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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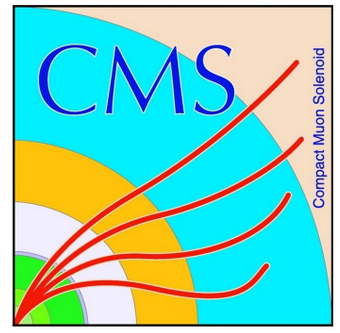
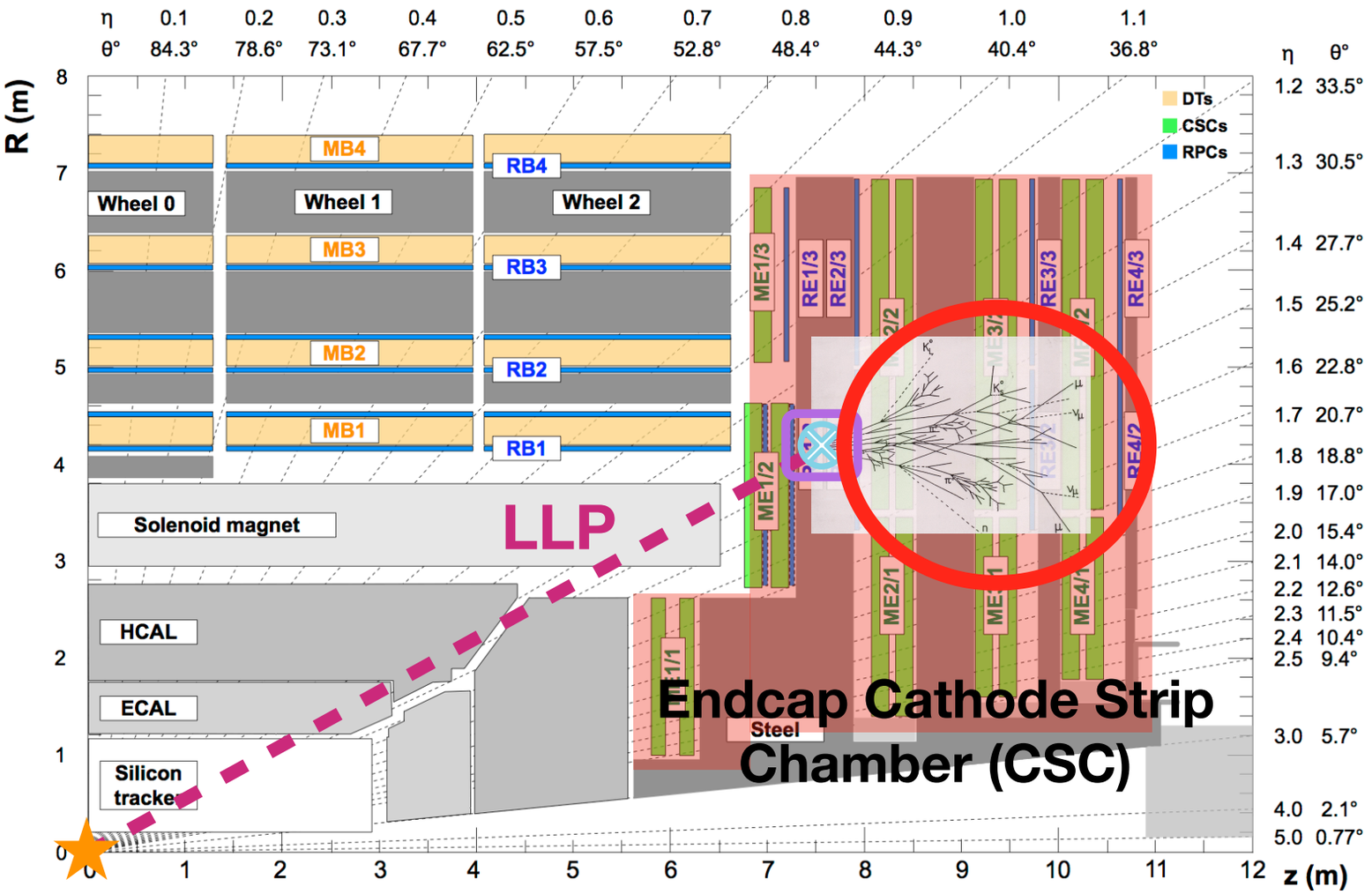
Caltech



