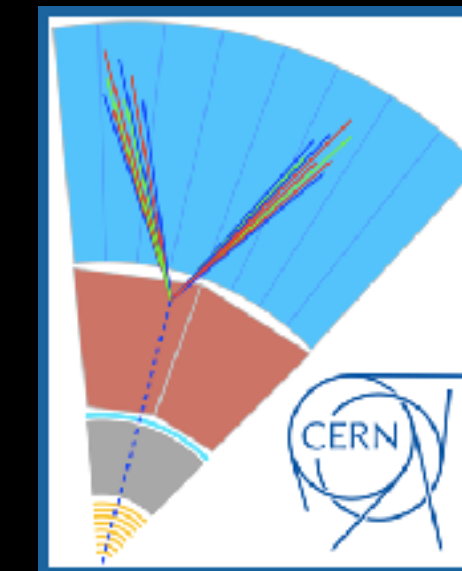


Long-Lived Particle Community



LLP9

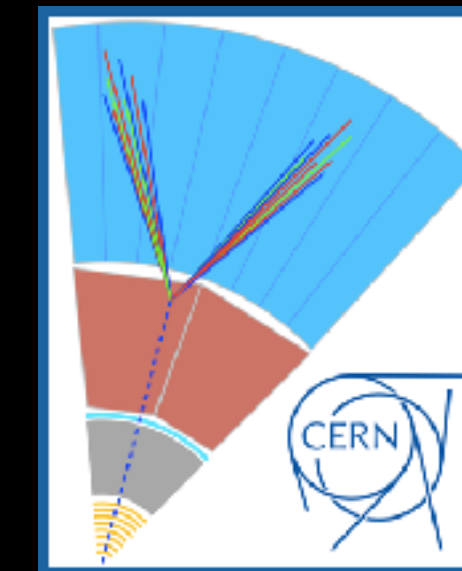
*Searching for **long-lived particles**
at the LHC and beyond:
Ninth workshop of the
LLP Community*

25-28 May 2021
Virtually, everywhere

indico.cern.ch/e/LLP_May_2021

James Beacham
[Duke University]

Long-Lived Particle Community



LLP9

Sign up for the *workshop of the LLP Community* for *long-lived particles* at the *LHC and beyond*:
email list:

[lhcllp](mailto:lhcllp@cern.ch)

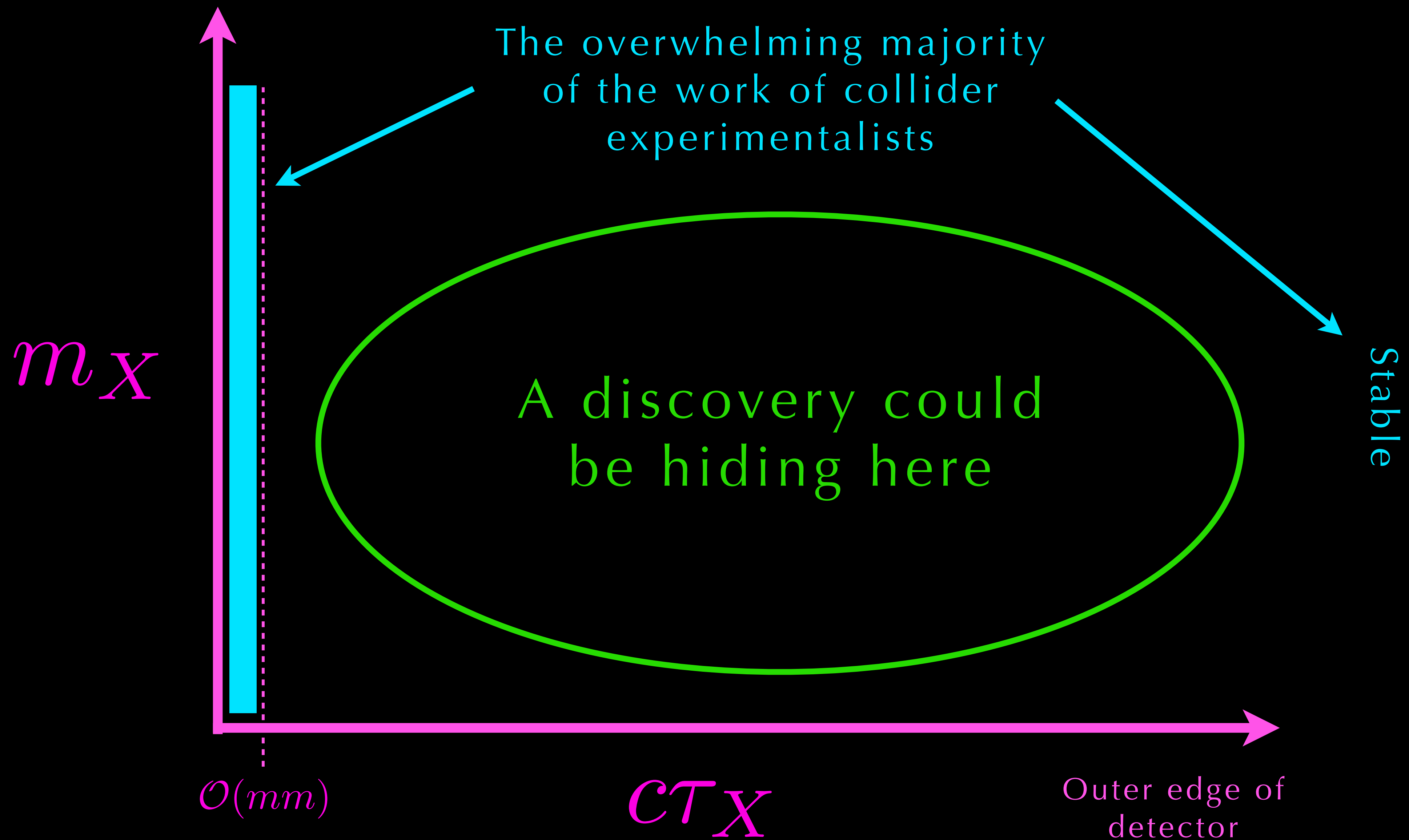
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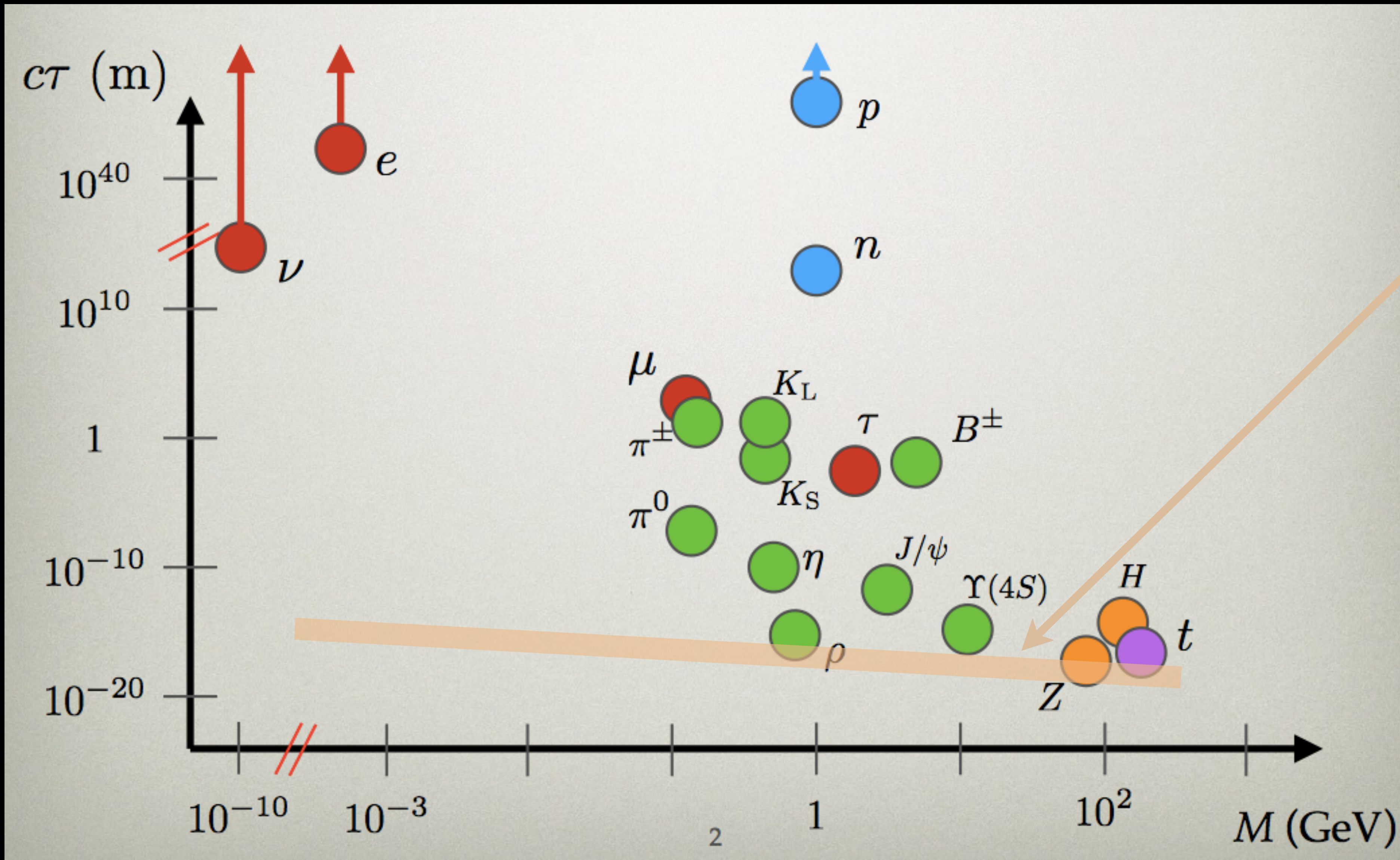
James Beacham
[Duke University]

