CURRICULUM VITAE

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EDUCATIONAL BACKGROUND

Aug. 2001 - Aug. 2006 :	**PhD** in Theoretical Particle Physics, Physics Department, University of Florida, Gainesville, FL
Feb. 1997 - Feb. 1999 :	**MS** in Physics, Pusan National University, Korea
Apr. 1993 - Feb. 1997 :	**BS** in Physics, Pusan National University, Korea

RESEARCH EXPERIENCE

Sep. 2006 - Present :	Research Associate at Fermilab
Aug. 2001 - Sep. 2006 :	Phenomenology Beyond the Standard Model (Thesis advisor: Prof. Konstantin Matchev)
Apr. 1997 - Nov. 1999 :	Field Theory (Advisor: Prof. Chang Gil Han) Second Quantization of Quantum Cellular Automata (MS Thesis)
Sep. 1995 - Nov. 1996 :	Undergraduate Research - Black Holes and General Relativity (Informal advisors: Prof. Deog Ki Hong and Prof. Yoonbai Kim)

AWARDS and SCHOLARSHIPS

Nov. 2005 :	Korean Graduate Student Research Award (supported by University of Florida alumni and the New York Times)
Fall 2005 :	College of Liberal Arts and Sciences graduate student travel award and Physics Department graduate student travel award, TeV4LHC Workshop, Fermilab, October 20-22, 2005
2002 - 2006 :	5 Certificates of achievement for outstanding academic accomplishments (International Center at the University of Florida)
Apr. 2005 :	Outstanding International Student Award
Fall 2004 :	Research Fellowship, High Energy Theory Group
Apr. 2004 :	Presidential Recognition ("in recognition of outstanding achievements and contribution to the University of Florida")
Dec. 2003 :	Physics Department Teaching Assistant of the Year
Summer 2002 :	Grinter Fellowship (teaching relief in the summer)
1997 - 1999 :	Teaching and research assistantships at Pusan National University
Nov. 1996 :	Seminar Award for Undergraduate Students (3 out of 250 students)
1994 - 1996 :	Academic Scholarship (full or partial tuition)
1993 :	First rank entrance scholarship (top 2%)

SUMMER SCHOOLS ATTENDED

- First CERN-Fermilab Hadron Collider Physics Summer School, August 9-18, 2006
- Prospects in Theoretical Physics summer program, Institute for Advanced Study, Princeton, NJ, July 18 - 29, 2005. Theme: “Introduction to Collider Physics”.
- TASI summer school, University of Colorado, Boulder, CO, June 6 - July 2, 2004. Theme: “Physics in $D \geq 4$”.
- Prospects in Theoretical Physics summer program, Institute for Advanced Study, Princeton, NJ, June 30 - July 11, 2003. Theme: “Cosmology, Particles and Strings”.

SEMINARS AND TALKS AT CONFERENCES/WORKSHOPS

- *“Two Universal Extra Dimensions”*
  - The 2008 Linear Collider Workshop (LCWS08) and the International Linear Collider meeting (ILC08) (November 16-20, 2008), UIC, IL
- *“Connecting LHC, ILC, and Quintessence”*
  - The 2008 Linear Collider Workshop (LCWS08) and the International Linear Collider meeting (ILC08) (November 16-20, 2008), UIC, IL
- *“Particle masses, spins and couplings at hadron colliders”*
  - CMS week (December 10, 2008), CMS, CERN
  - Theory seminar (December 4, 2008), CERN
  - Theory seminar (November 5, 2008), SLAC
  - Theory seminar (November 3, 2008), UC Davis
  - Theory seminar (October 31, 2008), LANL
  - Theory seminar (October 20, 2008), UC Berkeley
  - HEP seminar (September 23, 2008), ANL
- *“Measuring Masses and Spins of New Particles at Colliders”*
  - Aspen 2008 Winter Conference ”Revealing the Nature of Electroweak Symmetry Breaking”, Aspen, CO
  - The 17th Miniworkshop on Particle and Astroparticle Physics (Dec 13-15, 2007), Pusan National University, Pusan, Korea
  - Theory Seminars (Jan 23, 2007), Michigan State University, Lansing
  - Theory Seminars (Dec 15, 2006), University of Wisconsin, Madison
  - Theory Seminars (Nov 2, 2006), Fermilab

