Exotics searches at ATLAS

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on behalf of the ATLAS Collaboration

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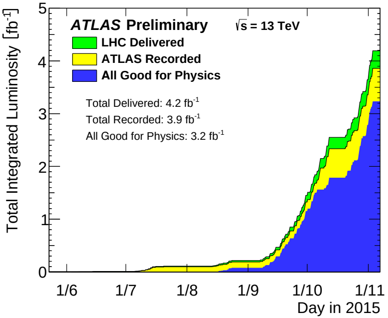
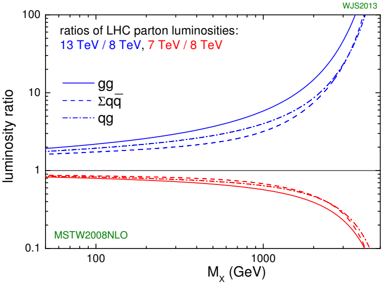
28th Rencontres de Blois

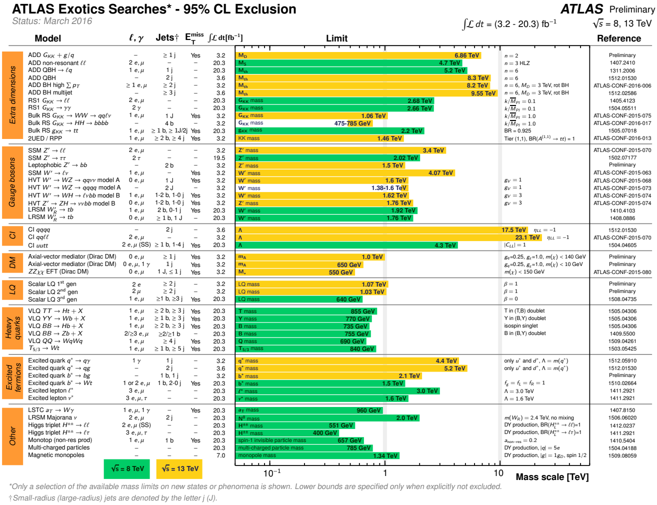
- Exotics ⇔ Direct search for BSM, not SUSY
- Run2 2015: $\sqrt{s} = 13\,\text{TeV}$, $L = 3.2\,\text{fb}^{-1}$ (1/6 wrt 8 TeV).





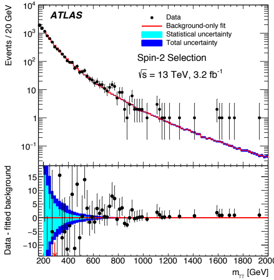
- Increase in energy compensate the lower luminosity

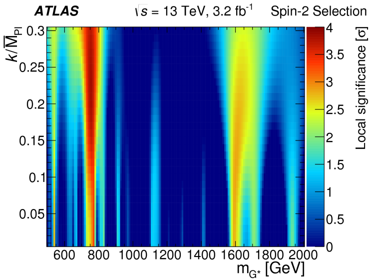
Exotics physics



- Many analyses updated with 13 TeV data, with improved limits

- See talk by Simone Mazza
- Search for RS-graviton, extended Higgs sector (LWA, NWA).
- Strategy: optimize two selections for spin-0 and spin-2. Fit background with a functional form or background template.
- Excess at $m_{\gamma\gamma} \simeq 750\,\text{GeV}$
- Apparently no other hard activity in the event



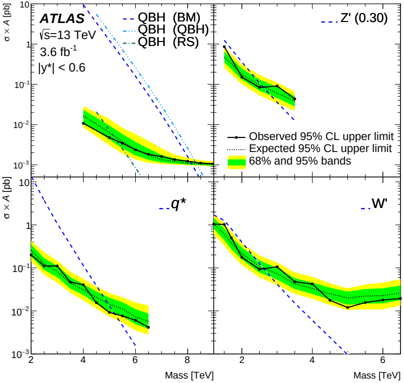


Diphoton

	Spin-2 Selection		Spin-0 Selection	
	Free width	Narrow width	Free width	Narrow width
	13 TeV			
Mass for the largest excess	750 GeV	770 GeV	750 GeV	750 GeV
Width over mass for the largest excess	8%	-	6%	-
Local significance	3.8	3.3	3.9	2.9
Global significance	2.1		2.1	
	8 TeV			
Local significance (at 13 TeV best-fit)	-		1.9	
	8 TeV - 13 TeV Compatibility			
Gluon–gluon scaling (4.7)	2.7	2.2	1.2	1.5
Quark–antiquark scaling (2.7)	3.3	2.4	2.1	2.0

- Other interesting channels: diboson, $Z\gamma$, dilepton, jj, ...

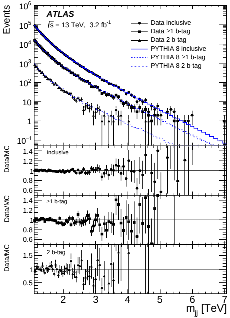
- QBH (ADD, RS1), q^*, W', leptophobic-Z', generic search (gaussian peak), contact interaction (CI)
- Mass and angular analysis $\chi = e^{2|y^*|} \simeq \frac{1+\cos\theta^*}{1-\cos\theta^*}$.

