Inclusive search for supersymmetry in hadronic final states at CMS

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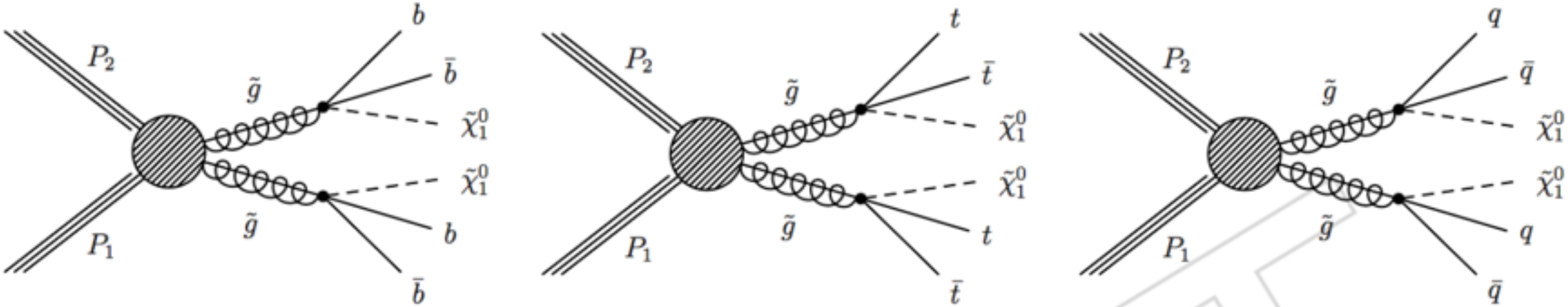
(On behalf of CMS Collaboration)

Motivation

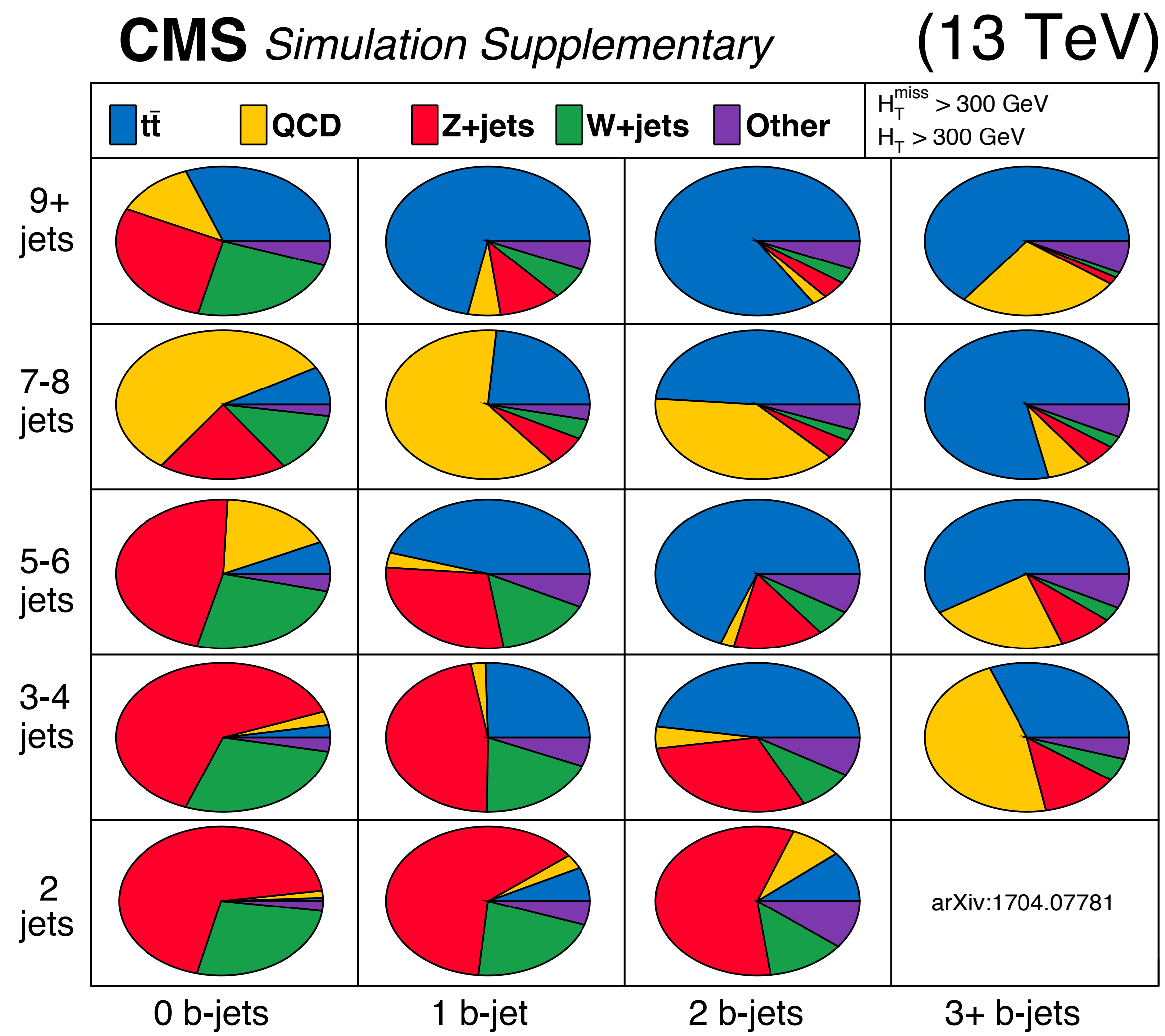
- Large branching fraction to hadronic final states is typical for signals
- Final states involve events with high jet multiplicity and missing transverse momentum
- This method of search could eventually decipher the mysteries surrounding the Higgs boson and the hierarchy problem
- Two such searches covered use a different object definition to explore different gluino searches as well as squark and other direct stop production models.
- Analysis cuts & search regions are defined so that the analysis is broadly applicable to many decay modes and many bins meaning a wide range of phase space is covered



Direct Gluino production

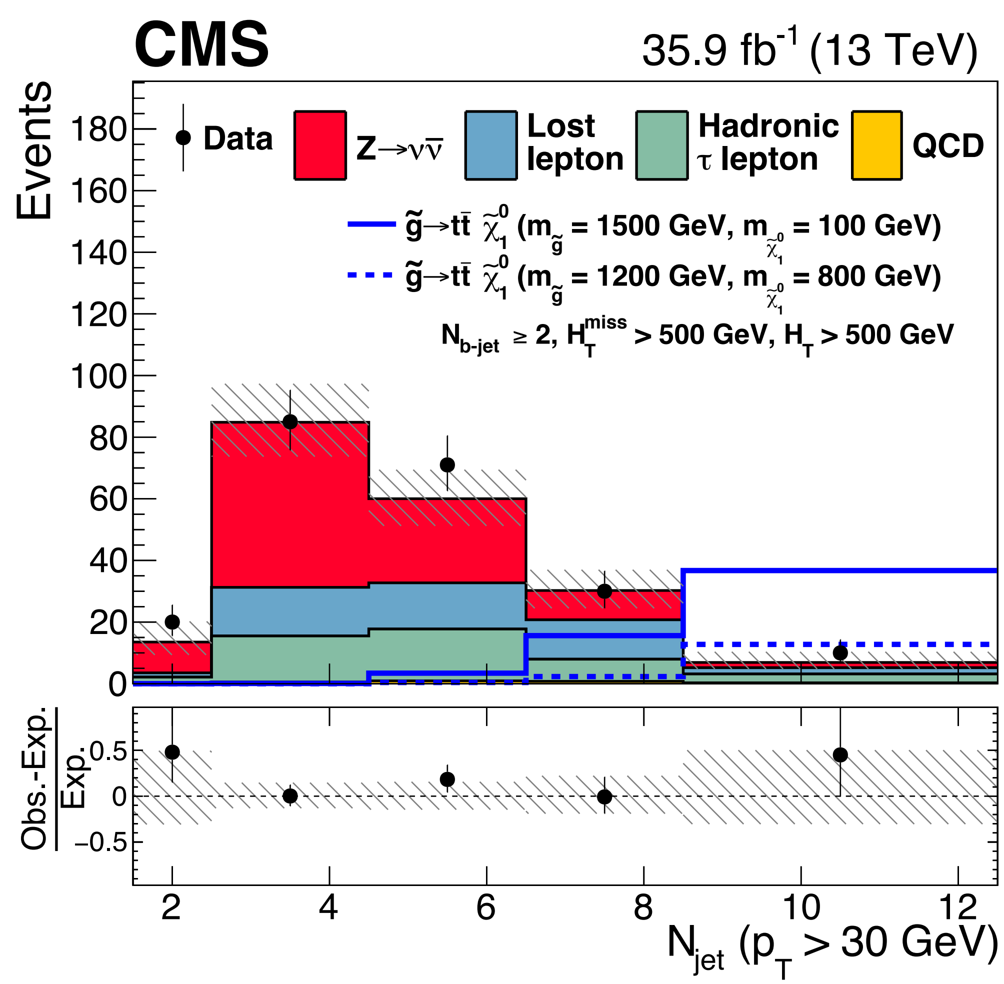
Common Object and Cuts

- Objects:
  - Number of b jets
  - Number of Jets
  - The scalar sum of the jet p_T which is called H_T $H_T = \sum_{jets} |\vec{p_T}|$
- To suppress backgrounds:
  - Lepton
    - lepton veto is used
  - QCD
    - Delta phi $\Delta\phi(P^{miss}_T, jet) > 0.3, 0.5$



