Electroweak precision measurements in ATLAS

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Motivation

Precision electroweak measurements provide

- stringent tests of Standard Model (EWSB mechanism especially) and its validity in TeV energy range;
- comparison with theory predictions of higher order QCD and QED effects;
- understanding of irreducible backgrounds for Higgs and BSM searches;
- an indirect search of the “new physics” via anomalous triple/quartic gauge couplings.

Effect of aGC on
kin. distributions

➤ This presentation will include the review of several most recent ATLAS SM electroweak measurements: diboson and triboson productions, VBF/VBS processes.

➤ New measurements use collision energy **13 TeV** with int. luminosity **from 3.2 up to 36.1 fb⁻¹** collected in 2015-2016 (Run2) and most precise are still using 7-8 TeV data (Run1).

➤ All measurements were used to set the limits on aTGC/aQGC parameters.

Introduction

Standard Model Production Cross Section Measurements

Status: July 2017

- Precision became enough for comparisons with NNLO theory predictions for diboson processes and for observation of triboson/VBF processes.

Single boson production

W/Z to leptons @ 7 TeV

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• Starting point:

Data: $L=4.5 \text{ fb}^{-1} \pm 1.8\%$

MC signal: Powheg+Pythia6; Main bkg: multijet, EWK+top.

Data-driven from MC sim.

• Measurements of:

■ Integrated and differential σ ; new PDF set from ATLAS, H1 and ZEUS; CKM matrix element $|V_{cs}|$.

$W \rightarrow \ell \nu$ $10720 \pm 3 \text{ (stat)} \pm 60 \text{ (syst)} \pm 190 \text{ (lumi)} \pm 130 \text{ (acc)}$

$Z/\gamma^* \rightarrow \ell \ell$ $990 \pm 1 \text{ (stat)} \pm 3 \text{ (syst)} \pm 18 \text{ (lumi)} \pm 15 \text{ (acc)}$

Cross-section ratio to check the PDF sets: some of predictions are far from data results.

• Systematics:

Main systematics are from signal modelling and multijet bkg.

Measurements are in agreement with predictions (NNLO QCD and NLO EWK).

Diboson/Triboson production

ATLAS
EXPERIMENT

Run Number: 207397, Event Number: 8300172

Date: 2012-07-23 20:45:59 UTC

$WV\gamma \rightarrow \mu\nu jj\gamma$ candidate event

• Starting point:

Data: $L=13.3 \text{ fb}^{-1} \pm 3.2\%$

MC signal: Powheg+Pythia8; Main bkg: misID leptons , ZZ , $\text{t}\bar{\text{t}}+\text{V}$, tZ ($\sim 25\%$ total for all bkg).
 reducible Est. from matrix method irreducible est. from MC sim. corr. with data

• Event selection for fiducial region:

$W^\pm Z \rightarrow l^\pm \nu l^\pm l^\pm$ ($l=e/\mu$): On shell Z – ll invariant mass within 10 GeV near Z peak, $m_T(W) > 30 \text{ GeV}$.

• Measurements of:

- Integrated σ , differential σ vs $p_T(Z)$, $m_T(WZ)$ and 1D aTGC limits.

$$\sigma_{W^\pm Z \rightarrow l^\pm \nu l^\pm l^\pm}^{\text{fid.}} = 66.2 \pm 1.8 (\text{stat.}) \pm 3.6 (\text{sys.}) \pm 2.1 (\text{lumi.}) \text{ fb.}$$

NLO cross section prediction deviates from data on 20%.

Comparison of data, NLO and NNLO predictions

NNLO MATRIX predictions can improve the situation.

K-factor from NLO to NNLO is ~ 1.15 .

• Systematics:

- Uncertainty dominated by misID lepton background and lepton ID efficiency.
- Dominant theory uncertainty due to QCD scale uncertainty.

• Differential measurements:

Agreement expected to be improved with NNLO predictions.

Measurement used to set the limits on aTGC parameters.

Another approach (EFT) limits were also set.

Dataset	Coupling	Expected	Observed
13 TeV	Δg_1^Z	[-0.017; 0.032]	[-0.016; 0.036]
	$\Delta \kappa_1^Z$	[-0.18; 0.24]	[-0.15; 0.26]
	λ^Z	[-0.015; 0.014]	[-0.016; 0.015]
8 and 13 TeV	Δg_1^Z	[-0.014; 0.029]	[-0.015; 0.030]
	$\Delta \kappa_1^Z$	[-0.15; 0.21]	[-0.13; 0.24]
	λ^Z	[-0.013; 0.012]	[-0.014; 0.013]

• Anomalous couplings

Charged vertex WWZ

Parameters from vertex function (effective Lagrangian) approach.

