Higgs and Dark Photon Searches

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Dark Photons

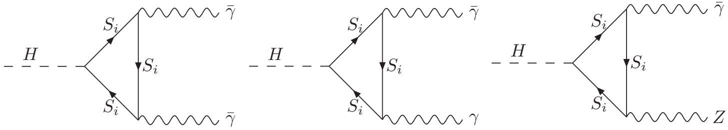
- Dark photons appear in several beyond the Standard Model physics scenarios, where a new $U(1)$ gauge group is added to the SM.
- Massive dark photons can be dark matter candidates, while massless dark photons can appear in models of self-interacting dark matter. (Cusp-vs-core, missing satellites.)
- 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

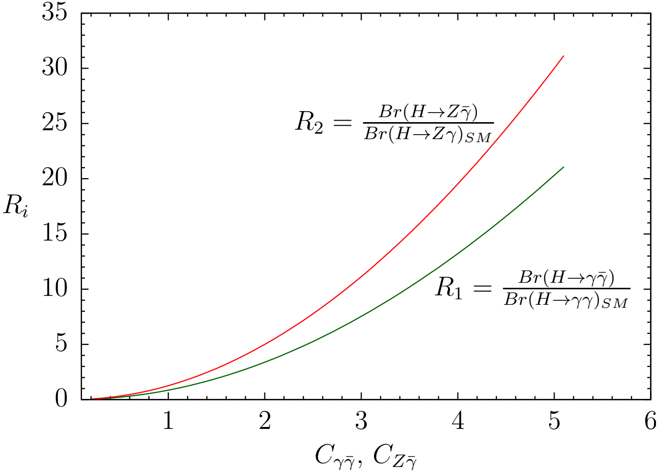
Couplings to the Higgs can be generated via messenger particles charged under $U(1)' \times U(1)$.



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

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

Higgs to New Physics Branching Ratios



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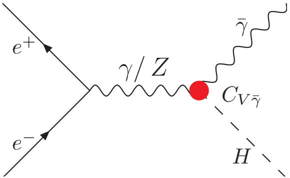
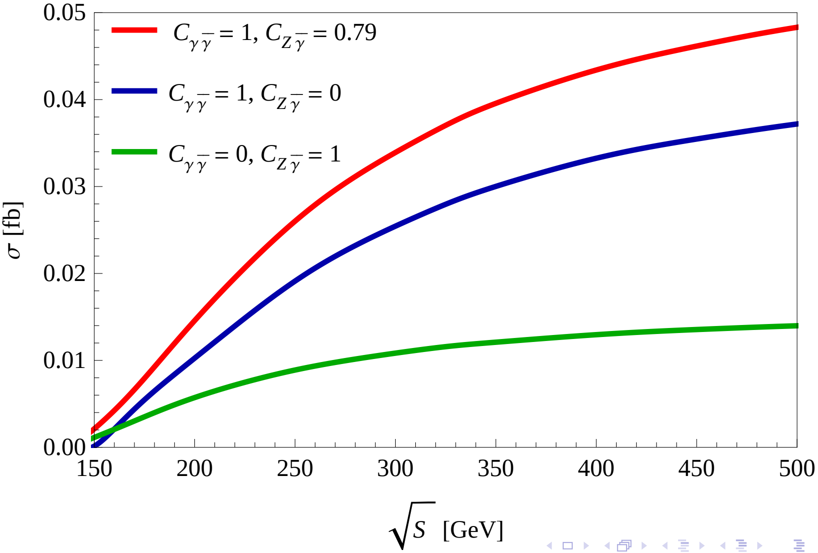
Higgs + Dark Photon production

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



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

Inclusive Production Cross Section



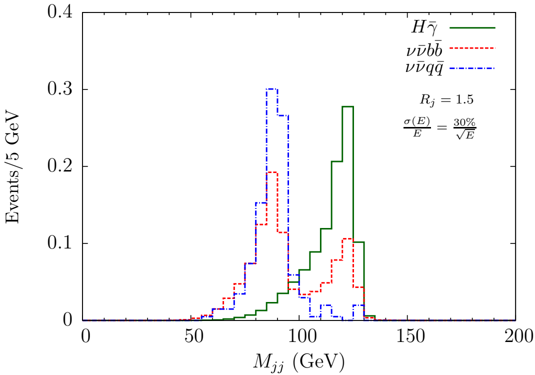
Event Selection

Initial event selection:

- Two b-jets with $p_T > 20$ GeV, $|\eta| < 2.5$, and $\Delta R(bb) > 0.4$
- Missing energy $\not{E} > 40$ GeV.

