JOURNAL OF CRITICAL REVIEWS

ISSN- 2394-5125 VOL 08, ISSUE 02, 2021

COLLIDER SIGNATURES OF NON-MINIMAL UNIVERSAL EXTRA DIMENSIONAL MODEL

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Abstract

Universal Extra Dimension models are those that have extra dimensions that are almost flat and in which all of the conventional model fields can move (UED). The Fourier modes of a field with more dimensions, known as Kaluza-Klein (KK) modes, get bigger, too. I think it's one of the particles from the standard model (SM), like quarks and leptons and gauge bosons. All of these have been found in particle physics experiments at the Large Hadron Collider. In two different ways, we tried to limit the nmUED parameter space. R-1 has stayed the same at 1 TeV. Even at 13 TeV, R-1 values above 1 TeV will push the masses of KK-excitations down to a point where their production cross-sections will be very small, even though they will be very big. As a result, we don't do that kind of thing anymore. Here, we'll show how the parameter space in scenario A is limited by both the data from Run I and from Run II of the LHC in the next parts. The spin-independent proton-LKP scattering cross-section (SI) was calculated and compared to the results of the LUX and XENON1T experiments, which were both done by the same group of people. Direct scattering can happen between the DM and a nucleon if there is a quark exchange in the t-channel or in the s-channel, which is where the h-exchange takes place. The main goal of this study was to look for signs of the nmUED model at the LHC. It turns out that no one has looked for signals from nmUED models at the LHC. As a result, for our purposes, we used model-independent restrictions on new physics that came from other BSM searches. It's the radius of compactification R and the coefficients of a BLT that are important are completely responsible for the particle spectrum in the model.

Keywords: collider, signature, non-minimal, universal, extra, dimensional, model, etc

1. INTRODUCTION

Universal Extra Dimension models are those that have extra dimensions that are almost flat and in which all of the conventional model fields can move (UED). The Fourier modes of a field with more dimensions, known as Kaluza-Klein (KK) modes, get bigger, too. I think it's one of the particles from the standard model (SM), like quarks and leptons and gauge bosons. All of these have been found in particle physics experiments at the Large Hadron Collider. As shown in the figure, two throats can be compacted into one. This results in an extra dimension that is "symmetric" under reflection about its midpoint, which can be seen as the result of two throats being compacted together. This is called KK-parity. For the nth KK mode, Pn = (1)n is given. Parity conservation prevents the lightest KK parity odd particle (LKP) from decaying into only zero modes because a standard model particle is a zero mode with an even parity. This makes the LKP inherently stable. They are often seen as dark matter theories because they have this feature (LKP stability) (DM). KK dark matter could come from the first excited state of a U(1)Y gauge boson called B1, which is the most common candidate for this (MUED).

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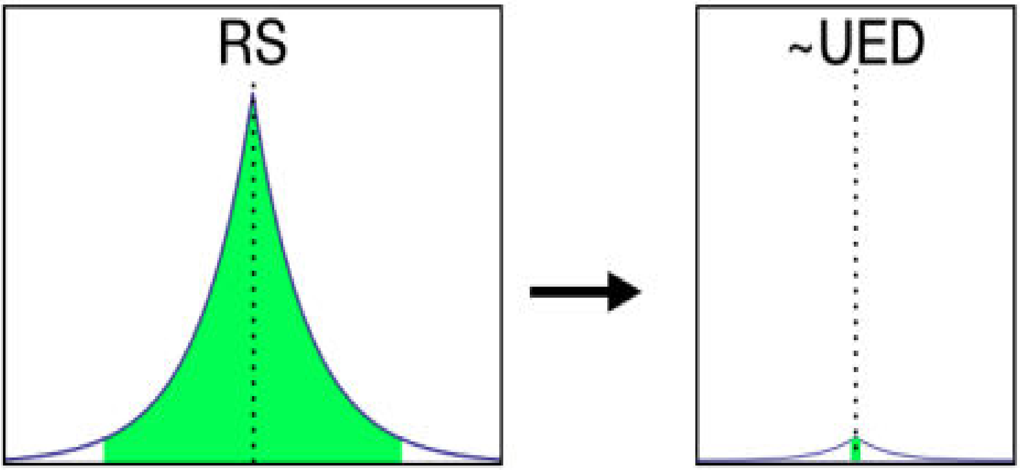

Figure 1: An effective description of a RS model after integrating out the part in the vicinity of UV could be regarded as a UED model