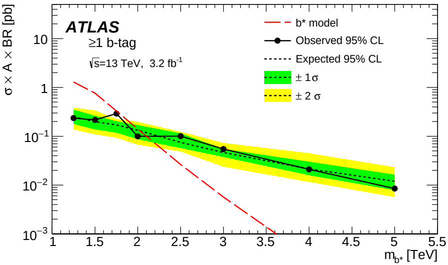


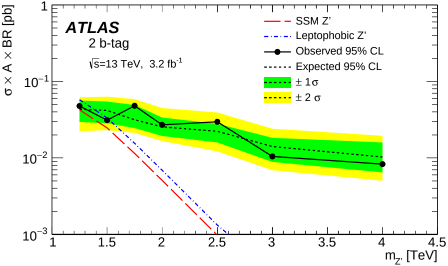
Model	95% CL Exclusion limit		
	Run 1 Observed	Observed 13 TeV	Expected 13 TeV
Quantum black holes, ADD (BLACKMAX generator)	5.6 TeV	8.1 TeV	8.1 TeV
Quantum black holes, ADD (QBH generator)	5.7 TeV	8.3 TeV	8.3 TeV
Quantum black holes, RS (QBH generator)	–	5.3 TeV	5.1 TeV
Excited quark	4.1 TeV	5.2 TeV	4.9 TeV
W'	2.5 TeV	2.6 TeV	2.6 TeV
Contact interactions ($\eta_{LL}=+1$)	8.1 TeV	12.0 TeV	12.0 TeV
Contact interactions ($\eta_{LL}=-1$)	12.0 TeV	17.5 TeV	18.1 TeV

- The generic search can be reinterpreted to other models

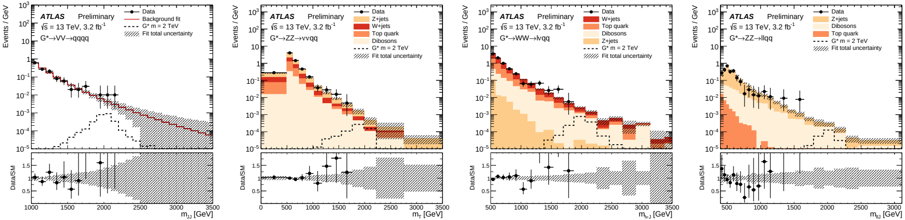
- Search for: $bg \rightarrow b^* \rightarrow gb$, $q\bar{q} \rightarrow Z' \rightarrow b\bar{b}$ (SSM (no statistics for a limit), leptophobic Z'), generic peak
- Production additionally increases by 2-3 with respect to valence quarks moving from 8 to 13 TeV
- leading $p_T > 440$ GeV, $|\eta| < 2.4$, $m_{jj} > 1.1$ TeV, $|y^*| < 0.6$, b-tagging
- Strategy: "1b", "2b" categories, search for a peak in m_{jj}, background fitted with functional form
- Main systematics: b-tagging efficiency



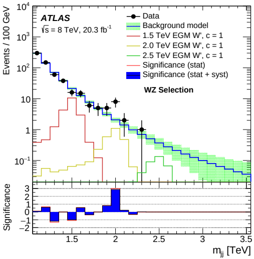


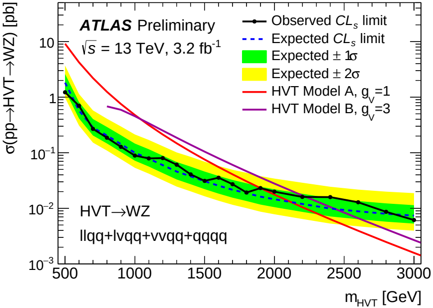


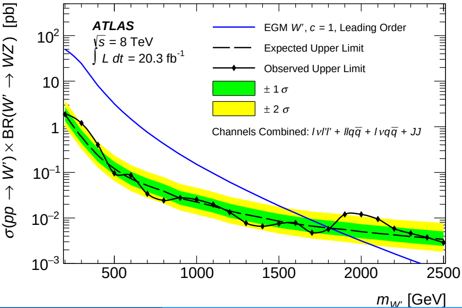
- Search for resonance: heavy CP-even scalar singlet ($\rightarrow WW/ZZ$), heavy vector boson triplet (HVT) $W' \rightarrow WZ$, $Z' \rightarrow WW$, RS spin-2 graviton $G \rightarrow WW/ZZ$,
- Decay modes: $\nu\nu qq$, $\ell\nu qq$, $\ell\ell qq$, $qqqq$
- Decays to W/Z to quarks are reconstructed as a single large jet (J). Tagging with substructure properties / jet mass methods.
- Using as discriminant variable invariant mass or transverse mass
- Main bkg: $qqqq$: multi-j; $\nu\nu qq$: $Z + j$, $W + j$, tt; $\ell\nu qq$: $W + j$, tt; $\ell\ell qq$: $Z + j$
- Strategy: $qqqq$ background fitted with functional form. For the others background estimated from control regions.



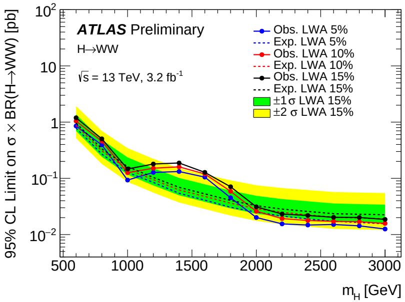
- Excess (2.5σ global) at 8 TeV in the WZ fully hadronic at 2 TeV
  - no excess in 13 TeV but not fully conclusive, need more data

