Searches for gluino pair production in the single lepton final state

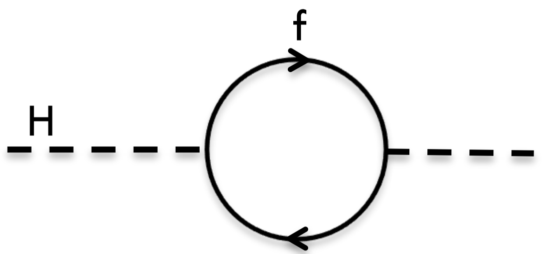
LHC Discussion, DESY

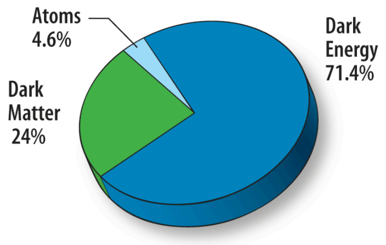
June 6th, 2016

Claudia Seitz, DESY

Physics beyond the Standard Model

- Unresolved questions of the SM
  - Hierarchy problem
    - Higgs mass should be at the Planck scale due to loop corrections from fermions to its mass
  - No unification of couplings at the Planck scale
  - No explanation for Dark Matter or Dark Energy





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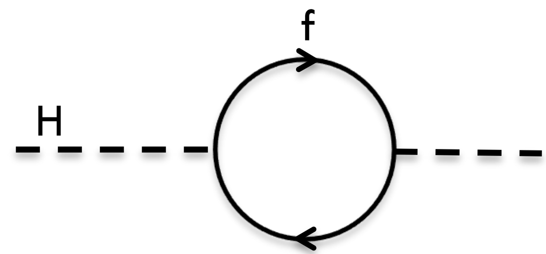
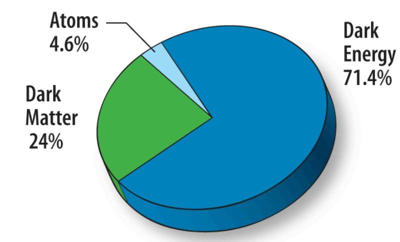
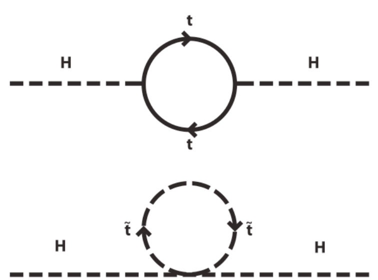
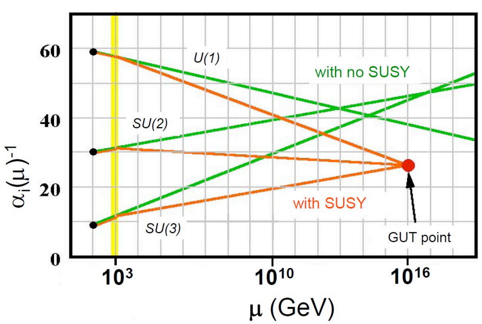




- Supersymmetry linking fermions <--> bosons proposes a solution



Sparticle loops cancel corrections to Higgs mass

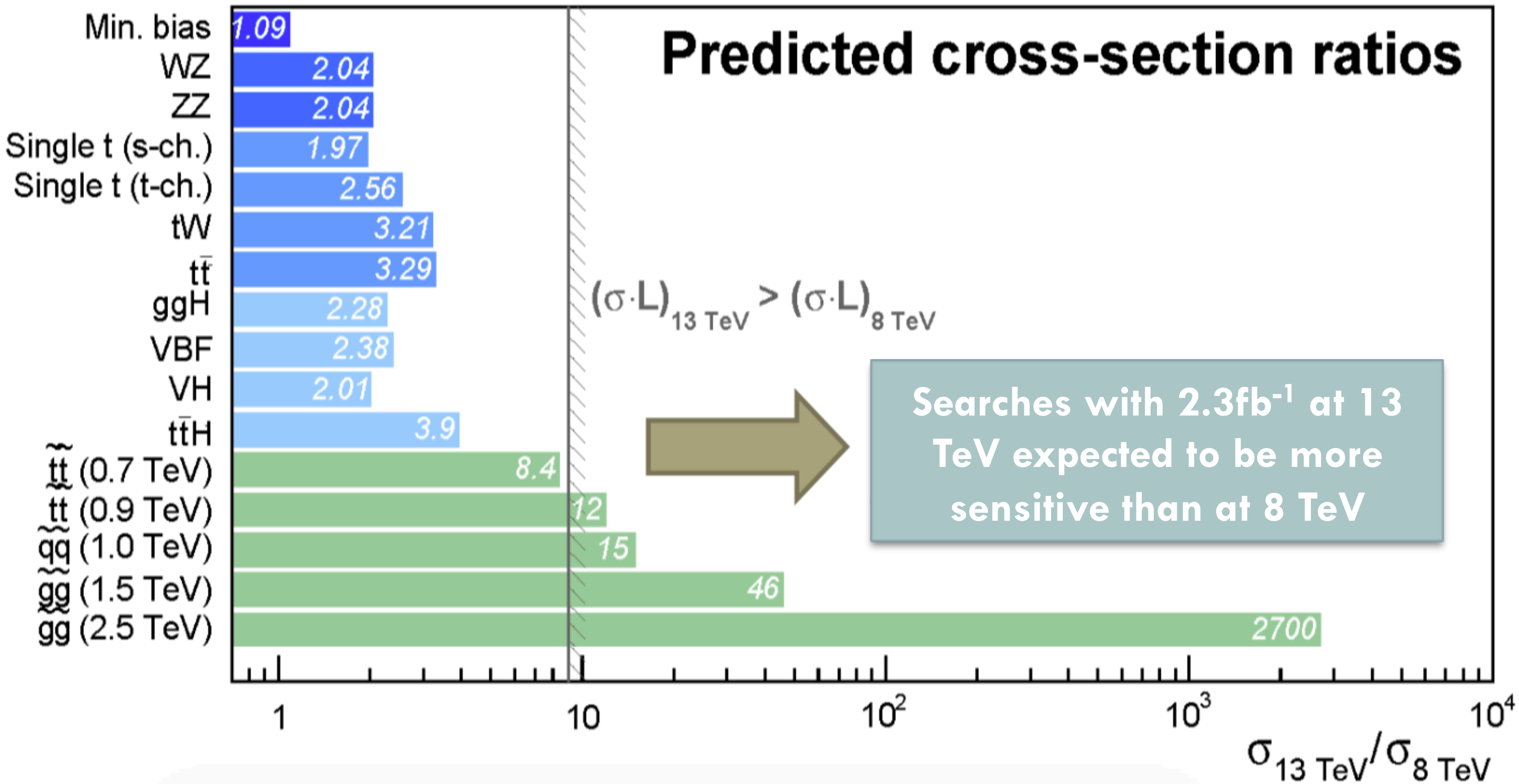


Possible unification of the gauge couplings at GUT scale

$$R = (-1)^{(2s+3B+L)} = \begin{cases} +1 & \text{SM} \\ -1 & \text{SUSY} \end{cases}$$

R-parity conservation implies the existence of a stable LSP as a dark matter candidate

Setting the stage for SUSY in Run 2



Early SUSY searches mostly aiming at gluino production:

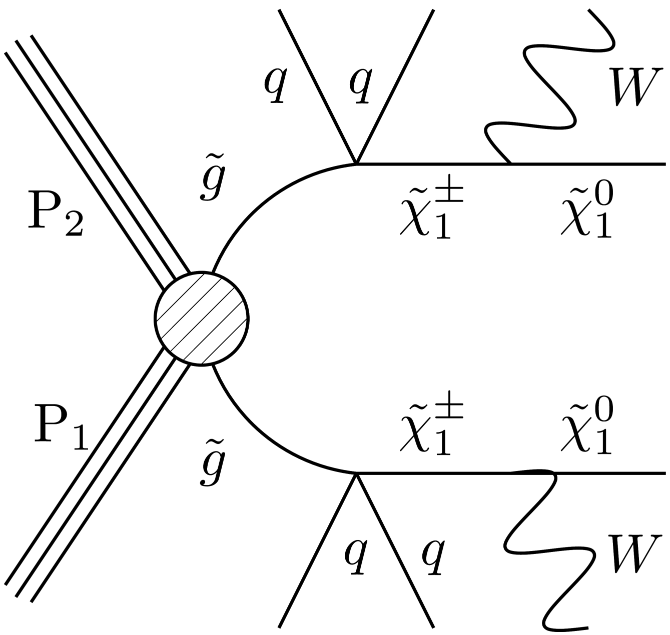
Expect gain in sensitivity due to large increase in cross section when compared to 8 TeV

