Non-resonant searches for new physics at the Large Hadron Collider

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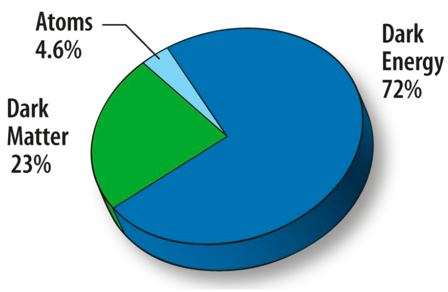
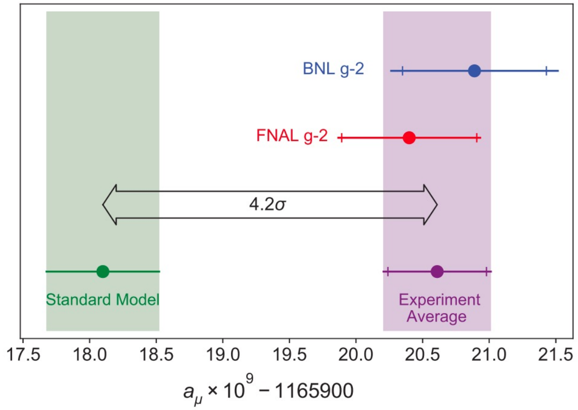
New Physics Searches at the LHC

- LHC provides excellent opportunities to search for BSM physics
- A wide range of new physics searches are conducted at the LHC
  - SUSY, leptoquarks, heavy leptons, axions, new dynamics/couplings
  - Many of BSM scenarios considered explain unresolved mysteries in SM
    - Hierarchy problem, dark matter, neutrino mass, muon g-2, B anomalies, W mass
  - Some of these BSM models produce the mass resonance: <u>see the Sergei's talk</u>
  - Some of them produce long-lived particles: <u>see Alberto's talk</u>
  - This talk will focus on searches for non-resonant BSM (or rare SM) signatures
    - Only a handful of recent results will be covered. See parallel talks and links on the right for more complete information

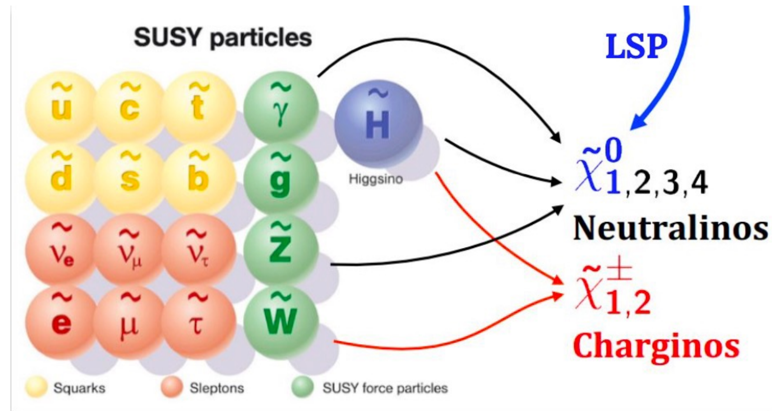


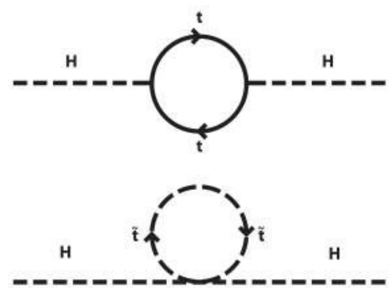


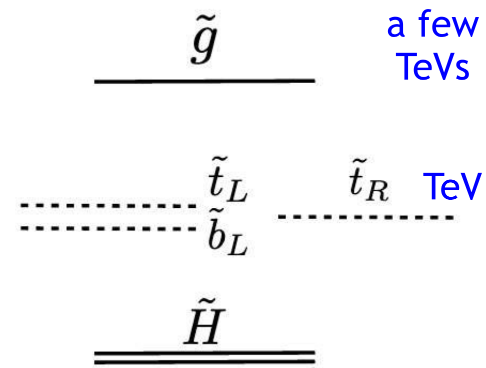
[ATLAS EXOT public results link]
[ATLAS SUSY public results link]
[CMS EXO public results link]
[CMS B2G public results link]
[CMS SUSY public results link]

Supersymmetry

- New symmetry between fermions and bosons
  - Introduces superpartners with spin differing by ½
- SUSY can explain some of SM shortcomings
  - Lightest SUSY particle serves as dark matter candidate
  - Natural solution to hierarchy problem with light gluino, stop, sbottom, and higgsino
  - Explain some of observed anomalies (e.g. smuon for g-2 measurement)
- Program of searches for R-parity conserving SUSY
  - Strong
  - Electroweak
  - 3rd generation

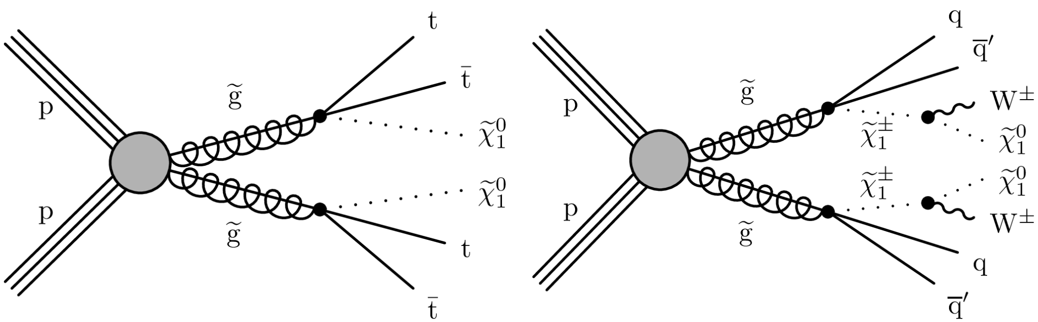






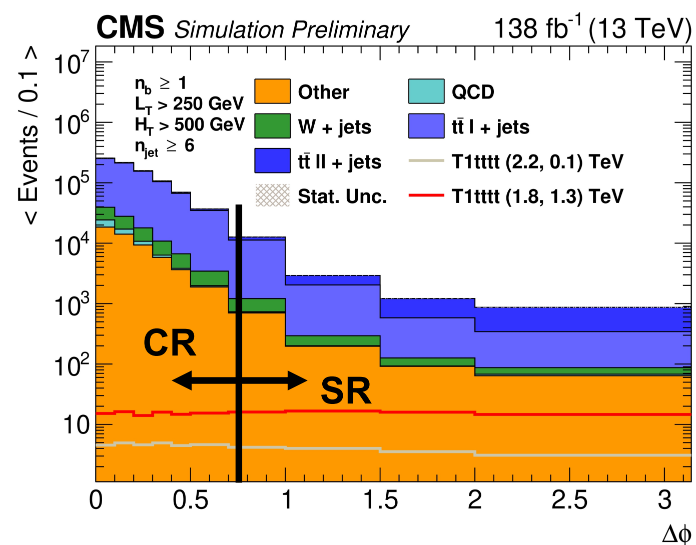
$$
\begin{aligned}
m_h^2 &= (m_h^2)_0 - \frac{1}{16\pi^2}\lambda^2\Lambda^2 + \frac{1}{16\pi^2}\lambda^2\Lambda^2 + \dots \\
&\approx (m_h^2)_0 + \frac{1}{16\pi^2}(m_{\tilde{f}}^2 - m_f^2)\ln(\Lambda/m_{\tilde{f}}) ,
\end{aligned}
$$

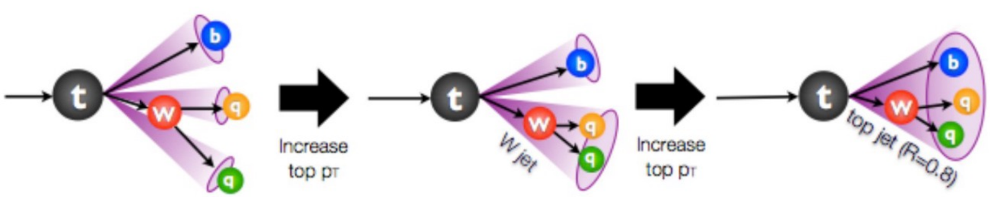
Searches for Gluinos

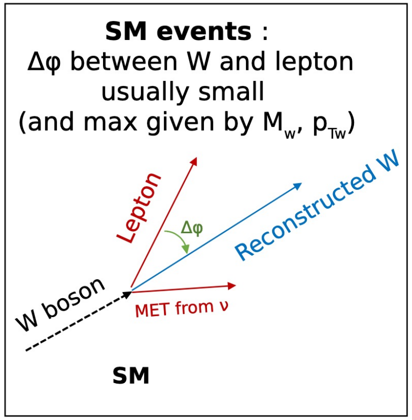


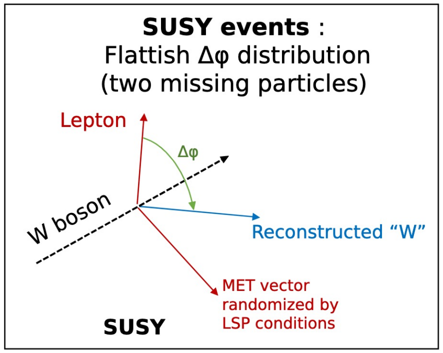
Main selections:

- One lepton (e or μ)
- $N_{jet} \geq 5$ (6) for 0-b (multi-b)
- High H_T, $L_T = p_T(lep) + MET$
- For multi-b: $N_b \geq 1$ and $N_{top} \geq 1$
  - Utilize DNN-based DeepAK8 for merged top, and resolved top tagger for lower pt top quarks

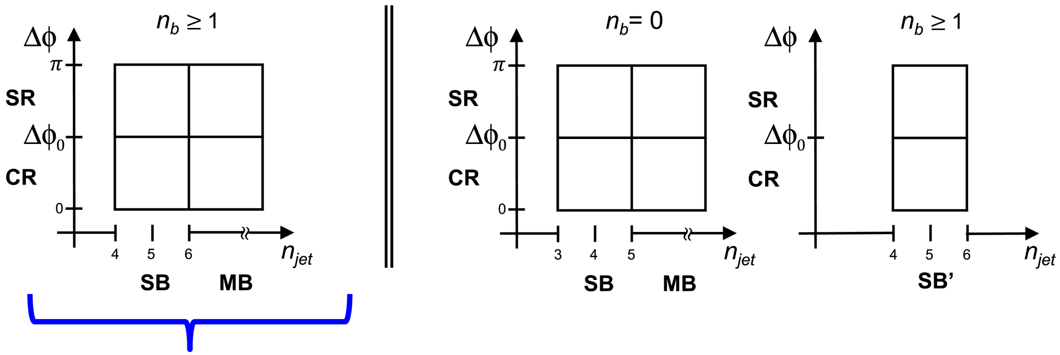




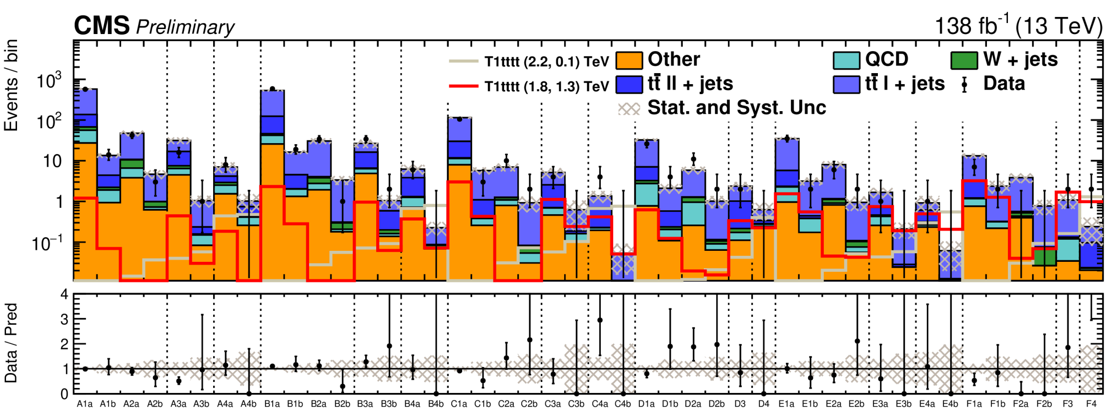




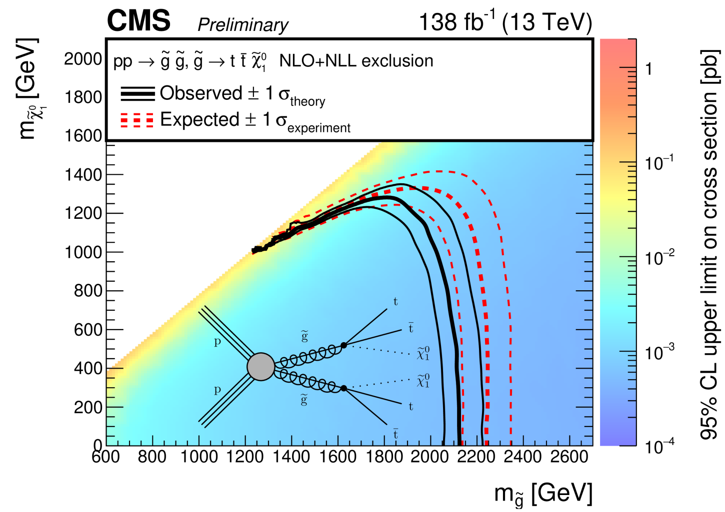
Searches for Gluinos

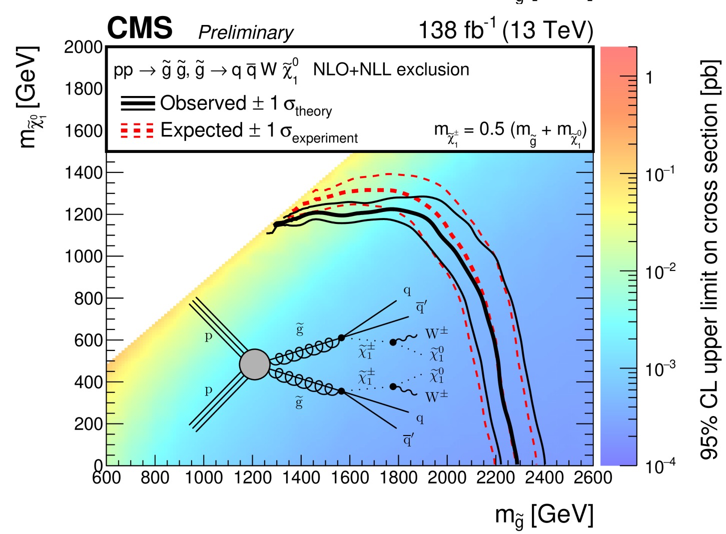


Further binned in N_{jet}, N_b, L_T, H_T, N_{top}



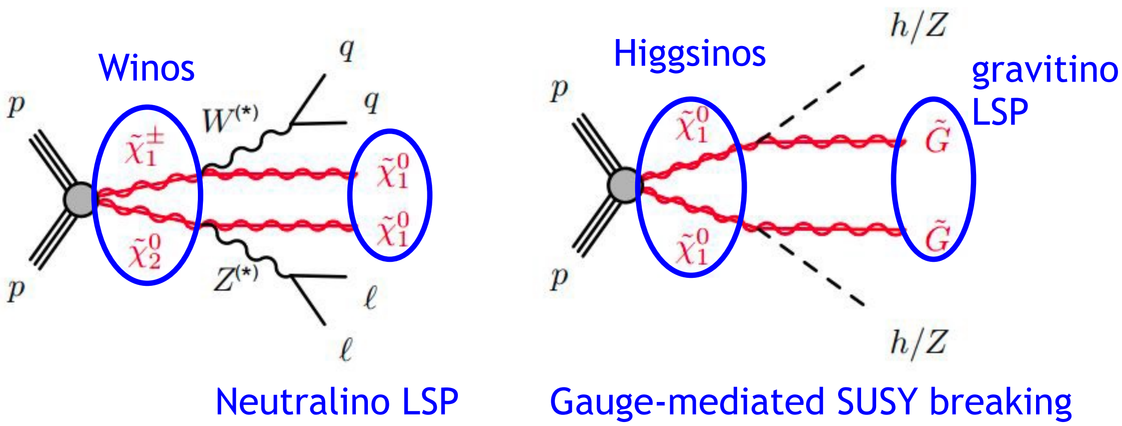
No statistically significant excess in data over the background estimations