Common Backgrounds

- Z(vv)+jets (Z Invisible)
  - Irreducible background, with genuine $P^{miss}{}_T$ from v's
- Lost lepton
  - Genuine $P^{miss}{}_T$ from leptonic W decay
  - Lepton fails acceptance of the detector, the reconstruction and identification efficiency
- QCD multijet
  - Fake $P^{miss}{}_T$ due to either significant jet momentum mis-measurements, or sources of anomalous noise



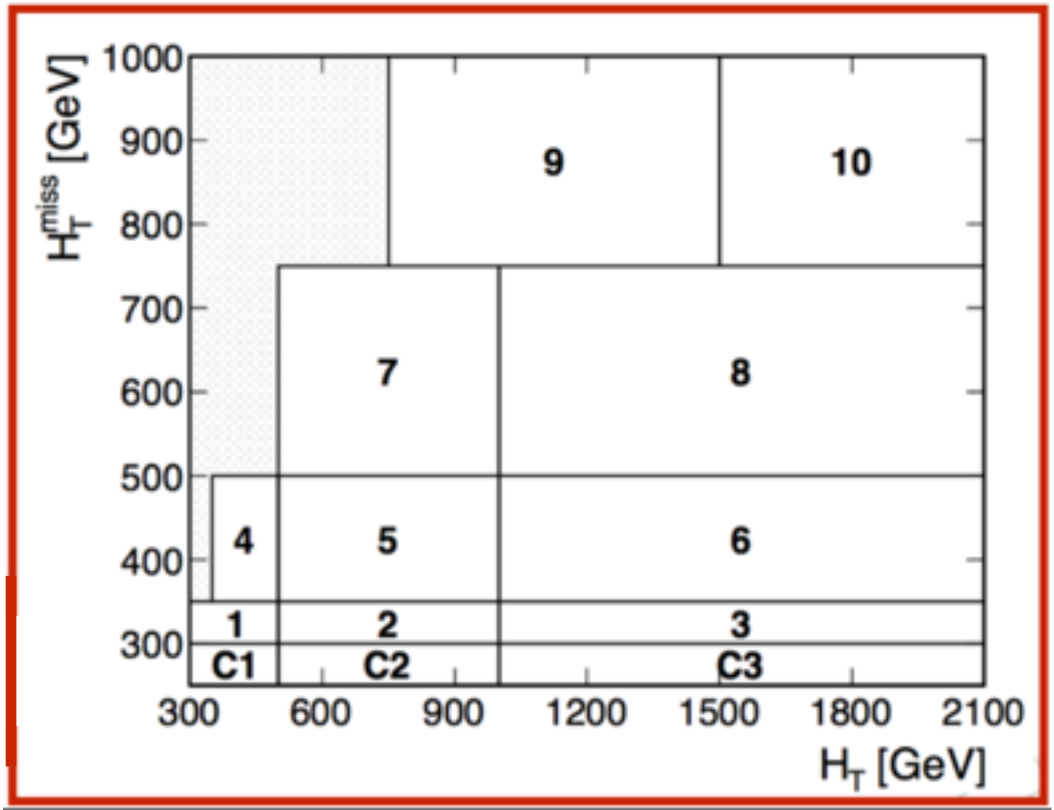
Search for supersymmetry in multijet events with missing transverse momentum in proton-proton collisions at 13 TeV

Uses MH_T

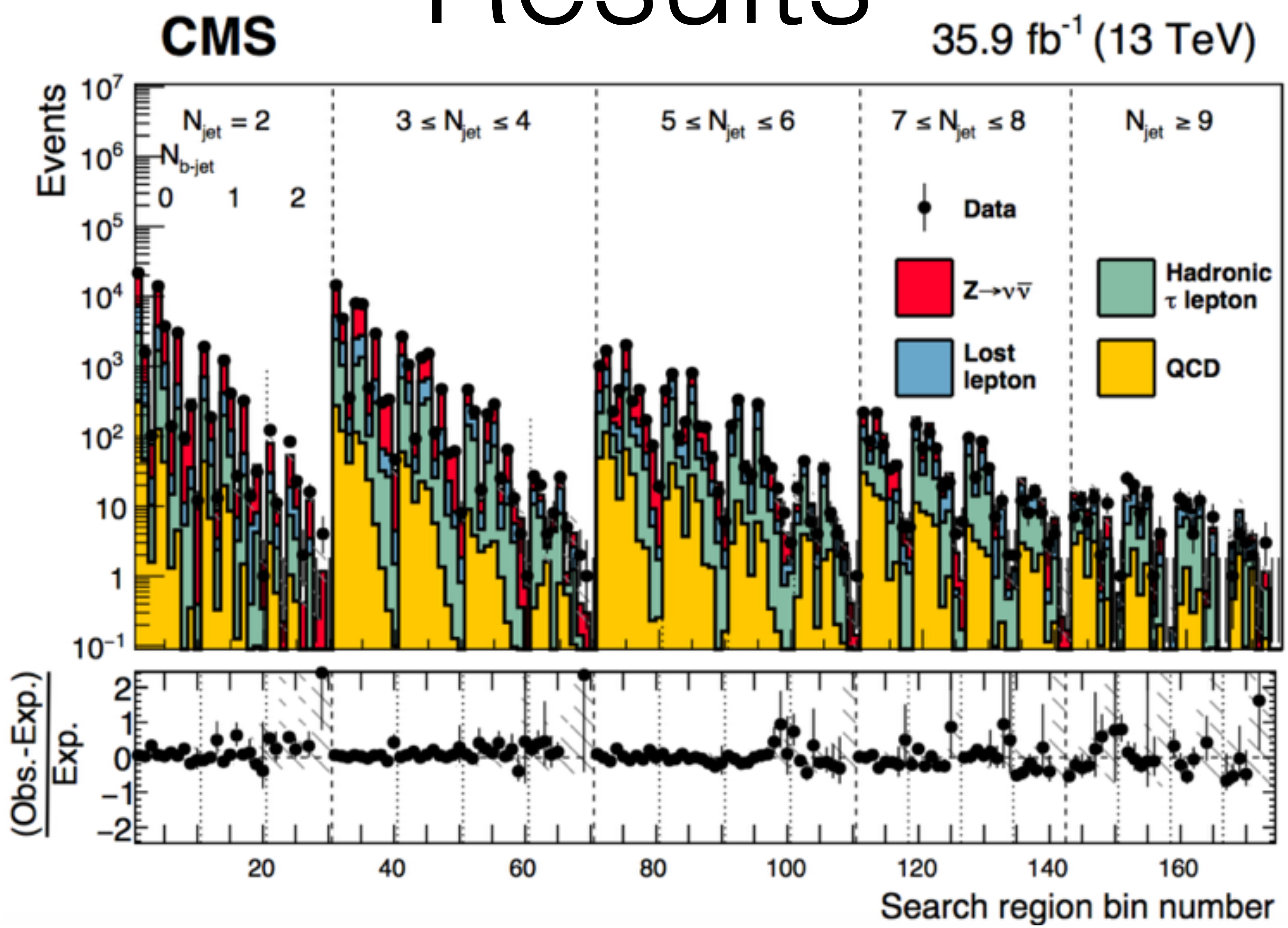
CMS-SUS-16-033
arXiv:1704.07781
Phys. Rev. D 96, 032003 (2017)
10.1103/PhysRevD.96.032003
https://arxiv.org/abs/1704.07781

Search Strategy

- 174 signal regions are used
- MH_T which is defined as the negative sum of the missing jet P_T $\quad H_T^{miss} = |-\sum_{jets} \vec{p_T}|$
- Lost lepton
  - Relate observed counts in control region to expected counts in signal region through Transfer factors
  - single lepton control region
- Z Invisible
  - Extrapolate from γ control region using p_T
  - γ as a proxy for Z(νν) momentum
- QCD
  - QCD multi-jet events have no intrinsic P^{miss}_T, only instrumental P^{miss}_T due to detector response is used to estimate this background

