LHC “excesses” (and Supersymmetry)

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(based on...) **1502.05712 (JHEP 1505 (2015) 133)**

1506.08803

1507.08273

SUSY 2015, Lake Tahoe

Several excesses at > 2.5σ 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	B0-> K*0 mu+ mu-	??

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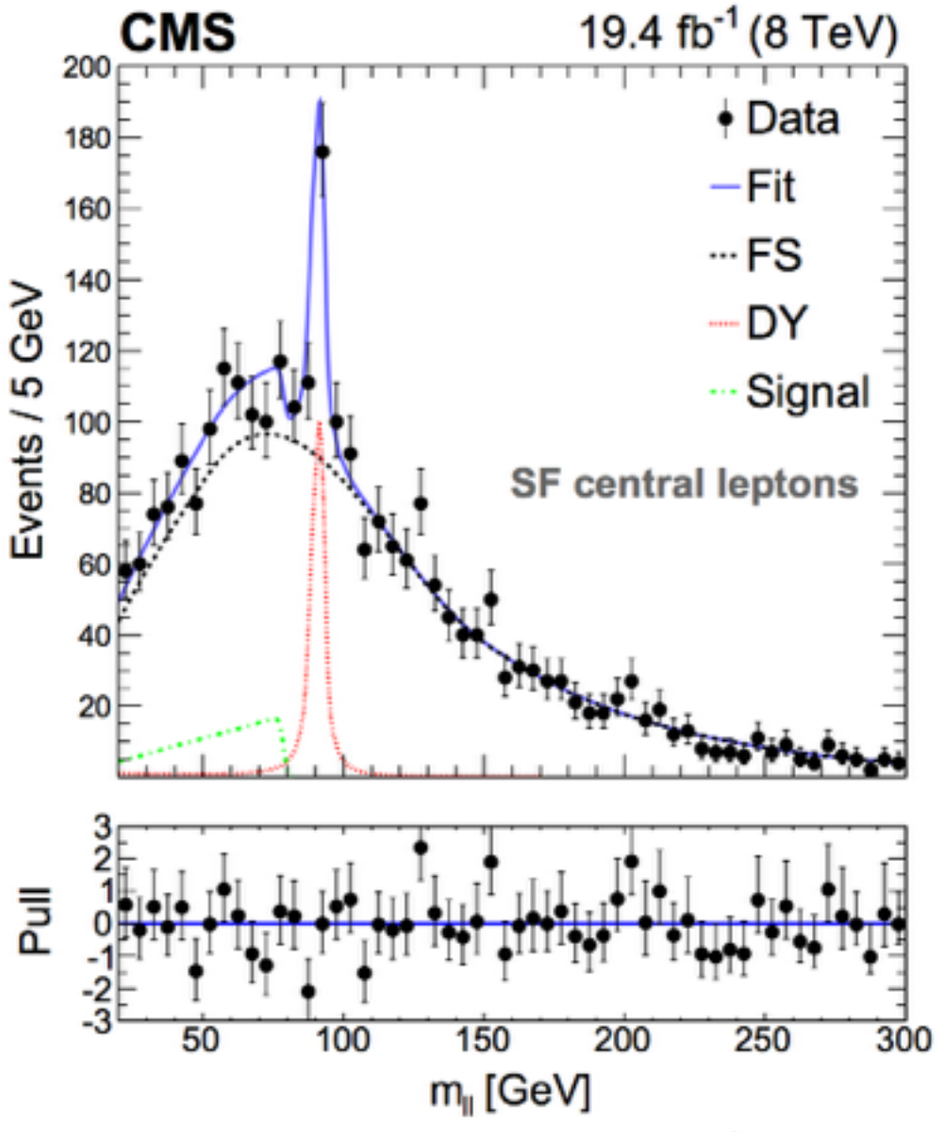
SUSY interpretations