Obtained limits:

• Starting point:

Data: $L=36.1 \text{ fb}^{-1} \pm 3.2\%$

MC signal: Sherpa 2.1; Main bkg: $t\bar{t}Z$, misID leptonic bkg (1-2% total).
 From MC sim. data-driven est. by sideband method

• Event selection for fiducial region:

$ZZ \rightarrow 4l (4l=4e/4\mu/2e2\mu)$: for each Z - $66 \text{ GeV} < m_{ll} < 116 \text{ GeV}$.

• Measurements of:

■ Integrated σ , differential σ in bins of 20 observables.

$$\sigma_{ZZ}^{\text{fid.}} = 46.4^{+2.4}_{-2.2} [\pm 1.5 \text{ (stat.)} \pm 1.0 \text{ (syst.)} {}^{+1.5}_{-1.4} \text{ (lumi.)}] \text{ fb}$$

NNLO prediction (MATRIX):

$$\sigma_{ZZ}^{\text{th}} = 42.9^{+1.9}_{-1.5} \text{ fb}$$

NLO EWK corrections are also applied.

Measurement is statistically dominated.

• Systematics:

- Uncertainty dominated by lepton reconstruction and ID efficiencies.
- Dominant theory uncertainty due to choice of MC generator.

• Differential measurements:

Agreement of differential cross sections with predictions is good.

• Anomalous couplings

Neutral vertices $ZZ\gamma$ and ZZZ
(forbidden in SM)

Coupling strength	Expected 95% CL [$\times 10^{-3}$]	Observed 95% CL [$\times 10^{-3}$]
f_4	-2.4, 2.4	-1.8, 1.8
f_4^Z	-2.1, 2.1	-1.5, 1.5
f_5	-2.4, 2.4	-1.8, 1.8
f_5^Z	-2.0, 2.0	-1.5, 1.5

• Starting point:

Data: $L=3.2 \text{ fb}^{-1} \pm 2.1\%$

MC signal: Powheg+Pythia8; Main bkg: $t\bar{t}$ +single top, DY, W+jets (~30% total).

Est. from CRs in data lep. misID rate from data

• Event selection for fiducial region:

$W^+W^- \rightarrow ll\nu\nu (l=e/\mu)$: $p_T(\nu\nu) > 20 \text{ GeV}$; $E_{T,\text{Rel}}(\text{miss}) > 15 \text{ GeV}$; $m_{e\mu} > 10 \text{ GeV}$; jet veto.

• Measurements of:

- Integrated σ .

$$\sigma_{WW}^{\text{tot}} = 142 \pm 5 \text{ (stat.)} \pm 13 \text{ (syst.)} \pm 3 \text{ (lumi.) pb} \quad \sigma(\text{nNNLO}+H_{\text{tot}})_{\text{th}} = 128.4^{+3.5}_{-3.8} \text{ pb}$$

Measurement is in agreement with nNNLO+H prediction.

• Systematics:

Main systematics are from JES, W+jet and multijet bkg, parton showering.

WW γ /WZ γ @ 8 TeV

[arXiv:1707.05597](https://arxiv.org/abs/1707.05597)

• Starting point:

Data: $L=20.2 \text{ fb}^{-1} \pm 1.9\%$

MC signal: Sherpa 2.1; Main bkg: $t\bar{t}\gamma$, $Z\gamma$ (lept.), $W\gamma$ (semi-lept.), misID bkg, etc.

Est. from MC sim. Simultaneous fit 2D sideband

• Event selection for fiducial region:

$WV\gamma \rightarrow e\nu\mu\nu\gamma$, ($lvjj\gamma$): $m_{e\mu} > 50 \text{ GeV}$ ($m_T > 30 \text{ GeV}$); $E_{T,\text{Rel}}(\text{miss}) > 15 \text{ GeV}$

($E_T(\text{miss}) > 30 \text{ GeV}$); no 3rd (2nd) lepton in event;

Jets veto (m_{jj} , $\Delta\eta_{jj}$, ΔR_{jj} anti-VBF cuts applied).

• Measurements of:

■ Integrated σ and limits, aQGC limits.

