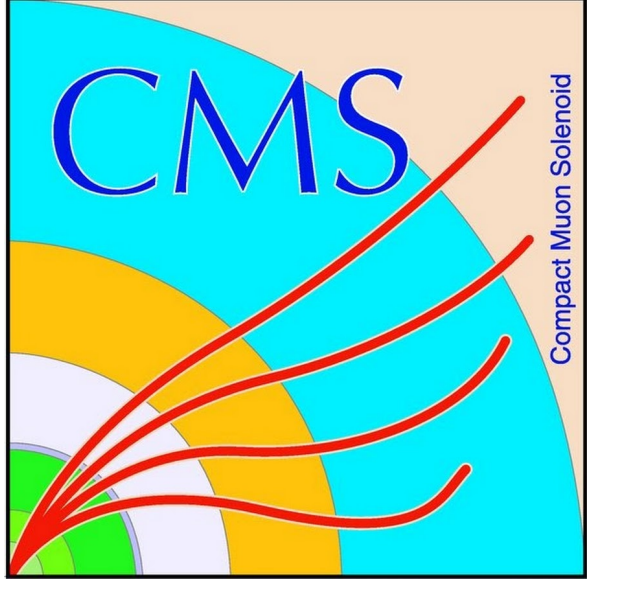


Search for Neutral Long-lived Particles with CMS Endcap Muon Detectors

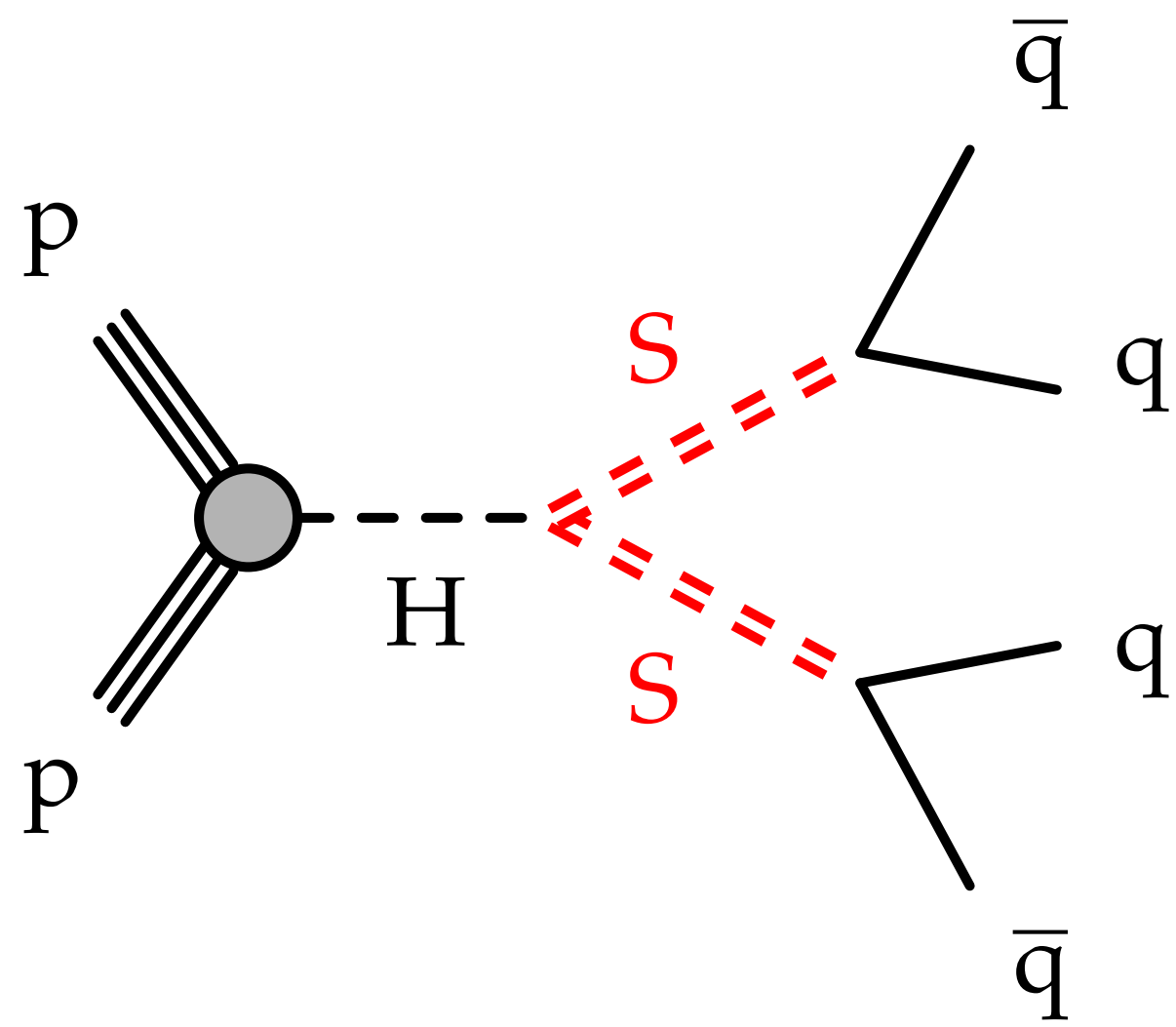


Christina Wang (Caltech)
on behalf of the CMS Collaboration



Long-lived Particles

- Long-lived particles are common in SM as well as BSM theories
- Well motivated and predicted in many BSM models: SUSY, Heavy neutral leptons, twin Higgs model

