Measurement of the $Z \to \tau\tau$ Cross Section with the ATLAS Detector

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Reference: ATLAS-CONF-2012-006

Motivation

- $Z \to \tau\tau$ process forms background in the Higgs boson searches (channel $H \to \tau\tau$)
- Complementary analysis to $Z \to ee$ and $Z \to \mu\mu$ precision measurements
- $Z \to \tau\tau$ tag and probe method used for measurements of the hadronic tau identification efficiency

Background estimation

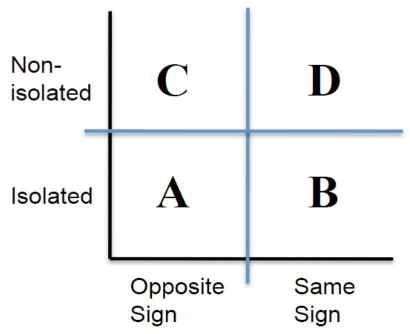
Non-dominant background (dibosons, $t\bar{t}$ in all final states, *W/Z*+jets in $\tau_e\tau_\mu$ channel) are taken from the **Monte Carlo simulations**, **other backgrounds are estimated using partially or fully data-driven methods**

W/Z+jets background ($\tau_\mu\tau_h$, $\tau_e\tau_h$)

- The probability for a jet to be identified as a hadronic tau is overestimated in Monte Carlo simulations
- Normalization factor derived in *W/Z* enriched control regions and used to correctly normalize the Monte Carlo predictions

Multijet background (all channels)

$$N_A^{QCD} = N_B^{QCD} \cdot \frac{N_C^{QCD}}{N_D^{QCD}} = N_B^{QCD} \cdot R_{OSSS}$$



- R_{OSSS} ratio is calculated in the QCD rich region (with inverse isolation requirements on lepton) and is used to extrapolate the number of multijet events from the region with isolated lepton and same sign requirement to the signal region

Final State	$\tau_\mu\tau_h$ (1.55 fb^{-1})	$\tau_e\tau_h$ (1.34 fb^{-1})	$\tau_e\tau_\mu$ (1.55 fb^{-1})
$\gamma^*/Z \to ll$	81 ± 7	64 ± 4	23 ± 4
$W \to l\nu$	186 ± 13	45 ± 5	< 0.5
$W \to \tau\nu$	49 ± 5	18 ± 2	< 0.5
$t\bar{t}$	31 ± 1	17 ± 1	2 ± 1
Diboson	15 ± 2	6 ± 1	18 ± 2
Multijet	432 ± 30	300 ± 21	13 ± 7
$\gamma^*/Z \to \tau\tau$	4544 ± 49	2029 ± 25	981 ± 26
N_{obs}	5184	2600	1035

Cross section measurement

$$\sigma(Z \to \tau\tau) \times B = \frac{N_{obs} - N_{bkg}}{A_Z \cdot C_Z \cdot L}$$

- B – branching fraction of the considered final state
- N_{obs} – number of observed events
- N_{bkg} – number of estimated background
- A_Z – geometrical and kinematic acceptance factor
- C_Z – correction factor (accounts for efficiency of triggering, reconstructing and identifying the $Z \to \tau\tau$ events)
- L – integrated luminosity

Final results

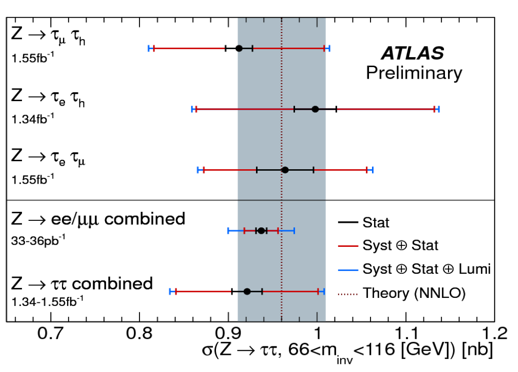
Cross section is measured for events with $66 < m_{inv}(\tau\tau) < 116$ GeV independently in all three channels

Final State	Total cross section $\sigma(Z \to \tau\tau, m_{inv}$ [66 – 116 GeV])
$\tau_\mu\tau_h$	0.91 ± 0.01 (stat) ± 0.09 (syst) ± 0.03 (lumi) nb
$\tau_e\tau_h$	1.00 ± 0.02 (stat) ± 0.13 (syst) ± 0.04 (lumi) nb
$\tau_e\tau_\mu$	0.96 ± 0.03 (stat) ± 0.09 (syst) ± 0.04 (lumi) nb