- *"Sources of Dilepton Events"*
  - Mini-Workshop on Early CMS Physics (June 8-9, 2007), Fermilab
- *"Kaluza-Klein Dark Matter in Universal Extra Dimensions"*
  - The Hunt for Dark Matter, A Symposium on Collider, Direct and Indirect Searches, (May 10-12), Fermilab
- *"Phenomenology of Universal Extra Dimensions"*
  - 14th International Conference on Supersymmetry and the Unification of Fundamental Interactions "'SUSY 2006' (June 12-17, 2006), University of California, Irvine, CA
  - HEP/Astro Seminars (May 24, 2006), Ohio State University
- *"SUSY or Extra Dimensions: that is question"*
  - High Energy Theory seminar (Dec 14, 2005), SLAC
  - High Energy Theory seminar (Dec 12, 2005), UC Davis
  - High Energy Theory seminar (Dec 7, 2005), UC Berkeley
  - High Energy Theory seminar (Dec 5, 2005), UC Santa Cruz
  - High Energy Theory seminar (Dec 2, 2005), UC Irvine
- *"Is it SUSY? Is it UED?"*
  - Theory seminar (Nov 18, 2005), University of Florida, Gainesville, FL
- *"Relic density of KK dark matter in UED"*
  - UF-FSU Symposium in High Energy Phenomenology (Nov 11, 2005), University of Florida, Gainesville, FL
- *"Discriminating Supersymmetry and Extra Dimensions at the LHC"*
  - 2005 Meeting of the Southeastern Section of the American Physical Society (Nov 10-12, 2005), University of Florida, Gainesville, FL
  - PHENO2005 (May 2-4, 2005), University of Wisconsin, Madison, WI
  - TeV4LHC Workshop (Oct 20-22, 2005), Fermilab, Batavia, IL
- *"The impact of beamstrahlung on precision measurements of new physics at very high energy e^+e^- collider"*
  - 2005 International Linear Collider Workshop (April 18-22, 2005), SLAC, Palo Alto
- *"Contrasting Supersymmetry and Universal Extra Dimensions at the CLIC Multi-TeV e^+e^- Collider"*

- 2005 International Linear Collider Workshop (April 18-22, 2005), SLAC, Palo Alto

- *"Search for the Level-2 Gauge Bosons of Universal Extra Dimensions at the LHC"*
  - TeV4LHC Workshop (Feb 3-5, 2005), Brookhaven National Laboratory, Upton, NY

- *"Collider phenomenology of universal extra dimensions"*
  - UF-FSU Symposium in High Energy Phenomenology (Dec 1, 2004), Florida State University, Tallahassee, FL
  - PHENO 2004 (April 26-28, 2004), University of Wisconsin, Madison, WI

COMPUTING SKILLS

- Languages : Fortran, C and (Visual) Basic
- Algebraic packages : LanHEP, Mathematica
- Feynman diagram calculators : FeynCALC, CompHEP/CalcHEP
- Event generators : CompHEP/CalcHEP, PYTHIA, ISAJET, MADGRAPH/MADEVENT
- Operating systems familiar with : Windows, Linux, OSX
- Dark matter programs : MicrOMEGAs, DARKSUSY

TEACHING ACTIVITIES

Jan. 2006 - Apr. 2006 :	Teaching Assistant at University of Florida (PHY2054, Discussion)
Aug. 2001 - Dec. 2005 :	Teaching Assistant at University of Florida (PHYS2048L, PHYS2054L)
Feb. 1993 - Jul. 2001 :	Private Tutor (in Mathematics and Physics)
Mar. 1999 - Dec. 1999 :	Teaching Assistant (Quantum Mechanics, Graduate Level)
Jul. 1997 - Jun. 1999 :	Teaching Assistant at Pusan National University (PHYS-LAB)

PERSONAL

Date of Birth : Oct. 10, 1974
Place of birth : Pusan, South Korea

Nationality : Korean (Republic of Korea)
Marital Status : Married, two children

REFERENCES

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Current projects

1. **Supersymmetric Higgs Bosons** (with P. Batra, M. Carena, E. Pontón, J. Zurita), in preparation

