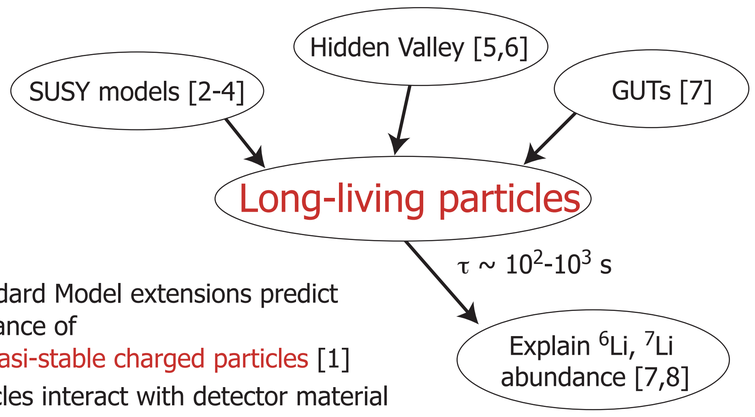
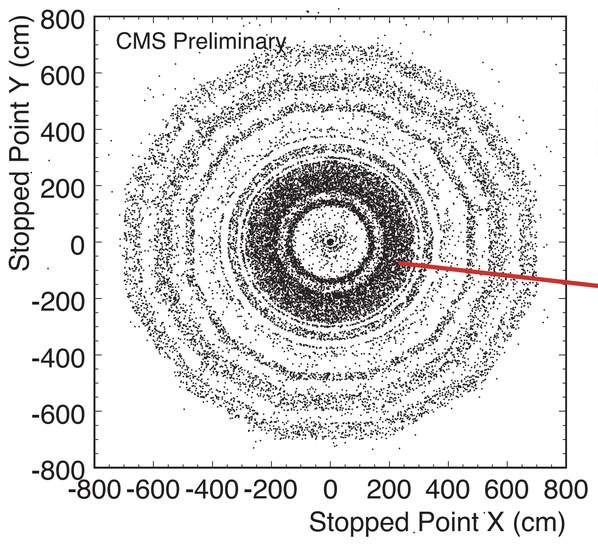
Search for Long-living Particles that Stop in CMS

F. Ratnikov (Karlsruhe Institute of Technology)
J. Brooke, C.S. Hill (University of Bristol)
S. Eno, K. Rossato, A. Skuja (University of Maryland)
A. Heister (Boston University)

Overview



- Many Standard Model extensions predict the existance of heavy quasi-stable charged particles [1]
- Such particles interact with detector material and may come to rest
- Then they decay seconds/hours/days/weeks later
- We search for decays of such particles at times when there are no LHC collisions
- Observation of out of time signal is an unambiguous sign of new physics
- Use "Split SUSY" gluino as a benchmark signal



Distribution of gluino stopping positions in the x-y plane, normal to the LHC beam axis.

Cartoon of number of stopped, undecayed gluinos in CMS as a function of time. We search for decays during gaps between LHC collisions.

Trigger & Analysis

Level-1 Trigger

- Calorimeter jet, E_t > 10 GeV, $|\eta|$ < 3.0
- Beam pickup veto

Gluino decaying in HCAL

During a period of no collisions

Higher-level Trigger

- HCAL noise filter
- Calorimeter jet, E > 20 GeV, $|\eta|$ < 3.0

Offline Analysis

Main backgrounds are instrumental noise and cosmic rays. Both have been studied with data taken in 2008.

Offline cuts :

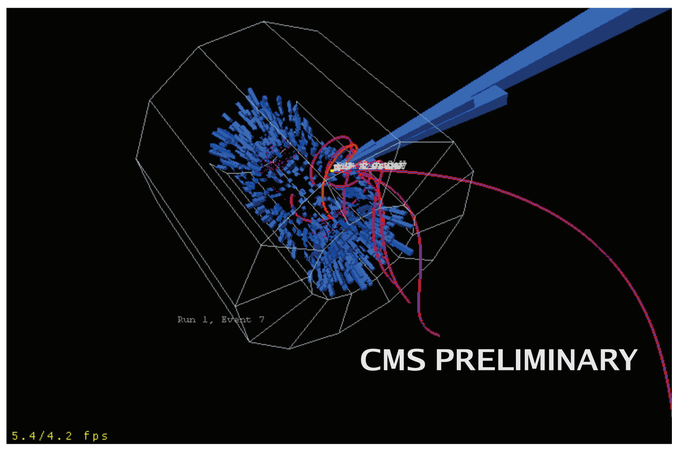
• N reconstructed muons	< 1 (Reject cosmics)
• Jet energy	> 50 GeV
• N towers containing 60% of jet energy	< 6
• N towers containing 90% jet energy	> 3
• HCAL pulse has well defined peak in time	(Reject HCAL noise)
• Exponential decay of HCAL pulse in time	(Reject HCAL noise)

