Exotic Searches with ATLAS

QFTHEP 2015
Samara, Russia

Rebecca Falla on behalf of the ATLAS Collaboration

Motivation

The Standard Model has been very successful but there are still problems

- Dark Matter
- Mass hierarchy problem
- Neutrino masses
- Gravity
- ……

Exotic theories could hold the answers to these questions

- Supersymmetry?
- Extra dimensions?
- WIMPS as dark matter candidates?
- Seesaw mechanism?
- New TeV scale interactions or particles?
- …..?

ATLAS Exotics Searches* - 95% CL Exclusion

Status: March 2015

ATLAS Preliminary

$\int \mathcal{L}\, dt = (1.0 - 20.3)\ \mathrm{fb}^{-1}$ $\sqrt{s} = 7, 8$ TeV

	Model	ℓ, γ	Jets	E_T^{miss}	$\int \mathcal{L}\, dt [\mathrm{fb}^{-1}]$	Mass limit		Reference
Extra dimensions	ADD $G_{KK} + g/q$	–	≥ 1 j	Yes	20.3	M_D 5.25 TeV	$n = 2$	1502.01518
	ADD non-resonant $\ell\ell$	$2e, \mu$	–	–	20.3	M_S 4.7 TeV	$n = 3$ HLZ	1407.2410
	ADD QBH $\rightarrow \ell q$	1 e, μ	1 j	–	20.3	M_{th} 5.2 TeV	$n = 6$	1311.2006
	ADD QBH	–	2 j	–	20.3	M_{th} 5.82 TeV	$n = 6$	1407.1376
	ADD BH high N_{trk}	2 μ (SS)	–	–	20.3	M_{th} 4.7 TeV	$n = 6$, $M_D = 3$ TeV, non-rot BH	1308.4075
	ADD BH high $\sum p_T$	≥ 1 e, μ	≥ 2 j	–	20.3	M_{th} 5.8 TeV	$n = 6$, $M_D = 3$ TeV, non-rot BH	1405.4254
	ADD BH high multijet	–	≥ 2 j	–	20.3	M_{th} 5.8 TeV	$n = 6$, $M_D = 3$ TeV, non-rot BH	Preliminary
	RS1 $G_{KK} \rightarrow \ell\ell$	2 e, μ	–	–	20.3	G_{KK} mass 2.68 TeV	$k/\overline{M}_{Pl} = 0.1$	1405.4123
	RS1 $G_{KK} \rightarrow \gamma\gamma$	2 γ	–	–	20.3	G_{KK} mass 2.66 TeV	$k/\overline{M}_{Pl} = 0.1$	Preliminary
	Bulk RS $G_{KK} \rightarrow ZZ \rightarrow qq\ell\ell$	2 e, μ	2 j / 1 J	–	20.3	G_{KK} mass 740 GeV	$k/\overline{M}_{Pl} = 1.0$	1409.6190
	Bulk RS $G_{KK} \rightarrow WW \rightarrow qq\ell\nu$	1 e, μ	2 j / 1 J	Yes	20.3	W' mass 700 GeV	$k/\overline{M}_{Pl} = 1.0$	1503.04677
	Bulk RS $G_{KK} \rightarrow HH \rightarrow b\bar{b}b\bar{b}$	–	4 b	–	19.5	G_{KK} mass 590-710 GeV	$k/\overline{M}_{Pl} = 1.0$	ATLAS-CONF-2014-005
	Bulk RS $g_{KK} \rightarrow t\bar{t}$	1 e, μ	≥ 1 b, $\geq$ 1J/2j	Yes	20.3	g_{KK} mass 2.2 TeV	BR = 0.925	ATLAS-CONF-2015-009
	2UED / RPP	2 e, μ (SS)	≥ 1 b, ≥ 1 j	Yes	20.3	KK mass 960 GeV		Preliminary
Gauge bosons	SSM $Z' \rightarrow \ell\ell$	2 e, μ	–	–	20.3	Z' mass 2.9 TeV		1405.4123
	SSM $Z' \rightarrow \tau\tau$	2 τ	–	–	19.5	Z' mass 2.02 TeV		1502.07177
	SSM $W' \rightarrow \ell\nu$	1 e, μ	–	Yes	20.3	W' mass 3.24 TeV		1407.7494
	EGM $W' \rightarrow WZ \rightarrow \ell\nu\, \ell'\ell'$	3 e, μ	–	Yes	20.3	W' mass 1.52 TeV		1406.4456
	EGM $W' \rightarrow WZ \rightarrow qq\ell\ell$	2 e, μ	2 j / 1 J	–	20.3	W' mass 1.59 TeV		1409.6190
	HVT $W' \rightarrow WH \rightarrow \ell\nu bb$	1 e, μ	2 b	Yes	20.3	W' mass 1.47 TeV	$g_V = 1$	Preliminary
	LRSM $W'_R \rightarrow t\bar{b}$	1 e, μ	2 b, 0-1 j	Yes	20.3	W' mass 1.92 TeV		1410.4103
	LRSM $W'_R \rightarrow t\bar{b}$	0 e, μ	≥ 1 b, 1 J	–	20.3	W' mass 1.76 TeV		1408.0886
CI	CI $qqqq$	–	2 j	–	17.3	Λ 12.0 TeV	$\eta_{LL} = -1$	Preliminary
	CI $qq\ell\ell$	2 e, μ	–	–	20.3	Λ 21.6 TeV	$\eta_{LL} = -1$	1407.2410
	CI $uutt$	2 e, μ (SS)	≥ 1 b, ≥ 1 j	Yes	20.3	Λ 4.35 TeV	$\lvert C_{LL} \rvert = 1$	Preliminary
DM	EFT D5 operator (Dirac)	0 e, μ	≥ 1 j	Yes	20.3	M_* 974 GeV	at 90% CL for $m(\chi) < 100$ GeV	1502.01518
	EFT D9 operator (Dirac)	0 e, μ	1 J, ≤ 1 j	Yes	20.3	M_* 2.4 TeV	at 90% CL for $m(\chi) < 100$ GeV	1309.4017
LQ	Scalar LQ 1st gen	2 e	≥ 2 j	–	1.0	LQ mass 660 GeV	$\beta = 1$	1112.4828
	Scalar LQ 2nd gen	2 μ	≥ 2 j	–	1.0	LQ mass 685 GeV	$\beta = 1$	1203.3172
	Scalar LQ 3rd gen	1 e, μ, 1 τ	1 b, 1 j	–	4.7	LQ mass 534 GeV	$\beta = 1$	1303.0526
Heavy quarks	VLQ $TT \rightarrow Ht + X, Wb + X$	1 e, μ	≥ 1 b, ≥ 3 j	Yes	20.3	T mass 785 GeV	isospin singlet	ATLAS-CONF-2015-012
	VLQ $TT \rightarrow Zt + X$	2/$\geq$3 e, μ	$\geq$2/$\geq$1 b	–	20.3	T mass 735 GeV	T in (T,B) doublet	1409.5500
	VLQ $BB \rightarrow Zb + X$	2/$\geq$3 e, μ	$\geq$2/$\geq$1 b	–	20.3	B mass 755 GeV	B in (B,Y) doublet	1409.5500
	VLQ $BB \rightarrow Wt + X$	1 e, μ	≥ 1 b, ≥ 5 j	Yes	20.3	B mass 640 GeV	isospin singlet	Preliminary
	$T_{5/3} \rightarrow Wt$	1 e, μ	≥ 1 b, ≥ 5 j	Yes	20.3	$T_{5/3}$ mass 840 GeV		Preliminary
Excited fermions	Excited quark $q^* \rightarrow q\gamma$	1 γ	1 j	–	20.3	q^* mass 3.5 TeV	only u^* and d^*, $\Lambda = m(q^*)$	1309.3230
	Excited quark $q^* \rightarrow qg$	–	2 j	–	20.3	q^* mass 4.09 TeV	only u^* and d^*, $\Lambda = m(q^*)$	1407.1376
	Excited quark $b^* \rightarrow Wt$	1 or 2 e, μ	1 b, 2 j or 1 j	Yes	4.7	b^* mass 870 GeV	left-handed coupling	1301.1583
	Excited lepton $\ell^* \rightarrow \ell\gamma$	2 e, μ, 1 γ	–	–	13.0	ℓ^* mass 2.2 TeV	$\Lambda = 2.2$ TeV	1308.1364
	Excited lepton $\nu^* \rightarrow \ell W, \nu Z$	3 e, μ, τ	–	–	20.3	ν^* mass 1.6 TeV	$\Lambda = 1.6$ TeV	1411.2921
Other	LSTC $a_T \rightarrow W\gamma$	1 e, μ, 1 γ	–	Yes	20.3	a_T mass 960 GeV		1407.8150
	LRSM Majorana ν	2 e, μ	2 j	–	2.1	N^0 mass 1.5 TeV	$m(W_R) = 2$ TeV, no mixing	1203.5420
	Higgs triplet $H^{\pm\pm} \rightarrow \ell\ell$	2 e, μ (SS)	–	–	20.3	$H^{\pm\pm}$ mass 551 GeV	DY production, BR($H_L^{\pm\pm} \rightarrow \ell\ell$)=1	1412.0237
	Higgs triplet $H^{\pm\pm} \rightarrow \ell\tau$	3 e, μ, τ	–	–	20.3	$H^{\pm\pm}$ mass 400 GeV	DY production, BR($H_L^{\pm\pm} \rightarrow \ell\tau$)=1	1411.2921
	Monotop (non-res prod)	1 e, μ	1 b	Yes	20.3	spin-1 invisible particle mass 657 GeV	$a_{non-res} = 0.2$	1410.5404
	Multi-charged particles	–	–	–	20.3	multi-charged particle mass 785 GeV	DY production, $\lvert q \rvert = 5e$	Preliminary
	Magnetic monopoles	–	–	–	2.0	monopole mass 862 GeV	DY production, $\lvert g \rvert = 1 g_D$	1207.6411

$\sqrt{s}$ = 7 TeV $\sqrt{s}$ = 8 TeV

10^{-1} 1   10   Mass scale [TeV]

*Only a selection of the available mass limits on new states or phenomena is shown.

From March 2015

Outline

I'll be showing recent exotic search results from ATLAS:

Long Lived Particle Searches

$H \to \gamma\gamma$ + MET

VLQ in Lepton + jets

$H \to Z_{(d)} Z_d \to 4l$

Z + lepton

$HH \to b\bar{b}b\bar{b}$

$t\bar{t}$ resonances in lepton + jets

Diboson resonances in boosted boson tagged jets

All results shown are from 2012 $\sqrt{s}$ = 8 TeV data, made public in May and June 2015. There are many more results which can be found here

Long Lived Particle Searches

Many new physics models give rise to new, massive particles with long lifetimes

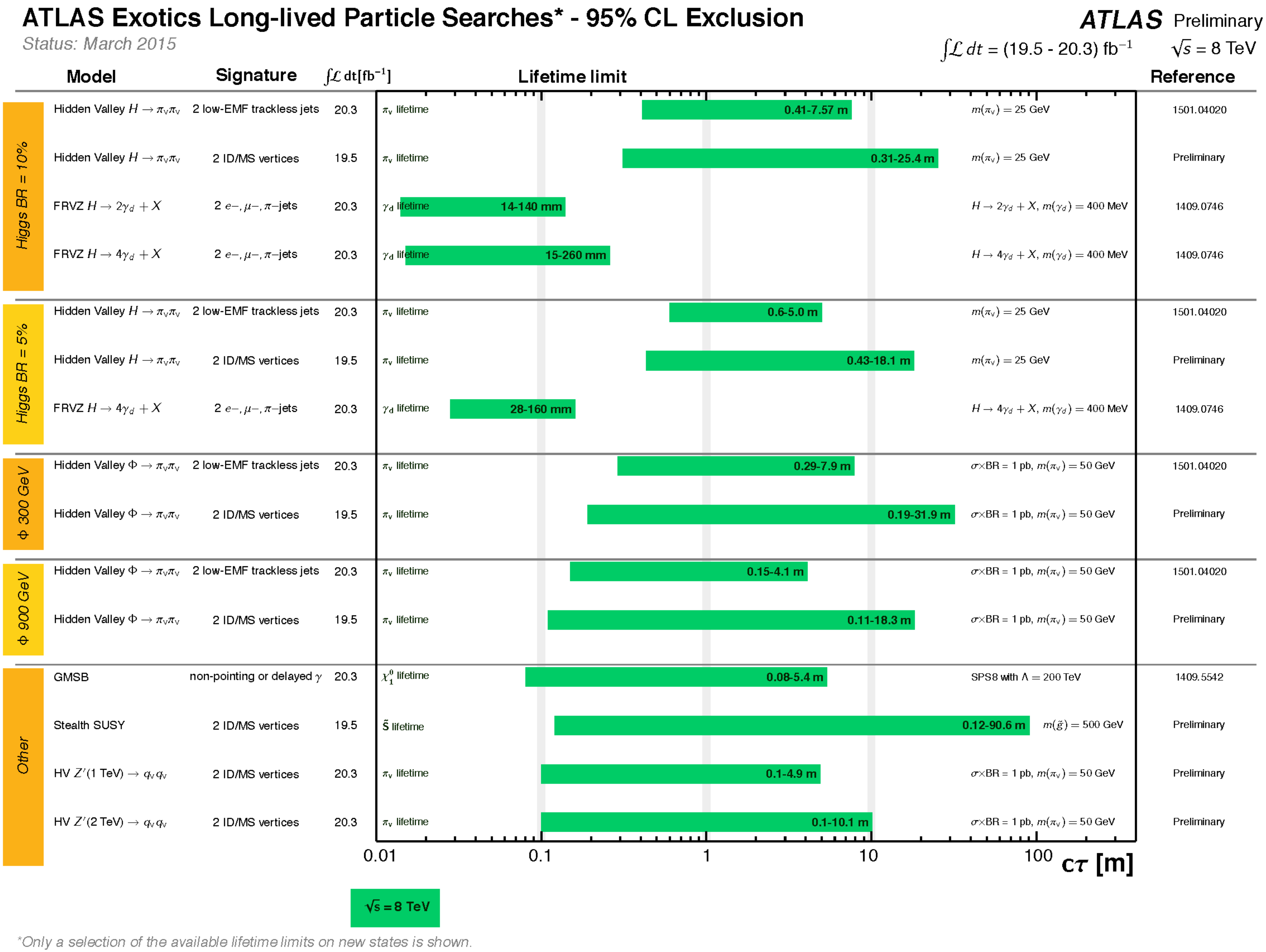
LLPs can arise in models with:

- Small coupling in decay chain
- Strong virtuality (decay to heavy particles)
- Small mass differences in decay chain
- Pair production of particles with conserved quantum numbers

