HH and Scalar+H resonant searches

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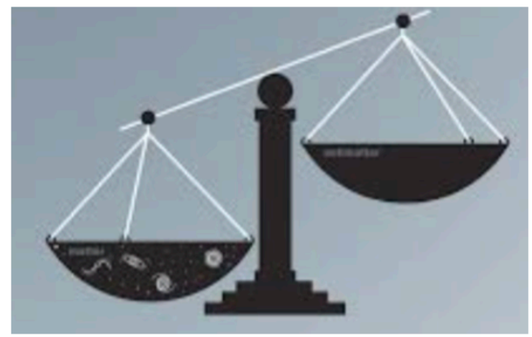
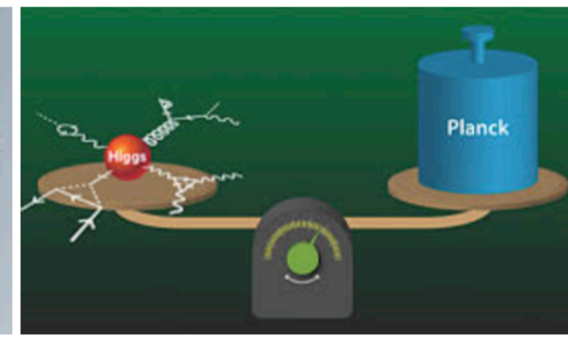
Beyond the Standard Model?

The Standard Model explains known particles and forces, confirmed by the 2012 Higgs boson discovery, but key mysteries remain.

These gaps drive the hunt for physics beyond the Standard Model

Some BSM Models

Extending the Higgs Sector – A Natural Next Step

Key Ideas:

- Many BSM frameworks extend the Higgs sector, e.g.:
  - Two-Higgs-Doublet Models (2HDM)
  - Supersymmetry (MSSM, hMSSM)
  - Hidden Abelian Higgs Models (HAHM)
- Predict additional particles: heavy neutral scalars (H/X), pseudoscalars (A), charged Higgs bosons ($H^{\pm}$, H^{++})
- Such decays provide distinctive experimental signatures for exploring BSM physics

Recent CMS searches covered in this talk

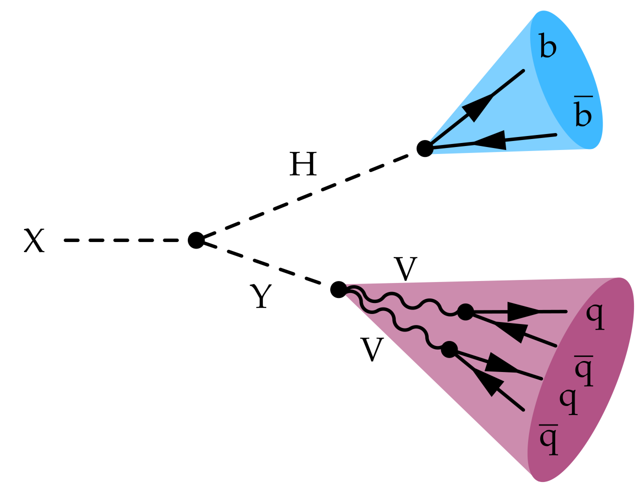
Full Run2 dataset: **138** fb^{-1} of pp collision at **13 TeV**

This dataset allow us to probe

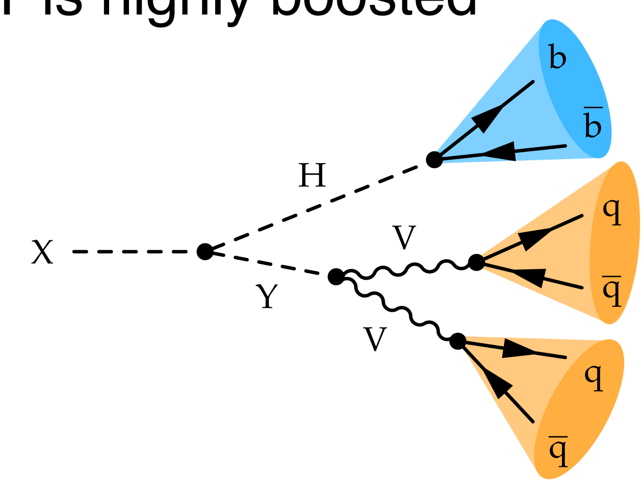
- $X \to YH, H \to b\overline{b}, Y \to VV \to 4q$ **(**B2G-PAS-23–007**)**
- $Z' \to H(Z)\gamma, H(Z) \to b\overline{b}$ **(**B2G-PAS-24-007**)**
- $X \to YH, H \to b\overline{b}, Y \to \gamma\gamma$ **(**arXiv:2508.11494**)**
- $X \to YH, H \to b\overline{b}, Y \to$ one large-area jet **(**B2G-PAS-24-015**)**

