

DE/ER/45864-1

FINAL TECHNICAL REPORT

Project: Collaborative Research Between Oklahoma State University and Fermilab

Several scientific projects were completed in the area of Theoretical High Energy Physics (Elementary Particles and Fields). The results obtained were published in refereed international journals and presented in several national and international conferences by the project personnel. A brief summary of the projects completed and the results obtained are given below.

A. Collider Physics and Extra Dimensions:

String theories predict that there may be extra compact space-like dimensions. We proposed new signals for the existence of such extra dimensions which can be tested in the Fermilab Tevatron Collider or at the upcoming Large Hadron Collider. These signals come from the productions and decays of the Kaluza-Klein excitations of the gauge bosons as well as quarks and leptons. The dominant signals are high transverse momentum dijets plus missing energy or high transverse momentum photons and missing energy. The observation of these signals could lead to the discovery of evidence of such extra dimensions.

B. Unification and Extra Dimensions

We proposed a supersymmetric model in six dimensions where the strong, weak and electromagnetic forces were unified as a single force, as well as the particles were unified (the gauge bosons, fermions as well as the Higgs bosons). In this project such a complete unification has been achieved for the first time in the framework of Quantum field theory. The model unifies not only the gauge couplings but also the Yukawa couplings, and in agreement with the current measurements of these parameters. We make several predictions which can be tested in the upcoming Large Hadron Collider.

C. Supersymmetry, Anomalous U(1) Symmetry and Lepton Flavor Violation

We solved the problem of negative slepton mass square using an anomalous U(1) symmetry, and studied the lepton flavor violation in such supersymmetry breaking scenario. Several key predictions have been made for the processes such as muon decaying to electron and a photon, $g-2$ of the muon and others. These predictions can be tested in the upcoming experiments at such as at the Brookhaven National Lab. We can also accommodate axion as the dark matter in this model.

DOE Patent Clearance Granted

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D. Neutrino Masses and Mixings

We proposed a new mechanism for the generation of the neutrino masses and the mixings at the two loop level. A new mechanism for explaining the LSND neutrino experiment was also proposed. This can be tested at the mini BoONE experiment at Fermilab. We also proposed a new mechanism for generating light neutrino mass introducing new soft supersymmetry breaking term and using it to generate neutrino mass. In this model, light neutrino mass is given by soft SUSY breaking scale square divided by the right-handed neutrino mass scale.

Conference Presentations

- (1) PHENO 2001 Symposium, Madison, WI, May 7-9, 2001. Talk presented by S. Nandi. Title of the talk: Collider signals of extra dimensions.
- (2) Conference on Underground Science, Rapid City, S.D. October 4-7, 2001 Attended by K.S. Babu.
- (3) PHENO 2002 Symposium, Madison, WI, April 23-25, 2002 Talk presented by S. Nandi. Title of talk: Orbifold breaking of gauge symmetry.
- (4) American Physical Society-Division of Particles and Fields Meeting (DPF '02), May 24-27, 2002. Talk presented by S. Nandi. Title of talk: Orbifold breaking of left-right gauge symmetry.
- (5) SUSY 2003 Conference, Hamburg, Germany, June 17-23, 2003. Talk presented by K.S. Babu.
- (6) International Conference on High Energy Physics, Amsterdam, Netherlands, July 24-30, 2002. Talk presented by K.S. Babu.
- (7) Conference on Particles, Strings and Cosmology (PASCOS 2003), Bombay, India, January 3-8, 2003. Talk presented by K.S. Babu.
- (8) SUGRA 20 Conference, Boston, MA March 17-21, 2003. Talk presented by S. Nandi. Title of the talk: Unification of gauge, Higgs and matter in extra dimensions.
- (9) Workshop on Future Hadron Colliders, Fermilab, Batavia, IL, October 16-18, 2003. Talk presented by S. Nandi. Title of talk: Signals of extra dimensions at VLHC.

Journal Articles

1. Anomalous $U(1)$ symmetry and lepton flavor violation; K.S. Babu, T. Enkhbat and I. Gogoladze, Nucl. Phys. B678: 233-257 (2004).
2. Test of Gauge-Yukawa Unification, I. Gogoladze, Y. Mimura, S. Nandi and K. Tobe, Phys. Lett. B575, 66-74 (2003).
3. Quark lepton quartification; K.S. Babu, E. Ma and S. Willenbrock, Phys. Rev. D69: 051301 (2004).
4. Gauged baryon parity and nuclear stability, K.S. Babu, I. Gogoladze and K. Wang, Phys. Lett B570: 32-38, (2003).

5. Gravity and matter in extra dimensions; C. Macesanu, A. Mitov and S. Nandi, Phys. Rev. D68: 084008 (2003).
6. Unity of elementary particles and forces in higher dimensions; I. Gogoladze, Y. Mimura and S. Nandi, Phys. Rev. Lett. 91: 141801 (2003).
7. Standard Model CP violation in polarized $B \rightarrow D \ell' \ell$; K.S. Babu, U.R.S. Balazi and I. Schienbein, Phys. Rev. D68: 014021 (2003).
8. Unitarity of higher dimensional Standard Model; R.S. Chivukula, D.A. Dicus, H-J. He and S. Nandi, Phys. Lett. B562: 109-117 (2003).
9. Unification of gauge, Higgs and matter in extra dimensions. I. Gogoladze, Y. Mimura and S. Nandi, Phys. Lett. B562, 307-315 (2003).
10. Gauge Higgs unification in the left-right model; I. Gogoladze and Y. Mimura and S. Nandi, Phys. Lett. B560, 204-213, (2004).
11. Finite theories and the SUSY flavor problem; K.S. Babu, T. Kobayashi and J. Kubo, Phys. Rev. D67: 075018 (2003).
12. Stabilizing the axion by discrete gauge symmetries; K.S. Babu, I. Gogoladze and K. Wang, Phys. Lett. B560: 214-222 (2003).
13. Natural R-parity, mu term, and fermion mass hierarchy from discrete gauge symmetries; K.S. Babu, I. Gogoladze and K. Wang, Nucl. Phys. B660: 322-342 (2003).
14. Two loop neutrino mass generation and its experimental consequences, K.S. Babu and C. Macesanu, Phys. Rev. D67: 073010 (2003).
15. Implications of a massless neutralino for neutrino physics; I. Gogoladze, J. Lykken, C. Macesanu and S. Nandi, Phys. Rev. D68: 073004 (2003).
16. Orbifold breaking of 3-3-1 model; I. Gogoladze, Y. Mimura and S. Nandi, Phys. Lett. B554: 81-91 (2003).
17. New signals for universal extra dimensions; C. Macesanu, C.D. McMullen and S. Nandi, Phys. Lett. B546: 253-260 (2002).
18. Finite grand unified themes and quark mixing matrix; K.S. Babu, T. Enkhbat and I. Gogoladze, Phys. Lett. B555: 238-242 (2003).
19. Collider implications of universal extra dimensions; C. Macesanu, C.D. McMullen and S. Nandi, Phys. Rev. D66: 015009 (2002).

20. Observable neutron-antineutron oscillations in seesaw models of neutrino mass; K.S. Babu and R.N. Mohapatra, Phys. Lett. B518: 269-275 (2001).
21. Solving the strong CP and the SUSY phase problem with parity symmetry; K.S. Babu, B. Dutta and R.N. Mohapatra, Phys. Rev. D65: 016005 (2002).
22. Classification of effective neutrino mass operators; K.S. Babu and C.N. Leung, Nucl. Phys. B619: 667-689 (2001).