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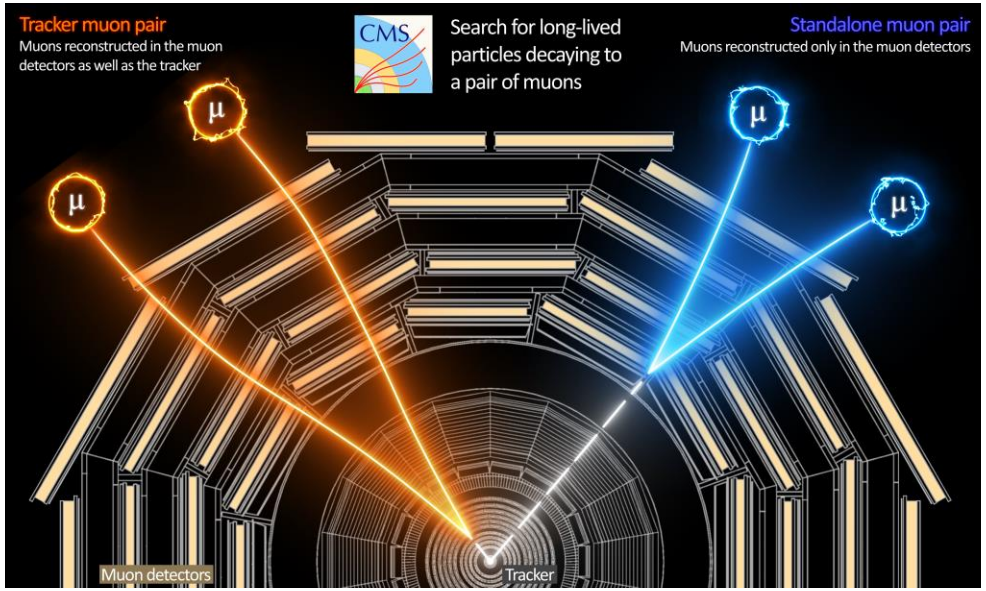

Search for long-lived particles at CMS

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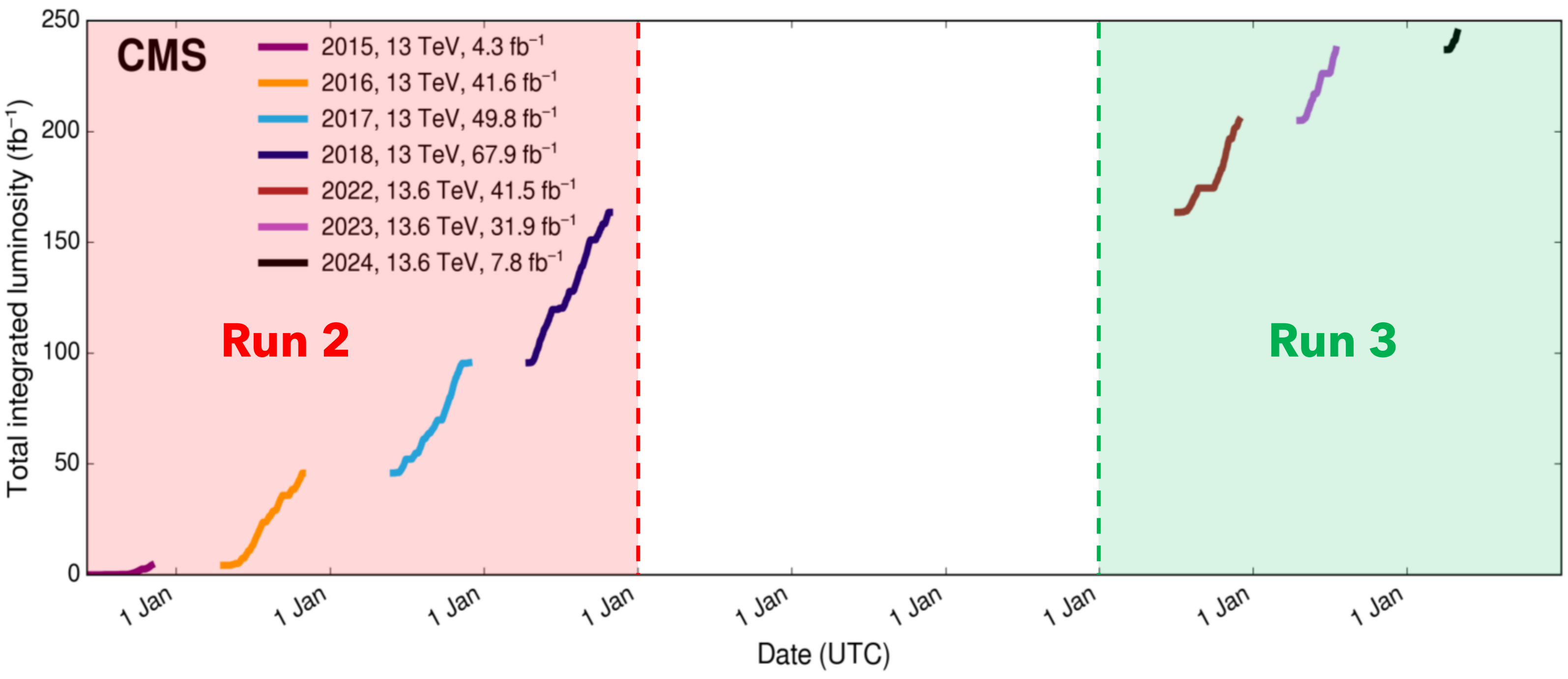
Introduction

