Measurement of inclusive four-lepton production at ATLAS

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Introduction

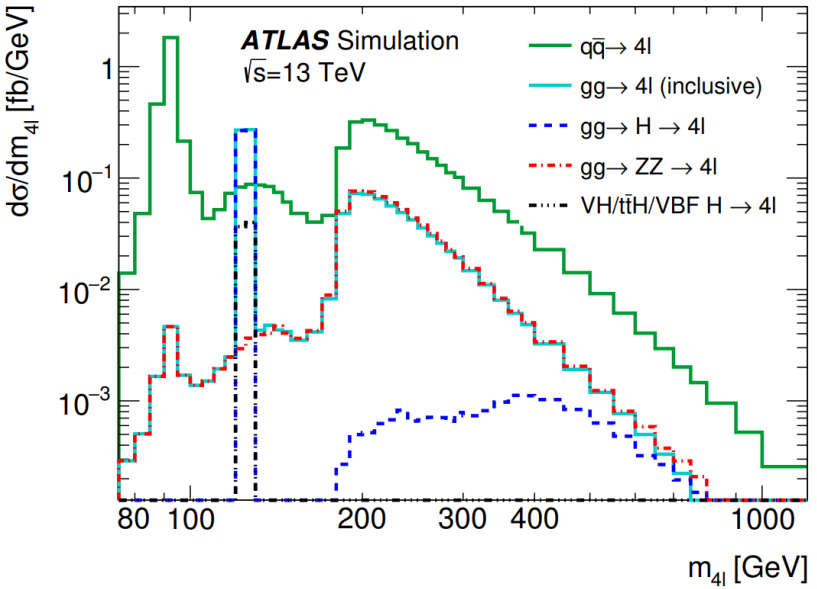
➢ Motivation

- four-lepton final state is “clean” and has rich physics
- allow precision test on the SM
- sensitive to BSM

➢ Introduction

- ATLAS Run-2 data corresponding to 139fb^{-1} of √s = 13 TeV pp collisions

- 10 variables are measured with differential cross-sections or double differential cross-sections (in slice of a second variable)



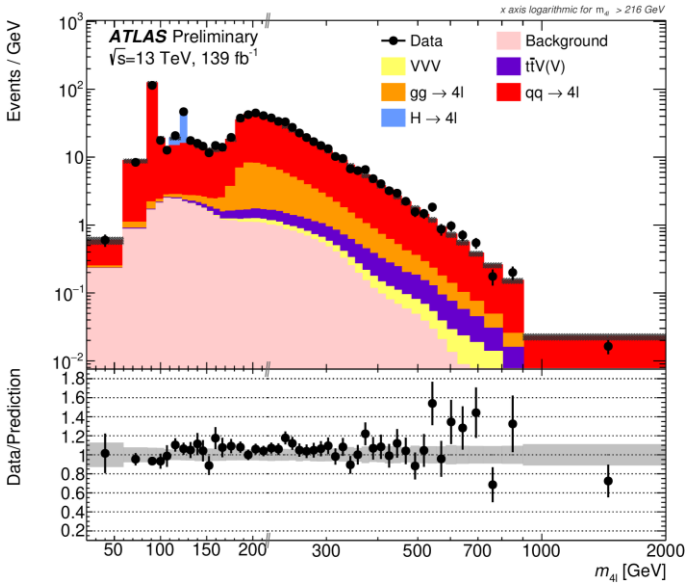
- potential of re-interpretation with all information in HEPData
  - constraints BSM B-L model based on the measurement are evaluated

Main aspects of the analysis

➢ Fiducial phase-space

- based on 4l final state, and try to be **inclusive** and **model-independent**

Lepton selection	
Muon selection	Bare, $p_T > 5$ GeV, $\|\eta\| < 2.7$
Electron selection	Dressed, $p_T > 7$ GeV, $\|\eta\| < 2.47$
Event selection	
Four-lepton signature	At least 4 leptons, with 2 Same-Flavour, Opposite-Sign pairs
Lepton kinematics	$p_T > 20/10$ GeV for leading two leptons
Lepton separation	$\Delta R_{ij} > 0.05$ for any leptons
J/ψ-Veto	$m_{ij} > 5$ GeVfor all SFOS pairs
Truth isolation	ptcone30/$p_T < 0.16$



➢ Background and uncertainties

- background from the **non-prompt leptons**
- **statistical uncertainty** dominant for most of the bins

➢ Detector correction

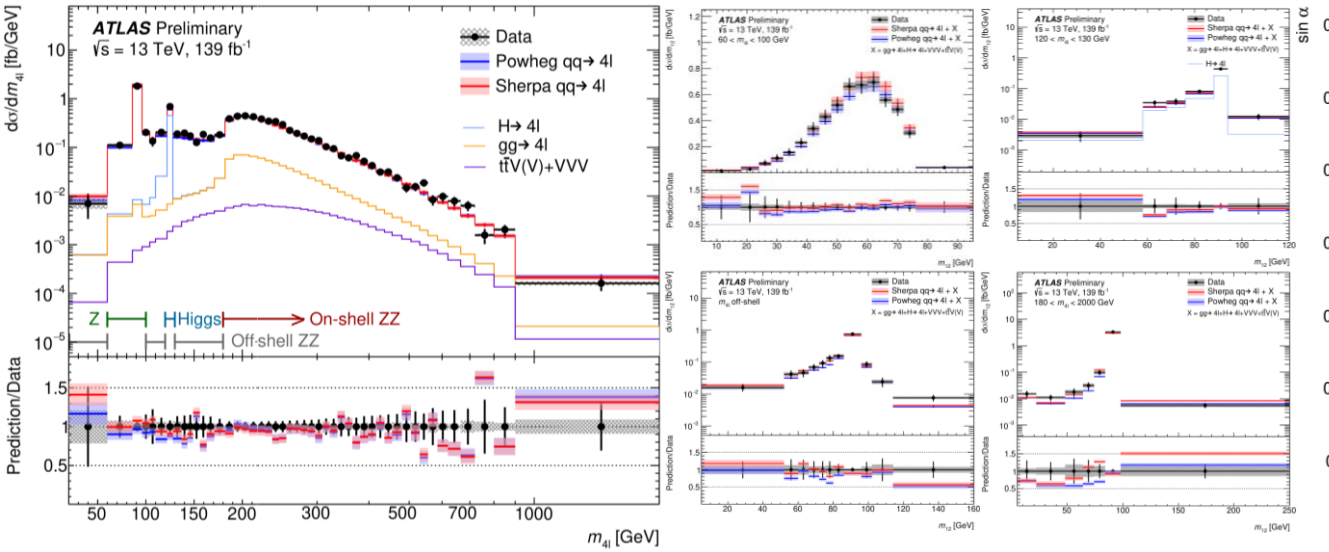
- unfolding technique introduced to correct detector effects and get "particle-level data"