Gluino induced simplified signal models

SUS-15-006
$\Delta\phi$, = 0b

SUS-15-006
$\Delta\phi$, ≥ 1b

SUS-15-007
MJ, ≥ 1b

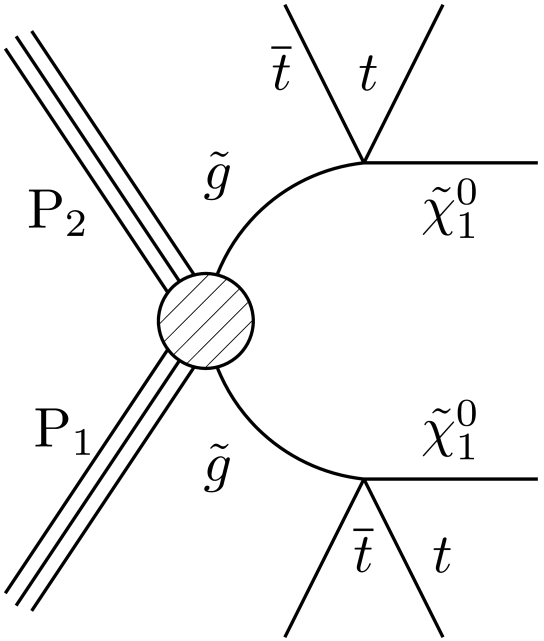


Decoupled mass spectrum

R-Parity conservation

Two parameters
m_{LSP} vs. $m_{sparticle}$

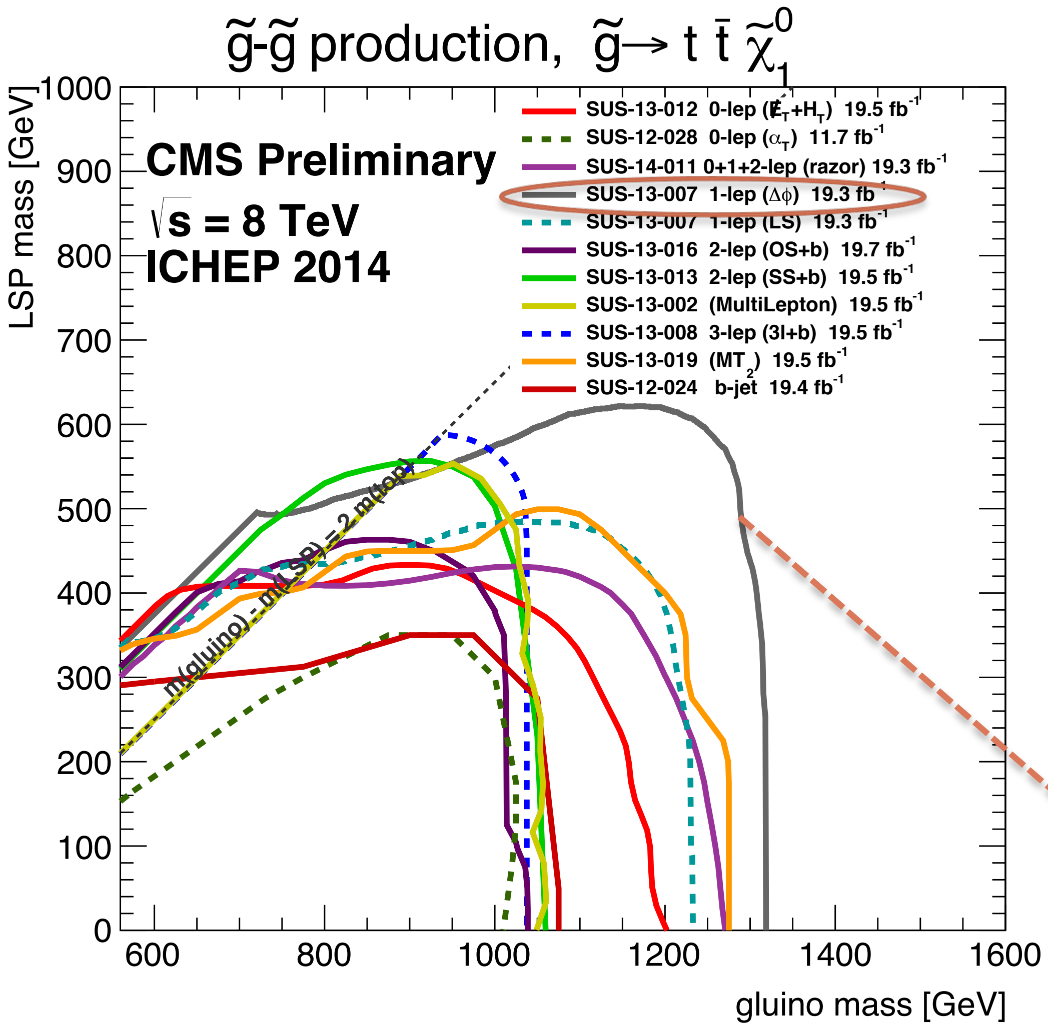
Mostly 100% BR

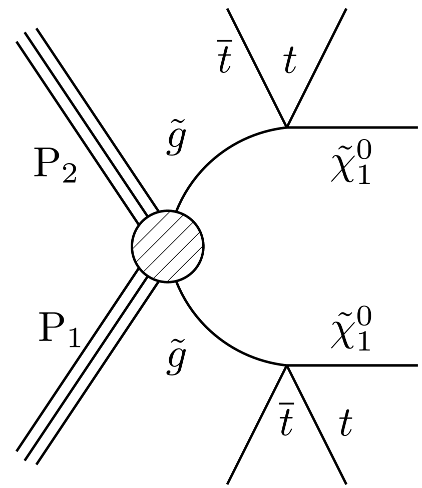


T5qqqqWW
0 b-jets

T1tttt
multiple b-jets

Recap of CMS Run 1: T1tttt

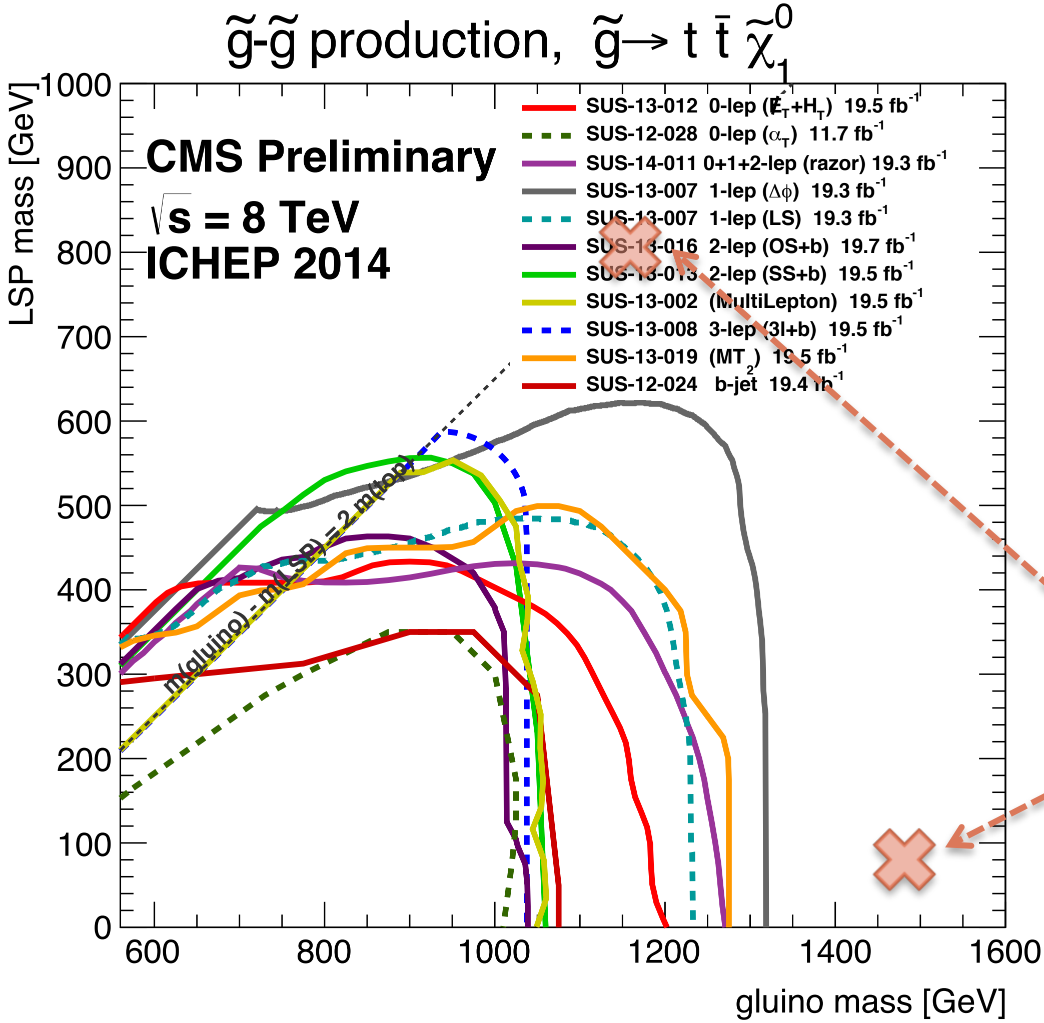


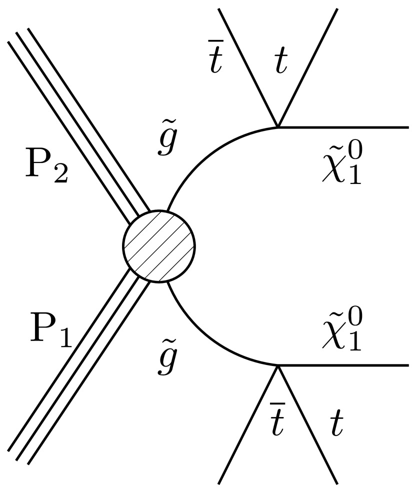


One lepton final state has a high probability when **four top quarks decay ~40%**

