

# Z + MET in supersymmetry

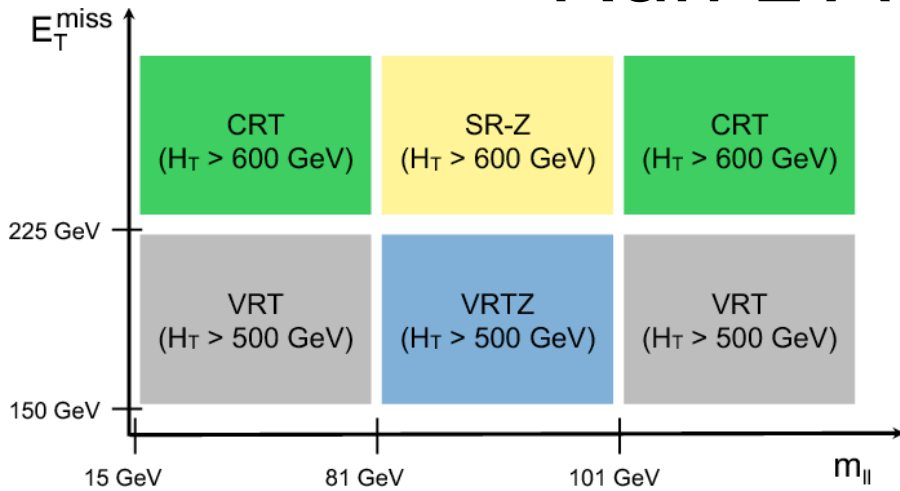
Ahmed Ismail

ANL/UIC

New Physics Interpretations at the LHC  
Argonne National Laboratory

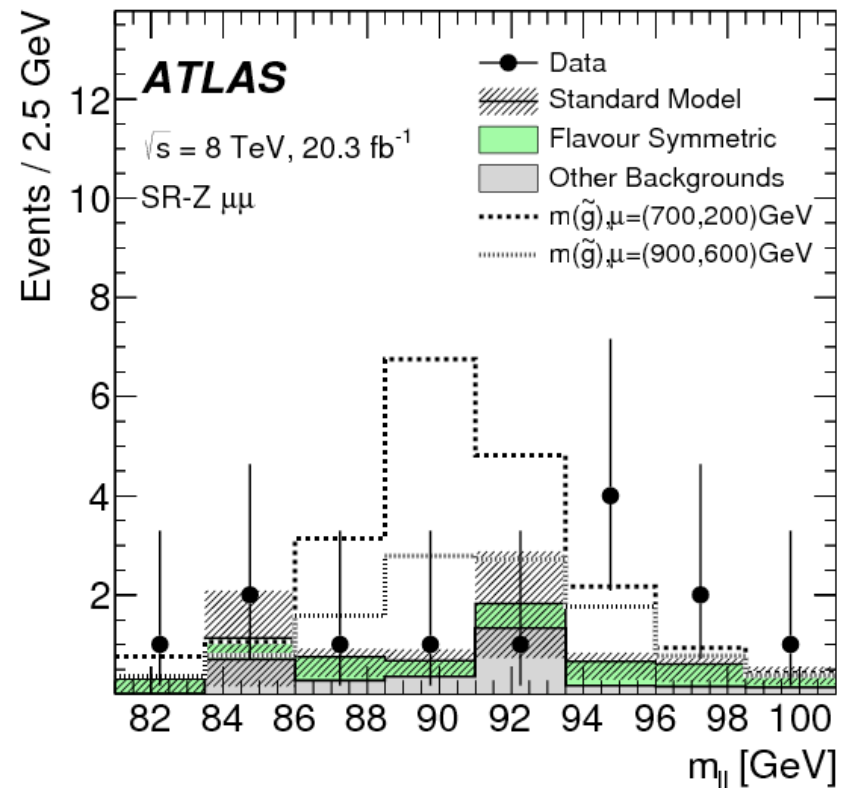
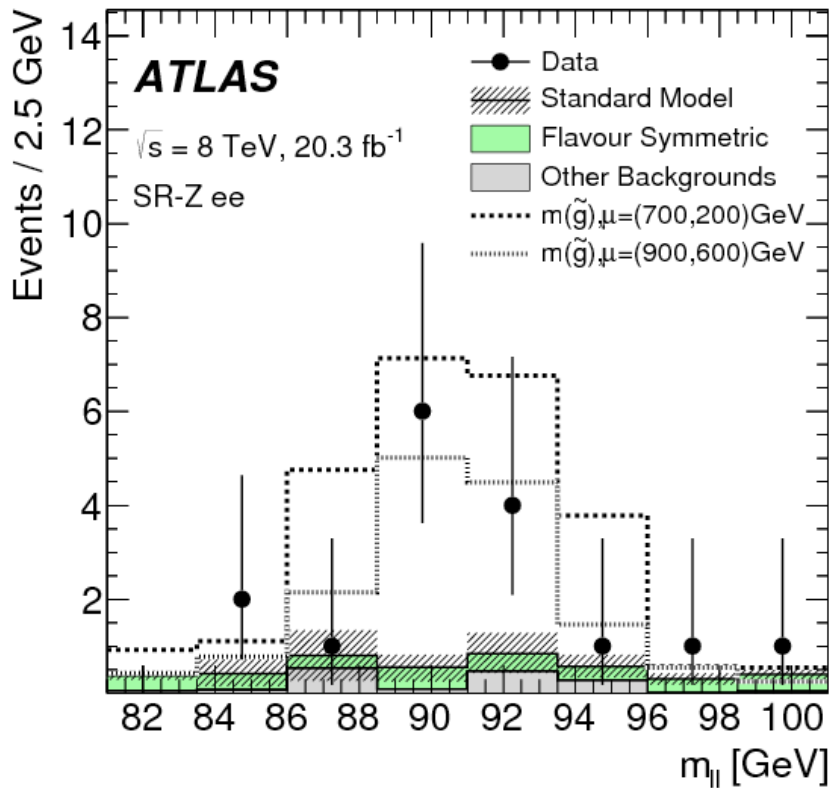
May 4, 2016

# Run 1 ATLAS search



Opposite sign same flavor leptons at  $m_Z \pm 10$  GeV

$10.6 \pm 3.2$  events expected, 29 observed; excess in e and  $\mu$



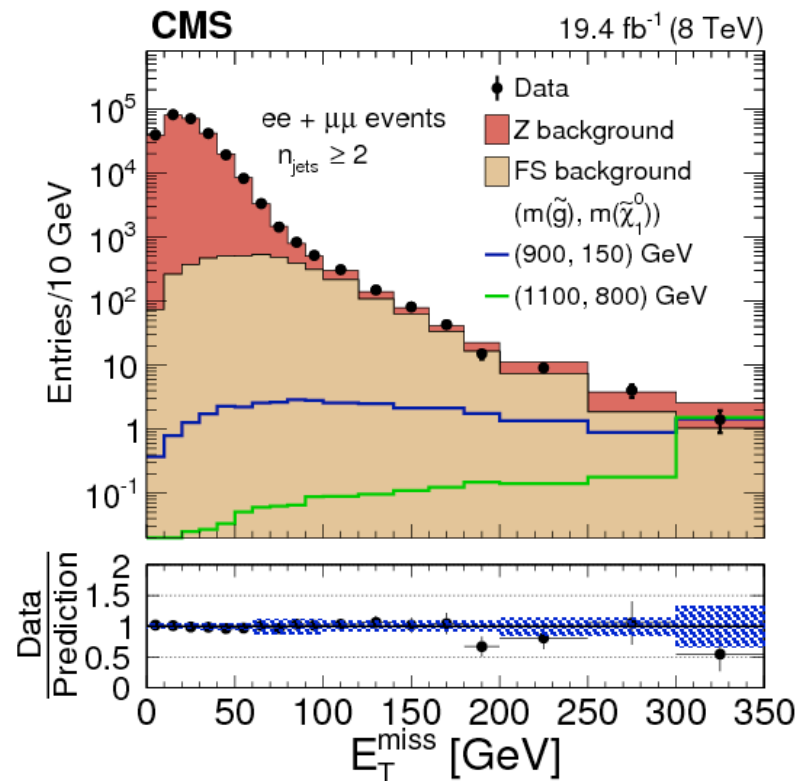
# Run 1 CMS search

On the other hand, CMS saw agreement with the SM in their search for leptonic Z + jets + MET