The lifetime frontier



Long-lived particles in the Standard Model

Diagram Shuve, additions Knapen, Craig, me

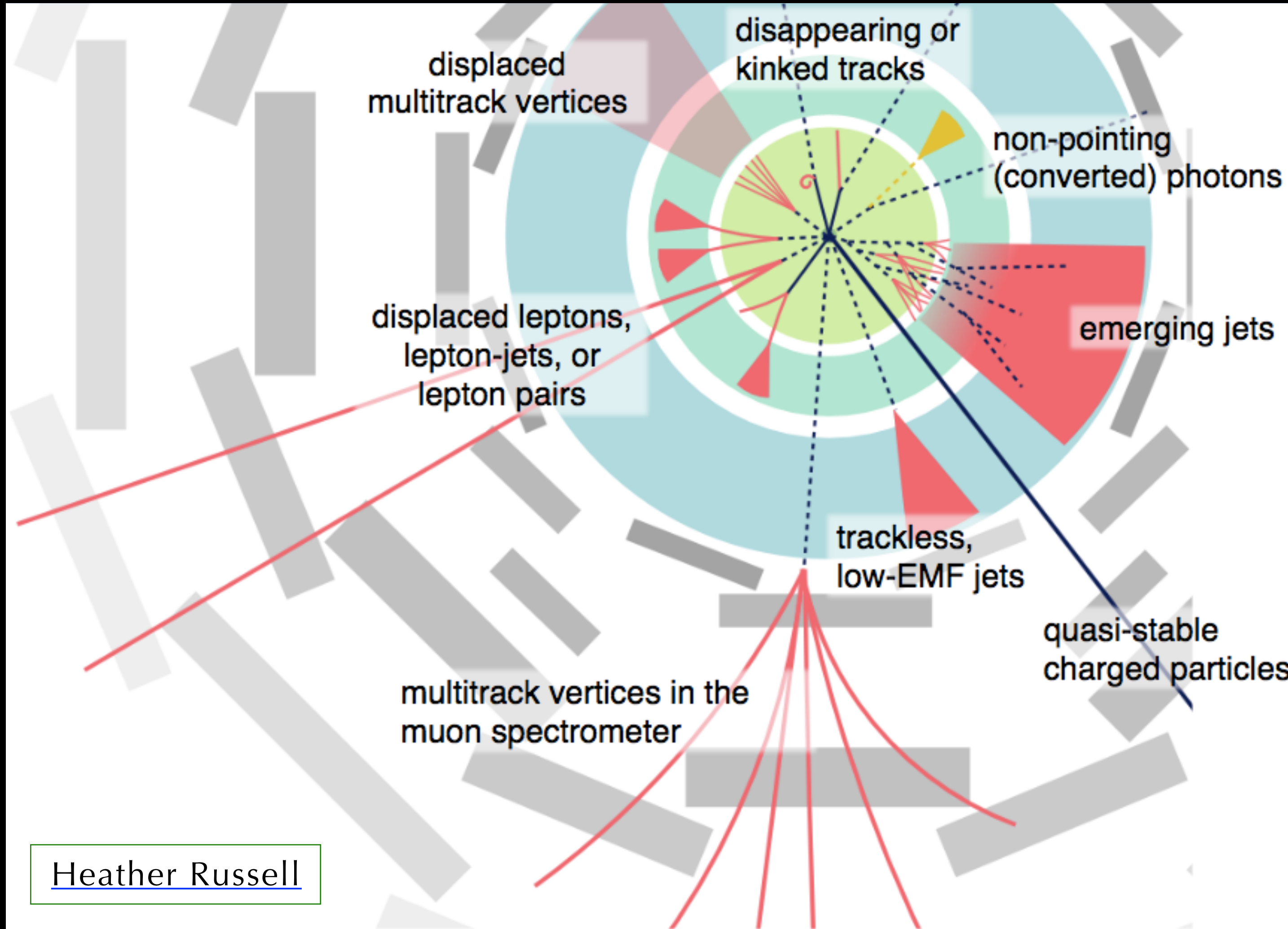


Naive
dimensional
analysis

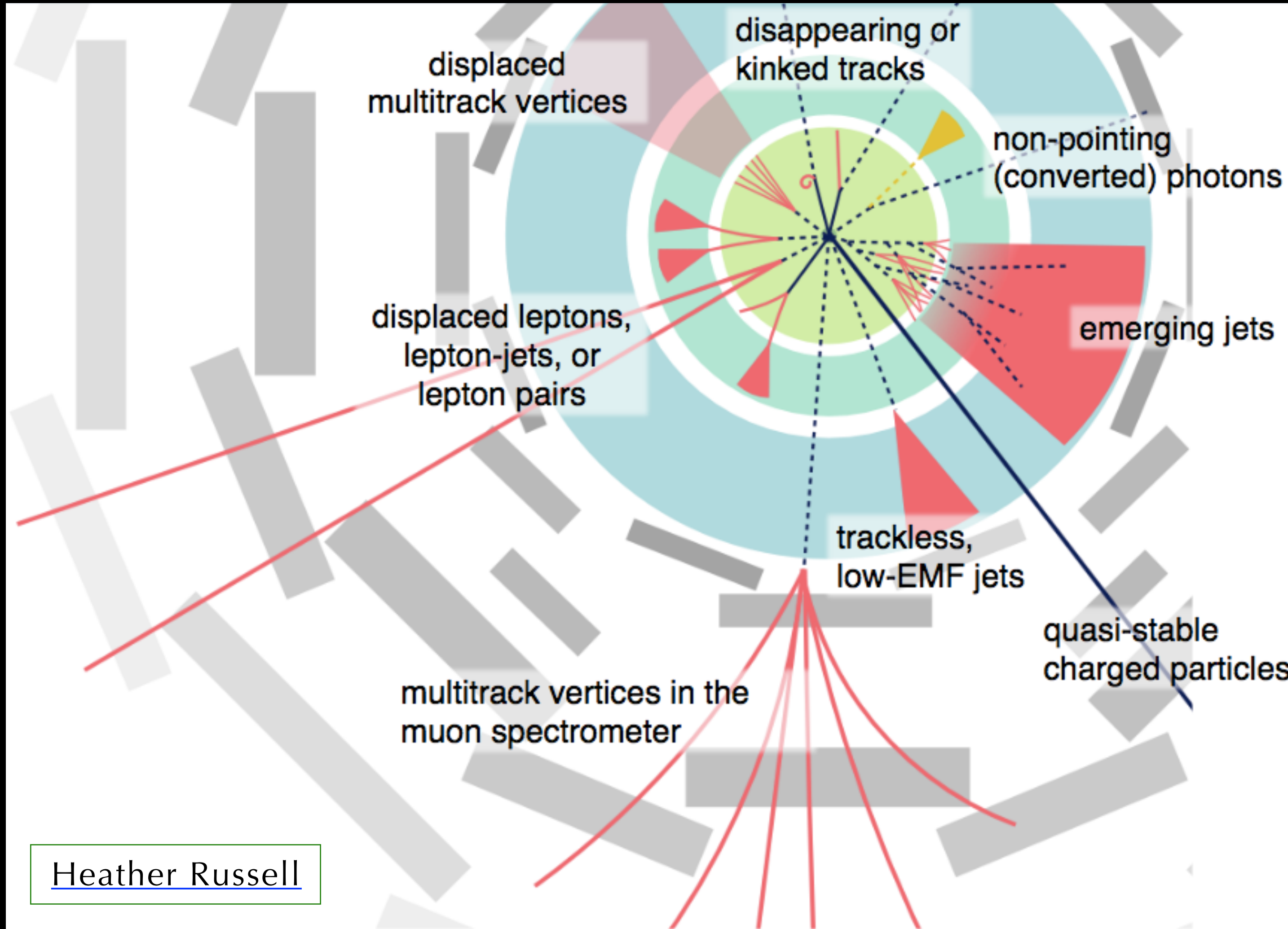
$$\tau = \frac{\hbar}{M}$$

Same
principles that
yield LLPs in
the SM can
generically
apply in BSM
theories

Long-lived particles from the main interaction points of the LHC

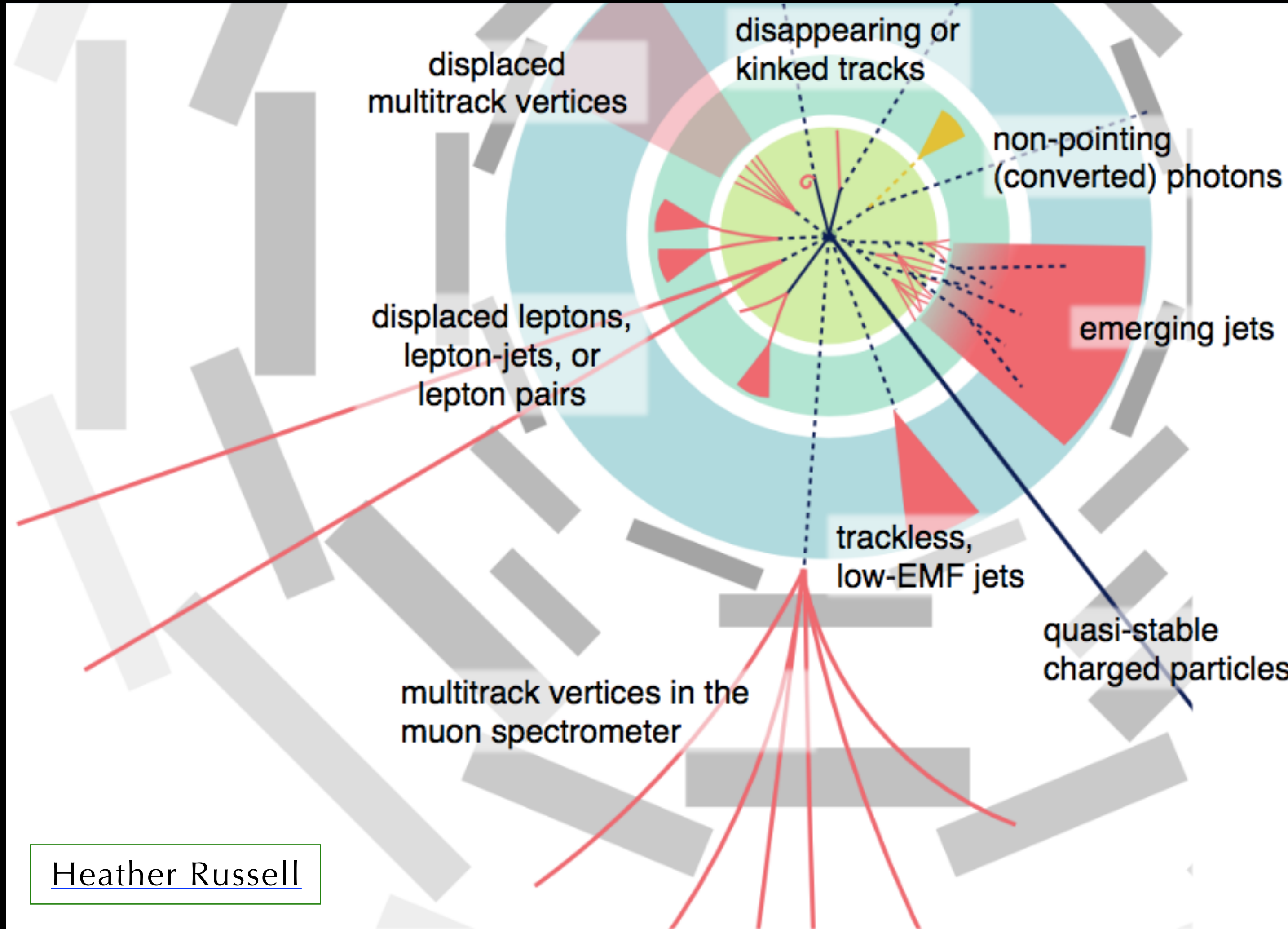


Long-lived particles from the main interaction points of the LHC



For an exhaustive discussion of long-lived particles at the LHC, see the [LLP Community white paper \[J. Phys. G 47 090501 \(2020\) \]](#) and the MATHUSLA physics case document [[Rept.Prog.Phys. 82 \(2019\) no.11, 116201 \]](#)

Long-lived particles from the main interaction points of the LHC



