

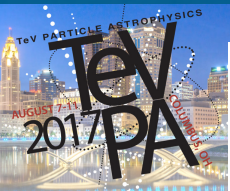
# Searches for dark matter beyond mono-jets at the ATLAS experiment

Rui Wang

Argonne National Laboratory

*On behalf of the ATLAS Collaboration*

*TeVPA 2017, August 11th, 2017*



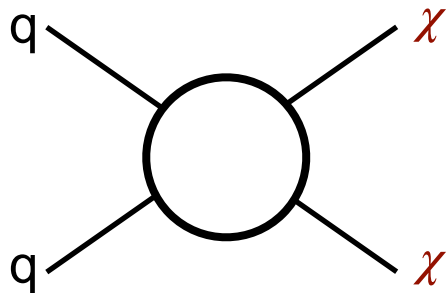
# DM models used at ATLAS

1507.00966

details in Wendy Taylor's talk

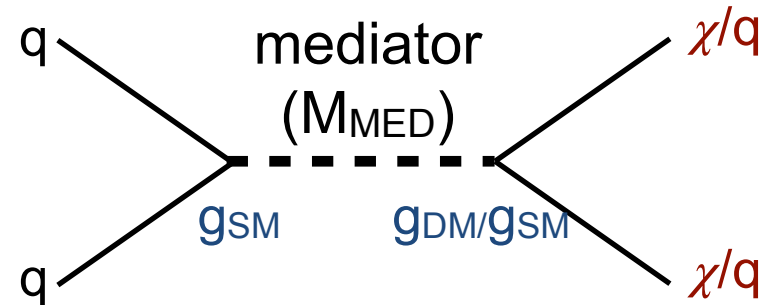
## Effective field Theory

- $m_{\text{DM}}$ ,  $M^*$ , underlying coupling type, DM types
- Valid when mediator of the interaction between SM and DM particles are very heavy



## Simplified model

- Standardized for ATLAS&CMS Run2
- Relatively light mediator (TeV-scale)
- Mediator has minimal decay width
- Minimal flavor violation
- Minimal set of parameters
  - Coupling structure,  $M_{\text{MED}}$ ,  $m_{\text{DM}}$ ,  $g_{\text{SM}}$  ( $g_q$ ),  $g_{\text{DM}}$

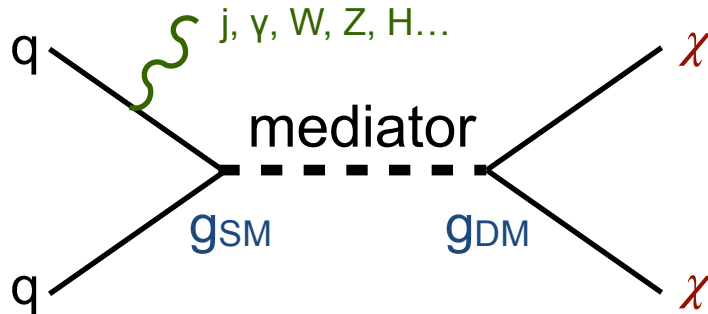


LHC DM forum and working group

— Antonio Boveia's talk

# DM search in Mono-X

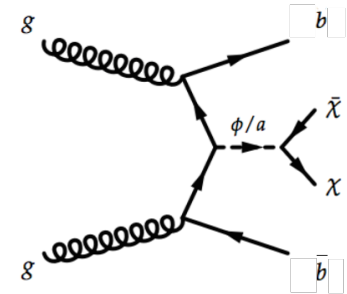
- Directly produced Dark Matter ( $g_q$  &  $g_{DM}$ )
  - Pair production of DMs
  - Mono-X signature
    - MET +  $bb$ ,  $tt$ ,  $Z(\ell\ell)$  covered by this talk
      - Using control regions to constrained background from known processes
      - Further suppress the backgrounds



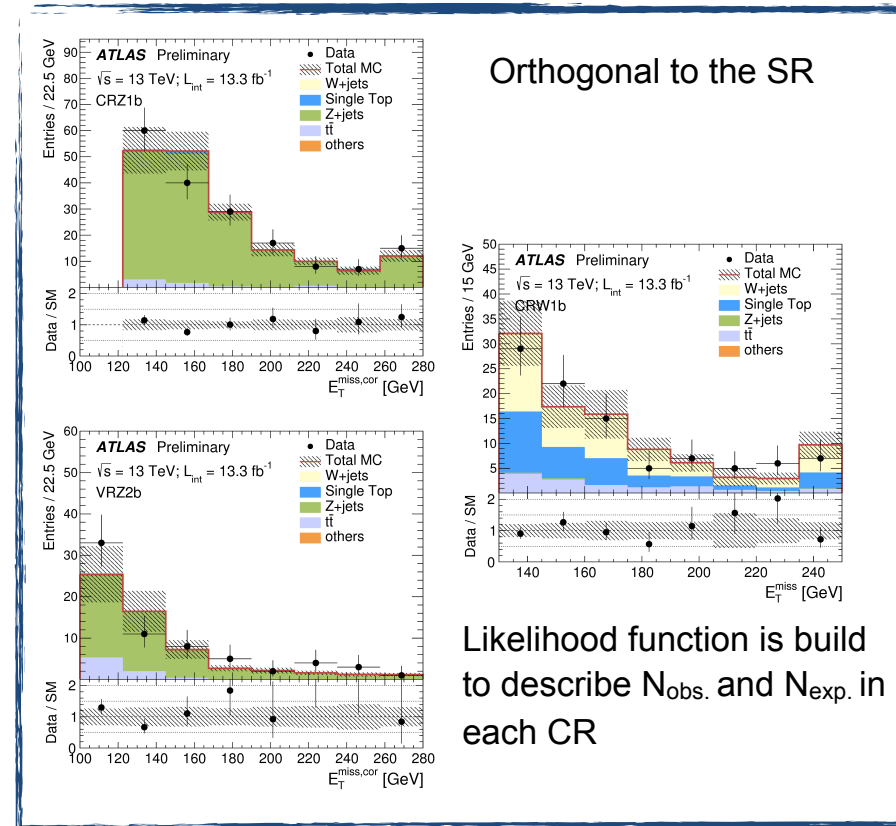
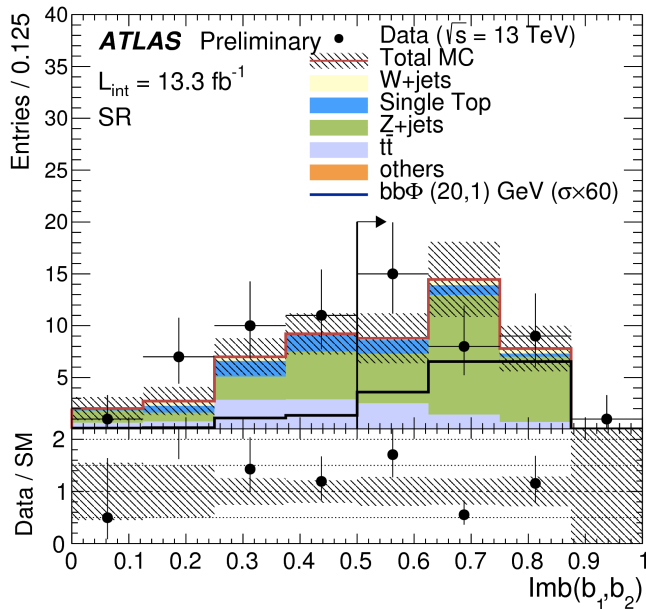
MET +  $\gamma$ ,  $W/Z(\text{had})$ , Higgs in Wendy Taylor's talk

# MET+bb

- Motivation to a search in association with Heavy Flavour quarks
- Mediator is a (pseudo-) scalar, DM is a dirac fermion
  - Assumes Yukawa-like couplings between mediator and SM fermions
- Events with  $E_{\text{miss}}^T > 150$  GeV, two b-tagged jets



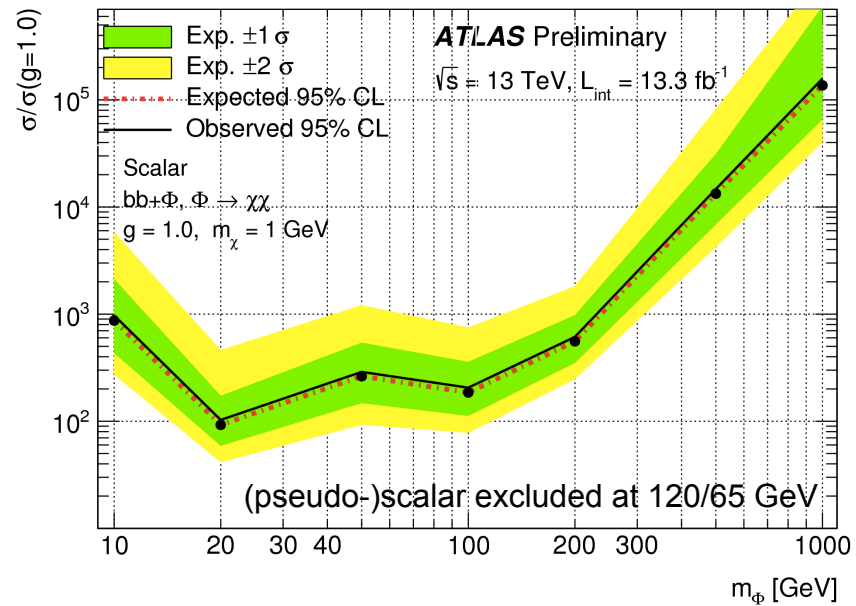
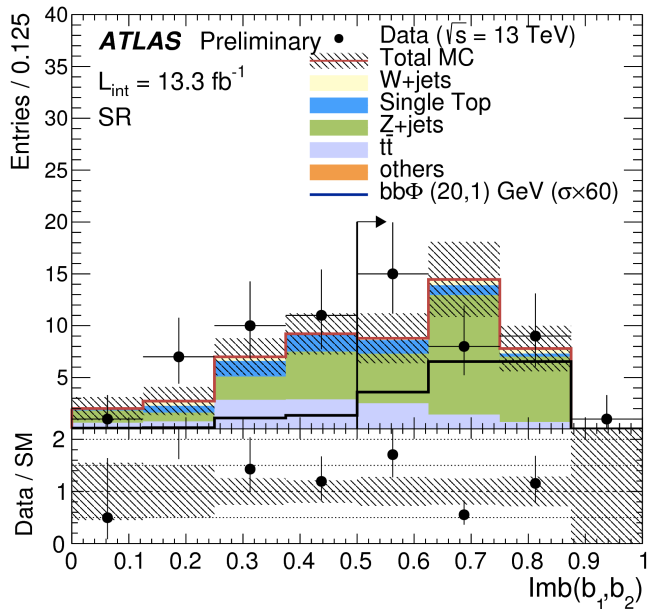
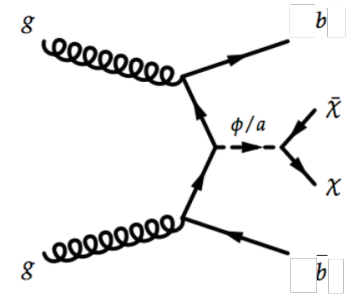
$N_{\text{obs.}}$  in the CRs are used in combined profile likelihood fit to determine the expected SM background yields in the SR



Likelihood function is build to describe  $N_{\text{obs.}}$  and  $N_{\text{exp.}}$  in each CR

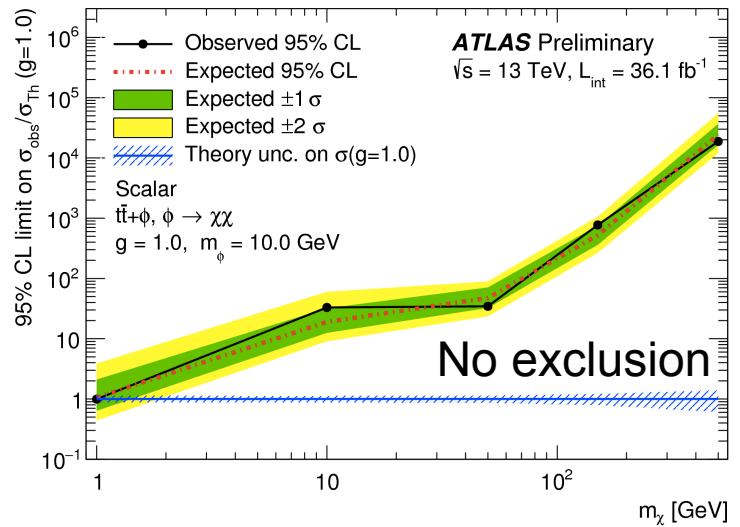
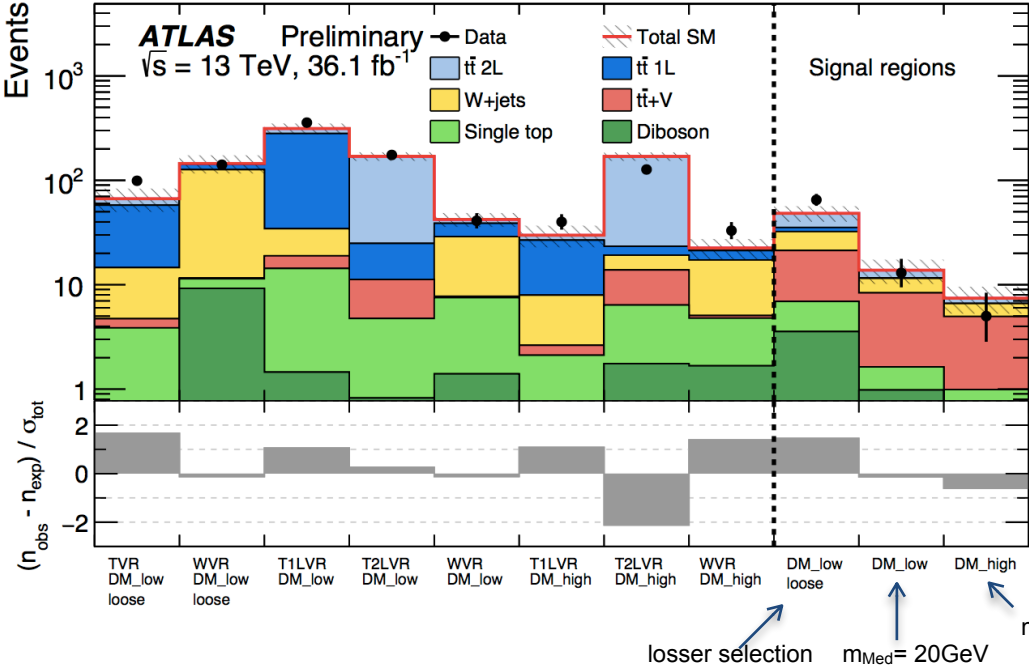
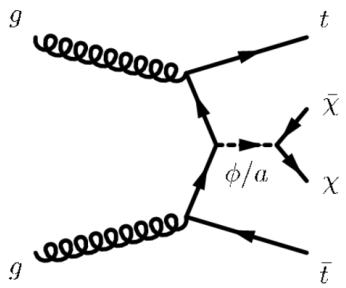
# MET+bb