1.1 Exploring non minimal Universal Extra Dimensional model at the LHC

The discovery of the Higgs boson at the LHC has once again shown that the Standard model is the best way to think about the universe (SM). However, because of two very strong experiments, a framework outside of the SM (BSM) is more important than ever. The first is, of course, the signs of neutrino masses that aren't zero. The second is evidence that Dark Matter is real (DM). Extra-dimensional models, which have been suggested as an alternative to supersymmetry in order to solve the SM's hierarchy problem, also work well for DM and neutrino mass theories. If you want to learn more about extra dimensions, we're especially interested in a model called the Universal Extra Dimensional (UED). It's just a 4 + 1 version of the SM. In a simple model, the extra space-like dimension is compacted on a circle of radius R, with R1 being the energy scale over which the new dynamics that emerge outside the SM would be possible to see. UED is different because the common SM particles have Kaluza Klein (KK) modes. It is the mass of KK-modes at the nth level. In math, the number n is called the KK number, and it's just quantized momentum in the y direction, which is called n. A Z2 (y y) symmetry is put in place in order to make chiral fermions and get rid of some unwanted degrees of freedom at the zero level, which is the same level as the SM. Orbifolding is the name of this method. At the nth level of KK, orbifolding makes a KK-parity called (1)n. KK-parity is why the lightest of all the KK-modes is so big and often doesn't have a lot to do with each other. This makes the KK-parity very stable, could be a candidate for DM. At each KK-level, the masses of SM particles' KKexcitations are tightly spaced. The importance of radial mass adjustment cannot be overstated, yet it is simple to implement. The radiative corrections you use an effective theory, on the other hand, you have to pay attention to the theory's (unknown) energy cut-off. This makes the theory's rules unpredictable. There is a loss of momentum conservation along the 5th dimension because of orb folding boundary constraints It means that if there are corrections that don't have zero mass, they have to be concentrated in a small area limits dimensions. At the cut-off scale, the minimal form of the UED model makes several unique assumptions that result in vanishing border radiative corrections.

2. REVIEW OF THE LITERATURE

Avnish Yadav, Kirtiman Ghosh, Tapoja Jha, and Saurabh Niyogi (2021) UED It's a well-thought-out and well-researched idea for (universal extra dimension). A dark matter (DM) candidate is found in the particle spectrum of UED, especially the lightest level-one Kaluza-Klein particle. This is one of the main reasons why it makes sense to look for dark matter. There are only two things you need to know to figure out the phenomenology of the minimal form of UED (mUED) scenario: the radius of compactification and the cutoff scale. There is a limit to how many DM relics can be found in the Universe, which can be found by looking at the WMAP/PLANCK data. When level-one quarks and gluons in UED scenarios are made and broken down at the Large Hadron Collider (LHC), they end up in multijet states. There is a 13 TeV centre of mass at the LHC, and the combined luminosity of the ATLAS search for multijet plus missing transverse energy signatures is 139 inverse femtobarn. We look into the ATLAS search for these things. Afterward, we move on to a less restrictive version of UED, called the nonminimal UED (nmUED), which has nonvanishing boundary-localized terms. This is because the ATLAS multijet search has already ruled out some of the mUED parameter space that the DM RD could have been used in. (BLTs). The inclusion of BLTs changes the dark matter and collider phenomenology of nmUED substantially. The ATLAS multijet plus missing transverse energy search yields tight limitations on the BLT parameters.

Avnish Yadav, Kirtiman Ghosh, Tapoja Jha, and Saurabh Niyogi (2020) UED (Universal Extra Dimension) is a very well-thought-out and well-researched storey that will happen. For example, the presence of a dark matter (DM) candidate in UED's particle spectrum, especially the LKP particle, is one of the main reasons why it makes sense. There are only two things you need to know about the phenomenology of the minimal form of UED (mUED) scenario: the radius of compactification and the cut-off scale. According to WMAP and PLANK, the density of relics in the universe (RD) is very low. When level-1 quarks and gluons are made and broken down at the Large Hadron Collider (LHC), they end up in multijet states. This is what we do at the LHC. We look at the ATLAS search for multijet plus missing transverse energy signatures at a 13 TeV centre of mass energy and 139 inverse femtobarn integrated luminosity. DM RD has already been ruled out by the ATLAS multijet search, so we move on to the non-minimal UED (nmUED), which has non-vanishing boundary-localized terms. This is because the mUED parameter space has already been narrowed down by the ATLAS search (BLTs). A lot changes when BLTs are added to nmUED. The dark matter and collider phenomenology changes a lot. The ATLAS search for missing transverse energy and the ATLAS multijet yields tight limitations on the BLT parameters.

