Search for long-lived massive particles at CMS

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Outline

• Introduction

• Searches for Heavy Stable Charged Particles at CMS
  ▪ stopped gluino/stop
  ▪ slowly moving gluino/stop/stau

• Conclusions
Introduction
Long-lived massive particle

Long-lived Massive Particles: charged or neutral
- $\sim$cm < $c\tau$ < detector scale: non-prompt decay inside detector
- $c\tau$ > detector scale: decay outside detector or readout time window. If charged $\rightarrow$ Heavy Stable Charged Particle (HSCP)

HSCP Production Mechanism:
- Pair production
- Cascade decay
• Lepton-like HSCP
  - GMSB stau
• R-hadron (strongly produced HSCPs hadronize with SM gluon/quarks)
  - Split Supersymmetry $\rightarrow$ gluino (hadronize to gluinoball, R-meson, R-baryon)
  - Baryogenesis motivated Minimal Supersymmetric Standard Model $\rightarrow$ stop
HSCP interactions in detector

Longer time of flight
- Non-relativistic \( \beta < 1 \)

Higher energy loss inside detector
- Lepton-like HSCPs behave like (heavy) muons with large ionization energy loss
- R-Hadron, also has hadronic interactions
  - Few GeV per interaction \( \rightarrow \) no showering in calorimeters
  - heavy parton acts as spectator, conversion to a different R-hadron species possible

Average R-hadron energy loss per hadronic interaction
HSCP detection

HSCPs can possibly stop inside ($\beta<0.3$) or slowly escape ($0.4<\beta<0.9$) detector

**Stopped HSCP**: look for energetic hadronic jet from HSCPs decaying when beam off or during beams collisions intervals

**Slowly moving HSCP**: measure $\beta$ from delayed time of flight (T.O.F) and tracker $dE/dx$ (ionization energy loss per path length)

- Can measure mass from $p/(\beta \gamma c)$

Two searches are complimentary and can confirm each other
Stopped HSCP Search
Stopped HSCP

Data Samples:
- 168 hours of trigger live-time LHC fills, peak luminosity up to $10^{33}$ cm$^{-2}$ s$^{-1}$
- 2010 data with peak luminosity of $10^{28} \sim 10^{32}$ cm$^{-2}$ s$^{-1}$, as background control sample

Selection:
- dedicated 50 GeV jet trigger with no signals from beam position and timing (BPTX) monitors in a window of ±1 Bunch Crossing (BX)
- 70 GeV jet energy requirement, beam-related, cosmic and instrumental background rejection
Stopped HSCP

Counting experiment and time-profile analysis are performed

<table>
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<th>Lifetime</th>
<th>( L_{\text{eff}}(pb^{-1}) )</th>
<th>Expected Bg</th>
<th>Observed</th>
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<tr>
<td>75 ns</td>
<td>4.3</td>
<td>0.11 ± 0.05</td>
<td>0</td>
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<tr>
<td>100 ns</td>
<td>12.5</td>
<td>0.35 ± 0.14</td>
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<td>1 ( \mu s )</td>
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<td>3.3 ± 1.3</td>
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<td>10 ( \mu s )</td>
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<td>10.1 ± 4.1</td>
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<td>30 ( \mu s \times 10^3 ) s</td>
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<td>10^4 s</td>
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<tr>
<td>10^5 s</td>
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<tr>
<td>10^6 s</td>
<td>7.5</td>
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</table>

1 LHC Fill

Counting Exp.
Stopped HSCP

- Gluino
  - $M_{\text{gluino}} - M_{\text{neutralino}} > 100$ GeV, $\text{Br}(\text{gluino} \rightarrow g + \text{neutralino}) = 100\%$, $m_{\text{gluino}} < 601$ GeV are excluded @95% C.L. for lifetimes from 10 $\mu$s to 1000 s

- Stop ← NEW Addition
  - For $M_{\text{stop}} - M_{\text{neutralino}} > 200$ GeV, $\text{Br}(\text{stop} \rightarrow \text{top} + \text{neutralino}) = 100\%$, $m_{\text{stop}} < 337$ GeV are excluded @95% C.L. for lifetimes from 10 $\mu$s to 1000 s

- Substantially extends our previous gluino limit (PRL 106 (2011) 011801) of 370 GeV

- 95% C.L. limits are also set for cross-section X BR X stopping efficiency to be interaction model independent
Slowly Moving HSCPs
Slowly Moving HSCP

1091 pb\(^{-1}\) data used with Muon and MET trigger
- Two analysis methods
  ✓ Tracker-only (discriminator \(I_{as}\) from tracker \(dE/dx\) measurement)
  ✓ Tracker+TOF (\(\beta^{-1}\) measurement from muon system in addition)
- Look for enhancement in high \(I_{as}\), high \(\beta^{-1}\) and high \(p_T\) region.
Slowly Moving HSCP

- Data-driven way to estimate background, utilizing the non-correlation between $I_{as}$ and $\beta^{-1}$ and $p_T$
- Mass prediction made from pseudo-exp, using $p$, $I_h$, and $\beta^{-1}$ PDF obtained from non-signal region
- Counting experiment in mass window $[M_{reco} - 2\sigma_{M_{reco}}, \ 2 \ TeV]$ is performed with optimized $I_{as}$, $\beta^{-1}$ and $p_T$ selection to get the best expected limit for each model mass point considered
Slowly Moving HSCP

95% C.L. mass limits are set for
- Cloud model interaction scenario
  - Gluino (10% $\sim$gg): 899 GeV, Gluino (50% $\sim$gg): 839 GeV
  - Stop: 620 GeV    GMSB Stau: 293 GeV ← NEW Addition
- Charge suppression interaction scenario
  - Gluino (10% $\sim$gg): 808 GeV, Stop: 515 GeV

Significant improvement over our previous gluino limit (JHEP 03 (2011) 024) of 311 GeV
Summary

• With ~1 fb\(^{-1}\) integrated luminosity, CMS searched both stopped and slow moving HSCPs
  – No significant excess observed
• 95% C.L. mass limits are set on
  – Gluino: 601 GeV, Stop: 337 GeV (stopped HSCP analysis)
  – Gluino: 899 GeV, Stop: 620 GeV, GMSB Stau: 293 GeV
    (slowly moving HSCP analysis)
  – Significant improvement over our 2010 data limits
• Results shown will be available
  https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsEXO

Stay tuned for more exciting exotica searches
Back Up