- Motivation to a search in association with Heavy Flavour quarks
- Mediator is a (pseudo-) scalar, DM is a dirac fermion
  - Assumes Yukawa-like couplings between mediator and SM fermions
- Events with  $E_{\text{miss}}^T > 150$  GeV, two b-tagged jets
- Background dominated by  $Z \rightarrow \nu\nu$ 
  - large dR between jets ( $> 2.8$ )
  - $\text{Imb}(b_1, b_2) = (p_T(b_1) - p_T(b_2)) / (p_T(b_1) + p_T(b_2)) > 0.5$



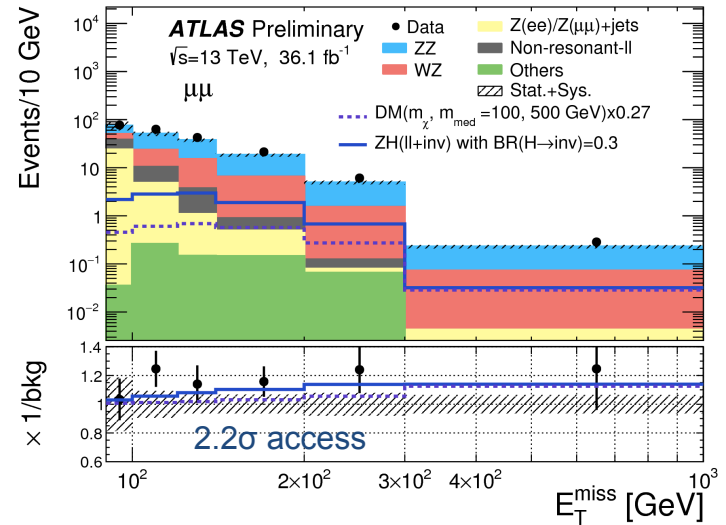
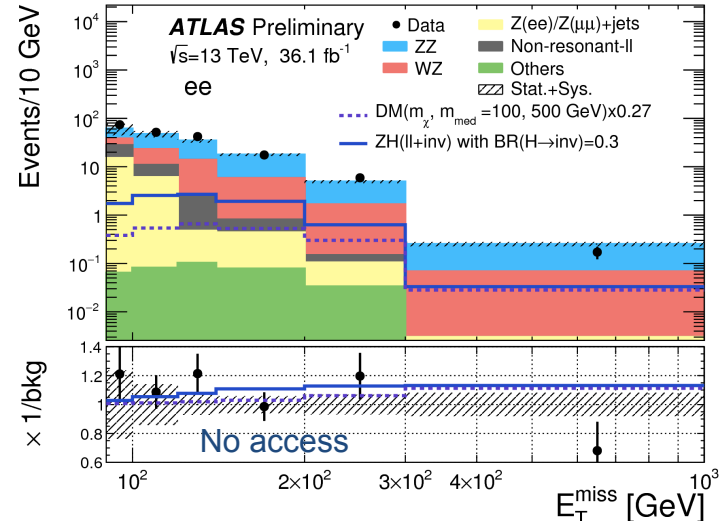
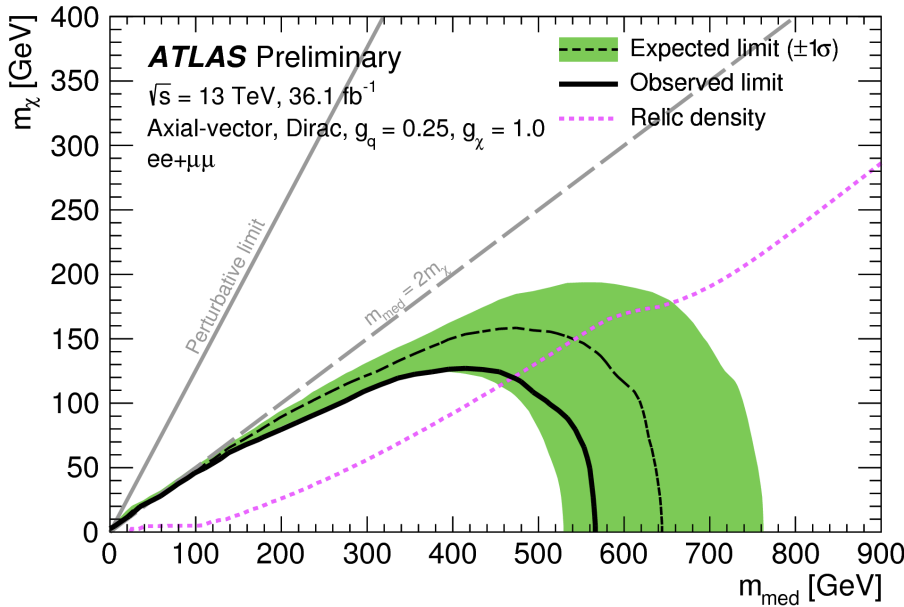
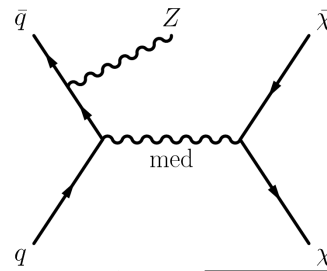
# MET+tt

- Motivation to a search in association with Heavy Flavour quarks
- Similar DM model as MET+bb
- Events with MET+tt(had, 1L, 2L)
  - Same final state as for SUSY 1-lepton EW searches



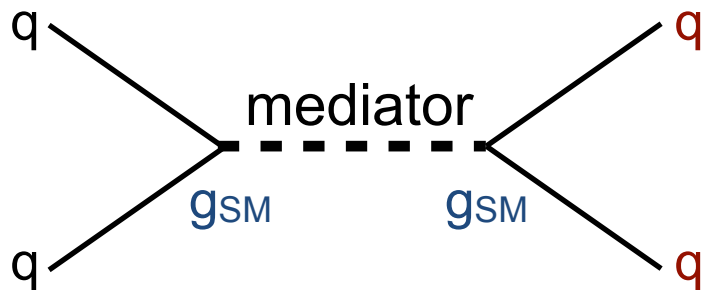
# MET+Z(II)

- Axial-vector mediator, DM is a dirac fermion
- Events with a boosted Z (ee/μμ pair) back-to-back with MET
  - MET > 90 GeV, MET/H<sub>T</sub>>0.6
  - ΔΦ(Z, MET) > 2.7, ΔR(l<sub>l</sub>) < 1.8, b-veto
- Background dominated by ZZ and WZ



# DM search in Di-X

- Search for mediator ( $g_q$  &  $g_q$ )
  - Pair production of SM final state
  - di-jet, di-b-jet, tt, di-lepton covered by this talk

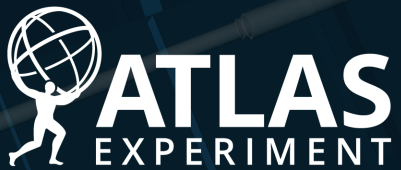


- Probing TeV resonances generically
- Mediator mass search usually limited by the trigger threshold
  - Special treatment needed to go to lower mass



Highest mass di-jet event

di-jet: EXOT-2016-21



Run: 305777

Event: 4144227629

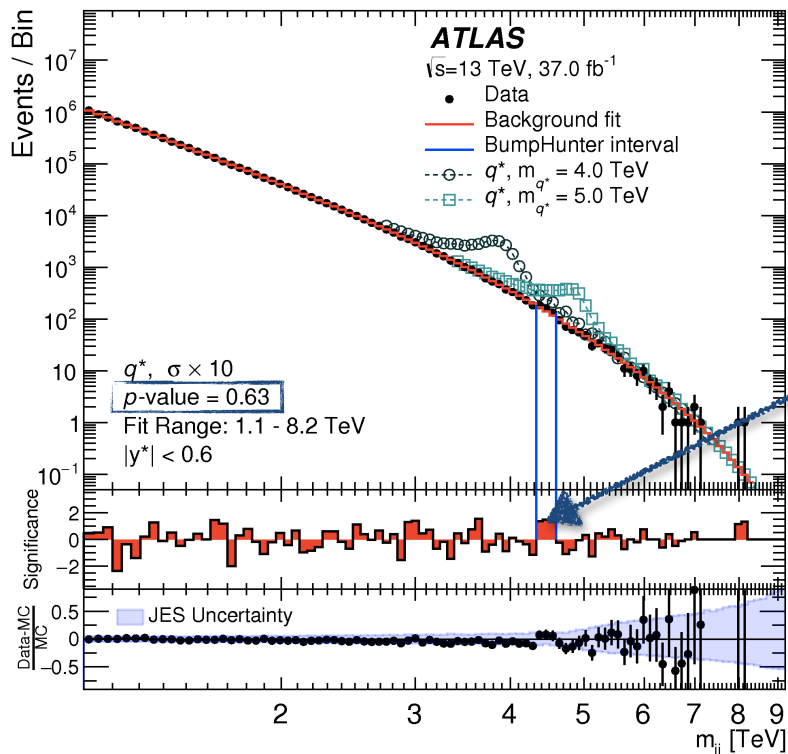
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Rui Wang

# Di-jet

- Narrow resonance search above 1.1 TeV
  - Signal jet trigger
  - $p_{T,1} (p_{T,2}) > 440 (60) \text{ GeV}$
  - $|y^*| < 0.6, y^* = (y_1 - y_2)/2$



Narrow peak on top of the smooth falling  
QCD background

Use *Bumphunter* to search for possible excess

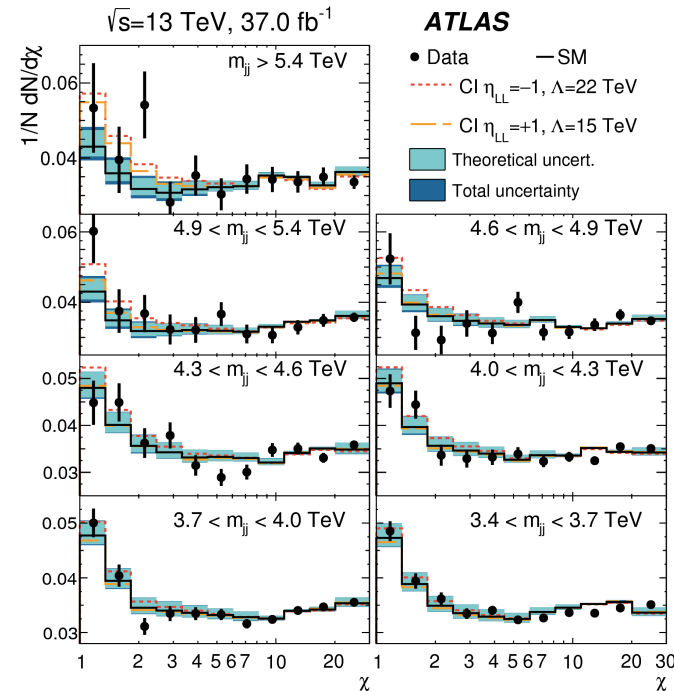
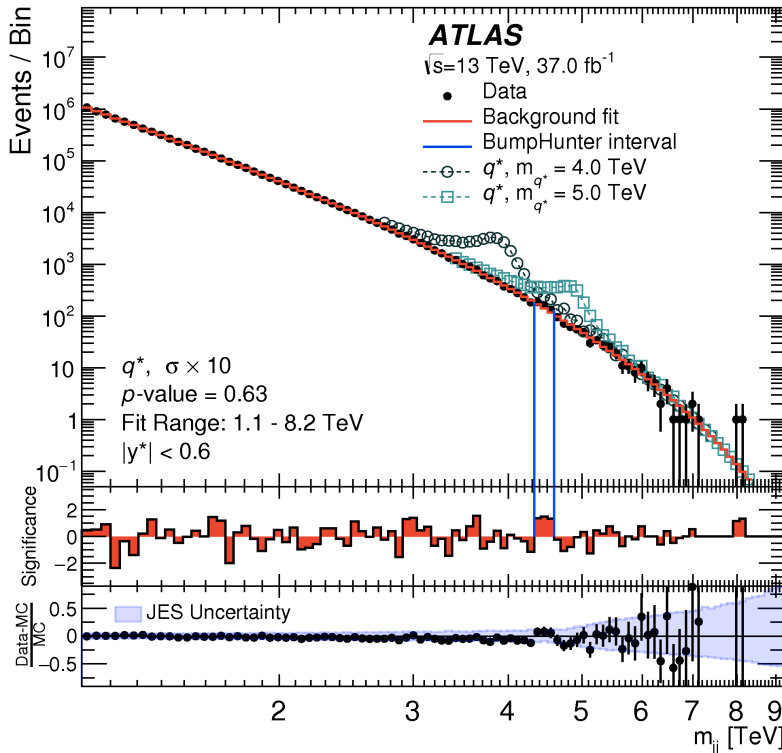
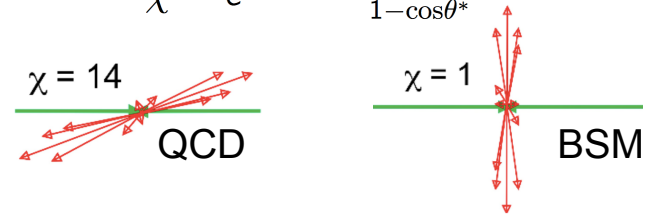
- Looking for the most significant deviation from the background spectrum
- Bump hunter **p-value** reflects the bins that have the smallest probability of arising from a background fluctuation (assuming poisson statistics)

