

Search for new exotic phenomena with the ATLAS detector at the LHC

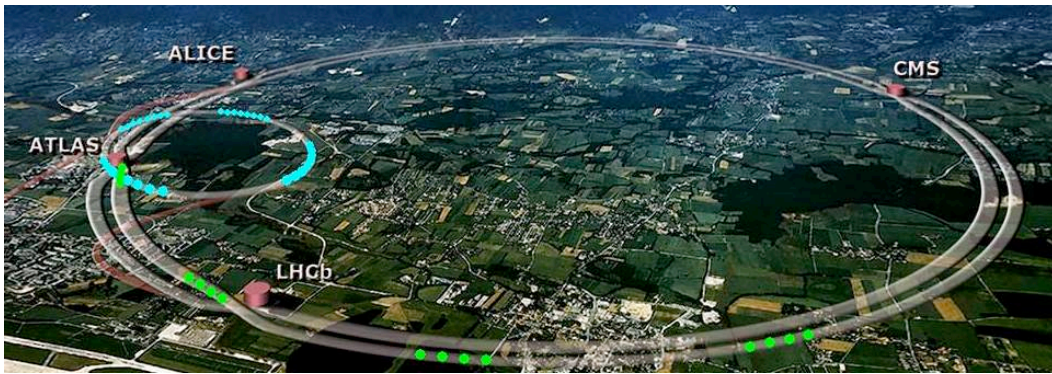
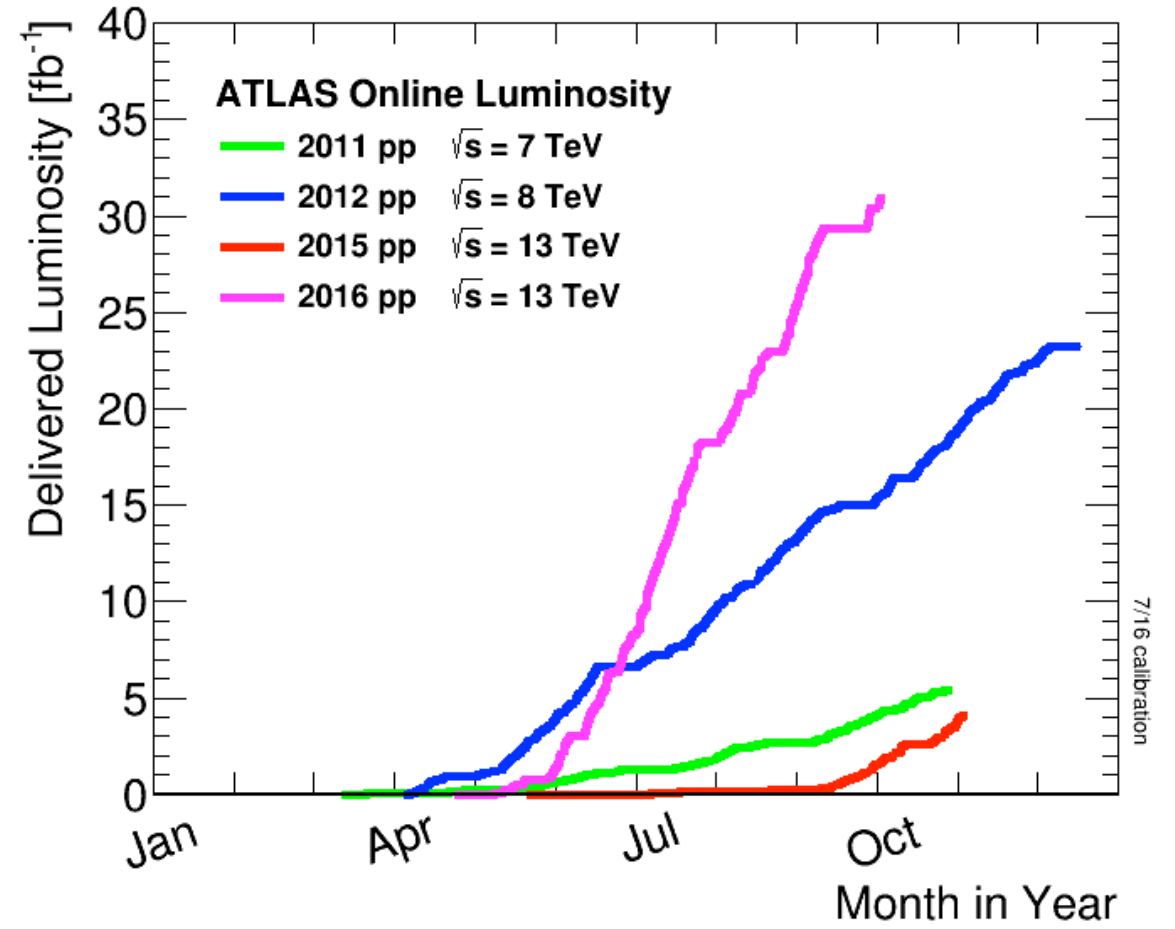
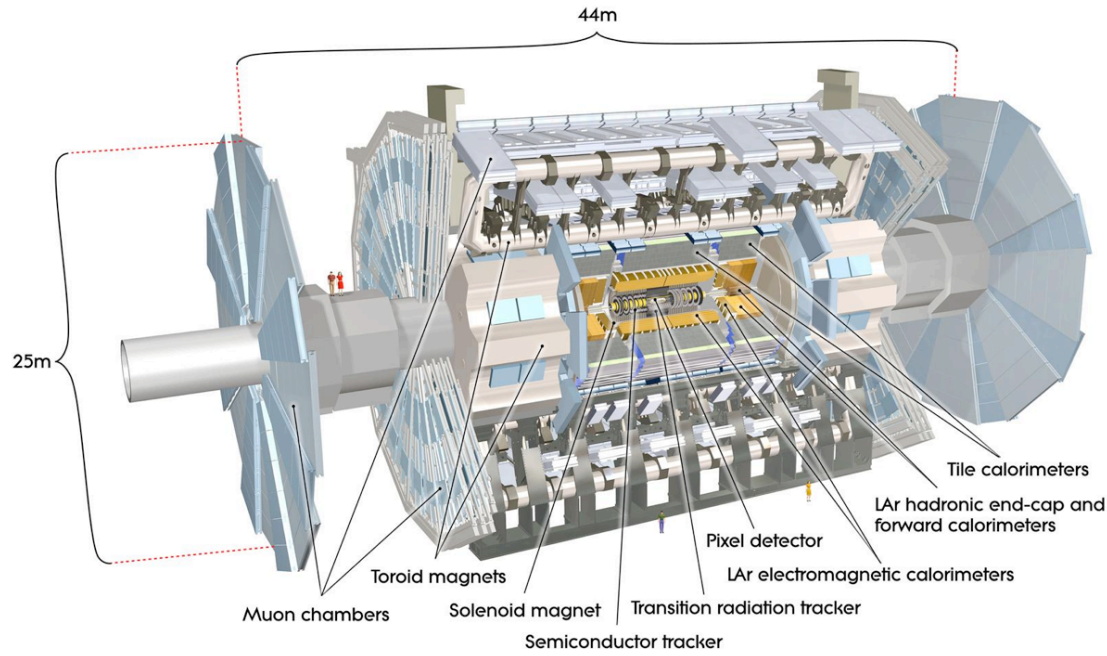
Olya Igonkina
(NIKHEF)

on behalf of ATLAS collaboration

Many new 13 TeV ATLAS results, cover only selected topics in the available time

See all results at
[ExoticsPublicResults twiki](#)

ATLAS @ LHC

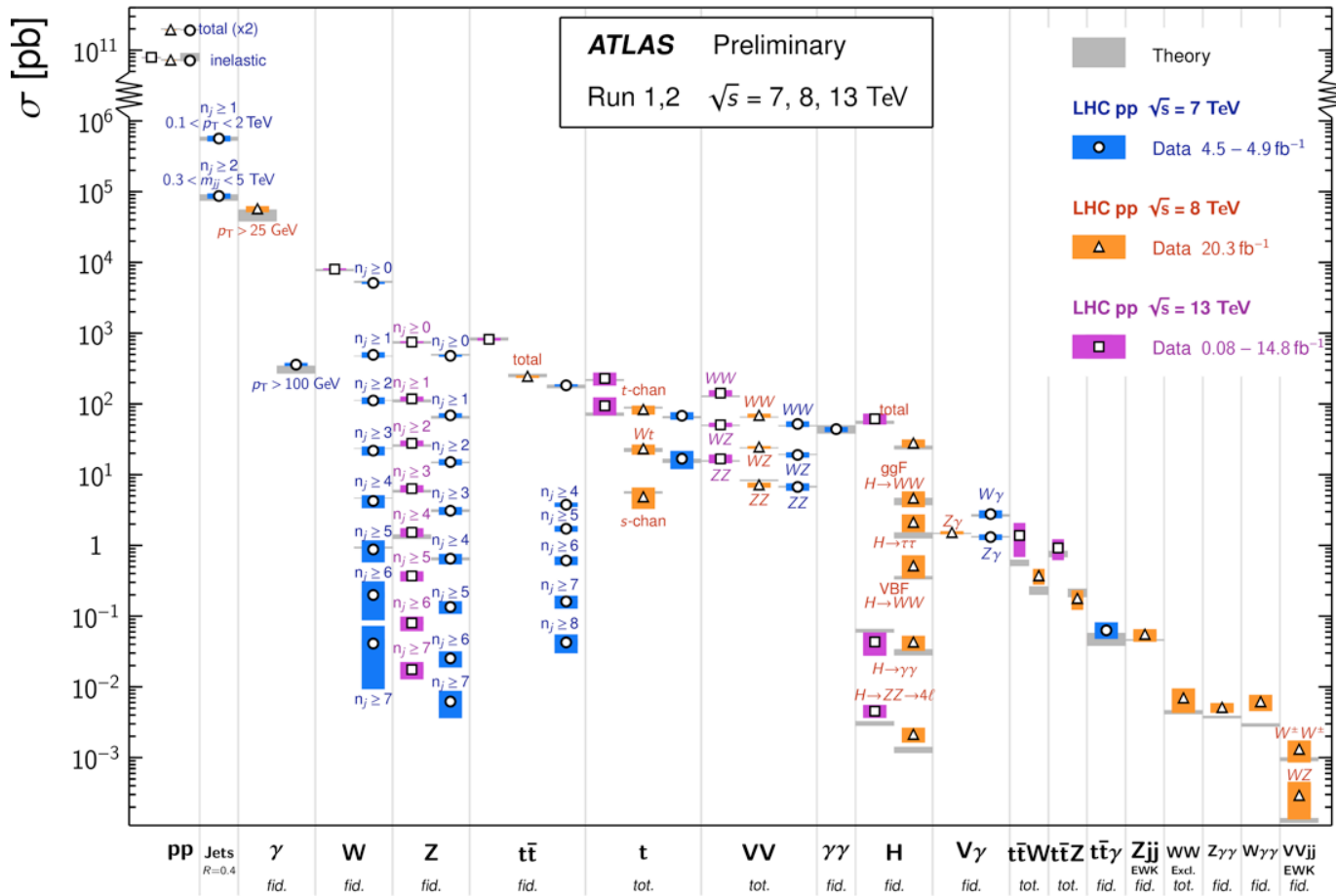


Total recorded on Oct 4th @ 13 TeV : 29.4 fb^{-1}
 Results shown today based on 13.2 or 15.4 fb^{-1}

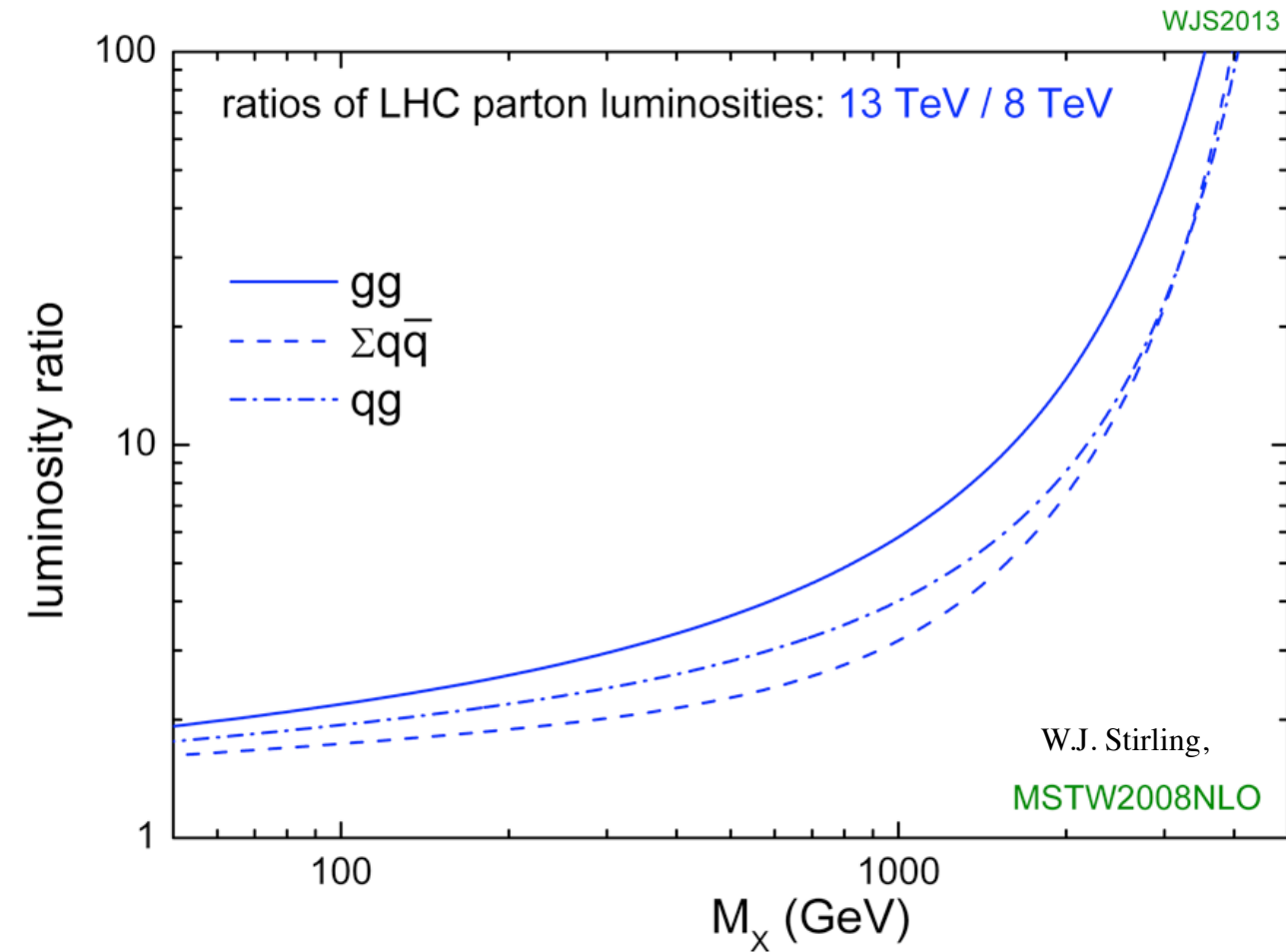
ATLAS Physics

Standard Model Production Cross Section Measurements

Status: August 2016



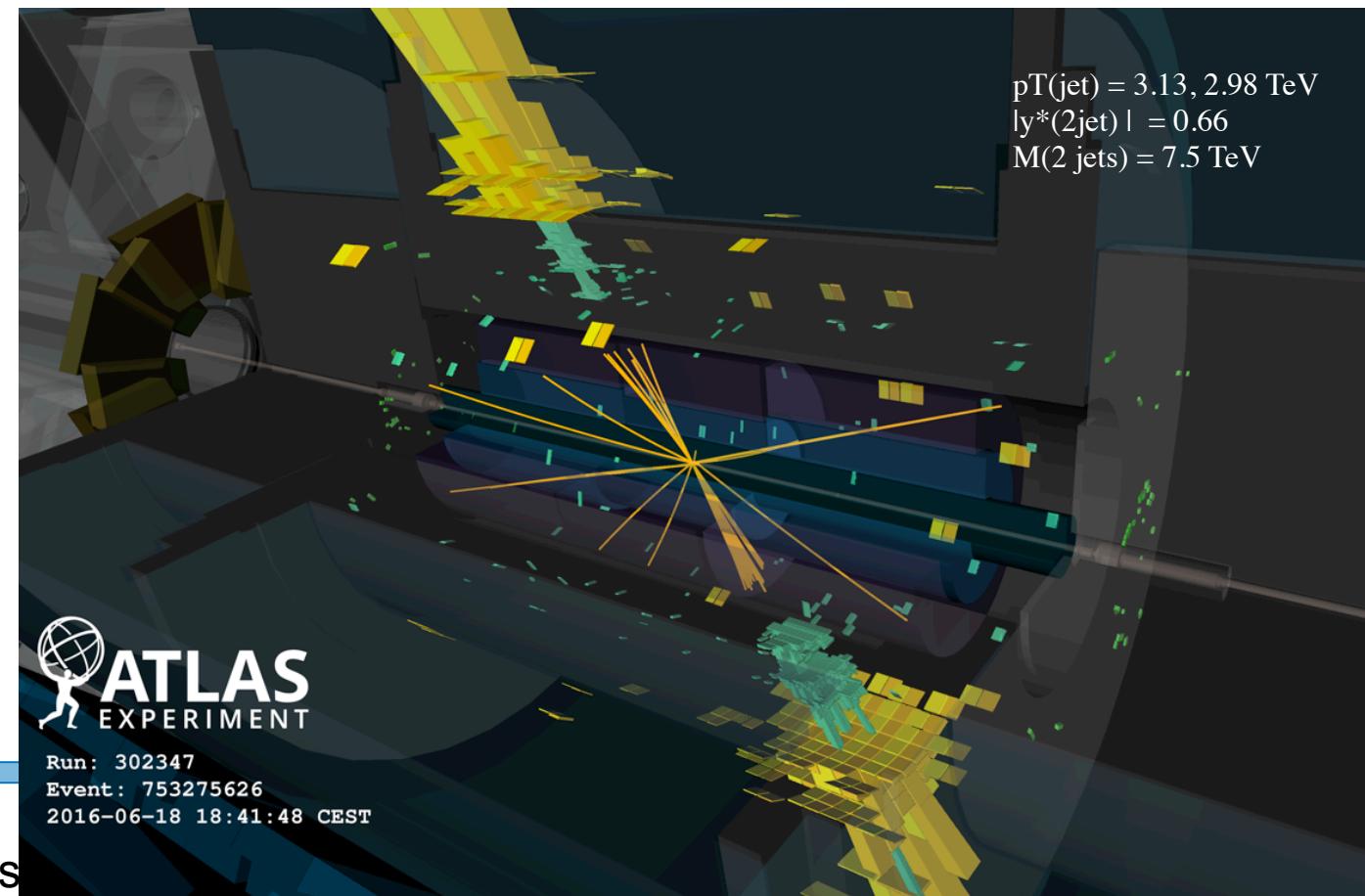
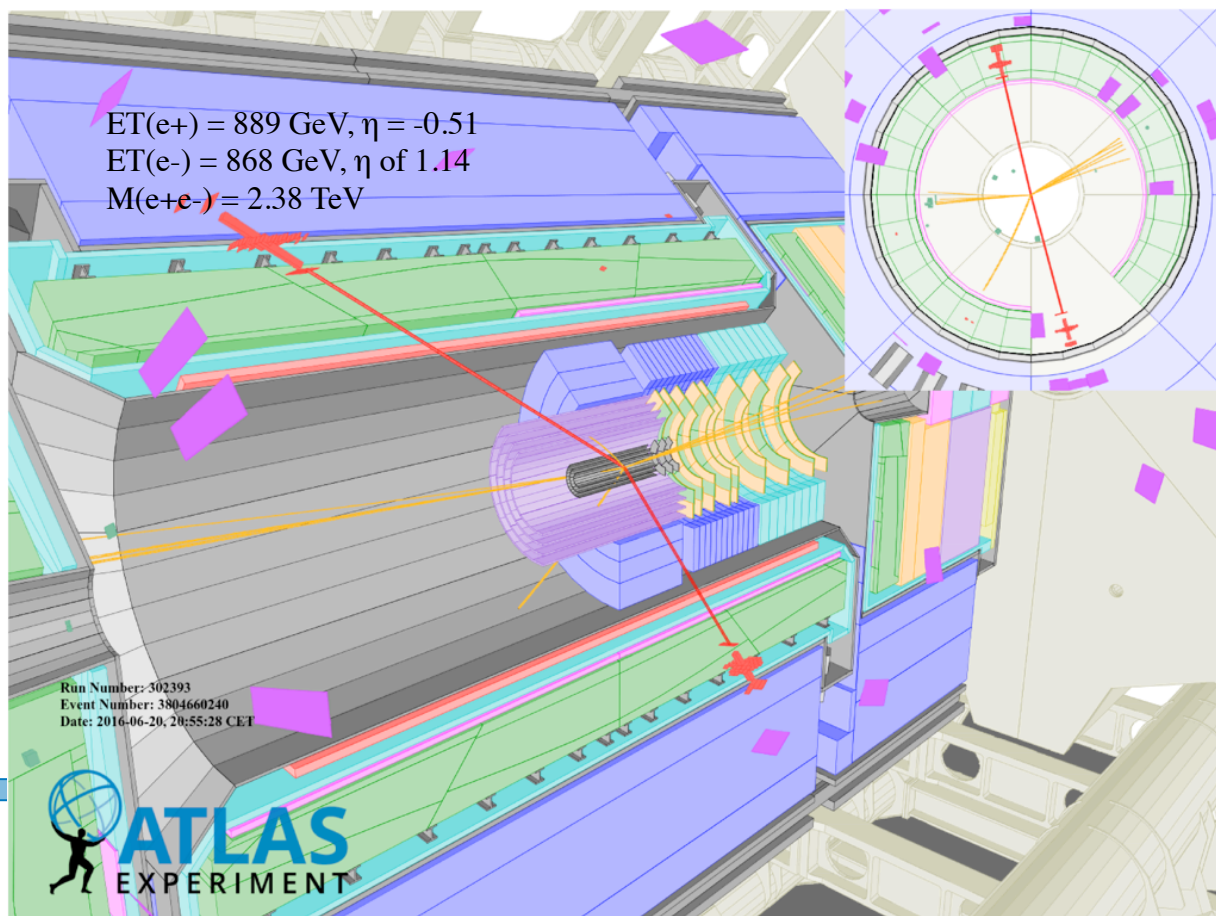
Excellent understanding of Standard Model processes!



