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Search for long-lived massive particles at CMS

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Several models of new physics, including split supersymmetry, predict the existence of a heavy particle, which lives longer than timescales of the bunch spacing of the LHC. We present the results of several searches for these particles, using various experimental techniques, such as time of flight and dE/dx. We present results of these searches based on data recorded with CMS in 2010 and 2011.

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1. Introduction

One of the main motivations of LHC experiments is to search for new massive ($\sim$ hundreds GeV) particles. While most searches focus on the prompt decay particles, some new physics also predict new heavy massive particles might be long-lived. If the $c\tau$ of these long-lived particles are longer than several *cm* and less than the detector scale at LHC, they behave as non-prompt decays inside detector. If $c\tau >$ detector scale, these new particles will mainly decay outside detector or readout time window. If charged, it undergoes at least ionization interaction inside a detector thus becomes directly detectable. These charged long-lived massive particles are called as Heavy Stable Charged Particles (HSCPs). HSCPs can be produced through direct pair production from Drell-Yan, cascade decay from heavier new particles or some new resonances. There's two categories of HSCP: lepton-like HSCP and R-hadron. Gauge Mediated SUSY Breaking (GMSB) stau is a well known example of lepton-like HSCP. R-hadron is formed by strongly produced HSCPs hadronized with SM gluon/quarks. Examples are gluino from Split Supersymmetry and stop from Minimal Supersymmetric Standard Model. Lepton-like HSCP behaves as a heavy muon with larger ionization energy loss due to slower β. R-hadron, in addition, also undergoes hadronic interactions inside a detector. As the heavy parton inside the R-hadron acts as spectator, only the SM gluon/quarks part (which carries only a tiny portion of the total kinetic energy) interacts, and this makes conversion to a different R-hadron species possible. HSCPs can possibly stop inside ($\beta <\sim$0.3) detector after losing all its kinetic energy due to ionization or additional hadronic interactions from R-hadrons, while HSCP with $\sim$0.4< $\beta <\sim$0.9 would slowly escape detector. Stopped HSCPs can be searched by looking for energetic hadronic jet from HSCPs decaying when beam is off or during beam collision intervals. For slowly moving HSCPs, measurements from delayed time of flight (T.O.F) and tracker dE/dx (ionization energy loss per path length) can be used to measure the β of the particle. Together with the momentum measurement, a mass can be measured from $p/\beta\gamma c$. The two searches are complimentary and can confirm each other once some signals show up. This proceeding reports 2011 results from the CMS [1] experiment at LHC, see Ref. [2] for a review on 2010 LHC results on HSCPs, Ref. [3] for a review on results from Tevatron experiments, and Ref. [4] for a comprehensive review on this topic for pre-LHC era.

2. Search for Stopped HSCPs at CMS

The search uses data recorded between April and July 2011, corresponding to 168 hours of trigger live-time LHC fills, with peak luminosity up to $10^{33} cm^{-2}s^{-1}$. 2010 data with peak luminosity of $10^{28} \sim 10^{32} cm^{-2}s^{-1}$ is used as background control sample. A dedicated 50 GeV jet trigger with no signals from beam position and timing (BPTX) monitors in a window of $\pm$1 Bunch Crossing (BX) around the triggered event is used. A 70 GeV jet energy requirement is applied offline, together with beam-related, cosmic and instrumental background rejections. Two analysis are performed: counting experiment and time-profile analysis. The later analysis is using the fact that for short lifetimes, a signal from a stopped HSCP decay is correlated in time with the collisions while backgrounds are flat in time. Therefore, it is possible to extract both background and signal contributions by fitting the observed events spectrum in time. In both analyses, no significant excess above expected background for any lifetime hypothesis is observed. The resulting model-

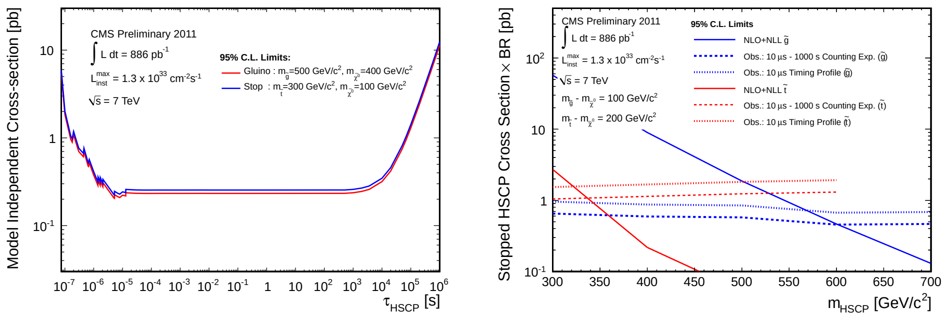

Figure 1: Left: model independent limits on production cross section times branching fraction times stopping probability for pair produced stops and gluinos, from the counting experiment. Right: limits on stop and gluino pair production cross section times branching fraction as a function of HSCP mass from both counting experiment and time-profile analyses.

