Search for Gluinos and Squarks

in events with

missing transverse momentum

DIS 2013: XXI. International workshop on Deep-Inelastic Scattering

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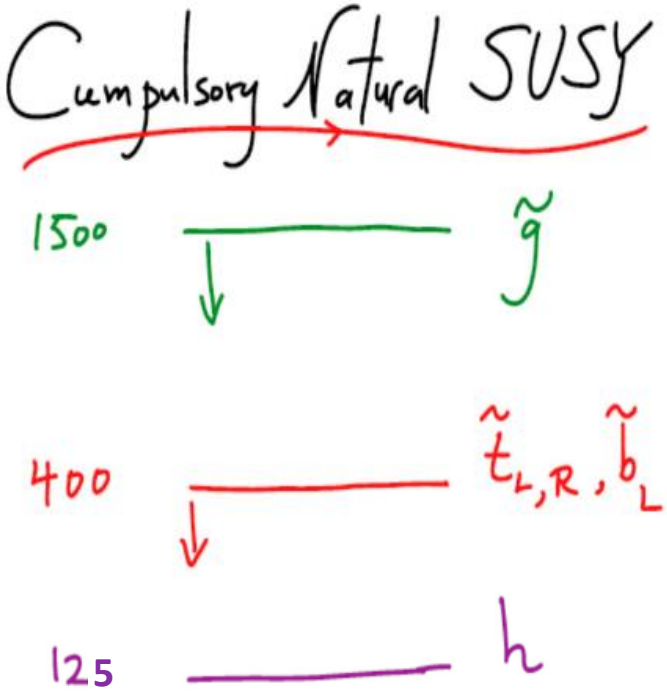
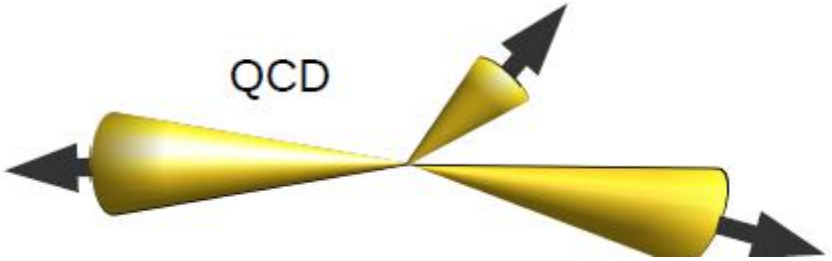
Introduction

- Discovery of the Higgs has spurred the interest in the mechanism that stabilizes the electro-weak scale.
- If this mechanism is Supersymmetry, then it is “natural” to expect relatively light gluinos and squarks.
- 7 TeV inclusive searches have revealed no signs of supersymmetry
- Focus has shifted to more dedicated searches constraining the parameter space of “simplified models” (SMS)
- this talk: Limits on Gluino- and Squark-production in hadronic and same-sign di-lepton channels



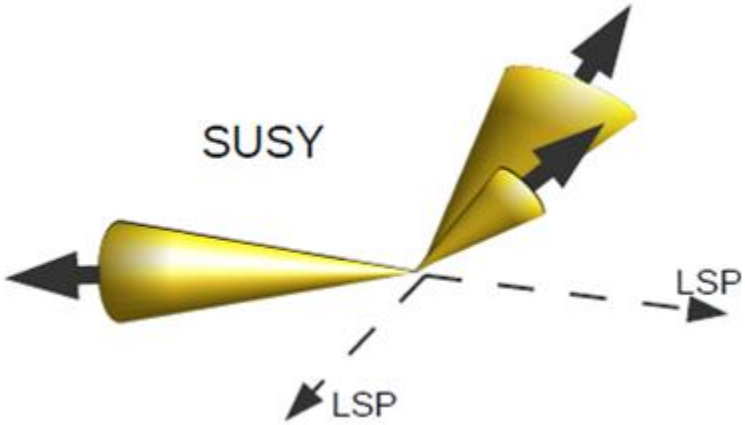
α_T search - The idea

Hadronic final states give largest branching, however QCD background is huge.



The QCD multi-jet background is suppressed by the dimensionless variable α_T

$$\alpha_T = \underbrace{\frac{E_T^{jet2}}{M_T}}_{\text{di-jet}} = \underbrace{\frac{1}{2} \times \frac{1-(\Delta H_T / H_T)}{\sqrt{1-(H_T^{miss}/H_T)^2}}}_{\text{multi-jet}}$$



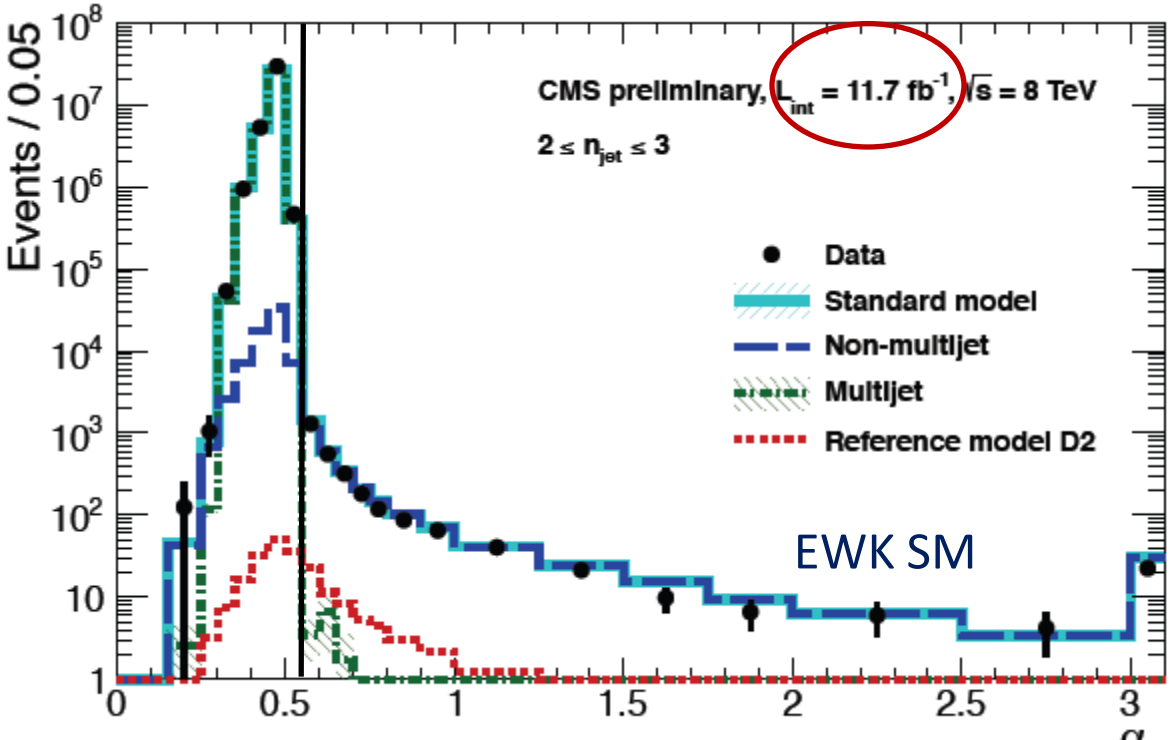
α_T uses jet-p_Ts and angular information but not the missing energy.

