Search for Supersymmetry in the single-lepton final state with the CMS experiment

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on behalf of the CMS collaboration

CMS

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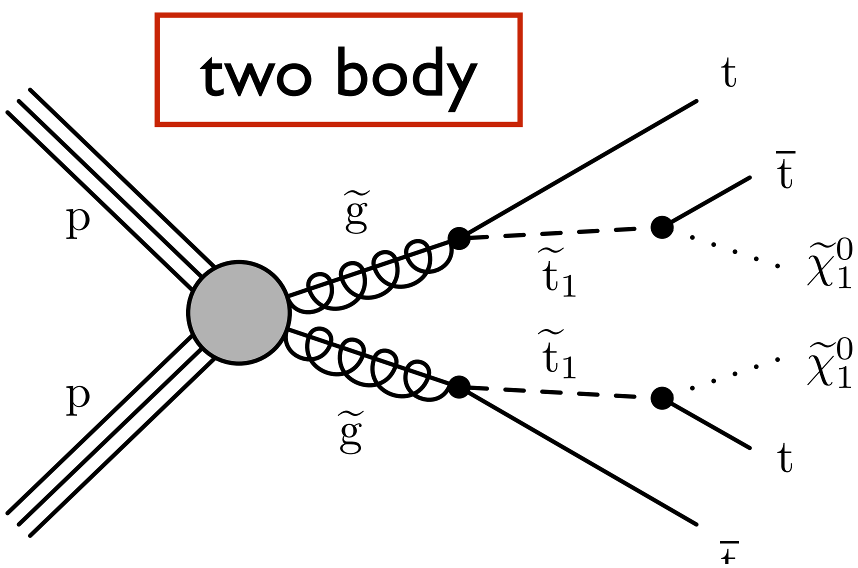
FWF

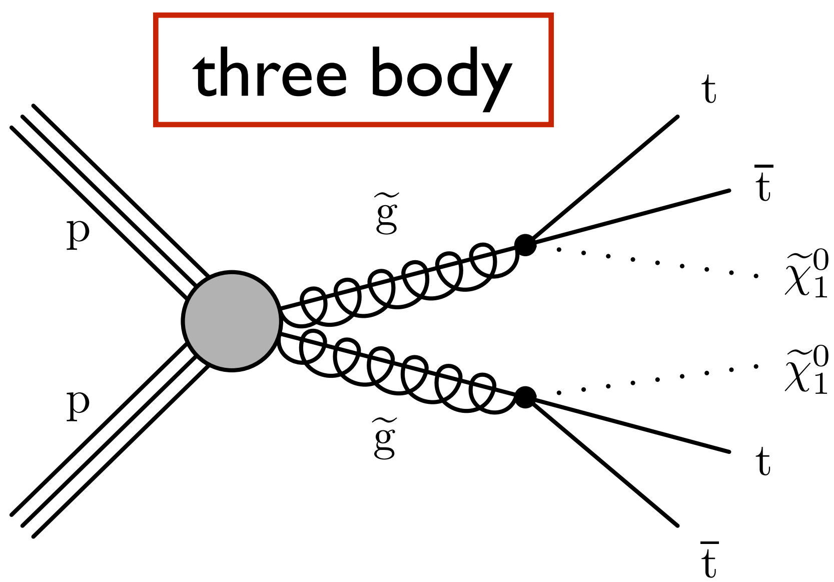
Introduction

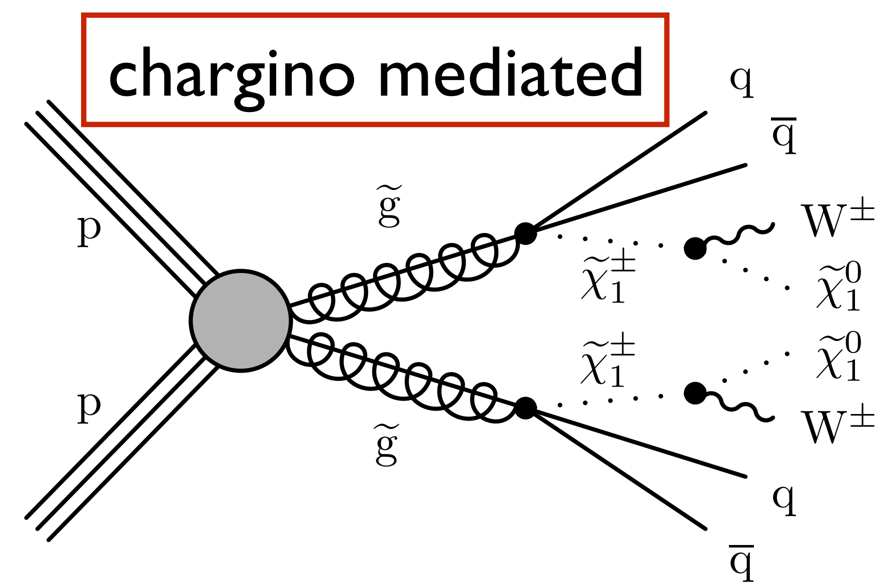
- Latest results on gluino pair production in single lepton final states
- For top squark pair production see Tom's (Tue) and Navid's (Thu) talks

M_J analysis: <u>CMS-SUS-16-037</u>
PRL 119 (2017) 151802

$\Delta\Phi$ analysis: <u>CMS-SUS-16-042</u>
submitted to PLB







1 lepton + multiple b-jets
high jet multiplicity
background: tt+jets

1 lepton + no b-jets
modest jet multiplicity
W+jets, tt+jets

Setting the stage

- Best exclusion limits for gluino pair production from Run 1 (8 TeV) came from single lepton analysis
- During Run 2 of the LHC (13 TeV) several public results with different datasets