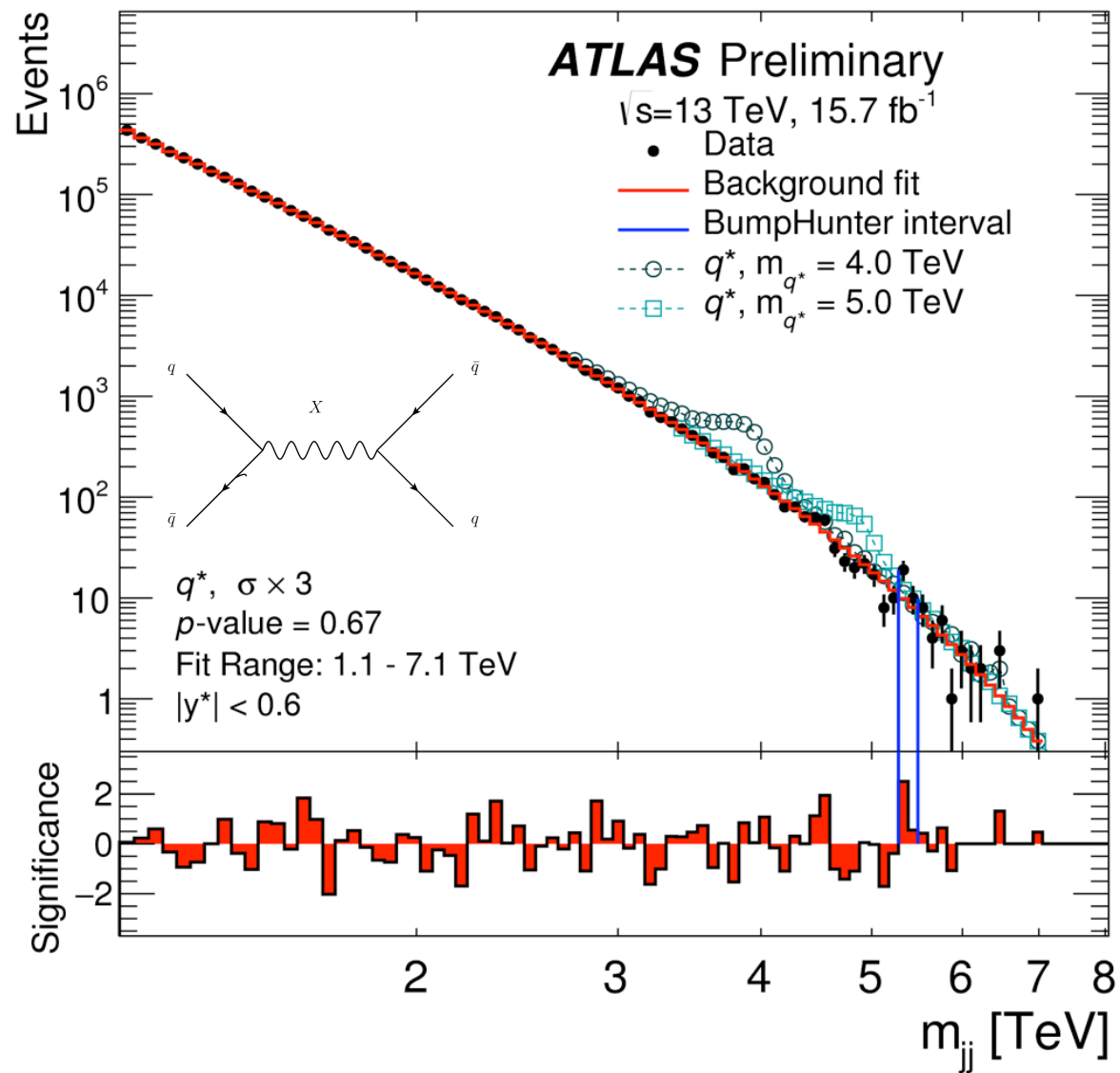
13 TeV data are particularly interesting for searching of new heavy states

Heavy resonances

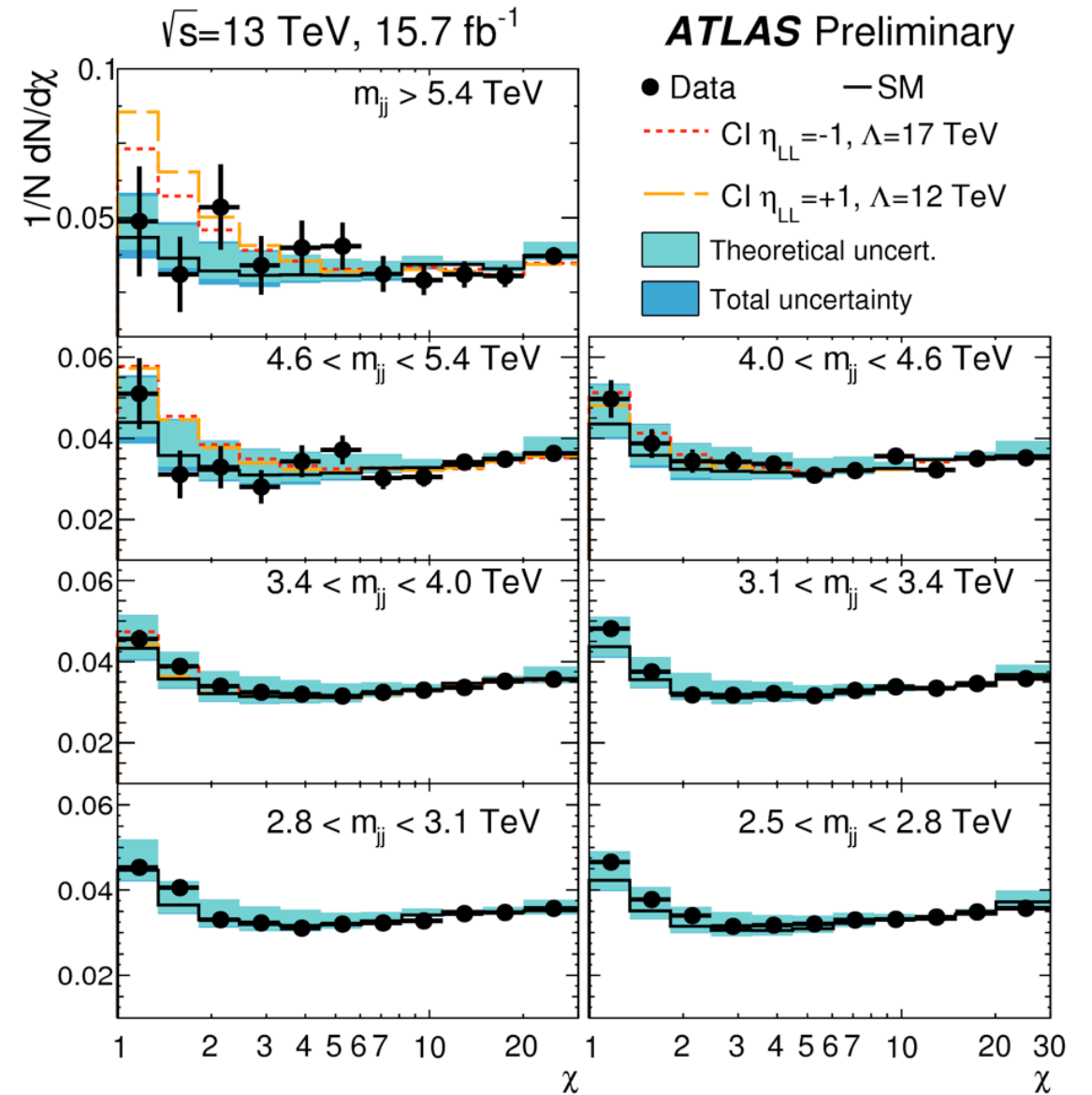
- Predicted by many BSM models
 - Heavy gauge bosons (Z' , W'); GUT inspired theories, Extra Higgs
 - Kaluza-Klein excitations, Randall-Sundrum extra dimensions
- Many ways to search for them : calculate invariant mass of few objects
- Challenge : understanding the detector to perfection (alignment, calibrations, high p_T reconstruction)



Di-jet resonance search



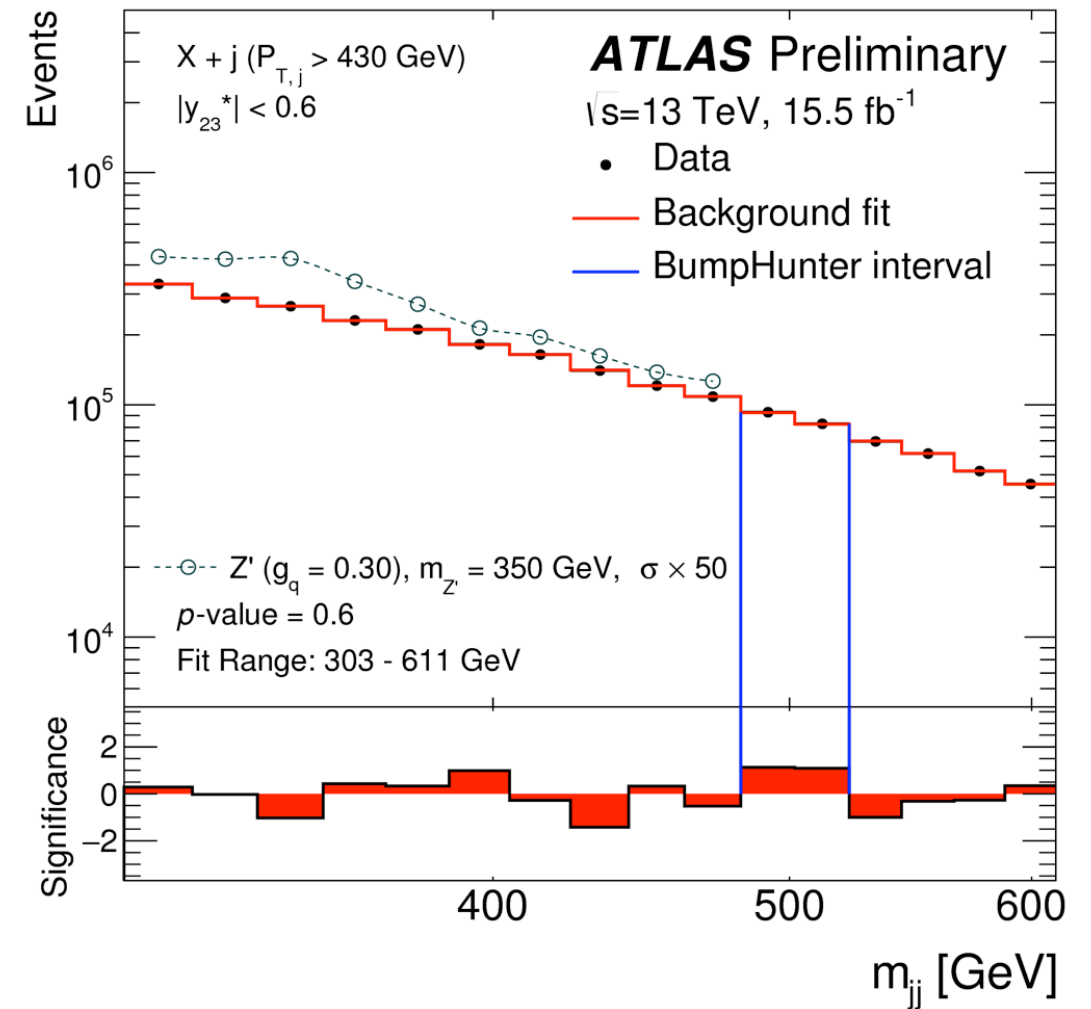
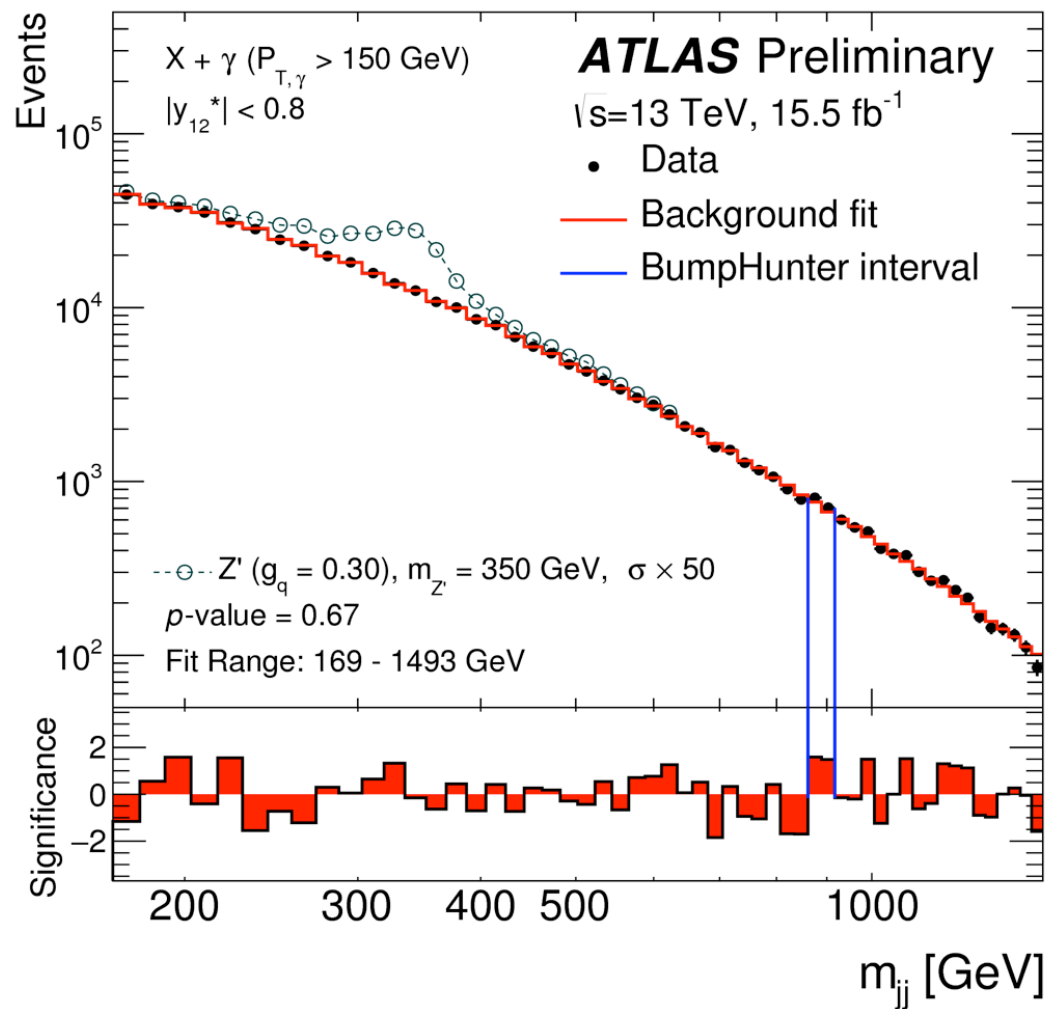
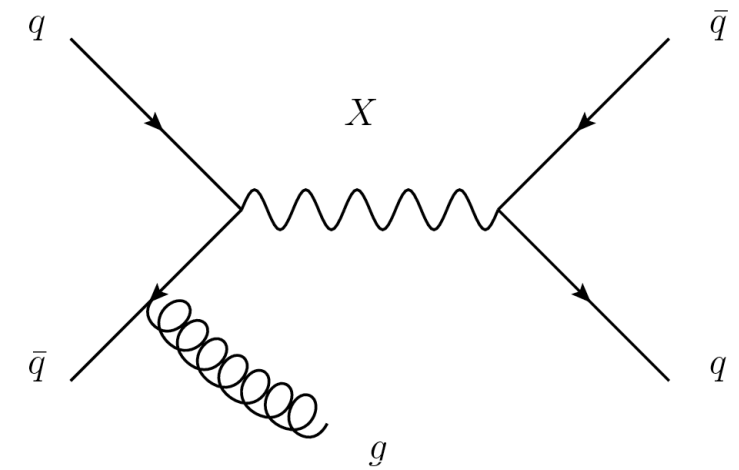
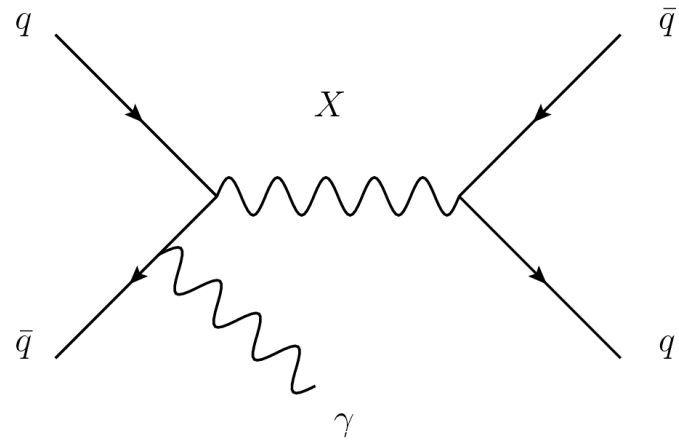
Conventional peak search:
 Mass of 2 very high p_T jets