Search in this final state gave most stringent limits on this model

Recap of CMS Run 1: T1tttt





Two benchmark scenarios were used to prepare the first searches at 13 TeV
T1tttt 1.2/0.8
T1tttt 1.5/0.1

Baseline selection and analysis strategy

SUS-15-006

= 0b | ≥ 1b

- One e/μ with pT > **25 GeV**
- H_T > 500 GeV
- **nJets ≥ 5 or ≥ 6,** lower nJet regions used for bkg estimate
- **L_T = lep p_T + MET > 250 GeV**

SUS-15-007

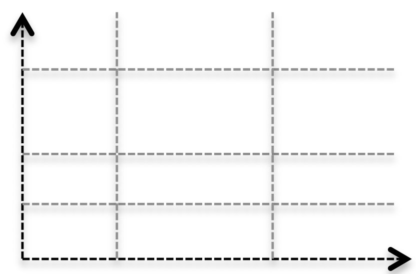
MJ, ≥ 1b

- One e/μ with pT > **20 GeV**
- H_T > 500 GeV
- **nJets ≥ 6**
- **MET > 200 GeV**

Both analyses use multiple exclusive search categories

L_T

+ nBjets categories



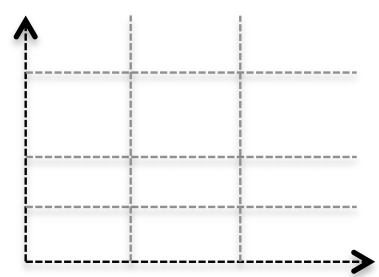
H_T

30 exclusive search bins for multi-b

10 exclusive search bins for 0-b

Bins in: nJets

MET



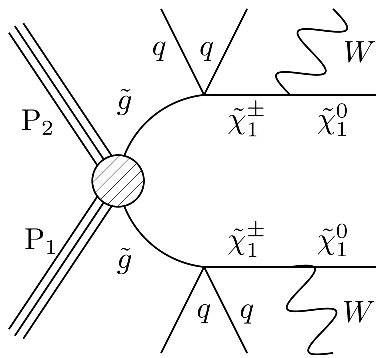
nBjets

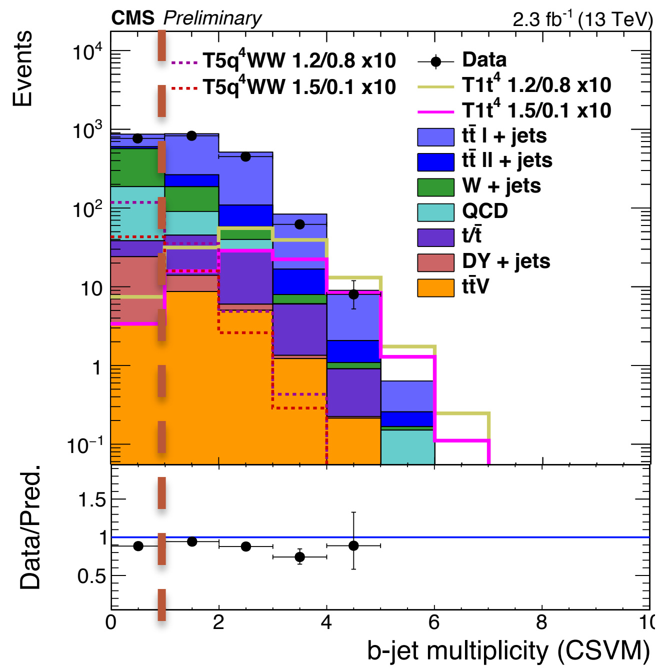
10 exclusive search bins

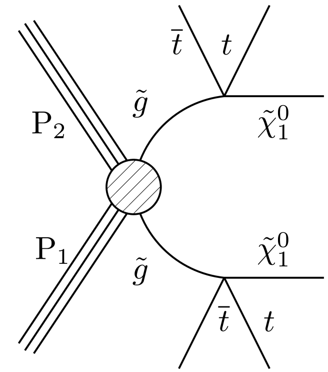
Two different signal scenarios

SUS-15-006

= 0b | ≥ 1b

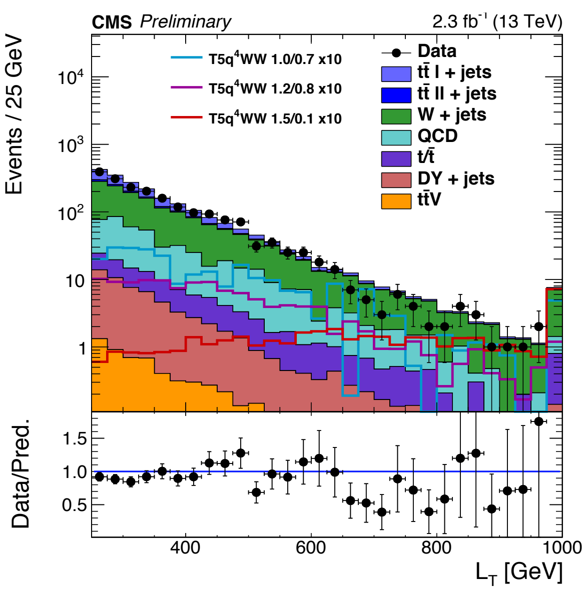






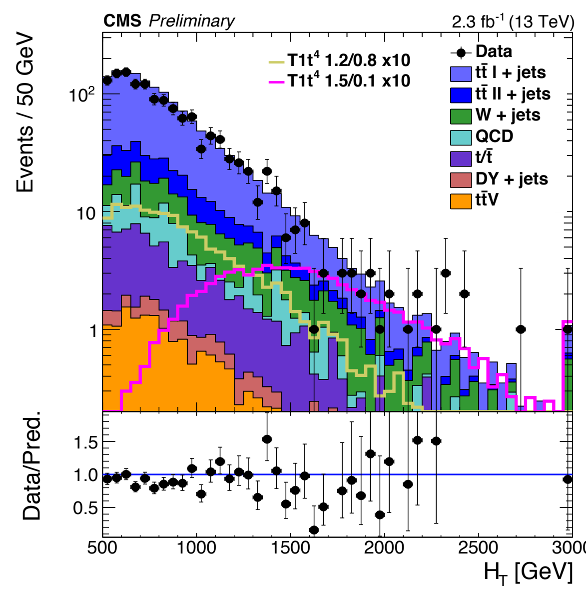
= 0b dominated by W+jets

≥ 1b dominated by tt+jets



H_T = sum p_T of all jets

L_T = lepton p_T + MET

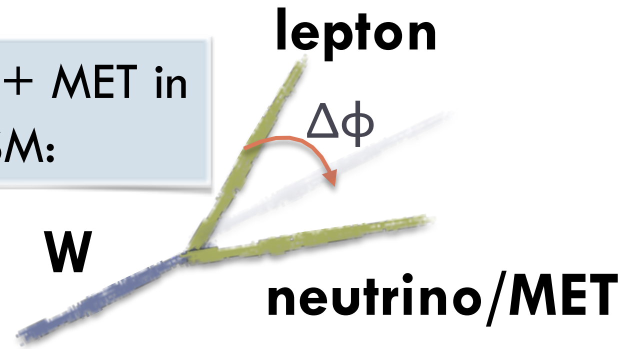


Why Δϕ as discriminating variable?