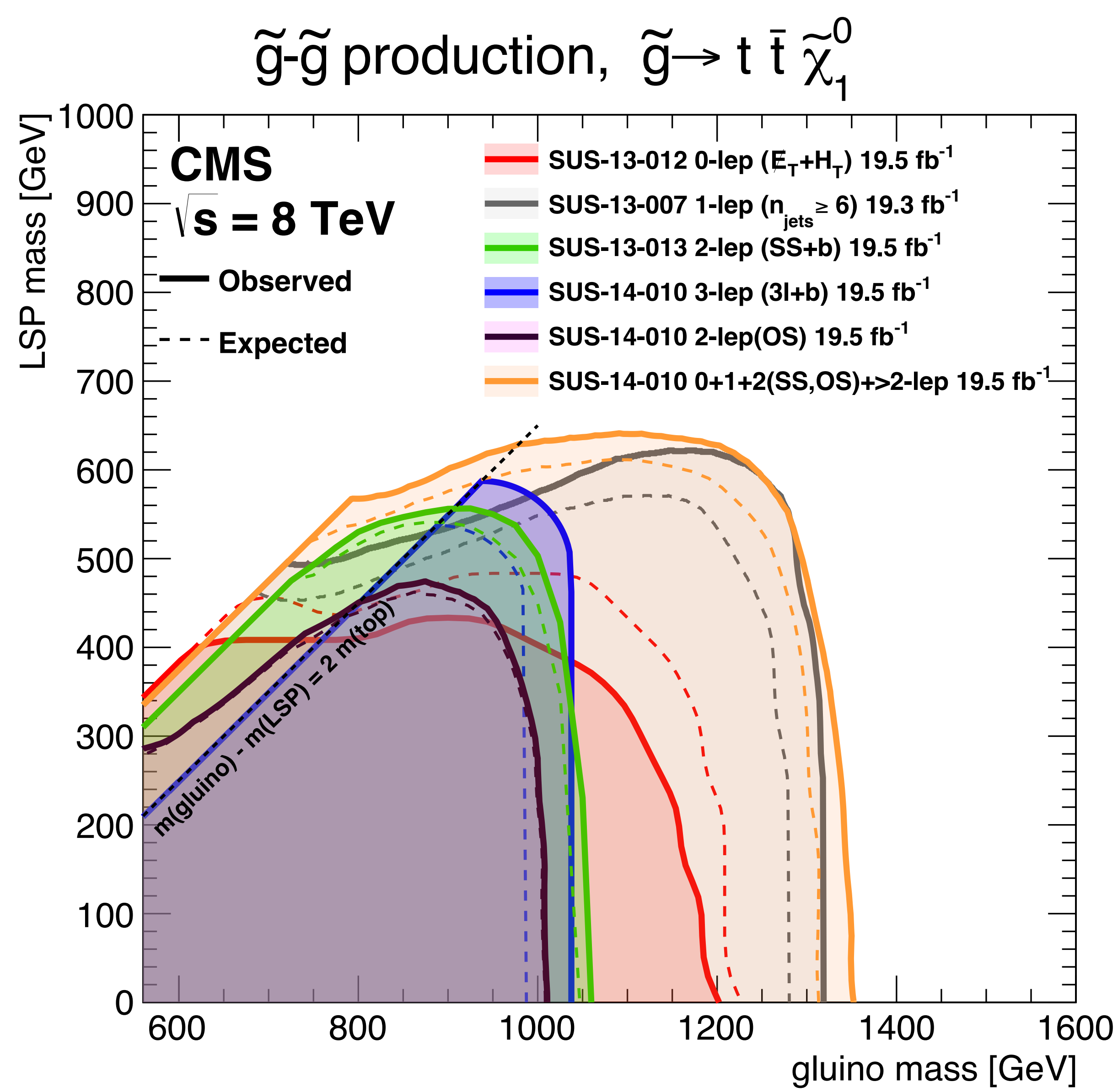
Moriond 2016: 2.3/fb

↓

ICHEP 2016: 12.9/fb

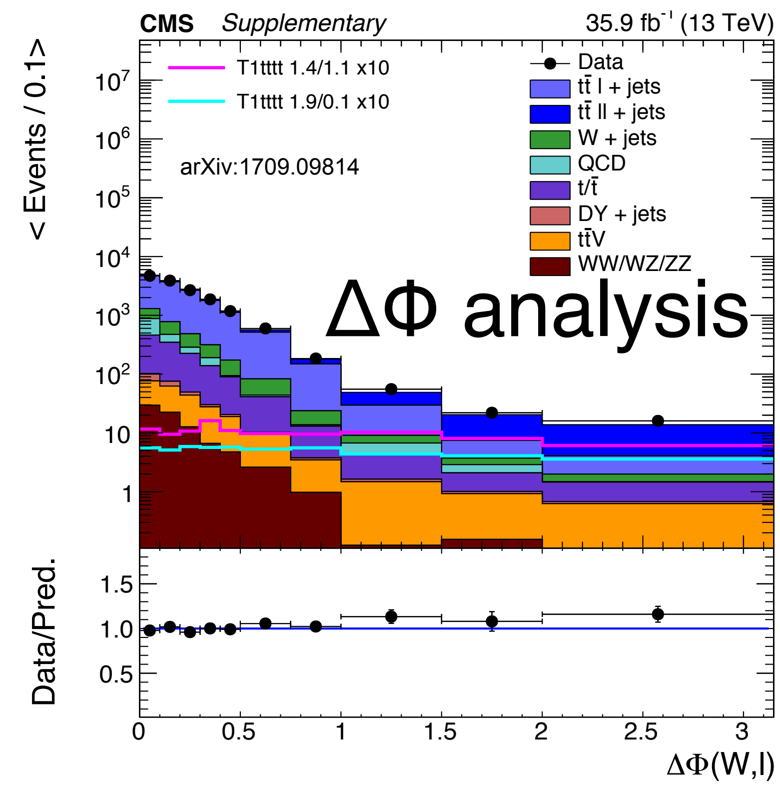
↓

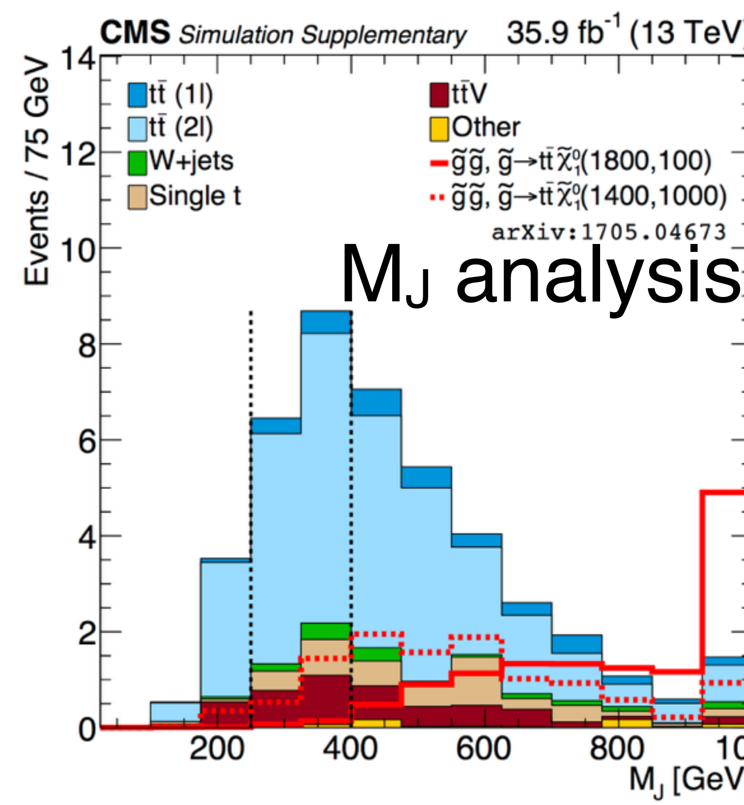
Moriond 2017: 35.9/fb



Search strategies

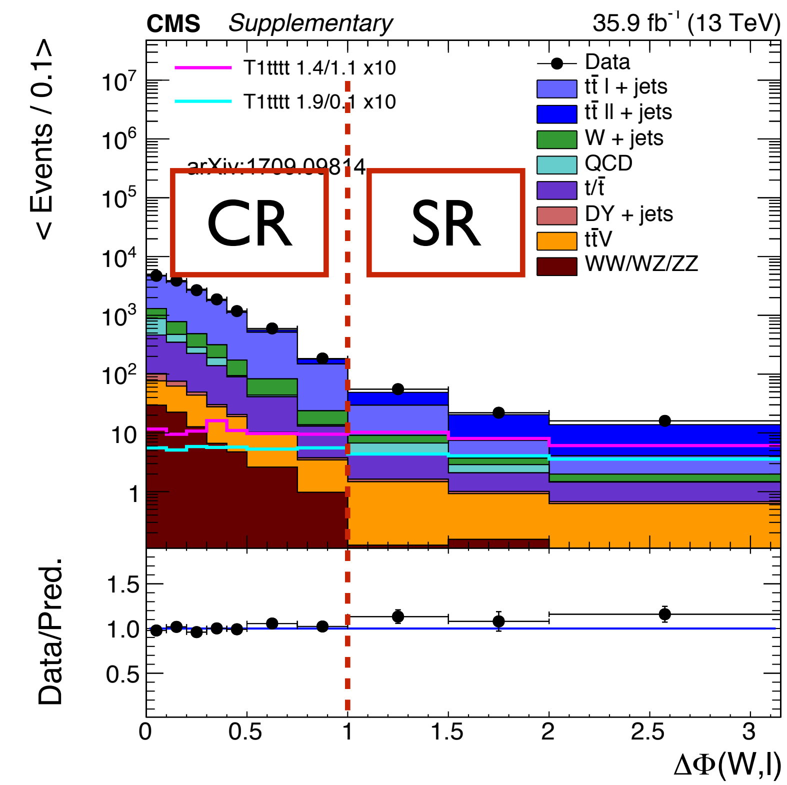
- Two separate analysis strategies:
  - Angular information of W boson candidate and lepton from its decay **ΔΦ**
  - Sum of masses of large-radius jets M_J
- Signals should become visible in the tails of the distributions M_J or **ΔΦ**
- Backgrounds are estimated using control regions in data
- Main background from tt+jets events with
  - 1 leptonic top decay
  - 2 leptonic top decays and one lost lepton: additional transverse momentum imbalance

