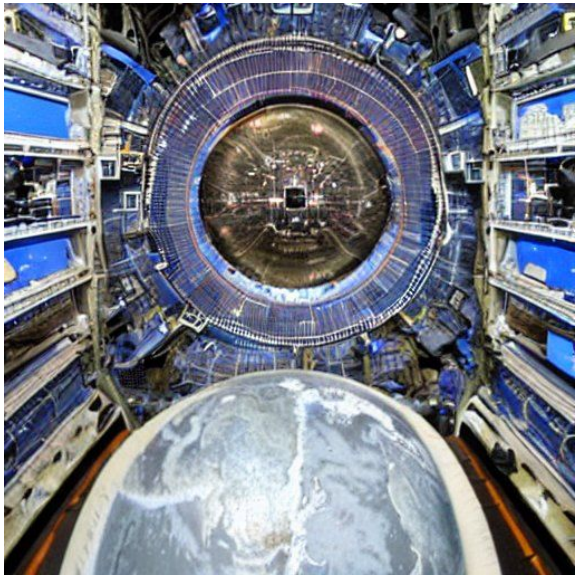
BSM searches relevant for flavour physics

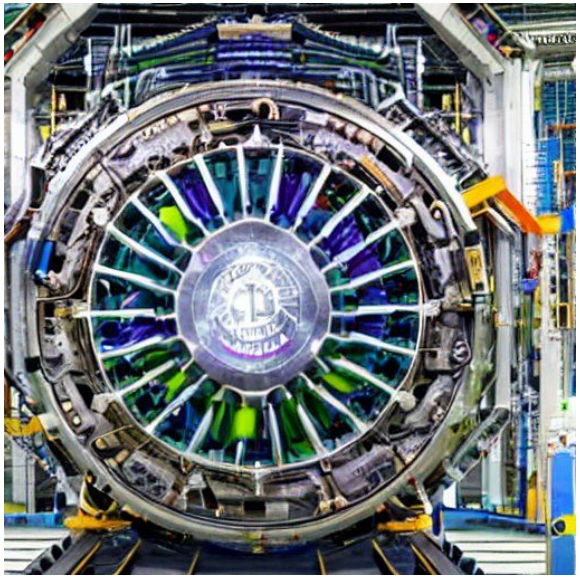
Vojtech Pleskot, Charles University
On behalf of ATLAS, CMS and LHCb

2. 6. 2023

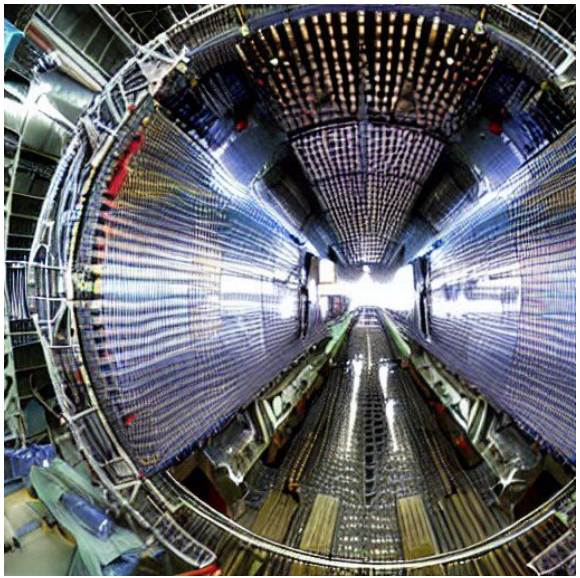
ATLAS



CMS



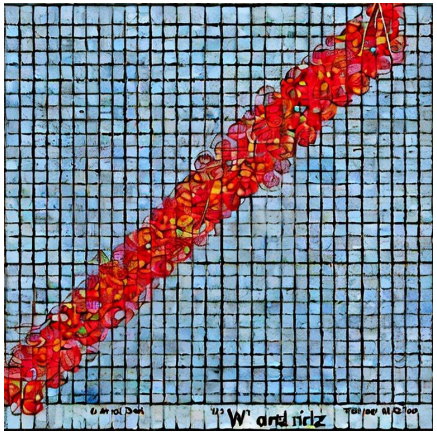
LHCb



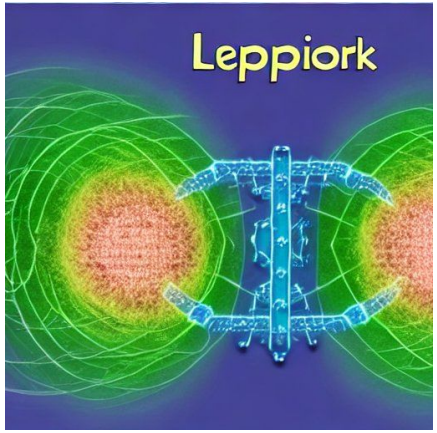
*Stable Diffusion artworks

Outline

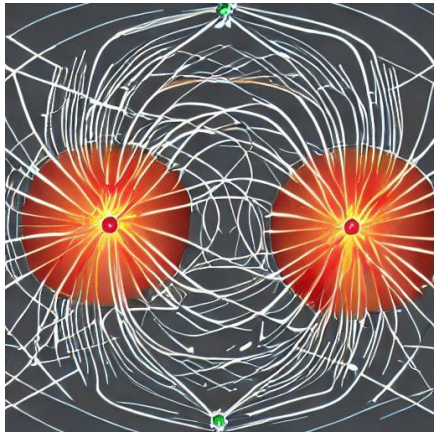
Z’ and W’



