

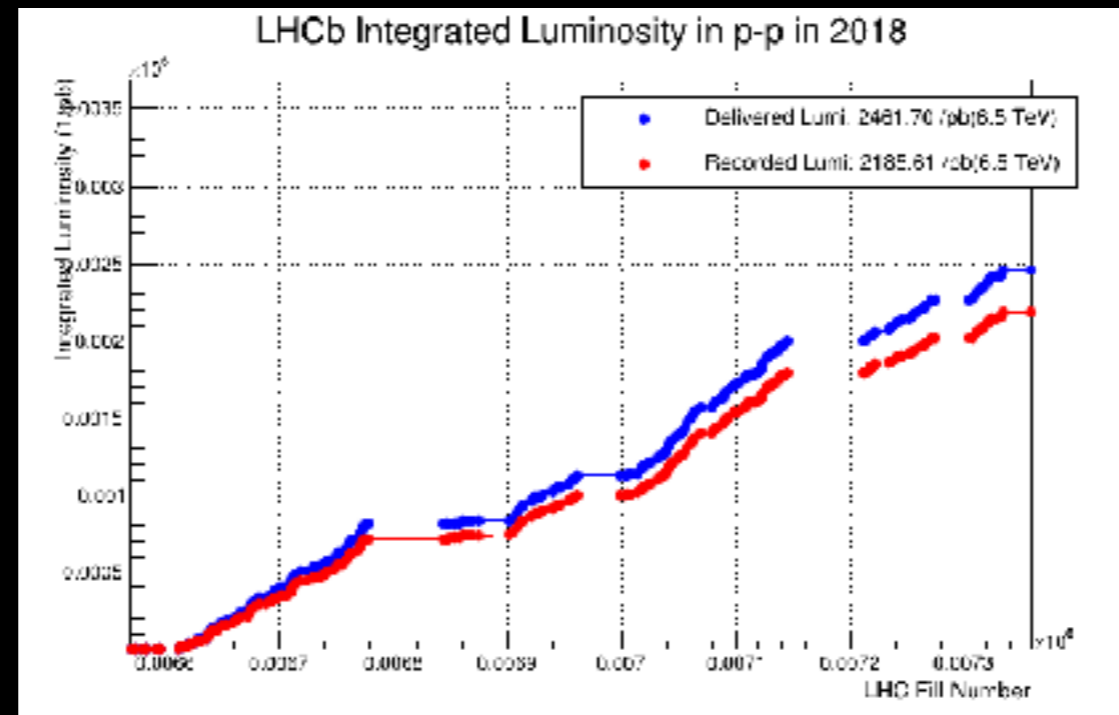
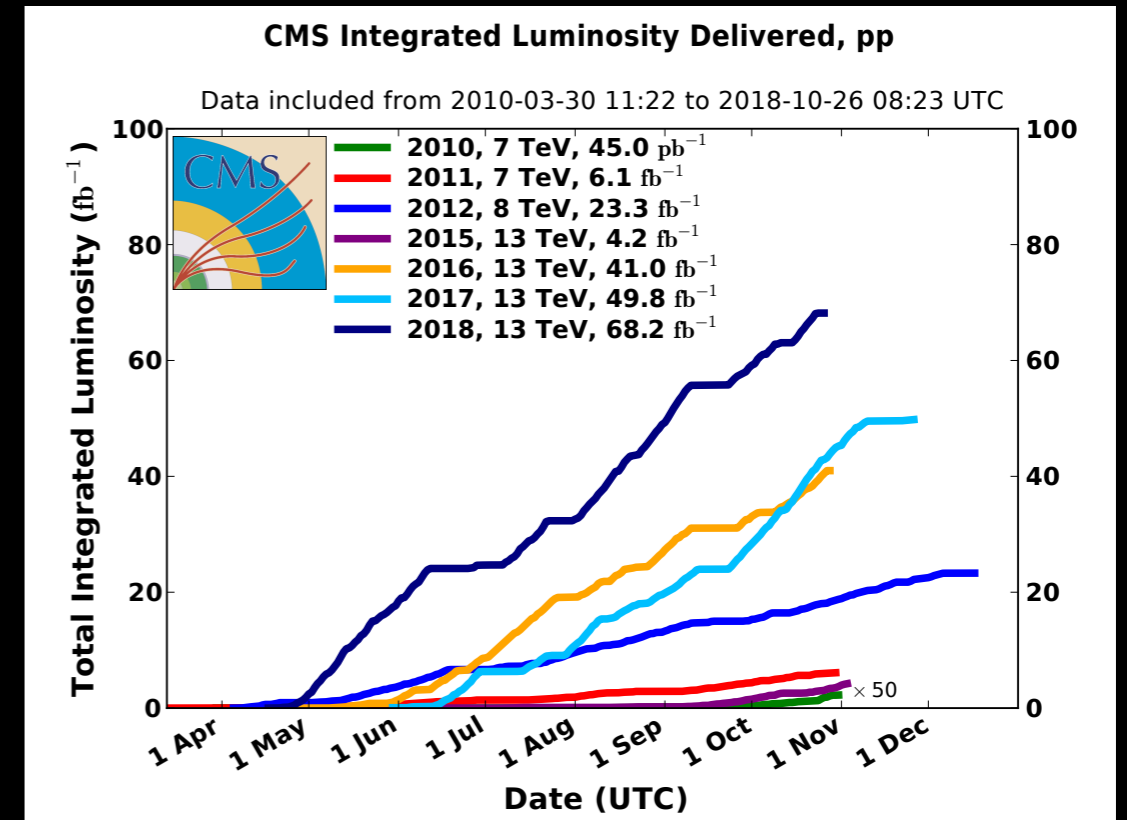
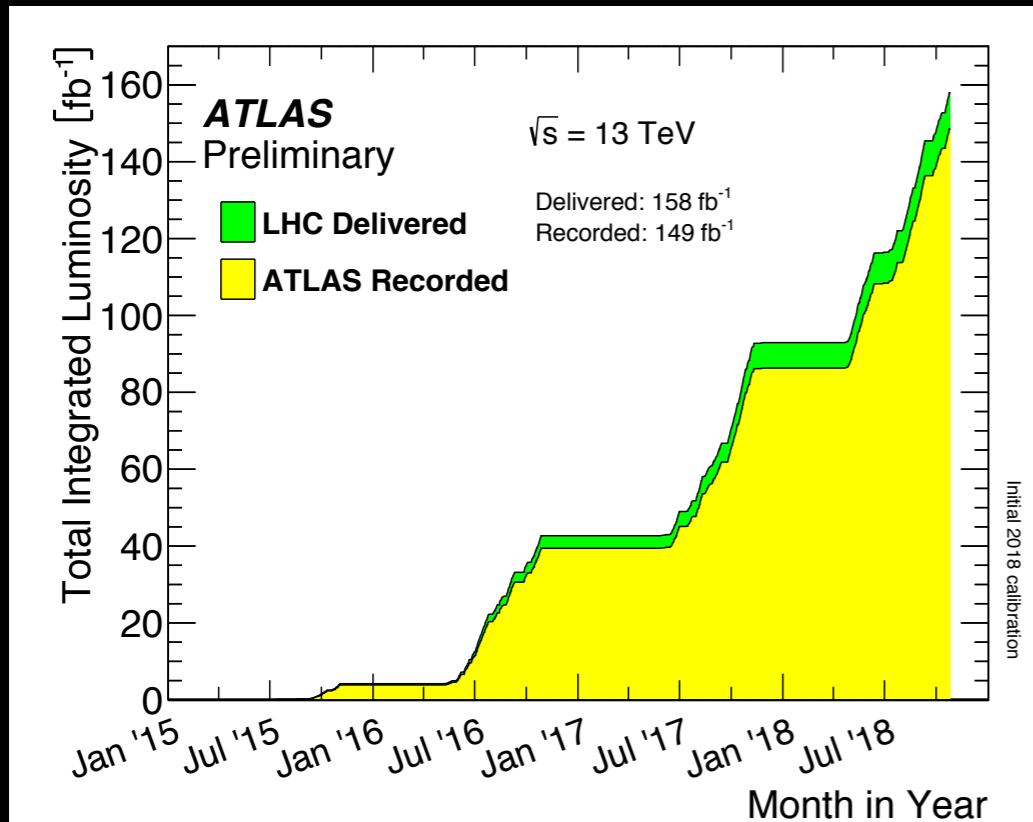
Searching for
long-lived particles
at the LHC:
Fifth workshop of the
LHC LLP Community

27-29 May 2019

CERN

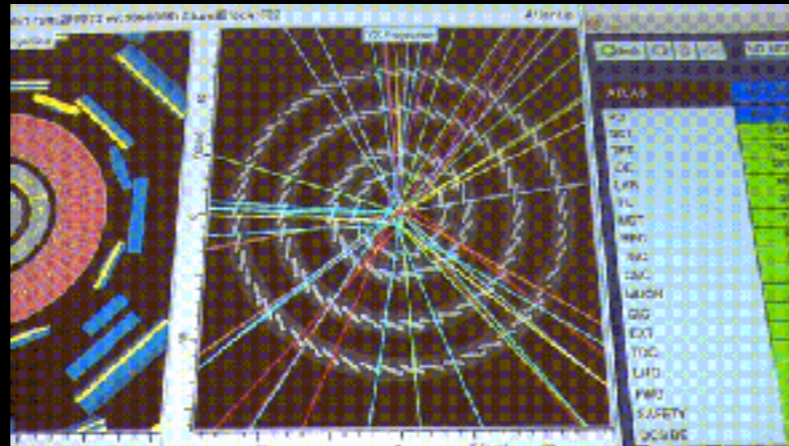
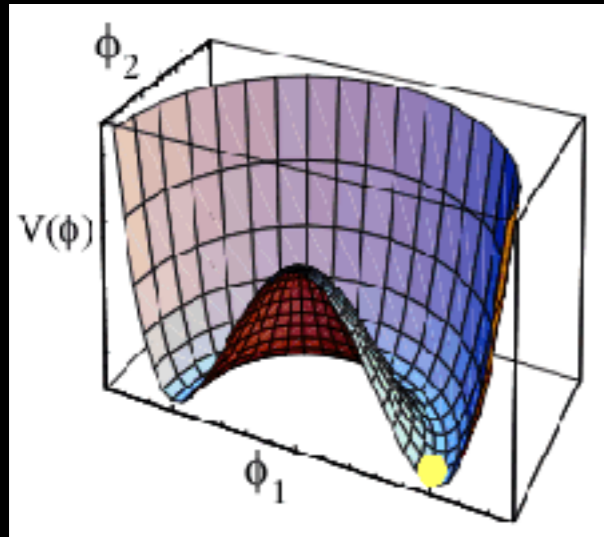
indico.cern.ch/e/LHC_LLP_May_2019