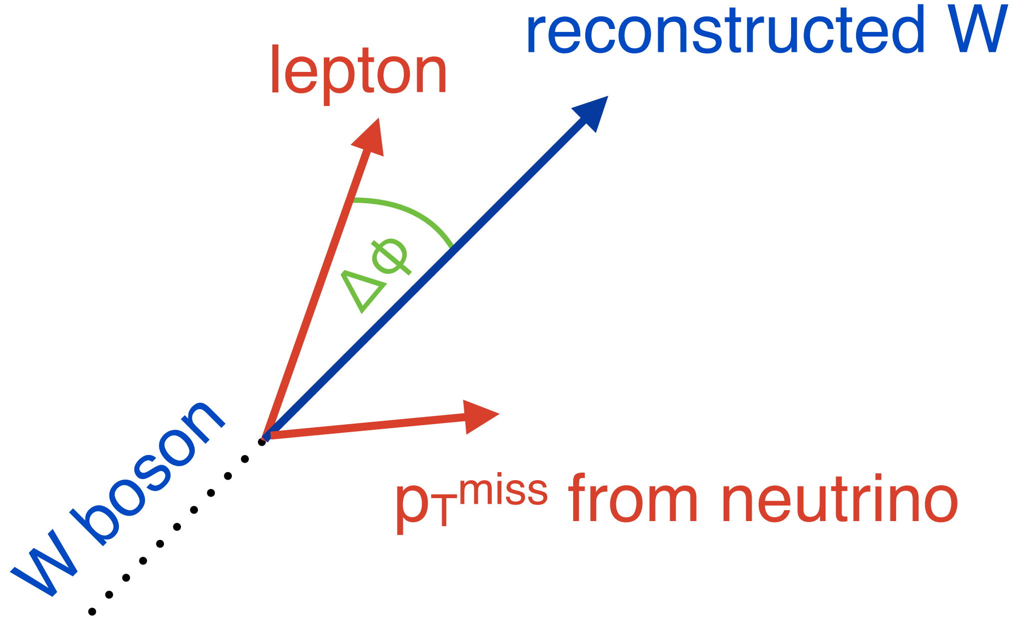


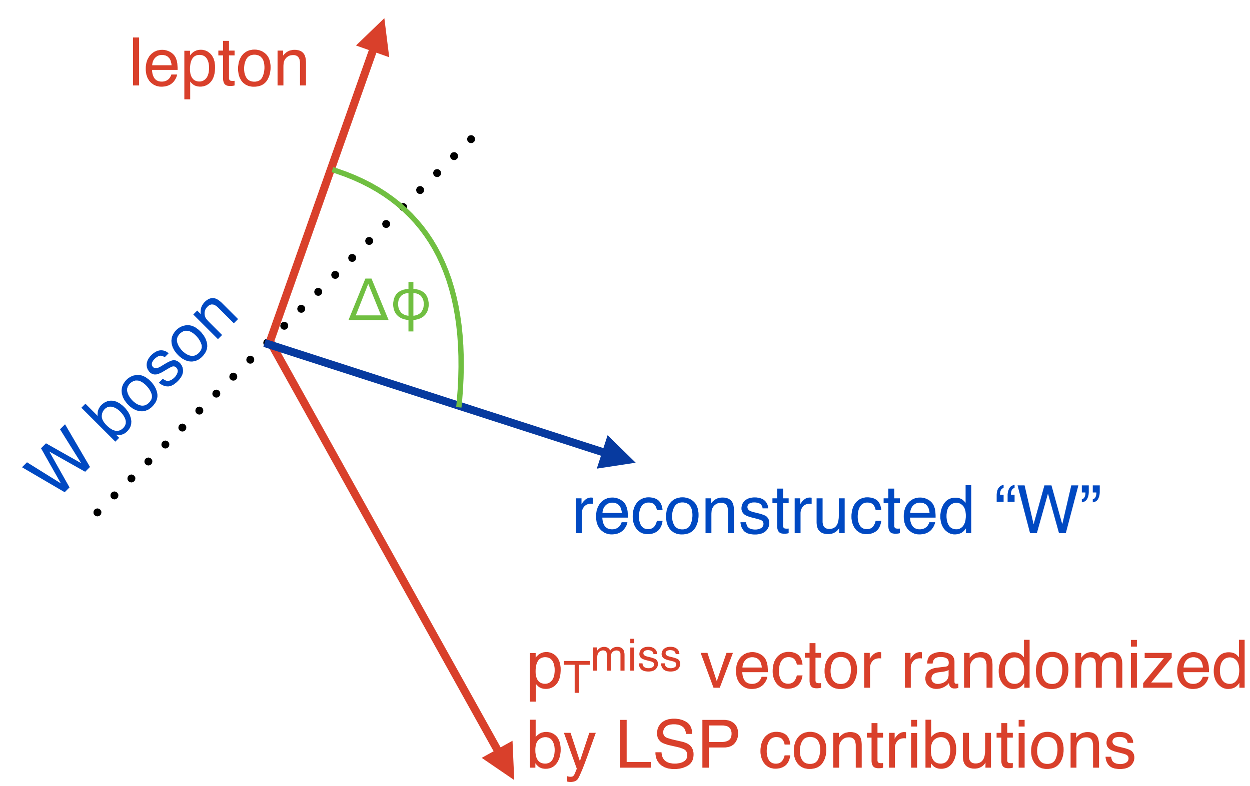


ΔΦ analysis

- **ΔΦ** distribution steeply falling for SM backgrounds : hypothetical signal events become visible
- p_T^{miss} direction randomized due to neutralino resulting in flat **ΔΦ** distribution for signals
- Further categorize in L_T (lepton p_T + p_T^{miss}), hadronic activity H_T (sum of jet p_T), N_{jet} and N_b



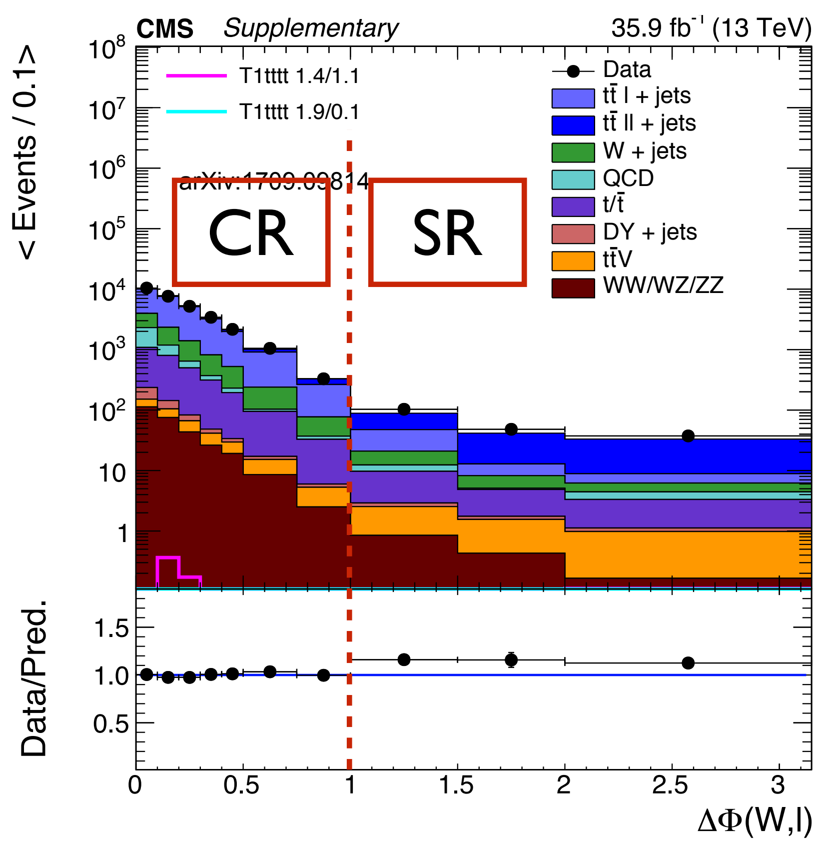


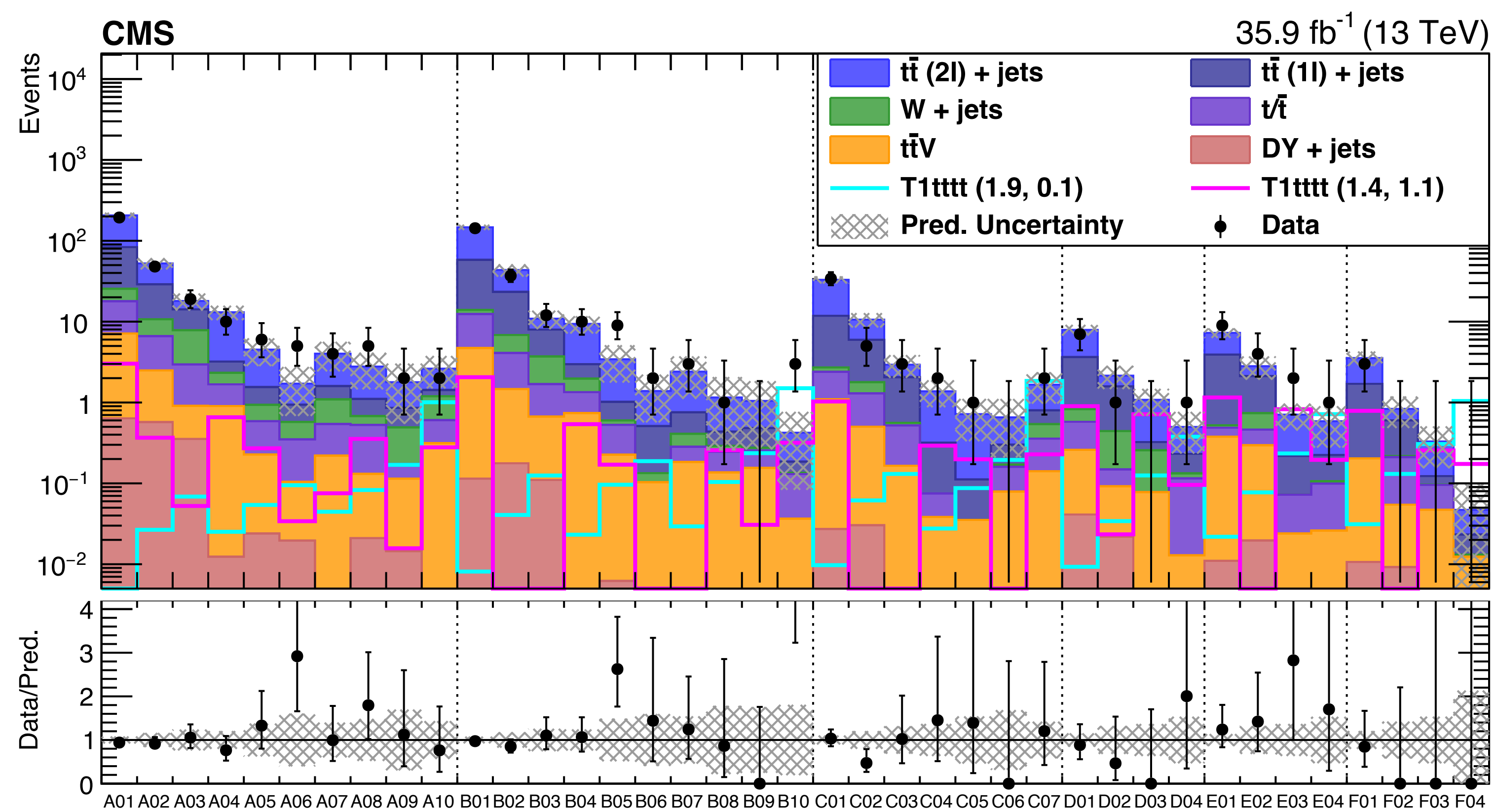


Background estimation multi-b

- Measure ratio R_{CS} = N(high **ΔΦ**)/N(low **ΔΦ**) in low N_{jet} region, apply R_{CS} to corrected count in high N_{jet}, low **ΔΦ** region
- Separate estimation of residual QCD multijet background
- Residual dependence of R_{CS} on N_{jet} corrected with **κ** factor from simulation