# Di-jet

- Narrow resonance search above 1.1 TeV
  - Signal jet trigger
  - $p_{T,1} (p_{T,2}) > 440 (60)$  GeV
  - $|y^*| < 0.6, y^* = (y_1 - y_2)/2$

- Angular search — sensitive to wide mediators or non-resonant signature

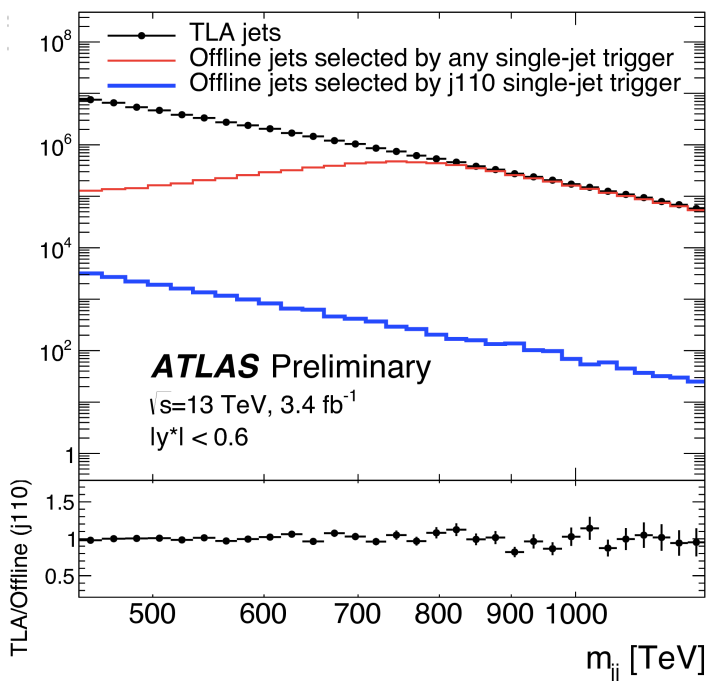
$$\chi = e^{2|y_1^*|} \sim \frac{1 + \cos\theta^*}{1 - \cos\theta^*}$$



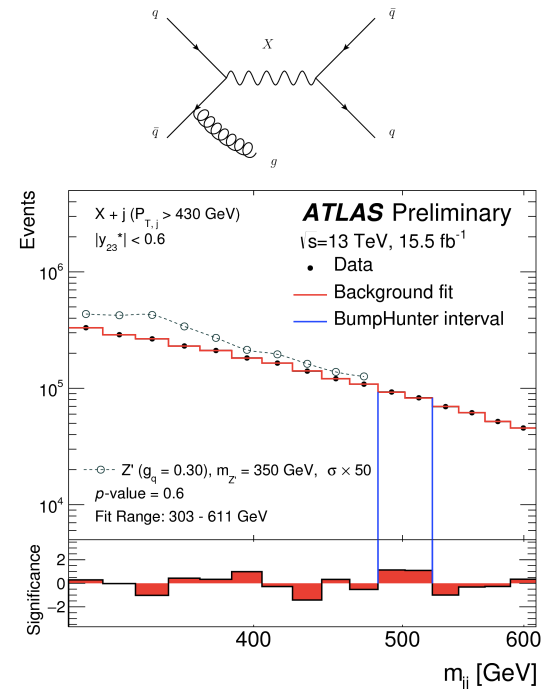
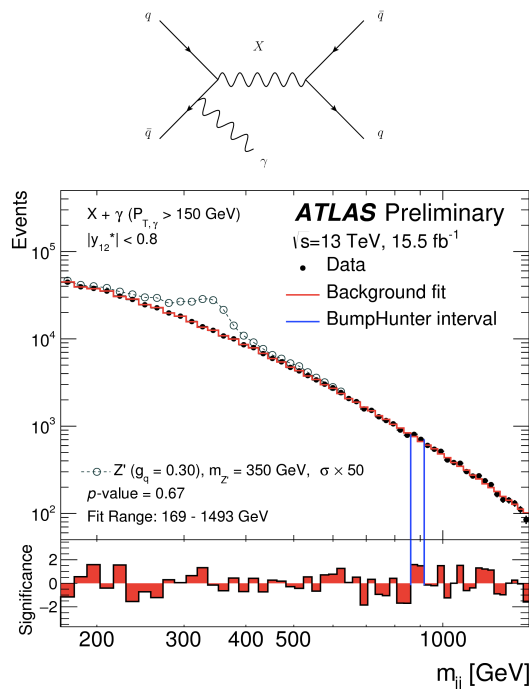
# TLA + di-jet ISR — Expand to lower $m_{jj}$

- TLA (trigger level analysis) — use Data Scouting stream
  - Stores partial event informations (~ 5% of full event)
  - dedicated jet calibration for trigger level (TL) jets

- Trigger selection on ISR objects
  - Jets  $p_T > 25$  GeV,  $|\eta| < 2.8$
  - $\gamma+JJ$  :  $\gamma$   $p_T > 150$  GeV,  $|y_{12}^*| < 0.8$ ,  $\Delta R_{\gamma, \text{closest}} > 0.85$
  - J+JJ :  $p_{T,1} > 430$  GeV,  $|y_{23}^*| < 0.6$



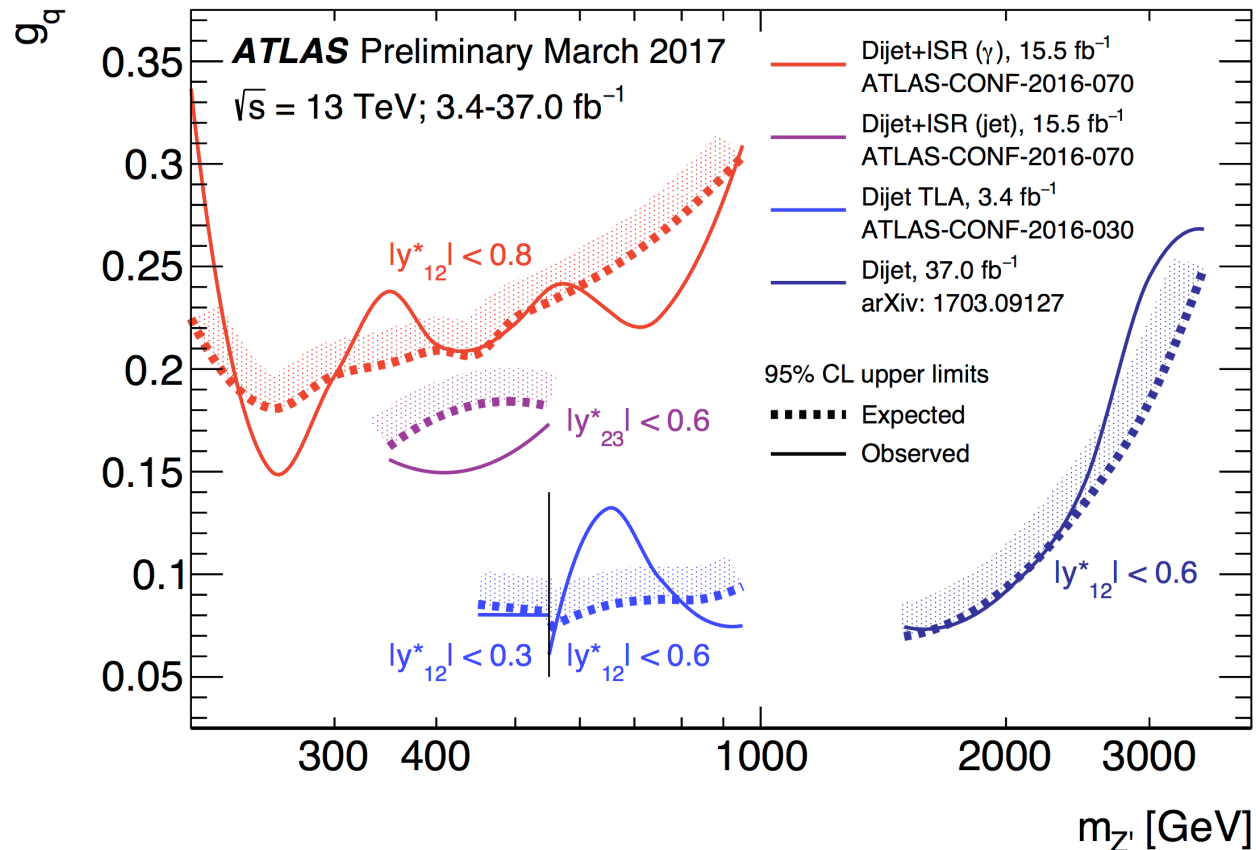
ATLAS-CONF-2016-030



ATLAS-CONF-2016-070

# Di-jet limits

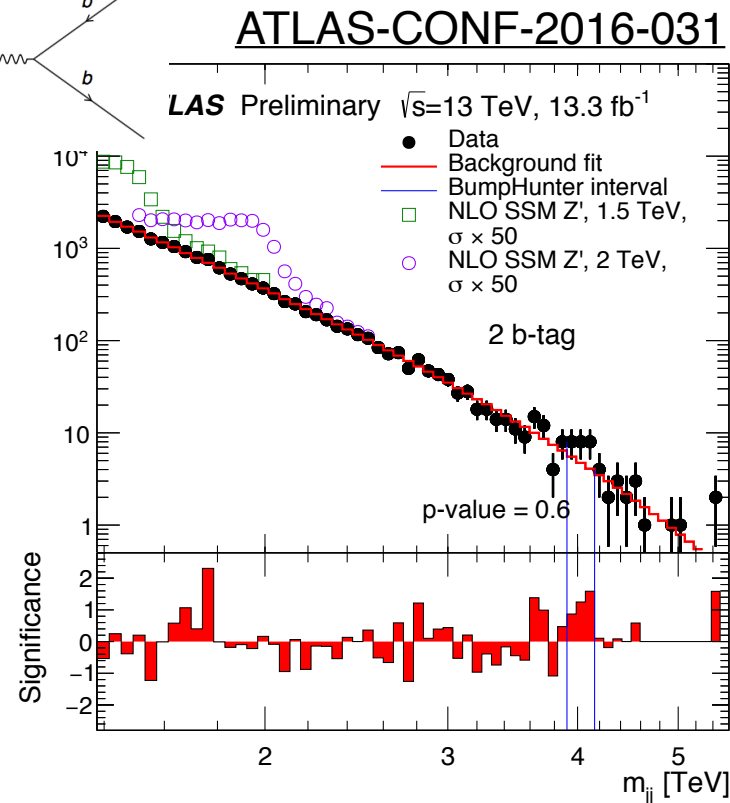
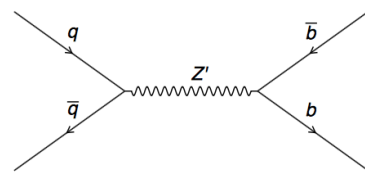
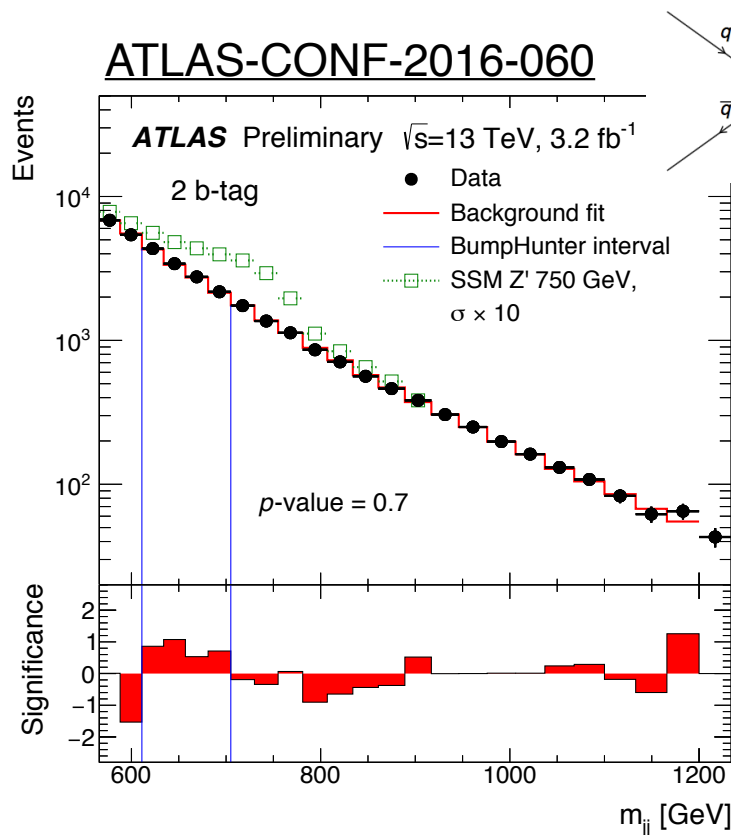
- ATLAS bounds in the coupling-mediator mass plane of leptophobic  $Z'$  DM mediator from di-jet searches using 2015 and 2016 data



