Classification Between VBF and ggF Production Processes for Dark Photon Jet Searches

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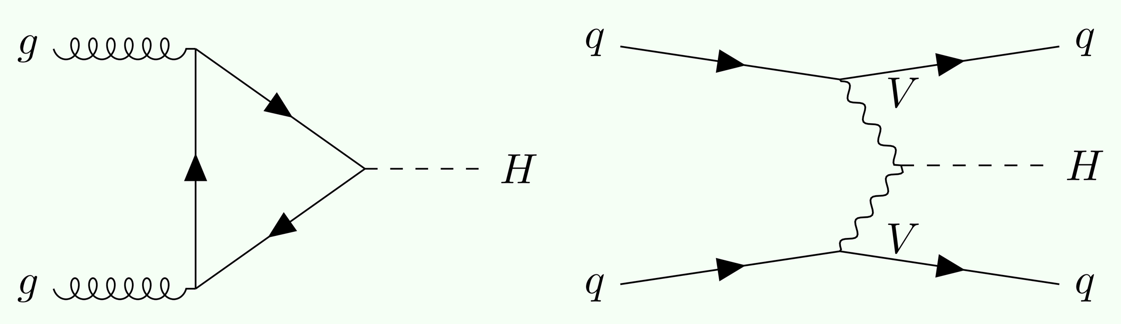
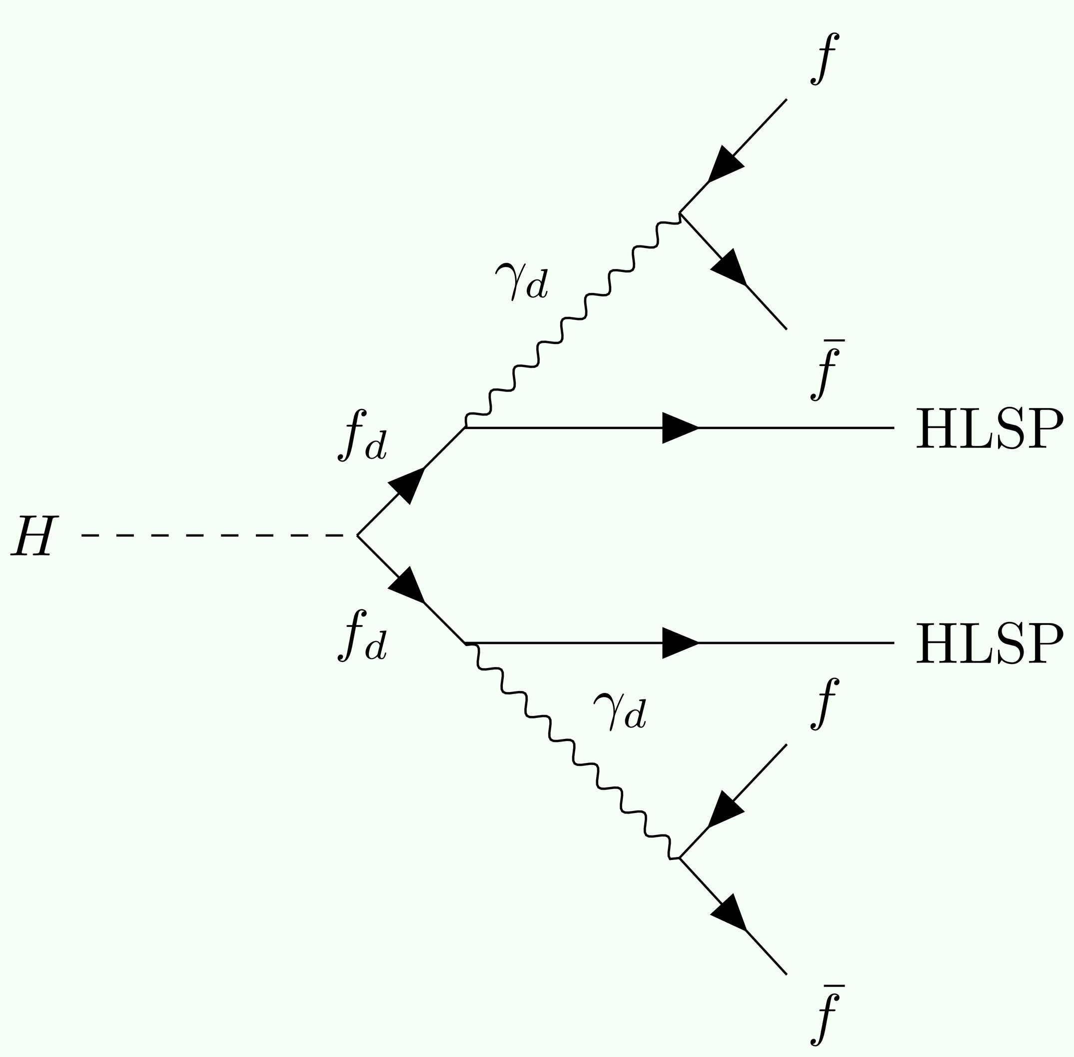
Motivation

The primary objective of this research is to improve the classification of dark photon production mechanisms coupled to a Higgs boson. Specifically, it aims to differentiate events where the Higgs boson is produced via gluon-gluon Fusion (ggF) from those generated by Vector-Boson Fusion (VBF). While the ggF mechanism is roughly an order of magnitude more likely than VBF and has been more extensively studied [1], the distinctive final state of VBF, characterized by two isolated high-energy jets, makes it more distinguishable from the background.



