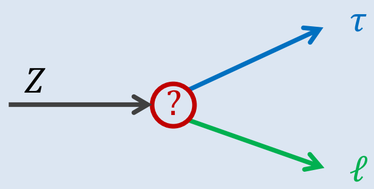
SEARCH FOR THE LEPTON FLAVOR VIOLATING DECAYS $Z \to e\tau$ AND $Z \to \mu\tau$ WITH THE ATLAS DETECTOR

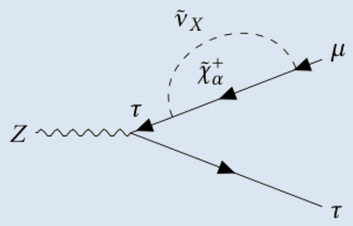
The 3rd International Conference on Charged Lepton Flavor Violation
17-19 June 2019, Fukuoka, Japan

Lepton Flavor Violation (LFV) in *Z* Decays

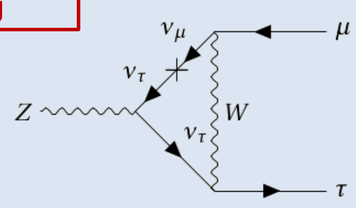
- Lepton flavor is an accidental symmetry of the Standard Model (SM)
- But LFV observed in neutrino mixing



Z LFV in SUSY

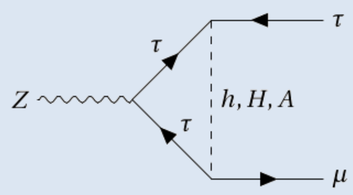


Z LFV via neutrino mixing



- ➢ Can we find LFV in the charged lepton sector?
- LFV $Z \to \ell\tau$ ($\ell = e, \mu$) decays at the LHC
  - *Z* is well-measured and abundantly produced at the LHC
  - In the SM via neutrino mixing:
    $\mathcal{B}(Z \to \ell\tau) \sim O(10^{-54})$ for $\ell = e, \mu$
- ➢ Any observation would be a clear signal for physics beyond the SM
  Ex.: heavy neutrinos, extended gauge sector, supersymmetry

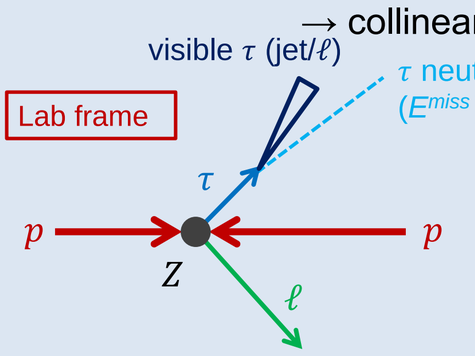
Z LFV in 2HDM models



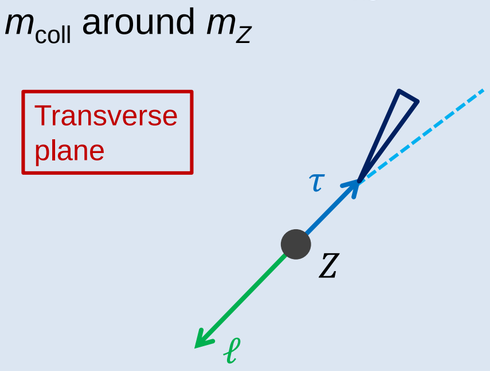
The $Z \to \ell\tau$ Signal

- $\ell\tau$ pair with opposite charge
- Back-to-back in transverse plane
- τ decays: visible decay products (τ_{vis}, i.e. jets or ℓ)
  neutrinos (E^{miss})
- Resonance at the *Z* rest mass m_Z:
  Boosted τ: ν is approximated to be collinear with τ_{vis}
  → collinear mass m_{coll} around m_Z

Lab frame



Transverse plane



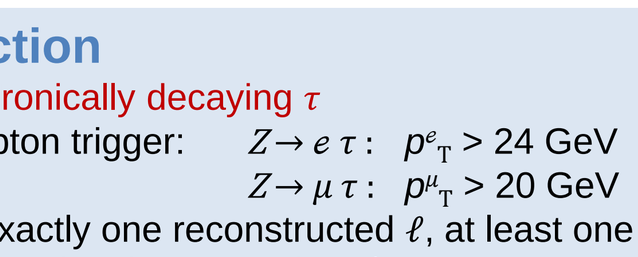
Backgrounds

- Major background (BG) processes
  - $Z \to \tau\tau \to \ell\tau_{had}$
  - $W(\to \ell\nu)$ + jets (jet mis-identified as τ)
  - $Z \to \ell\ell$ (ℓ mis-identified as τ)
- $Z \to \tau\tau$ and $Z \to \ell\ell$ are estimated from Monte Carlo simulation
- Jets mis-identified as τ (W+jets) are estimated in a data-driven method (fake factor method)
- Backgrounds are normalized to data
  - $Z \to \ell\ell$ in a very pure control region
  - $Z \to \tau\tau$ and fakes from W+jets are simultaneously fitted with the signal