Nabanita Ganguly and Anindya Datta (2018) Large Hadron Collider: We study the collider phenomenology of the nmUED model in the context of the Large Hadron Collider at the CERN lab. There are boundary localised operators with unknown coefficients on a S 1 / Z 2 orbifold that add to the Standard Model in 4 + 1 space-time dimensions. NmUED is a compact version of the Standard Model. These coefficients are used to figure out how to make the radiative adjustments, which aren't very precise because we don't know how the effective theory's cut-off scale works. It is possible to

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change the masses and couplings of the Kaluza Klein (KK) excitations with these parameters. Two different mass hierarchies for the KK-excitations were looked at. A detailed look at how KK-particles are made and how they die is also shown. Using the "Image missing" data from the LHC, we figure out the linked constraints on the masses of KK-particles. In the case of the production of strongly interacting particles, we figure out the linked constraints on the masses of KK-particles (in case of electroweak productions). We think that the lightest KK-particle could be a candidate for dark (DM) matter in our scenario. To figure out what kind of parameters we can use, we look at the universe's measured density of DM relics. The current state of a nmUED model is also looked at in light of data from direct detection by the DM. If you make and then break down 1 TeV KK-electroweak gauge bosons, you get a trilepton signature that is 1 ab 1 bright. This will happen in the not-too-distant future.

Thomas Flacke, Kyoungchul Kong, and Seong Chan Park (2014) The state of non-minimal universal extra dimension (UED) models is talked about. Paper: The main point of this paper is to see if the minimal UED model could be expanded to include bulk masses and components that are near the border. Consider data from the Large Hadron Collider and searches for dark matter, as well as precision electroweak physics and electroweak physics searches for dark matter. observations.

3. OBJECTIVES

- To explore non minimal Universal Extra Dimensional model at the LHC.
- To analyze the LHC Run I and Run II data to constrain scenario A.

4. RESEARCH METHODOLOGY

- In two separate cases, the strategies we employed to restrict the nmUED parameter space. R^{-1} has remained constant at 1 TeV. Even at 13 It will be hard for the masses of KK-excitations to rise above 1 TeV, so their production cross-sections will be very small. As a result, we don't do that kind of thing anymore. Here, we'll show how the parameter space in scenario A is limited by both the data from Run I and from Run II of the LHC in the next parts. Then, we talk about scenario B in the same way that we talked about scenario A before. If we look at the leptonic signal at the high-luminosity LHC, which comes mostly from scenario B, we'll also show how many different parameters we can look into there (HL-LHC). To figure out what might happen in these cases, we will look at things like the density of DM relics in the universe and the limits set by direct detection tests examined.

- The spin-independent proton-LKP scattering cross-section (σ SI) was calculated and compared to the results of the LUX and XENON1T experiments. An h-exchange in the t-channel or an s-channel quark exchange can cause direct scattering between the DM and a nucleon. The relative strength of the latter, on the other hand, is determined by the quark masses involved. MicrOMEGAs were used to calculate the DM relic density and SI.

5. DISCUSSION AND RESULT

5.1 Using the LHC Run I and Run II data to constrain scenario A

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this is what happened during the first run of the LHC's squark and gluino searches. The ATLAS collaboration was looking for final states that had lepton-free final states (l) and jet-free final states (j) with large T. It's the same thing we do for n = 1 KK-quarks and KK-gluons when we look at them through the nmUED lens. The values of rf and rgl are chosen to make sure that m (1) gl = 1.4 m (1) f. During R r 20R, we let all BLT coefficients be free to change. As long as the BLT coefficient is less than R, the zero-mode is tachyonic. This is because the KK-gauge boson scattering amplitudes have to be consistent with each other. This gives the upper limit of 20R. BLT coefficients that are used to scan the parameter space in this example are called Rgl, Rf, and REW. g (1)Q (1), Q (1)Q (1), Q (1)Q (1), g (1)Q (1), and g (1)g (1) are all possible doublet KK-quarks and KK-gluons. We look at all of them (1). Only the first two generations of KK-quarks are looked at, not the third. A lot of people have talked about how KK-quarks decay BRs and KK-gauge bosons decay BRs. However, before looking at the LHC signal in this case, keep in mind that leptons that come from their decays tend to be soft because there aren't a lot of KK-excitations in the EW sector with a lot of mass difference.

