Searches for supersymmetry in single or opposite-charged dilepton final states with CMS

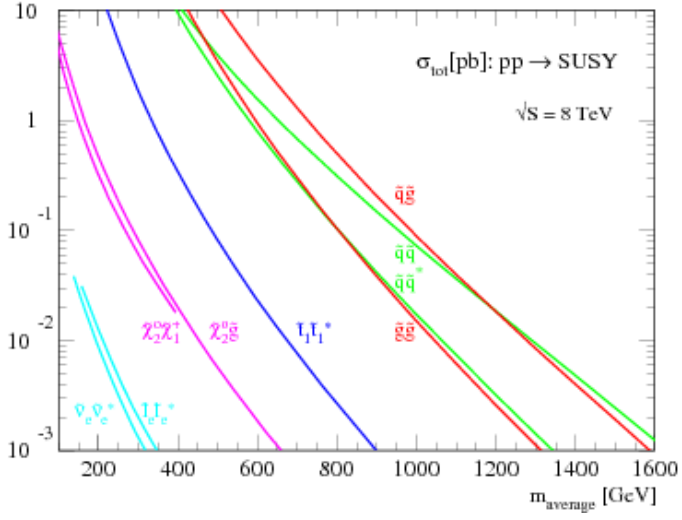
Basil Schneider, on behalf of the CMS Collaboration

Phenomenology 2017 Symposium

8 May 2017

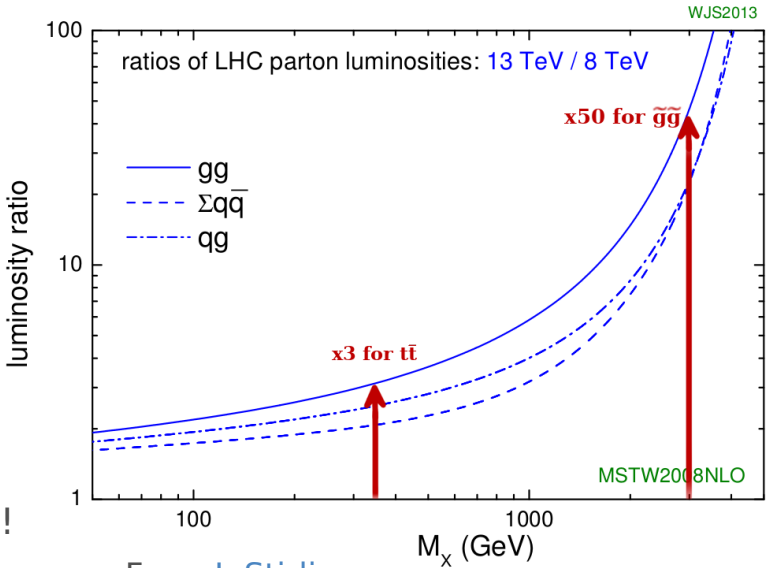
The Case for Gluino Searches

- Classic naturalness arguments require light higgsinos, stops, gluinos
- Gluinos with largest cross sections



tree-level:

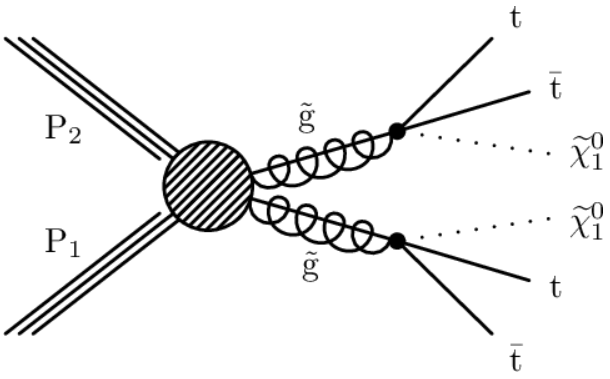
$$-\frac{m_Z^2}{2} = |\mu^2| + m_{H_u}^2 + \mathcal{O}\left(\frac{1}{\tan^2\beta}\right)$$



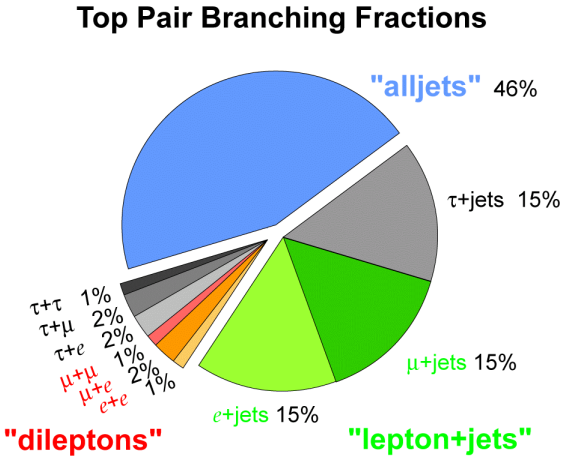
From J. Stirling

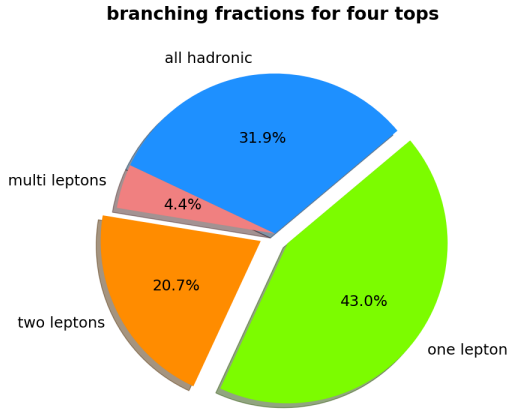
2016 data: 36 fb^{-1} of data
at $\sqrt{s}$ = 13 TeV
→ Perfect time to search for gluinos!

