Heavy Photon Search TEST RUN A Proposal to Search for Massive Photons at Jefferson Laboratory

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Abstract

The Heavy Photon Search Test Run is the first stage of the Heavy Photon Search experiment, which will search for new heavy vector boson(s), aka "heavy photons", at Jefferson Laboratory. The HPS Test Run was approved by the Jefferson Laboratory PAC 37 on January 14, 2011, and received funding from DOE HEP in July of 2012 to design, construct, and run test apparatus. The HPS experiment proper will utilize a compact, large acceptance forward spectrometer, silicon microstrip vertex tracker, and $PbWO_4$ electromagnetic calorimeter to search for electro-produced heavy photons decaying to e^+e^- in the mass range of 20 to 1000 MeV/c^2. Heavy photons would be visible as narrow resonances above the copious QED trident background, and by detection of their secondary decay vertices downstream of the target. High luminosities are required to search for heavy photons because of their weak couplings to electrons and the prolific backgrounds. HPS achieves great sensitivity by exploiting CEBAF's 100% duty cycle, high luminosities, and 40 MHz continuous readout, and by placing silicon microstrip detectors and the electromagnetic calorimeter used for triggering in close proximity to a hot electron beam. The purpose of the HPS Test Run is to verify detailed full Monte Carlo simulations that microstrip occupancies and ECal trigger rates are manageable in this environment with a simplified version of the HPS apparatus. The Test Run will also demonstrate that the tracker and ECal sensors and readout are operable, and that the data acquisition can run at very high rates. The Test Run apparatus is capable of high rate triggering, full track finding, momentum measurement, and vertexing, so it is capable of demonstrating the physics capability of the full HPS. In particular, the

Test Run apparatus is capable of extending the search for heavy photons into virgin territory with even modest run times.

Contents

1. INTRODUCTION

This proposal seeks funding for the first stage of the Heavy Photon Search Experiment which was approved by the Thomas Jefferson National Accelerator Facilitys Program Advisory Committee on January 14, 2011.PAC37 reviewed the scientific motivations for and the technical feasibility of HPS, and approved Stage I of the HPS proposal, the HPS Test Run, and urged it be scheduled before the end of 6 GeV running. They also granted approval for Stage II, the full HPS experiment, contingent on the success of the test run. Ideally, given the topical nature of heavy photon searches, Stage I of the proposal would run before the planned CEBAF shut down in the Summer of 2012, when its energy will be upgraded from 6 GeV to 12 GeV. The planned upgrade is scheduled to be completed by the end of 2013, with commissioning and some first running in 2014 and the resumption of a full experimental schedule in 2015. The full HPS run is planned for the 12 GeV era of CEBAF.

The highest priority goal of the HPS Test run is to validate the fundamental assumptions behind the design of the full HPS experiment and thereby prepare the foundation for full HPS approval. A critical design feature of the HPS is the placement of silicon microstrip detectors in close proximity to an intense electron beam and tracking and vertexing in the resultant high occupancy environment. The experiment is also dependent on placing an electromagnetic calorimeter just downstream of the tracking detectors, also in close proximity to the beam, and triggering on candidate e+e- pairs with good acceptance and efficiency and manageable rates. Measurements of tracker occupancies and trigger rates will allow us to understand the projected performance of the full experiment. Confirming that occupancies and trigger rates are manageable, which has been demonstrated in full Monte Carlo simulation, is our highest priority goal.

In order to reach this goal, the following must be accomplished. First, we must assemble the appropriate beamline, a magnet chicane, vacuum chambers, and beam diagnostics, to measure the beam sizes, halo, and stability required to measure occupancies and trigger rates. The CEBAF beam quality has been well-measured and is known to satisfy HPS experimental requirements, but, practice controlling and monitoring the incident electron beam is prerequisite for successful HPS operations. Second, we must instrument a silicon tracker/vertexer capable of making the occupancy measurements. We must produce working silicon sensors, front end readout, and DAQ capable of making the occupancy measurements, and capable of the high rate data acquisition needed for HPS. Third, we must implement an electromagnetic calorimeter based on existing $PbWO_4$ crystals and its readout and high speed DAQ, and construct a suitable temperature-controlled enclosure and the vacuum chamber which allows the crystals to be placed in close proximity to the beam.

