Highlights from long-lived particle searches in CMS

Steven Lowette
Vrije Universiteit Brussel – IIHE

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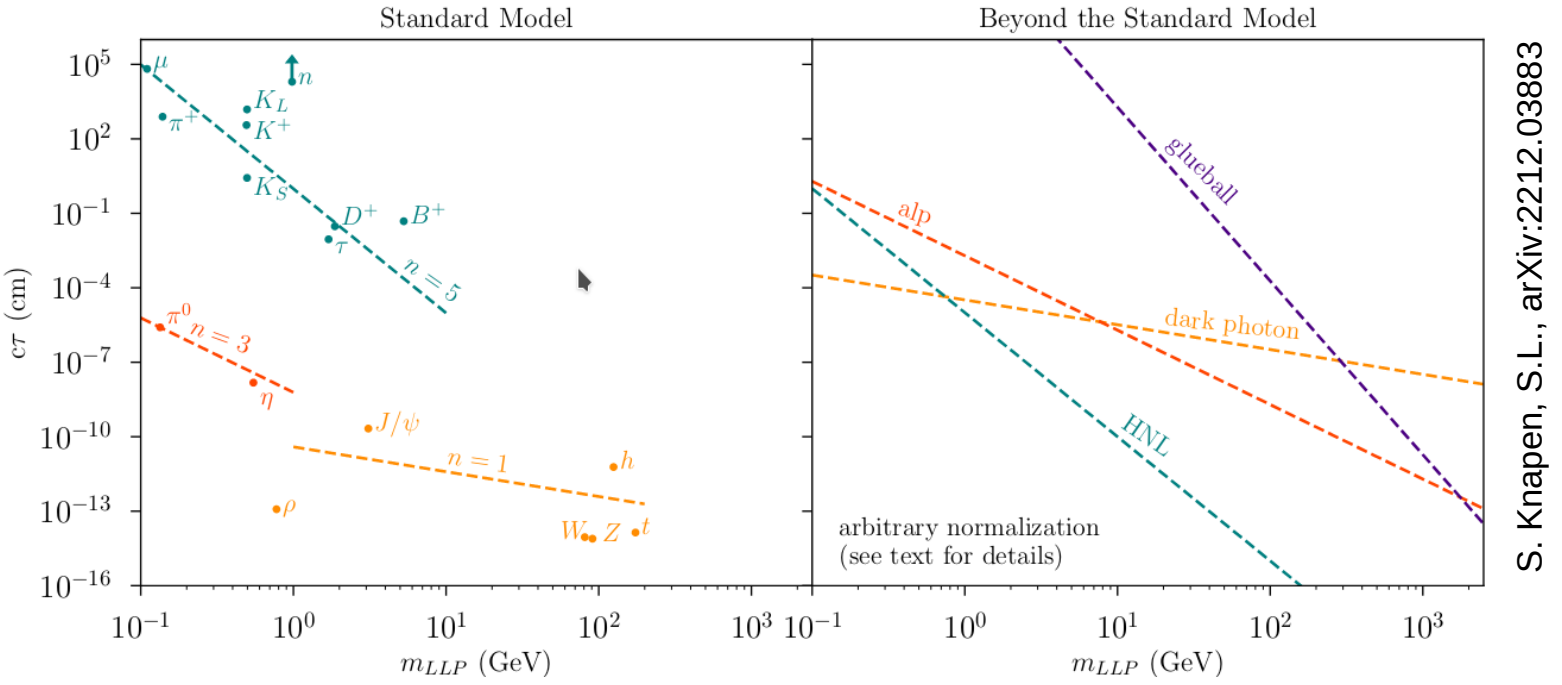
Why long-lived particles?

