



Inclusive searches for squarks and gluinos with the ATLAS detector

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On behalf of the ATLAS Collaboration



Introduction

- ◇ Supersymmetry (SUSY) is promising
- ◇ LHC is a hadron collider and cross-section of colored particle is very large

→ \tilde{q} and \tilde{g} search is one of the main analyses at LHC-ATLAS experiment

- ◇ In run1, we searched for SUSY signals in $\sqrt{s} = 8$ TeV collision using 20.3 fb^{-1} of ATLAS data
- ◇ In run2, we will search for SUSY signals in $\sqrt{s} = 13$ TeV collision



Run1 analysis

- analysis for large E_T^{miss} event
- multijet analysis event for small E_T^{miss} event



Typical event selection for large E_T^{miss} event

◇ Typical SUSY signal have large E_T^{miss}

Event selections for 0 lepton 4jet signal region (SR)

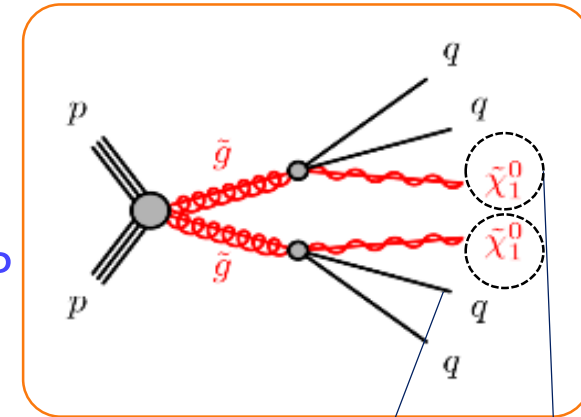
- 0 lepton
- $E_T^{\text{miss}} > 160 \text{ GeV}$
- 1st jet $p_T > 130 \text{ GeV}$
- Number of jet($p_T > 60 \text{ GeV}$) ≥ 4
- $\min \Delta\phi(\text{jet}_{i \leq 3}, E_T^{\text{miss}}) > 0.4$
- $\min \Delta\phi(\text{jet}_{i > 3}, E_T^{\text{miss}}) > 0.2$
- $E_T^{\text{miss}} / m_{\text{eff}}(4\text{jet}) > 0.25$
- $m_{\text{eff}} > 2200 \text{ GeV}$

Large E_T^{miss} from LSP

reduce QCD multijet background

Large mass of gluino

gluino signal event



LSP: undetected

$$m_{\text{eff}}: E_T^{\text{miss}} + \sum_{k=0}^{N_j} p_{T, \text{jet}, k}$$

Mainly from $Z(-\nu\nu)+\text{jets}$

expected SM background events
in 4jet SR

Diboson	0.34
<u>$Z/\gamma^* + \text{jets}$</u>	2.9
$W + \text{jets}$	1.2
$t\bar{t} (+\text{EW}) + \text{single top}$	0.6

dominant

$Z(\nu\nu) + \text{jets}$ BG is dominant



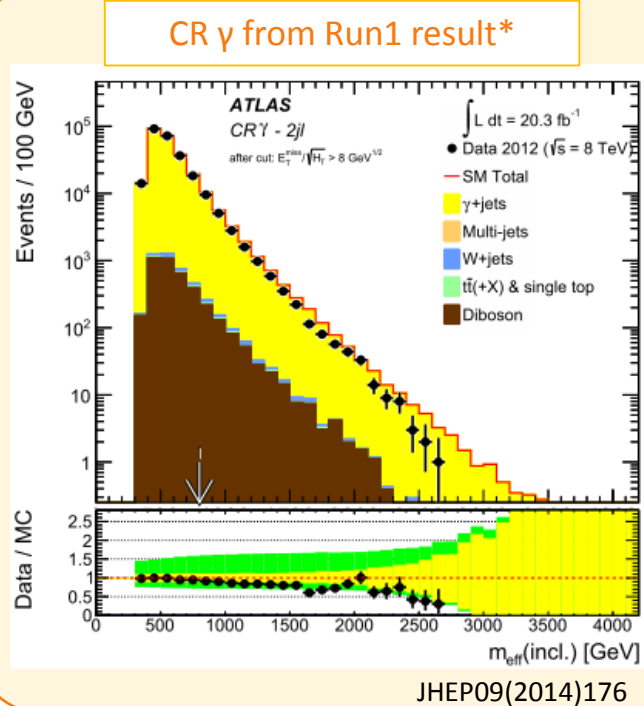
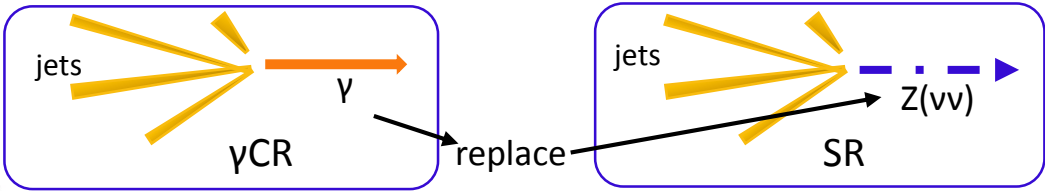
Background estimation for 0 lepton analysis

◇ Monte Carlo (MC) based Background (BG) estimation

- The high kinematic region is unreachable region even for standard model process and MC need to be controlled with data
- Normalize MC events in control region (CR) which is orthogonal to signal region (SR)
 - For Z(->vv)+jets, W+jets, and Top BGs
- $$N_{data}^{SR} = N_{MC}^{SR} \cdot \frac{N_{data}^{CR}}{N_{MC}^{CR}}$$

◇ Control region for MC normalization

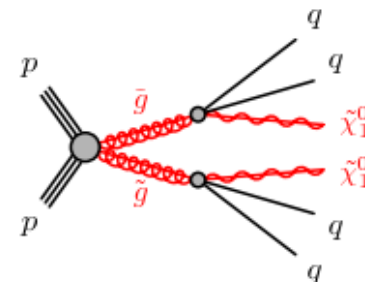
SR process	CRs	CR process
Z (->vv) +jets	γCR	γ+jets
W(->ℓν) +jets (ℓ is missed or τ jet)	W CR	W(->ℓν) +jets
Top	Top CR	t → b W(->ℓν)



