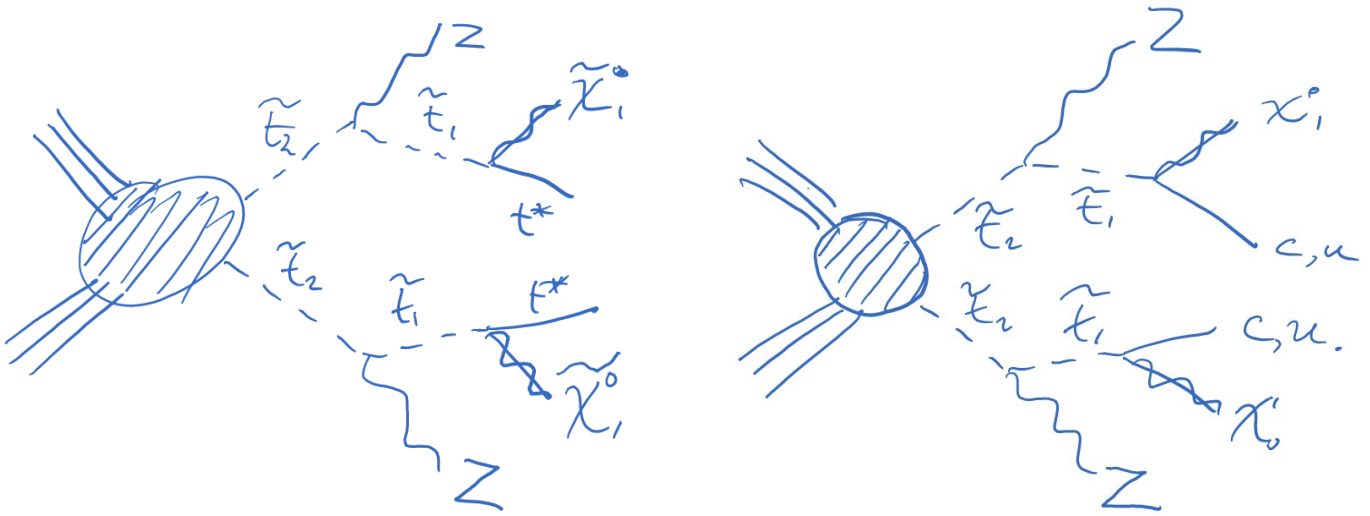
Mixed Stops
and the ATLAS on-Z Excess

(1508.02419)

Jack H Collins, Jeff Asaf Dror, Marco Farina

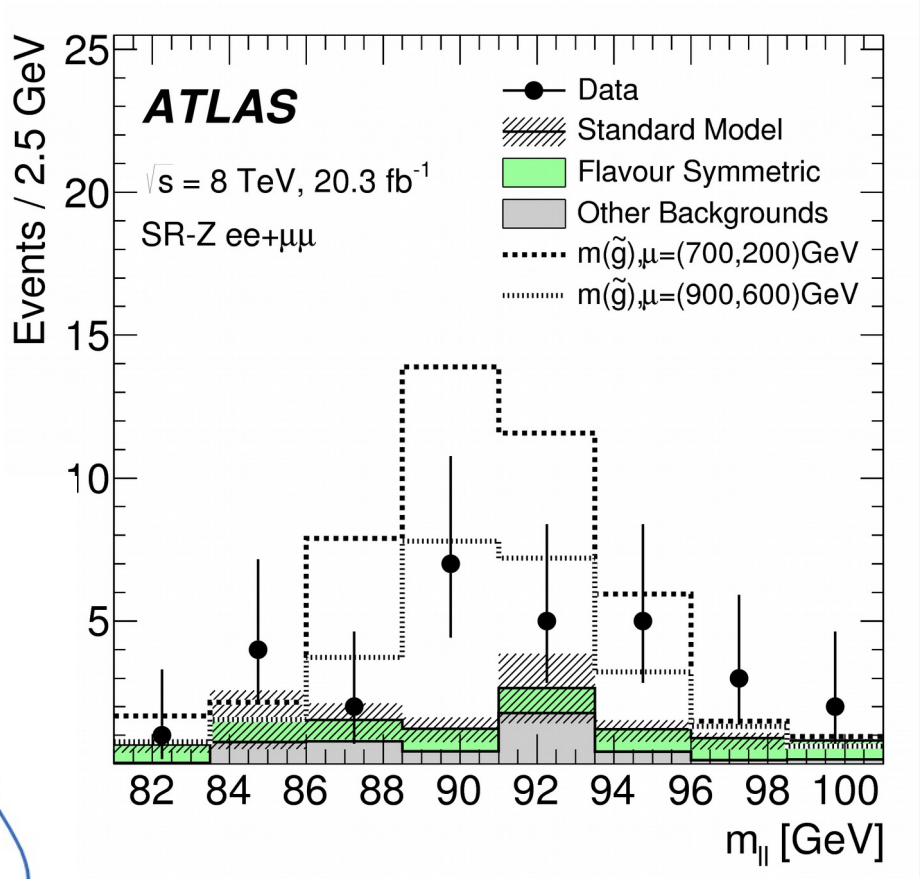


The ATLAS Excess

1503.03290

arXiv:1503.03290

"Search for supersymmetry in events containing a same-flavour opposite-sign dilepton pair, jets, and large missing transverse momentum in √s = 8 TeV pp collisions with the ATLAS detector"



Cuts:

$m_{ll} \simeq m_Z \quad (81 < \frac{m_{ll}}{GeV} < 101)$

$N_{jets} \geq 2$

$E_{T\,miss} > 225\ GeV$

$H_T > 600 \quad (H_T = \sum_i |p_{T\,i}|$ · signal jets · leading leptons)

$\Delta\phi_{jet,\,E_{T\,miss}} > 0.4$

Bg = 10.6 ± 3.2 events

Obs = 29 events

Significance = 3.0σ (local)

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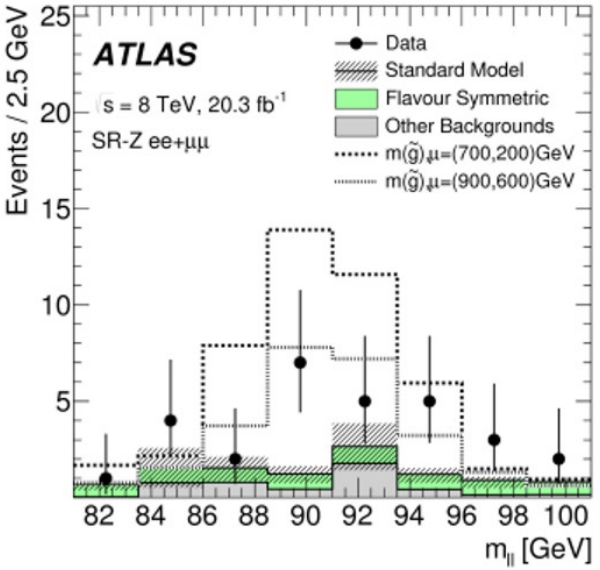

