Reinterpretation of CMS search for LLPs using endcap muon detectors

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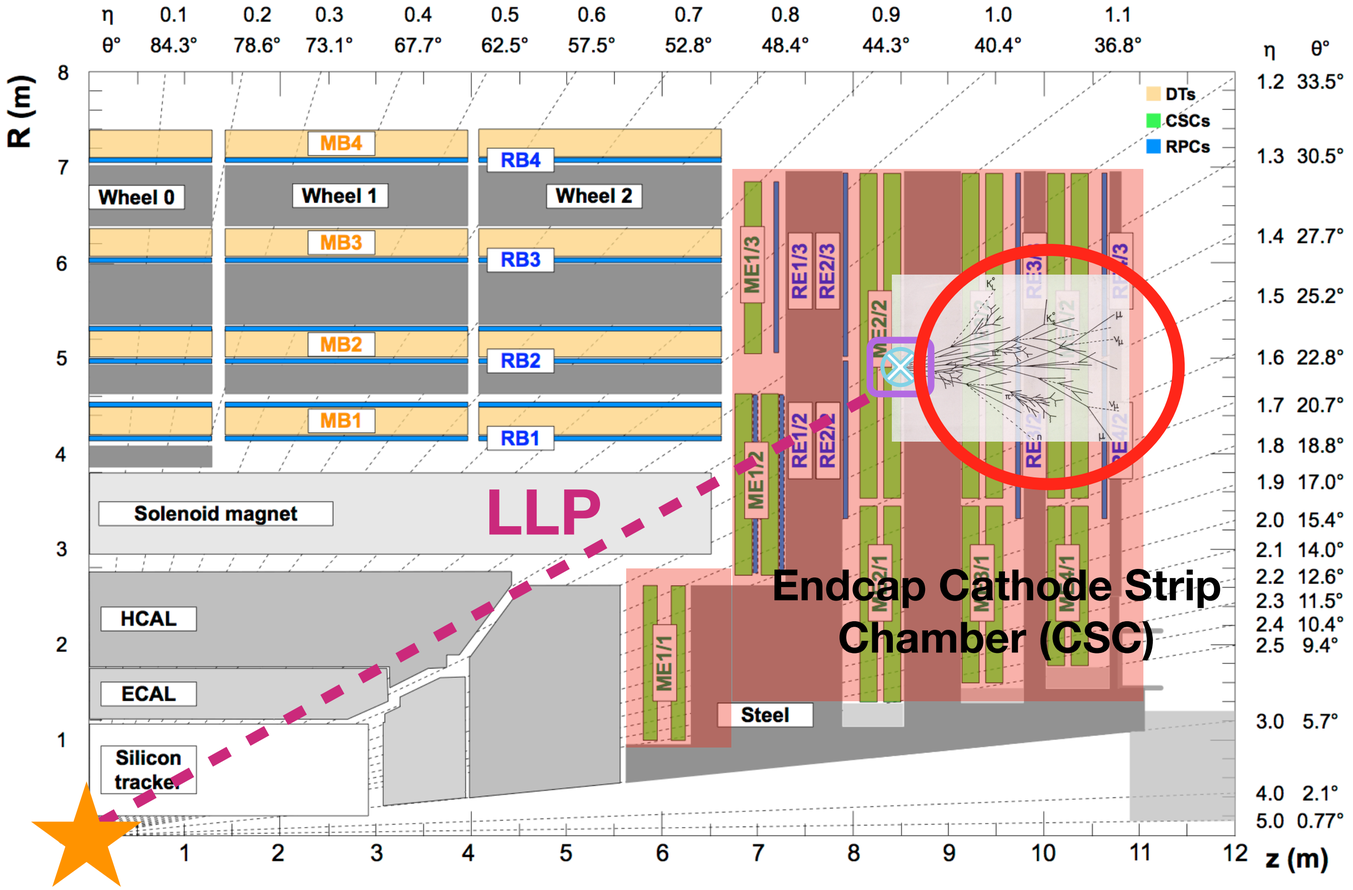
Caltech

Recent CMS Result: Muon System as a Sampling Calorimeter for LLPs

(Phys. Rev. Lett. 127, 261804)