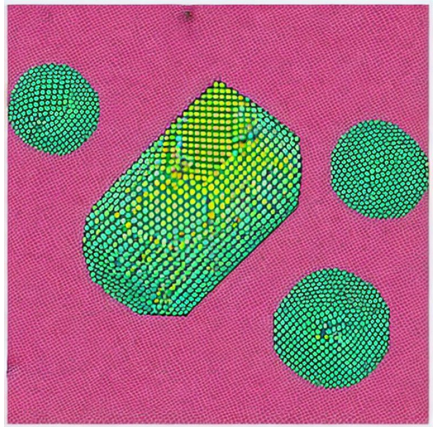
Leptoquarks



Excited fermions

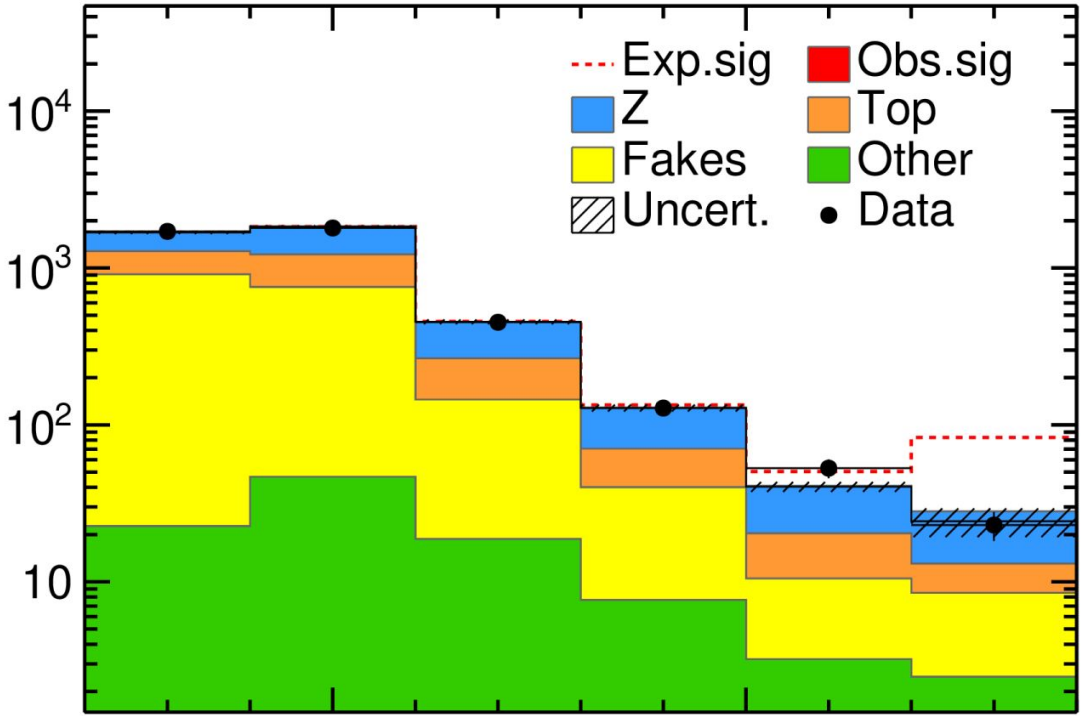


Vector-like leptons



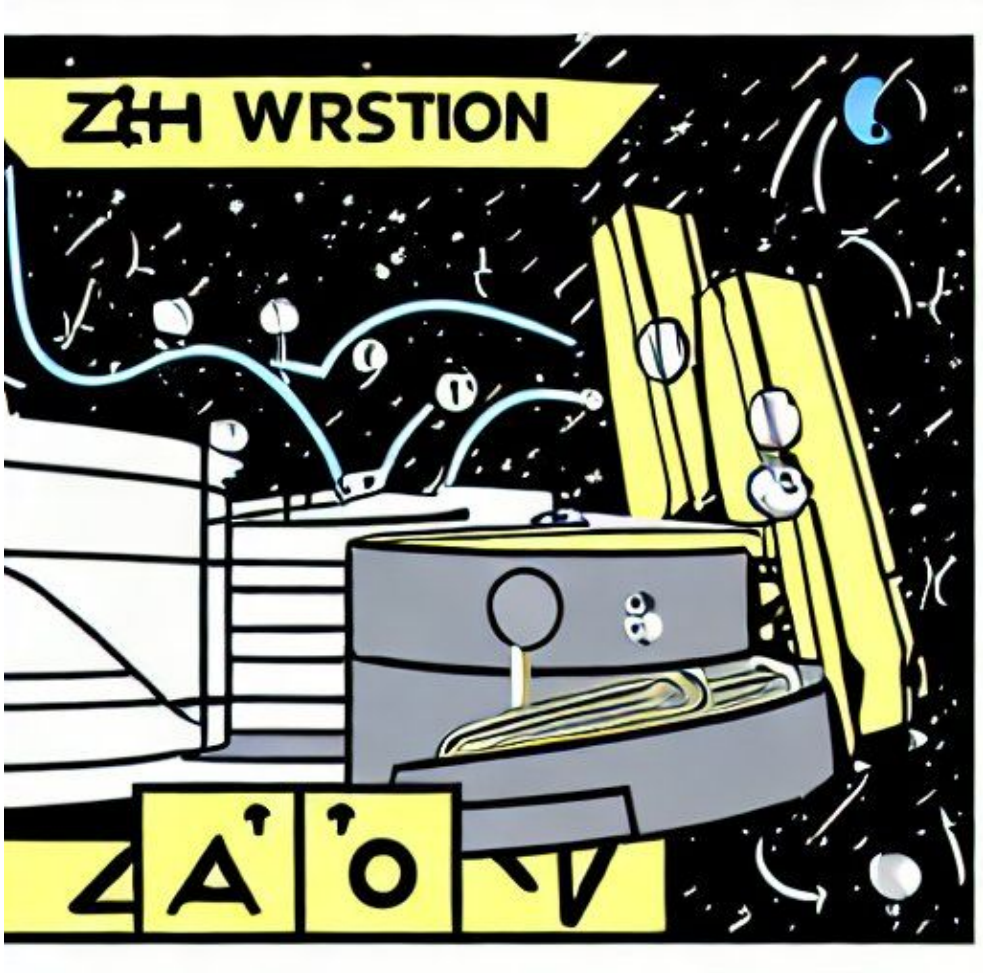
*Stable Diffusion artworks

General strategy



- compare data histogram with signal+background prediction
- signal
  - estimated with MC
- background
  - estimated with MC and/or data
- test statistic
  - profile likelihood ratio
- exclusion
  - when p-value < 0.05 (0.10)

Z’ and W’

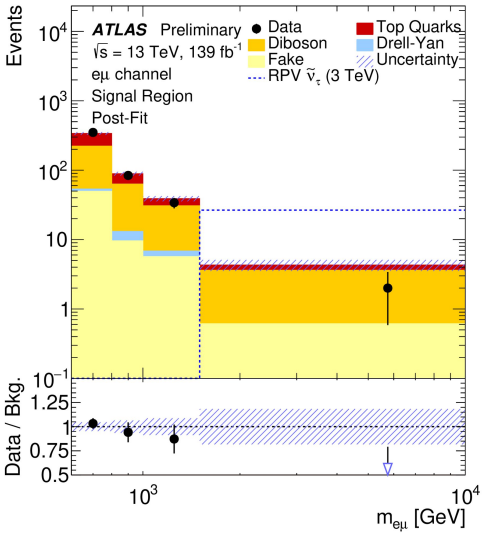


*Stable Diffusion artworks

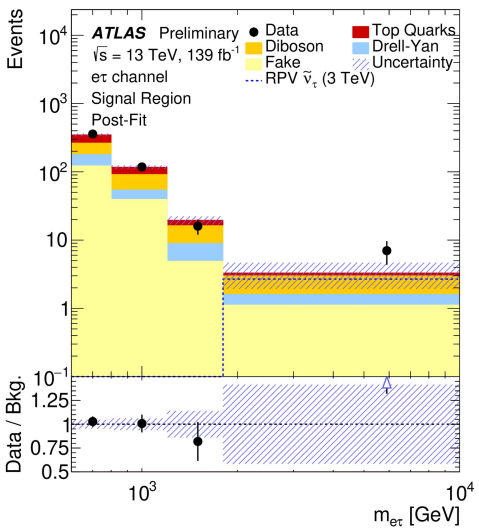
Lepton Flavour Violating Z’

ATLAS EXOT-2019-20

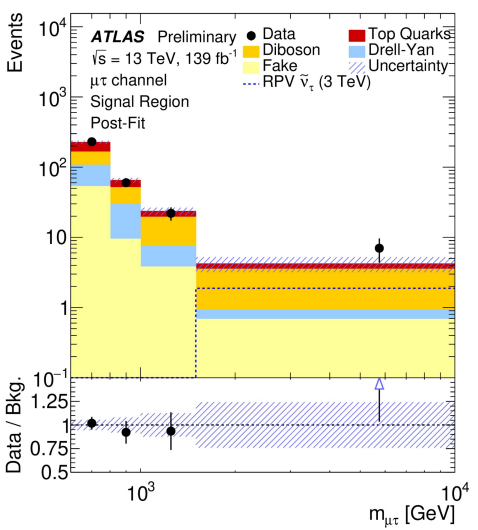
eμ



eτ$_{had}$



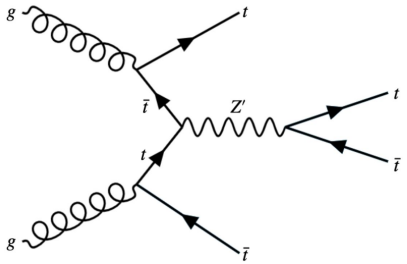
μτ$_{had}$



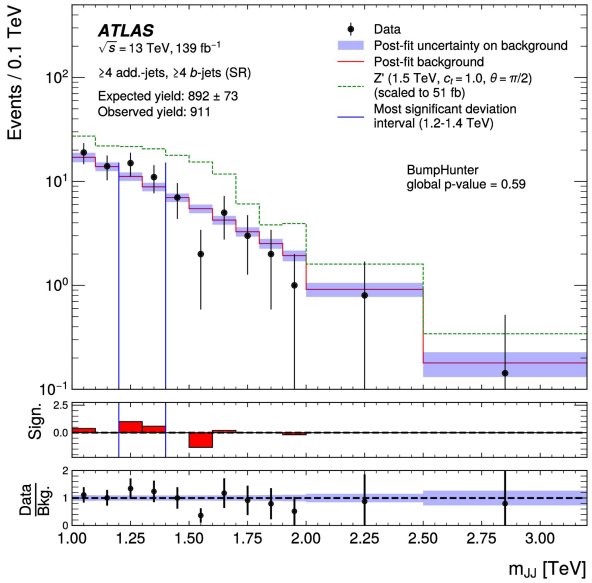
	Z’ decay	eμ	eτ	μτ
Limits [TeV]	ATLAS EXOT-2019-20	5.0	4.0	3.9
	CMS arXiv:2205.06709	5.0	4.3	4.1

Novel: Top-philic Z’ search

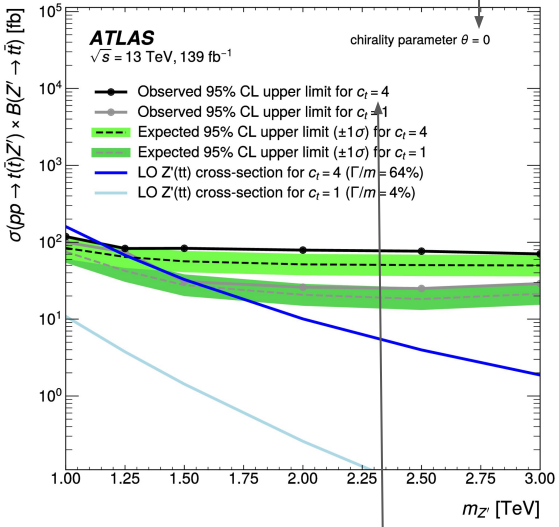
ATLAS arXiv:2304.01678



- Predicted e.g. by composite Higgs models
  - cancels large quantum corrections to the Higgs mass
- Data-driven background estimate
- Top pair from Z’ decays hadronically
- The other top pair decays semileptonically



Couples to left-handed top quarks

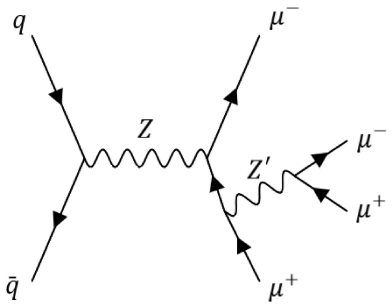


Coupling strength

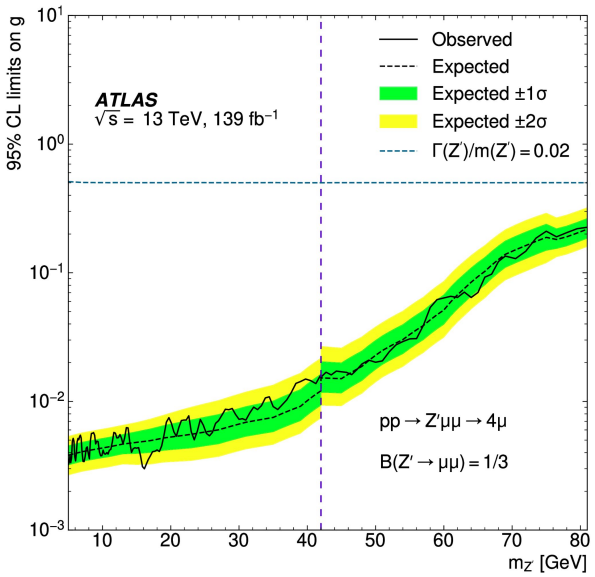
Z’ coupling just to 2nd and 3rd generations

