

BSM searches at the LHC



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on behalf of CMS and ATLAS Collaborations**

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Outline

▶ Exotic searches (with some SUSY interpretations)

- X+MET interpretations
 - ➔ MonoX
 - ➔ Razor
 - ➔ Higgs Portal
- Resonance searches
 - ➔ Dijet
 - ➔ Dilepton
 - ➔ Diphoton
- Long-lived searches
 - ➔ Displaced jets
 - ➔ Trackless jets
 - ➔ Displaced / delayed photons
 - ➔ Lepton jets
 - ➔ HSCP

▶ SUSY searches

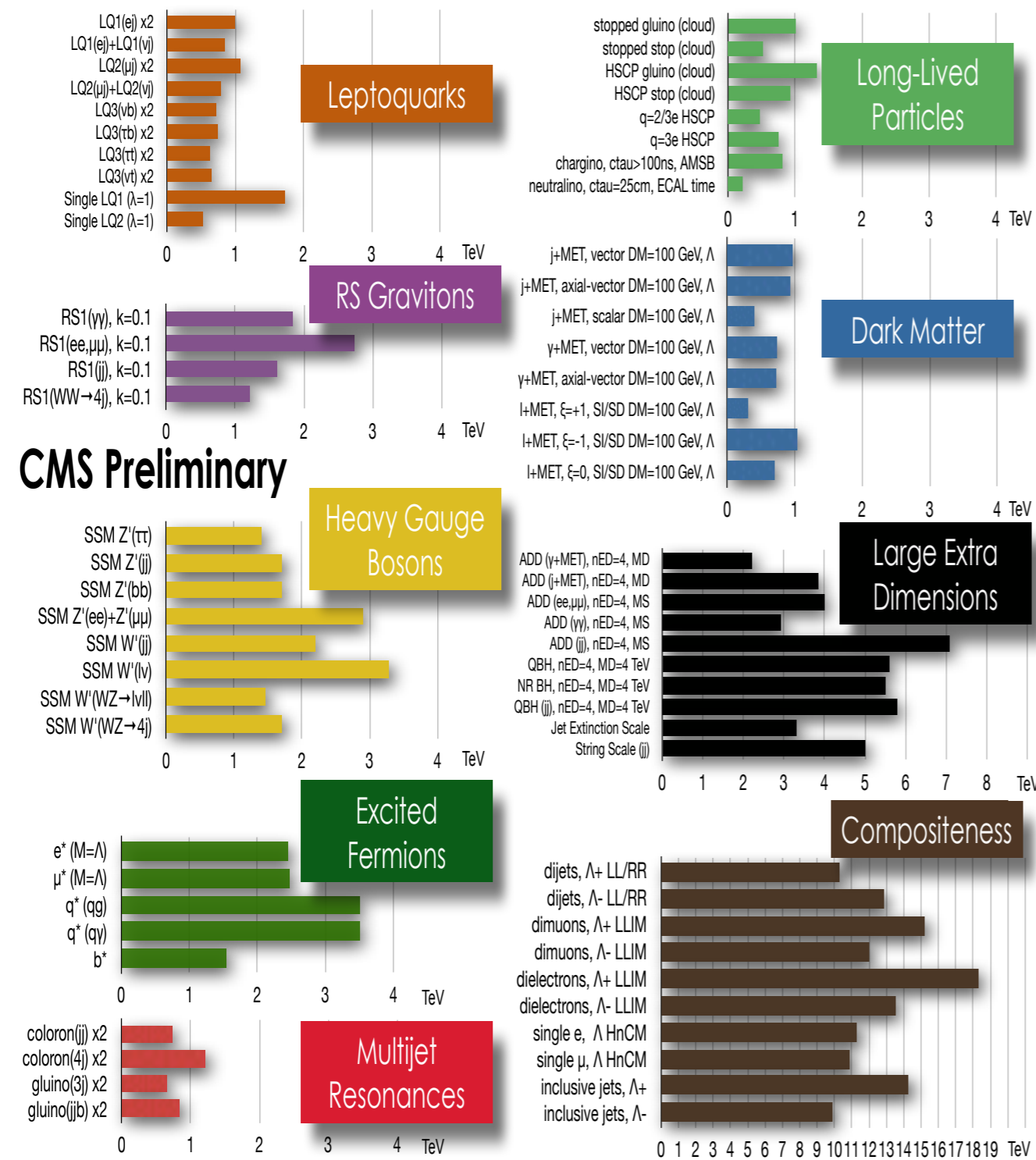
- SUSY inclusive searches
 - ➔ Hadronic
 - ➔ Single/di-[os/ss] lepton
 - ➔ Photon
- SUSY third-generation searches
- SUSY RPV searches

▶ Summary

⦿ In this talk, introduction to SUSY/EXO will be skipped and all results cannot be covered.

Exotic and supersymmetry searches

► ATLAS and CMS searches for new phenomena other than Supersymmetry. No evidence yet for the BSM.



ATLAS Exotics Searches* - 95% CL Exclusion
Status: July 2015

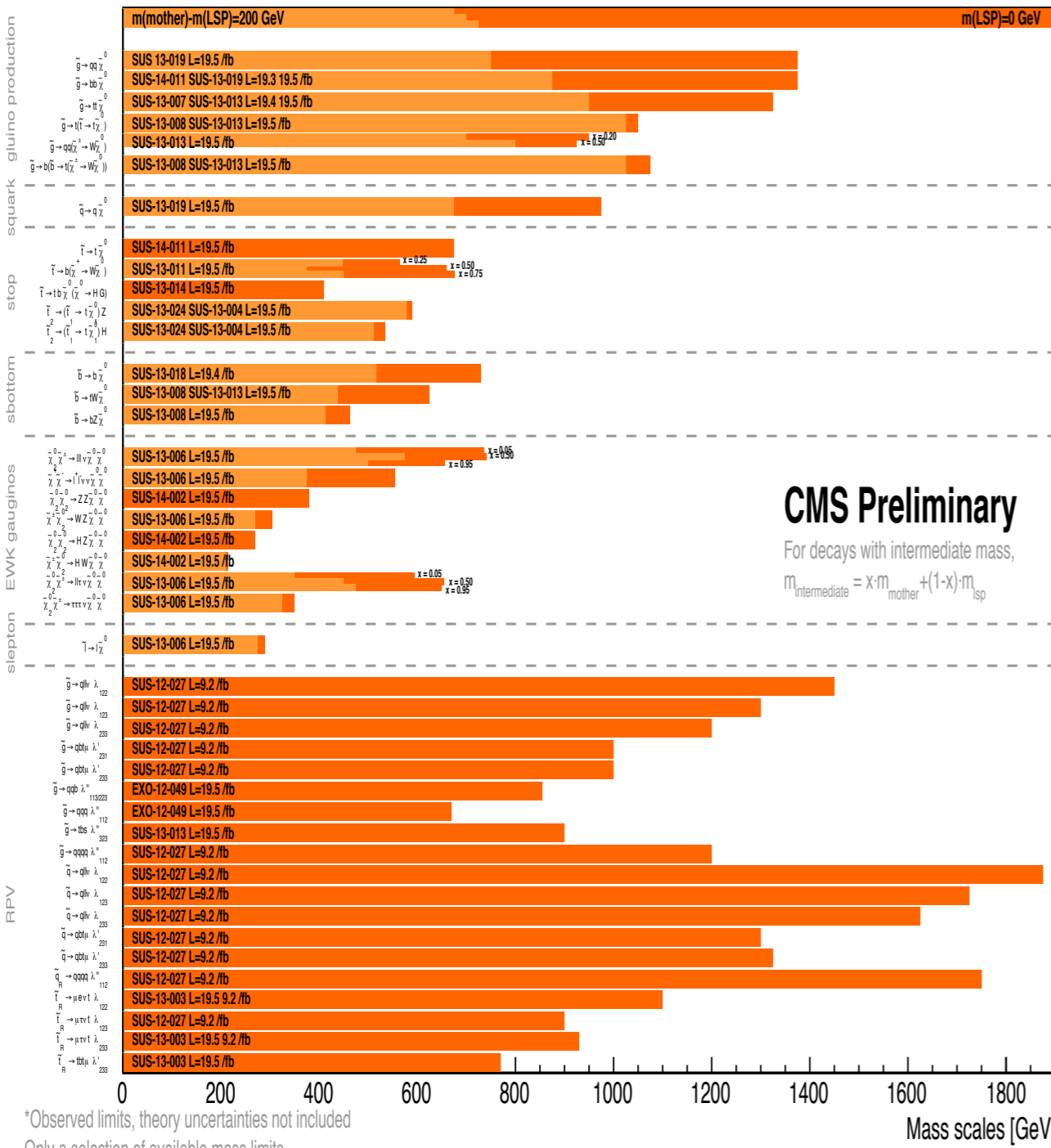
ATLAS Preliminary
 $\int \mathcal{L} dt = (4.7 - 20.3) \text{ fb}^{-1}$ $\sqrt{s} = 7, 8 \text{ TeV}$

Model	l, γ	Jets	E_T^{miss}	$\int \mathcal{L} dt (\text{fb}^{-1})$	Limit	Reference	
Extra dimensions	ADD $G_{XX} + g/\epsilon$	-	≥ 1j	Yes	20.3	M_{*} 3.26 TeV	
ADD non-resonant ll	2e, μ	-	-	20.3	M_{*} 4.7 TeV	n=2, 1802.01318	
ADD QBH → lq	1 e, μ	1j	-	20.3	M_{*} 3.2 TeV	n=3, 1407.24102	
ADD QBH	-	2j	-	20.3	M_{*} 3.02 TeV	n=6, 1311.2056	
ADD BH high N_{jet}	2 μ (SS)	-	-	20.3	M_{*} 4.7 TeV	n=6, 1407.1376	
ADD BH high $\sum p_T$	≥ 1 e, μ	≥ 2j	-	20.3	M_{*} 3.8 TeV	n=6, $M_{*} = 3 \text{ TeV}$, non-res BH, 1308.4075	
ADD BH high multiplet	-	≥ 2j	-	20.3	M_{*} 3.8 TeV	n=6, $M_{*} = 3 \text{ TeV}$, non-res BH, 1405.4254	
RS1 $G_{XX} \rightarrow ll$	2 e, μ	-	-	20.3	G_{XX} mass 3.66 TeV	1503.08988	
RS1 $G_{XX} \rightarrow \gamma\gamma$	2 γ	-	-	20.3	G_{XX} mass 2.66 TeV	1405.4123	
Bulk RS $G_{XX} \rightarrow ZZ \rightarrow q\bar{q}l\bar{l}$	2 e, μ	2j/1j	-	20.3	G_{XX} mass 740 GeV	1504.05011	
Bulk RS $G_{XX} \rightarrow WW \rightarrow q\bar{q}l\bar{l}$	1 e, μ	2j/1j	Yes	20.3	W' mass 750 GeV	1409.8190	
Bulk RS $G_{XX} \rightarrow HH \rightarrow b\bar{b}b\bar{b}$	-	4b	-	19.5	G_{XX} mass 500-720 GeV	1500.04677	
Bulk RS $G_{XX} \rightarrow ll$	1 e, μ	≥ 1b, ≥ 1l/0	Yes	20.3	Bulk mass 2.2 TeV	1506.00285	
RUED / RPP	2 e, μ (SS)	≥ 1b, ≥ 1j	Yes	20.3	W' mass 862 GeV	1505.07518	
Gauge bosons	SSM Z' → ll	2 e, μ	-	20.3	Z' mass 2.3 TeV	1405.4123	
SSM Z' → ττ	2 τ	-	-	19.5	Z' mass 2.00 TeV	1502.07177	
SSM W' → ll	1 e, μ	-	Yes	20.3	W' mass 3.24 TeV	1407.2494	
EGM W' → WZ → ll' l' l'	3 e, μ	-	Yes	20.3	W' mass 1.52 TeV	1406.4456	
EGM W' → WZ → q\bar{q}l\bar{l}	2 e, μ	2j/1j	-	20.3	W' mass 1.38 TeV	1409.8190	
EGM W' → WZ → qqee	-	2j	-	20.3	W' mass 1.3-1.5 TeV	1506.00952	
HVT W' → WH → llbb	1 e, μ	2b	Yes	20.3	W' mass 1.47 TeV	1500.08089	
LRSM W'_2 → cb	1 e, μ	2b, 0-1j	Yes	20.3	W' mass 1.30 TeV	1410.41103	
LRSM W'_3 → cb	0 e, μ	≥ 1b, ≥ 1j	-	20.3	W' mass 1.78 TeV	1408.3886	
CI	CI qqee	-	2j	-	17.3	A 12.0 TeV	1504.00067
CI qqll	2 e, μ	-	-	20.3	A 21.8 TeV	1407.2410	
CI qqtt	2 e, μ (SS)	≥ 1b, ≥ 1j	Yes	20.3	A 4.3 TeV	1504.04605	
DM	EFT D6 operator (Dirac)	0 e, μ	≥ 1j	Yes	20.3	M 874 GeV	at 90% CL for $m_{\chi} < 100 \text{ GeV}$, 1502.01318
EFT D6 operator (Dirac)	0 e, μ	1j, ≥ 1j	Yes	20.3	M 2.4 TeV	at 90% CL for $m_{\chi} < 100 \text{ GeV}$, 1308.407	
LQ	Scalar LQ 1 st gen	2 e	≥ 2j	-	20.3	LQ mass 1.06 TeV	β=1, Preliminary
Scalar LQ 2 nd gen	2 μ	≥ 2j	-	20.3	LQ mass 1.0 TeV	β=1, Preliminary	
Scalar LQ 3 rd gen	1 e, μ	≥ 1b, ≥ 1j	Yes	20.3	LQ mass 840 GeV	β=0, Preliminary	
Heavy quarks	VLQ $YY \rightarrow Hl + X$	1 e, μ	≥ 2b, ≥ 3j	Yes	20.3	Y mass 855 GeV	Y in (ll) doublet, 1505.04308
VLQ $YY \rightarrow Wb + X$	1 e, μ	≥ 1b, ≥ 3j	Yes	20.3	Y mass 770 GeV	Y in (ll') doublet, 1505.04308	
VLQ $BB \rightarrow Hb + X$	1 e, μ	≥ 2b, ≥ 3j	Yes	20.3	B mass 735 GeV	lepton singlet, 1505.04308	
VLQ $BB \rightarrow Zb + X$	2e, μ	≥ 2b, ≥ 3j	-	20.3	B mass 785 GeV	B in (ll') doublet, 1408.3500	
$T_{3,1} \rightarrow Wt$	1 e, μ	≥ 1b, ≥ 5j	Yes	20.3	$T_{3,1}$ mass 840 GeV	1503.06425	
Excited fermions	Excited quark $q' \rightarrow q\gamma$	1 γ	1j	-	20.3	q' mass 3.3 TeV	only q' and d', A = m(q'), 1308.3330
Excited quark $q' \rightarrow qg$	-	2j	-	20.3	q' mass 4.08 TeV	only q' and d', A = m(q'), 1407.1376	
Excited quark $q' \rightarrow Wt$	1 or 2 e, μ	1b, 2j (or 1j)	Yes	4.7	q' mass 870 GeV	left-handed coupling, 1301.1583	
Excited lepton $l' \rightarrow l\gamma$	2 e, μ, 1 γ	-	-	13.0	l' mass 2.2 TeV	A = 2.2 TeV, 1308.1364	
Excited lepton $l' \rightarrow lW, \nu Z$	3 e, μ, τ	-	-	20.3	l' mass 1.8 TeV	A = 1.8 TeV, 1411.2021	
Other	LSTC $\Delta\gamma \rightarrow W\gamma$	1 e, μ, 1 γ	-	Yes	20.3	W' mass 961 GeV	1407.8150
LRSM Majorana τ	2 e, μ	2j	-	20.3	W' mass 2.0 TeV	1506.06209	
Higgs triplet $HH^{\pm} \rightarrow ll'$	2 e, μ (SS)	-	-	20.3	W' mass 591 GeV	m(W ₃) = 2.4 TeV, no mixing, 1412.3237	
Higgs triplet $HH^{\pm} \rightarrow \tau\tau$	3 e, μ, τ	-	-	20.3	W' mass 400 GeV	DF production, BR(H [±]) → tt=1, 1411.2021	
Monotop (non-res prod)	1 e, μ	1b	Yes	20.3	spin-1 invisible particle mass 857 GeV	A _{ee} = 0.3, 1410.5454	
Multi-charged particles	-	-	-	20.3	multi-charged particle mass 765 GeV	DF production, g = 3e, 1504.04608	
Magnetic monopoles	-	-	-	7.0	monopole mass 1.34 TeV	DF production, g = 1/2, spin 1/2, Preliminary	

Exotic and supersymmetry searches

Exclusion limits of CMS and ATLAS SUSY searches.

Summary of CMS SUSY Results* in SMS framework



*Observed limits, theory uncertainties not included
Only a selection of available mass limits
Probe *up to* the quoted mass limit

ATLAS SUSY Searches* - 95% CL Lower Limits

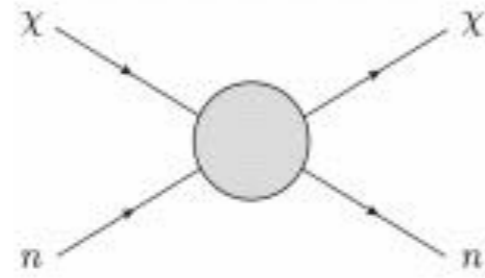
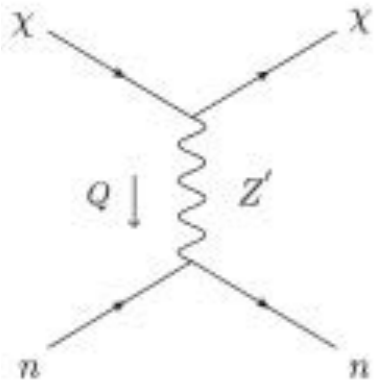
Model	$\epsilon, \mu, \tau, \gamma$	Jets	E_T^{miss} [GeV]	Mass limit	$\sqrt{s} = 7 \text{ TeV}$	$\sqrt{s} = 8 \text{ TeV}$	Reference	
Inclusive Searches	MSUGRA/CMSSM	0-3 e, μ / 2-7	2-10 jets/3-8	Yes	20.3	1.8 TeV	1507.05525	
	$\tilde{g}, \tilde{q} \rightarrow q\tilde{g}$	0	2-6 jets	Yes	20.3	850 GeV	1405.7675	
	$\tilde{g}, \tilde{q} \rightarrow q\tilde{q}$ (compressed)	mono-jet	1-3 jets	Yes	20.3	100-440 GeV	1507.05525	
	$\tilde{g}, \tilde{q} \rightarrow q\tilde{q} + \tilde{g} \rightarrow q\tilde{g}$	2 e, μ (0-2)	2 jets	Yes	20.3	780 GeV	1503.02290	
	$\tilde{g}, \tilde{q} \rightarrow q\tilde{q} + \tilde{g} \rightarrow q\tilde{g}$	0	2-6 jets	Yes	20.3	1.33 TeV	1405.7675	
	$\tilde{g}, \tilde{q} \rightarrow q\tilde{q} + \tilde{g} \rightarrow q\tilde{g}$	0-1 e, μ	2-6 jets	Yes	20	1.26 TeV	1507.05525	
	$\tilde{g}, \tilde{q} \rightarrow q\tilde{q} + \tilde{g} \rightarrow q\tilde{g}$	2 e, μ	0-3 jets	-	20	1.32 TeV	1501.02055	
	GMSB (if NLSP)	1-2 e, μ / 0-1	0-2 jets	Yes	20.3	1.5 TeV	1407.0603	
	GGM (bino NLSP)	2 γ	-	Yes	20.3	1.29 TeV	1507.05493	
	GGM (higgsino-bino NLSP)	7	1 b	Yes	20.3	1.3 TeV	1507.05493	
	GGM (higgsino-bino NLSP)	7	2 jets	Yes	20.3	1.25 TeV	1507.05493	
	GGM (higgsino NLSP)	2 e, μ (Z)	2 jets	Yes	20.3	850 GeV	1503.02290	
	Gravitino LSP	0	mono-jet	Yes	20.3	905 GeV	1502.01518	
	$\tilde{g}, \tilde{q} \rightarrow q\tilde{g}$	0	3 b	Yes	20.1	1.25 TeV	1407.0600	
	$\tilde{g}, \tilde{q} \rightarrow q\tilde{q}$	0	7-10 jets	Yes	20.3	1.1 TeV	1306.1841	
	$\tilde{g}, \tilde{q} \rightarrow q\tilde{q}$	0-1 e, μ	3 b	Yes	20.1	1.34 TeV	1407.0600	
	$\tilde{g}, \tilde{q} \rightarrow q\tilde{q}$	0-1 e, μ	3 b	Yes	20.1	1.3 TeV	1407.0600	
3rd gen. squarks & mixed	$\tilde{t}_1, \tilde{t}_1 \rightarrow t\tilde{t}$	0	2 b	Yes	20.1	100-620 GeV	1308.2031	
	$\tilde{t}_1, \tilde{t}_1 \rightarrow t\tilde{t}$	2 e, μ (SS)	0-3 b	Yes	20.3	375-440 GeV	1404.2500	
	$\tilde{t}_1, \tilde{t}_1 \rightarrow t\tilde{t}$	1-2 e, μ	1-2 b	Yes	4.7/20.3	110-187 GeV	1309.2102, 1407.0560	
	$\tilde{t}_1, \tilde{t}_1 \rightarrow t\tilde{t}$	0-2 e, μ	0-2 jets/1-2 b	Yes	20.3	90-191 GeV	1506.0916	
	$\tilde{t}_1, \tilde{t}_1 \rightarrow t\tilde{t}$	0	mono-jet+tag	Yes	20.3	210-700 GeV	1407.0600	
	$\tilde{t}_1, \tilde{t}_1 \rightarrow t\tilde{t}$	\tilde{t}_1 (natural CMSSM)	2 e, μ (Z)	1 b	Yes	20.3	90-240 GeV	1407.0600
	$\tilde{t}_1, \tilde{t}_1 \rightarrow t\tilde{t}$	3 e, μ (Z)	1 b	Yes	20.3	130-500 GeV	1403.0202	
	$\tilde{t}_1, \tilde{t}_1 \rightarrow t\tilde{t}$	3 e, μ (Z)	1 b	Yes	20.3	290-400 GeV	1403.0202	
3rd gen. squarks direct production	$\tilde{t}_1, \tilde{t}_1 \rightarrow t\tilde{t}$	2 e, μ	0	Yes	20.3	90-325 GeV	1403.0204	
	$\tilde{t}_1, \tilde{t}_1 \rightarrow t\tilde{t}$	2 e, μ	0	Yes	20.3	140-365 GeV	1403.0204	
	$\tilde{t}_1, \tilde{t}_1 \rightarrow t\tilde{t}$	2 τ	-	Yes	20.3	100-350 GeV	1407.0380	
	$\tilde{t}_1, \tilde{t}_1 \rightarrow t\tilde{t}$	3 e, μ	0	Yes	20.3	700 GeV	1402.7029	
	$\tilde{t}_1, \tilde{t}_1 \rightarrow t\tilde{t}$	2-3 e, μ	0-2 jets	Yes	20.3	420 GeV	1403.0204, 1407.0380	
	$\tilde{t}_1, \tilde{t}_1 \rightarrow t\tilde{t}$	4 e, μ	0	Yes	20.3	250 GeV	1501.07110	
	$\tilde{t}_1, \tilde{t}_1 \rightarrow t\tilde{t}$	4 e, μ	0	Yes	20.3	420 GeV	1403.0204	
	GGM (wino NLSP) weak prod.	1 e, μ + γ	-	Yes	20.3	124-361 GeV	1507.05493	
EW direct	Direct \tilde{t}_1, \tilde{t}_1 prod. long-lived \tilde{t}_1	Disapp. tag	1 jet	Yes	20.3	370 GeV	1303.3673	
	Direct \tilde{t}_1, \tilde{t}_1 prod. long-lived \tilde{t}_1	\tilde{t}_1 tag	-	Yes	18.4	482 GeV	1506.09302	
	Stable, stopped \tilde{t}_1 R-hadron	0	1-5 jets	Yes	27.9	832 GeV	1310.6884	
	Stable \tilde{t}_1 R-hadron	0	-	-	18.1	1.27 TeV	1411.6795	
	GMSB, stable $\tilde{t}_1, \tilde{t}_1 \rightarrow t\tilde{t}, \tilde{t}_1 \rightarrow t\tilde{g}$	1-2 μ	-	-	18.1	537 GeV	1411.6795	
	GMSB, $\tilde{t}_1 \rightarrow \tilde{t}_1 + \tilde{g}$, long-lived \tilde{t}_1	2 γ	-	Yes	20.3	435 GeV	1409.0542	
	$\tilde{g}, \tilde{t}_1 \rightarrow t\tilde{g} + \tilde{t}_1$	dipl. $\nu\tilde{\nu} + \nu\tilde{\nu}$	-	-	20.3	1.0 TeV	1504.05162	
	GGM $\tilde{g}, \tilde{t}_1 \rightarrow \tilde{t}_1 + \tilde{g}$	dipl. $\nu\tilde{\nu} + \nu\tilde{\nu}$	-	-	20.3	1.0 TeV	1504.05162	
Long-lived particles	Direct \tilde{t}_1, \tilde{t}_1 prod. long-lived \tilde{t}_1	Disapp. tag	1 jet	Yes	20.3	370 GeV	1303.3673	
	Direct \tilde{t}_1, \tilde{t}_1 prod. long-lived \tilde{t}_1	\tilde{t}_1 tag	-	Yes	18.4	482 GeV	1506.09302	
	Stable, stopped \tilde{t}_1 R-hadron	0	1-5 jets	Yes	27.9	832 GeV	1310.6884	
	Stable \tilde{t}_1 R-hadron	0	-	-	18.1	1.27 TeV	1411.6795	
	GMSB, stable $\tilde{t}_1, \tilde{t}_1 \rightarrow t\tilde{t}, \tilde{t}_1 \rightarrow t\tilde{g}$	1-2 μ	-	-	18.1	537 GeV	1411.6795	
	GMSB, $\tilde{t}_1 \rightarrow \tilde{t}_1 + \tilde{g}$, long-lived \tilde{t}_1	2 γ	-	Yes	20.3	435 GeV	1409.0542	
	$\tilde{g}, \tilde{t}_1 \rightarrow t\tilde{g} + \tilde{t}_1$	dipl. $\nu\tilde{\nu} + \nu\tilde{\nu}$	-	-	20.3	1.0 TeV	1504.05162	
	GGM $\tilde{g}, \tilde{t}_1 \rightarrow \tilde{t}_1 + \tilde{g}$	dipl. $\nu\tilde{\nu} + \nu\tilde{\nu}$	-	-	20.3	1.0 TeV	1504.05162	
RPV	LFV $\tilde{g}, \tilde{g} \rightarrow \tilde{g} + X, \tilde{g} \rightarrow \tilde{g} + \nu\tilde{\nu}$	$\tilde{g}, \tilde{g} \rightarrow \tilde{g} + \nu\tilde{\nu}$	-	-	20.3	1.7 TeV	1403.04430	
	Bilinear RPV CMSSM	2 e, μ (SS)	0-3 b	Yes	20.3	1.35 TeV	1404.2500	
	$\tilde{t}_1, \tilde{t}_1 \rightarrow t\tilde{t} + \tilde{g} \rightarrow q\tilde{q}$	4 e, μ	-	Yes	20.3	790 GeV	1405.0086	
	$\tilde{t}_1, \tilde{t}_1 \rightarrow t\tilde{t} + \tilde{g} \rightarrow q\tilde{q}$	3 e, μ + τ	-	Yes	20.3	450 GeV	1405.0086	
	$\tilde{g}, \tilde{g} \rightarrow \tilde{g} + \tilde{g}$	0	6-7 jets	-	20.3	917 GeV	1502.09086	
	$\tilde{g}, \tilde{g} \rightarrow \tilde{g} + \tilde{g}$	0	6-7 jets	-	20.3	870 GeV	1502.09086	
	$\tilde{g}, \tilde{g} \rightarrow \tilde{g} + \tilde{g}$	2 e, μ (SS)	0-3 b	Yes	20.3	850 GeV	1404.2500	
	$\tilde{t}_1, \tilde{t}_1 \rightarrow t\tilde{t}$	0	2 jets + 2 b	-	20.3	100-300 GeV	ATLAS CONF-2015-028	
	$\tilde{t}_1, \tilde{t}_1 \rightarrow t\tilde{t}$	2 e, μ	2 b	-	20.3	0.4-1.0 TeV	ATLAS CONF-2015-015	
Other	Scalar charm, $\tilde{t} \rightarrow \tilde{t}$	0	2 e	Yes	20.3	490 GeV	1501.01335	

*Only a selection of the available mass limits on new states or phenomena is shown. All limits quoted are observed minus 1 σ theoretical signal cross section uncertainty

X+MET interpretations

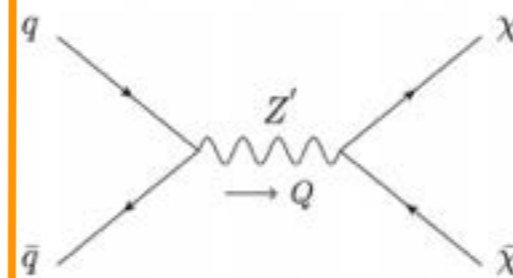
- DM case: limits are quoted in terms of the WIMP-Nucleon cross-section.