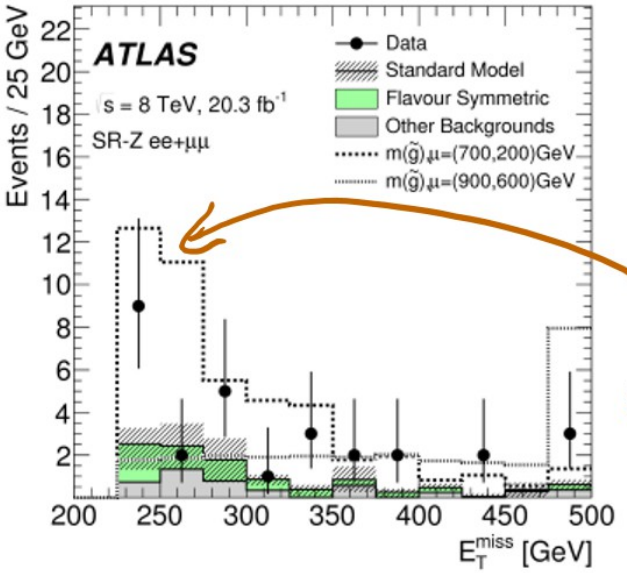

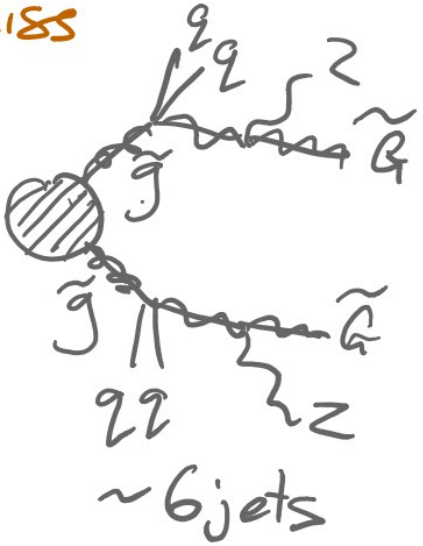

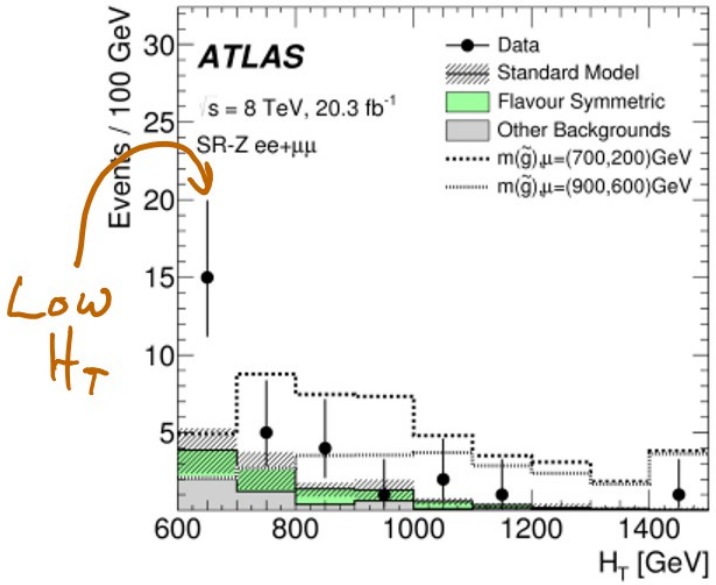

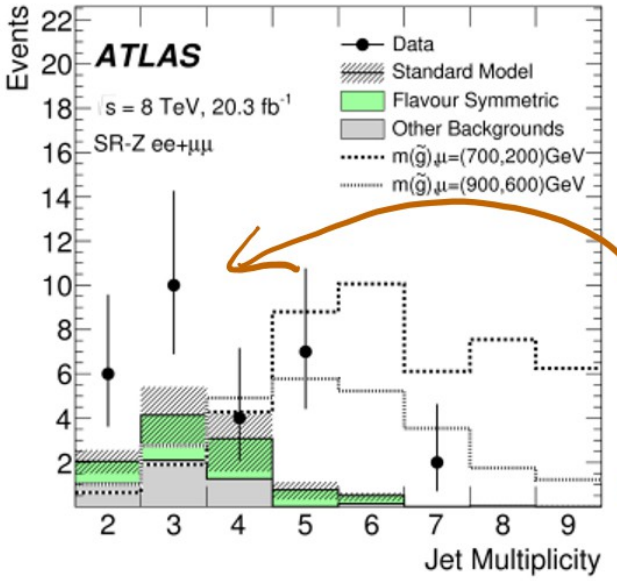

The CMS Search

1502.06031

Cut Comparison

	n_{jet}	$E_{T Miss}$/GeV	H_T/GeV
ATLAS	≥2	≥225	≥600
CMS	≥2,3	100-200, 200-300 ≥300	—

$n_{jet} \geq 2$

	low	mid	high
E_T^{miss} (GeV)	100–200	200–300	>300
DY background	336 ± 89	28.6 ± 8.6	7.7 ± 3.6
FS background	868 ± 57	45.9 ± 7.3	5.1 ± 2.3
Total background	1204 ± 106	74.5 ± 11.3	12.8 ± 4.3
Data	1187	65	7

$n_{jet} \geq 3$

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DY background	124 ± 33	12.7 ± 3.8	3.2 ± 1.8
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Total background	478 ± 43	39.2 ± 6.6	5.3 ± 2.3
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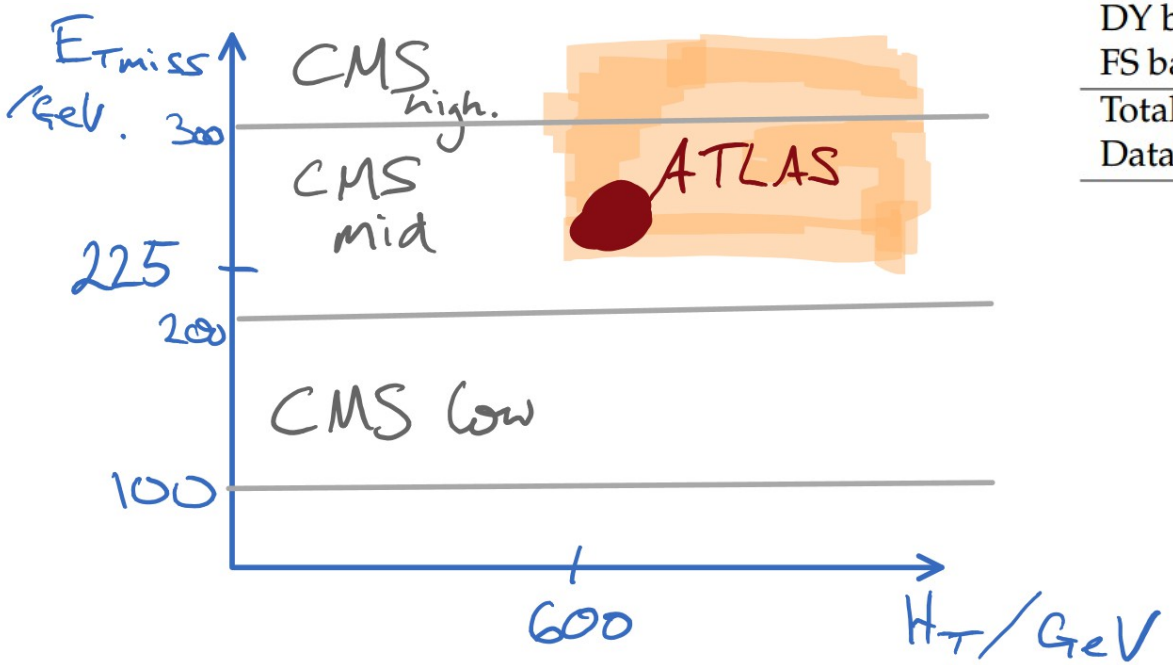

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Want 7-20 events in ATLAS region without falling foul of CMS search bins.

They also have different control regions for background estimation. Could there be background contamination?

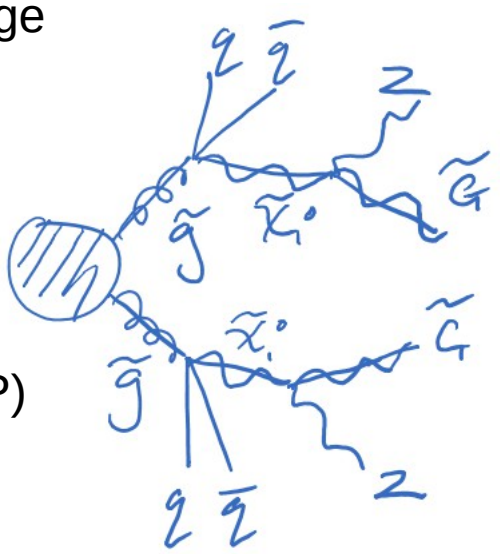
Explanations

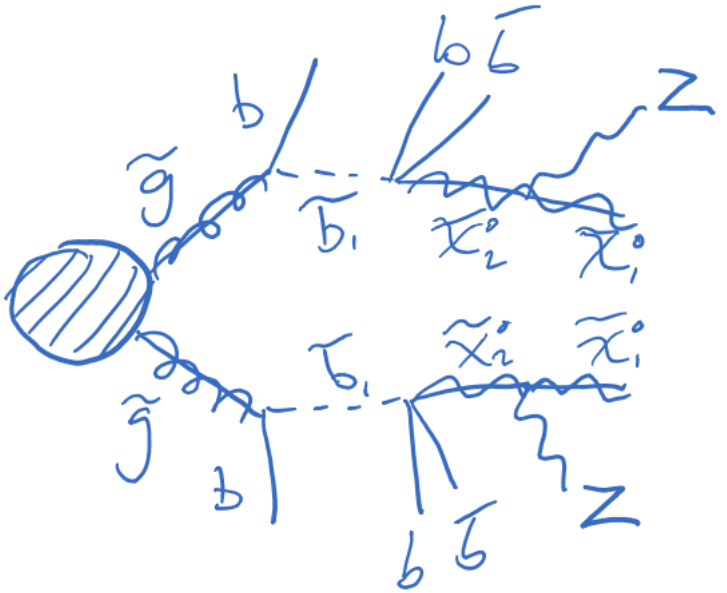
Generalized Gauge Mediation (GGM)