Secondary objectives for the HPS Test Run can be pursued when the apparatus is commissioned and useful running conditions are established. It should be straightforward to record random events in the tracker and provide samples of tracks in the SVT.Offline analysis can then determine tracker alignment, track finding efficiency, sensor efficiency and noise, and ultimately momentum and vertex resolution. Stable operating conditions and a successfully operating Ecal DAQ will enable commissioning of the trigger electronics. Assuming successful operation of the above-mentioned items, implemention of full rate, triggered data acquisition will be next and with it the possibility of triggering on e+e- pairs. This entire effort will enable tremendous strides toward our long term goal of preparing a fully operational HPS experiment.

The HPS Test Run apparatus has the potential to extend the search for a heavy photon into a virgin domain of heavy photon masses and couplings. This region is favored by ascribing the present 3.5 sigma discrepancy between the measured and predicted value for the muons anomalous magnetic moment to the effects of a heavy photon.

The physics which motivates the HPS Test Run is exactly that which motivates the full HPS, and is discussed in detail in the HPS proposal [1]. Briefly, HPS is searching for new heavy vector boson(s), aka heavy photons or dark photons or hidden sector photons, in the mass range of 20 MeV/c^2 to 1000 MeV/c^2.Heavy photons mix with the Standard Model photon through kinetic mixing, which induces their weak coupling to electrons, ϵe, where ϵ 10^{-3}. Heavy photons in this mass/coupling range are expected on very general theoretical grounds, and also motivated by recent astrophysical evidence suggesting they might mediate dark matter annihilations and/or dark matter interactions with ordinary matter. Since they couple to electrons, heavy photons are radiated in electron scattering and can subsequently decay into narrow e+e- resonances which can be observed above the copious QED trident background. For suitably small couplings, heavy photons travel detectable distances before decaying, providing a second signature. The HPS experiment exploits both of these signatures to search for heavy photons over a wide range of couplings, $\epsilon^2 > 10^{-10}$, and masses.

Existing constraints on heavy photon masses and couplings come from axion searches, the anomalous magnetic moments of the muon and electron, and direct searches for heavy photons in the B factory data and in recent electroproduction experiments conducted at Jefferson Lab and Mainz [2]. These constraints and the reach of the full Heavy Photon Search (HPS) experiment are shown in Fig.1. The potential reach of the HPS Test Run is also indicated. Roughly speaking, heavy photons are allowed below a coupling strength of few $\times 10^{-3}$ and throughout the mass range of 20-1000 MeV/c2. As indicated in the figure, the full HPS experiment will simultaneously explore two large regions of this parameter space. One HPS search region focuses on a wide range of heavy photon masses and moderate couplings with a traditional bump-hunt search, much of which other experiments plan to probe as well. The other region is unique, and utilizes both invariant mass and separated decay vertex information to provide unparalleled sensitivity to small couplings over the mass range $20 - 250$ MeV/c^2.

Physicists and engineers from SLAC, the Hall B Group at JLab and their collaborators, Fermilab, and UC Santa Cruz have developed both the full HPS proposal, and this HPS Test Run proposal. The full experiment utilizes a high acceptance forward spectrometer with precise momentum, vertexing, and calorimetric measurement capability. Technologically, the HPS depends upon the 40 MHz LHC-style readout capability of the silicon microstrip vertex/tracker, the matching high rate capability of a highly segmented PbWO4 calorimeter, and high rate triggering and data acquisition systems. Combined with CEBAFs superb duty-cycle, high intensities, and excellent beam properties, this high rate capability lets HPS achieve the high integrated luminosities required to search for heavy photons.