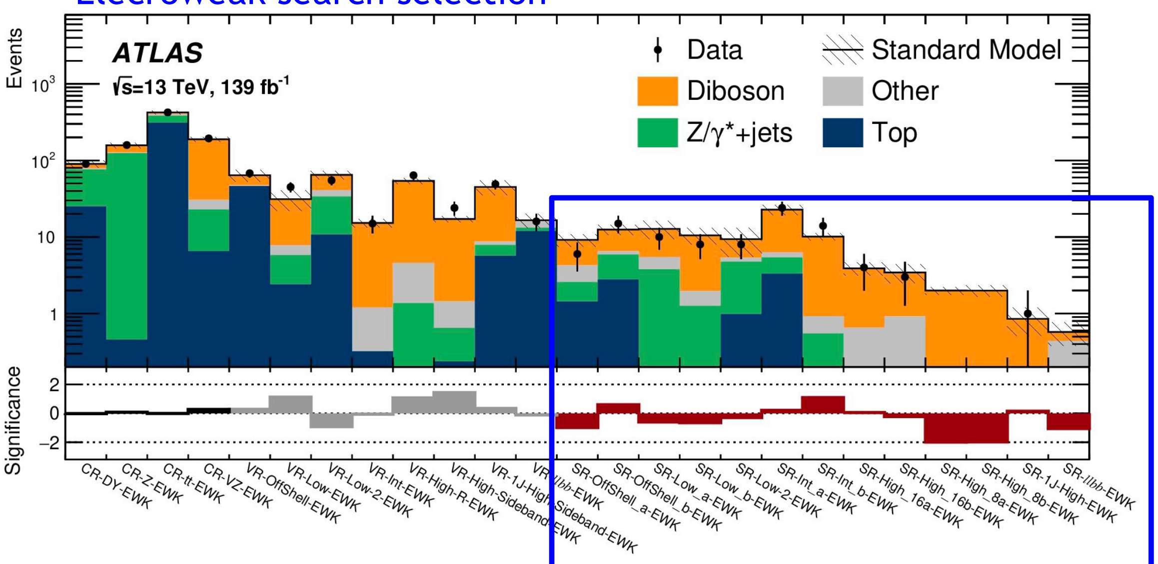


Extend exclusion by about 350 (200) GeV on gluino (neutralino) masses

Charginos/neutralinos w/ 2 leptons + jets



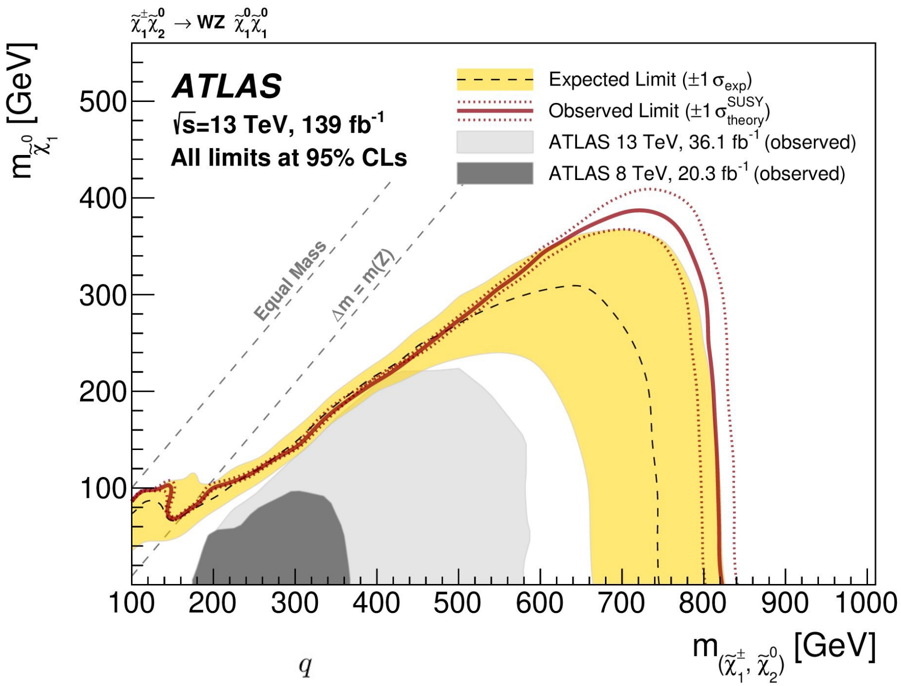
Elecroweak search selection

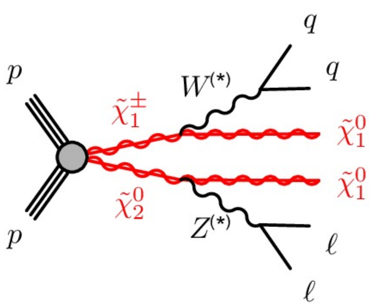


- Main selections:
  - 2 leptons, 1 or ≥ 2 jets, high MET significance, M_{T2}
  - Selection optimized for elecroweak SUSY signals and colored SUSY particles
- EWK search regions defined to target different SUSY particle masses
  - Binned in N_{jet}, N_b, MET significance, M_{ll}, ΔR_{jj}

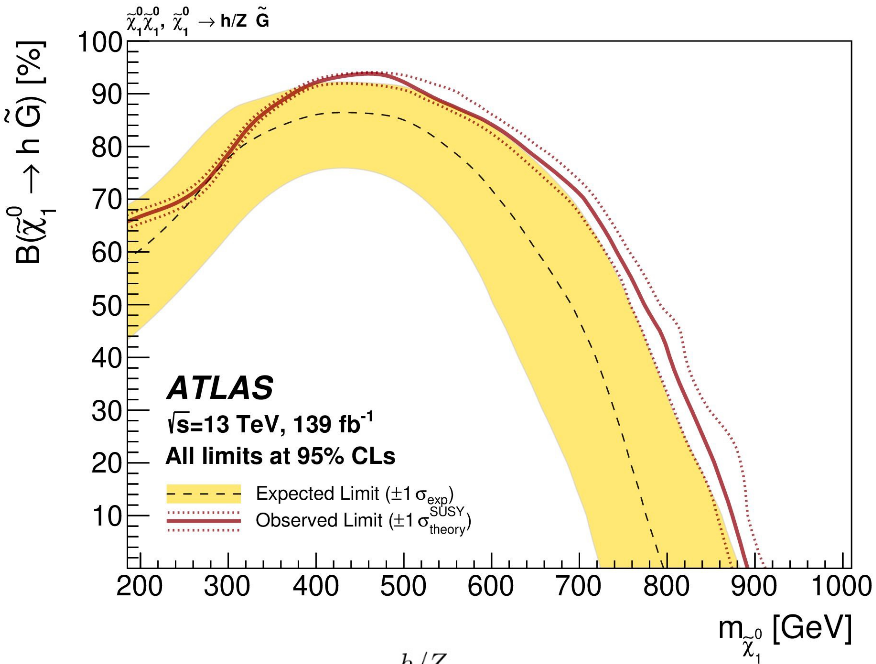
No statistically significant excess in data

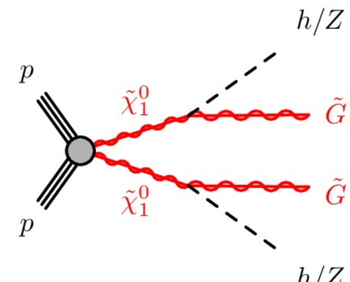
Charginos/neutralinos w/ 2 leptons + jets





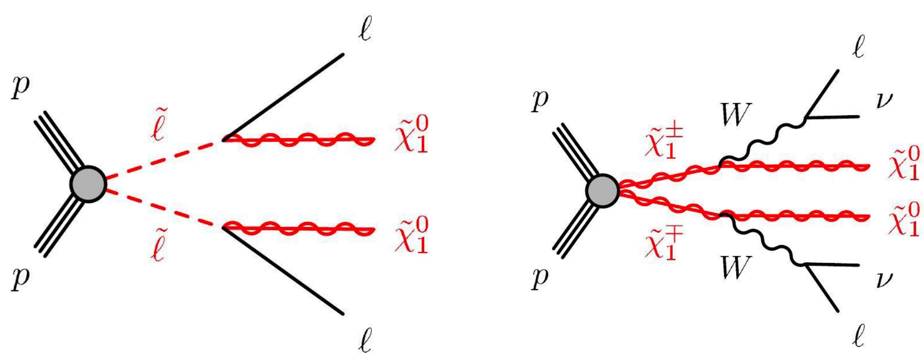
Significant extension of limits w.r.t. earlier searches



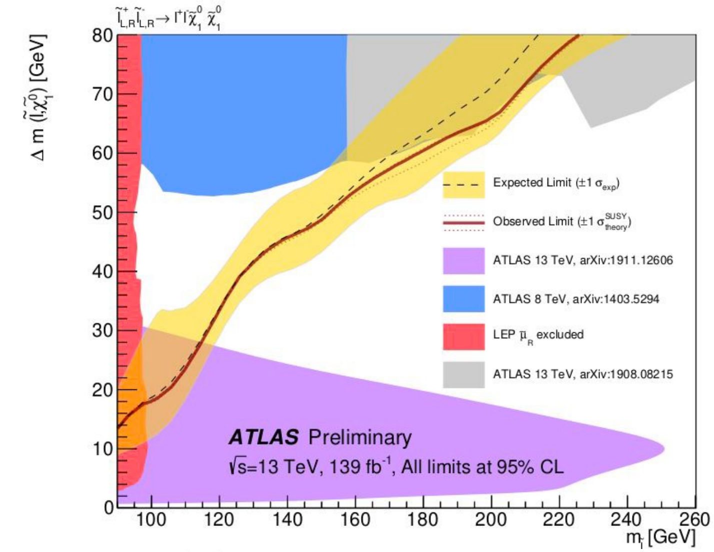


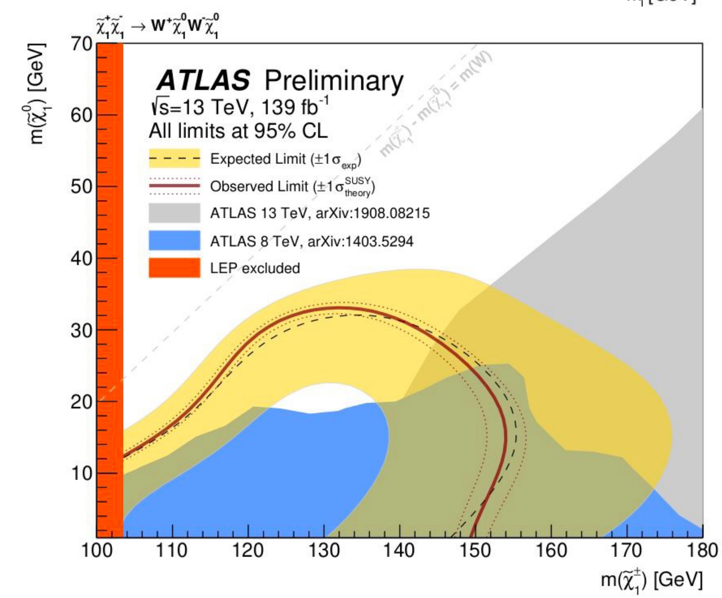
gravitino assumed to be massless

Charginos/neutralinos w/ 2 leptons + no jet

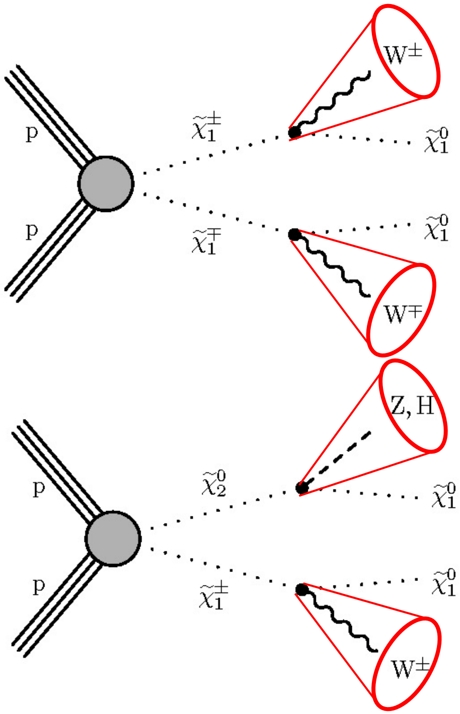


- ☐ Main selections: 2 leptons, no jet & large MET
- ☐ Focusing on difficult region with slepton-neutralino and chargino-neutralino mass difference of the order of W boson mass
  - ■ Challenging signature, very similar to WW
  - ■ LEP limits are still persisting
  - ■ The smuon limits are interesting in light of the muon g-2 anomaly
- ☐ Dedicated search strategy for each model
  - ■ The slepton search uses the data driven background estimation for the SF symmetric (e^+e^-/$\mu^+\mu^-$) background from DF ($e\mu$) CR.
  - ■ The chargino search deploys the BDT.
- ☐ Data compatible with SM background

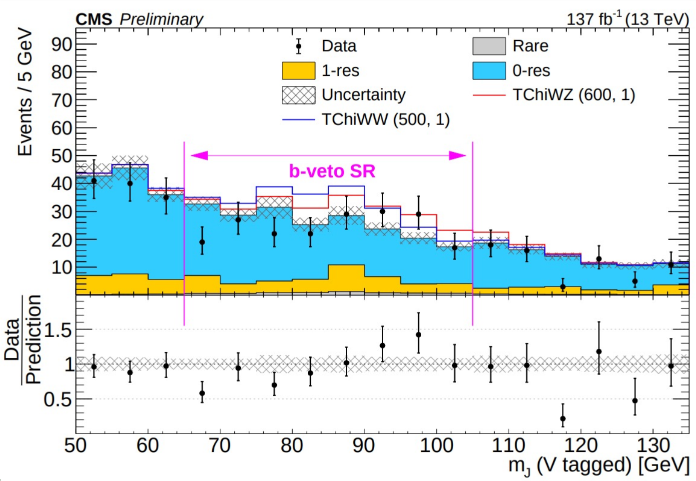


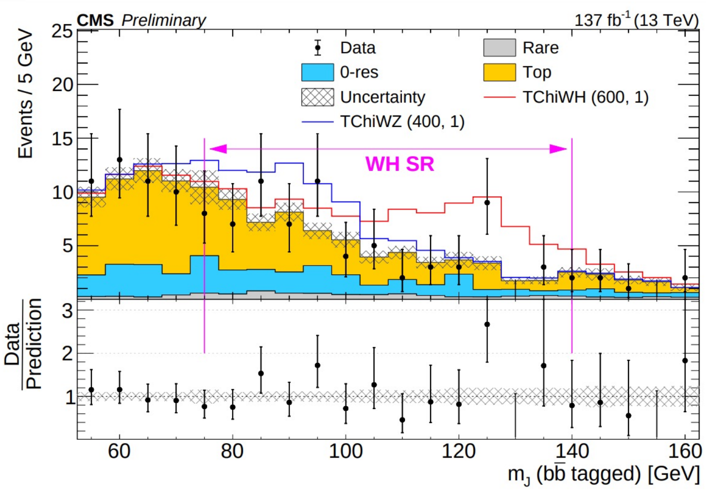


Charginos/neutralinos w/ boosted W/Z/H



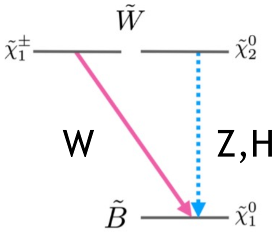
- Main selection: 2 bosons decay hadronically, giving two AK8 jets, no lepton, large MET
  - DNN to discriminate W/Z/H to qq decays from QCD jets.
- Two search regions:
  - b-veto: WW+MET & WZ+MET, W->qq', Z->qq
  - b-tag: WZ+MET & WH+MET, H/Z->bb & W->qq'
- Dominant Bkg: ttbar, W/Z+jets, estimated by data-driven methods
- No significant deviations from SM predictions