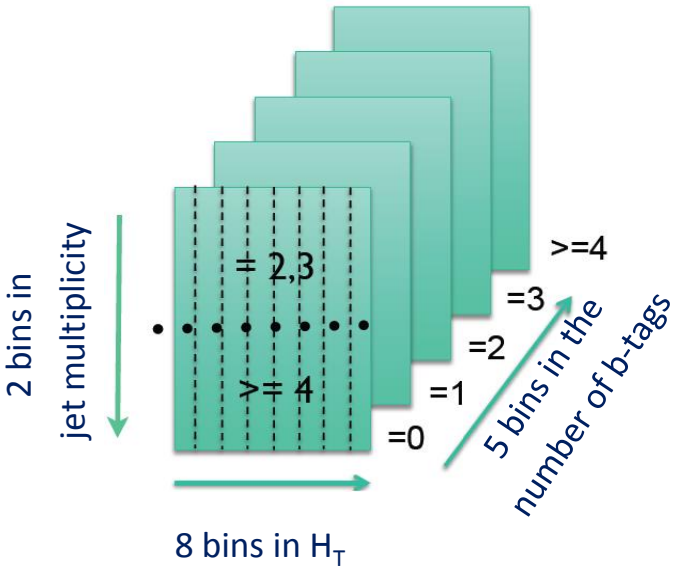
In well-measured dijet events:

$$\alpha_{T,\,\text{di-jet}} < 0.5$$

(H_T: scalar sum of jet-p_T, H_T^{miss}: neg. transversal vector sum of jet momenta)

α_T – The search





distribution of α_T inclusive in H_T and n-btag for 11.7 fb^{-1}.

- The search is binned in jet- and b-jet multiplicity and in H_T.
  - sensitivity to b-enriched models
- Dedicated lepton- (>10 GeV) and photon (>25 GeV) vetoes
- $\alpha_T > 0.55$ requirement

α_T – background prediction

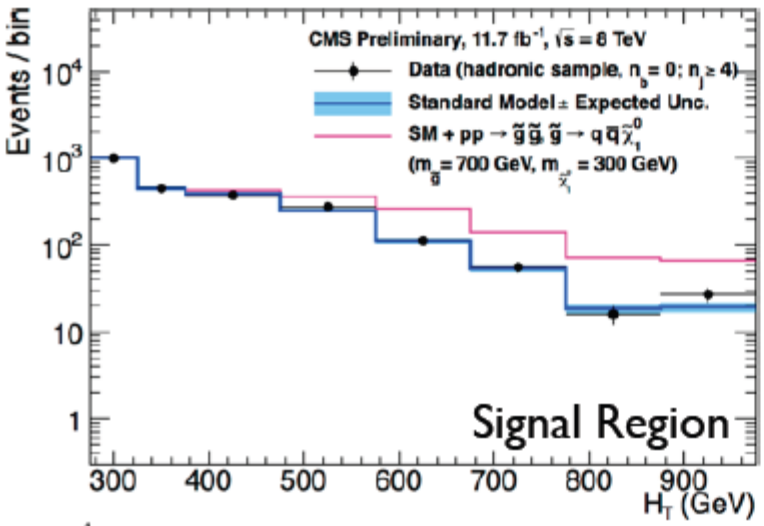
- background estimation of remaining EWK processes is binned in the same way using translation factors

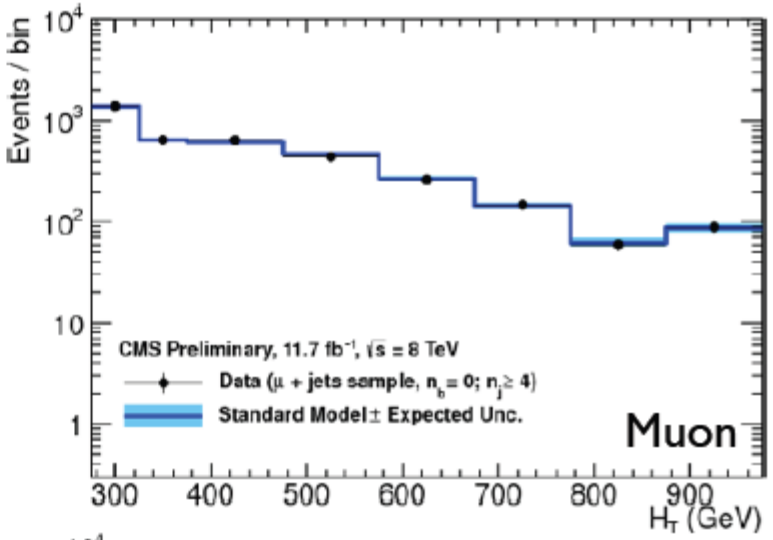
$$N_{\text{pred}}^{\text{signal}} = N_{\text{obs}}^{\text{control}} \times \frac{N_{\text{MC}}^{\text{signal}}}{N_{\text{MC}}^{\text{control}}}$$