The results are combined together by means of the BLUE (Best Linear Unbiased Estimate) method

$$\sigma(Z \to \tau\tau) = 0.92 \pm 0.02\,(\mathrm{stat}) \pm 0.08\,(\mathrm{syst}) \pm 0.03\,(\mathrm{lumi})\ \mathrm{nb}$$

The combined total cross section agrees well with NNLO theoretical expectations of 0.96 ± 0.05 nb



Measurement with 2011 data

- Tau lepton decays leptonically ($\tau \to e/\mu + 2\nu$, 35%) or hadronically ($\tau \to$ hadrons + ν, 65%)
- Three final states used for the cross section measurement with 2011 data
  - Muon + hadronic tau ($\tau_\mu\tau_h$): $Z \to \tau\tau \to \mu$ + hadrons + 3ν (22.5%)
  - Electron + hadronic tau ($\tau_e\tau_h$): $Z \to \tau\tau \to e$ + hadrons + 3ν (23.1%)
  - Electron + muon ($\tau_e\tau_\mu$): $Z \to \tau\tau \to e + \mu + 4\nu$ (6.2%)
- Data collected during 2011 corresponding to integrated luminosity of 1.55 fb^{-1} are used in $\tau_\mu\tau_h$ and $\tau_e\tau_\mu$ channels, 1.34 fb^{-1} in $\tau_e\tau_h$ channel

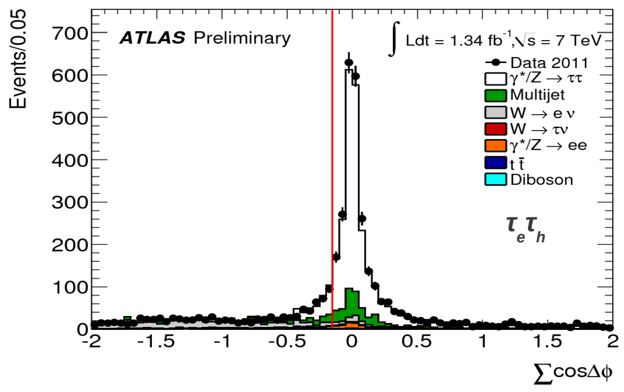
Event selection

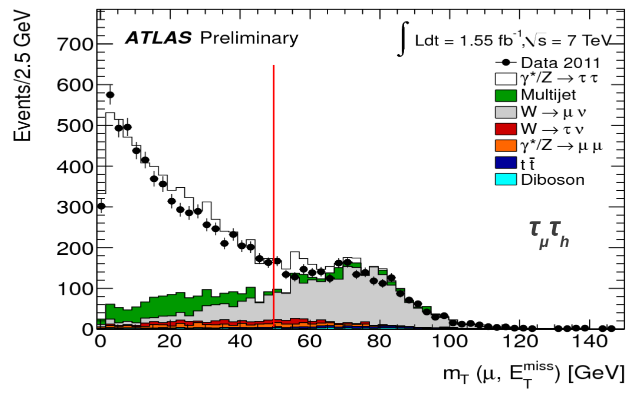
Trigger

- $\tau_\mu\tau_h$, $\tau_e\tau_\mu$: muon trigger with isolation requirement (threshold 15 GeV)
- $\tau_e\tau_h$: combined electron (threshold 15 GeV) + hadronic tau (threshold 20 GeV) trigger

W+jets suppression

- All channels: $\sum \cos(\Delta\varphi) = \cos(\varphi(l) - \varphi(E_T^{miss})) + \cos(\varphi(\tau_h) - \varphi(E_T^{miss})) > -0.15$
- $\tau_\mu\tau_h$, $\tau_e\tau_h$: $m_T = \sqrt{2 p_T(l) \cdot E_T^{miss} \cdot (1 - \cos\Delta\varphi(l, E_T^{miss}))} < 50$ GeV



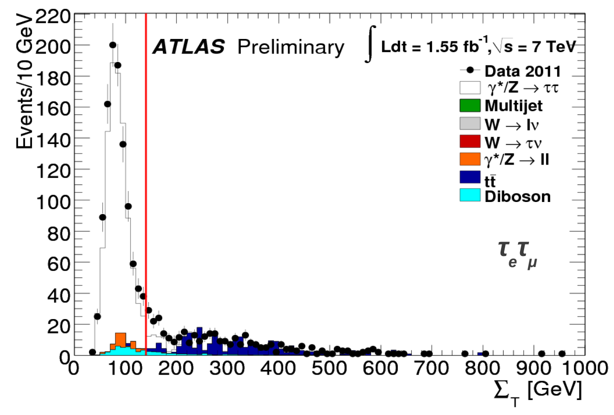


Z+jets suppression ($\tau_\mu\tau_h$, $\tau_e\tau_h$)