small coupling

suppressed phase space

$$\Gamma \sim \frac{\epsilon^2}{(8\pi)^{a-1}} \frac{m^n}{M^{n-1}}$$

heavy off-shell mediator



S. Knapen, S.L., arXiv:2212.03883

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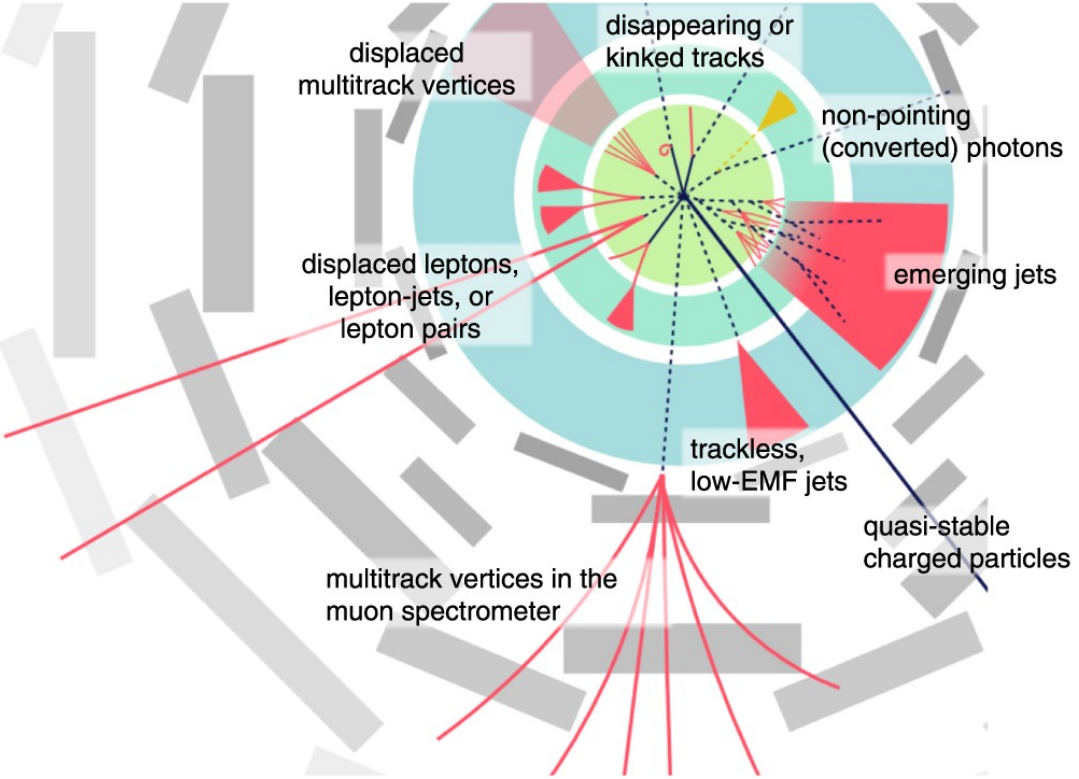
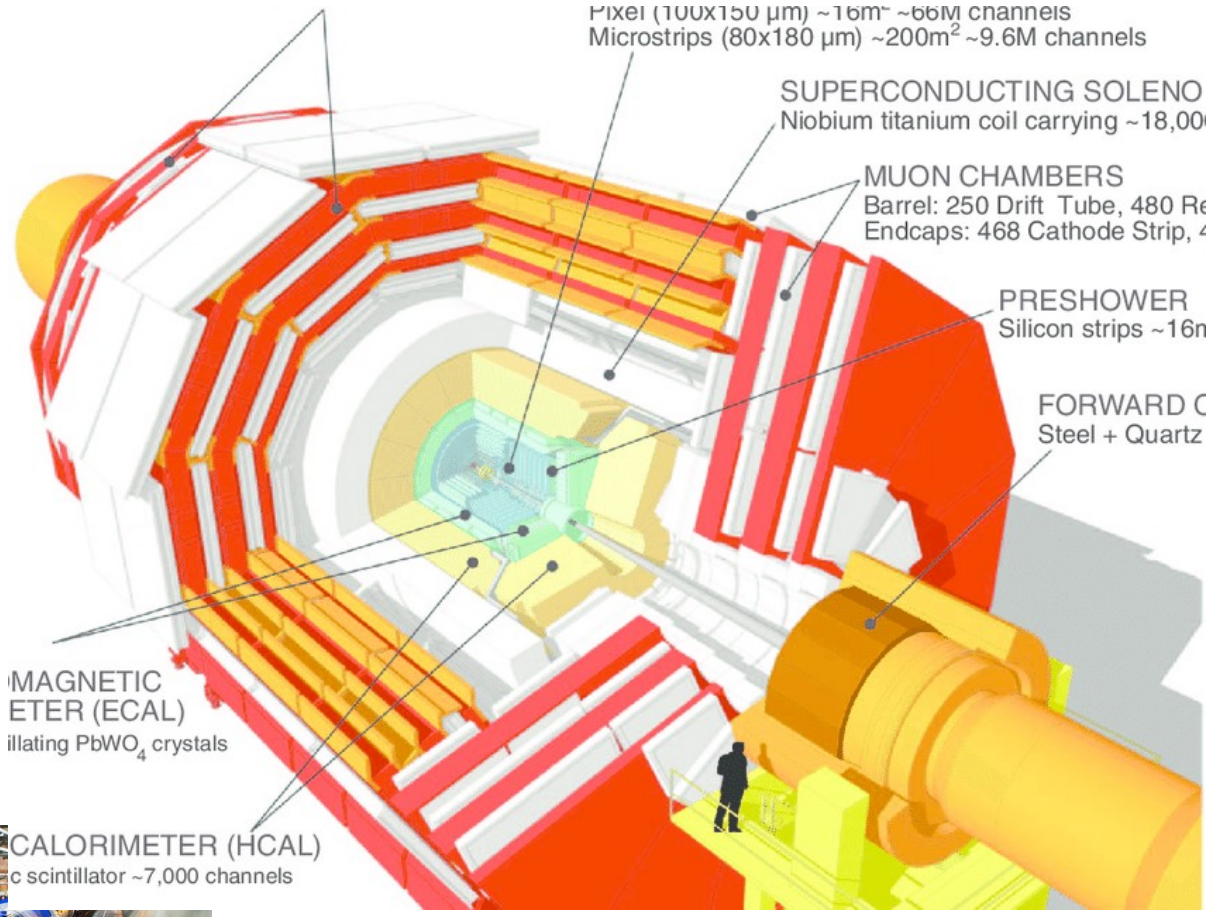
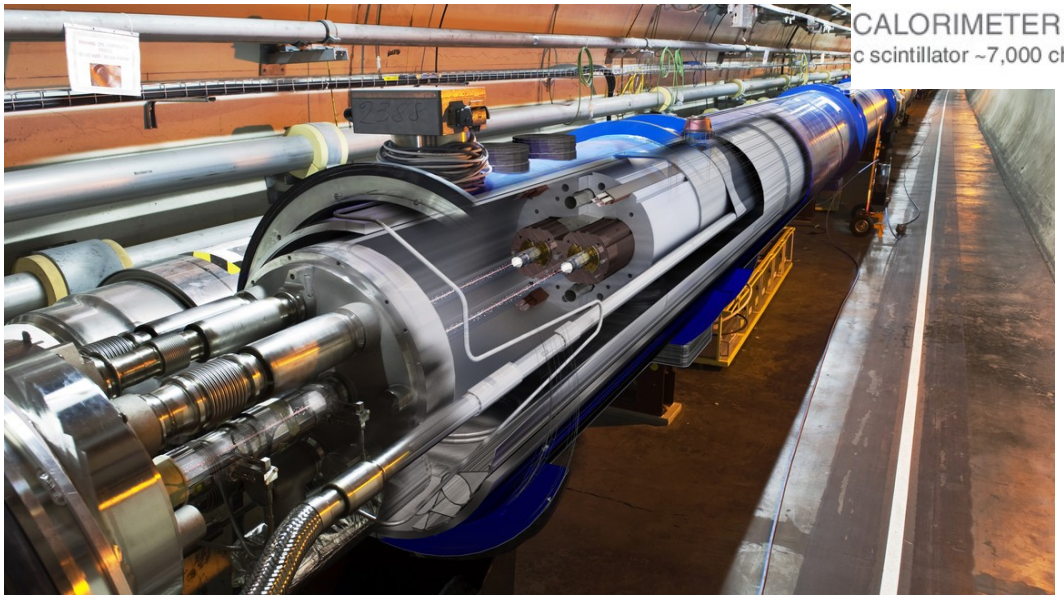


Heather Russell; 1903.04497

- theoretically motivated
- experimentally innovative
  - may need dedicated triggers
  - may require special reconstruction algorithms
  - unusual backgrounds
  - simulation can be challenging
- a discovery may already be waiting in our data

Our tools


Pixel (100x150 µm) ~16m² ~66M channels
Microstrips (80x180 µm) ~200m² ~9.6M channels
SUPERCONDUCTING SOLENO
Niobium titanium coil carrying ~18,00
MUON CHAMBERS
Barrel: 250 Drift Tube, 480 Re
Endcaps: 468 Cathode Strip,
PRESHOWER
Silicon strips ~16n
FORWARD C
Steel + Quartz
MAGNETIC
ETER (ECAL)
illating PbWO4 crystals
CALORIMETER (HCAL)
c scintillator ~7,000 channels