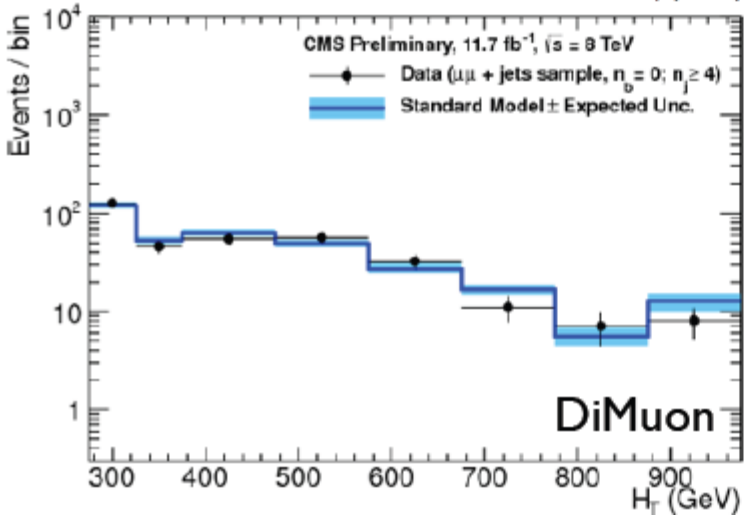
  - single-μ — W-Jets, TT-Jets, di-Boson, single top
  - single photon, di-μ — Z→ νν

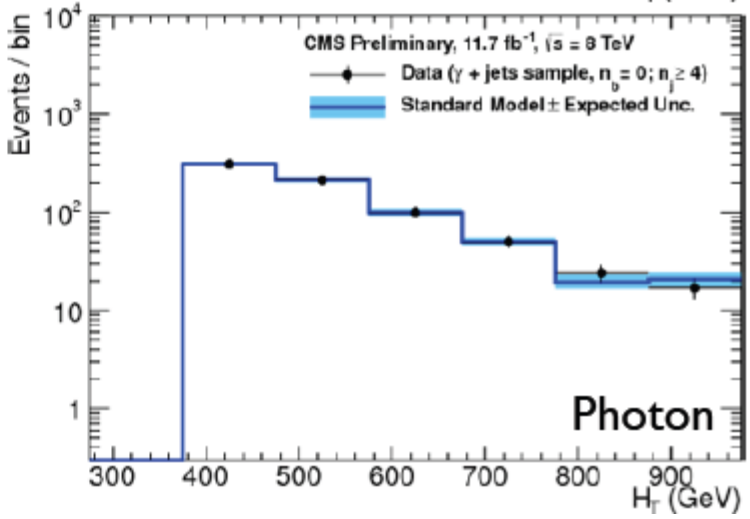
- remaining biases and mis-modelling will largely cancel
- A series of closure tests developed to assign systematic uncertainties (~10-30%)
- A simultaneous fit across all bins and samples is used to obtain the results.

Results


CMS Preliminary, 11.7 fb^{-1}, $\sqrt{s}$ = 8 TeV
Data (hadronic sample, $n_b = 0$; $n_j \geq 4$)
Standard Model ± Expected Unc.
SM + pp → $\tilde{g}\tilde{g}$, $\tilde{g} \to q\bar{q}\tilde{\chi}_1^0$
($m_{\tilde{g}}$ = 700 GeV, $m_{\tilde{\chi}_1^0}$ = 300 GeV)
Signal Region
Events / bin
H_T (GeV)

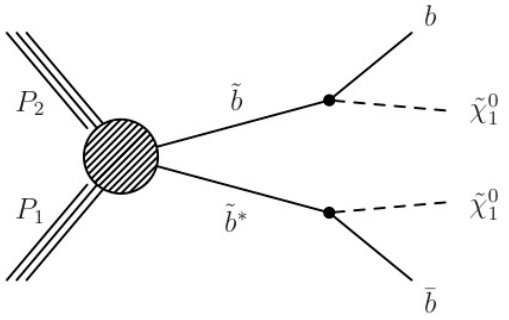

CMS Preliminary, 11.7 fb^{-1}, $\sqrt{s}$ = 8 TeV
Data (μ + jets sample, $n_b = 0$; $n_j \geq 4$)
Standard Model ± Expected Unc.
Muon
Events / bin
H_T (GeV)

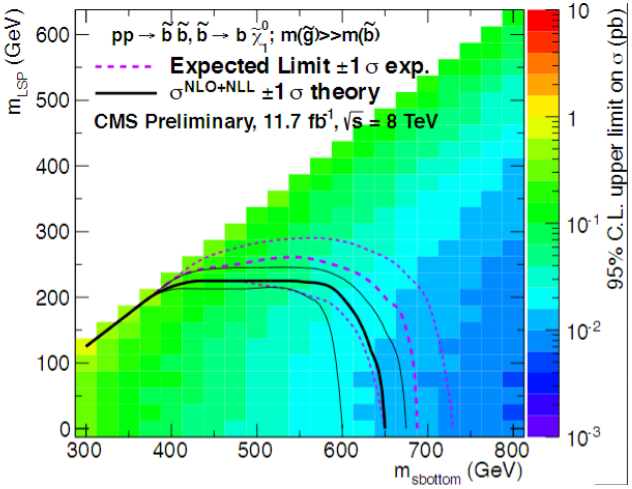

CMS Preliminary, 11.7 fb^{-1}, $\sqrt{s}$ = 8 TeV
Data (μμ + jets sample, $n_b = 0$; $n_j \geq 4$)
Standard Model ± Expected Unc.
DiMuon
Events / bin
H_T (GeV)


CMS Preliminary, 11.7 fb^{-1}, $\sqrt{s}$ = 8 TeV
Data (γ + jets sample, $n_b = 0$; $n_j \geq 4$)
Standard Model ± Expected Unc.
Photon
Events / bin
H_T (GeV)