Lepton channel for discovery



- Gluino decay via off-shell stop
- Final state with
  - several (b tagged) jets
  - large $H_T = \sum_{\text{jets}} p_T^{\text{jets}}$
  - p_T^{miss}
  - possibly leptons





Excellent discovery opportunity in events with one or two leptons!

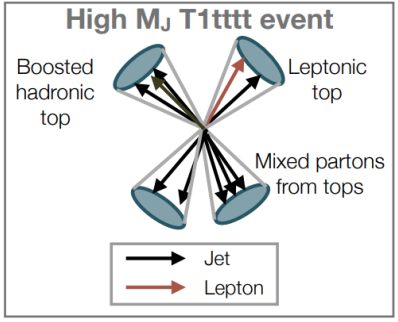
Mass of Large Jets (MJ) Analysis

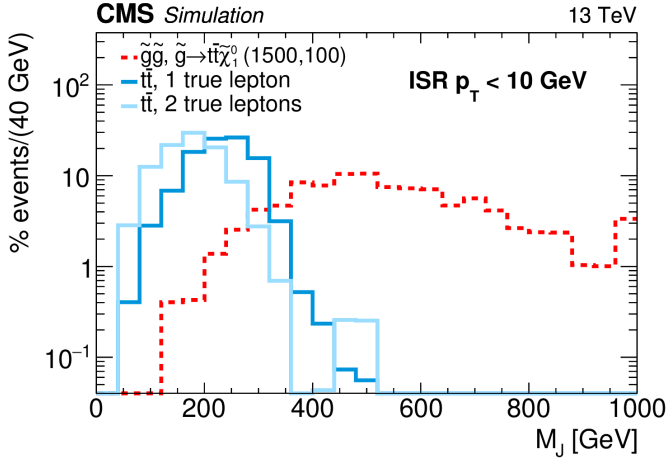
Baseline selection			
n_{lepton}	$=$	1	
n_{jets}	$\geq$	6	
n_b	$\geq$	1	
p_T^{miss}	$\geq$	200	GeV
$H_T + p_T^{\ell}$	$\geq$	500	GeV
m_T	$\geq$	140	GeV
M_J	$\geq$	400	GeV

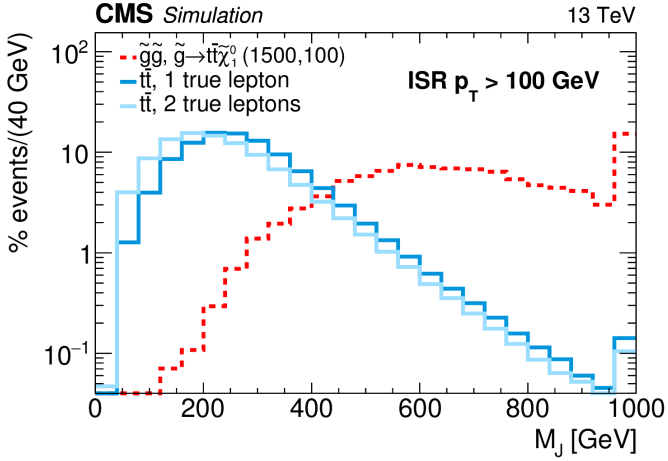
$$m_T = \sqrt{2 p_T^{\ell} p_T^{\mathrm{miss}} (1 - cos(\Delta\phi(l, p_T^{\mathrm{miss}}))}$$

$M_J = \sum_{J_i} m(J_i)$,
where J_i are anti-k_t clustered jets with R = 1.4

SUSY events have larger tails in M_J







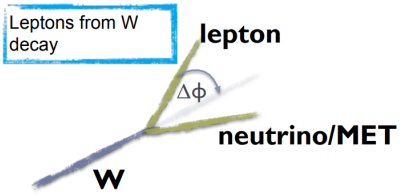
Main background: dileptonic ttbar with large ISR activity

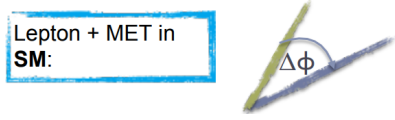
Delta phi (dPhi) Analysis

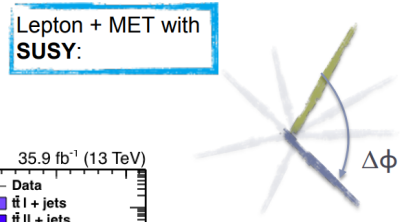
Baseline selection		
n_{lepton}	$=$	1
n_{jets}	$\geq$	6
H_T	$\geq$	500 GeV
$p_T^{miss} + p_T^{\ell}$	$\geq$	250 GeV
$\Delta\phi$	$\geq$	$0.5 - 1.0$

$\Delta\phi$: transverse angle lepton and reconstructed W

Select also events with 0 b tagged jets $\rightarrow$ interpretation with gluino decay via off-shell squarks