2. **Shedding Light on the Dark Sector with Direct WIMP production** (with P. Konar, K. Matchev, M. Perelstein), in preparation

3. **Prospects for T' discovery at the Tevatron** (with B. Dobrescu and R. Mahbubani), in preparation

4. **Measuring spin of the top at hadron colliders** (with K. Matchev), in preparation

Papers in Refereed Journals

1. **$\sqrt{\hat{s}}_{min}$: a global inclusive variable for determining the mass scale of new physics in events missing energy at hadron colliders** (with P. Konar and K. Matchev), arXiv:0812.1042 [hep-ph], submitted to JHEP

2. **Using Subsystem MT2 for Complete Mass Determinations in Decay Chains with Missing Energy at Hadron Colliders** (with M. Burns, K. Matchev, M. Park), arXiv:0810.5576 [hep-ph], submitted to JHEP

3. **A General Method for Model-Independent Measurements of Particle Spins, Couplings and Mixing Angles in Cascade Decays with Missing Energy at Hadron Colliders** (with M. Burns, K. Matchev, M. Park), **JHEP 10 (2008) 081**, arXiv:0808.2472 [hep-ph]

4. **Kaluza-Klein Dark Matter: Direct Detection vis-a-vis LHC** (with S. Arrenberg, L. Baudis, K. Matchev, J. Yoo), **Phys. Rev. D 78, 056002 (2008)**, arXiv:0805.4210 [hep-ph]

5. **Two universal extra dimensions and spinless photons at the ILC** (with A. Freitas), **JHEP 0802:068,2008**, arXiv:0711.4124 [hep-ph]

6. **Massive color-octet bosons and pairs of resonances at hadron colliders** (with B. Dobrescu and R. Mahbubani), **Phys. Lett. B670:119-123, 2008**, arXiv:0709.2378 [hep-ph]

7. **Spinless photon dark matter from two universal extra dimensions** (with B. Dobrescu, D. Hooper and R. Mahbubani), **JCAP 0710:012,2007**, arXiv:0706.3409 [hep-ph]

8. **Connecting LHC, ILC, and Quintessence** (with D. Chung, L. Everett and K. Matchev), **JHEP 0710:016,2007**, arXiv:0706.2375 [hep-ph]

9. **Leptons and Photons at the LHC: Cascades through Spinless Adjoints** (with B. Dobrescu and R. Mahbubani), **JHEP 0707:006,2007**, hep-ph/0703231

10. **Phenomenology of top partners at the ILC** (with S. Park), **JHEP 0708:038,2007**, hep-ph/0703057

11. **Discrimination of Supersymmetry and Universal Extra Dimensions at Hadron Colliders** (with A. Datta and K. Matchev), **Phys.Rev.D72:096006,2005**, hep-ph/0509246

12. **Precise Calculation of the Relic Density of Kaluza-Klein Dark Matter in Universal Extra Dimensions** (with K. Matchev), **JHEP 0601:038,2006**, hep-ph/0509119

13. **Contrasting Supersymmetry and Universal Extra Dimensions at the CLIC Multi-TeV e^+e^- Collider** (with M. Battaglia, A. Datta, A. De Roeck and K. Matchev), **JHEP 0507:033,2005**, hep-ph/0502041

Unrefereed Publications

1. **Kaluza-Klein Dark Matter: Direct Detection vis-a-vis LHC** (with S. Arrenberg, L. Baudis, K. Matchev, J. Yoo), in the proceedings of identification of dark matter 2008, AlbaNova University Centre, Stockholm, Sweden, August 18-22, 2008, arXiv:0811.4356 [hep-ph]

2. **Phenomenology of Universal Extra Dimensions** (with K. Matchev), **AIP Conf.Proc.903:451-454,2007**, in the proceedings of SUSY06, UC Irvine, hep-ph/0610057

3. **Tevatron-for-LHC Report: Preparations for Discoveries (Landscape Working Group Report)** (with A. Datta, K. Matchev for sections 4.1 and 4.2), hep-ph/0608322