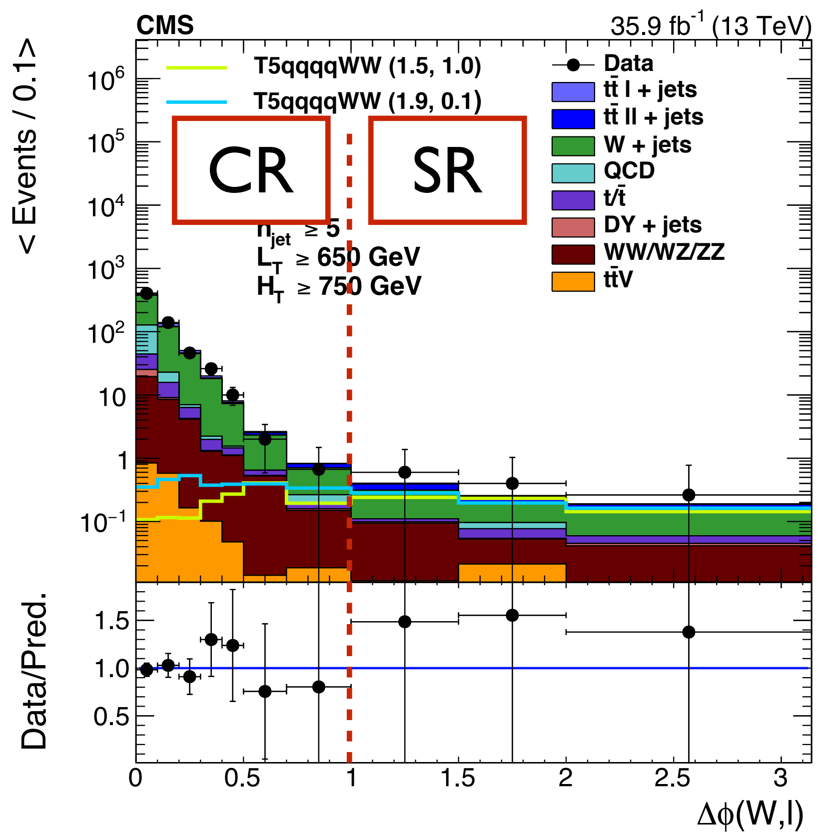
$$N_{\mathrm{pred}}(\mathrm{SR}) = R_{CS}\kappa \left[N_{\mathrm{data}}^{\mathrm{high-n_{jet}}}(\mathrm{CR}) - N_{\mathrm{QCD\ pred}}^{\mathrm{high-n_{jet}}}(\mathrm{CR}) \right]$$