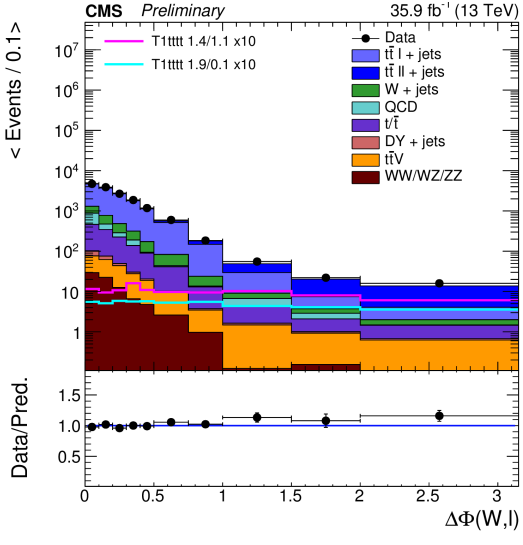


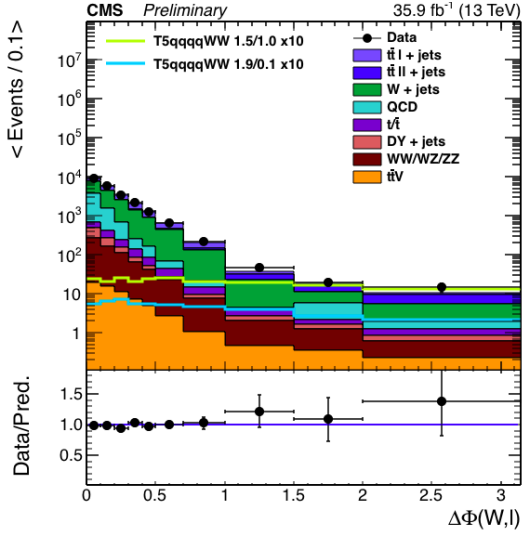




Main background: dileptonically decaying ttbar

$\geq$ 1 b tagged jet

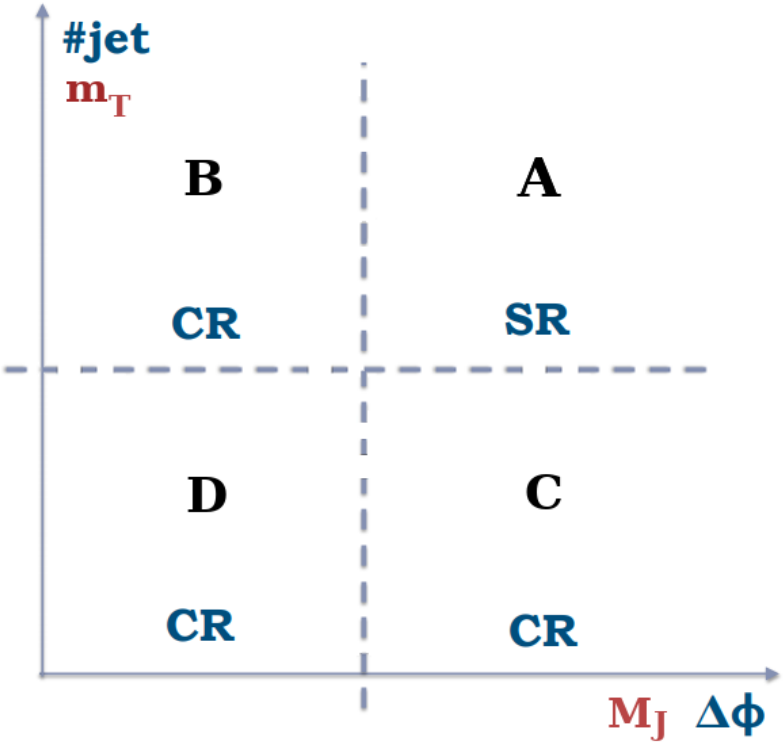




0 b tagged jets

MJ/dPhi Background Modeling

Both analyses use ABCD method

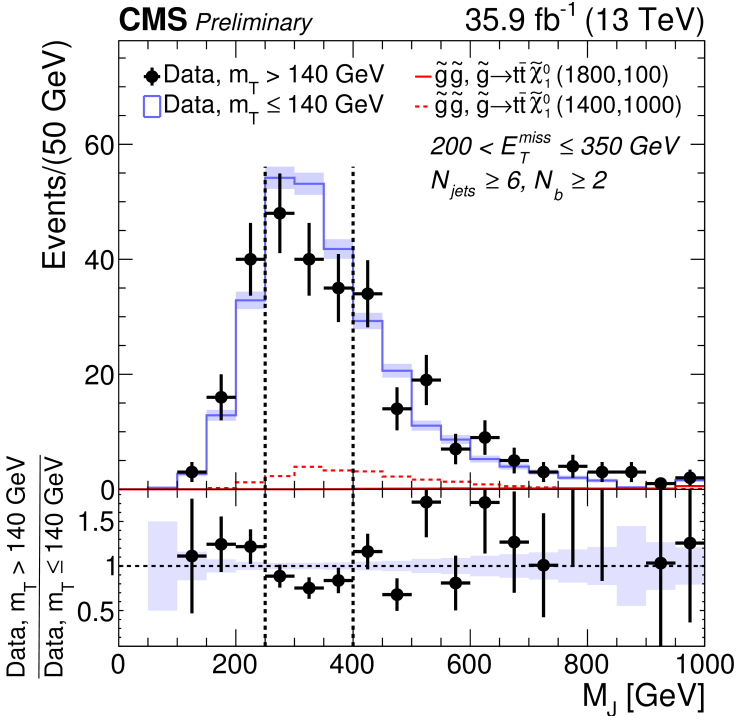


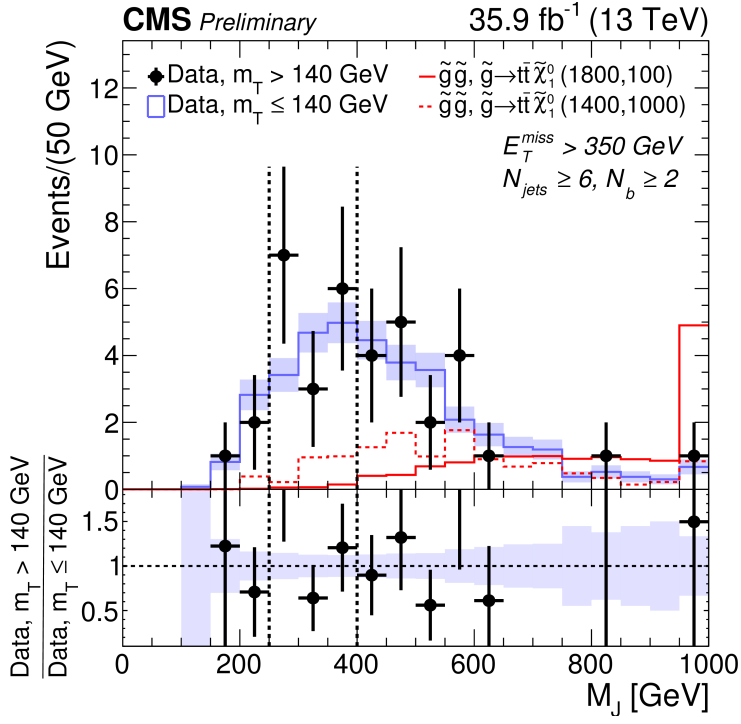
Per-bin correction factor determined in MC

- $A = B \cdot \frac{C}{D} \cdot \kappa$
- Fully data driven, except correction factor
