Search for Heavy Stable Charged Particles with the CMS detector at the LHC

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Heavy Stable (or quasi-stable) Charged Particles (HSCP) are predicted by various extensions to the Standard Model of the fundamental interactions among elementary particles. If this prediction reveals to be true, such particles should be produced at the Large Hadron Collider (LHC) and observable with the Compact Muon Solenoid (CMS) detector. Results of the search for slowly moving (or stopped) HSCP with an integrated luminosity of 4.7 fb^{-1} (0.9 fb^{-1}) is described.

1 Introduction

Heavy Stable (or quasi-stable) Charged Particles (HSCP) are predicted by various extensions to the Standard Model of the fundamental interactions among elementary particles. If this prediction reveals to be true, such particles should be produced at the Large Hadron Collider (LHC) and observable with the Compact Muon Solenoid (CMS) detector [1].

Given their large mass and the limited energy available in LHC collisions, the HSCP will be significantly slower than light ($\beta < 1$). Consequently, they will have an anomalously high ionization energy loss (dE/dx) that could be measured by the CMS Silicon Strip Tracker. A large fraction of these highly penetrating particles are also expected to reach the CMS Muon System, which could therefore be used to measure the time-of-flight (TOF) of the particles. The typical signature of an HSCP is therefore a high momentum track reaching the muon system that have an anomalously high dE/dx and TOF.

The interactions with matter experienced by a strongly-interacting HSCP, which is expected to form a bound state (R-hadron) in the process of hadronization, can lead to a change of its electric charge. A recent study on the modelling of the interaction of the HSCP with matter claims that certain species of HSCPs will always be neutral, and therefore undetectable, in the muon system. A complementary search, which does not require the HSCP to reach the muon system is therefore also presented. For low-β R-hadrons, the energy loss is sufficient to bring 20% to 40% of the produced particles to rest inside the detector volume. These stopped R-hadrons could decay seconds, days, or weeks later. These decays would be out-of-time with respect to LHC collisions and may well occur at times when there are no collisions or when there is no beam in the LHC machine. The observation of such decays, in what should be a quiet detector would be yet another unambiguous signature for the discovery of new physics.

2 Search for HSCP

This search for slowly-moving HSCP uses events from 7 TeV pp collisions produced by the LHC during the 2011 Run corresponding to an integrated luminosity of 4.7 fb^{-1} [2]. The events where selected using transverse missing energy (MET>150 GeV) and muon (muon pT>40GeV) triggers. The HSCP candidates are selected based on their pT, dE/dx and TOF. The absence of correlation between these three variables is exploited to predict the background in the signal region (high pT, high dE/dx and long TOF). Mass of the candidates, reconstructed from their momentum and dE/dx, is also used to further select the candidates. The Fig.1 [4] shows the reconstructed and predicted mass spectrum for a loose signal selection. A similar search not using the TOF information was also performed in order to be sensitive to HSCP being unobservable in the muon system. In both case, a good agreement between the observation and the prediction was found. A lower limit at the 95% confidence level (C.L.) on the mass of stable gluinos (stops) is set at 1091(734) GeV/c^2, using a conventional model of nuclear interactions that allows charged hadrons containing this particle to reach the muon detectors. A lower limit of 923 (623) GeV/c^2 is also set for a stable gluinos (stops) in a conservative scenario of complete charge suppression, where any R-hadron becomes neutral before reaching the muon detectors. Pair-Produced (GMSB-SP7) staus with mass lower than 306 (221) GeV/c^2 are also excluded at 95% C.L., see Fig.1.

3 Search for stopped HSCP

The search looks for the subsequent decay, of long-lived particles which have stopped in CMS, during time intervals where there were no pp collisions in the CMS experiment like during gaps between crossings in the LHC beam structure [3]. Such decays where recorded with a dedicated calorimeter trigger. In a dataset that is sensitive to an integrated luminosity of up to 0.9 fb^{-1}, depending on the particle lifetime, and a search interval corresponding to 168 hours of LHC operation. The background rate is estimated using data taken in 2010 with a low peaked luminosity and corresponding to more than 300 hours of LHC operation. No significant excess above background was observed, therefore 95% C.L. on gluino and stop production where set. These limits range over 13 orders of magnitude of particle lifetime as shown on Fig.2 [4]. These limits can be translated in limits on the mass of long-lived gluinos (stops) of 601 (337) GeV/c^2 for models in which the mass difference between the gluinos (stops) and the LSP is of 100 (200) GeV/c^2.

