

Searches for Supersymmetry with Photons at CMS

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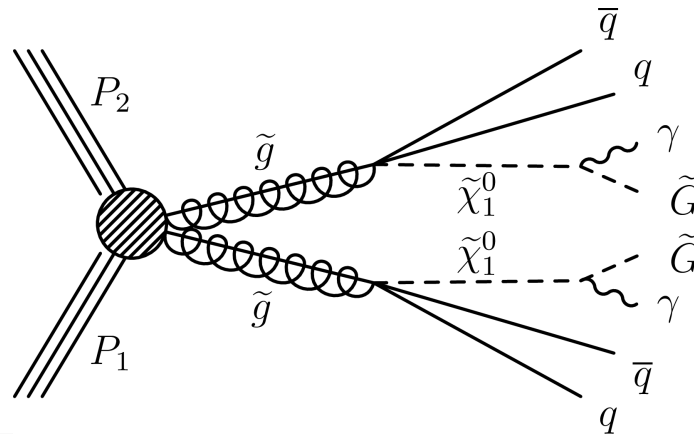
on behalf of the CMS Collaboration

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SUSY searches using photons are highly motivated

- Gauge Mediated SUSY breaking models produce decay chains with large branching ratio to photons
 - LSP is the gravitino
 - NLSP has large branching ratio to photons, Higgs, and Z
- The presence of photons suppresses SM background in a complementary way compared to typical SUSY searches \rightarrow probes complementary phase space
- Higgs $\rightarrow \gamma\gamma$ decay is a very powerful signature!

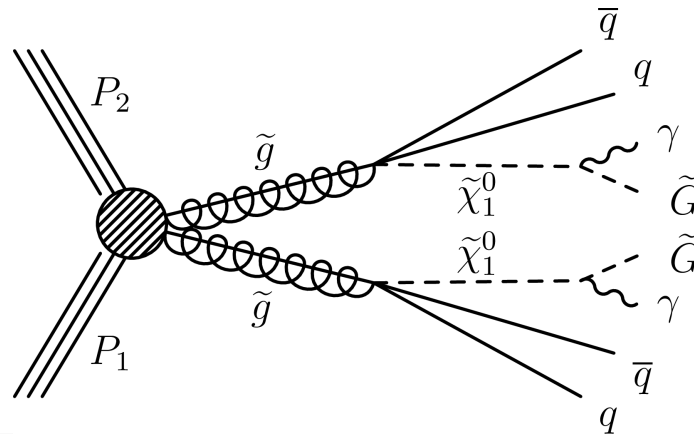


Overview

- 1) Strong limits on gluinos, and EWKinos (χ_2^0 , χ_1^\pm) excluding deep into the TeV region in many simplified models
- 2) Interesting excursions in the Higgs-aware search to watch out for with more data

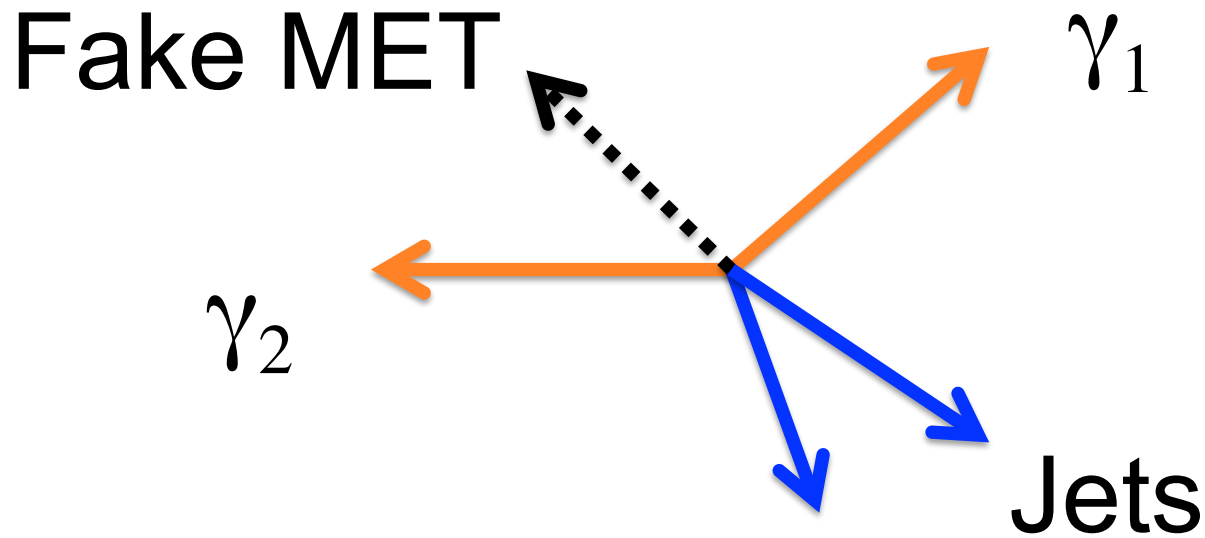
Diphoton + MET Search

- Uses 2.3 fb-1 from the 2015 dataset
- Select events with 2 photons
 - Central ($|\eta| < 1.44$)
 - $p_T > 40$ GeV
 - Pixel track seed veto (suppress electrons)
 - $M_{\gamma\gamma} > 105$ (trigger selection)
- Require baseline MET > 100 GeV
- Perform search in 4 exclusive MET bins:
 - (100,110) ; (110,120) ; (120,140) ; (140, Infinity)



Diphoton + MET Search

Dominant Background :
QCD $\gamma\gamma$ production (Fake MET)



QCD Bkg Estimation

Use Data-Driven Method

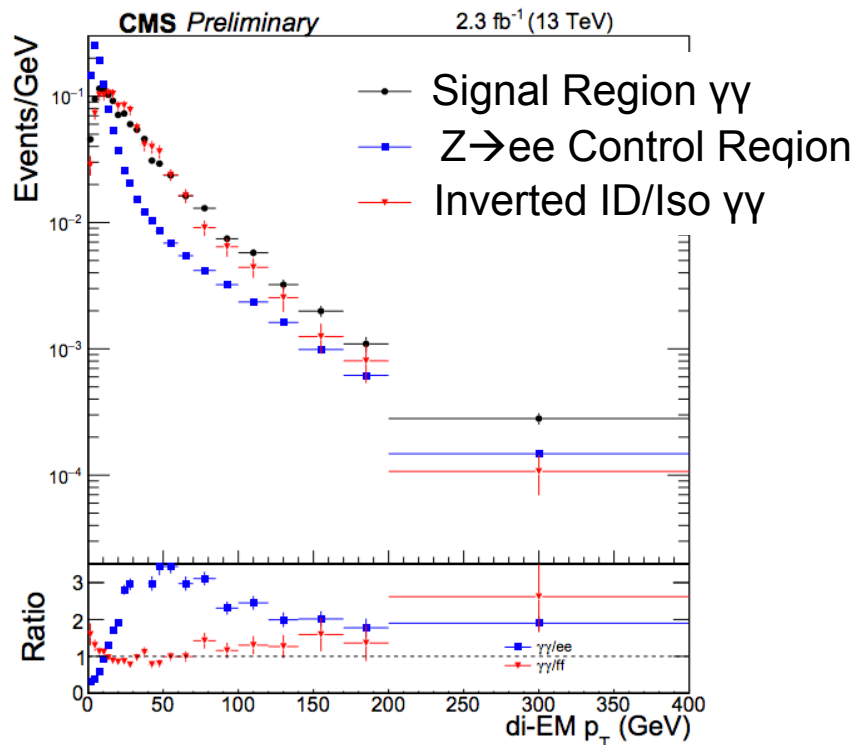
- Assume MET distribution is the same in $Z \rightarrow ee$ sample and inverted photon ID/isolation sample
- Use $Z \rightarrow ee$ control region to predict MET distribution for signal region
- Use inverted photonID/iso sample as cross-check