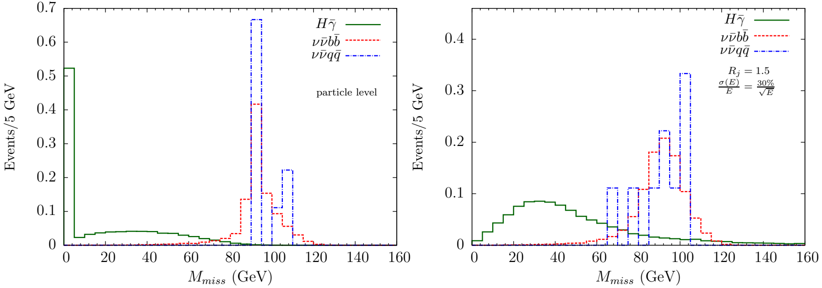
The main SM background is the $\nu\bar{\nu}b\bar{b}$ production, including the on shell $ZH \to \nu\bar{\nu}b\bar{b}$. There is also a subdominant contribution from $\nu\bar{\nu}q\bar{q}$, where both light jets are misstagged as b-jets. We assume 80% b-tagging efficiency and a miss-tag rate of 10^{-2}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

Jet Pair Invariant Mass Distribution



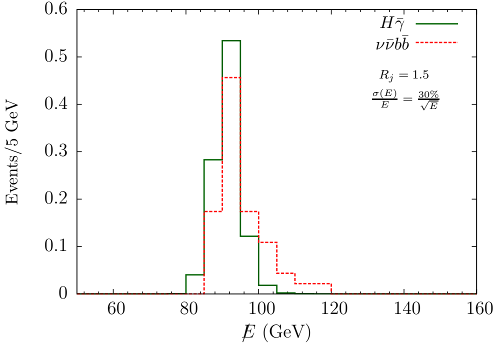
We require M_{jj} within 10% of the peak value of the simulated signal events. The distributions shown are normalized to one.

Missing Mass Distribution



Missing mass $M_{\mathrm{miss}} = \sqrt{\not{E}^2 - \not{p}^2}$ distributions for parton level events and after PYTHIA and jet energy smearing.
We require $M_{\mathrm{miss}} < 40$ GeV.

Missing Energy Distribution



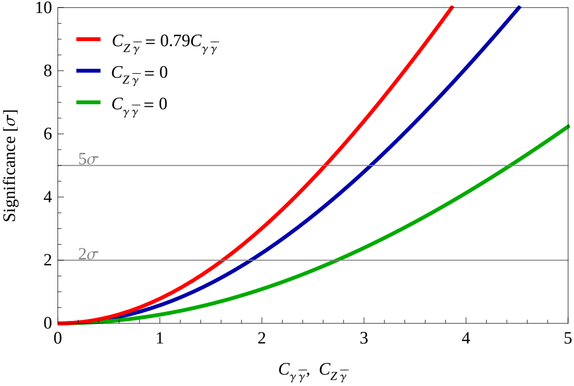
Missing energy distributions after applying the cuts on M_{jj} and $M_{\rm miss}$. We require 40 GeV $< \not{E} <$ 100 GeV.

Signal and Backgrounds After Cuts

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

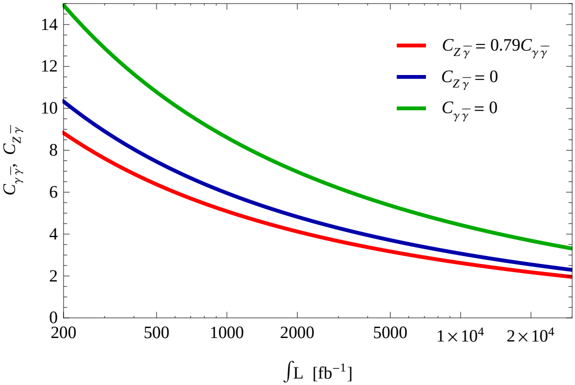
The cross section and acceptance after the cuts for the signal and SM background. The $\nu\bar{\nu}q\bar{q}$ background is negligible.

Discovery Reach



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

Discovery Reach



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

Conclusions

- The Higgs boson can act as a portal to a hidden sector responsible for e.g. dark matter, flavor hierarchy, EWSB etc.
- Production of a SM Higgs in association with a dark photon is a signature of such scenario.
- The effective coupling $C_{\gamma\bar{\gamma}}$ can be probed down to values corresponding to $BR(H \to \gamma\bar{\gamma}) \sim \mathcal{O}(1\%)$ in future e^+e^- colliders.