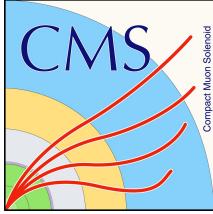

Search for long-lived particles decaying to displaced leptons

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on behalf of the CMS collaboration

LLPX
10.11.2021

arxiv.org/abs/2110.04809

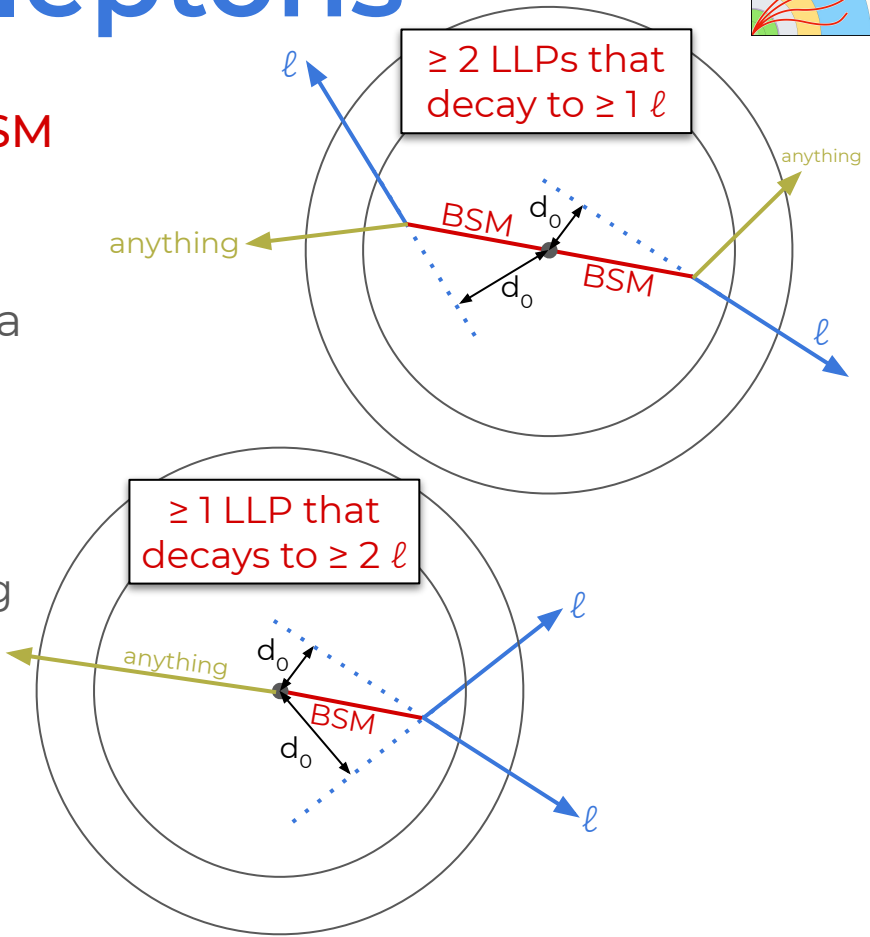
Displaced leptons

Very inclusive, signature-based search for **BSM LLPs** that decay to leptons (ℓ) in 2016-18 data

Look for ee, μμ, or eμ pairs where each ℓ has a large transverse impact parameter (d_0)

Why d_0?

- Identify displaced decays **without** requiring that ℓ form a common vertex
- Set **no explicit constraints** on non-lepton physics objects
- d_0 > ~100 μm removes nearly all SM bg



Select events with ≥ 2 ℓ

Use (slightly) atypical triggers for sensitivity to displaced ℓ:

- **μ** triggers with no impact parameter constraints
- **Photon** triggers in place of **e** triggers

In each channel (ee, eμ, or μμ), select events with ≥ 1 ℓ of each type:

