

On LHC “excesses”

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(based on...) 1502.05712 (JHEP 1505 (2015) 133)
 1506.08803
 1507.08273

IPMU 2015

08/09

Several excesses at $> 2.5\sigma$ level are found at ATLAS, CMS and LHCb

(not exhaustive...)

CMS	1407.3683	2.8σ	$2l + 2j$	RPV SUSY?
	1502.06031	2.6σ	jets plus dilepton plus MET	SUSY?
ATLAS	1503.03290	3.0σ	jets plus on-shell Z plus MET	SUSY?
	1506.00962	3.4σ	WW/WZ/ZZ resonance at ~ 2 TeV	Z'?
LHCb-CONF-2015-002		2.9σ	$B^0 \rightarrow K^{*0} \mu^+ \mu^-$	??

Several excesses at $> 2.5\sigma$ level are found at ATLAS, CMS and LHCb

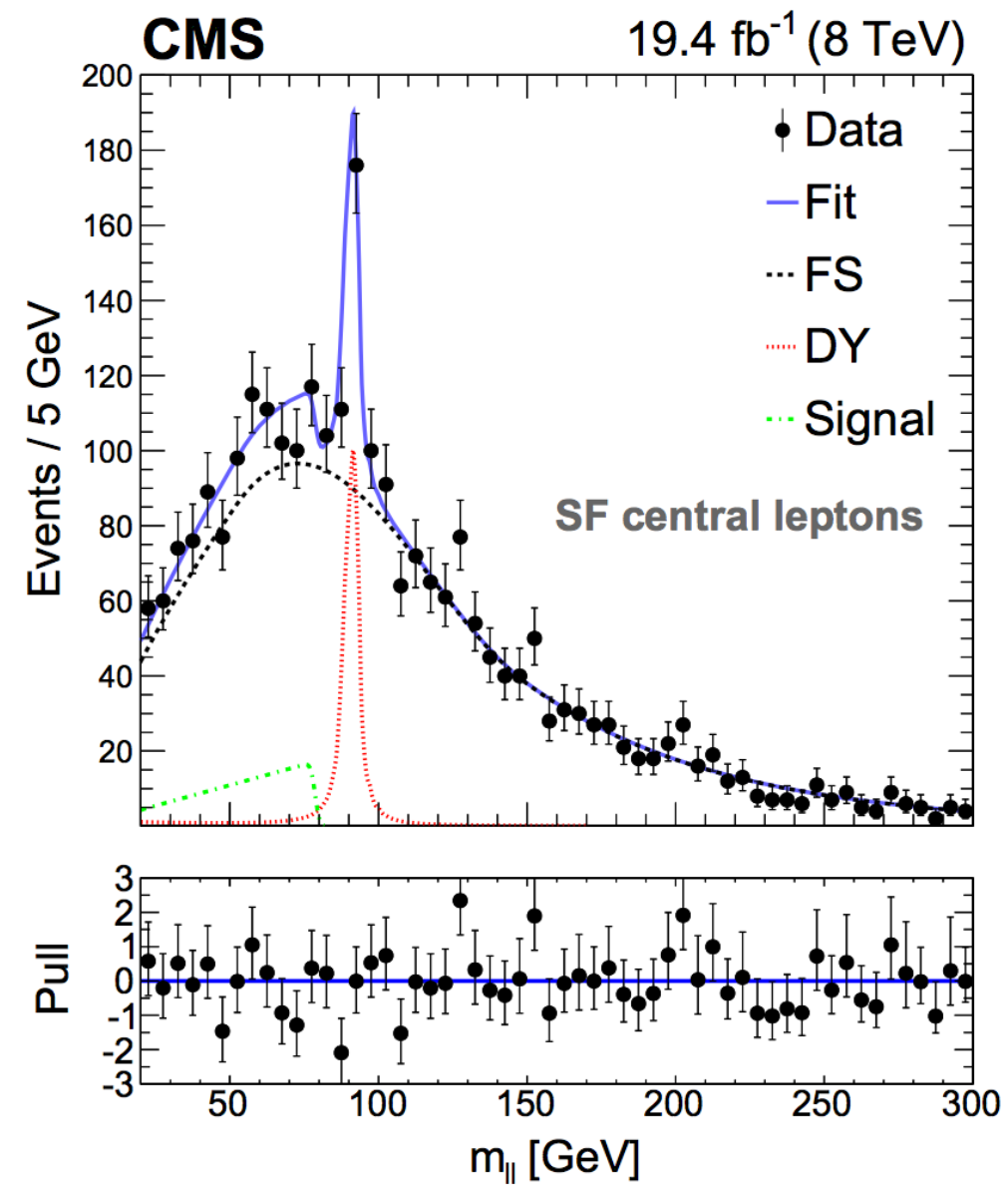
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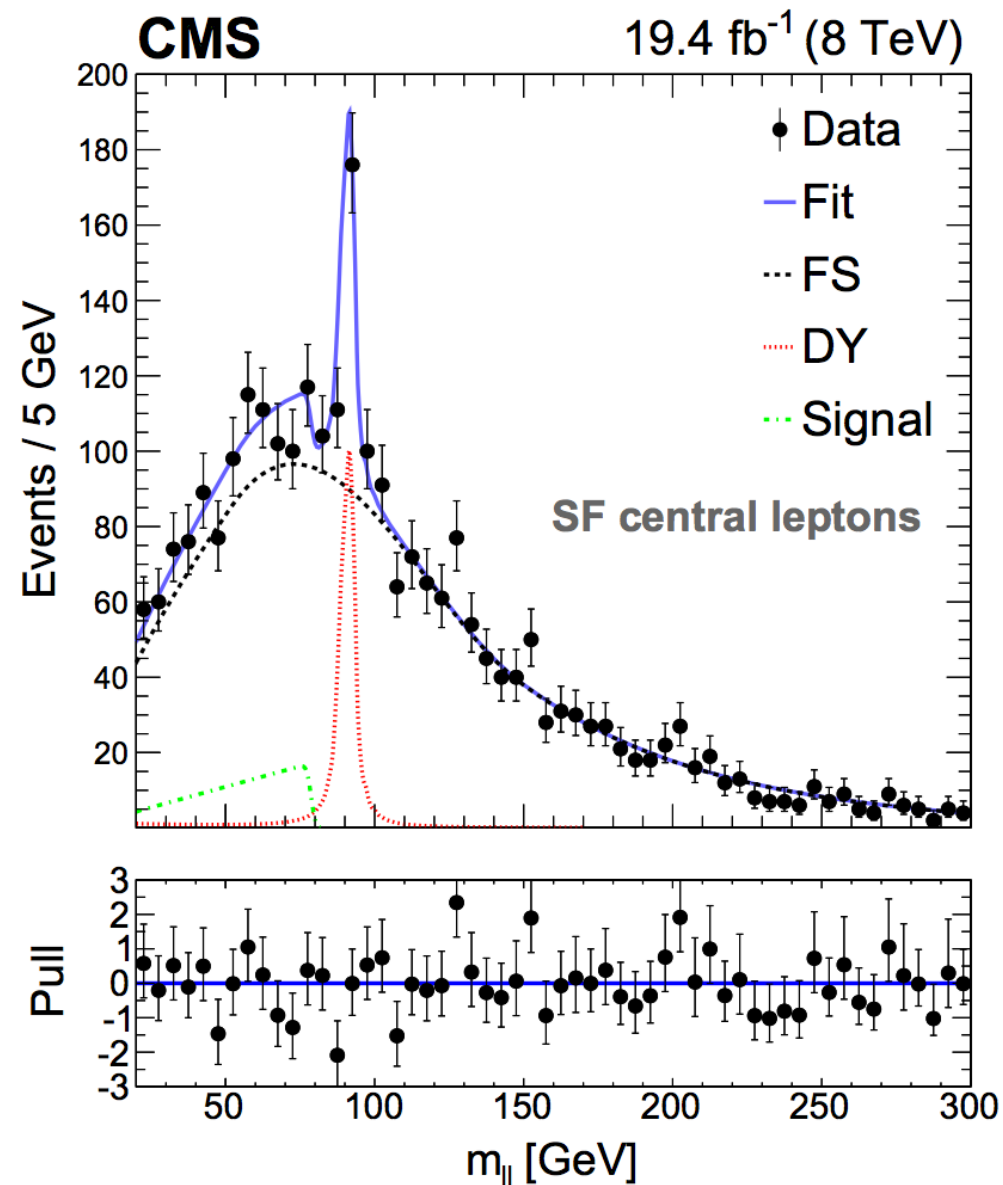
SUSY interpretations

new proposal to test the excess

CMS jets plus l^+l^- plus MET search (1502.06031)