4. **Identifying universal extra dimensions at CLIC** (with M. Battaglia, A. Datta, A. De Roeck and K. Matchev), in the proceedings of LCWS 2004, Paris, France

5. **The Impact of Beamstrahlung on Precision Measurements at CLIC** (with A. Datta and K. Matchev), in the proceedings of LCWS 2005, SLAC, hep-ph/0508161

6. **Contrasting Supersymmetry and Universal Extra Dimensions at colliders** (with M. Battaglia, A. Datta, A. De Roeck and K. Matchev), in the proceedings of LCWS 2005, SLAC, hep-ph/0507284

7. **Physics at the CLIC Multi-TeV Linear Collider** (CLIC Physics Working Group), **CERN-2004-005**, hep-ph/0412251

Books and Review Articles

1. **Invited review article on Dark Matter and Particle Physics, New Journal of Physics**, **contribution to Contrasting WIMP models: extra-dimensions versus SUSY** (with K. Matchev), in preparation

2. **Invited review article on Extra Dimensions, New Journal of Physics**, **contribution to Universal Extra Dimensions** (with K. Matchev), in preparation

3. **Particle Dark Matter (edited by Gianfranco Bertone)** (with K. Matchev, G. Servant), **contribution to extra dimensions at collider**, Cambridge University Press, in preparation

4. **Selected Problems in Physics** (with S. Na), **ISBN 89-88881-36-2**, Dong-Nam Publishing Company, Korea

SUMMARY OF PAST WORK AND RESEARCH INTERESTS

I am interested in particle and astroparticle phenomenology, and especially in signatures of new physics beyond the Standard Model. My research so far has concentrated on the following areas:

- Collider phenomenology of new physics at the LHC and ILC
- Phenomenology of dark matter
- Development of event generators and implementation of new models

I am particularly interested in determination of spins, masses and couplings. The study on kinematics is completely model-independent, can be applied in any BSM models as well as the standard model, and is necessary ingredient to better understand physics at the LHC. The complementarity/interplay between colliders (LHC and ILC) and cosmological observations (dark matter detection and WMAP) also plays important roles in complete understanding of new physics that will occur at the LHC. I am planning to continue to work on recent development on these areas and below I summarize some of my past and ongoing/future projects in more detail.

Collider phenomenology

Determination of masses, spins and couplings : If new physics beyond the standard model exists at the TeV scale, it is likely to be found rather quickly after the LHC begins to take physics data. After the discovery of a potential signal for new physics, SUSY for instance, emphasis will shift to a determination of the masses, spins and couplings of the supersymmetric particles, their decay modes and branching fractions and measurements of the cross sections of different SUSY processes. The masses of some supersymmetric particles can be measured in cascade decays. However it is crucial to also find out the spin information in order to determine the nature of new physics at the LHC. This is especially important when we have models which can fake each other such as SUSY, Universal Extra Dimensions (UED) [1] and little Higgs models with T-parity. A few years ago an asymmetry variable [2] was proposed to measure the spins of superpartners at the LHC. However, in our studies [3] and [4] we found that it does not always work (for example it fails in the case of degenerate mass spectra as in UED), although it rules out the absence of any spin correlations [3, 5]. Recently we have extend these results to other spin scenarios using invariant mass techniques [6]. We have a purely analytic approach to measurements of spins and couplings of heavy partners in cascade decays. The method is model-independent and can be applied to any cascade decays as well as standard model processes such as top quark decay. This work leads to many other possible projects. Another way to measure the spins of particles is to use production information. We apply this idea to top quark decay [7]. As long as the momenta of particles are fully reconstructed, one should be able to use this method to extract the spin information of the mother particle in cascade decays.

Recently various methods for the mass determination have been suggested; the invariant mass technique, the polynomial method, m_{T_2}-related methods, kink methods and so on. Nevertheless there is a decay that has not been discussed and in fact, has a topology similar to top quark decay with the identity of all three particles unknown in the decay. None of above methods measures all three masses in the decay. We present a complete mass determination using the m_{T_2} idea. The method is very general and powerful compared to other methods. We also improve upon the analytic solution of m_{T_2} [8]. These studies are based on kinematics and therefore the methods can be applied to any processes in models beyond the standard model.

