

Hidden Sector Portals: Displaced Signatures at the LHC

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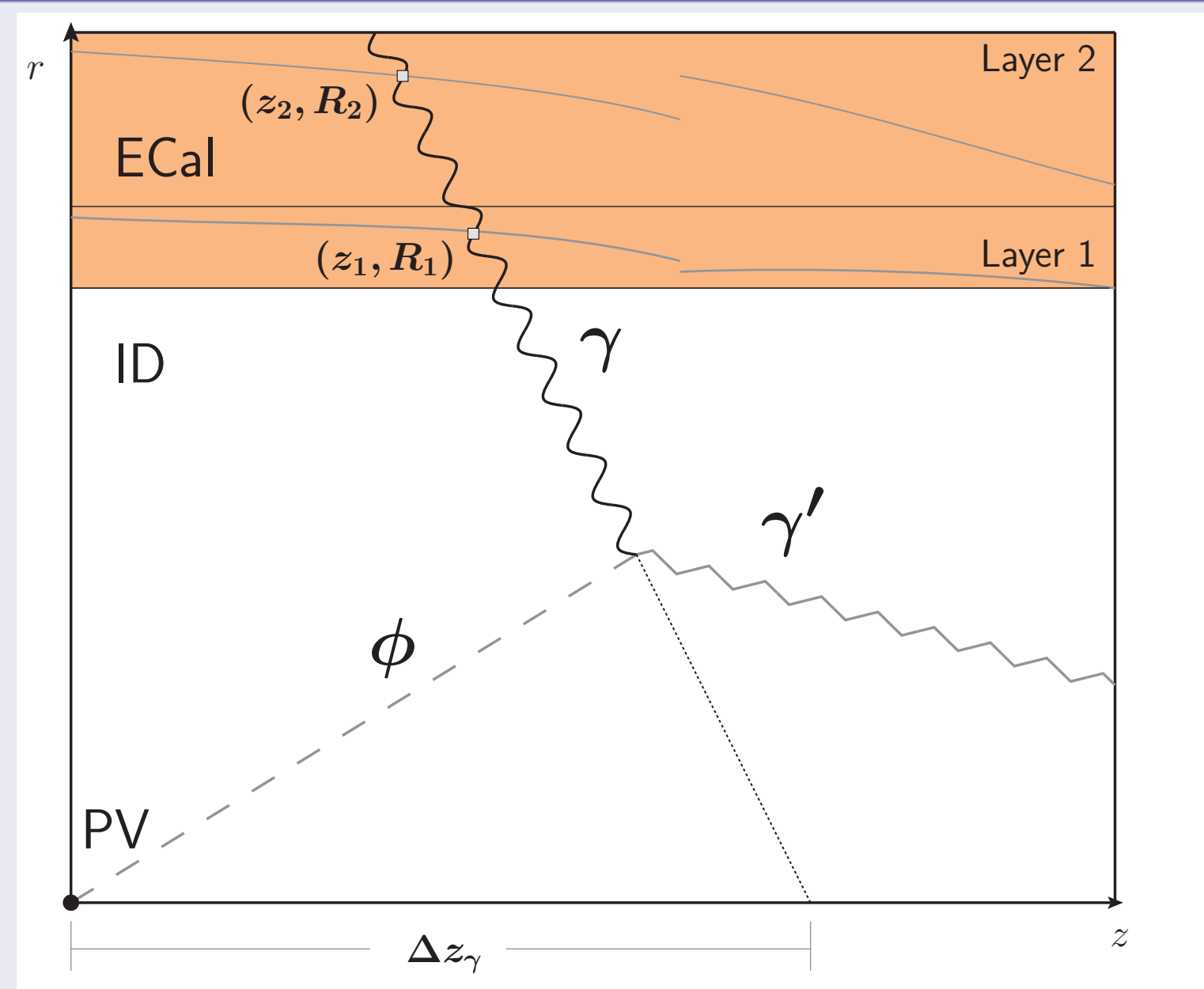
Background

- While LHC searches traditionally focus on prompt vertices, we study displaced vertices from long-lived particles.
- $U(1)' \times Z_2$ dark sector: ϕ, A'_μ odd under Z_2
- Higgs portal: $\lambda_{HS} \phi^2 |H|^2$
- Dimension-5 operator: $\frac{g_D}{2} \phi \tilde{F}'_{\mu\nu} B^{\mu\nu}$

Methods

- Simulated $t\bar{t}H$, ZH , and WH processes in MadGraph5 with $h \rightarrow \phi\phi$, $\phi \rightarrow \gamma\gamma'$
- Reconstructed displaced variables:
 - Δz_γ (longitudinal displacement of photons)
 - t_γ (relative timing delay at ECal)
- Full detector simulation via Delphes with post-processing analysis in PyROOT

