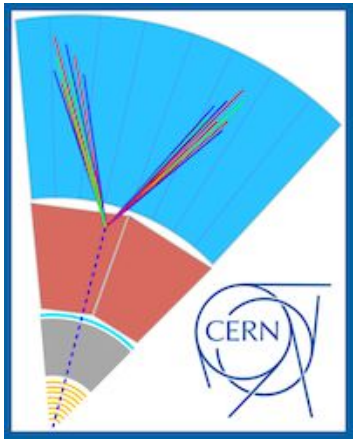
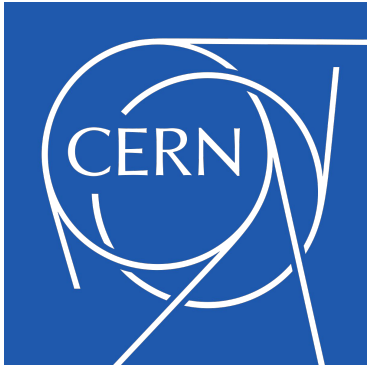
LHC LLP WG
Current status



Juliette Alimena (CERN)
on behalf of the WG convenors

LLP9 Workshop
May 28, 2021



The LHC LLP WG

Formed to complement the LLP Community (open to any and all LLP experiment or idea around the world), serves as a **formal bridge** with and between the approved LHC experiments, to focus on their main needs. The mandate of the WG consists aims for:

- Facilitate communication between the experimental and theoretical LLP communities
- Provide recommendations for benchmark models to be used in LLP interpretations
- Develop and/or validate MC tools for event generation
- Recommend the experiments on how to present results such it facilitate reinterpretation
- Discuss possible new search directions based on input from theory and/or experiment

Continue to have **regular WG meetings** typically embedded in LLP workshops (first meeting on May, 2020 @ LLP7 workshop), to discuss the **current status and future plans** (subscribe to lhc-llpwg@cern.ch @ e-groups, we also have a website). We also will have **topical public meetings** in between as needed.

The LHC LLP WG convenors

- **ATLAS:** James Beacham and Sascha Mehlhase
- **CMS:** Juliette Alimena and Albert de Roeck
- **FASER:** Dave Casper
- **LHCb:** Federico Leo Redi and Carlos Vázquez Sierra
- **MoEDAL:** James Pinfold
- **Theory:** Nishita Desai and José Zurita

Experimental convenors nominated by experiments' Physics Coordinators, theory convenors nominated by LPCC in consultation with experimental convenors. Reach us via lhc-llpwg-admin@cern.ch.

Theory perspective

General objectives and ideas which have been identified so far:

- Provide **standard tools for simulation** (UFO models, MC for **dark showers**),
- Provide **simplified models** targeting specific signatures and topologies,
- Provide suggestions on **how to present results** (standardise object definitions),
- **Feedback** from **experimentalists** in order **to provide reinterpretations**,
- Keep an **updated survey of coverage gaps** (very helpful for experiments).

Any other ideas? Let us know! Your input is <u>highly valuable</u>!

Experimental perspective

General objectives and ideas which have been identified so far:

- **Provide requested feedback to theorists, follow their recommendations!**
- Liaise with internal EXP WG convenors (propagate TH suggestions),
- Identify and discuss **potential triggers for LHC Run-3** conditions,
- Write new/implement **existing tools and algorithms** for **LLP searches**,
- Coordinate among the experiments in order to **exploit complementarity**,
- Provide recommendations for **HL-LHC phase/Run 4 and beyond.**

Any other ideas? Let us know! Your input is highly valuable!