These lead to signatures which we can look for:

- Non-pointing or delayed photons
- Out-of-time decays
- Lepton jets
- Large dE/dx
- Disappearing tracks
- Displaced jets/vertices
- Trackless jets
- …

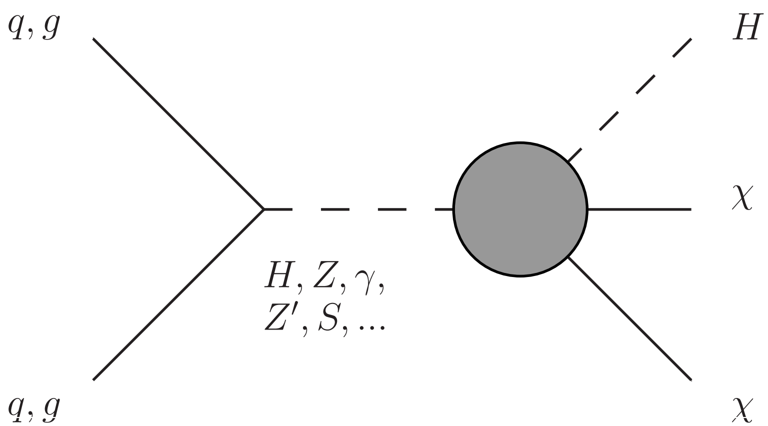
Long Lived Particle Searches Summary



Search for Dark Matter in H(→γγ) + MET

DM invisible to detector

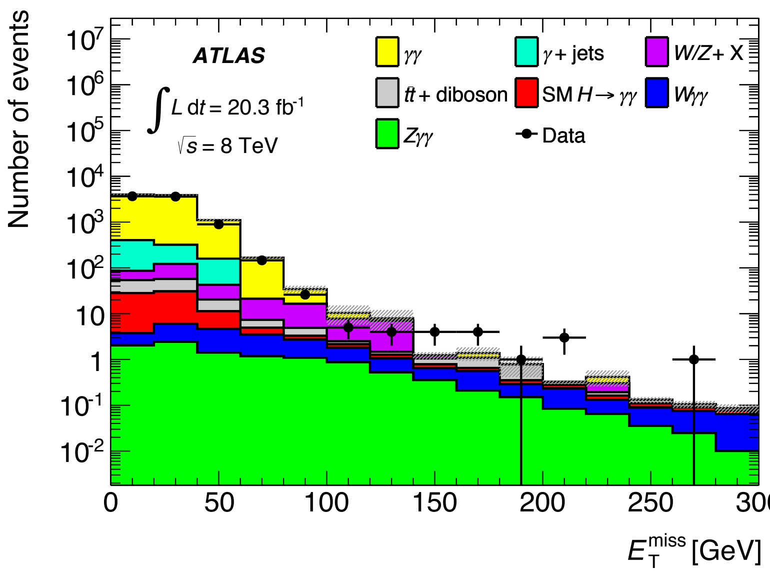
- Uses H→γγ to tag and trigger
- Look for large MET and local excess of events in $m_{\gamma\gamma}$ spectrum near m_H

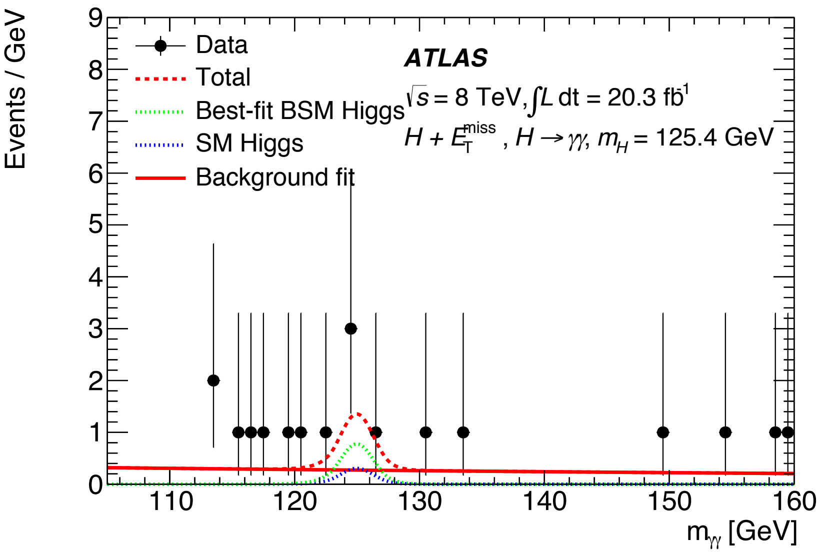


Main Cuts: 105 < $m_{\gamma\gamma}$ < 160 GeV, MET > 90 GeV

Backgrounds:

- SM Higgs bkgd from MC
- Continuum bkgds from $m_{\gamma\gamma}$ sideband

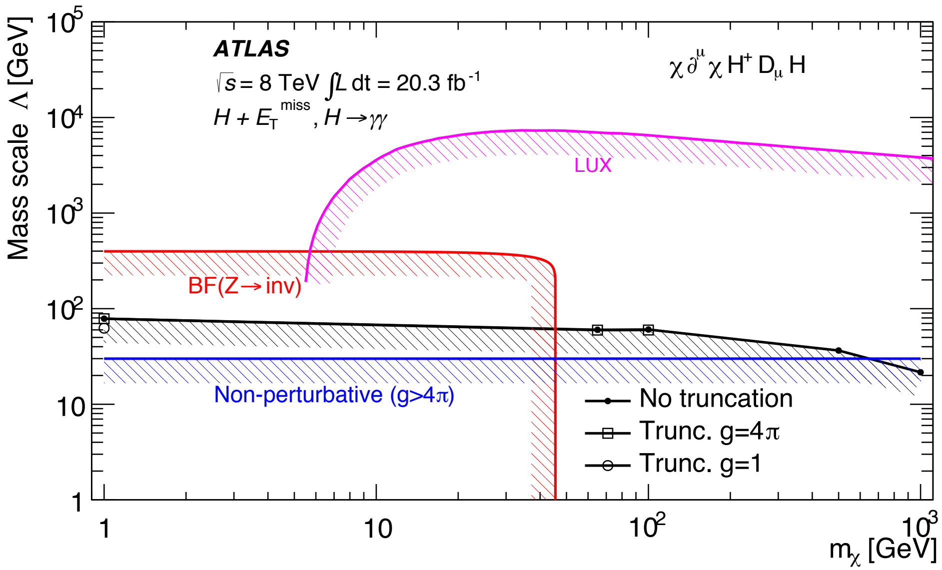


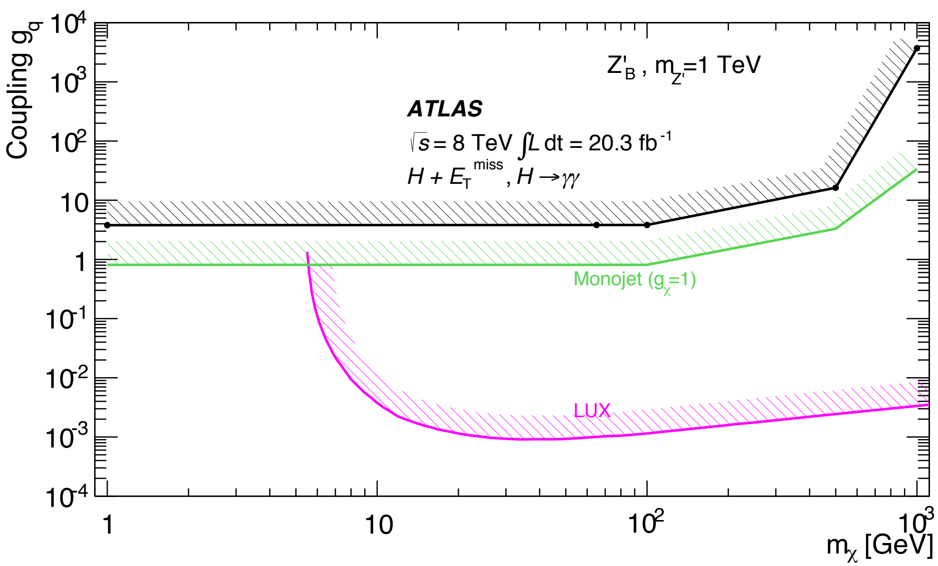


Search for Dark Matter in H(→γγ) + MET

1.4σ excess observed relative to expected limit

- Observed (expected) upper limit on the σ_{fid} is 0.70 (0.43) fb at 95% CL





Search for Vector Like Quark pairs and 4t in the lepton + jets final state

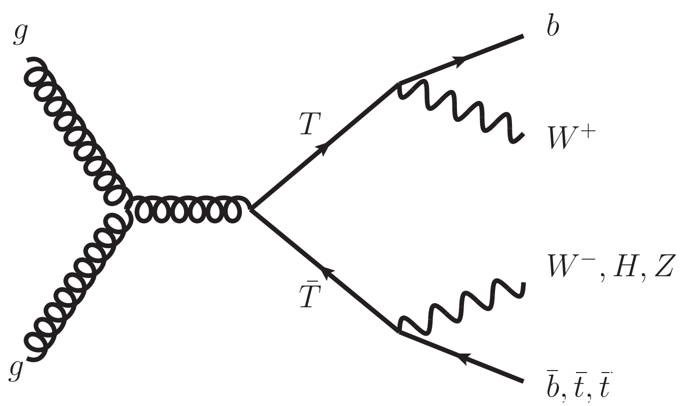
VLQs cancel out quadratic divergences to the Higgs Boson mass

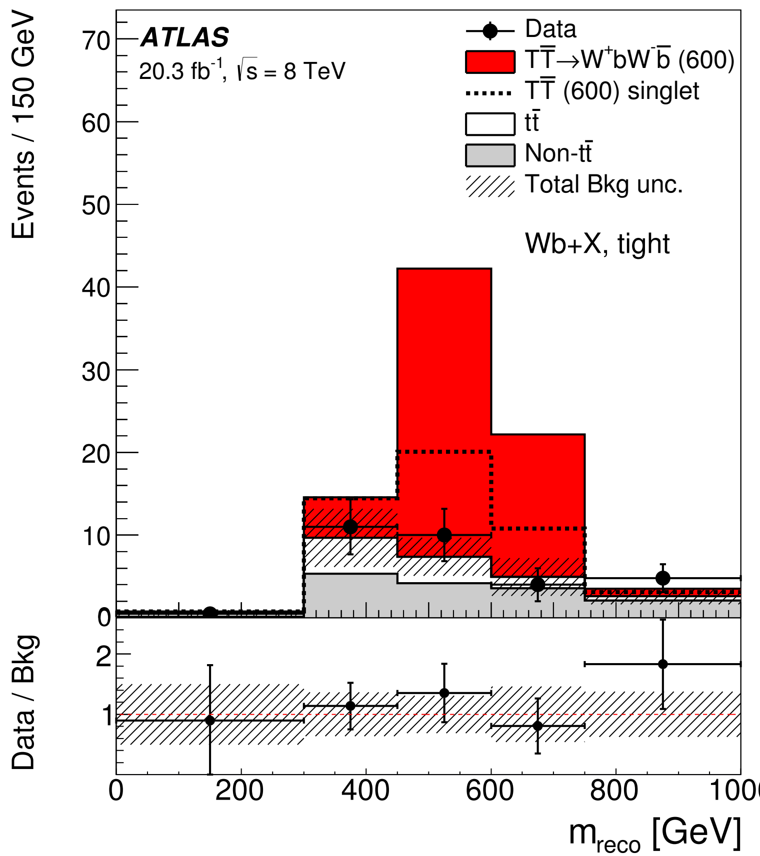
- Decays: T→Wb,Zt,Ht B→Wt,Zb,Hb

3 Analyses performed: $T\bar{T}$→Wb + X, $T\bar{T}$→Ht + X and $t\bar{t}t\bar{t}$ production, $B\bar{B}$ → Hb + X

$T\bar{T}$→Wb + X

- **Reconstruct T mass using boosted W bosons and b-tagged jets**





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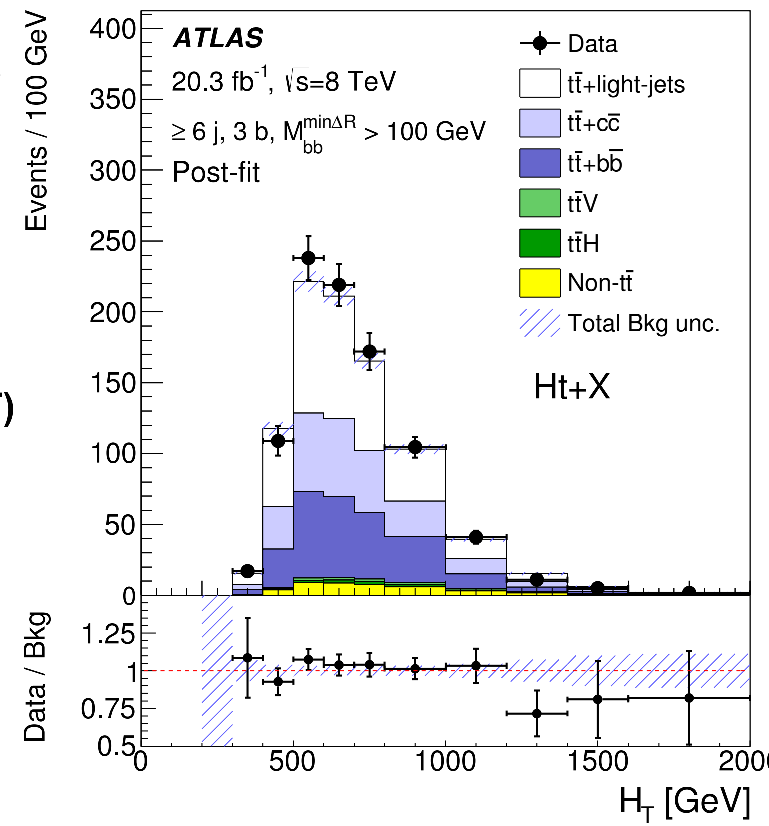
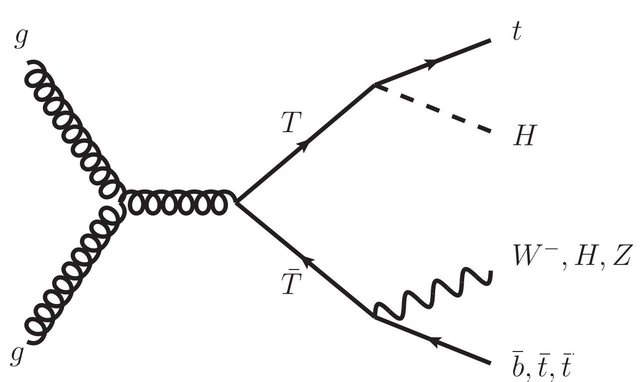
$T\bar{T}$→Ht + X and $t\bar{t}t\bar{t}$ production