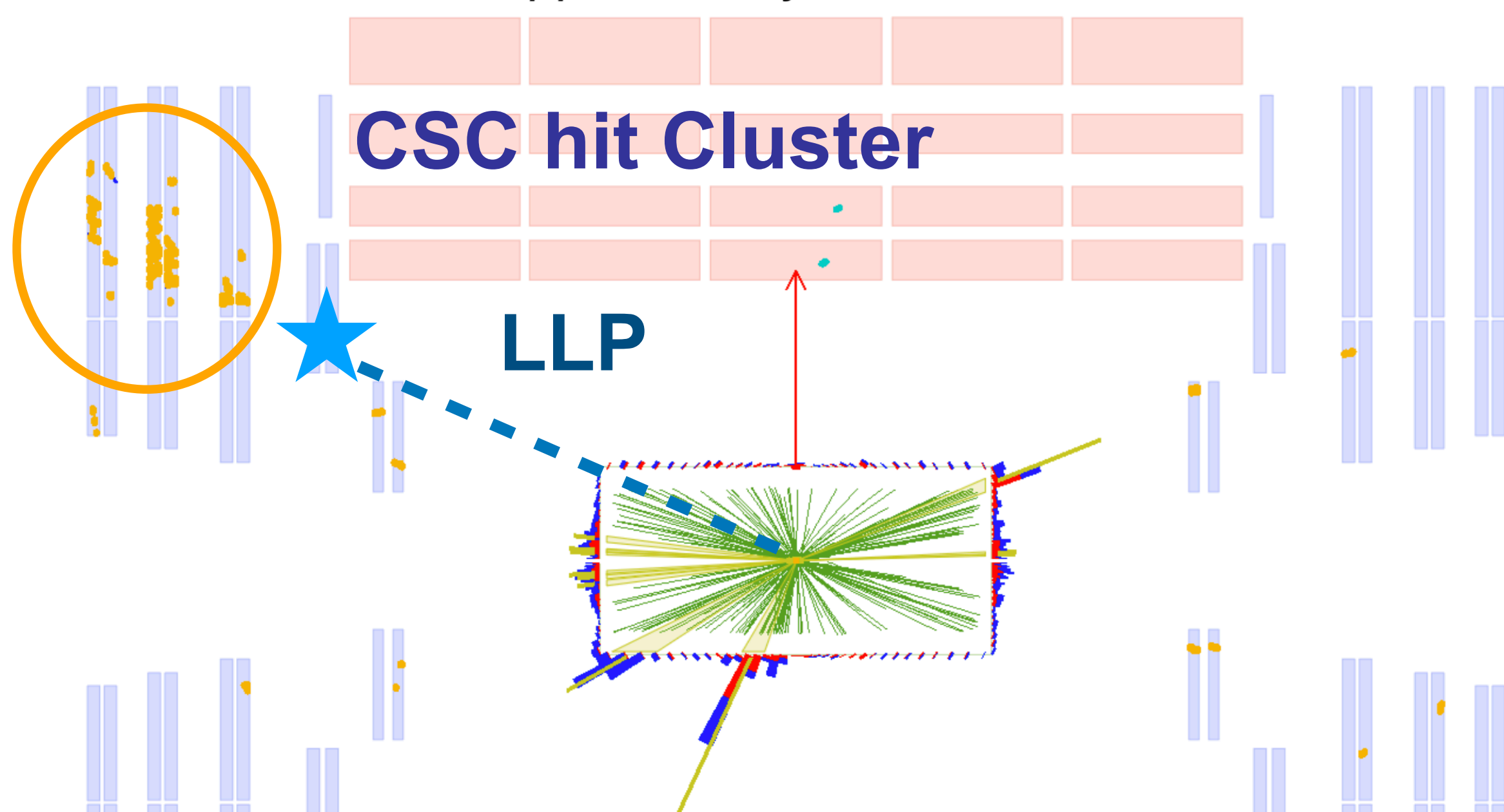


Feynman diagram of the twin Higgs model (S is long-lived)

CMS Muon System

- Covers decays far away from interaction point (sensitive to large $c\tau \sim m$)
- Excellent **background suppression** from shielding materials \rightarrow unique to CMS
- Steel interleaved with cathode strip chambers (CSCs) \rightarrow **sampling calorimeter**
- LLP decay will result in particle shower detected with a large hit multiplicity