In the same graphic, we show the results from Run II data. During Run II, the cyan region is eliminated from the LHC search in the 1l + mj + ∉T channel. For mγ (1)= 250 GeV, the bound on $m_Q(1)$ has been stretched to nearly 1.26 TeV. This figure isn't much higher than the one obtained from the 8 TeV data. Note that the greatest possible KK-mass for R^{-1} = 1 TeV is 1.78 TeV. As we set $m_{gl}(1)$ = 1.4 mQ(1), the mass of Q(1) for a $g^{(1)}$ with a mass of around 1.78 TeV would be around 1.27 TeV. In this example, this is the upper constraint on mQ(1), which explains the relatively minor change along the x-axis at 13 TeV. The overall area excluded by Run II data, on the other hand, is substantially larger than that of Run I.

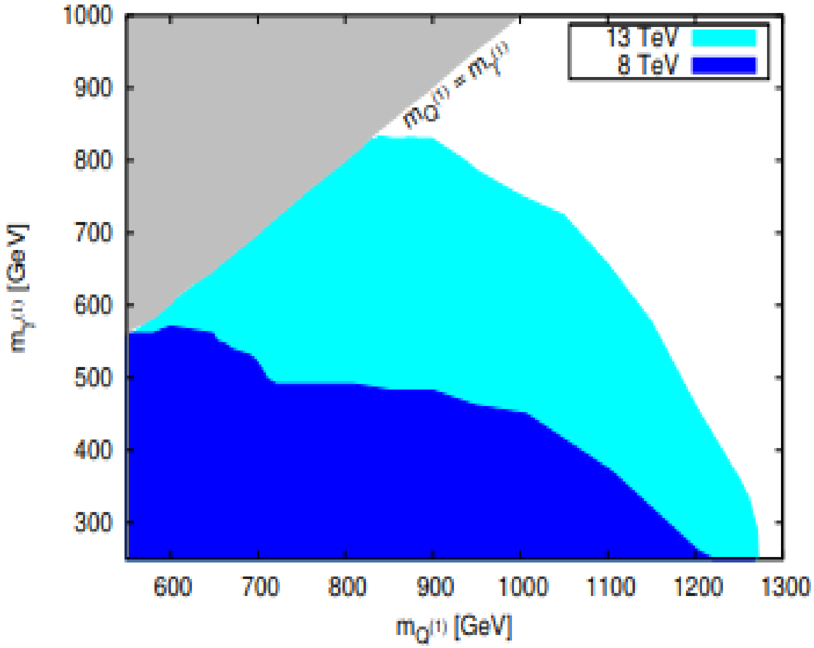


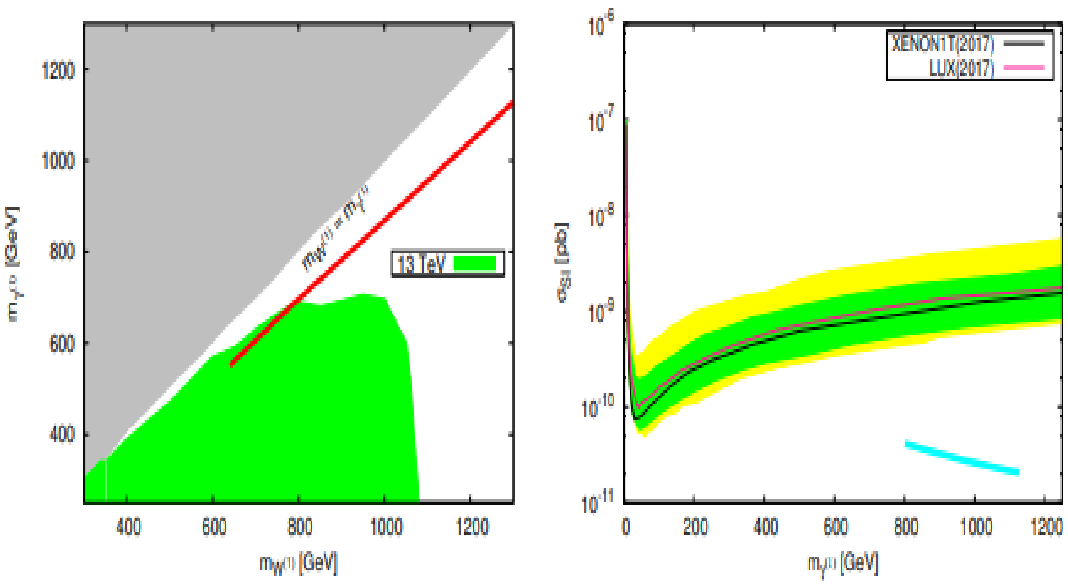
Figure 2: The blue and cyan regions represent the excluded parameter space in the mQ(1) −mγ (1) plane in the case of scenario A obtained by our simulation using the ATLAS data at Run I

and Run II respectively. The grey region corresponds to the part of the parameter space which is theoretically excluded as $W^{\pm(1)}/Z^{(1)}$ becomes a LKP there