new proposal to test the excess

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



opposite-sign same-flavor (OSSF) leptons are looked for

$$e^+e^- \text{or } \mu^+\mu^-$$

est. bkg: 730 ± 40 events

observed: 860

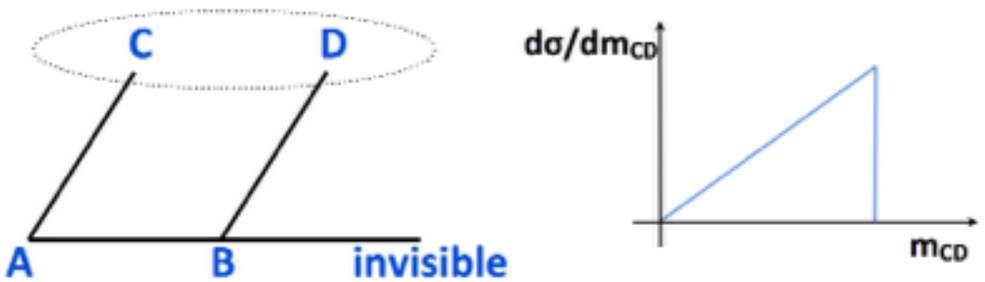
an excess of 130^{+48}_{-49} events

can be interpreted as a triangular "edge" peaked at

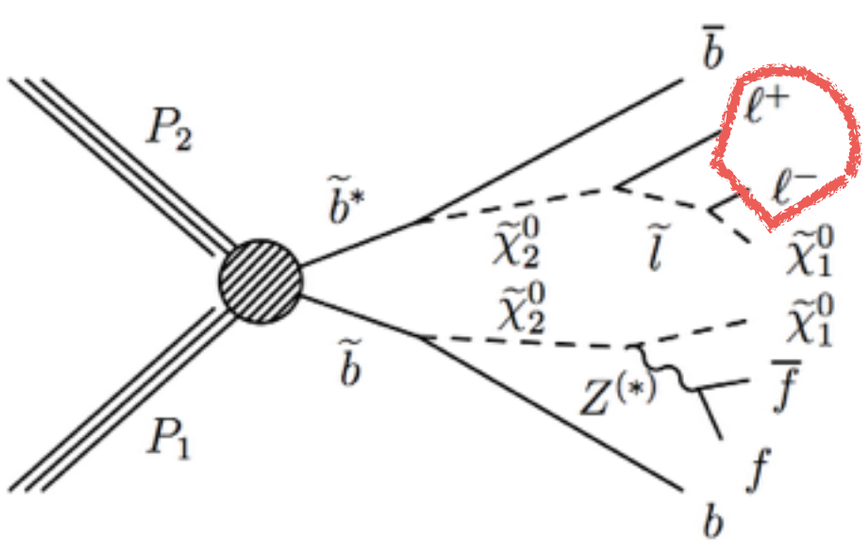
$$m_{l^+l^-} = 78.7 \text{ GeV}$$

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

Kinematical edge as a classical signature of SUSY



Theofilatos's slide (ICNFP 2014)



jets plus dilepton plus MET

Cascade decay of SUSY particle

Kinematic edge is formed via decays mediated by slepton

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

or a Z or Higgs boson

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

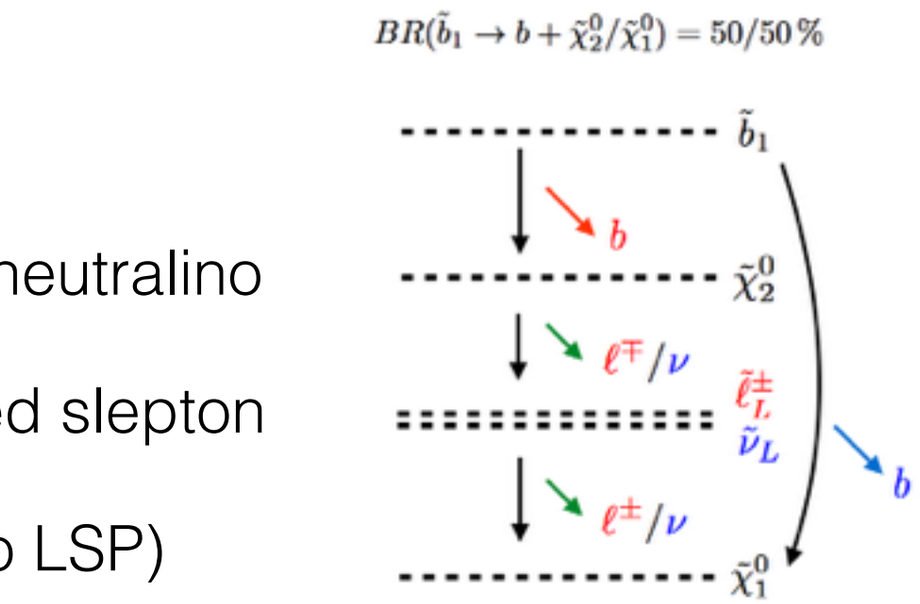
SUSY interpretations (sbottom cascade decay)

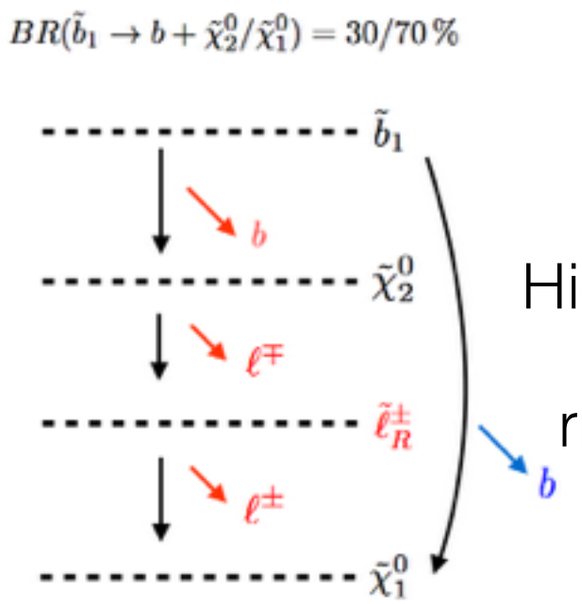
1502.05712

wino-like neutralino

left-handed slepton

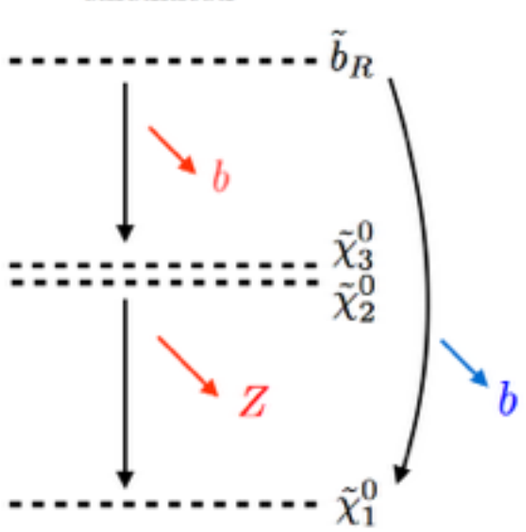
(bino LSP)

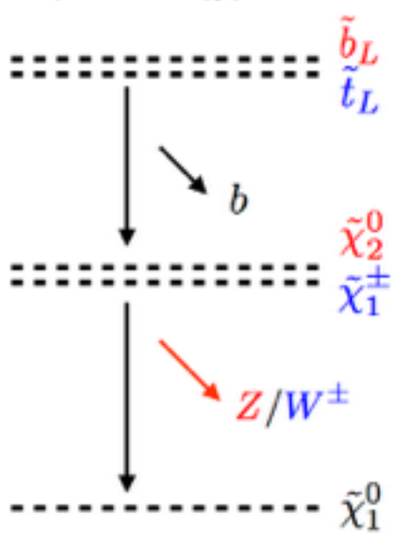




Higgsino-like neutralino

(bino LSP)





wino-like neutralino

(bino LSP)