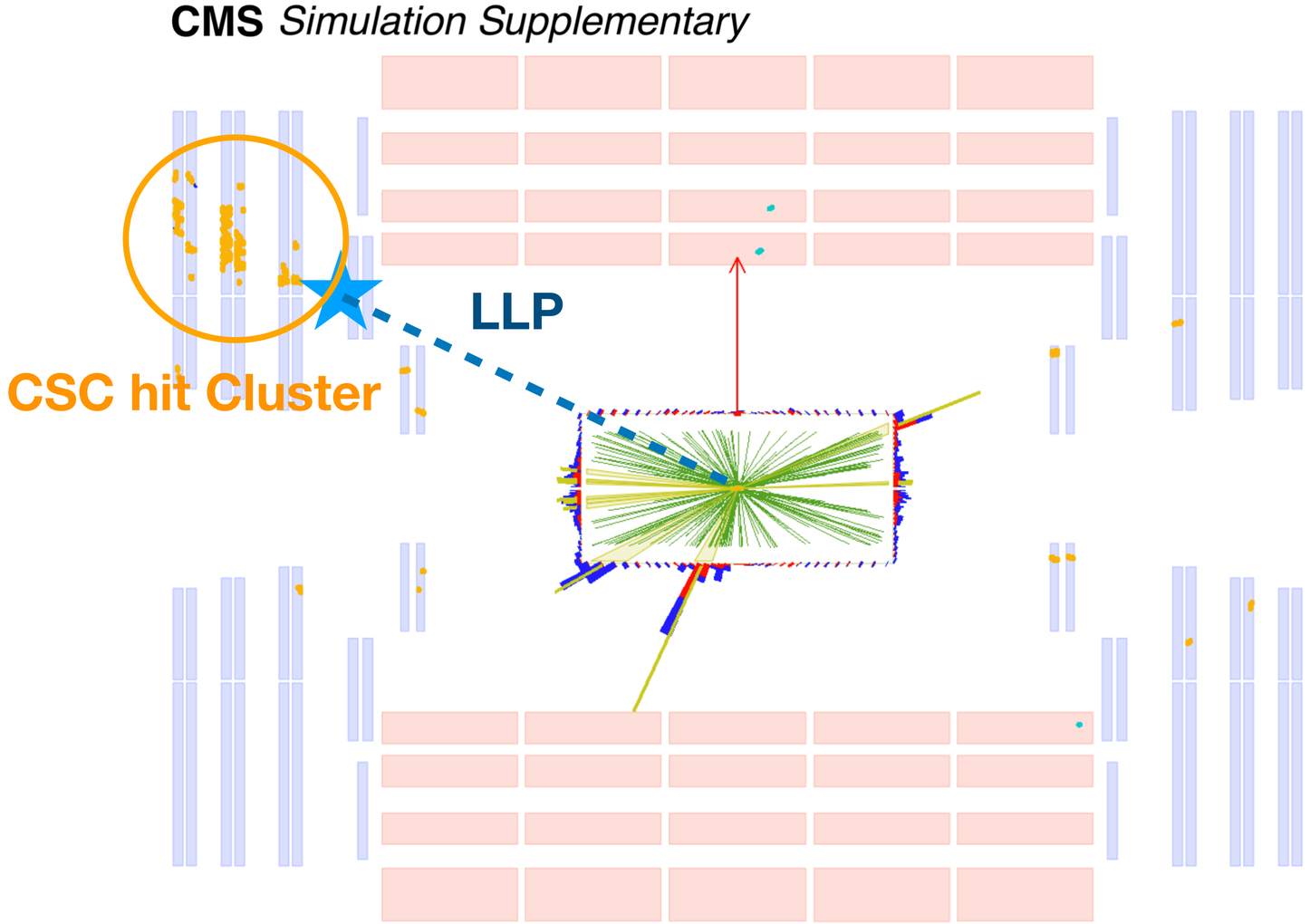


LLP decay and resulting particle shower is detected with a **large hit multiplicity**

- Excellent **background suppression** from shielding material
- Steel interleaved with active chambers → **sampling calorimeter**

Experimental Signature: Displaced Showers in the Muon System

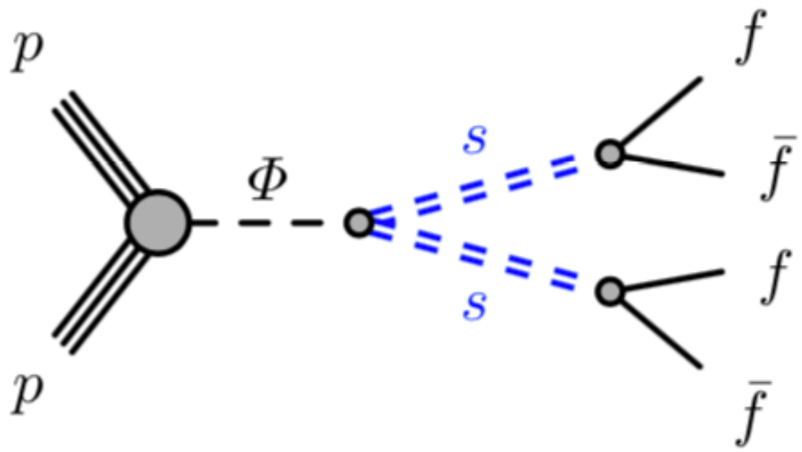
- Large **cluster of CSC hits (>100 hits)** in the muon system with no jets or tracks
- Muon system acts as a **sampling calorimeter:** sensitive to a broad range of decays



CMS Search Result

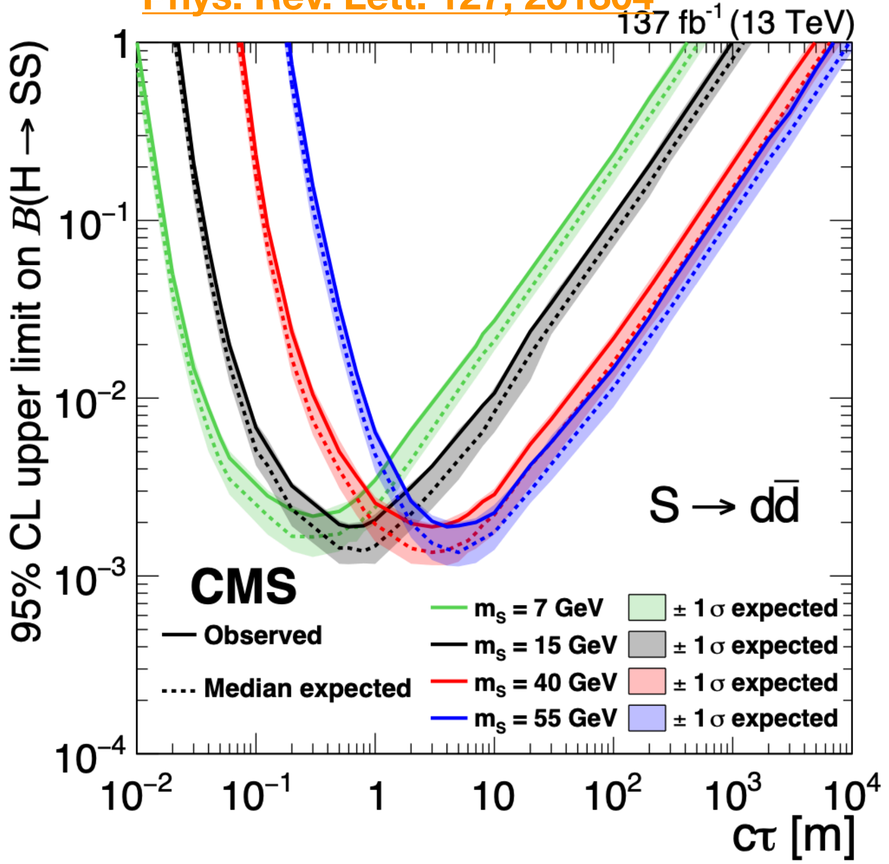
- The CMS paper interpreted the search result in Higgs-portal to scalar LLP
- Along with the CMS result, we released a set of detector response function parameterized using only gen-level LLP information that would allow for recasting of the analysis with other models: https://www.hepdata.net/record/104408