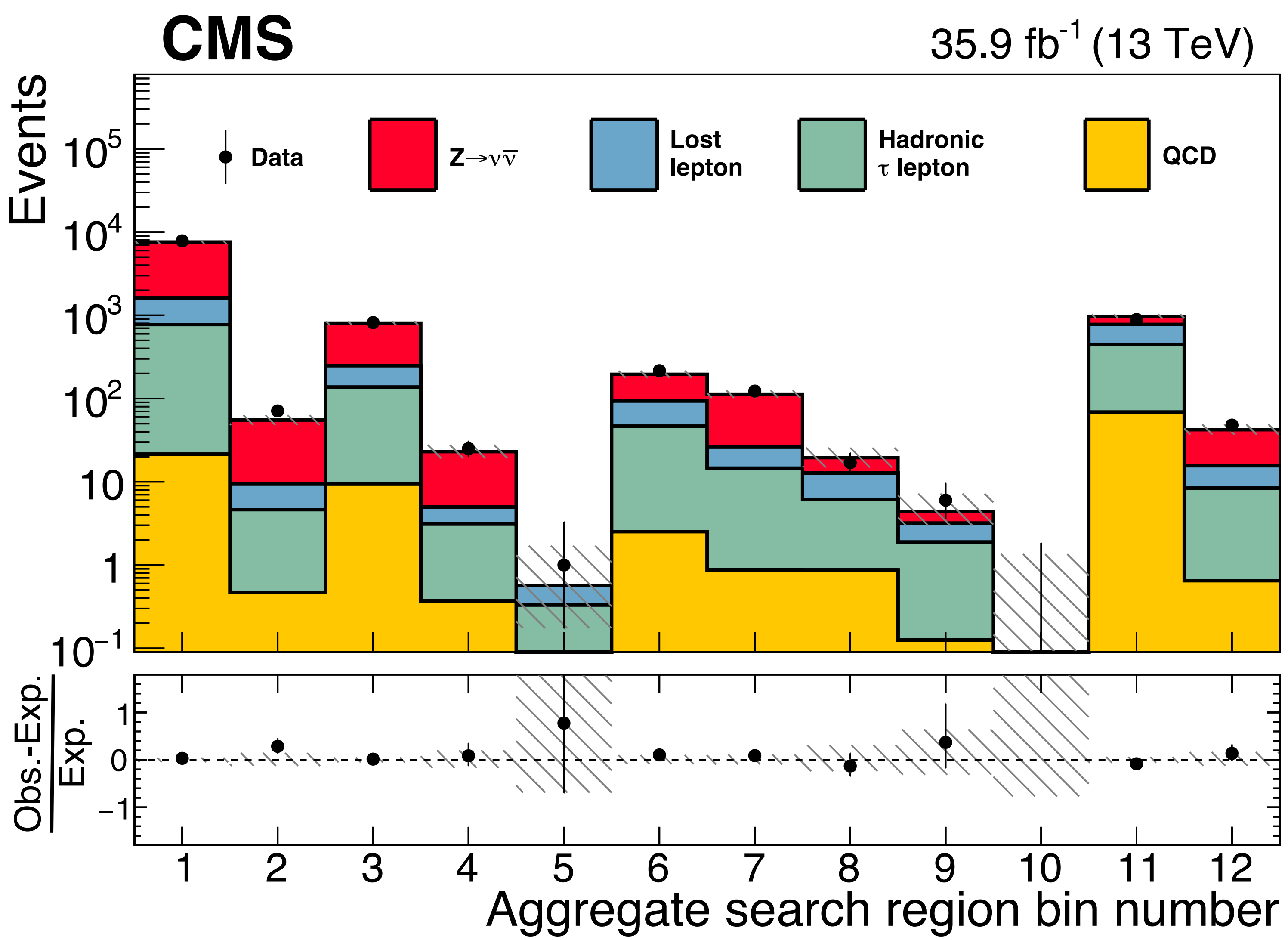


Results



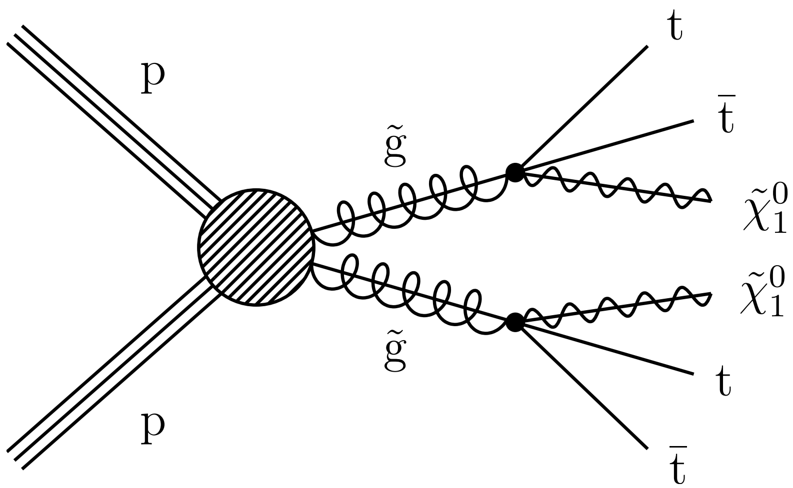
- No significant excess is seen

Facilitating Reinterpretation

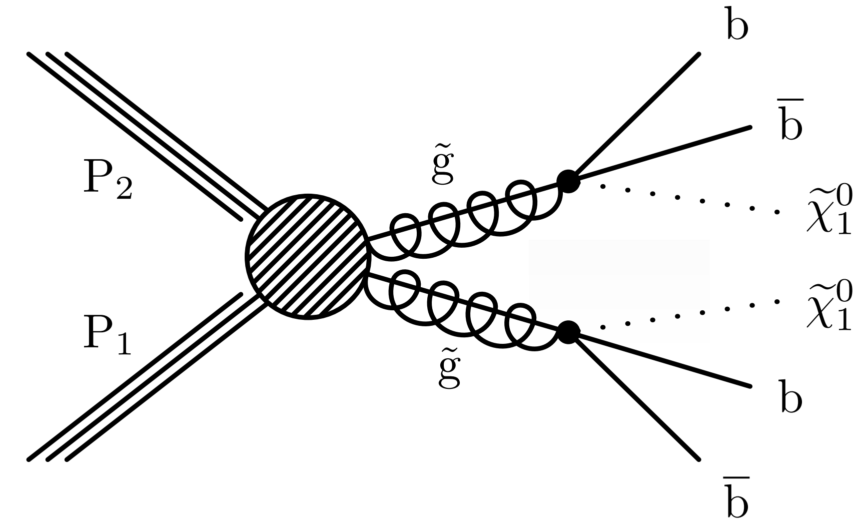


- Release small number bins that are more inclusive that give an overall view of sensitivity

