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Model with possible fields generated by higher dimensional superconducting cosmic strings

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Abstract

In this paper we investigate the theory behind the results in Roy and Bander (2009) [11]. In Roy and Bander (2009) [11] we calculated the magnetic dipole moment of the muon and the electric dipole moments of the muon, electron and the neutron (in a simple quark model) to first order in loop corrections in both S_1 and $S_1\backslash \mathbf{Z}_2$. In these calculations in Roy and Bander (2009) [11] we investigated the effect of fields possibly generated by higher dimensional superconducting cosmic strings (Witten, 1985 [12]) that interact with the charged fields on the manifold. In comparing the results in Roy and Bander (2009) [11] with standard model precision tests for the electric and magnetic dipole moments of the various fermions in the model, we were able to obtain upper limits on the compactification size as well as an upper limit for the new b parameter. This new model has several important phenomenological implications. One of these is a theoretical phenomenon that is a source for parity violation in QED processes as well as a new source for symmetry breaking. In this paper we will be presenting the theory of the model in the compactification $M_4 \otimes S_1\backslash \mathbf{Z}_2$ (orbifold geometry). The theory predicts nontrivial couplings of the Higgs and lepton fields to the SU(2) gauge bosons, these differ from the standard model couplings. The theory also expounds upon the standard model results for the masses of the charged fields in the model and has other significant physical implications. The model is rooted in the notion that very light charged particles traveling next to superconducting cosmic strings (Witten, 1985) [12] at distances on the order of the compactification size of the extra dimensional space, could generate currents that intern can create magnetic fields that interact with the particle fields on the UED manifold.

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1. Introduction

In this paper we examine the consequences of magnetic fields that could be produced by light charged particles traveling in proximity to superconducting cosmic strings [12], where the separation scale between the particle and the string is on the order of the compactification size of $S_1\backslash \mathbf{Z}_2$ [1–3]. These external magnetic fields will have some flux associated with the manifold of the model $M_4 \otimes S_1\backslash \mathbf{Z}_2$. In the limit of very small compactification size for this geometry, the predominant contribution of the magnetic flux will come from fields lines that are perpendicular to the extra coordinate (think of the 5-D manifold as a right cylinder) and are approximately static. This means that the dimensionality of the entire space for the model, in this limit, would be minimally 6-D (a five dimensional manifold and one more dimension for the field lines perpendicular to the 5th component of the manifold). The particle fields of the model are confined to the 5-D manifold. In this limit of small compactification size, we are only concerned with the effects of the magnetic fields produced by the string on the particle fields of the model contained on our 5-D manifold $M_4 \otimes S_1\backslash \mathbf{Z}_2$. Therefore, we will not be concerned of the actual dynamics, or the higher dimensional embedding, of the strings [15,16].

These fluxes affect the charged fields with nontrivial periodicities, where in general, these nontrivial periodicities are not simply a shift in mode number. With these fluxes, a new parameter is introduced, the flux parameter. This addition to an $SU(2) \otimes U(1)$ electroweak model in $M_4 \otimes S_1\backslash \mathbf{Z}_2$ provides a novel mechanism for parity violation in QED processes and thus affects the EDM's of various charged fermions in the model [11]. In [11] the fluxes gave a smaller upper limit for the EDM's of the muon than the current values [9] as well as comparable constraints of the compactification size for the geometry of the model.

The weak gauge bosons were neglected in the analysis in [11] because the weak mediated contributions to this geometry are a factor of $(m_{\text{lepton}}/M_W)^2$ smaller than the pure QED contributions for the anomalous magnetic dipole moment to one loop as can be seen in Eq. (48) of [7]. The pertinent Higgs diagrams were also included in the analysis in the derivation of Eq. (48) of [7]. Even with the inclusion of the fluxes, this suppression factor remains, thus the weak mediated and Higgs diagrams were ignored in the analysis in [11]. The fluxes also allow for a new way of $SU(2) \otimes U(1)$ symmetry breaking. In addition, we will find nontrivial couplings of the Higgs and lepton fields to the SU(2) gauge bosons due to the fluxes. The model we present here gives a physical source for these nontrivial periodicities. These nontrivial periodicities only affect the charged particles in the theory in a nonarbitrary way, we do not add these nontrivial periodicities in an ad-hoc fashion. The fluxes introduced in this paper have several phenomenological implications with respect to experiment as stated above.

We will present the masses of all the fields in the model in both the bulk 5-D space and also in the effective brane. The masses of the charged fields in the model will have flux dependence and in the zero mode limit these expressions expound upon the standard model results. Yet another interesting consequence of this new model is the solution to the degrees of freedom problem which arises when the charged W's acquire a mass before any Higgs mechanism due to the external flux.

Another important implication of the theory is the Higgs mechanism itself. We will see that a more complicated gauge is required for the mechanism and that this gauge goes smoothly into the unitary gauge in the limit as the flux goes to zero. The exact closed form expression for the gauge does not exist. Addition of leptons and quarks to the model proves challenging due to the nontrivial periodicity of the fields as we will see in Section 4. With this particular dimensionality we will also have unwanted 5th components of the gauge fields. These unwanted components are