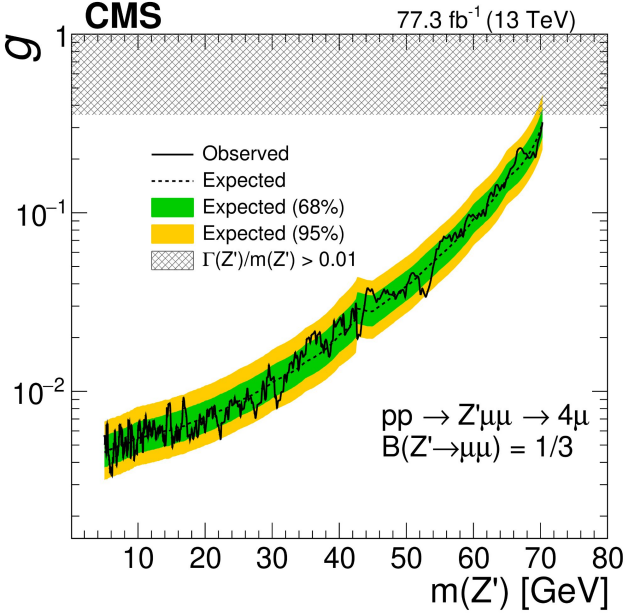
ATLAS arXiv:2301.09342

CMS arXiv:1808.03684



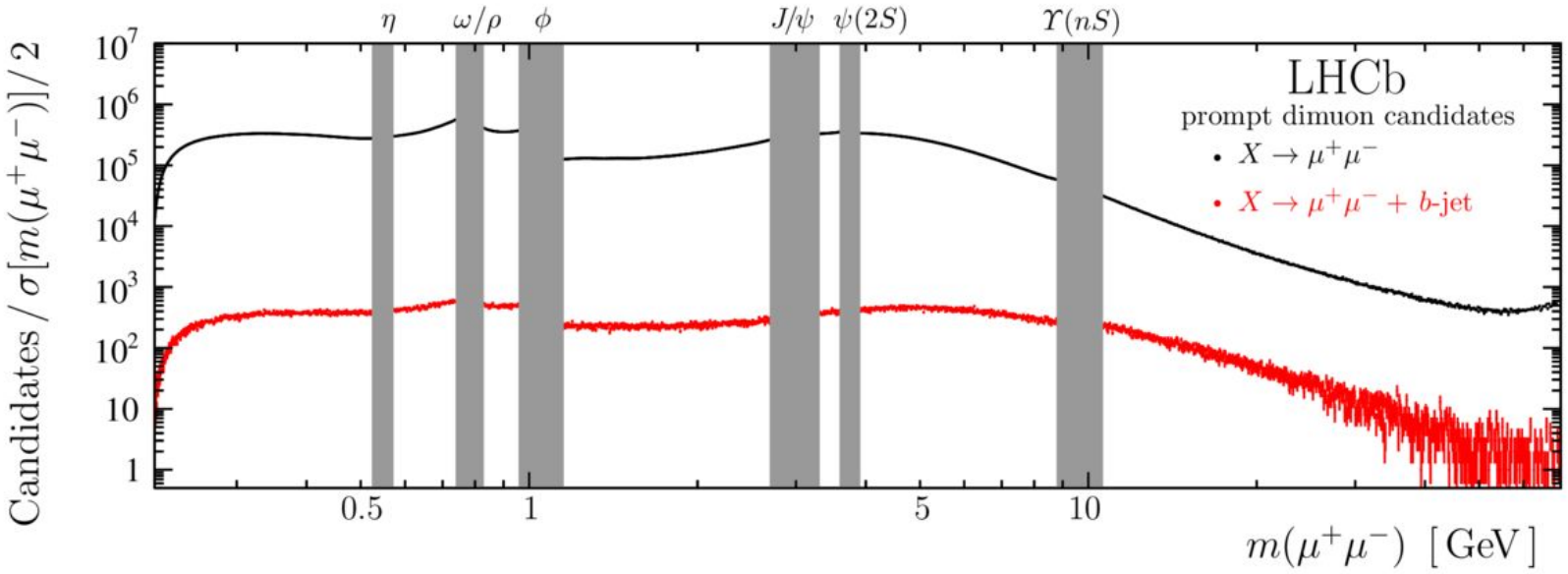
- In models with $U(1)_{L\mu-L\tau}$ symmetry
- Can explain the muon g-2 anomaly
- Deep Neural Network used in the ATLAS analysis





Low-mass μμ resonances

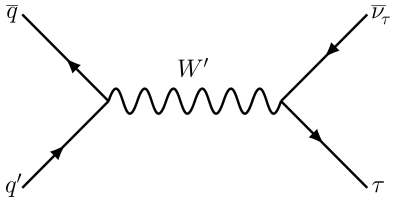
LHCb arXiv:2007.03923



- limits on cross-section of the pp→X→μμ process imposed in the mass range of [~0.2, 60] GeV

W’(→τν)

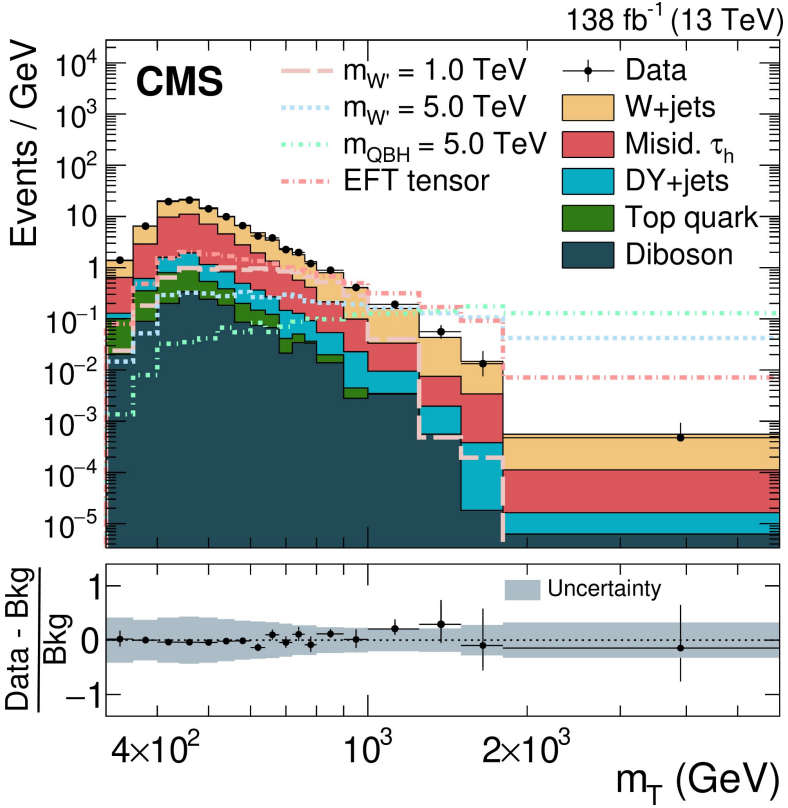
CMS arXiv:2212.12604



Limits on Sequential SM W’

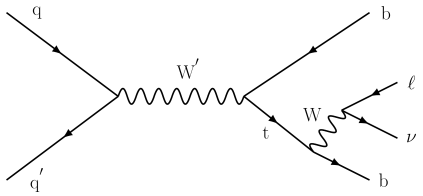
- similar performance of ATLAS and CMS

Limits [TeV]	W’ decay	e	μ	τ
	ATLAS-CONF-2021-025			5.0
	CMS arXiv:2212.12604			4.8
	ATLAS arXiv:1903.06248	4.9	4.5	
	CMS arXiv:2202.06075	5.4	5.6	

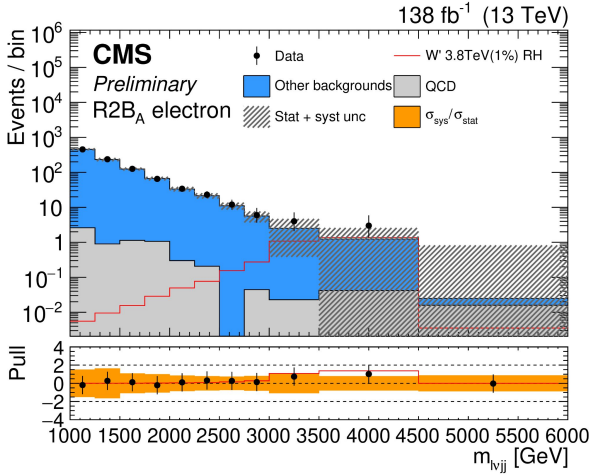


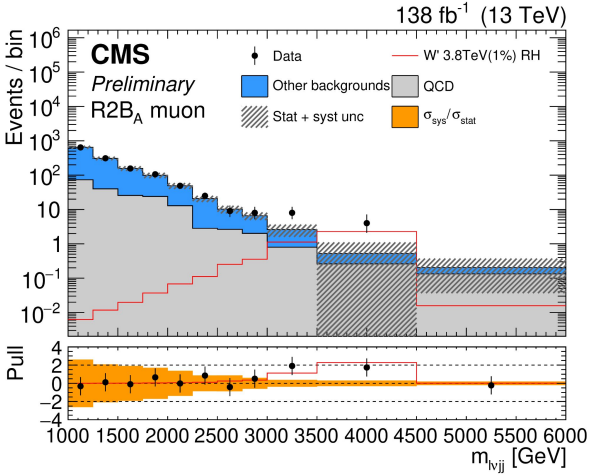
W’(→tb)

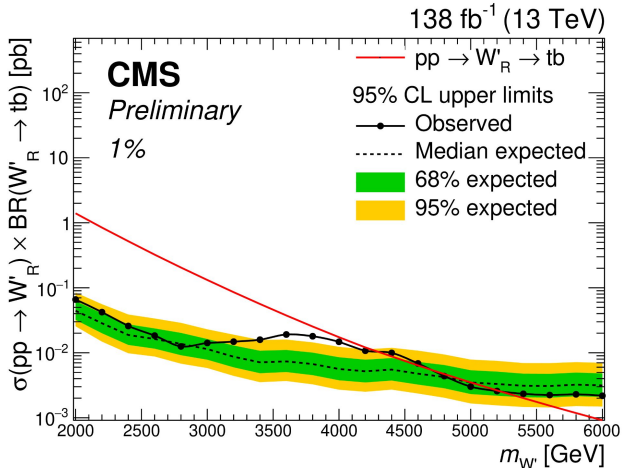
CMS-PAS-B2G-20-012



- Leptonic top decay
- Background estimated in a data-driven way!



