Sensitivity for $h \to Z_{(d)} Z_d$ at future colliders

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Proposal

Future colliders will search for new phenomena by probing the Standard Model either at greater precision [1] or at higher collision energies [2]. The impetus for this comes from phenomena that hint at physics beyond the Standard Model, like the observed dark matter content of the universe [3], apparent matter antimatter symmetry [4] and the lightness of the Higgs boson [5]. One possibility for why these phenomena have eluded observation at the LHC and previous colliders is that they are realized in beyond standard model sectors that exist close to the electroweak scale, but which are only weakly coupled to Standard Model particles. That is, they are realized as 'hidden' sectors [6].

One realization of such a hidden sector is an extra broken $U(1)_d$ gauge symmetry [7]. The hiddenness in this case can be realized by the $U(1)_d$ gauge boson and possible associated dark fermions not carrying any hypercharge coupling. However, two mechanisms allow for marginal couplings between the Standard Model and the $U(1)_d$ gauge boson Z_d. In general mixing between the Standard Model $U(1)$ hypercharge gauge boson and the Z_d are a priory not excluded [8, 9]. In this case of this mixing, Z_d attains an effective coupling to the Higgs boson [10]. Additionally, if the $U(1)_d$ mass is generated via a Higgs mechanism with a resulting dark scalar S, mixing between S and the Higgs is a priory possible too. Providing another another effective coupling between the Z_d and the Higgs boson [11].

This scenario allows the Higgs boson h to act as a window into the dark sector. Additionally, if there are no dark fermion states below the Z_d mass, the Z_d is expected decays back into Standard Model particles via the mixing with the Standard Model Z. Thus the existence of a Higgs coupled dark sector can leave the Higgs boson's invisible decay branching ratio at its Standard Model value. Instead the presence of the Z_d becomes apparent in the kinematic distribution of the Higgs boson's Standard Model final states.

Our group's expertise lies in searches of exotic Higgs decays, searches for $h \to ZZ_d$, $h \to Z_d Z_d$ as well as $S \to Z_d Z_d$ [12]. Our plan for Snowmass is to produce expected sensitivities for these searches at the ILC, and with additional person power also at other future colliders.

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