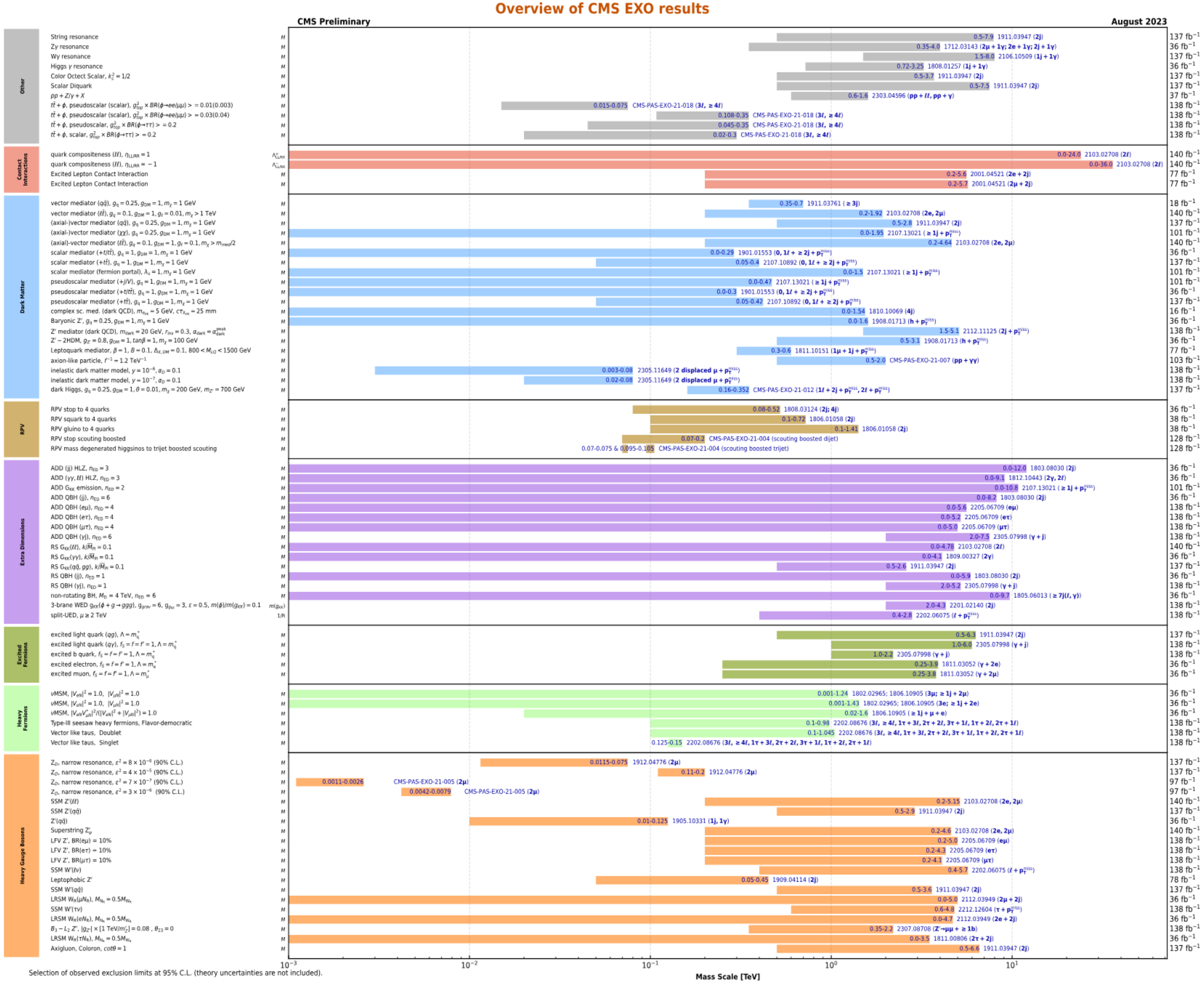
- After the **Higgs** discovery we have no clear guiding principle for **BSM** searches.
- As experimentalist, no preferred BSM theory:
  - We have an unprecedent amount of data from the LHC.
  - Exploit all details of this data looking for anything that looks different than SM.
  - Many possibilities, in this presentation we will cover the search for **long-lived particles**.
- We are currently in the middle of the **Run 3** data taking.
  - Highest CM energy ever reached **13.6 TeV**.
- We have used all the knowledge acquired during Run 2 to improve the current Run 3 analysis.



Introduction

Current searches performed in CMS (each line is a paper):

- Theory serves as a guidance to not leave any corner of the phase space unexplored.
- We unfortunately did not detect BSM physics…
  - but not for lack of trying.
- However, many fundamental questions are still open:
  - Nature of dark matter.
  - How neutrinos acquire mass.
  - Matter-antimatter asymmetry.
- **Strong motivation** to keep searching at the LHC.



Physics Beyond the Standard Model

- Where are we searching for BSM physics?
- Improve the precision of SM tests (e.g m_W, yukawa couplings).
- Target unobserved SM processes (diHiggs production).
- Search for deviations at the tails of distributions: effective field theories (EFT).