- Reject events with more than one lepton (muon or electron)

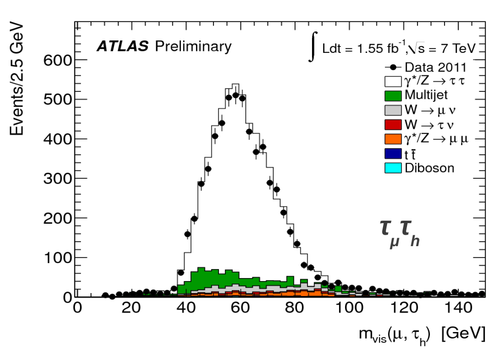
$t\bar{t}$ suppression ($\tau_e\tau_\mu$)

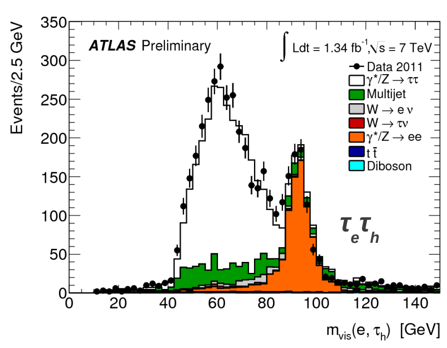
- $\Sigma_T = E_T(e) + E_T(\mu) + E_T(jets) + E_T^{miss} < 140$ GeV

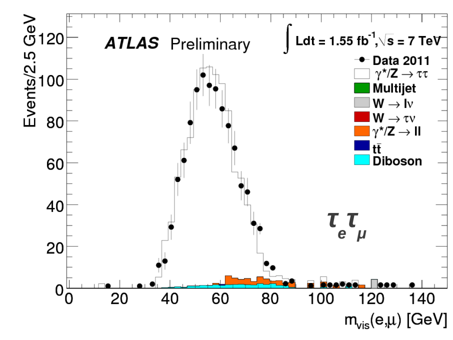


Visible mass cut (all channels)

- Invariant mass of the visible decay products between 35 and 75 GeV







Systematic uncertainties

Dominant sources of systematics

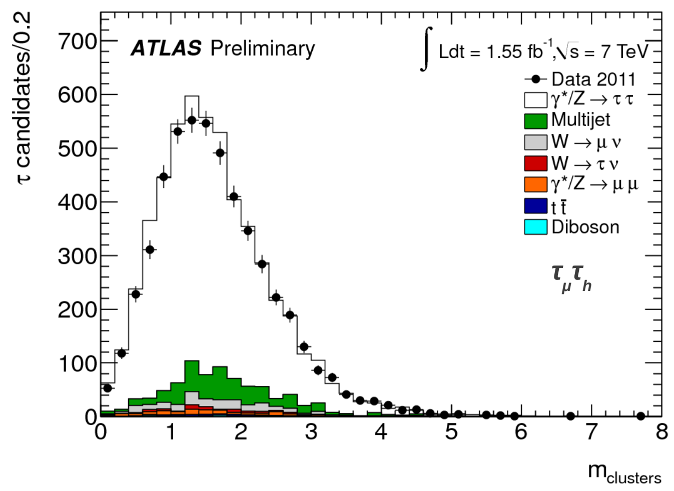
- Energy scale (up to 9% – all channels)
- Tau identification (5% – $\tau_\mu\tau_h$, $\tau_e\tau_h$) and tau trigger efficiency (5% – $\tau_e\tau_h$)
- Electron efficiency (up to 6% – $\tau_e\tau_\mu$, $\tau_e\tau_h$)
- Luminosity (4% – all channels)
- A_Z uncertainty (3% – all channels)

Variables used in the τ_h identification

Sample collected after the full selection has a relatively high purity in hadronic $\tau \to$ variables used by the τ_h identification are plotted in the $\tau_\mu\tau_h$ channel for signal-like τ candidates

Cluster mass

$$m_{clusters} = \sqrt{\left(\sum_{clusters} E\right)^2 - \left(\sum_{clusters} \vec{p}\right)^2}$$



BDT score

(tau identification omitted in the event selection for this special plot)