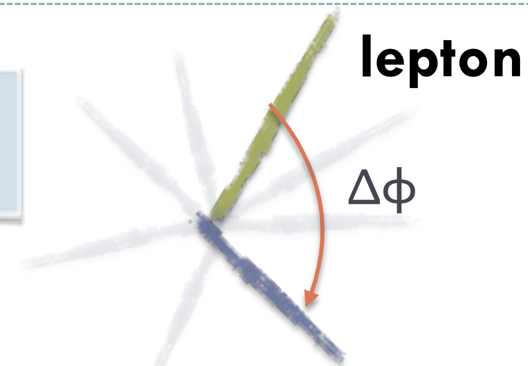
SUS-15-006

= 0b | ≥ 1b

Lepton + MET in SM:

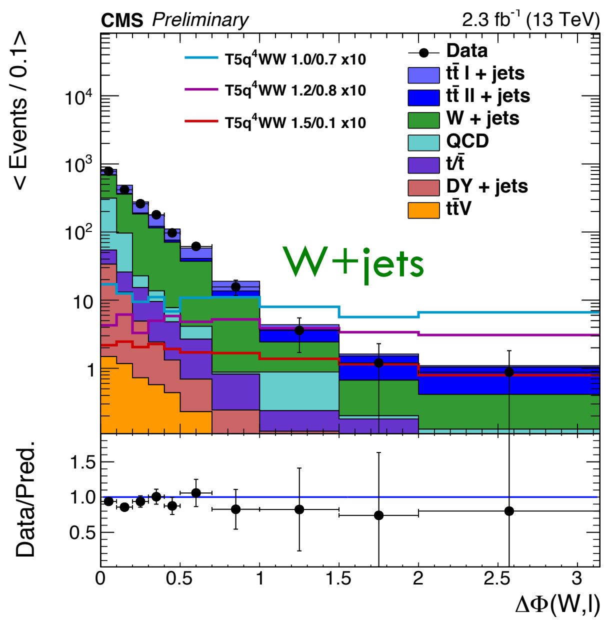


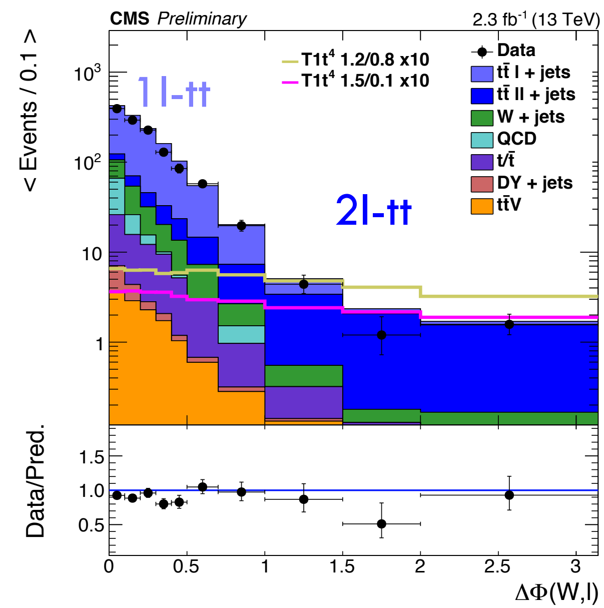
Lepton + MET with SUSY:



Δϕ: Angle between lepton and reconstructed W

MET (mostly) due to LSP → "randomized" reconstructed W → "randomized" Δϕ



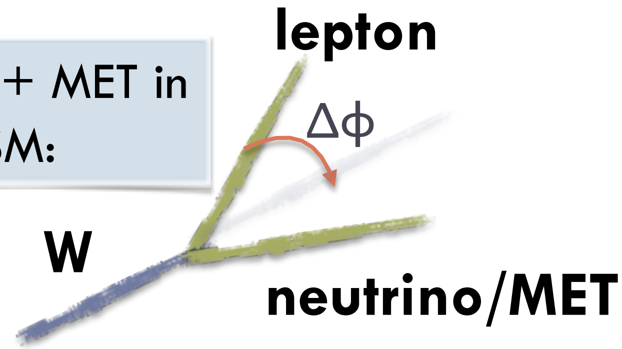


Why Δϕ as discriminating variable?

SUS-15-006

= 0b ≥ 1b

Lepton + MET in SM:



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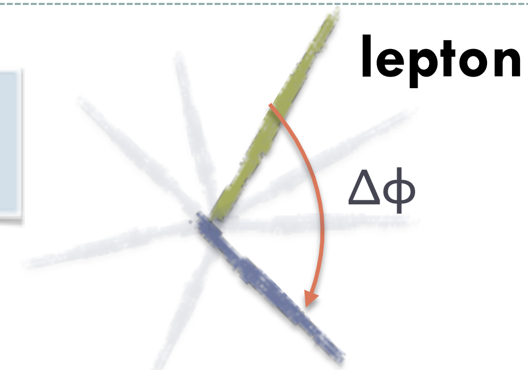

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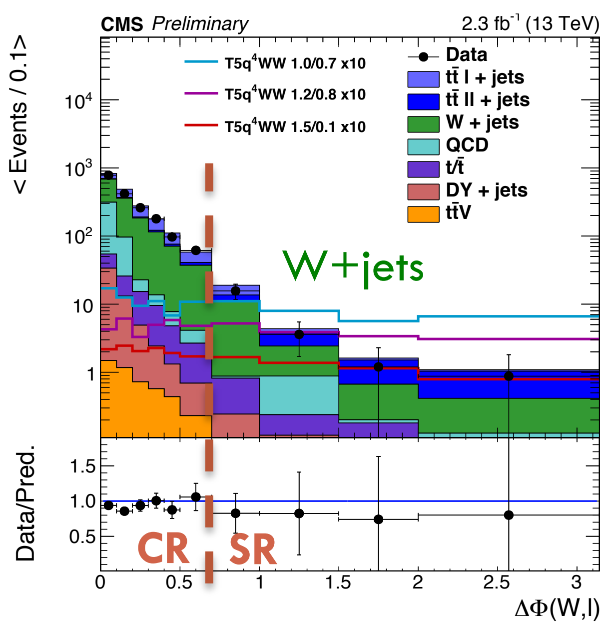
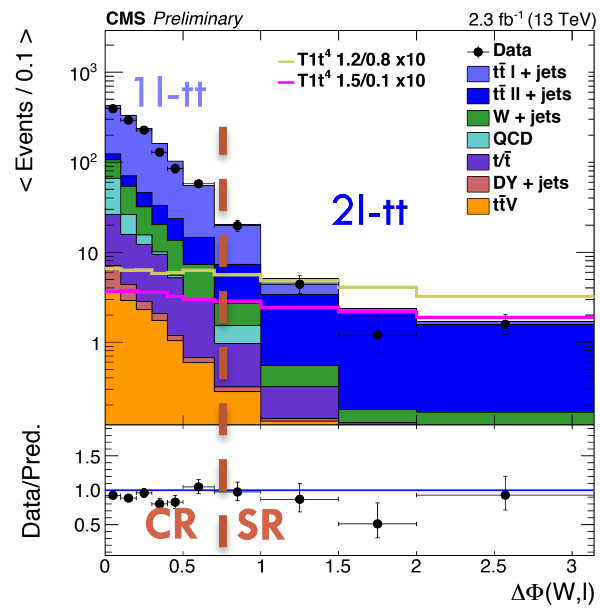


Dynamic Δϕ cut as function of L_T that defines signal and control regions

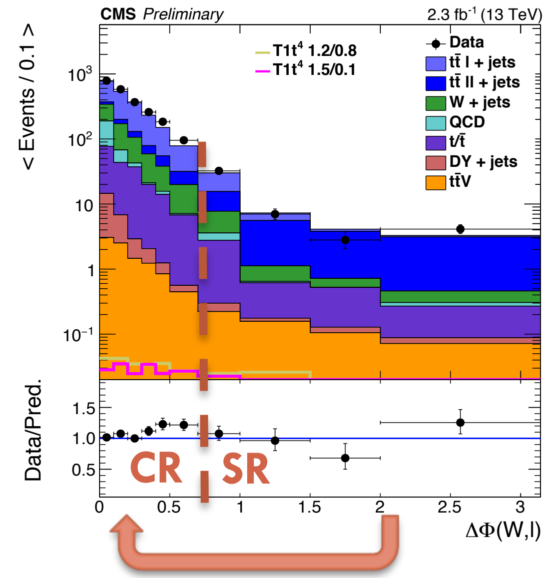


Background estimation method: R_{CS} method

SUS-15-006

= 0b | ≥ 1b

- Determine transfer factors R_{CS} between $\Delta\phi > X$ and $\Delta\phi < X$ from lower jet multiplicities side band bins
  - Residual differences between SB and MB are corrected by simulation
- Method is similar to an ABCD approach in nJets vs $\Delta\phi$