Direct detection

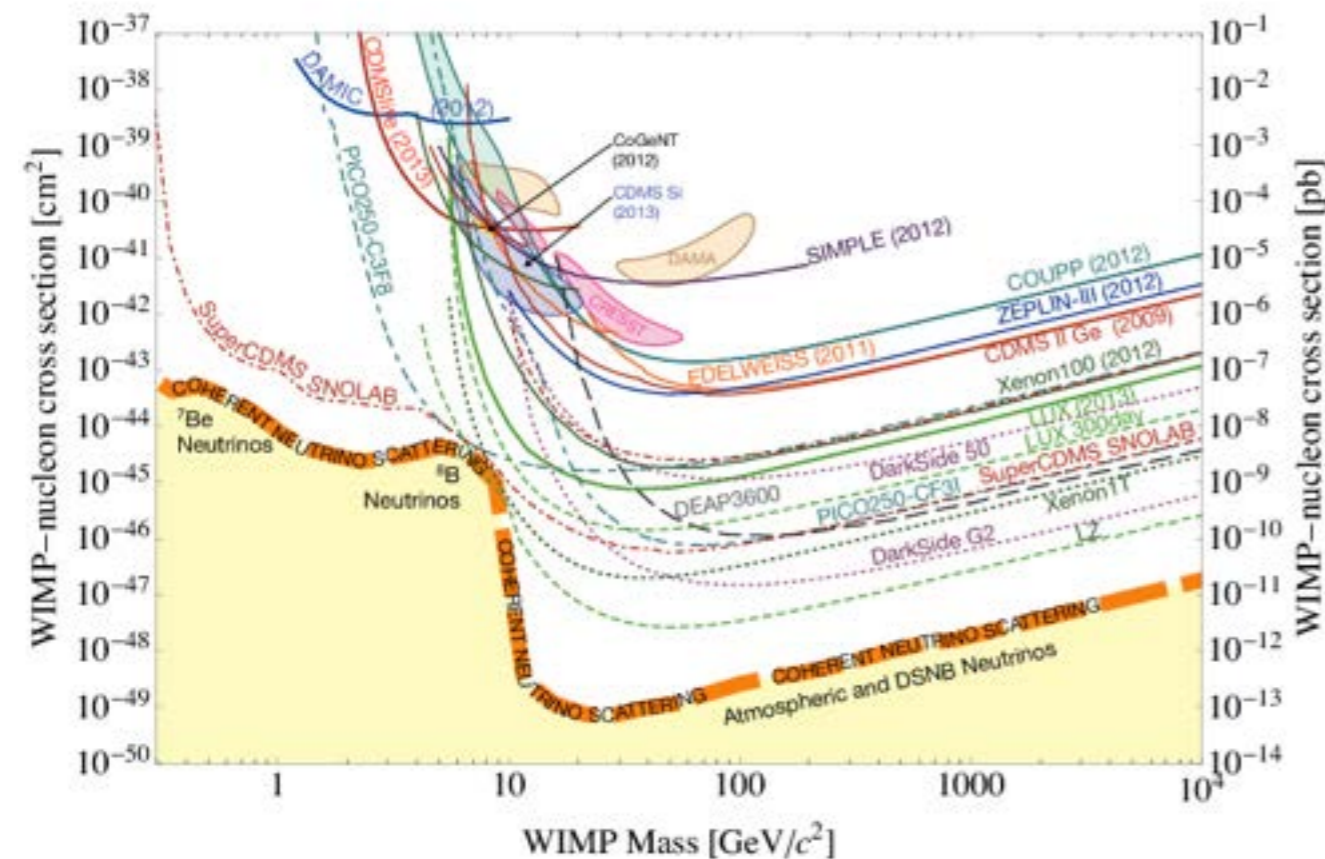
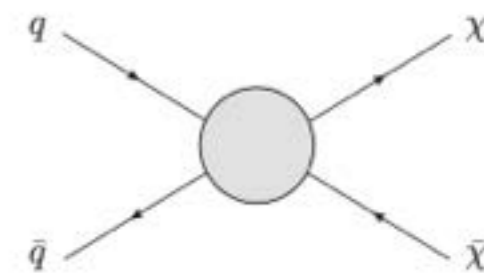


$$\sigma_n \sim \left(\frac{g_n g_\chi}{Q^2 - m_{Z'}^2} \right)^2 \approx \frac{g_n^2 g_\chi^2}{m_{Z'}^4} \left(1 + \frac{Q^2}{m_{Z'}^2} + \dots \right)^2$$

Collider



→
'Integrate out the mediator'



- ▶ Contact interaction if

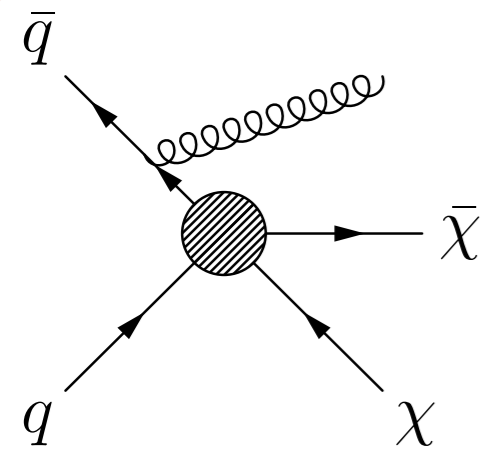
$$m_{Z'} \gg Q = \sqrt{2m_n E_R} \approx 50 \text{ MeV}$$

- ▶ **Use of effective field theory (EFT)** to place a limit on the contact interaction scale

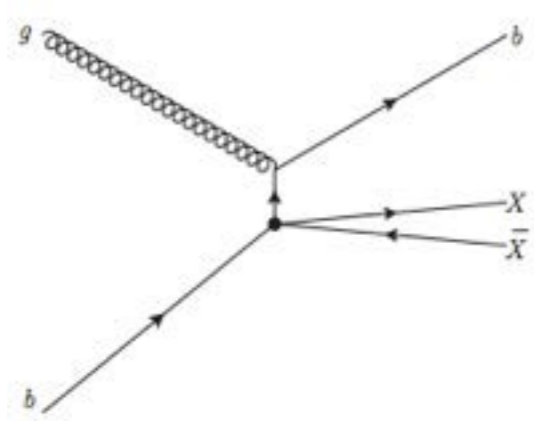
$$\Lambda \equiv \frac{m_{Z'}}{\sqrt{g_q g_\chi}}$$

- ▶ **Use simplified model**

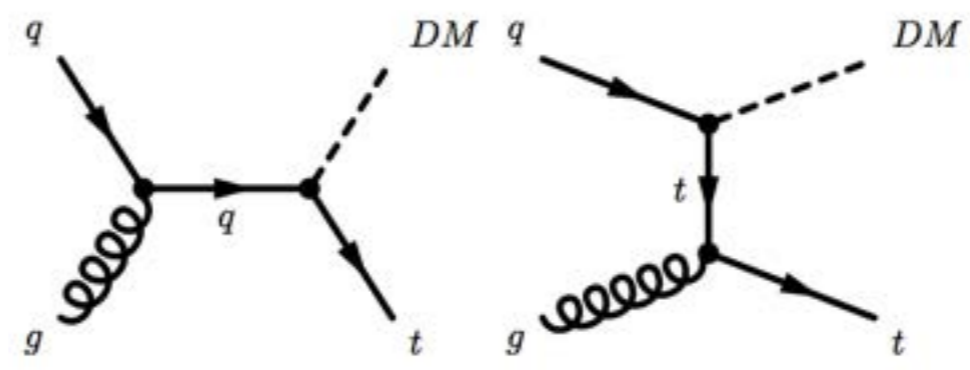
X+MET interpretations



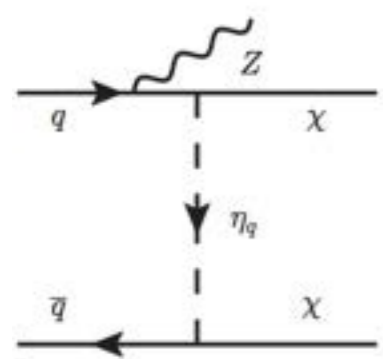
MonoJet / Razor



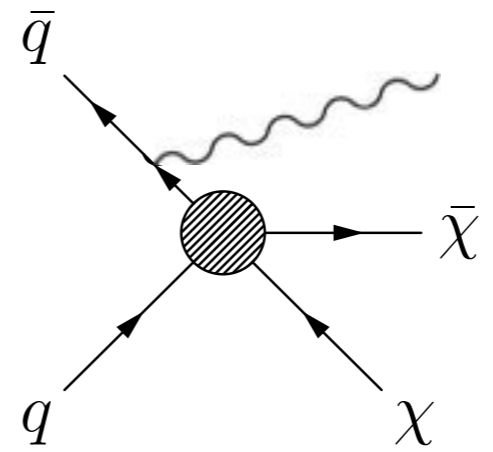
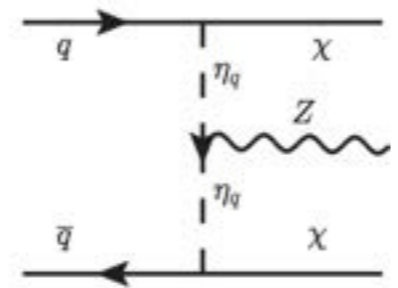
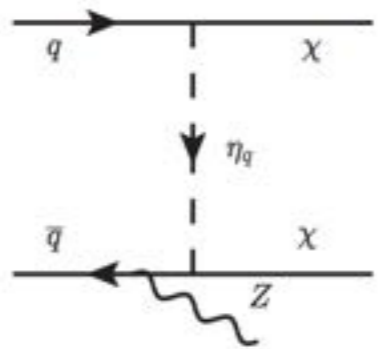
MonoB



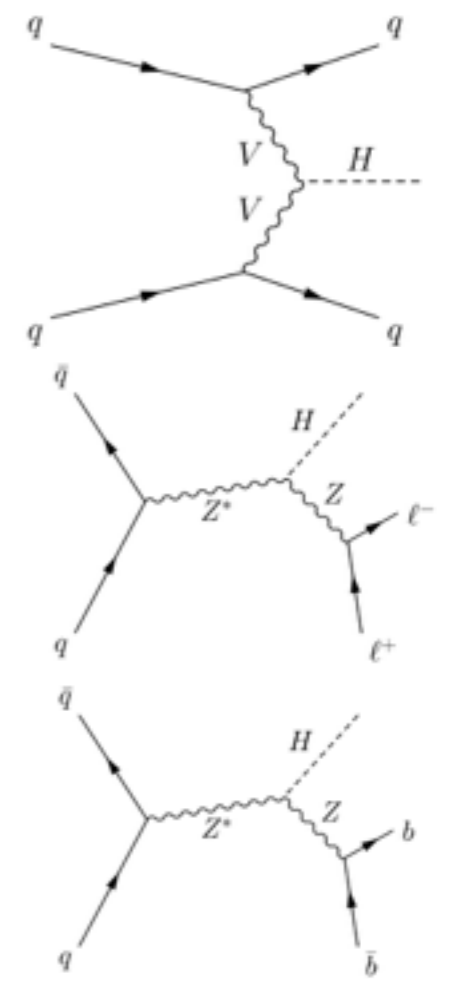
MonoTop



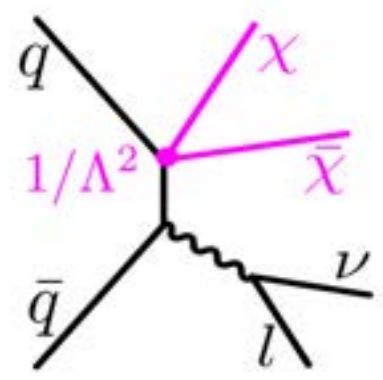
MonoZ



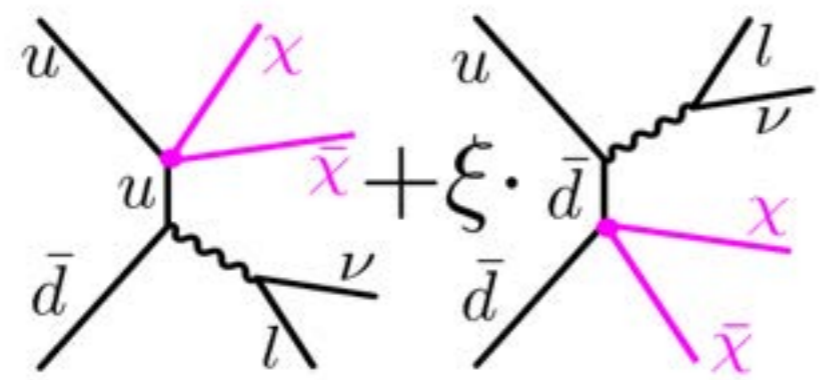
MonoPhoton



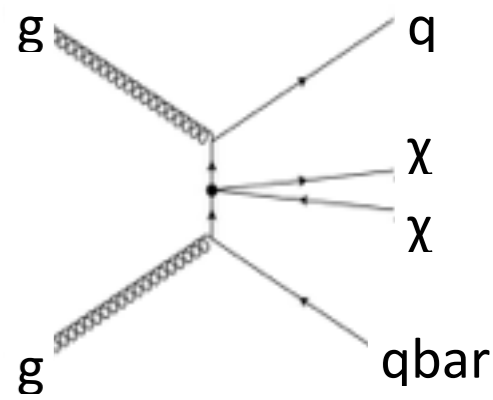
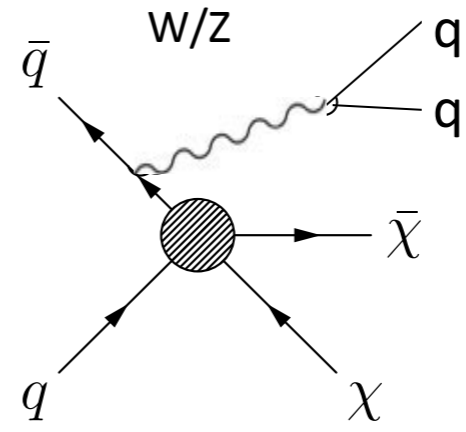
Higgs Portal



MonoW (monoLepton)



MonoW/Z (Hadronic)

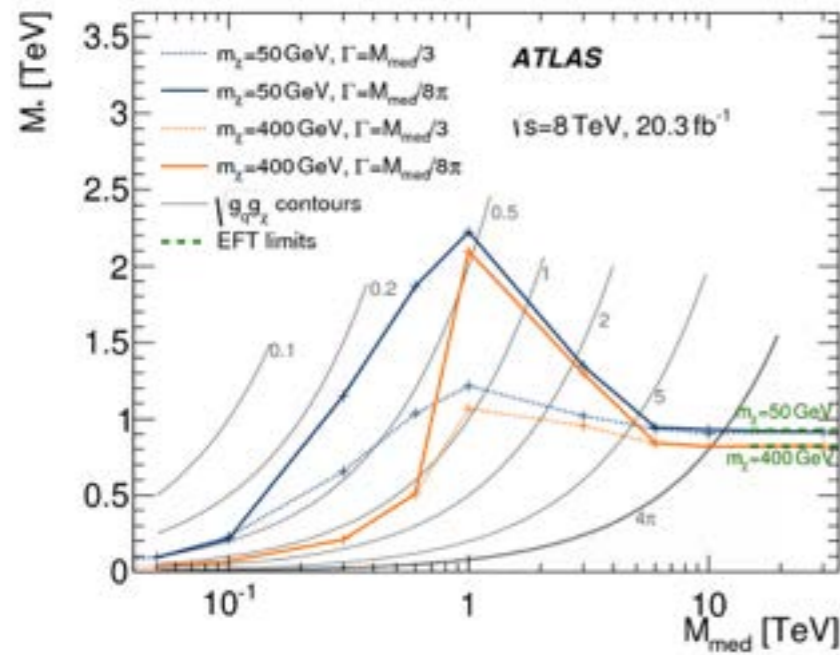


BBbar / TTbar

Jet+MET interpretations

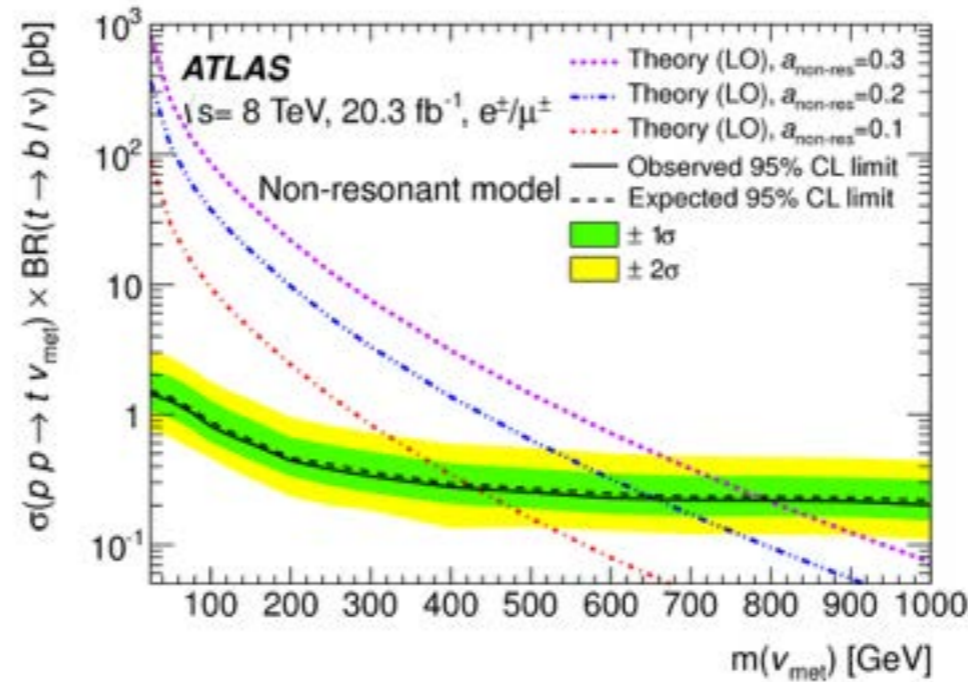
Monojet

ATLAS, Eur. Phys. J. C 75 (2015) 299



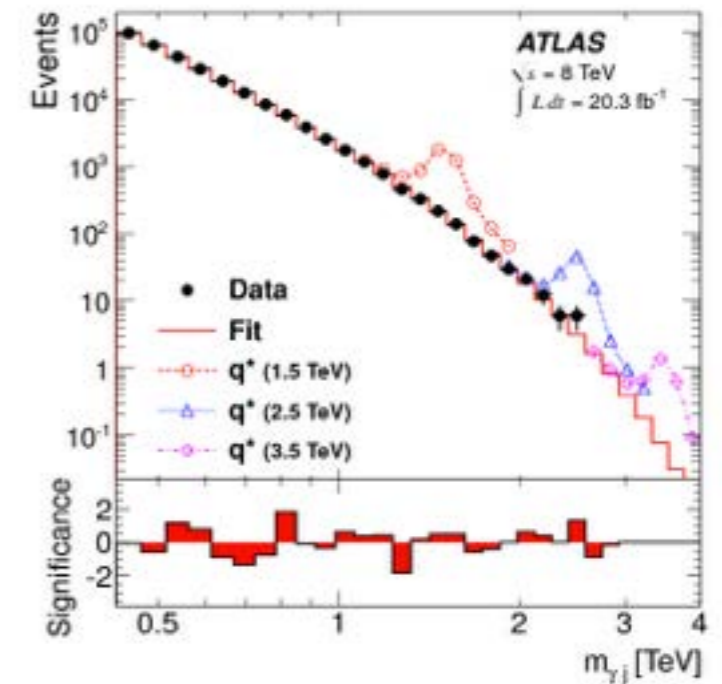
Monotop (leptonic/hadronic)

ATLAS, Eur. Phys. J. C 75 (2015) 79

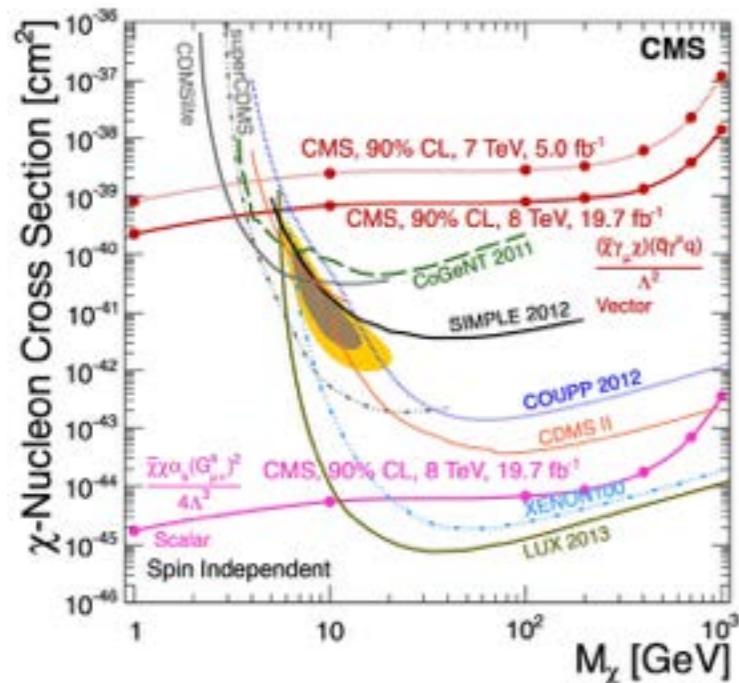


Monophoton

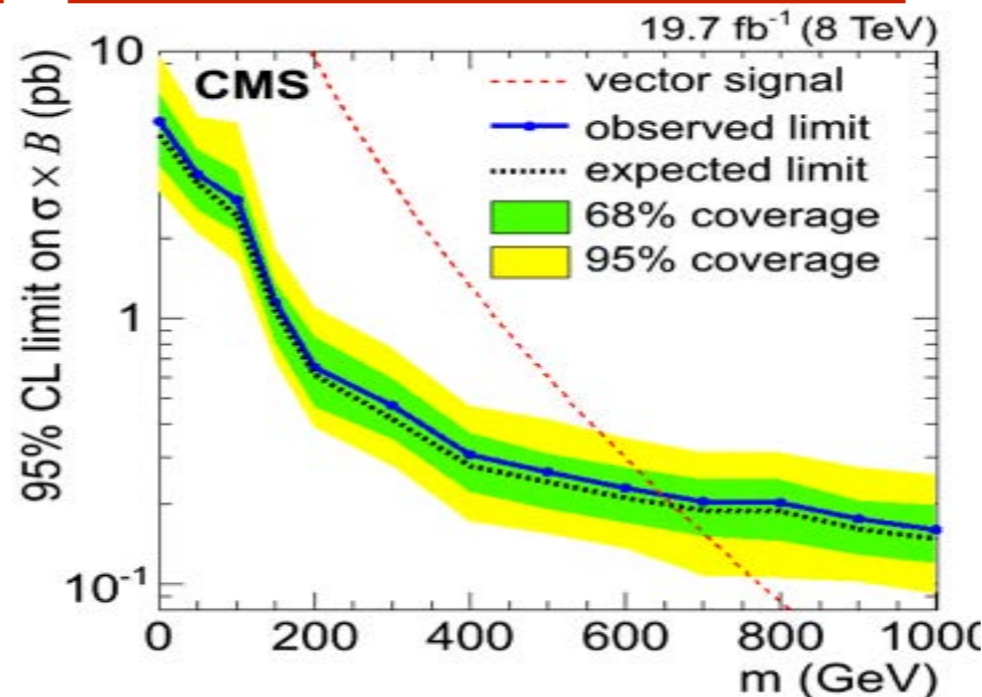
ATLAS, Phys. Lett. B 728 C (2014) 562



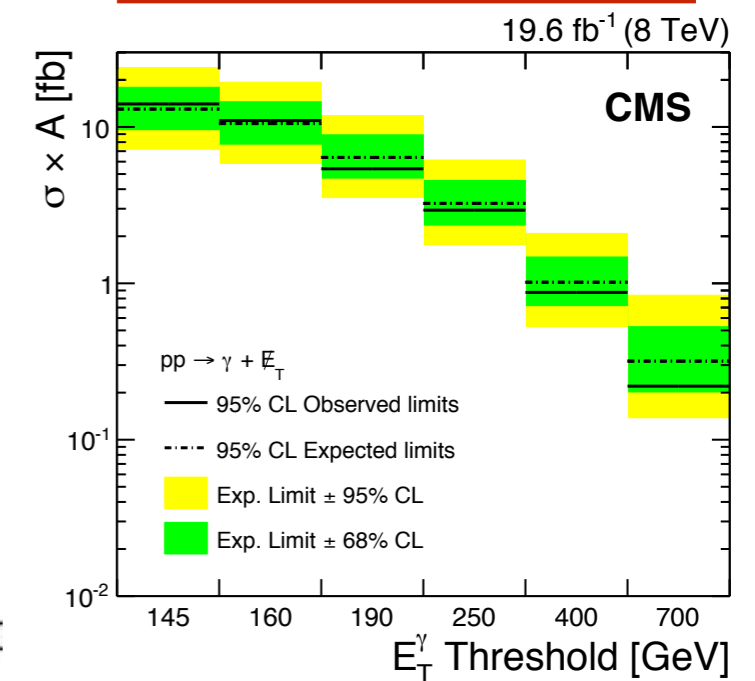
CMS, Eur. Phys. J. C 75 (2015) 235



CMS, Phys. Rev. Lett. 114, 101801

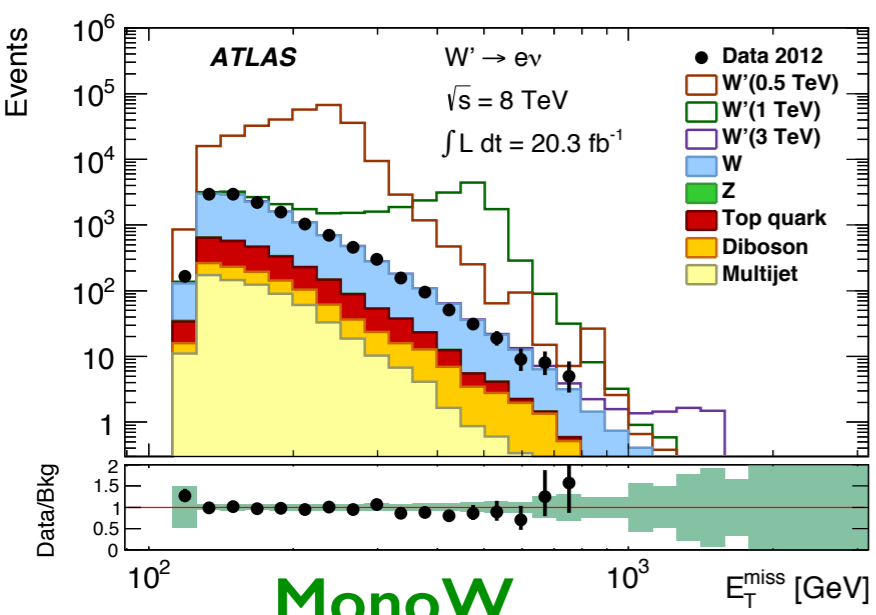


CMS, arXiv:1410.8812



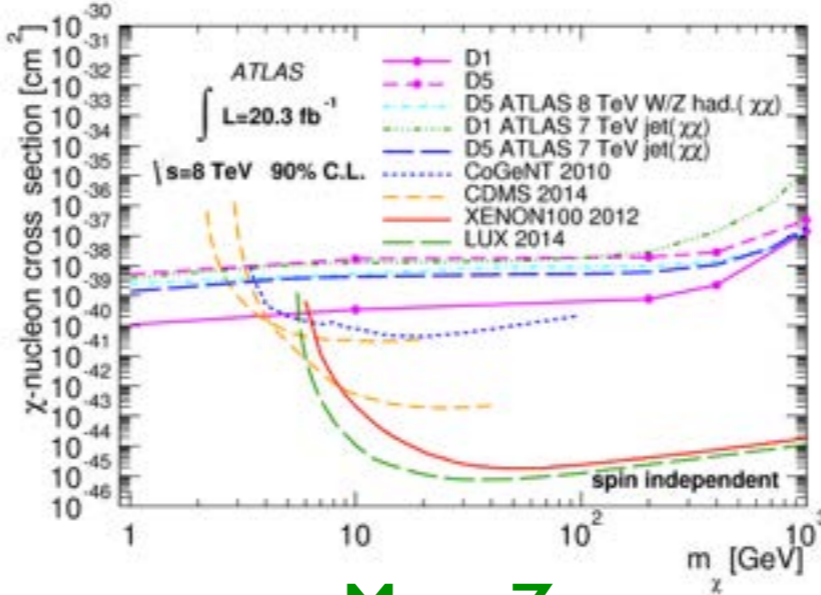
Boson+MET interpretations

ATLAS, JHEP09 (2014) 037



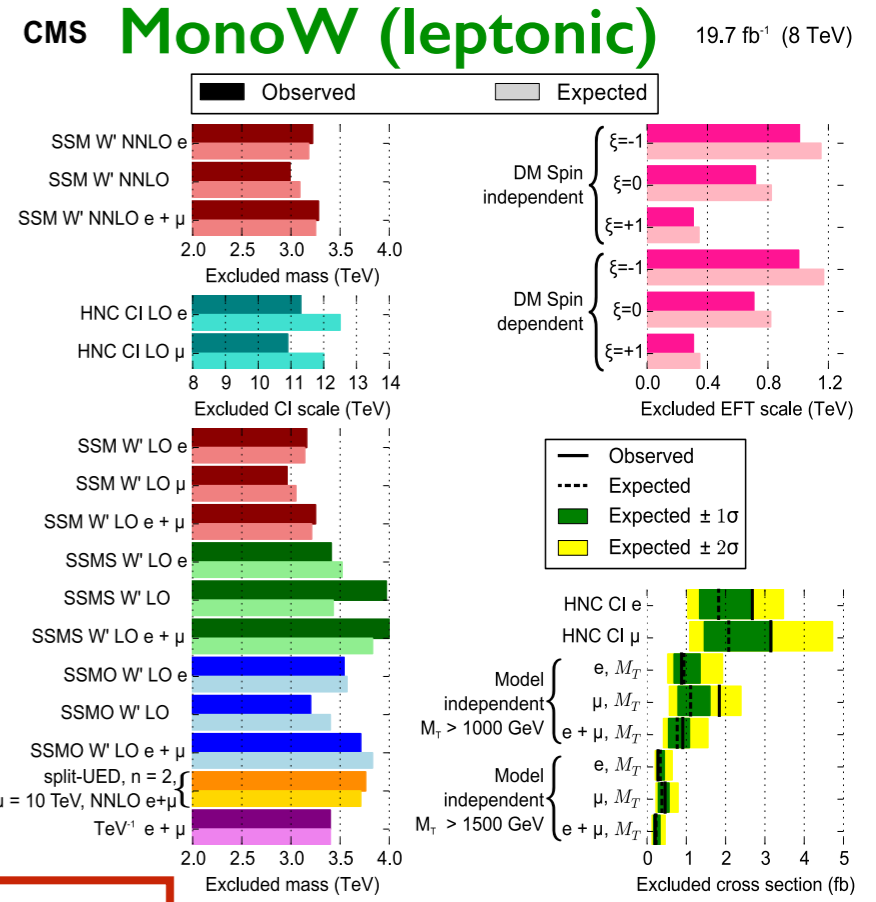
MonoW (leptonic)

ATLAS, Phys. Rev. D. 90, 012004

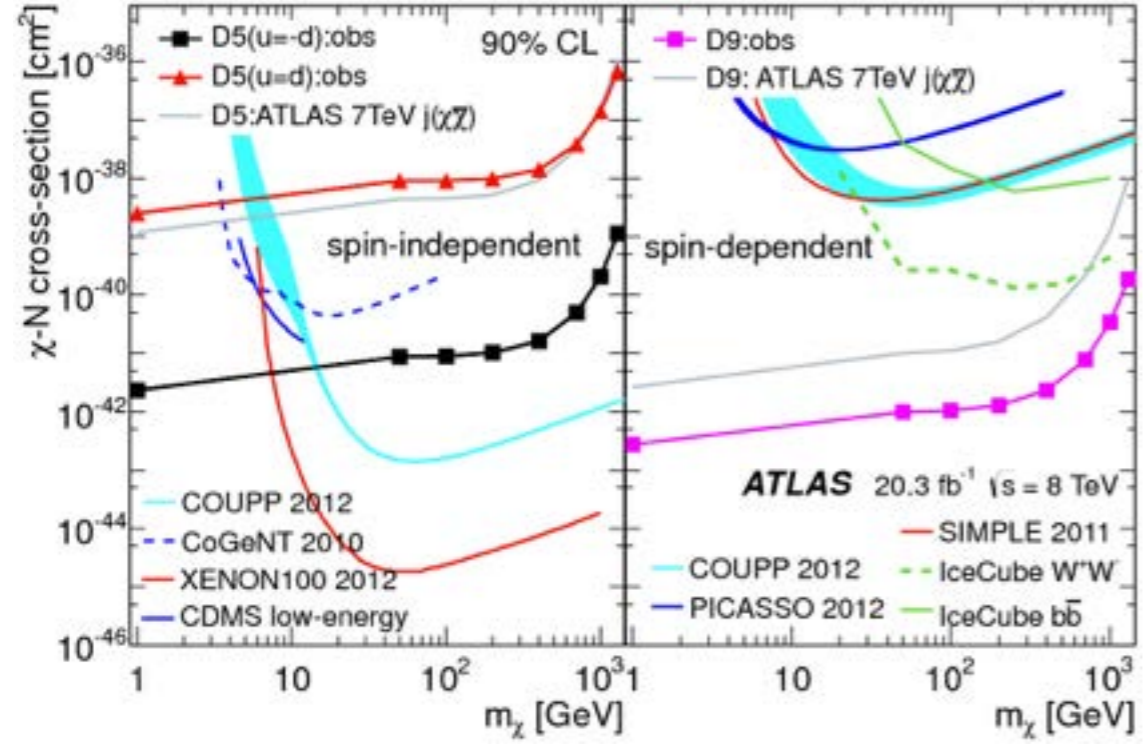


MonoZ (leptonic)