QCD Bkg Estimation

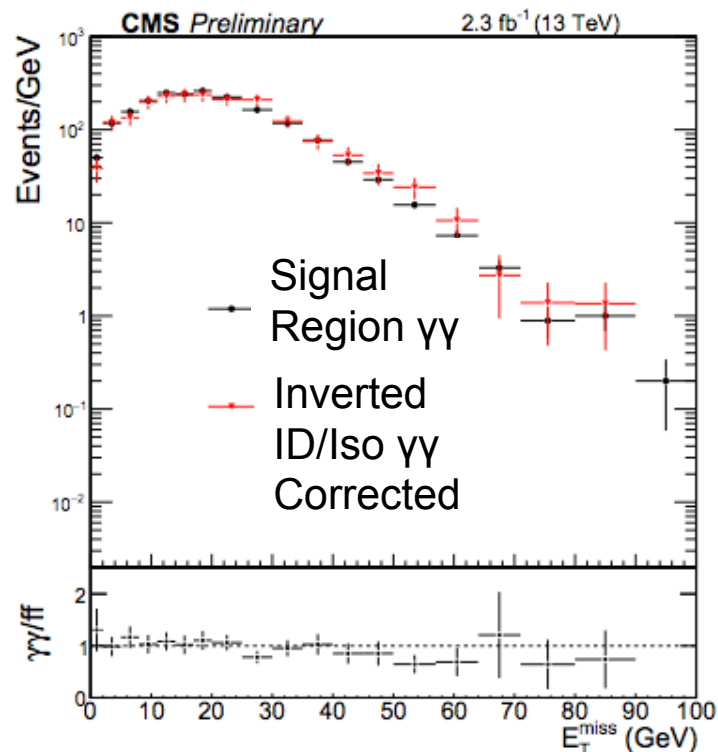
Use Data-Driven Method

- We do have to correct for difference in hadronic recoil
→ use MC simulation to correct for this

