WW/WZ semileptonic update

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Goal of the analysis

Measurement of the WW and WZ production cross section in the semileptonic final state in 4.7 fb^{-1} of pp collisions with the ATLAS detector at $\sqrt{s}$ = 7 TeV and limits on anomalous trilinear gauge couplings

Goals of the analysis:

- cross section measurement: $\sigma\left(WW/WZ \longrightarrow l\nu jj\right)$, $l = e, \mu$
- anomalous Triple Gauge Coupling limits

Data taking conditions:

- $\sqrt{s} = 7$ TeV
- integrated luminosity: $L = 4.7\ \mathrm{fb}^{-1}$
- Standard Model predictions:
  - $\sigma = 63 \pm 3.2$ pb
  - aTGC: all paramethers equal to zero

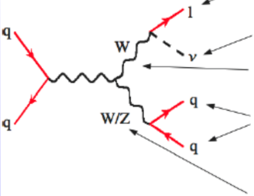
Overview

- process signature
- cross section measurement
- anomalous Triple Gauge Coupling limits

Jargon used

- there are two important *fits* in the analysis:
  - the fit to the $\not{E}_T$: a min-χ^2 optimization
  - the fit to extract the signal: a real logLikelihood fit
- *template*:
  - once a cutflow is defined, the analysis is done up to that level
  - systematics, when possible, redo the complete analysis steps
  - we call templates the histograms of M_{jj} at the end of the selection, nominal and systematics
  - templates are organized by processes: top, boson+jets. . .
- *QCD*:
  - multijet production due to strong interactions

Process signature



- Trigger on the charged lepton
- Require missing transverse energy
- Get a sample of inclusive W
- Look for at least two jets and form the invariant mass
- Fit the expected W/Z and background dijet mass shape to data to extract the diboson fraction

Background processes:

- W+jets – largest contribution
- Z+jets
- ttbar → WbWbbar → lv jj bbar
- QCD
- single top

this is a cut-based analysis

Main steps in the analysis

The final state is $WW/WZ \longrightarrow l\nu jj$, $l = e, \mu$.

- select events compatible with a $W \longrightarrow l\nu$ decay
  - trigger on a lepton (electron or muon)
  - cut on $\not{E}_T$ and M_T
- select events in which a W or a Z decays hadronically: $W \longrightarrow jj$ or $Z \longrightarrow jj$
  - prepare a list of *good jets*: p_T threshold, η range...
  - consider the two leading *good jets* as the candidate decay products
  - build the M_{jj} distribution
- do this for data:
  - electron-triggered events
  - muon-triggered events
- do this for Monte Carlo samples:
  - ttbar and single top
  - W+jets, Z+jets, both light- and heavy-flavour jets
  - Drell-Yang processes
  - WW, WZ
  - ZZ
- goal: to extract the semileptonically decaying WW/WZ production cross section from fitting the MC M_{jj} distribution to the data

Where do we extract QCD from?

- multijet events coming from QCD interactions are an important background
- a jet can easily fake a lepton
- we need to estimate the contribution to the dijet distribution due to the QCD
- basically, we need the *QCD template*

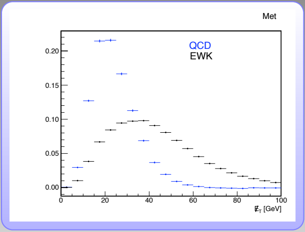
how we do this:

- Monte Carlo predictions are not reliable at estimating the rate of jets faking a lepton
- we use a data-driven method
- create a control sample dominated by QCD multijet background
- but kinematics as close as possible to those of the signal selection

since the QCD background to our analysis is due to jet that fake lepton, we create a selection enriched with QCD by changing the lepton identification criteria.

