Search for SUSY in Events with $H \longrightarrow \gamma\gamma$ Using the Razor Variables in CMS

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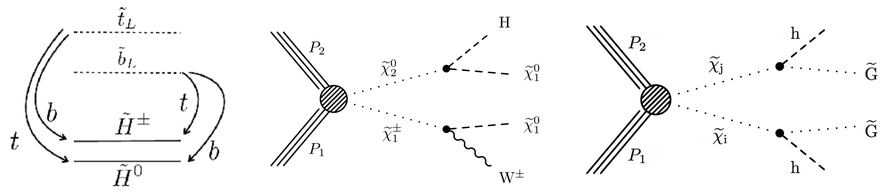
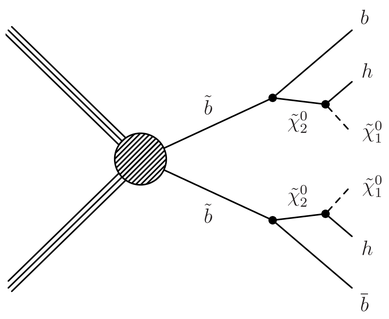
Introduction

- Many SUSY particles like to decay to Higgs



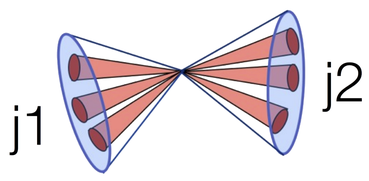
- $\mathbf{H \longrightarrow \gamma\gamma}$ is one of the best accessible channels due to suppression of background.
- Analysis LHC Run 1 data with **razor variables** reported an excess of $\mathbf{H \longrightarrow \gamma\gamma}$ events with a local (global) significance of $\mathbf{2.9\sigma}$ $(\mathbf{1.6\sigma})$.

- A simplified model of bottom squark production is considered with 15.2 $\mathbf{fb^{-1}}$ of 13 TeV data:
  - Assume $\mathbf{m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0} = 130\ GeV}$.
  - Such a model has event kinematics consistent with the Run 1 excess and is not ruled out by searches in other final states.



Razor Variables

- Higgs candidate and all identified jets are clustered into two **megajets**.
- The razor variables $\mathrm{M_R}$ and $\mathrm{R^2}$ are defined in terms of the momenta of the two megajets:



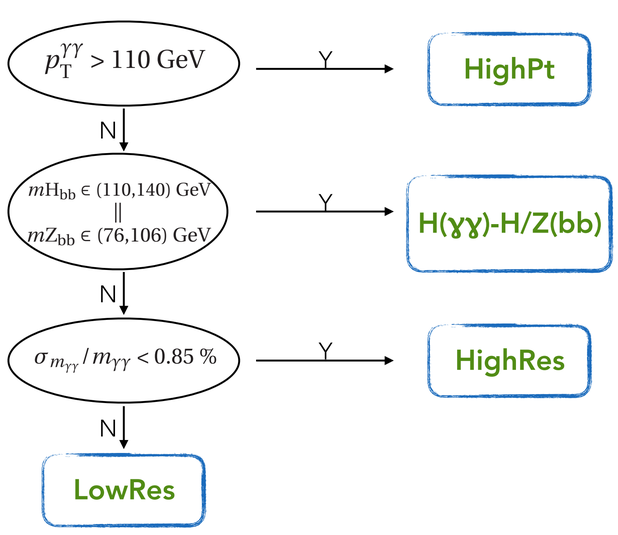
$$\mathrm{M_R} \equiv \sqrt{(|\vec{p}^{\,j_1}| + |\vec{p}^{\,j_2}|)^2 - (p_z^{j_1} + p_z^{j_2})^2},$$

$$\mathrm{R^2} \equiv \left(\frac{\mathrm{M_R^T}}{\mathrm{M_R}}\right)^2, \text{where } \mathrm{M_R^T} \equiv \sqrt{\frac{\mathrm{E_T^{miss}}(p_T^{j_1} + p_T^{j_2}) - \vec{p}_T^{\,miss} \cdot (\vec{p}_T^{\,j_1} + \vec{p}_T^{\,j_2})}{2}}.$$