References

[1] The CMS Collaboration, "The CMS experiment at the CERN LHC",JINST,0803,S08004, 2008.

[2] The CMS Collaboration, "Search for heavy long-lived charged particles in pp collisions at $\sqrt{s}$ =7 TeV", CMS-EXO-11-022, arXiv:1205.0272, 2011.

[3] The CMS Collaboration, "Search for Stopped HSCP in pp collisions at $\sqrt{s}$ =7 TeV", CMS-PAS-EXO-11-020, 2011.

[4] The CMS Collaboration, "Public CMS Exotica Results", https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsEXO.

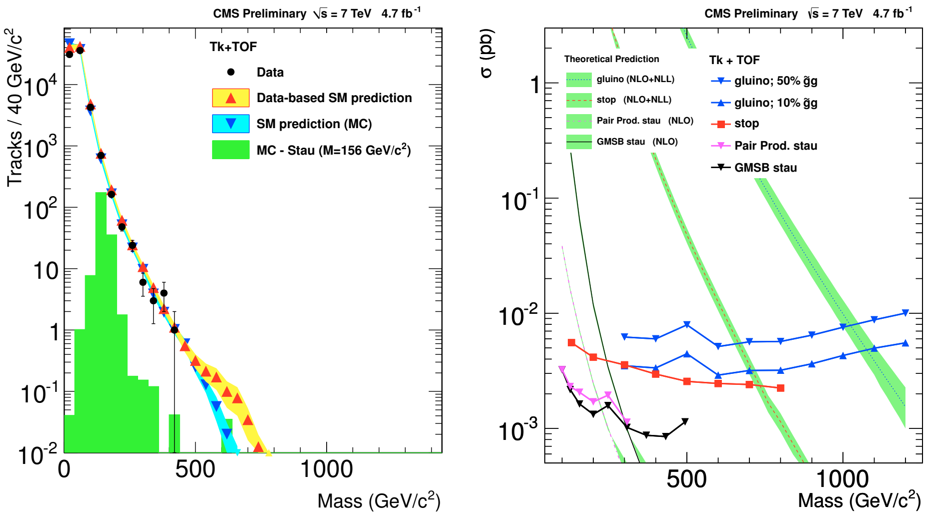

Figure 1: Left: Distribution of candidate mass for the loose selection of the tracker+TOF analysis. Shown are: data (black dots with the error bars), data-driven background estimate (red triangles) with its uncertainty (yellow band), simulated signal (green shaded histogram) and background prediction from MC using the same method as for data (blue inverted triangles). Right: Predicted theoretical cross section and observed 95% CL upper limits on the cross section for the different signal models considered: production of stops, gluinos, and staus; different fractions (f) of R-gluonball states produced after hadronization; standard and charge suppression (ch. suppr.) scenario for nuclear interactions experienced by R-hadrons. The uncertainties on the theoretical cross section are illustrated as bands around the central values.

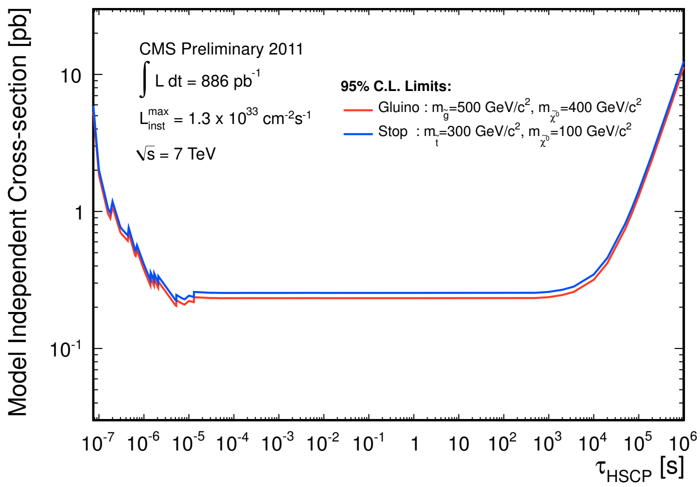

Figure 2: Observed 95%C.L. limits on HSCP pair production cross section times branching fraction times stopping probability, from the counting experiment. This is a reasonably model independent result. Separate curves are shown for gluino and stop, with masses detailed on the plot.