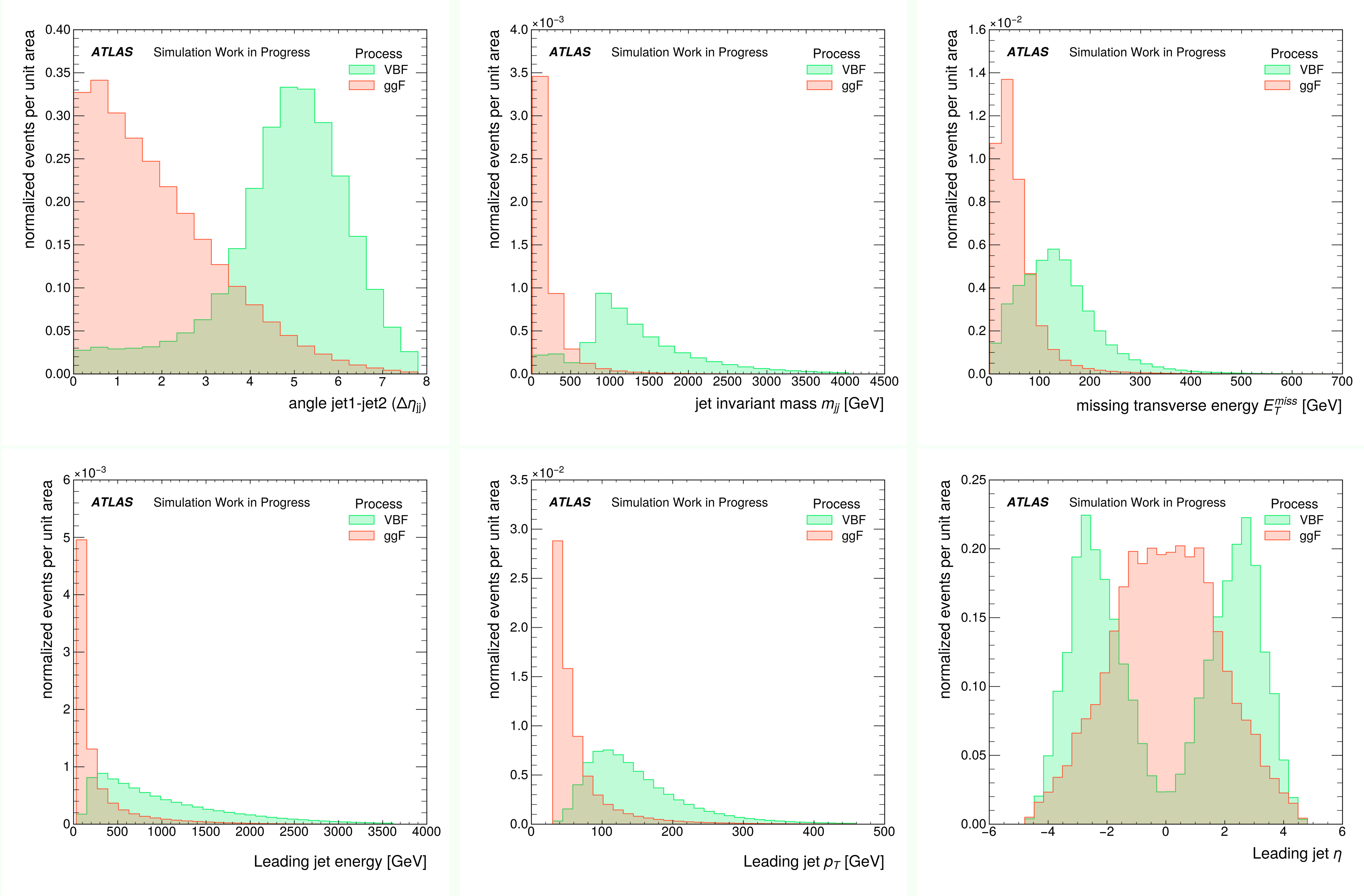
Model Used

The Falkowski-Ruderman-Volansky-Zupan (FRVZ) model [2] predicts that the Higgs boson couples to dark fermions (f_d), which then decay into dark photons (γ_d) and stable hidden light particles (HLSP). Finally, the dark photons decay into Standard Model fermions (f). The FRVZ model allows for the existence of long-lived particles, whose decay may be detected as jets of particles originating from outer regions of the detectors. These jets are known as Dark Photon Jets (DPJs).