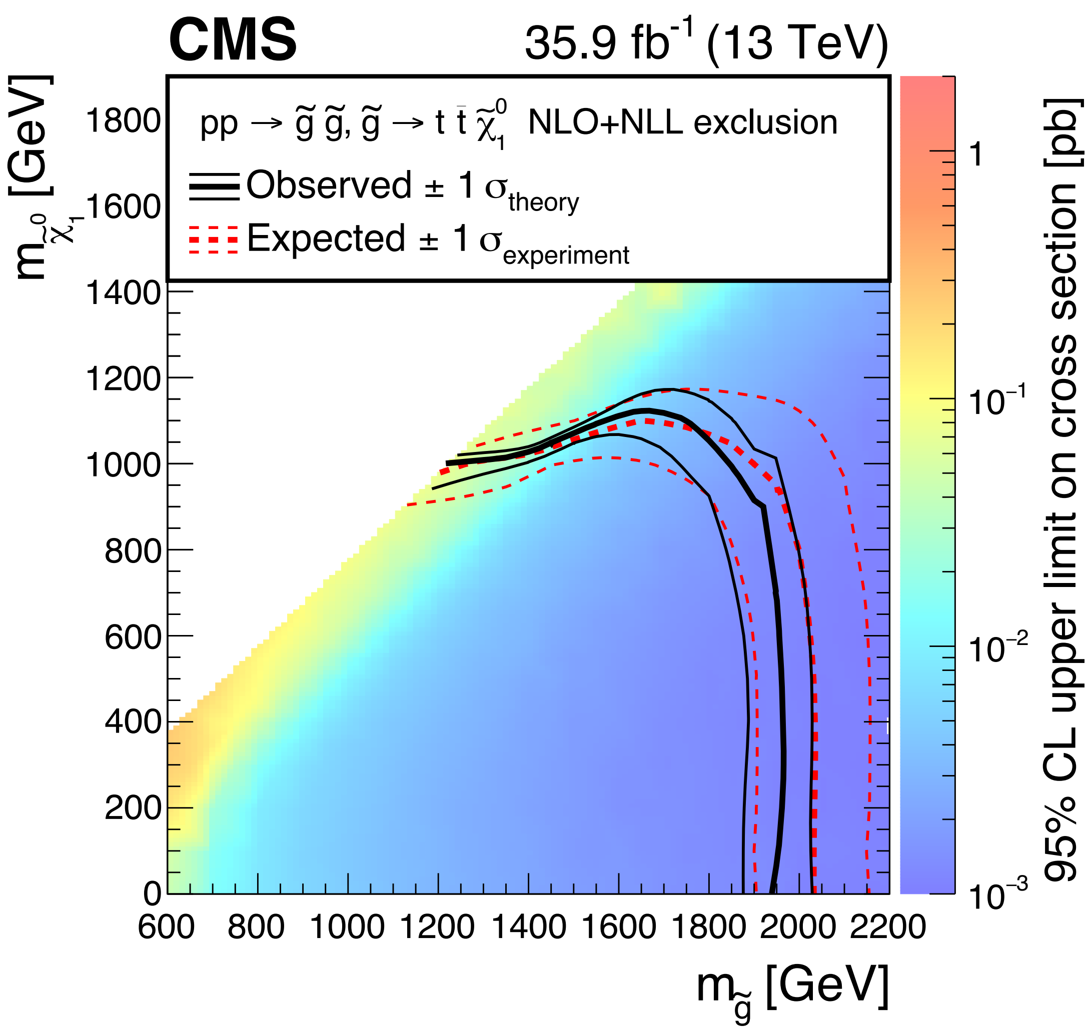
Limits



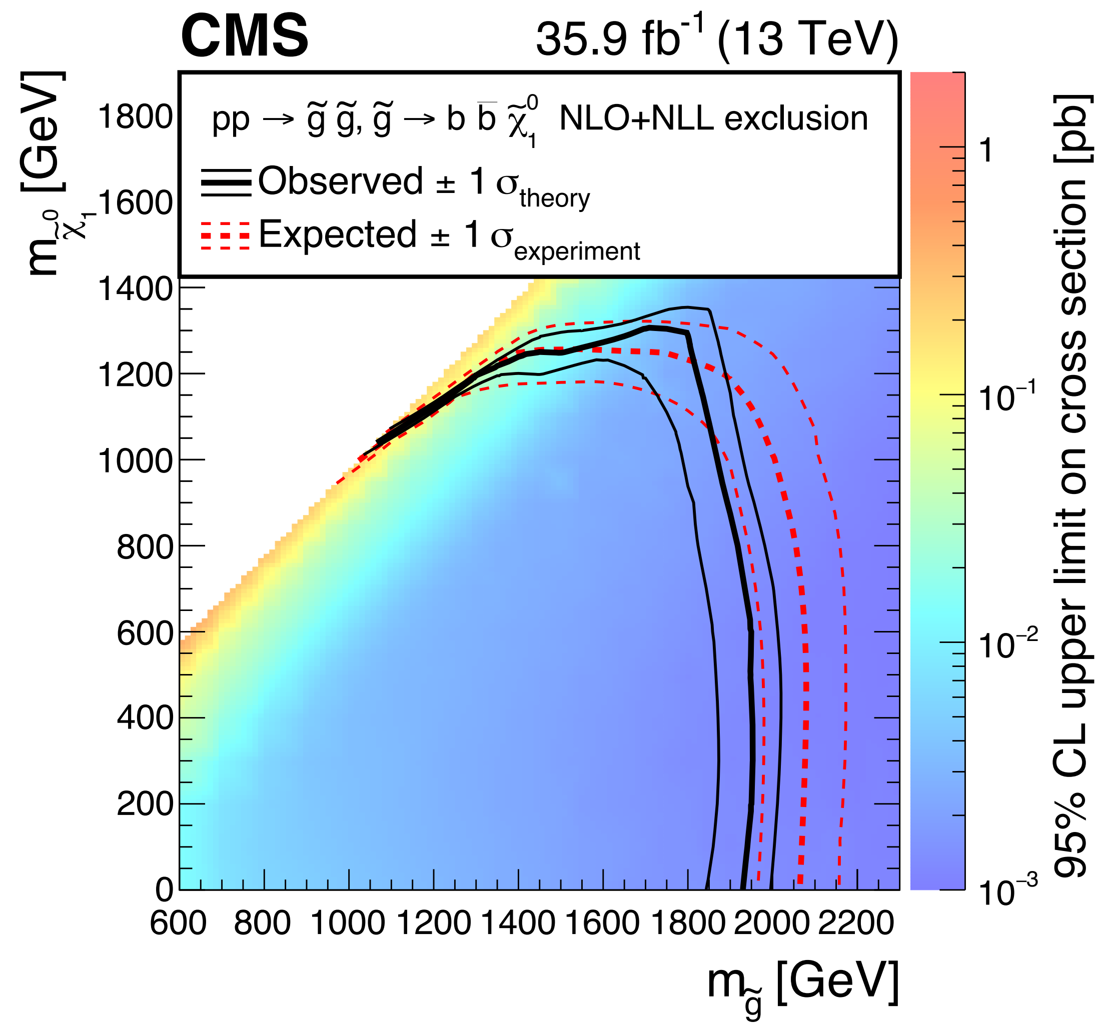
p
p
$\tilde{g}$
$\tilde{g}$
t
$\bar{t}$
$\tilde{\chi}_1^0$
$\tilde{\chi}_1^0$
t
$\bar{t}$



P_2
P_1
$\tilde{g}$
$\tilde{g}$
b
$\bar{b}$
$\tilde{\chi}_1^0$
$\tilde{\chi}_1^0$
b
$\bar{b}$



CMS
35.9 fb^{-1} (13 TeV)
pp → $\tilde{g}\tilde{g}$, $\tilde{g}$ → t $\bar{t}$ $\tilde{\chi}_1^0$ NLO+NLL exclusion
Observed ± 1 σ_{theory}
Expected ± 1 $\sigma_{experiment}$
$m_{\tilde{\chi}_1^0}$ [GeV]
$m_{\tilde{g}}$ [GeV]
95% CL upper limit on cross section [pb]



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Search for new phenomena with the M_{T2} variable in the all-hadronic final state produced in proton-proton collisions at a center mass energy of13 TeV

Uses M_{T2}

CMS-SUS-16-036
arXiv:1705.04650v2
Published in the European Physical Journal C
Eur. Phys. J C 77 (2017) 710
doi:10.1140/epjc/s10052-017-5267-x
https://arxiv.org/pdf/1705.04650.pdf

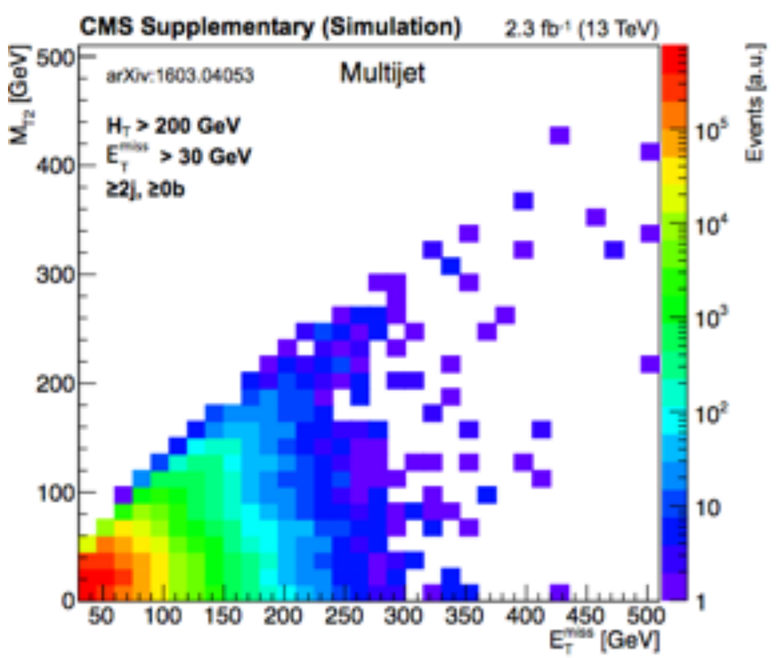
MT2 Variable

- M_{T2} is a generalization of the transverse mass M_T for decay chains with two unobserved particles

$$M_{T2}(m_X) = \min_{\vec{p}_T^{X(1)} + \vec{p}_T^{X(2)} = \vec{p}_T^{\text{miss}}} \left[\max\left(M_T^{(1)}, M_T^{(2)} \right) \right]$$