QCD evaluation

- shape is extracted from a QCD-enriched sample
  - invert quality requirements for electrons
  - invert pointing request for muons
  - orthogonal selection wrt the signal selection
- normalization is extracted fitting the $\not{E}_T$ for MC and data
  - technique used also in CDF
  - $\not{E}_T$ is the best variable which separate the W+jets contribution from the multijet



- boson + jet is left floating
- QCD and V+jets normalization are used for the fit
- tipical V+jets correction: less than 10 %

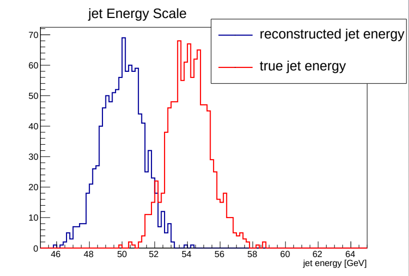
Preparing the input for the fit

- the selection cuts are applied to data and to Monte Carlo
- electron and muon channels are treated separately
- from MC, we obtain the nominal *templates*: dijet-mass distributions separated in processes
  - top
  - boson+jets
  - signal
  - QCD
- the *templates* are used as input for the *fit* to the data
- how do we take into account for systematic errors?

Generation of the systematic templates (I)

A real example: the Jet Energy Scale

- we select a region in η, p_T, detector properties, pile-up conditions
- we plot the jet **true** energy for 1000 jets in satisfying that selection
- we plot the jet **reconstructed** energy for 1000 jets in satisfying that selection
- they are different: we are wrong in estimating the Jet Energy Scale



- of course we do correct, but there is always an uncertainty in the correction
- how can affect this uncertainty the M_{jj} distribution?

Generation of the systematic templates (II)

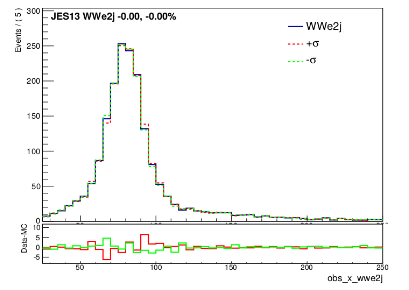
- how can we estimate the uncertainty on the M_{jj} due to the uncertainty on the JES?
- for a given $p_T - \eta$ region and pile-up conditions, we are ignorant about the true jet energy
- we know the correction we gave is the average correction, we are worrying about the uncertainty on this number
- let's say the set of corrections has a gaussian shape
- since we are ignorant on the true jet energy, we go the conservative way:
  - select -1σ jet energy correction
  - shift all the jet energies with -1σ
  - repeat this game for all the jets in the event
  - re-start the selection!! From the beginning
  - repeat with $+1\sigma$

Since the jet energy is changed for each jet in each event:

- the number of events in the dijet distribution will change
- the dijet shape will change

Generation of the systematic templates (III)

- two new *templates* are produced which describe our ignorance on the jet energy resolution
- actually, it is 2 more templates per process
- an example for the signal:



- these *templates* too are used in the *fit*

What is the meaning?

Will talk later about the fit, but the idea is that the *nominal templates* can float between $[+1, -1]$ σ *templates* to reflect our ignorance on the JES on the M_{jj} variable

Systematics in our previous measurement

The main contributions to the systematics came from MC statistics and Jet Energy Scale:

Source	$\Delta\sigma/\sigma[\%]$
Data Statistics	± 12
MC Statistics	± 18
W/Z+jets normalization	± 11
W/Z jets shape variation	± 5
Multijet shape and normalization	± 5
Top normalization	± 6
Top ISR/FSR	± 1
Jet energy scale (all samples)	± 12
Jet energy resolution (all samples)	± 6
Lepton reconstruction (all samples)	± 1
WW/WZ ISR/FSR	± 2
JES uncertainty on WW/WZ normalization	± 6
PDF (all samples)	± 2
Luminosity	± 3.9
Total systematics	± 28

JES improved treatment

- JES is derived from *in situ* measurements and systematic variations in MC simulations
- we treated the JES as a single contribution
- now we splitted it into various contributions
- the components are varied separately
- the templates are used in the fit and scaled by nuisance parameters
- some of the components do have direct physical meaning
- some of them are a combination of contributions built to minimize correlations

Uncertainity 1 , Effective JES Uncertainty Component 1
Uncertainity 2 , Effective JES Uncertainty Component 2
Uncertainity 3 , Effective JES Uncertainty Component 3
Uncertainity 4 , Effective JES Uncertainty Component 4
Uncertainity 5 , Effective JES Uncertainty Component 5
Uncertainity 6 , Effective JES Uncertainty Component 6
Uncertainity 7 , Eta intercalibration: stat uncertainties
Uncertainity 8 , Eta intercalibration: MC generator modelling uncertainty
Uncertainity 9 , High Pt term (temporary, 2010 uncertainty)
Uncertainity 10 , Closure of the calibration, relative to MC11b
Uncertainity 11 ,NPV pile-up Unc
Uncertainity 12 ,Mu pile-up Unc
Uncertainity 13 ,Close-by jet Unc
Uncertainity 14 ,Flavor Comp jet Unc
Uncertainity 15 ,Flavor Response jet Unc
Uncertainity 16 ,b-jet Unc