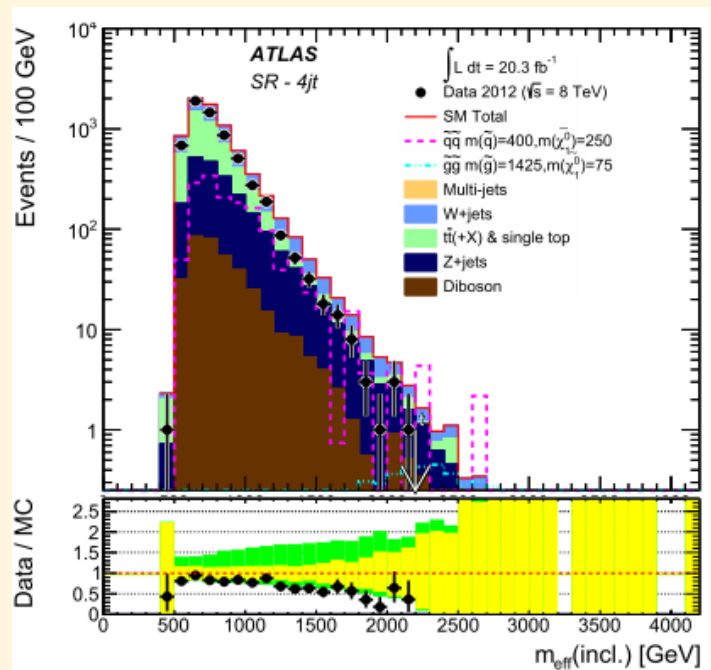
*before fit



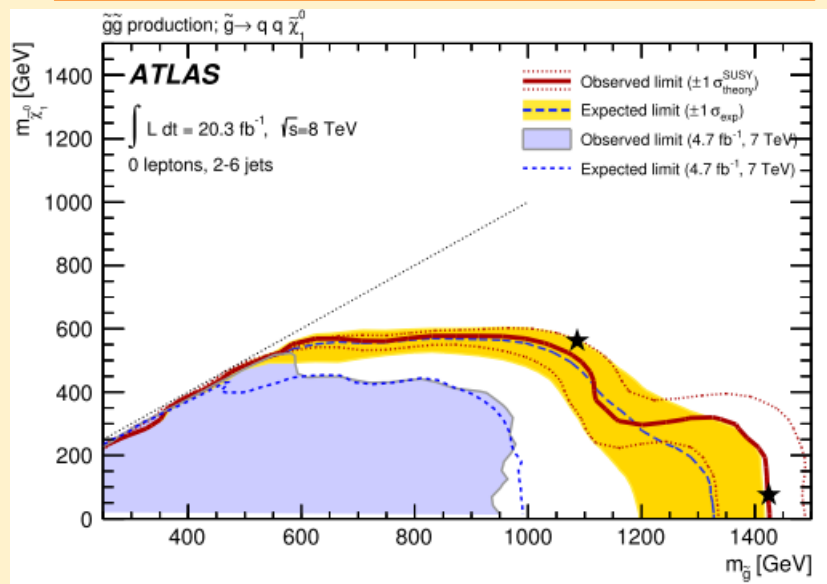
Run1 results with 0 lepton analysis



m_{eff} distribution in 4jet SR



limit for gluino direct decay model



arXiv:1507.05525

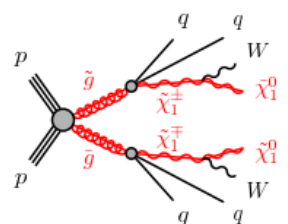
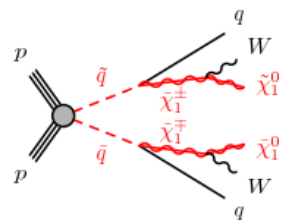
No significant excess was observed

$\Rightarrow m(\tilde{g}) \lesssim 1400 \text{ GeV}$ is excluded for $m(\tilde{\chi}_1^0)=0$

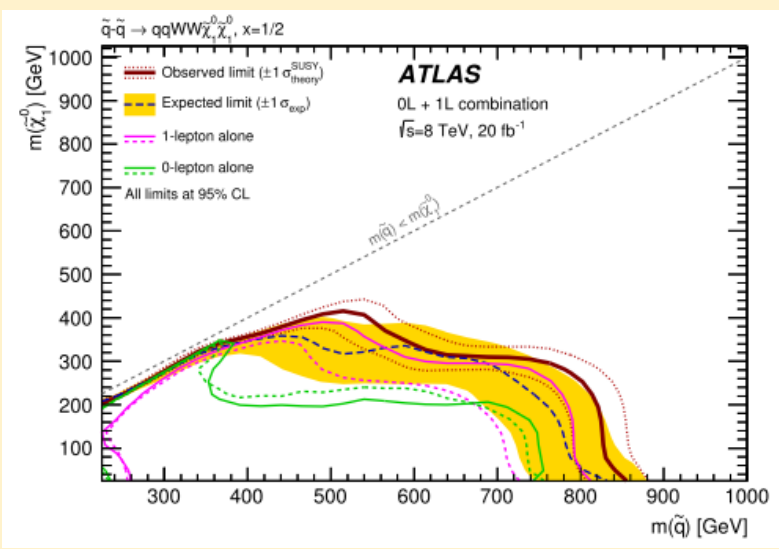


One-step decay

For the limit of one-step decay , 0 lepton & 1 lepton analyses are combined

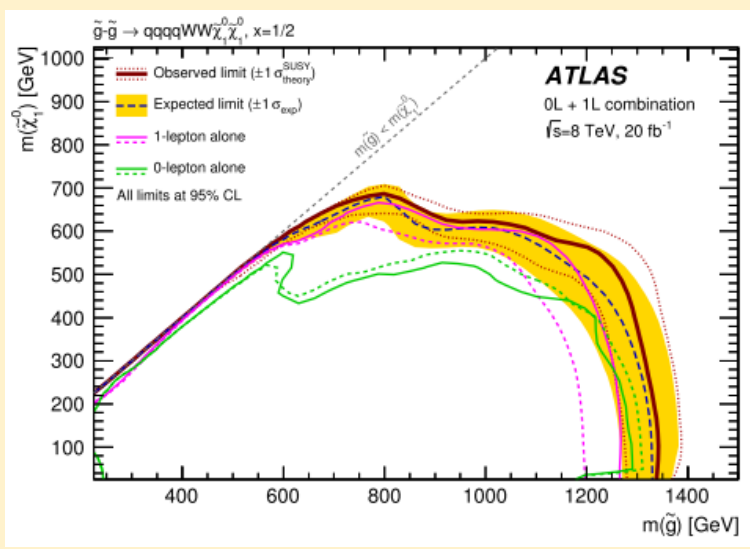


limit for \tilde{q} one-step decay model



arXiv:1507.05525

limit for \tilde{g} one-step decay model



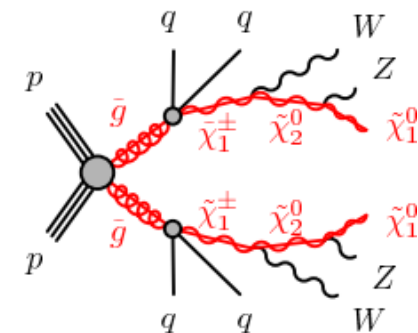
arXiv:1507.05525



Typical event selection for multijet analysis

◇ Long decay-chain -> Small E_T^{miss}

➡ Selection using large jet multiplicity



Event selections for 8jet signal region (SR)

- 0 lepton
- Number of jet ($p_T > 50$ GeV) = 8
- 0 B -jet
- $E_T^{\text{miss}} / \sqrt{H_T} > 4$ (VGeV) ←

$$H_T: \sum_{k=0}^{N_{jet}} p_{T,jet,k}$$

reduce QCD multijet background

expected SM background events
in 8jet SR

Total events before fit	36
$t\bar{t}$ before fit	3.5
W +jets before fit	2.9
Others before fit	2.4
Multi-jets	27 ± 3

