Search for supersymmetry in four W and multiple b-quark final state

Didar Dobur
University of Florida

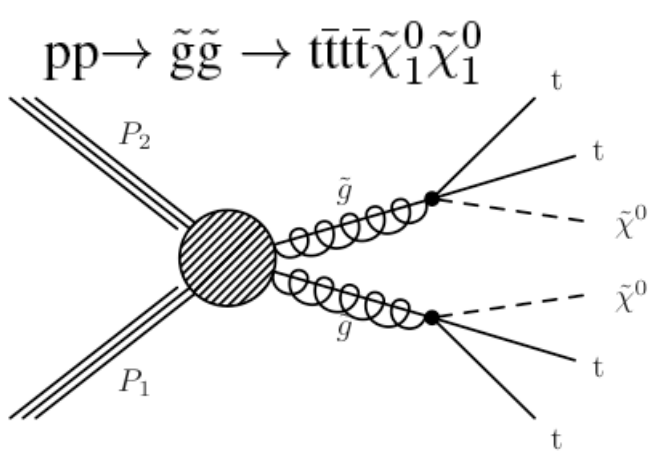
On behalf of the CMS collaboration

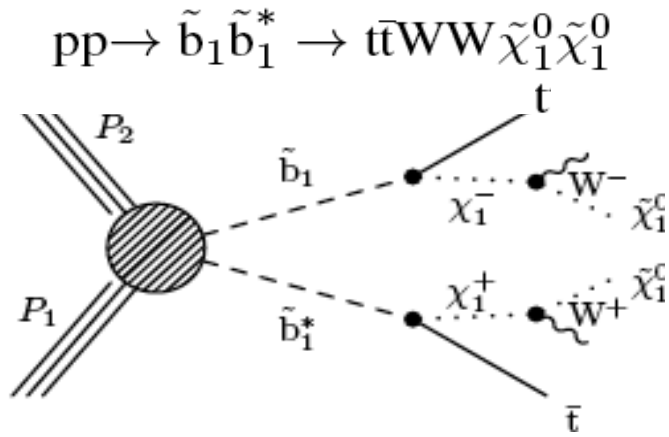
Large Hadron Collider Physics Conference
13-18 May, Barcelona

four W and multi-bjet signature

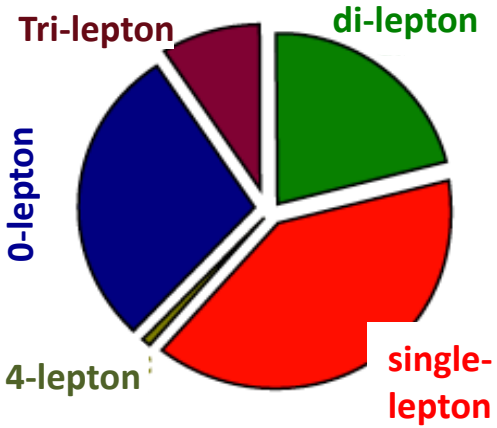
Spectacular signature to look for new physics!

Examples in supersymmetry:





4-W branching fraction



- **0-lepton:** large BR(20%), 12 jets!
- **single-lepton**: largest BR(40%) but large ttBar/WJets background!
- **OS di-lepton:** 20% BR, large ttBar background
- **SS di-lepton:** 10% BR, low background
- **multi-lepton:** 10% BR, very low background!

Outline

Performed searches in various final states to cover four-W and multi-bjet final states:

This talk

- multi-leptons and bjets (**new**, 19.5 fb^{-1}) PAS-SUS-13-008
- same-sign di-lepton and bjets (10.5 fb^{-1}) JHEP03 (2013) 037
- single lepton and bjets (19.5 fb^{-1}) PAS-SUS-13-007
- 0-lepton and bjets channel (19.5 fb^{-1}) arXiv:1305.2390

See the talk from Alessandro Gaz

For more details:

https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS

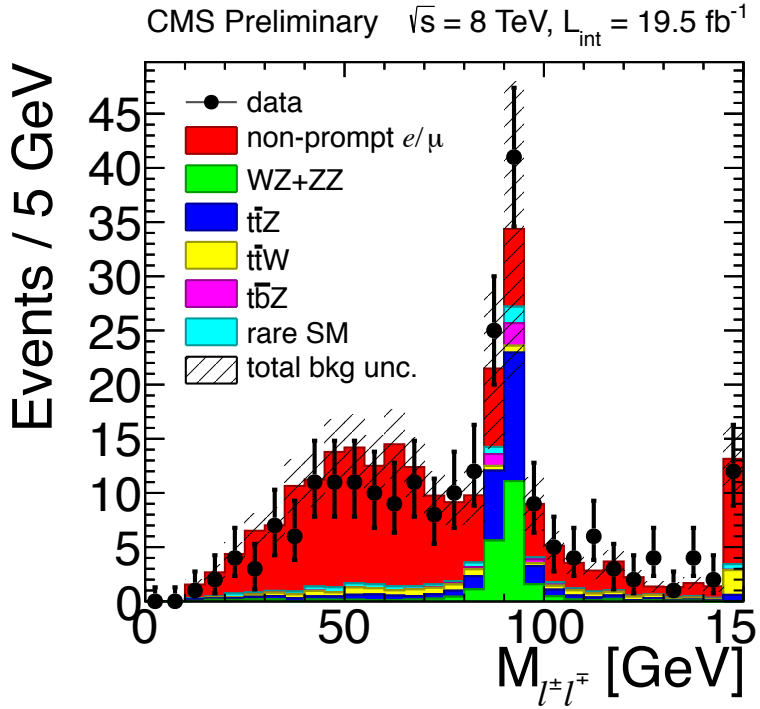
three-lepton + bjets

Event selection

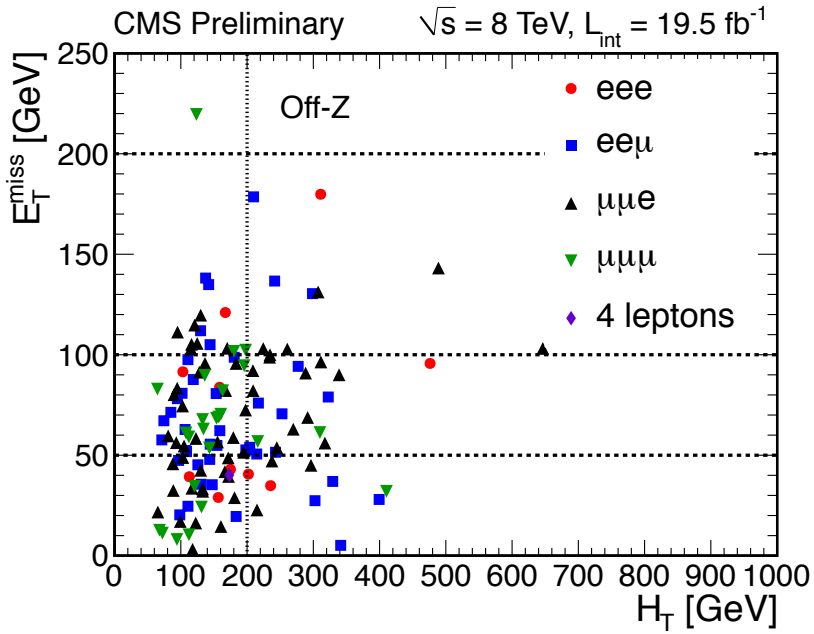
- 3 isolated high p_T leptons (e,μ)
- Njet ≥2, at least 1 b-jet
- MET > 50 GeV
- split events according to the presence of a Z candidate

Search strategy

- Form exclusive search regions using Njets, HT, MET and btagged jets
- perform a multi-bin fit to extract the upper limit on SUSY cross-section time BR

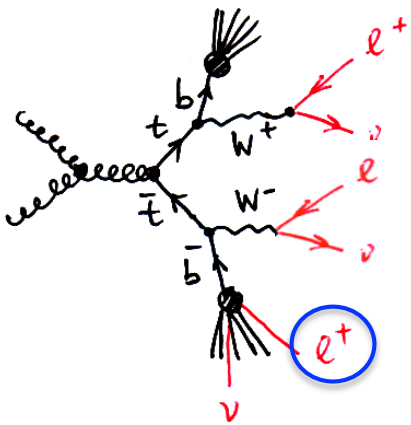


Selected events with no Z candidate

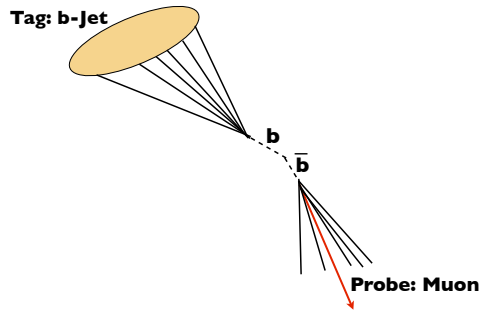


three-lepton + bjets : backgrounds

- non-prompt/misidentified leptons:
  - DY+jets strongly suppressed by b-requirement and high E_T^{miss}
  - $t\bar{t}$ is the main source of bkg: non-prompt leptons from b-jets
  - $t\bar{t} \rightarrow W(\ell\nu)W(\ell\nu)b(X\ell\nu)b$:
    - μ: over 95% are from b
    - e: 80% are from b