- MJ: 18 search bins in SR, by using
  - n_{jets}
  - n_{b}
  - p_T^{miss}
- dPhi: 67 search bins in SR, by using
  - n_{jets}
  - n_{b}
  - H_T
  - $(p_T^{\text{miss}} + p_T^{\ell})$
- Main uncertainties:
  - Jet energy scale
  - Limited MC statistics (due to fine binning)

MJ Distributions

Distributions in low m_T and high m_T normalized to each other



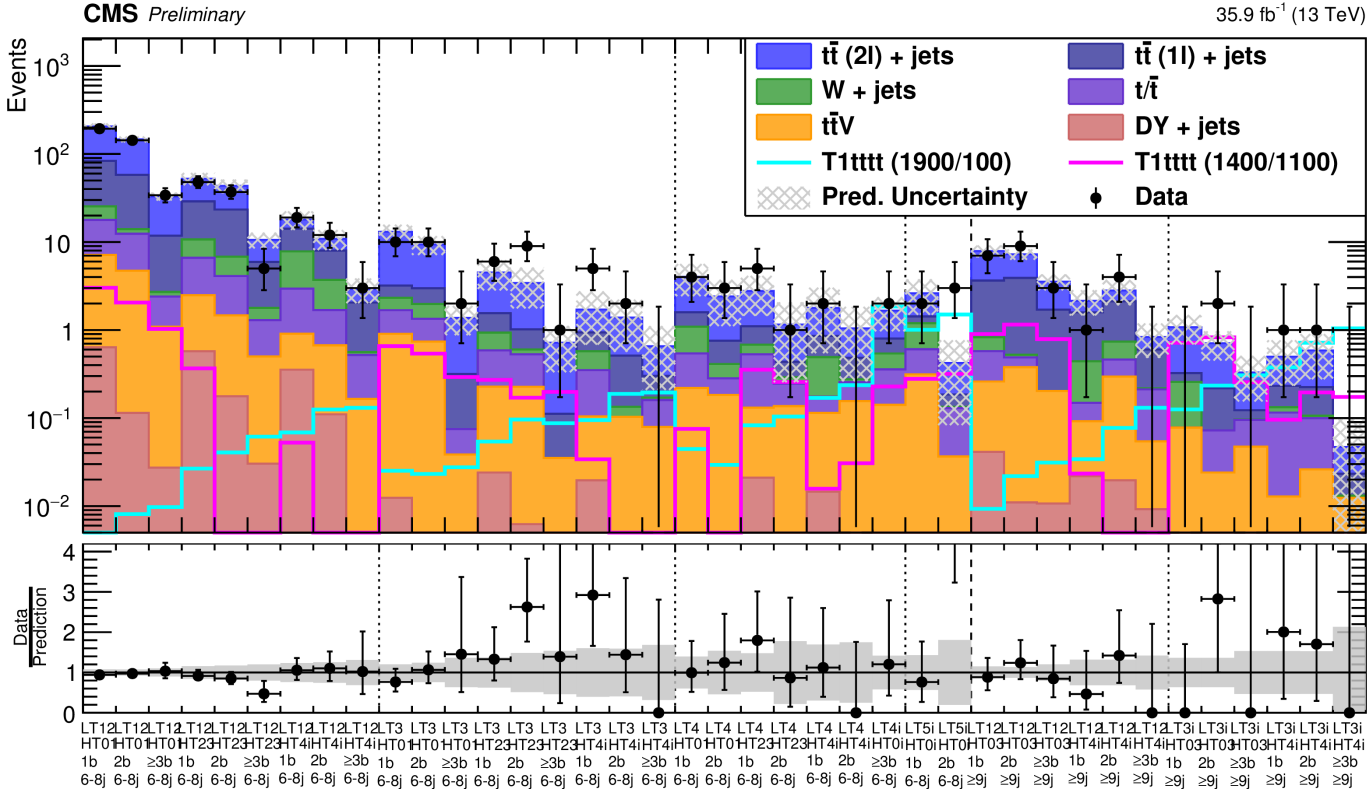


Background enriched region:
Ratio close to 1
$\Rightarrow M_J$ and m_T not correlated

