Cross section measurement of $pp \rightarrow \gamma^*/Z^0 \rightarrow \tau^+\tau^- \rightarrow e\mu+4\nu$ with the ATLAS detector

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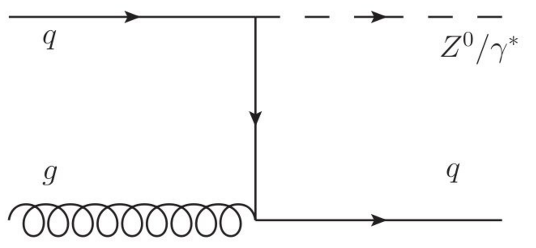
Motivation

- The cross section times branching fraction measurement of $pp \rightarrow \gamma^*/Z^0+X \rightarrow \tau^+\tau^-+X \rightarrow e\mu+4\nu+X$ is a good test of Standard Model predictions by comparison with theoretical calculations.
- Most important, the decay is an irreducible and dominant background in Higgs boson searches in the $\tau^+\tau^-$ decay channel.
→Its differential mass spectrum and normalisation have to be known precisely.
- The decay is well suited to test the various techniques of $m_{\tau\tau}$ mass reconstructions, to check their stability against systematics and their reproduction in MC simulation.

Data analysed:
recorded in 2010
corresponds to $L=36pb^{-1}$



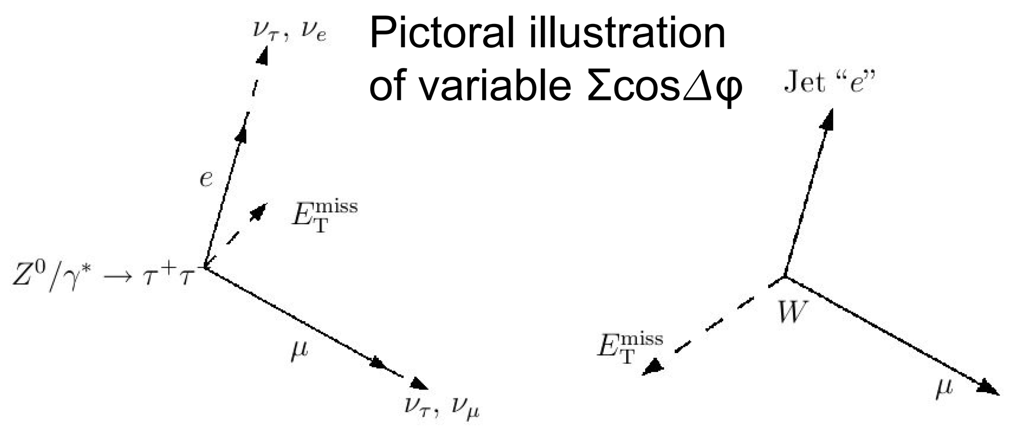
Background processes

- **QCD multijets:**
  - processes producing quarks or gluons
  - real leptons from heavy flavour quark decay
  - fake leptons from charged hadrons being misinterpreted as lepton candidates
- **$\gamma^*/Z^0 \rightarrow ee, \mu\mu$ + jets:**
  - additional jets are being misinterpreted as lepton candidate or contain real ones
  - in particular the low mass range mimics the signal
- **$W^\pm \rightarrow e^\pm\nu, \mu^\pm\nu, \tau^\pm\nu$ + jets:**
  - Additional jets may be misidentified as leptons
  - τ channel may decay leptonically or hadronically (misidentified as leptons)
  - fake rate of jets for electrons is higher than for muons, which makes $W^\pm \rightarrow \mu^\pm\nu$ more important background
- **$t\bar{t}$:**
  - Fully leptonic decay is a main background source.
  - In other decays jets are misinterpreted as leptons or contain real leptons.

Event Selection

Object Selection
- Electron: p_T>16 GeV, detector centrality
- Muon: p_T>10 GeV, detector centrality
- Jets: anti-kt algorithm with distance parameter dR<0.4, p_T>20 GeV,

Event Selection
- Exactly one eμ pair with opposite charge
- $\Sigma\cos\Delta\varphi = \cos[\varphi(l) - \varphi(E_T^{miss})] + \cos[\varphi(\tau) - \varphi(E_T^{miss})] > -0.15$
- $\Sigma(jets,e,\mu)+E_T^{miss}$ <150 GeV
- Invariant lepton-lepton mass 25 GeV<$m_{e\mu}$<80 GeV



Pictoral illustration of variable $\Sigma\cos\Delta\varphi$

Background Estimation of Electroweak Processes

Procedure for EW processes:

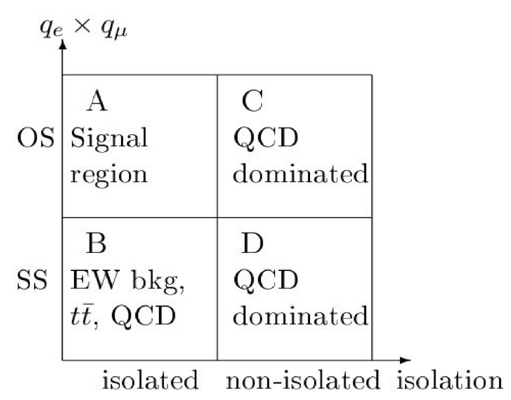
Control region is selected, in which electroweak processes are enriched:
- exactly one eμ pair with object selection
- one lepton is isolated
- $\Sigma(jets,e,\mu)+E_T^{miss}$ <150 GeV
- $m_T=(2p_T(l)\cdot E_T^{miss})^{1/2}\cdot(1-\cos\varphi(l,E_T^{miss}))$
  60 GeV<m_T<100 GeV

Shape and normalisation is checked with recorded data.
QCD multijet background estimated via the ABCD method

Result:
- Cross sections and branching ratios used agree well with data.
- Proves correctness of Monte Carlo simulations.

Procedure for QCD multijets

ABCD method: two variables are selected, spanning a 2-D plane, segmented into four regions, A, B, C, D. Only one region contains signal events. The variables need to be uncorrelated.



$$\frac{N^A_{QCD}}{N^B_{QCD}} = \frac{N^C_{QCD}}{N^D_{QCD}} \quad \Bigg| \quad N^i_{QCD} = N^i_{Data} - N^i_{EW\_bkg} - N^i_{t\bar{t}}$$

Results:

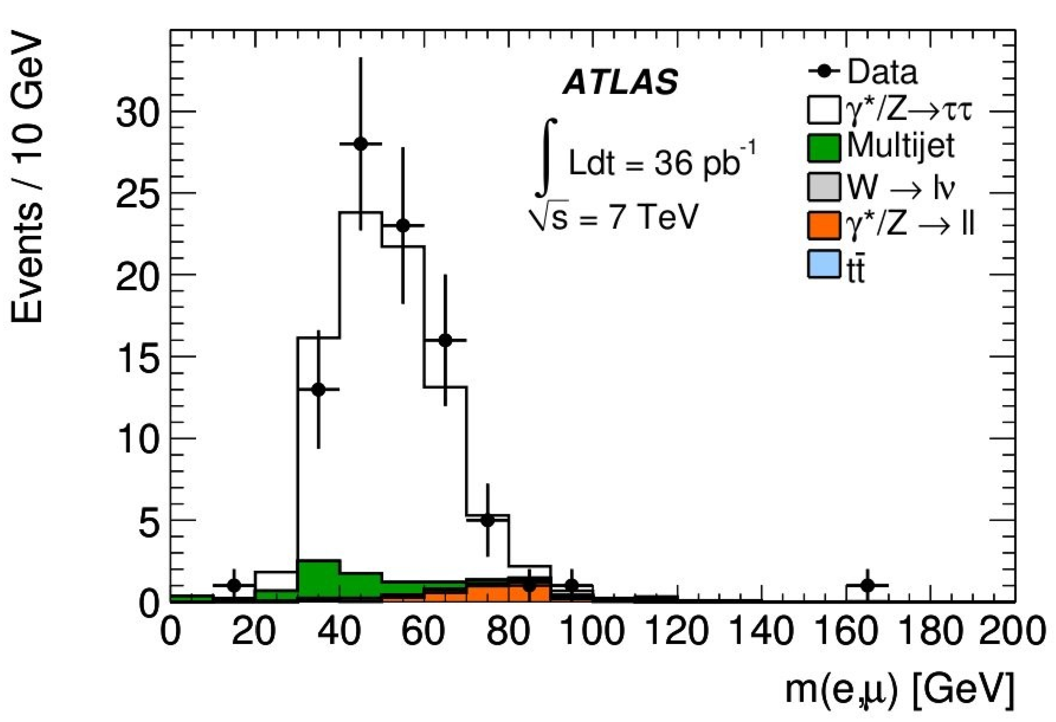
Expected and observed number of events for an integrated luminosity of 36 pb^{-1}.

	$\tau_e\tau_\mu$
$\gamma^*/Z \rightarrow \ell\ell$	1.9 ± 0.1
$W \rightarrow \ell\nu$	0.7 ± 0.2
$W \rightarrow \tau\nu$	< 0.2
$t\bar{t}$	0.15 ± 0.03
Diboson	0.48 ± 0.03
Multijet	6 ± 4
$\gamma^*/Z \rightarrow \tau\tau$	73 ± 1
Total expected events	82 ± 4
N_{obs}	85

Results

Mass distribution of lepton pair:

[2]



- Mass distribution after the full selection except for the cut on the invariant lepton-lepton mass.
- Shows a good agreement between data and Monte Carlo simulation → **differential mass spectrum and normalisation are verified for further Higgs studies.**

$$\sigma(pp\rightarrow\gamma^*/Z^0+X)\times BR(Z^0\rightarrow\tau^+\tau^-) = \frac{N_{obs} - N_{bkg}}{L \cdot A_Z \cdot C_Z \cdot B(\tau^+\tau^-\rightarrow e\mu+4\nu)}$$