$X \rightarrow YH, H \rightarrow b\bar{b}, Y \rightarrow VV \rightarrow 4q$

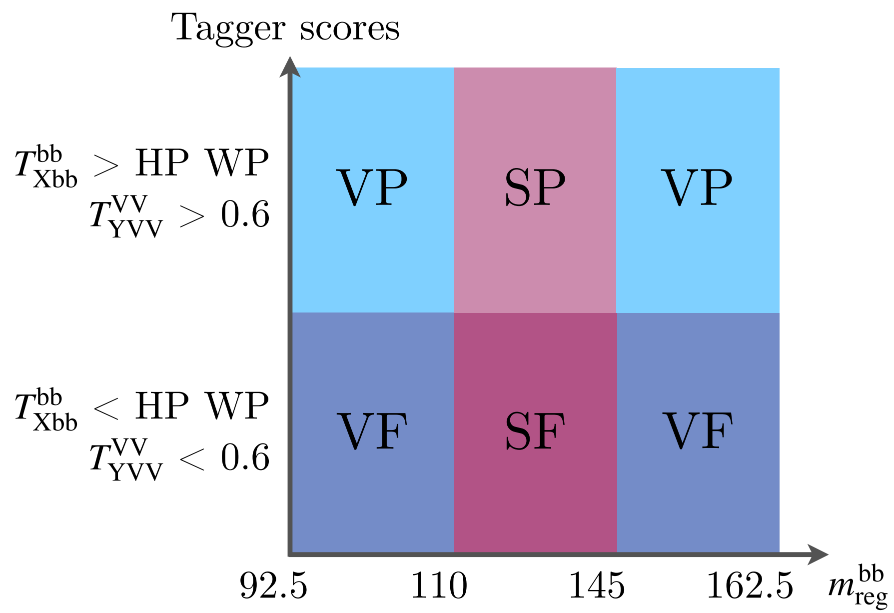
- Extended Higgs models, such as the next-to-MSSM and two-real-singlet model, predict heavier scalars that can decay into lighter ones.
- **Mass Range Probed**
  - 900 GeV < m_X < 4 TeV
  - 60 GeV < m_y < 2.8 TeV
- **Channel**
  - **boosed regime,** $H \rightarrow b\bar{b}$ is reco. as a larger jet
  - $Y \rightarrow VV \rightarrow 4q$ (semi- and fully-merged)
- **Key Features**
  - Machine-learning-based jet identification
  - Mass reconstruction algorithms
  - "particle transformer" for $Y \rightarrow 4q$ discrimination



