$pp \to \gamma^*/Z \to \tau\tau$ cross-section measurement and MSSM Higgs search

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Motivation

- τ leptons play an important role in new physics models, e.g. in Higgs searches
- all gauge bosons and their (leptonic) decay channels had been seen by ATLAS until the end of 2010 except for $\gamma^*/Z \to \tau\tau$

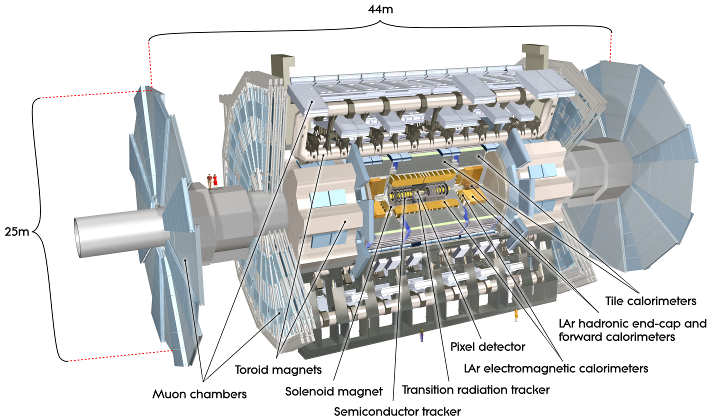
$\Rightarrow$ complete this list by observing $\gamma^*/Z \to \tau\tau$ events and measuring its cross-section

- $Z \to \tau\tau$ is an irreducible background for $\Phi \to \tau\tau$ searches

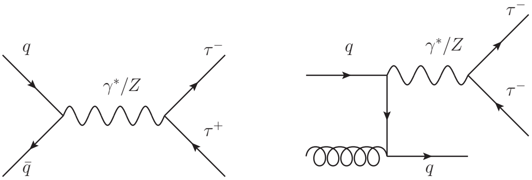
$\Rightarrow$ precise knowledge and understanding of its properties (decay kinematics, mass distribution) is essential

- test/tune different analysis and mass reconstruction techniques using the well-known SM process

The ATLAS detector



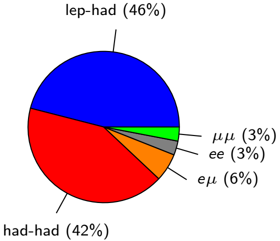
Event topology



$Z \to \tau\tau \to \ell\ell + 4\nu$

- small branching ratio but clear signature
- get rid of tricky $\gamma^*/Z \to ee/\mu\mu$ backgrounds by restricting the analysis to the $e\mu + 4\nu$ final state

$\Rightarrow$ isolated electron and isolated muon with low MET



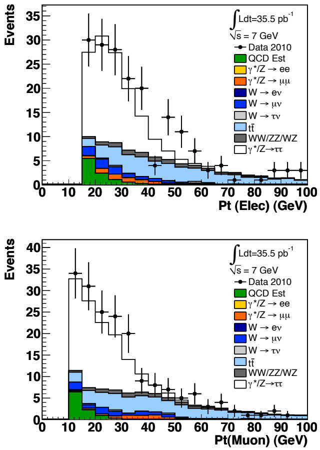
Object selection

Electrons

- passes the medium identification criteria
- fulfills isolation criteria
- $p_T > 16 GeV$

Muons

- reconstructed using information from the Inner detector and the muon spectrometer
- passes the isolation criteria
- $p_T > 10 GeV$



Event selection

Baseline selection

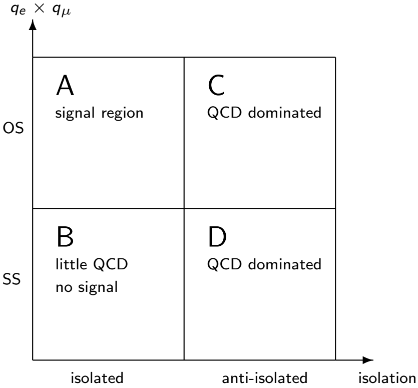
- electron trigger (EF_e15_medium)
- detector was fully operational
- at least one reconstructed vertex
- exactly one isolated electron and muon of opposite charge

Remaining background processes

1. QCD multi-jet events $\to$ estimated from data
2. $W \to \mu\nu$, $t\bar{t}$ suppressed by further cuts
3. electroweak backgrounds are taken from MC predicitions but the normalisation was checked in dedicated control regions

QCD multi-jet estimation

ABCD method

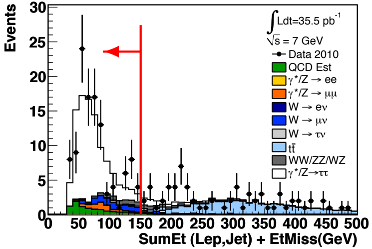


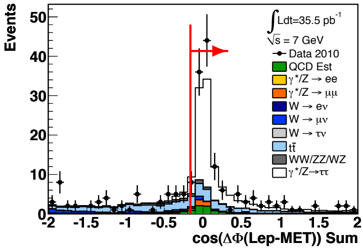
- assume that for QCD: $\frac{A}{B} = \frac{C}{D}$
- correct for electroweak contamination in control regions
- QCD shape is taken from region C

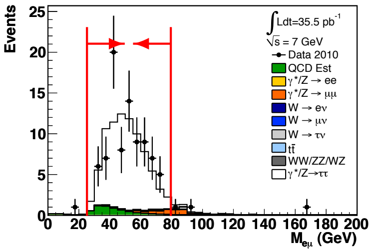
$\Rightarrow$ estimate for number of QCD events in signal region