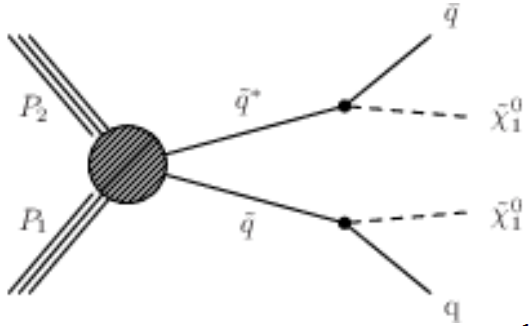
Interpretation

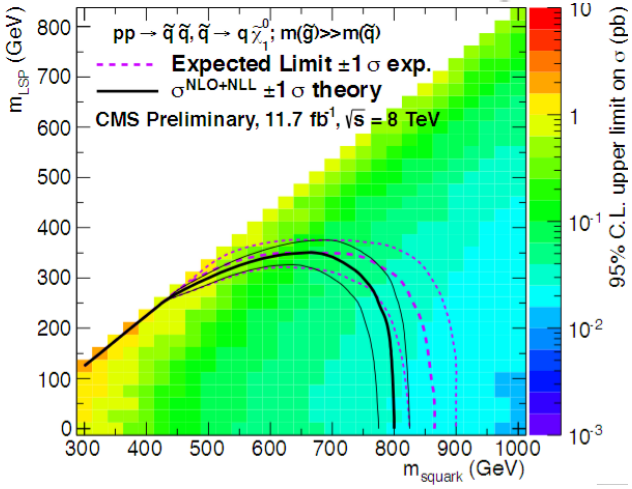
direct sbottom production



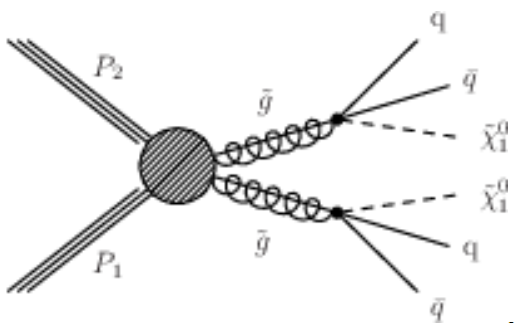


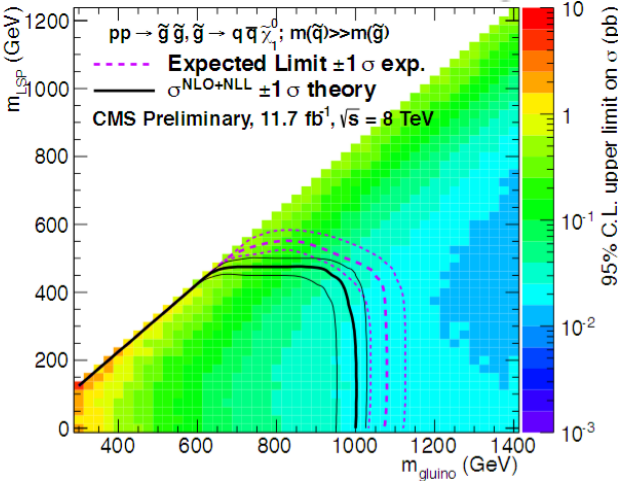
direct squark production





gluino mediated squark production





hadronic search using missing energy

Hadronic search strategy using bins of H_T and E_T^{miss}

- Selection: NJets ≥ 3, lepton veto
- N-btags (binned): =1, =2, ≥3
- E_T^{miss} (binned), HT (binned)

Protection against jet mismeasurement:

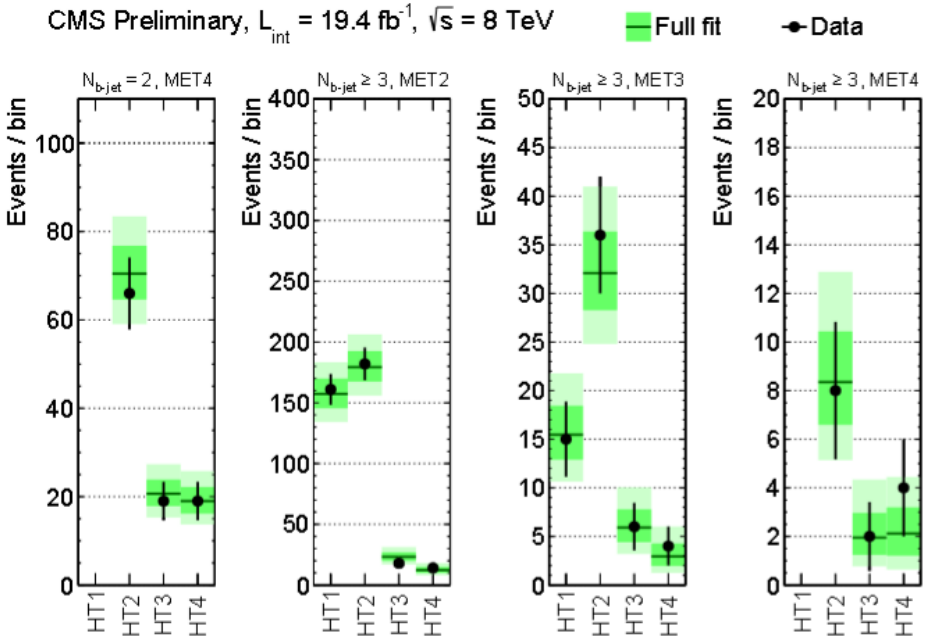
- $\Delta\phi = \min(\Delta\varphi(jet_i, E_T^{miss})/\sigma_i) > 4$

Bin	H_T (GeV)	E_T^{miss} (GeV)
1	400 – 500 (HT1)	125 – 150 (MET1)
2	500 – 800 (HT2)	150 – 250 (MET2)
3	800 – 1000 (HT3)	250 – 350 (MET3)
4	> 1000 (HT4)	> 350 (MET4)

Control samples for background shapes

- $Z \rightarrow \mu\mu/ee$ for $Z \rightarrow \nu\nu$
- 1-lepton control sample for top and W
- Inverted $\Delta\phi$ cut for QCD

hadronic search using missing energy



- observed yields well aligned with background-only hypothesis!

- fit all 165 observables simultaneously in signal- and control regions.

