \tan \beta$) parameter space.
- M_h^{125} & $M_{h,EFT}^{125}$ **Scenarios:** High SUSY scale in the EFT scenario yields $m_h \simeq 125$ GeV down to lower $\tan \beta$.
- **Exclusion Bounds:** Masses $m_A \lesssim 350$ GeV largely excluded at 95% CL across displayed $\tan \beta$ values.



M_h^{125} scenario [JHEP 07 (2023) 073, Fig. 13a]



$M_{h,EFT}^{125}$ scenario [JHEP 07 (2023) 073, Fig. 13b]