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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Long-Lived Particle Community



...in collaboration with the theory/pheno community and MoEDAL, MilliQan, MATHUSLA, FASER, CODEX-b, AL3X, ANUBIS, NA62, CLIC, FCC, etc.:
any **LLP**-related experiment worldwide

Formed to address one question:
How do we best ensure that we don't miss BSM **long-lived particle** signatures for the remainder of the LHC program — and beyond the LHC?

Long-lived particle white paper (Eds. Beacham & Shuve):
Public March 2019 — [J. Phys. G 47 090501 \(2020\)](https://arxiv.org/abs/1903.01622)

Workshops —
two per year

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

cern.ch/longlivedparticles

Long-lived particles beyond the LHC

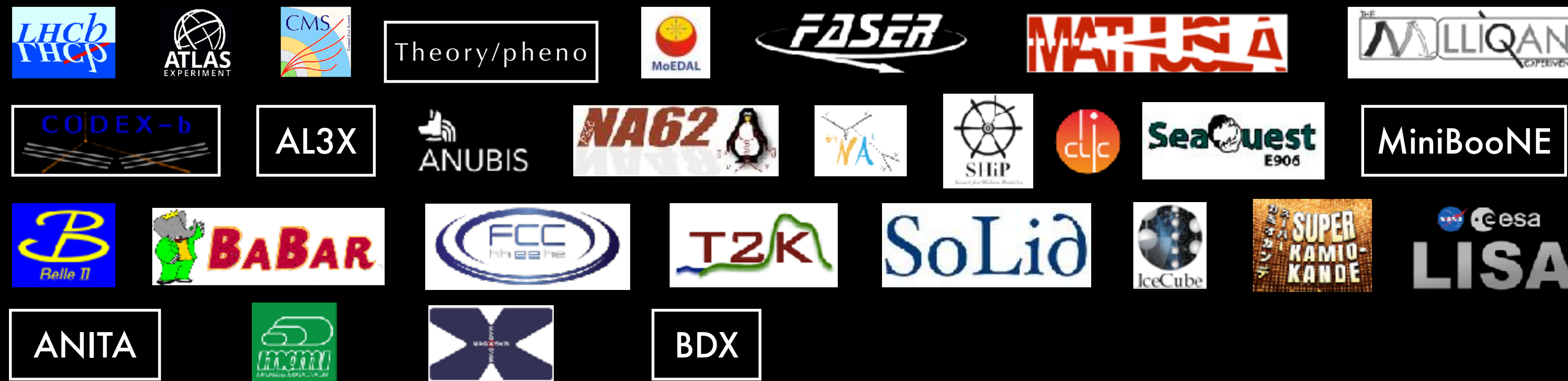
Our ability, as a field, to discover BSM LLPs, is not defined only by the interaction points of the LHC

