Searches for new phenomena in final states with 3^{rd} generation quarks using the ATLAS detector

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On behalf of ATLAS Collaboration

University of Hong Kong

SUSY 2024

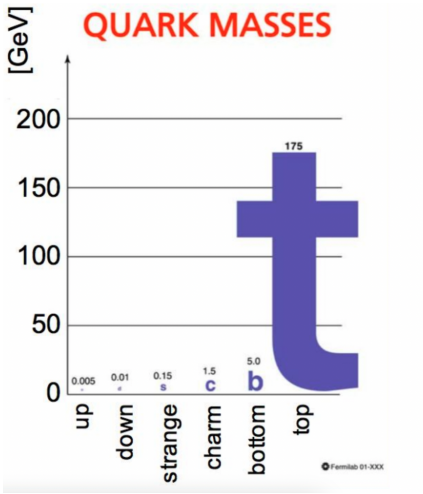
Madrid (Spain), June 10, 2024

Introduction

1. 3^{rd} generation quarks are among the heaviest particles in the Standard Model

   → *Very large Yukawa coupling.*

2. Unique signature that allows to reduce the Standard Model background.



Presenting here the latest results about the subject:

Exotic Higgs decays to tops

- $gg \to A/H \to t\bar{t}$: *arXiv:2404.18986*
- $t\bar{t}H/A \to t\bar{t}t\bar{t}$: *ATLAS-CONF-2024-002*

Dark mesons: *arXiv:2405.20061*

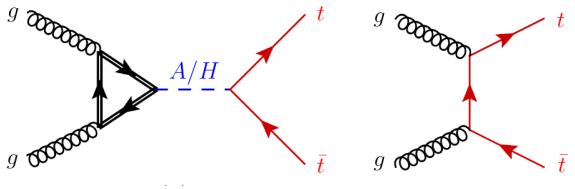
Vector-Like-Quarks (VLQ): *Phys. Lett. B 854 (2024) 138743*

Leptoquarks (LQs): *Phys. Lett. B 854 (2024) 138736*

Results related to SUSY will be shown at the talk from Edmund Xiang Lin Ting.

$gg \to A/H \to t\bar{t}$ (I)

arXiv:2404.18986



1 **Signal:** $gg \to A/H \to t\bar{t}$

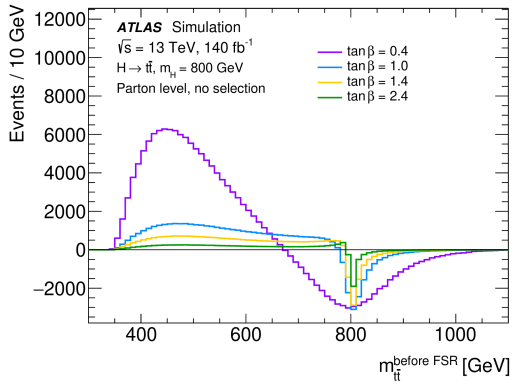
→ *Interference between signal and SM $t\bar{t}$ taken into account.*

2 **Final state:** 1L and 2L.

3 **Background:**

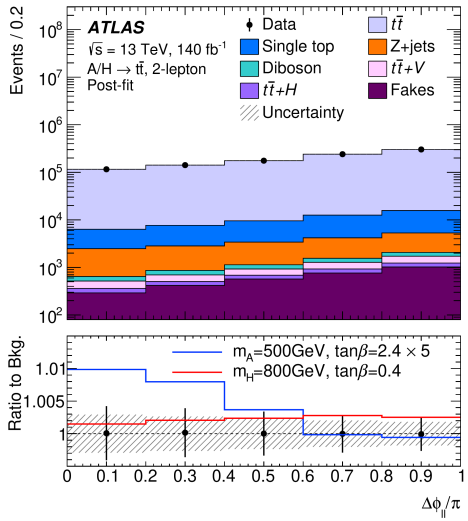
- Dominant: SM $t\bar{t}$
- Minor: W/Z+jets, single top, multijet, $t\bar{t}V$, VV, fakes (2L)

→ *Estimated with MC, with data-driven techniques for multijet and V+jets.*



4 **Strategy:**

- 1L channel: *Split based on the reconstruction of the hadronic decay of the top quark*
  - Resolved topology: reconstructed with small R-jets: 1b and 2b
    → *Split into bins of the angular variable* $|\cos\theta^*|$ (11 SRs)
  - Merged topology: reconstructed with large R-jets (1 SR).
- 2L channel:
  → *Split into bins of* $\Delta\phi_{\ell\ell}$ (5 SRs).



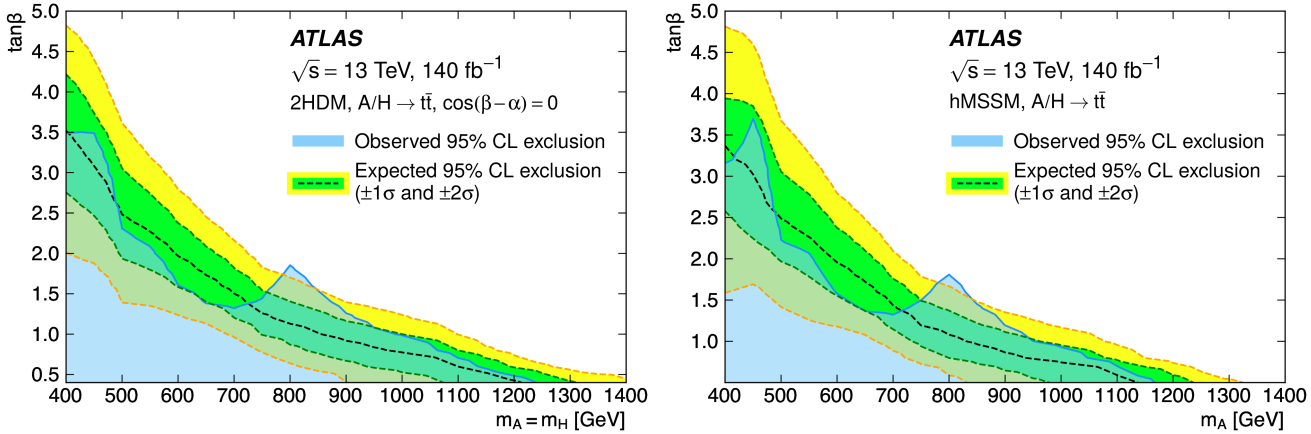
Final fit performed on $m_{t\bar{t}}$ (1L) and $m_{\ell\ell b\bar{b}}$ (2L).