The Large Hadron Collider is a big-data discovery machine

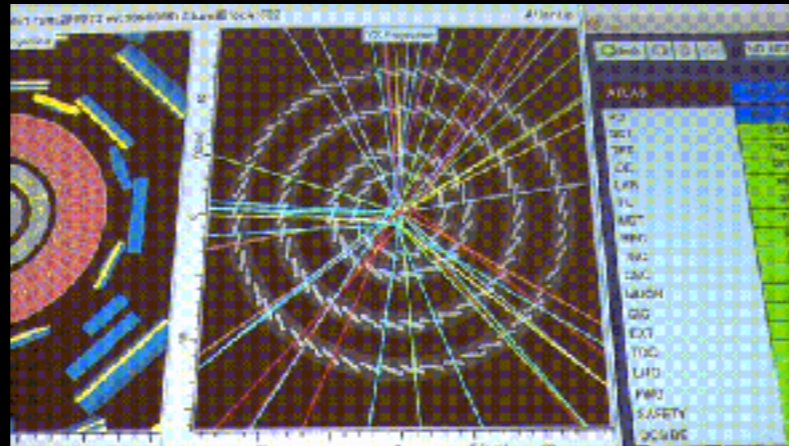
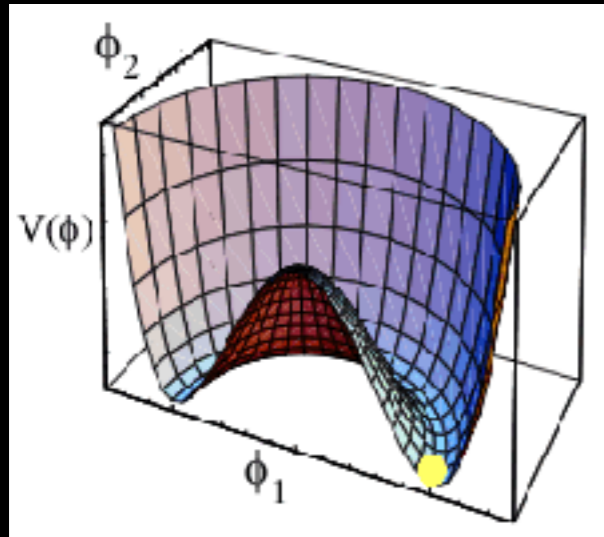


The first nine years have been a triumph

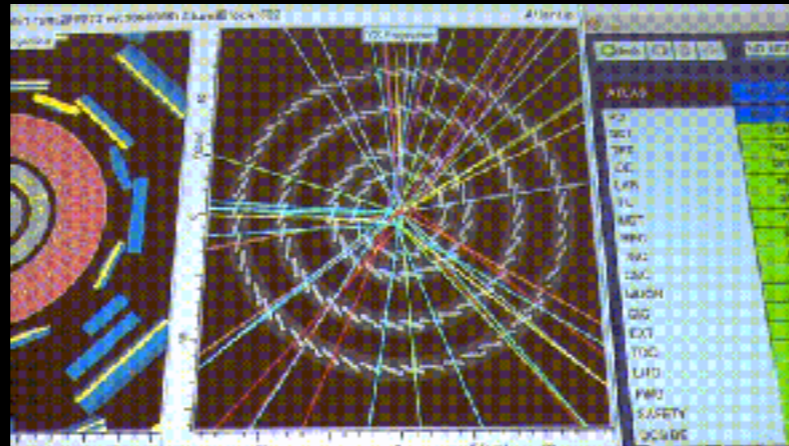
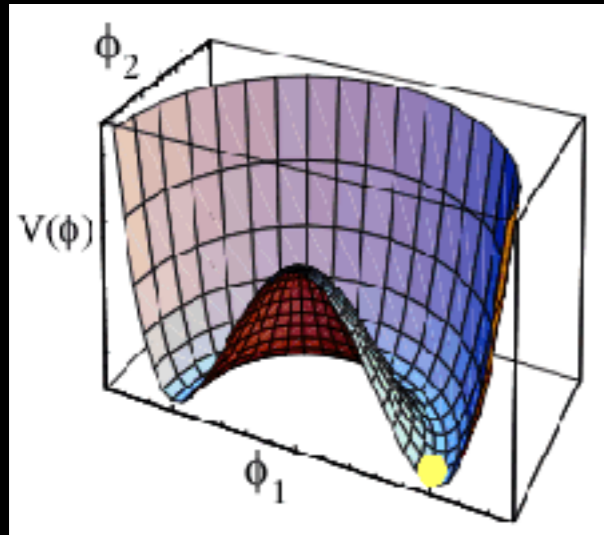
4 July 2012



4 July 2012

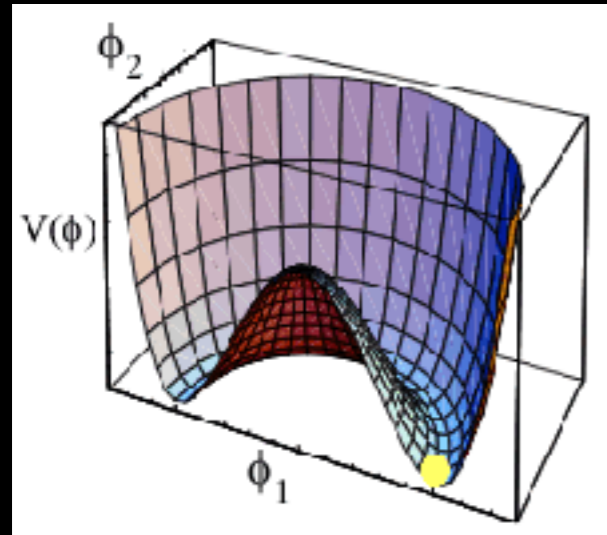


4 July 2012



The day
everything
changed

4 July 2012



The day
everything
changed

3 June 2015

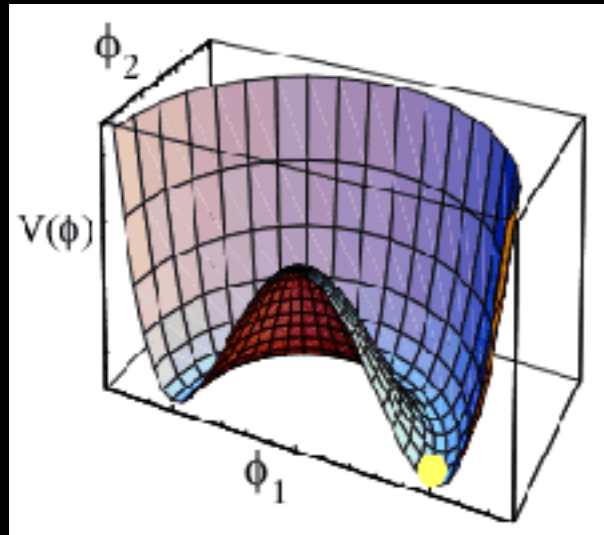


First proton-
proton collisions
at 13 TeV

4 July 2012

3 June 2015

2018



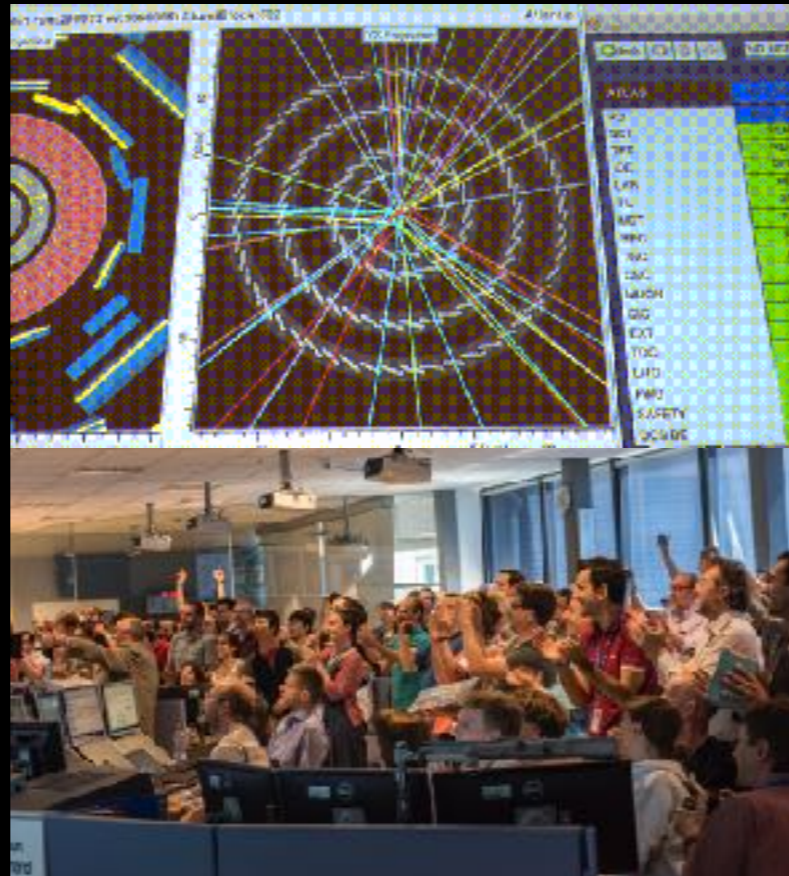
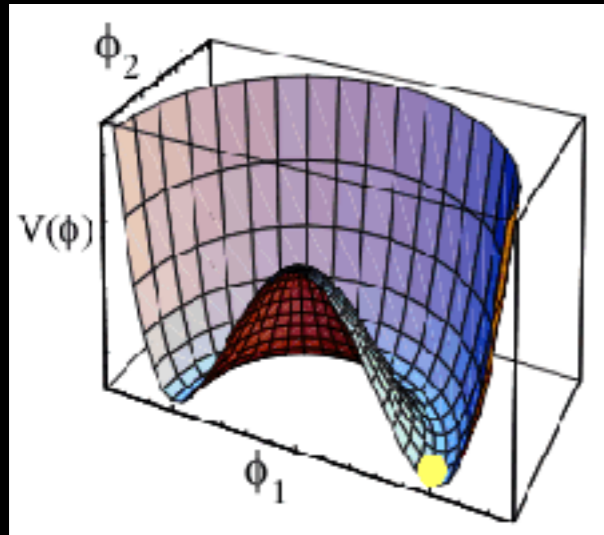
The day
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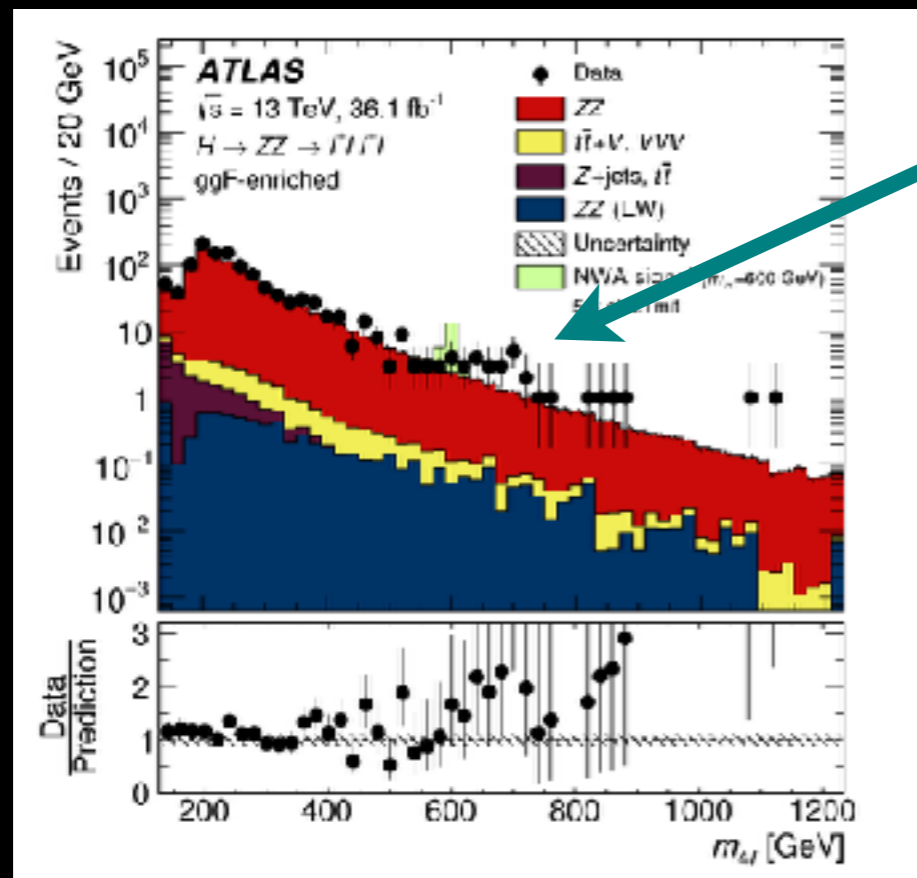
First proton-
proton collisions
at 13 TeV