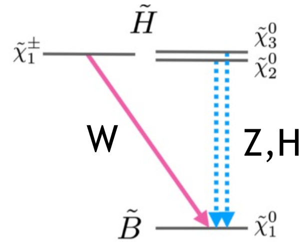


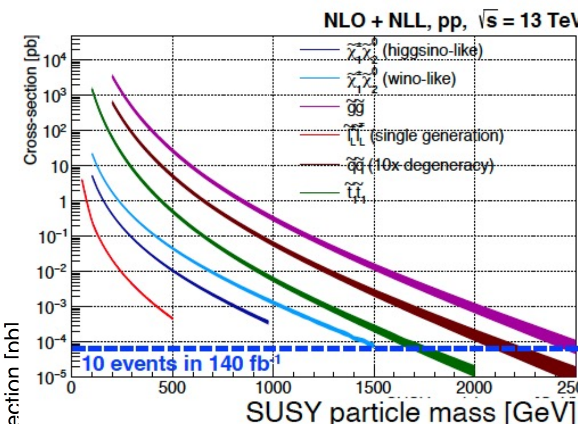


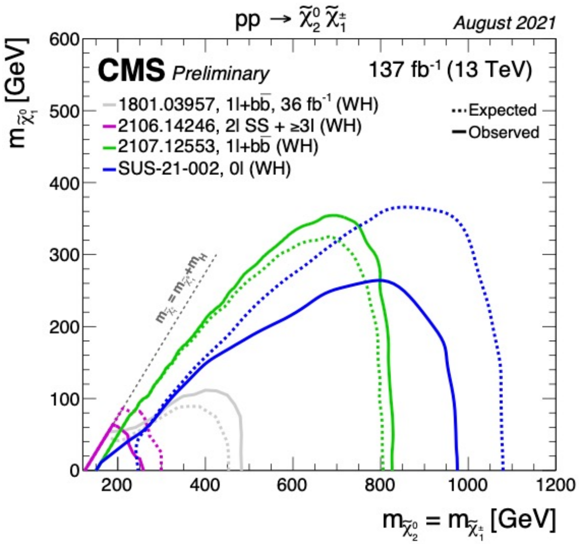
Charginos/neutralinos w/ boosted W/Z/H

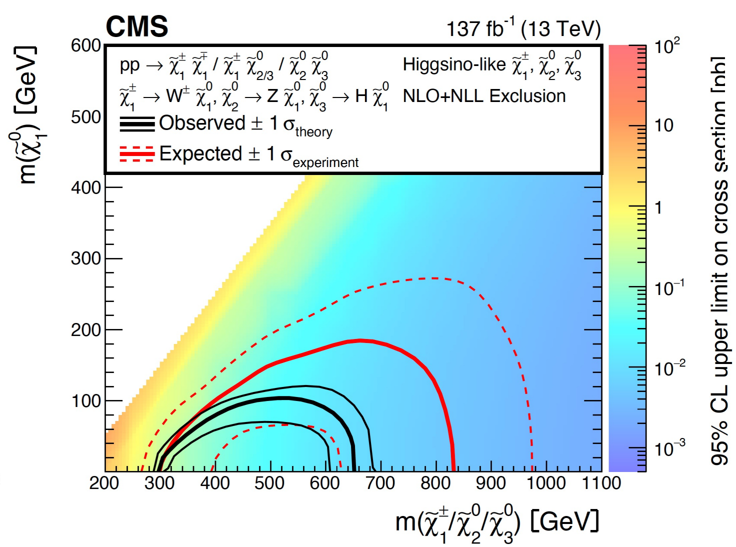
- Realistic wino scenarios involve $\chi^{\pm}_1 \chi^{\pm}_1$ and $\chi^{\pm}_1 \chi^0_2$ production. Two cases $\chi^0_2 \rightarrow Z + \chi^0_1$ with 100% BR or $\chi^0_2 \rightarrow H + \chi^0_1$ with 100% BR are considered.
- Search is also sensitive to higgsino models with $\chi^0_2 \rightarrow \chi^0_1 + Z$, $\chi^0_3 \rightarrow \chi^0_1 + H$.
- Searches started to become sensitive to low x-section higgsino production







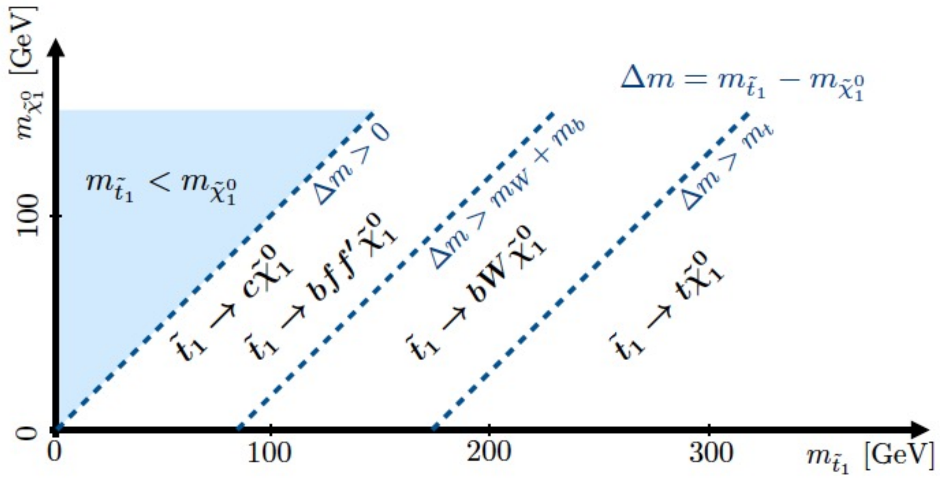




Similar ATLAS analsysis
SUSY-2018-41/

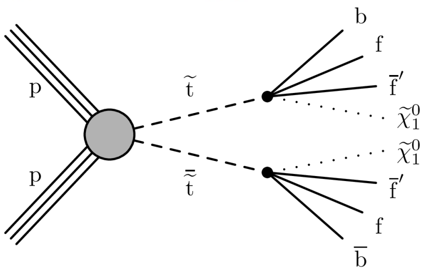
Searches for Top Squarks

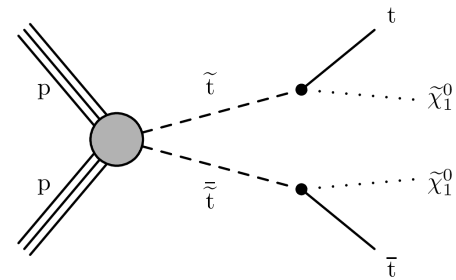
- Central to the naturalness problem
- Comprehensive top squark search program at the LHC
  - Different signatures depending on SUSY particle mass spectra and SUSY breaking mechanism

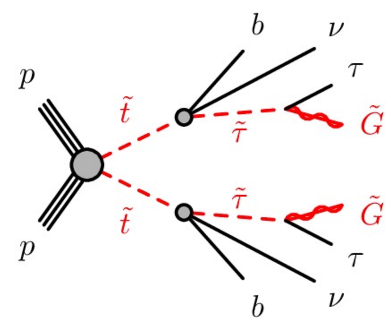


Run2 results targeting at stop pair production:

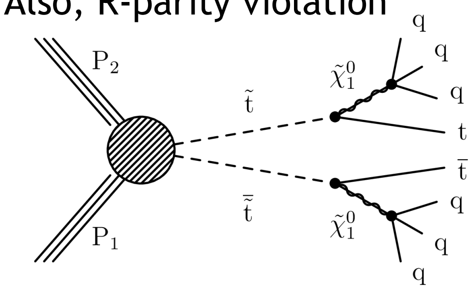
- 0ℓ: SUSY-2018-12 (ATLAS), SUS-19-010 (CMS)
- 1ℓ: SUSY-2018-07 (ATLAS), SUS-19-009 (CMS)
- 2ℓ: SUSY-2018-08 (ATLAS), SUS-19-011 (CMS)
- Combination (w/ corridor): SUS-20-002 (CMS)
- Stop with Zh: SUSY-2018-21 (ATLAS)
- Stop with taus: SUSY-2019-18 (ATLAS), SUS-19-003 (CMS)
- RPV/Stealth: SUSY-2019-04, SUSY-2018-38 (ATLAS), SUS-19-004 (CMS)



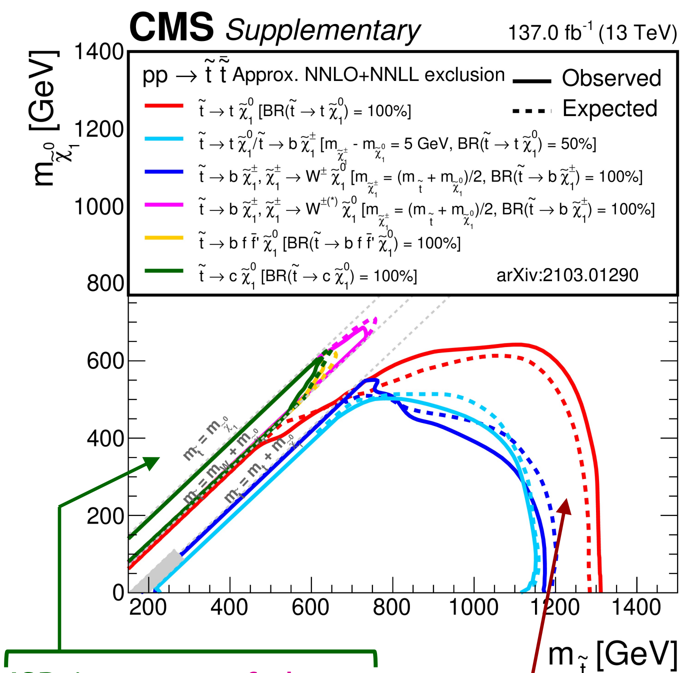




Also, R-parity violation

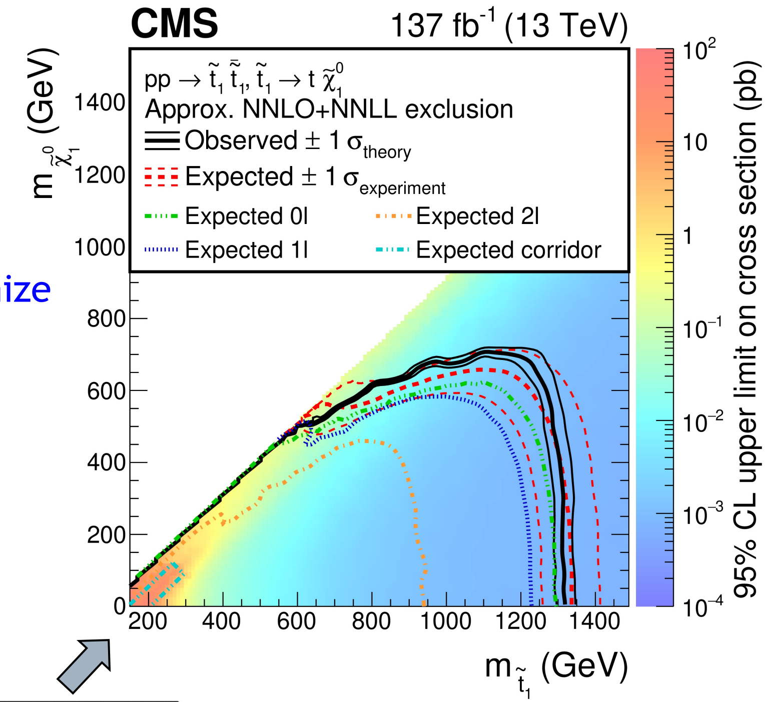


Searches for Top Squarks

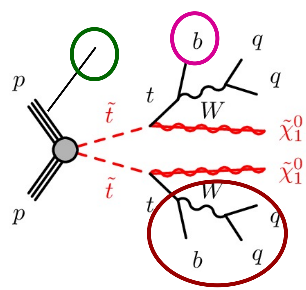


SUS-19-010

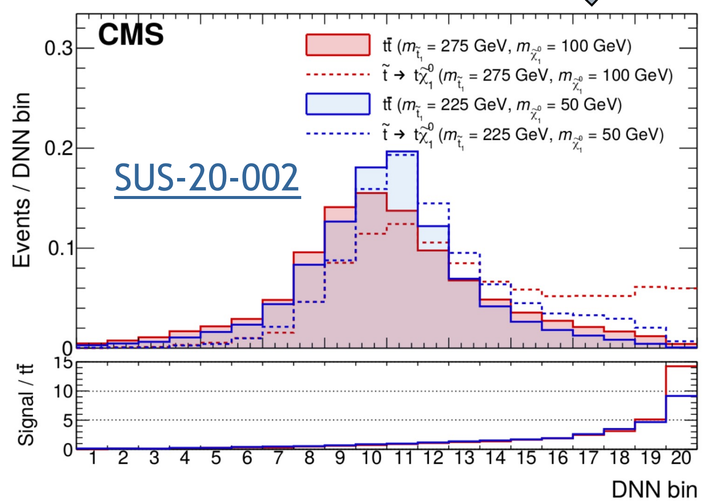
Combine multiple channels to maximize sensitivities



ISR jet tag, soft-b tag



DNN-based top tagging

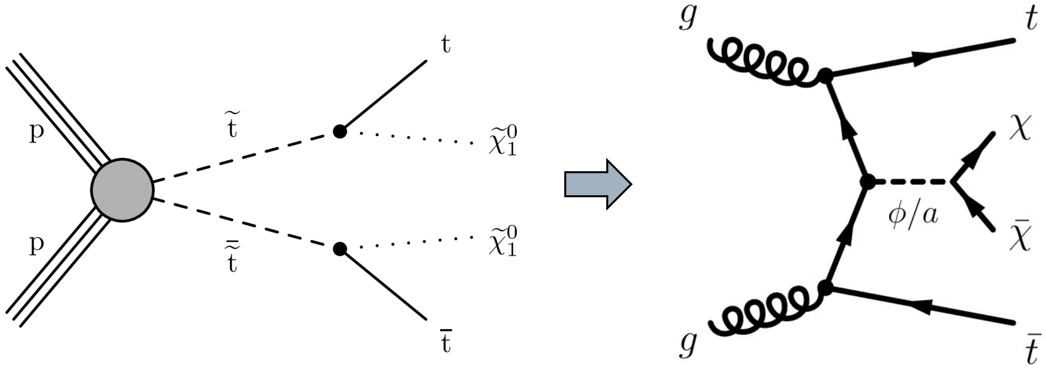


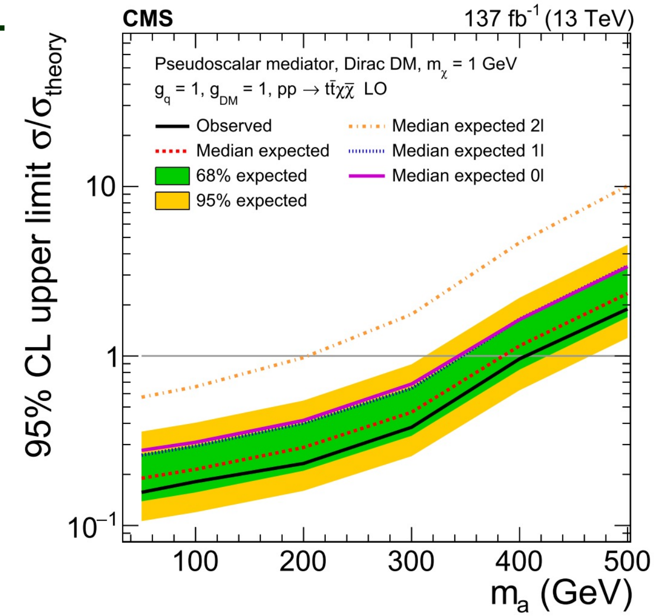
SUS-20-002

Dedicated search with DNN to discriminate signal from ttbar background to tackle the challenging phase space:
Inputs: dilepton p_T, lepton p_T, η, $\Delta\varphi$, $\Delta\boldsymbol{\eta}$, m_{jj}, MET, M_{T2}, H_T