$gg \to A/H \to t\bar{t}$ (II)

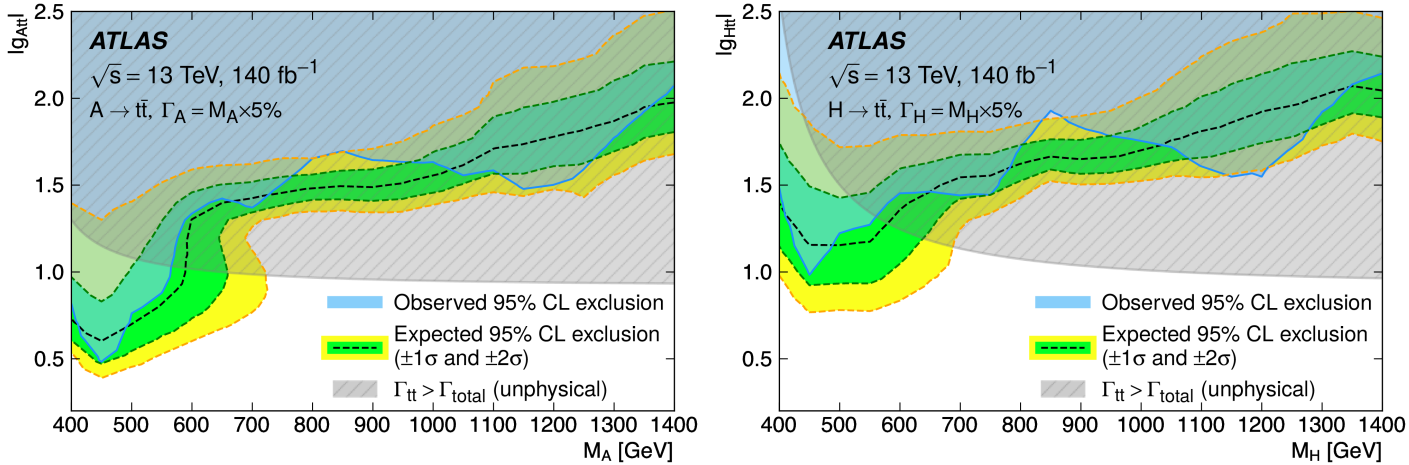
- No excess of events has been observed.

arXiv:2404.18986

- Interpretation done in the type-II 2HDM and hMSSM.



- Constraints on the coupling strength modifier $g_{A/Ht\bar{t}}$ as a function of the $m_{A/H}$ were also set for a generic scenario for different values of $\Gamma_{A/H}$.

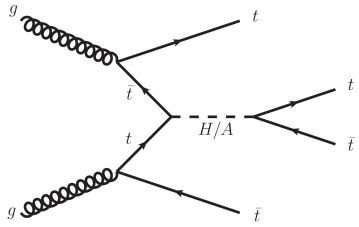


$t\bar{t}H/A \rightarrow t\bar{t}t\bar{t}$ (I)

ATLAS-CONF-2024-002

1 Signal: $t\bar{t}H/A \rightarrow t\bar{t}t\bar{t}$

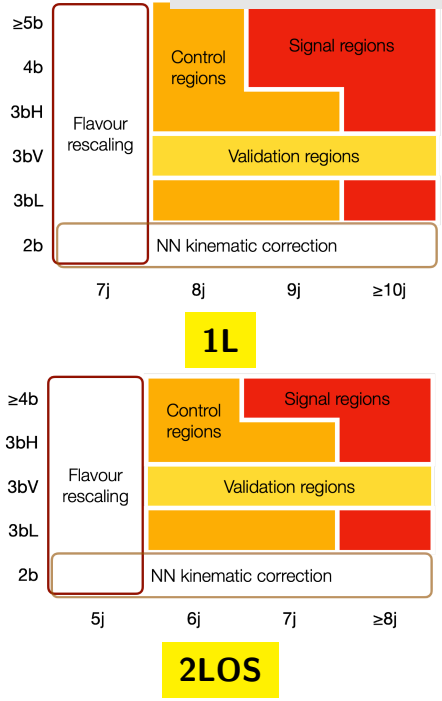
$\rightarrow$ *Final state involves high jet and b-jets multiplicities.*



2 Final state: 1L and 2LOS.

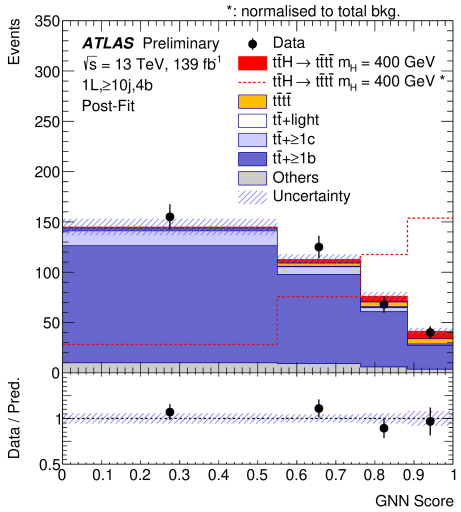
3 Background:

- $t\bar{t}$+jets ($> 90\%$).
  - Normalization of $t\bar{t}$+light, $t\bar{t}+\geq 1c$, and $t\bar{t}+\geq 1b$ corrected via flavour rescaling.
  - Kinematic mismodeling handled via a NN reweighing.
- Minor backgrounds estimated from MC.



4 Strategy:

- **Events selection:** categorized according to the jet multiplicity and *b*-tagging requirement
  - 1L: 6 CRs and 6 SRs.
  - 2LOS: 5 CRs and 4 SRs.
- **Signal discrimination:** Done via a GNN.