CMS, JHEP09 (2014) 037

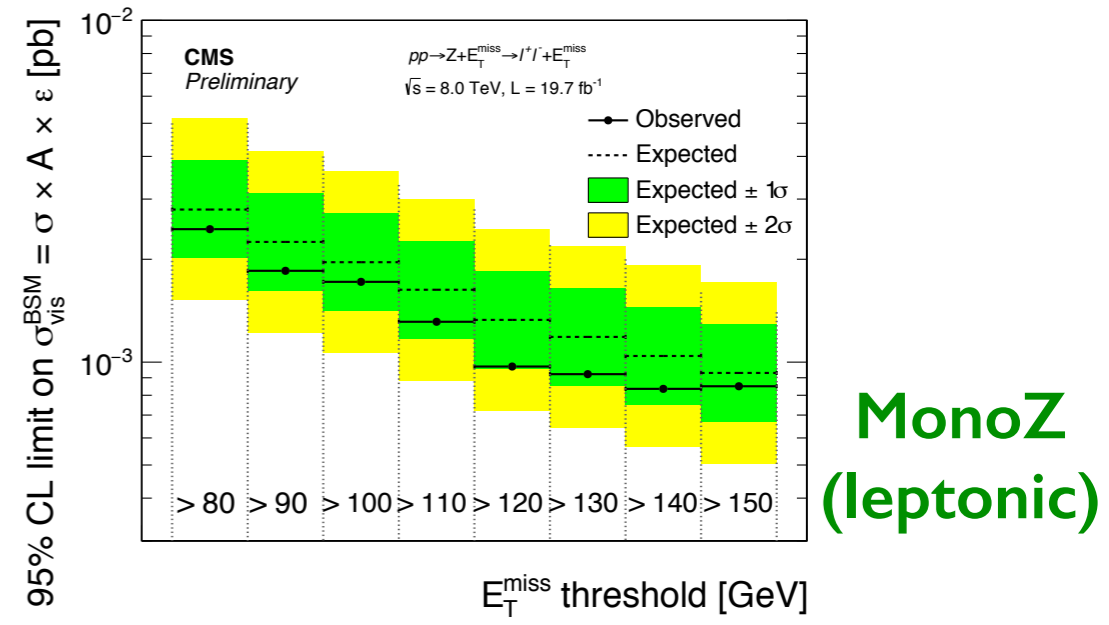


ATLAS, Phys. Rev. Lett. 112, 041802



MonoW,Z (Hadronic)

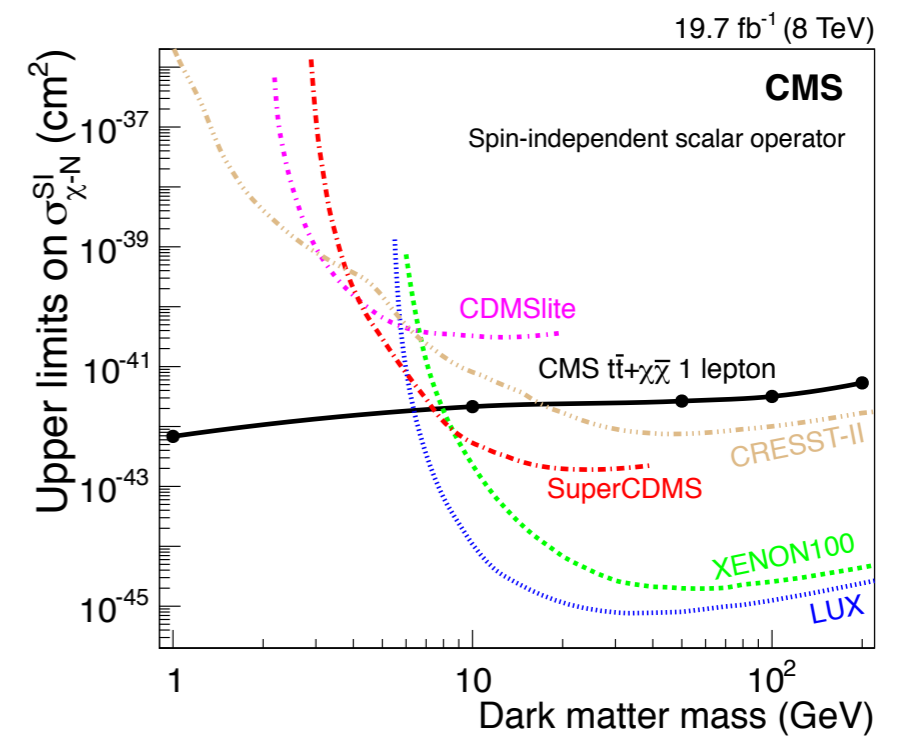
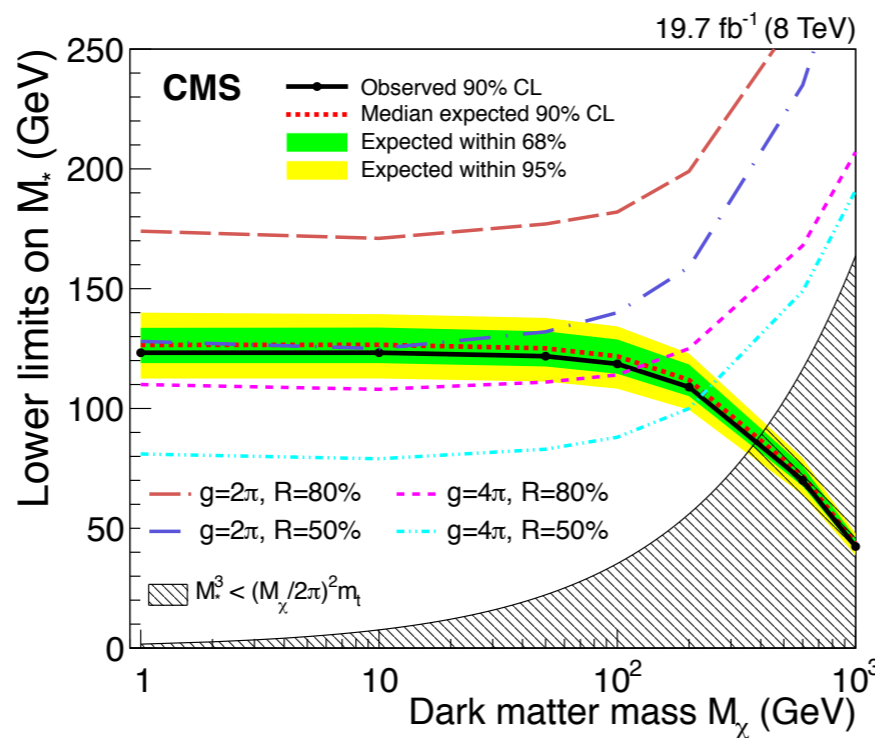
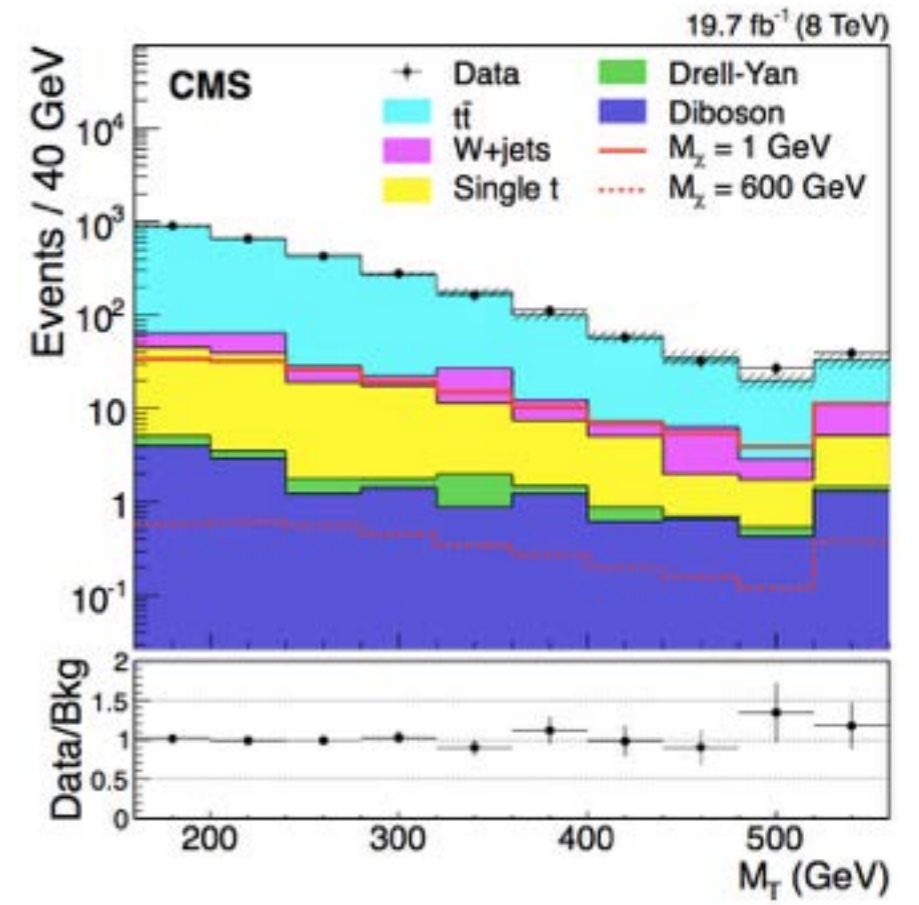
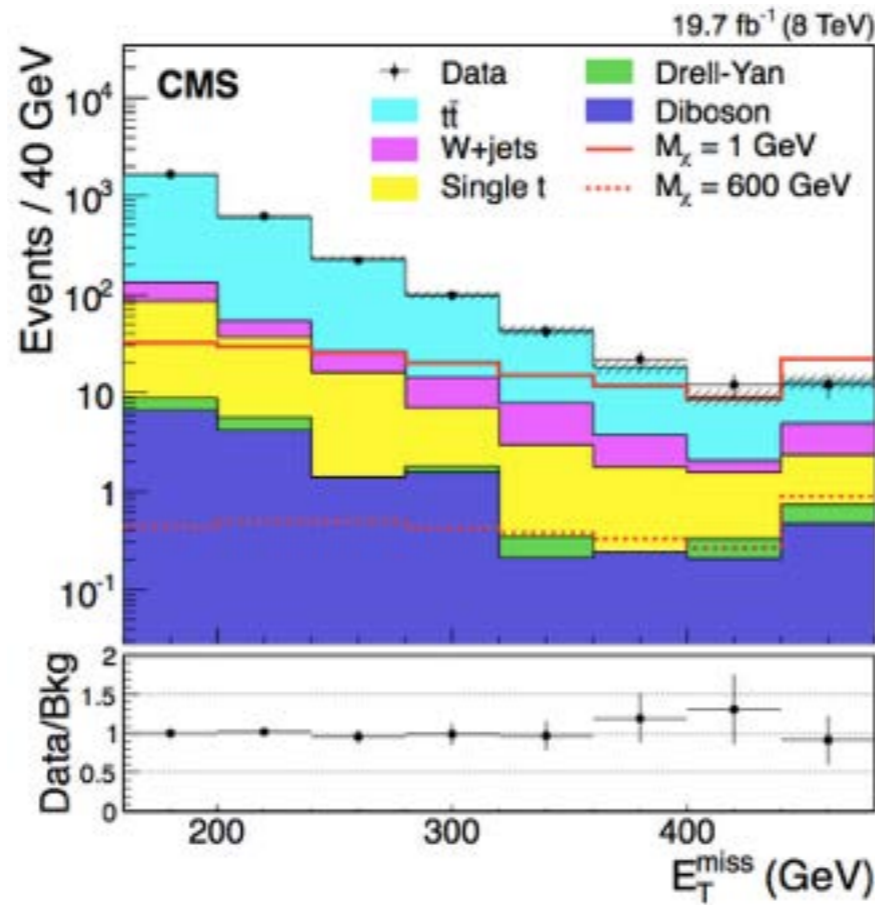
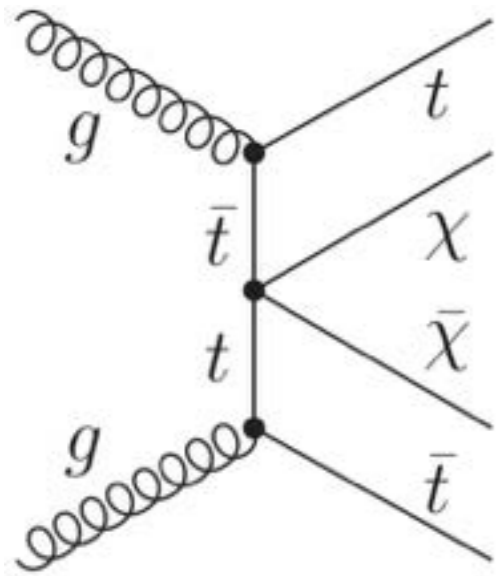
CMS, CMS-PAS-EXO-12-054



MonoZ (leptonic)

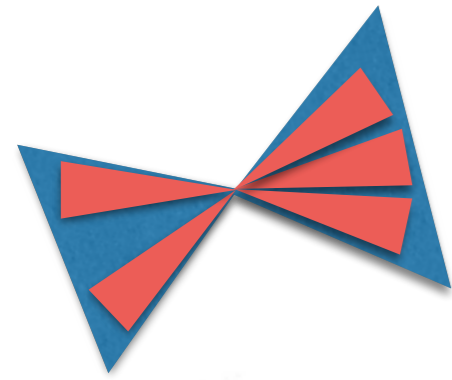
Top pair+MET interpretations

CMS, JHEP 06 (2015) 121



Dark matter interpretations: Razor variables

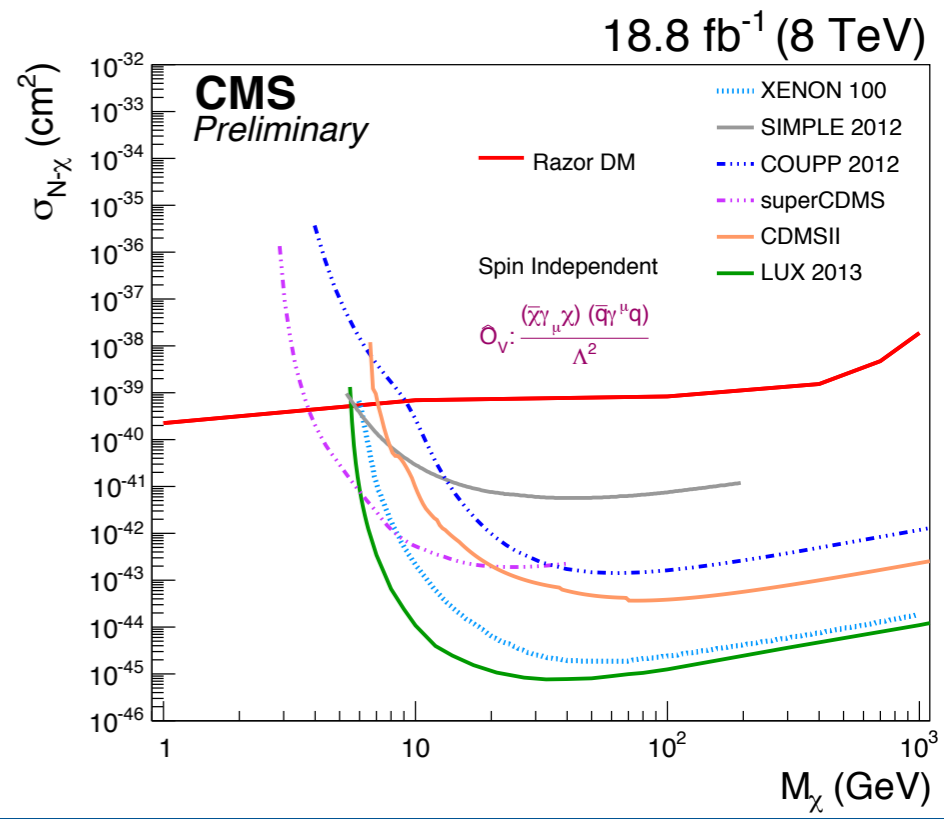
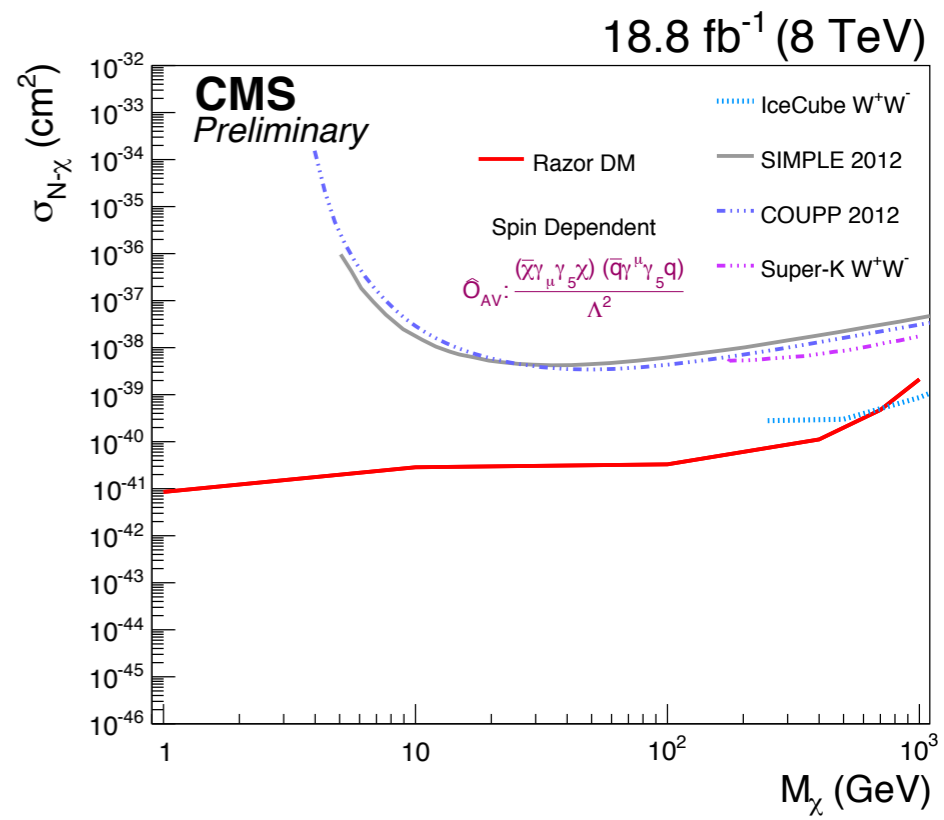
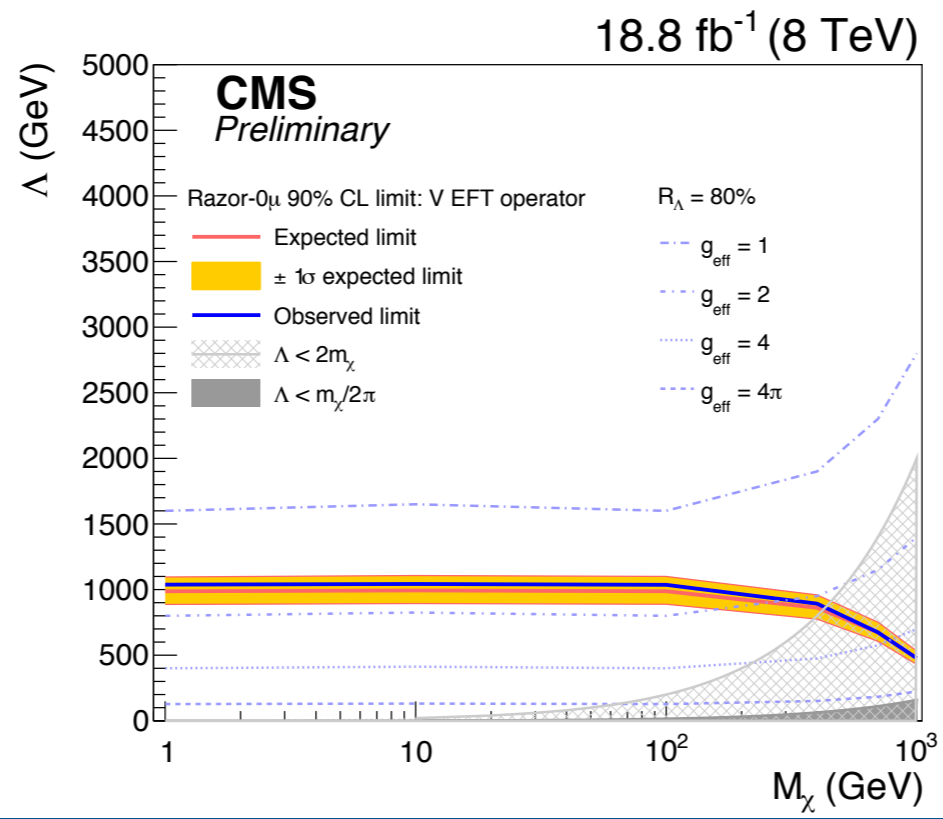
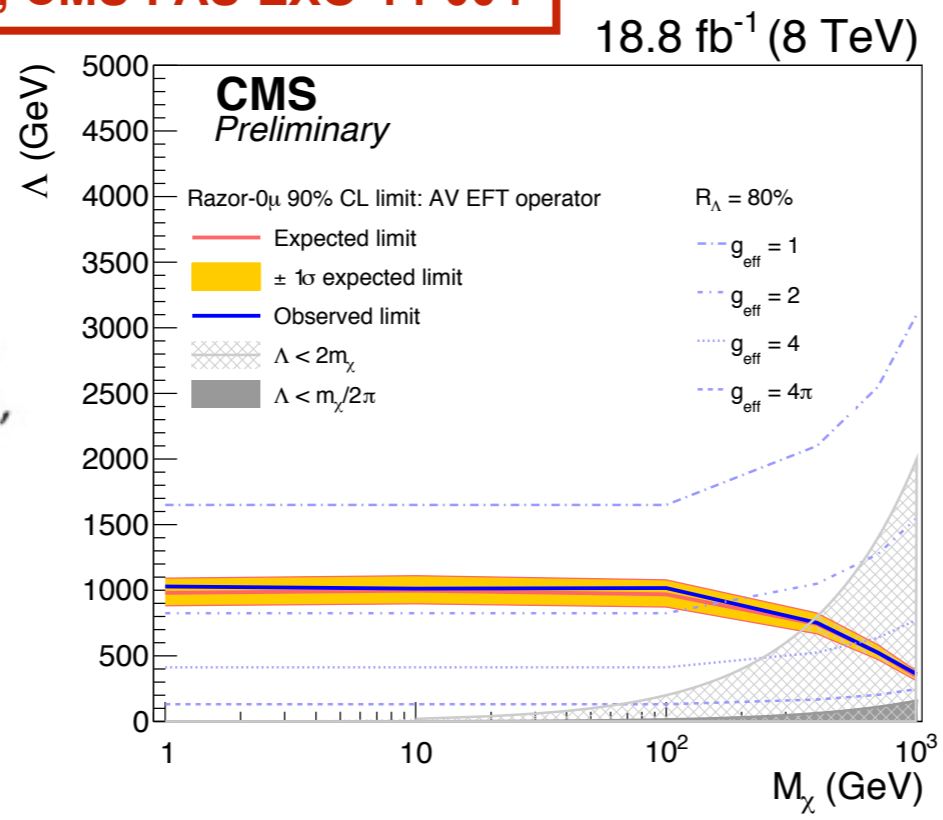
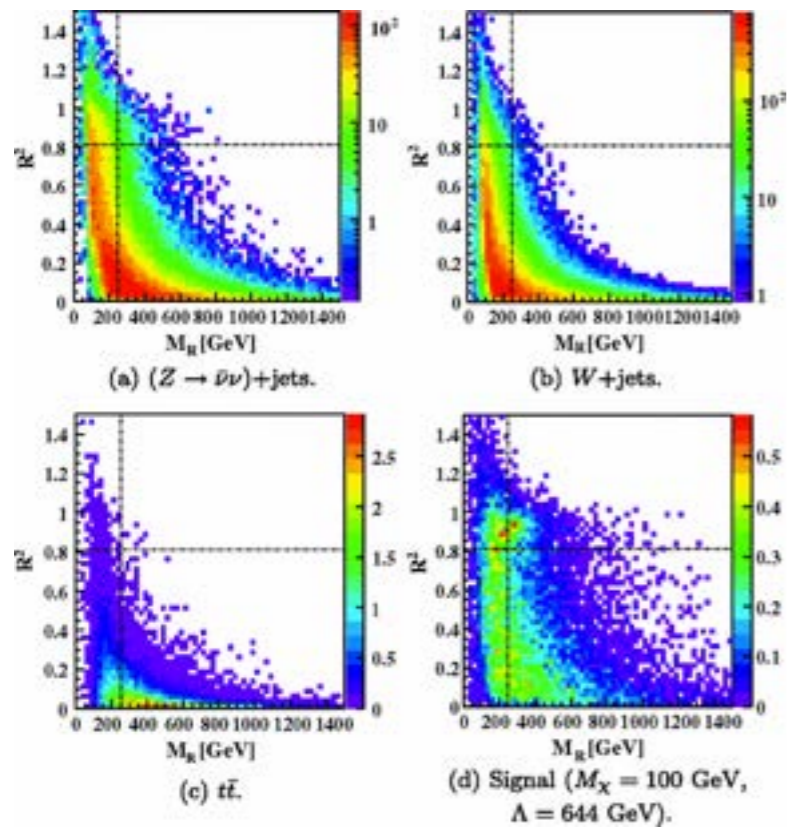
CMS, CMS-PAS-EXO-14-004



$$M_R \equiv \sqrt{(|\vec{p}_{J1}| + |\vec{p}_{J2}|)^2 - (p_z^{J1} + p_z^{J2})^2}$$

$$R \equiv \frac{M_T^R}{M_R}$$

Phys. Rev. D 86, 015010

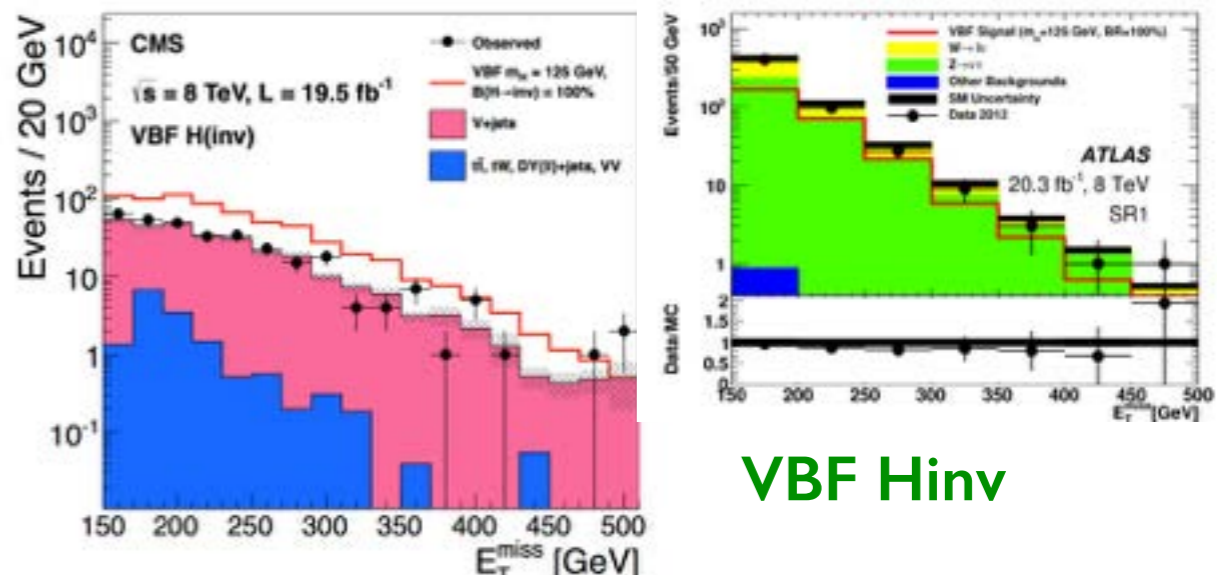


Dark matter interpretations: Higgs Portal

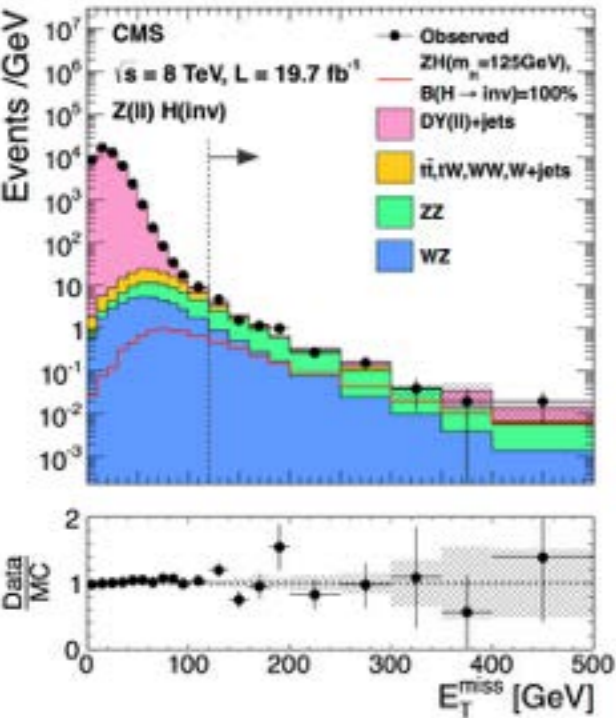
DM particles have the direct couplings to the SM Higgs sector, $H \rightarrow \chi \chi$

- ▶ Limits on branching fraction of Higgs to “invisible” particles used for limits on DM
- ▶ Can be scalar, vector or fermionic couplings
- ▶ Limits only up to DM mass $M_\chi < M_H/2$

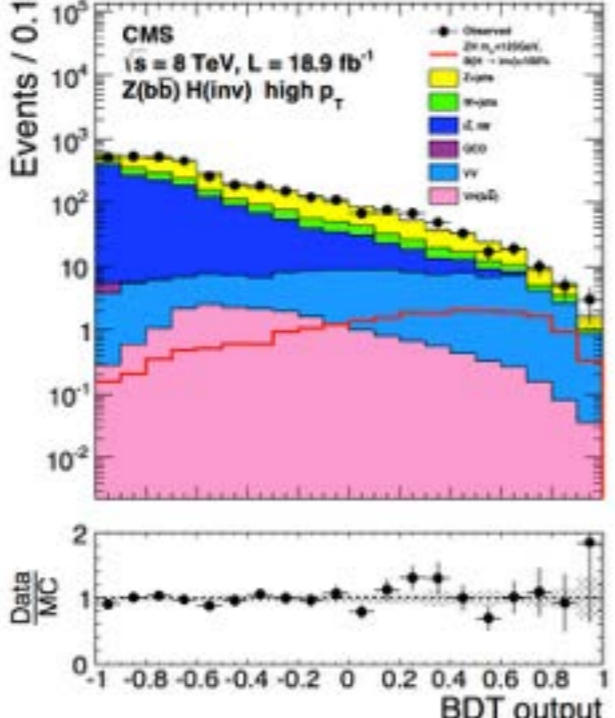
CMS, Eur. Phys. J. C 74 (2014) 2980
 ATLAS, arXiv:1508.07869