VBFNLO NLO prediction

$$\sigma_{\text{fid}}^{e\nu\mu\nu\gamma} = 1.5 \pm 0.9(\text{stat.}) \pm 0.5(\text{syst.}) \text{ fb}$$

$$\sigma_{\text{theo}} = 2.0 \text{ fb}$$

The measurement is statistically limited (significance is 1.4σ)

Semileptonic final states used to obtain the 95% C.L. limits.

• Anomalous couplings

Charged quartic vertices $WWZ\gamma$, $WW\gamma\gamma$

aQGC limits:

EFT approach used:

$$\mathcal{L}_{\text{eff}} = \mathcal{L}_{\text{SM}} + \sum_{j=0}^7 \frac{f_{M,j}}{\Lambda^4} \mathcal{O}_{M,j} + \sum_{j=0,1,2,5,6,7} \frac{f_{T,j}}{\Lambda^4} \mathcal{O}_{T,j}$$

dim 8 operators New physics scale

	WWWW	WWZZ	ZZZZ	WW γ Z	WW $\gamma\gamma$	ZZZ γ	ZZ $\gamma\gamma$	Z $\gamma\gamma\gamma$	$\gamma\gamma\gamma\gamma$
$\mathcal{L}_{S,0}, \mathcal{L}_{S,1}$	X	X	X	O	O	O	O	O	O
$\mathcal{L}_{M,0}, \mathcal{L}_{M,1}, \mathcal{L}_{M,6}, \mathcal{L}_{M,7}$	X	X	X	X	X	X	X	O	O
$\mathcal{L}_{M,2}, \mathcal{L}_{M,3}, \mathcal{L}_{M,4}, \mathcal{L}_{M,5}$	O	X	X	X	X	X	X	O	O
$\mathcal{L}_{T,0}, \mathcal{L}_{T,1}, \mathcal{L}_{T,2}$	X	X	X	X	X	X	X	X	X
$\mathcal{L}_{T,5}, \mathcal{L}_{T,6}, \mathcal{L}_{T,7}$	O	X	X	X	X	X	X	X	X
$\mathcal{L}_{T,8}, \mathcal{L}_{T,9}$	O	O	X	O	O	X	X	X	X

VBF/VBS production

VBF W @ 7 and 8 TeV

[Eur. Phys. J. C 77 \(2017\) 474](#)

• Starting point:

Data: $L=4.7 \text{ fb}^{-1} \pm 1.8\%$ @ 7 TeV and $20.2 \text{ fb}^{-1} \pm 1.9\%$ @ 8 TeV

MC signal: Powheg+Pythia8; Main bkg: QCD W, multijets, QCD Z, $t\bar{t}$.

data-driven norm. MC sim.

• Event selection for fiducial region:

$W_{jj} \rightarrow l\nu_{jj}$ ($l=e/\mu$): $E_T(\text{miss}) > 25 \text{ GeV}$; $m_T > 40 \text{ GeV}$; $m[jj] > 500 \text{ GeV}$; $\Delta Y[jj] > 2$; $\Delta R(j,l) > 0.3$.

• Measurements of:

■ Integrated σ , differential σ and aTGC limits.

Binned likelihood fit of $m[jj]$ constrained from QCD CR

Significance $> 5\sigma$!

$\sqrt{s}$	$\sigma_{\text{meas}}^{\text{fid}}$ [fb]	Powheg+Pythia	$\sigma_{\text{SM}}^{\text{fid}}$ [fb]
7 TeV	$144 \pm 23 \text{ (stat)} \pm 23 \text{ (exp)} \pm 13 \text{ (th)}$		144 ± 11
8 TeV	$159 \pm 10 \text{ (stat)} \pm 17 \text{ (exp)} \pm 15 \text{ (th)}$		198 ± 12

LHC electroweak Xjj production measurements

ATLAS

Stat. uncertainty Total uncertainty Theory uncertainty

Good agreement btw measured and predicted cross section (1.3 σ deviation for 8 TeV).

• Systematics:

- Uncertainty dominated by JES, JER, multijet background.
- Dominant theory uncertainty due to QCD scale uncertainty.

• Differential measurements:

Fairly good agreement with predictions.

• Anomalous couplings

Charged vertex WWZ/WW γ

Parameters from vertex function approach (effective Lagrangian).

