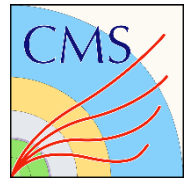
Displaced and delayed searches not using displaced vertices @ ATLAS + CMS

R Rosten (OSU) on Behalf of ATLAS and CMS

7th June 2021

LHCP9



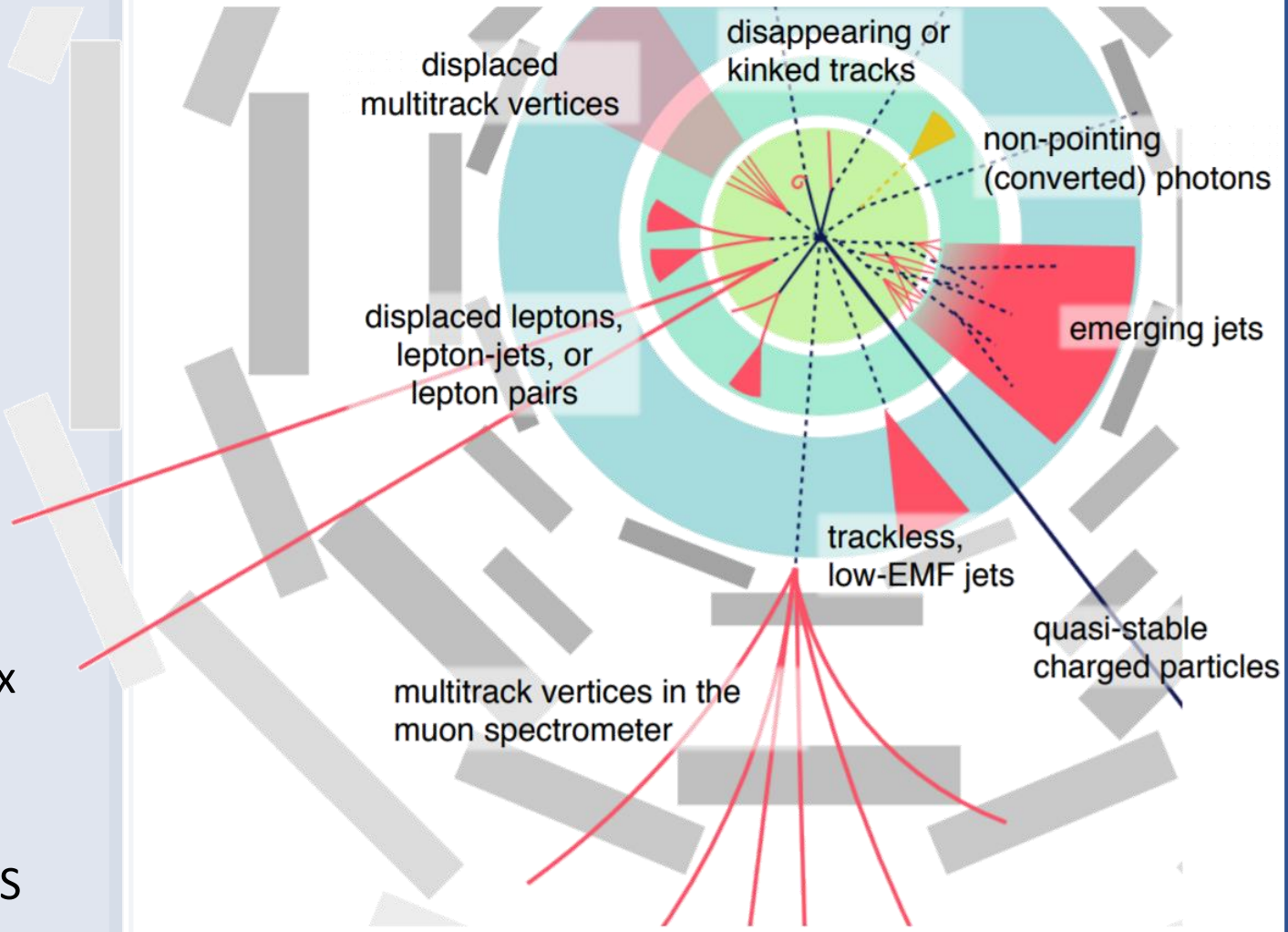
THE OHIO STATE UNIVERSITY

Introduction

- **Q: How can we look for LLPs that do not leave a reconstructable vertex?**
- **A: Is the LLP charged? What can it couple to? How long is its lifetime?**

- Rich field of signatures depending on the answer to the above… answer
- Just as displaced vertex LLP searches require careful analysis of data, non-vertex searches are challenging and varied

- Focus on one search each for ATLAS & CMS



LLPs with vertexing
C. Vazquez

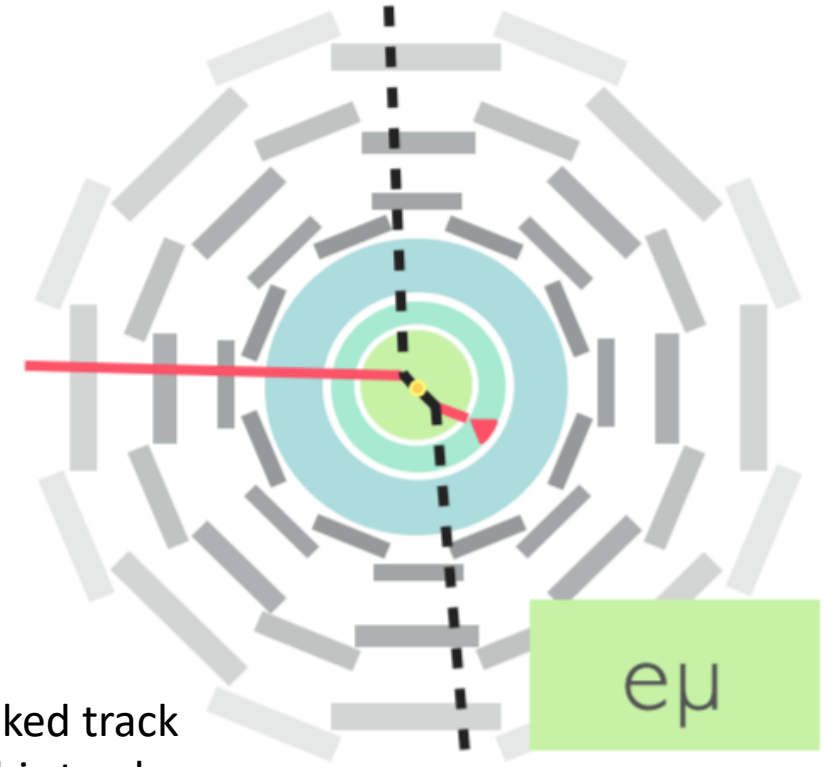
Disappearing tracks, Stopped Particles
E. Kuwertz