- **Dominant decay is H→$b\bar{b}$**
- **Focus on high jet & b-jet multiplicities**
- **Use H_T as discriminant: Σ(jet p_T, lepton p_T, MET)**
- **Also used to set limits on 4t production in several benchmark scenarios**





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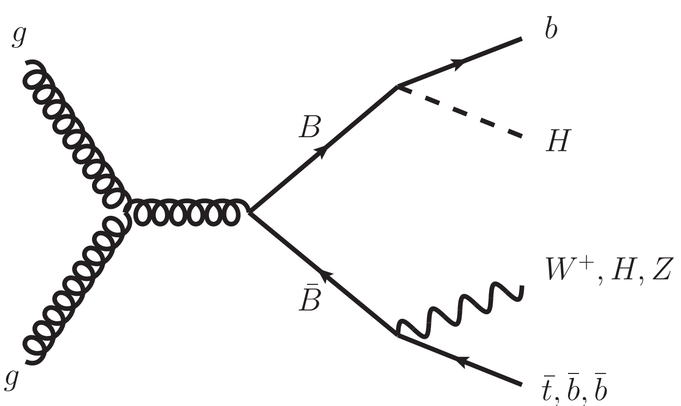
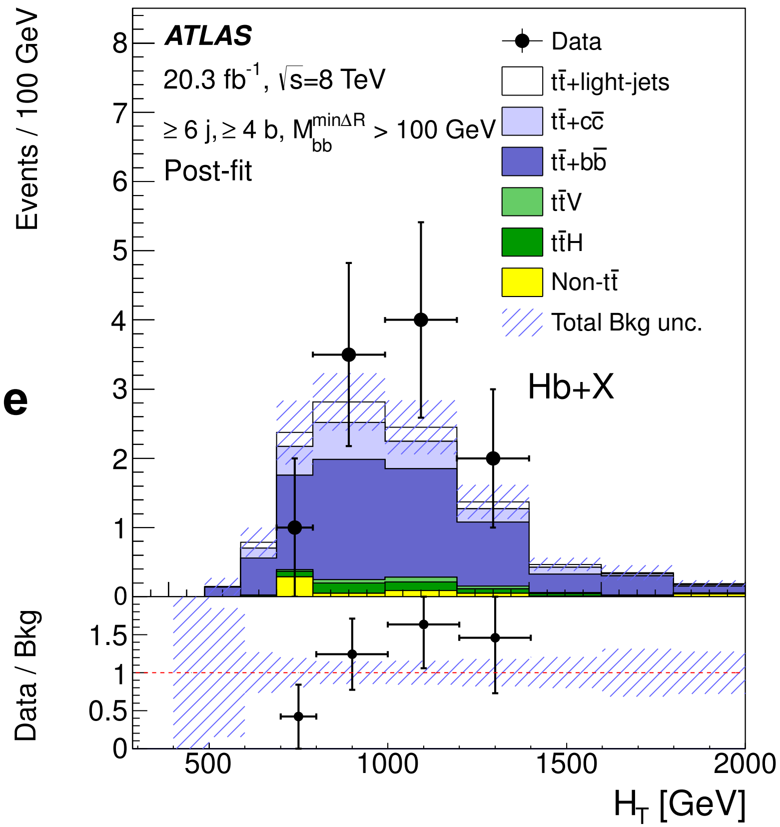
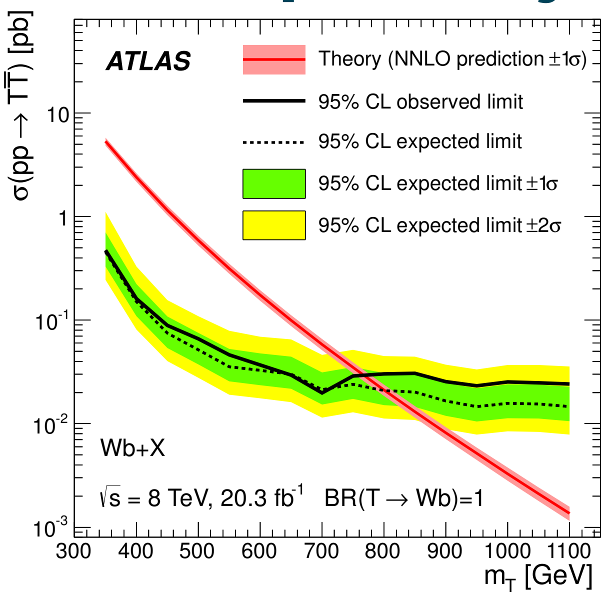
$B\bar{B}$ → Hb + X

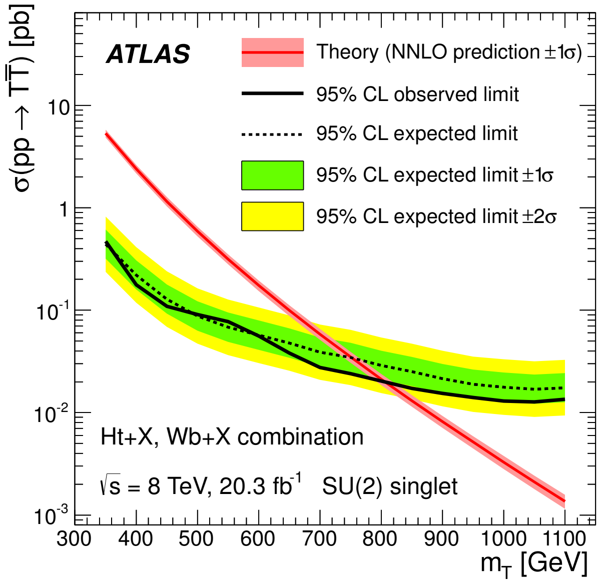
- **Same strategy as Ht + X but optimised for B→Hb**
- **Look at $B\bar{B}$→Hb$H\bar{b}$→(WW)b($b\bar{b}$)$\bar{b}$ where one W decays leptonically**

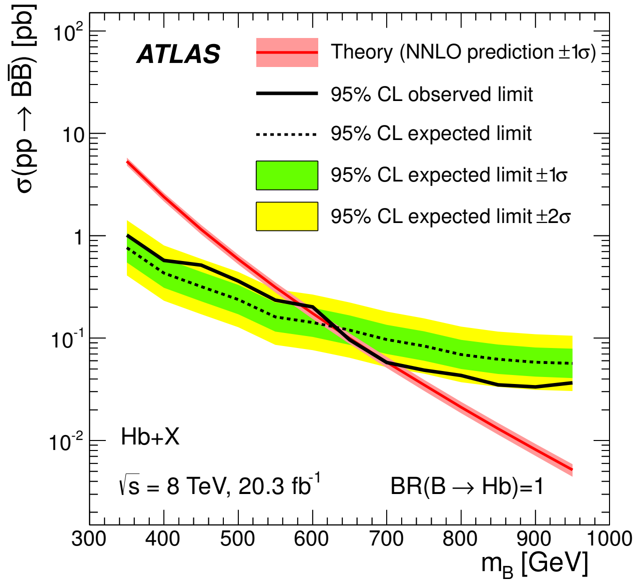


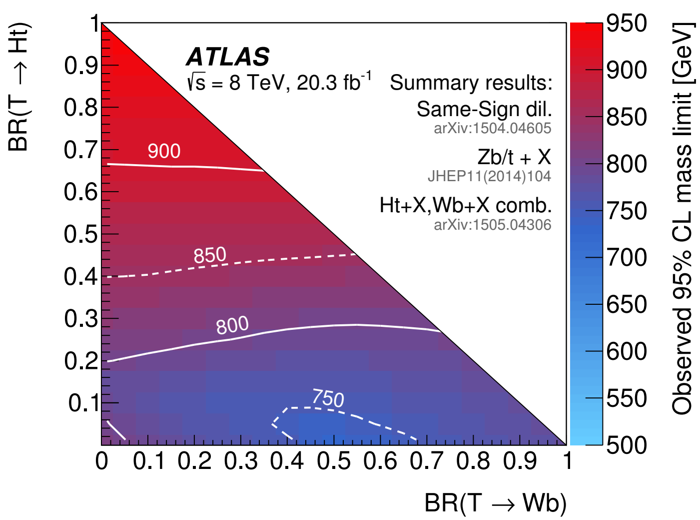


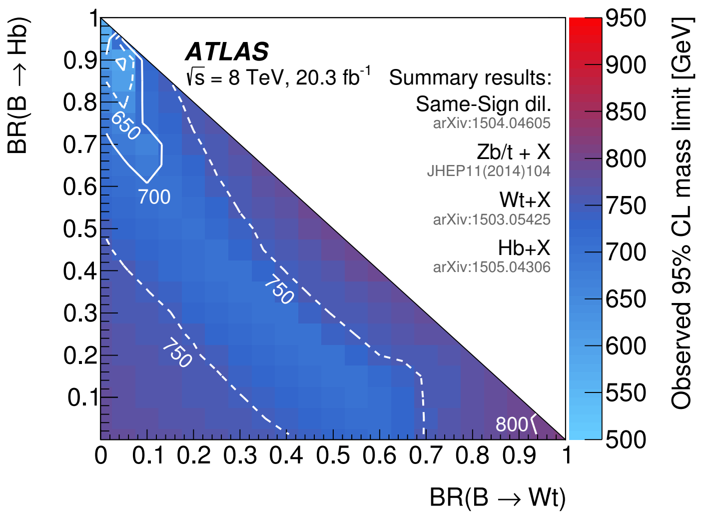
Search for Vector Like Quark pairs and 4t in the lepton + jets final state











See also:
Same-Sign dilepton, arXiv:1504.04605

Zb/t + X, JHEP11(2014)104

Wt + X, arXiv:1503.05425

Search for new light gauge bosons in $H \rightarrow Z_{(d)} Z_d \rightarrow 4l$

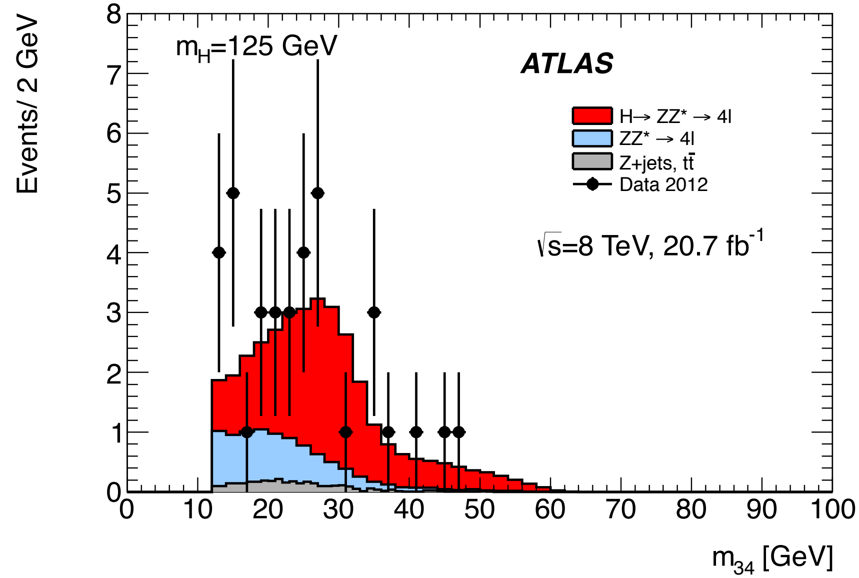
The presence of a dark sector which couples to the SM can be inferred from exotic intermediate decays of Higgs Bosons

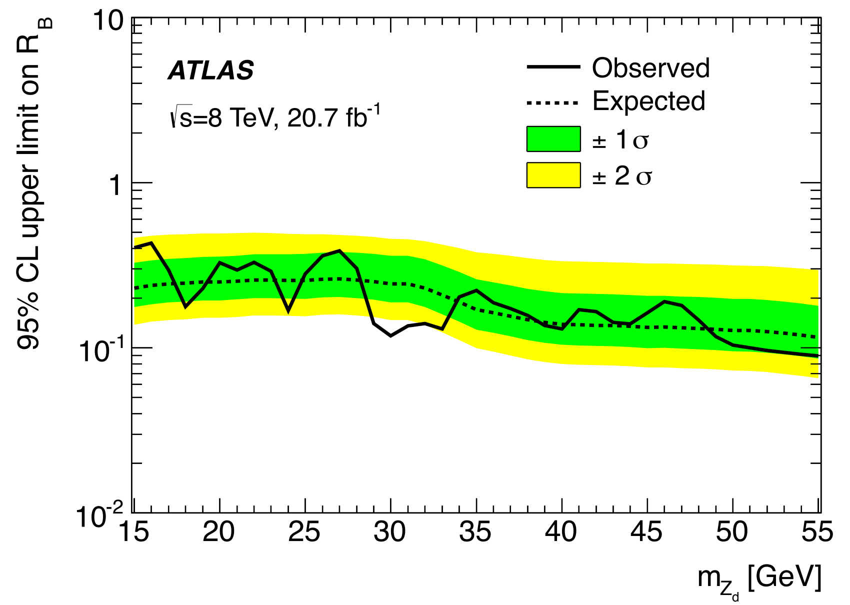
- Looking for $H \rightarrow ZZ_d/Z_dZ_d \rightarrow 4l$ (l = e/μ)

$H \rightarrow ZZ_d \rightarrow 4l$:

- **Define m_{12} as invariant mass of opp. Sign, same flavour lepton pair with m closest to Z boson**
- **m_{34} is invariant mass of remaining pair**
- **Look for local excess in m_{34}**

$$R_B = \frac{BR(H \rightarrow ZZ_d \rightarrow 4l)}{BR(H \rightarrow 4l)}$$





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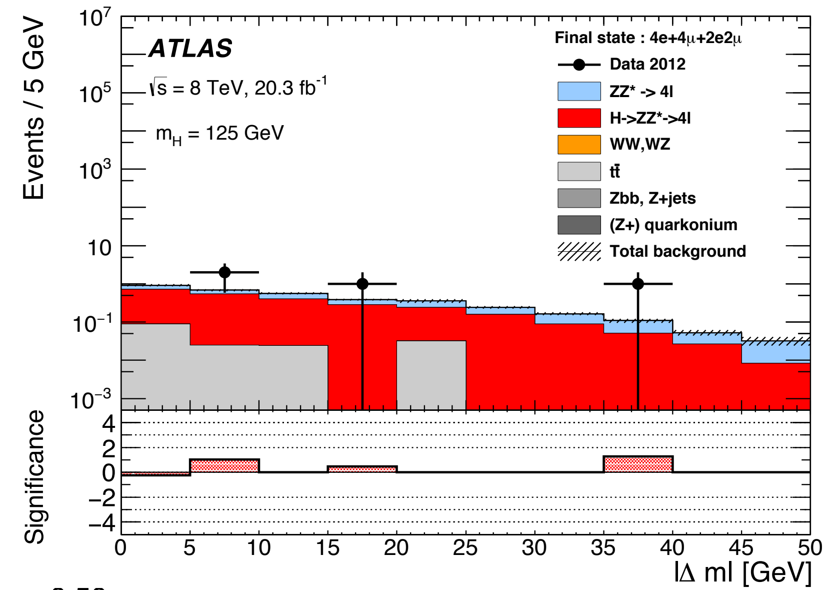

