Searches at ATLAS and CMS

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Mini-workshop on the frontier of LHC
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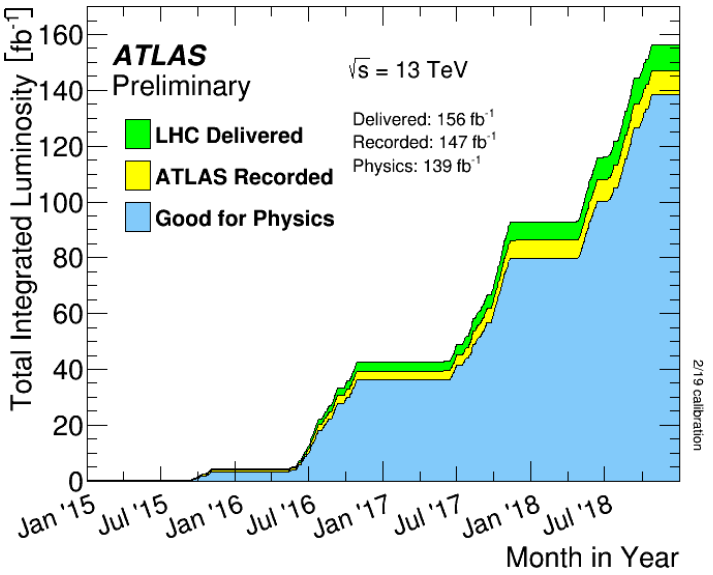
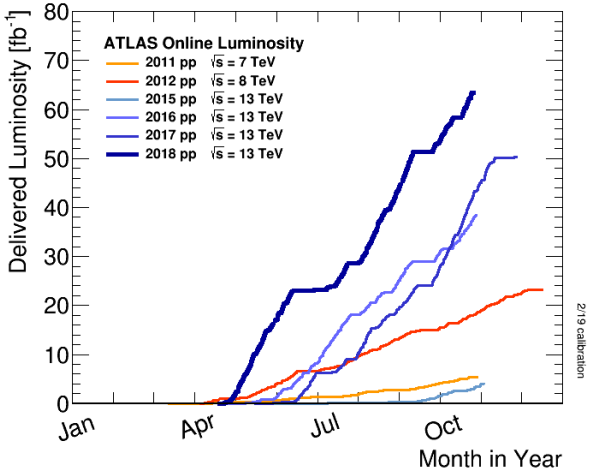
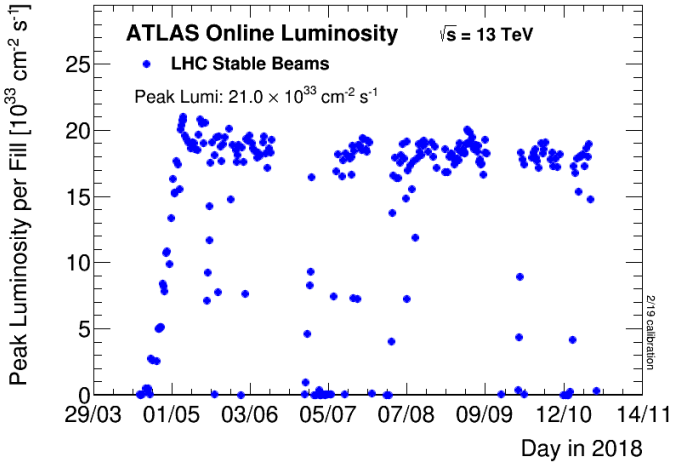
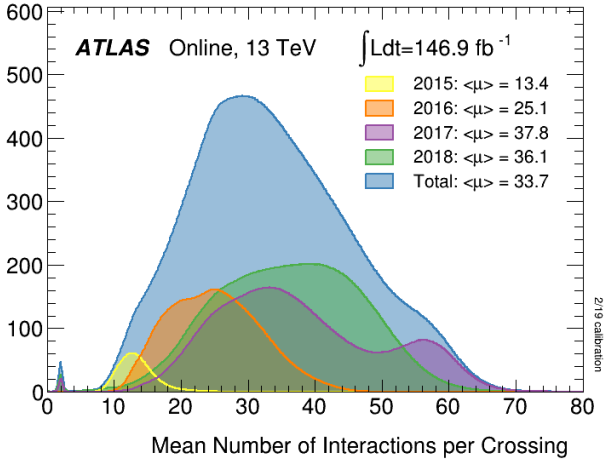
Overview

- ATLAS & CMS have kept probing new physics in Run2. However, no discovery yet!
- Excellent data taking efficiency(close to 100% for ATLAS); ~140fb^{-1} data is available for physics in both experiments
- Nice running of the LHC, and more challenge with higher average interactions per BC due to increasing instant luminosity