Anomalous Ionizing Particles, etc
C. Wulz

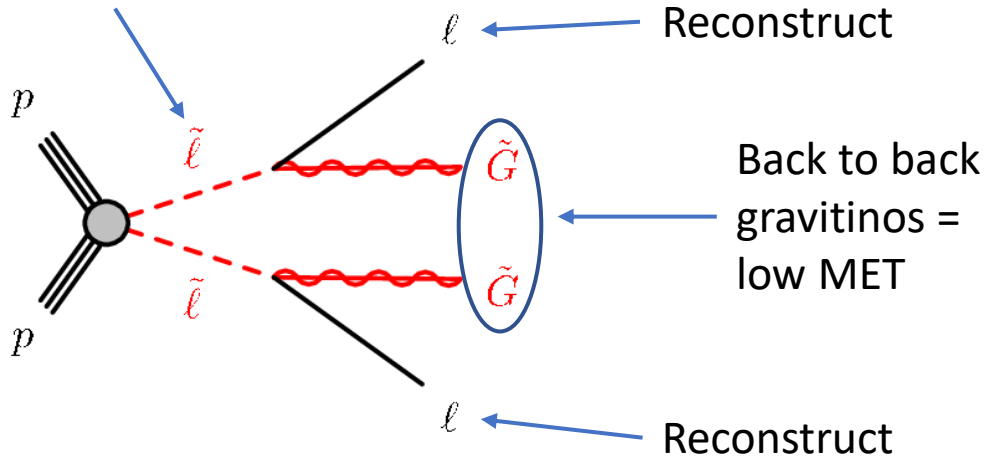
Displaced Leptons

Displaced Leptons

- Previous ATLAS and CMS LLP searches for lepton pairs mostly focused on leptons with a shared vertex
- Consider decay of charged LLP to **lepton** and neutral daughter, ex: GMSB SUSY **slepton decay**
- Could reconstruct a kinked track, but no need – **focus on leptons**, ignore slepton tracks
- No ISR/MET requirement needed

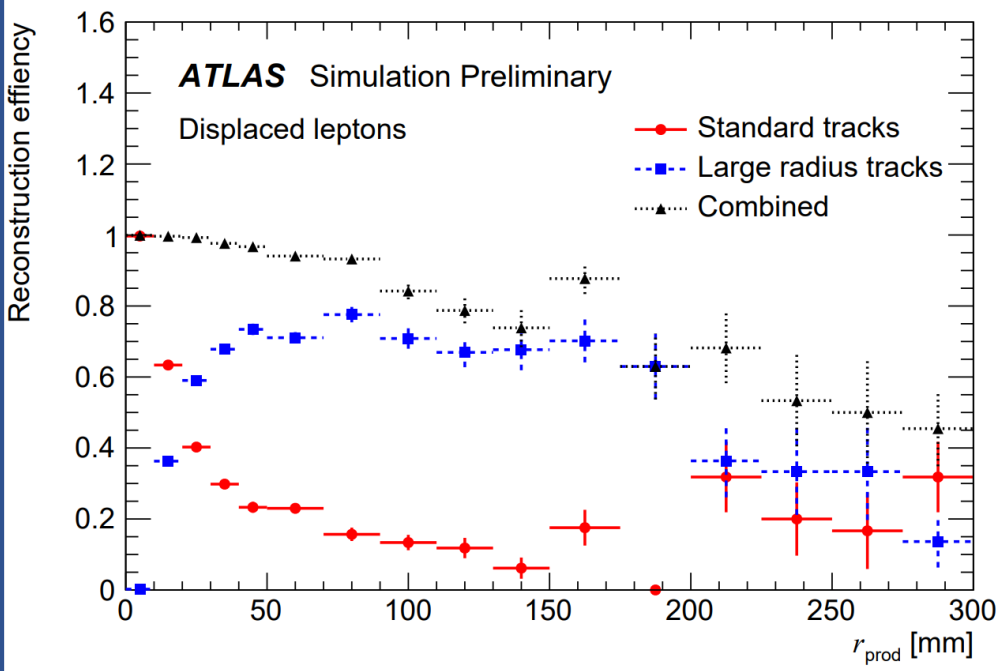


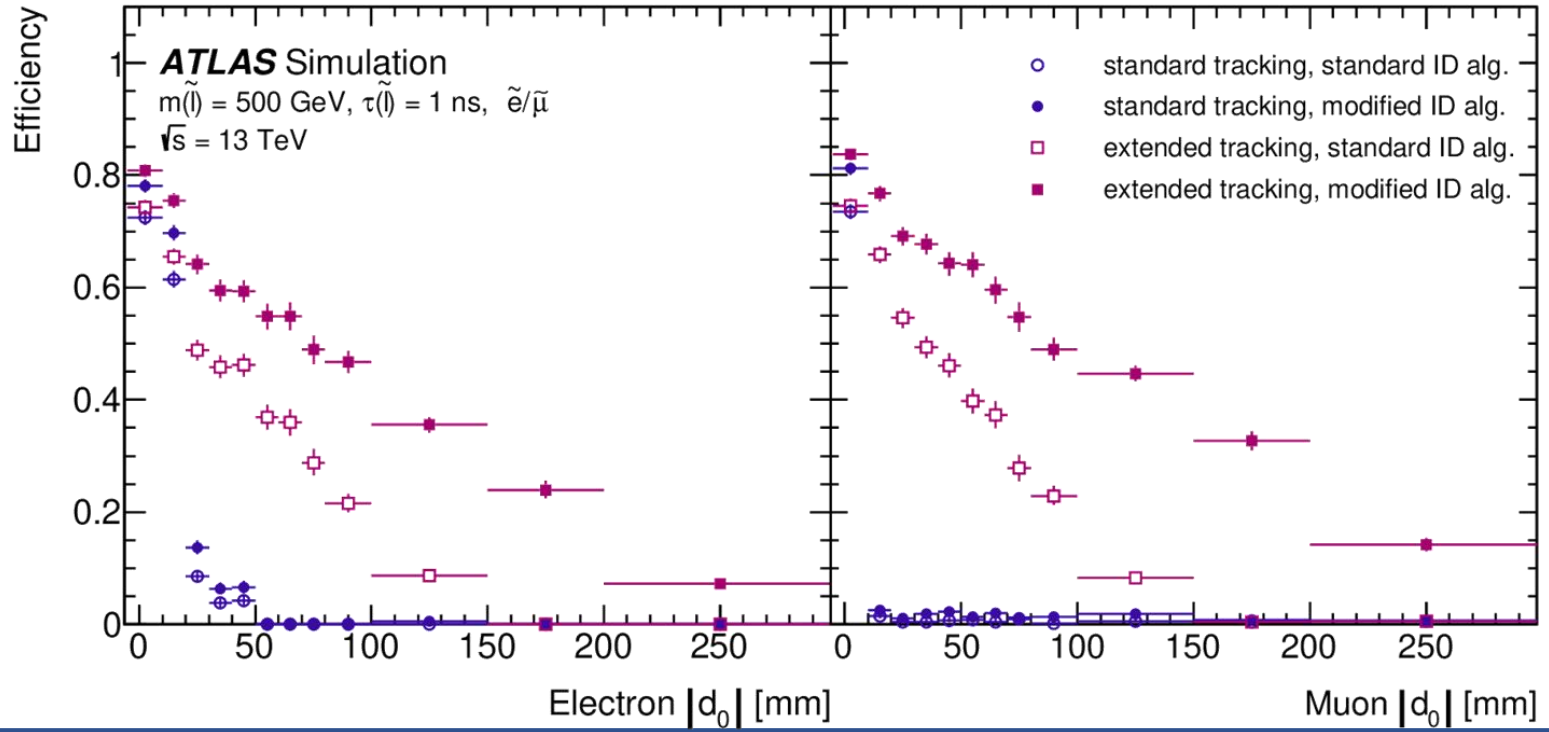
Not a kinked track search, this track does not matter