$R_{CS} = N_{SR}(SB)/N_{CR}(SB)$

	$\Delta\phi < X$ CR	$\Delta\phi > X$ SR
Low nJet (3-4j, 4-5j)	$R_{CS}(SB) = N_{SR}(SB)/N_{CR}(SB)$	
High nJet (≥ 5j, ≥ 6j)	$N_{CR}(MB)$	$\mathbf{N_{CR}(MB) \times k^{MC} \times R_{CS}\ (SB)}$

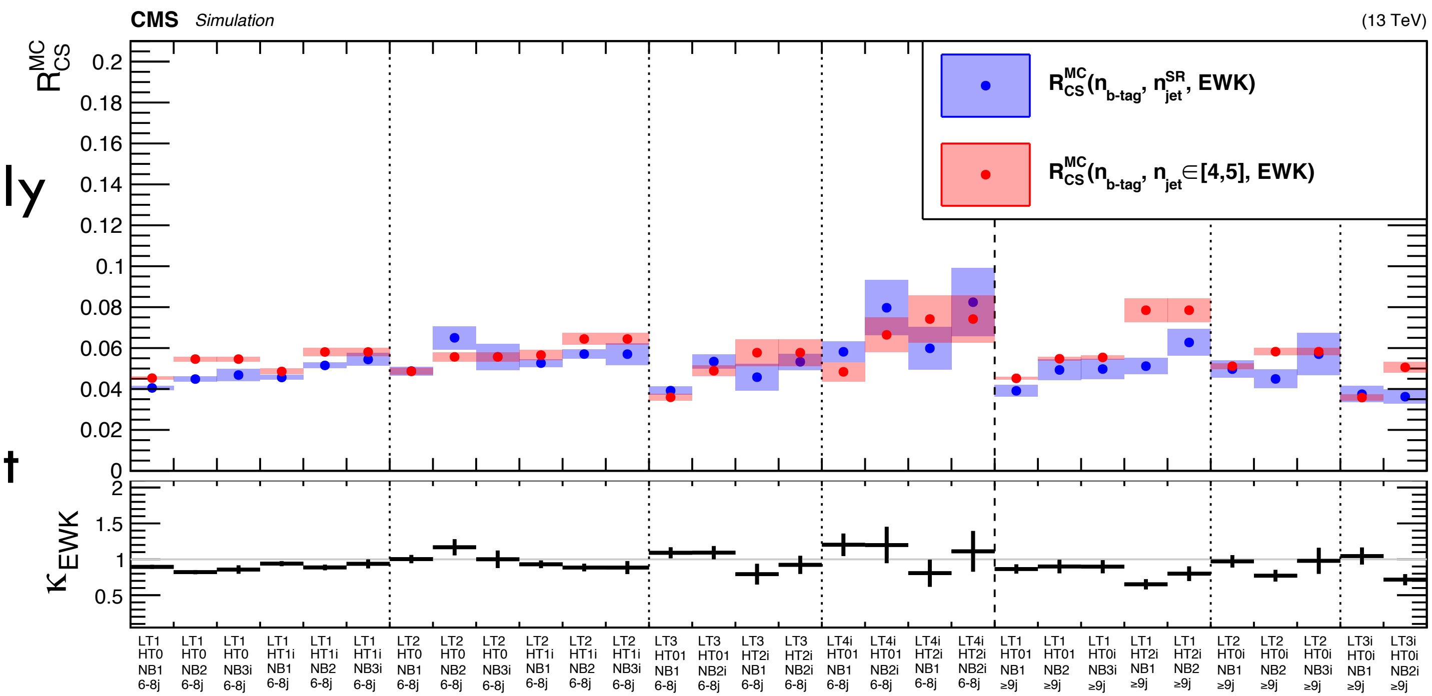
Region of interest

Correction factors from simulation

- Any residual difference on R_{cs} between the SB and MB is corrected by a k^{MC} factor from simulation
- Need to choose kinematically similar SB bins (same H_T, L_T)

R_{cs} in the SB follows closely R_{cs} in the MB

k^{MC} consistent with 1 for most bins



Background estimation method: R_{CS} method

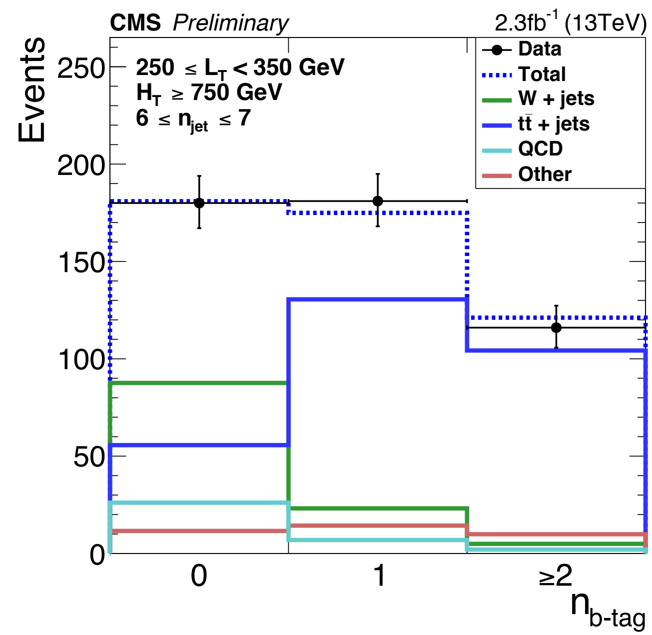
SUS-15-006

= 0b | ≥ 1b

- Different jet multiplicity side bands are used for W+jets, tt+jets and QCD
- Multi-b is dominated by tt+jets
- 0-b has equal parts W and tt
  - Two independent side bands for both components
  - Mixture is determined from fit to b-tag multiplicity in the $\Delta\phi$ < X of the high nJets search regions

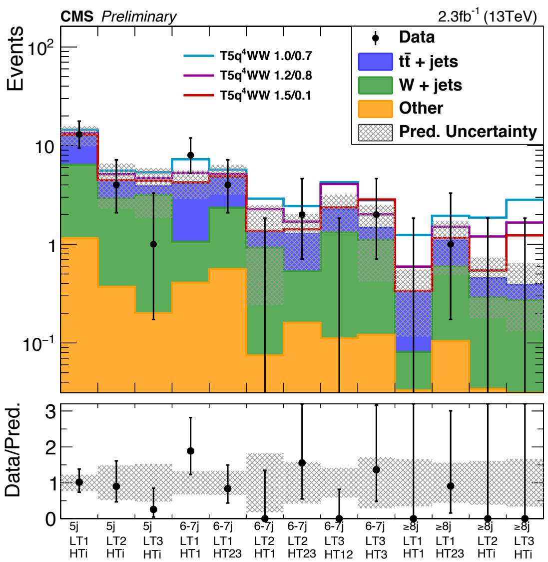
Analysis	Multi-b analysis	
$n_{\text{b-tag}}$	$n_{\text{b-tag}} = 0$	$n_{\text{b-tag}} \geq 1$
$n_{\text{jet}} = 3$	QCD Fit (el. sample)	
$n_{\text{jet}} = 4$	QCD Fit (el. sample)	R_{CS} det.
$n_{\text{jet}} = 5$		R_{CS} det.
$n_{\text{jet}} \geq 6$		MB

Analysis	Zero-b analysis	
$n_{\text{b-tag}}$	$n_{\text{b-tag}} = 0$	$n_{\text{b-tag}} = 1$
$n_{\text{jet}} = 3$	$R_{CS}(W^{\pm})$ det. (μ sample), QCD Fit (el. sample)	
$n_{\text{jet}} = 4$	$R_{CS}(W^{\pm})$ det. (μ sample), QCD Fit (el. sample)	$R_{CS}(t\bar{t})$ det.
$n_{\text{jet}} = 5$	MB	$R_{CS}(t\bar{t})$ det.
$n_{\text{jet}} \geq 6$	MB	