Ref: [https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CombinedSummaryPlots/EXOTICS/ATLAS\\_DarkMatterCoupling\\_Summary/ATLAS\\_DarkMatterCoupling\\_Summary.png](https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CombinedSummaryPlots/EXOTICS/ATLAS_DarkMatterCoupling_Summary/ATLAS_DarkMatterCoupling_Summary.png)

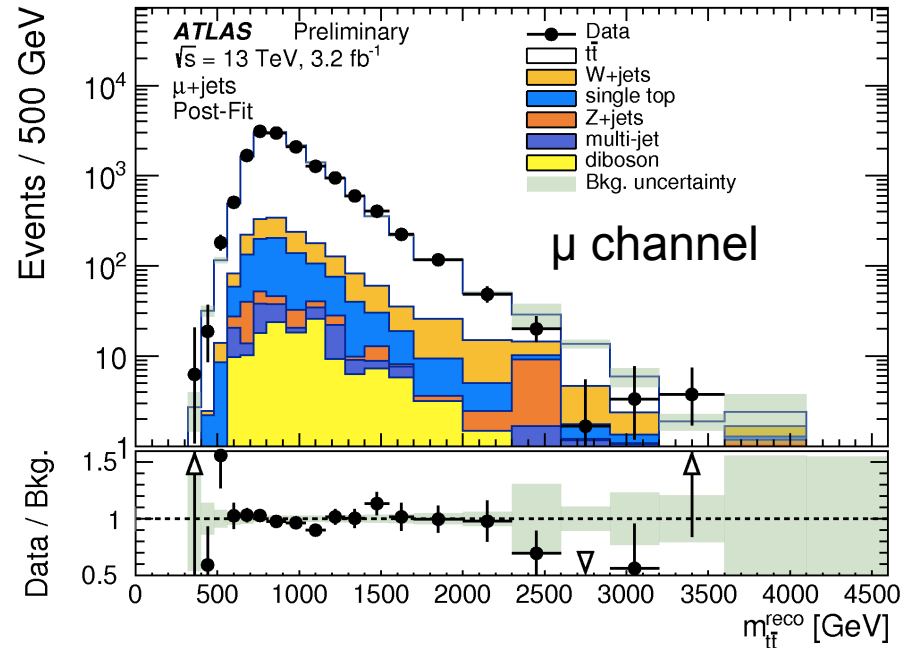
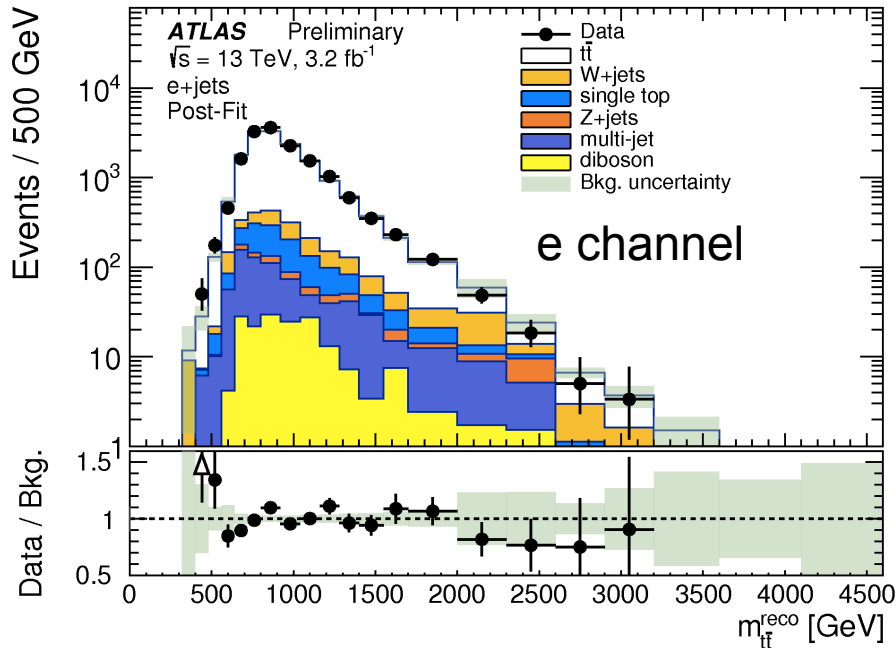
# Di-b-jet — couple preferentially to b-quark

- Narrow resonance search with b-tagged jets
- Low mass -  $570 < m_{jj} < 1200$  GeV
  - $p_{T,1}$  ( $p_{T,2}$ )  $> 250$  (60) GeV
  - $|y^*| < 0.6$ ,  $y^* = (y_1 - y_2)/2$
  - b-tagged trigger + offline 2 b-tag
- High mass —  $m_{jj} > 1380$  GeV
  - $p_{T,1}$  ( $p_{T,2}$ )  $> 430$  (60) GeV
  - $|y^*| < 0.6$ ,  $y^* = (y_1 - y_2)/2$
  - Offline 2 b-tag



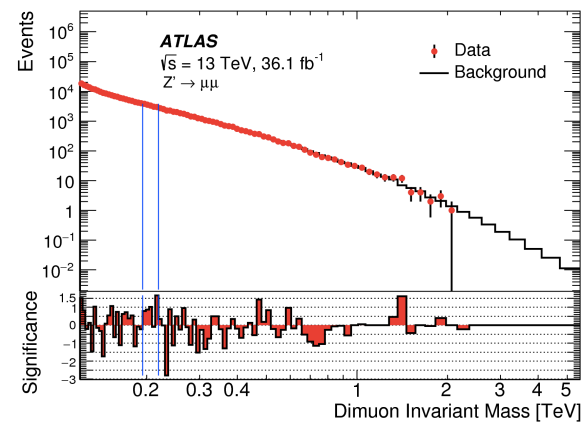
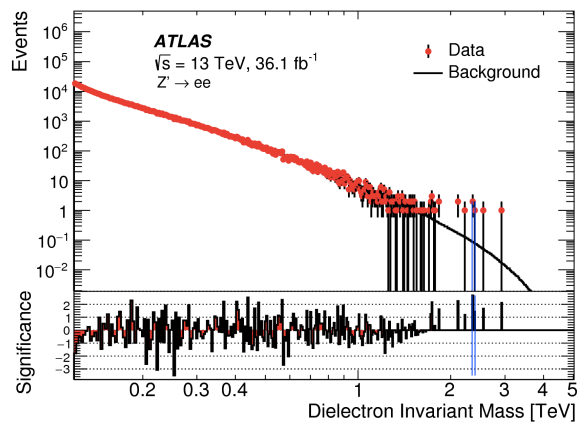
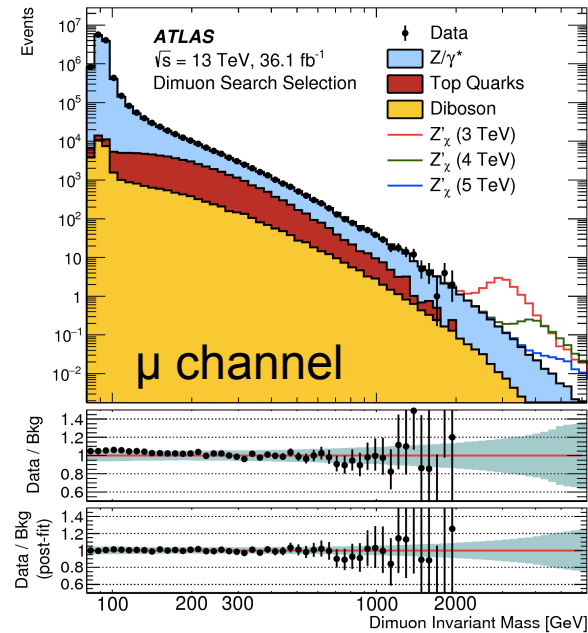
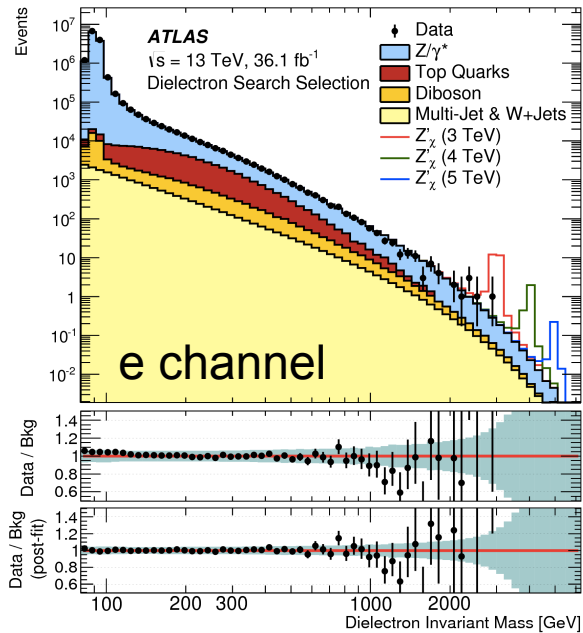
# ttbar resonance search

- DM couple preferentially to t-quark
- Events with exactly 1 electron or muon,
  - MET > 20 GeV, MET + MWT > 60 GeV ( $MWT = \sqrt{p_T^{lep} \cdot MET \cdot 2(1 - \cos\Delta\Phi(MET, lepton))}$ )
  - top-tagged large-R jets
  - 1 b-tagged track jet



# Di-lepton resonance search

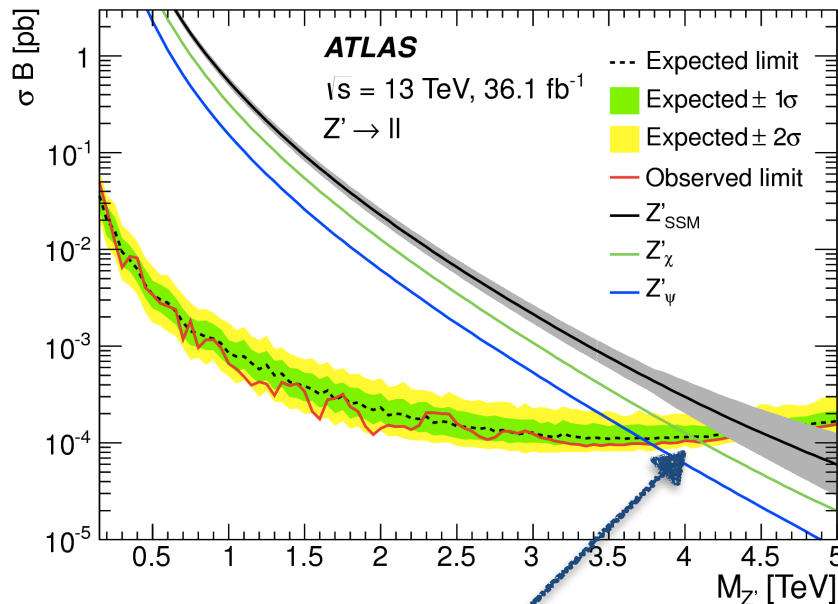
- Events with one pair of isolated  $e/\mu$  with  $p_T > 30$  GeV



