Study of the top-quark coupling to the Z boson at the LHC

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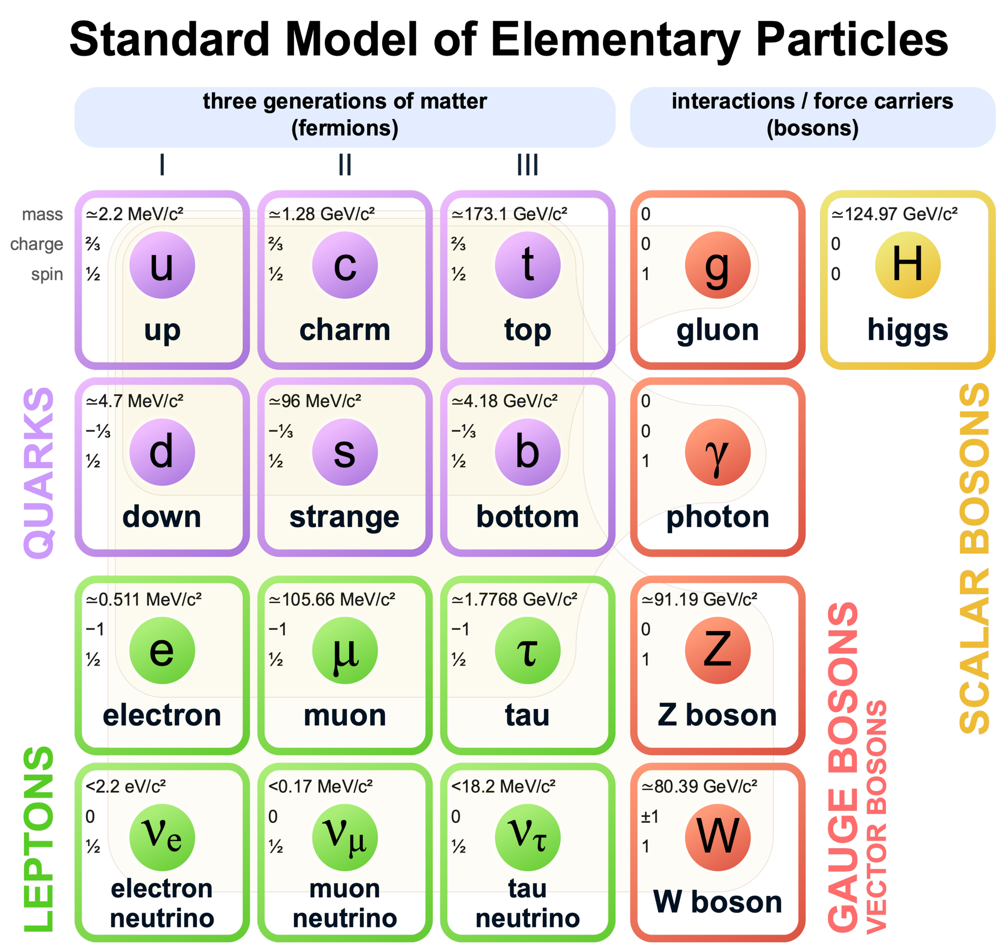
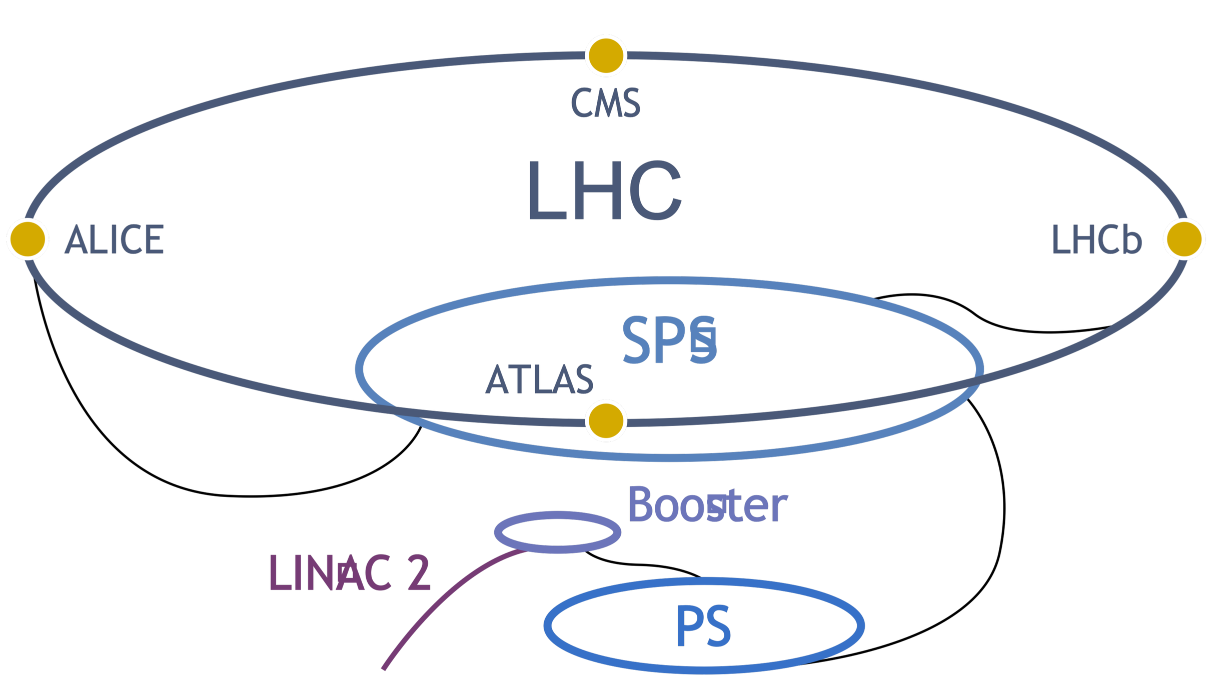
1 Introduction



