SUSY in Dileptonic final states at CMS

Second IPM Meeting on LHC Physics, IPM, TEHRAN (IPMLHC2013)

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for the CMS Collaboration

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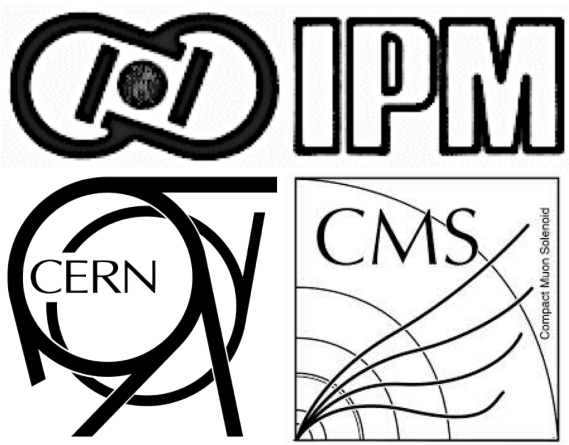
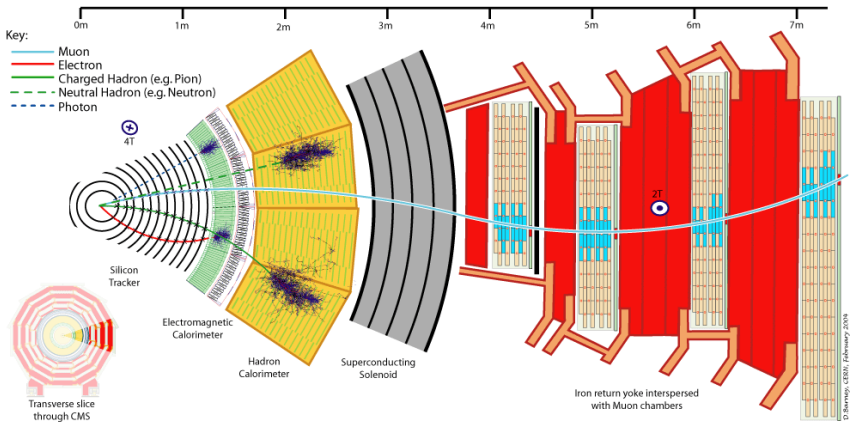
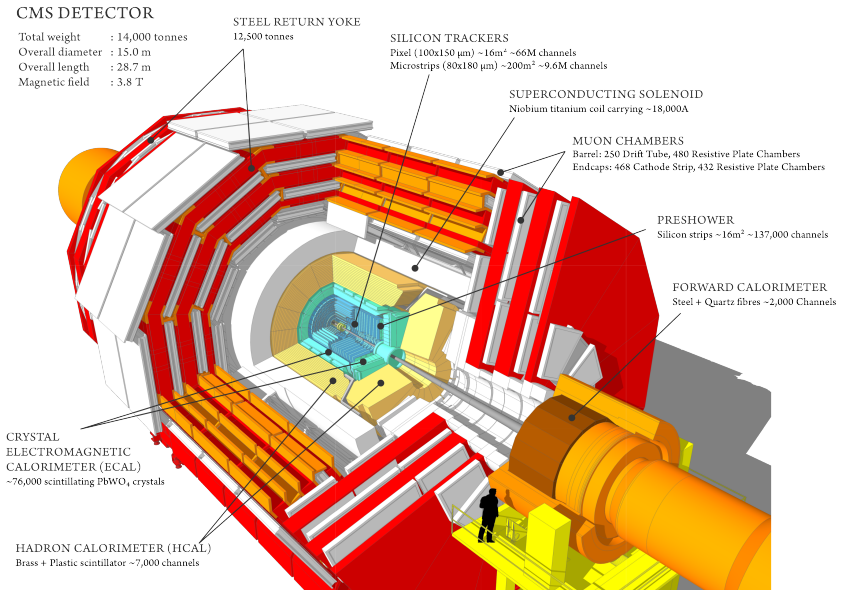


About CMS Detector

- A general purpose detector.
- Detecting Electrons, Muons, Photons and Charged and Neutral Hadrons.
- Reconstructing MET and Tagging $\tau-$leptons and b-quarks.
- Using the following Sub-Detectors:
  - Silicon Trackers
  - Crystal Electromagnetic Calorimeter (ECAL)
  - Hadron Calorimeter (HCAL)
  - Superconducting Solenoid
  - Forward Calorimeter
  - Muon Chambers





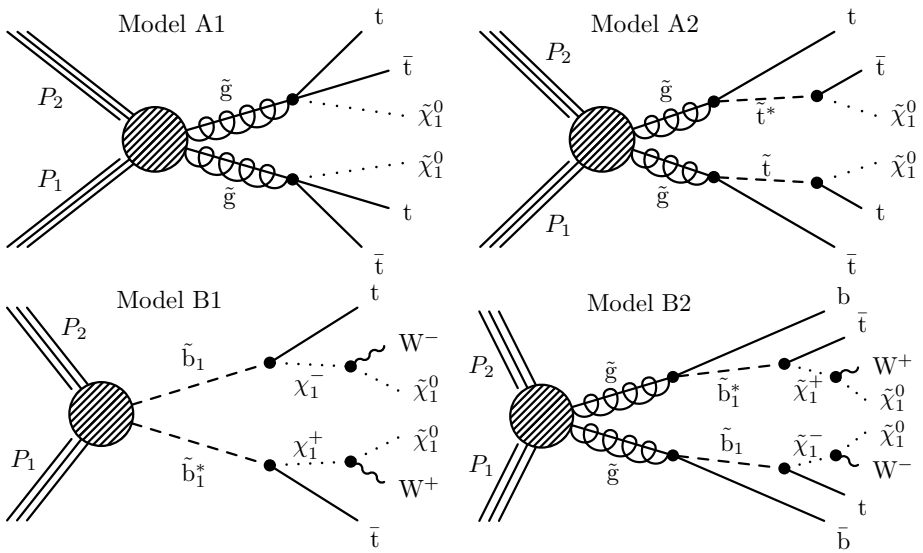
https://cms-docdb.cern.ch/cgi-bin/PublicDocDB/RetrieveFile?docid=11514&version=1&filename=cms_120918_03.png

Leptonic Final State

Thanks to the well-built Silicon Tracker and Robust and perfect Muon System of CMS, leptons (e, μ) are more precisely detected than other physics objects (at CMS).

A large number of BSM processes have leptons in their final states, as opposed to many SM backgrounds (e.g. QCD)

Di-Lepton states have sufficient production rate with background suppression



CMS DiLeptonic SUSY Searches

same-sign di-lepton final state:

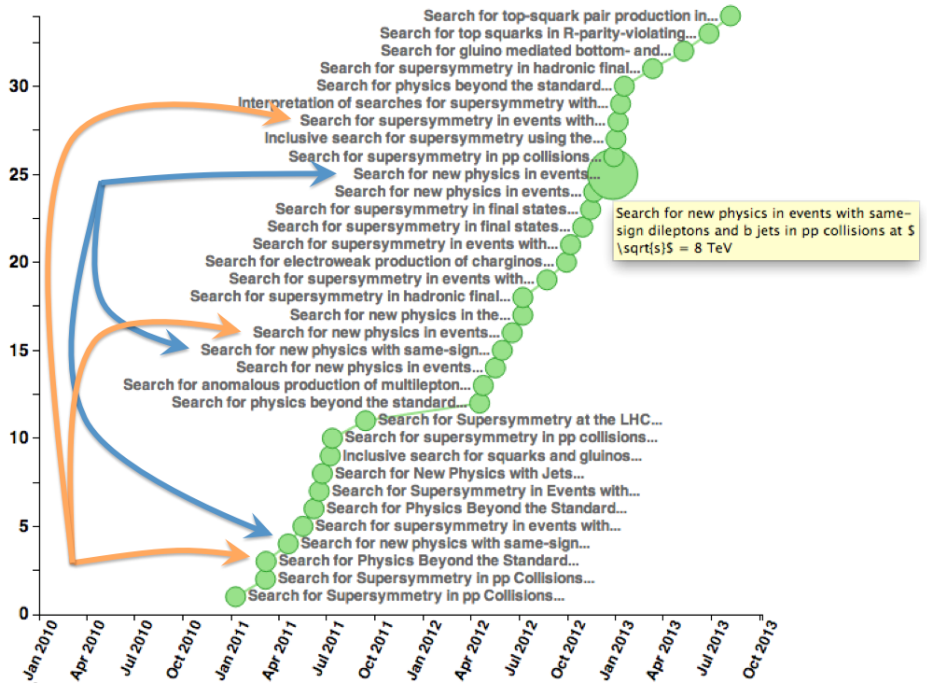
- **PAS-SUS-13-013**:
  8 TeV - 19.5/fb
- **JHEP03 (2013) 037**:
  8 TeV - 10.5/fb
- **PRL 109, 071803 (2012)**:
  7 TeV - 4.98/fb
- **JHEP08(2012)110**:
  7 TeV - 4.98/fb
- **...**

opposite-sign di-lepton final state:

- **PRD 87 (2013) 072001**:
  7 TeV - 4.98/fb (ANN)
- **PLB 718, 815-840 (2013)**:
  7TeV - 4.98/fb
- **...**

PAS-SUS-13-013

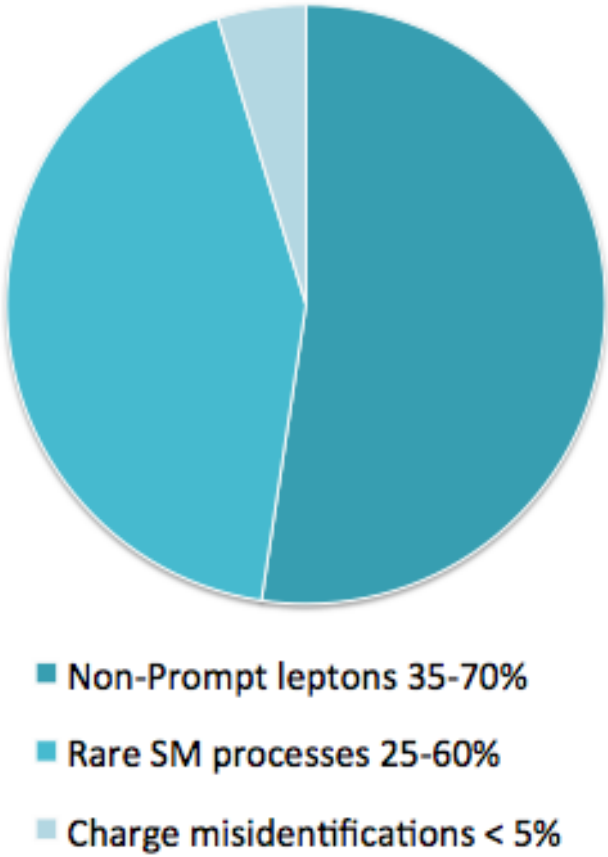
Search for new physics in events with same-sign dileptons and jets



http://cms.web.cern.ch/org/physics-papers-timeline

Backgrounds

- **Non-Prompt leptons (Fakes):**
  Leptons from heavy-flavour decay, misidentified hadrons, muons from light-meson decay in flight, electrons from unidentified photon conversions ...
- **Rare SM processes:**
  mostly from ttW, ttZ and diboson production.
- **Charge misidentifications:**
  opposite-sign isolated leptons where one of the charges is mismeasured.