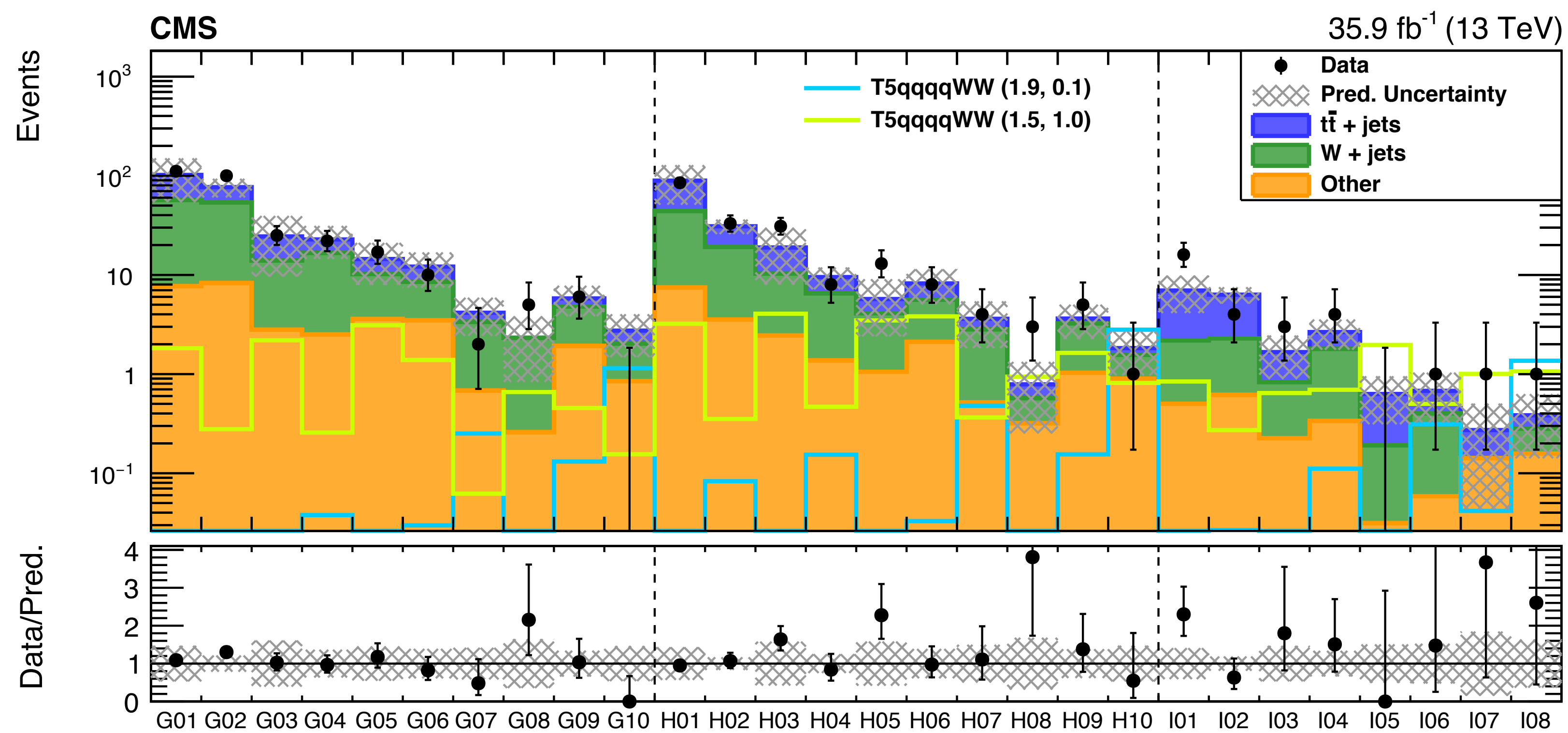




Background estimation 0b

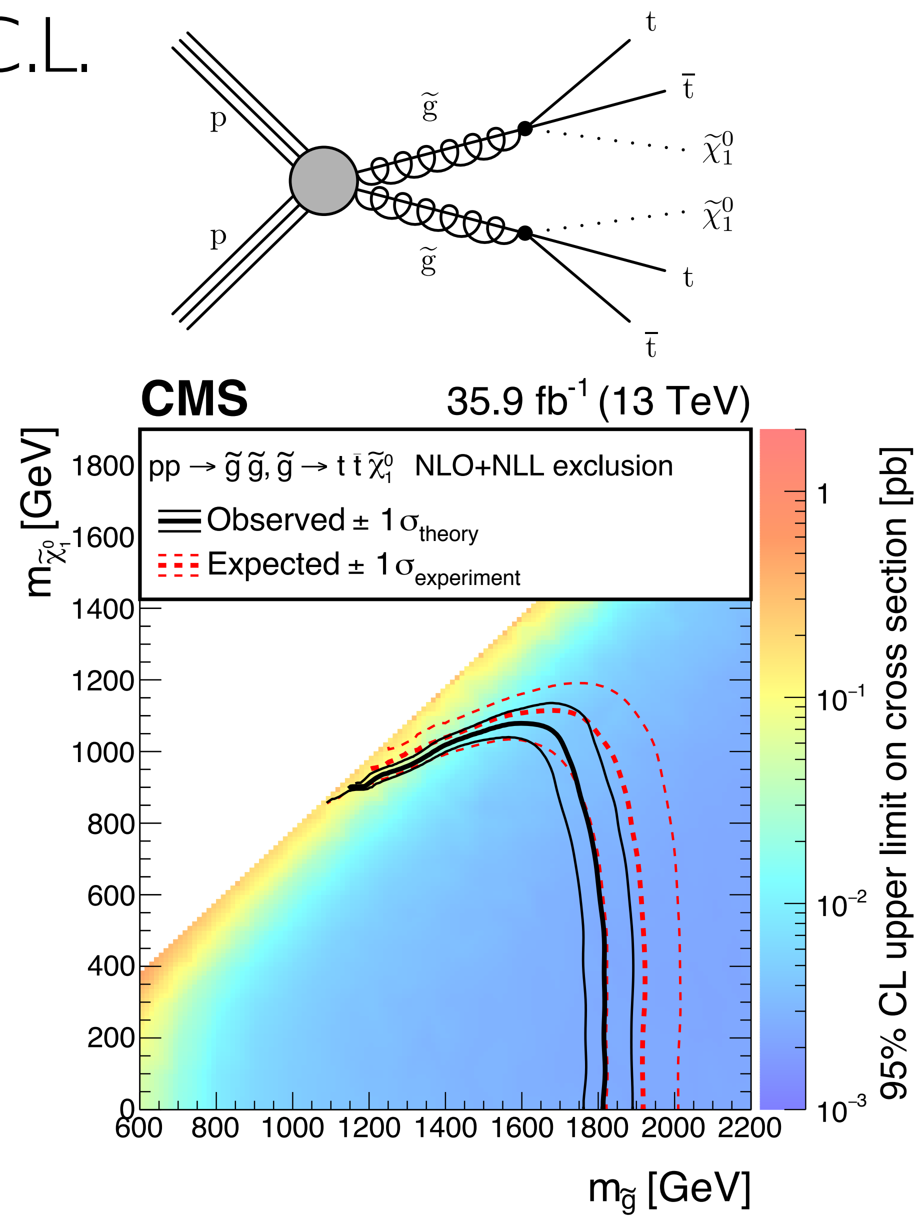
- For chargino mediated gluino decay no b-tagged jets expected:
  - Background is composition of W+jets and top quark pairs
- Estimate both backgrounds in separate control regions, measuring independent R_{CS} values
- Composition of backgrounds measured in low **ΔΦ** region, using fit of simulated b-jet multiplicity templates to data

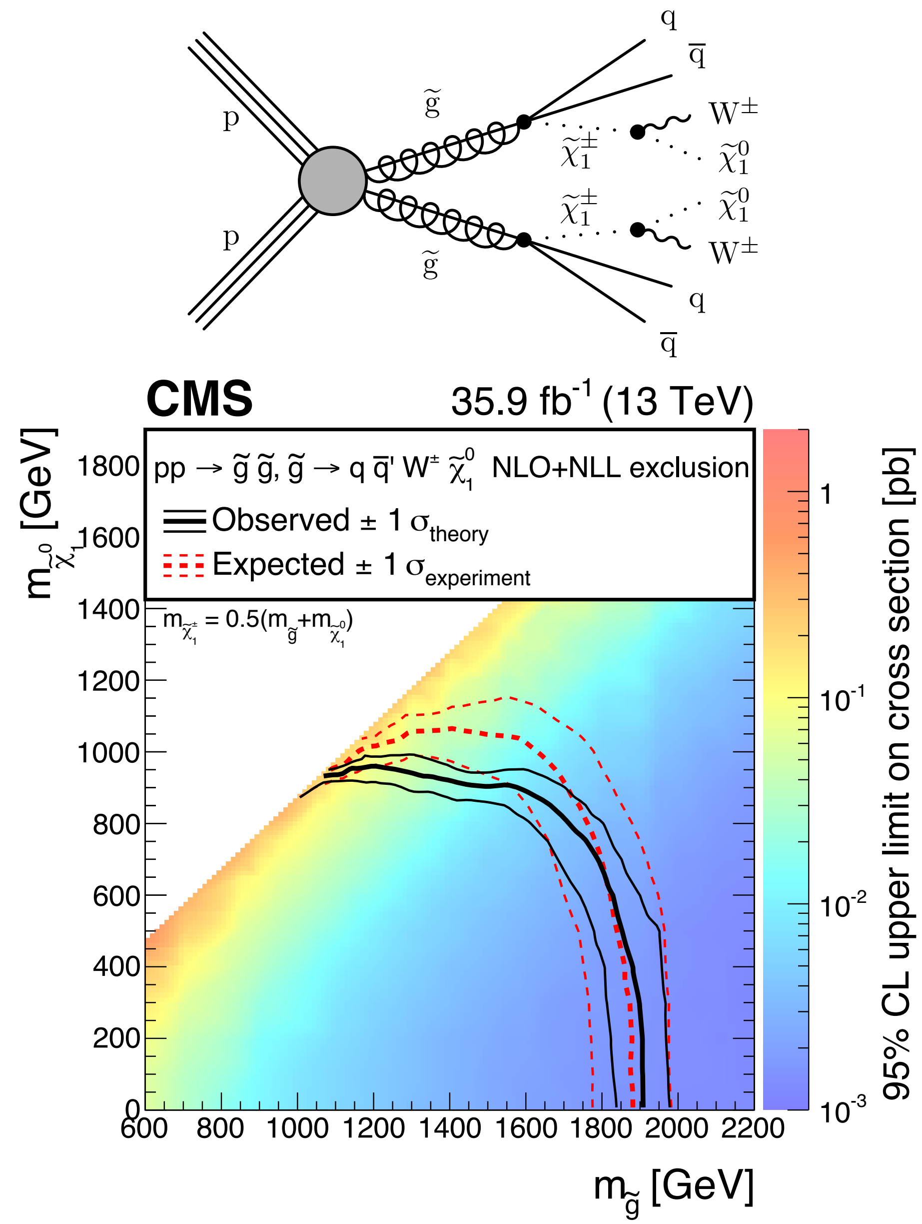




Results

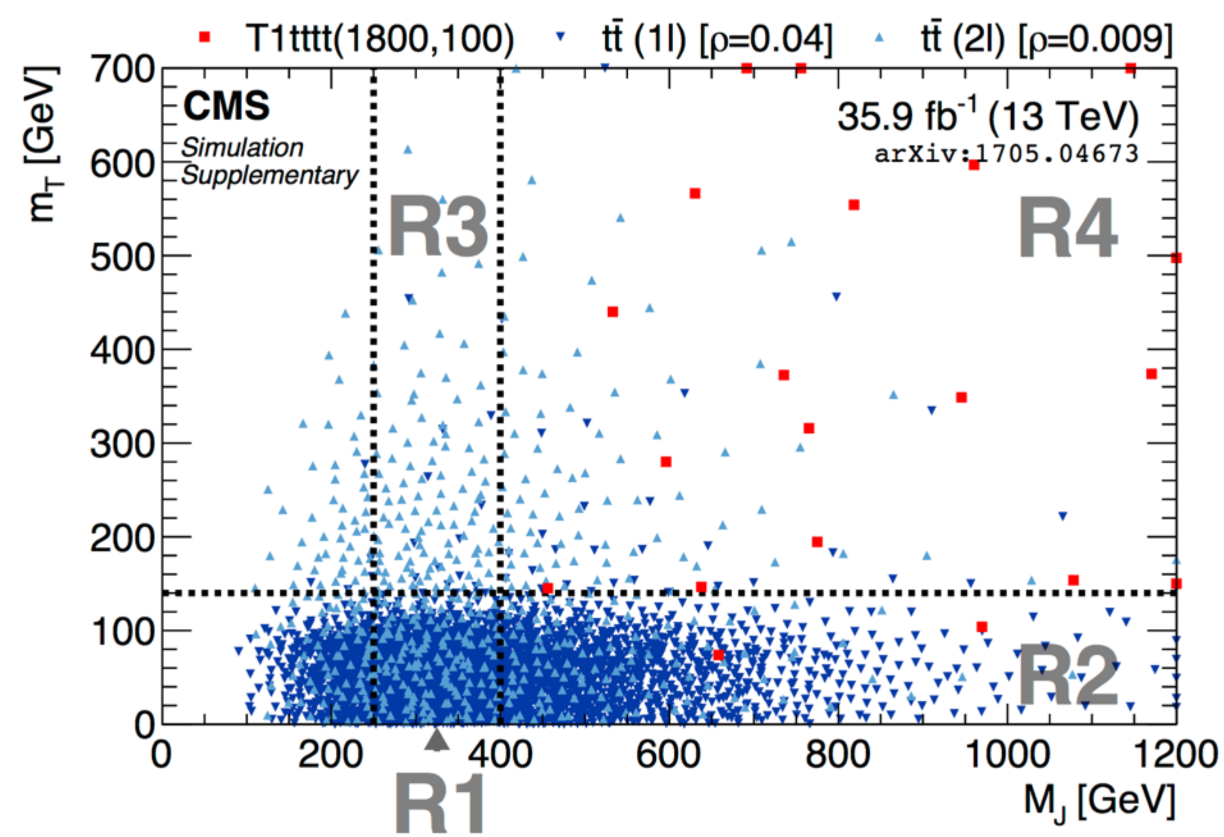
- Good agreement between SM prediction and observation in both channels: no sign of SUSY
- Profile likelihood method used to set limits on gluino pair production at the 95% C.L.





