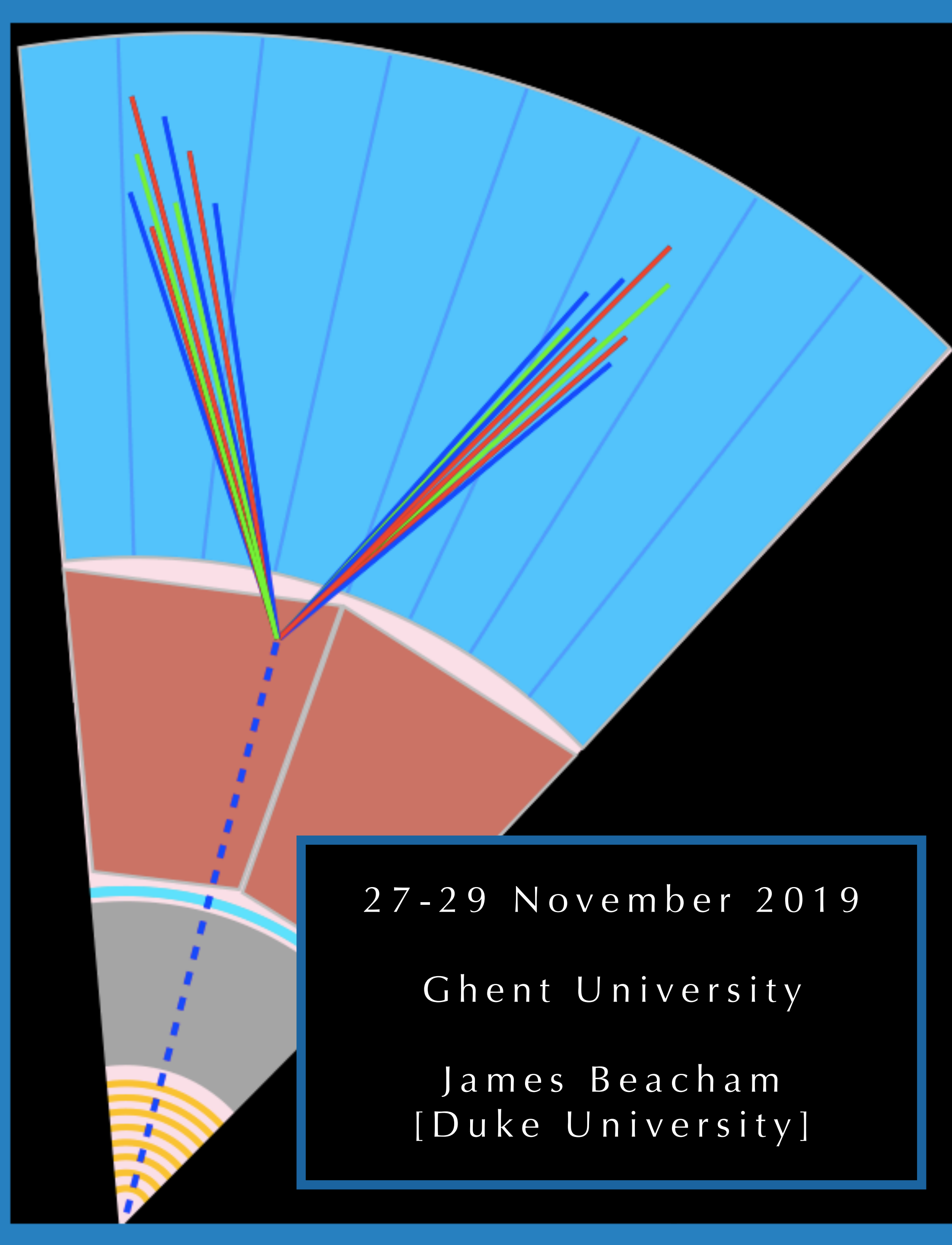


Searching for  
long-lived particles  
at the LHC



Sixth Workshop of the LHC  
Long-Lived Particle Community

[indico.cern.ch/e/LHC\\_LL\\_P\\_Nov\\_2019](https://indico.cern.ch/e/LHC_LL_P_Nov_2019)