VBF Hinv

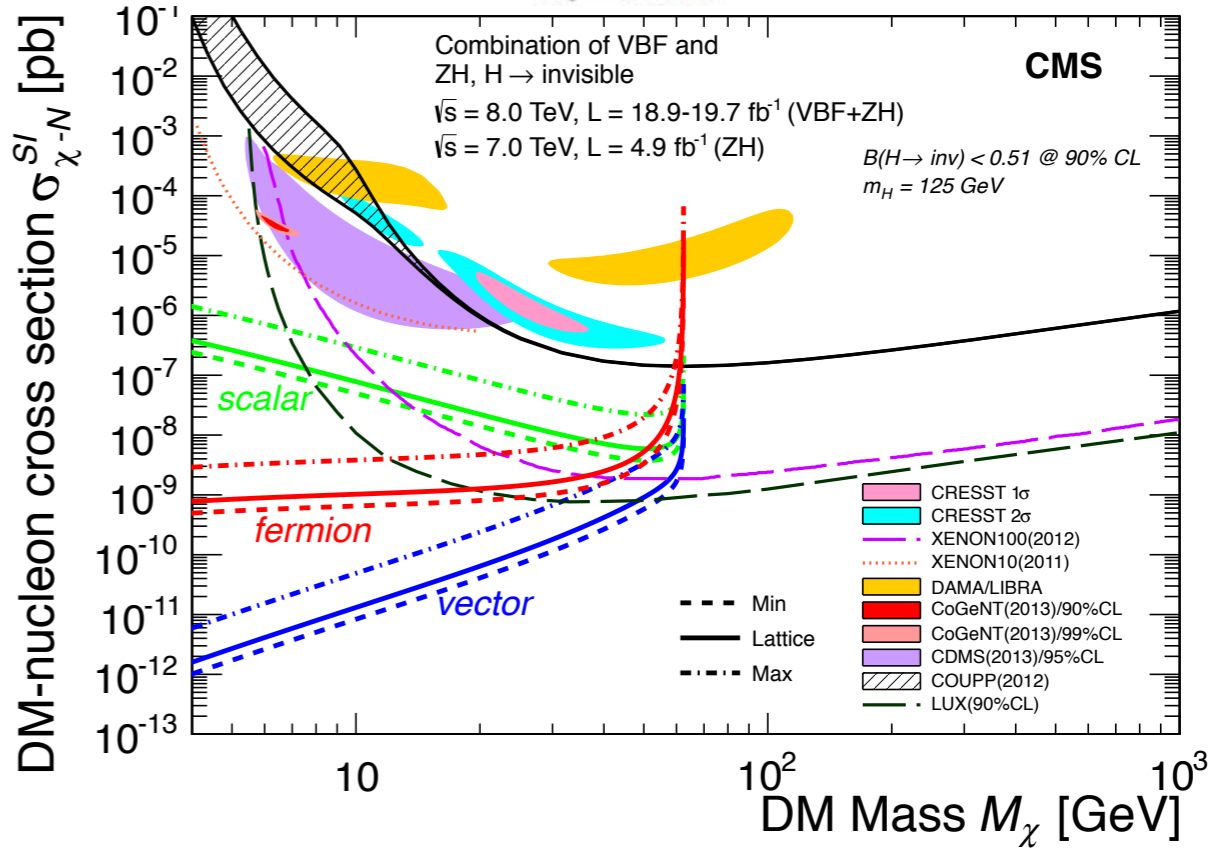


Z(ll)Hinv



Z(bb)Hinv

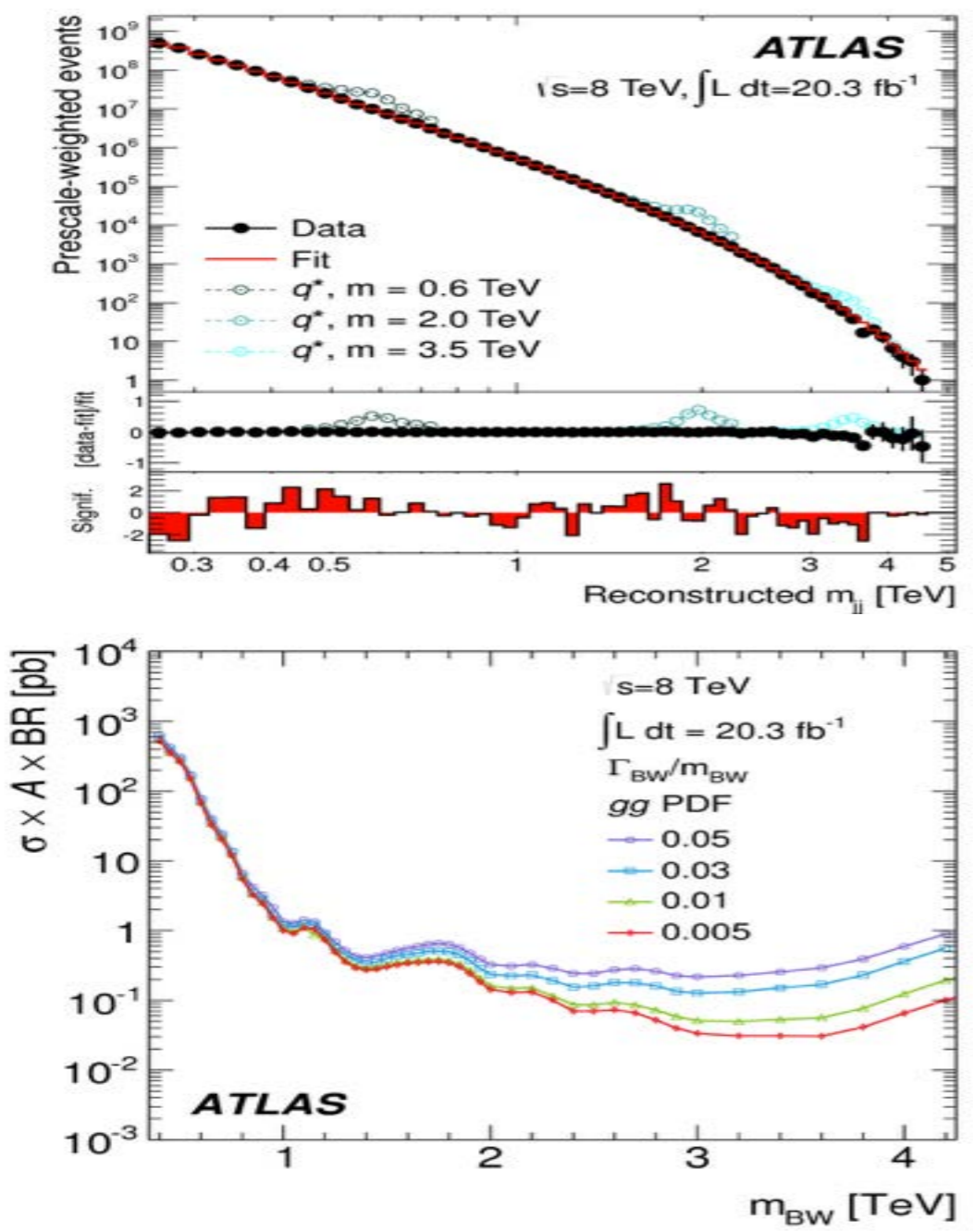
$m_H = 125 \text{ GeV}$, and $B(H \rightarrow \text{inv}) < 0.51$ at 90% CL, as a function of the DM mass. \rightarrow



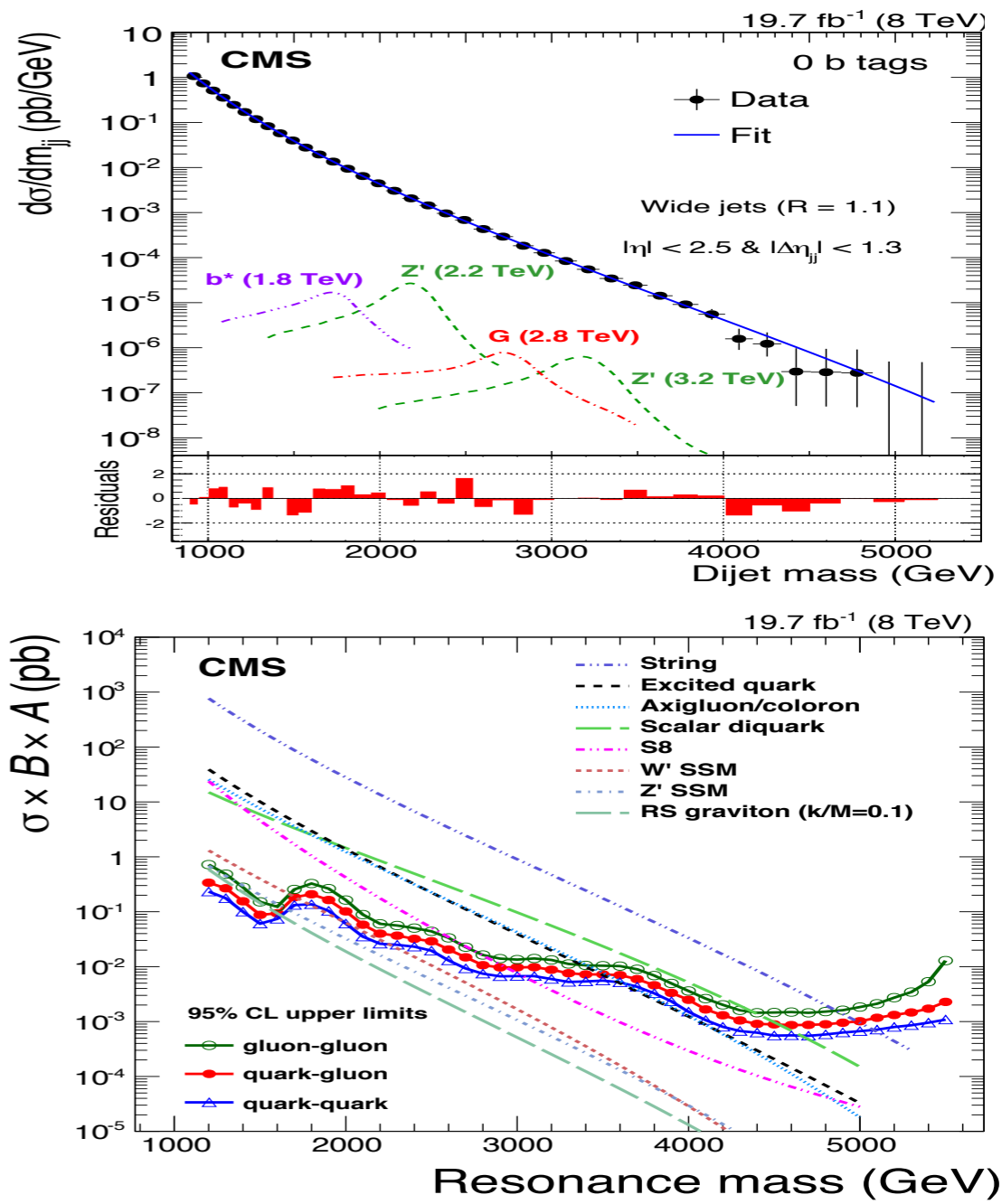
Resonance searches: Dijet resonances

- ▶ Almost fully data driven: assuming a smooth background and narrow bumps.
- ▶ Limits are interpreted to resonances (string, excited quarks, scalar diquark, W' , Z' , RS gravitons) and quantum black holes.

ATLAS, Phys. Rev. D 91, 052007

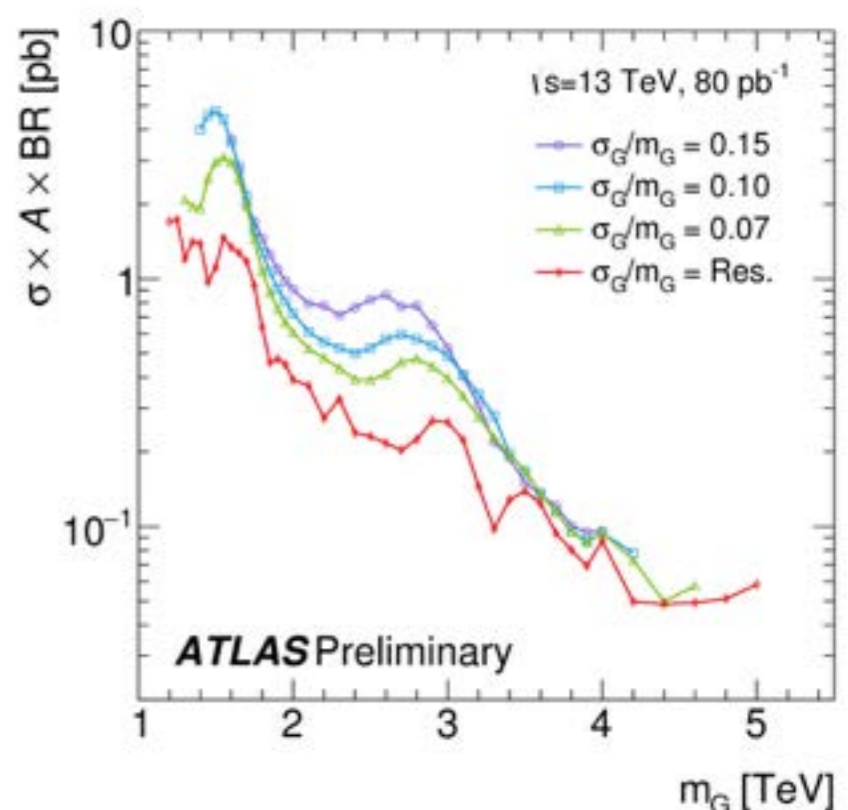
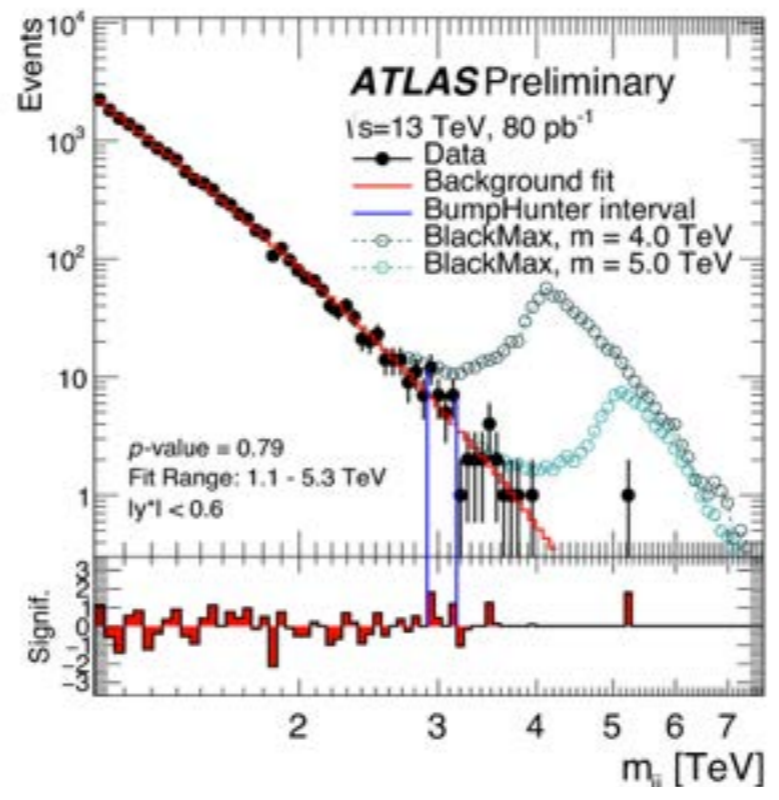
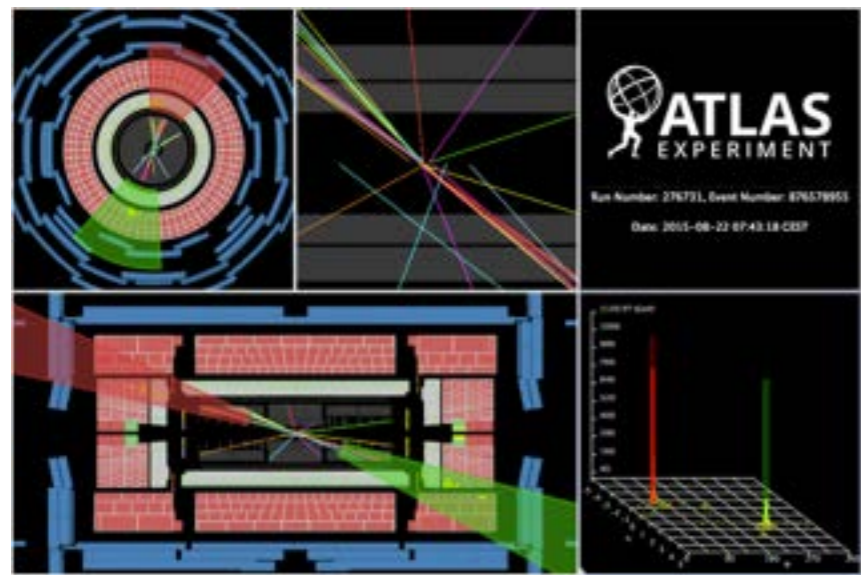


CMS, Phys. Rev. D 91, 052009

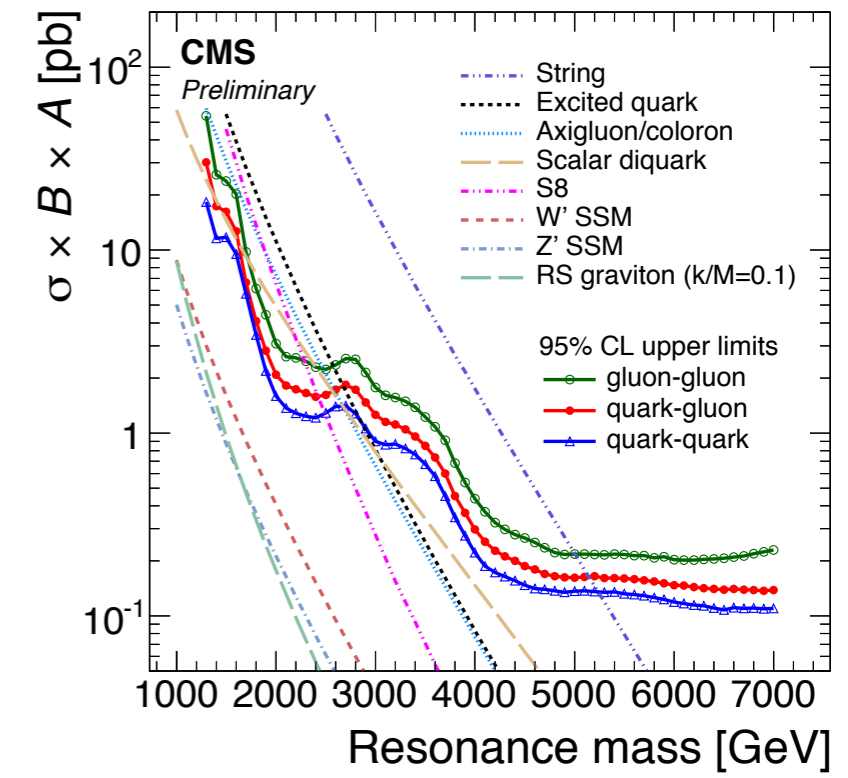
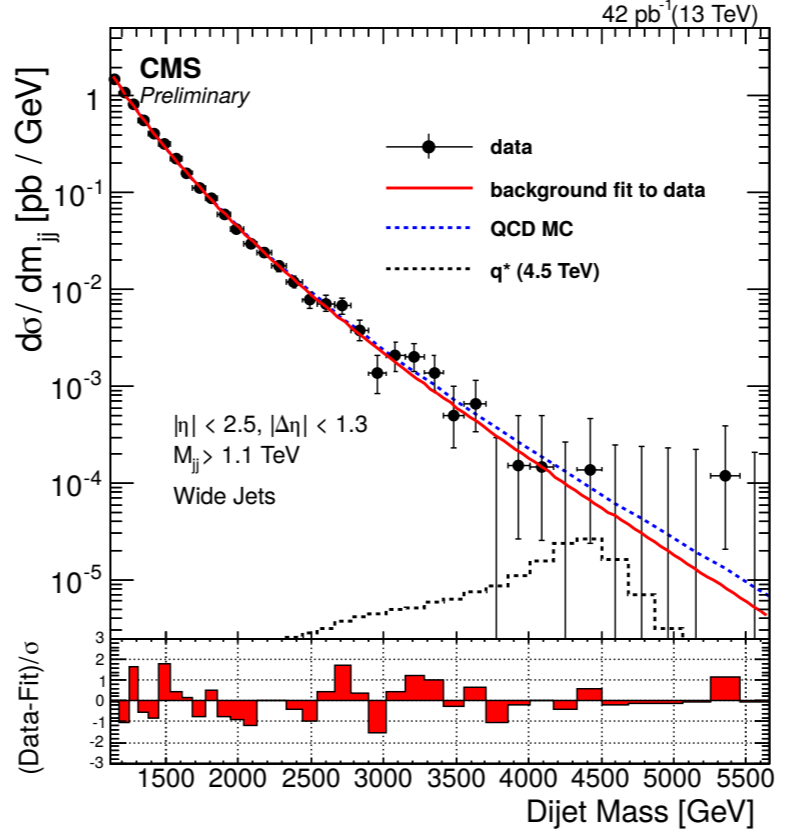
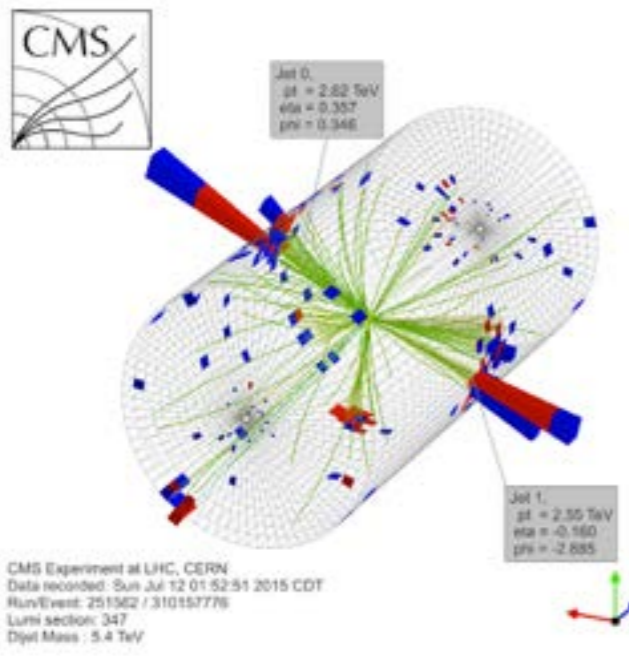


Resonance searches: Dijet resonances (13 TeV)

ATLAS, <https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2015-042/>



CMS, <https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsEXO15001>



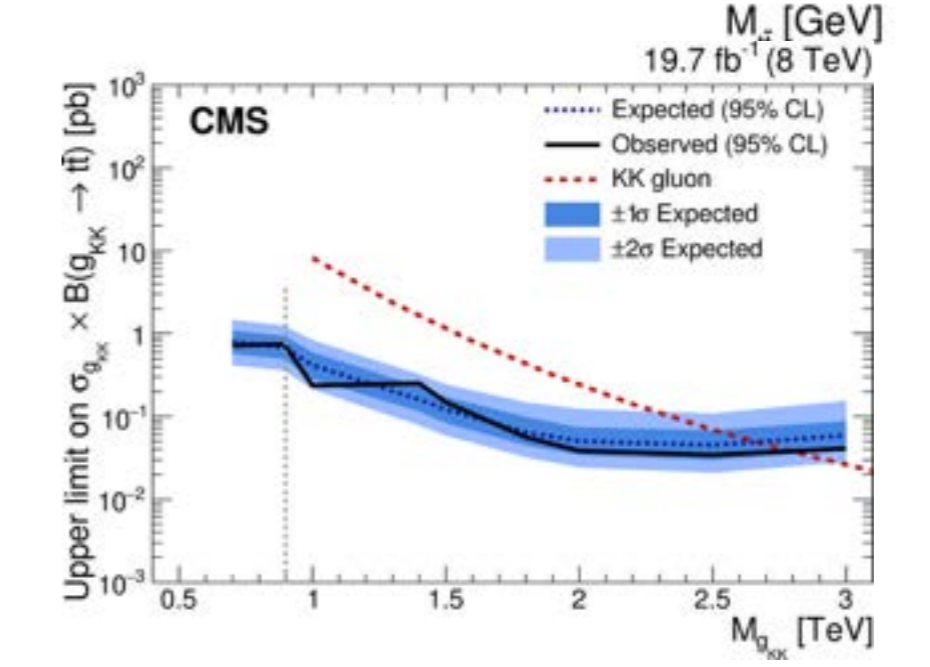
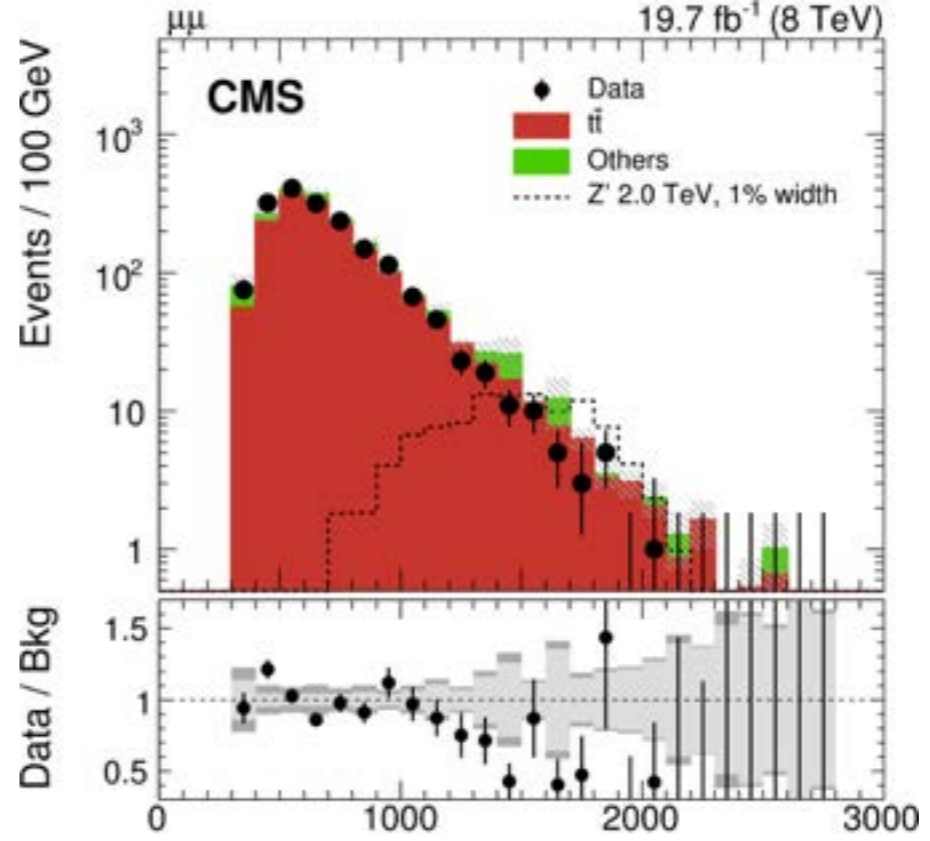
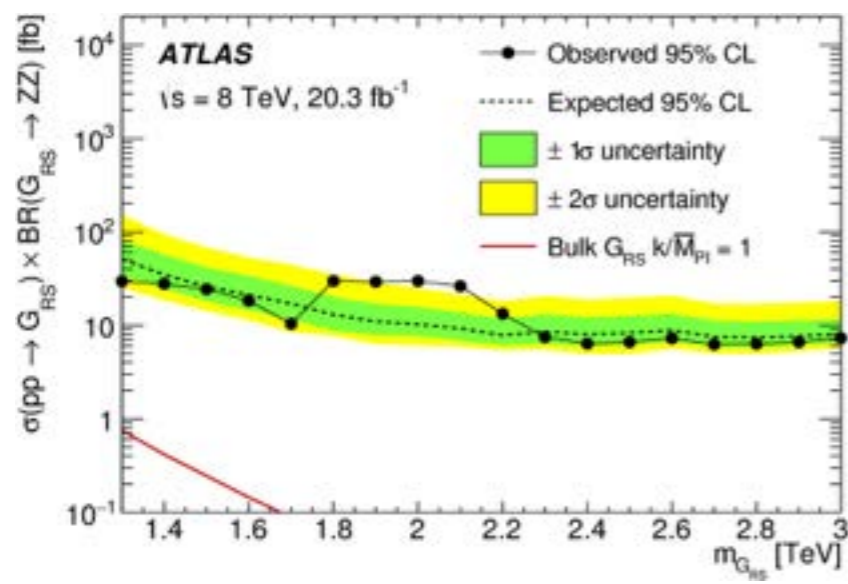
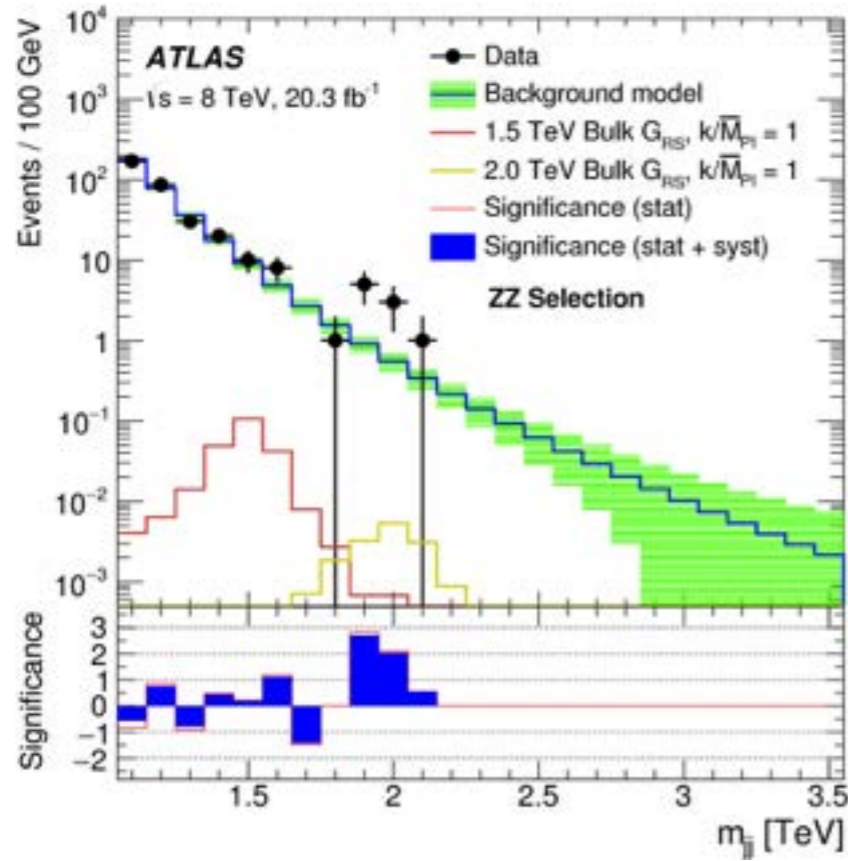
Resonance searches: Tagged jets resonances