independent limit on particle production cross-section $\times$ branching ratio $\times$ stopping probability is shown in the left panel of Fig. 1. The 95% C.L. limit presented is for gluino with $m_{\tilde{g}}$ = 500 GeV and $M_{\tilde{\chi}_1^0}$ = 400 GeV, and stop with $m_{\tilde{t}}$ = 300 GeV and $M_{\tilde{\chi}_1^0}$ = 100 GeV. Stop and gluino search results from both counting experiment and time-profile analysis are shown on the right panel of Fig. 1. Assuming a fixed visible energy M_{HSCP} - $M_{\tilde{\chi}_1^0} > 100$ GeV, $Br(\tilde{g} \to g + \tilde{\chi}_1^0)$ =100%, and $Br(\tilde{t} \to t + \tilde{\chi}_1^0)$ =100%, CMS is able to exclude $m_{\tilde{g}} < 601$ GeV at 95% C.L. for lifetimes from 10 μs to 1000 s. For stop, the corresponding mass limit is 337 GeV.

3. Search for Slowly Moving HSCPs at CMS

This search uses Muon and MET triggered events from 1.1 fb^{-1} data. Two analysis methods are used: Tracker+only and Tracker+TOF. The former is sensitive to R-hadrons being neutral in Muon detector, the latter increases sensitivity for tracks reconstructed as muons. Data-driven

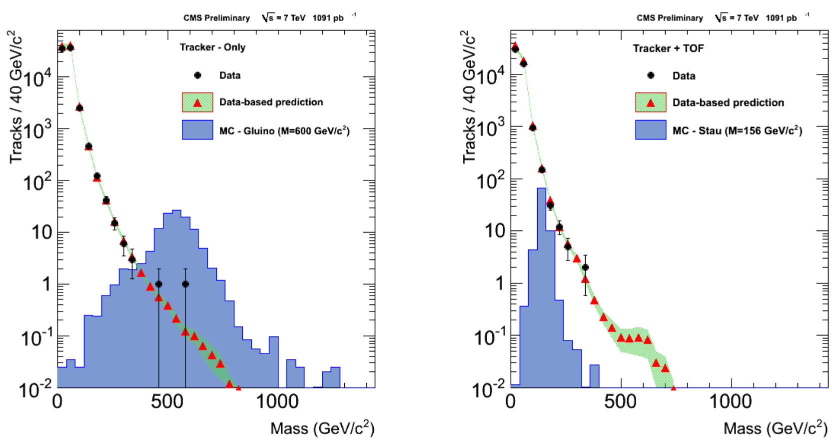

Figure 2: Mass distributions from Tracker+Only (left) and Tracker+TOF (right) Analysis.

way is used to estimate background, utilizing the non-correlation between dE/dx (I_{as}), $1/\beta$ and p_T.

Mass prediction is made from pseudo-experiment, using p and I_h PDFs obtained from non-signal region. Fig. 2 shows the mass spectrum after loose selection on I_{as}, $1/\beta$ and p_T for well reconstructed tracks. Then a counting experiment in mass window [M_{reco}- $2M_{reco}$, 2 TeV] is performed with optimized I_{as}, $1/\beta$ and p_T selection to get the best expected limit for each model mass point considered. As shown in Fig. 3, CMS obtained cross section limits for these models and scenarios: pair production of supersymmetric stop and gluinos; different fractions of gluino-gluon states produced after hadronization and R-hadron interaction in charge suppression (ch. suppr.) scenario.

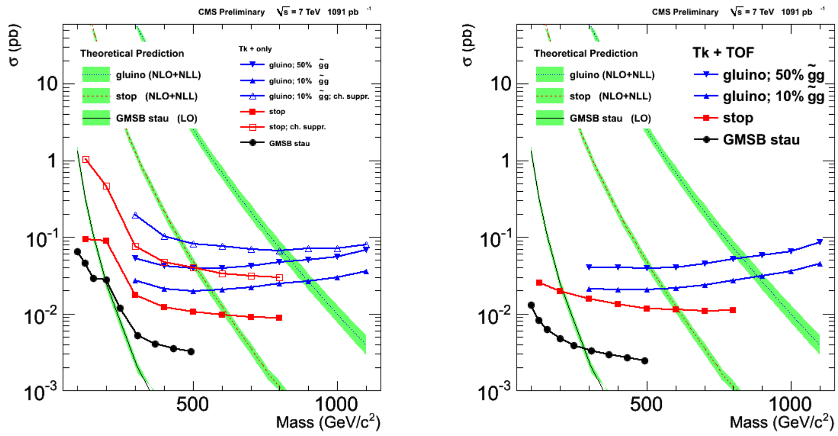

Figure 3: Observed cross section limits from the Tracker+Only(left) and Tracker+TOF (right) Analysis.

4. Conclusions

With $\sim 1\ fb^{-1}$ integrated luminosity, CMS searched both stopped and slow moving HSCPs. No significant excess are observed, and 95% C.L. mass limits of 601 GeV and 337 GeV are set for gluino with a fraction of 10% hadronizing to gluino-gluon states and stop respectively from the stopped HSCP analysis. From slowly moving HSCP analysis, mass limits are 899 GeV for Gluino, 620 GeV for stop, and 293 GeV for GMSB stau. Details of these searches are available in CMS public analysis summaries [5, 6]. These results have significantly improved over previous CMS published limits [7, 8] from 2010 data.

References

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