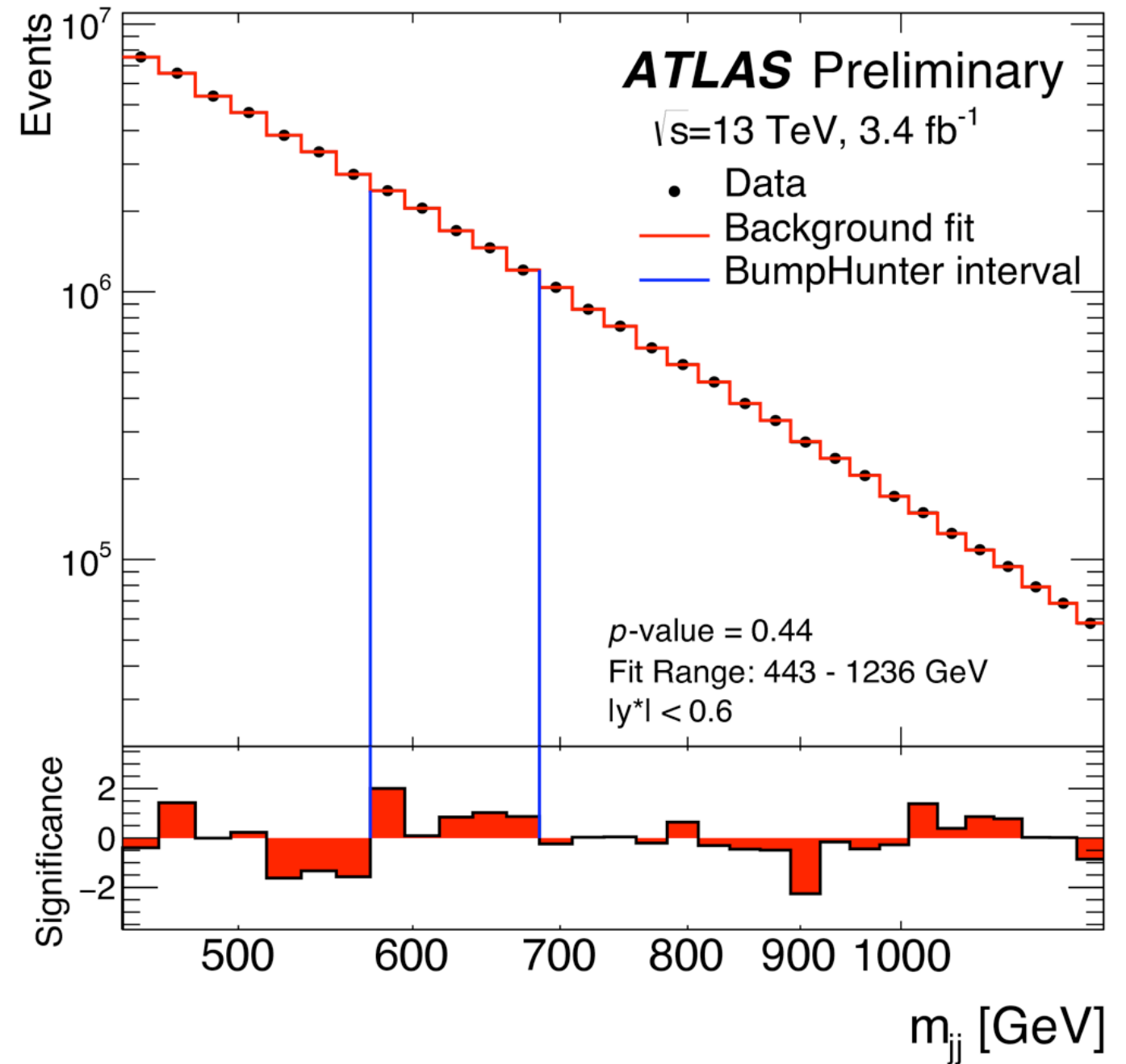
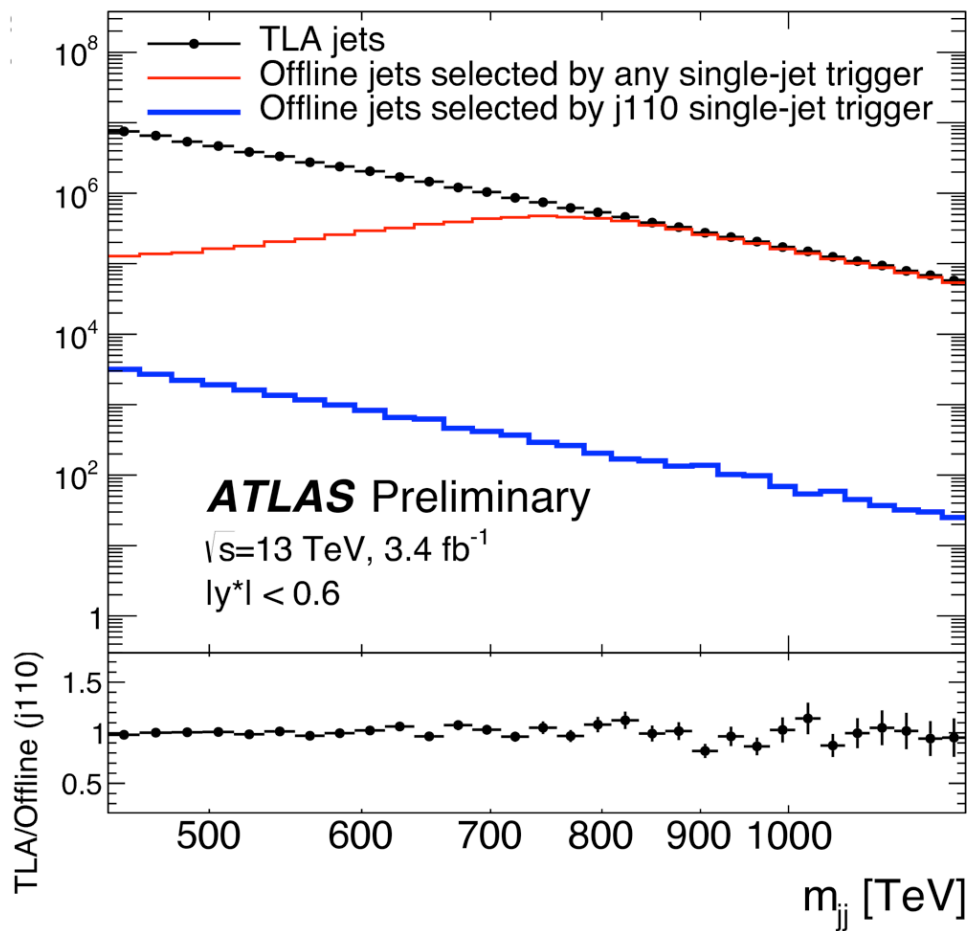
$$\chi = e^{|y_{j1} - y_{j2}|} \sim \frac{1 + \cos \theta^*}{1 - \cos \theta^*}$$

High statistics allows also angular analysis

Initial State Radiation di-jet search



Trigger Level Analysis di-jets



Record jets reconstructed at trigger level but do not record the rest of the event: High rate possible due to small size of event

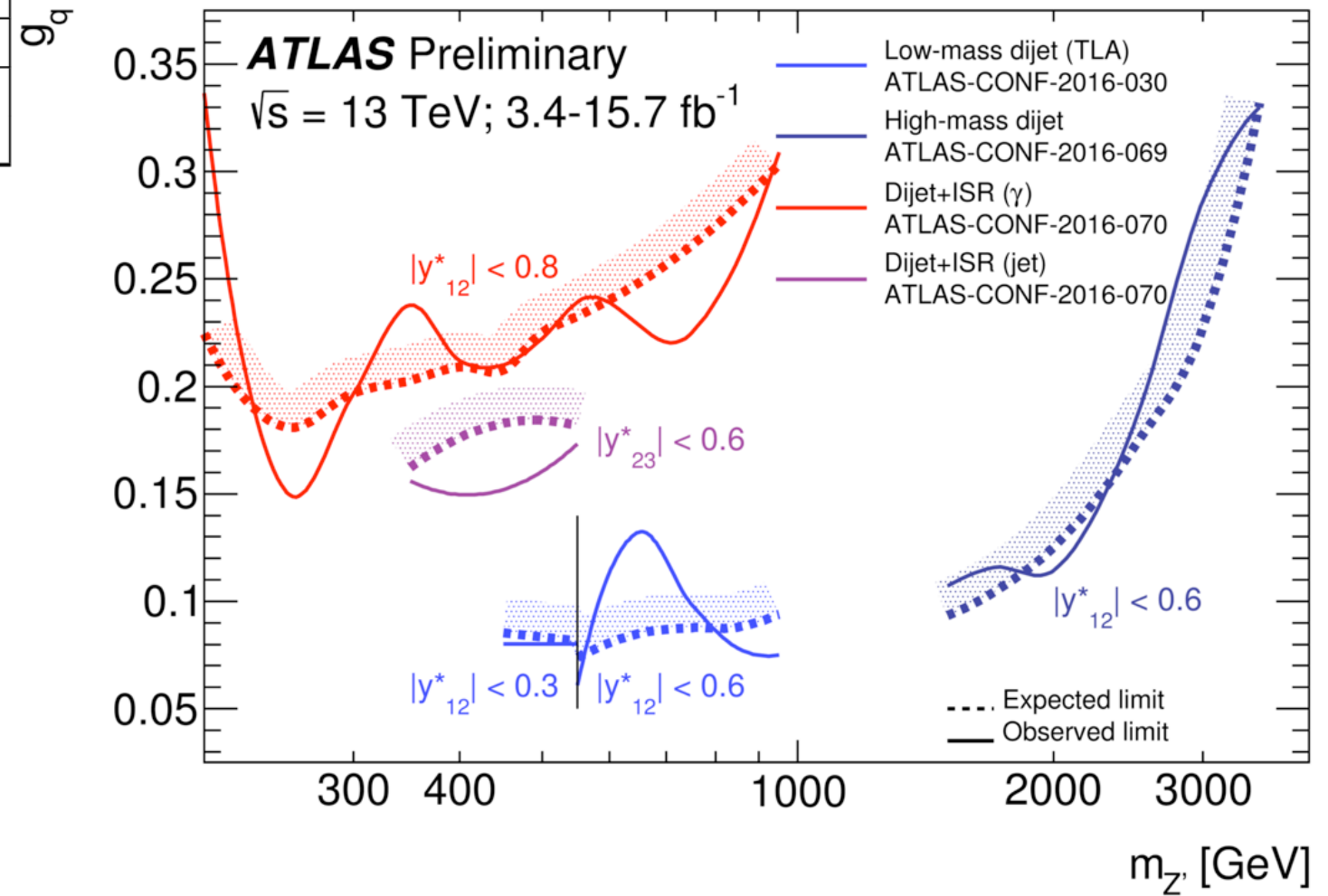
Di-jet searches Results

With High-mass di-jet search

Model	95% CL exclusion limit	
	Observed	Expected
Quantum black holes, ADD (BLACKMAX generator)	8.7 TeV	8.7 TeV
Excited quark	5.6 TeV	5.5 TeV
W'	2.9 TeV	3.3 TeV
W^*	3.3 TeV	3.3 TeV
Contact interactions ($\eta_{LL} = +1$)	12.6 TeV	13.7 TeV
Contact interactions ($\eta_{LL} = -1$)	19.9 TeV	23.7 TeV

With 3 di-jet searches

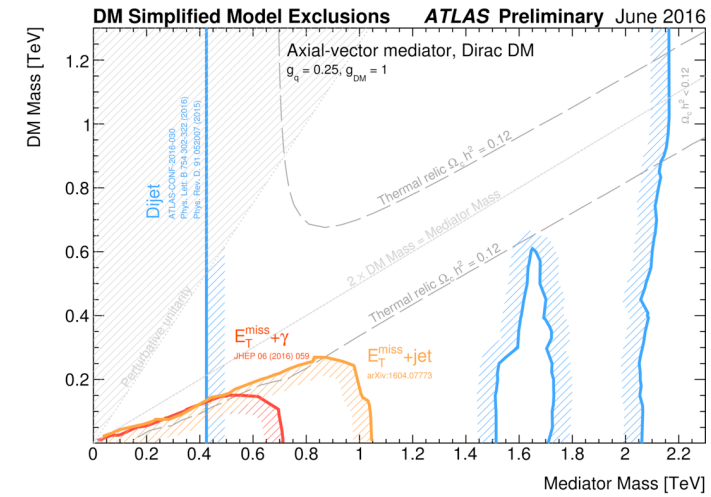
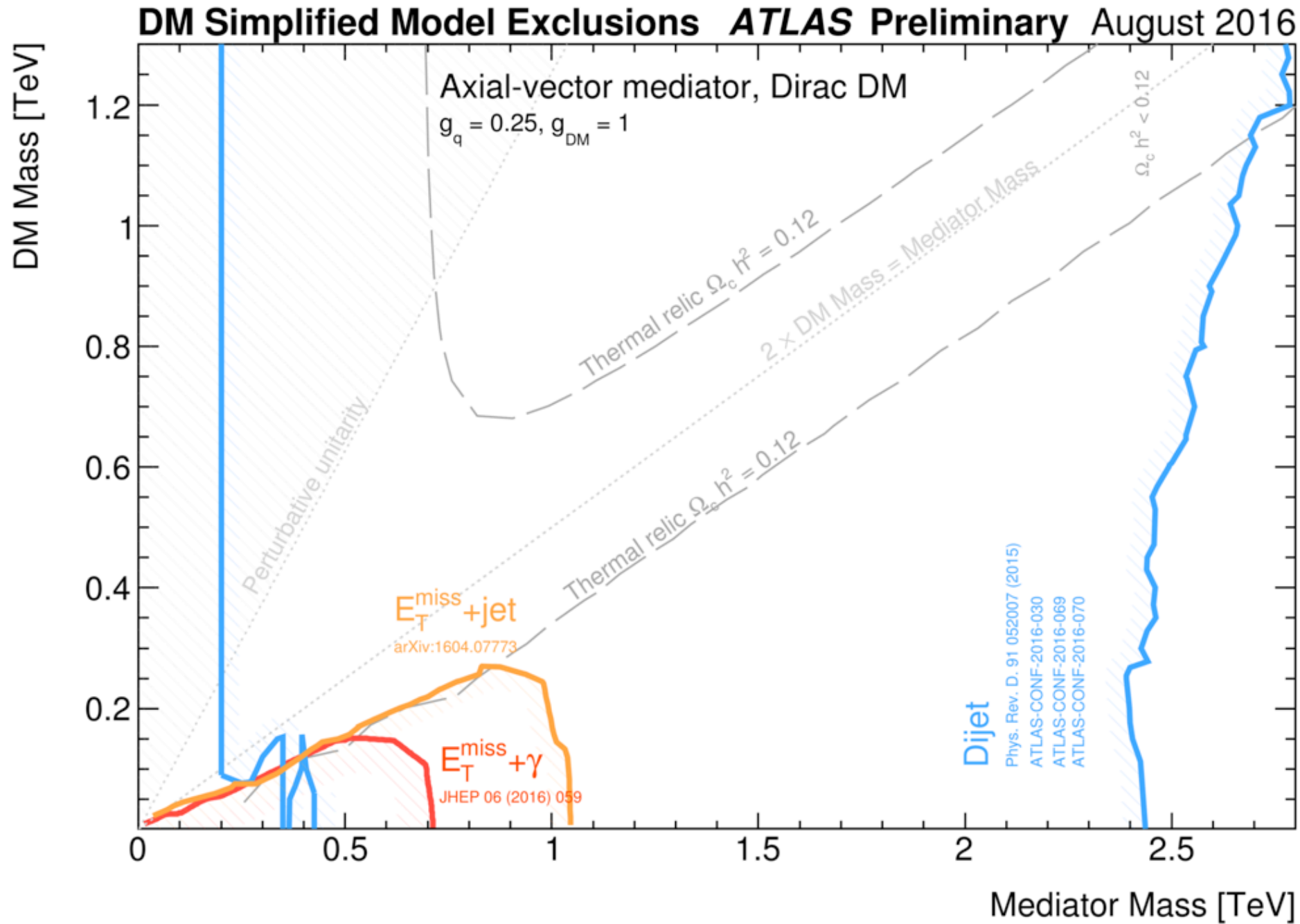
Leptophobic Z' model from arXiv:1507.00966



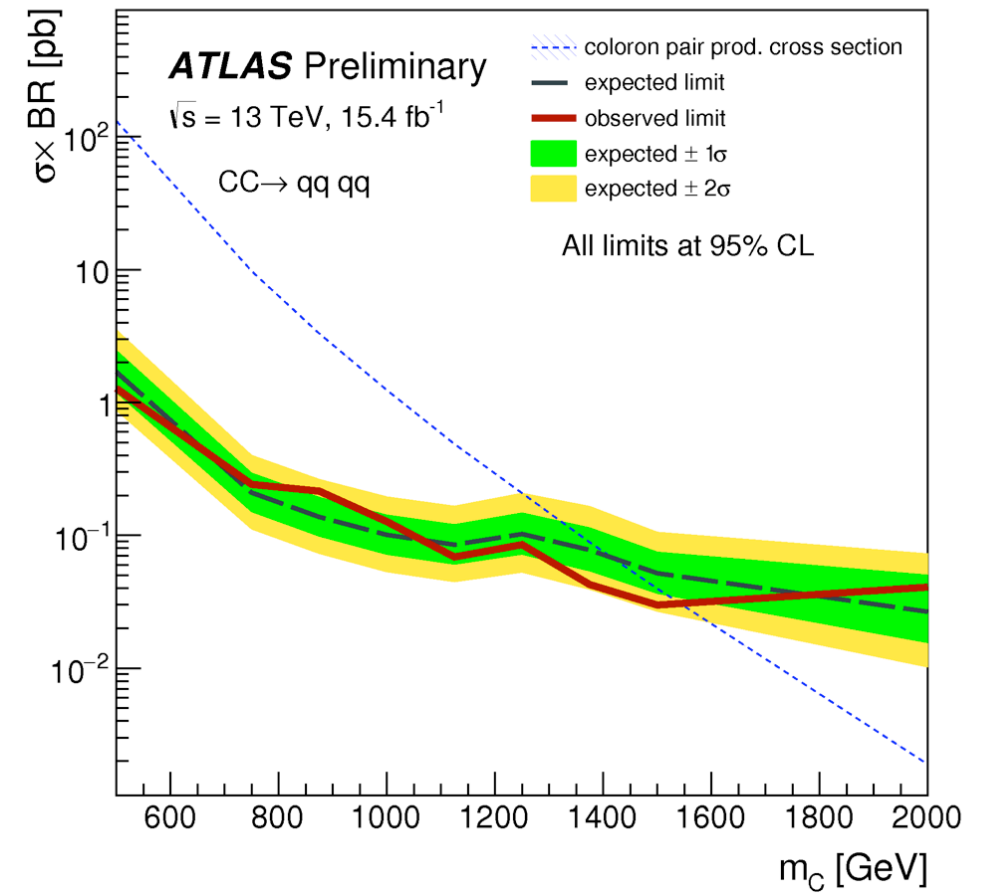
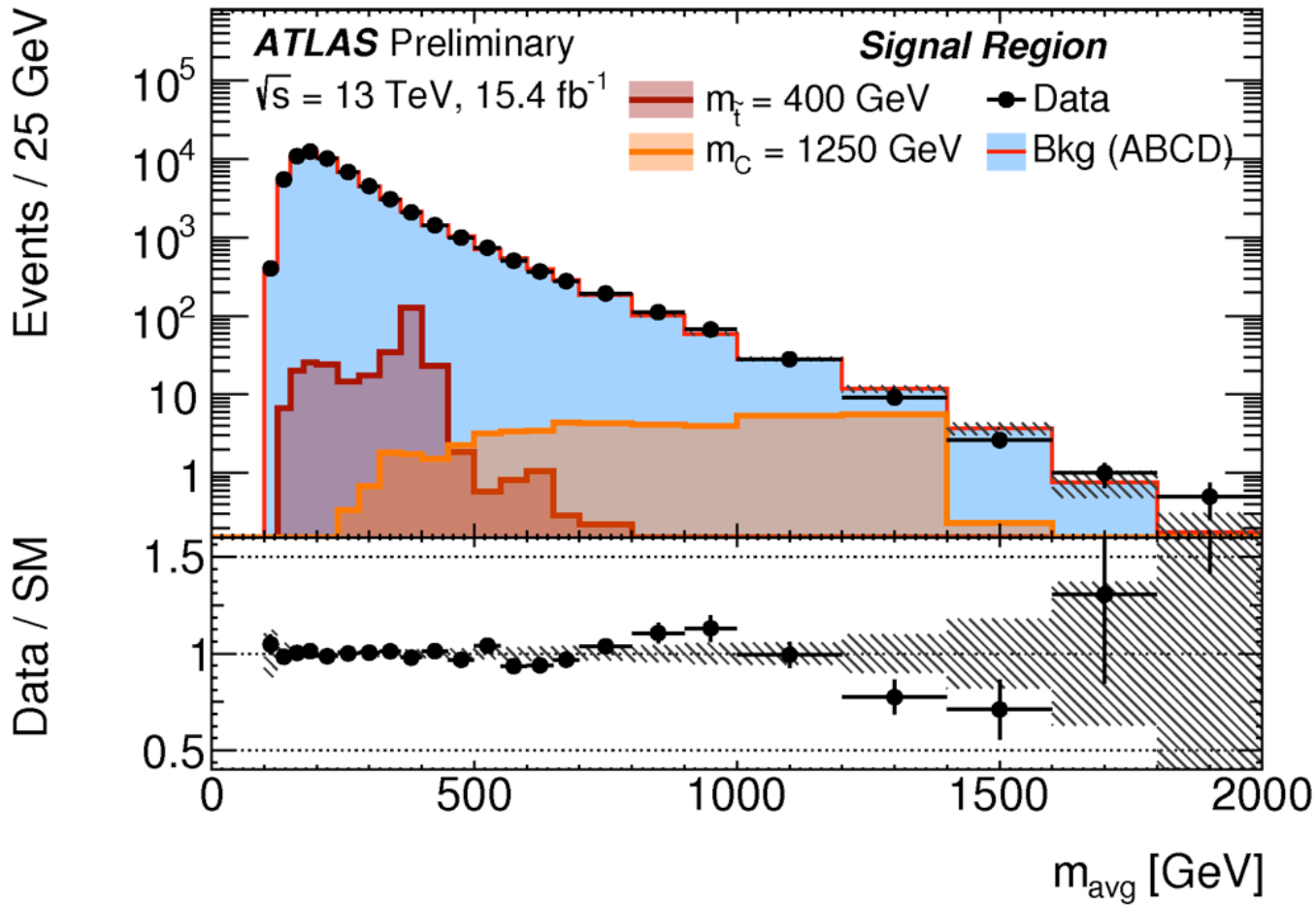
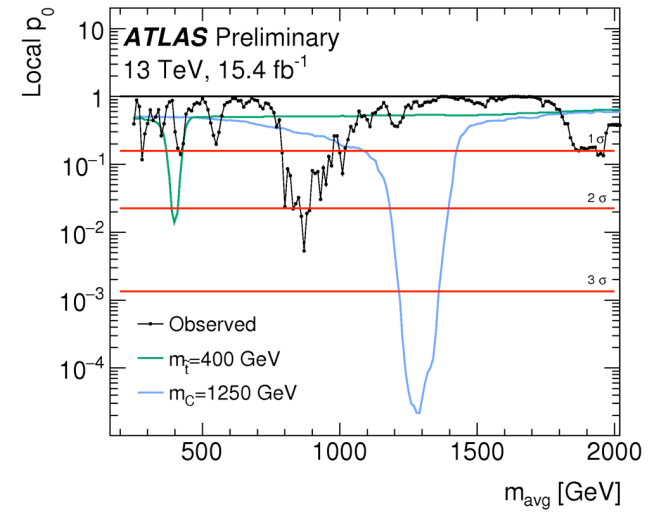
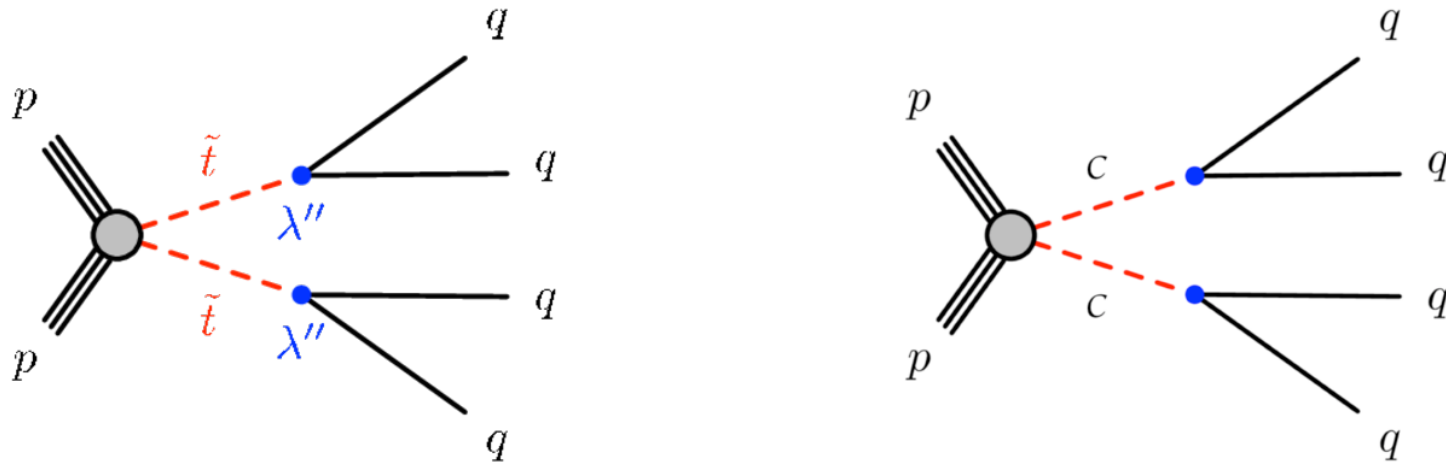
Dark Model interpretation