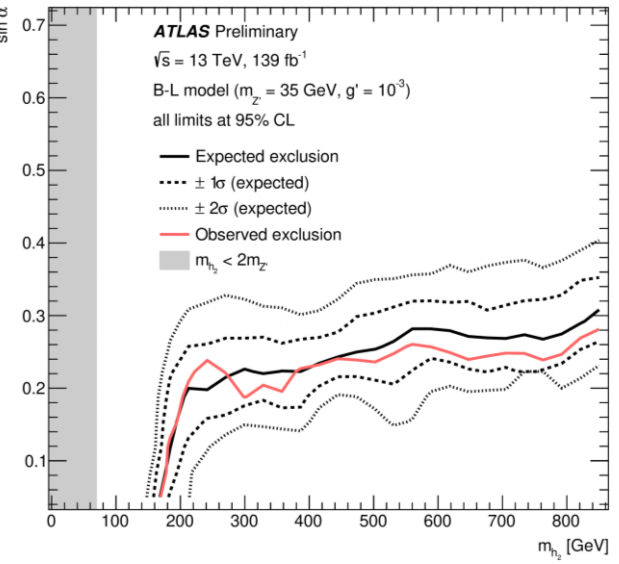
Results

➢ Cross-section

CONF note

- Fiducial cross-section inclusively and in slices of m4l
- the measurements extended the fiducial phase space and increased granularity compared to previous results





➢ $Z \to 4l$ Branching ratio

- $\mathcal{B}_{z\to 4l} = (4.41 \pm 0.30) \times 10^{-6}$
- most precise result and compatible with previous study

➢ Test on B-L model

- **exclusion** on m_{h_2} ~sinα parameter-space
- using the double differential distributions yields significantly stronger limits than the m4l distribution alone

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ATLAS EXPERIMENT

Submitted to: JHEP

CERN

CERN-EP-2020-100

17th July 2020

Measurements of inclusive and differential cross-sections of combined $t\bar{t}\gamma$ and $tW\gamma$ production in the $e\mu$ channel at 13 TeV with the ATLAS detector

Accepted by JHEP

Poster presentation

John Meshreki for the ATLAS collaboration

ICHEP 2020 (online) - 29.07.2020

ATLAS EXPERIMENT

BMBF-ErUM-Forschungsschwerpunkt ATLAS-EXPERIMENT

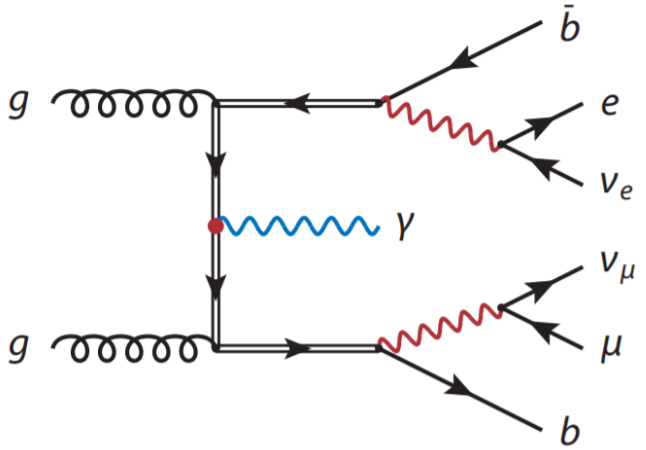
Ausbau von ATLAS am LHC: Physik mit dem ATLAS-Experiment

ErUM-FSP T02 ATLAS

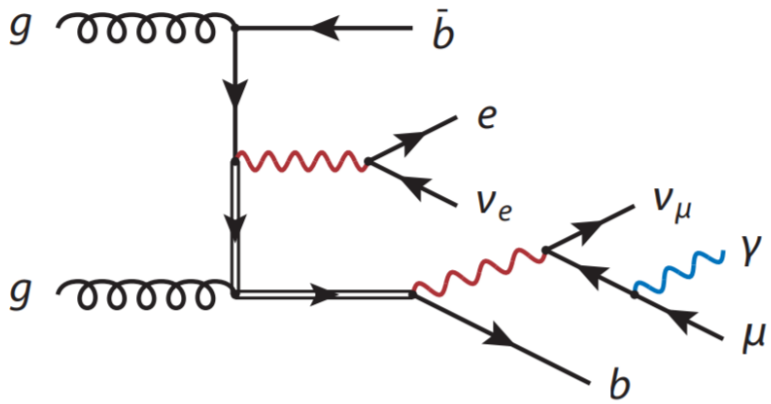
Motivation

- Precise measurement of top-quark pair production in association with a photon **probes the top-photon electroweak coupling**

- Measurements of **fiducial inclusive** and **differential $t\bar{t}\gamma$ + $tW\gamma$** cross-sections
  - in the $e\mu$ channel, **cleanest $t\bar{t}$ decay channel**
  - at **parton level**, to allow **comparison with the most recent theory prediction**



