3^{rd} Generation of SUSY @ CMS

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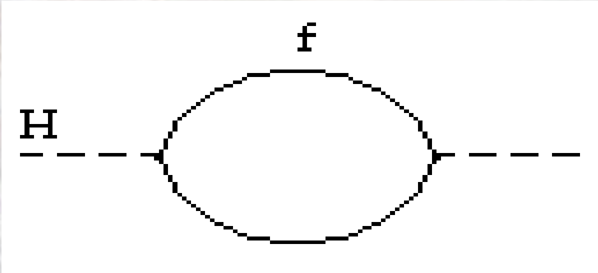
Disclaimer

- It is a short review of the CMS reach plan for search for 3rd generation of SUSY, for a complete review https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS
- Here SUSY is just a paradigm of any new physics in which stable neutral particles (e.g. Dark Matter candidates) are produced in the cascade of pair-produced heavy particles
- Some Materials are barrowed from

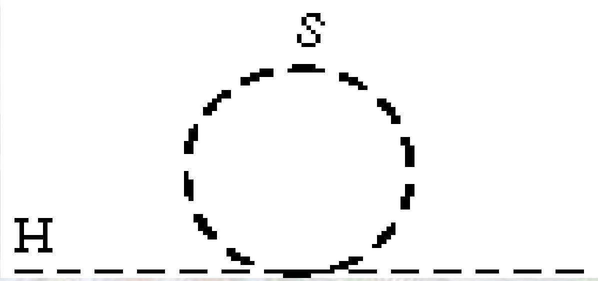
Maria D'Alfonso @ SUSY2013

Why SUperSYmmetry

SM describes a lot of experimental
results very precisely, but fermionic loop corrections to higgs mass diverge quadratically:



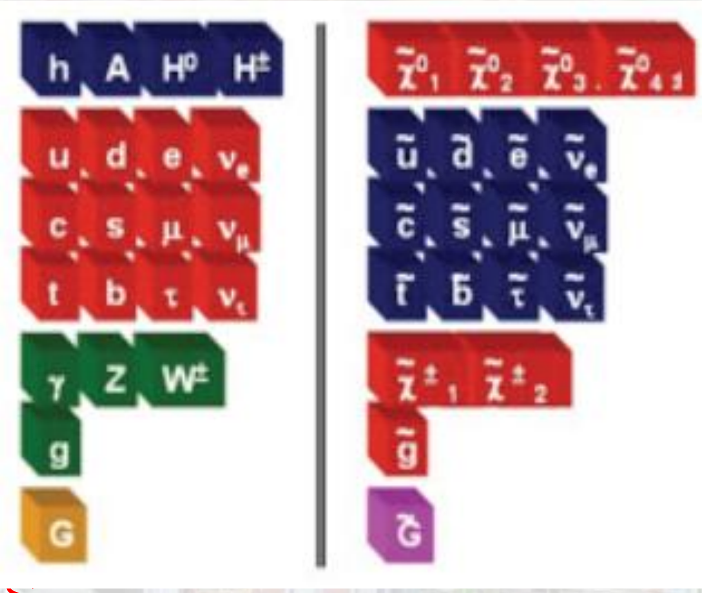
Huge disparity between EW scale and M_{pl} is not natural (Hierarchy Problem)



SUSY introduces new particles that cancel quadratic div and fill the scale between EW and M_{pl} (solves the hierarchy problem).

Important Features

- Every SM particle has a SUSY partner (sparticle) which are e same, but differ in spin by ½ .
- $R = (-1)^{2S+3B+L}$
- Consider R-parity conservatio
  → pair-production of sparticles
- Lightest SUSY particle (LSP) stable
  → dark matter candidate
- Hadron collider: squark/gluino production is dominant (if not too heavy).

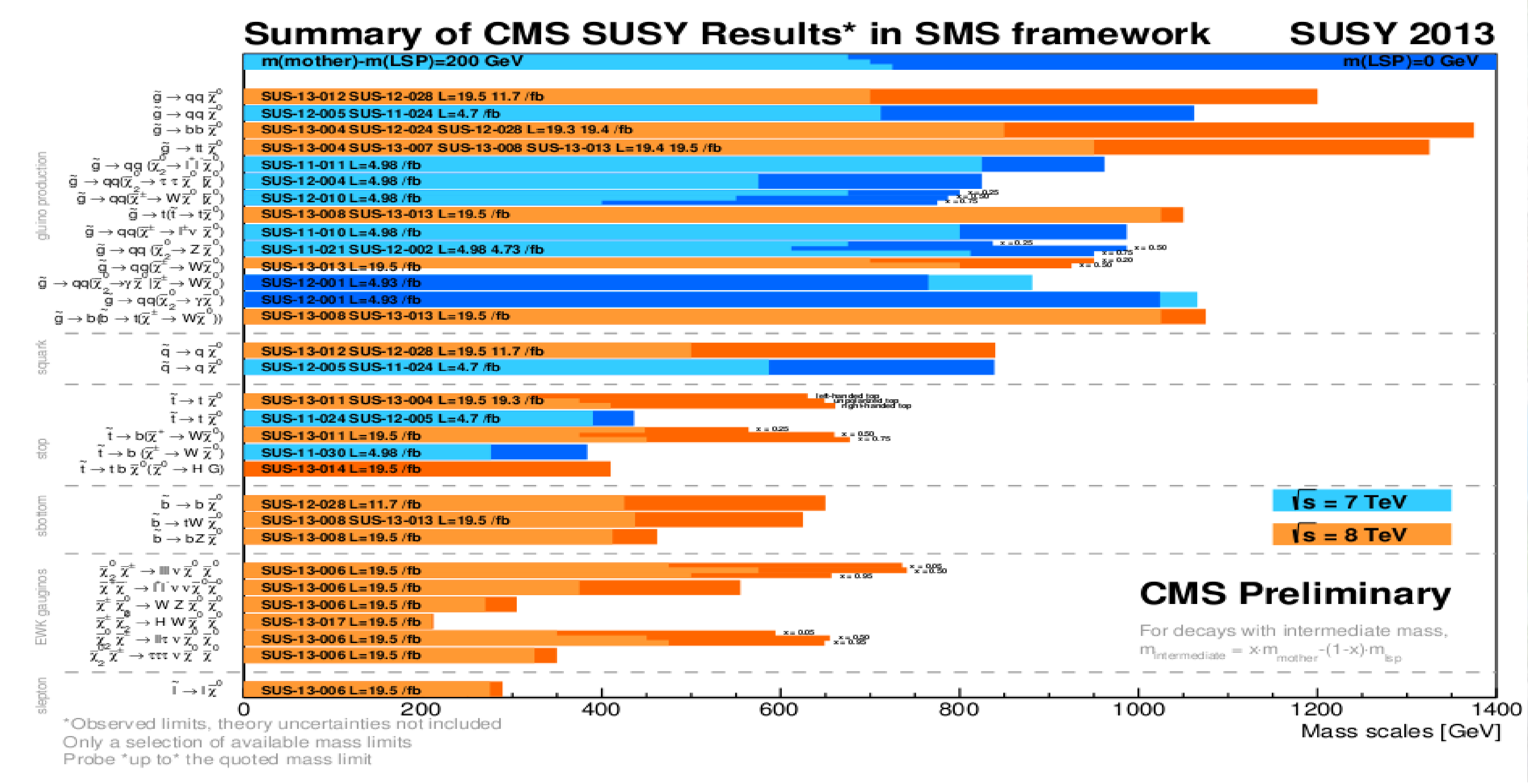


Post-Higgs Discovery Era

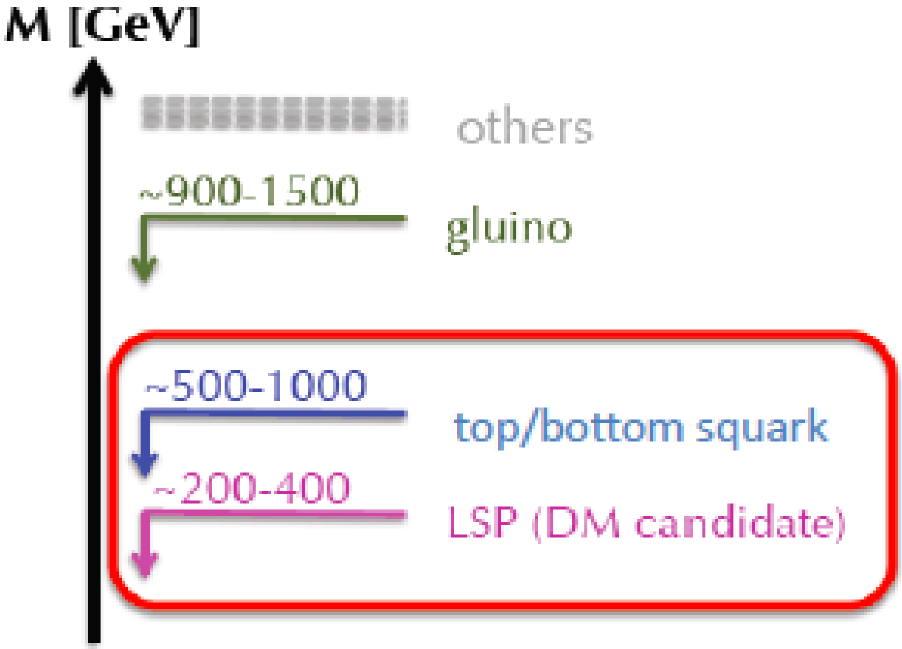
There is at least one Higgs with M_H = 125.0 GeV.

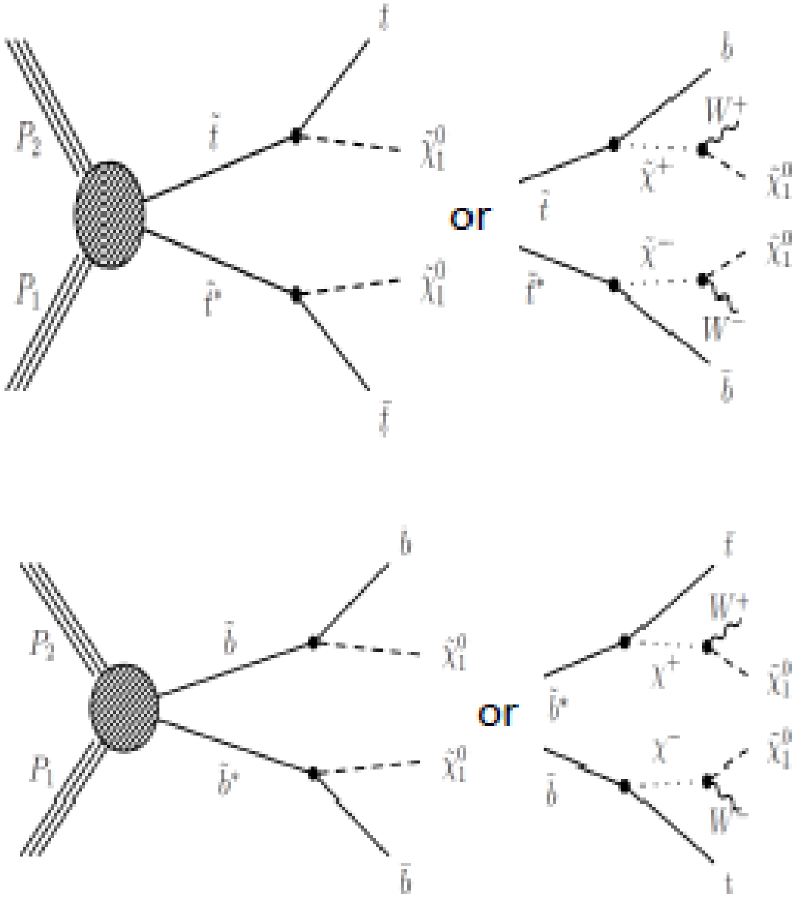
There is not any gluino/light squark with M < ~1 TeV.