Signal enriched region:
Sensitive to signal
No excess

dPhi Results

Data/background comparison in bins with > 1 b tagged jet

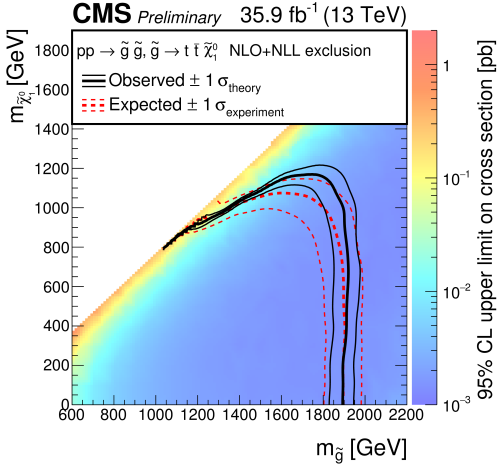


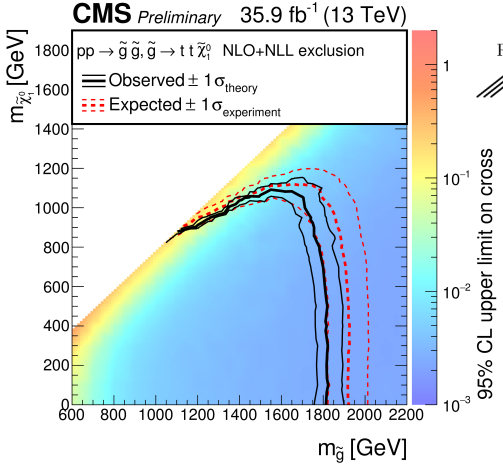
Data and prediction within uncertainties for all regions

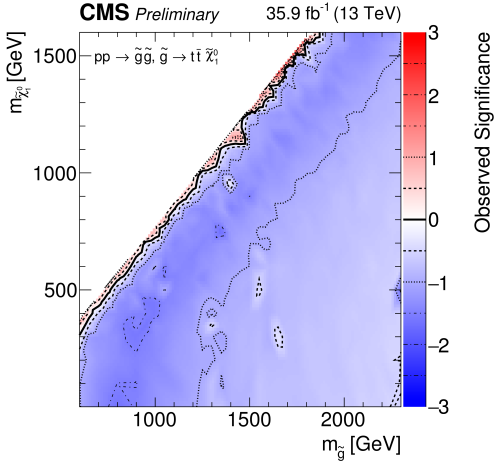
Fermilab

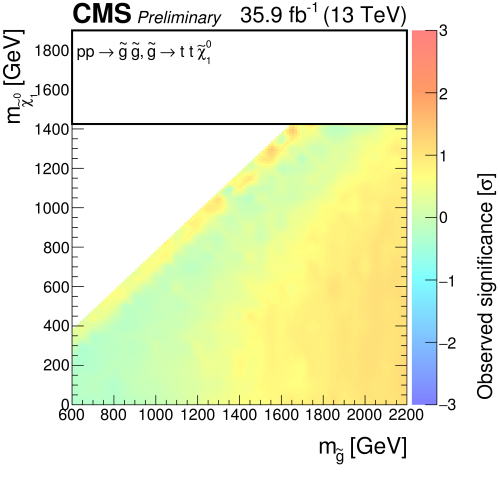
MJ/dPhi Exclusion Limits

MJ exclusion limit and observed significance

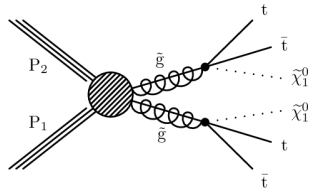








dPhi exclusion limit and observed significance



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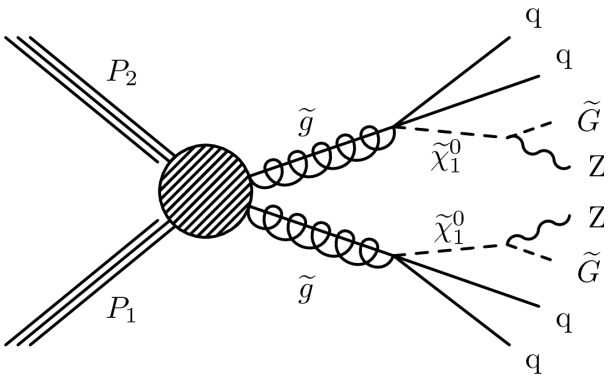
Opposite Sign Lepton (2LOS) Analysis



- Also consider other low fine tuning model: GMSB
- Model agnostic in terms of squarks
- Heavy $\tilde{\chi}_1^0$ and massless $\tilde{G}$ lead to Z resonance-like events

Select two opposite sign leptons with invariant mass close to Z, and define following signal regions:

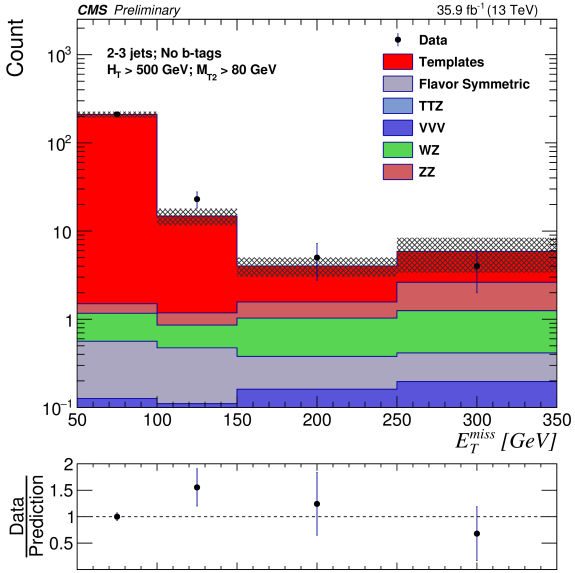
Strong on-Z Signal Regions					
Region	N_{jets}	$N_{\text{b-jets}}$	H_{T}	$M_{\text{T2}}(\ell\ell)$	$E_{\text{T}}^{\text{miss}}$ binning [GeV]
SRA b-veto	2–3	= 0	> 500 GeV	> 80 GeV	[100,150,250,∞]
SRB b-veto	4–5	= 0	> 500 GeV	> 80 GeV	[100,150,250,∞]
SRC b-veto	≥ 6	= 0	-	> 80 GeV	[100,150,∞]
SRA b-tag	2–3	≥ 1	> 200 GeV	> 100 GeV	[100,150,250,∞]
SRB b-tag	4–5	≥ 1	> 200 GeV	> 100 GeV	[100,150,250,∞]
SRC b-tag	≥ 6	≥ 1	-	> 100 GeV	[100,150,∞]

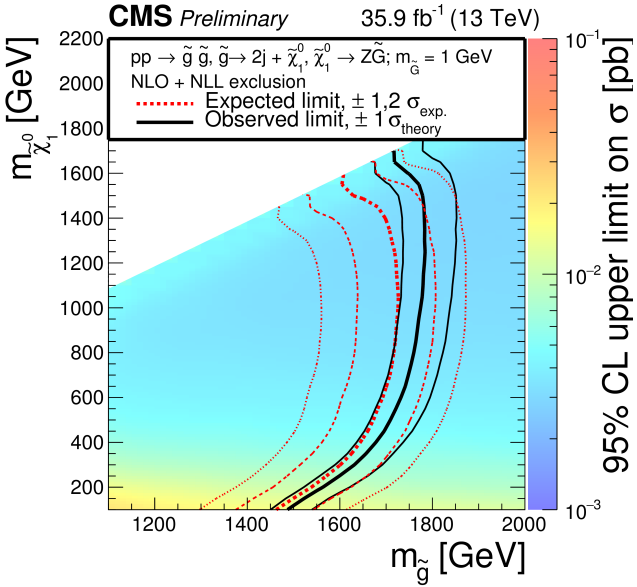
Search interprets results also in electroweak and light sbottom models

$$M_{T2}^2 \equiv \min_{\not{\mathbf{p}}_1+\not{\mathbf{p}}_2=\not{\mathbf{p}}_T} \left[\max\left\{m_T^2(\mathbf{p}_{Tl^-}, \not{\mathbf{p}}_1), m_T^2(\mathbf{p}_{Tl^+}, \not{\mathbf{p}}_2)\right\}\right]$$

2LOS Background Modeling

- Di- and triboson events measured in CR
- Flavor symmetric background estimated in opposite flavor enriched region
- p_T^{miss} in DY+jets background arise from detector mismeasurements; p_T^{miss} estimated in CR with γ+jets events; boson p_T distribution weighted to match Z+jets events



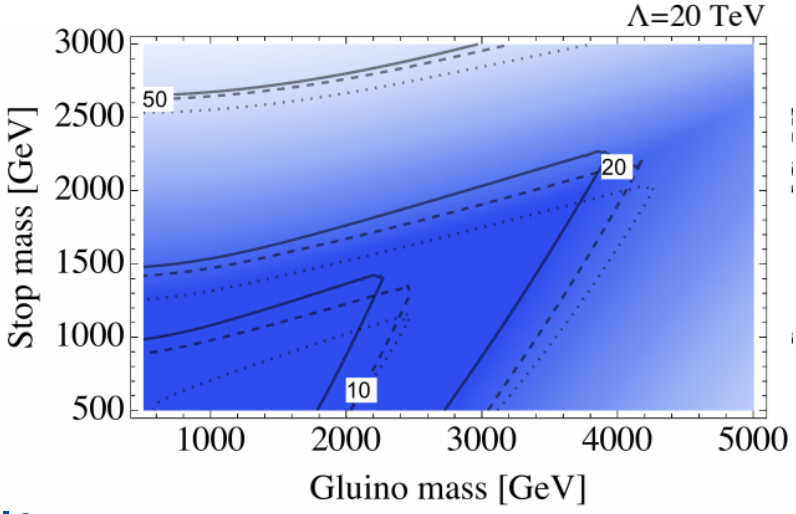


- No excess in any signal region → Limits improved by ~500 GeV!

Conclusions

- Naturalness remains one of driving forces to search for SUSY
- Presented searches for light gluinos
- No excess found in 36 fb^{-1} of LHC data, limits at 95 % CL set
- Limits on gluino mass improved to 1.9 TeV for $\tilde{\chi}_1^0$ LSP $\leq$ 1 TeV for gluinos decaying to $\tilde{\chi}_1^0$ via off-shell stop
- Limits on gluino mass improved to 1.8 TeV in GMSB model

- Are LHC results in tension with natural SUSY?
- $\rightarrow$ Depends on the amount of fine tuning Δ you are willing to accept
- At messenger scale Λ = 20 TeV, fine tuning of ~10 is almost ruled out
- Δ of SM is 10^{24}



From arXiv:1611.05873 [hep-ph]

$\Rightarrow$ SUSY is alive and well!