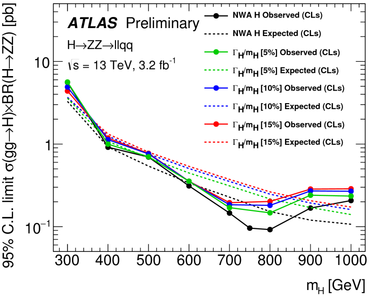




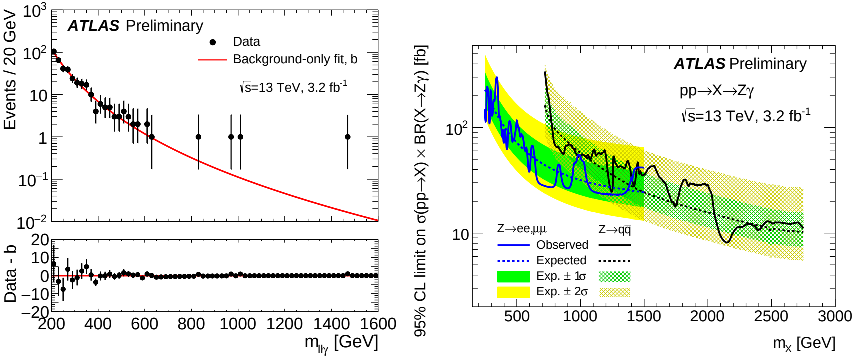


- High mass Higgs searches (NWA, LWA) + RS $G \to ZZ$
- $WW \to \ell\nu\ell\nu$: only different flavours used, $m_T = \sqrt{(E_T^{\ell\ell} + E_T^{\text{miss}})^2 - |\vec{p}_T^{\ell\ell} + \vec{E}_T^{\text{miss}}|^2}$ as observable
- $WW \to \ell\nu qq$: qq reconstructed as a single large jet J, invariant mass as observables ($p_T(\nu) = E_T^{\text{miss}}$, $p_z(\nu)$ from W mass constraint).
- $ZZ \to \ell\ell qq$: resolve analysis (two small separated jets, categories with b-tagging), merged analysis (one large jet).

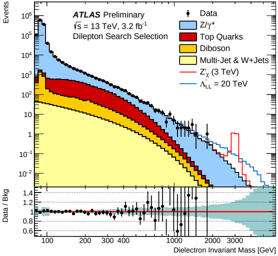


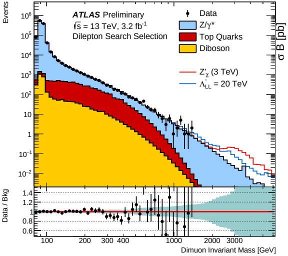


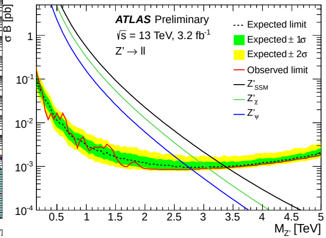
- Search for: narrow scalar boson $\gamma Z(\ell\ell/q\bar{q})$
- Background (hadronic): γj, jj (leptonic): SM $Z\gamma$, $Z+j$
- Strategy: hadronic decay reconstructed as a single large-jet (J). Leptonic limited at 1.5 TeV ($\Delta R = 0.3$). Background fitted with a functional form on data.
- Largest excess (local): 2σ at 350 GeV ($\ell\ell$), 1.8σ at 1.9 TeV ($q\bar{q}$).



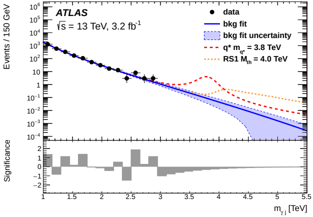
- Search for extended gauge groups (U(1)) Z'/W', GUT inspired model with E_6 groups (6 physical states Z'_χ, Z'_ψ, ...), SSM, RS spin-2 graviton, Z^*, CI
- Main background: DY, top, diboson, multijet
- Strategy: background model from MC or from control regions. Combined $ee/\mu\mu$ channels.

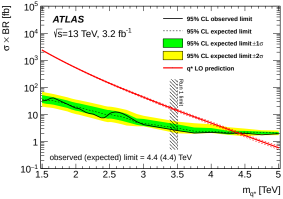


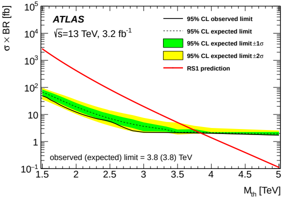


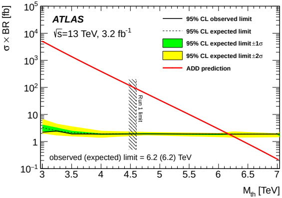


- Search for: $qg \to q^* \to q\gamma$, non-thermal QBH (ADD with 6 extra-dimensions, RS with 1 extra-dimension), generic peak
- Background: SM $qg \to q\gamma$
- Strategy: shape analysis, data-driven background model (functional form validated on MC, Sherpa and JetPhox)
- Major problem: modeling of the background invariant mass distribution over a wide mass range (14 orders of magnitude between 0.5 and 13 TeV)



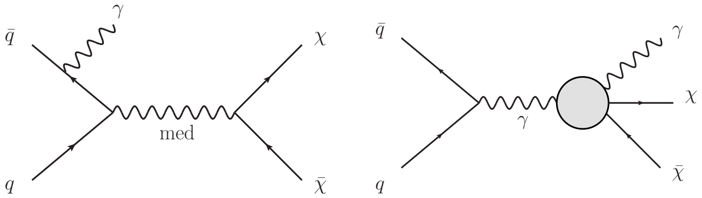


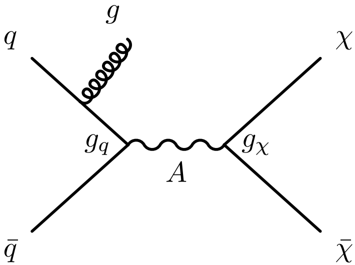




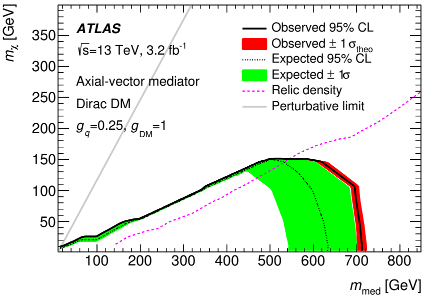
Dark matter

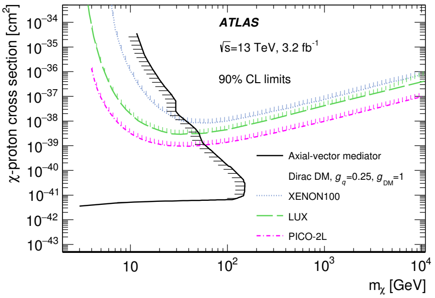
- See talk by Giuliano Gustavino
- explicit s-channel mediator (leptophobic Z'-like model) / EFT describing contact interaction $\gamma\gamma\chi\bar{\chi}$