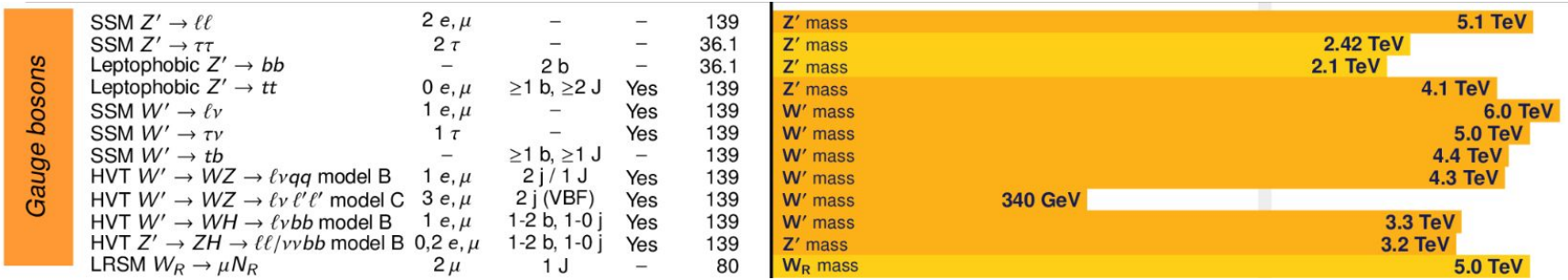




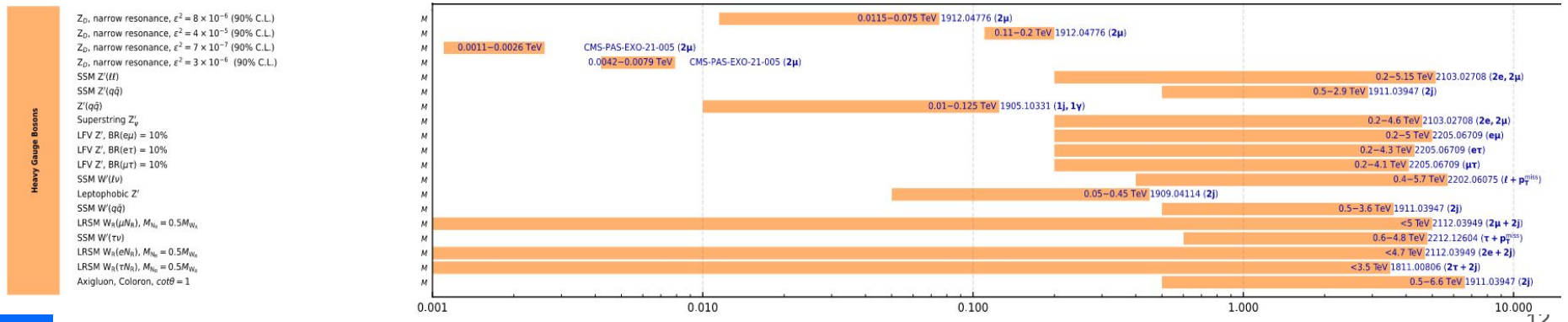
Limits [TeV]	W’ decay	tb
	ATLAS-CONF-2021-043 hadronic	4.4
	CMS-PAS-B2G-20-012 leptonic	4.3
	CMS arXiv:2104.04831 hadronic	3.4