ATLAS, arXiv:1506.00962

Boson-tagged jet

CMS, arXiv:1506.03062

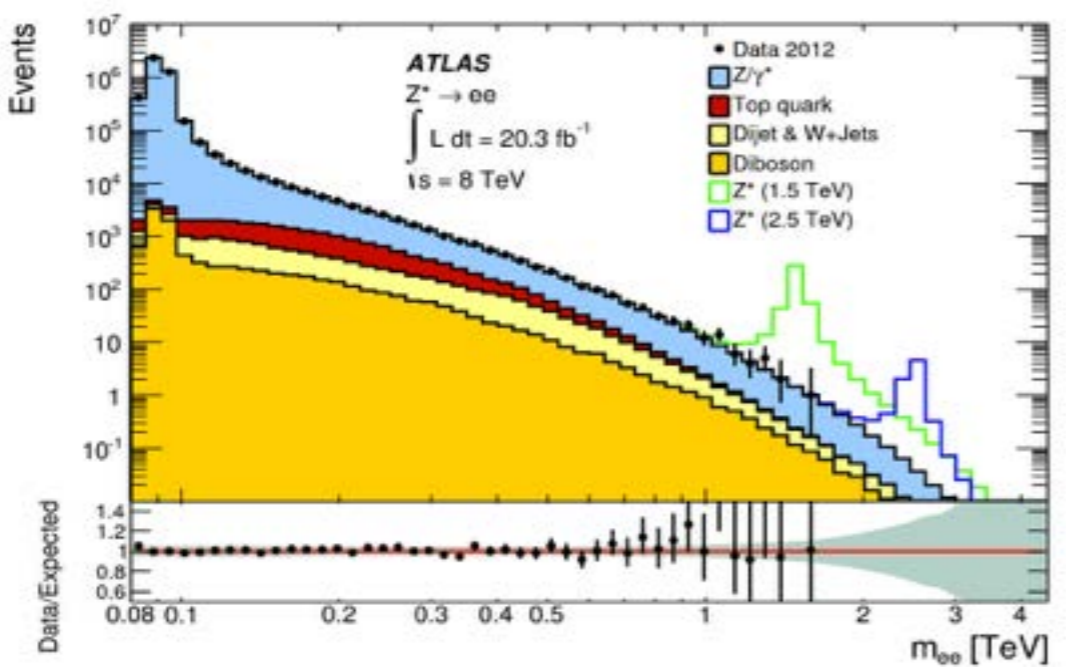
Top-tagged jet



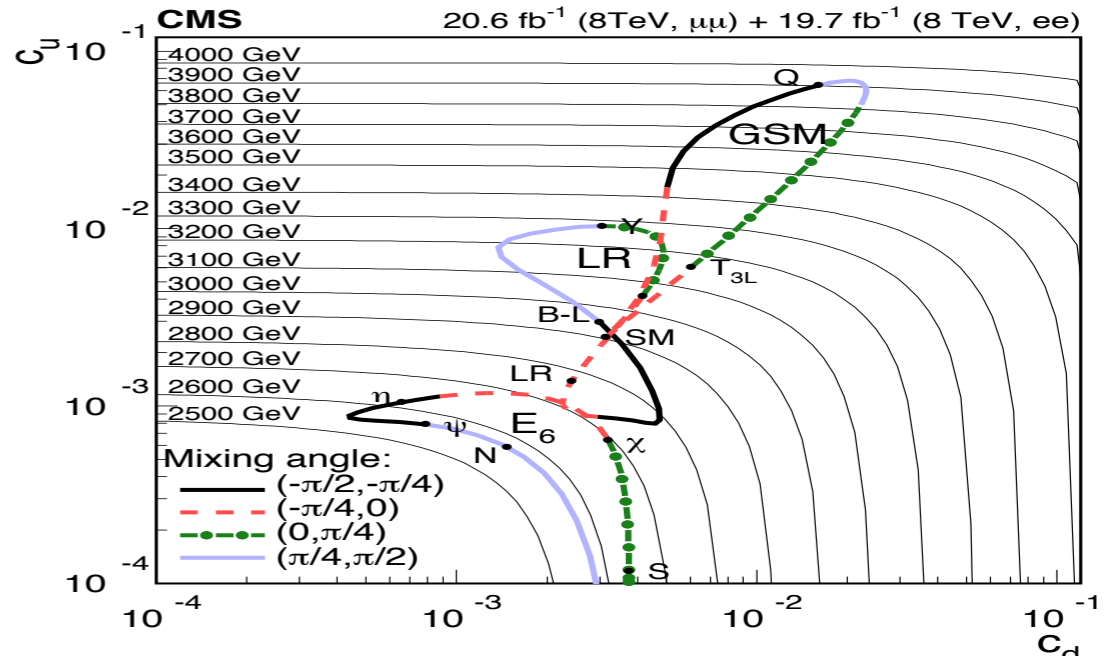
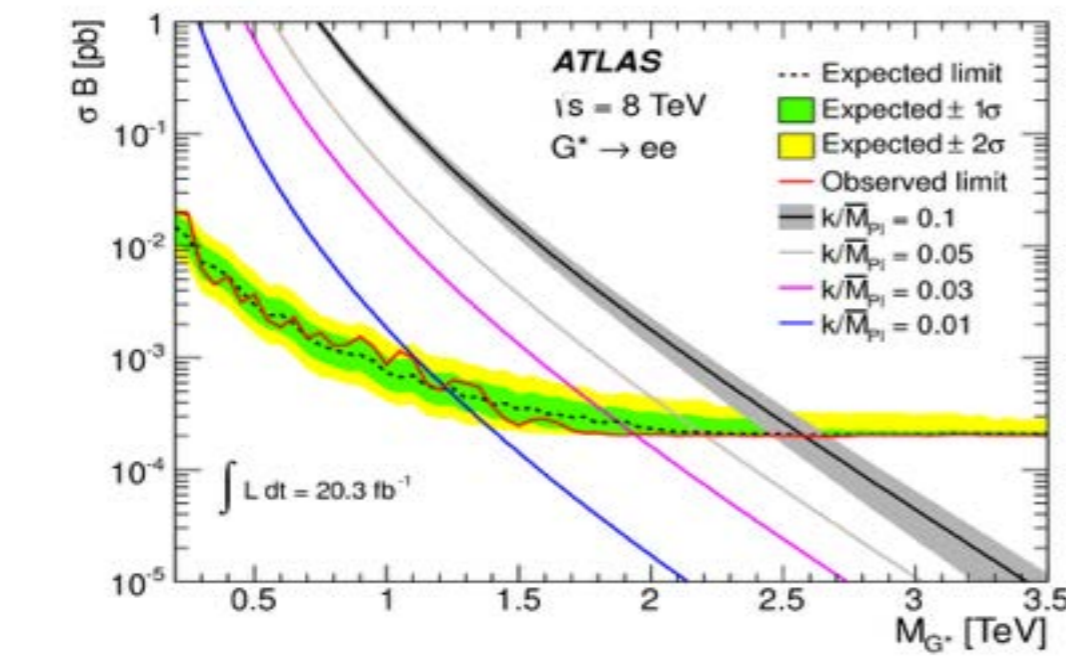
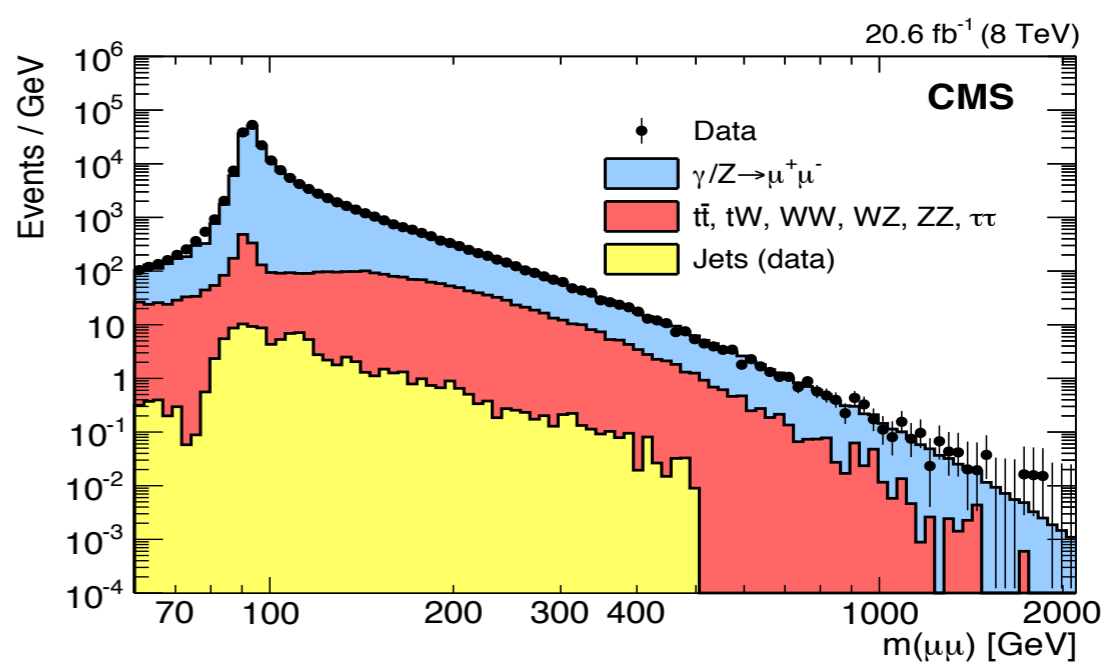
Resonance searches: Dilepton resonances

- ▶ Clean and excellent resolution even at higher masses.
- ▶ Limits can be interpreted in various models, e.g. Z' models, spin-2 graviton.

ATLAS, Phys. Rev. D 90, 052005



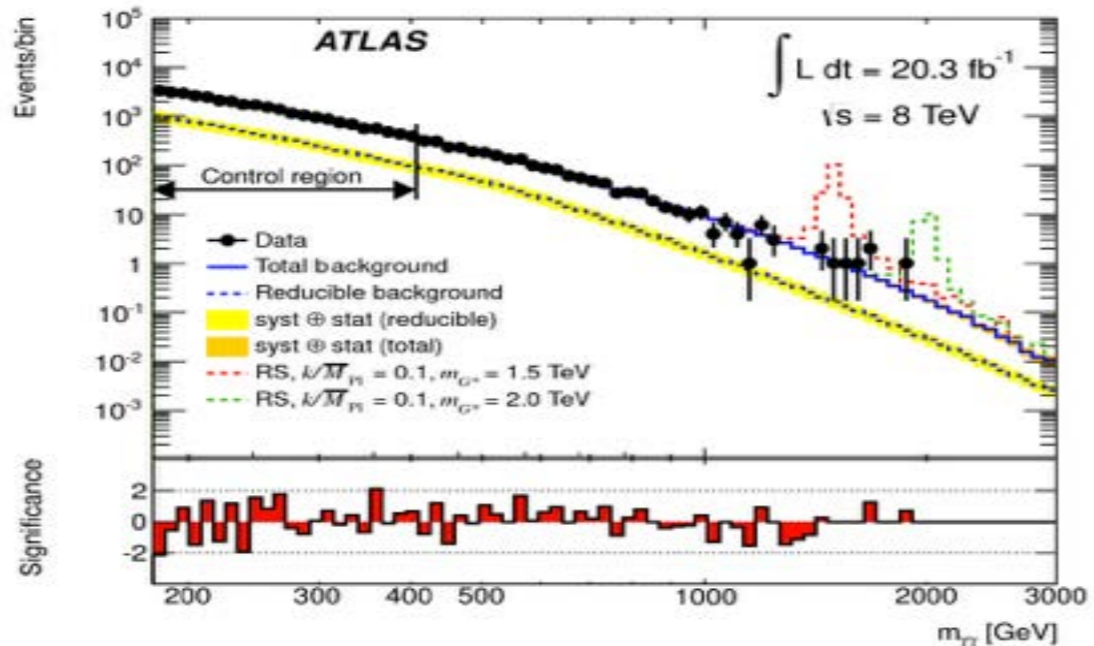
CMS, JHEP 04 (2015) 025



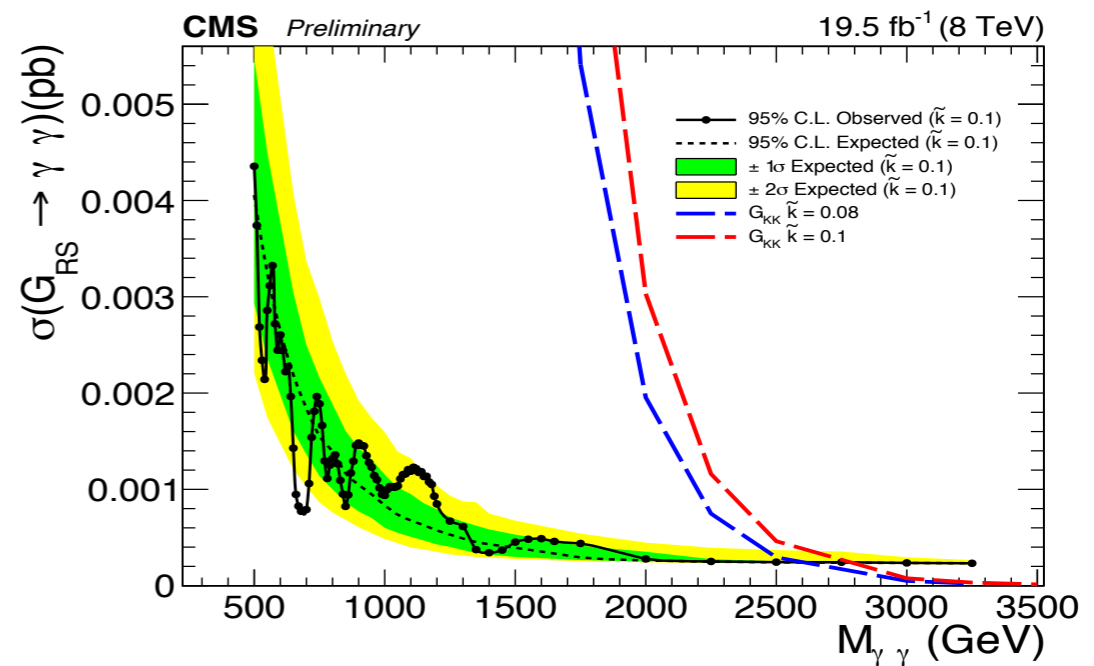
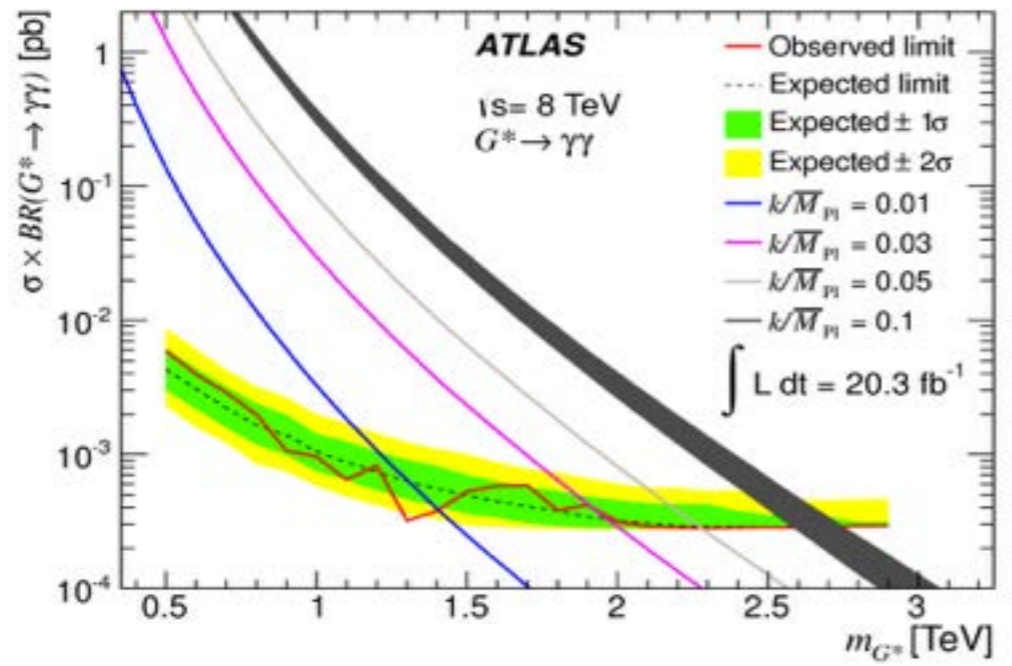
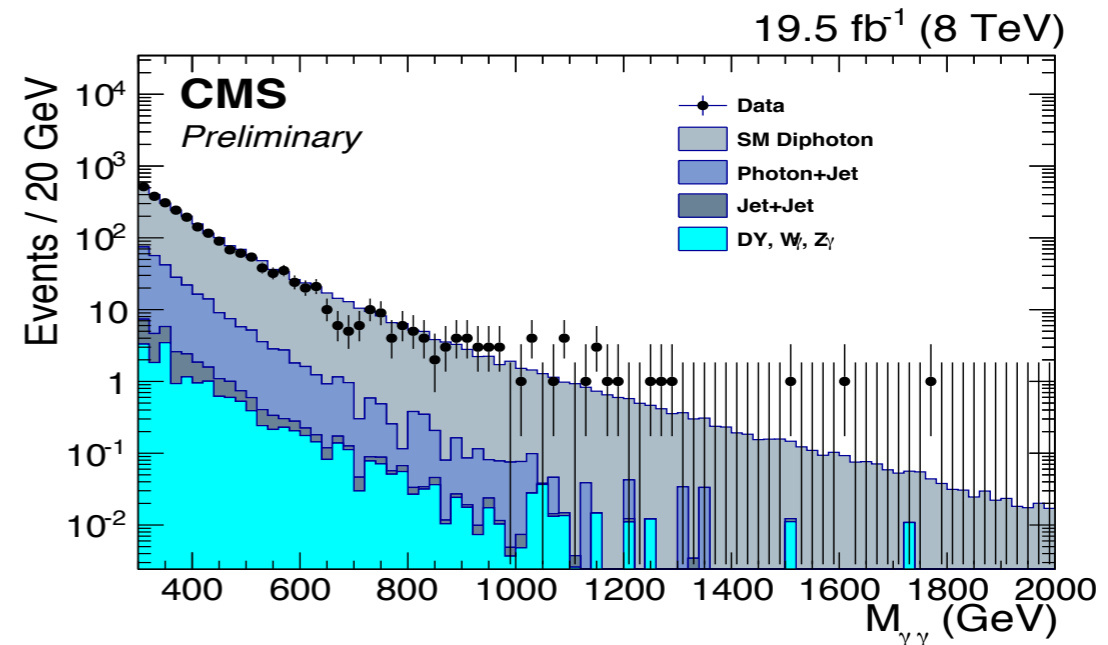
Resonance searches: Diphoton resonances

- ▶ Clean and sensitive to scalar and particularly to spin-2 (RS-Graviton) resonances.
- ▶ Limits are set on the mass of lightest graviton for couplings of $0.01 \leq k/\bar{M}_{PL} \leq 0.1$.

ATLAS, Phys. Rev. D 92, 032004

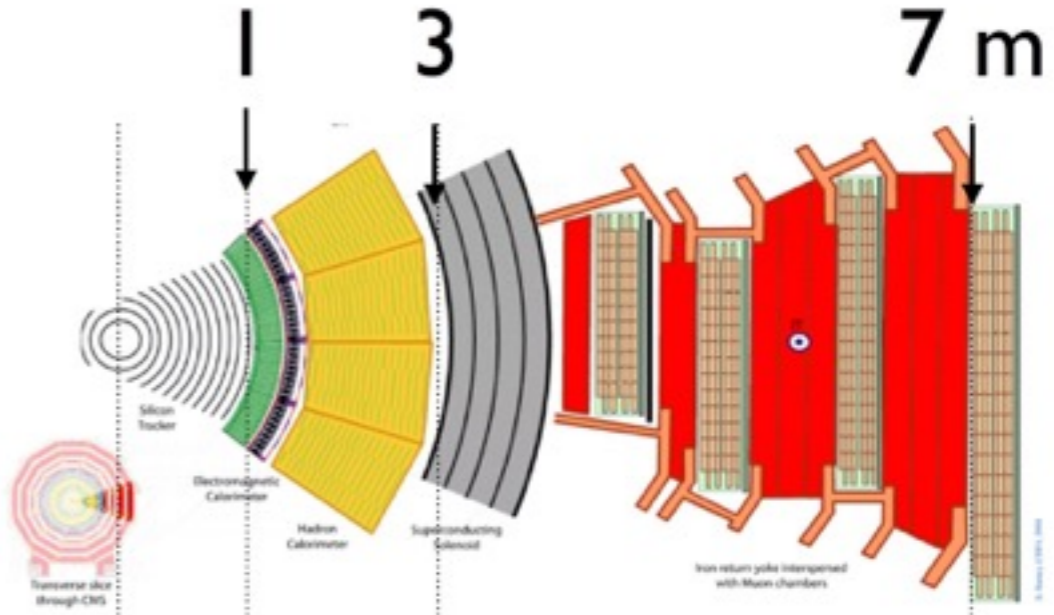


CMS, CMS-PAS-EXO-12-045



Long-lived searches

- ▶ Many models of new physics (e.g. hidden valley, weakly RPV SUSY, split SUSY with long-lived gluinos, Z' decays, little Higgs, etc.) include heavy particles with lifetimes large enough to allow them to travel measurable distances before decaying.
- ▶ Small SM background due to the significant lifetime.
- ▶ Searches for this kind of particle are signature driven. They need dedicated triggers.



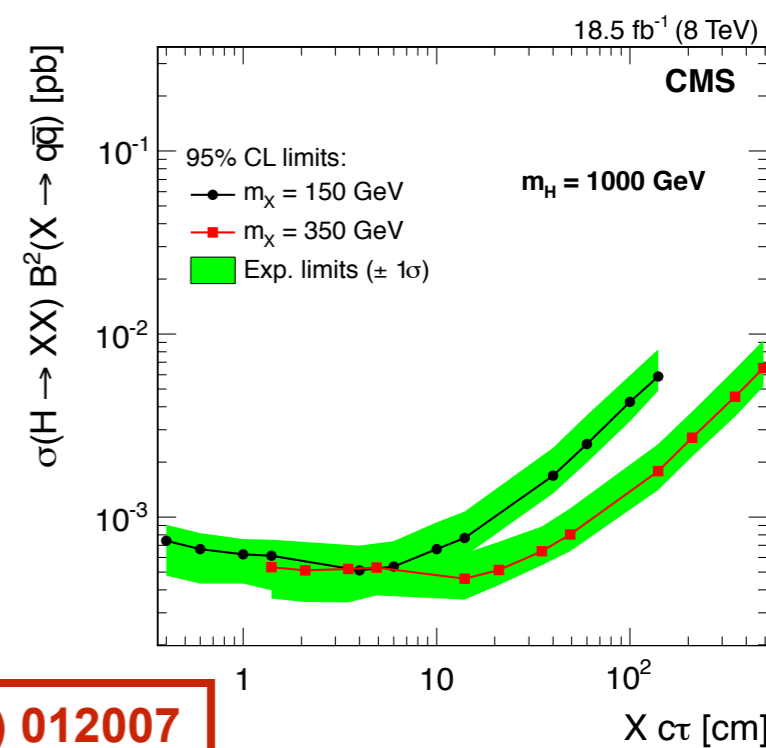
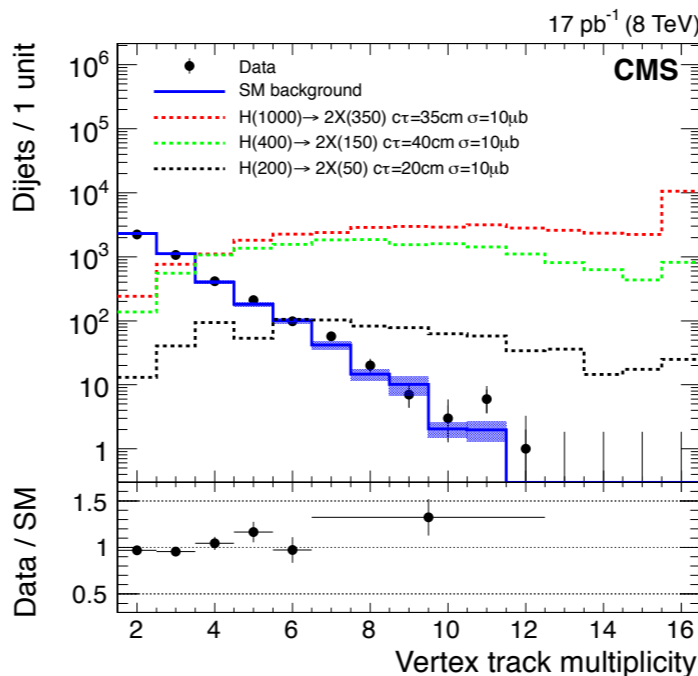
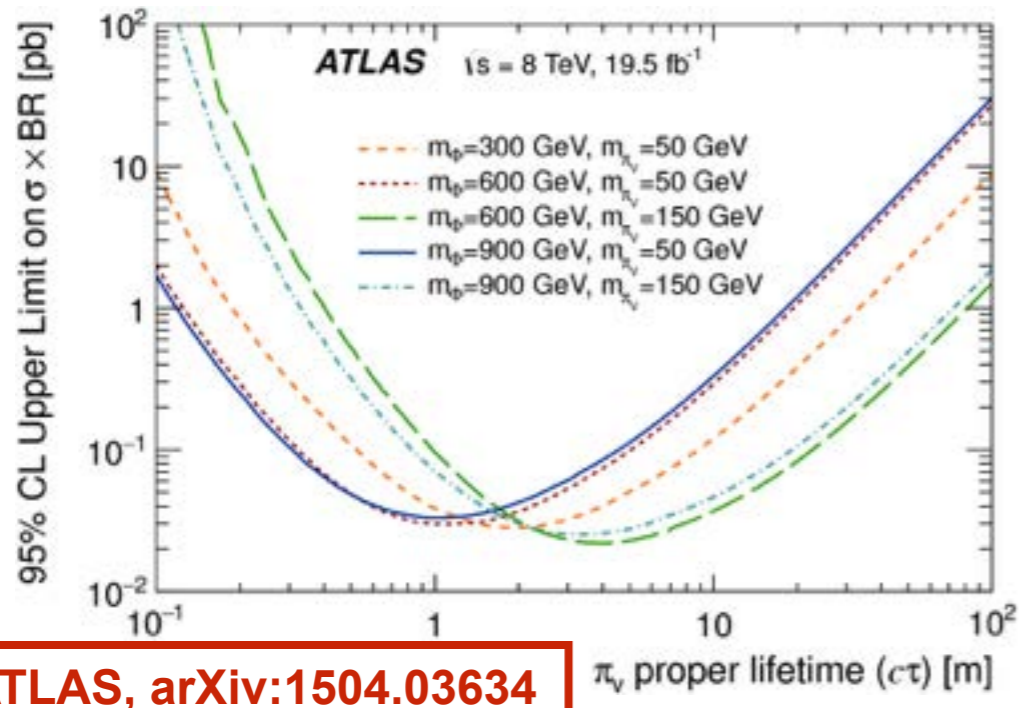
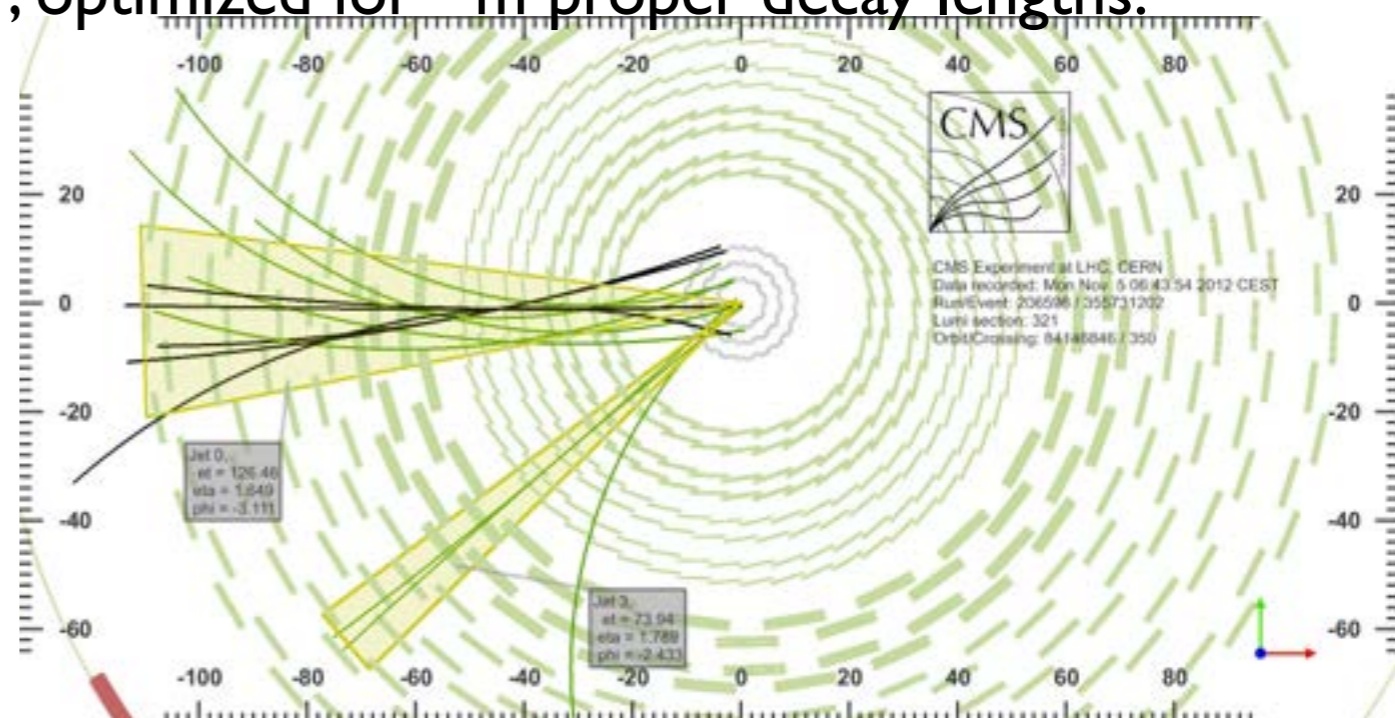
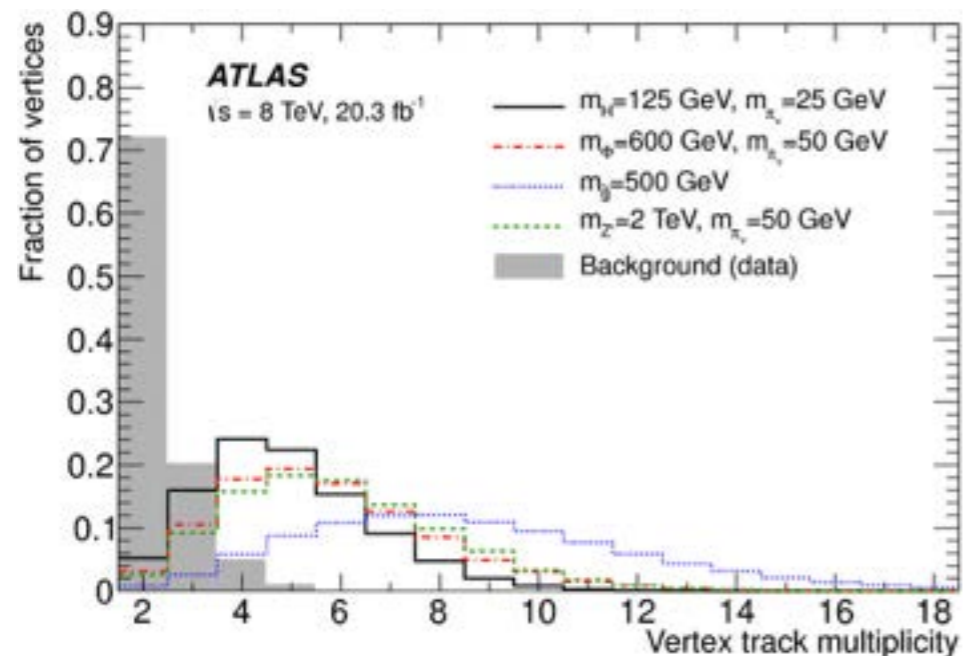
Region of BSM particle decay

displaced jets	NEW!	Phys. Rev. D 91, 012007 (2015) Phys. Lett. B 743, 15 (2015) arXiv:1504.03634
lepton jets		JHEP 11, 088 (2014)
displaced leptons	NEW!	arXiv:1411.6977 & EXO-14-012 PAS Phys. Rev. Lett. 114, 061801 (2015)
displaced vertices	NEW!	arXiv:1504.05162
displaced / delayed photons		EXO-14-017 PAS Phys. Rev. D 90, 112005 (2014)
prompt RPV	NEW!	arXiv:1502.05686 & arXiv:1503.04430 ATLAS-CONF-2015-015
stopped particles		Phys. Rev. D 88, 112006 (2013) arXiv:1501.05603
heavy stable charged particles	NEW!	JHEP 07 (2013) 122 JHEP 01, 068 (2015) arXiv:1506.05332
disappearing tracks		Phys. Rev. D 88, 112003 (2013) JHEP 01 (2015) 096
reinterpretations		ATLAS-CONF-2014-037 arXiv:1502.02522

Update from
<http://moriond.in2p3.fr/QCD/2015/WednesdayMorning/Wulsin.pdf>

Displaced jets / Displaced dijets

- ▶ Dedicated triggers are needed:
 - CMS: Total CAL trigger, optimized to \sim cm proper decay lengths.
 - ATLAS: Muon chamber vertexing trigger, optimized for \sim m proper decay lengths.