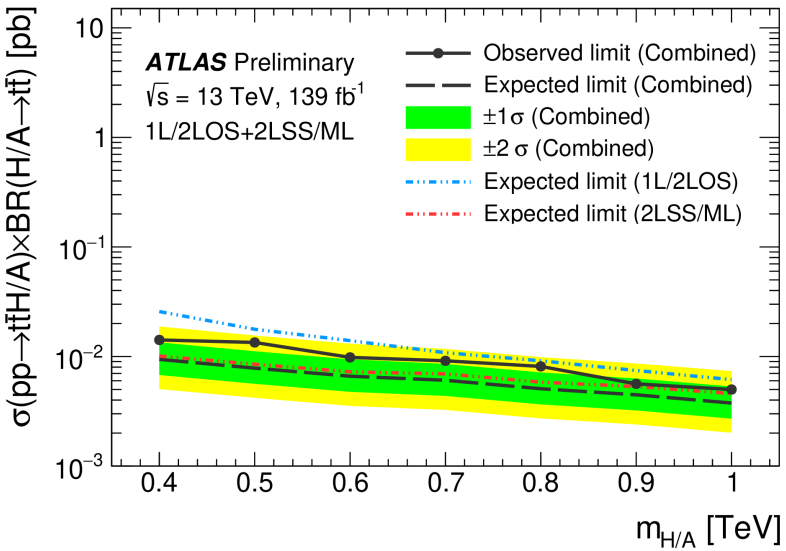
Final fit performed on H_T for the CRs and *GNN* score for the SRs.

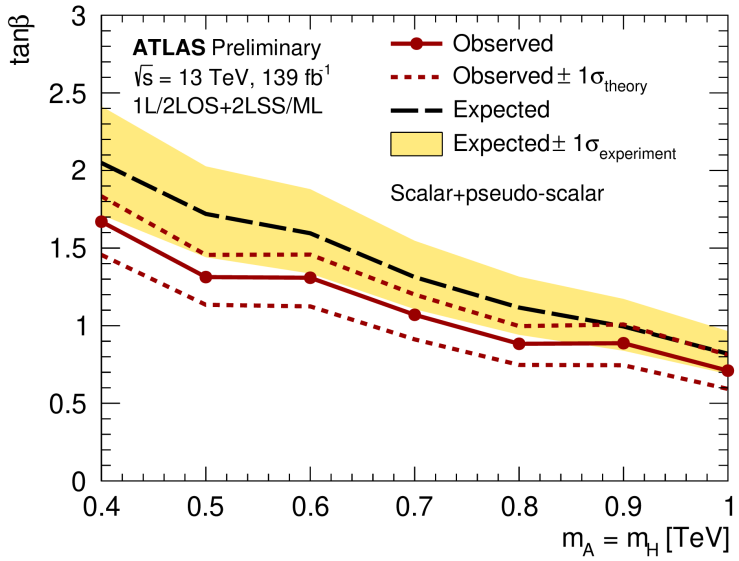
$t\bar{t}H/A \rightarrow t\bar{t}t\bar{t}$ (II)

ATLAS-CONF-2024-002

- No significant excess of events has been observed.
- Interpretation done as upper limits on the $\sigma(pp \rightarrow t\bar{t}H/A) \times \mathcal{B}(H/A \rightarrow t\bar{t})$ and on the $\tan\beta$ vs $m_{H/A}$ plane.

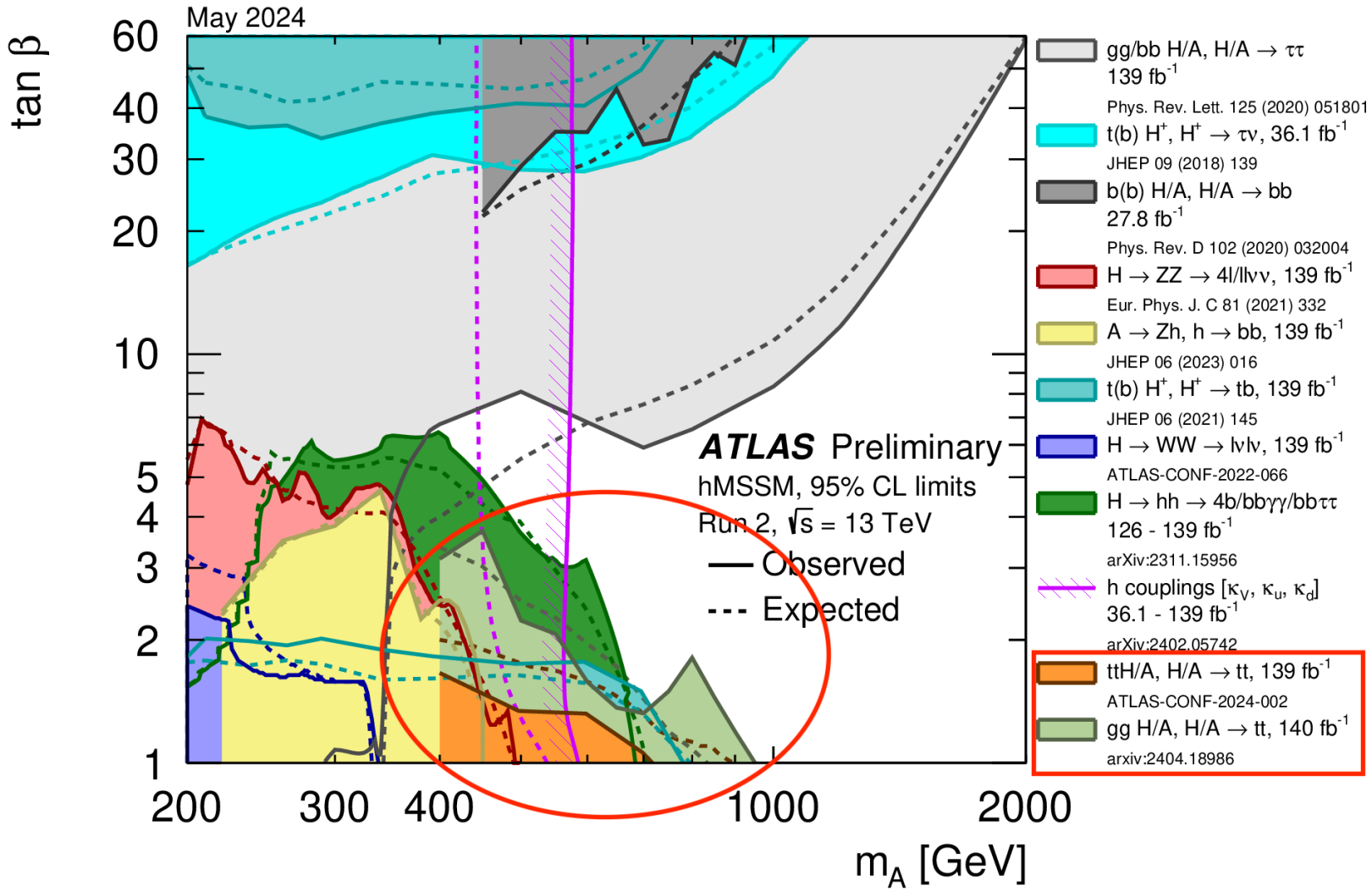
  $\rightarrow$ *Results combined with the ones from the SSML channel JHEP 07 (2023) 203.*





