A measurement of the high-mass $\tau\bar{\tau}$ production cross-section at $\sqrt{s}$ = 13 TeV with the ATLAS detector and constraints on new particles and couplings

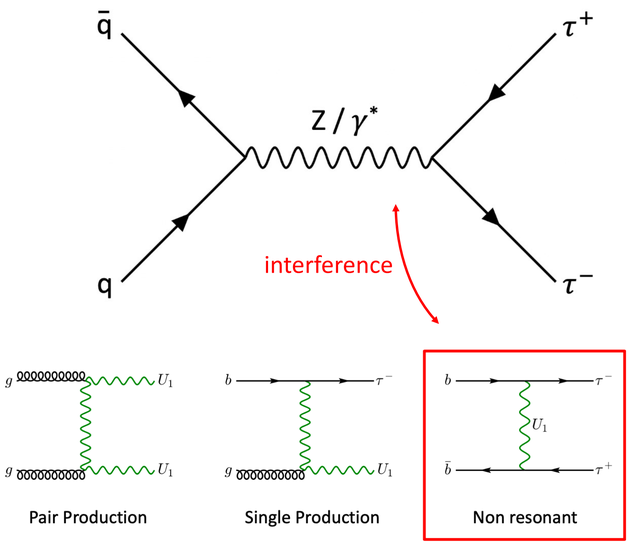
ATLAS EXPERIMENT

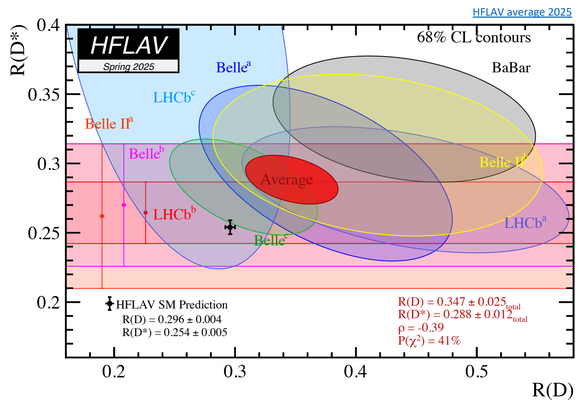
arXiv: 2503.19836

Physics motivations

- At high-mass Drell-Yan **pp** $\rightarrow \tau\bar{\tau}$ probes **new interactions** ...
- ... with enhanced couplings to the 3rd generation of fermions.
- The most prominent example: **R(D)/R(D*)** flavour **anomalies**

  $\Longrightarrow$ **3.8 σ** deviation from the global average.



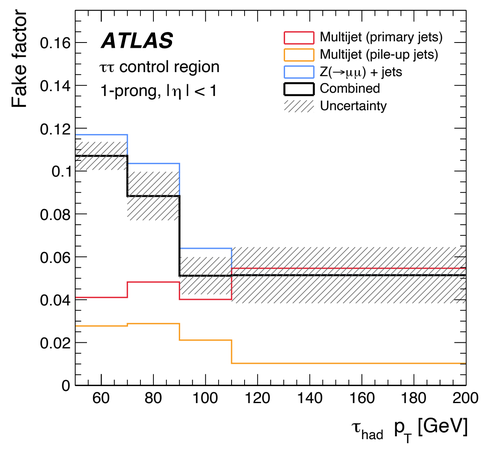


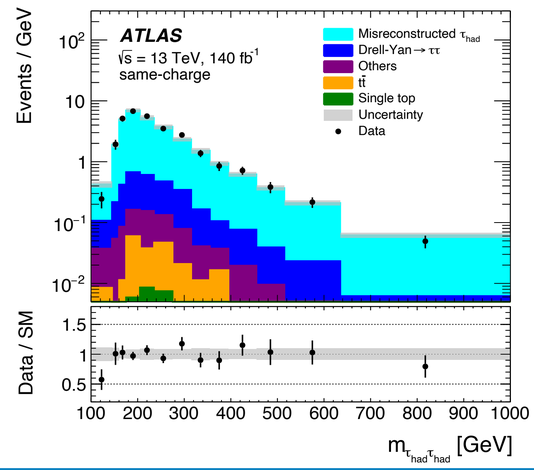
Analysis strategy

- Exploit $\tau_{had}\tau_{had}$ **channel**, separate events according to **b-jet multiplicity**.

	opposite sign			same sign		
	0b	1b	2+ b	0b	1b	2+ b
$\tau_{had}\,\tau_{had}$				Fake-Tau bkg. validation region		
$\tau_e\,\tau_{had}$ / $\tau_\mu\,\tau_{had}$	MC validation regions					

- Estimate of the background of jet mis-identified as **fake** τ_{had} with the **Universal Fake Factor method** (arXiv:2502:04156).