- Many other experimental projects search for, are potentially sensitive to, or could be designed to be sensitive to LLPs
- If it's a BSM particle you can produce in an experiment that has a $c\tau$ in the cm to km range before it decays and its decay products hit your detector, then it's a long-lived particle
- This leads to obvious and clear connections among multiple projects around the globe, complementary to those at the LHC

Long-lived particles beyond the LHC

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Long-lived particles beyond the LHC

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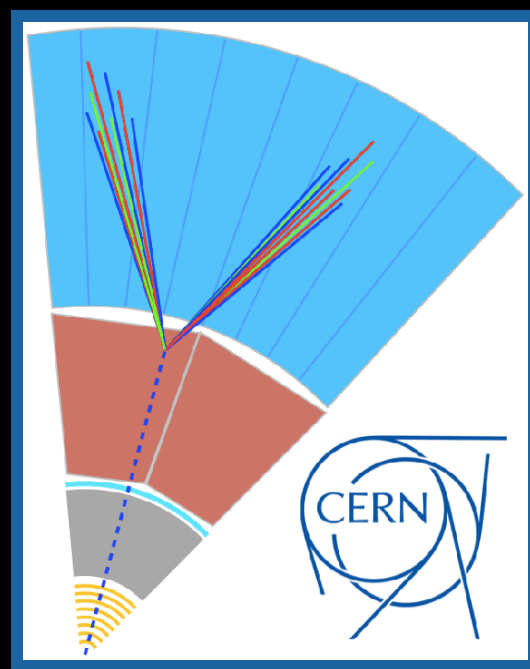
The message is clear: multiple projects around the

Don't overlook the lifetime frontier

For example, it's crucial that future projects like the FCC, EPC, CLIC/ILC, adopt accelerator and detector designs that maintain sensitivity to LLPs from the beginning



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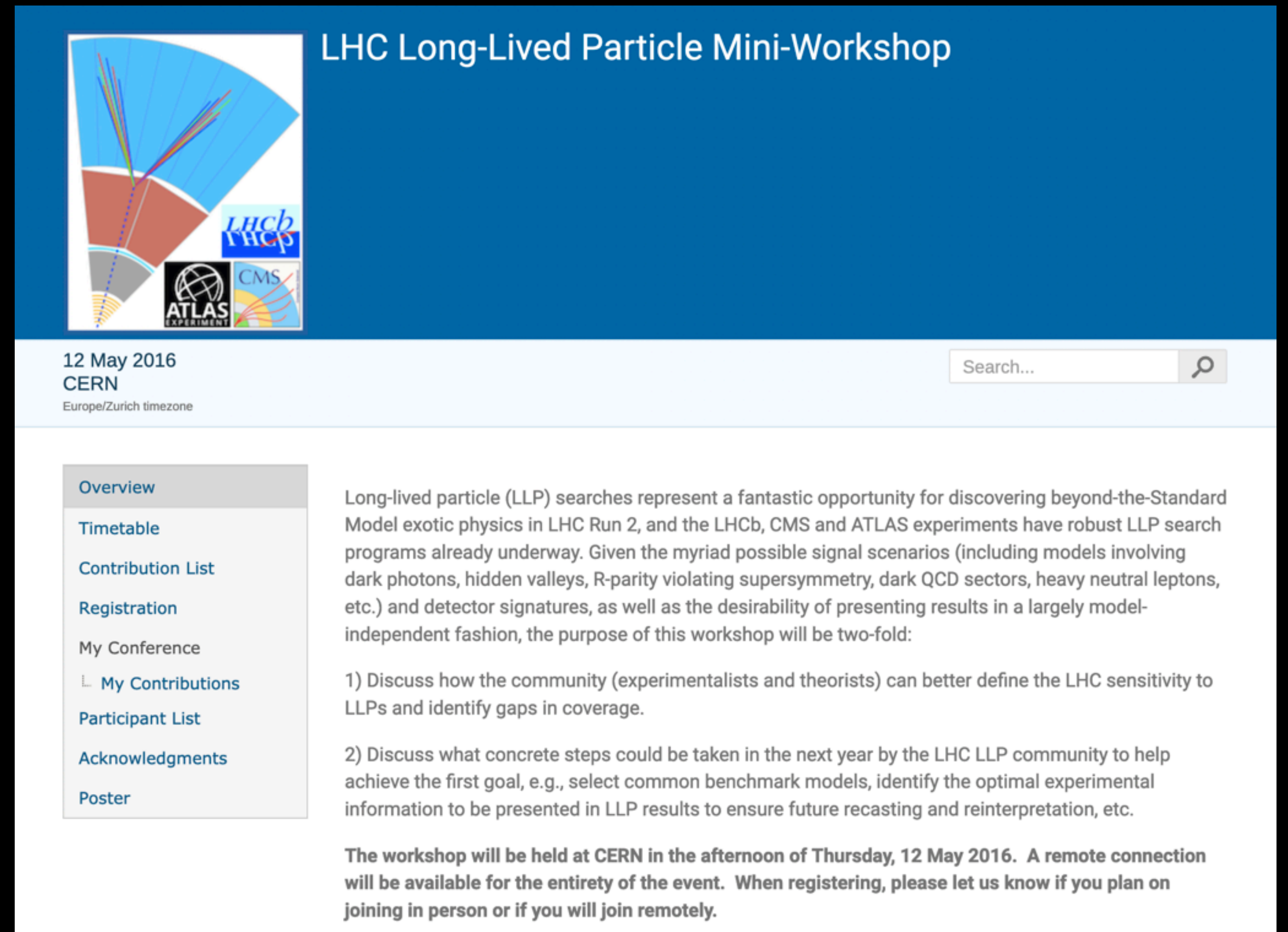


Five years of the Long-Lived Particle Community

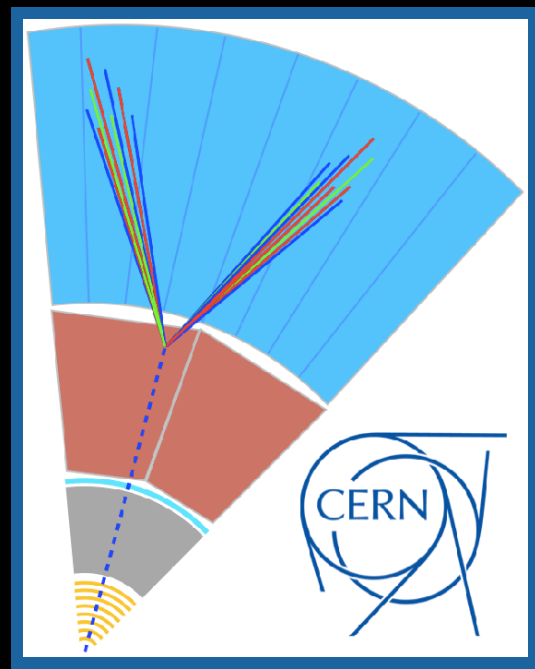
12 May 2016

The first LLP
Mini-Workshop

indico.cern.ch/event/517268/

The screenshot shows the Indico event page for the 'LHC Long-Lived Particle Mini-Workshop'. The page has a blue header with the event title and a logo featuring the CERN logo and logos for LHCb, ATLAS, and CMS. Below the header, the event date '12 May 2016' and location 'CERN' are listed, along with the time zone 'Europe/Zurich timezone'. A search bar is visible in the top right. On the left side, there is a navigation menu with links for 'Overview', 'Timetable', 'Contribution List', 'Registration', 'My Conference', 'My Contributions', 'Participant List', 'Acknowledgments', and 'Poster'. The main content area contains an introductory paragraph about LLP searches and two numbered goals for the workshop. The text states: 'Long-lived particle (LLP) searches represent a fantastic opportunity for discovering beyond-the-Standard Model exotic physics in LHC Run 2, and the LHCb, CMS and ATLAS experiments have robust LLP search programs already underway. Given the myriad possible signal scenarios (including models involving dark photons, hidden valleys, R-parity violating supersymmetry, dark QCD sectors, heavy neutral leptons, etc.) and detector signatures, as well as the desirability of presenting results in a largely model-independent fashion, the purpose of this workshop will be two-fold: 1) Discuss how the community (experimentalists and theorists) can better define the LHC sensitivity to LLPs and identify gaps in coverage. 2) Discuss what concrete steps could be taken in the next year by the LHC LLP community to help achieve the first goal, e.g., select common benchmark models, identify the optimal experimental information to be presented in LLP results to ensure future recasting and reinterpretation, etc. The workshop will be held at CERN in the afternoon of Thursday, 12 May 2016. A remote connection will be available for the entirety of the event. When registering, please let us know if you plan on joining in person or if you will join remotely.'