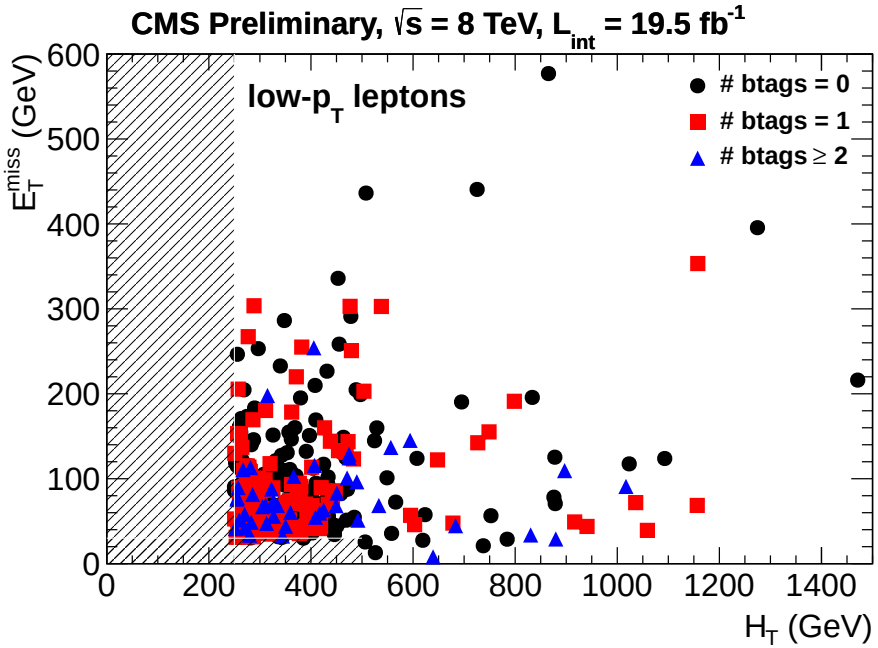


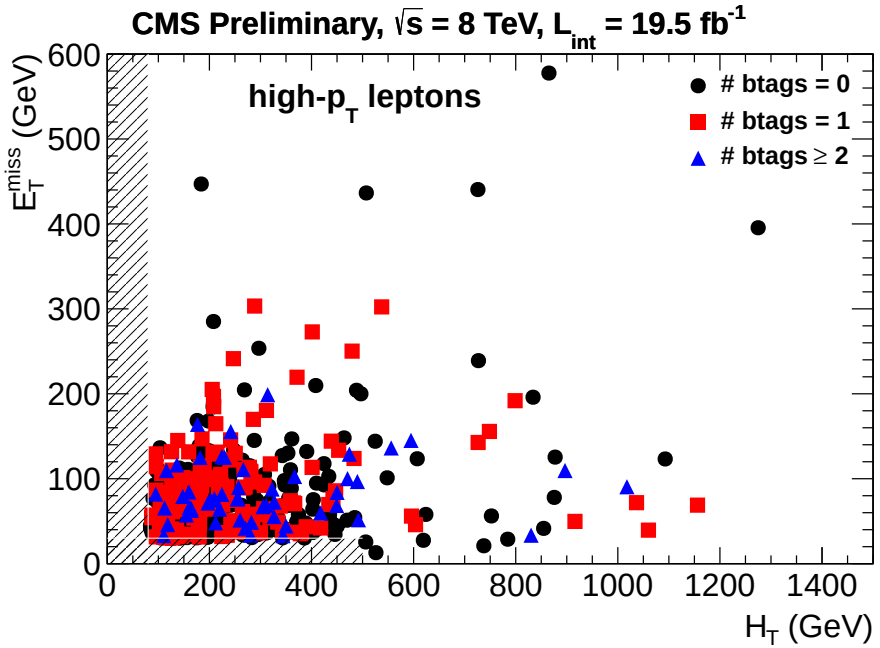
Searches: Baseline Signal Regions

high-(low-)p_T leptons: $p_T^{1,2} > 20(10)\mathrm{GeV}$

$\vec{E}_T^{miss} = -\sum_i \vec{p}_T^{\,i}$ and $H_T = \sum_{jets} |\vec{p}_T|$

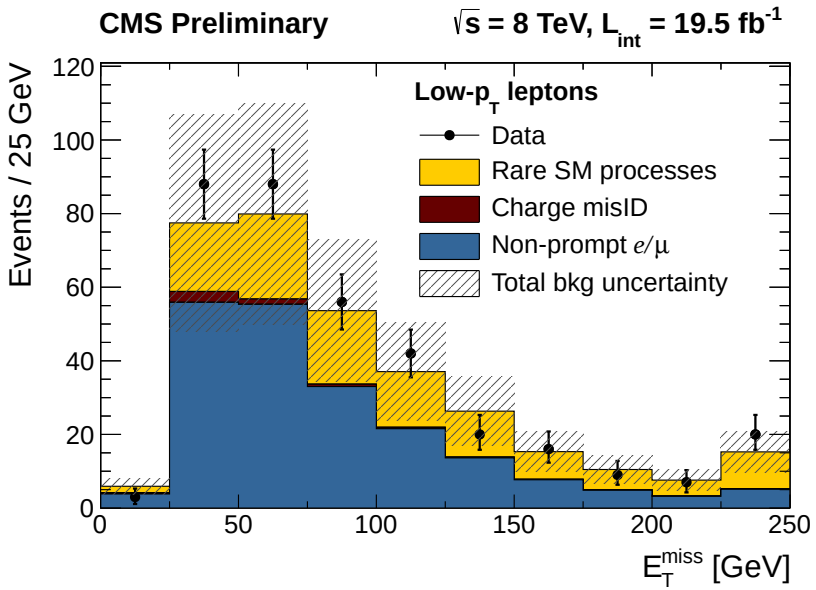
H_{T} (GeV)	$E_{\mathrm{T}}^{\mathrm{miss}}$ (GeV)	N_{jets}	$N_{\mathrm{b\text{-}jets}}$	SR
> 250 (80)	> 30 if $H_{\mathrm{T}} < 500$ else > 0	≥ 2	$= 0$	BSR0
> 250 (80)	> 30 if $H_{\mathrm{T}} < 500$ else > 0	≥ 2	$= 1$	BSR1
> 250 (80)	> 30 if $H_{\mathrm{T}} < 500$ else > 0	≥ 2	≥ 2	BSR2

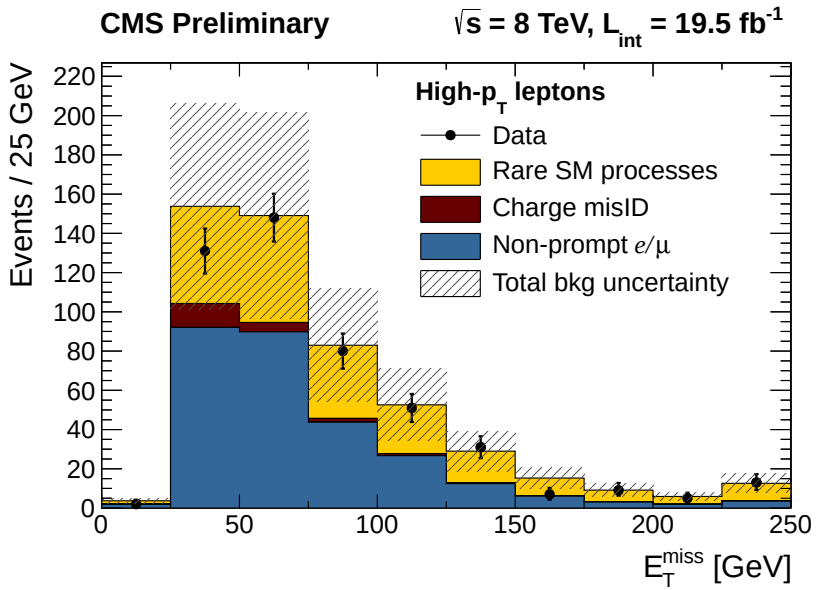


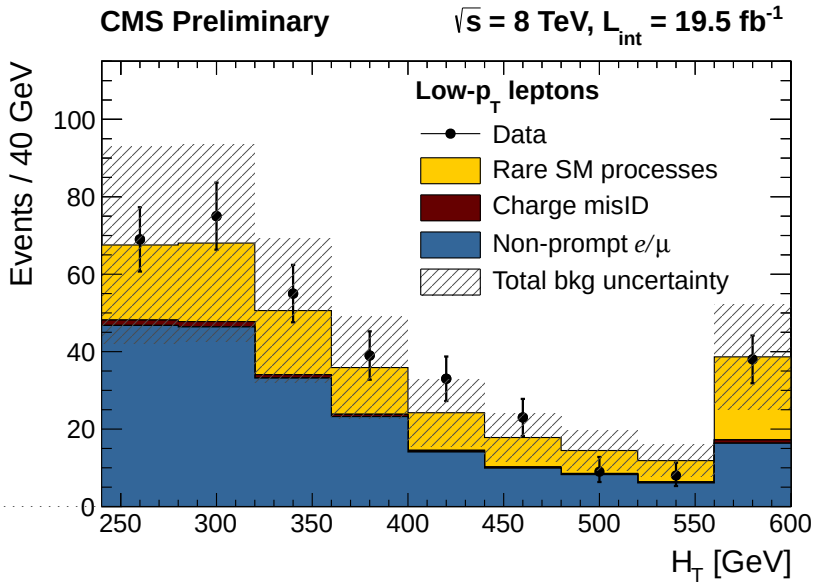


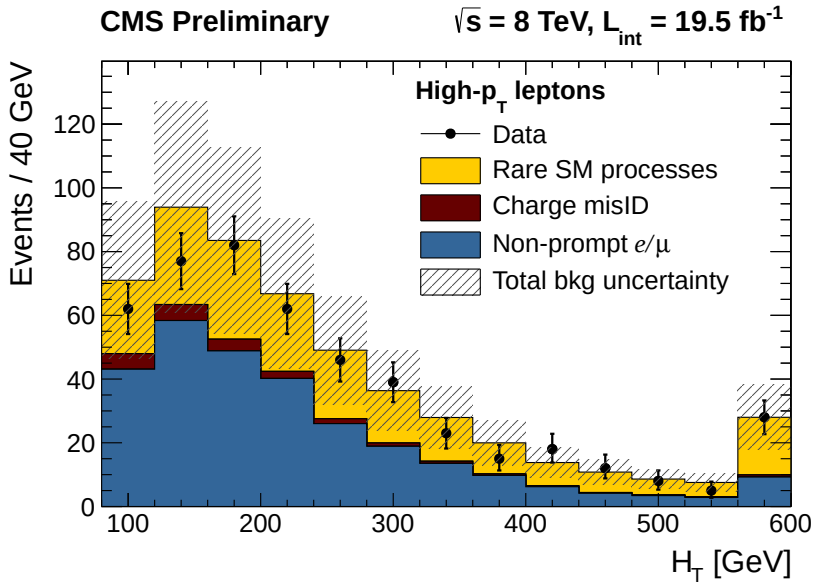
Distributions of E_T^{miss} versus H_T in the baseline signal regions BSR0, BSR1 and BSR2 for the low-pt (left) and the high-pt (right) analyses.