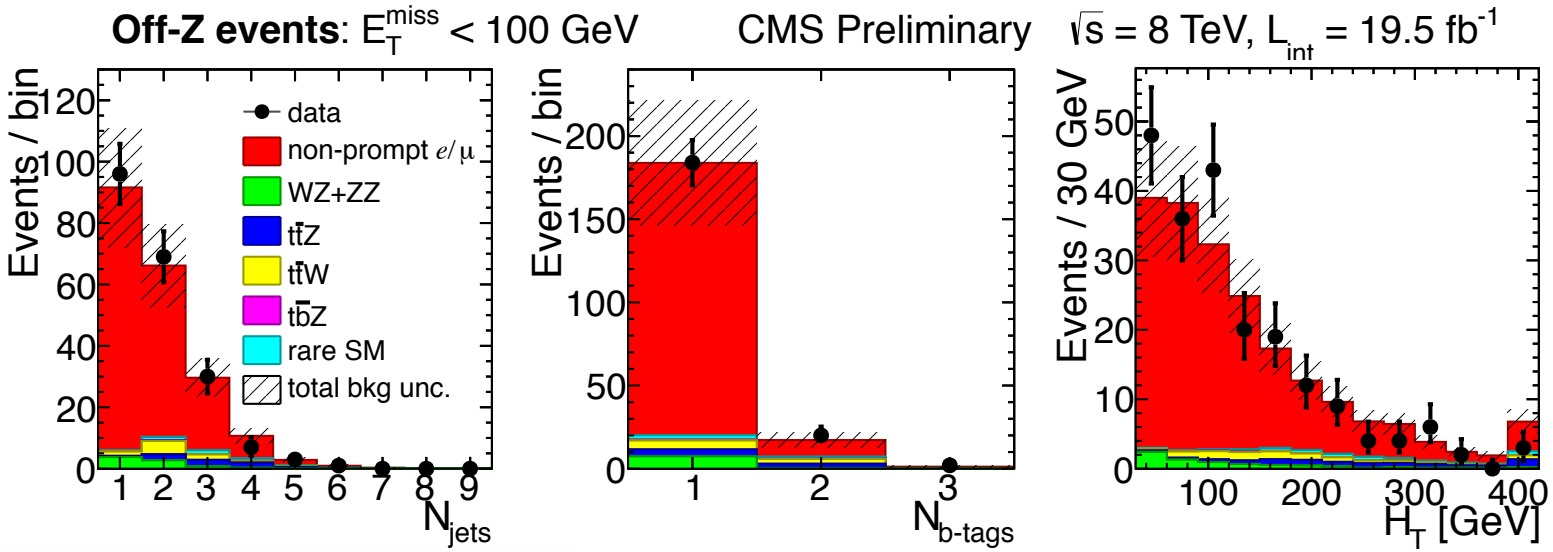


bbBar control sample

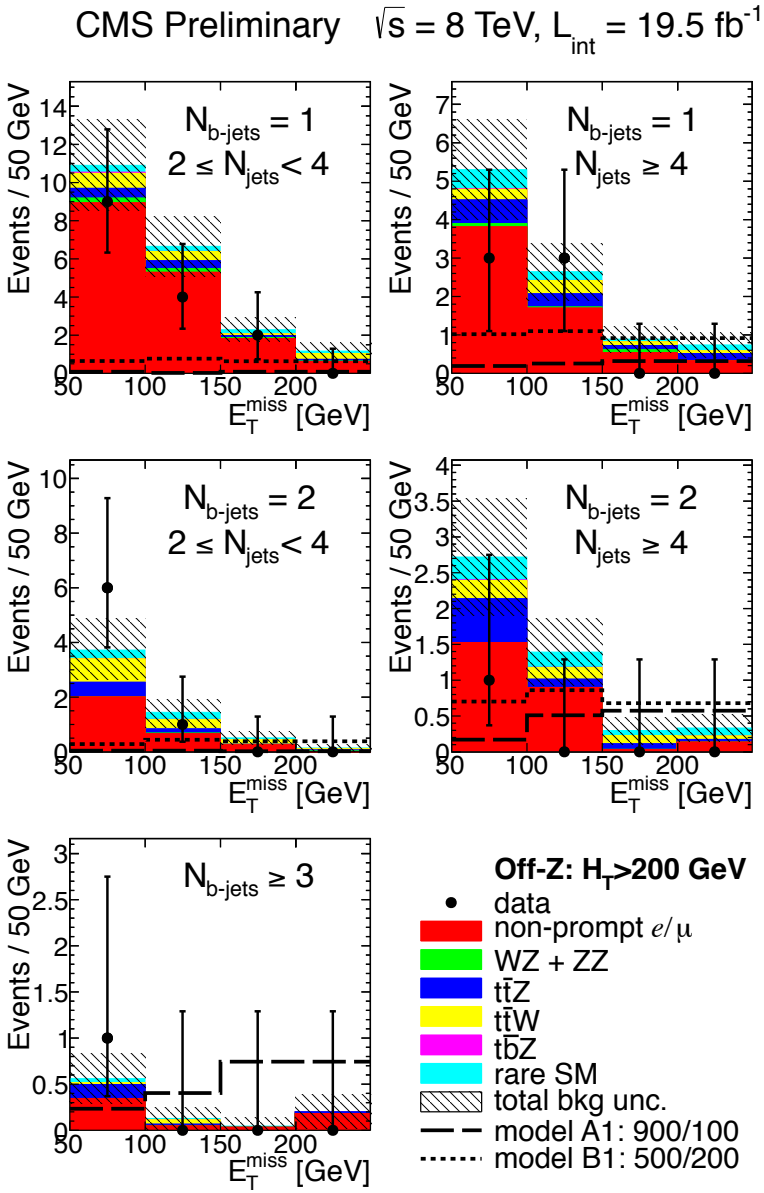


Measure the probability for a lepton from b-decay to be isolated

Validation in data, MET< 100 GeV



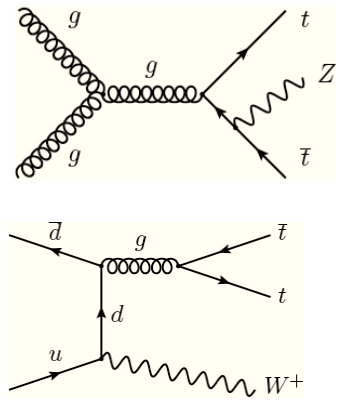
three-lepton + bjets: results



- Irreducible backgounds: Various sources of rare SM processes. MC simulations with NLO x-section

Samples	σ (pb)
$t\bar{t}W$	0.232
$t\bar{t}Z$	0.208
$t\bar{b}Z$	0.0114
$t\bar{t}WW$	0.002
WZ	1.0575
WWW	0.08217
ZZ	0.1769
WWZ	0.0633
ZZZ	0.004587
WZZ	0.01922
$W/Z/t\bar{t}+H(WW)$	0.2604
$W/Z/t\bar{t}+H(ZZ)$	0.0320
$W/Z/t\bar{t}+H(\tau\tau)$	0.0177

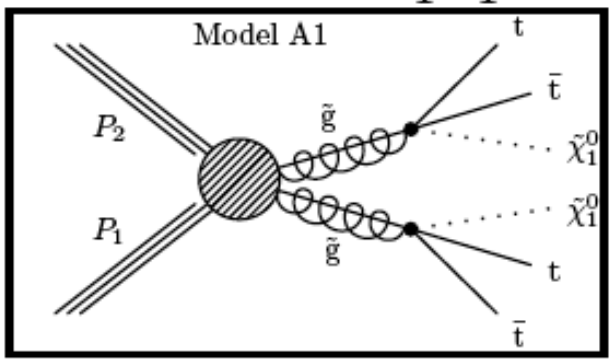
ttW/Z/H production



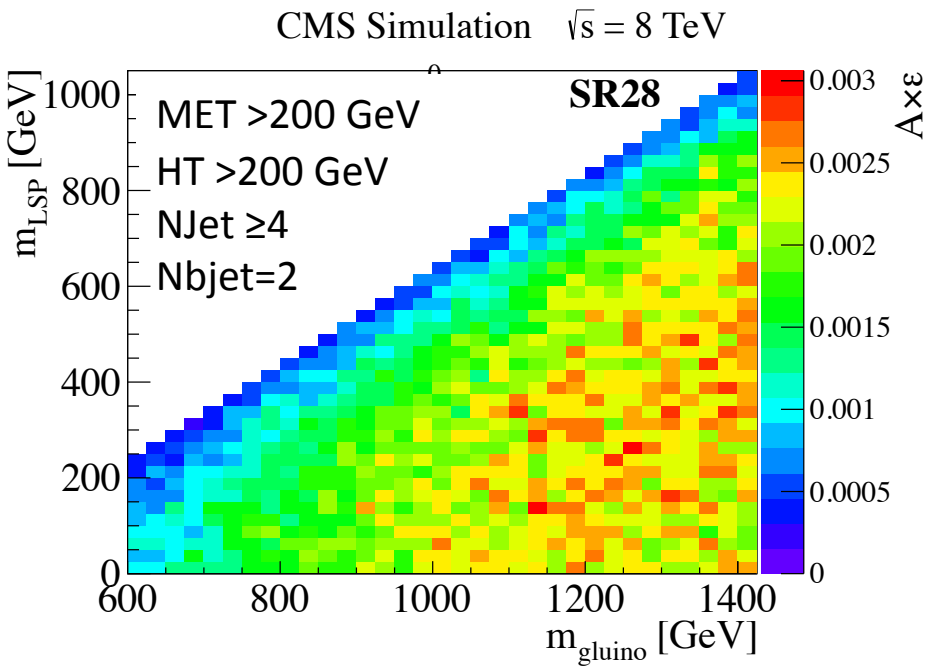
- Data agrees with the expected SM background
- results in exclusive search regions are used to set limit in SUSY production