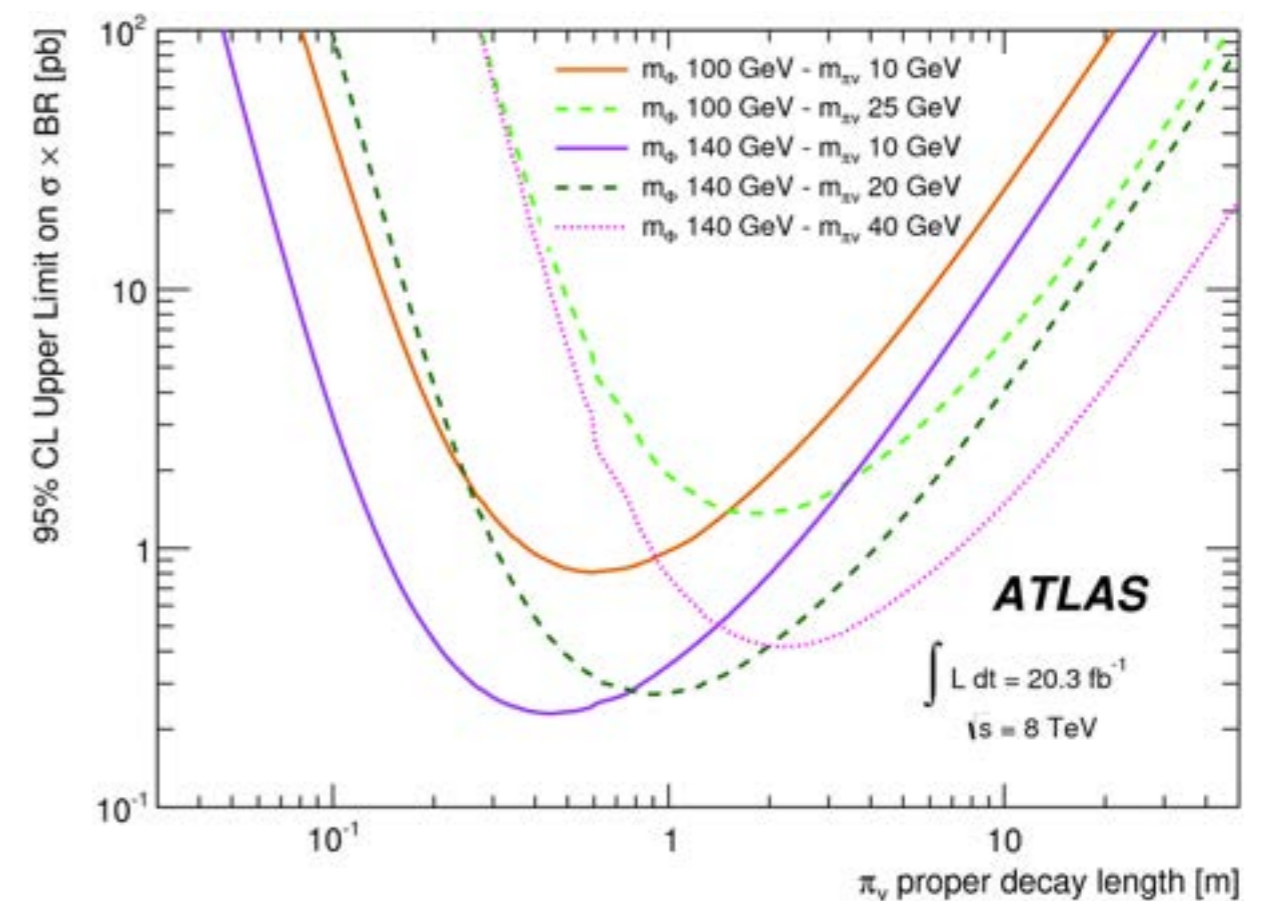
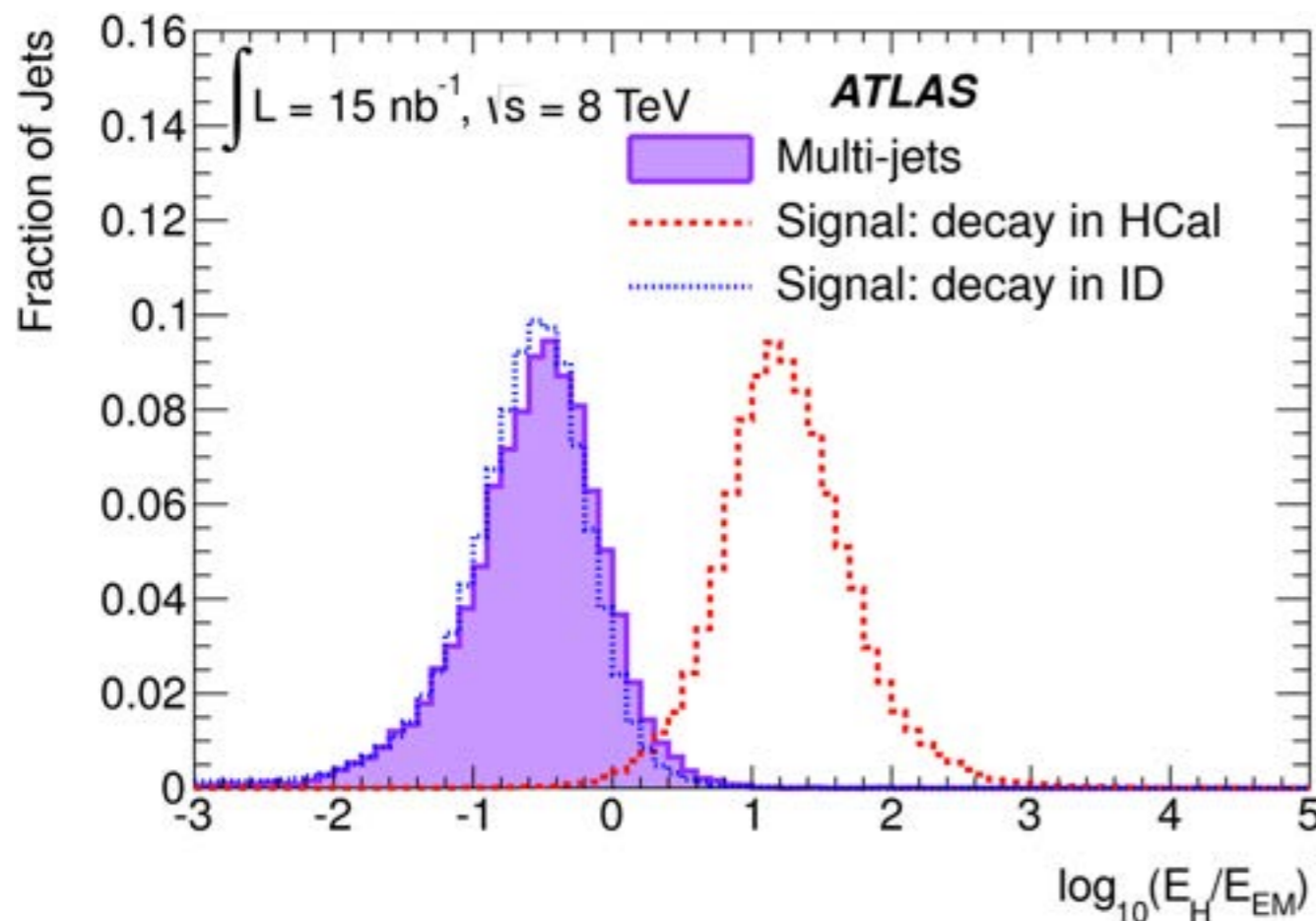
ATLAS, arXiv:1504.03634

CMS, Phys. Rev. D 91 (2015) 012007

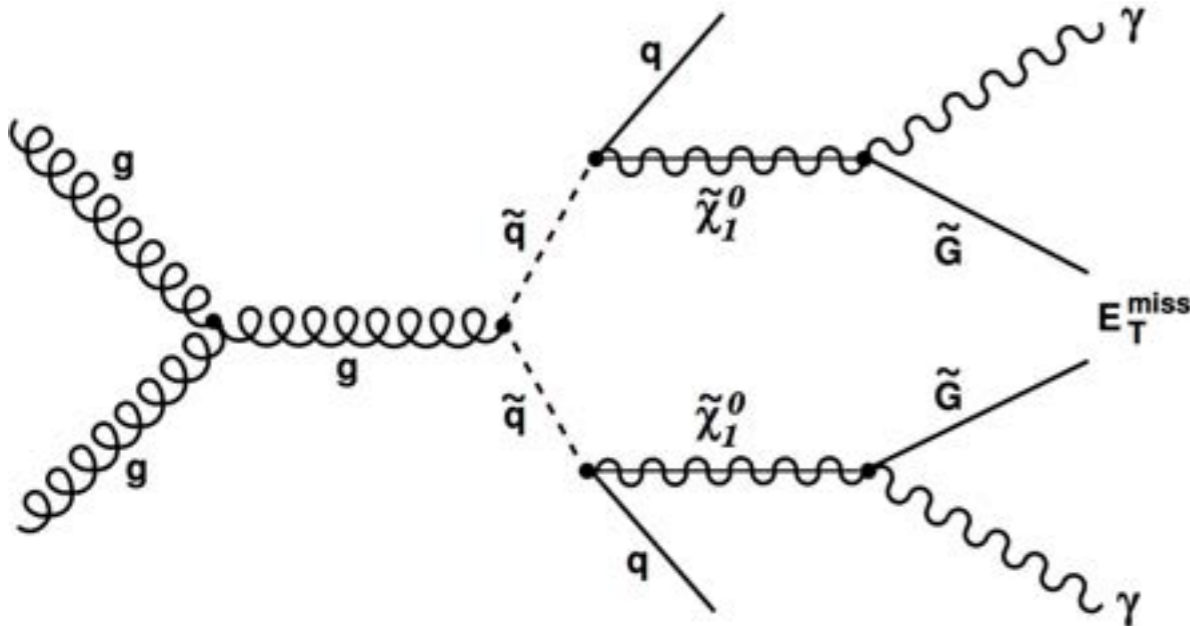
Trackless jets

ATLAS, Physics Letters B 743 (2015) 15-34

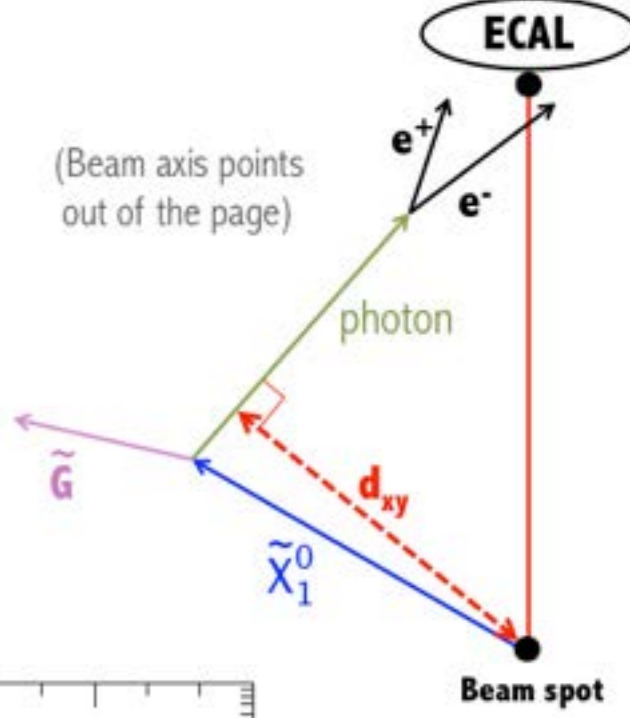
- ▶ Long-lived particles that decay to SM particles producing jets at the outer edge of the electromagnetic calorimeter or inside the hadronic calorimeter.
- ▶ Limits on the product of the scalar boson production cross section times branching ratio into long-lived neutral particles as a function of the proper lifetime of the particles.



Displaced / delayed photons

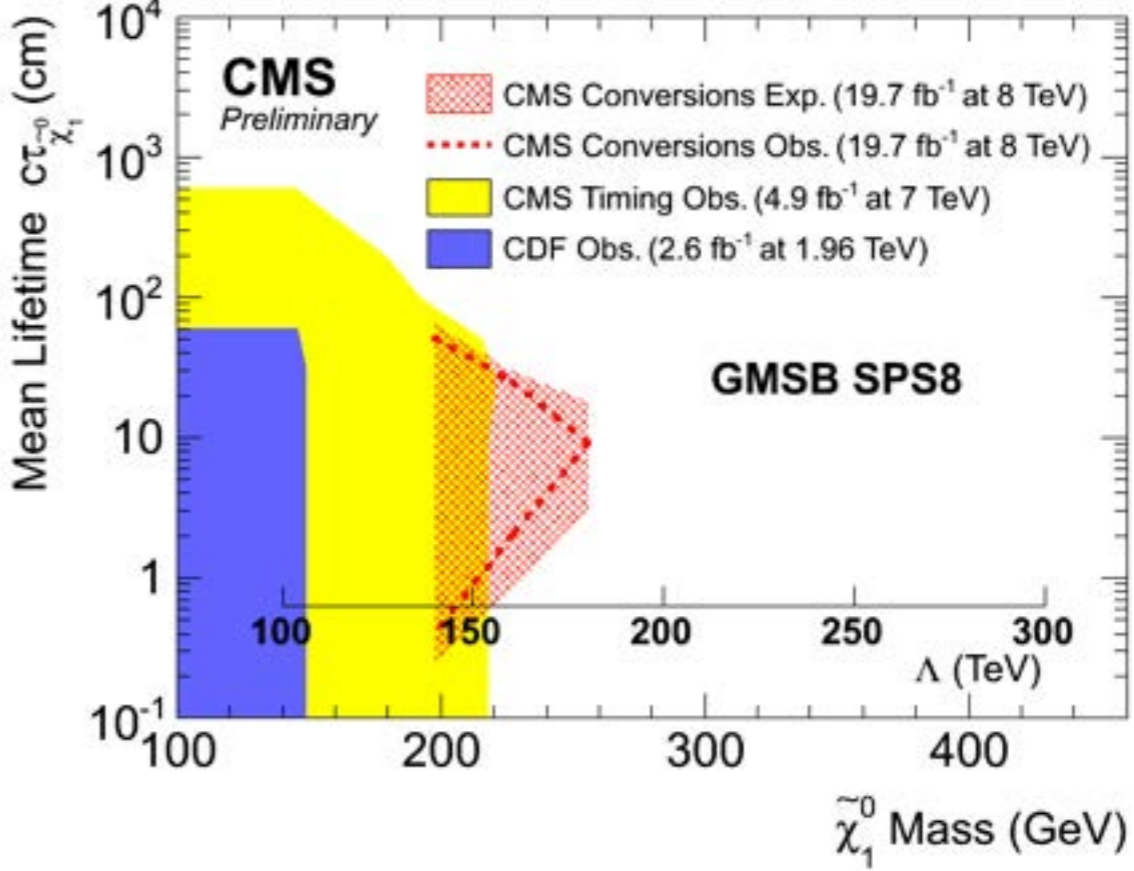
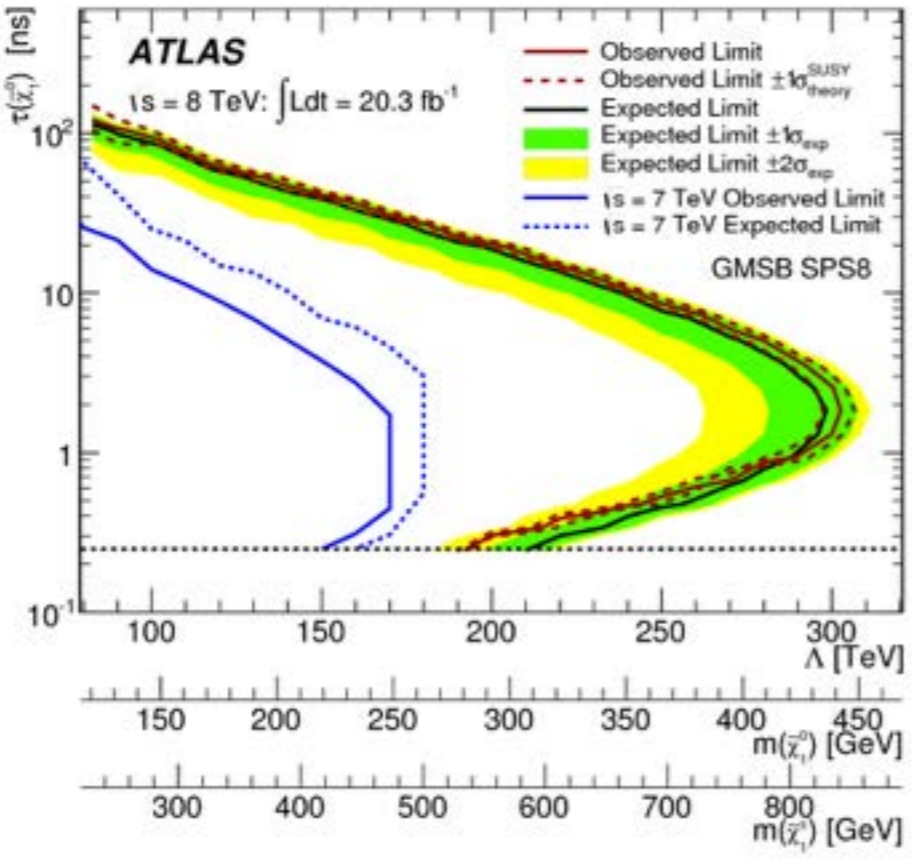


- ▶ Ex. lightest neutralino with nonzero lifetime into a gravitino and a photon.
- ▶ Look for photons that do not point back to PV.
 - ATLAS: intrinsic photon pointing capabilities.
 - CMS: back-tracking photon conversion.



ATLAS, Phys. Rev. D 90, 112005

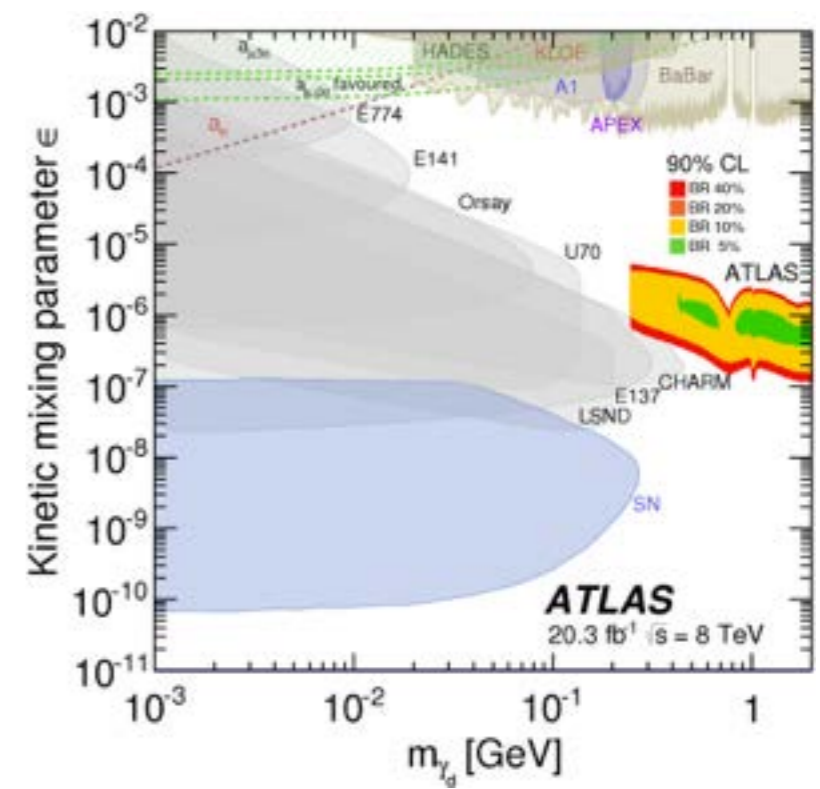
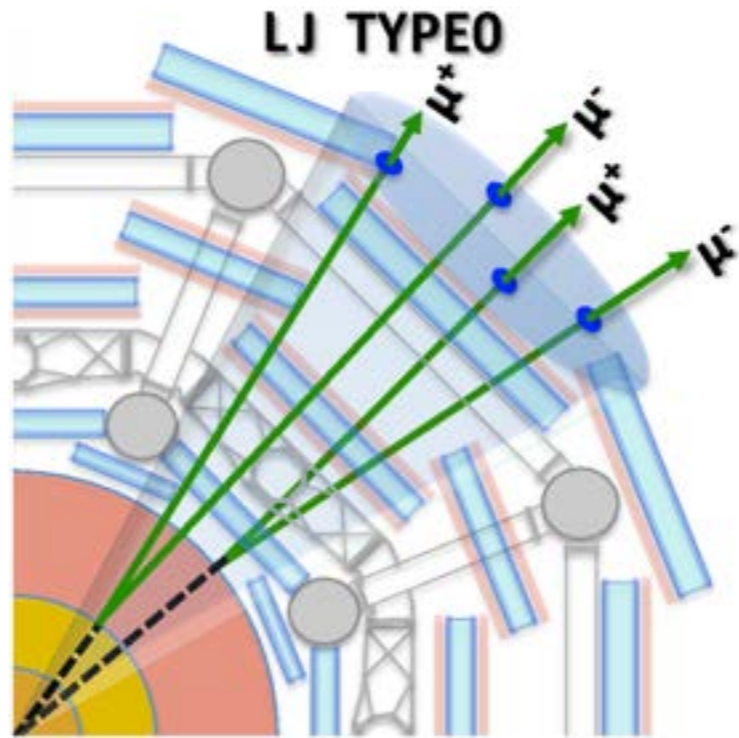
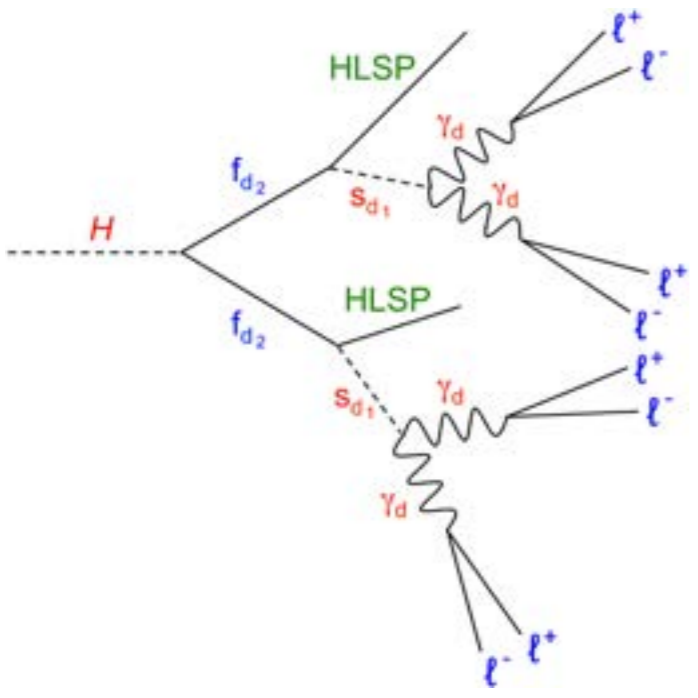
CMS, CMS-PAS-EXO-14-017



Lepton jets

ATLAS, JHEP 11 (2014) 088

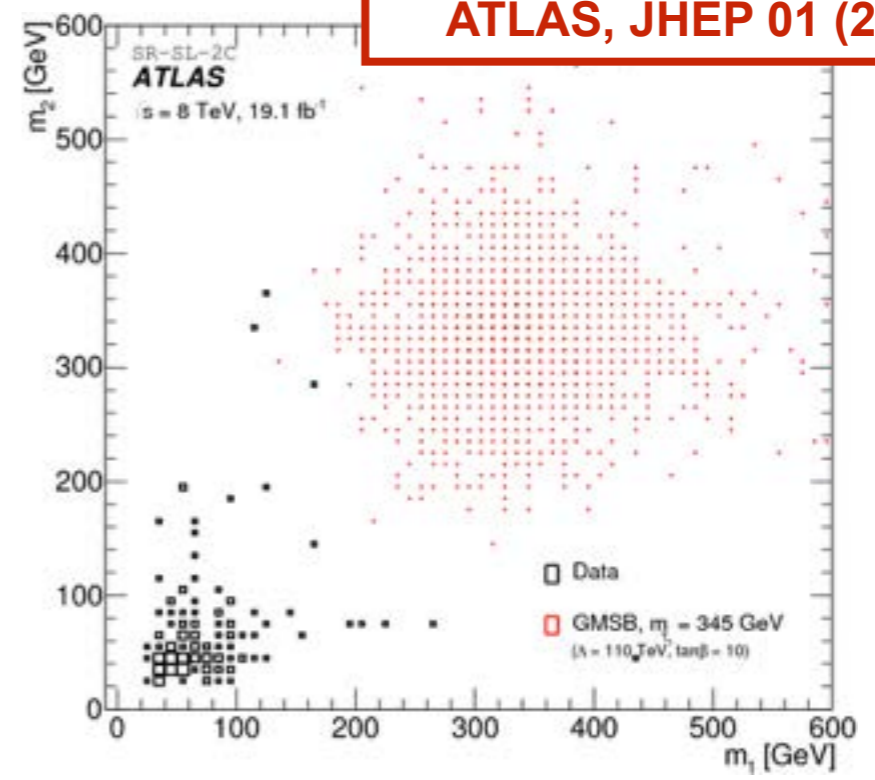
- ▶ Collimated jets of electrons/muons
- ▶ Sensitive to low mass dark matter photon scenarios with very weak coupling to the SM sector



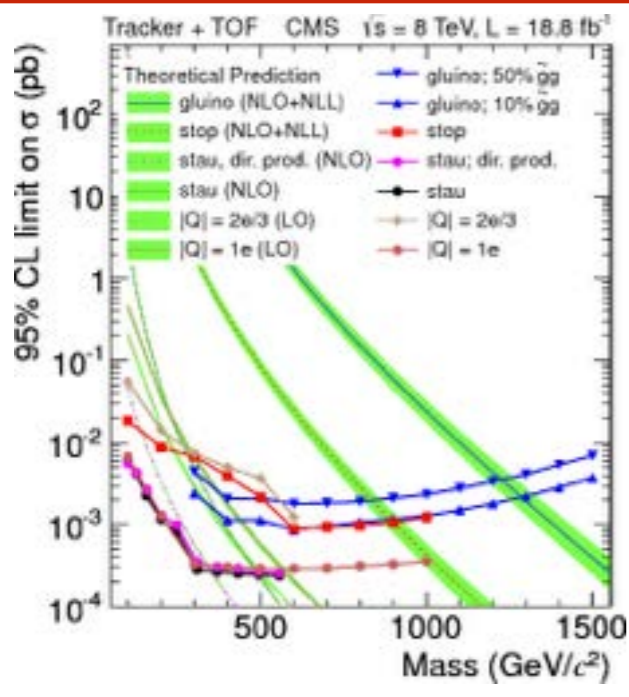
Heavy stable charged particles

- ▶ Identify slow ($\beta < 1$) particles by (i) large dE/dx from pixel tracker and (ii) late timing on calorimeter and muon systems.
- ▶ Reconstructed mass, $m_\beta = p/(\gamma\beta)$
- ▶ Main background is muons with mismeasured timing or dE/dx