Motivation: Search for LLPs in Muon System

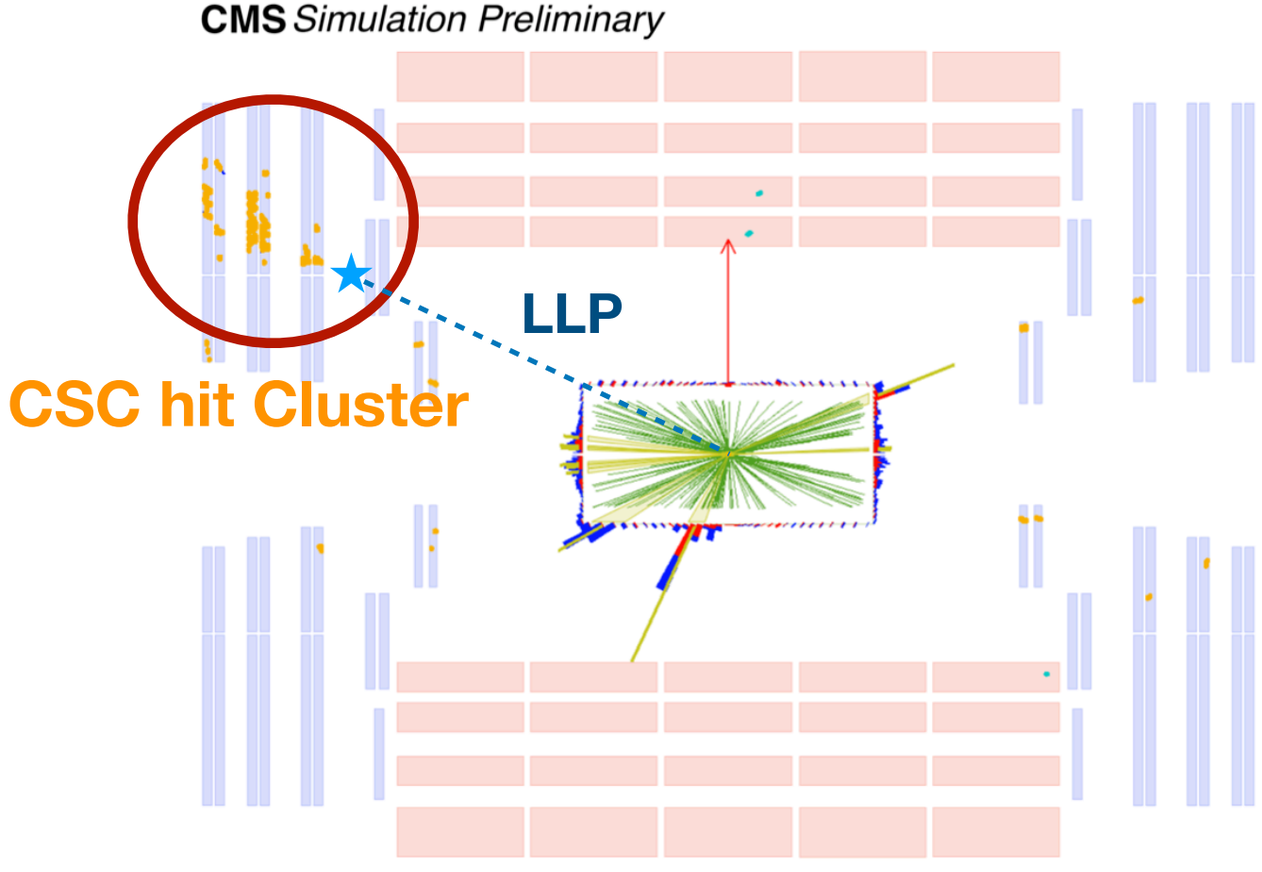


LLP decay and resulting particle shower is detected as **multi-hit signals** in the gas ionization chambers

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

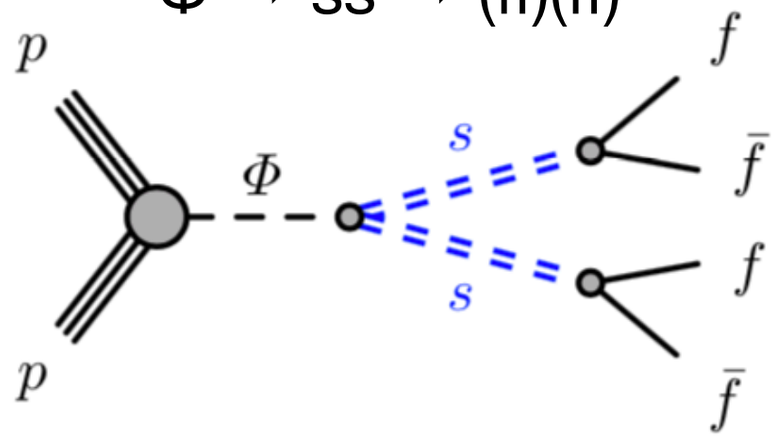
Experimental Signature: Showers in the Muon System

- 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:

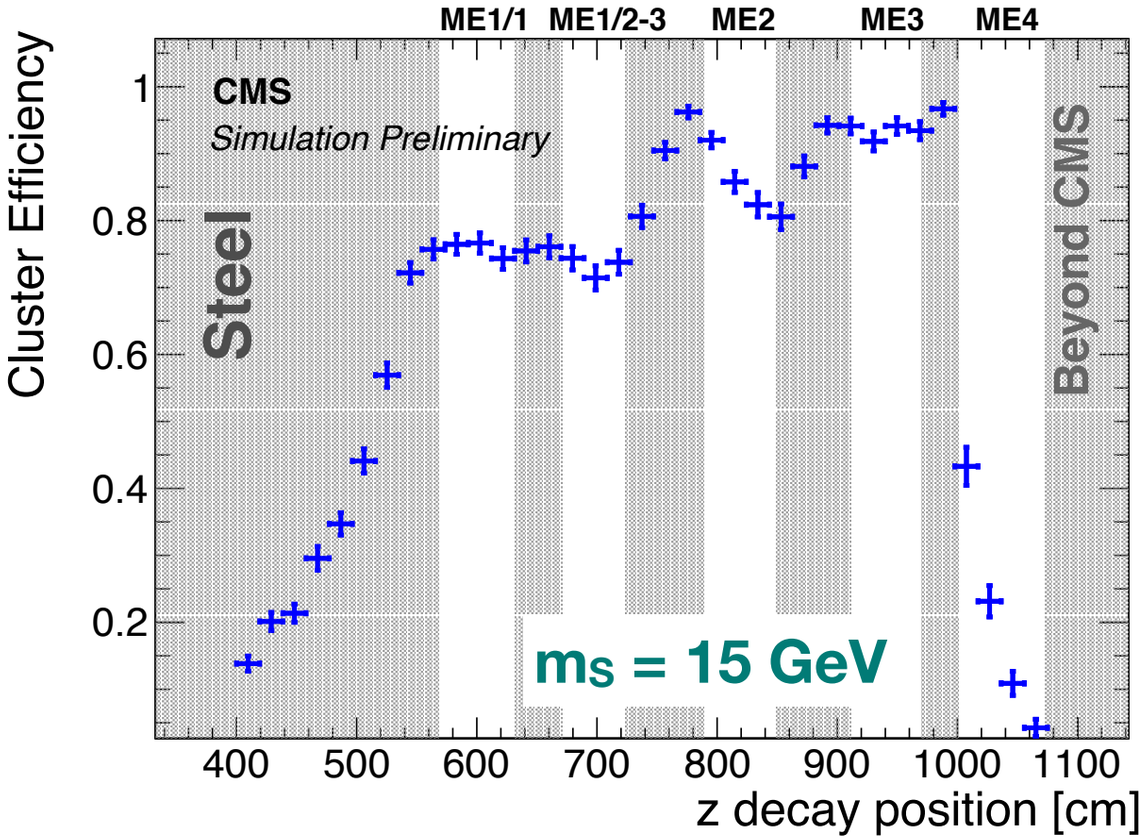
$\Phi \rightarrow ss \rightarrow (ff)(ff)$