Recoil distributions differ

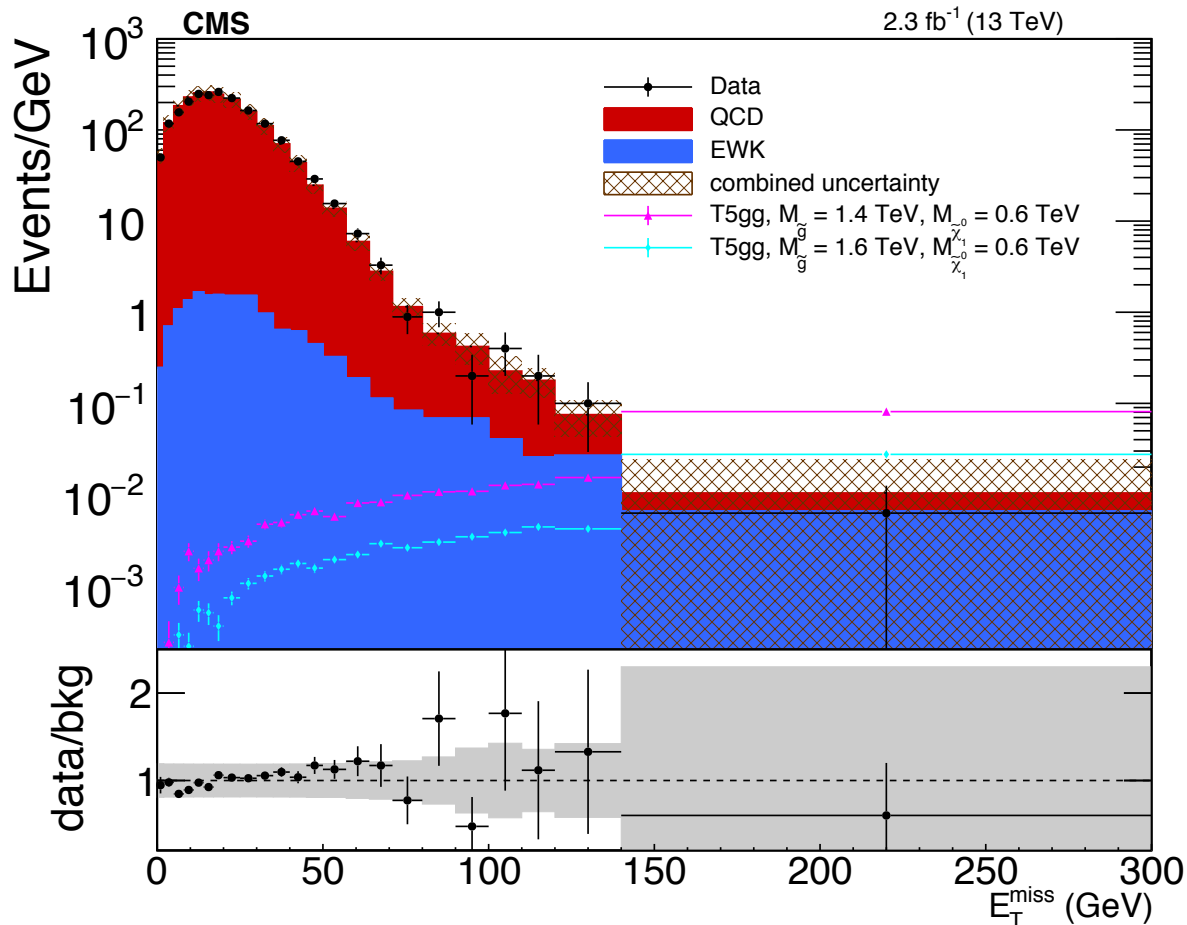


MET distributions agree well after recoil correction



Results

No significant deviation from SM bkg is observed

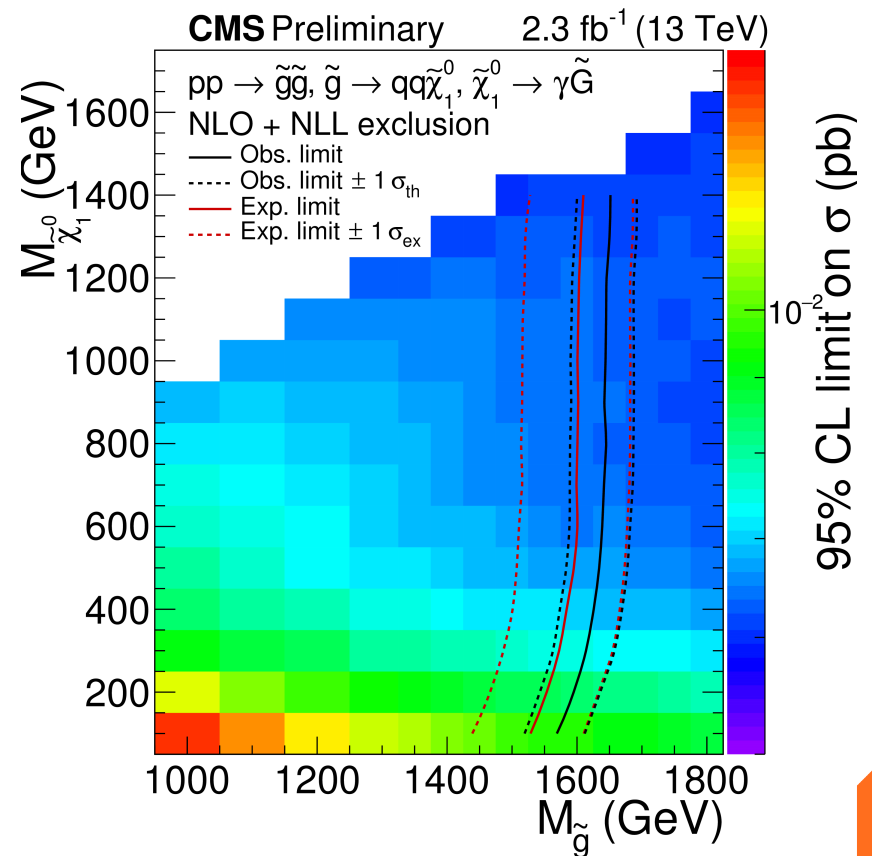


Results

No significant deviation from SM bkg is observed

- Derive limits on gluino-pair production

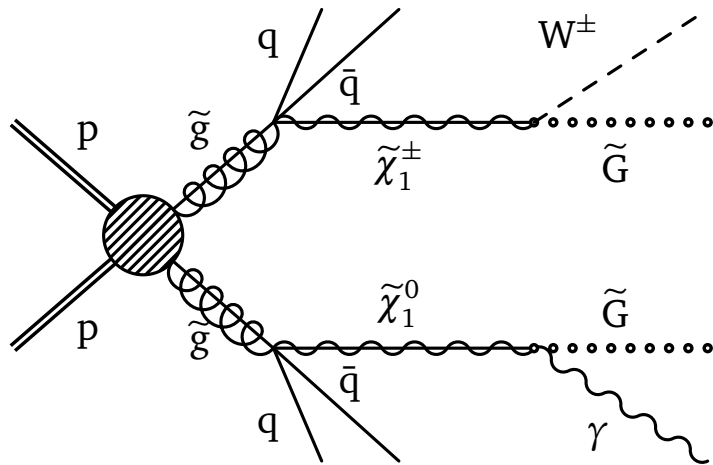
Exclude gluinos
with mass below
1.65 TeV



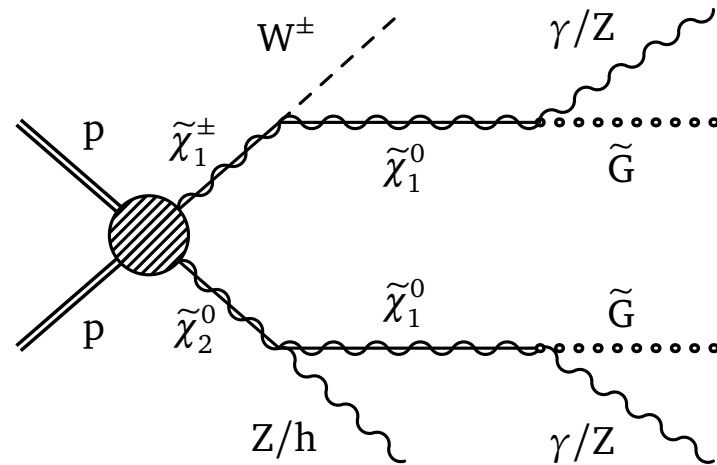
Photon + MET Search

- A complementary search using one photon and MET

W & γ final state



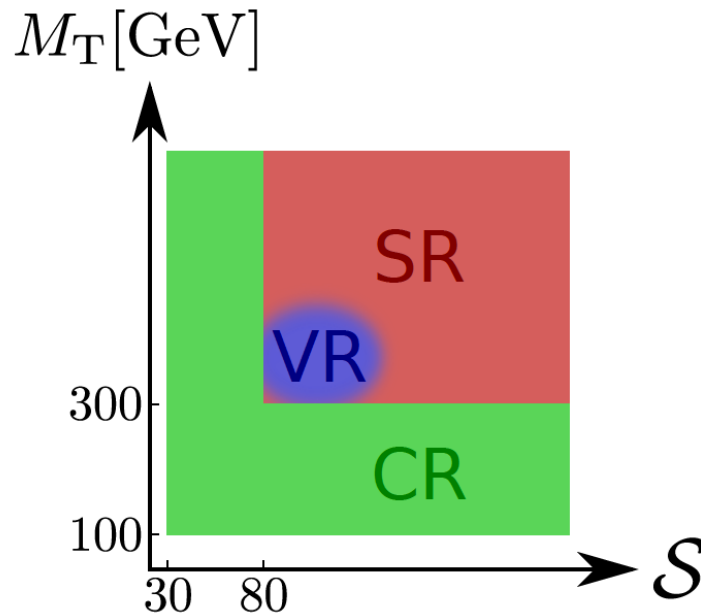
Generalized Gauge Mediation



$\tilde{\chi}_1^0$: bino $\tilde{\chi}_1^\pm$: wino
 $\tilde{\chi}_2^0$: wino 10

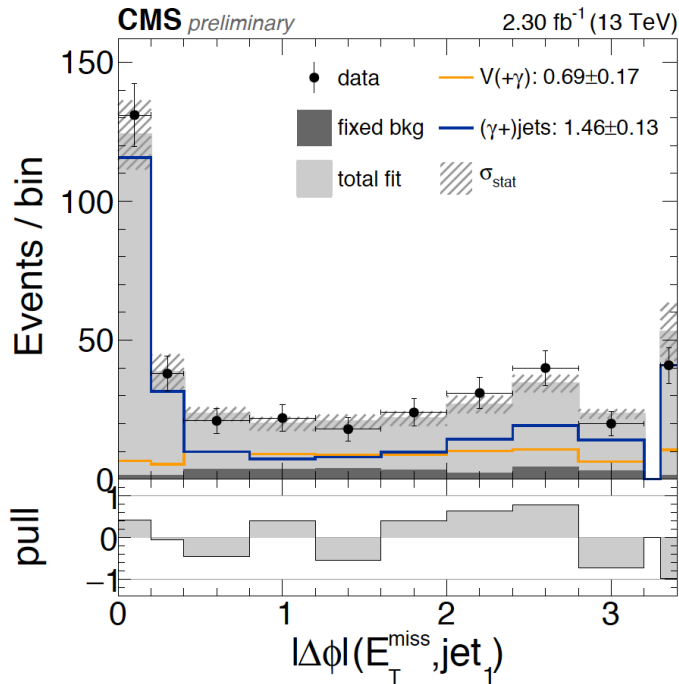
Photon + MET Search

- A complementary search using one photon and MET
 - Photon $p_T > 180$ GeV
 - MET Significance (S) and M_T are used to define the search region
 - Search performed in bins of $S_T^\gamma = \text{MET} + \sum_{\text{photons}} p_T$



Photon + MET Search

- Main Backgrounds:
 - $Z(\rightarrow \nu\nu)+\gamma$, $W(\rightarrow l\nu)+\gamma$
 - γ +jets
- Estimated using a template fit in the Control Region to the variable $\Delta\phi$ (MET, jet_1)