Comparison of $t\bar{t}H/A \to t\bar{t}t\bar{t}$ and $H/A \to t\bar{t}$

ATL-PHYS-PUB-2024-008



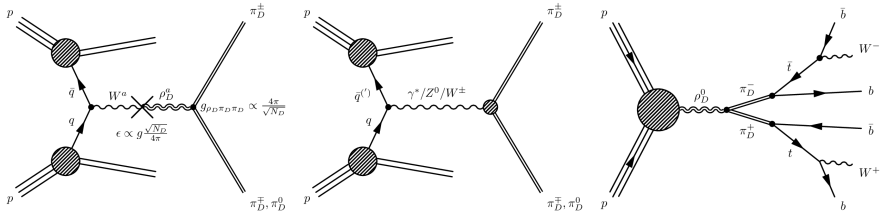
Dark mesons (I)

arXiv:2405.20061

1 **Signal:** $\pi_D^{\pm}\pi_D^0$ or $\pi_D^{\pm}\pi_D^{\mp}$

→ *For gaugephobic models the decay to top and bottom quarks dominates at high masses.*

→ *Experimental signature tttb and ttbb.*

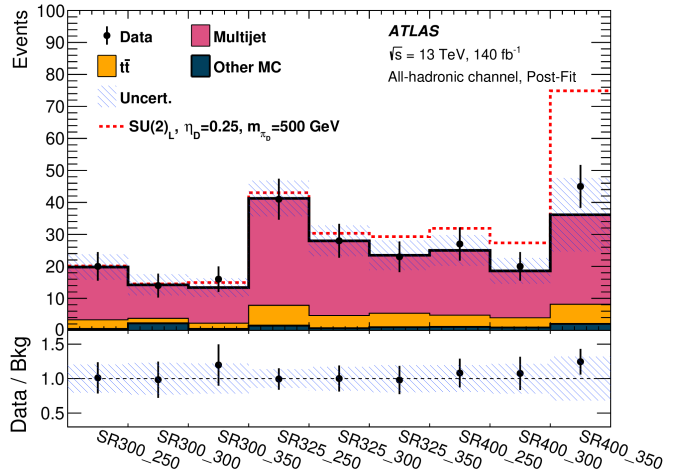


2 **Final state:** All hadronic and 1L.

3 **Background:**

- All hadronic: Dominated by multijet. Estimated from data-driven techniques.
- 1L: Dominated by $t\bar{t}$+jets. Normalized to data in the fit.

→ *Minor contributions taken from MC.*



4 **Strategy:**

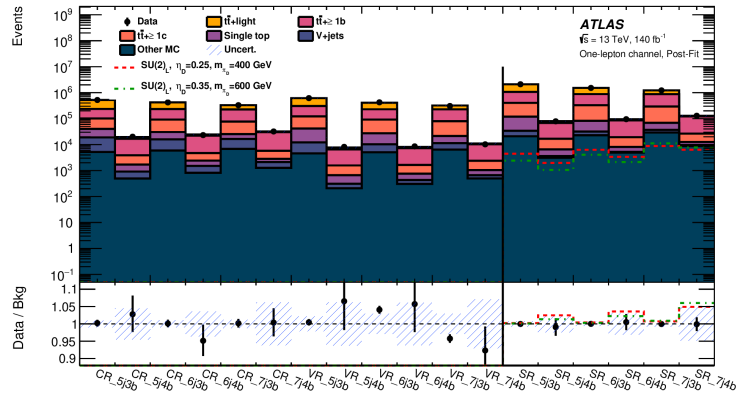
- All hadronic: Defined by the leading two large-R jets.

  → *SR subdivided into nine separate bins in the leading versus sub-leading large-R jet mass plane (9 SRs).*

  Fit done on the 9 SRs.

- 1L: Events classified into regions split into bins based on the number of jets and b-jets (6 SRs and 6 CRs).

  Fit done on the $m_{Jhad} + m_{Jlep}$ in the SRs and CRs.