More MC stat

- the most important contribution to the MC stat comes from W+jets
- requested more W+jets samples in order to reduce the MC syst contribution to the level of the JES

Sample	Requested New Stat
W0p	30M
W1p	4M
W2p	20M
W3p	4M
Wbb1p	0.8M
Wcc1p	1.5M
Wc1p	2M

- old value: 18 %
- new MC systematics: 12 %

Fit and cross section measurement

inputs to the fit:

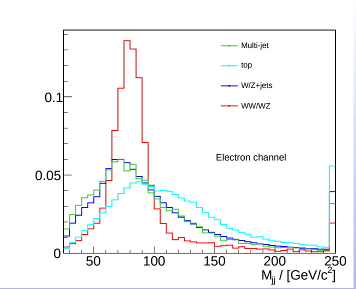
- the data
- the *nominal templates*
- the *templates* describing the systematics
- other rate systematics

The idea of the fit

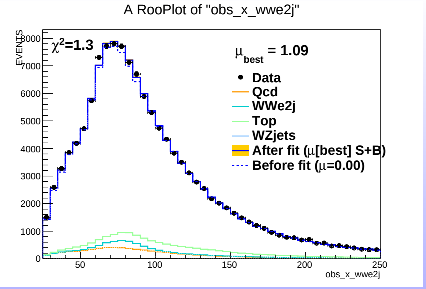
- do not fit the cross section directly
- rather, fit the signal strenght $\mu = \sigma^{\text{meas}}/\sigma^{\text{SM}}$
- fit method: a binned maximum-likelihood
- how do the *systematic templates* enter the fit?
- for each systematic, we introduce a number, a nuisance parameter: α_{syst}
- the nuisance parameters act as normalization factors
- their values tell in which direction the systematic is chosen for the fit

If $\alpha_{\text{JES},+1} = 0.1$, this means that the fit found a maximum for the likelihood when the M_{jj} template is $h^{\text{nominal}} + 0.1 \cdot h_{JES}^{+1}$.

M_{jj} distribution before fit



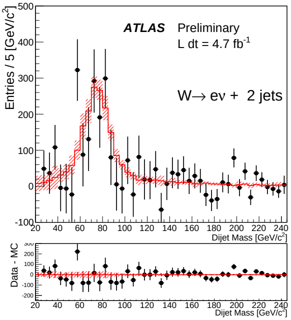
templates

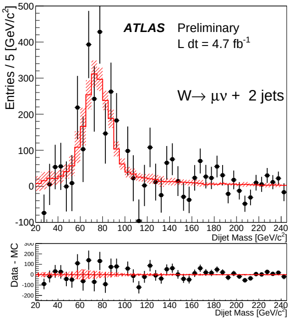


pre-fit results

Last fit results (I)

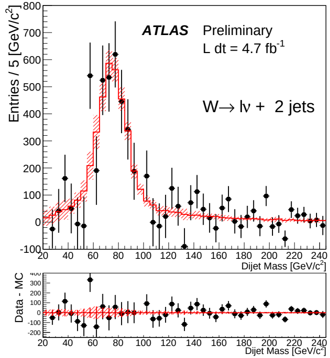
- we think that our understanding of the fit sensitivity to the various systematics is greatly improved
- fit configuration seems near to a freeze
- last results (splitted channels):





Last fit results (II)