ATLAS Exotics Searches* - 95% CL Upper Exclusion Limits

Status: March 2019

ATLAS Preliminary

$\int \mathcal{L}\, dt$ = (3.2 – 139) fb^{-1} $\sqrt{s}$ = 8, 13 TeV

	Model	ℓ, γ	Jets†	E_T^{miss}	$\int \mathcal{L}\, dt$[fb^{-1}]	Limit		Reference
Extra dimensions	ADD $G_{KK} + g/q$	0 e, μ	1 – 4 j	Yes	36.1	M_D 7.7 TeV	$n = 2$	1711.03301
	ADD non-resonant $\gamma\gamma$	2 γ	–	–	36.7	M_S 8.6 TeV	$n = 3$ HLZ NLO	1707.04147
	ADD QBH	–	2 j	–	37.0	M_{th} 8.9 TeV	$n = 6$	1703.09127
	ADD BH high $\sum p_T$	≥ 1 e, μ	≥ 2 j	–	3.2	M_{th} 8.2 TeV	$n = 6$, $M_D = 3$ TeV, rot BH	1606.02265
	ADD BH multijet	–	≥ 3 j	–	3.6	M_{th} 9.55 TeV	$n = 6$, $M_D = 3$ TeV, rot BH	1512.02586
	RS1 $G_{KK} \to \gamma\gamma$	2 γ	–	–	36.7	G_{KK} mass 4.1 TeV	$k/\overline{M}_{Pl} = 0.1$	1707.04147
	Bulk RS $G_{KK} \to WW/ZZ$	multi-channel			36.1	G_{KK} mass 2.3 TeV	$k/\overline{M}_{Pl} = 1.0$	1808.02380
	Bulk RS $G_{KK} \to WW/ZZ \to qqqq$	0 e, μ	2 J	–	139	G_{KK} mass 2.8 TeV	$k/\overline{M}_{Pl} = 1.0$	ATLAS-CONF-2019-003
	Bulk RS $g_{KK} \to tt$	1 e, μ	≥ 1 b, ≥ 1J/2j	Yes	36.1	g_{KK} mass 3.8 TeV	$\Gamma/m = 15\%$	1804.10823
	2UED / RPP	1 e, μ	≥ 2 b, ≥ 3 j	Yes	36.1	KK mass 1.8 TeV	Tier (1,1), $\mathcal{B}(A^{(1,1)} \to tt) = 1$	1803.09678
Gauge bosons	SSM $Z' \to \ell\ell$	2 e, μ	–	–	139	Z' mass 5.1 TeV		1903.06248
	SSM $Z' \to \tau\tau$	2 τ	–	–	36.1	Z' mass 2.42 TeV		1709.07242
	Leptophobic $Z' \to bb$	–	2 b	–	36.1	Z' mass 2.1 TeV		1805.09299
	Leptophobic $Z' \to tt$	1 e, μ	≥ 1 b, ≥ 1J/2j	Yes	36.1	Z' mass 3.0 TeV	$\Gamma/m = 1\%$	1804.10823
	SSM $W' \to \ell\nu$	1 e, μ	–	Yes	79.8	W' mass 5.6 TeV		ATLAS-CONF-2018-017
	SSM $W' \to \tau\nu$	1 τ	–	Yes	36.1	W' mass 3.7 TeV		1801.06992
	HVT $V' \to WV \to qqqq$ model B	0 e, μ	2 J	–	139	V' mass 4.4 TeV	$g_V = 3$	ATLAS-CONF-2019-003
	HVT $V' \to WH/ZH$ model B	multi-channel			36.1	V' mass 2.93 TeV	$g_V = 3$	1712.06518
	LRSM $W'_R \to tb$	multi-channel			36.1	W' mass 3.25 TeV		1807.10473
CI	CI $qqqq$	–	2 j	–	37.0	Λ 21.8 TeV	η_{LL}^-	1703.09127
	CI $\ell\ell qq$	2 e, μ	–	–	36.1	Λ 40.0 TeV	η_{LL}^-	1707.02424
	CI $tttt$	≥ 1 e, μ	≥ 1 b, ≥ 1 j	Yes	36.1	Λ 2.57 TeV	$\lvert C_{4t}\rvert = 4\pi$	1811.02305
DM	Axial-vector mediator (Dirac DM)	0 e, μ	1 – 4 j	Yes	36.1	m_{med} 1.55 TeV	g_q=0.25, g_χ=1.0, $m(\chi) = 1$ GeV	1711.03301
	Colored scalar mediator (Dirac DM)	0 e, μ	1 – 4 j	Yes	36.1	m_{med} 1.67 TeV	g=1.0, $m(\chi) = 1$ GeV	1711.03301
	$VV\chi\chi$ EFT (Dirac DM)	0 e, μ	1 J, ≤ 1 j	Yes	3.2	M_* 700 GeV	$m(\chi) < 150$ GeV	1608.02372
	Scalar reson. $\phi \to t\chi$ (Dirac DM)	0-1 e, μ	1 b, 0-1 J	Yes	36.1	m_ϕ 3.4 TeV	$y = 0.4$, $\lambda = 0.2$, $m(\chi) = 10$ GeV	1812.09743
LQ	Scalar LQ 1st gen	1,2 e	≥ 2 j	Yes	36.1	LQ mass 1.4 TeV	$\beta = 1$	1902.00377
	Scalar LQ 2nd gen	1,2 μ	≥ 2 j	Yes	36.1	LQ mass 1.56 TeV	$\beta = 1$	1902.00377
	Scalar LQ 3rd gen	2 τ	2 b	–	36.1	LQ_3^u mass 1.03 TeV	$\mathcal{B}(LQ_3^u \to b\tau) = 1$	1902.08103
	Scalar LQ 3rd gen	0-1 e, μ	2 b	Yes	36.1	LQ_3^d mass 970 GeV	$\mathcal{B}(LQ_3^d \to t\tau) = 0$	1902.08103
Heavy quarks	VLQ $TT \to Ht/Zt/Wb + X$	multi-channel			36.1	T mass 1.37 TeV	SU(2) doublet	1808.02343
	VLQ $BB \to Wt/Zb + X$	multi-channel			36.1	B mass 1.34 TeV	SU(2) doublet	1808.02343
	VLQ $T_{5/3}T_{5/3}/T_{5/3} \to Wt + X$	2(SS)/≥ 3 e, μ	≥ 1 b, ≥ 1 j	Yes	36.1	$T_{5/3}$ mass 1.64 TeV	$\mathcal{B}(T_{5/3} \to Wt) = 1$, $c(T_{5/3}Wt) = 1$	1807.11883
	VLQ $Y \to Wb + X$	1 e, μ	≥ 1 b, ≥ 1j	Yes	36.1	Y mass 1.85 TeV	$\mathcal{B}(Y \to Wb) = 1$, $c_R(Wb) = 1$	1812.07343
	VLQ $B \to Hb + X$	0 e, μ, 2 γ	≥ 1 b, ≥ 1j	Yes	79.8	B mass 1.21 TeV	$\kappa_B = 0.5$	ATLAS-CONF-2018-024
	VLQ $QQ \to WqWq$	1 e, μ	≥ 4 j	Yes	20.3	Q mass 690 GeV		1509.04261
Excited fermions	Excited quark $q^* \to qg$	–	2 j	–	139	q^* mass 6.7 TeV	only u^* and d^*, $\Lambda = m(q^*)$	ATLAS-CONF-2019-007
	Excited quark $q^* \to q\gamma$	1 γ	1 j	–	36.7	q^* mass 5.3 TeV	only u^* and d^*, $\Lambda = m(q^*)$	1709.10440
	Excited quark $b^* \to bg$	–	1 b, 1 j	–	36.1	b^* mass 2.6 TeV		1805.09299
	Excited lepton ℓ^*	3 e, μ	–	–	20.3	ℓ^* mass 3.0 TeV	$\Lambda = 3.0$ TeV	1411.2921
	Excited lepton ν^*	3 e, μ, τ	–	–	20.3	ν^* mass 1.6 TeV	$\Lambda = 1.6$ TeV	1411.2921
Other	Type III Seesaw	1 e, μ	≥ 2 j	Yes	79.8	N^0 mass 560 GeV		ATLAS-CONF-2018-020
	LRSM Majorana ν	2 μ	2 j	–	36.1	N_R mass 3.2 TeV	$m(W_R) = 4.1$ TeV, $g_L = g_R$	1809.11105
	Higgs triplet $H^{\pm\pm} \to \ell\ell$	2,3,4 e, μ (SS)	–	–	36.1	$H^{\pm\pm}$ mass 870 GeV	DY production	1710.09748
	Higgs triplet $H^{\pm\pm} \to \ell\tau$	3 e, μ, τ	–	–	20.3	$H^{\pm\pm}$ mass 400 GeV	DY production, $\mathcal{B}(H_L^{\pm\pm} \to \ell\tau) = 1$	1411.2921
	Multi-charged particles	–	–	–	36.1	multi-charged particle mass 1.22 TeV	DY production, $\lvert q\rvert = 5e$	1812.03673
	Magnetic monopoles	–	–	–	7.0	monopole mass 1.34 TeV	DY production, $\lvert g\rvert = 1g_D$, spin 1/2	1509.08059

$\sqrt{s}$ = 8 TeV | $\sqrt{s}$ = 13 TeV partial data | $\sqrt{s}$ = 13 TeV full data

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

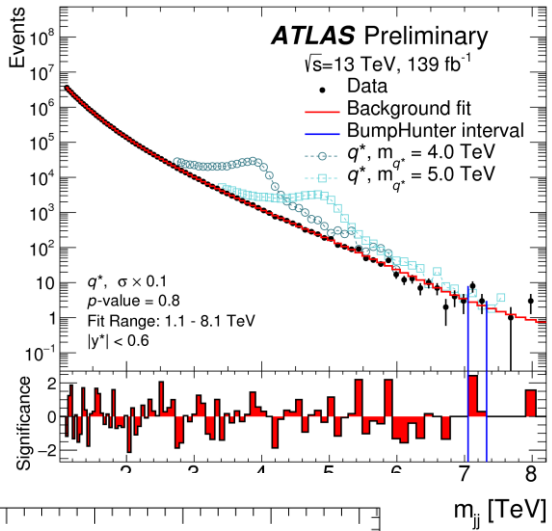
*Only a selection of the available mass limits on new states or phenomena is shown.

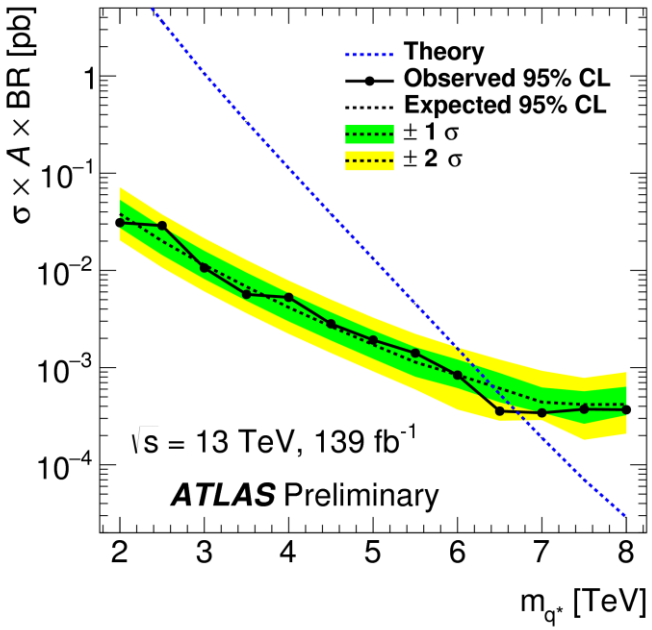
†Small-radius (large-radius) jets are denoted by the letter j (J).