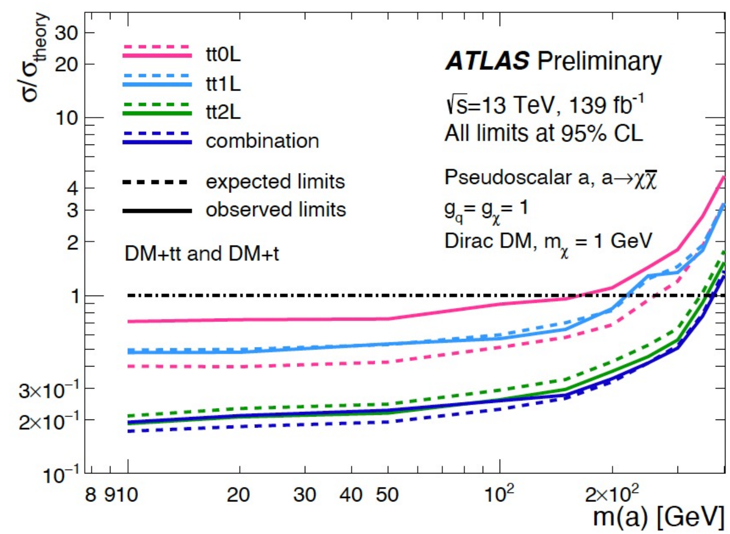
[CMS-SUS-20-002](), [ATLAS-CONF-2022-007]()

tt+DM





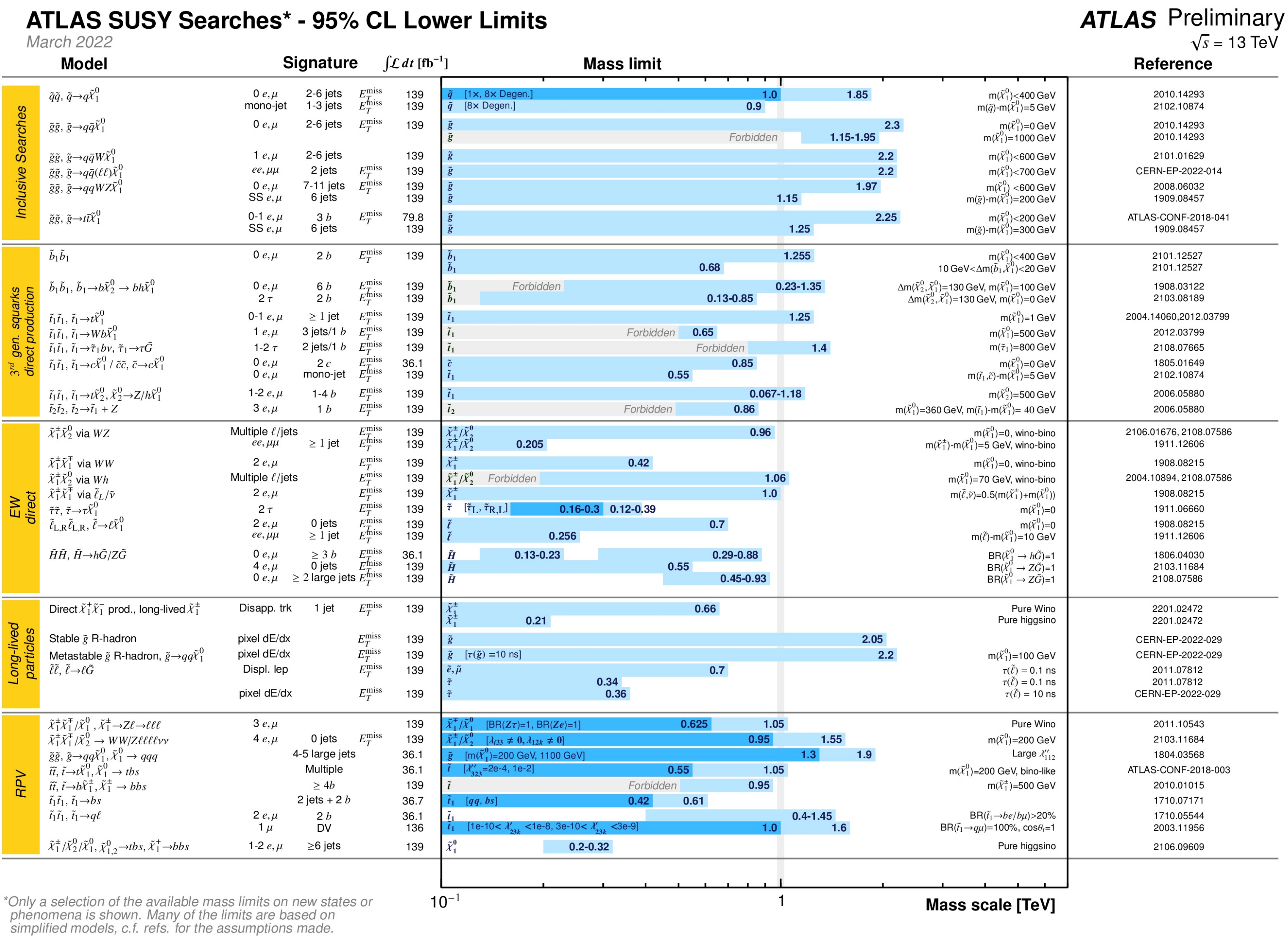
- Top squark searches are used to constrain other BSM models
- ATLAS recent combination includes both tt+DM and tt+H(->invisible) results



Reinterpretations of dedicated searches help us extract more interesting physics

ATL-PHYS-PUB-2022-013
CMS Summary plots

SUSY Search Summary



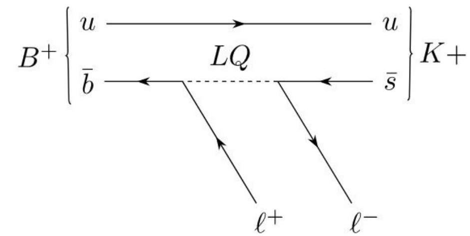
gluino limit ~ 2 TeV

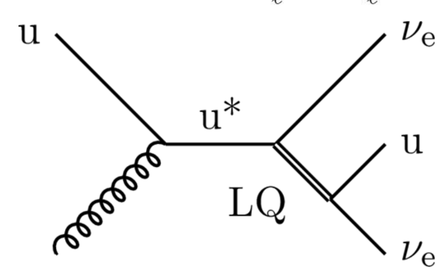
stop/sbottom limit ~ 1 TeV

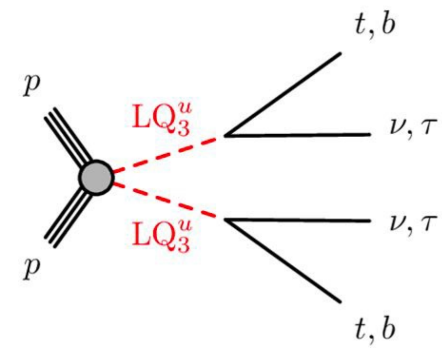
Electroweakino/ slepton limit < TeV

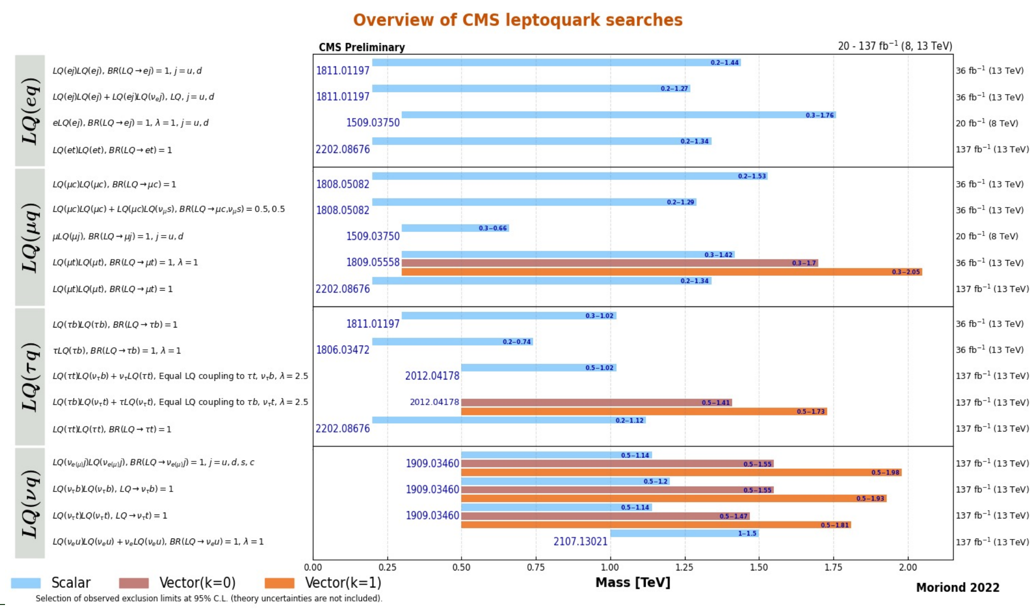
Leptoquarks (LQs)

- Leptoquarks (LQs) can couple to both leptons and quarks
  - Both scalar and vector bosons are possible
- Processes can violate lepton flavor universality
  - Strongly couple to 3rd generation SM fermions
  - LQs that couples to 3rd gen quarks and 2nd gen leptons could be possible explanation for recent B anomalies
- Predicted in GUTs and composite Higgs models



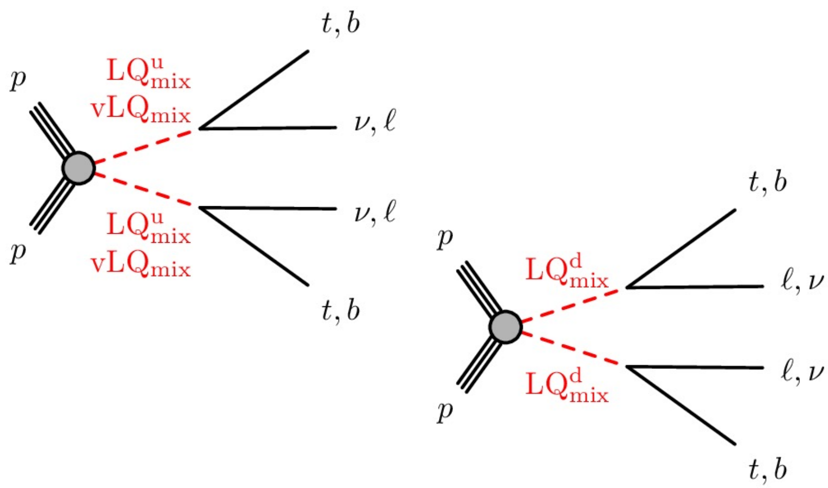


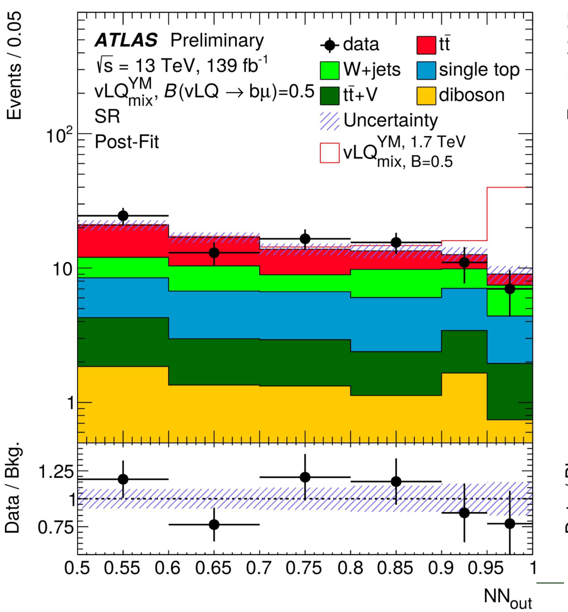


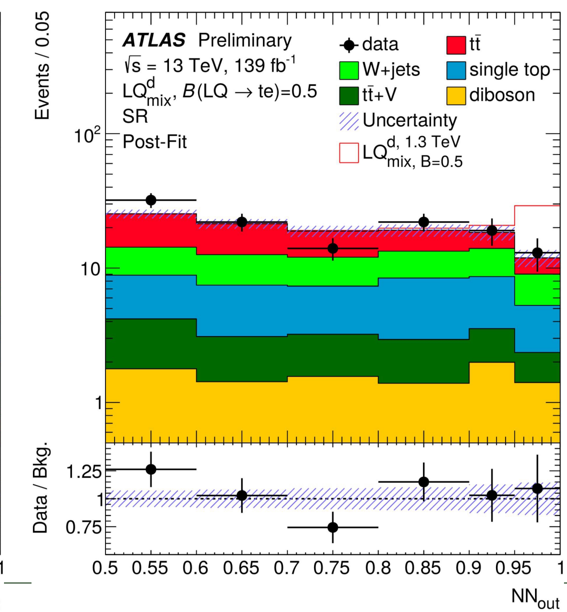


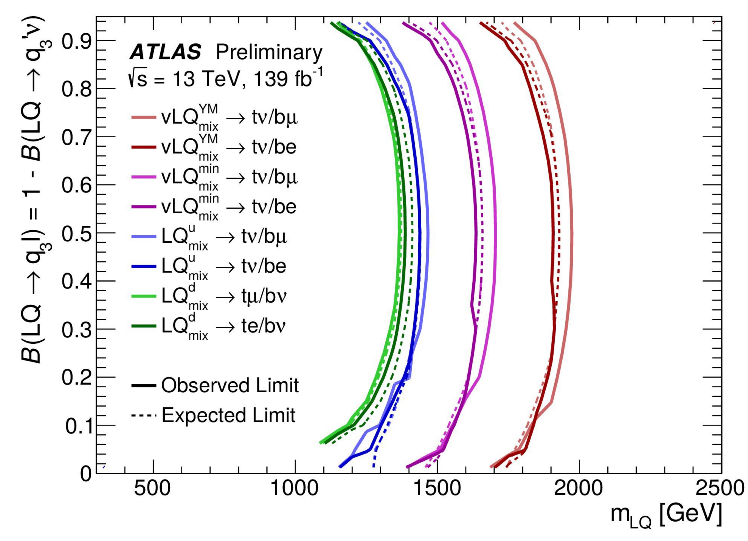
Search for scalar and vector leptoquarks

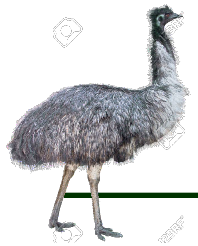
- Considers the LQ scenarios where the LQ decays into 1st & 2nd generation charged & neutral leptons
  - motivated by B anomalies
- Selections
  - 1 lepton, high MET, >=4 jets
  - Dedicated NN, separately for both scalar and vector LQs