Other Z’ and W’ searches

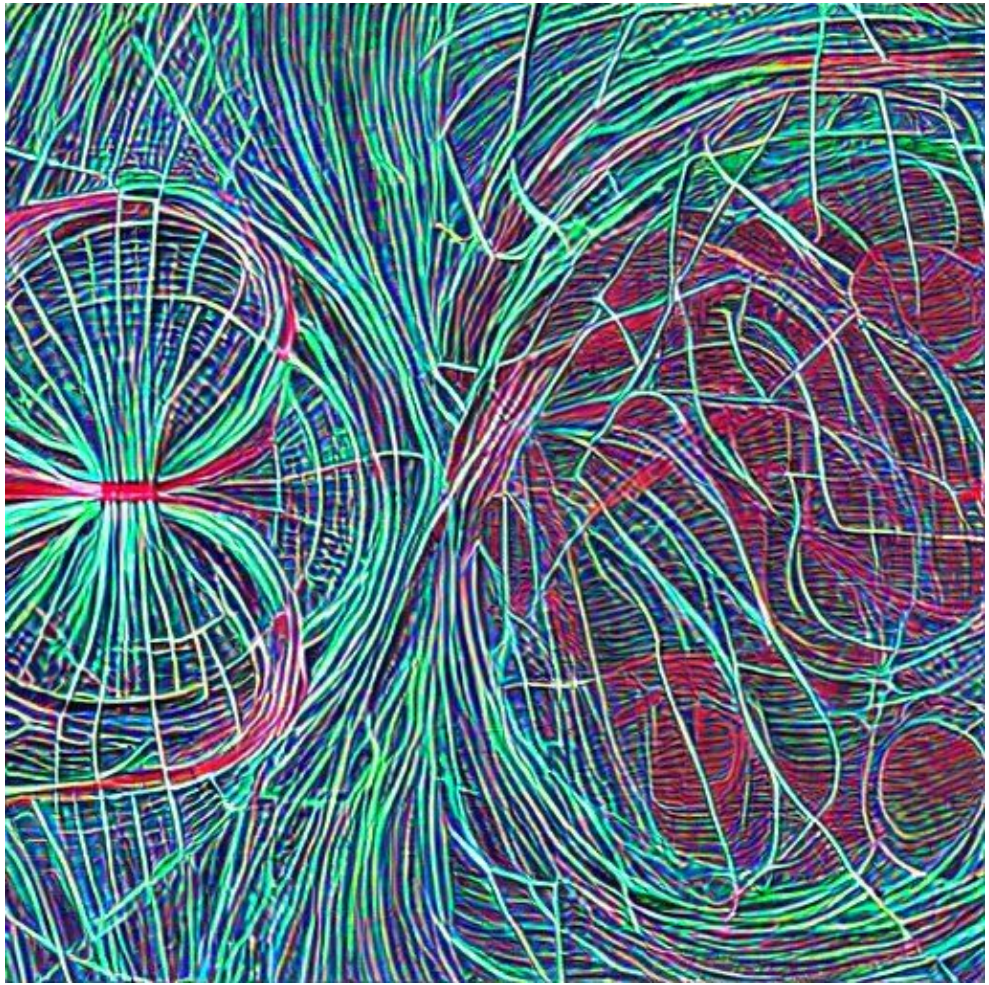
ATLAS



CMS



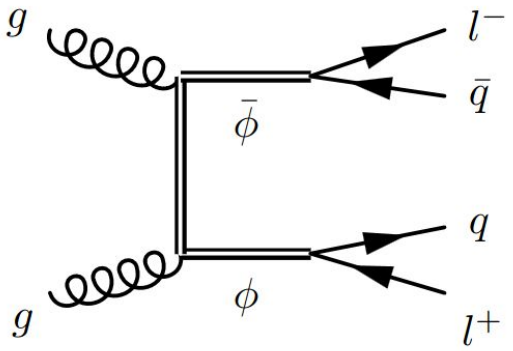
Leptoquarks



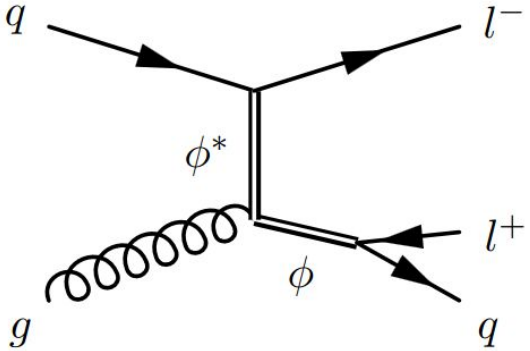
*Stable Diffusion artworks

Leptoquark landscape

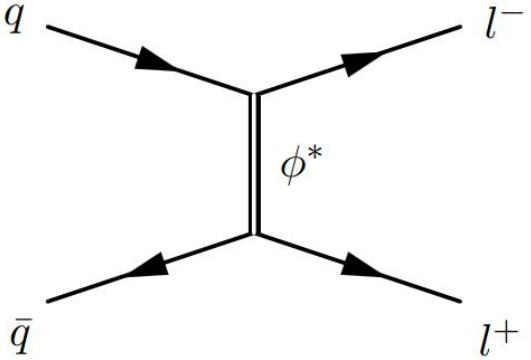
Pair production σ ~independent of λ



Single production $\sigma \sim \lambda^2$



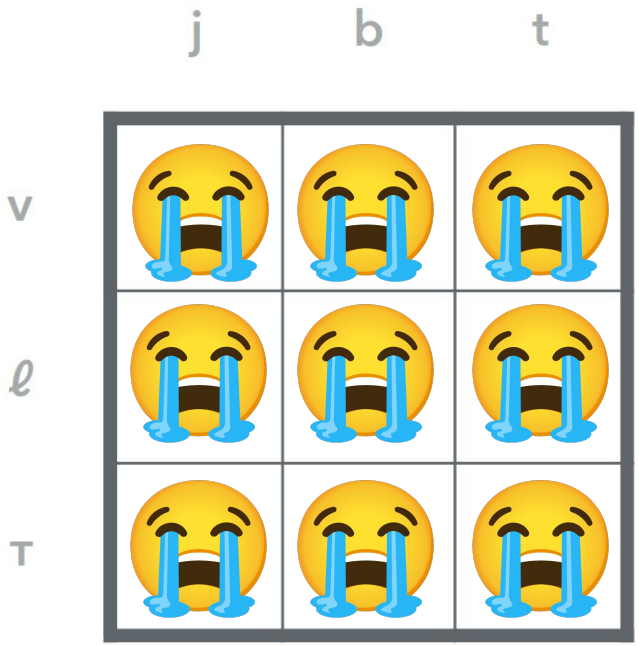
DY production $\sigma \sim \lambda^4$



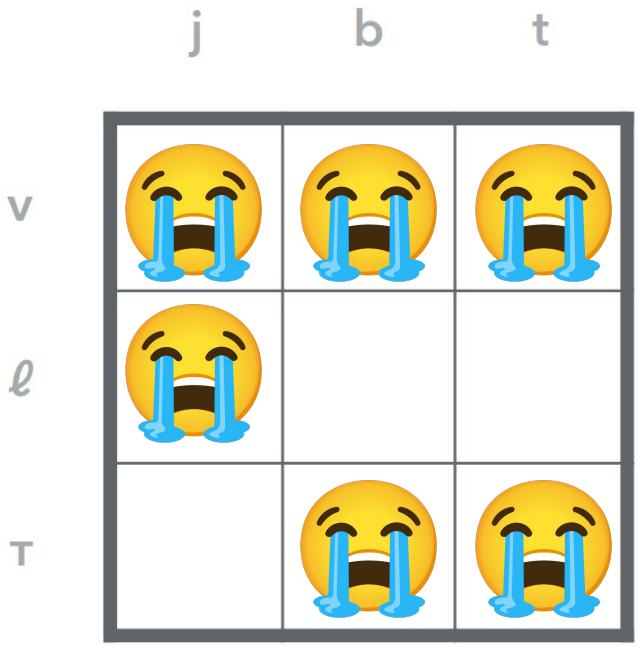
*arXiv:1706.05033, arXiv:1810.10017

Leptoquark searches

Pair production

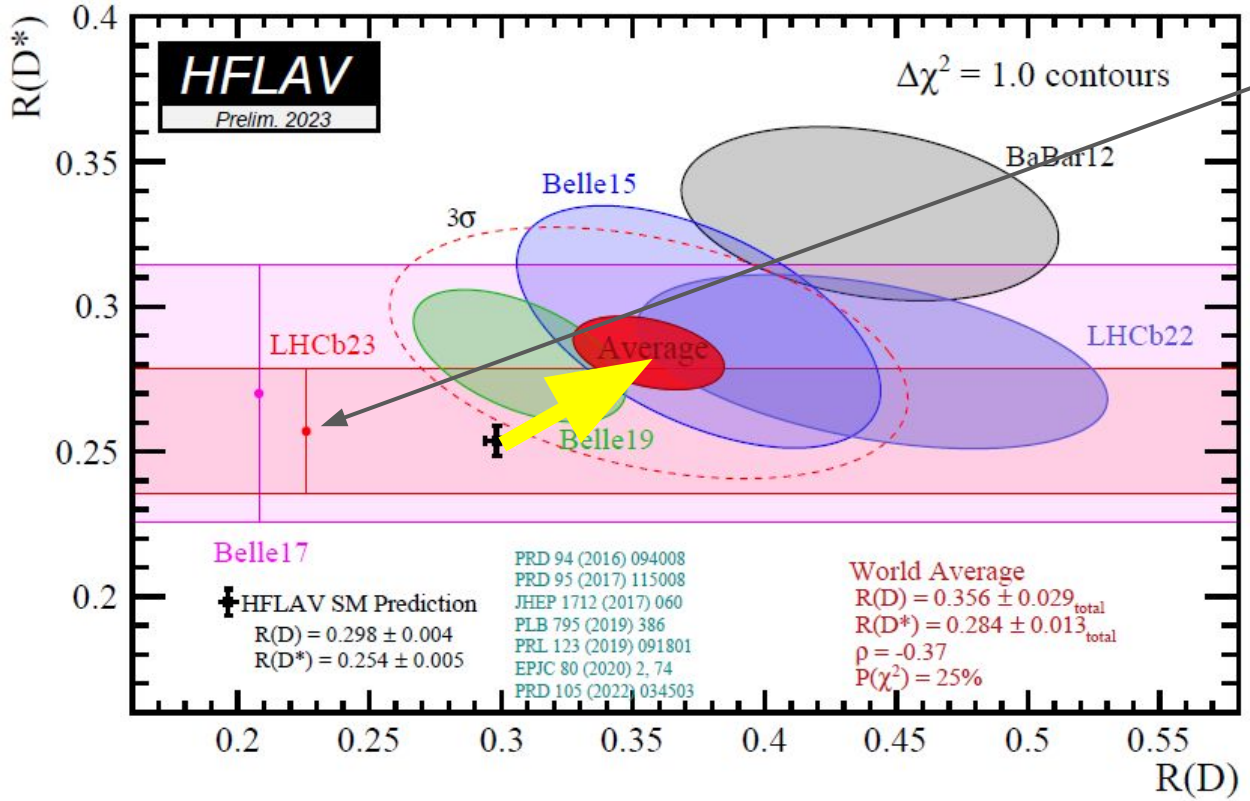


Single production



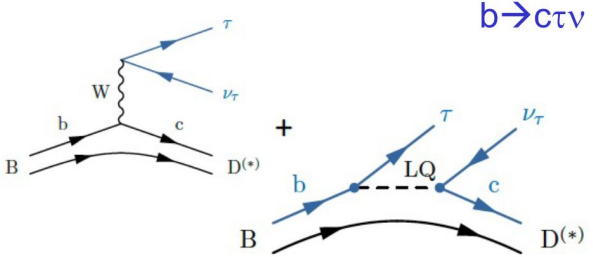
😭 = excluded by LHC searches within a certain (m, λ) range
Limits are mostly at masses of 1 - 1.5 TeV for scalar and 1.5 - 2 TeV for vector LQs

Interesting motivation for leptoquarks



New LHCb R(D*) measurement!
LHCb-PAPER-2022-052

b→cτν

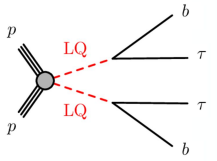


Important LQ couplings:

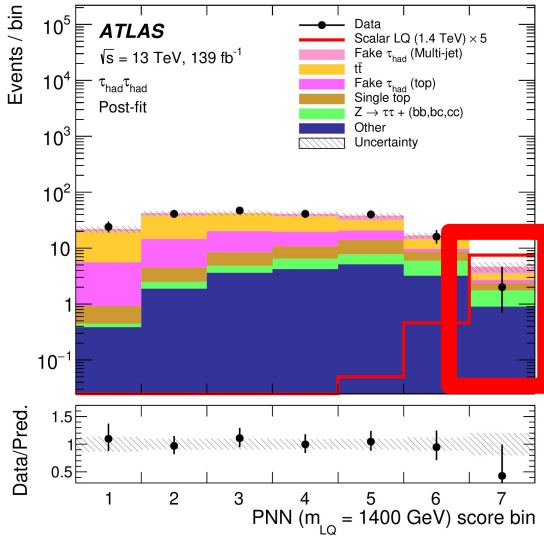
- LQ-b-τ
- LQ-c-ν_τ

New LQ-b-τ ATLAS searches

bτbτ final state



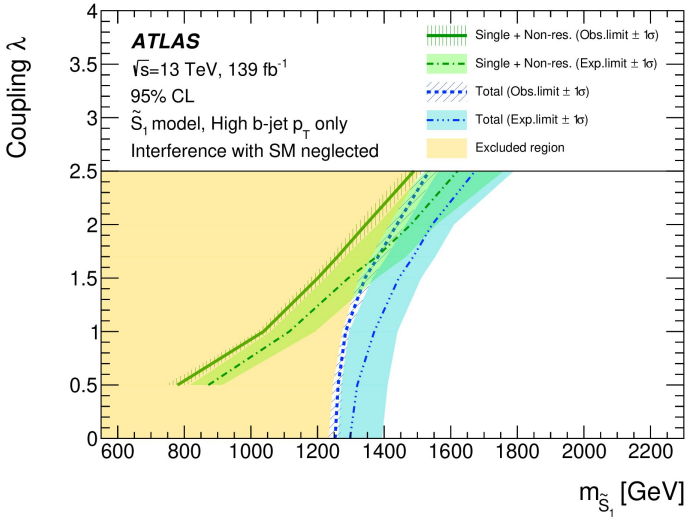
- just the pair production
- NN-based analysis
- limit: $m_{scalar} < 1.49$ TeV



arXiv:2303.01294

bττ final state

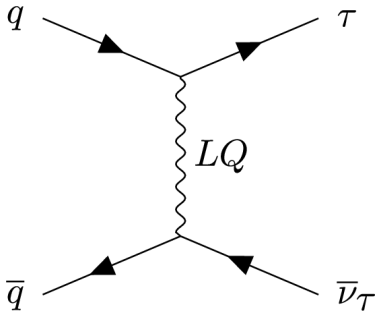
- Pair + single + DY production!
- Interference with SM DY production neglected
- Cut-based analysis



