Searches for long-lived particles and other unconventional signatures at CMS

Francesca Ricci-Tam on behalf of the CMS collaboration
Why long-lived particles?

- BSM searches at LHC have not found anything yet
- Important to also consider models with long-lived particles (LLPs) that may be escaping traditional search methods
- Summary of recent CMS LLP search results
- What kinds of topologies are we hunting for, and how?
Stopped particles

- LLPs that lose their kinetic energy traversing detector material and sit in the detector until they decay
- Search for decay signatures outside collision times
  - LL gluino→qqχ₀ or qqχ₀ (calorimeter search)
  - LL gluino→qqχ₀, χ₀→μ⁺μ⁻χ₀; LL MCHAMP→μ⁺μ⁻ (muon search)
- Calorimeter search: no collision vertices, few hits in muon segments, use timing and topological info to reject calorimeter noise
- Muon search: reject events with downward-traveling muons
- No excess observed
- Limits shown for muon search (top right) and calorimeter search (bottom right)
Heavy stable charged particles (HSCPs)

- Heavy charged LLPs with $\beta=v/c < 0.9$
- Identifiable by high dE/dx or by longer time of flight (TOF)
- Hadron-like HSCPs (split SUSY): gluinos or top squarks, mass 300-2600 GeV

- Lepton-like HSCPs (mGMSB): staus, mass 100-1600 GeV
- DY production of HSCPs with arbitrary charge $|Q| \geq e$, mass 100-2600 GeV
- No excess observed
Summary: gluino searches at CMS

Limits for gluino mass vs lifetime

HSCPs, stopped particles, and jets + missing energy searches
Inclusive displaced jets

- Dedicated trigger properties: jets with < 3 prompt tracks, ≥1 track with IP2D > 5σIP2D
- Displaced jet tagging variables: $\alpha_{\text{max}}$, $\hat{P}^{2D}_{\text{sig}}$, $\hat{\Theta}_{2D}$
- Distances probed: $c\tau$ (1-1000 mm)
- Limits shown for $X^0X^0\rightarrow$jet-jet and top squarks→$b$+lepton models
- No excesses observed
Displaced leptons

- LLP → eμ can occur in displaced SUSY: RPV provides LSP decays to SM particles
- Leptons required to have large transverse displacement $d_0$ from primary vertex
- $c\tau = 0.1$ cm to 100 cm: no excess observed above background
- Limits set for top squark mass vs lifetime
Disappearing tracks

- AMSB: $\chi^\pm \rightarrow \chi^0 \pi^\pm$ ($\chi^\pm$ has track; low-momentum $\pi^\pm$ means reconstruction is not successful $\Rightarrow$ the track “disappears”)
- Disappearing track: missing hits in outer tracker layers, low/no calo deposits, no hits in muon tracker
- $\chi^\pm$ lifetime $\approx O(1 \text{ ns})$
- High-momentum track: $> 2$ missing outer hits in tracker, calorimeter energy $< 10$ GeV
- No excesses observed; limits set on mass and lifetime of $\chi^\pm$
Conclusions

- Large parameter space still left to explore for models with LLPs
- What topologies should we be searching for?
- In what clever ways can we exploit the data we get from our detector?
- How can we generalize our searches to cover most ground?
- Let’s keep the discussion going!
BACKUP
Light bosons to dimuons

- 2D likelihood template for $m_{1\mu\mu}$, $m_{2\mu\mu}$
- NMSSM benchmark
  - $h_1 \rightarrow a_1a_1 \rightarrow 4\mu$
- Dark SUSY benchmark
  - $h \rightarrow n_1n_1 \rightarrow 2n_D 2\gamma_D$; each $\gamma_D \rightarrow 2\mu$

- Clean final state
- NMSSM: $m_{a_1} 0.25-3.55$ GeV, $m_{h_1} 90-150$ GeV
- Dark SUSY: $m_{\gamma_D} 0.25-8.5$ GeV
- Weak model dependence allows interpretations in other contexts as well

CMS Preliminary 2.8 fb$^{-1}$ (13 TeV)

- NMSSM 95% CL upper limits:
  - $m_{a_1} = 3.55$ GeV/c$^2$
  - $m_{a_1} = 2$ GeV/c$^2$
  - $m_{a_1} = 0.25$ GeV/c$^2$

- Reference model:
  - $\sigma(pp \rightarrow h \rightarrow 2a_1) = 0.03 \times \sigma_{SM}$
  - $B(a_1 \rightarrow 2\mu) = 7.7\%$

pp$\rightarrow h \rightarrow 2n_1 \rightarrow 2\gamma_D + 2n_D \rightarrow 4\mu + X$

 CMS Preliminary 2.8 fb$^{-1}$ (13 TeV)

- Kinetic mixing parameter $\epsilon$

- ATLAS $B = 40\%$
- CMS $B = 55\%$
- KLOE $B = 10\%$
- SN $B = 1\%$
- LSND $B = 1\%$
- APEX $B = 5\%$
- MAMI $B = 10\%$
- PHENIX $B = 1%$
- CHARM $B = 5\%$
- BaBar $B = 5\%$

- BR = 1%