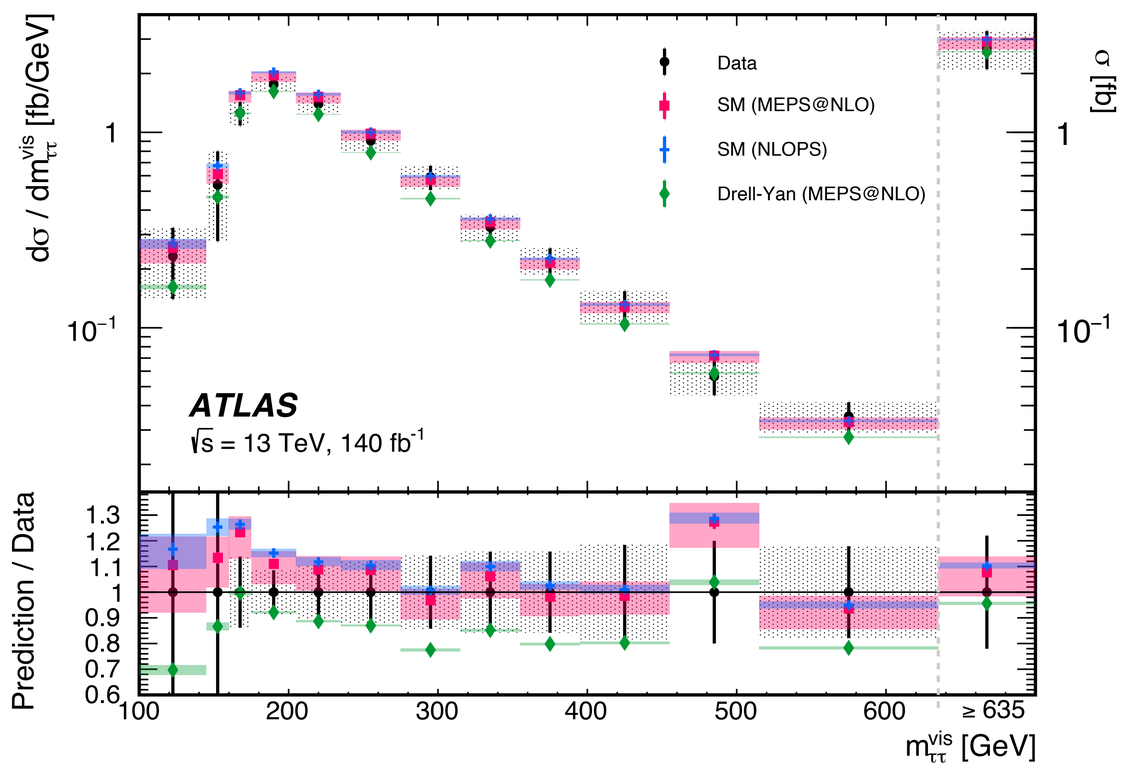
Unfolded cross-section measurement

- Iterative **Bayesian unfolding** with n_f = 2 iterations:
  - ➢ reconstruction efficiency (ϵ_j), fiducial fraction (f_i), unfolding matrix from Monte Carlo simulation.

$$N(t_j) = \frac{1}{\epsilon_j}\sum_i f_i \cdot N(r_i)_{\mathrm{obs}} \cdot P(t_j|r_i)_{n_f}$$

- **Agreement** with the **Standard Model** prediction.
- Drell-Yan and ttbar modelled with Sherpa 2.2.11 (**MEPS@NLO**) and Powheg+Phytia8 (**NLOPS**).

Cross-section inclusive in **all processess** contributing to τ**-lepton pair production**.



Constraints on leptoquakrs and Z' bosons

- Likelihood fit in 3 bins of **visible** $\mathbf{m_{\tau\tau}}$: [100, 250, 400, 1000] GeV across b-jet categories.
- **Constraints** on Vector/Scalar **leptoquarks** and **heavy Z' bosons** for several values of the model parameters.