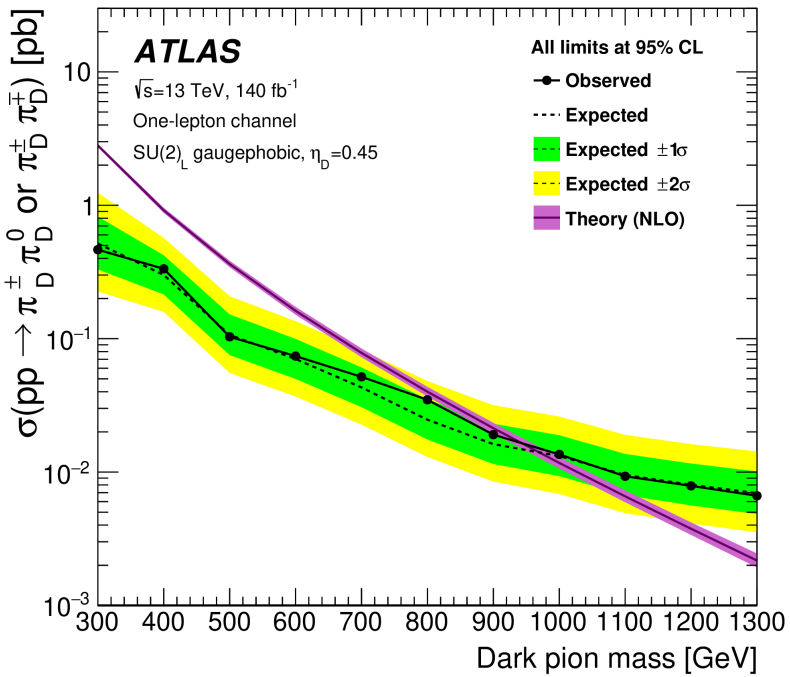


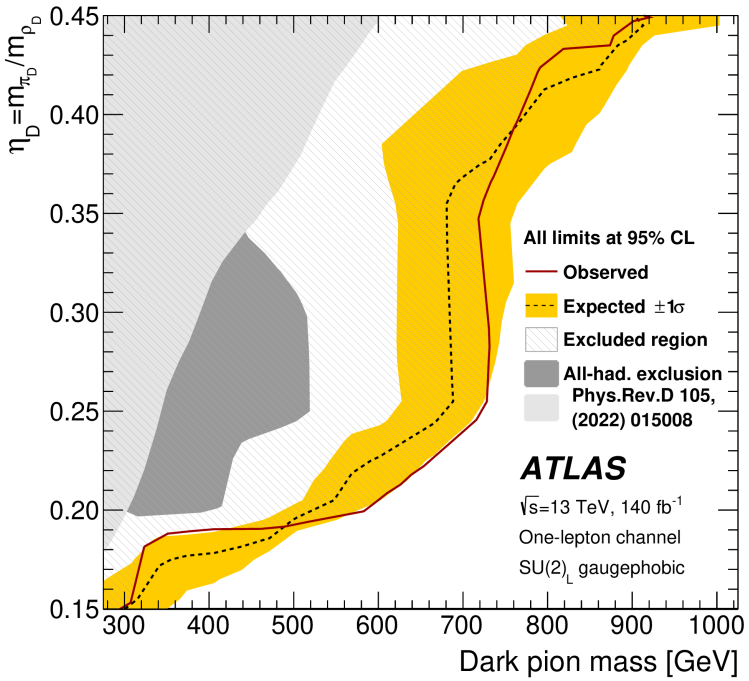
Dark mesons (II)

arXiv:2405.20061

- No significant excess of events has been observed.
- Upper limits on the $\sigma(\pi_D^{\pm}\pi_D^0$ or $\pi_D^{\pm}\pi_D^{\mp})$ computed

  → *Interpretation translated into limits on dark pion masses in the two-dimensional $\eta - m_{\pi_D}$ plane.*





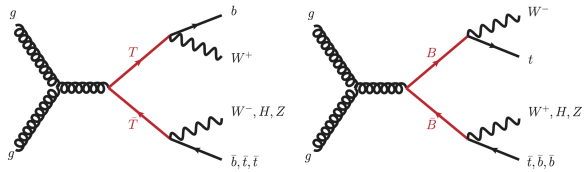
VLQ $T\bar{T} \rightarrow Wb + X$ (I)

Phys. Lett. B 854 (2024) 138743

1 **Signal:** $T\bar{T}$, $B\bar{B}$

→ *Search optimized for* $T\bar{T} \rightarrow WbW\bar{b}$.

→ *One W decays leptonically, the other decays hadronically.*

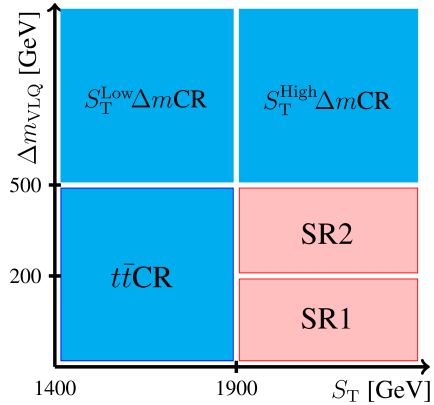


2 **Final state:** 1L + jets.

3 **Background:**

- Dominated by $t\bar{t}$, W+jets and single top

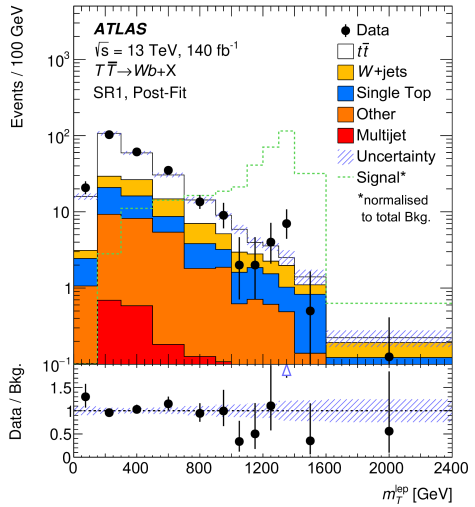
  → *Estimated with MC with data-driven corrections.*
- Multijet: Estimated with data-driven techniques.
- Remaining contributions estimated from MC.



4 **Strategy:**

- T candidates are reconstructed such that Δm between the T^{lep} and T^{had}, Δm_{VLQ}, candidates is minimized.
- m_T^{let} is the main discriminating variable.

  Fit done on m_T^{let} in the 2 SRs and 3 CRs.

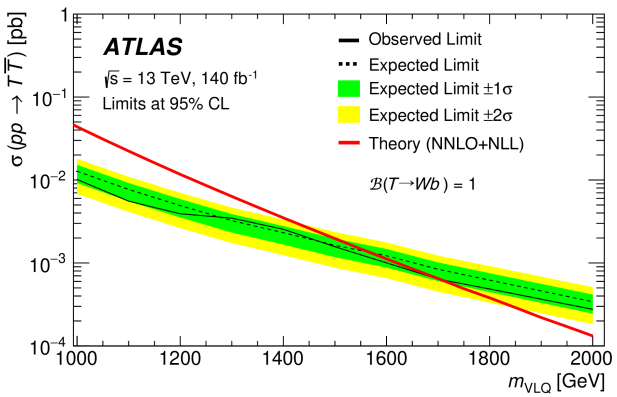


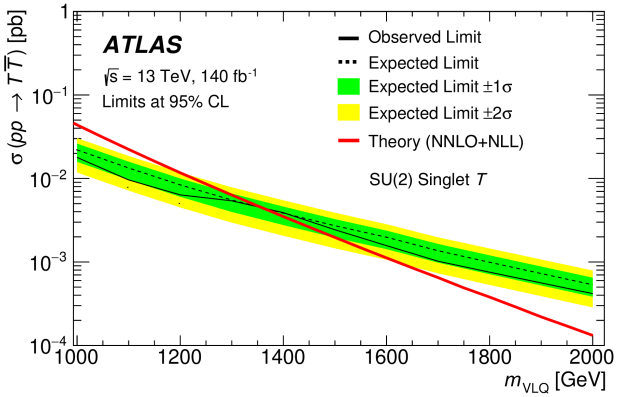
VLQ $T\bar{T} \to Wb + X$ (II)