multijets BG is dominant

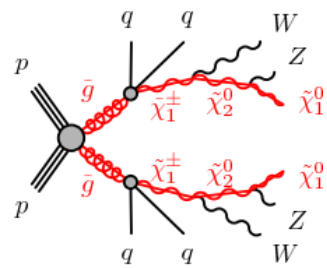
E_T^{miss} is from jet mis-measurement



BG estimation and run1 results

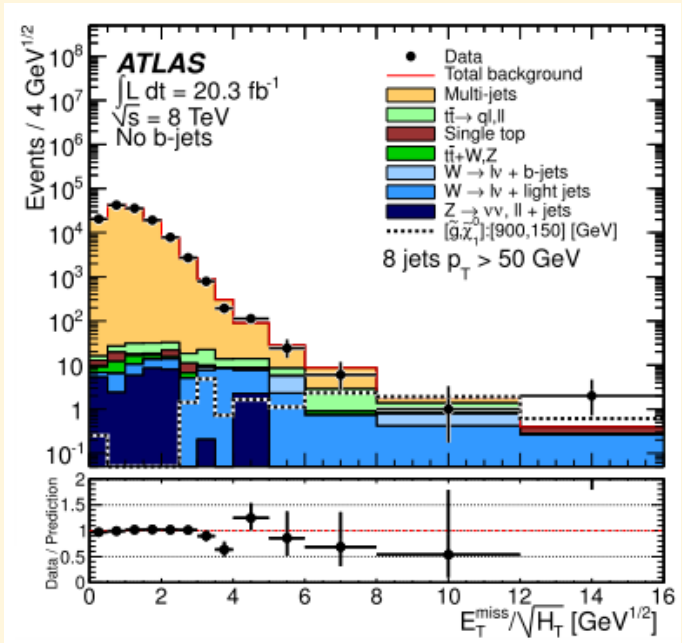
Dominant BG is QCD multijet events

➡ Estimate with data-driven method

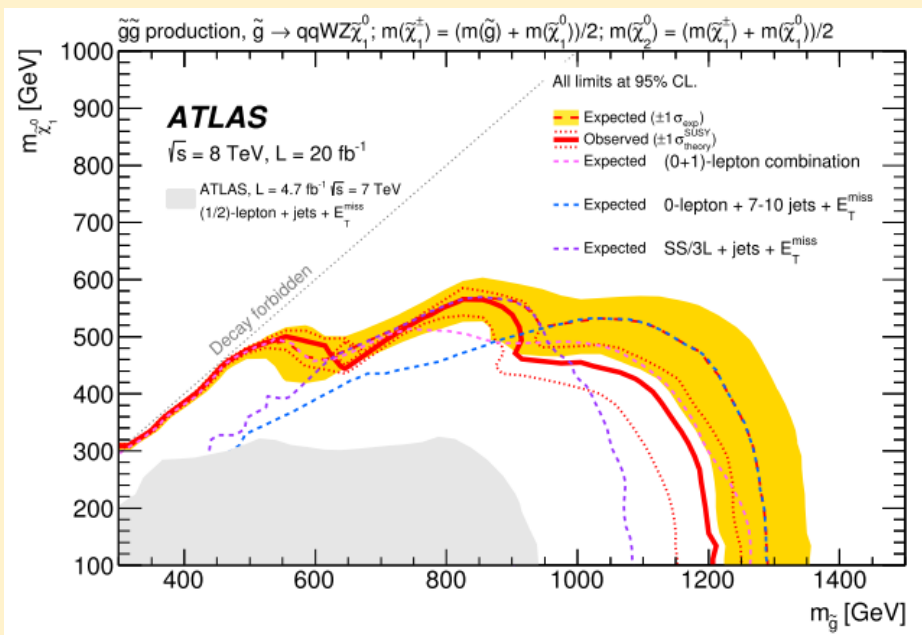


- Use $E_T^{\text{miss}}/\sqrt{H_T}$ shape from low jet multiplicity region
- $E_T^{\text{miss}}/\sqrt{H_T}$ shape is almost invariant with jet multiplicity