Limits:

	$\Lambda = 4$ TeV		$\Lambda = \infty$	
	Expected	Observed	Expected	Observed
Δg_1^Z	$[-0.39, 0.35]$	$[-0.32, 0.28]$	$[-0.16, 0.15]$	$[-0.13, 0.12]$
$\Delta \kappa_Z$	$[-0.38, 0.51]$	$[-0.29, 0.42]$	$[-0.19, 0.19]$	$[-0.15, 0.16]$
λ_V	$[-0.16, 0.12]$	$[-0.13, 0.090]$	$[-0.064, 0.054]$	$[-0.053, 0.042]$
$\tilde{\kappa}_Z$	$[-1.7, 1.8]$	$[-1.4, 1.4]$	$[-0.70, 0.70]$	$[-0.56, 0.56]$
$\tilde{\lambda}_V$	$[-0.13, 0.15]$	$[-0.10, 0.12]$	$[-0.058, 0.057]$	$[-0.047, 0.046]$

- Complementary to dibosons (s-channel exchange instead of t-channel);
- Form-factors introduced to preserve unitarity.

VBF Z @ 13 TeV

• Starting point:

Data: $L=3.2 \text{ fb}^{-1} \pm 2.1\%$

MC signal: Powheg+Pythia8; Main bkg: QCD Z, diboson, top.

• Measurement of:

- Integrated σ .

Good agreement between measurement and prediction.

Preliminary results

Very good agreement

8 TeV results on VBF Z already were with significance $>5\sigma$.

VBS $Z\gamma$ @ 8 TeV

[JHEP 07 \(2017\) 107](#)

• Starting point:

Data: $L=20.2 \text{ fb}^{-1} \pm 1.9\%$

MC signal: Sherpa 1.4; **Main bkg:** QCD $Z\gamma$, Z +jets – for $l\gamma$;

γ +jet, $W\gamma$, Z +jets, $W(\text{ev})$ – for $\nu\nu\gamma$.
 data-driven norm. 2D-sidband data-driven Z-peak method

• Event selection for fiducial region:

$Z\gamma jj \rightarrow l\gamma jj$ ($l=e/\mu$): $m_{ll} > 40 \text{ GeV}$; $m_{ll} + m_{ll\gamma} > 182 \text{ GeV}$; $m[jjj] > 500 \text{ GeV}$;

$Z\gamma jj \rightarrow \nu\nu\gamma jj$: $p_T(\text{miss}) > 100 \text{ GeV}$; $|\Delta\phi(p_T(\text{miss}), jj\gamma)| > 3\pi/4$; $|\Delta\phi(p_T(\text{miss}), \gamma)| > \pi/2$; $|\Delta\phi(E_T(\text{miss}), j)| > 1$;
 $m[jjj] > 600 \text{ GeV}$; $|\Delta Y| > 2.5$; $\zeta_\gamma < 0.3$; $p_T(\text{balance}) < 0.1$.

• Measurements of:

- Integrated σ for $l\gamma$ channel, σ limit for $\nu\nu\gamma$ channel and aQGC limits.

Channel	Phase-space region	Process type	Measured cross-section [fb]	Predicted cross-section [fb]
$Z(\ell^+\ell^-)\gamma jj$	Search region	EWK	1.1 ± 0.5 (stat) ± 0.4 (syst)	0.94 ± 0.09
$Z(\ell^+\ell^-)\gamma jj$	Search region	EWK+QCD	3.4 ± 0.3 (stat) ± 0.4 (syst)	4.0 ± 0.4
$Z(\ell^+\ell^-)\gamma jj$	Control region	EWK+QCD	21.9 ± 0.9 (stat) ± 1.8 (syst)	22.9 ± 1.9

- $150 < m[jjj] < 500 \text{ GeV}$ – CR for QCD $Z\gamma$;

- $M[jjj] > 500 \text{ GeV}$ – SR;

- Cross section measured just in $l\gamma$;

- Agreement is good;

- Significance is 2σ (observed);

- Upper limits: **1.06 fb** (0.99 fb exp.) - $\nu\nu\gamma$

- and **1.03 fb** (1.01 fb exp.) – $l\gamma$ (1D profile likelihood fit).

• Systematics:

- Uncertainty dominated by JES ($l\gamma$); $W\gamma$ bkg, Zjets bkg and JES ($\nu\nu\gamma$).
- Dominant theory uncertainty due to Sherpa modeling and EWK-QCD interference.

• Anomalous couplings

Vertices $WWZ\gamma/ZZZ\gamma/ZZ\gamma\gamma/Z\gamma\gamma\gamma$ (the latter three are forbidden in SM).