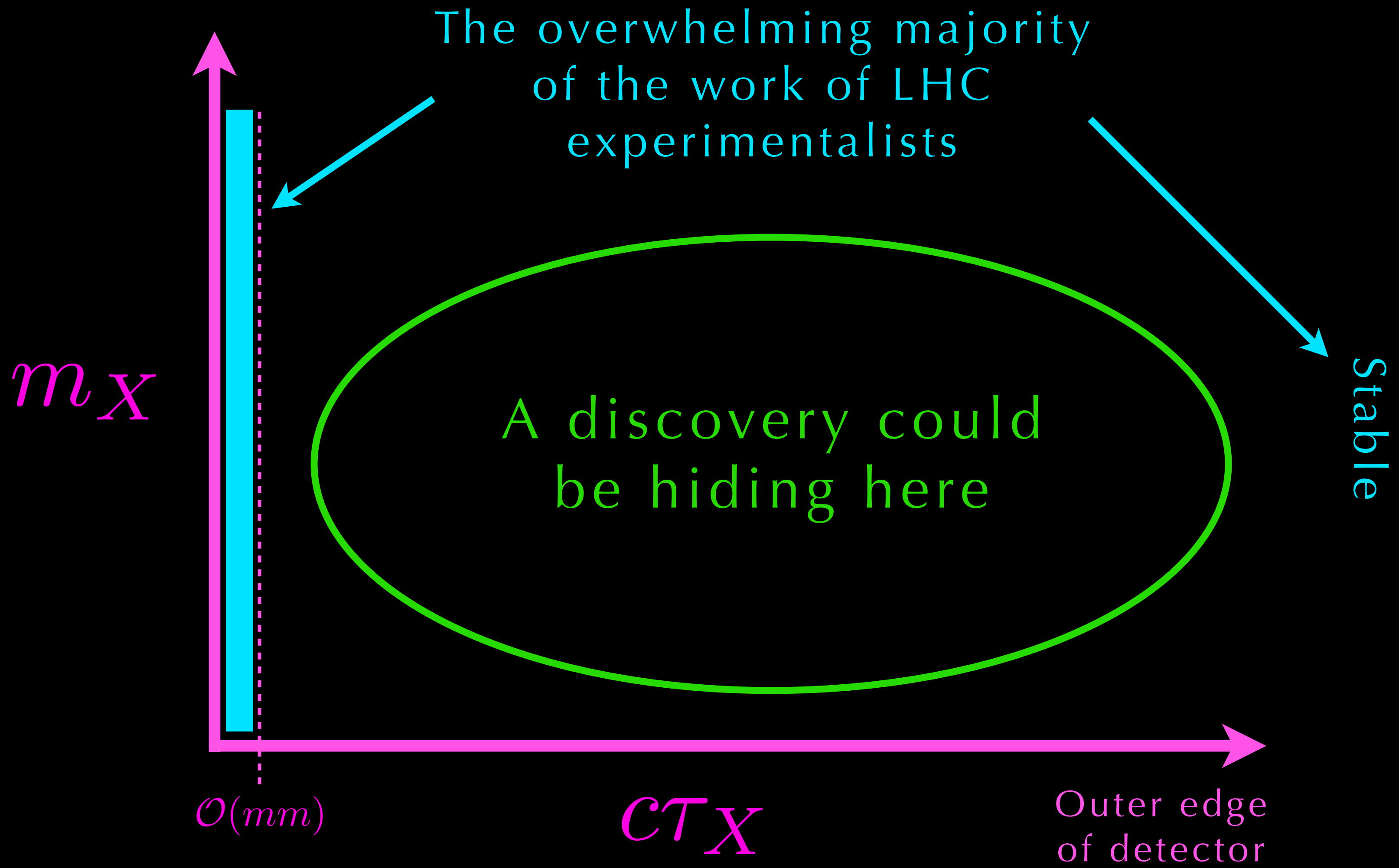


27-29 November 2019

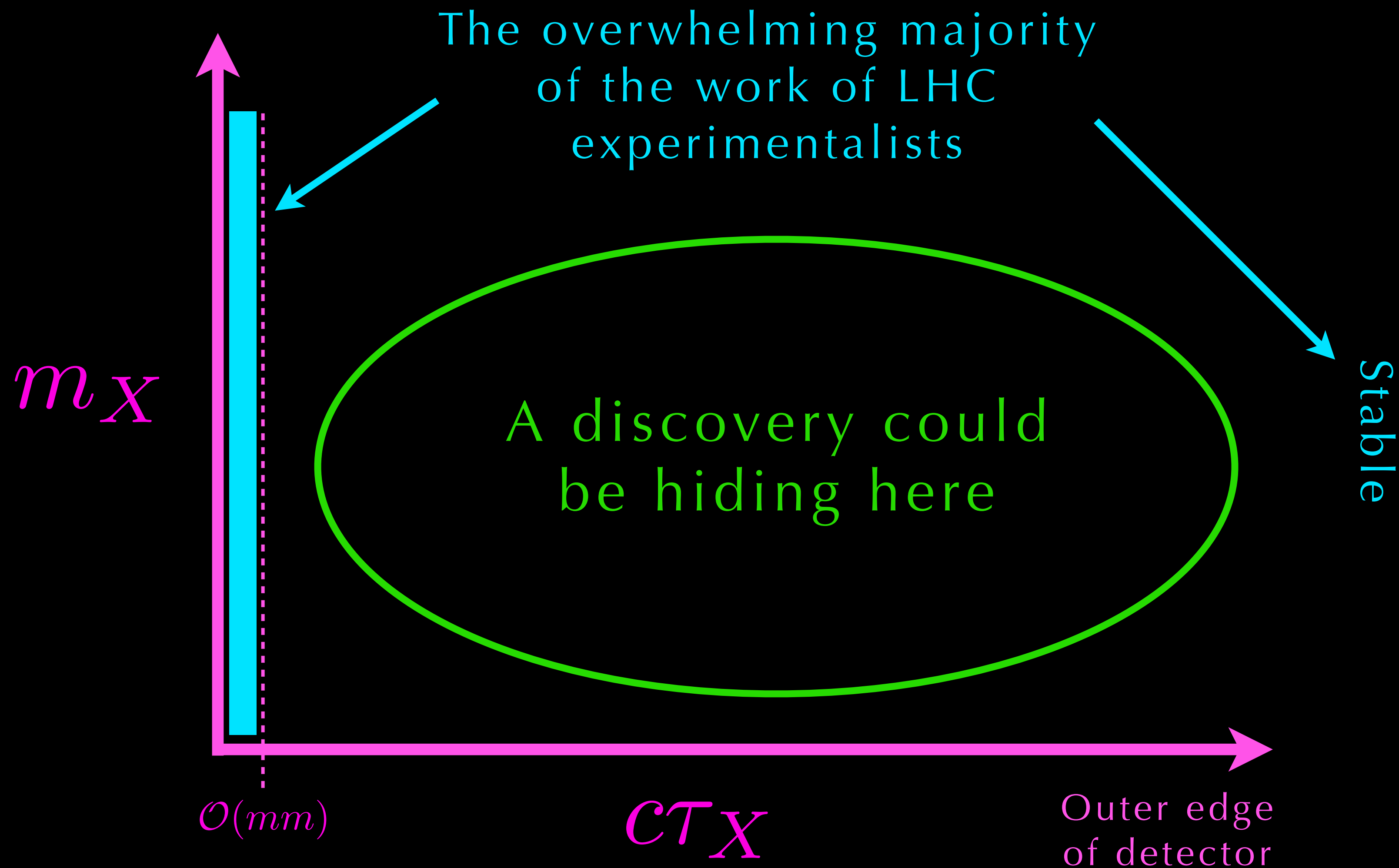
Ghent University

James Beacham  
[Duke University]