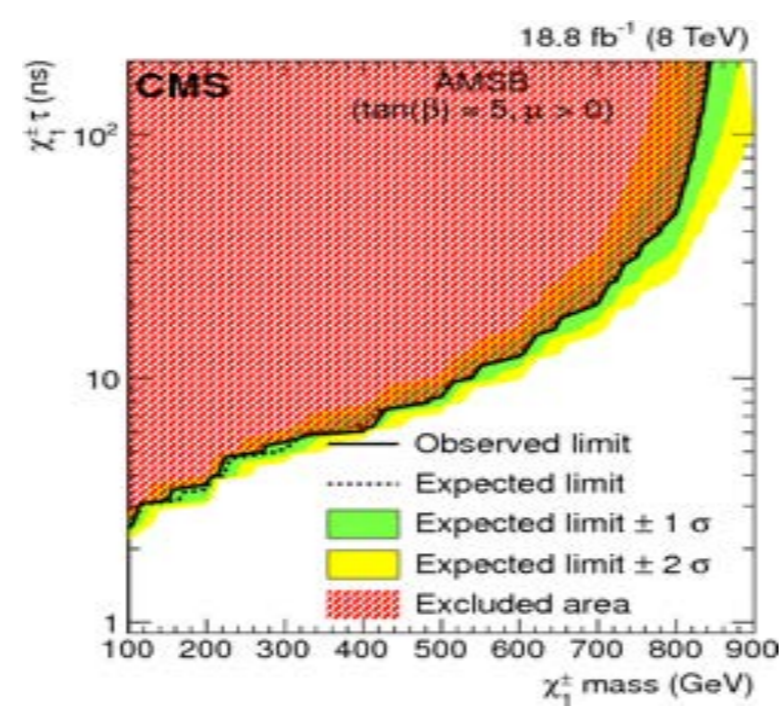
ATLAS, JHEP 01 (2015) 068



CMS, JHEP 07 (2013) 122

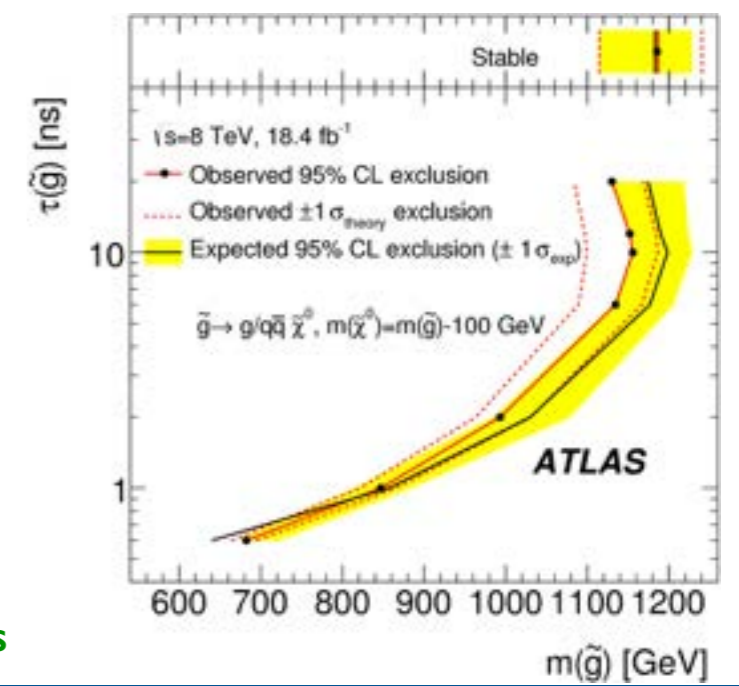


CMS, EPJC 73 (2015) 325



pMSSM, AMSB Reinterpretations

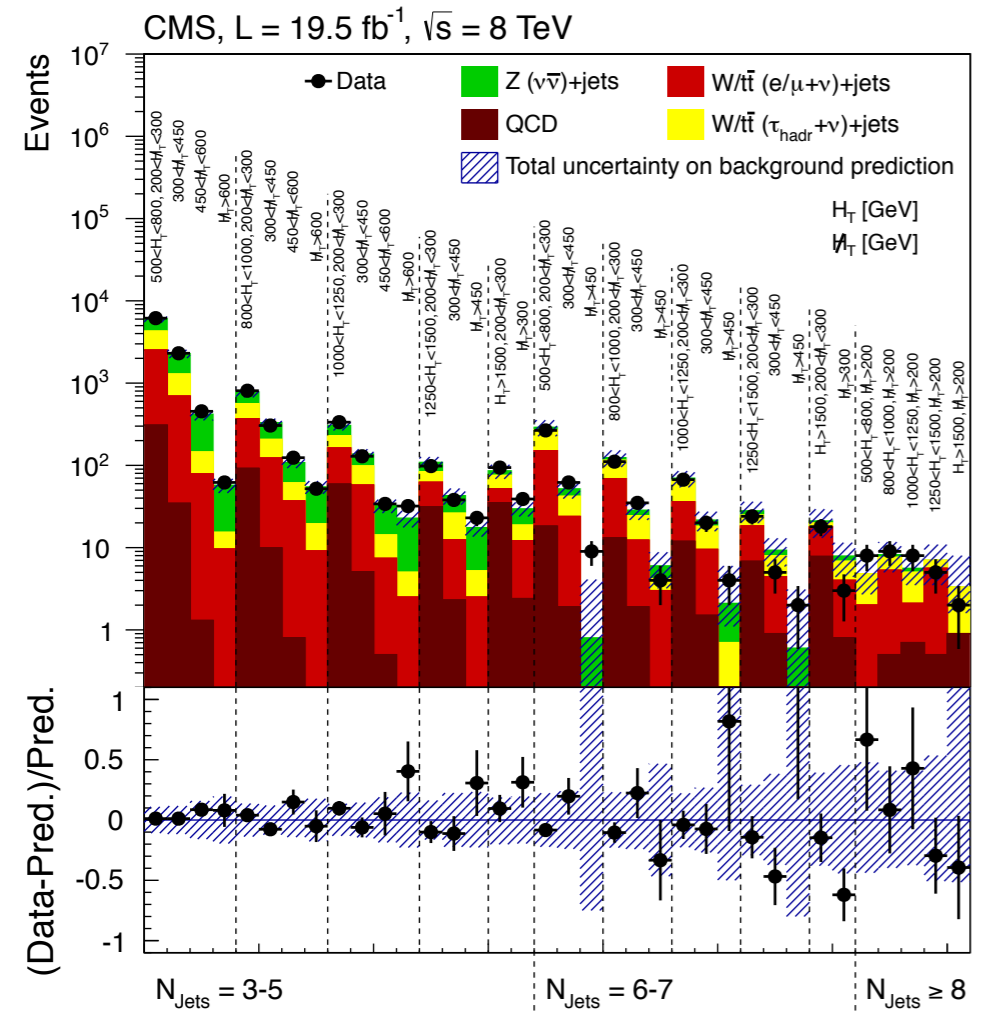
ATLAS, arXiv:1506.05332



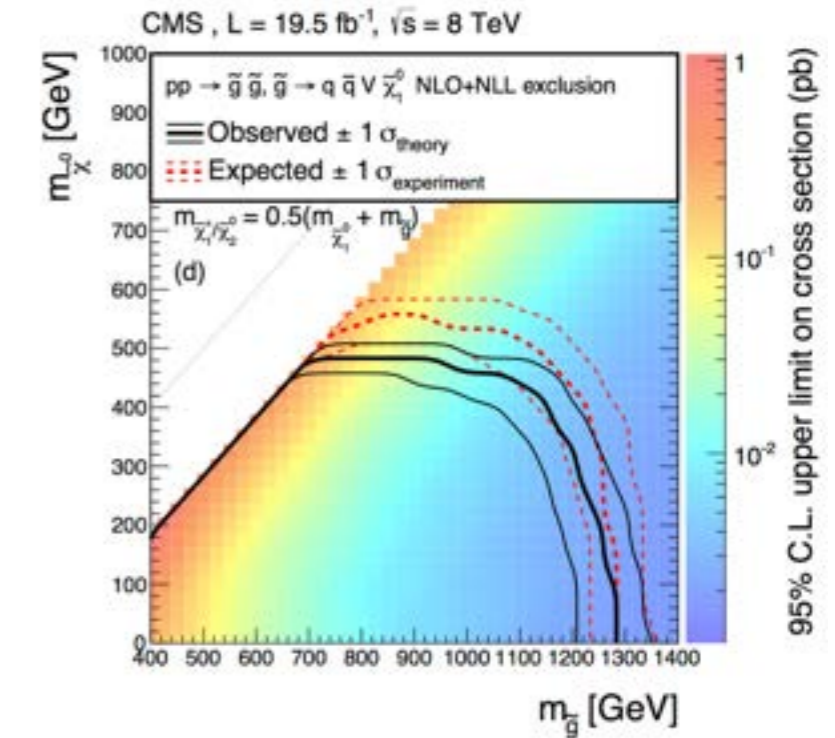
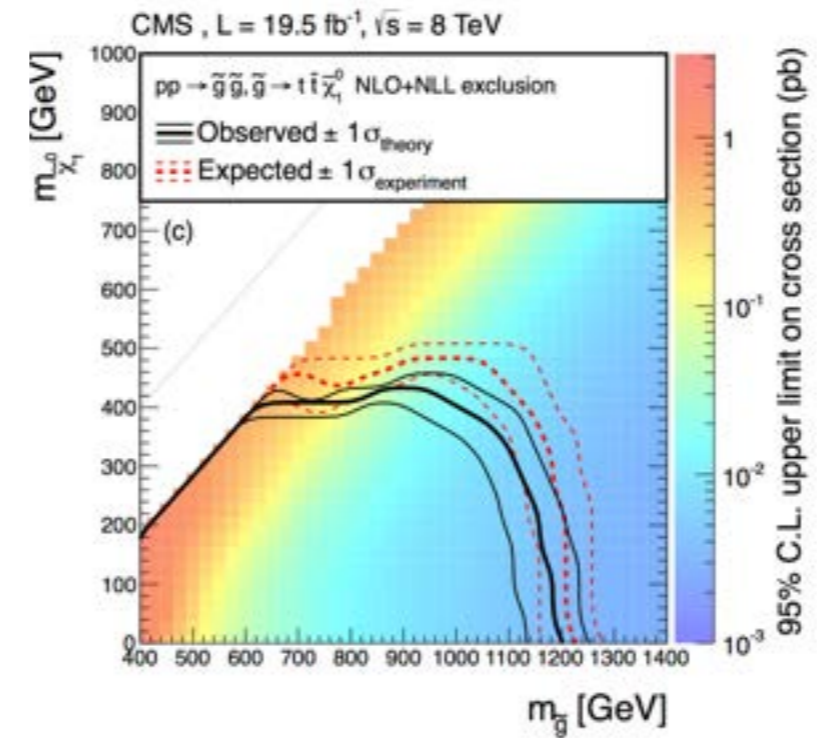
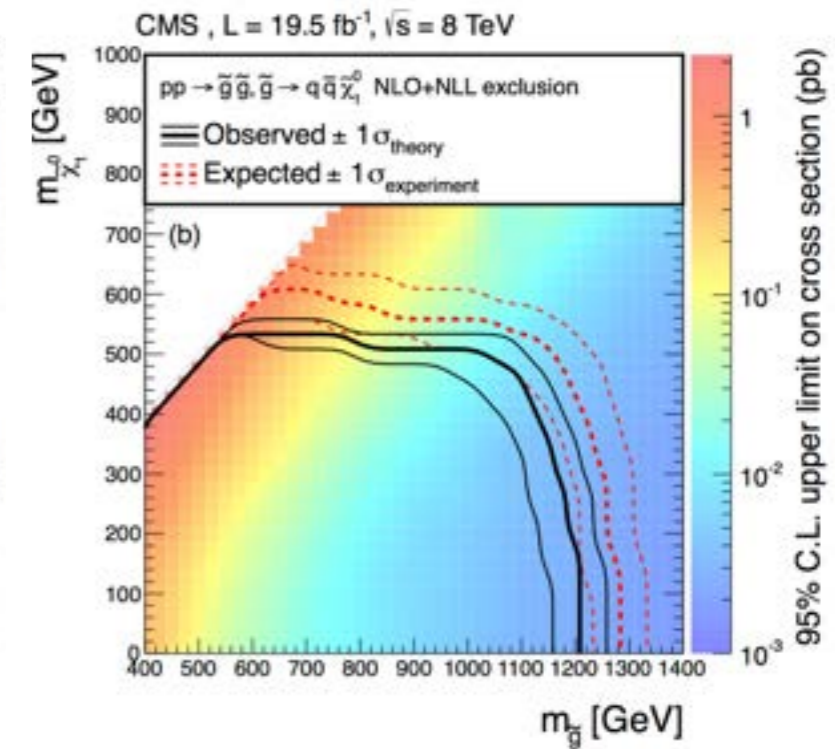
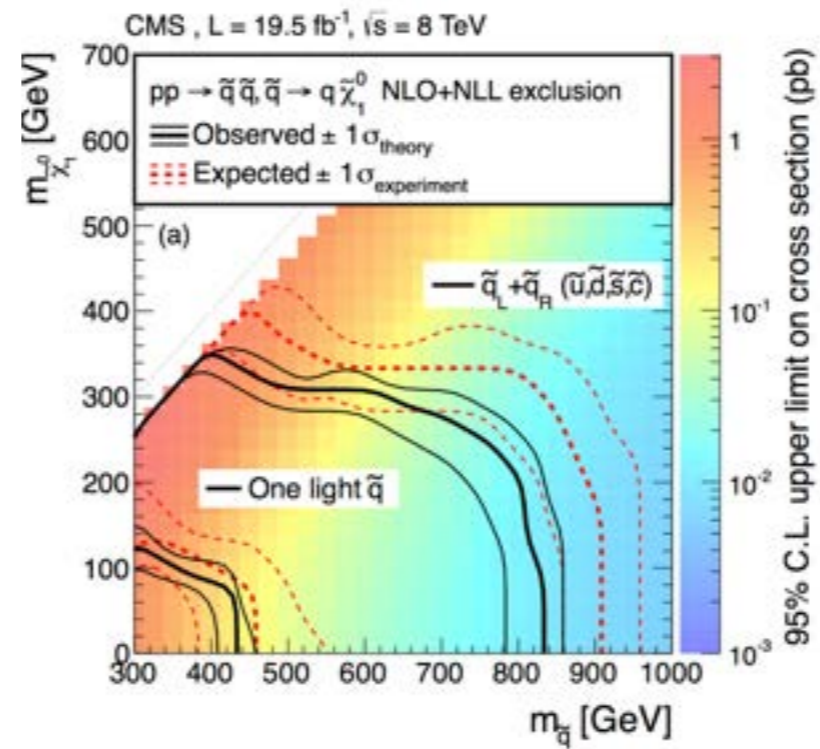
SUSY: Inclusive hadronic searches

► 36 signal regions were defined based on

- jet multiplicity (≥ 3)
- HT and missing HT
- DeltaPhi between leading jets and missing HT
- lepton vetos



CMS, JHEP 06 (2014) 055

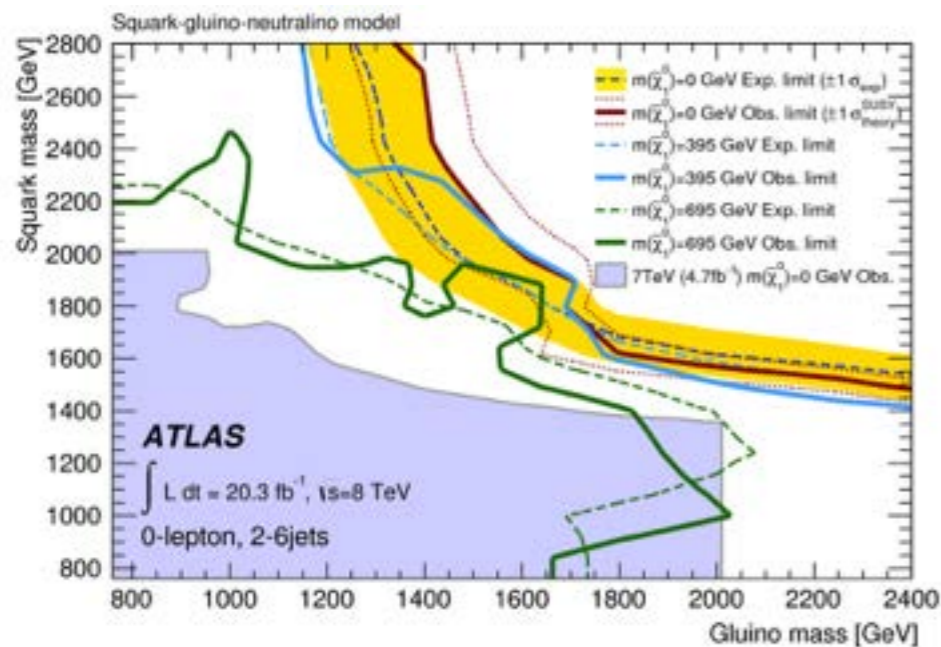


Exclusion limits in simplified supersymmetric models of squark or gluino pair production.

SUSY: Inclusive hadronic searches

ATLAS, JHEP 09 (2014) 176

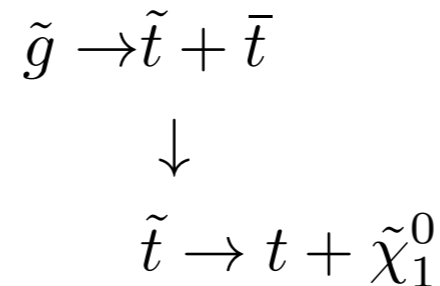
- ▶ 15 signal regions were analysed based on
 - 2-6 jet multiplicity
 - ➔ m_{eff}
 - Level of background rejection
 - $E_{\text{miss}} > 160 \text{ GeV}$
 - $E_{\text{miss}}/m_{\text{eff}}$ or $E_{\text{miss}}/\sqrt{\text{HT}}$



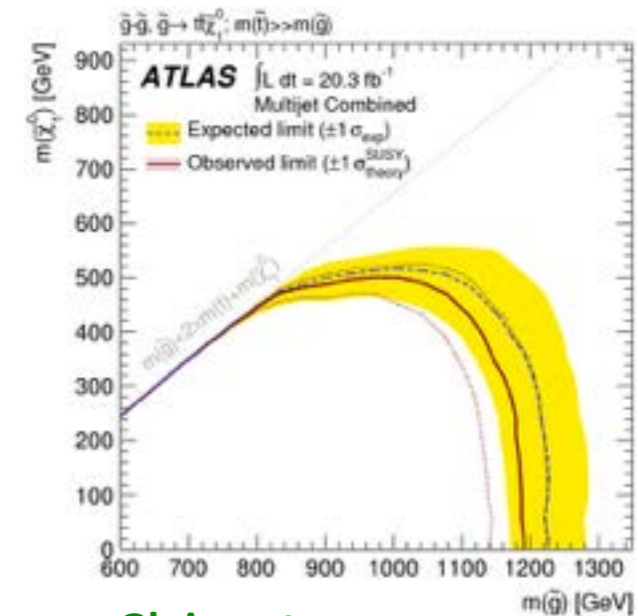
Strong production of gluinos and first- and second-generation squarks with direct decays to quarks and lightest neutralinos

ATLAS, JHEP 10 (2013) 130

- ▶ Consider long cascade decays, i.e.

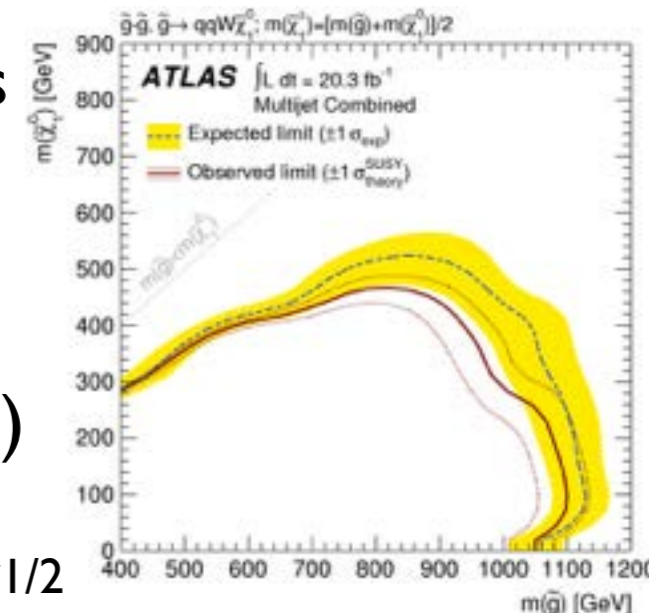


- ▶ 19 signal regions were analysed
 - Multi-jet + flavour
 - ➔ 7,8,9,10 jets
 - ➔ Jet $p_T > 50$ or 80 GeV
 - ➔ Jet $|\eta| < 2.0$
 - ➔ 0,1,2 b-tagged jets
 - ➔ $E_{\text{miss}}/\sqrt{\text{HT}} > 4 \text{ GeV}^{1/2}$
 - Multi-jet + Sum of jet masses
 - ➔ 8,9,10 jets
 - ➔ Jet $p_T > 50 \text{ GeV}$
 - ➔ Jet $|\eta| < 2.8$
 - ➔ Sum of jet masses ($R=1.0$) > 340 or 420 GeV
 - ➔ $E_{\text{miss}}/\sqrt{\text{HT}} > 4 \text{ GeV}^{1/2}$



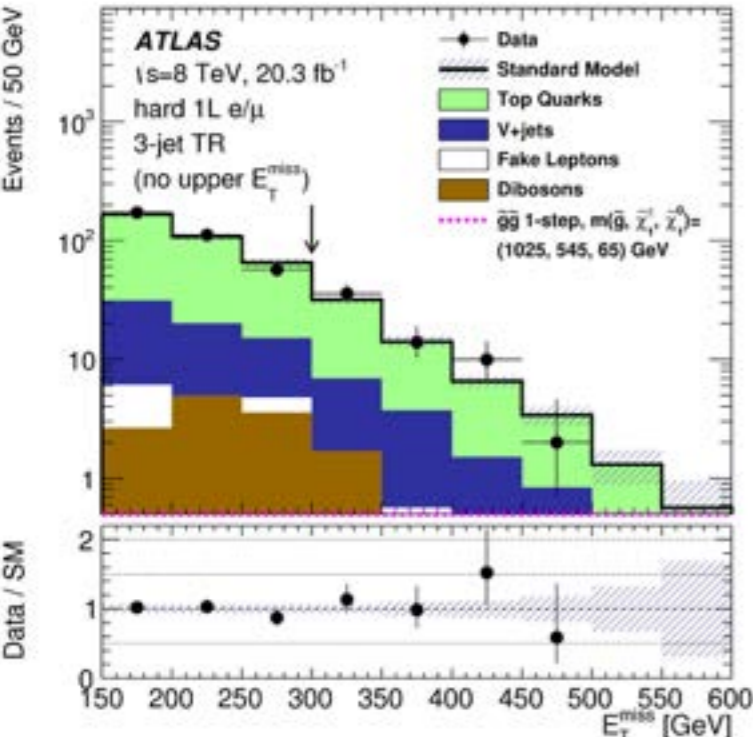
Gluino-stop

Gluino-squark (via chargino)

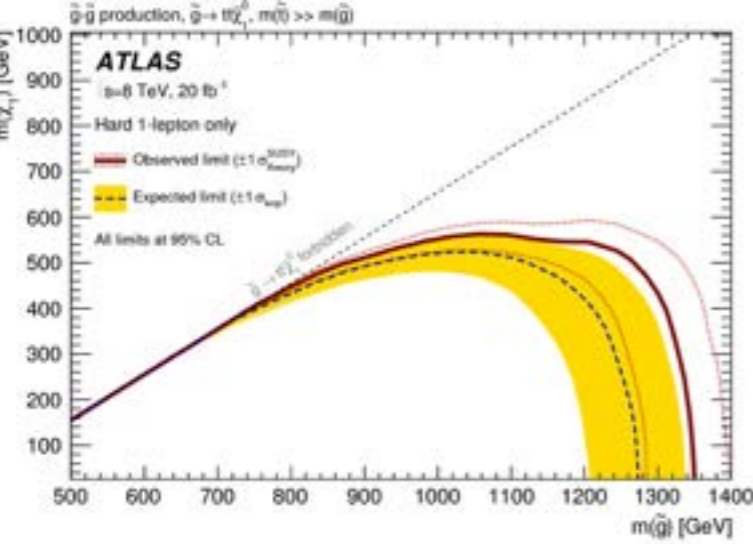


SUSY: Inclusive single/di-[os/ss] lepton searches

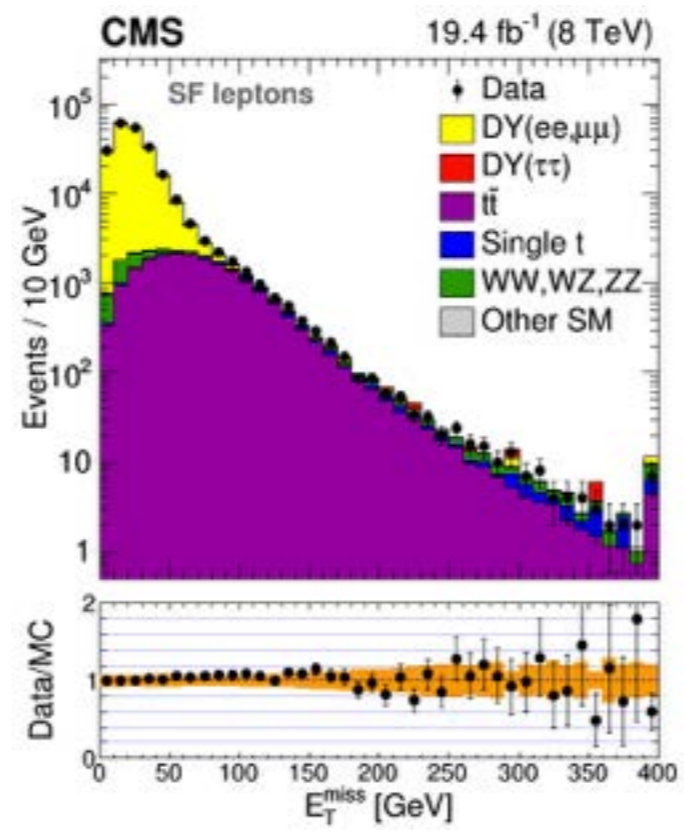
At least one isolated lepton (electron or muon), jets and MET



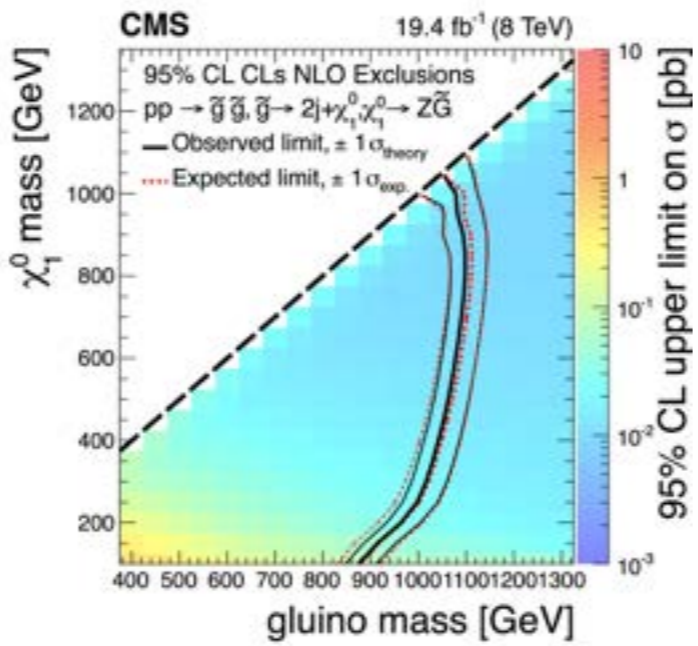
ATLAS, JHEP 04 (2015) 116



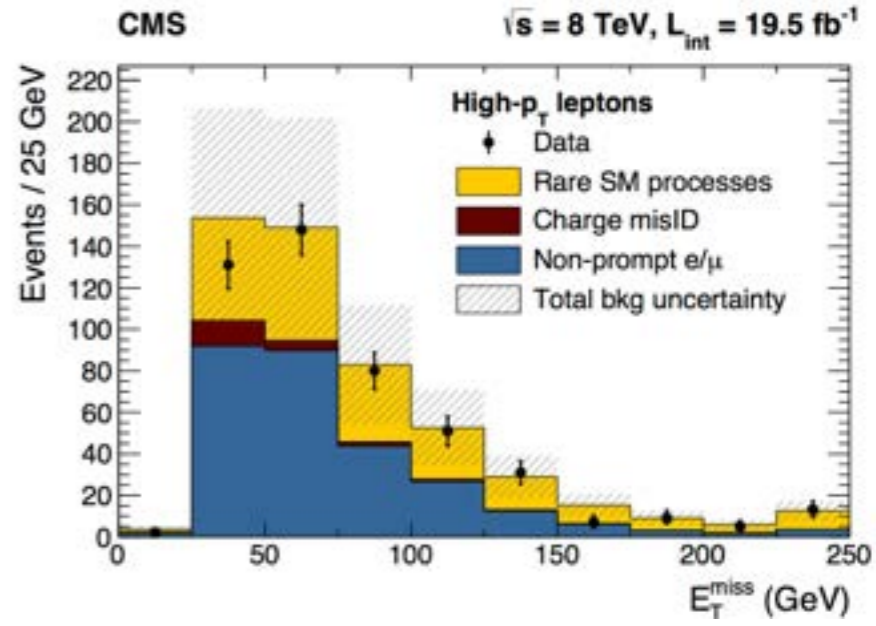
Two opposite-sign same-flavor leptons, jet, MET