Njet=8 SR from Run1 result



limit for \tilde{g} two-step decay model



arXiv:1507.05525

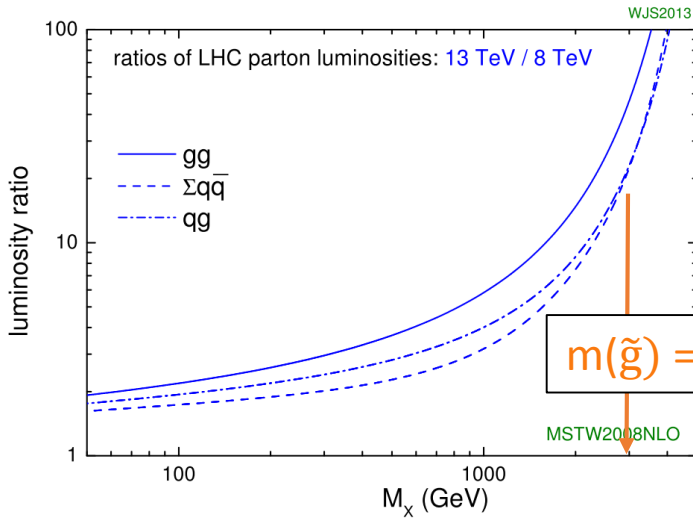
No significant excess was observed



For run2



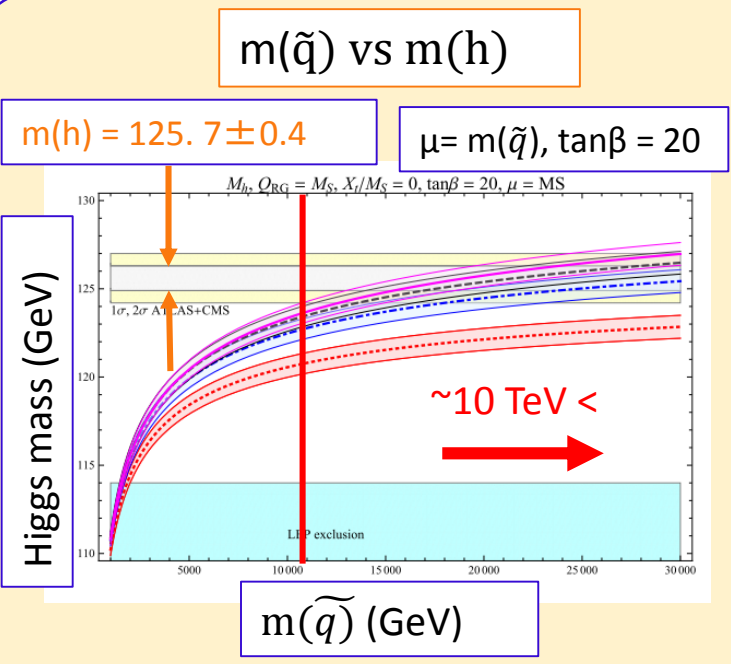
From 8 TeV to 13 TeV



Cross section increases by a factor of ~20

In MSSM, $m(\tilde{q})$ has correlation with $m(h)$

→ \tilde{g} search is important

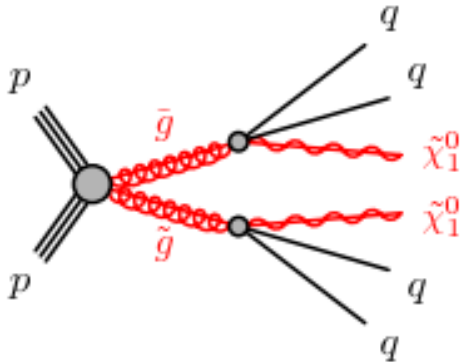


From P. Draper et al. eprint 1312.5743



Reach for gluino direct decay model

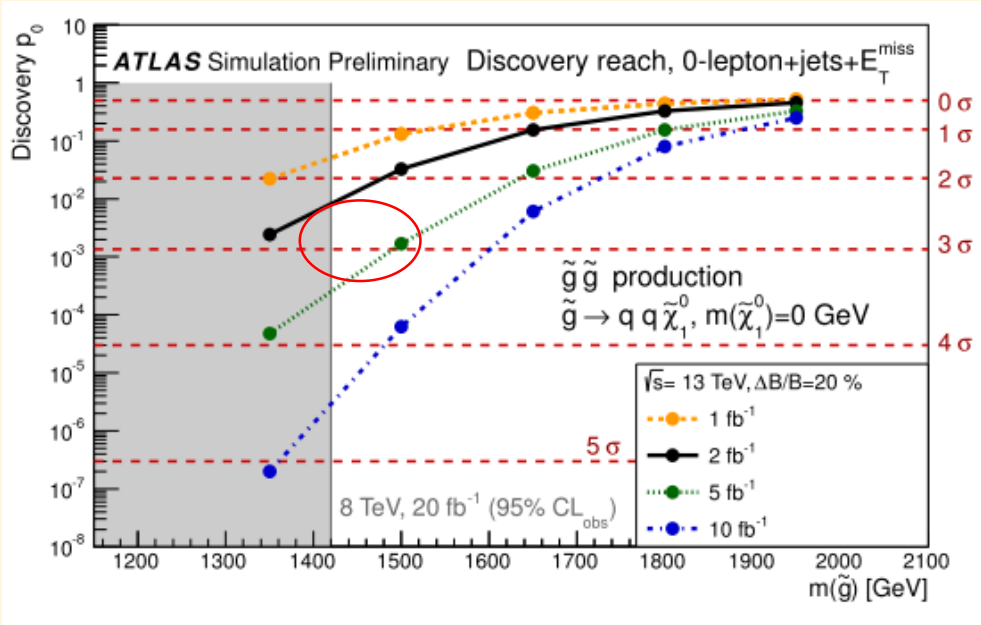
- ◇ Similar selection as run1 but with tighter cut
 - m_{eff} was optimized at every integrated luminosity



meff cut for each L_{int}		
\mathcal{L}_{int} (fb ⁻¹)	Mass of target gluinos (GeV)	m_{eff} (incl.) (GeV)
1	1350	> 2200
2	1350	> 2400
5	1500	> 2600
10	1650	> 2600

Unexplored region can be reached with 3σ in a few fb⁻¹

Reach for gluino direct decay case



ATL-PHYS-PUB-2015-005

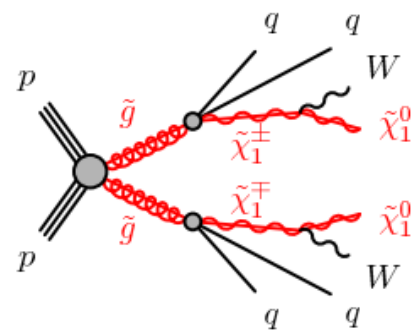


Reach for gluino one-step decay model

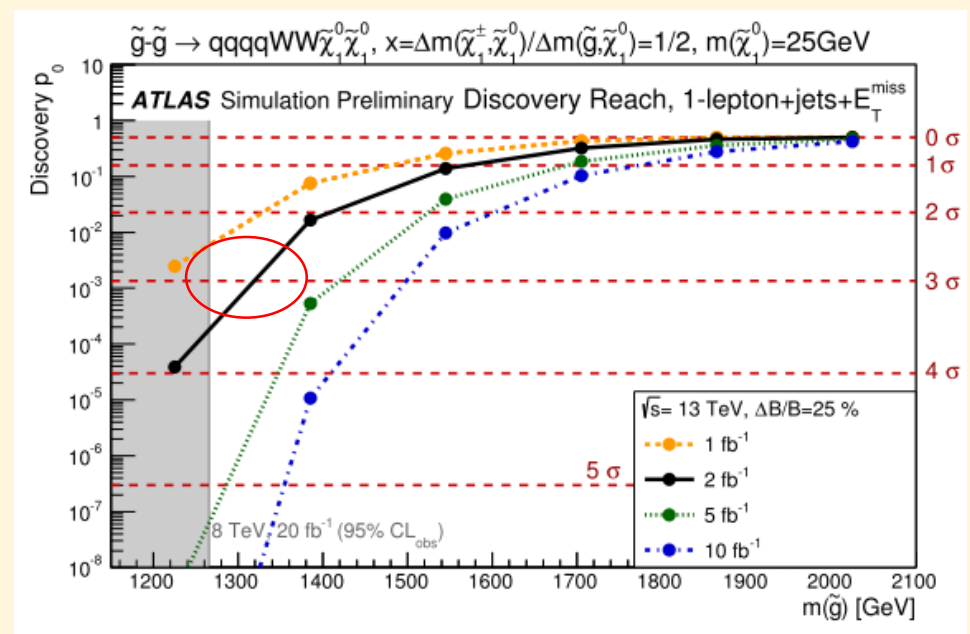
- ◇ 1 lepton is required for one-step decay model
- ◇ mT is used in addition to 0 lepton analysis

$$m_T : \sqrt{2 \cdot p_T^l \cdot E_T^{miss} \cdot (1 - \cos(\Delta\phi(l, E_T^{miss})))}$$

Unexplored region can be reached with 3σ in 2 fb⁻¹



Reach with gluino one-step decay case



ATL-PHYS-PUB-2015-005

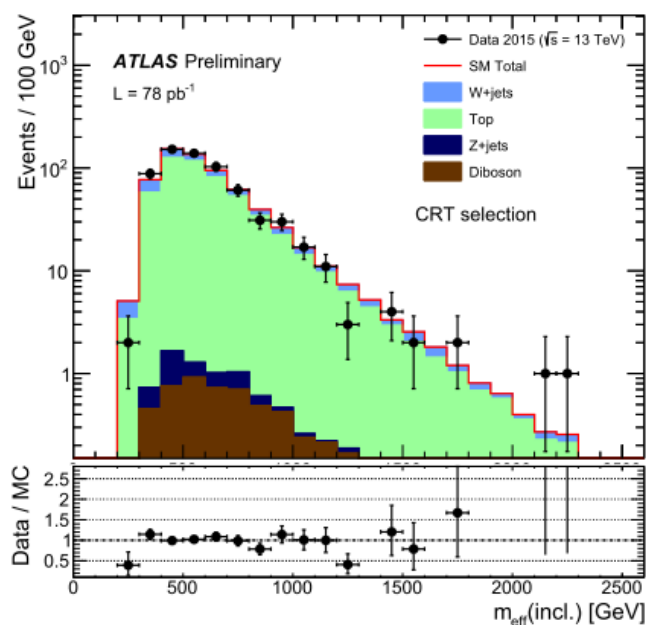
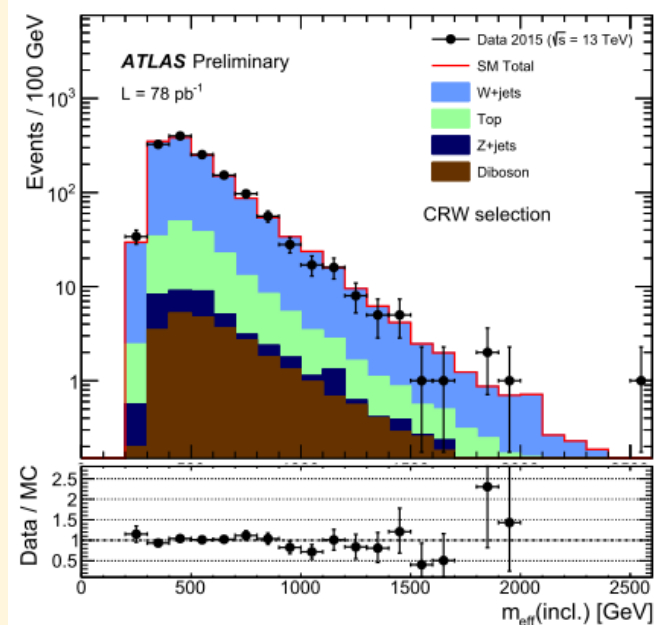


A first data in 50 ns bunch spacing

- ◇ We have 13 TeV data with 78 pb^{-1} integrated luminosity
- ◇ Non-collision backgrounds are well studied and under control

Non-collision background make fake signal in tail of E_T^{miss} or m_{eff}

m_{eff} distributions in CR at $\int L dt = 78 \text{ pb}^{-1}$



ATL-PHYS-PUB-2015-028



good agreement between data and MC



Conclusions

- No significant excess was observed in $\sqrt{s} = 8$ TeV
 - Gluinos with a mass smaller than ~ 1.4 TeV are excluded for massless neutralino
- At $\sqrt{s} = 13$ TeV collision 78 pb^{-1} data, good agreement between data and MC (or BG estimation)
 - Non-collision BGs are under control
 - BG estimation for early results is under control
- We can explore gluinos with mass ~ 1.5 TeV in 2015 with the ATLAS detector

Stay tuned for the Run2 results!