## Differences from ATLAS

MET > 100 GeV (compare to 225)  
 No  $H_T$  cut (compare to 600 GeV)

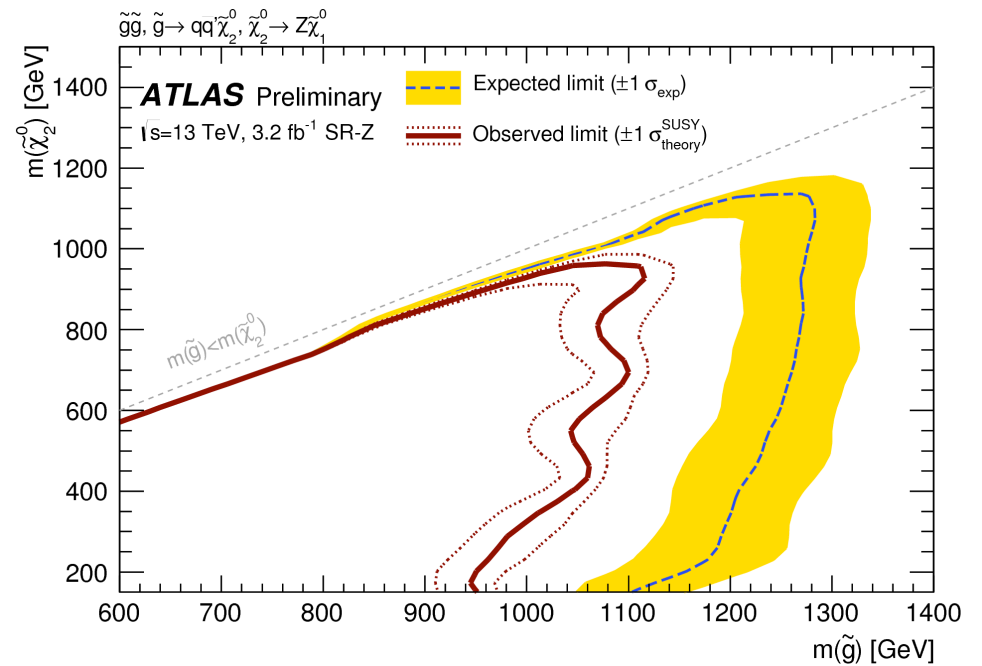
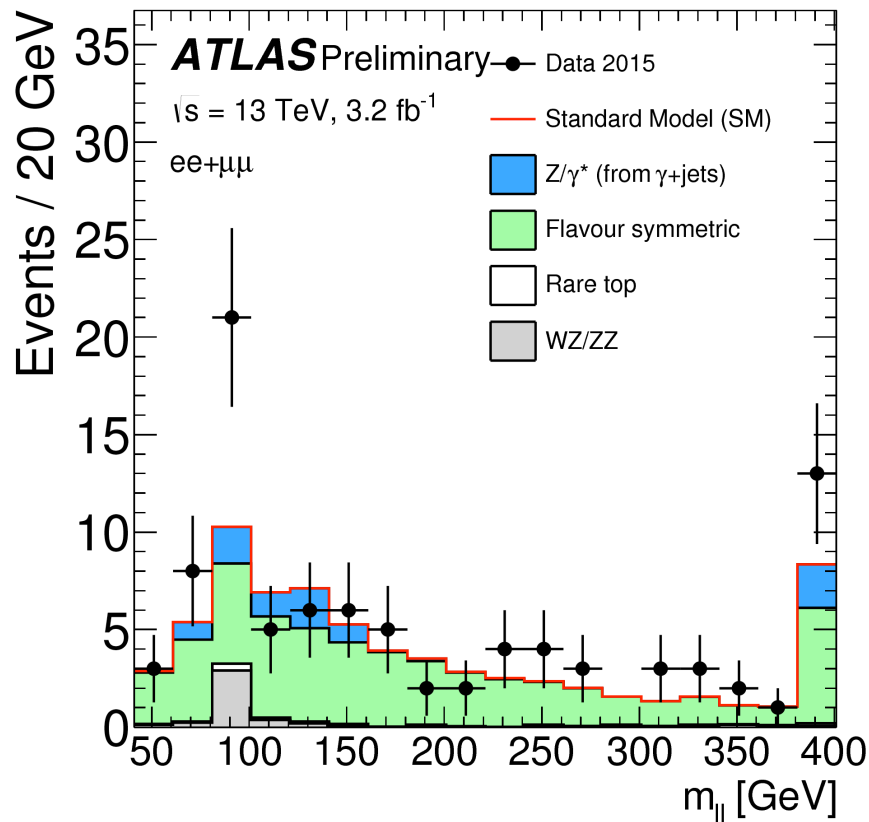
$E_T^{\text{miss}}$ (GeV)	100–200	200–300	>300
DY background	$336 \pm 89$	$28.6 \pm 8.6$	$7.7 \pm 3.6$
FS background	$868 \pm 57$	$45.9 \pm 7.3$	$5.1 \pm 2.3$
Total background	$1204 \pm 106$	$74.5 \pm 11.3$	$12.8 \pm 4.3$
Data	1187	65	7
GMSB signal yields			
$m_{\tilde{g}} = 900, m_{\tilde{\chi}_1^0} = 150$	$22.1 \pm 0.4$	$11.1 \pm 0.3$	$7.2 \pm 0.2$
$m_{\tilde{g}} = 1100, m_{\tilde{\chi}_1^0} = 800$	$1.1 \pm 0.04$	$1.6 \pm 0.05$	$7.6 \pm 0.1$



# Run 2 ATLAS search

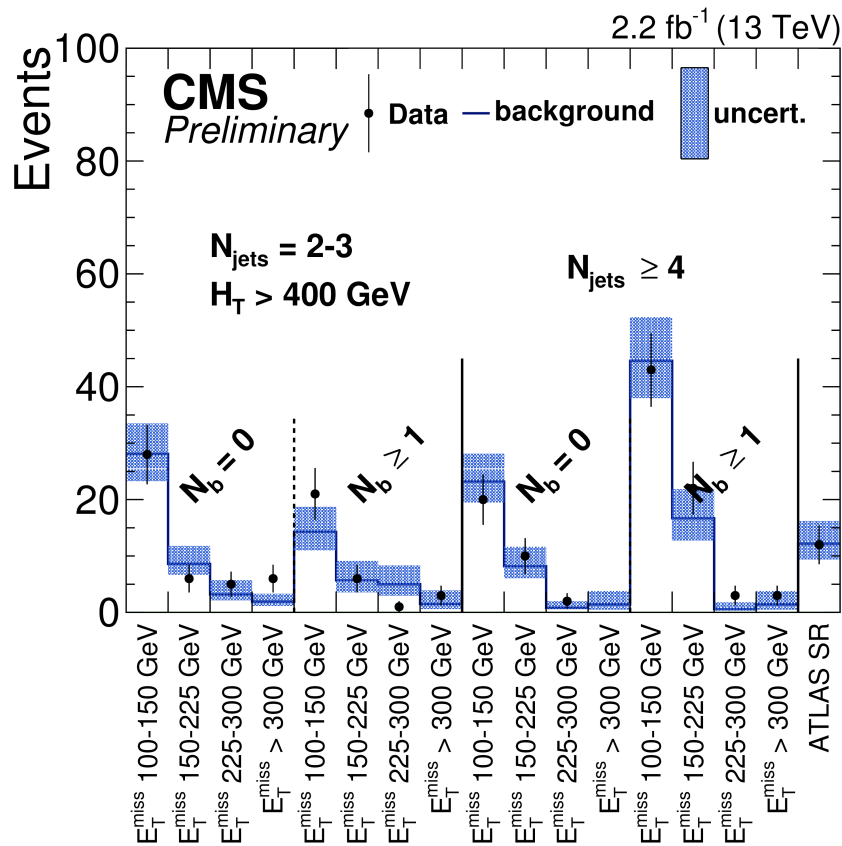
2.2 $\sigma$  excess with  $10.3 \pm 2.3$   
events expected, 21 observed