Outline

Latest activities

- Document on LLP triggers for Run 3 is in the final stages
- Document & code repository on how to simulate HNLs is in progress

Ideas for the near-future

- Simulation of dark showers
- Long-lived dark matter benchmarks
- Reinterpretation benchmarks

Triggers for Run 3

- **First WG deliverable**: Document on LLP triggers, in preparation for Run 3
- Provides a summary of LLP trigger ideas for the LHC Run 3
- Status:
  - Draft has gone through several iterations
  - It is now being circulated by the Physics Coordinators to the relevant groups in the experimental collaborations
  - Expect it to be public soon

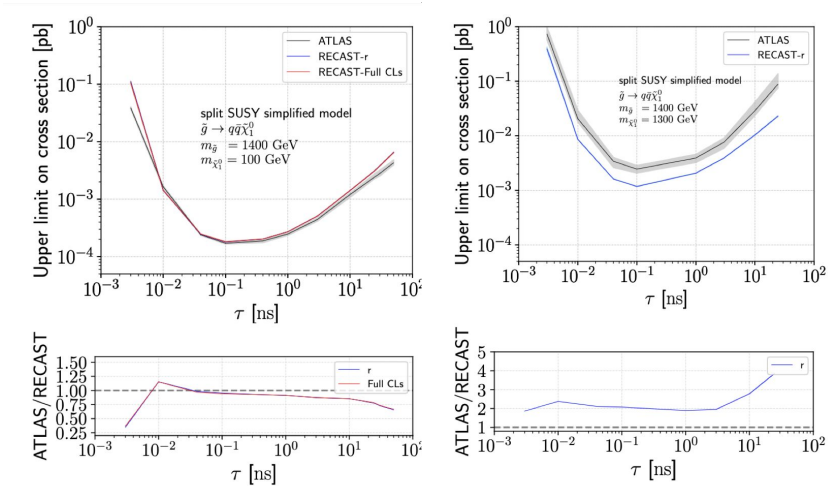
Heavy Neutral Leptons (HNLs)

- Agenda here
- Interest in the topic is raising with time
- We want people to let us know what we should tackle within the WG
  - For this please fill in this document
- Happy to see great progress on simulating HNLs
  - Please provide feedback!
- We feel close to converge on some very concrete results
  - *Pythia*: code is already implemented, need validation
  - *MadGraph*: new vSMEFT operators at dimension six
- For future communications subscribe to the mailing list

Reinterpretations - I

Two main problems when providing results for ready reinterpretation:

1. Standard object definitions do not exist
   - e.g. how well are “trackless jets” modeled by generator level stable particles with fastjet
   - so not easy to provide object-level efficiencies
2. Exotic objects may have non-standard behavior with detector material that gets lost when unweighting, even when efficiencies are provided



E.g. same efficiencies do not result in match for different benchmarks

Reinterpretations - II

Our solution: Keep active dialogue between theorists and experimentalists (e.g. very successful resolution of ATLAS & CMS disappearing track validation)

What more can be done?

1. Make comprehensive library of benchmark models for easy comparison between experiments + easy reinterpretation for theorists
    - These can be used in addition to experimentalists' own favorite benchmark
    - Not exclusive or mandatory
2. Implement "standard" versions of objects in public detector simulation code which can then be used to provide efficiencies
    - e.g. effort to implement displaced vertices in Delphes is ongoing

Reinterpretations - III

Other topics for discussion: How to adapt for increasing ML techniques

Ideas from discussion yesterday:

1. Preserve BDTs as pure C++/Python code
    - Part of this is already done
    - But how to guarantee right input data outside collaborations?
2. Simplified models-based exclusions still work because they rely only on published efficiency maps or exclusions in theory parameters
    - But experiments need to be careful to provide separate topologies (i.e. not multiple production/decay modes summed together)

Dark showers at the LHC - I

Several intriguing directions of study identified at dark showers tutorial and discussion yesterday:

1. Generate non-QCD like energy distributions as a stress test of experimental coverage

E.g. theory is higgsed and you mainly have dark gluons. This was studied in 2008-9 by Meade, Papucci and Volansky https://arxiv.org/pdf/0901.2925.pdf. This can be put into Pythia

https://arxiv.org/abs/2009.08981, computes hadronic cascades in large-coupling models that can be jetty or SUEPy depending on parameters.