Back up



Other channels not introduced

analysis channels

mono jet search

0 lepton with Razor variable

2lepton (+Razor)

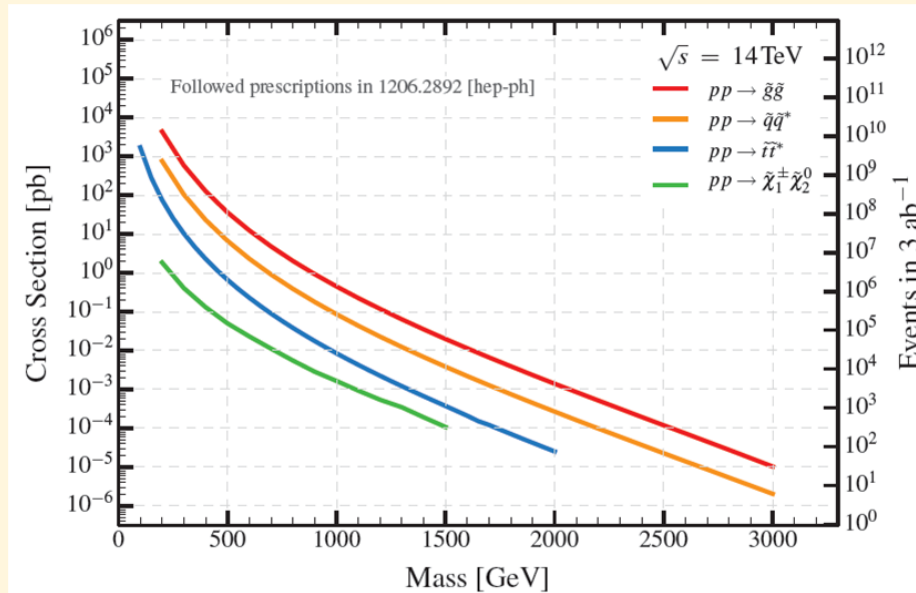
same sign 3 lepton

tau

0/1 lepton + 3 bjets



Cross sections of SUSY particles



crosssections of each SUSY particle



Target signals and final states

◇ Assumption

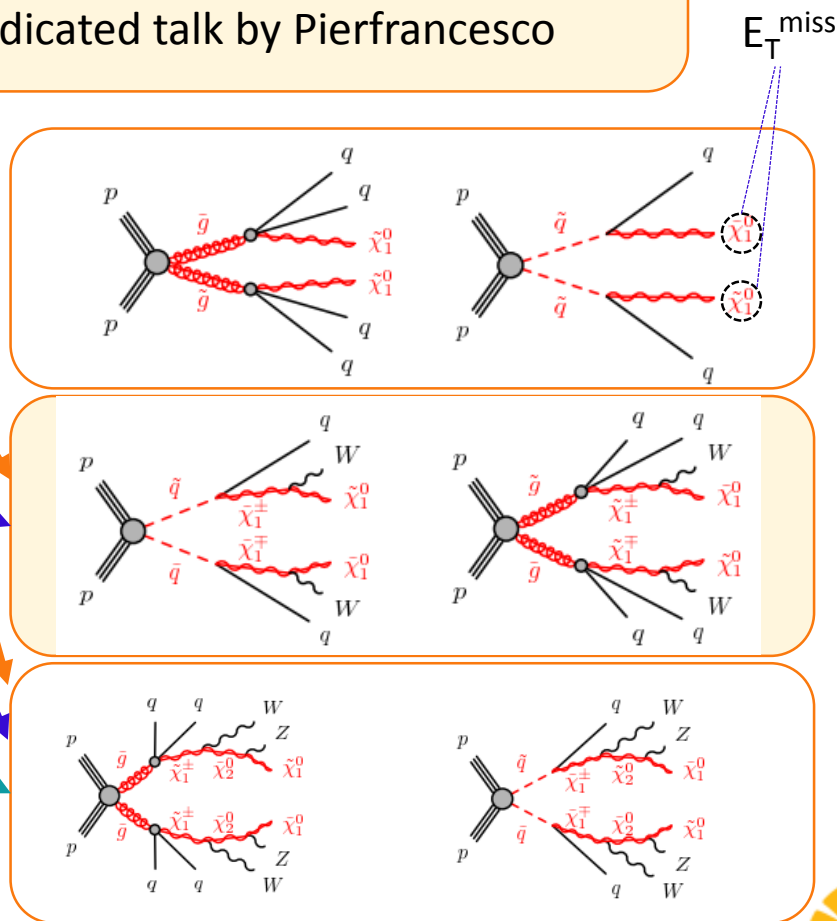
- $\tilde{g}\tilde{g}$, $\tilde{q}\tilde{q}$, or $\tilde{q}\tilde{g}$ production
- R-parity conservation
- \tilde{t} , \tilde{b} searches will be presented in a dedicated talk by Pierfrancesco

◇ Decay modes and target final states

- \tilde{g} , \tilde{q} direct decay, 1 or 2-step decay
- 0 lepton & E_T^{miss} & jets

- \tilde{g} one-step decay, two-step decay
- 1 lepton & E_T^{miss} & jets

- \tilde{g} two-step decay
- 0 lepton & multijets



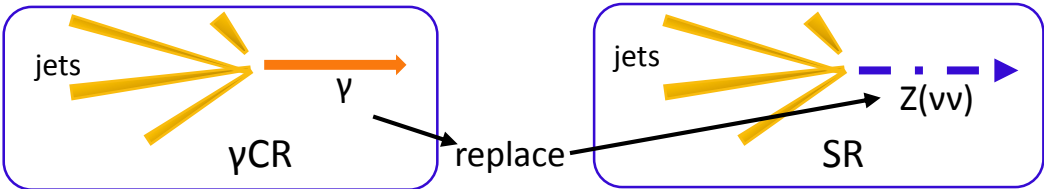
Background estimation for 0 lepton analysis

◇ Monte Carlo (MC) based Background (BG) estimation

- Normalize MC events in control region (CR) which is orthogonal to signal region (SR)
 - For Z(->vv)+jets, W+jets, Top BGs
- $$N_{data}^{SR} = N_{MC}^{SR} \cdot \frac{N_{data}^{CR}}{N_{MC}^{CR}}$$