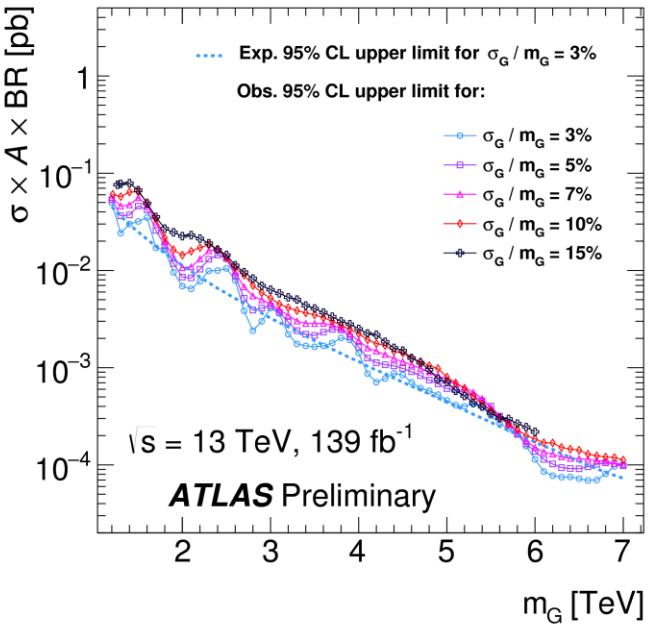
Dijet Resonances

ATLAS-CONT-2019-007

- Search for high mass resonance decaying into a pair of jets
- QCD predicts a smoothly-falling background, which is fit to data
- No excess is observed. Excited quarks(q*) is considered for limit setting
  - Exclude q* mass < 6.7 TeV @95% CL



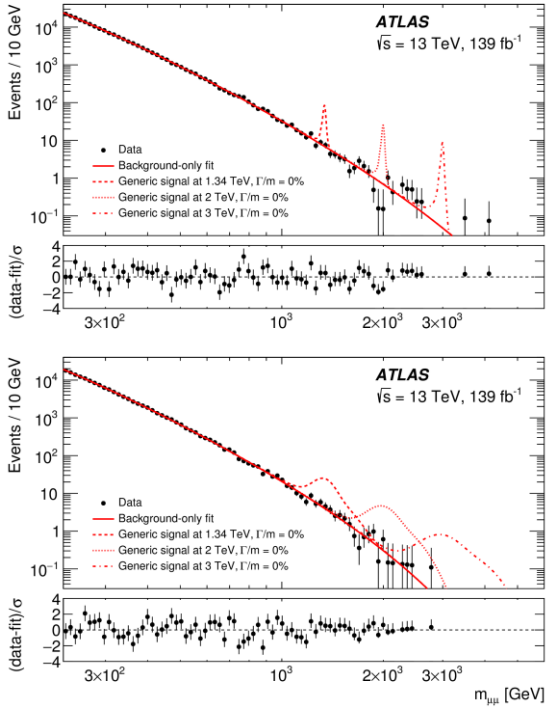


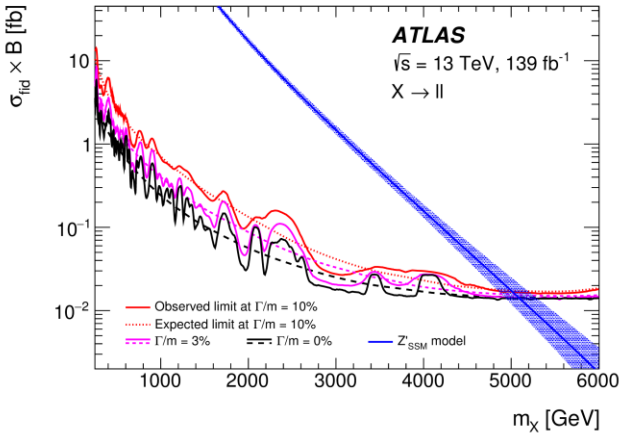


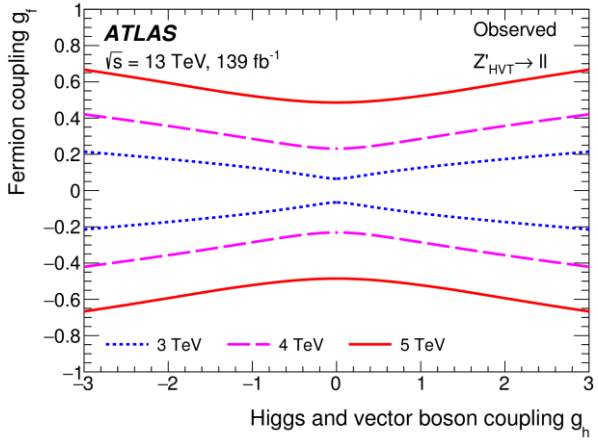
Di-lepton Resonances

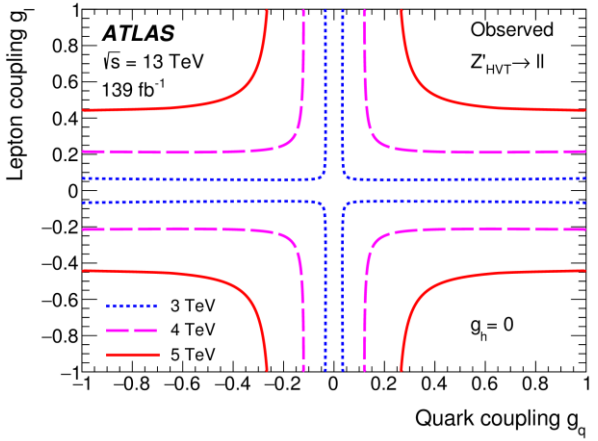
arxiv: 1903.06248

- Search for high mass resonance decaying into a pair of leptons(ee, μμ)
- Background is fitted to data using functional form
- No significant deviation from SM is observed. Exclude mass for SSM
  - ee: 4.9 TeV
  - μμ: 4.5 TeV



