Search for Neutral Long-lived Particles Decaying in the CMS Endcap Muon System

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on behalf of CMS Collaboration

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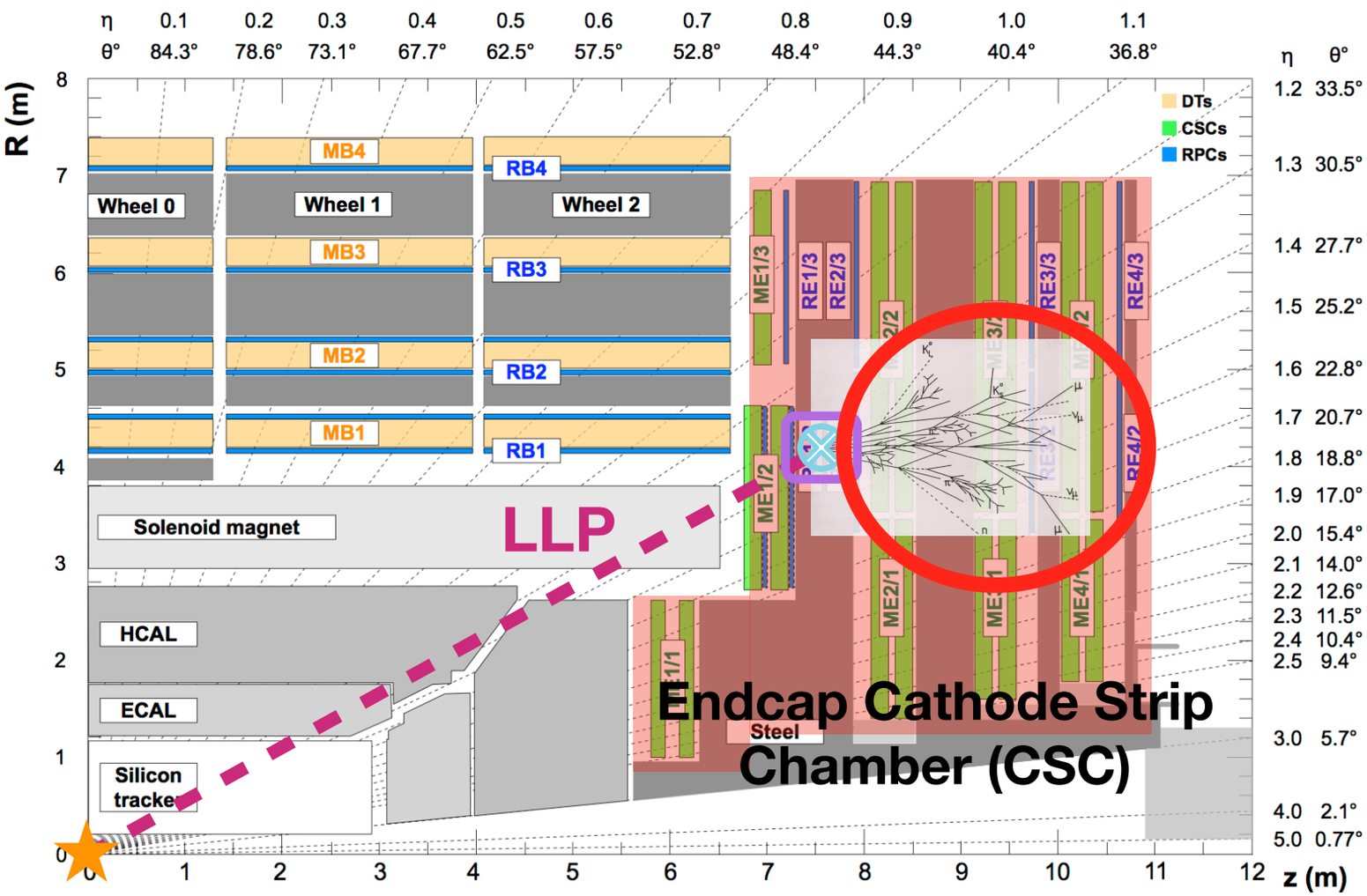
Motivation: Search for LLPs in Muon System