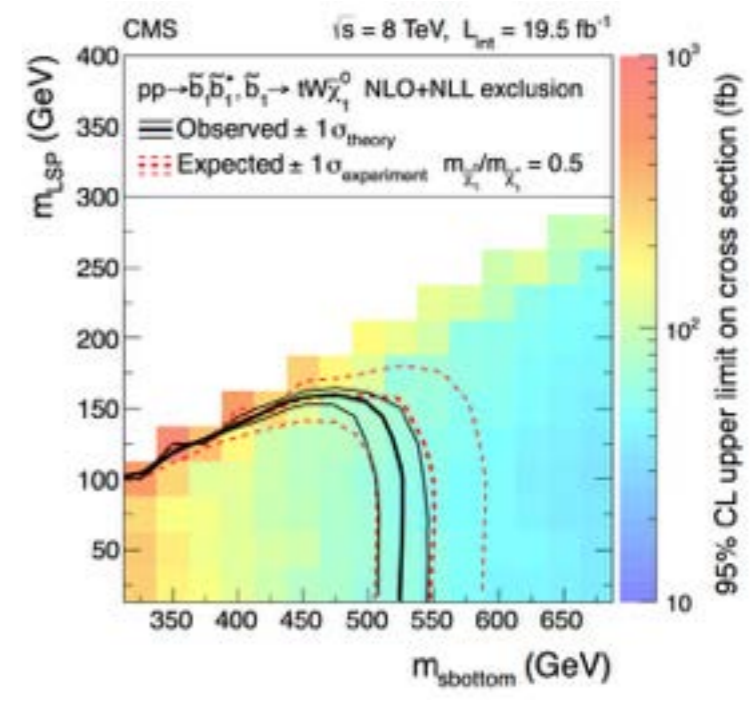
CMS, JHEP 04 (2015) 124



Same-sign leptons
Bins with low/high MET, HT, njets, and nB

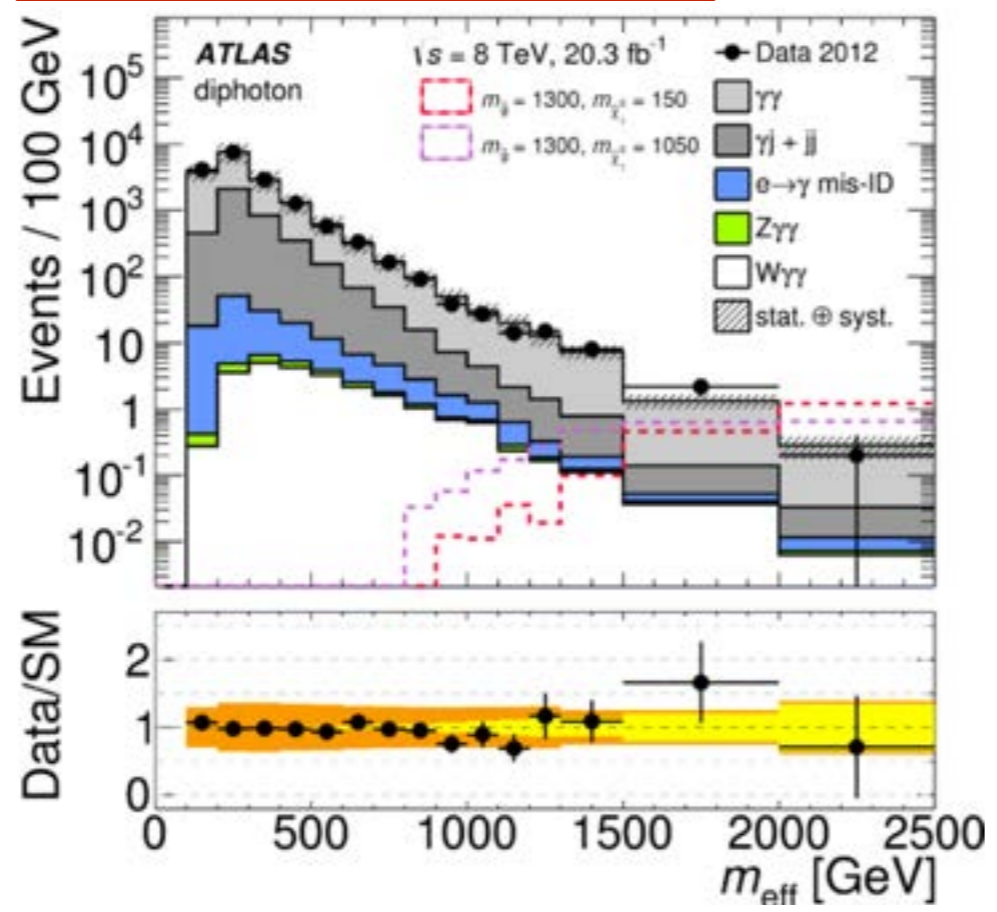


CMS, JHEP 01 (2014) 163

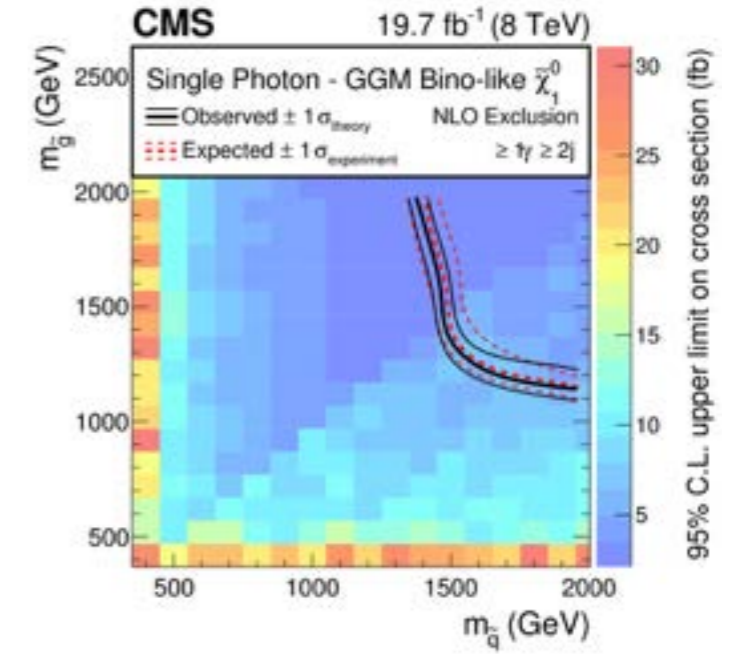
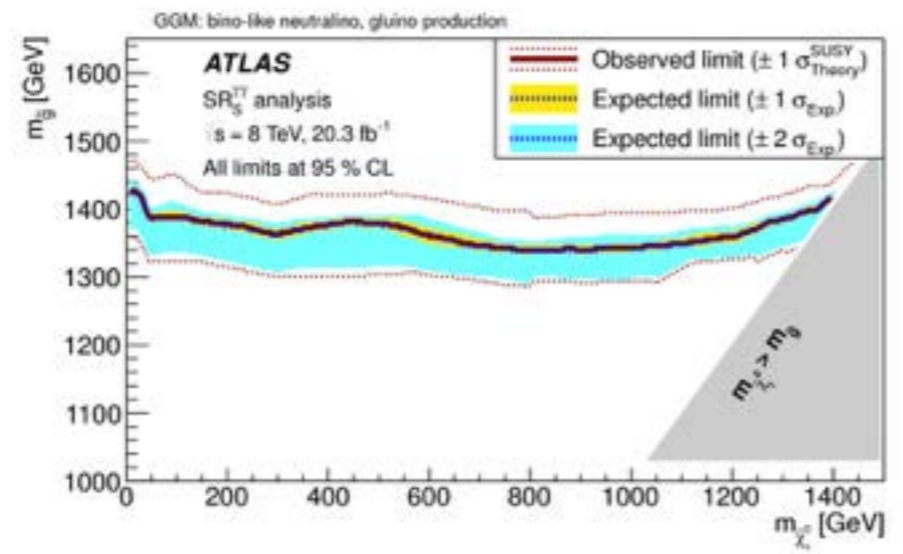
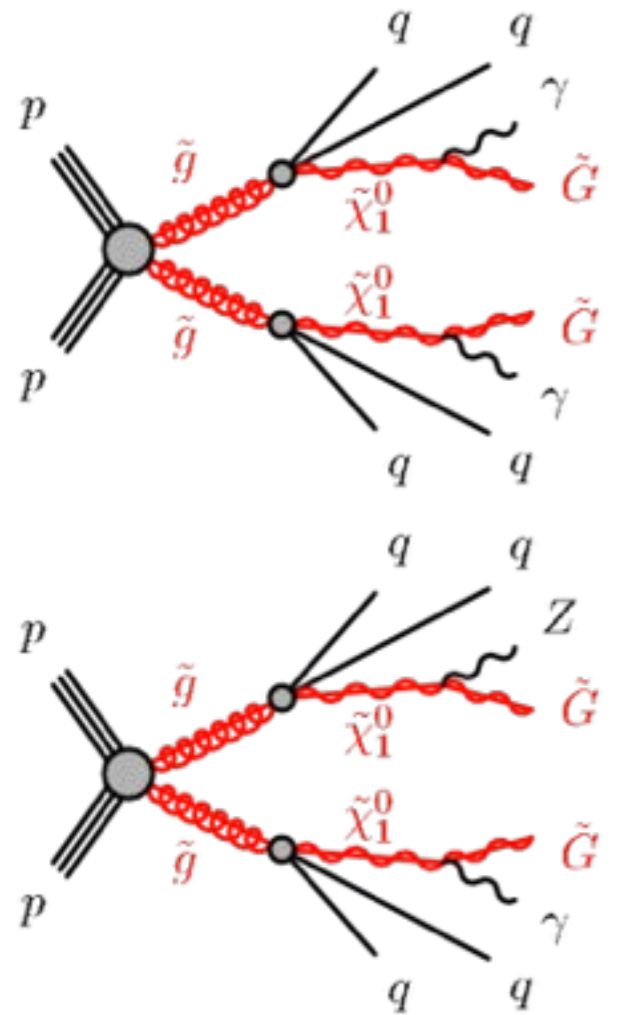
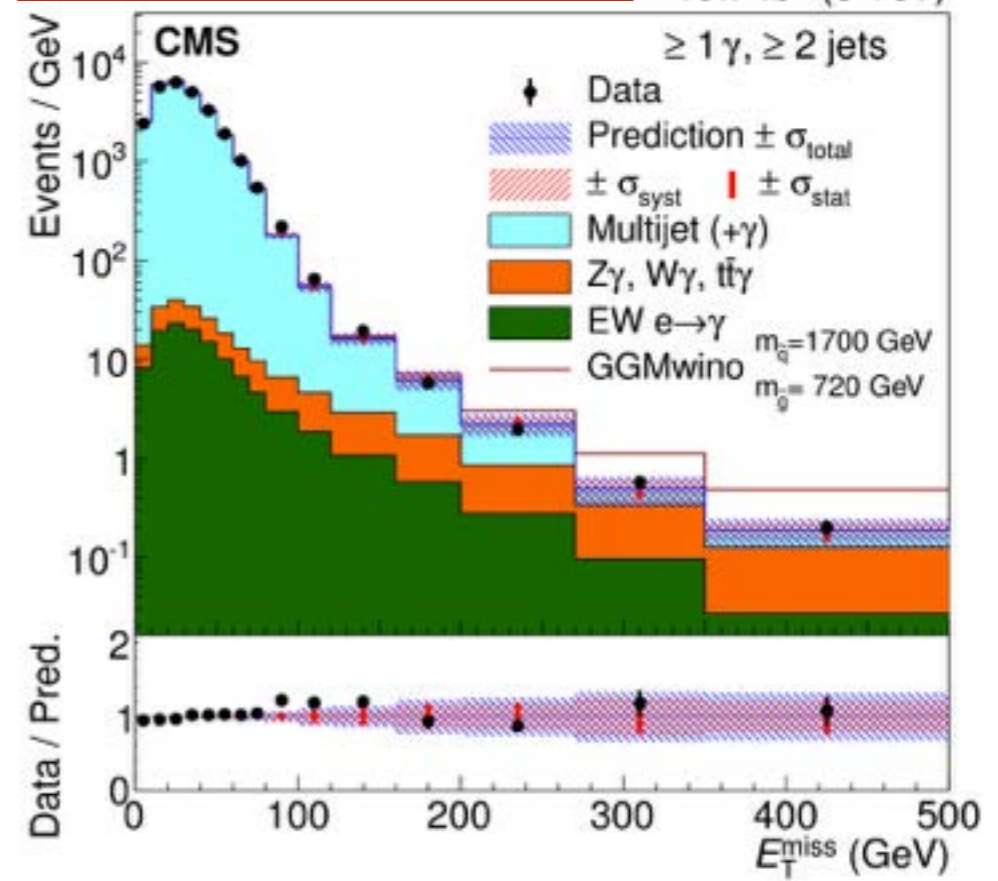


SUSY: Inclusive photon searches

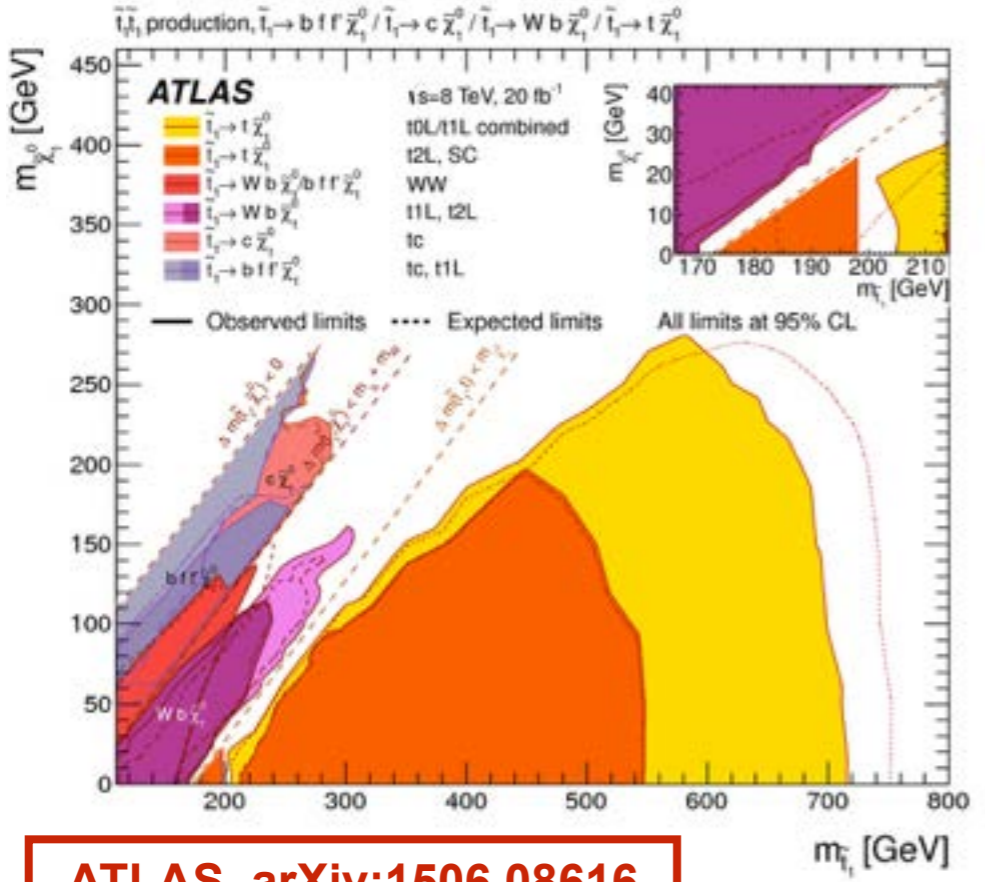
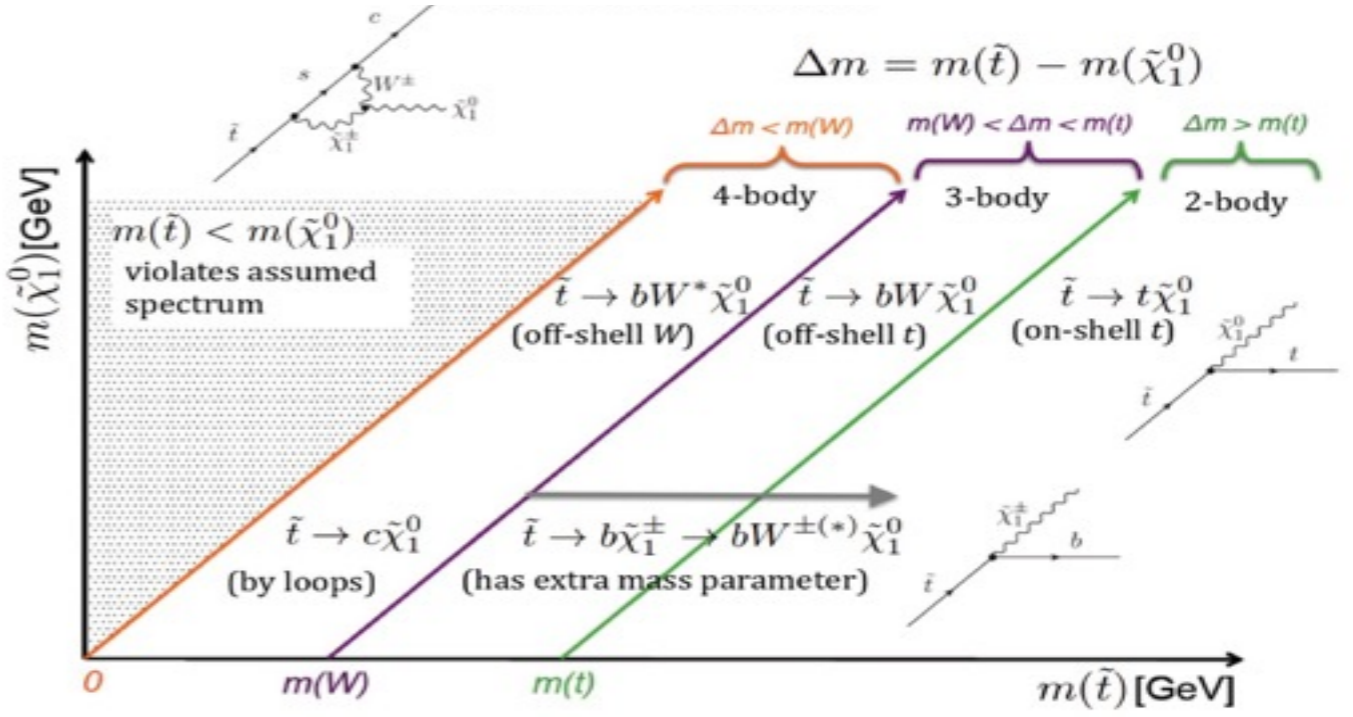
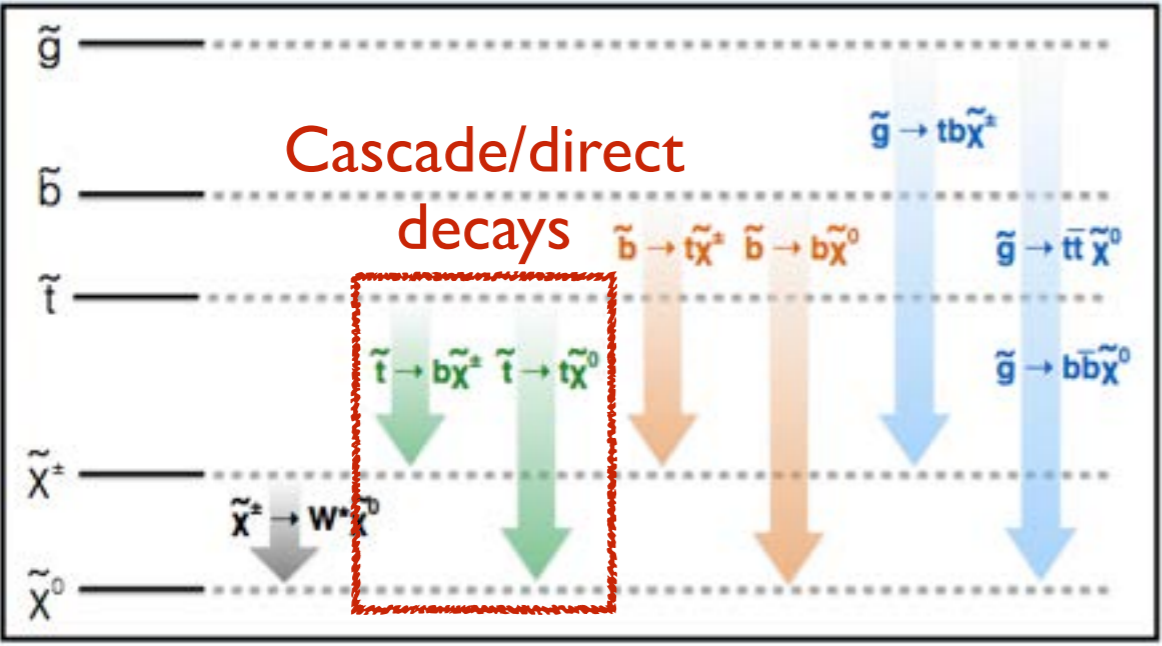
ATLAS, arXiv:1507.05493



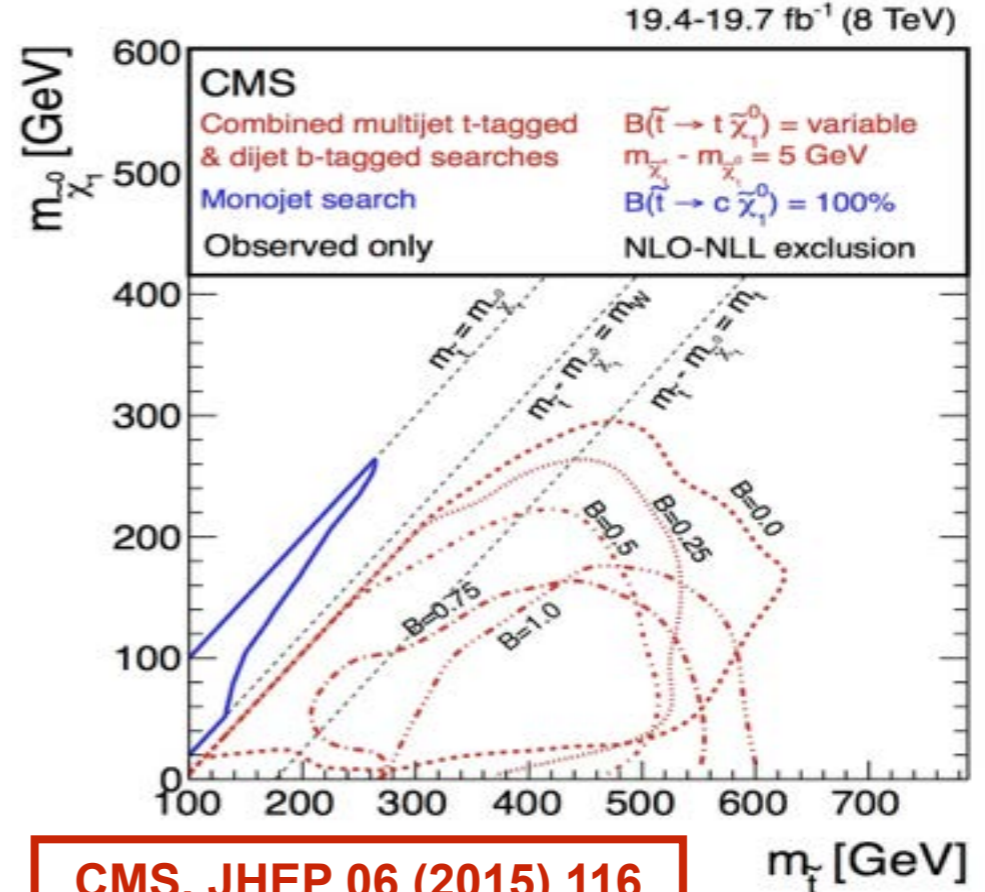
CMS, arXiv:1507.02898



SUSY: Third generation squark



ATLAS, arXiv:1506.08616



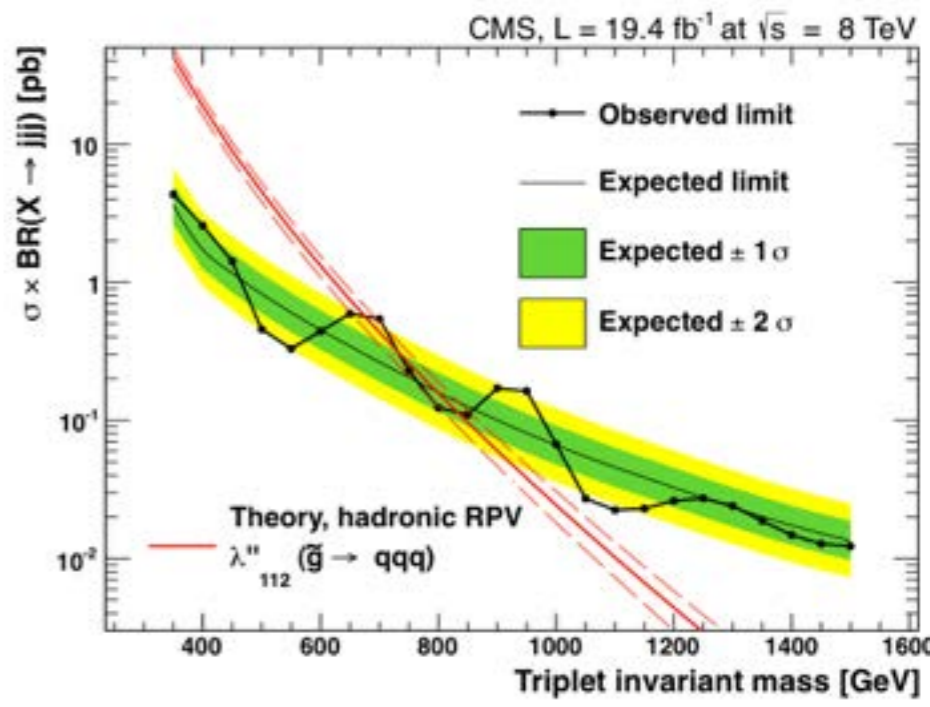
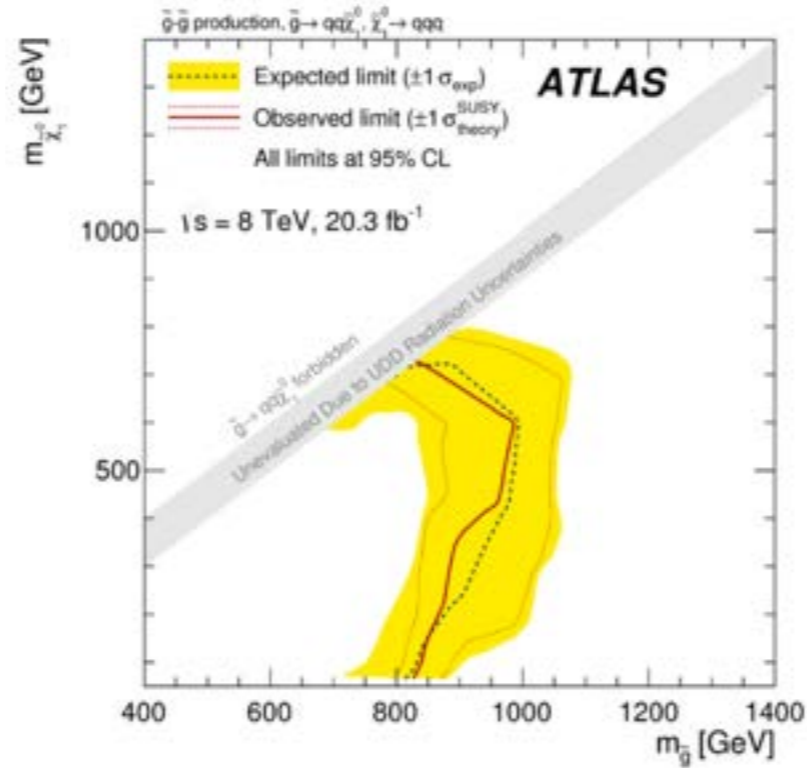
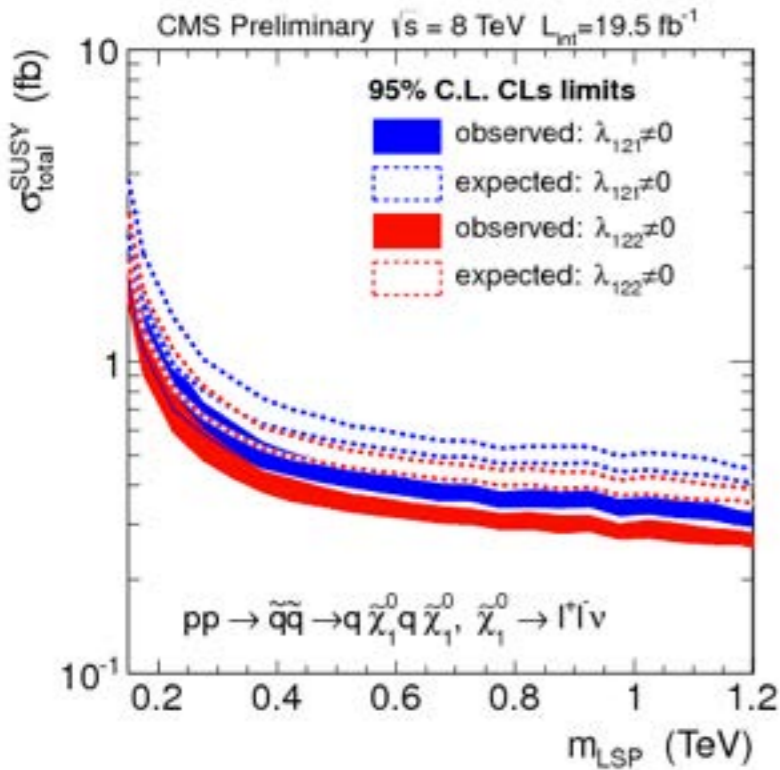
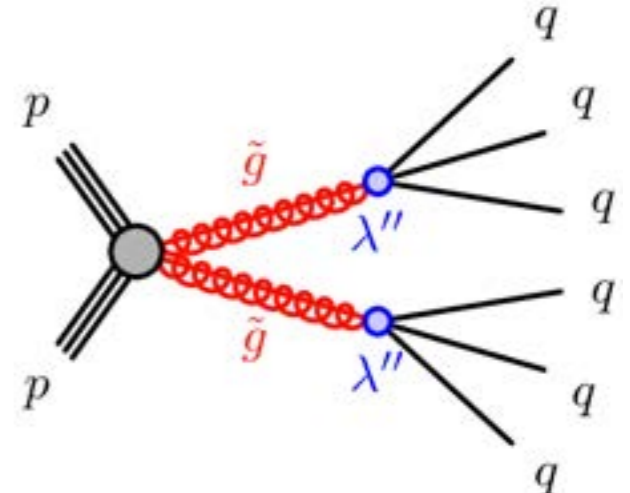
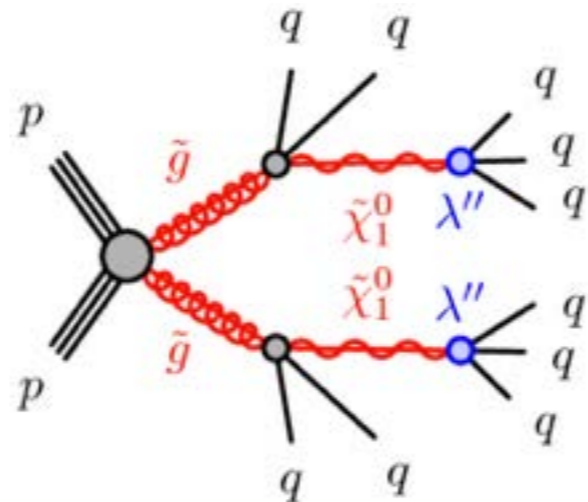
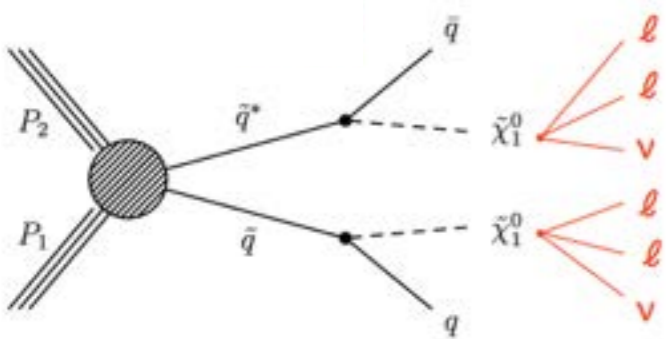
CMS, JHEP 06 (2015) 116

SUSY: R-parity violation

$$W_{\text{RPV}} = \mu'_i H_u L_i + \frac{1}{2} \lambda_{ijk} L_i L_j \bar{E}_k + \frac{1}{2} \lambda'_{ijk} L_i Q_j \bar{D}_k + \frac{1}{2} \lambda''_{ijk} \bar{U}_i \bar{D}_j \bar{D}_k$$

L-number violation

B-number violation



CMS, CMS-PAS-SUS-13-010

ATLAS, Phys. Rev. D 91, 112016

CMS, Phys. Lett. B 730 (2014) 193

Summary

- ▶ Search for physics beyond the standard model, SUSY and non-SUSY, is one of the main motivations for the LHC experiments
- ▶ ATLAS and CMS cover a large phase space to cover possible final states.
- ▶ Most SUSY and non-SUSY searches do not see significant excess from SM. Few “significant” deviations from SM which are needed to follow.
- ▶ For update results, specially for 13 TeV,
 - <https://twiki.cern.ch/twiki/bin/view/AtlasPublic/SupersymmetryPublicResults>
 - <https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS>
 - <https://twiki.cern.ch/twiki/bin/view/AtlasPublic/ExoticsPublicResults>
 - <https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsEXO>
 - <https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsB2G>