SUSY Strong Production Search with Leptonic Final State at ATLAS

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On behalf of the ATLAS collaboration

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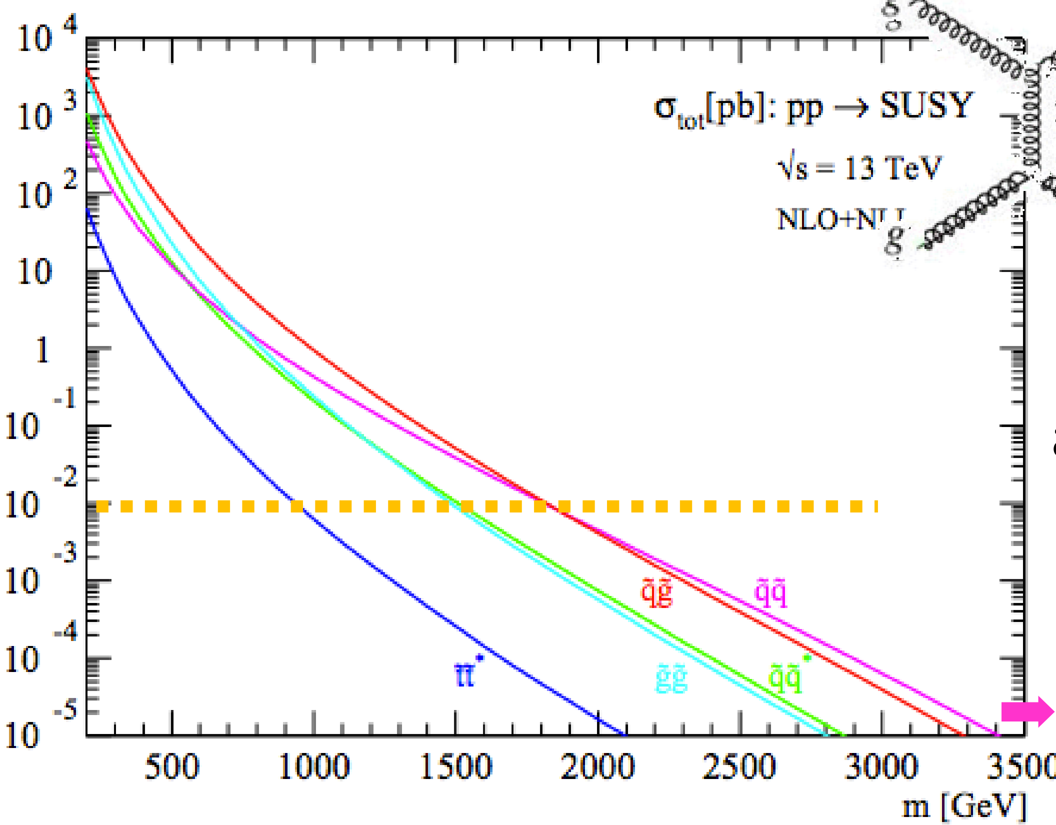
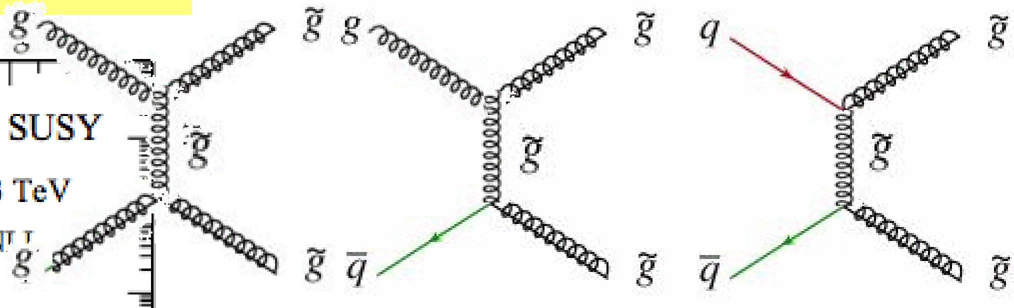
SUSY Production @ LHC

- **Large cross section on colored SUSY particle ($\tilde{g}$, $\tilde{q}$) at LHC**
  - SUSY particles produced by pair production (R-parity conservation)

SUSY production cross section @ LHC 13 TeV

$R \equiv (-1)^{2S+3(B-L)}$





- The xsec decreases rapidly as the mass increases
- Typical cross section: O(10) fb for gluino 1.5 TeV ($\tilde{g}\tilde{g}$)

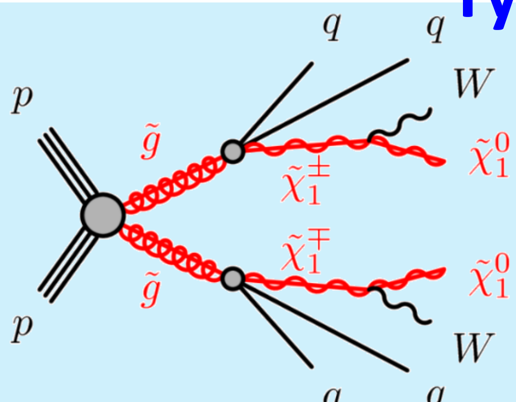
➡~100 events in 10 fb^{-1} Run2 data

We aim to detect them!

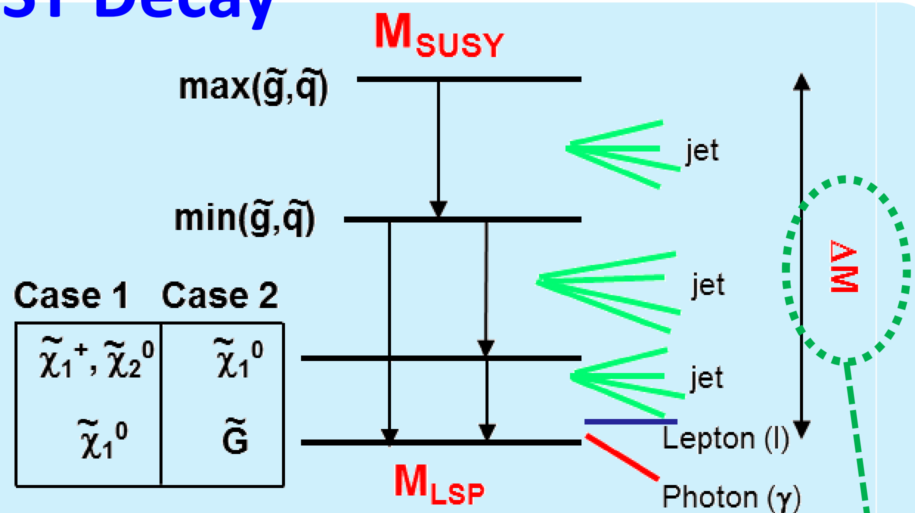
SUSY Particle Decay & Final State

- **Heavy gluino/squark decay into lighter particles**

Typical SUSY Decay



Many jets + Large $^{miss}E_T$ + Leptons b-jets …



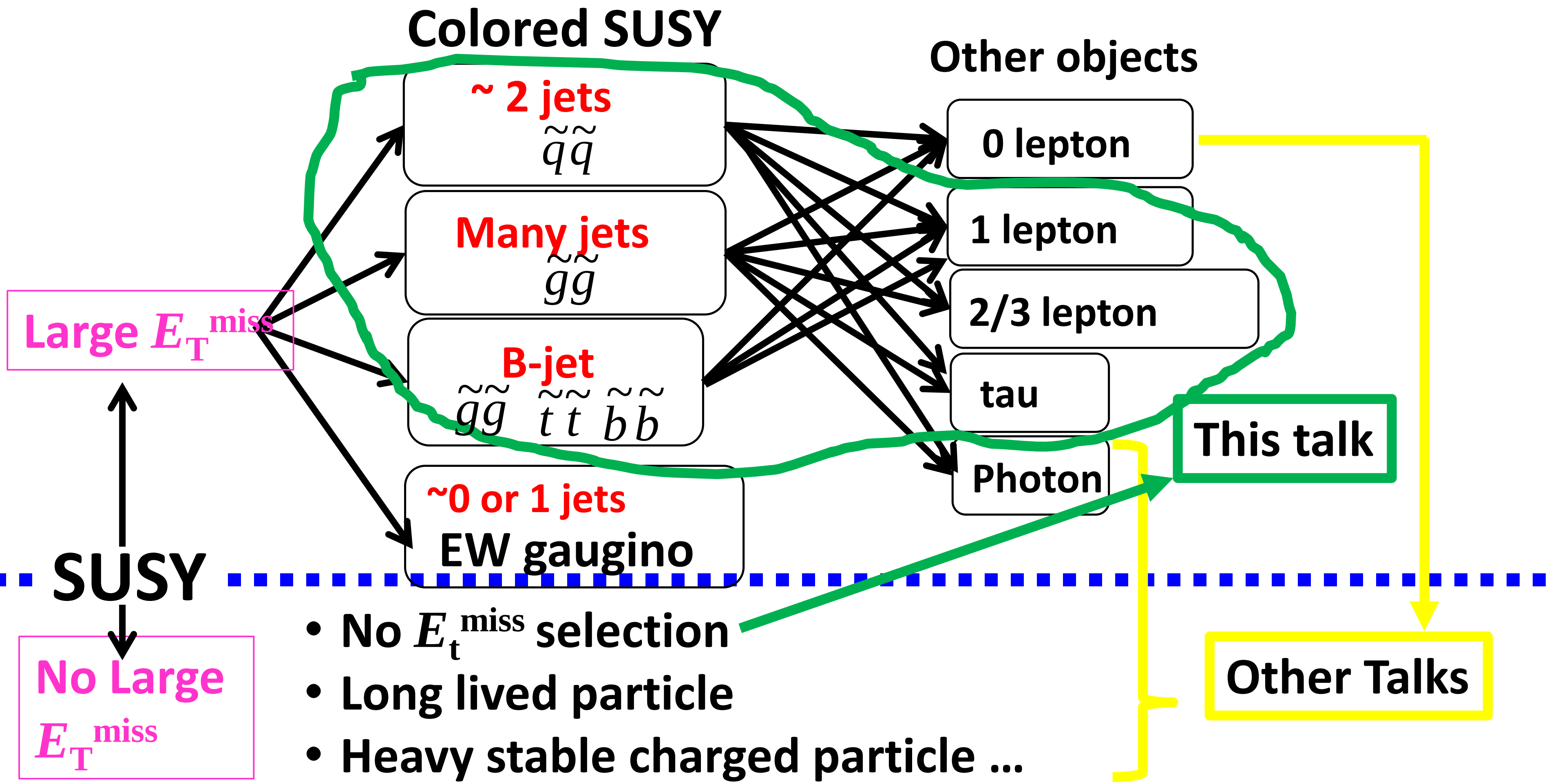
Final state of SUSY signal

1. Decay into LSP, finally ➡ Large E_T^{miss} in the final state
2. Two invisible particles ($\tilde{\chi}_1^0$) in final state ➡ No clear peak
3. Kinematics depends on mass difference between SUSY particles(ΔM)

A dedicated search is necessary to cover all phase spaces

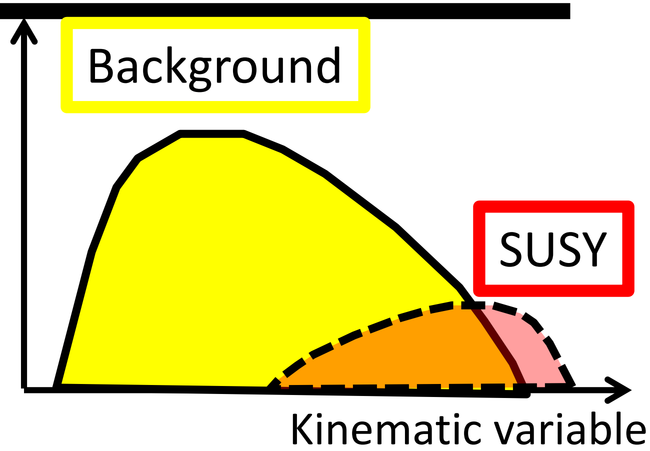
SUSY Search @ ATLAS

- **Various final states should be covered for the search of SUSY**
  - Topology based search, aiming to cover every SUSY signals

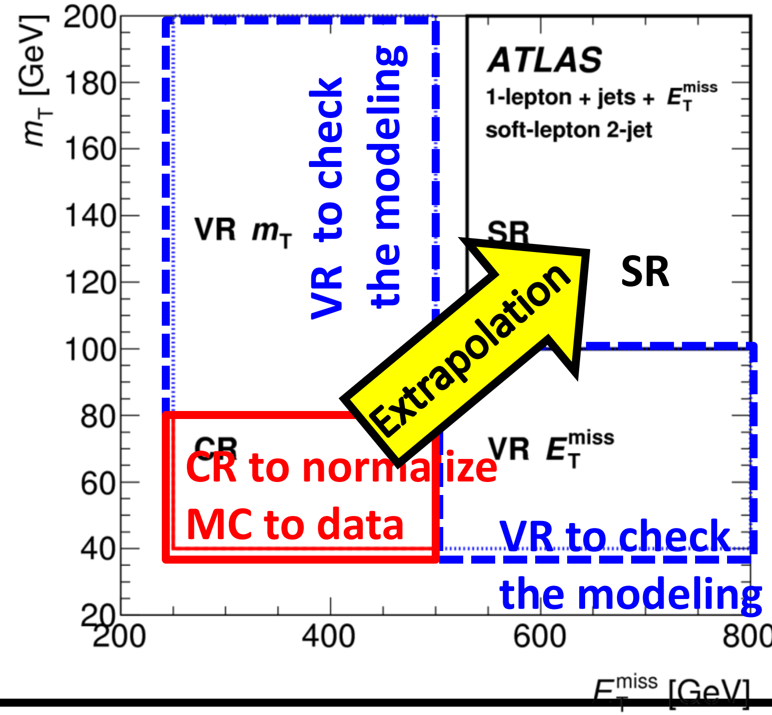


Background Estimation for SUSY Search

- **Background estimation is challenging for SUSY discovery!**
  - ▸ SUSY signal has no clear peak
  - ▸ appears at tail in kinematic distribution
  - ➡ extreme phase space
  - ➡ MC modeling is not perfect



- **Typical method at ATLAS**
  1. A dedicated Control Region (CR) to normalize MC to data
  2. Extrapolation of CR to Signal Region (SR) with well-modeled variables
  - ▸ Validation Region (VR) to make sure of the extrapolation modeling



Today's Content

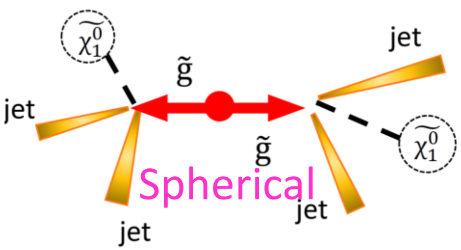
- One lepton in final state (15 fb^{-1})
- One lepton + Multiple-bjets in final state (36 fb^{-1})
- Two leptons (Same-sign)/ Three leptons in final state (36 fb^{-1})
- RPV one lepton final state (36 fb^{-1})

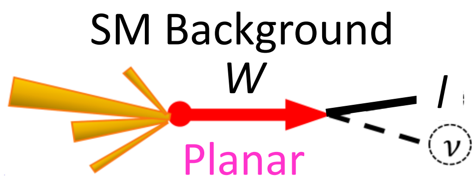
(‣ Two leptons (same-flavor, opposite-sign) final state (15 fb^{-1}))

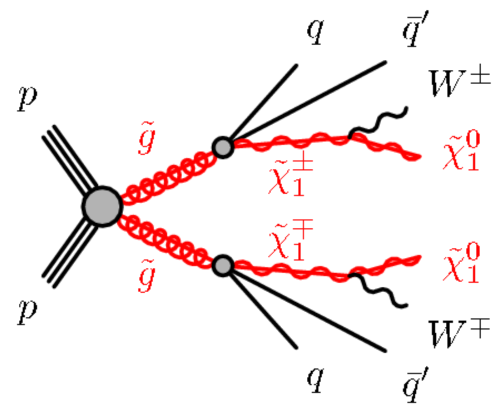
One-Lepton in Final State

Search for gluino/squark production with 1-lepton final state (15 fb^{-1})

- 1-lepton (e,μ)+ Multiple-jets + Large E_t^{miss}
- Event shape (Aplanarity)

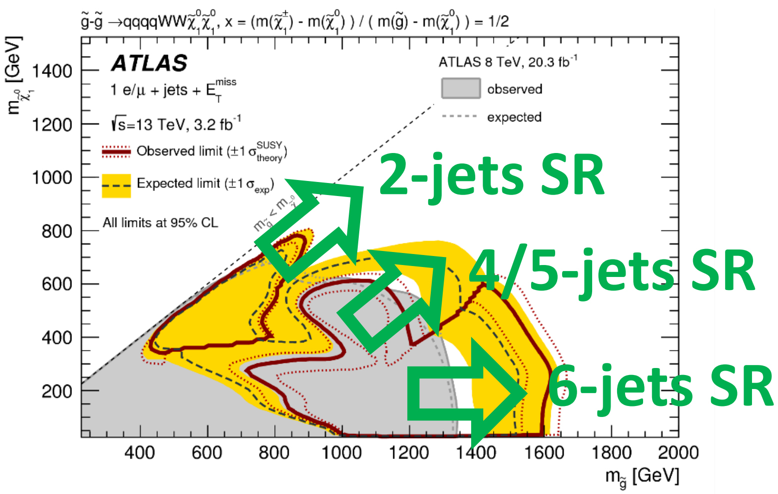


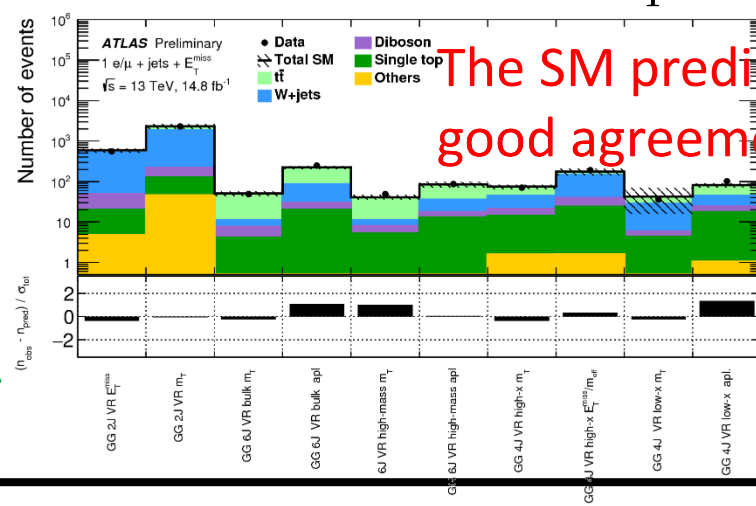




- Major Background: ttbar , W+jets
  - CRs defined at low m_T and Aplanarity

- Signal Regions (2/4/5/6-jets)

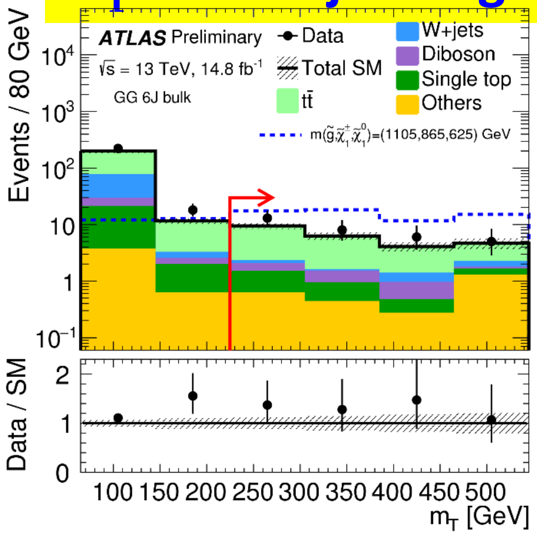




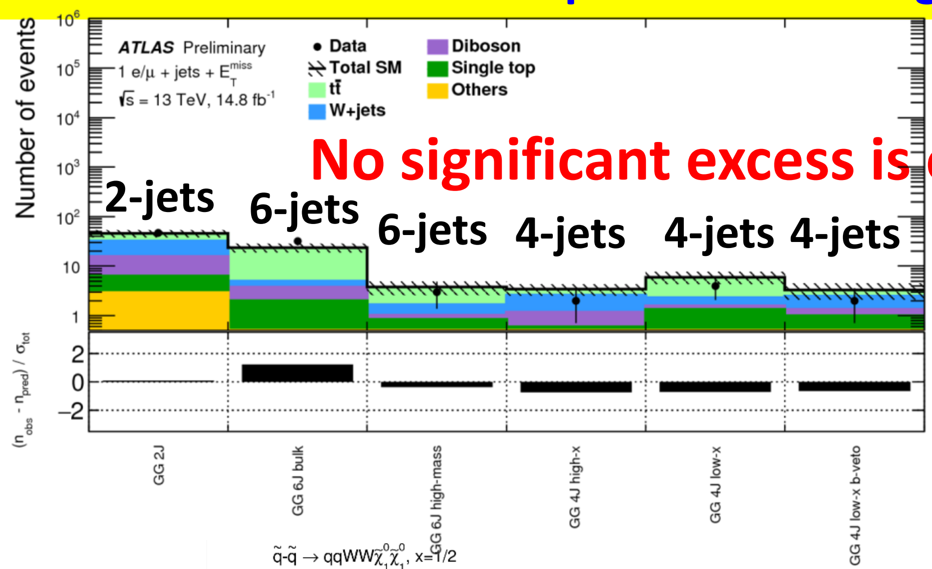
The SM prediction at VR is in good agreement with data

