INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

Name of the Student : Basabendu Barman

Roll Number : 156121033

Programme of Study : Ph.D.

Thesis Title:

Features of Vector Boson Dark Matter and Discovery Potential

Name of Thesis Supervisor(s) : Dr. Subhaditya Bhattacharya

Thesis Submitted to the Department/ Center : Physics

Date of completion of Thesis Viva-Voce Exam : 25.02.2021

Key words for description of Thesis Work : Dark matter, neutrino mass, unification, collider, effective theory

SHORT ABSTRACT

The discovery of the 'Higgs' boson, the last missing piece of the Standard Model (SM) of particle physics, at the Large Hadron Collider (LHC) in 2012 validates SM as the fundamental governing theory of strong, weak and electromagnetic interactions. SM is remarkably successful and has withstood over two decades of precision tests. It does, however, leave several questions unanswered, motivating the search for new physics (NP) beyond the SM. One of them being a particle description of non-luminous and non-baryonic form of matter, popularly known as dark matter (DM), well established via several astrophysical observations to constitute almost 26% energy budget of the universe. These observations suggest that DM is electromagnetically neutral and stable at the scale of universe's life time; although we do not have any idea about the intrinsic properties e.g., its spin (whether it is a spin-0, spin-1 or spin-1/2 particle) or the nature of its interaction with the visible sector. The focal theme of the thesis is to analyze the possibilities of a vector boson (spin-1) particle to be a potential DM candidate, its production via (i) thermal freeze-out and (ii) non thermal freeze-in to achieve correct relic density and its detection possibilities in direct and collider searches. Existence of non-zero but tiny neutrino mass is also a known feature that can not be explained within the SM paradigm. Seesaw mechanisms of different types thus have been ideated, and we aspire to address both DM and neutrino mass generation in the same model framework and highlight the connection wherever possible. Apart from Ultra Violet (UV) complete models, effective theory (EFT) approach to address vector boson DM has also been studied here. The thesis contains four main chapters of original work. The first work (Chapter. 3) elaborates upon a non-abelian (SU (2)) vector boson DM which can couple to SM quarks (along with exotic ones), and have interesting phenomenology at direct search and at the Large Hadron Collider (LHC). Unification of gauge couplings at high energy provide important constraints to the available parameter space. In the second work (Chapter. 4), a different realization of non-abelian vector DM is considered that can give rise to a multipartite DM scenario enabling DM-DM interactions to play a part. Freeze-in realization of vector boson DM is discussed in Chapter. 5 where the DM-SM interaction becomes feeble and provides distinguishable phenomenological con sequences. In this context, we derive a generic prescription of DM freeze-in from late decays of particle(s) frozen out of equilibrium. Finally, we focus on a dimension five operator that inherits an abelian vector boson DM and discuss the freeze-in production for large new physics scale in Chapter. 6. Importantly, we show the limitations of the vanilla UV freeze-in when the reheat temperature of the universe becomes comparable to the TeV-scale DM mass. Apart from that, SM along with its limitations are introduced in Chapter. 1. Chapter. 2 provides an in-depth description of DM, neutrino mass and GUT physics. We conclude in Chapter. 7, mentioning future directions to explore.