Third generation is the only accessible part of SUSY?!



Stop/Sbottom Production





Typical cross section stop/sbottom:
2 pb @ 300 GeV
0.025 pb @ 600 GeV

SM TTbar ~ 230 pb

SUSY13, Trieste, 8/29/13 M.D'Alfonso (CERN) 3

Stop Decays

No single signature dominates:

1. Fully hadronic

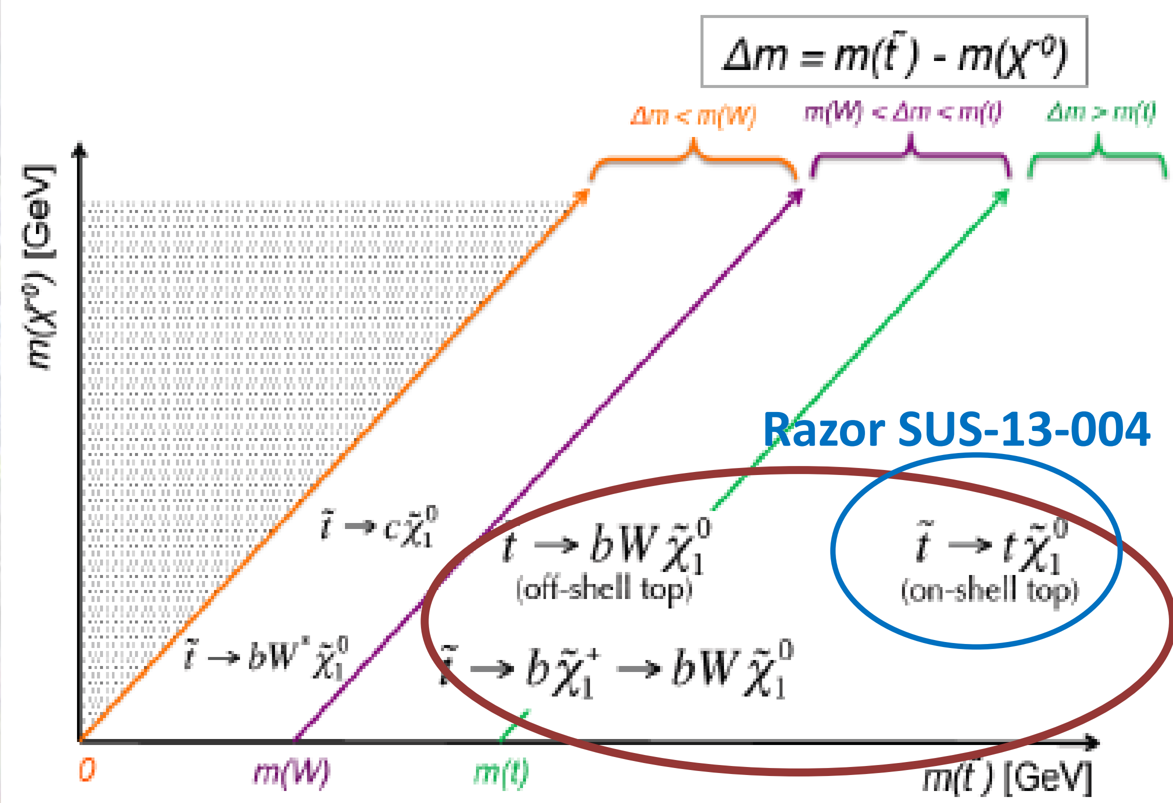
   high BR, large QCD bkg

2. SemiLeptonic

   moderate BR/bkg

3. Dileptonic

   low BR, small bkg

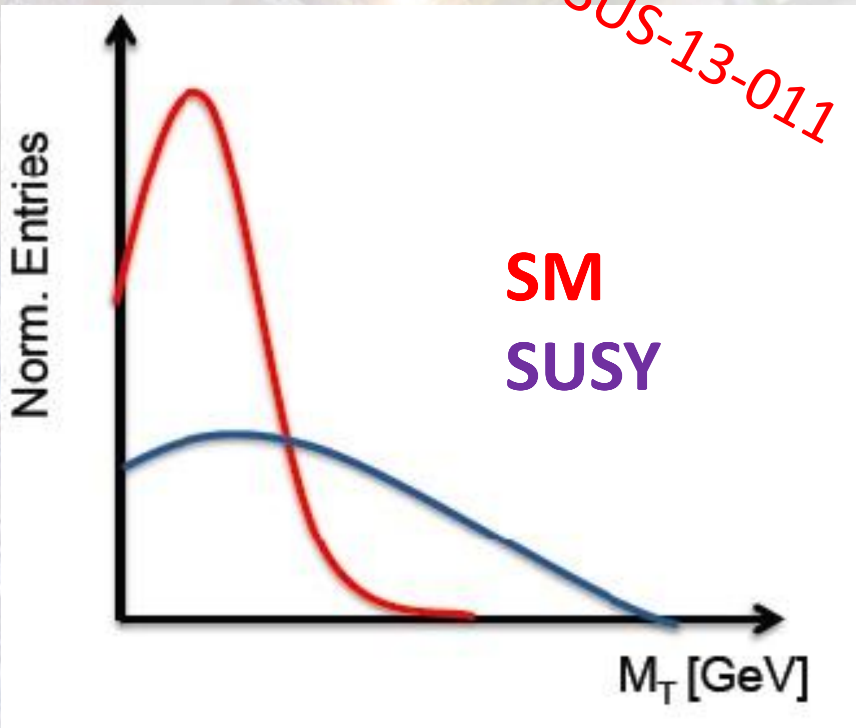


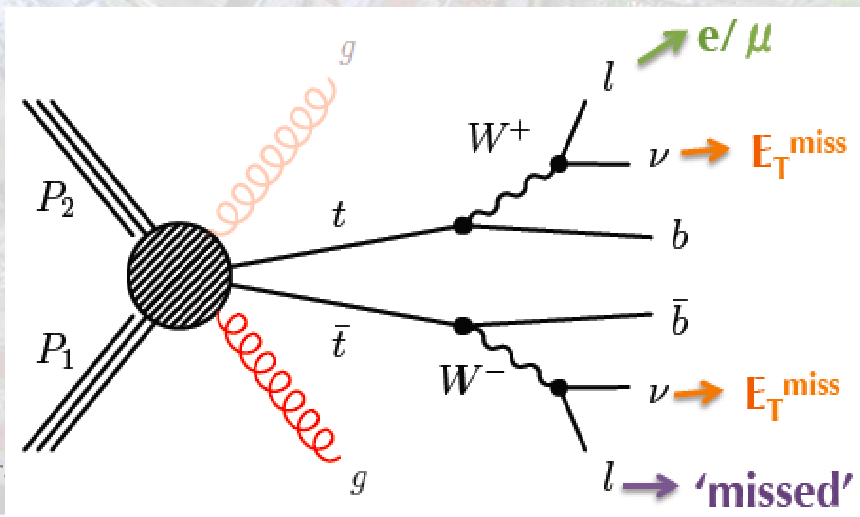
MET/MT SUS-13-011

Single Lepton

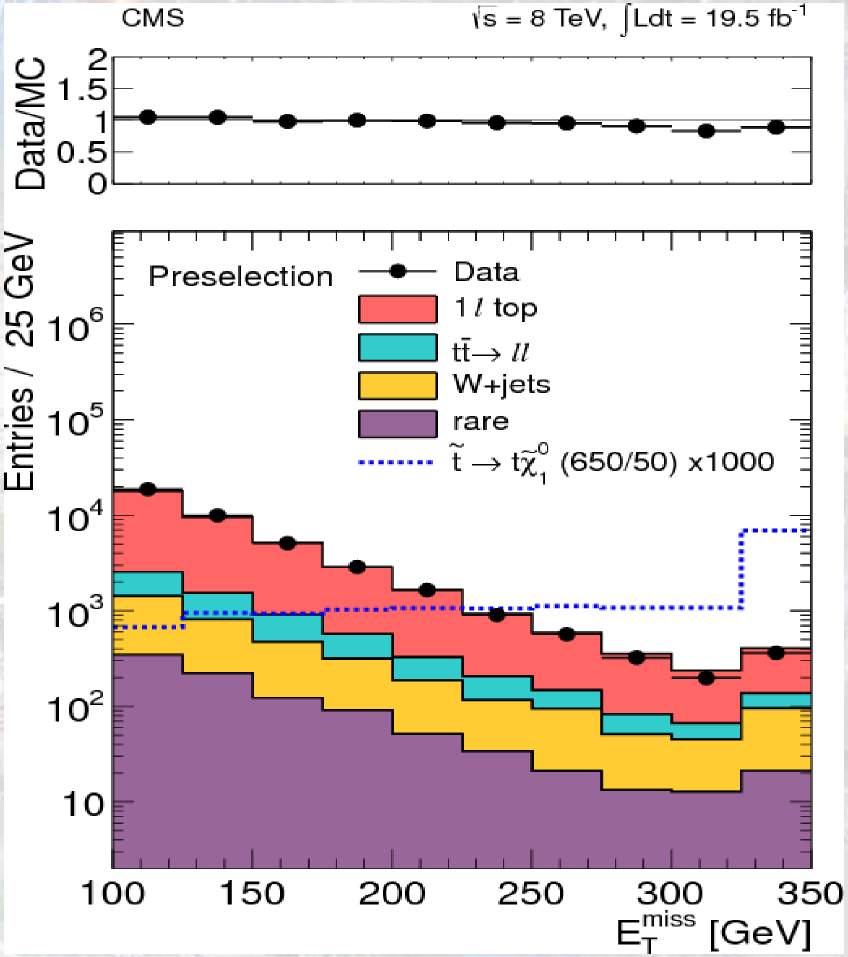
CMS PAS SUS-13-011

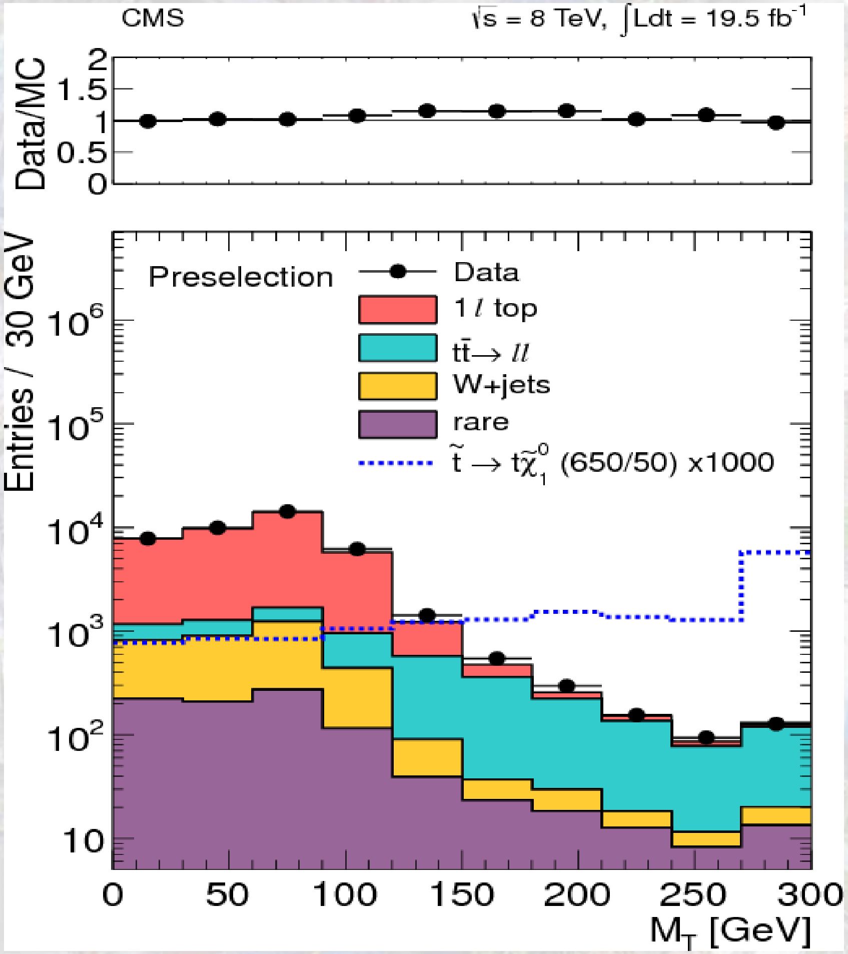
- One and only one lepton
- >= 4 jets with >= 1bjet
- Backgrounds
  - Wjets, ttbar, single top
  - Zjets when a lepton is lost
  - Any fake lepton
- M_T can be a discriminator





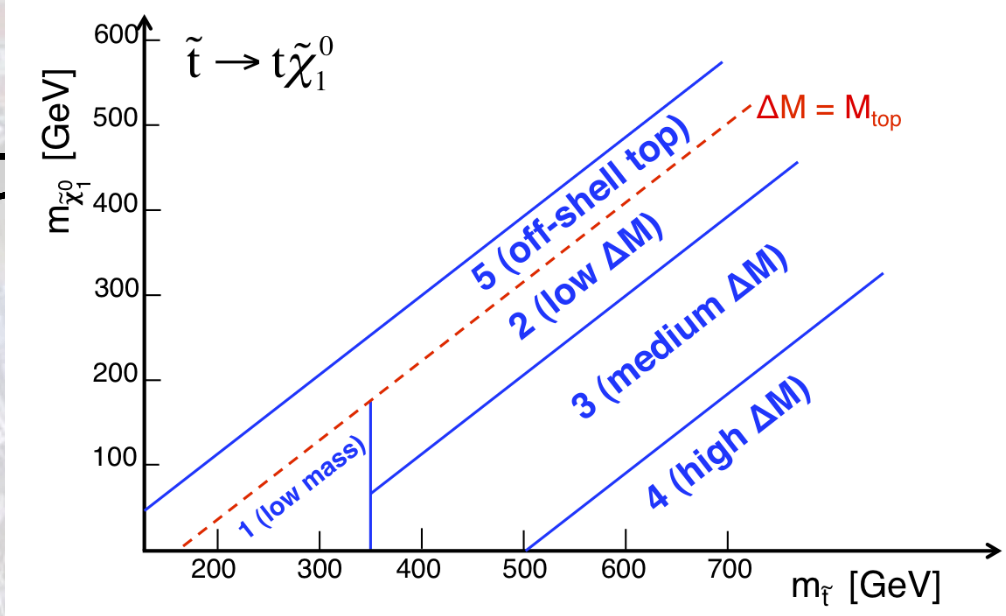
Data/MC Comparison
Data is well modeled in MC.





Selections

- BDT and cut & count