$m_{l^+l^-}$ peaked at

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

$$m_{\text{edge}} = m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0}: \quad \tilde{\chi}_2^0 \to \ell^\pm\ell^\mp\tilde{\chi}_1^0,$$

Testing the excess with other LHC searches

1502.05712

dibottom +MET search

stop search

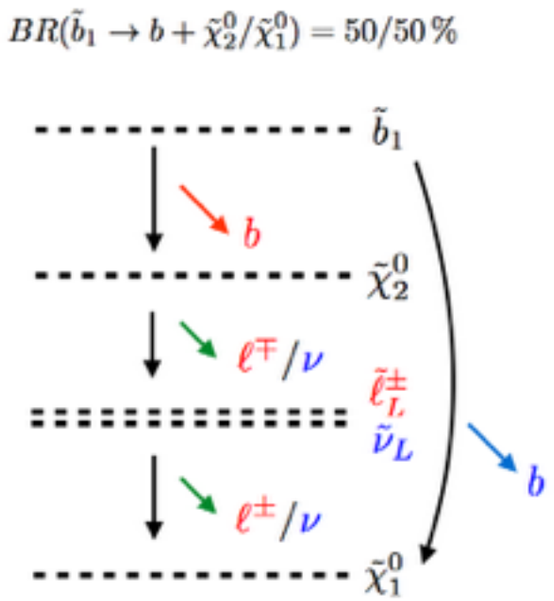
channel	search for	arXiv or CONF-ID	refs
$2-6j + 0\ell + \not{E}_T$	$\tilde{q}, \tilde{g}$	ATLAS-CONF-2013-047	[18]
		1405.7875	[19]
$2b + 0\ell + \not{E}_T$	$\tilde{t}, \tilde{b}$	1308.2631	[20]
$4j + 1\ell + \not{E}_T$	$\tilde{t}$	ATLAS-CONF-2013-037	[21]
$\geq 2j + \geq 1\ell + \not{E}_T$	$\tilde{q}, \tilde{g}$ (1 or 2ℓ)	ATLAS-CONF-2013-062	[22]
$2j + 2\ell + \not{E}_T$	dilepton edge	CMS-PAS-SUS-12-019	[1, 2]
$2j + \ell^{\pm}\ell^{\pm} + \not{E}_T$	$\tilde{q}, \tilde{g}, \tilde{t}, \tilde{b}$ (SS lepton)	ATLAS-CONF-2013-007	[23]
$2j + 2\ell + \not{E}_T$	$\tilde{t}(2\ell)$	ATLAS-CONF-2013-048	[24]
		1403.4853	[25]
$2, 3\ell + \not{E}_T$	$\tilde{\chi}^{\pm}, \tilde{\chi}^0, \tilde{\ell}$	1404.2500	[26]
		1405.7570	[27]
$3\ell + \not{E}_T$	$\tilde{\chi}^{\pm}, \tilde{\chi}^0$	1402.7029	[28]
$\geq 3\ell + \not{E}_T$	$\tilde{\chi}^{\pm}, \tilde{\chi}^0$	CMS-PAS-SUS-13-002	[10]

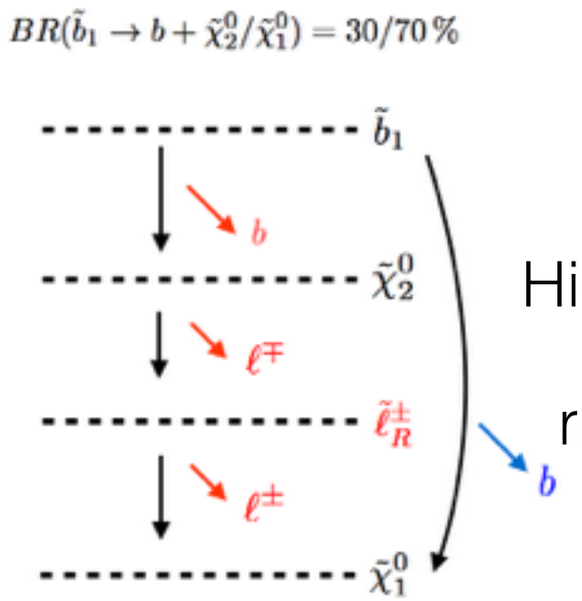
particularly constraining

wino-like neutralino

left-handed slepton

(bino LSP)