M_J analysis

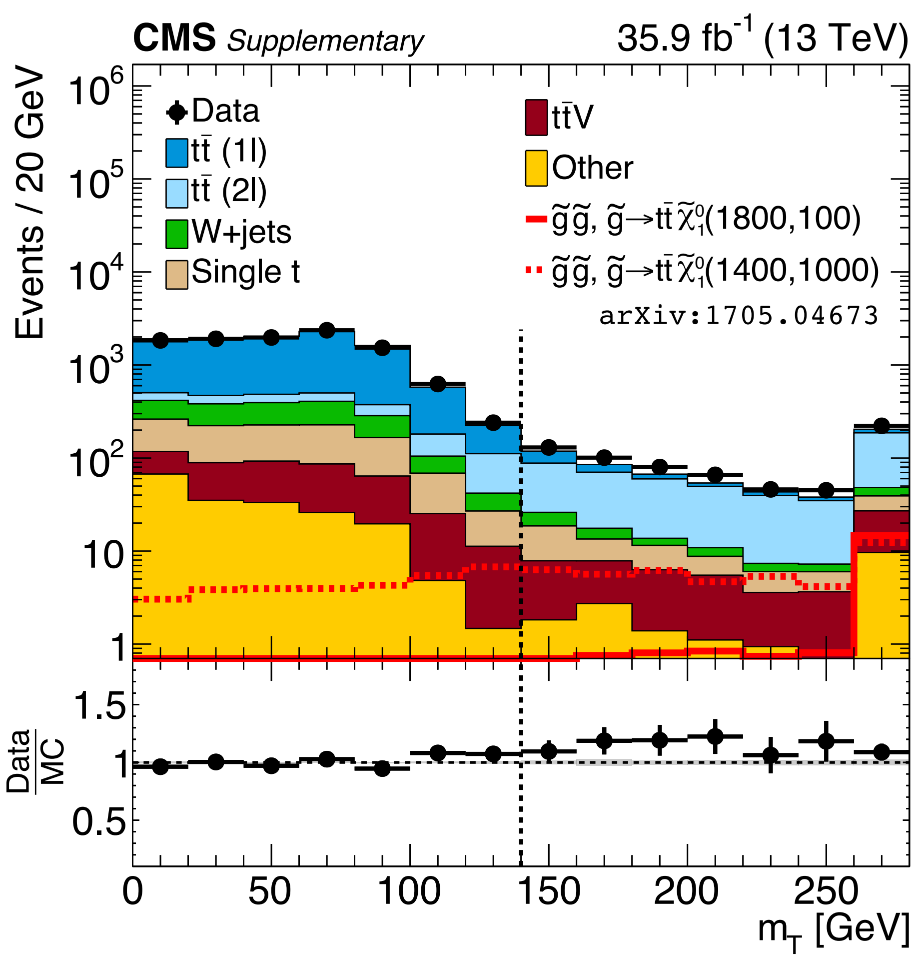
- Sum of masses of large-radius jets M_J and m_T used to categorize events
- Large radius jets are clustered from "standard" small-R jets including jets associated to isolated leptons
  - from R=0.4 to R=1.4 using anti-k_T algorithm
- Potential signals populate regions with high M_J and m_T
- For ttbar background M_J has a rough endpoint at 2 m_t
  - ISR contribution enhances M_J tail
- Further categorize in N_{jet}, N_b and p_T^{miss}
- Data-driven methods used to estimate SM backgrounds

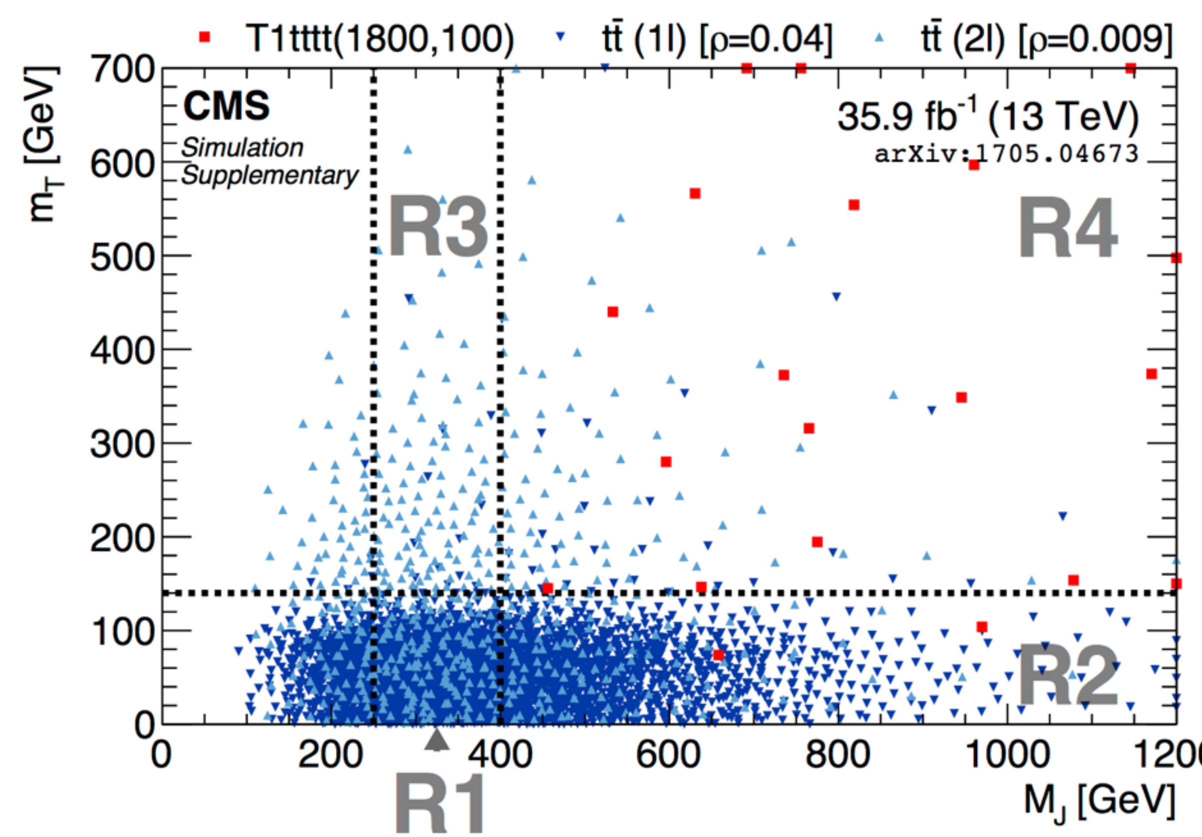


Background prediction

- tt+jets background split into 1 and 2l component by m_T threshold
- Estimate background using control regions R1, R2, R3
- κ (close to unity) corrects for residual m_T-M_J correlation

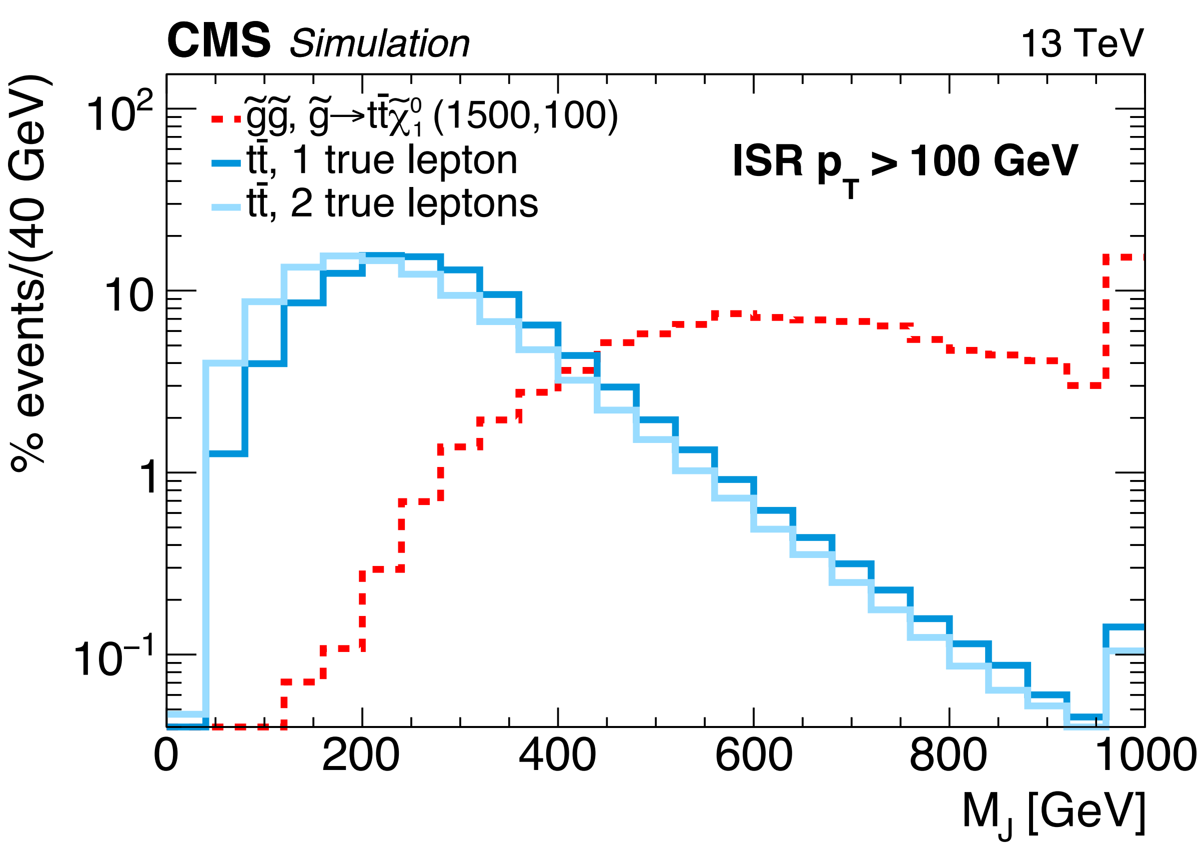
$$\mu_{R4}^{\mathrm{bkg}} = \kappa \mu_{R3}^{\mathrm{bkg}} \mu_{R2}^{\mathrm{bkg}} / \mu_{R1}^{\mathrm{bkg}} \qquad \kappa = \frac{\mu_{R4}^{\mathrm{MC\,bkg}} / \mu_{R2}^{\mathrm{MC\,bkg}}}{\mu_{R3}^{\mathrm{MC\,bkg}} / \mu_{R1}^{\mathrm{MC\,bkg}}}$$