- Different selections for different regions

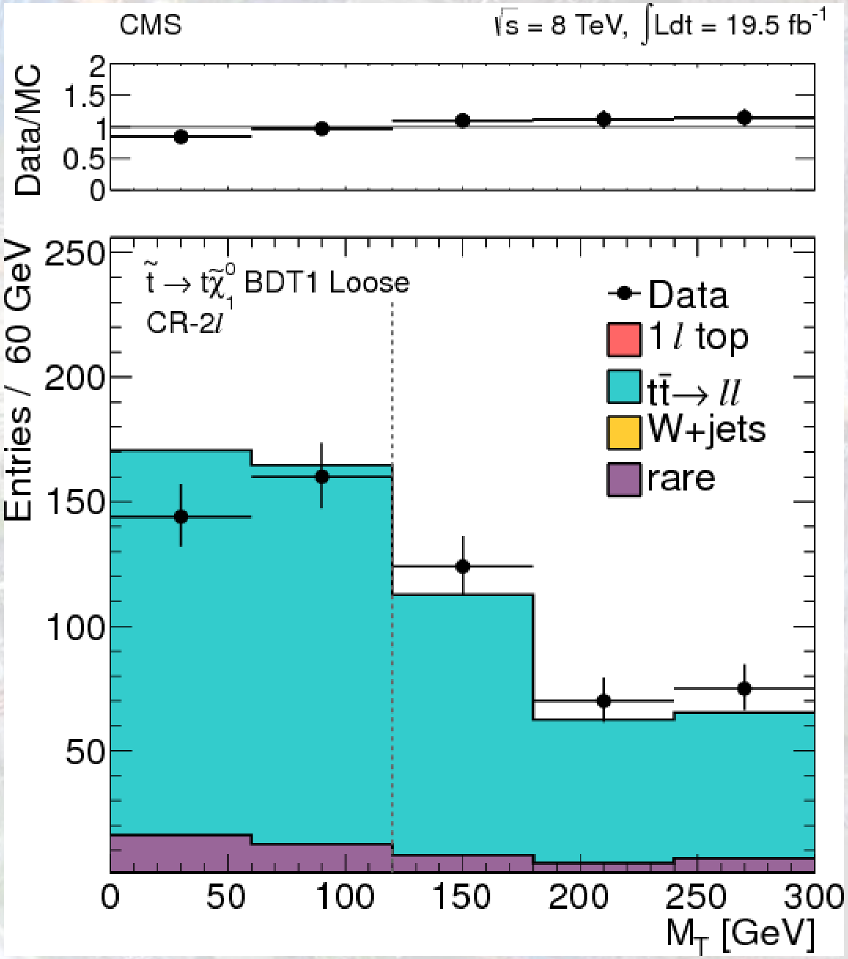


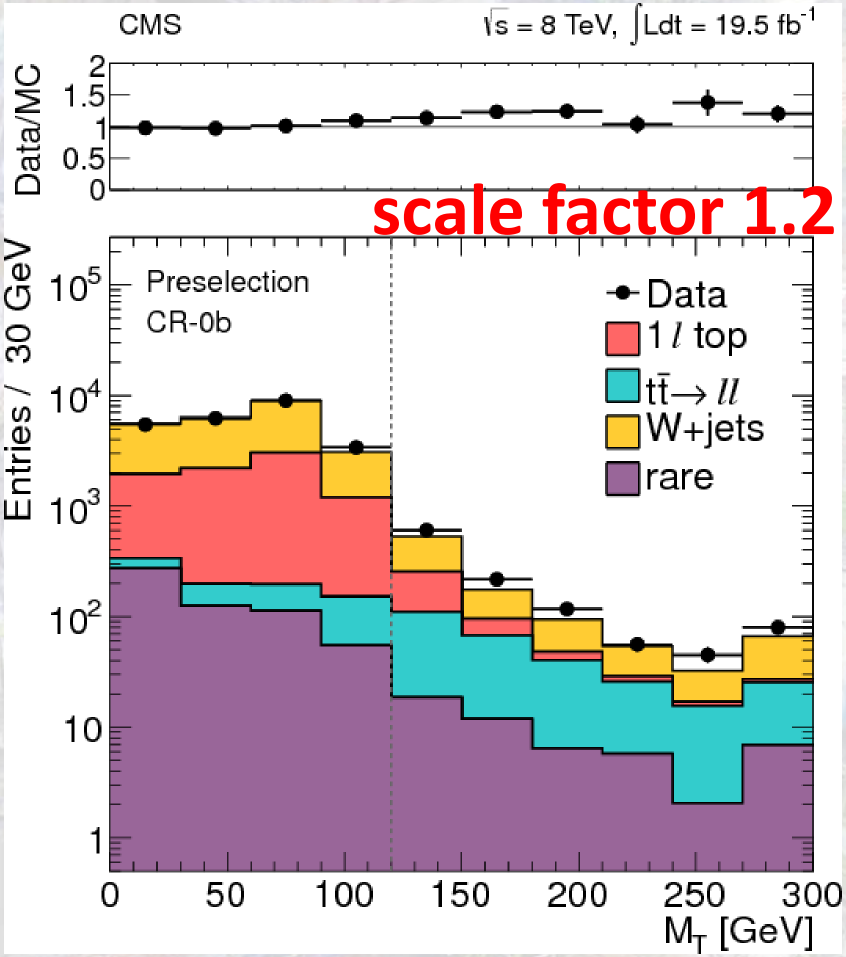
Selection	$\tilde{t} \rightarrow t\tilde{\chi}_1^0$ BDT	$\tilde{t} \rightarrow t\tilde{\chi}_1^0$ cut-based Low ΔM	$\tilde{t} \rightarrow t\tilde{\chi}_1^0$ cut-based High ΔM	$\tilde{t} \rightarrow b\tilde{\chi}_1^+$ BDT	$\tilde{t} \rightarrow b\tilde{\chi}_1^+$ cut-based Low ΔM	$\tilde{t} \rightarrow b\tilde{\chi}_1^+$ cut-based High ΔM
E_T^{miss}(GeV)	yes	$>150, 200, 250, 300$	$>150, 200, 250, 300$	yes	$>100, 150, 200, 250$	$>100, 150, 200, 250$
M_{T2}^W (GeV)	yes		>200	yes		>200
min $\Delta\phi$	yes	>0.8	>0.8	yes	>0.8	>0.8
H_T^{ratio}	yes			yes		
hadronic top χ^2	(on-shell top)	<5	<5			
leading b-jet p_T (GeV)	(off-shell top)			yes		>100
$\Delta R(\ell$,leading b-jet)				yes		
lepton p_T				(off shell W)		

Control Regions, 2l, 0b

Estimated bkg from MC are normalized to MT peak.

Control regions provide the scale factor for MT tail.