One-Lepton : Results

E_T^{miss} at 6-jets region

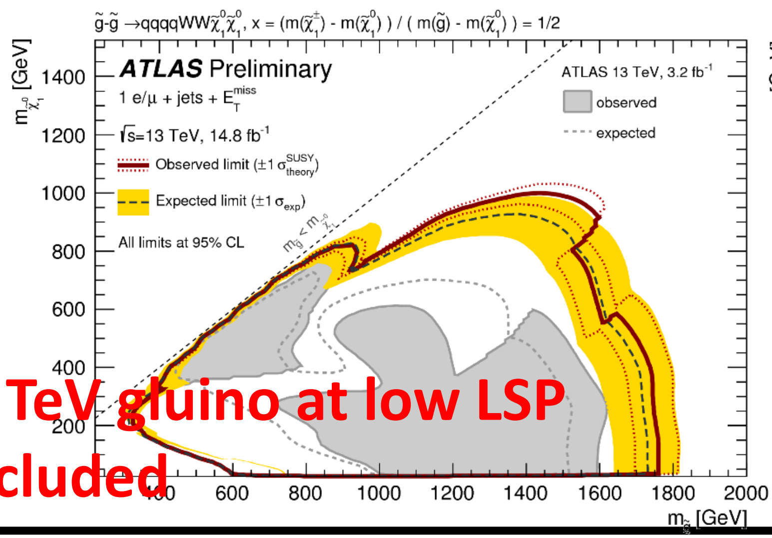


Observed data and the expected SM background

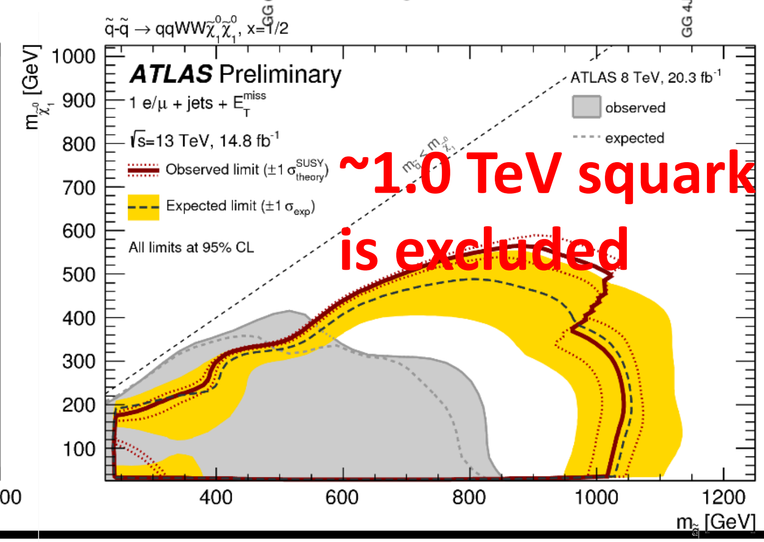


2-jets 6-jets 6-jets 4-jets 4-jets 4-jets

No significant excess is observed



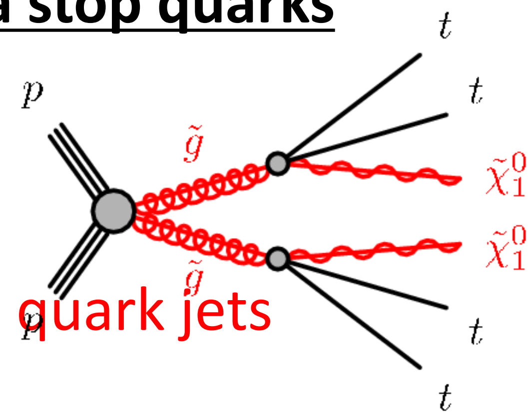
~1.8 TeV gluino at low LSP is excluded



~1.0 TeV squark at low LSP is excluded

Multiple b-jets in Final State

- **Search for gluino pair production with decays via stop quarks**
  - Motivated by
    - Light stop expected in view of 125 GeV Higgs
    - Large xsection of gluino pair production at LHC
  - 3 b-jets + 1-lepton + Large $E_{\mathrm{T}}^{\mathrm{miss}}$ + Additional light quark jets
  - 3 SRs for different $\Delta m (= m_{\tilde{g}} - m_{\tilde{\chi}0})$



A: 5-jet SR for large Δm (>~ 1.5 TeV)

➡ Highly boosted objects

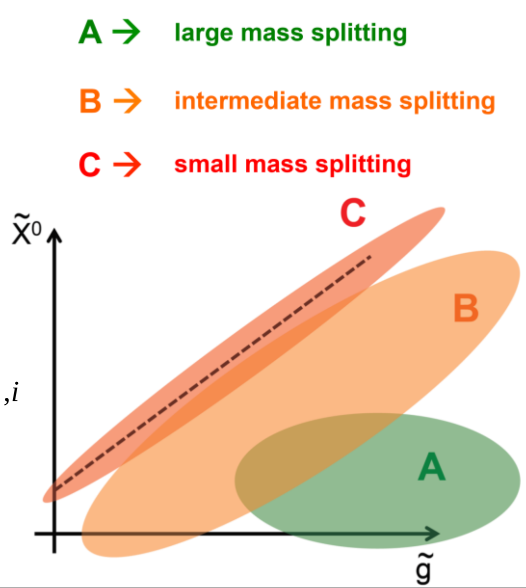
The decay products of a hadronically-decaying boosted top quarks can be reconstructed in a single large-radius re-clustered jet ⇒ Large total jet mass

$$M_J^{\Sigma} = \sum_{i \leq 4} m_{J,i}$$

B: 6-jet SR for intermediate Δm

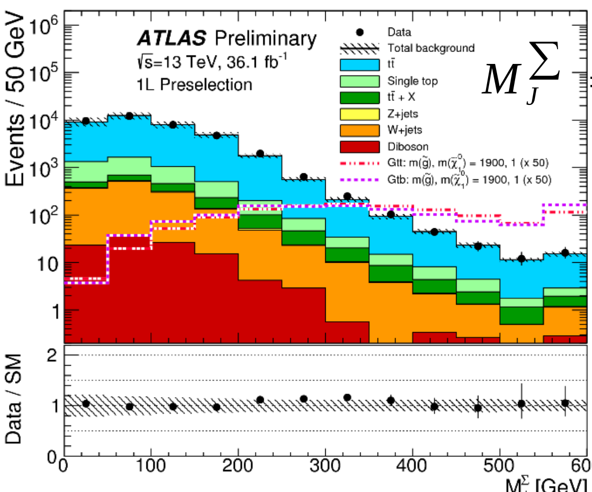
C: 7-jet SR for small Δm (<~ 300 GeV)

➡ Softer decay products



Multi-b: Background Estimation

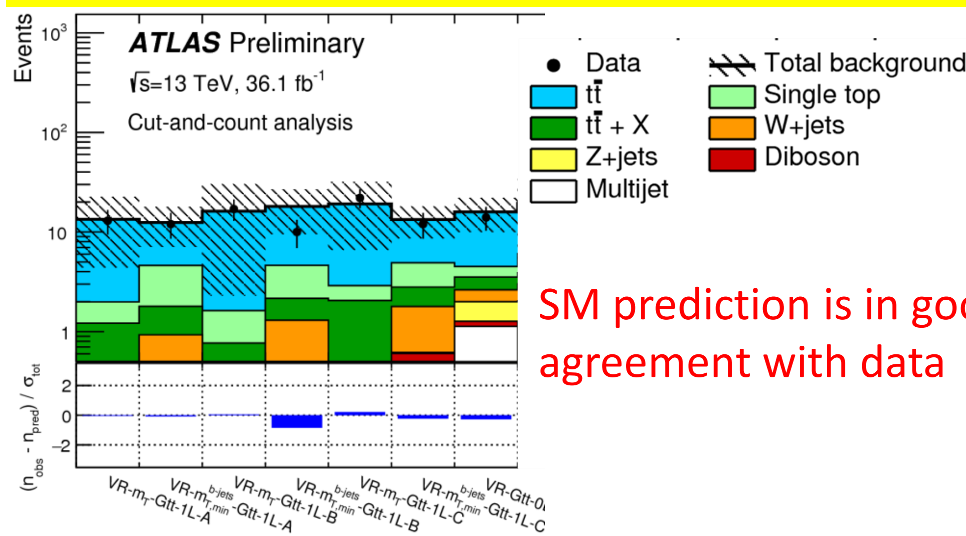
- **Main background : ttbar together with heavy and light flavor jets**
  - m_{eff} correction $\quad m_{eff} = \sum_i p_T^{jet_i} + \sum_j p_T^{l_j} + E_T^{miss} \qquad m_T = \sqrt{2 p_T^l E_T^{miss}\left(1-\cos\left[\Delta\phi\left(l, p_T^{miss}\right)\right]\right)}$
    - Correction factor extracted at two b-tagged jets and low $m_{T,\min}^{b-jets}$
    - Corrections for m_{eff} shape in MC modeling with respect to each m_{eff} bin
  - CRs defined in low m_{T} region
    - m_{T} extrapolation modeling is checked at VR (inverted selection on M_J^{Σ})



$$M_J^{\Sigma} = \sum_{i \le 4} m_{J,i}$$

Good modeling after m_{eff} correction

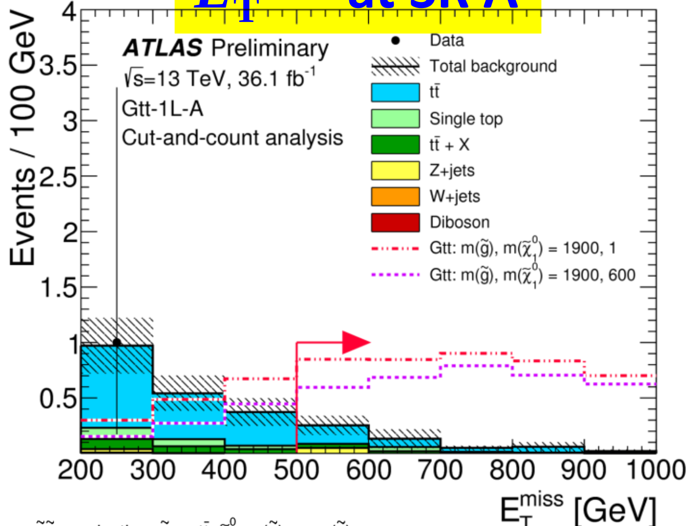
Observed data and the expected background at VR



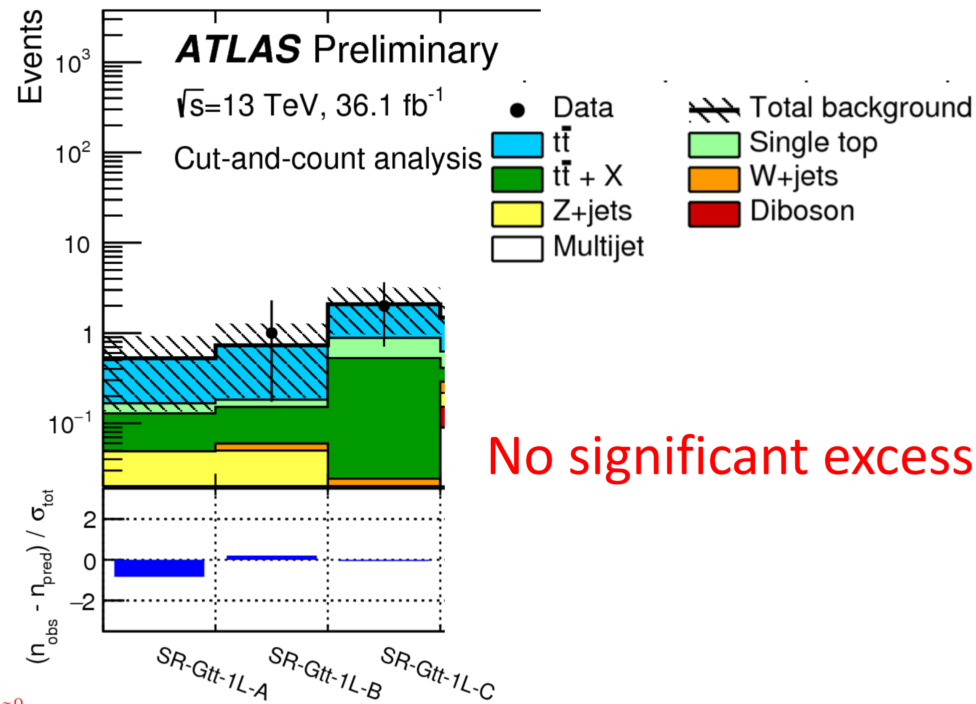
SM prediction is in good agreement with data

Multi-b: Results

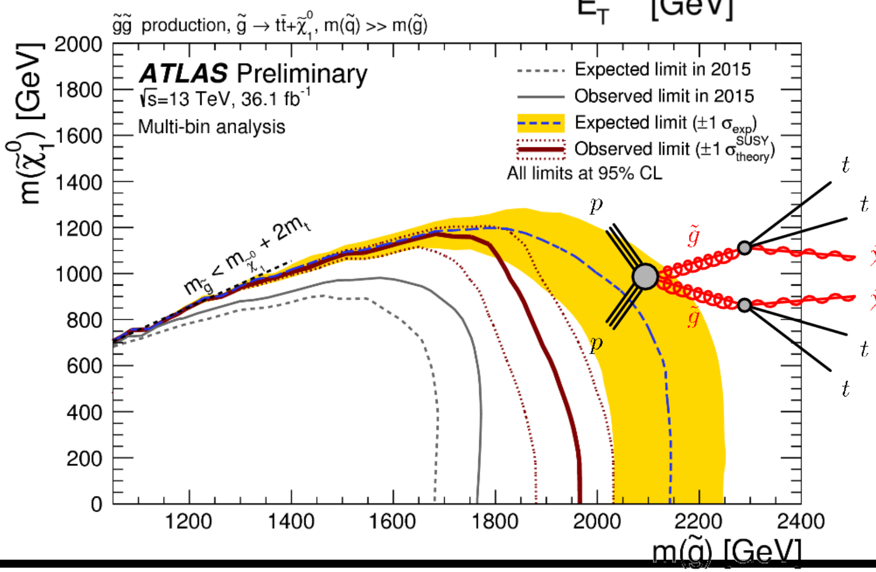
E_T^{miss} at SR A



Observed data and the expected SM background



No significant excess

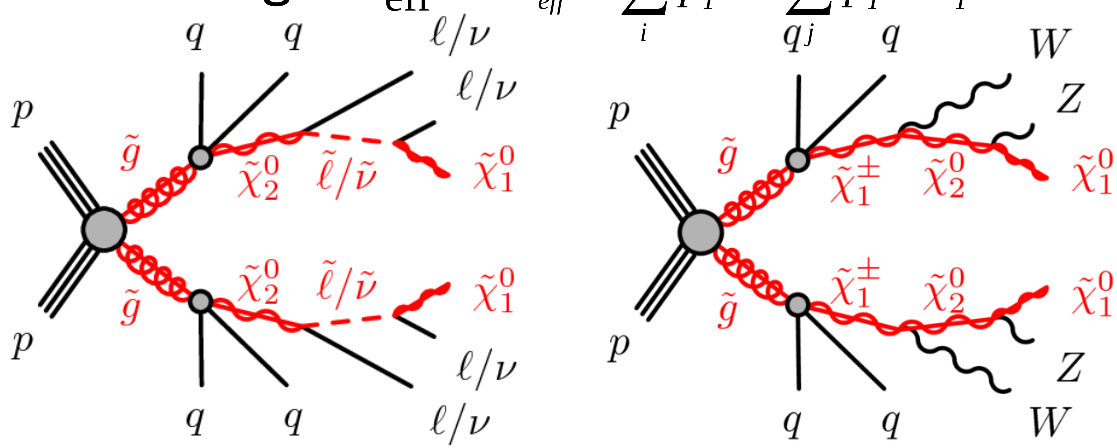


- No significant excess in 36.1 fb^{-1} data
- ~2 TeV gluino is excluded at low LSP mass

Same Sign Two/Three Leptons in Final State

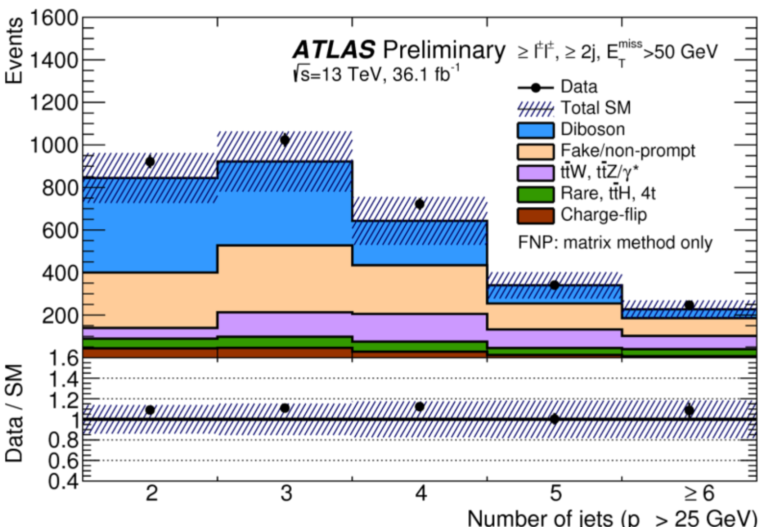
- **Search for gluino pair production with two leptons of the same electric charge (Same-Sign; SS) / three leptons (36 fb^{-1})**
  - Multi-leptons from long decay chain
  - SM process has a very small cross section
    - ➡ allow the use of looser kinematic requirements
    - ➡ Good sensitivity to scenarios with small $\Delta m(= m_{\tilde{g}} - m_{\tilde{\chi}^0})$
  - SR : SS 2-leptons/3-leptons + Large E_T^{miss} + Multiple-jets

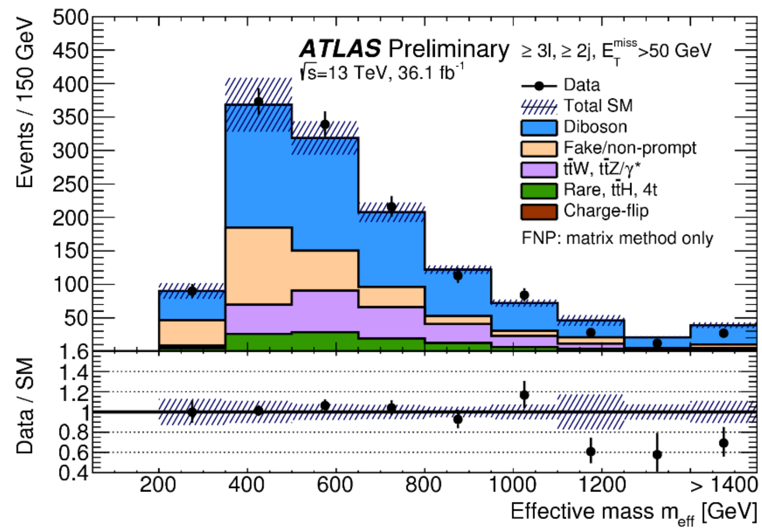
    Hard kinematics: Large m_{eff} $m_{eff} = \sum_i p_T^{jet_i} + \sum_j p_T^{l_j} + E_T^{miss}$



2L(SS)/3L: Background Estimation

- **Main sources of background**
  - Electron mis-measured charge
    - Estimation by charge-flip probability extracted in $Z/\gamma^{*} \rightarrow$ ee data
  - One fake/non-prompt lepton from heavy flavor hadron decays
    - Two data-driven methods (Matrix method and MC templates)
  - SM process with SS 2L/3L : ttV, diboson
    - Estimated from MC with dedicated VR to verify the modeling