Thus far no new
particle
discoveries
beyond the Higgs

New physics at the LHC in 2018

Our current extensive look at 13 TeV yields impressive agreement with Standard Model expectations and no huge, immediate resonances or excesses

EPJC (2018) 78: 293



There are no more guarantees (like a source of electroweak symmetry breaking “just around the corner”) and no ace-in-the-hole motivations; just huge open questions.

Requires us to shift from theory-driven search strategies to signature-driven ones.

We would certainly love some old-school theoretical guidance, but WIMP dark matter in tension, lack of plain vanilla SUSY, lack of twenty-jet events filled with strong gravity, etc.

Where could the new physics be hiding? What are we marginalizing?

Where is new physics at the LHC?

Precision Higgs measurements?

Exotic Higgs decays?

Top quark Higgs production?

Top anomalies?

Lepton flavor asymmetries?

Precision measurements of
Standard Model processes?

B physics irregularities?

All of these searches utilize a small number of very
well-studied more-or-less *prompt* objects

Where is new physics at the LHC?

CMS Exotica LLP
CMS SUSY RPV
LHCb Public Results
ATLAS Exotics
ATLAS SUSY

ATLAS EXPERIMENT — PUBLIC RESULTS

Exotic Physics Searches

This page contains public results from the ATLAS Exotics Working Group, which is searching for physics beyond the Standard Model with a signature-based program. Our aim is to cover all experimentally viable signatures focusing on non-supersymmetric models from Extra Dimensions and mini Black Holes to Dark Matter, extended Higgs models, and Compositeness to name a few.

If you have any question, please contact the group conveners (currently Gabriel Facini and Maria-Helene Geant): atlas-phys-exotica-conveners.

Filter Documents

Select the desired keywords to filter the results.
Selections within a section row are combined with a logical OR, while selections among different section rows are combined with a logical AND.

Global Selections:

CM Energy:

Analysis characteristics:

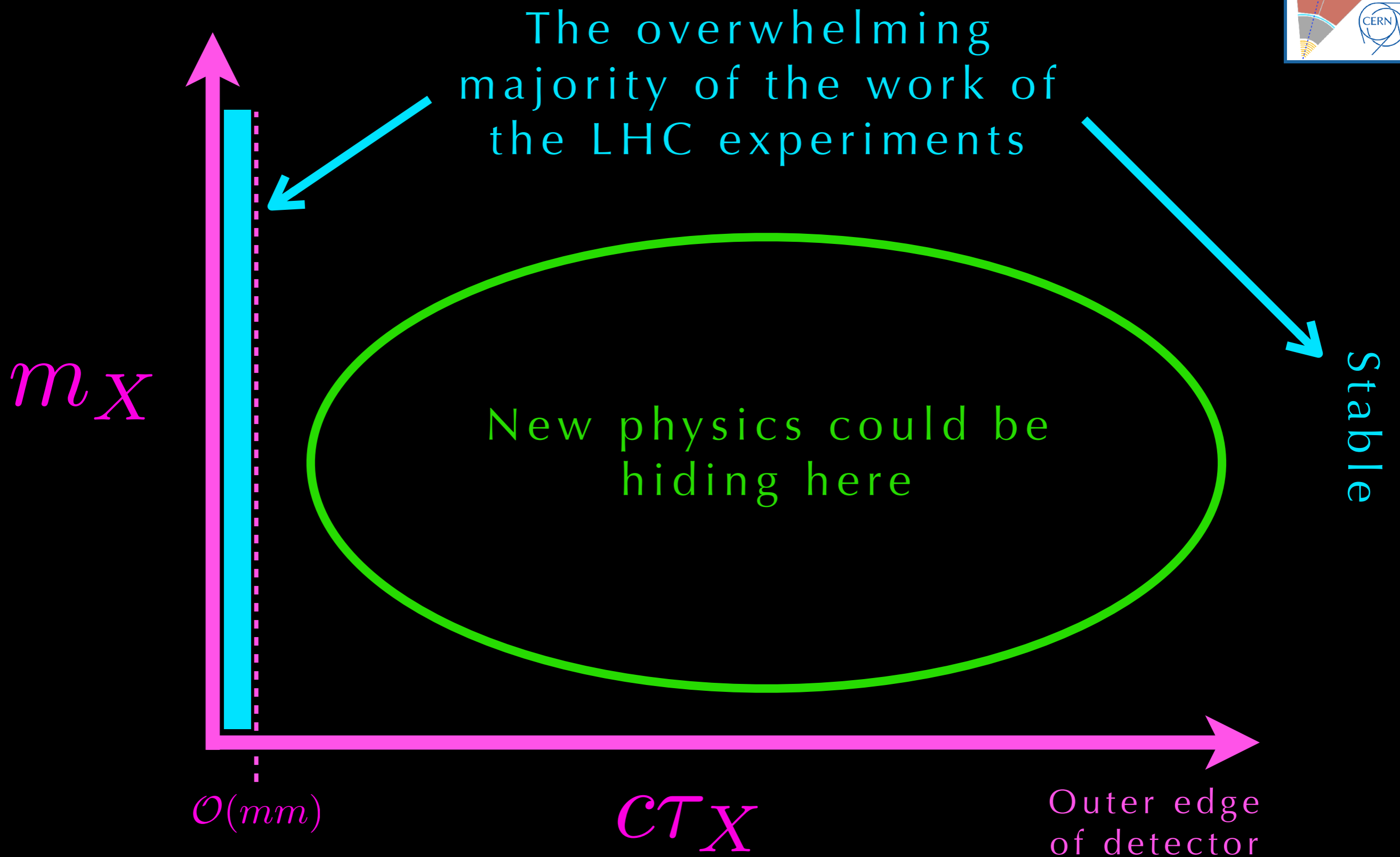
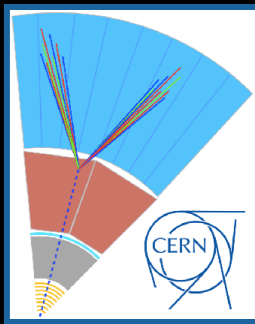
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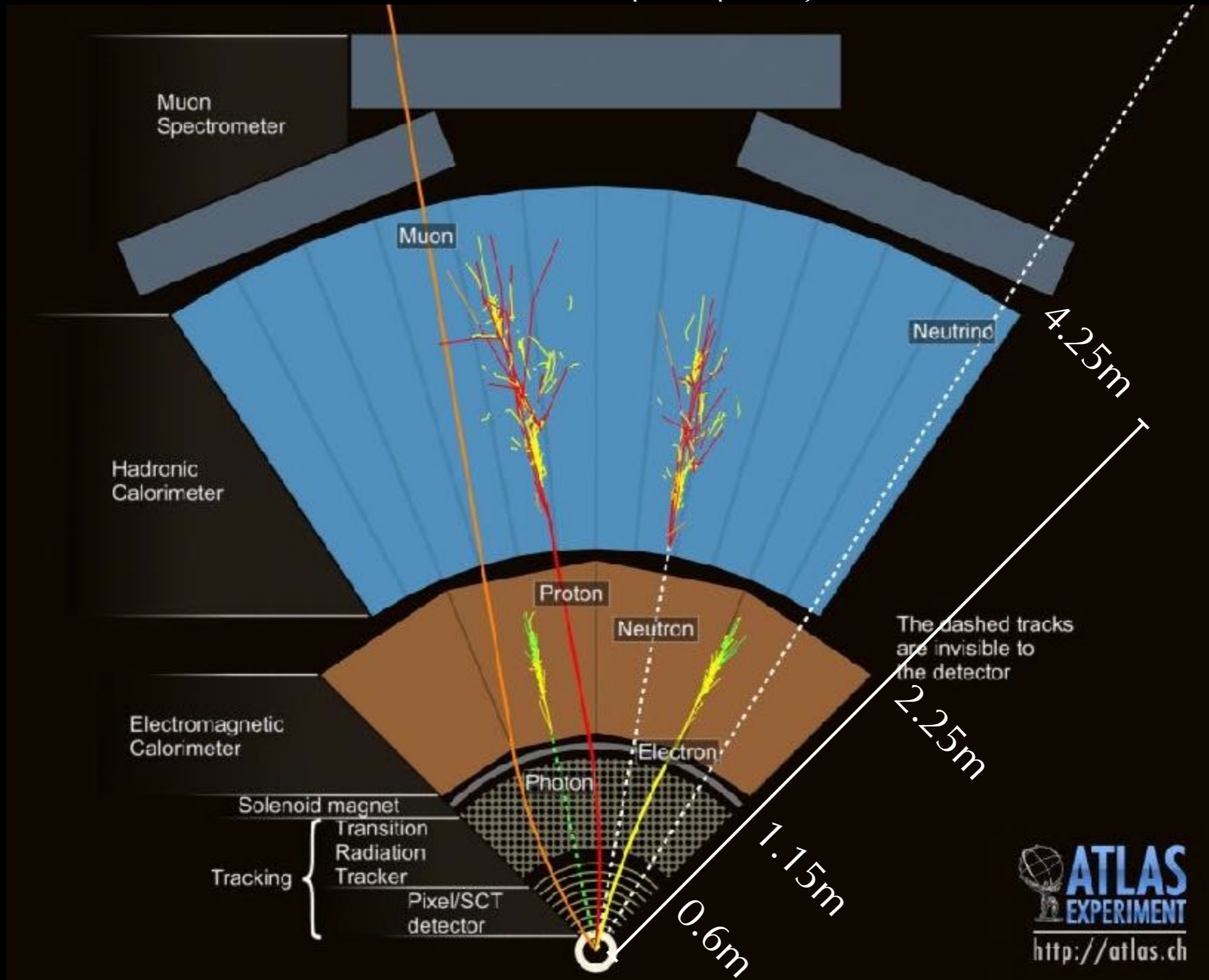
Papers and publications (20 shown of 221 total)
(Full list of ATLAS papers, [see here](#) for more info)