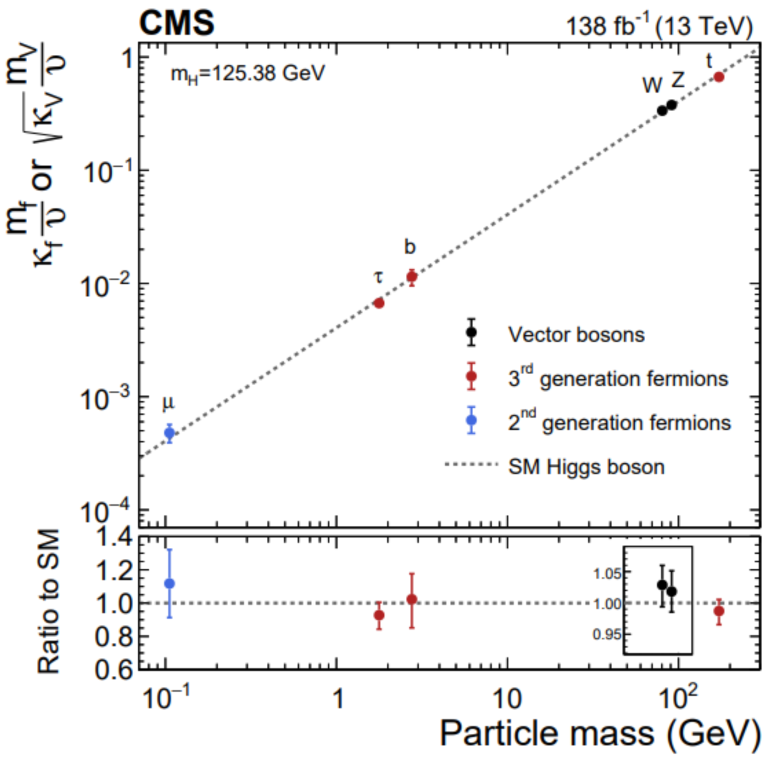
Wilson coefficient

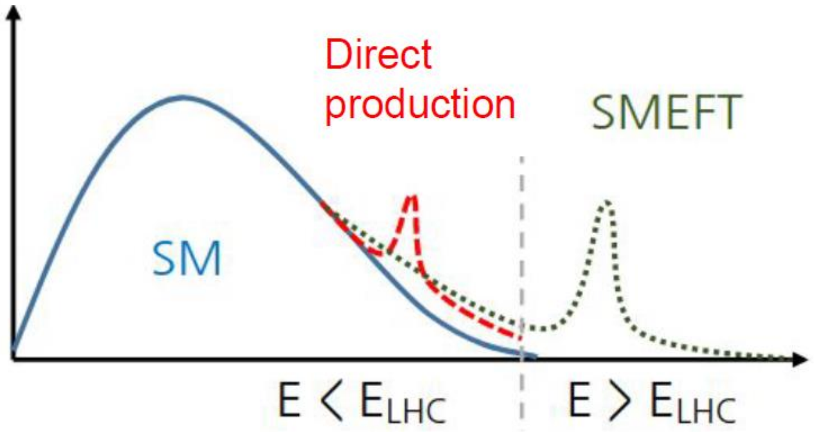
$$\mathcal{L} = \mathcal{L}_{SM} + \sum_i \frac{C_i}{\Lambda^2} O_i^{(6)}$$

UV scale

EFT operator

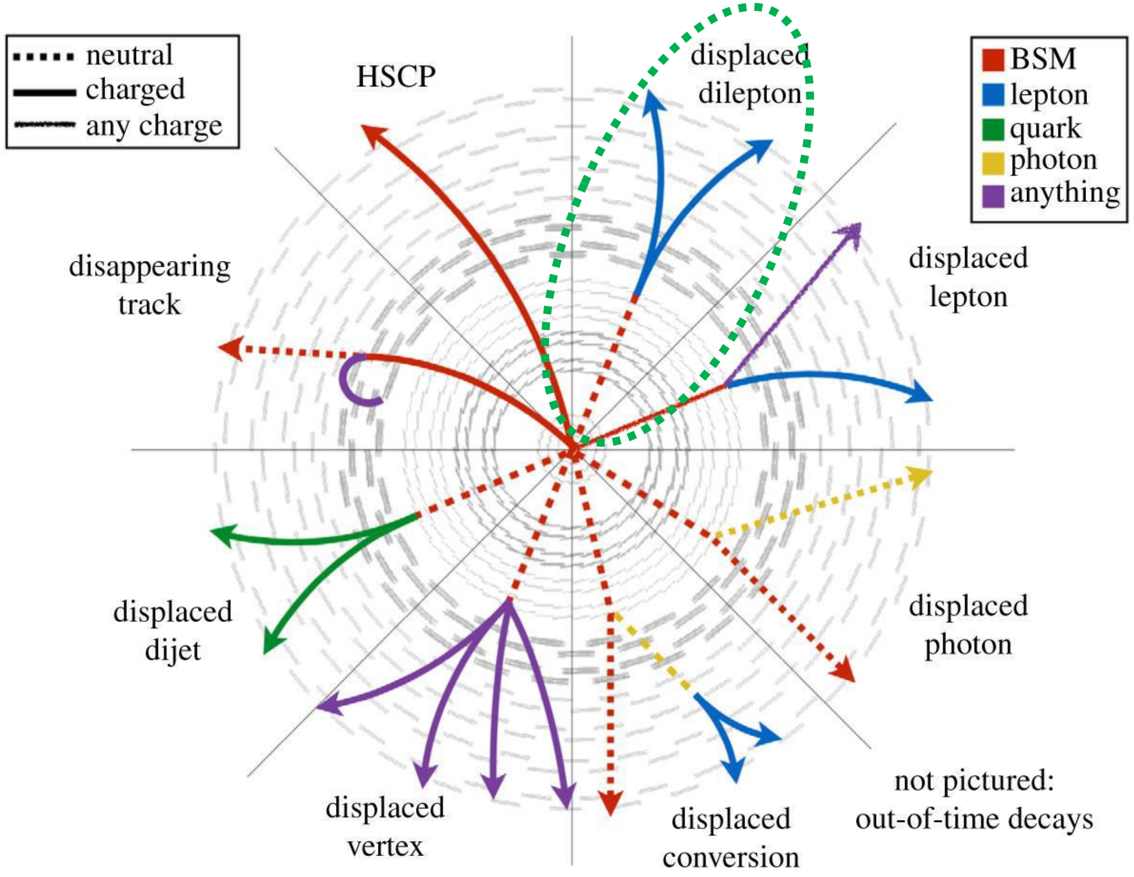
- **Probe new phase space (e.g long lived particles).**