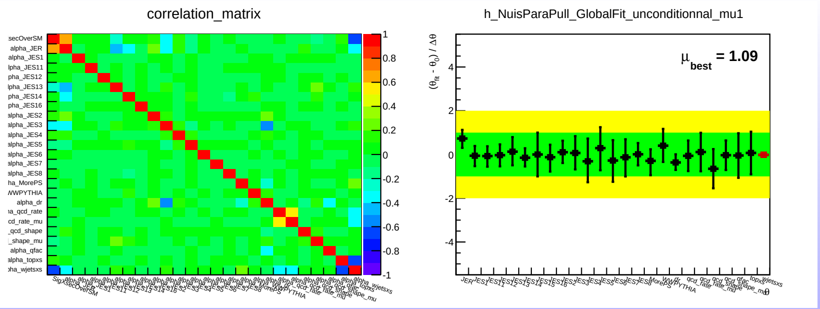
- combined e- and μ-channels



- SM expectation: $\sim 3 \cdot 10^5$ events
- analysis efficiency: $\sim 1\%$ $\longrightarrow$ expected ~ 3000 events
- SM prediction: $\sigma = 63 \pm 3.2$ pb
- our result: $\sigma = 70 \pm 8\,(\mathrm{stat.}) \pm 27\,(\mathrm{syst.})$ pb

Nuisance parameters after fit

Shift of the nuisance parameters with respect to the nominal value.
The high constraint on the W+jets cross section is understood.



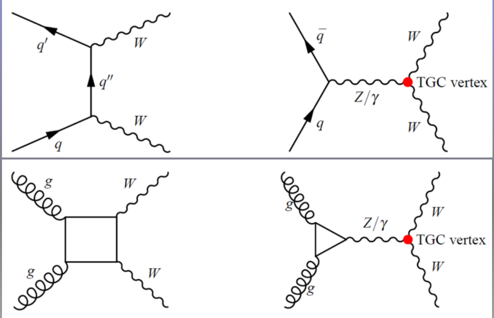
We verified that the constraints of the nuisance parameters are not due to the presence of signal in the fit.

anomalous TGC

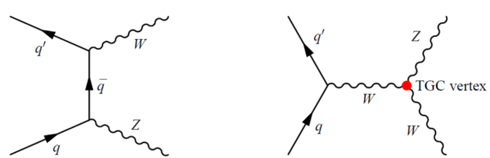
- Diboson production
- effective lagrangian overview
- adopted approch for aTGC limits

Diboson production diagrams

W^+W^-



$W^\pm Z$



Effective lagrangian in SM

- the most general $WW\gamma, Z$ effective Lagrangian has 14 couplings
- C and P conserving terms plus QED gauge invariance $\rightarrow$ 5 couplings
- TGC values according to SM: $g_1^Z = 1$, $k_{\gamma,Z} = 1$, $\lambda_{\gamma,Z} = 0$

$$
\begin{aligned}
i\mathcal{L}_{eff}^{WWV} \quad = \quad & g_{WWV}\Big[g_1^V\left(W_{\mu\nu}^\dagger W^\mu - W^{\dagger\,\mu}W_{\mu\nu}\right)V^\nu + \kappa_V\, W_\mu^\dagger W_\nu V^{\mu\nu} \\
& + \frac{\lambda_V}{m_W^2}\, W_{\rho\mu}^\dagger W^\mu{}_\nu V^{\nu\rho} - g_4^V\, W_\mu^\dagger W_\nu(\partial^\mu V^\nu + \partial^\nu V^\mu) \\
& + i g_5^V\, \varepsilon_{\mu\nu\rho\sigma}\left((\partial^\rho W^{\dagger\,\mu})W^\nu - W^{\dagger\,\mu}(\partial^\rho W^\nu)\right)V^\sigma \\
& + i\tilde{\kappa}_V W_\mu^\dagger W_\nu \tilde{V}^{\mu\nu} + i\frac{\tilde{\lambda}_V}{m_W^2}\, W_{\rho\mu}^\dagger W^\mu{}_\nu \tilde{V}^{\nu\rho}\Big].
\end{aligned}
$$

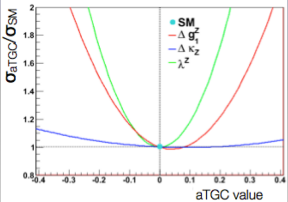
$W_{\mu\nu} = \partial_\mu W_\nu - \partial_\nu W_\mu$; same for $V_{\mu\nu}$; $\tilde{V}_{\mu\nu} = (1/2)\epsilon_{\mu\nu\rho\sigma}V^{\rho\sigma}$

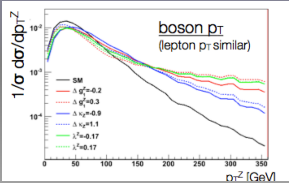
$g_{WW\gamma} = e$; $g_{WWZ} = e\cot\theta_W$

All-neutral TGC are forbidden in the SM at tree-level.