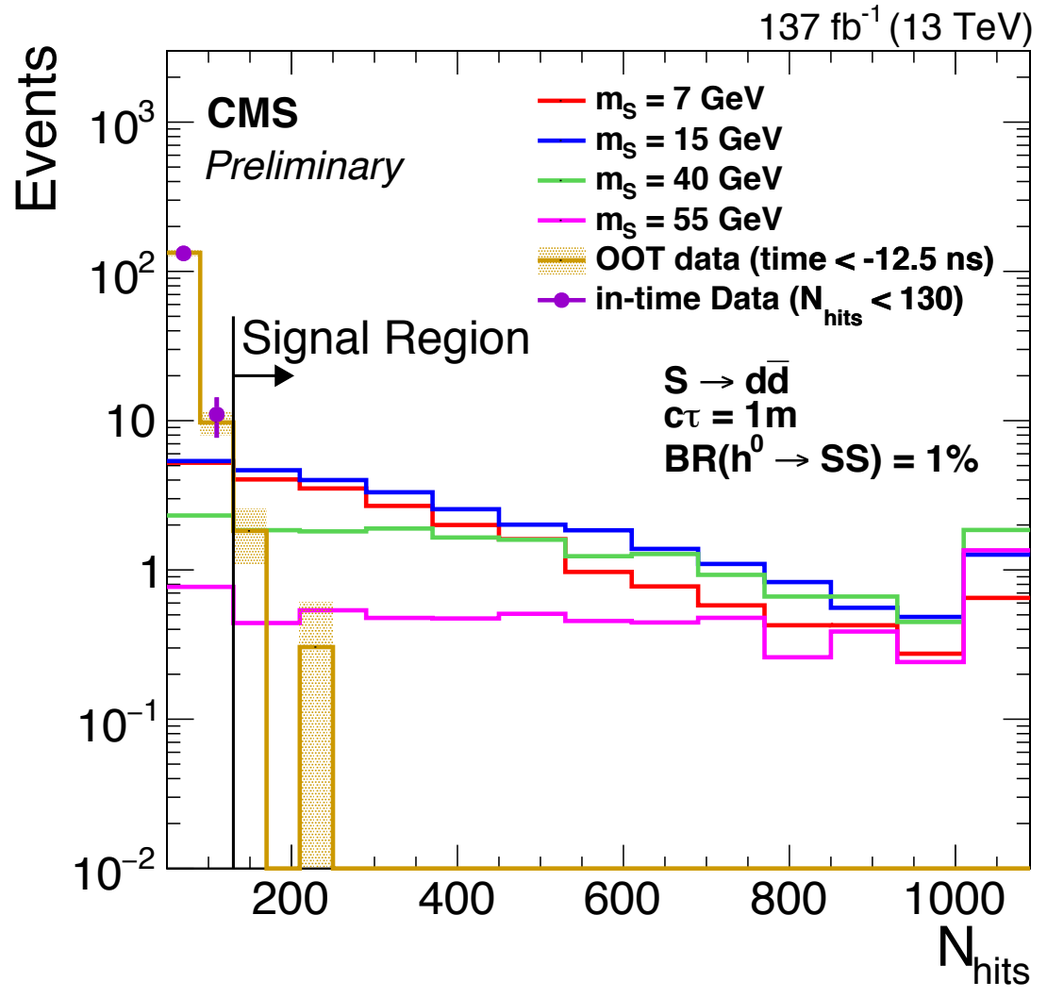


Analysis Strategy

- **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