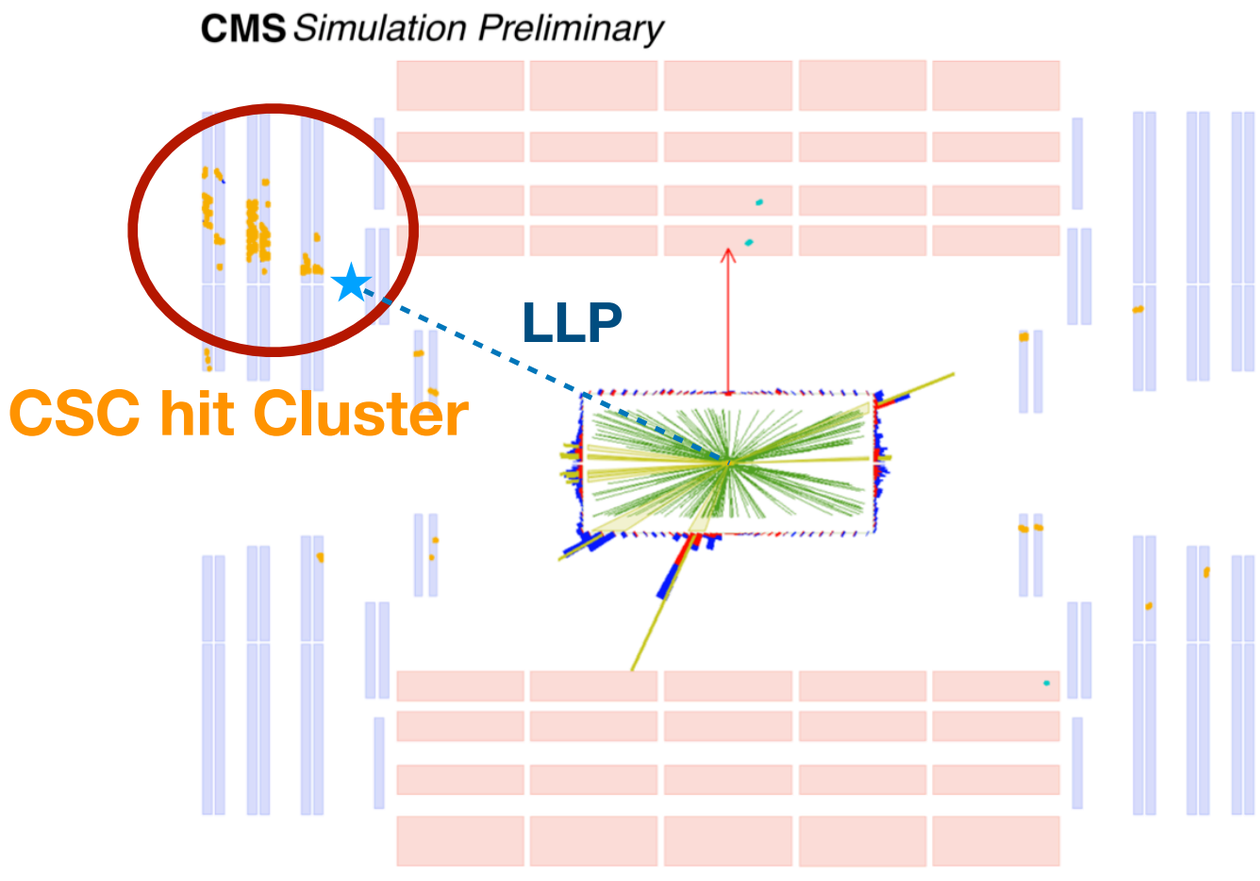


LLP decay and resulting particle shower is detected as **multi-hit signals** in the gas ionization chambers

- Covers a large geometric acceptance
- Covers decays far away from IP (sensitive to large $c\tau$)
- Excellent background suppression from shielding material

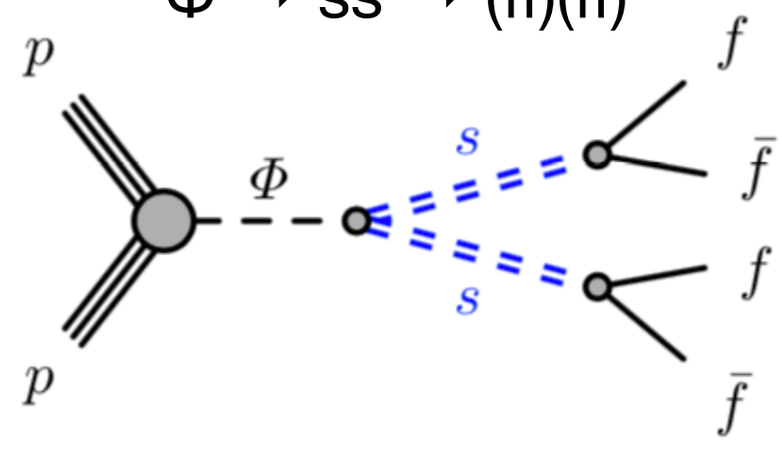
Experimental Signature: Showers in the Muon System