Short Title	Journal Reference	Date	√s (TeV)	L	Links
Search for highly ionising particles/monopoles NEW	Submitted to Phys. Rev. Lett.	24-MAY-19	13	36 fb ⁻¹	Documents 1905.10130 Inspire
Prompt and Displaced Heavy Neutral Lepton Search 2016 13 TeV NEW	Submitted to JHEP	23-MAY-19	13	36 fb ⁻¹	Documents 1905.08787 Inspire Journal

New physics X at the LHC



95% of our analysis effort at the LHC is dedicated to understanding five more-or-less prompt objects



95% of our analysis effort at the LHC is dedicated to understanding five more-or-less prompt objects

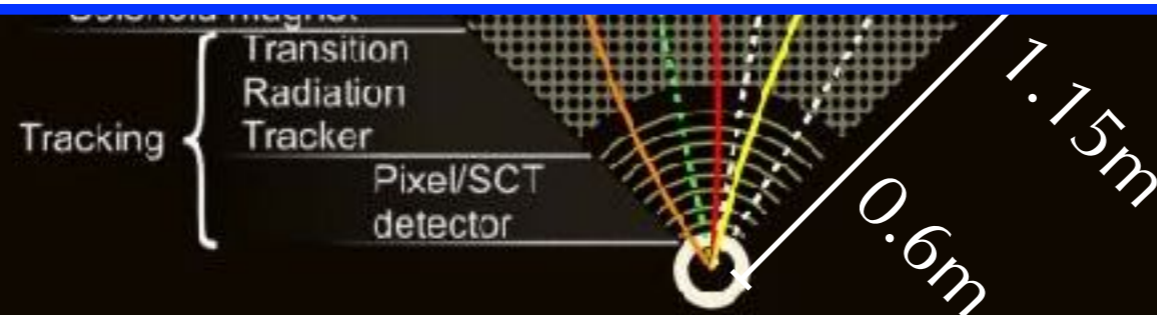
What we want:

- To reduce to negligible the chance that we'll miss new physics at the LHC

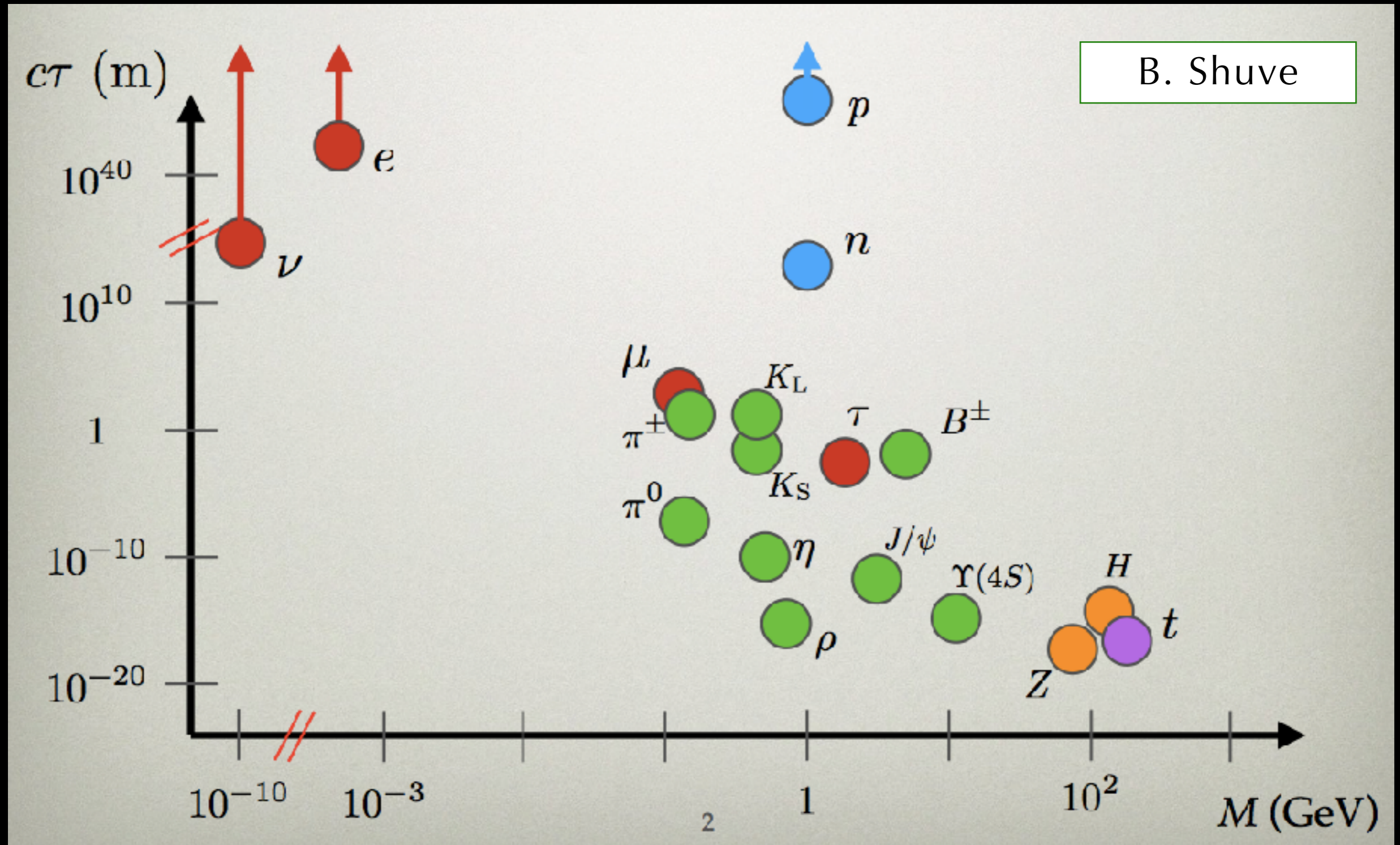
What we have:

- The most sophisticated general-purpose detectors ever built at the highest pp \sqrt{s} ever used, and these interaction points the only good source of Higgses, W s, etc., for several decades

Shift from **model-first / signature-second** to **signature-first / model-second mindset**



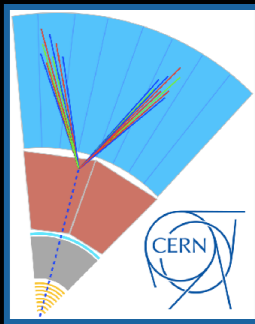
Long-lived particles at the LHC



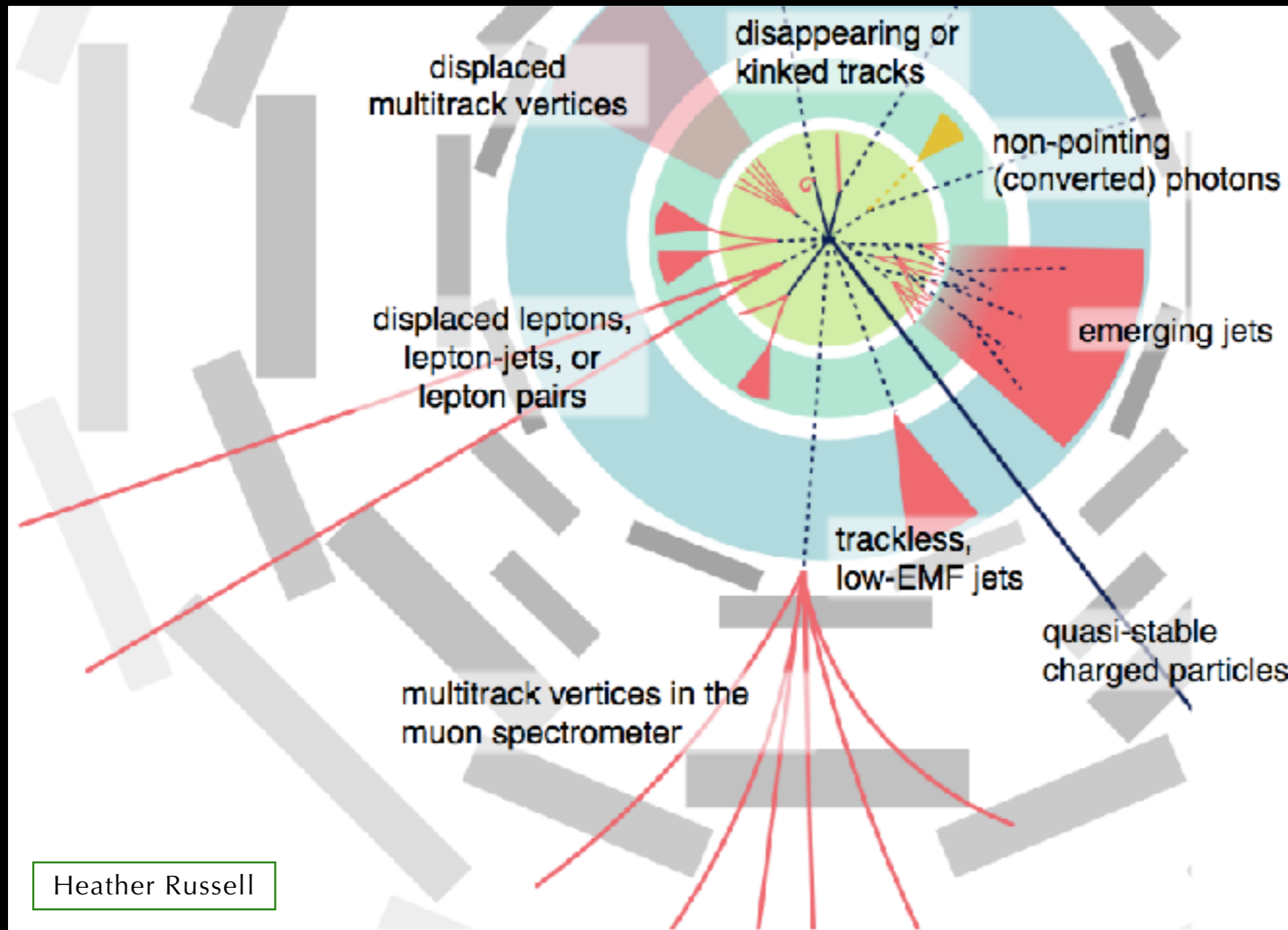
Same principles apply to BSM LLPs, which can generically appear