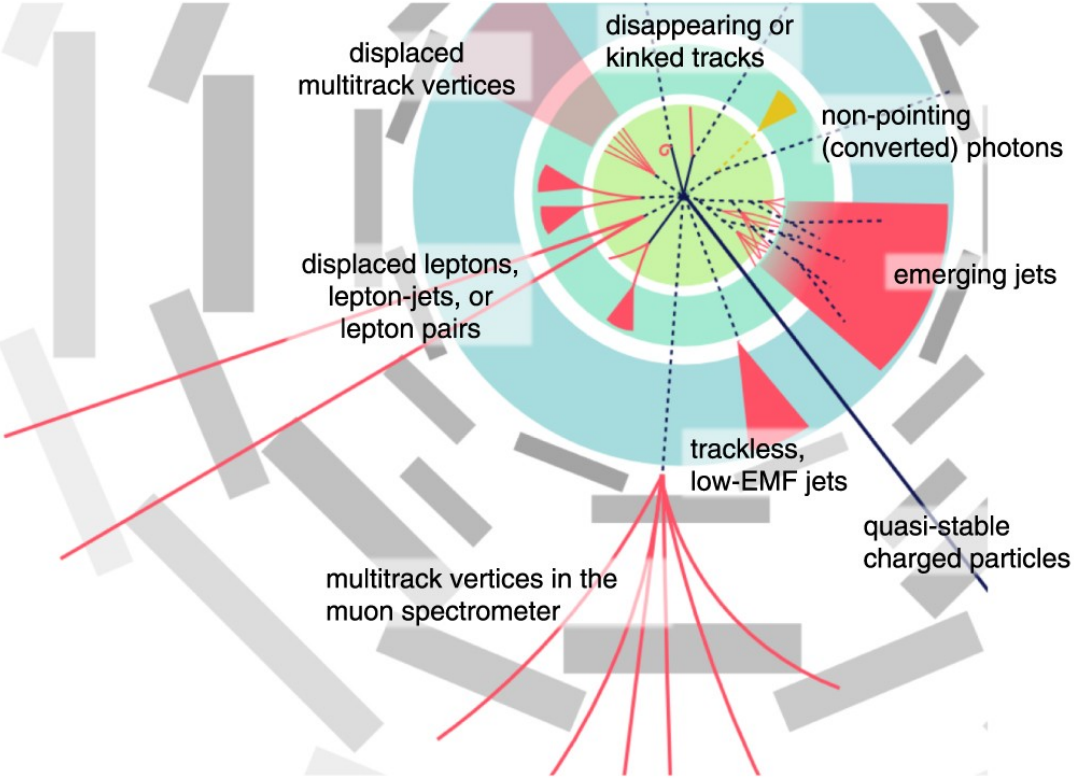


Long-lived particle searches

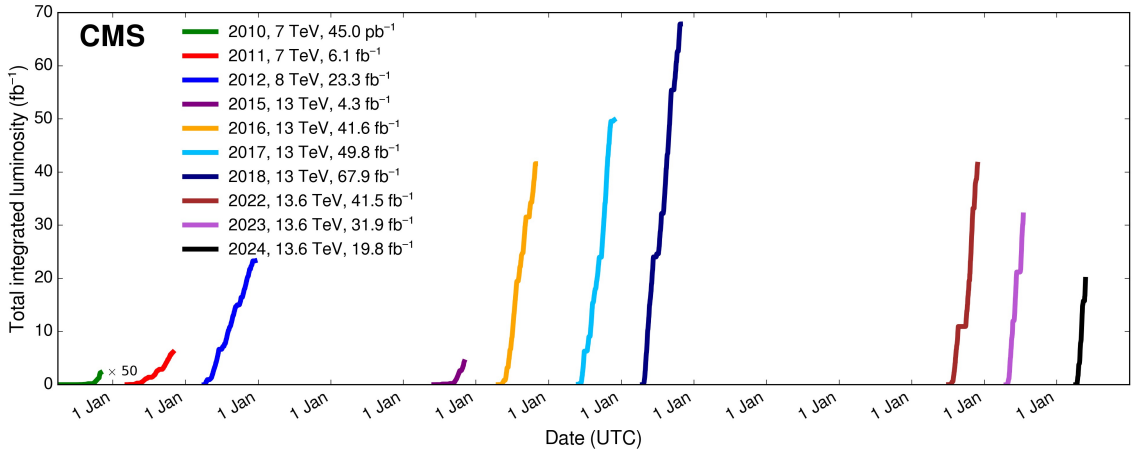
- exciting times!
  - thriving community in LHC and beyond

    see eg. arXiv:1903.04497
    J.Phys.G 47 (2020) 9, 090501

- experimental status
  - a rich set of searches have been performed using LHC Run-2 data
  - still new incoming LHC Run-2 results
  - Run-3 has started!



Heather Russell; 1903.04497



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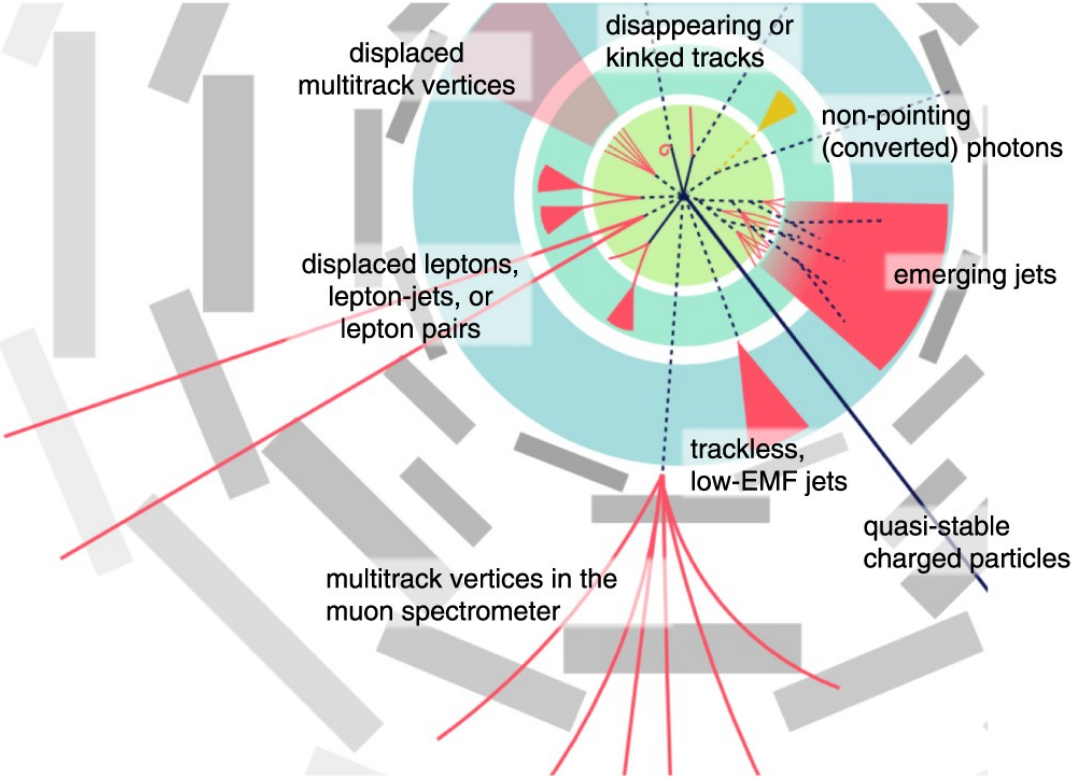


