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Differential cross-section measurements of the production of four charged leptons in association with two jets using the ATLAS detector

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Introduction

The pair production of Z bosons in association with two jets ($ZZjj$ production) in proton-proton collisions is sensitive to a diverse range of physical phenomena.

- The purely electroweak (EW) $ZZjj$ process [1] is sensitive to the WWZ and $WWZZ$ weak-boson self-interactions, which arise due to the non-Abelian nature of the electroweak interaction and can be predicted by effective field theory(EFT) extensions to SM.
- Theoretical predictions for the strong $ZZjj$ process are very sensitive to the accuracy of the perturbative QCD calculations.

In this paper [2], differential cross-section measurements for the production of four charged leptons in association with two jets are reported. The EFT operators in dimension 8 are tested using VBS and tri-boson processes.

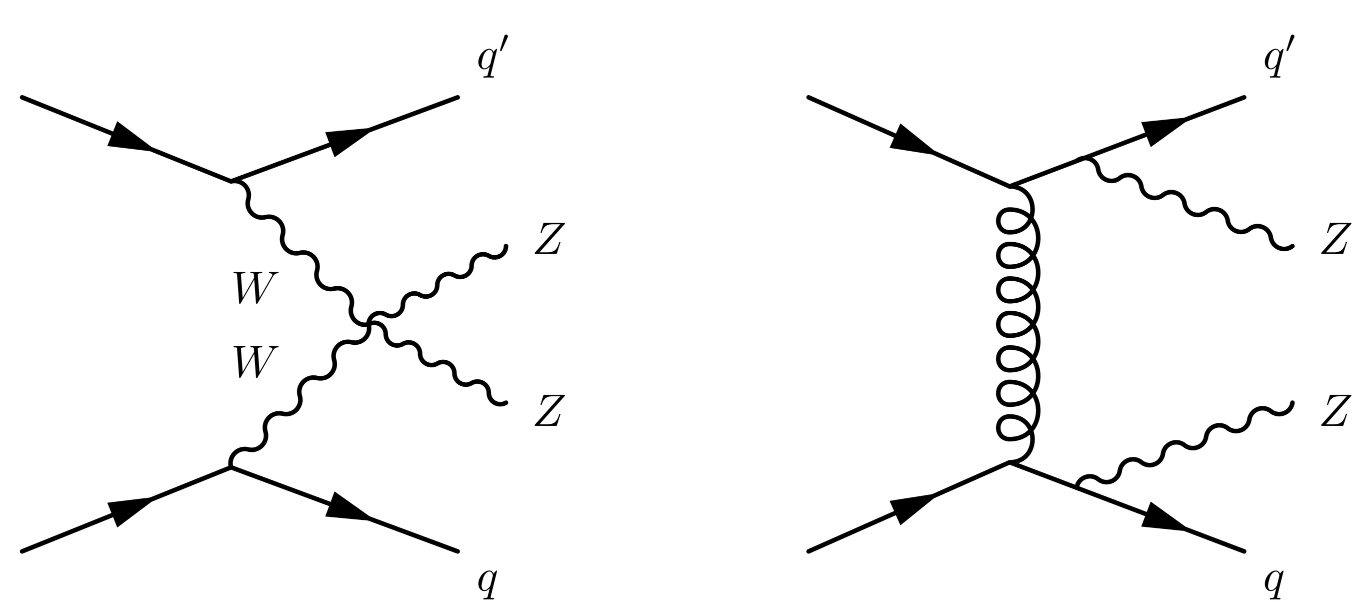

Figure 1: Example Feynman diagrams for EW $ZZjj$ production (left) and strong $ZZjj$ production (right).

Event selection

Events are required to have at least four(baseline) leptons and at least two jets. VBS-enhanced and VBS-suppressed regions are defined using the centrality of the four-lepton system,

$$\zeta = \left| \frac{[y_{4\ell} - 0.5(y_{j_1} + y_{j_2})]}{\Delta y_{jj}} \right|, \tag{1}$$

where $y_{4\ell}$ is the rapidity of the four lepton system and y_{j_1} (y_{j_2}) is the rapidity of the leading (subleading) jet in the dijet system.