1503.04184
1504.02752

NMSSM
(with singlino LSP)

1504.02244
1504.07869





MSSM with
RH sbottom

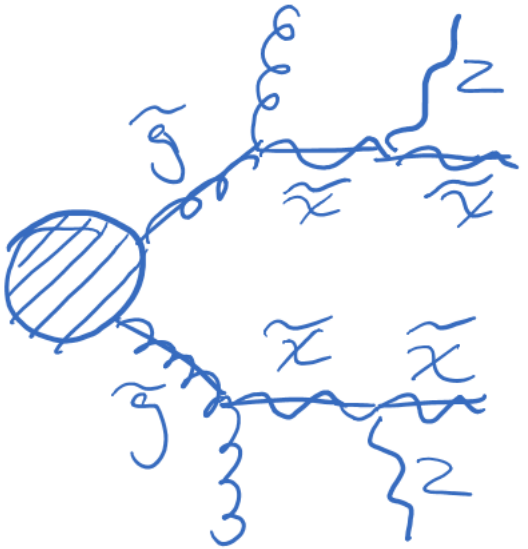
1504.04390

MSSM

1506.07161

NMSSM with
Goldstino LSP

1506.08803

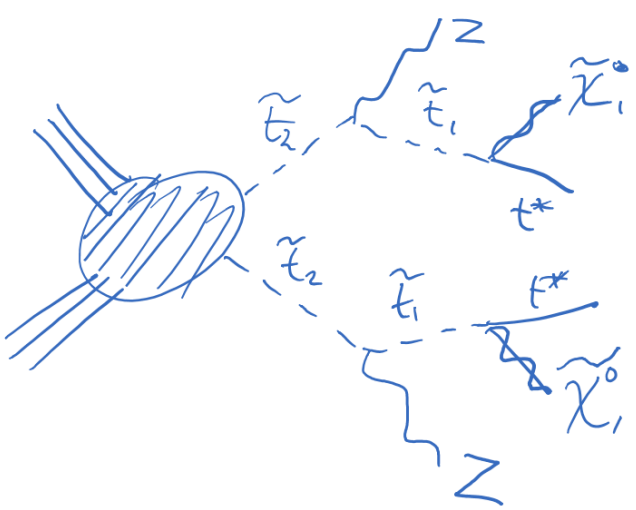


(N)MSSM with
light squarks

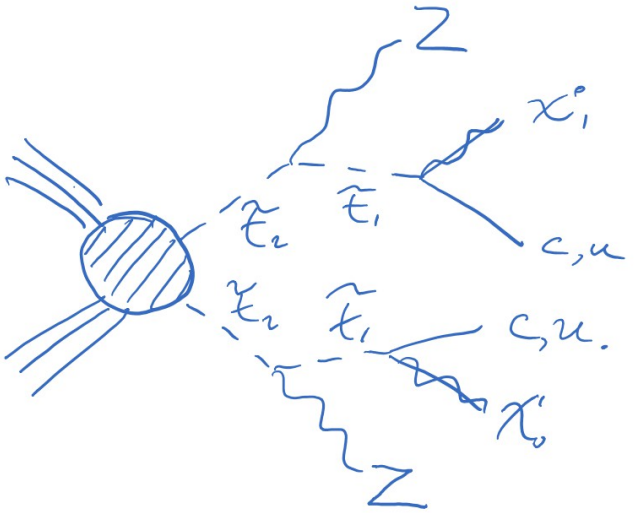
1506.05799
1508.07452
1507.08471

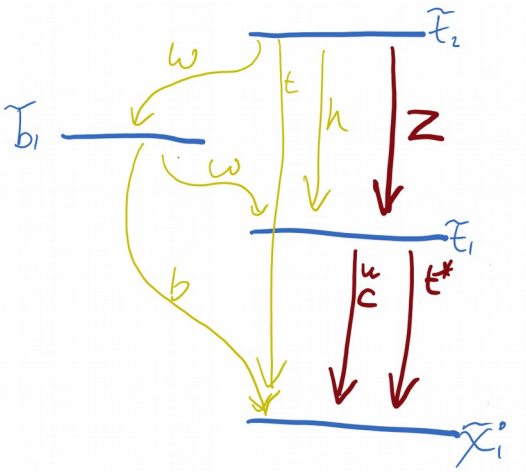
Light Stops?