Searches: The result of the background prediction

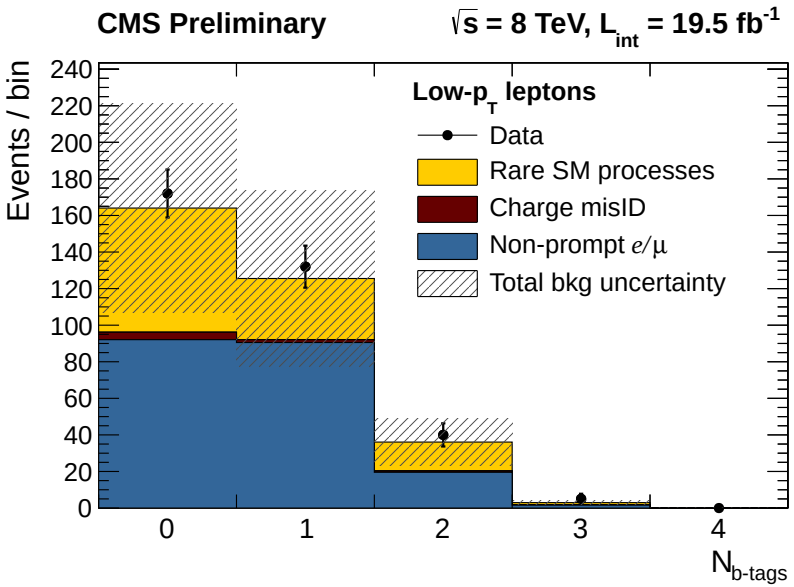


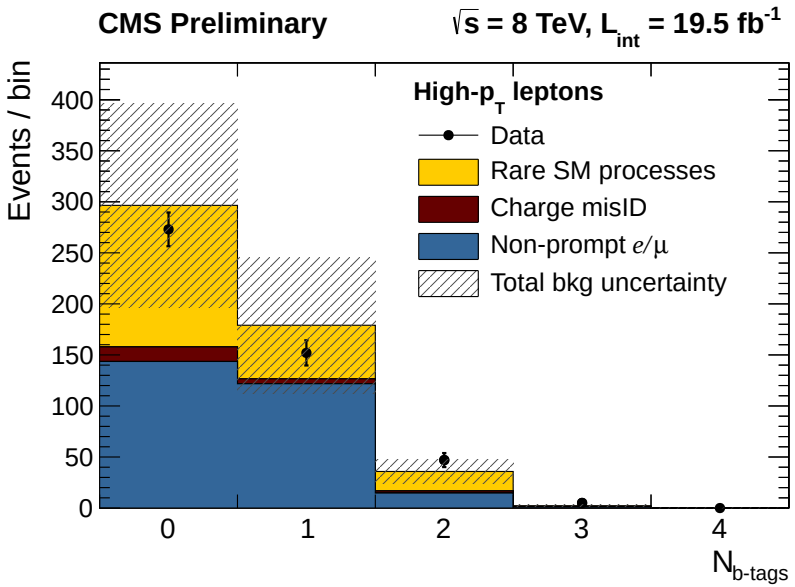


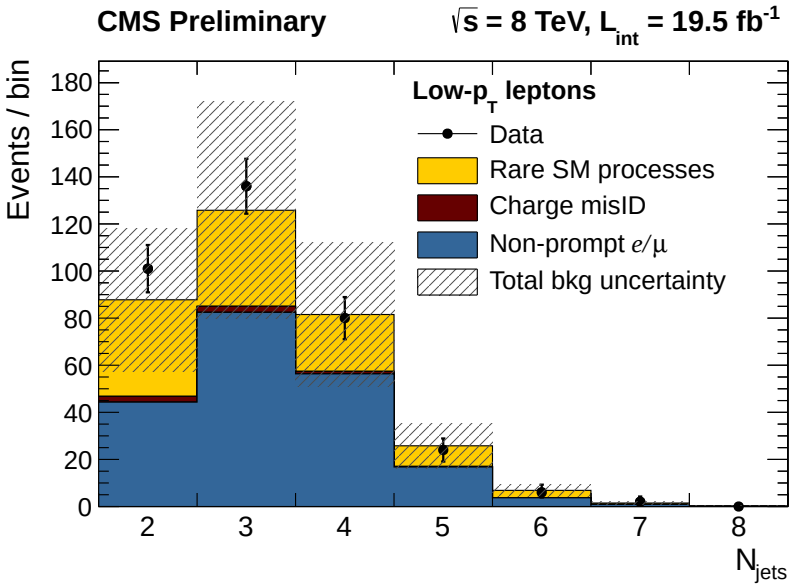


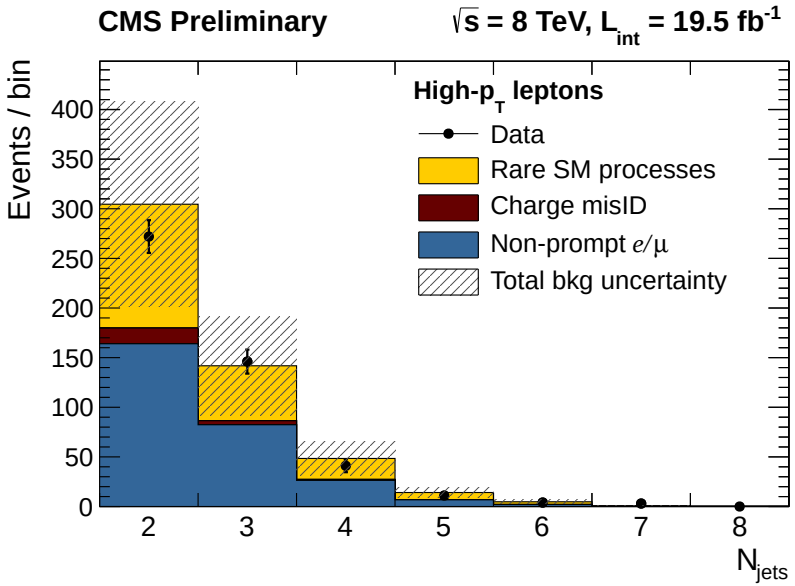


Searches: The result of the background prediction









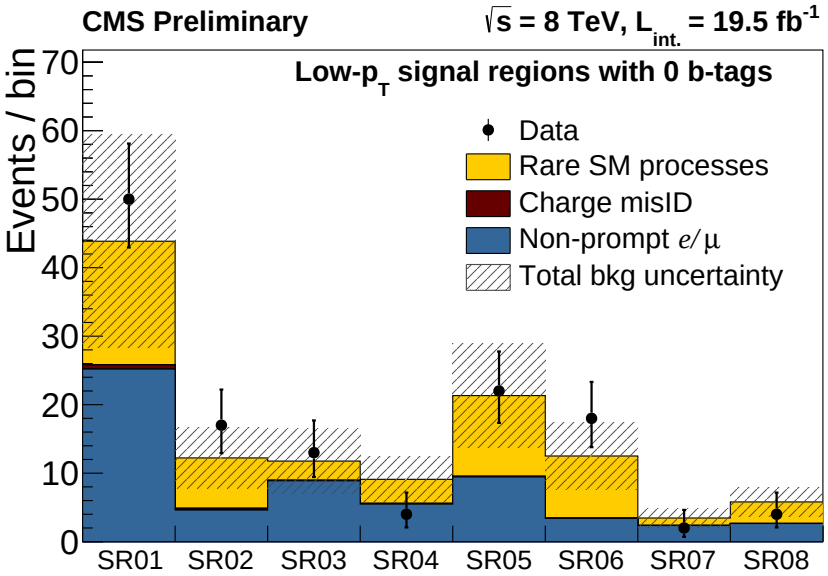
Searches: Search Regions

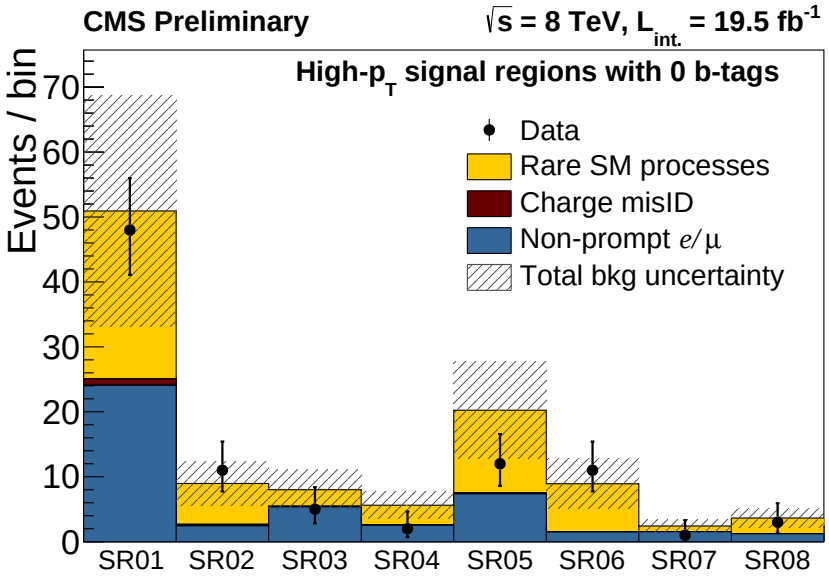
- Search regions (24) are optimized in bins of the number of jets and b-tagged jets, requirements of E_T^{miss} and H_T to cover a wide range of SUSY-particle production.
- 2 signal regions are also defined for RPV searches.

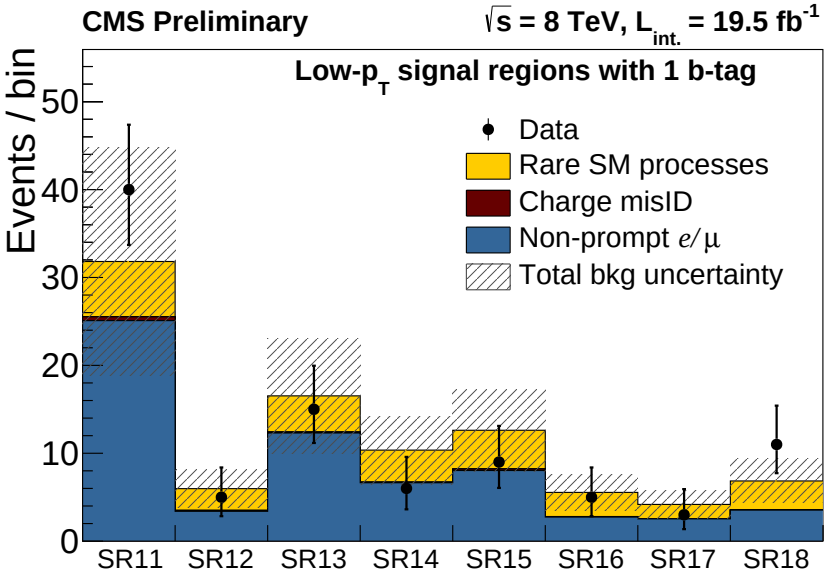
$N_{\text{b-jets}}$	$E_{\text{T}}^{\text{miss}}$ (GeV)	N_{jets}	$H_{\text{T}} \in [200, 400]$ (GeV)	$H_{\text{T}} > 400$ (GeV)
$= 0$	50-120	2-3	SR01	SR02
		≥ 4	SR03	SR04
	> 120	2-3	SR05	SR06
		≥ 4	SR07	SR08
$= 1$	50-120	2-3	SR11	SR12
		≥ 4	SR13	SR14
	> 120	2-3	SR15	SR16
		≥ 4	SR17	SR18