Schematic



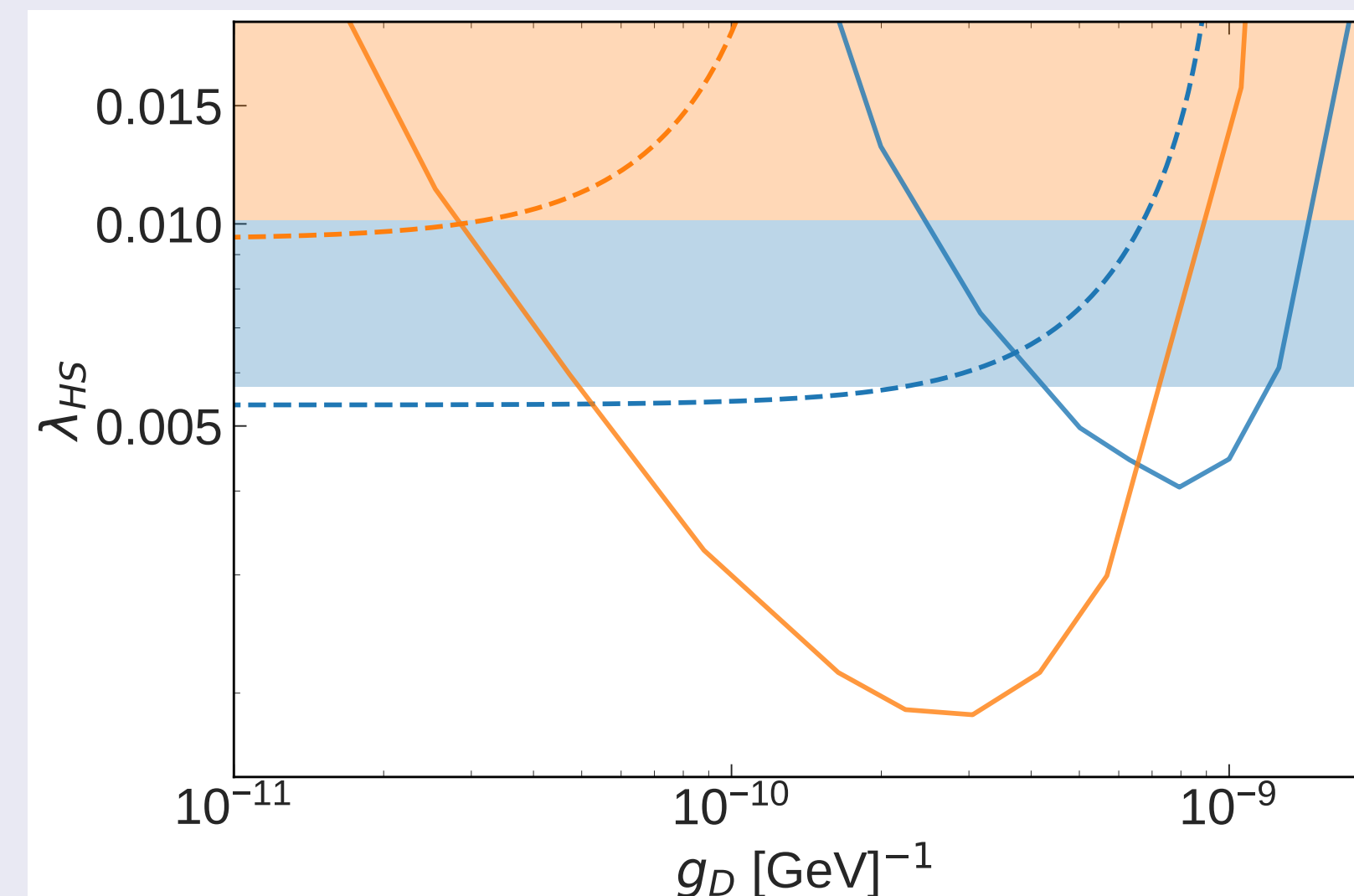
Simplified decay chain with displaced photon.

Cutflow Table (%)

Cut	$c\tau_\phi = 0.69$ m		$c\tau_\phi = 4.4$ m		
Trigger, $p_{\gamma T} > 10$ GeV, Acceptance	71		44		
Isolation, Efficiencies, Z-veto	39		18		
	Channel				
	1	2+	1	2+	
	$E_{\text{cell}} > 10$ GeV	15	20	11	3.2
	MET > 50 GeV	6.2	8.3	5.4	1.3
	$ \Delta z_\gamma > 300$ mm	2.2	1.8	2.6	0.46
$t_\gamma > 1$ (1.5) ns	0.20	0.45	0.89	0.27	