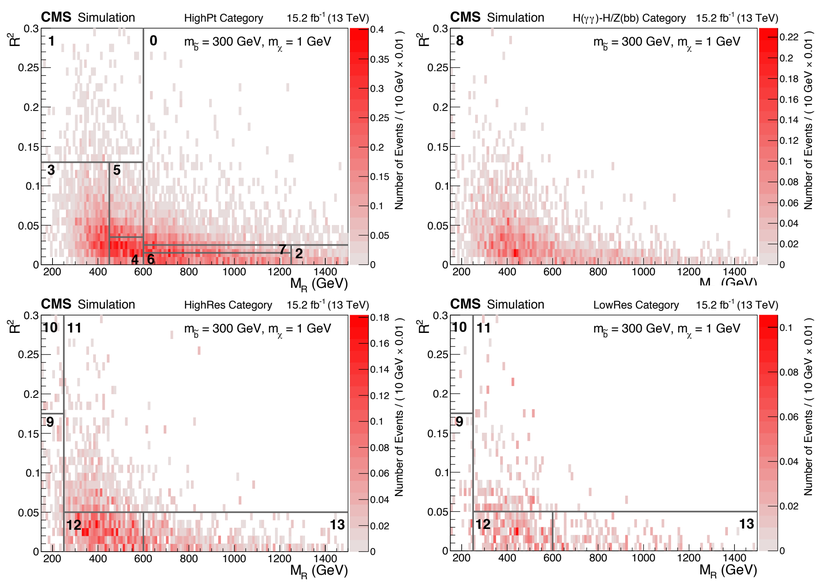
- For SUSY signals, $\mathrm{M_R}$ peaks at $\mathbf{M_\Delta \approx (m_{\tilde{q}}^2 - m_{\tilde{\chi}_1^0}^2)/m_{\tilde{q}}}$, and $\mathrm{M_R^T}$ has maximum value at $\mathbf{M_\Delta}$; while for standard model (SM) backgrounds like QCD multijet events the $\mathrm{M_R}$ and $\mathrm{R^2}$ are exponentially falling.
  - Traditional searches on high $\mathbf{p_T}$ and $\mathrm{E_T^{miss}}$ tails now become search of peak on exponentially falling background.
  - This also allows us to identify a 2D $\mathrm{M_R}$ - $\mathrm{R^2}$ region where SUSY signals are enhanced while SM backgrounds are reduced.

Event Selection and Categorization

- At least two photons and one jet:
  - $|\eta^\gamma| < 1.5$, $\mathbf{p_T^{\gamma_1}} > 40$ GeV, $\mathbf{p_T^{\gamma_2}} > 25$ GeV
  - $|\eta^j| < 3.0$, $\mathbf{p_T^j} > 30$ GeV
- Each event is then put into one of four categories depending on the $\mathbf{p_T}$ and mass resolution of the Higgs candidate and whether there is an additional H/Z(bb) event.



- Each event category is divided into several bins based on razor variables to further enhance S/B.

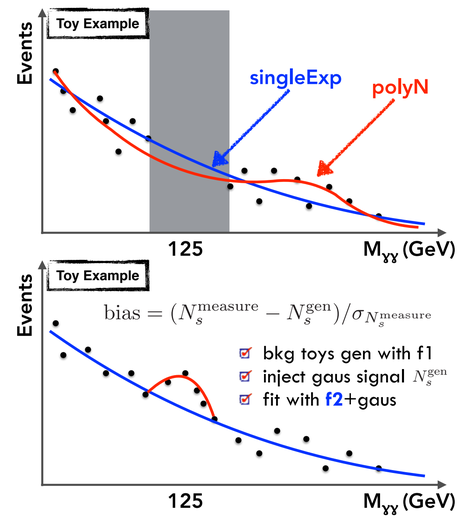


Background Estimation

- In each analysis category and $\mathrm{M_R}$ - $\mathrm{R^2}$ bin, SUSY signals are extracted by fitting to the $\mathbf{M_{\gamma\gamma}}$ spectrum.
- SM Higgs background and SUSY signal are each modeled with a double-sided crystal ball function fitted to MC simulation distribution.
- Non-resonant background form in each bin is determined by a data-driven fit to the $\mathbf{M_{\gamma\gamma}}$ spectrum:
  - First, fit the sideband data with each function candidates and exclude functions with large Akaike Information Criterion (AIC) score:

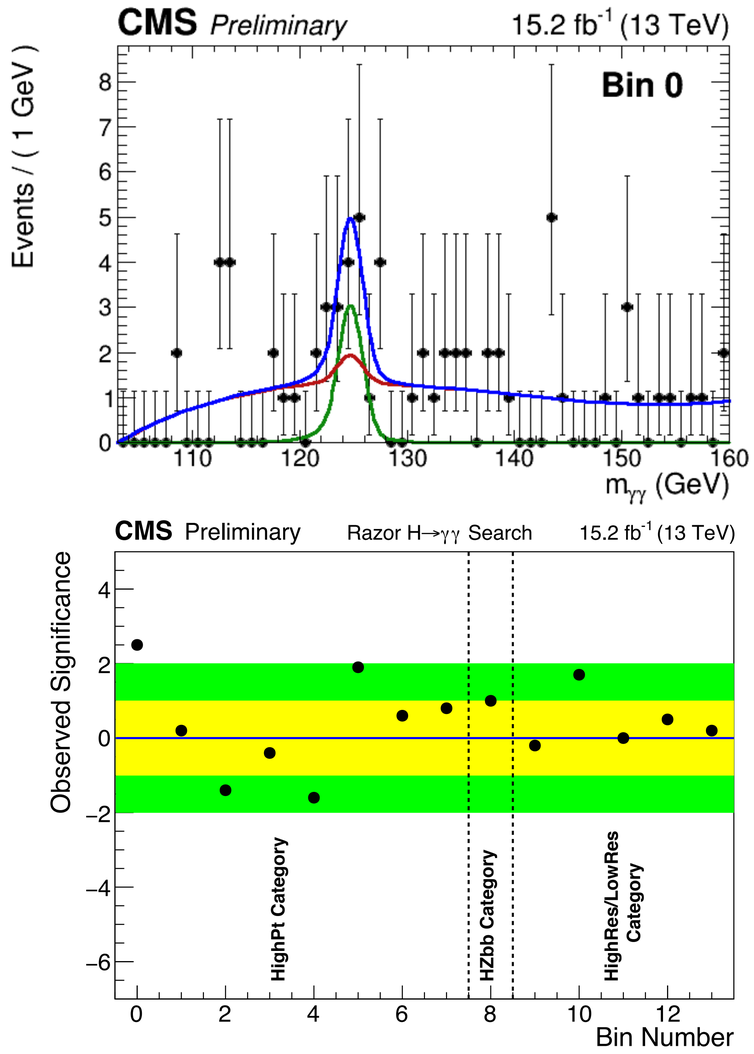
$$\mathbf{AIC} = -2\log(\mathcal{L}) + 2k + \frac{2k(k+1)}{N-k-1} \approx -2\log(\mathcal{L}) + 2k$$

  - Then, perform a bias test by toy experiments for each function pairs among the functions that pass AIC test.

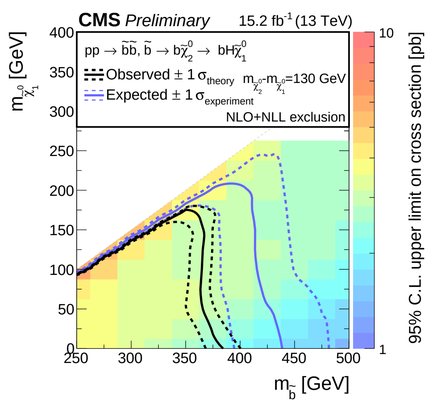


- The final function is chosen with a preferred order among the candidates that pass both AIC and bias test.

Fit Results and Limits on SUSY Masses



- Dominant systematics are fit uncertainties on the non-resonant background.
- The bin with the largest significance occurs in the HighPt category with $\mathrm{M_R} > 600$ GeV and $\mathrm{R^2} > 0.025$, with local (global) significance of 2.5σ (1.4σ).
- Sbottoms with mass below 350 GeV are excluded.



Conclusion

- A search for anomalous Higgs production from SUSY particle decays is performed with 15.2 $\mathbf{fb^{-1}}$ of 13 TeV data.
  - One Higgs is reconstructed with two photons.
  - The razor variables $\mathrm{M_R}$ and $\mathrm{R^2}$ are used to suppress SM backgrounds.
- The results are interpreted in terms of production cross-section limits on sbottoms pair production as a function of sbottom and LSP masses.

References: CMS-PAS-SUS-14-017 (Run 1), CMS-PAS-SUS-16-012 (Run 2).