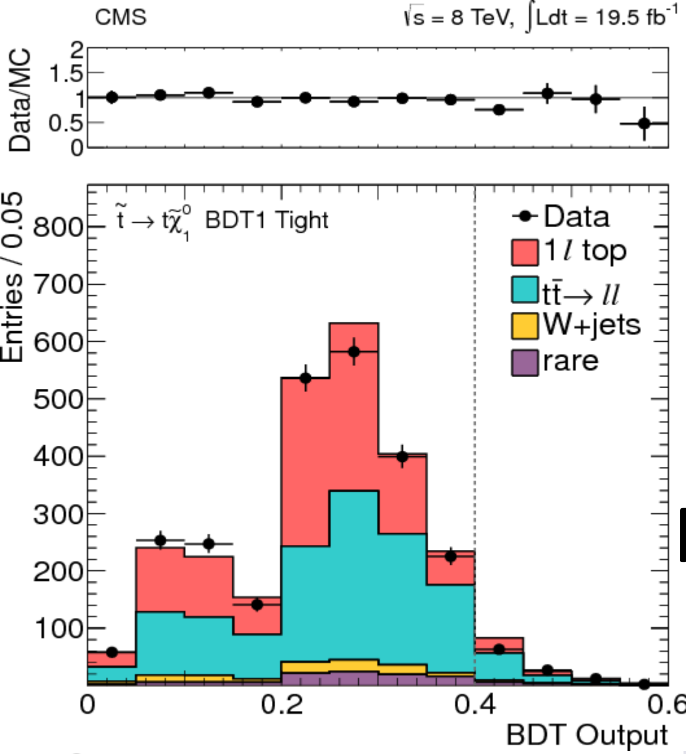


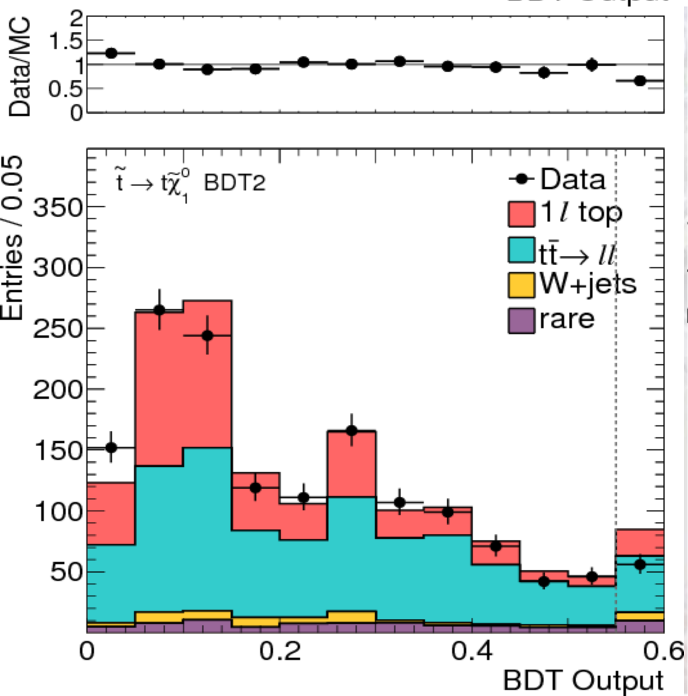


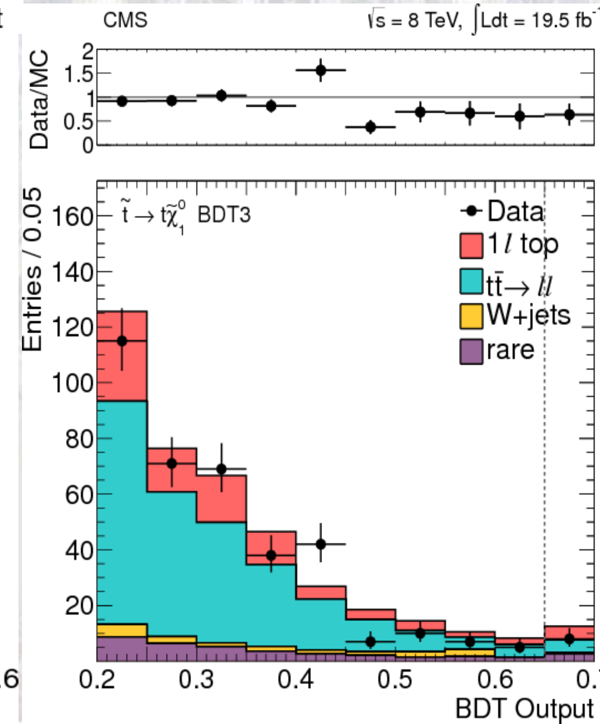
BDT output

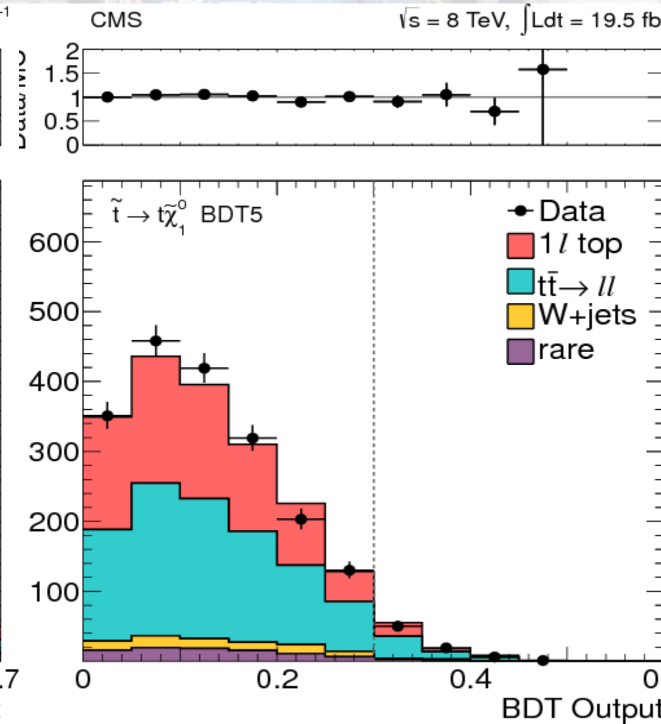
No Excess!

Non of the topologies/decay modes.









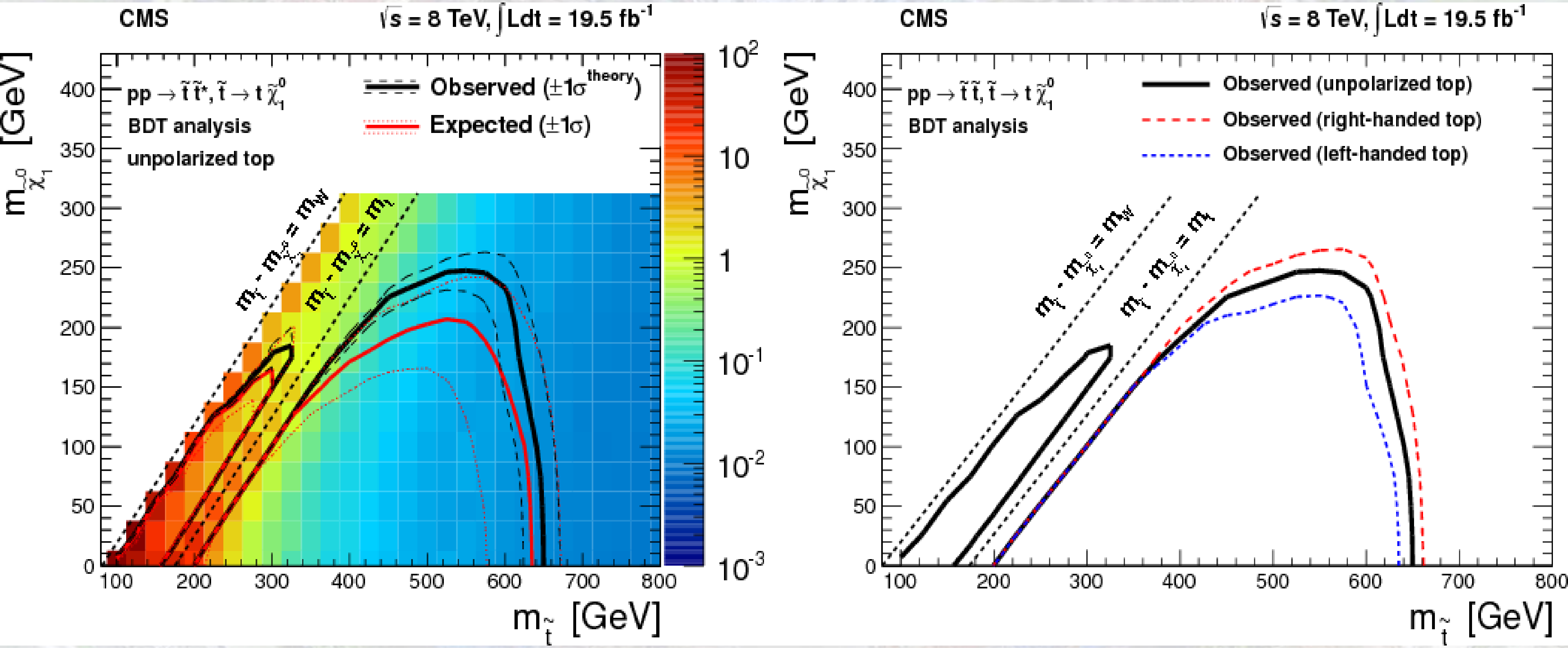
Event Yields

- Dileptonic ttbar is the main bkg everywhere.
- 1l from ttbar/single top is the next to leading one.
- Rare (ttV, VV, VVV, small x-sec) not negligible.

$\tilde{t} \to t\tilde{\chi}_1^0$						
Sample	BDT1 Loose	BDT1 Tight	BDT2	BDT3	BDT4	BDT5
$t\bar{t} \to \ell\ell$	438 ± 37	68 ± 11	46 ± 10	5 ± 2	0.3 ± 0.3	48 ± 13
1ℓ Top	251 ± 93	37 ± 17	22 ± 12	4 ± 3	0.8 ± 0.9	30 ± 12
W+jets	27 ± 7	7 ± 2	6 ± 2	2 ± 1	0.8 ± 0.3	5 ± 2
Rare	47 ± 23	11 ± 6	10 ± 5	3 ± 1	1.0 ± 0.5	4 ± 2
Total	763 ± 102	124 ± 21	85 ± 16	13 ± 4	2.9 ± 1.1	87 ± 18
Data	728	104	56	8	2	76
$\tilde{t} \to t\tilde{\chi}_1^0$ (250/50)	285 ± 8.5	50 ± 3.5	28 ± 2.6	4.4 ± 1.0	0.3 ± 0.3	34 ± 2.9
$\tilde{t} \to t\tilde{\chi}_1^0$ (650/50)	12 ± 0.2	7.2 ± 0.2	9.8 ± 0.2	6.5 ± 0.2	4.3 ± 0.1	2.9 ± 0.1

Interpretation in T2tt Scenario

- The results are interpreted in different scenarios.
- Polarized and upolarized tops are considered.



