Heavy Photon Search Thesis Proposal

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Overview

It is widely accepted that Dark Matter constitutes a large percentage of matter in the universe, but the Standard Model does not provide any candidates able to explain the majority of it [1]. This is one of the many reasons that have led to a number of theories extending the Standard Model, some positing that "hidden sectors" of additional particles and forces exist beyond the Standard Model as likely candidates. The Heavy Photon Search collaboration is designed to search for a hidden sector force, the heavy photon [2-4]. The heavy photon, or A', appears quite generally when the model contains an additional $U(1)$ gauge [5, 6]. These theories predict a dark photon will interact with the regular electromagnetic photon through kinetic mixing with an interaction term $\varepsilon e A'_{\mu} J^{\mu}_{\mathrm{EM}}$ [7, 8], where the parameter ε is expected to range between 10^{-12} and 10^{-2} [9].

Hidden sectors can be difficult to probe, as they must interact very weakly at best with the Standard Model to have avoided detection thus far. Due to the difficulty of studying purely gravitational interactions between small particles, theories which include alternative portals into hidden sectors are much easier to probe. There are some tantalizing hints from the observation of excess positrons and electrons in cosmic rays, that a dark photon may play a role in Dark Matter particle decay [10, 11], as well as the difference between the expected and observed anomalous magnetic moment of the muon [12].

The Heavy Photon Search collaboration will probe a mass range of $20\ \mathrm{MeV}$ to $1\ \mathrm{GeV}$ in an attempt to improve the existing constraints on the heavy photon. This will be done through a measurement of the heavy photon invariant mass and decay vertices [2]. To accomplish this, HPS uses both a calorimeter and a vertexing detector along with the Jefferson Lab high-intensity electron beam with $1.1\ \mathrm{GeV}$, $2.2\ \mathrm{GeV}$, and $6.6\ \mathrm{GeV}$ beam energies. The calorimeter will be designed with rapid triggering capability to handle the high-intensity electron beam and a high degree of segmentation to provide detailed energy deposition information and hit location for electron detection. The vertexing detector and its associated analyzing magnet will provide kinematic information. With this, HPS is expected to provide improved constraints over a wide area of previously unexplored regions.

Thesis Proposal

Kyle McCarty will analyze the results of the HPS 2016 data run to improve constraints on the heavy photon. He will do this by performing a "bump hunt" analysis, searching for energy resonances above background across the mass spectrum. Additionally, in the event that the 2016 data run seems likely to produce insufficient data, he will improve constraints on the 2014/2015 data set, by performing a similar bump hunt with improved analysis techniques by also including information from the recoil electron.

In addition to the bump hunt, Kyle will assist the collaboration in developing analysis software as well as take shifts during the running of the experiment. He will also work with the calorimeter, assisting in its testing and construction. He will relocate to Jefferson Laboratory in order to directly participate with the ECAL construction and testing, and all preparation for the data run as well as take full part in the data run itself.

References

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