Displaced Leptons

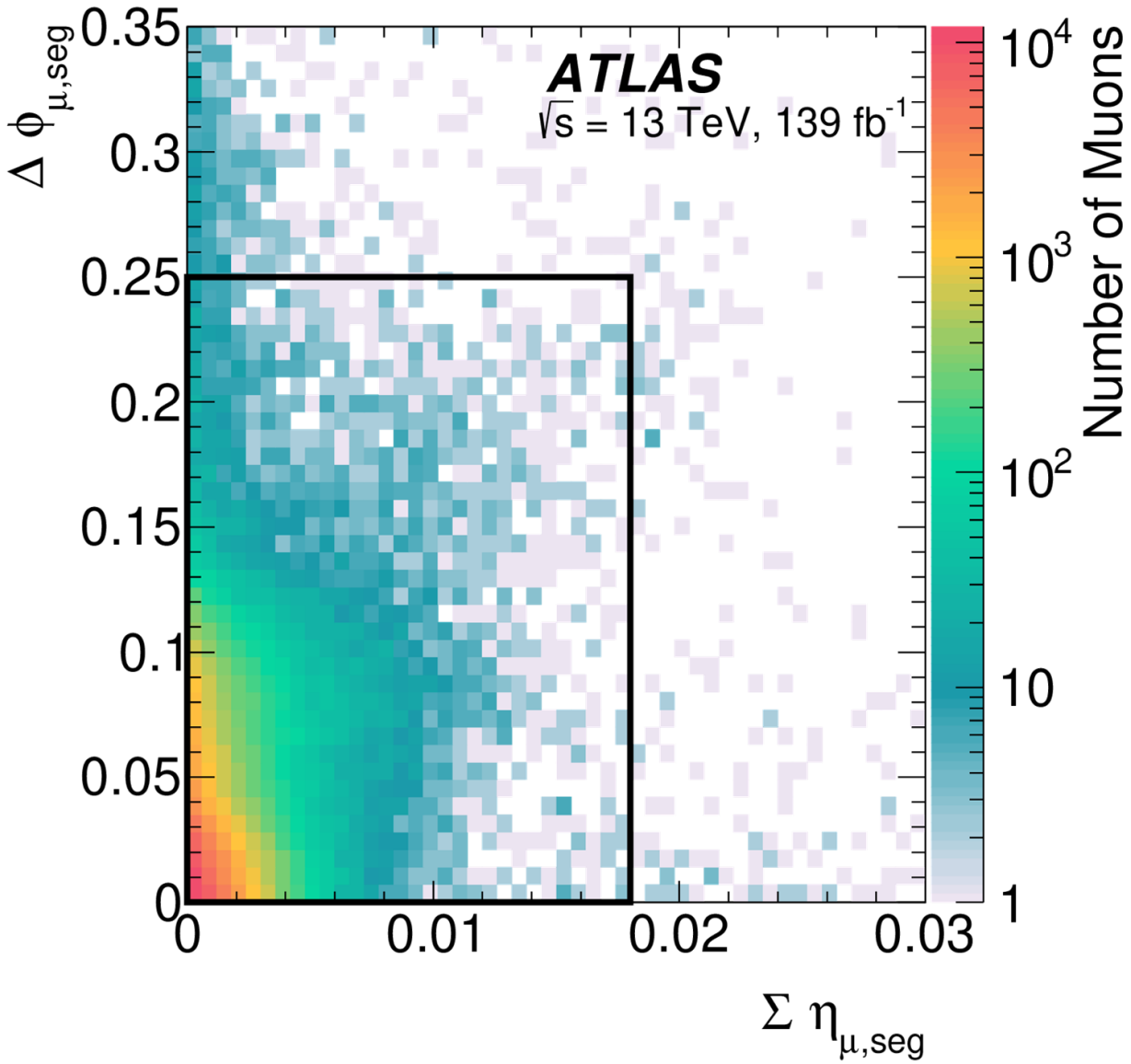
- Do not need slepton track, but do rely on displaced decay to suppress leptons from PV
- Need large radius tracking to reconstruct **high-d_0 tracks**
  - Standard tracking runs first
  - Leftover hits used for large radius tracking allowing for d_0 up to 300 mm
- Further **modify lepton reconstruction** to remove requirements on d_0 and the number of Pixel hits





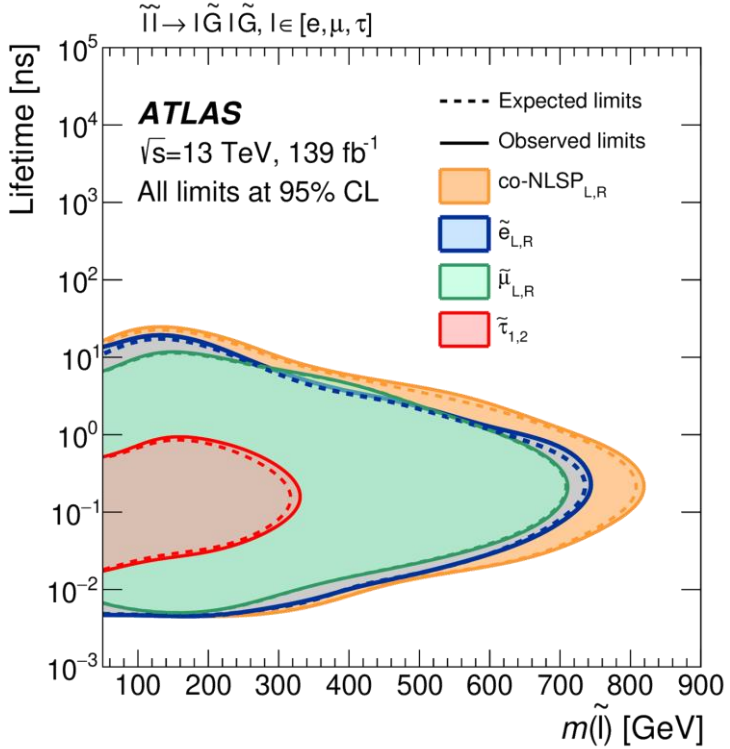
Displaced Leptons

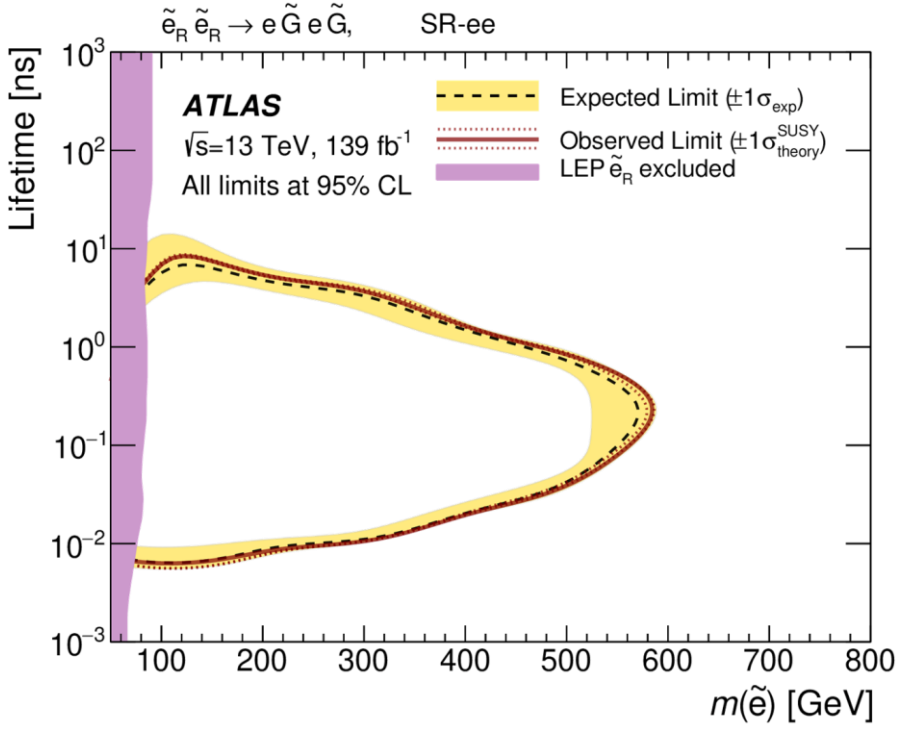
- Trigger on **MS-only muon** or **loose "photon"**
- Reduce backgrounds from interaction with materials by **requiring $\Delta R > 0.2$**
- Remove single muon cosmic ray muons by **tagging as cosmic** muons with a inline segment on the opposite side of ATLAS
- Background "dominated" by:
  - **combinatorial fakes** for **μe** and **ee**: estimated with ABCD method using the two leptons' quality
  - **cosmic rays** for **μμ**: estimated with ABCD using tag and quality info
- Background **<1 event**, observation 0 events