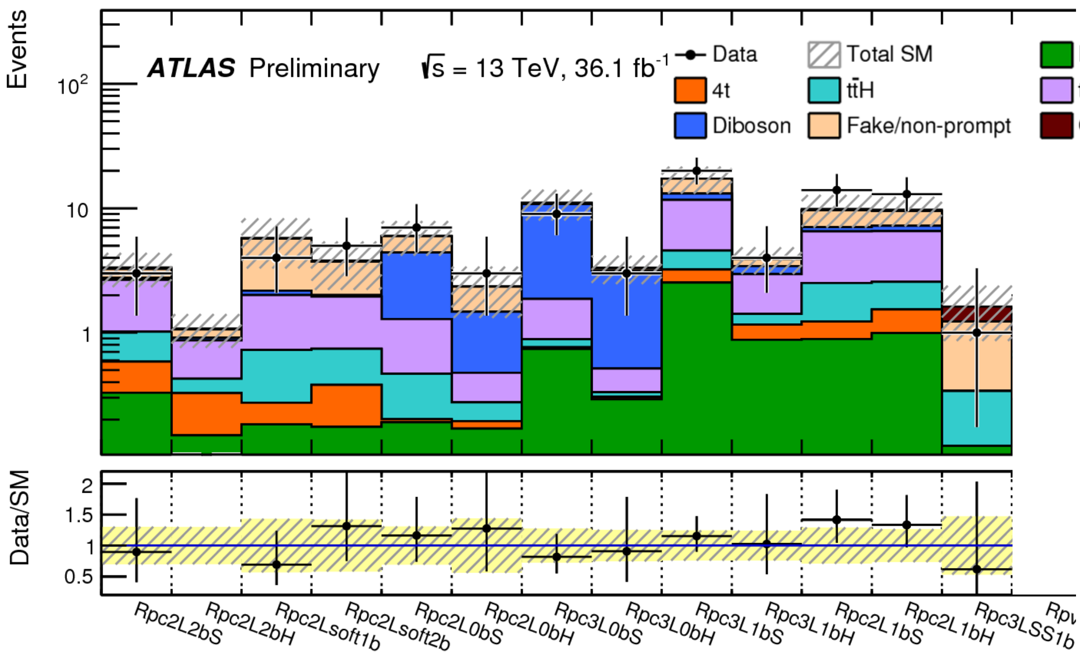




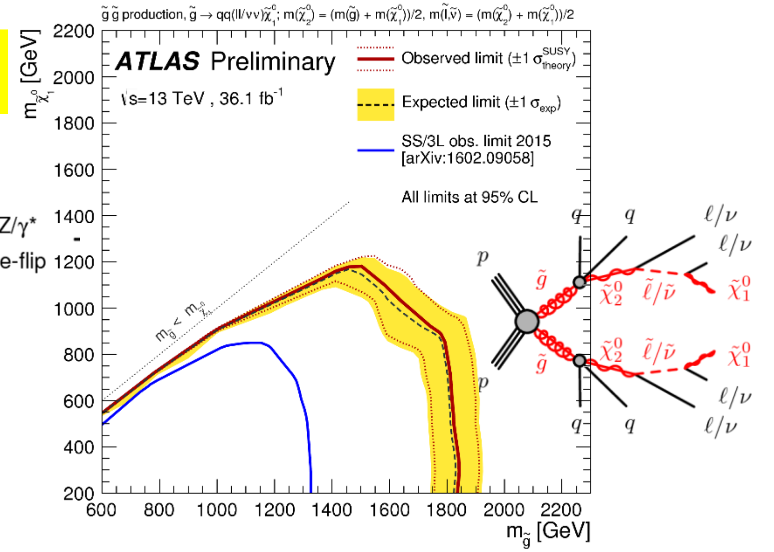
The background prediction is in good agreement with data

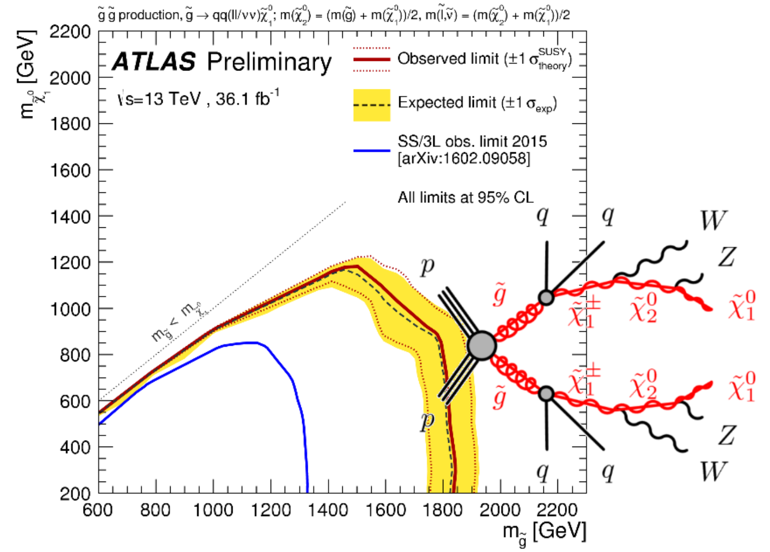
2L(SS)/3L: Results

Observed data and the expected SM background



- No significant excess
- Gluino mass below 1.6-1.8 TeV are excluded at low LSP mass

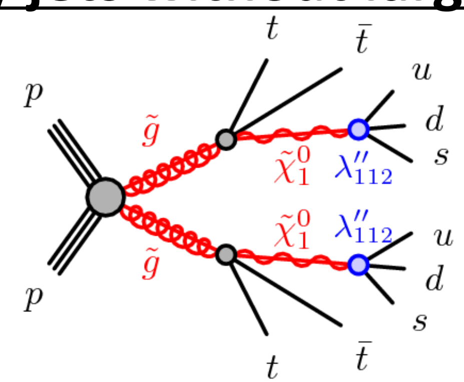


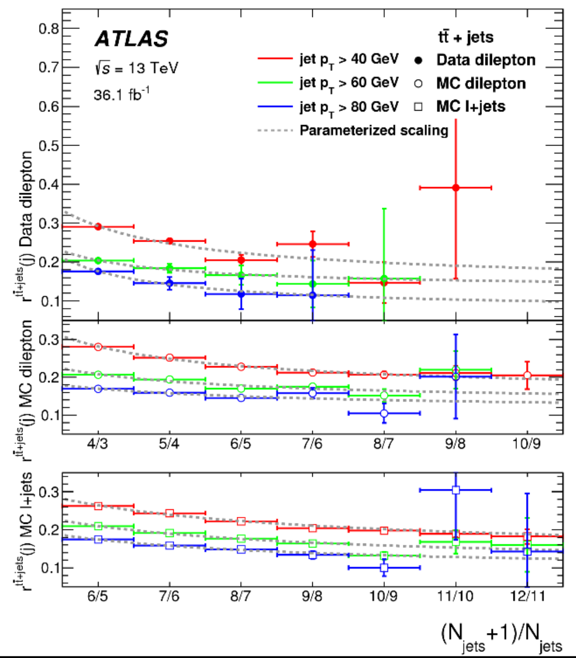


1-Lepton without Large E_T^{miss} in Final State

[Submitted to JHEP](#)

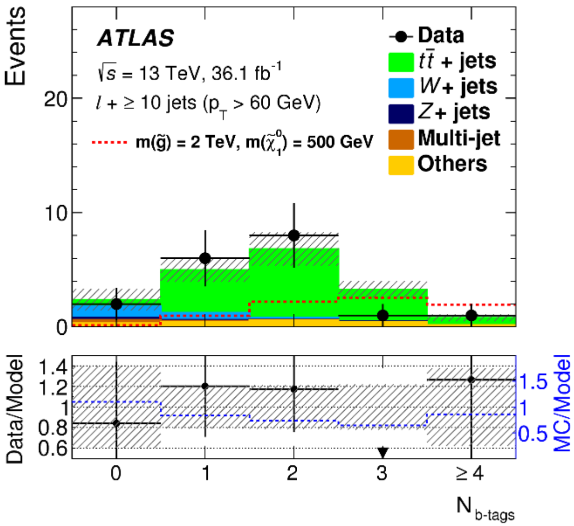
- **Search for the final state of 1-lepton + many jets without large E_T^{miss}**
  - 1-lepton + 8-12-jets + (b-tagged jets)
    - No requirement on E_T^{miss}
  - Benchmark : SUSY with RPV
  - SR: **8-12 jets** and **b-jet multiplicity**
  - Main background: ttbar+jets (W+ jets) at high (low) b-jet multiplicity
    - **The modeling of the background at high jet multiplicity suffers from large uncertainties**
    - Extraction of an initial template of the b-tag jet multiplicity in data (5-jets region) and parameterization of the evolution of the template to higher jet multiplicities



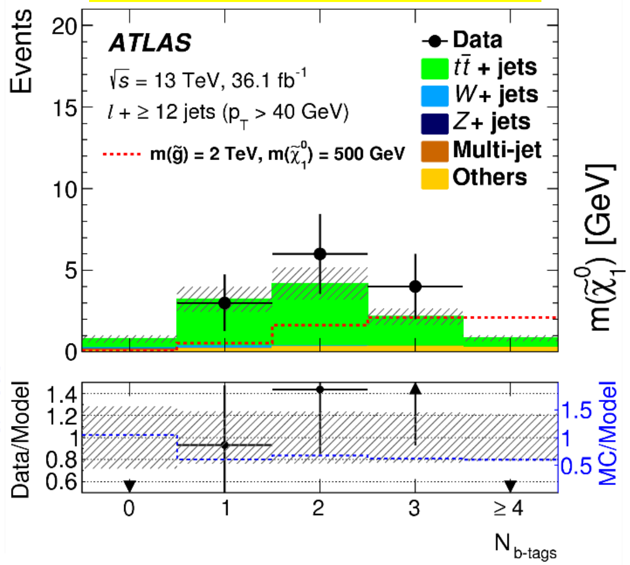


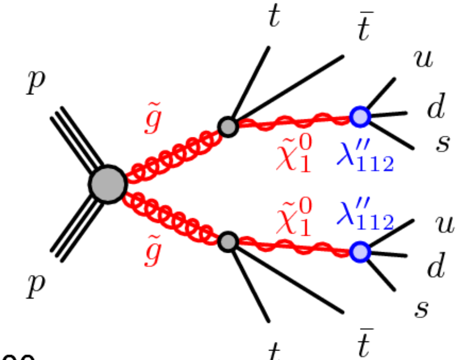
1-Lep without Large E_T^{miss} : Result

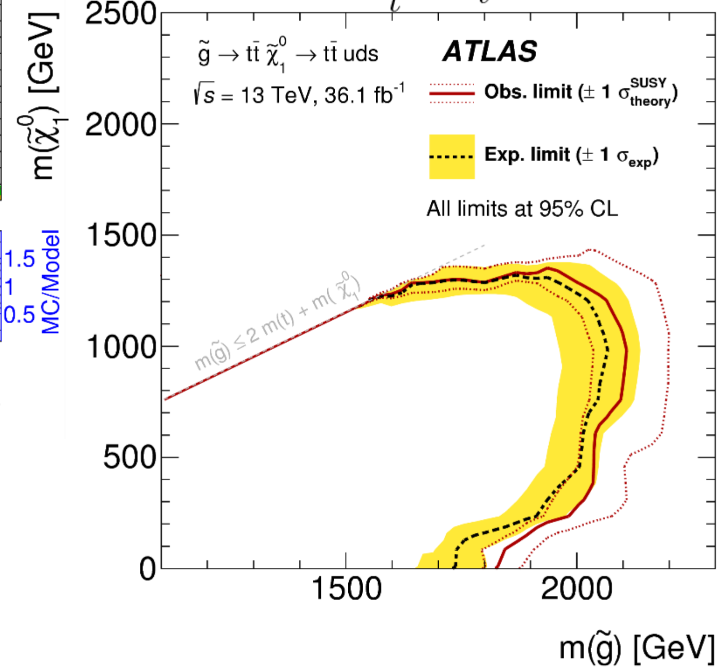
$N_{b\text{-jet}}$ at 10-jets (p_T>60 GeV)



$N_{b\text{-jet}}$ at 12-jets (p_T>40 GeV)



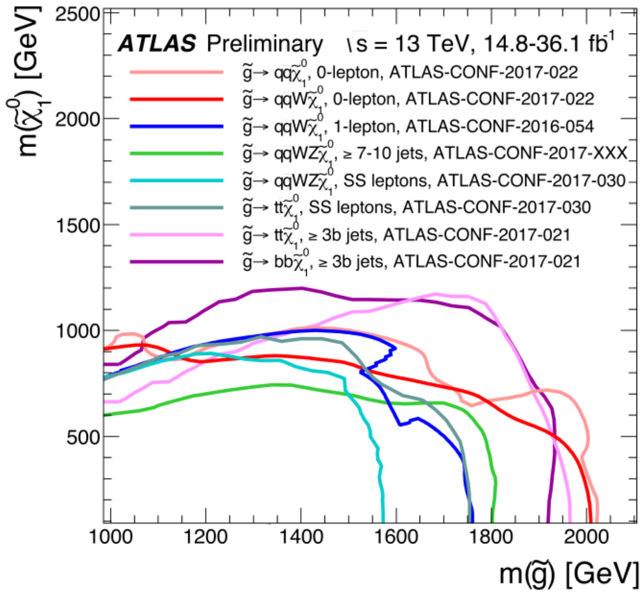




- **No significant excess observed**
- ~2 TeV gluino is excluded

Summary

- **ATLAS is exploring the energy frontier to discover SUSY !**
  - Topology based search
    - to cover all phase spaces of SUSY signal
    - not to lose any slight evidence of SUSY signal
- **SUSY searches in final states with leptons**
  - No clear sign of SUSY
  - Search region on gluino mass goes to ~2TeV
- **The LHC experiment has 3ab^{-1} program**
  - The experiment has just started
  - **Large increase in sensitivity in coming data**



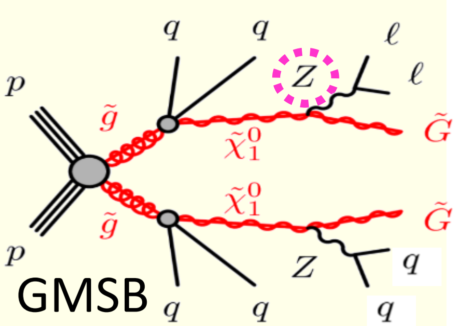
backup

Same-flavor Opposite-sign Two Leptons in Final State

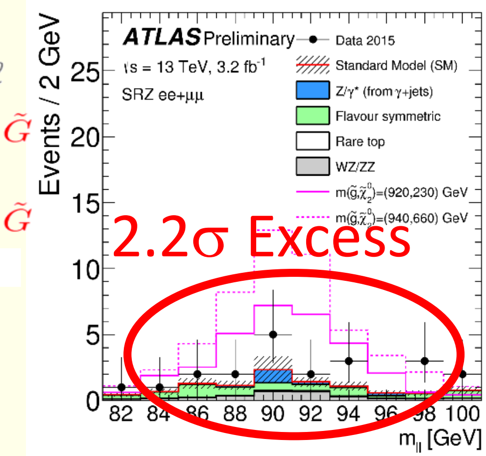
Eur. Phys. J C 77 (2017 144

- **Search for final states with 2-leptons (same-flavor(SS), opposite-sigh(OS), l^+l^-) from the gluino/squark decays (15 fb^{-1})**
  - 2 types of the search : on-shell Z or off-shell Z

On-shell Z (81 GeV< m_{ll} <101 GeV)

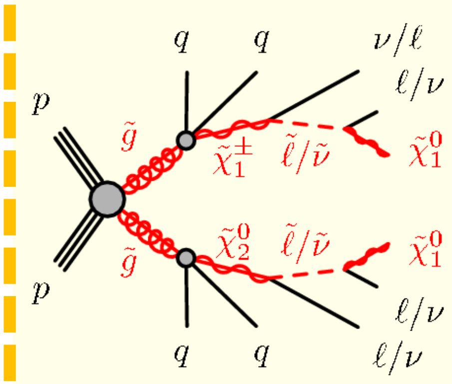


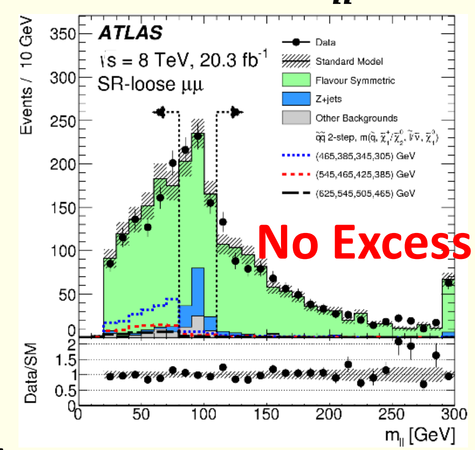
GMSB
Gravitino(LSP)



- **3σ excess at ATLAS Run1**
- **→ 2.2σ excess at Run2 2015**

Edge search (low, high m_{ll})



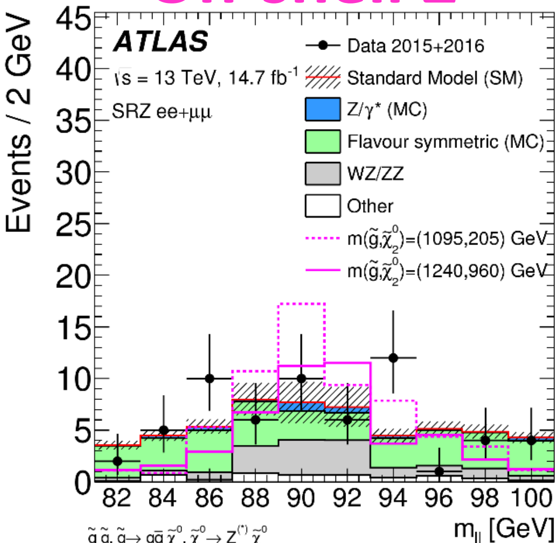


- kinematic endpoint in m_{ll}, depending on the mass difference
- **No excess at ATLAS**

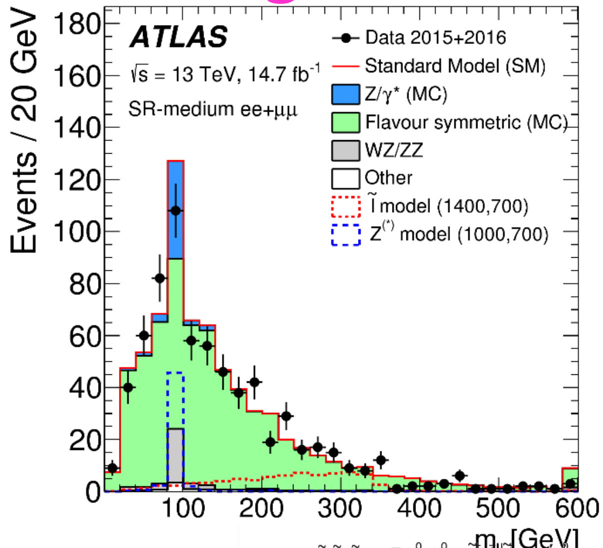
- **Dominant Background: Flavor symmetric background**
  - 2-leptons from independent $W \rightarrow l\nu$ ➡ Estimation by $e\mu$ data sample

SS OS Two Leptons : Results

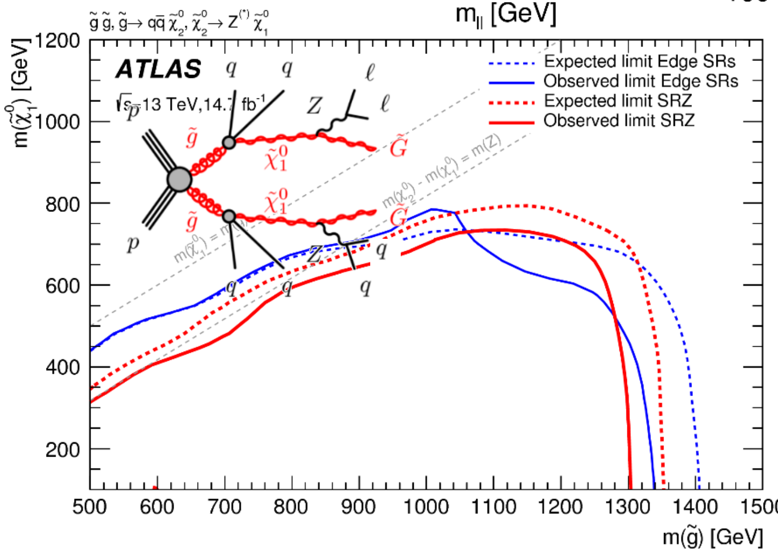
On-shell Z

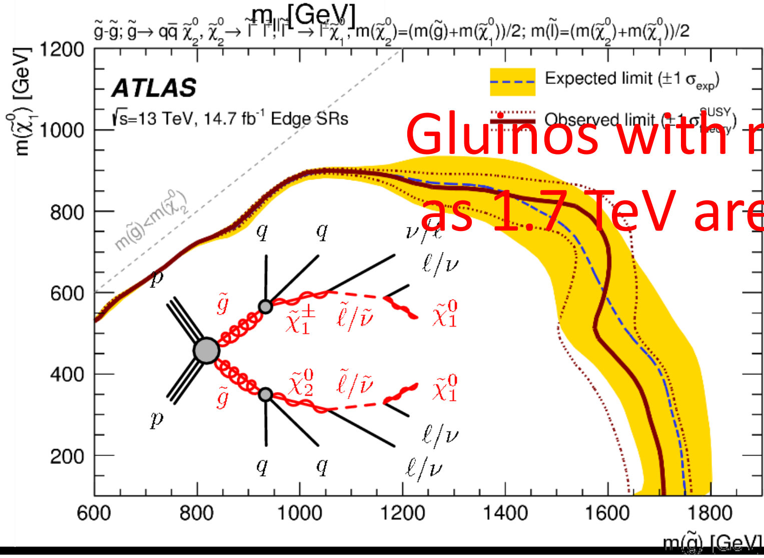


Edge search



The data in both searches consistent with the SM prediction

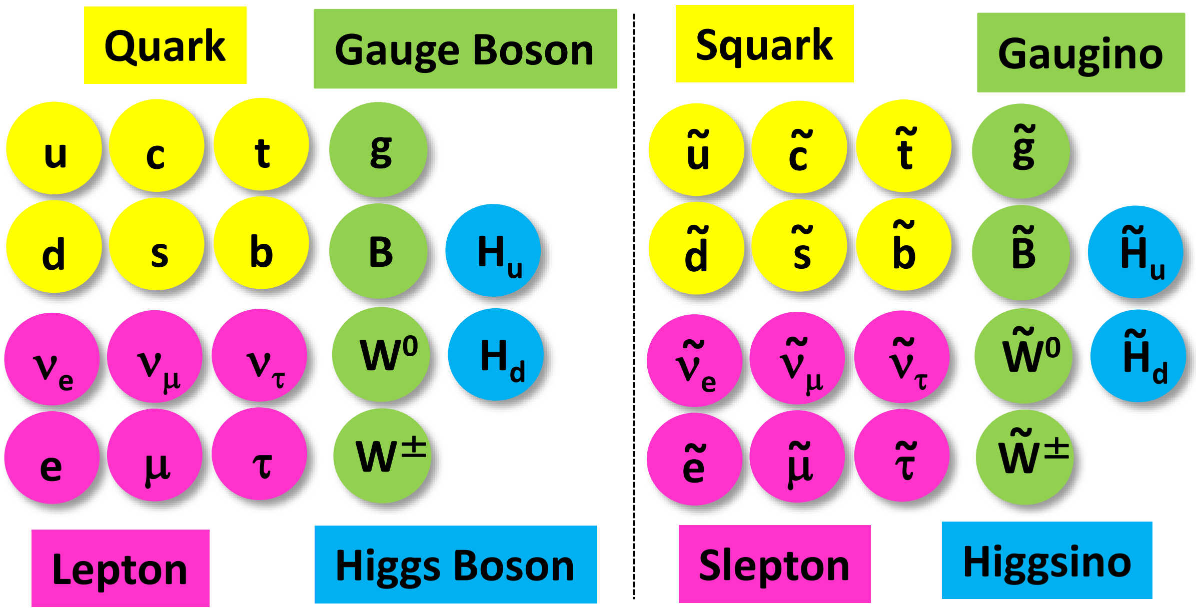




Gluinos with masses as large as 1.7 TeV are excluded

Supersymmetry (SUSY)