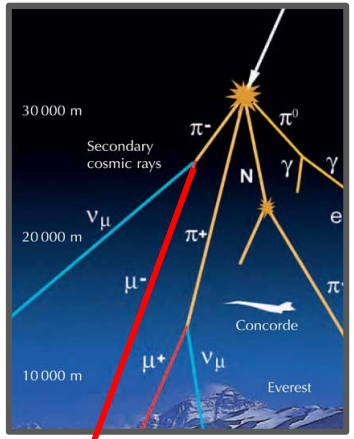
- ℓ must have fairly high momentum (p_T > 35–75 GeV)
- ℓ must be well reconstructed (in barrel, pass ~tight ℓ IDs)
- ℓ must be isolated (use custom iso, agnostic to ℓ-primary vertex association)

Set no constraints on jets, p_T^{miss}, ℓ charge, exact # of ℓ, etc

Remove specific backgrounds

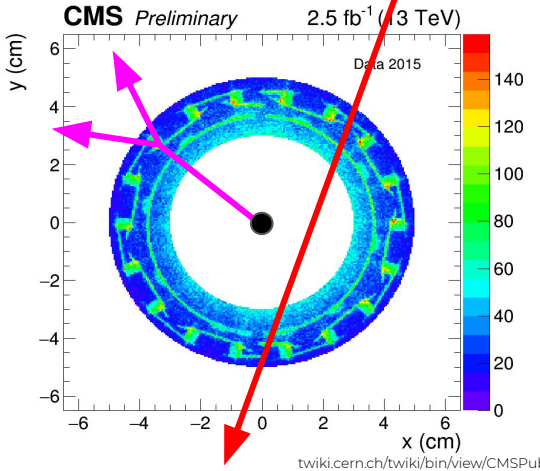
Cosmic ray μ

- Reject pairs of μ based on **relative time of arrival** and **3D angle**



Material interactions

- Reject pairs of ℓ that form a **common vertex** in **detector material**



twiki.cern.ch/twiki/bin/view/CMSPublic/TrackerMaterialPosition2015

Displaced decays of SM mesons

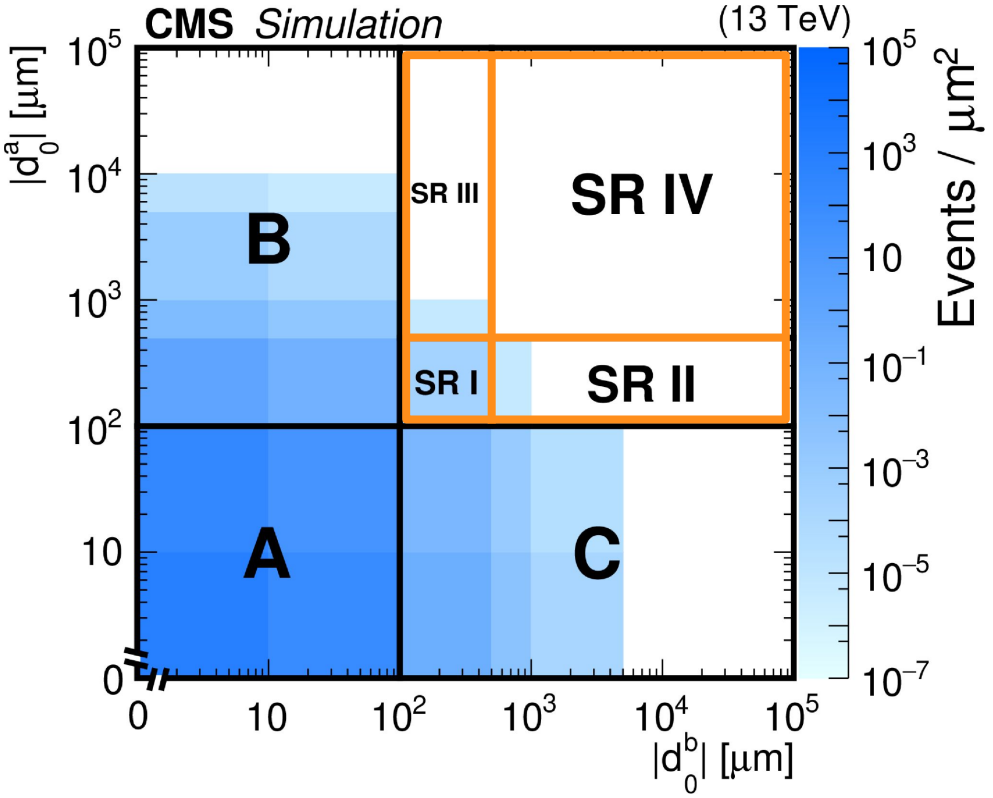
- Reject pairs of ℓ that are too close together (require $\Delta R > 0.2$)