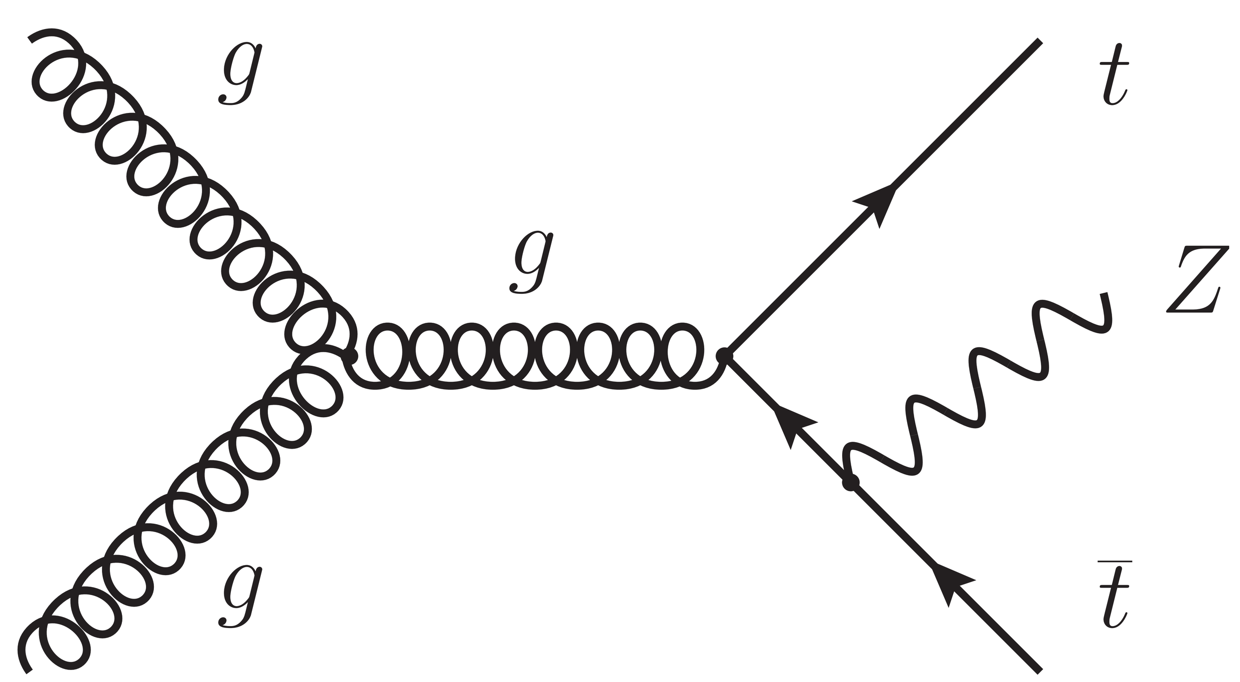
The Standard Model (SM) is a particle physics theory that describes the structure of matter. According to the SM all elementary particles are classified into two categories: bosons and fermions; and fermions are divided in two categories: quarks and leptons. The top quark is the third generation up-type quark of the SM and is the most massive elementary particle observed to date, approximately as heavy as a gold atom. Creating a top quark requires large amounts of energy and it is only possible through a particle accelerator known as the Large Hadron Collider (LHC). The LHC is the world's largest and most powerful particle collider and it lies in a tunnel 17 miles in circumference, 574 ft beneath the French-Swiss border near Geneva.