Five years of the Long-Lived Particle Community



1

Searches for long-lived particles at the LHC: Workshop of the LHC LLP Community

24-26 April 2017
CERN

Enter your search term

5

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

27-29 May 2019
CERN



Searches for long-lived particles at the LHC: Second workshop of the LHC LLP Community

17-20 October 2017
ICTP, Trieste, Italy



2

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

27-29 November 2019
University of Ghent

Enter your search term




6

3

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

16-18 May 2018
CERN



7

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

25-27 May 2020
Virtually, worldwide



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

23-25 October 2018
Amsterdam Science Park



4

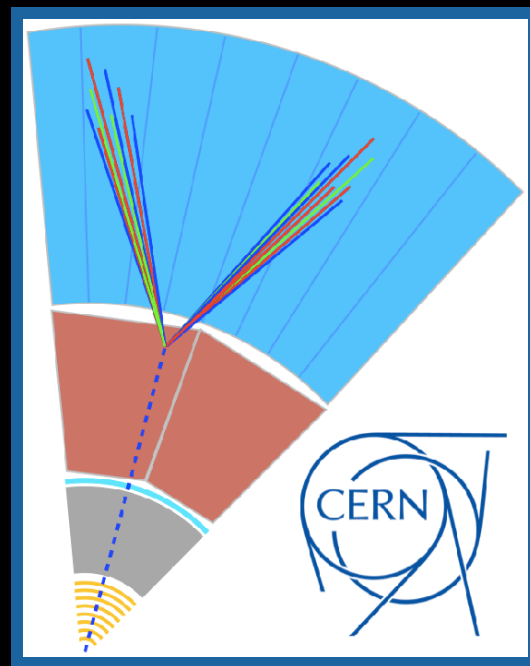
Searching for long-lived particles at the LHC and beyond: Eighth workshop of the LHC LLP Community

18-20 November 2020
Virtually, worldwide



8

Five years of the Long-Lived Particle Community



1

Searches for long-lived particles at the LHC: Workshop of the LHC LLP Community

24-26 April 2017
CERN
Europe/Zurich timezone

5

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

27-29 May 2019
CERN
Europe/Zurich timezone

Searches for long-lived particles at the LHC: Second workshop of the LHC LLP Community

17-20 October 2017
ICTP, Trieste, Italy
Europe/Rome

3

16-18 May 2013
CERN
Europe/Zurich timezone

9

Searching for long-lived particles at the LHC and beyond: Ninth workshop of the LLP Community

25-28 May 2021
Virtually, worldwide
Europe/Zurich timezone

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

20-22 October 2018
CERN
Europe/Zurich timezone

6

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

25-27 May 2020
Virtually, worldwide
Europe/Zurich timezone

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

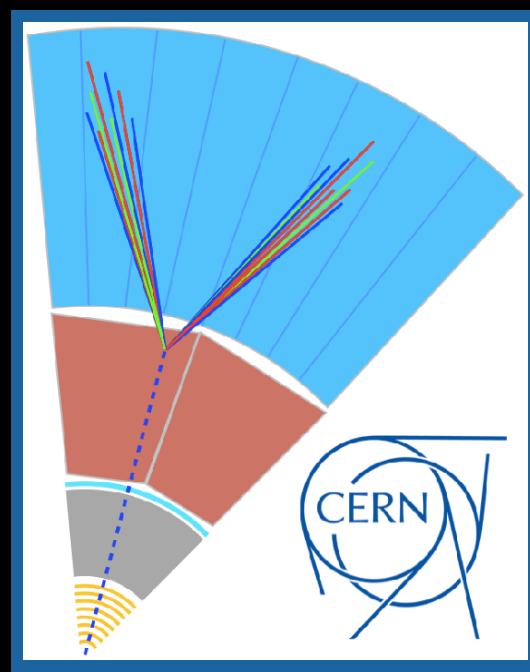
23-25 October 2018
Amsterdam Science Park
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4

Searching for long-lived particles at the LHC and beyond: Eighth workshop of the LHC LLP Community

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8



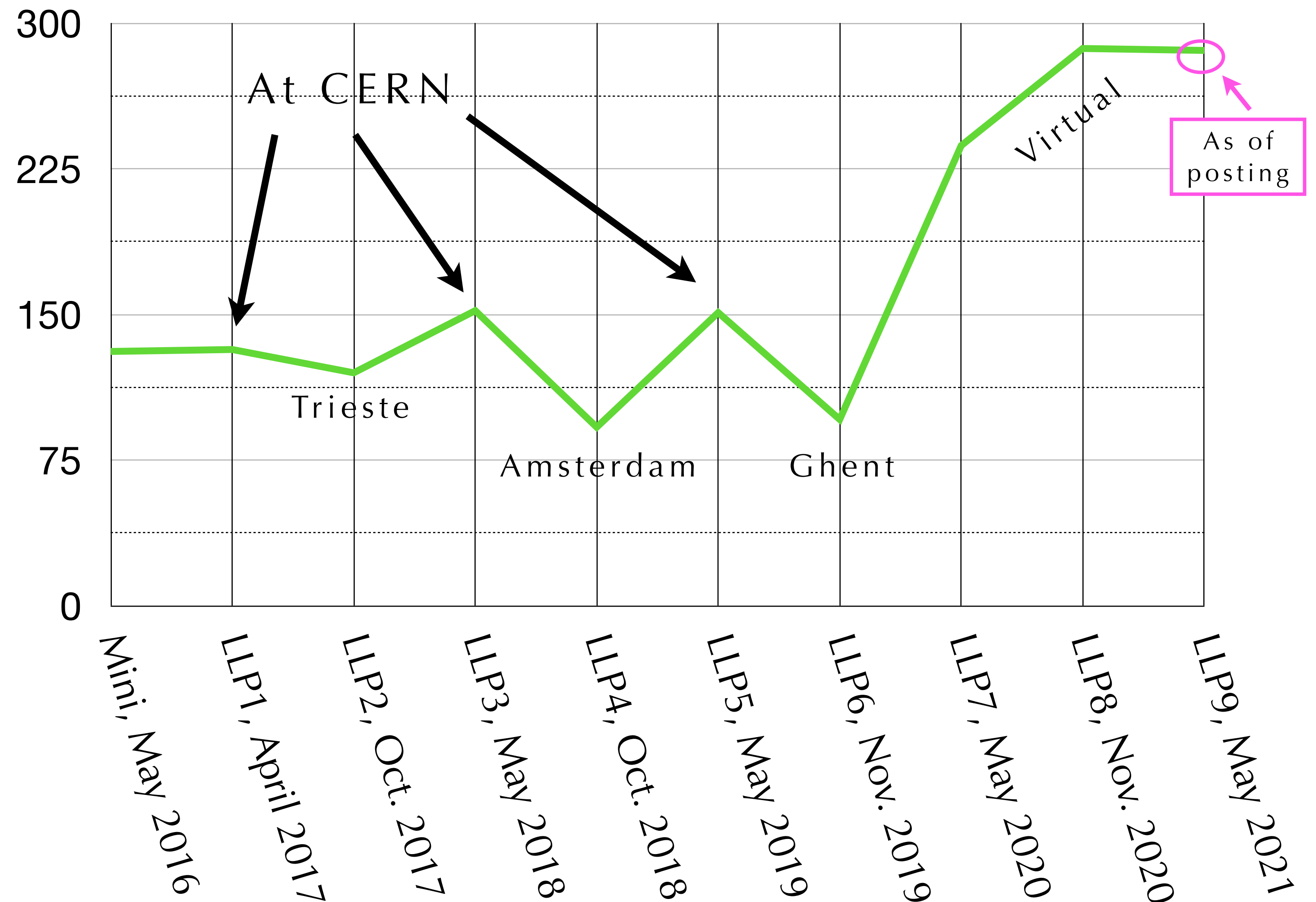
Five years of the Long-Lived Particle Community

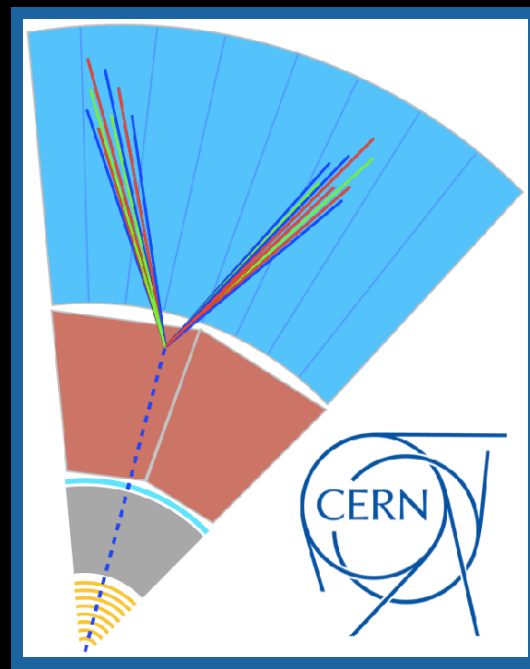
Two LLP Community workshops per year

Platform where new ideas originate

Multiple LLP projects, triggers, papers, and initiatives have been born here — not just from talks and brainstorming sessions but (pre-covid) over coffee, beer, dinner, in hallways, etc.

