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Original Article

Radion Effects on Bhabha Scattering

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Abstract: In this article, we have considered the possible signatures of radion through Bhabha scattering. The numerical results show that the total cross section with radion effects are about 1.43-19.70 pb.

This could have important implications for radion searches and for the measurement of the cross-section of the Bhabha scattering.

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Keywords: Radion, Bhabha scattering.

1. Introduction

As well known, there are many convincing evidences that 80% of the matters in the universe is composed of dark matters (DM).

In several extensions of the Standard Model, radion or u-boson is postulated [1-5].

On the other hand, the Randall-Sundrum (RS) Model is one of the attractive candidates to solve the gauge hierarchy problem in the Standard Model Many works have been done on the phenomenological aspects of radion in various colliders [6-9].

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As we well known, Bhabha scattering is among the key processes in particle physics. Recently, the authors have presented the results of the SANC group on the complete one-loop calculation of the electroweak radiative corrections to Bhabha scattering with polarized beams [10].

Very recently, we have investigated unparticle effects on Bhabha scattering [11] and on axion-like particles production in e^+e^- collisions [12]. In this paper, we investigate virtual radion effects via Bhabha scattering.

2. Radion Exchange and Cross Section

In this section, we will derive a formula for the cross-section of the process presented in Figure 2, which shows on of the possible processes, where a radion may intermediate a creation of e^+e^- in the e^+e^- scattering.

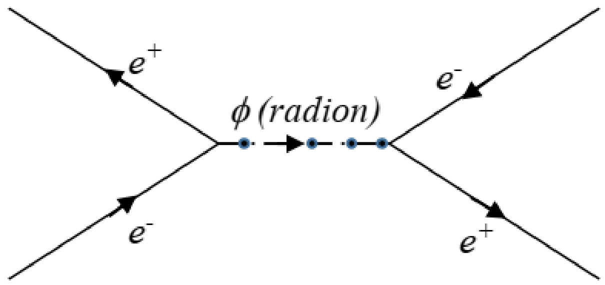

Fig.1. Feynman diagram for Bhabha scattering via radion

The propagator of a radion has the form

$$D_\phi(x) = \frac{-i}{q^2 - m_\phi^2 + i\varepsilon} \tag{1}$$

We need to note that the radion – electron – positron vertex

$$V_{\phi e^- e^+} = -\frac{3i}{2\langle\phi\rangle}\left(\hat{p}_1 - \hat{p}_2 - \frac{8}{3}m_e\right). \tag{2}$$

From eqs. (1) and (2), we obtain the amplitude for this process as follows

$$M = \bar{v}(p_2)\frac{-3i}{2\langle\phi\rangle}\left(\hat{p}_1 - \hat{p}_2 - \frac{8}{3}m_e\right)u(p_1)\frac{-i}{q^2 - m_\phi^2}\bar{u}(k_1)\frac{-3i}{2\langle\phi\rangle}\left(\hat{k}_1 - \hat{k}_2 - \frac{8}{3}m_e\right)v(k_2). \tag{3}$$

From this, we obtain

$$|M|^2 = \frac{81}{\langle\varphi\rangle^4\left(q^2 - m_\varphi^2\right)^2}\Big[p_1^2\left(p_1.p_2\right) - 2p_1^2p_2^2 + p_2^2\left(p_1.p_2\right)$$
$$+\frac{13}{3}m_e^2p_2^2 + \frac{13}{3}m_e^2p_1^2 - \frac{14}{9}m_e^2\left(p_1.p_2\right)\Big]\Big[k_1^2\left(k_1.k_2\right)$$
$$-2k_1^2k_2^2 + k_2^2\left(k_1.k_2\right) - \frac{14}{9}m_e^2\left(k_1.k_2\right) + \frac{13}{3}m_e^2k_2^2 + \frac{13}{3}m_e^2k_1^2\Big]. \tag{4}$$