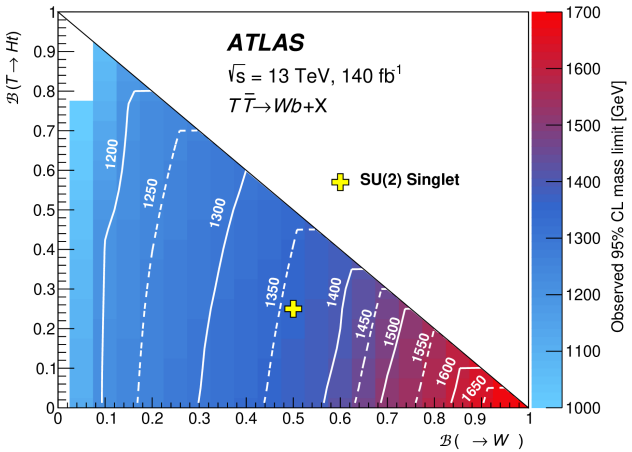
- No significant excess of events has been observed.
- Upper limits on the $\sigma(pp \to T\bar{T})$ were computed for the $\mathcal{B}(T \to Wb) = 1$ and the SU(2) singlet T scenarios.
- Upper limits for different branching rations scenarios also tested.

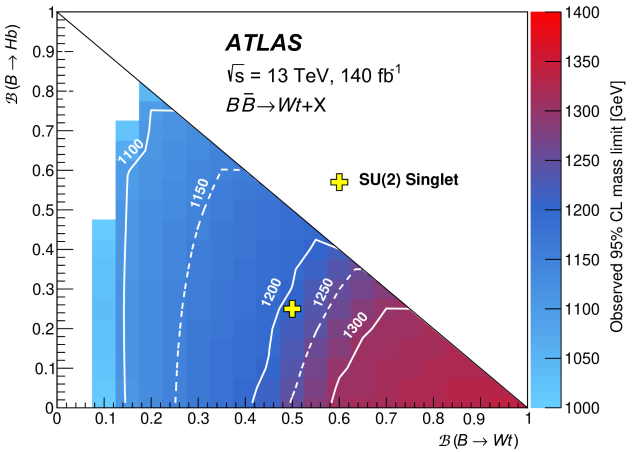
Phys. Lett. B 854 (2024) 138743

$\to$ *Results used to set limits on the $B\bar{B}$ production*







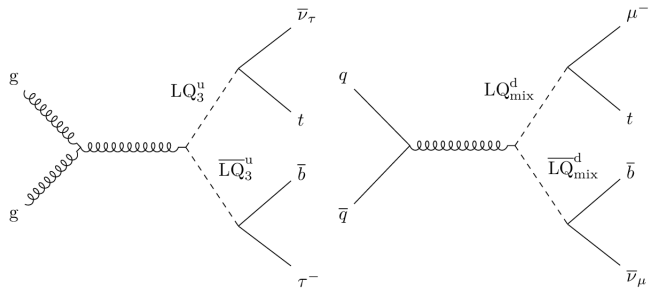


LQs (I)

Phys. Lett. B 854 (2024) 138736

1 **Signal:** LQs that decay into a lepton and either a top or bottom quark.

→ *Considering only pair prodution.*



2 **Strategy:** Combination of different final states with Run 2 data.

Search		Interpretation						Signal Region		
		Scalar				Vector				
Final State	Citation	$\mathrm{LQ}_3^{\mathrm{u}}$	$\mathrm{LQ}_3^{\mathrm{d}}$	$\mathrm{LQ}_{\mathrm{mix}}^{\mathrm{u}}$	$\mathrm{LQ}_{\mathrm{mix}}^{\mathrm{d}}$	$U_1^{\mathrm{YM/MC}}$	$\tilde{U}_1^{\mathrm{YM/MC}}$	N_ℓ	$N_{\tau_{\mathrm{had}}}$	$N_{b\mathrm{jets}}$
$t\nu b\tau$	Phys. Rev. D, 104 (2021) 112005	✓	✓	–	–	✓	–	0	1	≥ 2
$b\tau b\tau$	EPJC 83 (2023) 1075	✓	–	–	–	✓	–	$\{0,1\}$	$\{1,2\}$	$\{1,2\}$
$t\tau t\tau$	JHEP 06 (2021) 179	–	✓	–	–	–	✓	$\{1,2,3\}$	≥ 1	≥ 1
$t\nu b\ell$	JHEP 06 (2023) 188	–	–	✓	✓	–	–	1	–	≥ 1
$b\ell b\ell$	JHEP 10 (2020) 112	–	–	✓	–	–	–	2	–	$\{0,1,2\}$
$t\ell t\ell$ (2ℓ)	EPJC 81 (2021) 313	–	–	–	✓	–	–	2	–	–
$t\ell t\ell$ $(\geq 3\ell)$	ATLAS-CONF-2022-052	–	–	–	✓	–	–	$\{3,4\}$	–	≥ 2
$t\nu t\nu$	EPJC 80 (2020) 737	✓	–	✓	–	✓	–	0	0	≥ 2
$b\nu b\nu$	JHEP 05 (2021) 093	–	✓	–	✓	–	–	0	–	≥ 2

3 **Results:** Interpreted in the context of scalars LQ_3 and LQ_{mix}, and vector LQs, with an additional coupling of Yang-Mills type to gluons present of absent ('minimal coupling').