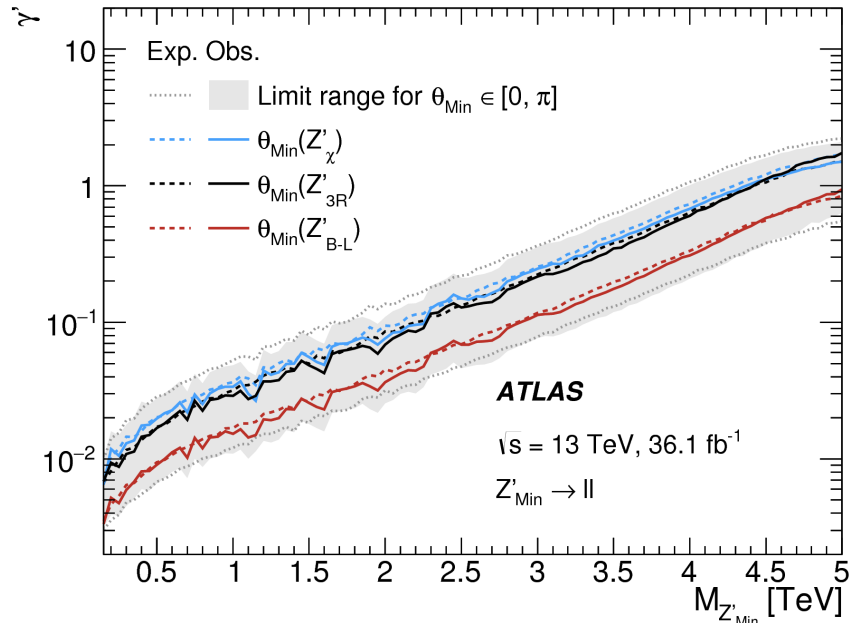


# Di-lepton resonance search

- Events with one pair of isolated  $e/\mu$  with  $p_T > 30$  GeV

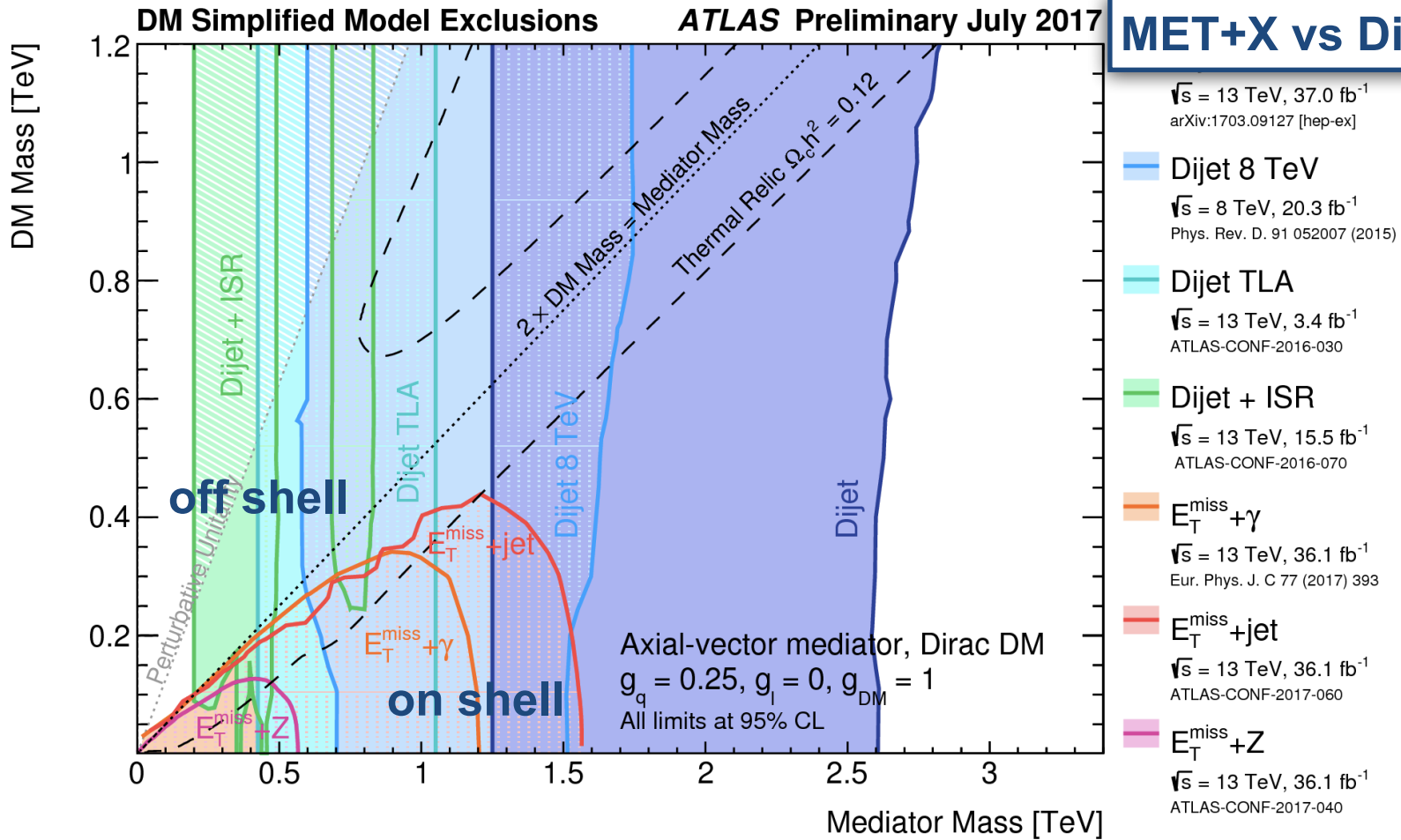


- Worse mass resolution in the  $\mu\mu$  channel than in the  $ee$  channel.
  - Rapidly falling signal cross-section
  - Increase of the off-shell production in the low-mass tail, and the natural width of the resonance
- Selection efficiency slowly decrease at very high pole masses (subdominant)



limits on the ratio of coupling strengths between the  $Z'$  boson and the  $Z$  boson, as a function of the  $Z'$  mass in the context of minimal  $Z'$  models

# Summary



- Extensive DM search program ongoing at ATLAS
- ATLAS is a telescope for new physics in multiple final states

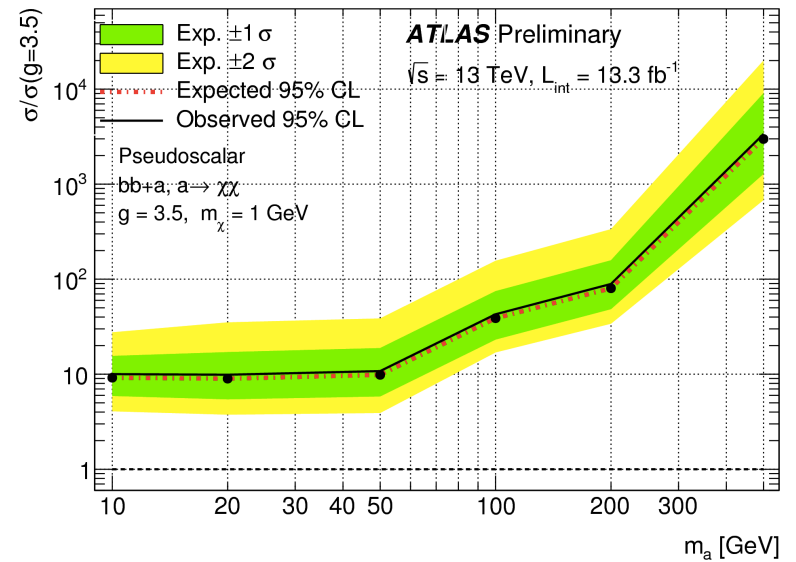
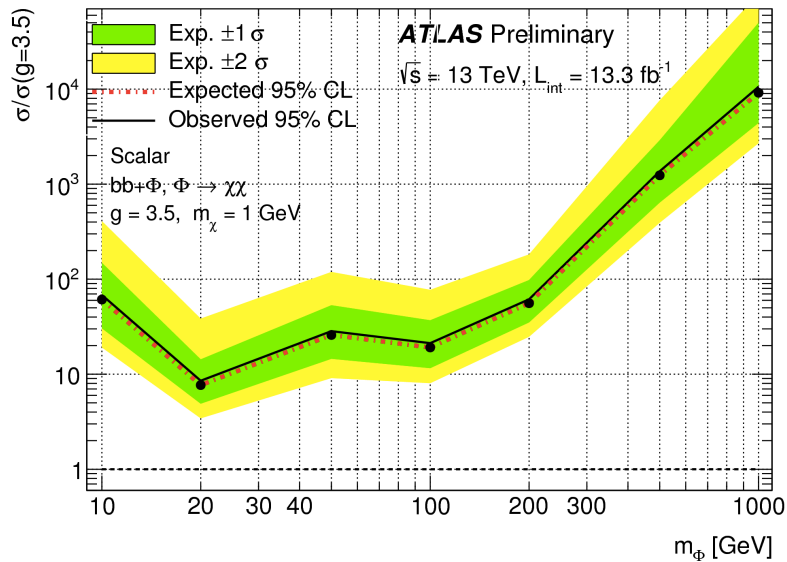
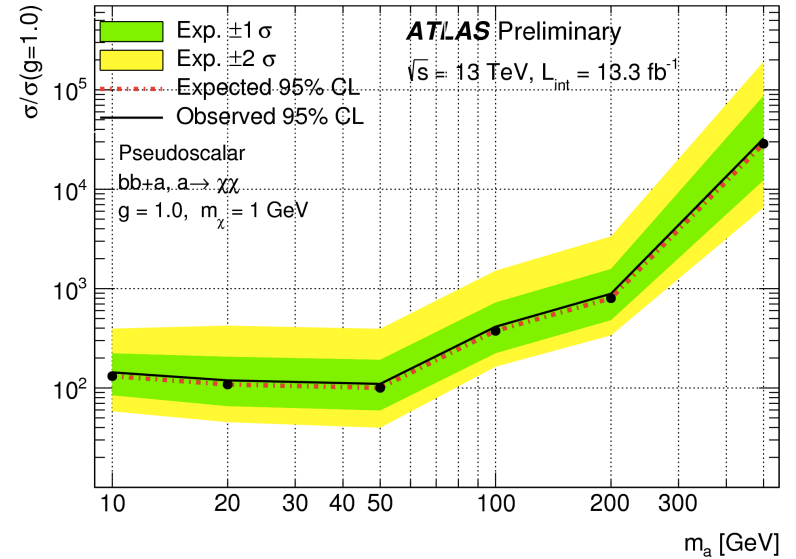
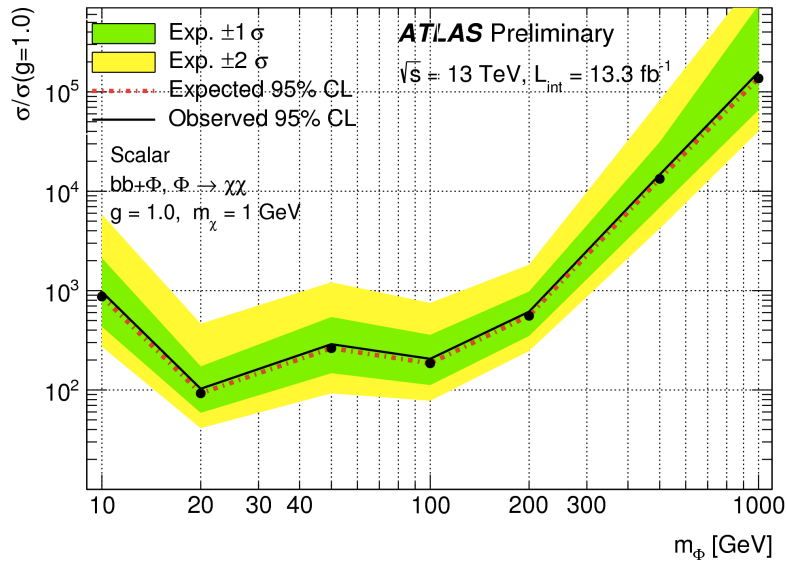
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# Backup

# MET+bb selection criterial

Quantity	SR	CRZ1b	VRZ2b	CRW1b	VRW1b	CRW2b	VRLR
$\mathcal{N}_{lepton}$ (baseline)	0	2 (SFOS)	2 (SFOS)	1	1	1	0
$\mathcal{N}_{lepton}$ (high-purity)	0	2 (SFOS)	2 (SFOS)	1	1	1	0
$\Delta\phi_{min}^j$	> 0.4	> 0.4	> 0.4	> 0.4	> 0.4	> 0.4	> 0.4
$\mathcal{N}_{jets}$	2 – 3	2 – 3	2 – 3	2 – 3	2 – 3	2 – 3	2 – 3
$\mathcal{N}_{bjets}$	= 2	= 1	= 2	= 1	= 1	= 2	= 2
jet 1 $p_T$ [GeV]	> 100	> 100	> 85	> 100	> 100	> 100	> 100
jet 2 $p_T$ [GeV]	> 20	> 20	> 20	> 30	> 30	> 20	> 20
jet 3 $p_T$ [GeV]	< 60	< 60	< 60	< 60	< 60	< 60	< 60
$p_T^{b-jet1}$ [GeV]	> 50	> 50	> 50	> 50	> 50	> 50	> 50
$E_T^{miss}$ [GeV]	> 150	< 100	< 80	> 130	> 150	> 120	> 150
$E_T^{miss,cor}$ [GeV]	-	> 120	> 100	-	-	-	-
$\Delta R_{min}$	> 2.8	> 2.8	> 2.8	> 2.5	> 2.8	> 2.8	< 2.5
$\Delta\eta(b_1, b_2)$	> 0.5	-	-	-	> 0.5	-	> 0.5
$Imb(b_1, b_2)$	> 0.5	-	-	-	-	-	> 0.5
$m_T^{lep}$	-	-	-	[30, 100]	[30, 100]	> 30	-
$m_{\ell\ell}$	-	[75, 105]	[80, 100]	-	-	-	-
lepton 1 $p_T$ [GeV]	-	> 30	> 30	> 30	> 30	> 30	-
lepton 2 $p_T$ [GeV]	-	> 25	> 25	-	-	-	-
$\Delta\phi(b_1, b_2)$	> 2.2	> 2.2	-	[1, 2.2]	> 2.2	> 2.2	> 2.2