# The lifetime frontier



# The lifetime frontier

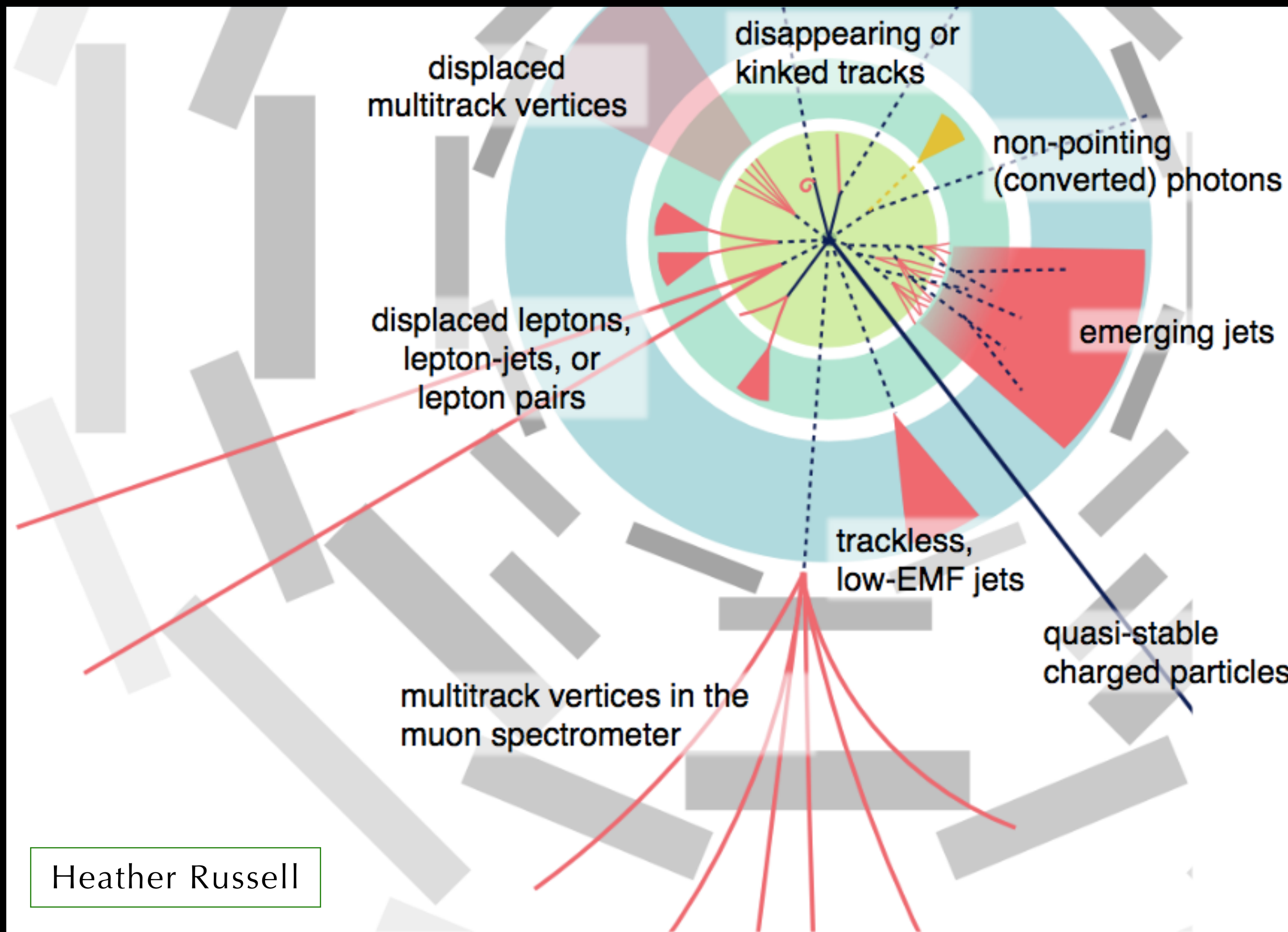


Large majority of ATLAS, LHCb, and CMS searches and analysis strategies assume the