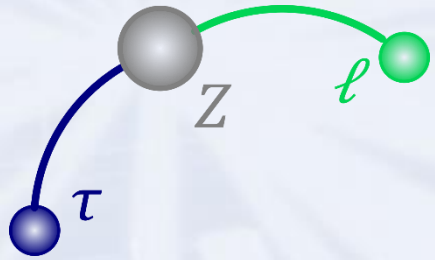
Probing Physics beyond the Standard Model:
A Search for Lepton-Flavour-Violating $Z \to \ell\tau$ Decays with the ATLAS EXPERIMENT

Around 8 billion Z decays

Lepton Flavour Violation (LFV)
- No LFV in the Standard Model (SM)
  … but in nature ⇒ υ oscillations
  … and in many beyond SM (BSM) theories
- LFV in the sector of charged leptons?
  - Example: $Z \to \ell\tau$ with $\ell = e, \mu$
  - $\mathcal{B}(Z \to \ell\tau) \sim O(10^{-54})$ with υ mixing

  → Any observation would be unambiguous sign of BSM physics



ATLAS search for $Z \to \ell\tau$
- Full Run 2 pp data set: $139\ \text{fb}^{-1}$ at $\sqrt{s} = 13\ \text{TeV}$
- First LHC analysis of $Z \to \ell\tau_{\text{lep}}$

World's strongest exclusion limits (at 95% CL)

$$\mathcal{B}(Z \to e\tau) < 5.0 \cdot 10^{-6}$$
$$\mathcal{B}(Z \to \mu\tau) < 6.5 \cdot 10^{-6}$$

Combining τ_{lep} & τ_{had} decays

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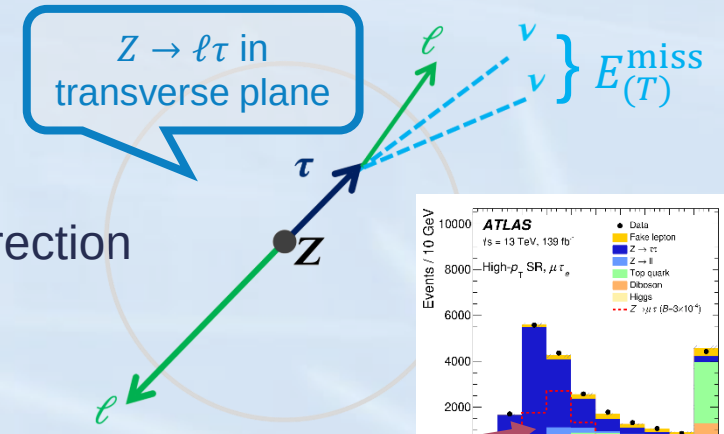
Signal $Z \to \ell\tau \to \ell\ell'\upsilon\bar{\upsilon}$

- $Z \to e\tau_\mu$ and $Z \to \mu\tau_e$
- Opposite-sign $e\mu$ pair
- Back-to-back in plane transverse to beam direction



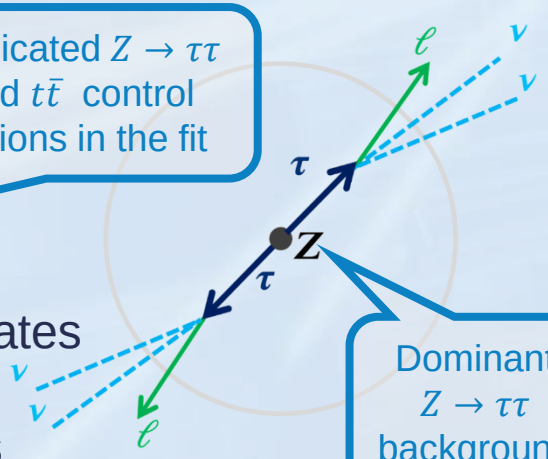
- $E^{\text{miss}}_{(\text{T})}$ from $\upsilon\bar{\upsilon}$ collinear with ℓ' from τ decay
  $\Rightarrow m(\ell\ell'\upsilon\bar{\upsilon}) \approx m_{\text{coll}}\,(\ell\ell' E^{\text{miss}}_{\text{T}})$ around m_Z

Backgrounds

- Prompt $e\mu$-pair
  - $Z \to \tau\tau \to \ell\ell' 4\upsilon$
  - Decays of $t\bar{t}$, two gauge bosons, …
  - Simulation-based estimates
- Misreconstructed ℓ
  - $Z \to \mu\mu$ with $\mu \to e$ fakes
  - $W(\to \ell\upsilon)$ + jets with jet $\to \ell$ fakes
    $\Longrightarrow$ estimated with data-driven fake factor method