  - **3 events observed**
  - **2 ±1 background events predicted**



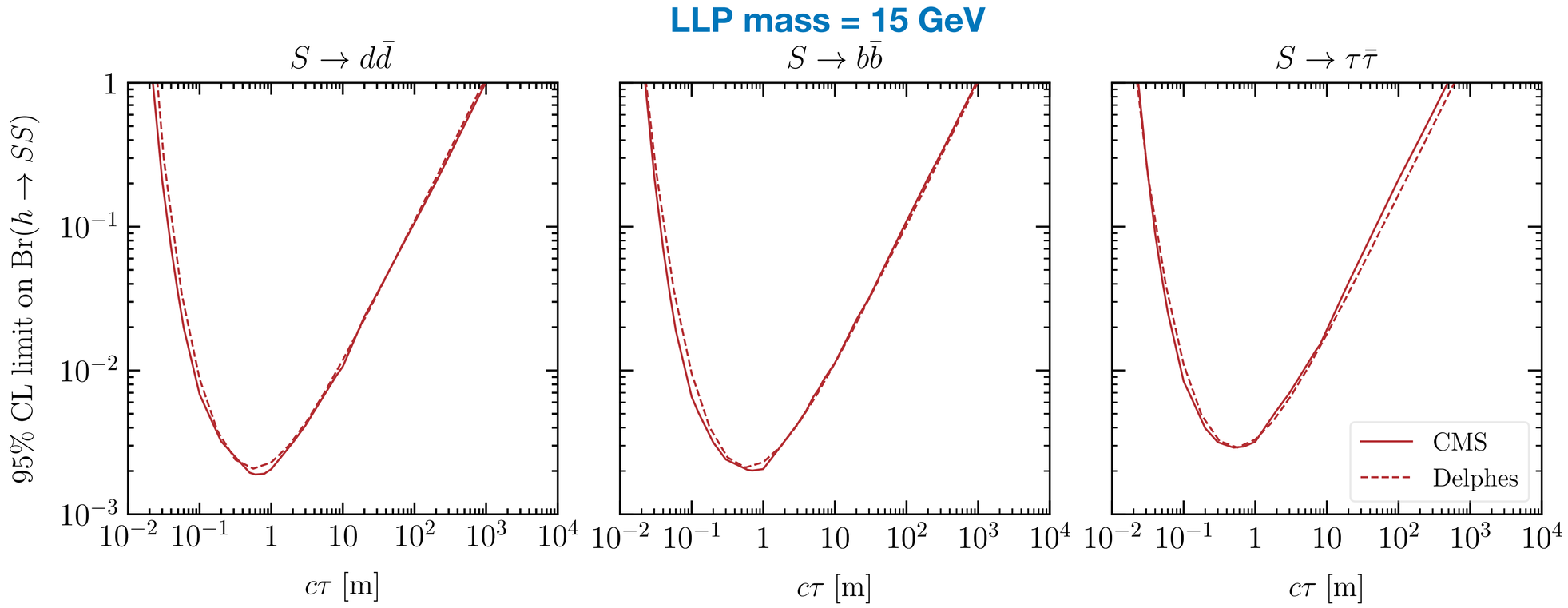
Twin Higgs model as benchmark model

Phys. Rev. Lett. 127, 261804



Delphes Module for Recasting

- Integrated the CSC cluster objects with the detector response functions as official Delphes classes and modules: https://github.com/delphes/delphes/pull/103
  - Validated that we are able to reproduce the limits from CMS for all 3 decay modes to within 30%
- We recasted the CMS analysis in a number of models: dark scalar, dark photon, ALPs, inelastic DM, hidden valley models, and HNL
  - Will focus on dark scalar, hidden valley, and HNL today
- We also invite everyone to use the new Delphes module for CSC clusters to reinterpret the analysis for any other model that predicts LLPs!
  - GMSB, RPV, split SUSY, milli-charged particles, charged LLP (stau) …



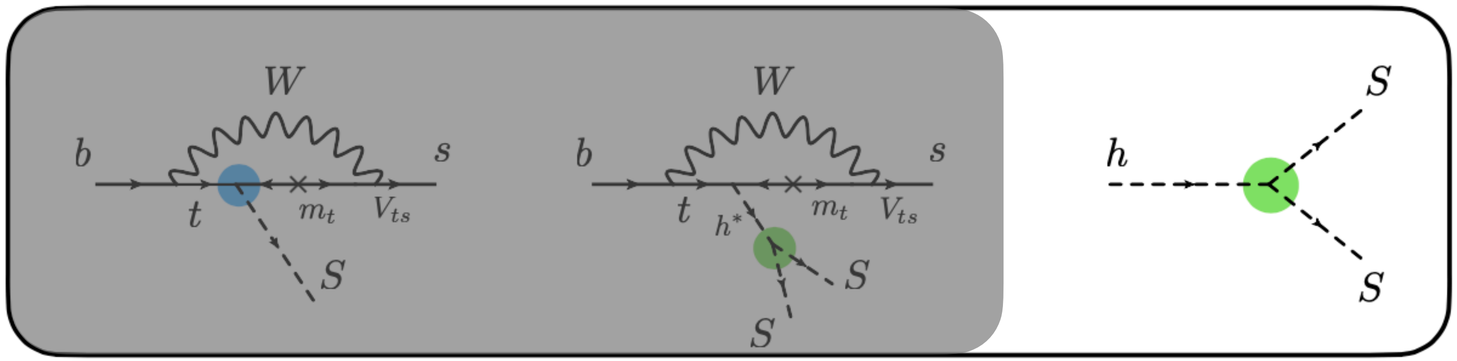
Light Scalar Model

$$\mathcal{L}_{SH} = \mathcal{L}_{\mathrm{SM}} + \overbrace{\frac{1}{2}\partial_\mu \hat{S}\,\partial^\mu \hat{S} - \frac{\mu_S^2}{2}\hat{S}^2}^{\mathcal{L}_{\mathrm{DS}}} - \overbrace{\left(A_{HS}\,\hat{S} + \lambda_{HS}\,\hat{S}^2\right)}^{\text{Higgs portal}} \hat{H}^\dagger \hat{H}$$