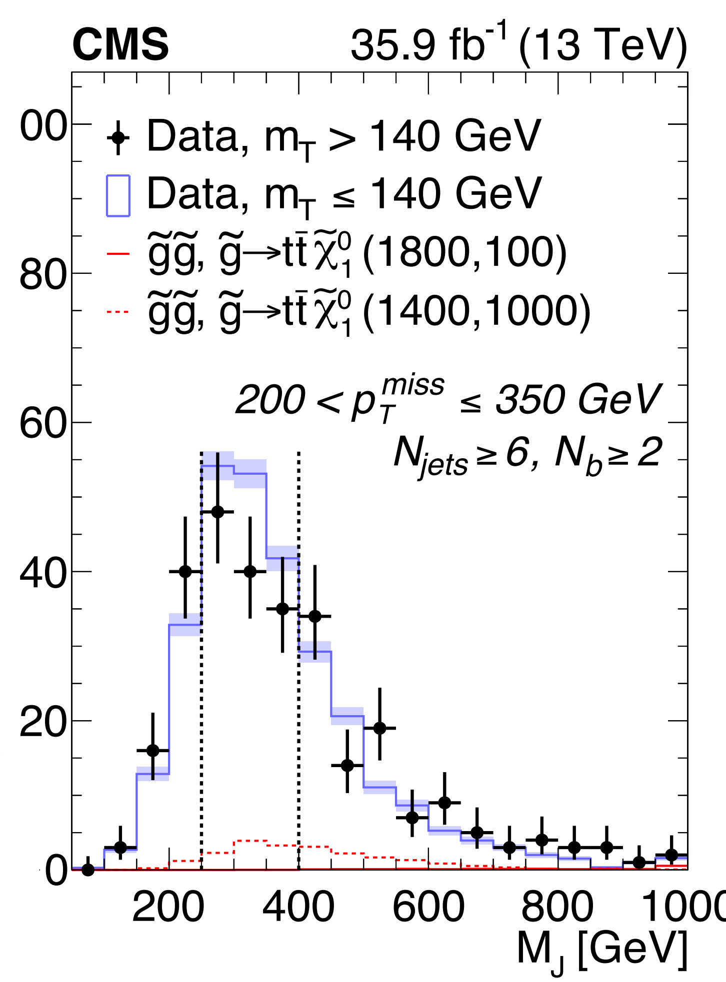


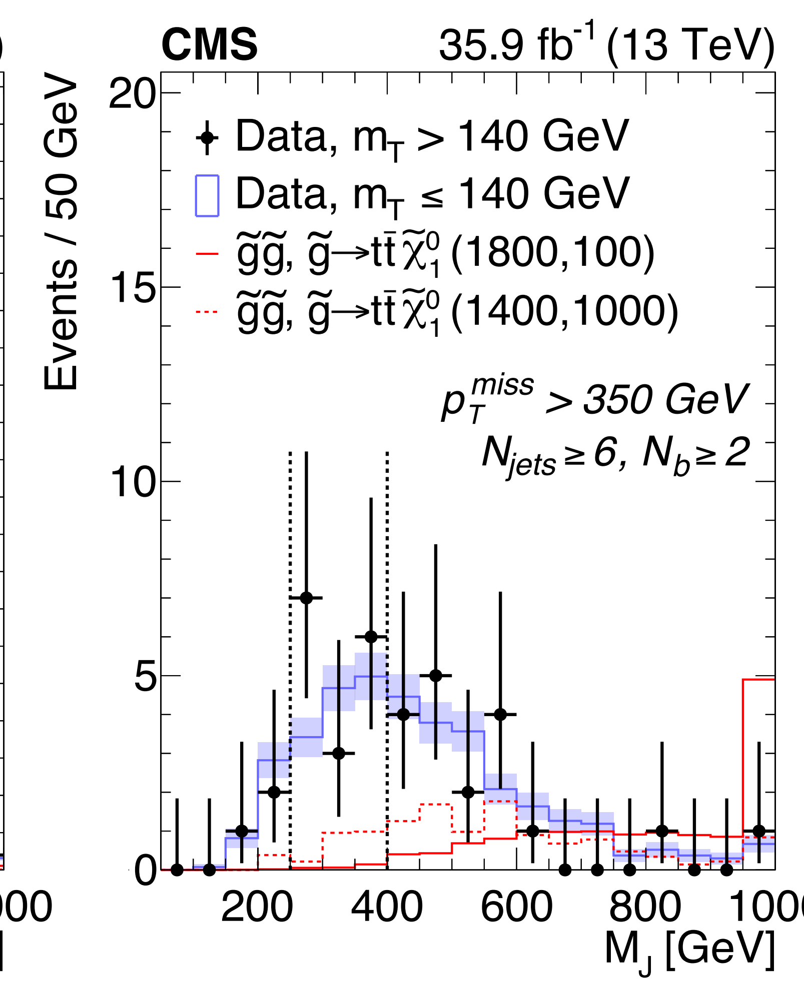


M_J distributions

- Shape comparison of M_J distribution for high/low m_T in different p_T^{miss} bins
- Good shape agreement, hypothetical signal observable in tails of the distribution