Heather Russell; 1903.04497

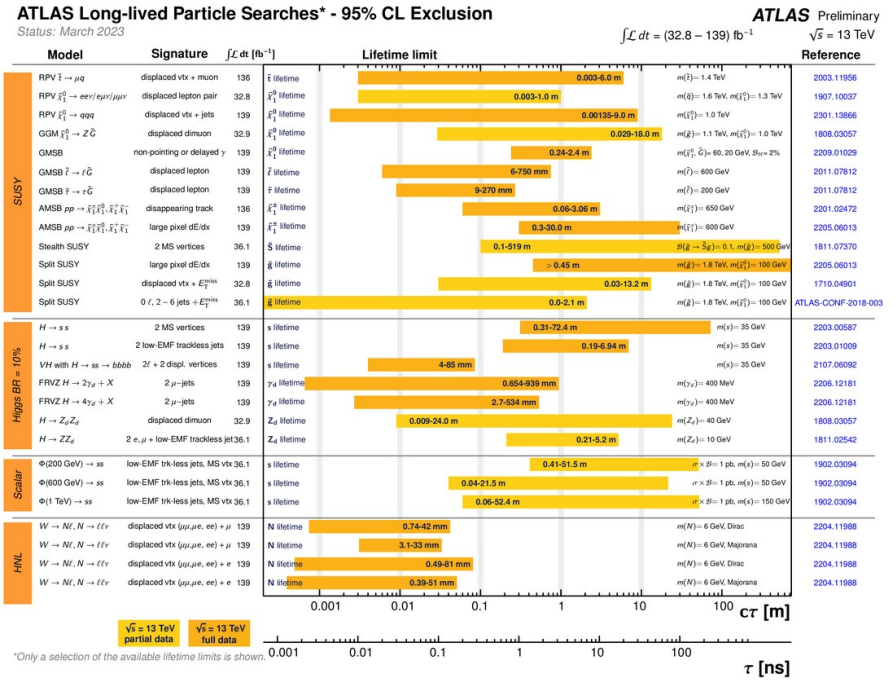
- this talk
  - a few recent highlights from the CMS experiment
  - some results also covered in very recent CMS review articles

    arXiv:2403.16134 : Enriching the physics program of the CMS experiment via data scouting and data parking

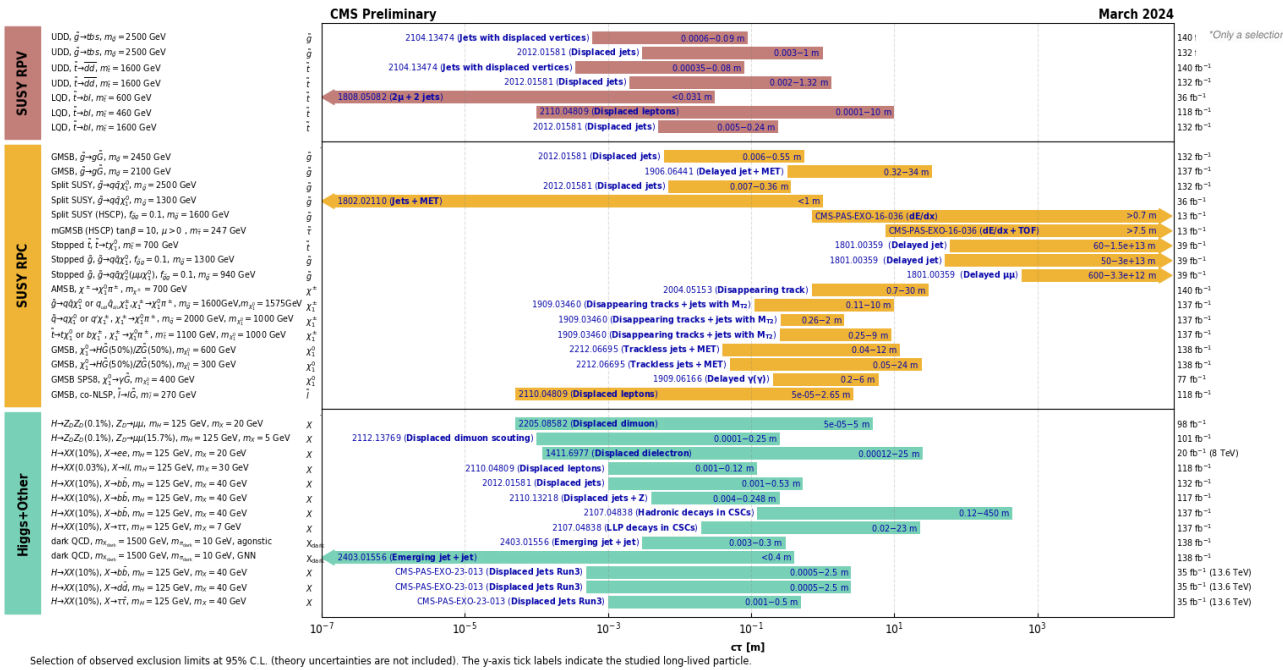
    arXiv:2405.13778 : Dark sector searches with the CMS experiment

    submitted to the arXiv: Review of searches for vector-like quarks, vector-like leptons, and heavy neutral leptons in proton-proton collisions at √s = 13 TeV at the CMS experiment

LLP results in ATLAS and CMS



[link]



[link]

Selection of observed exclusion limits at 95% C.L. (theory uncertainties are not included). The y-axis tick labels indicate the studied long-lived particle.

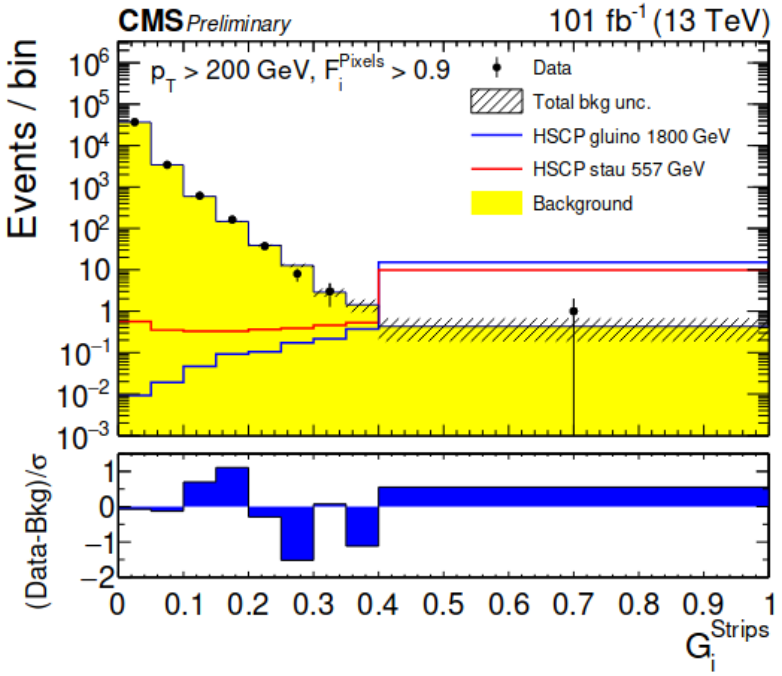
Search for Heavy Stable Charged Particles