≥ 2	50-120	2-3	SR21	SR22
		≥ 4	SR23	SR24
	> 120	2-3	SR25	SR26
		≥ 4	SR27	SR28

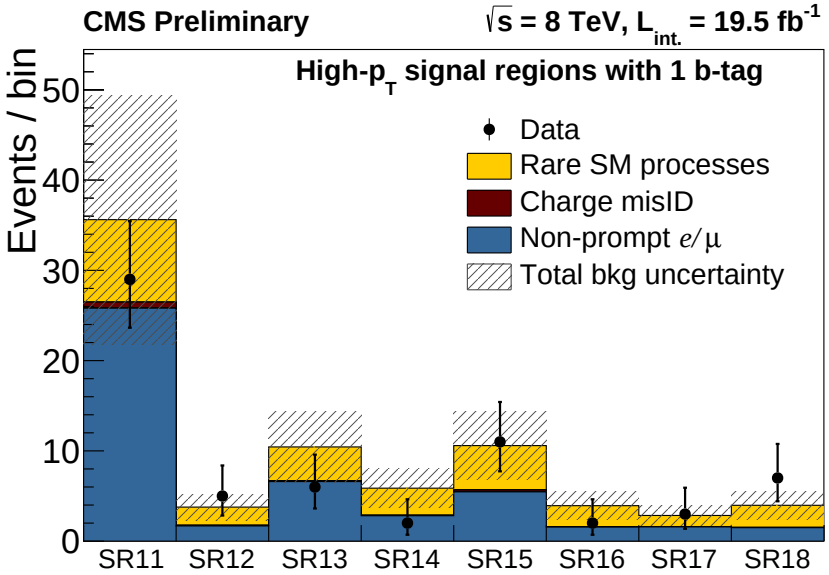
N_{jets}	$N_{\text{b-jets}}$	$E_{\text{T}}^{\text{miss}}$ (GeV)	H_{T} (GeV)	charge	SR
≥ 2	≥ 0	> 0	> 500	$++/--$	RPV0
≥ 2	≥ 2	> 0	> 500	$++/--$	RPV2
≥ 2	$= 1$	> 30	> 80	$++/--$	SStop1
≥ 2	$= 1$	> 30	> 80	$++$ only	SStop1++
≥ 2	≥ 2	> 30	> 80	$++/--$	SStop2
≥ 2	≥ 2	> 30	> 80	$++$ only	SStop2++

Results: Comparison between observation and predictions







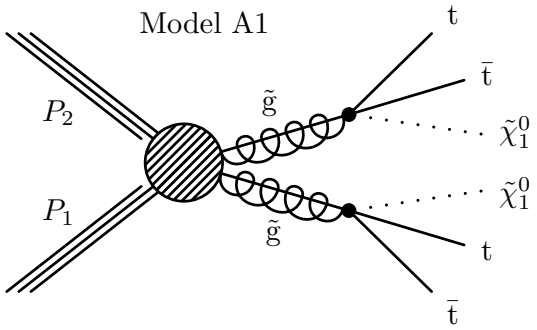


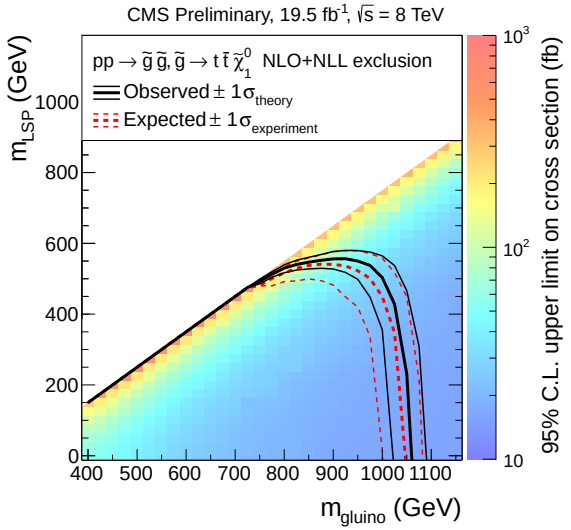
Results: Interpretation

- Since no significant excess over the expected SM background is observed, the results are used to set bounds on the parameters of various models of new physics.
- Limits are calculated 95% confidence level (CL) using the modified frequentist CLs method.
- For each model, the most sensitive, exclusive, signal regions are statistically combined for limit calculation.