LLP Community workshop registrations





Long-Lived Particle Community white paper

Public March 2019

Published September 2020

J. Phys. G 47 090501 (2020)

Major community effort

Two document editors,
Beacham & Shuve

19 additional chapter editors

201 authors / contributors / endorsers

145 citations to date

OPEN ACCESS




















IOP Publishing

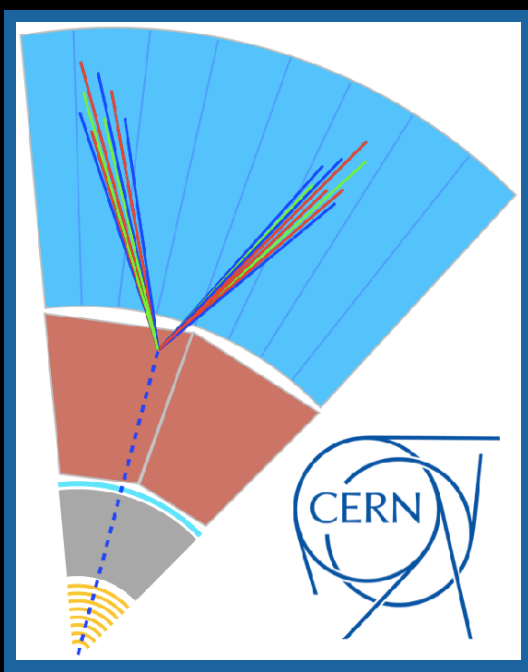
Journal of Physics G: Nuclear and Particle Physics

J. Phys. G: Nucl. Part. Phys. 47 (2020) 090501 (226pp)

<https://doi.org/10.1088/1361-6471/ab4574>

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

Juliette Alimena
(Experimental Coverage, Backgrounds, Upgrades)¹ ,
James Beacham
(Document Editor, Simplified Models)² , Martino Borsato
(Backgrounds, Upgrades)³ , Yangyang Cheng
(Upgrades)⁴, Xabier Cid Vidal
(Experimental Coverage)⁵ , Giovanna Cottin
(Simplified Models, Reinterpretations)^{6,7,8} , David Curtin
(Simplified Models)⁹ , Albert De Roeck
(Experimental Coverage)¹⁰ , Nishita Desai
(Reinterpretations)¹¹ , Jared A Evans
(Simplified Models, Experimental Coverage)¹² ,
Simon Knapen
(Dark Showers)¹³ , Sabine Kraml
(Reinterpretations)¹⁴ , Andre Lessa
(Reinterpretations)¹⁵, Zhen Liu
(Simplified Models, Backgrounds, Reinterpretations)¹⁶ ,
Sascha Mehlhase
(Backgrounds)¹⁷ , Michael J Ramsey-Musolf
(Simplified Models)^{18,19} , Heather Russell
(Experimental Coverage)²⁰ , Jessie Shelton
(Simplified Models, Dark Showers)²¹ , Brian Shuve
(Document Editor, Simplified Models, Simplified Models
Library)^{22,23} , Monica Verducci
(Upgrades)²⁴ , Jose Zurita
(Experimental Coverage)^{25,26} , Contributors & Endorsers:
Todd Adams²⁷, Michael Adersberger²⁸, Cristiano Alpigiani²⁹,



Long-Lived Particle Community: The future is bright

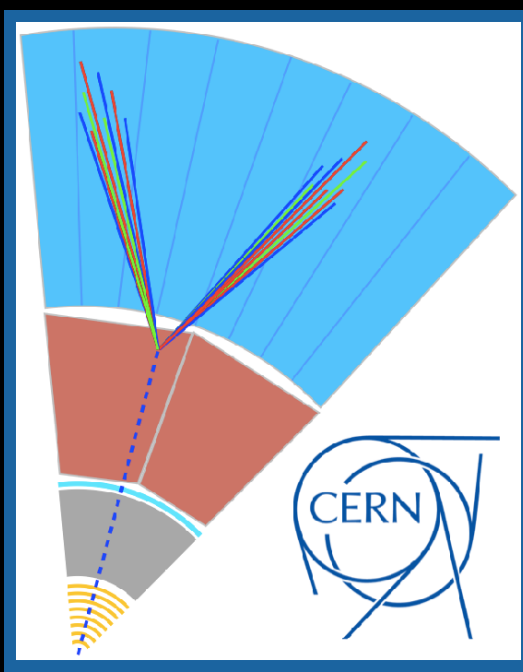
LLP Community next steps:

Multitude of opportunities to explore the edges of our knowledge and detector capabilities for LLPs around the globe and in the future

Might be the right time to propose a series of LLP Community white papers to follow up on the first

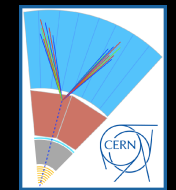
The LLP Community is the place for both new, practical ideas and speculative, boundary-pushing initiatives

LLP9 sessions on future colliders/detectors, synergies with FIPs, dark showers, etc.