SUSY：Unification of Fermion and Boson



Bino
Wino
2 Higgsino

} $\tilde{\chi}^0_{1,2,3,4}$

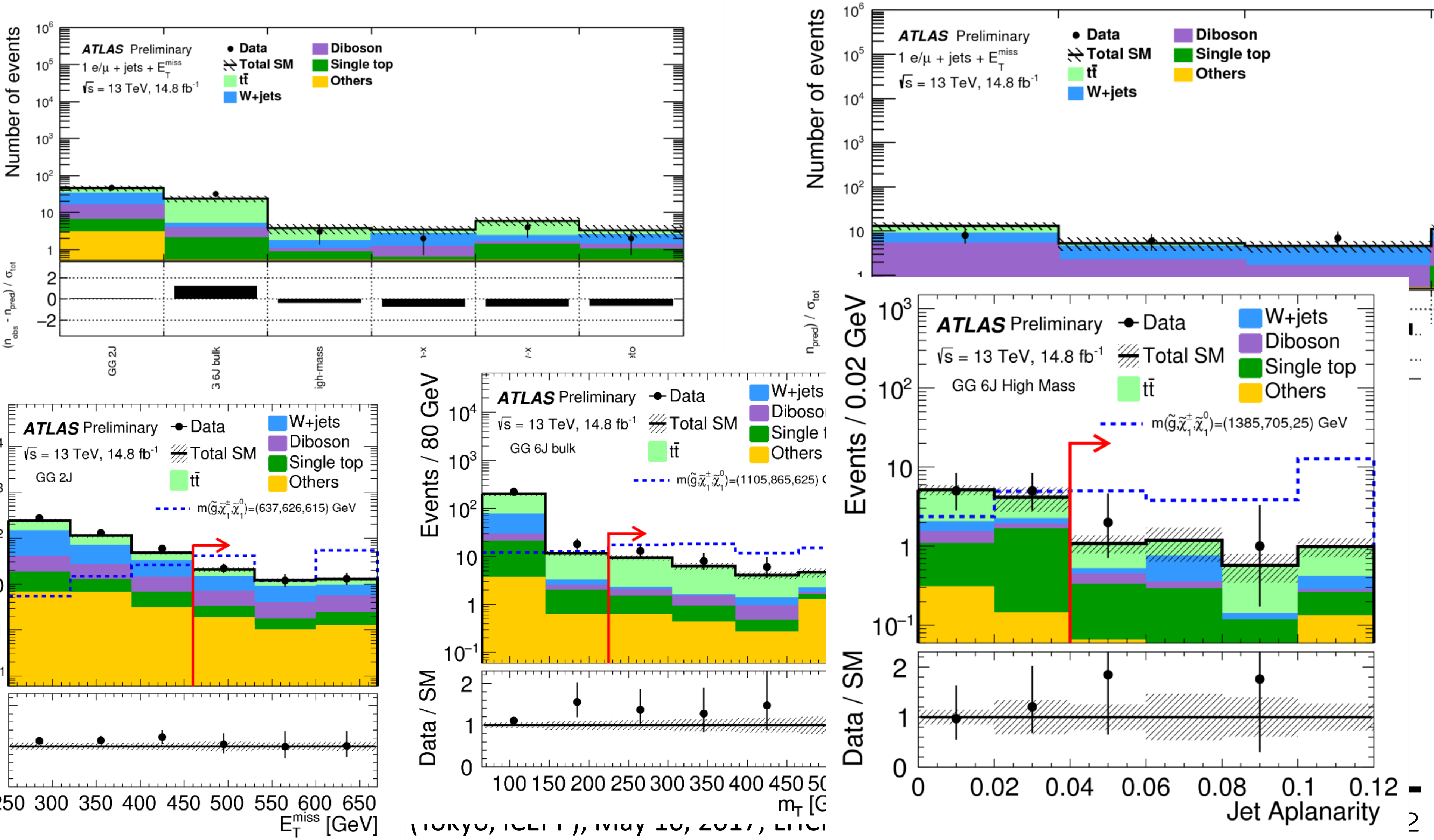
$\tilde{\chi}^0_1$:Lightest SUSY Particle (LSP) → DM candidate

Why SUSY？

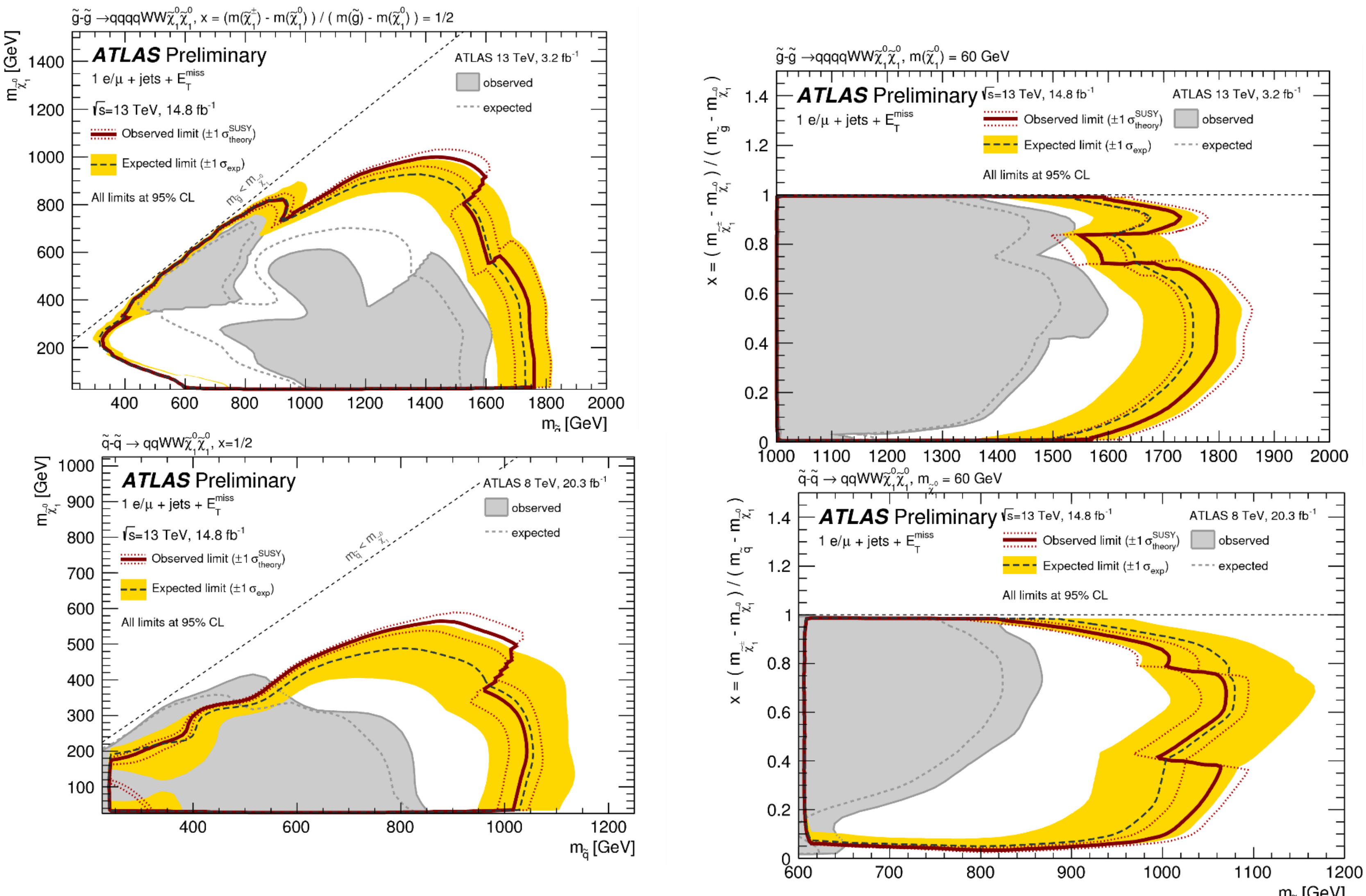
- Good dark matter candidate
- Higgs mass 125 GeV (MSSM prediction < ~150 GeV [1])
- GUT prefers SUSY

[1] Y. Okada, M.Yamaguchi T. Yanagita prog.Theor. Phys. **85** (1991).

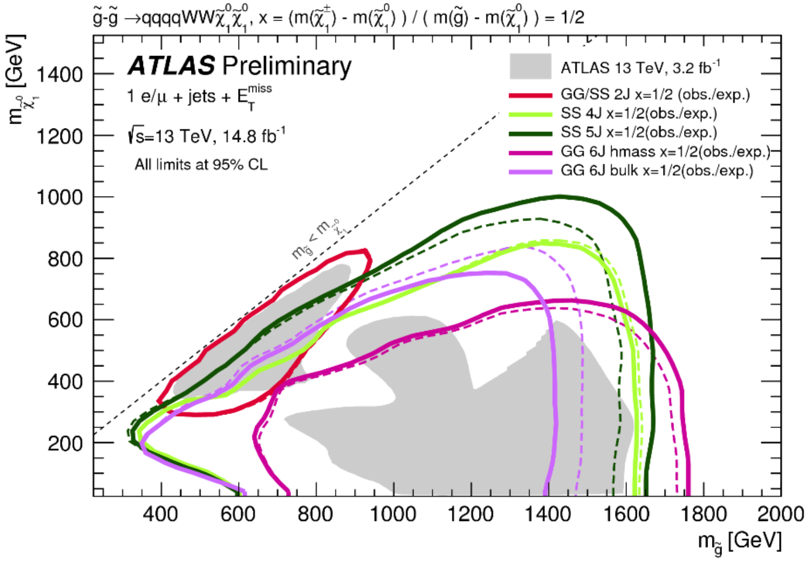
One-Lep 15fb-1

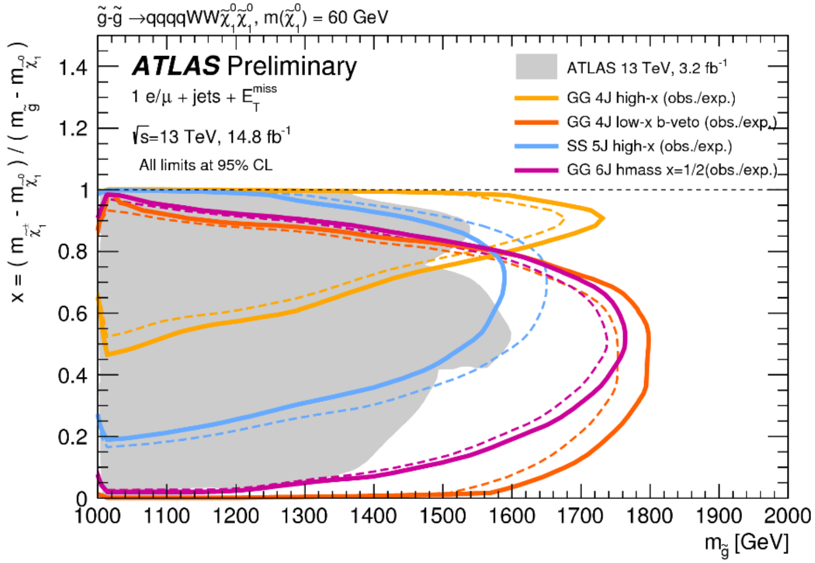


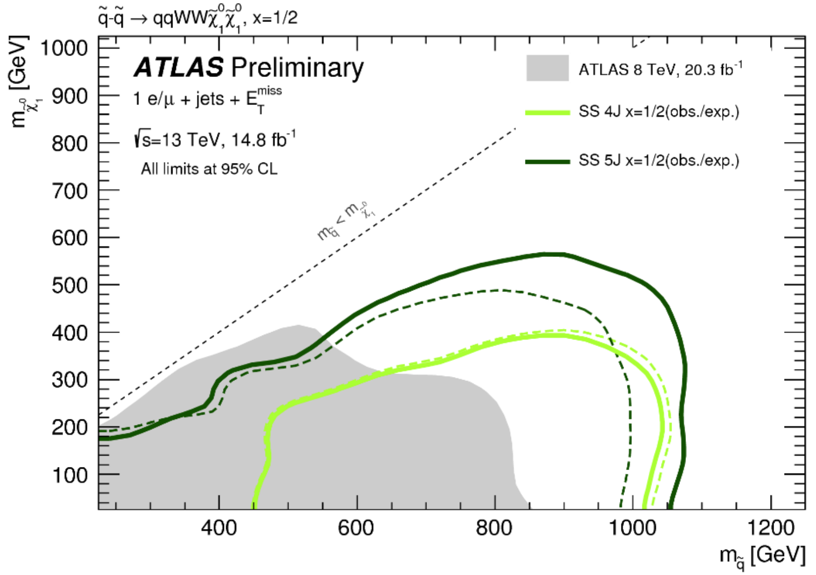
One-Lep 15fb-1

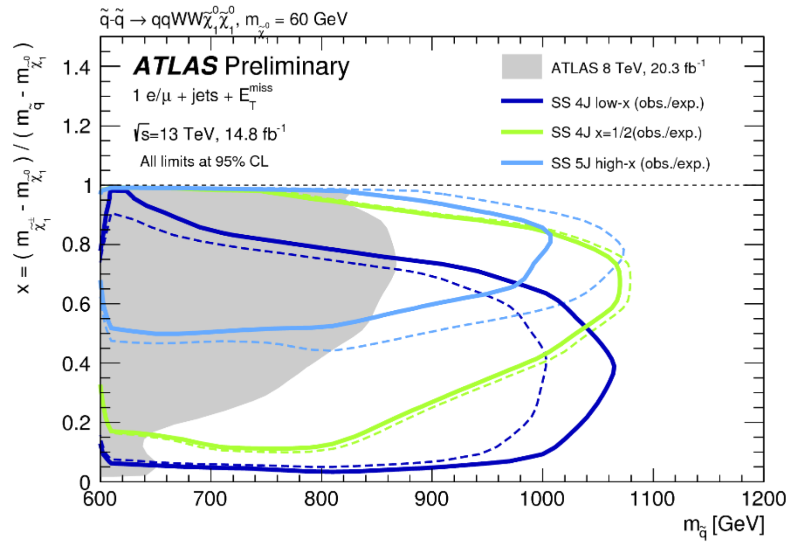


One-Lep 15fb-1





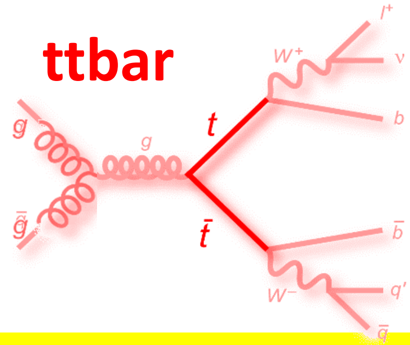




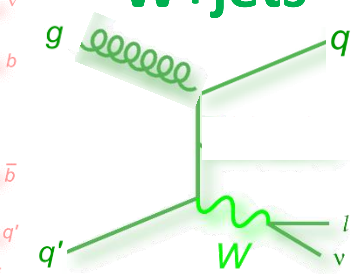
One-Lep :Background Estimation

- **<u>Major Background: ttbar , W+jets</u>**
  - CRs defined at low m_{T} and low Aplanarity
  - VRs for m_{T} and Aplanarity extrapolations

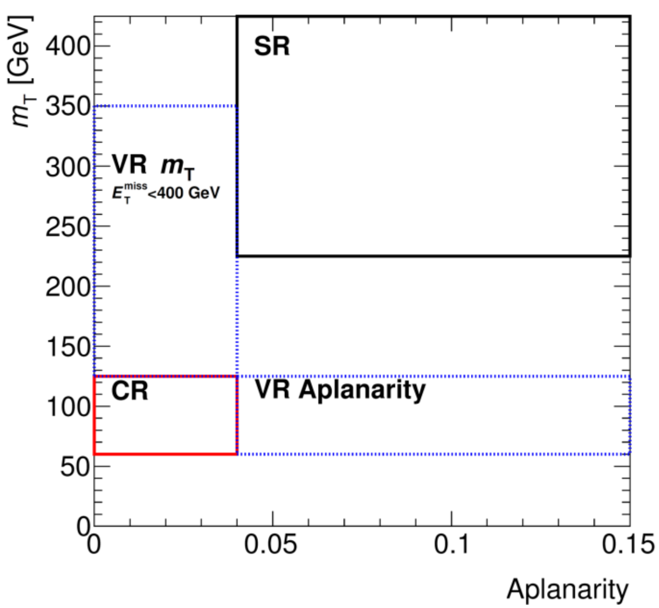
ttbar



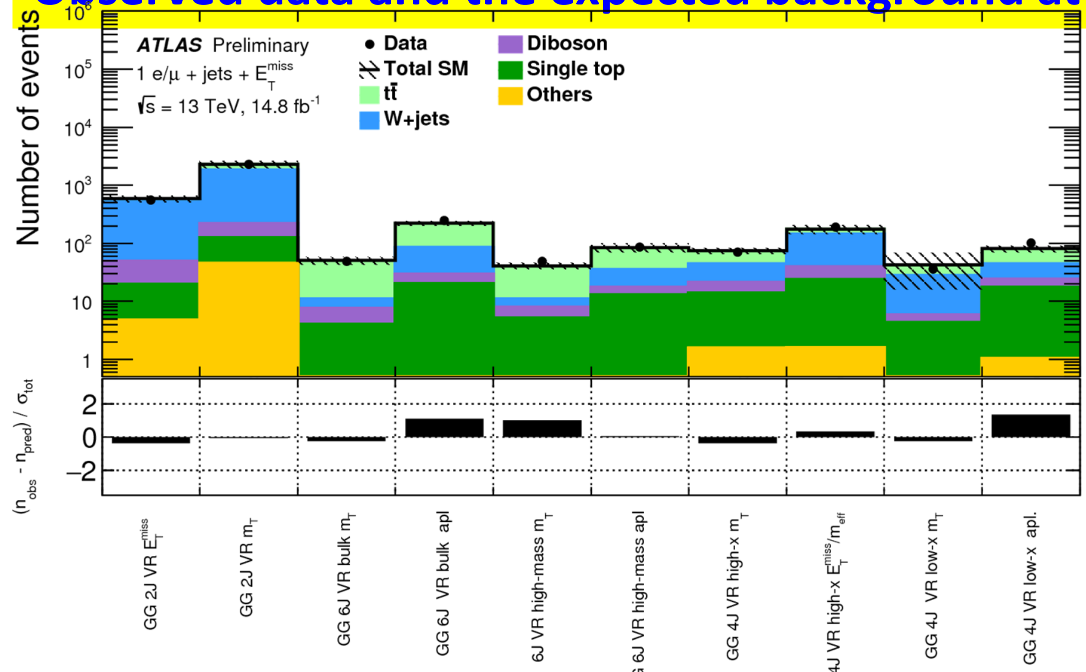
W+jets



$$m_T = \sqrt{2 p_T^l E_T^{miss}\left(1-\cos\left[\Delta\phi\left(l, p_T^{miss}\right)\right]\right)}$$



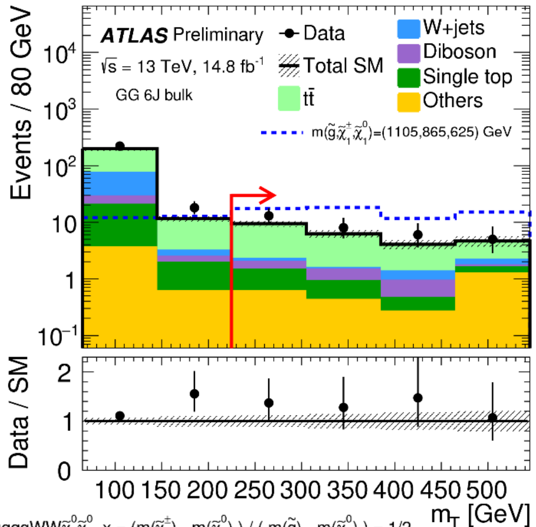
Observed data and the expected background at VR