EFT approach used:

$$\mathcal{L}_{\text{eff}} = \mathcal{L}_{\text{SM}} + \sum_{j=0}^7 \frac{f_{M,j}}{\Lambda^4} \mathcal{O}_{M,j} + \sum_{j=0,1,2,5,6,7} \frac{f_{T,j}}{\Lambda^4} \mathcal{O}_{T,j},$$

- Both $l\gamma$ and $\nu\nu\gamma$ channels ($l\gamma$ improves the limits by 10-30%);
- VBFNLO used for aQGC param;
- Form-factors introduced to preserve unitarity.

	Limits 95% CL	Measured [TeV^{-4}]	Expected [TeV^{-4}]
ATLAS $Z(\rightarrow \ell\bar{\ell}/\nu\bar{\nu})\gamma$ -EWK	f_{T9}/Λ^4	$[-3.9, 3.9]$	$[-2.7, 2.8]$
	f_{T8}/Λ^4	$[-1.8, 1.8]$	$[-1.3, 1.3]$
	f_{T0}/Λ^4	$[-3.4, 2.9]$	$[-3.0, 2.3]$
	f_{M0}/Λ^4	$[-76, 69]$	$[-66, 58]$
	f_{M1}/Λ^4	$[-147, 150]$	$[-123, 126]$
	f_{M2}/Λ^4	$[-27, 27]$	$[-23, 23]$
	f_{M3}/Λ^4	$[-52, 52]$	$[-43, 43]$
CMS $Z(\rightarrow \ell\bar{\ell})\gamma$ -EWK	f_{T9}/Λ^4	$[-4.0, 4.0]$	$[-6.0, 6.0]$
	f_{T8}/Λ^4	$[-1.8, 1.8]$	$[-2.7, 2.7]$
	f_{T0}/Λ^4	$[-3.8, 3.4]$	$[-5.1, 5.1]$
	f_{M0}/Λ^4	$[-71, 75]$	$[-109, 111]$
	f_{M1}/Λ^4	$[-190, 182]$	$[-281, 280]$
	f_{M2}/Λ^4	$[-32, 31]$	$[-47, 47]$
	f_{M3}/Λ^4	$[-58, 59]$	$[-87, 87]$
CMS $W(\rightarrow \ell\nu)\gamma$ -EWK	f_{T0}/Λ^4	$[-5.4, 5.6]$	$[-3.2, 3.4]$
	f_{M0}/Λ^4	$[-77, 74]$	$[-47, 44]$
	f_{M1}/Λ^4	$[-125, 129]$	$[-72, 79]$
	f_{M2}/Λ^4	$[-26, 26]$	$[-16, 15]$
	f_{M3}/Λ^4	$[-43, 44]$	$[-25, 27]$

Conclusions

- A lot of nice ATLAS SM electroweak results were presented.
- Most of recent results were obtained with 13 TeV collision energy.
- The amount of data allows to obtain the first evidence or observation of rare triboson and VBF/VBS processes. The latter ones tries to use MVA approaches to distinguish the signal from background.
- The level of accuracy leads to necessity of having higher-order corrected MC (NNLO and even higher).
- The sensitivity to aGC increasing rapidly and allow to search/constrain the new physics.
- Run2 is ongoing. Waiting for more exciting results soon!

Back-up slides

Latest aTGC results

Charged

July 2017

Central
Fit Value

CMS
ATLAS
D0
LEP

aTGC Limits @95% C.L.