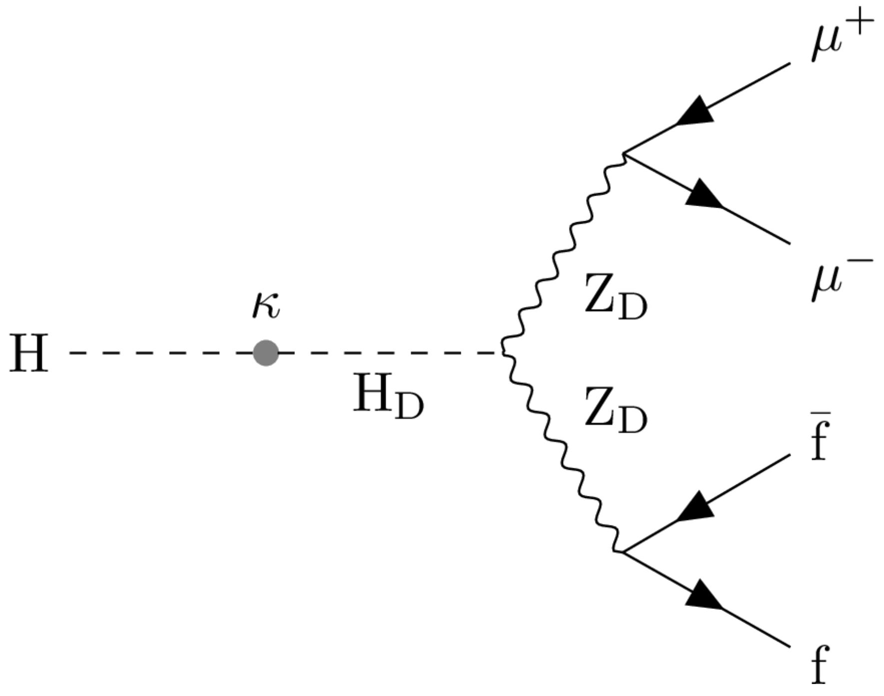
Long lived particles

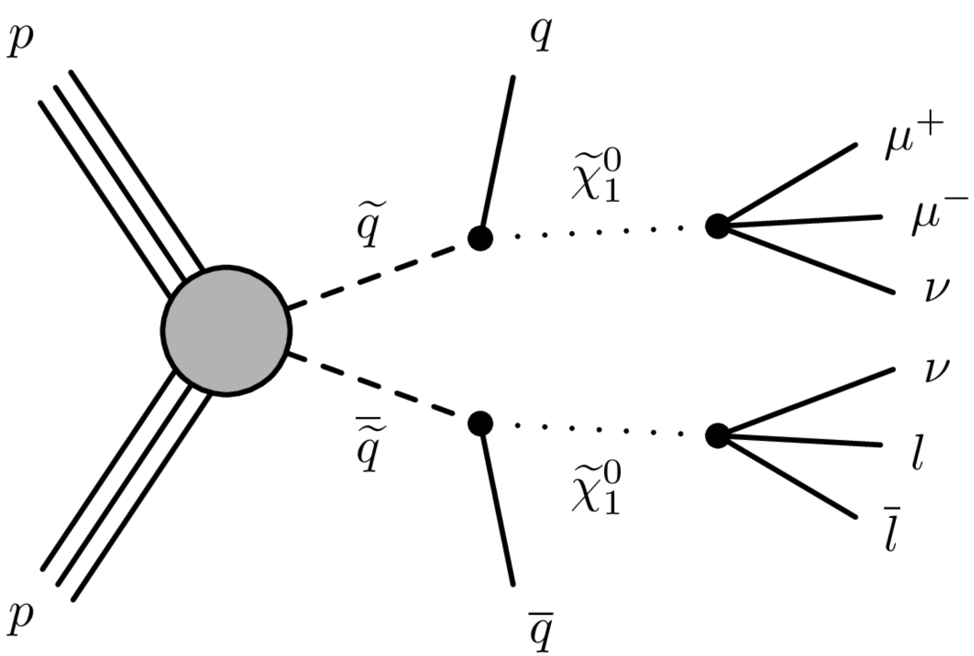
- **What are displaced muons?**
  - Muons that are not produced in the primary vertex (PV).
  - They can be produced through the decay of a **long-lived particle** (LLP).
  - Therefore, they do not have to point to the PV.
- **Why are they interesting:**
  - Signature of new physics.
  - Many exotic models can produce displaced muons:
    - RPV, Exotic Higgs models, dark photon, …
- **Challenges:**
  - They need a special reconstruction.
  - Highly displaced muons can be misidentified with low p_T non-displaced muons.



Theory models featuring LLPs

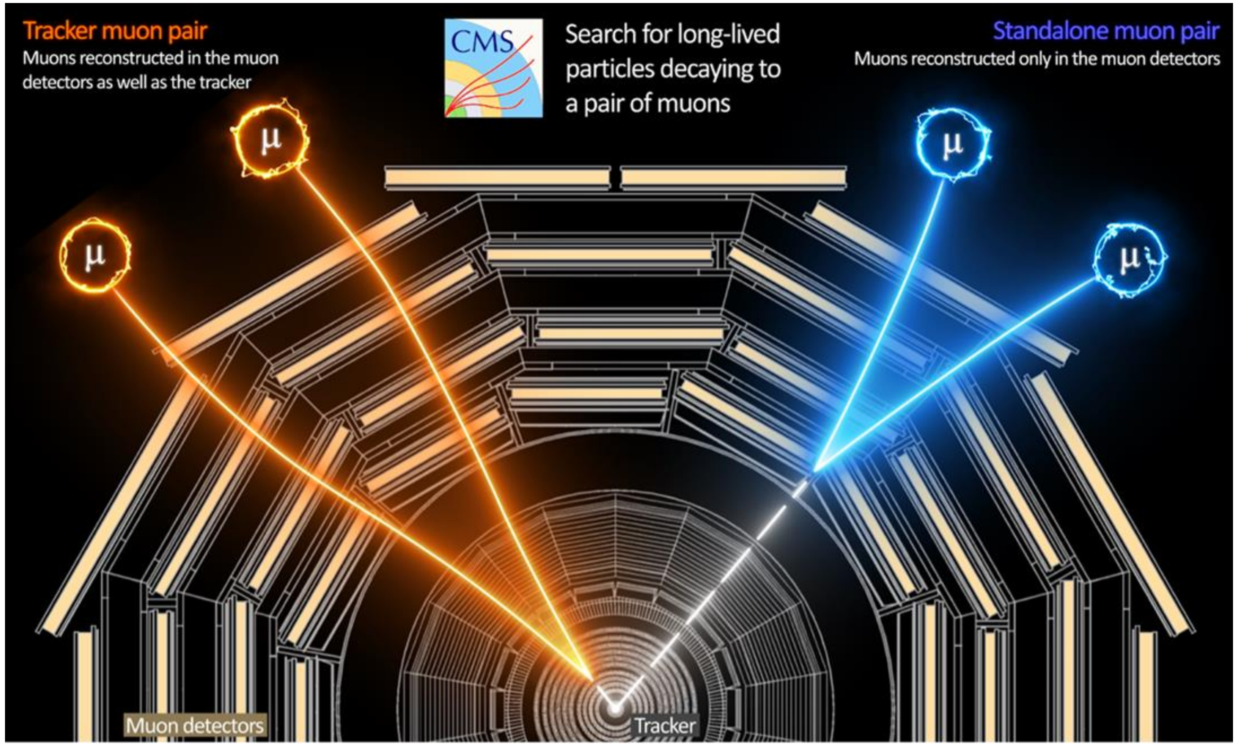
- Dark photon production in the decay of Higgs bosons.
  - Dark photons would travel a certain distance in the detector before decaying into 'displaced muons'.
- Simplified SUSY model, in which long-lived neutralinos decay to a pair of muons and a neutrino as a result of R-parity violation (RPV).