CMS jets plus l^+l^- plus MET search (1502.06031)



opposite-sign same-flavor (OSSF) leptons are looked for
 e^+e^- or $\mu^+\mu^-$

est. bkg: 730 ± 40 events

observed: 860

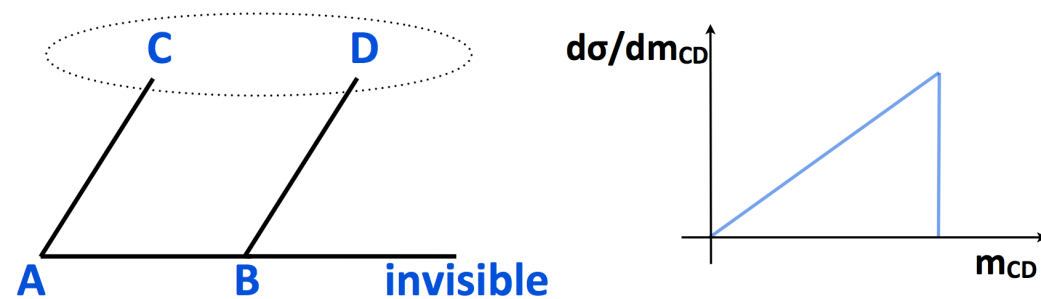
an excess of 130^{+48}_{-49} events

can be interpreted as a
triangular “edge” peaked at

$$m_{l^+l^-} = 78.7 \text{ GeV}$$

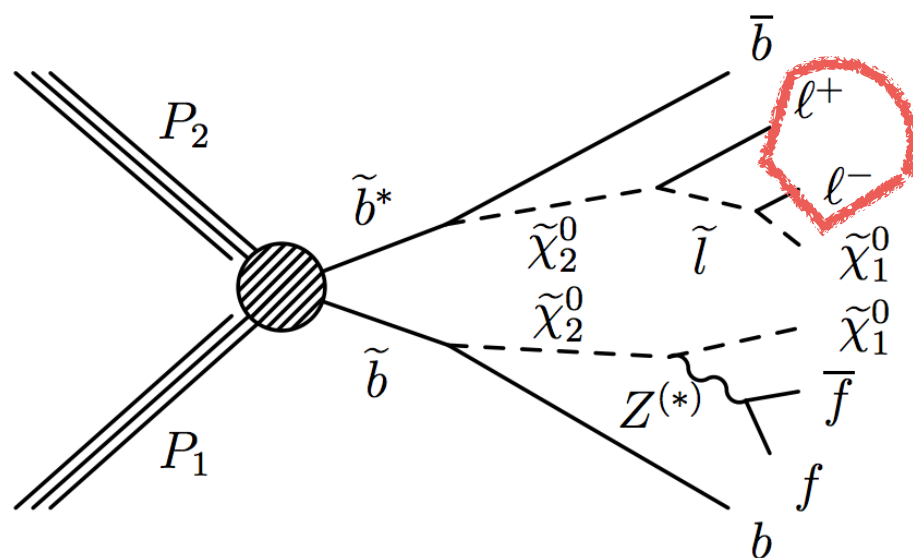
*the excess is found to be accompanied by b-tagged jets

Kinematical edge as a classical signature of SUSY



Theofilatos's slide (ICNFP 2014)

Cascade decay of SUSY particle



jets plus dilepton plus MET

Kinematic edge is formed via decays mediated by slepton

$$\tilde{\chi}_2^0 \rightarrow \tilde{\ell}^\pm \ell^\mp \rightarrow \ell^\pm \ell^\mp \tilde{\chi}_1^0,$$

or a Z or Higgs boson

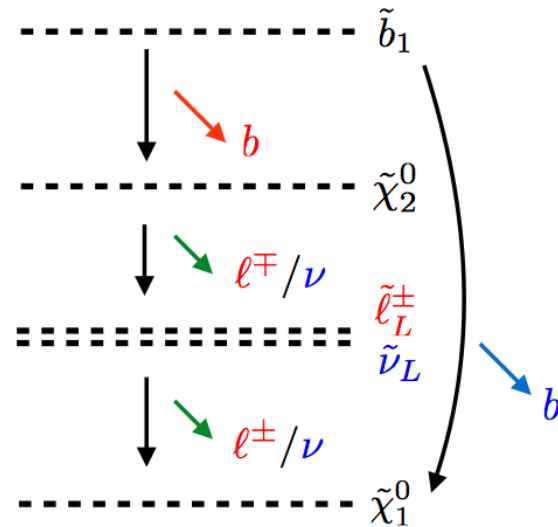
$$\tilde{\chi}_2^0 \rightarrow \ell^\pm \ell^\mp \tilde{\chi}_1^0,$$

SUSY interpretations (sbottom cascade decay)

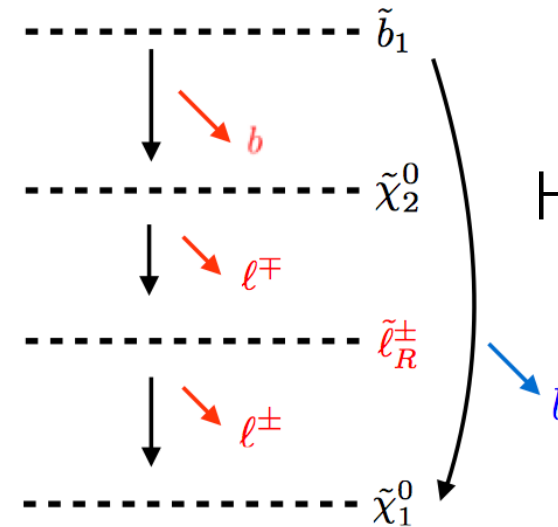
1502.05712

wino-like neutralino
left-handed slepton
(bino LSP)

$$BR(\tilde{b}_1 \rightarrow b + \tilde{\chi}_2^0/\tilde{\chi}_1^0) = 50/50\%$$

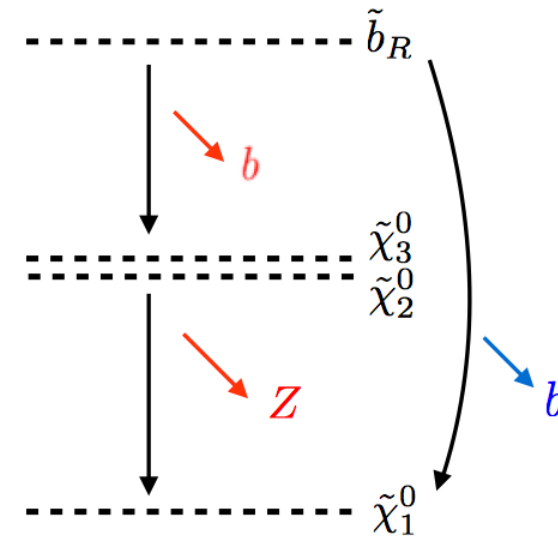


$$BR(\tilde{b}_1 \rightarrow b + \tilde{\chi}_2^0/\tilde{\chi}_1^0) = 30/70\%$$



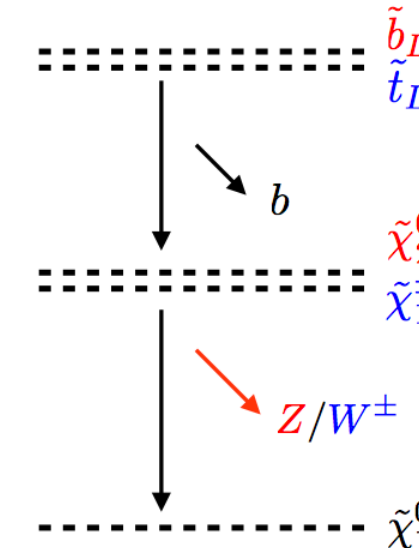
Higgsino-like neutralino
right-handed slepton
(bino LSP)

$$BR(\tilde{b}_R \rightarrow b + \tilde{\chi}_3^0/\tilde{\chi}_2^0/\tilde{\chi}_1^0) \text{ calculated}$$