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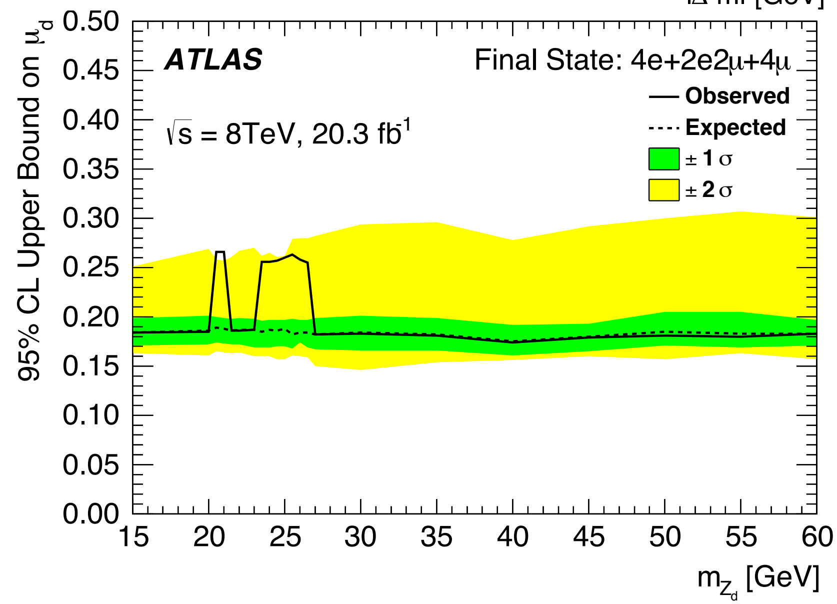
- Looking for $H \rightarrow ZZ_d/Z_dZ_d \rightarrow 4l$ ($l = e/\mu$)

$H \rightarrow Z_dZ_d \rightarrow 4l$:

- **Events are selected by requiring the difference in invariant mass of the dilepton pairs is minimized**
- **Upper limits are computed from a maximum likelihood fit**

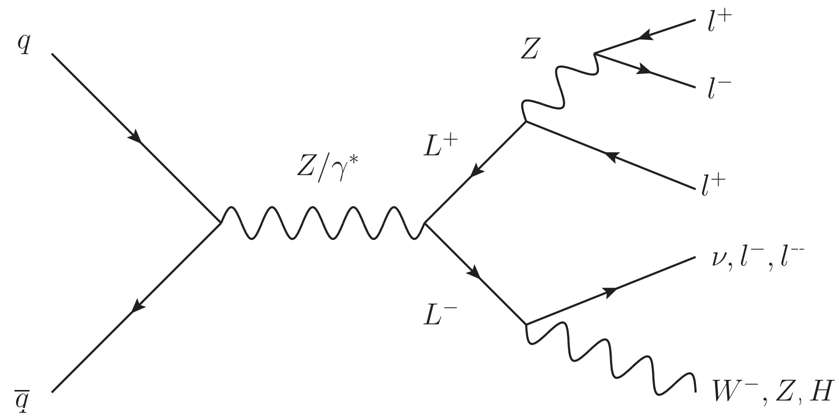
$$\mu_d = \frac{\sigma \times BR(H \rightarrow Z_dZ_d \rightarrow 4l)}{[\sigma \times BR(H \rightarrow ZZ^* \rightarrow 4l)]_{SM}}$$



Search for heavy lepton resonances in Z + lepton events

Many extensions to the SM predict heavy resonances in trileptons

- Seesaw
- Vector Like Leptons



Searching for heavy leptons, L^+, L^-, N^0 which decay to W/Z/H + l/ν (depending on charge)

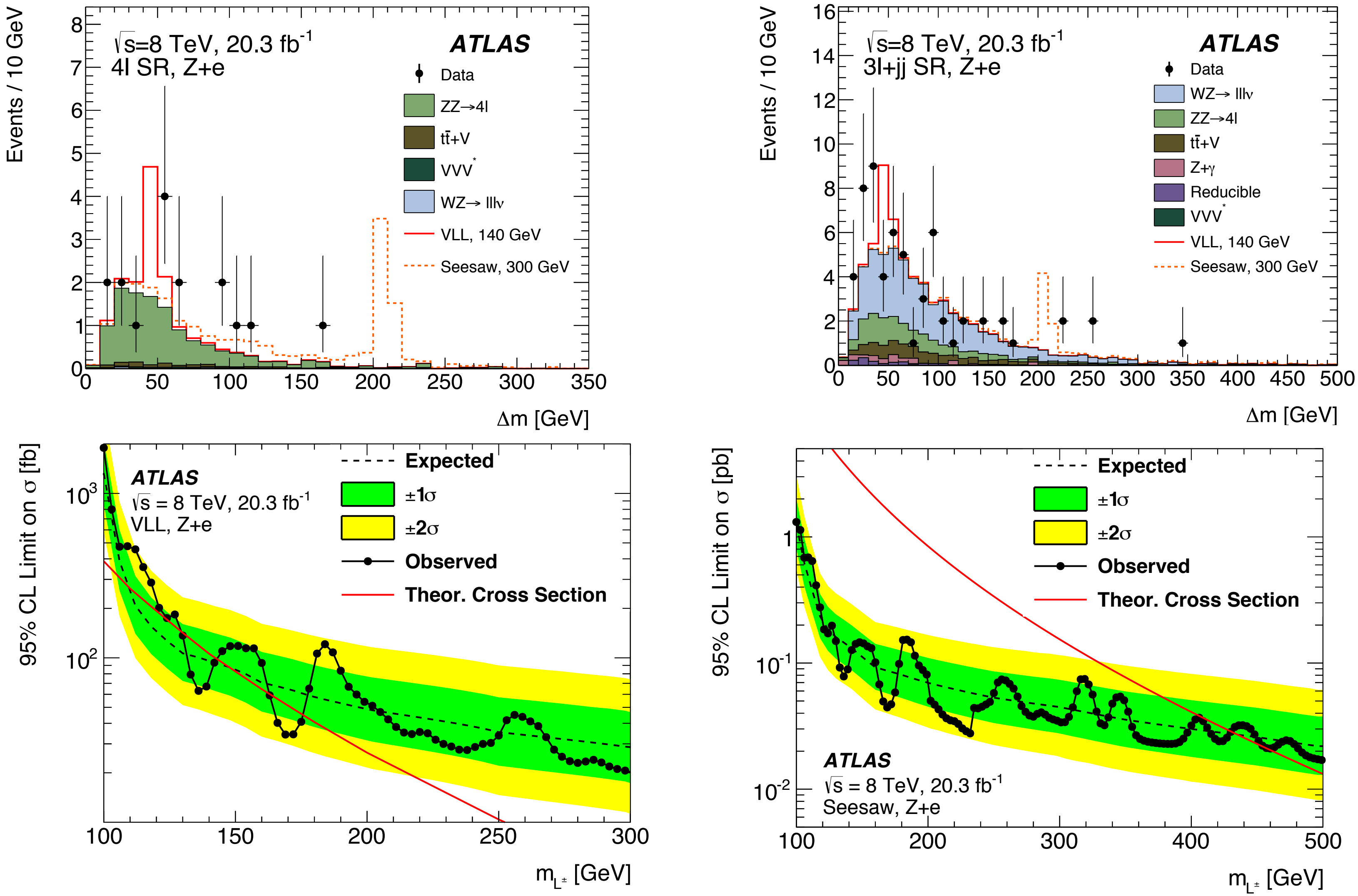
Looking in L → l+Z(ll) channel

Look for 3 leptons with 1 Z candidate, reconstruct m_L from invariant mass of the 3 leptons and use $\Delta M \equiv m_{3l} - m_Z$ as discriminating variable

Use 6 signal regions depending on 3rd lepton flavour and other side of event: 4l, 3l+jj, 3l-only

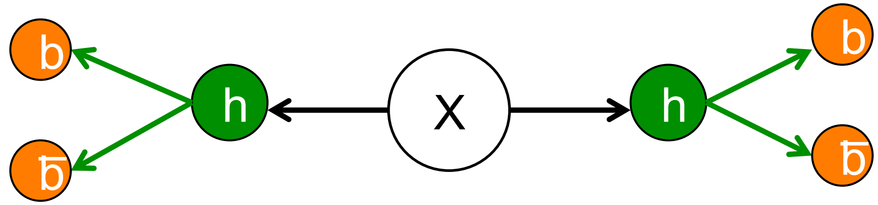
Backgrounds: WZ, ZZ and DY Z+γ taken from MC. Other bkgds are constrained from scaling control samples in data

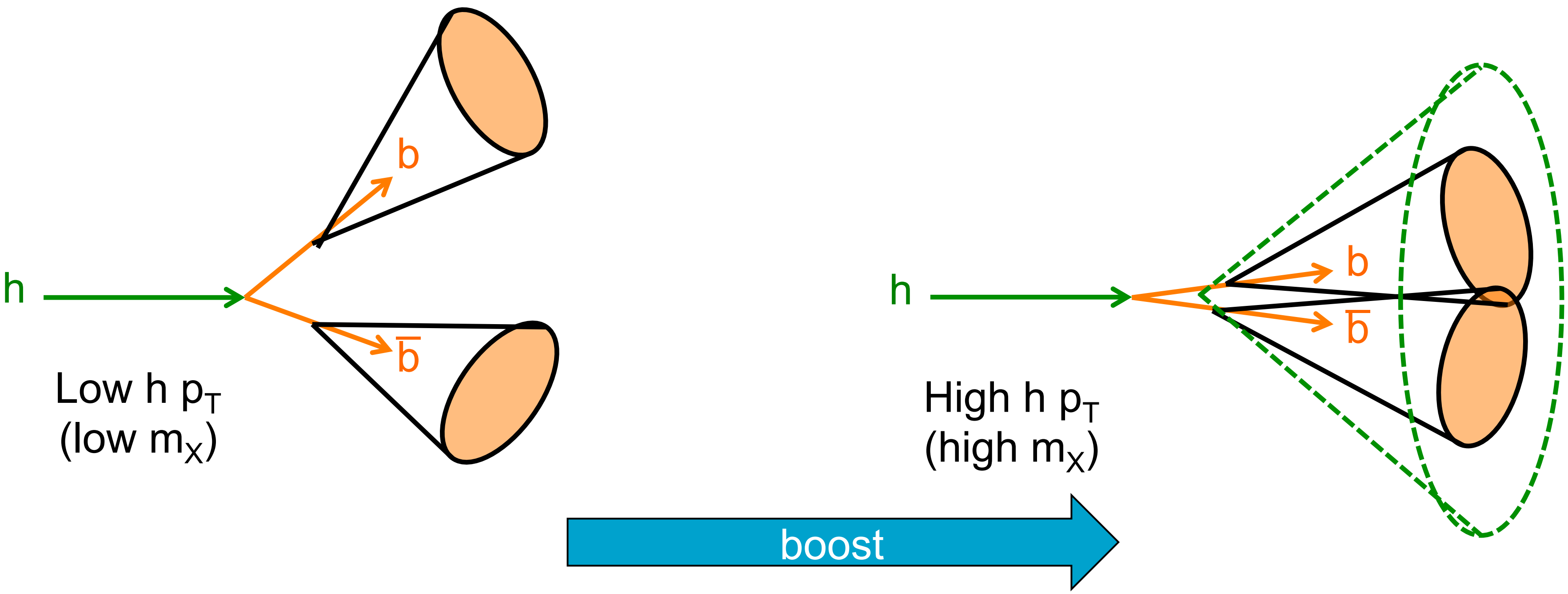
Search for heavy lepton resonances in Z + lepton events



Boosted Methods

Example: $X \rightarrow hh \rightarrow b\bar{b}b\bar{b}$





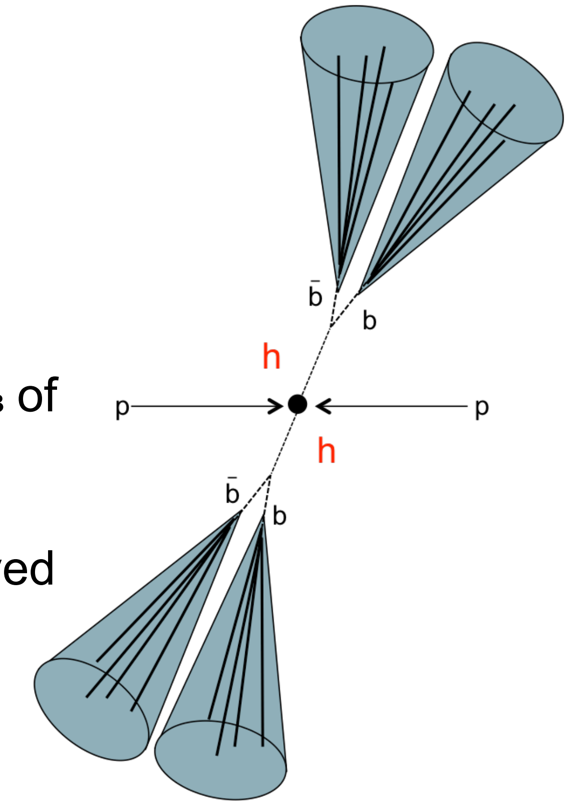
Rule of thumb for angular separation between decay products:

$$\Delta R \approx \frac{2m}{p_T}$$

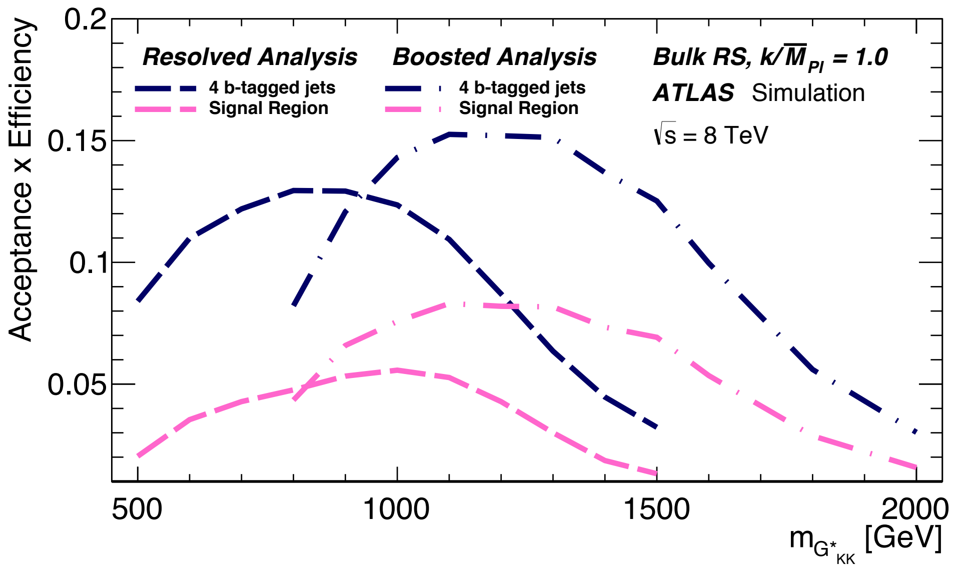
Higgs Boson Pair Production in the $b\bar{b}b\bar{b}$ Final State

