外国語要旨

Phenomenology of the Kaluza-Klein Graviton

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The Standard Model (SM) describes behavior of quantum fields under three fundamental interactions and the Higgs mechanism. The SM explains experimental results well. On the other hand, there are unresolved problems and phenomena, which the SM cannot explain. Among them, we focus on the gauge hierarchy problem and dark matter in this thesis. Extra dimensional models, the large extra dimensional model by Arkani-Hamed, Dimopoulos, and Dvali (ADD), and the warped extra dimensional model by Randall and Sundrum (RS), are candidates for solving the gauge hierarchy problem. We focus on these models, and an extended RS model containing dark matter. These extra dimensional models predict massive spin-2 particles, Kaluza-Klein gravitons (KK gravitons) due to gravity propagating in the extra dimension(s) and compactification of extra dimension(s).

First, we studied constraints on the parameter space of the ADD model and the RS model by considering the forward detectors at the Large Hadron Collider (LHC). Second, we focused on the RS model with dark matter particles, and constrained this model by using current results of ATLAS and CMS experiments at the LHC. Finally, we compared these constraints.

The forward detectors can indirectly observe processes that include the photon as an initial state. When a proton emits quasi-real photons, it does not decay into partons and can be detected by the forward detector. In this way, the forward detector can be used to determine whether the "intact" proton process occurred or not. However, pile-up effects can involve other processes in which the proton decays into partons. We also consider this effect, and constrain the extra-dimensional models accordingly. We focus on the process, $pp \to p\gamma p \to p\gamma q/gX$, where p is a proton, γ is a photon, q is a quark or anti-quark, g is a gluon, and X indicates unmeasured and unspecified particles. We assume the p-p collision at center of mass energy of 13 TeV, and an integrated luminosity 200/fb at the LHC. We found that the cut-off scale for the ADD model is $\Lambda_T = 6.3$ TeV at 95% confidence level. Current results (March, 2017) by the CMS group (13 TeV LHC with an integrated luminosity 2.6/fb) give a stronger constraint of $\Lambda_T = 9.4$ TeV at a 95% confidence level. In the RS model, for the first excited KK graviton $m_Y = 2.0$ (0.5) TeV, the scale parameter $\Lambda = 5.2$ (13) TeV is a lower limit.

In the RS model with dark matter particles, the KK graviton is a mediator between dark matter particles and SM particles. Dark matter particles have not yet been discovered at current experimental sensitivities. So far, only gravitational interactions have been attributed to dark matter, so we have considered KK gravitons in an extra-dimensional model as a possible mediator. We considered, (1) resonance of the KK graviton decaying into SM particles (resonance searches), and (2) KK gravitons decaying into dark matter and neutrinos with mono/multi jet(s) (missing energy searches) as signals, and then we determined constraints using current results from the LHC. For (1) the KK gravitons decaying into photons and leptons cases gave the strongest constraint. Using current results from the ATLAS and CMS experiments at the LHC, with the center of mass energies of 8 TeV and 13 TeV, the constraints for Λ are, $\Lambda \gtrsim 100$ TeV for $m_Y = 100\text{GeV}\sim 1$ TeV, $\Lambda = 54$ TeV for $m_Y =2$ TeV, and $\Lambda = 10$ (6) TeV for $m_Y = 4$ (4.5) TeV. (2) involves searches with missing energy, and this gives weaker constraints than the resonance searches in (1).

Constraints on the RS model parameters from the forward detectors are weaker than the constraints determined from the resonance signal of (1). For the scattering process we have focused on, KK graviton searches of the ADD model and the RS model via the forward detectors are not adequate. One reason is the background enhancement caused by pile up events. Another reason is that we focused on t-channel processes with a KK graviton propagator but that KK graviton resonance (s-channel) can have large scattering cross sections for the RS model with TeV scale KK graviton mass. In fact, we confirmed the KK graviton resonance signal (1) gave the strongest constraints on the RS model parameters. For the RS model, when KK graviton interactions with photons and leptons are suppressed, missing energy searches (2) can be competitive for low mass regions of the KK graviton.