- Lifetime is usually best treated as a free parameter

The LHC **LLP** Community



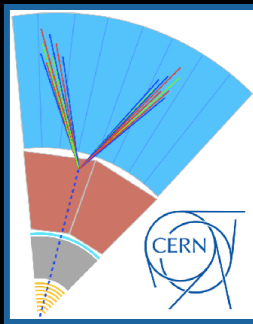
We map LLP signature space



What exactly do we mean by long-lived particle in the LHC context?

For our purposes, **LLP** = BSM particle that dies (gives up all its energy or decays to SM) somewhere in the detector acceptance of LHCb, CMS, ATLAS, MilliQan, MoEDAL, FASER, Codex-b, MATHUSLA, etc.

The LHC **LLP** Community



We map LLP signature space

Because of this, LLP searches are

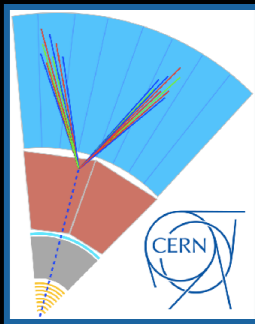
- Fun: Plenty of novel, innovative work to be done
- Challenging: Small analysis teams, difficult background estimates, hard to estimate systematic uncertainties

If we don't think about it critically and comprehensively, there's a danger we'll miss a potential discovery

Heather Russell

exactly do we
by long-lived
le in the LHC
context?

For our purposes, **LLP** = BSM particle that dies (gives up all its energy or decays to SM) somewhere in the detector acceptance of LHCb, CMS, ATLAS, MilliQan, MoEDAL, FASER, Codex-b, MATHUSLA, etc.



One question arose:

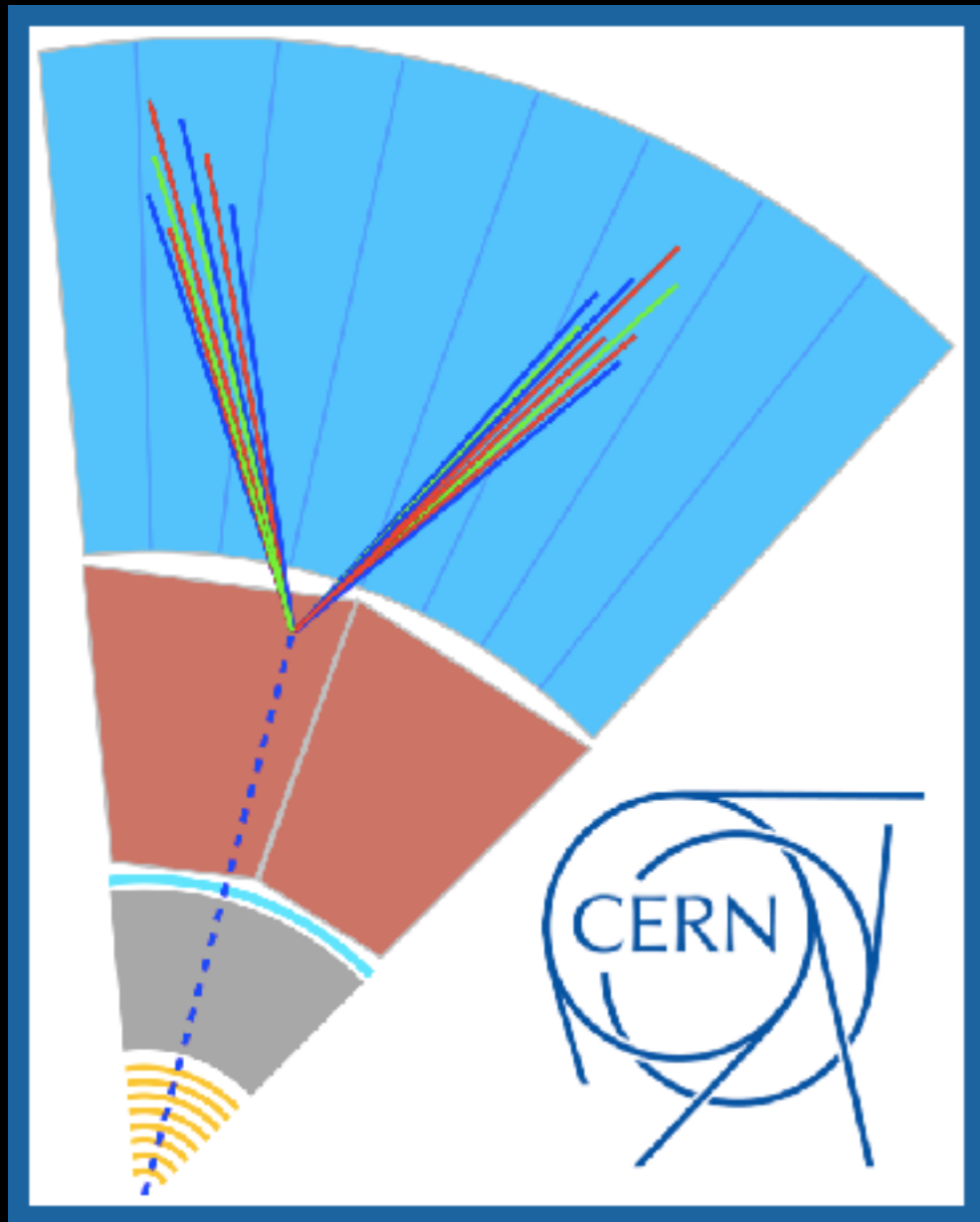
How do we best ensure that we don't miss
BSM LLP signatures for the remainder of the
LHC program and beyond?

Answer: Construct a space for the inter-experiment/
theory community to discuss and collect the results

Space: Working-workshops

Results: White papers and website

LHC Long-Lived Particle Community



...in collaboration with the theory/pheno community and MoEDAL, milliQan, MATHUSLA, FASER, Codex-b, AL3X, etc.

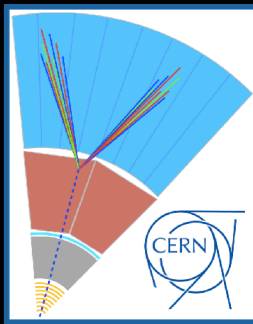
Workshops —
two per year

LHC **LLP** white paper:
11 March 2019 — [arXiv:1903.04497](https://arxiv.org/abs/1903.04497)
Submitted for publication in J. Phys. G

Join the CERN egroup: lhcllp

cern.ch/longlivedparticles

The LHC **LLP** Community Initiative



...in collaboration with the theory/pheno community and MoEDAL, milliQan, MATHUSLA, FASER, Codex-b, etc.

Workshops:

- Oct. 2018 — Fourth — Nikhef
- May 2018 — Third — CERN
- Oct. 2017 — Second — ICTP Trieste
- April 2017 — First — CERN

Continuing the work begun by several prior workshops

- May 2016 — LHC LLP Mini-Workshop — CERN
- May 2016 — “Experimental Challenges” — KITP
- Nov. 2015 — “LLP Signatures” — UMass Amherst

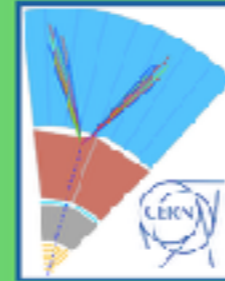
LHC LLP Community: Emphasis on “community”

Community is open to all

- By being here and participating, you’re already a member; welcome!

Workshops are informal and collaboration-centered

- Working-workshops, not a series of talks
- Prioritize discussion over presentations
- Slides are there to guide the discussion



27-29 May 2019
CERN
Paris/Saclay, France

Searching for long-lived particles at the LHC:
Fifth workshop of the LHC LLP Community



Community is collaboration – Collaboration is respect

To all community members:

- Yes, ask that physics question and make that suggestion!

To all session chairs and discussion leaders:

- Solicit comments from those who haven’t had a chance to talk!

We’re radically inclusive and radically anti-harrassment

- The CERN Code of Conduct is a great place to start

Overall we’re here to find new physics

- Both science and society suffer when ideas and thoughts aren’t heard because someone feels threatened, unwelcome, or marginalized
- Harrassment is antithetical to the intention of this workshop
 - We endeavor to create a positive and welcoming space!

The LHC LLP Community white paper

[arXiv:1903.04497](https://arxiv.org/abs/1903.04497)



Welcome to [INSPIRE](https://inspirehep.net), the High Energy Physics Information system. Please direct questions, comments or concerns to feedback@inspirehep.net.