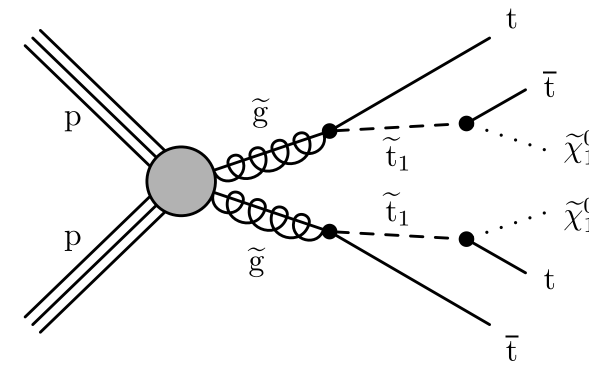


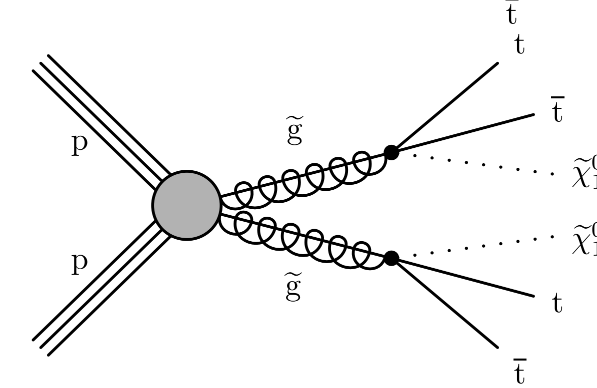




Results

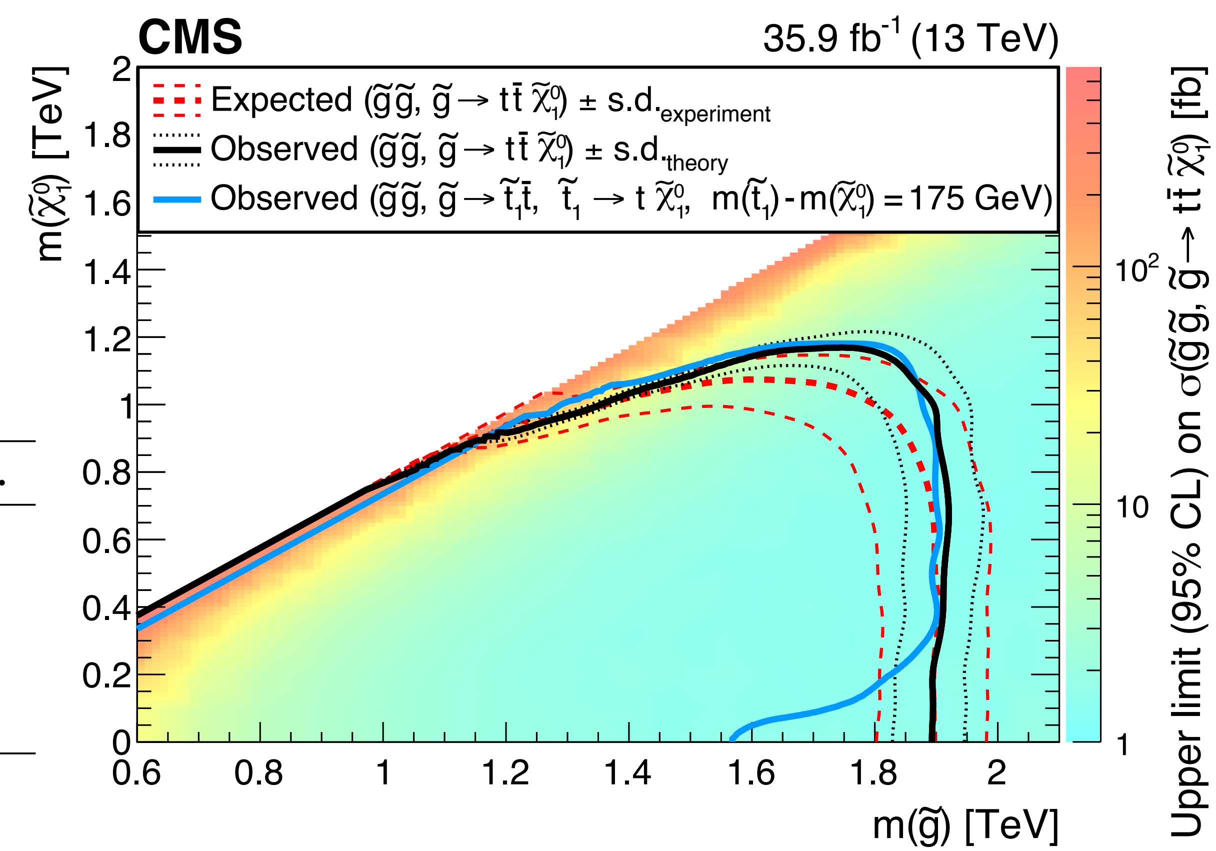
- Good agreement of predicted SM background and observation
- Very similar exclusion limits for two and three body decay models show independence of top squark mass
- For low neutralino masses sensitivity drops for on shell top squark production





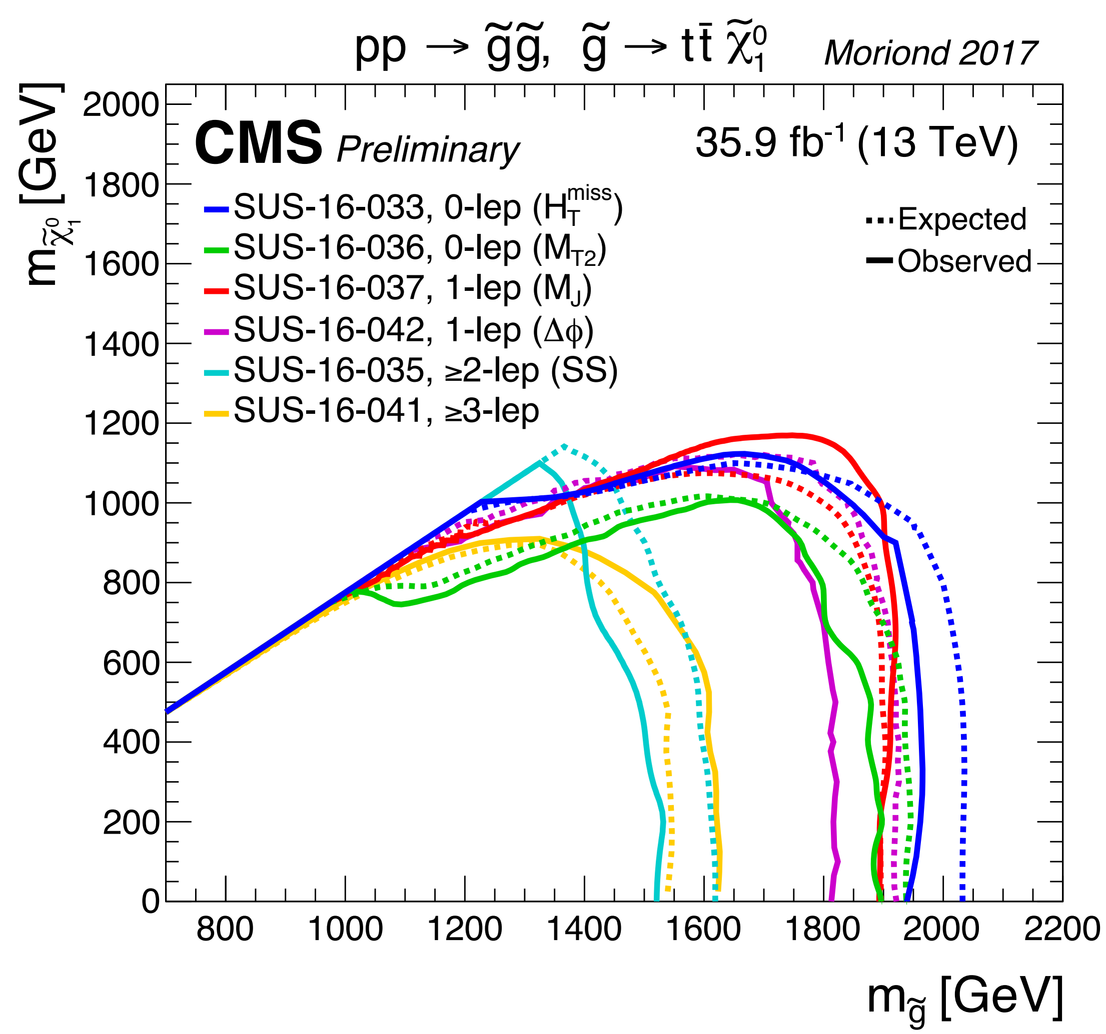
signal benchmarks

$p_{\mathrm{T}}^{\mathrm{miss}}$ [GeV]	N_{jets}	N_{b}	NC	C	κ	Pred.	Obs.
>200	≥ 9	≥ 3	3.4	6.9	1.4 ± 0.3	3.1 ± 0.8	2
>350	≥ 9	≥ 2	5.3	6.2	1.0 ± 0.4	2.7 ± 1.2	2
>500	≥ 6	≥ 3	5.4	2.1	1.7 ± 0.6	0.5 ± 0.4	1
>500	≥ 9	≥ 1	5.1	3.6	1.2 ± 0.4	0.4 ± 0.4	2



Results cont'd

- CMS exploits two separate analysis strategies in single lepton final state yielding compatible results: No sign of SUSY
- Outstanding LHC performance so far: Looking forward to results with ~150/fb at the end of Run 2 that ends in 2018



BACKUP

Event selection

- 1 e/μ with p_T > 25 GeV
- Events with additional lepton and isolated track vetoed
- Njet ≥ 6/5 (multi-b/0b)
- H_T > 500 GeV
- L_T > 250 GeV

ΔΦ analysis: CMS-SUS-16-042
submitted to PLB

- 1 e/μ with p_T > 20 GeV
- Events with additional lepton and isolated track vetoed
- Njet ≥ 6
- N_b ≥ 1
- S_T > 500 GeV
- p_T^{miss} > 200 GeV

M_J analysis: CMS-SUS-16-037
PRL 119 (2017) 151802

Systematic uncertainties $\Delta\phi$

Source	Uncertainty for multi-b [%]	Uncertainty for 0-b [%]
Dilepton control sample	0.9–7.0	0.3–18
JES	0.3–18	0.7–26
Tagging of b jets	0.1–0.9	0.1–2.5
Mistagging of light flavor jets	0.1–2.2	0.3–0.8
σ(W+jets)	0.3–9.3	0.3–10
$\sigma(t\bar{t})$	0.1–7.5	0.7–13
$\sigma(t\bar{t}V)$	0.2–20	0.1–3.8
W polarization	0.1–3.3	0.7–14
ISR reweighting ($t\bar{t}$)	0.5–7.0	0.2–11
Pileup	0.4–7.1	0.1–20
Statistical uncertainty in MC events	5–30	5–36

Source	Uncertainty [%]
Trigger	2
Pileup	10
Lepton efficiency	2
Isolated track veto	4
Luminosity	2.5
ISR	2–25
Tagging of b jets	1–6
Mistagging of light flavor jets	1–4
JES	3–40
Factorization/renormalization scale	1–3
p_T^{miss}	2–20