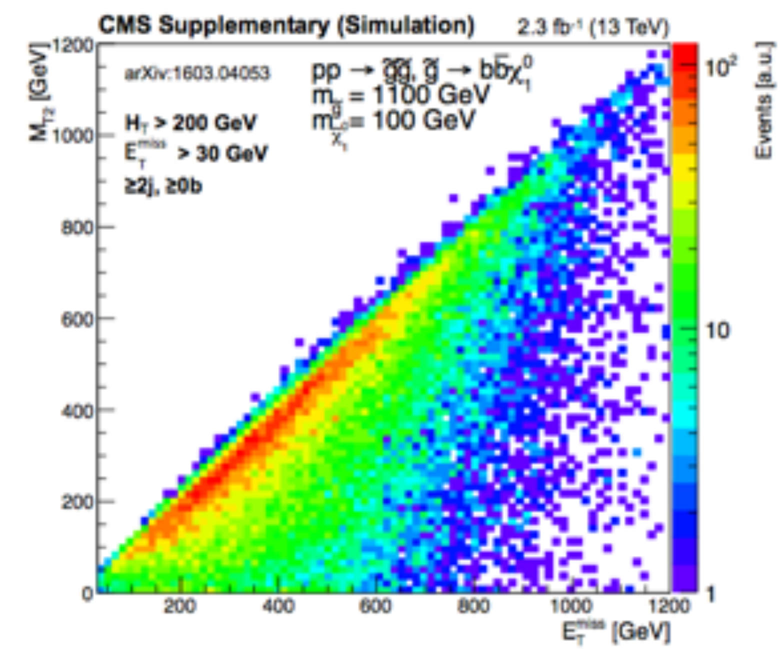
- Where M_T is the mass between two particles where one is unobserved $M_T^2 = 2E_{T,1}E_{T,2}\,(1 - \cos\theta)$

Multijet: back-to-back
→ $M_{T2} << p^{\text{miss}}_T$



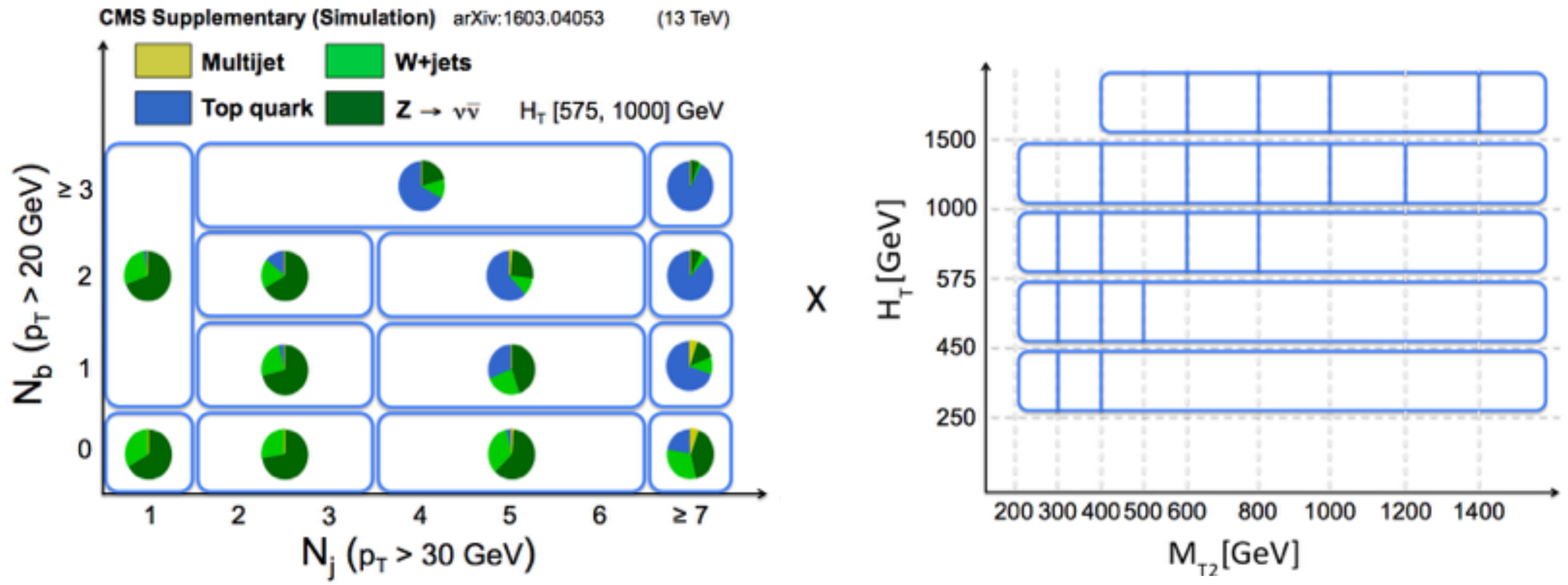
Useful because the Topology for SUSY particles is different than what is seen in the MultiJet events

SUSY: symmetric topology
→ $M_{T2} \sim p^{\text{miss}}_T$



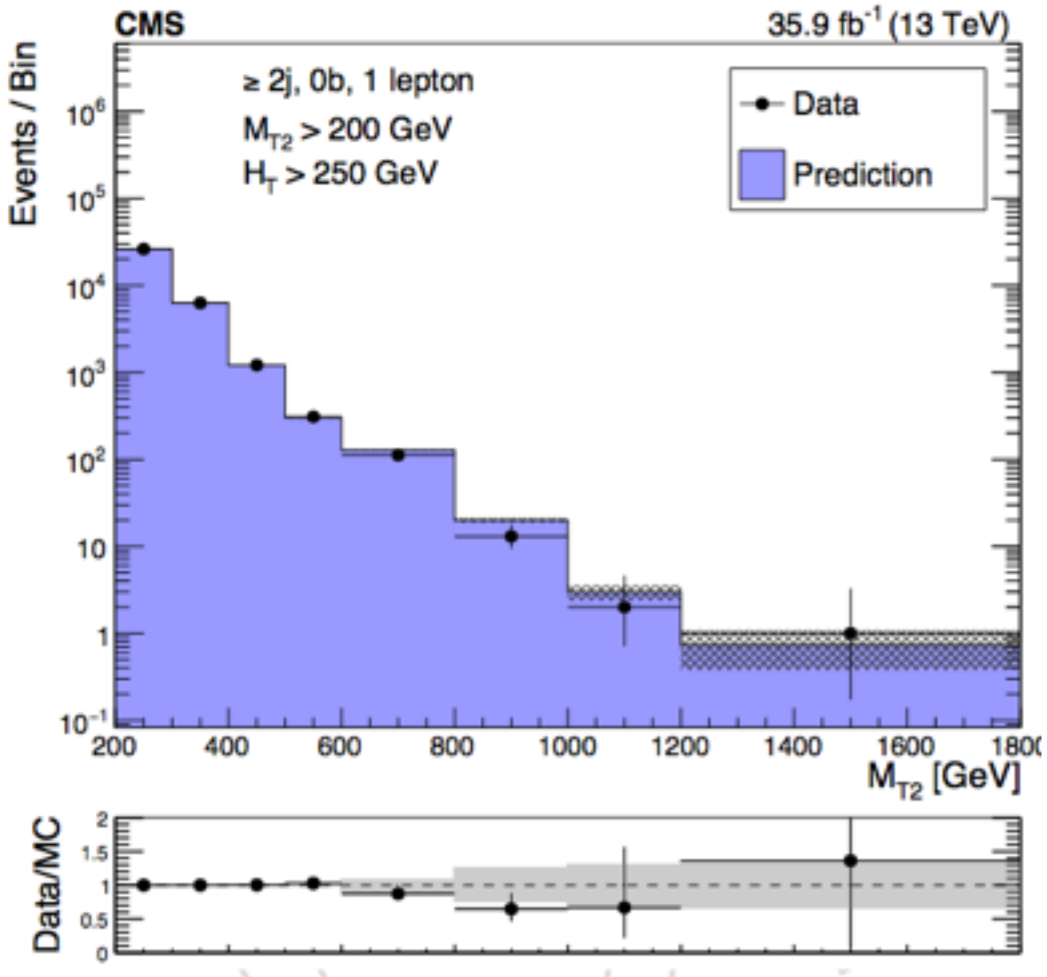
Search strategy

- 64 search bins used



Background Methods

- Lost Lepton
  - Transfer Factor related to observed counts in control region to expected counts in signal region
  - single lepton control region
  - Use the transfer factor to estimate background with modeling in M_{T2}
- Z (νν)+Jets
  - Dilepton control region is used
  - Pro: Same process: small uncertainty on transfer factor
  - Con: small branching fraction
  - Photons Pro: Largest cross section
  - con:Different mass/couplings, larger uncertainty on transfer factor
- QCD
  - Residual QCD evaluated from control regions