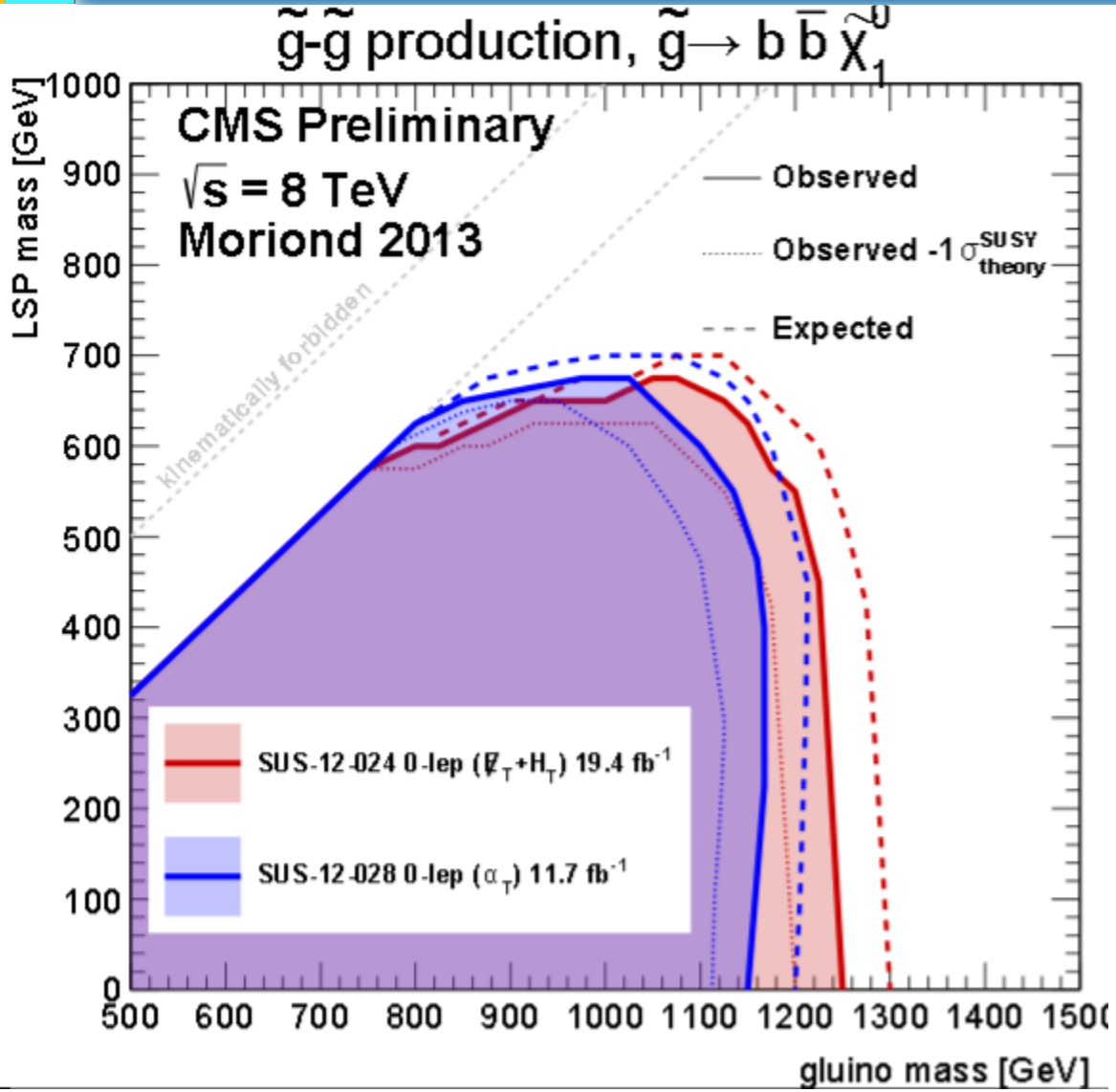
Left: most sensitive signal regions

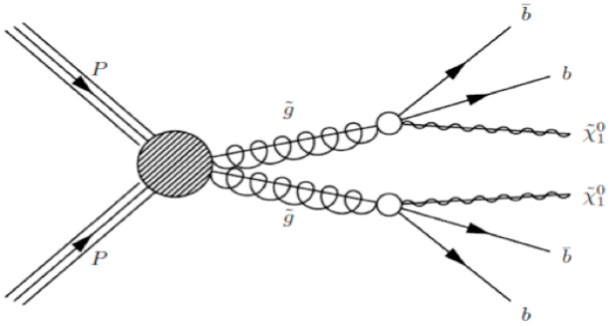
Below: predicted and observed yields

Observed number of events					
$N_{b-jet} \geq 3$	HT1	HT2	HT3	HT4	HT1-4
MET2	161	182	18	14	375
MET3	15	36	6	4	61
MET4	—	8	2	4	14
MET2-4	176	226	26	22	450

SM background predictions from fit					
$N_{b-jet} \geq 3$	HT1	HT2	HT3	HT4	HT1-4
MET2	157^{+13}_{-12}	179^{+13}_{-12}	$23.2^{+3.8}_{-3.4}$	$12.3^{+2.7}_{-2.3}$	372^{+19}_{-18}
MET3	$15.5^{+3.0}_{-2.6}$	$32.1^{+4.3}_{-3.8}$	$5.9^{+1.9}_{-1.5}$	$2.9^{+1.3}_{-1.0}$	$56.5^{+5.7}_{-5.4}$
MET4	—	$8.4^{+2.1}_{-1.8}$	$2.0^{+1.0}_{-0.7}$	$2.1^{+1.1}_{-0.9}$	$12.4^{+2.5}_{-2.2}$
MET2-4	173^{+13}_{-12}	220^{+14}_{-13}	$31.0^{+4.3}_{-3.8}$	$17.3^{+3.1}_{-2.8}$	441^{+20}_{-19}

gluino mediated sbottom production





Gluino mediated sbottom production:

Excluded gluino mass of 1200 GeV if m_{LSP} < 600 GeV

Red: hadronic MET&HT search (19.4 fb^{-1})