RAZOR

CMS PAS SUS-13-004

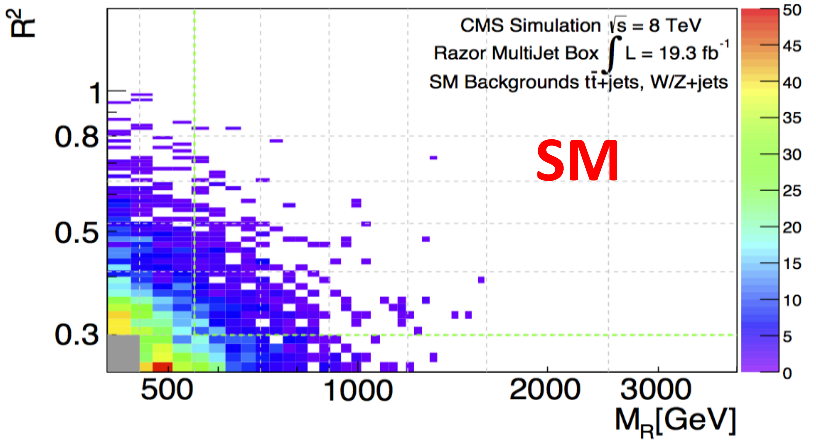
- Razor: Approximates the scale and distribution.

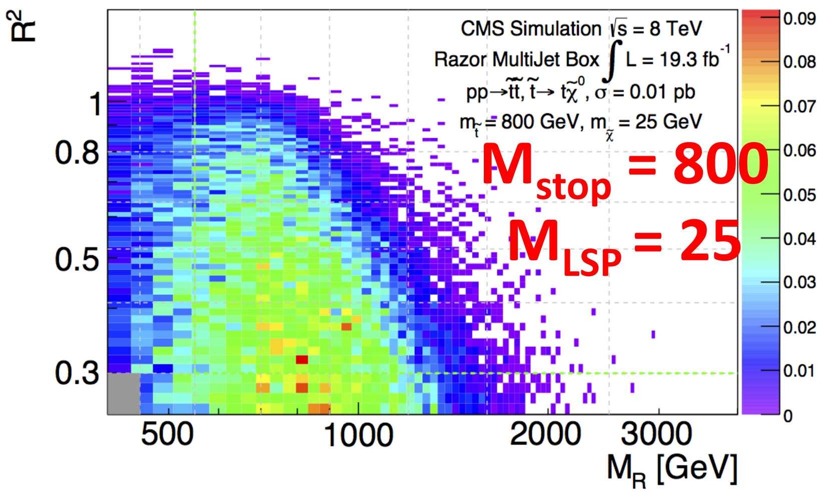
$$M_T^R \equiv \sqrt{\frac{E_T^{miss}(p_T^{j1} + p_T^{j2}) - \vec{E}_T^{miss} \cdot (\vec{p}_T^{\,j1} + \vec{p}_T^{\,j2})}{2}}$$

$$M_R \equiv \sqrt{(E_{j_1} + E_{j_2})^2 - (p_z^{j_1} + p_z^{j_2})^2}$$

$$R \equiv \frac{M_T^R}{M_R}$$

- > 2Jets: Minimizing the sum of M^2 of megajets.



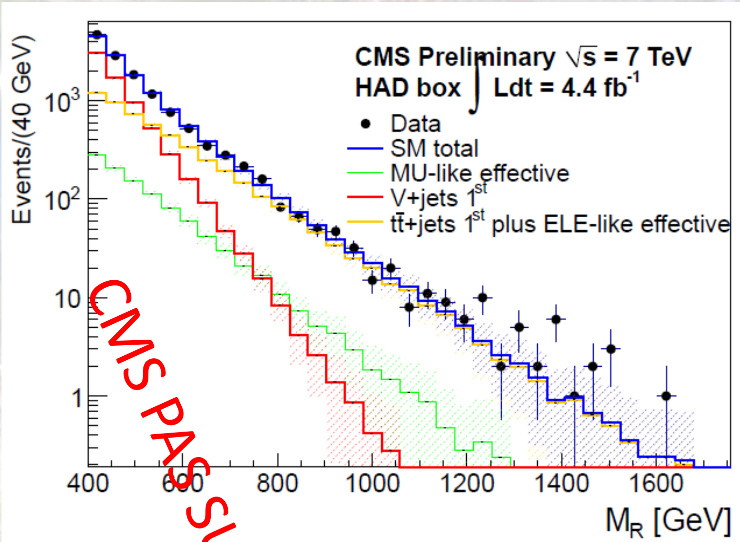


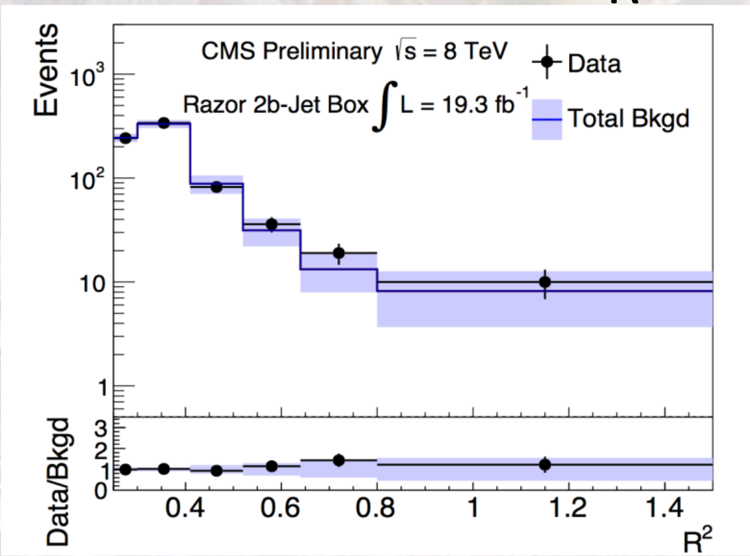
It is an inclusive search, with variety of selections, targeting different topologies.

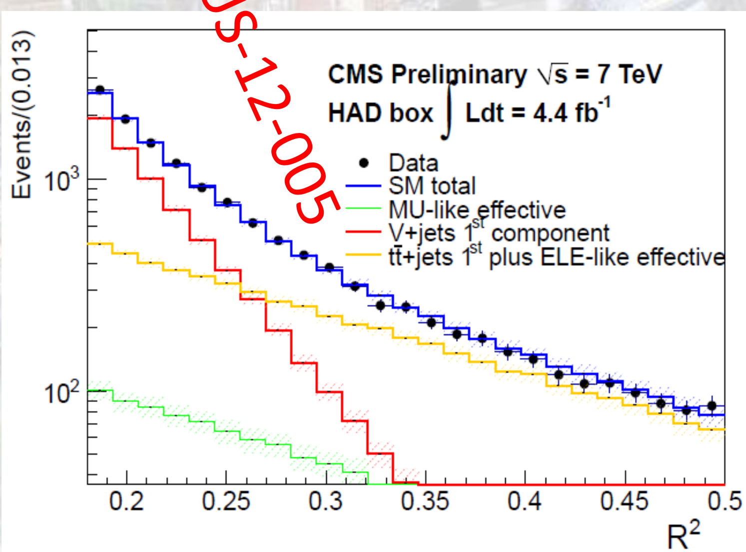
Box	lepton	b-tag	kinematic	jet
Dilepton Boxes				
MuEle	≥ 1 tight electron and ≥ 1 loose muon	≥ 1 b-tag	($M_R > 300$ GeV and $R^2 > 0.15$) and ($M_R > 450$ GeV or $R^2 > 0.2$)	≥ 2 jets
MuMu	≥ 1 tight muon and ≥ 1 loose muon	≥ 1 b-tag	($M_R > 300$ GeV and $R^2 > 0.15$) and ($M_R > 450$ GeV or $R^2 > 0.2$)	≥ 2 jets
EleEle	≥ 1 tight electron and ≥ 1 loose electron	≥ 1 b-tag	($M_R > 300$ GeV and $R^2 > 0.15$) and ($M_R > 450$ GeV or $R^2 > 0.2$)	≥ 2 jets
Single Lepton Boxes				
MuMultiJet	≥ 1 tight muon	≥ 1 b-tag	($M_R > 300$ GeV and $R^2 > 0.15$) and ($M_R > 450$ GeV or $R^2 > 0.2$)	≥ 4 jets
MuJet	≥ 1 tight muon	≥ 1 b-tag	($M_R > 300$ GeV and $R^2 > 0.15$) and ($M_R > 450$ GeV or $R^2 > 0.2$)	2 or 3 jets
EleMultiJet	≥ 1 tight electron	≥ 1 b-tag	($M_R > 300$ GeV and $R^2 > 0.15$) and ($M_R > 450$ GeV or $R^2 > 0.2$)	≥ 4 jets
EleJet	≥ 1 tight electron	≥ 1 b-tag	($M_R > 300$ GeV and $R^2 > 0.15$) and ($M_R > 450$ GeV or $R^2 > 0.2$)	2 or 3 jets
Hadronic Boxes				
MultiJet	none	≥ 1 b-tag	($M_R > 400$ GeV and $R^2 > 0.25$) and ($M_R > 550$ GeV or $R^2 > 0.3$)	≥ 4 jets
2b-Jet	none	≥ 2 b-tag	($M_R > 400$ GeV and $R^2 > 0.25$) and ($M_R > 550$ GeV or $R^2 > 0.3$)	2 or 3 jets

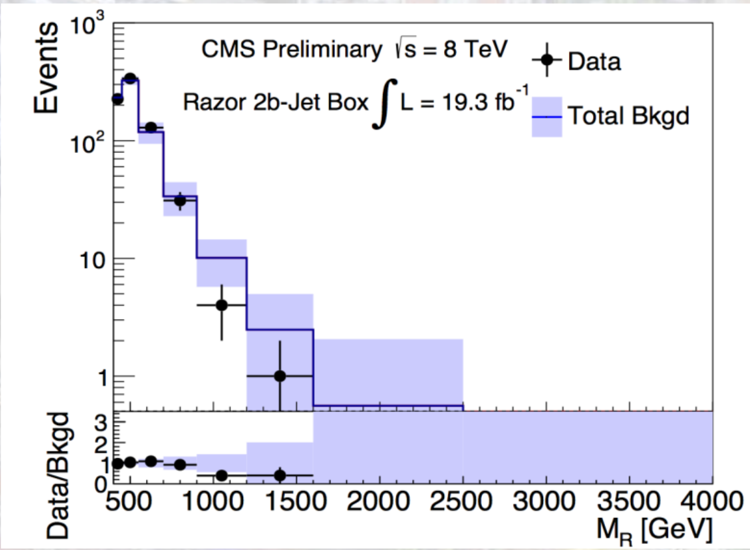
Stop Search

Bkg predicted by a fit to 2D templates (M_R, R^2)