At the LHC, two beams of protons collide at extremely high energies leading to the systematic production of very short-lived heavy elementary particles such as the top quark.

2 Top-quark neutral coupling at LHC

With the LHC operating close to its maximal energy, this is an exciting historical moment for particle physics, as it provides the unique opportunity to perform measurements on rare processes in order to study the properties of the top quark with unprecedented precision. Among such processes, the associated production of a top-quark pair with a Z boson, represented below, is the production channel that is most sensitive to the neutral-current coupling of the top quark, commonly referred to as the *ttZ* vertex.



The objective of this study is to enhance the sensitivity to possible new physics effects on the top quark coupling to the Z boson at the LHC. For that purpose, new differential kinematic distributions defined in the center-of-mass of the top quark pair and Z boson system are introduced:

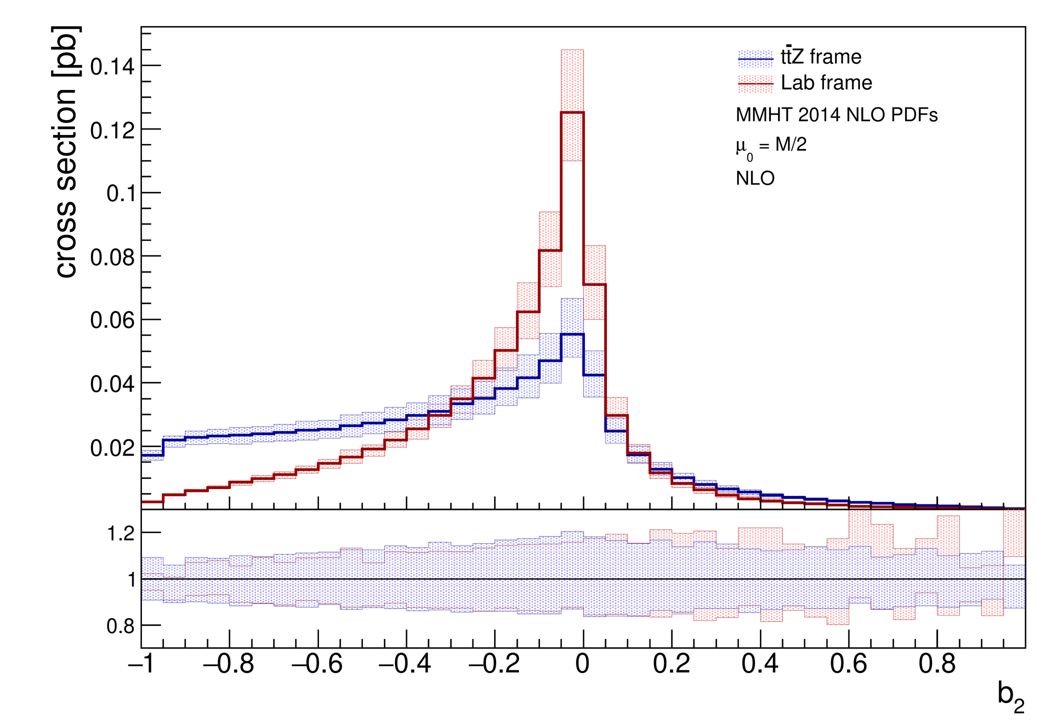
$$b_2^f = \frac{(\vec{p}_t^{\,f} \times \hat{k}_z).(\vec{p}_{\bar{t}}^{\,f} \times \hat{k}_z)}{|\vec{p}_t^{\,f}||\vec{p}_{\bar{t}}^{\,f}|},$$