Fully-merged ($m_Y \lesssim 0.1 m_X$)
,Y is highly boosted

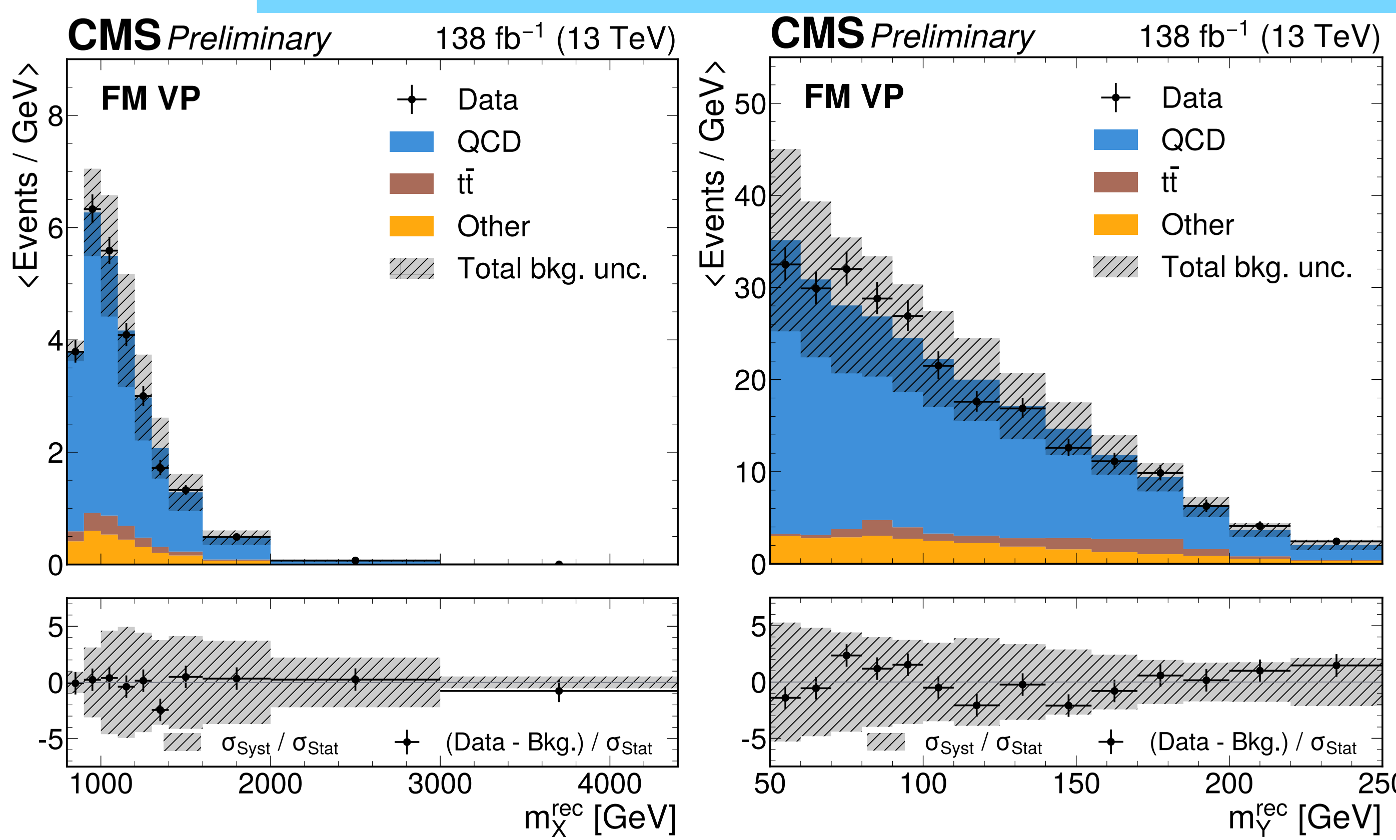


Semi-merged ($0.1m_X\, m_Y < m_X - m_H$)
,Y is less boosted



- Signal & Control Regions:
  - Using tagger score & H(bb) mass

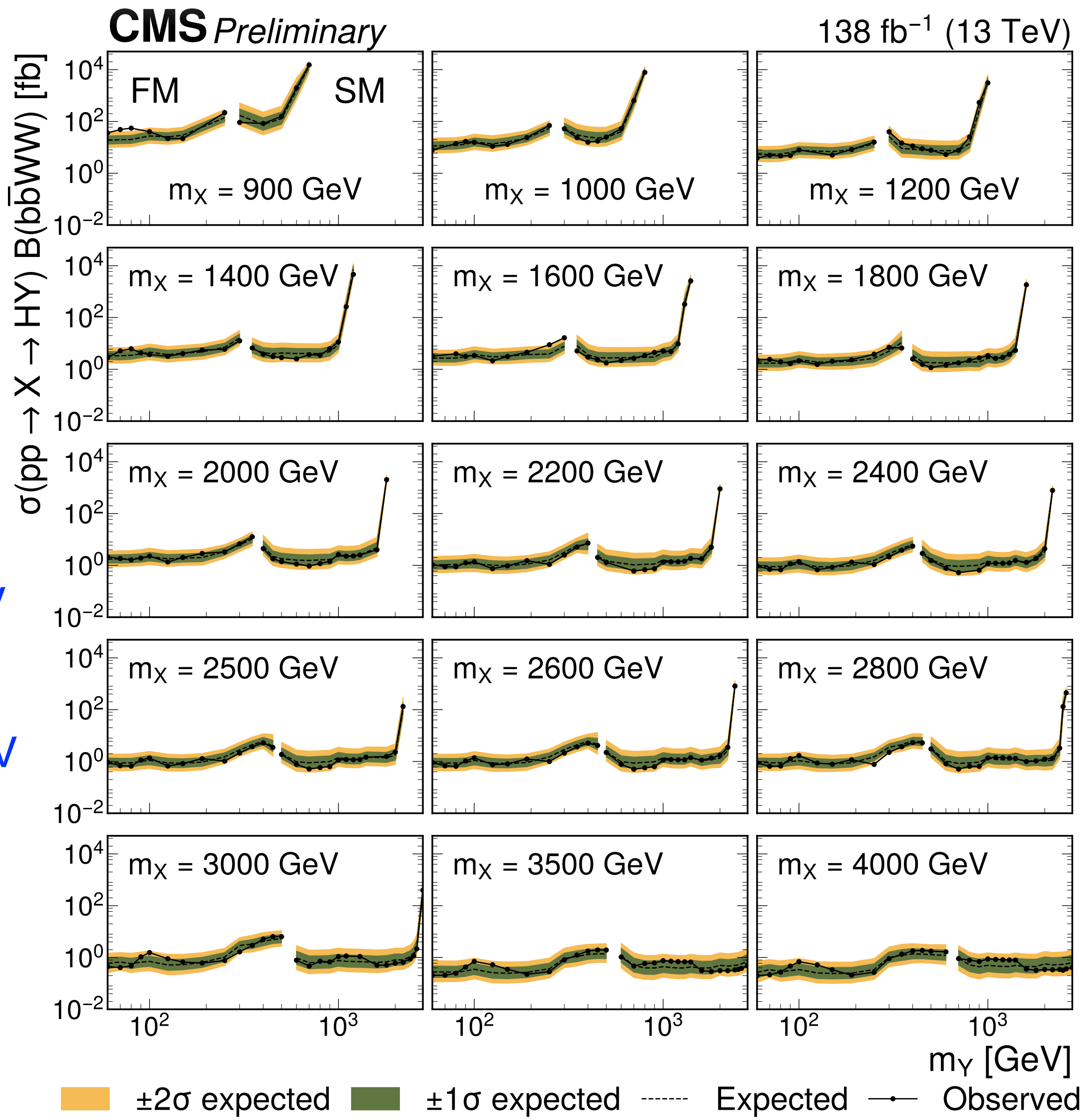
Validation in Higgs mass side bands



- Main backgrounds
  - (QCD & ttbar)

Results ($X \to YH, H \to b\bar{b}, Y \to VV \to 4q$)

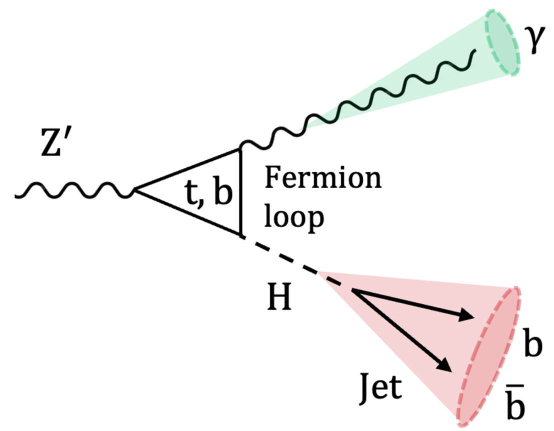
A simultaneous 2D binned maximum likelihood fit in m^{X}_{reco} and m^{Y}_{reco}



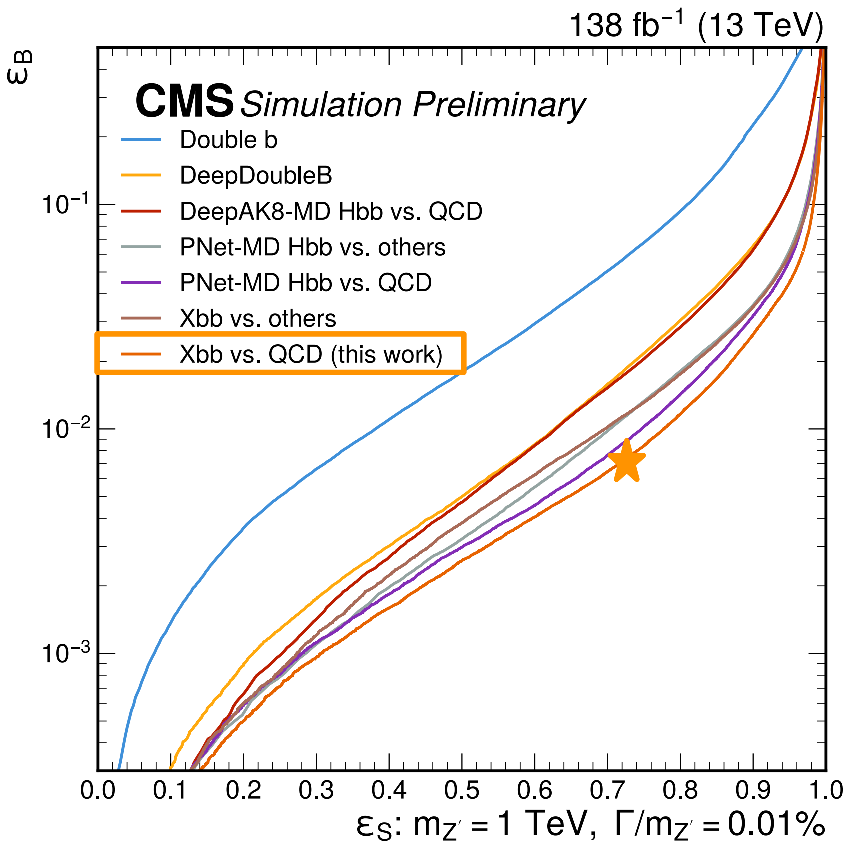
- Fully-merged category for m_X = 900 GeV and m_Y = 80 GeV with a local (global) significance of 3.3σ (below 1.0σ)
- Semi-merged category for m_X = 1200 GeV and m_Y = 900 GeV with a local significance of 1.7σ