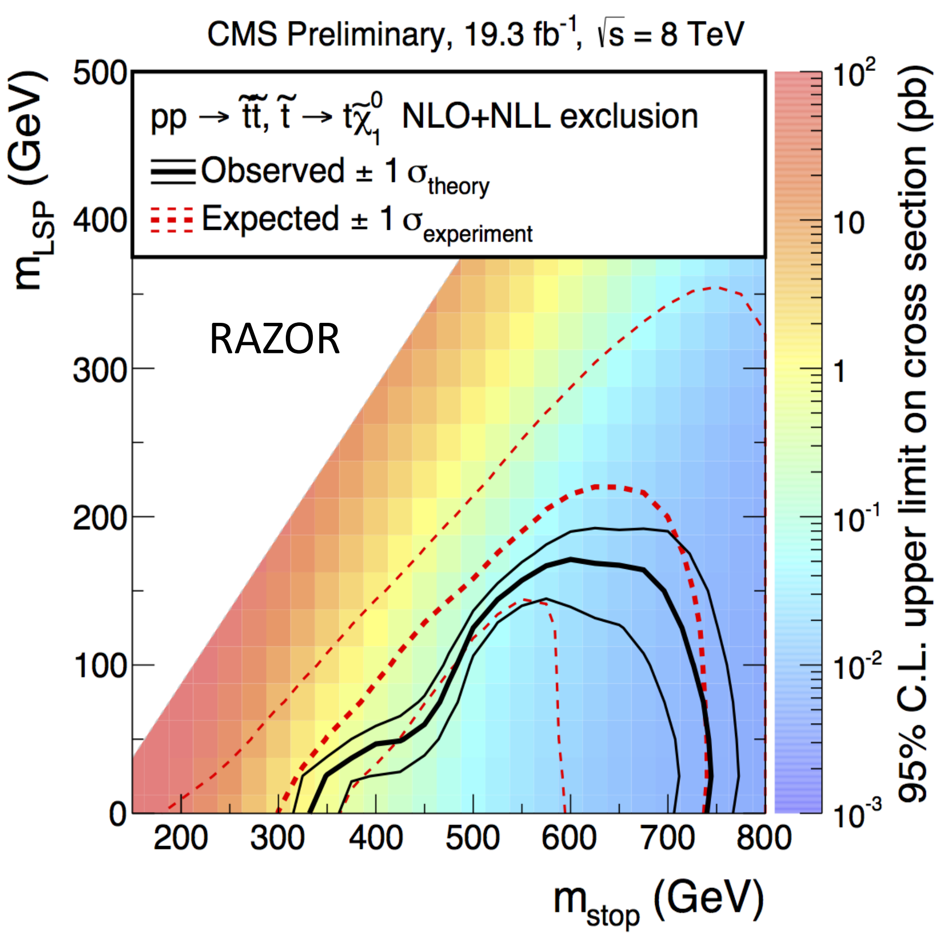


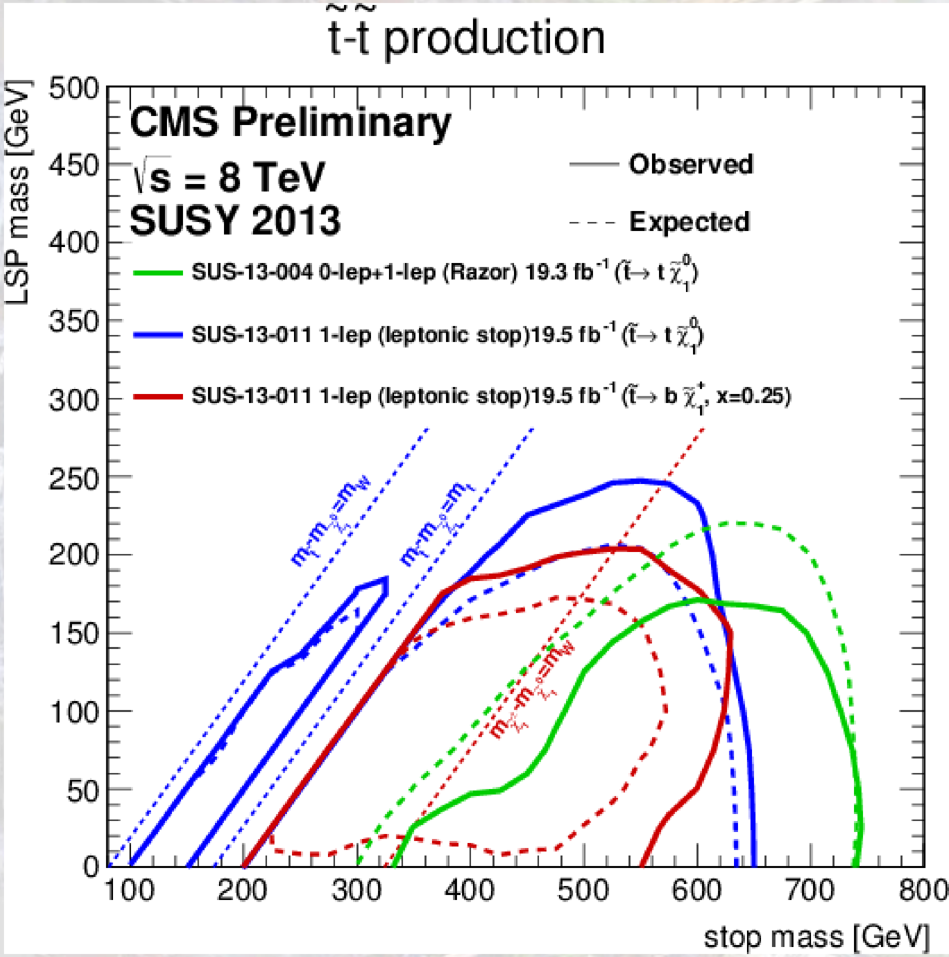






Summary of the direct stop search

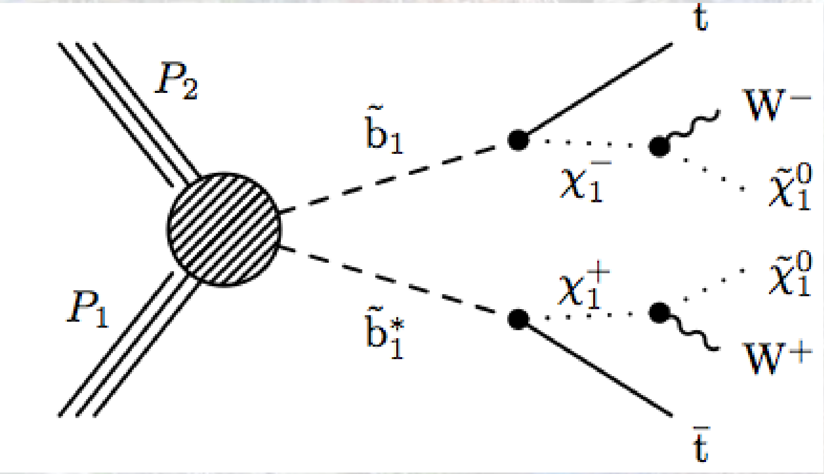


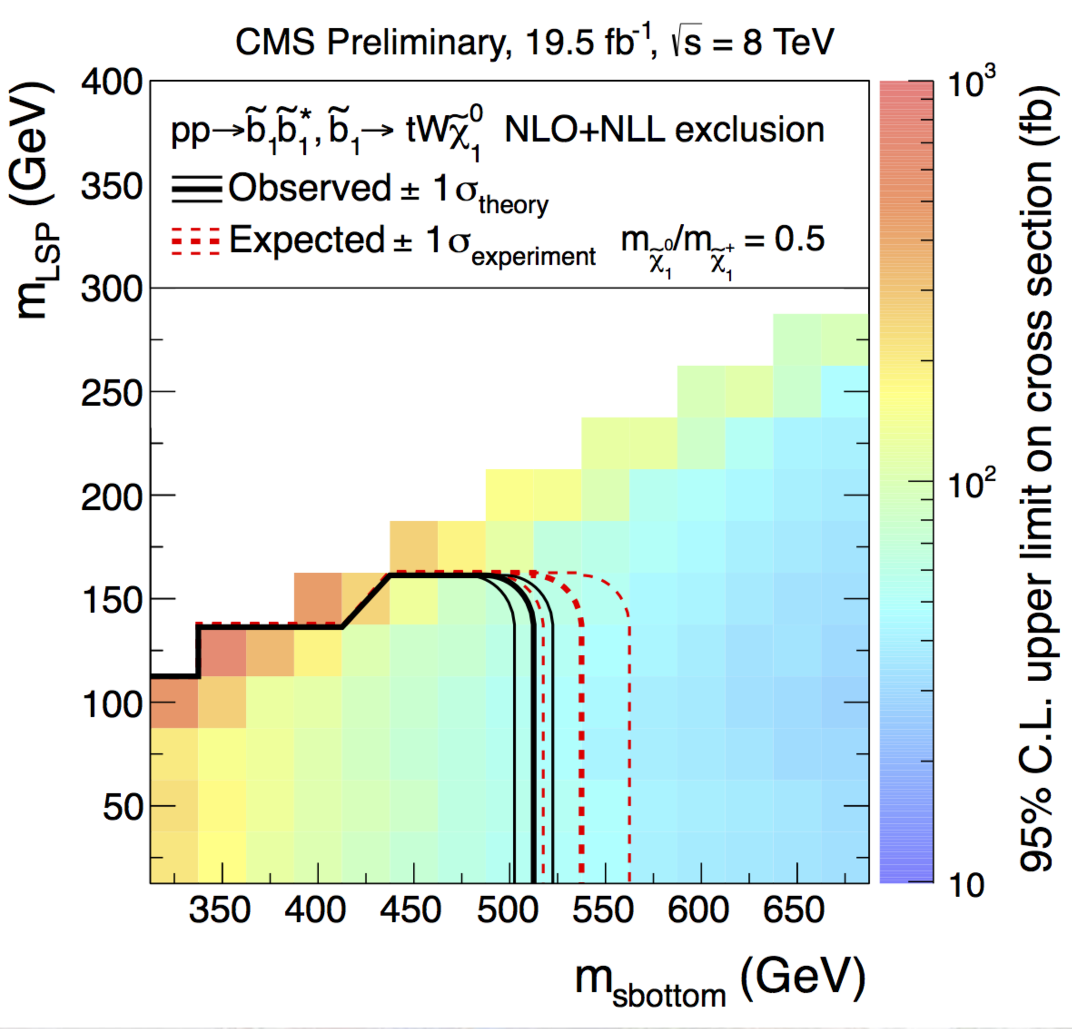


Constraints from Other Searches

CMS PAS SUS-13-013

- There are some searches, not tuned for 3rd gen, but can constrain the phase space.
- E.g, Same Sign dilepton +b. (heavy sbottom)