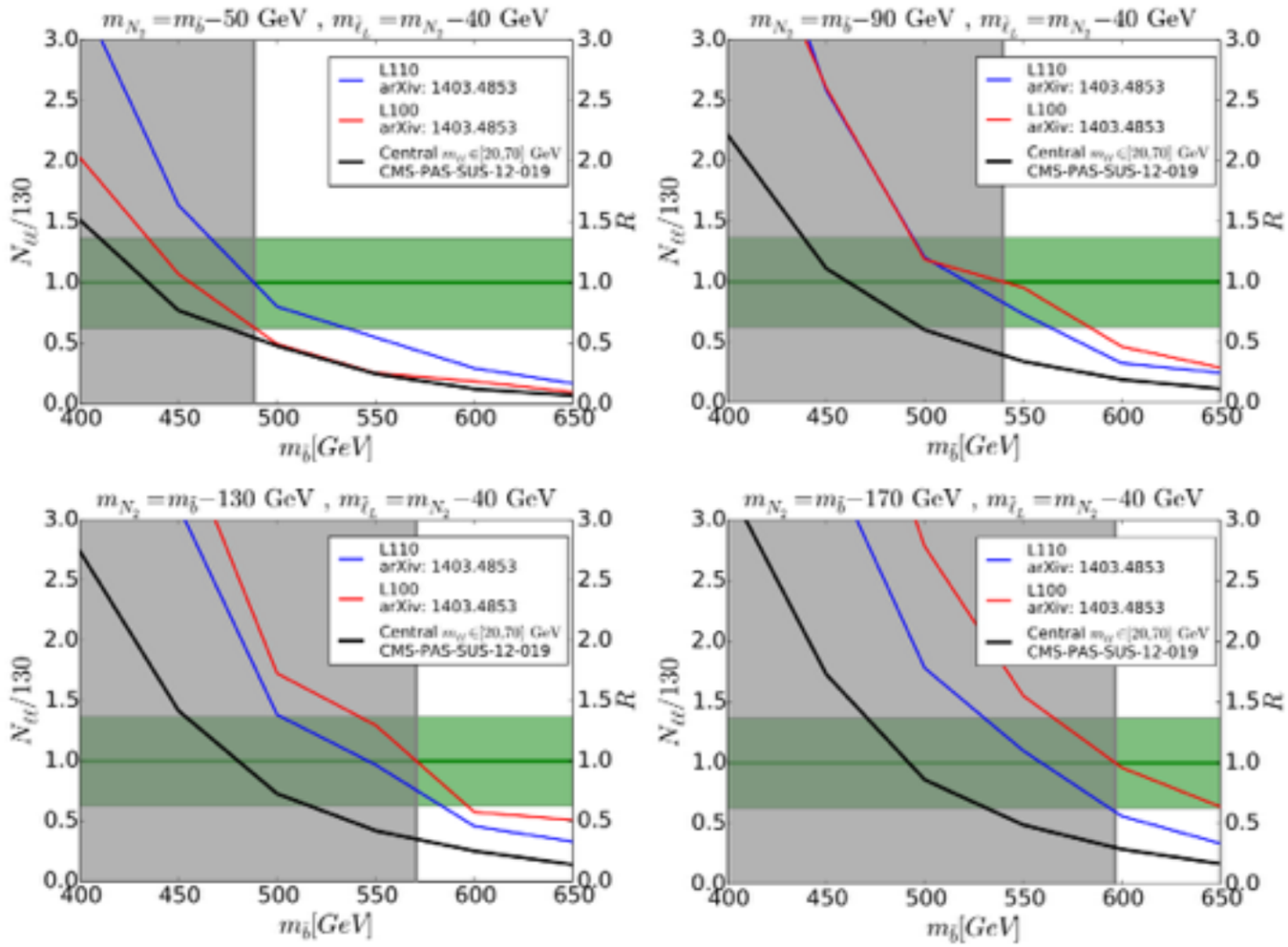
Higgsino-like neutralino

right-handed slepton

(bino LSP)

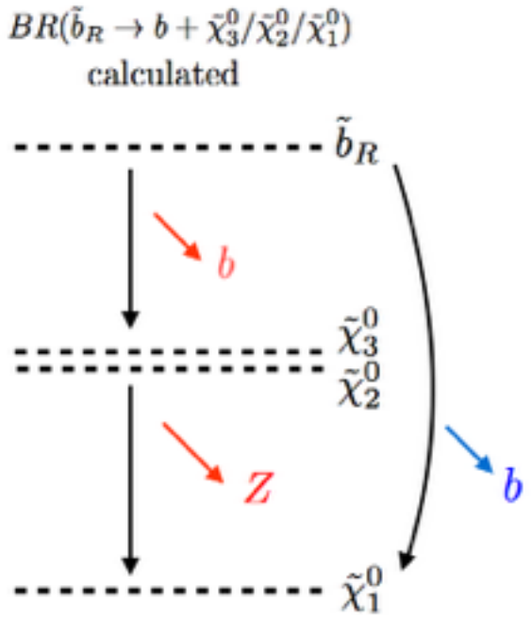
constrained by stop search looking for identical final states:

$$2j + 2\ell + \not{E}_T$$



Higgsino-like neutralino

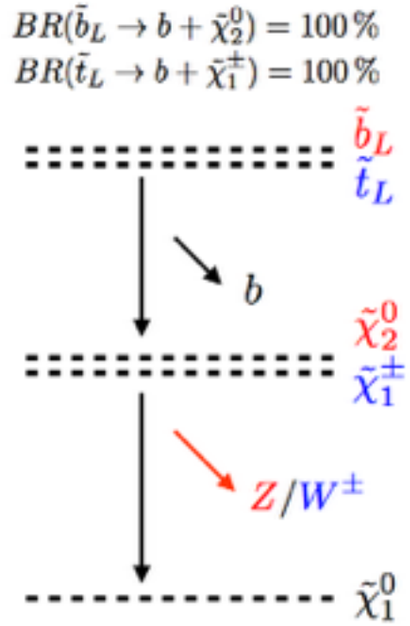
(bino LSP)



requires

$$\mathrm{Br}(\tilde{\chi}_2, \tilde{\chi}_3 \to Z^* \tilde{\chi}_1) \gtrsim 80\%$$