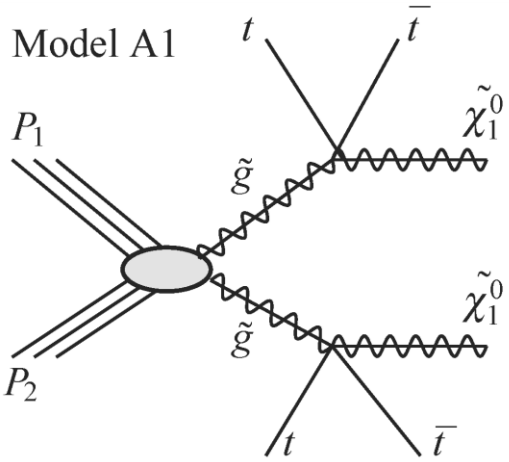
Blue: hadronic α_T search (11.7fb^{-1})

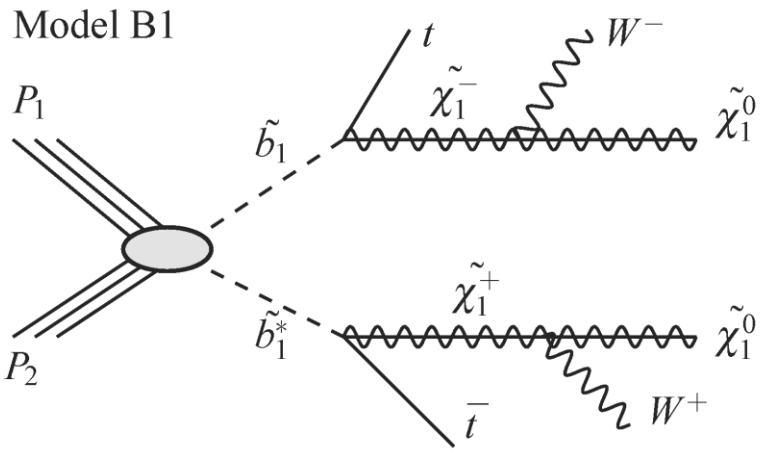
same sign di-lepton search

- Same-sign lepton events are very rare in the SM
- Predicted naturally in many SUSY scenarios, among them
  - gluino mediated stop production
  - sbottom production with a $\tilde{b} \rightarrow \tilde{\chi}^{+}$, t decay

No need for tight kinematical cuts

→ sensitivity to small mass splittings!





background estimation

- Event selection:

	P_T	η
electrons	$P_T > 20$ GeV	$\lvert\eta\rvert < 1.442$ or $1.566 < \lvert\eta\rvert < 2.4$
muons	$P_T > 20$ GeV	$\lvert\eta\rvert < 2.4$
jets	$P_T > 40$ GeV	$\lvert\eta\rvert < 2.4$
b-tagged jets	$P_T > 40$ GeV	$\lvert\eta\rvert < 2.4$

Background estimation:

- Charge mis-ID for electrons: strong bremstrahlung in tracker leading to charge-flip.

  Data driven technique using the Z-peak and measuring the ratio of SS and OS dilepton pairs.

  - 0.016% (barrel/barrel) – 0.2% (endcap/endcap)

- Single- and double-lepton fakes:

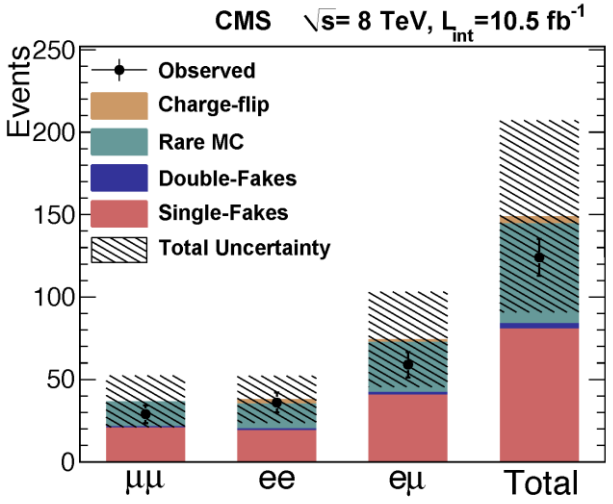
  Measured using “tight-to-loose” methods in data control regions (50% sys. uncertainty)

- ttW, ttZ (+ small diboson contribution)