No significant excess observed above the SM prediction

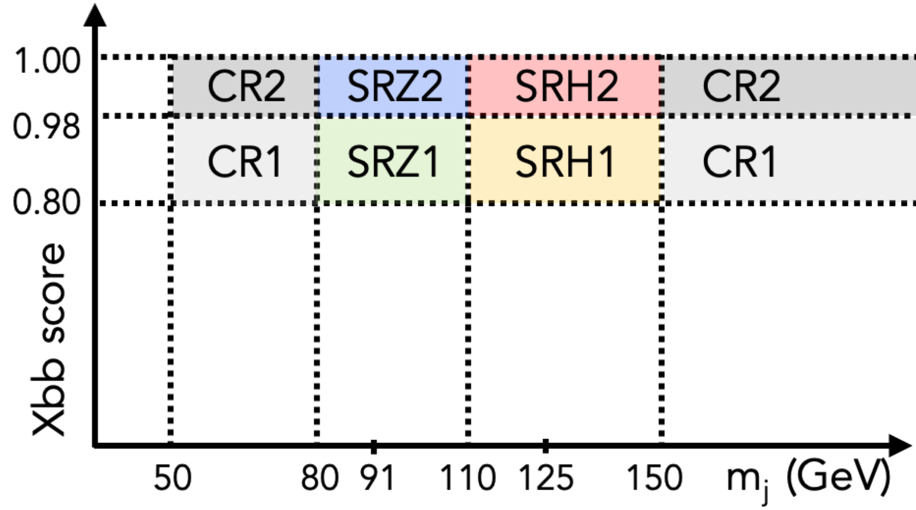
$Z' \to H(Z)\gamma, H(Z) \to b\bar{b}$



- Expanded the di-boson resonance search by including the uncovered $H(Z)\gamma$ decay channel.
- **Mass Range:** 700 GeV < $m(Z')$ < 3.5 TeV
- **Key Features**
  - Use the H/Z→bb decay mode with highest BR
  - Use parametric functions for BKG prediction in discrete profiling
  - Machine-learning-based jet identification
  - Mass reconstruction algorithms
  - "particle transformer" for background discrimination



- Signal & Control Regions:
  - Using tagger score & mj
- Main backgrounds
  - QCD+γ, Fakes γ, V+ γ



- Use standard parametric functions:

dijet2: $p_0 m^{p_1 + p_2 \log(m)}$

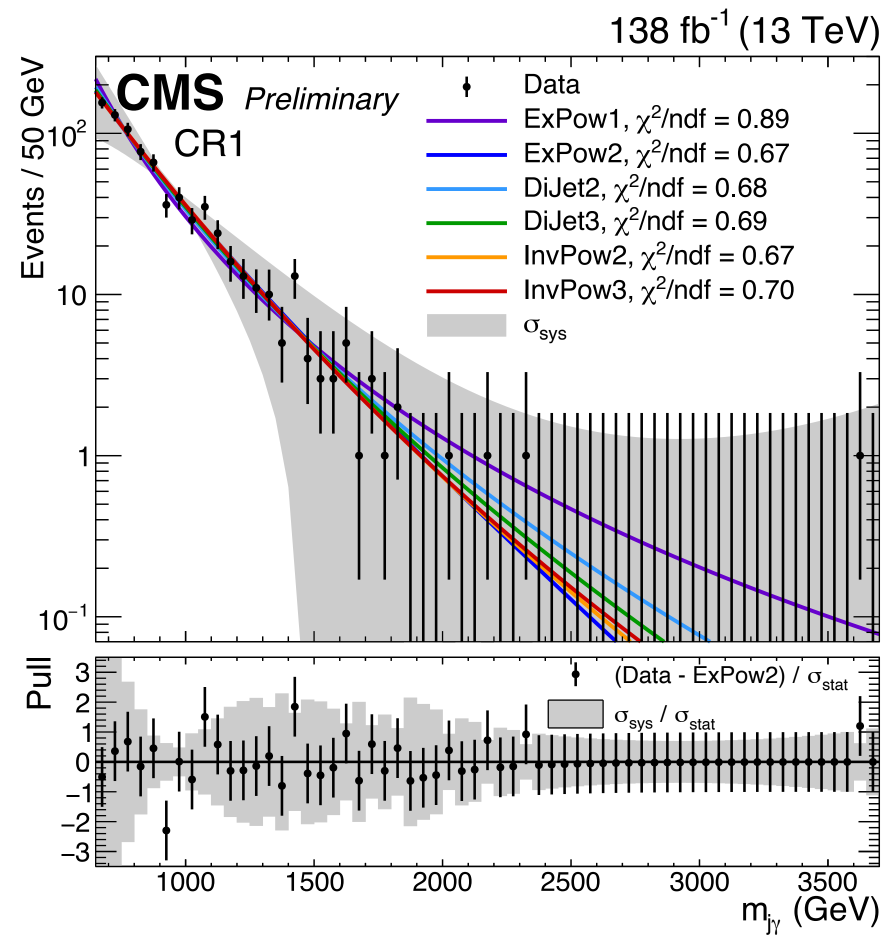
dijet3: $p_0 m^{p_1 + p_2 \log(m) + p_3 \log^2(m)}$