$t\bar{t}\gamma$



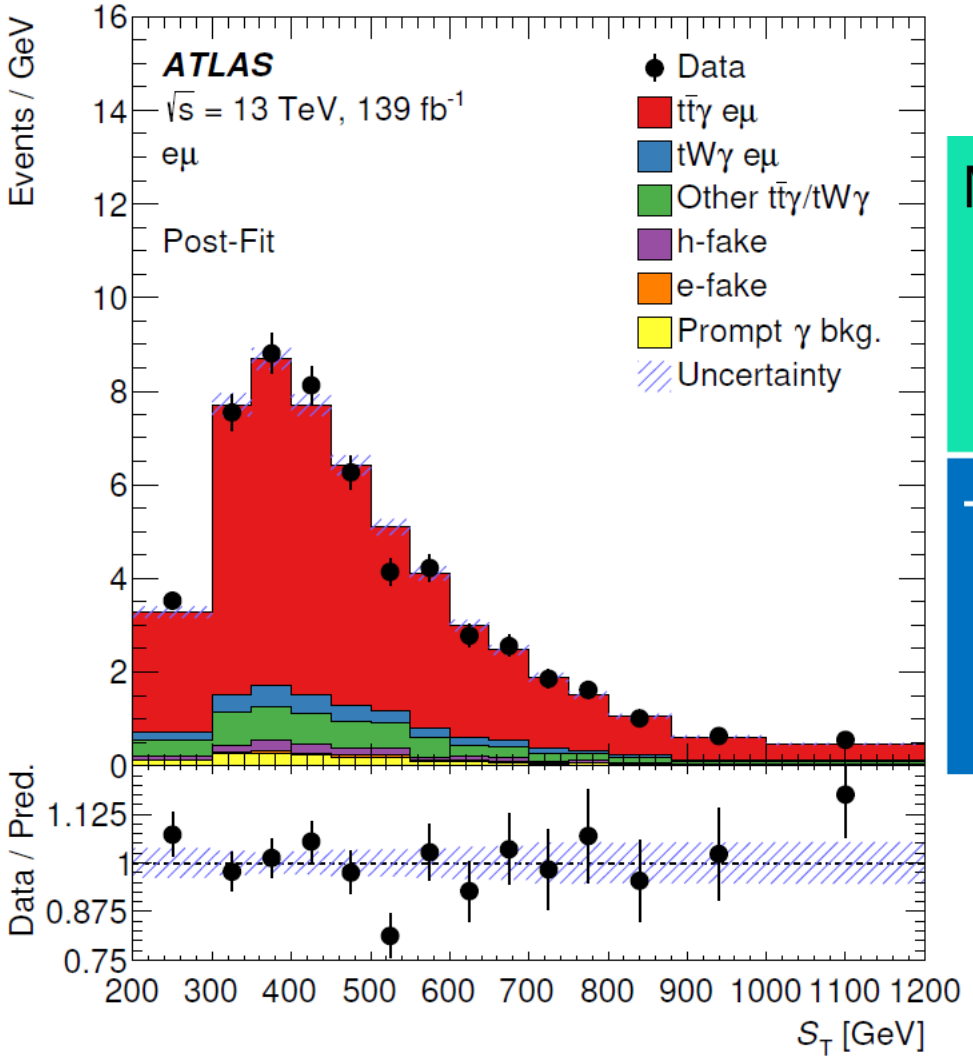
$tW\gamma$

- The measurements are compared with **leading order (LO) Monte Carlo (MC) simulations** and **state-of-the-art calculation** [1], where the latter is the **first full computation** of $t\bar{t}$ with a hard γ **at next-to-leading-order (NLO)** in quantum chromodynamics, for $pp \rightarrow bW\bar{b}W\gamma$ including all resonant and non-resonant diagrams, interferences, and off-shell effects

[1] JHEP 10 (2018) 158

Inclusive results

- **Fiducial inclusive cross-section** is extracted using a **binned Maximum Likelihood Fit to the S_T** distribution (S_T: scalar sum of all transverse momenta in the event, including leptons, photons, jets and missing transverse momentum)



Measured:

$$\sigma_{fiducial} = 39.6 \pm 0.8(stat)^{+2.6}_{-2.2}(syst)\ \text{fb} = 39.6\ ^{+2.7}_{-2.3}\ \text{fb}$$

Theory NLO:

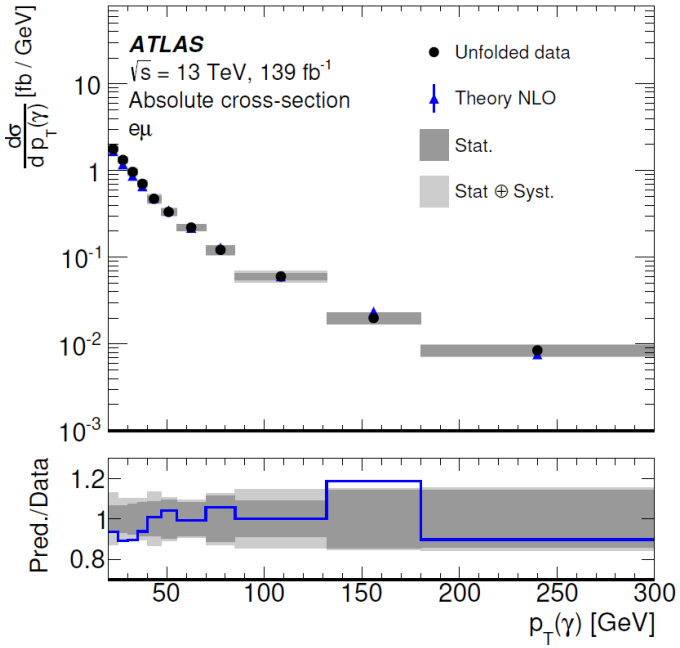
$$\sigma_{NLO} = 38.5\ ^{+1.2}_{-2.5}\ \text{fb}$$

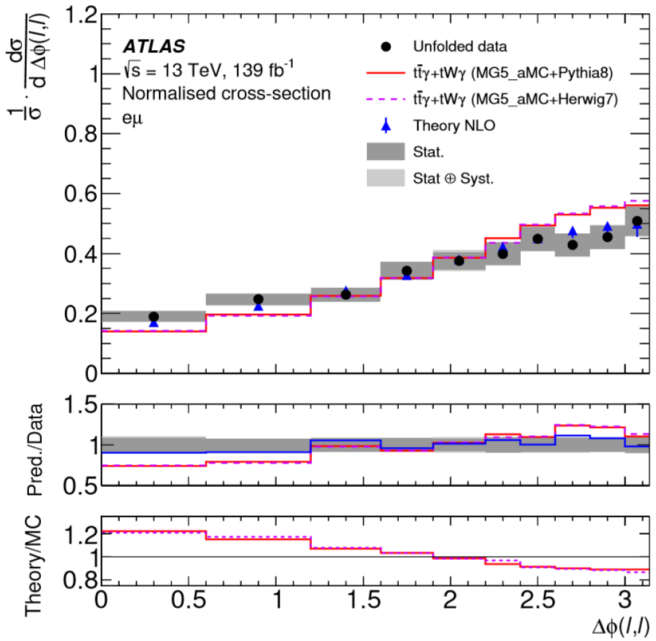
Good agreement within uncertainty!