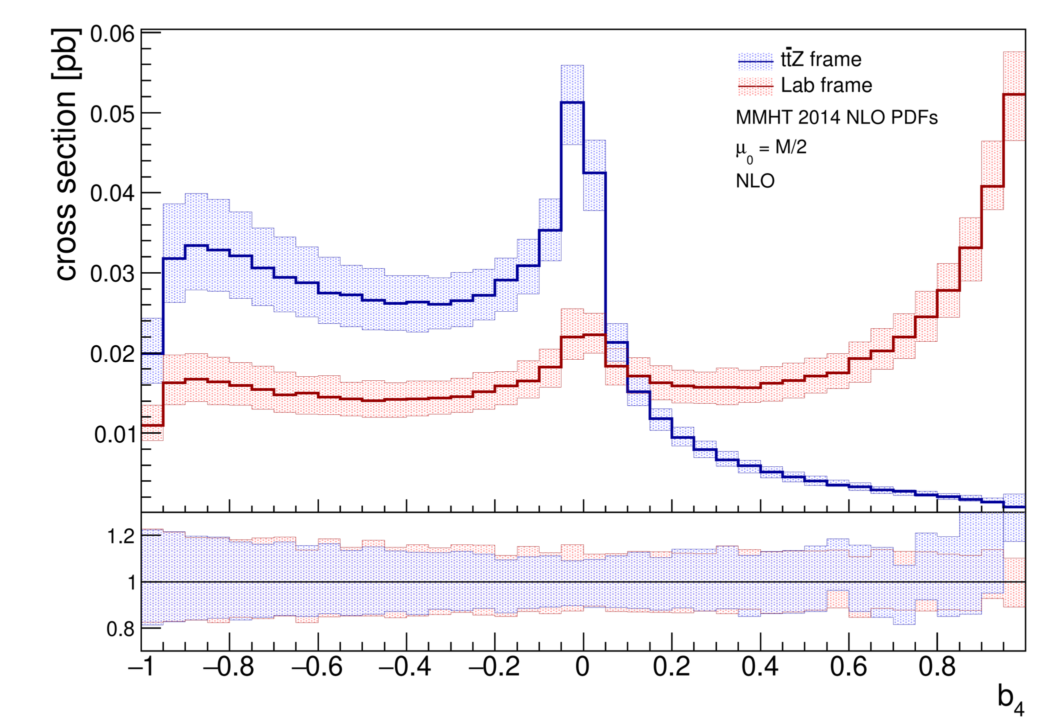
$$b_4^f = \frac{p_{t,z}^f \; p_{\bar{t},z}^f}{|\vec{p}_t^{\,f}||\vec{p}_{\bar{t}}^{\,f}|},$$

with f = LAB if the observables are evaluated in the laboratory frame and f = *ttZ* if the observables are evaluated in the *ttZ* rest frame. In order to probe possible new physics effects on the top-quark neutral coupling, the theoretical calculation of these differential kinematic distributions was performed with the highest possible precision. These calculations were carried out with the MadGraph5_aMC@NLO software code, assuming on-shell top quark, anti-top quark and Z boson particles, up to NLO in perturbation theory in QCD.

3 Results

The figures below show the theoretical results for the two differential distributions in the *ttZ* and lab rest frames.





4 Conclusion

- High precision theoretical calculations of differential kinematic distributions on the associated production of a Z boson with a top-quark pair at the LHC were carried out.
- These calculations will enable the determination of exclusion limits on beyond the SM top-quark anomalous contributions at a 95% Confidence Level. The proposed strategy will increase the sensitivity to new physics.

5 References

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- A. Broggio et al. PRD 96, 073005 (2017).
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- M. Aaboud et al. PRD 99, 072009 (2019).