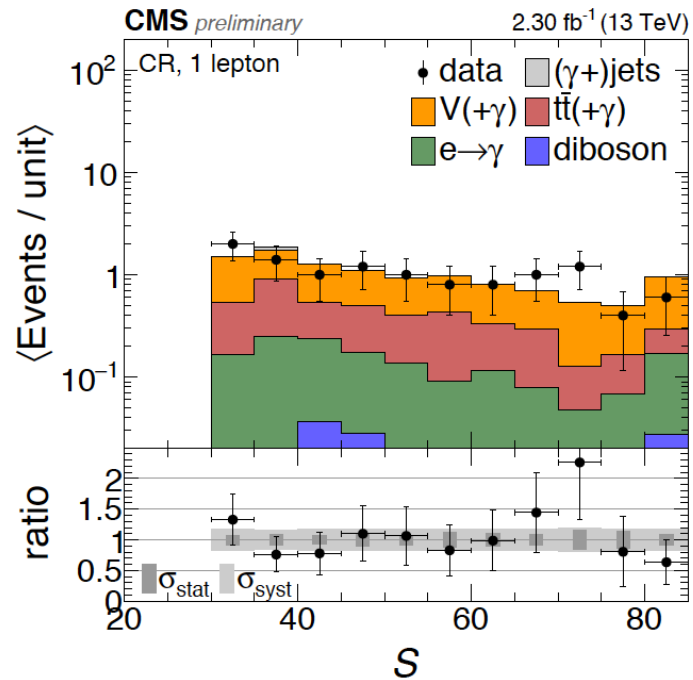
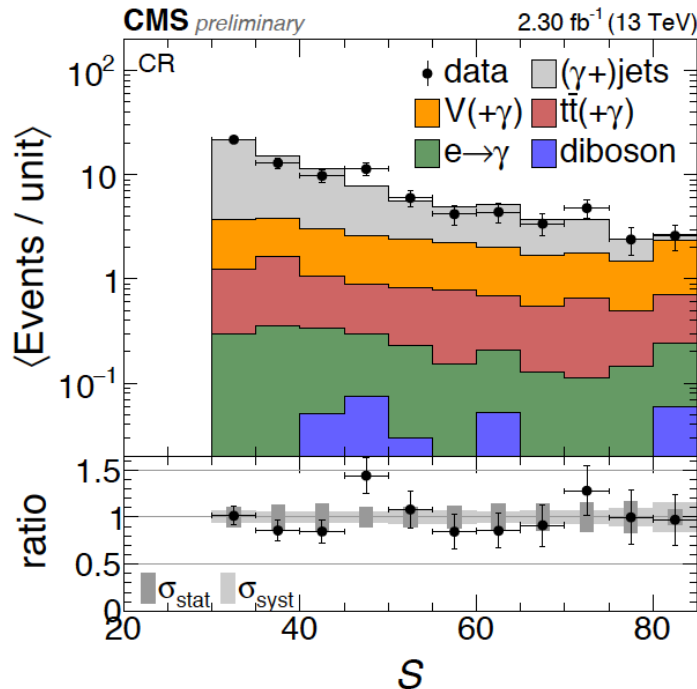
Fit Result

Scale Factor γ +jets = 1.46 ± 0.13

Scale Factor $V\gamma$ = 0.69 ± 0.17

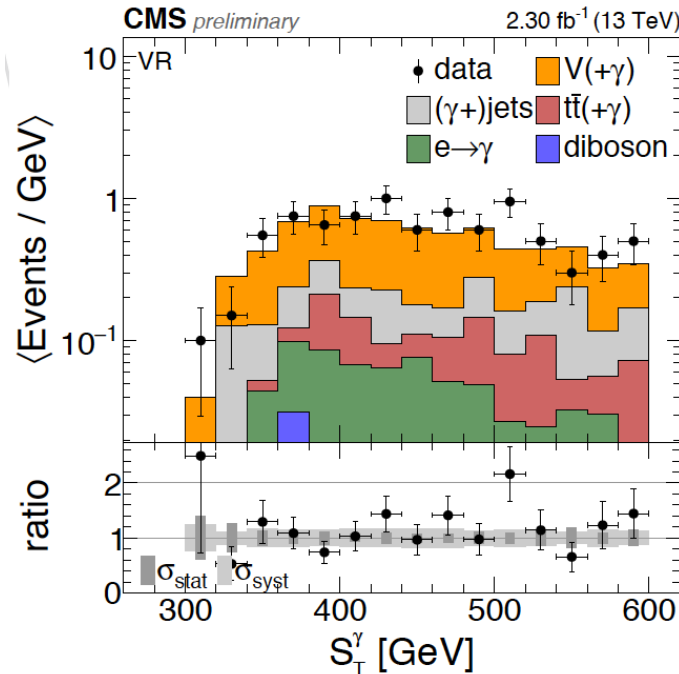
Photon + MET Search

- Systematic Uncertainty dominated by fit uncertainty for $V+\gamma$ normalization
- Bkg prediction is validated in
 - low M_T & low MET Significance CR
 - lepton+ γ CR



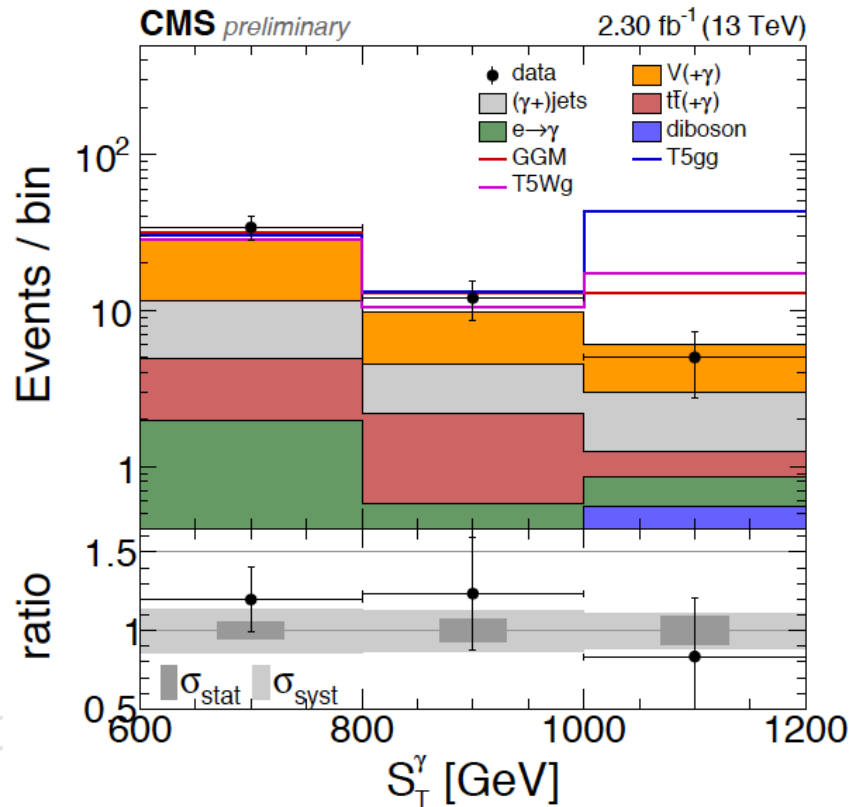
Photon + MET Search

- Systematic Uncertainty dominated by fit uncertainty for $V+\gamma$ normalization
- Bkg prediction is validated in
 - low M_T & low MET Significance CR
 - lepton+ γ CR
 - the region of $S_T^\gamma < 600$ GeV