- Neutral long-lived particles decaying in the muon system leave a signature with:
  - No tracks
  - No jets
  - Large **cluster of CSC hits (>100 hits)** in the muon system
- Muon system acts as a **sampling calorimeter:** sensitive to a broad range of decays
- **Unique signature** due to the presence of steel in the CMS muon system
- First search in CMS that uses this novel signature



Twin Higgs as benchmark model:

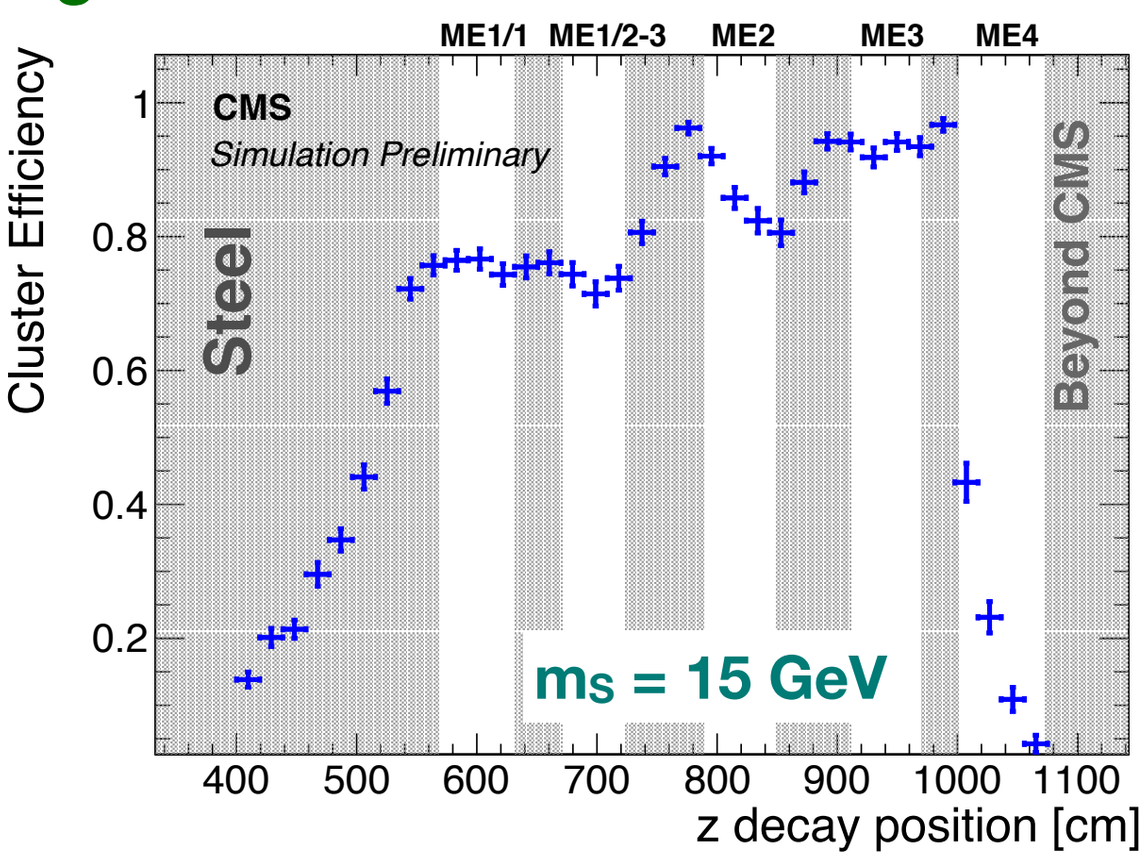
$\Phi \rightarrow ss \rightarrow (ff)(ff)$