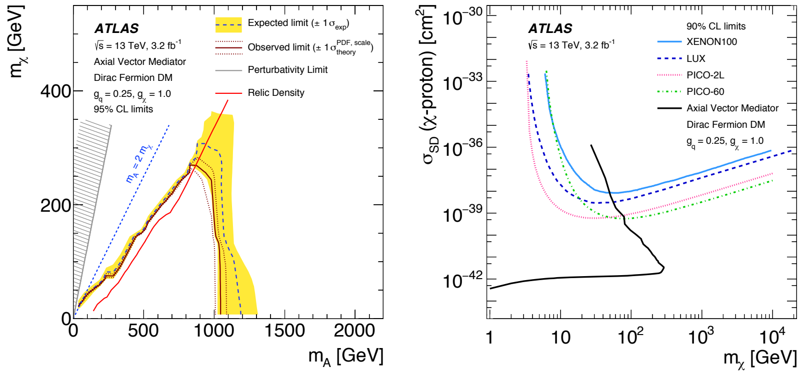


- Search for DM $q\bar{q} \rightarrow \chi\bar{\chi}$. Frameworks: 1) explicit s-channel mediator 2) EFT $\gamma\gamma\chi\bar{\chi}$. Large extra spatial dimensions (LED) graviton.
- Main background: $Z(\nu\nu)\gamma$
- Strategy: cut and count analysis. Background normalization from single-bin CRs ($W\gamma$, $Z\gamma$, $\gamma + j$). $Z(\nu\nu)\gamma$ normalization assumed to be equal to $Z(\ell\ell)\gamma$
- Statistical dominated, main systematics: electron fake-rate

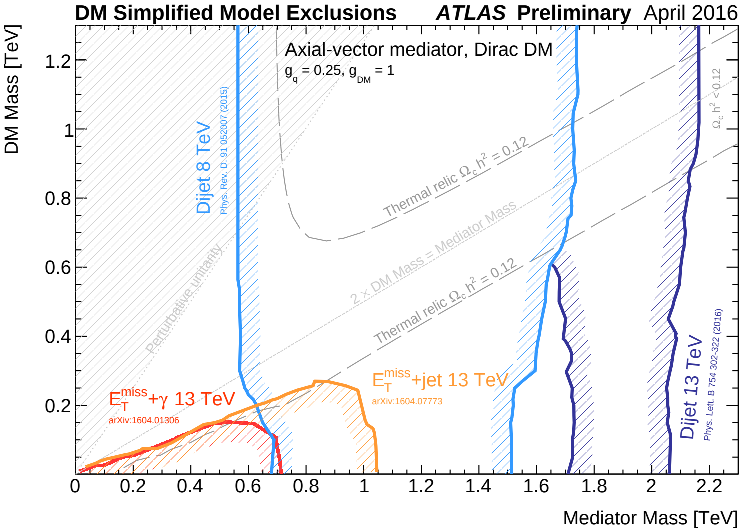




- Search for: DM with explicit s-channel mediator, ADD model for LED, $\tilde{t}_1 \to c + \tilde{\chi}_1^0$, $\tilde{b}_1 \to b + \tilde{\chi}_1^0$, $\tilde{q} \to q + \tilde{\chi}_1^0$
- Main background: $Z(\nu\nu) + j$, $W + j$
- Strategy: cut and count analysis. Most of the backgrounds from control regions. Different signal regions with increasing MET cut ($> 250\,\text{GeV} \ldots 700\,\text{GeV}$)

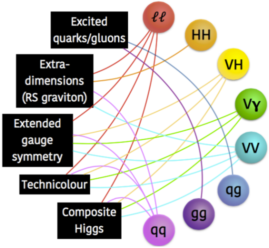


Limit computed in the lepto-phobic axial-vector mediator model.



Conclusions

- Many analyses in exotics, with different signatures and interpretations: see the full list of public results.
- Important to look at small couplings for already "excluded" masses
- Run2 data already competitive with Run1, thanks to the doubled energy
  - Usual question: how to be sure we are not missing something?
- Most important excess (by now): diphoton, 2σ global
  - LHC is ramping fast the luminosity, possibility of a discovery may be not so far

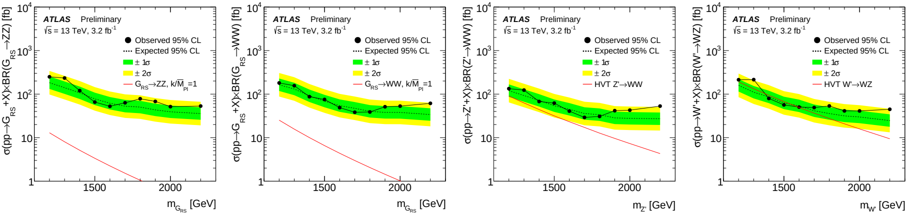



Thanks for your attention

Section 1

Backup

- Search for: HVT $W' \to WZ$ or $Z' \to WW$, spin2-graviton KK $G \to WW$ or ZZ
- Background as functional form: multijets, ...
- Very boosted decay, use large jets tagged with substructure properties and mass

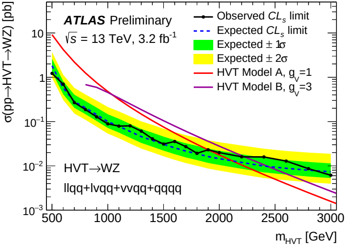


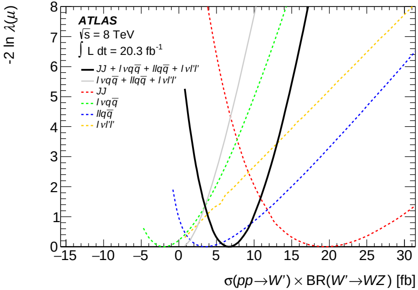
- Not enough statistics to exclude / confirm excess at $\sqrt{s} = 8\,\text{TeV}$ $m_{JJ} \simeq 2\,\text{TeV}$ (3.5σ local, 2.5σ global)