Higgsino-like neutralino
(bino LSP)

$$BR(\tilde{b}_L \rightarrow b + \tilde{\chi}_2^0) = 100\% \\ BR(\tilde{t}_L \rightarrow b + \tilde{\chi}_1^\pm) = 100\%$$



wino-like neutralino
(bino LSP)

m_{l+l-} peaked at

$$m_{\text{edge}} = m_{\tilde{\chi}_2^0} \sqrt{\left(1 - \frac{m_{\tilde{\ell}}^2}{m_{\tilde{\chi}_2^0}^2}\right) \left(1 - \frac{m_{\tilde{\chi}_1^0}^2}{m_{\tilde{\ell}}^2}\right)} : \quad \tilde{\chi}_2^0 \rightarrow \tilde{\ell}^\pm \ell^\mp \rightarrow \ell^\pm \ell^\mp \tilde{\chi}_1^0, \\ m_{\text{edge}} = m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0} : \quad \tilde{\chi}_2^0 \rightarrow \ell^\pm \ell^\mp \tilde{\chi}_1^0,$$

Testing the excess with other LHC searches

1502.05712

channel	search for	arXiv or CONF-ID	refs
$2-6j + 0\ell + \cancel{E}_T$	$\tilde{q}, \tilde{g}$	ATLAS-CONF-2013-047 1405.7875	[18] [19]
$2b + 0\ell + \cancel{E}_T$	$\tilde{t}, \tilde{b}$	1308.2631	[20]
$4j + 1\ell + \cancel{E}_T$	$\tilde{t}$	ATLAS-CONF-2013-037	[21]
$\geq 2j + \geq 1\ell + \cancel{E}_T$	$\tilde{q}, \tilde{g}$ (1 or 2 ℓ)	ATLAS-CONF-2013-062	[22]
$2j + 2\ell + \cancel{E}_T$	dilepton edge	CMS-PAS-SUS-12-019	[1, 2]
$2j + \ell^\pm \ell^\pm + \cancel{E}_T$	$\tilde{q}, \tilde{g}, \tilde{t}, \tilde{b}$ (SS lepton)	ATLAS-CONF-2013-007	[23]
$2j + 2\ell + \cancel{E}_T$	$\tilde{t}(2\ell)$	ATLAS-CONF-2013-048 1403.4853	[24] [25]
$2, 3\ell + \cancel{E}_T$	$\tilde{\chi}^\pm, \tilde{\chi}^0, \tilde{\ell}$	1404.2500 1405.7570	[26] [27]
$3\ell + \cancel{E}_T$	$\tilde{\chi}^\pm, \tilde{\chi}^0$	1402.7029	[28]
$\geq 3\ell + \cancel{E}_T$	$\tilde{\chi}^\pm, \tilde{\chi}^0$	CMS-PAS-SUS-13-002	[10]

dibottom +MET search

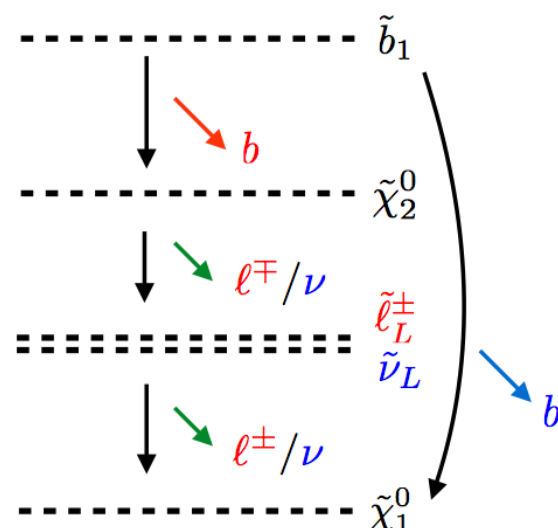
stop search

particularly constraining

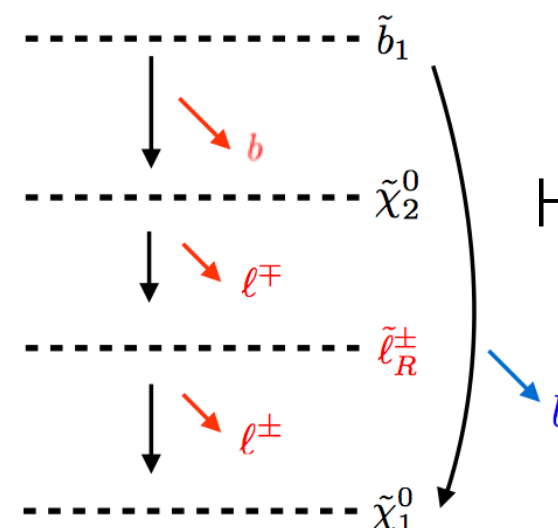
$$BR(\tilde{b}_1 \rightarrow b + \tilde{\chi}_2^0/\tilde{\chi}_1^0) = 50/50\%$$

$$BR(\tilde{b}_1 \rightarrow b + \tilde{\chi}_2^0/\tilde{\chi}_1^0) = 30/70\%$$

wino-like neutralino
left-handed slepton
(bino LSP)