Leptophobic Z' model from arXiv:1507.00966

Only 2015 data,
no dijet+ISR

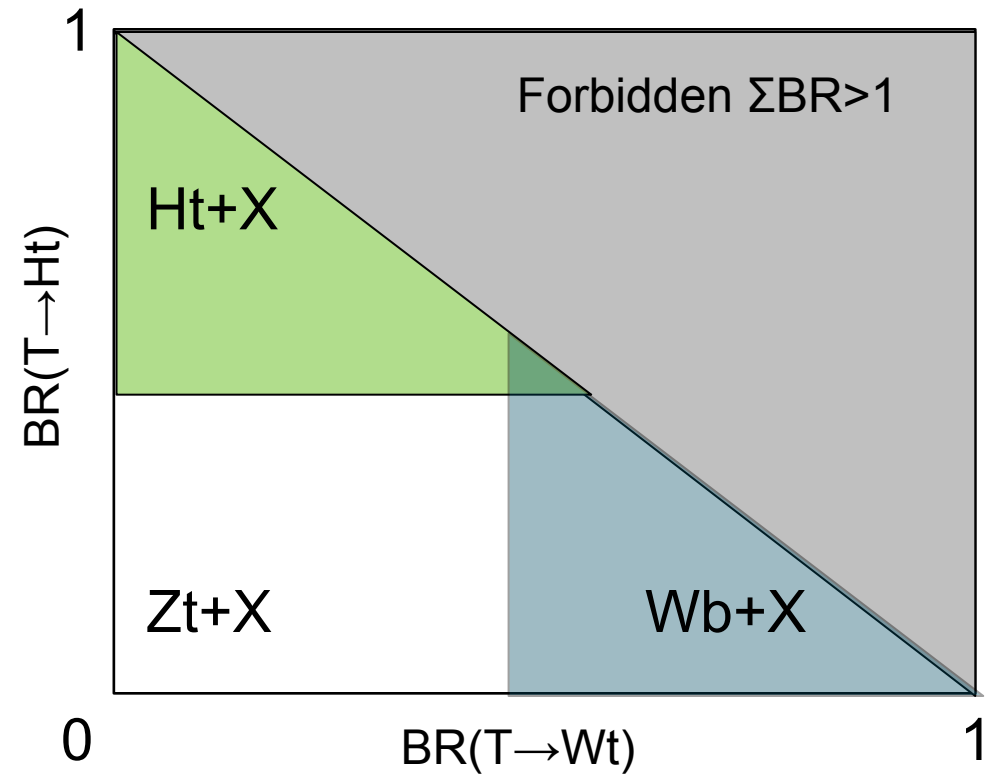
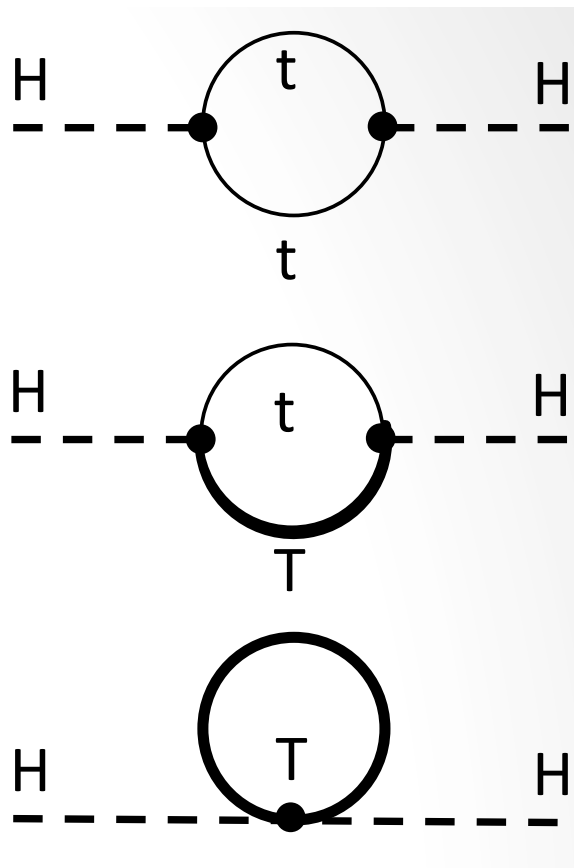
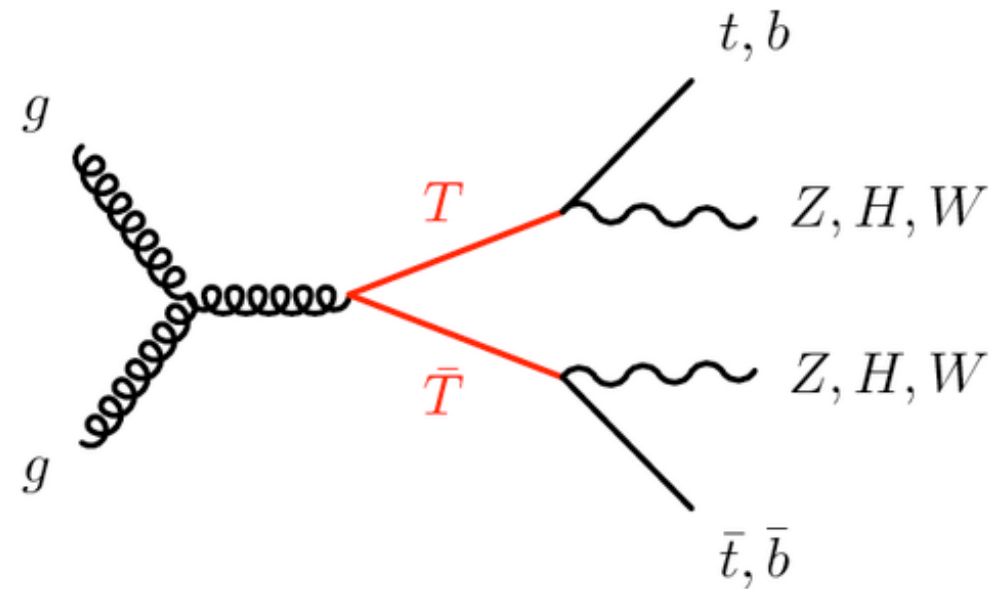


4-jet di-resonance search

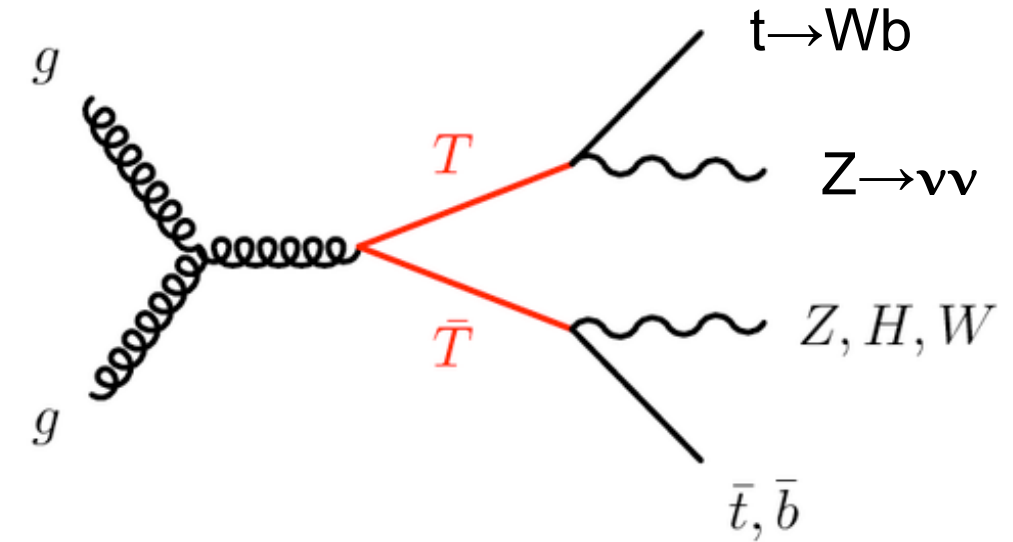
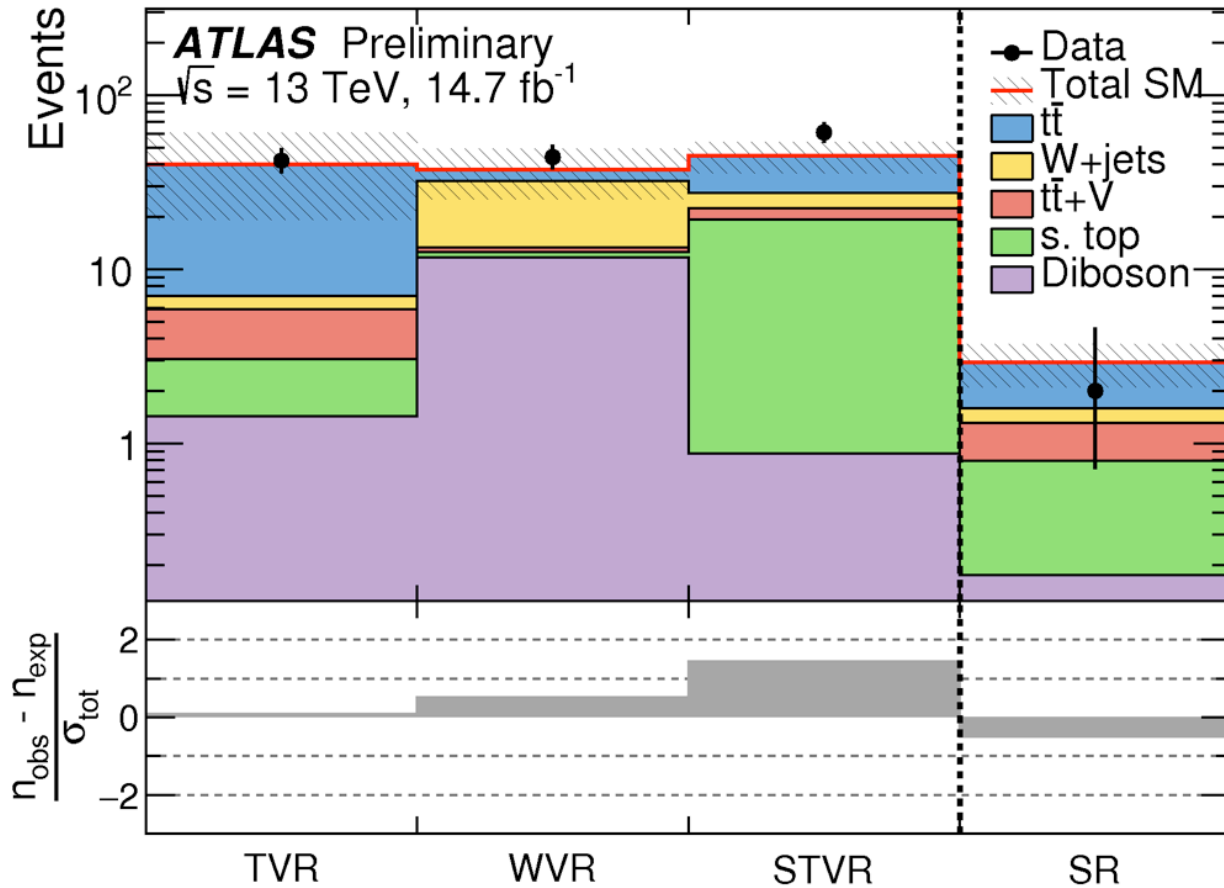


Vector-like quarks

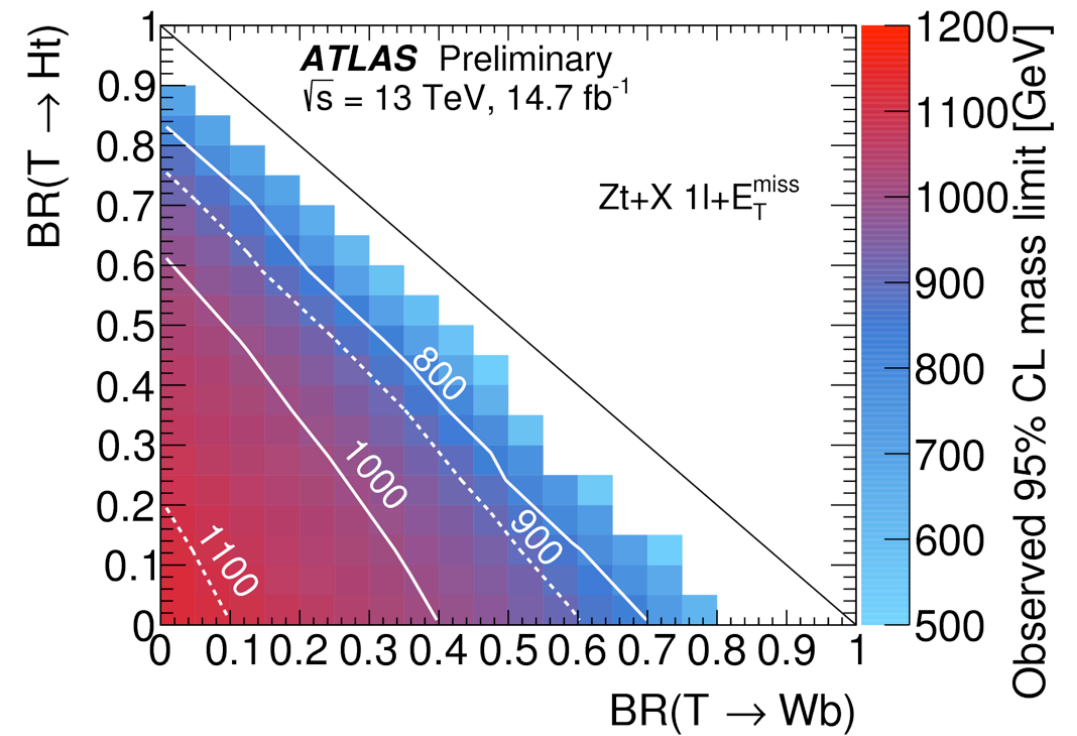
Vector-like top partner:
color-triplet fermion
with left and right coupling to W



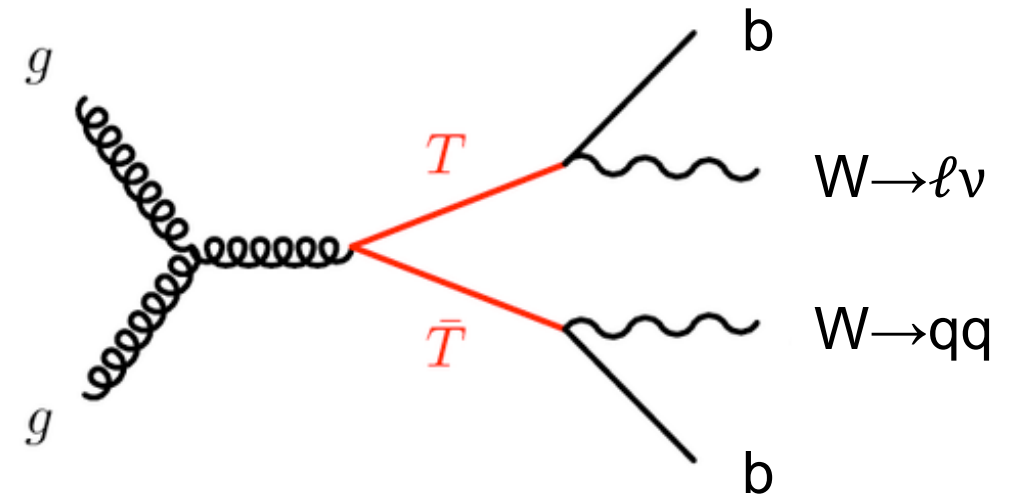
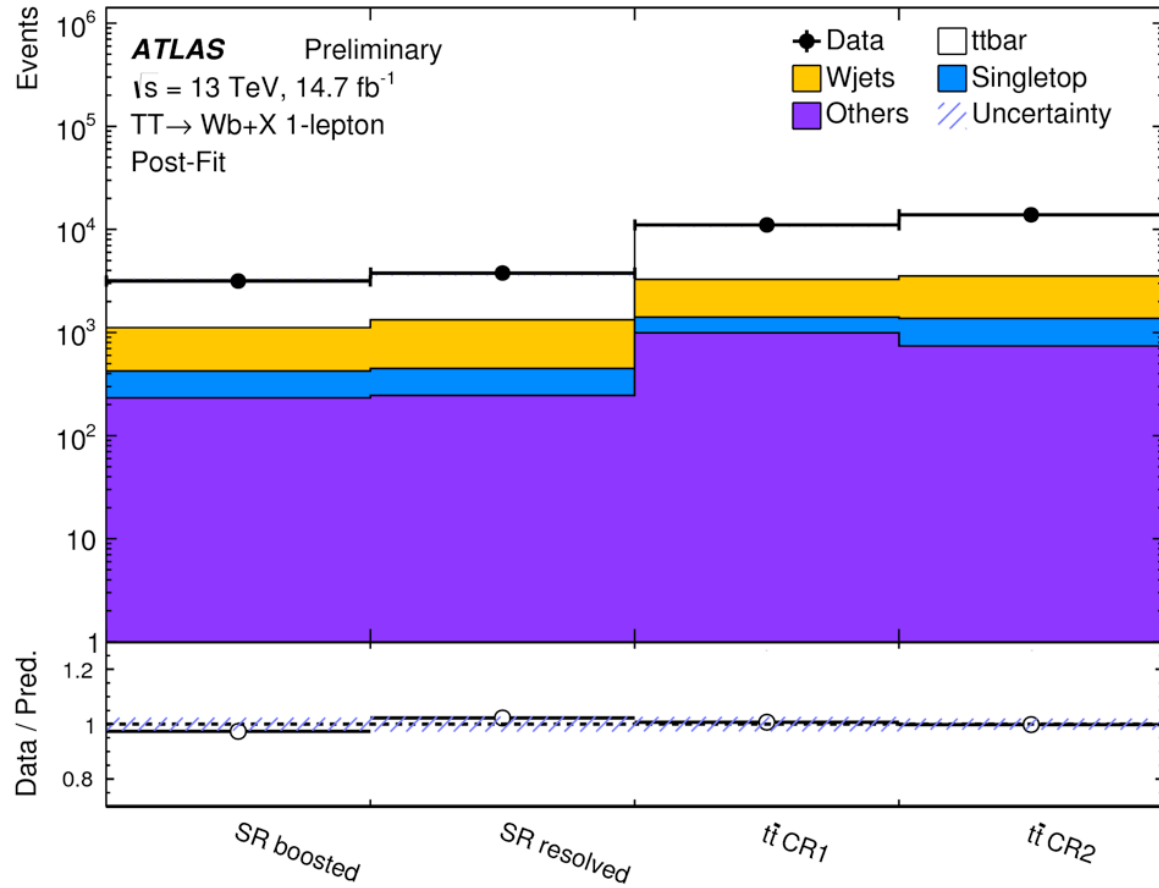
Vector-like quarks: $T \rightarrow Zt$