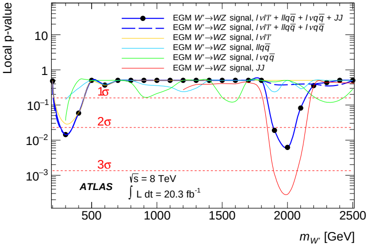
Diboson (fully hadronic)

- Very boosted decay, very collimated, large jet tagged with substructure properties and mass.
- Dominant background from multi-jets, others (V+jet, VV, top, ... quite smaller)
- Background modeled with a functional form, degree of freedom from likelihood ratio test
- Signals: Heavy Vector Triplet (HVT) $W' \to WZ$ or $Z' \to WW$, spin2-graviton KK $G \to WW$ or ZZ.
- dijet background from Pythia (but background is data-driven)
- jet antikt R=1 and 0.4 from topo-cluster and with R=0.2 from tracks. Track-jet are used to identify b-quarks. $H \to bb$ rejected. Cut on number of tracks associated to the large jet
- Lepton veto, $E_T^miss < 250$ GeV
- jet-$p_T > 200$ GeV, $|\eta| < 2$. Leading jet $p_T > 450$ GeV, $1 TeV < m_{JJ} < 2.5 TeV$, small separation $|\Delta y_{12}| < 1.2$ to reduce dijet background (t-channel). Require p_T balanced between two jets, as expected in case of heavy particle decay.
- Binned likelihood, effect on the background modeling checked with s+b fit.

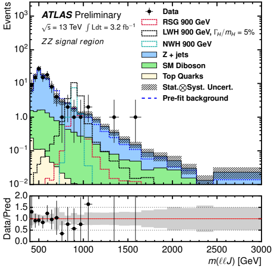
Diboson excess at 8 TeV

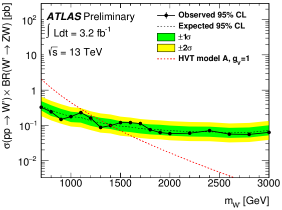


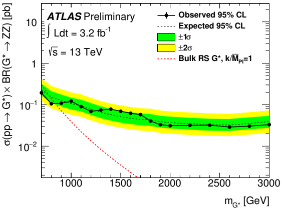


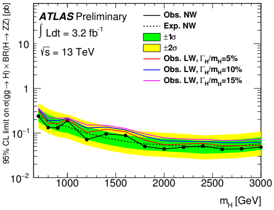


- Search for: Heavy Vector Triplet (HVT) model A ($W' \to ZW$), spin-2 graviton ($G^* \to ZZ$) and SM-like Higgs boson ($H \to ZZ$) narrow or wide
- Second boson (W or Z) reconstructed hadronically as a single jet (jet mass and jet substructure).
- Main background: $Z + j$ from CR extrapolated with MC





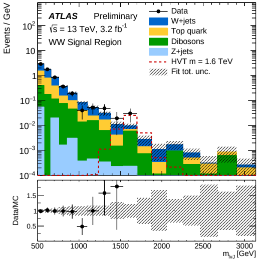




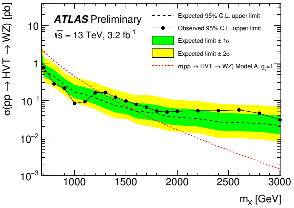
- observed (expected) lower mass limits are 1400 (1400) GeV for the W' and 850 (790) GeV for the G^*

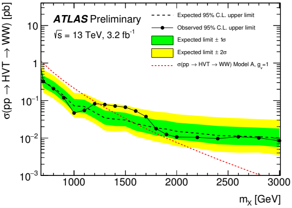
Diboson $ZZ/WZ \to \ell\ell qq$

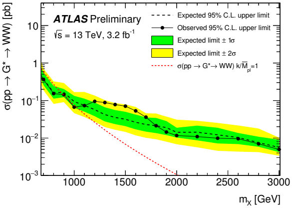
- Di-boson production: dominated by qq annihilation and small contribution from loop-induced gg interaction, with s, u and t-channel.
- Second boson (W or Z) reconstructed hadronically as a single jet (jet mass and jet substructure). Invariant mass between two leptons and large-R jet ($\ell\ell J$).
- ZW: search for Heavy Vector Triplet (HVT) model A ($W' \to ZW$)
- ZZ: search for spin-2 graviton ($G^* \to ZZ$) and SM-like Higgs boson ($H \to ZZ$) narrow or wide
- Main background: $Z + j$ (Sherpa NLO up to 2 partons + LO up to 4 partons), diboson (Sherpa NLO (1 or 0 partons) + LO (up to 3 additional partons), top (PowhegBox). Cross section at NNLO in QCD for Zj, NLO for diboson, NNLO in QCD + NNLL resummation of soft gluon terms for top.
- Selection, same flavor, opposite charge (only for muons):
  - electron: $E_T > 25$ GeV, $|\eta| < 2.47$ except crack. Identification, track isolation. Parameter of impact.
  - muon: $p_T > 25$ GeV, $|\eta| < 2.5$. Identification and track-isolation. Parameter of impact.
  - jet: antikt R=1.0. $p_T > 200$ GeV, $|\eta| < 2.0$
  - dilepton mass consistent with Z. Dilepton-$p_T > 0.4 m_{\ell\ell J}$, jet-$p_T > 0.4 m_{\ell\ell J}$. Jet substructure cut, mass around 15 GeV Z or W.
- Main systematics:jet substructure efficiency
- The corresponding observed (expected) lower mass limits are 1400 (1400) GeV for the W' and 850 (790) GeV for the G^*