The HPS Test Run will utilize a simplified version of the experiment, but test its crucial aspects. An existing analyzing magnet and vacuum chamber, already in place in Hall B at JLab, will be used in place of the larger magnet proposed for the full experiment. The other chicane magnets are already in place as well. The analyzing magnet will accommodate a simplified tracker-vertexer, which will use only 20 silicon microstrip detectors vs the 120 required for the full design, albeit with reduced acceptance and precision. The electromagnetic calorimeter for the test run will utilize only the existing PbWO4 crystal modules with photodetectors and preamplifiers.The data acquisition system for the tracker/vertexer and the ECal will use the front end components and architecture of the eventual system, but with a much reduced channel count. The data will be taken at 2.2 GeV where the reach extends at most to about 200 MeV/c2, obviating the need for the muon system, which will be deferred until the full HPS run. The vacuum system is also simplified. An existing vacuum chamber will be modified to accommodate the silicon tracker/vertexer, instead of being built from scratch, and existing beam pipes will be used where possible. The ECal will require construction of a new environmental enclosure and support structure, but they will be reused for the full experiment. The design is discussed in detail below. With all these simplifications, the cost of the test run is approximately one fourth that of the full, unstaged HPS. Many of the costs associated with the test run, including development of the silicon microstrip readout, prototyping the DAQ, and the support and environment control for the ECal, are direct investments in the full HPS.

In the following sections, we first discuss the proposed Test Run experimental setup, including the beamline, silicon tracker/vertexer, ECal, and the electronics and data acquisition systems. Then we review the performance of the apparatus as determined from detailed full Monte Carlo simulations. We conclude with a summary of critical outcomes for the experiment, including its potential reach, and the associated cost, proposed schedules, and personnel that will lead to the timely execution of the HPS Test Run before the scheduled CEBAF downtime.

2. EXPERIMENTAL SETUP

A. Overview

The HPS Test Run is a simplified, bare bones version of the full HPS apparatus, designed to confirm that backgrounds and trigger rates are as simulated and therefore manageable, but still powerful enough to provide real tracking and vertexing, reasonable acceptance, and full, high rate data acquisition capability. Consequently the HPS Test Run will provide the proof of principle for the full HPS experiment and has the potential to extend the search for heavy photons to as yet unexplored regions of parameter space.

Like the full experiment, the Test Run experiment relies upon the precision measurement of two quantities: the invariant mass of the A' decay products and the position of the decay vertex. By placing a tracking and vertexing detector immediately downstream of the target inside an analyzing magnet, the complete kinematic information required for A' reconstruction can be obtained from a single system, whose proximity to the target naturally maximizes the acceptance of a relatively compact detector and provides excellent momentum and vertexing resolution.

The Test Run Tracker replaces the six layer, 120 microstrip sensor design of the full experiment with a five layer system using just 20 sensors over all. Doing so will restrict the acceptance and tracking precision, but retain track finding, momentum measurement, and vertexing capability. Placement of detectors mimics that of the full design. Placing the planes of the tracker immediately downstream of the target means that the intense primary beam must pass directly through the middle of the tracking detector. There are two key consequences of this arrangement. Firstly, scattered beam particles and radiative secondaries are bent by the magnetic field to sweep out a dead zone where the particle fluxes would be damaging to the sensors as well as creating an environment too dense for pattern recognition.This necessitates a tracking geometry that keeps the sensors out of this region. However, since the energy released in the decay of a low mass A' is small relative to its boost, the opening angle between decay daughters can be quite small.Therefore, to maximize the acceptance for low masses, the size of the dead zone must be minimized and sensors placed as close as possible to the beam. Secondly, interactions of the primary beam with air or even helium at atmospheric pressure gives rise to low-momentum secondaries that generate unacceptable occupancies in the detector. The only way to keep the beam in a vacuum without severely compromising acceptance and vertex resolution is to enclose the entire tracking and vertexing system within a vacuum chamber as well. The Test Run apparatus tests both these features.