  → MC based prediction

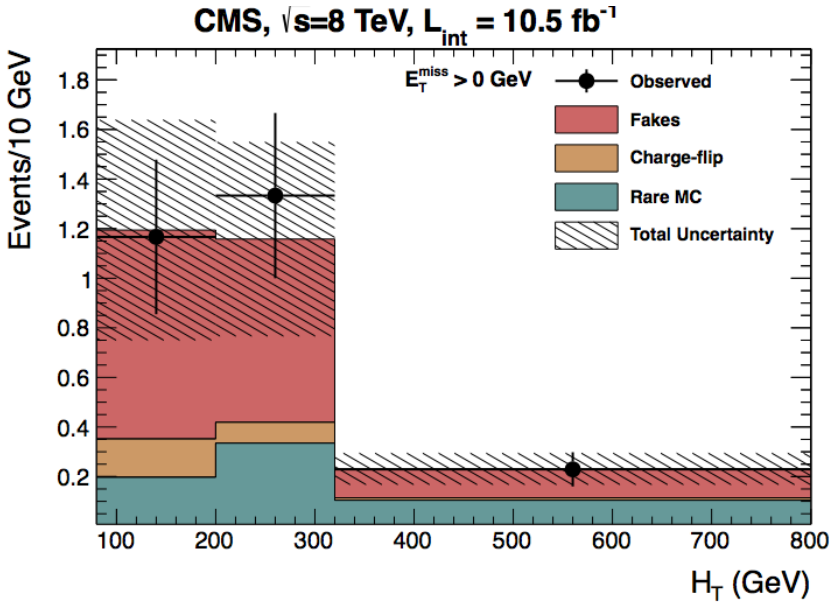
low-H_T E_T^{miss} control region

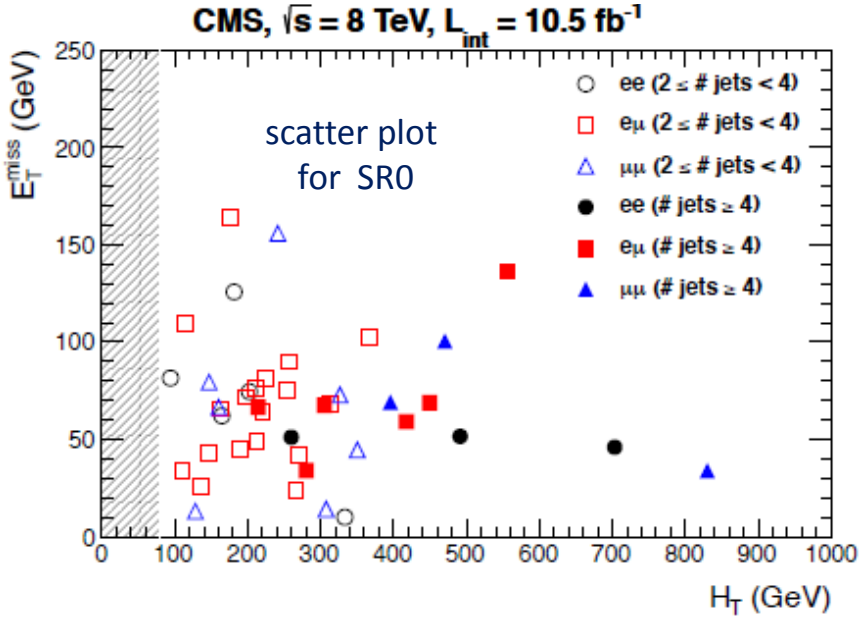
$H_T > 200$ GeV, NJet≥2, $E_T^{miss} > 50$ GeV



same-sign leptons

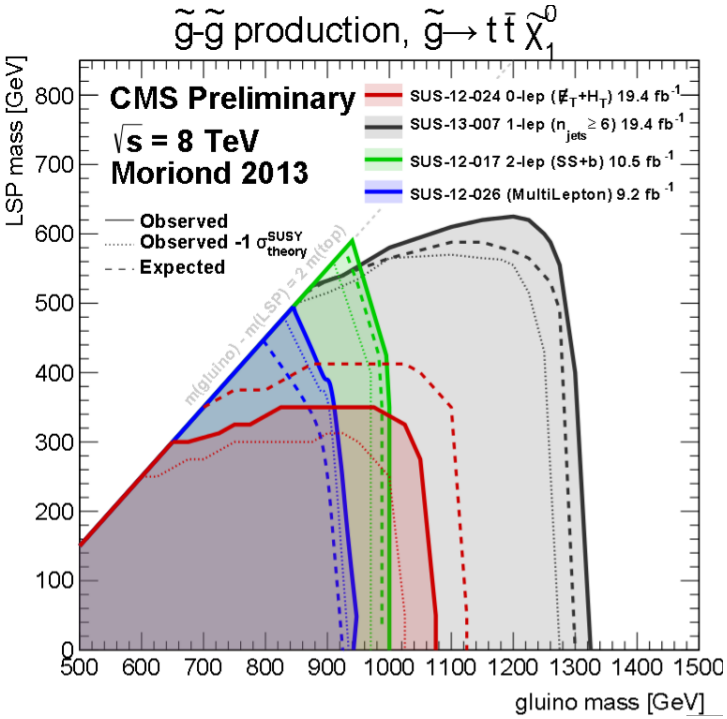
	SR0	SR1	SR2	SR3	SR4	SR5	SR6	SR7	SR8
No. of jets	≥ 2	≥ 2	≥ 2	≥ 4	≥ 4	≥ 4	≥ 4	≥ 3	≥ 4
No. of btags	≥ 2	≥ 2	≥ 2	≥ 2	≥ 2	≥ 2	≥ 2	≥ 3	≥ 2
Lepton charges	$++/--$	$++/--$	$++$	$++/--$	$++/--$	$++/--$	$++/--$	$++/--$	$++/--$
E_T^{miss}	>0 GeV	>30 GeV	>30 GeV	>120 GeV	>50 GeV	>50 GeV	>120 GeV	>50 GeV	>0 GeV
H_T	>80 GeV	>80 GeV	>80 GeV	>200 GeV	>200 GeV	>320 GeV	>320 GeV	>200 GeV	>320 GeV
Fake BG	25 ± 13	19 ± 10	9.6 ± 5.0	0.99 ± 0.69	4.5 ± 2.9	2.9 ± 1.7	0.7 ± 0.5	0.71 ± 0.47	4.4 ± 2.6
Charge-flip BG	3.4 ± 0.7	2.7 ± 0.5	1.4 ± 0.3	0.04 ± 0.01	0.21 ± 0.05	0.14 ± 0.03	0.04 ± 0.01	0.03 ± 0.01	0.21 ± 0.05
Rare SM BG	11.8 ± 5.9	10.5 ± 5.3	6.7 ± 3.4	1.2 ± 0.7	3.4 ± 1.8	2.7 ± 1.5	1.0 ± 0.6	0.44 ± 0.39	3.5 ± 1.9
Total BG	40 ± 14	32 ± 11	17.7 ± 6.1	2.2 ± 1.0	8.1 ± 3.4	5.7 ± 2.4	1.7 ± 0.7	1.2 ± 0.6	8.1 ± 3.3
Event yield	43	38	14	1	10	7	1	1	9
N_{UL} (13% unc.)	27.2	26.0	9.9	3.6	10.8	8.6	3.6	3.7	9.6
N_{UL} (20% unc.)	28.2	27.2	10.2	3.6	11.2	8.9	3.7	3.8	9.9
N_{UL} (30% unc.)	30.4	29.6	10.7	3.8	12.0	9.6	3.9	4.0	10.5