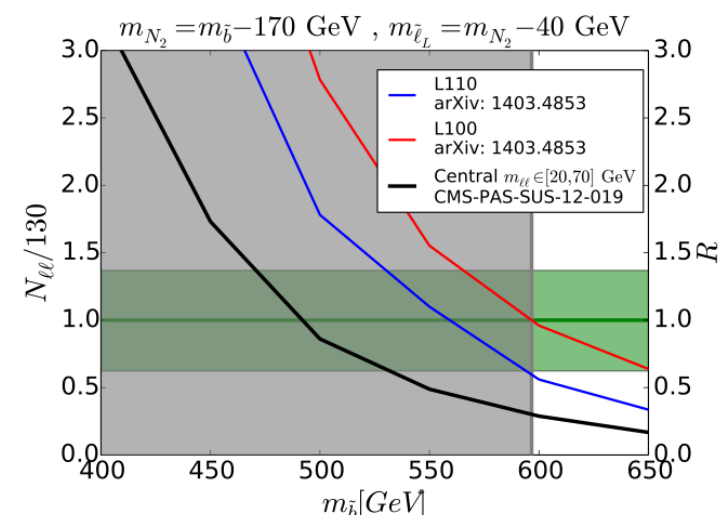
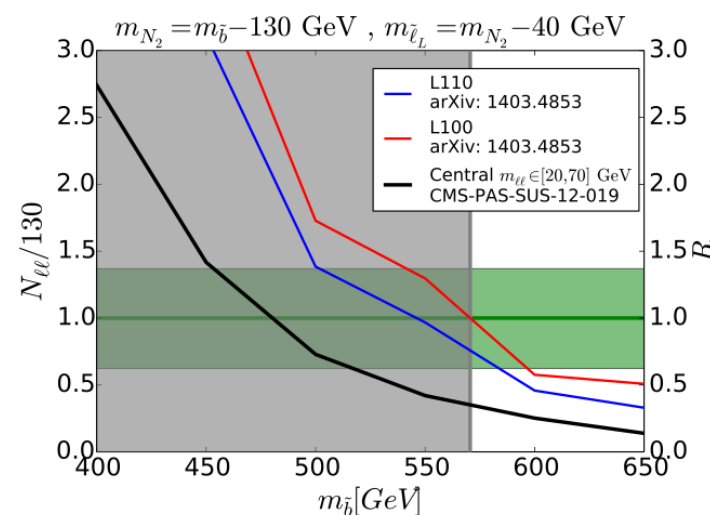
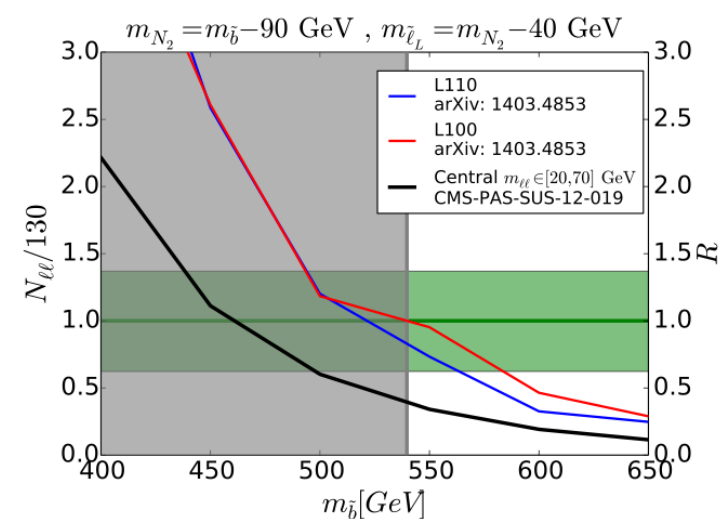
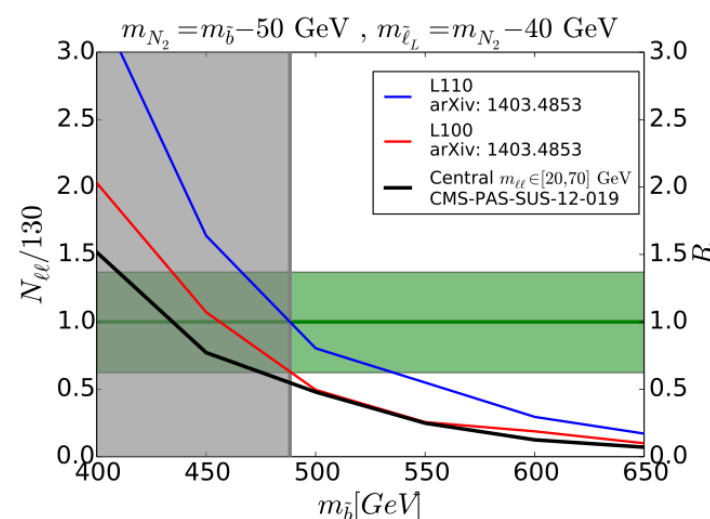


Higgsino-like neutralino
right-handed slepton
(bino LSP)



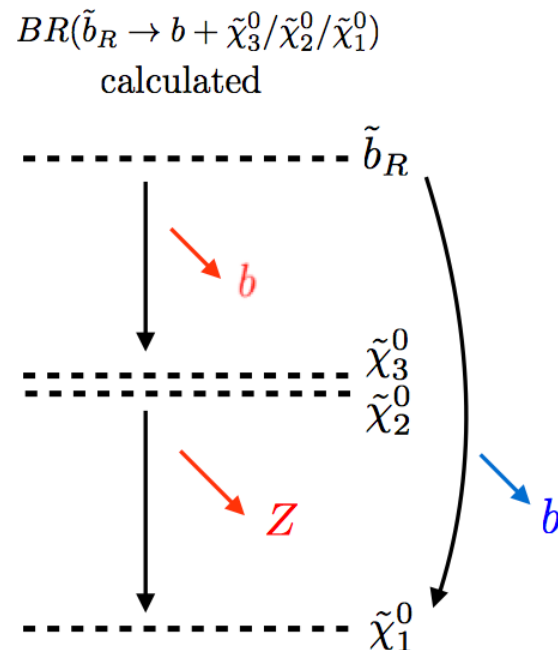
constrained by
stop search
looking for
identical final
states:

$$2j + 2\ell + \cancel{E}_T$$



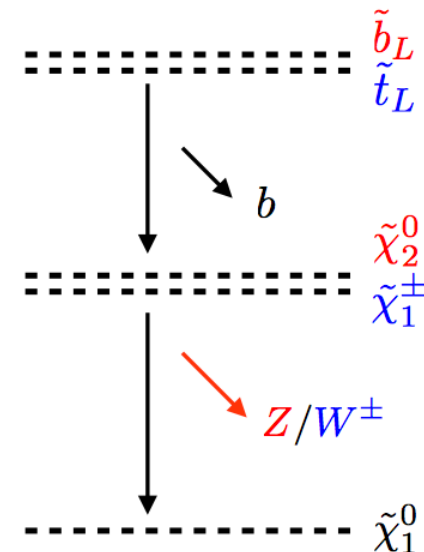
Higgsino-like neutralino

(bino LSP)



$$BR(\tilde{b}_L \rightarrow b + \tilde{\chi}_2^0) = 100\%$$

$$BR(\tilde{t}_L \rightarrow b + \tilde{\chi}_1^\pm) = 100\%$$



wino-like neutralino

(bino LSP)

requires

$$Br(\tilde{b} \rightarrow \tilde{\chi}_2/\tilde{\chi}_3) \gtrsim 80\%$$

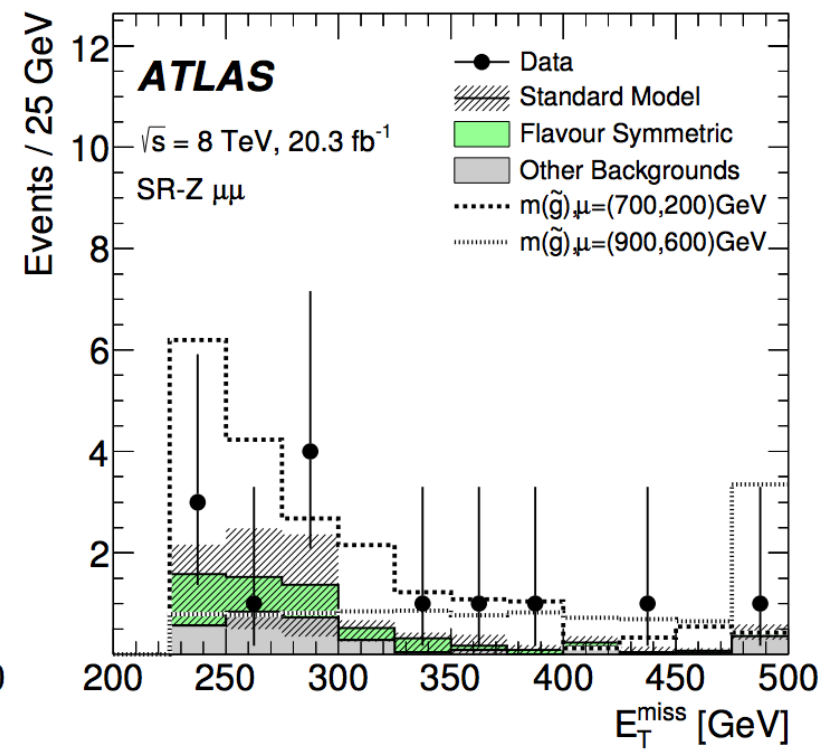
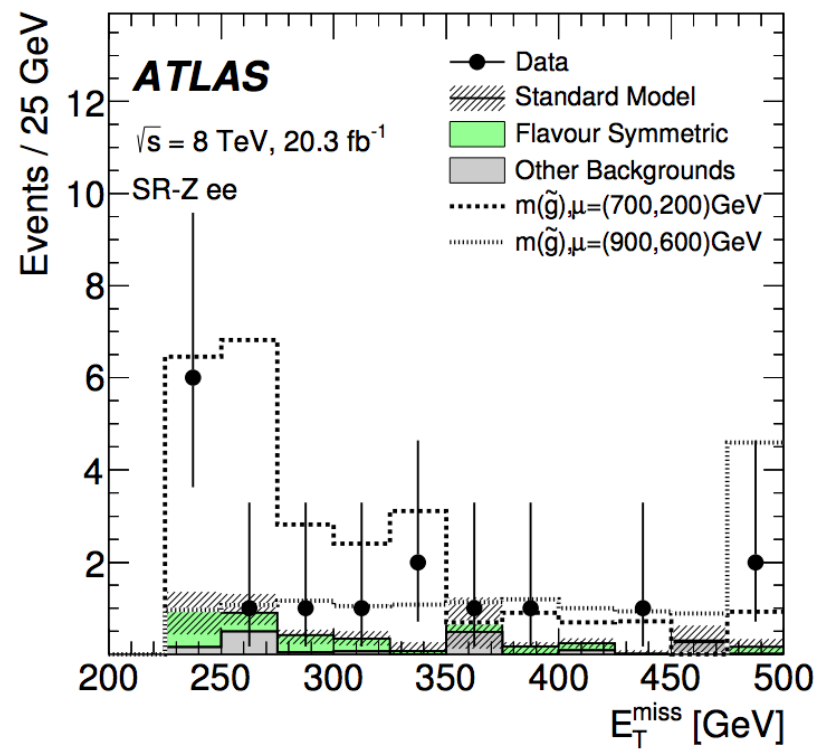
otherwise, this scenario is
constrained by dibottom + MET
search