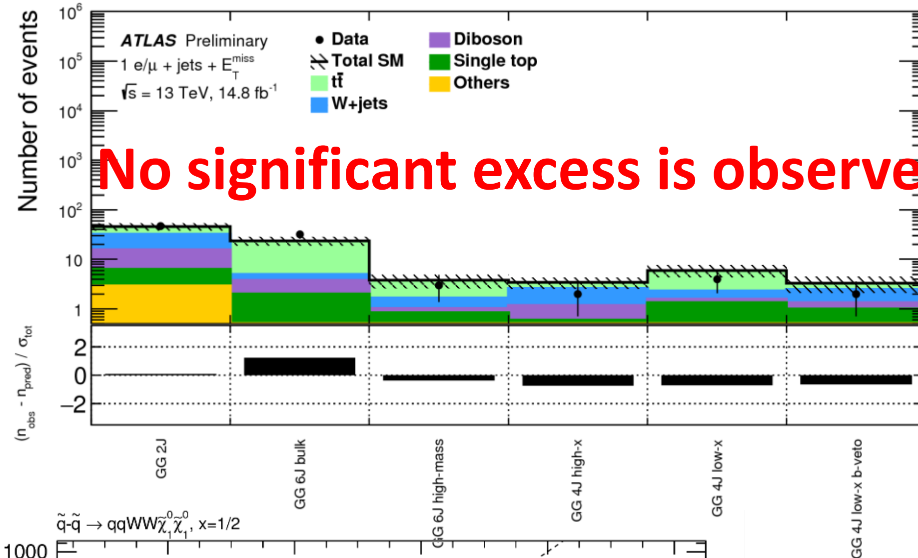
SM prediction is in good agreement with data

One-Lep : Results

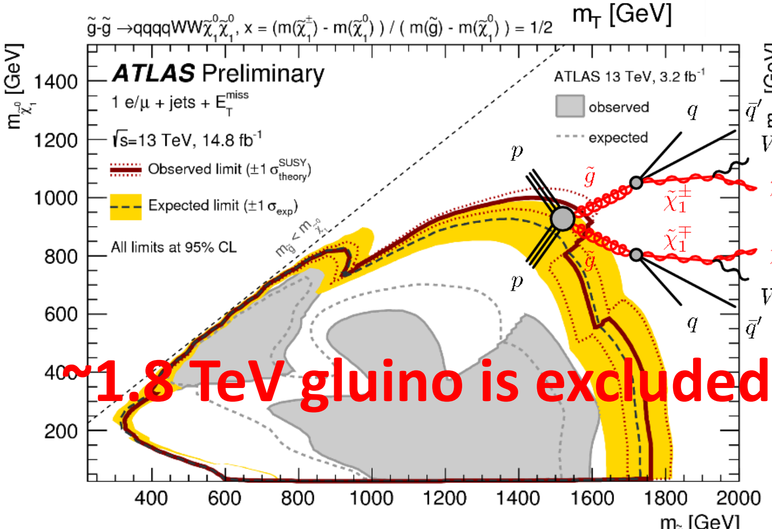
E_T^{miss} at 6-jets region



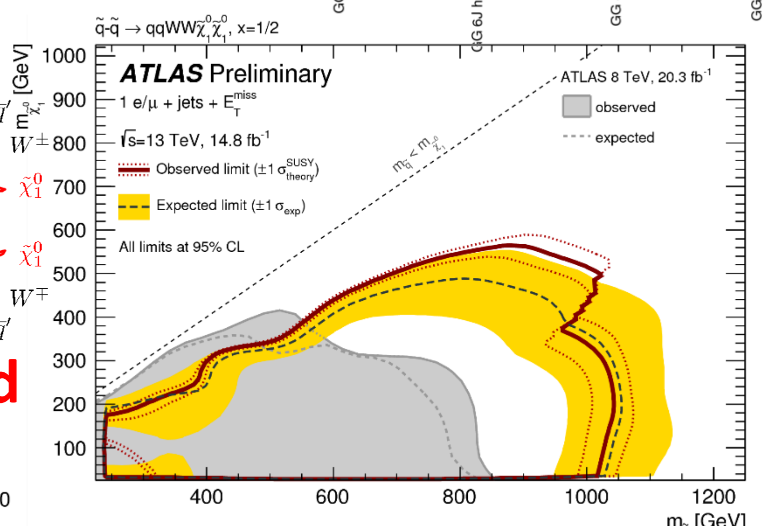
Observed data and the expected SM background



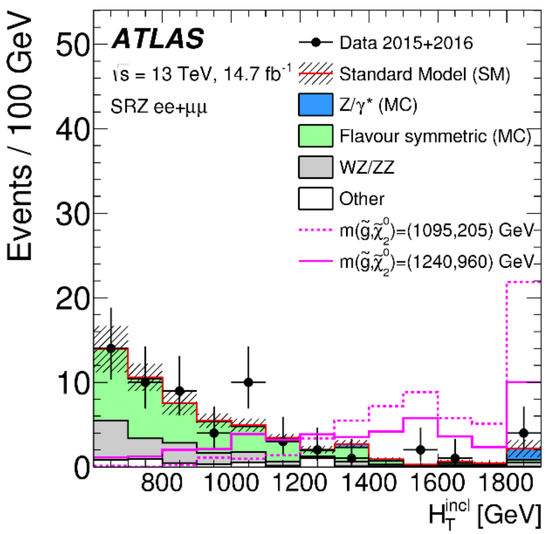
No significant excess is observed

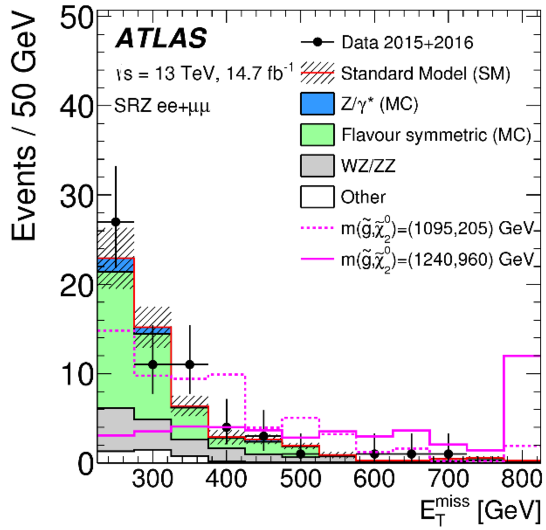


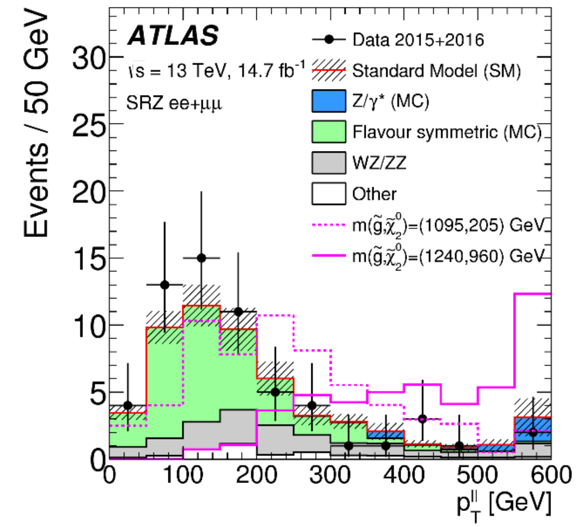
~1.8 TeV gluino is excluded

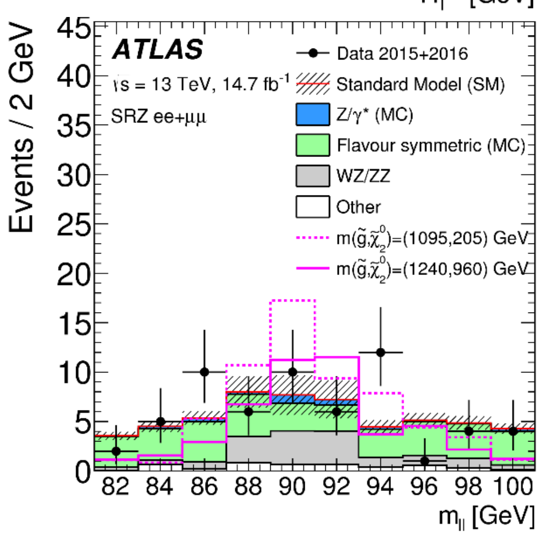


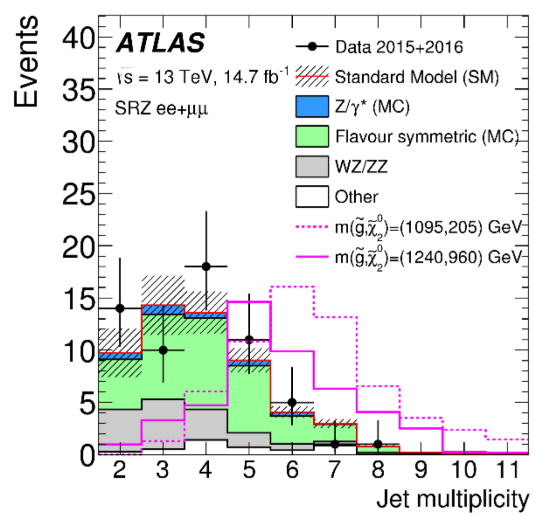
Same-flavor Opposite-sign Two Leptons in Final State

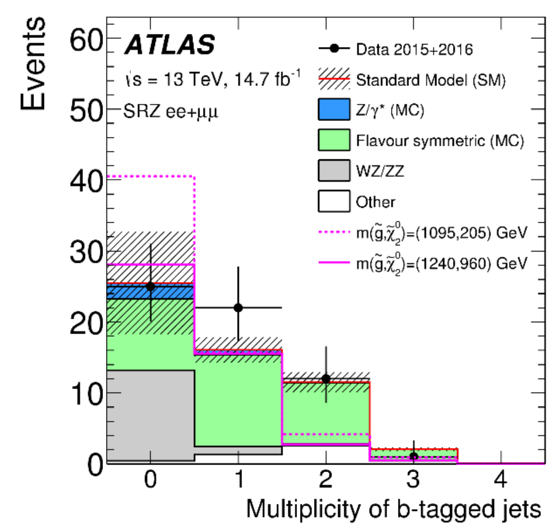




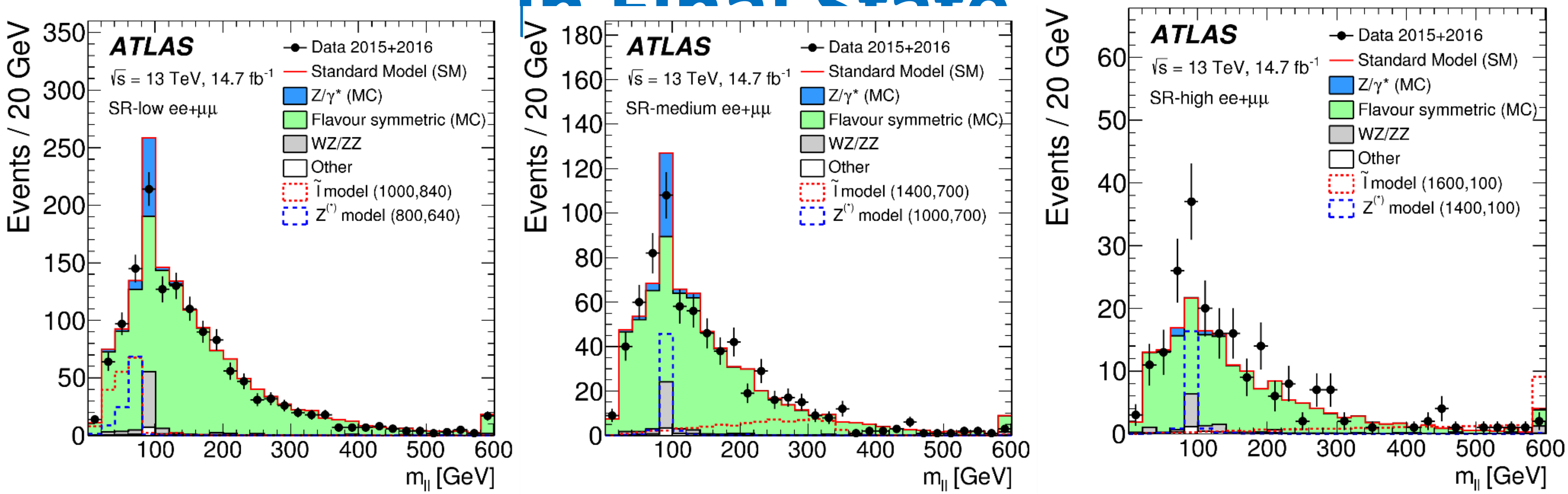


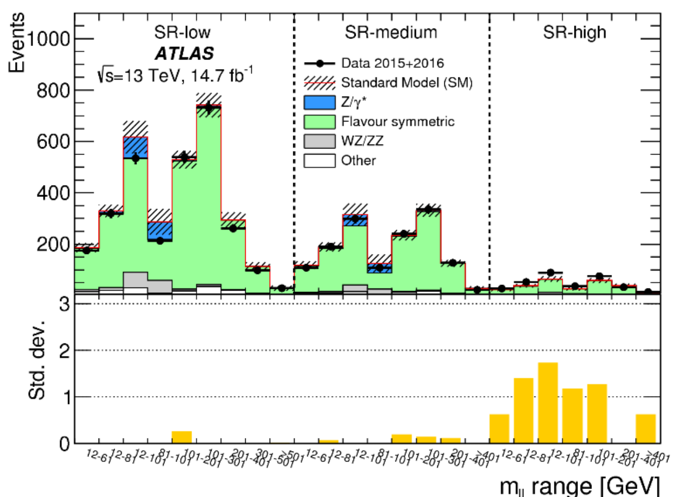




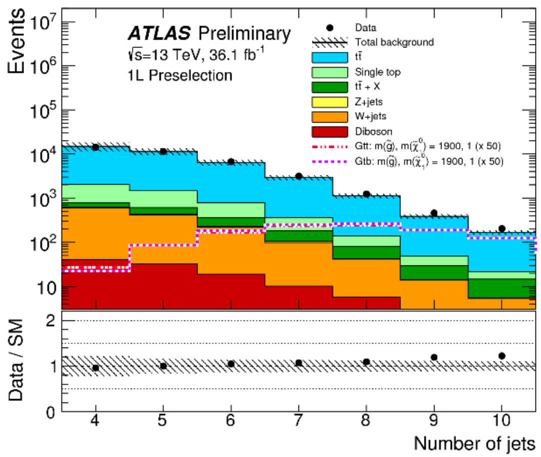


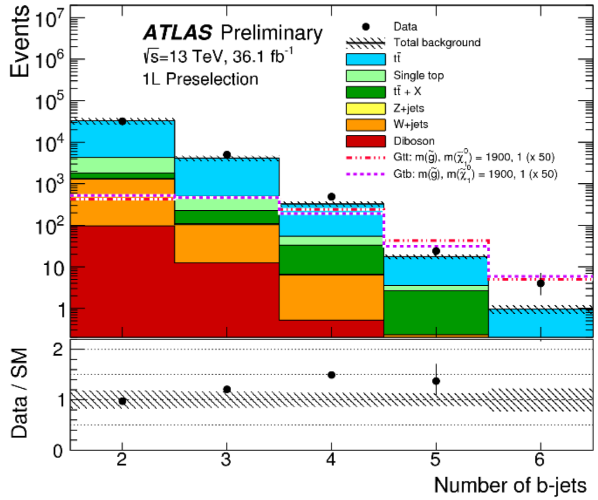
Same-flavor Opposite-sign Two Leptons in Final State

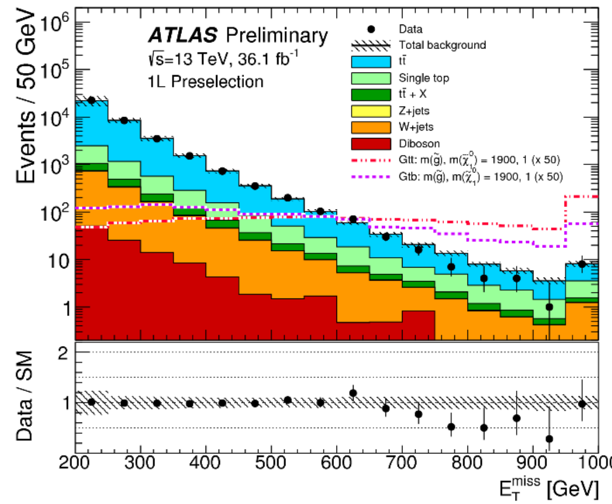




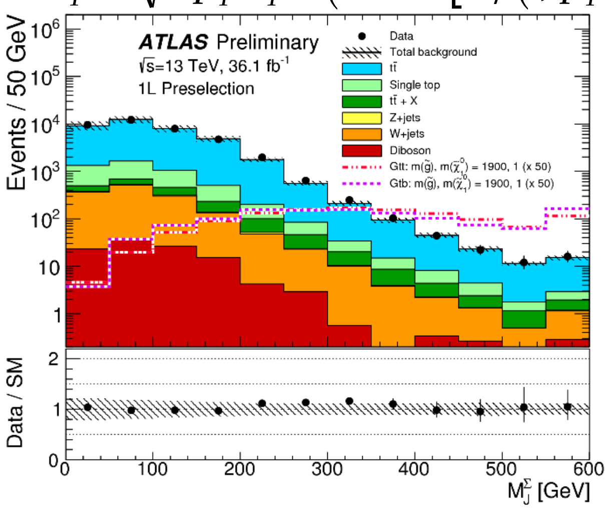
Multi-b

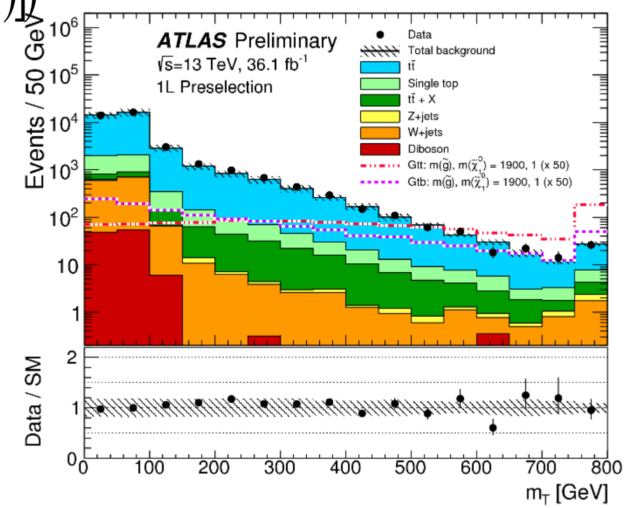


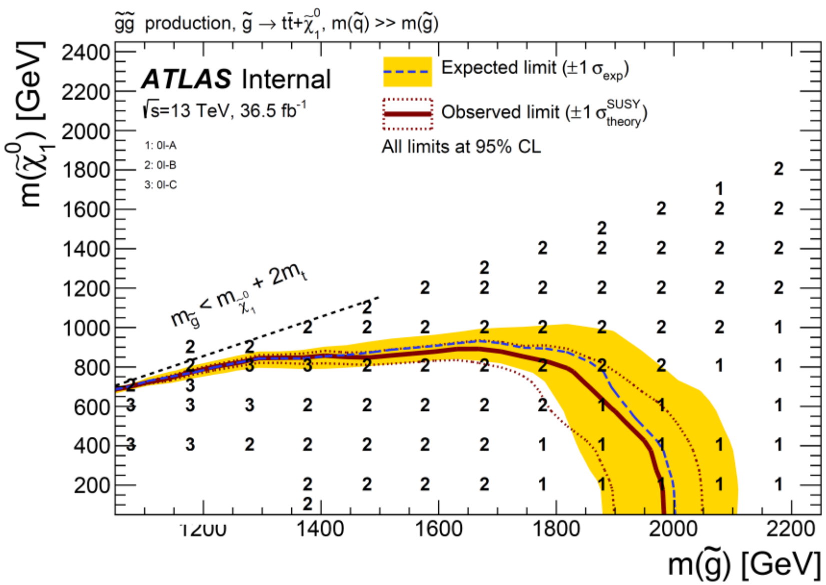


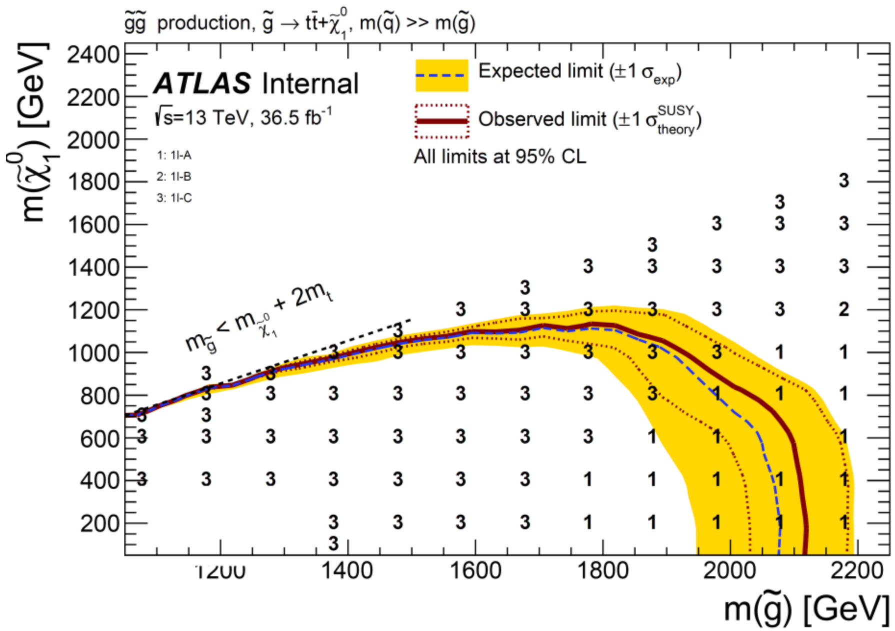


$$m_T = \sqrt{2 p_T^l E_T^{miss}\left(1-\cos\left[\Delta\phi\left(l, p_T^{miss}\right)\right]\right)}$$