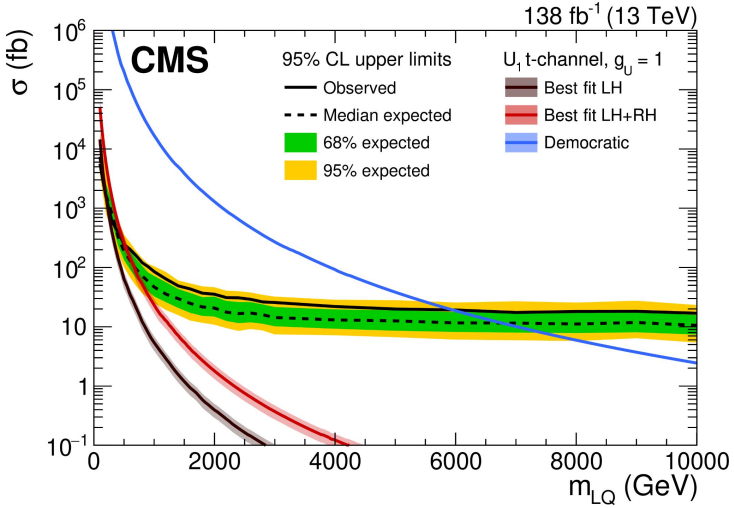
arXiv:2305.15962

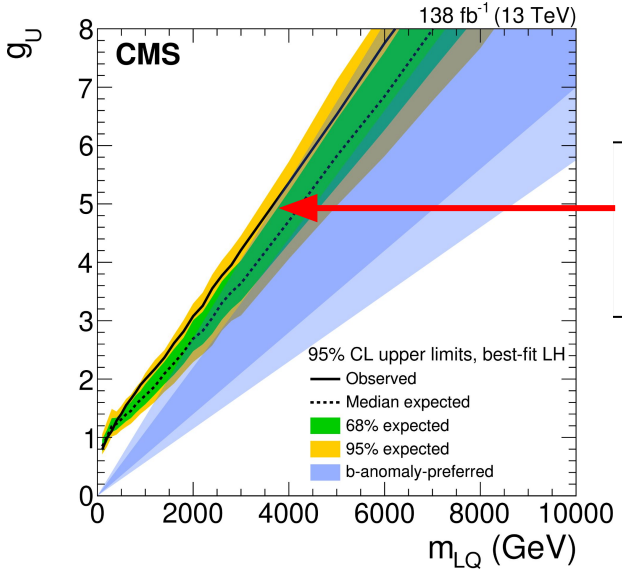
Novel: non-resonant LQ search!

CMS arXiv:2212.12604



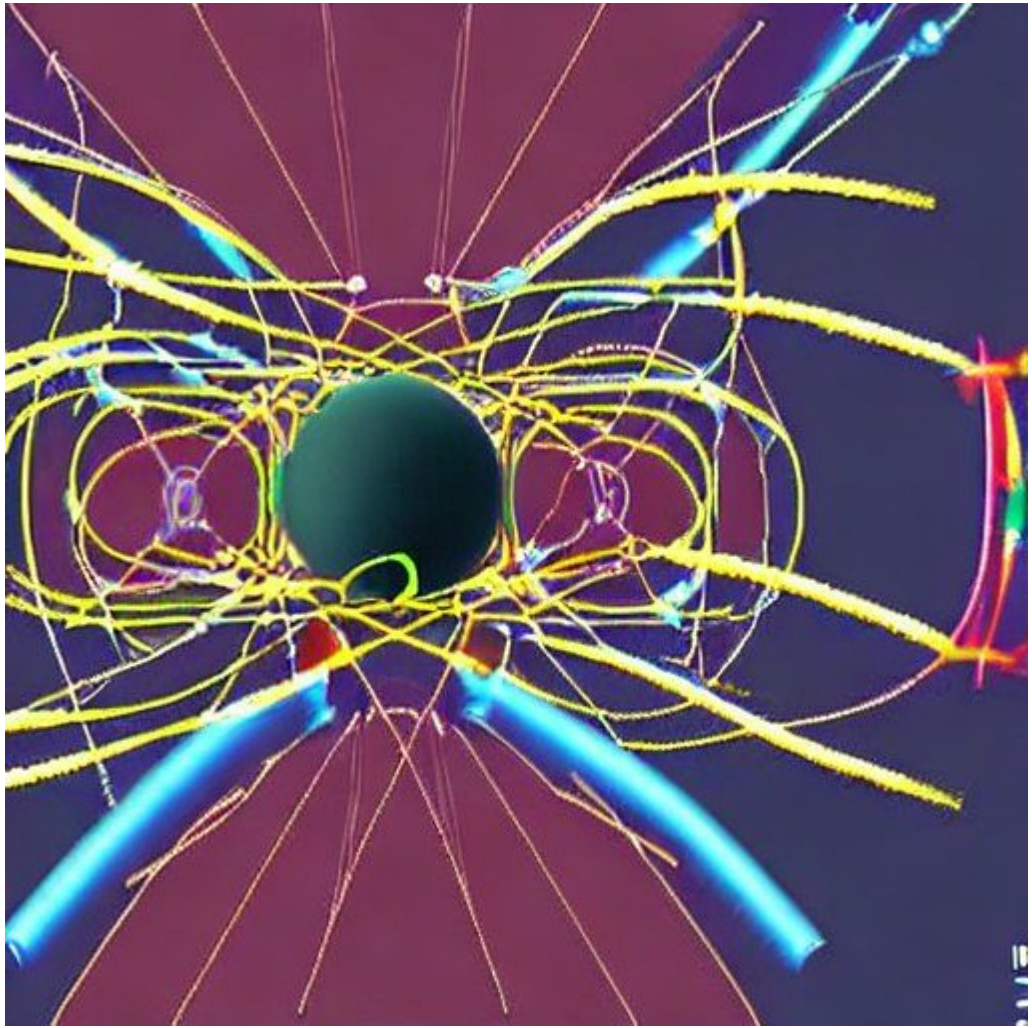
- U(1) vector LQ describing R(K*) and R(D*) data searched for
  - three different scenarios of LQ coupling to SM fermions
- Mass reach increases rapidly with g_U!
  - touching the region preferred by the R(K*) and R(D*) data!





Just couplings to left-handed SM fermions considered here.

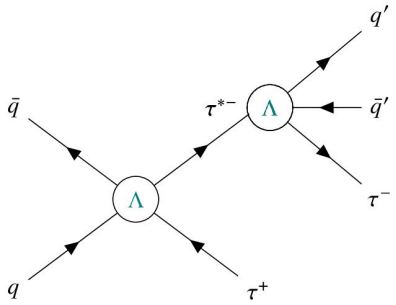
Excited fermions



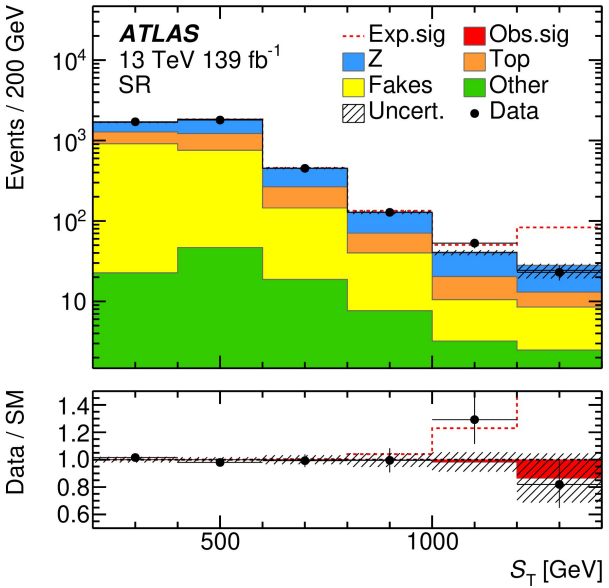
*Stable Diffusion artworks

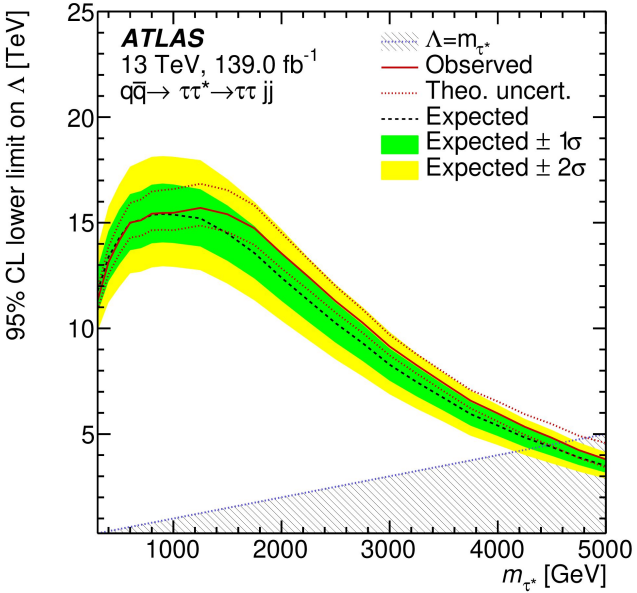
Novel at the LHC:
Dedicated excited τ-lepton search

ATLAS arXiv:2303.09444



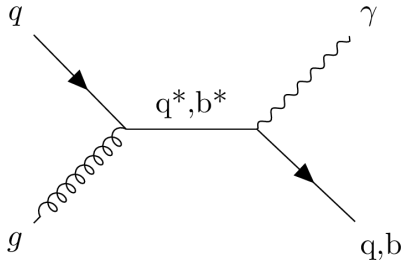
- ττjj final state
- 4-fermion contact interaction production and decay
- excluded: m_{τ^*} up to 4.6 TeV