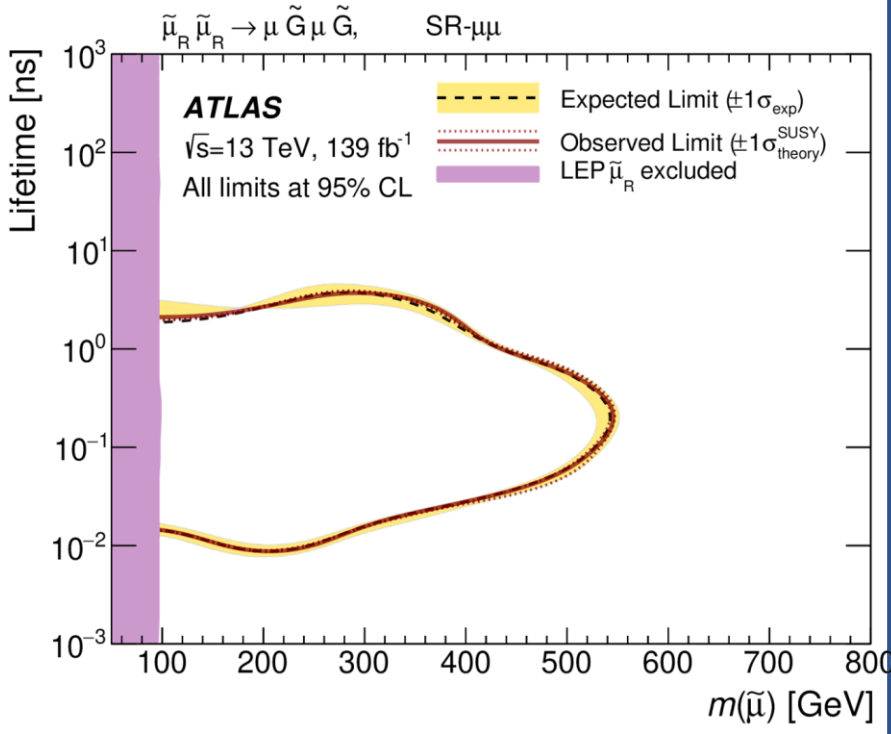


Displaced Leptons

- **Previous limits** on slepton mass of **~90 GeV** from **LEP** for $\tilde{\mu}$ and $\tilde{e}$, and from **OPAL** for $\tilde{\tau}$
- Limits on $\tilde{\tau}$ limited due to branching fraction of τ to leptons
- Lack of constraints on MET, jets, and vertices **invites reinterpretation** under other models