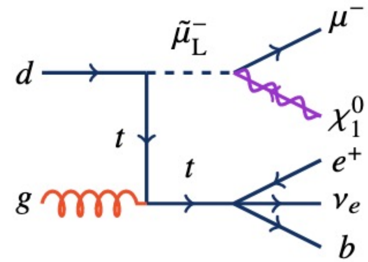
e/mu asymmetry

- Measure

$$\rho \equiv \frac{\sigma(pp \to e^+\mu^- + X)}{\sigma(pp \to e^-\mu^+ + X)}$$

very generally in broad regions of data

- Some BSM models predicts >1
  - SUSY (slepton), LQ , …
- Event selection
  - 2 leptons (e/μ), high ΣMT
  - Search bins based on M_{T2}, MET significance, $H_p = p_T(e) + p_T(\mu) + p_T(j1)$
- The measurement consistent with 1
  - Place constraints on LQ and smuon



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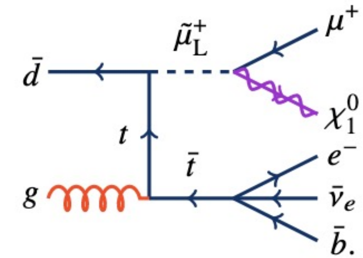
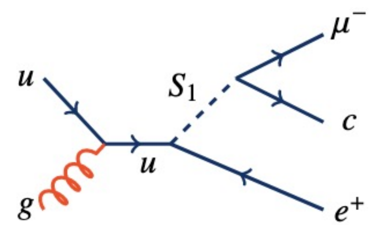
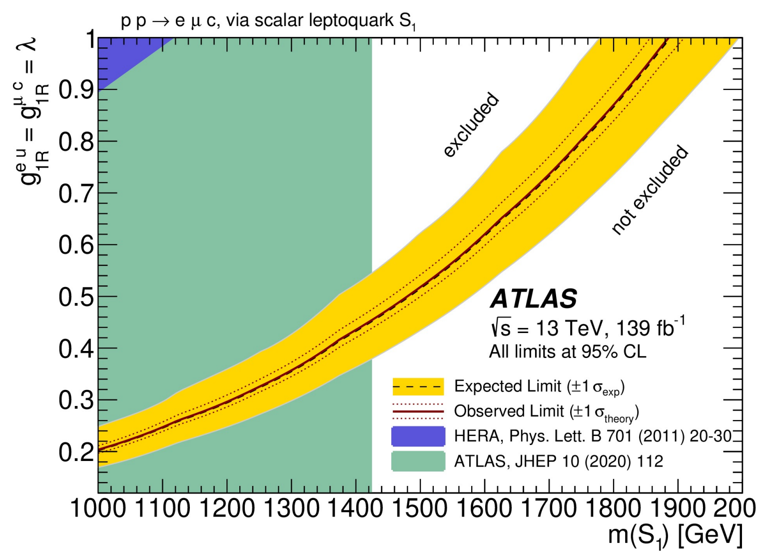
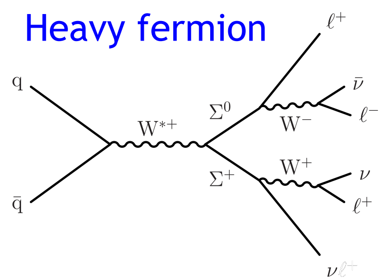


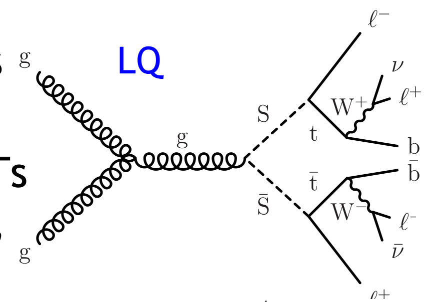


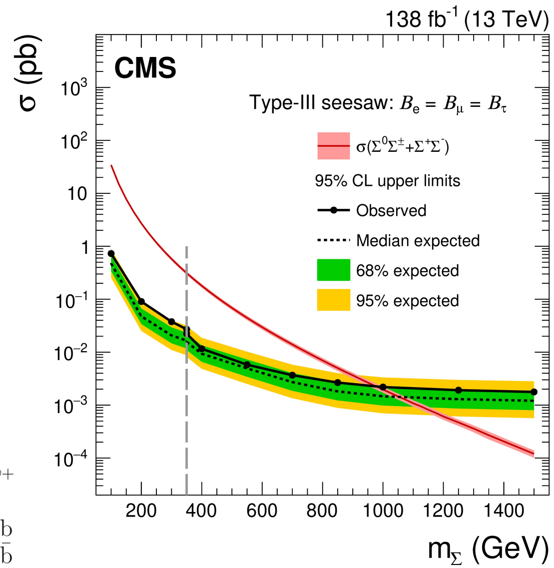


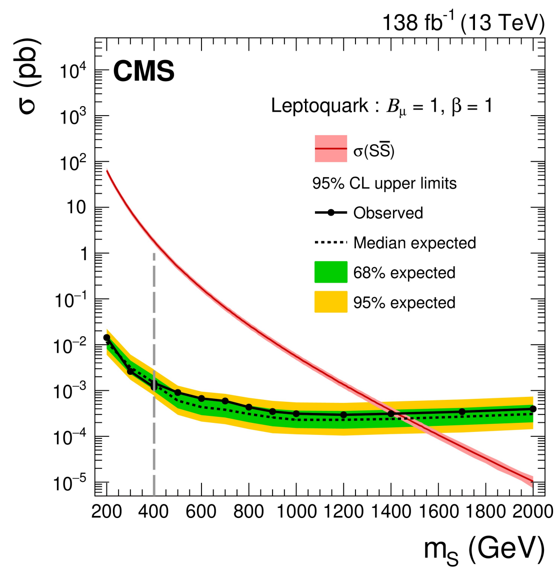
Inclusive non-resonant multilepton search

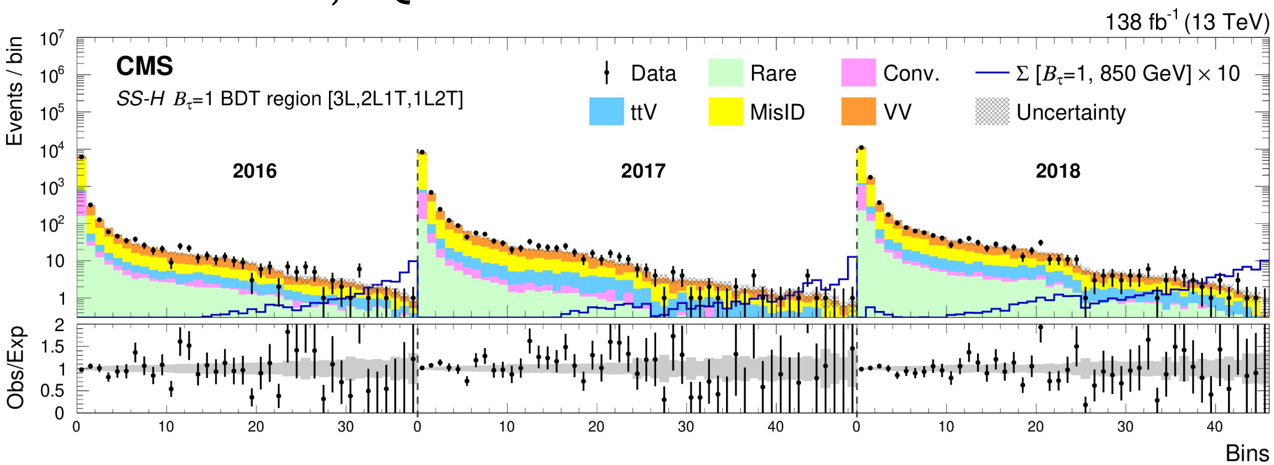
- Sensitive to various new physics models: type-III seesaw heavy fermion, vector-like lepton (VLL), scalar leptoquark (LQ)
- Signatures & main selections
  - 3 or >=4 leptons
  - Model independent search regions based on L_T+MET, S_T, N_b, H_T etc
  - In addition, model-dependent BDTs trained for type-III seesaw lepton, VLL, LQs & different masses







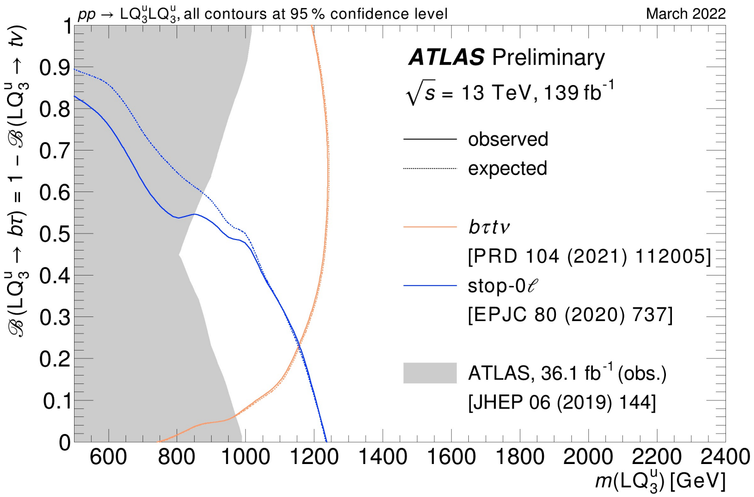


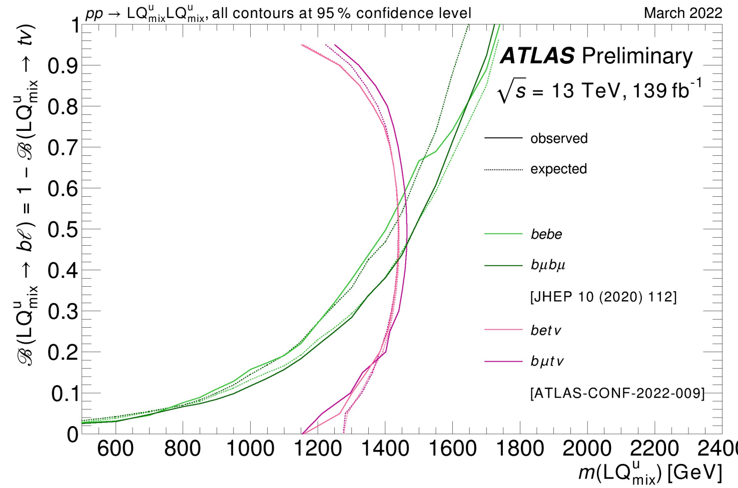


LQ Search Summary

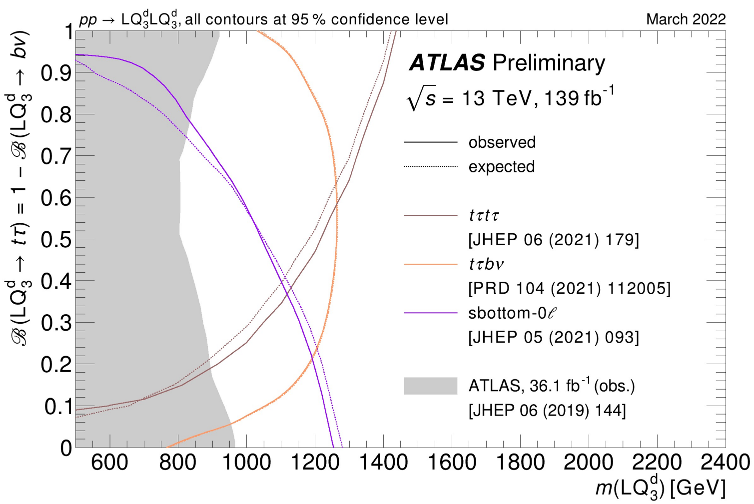
LQ → 3rd gen | LQ → mixed gen

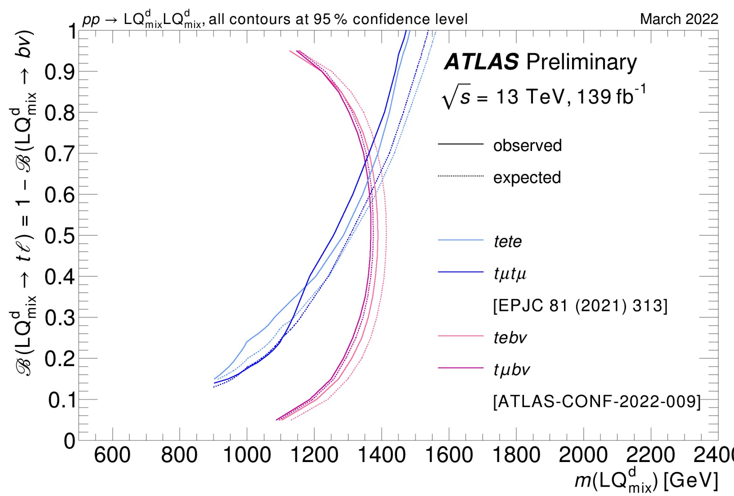
LQ up type



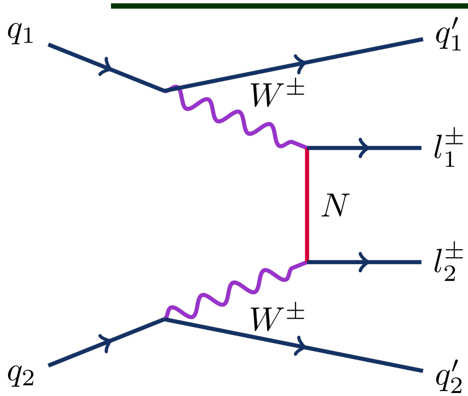


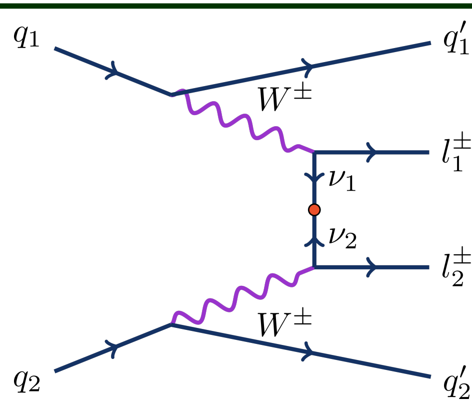
LQ down type





Majorana neutrinos

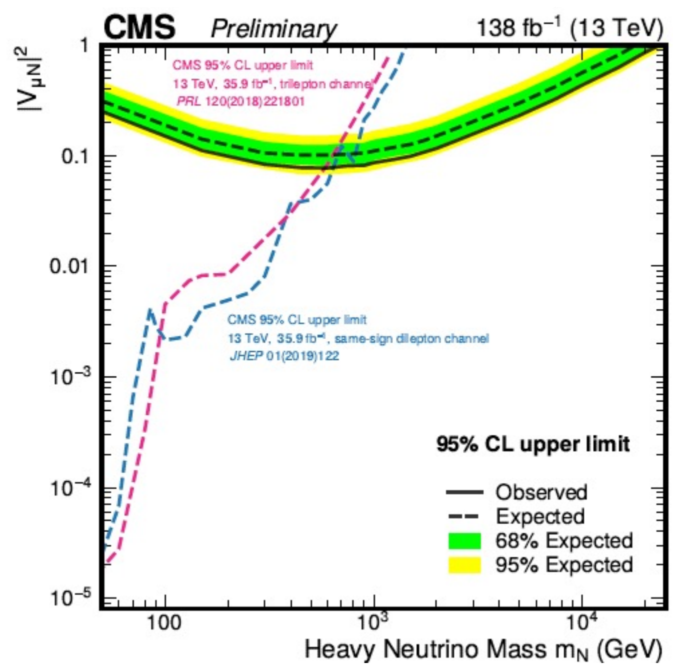




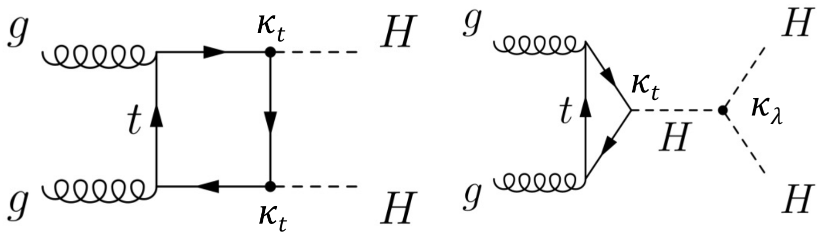
- Address neutrino mass
  - Heavy Majorana neutrino (HMN) from seesaw -> neutrinoless VBF t-channel (high mass sensitivity)
  - Analogous to neutrinoless double **β** decay, but with μ (instead of e)
- Signature: two same sign μμ, VBF jets

First constraints for this process!