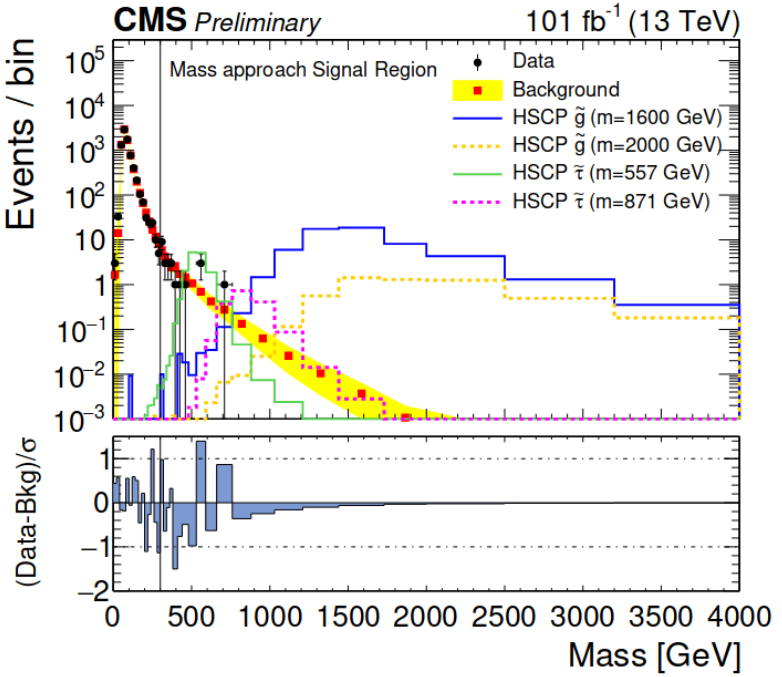
CMS-PAS-EXO-18-002

- striking signature
  - muon trigger, 2017-2018 data
  - isolated high-momentum, central track
  - large ionization (dE/dx) in the tracker

note: also beta measured in muon detector
→ follow up analysis

- approach 1: ionization in strip detectors
  - background from pixel-strip independence
- approach 2: mass spectrum
  - background using pT-vs-ionization

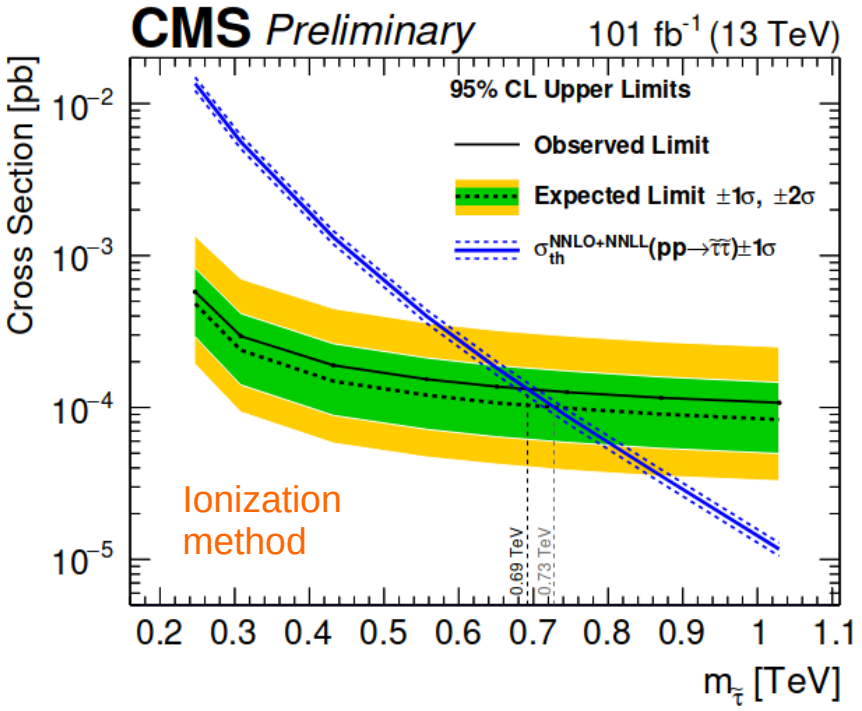


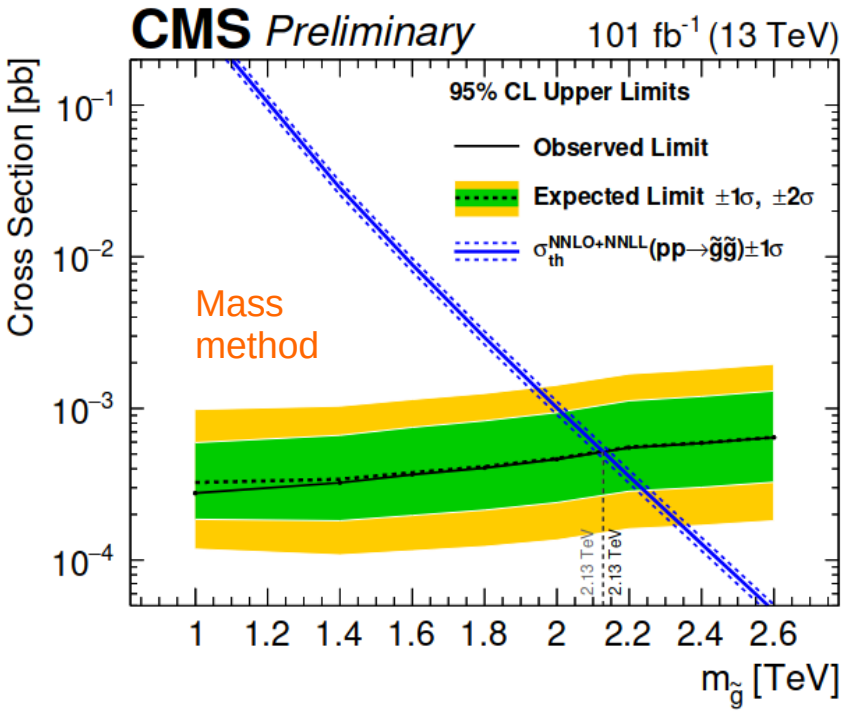


Search for Heavy Stable Charged Particles

CMS-PAS-EXO-18-002

- data well described by background
- interpretation in terms of many long-lived signals (eg. stau, gluino, stop,…)
  - ionization method: better limits at low signal
  - mass method: more efficient at large masses