New physics models predict enhanced Higgs Boson pair production rates over the SM

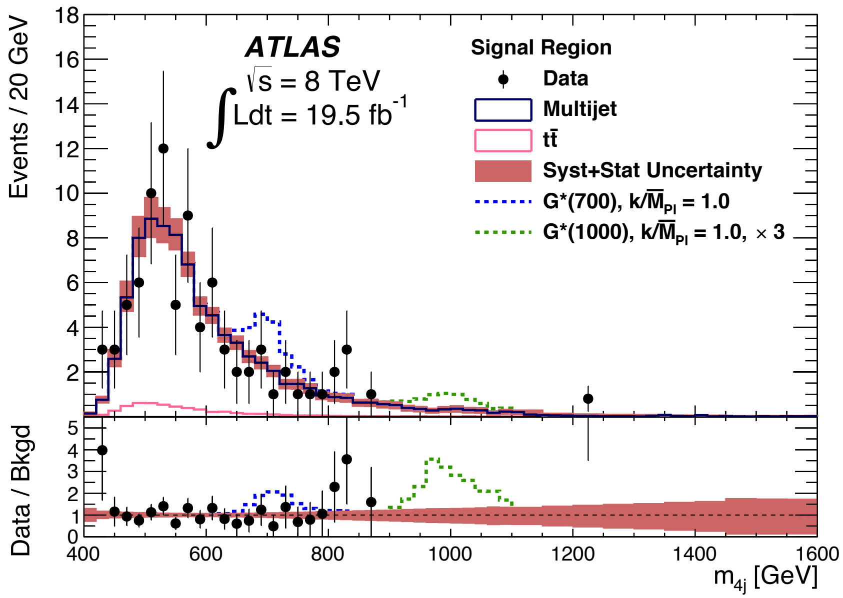
Boosted Higgs gives clear event topology
Large BR($H\to b\bar{b}$) means that the 4b final state happens ~⅓ of the time

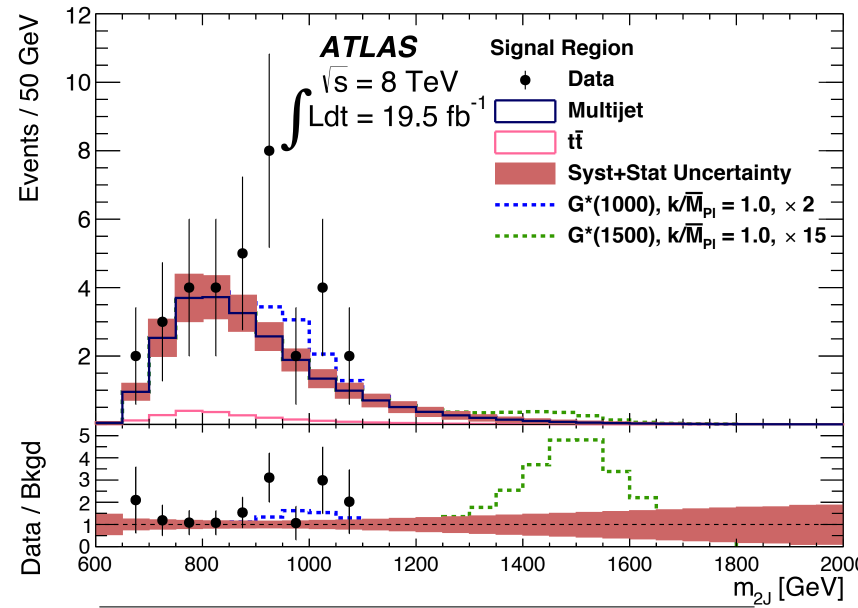


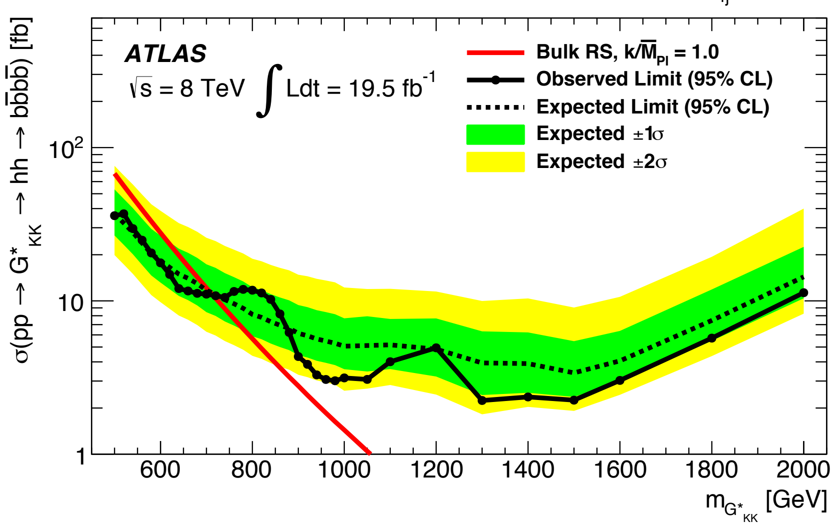
Analysis based on two complementary approaches – resolved and boosted



Higgs Boson Pair Production in the $b\bar{b}b\bar{b}$ Final State







$k/\bar{M}_{\rm Pl}$	95% CL Excluded $G^*_{\rm KK}$ Mass Range [GeV]
1.0	500 – 720
1.5	500 – 800 and 870 – 910
2.0	500 – 990

Upper limit on SM hh non-resonant production,

$\sigma(pp \to hh \to b\bar{b}b\bar{b})$ = 202 fb (95% CL)

[SM prediction of 3.6 ± 0.5 fb]

World's best limit!!

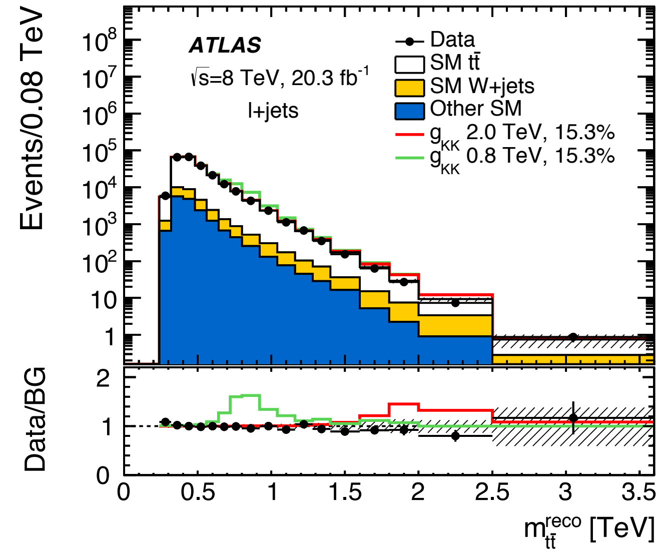
$t\bar{t}$ Resonances using lepton + jet events

Many extensions to the SM predict heavy resonances with large BR to top-pairs

Lepton + jets final state has large BR & also good background discrimination

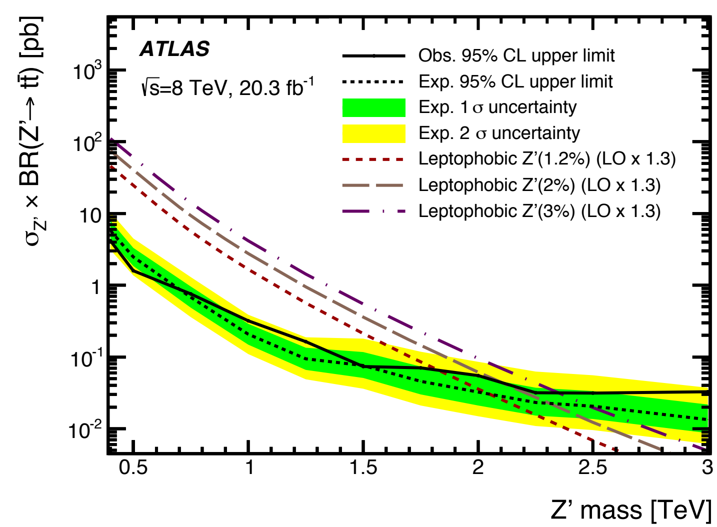
Analysis based on two approaches "resolved" and "boosted". If event fails boosted try resolved.

- Resolved: 1 lepton, ≥ 4 small radius jets, ≥ 1 b-tagged jet, MET > 20 GeV, MET + m_T > 60 GeV
- Boosted: same as resolved but require a trimmed Anti-K_T 1.0 jet p_T > 300 GeV, m > 100 GeV



No excesses found so limits on masses and cross-sections were made

- Observed limits exclude $m_{Z'}$ < 1.8 TeV and m_{gKK} < 2.2 TeV



High Mass Diboson Resonances with Boson-Tagged Jets

Many extensions to the SM predict high mass resonances in dibosons

- ➢ Bulk-RS graviton → WW/ZZ
- ➢ Extended gauge model: W' →WZ

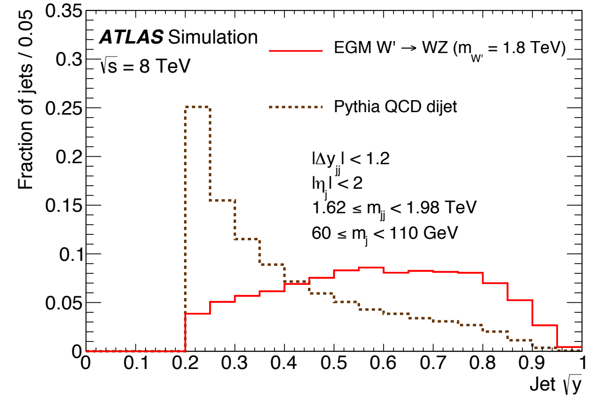
All hadronic final state has large BR compared to leptonic and semileptonic decays

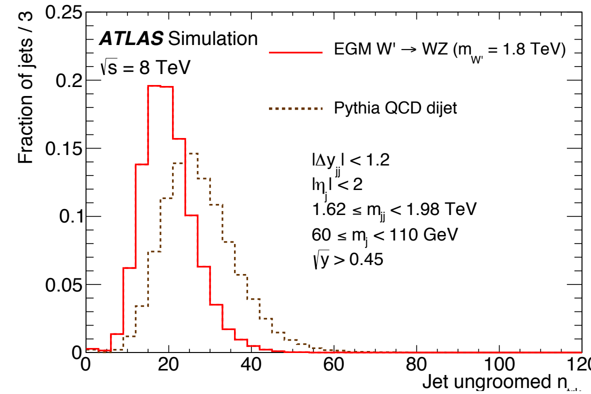
Boosted boson tagging to suppress backgrounds

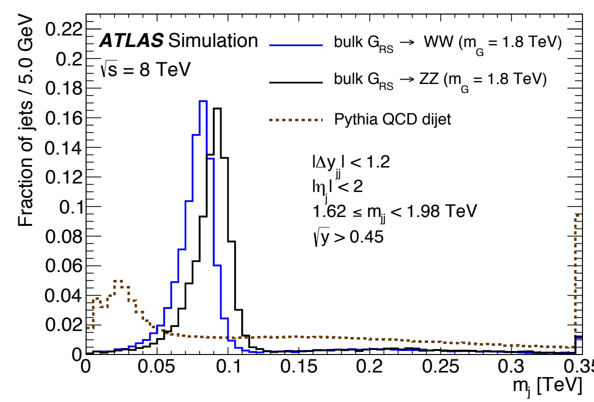
- ➢ 2 C/A 1.2 jets with m_{2J} > 1.05 TeV
- ➢ $\sqrt{y} \geq 0.45$, $n_{track} < 30$, $|m_j - m_V| < 13$ GeV

Search for bumps on steeply falling background

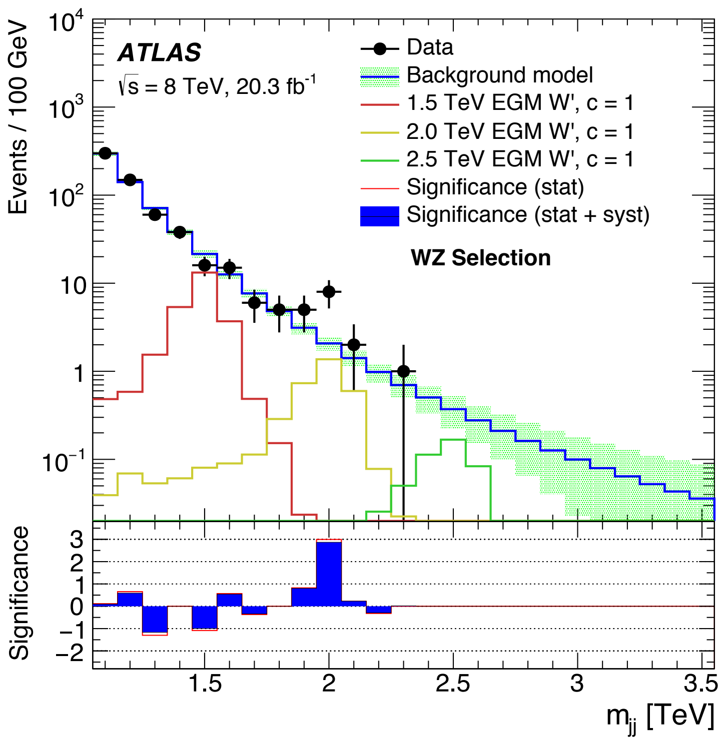
- ➢ Background taken from fit to data
- ➢ Signal shape from MC