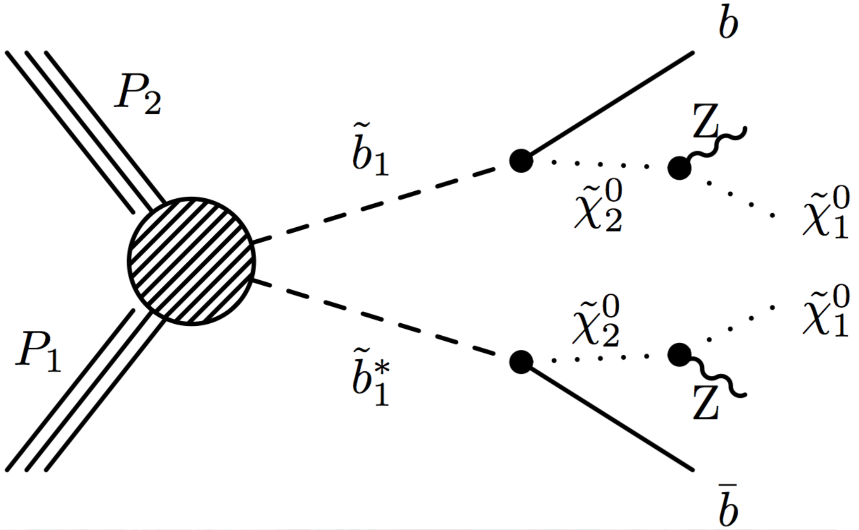


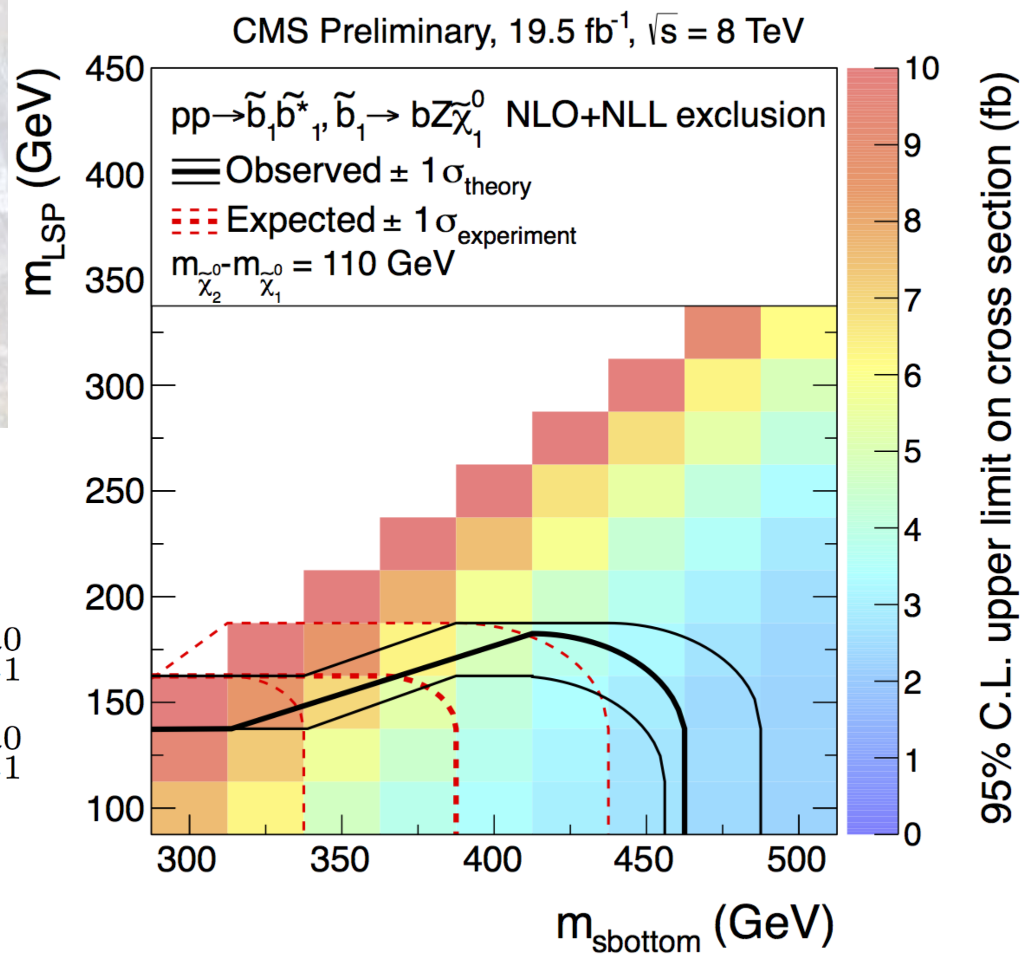


CMS PAS SUS-13-008

3 Lepton + b

A classic channel for SUSY search (3l + jets) gets sensitive to 3[rd] generation after asking for an extra bjet.

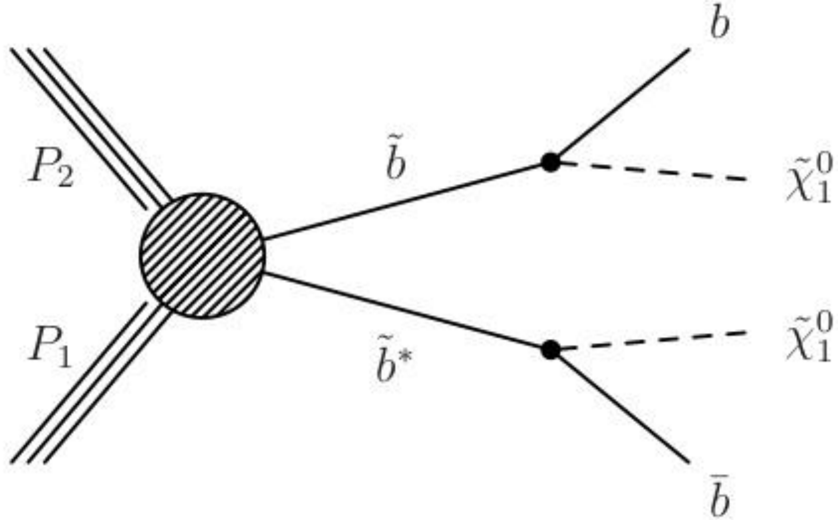


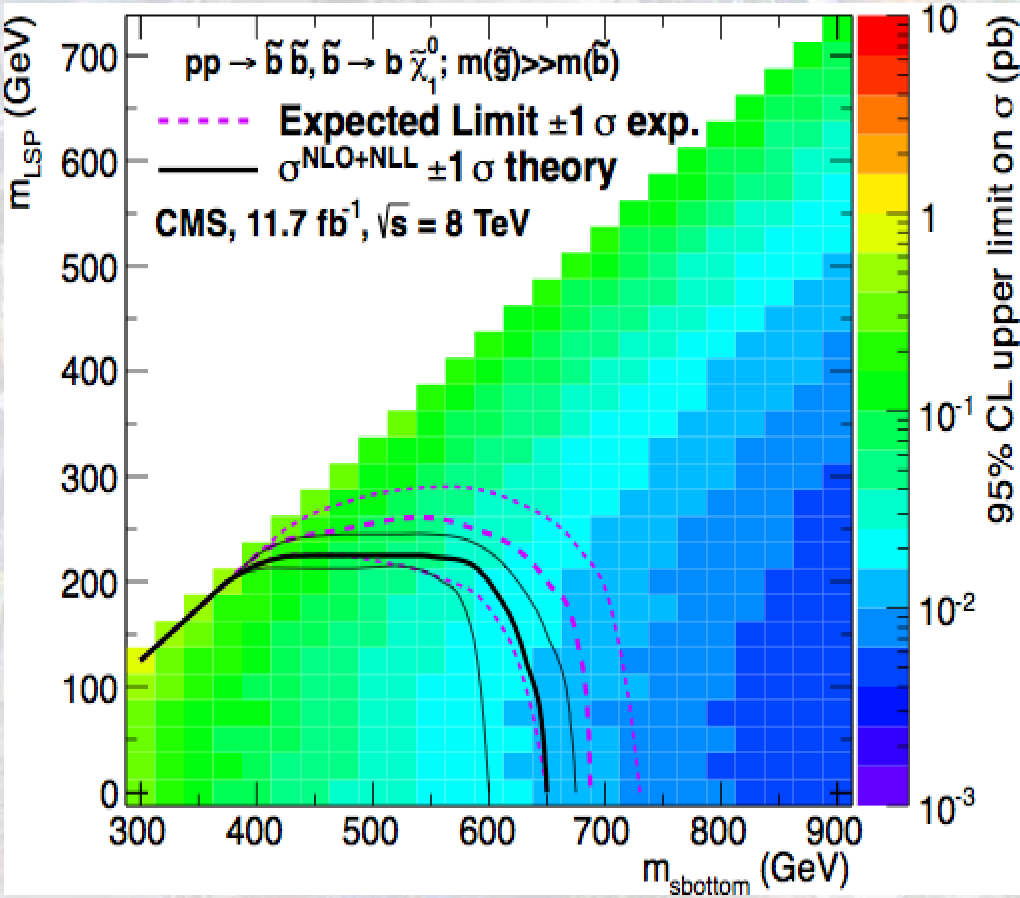


α_T + b

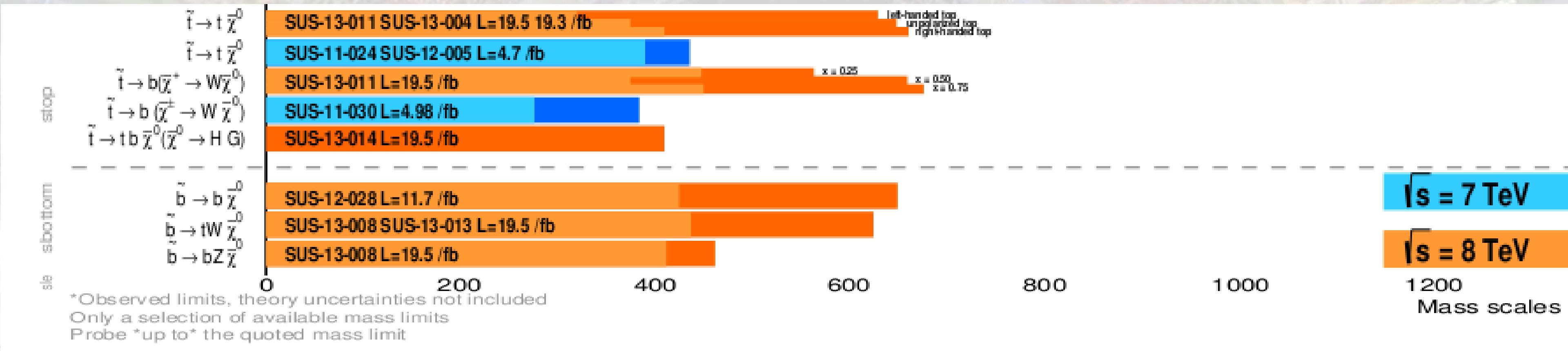
CMS PAS SUS-12-028

A QCD safe, hadronic search for SUSY asks for an extra b.