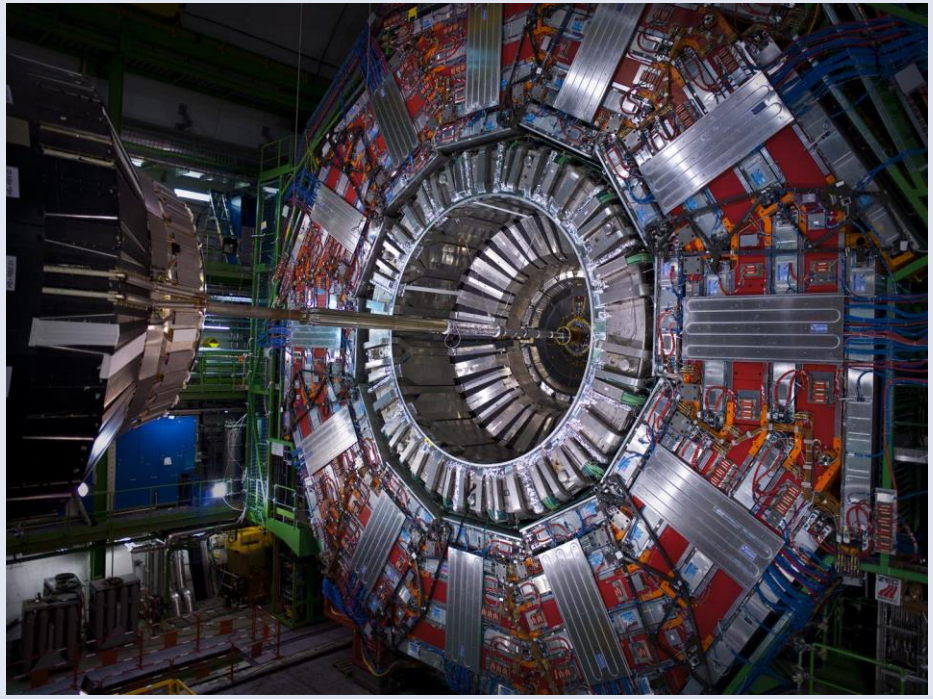




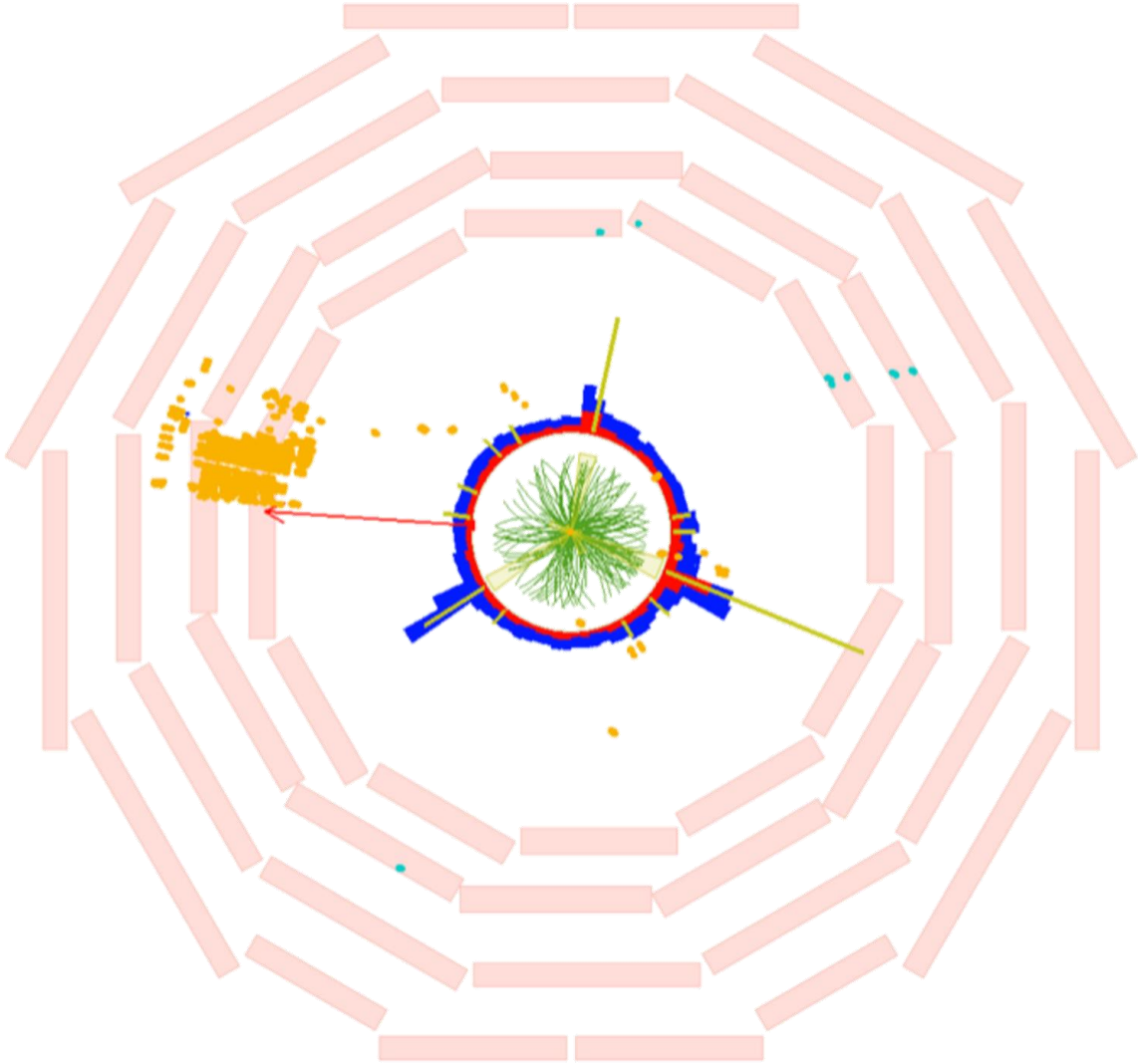


LLPs in the Endcap MS

- CMS MS is wonderfully **dense**
  - **Excellent coverage** with sensitive muon chambers to detect activity
  - Large amount of **steel** with full coverage to **absorb background**



CMS *Simulation Preliminary*



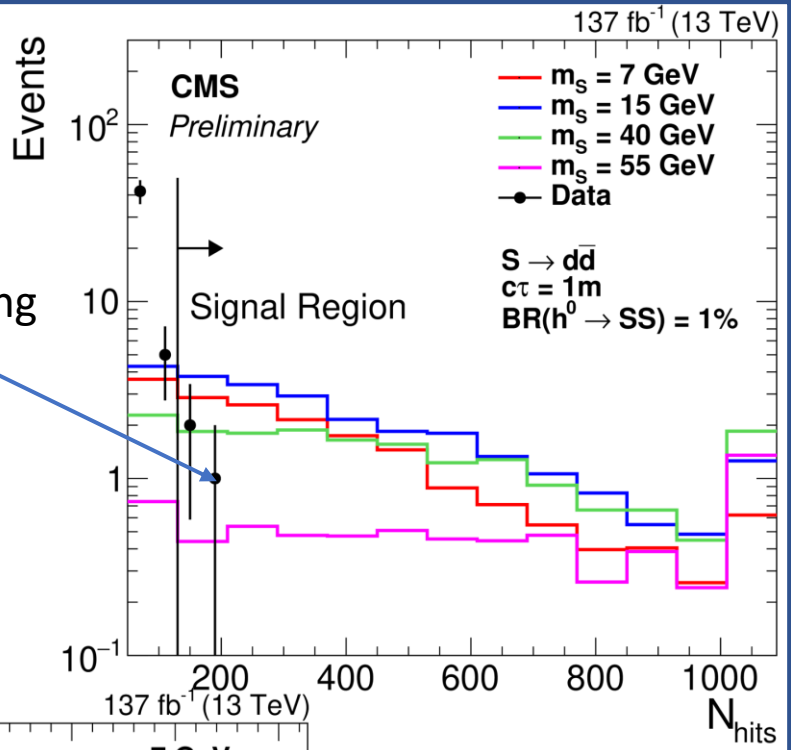
$h^0 \to SS \to b\bar{b}$ $h^0 \to SS \to \tau\bar{\tau}$ $h^0 \to SS \to d\bar{d}$

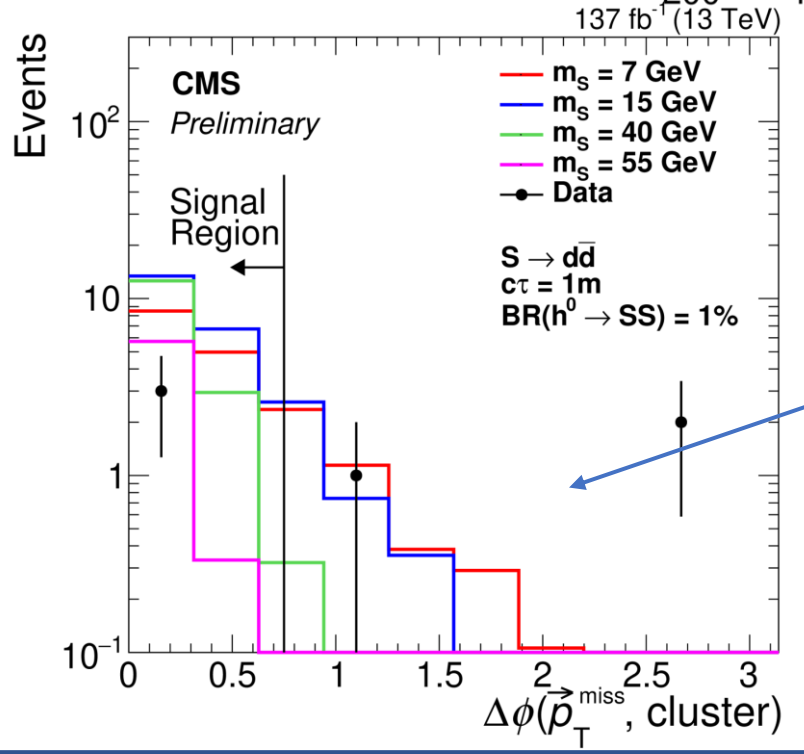
LLPs in the Endcap MS

LLPs in CMS EMS

- Seek **isolated cluster of hits** in the CMS MS endcap
- **Trigger on MET** from decay + ISR jet
- Offline require $p_T^{miss} > 200$ GeV and at least one jet with $p_T > 50$ GeV
- Suppress background from W and top production by **vetoing on hard electrons and muons**

- Punch through jets
- Hard bremsstrahlung from muons
- SM particles, ex K_L^0
- Hopefully signal