Flavour Conserving



Flavour Violating

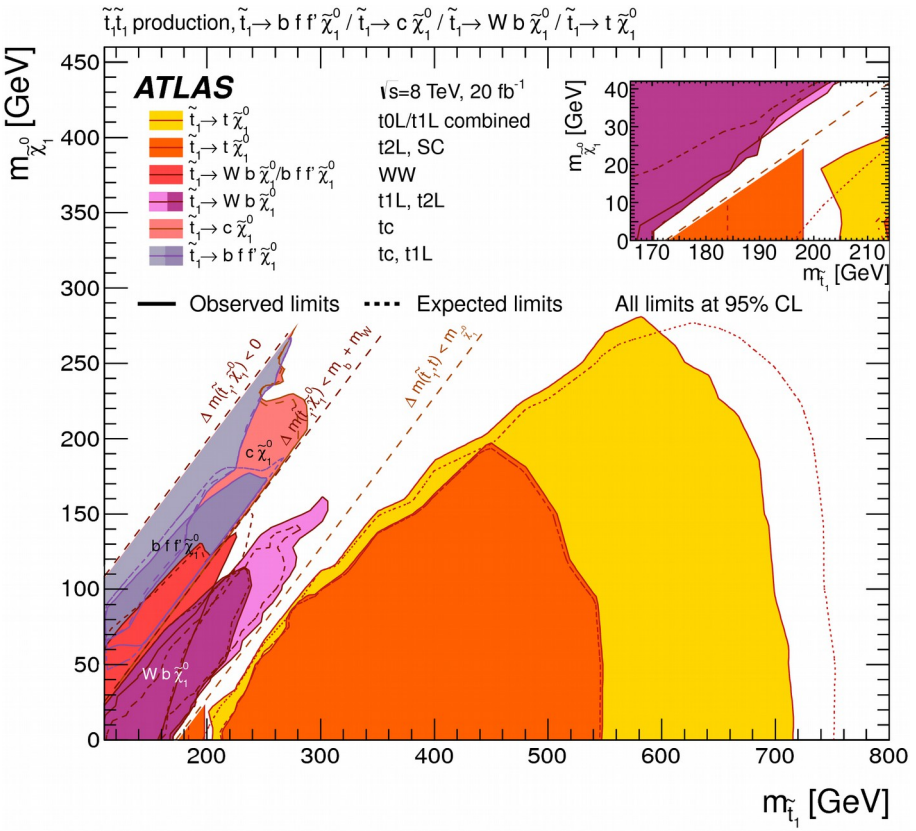


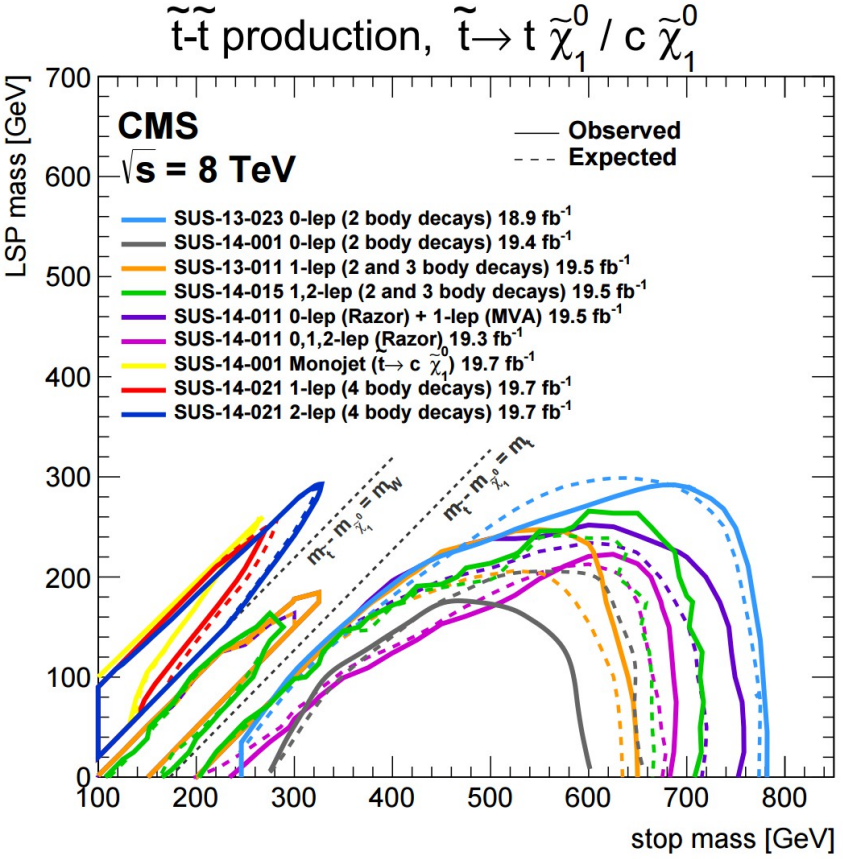


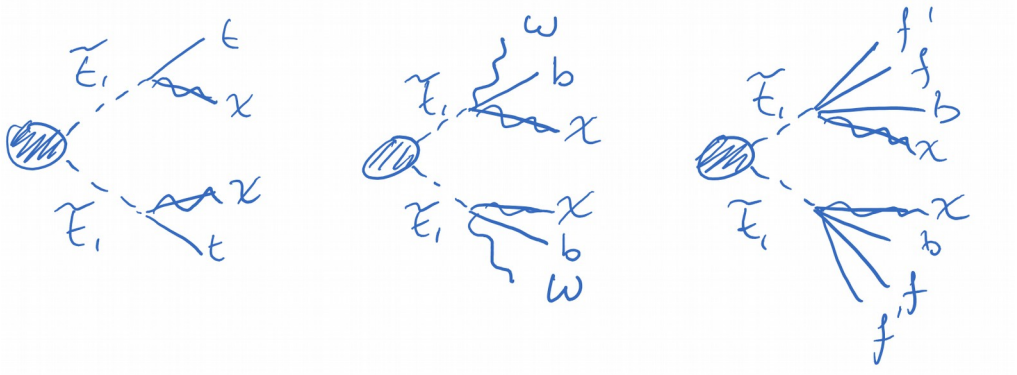
- $\tilde{t}_2 \to \tilde{t}_1 Z$ decay expected with Large $\tilde{t}_L$-$\tilde{t}_R$ Mixing from A-terms

- $\tilde{t}_1 \to t\tilde{\chi}$
  $\tilde{t}_1 \to Wb\tilde{\chi}^0$
  $\tilde{t}_1 \to ff'b\tilde{\chi}^0$
  $\tilde{t}_1 \to c\tilde{\chi}^0 / u\tilde{\chi}^0$

Light Stop Searches: Flavour Conserving



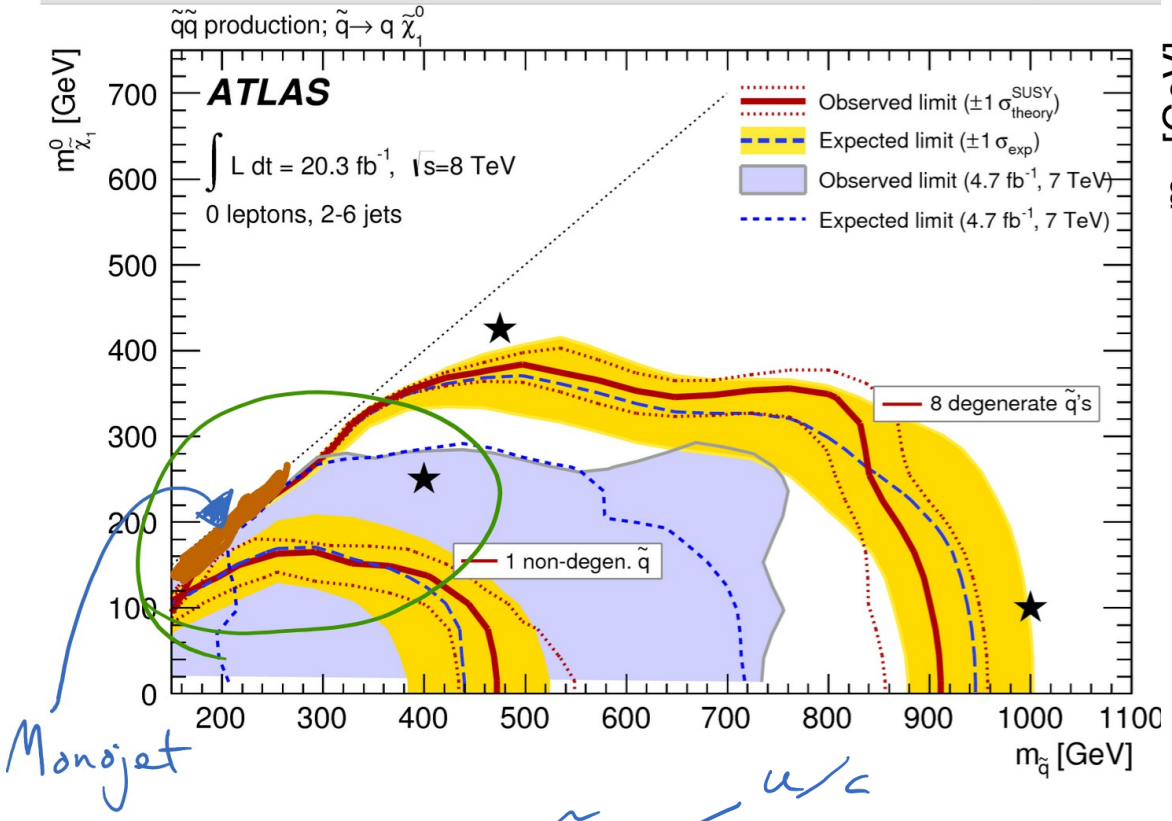




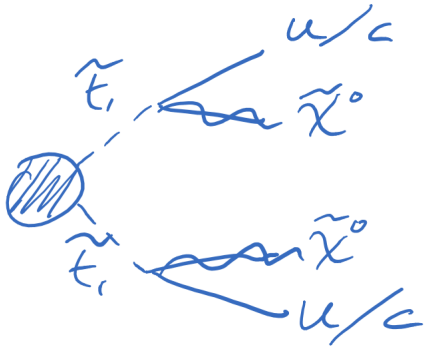
$m_{\tilde{t}_1} \gtrsim 280$ GeV (4-body regime)

Light Squark Searches (or flavour violating stop)

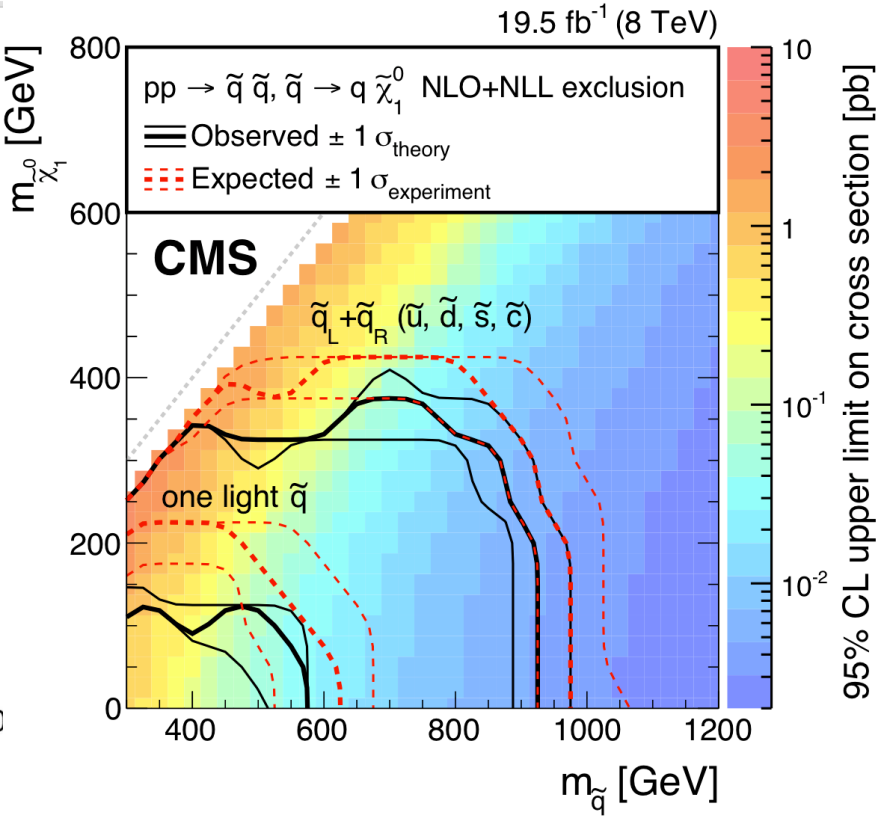
1405.7875



Monojet



1502.04358



Simplified Model Details

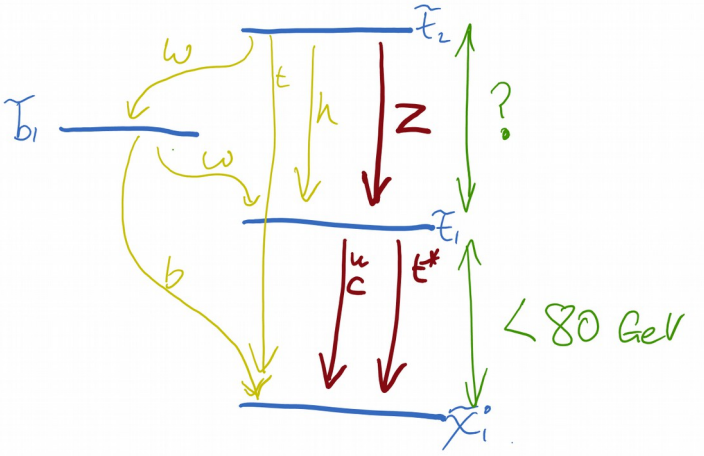
- Large $\tan\beta$, Higgs decoupling limit