2. Use Pythia to cover signature space rather than focussing on getting the hadronic spectrum exactly right. --- How to do this needs more thought

3. Implementing a more complicated hadronization spectrum in Pythia to test if significant differences occur: start by using 3 non-degenerate quarks.

Dark showers at the LHC - II

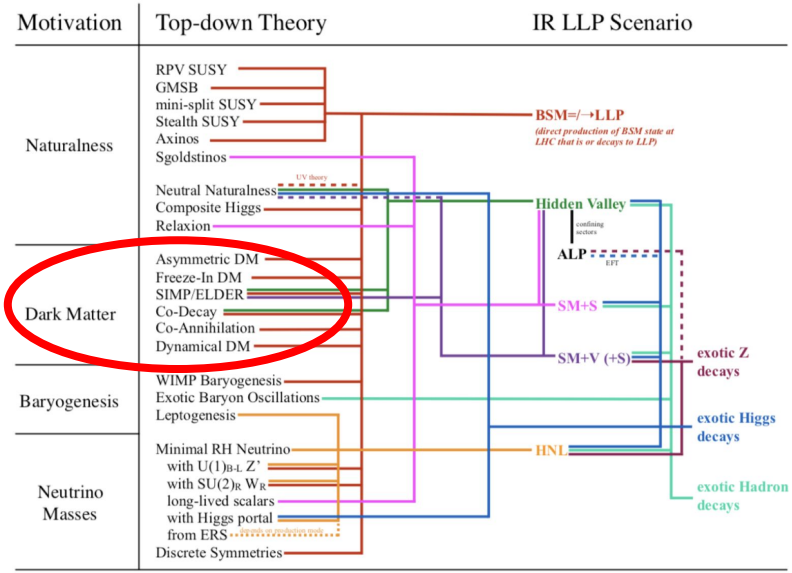
As you can see, many ideas from the Pythia HiddenValley discussion session are more theory-based and more general to dark showers phenomenology

- Well-suited for individual projects or LLP Community documents

One good, concrete project for the LHC LLP WG could be a brief “How to simulate dark showers at the LHC” document that summarizes the instructions and tutorials from yesterday and collects all the tools in one place

Long-Lived Dark Matter (LLDM) - I

- The “long-lifetime” limit of the DMWG benchmark models was put forward in [Buchmuller et al, 1704.06515, *JHEP* 09 (2017) 076].
- An incomplete collection of LLDM models can be found in Curtin et al [1806.07396, *Rept.Prog.Phys.* 82 (2019) 11, 116201].
- ATLAS/CMS use coannihilation in WIMPs (pure Higgsino, pure Wino in MSSM) as benchmark model for e.g: disappearing tracks.
- Also recent surge in activity in freeze-in [see e.g Sam Junius’s talk]. Initial discussions in the context of the *Initiative for Dark Matter in Europe* (IDMEU) https://indico.cern.ch/event/1016060
- Informal discussions with DMWG indicate interest in studying inelastic dark matter.
- Also studies for <= 10 GeV dark matter (e.g: milli-charged) matter in the context of PBC / FIPS (see Maxim Pospelov’s talk and arXiv:2102.12143, sent to EPJC)



LLDM - II

Questions for discussion:

- Do we need another (more complete, more comprehensive, more detailed) catalog of theory models?
- Is there a need to agree on common benchmarks for e.g: freeze-in DM, inelastic DM, millicharged DM, etc? (MSSM benchmarks seem to work fine and were used for European Strategy plots and for other future collider phenomenological studies.)
- Is there a specific need for tools (event generator, relic density calculators, direct detection constraints)?

Summary

- Run 3 trigger document (first LHC LLP WG deliverable) getting close
- Document and code repository for HNL simulation are being developed
- However, **many more ideas can be covered**
- Lots of inspiration from the community workshops
- **We want your opinion and for you to join us!**

Backup