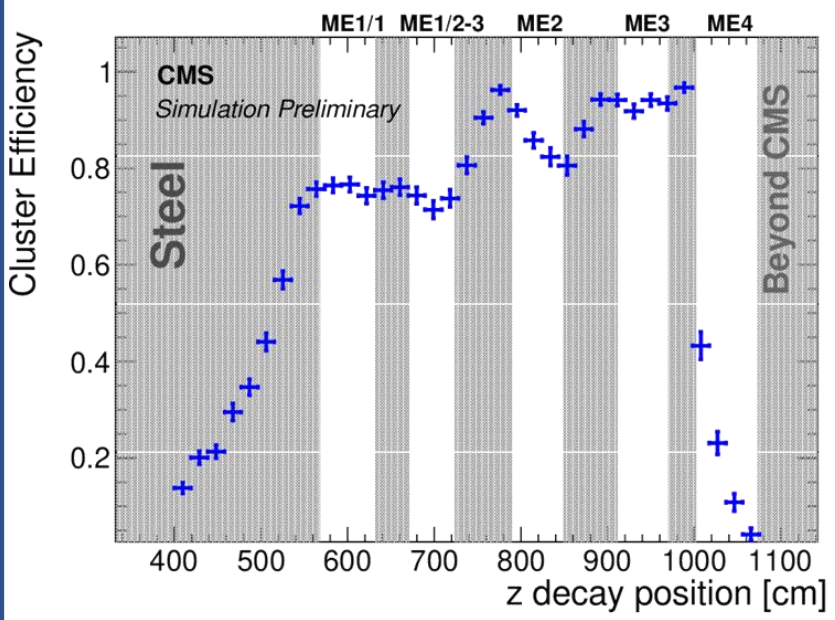


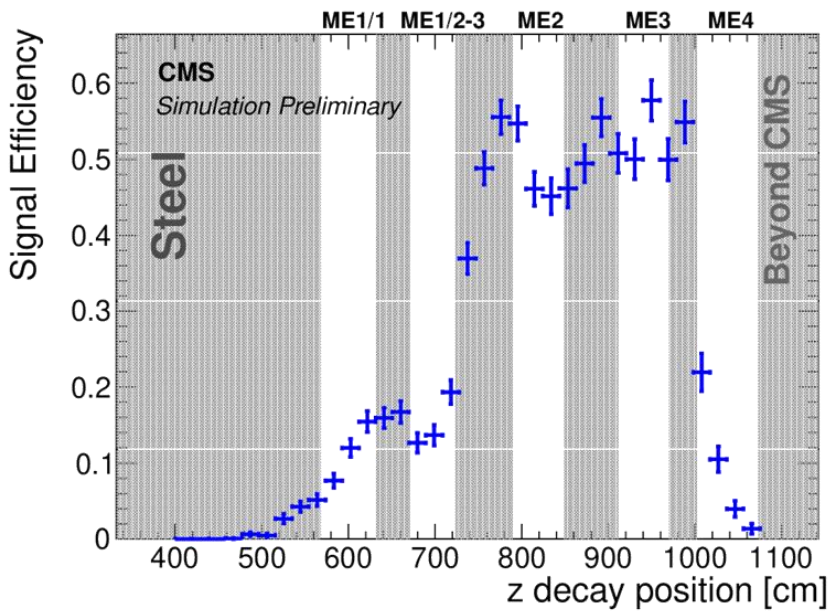


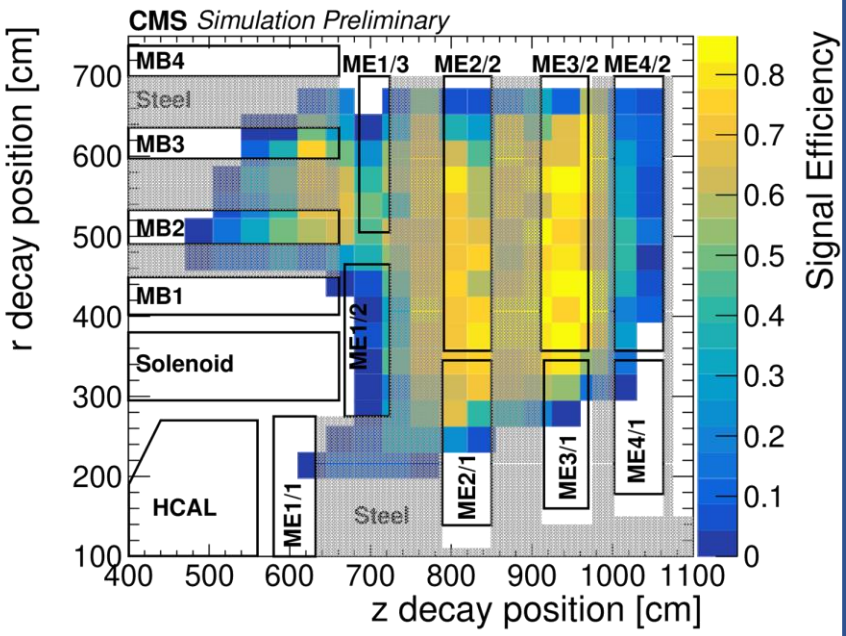
Background after all cuts primarily SM particles from pileup – independent of p_T^{miss}

LLPs in the Endcap MS

- Background suppressed by **vetoing on clusters** with any hits on innermost ϕ-rings of stations with **least amount of shielding**
- Reject clusters with $|\eta| > 2.4$ to suppress **muon bremsstrahlung** background
- Have a **dedicated cluster identification** algorithm with a factor of 3 suppression of remaining background