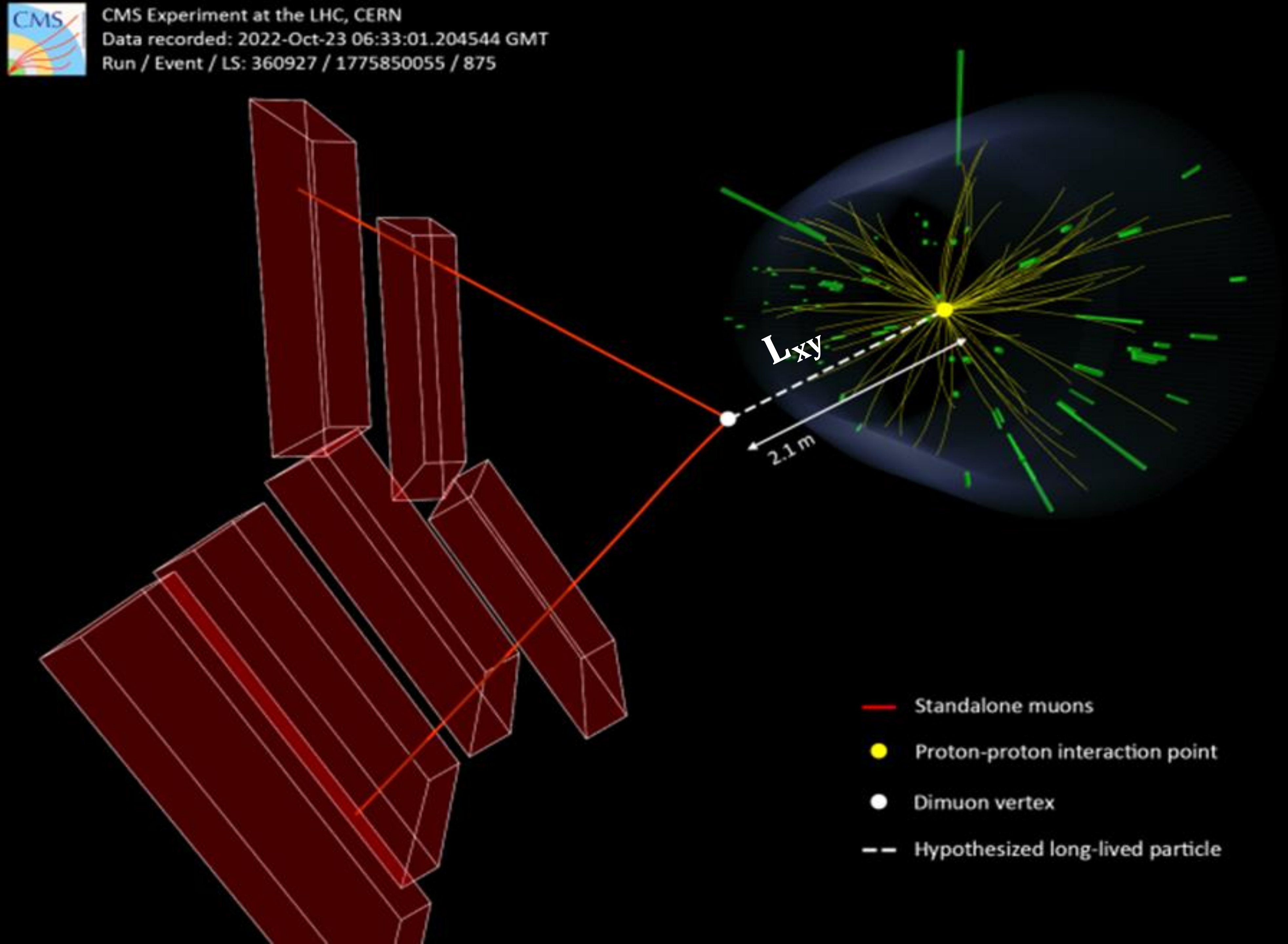


Displaced dimuon search at 13.6 TeV

- Generic, inclusive search for long-lived particles decaying into pairs of oppositely-charged muons (displaced dimuons) within the tracker and beyond.
- Analyzed **data collected in 2022 at 13.6 TeV** ($36.6\ \mathrm{fb}^{-1}$).
- **Two types of muons considered:**
  - **DSA**: displaced standalone muons (muon system only).
  - **TMS**: global + tracker muons (muon system + tracker).

