

**Study of particle physics models with
implication for dark matter and cosmic ray
phenomenology**

A thesis submitted in partial fulfillment of
the requirements for the degree of

Doctor of Philosophy

by

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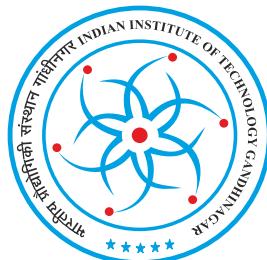
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DISCIPLINE OF PHYSICS

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2015

To
My Family

Declaration

I declare that this written submission represents my ideas in my own words and where others' ideas or words have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission. I understand that any violation of the above can cause disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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CERTIFICATE

It is certified that the work contained in the thesis titled "**Study of particle physics models with implication for dark matter and cosmic ray phenomenology**" by **Mr. Gaurav Kumar Tomar** (Roll No. 11330006), has been carried out under my supervision and that this work has not been submitted elsewhere for a degree.

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Abstract

There are many observations in particle physics and cosmology, which seek physics beyond standard model for their explanation. Some of them are : The excess of positron over cosmic ray background observed by AMS-02 experiment, the 3.6σ discrepancy between muon ($g - 2$) measurement by BNL and its standard model prediction, and the absence of Glashow-resonance in the PeV neutrino events at IceCube. As the thesis title indicates this work is about the study of particle physics models which not only explain the mentioned observations but also give a suitable candidate of dark matter with correct relic density.

In the work presented here we have proposed a gauged horizontal symmetry model for which we introduce a 4th generation of fermions into SM. We then introduce a $SU(2)_{HV}$ vector gauge symmetry between the 4th generation leptons and muon families. The 4th generation right-handed neutrino is identified as dark matter which annihilates into leptons final state $(\mu^+ \mu^-, \nu_\mu^c \nu_\mu)$ giving rise to correct relic density. In this model, dark matter is leptophilic in nature, so it can explain AMS-02 positron excess remaining consistent with stringent bounds from antiproton. It is also possible to alleviate the discrepancy in muon ($g - 2$) from 4th generation charge lepton, $SU(2)_{HV}$ gauge boson, and from neutral and charged scalars. In this way, both the signals, muon ($g - 2$) and the excess of positron can be explained simultaneously. We have also studied an alternative left-right model called dark left-right model, where it is possible to accommodate a suitable dark matter candidate. The second generation right-handed neutrino is identified as dark matter which dominantly annihilates into leptons final state. So it is possible to explain AMS-02 positron excess and lift the stringent bounds from antiproton. The singly and doubly charged scalars in dark left-right model also contribute to muon ($g - 2$) and so both the signatures can also be related in this model.

Another part of this thesis deals with the absence of Glashow resonance at IceCube PeV neutrino events. The IceCube collaboration has observed neutrino of very high energy which goes upto ~ 3 PeV, but did not see any events at Glashow resonance. The Glashow resonance gives rise to an enhanced cross-section for $\bar{\nu}_e$

at resonance energy 6.3 PeV which increases the detection rate of $\bar{\nu}_e$ by a factor of ~ 10 . This implies that at least some of the events should have been observed at Glashow resonance, but none were. We proposed a new mechanism which can explain why neutrinos arising from astrophysical process may be suppressed. We assume a Lorentz violating higher dimensional operator, which modified dispersion relation of neutrinos (antineutrinos). As a result, pion and kaon decay widths get suppressed and we observe a cutoff in the neutrino spectrum which is consistent with IceCube data.

Keywords: Dark Matter, Beyond Standard Model, Relic abundance, Gauge extension, Muon magnetic moment, PeV neutrino events.

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List of Publications

Publications in journals

1. **Gaurav Tomar**, Subhendra Mohanty, and Sandip Pakvasa, *Lorentz Invariance Violation and IceCube Neutrino Events*, JHEP 1511 (2015) 022, doi: [10.1007/JHEP11\(2015\)022](https://doi.org/10.1007/JHEP11(2015)022), arXiv:1507.03193.
2. Tanushree Basak, Subhendra Mohanty, and **Gaurav Tomar**, *Explaining AMS-02 positron excess and muon anomalous magnetic moment in dark left-right gauge model*, JHEP 1603 (2016) 062, doi: [10.1007/JHEP03\(2016\)062](https://doi.org/10.1007/JHEP03(2016)062), arXiv:1501.06193.
3. **Gaurav Tomar**, and Subhendra Mohanty, *Muon anomalous magnetic moment and positron excess at AMS-02 in a gauged horizontal symmetric model*, JHEP 1411 (2014) 133, doi: [10.1007/JHEP11\(2014\)133](https://doi.org/10.1007/JHEP11(2014)133), arXiv:1403.6301.

Conference Papers

1. **Gaurav Tomar**, *Explaining muon magnetic moment and AMS-02 positron excess in a gauged horizontal symmetric model*, XXI DAE-BRNS High Energy Physics Symposium, IIT Guwahati, Assam, India, December 8-12, 2014, Springer Proceedings in Physics, doi: [10.1007/978-3-319-25619-1_66](https://doi.org/10.1007/978-3-319-25619-1_66), arXiv:1507.01797.