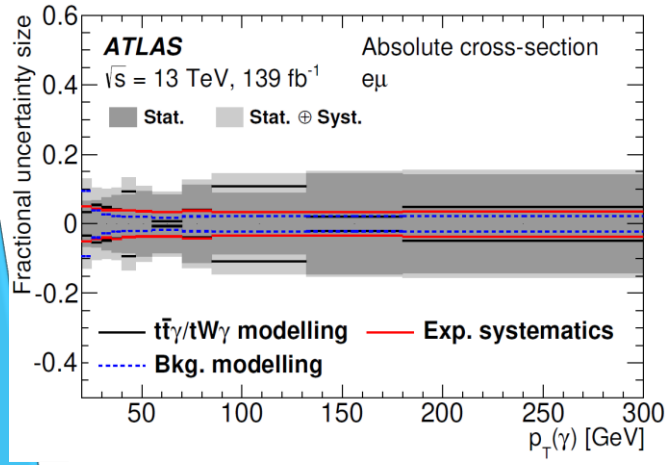
Category	Uncertainty
$t\bar{t}\gamma/tW\gamma$ modelling	3.8%
Background modelling	2.1%
Photons	1.9%
Luminosity	1.8%
Jets	1.6%
Pile-up	1.3%
Leptons	1.1%
Flavour-tagging	1.1%
MC statistics	0.4%
Soft term E_T^{miss}	0.2%
$tW\gamma$ parton definition	2.8%
Total syst.	6.3%

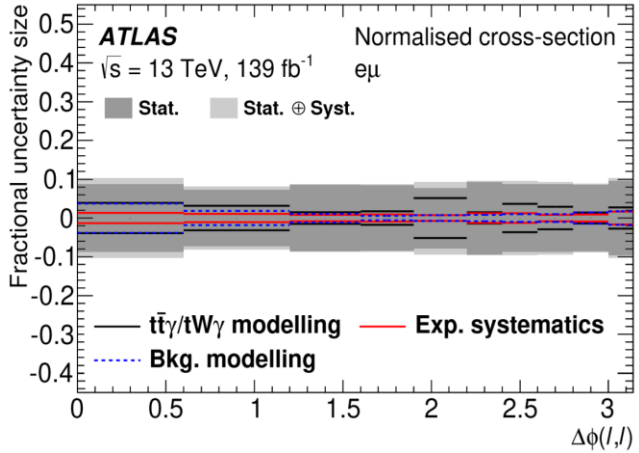
Differential results

- **Fiducial differential** (absolute and normalised) **cross-sections** are measured as functions of $P_T(\gamma)$, $|\eta(\gamma)|$, $\Delta R(l,\gamma)$, $\Delta\eta(l,l)$, $\Delta\Phi(l,l)$ using the **Iterative Bayesian Unfolding** method





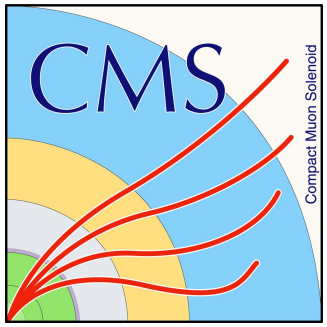




- The shape of the measured fiducial differential cross-sections is well described by the NLO calculation, while the LO MC simulation fails to describe such shape for some variables, such as $\Delta\Phi(l,l)$

- The precision of the measurements is dominated by the statistical uncertainties

- The systematic uncertainties of the measurements are dominated by the background and signal modelling



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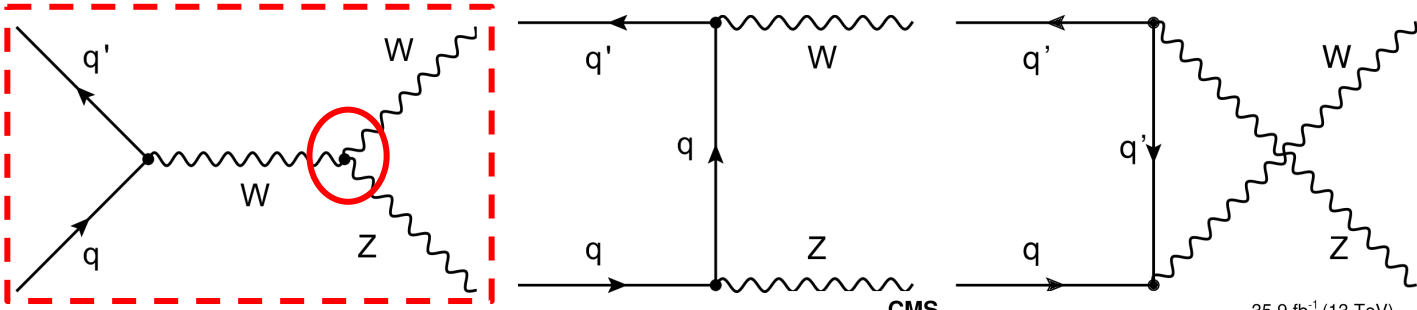
Measurements of the pp→WZ **inclusive** and **differential** production cross section and constraints on charged anomalous triple gauge couplings at **13 TeV**