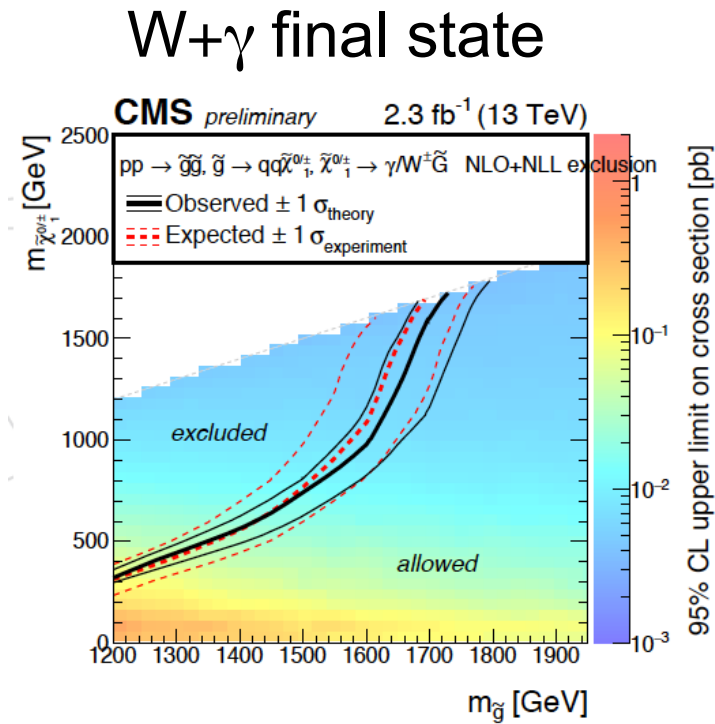
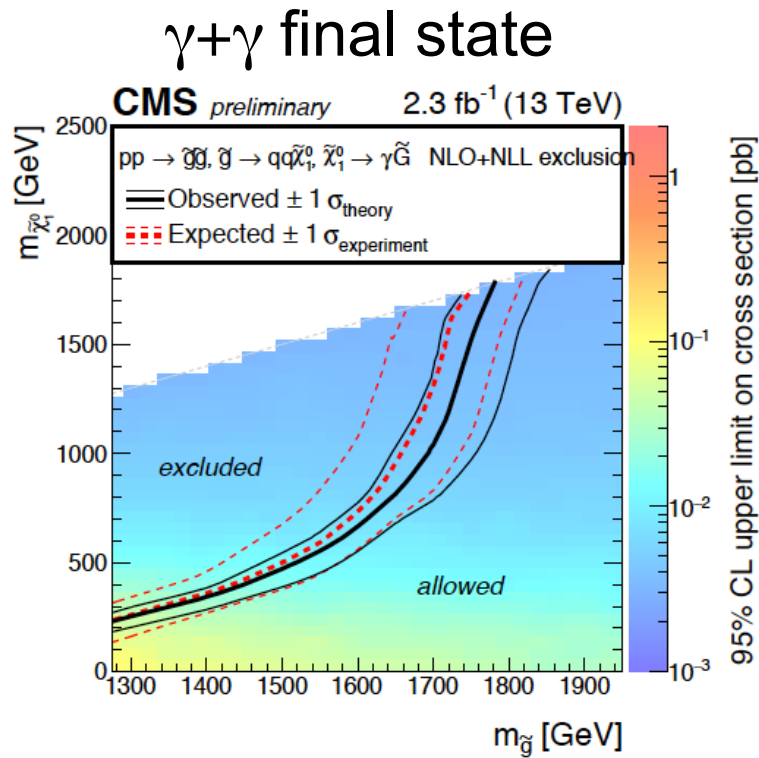
Results

- Observe no significant deviation to the SM bkg prediction



Results

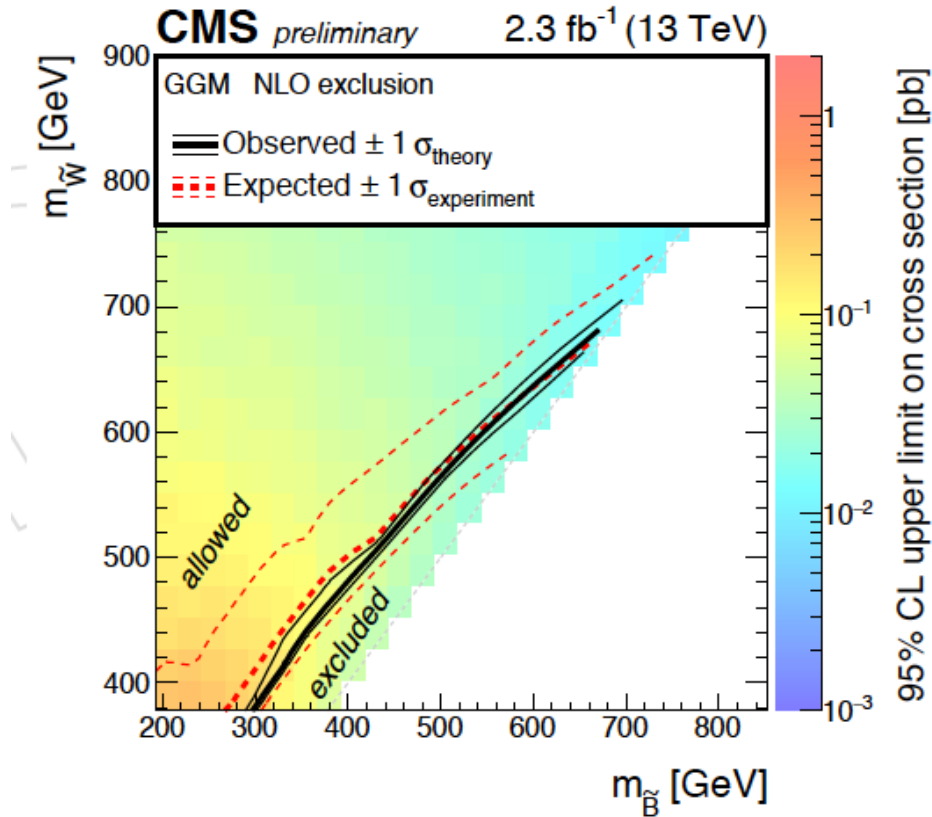
- Observe no significant deviation to the SM bkg prediction
- Derive Limits on gluino-pair production:



- Achieve complementary exclusion compared to Diphoton+MET search

Results

- Observe no significant deviation to the SM bkg prediction
- Derive limits on gluino-pair production
- Derive limits for GGM scenario

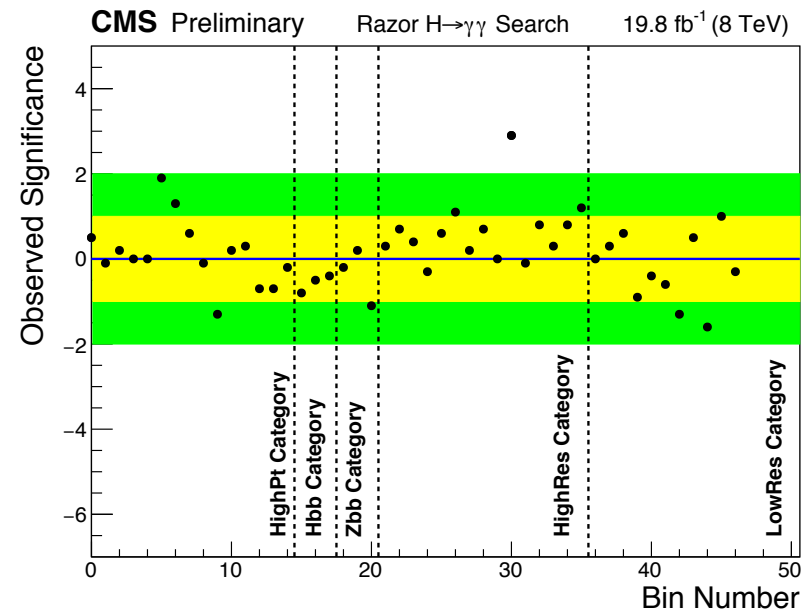
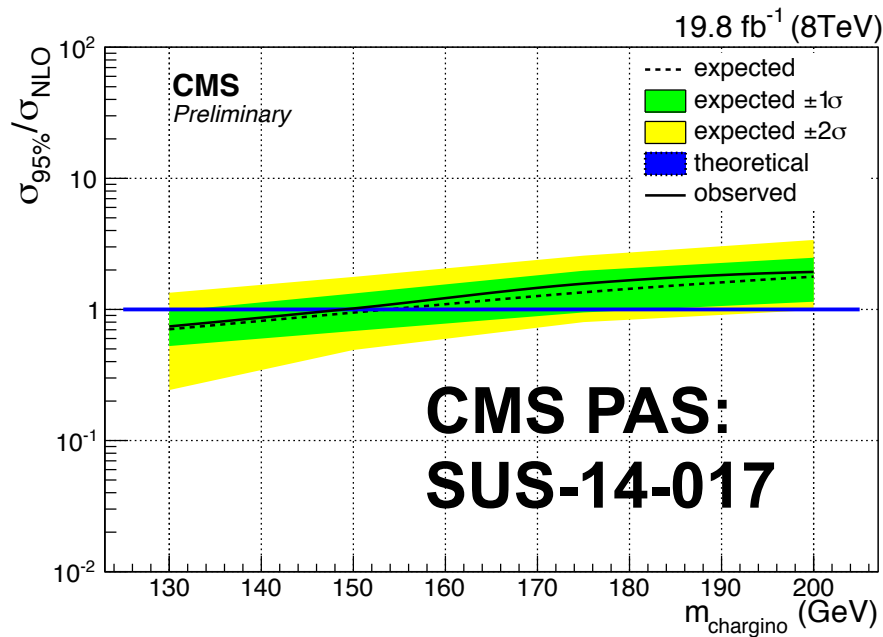