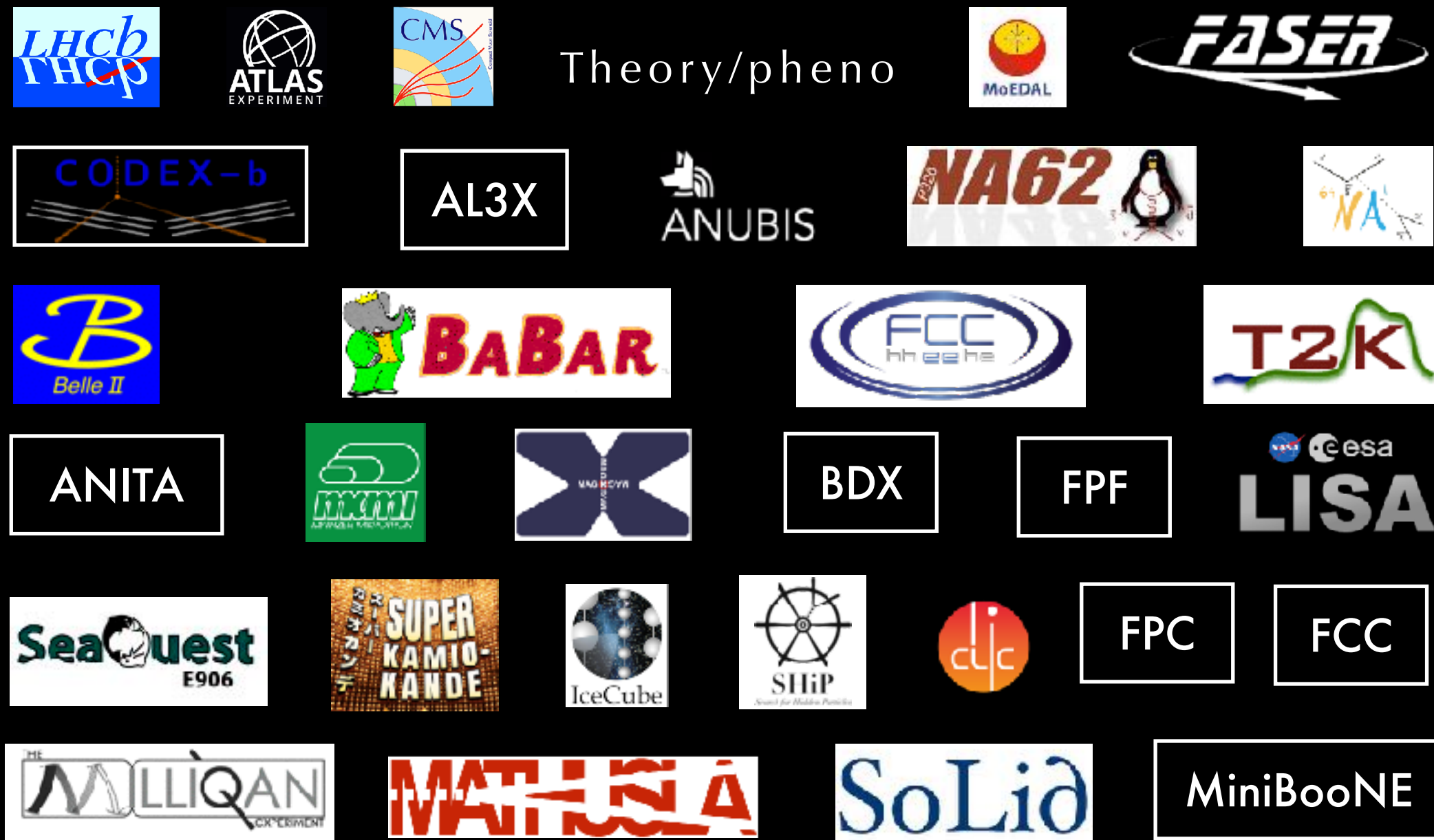


Long-Lived Particle Community: The future is bright

We also have a fairly new tool to use: The LHC LLP WG
Sign up for the lhcllpwg list here
LHC LLP WG session on Friday



LLP Community



Established in 2016 for any new LLP experiment, idea, or project at all, around the globe

LHC LLP WG



Established in 2020 to serve as a formal bridge with the relevant physics groups of the approved LHC experiments

Some projects and ideas that arise in the LLP Community workshops can be naturally executed under the LHC LLP WG banner

Other projects are better served within the broader LLP Community

Take-home message: There is plenty to be explored and many tools with which to explore!

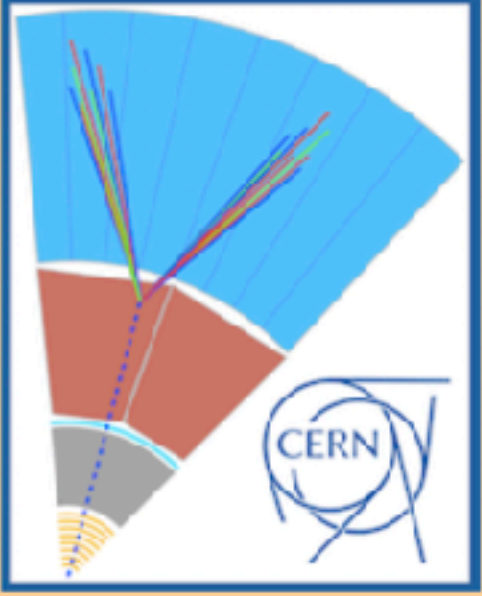
LLP Community: Emphasis on “community”

Community is open to all

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

Workshop is informal and collaboration-centered

- Discussion is of the highest priority



Searching for long-lived particles at the LHC and beyond:
Ninth workshop of the LLP Community

25-28 May 2021
Virtually, worldwide
Europe/Zurich timezone

The poster features a central graphic with a blue fan-like shape containing several colored lines (red, green, blue) that appear to represent particle tracks or paths. Below this graphic is the CERN logo, which consists of a circle with the word 'CERN' inside and a stylized particle detector structure.

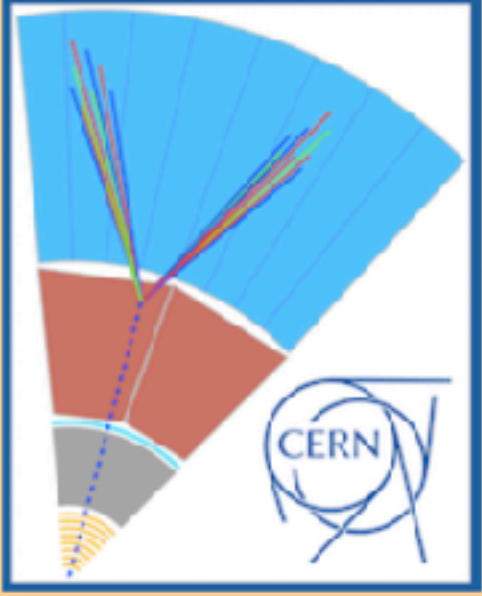
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The poster features a central graphic with a blue fan-like shape on the left, a red and orange fan-like shape in the middle, and a grey fan-like shape on the right. A blue dashed line curves through the shapes. The CERN logo is visible in the bottom right corner of the graphic.

Community is collaboration – Collaboration is respect

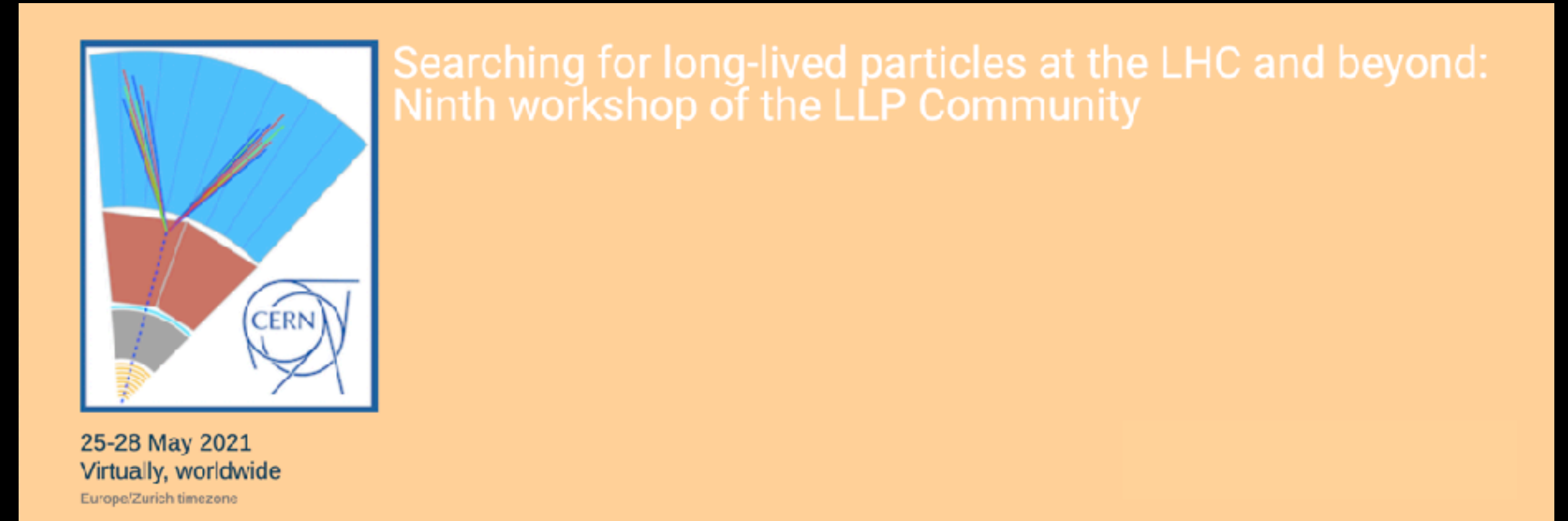
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Community is collaboration – Collaboration is respect

To all community members:

- Yes, ask a question and make a suggestion!

To all session chairs:

- Give ample space in discussion periods for those who haven't had a chance to talk!