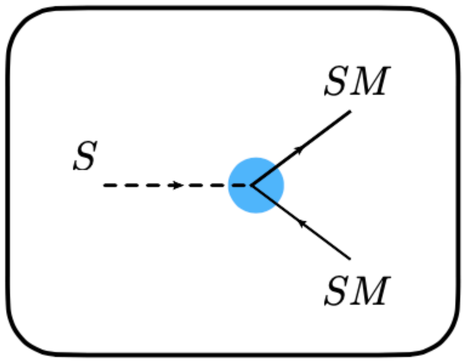
controls the $\hat{H} - \hat{S}$ mixing

controls $Br(H \to SS)$

production



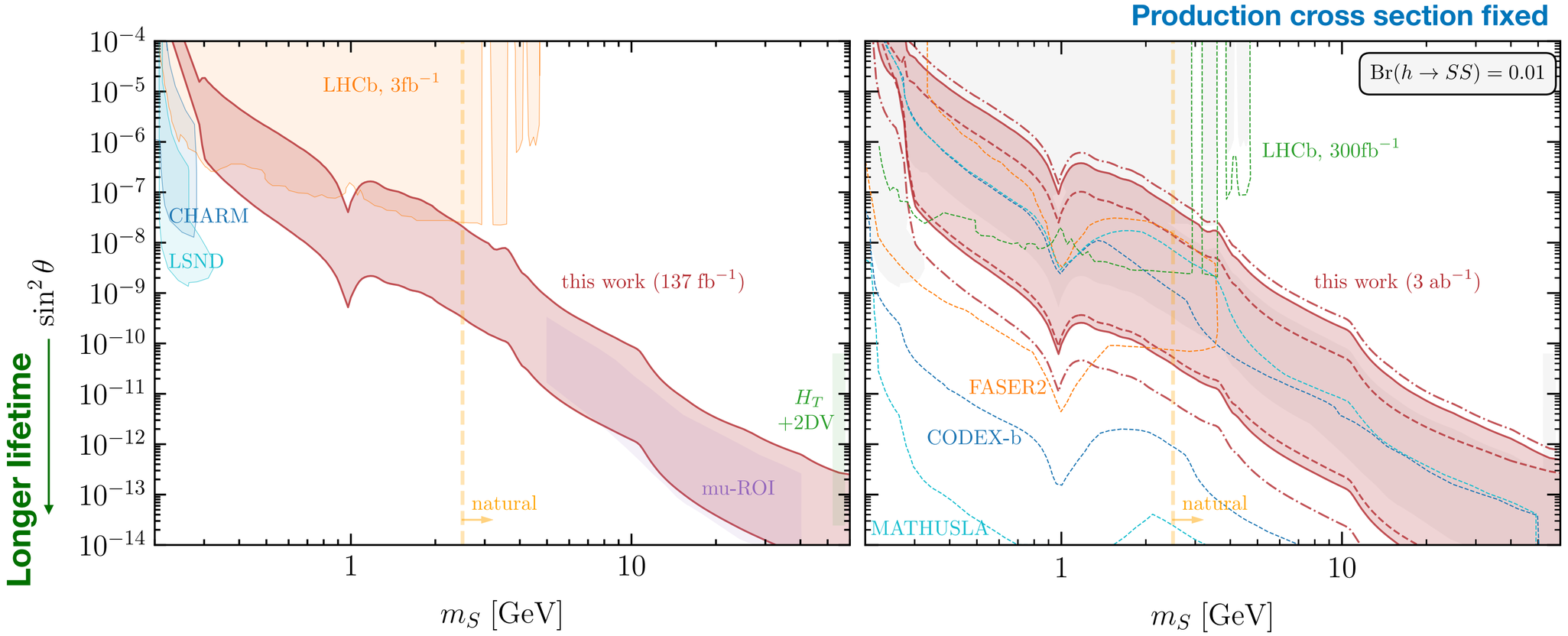
decay



No reach in this analysis
(due to MET > 200 GeV cut)