Signal region backgrounds

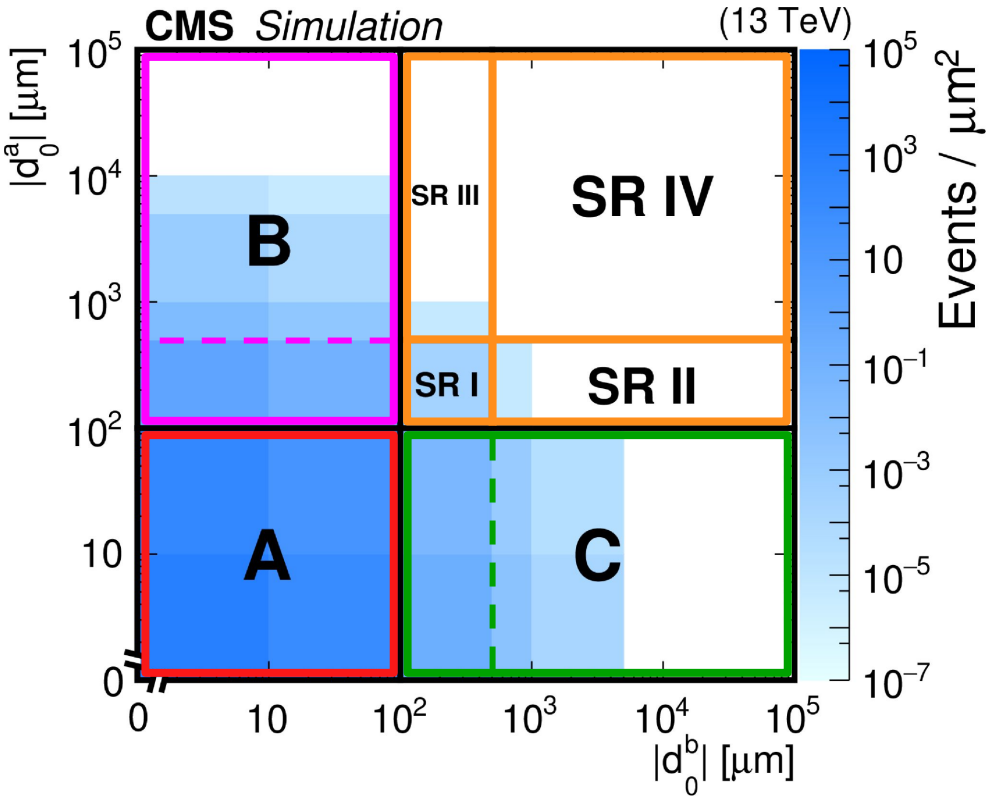
Define **control regions** (CRs)
- ≤ 1 ℓ with $|d_0| > 100$ μm

Define signal region (SR)
- ≥ 2 ℓ with 100 μm < $|d_0| < 10$ cm

Remaining SR backgrounds:
1. Promptly decaying ℓ with poorly measured d_0
2. ℓ from τ decays
   - decay length ≈ 87 μm
3. ℓ from heavy-flavor meson decays
   - decay length ≈ 500 μm