Free parameters:

$m_{\tilde{t}_1}$, $m_{\tilde{t}_2}$, $\cos\theta_{\tilde{t}}$, $m_{\tilde{\chi}_1^0}$ — sets m_{b_1} & BR($t_2 \to t_1 Z$)

$$\begin{pmatrix}\tilde{t}_1\\ \tilde{t}_2\end{pmatrix} = \begin{pmatrix} c_{\theta_{\tilde{t}}} & -s^*_{\theta_{\tilde{t}}} \\ s_{\theta_{\tilde{t}}} & c_{\theta_{\tilde{t}}}\end{pmatrix}\begin{pmatrix}\tilde{t}_L\\ \tilde{t}_R\end{pmatrix}$$

$$m^2_{\tilde{b}_1} = m^2_{\tilde{t}_1} c^2_{\theta_{\tilde{t}}} + m^2_{\tilde{t}_2} s^2_{\theta_{\tilde{t}}} - m^2_t - \Delta_{\tilde{u}_L} + \Delta_{\tilde{d}_L}.$$



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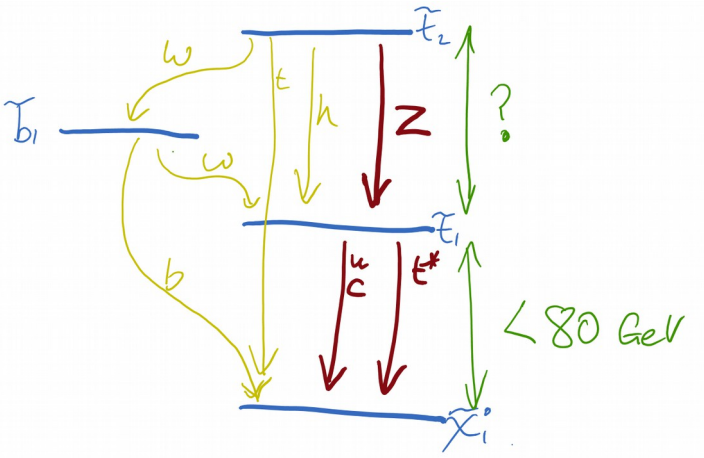
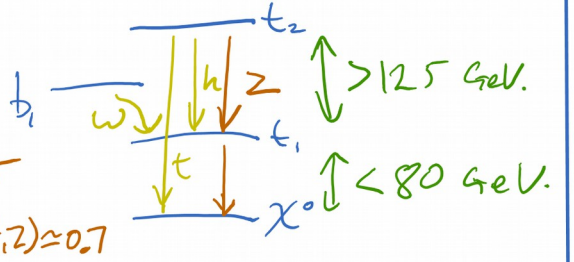
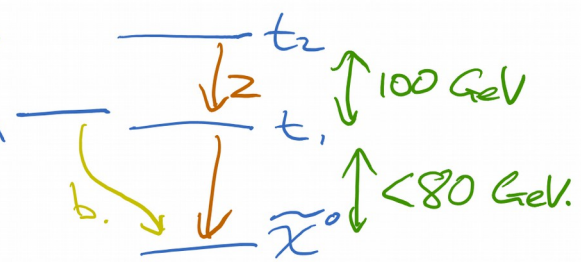
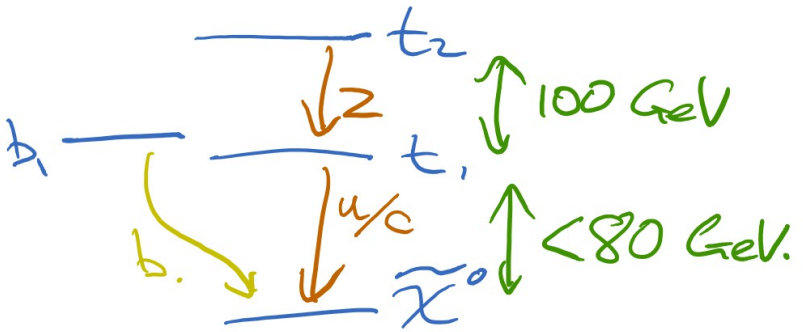
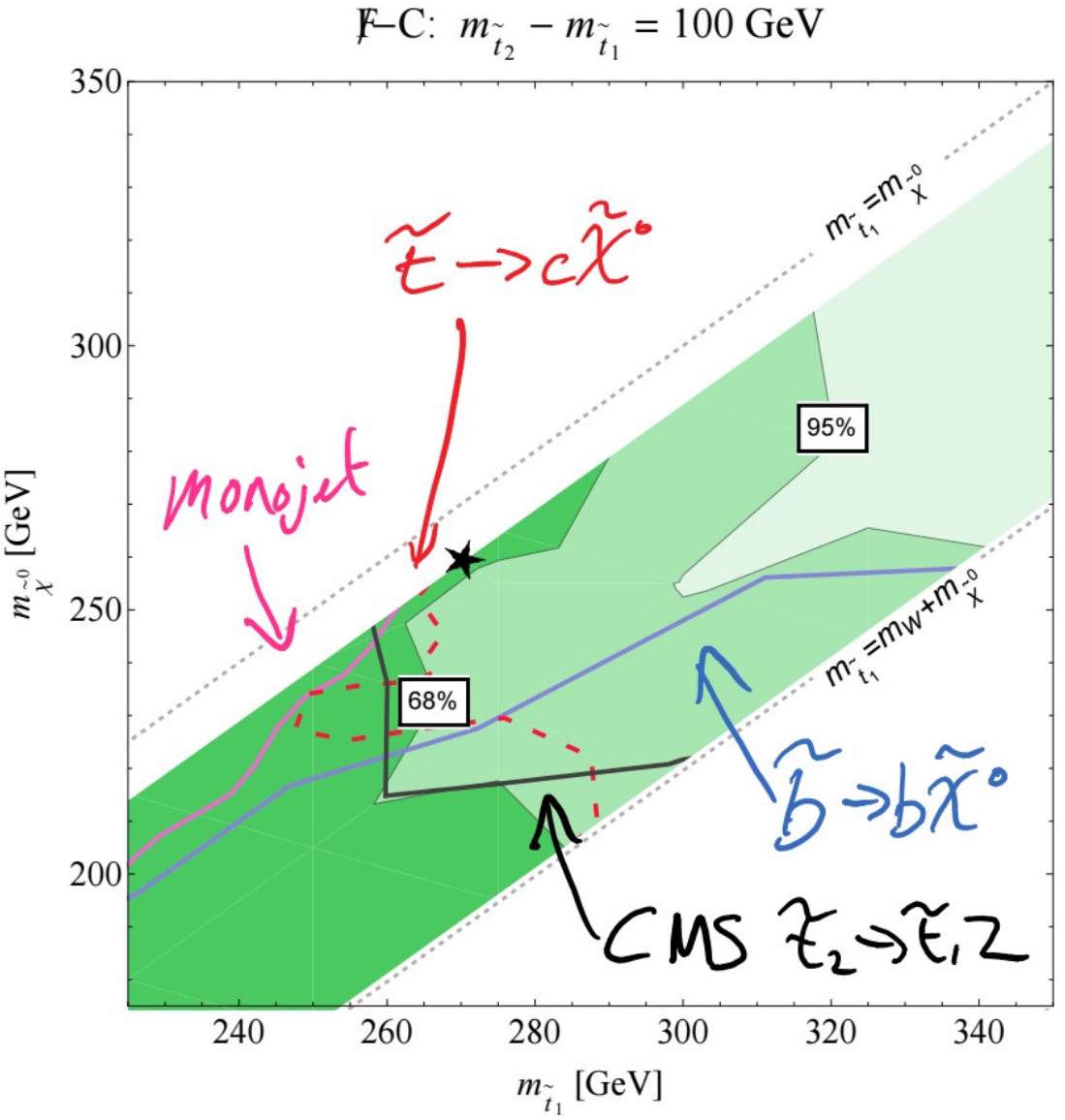


