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Search for the vector-boson-fusion–produced Standard Model Higgs boson decaying to bottom quarks with the ATLAS detector

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Summary. — Since the discovery of the Higgs boson in 2012 several measurements have investigated the properties of this new particle, providing detailed information concerning its coupling to vector bosons. Conversely, little is known about the Higgs bosons coupling to fermions. In this context, more accurate studies must be conducted in order to further test the validity of the Standard Model: fermionic decay modes need Run-2 statistics to reach a high significance. In particular, the VBF $H \to b\bar{b}$ channel is extremely promising due to its particular topology. In this contribution a search for a VBF-produced Higgs boson in the bottom-pair decay channel conducted with the ATLAS experiment will be presented. Focus will be put on the results obtained from Run-1 and the improvements in Run-2.

1. – Introduction

The search for the Standard Model Higgs boson [1-4] is one of the main goals of the LHC physics program. The Higgs boson has been discovered in 2012 by the ATLAS [5] and CMS [6] Collaborations, and since then several analyses have focused on studying the properties of this new boson mainly in the bosonic sector, which provides clear signatures. Conversely, the study of its coupling with fermions is extremely challenging.

Such a particle can be produced at the LHC through several different mechanisms. Unlike the gluon-gluon fusion mechanism —which, albeit possessing the largest value for the expected production cross-sections, has too overwelming a QCD background to allow a measurement— the vector boson fusion (VBF) mechanism provides a peculiar event topology that needs to be exploited at trigger level: two central jets, stemming from the decay products of the Higgs boson; and two jets in the backward/forward region of the

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detector, coming from light quarks. Besides that, the expected dominant decay mode is to pairs of b-quarks, with a branching ratio of $\sim$58%.

This paper will summarize the results of a search for a Higgs boson in these channels obtained by analysing the data collected during the 2012 data-taking campaign (Run-1), and the improvements applied in the expectation of the analysis of data collected during the 2016 data-taking campaign (Run-2).

2. – Results from Run-1

Using $20.2\,\mathrm{fb}^{-1}$ of data from $8\,\mathrm{TeV}$ collisions, the ATLAS experiment put a limit of 4.4 times the cross-section times the branching ratio of VBF $H \to b\bar{b}$ production, with a yield of -0.8 ± 2.3 times the predicted value [7]. The accuracy of the measurement is limited by the systematic uncertainty, the main contribution coming from the background-modelling systematic errors that dominate over the statistical uncertainty.

3. – Analysis improvements

The Run-2 analysis follows the same strategy adopted for Run-1: a multivariate (MVA) approach, for a stronger signal/background discrimination power; and a simultaneous profile likelihood fit on the mutually exclusive MVA output variable's regions, for the signal extraction. However, several improvements have been introduced in order to address the main issues observed during the Run-1 analysis: low trigger acceptance and high background modelling systematic contribution.

In addition, the analysis will derive benefit from the combination with a complementary channel, which requires the presence of an additional impulsive photon. Such a search has already been published by the ATLAS Collaboration with the early data collected during 2015 and 2016 [8].

3˙1. *Trigger*. – The use of triggers aimed at targeting the VBF topology highly enhances the sensitivity to the signal. Unfortunately such triggers were deployed, during Run-1, only for a limited ammount of time ($\sim$20% of the data-taking period).

These VBF-specific triggers were revised and tuned for the new running conditions (higher center-of-mass energy and luminosity). Two triggers have been deployed for the whole 2016 data-taking period: one requiring at least four jets, two of which b-tagged, in the central region of the detector ($|\eta| < 2.8$); the other requiring two central b-tagged jets and one additional jet in the backward/forward region of the detector ($|\eta| > 3.1$).

3˙2. *Systematic errors*. – The impact of the sistematic contributions has been reduced by revising the background modelling strategy. Instead of using different functions for each region of the MVA's output, the number of floating parameters have been highly reduced by using a common function and a linear correction in each region. This strategy, in addition to an expected higher statistics, will greatly improve the description of the non-resonant background and thus reduce the background modelling uncertainty.

4. – Conclusions

The results and improvements on a search for a VBF-produced Higgs boson in the b-quarks pair decay channel have been presented. The analysis is expected to provide a significant improvement over Run-1 results.

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