◇ Control region for MC normalization

SR process	CRs	CR process	Selection
Z (->vv) +jets	γCR	γ+jets	- one photon - assume γ as E_T^{miss} and apply the similar selections for SR
W(->ℓν) +jets (ℓ is missed or τ jet)	W CR	W(->ℓν) +jets	-one e/μ - treat e/μ as jet and apply the similar selections for SR - $m_T \in [30,100]$ and b-jet vetoed
Top	Top CR	$t \rightarrow b W(->\ell\nu)$	-one e/μ - treat e/μ as jet and apply the similar selections for SR - $m_T \in [30,100]$ and b-jet tagged



$$m_T : \sqrt{2 \cdot p_T^l \cdot E_T^{miss} \cdot (1 - \cos(\Delta\phi(l, E_T^{miss})))}$$

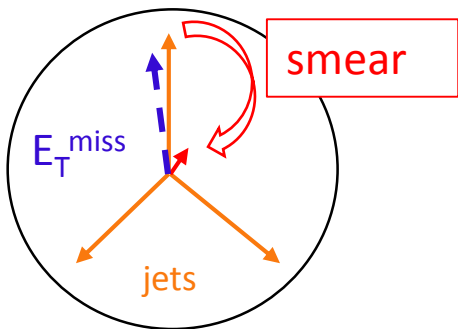


Background estimation for 0 lepton analysis 2

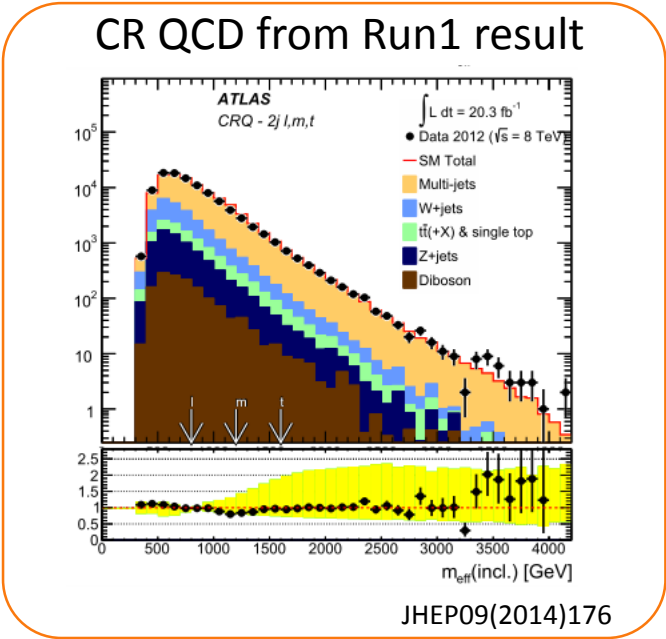
◇ Data-Driven BG estimation

- Jet smearing method
 - For QCD multijet BGs (fake E_T^{miss} from mismeasurement)
 - Measure jet response function with data
 - Response function : $\frac{\text{jet } p_T^{\text{reconstructed}}}{\text{jet } p_T^{\text{true}}}$
 - Smear all jets in low E_T^{miss} seed event
 - Normalize smeared events in CR QCD
 - Inverted cuts of QCD events reduction cuts for SR

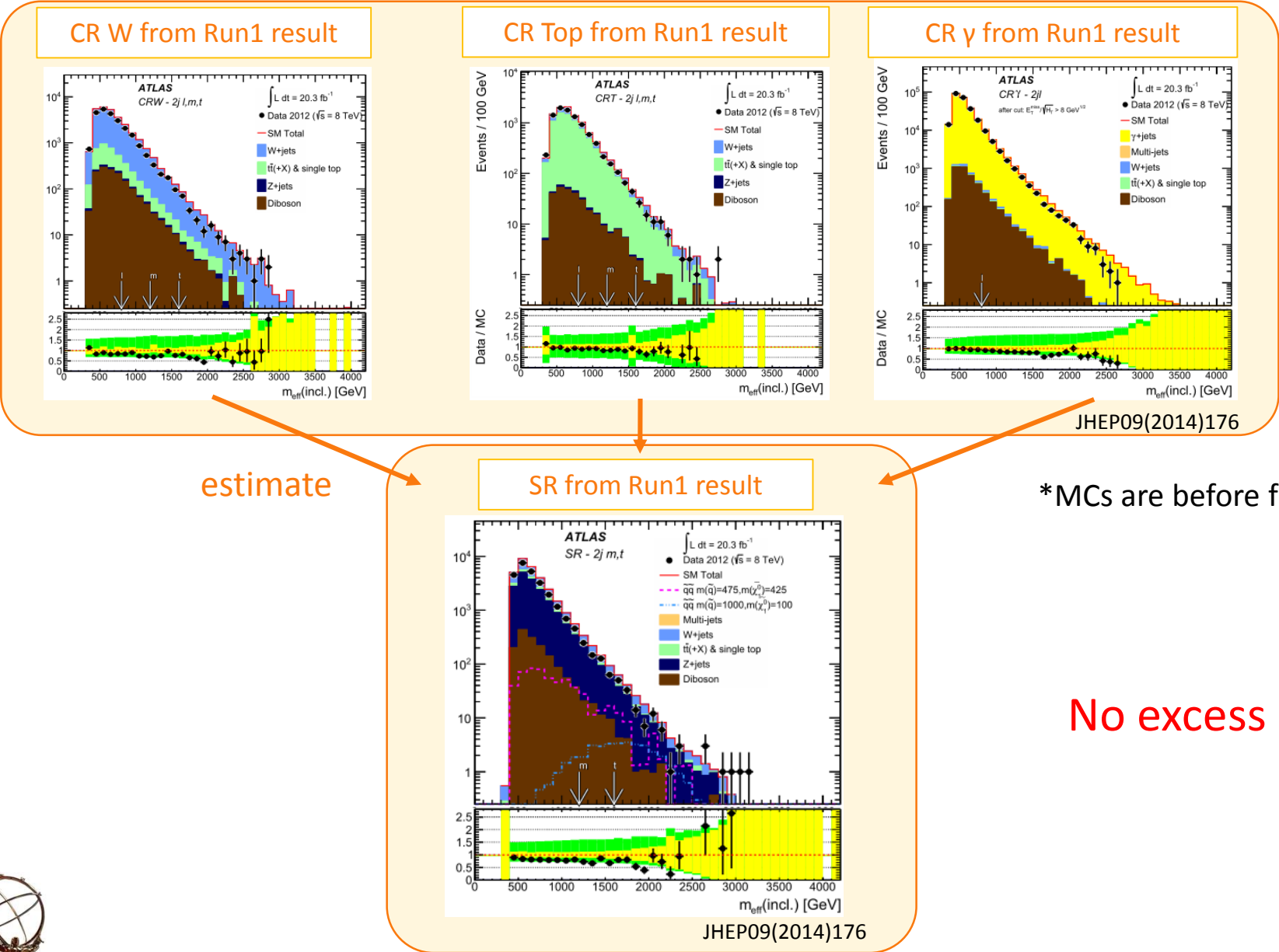
conceptual figure of jet smearing



$$m_{\text{eff}}: E_T^{\text{miss}} + \sum_{k=0}^{N_j} p_{T \text{ jet},k}$$



Results of 0 lepton analysis (from 2jet region)



estimate

JHEP09(2014)176

*MCs are before fit

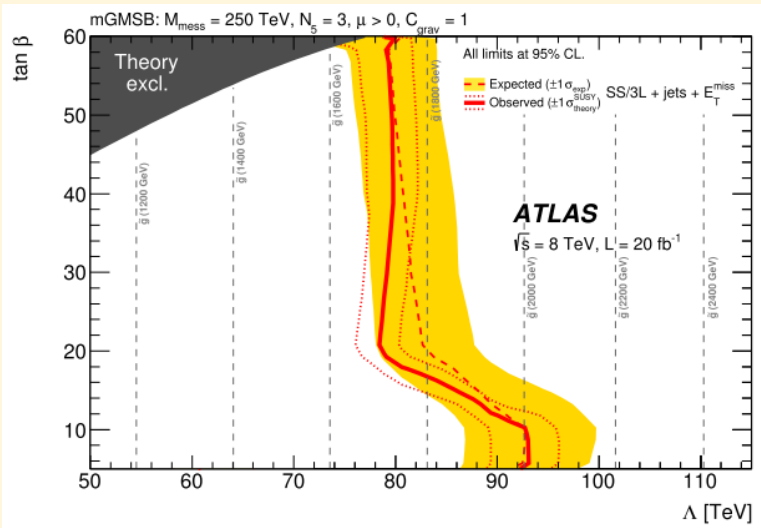
No excess !