expow1: $p_0 m^{p_1}$

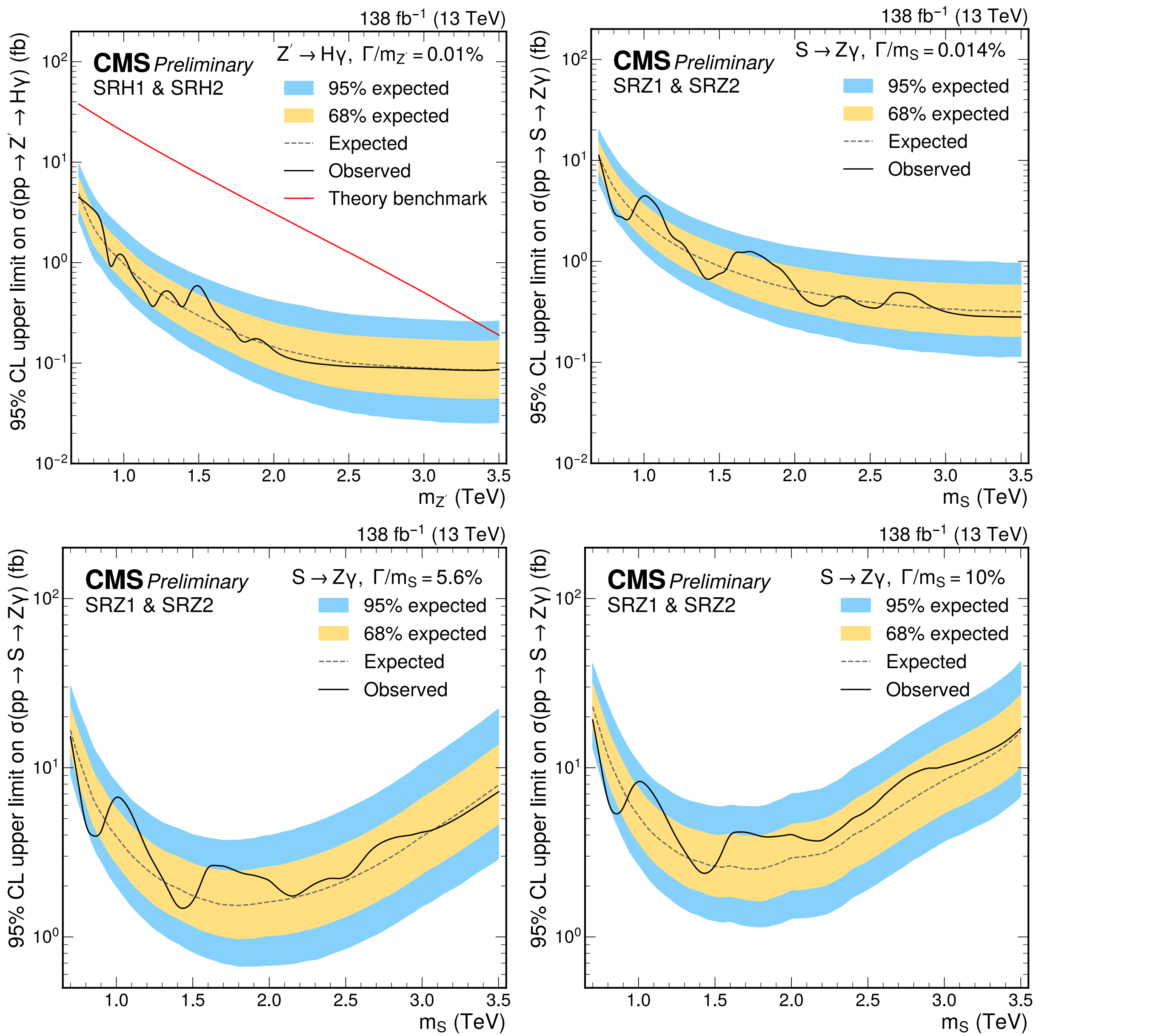
expow2: $p_0 m^{p_1} e^{p_2 m}$

invpow2: $p_0 (1 + p_1 m)^{p_2}$

invpow3: $p_0 (1 + p_1 m)^{p_2 + p_3 m}$



Results ($Z' \to H(Z)\gamma, H(Z) \to b\bar{b}$)