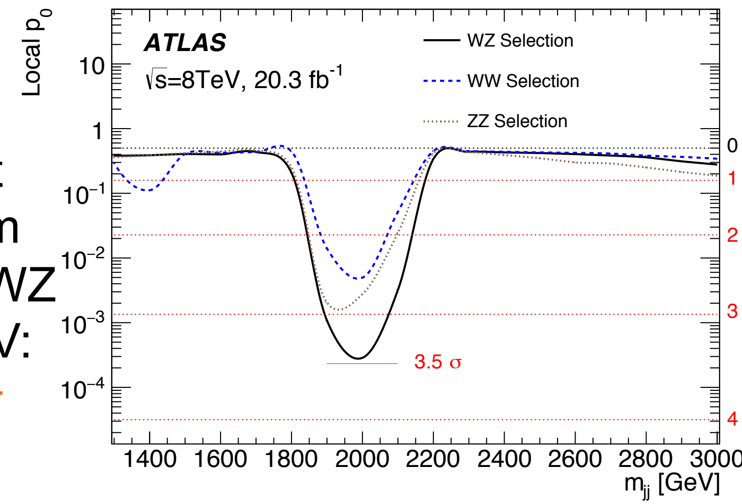




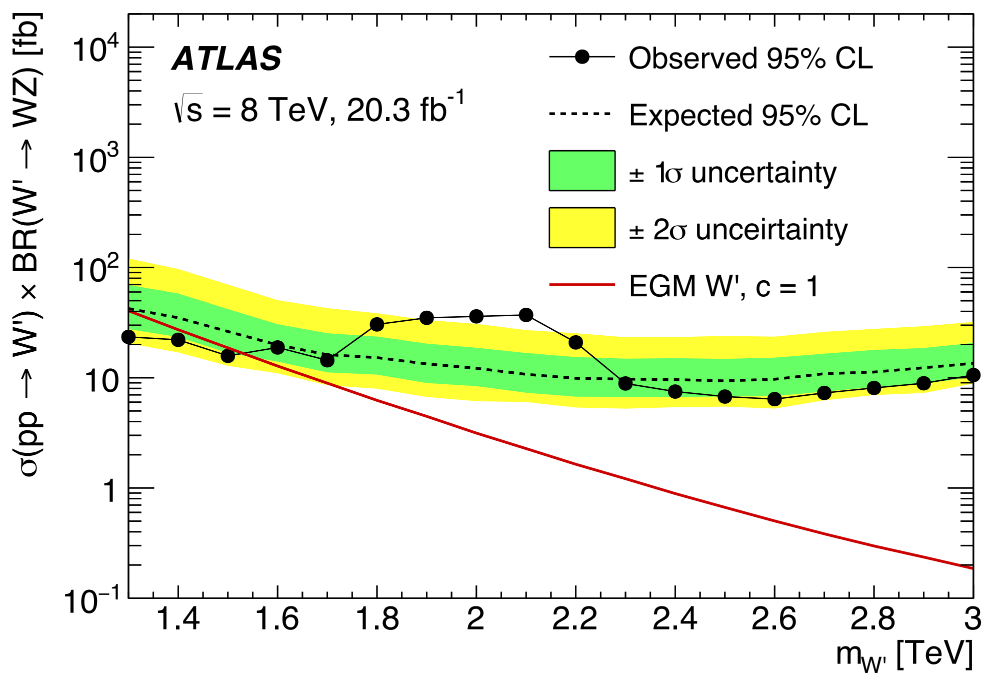
High Mass Diboson Resonances with Boson-Tagged Jets



Most significant discrepancy from background is in WZ selection at 2 TeV: 3.4σ local, 2.5σ global



EGM W' excluded for 1.3 < $m_{W'}$ < 1.5 TeV

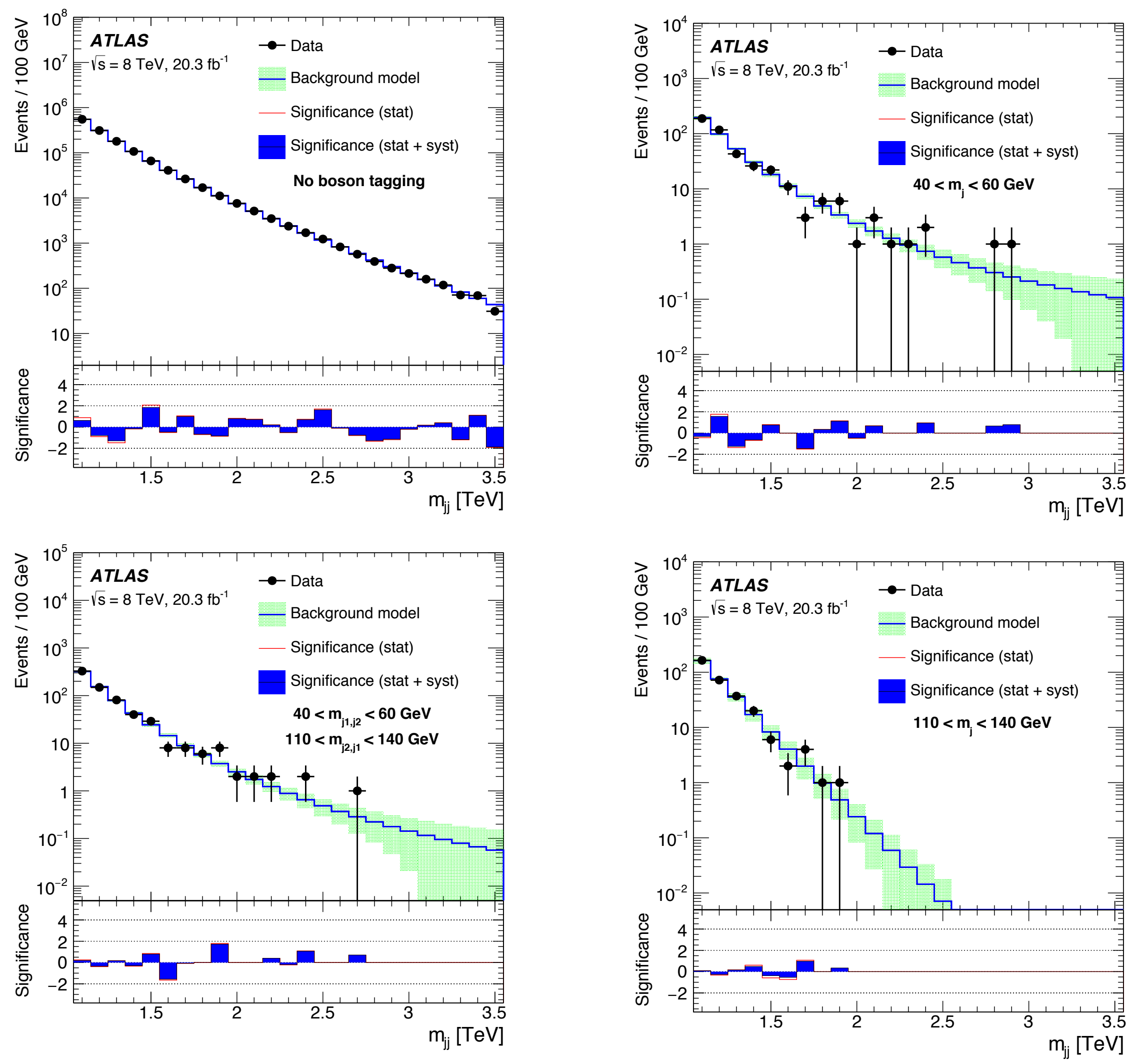


arXiv:1506.00962

High Mass Diboson Resonances with Boson-Tagged Jets

Checked for mistakes, bugs and shaping effects in

- Detector/data taking
- Jet reconstruction
- Event selection



Summary

Many exotic searches have been performed on the Run-1 data with ATLAS

I've presented here 7 of them, but many more can be found at ExoticsPublicResults

Many limits have been placed on models

With the large increase in energy for Run 2, new physics may be just around the corner!!

ATLAS Exotics Searches* - 95% CL Exclusion

Status: March 2015

ATLAS Preliminary

$\int \mathcal{L}\, dt = (1.0 - 20.3)\ fb^{-1}$ $\sqrt{s} = 7, 8$ TeV

	Model	ℓ, γ	Jets	E_T^{miss}	$\int \mathcal{L}\, dt[fb^{-1}]$	Mass limit		Reference
Extra dimensions	ADD $G_{KK} + g/q$	–	≥ 1 j	Yes	20.3	M_D 5.25 TeV	$n = 2$	1502.01518
	ADD non-resonant $\ell\ell$	$2e, \mu$	–	–	20.3	M_S 4.7 TeV	$n = 3$ HLZ	1407.2410
	ADD QBH $\to \ell q$	$1\ e, \mu$	1 j	–	20.3	M_{th} 5.2 TeV	$n = 6$	1311.2006
	ADD QBH	–	2 j	–	20.3	M_{th} 5.82 TeV	$n = 6$	1407.1376
	ADD BH high N_{trk}	$2\ \mu$ (SS)	–	–	20.3	M_{th} 4.7 TeV	$n = 6$, $M_D = 3$ TeV, non-rot BH	1308.4075
	ADD BH high $\sum p_T$	$\geq 1\ e, \mu$	≥ 2 j	–	20.3	M_{th} 5.8 TeV	$n = 6$, $M_D = 3$ TeV, non-rot BH	1405.4254
	ADD BH high multijet	–	≥ 2 j	–	20.3	M_{th} 5.8 TeV	$n = 6$, $M_D = 3$ TeV, non-rot BH	Preliminary
	RS1 $G_{KK} \to \ell\ell$	$2\ e, \mu$	–	–	20.3	G_{KK} mass 2.68 TeV	$k/\overline{M}_{Pl} = 0.1$	1405.4123
	RS1 $G_{KK} \to \gamma\gamma$	$2\ \gamma$	–	–	20.3	G_{KK} mass 2.66 TeV	$k/\overline{M}_{Pl} = 0.1$	Preliminary
	Bulk RS $G_{KK} \to ZZ \to qq\ell\ell$	$2\ e, \mu$	2 j / 1 J	–	20.3	G_{KK} mass 740 GeV	$k/\overline{M}_{Pl} = 1.0$	1409.6190
	Bulk RS $G_{KK} \to WW \to qq\ell\nu$	$1\ e, \mu$	2 j / 1 J	Yes	20.3	W' mass 700 GeV	$k/\overline{M}_{Pl} = 1.0$	1503.04677
	Bulk RS $G_{KK} \to HH \to b\bar{b}b\bar{b}$	–	4 b	–	19.5	G_{KK} mass 590-710 GeV	$k/\overline{M}_{Pl} = 1.0$	ATLAS-CONF-2014-005
	Bulk RS $g_{KK} \to t\bar{t}$	$1\ e, \mu$	≥ 1 b, ≥ 1J/2j	Yes	20.3	g_{KK} mass 2.2 TeV	BR = 0.925	ATLAS-CONF-2015-009
	2UED / RPP	$2\ e, \mu$ (SS)	≥ 1 b, ≥ 1 j	Yes	20.3	KK mass 960 GeV		Preliminary
Gauge bosons	SSM $Z' \to \ell\ell$	$2\ e, \mu$	–	–	20.3	Z' mass 2.9 TeV		1405.4123
	SSM $Z' \to \tau\tau$	$2\ \tau$	–	–	19.5	Z' mass 2.02 TeV		1502.07177
	SSM $W' \to \ell\nu$	$1\ e, \mu$	–	Yes	20.3	W' mass 3.24 TeV		1407.7494
	EGM $W' \to WZ \to \ell\nu\ \ell'\ell'$	$3\ e, \mu$	–	Yes	20.3	W' mass 1.52 TeV		1406.4456
	EGM $W' \to WZ \to qq\ell\ell$	$2\ e, \mu$	2 j / 1 J	–	20.3	W' mass 1.59 TeV		1409.6190
	HVT $W' \to WH \to \ell\nu bb$	$1\ e, \mu$	2 b	Yes	20.3	W' mass 1.47 TeV	$g_V = 1$	Preliminary
	LRSM $W'_R \to t\bar{b}$	$1\ e, \mu$	2 b, 0-1 j	Yes	20.3	W' mass 1.92 TeV		1410.4103
	LRSM $W'_R \to t\bar{b}$	$0\ e, \mu$	≥ 1 b, 1 J	–	20.3	W' mass 1.76 TeV		1408.0886
CI	CI $qqqq$	–	2 j	–	17.3	Λ 12.0 TeV	$\eta_{LL} = -1$	Preliminary
	CI $qq\ell\ell$	$2\ e, \mu$	–	–	20.3	Λ 21.6 TeV	$\eta_{LL} = -1$	1407.2410
	CI $uutt$	$2\ e, \mu$ (SS)	≥ 1 b, ≥ 1 j	Yes	20.3	Λ 4.35 TeV	$\lvert C_{LL} \rvert = 1$	Preliminary
DM	EFT D5 operator (Dirac)	$0\ e, \mu$	≥ 1 j	Yes	20.3	M_* 974 GeV	at 90% CL for $m(\chi) < 100$ GeV	1502.01518
	EFT D9 operator (Dirac)	$0\ e, \mu$	1 J, ≤ 1 j	Yes	20.3	M_* 2.4 TeV	at 90% CL for $m(\chi) < 100$ GeV	1309.4017
LQ	Scalar LQ 1st gen	$2\ e$	≥ 2 j	–	1.0	LQ mass 660 GeV	$\beta = 1$	1112.4828
	Scalar LQ 2nd gen	$2\ \mu$	≥ 2 j	–	1.0	LQ mass 685 GeV	$\beta = 1$	1203.3172
	Scalar LQ 3rd gen	$1\ e, \mu, 1\ \tau$	1 b, 1 j	–	4.7	LQ mass 534 GeV	$\beta = 1$	1303.0526
Heavy quarks	VLQ $TT \to Ht + X, Wb + X$	$1\ e, \mu$	≥ 1 b, ≥ 3 j	Yes	20.3	T mass 785 GeV	isospin singlet	ATLAS-CONF-2015-012
	VLQ $TT \to Zt + X$	$2/\geq 3\ e, \mu$	≥2/≥1 b	–	20.3	T mass 735 GeV	T in (T,B) doublet	1409.5500
	VLQ $BB \to Zb + X$	$2/\geq 3\ e, \mu$	≥2/≥1 b	–	20.3	B mass 755 GeV	B in (B,Y) doublet	1409.5500
	VLQ $BB \to Wt + X$	$1\ e, \mu$	≥ 1 b, ≥ 5 j	Yes	20.3	B mass 640 GeV	isospin singlet	Preliminary
	$T_{5/3} \to Wt$	$1\ e, \mu$	≥ 1 b, ≥ 5 j	Yes	20.3	$T_{5/3}$ mass 840 GeV		Preliminary
Excited fermions	Excited quark $q^* \to q\gamma$	$1\ \gamma$	1 j	–	20.3	q^* mass 3.5 TeV	only u^* and d^*, $\Lambda = m(q^*)$	1309.3230
	Excited quark $q^* \to qg$	–	2 j	–	20.3	q^* mass 4.09 TeV	only u^* and d^*, $\Lambda = m(q^*)$	1407.1376
	Excited quark $b^* \to Wt$	1 or 2 e, μ	1 b, 2 j or 1 j	Yes	4.7	b^* mass 870 GeV	left-handed coupling	1301.1583
	Excited lepton $\ell^* \to \ell\gamma$	$2\ e, \mu, 1\ \gamma$	–	–	13.0	ℓ^* mass 2.2 TeV	$\Lambda = 2.2$ TeV	1308.1364
	Excited lepton $\nu^* \to \ell W, \nu Z$	$3\ e, \mu, \tau$	–	–	20.3	ν^* mass 1.6 TeV	$\Lambda = 1.6$ TeV	1411.2921
Other	LSTC $a_T \to W\gamma$	$1\ e, \mu, 1\ \gamma$	–	Yes	20.3	a_T mass 960 GeV		1407.8150
	LRSM Majorana ν	$2\ e, \mu$	2 j	–	2.1	N^0 mass 1.5 TeV	$m(W_R) = 2$ TeV, no mixing	1203.5420
	Higgs triplet $H^{\pm\pm} \to \ell\ell$	$2\ e, \mu$ (SS)	–	–	20.3	$H^{\pm\pm}$ mass 551 GeV	DY production, BR($H_L^{\pm\pm} \to \ell\ell$)=1	1412.0237
	Higgs triplet $H^{\pm\pm} \to \ell\tau$	$3\ e, \mu, \tau$	–	–	20.3	$H^{\pm\pm}$ mass 400 GeV	DY production, BR($H_L^{\pm\pm} \to \ell\tau$)=1	1411.2921
	Monotop (non-res prod)	$1\ e, \mu$	1 b	Yes	20.3	spin-1 invisible particle mass 657 GeV	$a_{non-res} = 0.2$	1410.5404
	Multi-charged particles	–	–	–	20.3	multi-charged particle mass 785 GeV	DY production, $\lvert q \rvert = 5e$	Preliminary
	Magnetic monopoles	–	–	–	2.0	monopole mass 862 GeV	DY production, $\lvert g \rvert = 1 g_D$	1207.6411

