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Dark matter signals description in the scattering processes in the generalized Yukawa model

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According to present day results of the LHC experiment data analysis, there were no dark matter candidates found. The purpose of this work is to present a possible theoretical explanation why it could be so.
In our consideration, we propose a simple dark matter model of the heavy fermions described by the field ψ. A visible matter is modeled by the pair of scalar fields – light ϕ and heavy χ. These fields interact with dark matter through Yukawa's couplings. Besides, there is the doublet of fermions fields ψ_1 and ψ_2 interacting with ϕ and χ with different couplings. The Yukawa model is chosen as the simplest one for the interaction carrier, which allows us to take into consideration the qualitatively important effect of the coupling constant values. At the same time, the transformation properties of visible fields are not accounted for as inessential. We start from the Lagrangian:

$$\mathcal{L} = \frac{1}{2}\left[(\partial_\nu \phi)^2 - \mu^2\phi^2\right] + \frac{1}{2}\left[(\partial_\nu \chi)^2 - \Lambda^2\chi^2\right] + \tag{1}$$

$$+ \sum_{a=1;2} \bar{\psi}_a \left(i\gamma^\nu \partial_\nu - g_\phi \phi - g_\chi \chi - m\right)\psi_a + \bar{\Psi}\left(i\gamma^\nu\partial_\nu - M\right)\Psi - \tag{2}$$

$$-\lambda\phi^4 + \rho\phi^2\chi^2 - \xi\chi^4 - G_\chi\bar{\Psi}\chi\Psi. \tag{3}$$

As we see, fermions interact with each other via the interchange of scalar particles. It can be considered as the effective four-fermions vertexes. Probability of certain scenario of interaction – through ϕ or χ field – depends on the mixing angle between these two fields. Moreover, the polarization tensor of χ contains also the contribution of the Ψ fermion loop. Hence, the differential cross-section σ of the four-fermions interaction depends on the mass of the dark matter particle and the mixing angle between scalar fields. We set this angle to be equaled 10^{-3}-10^{-4}, while the mass of Ψ is much bigger than the mass of ψ_1 or ψ_2. Because of this, a cross-section width becomes significant, so that such a signal can be missed in the data analysis on the LHC as a noise. This is probably because the narrow width approximation is applied in processing of data treating applied by Collaborations. Taking into account the facts listed above, the differential cross-section of the four-fermion interaction is obtained and its spatial angular dependence is investigated. The renormalisations of the couplings and masses are fulfilled. We investigate how the σ changes dependently on the Ψ field mass and the mixing angle of scalar fields. Process $\bar{\psi}_1\psi_1 \to \bar{\psi}_2\psi_2$ is considered.

A. Gulov, A. Kozhushko, V. Skalozub. Global search for the Z' boson in scattering processes - Дніпро: ЛІРА, 2018. - 124 с.

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