LQs: LQ_3 (II)

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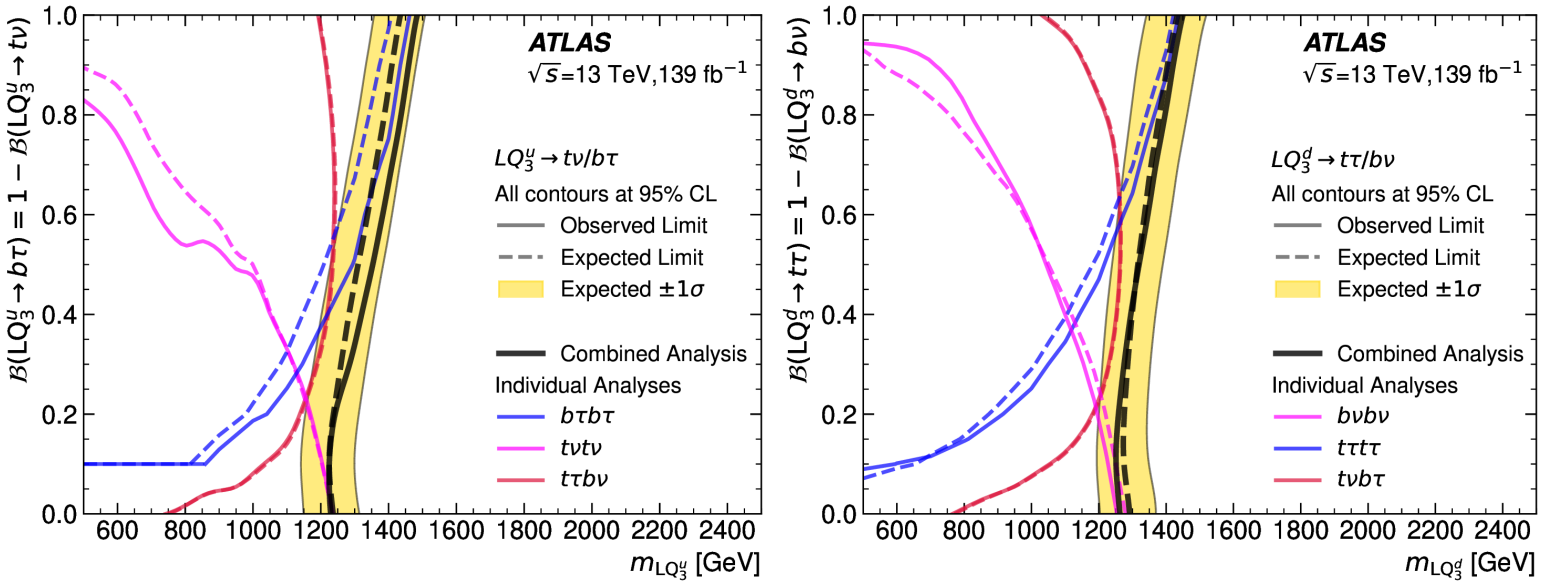

LQs: LQ_{mix} (III)

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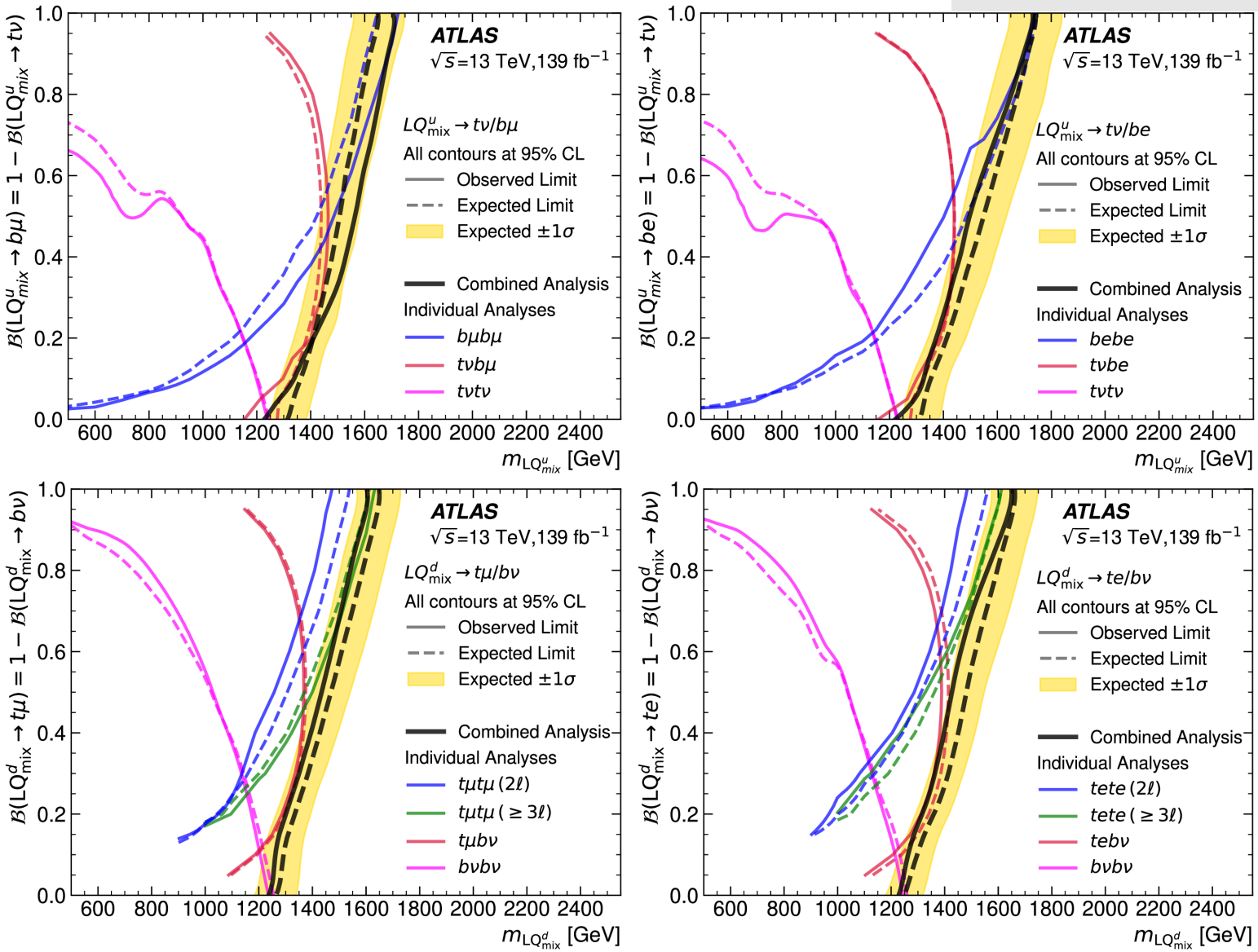