$\sqrt{s}$ = 7 TeV $\sqrt{s}$ = 8 TeV

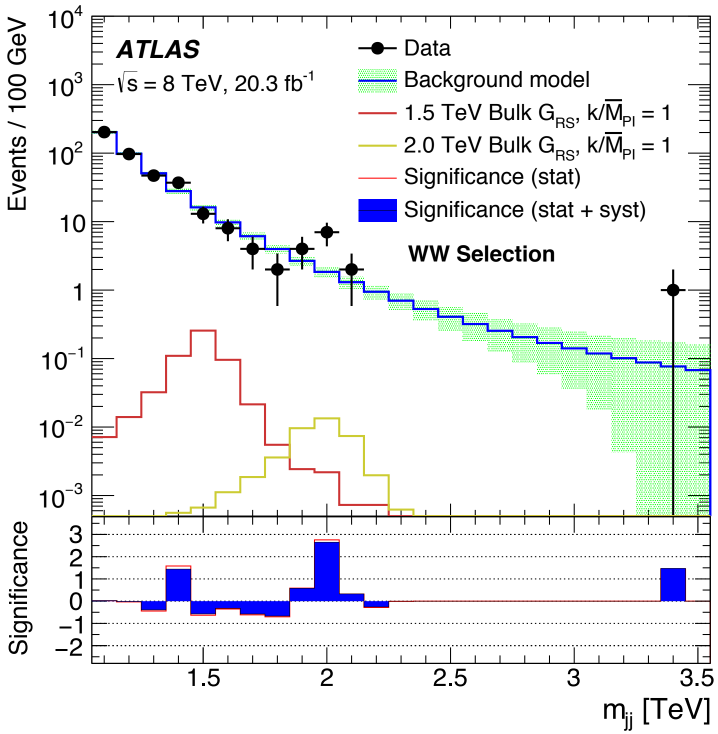
10^{-1} 1 10 Mass scale [TeV]

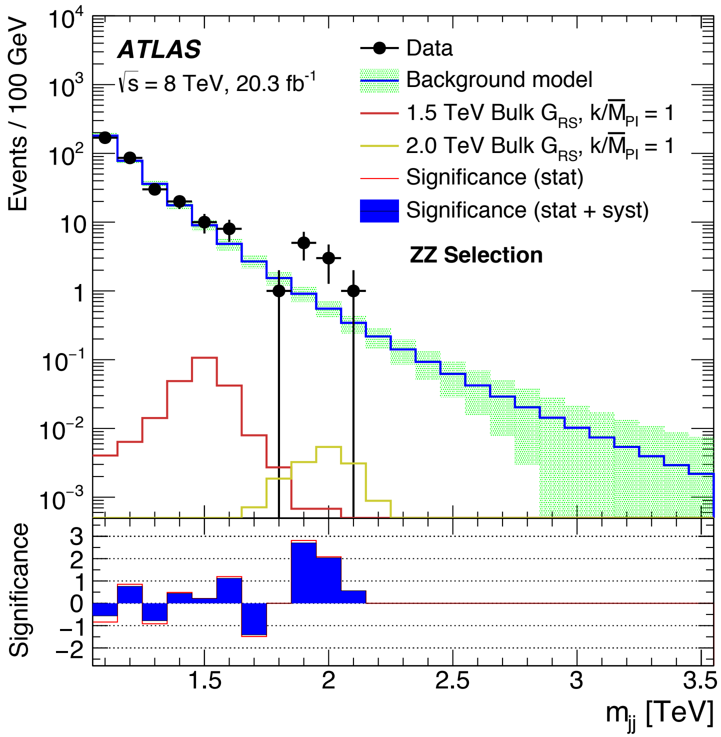
*Only a selection of the available mass limits on new states or phenomena is shown.

Thanks for Listening!

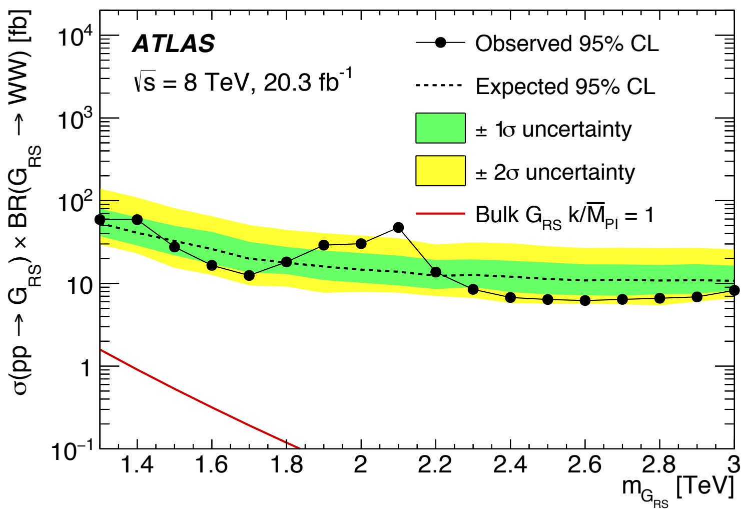
EXTRA SLIDES

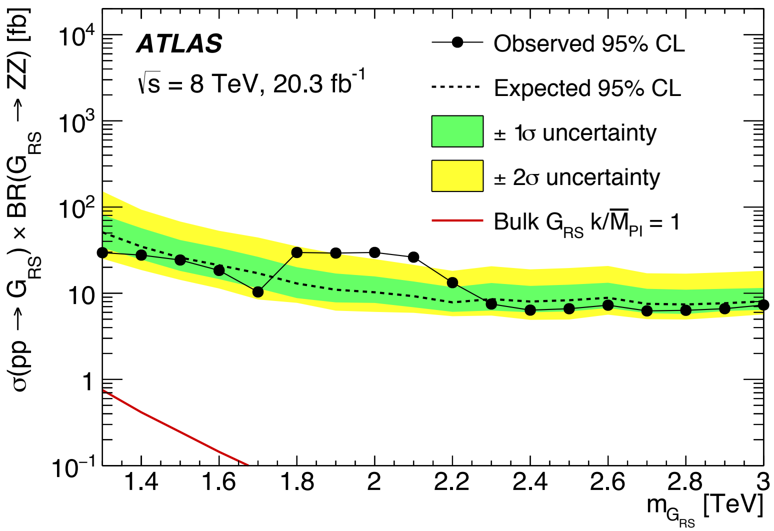
High Mass Diboson Resonances with Boson-Tagged Jets





High Mass Diboson Resonances with Boson-Tagged Jets





High Mass Diboson Resonances with Boson-Tagged Jets

Parametric fit to background: $$\frac{dn}{dx} = p_1 (1-x)^{p_2 - \xi p_3} x^{p_3}$$

Where:

- $X = m_{JJ}/\sqrt{s}$
- p_1 is a normalisation factor
- p_2 and p_3 are dimensionless shape parameters
- ξ is a dimensionless constant chosen after the fitting to minimize the correlations between p_1 and p_2

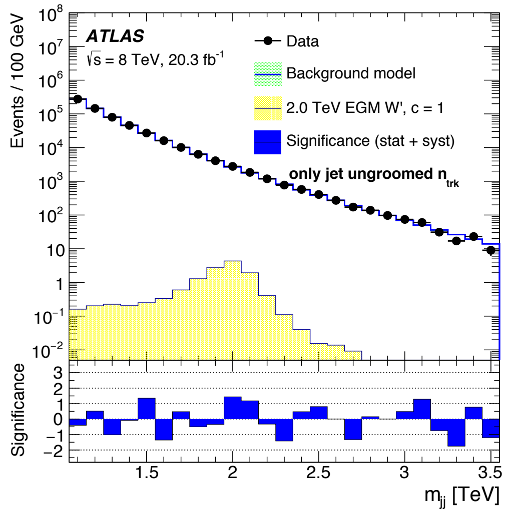
High Mass Diboson Resonances with Boson-Tagged Jets Cross Checks

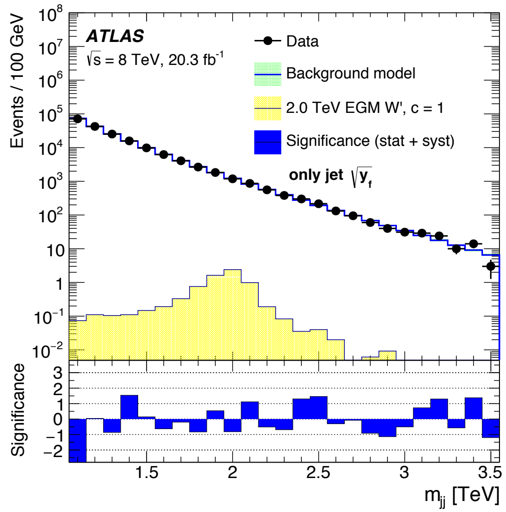
Checked for mistakes, bugs and shaping effects in

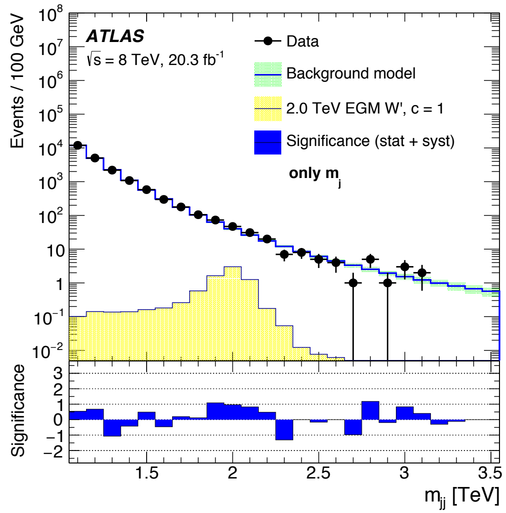
- ➢ Detector/data taking
- ➢ Jet reconstruction
- ➢ Event selection

e.g.

- ➢ **look at the effect of single cuts on the distribution**
- ➢ Look at the effect of N-1 cuts on the distribution