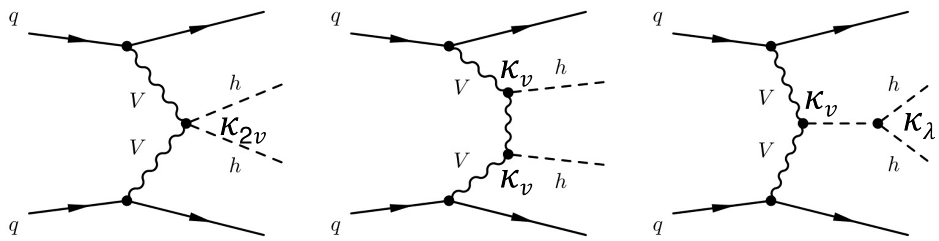
- Data compatible with SM Bkg
- Limits:
  - HMN exclusion up to m_N = 23 TeV!
  - Also constrain the EFT dim-5 Weinberg operator $C_5^{ll'}$



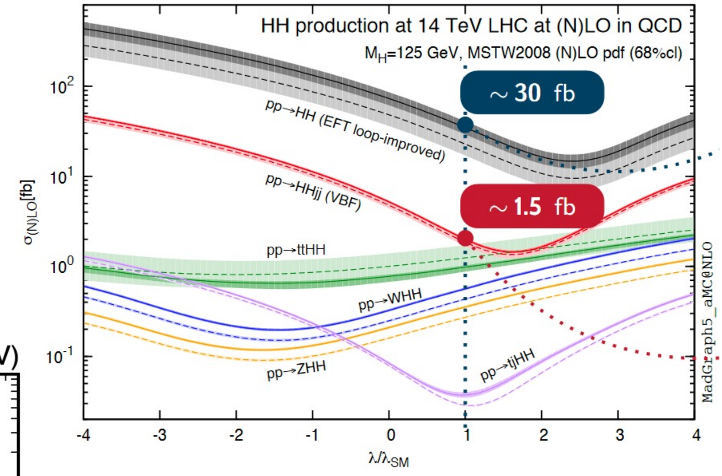
Non-Resonant H(bb)H(bb)



Gluon Fusion (ggF)



Vector boson fusion (VBF)

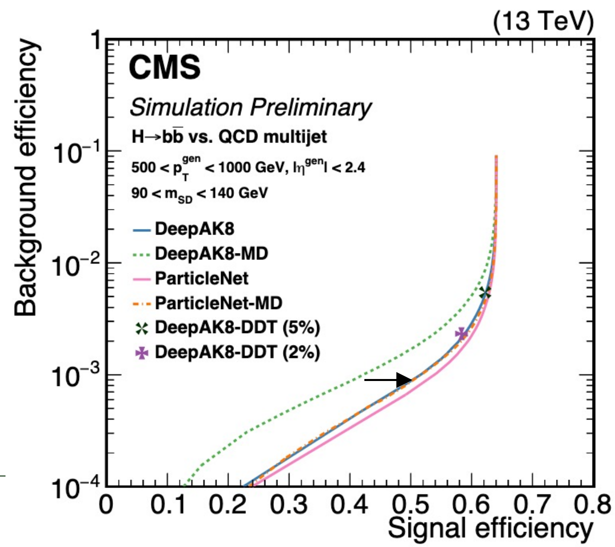


Motivations

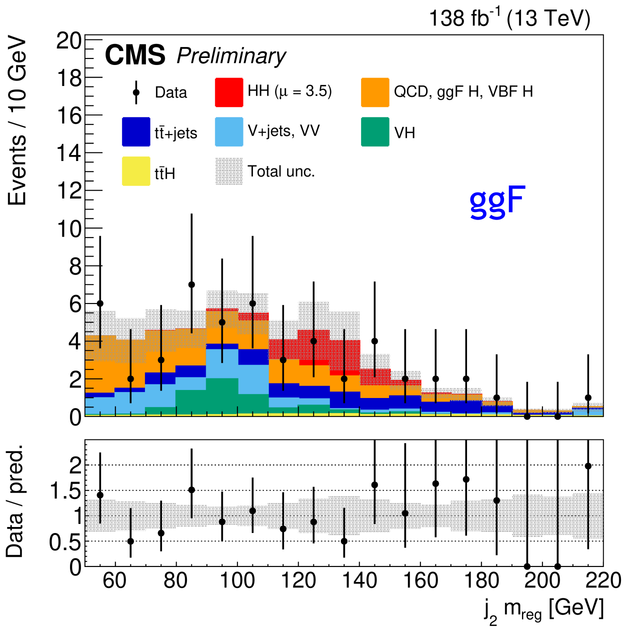
- ☐ Probe the Higgs trilinear coupling
- ☐ VBF HH also sensitive to κ_{2v} (HHVV)
- ☐ Probe also potential BSM terms

Analysis feature & main selection

- ☐ Two AK8 jets, utilize DNN "ParticleNet" X->bb tagger



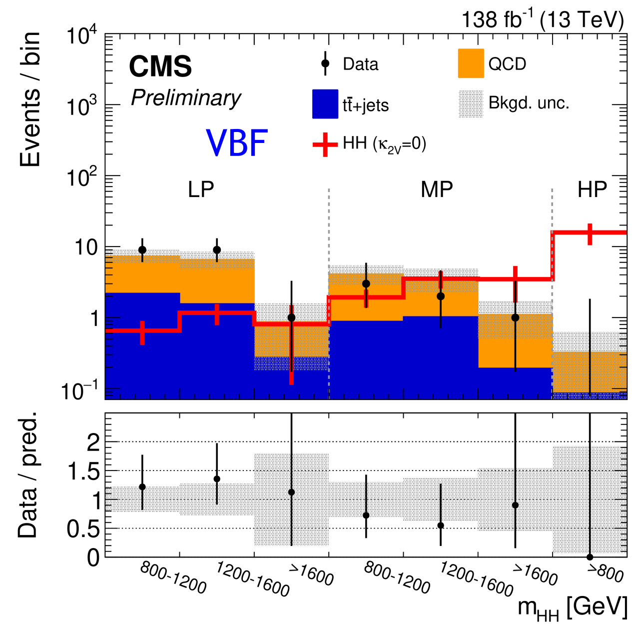
Non-Resonant H(bb)H(bb)

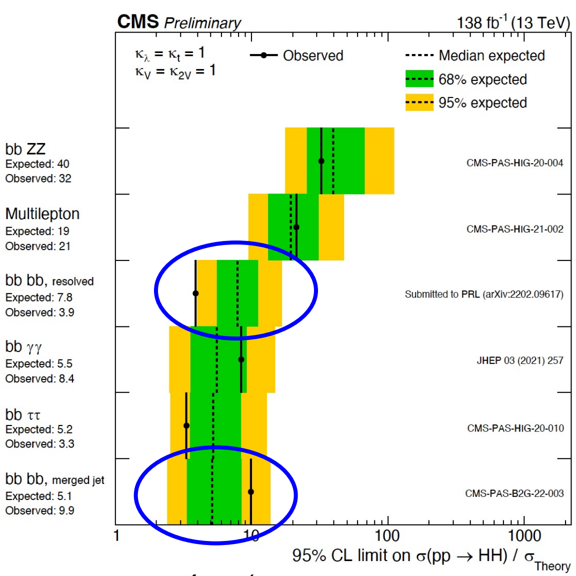


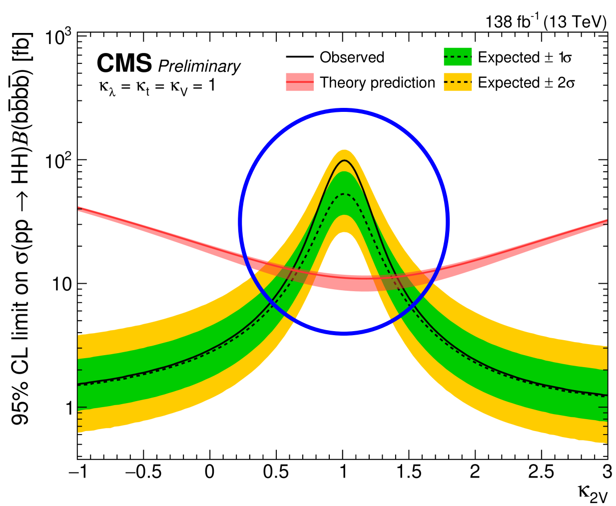
Data and SM predictions are in agreement

Competitive sensitivity on the HH signal strength

The first indirect evidence for HHVV coupling in the SM!
(excluding κ_{2v} =0 for the first time)







Other non-resonant HH searches

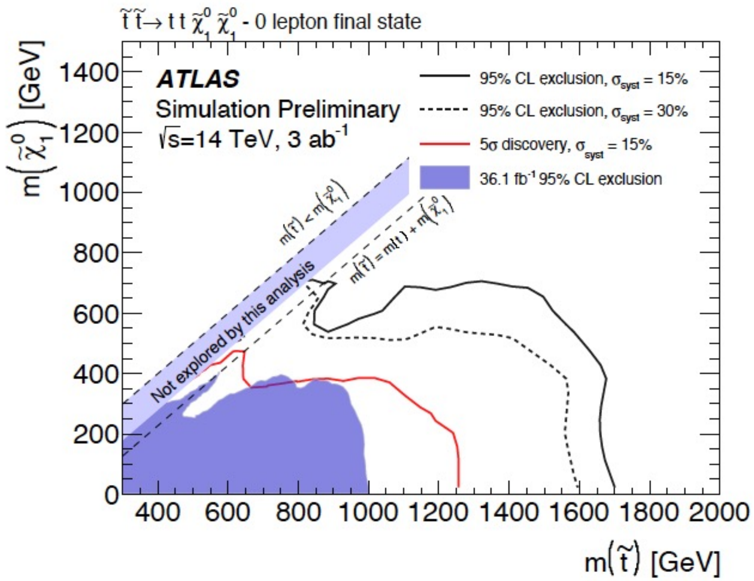
- ☐ HH→bb$\gamma\gamma$ (HDBS-2018-34)
- ☐ VBF HH→bbbb (HDBS-2018-18)
- ☐ HH→bbWW (HDBS-2018-33)
- ☐ HH→bb$\tau\tau$ (ATLAS-CONF-2021-030)
- ☐ ggF+VBF HH→bbbb resolved (CMS-PAS-HIG-20-005)
- ☐ HH→multiLepton (CMS-PAS-HIG-21-002)
- ☐ HH→bb$\tau\tau$ (CMS-PAS-HIG-20-010)

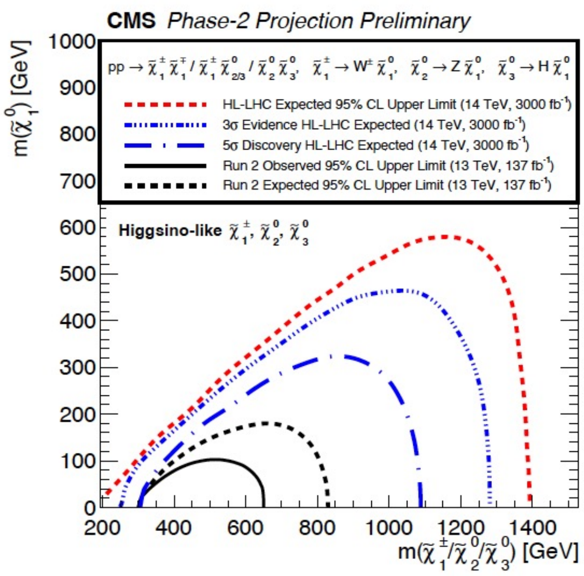
See also parallel session talks [ATLAS | CMS]

Summary

- Large number of BSM (and rare SM) non-resonant signatures have been explored with LHC Run2 data.
  - Sensitivity significantly improved with new analysis techniques.
  - Several new models/signatures explored for the first time.
- No clear evidence for BSM yet, but significantly extended range of model phase-space excluded.
- Stay tuned for upcoming LHC Run-3 and also for HL-LHC eras!

ATL-PHYS-PUB-2022-018

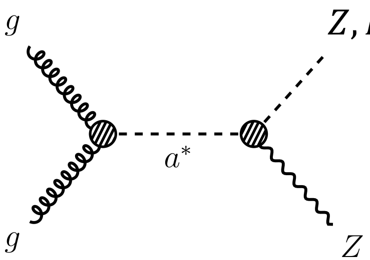


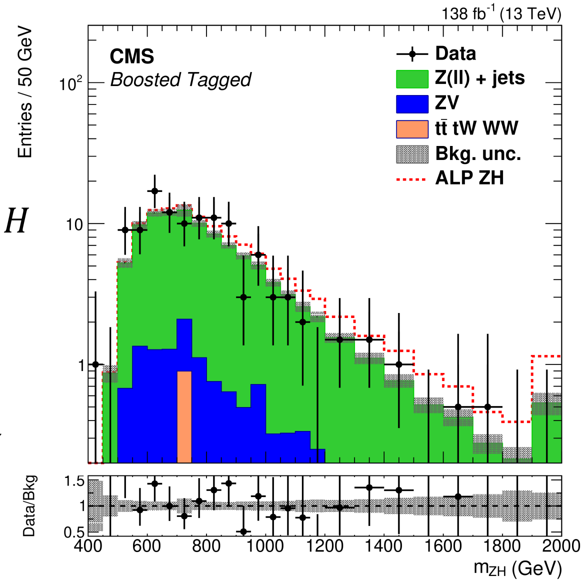


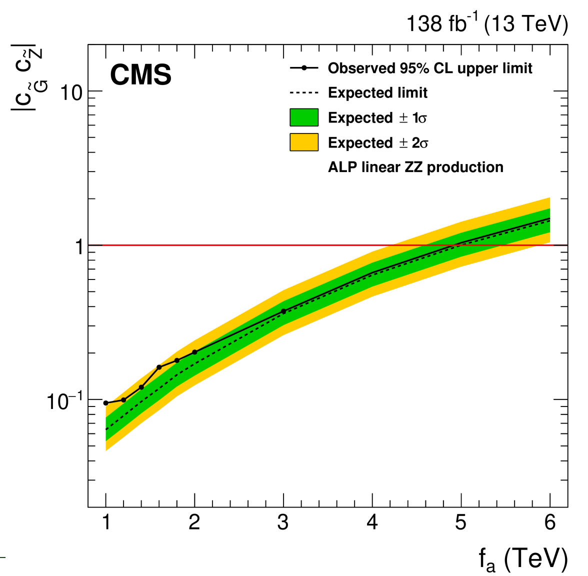
Backup

Axion-like particles (ALP/a)