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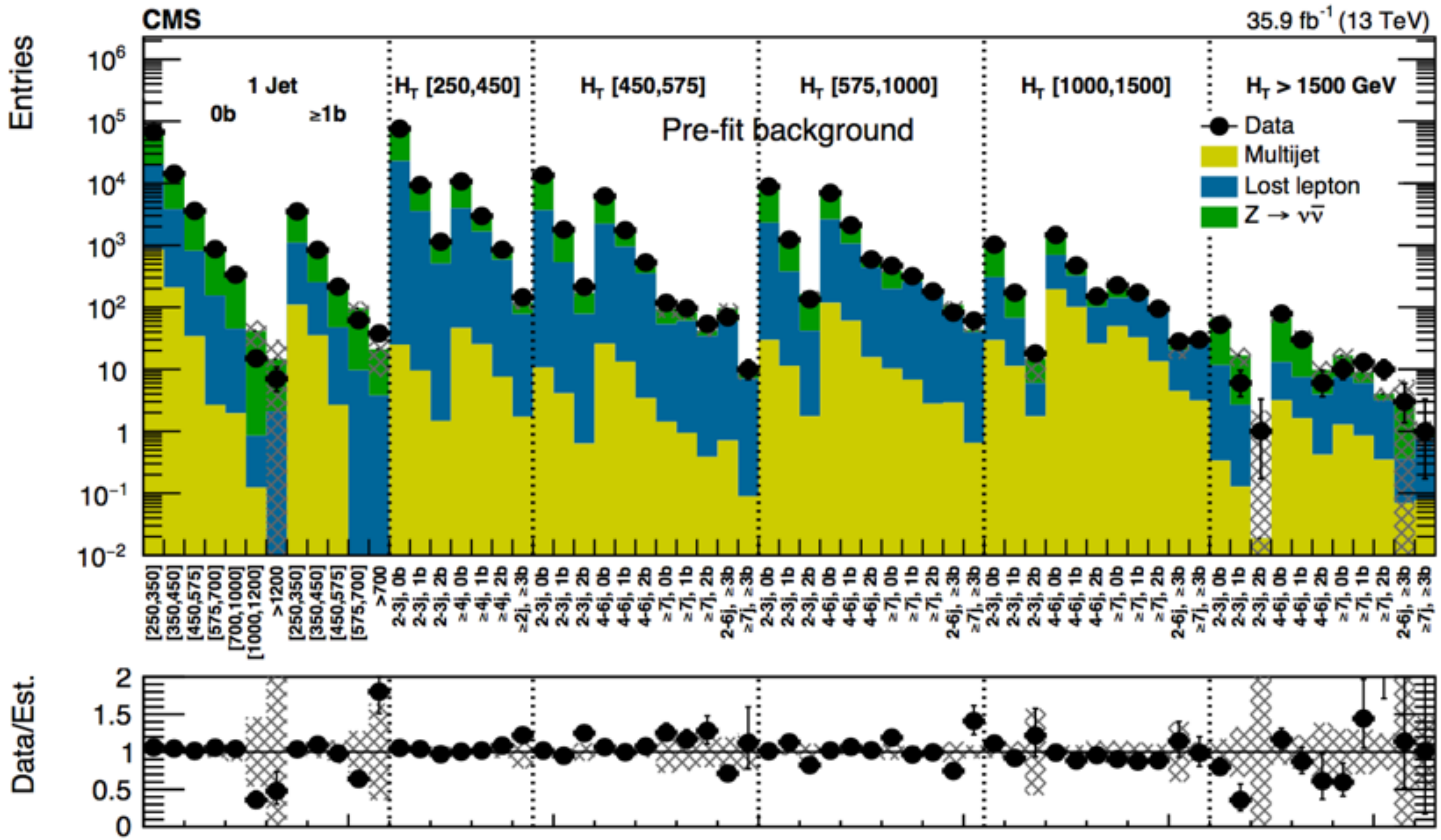
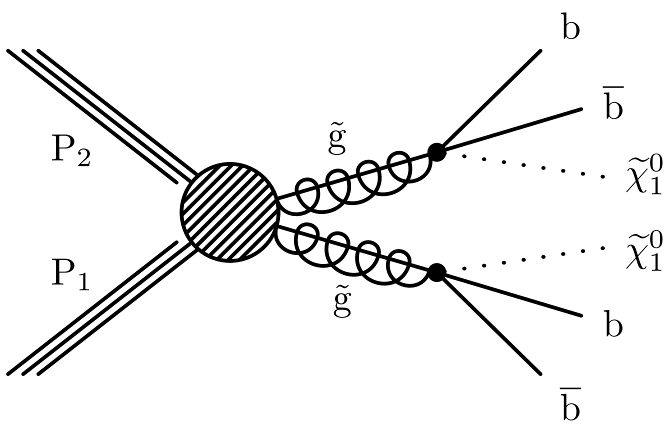
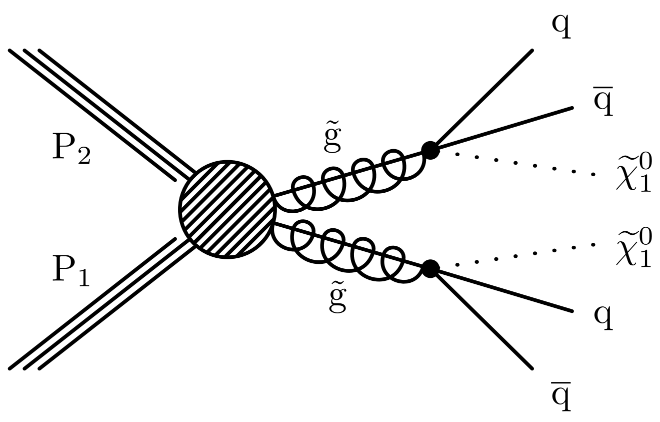