Bárbara Álvarez González on behalf of the CMS Collaboration

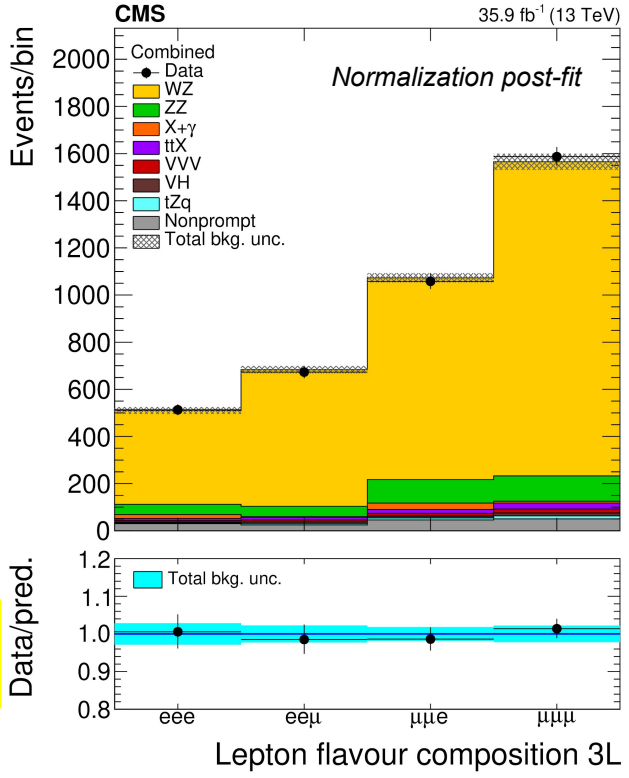
Motivation



- The production process pp→WZ is studied in the **trilepton** final state at **13 TeV**, using the full **2016** data set with a total integrated luminosity of **35.9 fb^{-1}** collected with the CMS detector **Reference:** JHEP 04 (2019) 122
- WZ associated production provides a unique test of the SM predictions for **trilinear** gauge couplings: unique probe of the **charged SM WWZ coupling**
- Deviations from the **SM predictions**, both in the total and differential cross sections, would indicate hints of **new phenomena**

Binned likelihood fit to the 4 flavor categories to extract the signal

Lepton ID is designed to reduce the non-prompt lepton in the selection



Total and fiducial cross section

The **inclusive cross section** is measured to be

$\sigma_{tot}(pp\to WZ)=48.09^{+1.00}_{-0.96}(stat)^{+0.44}_{-0.37}(theo)^{+2.39}_{-2.17}(syst)\pm 1.39\ (lumi)$ pb,

resulting in a total uncertainty of −2.78/+2.98 pb

Category	Fiducial cross section [fb]
eee	$63.7^{+3.8}_{-3.7}\,(stat)^{+0.6}_{-0.6}\,(theo)^{+5.3}_{-4.7}\,(syst)\pm 1.9\,(lumi)$
eeμ	$61.6^{+3.0}_{-2.9}\,(stat)^{+0.6}_{-0.5}\,(theo)^{+3.7}_{-3.3}\,(syst)\pm 1.9\,(lumi)$
e$\mu\mu$	$63.4^{+2.6}_{-2.6}\,(stat)^{+0.6}_{-0.5}\,(theo)^{+3.5}_{-3.2}\,(syst)\pm 1.9\,(lumi)$
$\mu\mu\mu$	$67.1^{+2.1}_{-2.0}\,(stat)^{+0.6}_{-0.5}\,(theo)^{+3.3}_{-3.0}\,(syst)\pm 1.9\,(lumi)$
Combined	$257.5^{+5.3}_{-5.0}\,(stat)^{+2.3}_{-2.0}\,(theo)^{+12.8}_{-11.6}\,(syst)\pm 7.4\,(lumi)$

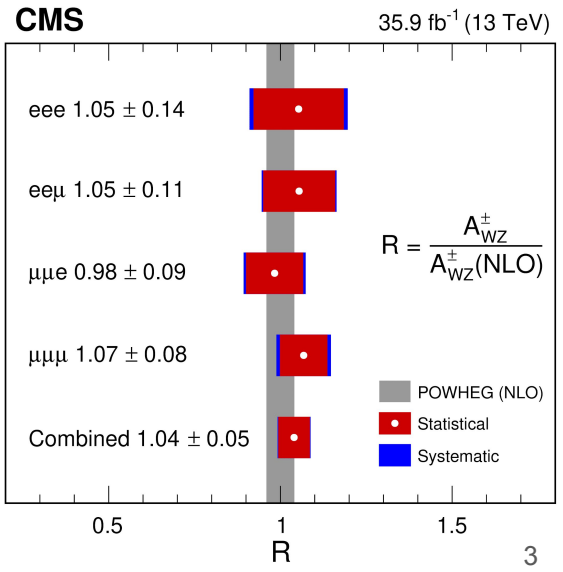
Result dominated by systematic uncertainties

Source	Combined	eee	eeμ	e$\mu\mu$	$\mu\mu\mu$
Electron efficiency	1.9	5.9	3.9	1.9	—
Electron energy scale	0.3	0.9	0.2	0.6	—
Muon efficiency	1.9	—	0.8	1.8	2.6
Muon momentum scale	0.5	—	0.7	0.3	0.9
Trigger efficiency	1.9	2.0	1.9	1.9	1.8
Jet energy scale	0.9	1.6	1.0	1.7	0.8
b-tagging (id.)	2.6	2.7	2.6	2.6	2.4
b-tagging (mis-id.)	0.9	1.0	0.9	1.0	0.7
Pileup	0.8	0.9	0.3	1.3	1.4
ZZ	0.6	0.7	0.4	0.8	0.5
Nonprompt norm.	1.2	2.0	1.2	1.5	1.0
Nonprompt (EWK subtr.)	1.0	1.5	1.0	1.3	0.8
VVV norm.	0.5	0.6	0.6	0.6	0.5
V H norm.	0.2	0.2	0.3	0.2	0.2
$t\bar{t}$ V norm.	0.5	0.5	0.5	0.5	0.5
tZq norm.	0.1	0.1	0.1	0.1	0.1
X+γ norm.	0.3	0.8	< 0.1	0.7	< 0.1
Total systematic	4.7	7.8	5.8	5.4	4.6
Integrated luminosity	2.8	2.9	2.8	2.9	2.8
Statistical	2.1	6.0	4.8	4.1	3.1
Total experimental	6.0	10.8	8.0	7.5	6.3
Theoretical	0.9	0.9	0.9	0.9	0.9