- Search for: HVT, KK-graviton, heavy Higgs models.
- Backgrounds: $W + j$ (shape from simulation + normalization in CR), top
- Main uncertainty on the shape of W/Z+jets







Diboson $WW/WZ \to \ell\nu qq$

- Difficult to resolve the two jets from W/Z: use large jet and substructure
- Signals: Heavy vector triplet (HVT). New boson (V') couples to the Higgs and the SM gauge bosons and to fermions. Kaluza-Klein (KK) graviton (G^*) for narrow decay into WW. Narrow (4 GeV) and large (5-15%) width heavy Higgs models (above 15% already excluded).
- Main background from $W + j$ (Sherpa), top quarks (PowhegBox), multijets, diboson (Sherpa) and $Z + j$ (Sherpa).
- Selection:
  - electrons: identification, $p_T > 25$ GeV, $|\eta| < 2.47$ excluding crack, calo and track-isolation, impact parameter
  - muons: identification, $p_T > 25$ GeV, $|\eta| < 2.5$, impact parameter
  - jets: antikt R=1 (large jets) with boson tagger using jet substructure and jet-mass or with R=0.2 (small jets)
  - event: $E_T^{miss} > 100$ GeV, 1 lepton, $p_T(\ell\nu) > 200$ GeV, $p_T(J)/m_{\ell\nu J} > 0.4$ and $p_T(\ell\nu)/m_{\ell\nu J} > 0.4$ since the two bosons are mostly in the central part of the detector. Cut on the Z or W mass using the jet mass.
- Background estimation
  - Control regions defined for top and W+jets.
  - W/Z+jets, top background from simulation, normalization data-driven using control regions.
  - top from simulation with NLO cross section
  - multijet data-driven, and negligible
- Main uncertainty on the shape of W/Z+jets, computed comparing data-driven to simulation

Dijet mass analysis

- Mass analysis: quantum black-holes (ADD, RS1), exited quarks ($qg \to q^* \to qg$, $q = u, d$), W', leptophobic-Z', generic search, high-mass tail change and χ: contact interaction (new mediating particles)
- shape from simulation in various m_{jj} ranges. Main uncertainties from scales (max 20%), jet energy scale (25%).
- search for resonant and non-resonant excess in the invariant mass spectrum
- background modeled with a functional form, likelihood ratio test to choose the number of degrees of freedom
- BumbHunter to search for an excess
- jets reconstructed with antikt 0.4 from topological cluster
- dijet mass resolution: 2.4% (2 TeV), 2% (5 TeV). Jet energy scale uncertainty 1-3%
- QCD background from Pythia 8 reweighted to NLOJET++ (NLO)
- Selection $p_T > 440, 50$ GeV, high trigger efficiency for $|y^*| < 1.7$, $|y^*| < 0.6$ ($\chi < 3.3$) to reduce QCD background, $m_{jj} > 1.1$ TeV
- Mass analysis: Bayesian limits with constant prior for the cross section approximately 50-300 fb for masses below 2 TeV to 2-20 fb for masses above 4 TeV

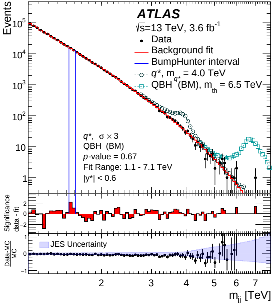
Dijet angular analysis

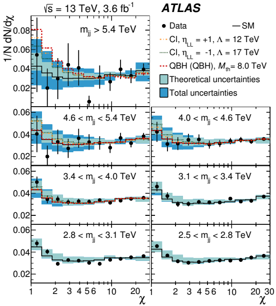
- angular analysis: θ^*: polar angle in the dijet center of mass frame. Many theories BSM predict activity at large angles with respect to the beam.

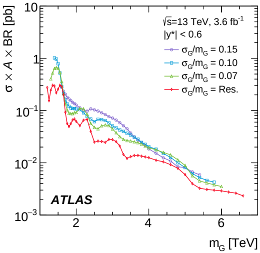
$$\chi = e^{2|y^*|} \simeq \frac{1+\cos\theta^*}{1-\cos\theta^*} \qquad y^* = (y_3 - y_4)/2 = \text{ rapidity between two jets}$$

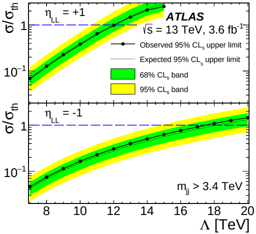
. χ is Lorentz invariant and uniform in the SM

- angular analysis: $|y^*| < 1.7$ ($\chi < 30$) and $y_B = (y_3 + y_4)/2 < 1.1$, $m_{jj} > 2.5$ TeV
- CLs from profiled likelihood ratio for contact interaction and QBH
- With the angular selection, 95% confidence-level lower limits are set on the compositeness scale of contact interactions at 12.0 TeV (17.5 TeV) for destructive (constructive) interference between the new interaction and QCD processes


ATLAS
√s=13 TeV, 3.6 fb-1
Data
Background fit
BumpHunter interval
q*, mq* = 4.0 TeV
QBH (BM), mth = 6.5 TeV
q*, σ × 3
QBH (BM)
p-value = 0.67
Fit Range: 1.1 - 7.1 TeV
|y*| < 0.6
Events
Significance data - fit
JES Uncertainty
Data-MC / MC
mjj [TeV]


√s = 13 TeV, 3.6 fb-1
ATLAS
Data
SM
CI, ηLL = +1, Λ = 12 TeV
CI, ηLL = -1, Λ = 17 TeV
QBH (QBH), Mth= 8.0 TeV
Theoretical uncertainties
Total uncertainties
1/N dN/dχ
mjj > 5.4 TeV
4.6 < mjj < 5.4 TeV
4.0 < mjj < 4.6 TeV
3.4 < mjj < 4.0 TeV
3.1 < mjj < 3.4 TeV
2.8 < mjj < 3.1 TeV
2.5 < mjj < 2.8 TeV
χ