LQs: $U_1^{YM/MC}$ (IV)

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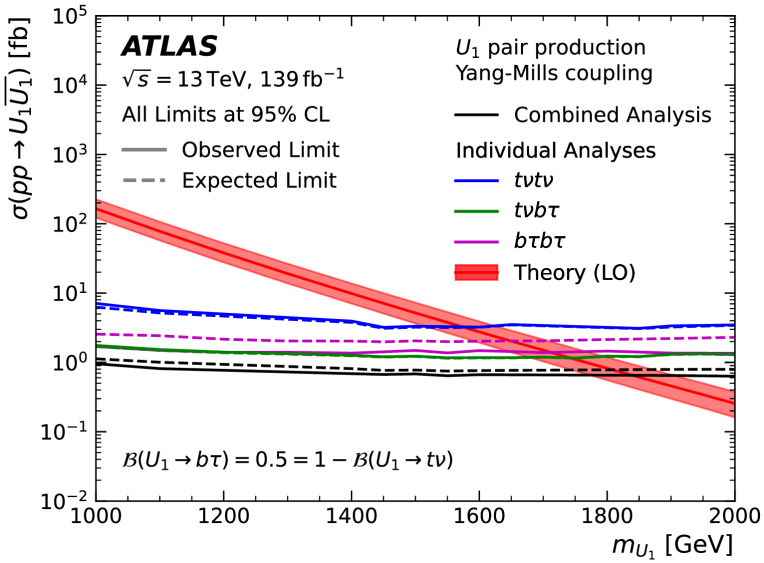

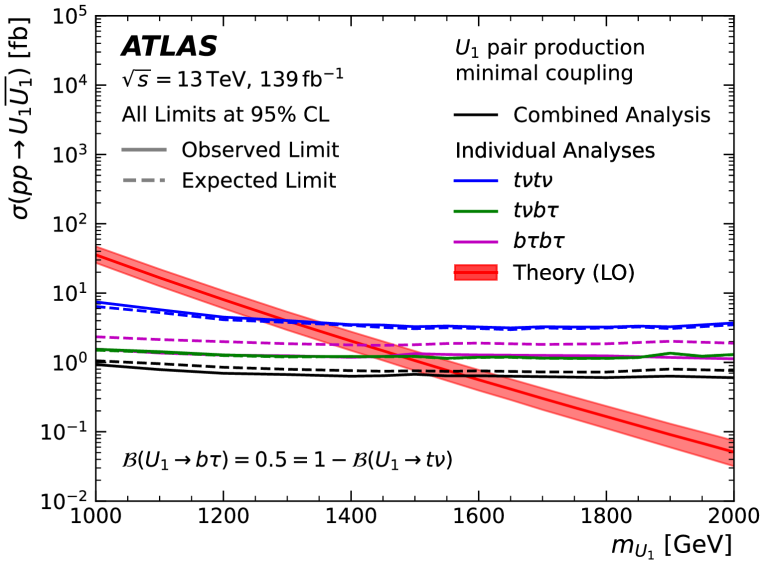

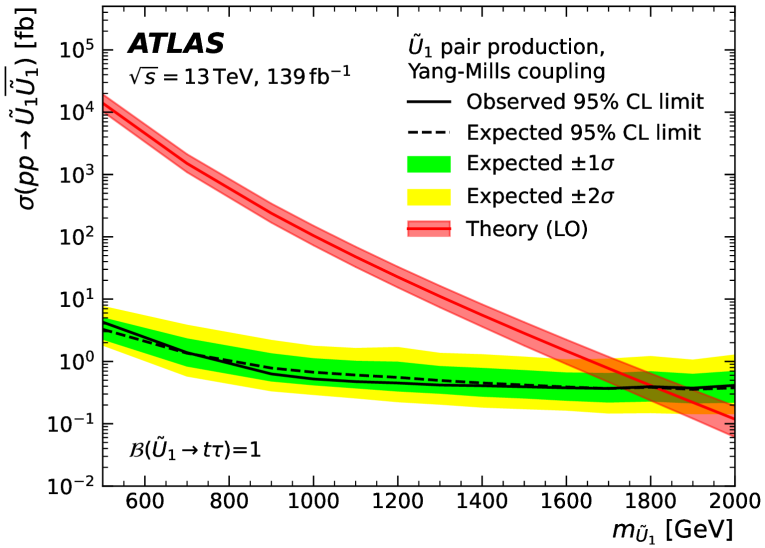

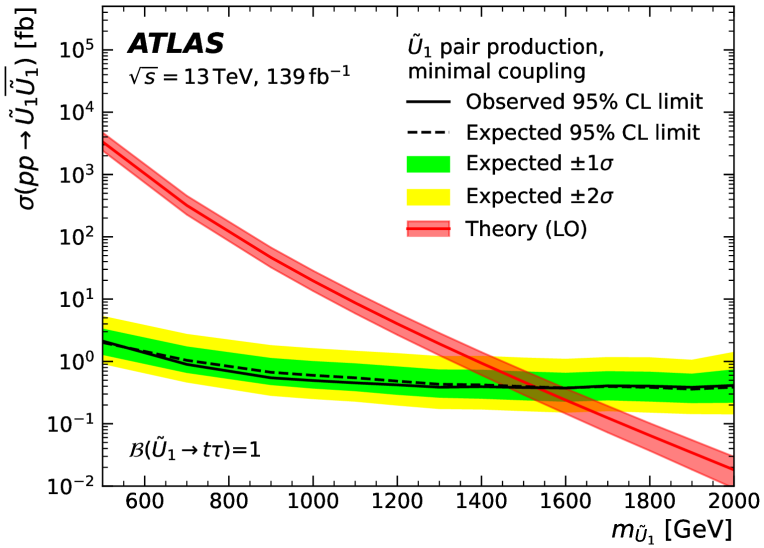

Summary

- ATLAS has an extensive program to look for New Physics with 3^{rd} generation quarks.
- No evidence for new phenomena with 3^{rd} generation quarks has been found

  $\rightarrow$ *Upper limits on the production cross-section and constraints on the relevant parameters of the benchmark models have been set.*

- Still a lot of work to be done...

Waiting for more data from the LHC Run 3!

BACKUP