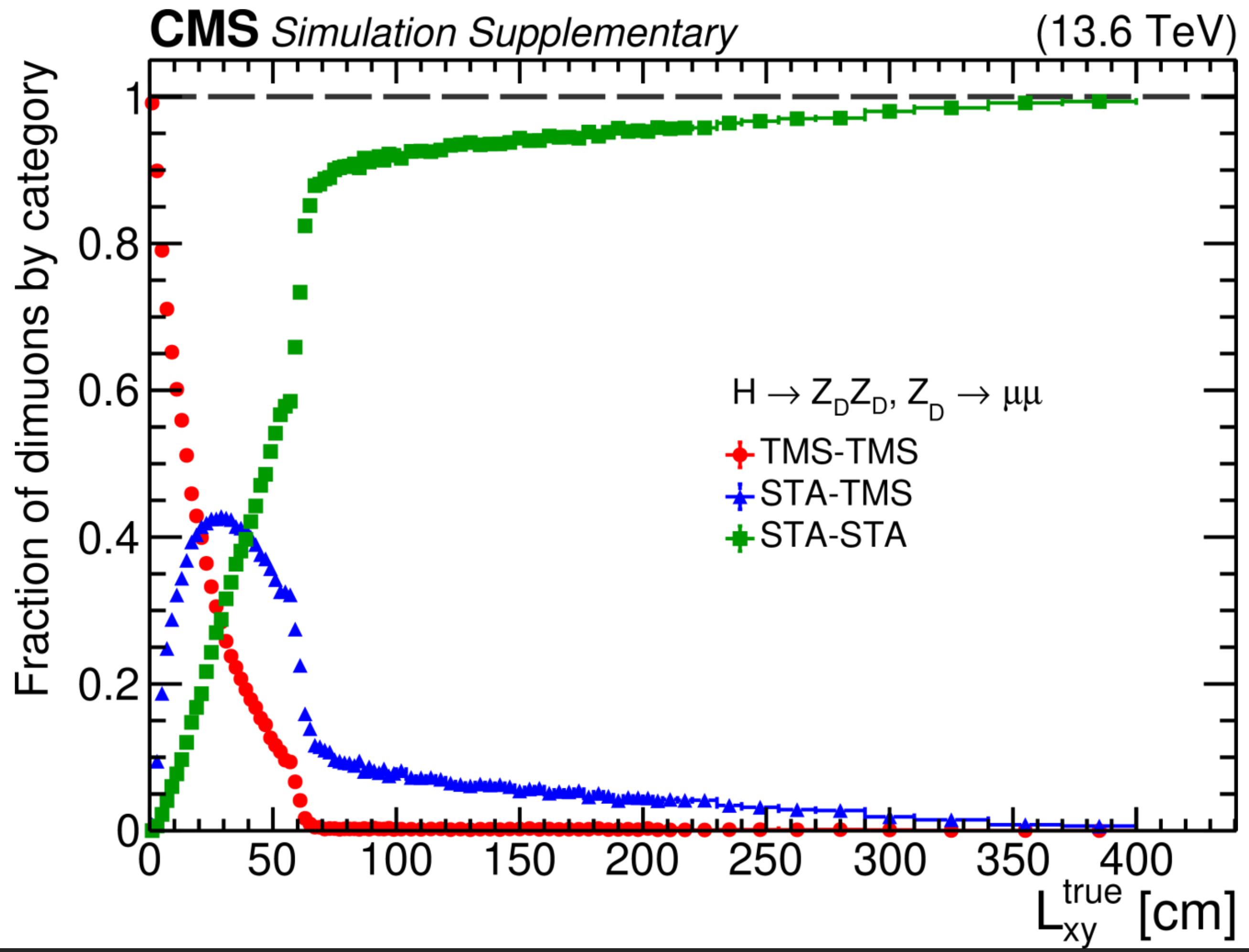


- **Vertex fit:**
  - Dimuon candidates are formed from pairs of muons passing the muon identification criteria.
  - Each pair of selected muon tracks is fit to a common vertex.

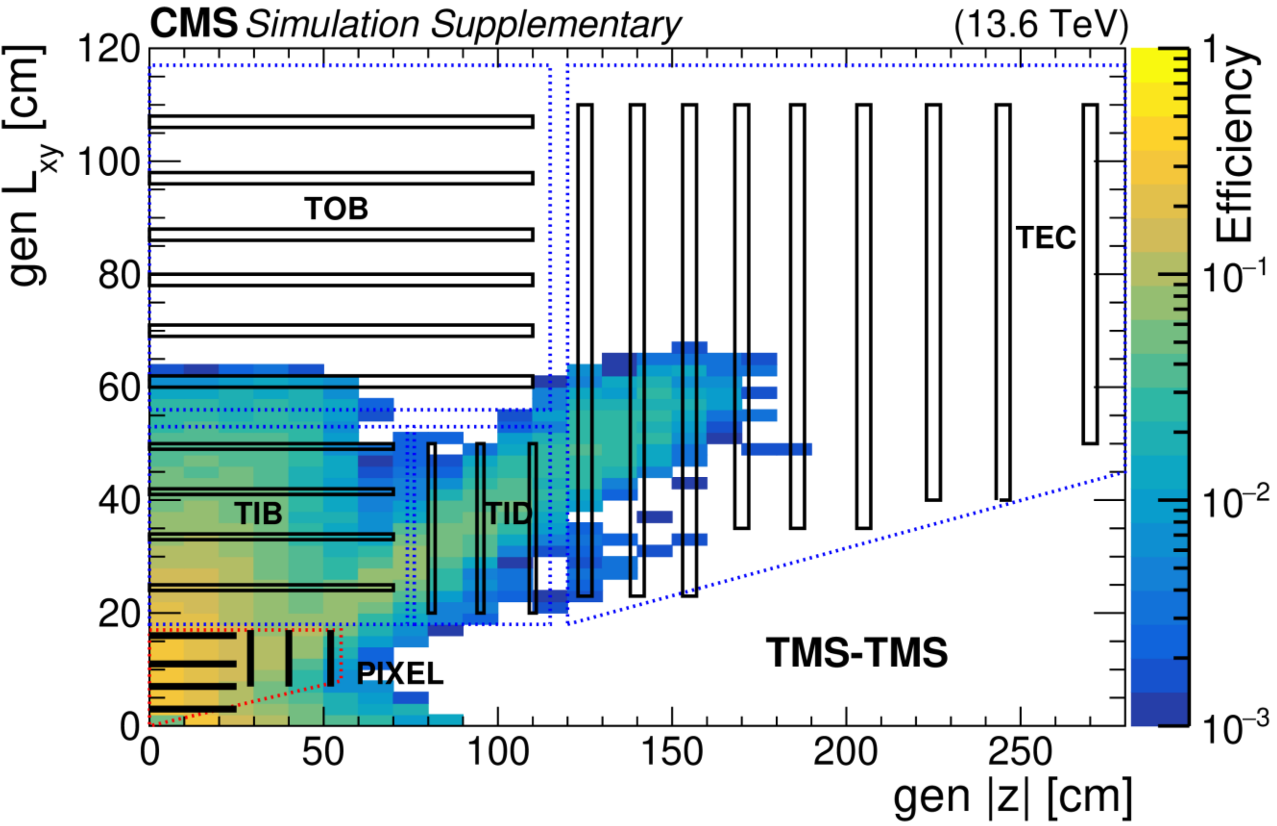

CMS Experiment at the LHC, CERN
Data recorded: 2022-Oct-23 06:33:01.204544 GMT
Run / Event / LS: 360927 / 1775850055 / 875
Lxy
2.1 m
Standalone muons
Proton-proton interaction point
Dimuon vertex
Hypothesized long-lived particle