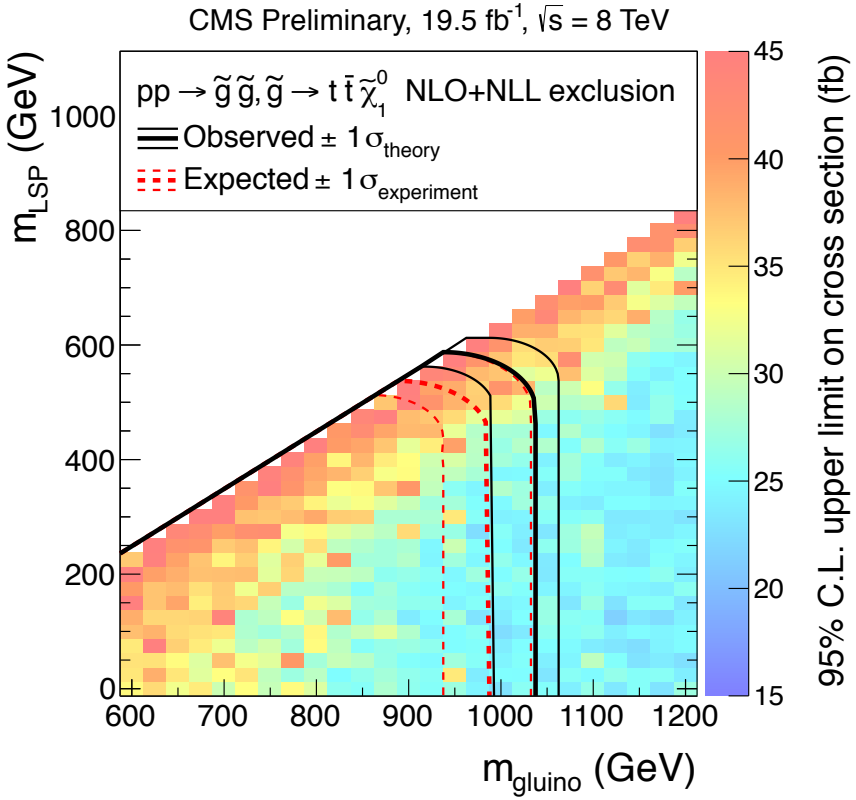
three-lepton + bjets: interpretation

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



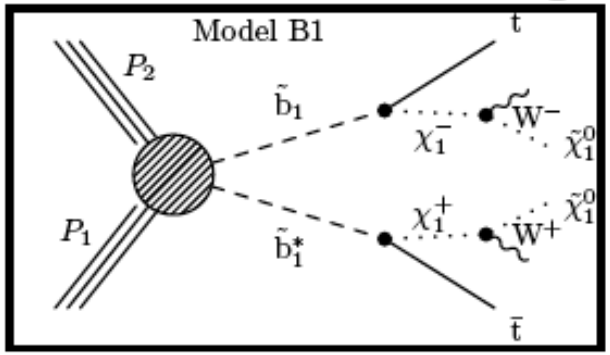
- Signal sample with Pythia, in M_{LSP}-$M_{gluiono}$ mass plane
- Search regions with Nbjet=2 and 3 are used
- Probe gluino masses up to ~1 TeV GeV