Variable	SR	TCR	WCR
E_T^{miss}	$> 350 \text{ GeV}$	$> 300 \text{ GeV}$	
m_T^W	$> 170 \text{ GeV}$	$m_T^W \in [30, 90] \text{ GeV}$	
am_{T2}	$> 175 \text{ GeV}$	$> 100 \text{ GeV}$	
$H_{T,\text{sig}}^{\text{miss}}$	> 12		
small- R jet p_T	$> 120, 80, 50, 25 \text{ GeV}$	$> 120, 80, 50, 25 \text{ GeV}$	
number of b -tagged jets	≥ 1	≥ 1	$= 0$
number of large- R jets	≥ 2	≥ 2	
large- R jet mass	$> 80, 60 \text{ GeV}$	$> 80, 60 \text{ GeV}$	
large- R jet p_T	$> 290, 290 \text{ GeV}$ if $E_T^{\text{miss}} < 450 \text{ GeV}$ $> 200, 200 \text{ GeV}$ if $E_T^{\text{miss}} > 450 \text{ GeV}$	$> 200 \text{ GeV}$	

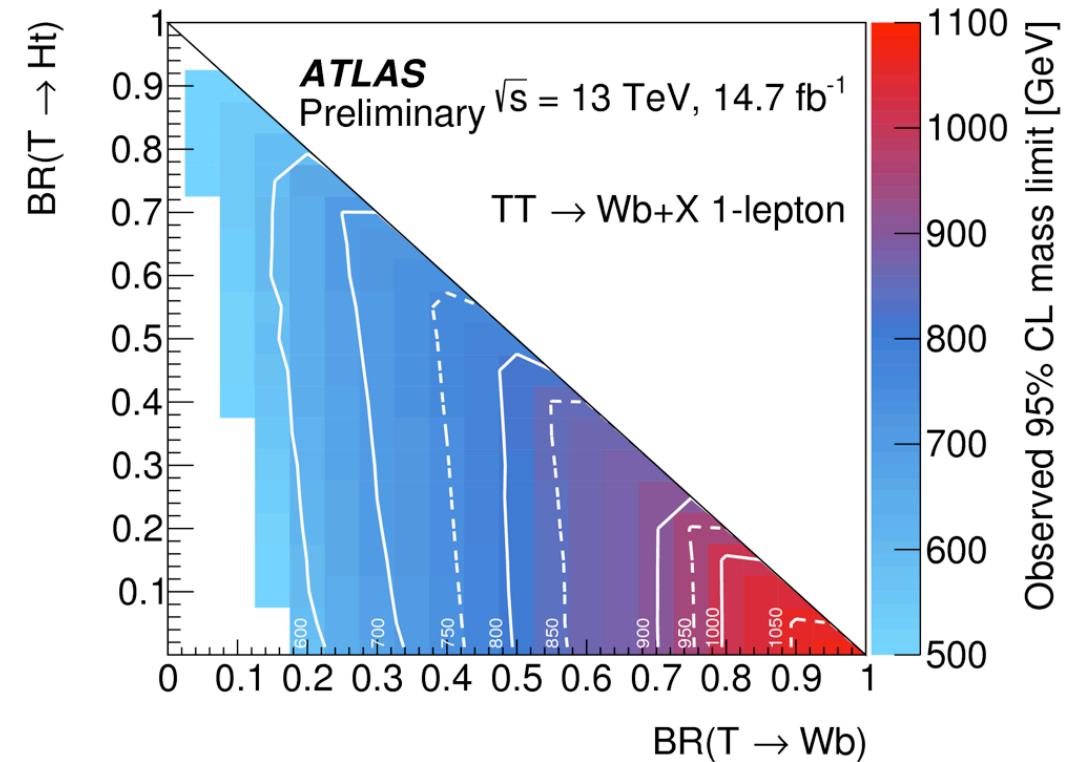


Vector-like quarks : $T \rightarrow Wb$

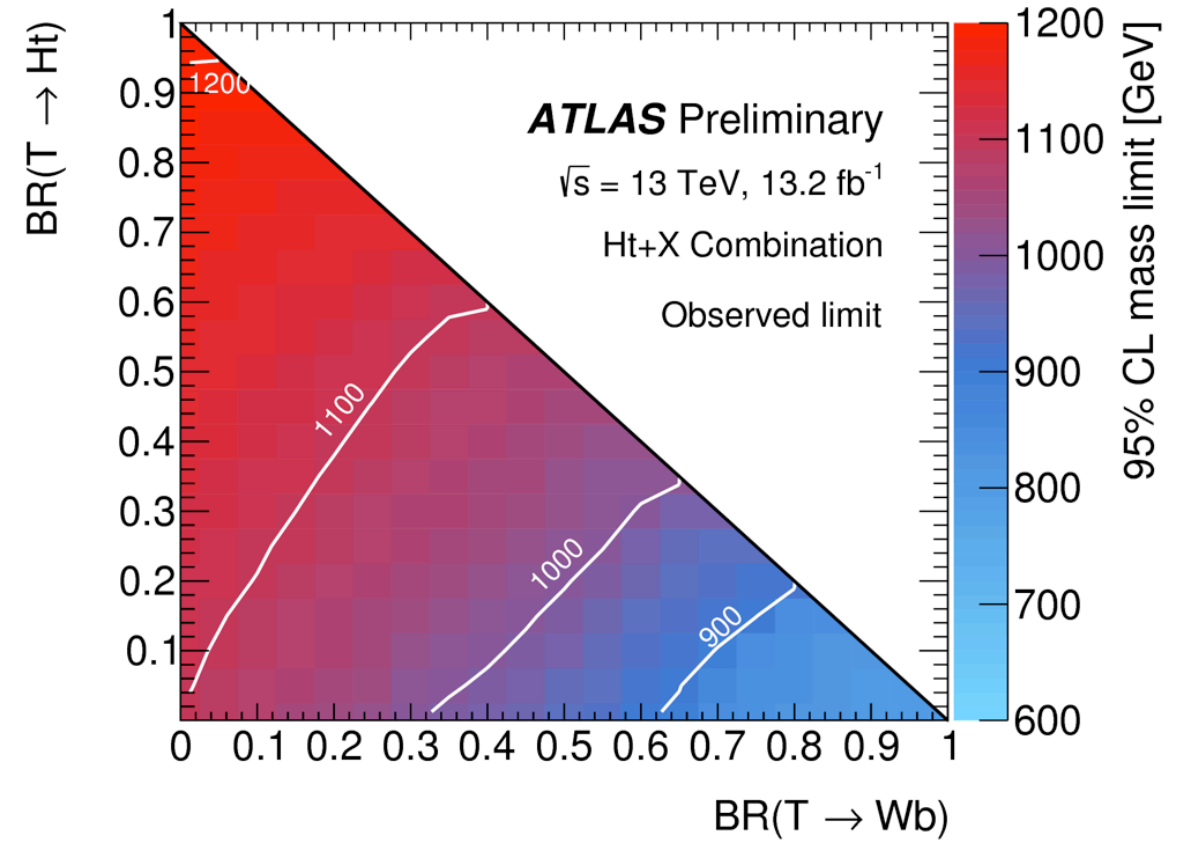
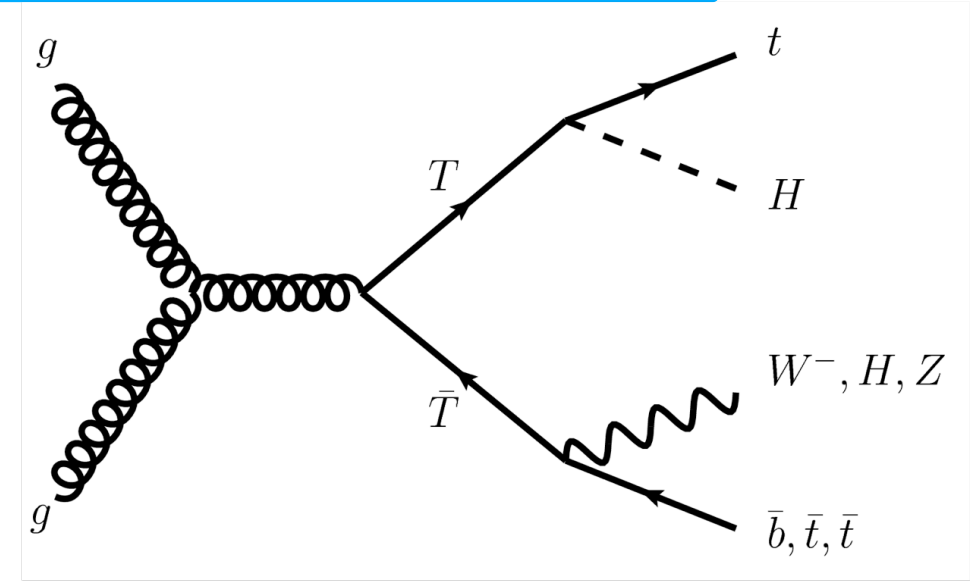
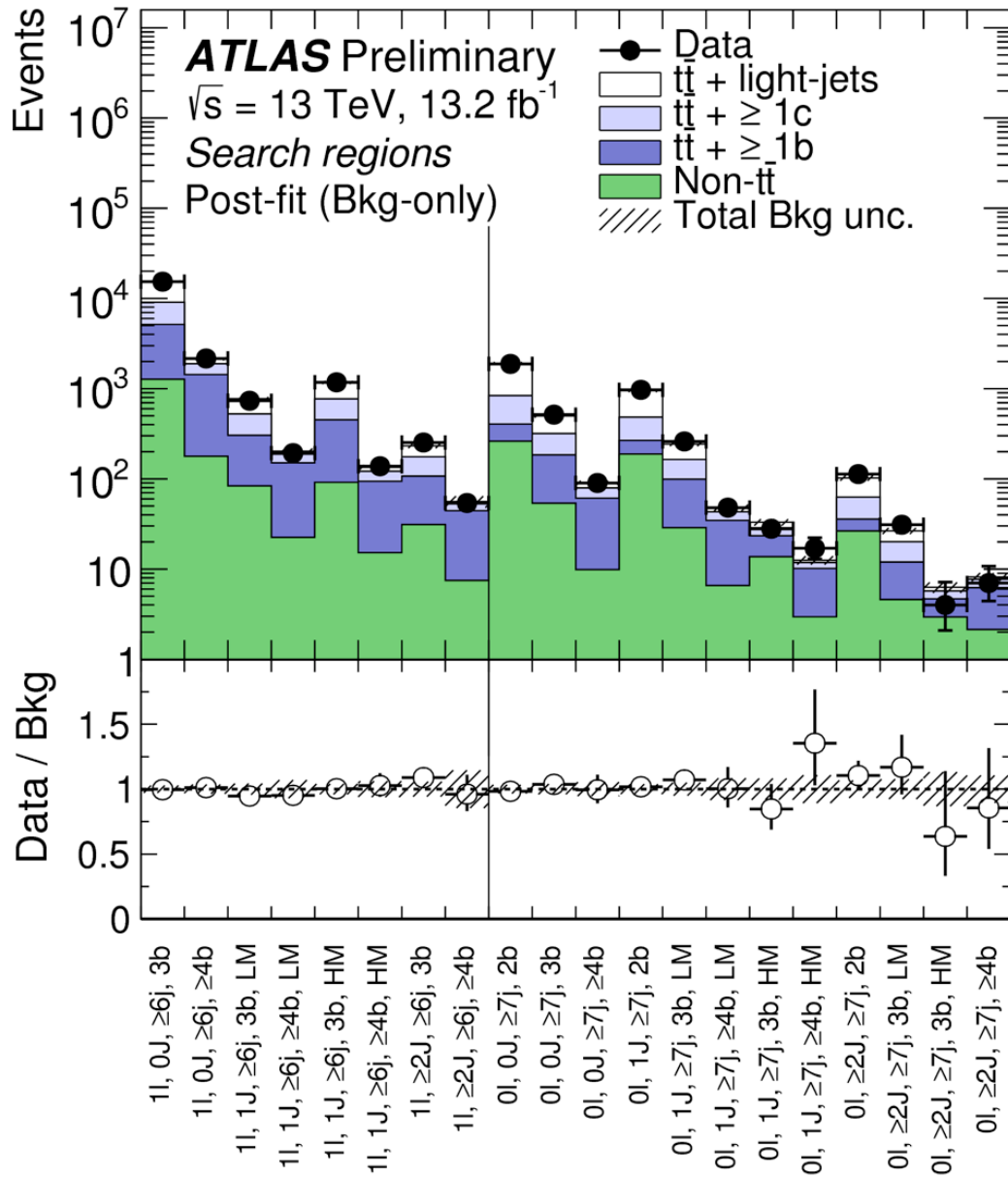


Region	S_T	$\Delta R(\text{lep}, \nu)$	Small- R jets	Large- R jets
Boosted signal region	$> 1200 \text{ GeV}$	< 0.8	≥ 3	≥ 1
Resolved signal region	$> 1200 \text{ GeV}$	< 0.8	≥ 4	$= 0$
$t\bar{t}$ control region 1	$> 700 \text{ GeV}$	> 1.0	≥ 3	≥ 1
$t\bar{t}$ control region 2	$750 - 1200 \text{ GeV}$	< 1.0	≥ 3	≥ 1

Additionally: $E_{T\text{miss}} > 60 \text{ GeV}$,
 $p_T(\text{lep}) > 25 \text{ GeV}$, $p_T(\text{jet}) > 25 \text{ GeV}$



Vector-like quarks : $T \rightarrow Ht$

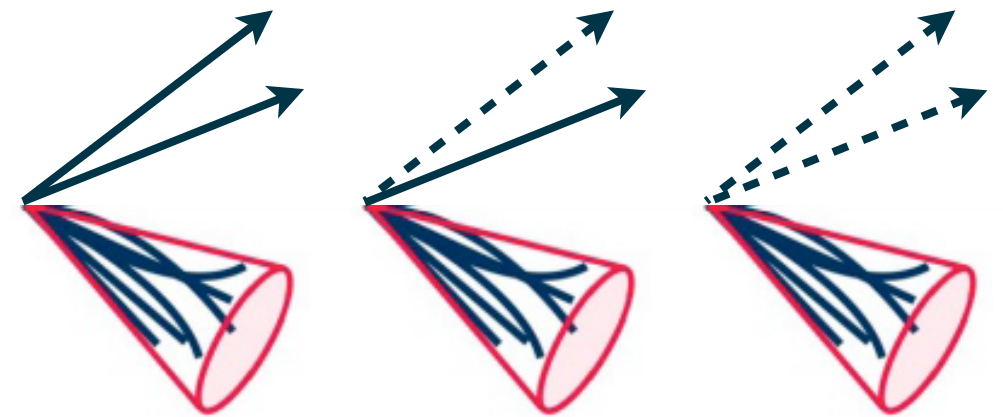


Leptons, big cone jets and small cone jets

Di-boson Resonances

- Many final states:

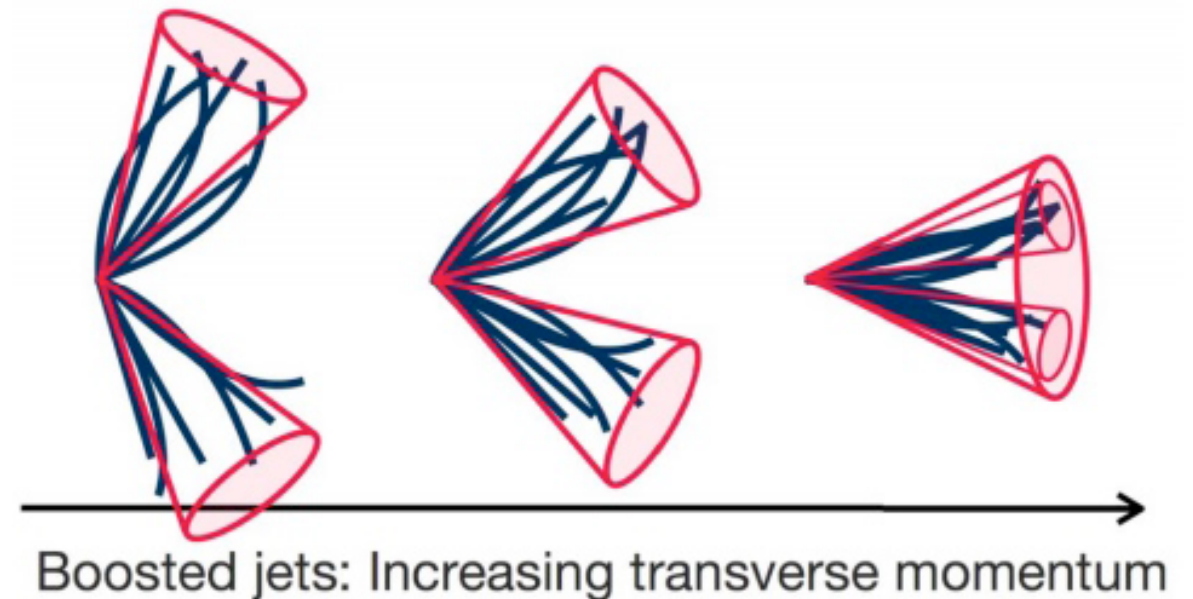
- $VV \rightarrow \ell\ell qq, \ell\nu qq, \nu\nu qq, qq qq$
- $VH \rightarrow \ell\ell bb, \ell\nu bb, \nu\nu bb, qq bb$
- $HH \rightarrow bbbb$



jets, leptons, missing energy

- Wide range of bosons p_T :

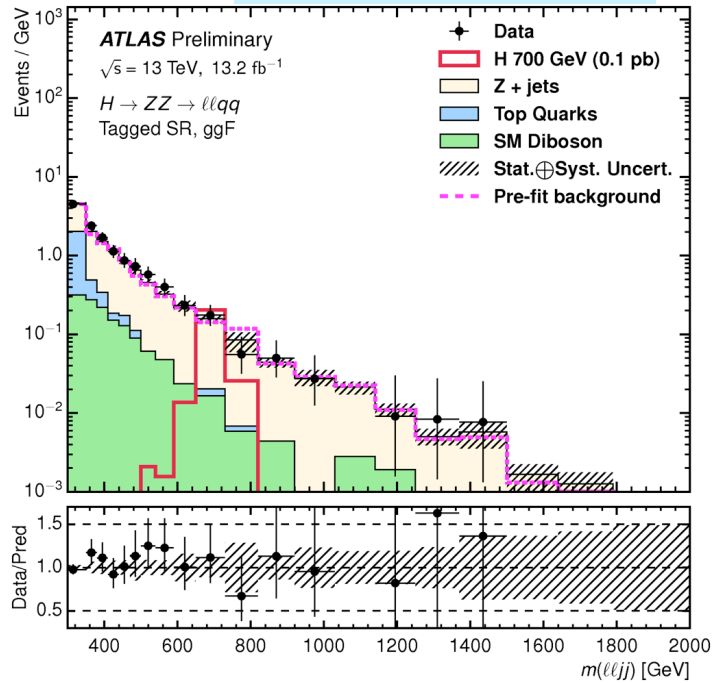
- Resolved : 2 small cone jets
- Boosted : 1 large cone jet



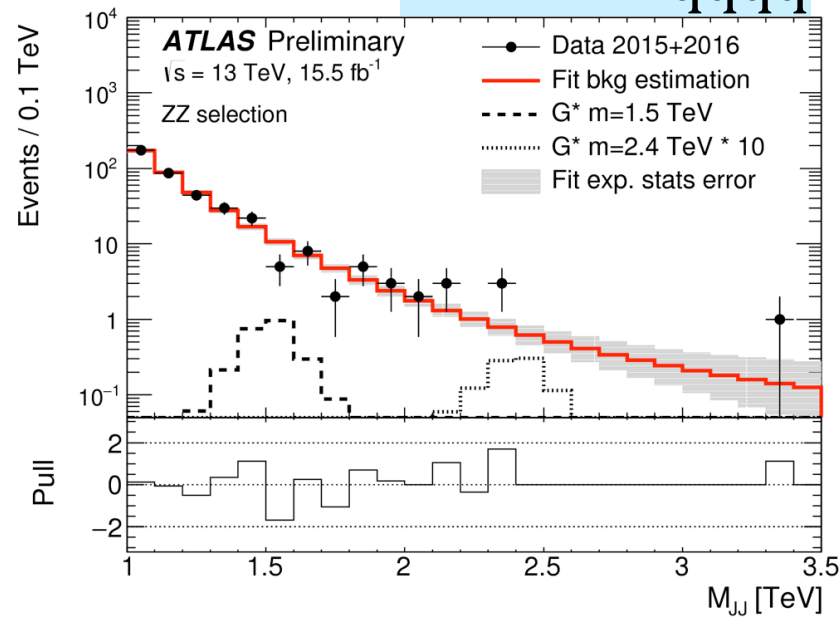
- Different techniques to analyse jet substructure