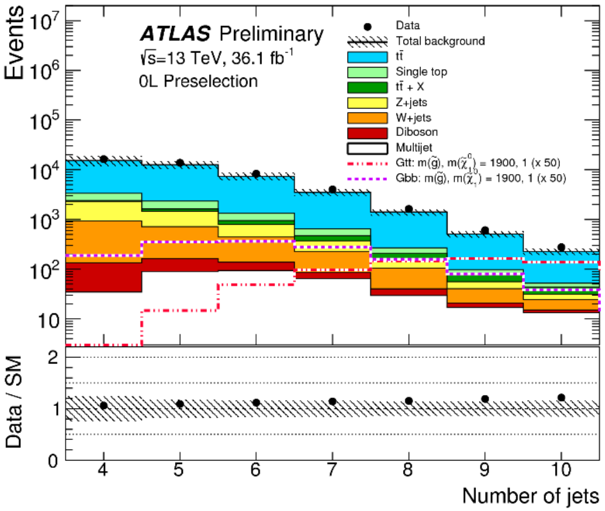


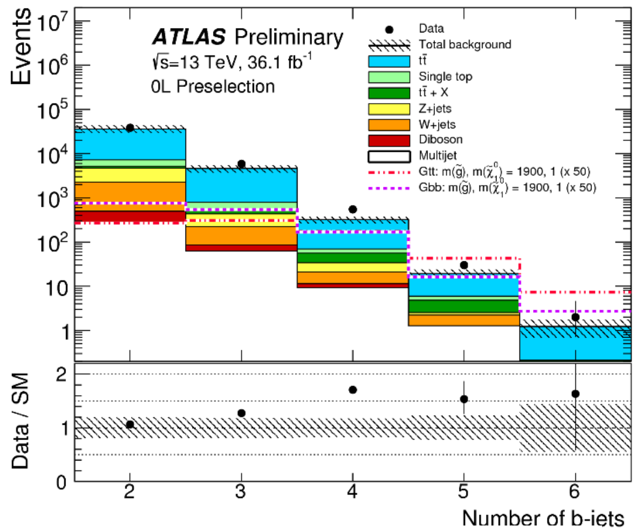


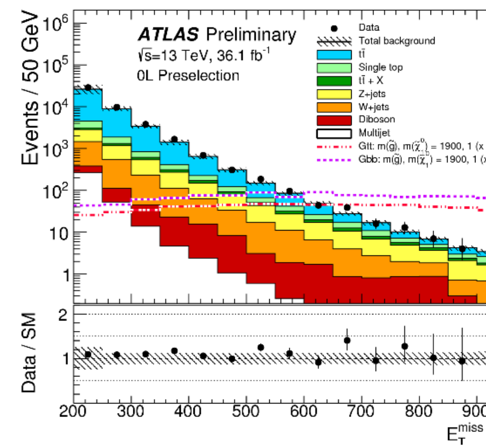


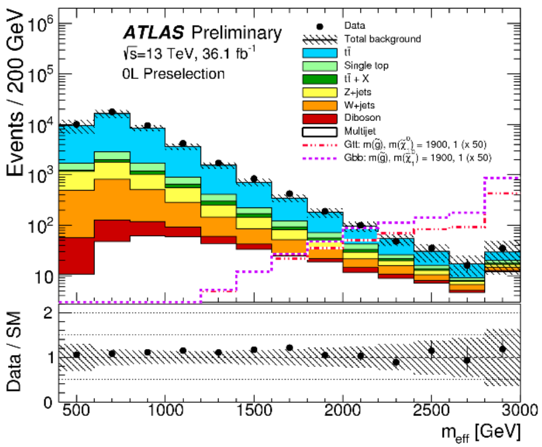
1L SR has a much better sensitivity than 0L SR

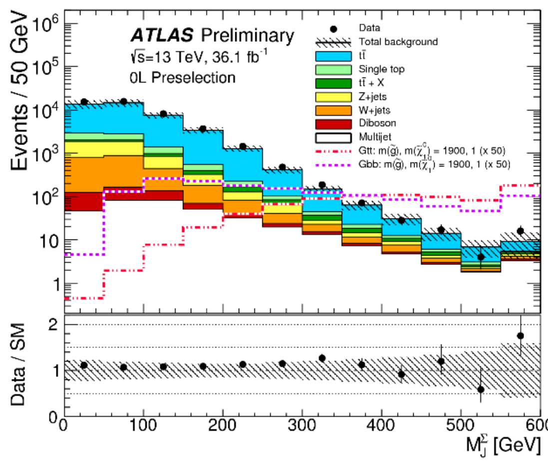
Multi-b

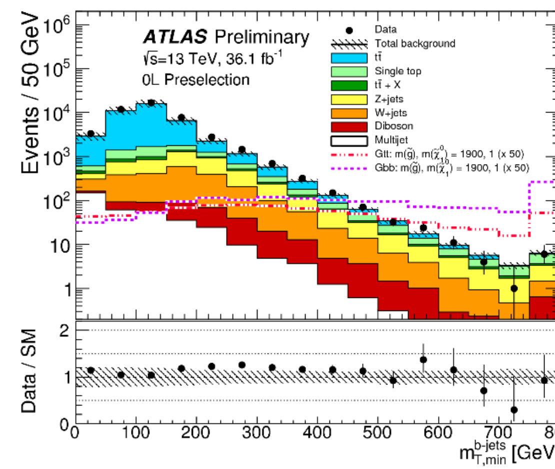

ATLAS Preliminary
√s=13 TeV, 36.1 fb⁻¹
0L Preselection
Data
Total background
tt̄
Single top
tt̄ + X
Z+jets
W+jets
Diboson
Multijet
Gtt: m(g̃), m(χ̃⁰₁) = 1900, 1 (x 50)
Gbb: m(g̃), m(χ̃⁰₁) = 1900, 1 (x 50)
Events
Data / SM
Number of jets


ATLAS Preliminary
√s=13 TeV, 36.1 fb⁻¹
0L Preselection
Data
Total background
tt̄
Single top
tt̄ + X
Z+jets
W+jets
Diboson
Multijet
Gtt: m(g̃), m(χ̃⁰₁) = 1900, 1 (x 50)
Gbb: m(g̃), m(χ̃⁰₁) = 1900, 1 (x 50)
Events
Data / SM
Number of b-iets


ATLAS Preliminary
√s=13 TeV, 36.1 fb⁻¹
0L Preselection
Data
Total background
tt̄
Single top
tt̄ + X
Z+jets
W+jets
Diboson
Multijet
Events / 50 GeV
Data / SM


ATLAS Preliminary
√s=13 TeV, 36.1 fb⁻¹
0L Preselection
Data
Total background
tt̄
Single top
tt̄ + X
Z+jets
W+jets
Diboson
Multijet
Gtt: m(g̃), m(χ̃⁰₁) = 1900, 1 (x 50)
Gbb: m(g̃), m(χ̃⁰₁) = 1900, 1 (x 50)
Events / 200 GeV
Data / SM
m_eff [GeV]

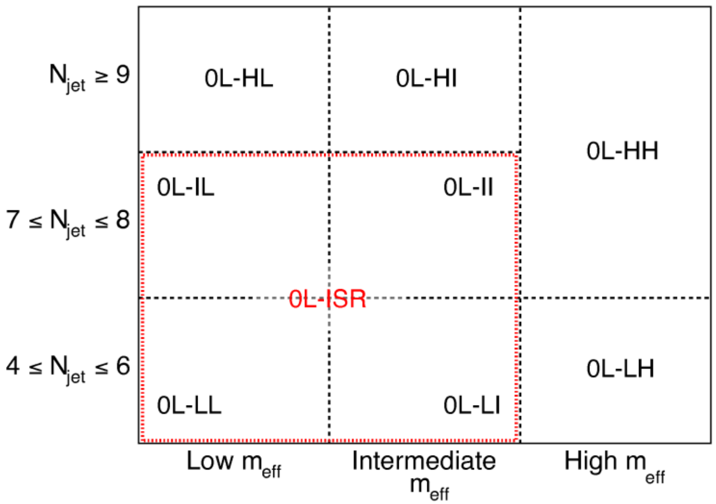

ATLAS Preliminary
√s=13 TeV, 36.1 fb⁻¹
0L Preselection
Data
Total background
tt̄
Single top
tt̄ + X
Z+jets
W+jets
Diboson
Multijet
Gtt: m(g̃), m(χ̃⁰₁) = 1900, 1 (x 50)
Gbb: m(g̃), m(χ̃⁰₁) = 1900, 1 (x 50)
Events / 50 GeV
Data / SM
M_J^Σ [GeV]


ATLAS Preliminary
√s=13 TeV, 36.1 fb⁻¹
0L Preselection
Data
Total background
tt̄
Single top
tt̄ + X
Z+jets
W+jets
Diboson
Multijet
Gtt: m(g̃), m(χ̃⁰₁) = 1900, 1 (x 50)
Gbb: m(g̃), m(χ̃⁰₁) = 1900, 1 (x 50)
Events / 50 GeV
Data / SM

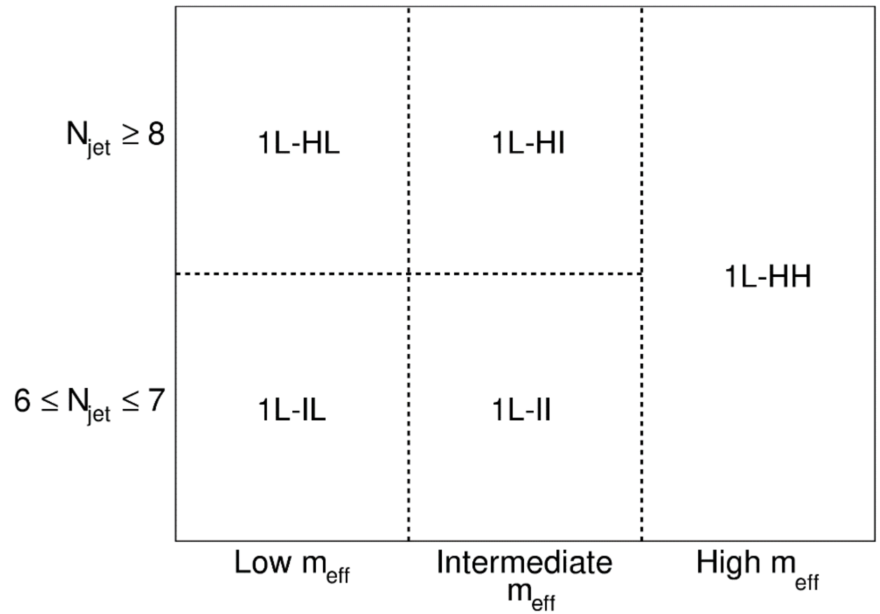
Criteria common to all Gtt 1-lepton regions ≥ 1 signal lepton, $p_T{}^{jet} > 30$ GeV, $N_{b\text{-jets}} \geq 3$			
	Variable	SR	CR
Region A (Large Δm)	N_{jet}	≥ 5	$= 5$
	m_T	> 150	< 150
	$m_{T,min}^{b\text{-jets}}$	> 120	–
	E_T^{miss}	> 500	> 300
	m_{eff}^{incl}	> 2200	> 1700
	M_J^{Σ}	> 200	> 150
Region B (Moderate Δm)	N_{jet}	≥ 6	$= 6$
	m_T	> 150	< 150
	$m_{T,min}^{b\text{-jets}}$	> 160	–
	E_T^{miss}	> 450	> 400
	m_{eff}^{incl}	> 1800	> 1500
	M_J^{Σ}	> 200	> 100
Region C (Small Δm)	N_{jet}	≥ 7	$= 7$
	m_T	> 150	< 150
	$m_{T,min}^{b\text{-jets}}$	> 160	–
	E_T^{miss}	> 350	> 350
	m_{eff}^{incl}	> 1000	> 1000

Criteria common to all Gtt 1-lepton regions: ≥ 1 signal lepton, $p_T{}^{jet} > 30$ GeV , $N_{b\text{-jet}} \geq 3$					
	Variable	Signal region	Control region	VR-m_T	VR-$m_{T,min}^{b-jets}$
Criteria common to all regions of the same type	$N^{Signal\ Lepton}$	≥ 1	≥ 1	≥ 1	≥ 1
	$p_T{}^{jet}$	> 30	> 30	> 30	> 30
	$N_{b\text{-jet}}$	≥ 3	≥ 3	≥ 3	≥ 3
Region A (Large mass splitting)	N^{jet}	≥ 5	$== 5$	≥ 5	> 5
	m_T	> 150	< 150	> 150	< 150
	$m_{T,min}^{b-jets}$	> 120	–	–	> 120
	E_T^{miss}	> 500	> 300	> 300	> 400
	m_{eff}^{incl}	> 2200	> 1700	> 1600	> 1400
	$M_J^{\Sigma,4}$	> 200	> 150	< 200	> 200
Region B (Moderate mass splitting)	N^{jet}	≥ 6	$== 6$	≥ 6	> 6
	m_T	> 150	< 150	> 200	< 150
	$m_{T,min}^{b-jets}$	> 160	–	–	> 140
	E_T^{miss}	> 450	> 400	> 250	> 350
	m_{eff}^{incl}	> 1800	> 1500	> 1200	> 1200
	$M_J^{\Sigma,4}$	> 200	> 100	< 100	> 150
Region C (Small mass splitting)	N^{jet}	≥ 7	$== 7$	≥ 7	> 7
	m_T	> 150	< 150	> 150	< 150
	$m_{T,min}^{b-jets}$	> 160	–	< 160	> 160
	E_T^{miss}	> 350	> 350	> 300	> 300
	m_{eff}^{incl}	> 1000	> 1000	> 1000	> 1000

Multi-b

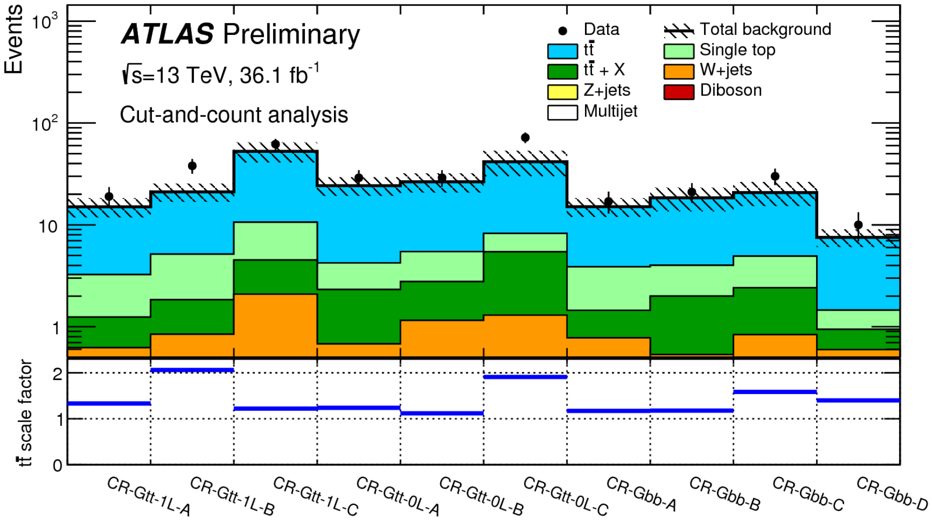


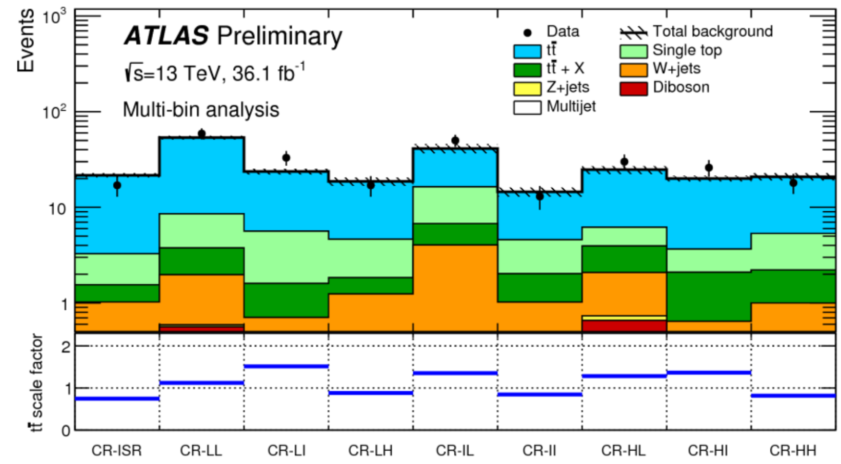
N_jet ≥ 9
7 ≤ N_jet ≤ 8
4 ≤ N_jet ≤ 6
0L-HL
0L-HI
0L-HH
0L-IL
0L-II
0L-ISR
0L-LL
0L-LI
0L-LH
Low m_eff
Intermediate m_eff
High m_eff

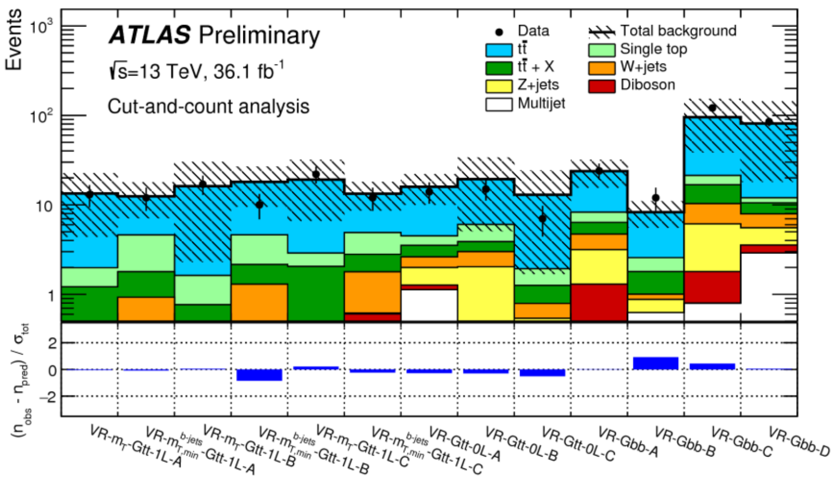


N_jet ≥ 8
6 ≤ N_jet ≤ 7
1L-HL
1L-HI
1L-HH
1L-IL
1L-II
Low m_eff
Intermediate m_eff
High m_eff

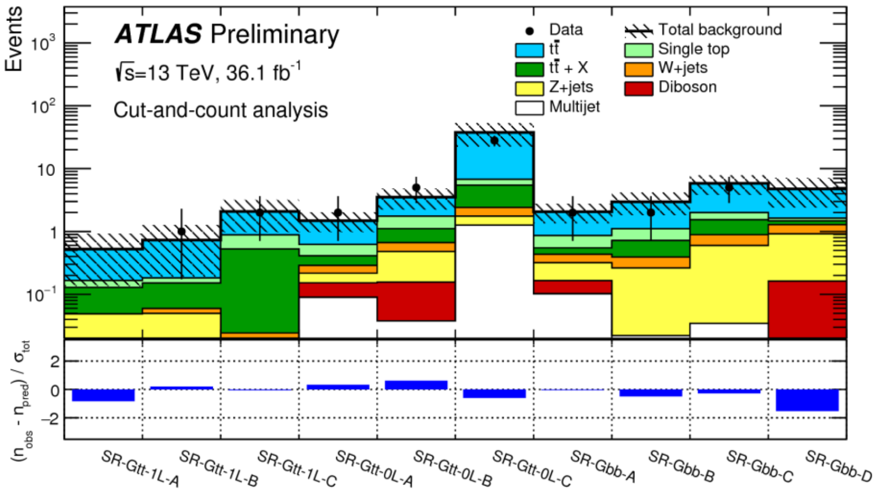
Multi-b

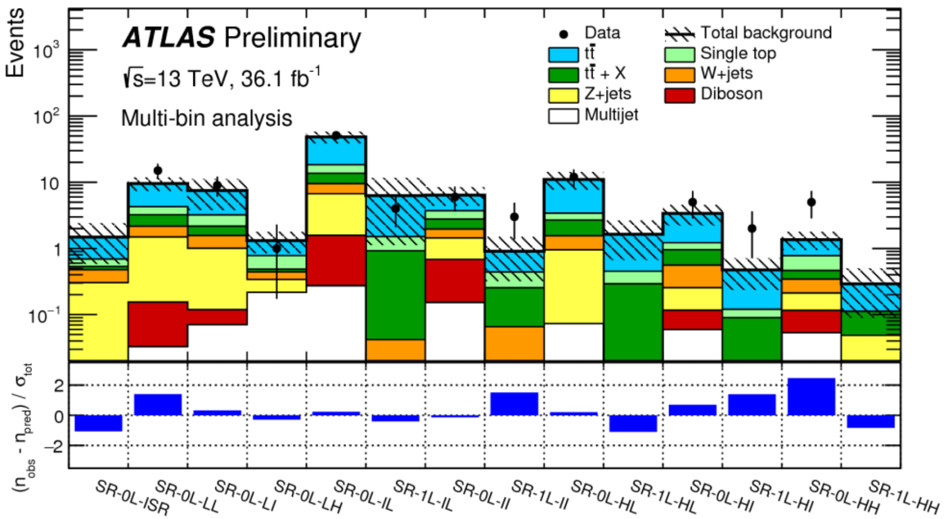

ATLAS Preliminary
√s=13 TeV, 36.1 fb⁻¹
Cut-and-count analysis
Data
tt̄
tt̄ + X
Z+jets
Multijet
Total background
Single top
W+jets
Diboson
Events
tt̄ scale factor
CR-Gtt-1L-A
CR-Gtt-1L-B
CR-Gtt-1L-C
CR-Gtt-0L-A
CR-Gtt-0L-B
CR-Gtt-0L-C
CR-Gbb-A
CR-Gbb-B
CR-Gbb-C
CR-Gbb-D