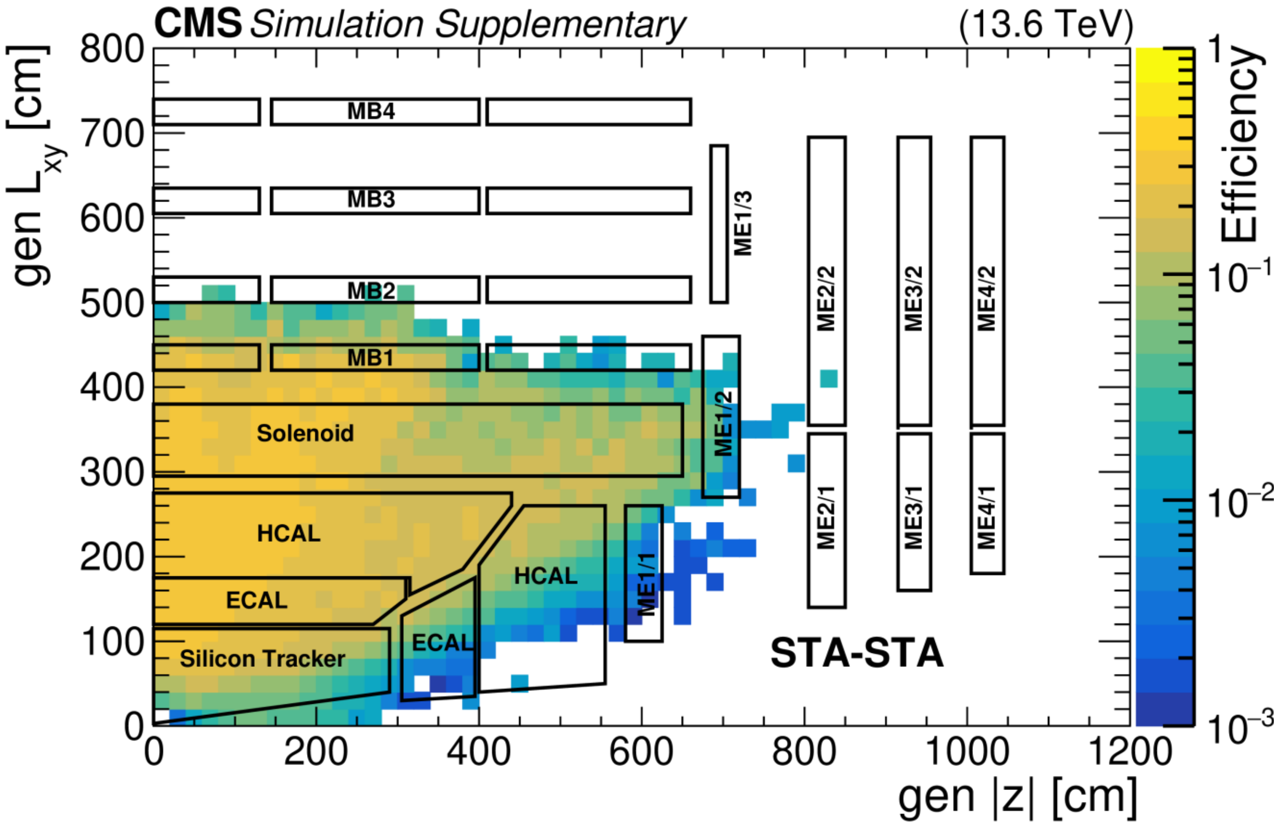
Displaced dimuon search at 13.6 TeV

- Search uses 3 dimuon categories, STA-STA, STA-TMS, TMS-TMS..