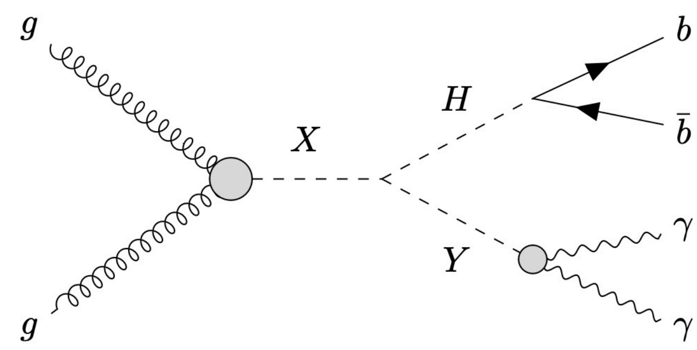


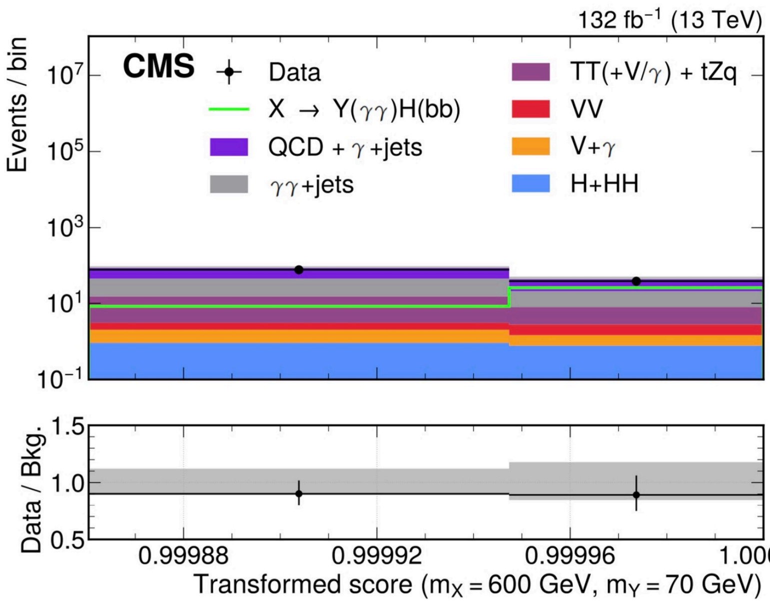
A unbinned maximum likelihood fit is performed

No significant excess observed above the SM prediction

$X \to YH, H \to b\bar{b}, Y \to \gamma\gamma$

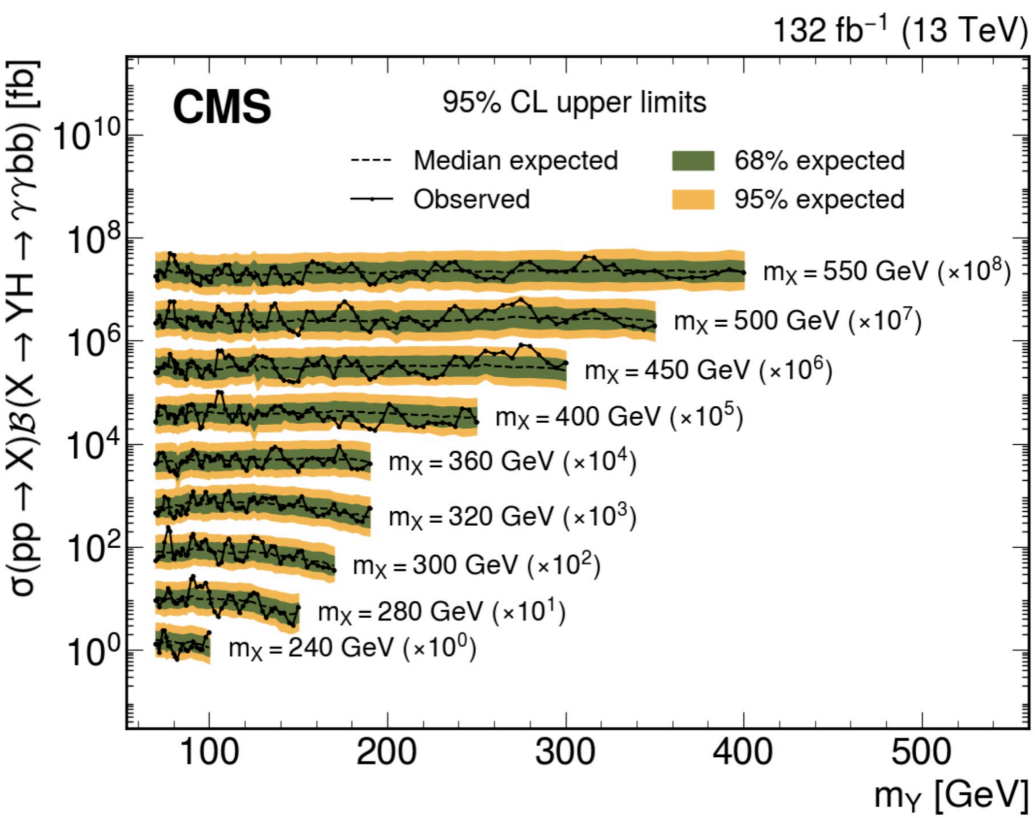
- Extended Higgs models, such as the next-to-MSSM and two-real-singlet model, predict heavier scalars that can decay into lighter ones.
- **Mass Range:**
  - 240 GeV < m_X < 1 TeV
  - 70 GeV < m_y < 0.8 TeV
- **Reconstruction & categorization**
  - pNN with optimal performance for all masses
  - output of pNN is transformed for each mass point so that the background MC is flat in the transformed score
  - Categories are defined based on NN score and $m_{\gamma\gamma}$