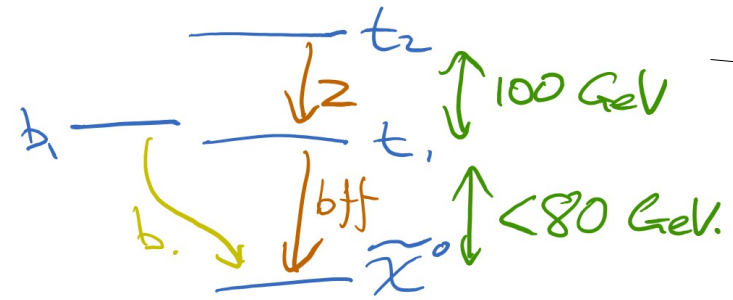
	Split:	Compressed
	 $\cos\theta_{\tilde{t}} = 0.5$ $\Rightarrow BR(t_2 \to t_1 Z) \simeq 0.7$	 $BR(t_2 \to t_1 Z \simeq 1)$ $\Rightarrow m_{b_1}$ is free.
Flavour conserving $\tilde{t}_1 \to f f' b \tilde{\chi}^0$	✗	✓
Flavour violating $\tilde{t}_1 \to u\tilde{\chi}^0 / c\tilde{\chi}^0_1$	✓	✓

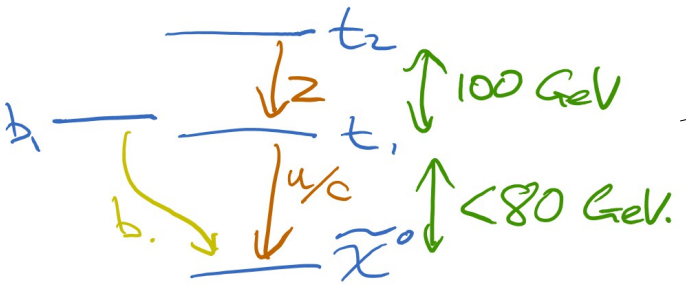
Results:
Flavour Violating, compressed t1–t2