constrained by
stop search

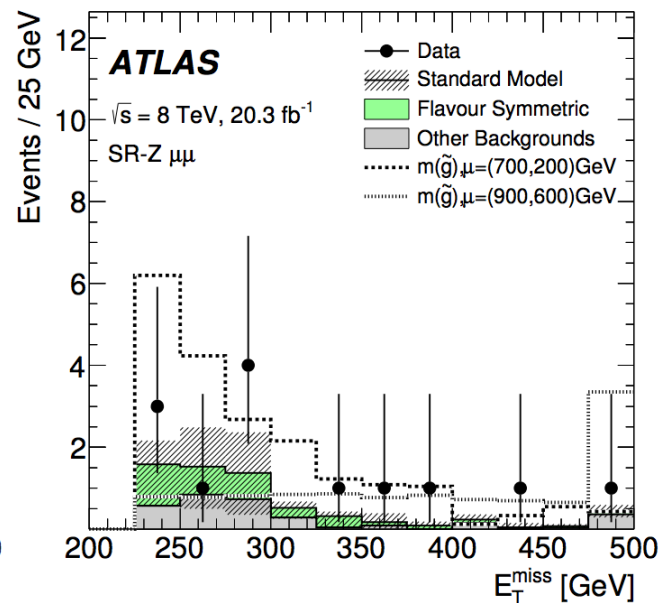
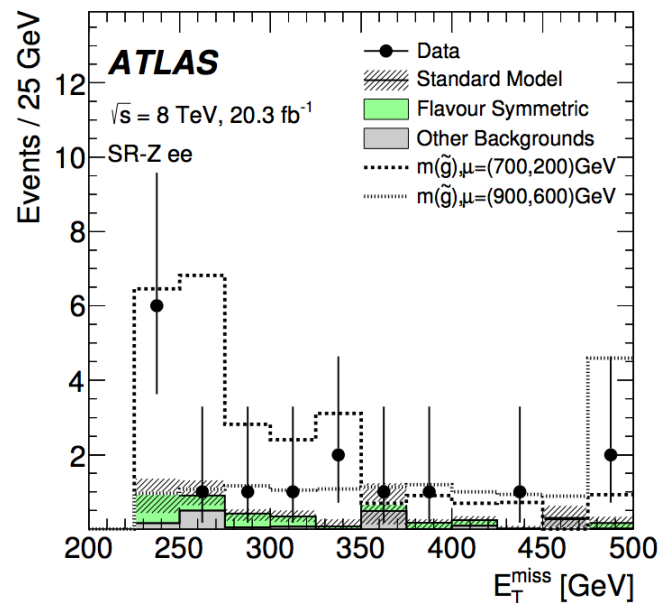
$$\tilde{t} \rightarrow W^{(*)}b$$

We do not find suitable MSSM scenario to explain the excess

ATLAS jets plus on-Z leptons plus MET search (1503.03290)



ATLAS jets plus on-Z leptons plus MET search (1503.03290)



est. bkg: 10.6 ± 3.2 events
 observed: 29

interpreted with GMSB models in the paper

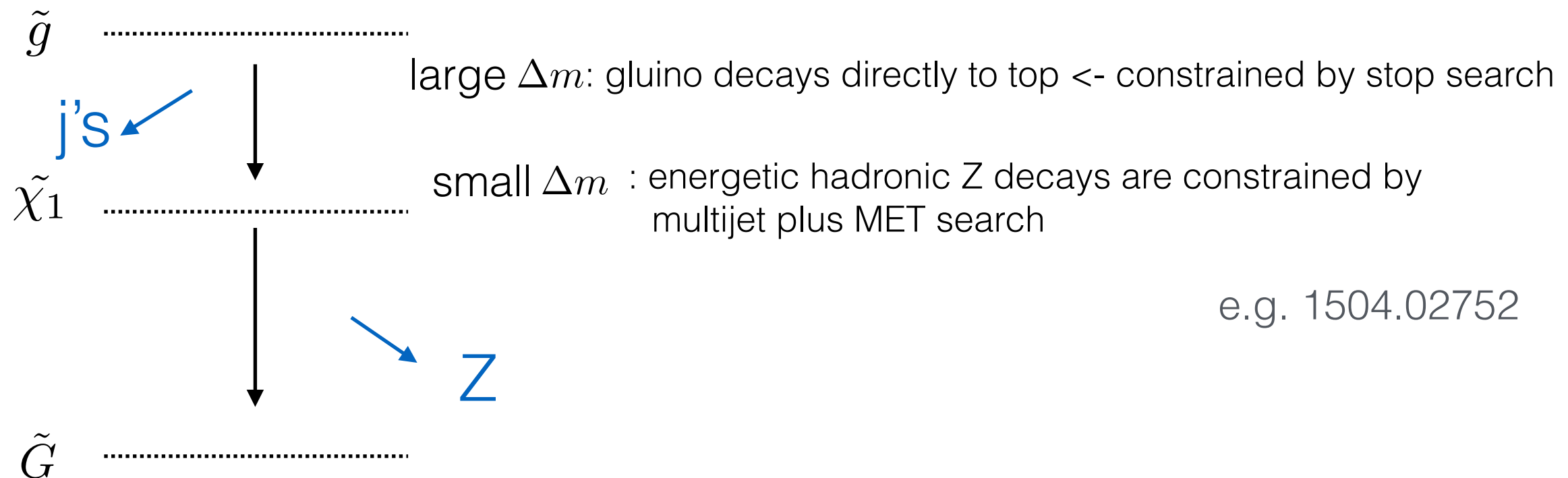
$$\tilde{g} \rightarrow jj\tilde{\chi} \rightarrow jj\tilde{G} + Z$$