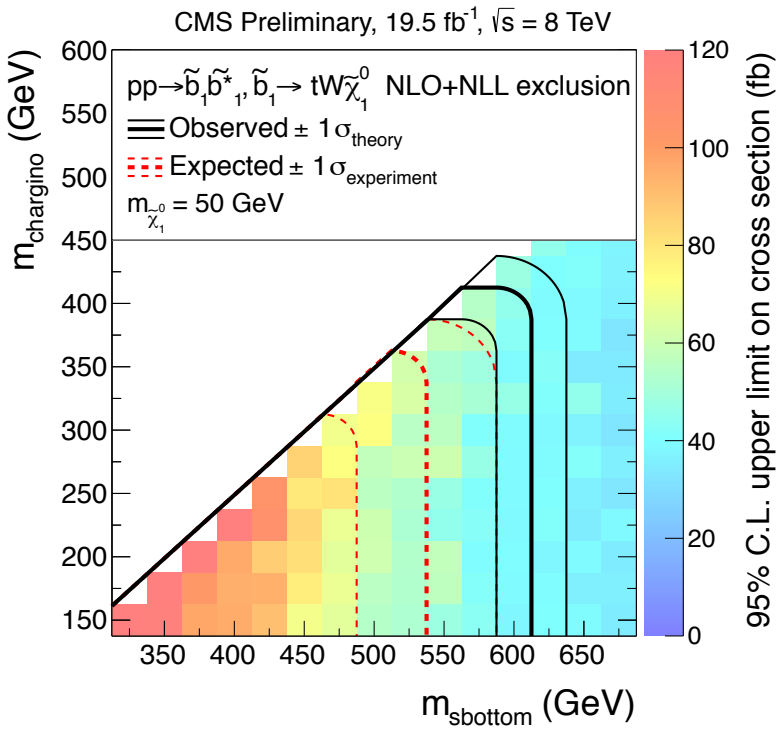


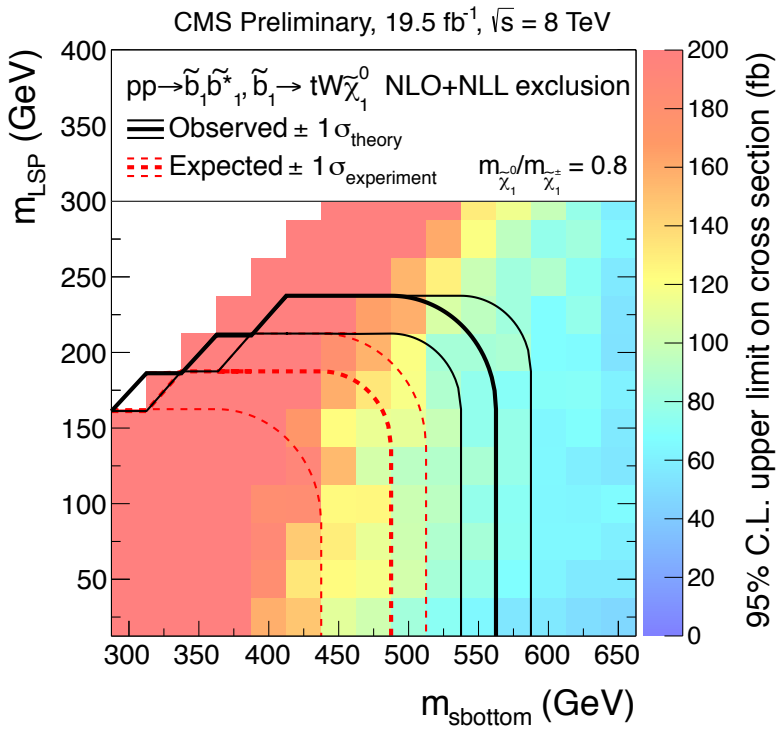
three-lepton + bjets: interpretation

$$pp \to \tilde{b}_1 \tilde{b}_1^* \to t\bar{t}WW\tilde{\chi}_1^0\tilde{\chi}_1^0$$



- Signal sample with MADGRAPH up to 2 add. partons
  - $M_{chargino}$ vs. $M_{sbottom}$, M_{LSP} = 50 GeV
  - M_{LSP} vs. $M_{sbottom}$, $M_{LSP}/M_{chargino}$=0.8
- Search regions with Nbjet=1 and 2 are used
- Probe sbottom masses up to ~600 GeV



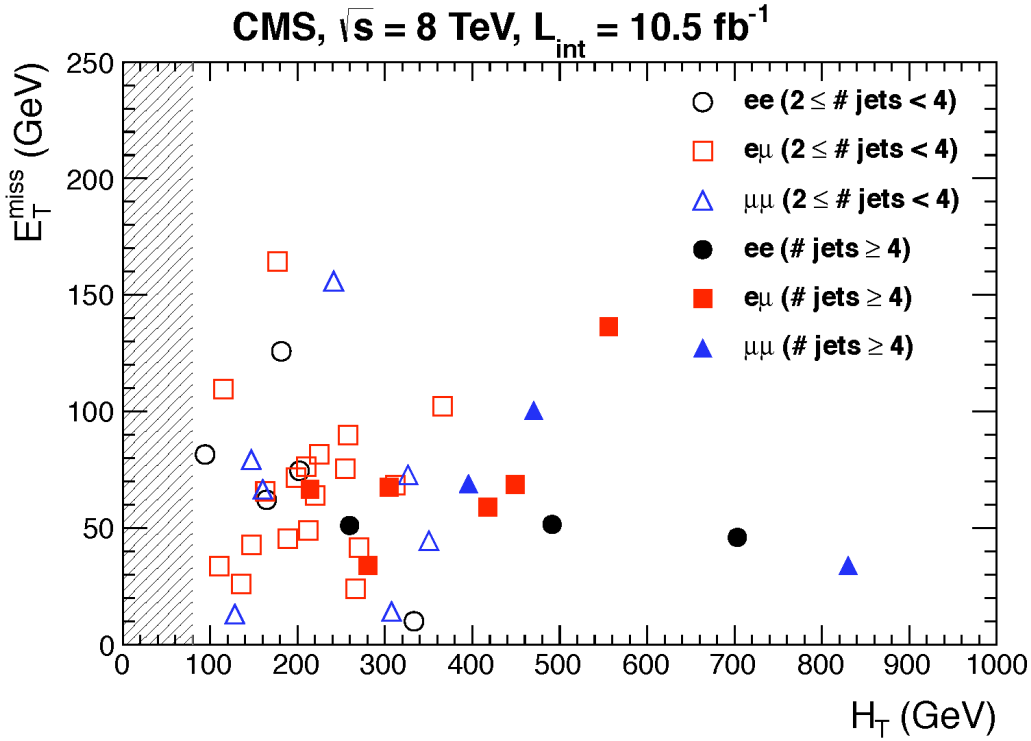


same-sign di-leptons

Event selection

- 2 isolated same-charge high p_T leptons (e,μ)
- Njet ≥2
- at least 2 b-jet, reduce ttBar background
- MET > 50 GeV
- Veto low mass di-leptons

Selected events in MET-HT plane



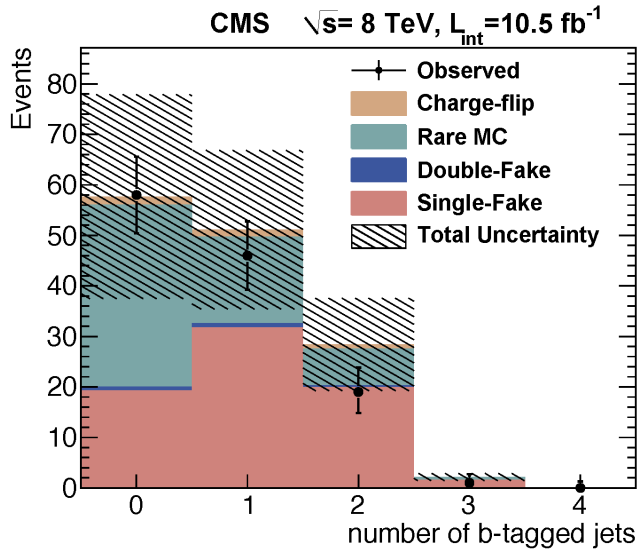
Search strategy

- Search is designed to cover wider spectrum of new physics models including RPV
- Search variables, Njets, HT, MET

same-sign di-leptons: results

Backgrounds

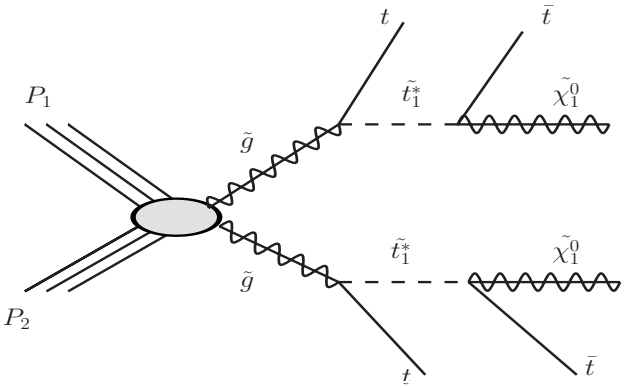
- non-prompt/misidentified leptons: Predicted using data-driven techniques
- Rare SM processes : use simulations to predict this background with large systematic uncertainties
- Charge mis-measurement (small): OS dileptons in DY, ttBar with charge mis-measurement. **muons:** from cosmic ray data (~10^{-5}), **electrons:** Use Z events (10^{-3} – 10^{-4})