Fiducial results are extrapolated to the total WZ production cross section for **$60 < m_Z^{OSSF} < 120$ GeV**

The result is in good agreement with the **MATRIX NNLO** prediction

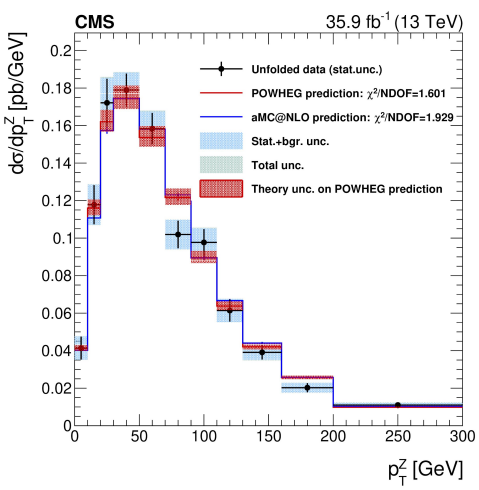
Total cross section can be split in **W^+Z** and **W^-Z** and measure the asymmetry statistically dominated

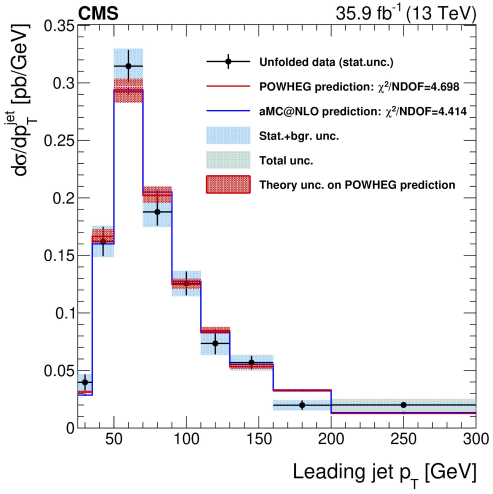


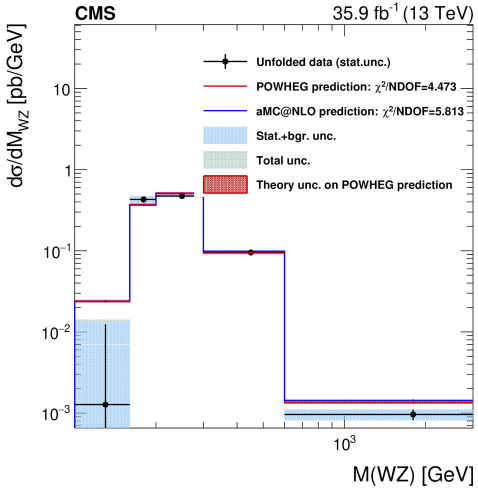
*theoretical prediction with **NNPDF3.0 NLO***

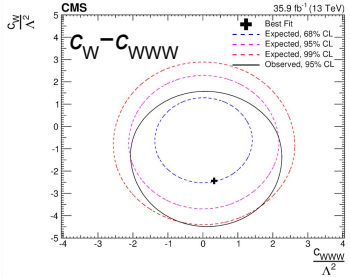
Differential Cross Sections & Anomalous Couplings

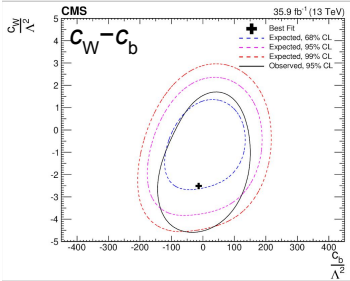
Differential cross sections are measured as a function of p_T^Z, leading jet p_T, and $M(WZ)$
Results are compared with predictions from the **POWHEG** and **MadGraph5_MC@NLO** generators

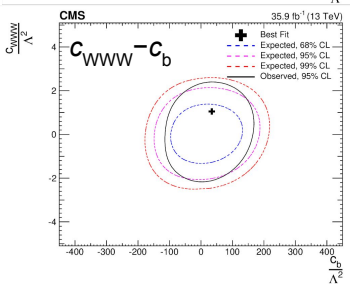












In addition, confidence intervals for anomalous triple gauge boson couplings are extracted for each of the possible one- and two-dimensional combinations of the anomalous couplings parameters, using the *M*(WZ) variable in a maximum likelihood fit

.

The confidence intervals obtained represent the most stringent results on the anomalous **WWZ triple gauge coupling** to date

Probing the prospective FCC-he sensitivities on the electromagnetic dipole moments of the top-quark

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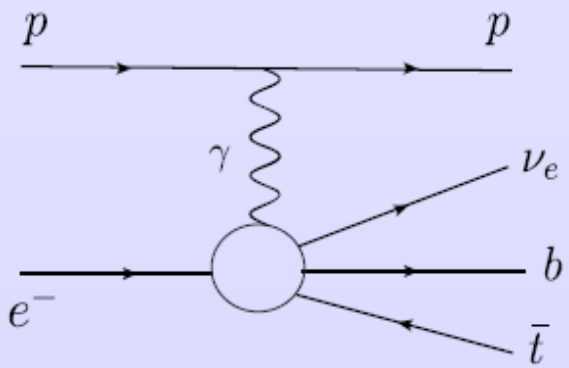
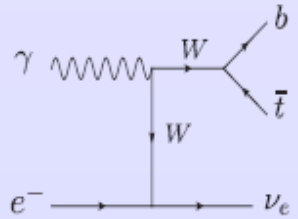
Abstract

The measurement of the top-quark anomalous electromagnetic couplings is one of the most important goals of the top-quark physics program in the present and future collider experiments. This would provide direct information on the non-standard interactions of the top-quark. We study a top-quark pair production scenario at the Future Circular Hadron-Electron Collider (FCC-he) through $e^- p \to e^- \gamma p \to \bar{t}\nu_e b p$ collisions, which will provide information about sensitivities on anomalous $\hat{a}_V$ and $\hat{a}_A$ couplings at a 95% C.L., and the possibility of probing new physics.