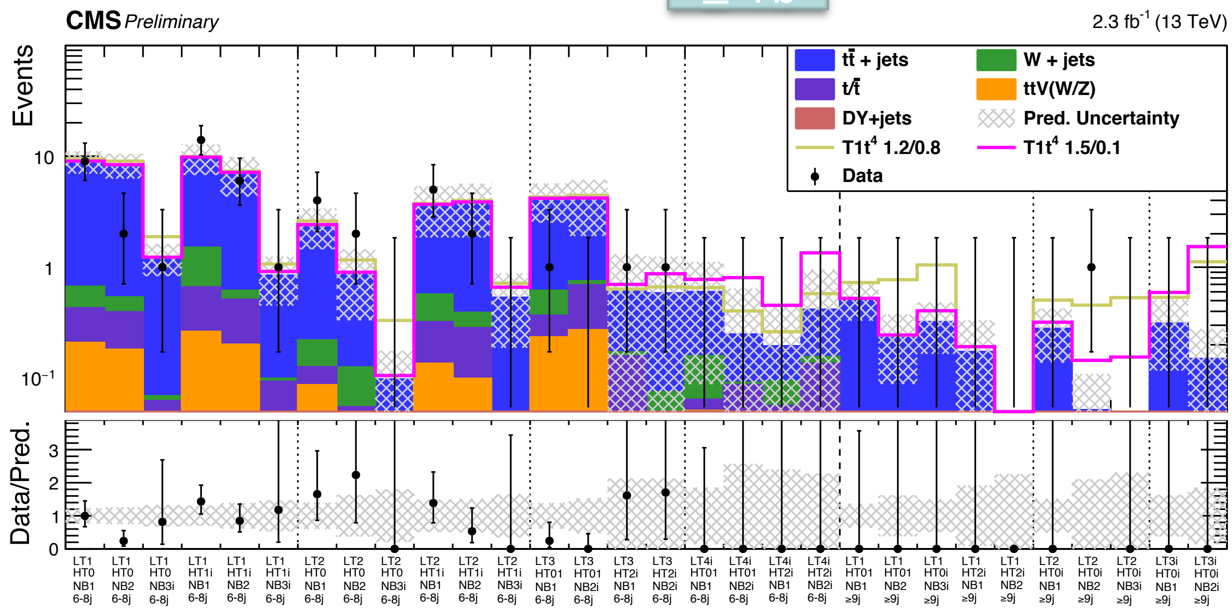


Results

= 0b



≥ 1b

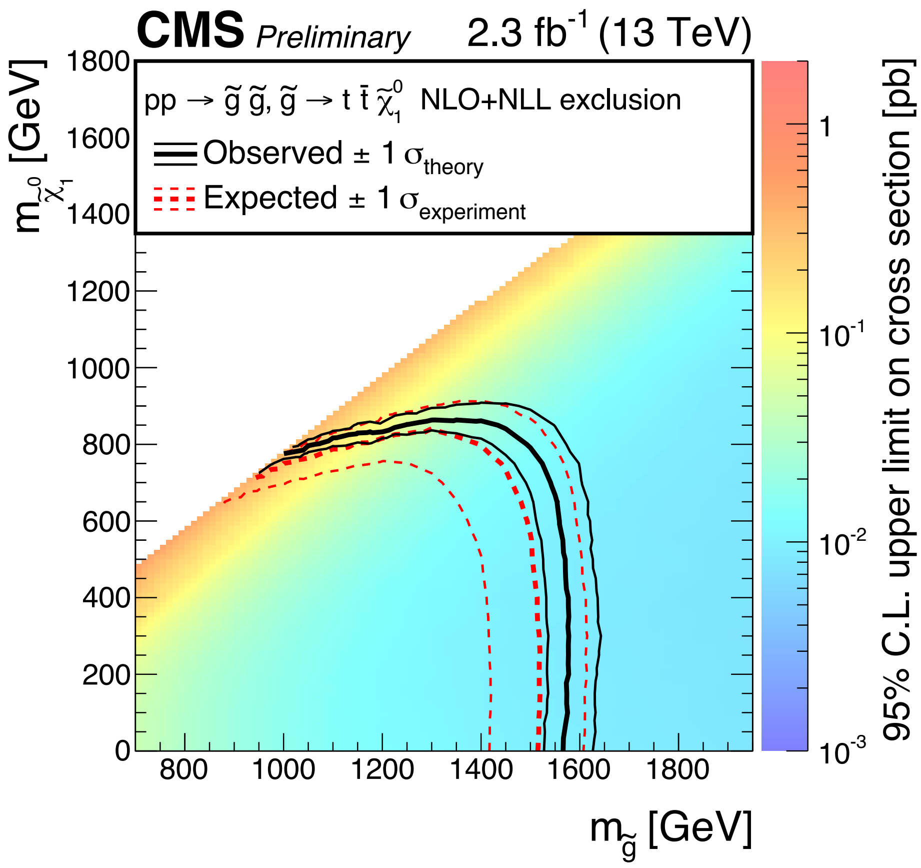


- Good agreement between prediction and observation
- Placing limits on T5qqqqWW and T1tttt model

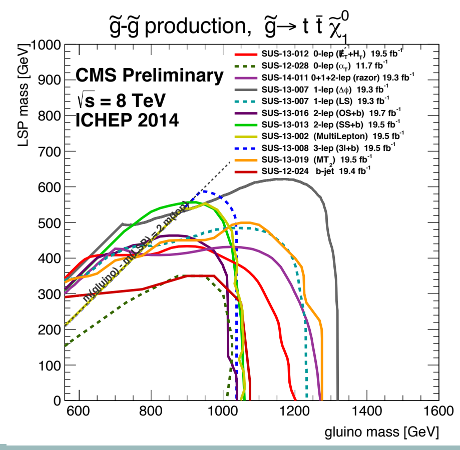
Limits on T1tttt

SUS-15-006

$\Delta\phi$, $\geq$ 1b



- Profile likelihood method with asymptotic approximation used to set limits at the 95% C.L.
- Gluino mass excluded up to 1575 GeV for LSP masses below 800 GeV in this simplified model

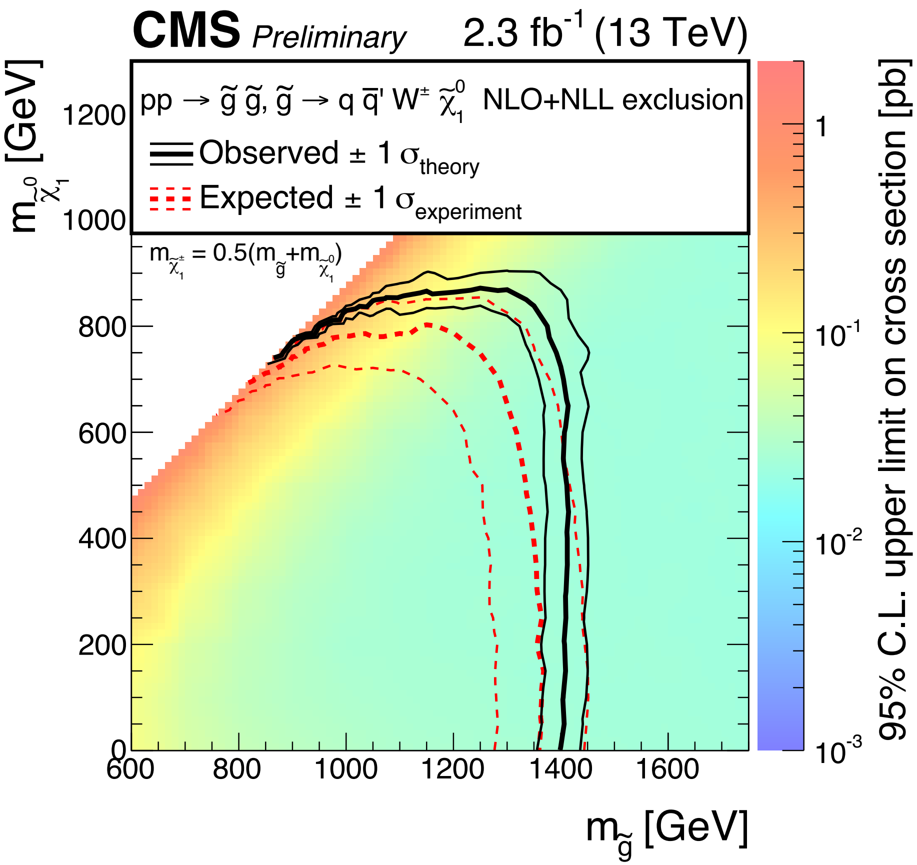


Extending 8 TeV results by 250 GeV

Limits on T5qqqqWW

SUS-15-006

$\Delta\phi$, = 0b



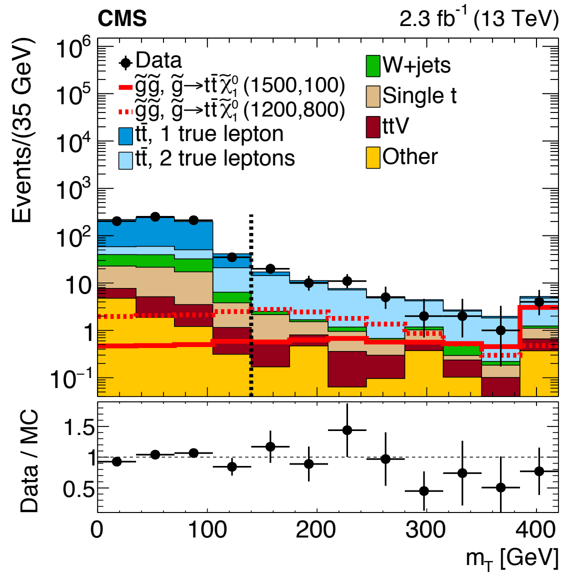
- Profile likelihood method with asymptotic approximation used to set limits at the 95% C.L.
- Gluinos below 1400 GeV are excluded for neutralino masses below 725 GeV