new particle decays promptly

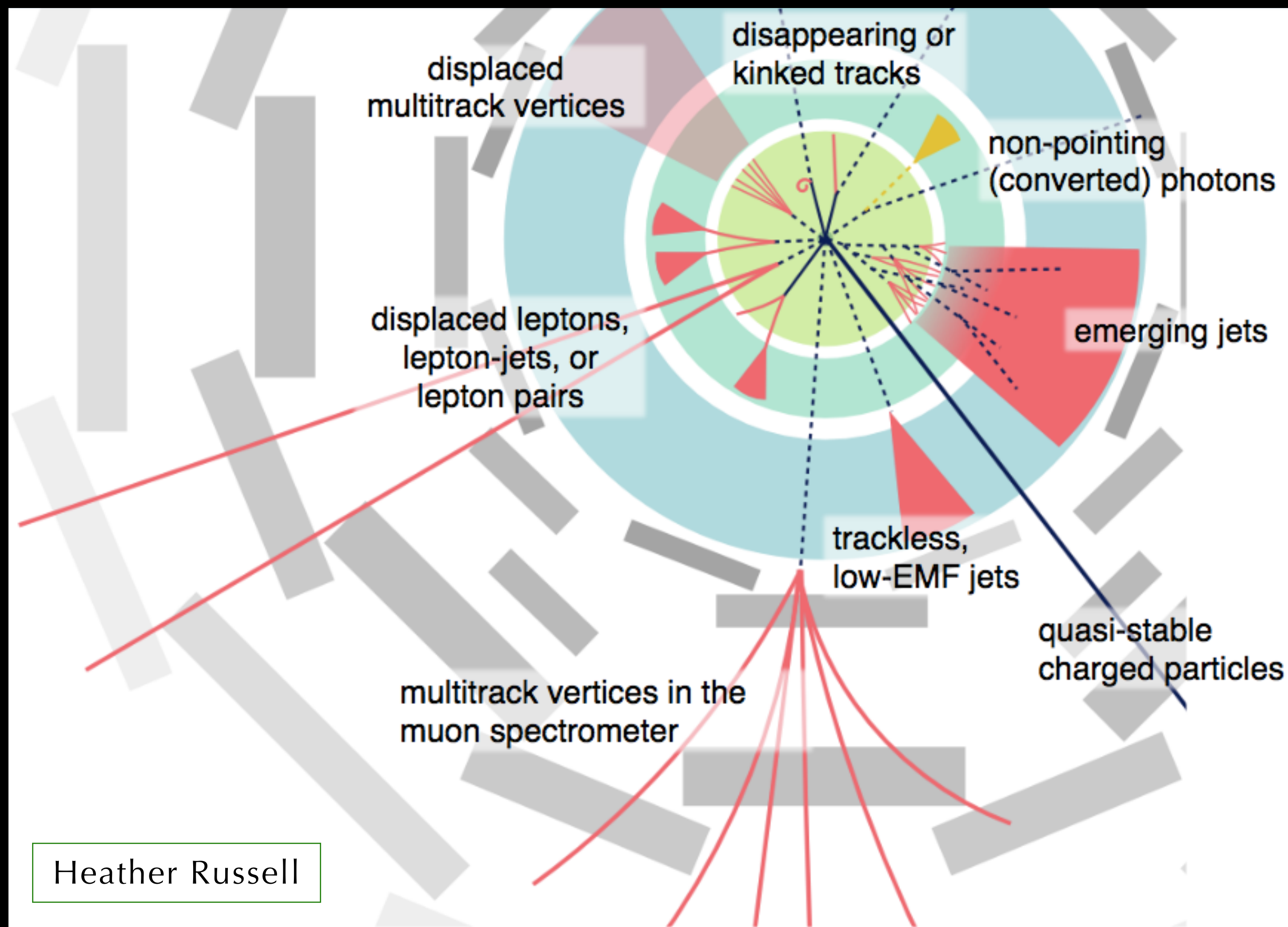
Particle lifetimes in the SM span a very wide range and long lifetimes can generically appear in BSM theories