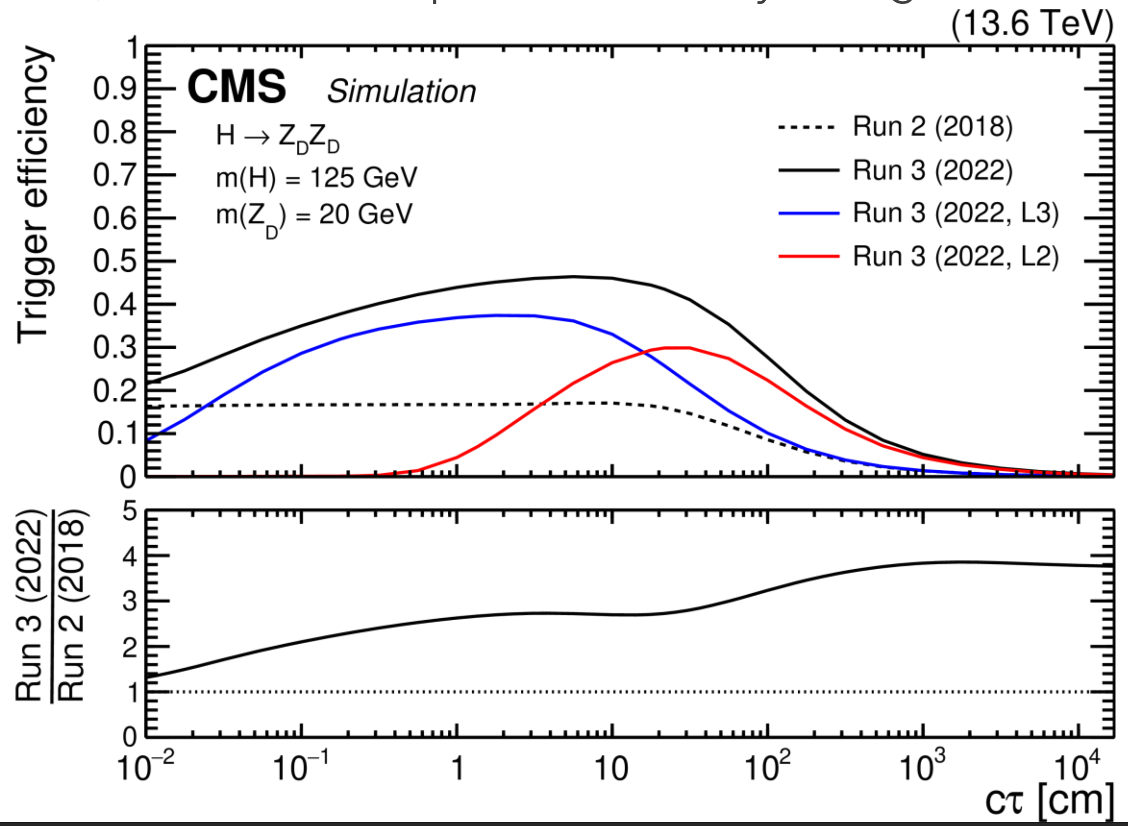
Displaced dimuon search at 13.6 TeV





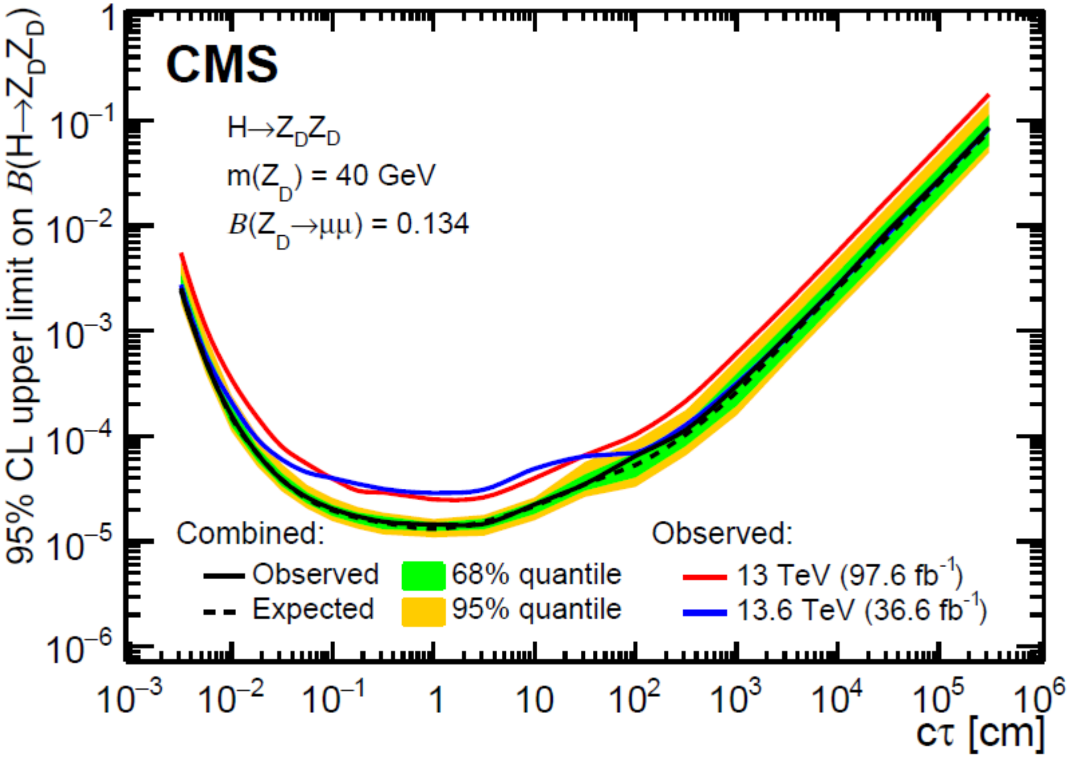
Displaced dimuon search at 13.6 TeV

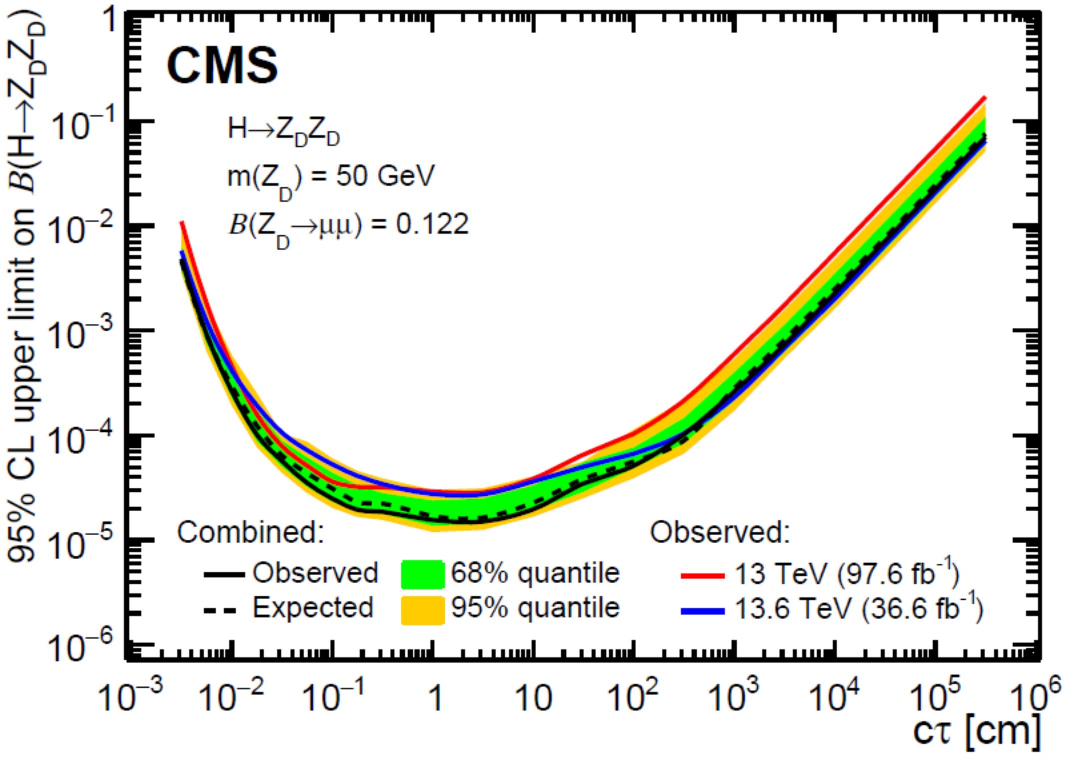
- Not all collisions can be recorded. If an event is not recorded it is lost forever.
  - The **trigger** is the system that takes the decision to save an event.
  - Two systems conform the CMS trigger: **L1** (hardware based) and **HLT** (software based).
- For an LLP search it is crucial to develop good triggers to record the collisions.
- Run 2 search was limited by: high $\boldsymbol{p_T}$ thresholds (23 GeV) at HLT; and drop of L1 efficiency at large **displacement** due to beam spot constrained p_T.
- **Improvements for Run 3:**
  - **New L1 seeds** lowering p_T thresholds and including unconstrained p_T.
  - **New HLT paths** lowering p_T thresholds for muons passing loose displacement cuts.
- Substantial **improvement** in efficiency, up to a **factor of 4**, at masses of a few tens of GeV and large $c\tau$.



Displaced dimuon search at 13.6 TeV

- Comparable or better sensitivity than Run 2 with only 38% of the data.
- Improvement coming from trigger developments for Run 3.





Summary

- BSM particles could have different lifetimes, charges, masses, and/or interactions compared to known SM particles.
- We don't know if they exist, data will tell.
  - The phase space is broad and still largely unexplored.
- Growing field in active R&D.
  - Plenty of lessons learned during Run 2.
  - New triggers for Run 3.

Thanks!