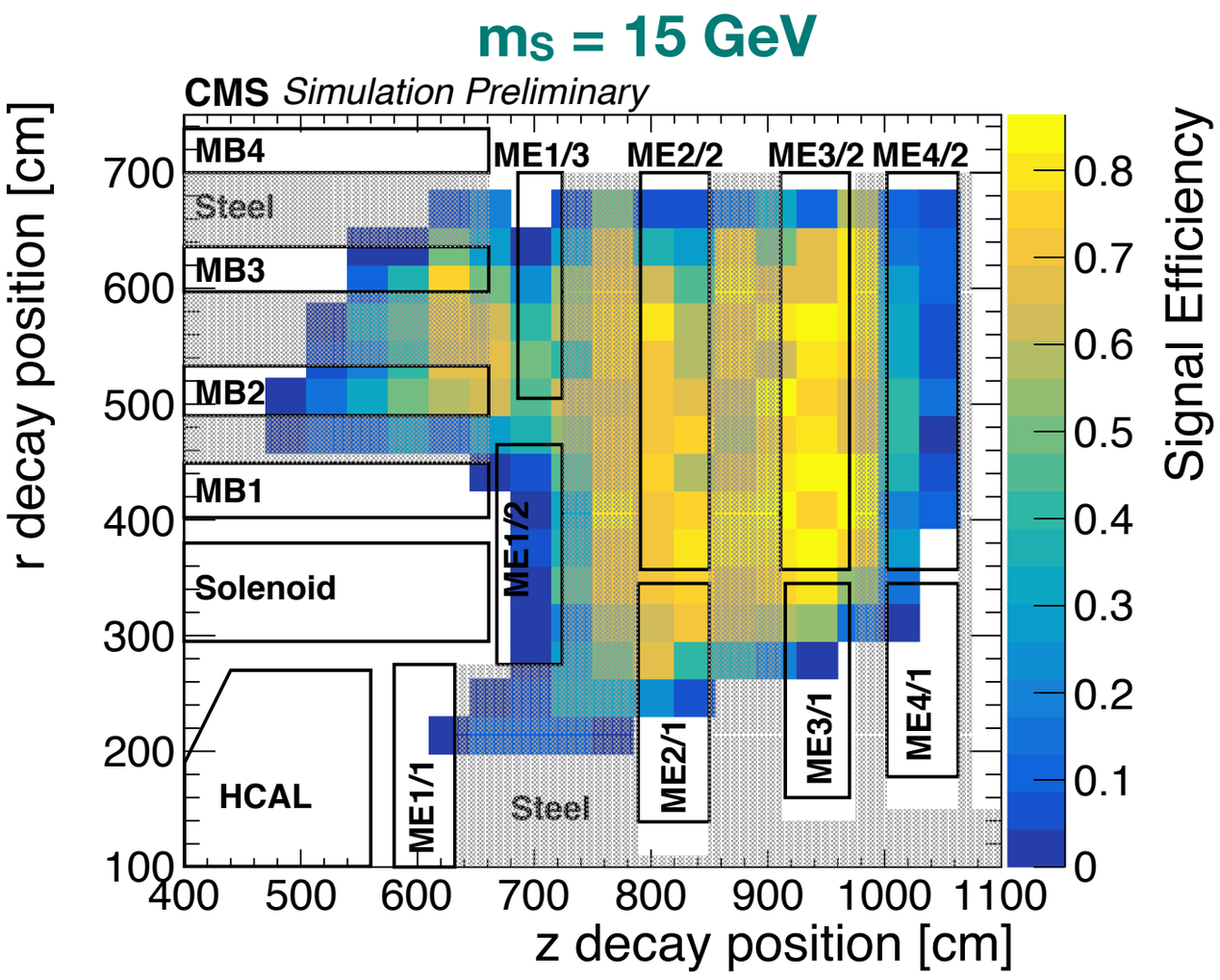




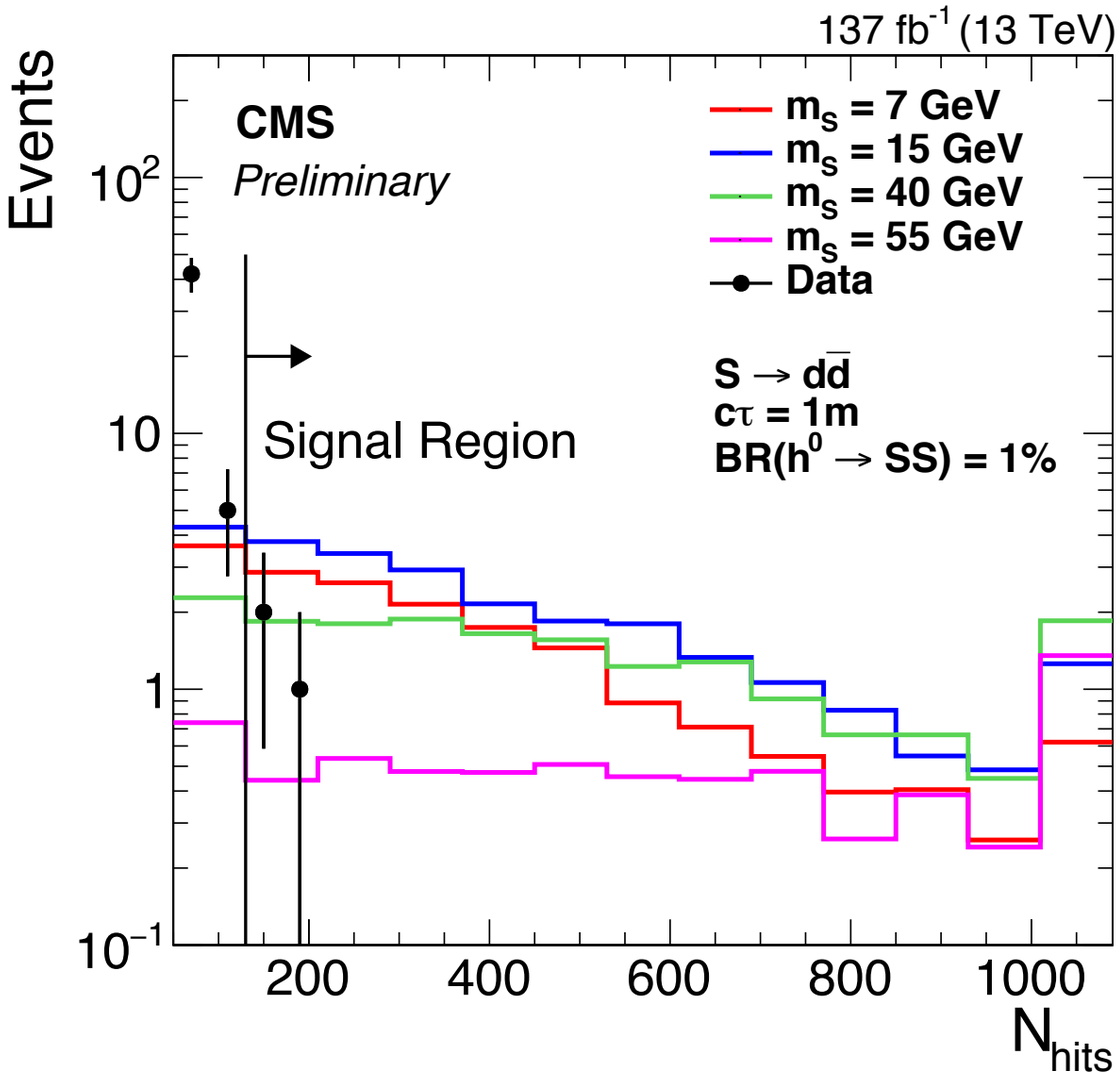