√s=13 TeV, 3.6 fb-1
|y*| < 0.6
σG/mG = 0.15
σG/mG = 0.10
σG/mG = 0.07
σG/mG = Res.
ATLAS
σ × A × BR [pb]
mG [TeV]

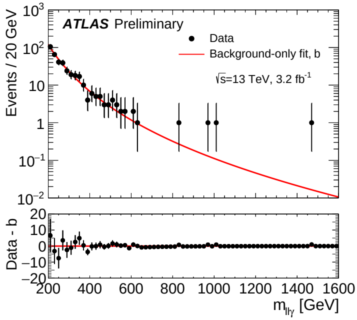

ηLL = +1
ATLAS
√s = 13 TeV, 3.6 fb-1
Observed 95% CLs upper limit
Expected 95% CLs upper limit
68% CLs band
95% CLs band
ηLL = -1
mjj > 3.4 TeV
σ/σth
Λ [TeV]

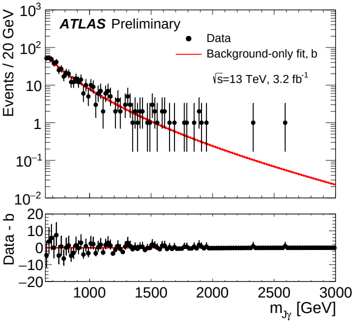
- Limits on: exited quarks ($qg \rightarrow q^* \rightarrow q\gamma$), non-thermal quantum black-holes (ADD with 6 extra-dimensions, RS with 1 extra-dimension), generic peak for several widths
- Background: SM $qg \rightarrow q\gamma$
- Selection: $\Delta\eta(\gamma, j) > 1.6$, photon: $p_T >$150 GeV, identification, $|\eta| <$1.37 (barrel-only), calorimetric isolation, jet-$p_T >$150 GeV
- Strategy: shape analysis, data-driven background model (validated on MC, Sherpa and JetPhox)
- Major problem: modeling of the background invariant mass distribution over a wide mass range (14 orders of magnitude between 0.5 and 13 TeV)

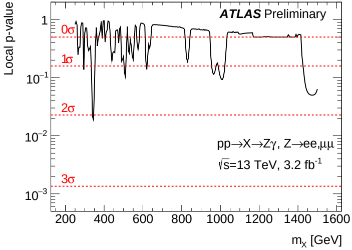
$Z\gamma$

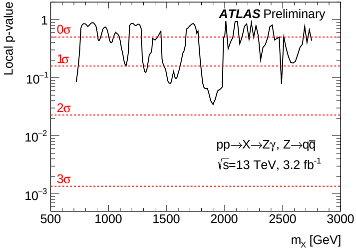
- Z leptonic and hadronic decays, upper limits on $\sigma \times Br$ of a narrow (4 MeV) scalar boson (Higgs like spin 0 via gg-fusion) with mass 250 GeV - 2.75 TeV.
- Narrow resonance $Z \rightarrow ll/qq$ (qq dominant at high-mass)
- Main background, leptonic analysis: continum $Z\gamma$ production + jet faking photons, hadronic analysis: γj and dijet
- Selection efficiency on Z: 77%
- Background modeled with a functional form. Degree of freedom from F-test. Spurious signal as systematics: signal fitted on a sample mixing $Z + \gamma$ and $Z + j$ (90% and 10% measured on data for leptonic analysis) or on $\gamma + j$ (for hadronic analysis, 93% of the background)
- Background from Sherpa, signal from Powheg
- Z leptonic selection: opposite sign, same flavor, photon-p_T ¿ 0.3 $m_{Z\gamma}$
- Z hadronic selection: photon $p_T > 250$ GeV. Jet substructure and jet invariant mass cuts. Lepton veto.
- photon: $|\eta| < 2.37$ except crack region, $p_T > 15$ GEV, identification, isolation.
- electron: $p_T > 10$ GeV $|\eta|$ ¡ 2.47 excluding crack, identification, isolation
- muons $|\eta| < 2.7$, identification, $p_T > 10$ GeV, isolation
- jet antikt $R = 1$: $p_T > 200$ GeV, $|\eta| < 2$. Soft small jets $R = 0.2$ removed from the large jet. Cuf on jet-substructure quantity to identify boosted Z. Mass close to the Z (15 GeV).
- In the leptonic channel correction for FSR, Z-mass-constrain, pointing.
- Signal model: double sided CB (leptonic) or sum of CB and gaussian (hadronic). Efficiency: 28%-43% (leptonic), 11%-15% (hadronic)
- Statistical dominated. Main uncertainties. Leptonic: photon and electron resolution, spurious signal, luminosity. Statistical dominated. Hadronic: jet mass resolution, jet and

$Z\gamma$


ATLAS Preliminary
Data
Background-only fit, b
√s=13 TeV, 3.2 fb-1
Events / 20 GeV
Data - b
m_llγ [GeV]

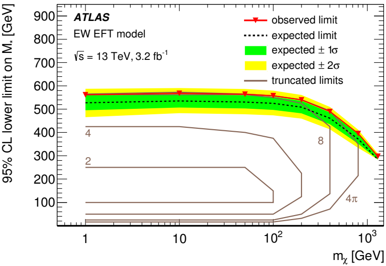

ATLAS Preliminary
Data
Background-only fit, b
√s=13 TeV, 3.2 fb-1
Events / 20 GeV
Data - b
m_Jγ [GeV]