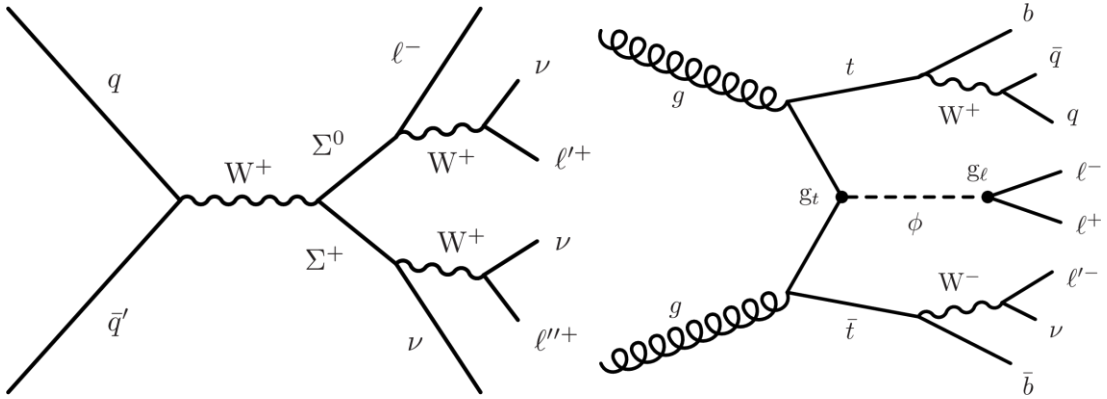


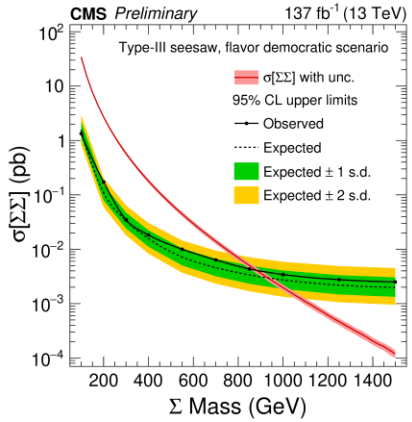




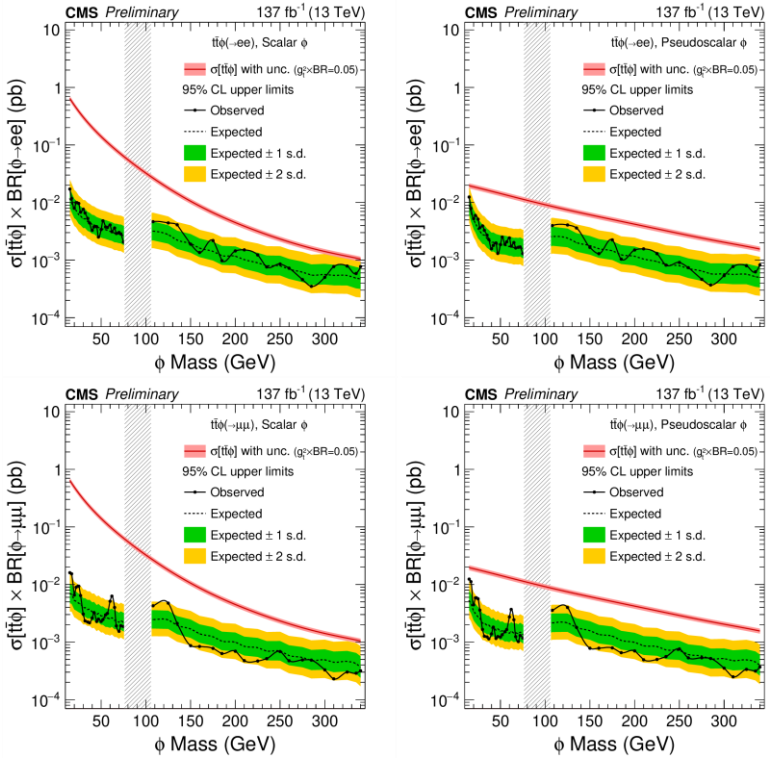
Multi-lepton final states

EXO-19-002-pas





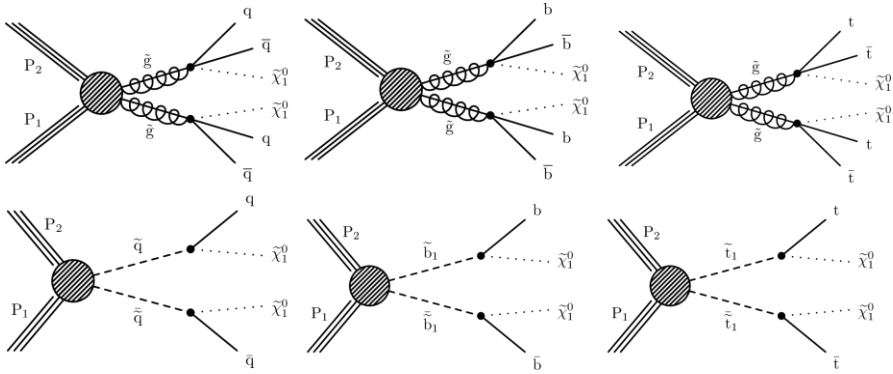
- Targeted models: type-III seesaw heavy fermions and light scalar or pseudoscalar extension to the SM
- At least 3 leptons in the final state
  - Non-resonant excess for heavy fermions
  - Resonant dilepton mass for light scalar(pseudoscalar)
- No significant excess on top of the SM:
  - Exclude heavy fermions of type-III seesaw below 880 GeV
  - First limits on light scalar(pseudoscalar), excluding mass range of 15-75 GeV and 108-340 GeV

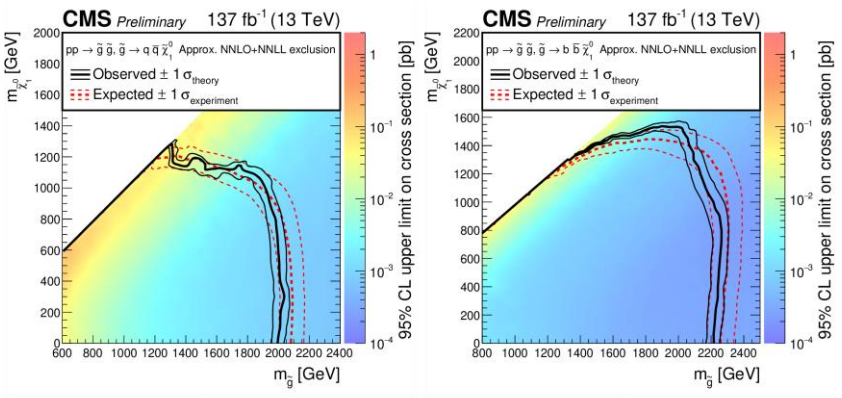


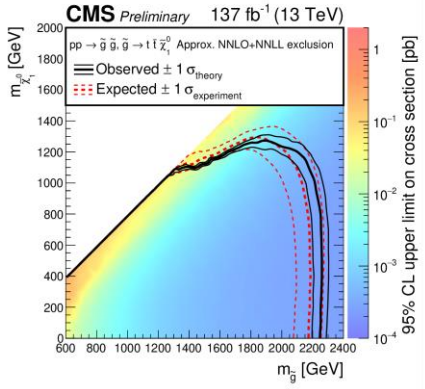
Search for multiple jets & E_T^{miss}

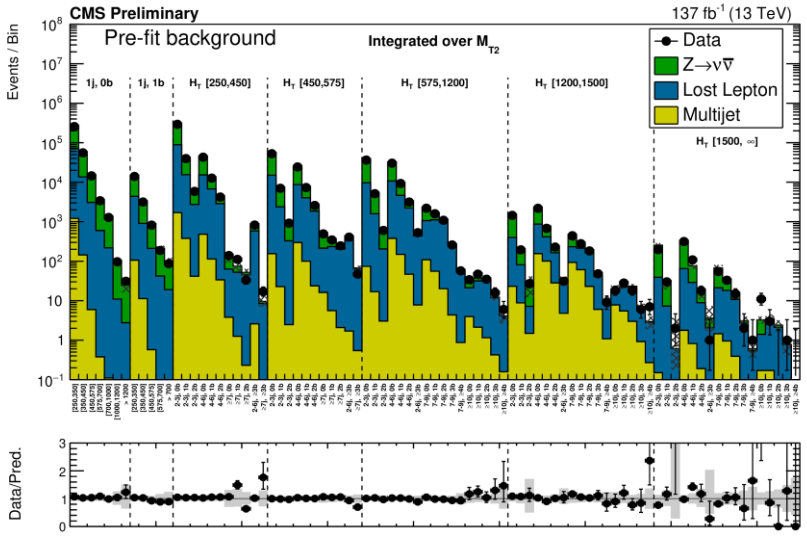
- Searches for gluinos and squarks with final states containing several jets and significant transverse momentum imbalance
- Two related searches:
  - Inclusive search using # of jets, b tagged jets, M_{T2}, …
  - Search for disappearing tracks due to long-lived charged particles
- No excess event yield is observed
  - Exclude mass up to 2.25, 1.77, 1.26 and 1.225 TeV for gluinos, light-flavor squarks, bottom squarks and top squarks, respectively

SUS-19-005-PAS





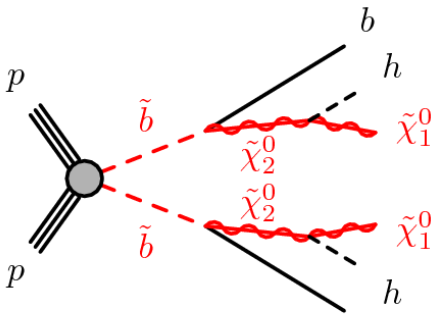


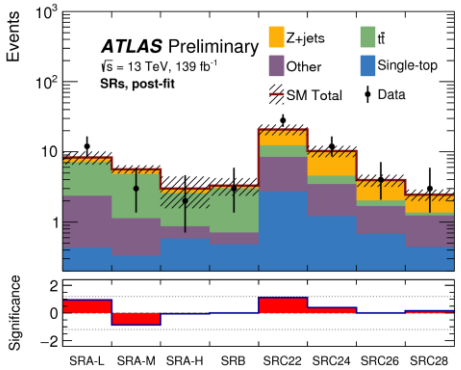


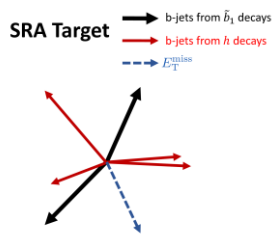
3rd generation SUSY

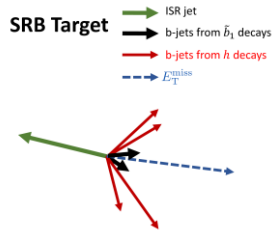
ATLAS-CONF-2019-011

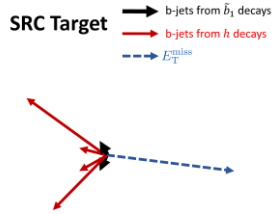
- Search for pair production of sbottom quark involving Higgs bosons
- Final states contain many quarks(up to 6 b-jets), E_T^{miss}, and zero charged leptons
- Categorize 3 signal regions to target different mass scenarios
- No excess compared to the SM
  - For $m(\tilde{\chi}_1^0)$= 60 GeV, exclude sbottom up to 1.45 TeV and $m(\tilde{\chi}_2^0)$ up to 1.1 TeV
  - For $\Delta m(\tilde{\chi}_2^0, \tilde{\chi}_1^0)$= 130 GeV, exclude sbottom up to 1.2 TeV for $m(\tilde{\chi}_2^0)$ up to 750 GeV