JHEP09(2014)176

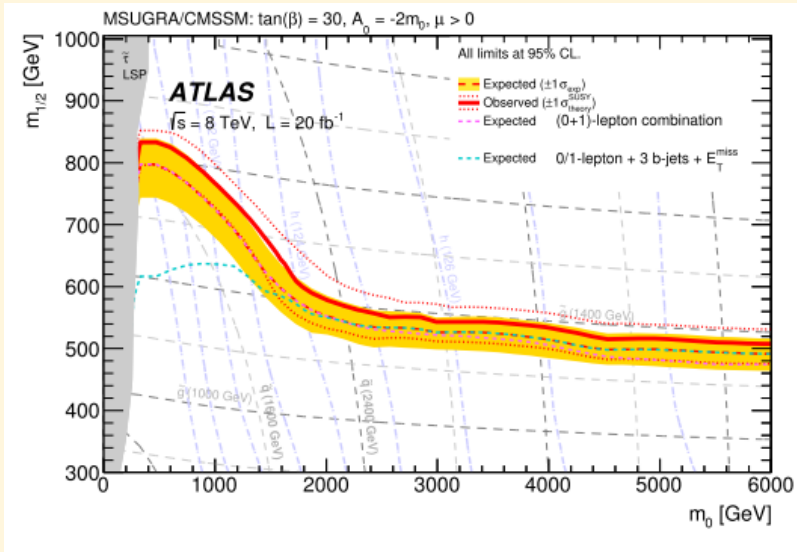


Limit from Run1 results

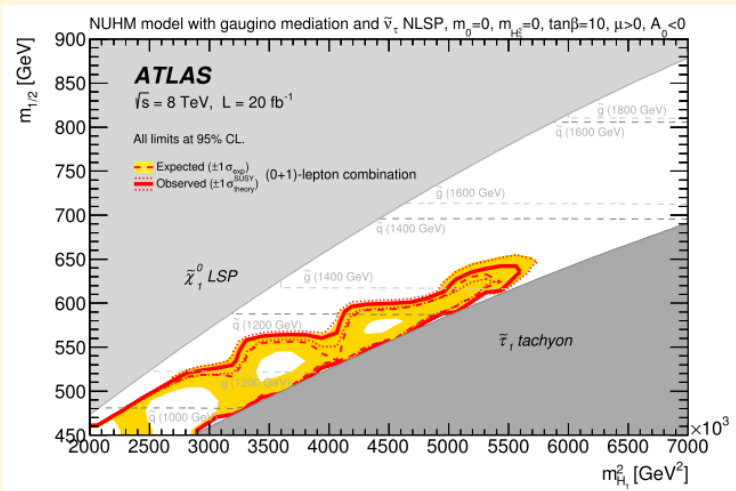
limit for m GMSB



m0 vs m1/2 plane exclusion limit

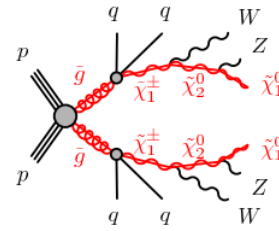
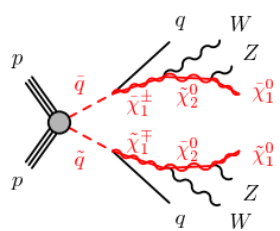