CSC Hit Cluster Identification

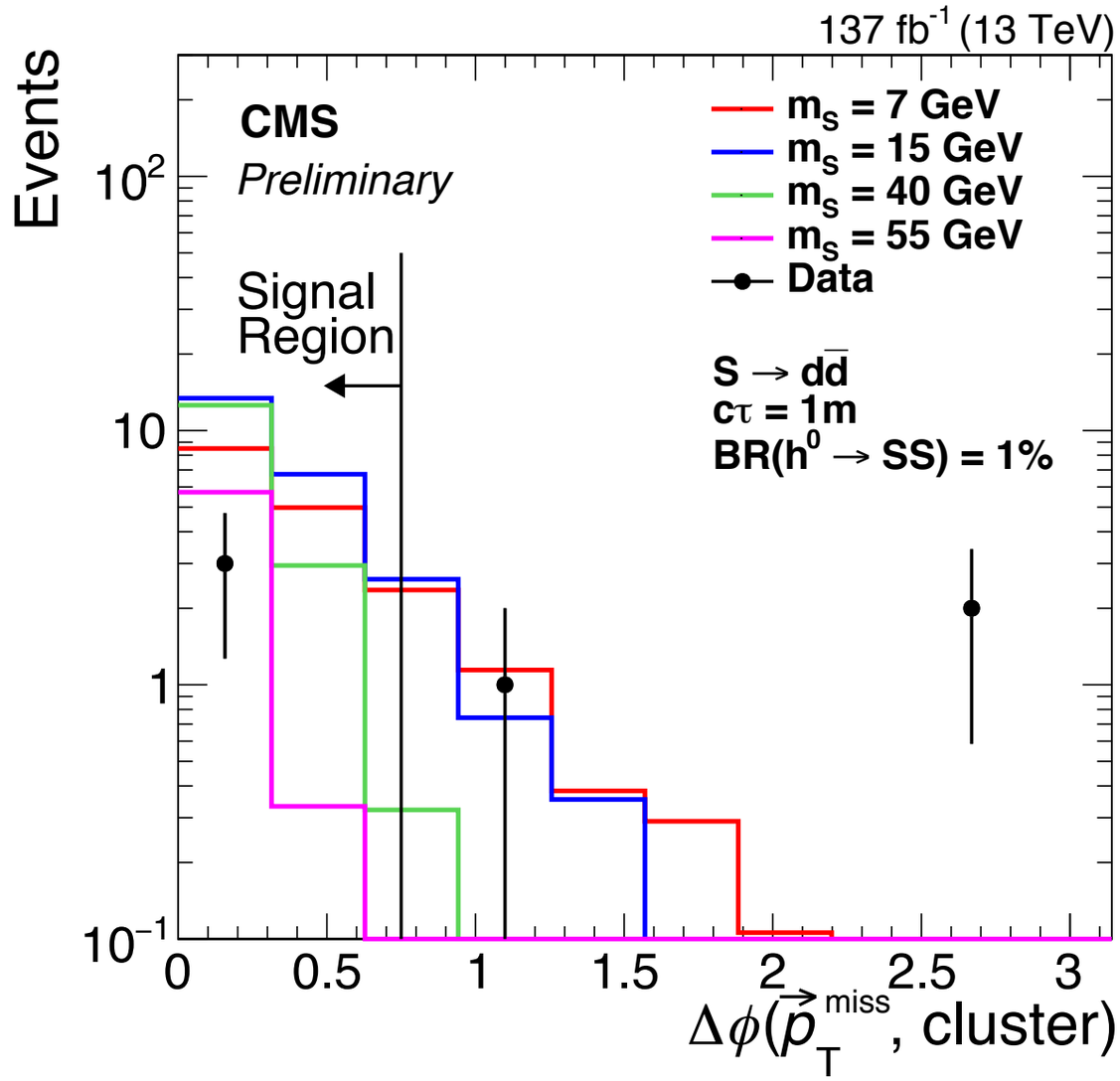
Reject background from the main collision