Total background rate **3.9 x 10^{-4} Hz**
Signal efficiency **16.4 %**

References

[1] M. Fairbairn et al., Phys. Rept. 438 (2007) 1–63.
[2] S. Dimopoulos, M. Dine, S. Raby et al., Phys. Rev. Lett. 76 (1996) 3494–3497
[3] H. Baer, K.-m. Cheung, and J. F. Gunion, Phys. Rev. D59 (1999) 075002
[4] T. Jittoh, J. Sato, T. Shimomura et al., Phys. Rev. D73 (2006) 055009
[5] M. J. Strassler and K. M. Zurek, Phys. Lett. B651 (2007) 374–379
[6] M. J. Strassler, arXiv:hep-ph/0607160.
[7] A. Arvanitaki et al., Phys. Rev. D79 (2009) 105022.
[8] T. Jittoh et al., Phys. Rev. D78 (2008) 055007
[9] N. Arkani-Hamed and S. Dimopoulos, JHEP 06 (2005) 073
[10] R. Mackeprang and A. Rizzi, Eur. Phys. J. C50 (2007) 353–362.

Simulation



Event display of the decay of a gluino stopped in CMS HCAL

- Need to simulate processes that are very long compared with normal HEP simulation
- Developed custom 3-phase process to simulate any lifetime
- Phase 1 simulates stopping process
- Phase 2 simulated decay process
- Phase 3 uses results of Phase 1 & 2 in Toy MC to simuilate trigger live time

Phase 1
Simulate R-hadron* stopping in CMS
- Produce gluino, hadronize
- Propagate R-hadrons until they stop
- Write out stopping positions

Nuclear interactions of R-hadrons with matter based on "cloud model" [10]

Uses PYTHIA, GEANT

→

Phase 2
Simulate detector response to gluino decay
- Force R-hadron decay at one of the stopping positions
- Simulate detector response to decay products
- Emulate trigger and run cosmic reconstruction

Uses PYTHIA, GEANT

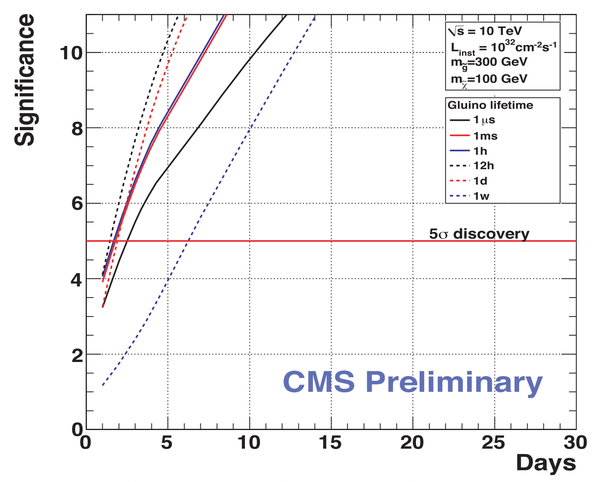
→

Phase 3
Estimate sensitivity to different lifetimes
- Simulates time of gluino production and decay
- Simulate LHC orbit structure
- Estimate probability that decay occurs when there is no beam