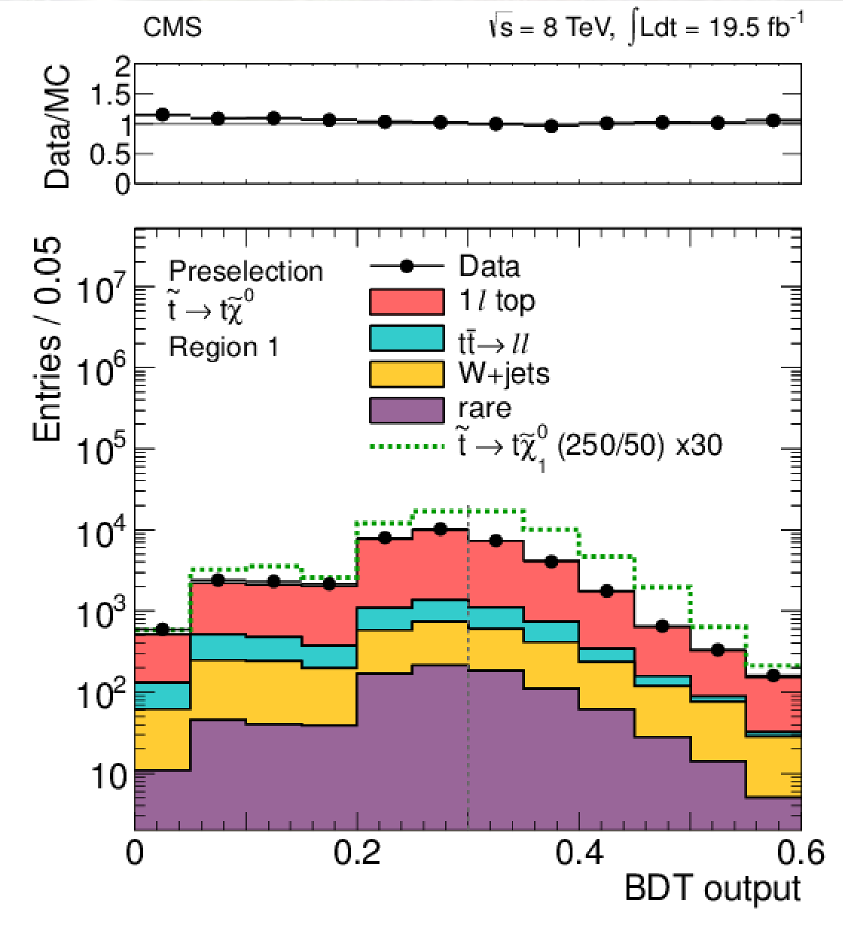
Summary and Conclusion

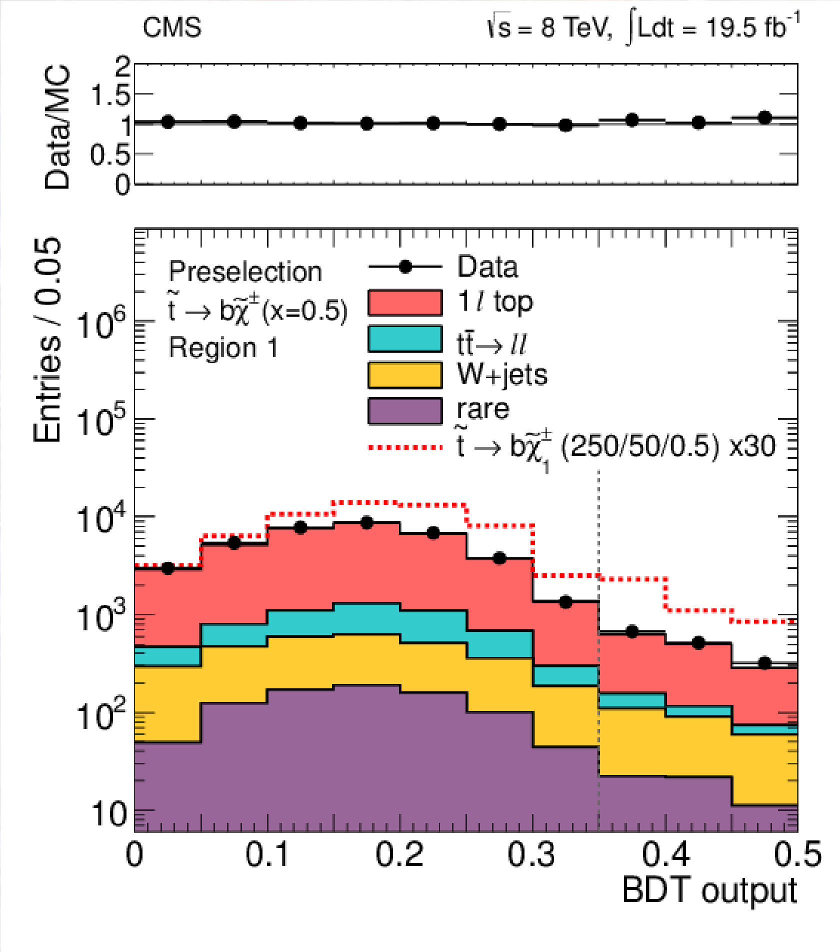


- CMS has a reach plan to search for 3rd generation of SUSY.
- Stau is the missing part, will be covered soon.
- Be tuned for SUSY results in 14 TeV @ 2015.

Back up

Data/MC Comparison for BDT





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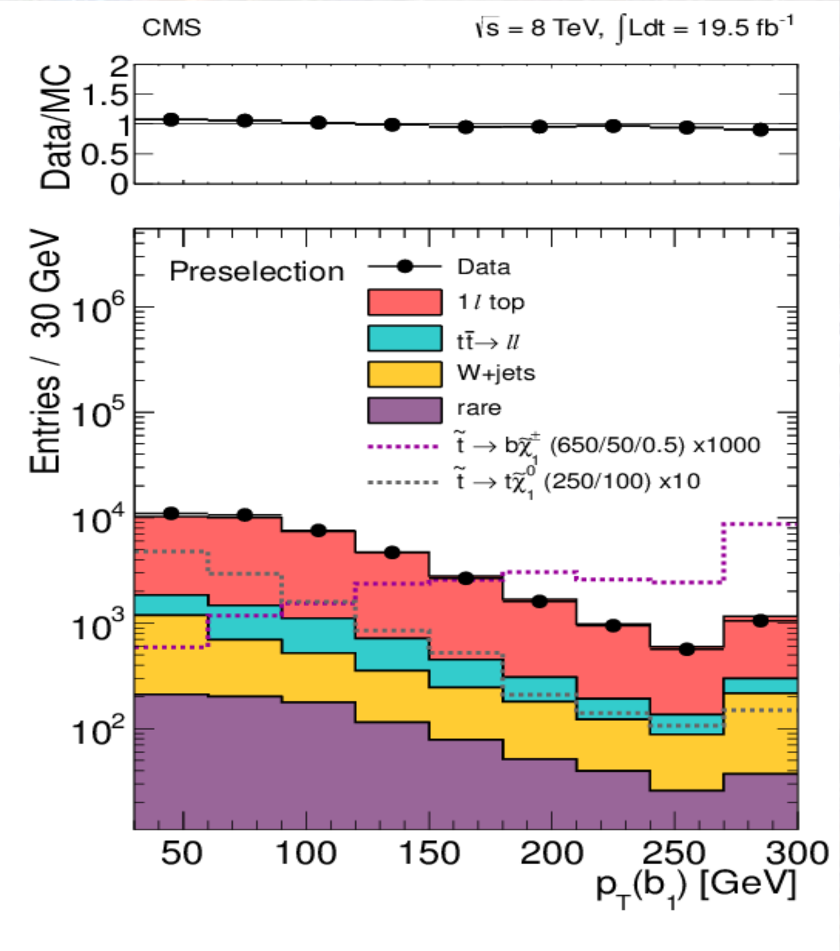

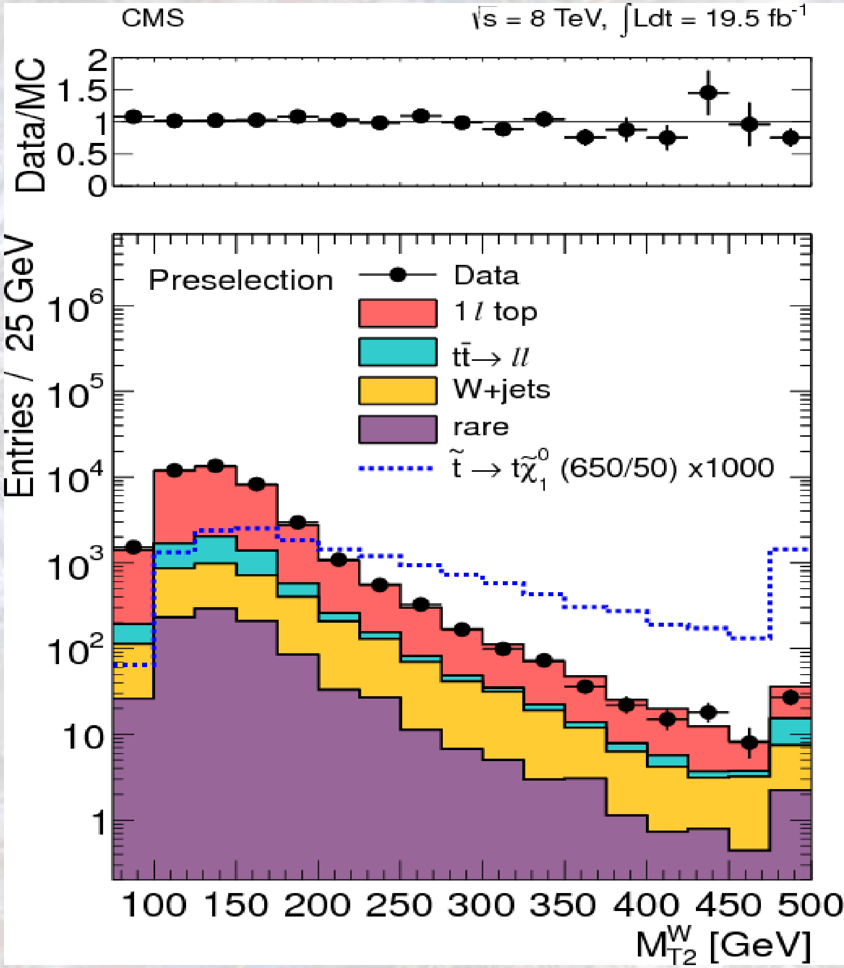

Uncertainties!
1Lepton Stop Search

$\tilde{t} \to t\tilde{\chi}_1^0$						
Sample	BDT1 Loose	BDT1 Tight	BDT2	BDT3	BDT4	BDT5
M_T peak data and MC (stat)	1.0	2.1	2.7	5.3	8.7	3.0
$t\bar{t} \to \ell^+\ell^-$ N_{jets} modeling	1.7	1.6	1.6	1.1	0.4	1.7
$t\bar{t} \to \ell^+\ell^-$ (CR-ℓt and CR-2ℓ tests)	4.0	8.2	11.0	12.5	7.2	13.8
2nd lepton veto	1.5	1.4	1.4	0.9	0.3	1.4
$t\bar{t} \to \ell^+\ell^-$ (stat)	1.1	2.8	3.4	7.0	7.4	3.3
W+jets cross section	1.6	2.2	2.8	1.7	2.7	2.2
W+jets (stat)	1.1	1.9	2.0	4.6	10.8	5.2
W+jets SF uncertainty	8.3	7.7	6.8	8.1	9.7	8.6
1-ℓ Top (stat)	0.4	0.8	0.8	1.4	4.4	1.2
1-ℓ Top tail-to-peak ratio	9.0	11.4	12.4	19.6	28.5	9.1
rare cross sections	1.8	3.0	4.0	8.1	15.7	0.7
Total	13.4	17.1	19.3	27.8	38.4	20.2