Background estimation



Estimate bg from all sources with single, data-driven ABCD method

- Use number of events in each CR (N_A, N_B, N_C) to estimate N_{SR}
- $N_{SR} = (N_B \times N_C) / N_A$
- Apply correction to $N_{SR\,I}$ to account for correlation from $Z \to \tau\tau$

Validate method

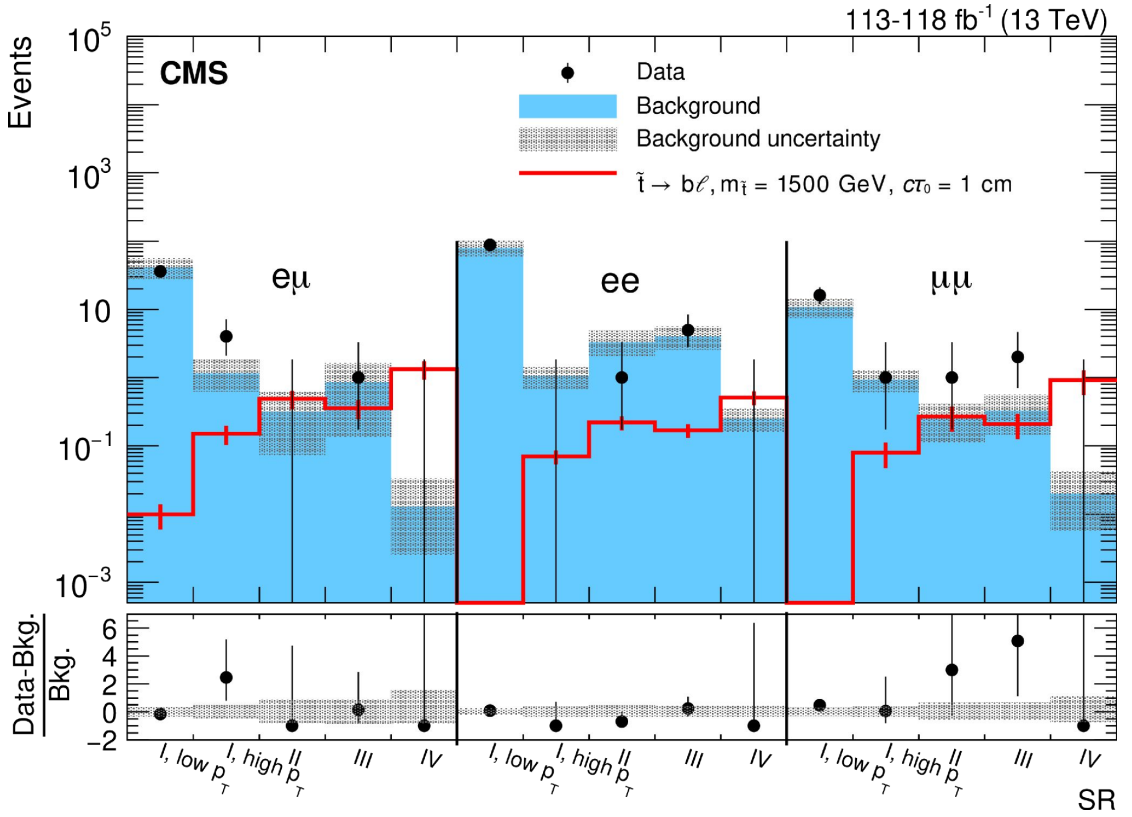
- Data and MC closure tests in CRs
- MC closure tests in SRs
- Dedicated studies to ensure cosmic-ray μ, material interactions, and pairs of ℓ from SM hadrons do not meaningfully contribute

Results

Bin SR in ℓ d_0 and p_T to maximize sensitivity to range of LLP lifetimes and masses

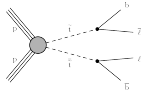
Background predictions
- ≤ ~1 event in most SRs
- << 1 event in most-displaced SR