ATLAS Preliminary
√s=13 TeV, 36.1 fb⁻¹
Multi-bin analysis
Data
tt̄
tt̄ + X
Z+jets
Multijet
Total background
Single top
W+jets
Diboson
Events
tt̄ scale factor
CR-ISR
CR-LL
CR-LI
CR-LH
CR-IL
CR-II
CR-HL
CR-HI
CR-HH

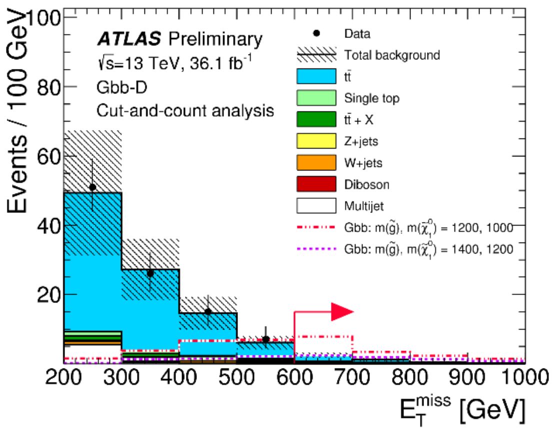

ATLAS Preliminary
√s=13 TeV, 36.1 fb⁻¹
Cut-and-count analysis
Data
tt̄
tt̄ + X
Z+jets
Multijet
Total background
Single top
W+jets
Diboson
Events
VR-Gtt-0L-A
VR-Gtt-0L-B
VR-Gtt-0L-C
VR-Gbb-A
VR-Gbb-B
VR-Gbb-C
VR-Gbb-D

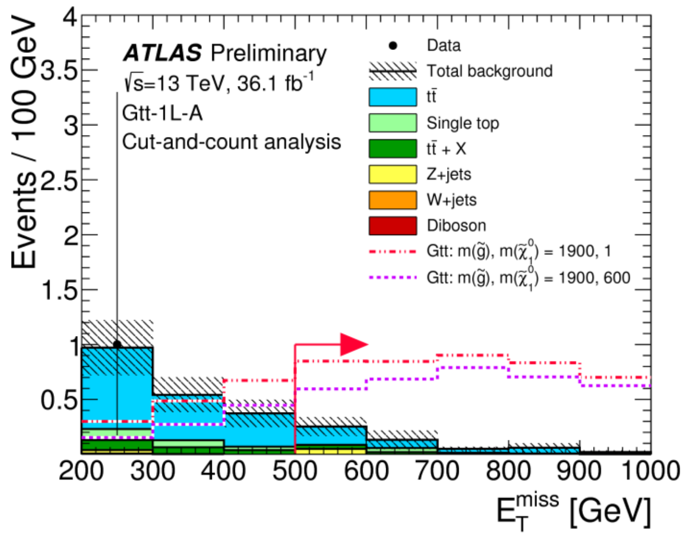
Multi-b

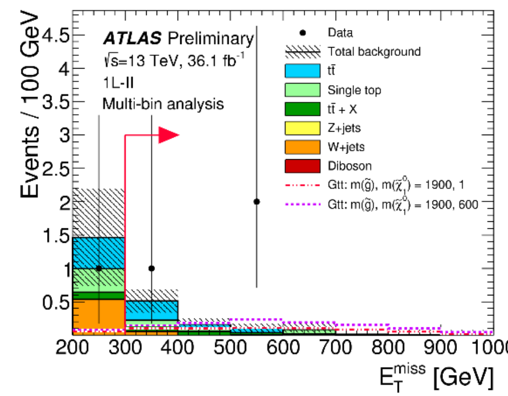

ATLAS Preliminary
√s=13 TeV, 36.1 fb⁻¹
Cut-and-count analysis
Data
tt̄
tt̄ + X
Z+jets
Multijet
Total background
Single top
W+jets
Diboson
Events
(n_obs - n_pred) / σ_tot
SR-Gtt-1L-A
SR-Gtt-1L-B
SR-Gtt-1L-C
SR-Gtt-0L-A
SR-Gtt-0L-B
SR-Gtt-0L-C
SR-Gbb-A
SR-Gbb-B
SR-Gbb-C
SR-Gbb-D

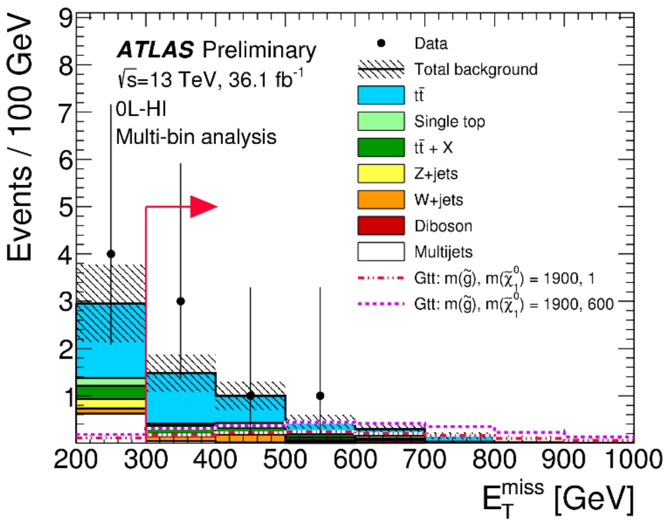

ATLAS Preliminary
√s=13 TeV, 36.1 fb⁻¹
Multi-bin analysis
Data
tt̄
tt̄ + X
Z+jets
Multijet
Total background
Single top
W+jets
Diboson
Events
(n_obs - n_pred) / σ_tot
SR-0L-ISR
SR-0L-LL
SR-0L-LI
SR-0L-LH
SR-0L-IL
SR-1L-IL
SR-0L-II
SR-1L-II
SR-0L-HL
SR-1L-HL
SR-0L-HI
SR-1L-HI
SR-0L-HH
SR-1L-HH

Multi-b

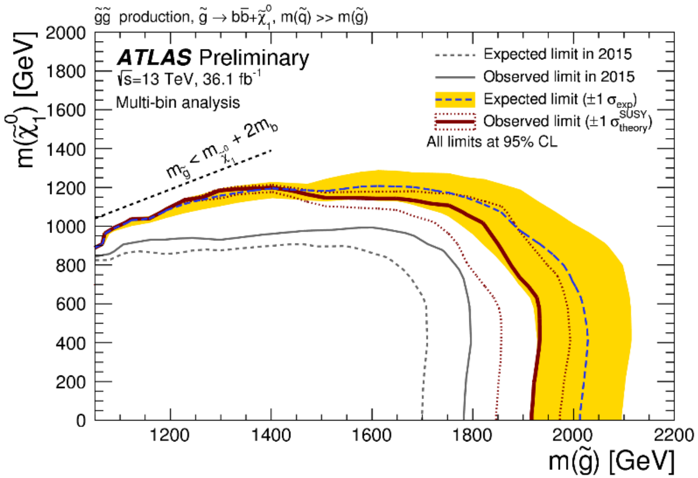

ATLAS Preliminary
√s=13 TeV, 36.1 fb⁻¹
Gbb-D
Cut-and-count analysis
Data
Total background
tt̄
Single top
tt̄ + X
Z+jets
W+jets
Diboson
Multijet
Gbb: m(g̃), m(χ̃⁰₁) = 1200, 1000
Gbb: m(g̃), m(χ̃⁰₁) = 1400, 1200
Events / 100 GeV
E_T^miss [GeV]


ATLAS Preliminary
√s=13 TeV, 36.1 fb⁻¹
Gtt-1L-A
Cut-and-count analysis
Data
Total background
tt̄
Single top
tt̄ + X
Z+jets
W+jets
Diboson
Gtt: m(g̃), m(χ̃⁰₁) = 1900, 1
Gtt: m(g̃), m(χ̃⁰₁) = 1900, 600
Events / 100 GeV
E_T^miss [GeV]

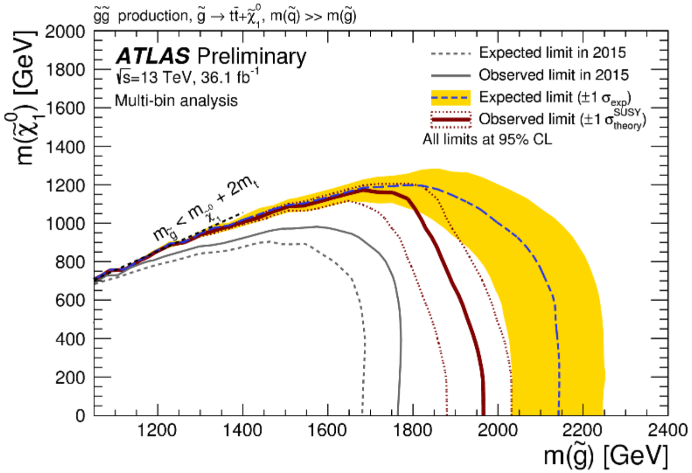

ATLAS Preliminary
√s=13 TeV, 36.1 fb⁻¹
1L-II
Multi-bin analysis
Data
Total background
tt̄
Single top
tt̄ + X
Z+jets
W+jets
Diboson
Gtt: m(g̃), m(χ̃⁰₁) = 1900, 1
Gtt: m(g̃), m(χ̃⁰₁) = 1900, 600
Events / 100 GeV
E_T^miss [GeV]


ATLAS Preliminary
√s=13 TeV, 36.1 fb⁻¹
0L-HI
Multi-bin analysis
Data
Total background
tt̄
Single top
tt̄ + X
Z+jets
W+jets
Diboson
Multijets
Gtt: m(g̃), m(χ̃⁰₁) = 1900, 1
Gtt: m(g̃), m(χ̃⁰₁) = 1900, 600
Events / 100 GeV
E_T^miss [GeV]

Multi-b

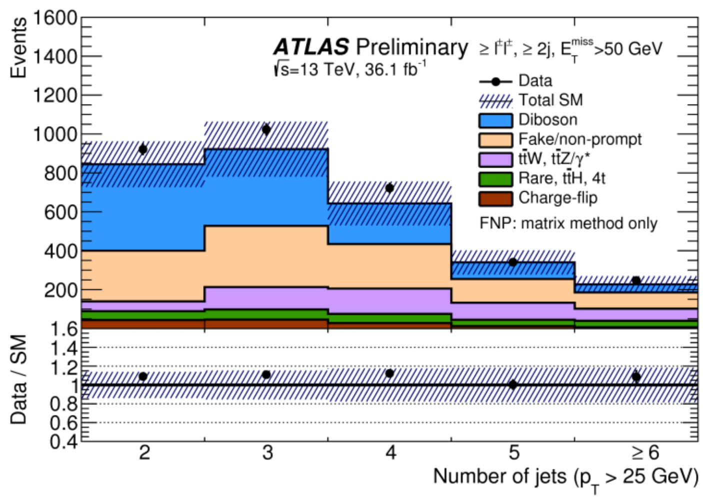


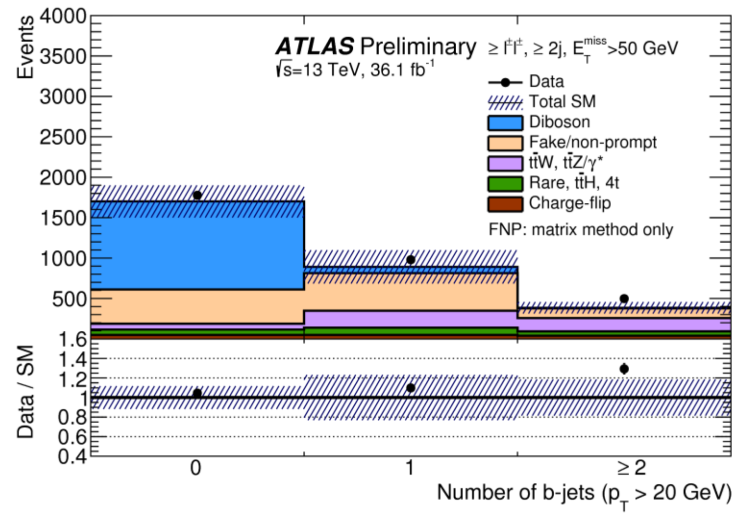
g̃g̃ production, g̃ → bb̄+χ̃$_1^0$, m(q̃) >> m(g̃)
ATLAS Preliminary
√s=13 TeV, 36.1 fb^{-1}
Multi-bin analysis
Expected limit in 2015
Observed limit in 2015
Expected limit (±1 σ$_{exp}$)
Observed limit (±1 σ$^{SUSY}_{theory}$)
All limits at 95% CL
m$_{g̃}$ < m$_{χ̃_1^0}$ + 2m$_b$
m(χ̃$_1^0$) [GeV]
m(g̃) [GeV]

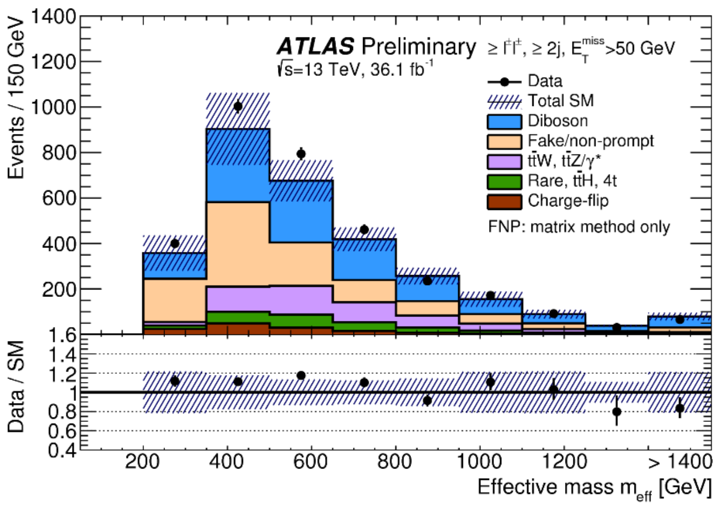


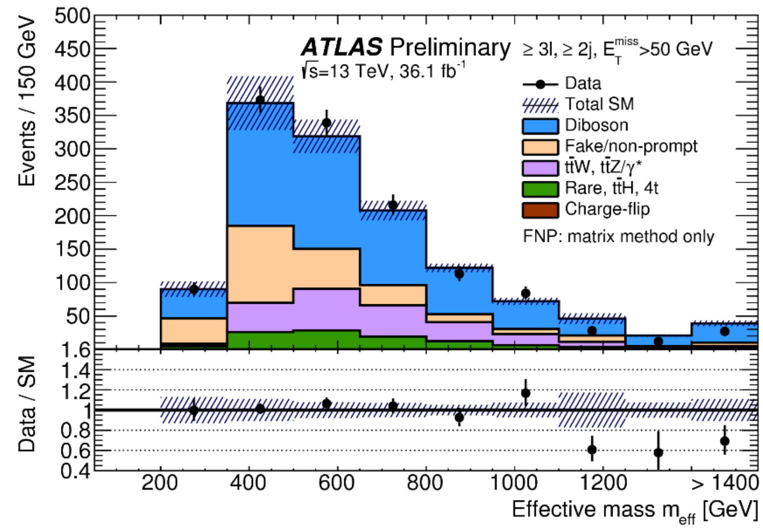
g̃g̃ production, g̃ → tt̄+χ̃$_1^0$, m(q̃) >> m(g̃)
ATLAS Preliminary
√s=13 TeV, 36.1 fb^{-1}
Multi-bin analysis
Expected limit in 2015
Observed limit in 2015
Expected limit (±1 σ$_{exp}$)
Observed limit (±1 σ$^{SUSY}_{theory}$)
All limits at 95% CL
m$_{g̃}$ < m$_{χ̃_1^0}$ + 2m$_t$
m(χ̃$_1^0$) [GeV]
m(g̃) [GeV]

SS/3L 36fb-1

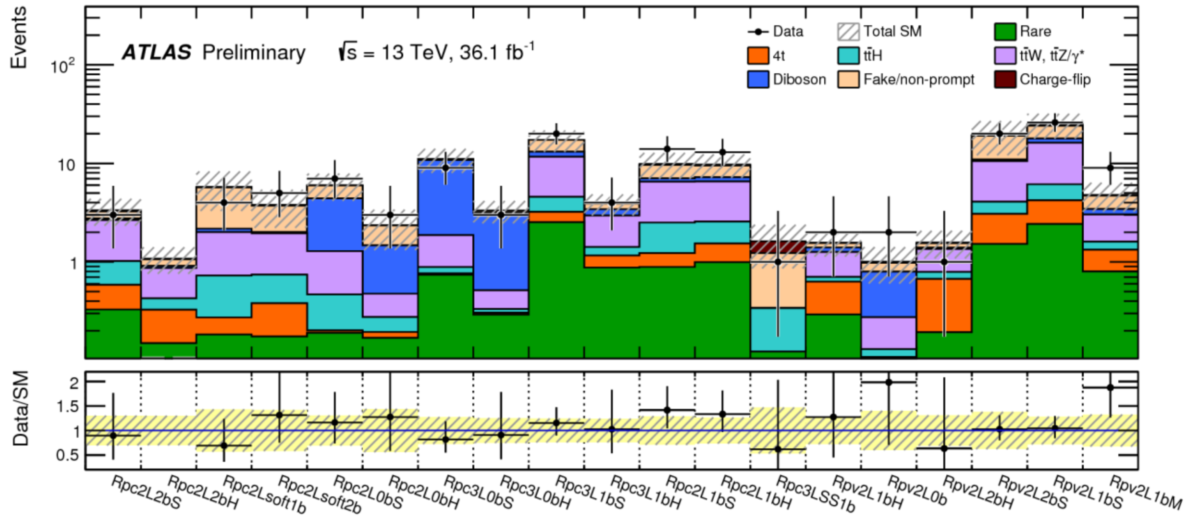

ATLAS Preliminary ≥ l±l±, ≥ 2j, E_T^{miss}>50 GeV
√s=13 TeV, 36.1 fb-1
Data
Total SM
Diboson
Fake/non-prompt
tt̄W, tt̄Z/γ*
Rare, tt̄H, 4t
Charge-flip
FNP: matrix method only
Events
Data / SM
Number of jets (p_T > 25 GeV)


ATLAS Preliminary ≥ l±l±, ≥ 2j, E_T^{miss}>50 GeV
√s=13 TeV, 36.1 fb-1
Data
Total SM
Diboson
Fake/non-prompt
tt̄W, tt̄Z/γ*
Rare, tt̄H, 4t
Charge-flip
FNP: matrix method only
Events
Data / SM
Number of b-jets (p_T > 20 GeV)

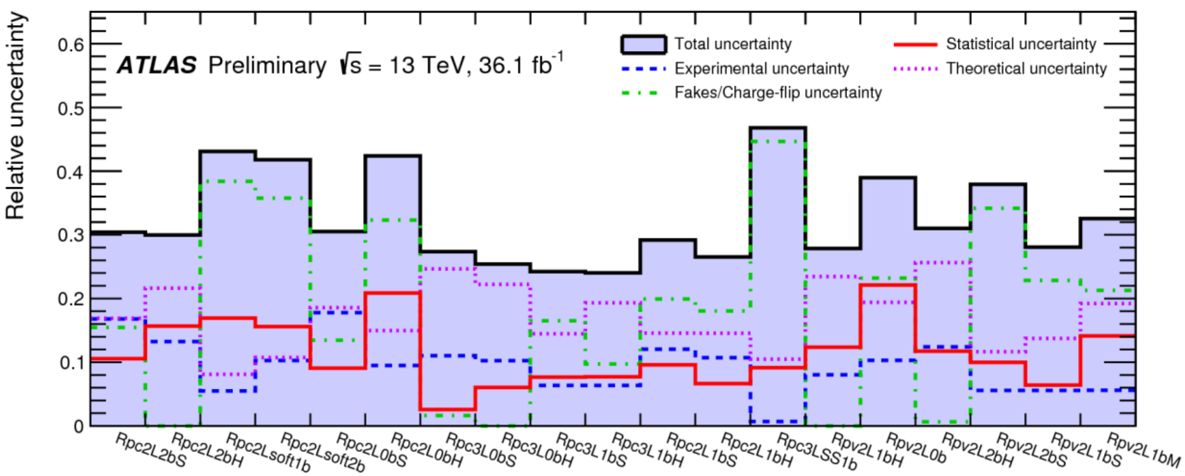

ATLAS Preliminary ≥ l±l±, ≥ 2j, E_T^{miss}>50 GeV
√s=13 TeV, 36.1 fb-1
Data
Total SM
Diboson
Fake/non-prompt
tt̄W, tt̄Z/γ*
Rare, tt̄H, 4t
Charge-flip
FNP: matrix method only
Events / 150 GeV
Data / SM
Effective mass m_{eff} [GeV]