gluino

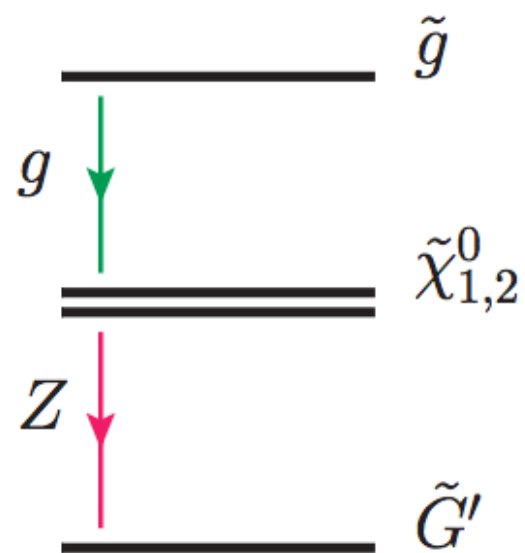
Higgsino

gravitino

GMSB models are constrained by other LHC searches

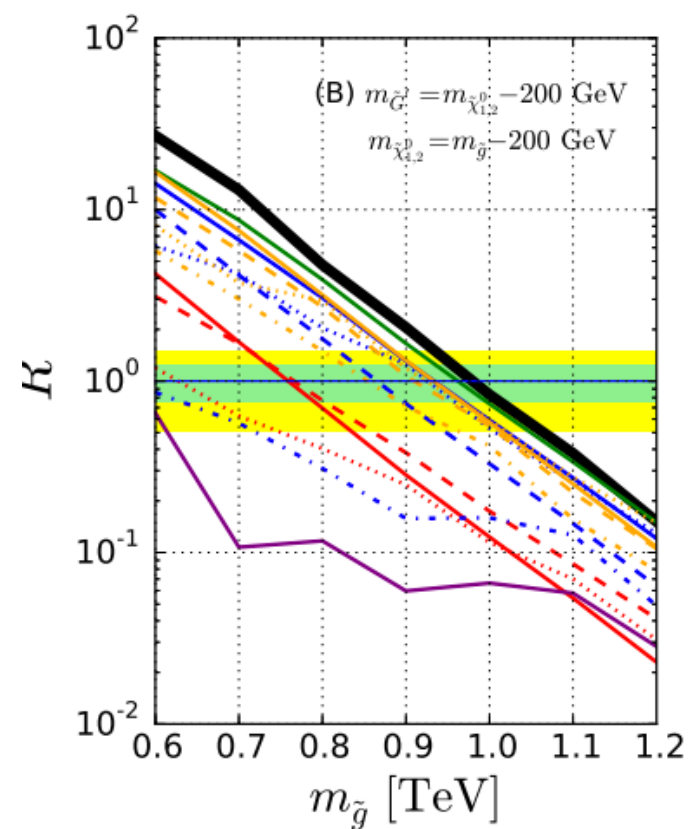


A rather compressed mass spectrum is required to avoid these constraints

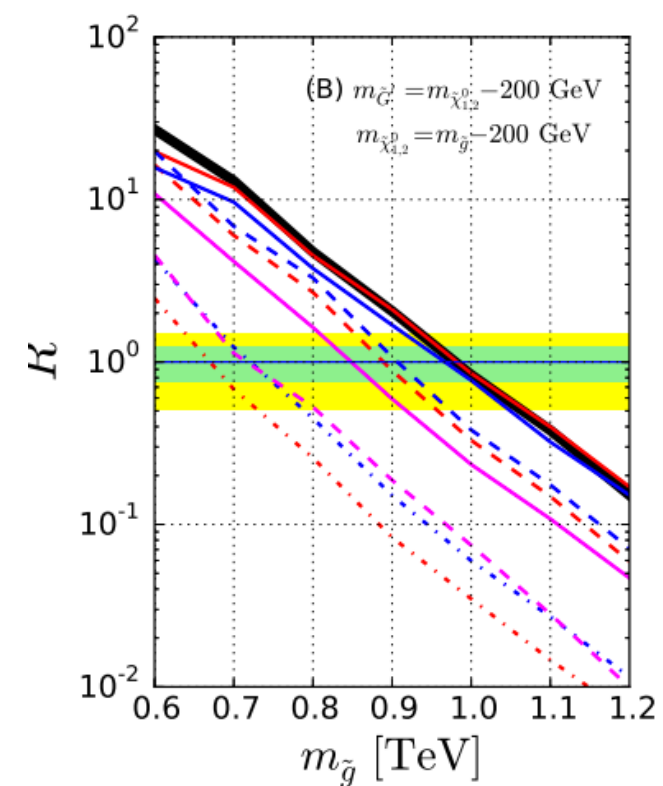


small Δm usually leads to gluino two-body decay to gluon due to large top Yukawa coupling

Singlino/goldstino



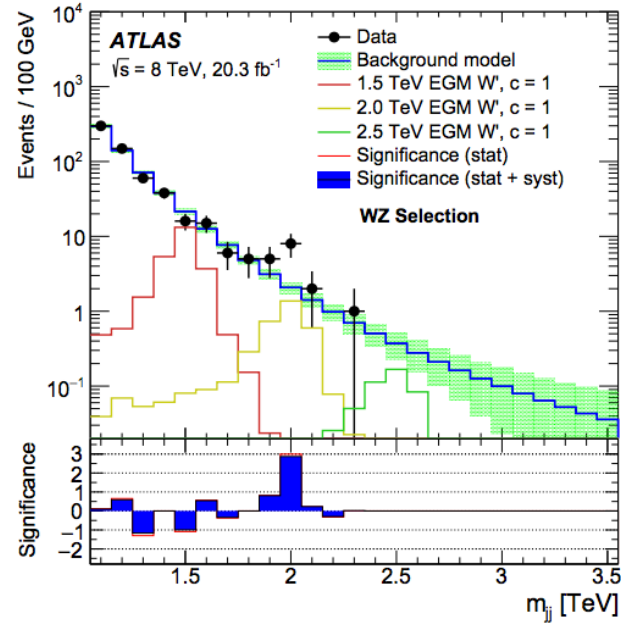
multijet constraints



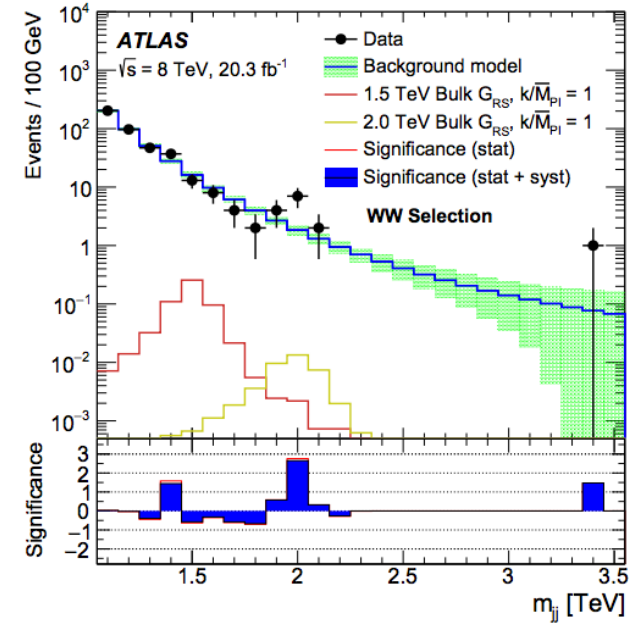
CMS on-Z constraints

marginally allowed by other LHC searches

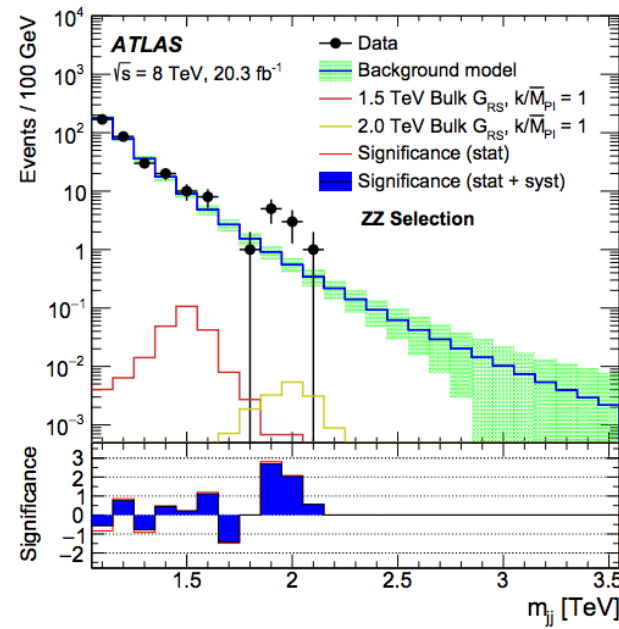
ATLAS diboson excess (1506.00962)