m_T and MJ as discriminating variables

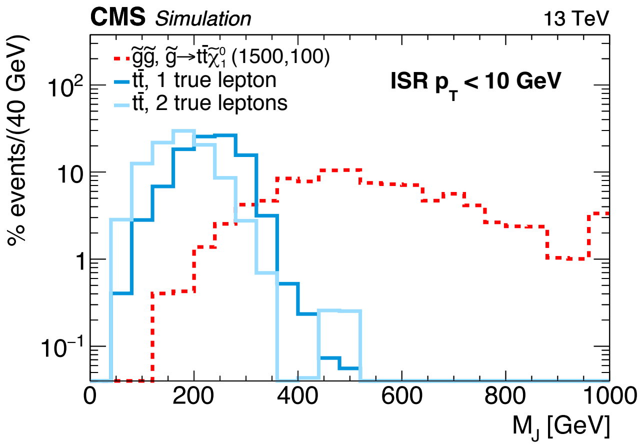
SUS-15-007

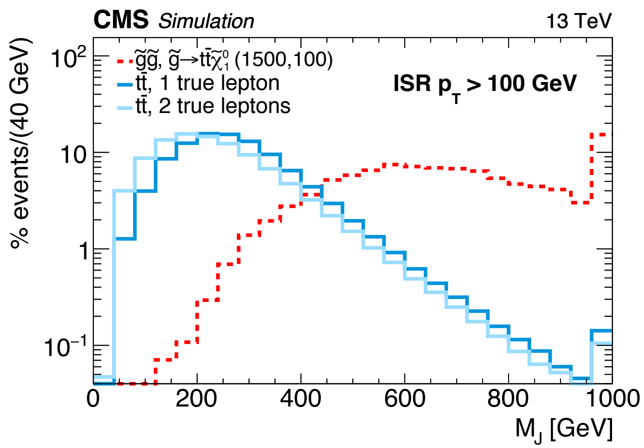
MJ, ≥ 1b

- Transverse mass m_T: between lepton and MET has endpoint around W mass for 1l-tt and longer tail for 2l-tt events



- Sum of masses of large R jets MJ
  - Small radius (anit-kT 0.4) jets + lepton are clustered into large radius (anit-kT 1.2) jets
  - MJ = sum of large jet masses





Without ISR MJ of the tt system has endpoint at twice the top mass while the signal shape is unaffected.

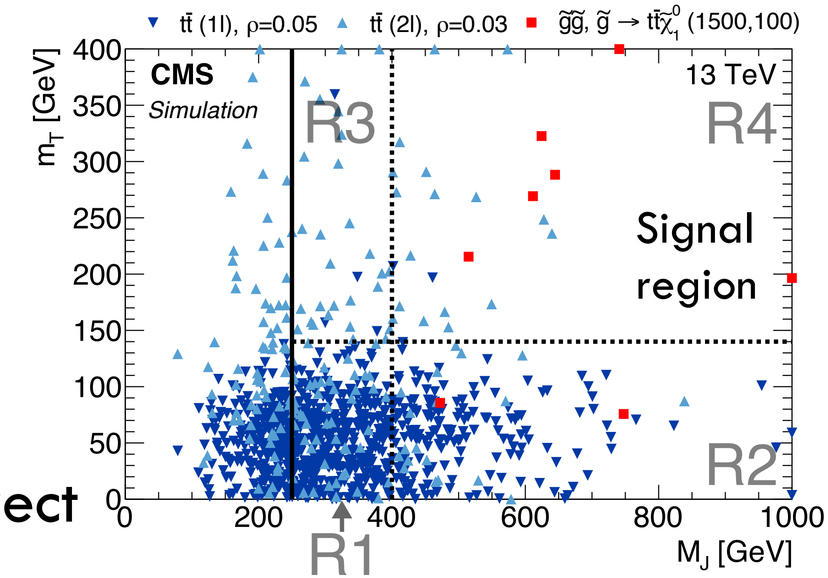
Background prediction

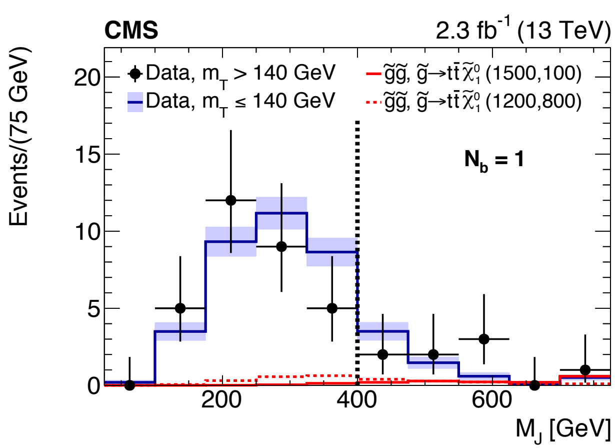
SUS-15-007
MJ, ≥ 1b

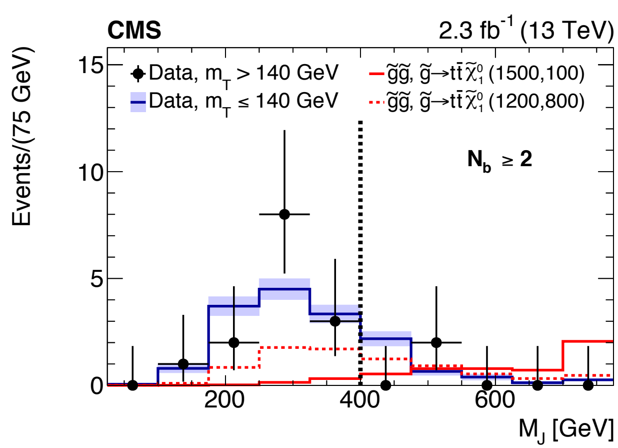
- Background estimation based on m_T and MJ being uncorrelated
- Background in R4 is predicted with ABCD method

$$N_{R4} = k^{MC} \times [N_{R2} \times N_{R3} / N_{R1}]^{Data}$$

- Correction factor k^{MC} used to correct small residual differences





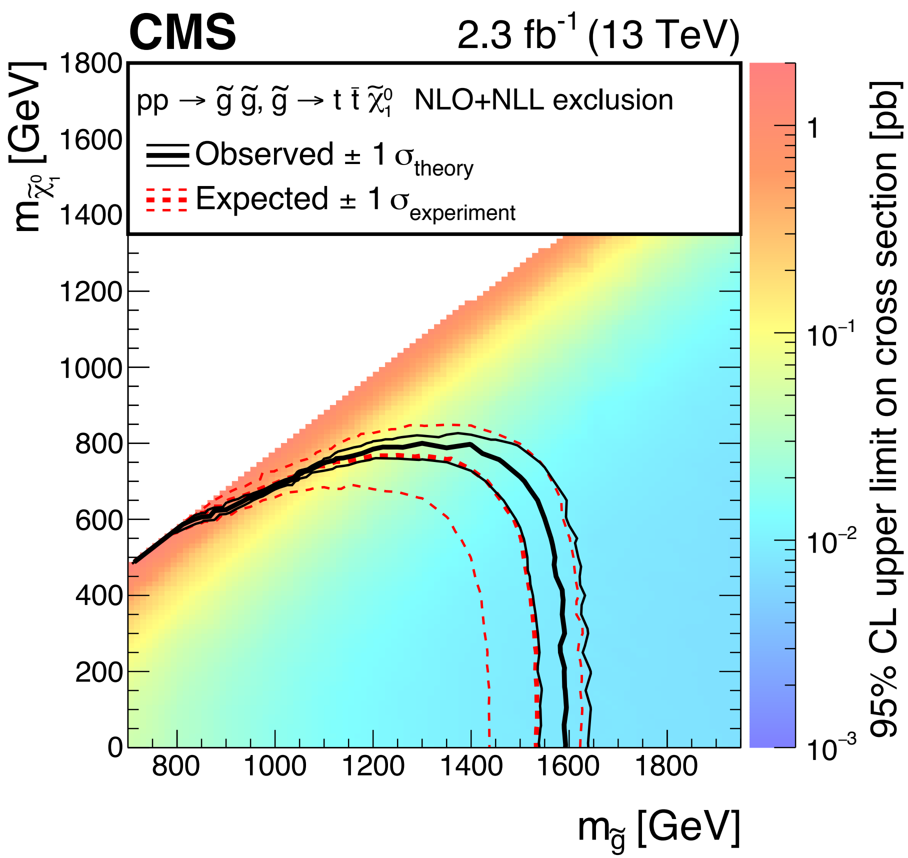


Check the validity of the bkg estimation method by comparing MJ distributions for low and **high** m_T regions