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Information | References (616) | Citations (16) | Files | Plots

Searching for long-lived particles beyond the Standard Model at the Large Hadron Collider

Juliette Alimena (Ohio State U.), James Beacham (Duke U.), Martino Borsato (Heidelberg U.), Yangyang Cheng (Cornell U., LNS), Xabier Cid Vidal (Santiago de Compostela U.), Giovanna Cottin (Taiwan, Natl. Taiwan U.), Albert De Roeck (CERN), Nishita Desai (Tata Inst.), David Curlin (Toronto U.), Jared A. Evans (Cincinnati U.) *et al.* [Show all 201 authors](#)

Mar 11, 2019 - 301 pages

e-Print: [arXiv:1903.04497](https://arxiv.org/abs/1903.04497) [hep-ex] | PDF

Abstract (arXiv)

Particles beyond the Standard Model (SM) can generically have lifetimes that are long compared to SM particles at the weak scale. When produced at experiments such as the Large Hadron Collider (LHC) at CERN, these long-lived particles (LLPs) can decay far from the interaction vertex of the primary proton-proton collision. Such LLP signatures are distinct from those of promptly decaying particles that are targeted by the majority of searches for new physics at the LHC, often requiring customized techniques to identify, for example, significantly displaced decay vertices, tracks with atypical properties, and short track segments. Given their non-standard nature, a comprehensive overview of LLP signatures at the LHC is beneficial to ensure that possible avenues of the discovery of new physics are not overlooked. Here we report on the joint work of a community of theorists and experimentalists with the ATLAS, CMS, and LHCb experiments --- as well as those working on dedicated experiments such as MoEDAL, milliQan, MATHUSLA, CODEX-b, and FASER --- to survey the current state of LLP searches at the LHC, and to chart a path for the development of LLP searches into the future, both in the upcoming Run 3 and at the High-Luminosity LHC. The work is organized around the current and future potential capabilities of LHC experiments to generally discover new LLPs, and takes a signature-based approach to surveying classes of models that give rise to LLPs rather than emphasizing any particular theory motivation. We develop a set of simplified models; assess the coverage of current searches; document known, often unexpected backgrounds; explore the capabilities of proposed detector upgrades; provide recommendations for the presentation of search results; and look towards the newest frontiers, namely high-multiplicity "dark showers", highlighting opportunities for expanding the LHC reach for these signals.

On the arXiv
11 March 2019

Submitted for
publication in J.
Phys. G

257 pages
(301 w/references)

201 authors /
contributors /
endorsers

21 editors

616 references

16 citations
already

The LHC LLP Community white paper

[arXiv:1903.04497](https://arxiv.org/abs/1903.04497)

Searching for long-lived particles beyond the Standard Model at the Large Hadron Collider

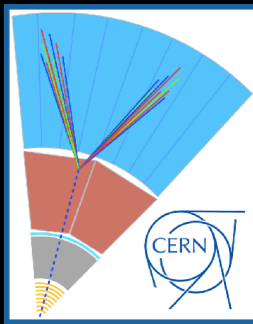
April 23, 2019

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A comprehensive document — a combination **review paper**, set of **recommendations**, accounting of **open discovery possibilities**, record of **accumulated knowledge**, and **speculation** for the future — that (paired with the MATHUSLA physics case document [arXiv:1806.07396](https://arxiv.org/abs/1806.07396)) serves as the **definitive guide to LLP searches at the LHC ... as of 11 March 2019**



Searching for long-lived particles beyond the Standard Model at the Large Hadron Collider

April 23, 2019

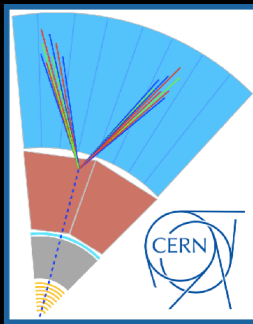
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White paper: Focused on experimental signature

[arXiv:1903.04497](https://arxiv.org/abs/1903.04497)



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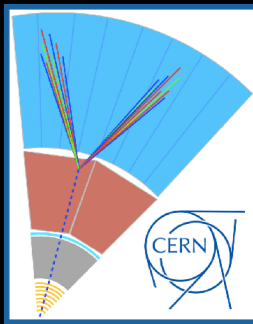
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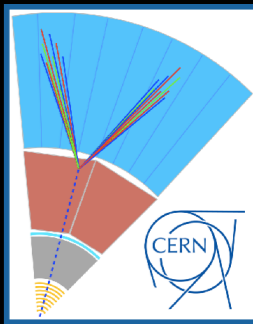
Editors:

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White paper: Focused on experimental signature

[arXiv:1903.04497](https://arxiv.org/abs/1903.04497)



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Simplified model proposal organized around generic classes of LLP production and decay mode, always with an eye toward what the detectors might be able to do

of the discovery of new physics are not overlooked. Here we report on the joint work of the ATLAS, CMS, and LHCb experiments, as well as other experiments such as MoEDAL, milliQan, MATHUSLA, and the development of LLP searches into the future, both in the upcoming Run 3 and Run 4. We discuss the current and future potential capabilities of the LHC experiments to generally discover new LLPs, and takes a signature-based approach to LLP searches, emphasizing any particular theoretical model. We develop a set of simplified models, assess the coverage of current searches, and provide recommendations for the presentation of search results; and look towards the future, highlighting opportunities for experimental searches for these signals.

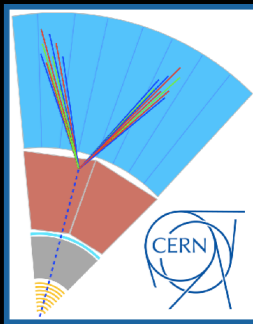
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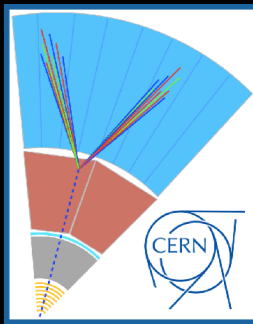
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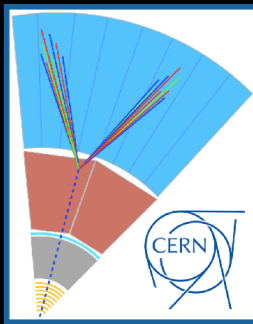
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Experimental coverage:
How well do the
existing searches cover
the parameter space?

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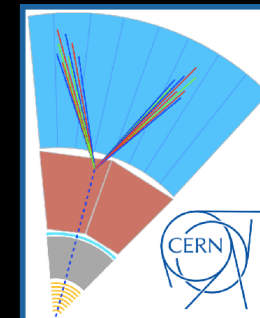
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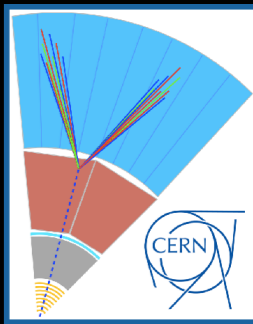
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Backgrounds to LLP searches can be small but unexpected. Collected wisdom and reference here.

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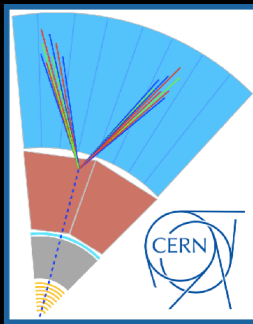
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White paper: Focused on experimental signature

[arXiv:1903.04497](https://arxiv.org/abs/1903.04497)



Searching for long-lived particles beyond the Standard Model at the Large Hadron Collider

April 23, 2019

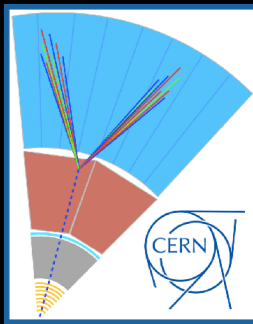
Particles beyond the Standard Model (SM) can generically have lifetimes that are long compared to SM particles at the weak scale. When produced at experiments such as the Large Hadron Collider (LHC) at CERN, these long-lived particles (LLPs) can decay far from the interaction point of the primary proton-proton collision. Such LLP signatures are distinct from those of decaying particles that are targeted by the majority of searches for new physics at the LHC, requiring customized techniques to identify, for example, significantly displaced decay tracks with atypical properties, and short track segments. Given their non-standard signatures, a comprehensive overview of LLP signatures at the LHC is beneficial to ensure that possibilities for the discovery of new physics are not overlooked. Here we report on the joint work of the community of theorists and experimentalists with the ATLAS, CMS, and LHCb experiments, as well as those working on dedicated experiments such as MoEDAL, milliQan, MATHUSRA, and FASER — to survey the current state of LLP searches at the LHC, and to discuss the development of LLP searches into the future, both in the upcoming Run 3 and High Luminosity LHC. The work is organized around the current and future potential capabilities of the LHC experiments to generally discover new LLPs, and takes a signature-based approach to surveying classes of models that give rise to LLPs rather than emphasizing any particular theoretical model. We develop a set of simplified models, assess the coverage of current searches, provide recommendations for the presentation of search results, and look towards the future by highlighting opportunities for experimental upgrades to search for these signals.

What triggers are missing? What upgrade studies should be done to advocate for new detector components? Long-term discussion, addressed at this week's workshop and in the future.

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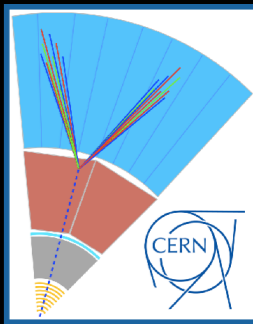
Editors:

Juliette Alimena⁽¹⁾ (Experimental Coverage, Backgrounds, Upgrades), James Beacham⁽²⁾ (Editor, Simplified Models), Marino Borsato⁽³⁾ (Backgrounds, Upgrades), Yangyan Chen⁽⁴⁾ (Upgrades), Xavier Cid Vidal⁽⁵⁾ (Experimental Coverage), Giovanna Cottin⁽⁶⁾ (Simplified Models, Reinterpretations), Albert De Roeck⁽⁷⁾ (Experimental Coverage), Nishita Desai⁽⁸⁾ (Simplified Models), David Curtin⁽⁹⁾ (Simplified Models), Jared A. Evans⁽¹⁰⁾ (Simplified Models, Experimental Coverage), Simon Knapen⁽¹¹⁾ (Dark Showers), Sabine Kraml⁽¹²⁾ (Reinterpretations), Andre L. L. Liu⁽¹³⁾ (Simplified Models, Backgrounds, Reinterpretations), Sascha Mielke⁽¹⁴⁾ (Simplified Models), Michael J. Ramsey-Musolf^(15,126) (Simplified Models), Heather Russell⁽¹⁷⁾ (Experimental Coverage), Jessie Shelton⁽¹⁸⁾ (Simplified Models, Dark Showers), Brian Shuve^(19,20) (Documentation, Simplified Models, Simplified Models Library), Monica Verducci⁽²¹⁾ (Upgrades), and John... (Experimental Coverage)