Same signal region as 8 TeV  
analysis



# Run 2 CMS search

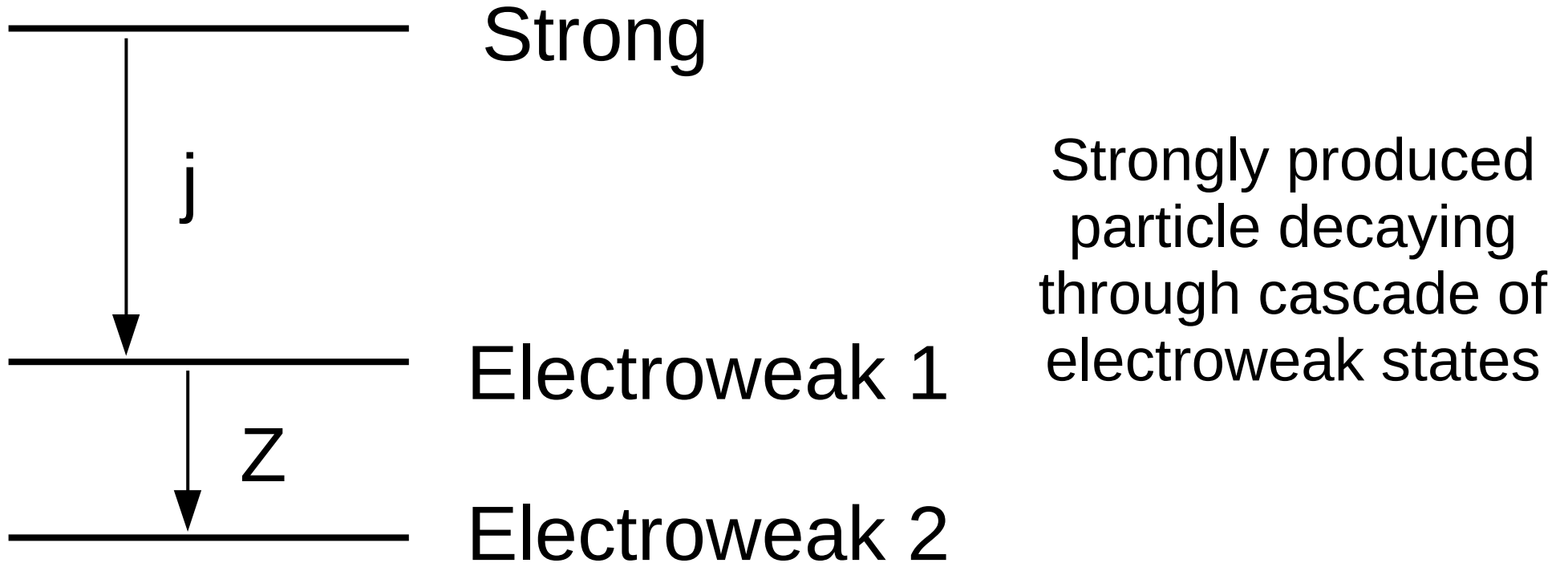
Agreement with the SM, now using ATLAS-like signal region (among others)



Differences in background estimations, object cuts?

See Tuesday talks by R. Castello, T. Holmes

# General strategy



Strongly produced particle decaying through cascade of electroweak states

Need to suppress decay of colored parent to lightest new particle

e.g. very weakly interacting lightest particle, compressed spectrum, composition of states

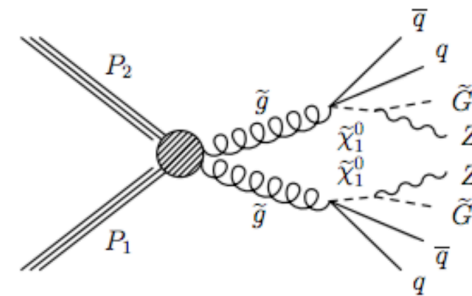
# Some theory interpretations

## Gauge mediation

Allanach, Raklev, Kvellestad

Barenboim et al.

...

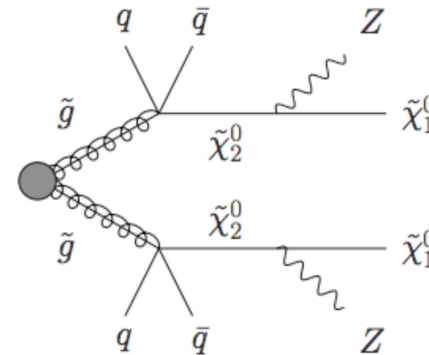


## NMSSM with decay to singlino

Cao et al.

Ellwanger

...