We're radically inclusive and radically anti-harrassment

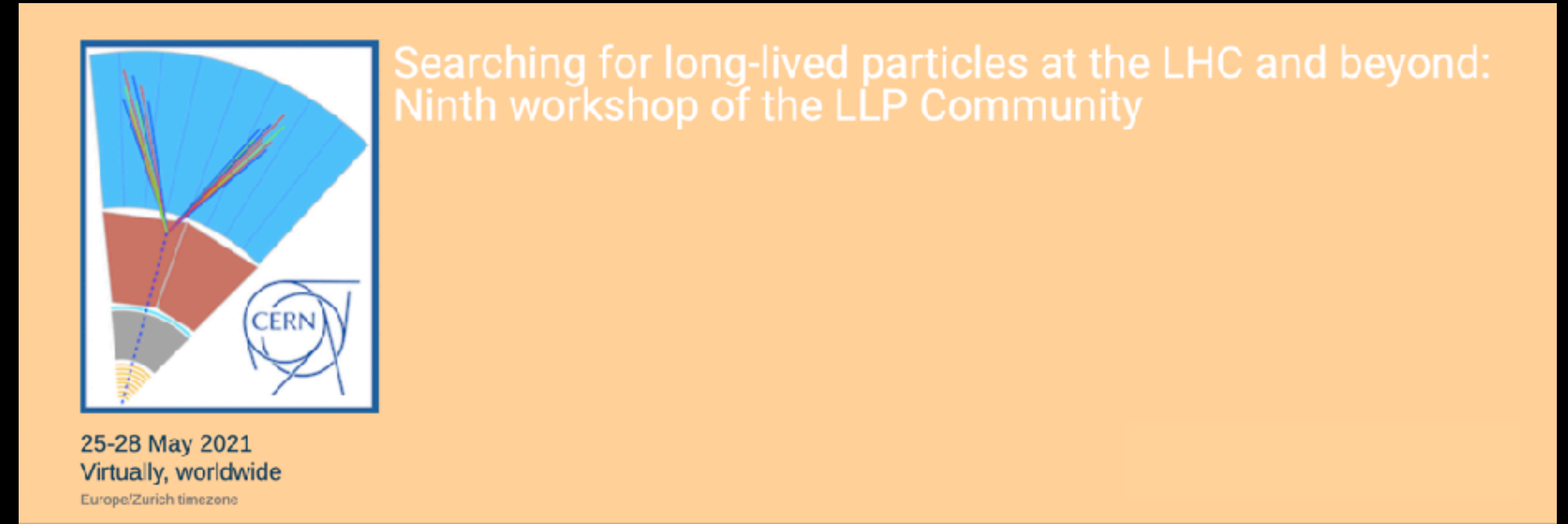
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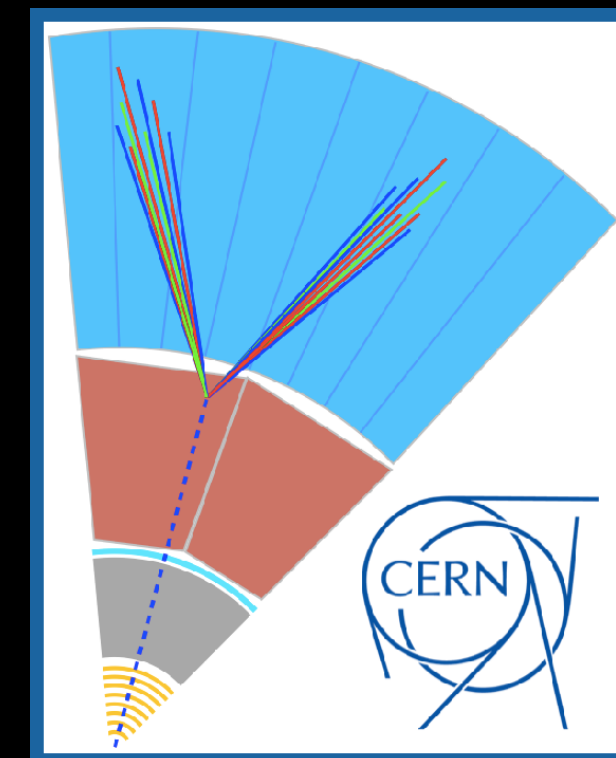
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We're radically inclusive and radically anti-harrassment

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
- This applies whether virtually or in person
- Harrassment is antithetical to the intention of this workshop
- We endeavor to create a positive and welcoming space!



#LLP9 is our third fully virtual workshop

The new, virtual normal of the pandemic era

- All plenary format, with both sessions of talks but with an emphasis on “working group” sessions, as in the past

Tuesday, 25 May

- 14:00 — Intro and updates from LHCb, CMS, & ATLAS
- 15:15 — *Workshop photo*
- 15:30 — FIPs
- 16:00 — Dedicated LLP detectors and projects

Wednesday, 26 May

- 14:00 — Heavy neutral leptons session
- 15:10 — Re-interpretations session
- 16:35 — Non-standard backgrounds for the HL-LHC
- 17:45 — Lightning round / new ideas

Thursday, 27 May

- 14:00 — Lightning round / new ideas
- 15:00 — Dark showers simulation tools session (hands-on!) and discussion of Pythia’s HiddenValley)
- 18:15 — Lightning round / new ideas

Friday, 28 May

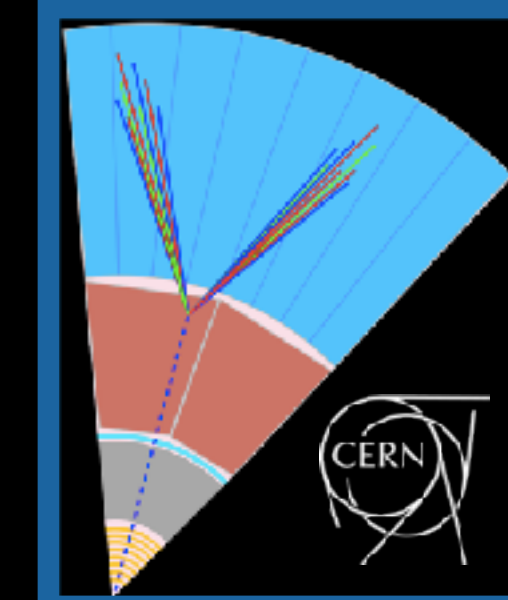
- 14:00 — Lightning round / new ideas
- 15:00 — LHC LLP WG meeting
- 16:10 — LLPs at future (muon) colliders
- 17:20 — How to optimally catch LLPs at a future hadron collider? — brainstorming
- 18:05 — Lightning round / new ideas

Mattermost channel:

[mattermost.web.cern.ch/
llpcommunity](https://mattermost.web.cern.ch/llpcommunity)

LLPX

Long-Lived Particle
Community



Next workshop: **LLPX**

*Searching for **long-lived particles**
at the LHC and beyond:
Tenth workshop of the
LLP Community*

Tentatively: 9-12 November 2021

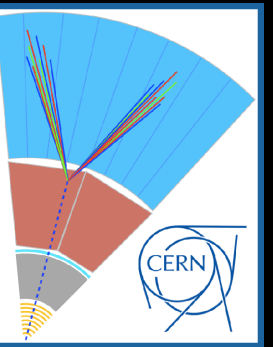
indico.cern.ch/e/LLP Nov 2021

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

LLP9

Long-Lived Particle
Community

Searching for *long-lived particles*
at the LHC and beyond:
Ninth workshop of the
LLP Community



25-28 May 2021
Virtually, everywhere

Organizers

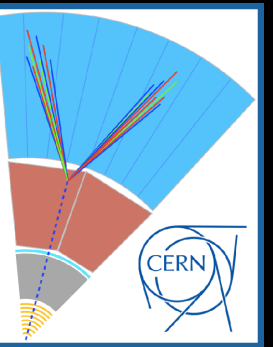
Nishita Desai
Karri Folan Di Petrillo
Federico Leo Redi
Albert De Roeck
Carlos Vazquez Sierra
James Beacham
José Francisco Zurita
Juliette Alimena
Katherine Pachal
Louie Corpe
Matthew Citron
Sascha Mehlhase

[indico.cern.ch/e/LLP May 2021](https://indico.cern.ch/e/LLP_May_2021)

LLP9

Long-Lived Particle
Community

*Searching for long-lived particles
at the LHC and beyond:
Ninth workshop of the
LLP Community*



25-28 May 2021
Virtually, everywhere

Workshop goal:

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

Welcome!

Organizers

Nishita Desai
Karri Folan Di Petrillo
Federico Leo Redi
Albert De Roeck
Carlos Vazquez Sierra
James Beacham
José Francisco Zurita
Juliette Alimena
Katherine Pachal
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[indico.cern.ch/e/LLP May 2021](https://indico.cern.ch/e/LLP_May_2021)