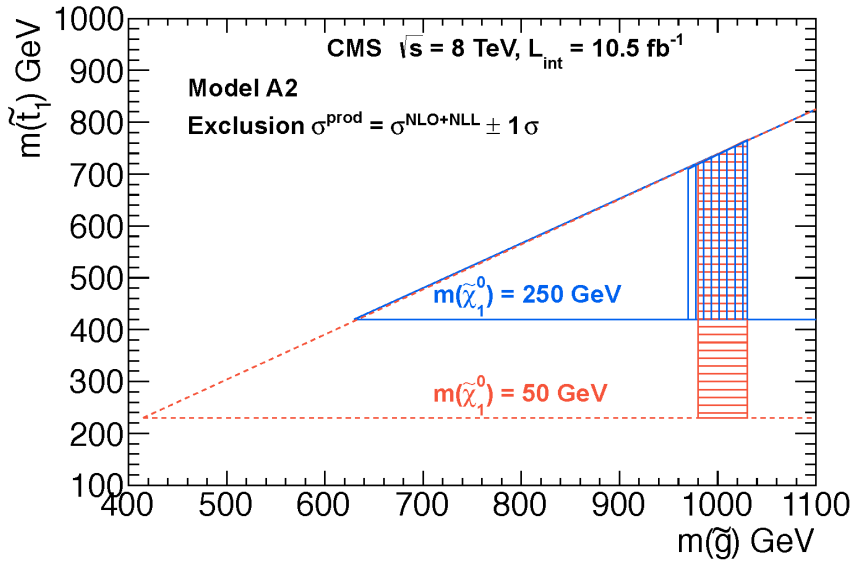
	SR0	SR1	SR2	SR3	SR4	SR5	SR6	SR7
No. of jets	≥ 2	≥ 2	≥ 2	≥ 4	≥ 4	≥ 4	≥ 4	≥ 3
No. of btags	≥ 2	≥ 2	≥ 2	≥ 2	≥ 2	≥ 2	≥ 2	≥ 3
Lepton charges	$++/--$	$++/--$	$++$	$++/--$	$++/--$	$++/--$	$++/--$	$++/--$
E_T^{miss}	>0 GeV	>30 GeV	>30 GeV	>120 GeV	>50 GeV	>50 GeV	>120 GeV	>50 GeV
H_T	>80 GeV	>80 GeV	>80 GeV	>200 GeV	>200 GeV	>320 GeV	>320 GeV	>200 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
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
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
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
Event yield	43	38	14	1	10	7	1	1

Same-sign di-leptons: interpretation

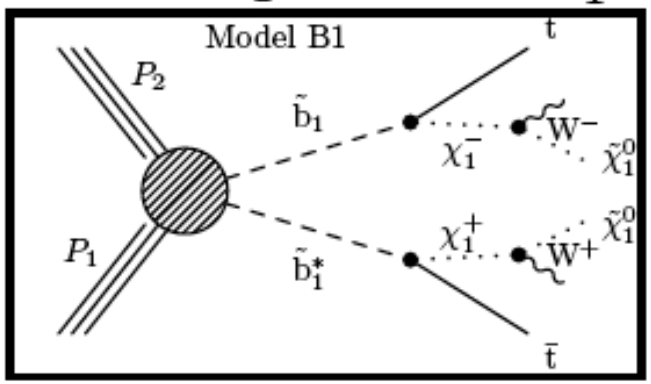
$$pp \to \tilde{g}\tilde{g} \to t\bar{t}t\bar{t}\tilde{\chi}_1^0\tilde{\chi}_1^0$$



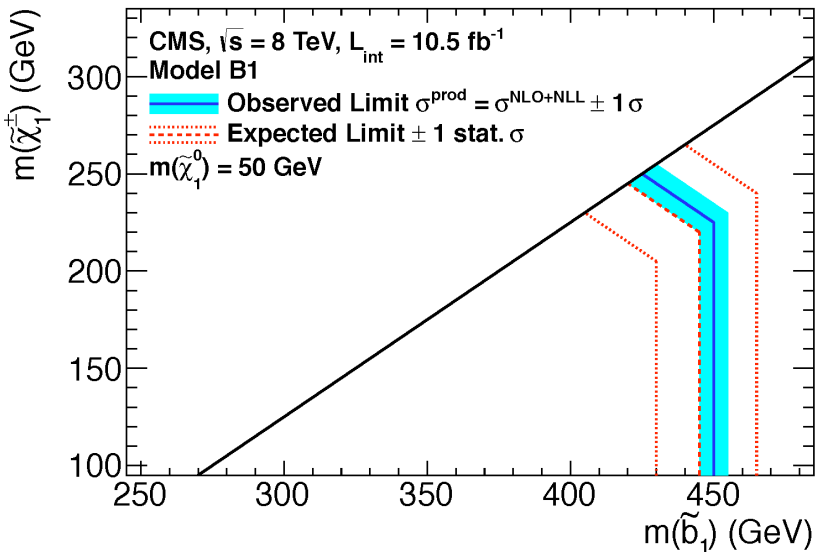
- signal selection efficiency ~ 1%



$$pp \to \tilde{b}_1\tilde{b}_1^* \to t\bar{t}WW\tilde{\chi}_1^0\tilde{\chi}_1^0$$