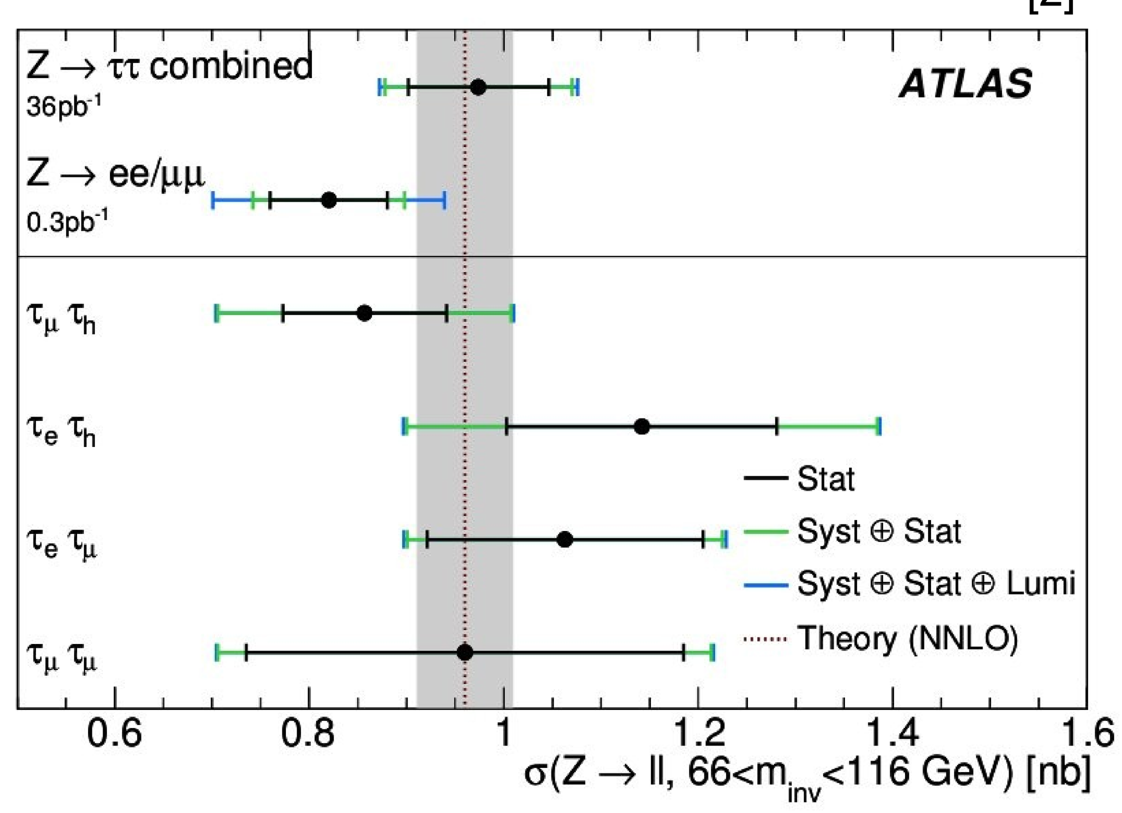
N_{obs}... Number of observed events
N_{bkg}... Number of events from background processes
A_Z... geometrical and kinemtic acceptance
C_Z... selection efficiency
B ... Branching ratio of $(\tau^+\tau^-\rightarrow e\mu+4\nu)$

	$\tau_e\tau_\mu$
N_{obs}	85
$N_{obs} - N_{bkg}$	$76 \pm 10 \pm 1$
A_Z	0.114 ± 0.003
C_Z	0.29 ± 0.02
B	0.0620 ± 0.0002
$\mathcal{L}$	$35.5 \pm 1.2\ pb^{-1}$

$$\sigma(pp\rightarrow\gamma^*/Z^0+X)\times BR(Z^0\rightarrow\tau^+\tau^-) = (1.06\pm0.14\pm0.08\pm0.04)\ nb$$

Comparison with other measurements

[2]



→All results show agreement within their uncertainties.
→Knowledge of the normalisation of the $\gamma^*/Z^0 \rightarrow \tau^+\tau^-$ background for Higgs searches is verified.

Publications

[1] ATLAS Collaboration, G.Aad et al., *First Observation of the process $Z \rightarrow \tau\tau \rightarrow$ emu + 4nu with the ATLAS Detector*, ATLAS-CONF-2011-045

[2] ATLAS Collaboration, G.Aad et al., *Measurement of the $Z\rightarrow \tau\tau$ Cross Section with the ATLAS Detector*, Physical Review D **84** (2011) 112006, arxiv:1108:2016 [hep-ex].

Gain from the Graduiertenkolleg

- Possibility to attend special seminars in block courses
- Possibility to attend GK courses
- Financial support for conferences and international schools
- Contact to theoretical colleagues within the GK

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DRESDEN concept

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