# MET+bb limits

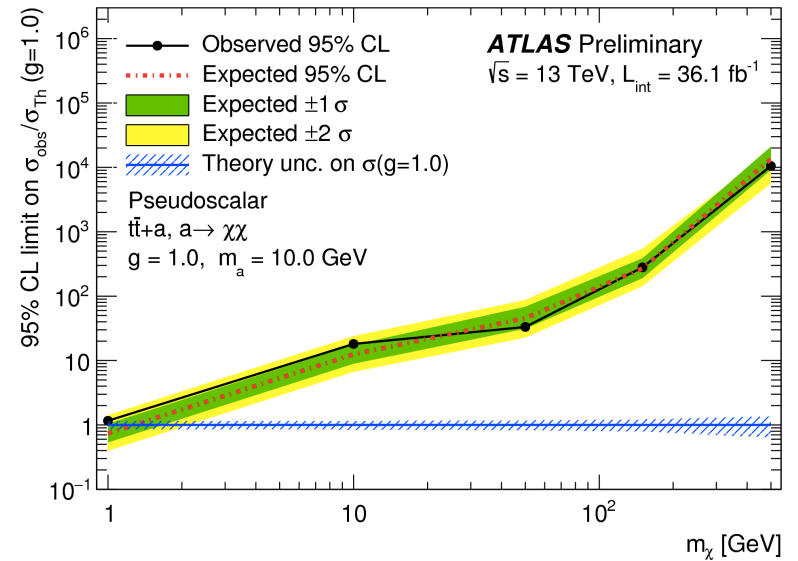
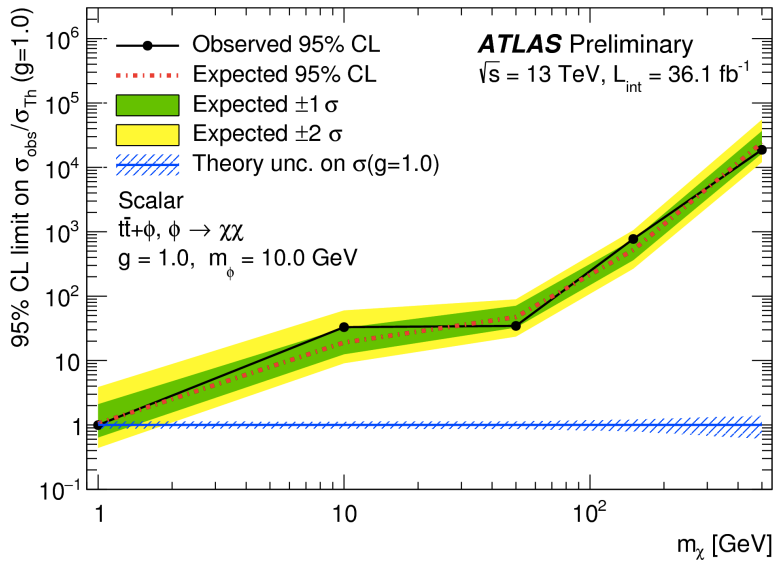
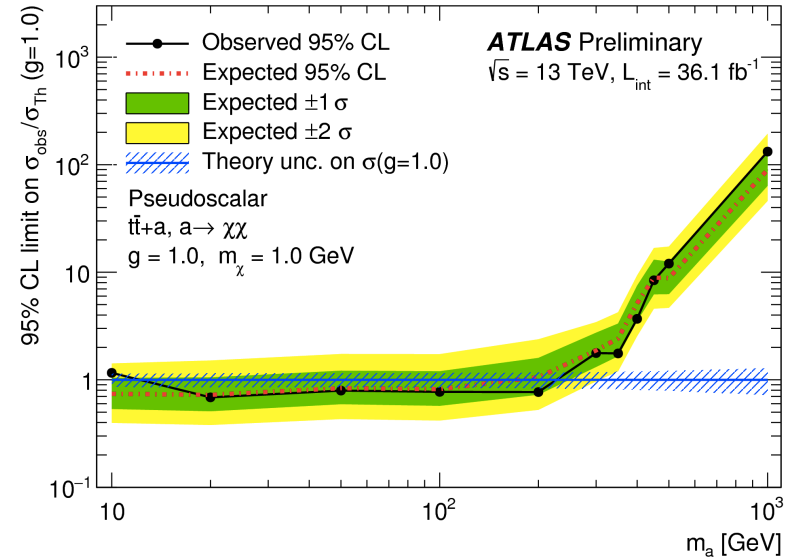
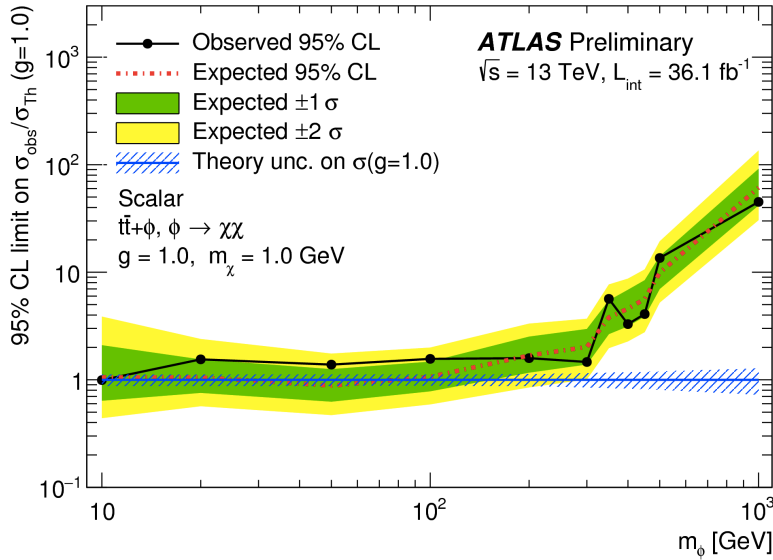


# MET+tt signal selection criterial

ATLAS-CONF-2017-037

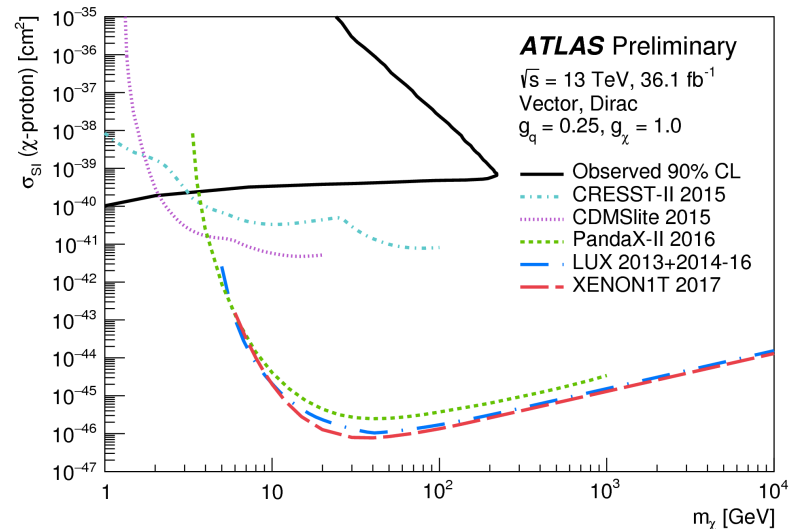
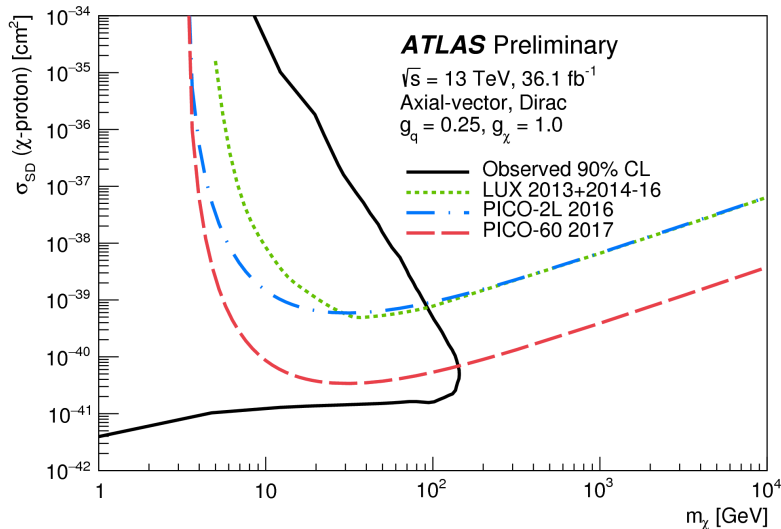
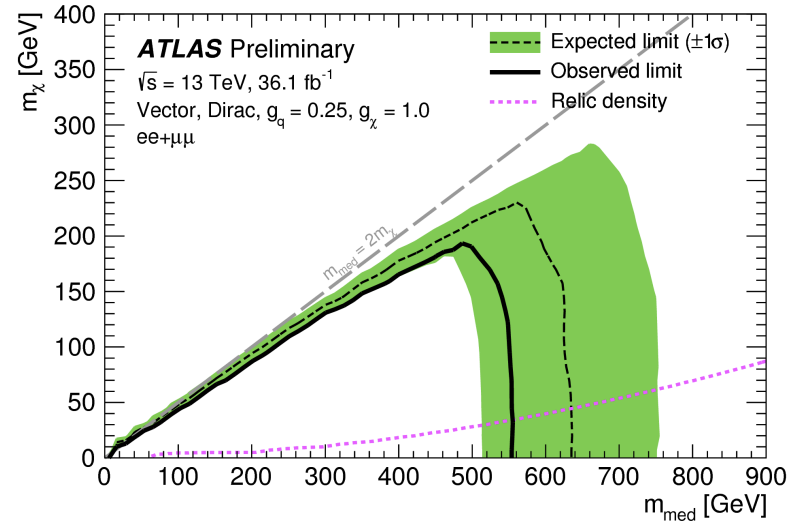
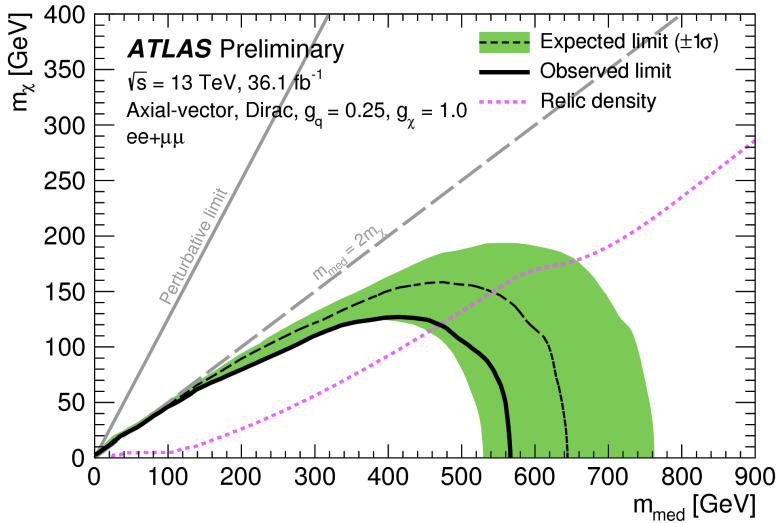
Signal region	DM_low_loose	DM_low	DM_high
Preselection	high- $E_T^{\text{miss}}$ preselection		
Number of (jets, $b$ -tags)	( $\geq 4, \geq 1$ )	( $\geq 4, \geq 1$ )	( $\geq 4, \geq 1$ )
Jet $p_T$ [GeV]	$> (60, 60, 40, 25)$	$> (120, 85, 65, 25)$	$> (125, 75, 65, 25)$
$b$ -tagged jet $p_T$ [GeV]	–	$> 60$	–
$E_T^{\text{miss}}$ [GeV]	$> 300$	$> 320$	$> 380$
$m_T$ [GeV]	$> 120$	$> 170$	$> 225$
$H_{T,\text{sig}}^{\text{miss}}$	$> 14$	$> 14$	–
$am_{T2}$ [GeV]	$> 140$	$> 160$	$> 190$
$m_{\text{top}}^{\text{reclustered}}$ [GeV]	–	$> 130$	$> 130$
$\Delta\phi(\vec{p}_T^{\text{miss}}, \ell)$	$> 0.8$	$> 1.2$	$> 1.2$
$ \Delta\phi(\text{jet}_i, \vec{p}_T^{\text{miss}}) $	$> 1.4$	$> 1.0$	$> 1.0$
$ \Delta\phi(j_{1,2}, \vec{p}_T^{\text{miss}}) $		$> 0.4$	
$m_{T2}^\tau$ based $\tau$ -veto [GeV]		$> 80$	
exclusion technique	cut-and-count	cut-and-count	cut-and-count

# MET+tt limits



# MET+Z(II) limits

$m_{\text{Med}}$  excluded at 560 GeV for light DM,  $m_{\text{DM}}$  excluded at 130 GeV for  $m_{\text{Med}} = 400$  GeV