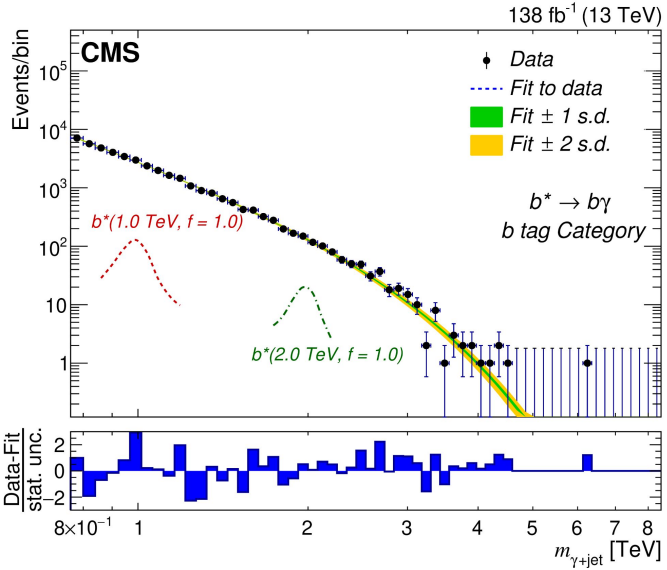


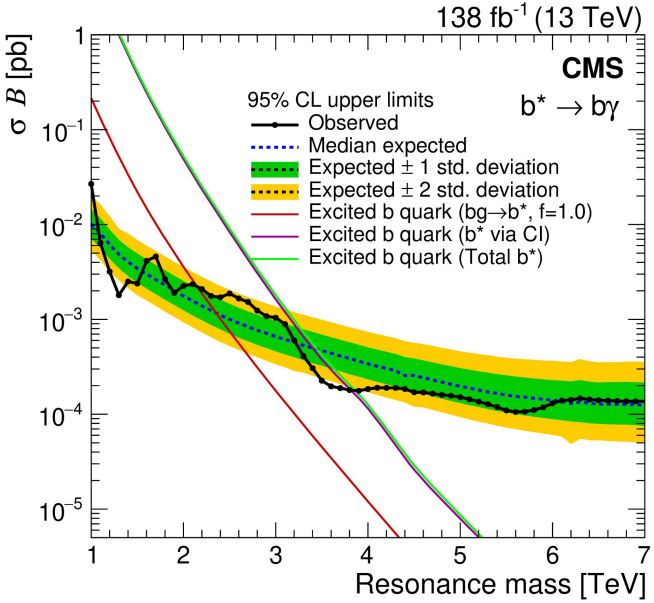
Excited b-quark search

CMS arXiv:2305.07998



- γ+jet resonance search
- Production of b*: 4-fermion contact interaction plus b+g
  - CI dominates
- Excluded: m_{b^*} up to 3.8 TeV

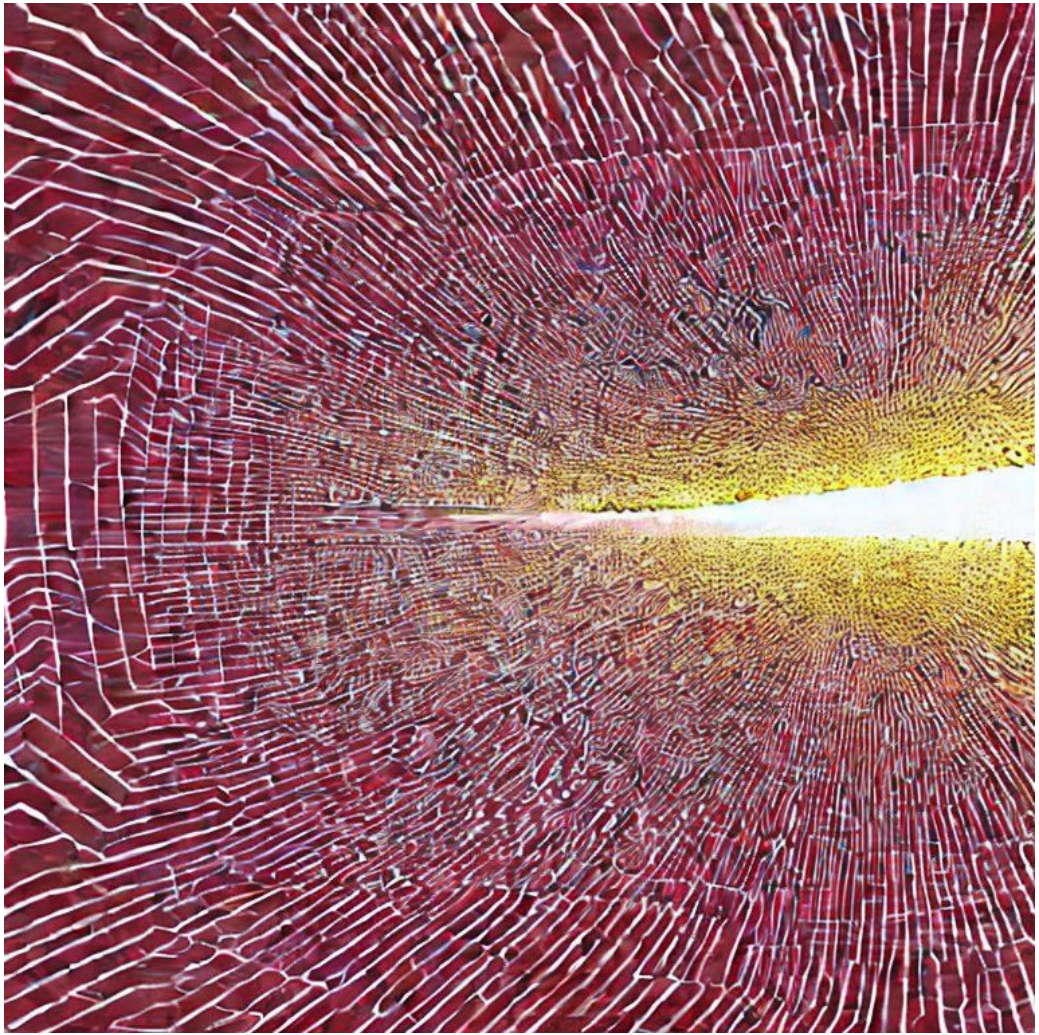




Excited fermions summary

		e*	μ*	τ*	ν*	q*	b*	t*
Limits [TeV]	ATLAS arXiv:1906.03204	4.6						
	ATLAS arXiv:1411.2921		3.0		1.6			
	CMS arXiv:1811.03052	3.9	3.8					
	ATLAS arXiv:2303.09444			4.6				
	ATLAS arXiv:1910.08447					6.7		
	CMS arXiv:1911.03947					6.3		
	ATLAS arXiv:1910.00447						3.2	
	CMS arXiv:2305.07998						3.8	
	CMS arXiv:1711.10949							1.2

Vector-like leptons

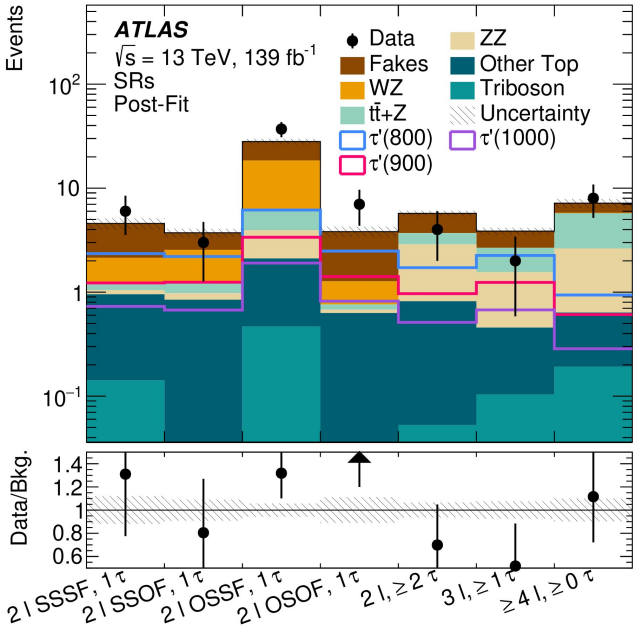


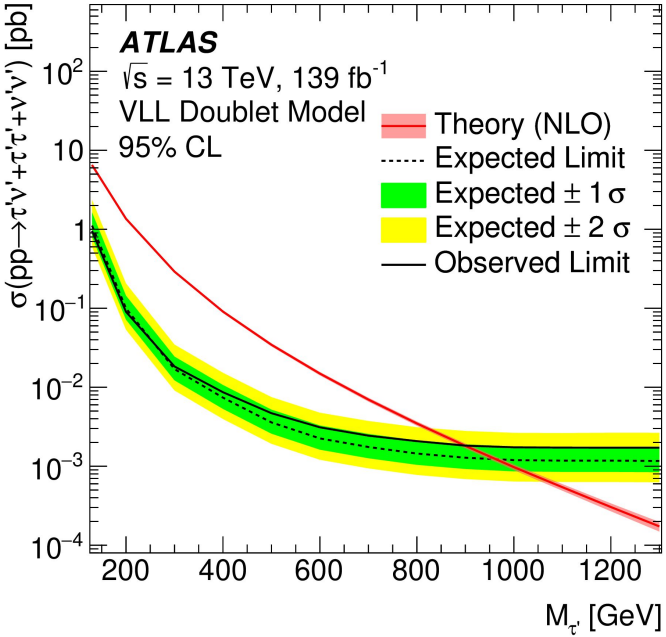
*Stable Diffusion artworks

Vector-like lepton search

ATLAS arXiv:2303.05441

- 4th generation of fermions (non-chiral)
- Complex analysis with many SRs!
- BDT helps