limit for NUHM

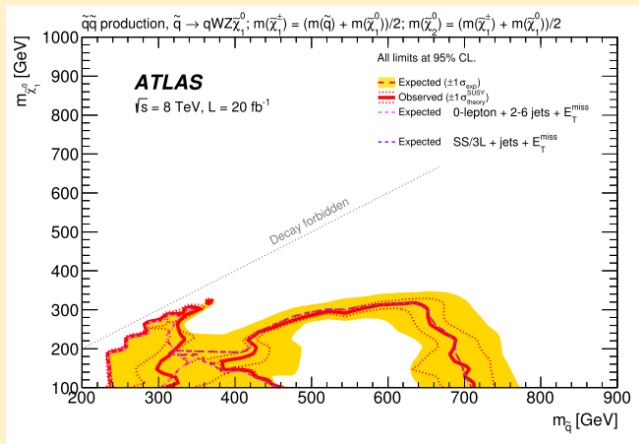


Simplified model interpretation 2

Multijets analysis is important for two-step decay model

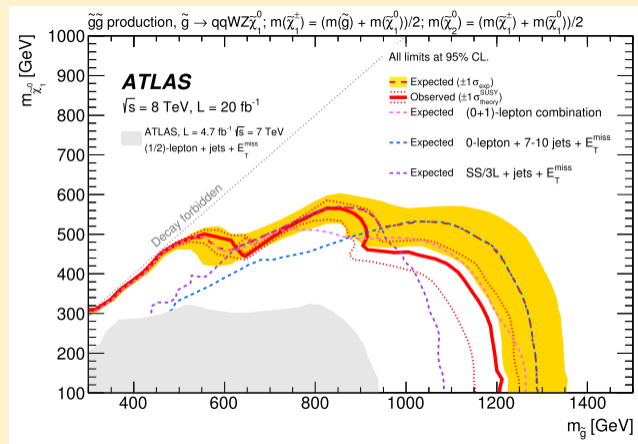


limit for \tilde{q} two-step decay model



arXiv:1507.05525

limit for \tilde{g} two-step decay model

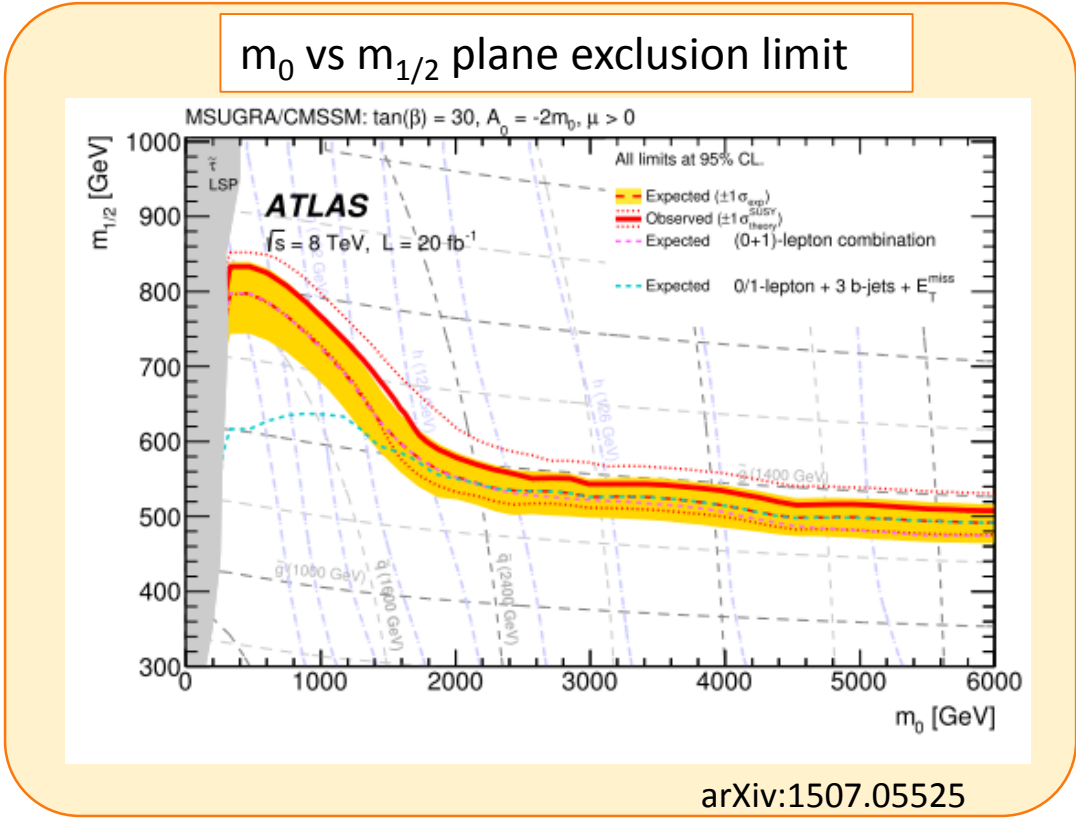


arXiv:1507.05525



mSUGRA/CMSSM interpretation

For the limit of mSUGRA, 0-lepton and 1-lepton searches are combined



➡ $m_{1/2} \lesssim 500 \text{ GeV}$ is excluded for any scalar mass



Reach with 1 lepton analysis

2/fb

Variables	cut value
# of lepton ($p_T > 35$ GeV)	$==1$
2 nd jet p_T (GeV)	> 200
4 th jet p_T (GeV)	> 75
5 th jet p_T (GeV)	> 25
$m_T(\ell, E_T^{\text{miss}})$ (GeV)	> 350
E_T^{miss} (GeV)	> 200
m_{eff} (with lepton) (GeV)	> 1600

5/fb

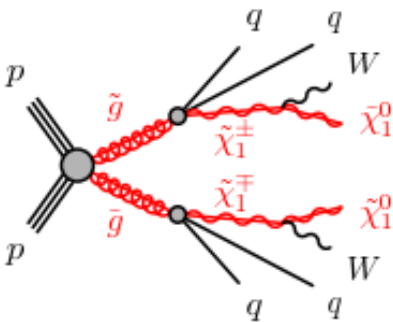
Selections for SR

Variables	cut value
# of lepton ($p_T > 35$ GeV)	$==1$
1 st jet p_T (GeV)	> 150
5 th jet p_T (GeV)	> 100
$m_T(\ell, E_T^{\text{miss}})$ (GeV)	> 250
E_T^{miss} (GeV)	> 200
m_{eff} (with lepton) (GeV)	> 1400



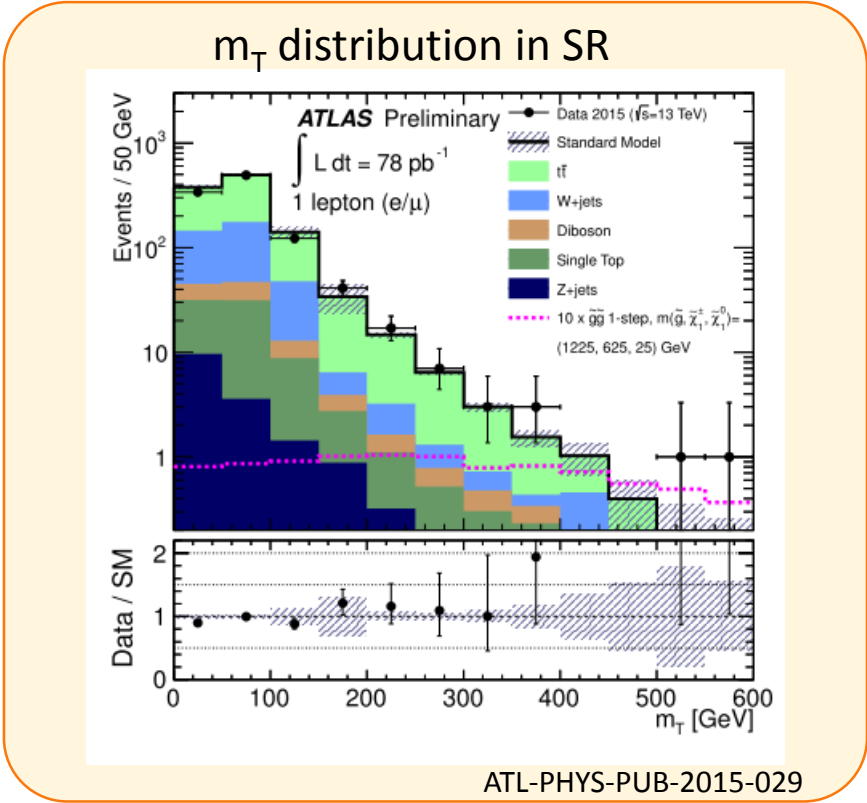
Signal Region for 1-lepton analysis

◇ Loose Signal Region only for small statistics



Selections for SR

Variables	cut value
lepton pT (GeV)	> 24
E _T ^{miss} (GeV)	> 100
4 th jet pT (GeV)	> 30

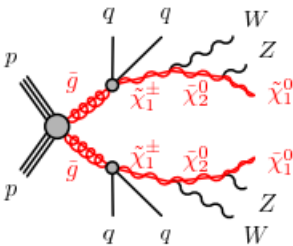


Good agreement between data and the background estimation

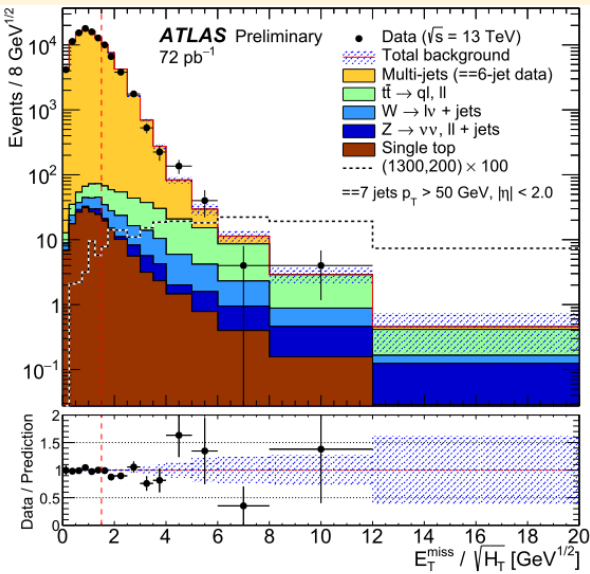


Signal Region for multijets analysis

◇ Loose Signal Region only for small statistics



$E_T^{miss}/\sqrt{H_T}$ distribution in SR



ATL-PHYS-PUB-2015-030

Selections for SR

Variables	cut value
# of leptons	==0
Njet(pT > 50 GeV)	== 7

QCD multijet events are estimated from 6 jet CR

➡ Good agreement between data and the background estimation