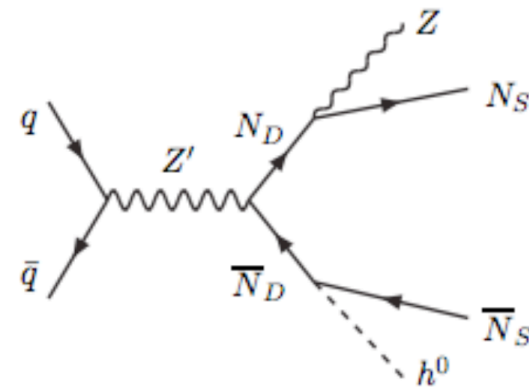
## Mixed stops

Collins, Dror, Farina

## Non-SUSY

Dobrescu

Vignaroli



# Tension between results?

ATLAS vs. CMS at 8 TeV:  
different kinematic regions,  
can be evaded



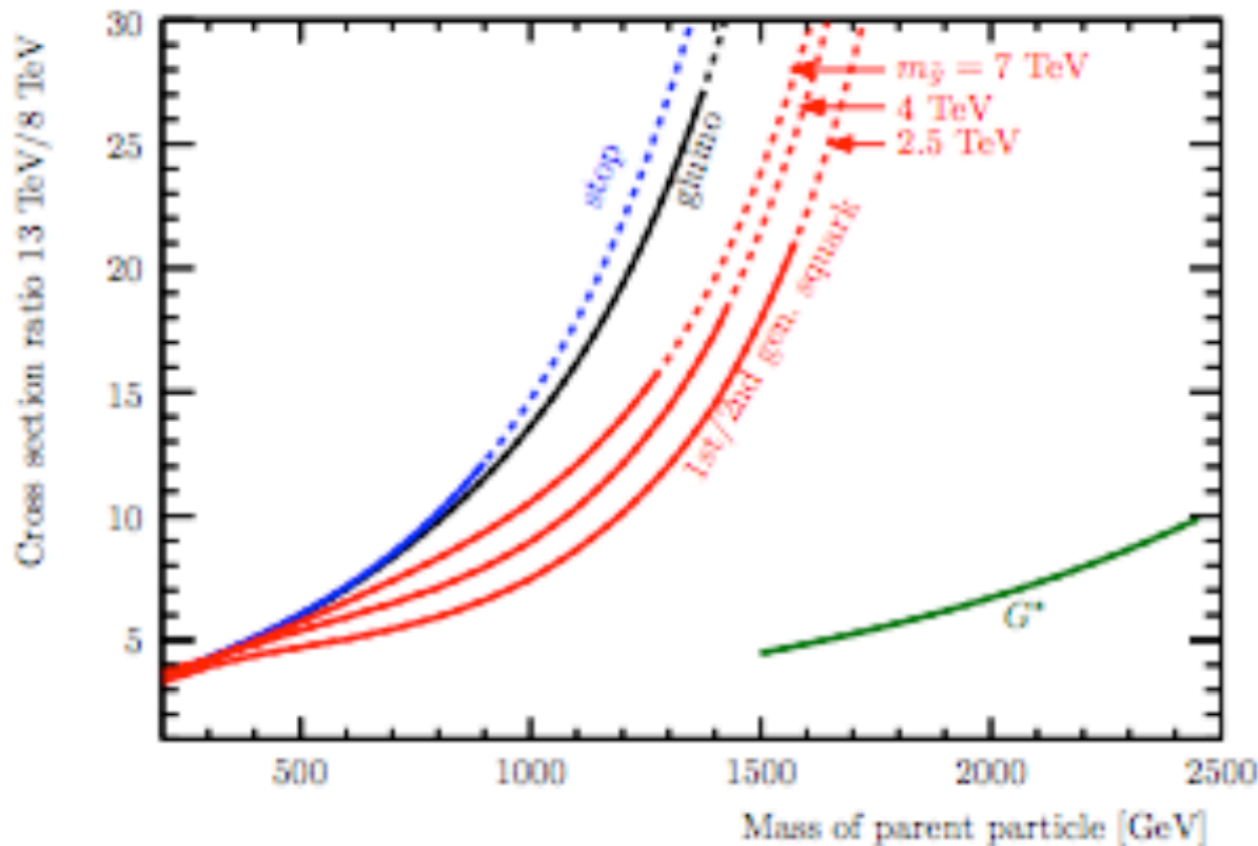
ATLAS vs. CMS at 13 TeV: more difficult without better  
understanding of background and/or statistical  
fluctuations, given nearly identical signal regions

8 TeV vs. 13 TeV: depends on parton luminosity ratios,  
i.e. mass/initial state



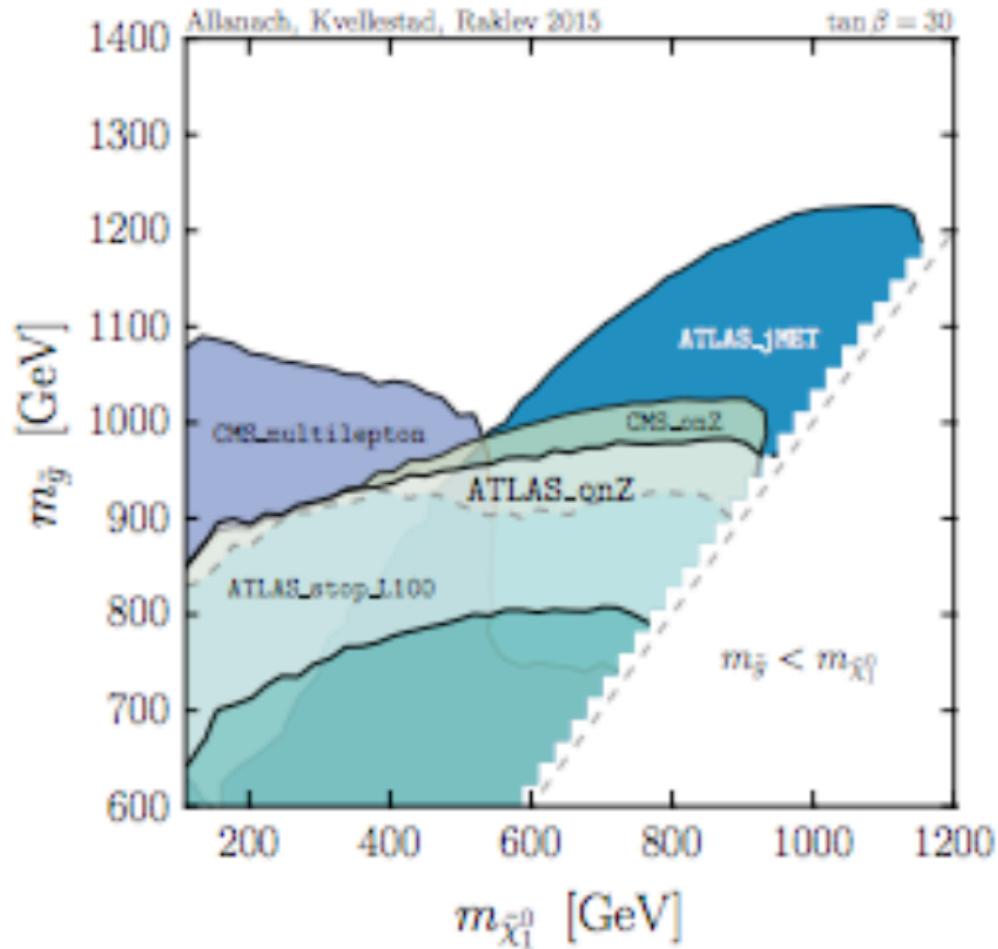
# Tension between results?

For quark-initiated production and/or lighter particles, slower scaling with CM energy helps