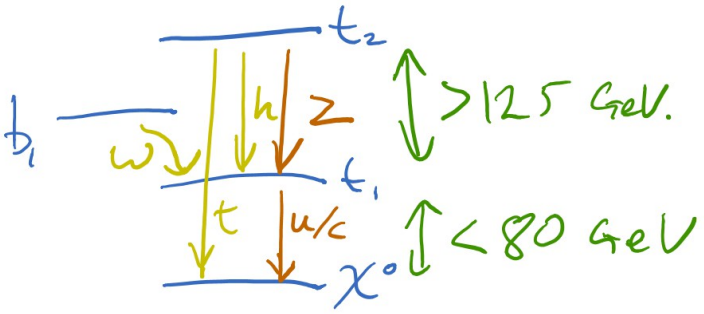


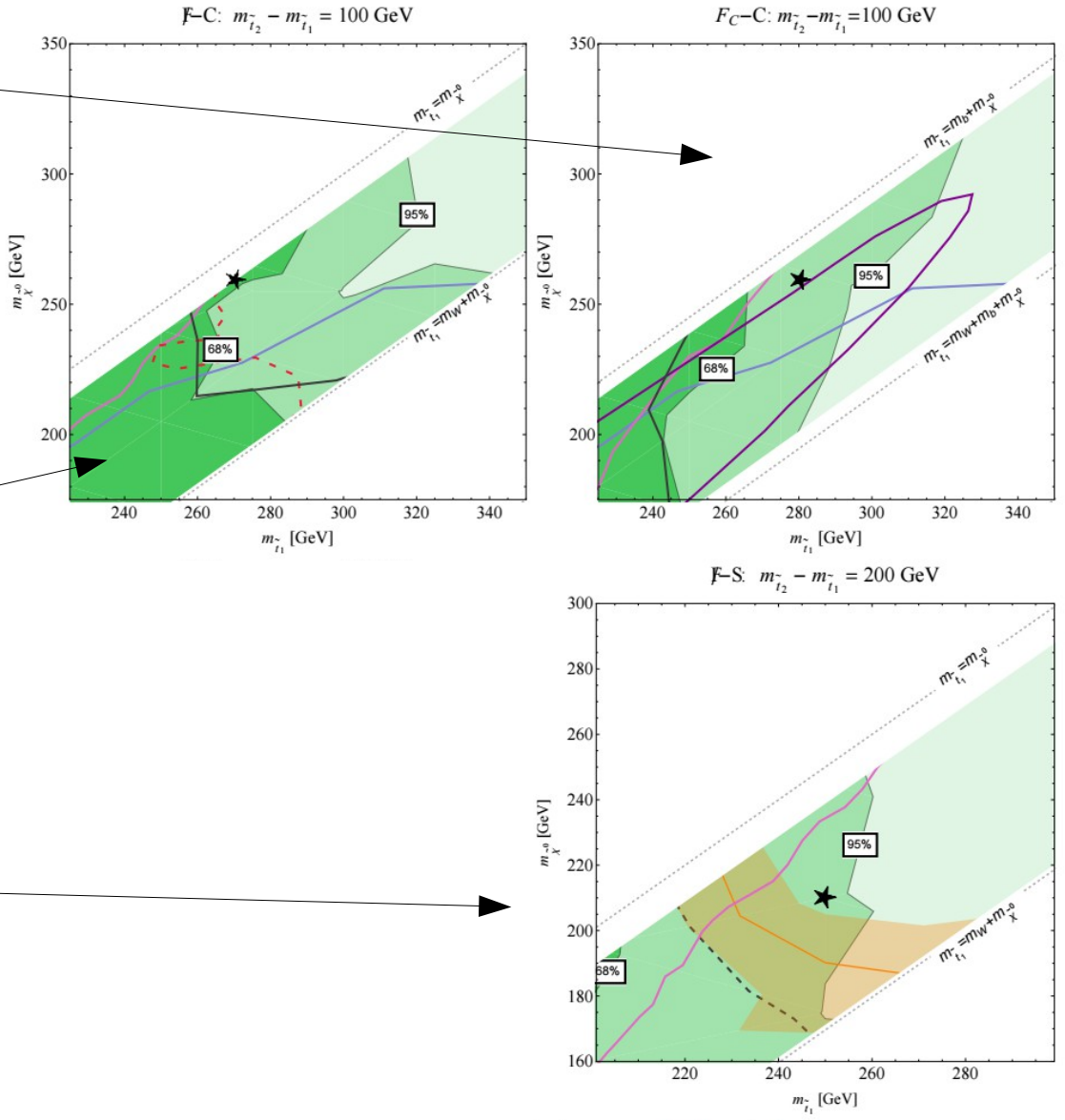


Results

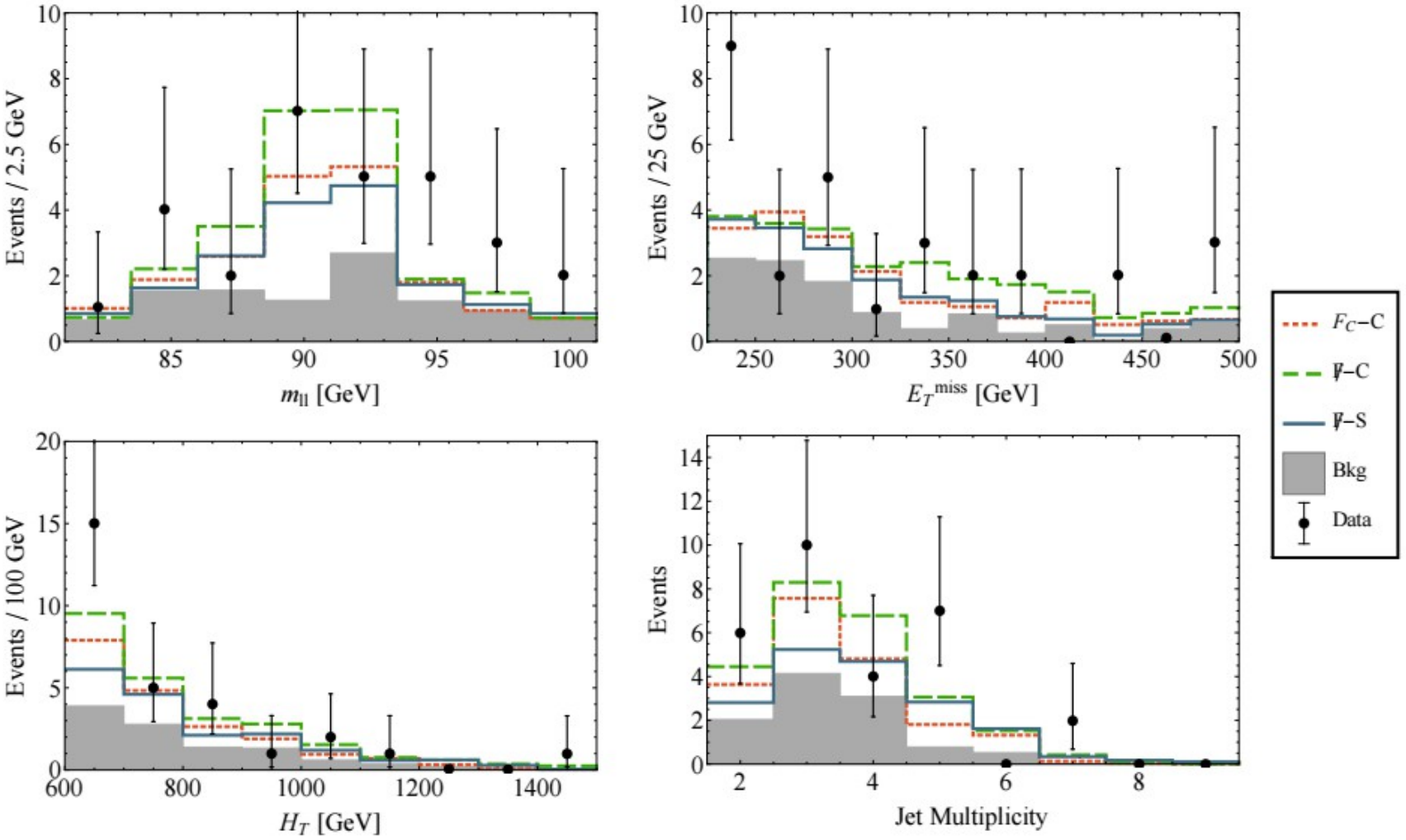

t_2
Z
100 GeV
b_1
t_1
bff
b
$\tilde{\chi}^0$
<80 GeV.


t_2
Z
100 GeV
b_1
t_1
u/c
b
$\tilde{\chi}^0$
<80 GeV.


t_2
h
Z
>125 GeV.
b_1
W
t_1
t
u/c
$\tilde{\chi}^0$
<80 GeV

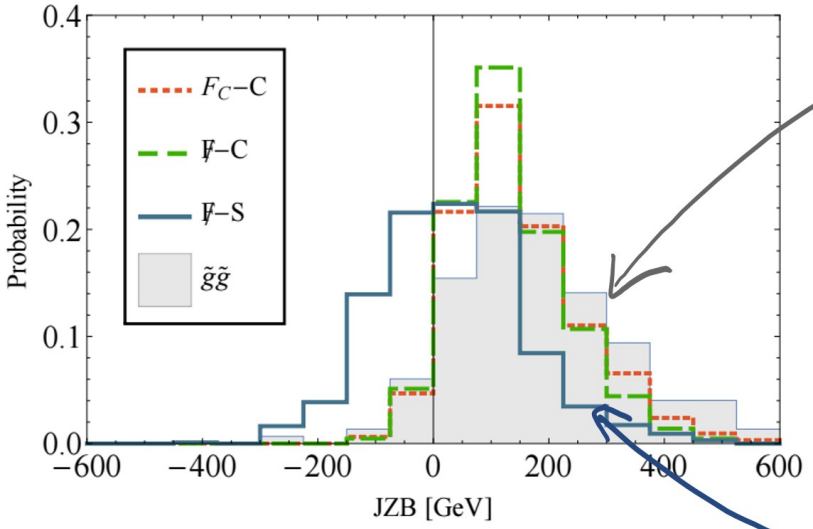

F–C: $m_{\tilde{t}_2} - m_{\tilde{t}_1} = 100$ GeV
F_C–C: $m_{\tilde{t}_2} - m_{\tilde{t}_1} = 100$ GeV
F–S: $m_{\tilde{t}_2} - m_{\tilde{t}_1} = 200$ GeV
$m_{\tilde{\chi}^0}$ [GeV]
$m_{\tilde{t}_1}$ [GeV]
$m_{\tilde{t}_1} = m_{\tilde{\chi}^0}$
$m_{\tilde{t}_1} = m_b + m_{\tilde{\chi}^0}$
$m_{\tilde{t}_1} = m_W + m_{\tilde{\chi}^0}$
$m_{\tilde{t}_1} = m_W + m_b + m_{\tilde{\chi}^0}$
68%
95%
$\tilde{b}_1 \to b\tilde{\chi}^0$
Monojet
$\tilde{t}_1 \to bff'\tilde{\chi}^0$
CMS on–Z
$\tilde{t}_1 \to c\tilde{\chi}^0$
jets+MET

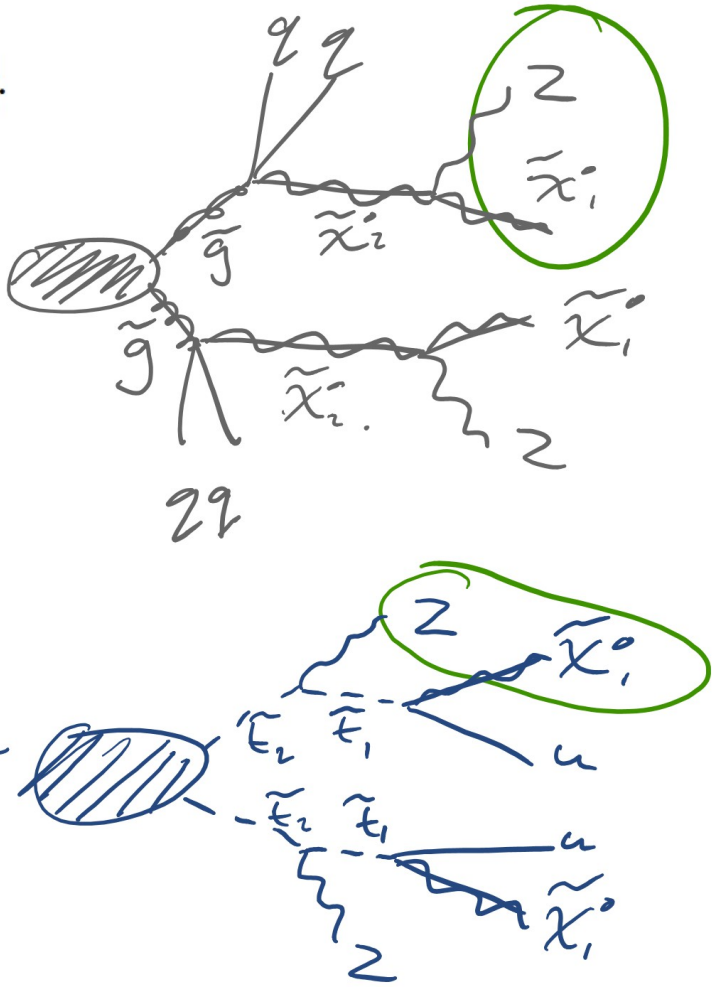
Results


Events / 2.5 GeV
m_{ll} [GeV]
Events / 25 GeV
E_T^{miss} [GeV]
Events / 100 GeV
H_T [GeV]
Events
Jet Multiplicity
F_C–C
F–C
F–S
Bkg
Data

Jet-Z Balance (JZB) and Background Contamination

$$\mathrm{JZB} \equiv \Big|\sum_{i\in\mathrm{jets}} \vec{p}_T^{\,i}\Big| - \big|\vec{p}_T^{\,(Z)}\big| = \big|\vec{E}_T^{\mathrm{miss}} + \vec{p}_T^{\,Z}\big| - \big|\vec{p}_T^{\,(Z)}\big|.$$