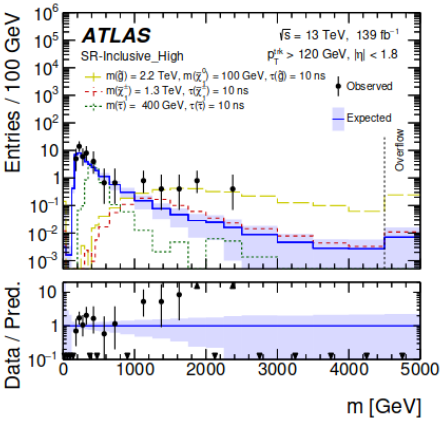


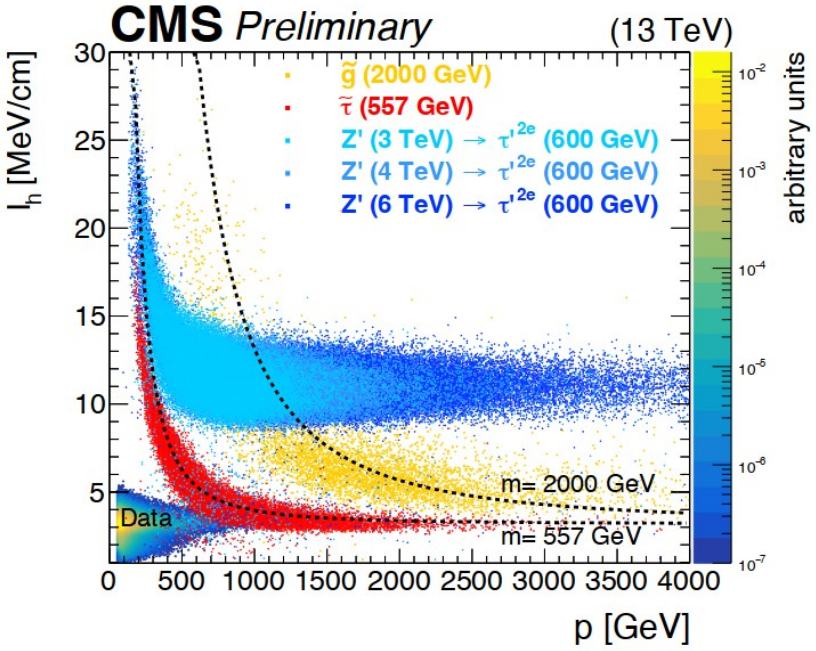
Search for Heavy Stable Charged Particles

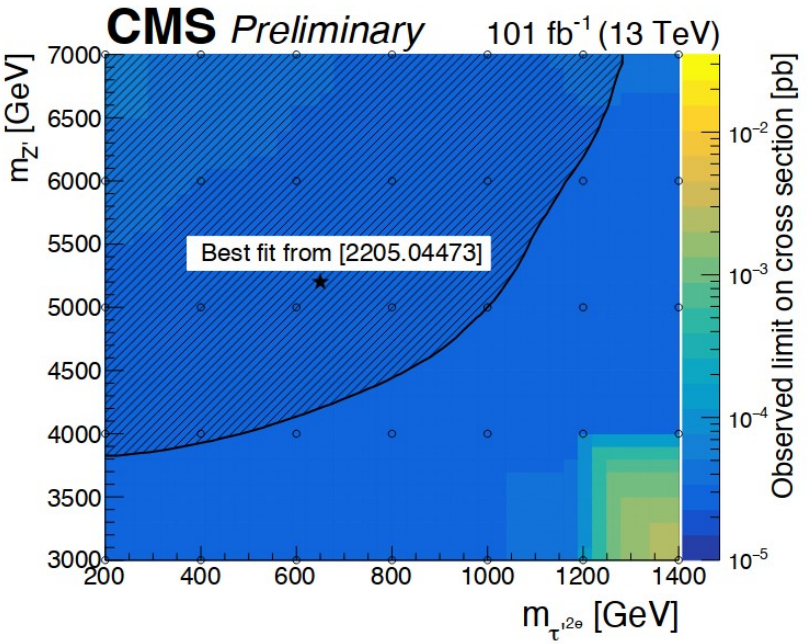
CMS-PAS-EXO-18-002

- additional interpretation for |charge| = 2e particle
  - triggered by 3.3σ excess from ATLAS [JHEP 06 (2023) 158]
  - explained by model with $Z' \rightarrow \tau'^{(+2e)}\ \tau'^{(-2e)}$ [JHEP 08 (2022) 012]

    high ionization with beta ~ 1
  - incompatible with the data

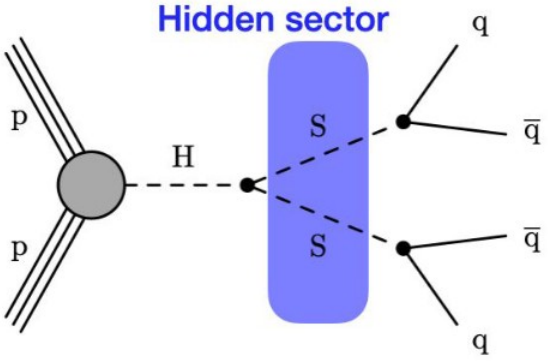






Search for Displaced Jet Pairs

CMS-PAS-EXO-23-013



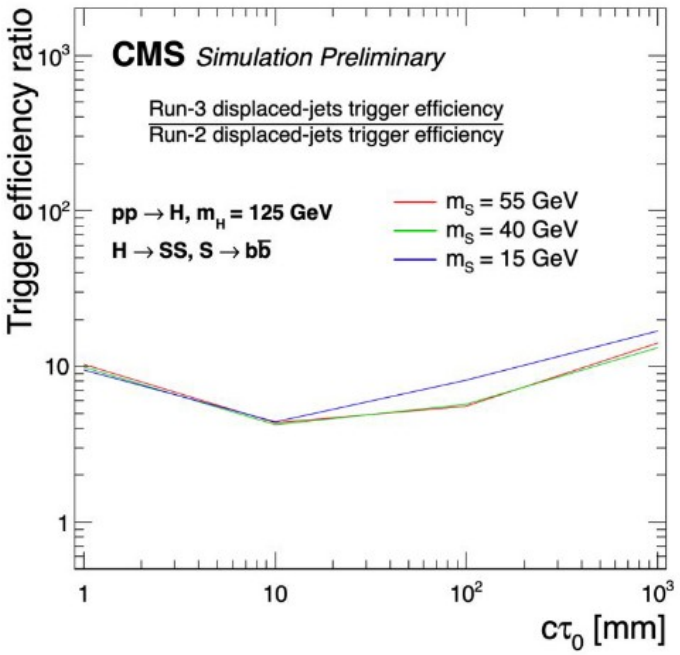
- Higgs mixed with new scalar can lead to long-lived decays with jets
  - m(S) < m(H)/2
  - lots of phase space for hadronic decays
- also other models, eg. RPV gluinos, stops

- data selected with dedicated displaced-jet trigger
  - factor 4-17 (!) improvement from improved displaced jet trigger for Run3

- also new displaced vertex reconstruction algorithm

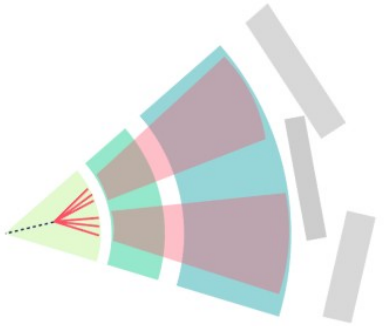
Run 3!

