

# Higgs and Dark Photon Searches

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## 1 Introduction

## 2 $e^+e^- \rightarrow H\bar{\gamma}$

# Dark Photons

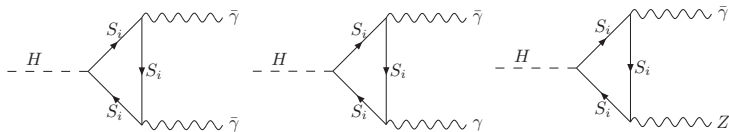
- Dark photons appear in several beyond the Standard Model physics scenarios, where a new  $U(1)$  gauge group is added to the SM.
- Massive dark photons can be dark matter candidates, while massless dark photons can appear in models of self-interacting dark matter. (Cusp-vs-core, missing satellites.)
- Unbroken  $U(1)$  results in a massless dark photon. Motivated e.g. in a model for radiative origin of the SM Yukawa couplings. [arXiv:1310.1090 [hep-ph]]

# Coupling to the SM

- Dark photons can couple to the SM particles via the kinetic mixing operator  $F'_{\mu\nu}F^{\mu\nu}$ , or via loop-induced dimension 5 operators.
- The kinetic mixing of massless Dark Photons can be transformed away by field redefinitions. Generally this results in millicharges for the particles initially charged under the hidden  $U(1)$ .
- If the tree-level kinetic mixing is set to zero, the possible loop-induced mixing vanishes on-shell.
- If there are particles charged under both the hidden and the SM  $U(1)$ , there will be loop-induced couplings between the dark photon and the SM.

# Coupling to the SM

Couplings to the Higgs can be generated via messenger particles charged under  $U(1)' \times U(1)$ .

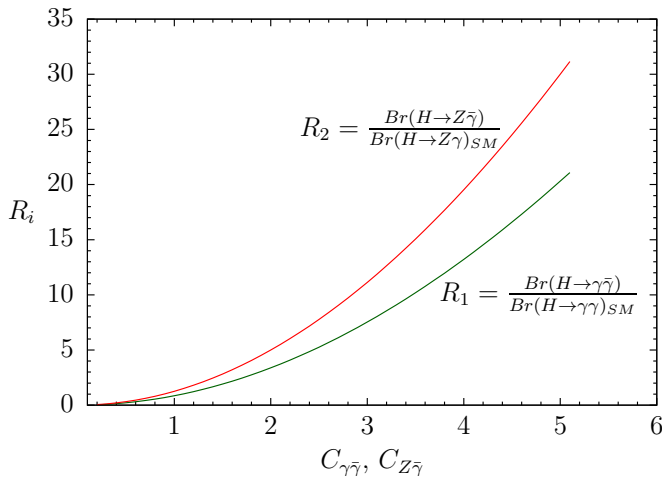


Similar diagrams will also contribute to the  $H \rightarrow \gamma\gamma$ ,  $H \rightarrow ZZ$  decay widths.

Effective Lagrangian:

$$\mathcal{L}_{\text{DP}_H} = \frac{\alpha}{\pi} \left( \frac{C_{\gamma\bar{\gamma}}}{v} \gamma^{\mu\nu} \bar{\gamma}_{\mu\nu} H + \frac{C_{Z\bar{\gamma}}}{v} Z^{\mu\nu} \bar{\gamma}_{\mu\nu} H + \frac{C_{\bar{\gamma}\gamma}}{v} \bar{\gamma}^{\mu\nu} \gamma_{\mu\nu} H \right)$$