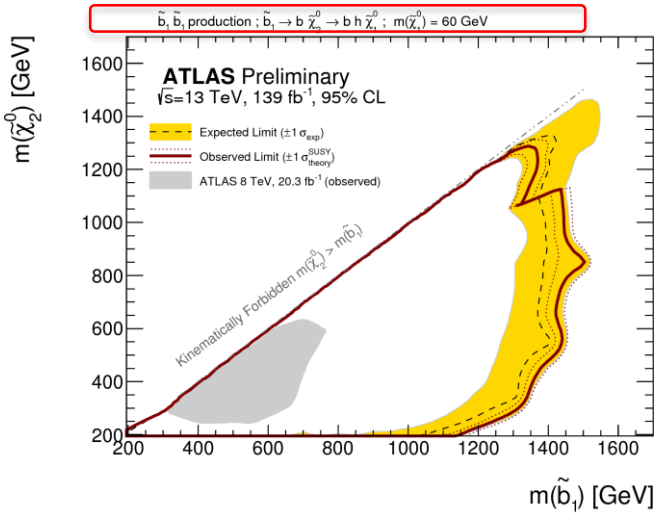


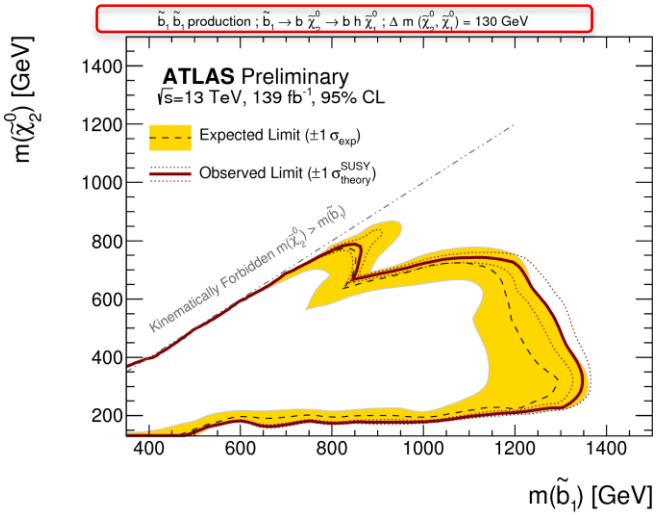




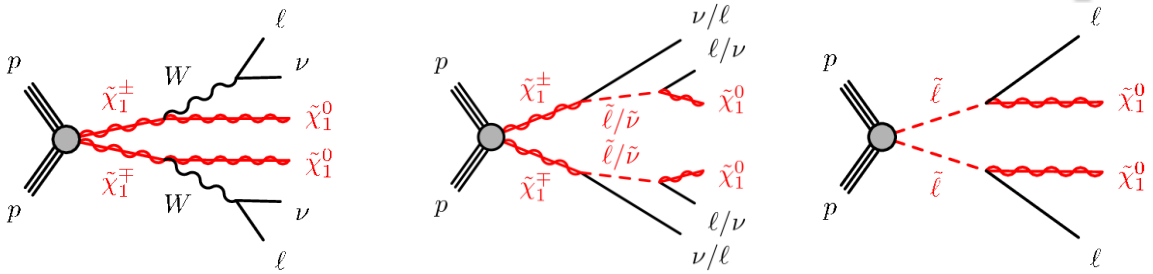






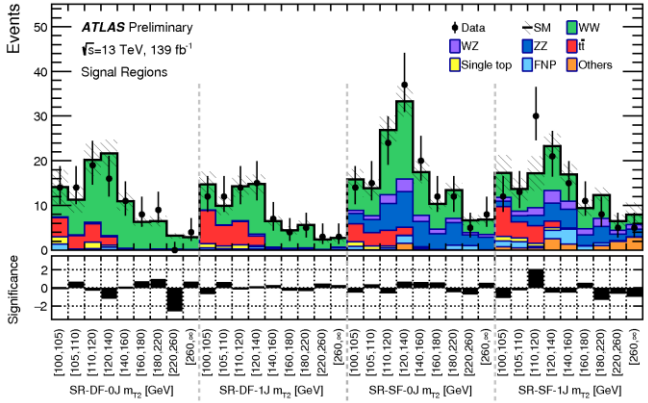


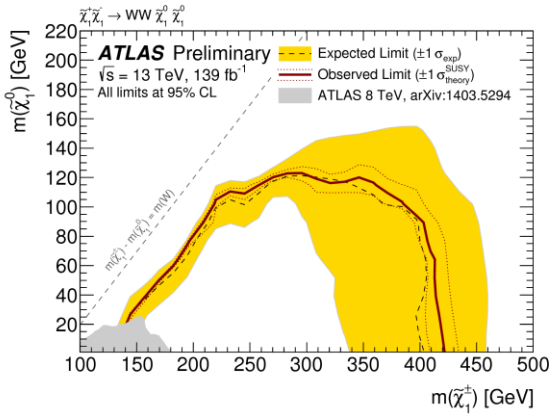
Search for EW processes

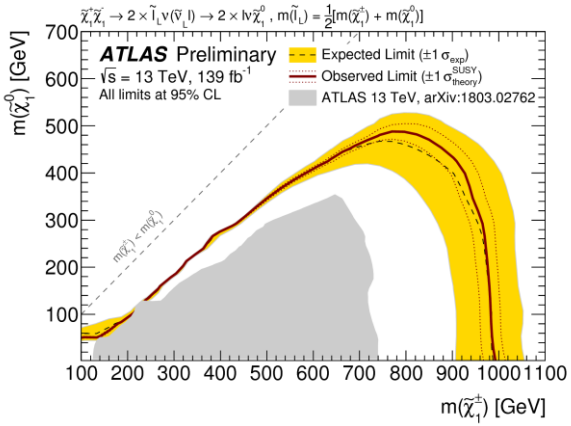


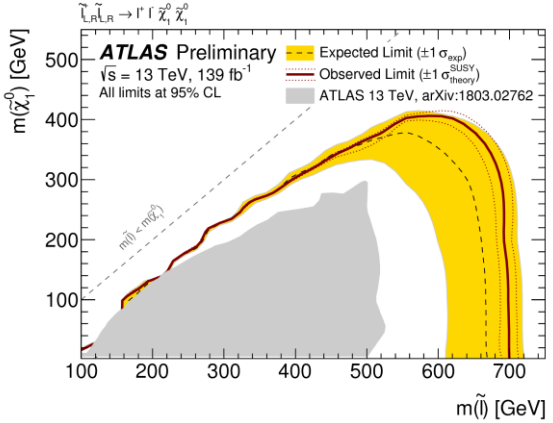
[ATLAS-CONF-2019-008]

- Search for electroweak production of charginos and sleptons decaying into final states with two leptons and E_T^{miss}
- stranverse mass m_{T2} is used for discrimination
- No excess is observed
  - Exclude mass < 420, 1000, 700 GeV when $m(\tilde{\chi}_1^0)$= 0 GeV for 3 cases, respectively



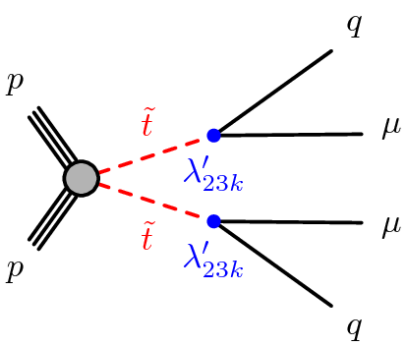




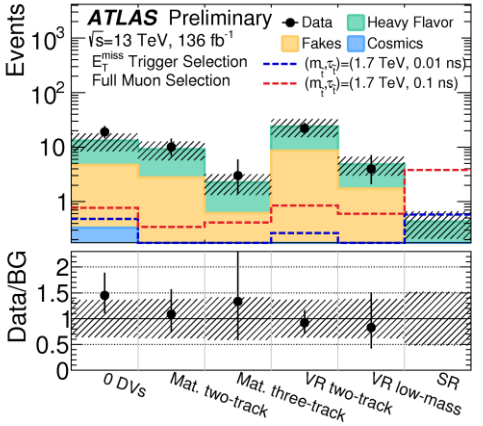


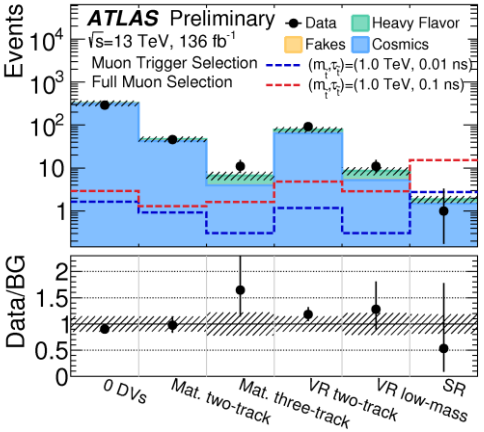
Search for long-lived particles

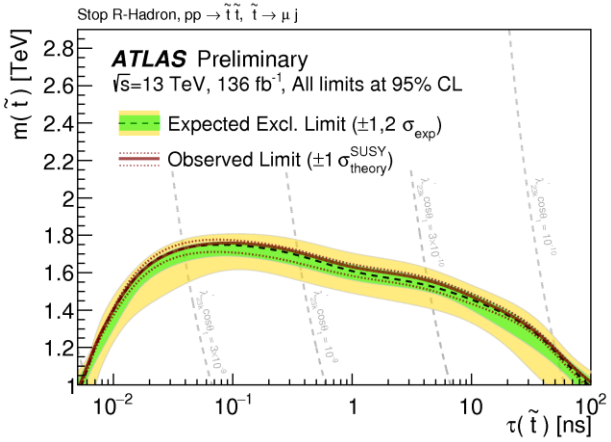
ATLAS-CONF-2019-006

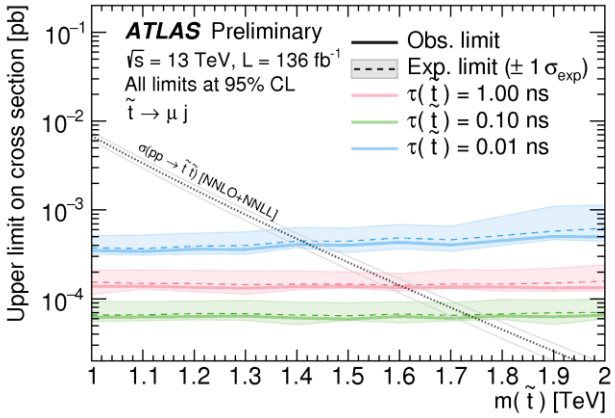


- Search for long-lived particles in RPV decaying into≥1 μ + hadrons
- Observed events yields are compatible with the SM expectation
- Set exclusion limits for pair-production of long-lived top squarks using a small RPV coupling
  - Exclude mass<1.7(1.3) TeV for lifetime of 0.1(0.01-30) ns