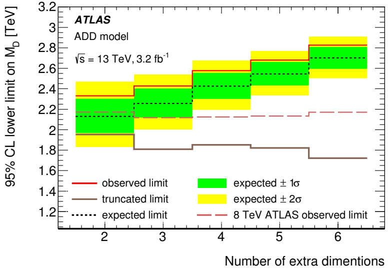

ATLAS Preliminary
0σ
1σ
2σ
3σ
pp→X→Zγ, Z→ee,μμ
√s=13 TeV, 3.2 fb-1
Local p-value
m_X [GeV]


ATLAS Preliminary
0σ
1σ
2σ
3σ
pp→X→Zγ, Z→qq̄
√s=13 TeV, 3.2 fb-1
Local p-value
m_X [GeV]

Monophoton (photon + MET)
Submitted to JHEP, 1604.01306

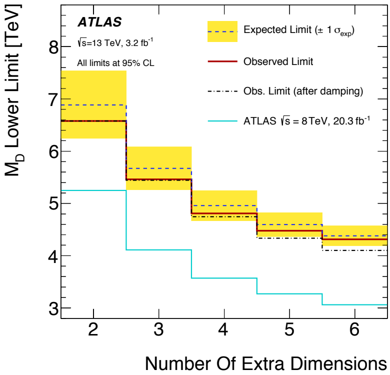
- Search for DM $q\bar{q} \rightarrow \chi\bar{\chi}$: γ(ISR) + MET
  - s-channel mediator with axial-vector interactions, 5 parameters: WIMP mass m_χ, mediator-mass m_{med}, width of the mediator Γ_{med}, coupling of mediator to quarks g_q, coupling of mediator to WIMP g_χ
- tight, isolated photons, $p_T > 150\,\text{GeV}$, $|\eta| < 2.37$
- MET$> 150\,\text{GeV}$, $\Delta\phi(\gamma, MET) > 0.4$, reject if $\Delta\phi(MET, j) < 0.4$ or multiple jets
- No electrons, no muons
- CRs: 1muCR ($W\gamma$), 2muCR 2eleCR ($Z\gamma$), PhJetCR ($\gamma + j$)
- scale factors: $k_{W\gamma} = 1.50 \pm 0.26$, $k_{Z\gamma} = 1.19 \pm 0.21$, $k_{\gamma j} = 0.98 \pm 0.28$
- Number of events in SR (264) compatible with SM (295 ± 34)
- Limit on $\sigma \times A$ using as efficiency as the lowest among the considered signals (78%): 17.8 fb at 95% CL





Monojet

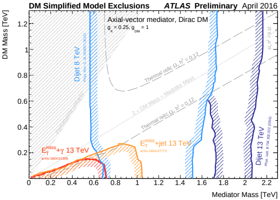
- s-channel exchange of a spin-1 mediator particle with axial-vector couplings is considered, connecting the quarks to WIMPs of a Dirac fermion type.
- defined by four free parameters: the WIMP mass m_χ, the mediator mass m_A, the coupling of the mediator to WIMPs (g_χ) and the flavor-universal coupling to quarks (g_q)
- MET $> 250\,\text{GeV}$, jet-$p_T > 250\,\text{GeV}$, $|\eta| < 2.4$, $\Delta\phi(jet, p_T^{\text{miss}}) > 0.4$, lepton-veto
- Simultaneous fit of CR+SR (repeated for every SR). Limit of visible cross sections.



Dijet with 1 or 2b

- b-tagging: MVA with impact parameters of tracks associated with the jet, the presence of displaced secondary vertices, and the reconstructed flight paths of b and c hadrons associated with the jet. 85% efficiency (from $t\bar{t}$). Data-driven correction.

Limit computed in the lepto-phobic axial-vector mediator model. Regions in a dark matter mass–mediator mass plane excluded at 95% CL by a selection of ATLAS dark matter searches, for one possible interaction between the Standard Model and dark matter, the lepto-phobic axial-vector mediator described in arXiv:1507.00966. The exclusions are computed for a dark matter coupling gDM $= 1.0$ and a quark coupling $g_q = 0.25$ universal to all flavors, a value chosen to weaken the constraints from searches for the mediator decaying to jets. The exclusions from the ATLAS dijet searches are derived from the limits provided on Gaussian-shaped resonances following the procedure recommended by ATLAS in Appendix A of Phys. Rev. D91 052007 (2015). Dashed curves labeled "thermal relic" indicate combinations of dark matter and mediator mass that are consistent with a dark matter density of $\Omega_c = 0.12h^{-2}$ and a standard thermal history, as computed in MadDM. Between the two curves, annihilation processes described by the simplified model deplete Ω_c below 0.12 h^{-2}. A dotted curve indicates the kinematic threshold where the mediator can decay on-shell into dark matter. Points in the plane where the model is in tension with the perturbative unitary considerations of JHEP 02 016 (2016) are indicated by the shaded triangle at the upper left. The exclusion regions, relic density contours, and unitarity curve are not applicable to other choices of coupling values or model.



Considered models

- Exited quarks: consequence of quark compositeness models that were proposed to explain the generational structure and mass hierarchy of quarks
- HVT (Heavy Vector Triplet): $W' \to WZ$, $Z' \to WW$. Generic framework, to search narrow vector resonances. Dominant production from $q\bar{q}$ s-channel. HVT $\neq$ EGM (e.g. EGM considers off-shell production).
- EGM (Extended Gauge model) (used in Run1 diboson hadronic): $W' \to WZ$. WWZ coupling as in the SM but scaled to keep W' width narrow.
- Z': many extensions to the SM with an additional U(1) group
- Extradimensions: lower the scale of gravity in an higher-dimensional space. Quantum black holes, string balls.
- spin-2 graviton: Kaluza-Klein (KK) modes of the graviton in a Randall-Sundrum (RS) model
- ADD: n additional flat extra dimensions
- Higgs NWA (narrow width approximation): width smaller than the experimental resolution. Interference with SM negligible.
- Higgs LWA (large width approximation): several widths considered $5 - 15\%$ (larger already excluded)