otherwise, this scenario is constrained by dibottom + MET search



wino-like neutralino

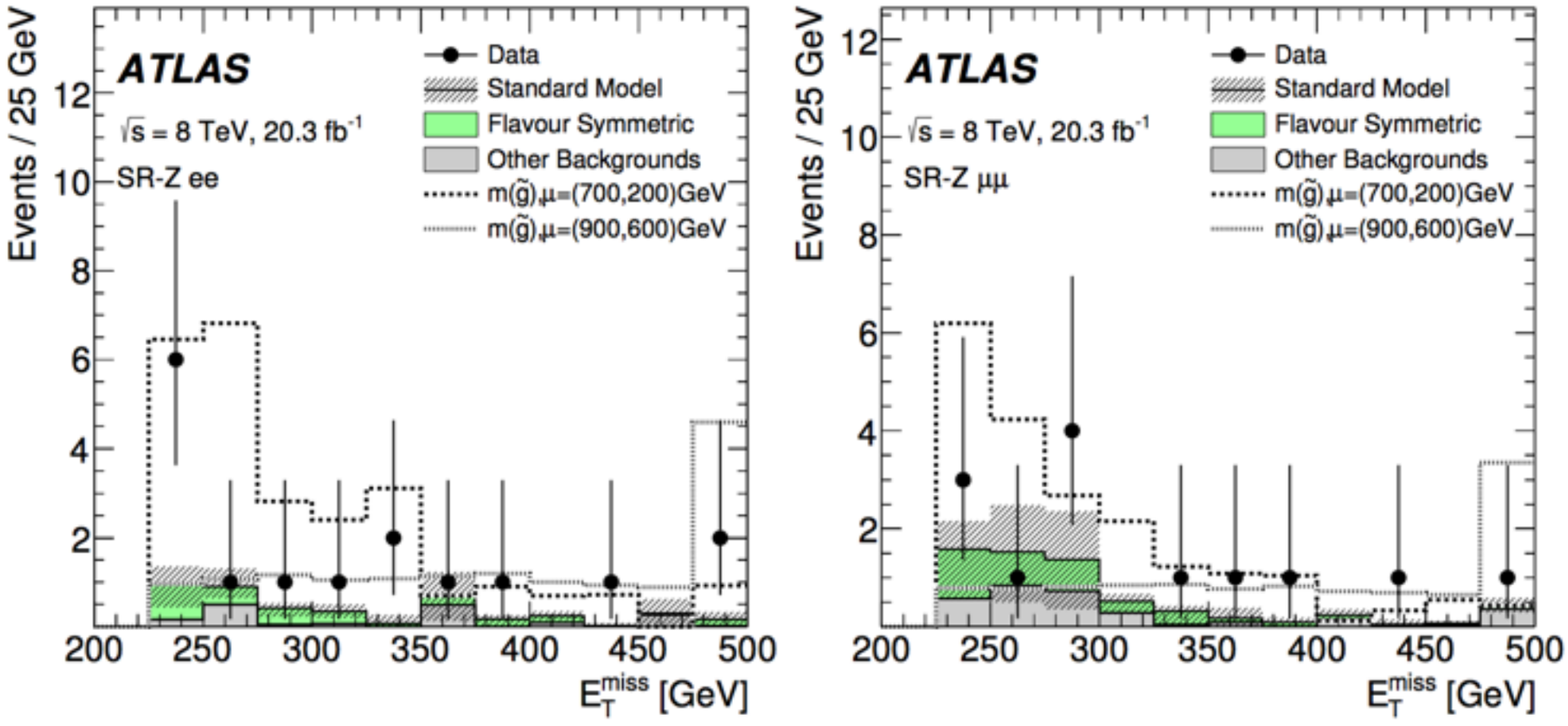
(bino LSP)

constrained by stop search

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

We do not find suitable MSSM scenario to explain the excess

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

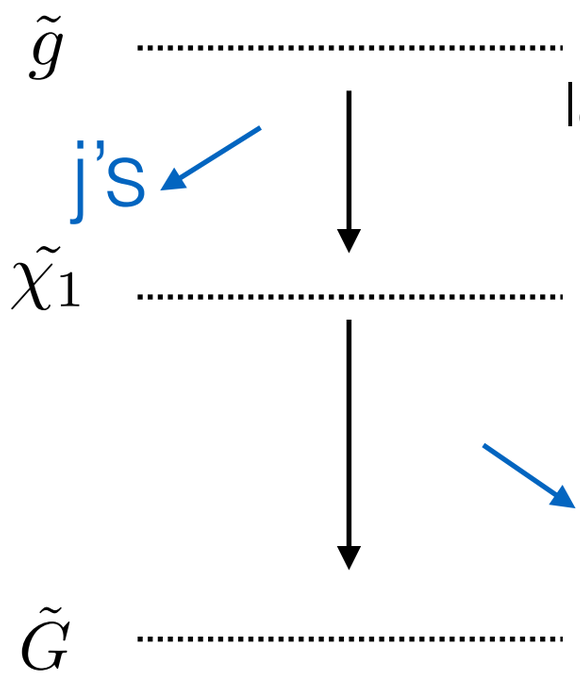


interpreted with GMSB models in the paper

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

gluino Higgsino gravitino

GMSB models are constrained by other LHC searches



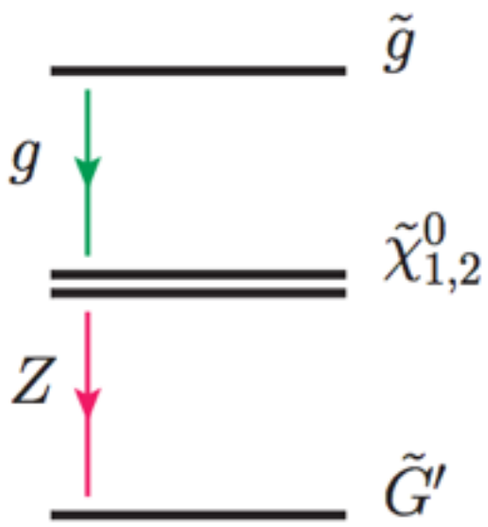
large Δm: gluino decays directly to top <- constrained by stop search

small Δm : energetic hadronic Z decays are constrained by multijet plus MET search