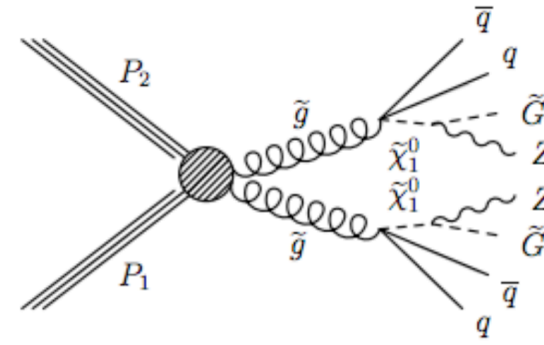
Lu, Shirai, Terada  
1601.05777

# Fitting with gluino cascades



Allanach, Raklev, Kvellestad, 1504.02752

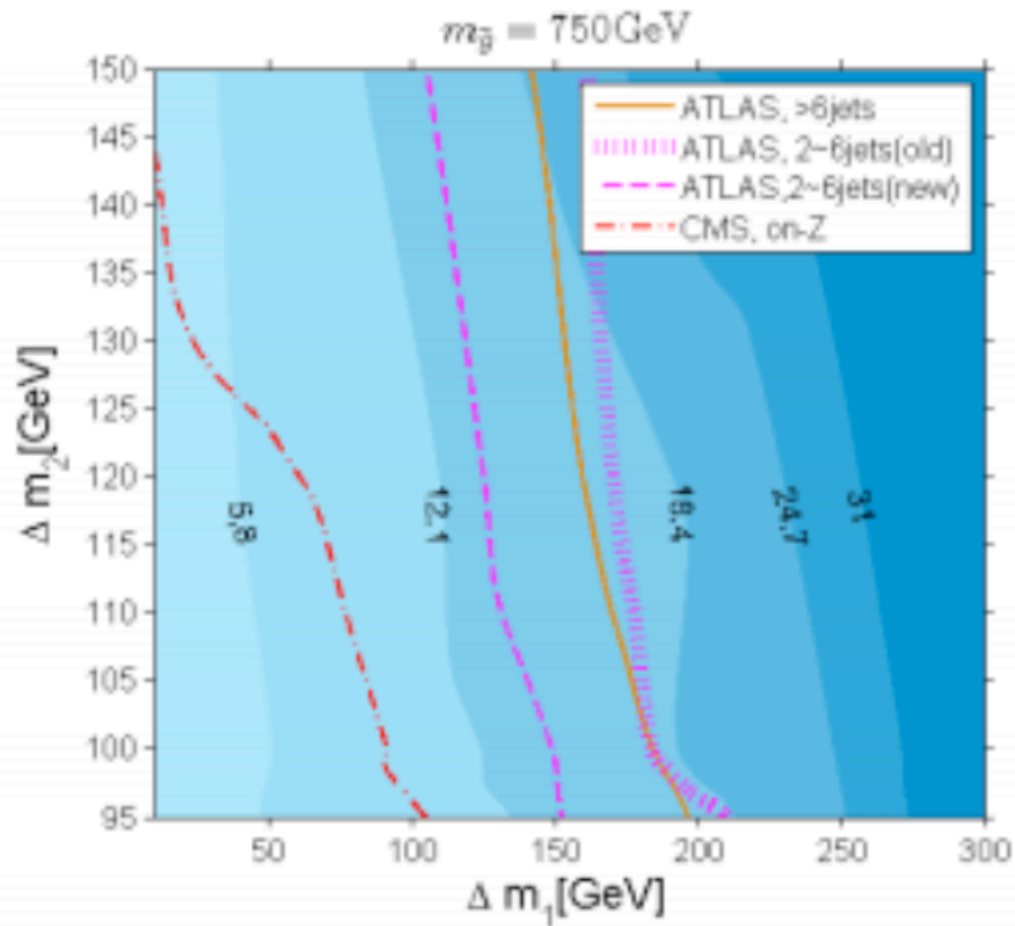
see also Barenboim et al., 1503.04184



Tension between  
parameter space fitting  
ATLAS excess and CMS  
result

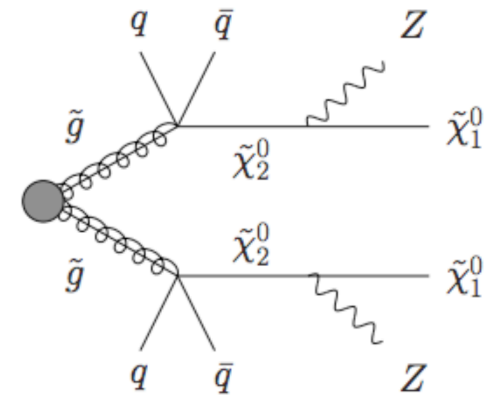
ATLAS jets + MET, CMS  
multileptons make it  
extremely difficult for the  
GMSB simplified model

# Fitting with gluino cascades



Cao et al., 1504.07869

see also Ellwanger, 1504.02244



Reduce MET by making lightest state massive first neutralino, rather than gravitino

Possible in NMSSM scenarios, with gluino  $\rightarrow$  bino  $\rightarrow$  singlino

# Squark cascade in MSSM



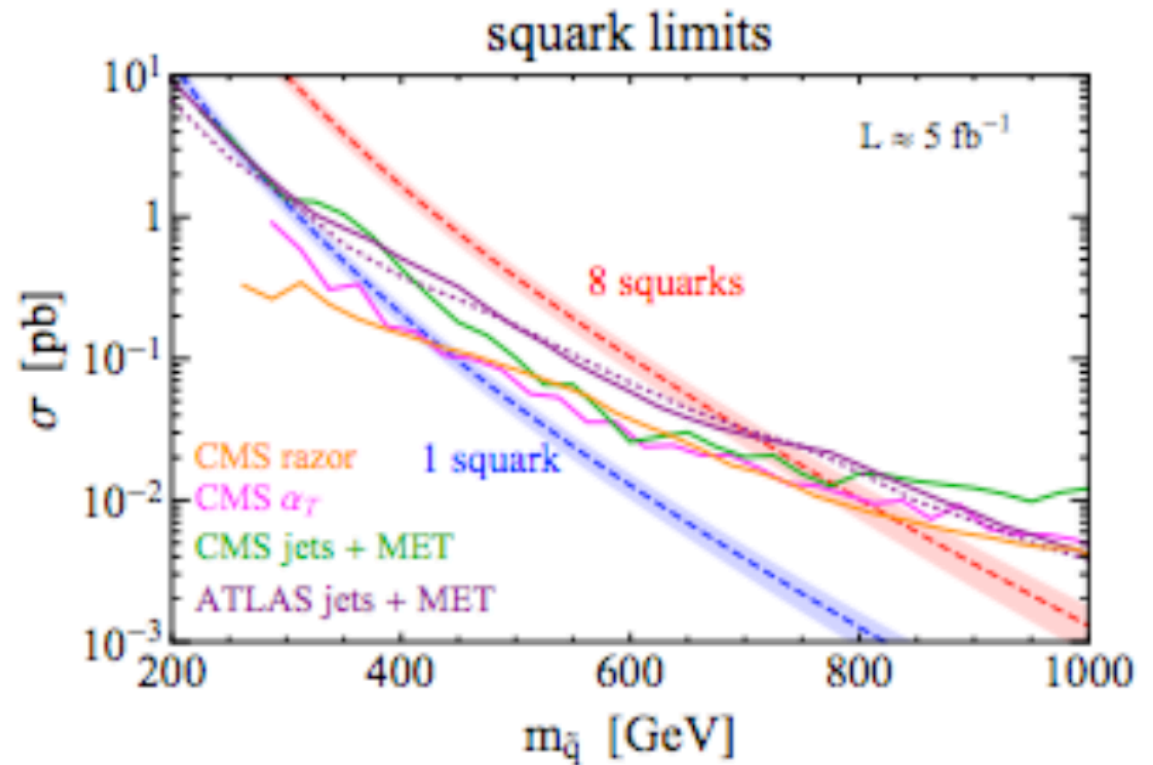
Higgsino multiplet includes two neutral and one charged state, so  $W$  decays also occur

Could also have RH squark  $\rightarrow$  bino  $\rightarrow$  wino

# Squark cascade in MSSM

Allow non-degenerate masses for squarks in different  $SU(2)_L$  multiplets, easing limits from jets + MET at cost of lower overall cross section

