Licentiate Thesis

Astrophysical and Collider Signatures of Extra Dimensions

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Cover illustration: A Feynman diagram contributing to the three leptons and large missing energy signal, in a model where right-handed neutrinos propagate in an extra dimension. Taken from Ref. [3].

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Abstract

In recent years, there has been a large interest in the subject of extra dimensions in particle physics. In particular, a number of models have been suggested which provide solutions to some of the problems with the current Standard Model of particle physics, and which could be tested in the next generation of high-energy experiments. Among the most important of these models are the large extra dimensions model by Arkani-Hamed, Dimopoulos, and Dvali, the universal extra dimensions model, and models allowing right-handed neutrinos to propagate in the extra dimensions. In this thesis, we study phenomenological aspects of these three models, or simple modifications of them.

The Arkani-Hamed–Dimopoulos–Dvali model attempts to solve the gauge hierarchy problem through a volume suppression of Newton's gravitational constant, lowering the fundamental Planck scale down to the electroweak scale. However, this solution is unsatisfactory in the sense that it introduces a new scale through the radius of the extra dimensions, which is unnaturally large compared to the electroweak scale. It has been suggested that a similar model, with a hyperbolic internal space, could provide a more satisfactory solution to the problem, and we consider the hadron collider phenomenology of such a model.

One of the main features of the universal extra dimensions model is the existence of a potential dark matter candidate, the lightest Kaluza–Klein particle. In the so-called minimal universal extra dimensions model, the identity of this particle is well defined, but in more general models, it could change. We consider the indirect neutrino detection signals for a number of different such dark matter candidates, in a five- as well as a six-dimensional model.

Finally, right-handed neutrinos propagating in extra dimensions could provide an alternative scenario to the seesaw mechanism for generating small masses for the left-handed neutrinos. Since extra-dimensional models are non-renormalizable, the Kaluza–Klein tower is expected to be cut off at some high-energy scale. We study a model where a Majorana neutrino at this cutoff scale is responsible for the generation of the light neutrino masses, while the lower modes of the tower could possibly be observed in the Large Hadron Collider. We investigate the bounds on the model from non-unitarity effects, as well as collider signatures of the model.

Key words: Extra dimensional quantum field theories, universal extra dimensions, Kaluza–Klein dark matter, Arkani-Hamed–Dimopoulos–Dvali model, hierarchy problem, neutrino mass, seesaw mechanism, Large Hadron Collider phenomenology.

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