Razor $H \rightarrow \gamma\gamma$ Search

- Use Higgs $\rightarrow \gamma\gamma$ decay as a tag & search inclusively for excesses in razor variables (M_R & R^2)
- Sensitive to scenarios with large branching ratios to Higgs

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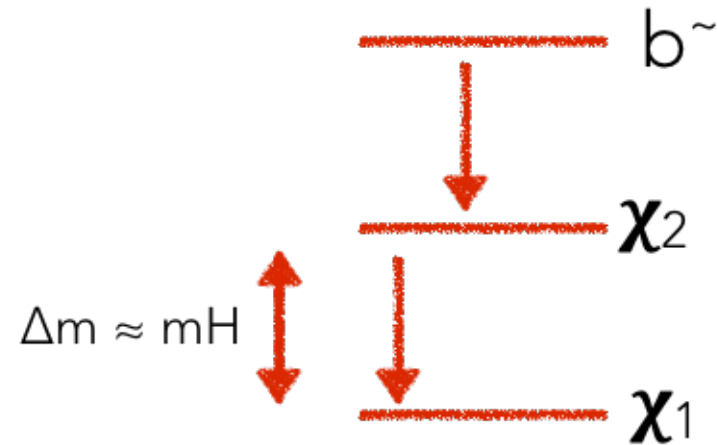
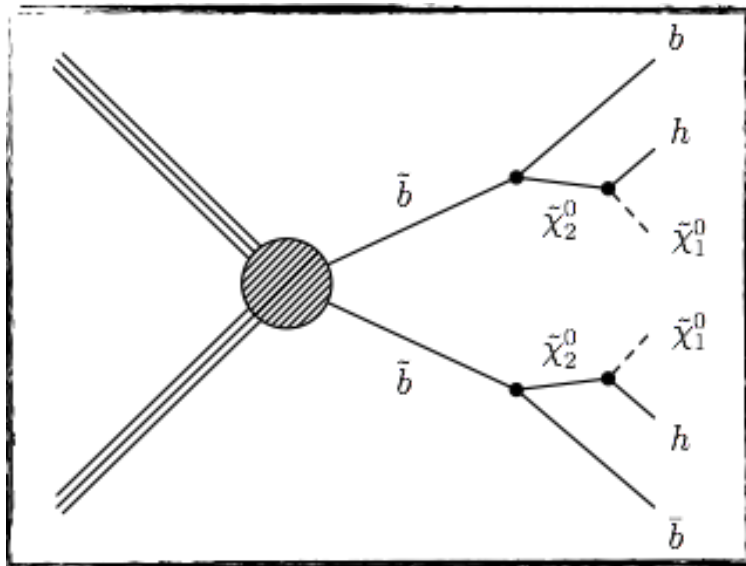


- The first result using this unique signature was released for Run1
- Interpreted in terms of EWK SUSY simplified models

$$\chi_2^0 \chi_1^\pm \rightarrow W H \chi_1^0 \chi_1^0$$

Razor $H \rightarrow \gamma\gamma$ Search

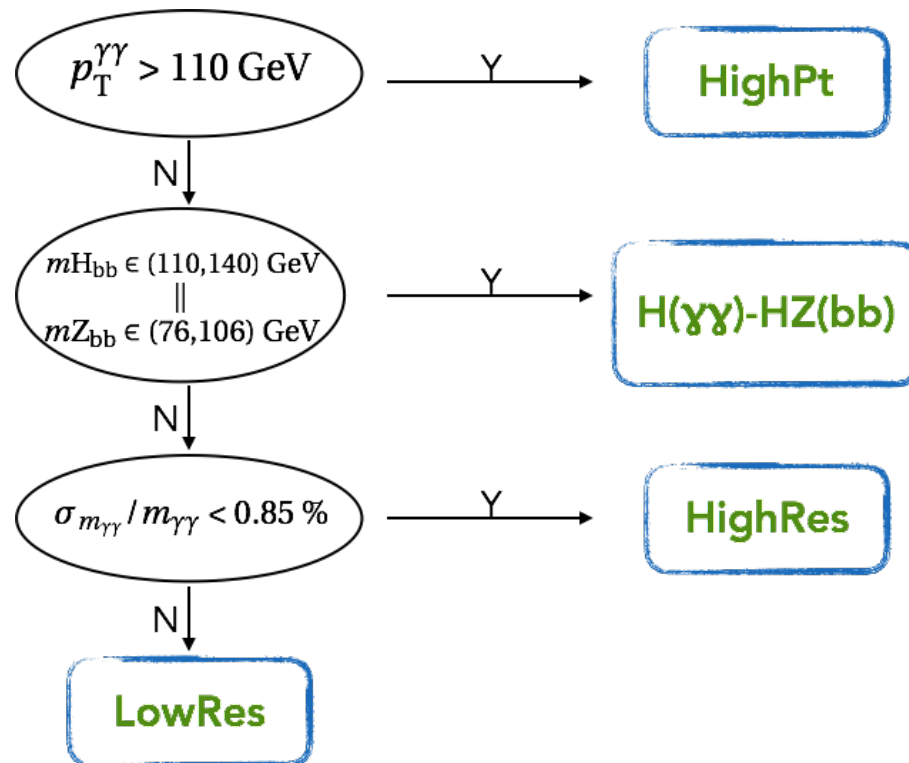
- Use Higgs $\rightarrow \gamma\gamma$ decay as a tag & search inclusively for excesses in razor variables (M_R & R^2)
- Sensitive to scenarios with large branching ratios to Higgs



- In Run 2, we interpret the search using a sbottom pair production simplified model with **sbottom $\rightarrow b H \chi_1^0$**