e.g. 1504.02752

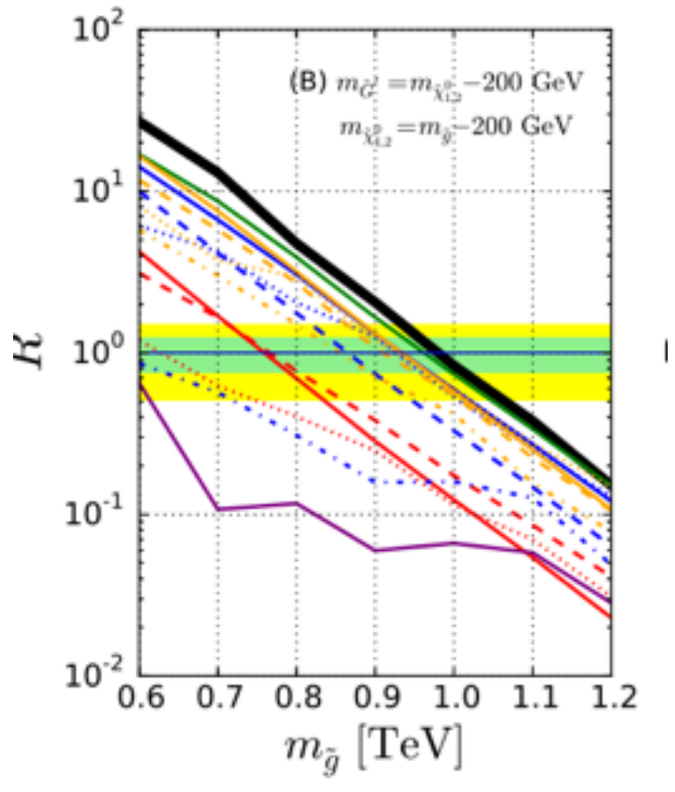
A rather compressed mass spectrum is required to avoid these constraints

1506.08803

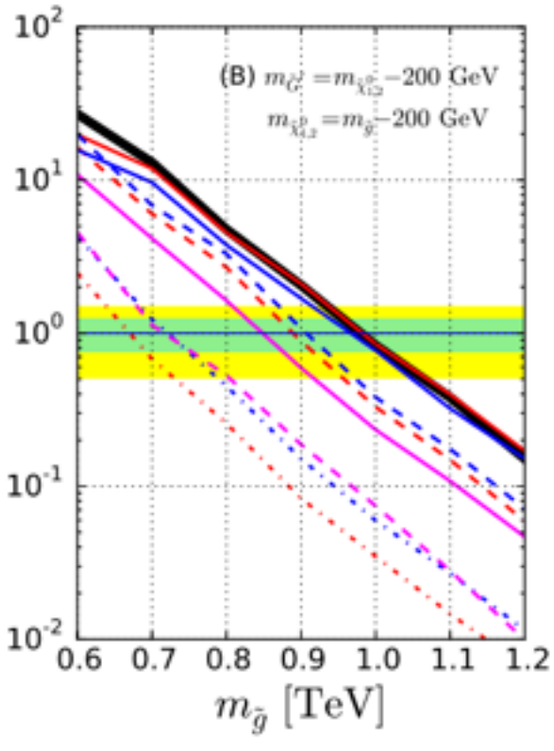


small Δm usually leads to gluino two-body decay to gluon due to large top Yukawa coupling

Singlino/goldstino



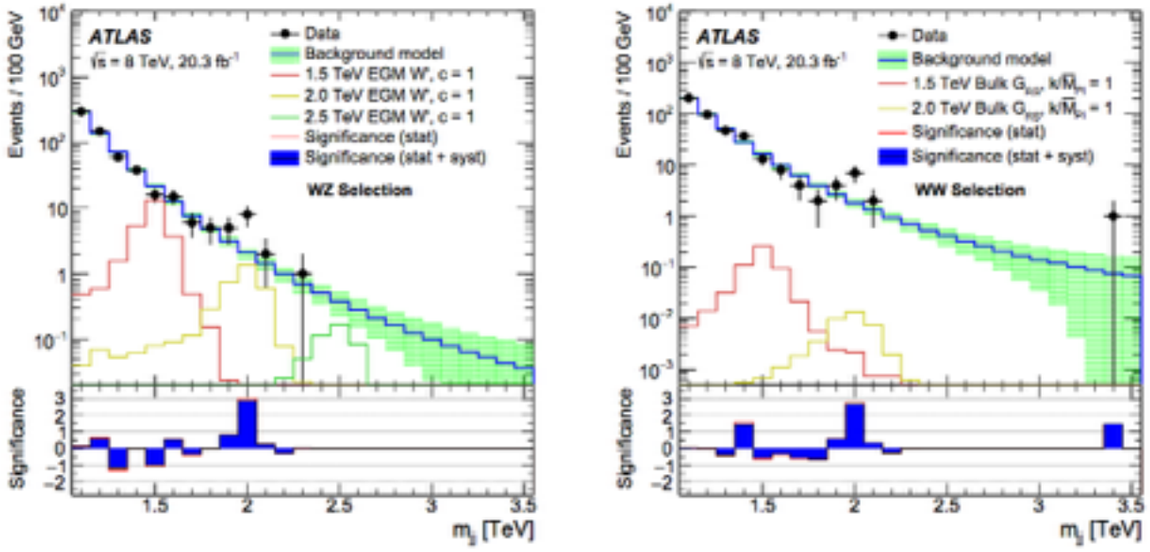
multijet constraints

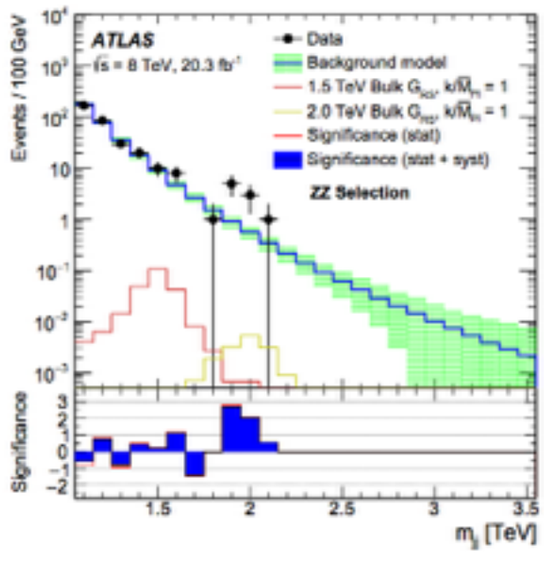


CMS on-Z constraints

marginally allowed by other LHC searches

ATLAS diboson excess (1506.00962)