CMS Simulation Supplementary

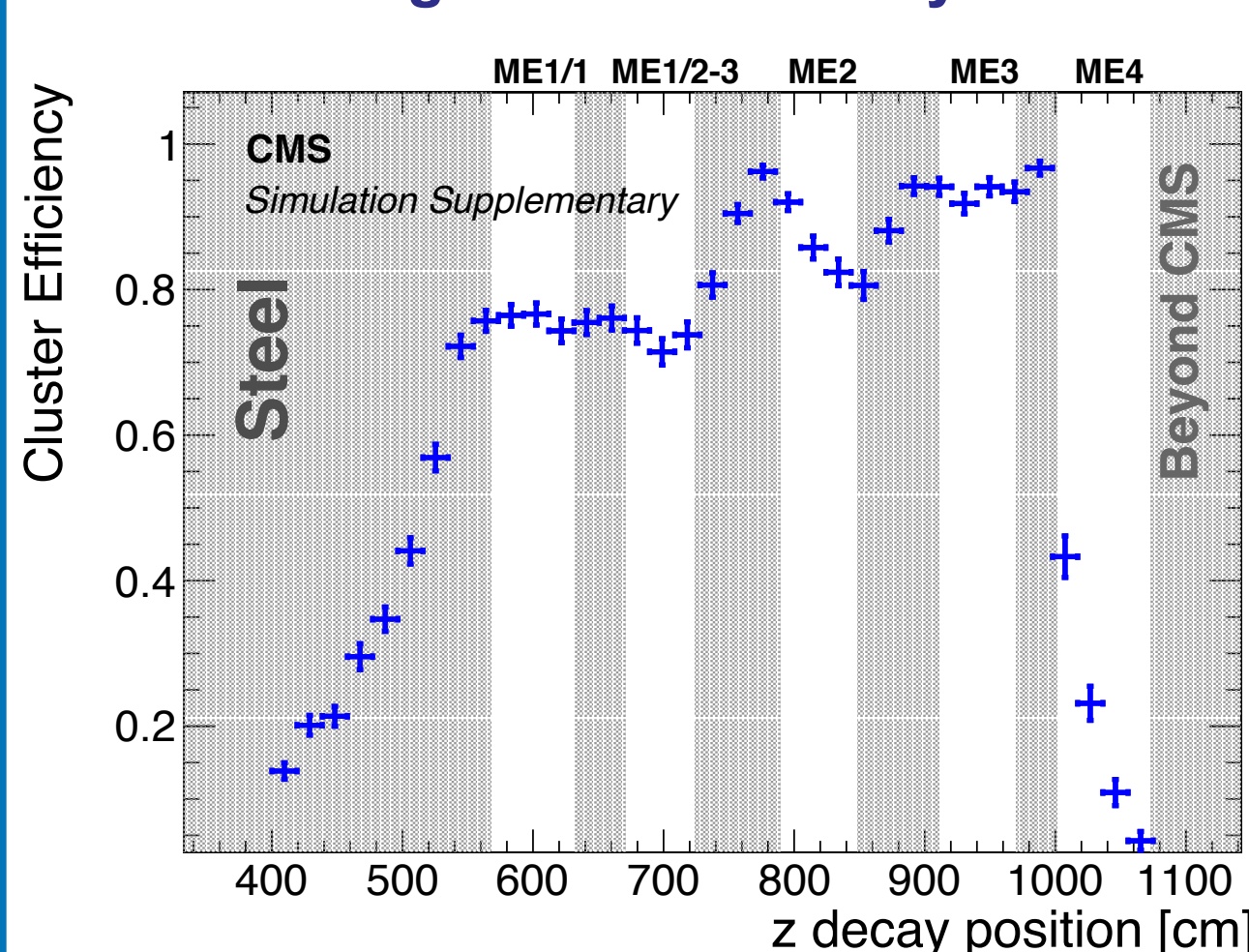


The event display of a simulated signal event for an LLP mass of 40 GeV, $c\tau$ of 1m, and $S \rightarrow b\bar{b}$ in rz -plane. The LLP decayed in the muon system (indicated by the blue star) and produced a **CSC hit cluster with 711 hits (orange dots)**. The **green lines** represent the tracks. The **yellow lines** represent jets. The **red arrow** represents the MET direction. The **red** and **blue** cones represent the ECAL and HCAL energy deposits, respectively.