Model	Model parameter	Analysis	Signal Regions used
A1		high-p_T	21–28
A2	$m_{\chi_1^0} = 50$ GeV	high-p_T	21–28
B1	$m_{\chi_1^0} = 50$ GeV	high-p_T	11–18, 21–28
B1	$x = m_{\chi_1^0}/m_{\chi_1^\pm} = 0.5$	high-p_T	11–18, 21–28
B1	$x = m_{\chi_1^0}/m_{\chi_1^\pm} = 0.8$	low-p_T	11–18, 21–28
B2	$m_{\chi_1^0} = 50$ GeV, $m_{\chi_1^\pm} = 150$ GeV	high-p_T	21–28
B2	$m_{\chi_1^0} = 50$ GeV, $m_{\chi_1^\pm} = 300$ GeV	high-p_T	21–28
C1	$x = 0.5$	high-p_T	01–08
C1	$x = 0.8$	low-p_T	01–08
RPV		high-p_T	RPV2
$pp \rightarrow t\bar{t} + t\bar{t}$		high-p_T	SStop1, SStop2
$pp \rightarrow t\bar{t}$		high-p_T	SStop1++, SStop2++
$pp \rightarrow t\bar{t}t\bar{t}$		high-p_T	21–28

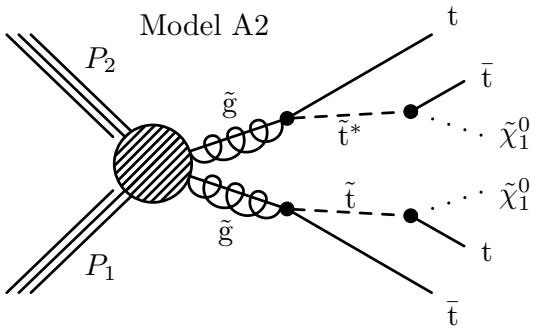
Results: Probing Model A1

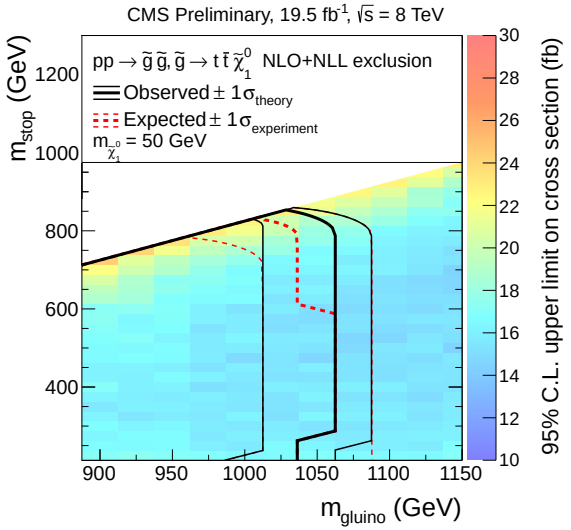




- The gluino undergoes a three body decay $\tilde{g} \to t\bar{t}\tilde{\chi}_1^0$ mediated by an off-shell top squark.
- Four on-shell W bosons and four b quarks are produced.
- Search regions SR21-SR28 where high-p_T leptons are required.
- Exclusion contour as a function of gluino mass and $\tilde{\chi}_1^0$ mass

Results: Probing Model A2

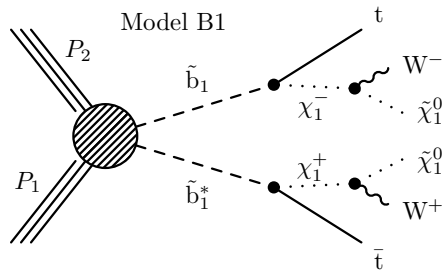


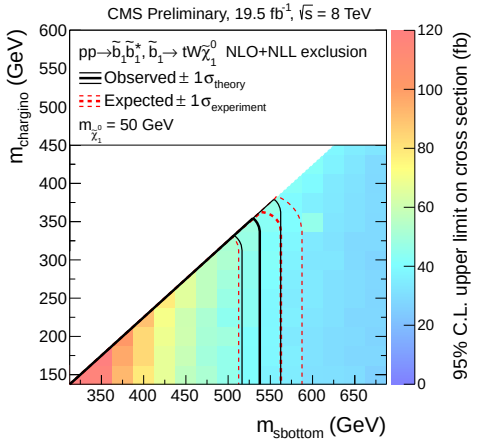


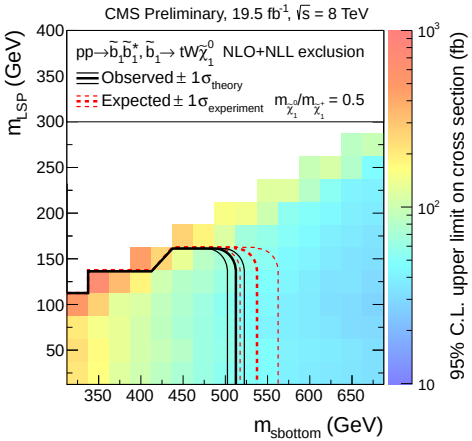
- The gluino decays to a top quark and an anti-top squark, decaying into an anti-top quark and a neutralino.
- Four on-shell W bosons and four b quarks are produced.
- Search regions SR21-SR28 where high-p_T leptons are required.
- Exclusion contour as a function of gluino mass and stop mass. $\tilde{\chi}_1^0$ mass is set to 50GeV.

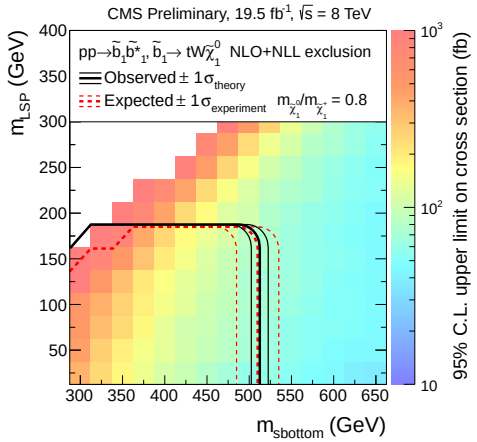
Results: Probing Model B1

- Model B1 consists of bottom-squark pair production. Then decay chain continues with $\tilde{b}_1 \to t(\tilde{\chi}_1^{\pm} \to W^{\pm}\tilde{\chi}_1^0)$
- To set limits on the $\tilde{\chi}_1^{\pm}$ and $\tilde{b}$ masses, $m_{\tilde{\chi}_1^0}$ is considered 50GeV.
- Using the ratio $x = m_{\tilde{\chi}_1^0}/m_{\tilde{\chi}_1^{\pm}}$ with $x = 0.5$ and $x = 0.8$, the exclusion contour on the $(m_{LSP} - m_{sbottom})$ plane is calculated.
- The value of x determines whether the top and W are produced on- or off-shell.
- Search regions SR11-18 and SR21-SR28
- The low-(high-)p_T lepton selection for $x = 0.8$(other scenarios).