High Mass Diboson Resonances with Boson-Tagged Jets Cross Checks

Checked for mistakes, bugs and shaping effects in

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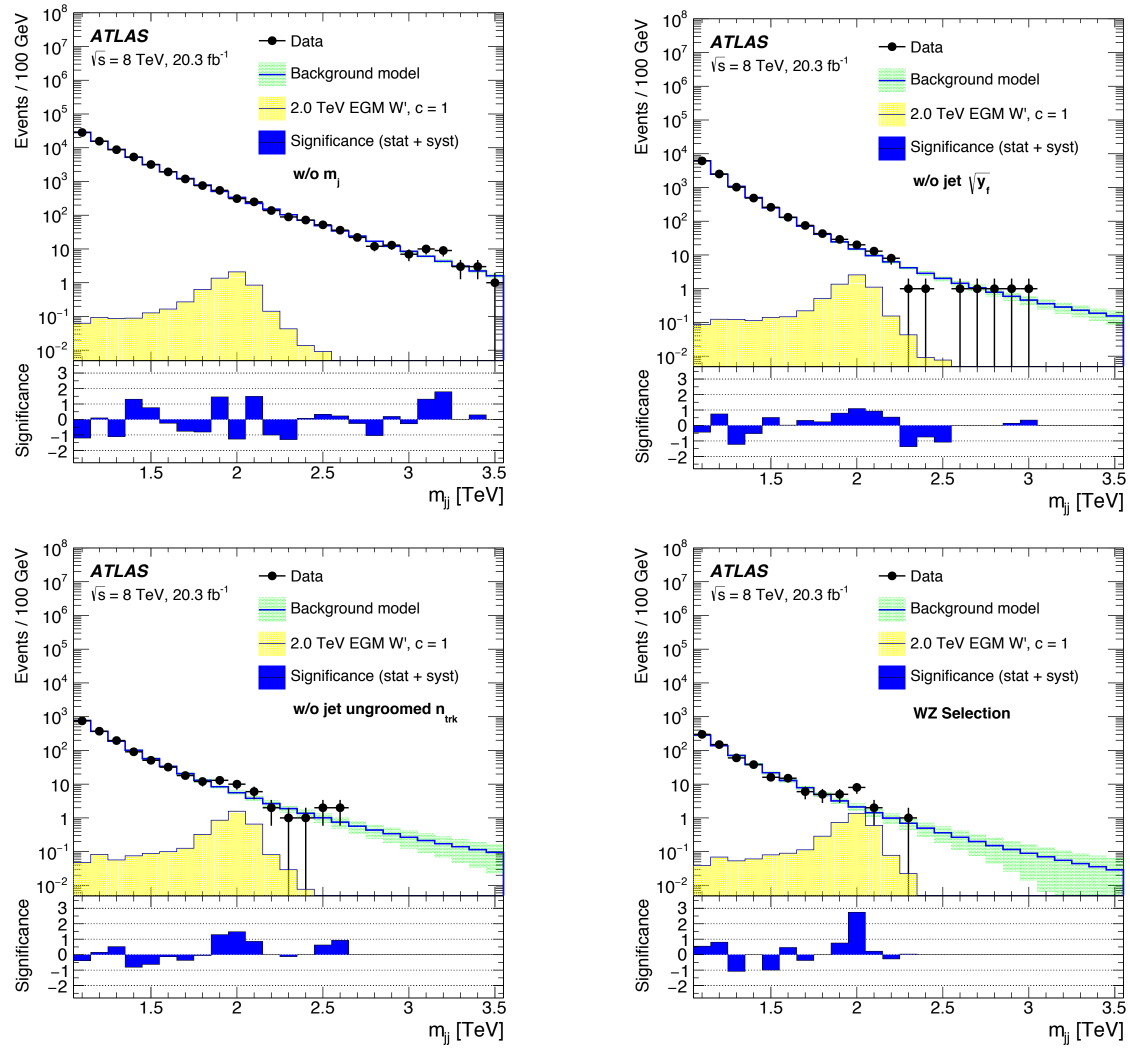
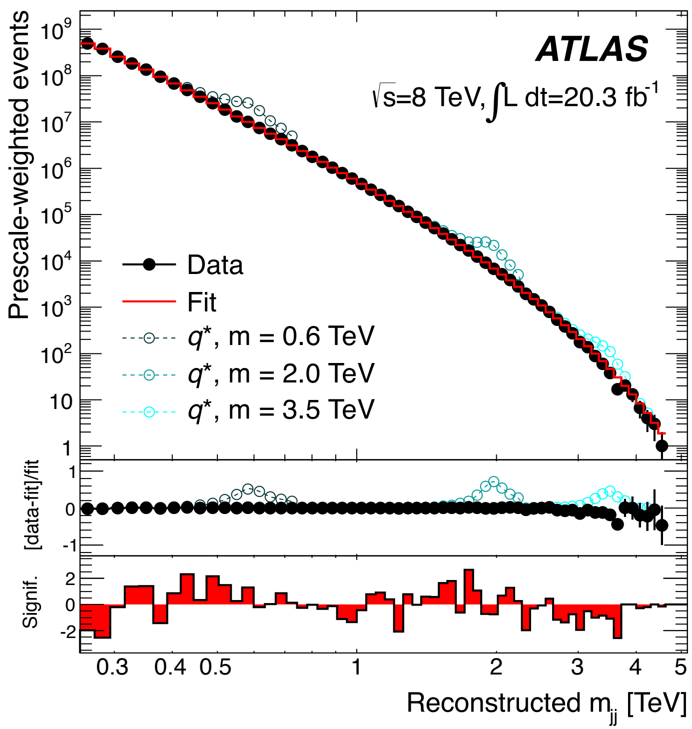
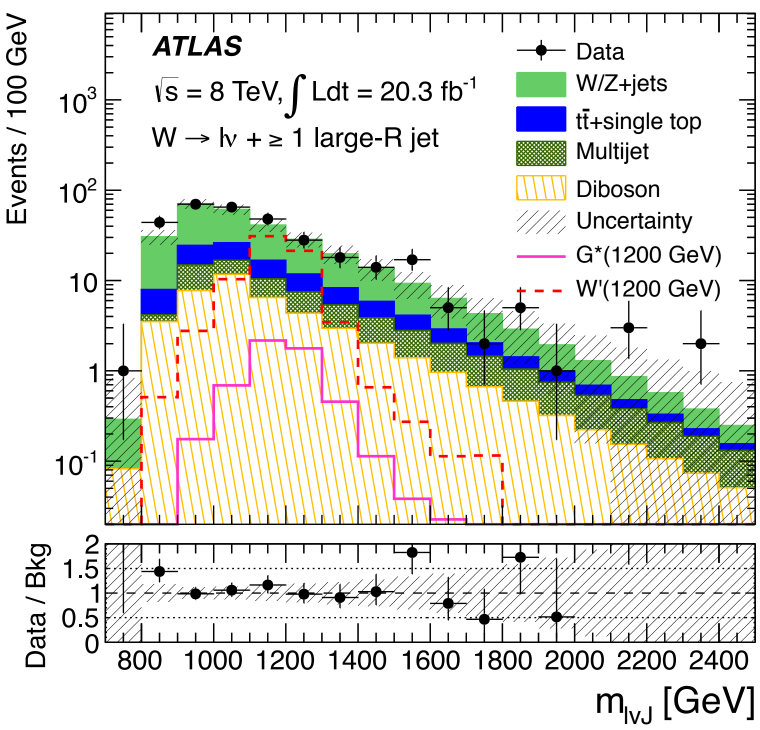


High Mass Diboson Resonances with Boson-Tagged Jets – Similar Analyses

ATLAS resolved dijet search
arXiv:1407.1376

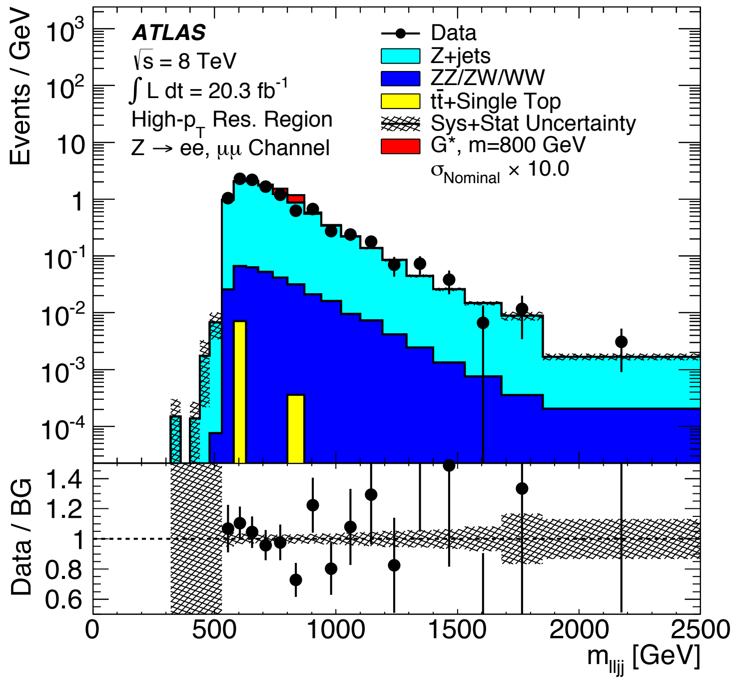


ATLAS semileptonic search W(lν)Z(jj)
arXiv:1503.04677

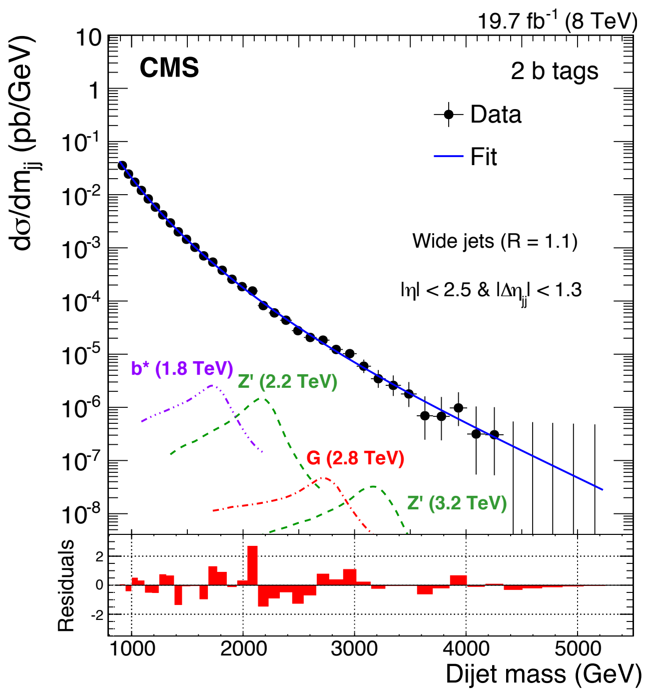


High Mass Diboson Resonances with Boson-Tagged Jets – Similar Analyses

ATLAS semileptonic search W(jj)Z(ll)
arXiv:1409.6190



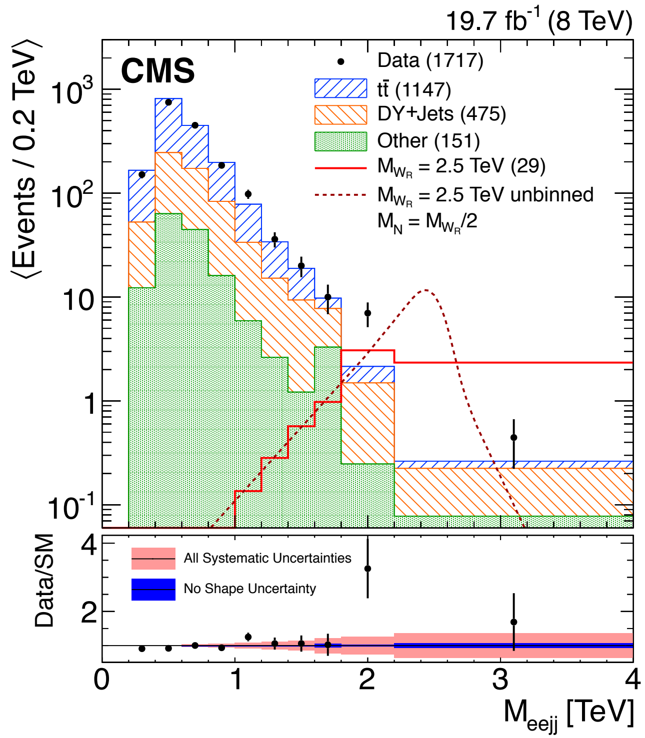
CMS dijet search
arXiv:1501.04198
Phys. Rev. D 91, 052009 (2015)



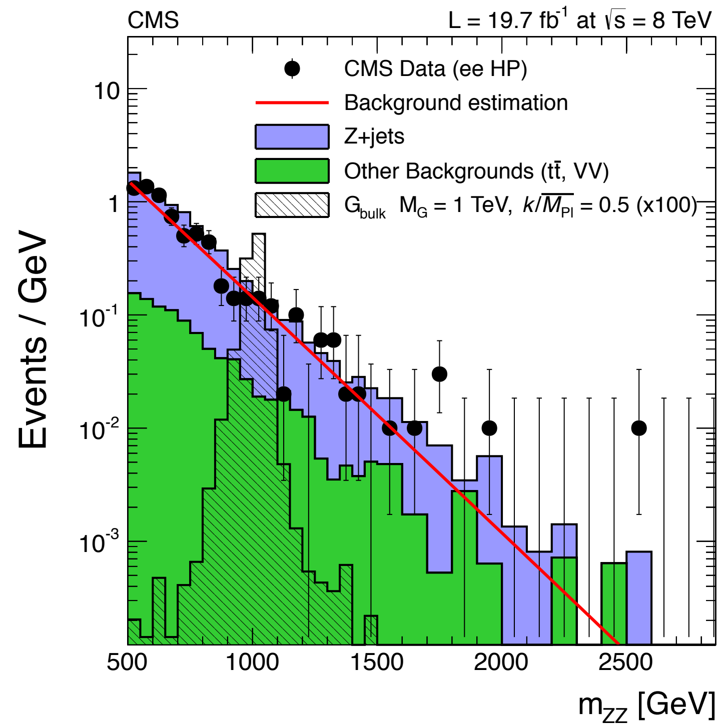
Tiny blip at 2 TeV in 2 b-tag channel

High Mass Diboson Resonances with Boson-Tagged Jets – Similar Analyses

CMS right-handed boson search
arXiv:1407.3683
Eur. Phys. J. C 74 (2014) 3149



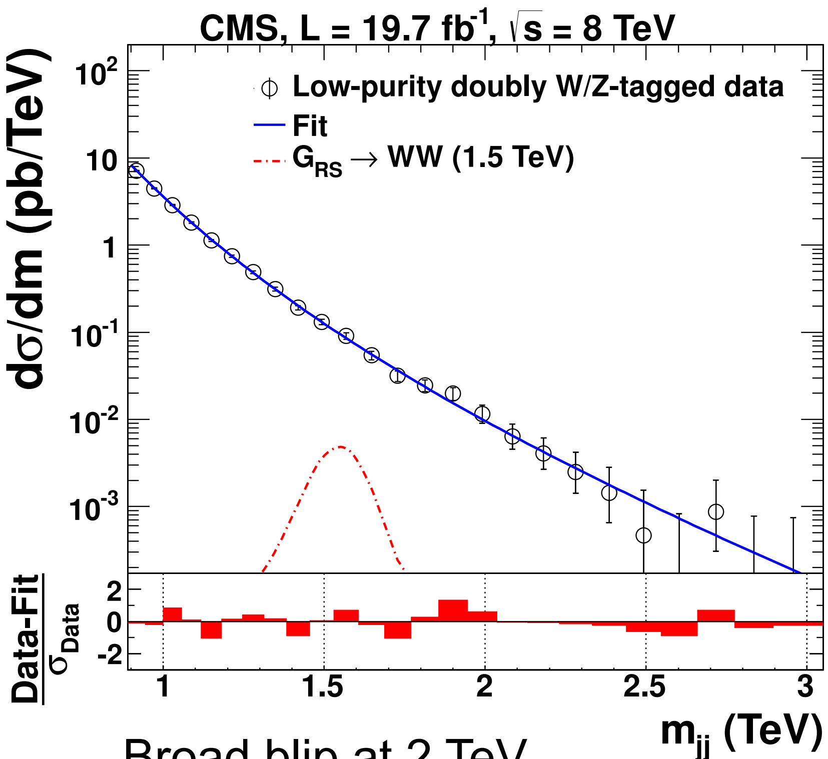
CMS semileptonic WW WZ ZZ search
arXiv:1405.3447
JHEP 08 (2014) 174



Excess at 2 TeV only seen in eejj channel

High Mass Diboson Resonances with Boson-Tagged Jets – Similar Analyses

CMS fully hadronic WW WZ ZZ search
arXiv:1405.1994
JHEP 08 (2014) 173



Broad blip at 2 TeV