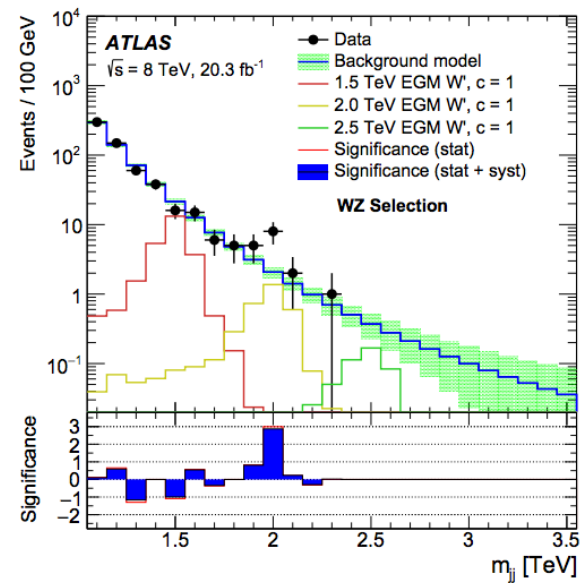
(a)



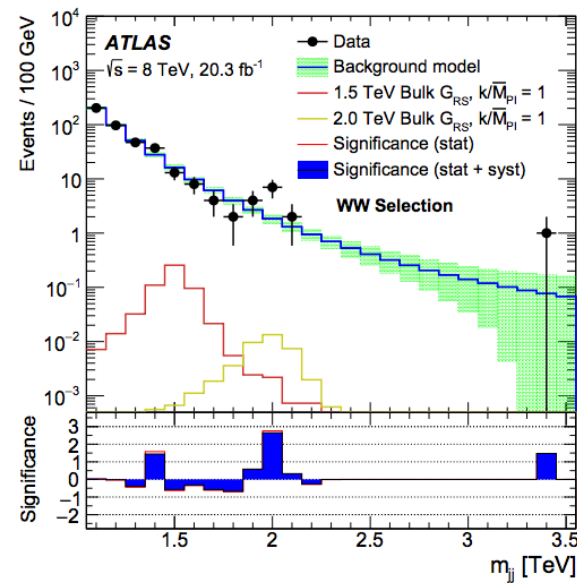
(b)



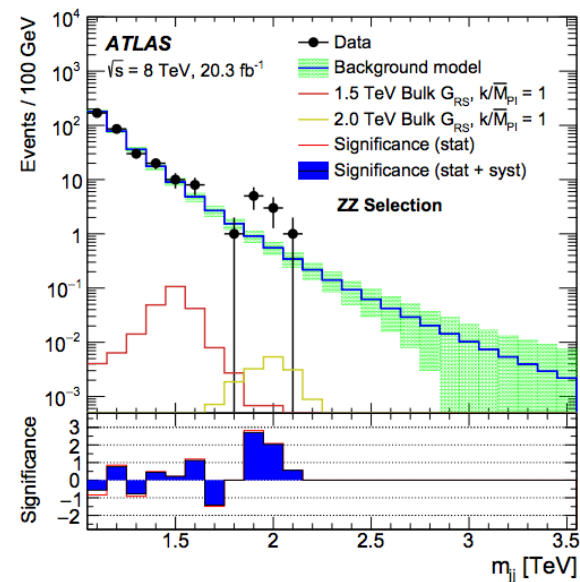
ATLAS diboson excess (1506.00962)



(a)



(b)



$$pp \rightarrow X \rightarrow JJ$$

ATLAS looks for **fat jets** with mass approximately the same as W or Z boson

Excesses are seen in WW,ZZ,WZ channels for resonance mass around 2 TeV

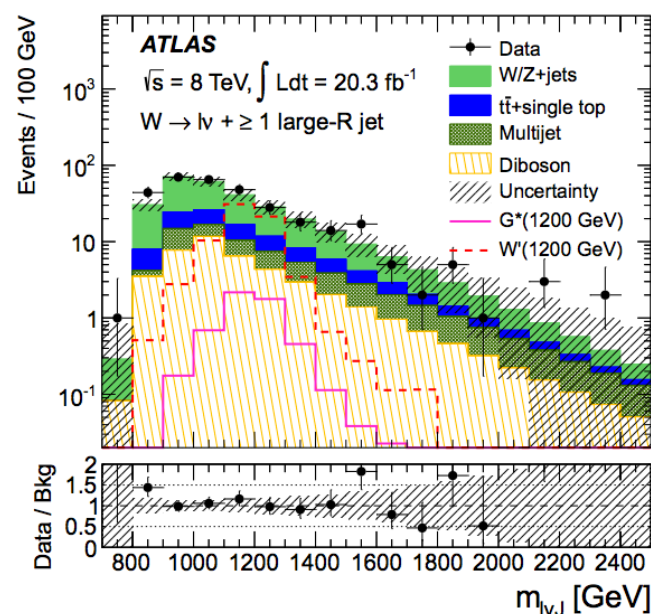
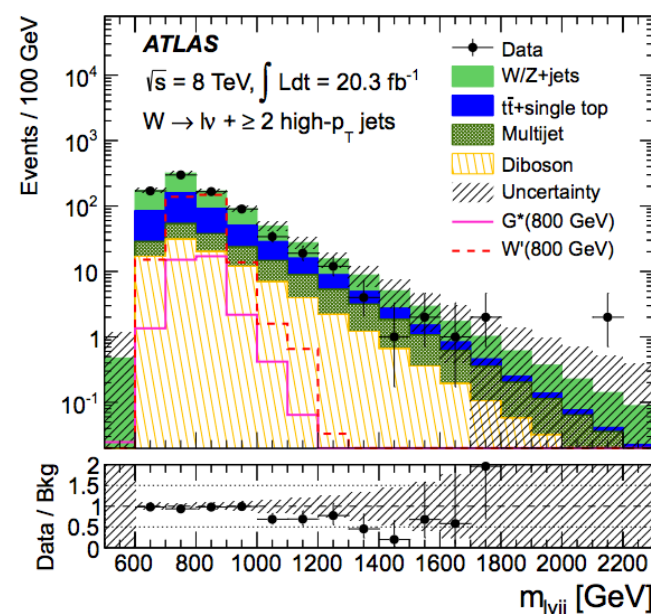
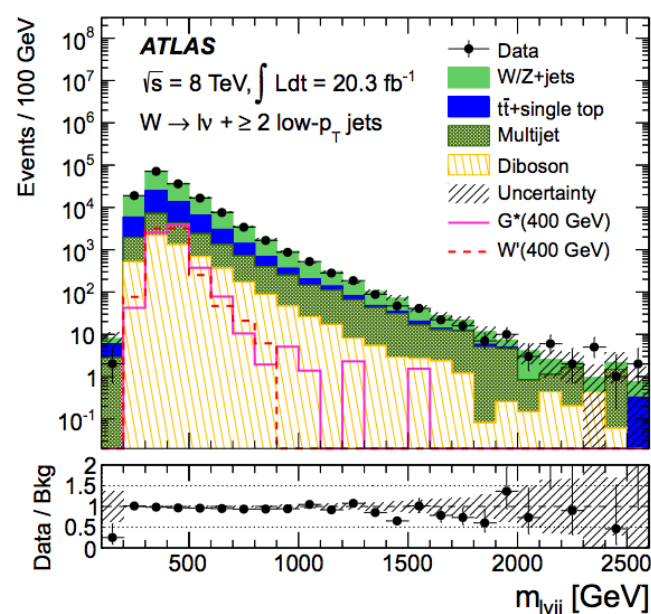
see today's talks for NP interpretations