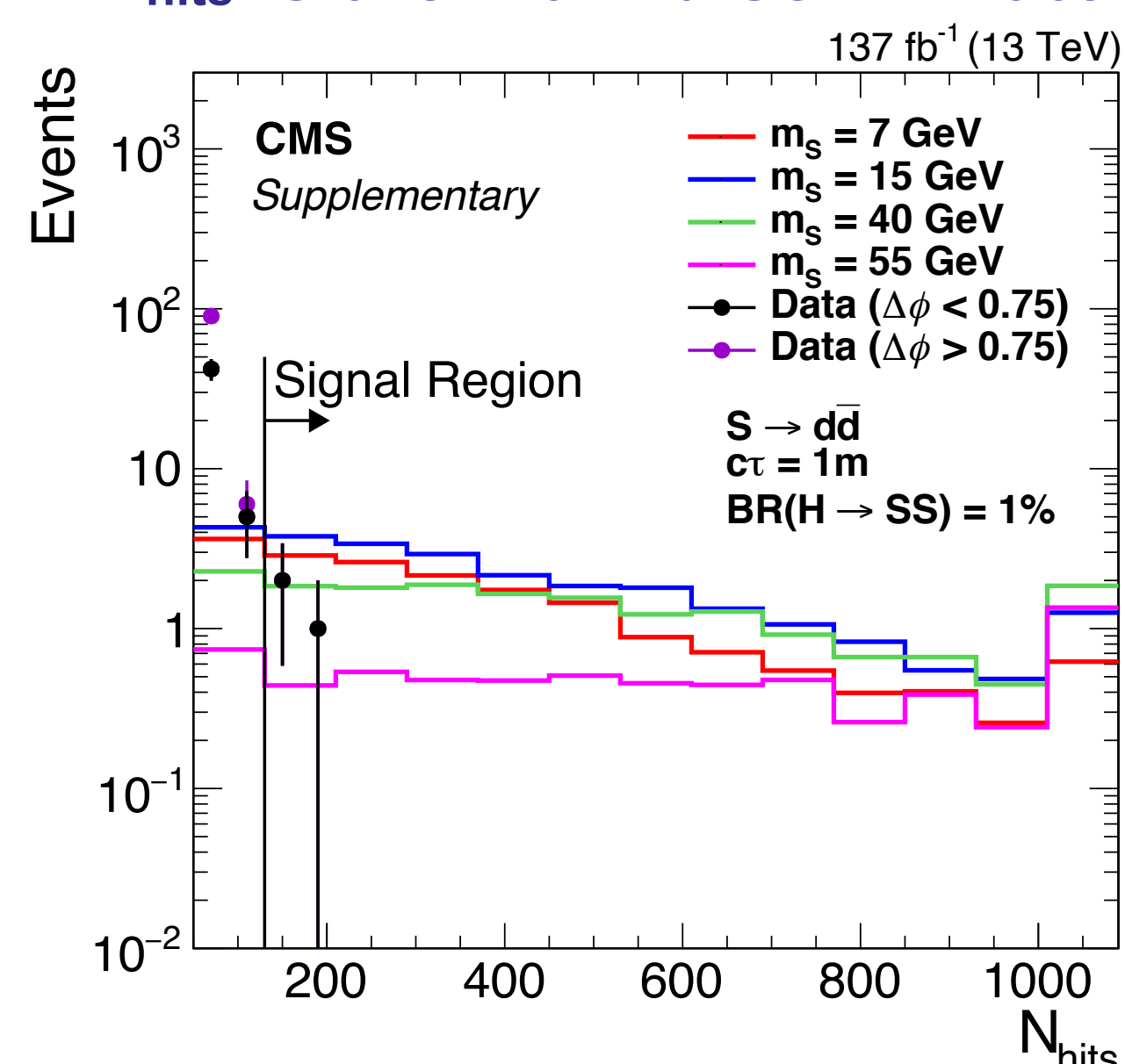
Search Strategy

- Trigger with high MET due to lack of dedicated trigger ($\sim 1\%$ efficiency)
- Look for 1 CSC hit cluster with high multiplicity (>130 hits) isolated from jets and muons