Backgrounds that contain one or more non-prompt leptons arise from $WZjj$ production and tt production are estimated using a data-driven method. The yields are measured in a control region enriched in non-prompt leptons and extrapolated to the signal region using a scaling factor based on the non-prompt lepton efficiency.

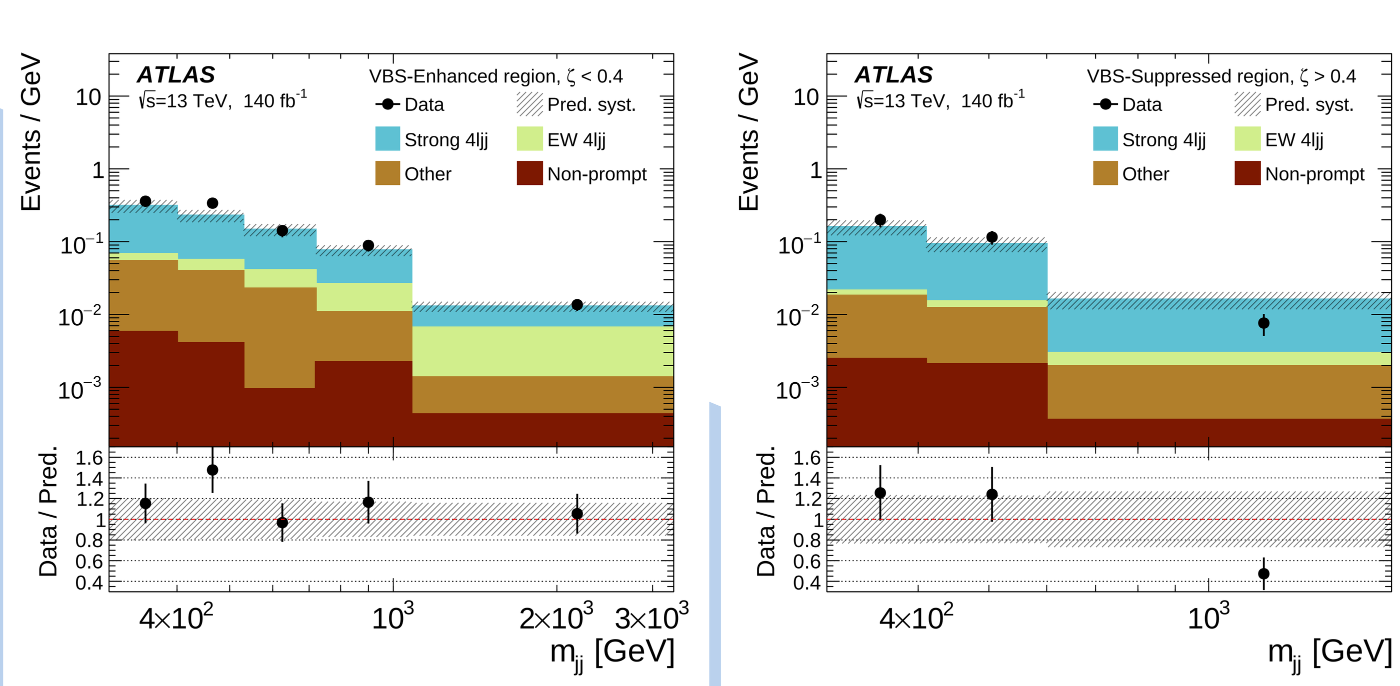

Figure 2: Predicted and observed yields as a function of m_{jj}, measured in the VBS-enhanced (left) and VBS-suppressed (right) regions.

Differential cross sections

The differential cross-sections for $ZZjj$ production are measured as a function of observables that collectively (i) characterise vector-boson scattering processes, (ii) probe the polarisation, parity and charge conjugation properties of the $ZZjj$ process, and (iii) probe the real emission of quarks and gluons from the $ZZjj$ process.