- ALPs are well motivated as neutral pseudo-scalar pseudo-Goldstone bosons of a new spontaneously broken global symmetry
- First search of ALPs in diboson final states!
- Basic selection:
  - 2 leptons from Z->ll
  - Boosted Z/H->J tagging or resolved Z/H->jj selection
  - SR1: m_J or m_{jj} = [65-105] GeV,
    SR2: m_J or m_{jj} = [95-135] GeV,
    SB: [30-65], [135-180] GeV.
  - Sideband (SB) used for modeling of main background: Z(ll)+jets





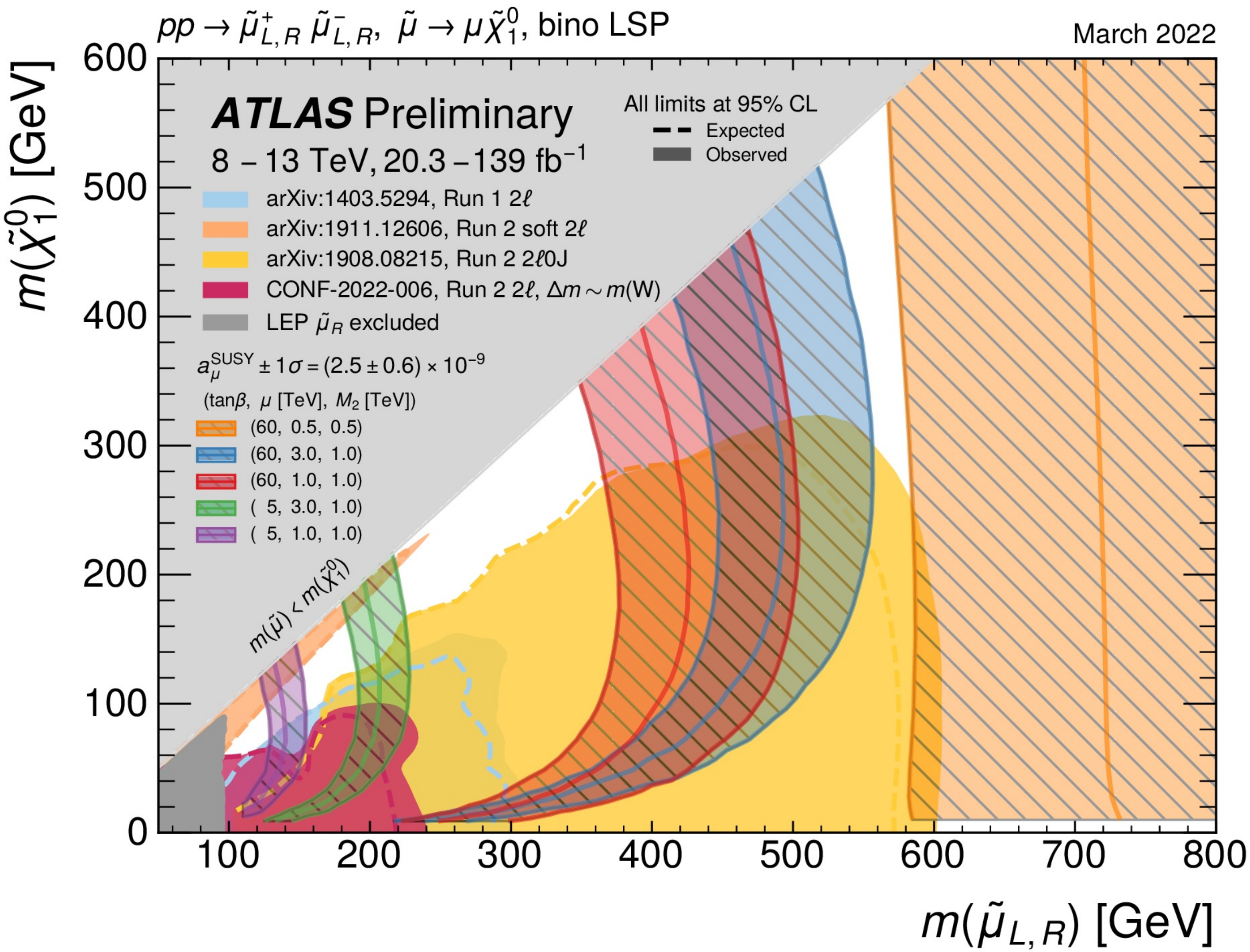


More comprehensive talk coveribng ALP by Yusheng Wu

Searches for Gluinos

n_{jet}	n_b	L_T [GeV]	H_T [GeV]	n_t	Bin name	T1tttt signal events (1.8, 1.3) TeV	T1tttt signal events (2.2, 0.1) TeV	Predicted background events	Observed events
[6, 8]	1	[250, 450]	[500, 1500]	1	A1a	1.2 ± 0.1	<0.1	576 ± 29	570
				≥2	A1b	0.07 ± 0.02	<0.1	13 ± 2	14
			≥1500	1	A2a	<0.1	0.01 ± 0.01	47 ± 7	42
				≥2	A2b	<0.1	0.04 ± 0.01	5 ± 1	3
		[450, 600]	≥500	1	A3a	0.44 ± 0.06	0.04 ± 0.01	31 ± 6	16
				≥2	A3b	0.03 ± 0.02	0.06 ± 0.01	1.0 ± 0.3	1
		≥600	≥500	1	A4a	0.18 ± 0.04	0.44 ± 0.02	7 ± 2	8
				≥2	A4b	<0.1	0.48 ± 0.02	1.0 ± 0.5	0
	2	[250, 450]	[500, 1500]	1	B1a	2.3 ± 0.1	0.01 ± 0.01	532 ± 26	586
				≥2	B1b	0.28 ± 0.04	0.01 ± 0.01	16 ± 2	19
			≥1500	1	B2a	<0.1	0.03 ± 0.01	30 ± 5	34
				≥2	B2b	<0.1	0.06 ± 0.01	3.4 ± 0.8	1
		[450, 600]	≥500	1	B3a	1.0 ± 0.1	0.07 ± 0.01	27 ± 6	34
				≥2	B3b	0.06 ± 0.02	0.09 ± 0.01	1.1 ± 0.5	2
		≥600	≥500	1	B4a	0.37 ± 0.05	0.67 ± 0.03	6.2 ± 1.6	6
				≥2	B4b	0.07 ± 0.02	0.80 ± 0.03	0.23 ± 0.08	0
	≥3	[250, 450]	[500, 1500]	1	C1a	3.0 ± 0.1	0.01 ± 0.01	115 ± 7	105
				≥2	C1b	0.43 ± 0.06	<0.1	6 ± 1	3
			≥1500	1	C2a	0.01 ± 0.01	0.03 ± 0.01	7 ± 2	10
				≥2	C2b	<0.1	0.07 ± 0.01	1.0 ± 0.4	2
		[450, 600]	≥500	1	C3a	1.1 ± 0.1	0.06 ± 0.01	5 ± 1	4
				≥2	C3b	0.24 ± 0.04	0.10 ± 0.01	0.63 ± 0.43	0
		≥600	≥500	1	C4a	0.42 ± 0.05	0.67 ± 0.02	1.4 ± 0.4	4
				≥2	C4b	0.05 ± 0.02	0.76 ± 0.03	0.05 ± 0.04	0
≥9	1	[250, 450]	[500, 1500]	1	D1a	0.62 ± 0.06	<0.1	32 ± 3	26
				≥2	D1b	0.12 ± 0.03	<0.1	2.1 ± 0.6	4
			≥1500	1	D2a	0.02 ± 0.01	0.01 ± 0.01	6 ± 1	11
				≥2	D2b	0.02 ± 0.01	0.02 ± 0.01	1.0 ± 0.3	2
		[450, 600]	≥500	≥1	D3	0.34 ± 0.05	0.04 ± 0.01	2.3 ± 0.6	2
		≥600	≥500	≥1	D4	0.23 ± 0.04	0.40 ± 0.02	0.6 ± 0.3	0
	2	[250, 450]	[500, 1500]	1	E1a	1.5 ± 0.1	0.01 ± 0.01	35 ± 3	35
				≥2	E1b	0.55 ± 0.06	<0.1	3.2 ± 0.7	2
			≥1500	1	E2a	0.05 ± 0.02	0.02 ± 0.01	8 ± 2	6
				≥2	E2b	0.04 ± 0.02	0.05 ± 0.01	1.0 ± 0.4	2
		[450, 600]	≥500	1	E3a	0.75 ± 0.07	0.04 ± 0.01	1.7 ± 0.5	1
				≥2	E3b	0.19 ± 0.03	0.06 ± 0.01	0.2 ± 0.1	0
		≥600	≥500	1	E4a	0.50 ± 0.05	0.30 ± 0.02	0.9 ± 0.4	1
				≥2	E4b	0.21 ± 0.04	0.55 ± 0.02	0.06 ± 0.04	0
	≥3	[250, 450]	[500, 1500]	1	F1a	3.2 ± 0.1	0.01 ± 0.01	13 ± 2	7
				≥2	F1b	1.27 ± 0.08	<0.1	2.4 ± 0.8	2
			≥1500	1	F2a	0.04 ± 0.02	0.03 ± 0.01	4 ± 1	0
				≥2	F2b	0.07 ± 0.02	0.09 ± 0.01	0.7 ± 0.3	0
		[450, 600]	≥500	≥1	F3	1.7 ± 0.1	0.16 ± 0.01	1.1 ± 0.4	2
		≥600	≥500	≥1	F4	1.0 ± 0.1	1.30 ± 0.03	0.2 ± 0.2	2

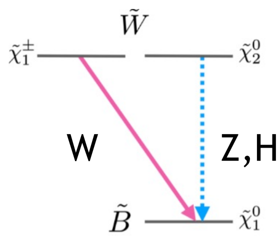
n_{jet}	L_T [GeV]	H_T [GeV]	$\Delta\phi$	n_W	Bin name	T5qqqqWW signal events (1.8, 1.3) TeV	T5qqqqWW signal events (2.2, 0.1) TeV	Predicted background events	Observed events
5	[250, 350]	[500, 750]	>1	0	G0a	1.2 ± 0.1	<0.1	342 ± 24	333
				≥1	G0b	0.46 ± 0.08	<0.1	70 ± 8	77
		750		0	G1a	0.35 ± 0.07	0.03 ± 0.01	292 ± 22	304
				≥1	G1b	0.14 ± 0.04	0.02 ± 0.01	69 ± 10	62
	[350, 450]	[500, 750]	>1	0	G2a	1.8 ± 0.2	<0.1	71 ± 8	63
				≥1	G2b	0.60 ± 0.09	<0.1	14 ± 5	25
		750		0	G3a	0.44 ± 0.08	0.04 ± 0.01	66 ± 8	44
				≥1	G3b	0.24 ± 0.06	0.03 ± 0.01	14 ± 4	13
	[450, 650]	[500, 750]	>0.75	0	G4a	2.1 ± 0.2	<0.1	52 ± 7	45
				≥1	G4b	1.1 ± 0.1	<0.1	12 ± 3	9
		[750, 1250]		0	G5a	0.9 ± 0.1	0.03 ± 0.01	42 ± 6	35
				≥1	G5b	0.35 ± 0.07	<0.1	10 ± 3	6
		≥1250		0	G6a	<0.1	0.17 ± 0.02	16 ± 3	19
				≥1	G6b	<0.1	0.13 ± 0.02	3 ± 1	3
	≥650	[500, 1250]	>0.5	0	G7a	1.3 ± 0.1	0.13 ± 0.02	33 ± 8	32
				≥1	G7b	0.30 ± 0.06	0.04 ± 0.01	7 ± 2	8
		≥1250		0	G8a	0.15 ± 0.05	1.78 ± 0.07	11 ± 3	8
				≥1	G8b	0.04 ± 0.02	1.08 ± 0.05	0.6 ± 0.4	2
[6, 7]	[250, 350]	[500, 1000]	>1	0	H1a	2.6 ± 0.2	<0.1	281 ± 22	292
				≥1	H1b	1.3 ± 0.1	<0.1	71 ± 9	71
		≥1000		0	H2a	0.23 ± 0.06	0.05 ± 0.01	121 ± 11	121
				≥1	H2b	0.18 ± 0.05	0.02 ± 0.01	29 ± 5	21
	[350, 450]	[500, 1000]	>1	0	H3a	3.1 ± 0.2	<0.1	51 ± 6	71
				≥1	H3b	1.6 ± 0.2	0.01 ± 0.01	12 ± 3	15
		≥1000		0	H4a	0.31 ± 0.07	0.09 ± 0.01	31 ± 7	21
				≥1	H4b	0.12 ± 0.04	0.08 ± 0.01	6 ± 2	6
	[450, 650]	[500, 750]	>0.75	0	H5a	3.1 ± 0.2	<0.1	19 ± 4	17
				≥1	H5b	1.6 ± 0.2	<0.1	5 ± 2	9
		[750, 1250]		0	H6a	2.8 ± 0.2	0.01 ± 0.01	29 ± 4	18
				≥1	H6b	1.4 ± 0.1	<0.1	7 ± 2	4
		≥1250		0	H7a	0.4 ± 0.07	0.45 ± 0.03	15 ± 3	14
				≥1	H7b	0.2 ± 0.05	0.33 ± 0.03	3 ± 1	1
	≥650	[500, 1250]	>0.5	0	H8a	2.5 ± 0.2	0.09 ± 0.01	13 ± 3	17
				≥1	H8b	0.9 ± 0.1	0.05 ± 0.01	4 ± 1	4
		≥1250		0	H9a	0.8 ± 0.1	3.9 ± 0.1	9 ± 3	6
				≥1	H9b	0.34 ± 0.07	2.44 ± 0.08	2 ± 1	1
≥8	[250, 350]	[500, 1000]	>1	0	I1a	0.8 ± 0.1	<0.1	23 ± 5	25
				≥1	I1b	0.33 ± 0.07	<0.1	7 ± 3	5
		≥1000		0	I2a	0.30 ± 0.07	0.04 ± 0.01	22 ± 5	23
				≥1	I2b	0.16 ± 0.05	0.01 ± 0.01	8 ± 2	12
	[350, 450]	[500, 1000]	>1	0	I3a	0.8 ± 0.1	<0.1	3.0 ± 0.7	10
				≥1	I3b	0.36 ± 0.07	<0.1	1.1 ± 0.4	0
		≥1000		0	I4a	0.57 ± 0.09	0.07 ± 0.01	5 ± 1	5
				≥1	I4b	0.36 ± 0.07	0.06 ± 0.01	3 ± 1	2
	[450, 650]	[500, 1250]	>0.75	0	I5a	1.5 ± 0.1	<0.1	3.4 ± 0.9	4
				≥1	I5b	1.0 ± 0.1	<0.1	0.5 ± 0.3	1
		≥1250		0	I6a	0.40 ± 0.07	0.26 ± 0.03	2.6 ± 0.8	2
				≥1	I6b	0.18 ± 0.05	0.17 ± 0.02	0.5 ± 0.3	2
	≥650	[500, 1250]	>0.5	≥0	I7	1.4 ± 0.1	0.02 ± 0.01	1.5 ± 0.6	2
		≥1250			I8	1.4 ± 0.1	3.58 ± 0.09	1.5 ± 0.7	1