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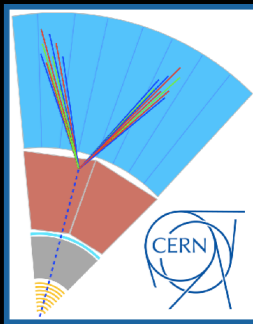
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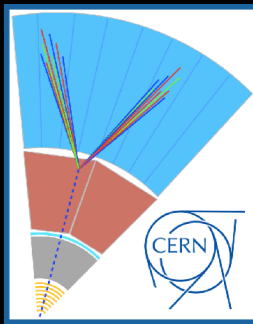
Editors:

Juliette Alimena⁽¹⁾ (Experimental Coverage, Backgrounds, Upgrades), James Beacham⁽²⁾ (Editor, Simplified Models), Marino Borsato⁽³⁾ (Backgrounds, Upgrades), Yangyan Chen⁽⁴⁾ (Upgrades), Xavier Cid Vidal⁽⁵⁾ (Experimental Coverage), Giovanna Cottin⁽⁶⁾ (Simplified Models, Reinterpretations), Albert De Roeck⁽⁷⁾ (Experimental Coverage), Nishita Desai⁽⁸⁾ (Simplified Models), David Curtin⁽⁹⁾ (Simplified Models), Jared A. Evans⁽¹⁰⁾ (Simplified Models, Experimental Coverage), Simon Knapen⁽¹¹⁾ (Dark Showers), Sabine Kraml⁽¹²⁾ (Reinterpretations), Andre L. L. Liu⁽¹³⁾ (Simplified Models, Backgrounds, Reinterpretations), Sascha Mielke⁽¹⁴⁾ (Simplified Models), Michael J. Ramsey-Musolf^(15,126) (Simplified Models), Heather Russell⁽¹⁷⁾ (Experimental Coverage), Jessie Shelton⁽¹⁸⁾ (Simplified Models, Dark Showers), Brian Shuve^(19,20) (Documentation, Simplified Models, Simplified Models Library), Monica Verducci⁽²¹⁾ (Upgrades), Jochen

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White paper: Focused on experimental signature

[arXiv:1903.04497](https://arxiv.org/abs/1903.04497)



Searching for long-lived particles beyond the Standard Model at the Large Hadron Collider

April 23, 2019

Particles beyond the Standard Model (SM) can generically have lifetimes that are to SM particles at the weak scale. When produced at experiments such as the Large Hadron Collider (LHC) at CERN, these long-lived particles (LLPs) can decay far from the interaction point of the primary proton-proton collision. Such LLP signatures are distinct from those of decaying particles that are targeted by the majority of searches for new physics at the LHC, requiring customized techniques to identify, for example, significantly displaced decay tracks with atypical properties, and short track segments. Given their non-standard nature, a comprehensive overview of LLP signatures at the LHC is beneficial to ensure that possible signatures of the discovery of new physics are not overlooked. Here we report on the joint work of the ATLAS, CMS, and LHCb experiments, as well as the MoEDAL, milliQan, MATHUSRA, and MIPSHINE LLP searches at the LHC, and to discuss the development of LLP searches into the future, both in the upcoming Run 3 and beyond. We provide an overview around the current and future potential capabilities of the LHC experiments to generally discover new LLPs, and takes a signature-based approach to LLPs rather than emphasizing any particular theoretical model. We develop a set of simplified models, assess the coverage of current searches, and provide recommendations for the presentation of search results; and look towards future opportunities for experimental searches for LLPs.

Editors:

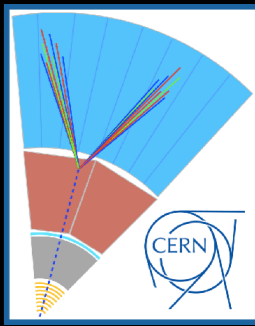
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QCD-like (more or less) dark sectors: What kinds of experimental signatures are between emerging jets and SUEP?

Longer-term work on uncharted territory; still examining how we know what we don't know.

White paper: Simplified Models chapter



Signature first, model second

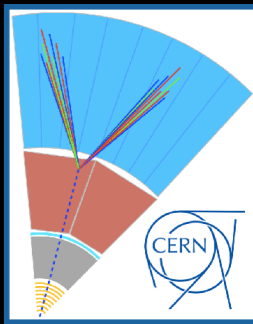
- General classes of motivations that can give rise to LLPs are many
 - Dark photons
 - Hidden valleys
 - R-parity-violating supersymmetry
 - Dark QCD-like sectors
 - Heavy neutral leptons
 - Etc.

Instead of probing the parameter space of your favorite model, think about the more generic kinds of ways an LLP could be produced at the LHC interaction points and then how it could appear in the detector

- Much clearer way of comparing searches and noting whether and to what extent certain signatures have been covered
- Creates a useful grammar of LLP signatures/searches across experiment

Experimental coverage chapter

Both a review document and a list of discovery opportunities



A critical component of any discussion of long-lived particle searches at the LHC is the comprehensive review of the existing searches from ATLAS, CMS, and LHCb, and an assessment of their coverage and any gaps therein. This is an inherently challenging task, given the varied and atypical objects often defined and utilized in LLP analyses and the differences among the experiments. As such, the following discussion assumes little-to-no background on LLP search strategies and includes a high level of detail regarding the current analyses. The focus of the discussion is on the existing studies, while acknowledging that the landscape for new physics models and LLP signatures can be broader than the ones described here.

3.6 Discovery Opportunities: Overview of Gaps in Coverage

In the preceding sections (3.1–3.5.3), we have examined the so-called “coverage” of existing searches for LLPs at the LHC with the explicit and express purpose of identifying uncovered realms and places where discoveries could be hiding. Here, we summarize these gaps and potential opportunities for LLP discovery in bullet form, as a to-do list for the experimental community.

1. All-hadronic LLP decays

- Associated-object triggers (especially motivated by Higgs-like VBF and VH production modes) need to be more comprehensively used to improve sensitivity to low- p_T objects
- Improvements are needed in sensitivity at lower masses & lifetimes (e.g., for LLPs produced in Higgs decays)
- Single hadronic DVs need to be looked for in searches that currently use two (such as decays in ATLAS HCAL and MS)
- Possibilities need to be explored for online reconstruction

3. Semi-Leptonic

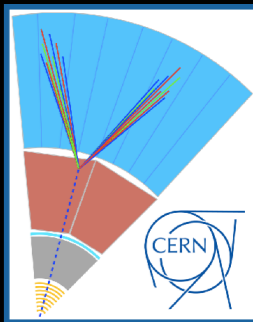
- Searches do not exist and need to be done for masses below or about 30 GeV, theoretically well motivated by Majorana neutrinos.
- Searches need to be performed for all flavor combinations (for example, one CMS search only covers $e^\pm\mu^\mp$), as well as same-sign vs. opposite-sign leptons
- Currently unknown improvements need to be made to relax or modify isolation criteria wherever possible to recover sensitivity to boosted semi-leptonic decays
- Searches need to be done that better exploit triggering on associated objects for improved sensitivity to low-mass objects, or to employ high-multiplicity lepton triggers if there are multiple LLPs

5. Other exotic long-lived signatures

- Disappearing tracks with $c\tau \sim \text{mm}$ are very hard to probe, and new ideas and detector components are needed to extend sensitivity to this potential discovery regime. It's unclear if the ATLAS insertable B-layer will be present in HL-LHC run and how sensitivity to the disappearing track topology will improve with the replacement of the current inner detector with the new ITk (Inner Tracker), or whether new tracking layers very close to the beam line can be added. It's an open question as to what is the lowest distance at which new layers (or double layers) can be inserted. Another open question that needs to be answered is whether there are any prospects for disappearing tracks at LHCb with an upgraded detector.
- No dedicated searches for quirks exist at the LHC, a huge, open discovery possibility for ATLAS, CMS, and LHCb.

Experimental coverage chapter

Both a review document and a list of discovery opportunities



A critical component of any discussion of long-lived particle searches at the LHC is the comprehensive review of the existing searches from ATLAS, CMS, and LHCb, and an assessment of their coverage and any gaps therein. This is an inherently challenging task, given the varied and atypical objects often defined and utilized in LLP analyses and the differences among the following discussion assumes little-to-no overlap in search strategies and includes a high level of detail in the analyses. The focus of the discussion is on the discovery opportunities while acknowledging that the landscape of LLP signatures can be broader than what is currently covered.

3. Semi-Leptonic

- Searches do not exist and need to be done for masses below or about 30 GeV, theoretically well motivated by Majorana

Completely separate chapter
on *dark showers*:
Phenomenology of dark-
QCD-like sectors, from
emerging jets to SUEPs (soft,
unclustered energy patterns)
— uncharted territory
(beginning to be charted)

3.6 Discovery Opportunities: Overview

In the preceding sections (3.1–3.5.3), we have discussed the explicit and express purpose of identifying and places where discoveries could be made. In this section, we discuss these gaps and potential opportunities in a form, as a to-do list for the experiments.

1. All-hadronic LLP decays

- Associated-object triggers (especially motivated by Higgs-like VBF and VH production modes) need to be more comprehensively used to improve sensitivity to low- p_T objects
- Improvements are needed in sensitivity at lower masses & lifetimes (e.g., for LLPs produced in Higgs decays)
- Single hadronic DVs need to be looked for in searches that currently use two (such as decays in ATLAS HCAL and MS)
- Possibilities need to be explored for online reconstruction

needed for all flavor combinations. The current search only covers $e^\pm\mu^\mp$, as well as searches for single leptons.

Improvements need to be made to recover sensitivity wherever possible to recover sensitivity to single-leptonic decays.