High luminosities are needed to search for heavy photons with small couplings and masses in the 100 MeV range. Utilizing CEBAFs essentially continuous duty cycle, the experiment can simultaneously maximize luminosity and minimize backgrounds by employing detectors with short livetimes and rapid readout. Silicon tracking sensors are ideal from this perspective, since they collect ionization in 10s of nanoseconds and produce pulses as short as 50-100 nanoseconds. Thanks to electronics developed for the LHC, the sensors can be read out continuously at 40 MHz.The test run sensors will prototype the designs for the full HPS experiment, utilize the same readout chip, employ the same hybrid, and depend on the same high speed DAQ. The electromagnetic calorimeter just downstream of the tracker uses detectors with comparably short livetimes and high rate capability. It performs two essential functions for the experiment: triggering and electron identification. The device is highly segmented. It is fast, able to readout at rates comparable to those in the tracker, and able to provide good spatial and energy information to the trigger electronics. Like the tracker system, the electromagnetic calorimeter is split to avoid impinging on the dead zone.The beam and radiative secondaries pass through the calorimeter in vacuum, to avoid generating unnecessary backgrounds. The Test Run Ecal will utilize the existing PBWO4 crystals,existing APDs and readout boards,and DAQ that will be subsequently incorporated into the full experiment. A new temperature-controlled enclosure and ecal vacuum chamber needed for the test run will be re-used for the full HPS run. Only the existing crystals will be used for the test run, so acceptance will be smaller than that for the full HPS, but it will be well-matched to that of the test run tracker and more than adequate for a comprehensive test of trigger rates.

The HPS Test Run will use 2.2 GeV incident electrons and be sensitive to A masses up to about 150 MeV/c2. Consequently, the muon system which is part of the full HPS design is not needed for the Test Run, and its construction will be deferred until higher energies are run. This system is perhaps the most conventional and robust of the detector systems in HPS, and the one least stressed by extreme background or rate conditions. So its omission in the Test Run does not compromise our checks of future HPS capability in any significant way.

The various elements of the experiment are discussed in more detail below, beginning with the beamline, continuing with the tracker/vertexer, electromagnetic calorimeter, and concluding with the electronics and DAQ.

B. Beamline Elements

1. Layout

The HPS test experiment will utilize a setup located upstream of the CLAS detector. It will use the same three magnet chicane that is used for the CLAS two photon exchange experiment (TPE). The layout of the beam line and the chicane is shown in Figure 2.2.1.1. The Hall B pair spectrometer magnet, 18D36 (pole length 91.44 cm, max-field 1.5 T), will serve as the analyzing magnet. The dipole field direction (Y) is perpendicular to the horizontal (XZ) plane. A Hall B Frascati H magnets (pole length 50 cm, max-field 1.2 T) will be used as the first and the last dipoles of the chicane. The analyzing magnet will be operated at a 0.5T-m field. The two bending magnets will be set to 0.25T-m fields. The distance between the centers of the magnets and the location of the chicane will be exactly the same as for the TPE run. The only change that will be made to the TPE chicane layout is a transverse displacement of the analyzing magnet by about 4 inches (to beam left) in order to optimize the detector acceptance for e+ and e-.The detector package will include five layers of silicon detectors, mounted inside the vacuum box in the high field region of the analyzing magnet, see Figure 2.2.1.2. The existing vacuum box of the Hall B pair spectrometer will be used to host the tracker and the target. The silicon tracker is described in Section 2.3 below. Downstream of the analyzing magnet there will be an electromagnetic calorimeter for triggering, and for electron and positron identification (see Section 2.4). The target foil will be positioned at the beginning of the analyzing dipole pole. The distance from the target to the first layer of the silicon tracker will be 10 cm. The distance from the target to the face of the electromagnetic calorimeter is 137 cm. There will be continuous vacuum for the electron beam line through the entire setup ending in the Hall B electron beam dump.Since the chicane layout is the same as for the TPE run, no new equipment is needed to run the chicane. The analyzing magnet, the Hall B pair spectrometer dipole, has its own power supply. The Frascati H magnets will use one common power supply that will be borrowed from the Hall B Moller polarimeter. There will be a shunt installed between the two Frascati magnets to allow independent small changes in currents on those two magnets (as it was done during the TPE experiment). Both power supplies are bipolar, so the magnets can be degaussed when needed. New beam line elements that will be needed for the HPS test run are the upstream flange of the vacuum box of the analyzing magnet, a vacuum chamber between the top and bottom parts of the calorimeter that will be connected to the tracker vacuum box, and a vacuum box behind the calorimeter through the third magnet. For the beam line upstream of the analyzing magnet vacuum box and downstream of the third magnet, the standard vacuum beam line of Hall B, with a few small modifications, will be used. Figure 2.2.1.1. Layout of the HPS test run setup upstream the CLAS detectorFigure 2.2.1.2. Layout of the HPS test run chicane and detector package.