$$pp \to X \to J\,J$$

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

~~no SUSY interpretation in the literature…~~

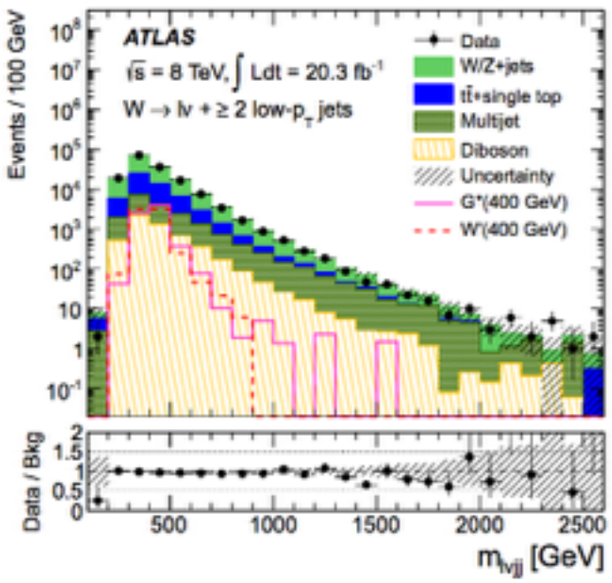
1508.05632

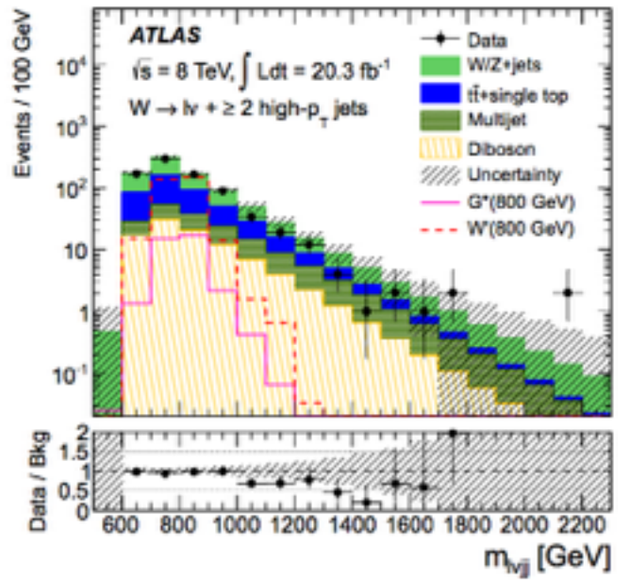
Excesses are only observed in the hadronic channels

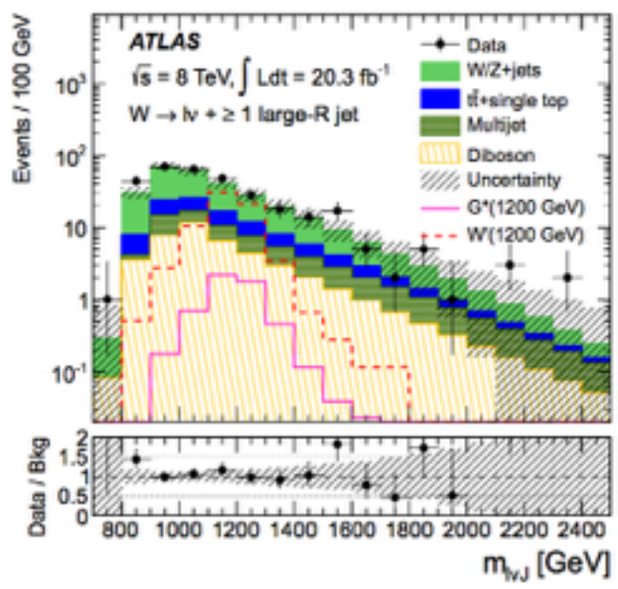
$$W \to jj,\ l\nu$$

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

a variety of final states are expected







no excess observed in the semi-leptonic diboson channel

1503.04677

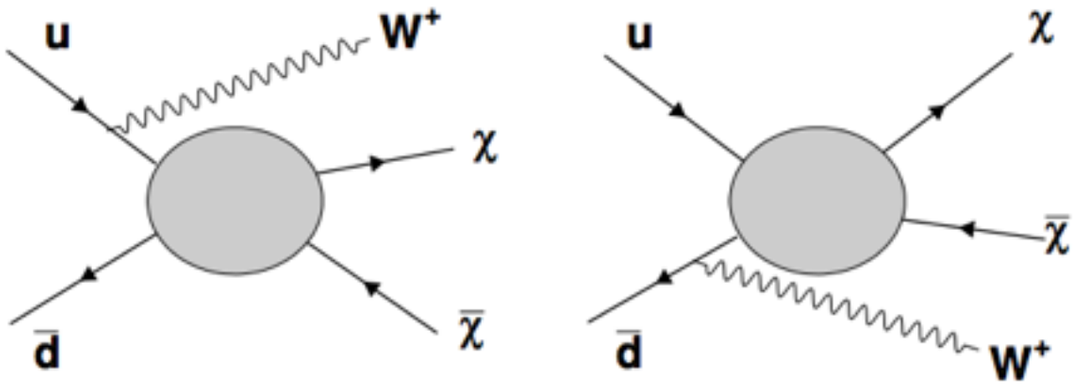
We propose to utilize mono-(fat)jet searches to further test the excess