Reference: MJ

Available on the CERN CDS information server CMS PAS SUS-16-037

CMS Physics Analysis Summary

Contact: cms-pag-conveners-susy@cern.ch 2017/03/22

Search for supersymmetry in pp collisions at $\sqrt{s} = 13$ TeV in the single-lepton final state using the sum of masses of large-radius jets

The CMS Collaboration

Abstract

Results are reported from a search for supersymmetric particles in proton-proton collisions in the final state with a single high transverse momentum lepton; multiple jets, including at least one b-tagged jet; and large missing transverse momentum. The search uses a 35.9 fb^{-1} sample of proton-proton collision data at $\sqrt{s} = 13$ TeV accumulated by the CMS experiment at the LHC. The observed event yields in the signal regions are consistent with those expected for standard model backgrounds. The results are interpreted in the context of simplified models of supersymmetry involving gluino pair production, with gluino decay into either on- or off-mass-shell top squarks. Assuming that the top squarks decay into a top quark plus a stable, weakly interacting neutralino, scenarios with gluino masses up to about 1.9 TeV are excluded at a 95% CL for neutralino masses up to about 1 TeV.

Reference: dPhi

Available on the CERN CDS information server CMS PAS SUS-16-042

CMS Physics Analysis Summary

Contact: cms-pag-conveners-susy@cern.ch 2017/03/28

Search for supersymmetry in events with one lepton and multiple jets in proton-proton collisions at $\sqrt{s} = 13$ TeV with 2016 data

The CMS Collaboration

Abstract

A search for supersymmetry is performed with proton-proton collision data recorded by the CMS experiment with a center-of-mass energy of 13 TeV and an integrated luminosity of 35.9 fb^{-1}. Data containing a single lepton are sorted into several exclusive search regions based on the number of jets and *b*-tagged jets, the scalar sum of the jet transverse momenta, and the scalar sum of the missing transverse momentum and the transverse momentum of the lepton. The observed number of events are consistent with the background expectation and the results are interpreted with two simplified supersymmetric models of gluino pair production. In the first model, each gluino decays via a three-body process to top quarks and a neutralino, which is associated with the observed missing transverse momentum in the event. Gluinos with masses up to 1.8 TeV are excluded for neutralino masses below 800 GeV. In the second model, each gluino decays via a three-body process to two light quarks and a chargino, which subsequently decays to a *W* boson and a neutralino. The mass of the chargino is taken to be midway between the gluino and neutralino masses. In this model, gluinos with masses below 1.9 TeV are excluded for neutralino masses below 300 GeV.

Reference: 2LOS

Available on the CERN CDS information server CMS PAS SUS-16-034

CMS Physics Analysis Summary

Contact: cms-pag-conveners-susy@cern.ch 2017/03/28

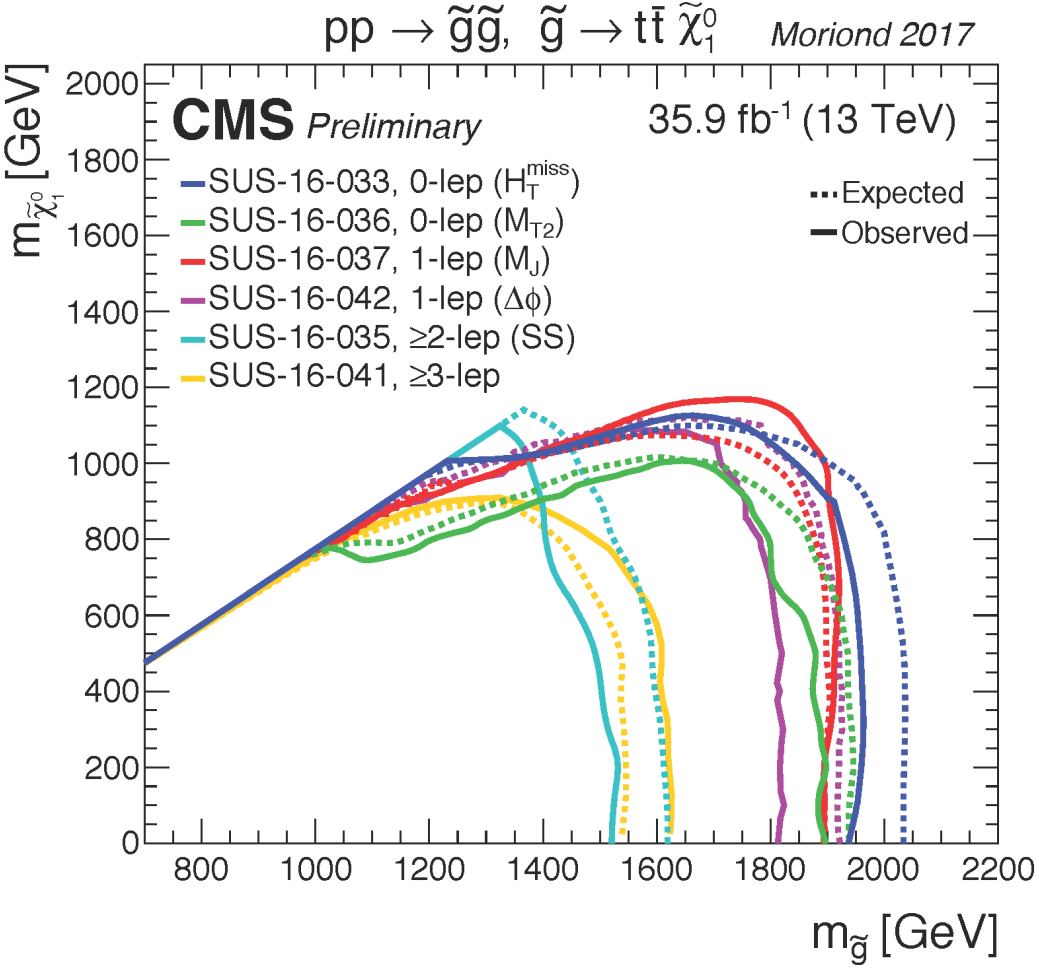
Search for new physics in final states with two opposite-sign, same-flavor leptons, jets, and missing transverse momentum in pp collisions at $\sqrt{s} = 13$ TeV