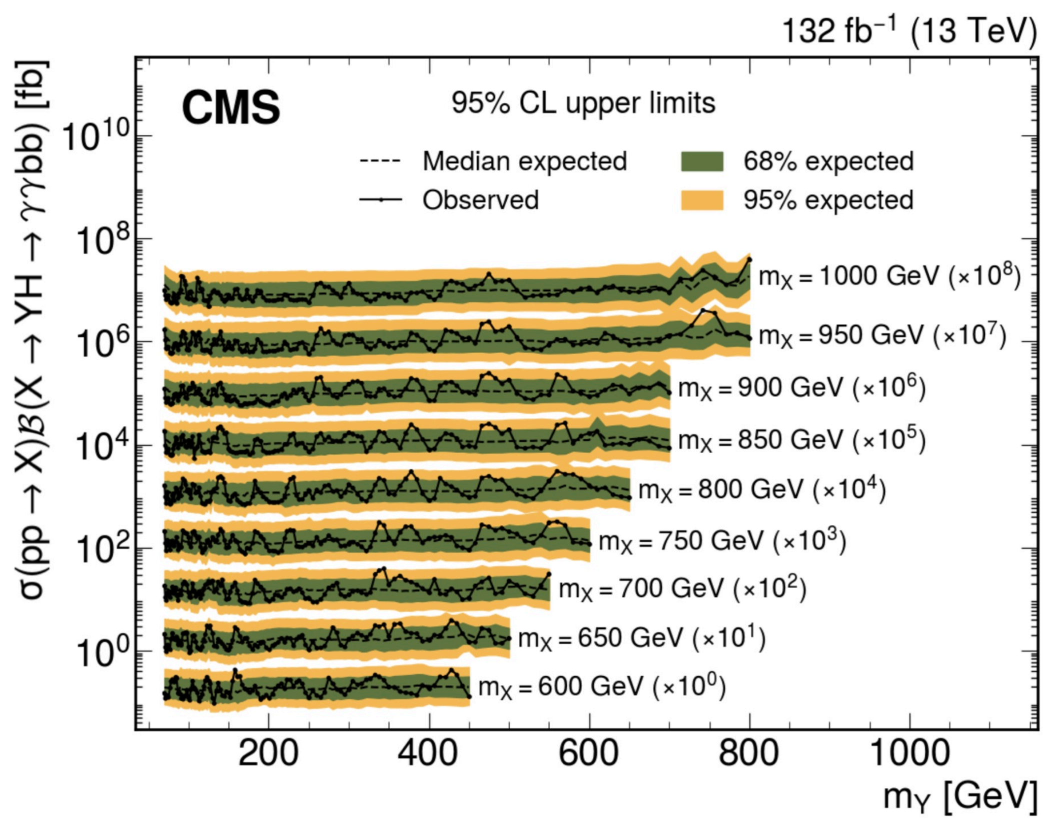




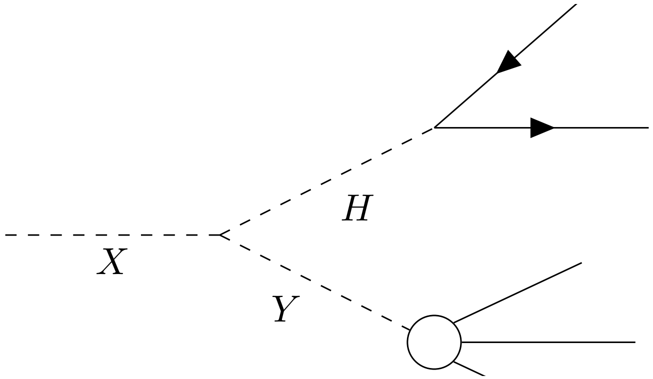
Results ($X \to YH, H \to b\bar{b}, Y \to \gamma\gamma$)

- In general, the data are found to be compatible with the standard model expectation
- A local significance of 3.33σ is observed at M_X=300GeV, M_Y=70GeV
  - Its global significance is 0.65σ considering look-elsewhere effect