1507.08273

$$WZ \to \boxed{jj} + \nu\bar{\nu}$$

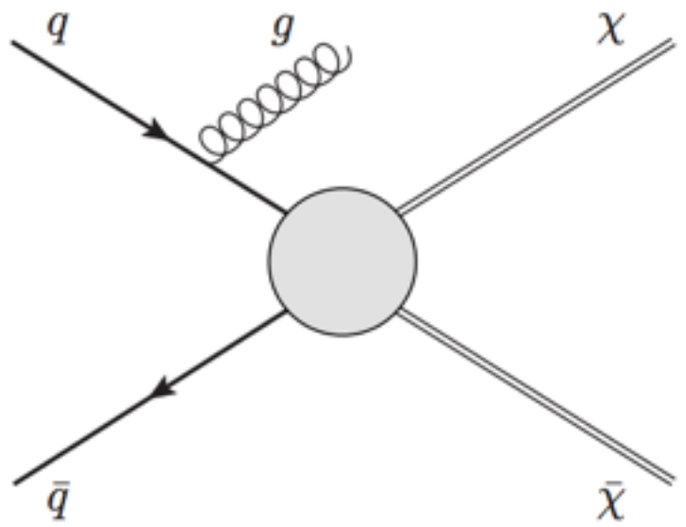
$$ZZ \to \boxed{jj} + \nu\bar{\nu}$$

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



1309.4017

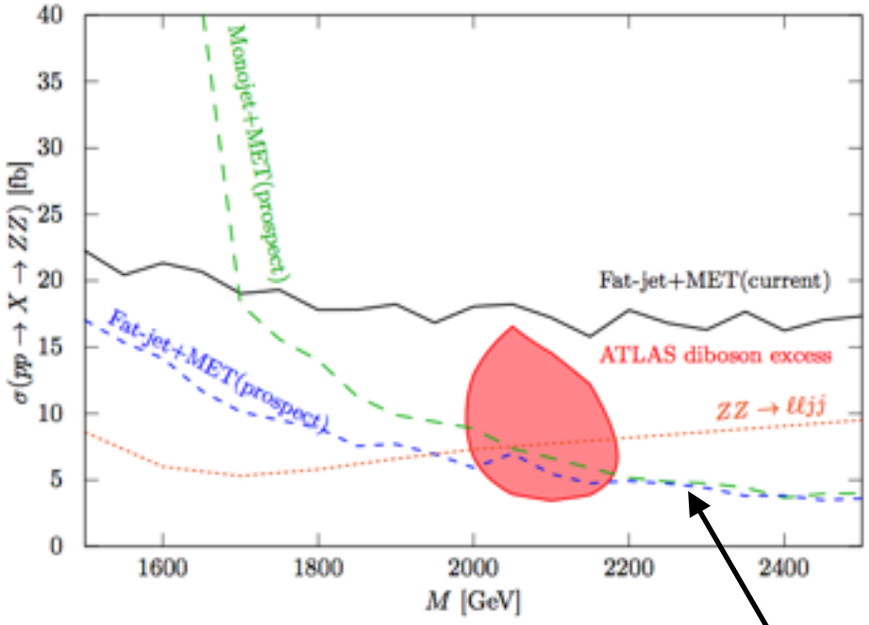
$\mathrm{MET} > 500\mathrm{GeV}$



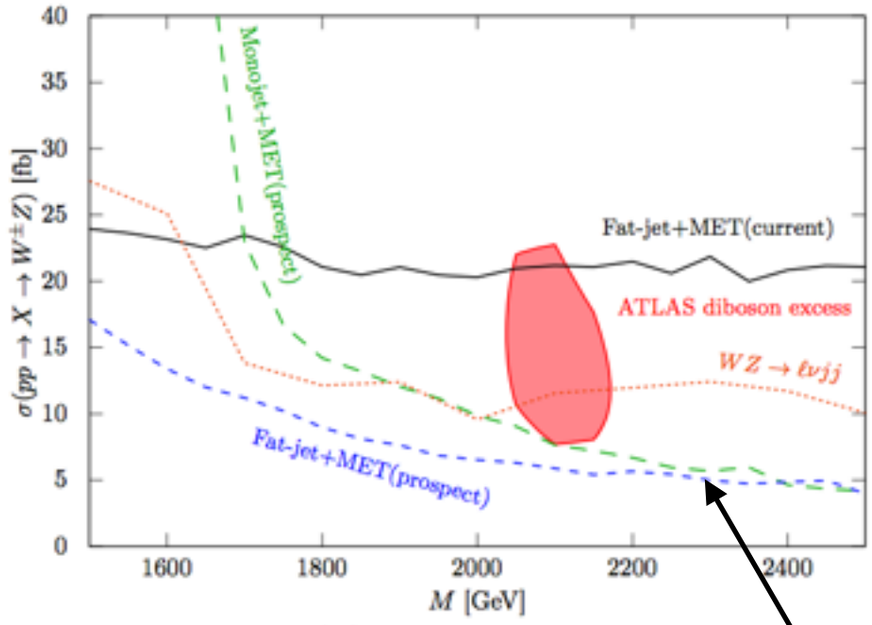
1502.01518

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

1507.08273



(a) $X \to ZZ$



(b) $X \to WZ$

optimized cut

optimized cut

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

$\mathrm{MET} > 800\mathrm{GeV}$ for mono fat-jet search ← can exclude xsection down to 7 fb

$\mathrm{MET} > 900\mathrm{GeV}$ for monojet search ← can exclude xsection down to 9 fb

Conclusions

inconclusive despite the excesses….

Looking forward to the next run of the LHC