Dedicated $Z \to \tau\tau$ and $t\bar{t}$ control regions in the fit

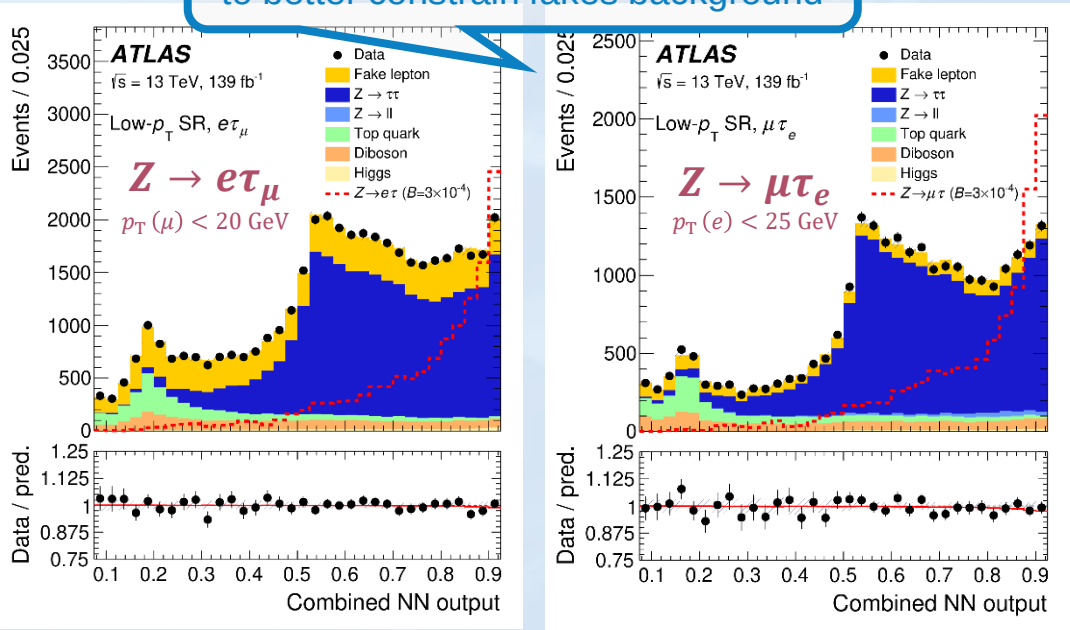
Dominant $Z \to \tau\tau$ background



Event Selection

- Signal region based on multiplicities and kinematic selections
- Optimum signal-background discrimination with Neural Network (NN) classifier
  - Exploit all correlations of the e-μ-$E^{\text{miss}}_{\text{T}}$ system
  - Trained to discriminate against $Z \to \tau\tau$, two gauge boson, $t\bar{t}$ background
  - Final discriminant in the fit

Signal regions divided into 2 p_{T} bins to better constrain fakes background

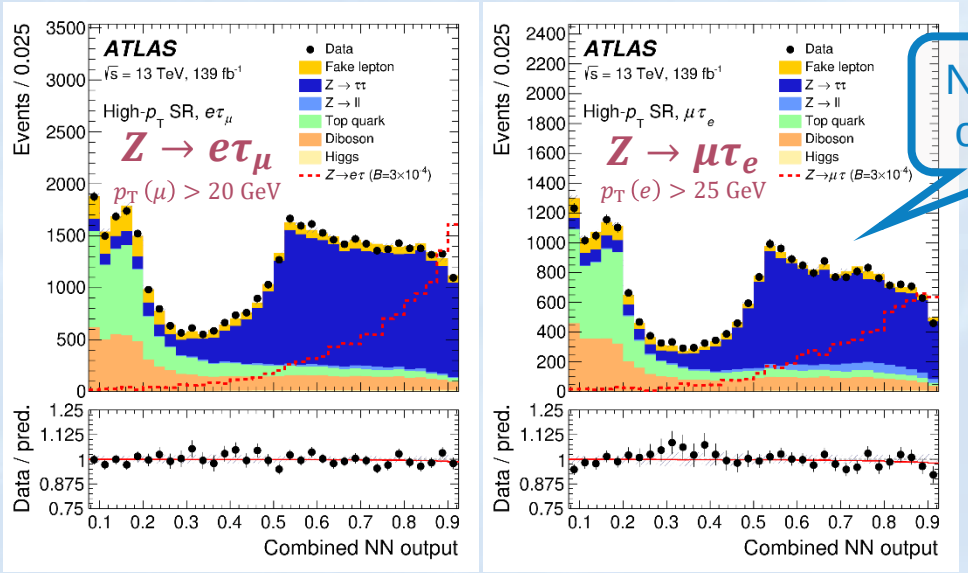


Results

- No statistically significant deviation from the SM observed 😐
- Combination of $Z \to \ell\tau_{\text{lep}}$ and $Z \to \ell\tau_{\text{had}}$ results
- Still statistically limited

World's strongest limits!
2× more stringent
than LEP results

Final state, polarization assumption	Observed (expected) upper limit on $\mathcal{B}(Z \to \ell\tau)$ [$\times 10^{-6}$] at 95% CL $e\tau$	$\mu\tau$
$\ell\tau_{\text{had}}$ Run 1 + Run 2, unpolarized τ	8.1 (8.1)	9.5 (6.1)
$\ell\tau_{\text{had}}$ Run 2, left-handed τ	8.2 (8.6)	9.5 (6.7)
$\ell\tau_{\text{had}}$ Run 2, right-handed τ	7.8 (7.6)	10 (5.8)
$\ell\tau_{\ell'}$ Run 2, unpolarized τ	7.0 (8.9)	7.2 (10)
$\ell\tau_{\ell'}$ Run 2, left-handed τ	5.9 (7.5)	5.7 (8.5)
$\ell\tau_{\ell'}$ Run 2, right-handed τ	8.4 (11)	9.8 (13)
Combined $\ell\tau$ Run 1 + Run 2, unpolarized τ	5.0 (6.0)	6.5 (5.3)
Combined $\ell\tau$ Run 2, left-handed τ	4.5 (5.7)	5.6 (5.3)
Combined $\ell\tau$ Run 2, right-handed τ	5.4 (6.2)	7.7 (5.3)



No $Z \to \ell\tau$ observed

- Parity conserving $Z\ell\tau$ vertex (unpolarised τ)
- Maximally parity violating $Z\ell\tau$ vertex (left-/right-handed τ)

This poster

Our Papers

- ▶ arXiv:2010.02566 (acc. at Nature Physics)
- ▶ arXiv:2105.12491 (sub. to PRL)

This poster

arXiv:2010.02566

arXiv:2105.12491