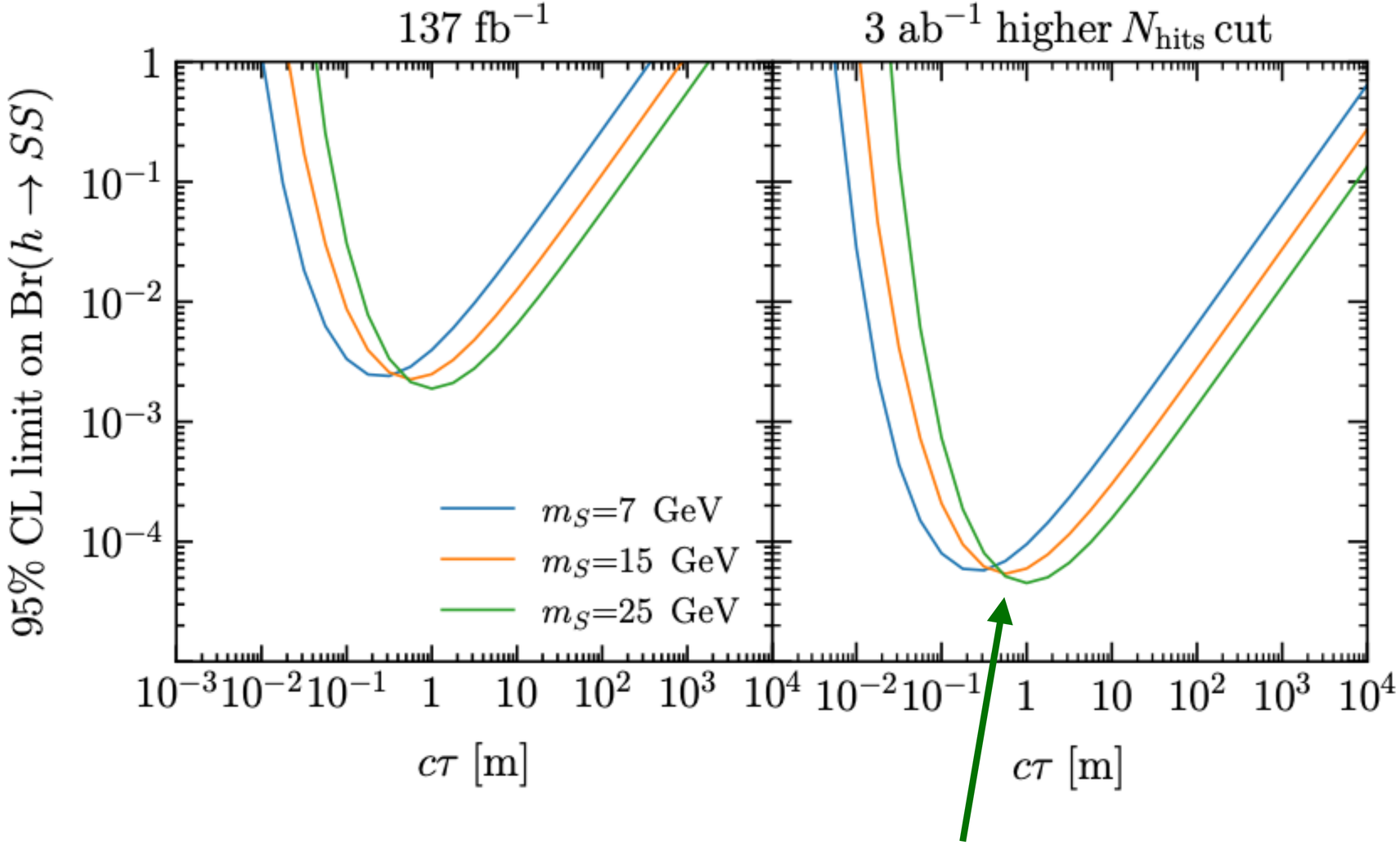
Production and decay channels are decoupled

Light Scalar Reinterpretation



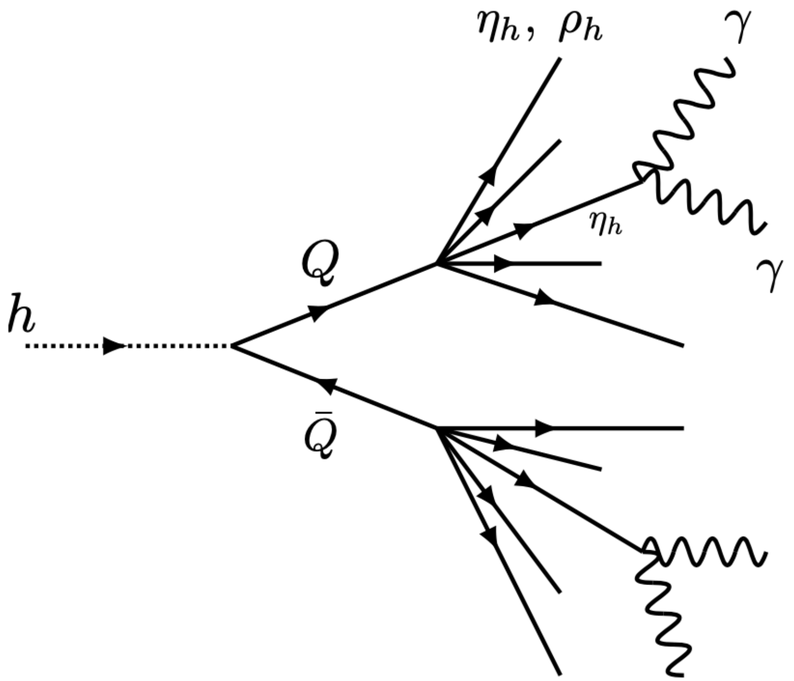
- m_S controls the decay mode and affects the acceptance
- 3 search strategies considered for phase 2:
  - Solid line : same analysis strategy and simply scale the result by luminosity
  - Dot-dashed line: increase N_{hit} cut until 0 bkg is achieved
  - Dotted line: remove MET cut and require 2 CSC clusters

Light Scalar Model



- With Phase 2 Projection, we will be able to reach **BR(h → SS) ~ 5e-5** at lifetime of a few meters, complementary to dedicated LLP experiments that are most sensitive to cτ of 10 - 100 m

