The Search for Detectable WIMPs

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Introduction

The existence of dark matter is essentially established through observations of gravitational anomalies, but its nature is still highly contested [2]. For compelling reasons, we assume, in this project, that it also likely interacts via a weak interaction, through a dark Z boson (or dark photon), Z_d, analogous to its Standard Model counterparts. Many attempts have been made to detect such WIMPs (Weakly Interacting Massive Particles), and one such attempt is being proposed for the Belle II experiment, recording data at the SuperKEKB positron-electron collider in Japan.

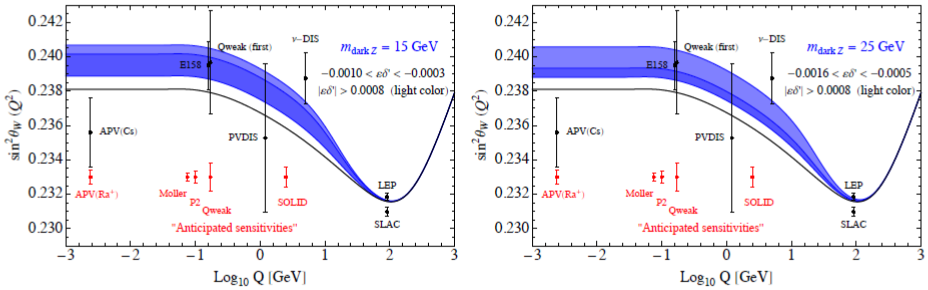
At the positron-electron collider, precision measurements of parity violation could be made, using polarized-electron beams at relatively low energies (about 10 GeV). Since a Z_d boson is analogous to the Standard Model Z boson, it too should exhibit parity violation. The hope is to detect the indirect effects of this parity violation, and find it to be distinct from the parity violations predicted by the Standard Model, hence moving beyond the Standard Model.

Proposed Project and Timeline

The objective of this project is to develop the theoretical backing to help justify the potential upgrade, to introduce polarization to the electron beams, of the SuperKEKB. The main focus is on, what dark boson masses (m_{Z_d}) are implied by the potential measurements of mixing angle (made possible by the upgrade), made at the energy scales of the Belle II experiment.

Project Goals:

1. Replicate the calculations performed by Davoudiasl et. al (Ref. [1]), and output plots as shown in Figure 1. The purpose of this is to primarily familiarize oneself with the fundamental framework of the problem at hand.



(a) (b)

Figure 1: Effective weak mixing angle running as a function of Q^2 shift (the blue band) due to an intermediate mass Z_d for (a) m_{Z_d} = 15 GeV and (b) m_{Z_d} = 25 GeV; Davoudiasl et. al (Ref. [1])

2. Perform similar calculations to the one above, for different m_{Z_d} values
3. Find allowed m_{Z_d} values, for regions **within** $\pm 5\sigma$ of the Standard model curve in Figure 1
4. Find allowed m_{Z_d} values, for regions **outside** $\pm 5\sigma$ of the Standard model curve in Figure 1 i.e. for discoveries that very distinctly lie beyond the Standard Model.
5. Attempt to outline some of the cosmological implications of different m_{Z_d} values, and explore possibilities of how a discovery of a specific m_{Z_d} value, at Q = 10.58 GeV, could be confirmed by other cosmology driven projects.

It is expected that 1. would take up a significant portion of Fall term 2019, and 2., 3. & 4., would follow comparatively quicker. The hope is to be working on 5. from early February (2020) onward, until the end of Spring term 2020. Numerical limitations might cause a few setbacks during the actual solving of the problem, but no such problems are anticipated at this time.

References

[1] Davoudiasl et. al; Low Q^2 Weak Mixing Angle Measurements and Rare Higgs Decays; 2015; arXiv1507.00352

[2] Davoudiasl et. al: Dark Z implications for Parity Violation, Rare Meson Decay and Higgs Physics; 2012; arXiv1203.2947