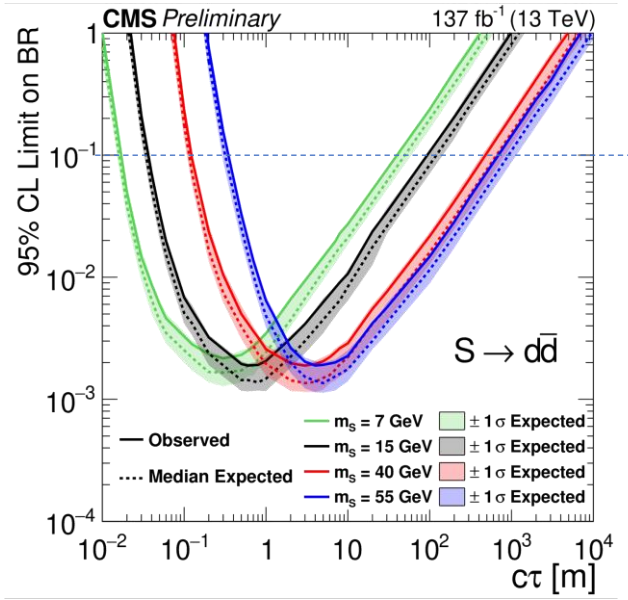


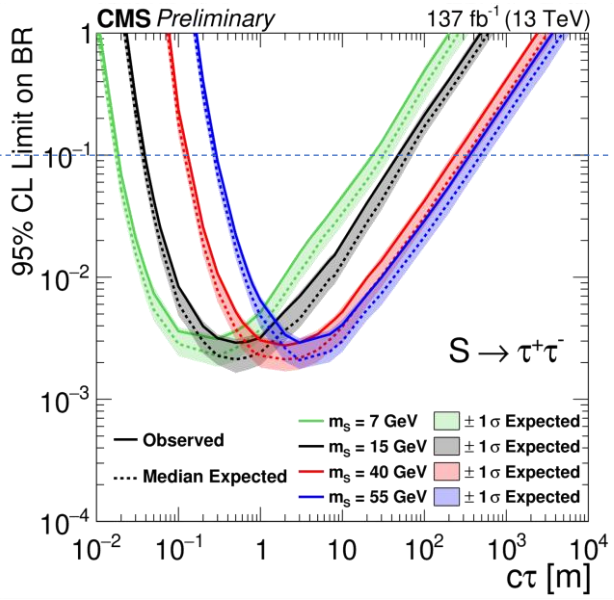


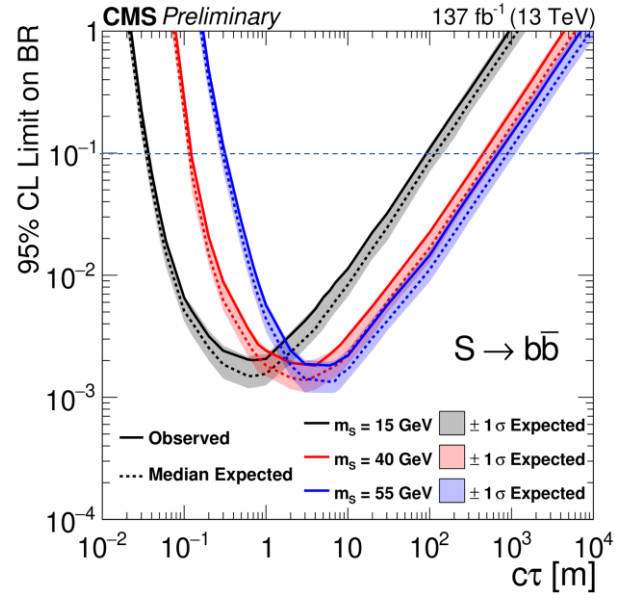


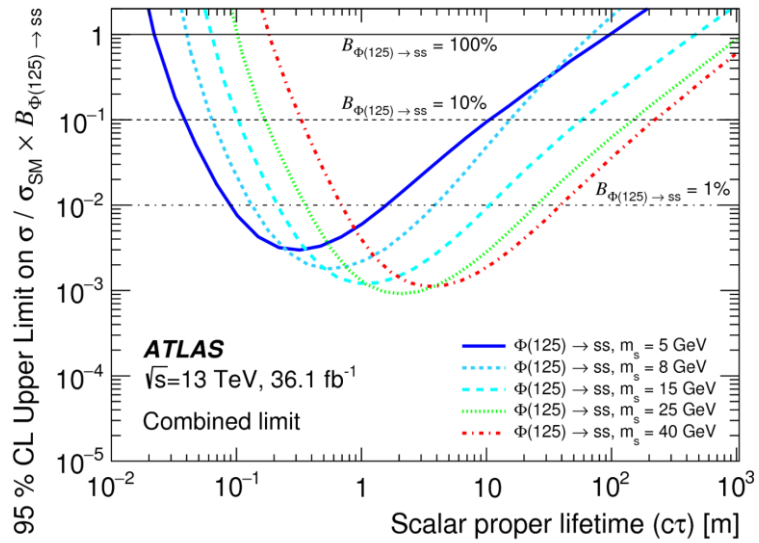
LLPs in the Endcap MS

- Final background determined with **ABCD** method using N_{hits} and $\Delta\phi(\vec{p}_T^{miss}, cluster)$
  - Predicted background: 2.0 ± 1.0
  - Observed events: 3
- Resulting **limits best yet at $c\tau > 100$ m** for low m_S
  - Factor of 6 improvement for m_S = 7 GeV
  - Factor of 2 improvement for heavier masses









Summary

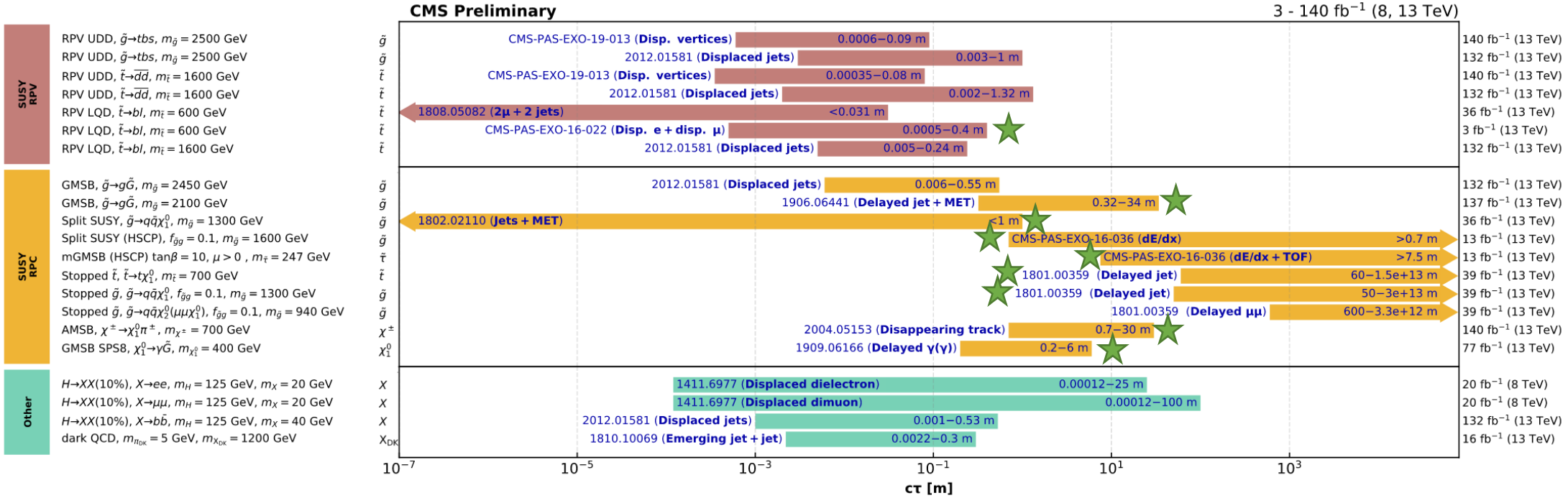
- Diverse array of signatures from LLPs that do not involve a reconstructed vertex
- Challenges much the same as with vertex searches – triggering, dedicated reconstruction, etc
- ATLAS & CMS have many ongoing searches in addition to recent results – remain competitive

Look forward to continued LLP papers and advances as we approach Run-III and beyond!