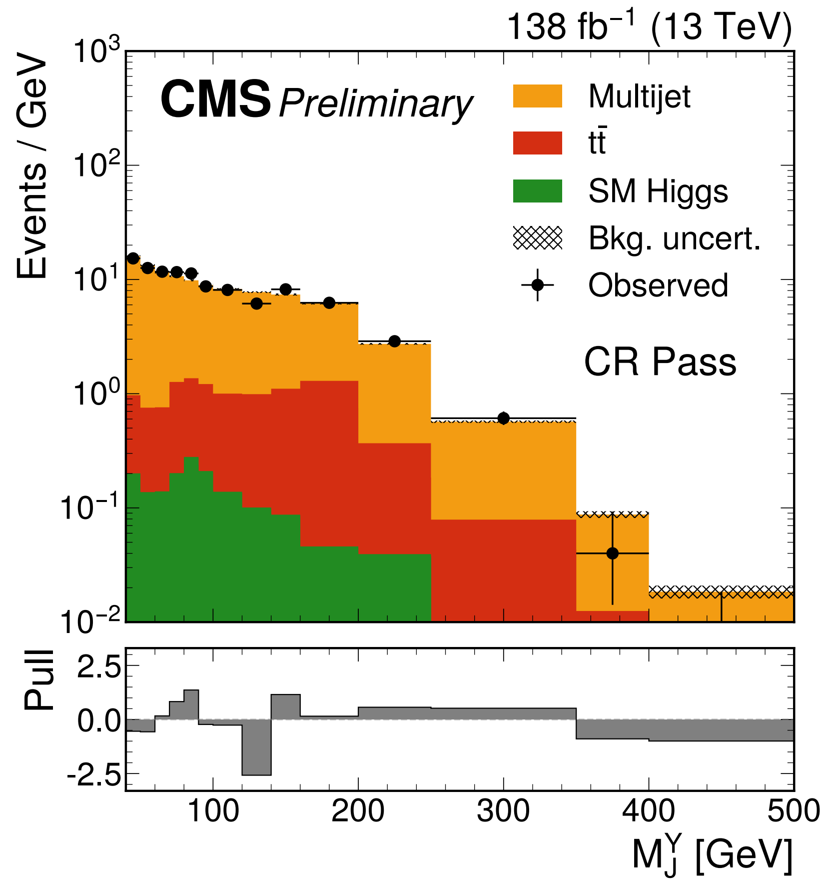




$X \rightarrow YH, H \rightarrow b\bar{b}, Y \rightarrow$ an anomalous jet

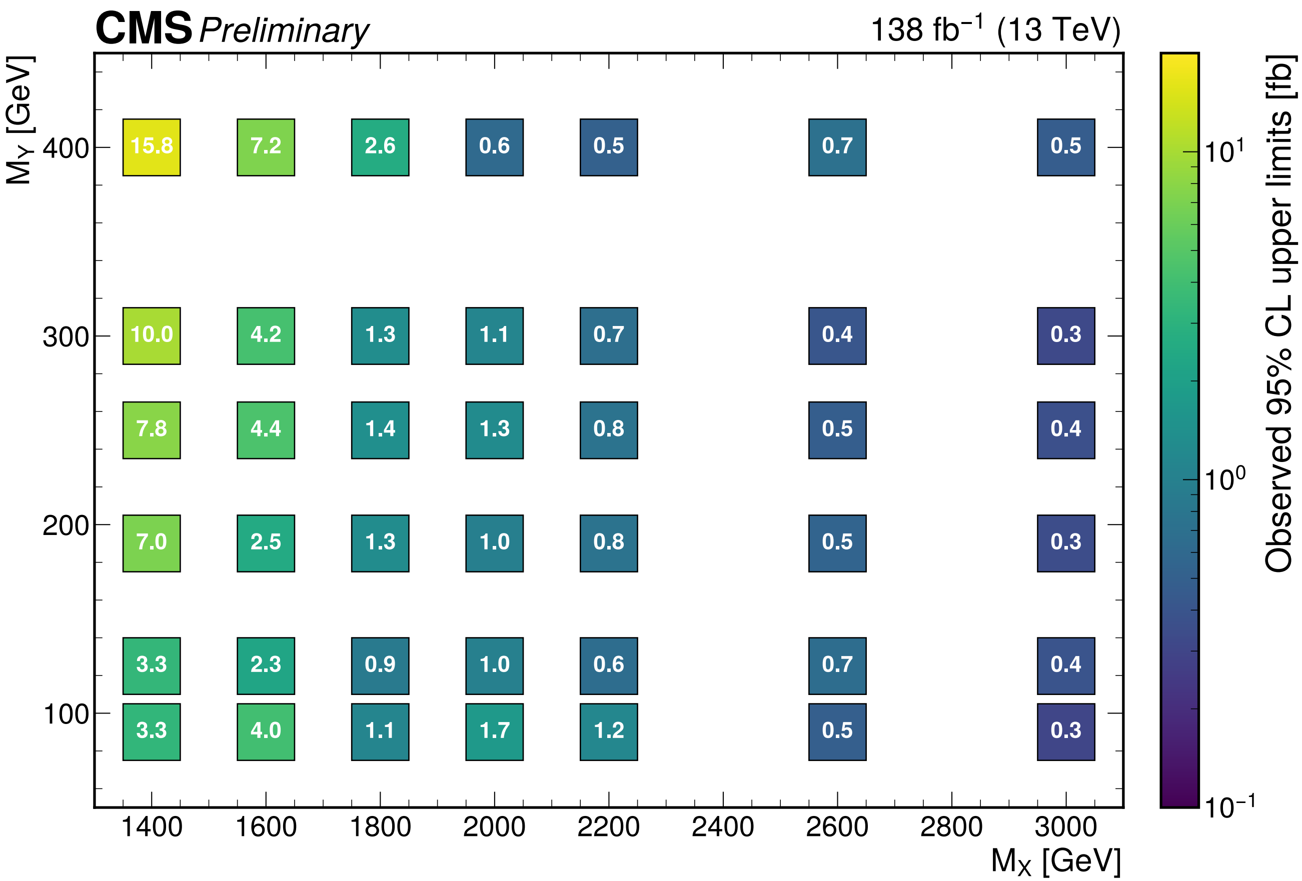


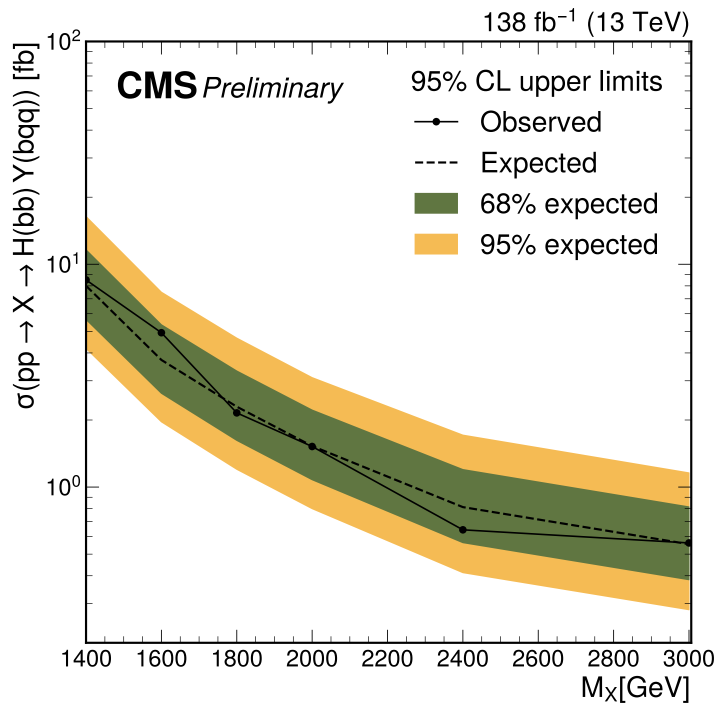
- Less constrained compared to "traditional" searches
  - Captures a wider range of potential signals
- **Mass Range:**
  - 1.4 TeV < m_X < 3 TeV
  - 90 GeV < m_y < 400 GeV
- **Key features**
  - Use of Particle NetXbb tagging for H candidate for mass between 100 to 150 GeV
  - Use of Autoencoder to tag anomalous jet/Y candidate
  - Anomaly tagging and particle are used to define analysis region (CRs and SRs)
  - Search for bump in 2D plane ($m_{jj} - m_j^Y$)



Results ($X \to YH, H \to b\bar{b}, Y \to$ an anomalous jet)

No significant excess observed above the SM prediction





Largest local significance of 2.06σ is observed for MX = 1600 GeV and MY = 90 GeV

Summary

- A rich CMS program of resonances searches decaying to HH or HY
- Presented following recent results
  - $X \to YH, H \to b\bar{b}, Y \to VV \to 4q$ (B2G-PAS-23–007)
  - $Z' \to H(Z)\gamma, H(Z) \to b\bar{b}$ (B2G-PAS-24-007)
  - $X \to YH, H \to b\bar{b}, Y \to \gamma\gamma$ (arXiv:2508.11494)
  - $X \to YH, H \to b\bar{b}, Y \to$ one large-area jet (B2G-PAS-24-015)
- **No significant excess observed above the SM prediction**
  - BSM physics is still hidding
  - More decay channels being explored, more statistics to come (i.e. combinations and Run3 results)