- 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

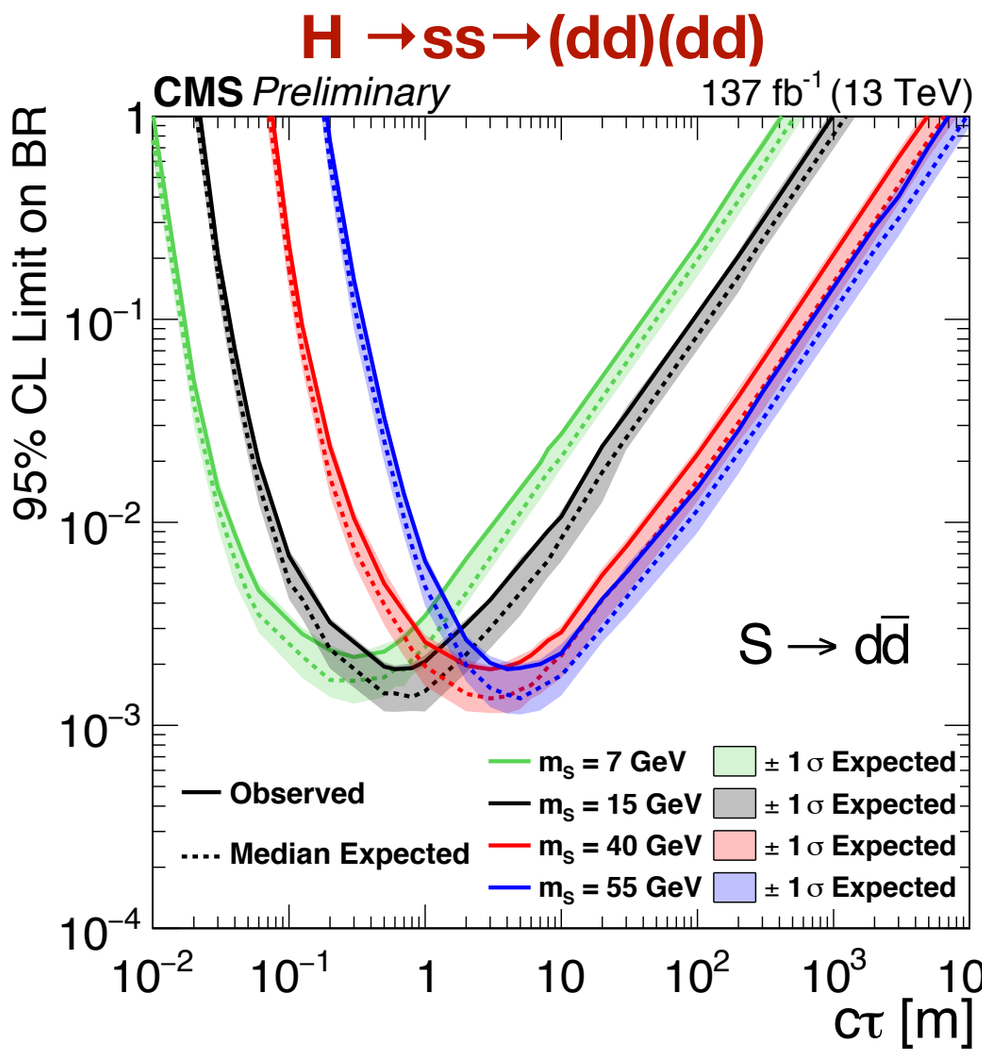


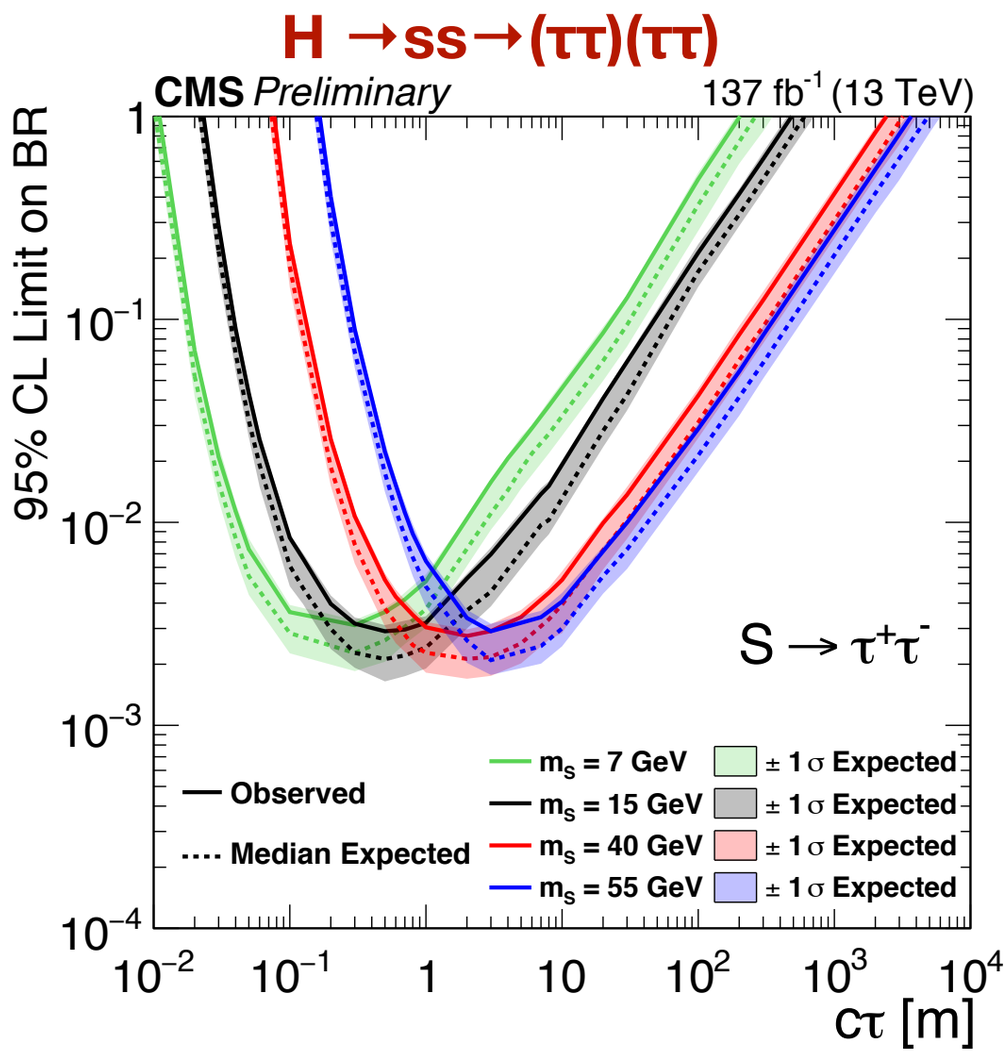


Predict 2 ± 1 background events and observed 3 events

- 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

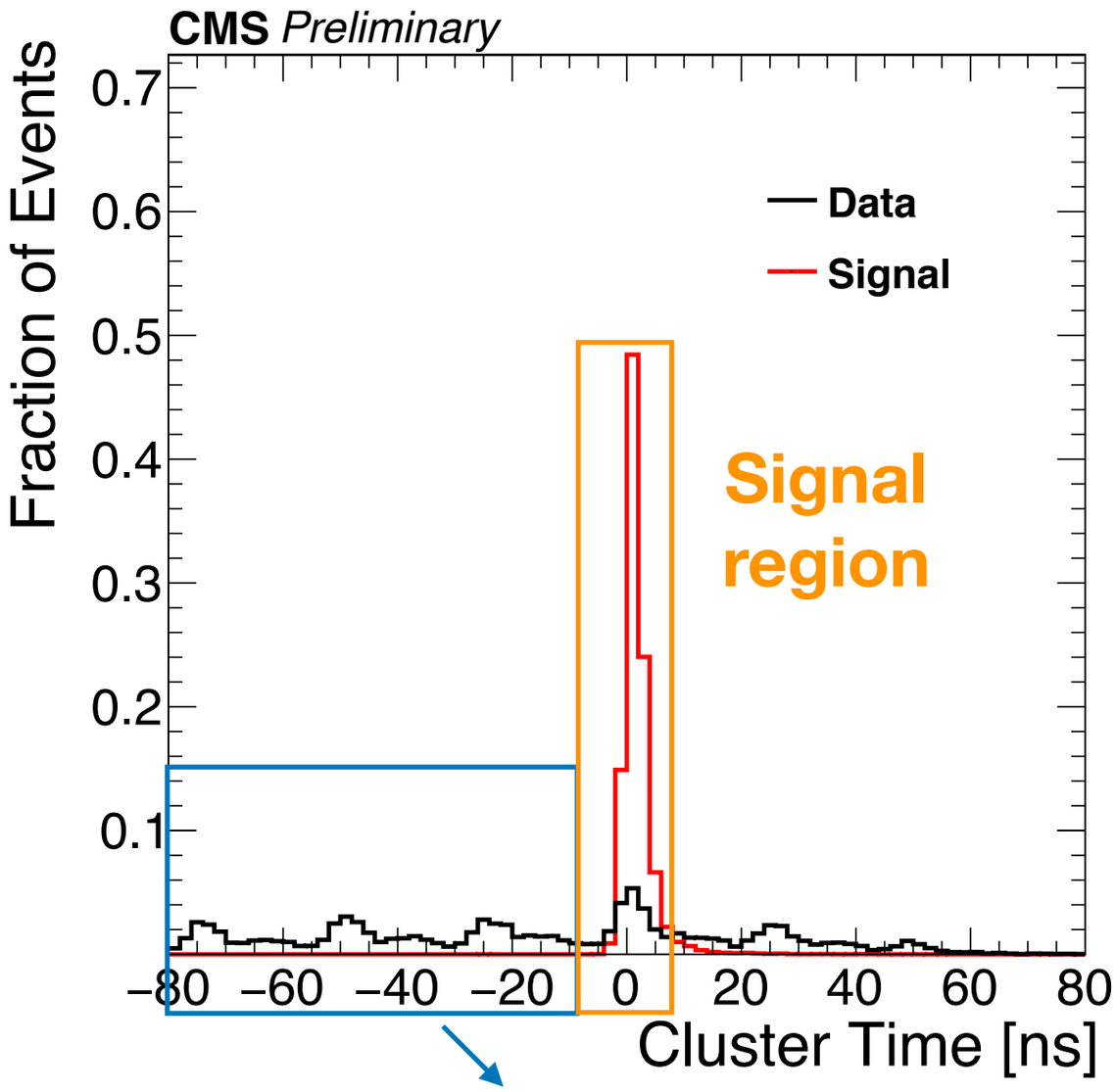
Summary & Outlook

- 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

BACKUP SLIDES

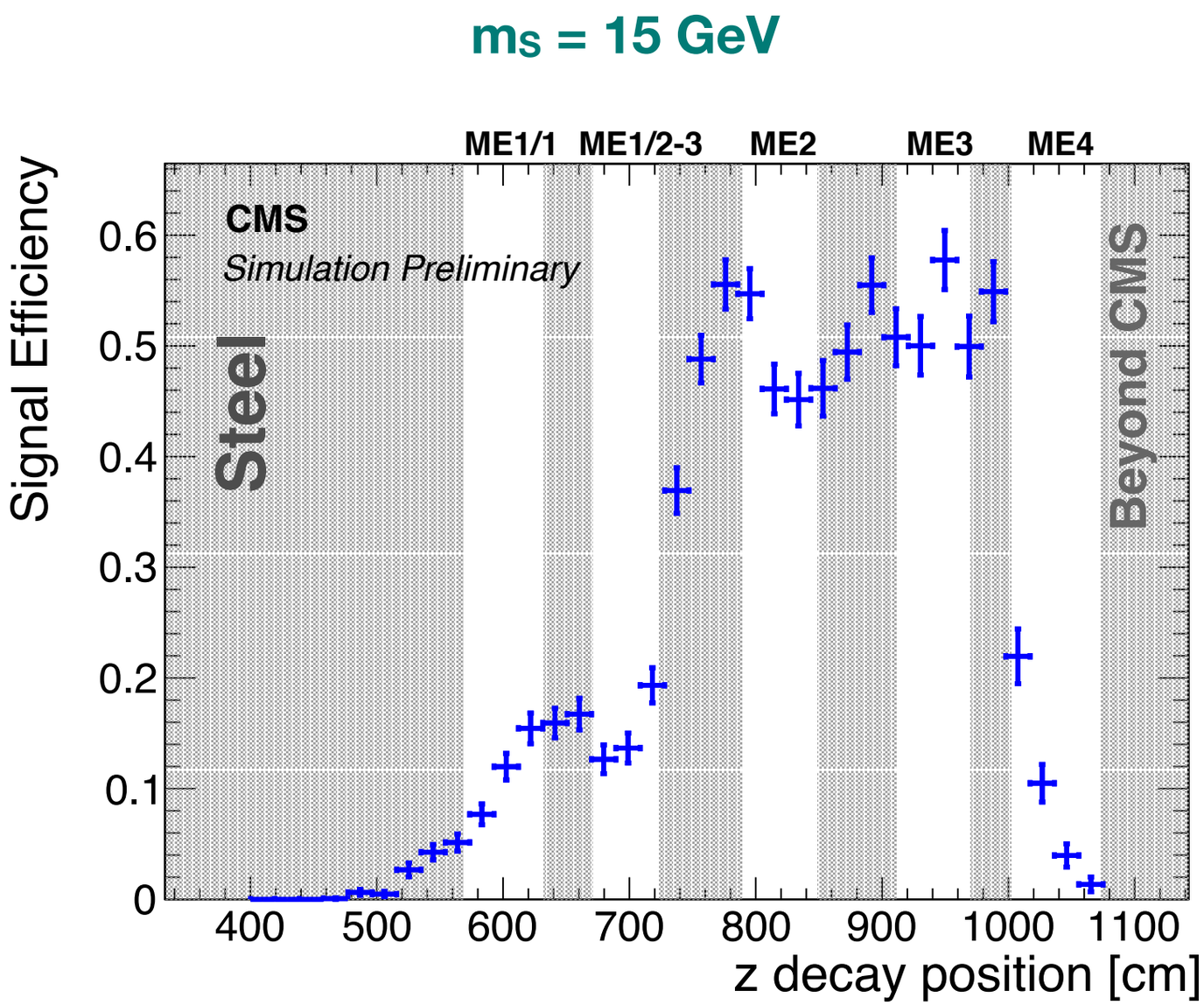
Cluster Time

- 5x background rejection by requiring CSC clusters to be **in-time (-5 ns < t < 12.5 ns)**
