ID: MSCA-2020-JDHondt03

Title: Turning precise measurements at particle colliders into searches for new physics

Top quark, Higgs and heavy flavor physics with the CMS experiment at the LHC at CERN

With the discovery of the Higgs boson in 2012 at CERN, the Standard Model of particle physics marked its final triumph by adding a unique particle that relates to the masses of elementary particles. At the same time, this discovery opened a variety of new questions, which are potentially even more fundamental. In many ways the scalar or Higgs sector provides a unique window to search for new physics phenomena that would address these open questions (e.g. Excellence of Science project, https://be-h.be). **The interplay of the Higgs boson with the heaviest fundamental particle, the top quark, provides a powerful tool to explore phenomena at energy scales not yet directly achievable in particle collisions**. The Large Hadron Collider at CERN will continue to provide high-energy proton collisions in which Higgs bosons and top quarks emerge together. By confronting precise measurements of these processes with precise predictions, a novel search can be conducted into yet unknown territory.

Very recently, the interplay between the Higgs boson and the top quark is made concrete at the LHC in the collision processes in which both particles appear. Due to the decay of the top quark and the Higgs boson and due to the main features of the background processes, these studies involve the reconstruction of several heavy quarks in the final state, like bottom and charm quarks. A coherent understanding of proton collision processes resulting in a variety of final states, such as ttH, tHq, tt+heavy flavor, is key towards a solid interpretation in light of new physics. Additionally, the research will contribute to a better understanding of the interaction between the Higgs boson and bottom (or even charm) quarks.

The HEP@VUB team welcomed a long list of leaders of the heavy-flavour identification or b/c-tagging team at the CMS experiment pioneering for example the development of Machine Learning algorithms for the classification of bottom quark jets from other jets (e.g. JINST 13 (2018) 05) and the development of charm tagging algorithms. Turning precise measurements into searches evolves through the use of Effective Field Theories (EFT) which we frequently used for example for top quark FCNC searches. Moreover, taking into account our experience in the application of Machine Learning tools, we pioneered the novel use of Machine Learning tools to optimize searches using precise measurements in an EFT approach (e.g. JHEP 11 (2018) 131). Our involvement in top quark physics and related searches resulted in about 20 PhD theses.

The collision data to be collected by the CMS experiment during the LHC Run 3 will provide a unique opportunity to measure precisely the top-Higgs sector and related processes. Via an EFT approach and novel Machine Learning tools they can be transformed into powerful searches for deviations from Standard Model predictions. On the phenomenological front we collaborate frequently with the groups of Fabio Maltoni and Benjamin Fuks, while we have direct access to our major TIER-2 computing facility deployed in Brussels.

Supervisor: Jorgen.DHondt@vub.be

Research Group: https://www.iihe.ac.be/

To apply: https://www.vub.ac.be/en/european-liaison-office#apply-msca-if