CMS-DP-2023-043

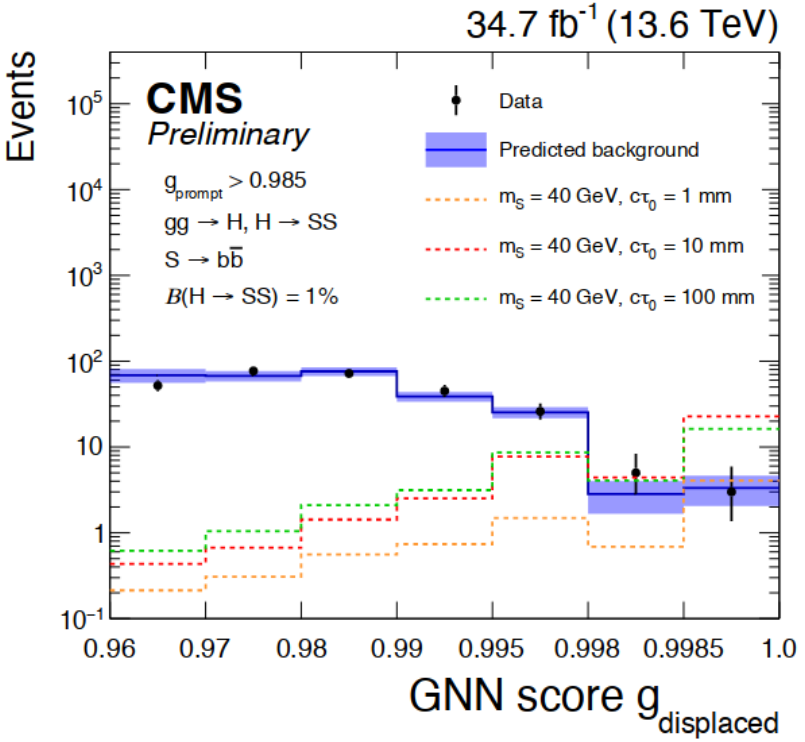


Search for Displaced Jet Pairs

CMS-PAS-EXO-23-013



- 2 GNN-based LLP taggers
  - using relation between tracks and Displaced Vertex
  - GNN_d: displaced activities during the LLP decay
  - GNN_p: lack of prompt activities during the LLP production
- background predicted from data
  - using decorrelation of the 2 taggers



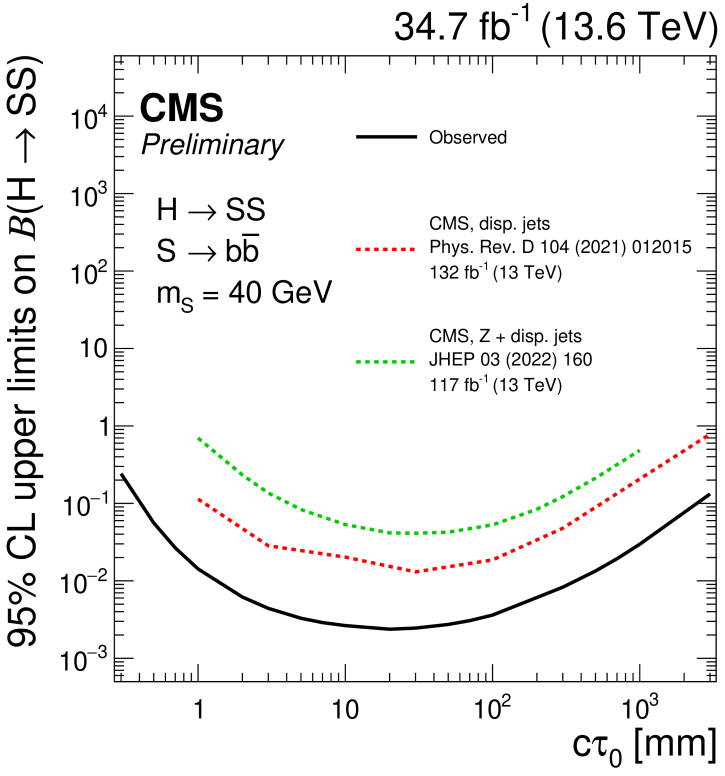
Run 3!

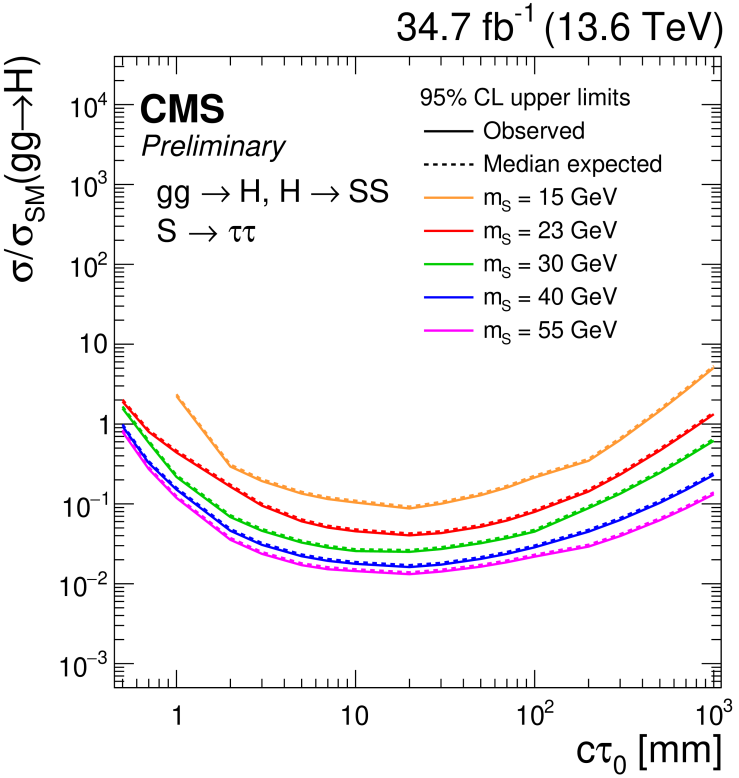
Search for Displaced Jet Pairs

Run 3!

CMS-PAS-EXO-23-013

- data well described by background prediction
- stringent constraints on considered models
  - outperforming previous results by a lot, with less data!