Effective lagrangian for aTGC

- g_1^Z, κ_Z, κ_γ, λ_Z and λ_γ are the terms entering the aTGC for the diboson (not neutral diboson)
- the idea is to set limits for the variations from the SM values for these parameters
- $p_T(Z)$, $p_T(W)$ and the cross section could change with aTGC





- NLO calculation increase the same regions: need to use an NLO MC generator; should move from Herwig to MC@NLO
- three possible scenarios:
  - LEP: $\Delta\kappa_\gamma = (\cot\theta_W)^2(\Delta g_1^Z - \Delta\kappa_Z)$, $\lambda_Z = \lambda_\gamma$ (3 parameters)
  - HISZ: $\Delta g_1^Z = \Delta\kappa_Z/(\cos^2\theta_W - \sin^2\theta_W)$, $\Delta\kappa_\gamma = 2\Delta\kappa_Z\cos^2\theta_W/(\cos^2\theta_W - \sin^2\theta_W)$ (2 parameters)
  - equal couplings: $\Delta\kappa_Z = \Delta\kappa_\lambda$, $\lambda_Z = \lambda_\gamma$ (2 parameters)

How the aTGCs enter in the game?

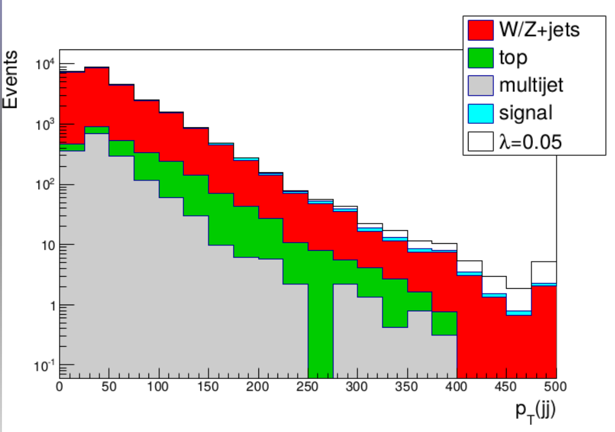
- choose a scheme: LEP, for example
- re-calculate the Born-processes
- you can see that the corrections enter linearly
- example of W^+W^- amplitude

$$A = A_0 + \Delta g_1^Z A_{gZ} + \Delta\kappa_Z A_{\kappa Z} + \lambda_Z A_{\lambda Z} + \Delta g_1^\gamma A_{g\gamma} + \Delta\kappa_\gamma A_{\kappa\gamma} + \lambda_\gamma A_{\lambda\gamma}$$

- in the end, the cross-section is a quadratic form
- we can obtain the new aTGC prediction by simply weighting the SM!
- select a working point
- calculate the weights
- re-build the distributions

aTGC limits with LEP scheme

Different kinematic variables heve been tested; the most sensible one seems to be the $p_T(jj)$; this has been used to preliminarly study the aTGC:



Comparison with CMS results

- CMS has already published a study on the semileptonic diboson channel: see here
- cross section result: $68.9 \pm 8.7\,(\mathrm{stat.}) \pm 9.7\,(\mathrm{syst.}) \pm 1.5\,(\mathrm{lum.})$
- our current result: $\sigma(\mathrm{WW} + \mathrm{WZ}) = 70 \pm 8\,(\mathrm{stat.}) \pm 27\,(\mathrm{syst.})$ pb
- aTCG limits:
  - $-0.038 < \lambda < 0.030$
  - $-0.11 < \Delta\kappa_\gamma < 0.14$
- our preliminary aTCG limits (LEP scheme):
  - $-0.040 < \lambda < 0.039$
  - $-0.20 < \Delta\kappa_\gamma < 0.22$
- not yet understood which scheme CMS adopted for aTGC
- for ATLAS, $p_T(jj)$ systematics is still being finalized

Editorial Board report

- the Editorial Board is responsible for checking an analysis before it is exposed to the ATLAS community
- impressive amount of material
- updates are also given periodically to the SM group
- the fitting procedure is much more under control and understood
- a few items are still being discussed
- next meeting with the EB: Dec,18$^{\rm th}$