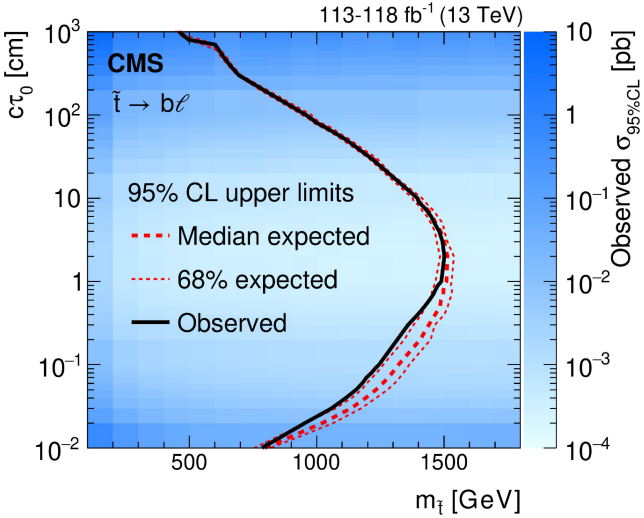
Observed yields are consistent with bg-only hypothesis



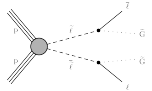
Interpretations

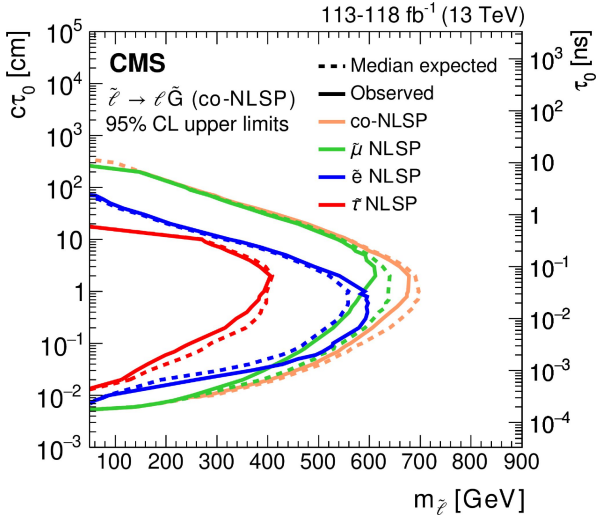
Constrain production of RPV top squarks and GMSB sleptons and the BR of Higgs bosons to long-lived scalars across wide range of new-particle lifetimes



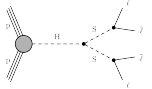


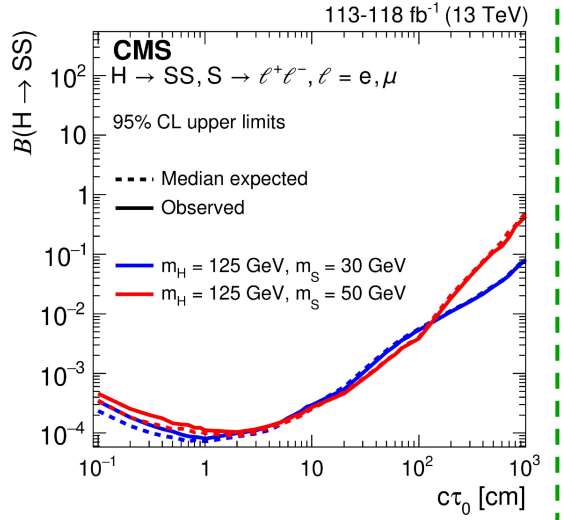
~600 GeV improvement over previous CMS displaced ℓ exclusion





Most sensitive limits to date for $c\tau \lesssim 0.8$ cm





Most sensitive limits to date for $0.1 \lesssim c\tau \lesssim 1000$ cm

Summary

We have performed an **inclusive, signature-based** search for BSM LLPs that decay to leptons **without requiring the leptons to form a common vertex**

Observation is consistent with bg-only hypothesis, so results are used to constrain several new physics scenarios

- **Most sensitive limits to date in several regions of parameter space**

Paper submitted to EPJC

arxiv.org/abs/2110.04809

Additional material

$|d_0|$ distributions