Obliges us to perform dedicated searches for **long-lived** BSM particles

# Long-lived particles in the central LHC detectors and beyond

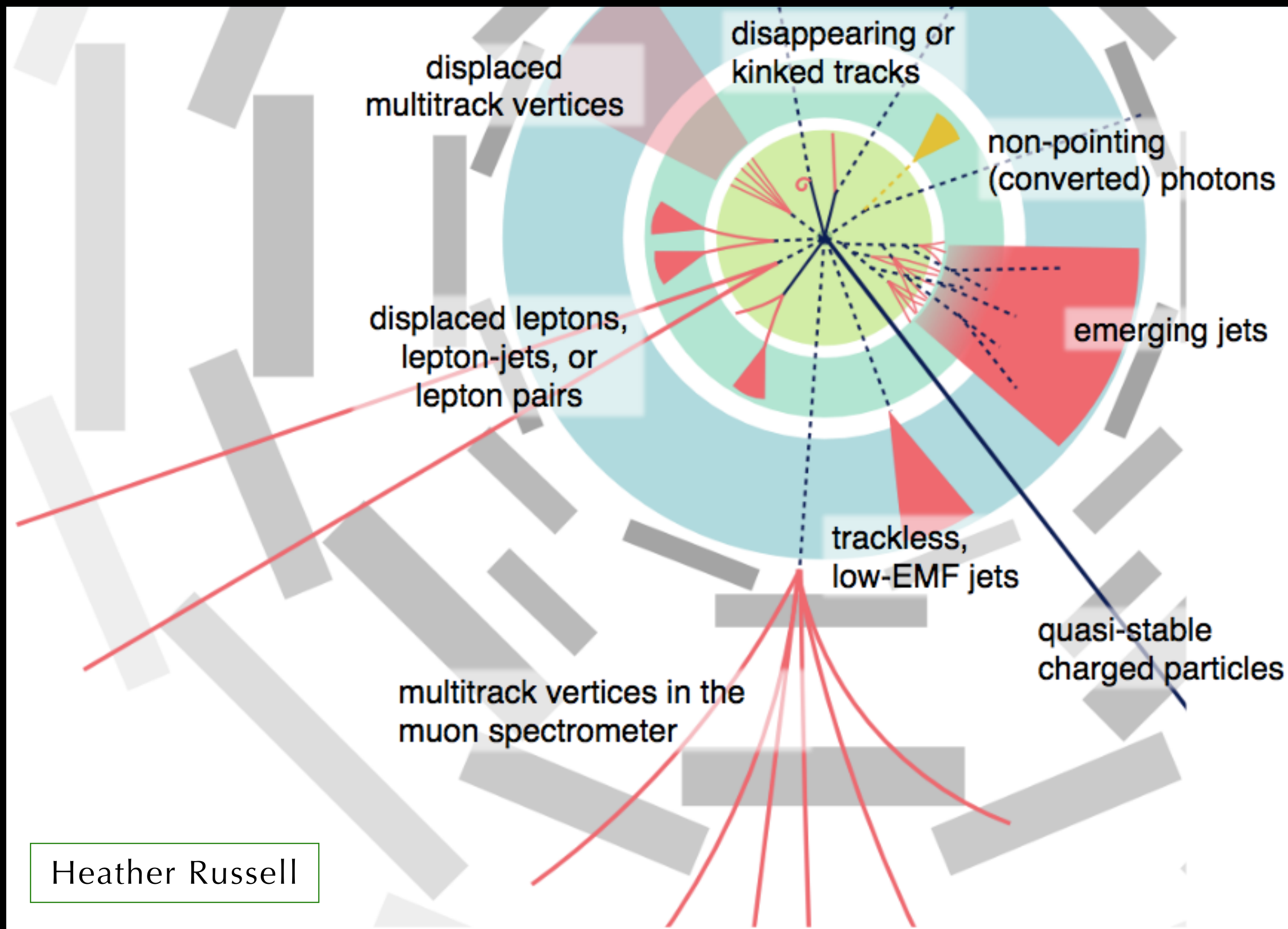


# Long-lived particles in the central LHC detectors and beyond



For our purposes, **LLP** = BSM particle with a non-negligible lifetime that gives up most of its energy or decays to SM somewhere in the detector acceptance of LHCb, CMS, ATLAS, MilliQan, MoEDAL, FASER, CODEX-b, MATHUSLA, AL3X, ANUBIS, etc.

# Long-lived particles in the central LHC detectors and beyond



We've been doing these searches since day one of the LHC (and at LEP, & Tevatron), but until ~2016, they were always considered fringe, and they still make up less than 10% of our "exotic" searches

Public results with the central LHC detectors

CMS Exotica LLP

CMS SUSY RPV

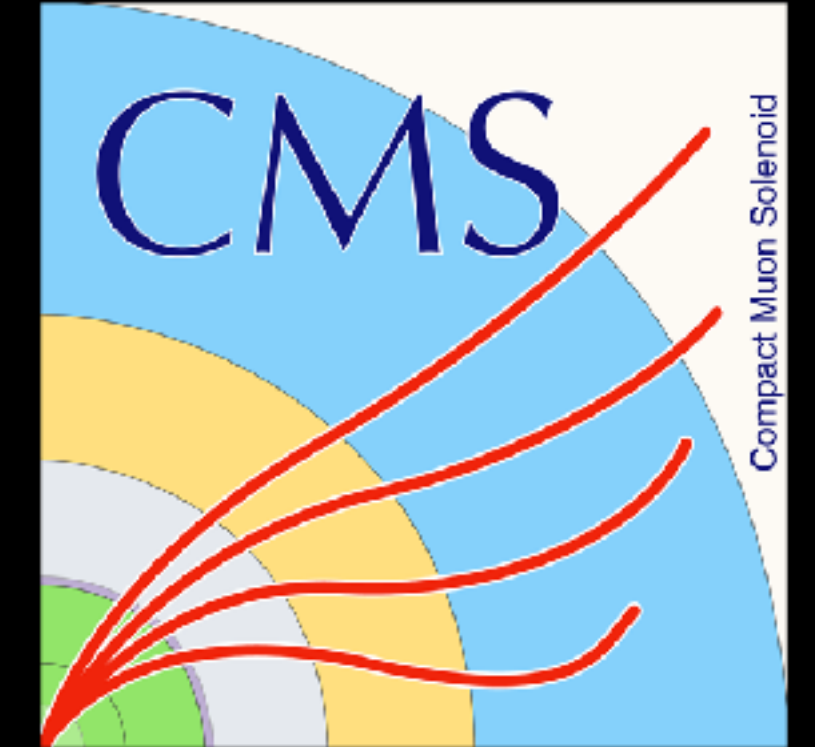
LHCb Public Results

ATLAS Exotics

ATLAS SUSY

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# LHC Long-Lived Particle Community



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

---

Formed to address one question:  
How do we best ensure that we don't miss BSM **LLP** signatures for the remainder of the LHC program?

---

Workshops —  
two per year

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

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Join the CERN egroup: [lhc-llp](mailto:lhc-llp)

[cern.ch/longlivedparticles](https://cern.ch/longlivedparticles)

# 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 only a series of talks
- Prioritize discussion over presentations
- Slides are there to guide the discussion





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*Community is collaboration – Collaboration is respect*

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*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

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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) (to appear in J. Phys. G)

The screenshot shows the INSPIRE HEP website interface. At the top left is the INSPIRE HEP logo. To its right is a welcome message: "Welcome to INSPIRE, the High Energy Physics information system. Please direct questions, comments or concerns to [feedback@inspirehep.net](mailto:feedback@inspirehep.net)." Below this is a navigation bar with links: HEP :: HEPNAMES :: INSTITUTIONS :: CONFERENCES :: JOBS :: EXPERIMENTS :: JOURNALS :: HELP. The main content area has tabs for Information, References (616), Citations (48), Files, and Plots. The selected tab is Information. The title of the paper is "Searching for Long-Lived Particles beyond the Standard Model at the Large Hadron Collider". The authors listed are 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 Curtin (Toronto U.), Jared A. Evans (Cincinnati U.) et al. There is a link "Show all 201 authors". The date is "Mar 11, 2019 - 301 pages". The e-Print link is "arXiv:1903.04497 [hep-ex] | PDF". The abstract text is as follows:

**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

257 pages  
(301 w/references)

201 authors /  
contributors / endorsers

21 editors

616 references

48 citations to date

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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) / [Rept.Prog.Phys. 82 \(2019\) no.11, 116201](https://doi.org/10.1093/rpd/82/11/116201)) serves as a definitive guide to LLP searches at the LHC

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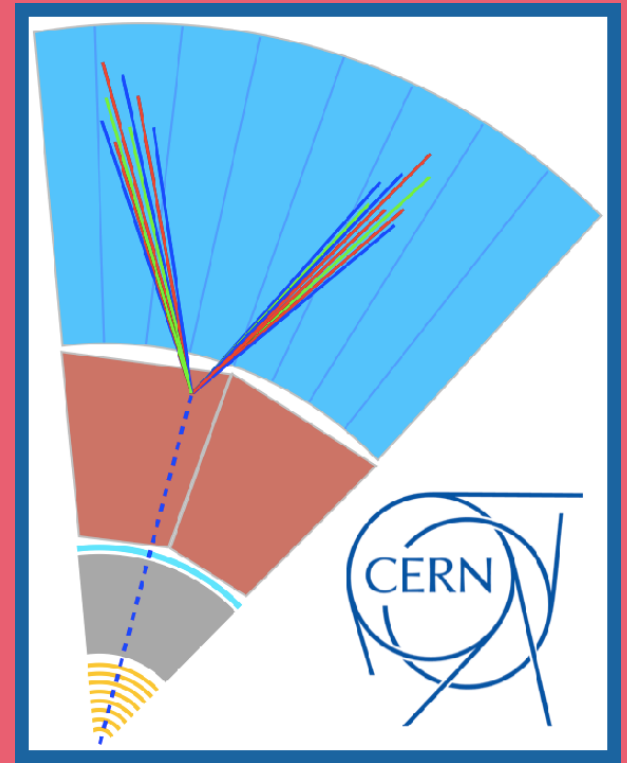
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# LHC Long-Lived Particle Community



Next workshop

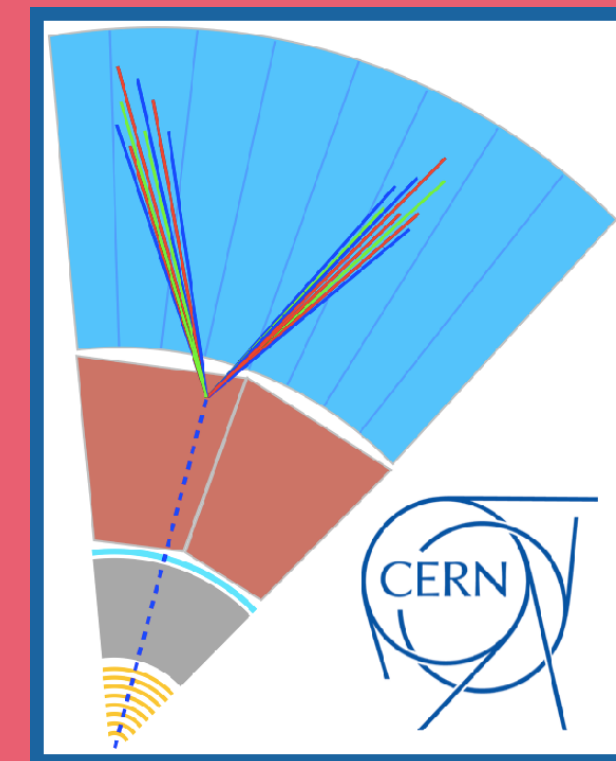
*Searching for long-lived particles  
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Seventh workshop of the  
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25-27 May 2020  
CERN

[https://indico.cern.ch/e/LHC LLP May 2020](https://indico.cern.ch/e/LHC%20LLP%20May%202020)

Join the CERN egroup: [lhcllp](mailto:lhcllp@cern.ch)

# LHC Long-Lived Particle Community



Future future:

Fall workshop 2020 (LHCLLP8)  
in Japan!

More details forthcoming

Next workshop

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# FIPs 2020

Feebly-Interacting Particle workshop

CERN — 27-29 May 2020

Website and official announcement forthcoming

What are FIPs? Roughly: Any new physics with coupling  $\lll 1$  and mass below the EW scale

Examples: Light DM and related mediators (dark scalar, dark vector, etc.), axions/ALPs, HNLs, etc.