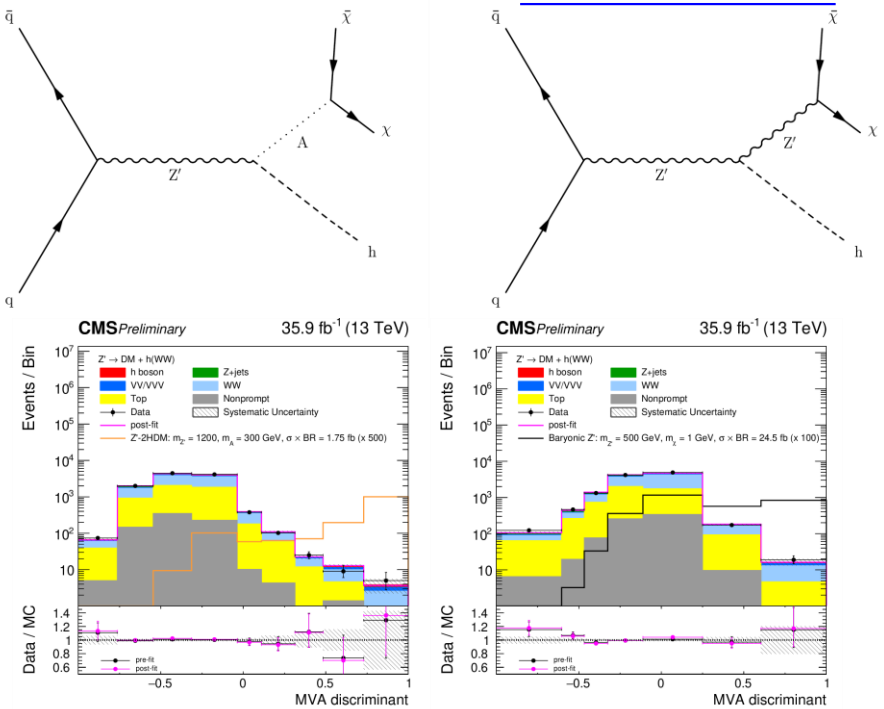


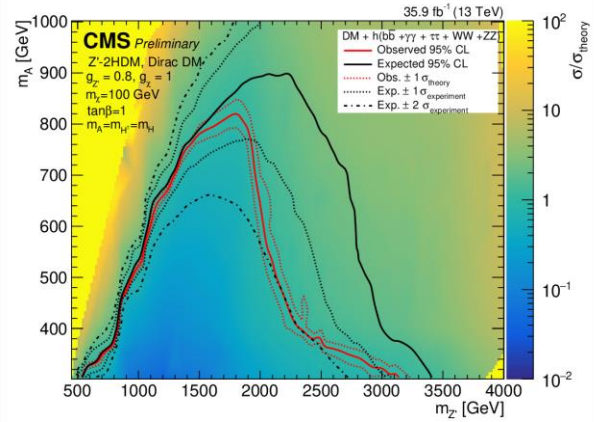


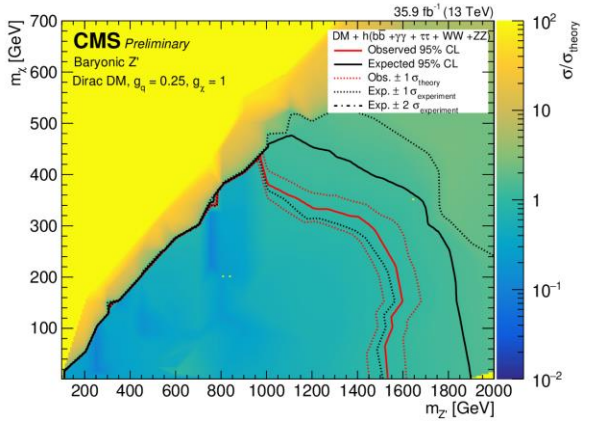
Dark matter associated with Higgs boson

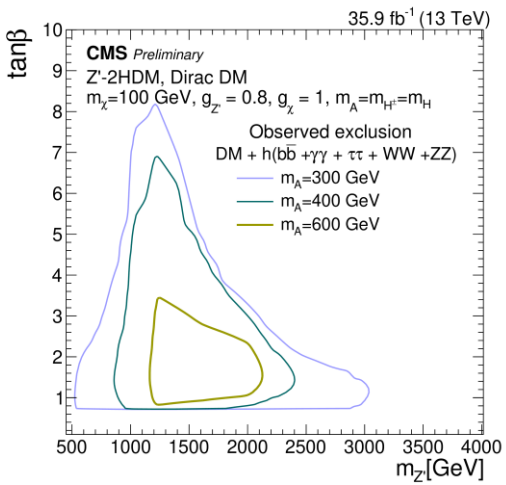
- Search for dark matter particles using Higgs+large E_T^{miss}
- 5 Higgs decay channels are covered
  - H->bb,ττ,γγ,WW,ZZ
- No excess. Combine 5 channels to set limits for 2 benchmark simplified models
  - Z'-2HDM; Baryonic Z'

EXO-18-011-PAS







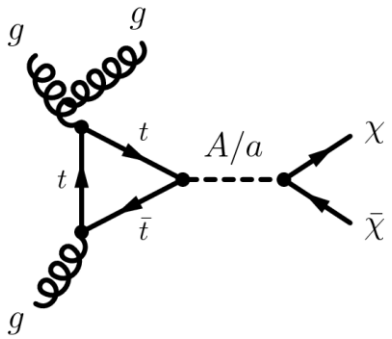


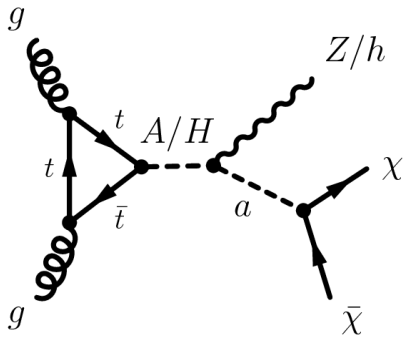
Mediator-based dark matter

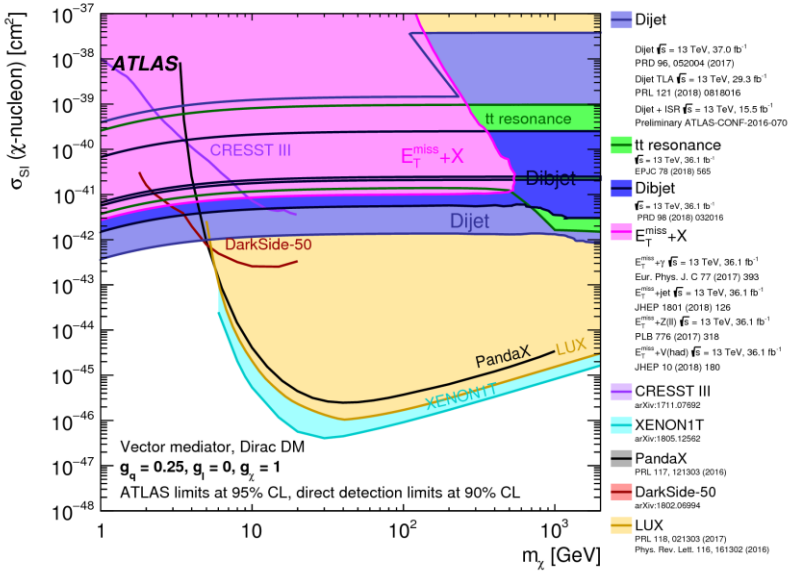
- Overview of ATLAS searches for mediator-based DM