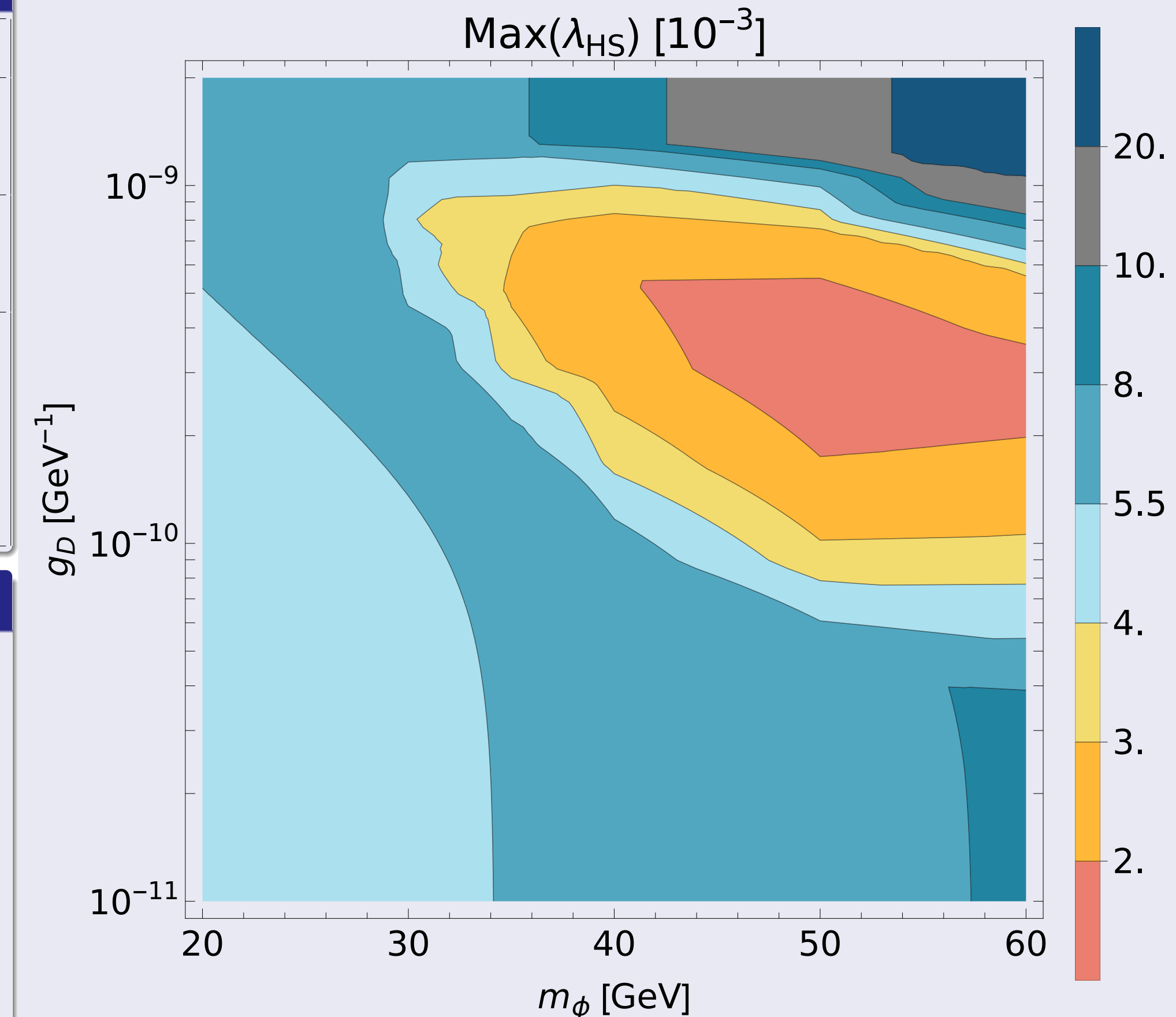
LHC Constraints

- Combined analysis of $h \rightarrow \phi\phi$ constraints:
 - Displaced photons (solid)
 - Higgs invisible decays (dashed)
 - Undetected decays (shaded)
- Shown for benchmark points with $m_\phi = 30, 60$ GeV (blue, orange) and $m_{\gamma'} = 1$ GeV
- Displaced photon search shows maximal sensitivity for $c\tau_\phi \approx 2.2$ m (optimal balance between detection efficiency and displacement)



Constraints on Higgs portal coupling λ_{HS} vs g_D .

Main Result: Contour Plot



λ_{HS} exclusion contours in (m_ϕ, g_D) plane ($m_{\gamma'} = 1$ GeV)

Interpretation

- Middle region** ($\lambda_{HS} \sim 2 - 5.5 \times 10^{-3}$): Displaced photon search dominates, sensitive when ϕ decays within tracker ($c\tau_\phi \sim \mathcal{O}(1)$ m)
- Upper-right**: Higgs to undetected decays constrain λ_{HS} independently of g_D value
- Lower-left**: Higgs invisible decays dominate as both ϕ escape detector ($c\tau_\phi \gg$ detector size)