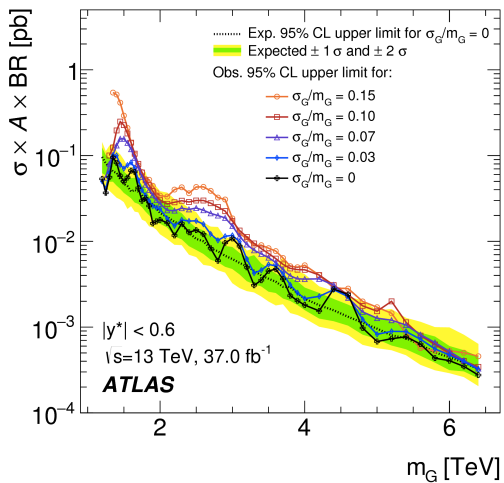




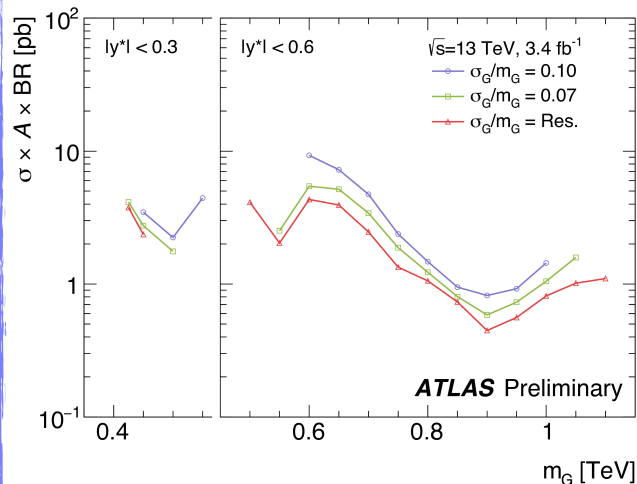
# Generaical Gaussian limits

EXOT-2016-21  
 ATLAS-CONF-2016-030  
 ATLAS-CONF-2016-070

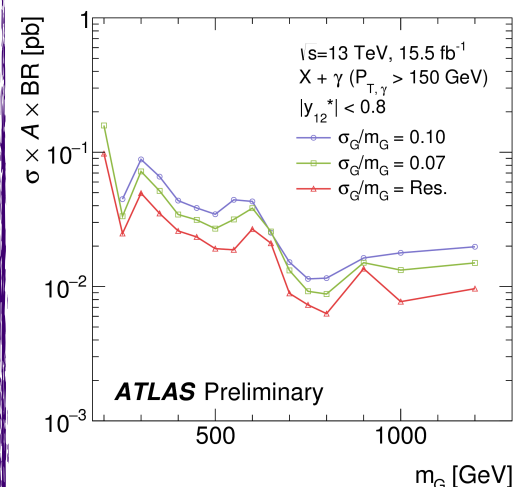
## Di-jet resonance search



## TLA

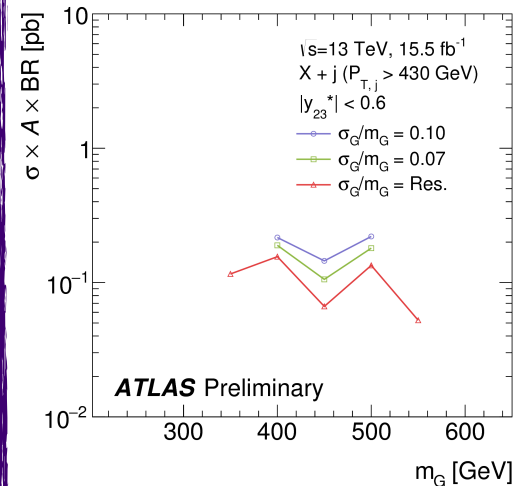
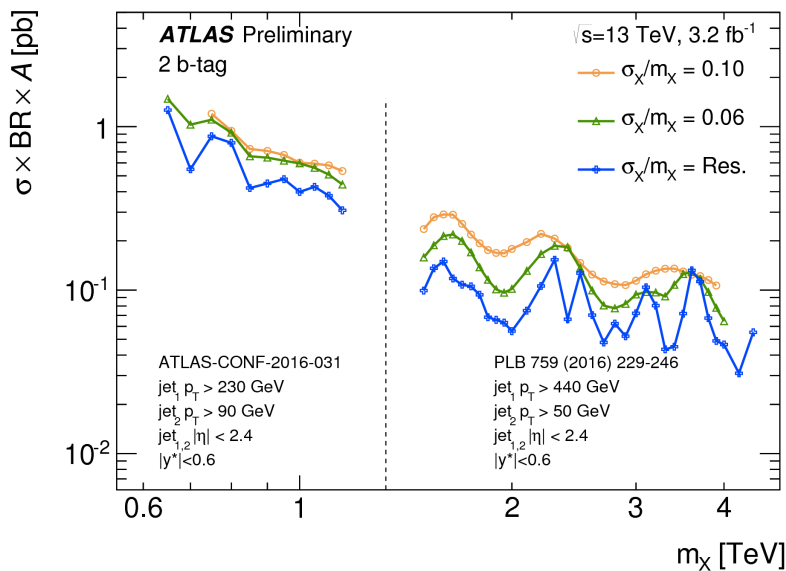


## Di-jet+ISR



## Di-b-jet search

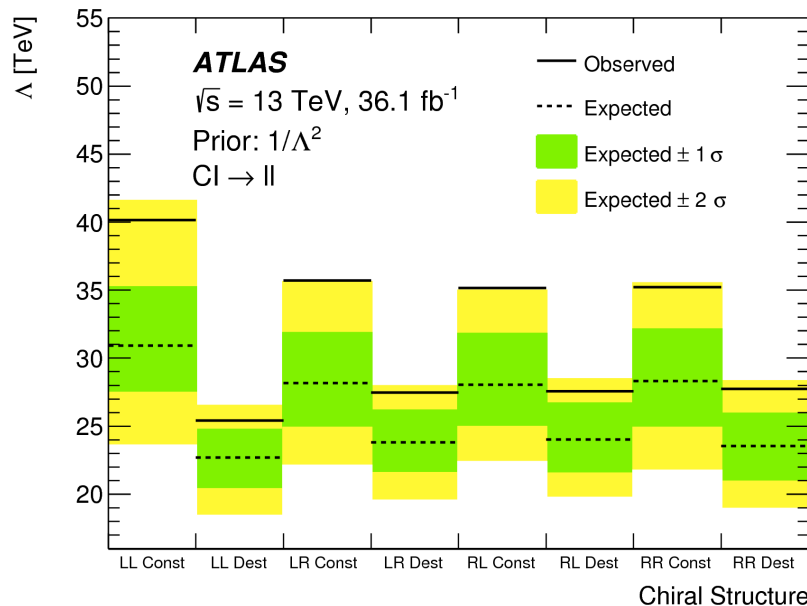
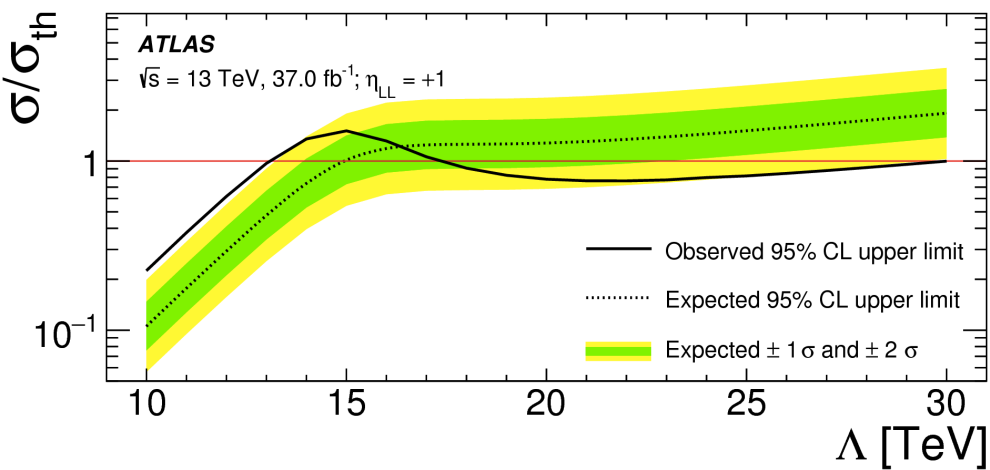
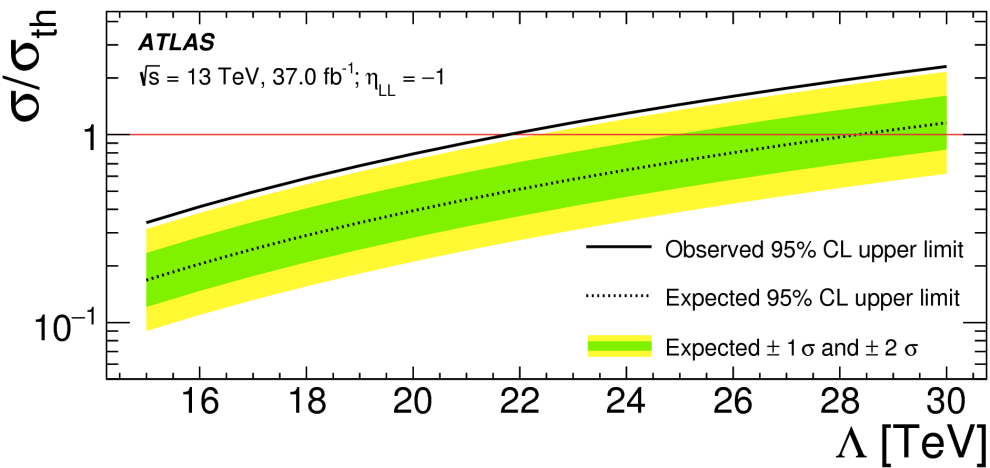
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# contact interaction limits