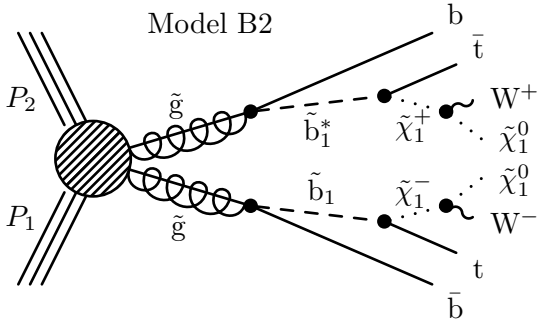


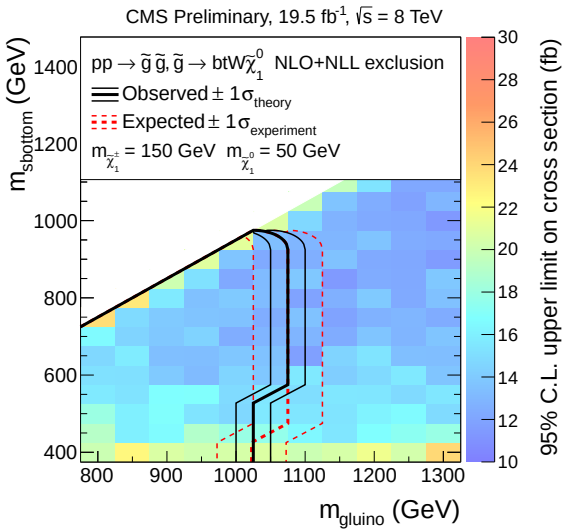


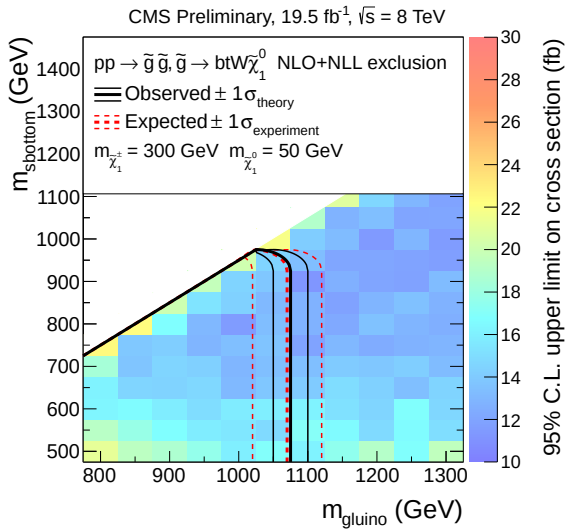




Results: Probing Model B2

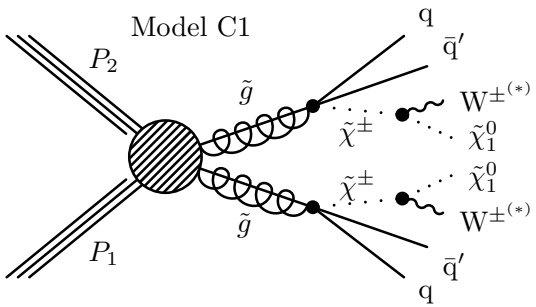


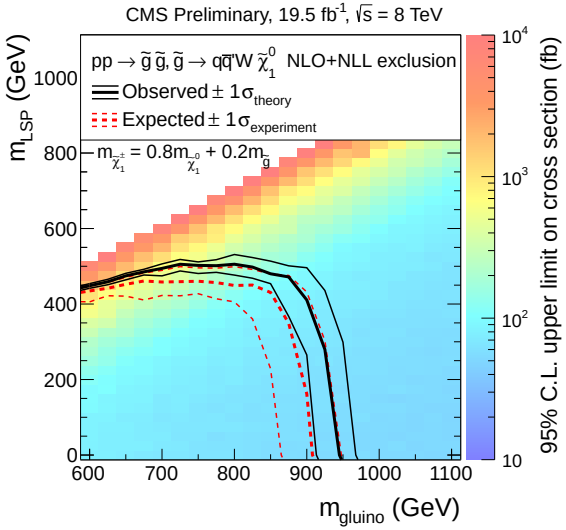


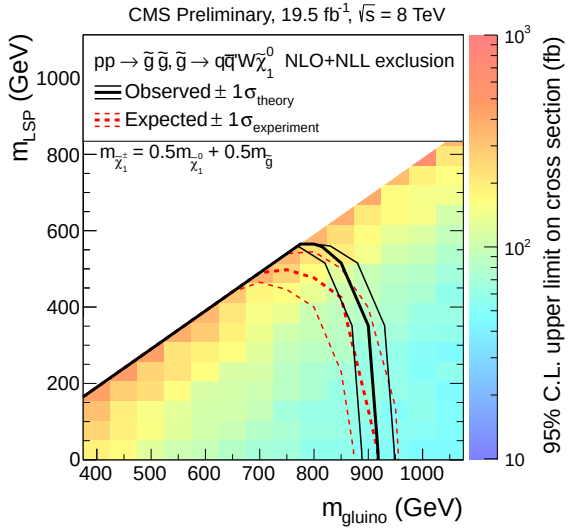


- Model B2 is a gluino pair production. Then $\tilde{g}$ decays to b and $\tilde{b}$.
- Using the search regions SR21-SR28, high-p_T lepton selection and $m_{\tilde{\chi}_1^0} = 50$GeV.
- For two fixed masses of $\tilde{\chi}_1^\pm$, 150 and 300 GeV, the upper bound on the $\tilde{g}$ and $\tilde{b}$ masses are calculated.

Results: Probing Model C1



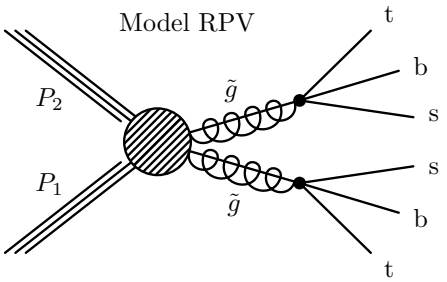


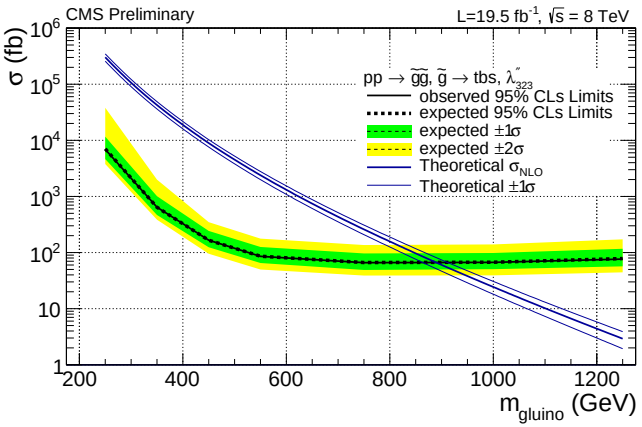


- Produced gluino decays to light quarks and a chargino mediated by heavy virtual squarks. Then $\tilde{\chi}_1^{\pm} \to W^* \tilde{\chi}_1^0$.
- Same-sign and opposite-sign W pairs have equal fraction.
- Exclusion contour is provided as a function of $m_{\tilde{g}}$ and m_{LSP} while $m_{\tilde{\chi}_1^{\pm}} = 0.5m_{\tilde{\chi}_1^0} + 0.5m_{\tilde{g}}$ and $m_{\tilde{\chi}_1^{\pm}} = 0.8m_{\tilde{\chi}_1^0} + 0.2m_{\tilde{g}}$
- The search regions SR01-SR08, with both low- and high-p_T lepton selection.