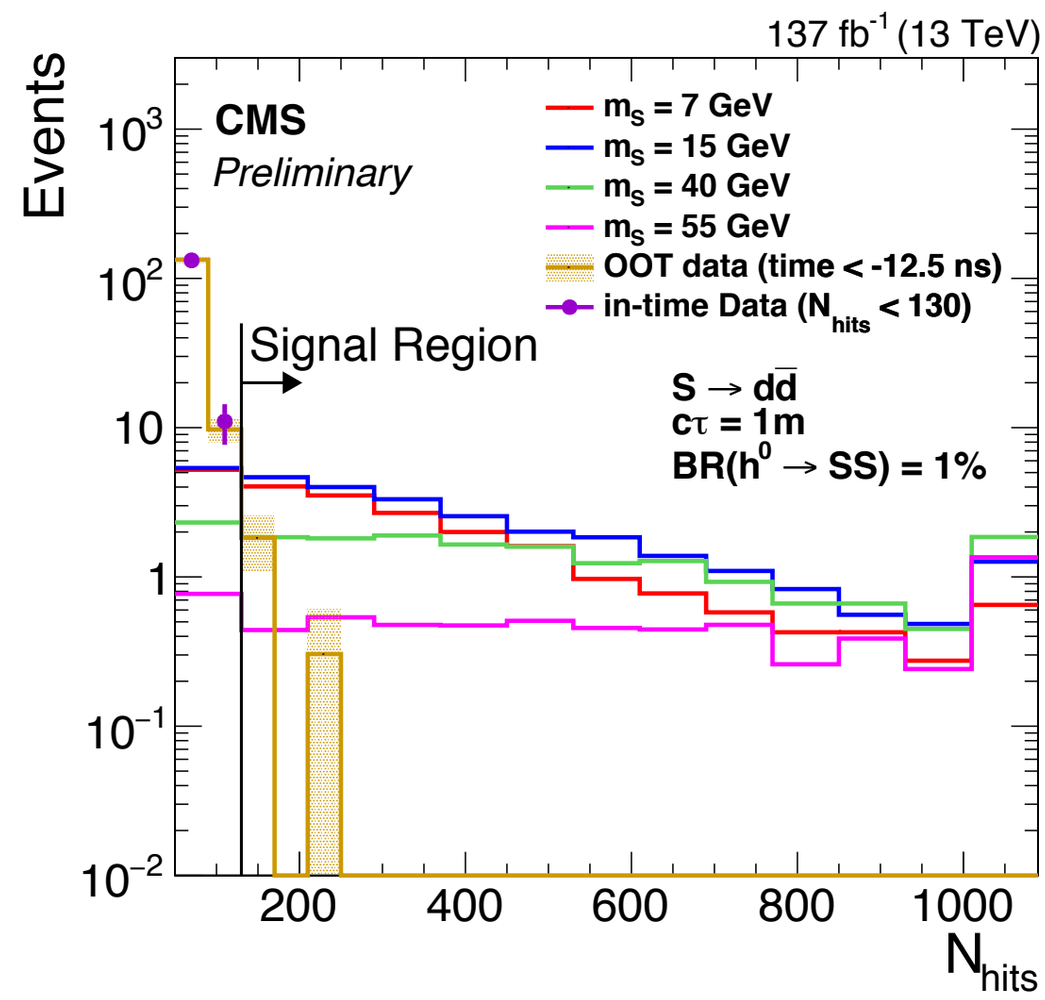


Analysis Strategy

- **Event selection:** select high MET and boosted Higgs phase space
  - Trigger on **MET** (lack of dedicated trigger, trigger efficiency is ~1%)
- Use **CSC cluster ID** selections to enhance signal purity and reject background from main collision— exact definition on next slide
- N_{hits} serves as the main discriminator