- signal selection efficiency ~ 0.5%



Single-lepton + bjets

Event selection

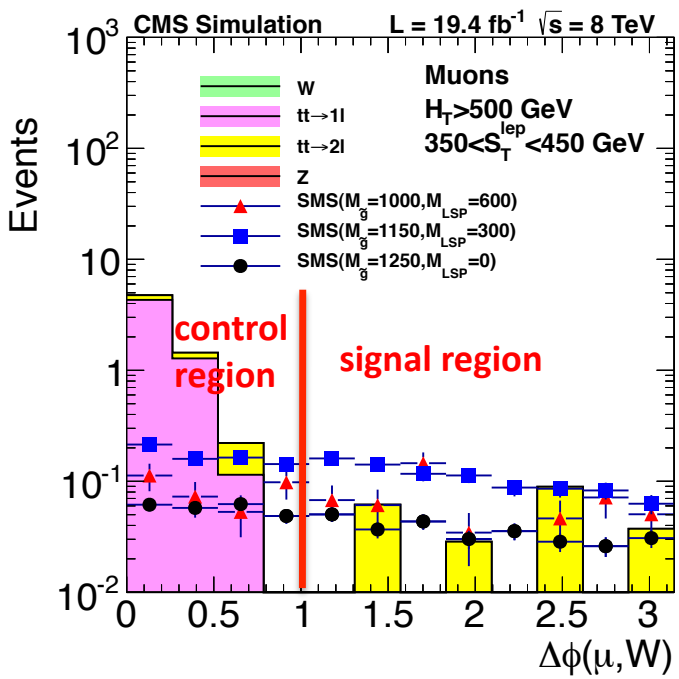
- 1 isolated high p_T lepton (e,μ)
- veto second lepton
- Njet ≥6, at least 2 b-jet
- HT > 500 GeV

Search strategy

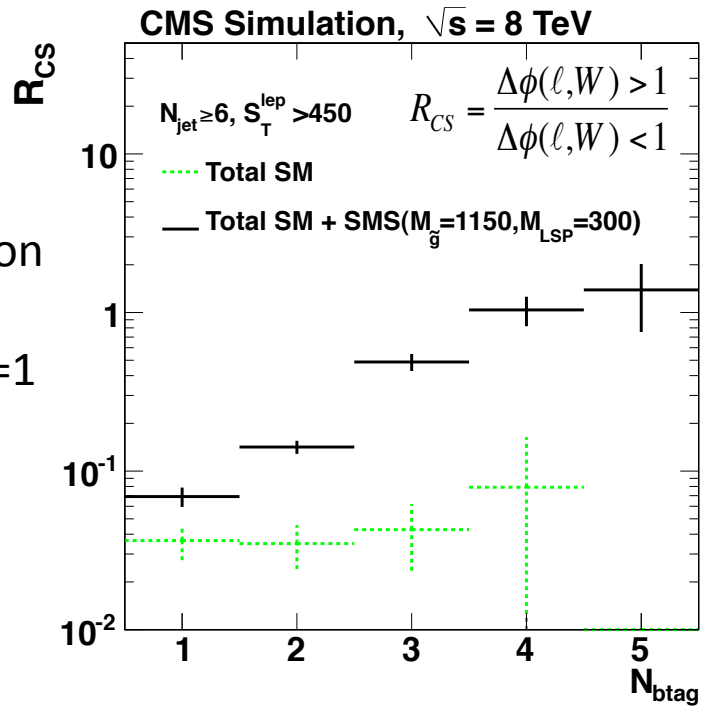
- Search is designed for four-top + large MET
- Exclusive search regions in Nbjets(=2,≥3) and

$$S_T^{Lep} = \sqrt{p_T^2(W) + M_T^2(W)} \qquad \Delta\phi(\ell,W) > 1$$

Δϕ(ℓ,W)



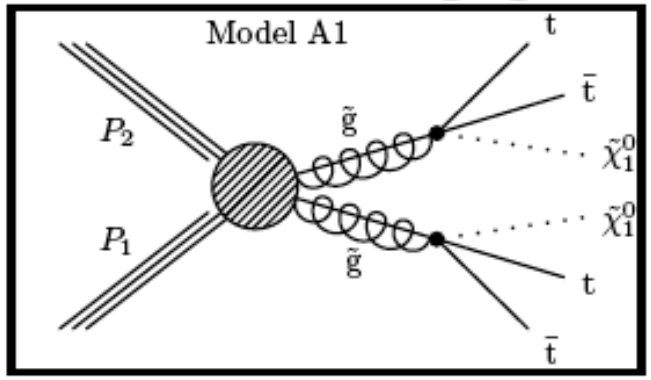
- ttBar/Wjets background: Use Δϕ(ℓ,W) < 1 to extrapolate to signal region where the transfer factor Rcs is measured in Nbjet=1 region.
- QCD negligible in signal region