BackUp

Summary Plots

★ Non-vertex based LLP search

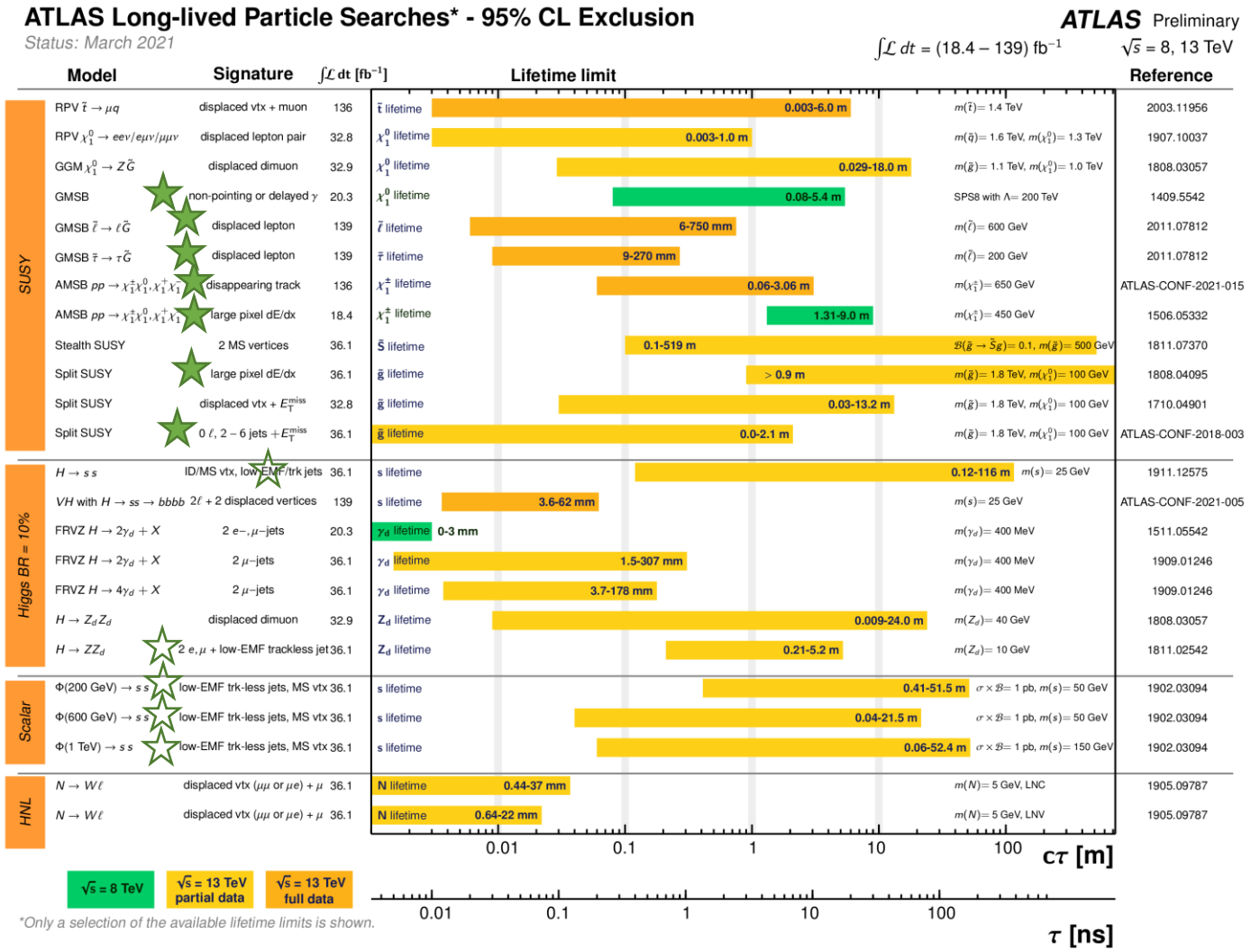


Selection of observed exclusion limits at 95% C.L. (theory uncertainties are not included). The y-axis tick labels indicate the studied long-lived particle.

Summary Plots

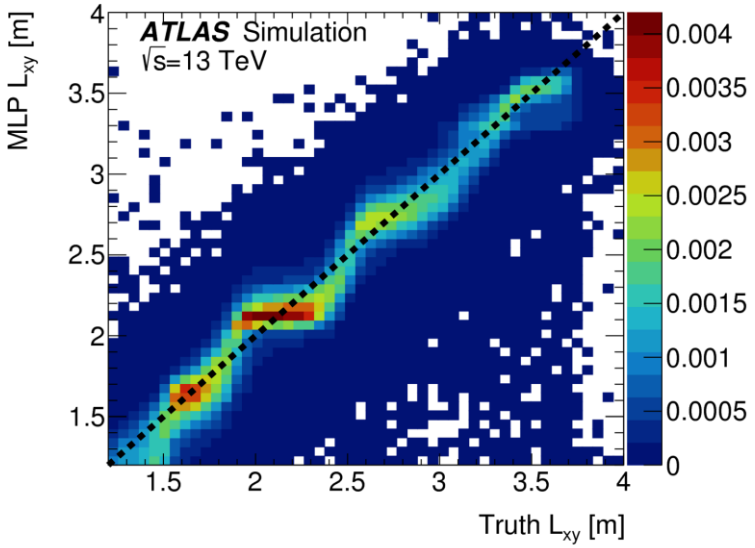
★ Non-vertex based LLP search

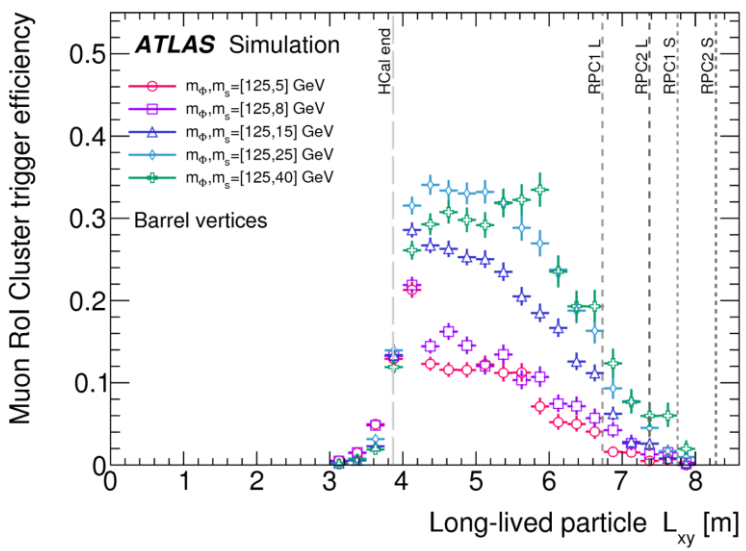
☆ Low EMF jet from neutral LLP decay does not use vertexing

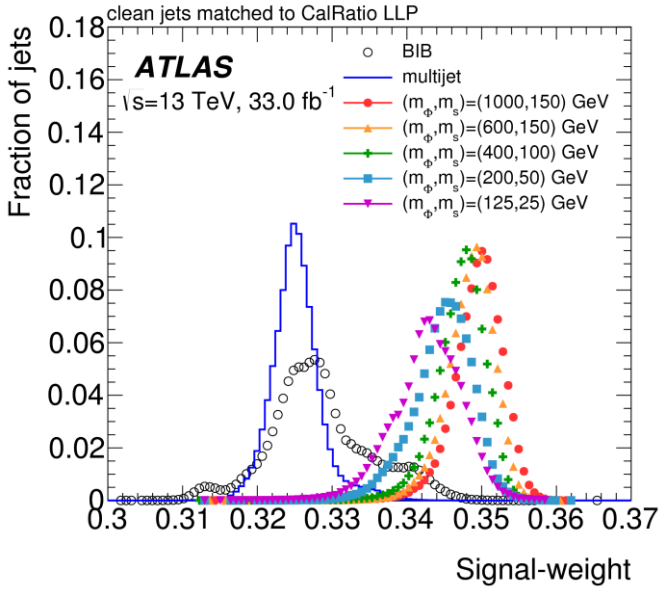


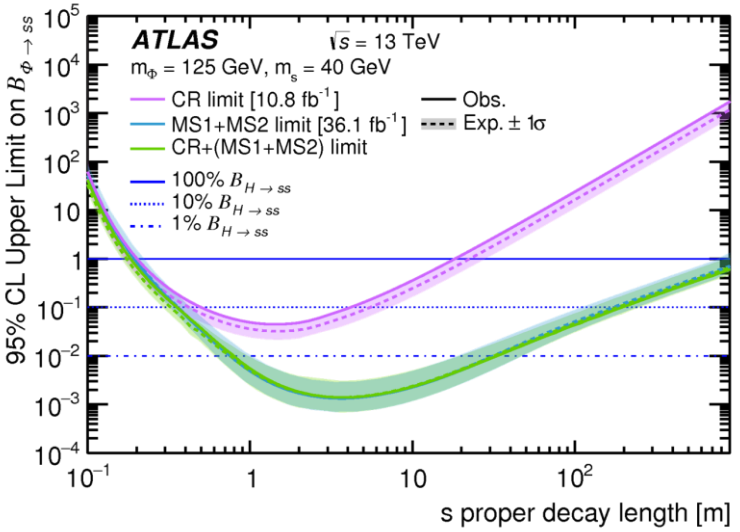
Calratio + MS

- Calratio/CR jet : Jet from a neutral LLP decaying in the hadronic calorimeter
  - Has a dedicated trigger
  - MLP used to identify jets from displaced
  - BDTs (2) used to separate signal from background
- MS vertex : Reconstructed vertex from a neutral LLP decaying in the MS
  - Has a dedicated trigger
  - Dedicated vertexing algorithm performs tracking and vertex finding in the MS
  - Search for two MS vertices, or one vertex and an associated object









Delayed Photons

- Consider photon resulting from a neutral LLP decay
  - Shower axis will not align with IP-originating photon
  - Photon timing will be < *c*
- Use a dedicated photon trigger targeting skewed shower shape
- Remove prompt timing requirement for reconstruction and use the spatial distribution of energy to ID candidates
- Saw order of magnitude improvements in limit on neutralino lifetime