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Studying the VBF Hjj and Hjjj Higgs Boson Production in QCD and EFT Theory

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The advent of the LHC has transformed hadron physics into a high-precision field, where large pT events at large angles are not uncommon. The search for physics beyond the Standard Model (SM) implies not only the inclusion of higher-order corrections to SM processes but also a change in the search strategy based on theoretical predictions [1]. At the same time, it is necessary to have universal and accurate simulations for different models, including not only QCD theory but also others, such as the effective field theory (EFT) [2].
The Higgs boson signal in 2012 was just the beginning of studying its properties: how strongly it interacts with other particles, to see the production and decay modes of the Higgs boson connected with the information on its couplings to elementary particles. The study of the vector-boson fusion (VBF) Higgs boson production processes is related to the accuracy of the electroweak coupling constant measurement, which is necessary to test the mechanism of spontaneous electroweak symmetry breaking. Therefore, it is extremely important to separate VBF events from other background processes, which are achieved by the signature of the VBF process: the Higgs boson is selected in association with two jets that are strongly separated in rapidity and form a two-jet system with a high invariant mass to suppress the contribution of the s-channel. Perturbative next-to-leading order (NLO) corrections to the QCD Higgs boson production event are considered, in which the two hardest jets have a rapidity of less than 4.5, which guarantees their detection in the opposite hemispheres [3].
We also study Higgs boson production via VBF in a three-jet association to match NLO-QCD calculations with the parton shower program. To describe the jet activity properties in VBF reactions, additional jets are used to suppress QCD backgrounds by central jet vetoes. Uncertainties due to parton shower effects are moderate for the third-jet distributions, in contrast to calculations for Higgs production in a two-jet association.
We carried out modeling of the VBF Higgs boson production cross sections with appropriate kinematic restrictions [3]. The process modeling within the framework of QCD with and without the NNPDF30_nnlo_as_0118 pdf function was considered. As a part of the search for physics beyond the SM, we compared the modeling of SM, MSSM, and NMSSM processes in the framework of Hjj cross-section calculations, presented in Table 1.
To understand the kinematics of the process and to ensure the correctness of the chosen kinematic constraints, simulations of the distribution of transverse momentum and rapidity were carried out in Fig. 1.
EFT with massive fields finds a broad range of applications in particle physics, including quantum chromodynamics, high spin particles, and dark matter candidates. This method is agnostic to how electroweak symmetry is broken, so the consideration of mass eigenstates allows the formulation of EFT to be much simpler and more convenient for phenomenological applications. In the framework of the Higgs effective field theory [2] we considered its link to a few scenarios of physics beyond the SM and received the corresponding production cross-sections [4].
We also presented a realization of Higgs boson production via VBF in association with three jets. Due to the low virtuality of the exchanged weak bosons, the tagging jets arising from the scattered quarks are located in the front and back regions of the detector, while the central region exhibits little jet activity due to the t-channel exchange. These features can be used to suppress QCD backgrounds with a large cross-section at the LHC. The inclusion of the kinematic constraints and the use of the MadGraph5_aMC@NLO computer program makes it possible to calculate the cross sections of the three-jet processes.
Comparison of the obtained data for three-jet events with the data for two-jet processes leads us to the conclusion about the same nature of the behavior of the obtained data (with minor exceptions), i.e.: a decrease in the cross-section of the process with an increase in the invariant mass of the two jets; an increase in the cross-section with an increase in the energy at the collider from 13 to 100 TeV; the largest value of the cross-section for the Nmssm model. In addition, we carried out modeling of the BSM theories and found that the

largest cross section is for the Nmssm model. Comparison with the EFT, which is popular recently due to its flexibility and universality, led us to the conclusion that the cross sections of the Higgs boson production calculated within the framework of this theory are larger for the EFT SM model compared to the SM QCD calculations. The kinematic distributions constructed by us confirmed a strict dependence on the transverse momentum value and indicated a large number of events at large angles.

Table 1. Production cross-sections for process pp hjj within three models with pdf function.

Fig. 1. Transverse momentum distributions for the pp $\longrightarrow$hjj process at 14 TeV (left) and for the rapidity for (right).

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