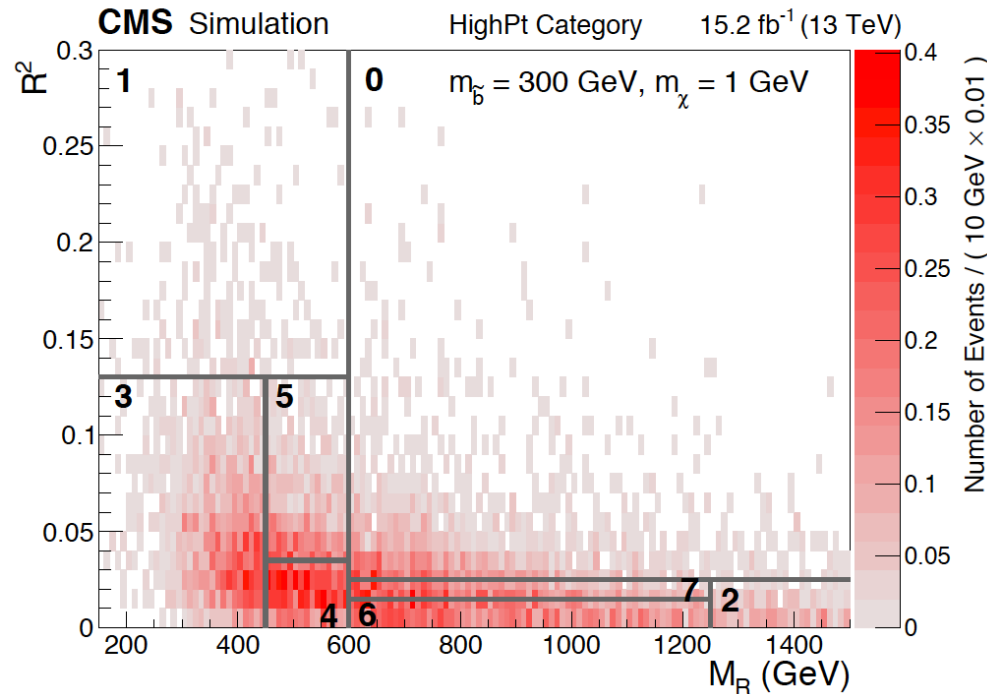
Razor $H \rightarrow \gamma\gamma$ Search

- Select events with 2 photons and choose Higgs candidate as the pair that maximizes $(p_{T1} + p_{T2})$
- Categorize based on $p_T^{\gamma\gamma}$, a 2nd $H \rightarrow bb$ pair, and Higgs mass resolution



Razor $H \rightarrow \gamma\gamma$ Search

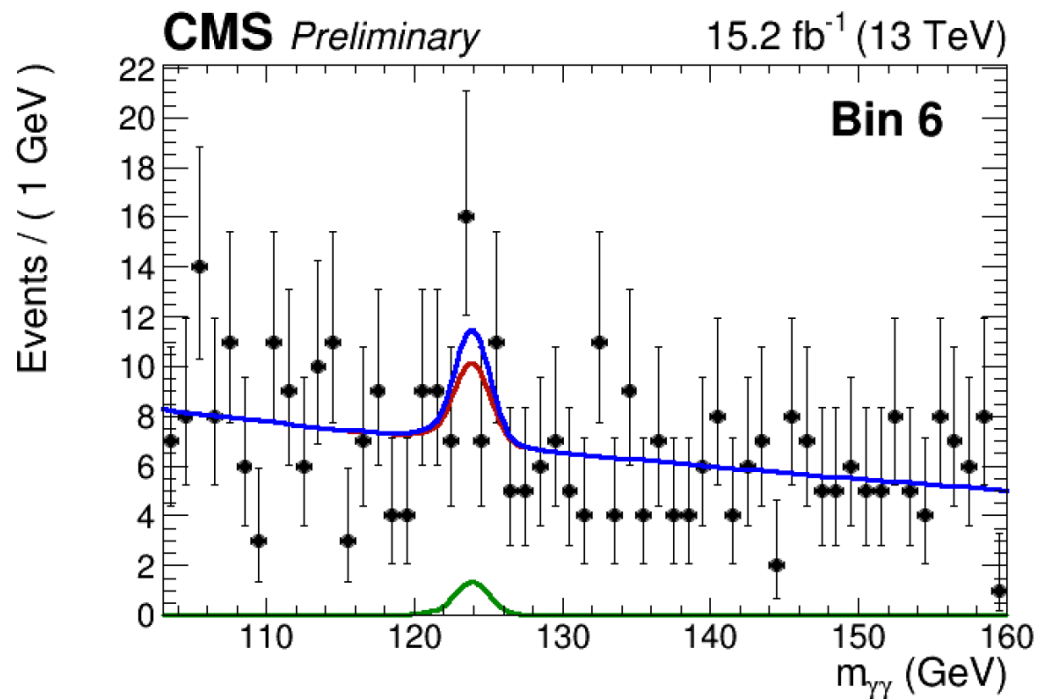
- Select events with 2 photons and choose Higgs candidate as the pair that maximizes $(p_{T1} + p_{T2})$
- Categorize based on $p_{T}^{\gamma\gamma}$, a 2nd $H \rightarrow bb$ pair, and Higgs mass resolution
- Then bin in the razor variables M_R & R^2



Signal occupies
larger M_R & R^2
regions

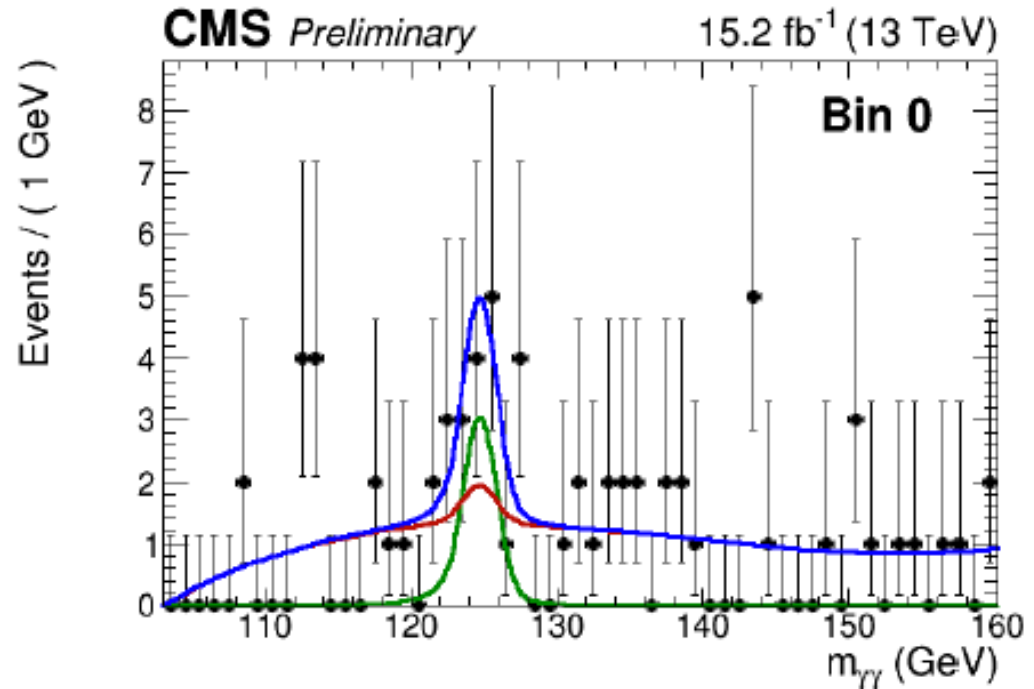
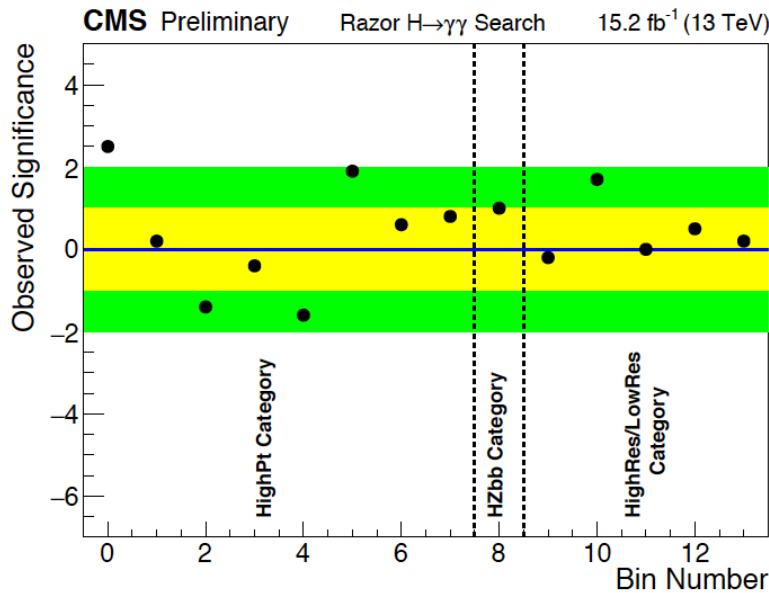
Razor $H \rightarrow \gamma\gamma$ Search