Latest aTGC results

Charged

July 2017

Latest aTGC results

Neutral

May 2017

Latest aTGC results

Neutral

April 2016

Latest aQGC results

M-family operators

July 2017

CMS
ATLAS

Channel	Limits	$\int \mathcal{L} dt$	$\sqrt{s}$
WV γ	[-1.3e+02, 1.3e+02]	20.2 fb $^{-1}$	8 TeV
WV γ	[-7.7e+01, 8.1e+01]	19.3 fb $^{-1}$	8 TeV
Z γ	[-7.1e+01, 7.5e+01]	19.7 fb $^{-1}$	8 TeV
Z γ	[-7.6e+01, 6.9e+01]	20.2 fb $^{-1}$	8 TeV
W γ	[-7.7e+01, 7.4e+01]	19.7 fb $^{-1}$	8 TeV
ss WW	[-3.3e+01, 3.2e+01]	19.4 fb $^{-1}$	8 TeV
ss WW	[-6.0e+00, 5.9e+00]	35.9 fb $^{-1}$	13 TeV
$\gamma\gamma \rightarrow WW$	[-2.8e+01, 2.8e+01]	20.2 fb $^{-1}$	8 TeV
$\gamma\gamma \rightarrow WW$	[-4.2e+00, 4.2e+00]	24.7 fb $^{-1}$	7.8 TeV
WV γ	[-2.1e+02, 2.1e+02]	20.2 fb $^{-1}$	8 TeV
WV γ	[-1.3e+02, 1.2e+02]	19.3 fb $^{-1}$	8 TeV
Z γ	[-1.9e+02, 1.8e+02]	19.7 fb $^{-1}$	8 TeV
Z γ	[-1.5e+02, 1.5e+02]	20.2 fb $^{-1}$	8 TeV
W γ	[-1.2e+02, 1.3e+02]	19.7 fb $^{-1}$	8 TeV
ss WW	[-4.4e+01, 4.7e+01]	19.4 fb $^{-1}$	8 TeV
ss WW	[-8.7e+00, 9.1e+00]	35.9 fb $^{-1}$	13 TeV
$\gamma\gamma \rightarrow WW$	[-1.1e+02, 1.0e+02]	20.2 fb $^{-1}$	8 TeV
$\gamma\gamma \rightarrow WW$	[-1.6e+01, 1.6e+01]	24.7 fb $^{-1}$	7.8 TeV
Z $\gamma\gamma$	[-5.1e+02, 5.1e+02]	20.3 fb $^{-1}$	8 TeV
W $\gamma\gamma$	[-7.0e+02, 6.8e+02]	19.4 fb $^{-1}$	8 TeV
W $\gamma\gamma$	[-2.5e+02, 2.5e+02]	20.3 fb $^{-1}$	8 TeV
WV γ	[-5.7e+01, 5.7e+01]	20.2 fb $^{-1}$	8 TeV
Z γ	[-3.2e+01, 3.1e+01]	19.7 fb $^{-1}$	8 TeV
Z γ	[-2.7e+01, 2.7e+01]	20.2 fb $^{-1}$	8 TeV
W γ	[-2.6e+01, 2.6e+01]	19.7 fb $^{-1}$	8 TeV
Z $\gamma\gamma$	[-8.5e+02, 9.2e+02]	20.3 fb $^{-1}$	8 TeV
W $\gamma\gamma$	[-1.2e+03, 1.2e+03]	19.4 fb $^{-1}$	8 TeV
W $\gamma\gamma$	[-4.4e+02, 4.7e+02]	20.3 fb $^{-1}$	8 TeV
WV γ	[-9.5e+01, 9.8e+01]	20.2 fb $^{-1}$	8 TeV
Z γ	[-5.8e+01, 5.9e+01]	19.7 fb $^{-1}$	8 TeV
Z γ	[-5.2e+01, 5.2e+01]	20.2 fb $^{-1}$	8 TeV
W γ	[-4.3e+01, 4.4e+01]	19.7 fb $^{-1}$	8 TeV
WV γ	[-1.3e+02, 1.3e+02]	20.2 fb $^{-1}$	8 TeV
W γ	[-4.0e+01, 4.0e+01]	19.7 fb $^{-1}$	8 TeV
WV γ	[-2.0e+02, 2.0e+02]	20.2 fb $^{-1}$	8 TeV
W γ	[-6.5e+01, 6.5e+01]	19.7 fb $^{-1}$	8 TeV
WV γ	[-2.5e+02, 2.5e+02]	20.2 fb $^{-1}$	8 TeV
W γ	[-1.3e+02, 1.3e+02]	19.7 fb $^{-1}$	8 TeV
ss WW	[-6.5e+01, 6.3e+01]	19.4 fb $^{-1}$	8 TeV
ss WW	[-1.2e+01, 1.2e+01]	35.9 fb $^{-1}$	13 TeV
WV γ	[-4.7e+02, 4.7e+02]	20.2 fb $^{-1}$	8 TeV
W γ	[-1.6e+02, 1.6e+02]	19.7 fb $^{-1}$	8 TeV
ss WW	[-7.0e+01, 6.6e+01]	19.4 fb $^{-1}$	8 TeV
ss WW	[-1.3e+01, 1.3e+01]	35.9 fb $^{-1}$	13 TeV

-2000

0

2000

4000

aQGC Limits @95% C.L. [TeV $^{-4}$]

Latest aQGC results

T-family operators

July 2017