# Higgs to New Physics Branching Ratios



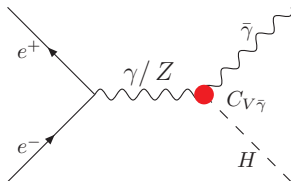
# Contents

## 1 Introduction

## 2 $e^+e^- \rightarrow H\bar{\gamma}$

# Higgs + Dark Photon production

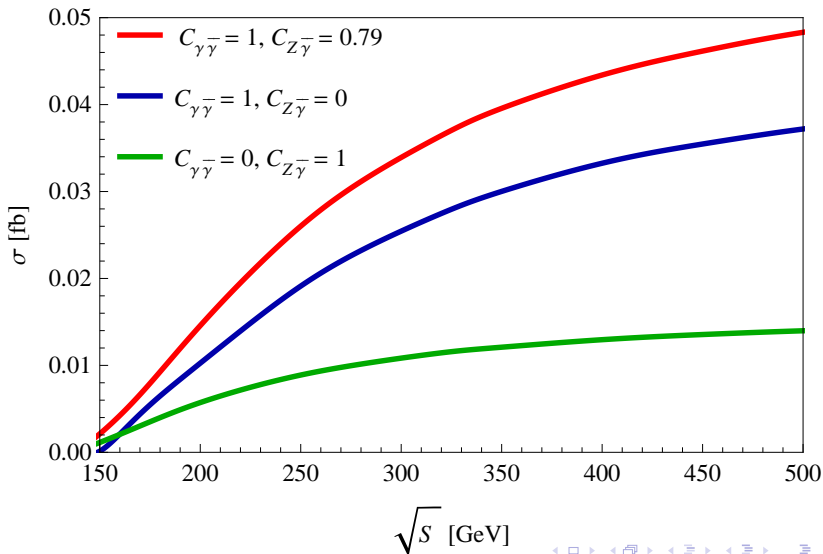
The process  $e^+e^- \rightarrow H\bar{\gamma}$  is generated by the s-channel diagram:



We look at the final state  $H \rightarrow b\bar{b}$ , so that the signal is two  $b$ -jets plus missing energy.



## Inclusive Production Cross Section



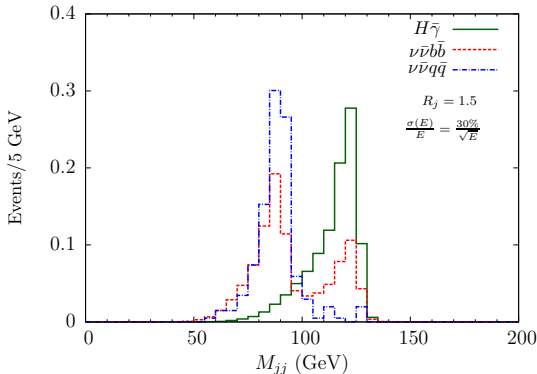
# Event Selection

Initial event selection:

- Two  $b$ -jets with  $p_T > 20$  GeV,  $|\eta| < 2.5$ , and  $\Delta R(bb) > 0.4$
- Missing energy  $\cancel{E} > 40$  GeV.

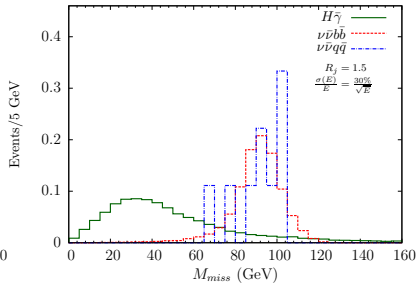
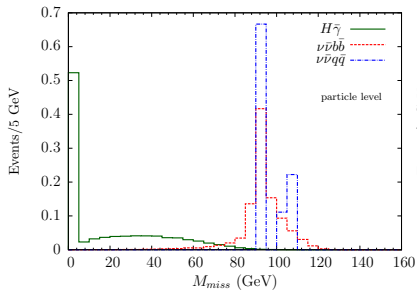
The main SM background is the  $\nu\bar{\nu}b\bar{b}$  production, including the on shell  $ZH \rightarrow \nu\bar{\nu}b\bar{b}$ . There is also a subdominant contribution from  $\nu\bar{\nu}q\bar{q}$ , where both light jets are misstaged as  $b$ -jets. We assume 80%  $b$ -tagging efficiency and a miss-tag rate of  $10^{-2}$  for light jets.