- due to limiting statistics a cut factorisation was used to propagate the QCD estimate to the end of the cut flow

Background suppression







Methodology for cross-section calculation

$$\sigma_{fid}\left(pp \to \gamma^*/Z \to \tau\tau \to e\mu + 4\nu\right) = \frac{N_{Data} - N_{Bkg}}{L}$$
$$\sigma_{tot}\left(pp \to \gamma^*/Z \to \tau\tau \to e\mu + 4\nu\right) = \frac{N_{Data} - N_{Bkg}}{L \cdot A_Z \cdot C_Z}$$

with

- N_{Data} – number of observed data events
- N_{Bkg} – number of estimated background events
- L – integrated luminosity
- A_Z – geometrical and kinematic acceptance for the signal process
- C_Z – correction factor for selection efficiencies

Systematic uncertainties

Background estimation

Source	Uncertainty (%)			
	$Z/\gamma^* \to ee,\mu\mu$	W + jets	$t\bar{t}$	Multijet
Muon p_T	0.12	0.00	0.42	0.05
Muon scale factor	1.23	1.82	1.72	4.89
Elec scale factor	5.38	6.37	5.92	4.66
Elec/Cluster/Jet E	7.48	11.86	9.27	2.59
Vertex Weight	0.55	0.55	0.58	0.64
Lumi	3.40	3.40	3.40	3.79
Cross Section	5.00	5.00	7.00	5.64
OTX Sys	0.37	0.37	0.40	0.30
Elec Charge	0.28	0.28	0.28	0.31
Jet cleaning	2.10	0.79	16.24	0.40
QCD estimation	–	–	–	13.00
Total Systematic	11.31	14.91	21.18	16.38

Acceptance A_Z

CTEQ eigenvector set	1.3%
PDF set	1.8%
model dependence	1.8%
total	2.9%

Correction C_Z

electron SF	6.1%
muon SF	2.6%
energy scale	1.7%
others	$\approx$ 1%
total	7.0%

Result

ATLAS-CONF-2011-045

		value	stat.	syst.
N_{Data}	$=$	85		
N_{Bkg}	$=$	8.94	$\pm$ 4.12	$\pm$ 0.84
A_Z	$=$	0.1139	$\pm$ 0.0004	$\pm$ 0.0033
C_Z	$=$	0.2887	$\pm$ 0.005	$\pm$ 0.020
$L[pb^{-1}]$	$=$	35.51	$\pm$ 0	$\pm$ 1.21

$$\sigma^{tot}_{\gamma^*/Z} \cdot \mathcal{BR}(\gamma^*/Z \rightarrow \tau\tau \rightarrow e\mu + 4\nu) = (65.85 \pm 8.82(stat) \pm 4.82(sys) \pm 2.24(lumi))\ pb$$

$$\sigma^{tot}_{\gamma^*/Z} \cdot \mathcal{BR}(\gamma^*/Z \rightarrow \tau\tau) = (1062.6 \pm 142.3(stat.) \pm 77.7(sys) \pm 36.17(lumi) \pm 4.3(theo))\ pb$$

$$\sigma^{theory}_{\gamma^*/Z} \cdot \mathcal{BR}(\gamma^*/Z \rightarrow \tau\tau) = (964 \pm 15(PDF) \pm 10(\alpha_S))\ pb$$

- reasonable agreement with theory prediction
- dominated by statistical uncertainty
- largest background arises from the (conservative) QCD estimation

Current search strategies in ATLAS

Motivation for MSSM

- minimal SUSY extension to the SM $\rightarrow$ same theoretical motivations as SUSY
- tree-level predictions in terms of the parameters m_A and $\tan\beta$
- predicts 5 Higgs bosons: $\Phi = h/H/A$ and $H^{\pm}$
- couplings between Higgs bosons and down-type fermions are enhanced by $\tan\beta \rightarrow b$-associated Higgs production and $\Phi \rightarrow \tau^-\tau^+$ become important

Search strategies for $\Phi \rightarrow \tau^+\tau^-$ (ATLAS-CONF-2011-132)

- different analyses for the $\tau_h\tau_h, \tau_h\ell$ and $e\mu$ final state
- fully inclusive analyses
- simple cut-and-count approach for limit setting

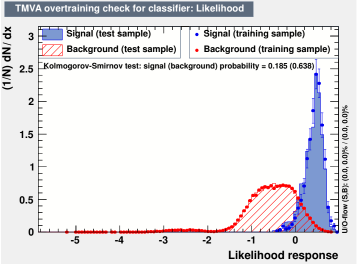
Goals of my diploma thesis

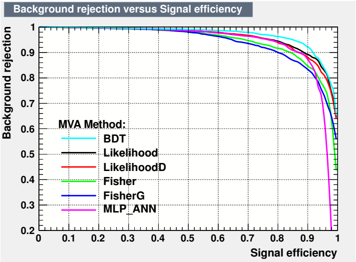
Goals

- investigate feasibility of MVA for increasing the sensitivity
- test other methods for limit extraction (e.g. template fit)

Current status

- baseline selection frozen and most technicalities solved
- check of important backgrounds in dedicated control regions done
- TMVA setup for testing different MVA methods in place





Summary and outlook

Summary

- contributed to the $\gamma^*/Z \to \tau\tau$ cross-section measurement with $L = 35pb^{-1}$
- development of multi-variate analysis for MSSM Higgs search in the $\Phi \to \tau\tau \to e\mu + 4\nu$ channel

Outlook

- fix MVA analysis
- estimate systematic uncertainties
- test template fit for limit extraction
- (planned contributions to mass reconstruction in di-tau final states)