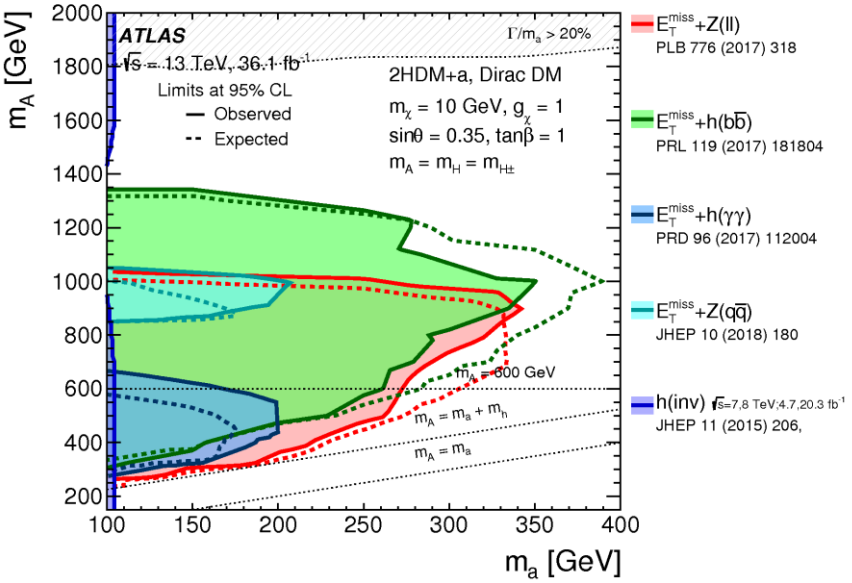
arxiv: 1903.01400

- Results of a variety of final states are interpreted in terms of different sets of models, complementary to direct searches and sensitive to low DM masses
  - Spin-1 and spin-0 single-mediator DM simplified models
  - Extended Higgs sector plus an additional vector or pseudo-scalar mediator





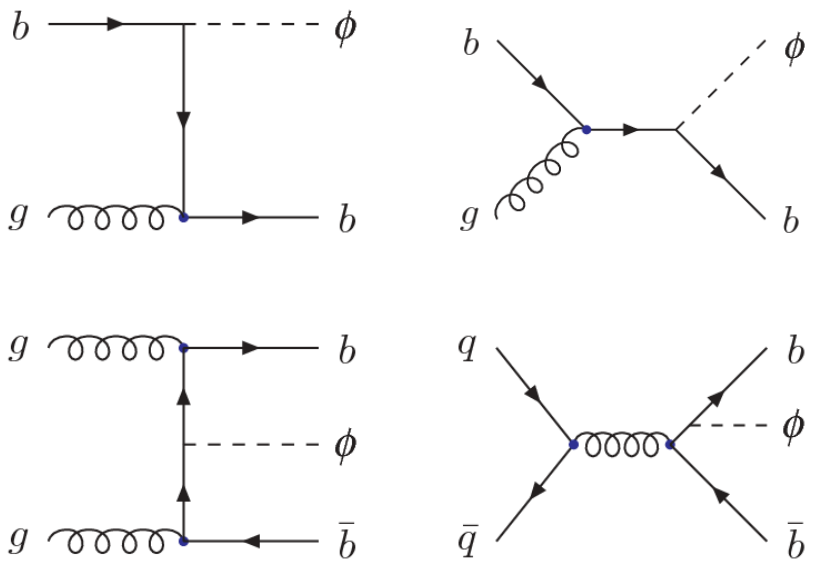


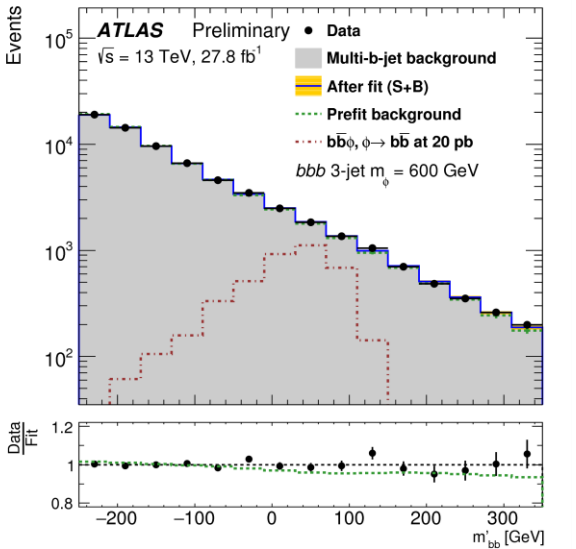


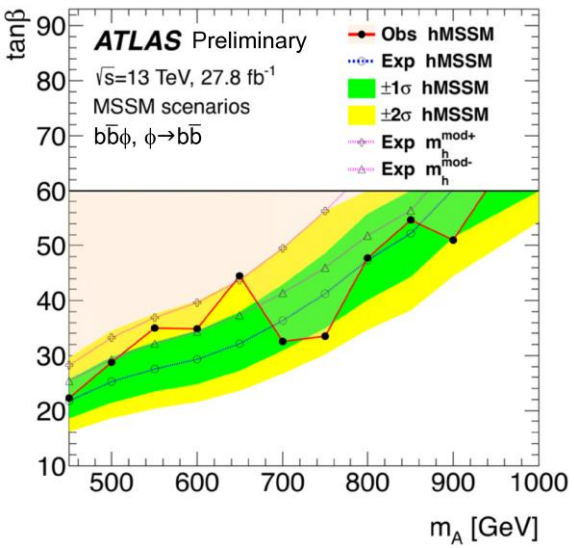
BSM Higgs (1)

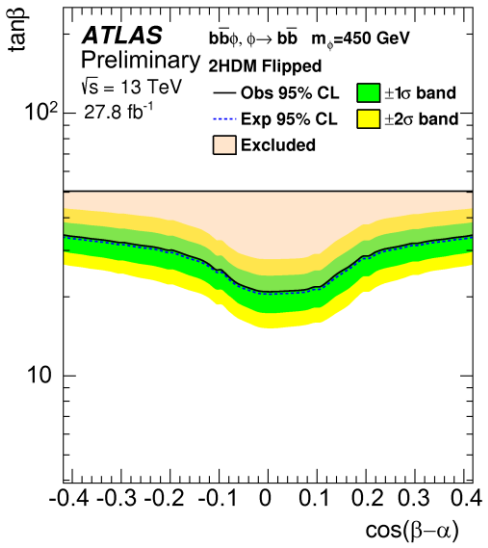
ATLAS-CONF-2019-010

- Search for heavy neutral Higgs bosons produced in association with one or two b-quarks and decaying to b-quark pairs
- No excess is observed. Interpret results with 2HDM and MSSM
  - Exclude mass in 450 -1400 GeV