Searches that better exploit triggering on single-lepton triggers improved sensitivity to low-mass objects. Multiplicity lepton triggers if there are

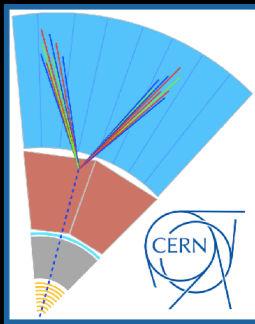
signatures

with $c\tau \sim \text{mm}$ are very hard to probe, and new detector components are needed to extend the discovery regime. It's unclear if this layer will be present in HL-LHC run

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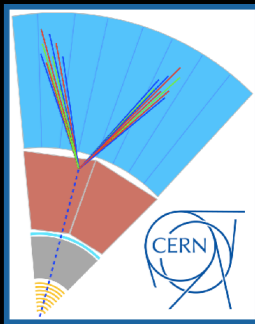
LHC LLP: Moving forward



LHC LLP Community now and in the future

- Twice yearly workshop schedule, spring (at CERN) and fall (mobile) — sounding board for your ideas
- New LLP ideas, new signatures, improvements in coverage, evolving high-priority searches and studies, etc.
- Simplified models are just that, simplified, so already some organic interest in studying some of the classes of motivations in detail, leveraging the strength of the community
 - HNL enthusiasts have already started a study group / task force to do this for displaced heavy neutrino signatures — *An entire breakout working group devoted to this at the present workshop!*
 - DM/dark photon version of this would be interesting, too, and some strong interest shown recently
 - Will likely be a key component of the fall workshop
- And as an example of how last workshop's idea becomes the next workshop's focus, this week we have *an entire breakout working group devoted to exploring the way machine learning can aid LLP searches*
- Reinterpretations of LLP searches is a continually vital topic — *our third breakout working group this week*

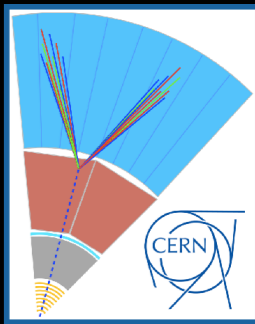
LHC LLP: Moving forward



- Future work: A follow-up white paper dedicated to very blue-sky upgrade ideas and studies?
- Community consideration of LLP signatures at both future detectors *and* future colliders — *many talks this week*
 - Some work already done for FCC-hh/ee, CEPC, electron-proton, CLIC, ILC, etc., but still some opportunities
 - Lessons learned from detector design at the LHC can inform the priorities of future machines
- Closer collaboration between ML and LLP communities
 - Working group this week
 - Dedicated workshop in the future
- Dedicated detectors for LLPs at the LHC
 - FASER recently approved — wonderful! Now how to we get all of the other proposals to the same stage?
- Your idea goes here
- Join us on Wednesday afternoon for a roundtable discussion about next-steps and priorities for the community

The strength of the community isn't white papers or recommendations but *as a platform where new ideas can foment and flourish*

The future is experimental



Our job as physicists is not to find SUSY or WIMP dark matter or sequential SM Z' or QBH or VLQs or...

After our first look at 13 TeV, our traditional motivation paradigms are fading or dead

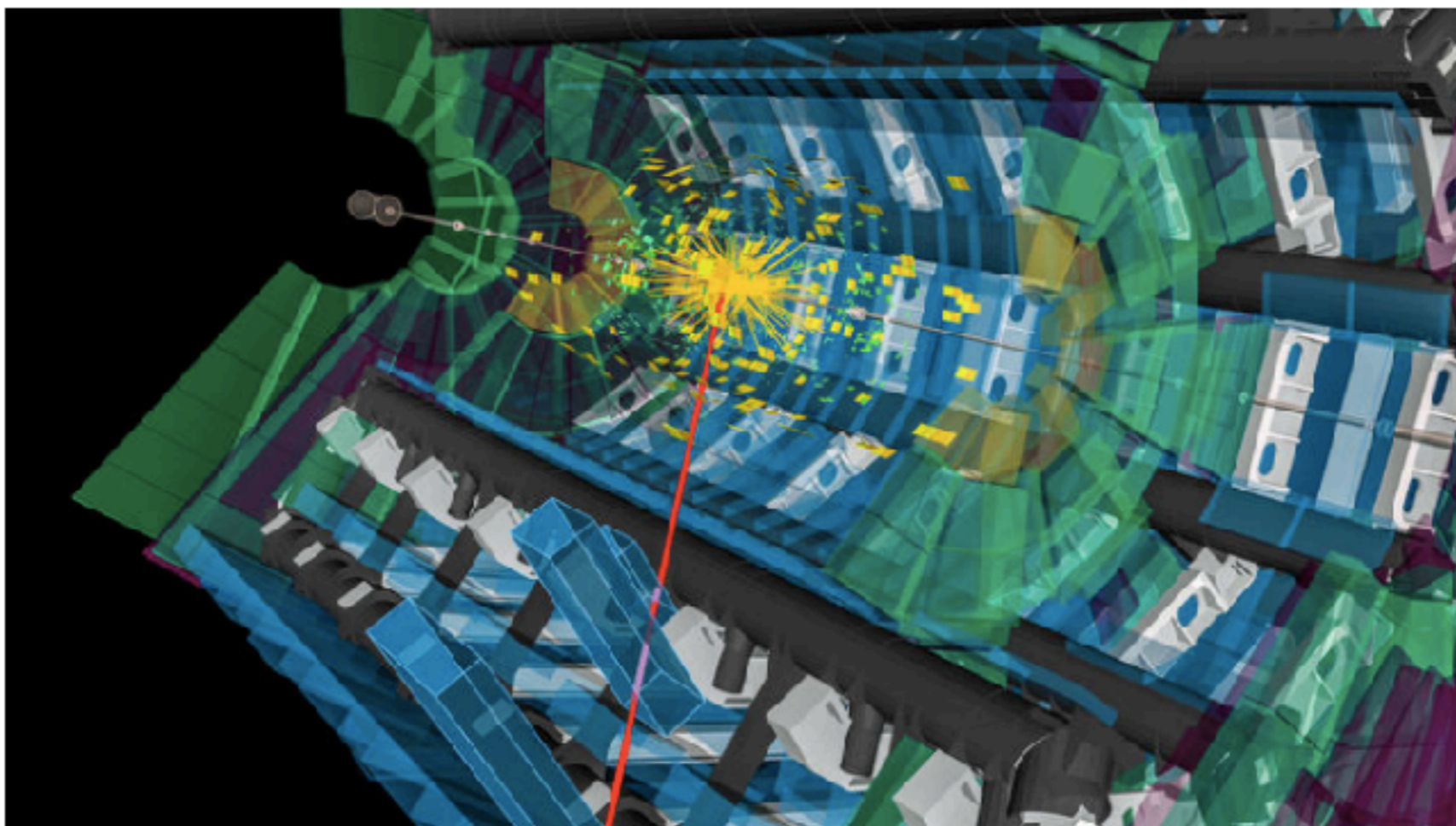
The Higgs discovery only answered one open question — does the SM Higgs exist? — and raised a bunch of others!

But these other questions are no longer accompanied by guaranteed discoveries

Scary: Where do we look?

Freedom: Everywhere! We have one of the most sophisticated devices ever built at our disposal, and our job is to push it to its limits, to map out all available experimental object space

This means bold new ideas involving LLPs. 2019 is the perfect time to be bold!



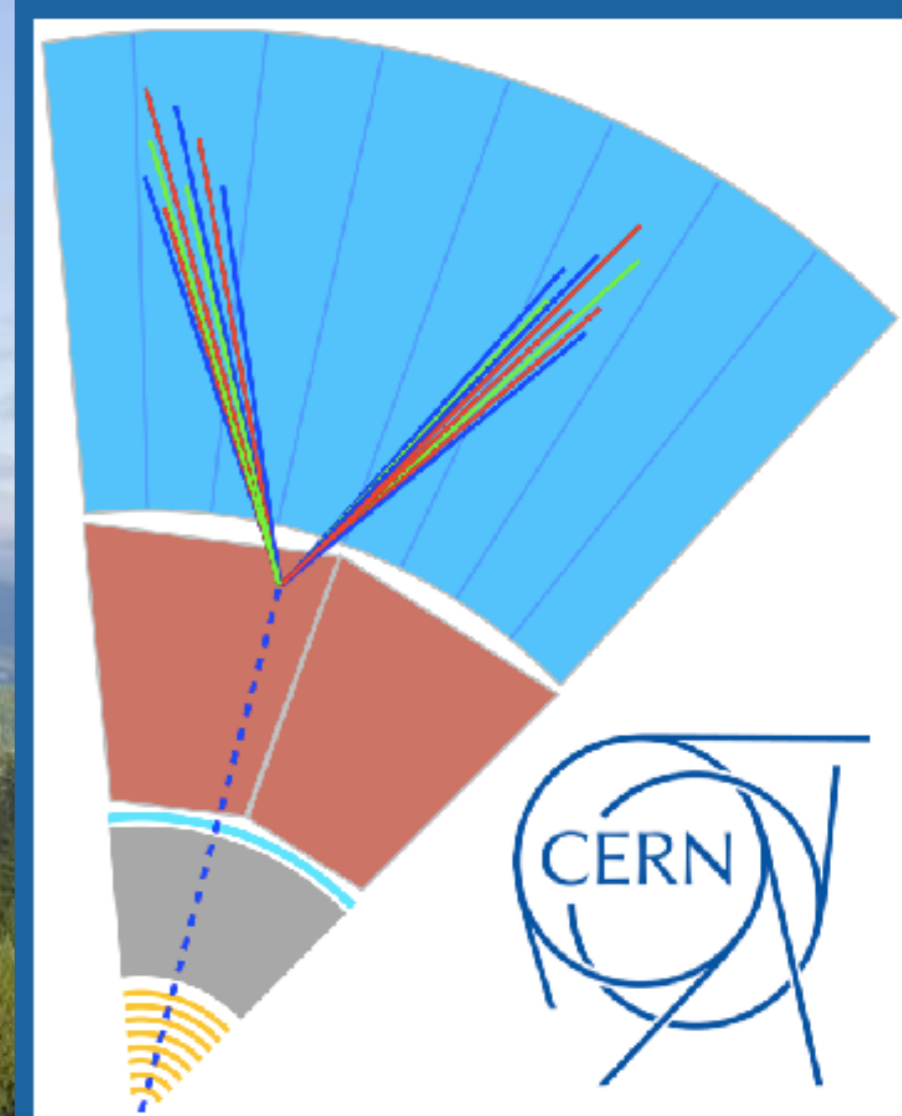
In a simulated event, the track of a decay particle called a muon (red), displaced slightly from the center of particle collisions, could be a sign of new physics. ATLAS EXPERIMENT © 2019 CERN

Atom smasher could be making new particles that are hiding in plain sight

By [Adrian Cho](#) May. 22, 2019, 12:20 PM

Are new particles materializing right under physicists' noses and going unnoticed? The world's great atom smasher, the Large Hadron Collider (LHC), could be making long-lived particles that slip through its detectors, some researchers say. Next week, they will gather at the LHC's home, CERN, the European particle physics laboratory near Geneva, Switzerland, to discuss how to capture them. They argue the LHC's next run should emphasize such searches, and some are calling for new detectors that could sniff out the fugitive particles.

[Link](#)



Workshop goal:
Map the future.
You're doing it right now.

Searching for
long-lived particles
at the LHC:
Fifth workshop of the
LHC LLP Community

27-29 May 2019

CERN

indico.cern.ch/e/LHC_LLP_May_2019