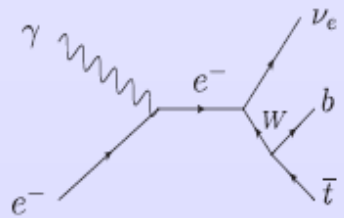
2 Single top-quark production via the process $e^-p \to e^-\gamma p \to \bar{t}\nu_e bp$

We study in a model-independent way the dipole moments of the top-quark through the process of single top-quark production $e^-p \to e^-\gamma p \to \bar{t}\nu_e bp$. Fig. 1 shows the schematic diagram for the process $e^-p \to e^-\gamma p \to \bar{t}\nu_e bp$ and the Feynman diagrams contributing to the reaction $e^-\gamma \to \bar{t}\nu_e b$.





(1)



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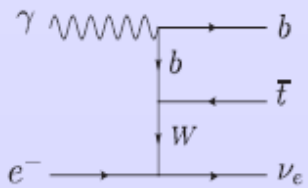

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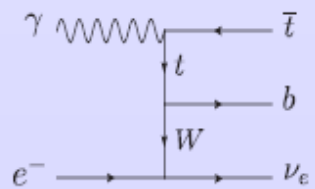

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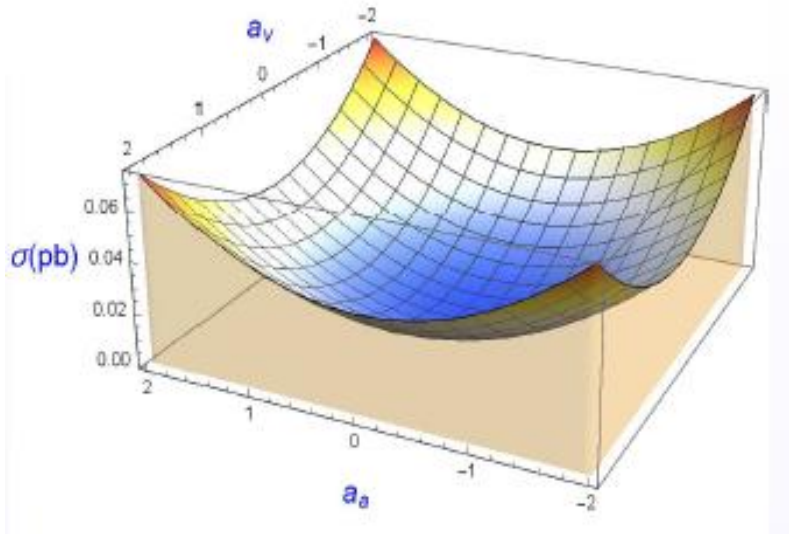
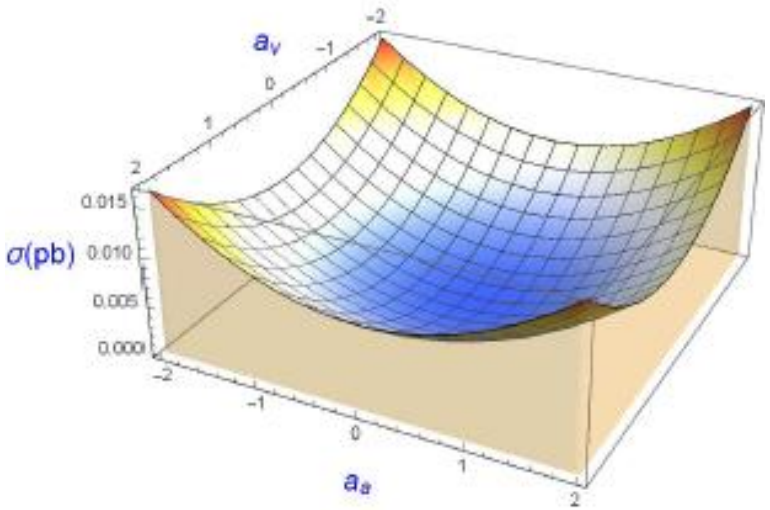
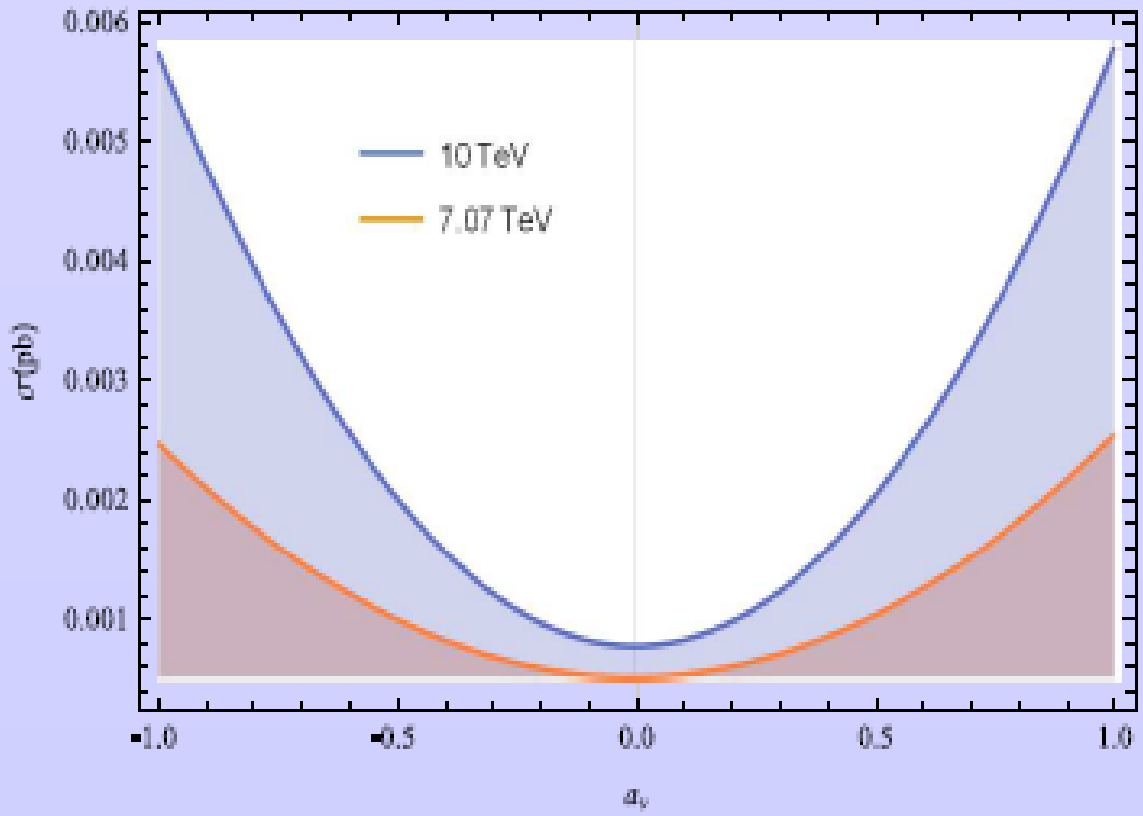