VV resonances

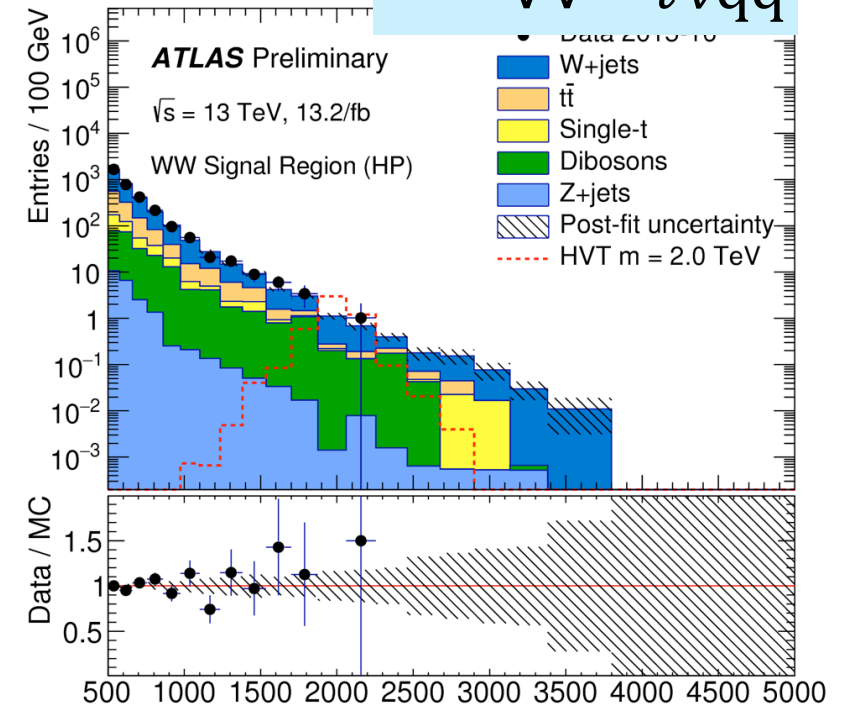
$VV \rightarrow \ell\ell qq$



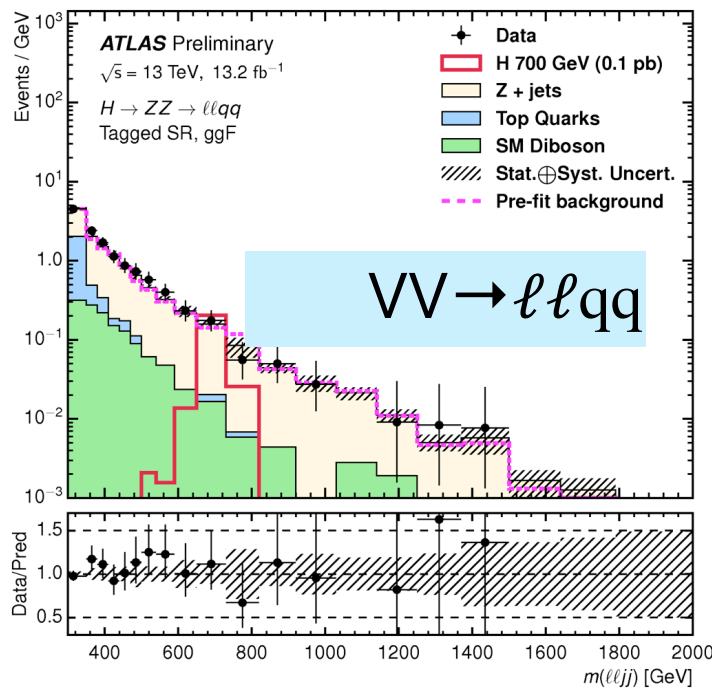
$VV \rightarrow qqqq$



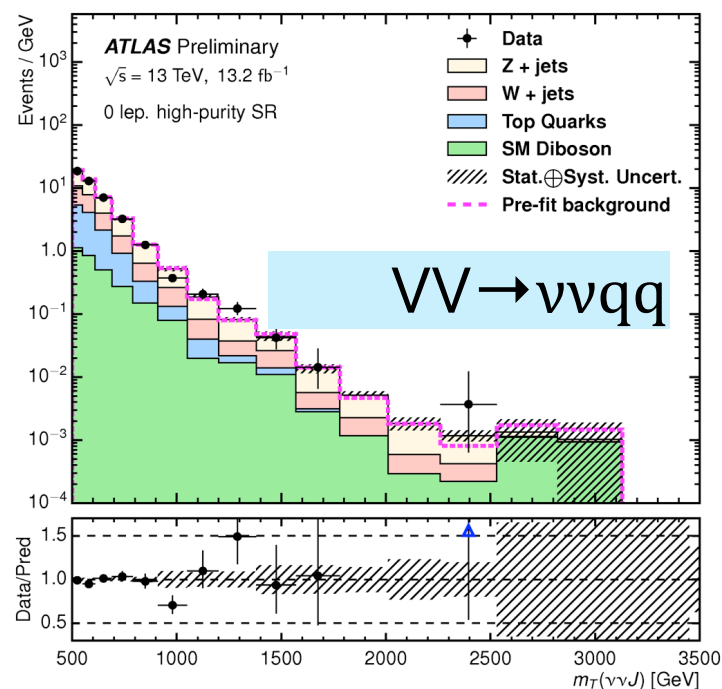
$VV \rightarrow \ell\nu qq$



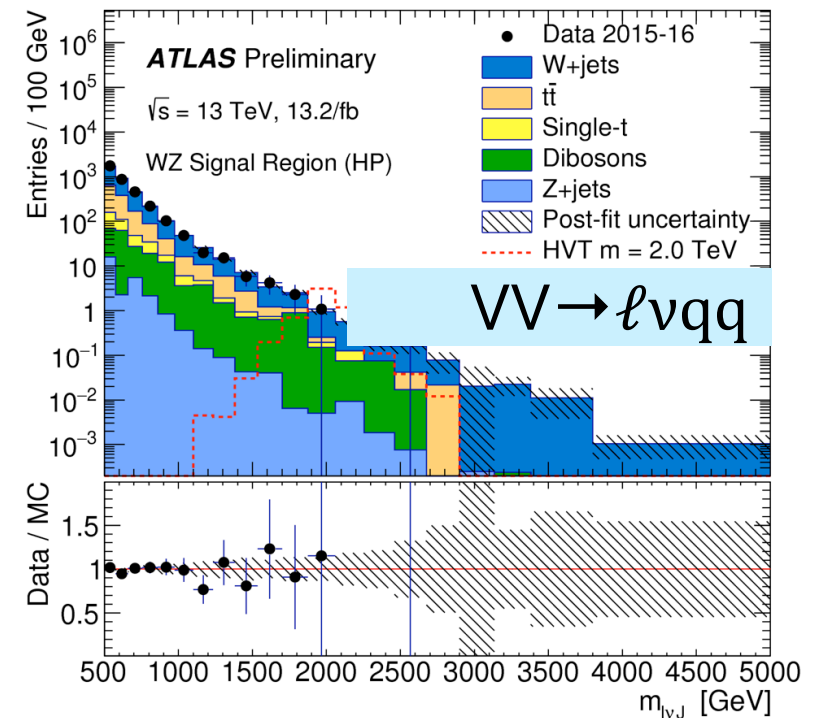
$VV \rightarrow \ell\ell qq$



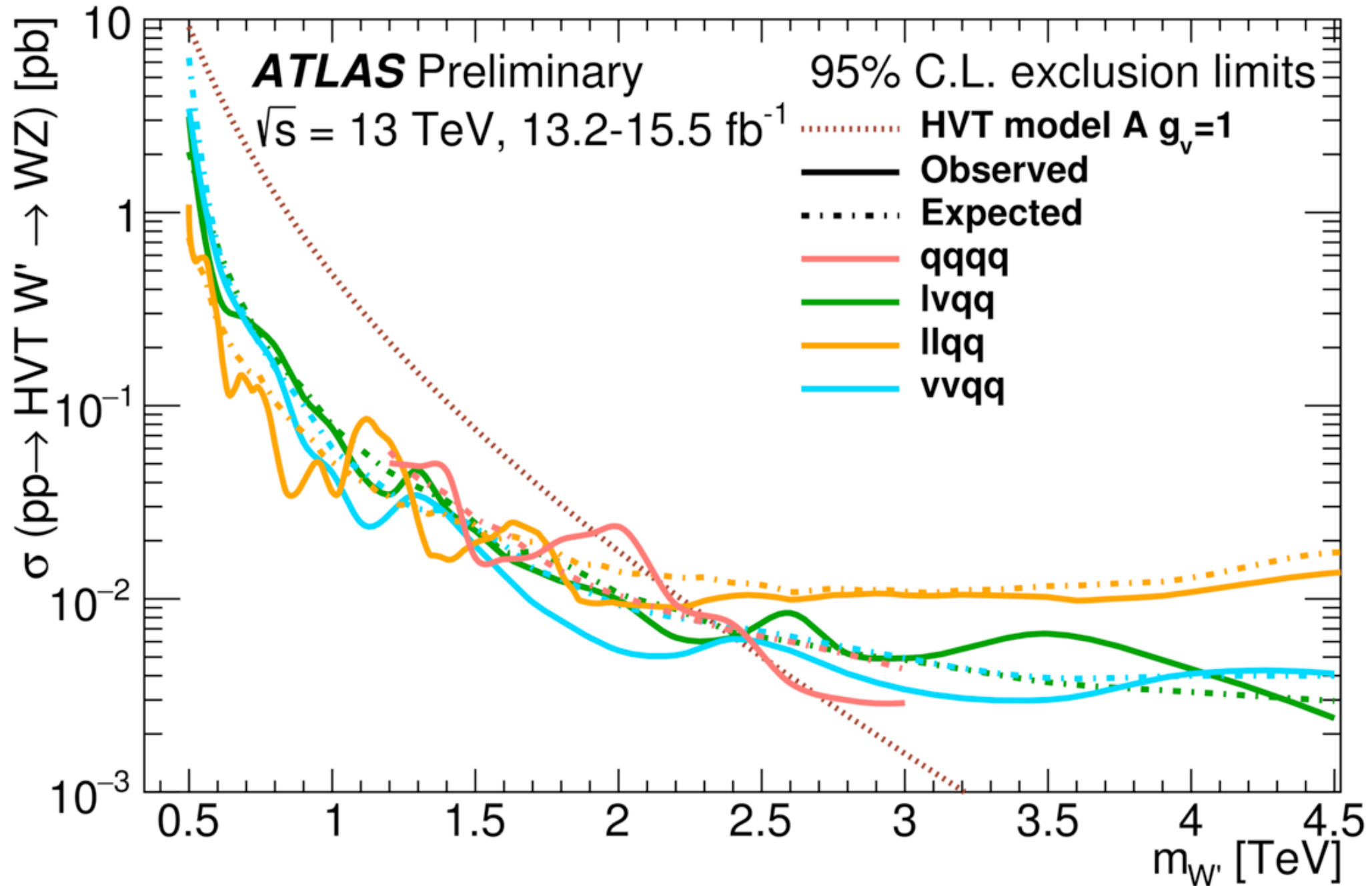
$VV \rightarrow \nu\nu qq$



$VV \rightarrow \ell\nu qq$

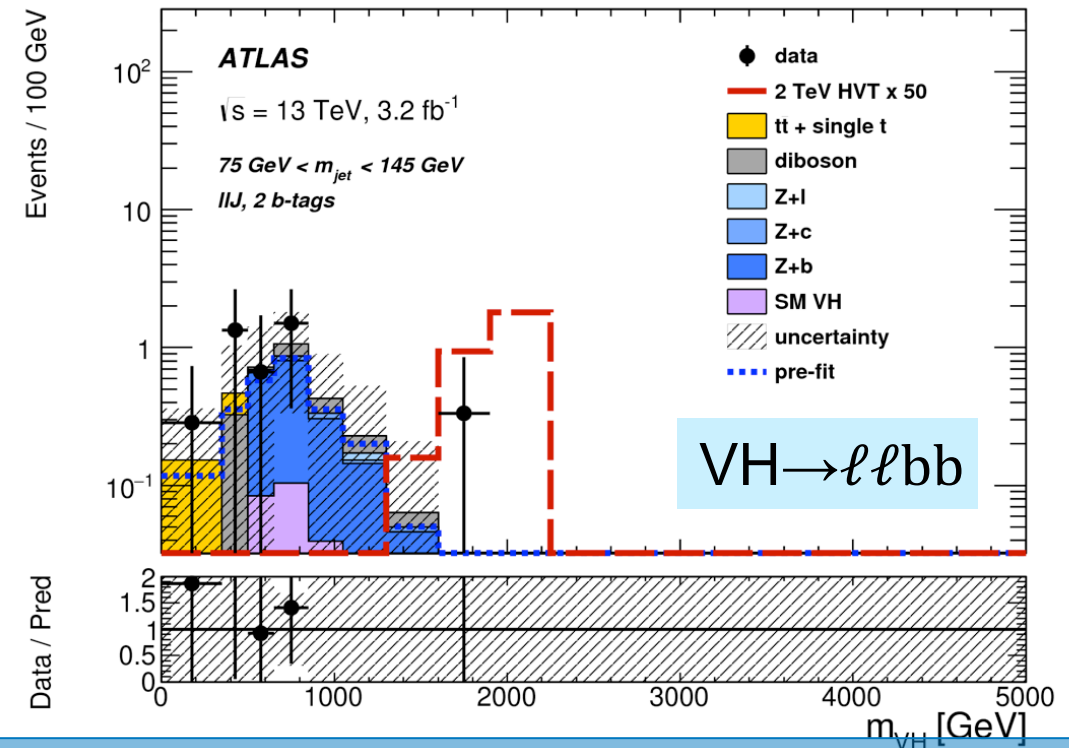
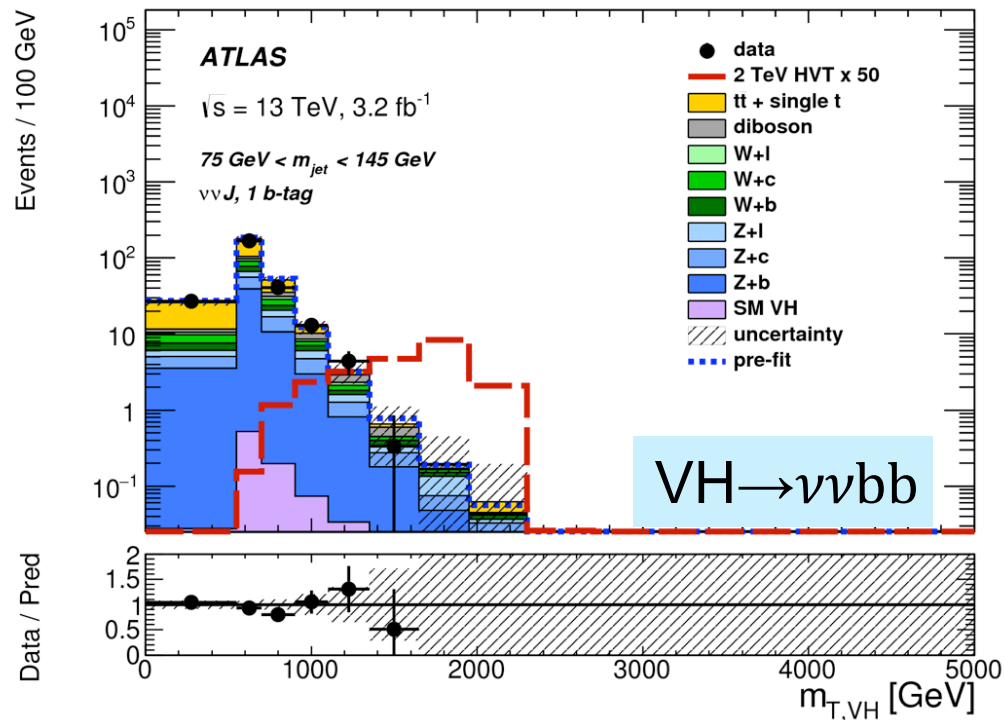
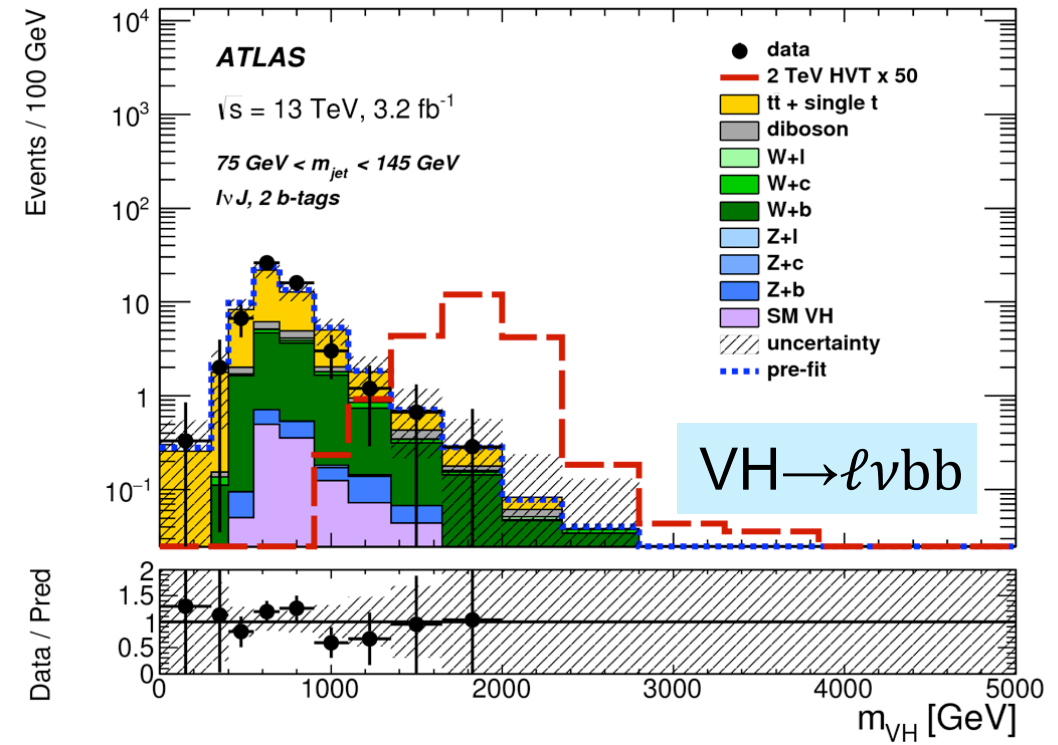
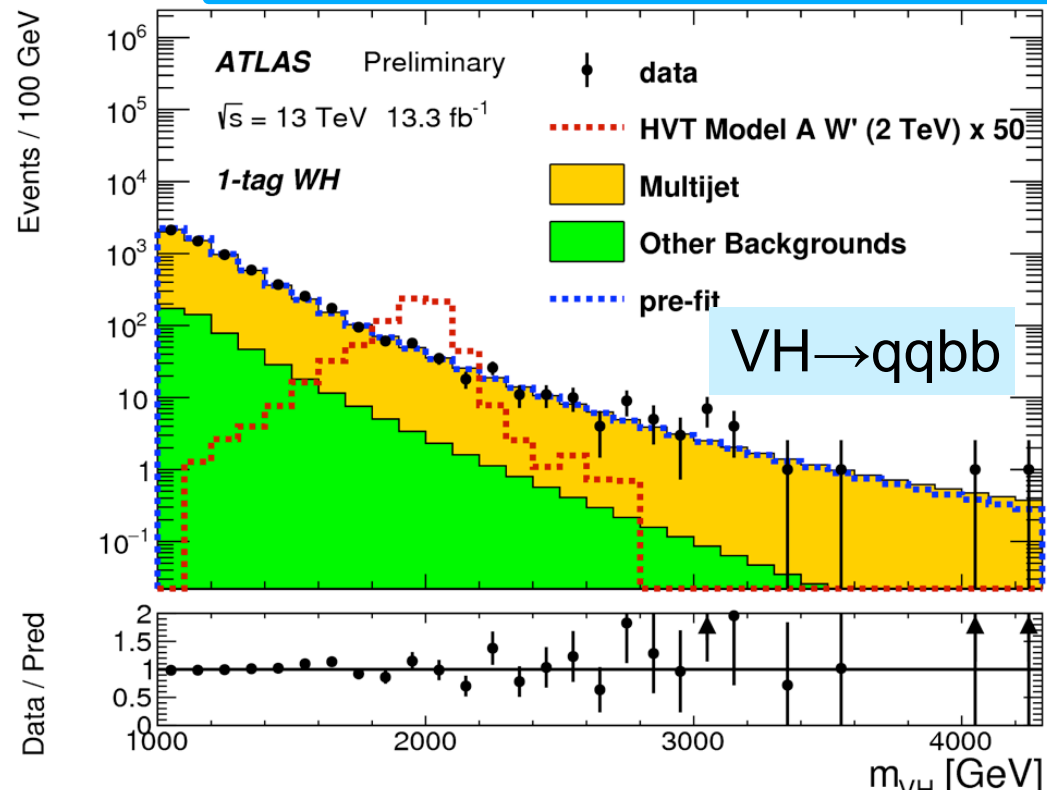