High cluster reconstruction efficiency throughout the muon system



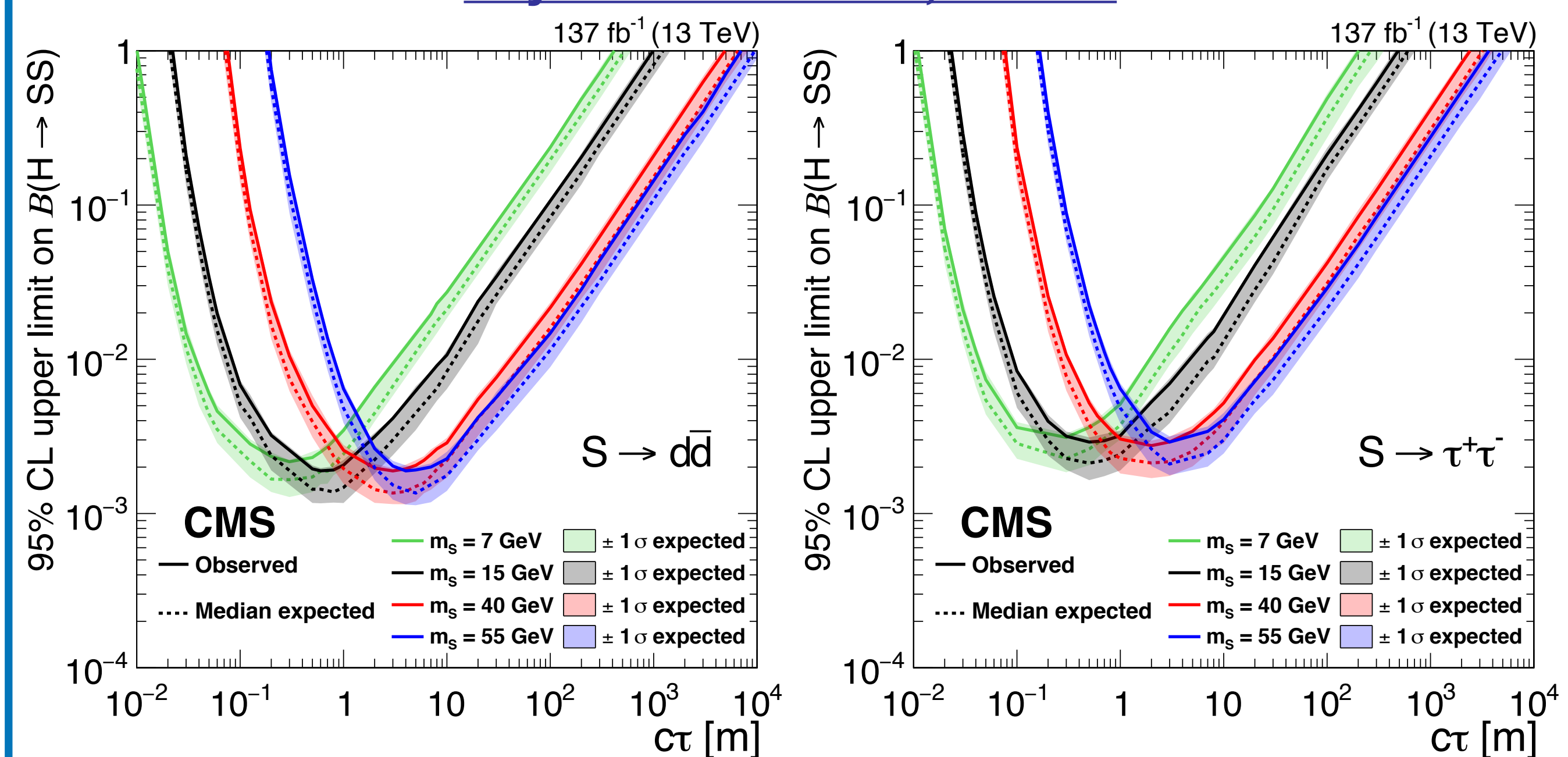
N_{hits} is the main discriminator



Result

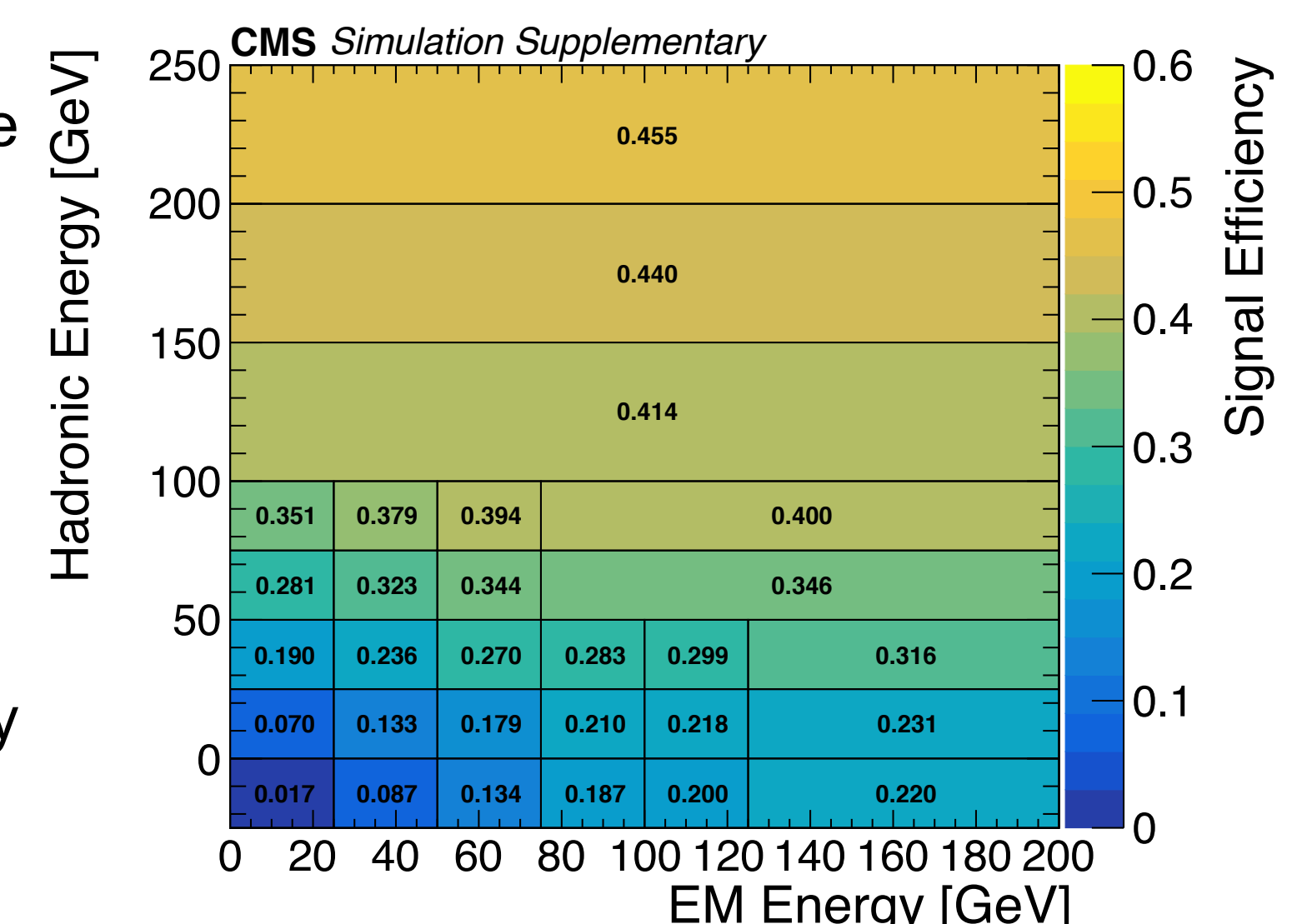
- 3 events observed (2 ± 1 expected)
- Analysis sensitivity is **independent of LLP mass** \rightarrow only sensitive to LLP energy
- Achieve first sensitivity to τ decay mode at $\text{BR}(H \rightarrow S\bar{S}) \sim 10^{-3}$

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CMS Detector Response Function