Hidden Valley Models

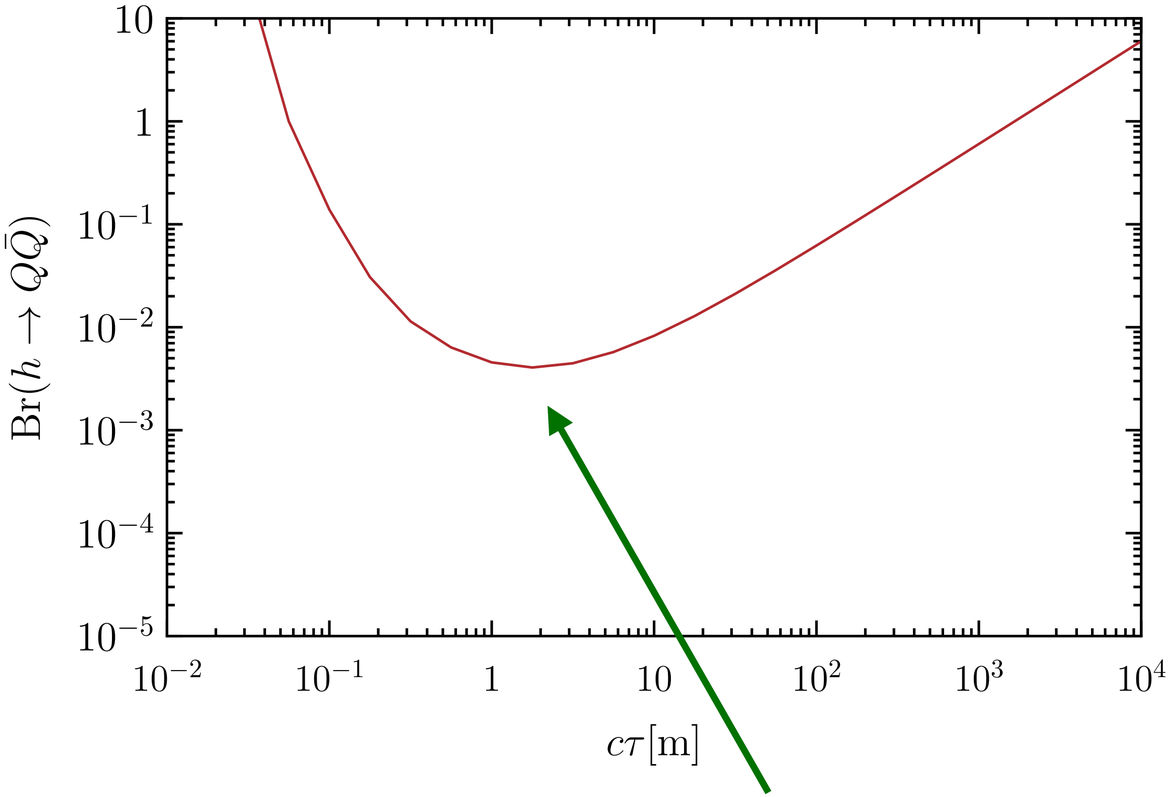


- We assume ρ_h to decay into $\eta_h\eta_h$, targeting high LLP multiplicity
- η_h is the LLP and decays to $\gamma\gamma$ to be conservative and it's hard to probe with other searches

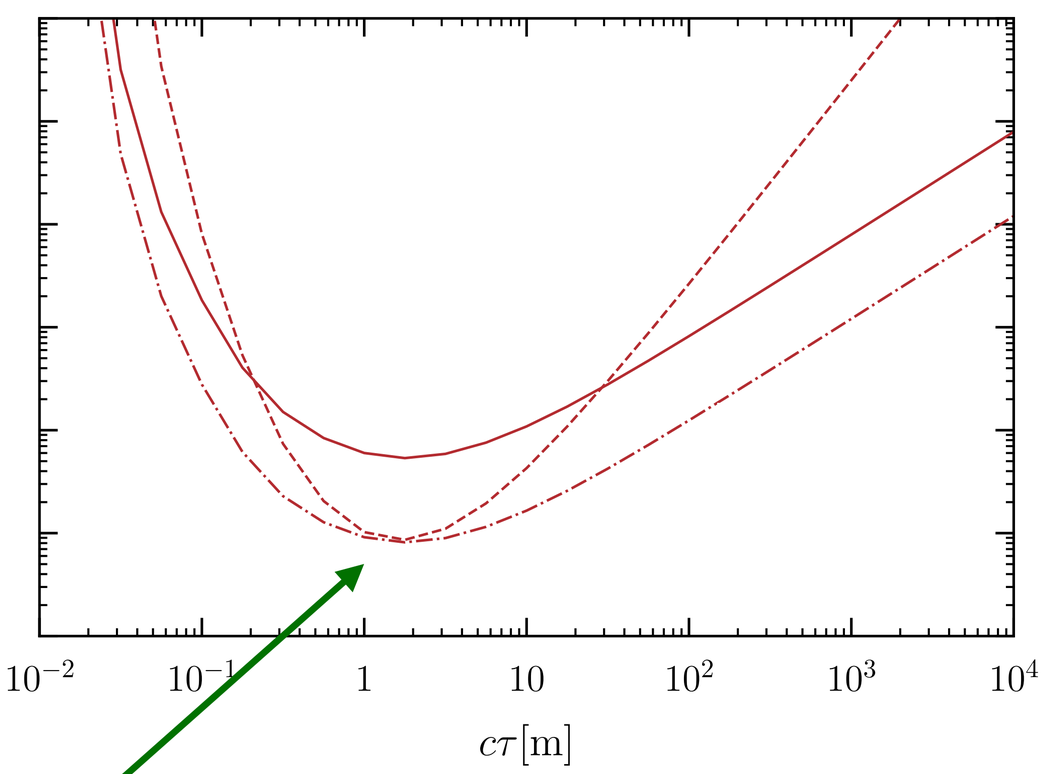
Hidden Valley Reinterpretation

LLP mass = 8 GeV

Run 2 recast (137 fb^{-1})

