Note:

These comments to the simplified model for long-lived particle section contain input from **Andreas Albert, Oliver Buchmueller, Kristian Hahn, Stephen Mrenna,** and **Marco Trovato**.

General Comments

- **Limitation of simplified models:**
  Besides listing the pros of the simplified models it would be important to list their cons and limitations. In Section 1.1 challenges of using Simplified models are briefly listed, but this seems not comprehensive enough. You might consider to extent this section part and corresponding discussion or perhaps even (maybe in form of an Appendix) and a complete sections on the simplified-models limitations for the LLP.

- **Lack of clear recommendation and technical discussion:**
  The current draft is mainly outlining theoretical and phenomenological aspects of simplified models for long-lived particle scenarios. While this is useful and interesting on an academic level it does not provide sufficient input to the experimental community in order to establish a real and concrete long-lived search programme using simplified models to benchmark it. The recommendations of the Dark Matter working group arXiv:1703.05703, arXiv:1603.04156 could serve as examples on how to provide hands-on information than can be directly used by the experiments. For example, at the end of the section the limitations of the infrastructure in handling cases where the colour charged LLP decays in flight are mentioned However, there are also severe limitations in the interplay between ME (MadGraph), showering (Pythia8) and detector interactions (GEANT4). These are not discussed at all in the draft and it might be worthwhile to consider adding a section about it. Below now a list of technical discussion items that are left open in the current draft but are essential for the implementation of the concept within the experiments:

  - **MadGraph.vs.Pythia**
    One point that is stressed often in the draft is that the simplified models should allow for a factorization of production and decay of long-lived particles. While this is indeed correct, there is little information in the draft about how this is to be achieved. For example, it appears that the plan is to provide UFOs to handle both production and decay. The specifics are then handled by MadGraph parameters. If this is indeed the proposed method, it might be unnecessarily complicated. UFOs in MadGraph are not at always suited for dynamic user requests such as "decay particle X to Y". As an alternative it might be more useful to use the workflows outlined also in **arXiv:1704.06515**: produce the LL particle in MG, decay it in Pythia. This might make it easier in practice to produce samples, as there is no need to "hack: any UFO implementation to mimic what Pythia does out-of-the-box. This, however, would raise the question if the angular distribution of the decay products is accurate enough in this approach. So, there will be pros and cons for each of the implementation choices, but no it is really being discussed.
  - **GEANT**
    As it was also discussed during the workshop, there still is no general solution for interfacing all of this with GEANT for charged LL particles. This is a common problem to all experiments and it was agreed to start a dialogue with the GEANT authors in search of a solution. This draft could (should?) outline the problem and also define some milestones towards a solution. This could include a proposal of a dialogue with GEANT4 but more importantly it should list the current shortcomings and sketch out, at least a high-level plan, to overcome them.

Detailed comments per page

pg 4, middle part: This sentence reads a bit wired:
"Furthermore, as LLP searches involve aspects of detector response that cannot be reliably simulated with public Monte Carlo tools, it is notoriously difficult for individuals outside of the experimental collaborations to accurately apply search results to new theoretical models, potentially jeopardizing their future utility."

pg5, par1: Why Refs 1 and 3 (are these studies of existing signatures, or proposing
7 something new)?

pg5,par2: The limitations of detector response models can apply to private (internal) simulations as well.

pg5,par3 An (implicit) fifth criterion is (v) communicable or shareable.

pg7,sec1.1 Five items in this list would then match the five criterion listed before.

pg 7 : "#1 and #5 are somewhat in tension ...". The tension could be relieved a bit by adding "Use a minimal ^but sufficient^ set ..." in #1?

pg 10-11: Might be nice to have to pseudo-feynman diagrams for DPP, HP, etc. to help fix the distinctions for the reader?

pg11,par1: In the Heavy Resonance bullet, you might add the complementarity with bump searches.

pg 11: Section 1.3.2, para2, first sentence: maybe "many ^LLP^ decay modes"? One might otherwise read this as the overall final state.

pg 11: Section 1.3.2, the rest of the para2: I think there are two points being made. 1) one might be able to search inclusively for displaced decay products and 2) displaced searches can relax other selection requirements because displacement itself kills most SM background. I feel those two points are somewhat conflated at the moment. 1) deals with the LLP decay, while 2) addresses the final state.

p11,parLast: Is a SM object a particle? a parton? The class of decays \char -> N1 Pion seems to be missing. This is generic – see your Ref.[2].

p12,parTop: Can a phase-space suppressed decay, like 4body decay of top quarks, have a more complex topology?

p12: Do leptoquarks fit into any of these categories?

p13,parBot: The subsection Invisible Final-State Particles seems to have a strange title. The LLP decays are driven by either a weak coupling or phase-space suppression (or both, with one dominating). If just a weak coupling, the decays can be hard. If there is little phase space for the decay, then I expect soft decay products. It is the same thing as written, but without any need to refer to invisible decay products.

p14,sec1.4,par2: I would clarify early between the LL particle and the (colored) parton.

pg 15: Table 1.1: the box contents (eg: "SUSY") essentially correlate with the row label and could therefore be replaced with a checkmark or X, as the caption actually indicates. The only caveat is DM, but I suppose one could just add an asterisk or something to denote this?

p16,par1 Maybe clarify that the bino-like neutralino has a RPV decay.

pg: 17: Table 1.2: same comment than on Table 1.1

p18,par1: not sure how precise these predictions are. There are assumptions built into this (such as the fraction of gluino-gluon states). Perhaps saying “the default settings of Pythia8 predict”.

p18,par3: The correct (QCD) treatment here is important. In the current model, the (e.g.) gluino picks up a colored cloud to form a singlet R-hadron. The R-hadron, when it decays, is split back into the gluino and cloud. The gluino decays via matrix elements (or maybe just phase space). Then all the color–connections are formed, showering and hadronization proceeds AT the displaced vertex. If the gluino alone is propagated and decays, it has color–connections with the initial state. Most of the decay products could then be in a string at the origin. This sounds to me like more than a Lambda/Q effect. Of course, if the MG decay is important, then these two pieces need to be put together.

p19,par1: Please change parton-shower (program) to event-generator.

pg: 19: end of the para1: It would be appropriate to cite and summarize the conclusions of our paper ([11]) here.

pg 19: last para: "only four ^classes of^ already-available". There are several DMF models, for example.

p20,par1: Why not just the pMSSM?

pg 20: DM-SM: [11] should certainly be cited / discussed here.

p32: Please update the Pythia8 reference:

@article{Sjostrand:2014zea,
author = "Sjo¨strand, Torbjo¨rn and Ask, Stefan and Christiansen, Jesper R. and Corke, Richard and Desai, Nishita and Ilten,Philip and Mrenna, Stephen and Prestel, Stefan and Rasmussen, Christine O. and Skands, Peter Z.",
title = "{An Introduction to PYTHIA 8.2}",
journal = "Comput. Phys. Commun.",
volume = "191",
year = "2015",
pages = "159-177",
doi = "10.1016/j.cpc.2015.01.024",
eprint = "1410.3012",
archivePrefix = "arXiv",
primaryClass = "hep-ph",
reportNumber = "LU-TP-14-36, MCNET-14-22, CERN-PH-TH-2014-190, FERMILAB-PUB-14-316-CD, DESY-14-178, SLAC-PUB-16122",
SLACcitation = "%%CITATION = ARXIV:1410.3012;%%"
}