In center of mass frame, four – moments of particles are defined

$$p_1 = (E, \vec{p}); p_2 = (E, -\vec{p}); k_1 = (E, \vec{k}); k_2 = (E, -\vec{k})$$

and
$$q^2 = (p_1 + k_2)^2 = 4E^2 = S$$

where S is the center of mass energy. Neglecting the mass of electron

$$|M|^2 = \frac{256 m_e^4}{\langle\phi\rangle^4 (S - m_\phi^2)^2} \frac{S^2}{16} (1 + \cos\theta)^2 \quad (5)$$

the differential cross section is

$$\frac{d\sigma}{d\Omega} = \frac{m_e^4 S}{4\langle\phi\rangle^4 \pi (S - m_\phi^2)^2} (1 + \cos\theta)^2 . \quad (6)$$

Therefore, the total cross section is

$$\sigma = \frac{2}{3} \frac{m_e^4 S}{\langle\phi\rangle^4 \pi (S - m_\phi^2)^2} . \quad (7)$$

Finally, from (6) and (7) we get

$$\frac{d\sigma}{\sigma d(\cos\theta)} = \frac{3}{8} (1 + \cos\theta)^2 . \quad (8)$$

In Fig.2, we plot the $\frac{d\sigma}{\sigma d(\cos\theta)}$ with respect to $\cos\theta$. As we can observe from Fig.2 the $\frac{d\sigma}{\sigma d(\cos\theta)}$ has a minimum for $\cos\theta = -1$

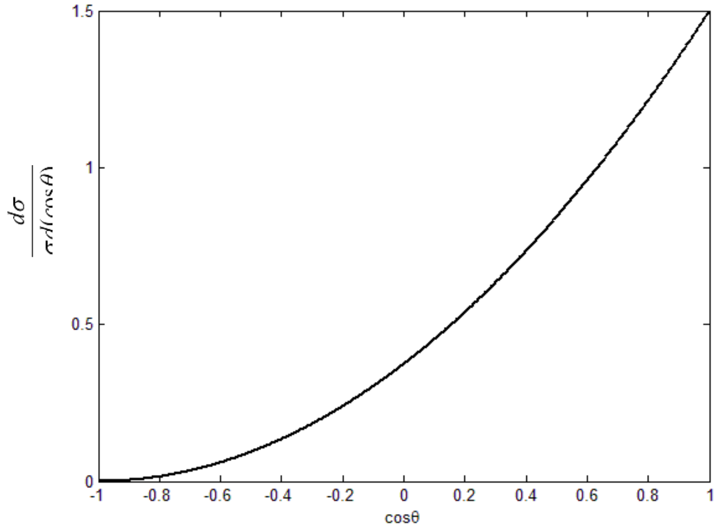

Fig.2. The $\frac{d\sigma}{\sigma d(\cos\theta)}$ with respect to $\cos\theta$.

Table 1. The $\frac{d\sigma}{\sigma d(\cos\theta)}$ at different $\cos\theta$.

$\cos\theta$	-1	-0.8	-0.5	0	0.5	0.8	1
$\frac{d\sigma}{\sigma d(\cos\theta)}$	0	0.015	0.09375	0.375	0.84375	1.25	1.5

Let us now turn to the numerical analysis. We take $\langle\phi\rangle = 1TeV; m_\phi = 200GeV$ as input parameters. In Fig. 3, we plot the differential cross sections and the total cross sections as a function of $\cos\theta$.