3 Cross-section of $e^- p \to e^- \gamma p \to \bar{t} \nu_e b p$



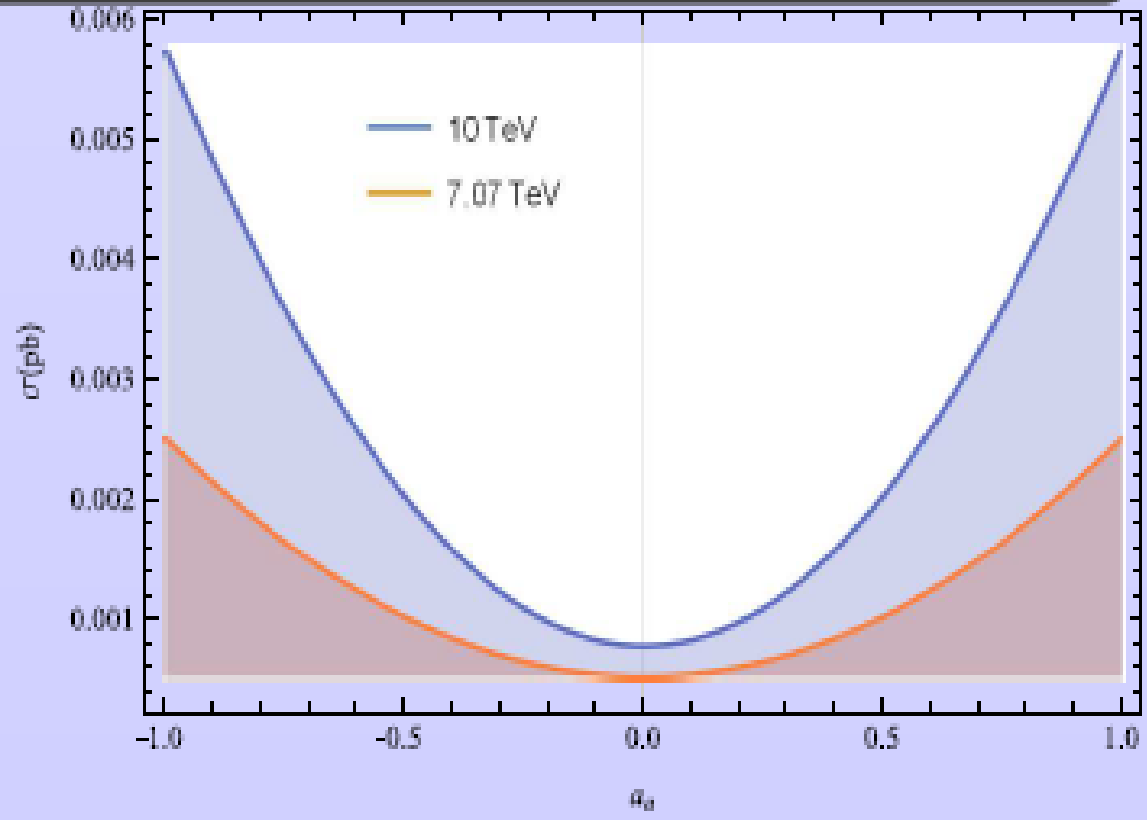


FIG. 2: The total cross sections of the process $e^- p \to e^- \gamma p \to \bar{t} \nu_e b p$ as a function of $\hat{a}_V$ and $\hat{a}_A$ for center-of-mass energies of $\sqrt{s} = 7.07, 10 TeV$ at the FCC-he.

4.2 Conclusion

We sensitivity study is cut-based, polarized electron beam and sources of systematic uncertainties such as leptons and b-jet identification, as well as in a $\chi^2(\hat{a}_V, \hat{a}_A)$ test to extract, enhance and optimize the expected signal cross-section and the sensitivity on $\hat{a}_V$ and $\hat{a}_A$. We find that the total cross-section $\sigma(e^-p \to e^-\gamma p \to \bar{t}\nu_e bp)$ has a strong dependence on the anomalous couplings $\hat{a}_V$ and $\hat{a}_A$, as well as with the center-of-mass energies of the FCC-he and therefore strong sensitivity estimated are obtained on $\sigma(e^-p \to e^-\gamma p \to \bar{t}\nu_e bp)$ and $\hat{a}_V$ ($\hat{a}_A$). Our results show that with the process $e^-p \to e^-\gamma p \to \bar{t}\nu_e bp$ at the FCC-he, the sensitivity estimated on the MM and the EDM of the top-quark can be significantly strengthened. At this time, the FCC-he is an excellent option for the electron-proton collider. It will be useful for any new physics study. Fortunately, future of e^-p colliders remain promising as it is a natural option like a hybrid between the hadron pp and linear e^+e^- colliders.

References

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