Measurement of the $Z\to\tau\tau$ and $W\to\tau\nu$ Cross Sections with the ATLAS detector

The measurement of the $W$ and $Z$ boson production cross-sections with tau leptons in the final state is important in demonstrating the capabilities of the ATLAS detector in probing for new physics. The study of $W$ and $Z$ bosons with taus in the final state allows the measurement of the tau trigger, reconstruction, and identification efficiencies in data. Reconstruction and identification of tau leptons is important for Standard Model Higgs ($H\to\tau\tau$) searches as well as in Supersymmetry models involving charged Higgs.

Tau leptons decay hadronically 65% of the time and leptonically ($e/\mu$) 35% of the time. The $W$ boson production cross-section is measured when the tau decays hadronically ($W\to\tau\nu$, while the $Z$ boson production cross-section is measured in 4 final states where the final visible decay products are: an electron and a hadronic tau ($\tau_e\tau_h$), a muon and a hadronic tau ($\tau_\mu\tau_h$), an electron and a muon ($\tau_e\tau_\mu$), and two muons ($\tau_\mu\tau_\mu$). The total cross-section is measured in all 5 final states by:

$$\sigma = \frac{N}{B_{\text{exp}}}$$

Where $B$ is the branching ratio, $A$ accounts for the theoretical acceptance, $C$ is the detector efficiency, and $L$ is the integrated luminosity (36 pb$^{-1}$).

$W\to\tau\nu\tau_\nu$:  
- Trigger on hadronic tau and missing energy ($E_T^{\text{miss}}$)  
- Use Tight $\tau$ identification (Boosted Decision Tree (BDT))

**QCD Suppression:** ABCD method:
- $S_{N_{\text{overlap}}} > 6.0$
- $E_T^{\text{miss}} > 30$ GeV
- $Z/\gamma$+$W$/$W$ suppression:
- Veto event with identified $e/\mu$
- Background Estimation (ABCD):
  - Electroweak (EW) backgrounds estimated from MC:
    - $W+\tau$ shape verified with embedding
    - Replace $\mu$ in data with simulated $\tau$ run for full reconstruction
  - Multijet: Tight vs. Loose-not-Tight $\tau$ and $S_{N_{\text{overlap}}} > 6.0$ vs. $S_{N_{\text{overlap}}} < 4.5$
  - Must show that the $S_{N_{\text{overlap}}}$ is independent of the $\tau$ identification and that regions CBD have negligible signal and EW contamination.

**Final Results**

$W\to\tau\nu\nu$:
- $0.97 \pm 0.07_{\text{stat}} \pm 0.03_{\text{syst}} \pm 0.03_{\text{lumi}}$ nb

$W\to\tau\nu\tau_\nu$:
- $11.1 \pm 0.3_{\text{stat}} \pm 1.7_{\text{syst}} \pm 0.4_{\text{lumi}}$ nb

**$Z\to\tau\tau$**

$Z\to\tau\tau$
- Trigger on lepton (e/$\mu$)  
- Require Tight $\tau$ (cut based)

$Z\to\ell\ell$ Suppression:
- Require exactly one lepton

**$\tau$ ID Suppression**
- Trigger on electron

**$\ell+\text{jets}$ Suppression**
- $m_{\ell+\text{jets}} > 150$ GeV

**$\tau_\mu\tau_\mu$**
- Trigger on muon
- Require two oppositely charged muons.

**$Z\to\ell\ell$**
- Use BDT to separate from signal

**Background Estimation (ABCD):**

- Electroweak (EW) Backgrounds Estimated from Monte Carlo (MC):
  - $W+\tau$ jets MC normalized to data
- Multijet: OS vs. SS and isolated vs. non-isolated ($Z\to\ell\ell$)
  - Must show ratio of Opposite to Same Sign Events is independent of isolation and that regions CBD have negligible signal and EW contamination.

**Visible Mass:**

$Z\to\tau\tau$
- $m_{\tau_\mu\tau_\mu}$

References:
- ATLAS-CONF-2011-010
- ATLAS-CONF-2010-097
- JHEP 12, 060 (2010)
- ATLAS-CONF-2011-077