Update on the Heavy Photon Search Experiment

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The Heavy Photon Search (HPS) experiment at Jefferson Lab, E12-11-006, is searching for new heavy vector-boson(s) aka 'heavy' or 'dark' photon(s), A', in the mass range of 20 MeV/c^2 to 500 MeV/c^2 and couplings $\epsilon > 10^{-10}$. The experiment was first proposed to PAC37 in 2011 and received C2 approval. Then, after the test run in May 2012, PAC39 gave a C1 approval with "A" rating. At PAC41, the 39 PAC days of the HPS beam time out of the fully approved 180 days, have been granted "High Impact" status. After two successful engineering runs in 2015 and 2016 with 1.1 GeV and 2.2 GeV beams, amounting total of 15 PAC days of beam time, HPS has been fully approved by Jefferson Lab management. The engineering runs, with merely 2 PAC days of production data at each energy, resulted in the first HPS physics publications as well as two technical papers on detector and beamline performances, and six Ph.D. theses. The engineering runs also lead to the important upgrades of the HPS detector and the trigger system that enhanced its performance significantly especially for A' displaced vertex searches. HPS completed its first physics run in September of 2019 using a 4.56 GeV electron beam and the upgraded HPS detector. Collected data amounts to about 12 days of production running at proposed luminosity. We expect to cover a significant region of the parameter space in a displaced vertex search.

In this document, we present the current status of the field and the HPS experiment with the final results of the engineering run, status of the data analysis of the first physics run, upgraded detector performance and a plan for future running.

CONTENTS

1. INTRODUCTION

Stepan/John/Tim/Maurik - no more than 1.5 pages

The LHC, as well as direct and indirect detection experiments, have significantly constrained one of the best-motivated weak-scale DM models (WIMPs as dark matter candidates). In contrast, scenarios involving a light hidden sector dark matter with mediators in the MeV-GeV range has garnered a good deal of attention. Models with hidden U(1) gauge symmetry, with a "dark" or "hidden sector" photons, are particularly attractive as they can be tested experimentally. If they exist, heavy photons mix with ordinary photons through kinetic mixing, which induces their weak coupling to electrons, ϵe, where e is the electron charge and $\epsilon \leq 10^{-2}$. Since they couple to electrons, heavy photons are radiated in electron scattering and can subsequently decay into e^+e^-. If ϵ is large enough, $\epsilon^2 \approx 10^{-6}$, they would appear as a narrow mass peak in the $\mathrm{e}^+\mathrm{e}^-$ invariant mass distribution, which can be observed above the copious QED trident background. For suitably small couplings, $10^{-10} < \epsilon^2 < 10^{-8}$, heavy photons travel detectable distances before decaying, providing a second signature. The HPS experiment exploits both these signatures to search for heavy photons over a wide range of couplings, $\epsilon^2 > 10^{-10}$, and masses, 20 MeV/$c^2 < \mathrm{M}_{A'} < 500$ MeV/c^2, using a compact, large acceptance forward spectrometer containing a silicon microstrip vertex tracker (SVT), scintillation hodoscope, and a PbWO_4 electromagnetic calorimeter (ECal).

2. MOTIVATION FOR DARK PHOTON SEARCHES

Rouven/Philip/Natalia/Tim - No more than 3-pages

Low mass dark matter

Current status of the field

New targets for HPS

3. SUMMARY OF 2015/2016 RUNS

Maurik/Stepan/Matt G/Omar/John - no more than 3 pages

3.1. Engineering run setup and performance

3.2. Physics results

4. FIRST PHYSICS RUN

Stepan/Tim/Maurik - No more than 5 pages

4.1. Upgraded HPS detector

Stepan/Tim/Rafo

4.2. 2019 run

Stepan/Tim/Maurik - 4 pages

4.3. Detector performance

Norman/Cameron/Rafo/Nathan - 4 pages

4.4. Data analysis progress and the expected reach

Matt G./Omar

5. FUTURE RUNNING

Stepan/John/Maurik/Tim - 2 pages

5.1. Upcoming run in 2021 at 3.8 GeV

Detector repairs and modifications

Expected reach

5.2. HPS beyond 2021

Run plan for the remaining beam time, 105 PAC days

Expected reach at all proposed energy settings

6. SUMMARY

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