Long-lived particle searches at the ATLAS, CMS and LHCb experiments at the Large Hadron Collider at CERN

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1 Introduction

Long-lived particle (LLP) searches represent a fantastic opportunity for discovering beyond-the-Standard Model physics at CERN's Large Hadron Collider (LHC). The LHCb, CMS and ATLAS experiments have already conducted several searches for LLPs in proton-proton collision data in LHC Run 1, at center-of-mass energies of 7 and 8 TeV, and at the beginning of LHC Run 2, at 13 TeV. Such searches often require signficantly customized analysis strategies involving non-standard detector objects, reconstruction methods and triggers. As a result, they have received modest coordinated attention compared to the overwhelming majority of LHC searches for particles that decay promptly and yield well-defined and well-calibrated detector objects.

With the successful establishment of a wide range of null results from the mainstream searches for prompt objects with the first data taken at 13 TeV — typically searching for particles and phenomena that benefit most from the sizable increase in center-of-mass energy — the challenge and goal for the remainder of the LHC research program is to design optimal searches for as wide a range of detector signatures as possible, to ensure that new physics is uncovered wherever it may be hiding. Given the myriad possible signal scenarios that can feature LLPs (including models involving dark photons, hidden valleys, R-parity violating supersymmetry, dark QCD sectors, heavy neutral leptons, etc.) and the attendant detector signatures, as well as the desirability of presenting results in a largely model-independent fashion, the LHC LLP Community (experimentalists and theorists) here summarizes the current state of such searches to better define LHC sensitivity to LLPs, to identify optimal experimental information to be presented in LLP results to ensure future recasting and reinterpretation, and to discuss prospects for future searches in Runs 2 and 3 and at the High-Luminosity LHC. Several workshops and conferences have been held in 2015 and 2016 [1] that have underscored the need to continue and evolve the study of LLP signatures at the LHC experiments to achieve these goals and this document is a compendium of notes and material from these events, as well as new, complementary studies.

This document is organized as follows.

[1] The Long-Lived Particle Signatures Workshop at the University of Massachusetts, Amherst, in November of 2015; "Searching for Exotic Hidden Signatures with ATLAS in LHC Run 2" in Cosenza, Italy, in March of 2016; [the KITP workshop]; and the "LHC Long-Lived Particles Mini-Workshop" in May of 2016

2

General motivations for LHC LLP searches

[Here the theory community will present a discussion of how particles obtain LHC-detector-visible (and beyond) lifetimes in BSM models and describe curated classes of models (including exhaustive citations) that highlight the ways in which the lifetime frontier is an ideal place where new physics could be hiding.

Then each of the experiments will contribute a discussion of why LLP searches are challenging and require non-standard methods.]

Figure 2.1 comes from an ATLAS search [1].

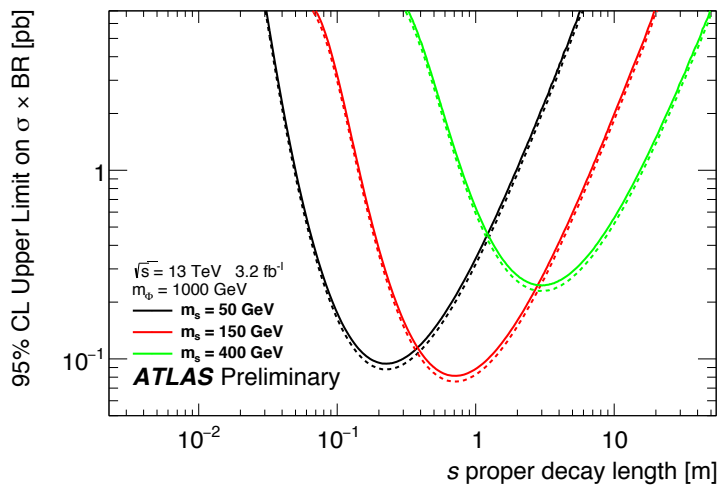

Figure 2.1: ATLAS search for a high-mass scalar Φ decaying to long-lived scalars, s, at $\sqrt{s} = 13$ TeV. From Ref. Blah.

3
Experimental signatures

Breaking down the possible LLP discovery methods at the LHC by detector signature.

3.1 Signature One

3.1.1 Theoretical motivations

3.1.2 Existing searches and limits

3.1.3 Known gaps in coverage

3.1.4 Proposals to improve coverage and sensitivity of existing searches

3.2 Signature Two

4
Recommendations for the presentation of search results

How should the experiments present results to ensure optimal recastability and reinterpretation? A minimal set of efficiencies, model-independent experimental quantities, etc.

5
Prospects for LLP searches in Runs 2 and 3 of the LHC and the HL-LHC

Calculate, estimate, extrapolate and speculate.

6
Conclusions

Conclude and finish.

7
Acknowledgements

Recognition and thanks.

A
Appendix: Explicit example of recommendations for search results

A worked-out example.

Bibliography

[1] *Search for long-lived neutral particles decaying in the hadronic calorimeter of ATLAS at* $\sqrt{s} = 13$ TeV *in* 3.2 fb^{-1} *of data*, ATLAS-CONF-2016-103 (2016).