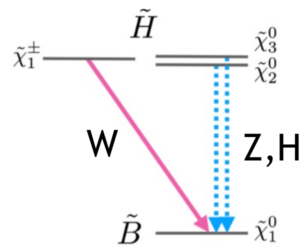


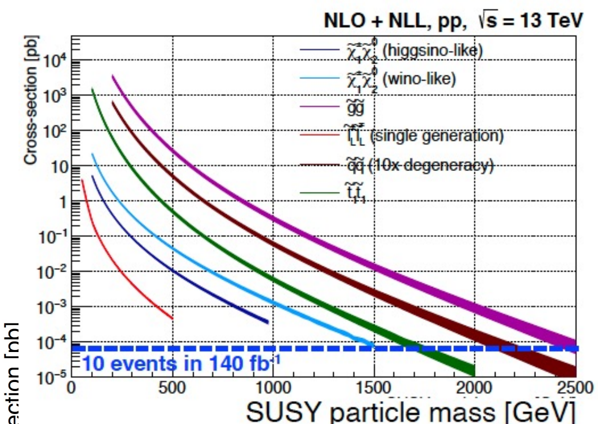
$pp \to \tilde{\mu}^+_{L,R}\,\tilde{\mu}^-_{L,R},\ \tilde{\mu} \to \mu\tilde{\chi}^0_1$, bino LSP
March 2022
ATLAS Preliminary
8 – 13 TeV, 20.3 – 139 fb^{-1}
All limits at 95% CL
Expected
Observed
arXiv:1403.5294, Run 1 2ℓ
arXiv:1911.12606, Run 2 soft 2ℓ
arXiv:1908.08215, Run 2 2ℓ0J
CONF-2022-006, Run 2 2ℓ, $\Delta m \sim m(W)$
LEP $\tilde{\mu}_R$ excluded
$a_\mu^{SUSY} \pm 1\sigma = (2.5 \pm 0.6) \times 10^{-9}$
($\tan\beta$, μ [TeV], M_2 [TeV])
(60, 0.5, 0.5)
(60, 3.0, 1.0)
(60, 1.0, 1.0)
(5, 3.0, 1.0)
(5, 1.0, 1.0)
$m(\tilde{\mu}) < m(\tilde{\chi}^0_1)$
$m(\tilde{\chi}^0_1)$ [GeV]
$m(\tilde{\mu}_{L,R})$ [GeV]

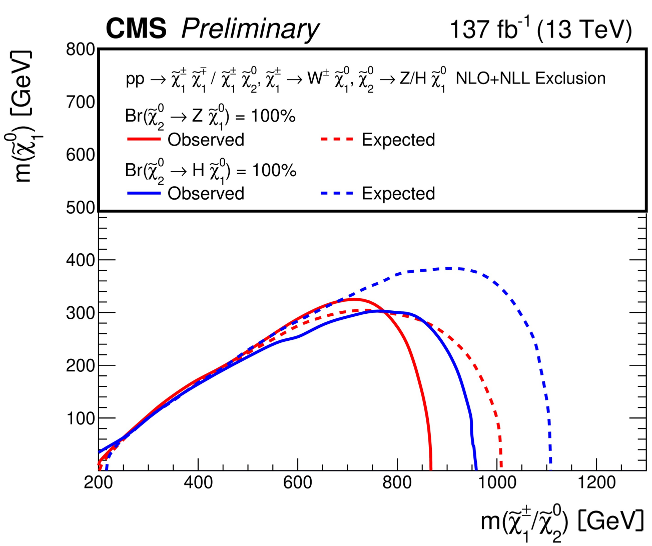
Charginos/neutralinos in Jets+MET

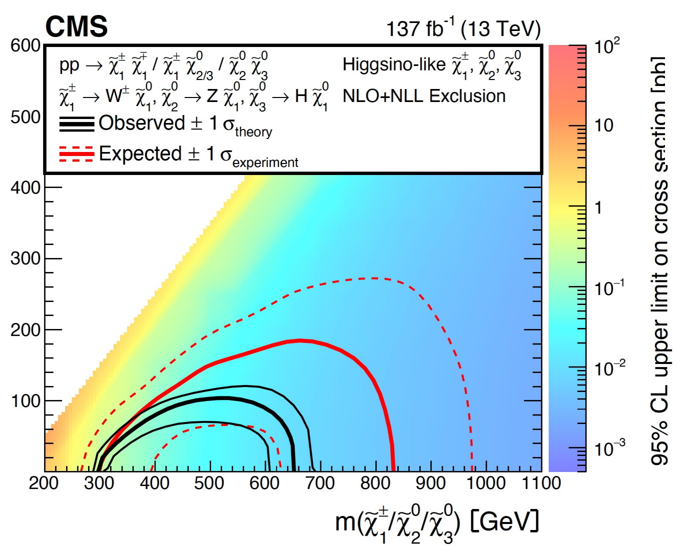
- Realistic wino scenarios involve $\chi^{\pm}{}_1\, \chi^{\pm}{}_1$ and $\chi^{\pm}{}_1\, \chi^0{}_2$ production. Two cases $\chi^0{}_2 \rightarrow Z + \chi^0{}_1$ with 100% BR or $\chi^0{}_2 \rightarrow H + \chi^0{}_1$ with 100% BR are considered.
- Search is also sensitive to higgsino models with $\chi^0{}_2 \rightarrow \chi^0{}_1 + Z$, $\chi^0{}_3 \rightarrow \chi^0{}_1 + H$.
- Searches started to become sensitive to low x-section higgsino production







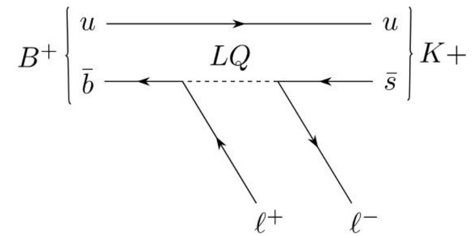


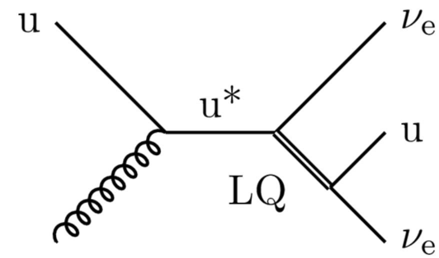


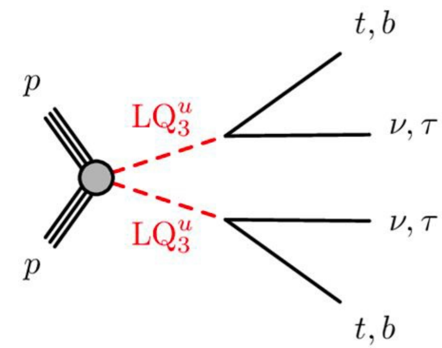
Similar ATLAS analsysis
[SUSY-2018-41/]

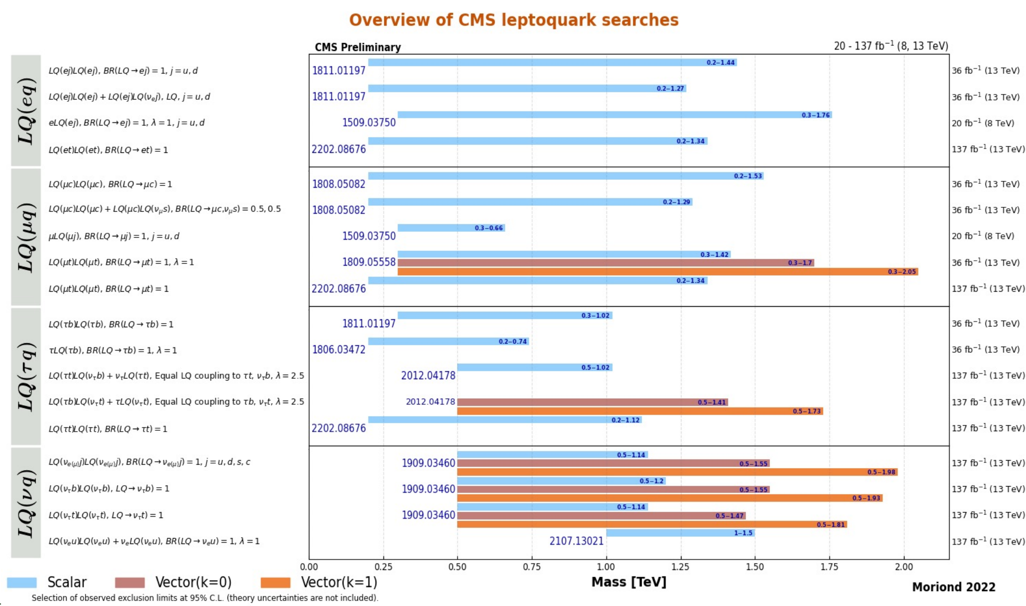
Leptoquarks (LQs)

- Leptoquarks (LQs) can couple to both leptons and quarks
  - Both scalar and vector bosons are possible
- Carry fractional electric charge
- Processes can violate lepton flavor universality (LFU)
  - Strongly couple to 3rd generation SM fermions
  - Possible explanation for recent B anomalies
- Predicted in GUTs and composite Higgs models







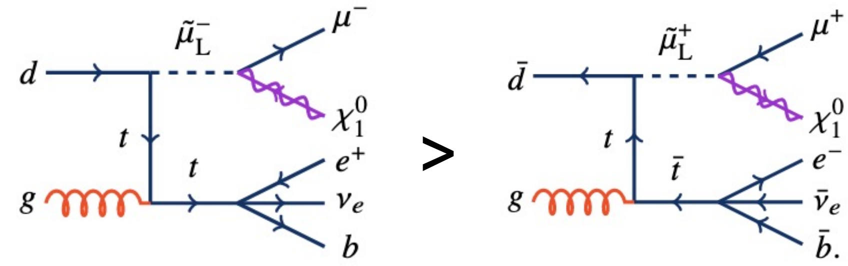


e/mu asymmetry

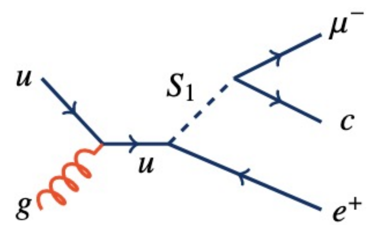
- Measure

$$\rho \equiv \frac{\sigma(pp \to e^+\mu^- + X)}{\sigma(pp \to e^-\mu^+ + X)}$$

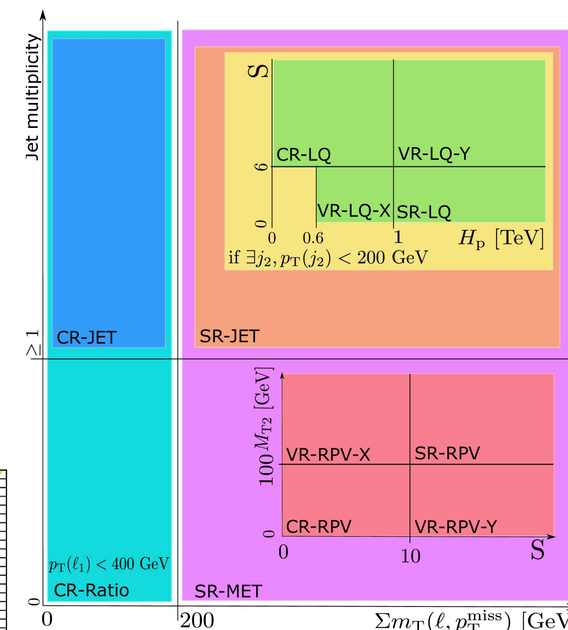
very generally in broad regions of data



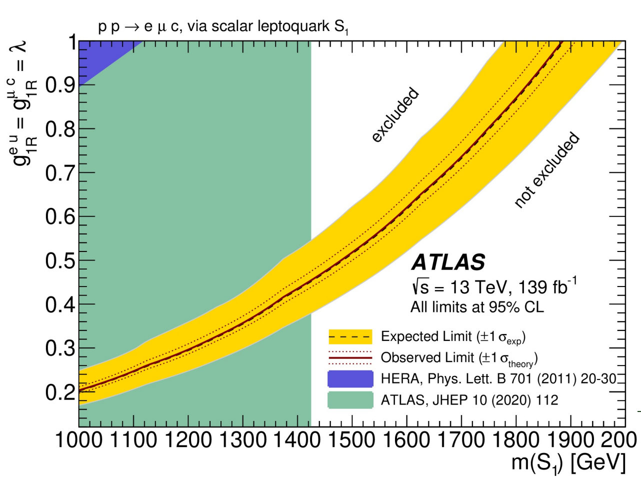
- Some BSM models predicts >1
  - SUSY (slepton), LQ , …



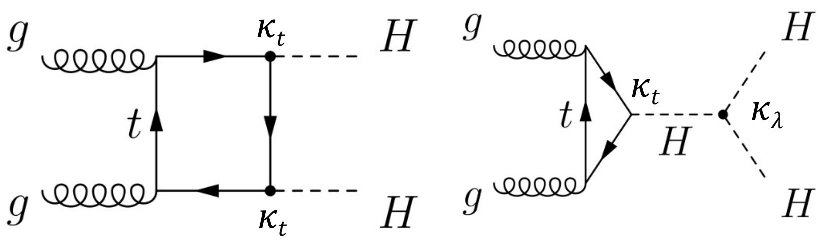
- Event selection
  - 2 leptons (e/μ), high ΣMT
  - Search bins based on M_{T2}, MET significance, H_p=p_T(e)+p_T(μ)+p_T(j1)



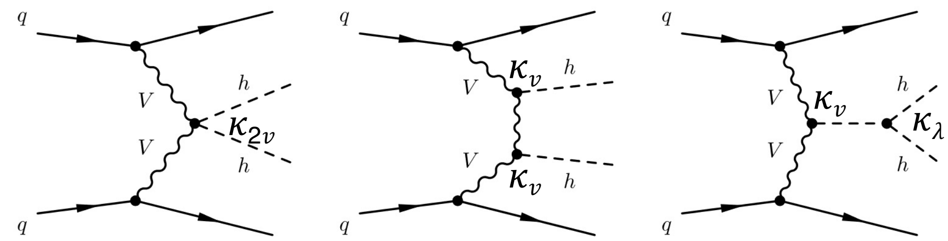
- The measured ratio consistent with 1
  - Place constraints on LQ and smuon



Non-Resonant H(bb)H(bb)



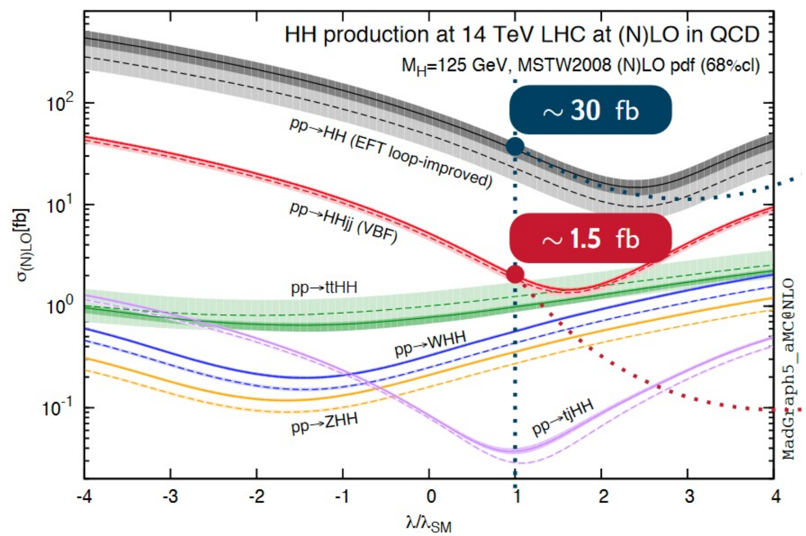
Gluon Fusion (ggF)



Vector boson fusion (VBF)

Motivations

- Probe the Higgs trilinear coupling
- VBF HH also sensitive to κ_{2v} (HHVV)
- Probe also potential BSM terms



Analysis feature & selections

- Two AK8 jets and utilize
  DNN "ParticleNet" X->bb tagger
- ggF channel
  - BDT to separate HH from main Bkgs (QCD, tt)
  - 2nd jet tagger score
- VBF channel
  - DNN ParticleNet bb-tag score, two VBF (AK4) jets with large $\Delta\eta(jj)$ & m_{jj}