High cluster reconstruction efficiency

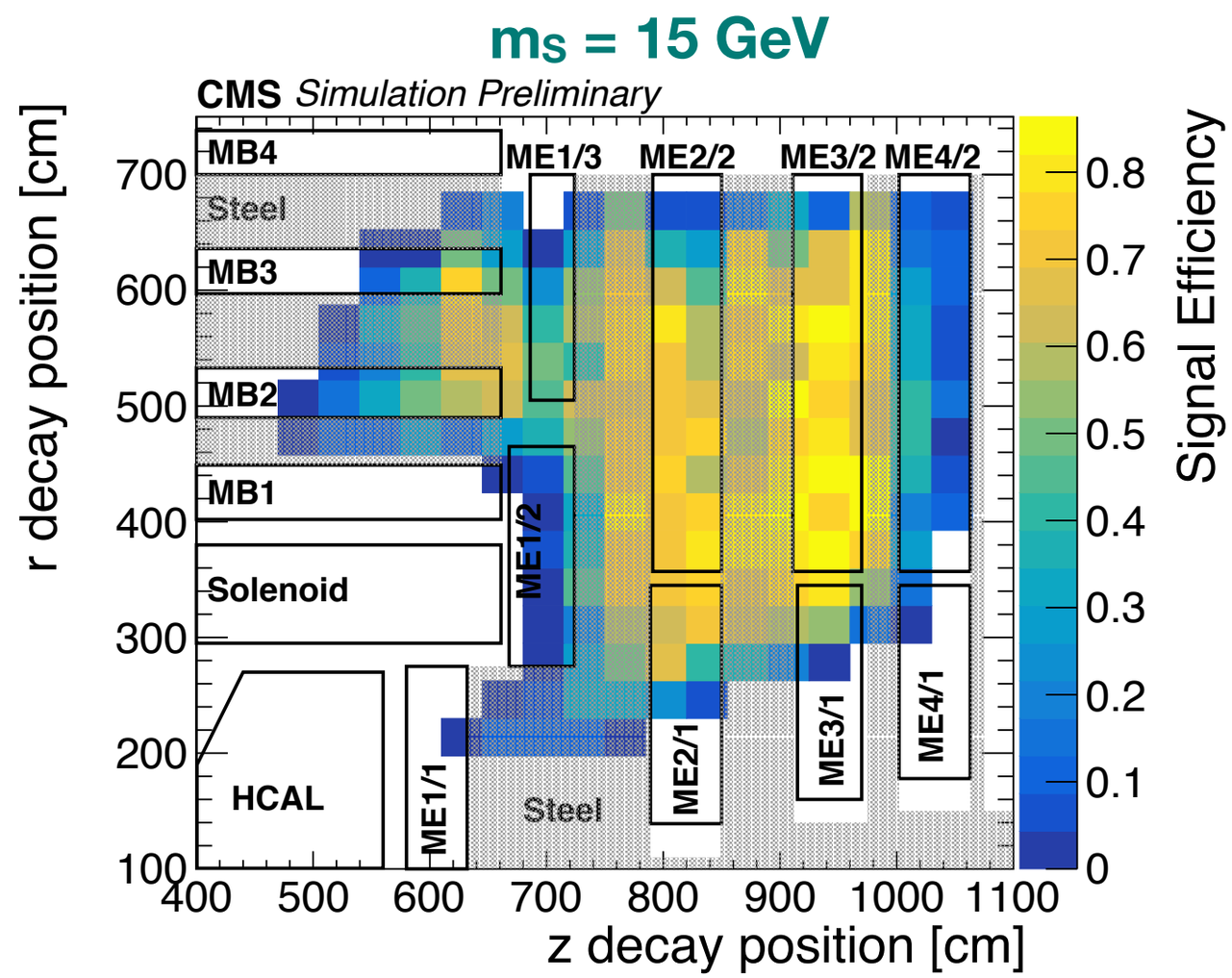




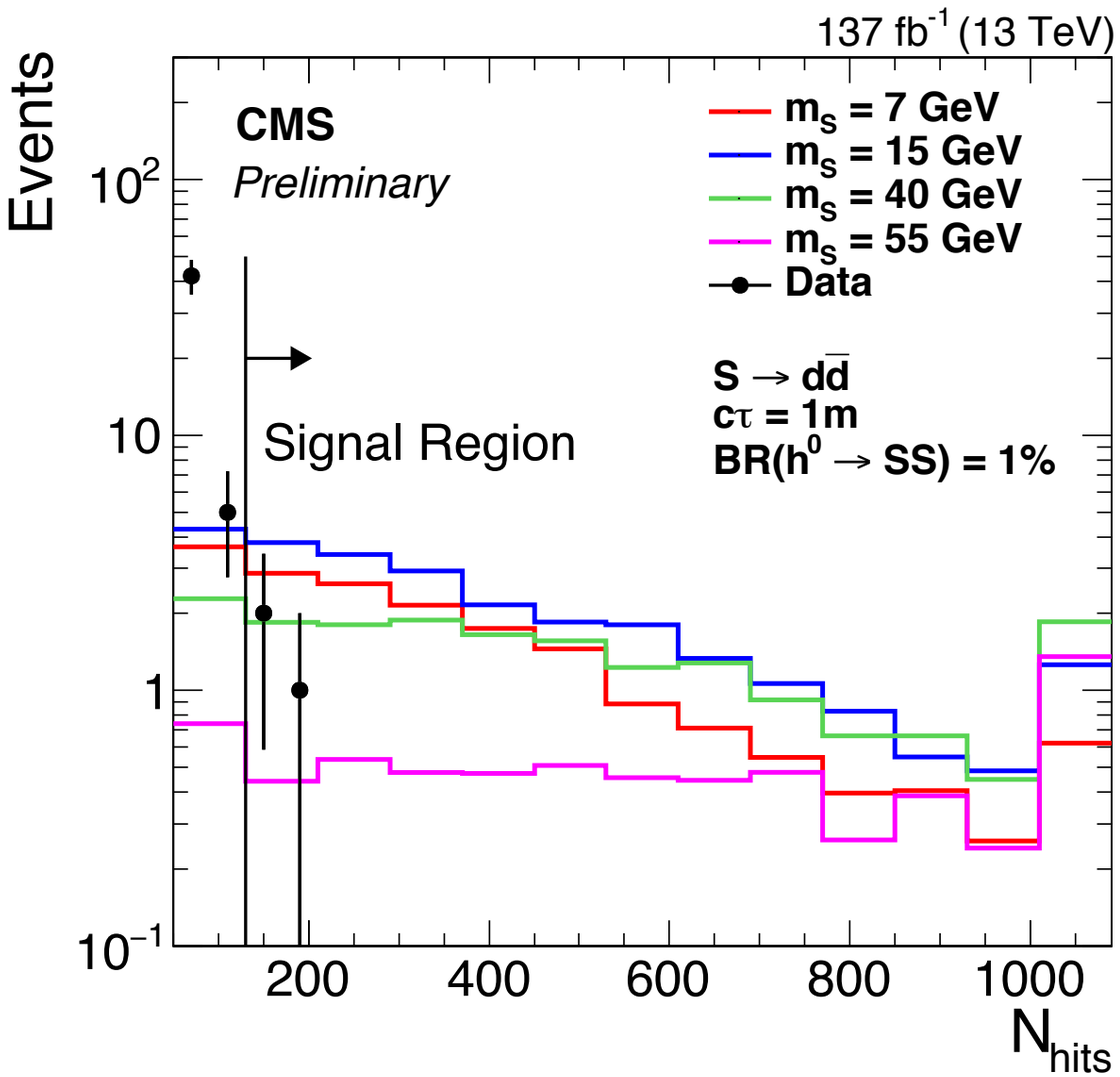