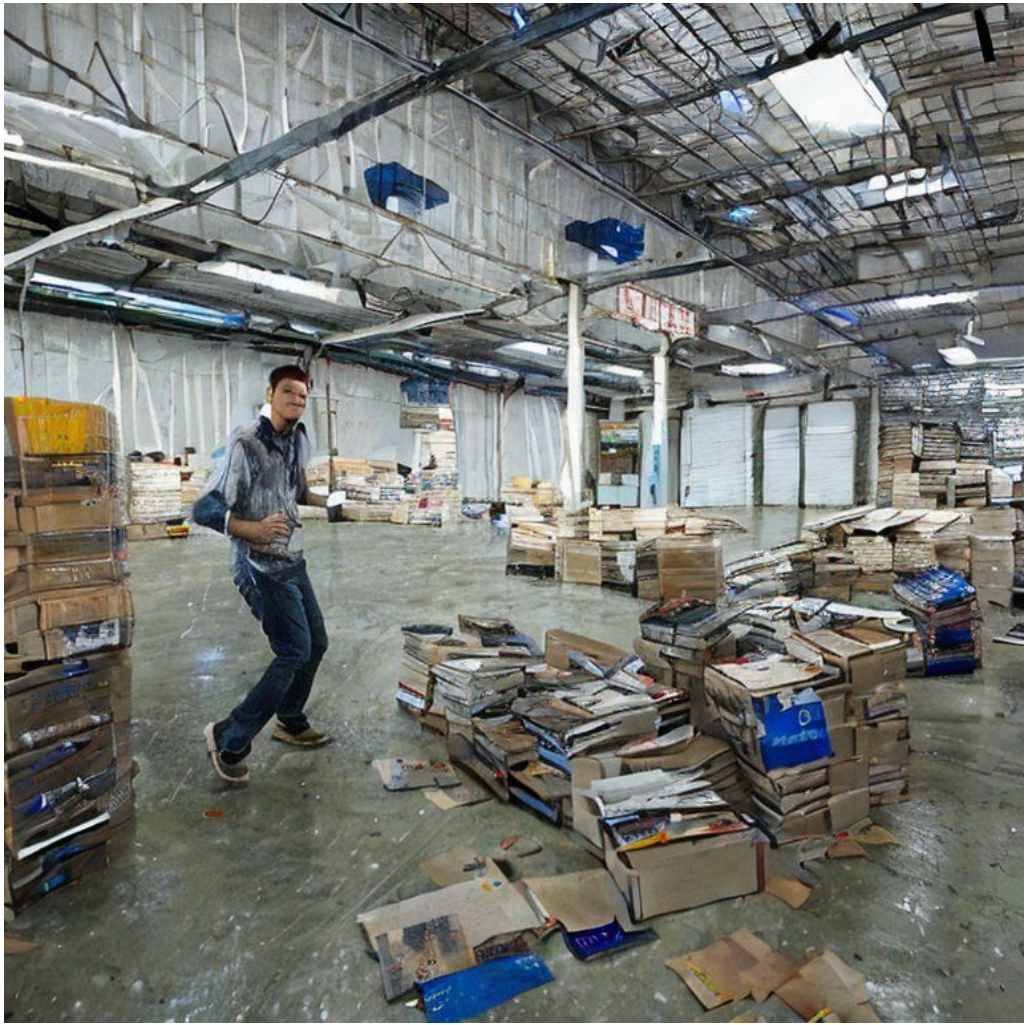
Limits [TeV]	ATLAS arXiv:2303.05441	0.9
	CMS arXiv:2202.08676	1.045

Summary

- Presented: searches for Z’, W’, leptoquarks, excited fermions and vector-like leptons
- LHC offers very rich search programme
- No excess have been found, yet
- Stay tuned!

*Stable Diffusion artworks

Backup

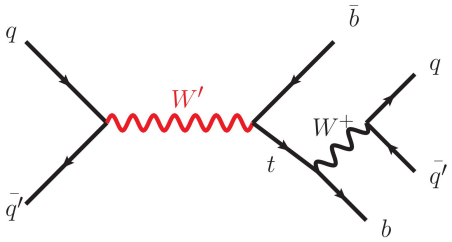


*Stable Diffusion artworks

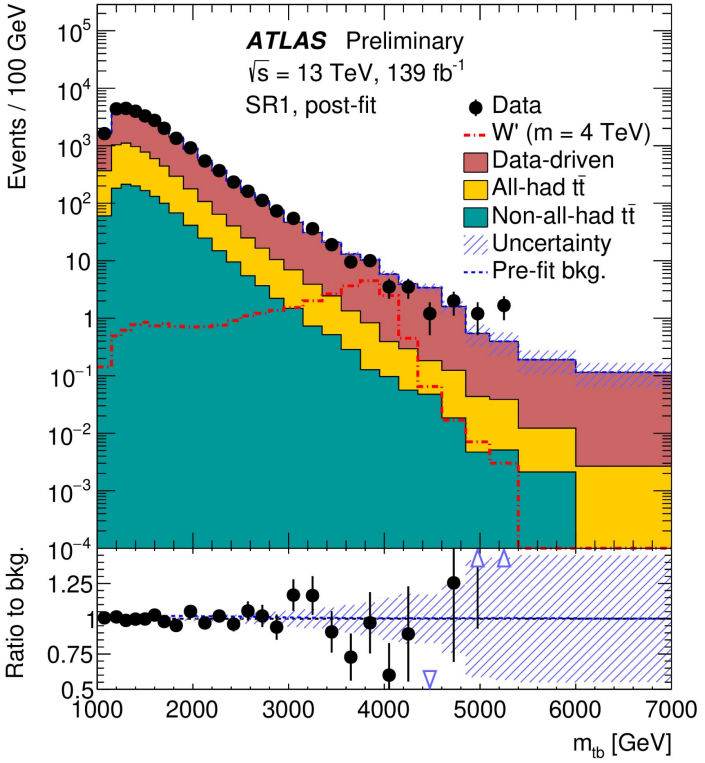
W’(→tb)

ATLAS-CONF-2021-043

- Hadronic top decays
- Leptophobic right-handed W’
- Main multijet background estimated in a data-driven way!
- DNN top-tagging used

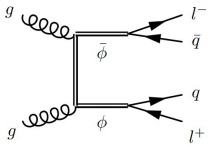


W’ decay limits [TeV]	tb
ATLAS-CONF-2021-043 hadronic	4.4
CMS-PAS-B2G-20-012 leptonic	4.3
CMS arXiv:2104.04831 hadronic	3.4

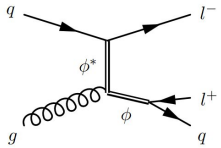


Leptoquark landscape

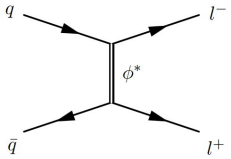
Pair production $\sigma \sim \lambda^0$

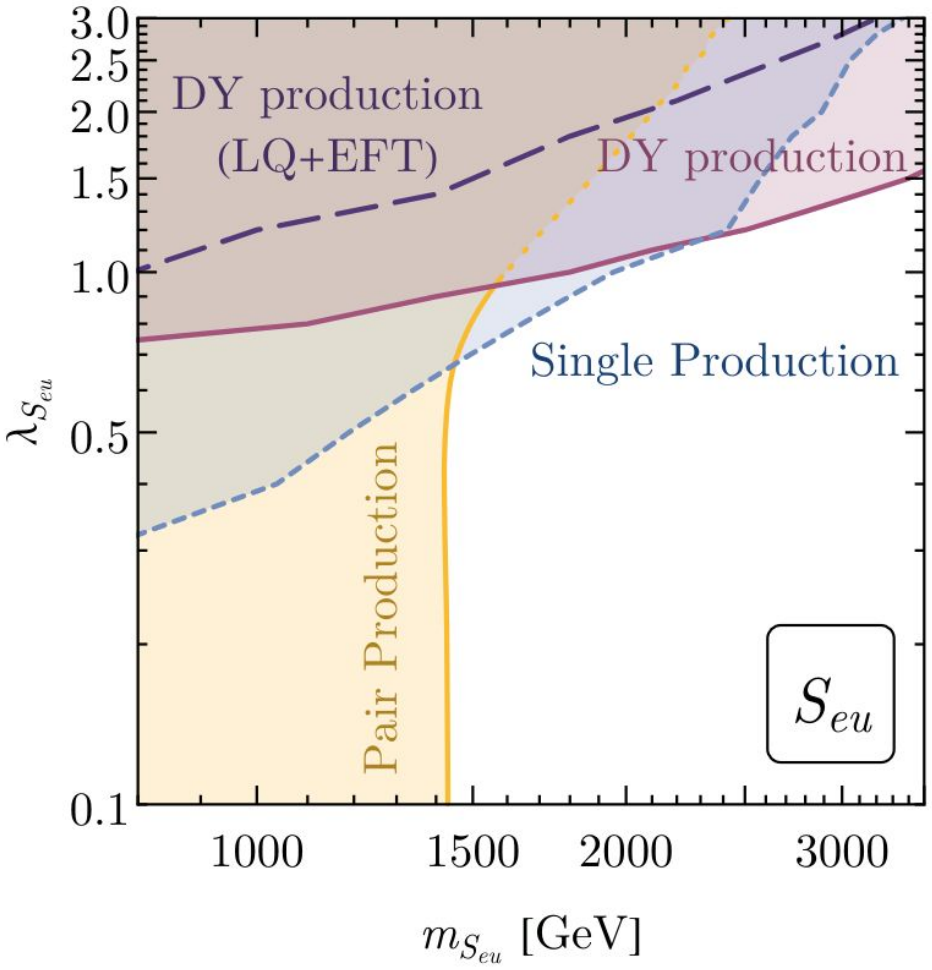


Single production $\sigma \sim \lambda^2$



DY production $\sigma \sim \lambda^4$

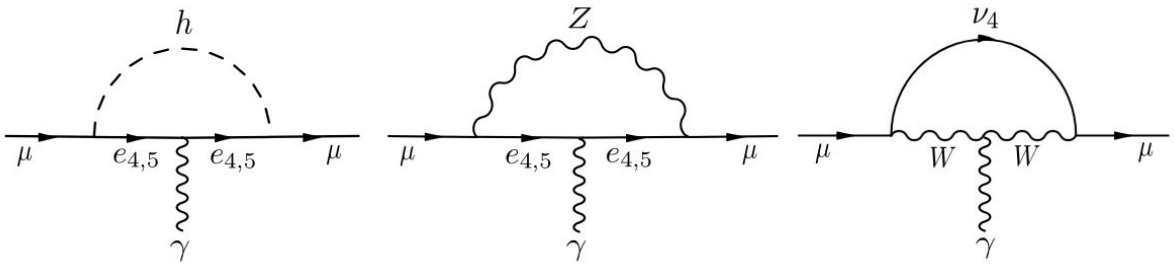




*arXiv:1706.05033, arXiv:1810.10017

Vector-like leptons

- Muon g-2 explanation:



- Can explain mass hierarchy of SM fermion generations by mixing

- Production and decays probed
  - so far, just couplings to the τ-lepton considered