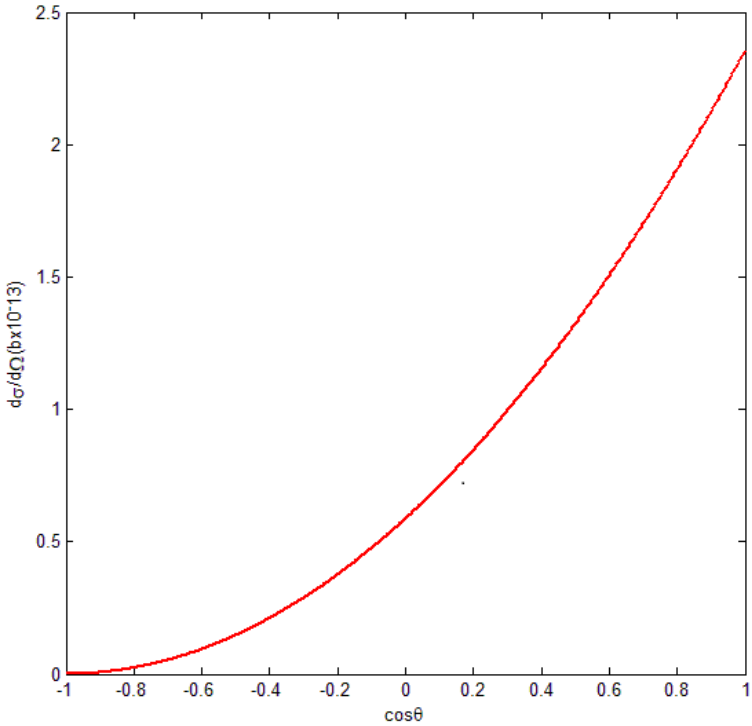

Fig. 3. The variation of $\frac{d\sigma}{d\Omega}$ as a function of $\cos\theta$.

As we see from the Fig.3 that the radion effects quickly go up as $cos\theta$ becomes larger.

In the following, we give the numerical values of the differential cross section with radion effects in Table 2.

Table 2. The differential cross sections with radion effects at different $\cos\theta$

$\cos\theta$	-1	-0.8	-0.7	-0.5	0	0.5	0.7	0.8	1
$\frac{d\sigma}{d\Omega}(pb)$	0	0.00299	0.00674	0.01873	0.07492	0.1685	0.2165	0.2427	0.2996

For the next step, we give the numerical values of the total cross – sections with radion effects at different energies in Figure 4 and Table 3.

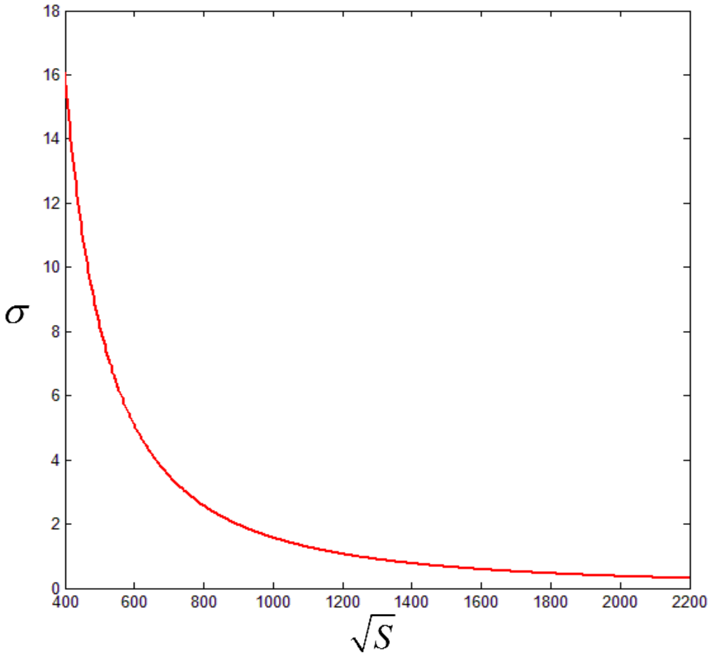

Fig.4. The variation of $\boldsymbol{\sigma}$ as a function of $\sqrt{S}$. Here, we take $\langle\phi\rangle = 1TeV; m_\phi = 200GeV$.

Table 3. The total cross sections with radion effects at different energies

$\sqrt{S}$ (GeV)	600	900	1200	1500	1800	2000
$\sqrt{S}$ (pb)	19.70	7.65	4.12	2.85	1.77	1.43

As we can observe from Fig.4, the σ decreases with increasing $\sqrt{S}$. Furthermore, we see from the table 3 that the total cross-sections should be about 1.43 – 19.70 pb. Interestingly, the cross-sections in Bhabha scattering via radion exchange are larger than those in Bhabha scattering via unparticle exchange by 4.65 – 35.75 times of magnitude.

To conclude, in this paper we have investigated the radion effects on Bhabha scattering. We have found that the effects of the radion can be strong. Our results are attractive because of possible connection to radion. We hope that future experiments will confirm the existence of radion. Works along these lines are in progress.

Acknowledgements

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