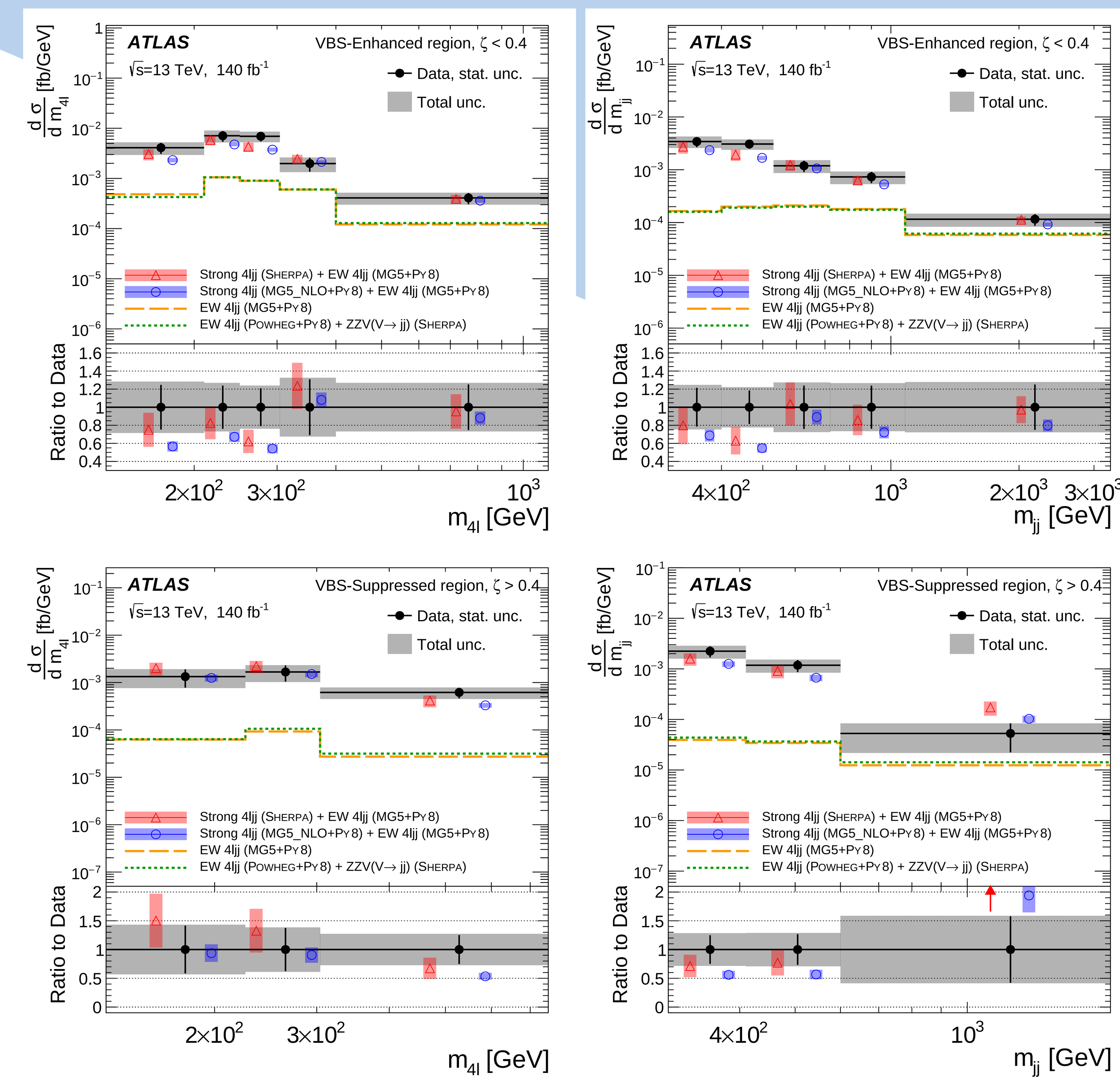

Figure 3: Differential cross-sections for inclusive $ZZjj$ production in the VBS-enhanced(top) and VBS-suppressed(bottom) regions as a function of m_{4l} (left) and m_{jj} (right).