VV resonances



Channels are not combined

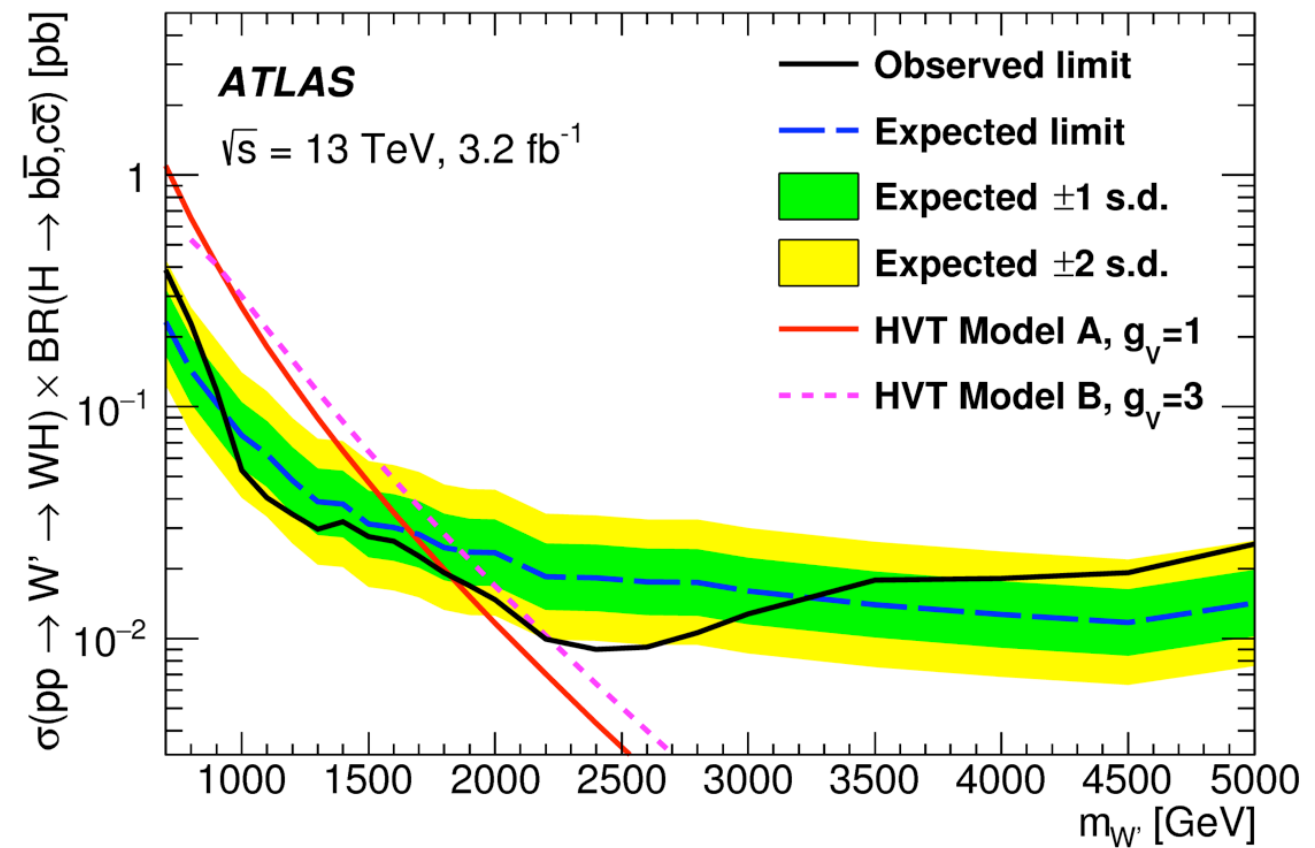
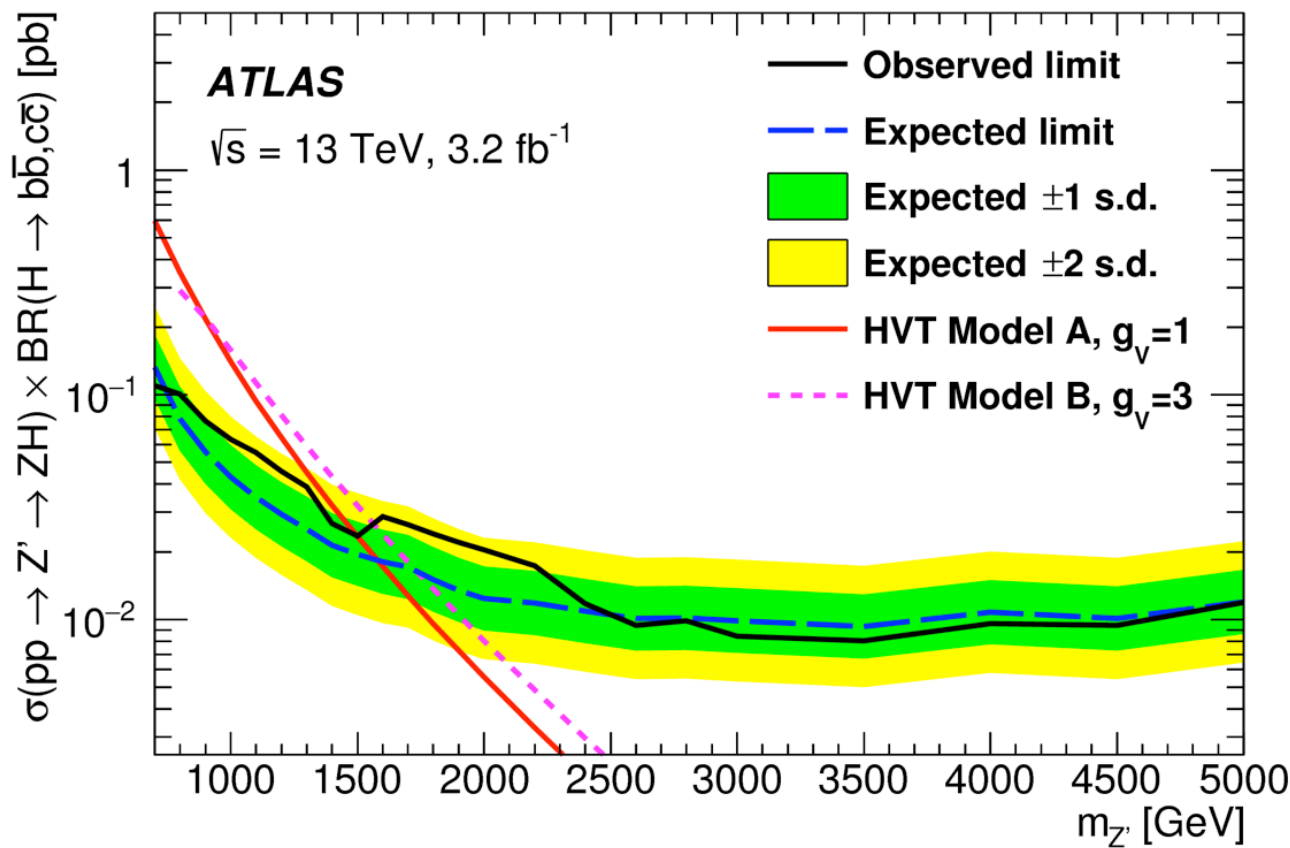
VH Resonances



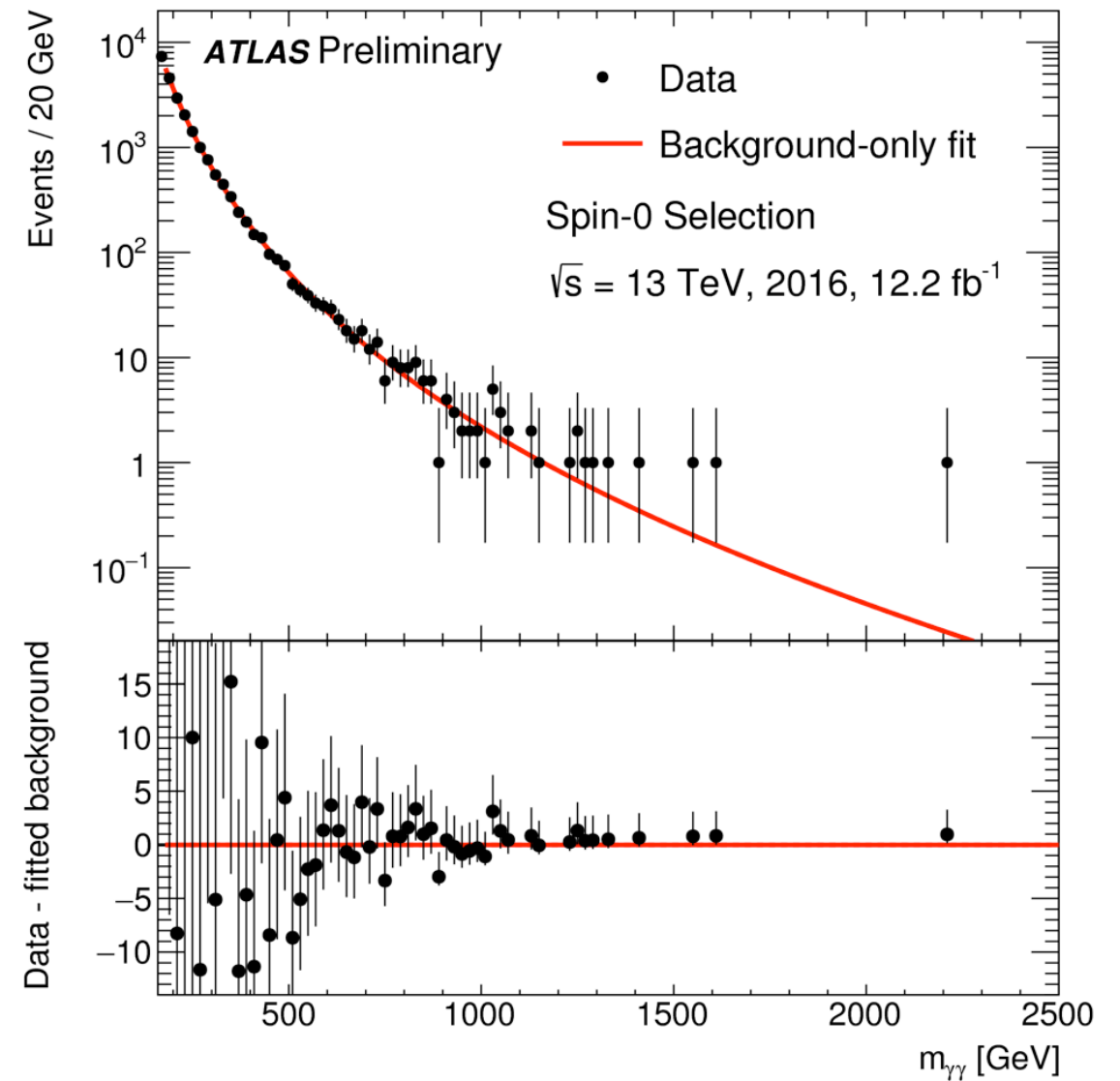
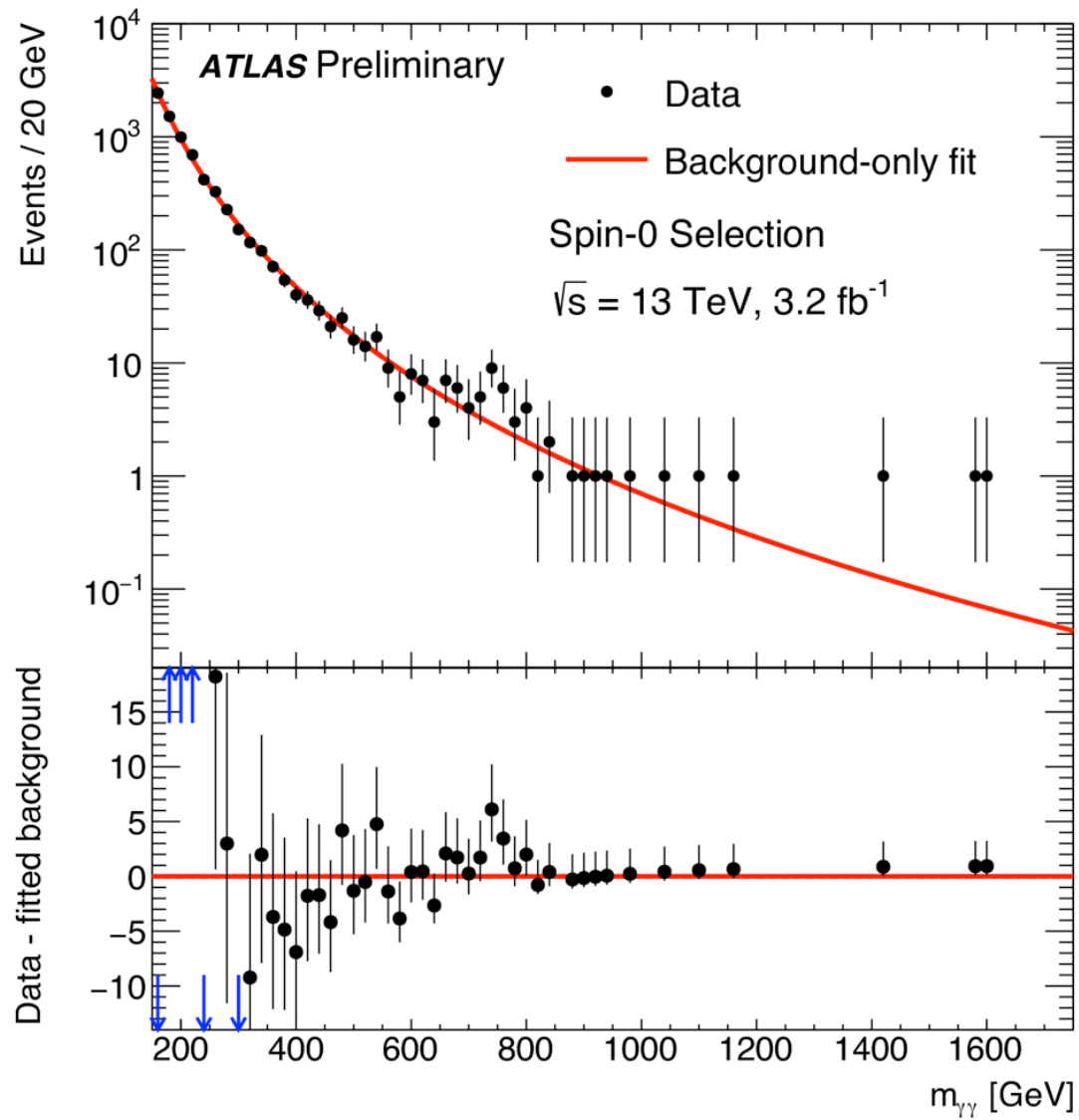
W', Z' results in HVT model

Heavy vector triplet model

Model A - similar to SM gauge group
 Model B - similar to composite Higgs

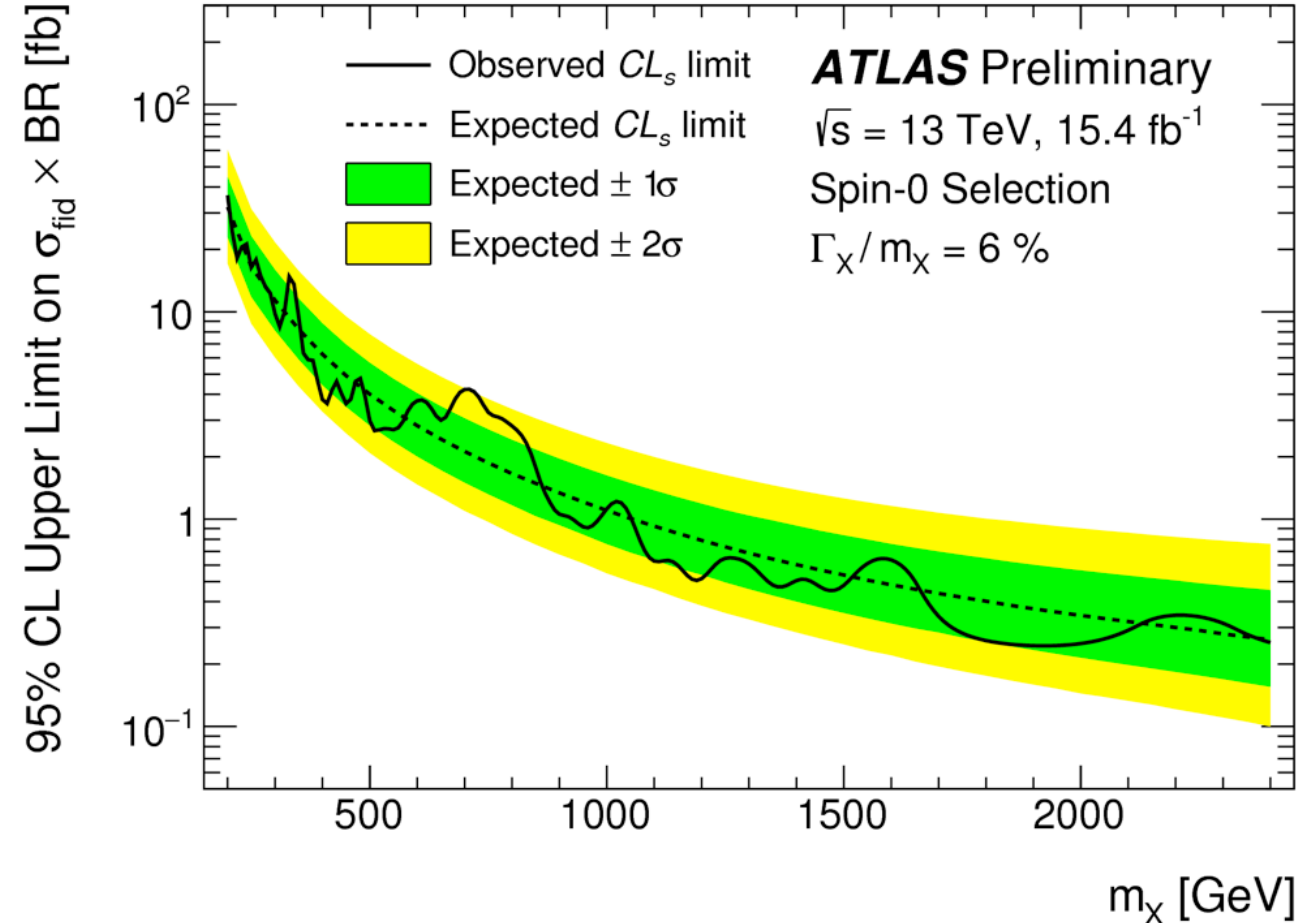
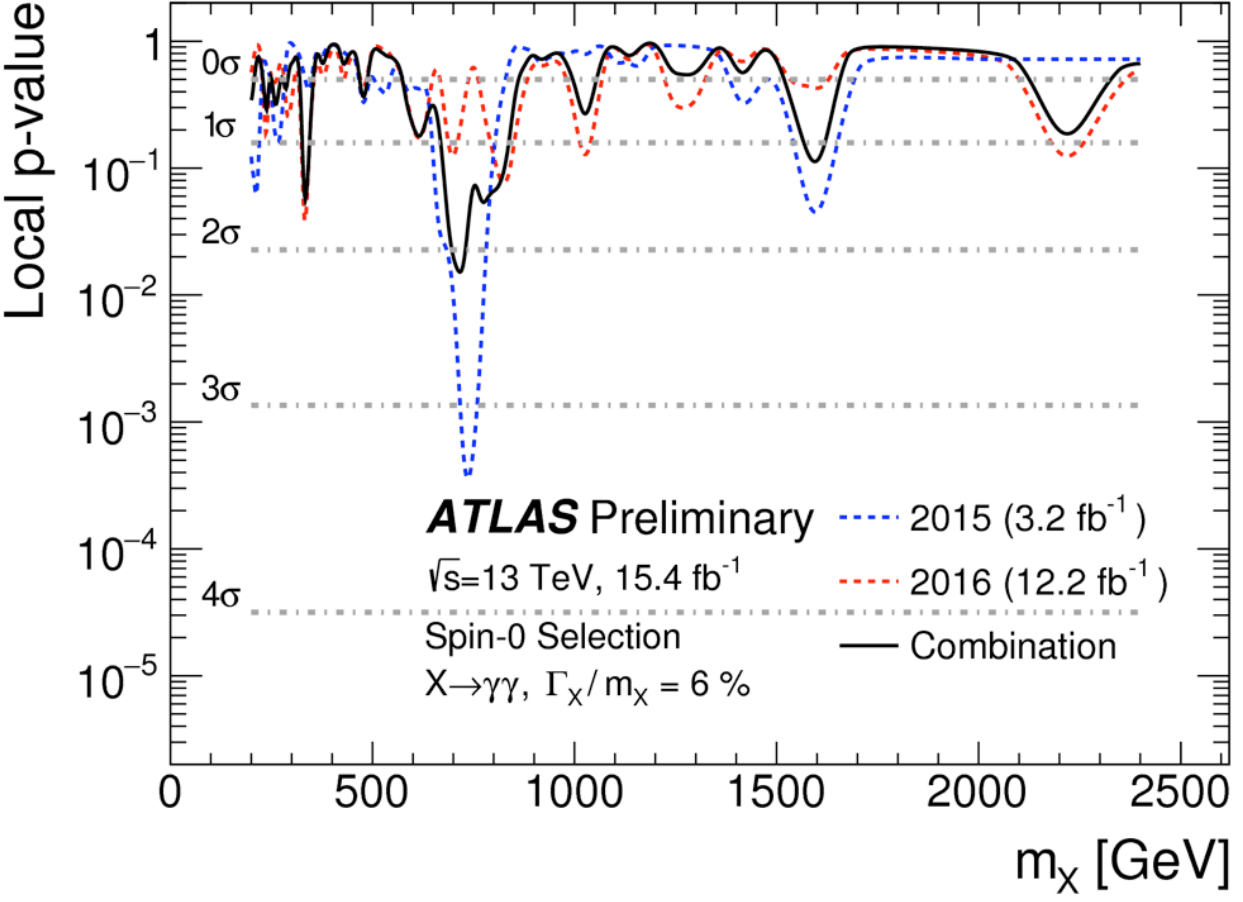