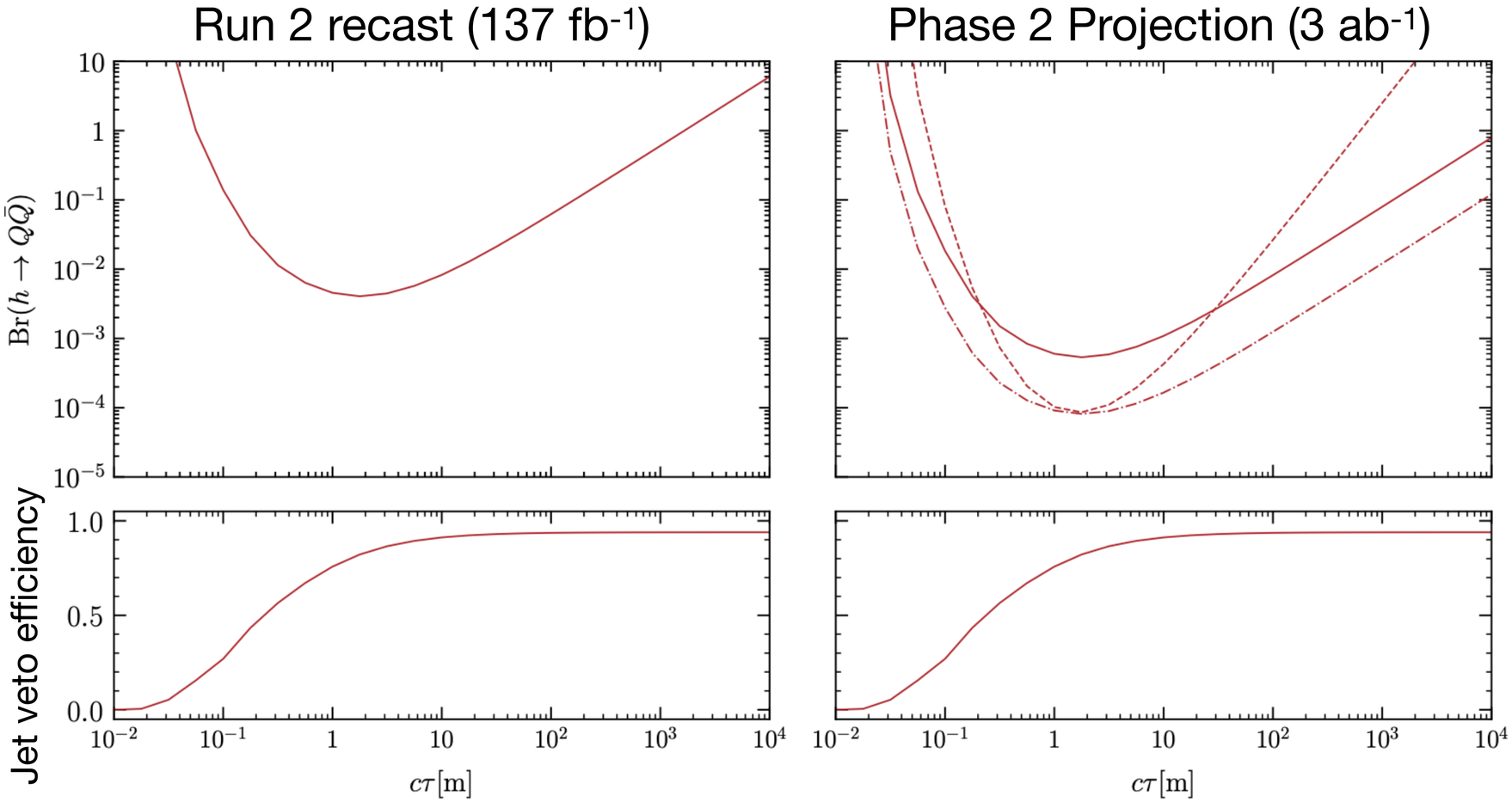


Phase 2 Projection (3 ab^{-1})



- Reaching BR 3e-3 with 137fb^{-1} and 1e-4 with 3ab^{-1}
- Currently there are no other experiments that set limit on this model

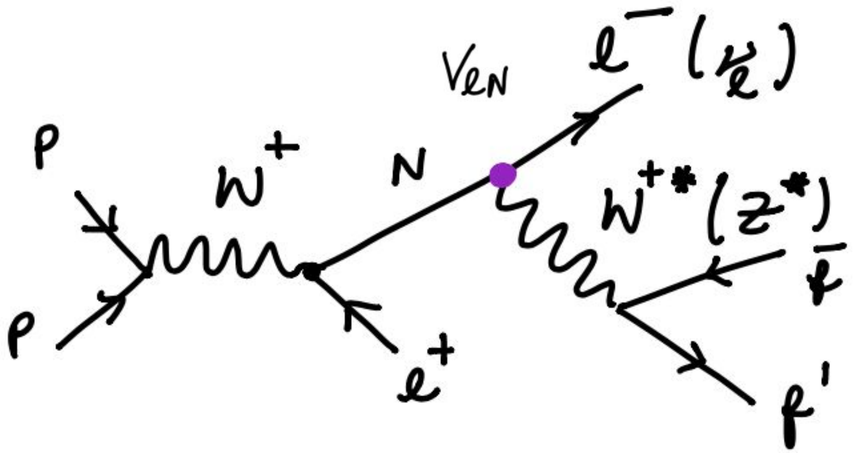
Hidden Valley Reinterpretation



- At low lifetime, the current search strategy limits the sensitivity by applying a jet veto, where the LLPs that decay in muon system are vetoed by LLPs decayed in tracker that create jets in the same direction
  - In this model, LLPs originating from the same dark quark usually come from the same direction
- At long lifetime, higher LLP multiplicity results in more stringent limit than the scalar model

Heavy Neutral Leptons

G. Cottin



$$\Gamma \sim G_F^2 \; m_N^5 \; |V_{eN}|^2$$

Small mixing & ~ GeV scale HNL ⇒ LLP!