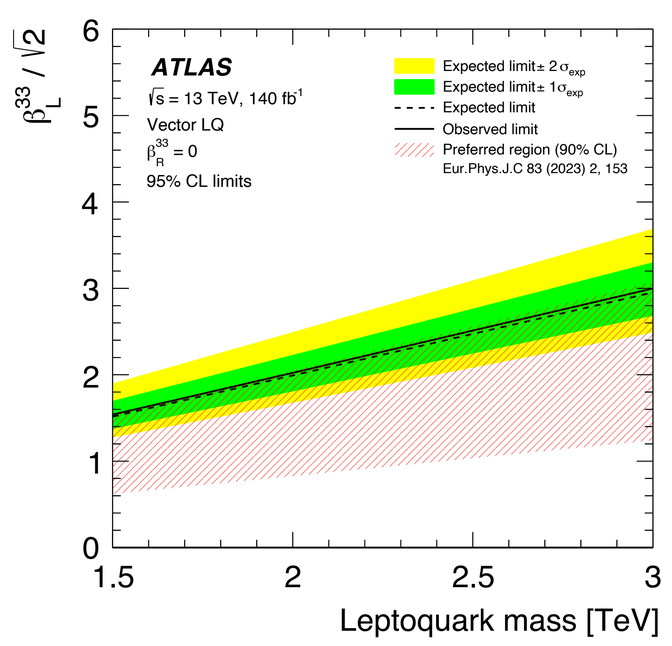
Leptoquark lagrangian

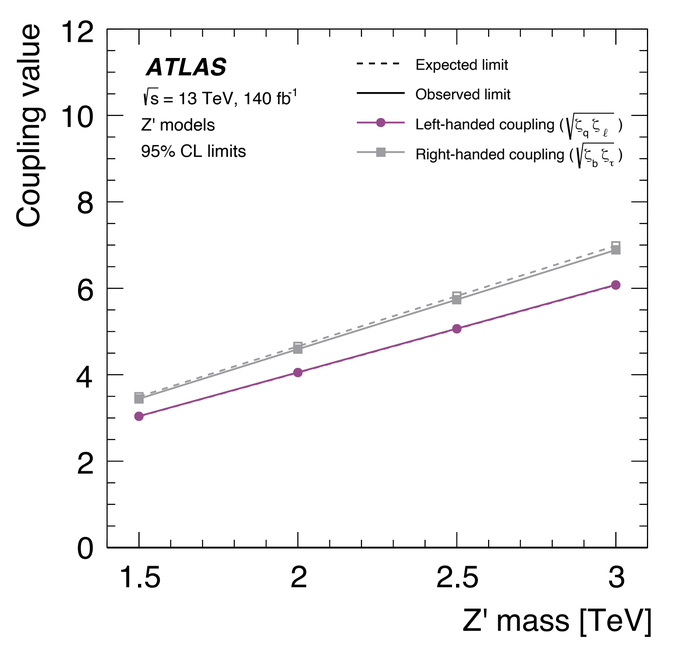
$$\Delta\mathcal{L} = U^\mu(\beta_L^{i3}\bar{q}_L^i\gamma_\mu\ell_L^3 + \beta_R^{i3}\bar{q}_R^i\gamma_\mu\tau_R)/\sqrt{2}$$

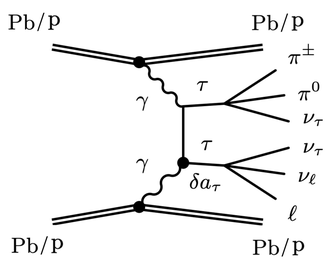
$$\beta_R = \begin{pmatrix}0&0&0\\0&0&0\\0&0&\beta_R^{b\tau}\end{pmatrix} \quad \beta_L = \begin{pmatrix}0&0&\beta_L^{d\tau}\\0&\beta_L^{s\mu}&\beta_L^{s\tau}\\0&\beta_L^{b\mu}&1\end{pmatrix}$$

Z' boson lagrangian

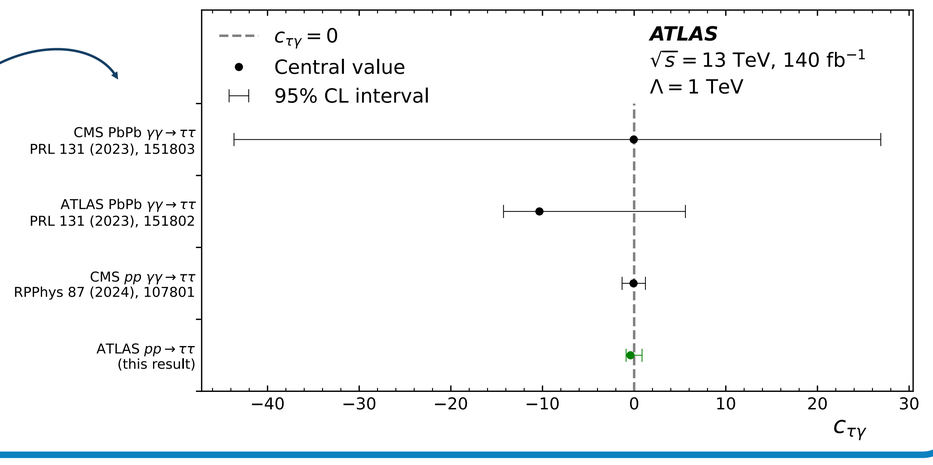
$$\Delta\mathcal{L} = Z'^\mu(\zeta_q\bar{q}_L^3\gamma_\mu q_L^3 + \zeta_u\bar{t}_R\gamma_\mu t_R + \zeta_d\bar{b}_R\gamma_\mu b_R - 3\zeta_\ell\bar{\ell}_L^3\gamma_\mu\ell_L^3 - 3\zeta_\tau\bar{\tau}_R\gamma_\mu\tau_R)/(2\sqrt{6})$$







$$\delta a_\tau = \frac{2\sqrt{2}m_\tau v}{e}\frac{\mathrm{Re}[c_{\tau\gamma}]}{\Lambda^2}$$



- Constraints on **EFT** Higgs / Gauge sector / four fermion **operators**, including those affecting $a_\tau = (g-2)/2$ of the τ-lepton.

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