Di-photon resonances



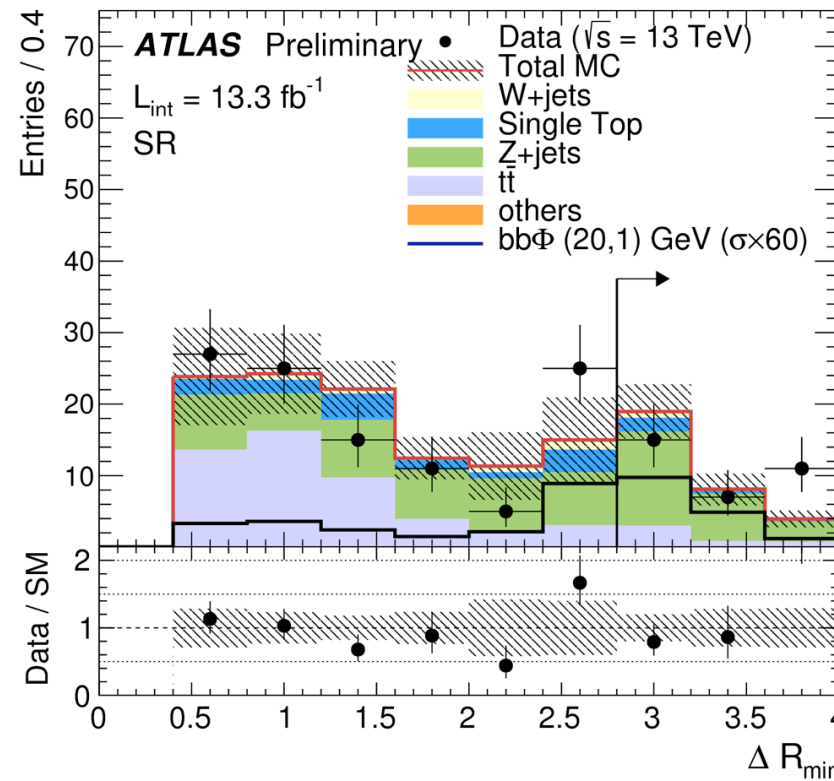
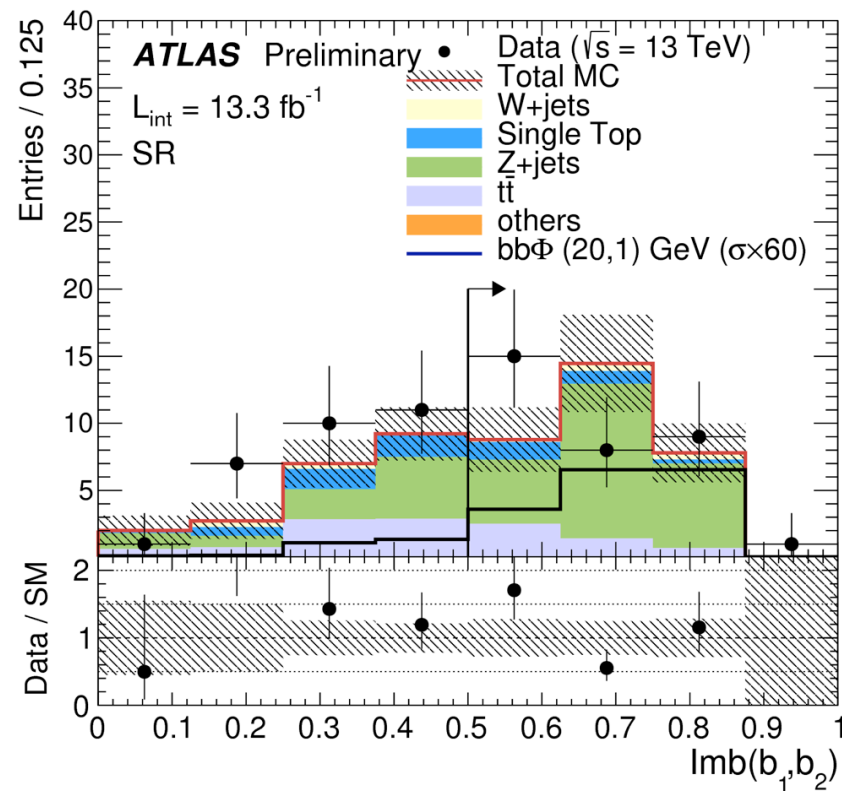
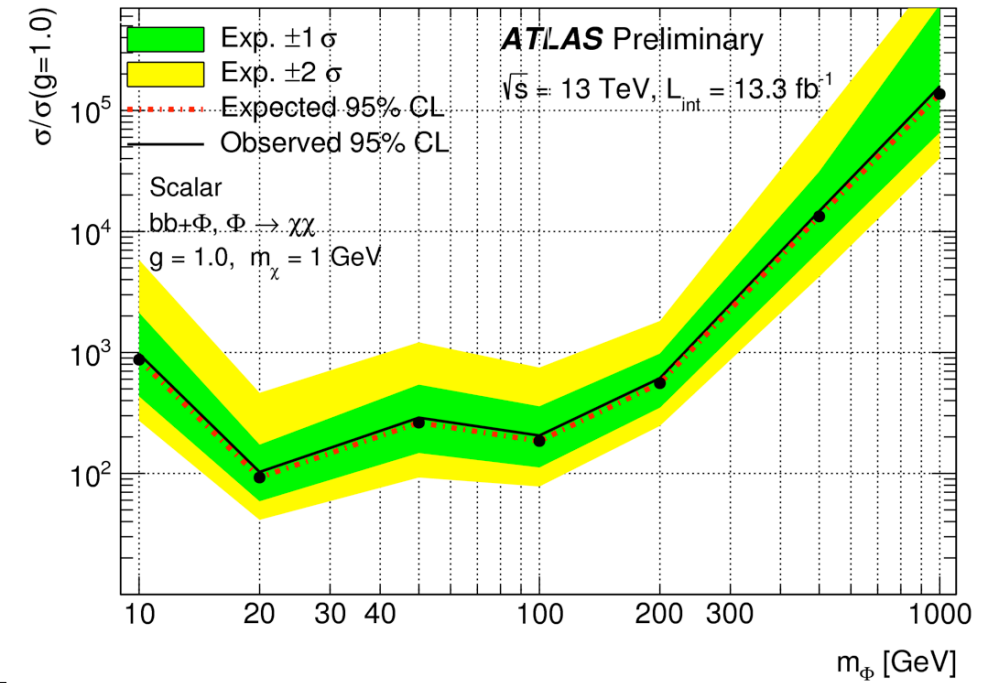
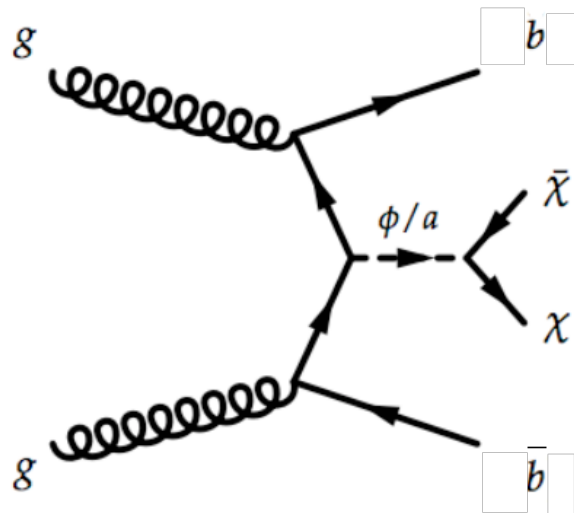
Unfortunately, no signal at $m(\gamma\gamma) \sim 750 \text{ GeV}$

Di-photon resonances



Unfortunately, no signal at $m(\gamma\gamma) \sim 750$ GeV

Dark Matter searches



Newest results
on Dark Matter
(see the whole list at
[ExoticsPublicResults twiki](#))

ATLAS Exotics Searches* - 95% CL Exclusion

Status: August 2016

ATLAS Preliminary

$$\int \mathcal{L} dt = (3.2 - 20.3) \text{ fb}^{-1}$$

$$\sqrt{s} = 8, 13 \text{ TeV}$$

Model	ℓ, γ	Jets [†]	E_T^{miss}	$\int \mathcal{L} dt [\text{fb}^{-1}]$	Limit	Reference	
Extra dimensions	ADD $G_{KK} + g/q$	-	$\geq 1 j$	Yes	3.2	M_D 6.58 TeV	$n = 2$ 1604.07773
	ADD non-resonant $\ell\ell$	$2 e, \mu$	-	-	20.3	M_S 4.7 TeV	$n = 3 \text{ HLZ}$ 1407.2410
	ADD QBH $\rightarrow \ell q$	$1 e, \mu$	$1 j$	-	20.3	M_{th} 5.2 TeV	$n = 6$ 1311.2006
	ADD QBH	-	$2 j$	-	15.7	M_{th} 8.7 TeV	$n = 6$ ATLAS-CONF-2016-069
	ADD BH high $\sum p_T$	$\geq 1 e, \mu$	$\geq 2 j$	-	3.2	M_{th} 8.2 TeV	$n = 6, M_D = 3 \text{ TeV, rot BH}$ 1606.02265
	ADD BH multijet	-	$\geq 3 j$	-	3.6	M_{th} 9.55 TeV	$n = 6, M_D = 3 \text{ TeV, rot BH}$ 1512.02586
	RS1 $G_{KK} \rightarrow \ell\ell$	$2 e, \mu$	-	-	20.3	$G_{KK} \text{ mass}$ 2.68 TeV	$k/\overline{M}_{Pl} = 0.1$ 1405.4123
	RS1 $G_{KK} \rightarrow \gamma\gamma$	2γ	-	-	3.2	$G_{KK} \text{ mass}$ 3.2 TeV	$k/\overline{M}_{Pl} = 0.1$ 1606.03833
	Bulk RS $G_{KK} \rightarrow WW \rightarrow qq\ell\nu$	$1 e, \mu$	$1 J$	Yes	13.2	$G_{KK} \text{ mass}$ 1.24 TeV	$k/\overline{M}_{Pl} = 1.0$ ATLAS-CONF-2016-062
	Bulk RS $G_{KK} \rightarrow HH \rightarrow bbbb$	-	$4 b$	-	13.3	$G_{KK} \text{ mass}$ 360-860 GeV	$k/\overline{M}_{Pl} = 1.0$ ATLAS-CONF-2016-049
	Bulk RS $G_{KK} \rightarrow tt$	$1 e, \mu$	$\geq 1 b, \geq 1J/2j$	Yes	20.3	$G_{KK} \text{ mass}$ 2.2 TeV	BR = 0.925 1505.07018
2UED / RPP	$1 e, \mu$	$\geq 2 b, \geq 4 j$	Yes	3.2	KK mass 1.46 TeV	Tier (1,1), BR($A^{(1,1)} \rightarrow t\bar{t}$) = 1 ATLAS-CONF-2016-013	
Gauge bosons	SSM $Z' \rightarrow \ell\ell$	$2 e, \mu$	-	-	13.3	$Z' \text{ mass}$ 4.05 TeV	ATLAS-CONF-2016-045
	SSM $Z' \rightarrow \tau\tau$	2τ	-	-	19.5	$Z' \text{ mass}$ 2.02 TeV	1502.07177
	Leptophobic $Z' \rightarrow b\bar{b}$	-	$2 b$	-	3.2	$Z' \text{ mass}$ 1.5 TeV	1603.08791
	SSM $W' \rightarrow \ell\nu$	$1 e, \mu$	-	Yes	13.3	$W' \text{ mass}$ 4.74 TeV	ATLAS-CONF-2016-061
	HVT $W' \rightarrow WZ \rightarrow qq\nu\nu$ model A	$0 e, \mu$	$1 J$	Yes	13.2	$W' \text{ mass}$ 2.4 TeV	$g_V = 1$ ATLAS-CONF-2016-082
	HVT $W' \rightarrow WZ \rightarrow qqqq$ model B	-	$2 J$	-	15.5	$W' \text{ mass}$ 3.0 TeV	$g_V = 3$ ATLAS-CONF-2016-055
	HVT $V' \rightarrow WH/ZH$ model B	multi-channel	-	-	3.2	$V' \text{ mass}$ 2.31 TeV	$g_V = 3$ 1607.05621
	LRSM $W'_R \rightarrow t\bar{b}$	$1 e, \mu$	$2 b, 0-1 j$	Yes	20.3	$W' \text{ mass}$ 1.92 TeV	1410.4103
	LRSM $W'_R \rightarrow t\bar{b}$	$0 e, \mu$	$\geq 1 b, 1 J$	-	20.3	$W' \text{ mass}$ 1.76 TeV	1408.0886
CI	CI $qqqq$	-	$2 j$	-	15.7	Λ 19.9 TeV $\eta_{LL} = -1$	ATLAS-CONF-2016-069
	CI $\ell\ell qq$	$2 e, \mu$	-	-	3.2	Λ 25.2 TeV $\eta_{LL} = -1$	1607.03669
	CI $uutt$	$2(SS)/\geq 3 e, \mu \geq 1 b, \geq 1 j$	Yes	20.3	Λ 4.9 TeV	$ C_{RR} = 1$ 1504.04605	
DM	Axial-vector mediator (Dirac DM)	$0 e, \mu$	$\geq 1 j$	Yes	3.2	m_A 1.0 TeV	$g_0=0.25, g_i=1.0, m(\chi) < 250 \text{ GeV}$ 1604.07773
	Axial-vector mediator (Dirac DM)	$0 e, \mu, 1 \gamma$	$1 j$	Yes	3.2	m_A 710 GeV	$g_0=0.25, g_i=1.0, m(\chi) < 150 \text{ GeV}$ 1604.01306
	ZZ $\chi\chi$ EFT (Dirac DM)	$0 e, \mu$	$1 J, \leq 1 j$	Yes	3.2	M_χ 550 GeV	$m(\chi) < 150 \text{ GeV}$ ATLAS-CONF-2015-080
LQ	Scalar LQ 1 st gen	$2 e$	$\geq 2 j$	-	3.2	LQ mass 1.1 TeV	$\beta = 1$ 1605.06035
	Scalar LQ 2 nd gen	2μ	$\geq 2 j$	-	3.2	LQ mass 1.05 TeV	$\beta = 1$ 1605.06035
	Scalar LQ 3 rd gen	$1 e, \mu$	$\geq 1 b, \geq 3 j$	Yes	20.3	LQ mass 640 GeV	$\beta = 0$ 1508.04735
Heavy quarks	VLQ $TT \rightarrow Ht + X$	$1 e, \mu$	$\geq 2 b, \geq 3 j$	Yes	20.3	T mass 855 GeV	T in (T,B) doublet 1505.04306
	VLQ $YY \rightarrow Wb + X$	$1 e, \mu$	$\geq 1 b, \geq 3 j$	Yes	20.3	Y mass 770 GeV	Y in (B,Y) doublet 1505.04306
	VLQ $BB \rightarrow Hb + X$	$1 e, \mu$	$\geq 2 b, \geq 3 j$	Yes	20.3	B mass 735 GeV	isospin singlet 1505.04306
	VLQ $BB \rightarrow Zb + X$	$2/\geq 3 e, \mu$	$\geq 2/\geq 1 b$	-	20.3	B mass 755 GeV	B in (B,Y) doublet 1409.5500
	VLQ $QQ \rightarrow WqWq$	$1 e, \mu$	$\geq 4 j$	Yes	20.3	Q mass 690 GeV	1509.04261
	VLQ $T_{5/3} T_{5/3} \rightarrow WtWt$	$2(SS)/\geq 3 e, \mu \geq 1 b, \geq 1 j$	Yes	3.2	$T_{5/3} \text{ mass}$ 990 GeV	ATLAS-CONF-2016-032	
Excited fermions	Excited quark $q^* \rightarrow q\gamma$	1γ	$1 j$	-	3.2	$q^* \text{ mass}$ 4.4 TeV	only u^* and d^* , $\Lambda = m(q^*)$ 1512.05910
	Excited quark $q^* \rightarrow qg$	-	$2 j$	-	15.7	$q^* \text{ mass}$ 5.6 TeV	only u^* and d^* , $\Lambda = m(q^*)$ ATLAS-CONF-2016-069
	Excited quark $b^* \rightarrow bg$	-	$1 b, 1 j$	-	8.8	$b^* \text{ mass}$ 2.3 TeV	ATLAS-CONF-2016-060
	Excited quark $b^* \rightarrow Wt$	$1 \text{ or } 2 e, \mu$	$1 b, 2-0 j$	Yes	20.3	$b^* \text{ mass}$ 1.5 TeV	$f_L = f_R = 1$ 1510.02664
	Excited lepton ℓ^*	$3 e, \mu$	-	-	20.3	$\ell^* \text{ mass}$ 3.0 TeV	$\Lambda = 3.0 \text{ TeV}$ 1411.2921
	Excited lepton ν^*	$3 e, \mu, \tau$	-	-	20.3	$\nu^* \text{ mass}$ 1.6 TeV	$\Lambda = 1.6 \text{ TeV}$ 1411.2921
Other	LSTC $a_T \rightarrow W\gamma$	$1 e, \mu, 1 \gamma$	-	Yes	20.3	$a_T \text{ mass}$ 960 GeV	1407.8150
	LRSM Majorana ν	$2 e, \mu$	$2 j$	-	20.3	$N^0 \text{ mass}$ 2.0 TeV	$m(W_R) = 2.4 \text{ TeV, no mixing}$ 1506.06020
	Higgs triplet $H^{\pm\pm} \rightarrow ee$	$2 e (SS)$	-	-	13.9	$H^{\pm\pm} \text{ mass}$ 570 GeV	DY production, BR($H_L^{\pm\pm} \rightarrow ee$)=1 ATLAS-CONF-2016-051
	Higgs triplet $H^{\pm\pm} \rightarrow \ell\tau$	$3 e, \mu, \tau$	-	-	20.3	$H^{\pm\pm} \text{ mass}$ 400 GeV	DY production, BR($H_L^{\pm\pm} \rightarrow \ell\tau$)=1 1411.2921
	Monotop (non-res prod)	$1 e, \mu$	$1 b$	Yes	20.3	spin-1 invisible particle mass 657 GeV	$a_{\text{non-res}} = 0.2$ 1410.5404
	Multi-charged particles	-	-	-	20.3	multi-charged particle mass 785 GeV	DY production, $ q = 5e$ 1504.04188
	Magnetic monopoles	-	-	-	7.0	monopole mass 1.34 TeV	DY production, $ g = 1g_D, \text{ spin } 1/2$ 1509.08059

$\sqrt{s} = 8 \text{ TeV}$ $\sqrt{s} = 13 \text{ TeV}$

10⁻¹ 1 10 Mass scale [TeV]

*Only a selection of the available mass limits on new states or phenomena is shown. Lower bounds are specified only when explicitly not excluded.

†Small-radius (large-radius) jets are denoted by the letter j (J).

Summary

- The LHC is performing extremely well, expecting more than 30 fb^{-1} by the end of this year
- 13 TeV is very interesting new territory w.r.t 8 TeV - in particular cross-section of heavy resonances is significantly higher
- Many searches of heavy new particles is performed
 - so far no news
 - di-photon resonance from 2015 is not confirmed
- Analyses are constantly improved
 - New boosted techniques allows to analyse jet substructure
 - New trigger approach - allows to analyse also lower mass regions
- Work is ongoing - more results in winter