- Dominant background is non-resonant QCD $\gamma\gamma$ production
- Signal is extracted via a fit to $m_{\gamma\gamma}$ spectrum:
 - Non-resonant bkg : exponential / bernstein polynomial
 - SM Higgs & SUSY signal : shape extracted from MC



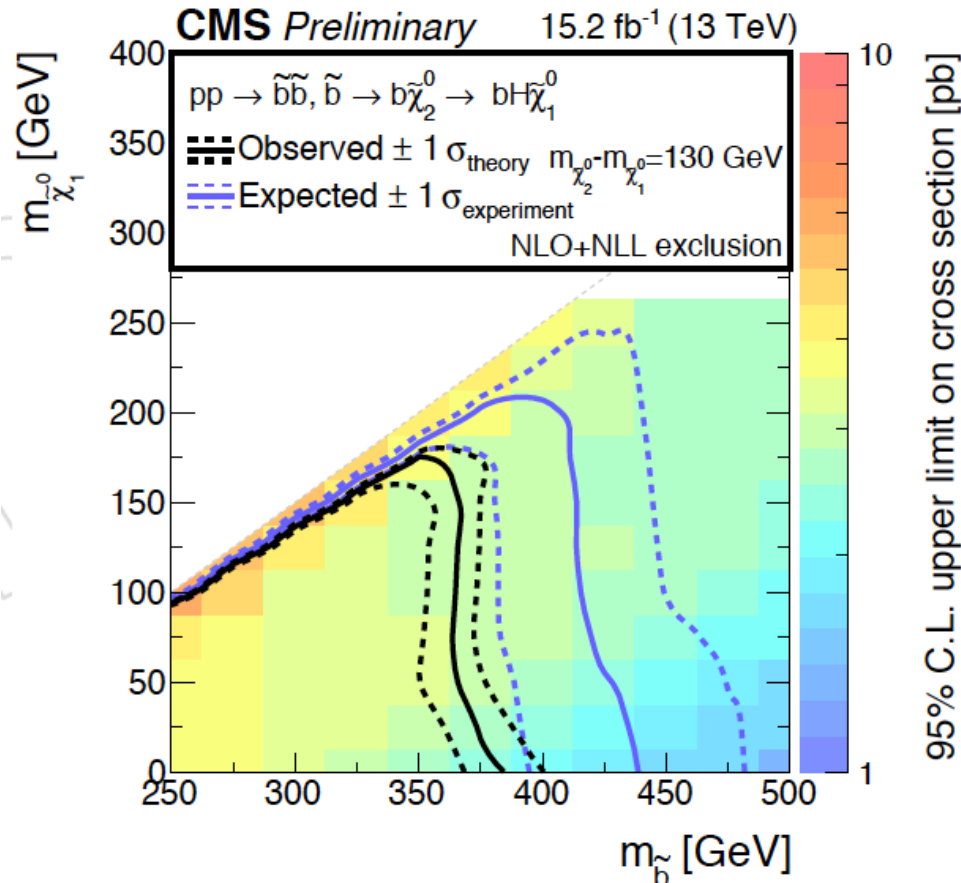
Razor $H \rightarrow \gamma\gamma$ Search

- Most significant deviation is 2.5σ local (1.4σ global) and occurs in the HighPt category ($M_R > 600$ & $R^2 > 0.025$)
- **A very interesting bin to watch with more data this year**



Razor $H \rightarrow \gamma\gamma$ Search

- Obtain fairly strong limits on sbottom pair production simplified model decaying to b, Higgs & LSP
- Exclude sbottoms up to masses of 360 GeV



Summary

- Searches for SUSY using photons are pushing the sensitivity frontiers on many fronts:
 - Gluino-pair production in GGM
 - Electroweak production in GGM
 - SUSY scenarios involving large branching ratio to Higgs
- Starting to explore phase space and parameter space that have never been explored before
- Stay tuned for a very exciting near future.

Backups

QCD Bkg Estimation

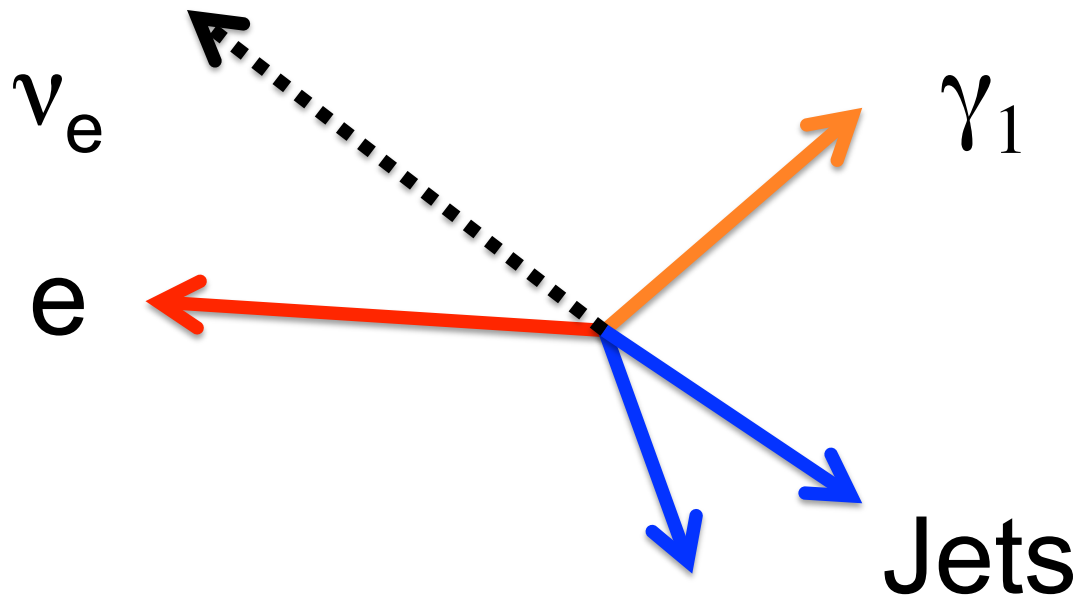
Use Data-Driven Method

- Systematic uncertainties dominated by the shape difference between the Inverted ID/Iso CR and the $Z \rightarrow ee$ CR : 12% - 150%
- Other systematics due to:
 - Recoil correction statistical uncertainties : 15-39%
 - Recoil dependence on jet multiplicity : 15-34%

Diphoton + MET Search

Two Main Backgrounds :

- 1) QCD $\gamma\gamma$ production (Fake MET)
- 2) $W\gamma$ production (electron fakes γ)



W+ γ Bkg Estimation

Use Data-Driven Method

- Measure electron $\rightarrow\gamma$ misID rate using tag and probe method on $Z\rightarrow ee$ control sample : $f_{e\rightarrow\gamma} = 0.021$
- Select electron+ γ control region & scale the sample by $f_{e\rightarrow\gamma} / (1 - f_{e\rightarrow\gamma})$ to predict the $W\gamma$ bkg in the signal region
- Systematic uncertainty (from misID rate measurement) is 19%