CSC Hit Cluster Identification

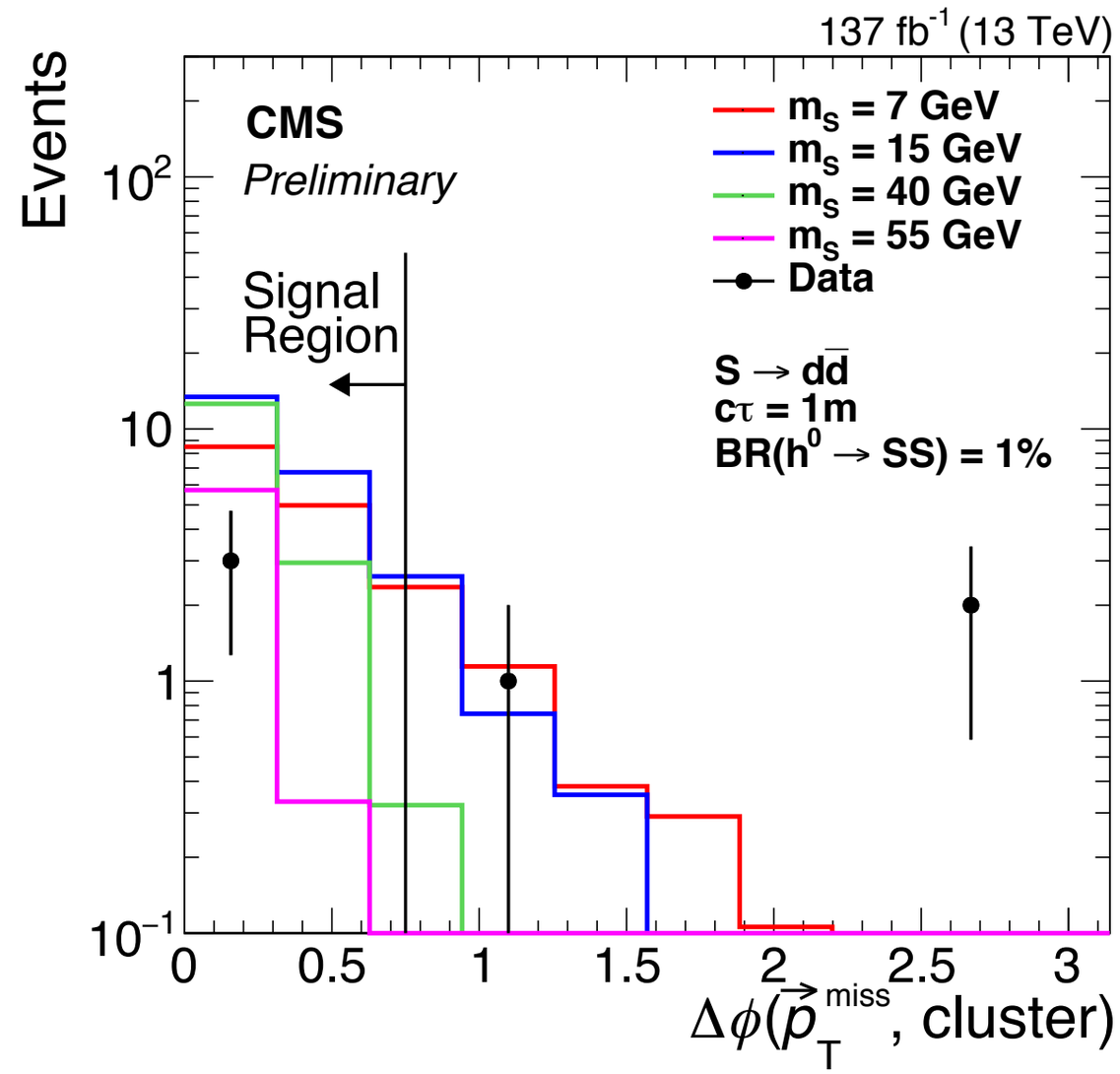
Reject background from the main collision