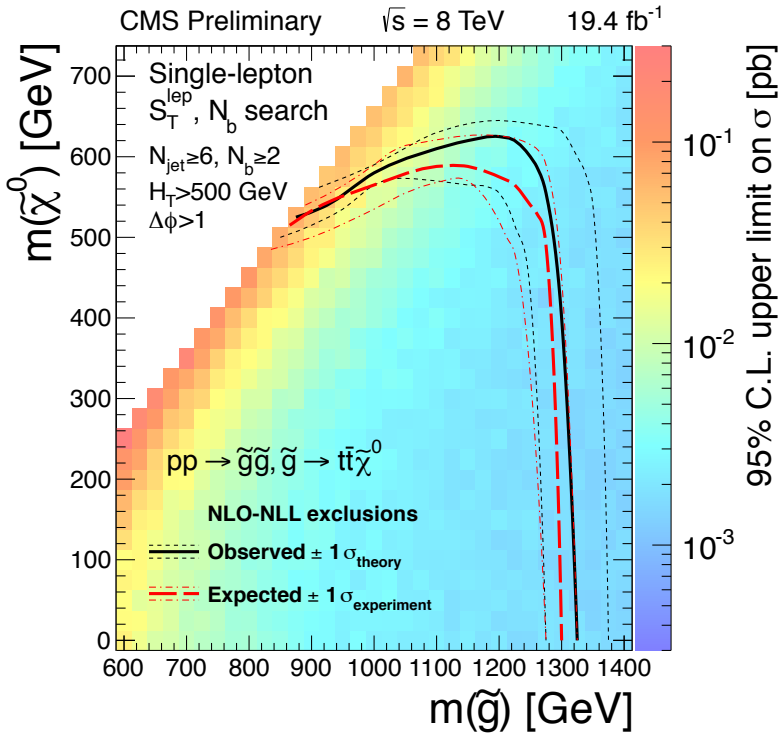


Single-lepton + bjets: Interpretation

		S_T^{lep} [GeV]	prediction	observation
N_b=2	Muons	[250,350]	6.00 ± 2.40 (2.23)	9
		[350,450]	1.37 ± 1.19 (1.12)	2
		>450	0.0 ± 0.66 (0.66)	0
	Electr.	[250,350]	3.83 ± 1.84 (1.75)	9
		[350,450]	2.74 ± 2.02 (1.86)	2
		>450	0.0 ± 0.42 (0.42)	0
$N_b \geq 3$	Muons	[250,350]	1.92 ± 0.95 (0.84)	0
		[350,450]	0.57 ± 0.58 (0.52)	0
		>450	0.0 ± 0.22 (0.22)	0
	Electr.	[250,350]	1.89 ± 1.03 (0.94)	4
		[350,450]	0.85 ± 0.80 (0.70)	0
		>450	0.0 ± 0.08 (0.08)	0

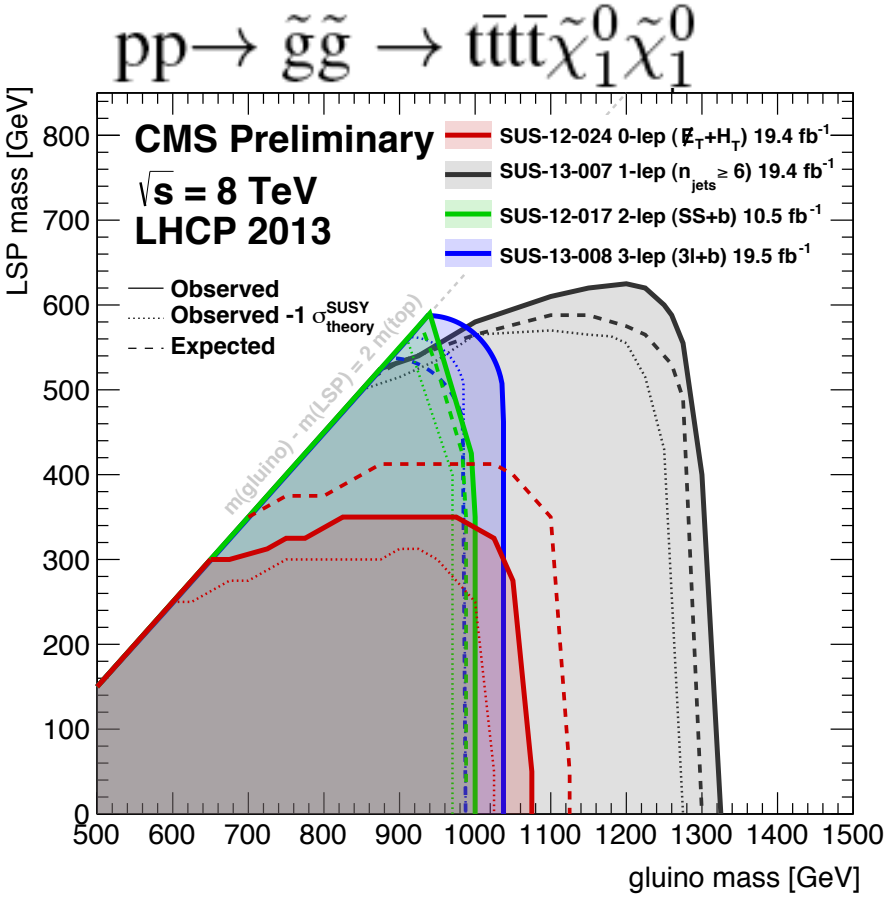
$pp \rightarrow \tilde{g}\tilde{g} \rightarrow t\bar{t}t\bar{t}\tilde{\chi}_1^0\tilde{\chi}_1^0$





- Very powerful discriminator dϕ(W,lepton)
- Small background and large signal efficiency (1-2%)
- Probe masses up to 1.3 TeV of gluino mass

Summary



- Various final states covering four-W & multi-bjet signature
- For gluino pair-production leading to 4-top + 2LSP, single lepton channel provides the best sensitivity for most of the phase-space, SS di-leptons, 3-leptons probed compressed mass spectra better
- A statistical combination of these results might improve the sensitivity along the diagonal
- For the simplified models considered Mgluino (Msbottom) up to 1.3 TeV (600 GeV) are excluded with 95%CL

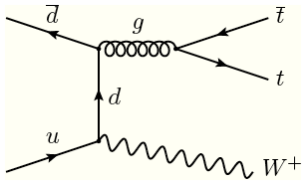
Backup

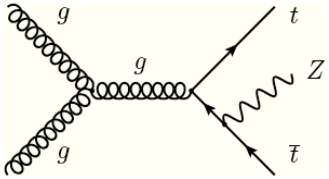
same-sign di-leptons: backgrounds

- **non-prompt/misidentified leptons:** Predicted using data-driven techniques (similar to multi-lepton + bjet)

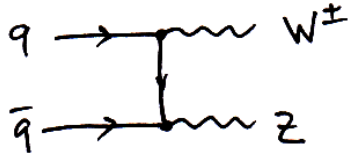
- **Rare SM processes :** (Irreducible) use simulations to predict this background with large systematic uncertainties

ttW/Z/H/γ production

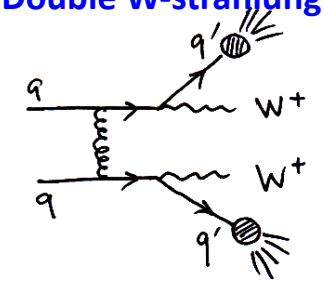




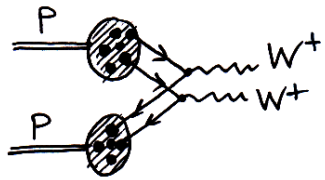
Di-boson production



Double W-strahlung



Double-parton scattering



- **Charge mis-measurement (small):** OS dileptons in DY, ttBar

muons: measured from cosmic ray data (~10^{-5})

electrons: Use Z events to predict change mis-id: depending on the pseudorapidity it varies 10^{-3} – 10^{-4}