Mahbubani et al., 1212.3328

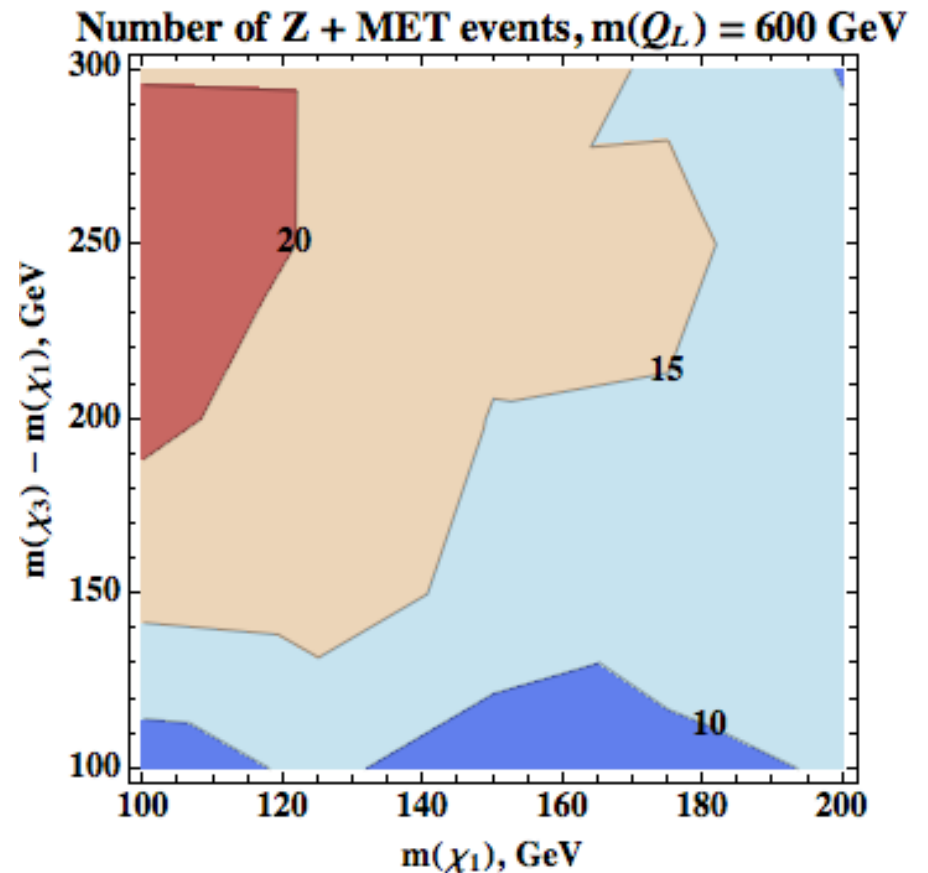


Can fit Z + MET excess well for 4 light flavor squarks, e.g. assume RH squarks decoupled

# Squark cascade in MSSM

Before considering other constraints, can accommodate  $\sim 18$  event excess at Run 1 in ATLAS Z + MET search region

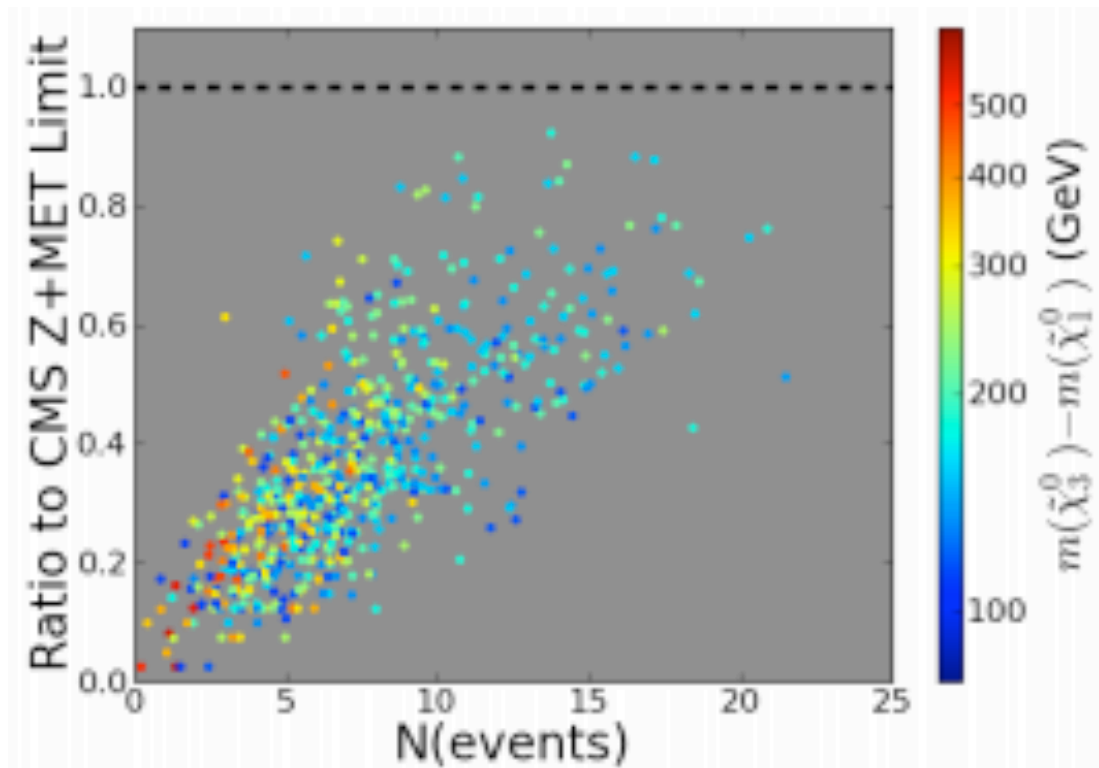
Simplified model grid generated around point in phenomenological MSSM parameter scan



Glino at 2.8 TeV, rest of spectrum decoupled

# CMS 8 TeV on-Z search

Correlation between ATLAS and CMS Z + jets + MET search regions, but points predicting many Z events in ATLAS are still away from the current CMS limit



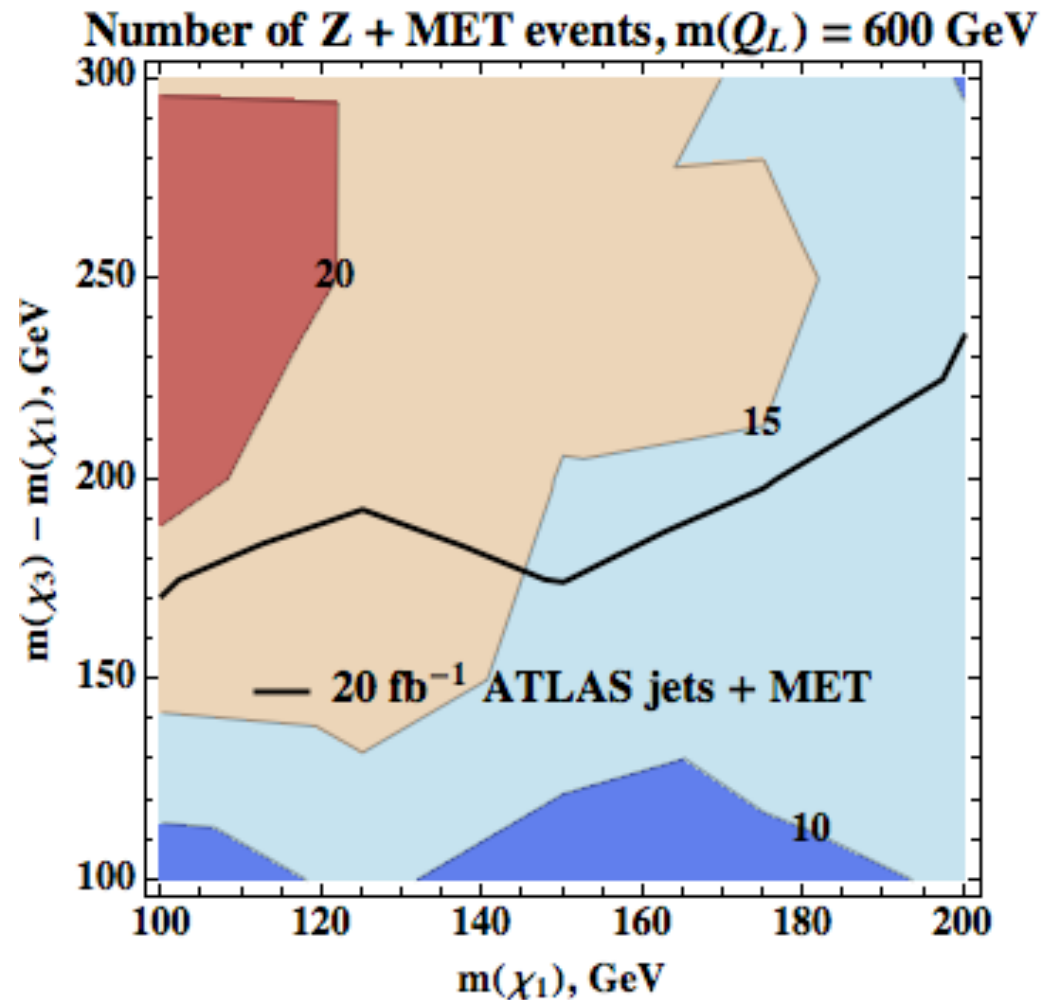
Color code indicates bino-Higgsino splitting