Application of mass/spin/coupling measurements to the standard model : The methods that we have developed are applicable not only to the BSM particles but also to the particles in the standard model. With the experimental data taken at the Tevatron, one can try to improve measurements of particle properties using these methods and extend the ideas to the LHC. One can also numerically check the applicability of above methods and try to improve the ideas.

Higgs physics : We investigate the tension between the LEP II bound on the Higgs mass and the MSSM prediction, taking a model-independent approach using the higher dimensional operators as has been discussed recently in the context of dimension 5 operators. We extend the results to dimension 6 operators and discuss its phenomenological implications at colliders. We also show how specific models can be embedded in our framework [9]. One can also look at the effect of these higher dimensional operators on electroweak baryogenesis and electroweak symmetry breaking.

Signatures of new physics at the LHC and model discrimination : A variety of possibilities exist for new physics at the TeV scale – supersymmetry, large or small extra dimensions, technicolor, composite and little higgs – with a large number of models in each category. All of these models share a handful of signals that will be the focus of early LHC searches. Although many of these signals are universal, it is useful to explore them in the context of specific representative models. This will determine the power of the LHC in differentiating between similar models. We recently investigated a specific scenario, Universal Extra Dimensions, where all the Standard Model particles propagate in the bulk of one or more dimensions as originally proposed in [1]. The collider signatures of this scenario are very similar to those of supersymmetry (SUSY), and differentiating between the two at a hadron collider is a big challenge. Our research therefore has been focused on finding methods for their discrimination. In [3], we studied the discovery reach of the Tevatron and the LHC for level 2 Kaluza-Klein modes which would indicate the presence of extra dimensions. We determined the discovery reach of the Tevatron and the LHC for the level 2 KK modes of the photon and the Z, which could be discovered as narrow dilepton resonances. Their degeneracy would be a smoking gun for flat extra dimensions. With B. Dobrescu and R. Mahbubani we investigated the phenomenology of two Universal Extra Dimensions at the Tevatron and the LHC and found that multi-lepton signatures are generic in this model due to the existence of spinless adjoints. In this model the hypercharge gauge boson, which is a good dark matter candidate in 5 dimensional UED, now decays into a photon and its scalar partner (spinless photon) [10]. Inspired by color-octet KK bosons, we studied a generic feature of pair production of color octet bosons at hadronic colliders and found that these bosons lead to interesting di-dijets (4 jets) signatures, for which each dijet reconstructs a resonance of the same mass. Even in the absence of dijet resonances, the di-dijet resonances can still arise and be found during early phase running of the LHC [11]. The discrimination among different models at the LHC, and measurements of spins and couplings are very important studies and their importance is also discussed in the prioritized list of projects that the steering committee for the LHC Theory Initiative proposed.

New physics signals at linear colliders: Many models for new physics have rather similar experimental signatures at hadron colliders [12]. The proper interpretation of an LHC discovery in either case may therefore require further data from a lepton collider. In [4, 13, 14], we identified methods for discriminating between the two scenarios (Universal Extra Dimensions and supersymmetry) at a linear collider. We studied Kaluza-Klein muon pair production in Universal Extra Dimensions in parallel with smuon pair production in supersymmetry, accounting for the effects of detector resolution, beam-beam interactions and accelerator induced backgrounds. We found that the angular distributions of the final state muons, the energy spectrum of the radiative return photon and the total cross-section measurement are powerful discriminators between the two models. Accurate determination of the particle masses can be obtained both by a study of the momentum spectrum of the final state leptons and by a scan of the particle pair-production thresholds. It would be very interesting to look at other final states, gauge boson final states, for example. This can be easily studied using our implementation of the UED in the CompHEP event generator. With A. Freitas, I extended this spin study to two Universal Extra Dimensions, considering $\gamma\gamma + \not{E}_T$ final states as well as $e^+e^- + \not{E}_T$ channel [15]. We also computed the ILC reach for (1,1) states of spinless bosons. A similar study was carried out for the top partners in the case of little Higgs model with T-parity [16].