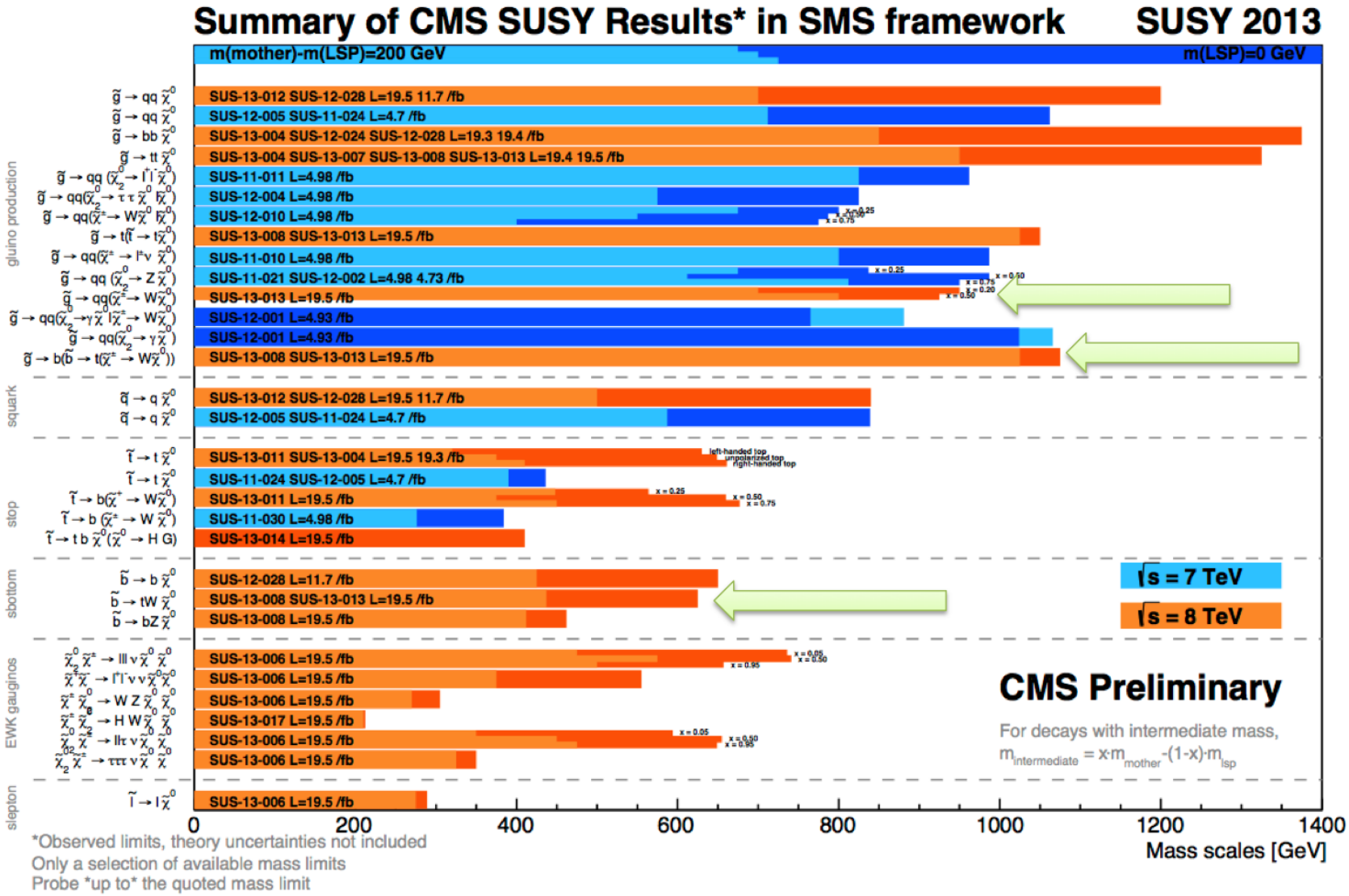
Results: Probing Model RPV

- Gluino pair production with gluino decay to three quarks: $\tilde{g} \rightarrow tbs(\bar{t}\bar{b}\bar{s})$ in the context of model RPV.
- Same-sign W pairs with a 50% probability.
- The search region RPV2 with high-p_T lepton selection.
- Only one parameter $m_{\tilde{g}}$.





Results: Mass Scales

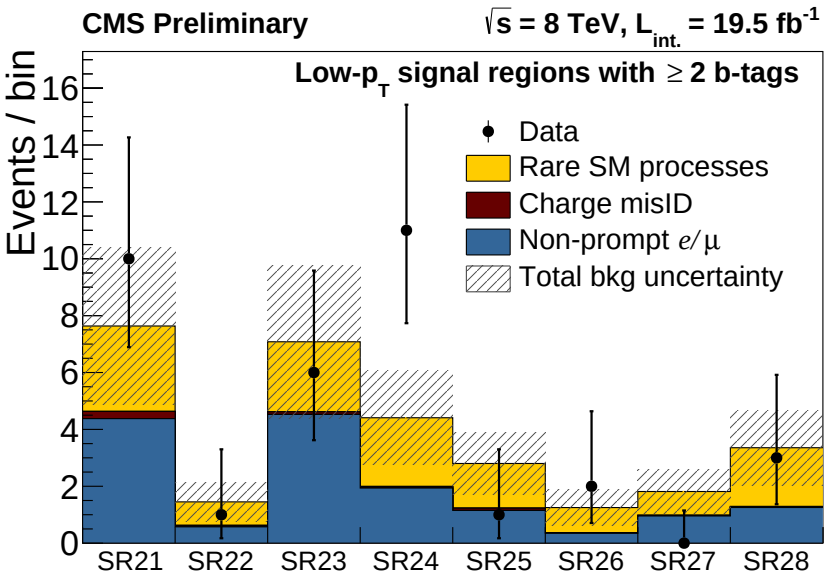


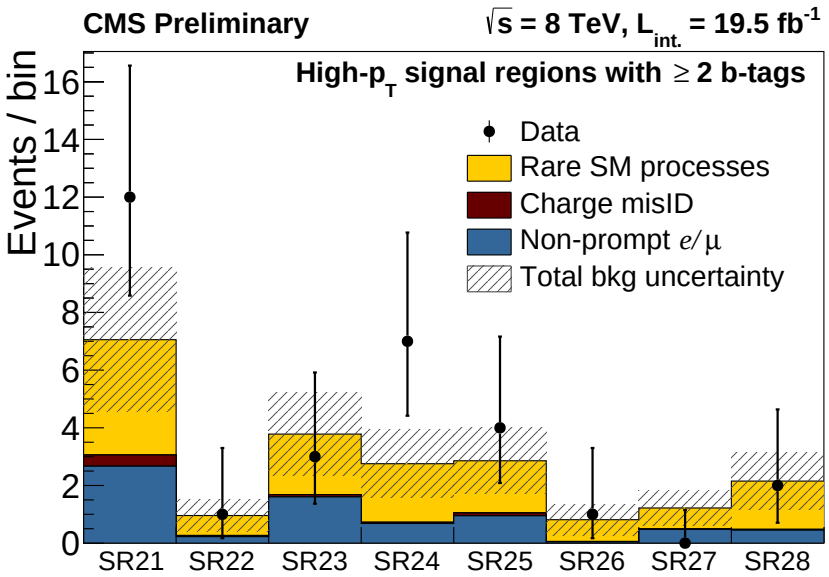
Summary

- The last results of CMS searches for supersymmetry in the same-sign di-lepton channel were presented.
- No data excess over the expected SM background is observed.
- Data is consistent with the Standard Model expectation.
- Interpretation of the results, in the context of Simplified Models of Supersymmetry, were presented.
- Further results are on the way, visit `https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS`

Ref:
Search for new physics in events with same-sign dileptons and jets CMS PAS SUS-13-013

Thanks


CMS Preliminary
√s = 8 TeV, L_int. = 19.5 fb^-1
Low-p_T signal regions with ≥ 2 b-tags
Data
Rare SM processes
Charge misID
Non-prompt e/μ
Total bkg uncertainty
Events / bin
0
2
4
6
8
10
12
14
16
SR21
SR22
SR23
SR24
SR25
SR26
SR27
SR28


CMS Preliminary
√s = 8 TeV, L_int. = 19.5 fb^-1
High-p_T signal regions with ≥ 2 b-tags
Data
Rare SM processes
Charge misID
Non-prompt e/μ
Total bkg uncertainty
Events / bin
0
2
4
6
8
10
12
14
16
SR21
SR22
SR23
SR24
SR25
SR26
SR27
SR28