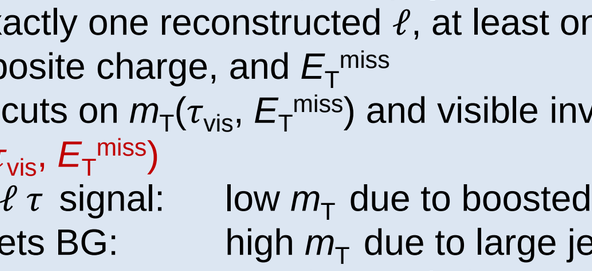
Event Selection

- Focus on hadronically decaying τ
- Use single lepton trigger: $Z \to e\tau$: $p^e_T > 24$ GeV
  $Z \to \mu\tau$: $p^\mu_T > 20$ GeV
- Events with exactly one reconstructed ℓ, at least one reconstructed $\tau_{had\text{-}vis}$ with opposite charge, and E_T^{miss}
- Signal region: cuts on $m_T(\tau_{vis}, E_T^{miss})$ and visible invariant mass m_{vis}
  - $m_T(\tau_{vis}, E_T^{miss})$
    $Z \to \ell\tau$ signal: low m_T due to boosted τ decay
    W+jets BG: high m_T due to large jet p_T and large opening angle between ν and jet
    $Z \to \tau\tau$ BG: on average high m_T due to two τ decaying in opposite directions

m_T of simulated $Z \to \ell\tau$ and BG events



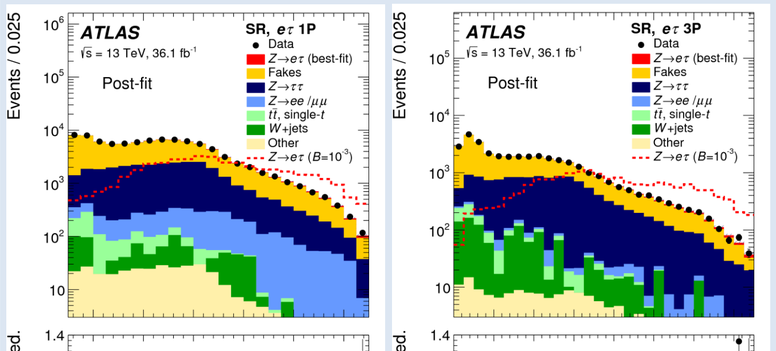
m_{vis} and m(track, ℓ) of simulated $Z \to \ell\tau$ and BG events



- m_{vis}
  $Z \to \ell\ell$ BG: resonance at m_Z
  $Z \to \ell\tau$ signal: no resonance due to E^{miss} of neutrinos
- Neural Network (NN) classifier
  - Binary classifiers in signal region for
    $Z \to \tau\tau$, W+jets and $Z \to \ell\ell$
    finally combined to one single classifier
  - Inputs: kinematic variables of reconstr. ℓ, $\tau_{had\text{-}vis}$ and E_T^{miss}, + m_{coll}, m_{vis} and $\Delta\alpha$ (variable sensitive to number of ν)
  - Training with Monte Carlo simulation samples

Results

- Data sample:
  36.1 fb^{-1} of integrated luminosity of pp-collisions
  at a center-of-mass energy of $\sqrt{s}$=13 TeV
  recorded with the ATLAS detector in 2015 and 2016
- Binned likelihood fit to the combined NN output
  with $\mathcal{B}(Z \to \ell\tau)$ as free parameter
- No statistically significant excess of events above the expected BG



- ➢ Set upper CL_s limits at the 95 % confidence level

$\mathcal{B}(Z \to e\tau) < 5.8 \times 10^{-5}$
(expected: 2.8×10^{-5})
→ 2.3σ excess

First ATLAS result on this channel

$\mathcal{B}(Z \to \mu\tau) < 2.4 \times 10^{-5}$
(expected: 2.4×10^{-5})

Combined with previous result at 8 TeV:
$\mathcal{B}(Z \to \mu\tau) < 1.3 \times 10^{-5}$

Outlook

- Use full ATLAS run 2 (2015-2018) data set of 140 fb^{-1}
- Plan to include channels with $\tau \to \ell\nu$
- ➢ Much improved upper limits can be expected

Ann-Kathrin Perrevoort (Nikhef) on behalf of the ATLAS collaboration

Reference: Phys. Rev. D 98 (2018) 092010