ATLAS Preliminary ≥ 3l, ≥ 2j, E_T^{miss}>50 GeV
√s=13 TeV, 36.1 fb-1
Data
Total SM
Diboson
Fake/non-prompt
tt̄W, tt̄Z/γ*
Rare, tt̄H, 4t
Charge-flip
FNP: matrix method only
Events / 150 GeV
Data / SM
Effective mass m_{eff} [GeV]

SS/3L 36fb-1

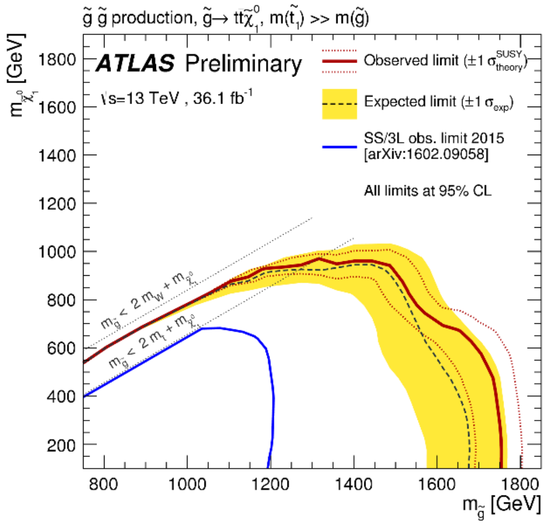


ATLAS Preliminary
$\sqrt{s}$ = 13 TeV, 36.1 fb^{-1}
Events
Data/SM
Data
Total SM
Rare
4t
$t\bar{t}H$
$t\bar{t}W$, $t\bar{t}Z/\gamma^*$
Diboson
Fake/non-prompt
Charge-flip
Rpc2L2bS
Rpc2L2bH
Rpc2Lsoft1b
Rpc2Lsoft2b
Rpc2L0bS
Rpc2L0bH
Rpc3L0bS
Rpc3L0bH
Rpc3L1bS
Rpc3L1bH
Rpc2L1bS
Rpc2L1bH
Rpc3LSS1b
Rpv2L1bH
Rpv2L0b
Rpv2L2bH
Rpv2L2bS
Rpv2L1bS
Rpv2L1bM

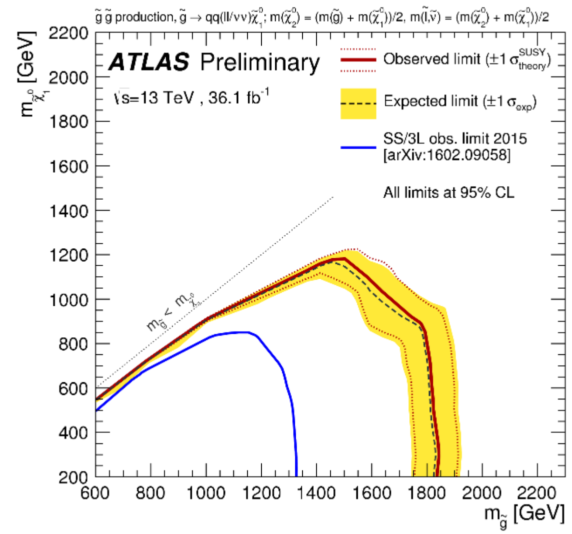


ATLAS Preliminary
$\sqrt{s}$ = 13 TeV, 36.1 fb^{-1}
Relative uncertainty
Total uncertainty
Statistical uncertainty
Experimental uncertainty
Theoretical uncertainty
Fakes/Charge-flip uncertainty
Rpc2L2bS
Rpc2L2bH
Rpc2Lsoft1b
Rpc2Lsoft2b
Rpc2L0bS
Rpc2L0bH
Rpc3L0bS
Rpc3L0bH
Rpc3L1bS
Rpc3L1bH
Rpc2L1bS
Rpc2L1bH
Rpc3LSS1b
Rpv2L1bH
Rpv2L0b
Rpv2L2bH
Rpv2L2bS
Rpv2L1bS
Rpv2L1bM

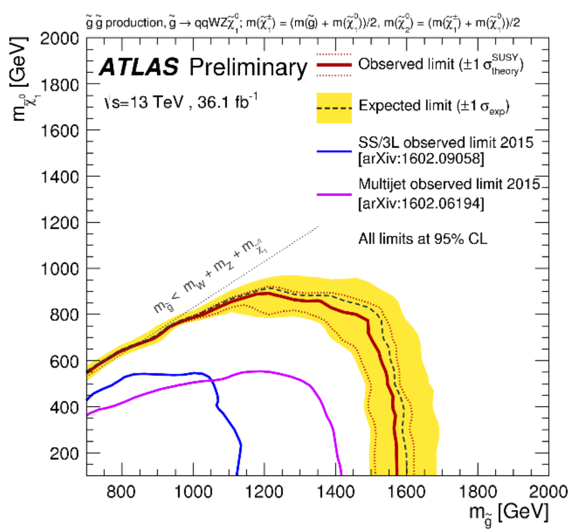
SS/3L 36fb-1



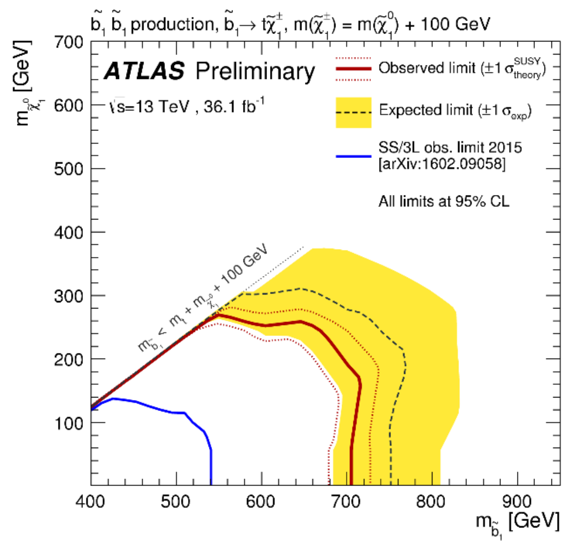
g̃ g̃ production, g̃→ ttχ̃⁰₁, m(t̃₁) >> m(g̃)
ATLAS Preliminary
√s=13 TeV , 36.1 fb⁻¹
Observed limit (±1 σ^SUSY_theory)
Expected limit (±1 σ_exp)
SS/3L obs. limit 2015
[arXiv:1602.09058]
All limits at 95% CL
m_g̃ < 2 m_W + m_χ̃⁰₁
m_g̃ < 2 m_t + m_χ̃⁰₁
m_χ̃⁰₁ [GeV]
m_g̃ [GeV]



g̃ g̃ production, g̃ → qq(ll/νν)χ̃⁰₁; m(χ̃⁰₂) = (m(g̃) + m(χ̃⁰₁))/2, m(l̃,ν̃) = (m(χ̃⁰₂) + m(χ̃⁰₁))/2
ATLAS Preliminary
√s=13 TeV , 36.1 fb⁻¹
Observed limit (±1 σ^SUSY_theory)
Expected limit (±1 σ_exp)
SS/3L obs. limit 2015
[arXiv:1602.09058]
All limits at 95% CL
m_g̃ < m_χ̃⁰₁
m_χ̃⁰₁ [GeV]
m_g̃ [GeV]

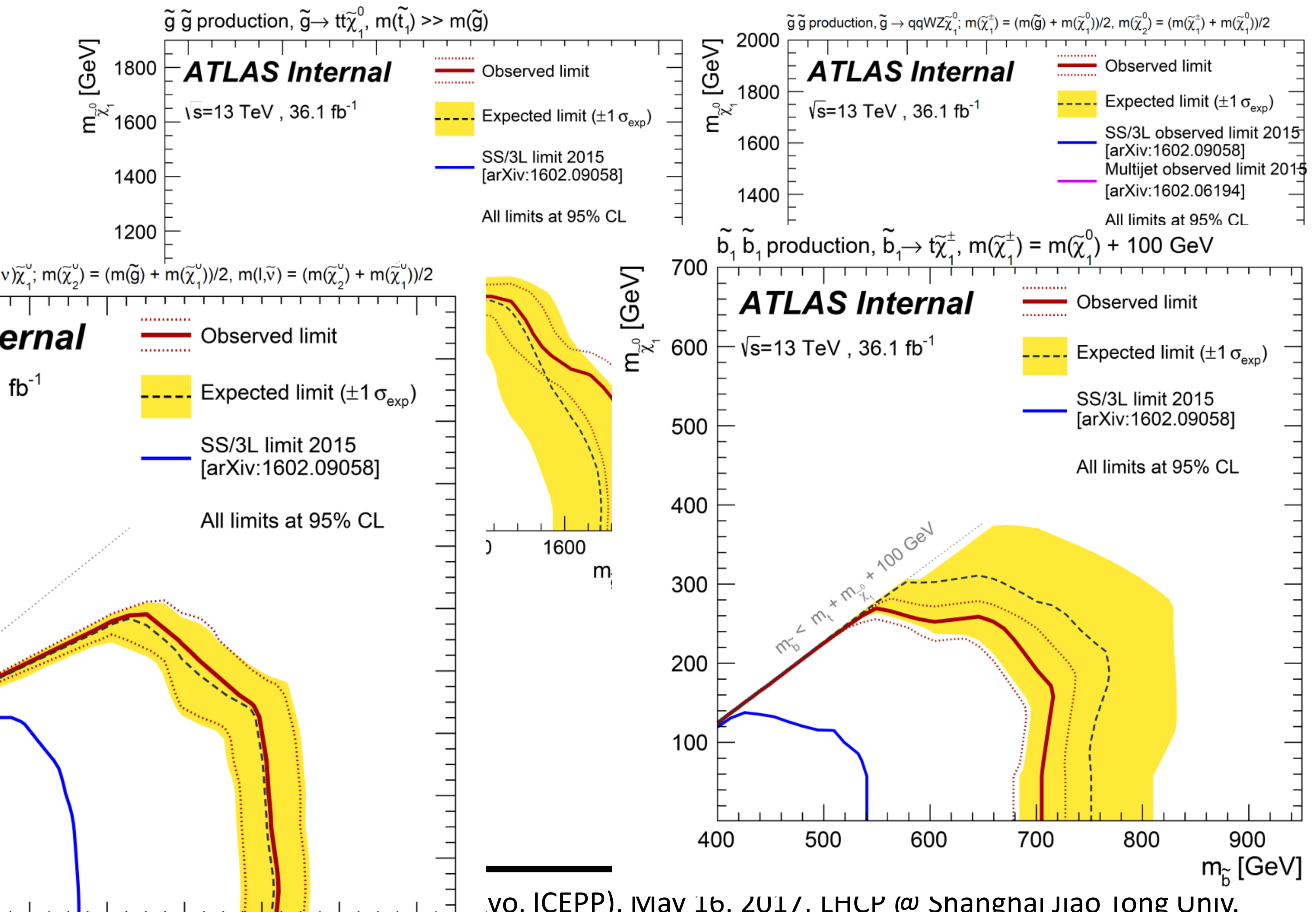


g̃ g̃ production, g̃ → qqWZχ̃⁰₁; m(χ̃±₁) = (m(g̃) + m(χ̃⁰₁))/2, m(χ̃⁰₂) = (m(χ̃±₁) + m(χ̃⁰₁))/2
ATLAS Preliminary
√s=13 TeV , 36.1 fb⁻¹
Observed limit (±1 σ^SUSY_theory)
Expected limit (±1 σ_exp)
SS/3L observed limit 2015
[arXiv:1602.09058]
Multijet observed limit 2015
[arXiv:1602.06194]
All limits at 95% CL
m_g̃ < m_W + m_Z + m_χ̃⁰₁
m_χ̃⁰₁ [GeV]
m_g̃ [GeV]



b̃₁ b̃₁ production, b̃₁→ tχ̃±₁, m(χ̃±₁) = m(χ̃⁰₁) + 100 GeV
ATLAS Preliminary
√s=13 TeV , 36.1 fb⁻¹
Observed limit (±1 σ^SUSY_theory)
Expected limit (±1 σ_exp)
SS/3L obs. limit 2015
[arXiv:1602.09058]
All limits at 95% CL
m_b̃₁ < m_t + m_χ̃⁰₁ + 100 GeV
m_χ̃⁰₁ [GeV]
m_b̃₁ [GeV]

SS/3L 36fb-1



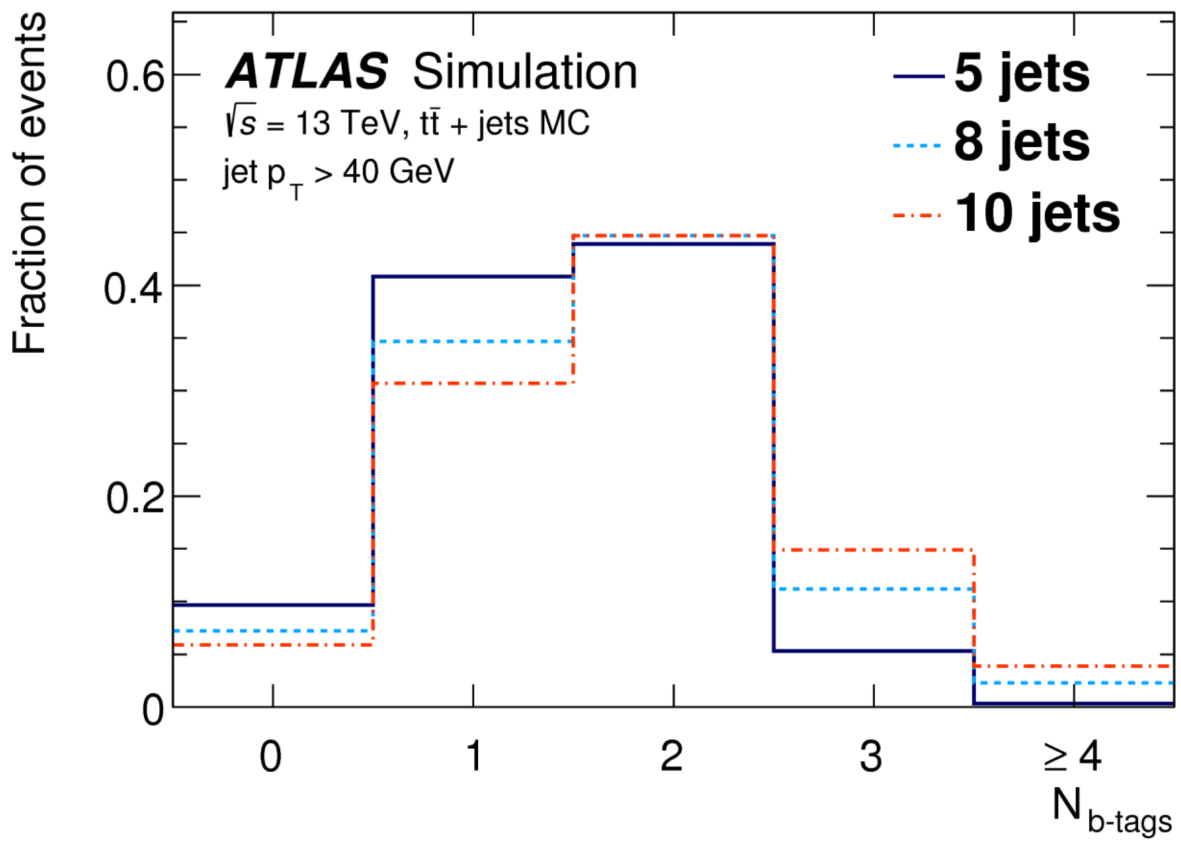
$\tilde{g}\tilde{g}$ production, $\tilde{g} \rightarrow tt\tilde{\chi}_1^0$, $m(\tilde{t}_1) >> m(\tilde{g})$
ATLAS Internal
$\sqrt{s}$=13 TeV , 36.1 fb^{-1}
Observed limit
Expected limit ($\pm 1 \sigma_{exp}$)
SS/3L limit 2015
[arXiv:1602.09058]
All limits at 95% CL
$m_{\tilde{\chi}_1^0}$ [GeV]
1800
1600
1400
1200
$\tilde{g}\tilde{g}$ production, $\tilde{g} \rightarrow qqWZ\tilde{\chi}_1^0$; $m(\tilde{\chi}_1^\pm) = (m(\tilde{g}) + m(\tilde{\chi}_1^0))/2$, $m(\tilde{\chi}_2^0) = (m(\tilde{\chi}_1^\pm) + m(\tilde{\chi}_1^0))/2$
ATLAS Internal
$\sqrt{s}$=13 TeV , 36.1 fb^{-1}
Observed limit
Expected limit ($\pm 1 \sigma_{exp}$)
SS/3L observed limit 2015
[arXiv:1602.09058]
Multijet observed limit 2015
[arXiv:1602.06194]
All limits at 95% CL
2000
1800
1600
1400
$m(\tilde{\chi}_2^0) = (m(\tilde{g}) + m(\tilde{\chi}_1^0))/2$, $m(l,\tilde{\nu}) = (m(\tilde{\chi}_2^0) + m(\tilde{\chi}_1^0))/2$
ernal
fb^{-1}
Observed limit
Expected limit ($\pm 1 \sigma_{exp}$)
SS/3L limit 2015
[arXiv:1602.09058]
All limits at 95% CL
1600
$\tilde{b}_1\tilde{b}_1$ production, $\tilde{b}_1 \rightarrow t\tilde{\chi}_1^\pm$, $m(\tilde{\chi}_1^\pm) = m(\tilde{\chi}_1^0) + 100$ GeV
ATLAS Internal
$\sqrt{s}$=13 TeV , 36.1 fb^{-1}
Observed limit
Expected limit ($\pm 1 \sigma_{exp}$)
SS/3L limit 2015
[arXiv:1602.09058]
All limits at 95% CL
$m_{\tilde{b}} < m_t + m_{\tilde{\chi}_1^0} + 100$ GeV
$m_{\tilde{\chi}_1^0}$ [GeV]
700
600
500
400
300
200
100
400
500
600
700
800
900
$m_{\tilde{b}}$ [GeV]

SS/3L 36fb-1

Validation Regions	$t\bar{t}W$	$t\bar{t}Z$	$WZ4j$	$WZ5j$	$W^{\pm}W^{\pm}jj$
$t\bar{t}Z/\gamma^*$	6.2 ± 0.9	123 ± 17	17.8 ± 3.5	10.1 ± 2.3	1.06 ± 0.22
$t\bar{t}W$	19.0 ± 2.9	1.71 ± 0.27	1.30 ± 0.32	0.45 ± 0.14	4.1 ± 0.8
$t\bar{t}H$	5.8 ± 1.2	3.6 ± 1.8	1.8 ± 0.6	0.96 ± 0.34	0.69 ± 0.14
$t\bar{t}t\bar{t}$	1.02 ± 0.22	0.27 ± 0.14	0.04 ± 0.02	0.03 ± 0.02	0.03 ± 0.02
$W^{\pm}W^{\pm}$	0.5 ± 0.4	$--$	$--$	$--$	26 ± 14
WZ	1.4 ± 0.8	29 ± 17	200 ± 110	70 ± 40	27 ± 14
ZZ	0.04 ± 0.03	5.5 ± 3.1	22 ± 12	9 ± 5	0.53 ± 0.30
Rare	2.2 ± 0.5	26 ± 13	7.3 ± 2.1	3.0 ± 1.0	1.8 ± 0.5
Fake/non-prompt leptons	18 ± 16	22 ± 14	49 ± 31	17 ± 12	13 ± 10
Charge-flip	3.4 ± 0.5	$--$	$--$	$--$	1.74 ± 0.22
Total SM background	57 ± 16	212 ± 35	300 ± 130	110 ± 50	77 ± 31
Observed	71	209	257	106	99

Validation Region Name	$N_{\text{lepton}}^{\text{signal}}$	$N_{b-\text{jets}}$	N_{jets}	$p_{\text{T,jet}}$ [GeV]	$E_{\text{T}}^{\text{miss}}$ [GeV]	m_{eff} [GeV]	Other
$t\bar{t}W$	$= 2SS$	≥ 1	$\geq 4\ (e^{\pm}e^{\pm}, e^{\pm}\mu^{\pm})$ $\geq 3\ (\mu^{\pm}\mu^{\pm})$	> 40 > 25	> 45	> 550	$p_{\text{T}}(\ell_2) > 40$ GeV $\sum p_T^{b-jet} / \sum p_T^{jet} > 0.25$
$t\bar{t}Z$	≥ 3 ≥ 1 SFOS pair	≥ 1	≥ 3	> 35	–	> 450	$81 < m_{\text{SFOS}} < 101$ GeV
$WZ4j$	$= 3$	$= 0$	≥ 4	> 25	–	> 450	$E_{\text{T}}^{\text{miss}} / \sum p_T^{\ell} < 0.7$
$WZ5j$	$= 3$	$= 0$	≥ 5	> 25	–	> 450	$E_{\text{T}}^{\text{miss}} / \sum p_T^{\ell} < 0.7$
$W^{\pm}W^{\pm}jj$	$= 2SS$	$= 0$	≥ 2	> 50	> 55	> 650	veto $81 < m_{e^{\pm}e^{\pm}} < 101$ GeV $p_{\text{T}}^{\ell_2} > 30$ GeV $\Delta R_{\eta}(\ell_{1,2}, j) > 0.7$ $\Delta R_{\eta}(\ell_1, \ell_2) > 1.3$
All VRs	Veto events belonging to any SR						

RPV 1L



ATLAS Simulation
√s = 13 TeV, tt̄ + jets MC
jet p_T > 40 GeV
5 jets
8 jets
10 jets
Fraction of events
0.6
0.4
0.2
0
0
1
2
3
≥ 4
N_b-tags