  - For background, after the vetos the time structure shows contribution from OOT pileup
  - Signals concentrate in the in-time window
- Allow us to define an **early OOT validation region (t < -12.5 ns)** for background estimation



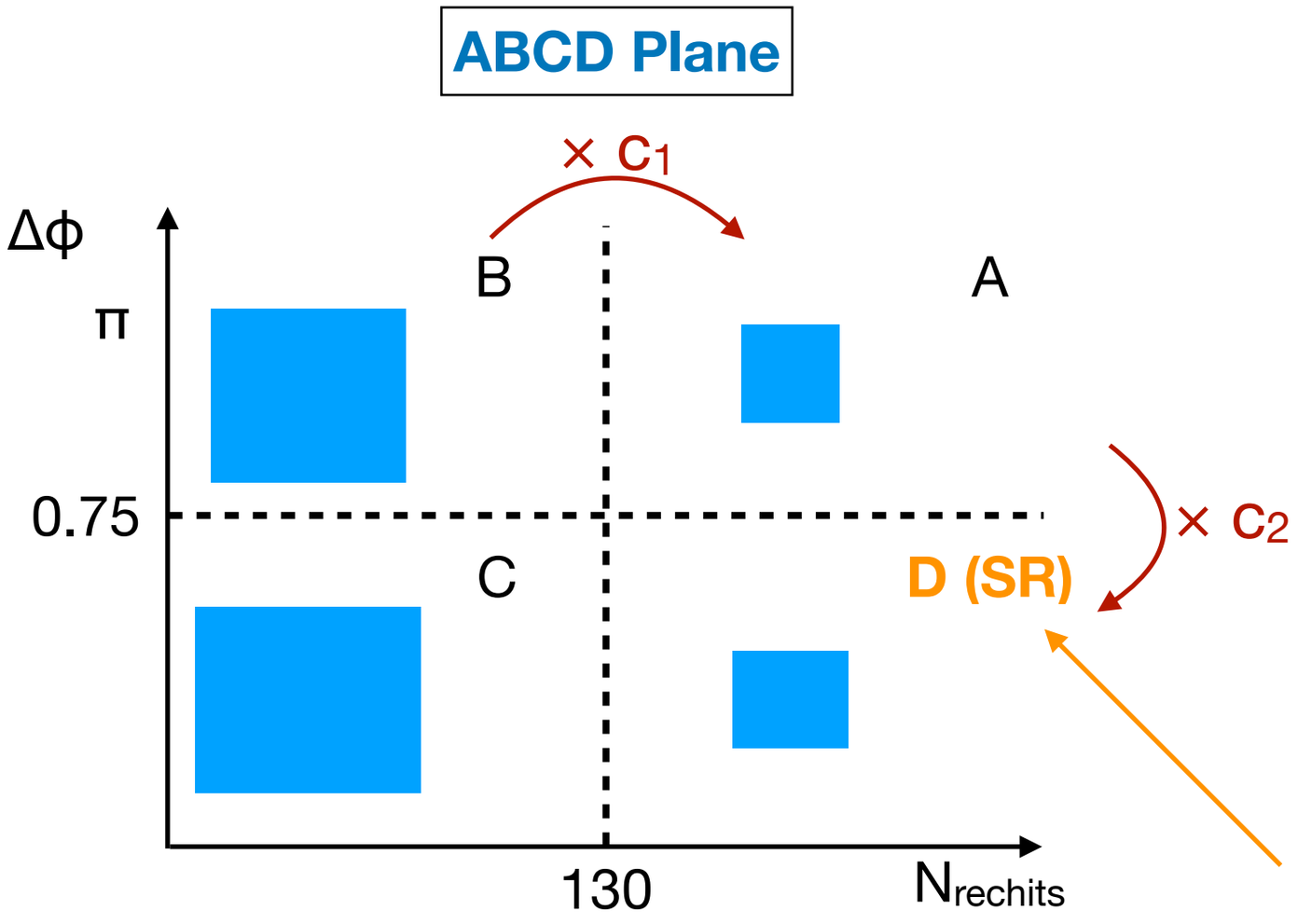
$$\textbf{cluster time} = \frac{\sum_{i=1}^{N_{rechits}} t_i}{N_{rechits}}$$

Signal Efficiency vs Z Decay Position



~50% signal efficiency when LLP decays between ME1 and ME4

Data Driven Background Estimation



$$D = A \times \frac{C}{B}$$

$$N_A = c_1 \times Bkg_B + \mu \times SigA$$
$$N_B = Bkg_B + \mu \times SigB$$
$$N_C = c_2 \times Bkg_B + \mu \times SigC$$
$$N_D = c_1 \times c_2 \times Bkg_B + \mu \times SigD$$

$c_1 = Bkg_A / Bkg_B$

$c_2 = Bkg_C / Bkg_B$

4 unknowns: c_1, c_2, μ, Bkg_B

	A	B	C	D (SR)	Bkg prediction
Events	3	96	47	3	2 ± 1

- Δϕ(cluster, MET) and $N_{rechits}$ are independent for background
- Method has been validated in two separate **validation regions**
- No excess above SM prediction observed

Unique Opportunity for CMS

12-27 interaction lengths of shielding material in the CSC