Excesses are only observed in the hadronic channels

$$W \rightarrow jj, l\nu$$

a variety of final states is expected

$$Z \rightarrow jj, l^+l^-, \nu\bar{\nu}$$



no excess is observed in the semi-leptonic diboson channel

1503.04677

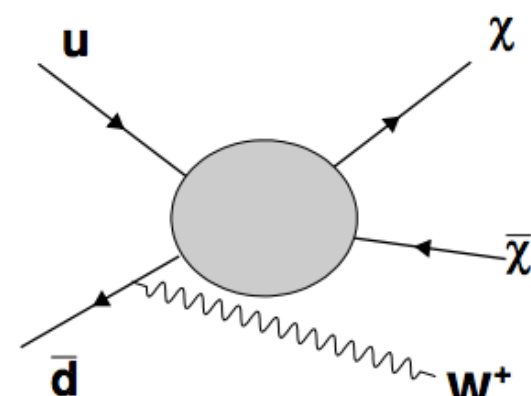
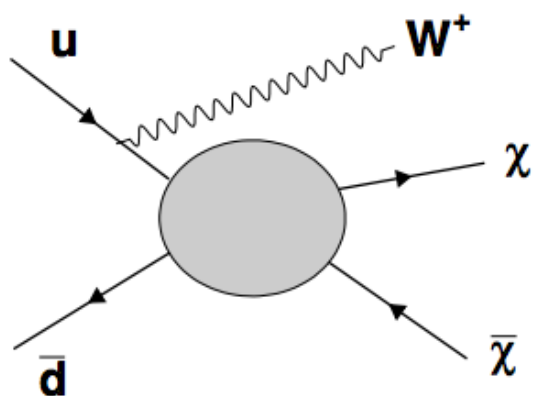
We propose to utilize mono-(fat)jet searches
to further test the excess

1507.08273

$$WZ \rightarrow jj + \nu\bar{\nu} \quad (\text{MET})$$

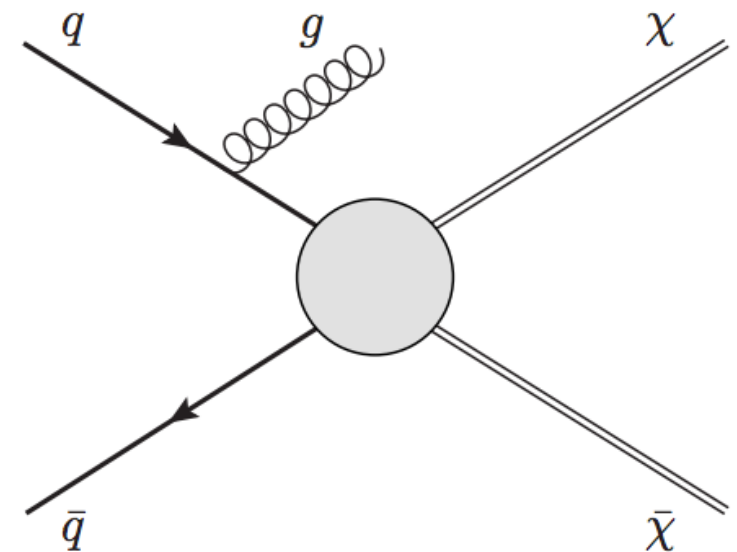
$$ZZ \rightarrow jj + \nu\bar{\nu}$$

jets are highly boosted and can be tagged as a “fat” jet



1309.4017

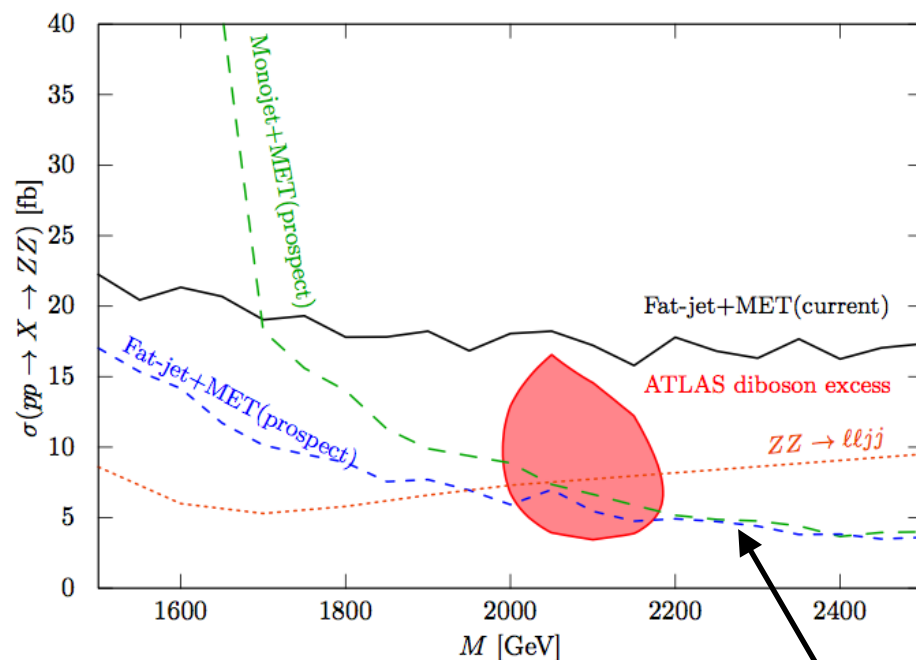
$\text{MET} > 500\text{GeV}$



1502.01518

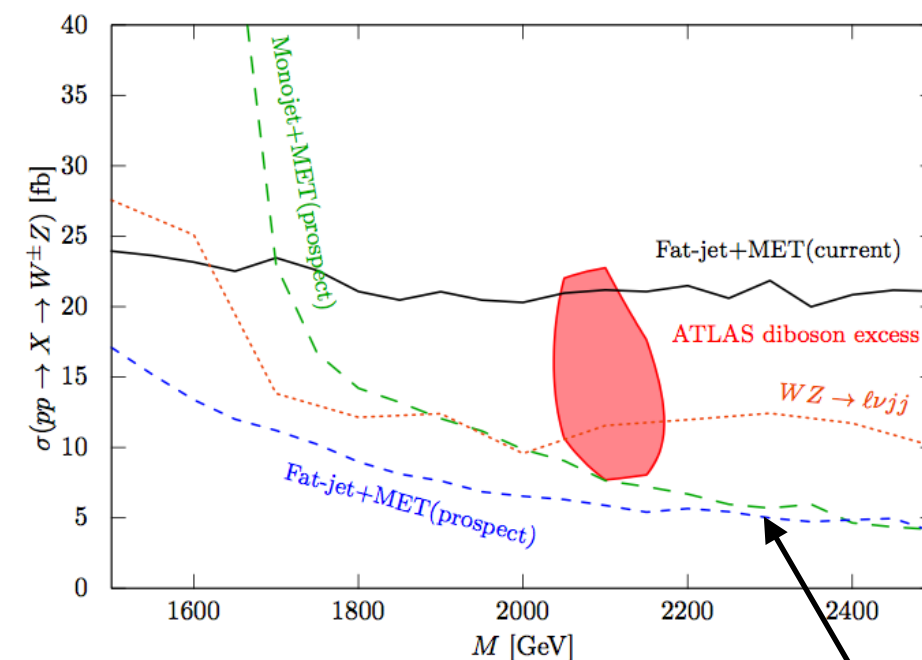
$\text{MET} > 700\text{GeV}$

1507.08273



(a) $X \rightarrow ZZ$

optimized cut



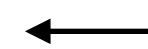
(b) $X \rightarrow WZ$

optimized cut

Current limits of mono-(fat)jet search are weak, but optimizing the MET cut can greatly improve the bound

$MET > 800\text{GeV}$

for mono fat-jet search



can exclude xsection
down to 7 fb

$MET > 900\text{GeV}$

for monojet search



can exclude xsection
down to 9 fb

Conclusions

inconclusive.

No clear excesses observed simultaneously by both collaborations

Excesses are constrained in various ways by other LHC searches

Looking forward to the next run of the LHC