Analyzed Data

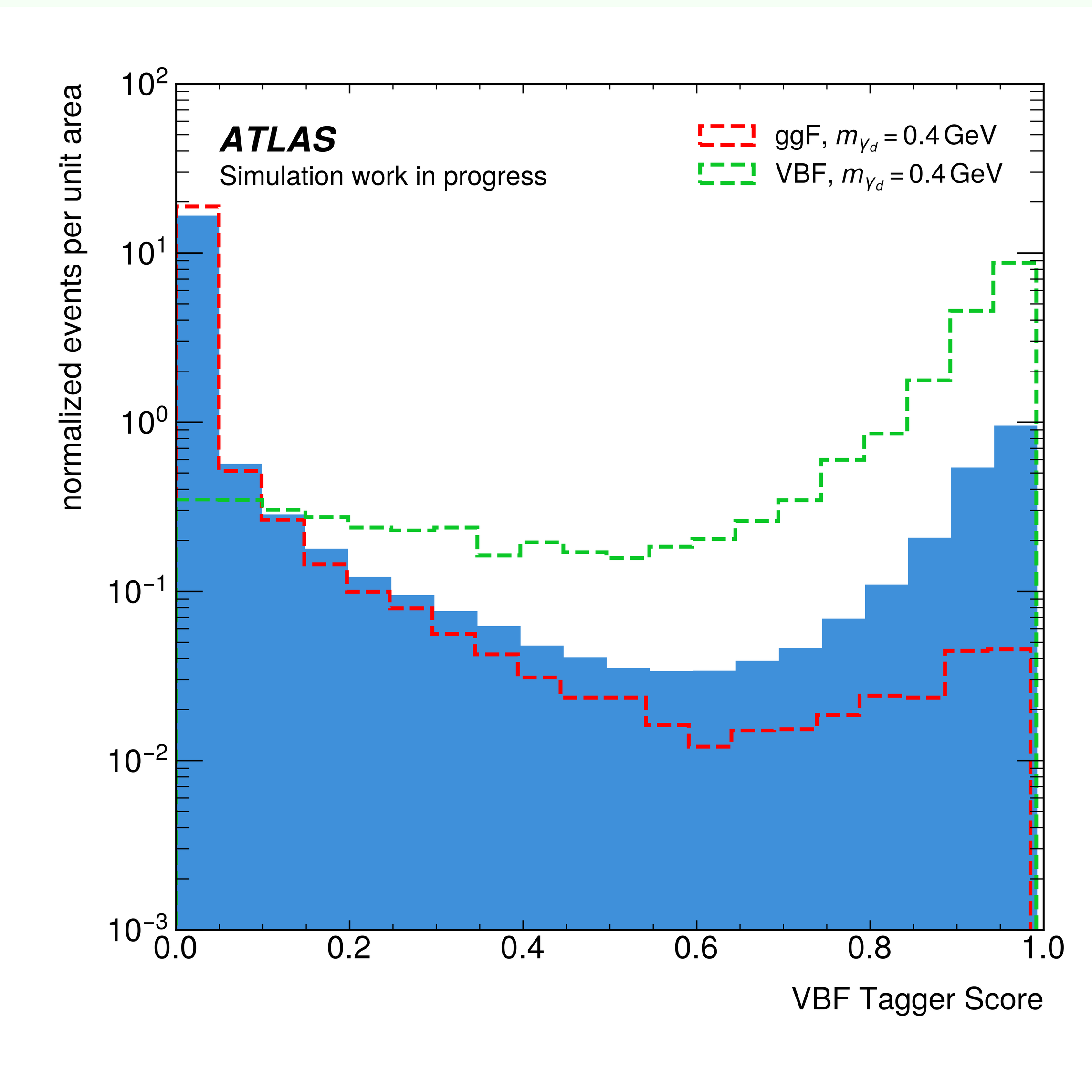
Simulated data from DPJ detections in the ATLAS detector during Run-2 were used, covering a wide range of possibilities. Simulations included varying masses of the Dark Photon ($m_{\gamma_d} \in [0.017, 15]$ GeV), masses of the dark fermion ($m_{f_d} \in [5, 45]$ GeV), dark photon decay times ($\gamma_d c\tau \in [2, 1000]$ mm), and masses of the hidden light stable particle ($m_{HLSP} \in [2, 10]$ GeV). The simulations provided multiple data points on the detected DPJs, with the most relevant variables displayed in the figures below:

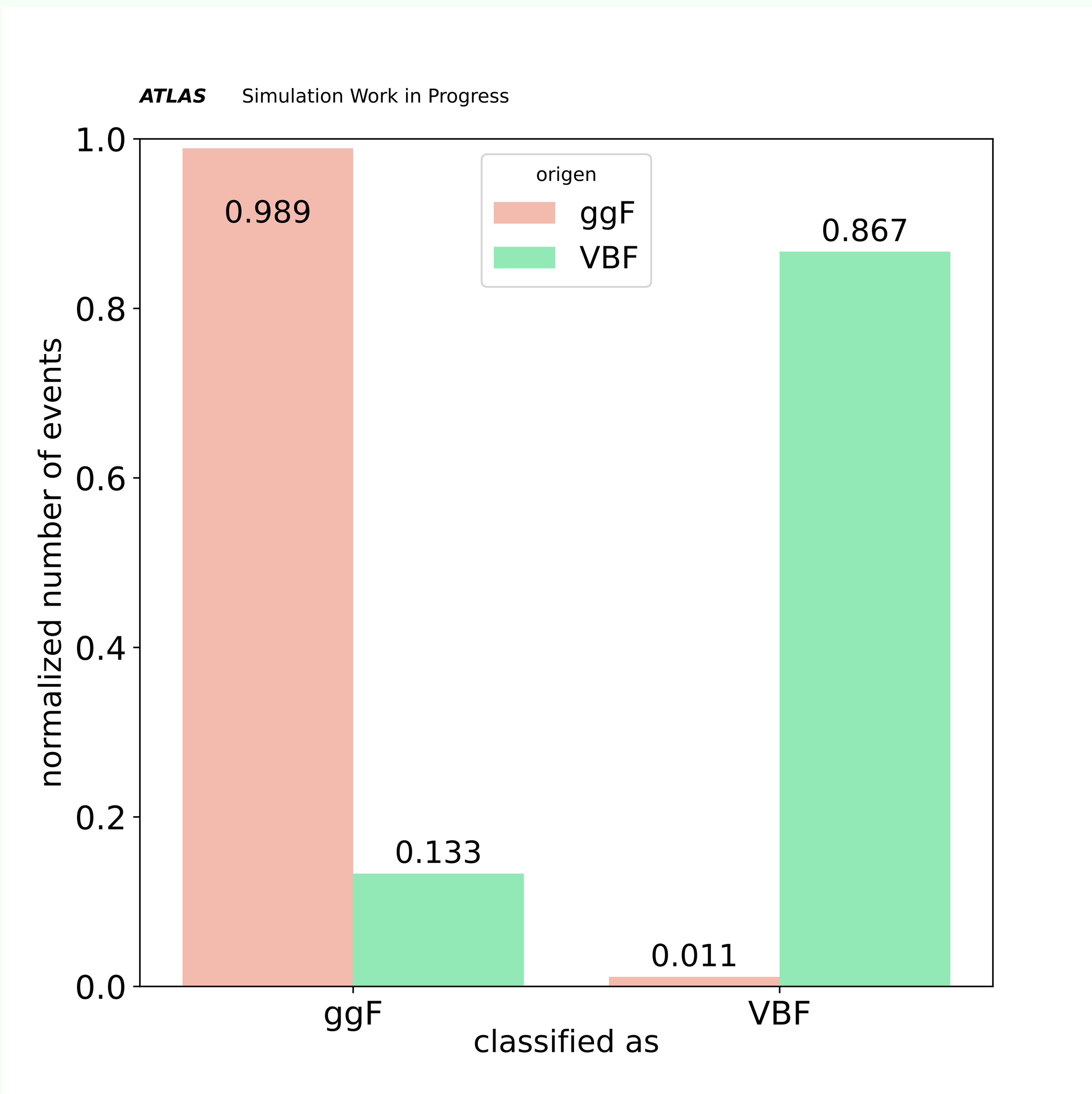


The subleading jet information was also used. Several differences can be observed between the histograms of VBF and ggF processes so is possible to apply a classification using Machine learning (ML) or Deep Learning (DL).

Results

ML and DL models were implemented to classify DPJs originating from ggF or VBF production mechanisms. The best results were obtained using XGBoost, the following figures show them:





The left graph represents a normalized probability distribution of events based on the classifier's score. The right graph shows the classification of ggF and VBF based on whether they were correctly classified. The successful classification rate just from cuts where approximately for ggF was approximately 99%, while for VBF it was around 87%.

References

[1] Search for light long-lived neutral particles that decay to collimated pairs of leptons or light hadrons in pp collisions at $\sqrt{s}$ = 13 TeV with the ATLAS detector
[2] Falkowski, A., Ruderman, J.T., Volansky, T. et al. Hidden Higgs decaying to lepton jets. J. High Energ. Phys. 2010, 77 (2010).

Acknowledgments

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