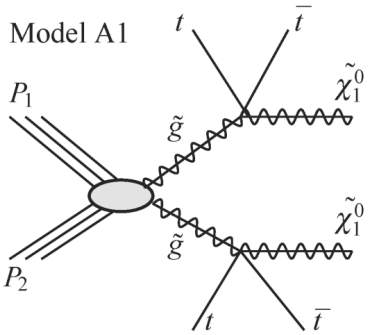


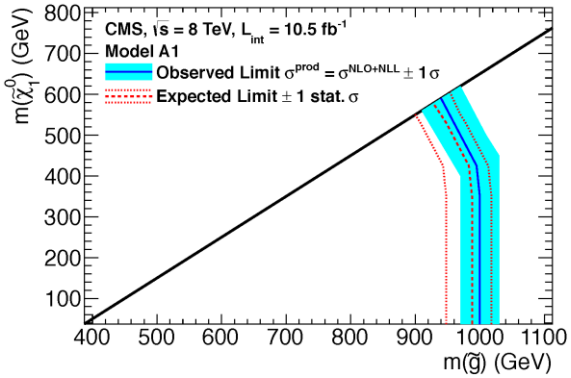


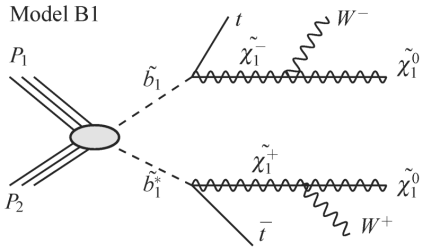
same-sign leptons

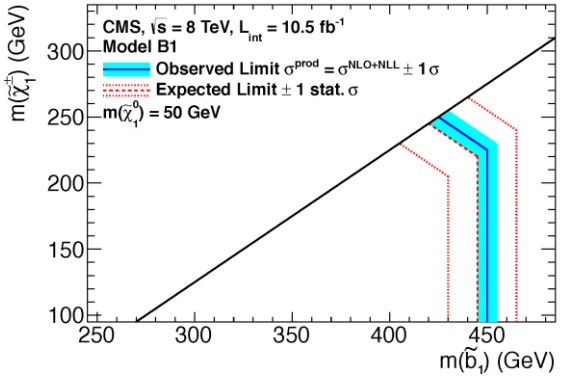
- No excess beyond SM found
- Limits quite insensitive to m_{LSP}
- Exclude 1TeV gluino and 450 GeV sbottom ($\rightarrow \tilde{\chi}^+ t$)











- Combination of all CMS limits on gluino mediated stop production excludes $m_{gl} < 1.3$ TeV (Model A1)

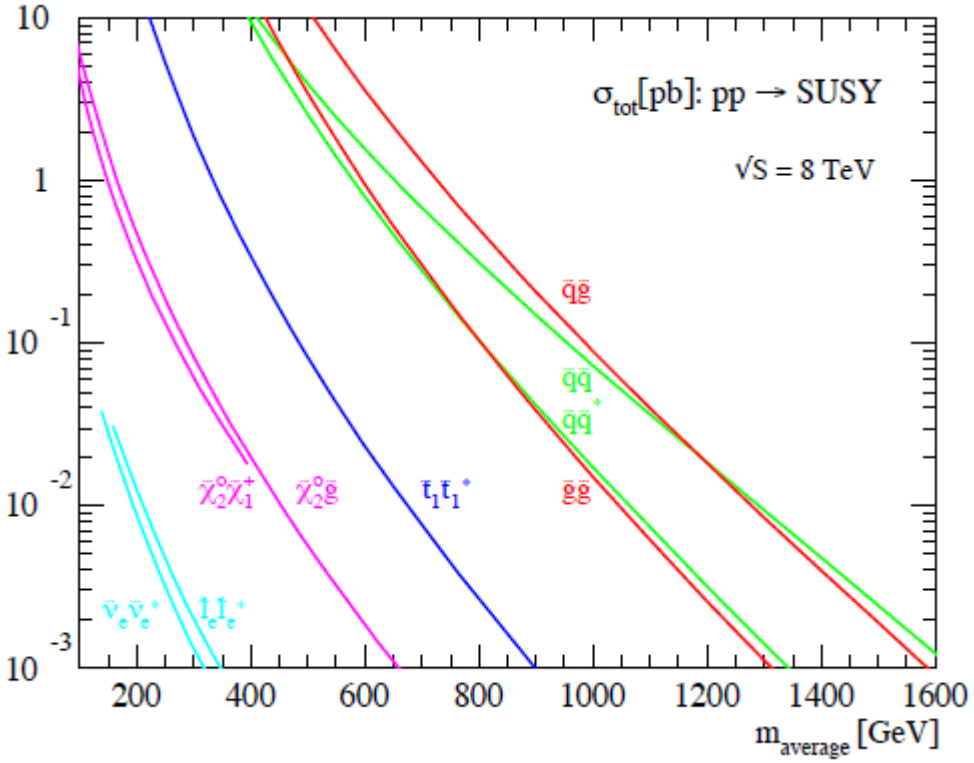
Conclusions

- Presented several new results on Gluino and Squark production with up to 20fb^{-1} of 8TeV data and using shape based analysis with many signal regions.
- Nothing found so far!
- Severly constrained many well motivated SUSY scenarios

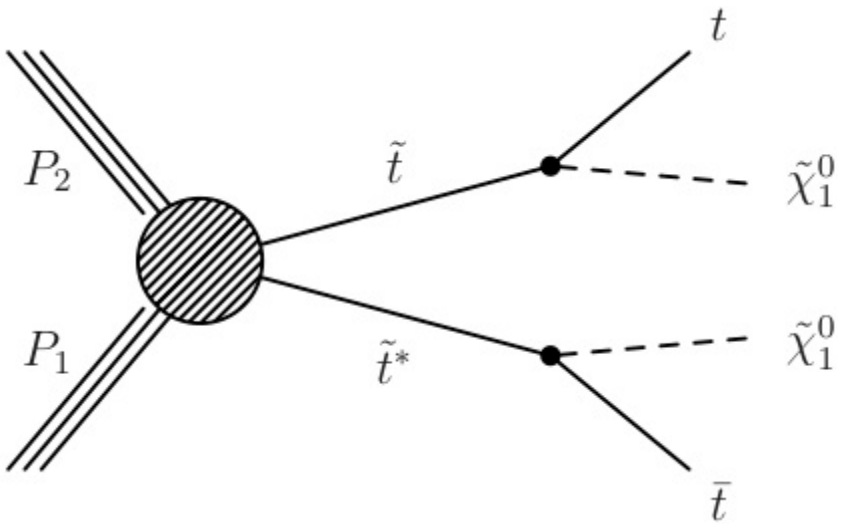
Links: All CMS SUSY results:
https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS
hadronic searches
https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS12028
https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS12024
same-sign + b
https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS12017

Backup

prospino SUSY production x-sec



α_T limits on stop production



Search regions: Njet ≥ 4 and Nbjet = 1 or Nbjet = 2