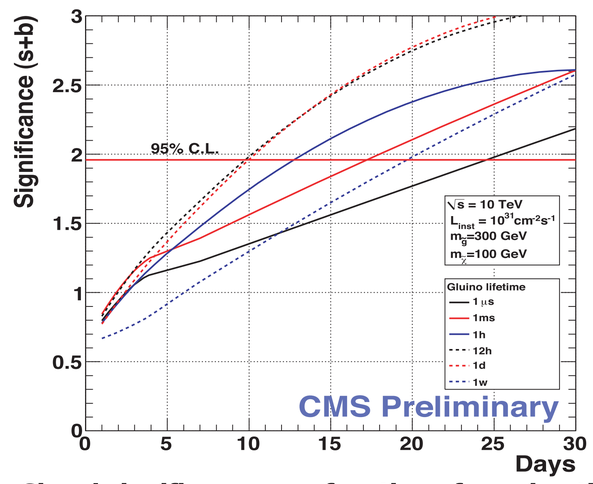
Custom toy MC

*** R-hadron - hadron containing superparticle, like ($\tilde{g}q\bar{q}$)**

Long-living R-hadrons Discovery Potential

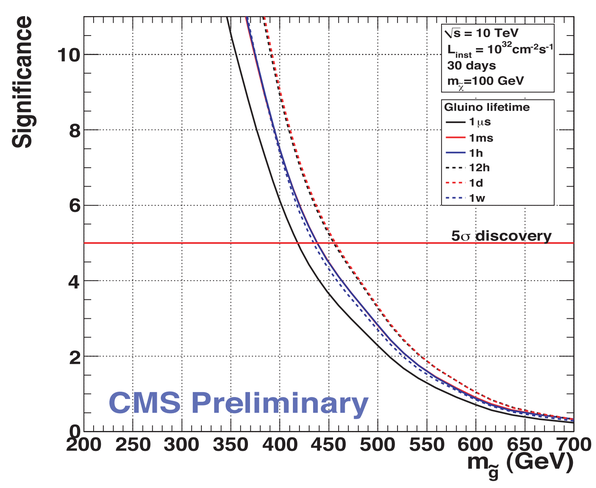


Signal significance as a function of running time
$m_{\tilde{g}}$ = 300 GeV, m_χ = 100 GeV, L = 10^{32} $cm^{-2}s^{-1}$

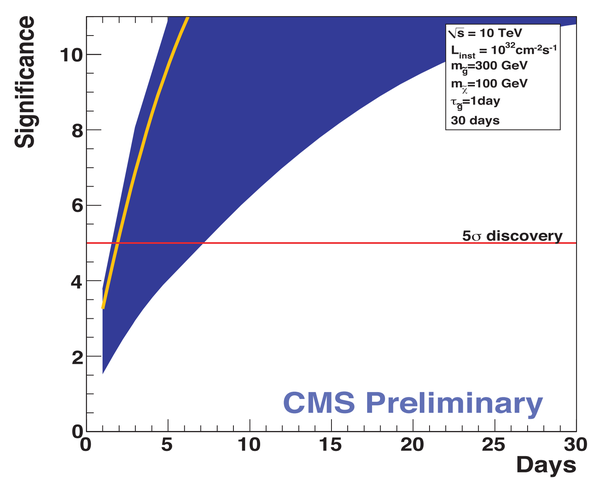


Signal significance as a function of running time
$m_{\tilde{g}}$ = 300 GeV, m_χ = 100 GeV, L = 10^{31} $cm^{-2}s^{-1}$

- Low background rate allows **very early discovery** with small amount of data
- Provided instantaneous luminosity is high enough!
- Even at low luminosity (10^{31} $cm^{-2}s^{-1}$) **limit can be set** after days of data-taking
- Generic search is not exposed to significant uncertainties; **backgrounds have already been measured** from data
- Interpretation of results in terms of a particular model are subject to systematics
- Eg. for "Split-SUSY" gluino, significant uncertainty of nuclear interactions of R-hadron (bound state of the gluino with quarks and gluons) with normal matter



Discovery reach in gluino mass: m_χ = 100 GeV, after 30 days running at L = 10^{32} $cm^{-2}s^{-1}$
Steeply falling curve is mostly due to signal cross-section



Effect on signal significance of uncertainty in nuclear interactions
$m_{\tilde{g}}$ = 300 GeV, m_χ = 100 GeV, L = 10^{32} $cm^{-2}s^{-1}$

Summary

- Very productive collaboration between Alliance and UK and US Universities
- Analysis covers 12 orders of magnitude of R-hadrons lifetime
- Sensitive to gluino masses below 500 GeV during first year of CMS operation
- Early new physics results produced by LHC