- Reject clusters from **punch-through jets** and **muon bremstralung shower**:
  - Veto clusters matched to jets and muons ($\Delta R < 0.4$)
  - Active vetos in first station (ME11/12)
- ~50% signal efficiency when LLP decays between ME1 and ME4
- Background rejection is ~10^6



Data-driven Background Estimation

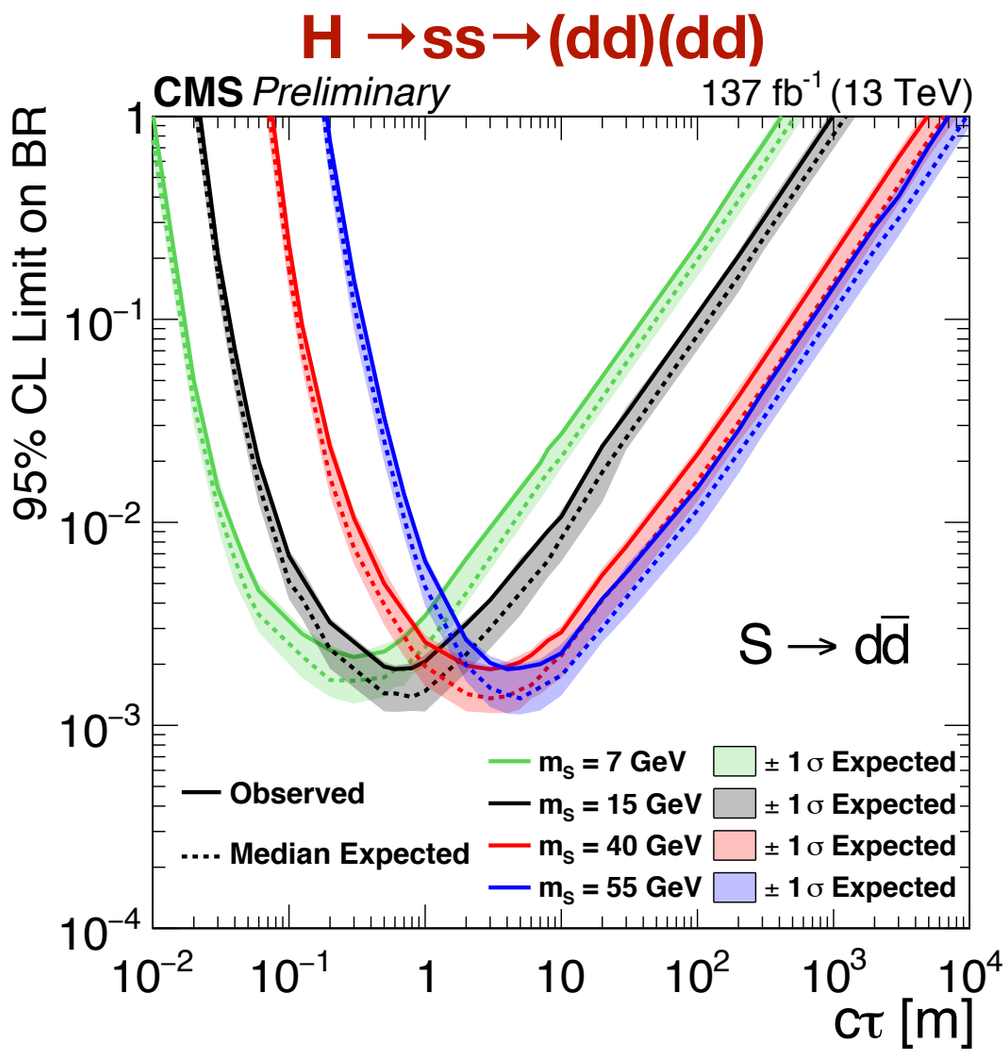


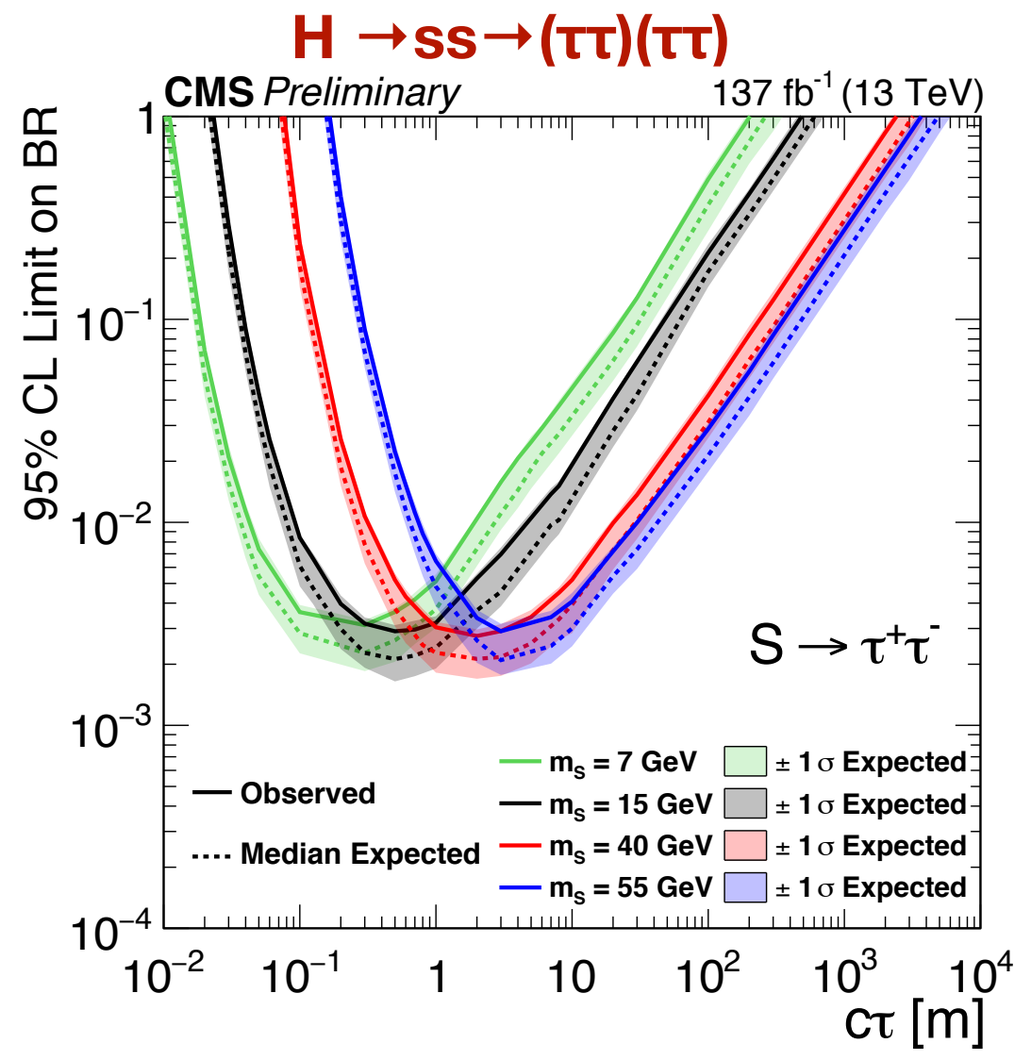


Predict 2 ± 1 background events and observed 3 events

- N_{hits} is the main discriminator for the analysis with large signal to bkg separation
- Cluster and MET directions are aligned for signal
- Data-driven background estimation performed to extract signal using two independent variables for background

Observed and Expected Limits





- Limits for S → bb are within 3% to that for S → dd.
- Analysis sensitivity is independent of the **LLP decay modes** and **masses**
- Provides current best LHC limit for LLPs with cτ above 6, 20, and 40 m for mass of 7, 15, and 40 GeV respectively.
- Achieve first sensitivity to **τ decay modes** at BR(H →ss) = 10^{-3} level

Summary & Outlook

- Presented first search for LLPs using the CMS endcap muon system as a sampling calorimeter to identify displaced hadronic showers
- Provides current best LHC limit for LLPs with $c\tau$ above 6, 20, and 40 m for mass of 7, 15, and 40 GeV respectively.
- This result is the start of an **exciting new probe for BSM LLP Physics** with many improvements and directions to come:
  - New L1+HLT triggers for Run3
  - Alternative production modes
  - Low LLP mass reach