Modest splittings  $\sim 100$ - $200$  GeV preferred for both sufficient Z events and compatibility with jets + MET

# Jets + MET

Run 1 search limits  
squark cascade  
scenario

Still possible to  
achieve on-Z excess  
in squark cascade  
model while evading  
other constraints

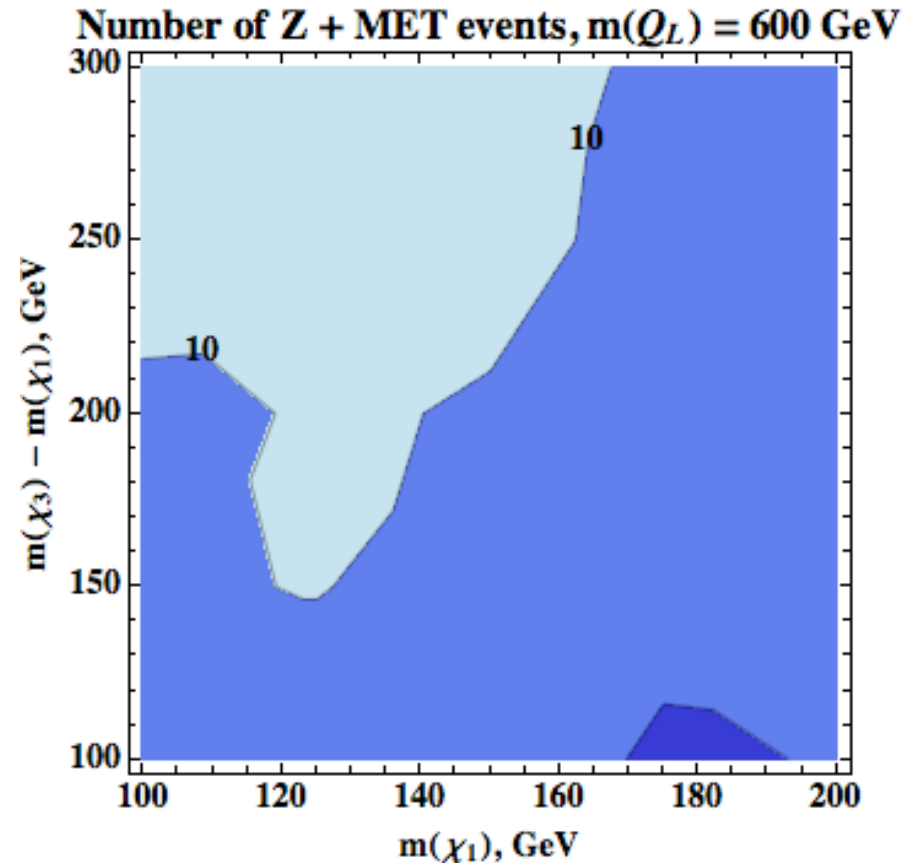




# 13 TeV Z + MET search

At Run 2, can get much of ATLAS ~11 event excess with region favored by 8 TeV results

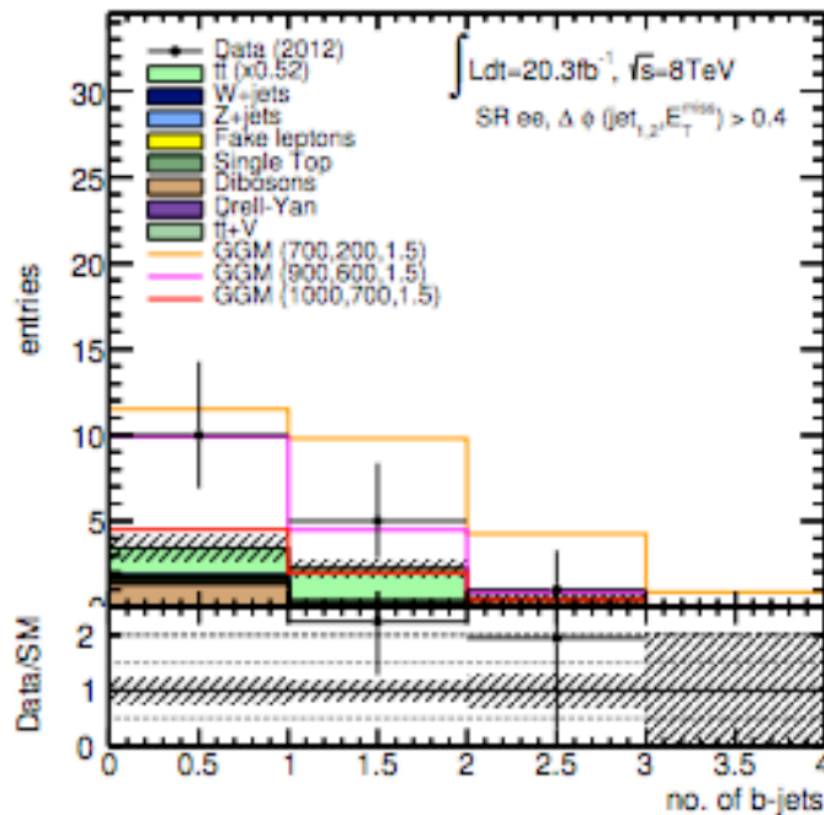
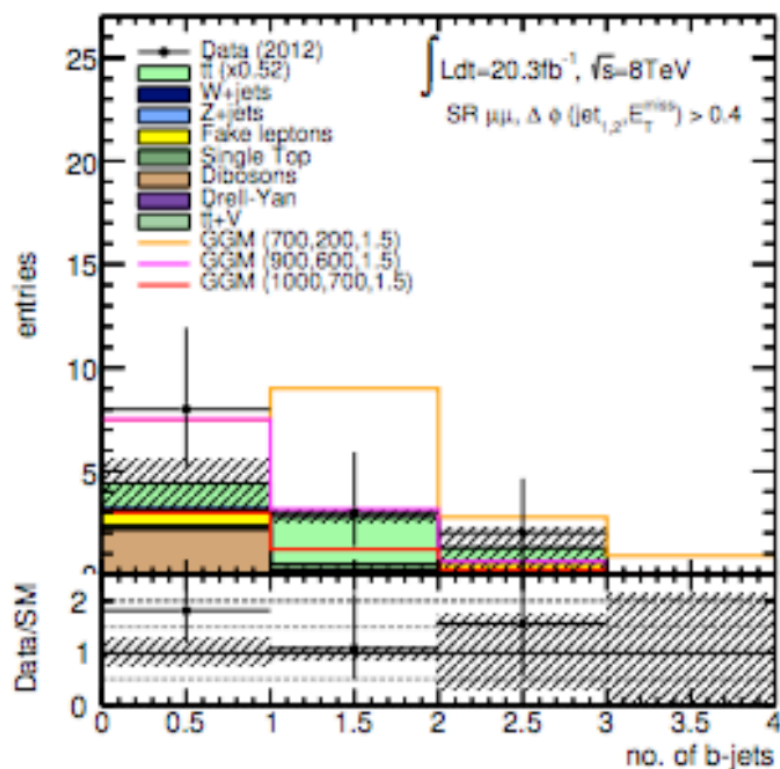
Mild tension with CMS remains to be clarified