# Jet Pair Invariant Mass Distribution



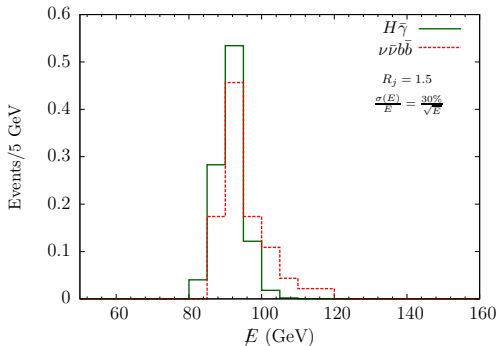
We require  $M_{jj}$  within 10% of the peak value of the simulated signal events. The distributions shown are normalized to one.

## Missing Mass Distribution



Missing mass  $M_{miss} = \sqrt{E^2 - \mathbf{p}^2}$  distributions for parton level events and after PYTHIA and jet energy smearing. We require  $M_{miss} < 40$  GeV.

# Missing Energy Distribution



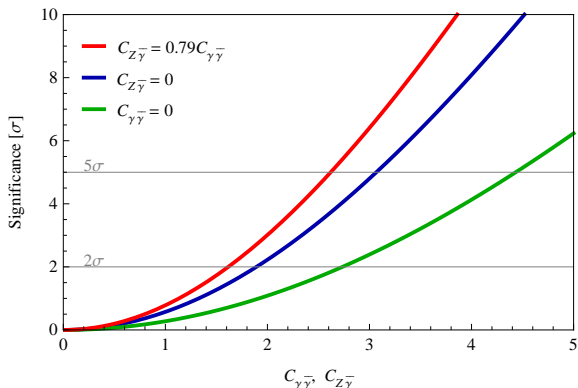
Missing energy distributions after applying the cuts on  $M_{jj}$  and  $M_{\text{miss}}$ . We require  $40 \text{ GeV} < \cancel{E} < 100 \text{ GeV}$ .

## Signal and Backgrounds After Cuts

Process	Cross section (fb)	Acceptance (%)
$H\bar{\gamma}$ ( $C_{Z\bar{\gamma}} = 0$ )	$10.1 \times 10^{-3} C_{\gamma\bar{\gamma}}^2$	17.3
$H\bar{\gamma}$ ( $C_{\gamma\bar{\gamma}} = 0$ )	$4.8 \times 10^{-3} C_{Z\bar{\gamma}}^2$	17.3
$H\bar{\gamma}$ ( $C_{Z\bar{\gamma}} = 0.79 C_{\gamma\bar{\gamma}}$ )	$13.8 \times 10^{-3} C_{\gamma\bar{\gamma}}^2$	17.3
SM $\nu\bar{\nu}b\bar{b}$	115.	0.08

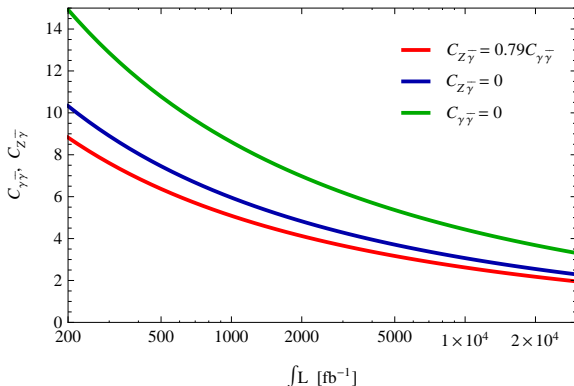
The cross section and acceptance after the cuts for the signal and SM background. The  $\nu\bar{\nu}q\bar{q}$  background is negligible.

# Discovery Reach



The projected sensitivity for the effective couplings for  $10^4 \text{ fb}^{-1}$  at a 240 GeV  $e^+e^-$  collider.

## Discovery Reach



The projected  $5\sigma$ -sensitivity for the effective couplings for a 240 GeV  $e^+e^-$  collider.