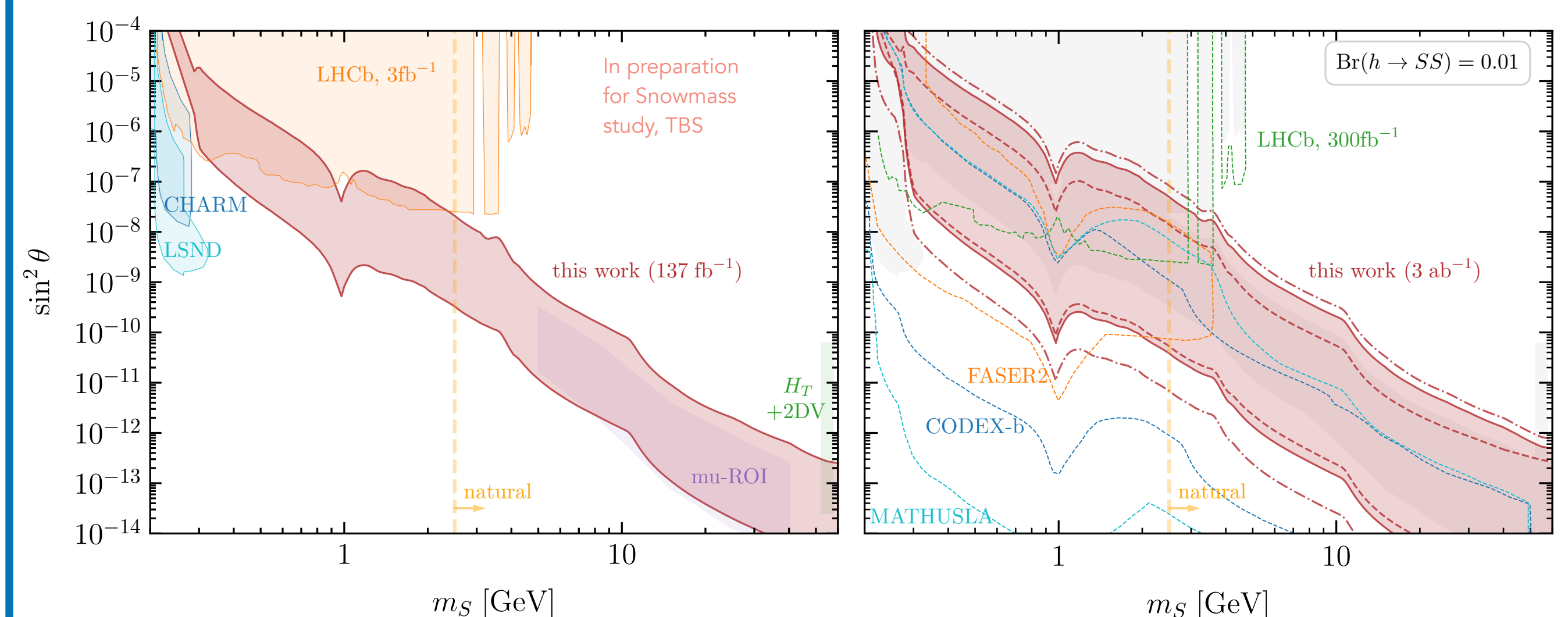
- Cluster-level detector response parameterized in generator-level LLP energy and decay position ([HEPData entry](#))
- Fast simulation of CSC cluster object has been validated and integrated into official Delphes framework
- Allow for reinterpretation to any models



Cluster efficiency in one region of the muon system as a function of generator-level LLP EM and hadronic energy.

Phenomenology

- In collaboration with Caltech theorists Michele Papucci and Andrea Mitridate, we recasted the CMS Run 2 result and projected sensitivity for Phase 2
- We explored several models: dark scalar, dark photon, axion-like particles, inelastic dark matter, and hidden valley models (more coming)
- For most models, the analysis covers previously unconstrained regions of the parameter space and complements the reach of dedicated LLP detectors



Constraints on light scalars produced in Higgs decays for $\text{BR}(H \rightarrow S\bar{S}) = 0.01$.

Left: Comparison of our current reach (red region) with existing limits.

Right: Projections of our constraints for a luminosity of 3 ab^{-1} (red region). The three red contours correspond to three search strategies considered for Phase 2 (Solid line: same analysis strategy and simply scale the result by luminosity; Dot-dashed line: increase N_{hits} cut until 0 background is achieved; Dotted line: remove MET cut and require 2 CSC clusters)