Jets + MET likely to test scenario at 13 TeV, but current bounds are weaker than at 8 TeV given low masses

# Further thoughts on distributions

Statistics are low, and most look background-like



M. Schreyer, CERN-THESIS-2015-149

If excess persists, use kinematics, b-tags, ... to discriminate between explanations

# Summary

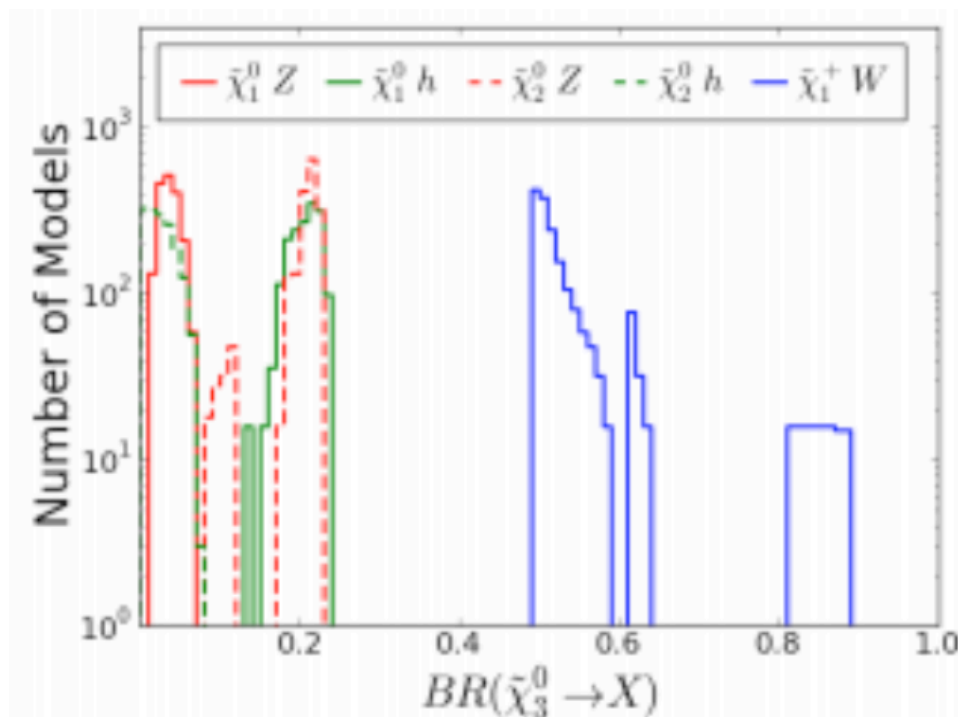
With mixed 13 TeV results from ATLAS and CMS, the status of the Z + jets + MET excess seen by ATLAS at Run 1 remains unclear

Explanations involving lighter particles tend to do better in resolving the tension, e.g. squarks decaying through electroweak cascade

For now we wait for more data....



# Neutralino branching ratios

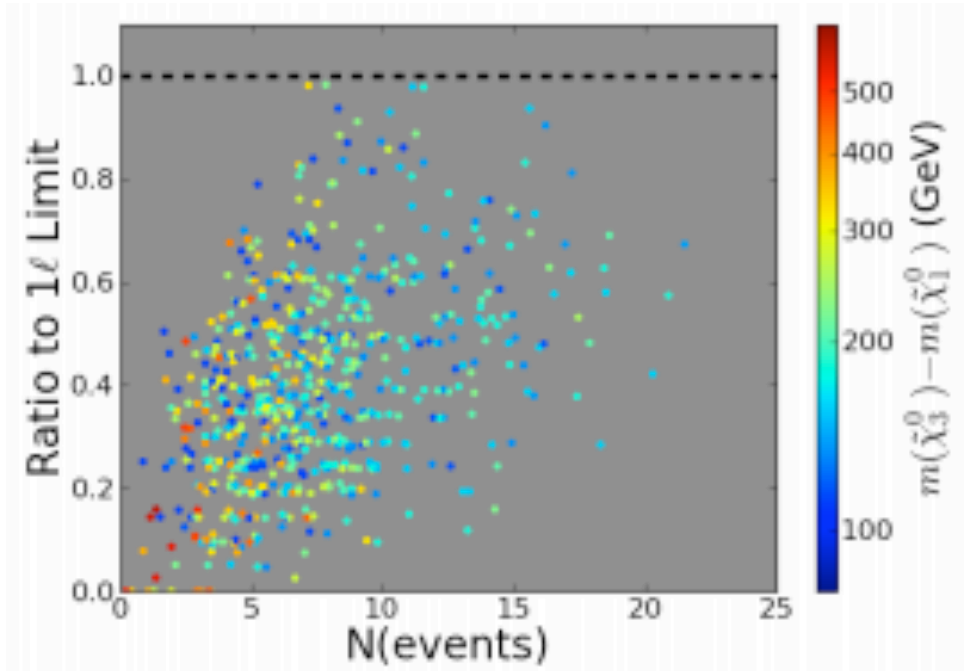
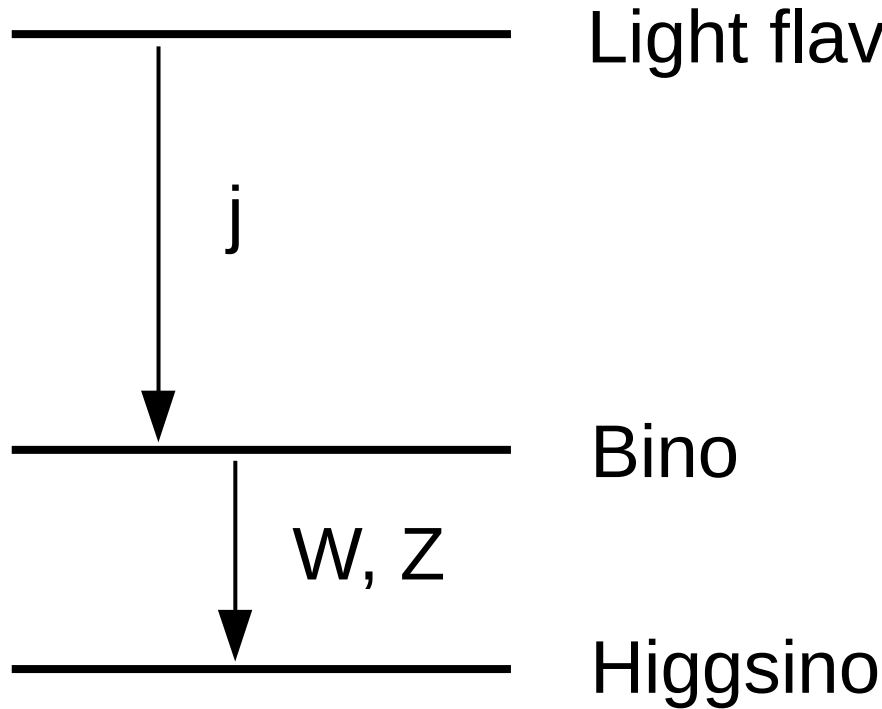


Models predicting 5 or more events in ATLAS Z + jets + MET search region only

W often produced in bino  $\rightarrow$  higgsino decay

However, single lepton + jets + MET search is generally compatible with spectra accommodating excess in Z + MET signal region

# Other constraints



$W$  decay can produce single lepton, but bounds from one lepton ATLAS search are loose and signal strengths in one lepton and  $Z + \text{jets} + \text{MET}$  search regions appear uncorrelated