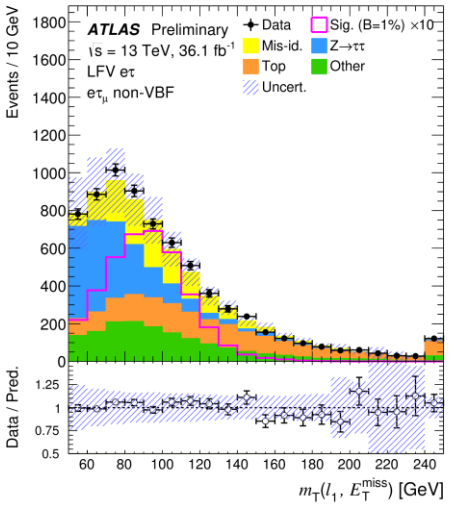


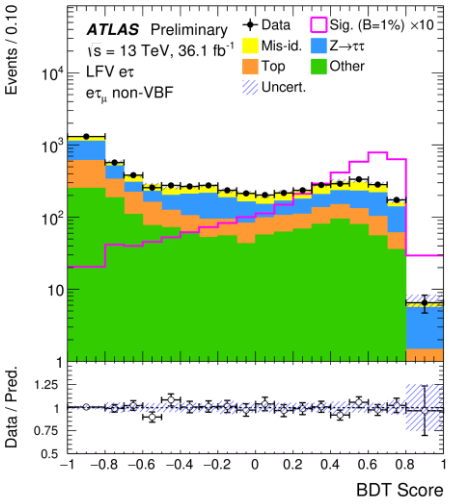


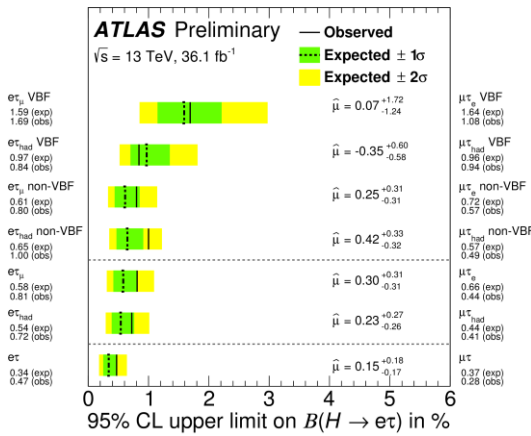
BSM Higgs (2): LFV

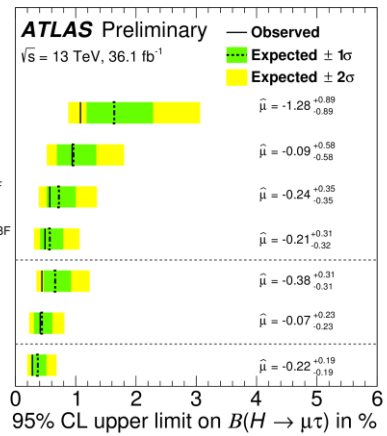
ATLAS-CONF-2019-013

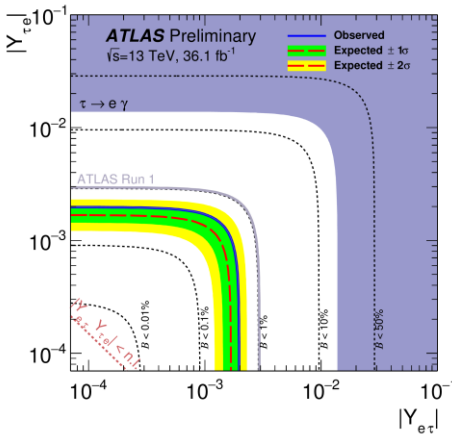
- Search for Lepton Flavor Violation in Higgs boson decays, H->eτ and H->μτ
- BDT is explored for better discrimination
- No signal is observed. Set upper limits on BR of the 2 channels
  - H->eτ: 0.47%
  - H->μτ: 0.28%

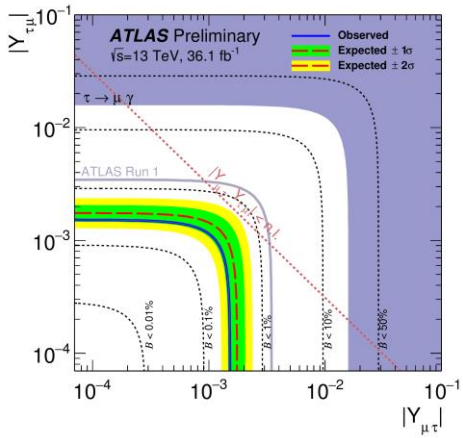






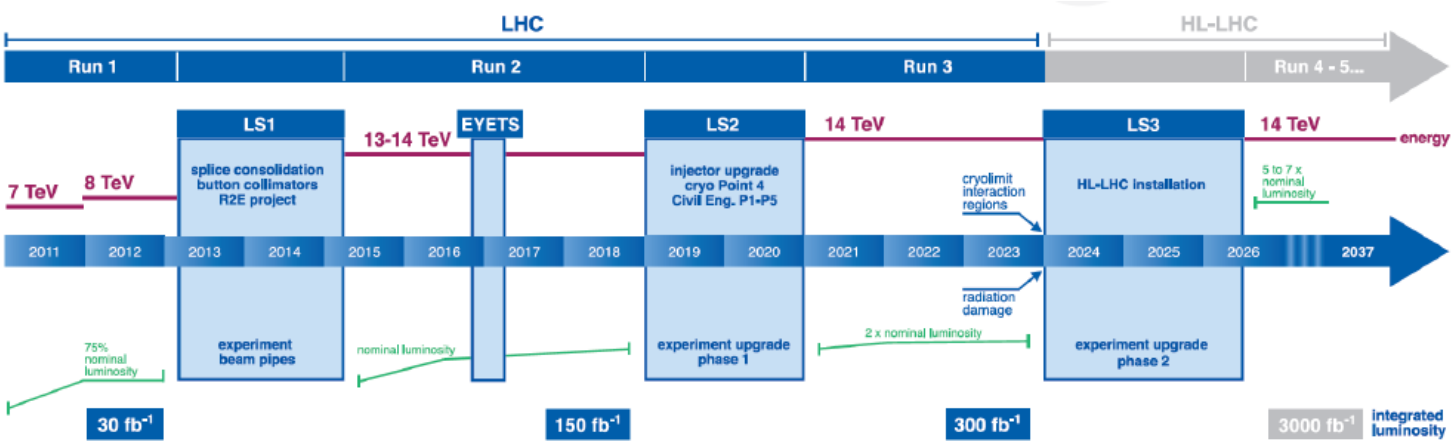






Summary

- Smooth running of the LHC and detectors
  - The peak luminosity($2x10^{34}cm^{-2}s^{-1}$) is twice the designed
- Fruitful results of new physics searches in multiple aspects and tested a variety of BSM theories.
  - Some analyses have utilized the full Run2 datasets. More will do
- LHC will resume running at 14 TeV in Run3. Look forward to more exciting physics!



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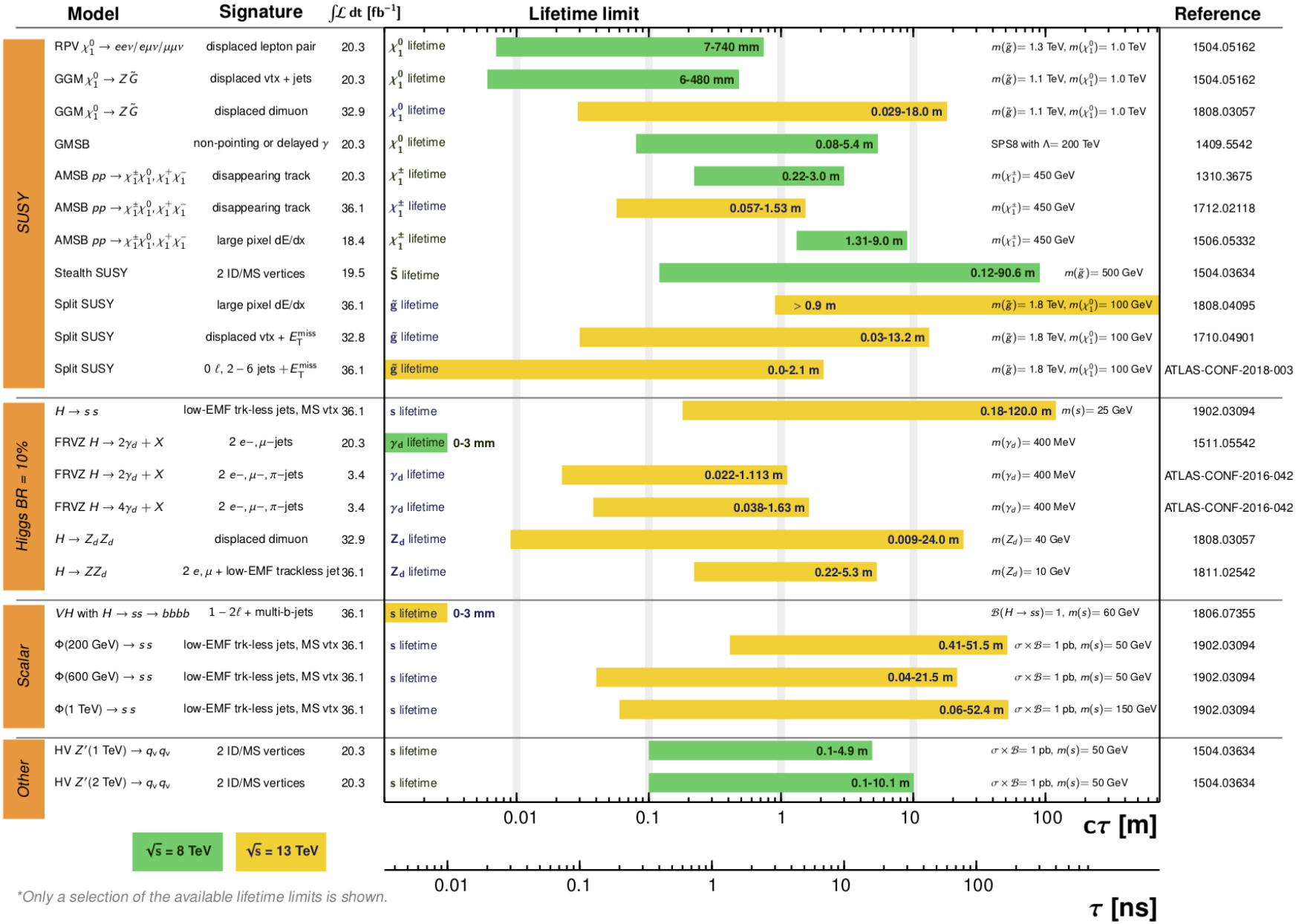
ATLAS Long-lived Particle Searches* - 95% CL Exclusion

Status: March 2019

ATLAS Preliminary

$\int \mathcal{L}\, dt$ = (3.4 – 36.1) fb^{-1} $\sqrt{s}$ = 8, 13 TeV



*Only a selection of the available lifetime limits is shown.