- No excess is seen

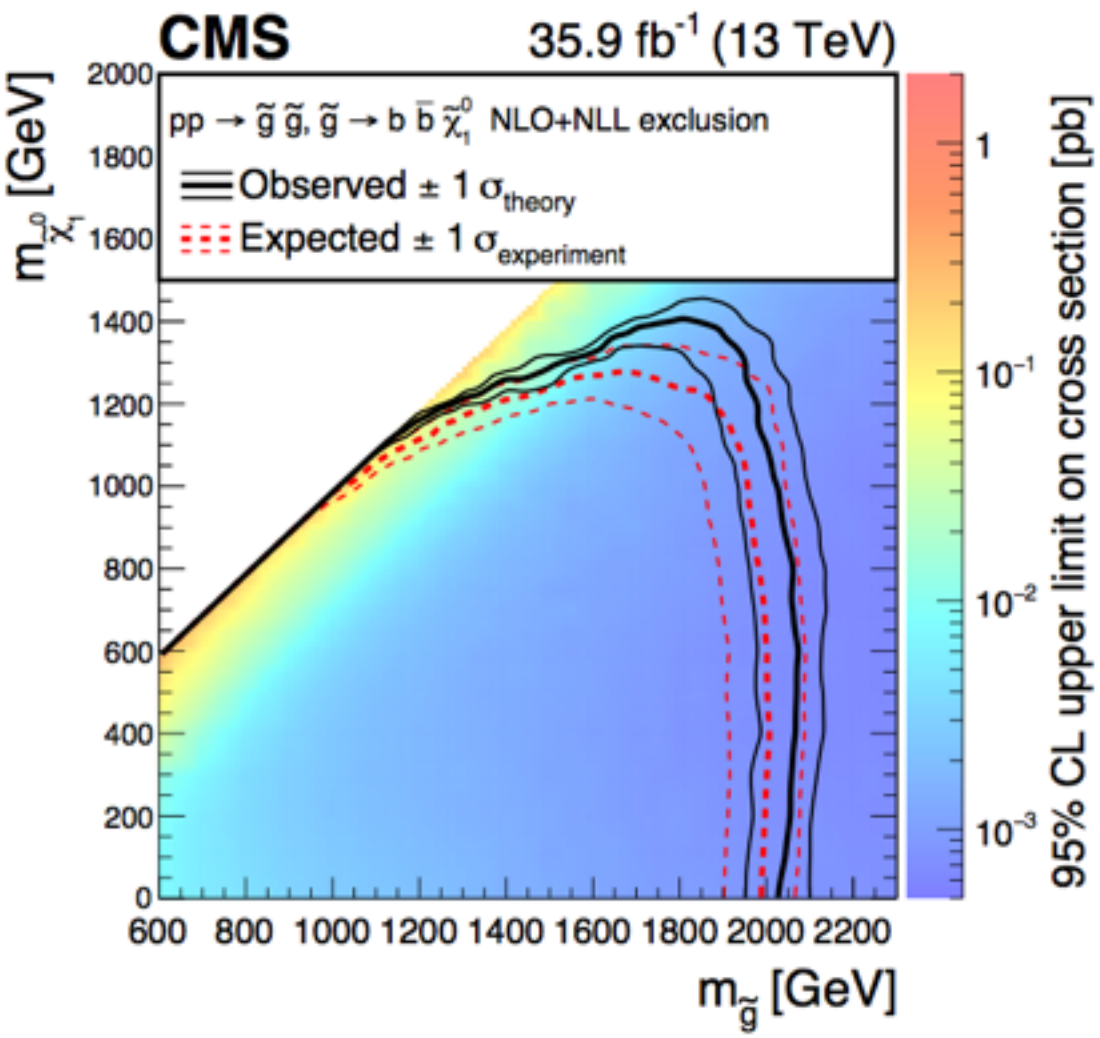
Limits



P2
P1
g̃
g̃
b
b̄
$\tilde{\chi}_1^0$
$\tilde{\chi}_1^0$
b
b̄



P2
P1
g̃
g̃
q
q̄
$\tilde{\chi}_1^0$
$\tilde{\chi}_1^0$
q
q̄



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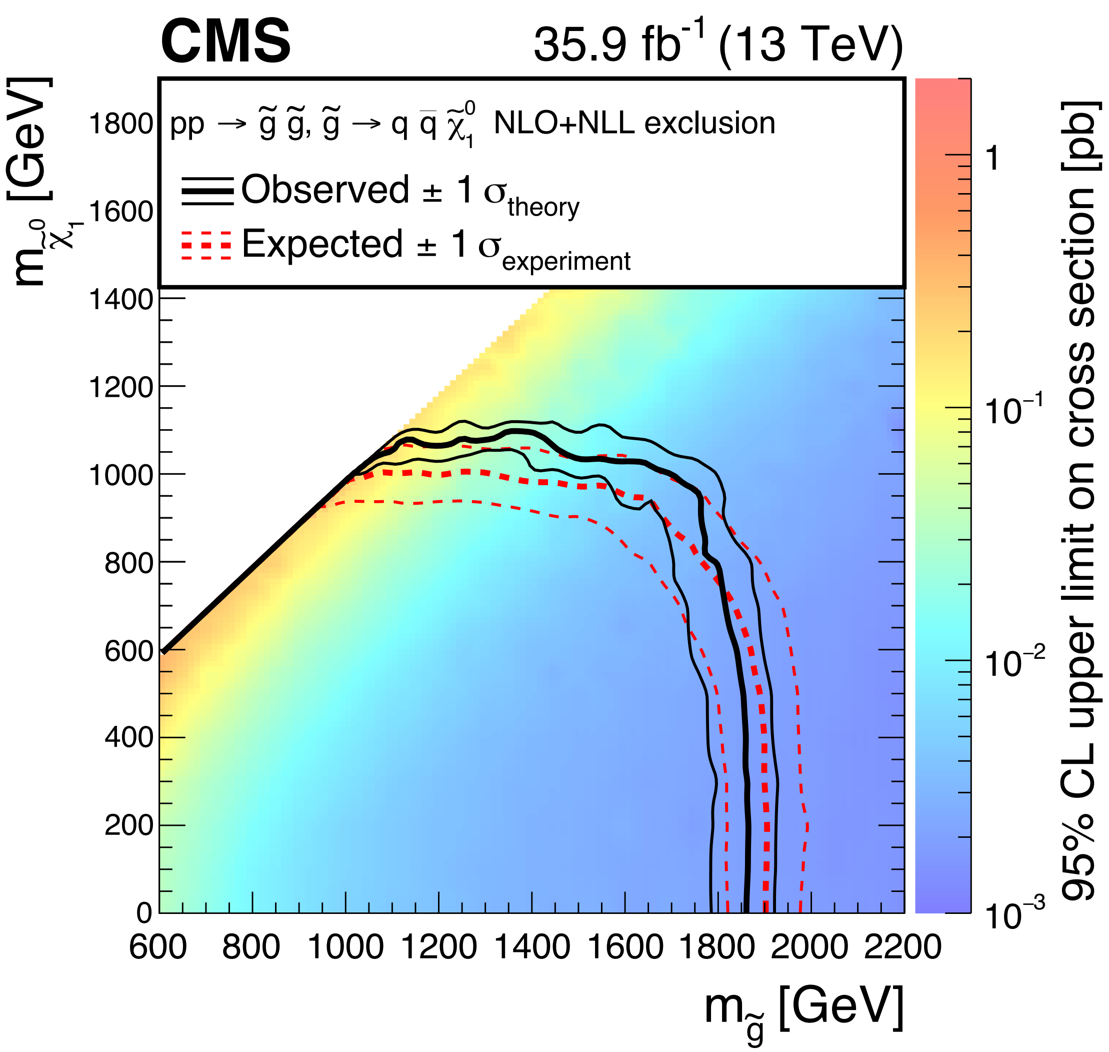

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35.9 fb^{-1} (13 TeV)
pp → g̃ g̃, g̃ → q q̄ $\tilde{\chi}_1^0$ NLO+NLL exclusion
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Expected ± 1 $\sigma_{experiment}$
$m_{\tilde{\chi}_1^0}$ [GeV]
$m_{\tilde{g}}$ [GeV]
95% CL upper limit on cross section [pb]

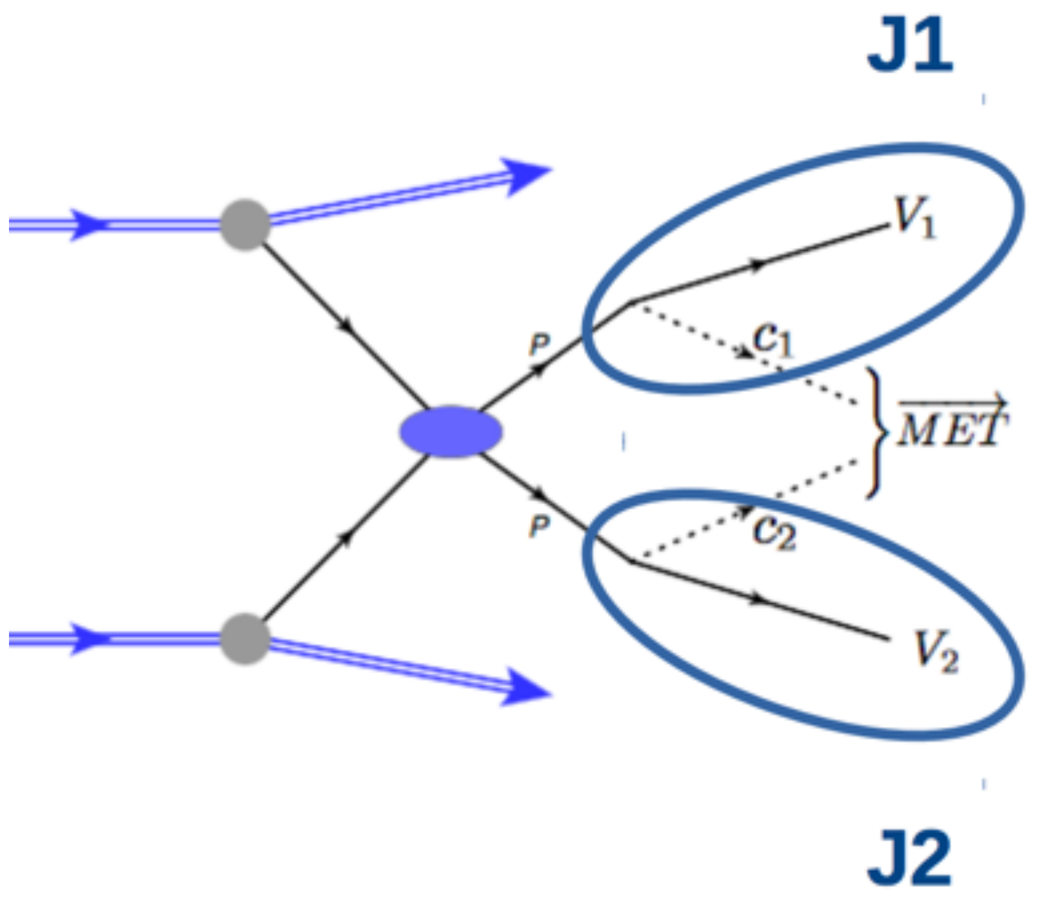
Conclusion

- Two SUSY hadronic analysis are presented here: CMS-SUS-16-033, CMS-SUS-16-036
- Both analysis can serve as cross checks for the other and have found to give similar results in over lapping models
- No significant excess is seen
- The results seen in 2016 surpass what was seen Run1
- Stay tuned for 2017 and 2018!
- References:
  - https://arxiv.org/pdf/1705.04650.pdf
  - https://arxiv.org/abs/1704.07781