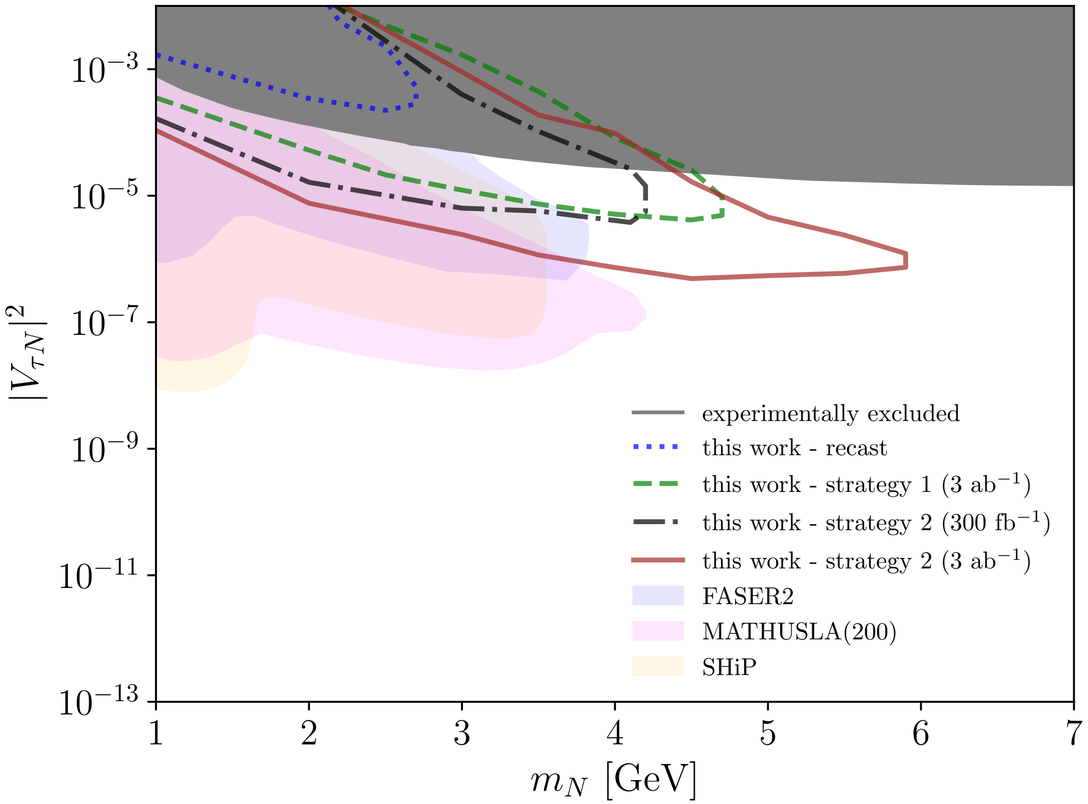
- Latest HNL searches at the LHC use prompt lepton triggers (e/μ) and displaced vertex signature targeting leptonic decays of W*/Z*
- Tau mixing is not covered yet at the LHC
- **Muon detector shower: target HNLs decaying in the muon system, sensitive to particle showers from the displaced lepton and inclusive W*/Z* decays**

HNL Reinterpretation

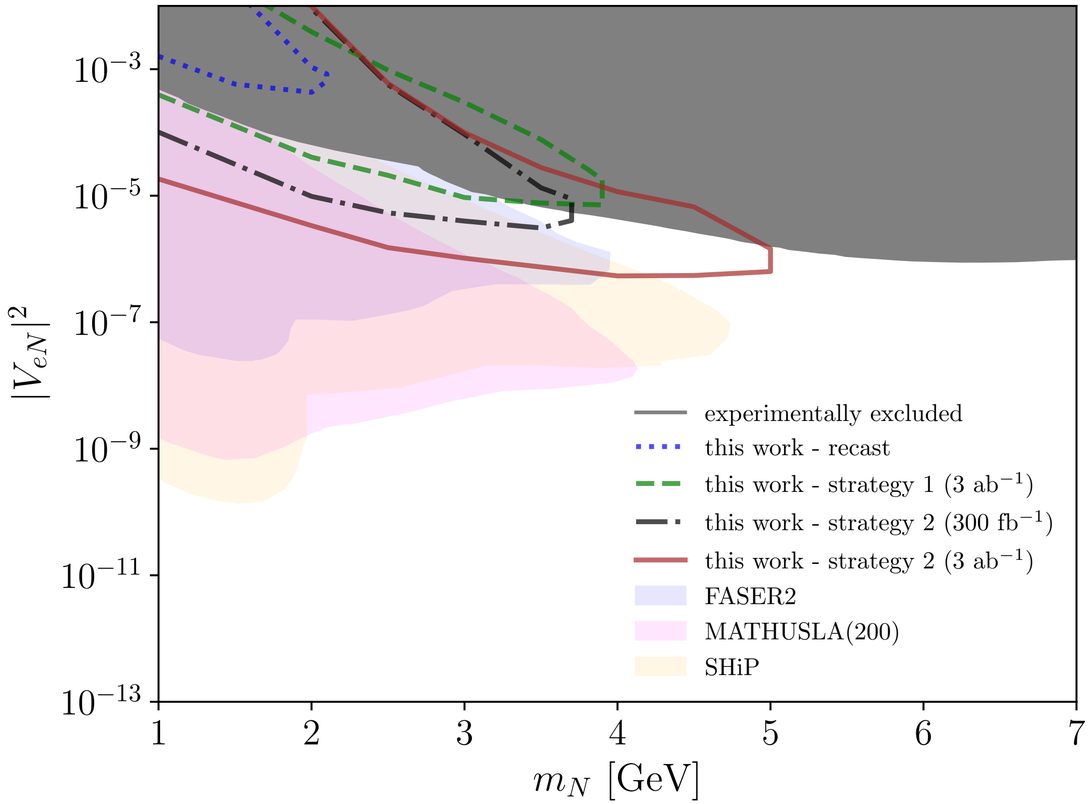
Giovanna's talk at LLP11

Paper submitted to arXiv 2 days ago!

τ-type



Electron-type



- **Can reach mixings as low as ~5 x 10^{-7} and HNL masses between 1 and 6 GeV for both electron and τ-type**
  - Strategy 1 : Maintains high MET trigger but with a tighter N_{hit} cut.
  - Strategy 2: Lower MET cut > 50 GeV and increased N_{hit}. Enabled by the new dedicated trigger for Run 3

Summary

- Presented reinterpretation and sensitivity projections in a number of benchmark models, significantly extending the physics scope of recent CMS result
- We highlight a few representative models: dark scalar model, heavy neutral leptons, and hidden valley models
- For most benchmark models, the analysis covers previously unconstrained regions of the parameter space and is complementary to dedicated LLP experiments
  - New dedicated trigger in run3 would also open up possibilities for more models and search strategies
- We invite anyone interested to use the new Delphes module to reinterpret the analysis with their favorite model