The CMS Collaboration

Abstract

A search is presented for physics beyond the standard model in final states with two opposite-sign, same-flavor leptons, jets, and missing transverse momentum. The data sample corresponds to an integrated luminosity of 35.9 fb^{-1} of proton-proton collisions at $\sqrt{s} = 13$ TeV collected with the CMS detector at the LHC in 2016. The analysis uses the invariant mass of the lepton pair, searching for a kinematic edge or a resonant-like excess compatible with the Z boson mass. The search for a kinematic edge targets strong production while the resonance search targets both strongly and electroweakly produced new physics. Both search modes use several event categories, based on observables related to the lepton pair and the hadronic system, in order to increase the sensitivity to new physics. A fit is also employed to search for a possible kinematic edge position in the strong, non-resonant search. The observations in all signal regions are consistent with the expectations from the standard model, and the results are interpreted in the context of simplified models of supersymmetry.

Backup: Exclusion contour comparison



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Backup: Fine tuning measure

Definition of fine tuning follows the Barbieri-Giudice measure (Nucl. Phys. B306 (1988) 63–76):

$$\Delta_{M^2} = \left| \frac{\partial \log m_h^2}{\partial \log M^2} \right|$$

where M is a UV mass-squared parameter (e.g. μ, M_3, or m_{Q^3})

Backup: MJ/dPhi Baseline Selection

MJ analysis:

- lepton with p_T^l > 20 GeV
- veto events with an additional lepton or isolated track
- $S_T = H_T + p_T^l$ > 500 GeV
- p_T^{miss} > 200 GeV
- $m_T \geq$ 140 GeV
- $\geq$ 6 small-R jets
- $\geq$ 1 small-R b tagged jet

$\Rightarrow$ Bin in n_{jets}, n_{b}, p_T^{miss}
18 search bins defined

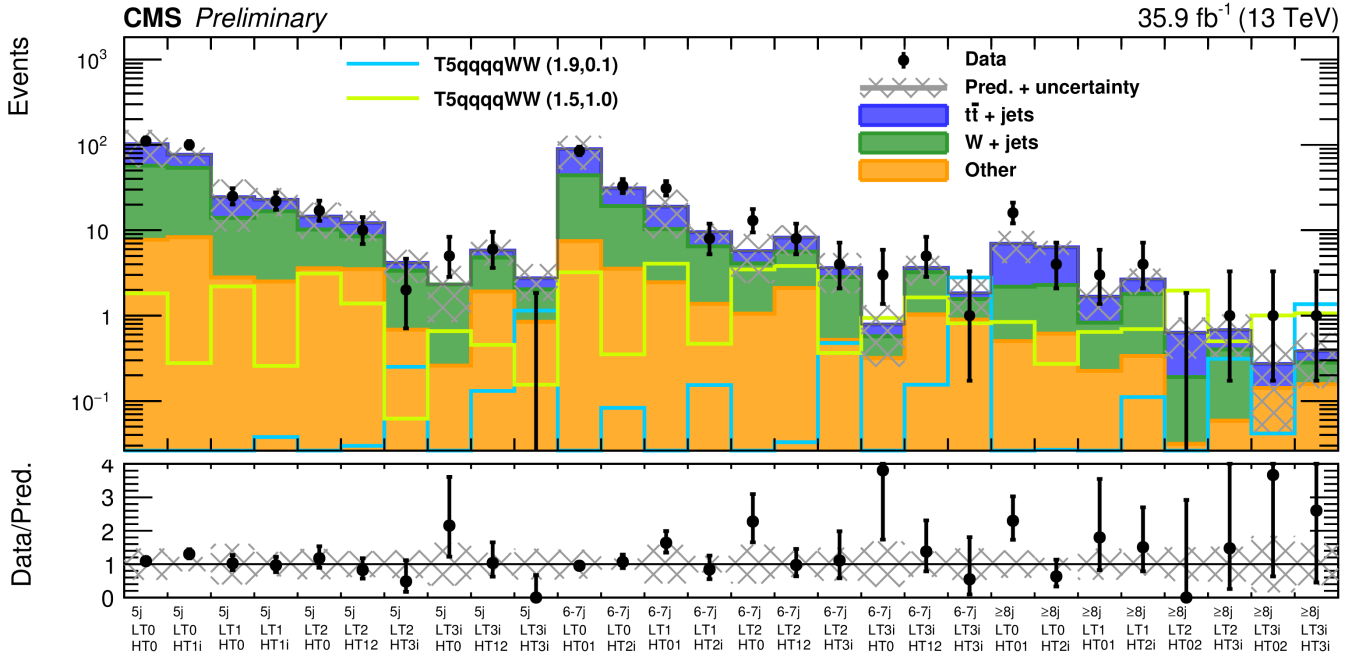
dPhi analysis:

- lepton with p_T^l > 25 GeV
- veto events with an additional lepton or isolated track
- H_T > 500 GeV
- $L_T = p_T^{\text{miss}} + p_T^l$ > 250 GeV
- $\geq$ 5 (6) jets
- 0 ($\geq$ 1) b tagged jet

$\Rightarrow$ Bin in n_{jets}, n_{b}, H_T, L_T
28 (39) bins with 0 ($\geq$ 1) b tagged jet defined

Backup: dPhi Distributions (0-b)

Data/background comparison in bins with 0 b tagged jets



Data and prediction within uncertainty for all regions

Backup: dPhi Kappa correction factors