These studies are based on observation of the standard model particles that decayed from heavy partners in cascade decays. However when the lightest particle, which happens to be the dark matter candidate in many models beyond the standard model, is produced at the ILC, one detects nothing! One way to observe this signal is to attach an ISR photon and We are currently working on improving upon the previous studies that exploit the connection between colliders and cosmology. We also try to make measurements of masses and discriminate different models, using polarized e^+e^- beams [17].

Beamstrahlung physics at linear colliders: I am interested in understanding beam physics. The well known approximation [18, 19, 20] to beamstrahlung fails to correctly parameterize the actual physical situation at very high energy e^+e^- colliders such as CLIC. In [21] we showed that it is important to understand the beamstrahlung spectra in order to precisely measure the new physics parameters at linear colliders. However, our work was done numerically and we are still missing an analytic approximation which can be generally applied for the case of a very high energy linear collider. Finding an improved analytic solution for the general case is very challenging since the corresponding Sokolov-Ternov solution is rather complicated and the rate equation is an integro-differential equation.

We also plan to investigate the spectrum of the beamstrahlung photons.

Dark Matter

Relic density of Kaluza-Klein dark matter: The dark matter problem is one of the main motivations for new physics beyond the Standard Model. There are several scenarios of new physics at the TeV scale which predict the existence of a dark matter candidate. In models with Universal Extra Dimensions, the lightest Kaluza-Klein particle (LKP) can be a good dark matter candidate. The Kaluza-Klein (KK) particle spectrum at level one is rather degenerate [22], and there are many coannihilation processes which may be relevant for the precise determination of the LKP relic density. In [23], we extended the calculation of [24], to include coannihilation processes with *all* level one KK particles. In our computation we considered the most general KK particle spectrum, without any simplifying assumptions. In particular, we did not assume a completely degenerate KK spectrum and instead retained the dependence on each individual KK mass. As an application of our results, we calculated the Kaluza-Klein relic density in the Minimal UED model [12, 22], turning on coannihilations with all level one KK particles. We then went beyond the minimal model and discussed the size of the coannihilation effects separately for each class of level 1 KK particles. We found that coannihilations with colored particles can significantly raise the upper bound on the LKP mass. Our results provide a basis for consistent relic density computations in UED with an arbitrary mass spectrum. Later with B. Dobrescu, D. Hooper and R. Mahbubani, we computed the relic density of spinless adjoint dark matter in two Universal Extra Dimensions [25] and found that there may be some tension between constraints from the dark matter side and electroweak precision measurements. This can be avoided once coannihilation processes are turning on.

The other unknown component of our universe is dark energy, which is often described using a scalar field. In a kination-dominated scenario, the scalar field affects the Hubble expansion parameter at the time of dark matter decoupling. Therefore one needs to revisit the computation of relic density in the presence of such a scalar field. The density deficit can be enhanced due to this scalar field and we have investigated the collider implication of such a scenario at the LHC and ILC [26].

Direct detection of Kaluza-Klein dark matter: In the minimal UED model, the LKP is the KK mode of the hypercharge gauge boson of the Standard Model. The upper bound on the LKP mass derived from cosmology can be relaxed if colored KK modes such as KK quarks are degenerate with the LKP and dilute its relic density through coannihilations. Such degenerate spectra are especially difficult to probe at colliders. However, this is precisely the case when the direct detection rates are also enhanced [27]. In [28] we derived the direct detection limits on KK dark matter which follow from the recent CDMS and XENON results. In our analysis we specifically concentrated on degenerate scenarios where dark matter searches are complementary to collider searches. We also considered other types of LKP candidates which arise in nonminimal UED models such as the partner of Z (Z_1) and the spinless photon (γ_H).

Positron excess from dark matter annihilations: Refs. [29] and [30] investigated whether dark matter annihilations in SUSY or UED can explain the data from the PAMELA experiment. In [30], it was realized that SUSY does not produce enough positron excess and the authors assumed substructure in the galactic halo to compensate for it. Such substructure can be present in realistic halo models such as the caustic model. An alternative explanation can be provided by UED, which according to [29] does not need any halo substructure since it already produces enough positron excess. One can therefore constrain the galactic halo distributions once we determine the identity of the dark matter from elsewhere, for example in collider experiments. For instance, if the dark matter is a spin 1 particle, UED is preferred and we do not need substructure in the halo, while if the dark matter is found to be spin 1/2, we do need substructure like caustics.