## Dijet angular search

## dilepton search



# ATLAS Exotics Searches\* - 95% CL Upper Exclusion Limits

Status: July 2017

ATLAS Preliminary

$\int \mathcal{L} dt = (3.2 - 37.0) \text{ fb}^{-1}$

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

Model		$\ell, \gamma$	Jets <sup>†</sup>	$E_{\text{T}}^{\text{miss}}$	$\int \mathcal{L} dt [\text{fb}^{-1}]$	Limit	Reference
Extra dimensions	ADD $G_{KK} + g/q$	$0 e, \mu$	$1 - 4 j$	Yes	36.1	$M_D$ 7.75 TeV	$n = 2$
	ADD non-resonant $\gamma\gamma$	$2 \gamma$	-	-	36.7	$M_S$ 8.6 TeV	$n = 3$ HLZ NLO
	ADD QBH	-	$2 j$	-	37.0	$M_{\text{th}}$ 8.9 TeV	$n = 6$
	ADD BH high $\sum p_T$	$\geq 1 e, \mu$	$\geq 2 j$	-	3.2	$M_{\text{th}}$ 8.2 TeV	$n = 6, M_D = 3 \text{ TeV}$ , rot BH
	ADD BH multijet	-	$\geq 3 j$	-	3.6	$M_{\text{th}}$ 9.55 TeV	$n = 6, M_D = 3 \text{ TeV}$ , rot BH
	RS1 $G_{KK} \rightarrow \gamma\gamma$	$2 \gamma$	-	-	36.7	$G_{KK}$ mass 4.1 TeV	$k/\bar{M}_{pl} = 0.1$
	Bulk RS $G_{KK} \rightarrow WW \rightarrow qq\ell\nu$	$1 e, \mu$	$1 J$	Yes	36.1	$G_{KK}$ mass 1.75 TeV	$k/\bar{M}_{pl} = 1.0$
	2UED / RPP	$1 e, \mu$	$\geq 2 b, \geq 3 j$	Yes	13.2	KK mass 1.6 TeV	Tier (1,1), $\mathcal{B}(A^{(1,1)} \rightarrow tt) = 1$
Gauge bosons	SSM $Z' \rightarrow \ell\ell$	$2 e, \mu$	-	-	36.1	$Z'$ mass 4.5 TeV	
	SSM $Z' \rightarrow \tau\tau$	$2 \tau$	-	-	36.1	$Z'$ mass 2.4 TeV	
	Leptophobic $Z' \rightarrow bb$	-	$2 b$	-	3.2	$Z'$ mass 1.5 TeV	
	Leptophobic $Z' \rightarrow tt$	$1 e, \mu$	$\geq 1 b, \geq 1J/2j$	Yes	3.2	$Z'$ mass 2.0 TeV	$\Gamma/m = 3\%$
	SSM $W' \rightarrow \ell\nu$	$1 e, \mu$	-	Yes	36.1	$W'$ mass 5.1 TeV	
	HVT $V' \rightarrow WW \rightarrow qq\bar{q}\bar{q}$ model B	$0 e, \mu$	$2 J$	-	36.7	$V'$ mass 3.5 TeV	$g_V = 3$
	HVT $V' \rightarrow WH/ZH$ model B	multi-channel	-	-	36.1	$V'$ mass 2.93 TeV	$g_V = 3$
	LRSM $W'_R \rightarrow tb$	$1 e, \mu$	$2 b, 0-1 j$	Yes	20.3	$W'$ mass 1.92 TeV	
LRSM $W'_R \rightarrow tb$	$0 e, \mu$	$\geq 1 b, 1 J$	-	20.3	$W'$ mass 1.76 TeV		
CI	CI $qq\bar{q}\bar{q}$	-	$2 j$	-	37.0	$\Lambda$ 21.8 TeV	$\eta_{LL}^-$
	CI $\ell\ell q\bar{q}$	$2 e, \mu$	-	-	36.1	$\Lambda$ 40.1 TeV	$\eta_{LL}^-$
	CI $u\bar{u}t\bar{t}$	$2(SS) \geq 3 e, \mu$	$\geq 1 b, \geq 1 j$	Yes	20.3	$\Lambda$ 4.9 TeV	$ C_{RR}  = 1$
DM	Axial-vector mediator (Dirac DM)	$0 e, \mu$	$1 - 4 j$	Yes	36.1	$m_{\text{med}}$ 1.5 TeV	$g_a = 0.25, g_t = 1.0, m(\chi) < 400 \text{ GeV}$
	Vector mediator (Dirac DM)	$0 e, \mu, 1 \gamma$	$\leq 1 j$	Yes	36.1	$m_{\text{med}}$ 1.2 TeV	$g_a = 0.25, g_t = 1.0, m(\chi) < 480 \text{ GeV}$
	$VV\chi\chi$ EFT (Dirac DM)	$0 e, \mu$	$1 J, \leq 1 j$	Yes	3.2	$M_*$ 700 GeV	$m(\chi) < 150 \text{ GeV}$
LQ	Scalar LQ 1 <sup>st</sup> gen	$2 e$	$\geq 2 j$	-	3.2	LQ mass 1.1 TeV	$\beta = 1$
	Scalar LQ 2 <sup>nd</sup> gen	$2 \mu$	$\geq 2 j$	-	3.2	LQ mass 1.05 TeV	$\beta = 1$
	Scalar LQ 3 <sup>rd</sup> gen	$1 e, \mu$	$\geq 1 b, \geq 3 j$	Yes	20.3	LQ mass 640 GeV	$\beta = 0$
Heavy quarks	VLQ $TT \rightarrow Ht + X$	$0$ or $1 e, \mu$	$\geq 2 b, \geq 3 j$	Yes	13.2	T mass 1.2 TeV	$\mathcal{B}(T \rightarrow Ht) = 1$
	VLQ $TT \rightarrow Zt + X$	$1 e, \mu$	$\geq 1 b, \geq 3 j$	Yes	36.1	T mass 1.16 TeV	$\mathcal{B}(T \rightarrow Zt) = 1$
	VLQ $TT \rightarrow Wb + X$	$1 e, \mu$	$\geq 1 b, \geq 1J/2j$	Yes	36.1	T mass 1.35 TeV	$\mathcal{B}(T \rightarrow Wb) = 1$
	VLQ $BB \rightarrow Hb + X$	$1 e, \mu$	$\geq 2 b, \geq 3 j$	Yes	20.3	B mass 700 GeV	$\mathcal{B}(B \rightarrow Hb) = 1$
	VLQ $BB \rightarrow Zb + X$	$2/\geq 3 e, \mu$	$\geq 2/\geq 1 b$	-	20.3	B mass 790 GeV	$\mathcal{B}(B \rightarrow Zb) = 1$
	VLQ $BB \rightarrow Wt + X$	$1 e, \mu$	$\geq 1 b, \geq 1J/2j$	Yes	36.1	B mass 1.25 TeV	$\mathcal{B}(B \rightarrow Wt) = 1$
	VLQ $QQ \rightarrow WqWq$	$1 e, \mu$	$\geq 4 j$	Yes	20.3	Q mass 690 GeV	
Excited fermions	Excited quark $q^* \rightarrow qg$	-	$2 j$	-	37.0	$q^*$ mass 6.0 TeV	only $u^*$ and $d^*$ , $\Lambda = m(q^*)$
	Excited quark $q^* \rightarrow q\gamma$	$1 \gamma$	$1 j$	-	36.7	$q^*$ mass 5.3 TeV	only $u^*$ and $d^*$ , $\Lambda = m(q^*)$
	Excited quark $b^* \rightarrow bg$	-	$1 b, 1 j$	-	13.3	$b^*$ mass 2.3 TeV	
	Excited quark $b^* \rightarrow Wt$	$1$ or $2 e, \mu$	$1 b, 2-0 j$	Yes	20.3	$b^*$ mass 1.5 TeV	$f_g = f_t = f_R = 1$
	Excited lepton $\ell^*$	$3 e, \mu$	-	-	20.3	$\ell^*$ mass 3.0 TeV	$\Lambda = 3.0 \text{ TeV}$
	Excited lepton $\nu^*$	$3 e, \mu, \tau$	-	-	20.3	$\nu^*$ mass 1.6 TeV	$\Lambda = 1.6 \text{ TeV}$
Other	LRSM Majorana $\nu$	$2 e, \mu$	$2 j$	-	20.3	$N^0$ mass 2.0 TeV	$m(W_R) = 2.4 \text{ TeV}$ , no mixing
	Higgs triplet $H^{\pm\pm} \rightarrow \ell\ell$	$2, 3, 4 e, \mu$ (SS)	-	-	36.1	$H^{\pm\pm}$ mass 870 GeV	DY production
	Higgs triplet $H^{\pm\pm} \rightarrow \ell\tau$	$3 e, \mu, \tau$	-	-	20.3	$H^{\pm\pm}$ mass 400 GeV	DY production, $\mathcal{B}(H_L^{\pm\pm} \rightarrow \ell\tau) = 1$
	Monotop (non-res prod)	$1 e, \mu$	$1 b$	Yes	20.3	spin-1 invisible particle mass 657 GeV	$a_{\text{non-res}} = 0.2$
	Multi-charged particles	-	-	-	20.3	multi-charged particle mass 785 GeV	DY production, $ q  = 5e$
	Magnetic monopoles	-	-	-	7.0	monopole mass 1.34 TeV	DY production, $ g  = 1g_D$ , spin 1/2

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

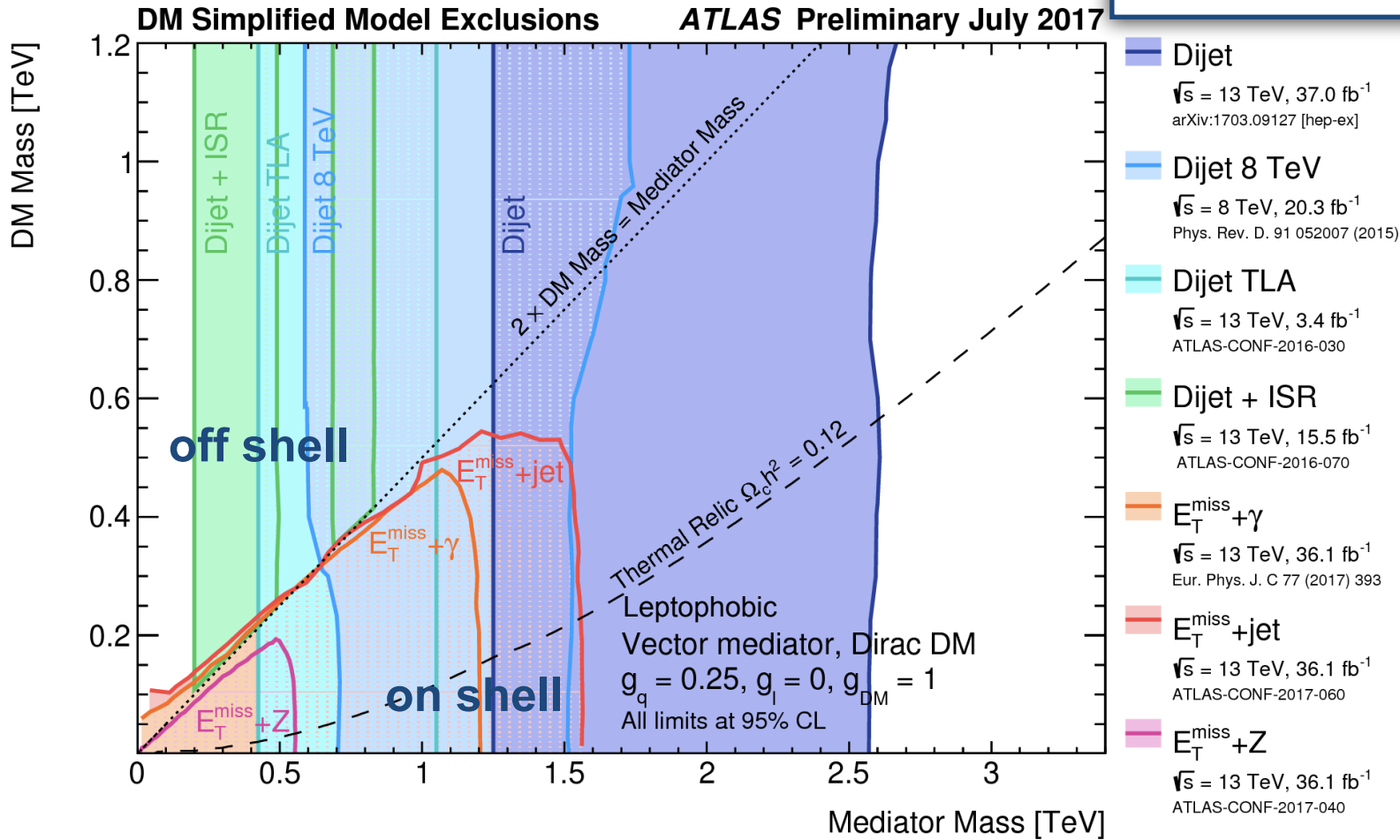
10<sup>-1</sup> 1 10 Mass scale [TeV]

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

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

# ATLAS limit on vector mediator

**MET+X vs Di-X**

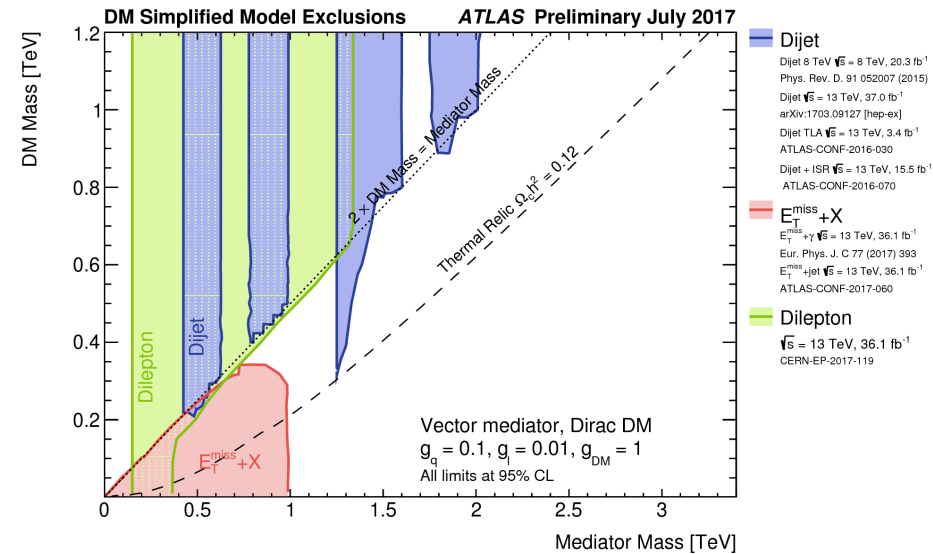
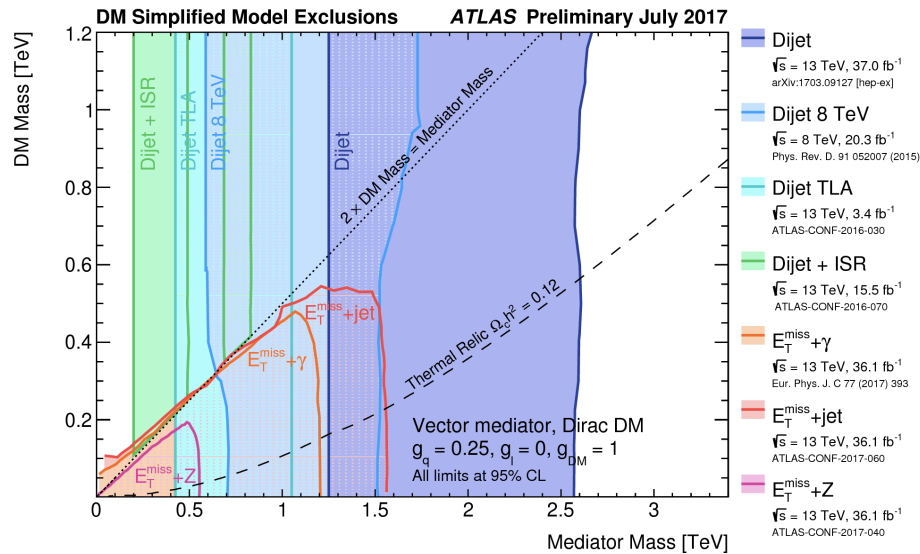


Ref: [https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CombinedSummaryPlots/EXOTICS/ATLAS\\_DarkMatter\\_Summary/ATLAS\\_DarkMatter\\_Summary.png](https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CombinedSummaryPlots/EXOTICS/ATLAS_DarkMatter_Summary/ATLAS_DarkMatter_Summary.png)

# ATLAS limit on vector mediator

$$g_q=0.25, q_l=0, q_{DM}=1$$

$$g_q=0.1, q_l=0.01, q_{DM}=1$$



Ref: [https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CombinedSummaryPlots/EXOTICS/ATLAS\\_DarkMatter\\_Summary/ATLAS\\_DarkMatter\\_Summary.png](https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CombinedSummaryPlots/EXOTICS/ATLAS_DarkMatter_Summary/ATLAS_DarkMatter_Summary.png)

Rui Wang

Ref: [https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CombinedSummaryPlots/EXOTICS/ATLAS\\_DarkMatter\\_Summary\\_Vector\\_ModifiedCoupling/ATLAS\\_DarkMatter\\_Summary\\_Vector\\_ModifiedCoupling.png](https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CombinedSummaryPlots/EXOTICS/ATLAS_DarkMatter_Summary_Vector_ModifiedCoupling/ATLAS_DarkMatter_Summary_Vector_ModifiedCoupling.png)