Limits on T1tttt

SUS-15-007

MJ, ≥ 1b



- Profile likelihood method with asymptotic approximation used to set limits at the 95% C.L.
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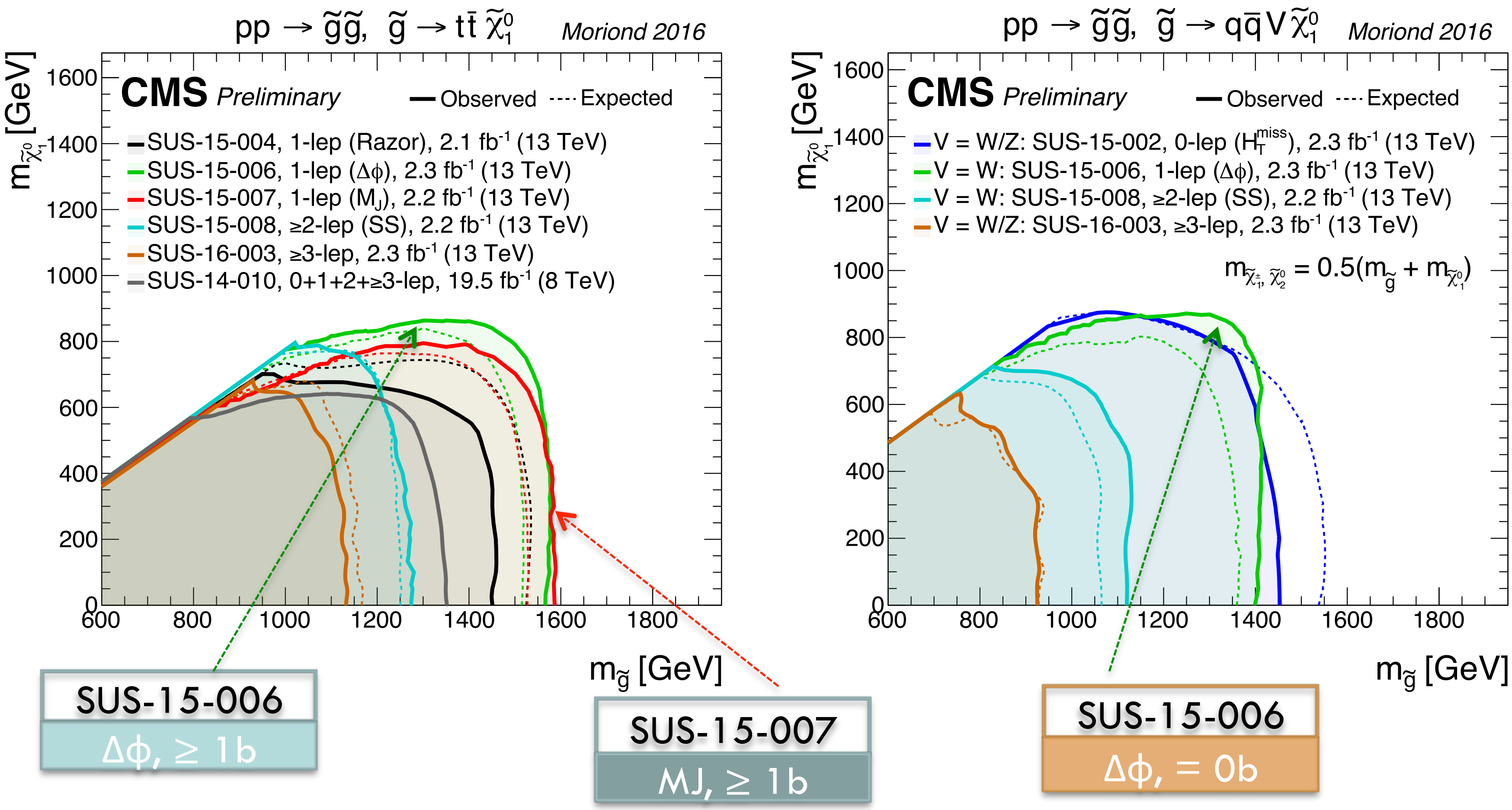
Comparison with other analyses

- Leptonic searches cover a large area of phase space



Summary

- Run2 of the LHC is in full swing

- Many SUSY searches are being performed
  - Unfortunately no sign yet
  - Even with low luminosity limits on simplified models already extent previous searches at 8 TeV by multiple 100 GeV

- Three single lepton results shown for two different models
  - Two different search approaches within the single lepton final state yield similar results
  - In case of an excess can double check each other

- Stay tuned for results this year, will keep the momentum going as more data is coming in

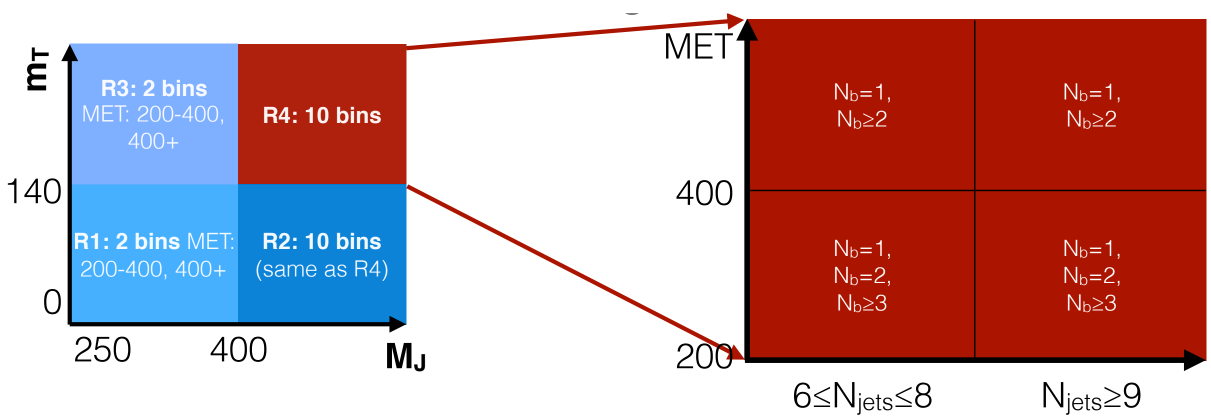
Backup

Signal regions

n_{jet}	$n_{\text{b-tag}}$	L_T [GeV]	H_T [GeV]	$\Delta\Phi$
[6,8]	$=1, =2, \geq 3$	$[250, 350]$	$[500, 750]$, ≥ 750	1.0
		$[350, 450]$	$[500, 750]$, ≥ 750	0.75
	$=1, \geq 2$	$[450, 600]$	$[500, 1250]$, ≥ 1250	
		≥ 600	$[500, 1250]$, ≥ 1250	0.5
≥ 9	$=1, =2$	$[250, 350]$	$[500, 1250]$, ≥ 1250	1.0
	≥ 3		≥ 500	
	$=1, =2, \geq 3$	$[350, 450]$	≥ 500	0.75
	$=1, \geq 2$	≥ 450	≥ 500	
5	0	$[250, 350]$, $[350, 450]$, ≥ 450	≥ 500	1.0
[6,7]		$[250, 350]$, $[350, 450]$	$[500, 750]$, ≥ 750	
		≥ 450	$[500, 1000]$, ≥ 1000	0.75
≥ 8		$[250, 350]$	$[500, 750]$, ≥ 750	1.0
		$[350, 450]$, ≥ 450	≥ 500	0.75

SUS-15-006

= 0b | ≥ 1b



SUS-15-007

MJ, ≥ 1b

Systematic uncertainties

Source	Uncertainty [%] for multi-b	Uncertainty [%] for zero-b
dilepton control sample	8-20	8-40
JEC	0.2-11	0.6-8.2
b-tagging	0.1-17	1.4-4.5
$\sigma(\mathrm{W}+\text{jets})$	0.3-6.4	<2.5
W polarization variation	0.1-2	0.2-3.4
$\sigma(\mathrm{t\bar{t}}V)$	0.1-5	0.2-2.9
top p_{T} reweighting	0.1-10	0.1-7.1
pileup	0.3-23	0.1-10
R_{CS} fit	–	3.3-35
Total	8.0-28	10-54
MC statistics	3-30	8-48

SUS-15-006

$= 0$b | ≥ 1b

Source	Fractional uncertainty [%]
Lepton efficiency	1–5
Trigger efficiency	1
b tagging efficiency	1–15
Jet energy corrections	1–30
Renormalization and factorization scales	1–5
Initial state radiation	1–35
Pileup	5
Integrated luminosity	3

SUS-15-007

MJ, ≥ 1b