Computational Tools

Implementation of new physics models and loop-induced couplings in event generators: In order to disentangle the signatures of new physics at the LHC, it is important to have as many models as possible available in event generators. Spin correlations are often important to understand the nature of the new particles. We have implemented the general model of Universal Extra Dimensions in CompHEP/CalcHEP [31], which correctly accounts for the spins of the KK particles. We have done extenssive cross checks and used the UED model files for our studies [3, 4, 13, 14, 21, 23]. The current model file contains level 1 and level 2 KK particles with the correct masses and widths including one-loop radiative corrections [22]. We also implemented KK number violating but KK parity conserving interactions as well. We have extended implementation to the case of two Universal Extra Dimensions, including 1-loop decay of the hypercharge gauge boson into the spinsless photon and a standard model photon [25, 15, 10]. We are now in the process of generalizing to couplings such as $h \to \gamma\gamma$, $h \to \gamma Z$, $gg \to h$ and so on. Such couplings can be thought as an effective coupling like a form factor. Since tree level Feynman diagram calculators do not have such vertices, it will be very useful to parametrize such couplings so that we can use them in tree-level calculations relevant for collider phenomenology.

References

[1] T. Appelquist, H. C. Cheng and B. A. Dobrescu, "Bounds on universal extra dimensions," Phys. Rev. D **64**, 035002 (2001) [arXiv:hep-ph/0012100].

[2] A. J. Barr, "Using lepton charge asymmetry to investigate the spin of supersymmetric particles at the LHC," Phys. Lett. B **596**, 205 (2004) [arXiv:hep-ph/0405052].

[3] A. Datta, K. Kong and K. T. Matchev, "Discrimination of supersymmetry and universal extra dimensions at hadron colliders," arXiv:hep-ph/0509246.

[4] M. Battaglia, A. K. Datta, A. De Roeck, K. Kong and K. T. Matchev, "Contrasting supersymmetry and universal extra dimensions at colliders," arXiv:hep-ph/0507284.

[5] J. M. Smillie and B. R. Webber, "Distinguishing spins in supersymmetric and universal extra dimension models at the Large Hadron Collider," arXiv:hep-ph/0507170.

[6] M. Burns, K. Kong, K. T. Matchev and M. Park, "A General Method for Model-Independent Measurements of Particle Spins, Couplings and Mixing Angles in Cascade Decays with Missing Energy at Hadron Colliders," arXiv:0808.2472 [hep-ph].

[7] K. Kong and K. Matchev, "Measuring spin of the top at hadron colliders," in preparation.

[8] M. Burns, K. Kong, K. Matchev and M. Park, "Using M_{T2} for complete mass determination in cascade decays with missing energy at hadron colliders," in preparation.

[9] P. Batra, M. Carena, K. Kong, E. Pontón, and J. Zurita, "Supersymmetric Higgs Bosons," in preparation.

[10] B. A. Dobrescu, K. Kong and R. Mahbubani, "Leptons and photons at the LHC: Cascades through spinless adjoints," JHEP **0707**, 006 (2007) [arXiv:hep-ph/0703231].

[11] B. A. Dobrescu, K. Kong and R. Mahbubani, "Massive color-octet bosons and pairs of resonances at hadron colliders," arXiv:0709.2378 [hep-ph].

[12] H. C. Cheng, K. T. Matchev and M. Schmaltz, "Bosonic supersymmetry? Getting fooled at the LHC," Phys. Rev. D **66**, 056006 (2002) [arXiv:hep-ph/0205314].

[13] M. Battaglia, A. Datta, A. De Roeck, K. Kong and K. T. Matchev, "Contrasting supersymmetry and universal extra dimensions at the CLIC multi-TeV e+ e- collider," JHEP **0507**, 033 (2005) [arXiv:hep-ph/0502041].

[14] CLIC Physics Working Group *et al.*, "Physics at the CLIC multi-TeV linear collider," arXiv:hep-ph/0412251.

[15] A. Freitas and K. Kong, "Two universal extra dimensions and spinless photons at the ILC," JHEP **0802**, 068 (2008) [arXiv:0711.4124 [hep-ph]].

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