Thank you
Back up

M_{T2}

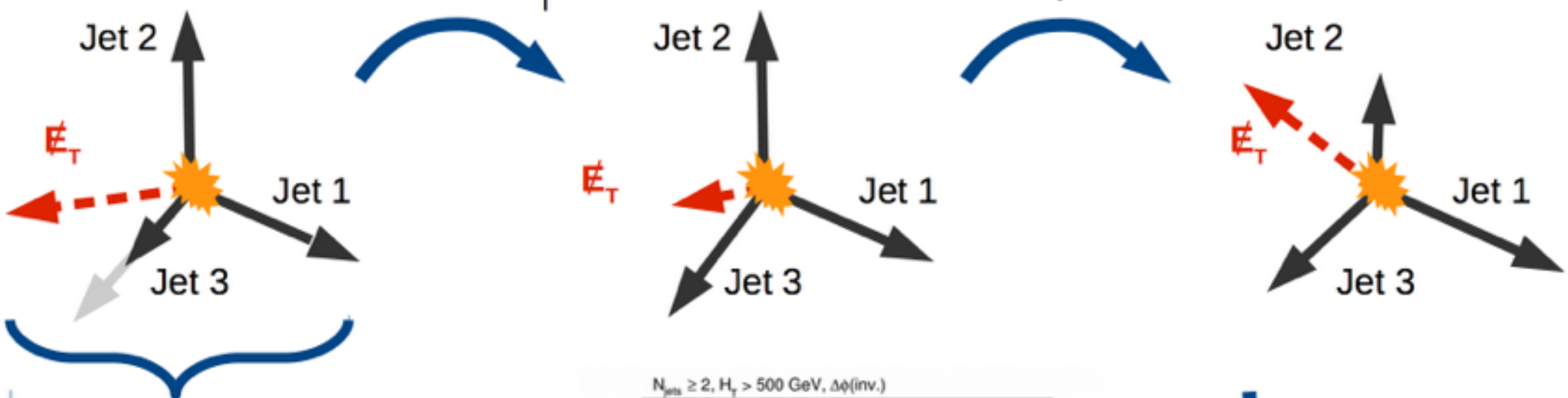
- Split visible part of event into 2 hemispheres (pseudojets) for calculation of M_{T2}



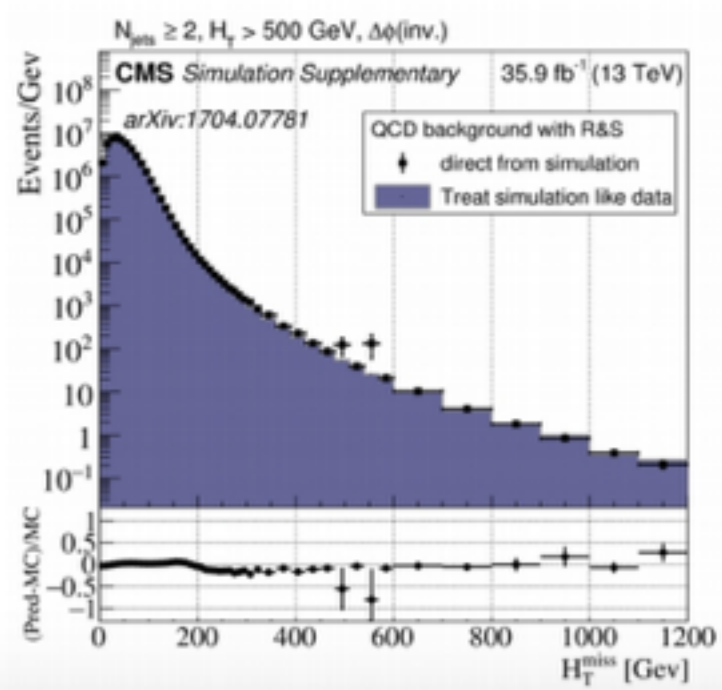
QCD Estimate: Rebalance and Smear

Rebalance jets to true hard scatter event with $ME_T \approx 0$

Smear jets according to response



QCD multi-jet events have no intrinsic ME_T, only **instrumental ME_T** due to detector response that depends on η & p_T of jets



Good agreement with out of the box simulation

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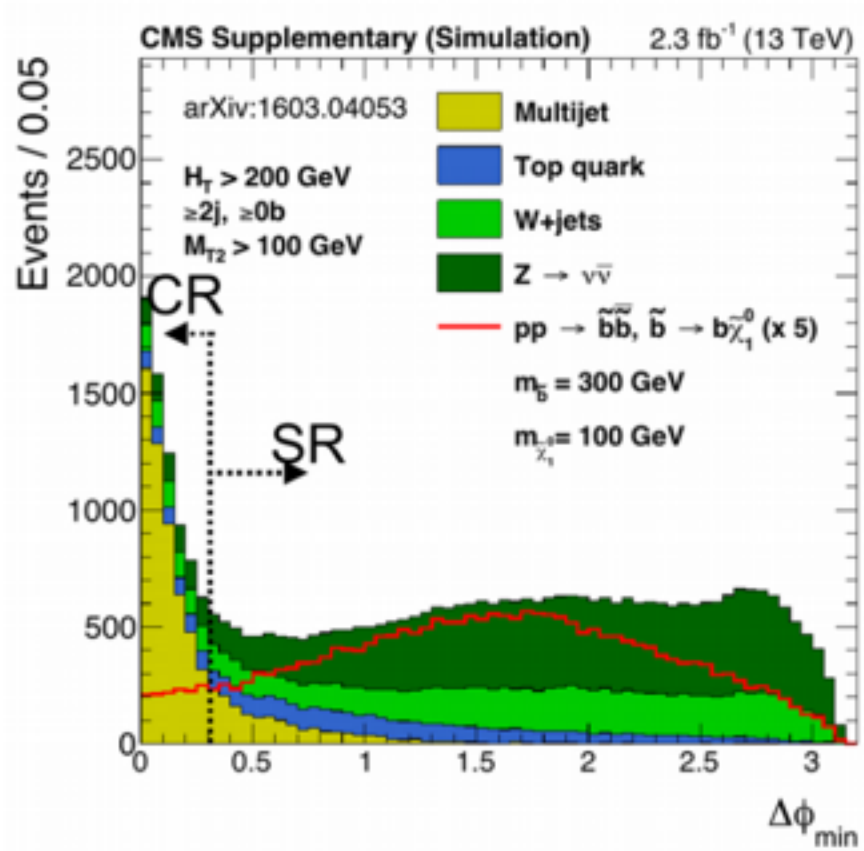
QCD background estimate via delta Phi

- Invert $\Delta\varphi(ME_T, \text{jets})$ cut

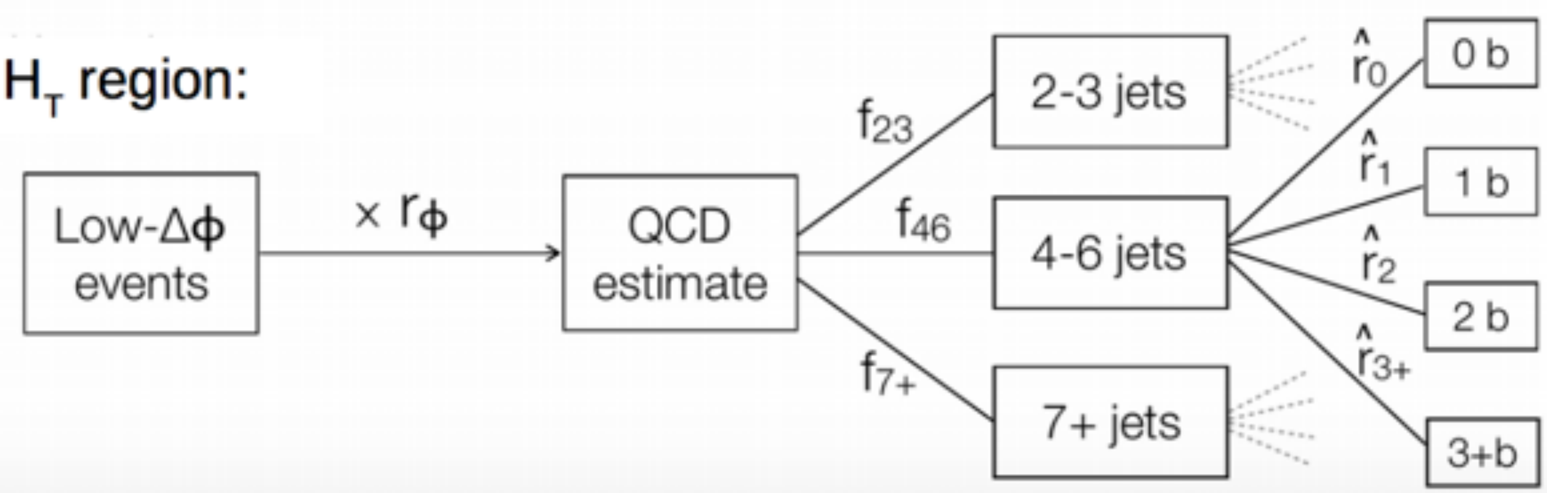
$$r_\phi = \frac{N(\Delta\phi_{min}(jets, E_T^{miss}) > 0.3)}{N(\Delta\phi_{min}(jets, E_T^{miss}) < 0.3)}$$

- Fit r_φ at low M_{T2} & extrapolate to signal region inclusively in each H_T region
  - → Then split among N_j/N_b with data based transfer factors
- N_{CR} coming from signal triggers



$$N_{QCD}^{SR} = N^{CR}(H_T, M_{T2}) \cdot r_\phi(M_{T2}) \cdot f_j(H_T) \cdot r_b(N_j)$$

In each H_T region:



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