Before concluding this section, it is worth noting that $\gamma^{(1)}$ is the LKP and a rival for the DM in terms of KK-parity conservation. We know for sure that a situation where rB = rW is bad because there is a lot of DM at this time. Because the LKP has a very small mass difference from the LKP and KK-EW gauge bosons, co-annihilation with $W^{\pm(1)}/Z^{(1)}$ becomes relevant along with self-annihilation of the LKP. As a result, the relic density is substantially lower than experimental values derived from WMAP/Planck data.

5.2 Using LHC data and future forecasts to constrain scenario B

At the n = 1 KK-level, assuming rB and rW are equal, the EW spectra would be severely compressed. So, the decay products of the KK-EW gauge bosons W(1) and Z (1) would be very soft, which would make it easy to avoid cutting-based analysis. It's also worth noting that, because of the compressed form of the spectrum, the DM's relic abundance is a lot lower than it was found to be. A collider search or the value of the DM relic density in the universe didn't show any big changes in mass. in such a scenario. In the $m_W\pm(1)$ -mγ (1) plane of fig. 3, the APS for scenario B is shown (a). In plot, the mass of $Z^{(1)}$, which is also regulated by rW, is not displayed. The LHC trilepton search rules out $W^{\pm(1)}$ up to 1.1 TeV for $m\gamma_{(1)}$ = 250 GeV, while all $W^{\pm(1)}$ are allowed for m (1) > 700 GeV, as shown in fig. 3(a). We also show the area (red dots) that WMAP and Planck data can show if (1) is the DM candidate in the same picture. The LKP pair is broken up into f f. is responsible for the majority of the DM relic density. W^+W^- and ZZ are made up of a small percentage of the total. The LHC 3l + ∉T search at Run II has already ruled out the DM permitted band below $m_{W\pm(1)}$ = 800 GeV.



(a) (b)

ISSN- 2394-5125 VOL 08, ISSUE 02, 2021

Figure 3: Left: The green region represents the excluded part of the nmUED parameter space for scenario B in the mW±(1) − m_γ (1) The ATLAS collaboration's 3l + ∉T search during Run II produced a plane. The grey area is theoretically off-limits. The red dots match the WMAP/Planck data for the universe's DM relic density. LUX and XENON1T results are shown as solid pink and black lines, respectively, in the DM direct detection results for scenario B. Both WMAP/Planck data and LHC constraints are satisfied by cyan spots. The sensitivity bands of the XENON1T data are shown in green and yellow, respectively

In this scenario, we also look into the possibilities of detecting the DM directly. An s-A quark exchange called KK-quark exchange can be used to scatter the DM with a nucleon without having to change the spin of the nucleon. However, because heavy KK-quarks will make the s-channel less effective, the latter will win over the first. It's shown in figure 3(b) as a function of m. (1). Test results from the most recent LUX and XENON1T tests are shown in pink and black lines. The XENON1T is much stronger than the LUX. The places in this section that are in line with the data from WMAP and Planck are shown. and collider limits are also shown. This nmUED scenario is in good agreement with the direct detection data, as shown in fig. 3(b).

6. CONCLUSION

The primary goal of this research was to search It's for LHC-based signs of the nmUED model. It turns out that no one has looked for signals from nmUED models at the LHC. As a result, for our purposes, we used model-independent restrictions on new physics that came from other BSM searches. All of the particle spectrum in our model is caused by the compactification radius R and BLT coefficients, which are the only two things that make up the model. These BLT coefficients also play a big role in how KK-excitations interact with each other, which in turn affects their production cross-sections and decay rates. Different BRs of these KK-particles' different decay modes were shown to show how the relative rates of different final states were explained. We also stressed how important the BLT coefficients were in the decays of KK-particles. The collider's phenomenology has been looked at in two different nmUED scenarios. The two scenarios differ in how the BLT coefficients are ranked (and hence among the masses of distinct KK-excitations).

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