- $m_{\tilde{t}_2} - m_{\tilde{t}_1} \sim 100$ GeV

$\Rightarrow p_{TZ} \ll E_{Tmiss}$

$m_{\tilde{t}_2} \gg m_{\tilde{t}_1}$

$\Rightarrow \hat{p}_{TZ} \sim -\hat{E}_{Tmiss}$

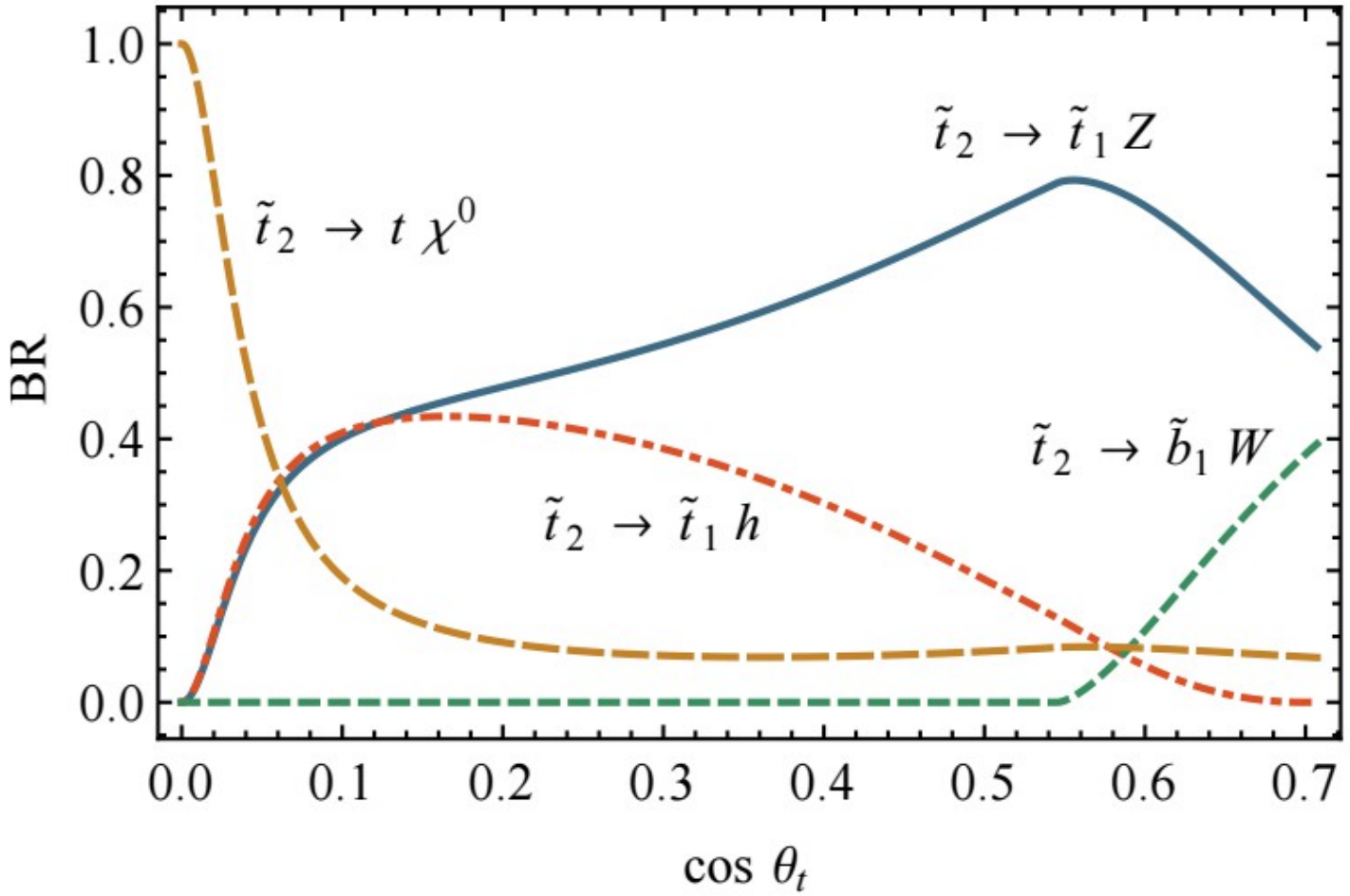
JZB: 1201.3748

Summary and Ideas

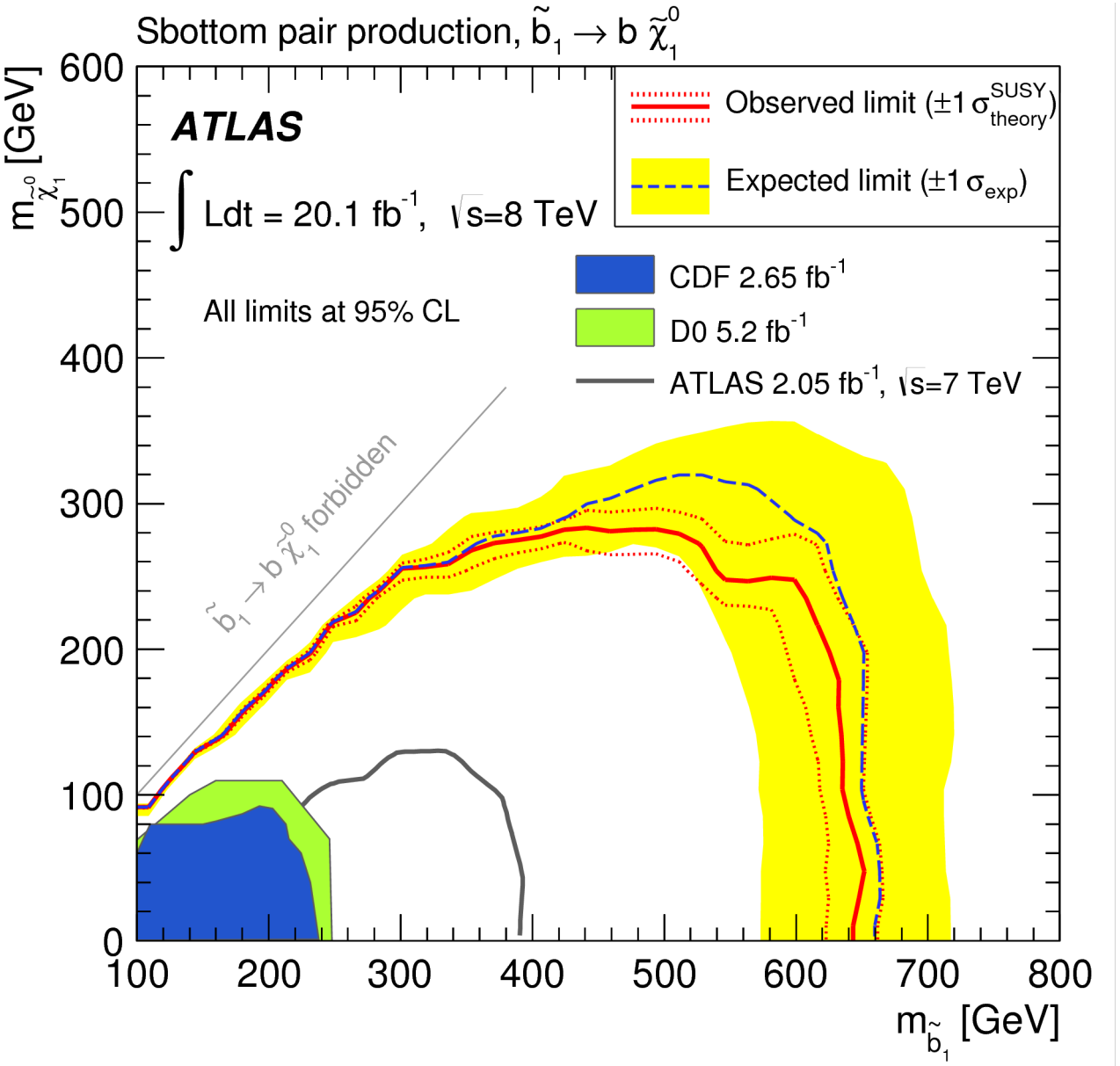
- 3σ ATLAS excess in dileptons on Z peak, jets + MET, first sign of SUSY?
- Possibly by light stops with (m_{t2}, m_{t1}, m_{χ}) ~ (370, 270, 250) GeV, with flavour-violating t1 → uχ or cχ.
- Scenarios with flavour conserving decays or a heavier t_2 are also possible, but disfavoured.
- Possibility of background contamination using JZB. JZB could also be a useful discriminator for new physics explanations.

- If the excess persists, it would be interesting to explore mixed flavour-conserving and flavour-violating decays. This could relax the mass limits by ~50 GeV (1408.4662), which would have a big impact on signal event rates.
- There are also ~2σ excesses in a search for Z → ll, jets + MET with at least one b-jet (SUS-13-008), and in same sign dileptons, jet and MET with b-jets (1507.01601). All of these are possible signatures of a SUSY spectrum containing light stops. Maybe we can explain all of them at once?
- Some BMSSM models predict also large left-right mixing in the sbottom sector. Maybe $b_2 \rightarrow b_1 Z$ can contribute to the excess too.

Auxilliary Slide 1: Split BRs



Auxilliary Slide 2: Sbottom limits



Auxilliary Slide 2: ISR uncertainties