

The effect of the scalar unparticle on the production of Higgs–radion at high energy colliders

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Abstract

An attempt is made to present the influence of the scalar unparticle on some scattering processes in the Randall–Sundrum model. The contribution of the scalar unparticle on the production of Higgs–radion at high energy colliders is studied in detail. We evaluate the production cross-sections in the electron–positron (e^+e^-), photon–photon ($\gamma\gamma$) and gluon–gluon (gg) collisions, which depend strongly on the collision energy \sqrt{s} , the scaling dimension d_U of the unparticle operator \mathcal{O}_U and the energy scale Λ_U . Numerical evaluation shows that the cross-sections for the pair production of scalar particles are much larger than that of the associated production of the scalar particle with unparticle under the same conditions.

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1. Introduction

The Standard model (SM) is the successful model in describing the elementary particle physics. Recently, the 125 GeV Higgs is discovered by the ATLAS and CMS collaborations [1,2], which has completed the particle spectrum of the SM. Although the SM has been considered to be successful model, the model suffers from many theoretical drawbacks. In 1999, Lisa Randall and Raman Sundrum suggested the Randall–Sundrum (RS) model to extend the SM and solve the hierarchy problem naturally [3,4]. The RS setup involves two three-branes bounding

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a slice of 5D compact anti-de Sitter space. Gravity is localized at the UV brane, while the SM fields are supposed to be localized at the IR brane. The separation between the two 3-branes leads directly to the existence of an additional scalar called the radion (ϕ), corresponding to the quantum fluctuations of the distance between the two 3-branes [5–7].

In the Lagrangian of the Standard model, the scale invariance is broken at or above the electroweak scale [8,9]. The scale invariant sector has been considered as an effective theory at TeV scale and that if it exists, it is made of unparticle suggested by Geogri [10,11]. Based on the Banks–Zaks theory [12], unparticle stuff with nontrivial scaling dimension is considered to exist in our world. The invariant Banks–Zaks field can be connected to the SM particles [13]. Recently, the possibility of the unparticle has been studied with CMS detector at the LHC [14,15].

The effects of unparticle on properties of high energy colliders have been intensively studied in Refs. [16–26]. However, the influence of scalar unparticle on the production of particles at the high energy colliders have not yet been concerned in the RS model. In this work, the contribution of the scalar unparticle on the production of Higgs–radion at the e^+e^- , $\gamma\gamma$ and gg colliders are studied in detail. The layout of this paper is as follows. In Section 2, we give a review of the RS model and the mixing of Higgs–radion. The contribution of the scalar unparticle on the production of Higgs–radion at high energy colliders are calculated in Section 3. Finally, we summarize our results and make conclusions in Section 4.

2. A review of Randall–Sundrum model and the mixing of Higgs–radion

The RS model is based on a 5D spacetime with non-factorizable geometry. The single extra dimension is compactified on an S^1/Z_2 orbifold of which two fixed points accommodate two three-branes (4D hyper-surfaces), the UV brane and the IR brane. The four dimensional effective action is obtained by integrating out the extra dimension. The classical action describing the above set-up is given by [3]

$$S = S_{gravity} + S_{IR} + S_{UV}, \quad (1)$$

$$S_{gravity} = \int d^5x \sqrt{-G} \left(-\Lambda + 2M^3 R \right), \quad (2a)$$

$$S_{IR} = \int d^4x \sqrt{-g_{IR}} (\mathcal{L}_{IR} - V_{IR}), \quad (2b)$$

$$S_{UV} = \int d^4x \sqrt{-g_{UV}} (\mathcal{L}_{UV} - V_{UV}), \quad (2c)$$

where M is the five dimensional Planck scale, $G = \det G_{MN}$, Λ is a bulk cosmological constant, R is the 5D Ricci scalar. In the RS model, the values of the bare parameters are determined by the Planck scale and the applicable value for size of the extra dimension is assessed by $kr_c\pi \simeq 35$ (r_c – the compactification radius and k – the bulk curvature). Thus the weak and the gravity scales can be naturally generated. Consequently, the hierarchy problem is addressed. The gravity-scalar mixing is described by the following action [5]

$$S_\xi = \xi \int d^4x \sqrt{g_{vis}} R(g_{vis}) \hat{H}^+ \hat{H}, \quad (3)$$

where ξ is the mixing parameter, $R(g_{vis})$ is the Ricci scalar for the metric $g_{vis}^{\mu\nu} = \Omega_b^2(x)(\eta^{\mu\nu} + \varepsilon h^{\mu\nu})$ induced on the visible brane, $\Omega_b(x) = e^{-kr_c\pi} (1 + \frac{\phi_0}{\Lambda_\phi})$ is the warp factor, ϕ_0 is the canonically normalized massless radion field, \hat{H} is the Higgs field in the 5D context before rescaling to

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