Search for heavy stable charged particles with the CMS experiment and contribution to the upgrade of the silicon detector

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Successful with the discovery of the Higgs boson in 2012, the LHC scientific program has extended our knowledge of particle physics in several sectors. However, despite large efforts made by the collaborations, the LHC did not yet succeed in one of its main goal: observing phenomena beyond the Standard Model (SM) predictions. After having performed numerous searches of signatures motivated by models beyond the SM, the collaborations are trying to enlarge their coverage by giving emphasis on hypotheses which were not sufficiently covered. While most of the searches focused on promptly decaying new particles, we will focus on long-lived exotic particles.

The main subject of the PhD is devoted to the search of new particles with an electrical charge, a high mass (>200 GeV/c^2) and a lifetime large enough to render the particle stable at the scale of the detector (typically greater than few nanoseconds). Many well-motivated models can predict such particles. It is notably the case for the supersymmetry (SUSY) where new particles such as the gluinos, staus or charginos are likely to be long-lived in some SUSY models (e.g., gluinos in Split SUSY).

If such particles exist, due to their large mass, they will be produced with a speed lower than c (typically <0.9 c) and consequently their interaction with the active volume of the detector will lead to signals much larger than the typically ultra-relative particles. Then by combining the measurements of the track momenta and the ratio of dE/dx (energy loss per unit of length) obtained by the silicon strip detector, it is possible to estimate the mass of the searched particle which will be a striking signature. Moreover, the external layers of the CMS apparatus (muon chambers) have the ability to measure the time-of-flight with a resolution of about few ns. This measurement gives a direct estimate of the velocity and thus offer a unique feature for the searched signal.

An analysis of the Run II data (2016-2018) is ongoing and should lead to a publication in the coming months. The sensitivity already reaches up to about 2 TeV for the gluino mass (lower bound). However, such high mass particles would be produced with a very small velocity (as well as a low cross-section) and former studies have shown a drop of signal efficiency.

The first part of the PhD will be devoted to the preparation of the Run III data-taking and studies need to be performed in order to verify that the trigger and reconstruction efficiency will remain large enough. If needed, the trigger strategy will have to be revisited prior to data-taking and the particle reconstruction algorithms may be adapted if possible. Modern analysis techniques will be newly deployed in this search, using the expertise that the IPHC team build on the tracker other the past years.

While Run III will almost double the integrated luminosity with an increase of the centre-of-mass energy (from 13 to 14 TeV) beneficial to the production of high mass particles, the additional analysis improvements developed by the PhD student should improve the sensitivity to the searched signal substantially.

While the Run III will achieve the LHC program, a high luminosity phase will start in 2027 and is characterized by an increase of the instantaneous luminosity by a factor 2.5 and the integrated one should be decupled. However, in order to sustain the constraining LHC environment and to achieve the scientific goals, the detector requires to be upgraded. Among the most notable changes, there is the construction of an innovative silicon tracker with trigger capability (at 40 MHz).

IPHC plays a leading role in the construction of this future tracker, especially for the external part of its barrel. More than 2000 double-sided silicon strip modules will be assembled on mechanical structure before being tested, qualified and shipped to CERN for final integration. Part of the PhD program will be devoted to an instrumental activity related to the future CMS tracker which may include qualification tests.

Spin-off activities on the simulation or reconstruction sides related to the tracker could be envisaged as well as a preparation for search of heavy stable charged particles with the future detector. Indeed, while the tracker will deliver less dE/dx related information, a new timing detector will offer a ~ 30 ps resolution, thus the search of the considered signal has to be entirely revisited.