Complementary to high-energy searches

FIP searches at colliders (including ATLAS, CMS, LHCb), extracted beams, neutrinos' near detectors, direct and indirect DM detection, Axions/ALPs experiments, theory of HNL, light DM, axions, and FIPs at large





# Focus for LHCLLP6

This workshop is about what's new

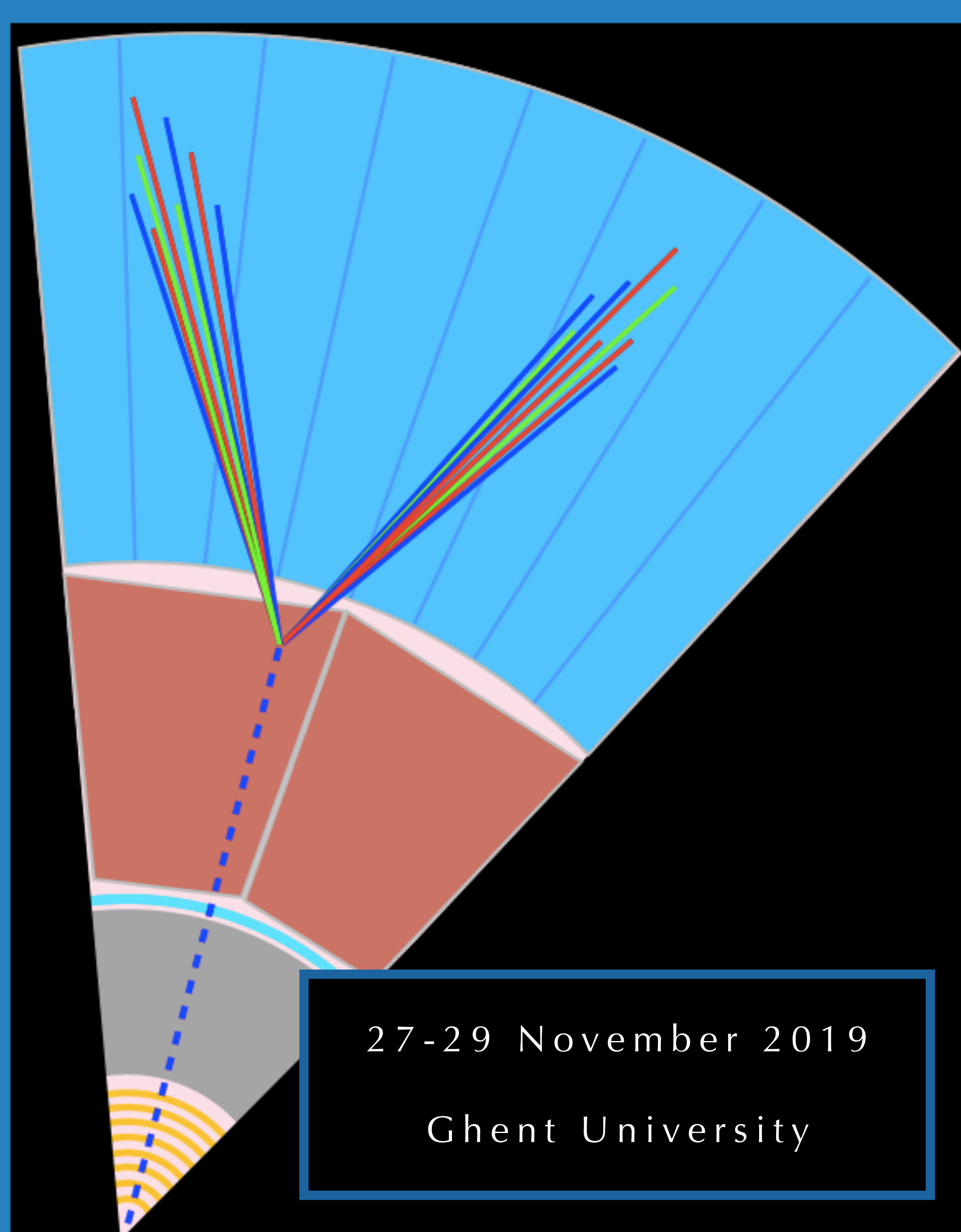
- Dedicated talks about the newest LLP results from the central detectors of the LHC since last workshop rather than snapshot talks
- New models that could give rise to LLP signatures we've been overlooking
- New triggering ideas
- New updates from dedicated detectors and other facilities, including calibration run results
- New developments in machine learning techniques for LLP searches
- Hottest and latest in the realm of heavy neutral leptons, searches and models
- Latest thoughts on the connections between dark matter and LLP searches

Searching for  
long-lived particles  
at the LHC



Sixth Workshop of the LHC Long-Lived Particle Community

[indico.cern.ch/e/LHC LLP Nov 2019](https://indico.cern.ch/e/LHC_LLP_Nov_2019)



27-29 November 2019

Ghent University

Searching for  
long-lived particles  
at the LHC

Workshop goal:

Map the future of the  
lifetime frontier. You're  
doing it right now.

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