Searches for long-lived particles with the CMS detector

DPF 2017

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on behalf of the CMS Collaboration
Long-lived and Non-Conventional

- Searches for particles that don’t decay to SM particles within < 5 microns (approx.)
  - could be “stable”, could have displaced decay vertex, could have out-of-time signal
- Many models
  - hidden valleys, RPV SUSY, Split SUSY, magnetic monopoles
  - small coupling, small mass splitting
- Non-standard signal in detector
HSCPs
Heavy, stable, charged particles

- Massive (M > 100 GeV)
- Stable (does not decay within detector)
- Charged
- Unique signatures
  - large ionization in detector
  - long time-of-flight to outer detectors
- Lepton-like, R-hadron models
HSCP Searches
Two related searches

**Tracker $dE/dx$**
- Sensitive to HSCPs that don’t make it to muon system

**Tracker $dE/dx + muon TOF$**
- HSCPs traversing full detector

Mass calculated from $dE/dx$
HSCP Results
Observations consistent with expectation

Tracker dE/dx

Tracker dE/dx + muon TOF

EXO-17-036
Stopped Particles

- Energy loss can result in HSCP stopping within detector
- Particle decays at a much later time
- Search for
  - decay in calorimeter
  - decay in muon system
- Require decay when no colliding beams present
- Combined 2015+2016 datasets
- Backgrounds
  - cosmic rays
  - beam halo
  - detector noise
Calorimeter Signature
large energy deposition in calorimeter

- $E(\text{jet}) > 70 \text{ GeV}
- \text{Out of time with collisions (≥2 bunch crossings from proton bunches)}
- \text{Backgrounds scaled from vetoed events}
- \text{Two signal models: gluinos and stops}

<table>
<thead>
<tr>
<th>Period</th>
<th>Livetime (hrs)</th>
<th>Noise</th>
<th>Cosmics</th>
<th>Halo</th>
<th>Total</th>
<th>Observed</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015 control</td>
<td>-</td>
<td>$0.3^{+2.4}_{-0.3}$</td>
<td>$1.7 \pm 0.6$</td>
<td>0</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>2015</td>
<td>135</td>
<td>$0.4^{+2.9}_{-0.4}$</td>
<td>$2.6 \pm 0.9$</td>
<td>$1.1 \pm 0.1$</td>
<td>$4.1^{+3.0}_{-1.0}$ (the median is 6.2)</td>
<td>4</td>
</tr>
<tr>
<td>2016 control</td>
<td>-</td>
<td>$0^{+2.2}_{-0.0}$</td>
<td>$2.5 \pm 0.9$</td>
<td>0</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>2016</td>
<td>586</td>
<td>$0^{+9.8}_{-0.0}$</td>
<td>$8.8 \pm 3.1$</td>
<td>$2.6 \pm 0.2$</td>
<td>$11.4^{+10.3}_{-3.1}$ (the median is 17.4)</td>
<td>13</td>
</tr>
</tbody>
</table>
Calorimeter Signature

no excess observed

EXO-16-004

August 2, 2017

Searches for Long-lived Particles with the CMS Detector - T. Adams
Muon Signature

muons from decay

- Require two muon tracks
  - upper and lower part of detector
  - \( \Delta t = t_{\text{upper}} - t_{\text{lower}} \)
- Background: extrapolate timing difference
- Two signal models: gluinos and \( |Q| = 2e \)
- No events observed
Delayed Muons

Gluino

\[ |Q| = 2e \]

EXO-17-004

August 2, 2017

Searches for Long-lived Particles with the CMS Detector - T. Adams
Displaced Vertices

Decay to Jets

- Search for long-lived neutral particles decaying into one (or more jets)
- Several models
  - $X^0 \rightarrow jj$ ($X^0$ pair produced)
  - stop $\rightarrow b\ell$ ($\ell = e, \mu, \tau$) (stop pair produced)
- Displaced jet tagging
- Require 2 or more tagged jets
Displaced Jets

No excess found

- $N_{\text{tag}} = 2$
  - Observed: 1 event
  - Expected: $1.09 \pm 0.16$

- $N_{\text{tag}} \geq 3$
  - Observed: 0 events
  - Expected: $(4.9 \pm 1.0) \times 10^{-4}$

EXO-16-003
Searching Far and Wide…

Summary

• CMS has performed a wide range of searches for long-lived and non-conventional signatures
  – displaced leptons, delayed photons, disappearing tracks, fractionally charged particles, multiply charged particles
• Signature based searches offer significant discovery potential
• Challenging analyses
• New techniques under development
• http://cms.cern/