Effective field theory interpretation

For measurements sensitive to vector-boson scattering, dimension-eight effective field theory(EFT) modelling can be a tool to search for signatures of physics beyond SM. The SM Lagrangian is extended with new interactions encoded in dimension-eight operators.

Wilson coefficient	$\lvert\mathcal{M}_{d8}\rvert^2$ Included	95% confidence interval [TeV^{-4}] Expected	Observed
$f_{T,0}/\Lambda^4$	yes	[-0.98, 0.93]	[-1.00, 0.97]
	no	[-23, 17]	[-19, 19]
$f_{T,1}/\Lambda^4$	yes	[-1.2, 1.2]	[-1.3, 1.3]
	no	[-160, 120]	[-140, 140]
$f_{T,2-9}/\Lambda^4$	...	...	...

Table 1: Expected and observed 95% confidence interval for the dimension-eight Wilson coefficients.

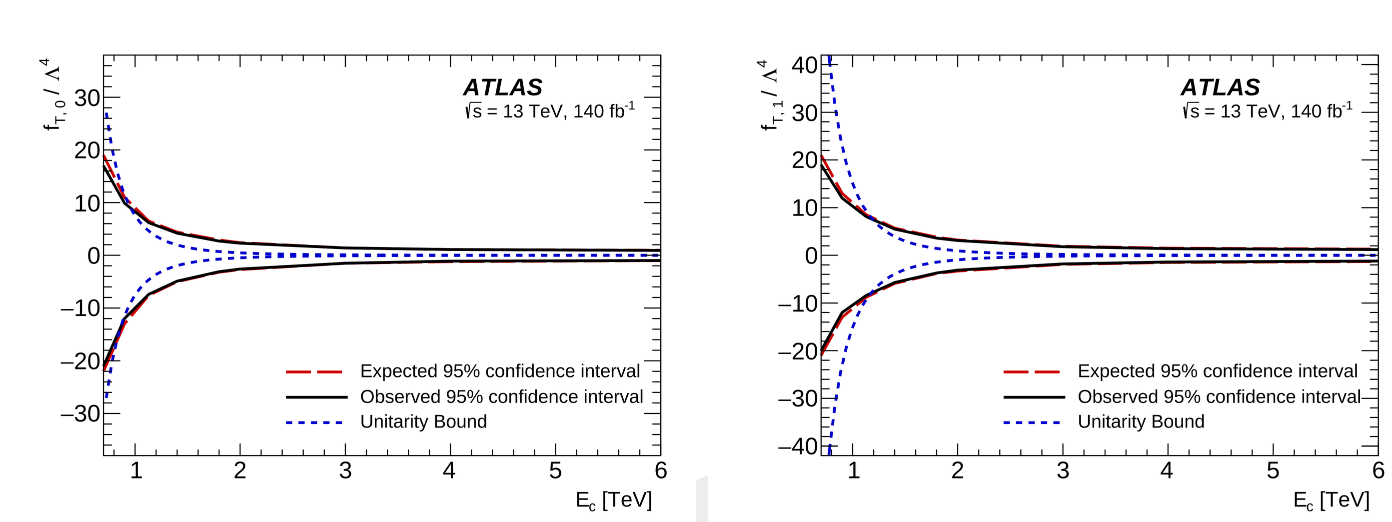

Figure 4: Expected and observed 95% confidence interval for the $f_{T,0}$ and $f_{T,1}$ Wilson coefficients as a function of a cut-off scale, E_c.

Conclusion

The differential cross-section measurements are consistent with Standard Model expectations. In the Standard Model effective field theory, constraints are set on anomalous weak-boson self-interactions induced by dimension-six and dimension-eight operators.

References

[1] Observation of electroweak production of two jets and a z-boson pair. *Nature Physics*, 19(2):237–253, 2023.

[2] Georges Aad, B Abbott, Kira Abeling, Nils Julius Abicht, SH Abidi, Asmaa Aboulhorma, Halina Abramowicz, Henso Abreu, Yiming Abulaiti, AC Abusleme Hoffman, et al. Differential cross-section measurements of the production of four charged leptons in association with two jets using the atlas detector. *Journal of High Energy Physics*, 2024(1):1–51, 2024.