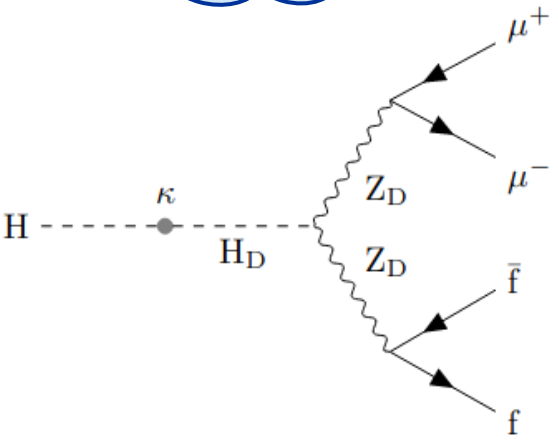


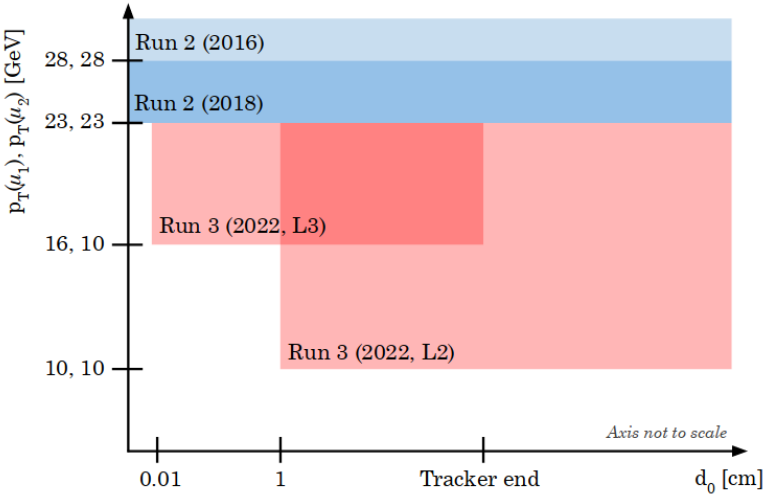


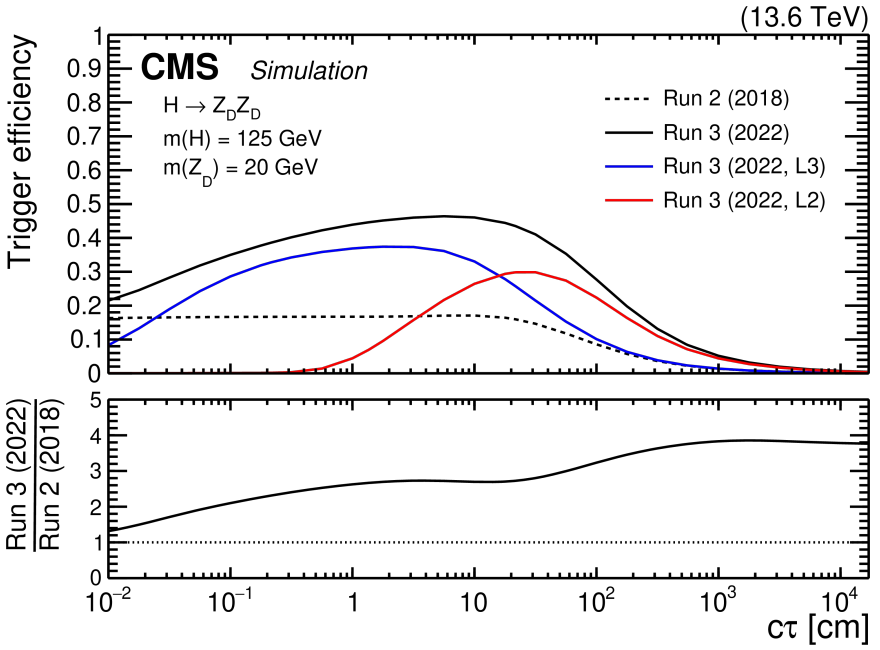
Search for Displaced Muon Pairs

JHEP 05 (2024) 047

- dark Higgs mixed with Higgs
  - decay back to SM via dark photon
  - also other models, eg. RPV SUSY
- selection: at least 1 diplaced muon pair
- new improved triggers for displaced dimuons developed fc
  - improvements at L1 trigger to avoid beamspot constraint
  - improvements in high-level trigger to lower thresholds



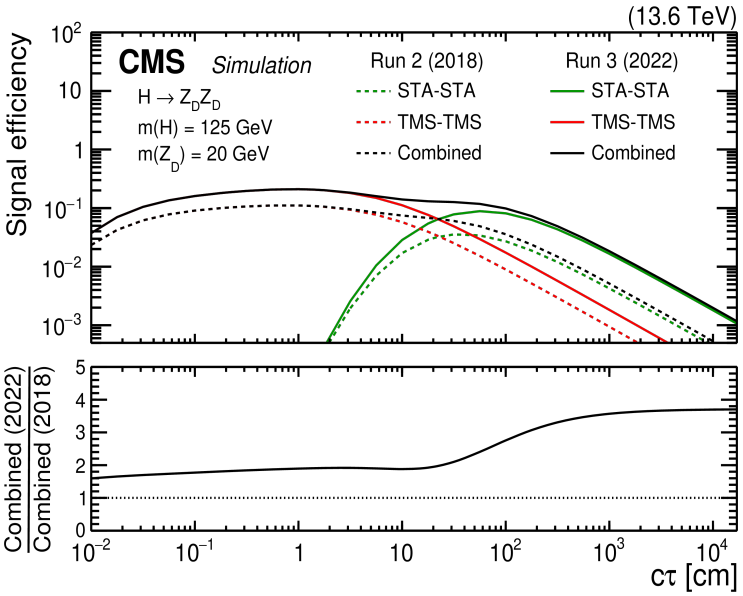


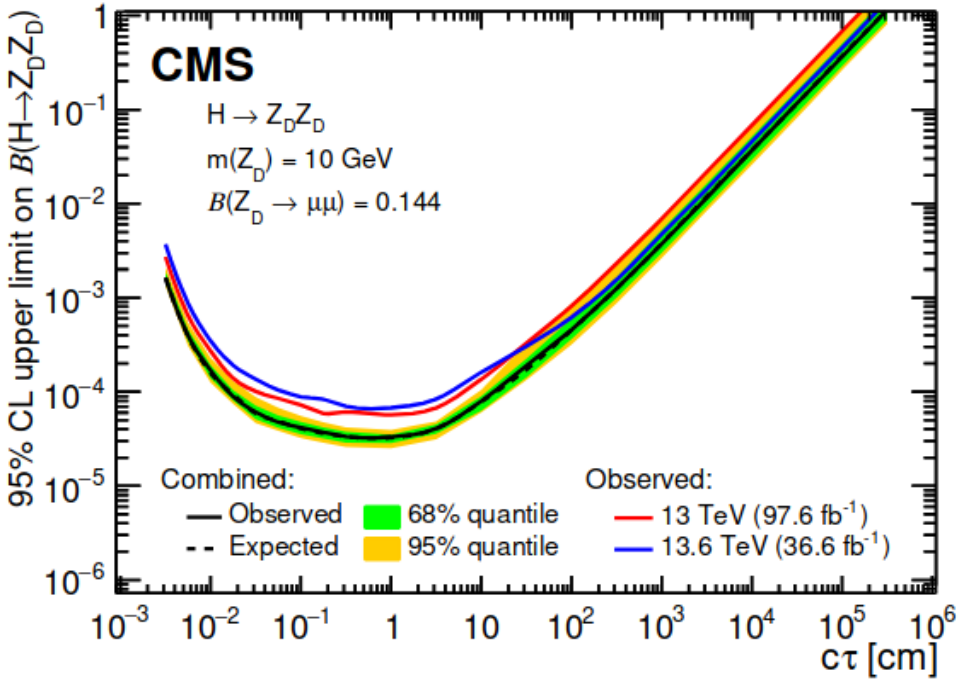


Search for Displaced Muon Pairs

JHEP 05 (2024) 047

- large improvement retained in offline selection over Run-2 analysis
- background prediction matches data
- similar sensitivity obtained as Run-2 but with only 1/3rd of the data set





Run 3!

Outlook

- LLPs are theoretically motivated, and experimentally motivating
- Going to great lengths to mine LHC Run-2 data for signs of LLPs
  - impressive list of results, still new ones coming in
  - large diversity in signatures and approaches
  - formidable ingenuity in analyses
  - several recent new results from CMS presented
- LHC Run-3 has taken off swiftly
  - detector improvements in LHC LS2
  - new and improved triggers and data taking strategies
  - other experiments weighing in as well
- Also HL-LHC will bring a big boost to LLPs
  - only started to scratch the surface of new detector capabilities
  - still other detectors being planned

Backup