2. Running Conditions

HPS test run will use $\sim$ 2.2 GeV electron beam incident on a tungsten (W) target. Beam currents of up to 200nA will be used on tungsten target foils with thicknesses from $4\mu m$ (0.125% RL) to $8\mu m$ (0.25% RL). The high intensity electron beam incident on the tungsten target will generate a significant amount of electromagnetic radiation, composed mainly of bremsstrahlung photons, electrons which have radiated, Moller electrons, and beam particles which have multiple Coulomb scattered. In the dipole field, this radiation will create a sheet of flame in the bending plane (XZ), at the beam height, $Y \sim 0$.Detectors will be positioned above and below the beam plane, leaving a small gap for the bremsstrahlung and multiple Coulomb scattered beam andbeam backgrounds to pass through. The gap between the upper and lower planes of the silicon tracker will be approximately 15 mrad. This angular gap will be maintained between the upper and lower parts of the calorimeter as well.

Operational experience shows that the CEBAF beam is very clean, and is contained within ± 1 mm with halo at the level of less than 10^{-5}, so it will easily pass through the dead zone gap. In Figure 2.2.2.1 the beam profile measured using a wire harp during one of the recent CLAS experiments at 2.2 GeV is presented. Beam sizes of $< 100\mu m$ are typical for the B-line. It should be noted that the profile measured with the wire scanner includes not only the actual beam size but also any ¿100 Hz beam motion. Studies are needed to decouple beam motion from the actual beam size.

The beam sizes presently achievable in Hall B are suitable for muchof the test run. However, for checking the vertexing performance and acquiring physics data, an asymmetric beam profile is desirable. Since the vertex resolution in the non-bend plane will be high, beam sizes of $20 - 30\mu m$ in the Y direction are preferable.The momentum measurement will not benefit from small beam sizes in the X direction, and small beam sizes in both dimensions will overheat the target foil. For these reasons the required beam sizes for part of the run will be $\sigma_X \sim 250\mu m$ and $\sigma_Y \sim 30\mu m$.

The HPS beam parameter requirements are presented in Table 2.2.2.1.

None of the CLAS experiments have requested such small $(20 - 30\mu m)$ beam sizes. The optics

Parameter	Requirement/Expectation	Unit
E	2200	MeV
δp/p	$< 10^{-4}$	
Current	< 200	nA
Current Instability	< 5	%
σ_x	< 300	μm
σ_y	< 40	μm
Position Stability	< 30	μm
Divergence	< 100	μrad
Beam Halo ($> 5\sigma$)	$< 10^{-5}$	

TABLE I: Required beam parameters.

program ELEGANT is used to determine the optimized element parameters of the B-line optics in order to achieve these beam sizes at the HPS test run target location. An emittance of $\sigma_x = 1x10^{-9}$ m-rad and $\sigma_y = 1x10^{-9}$ m-rad are used as input.These values are a factor of three larger than the design values so the beam size could be smaller by 3 if the emittance is near the design value. The results from the first optimization run for the horizontal and vertical beam sizes for a 2 pass beam at 2.2 GeV are shown in Figure 2.2.3.2. The goal of the optimization was to achieve the smallestpossible beam sizes in both X and Y. With the existing B-line optics, beam sizes of $\sim 30\mu m$ is achievable. The second optimization run determined beamline parameters for an asymmetric beam. Results of this optimization are presented in Figure 2.2.3.3. An asymmetric beam profile with $\sigma_X 250\mu m$ and $\sigma_Y 20\mu m$ is also achievable.

Figure 2.2.2.1: Hall B 2.2GeV beam profile measured during one of recent CLAS experiment.

Figure 2.2.3.2. Beam sizes in X and Y along the B-line in the upstream tunnel and in the region of the HPS test run setup. At the HPS target beam size of $\sigma \sim 30\mu m$ can be achieved with existing B-line optics.

Figure 2.2.3.3. Beam sizes in X and Y along the B-line in the upstream tunnel and in the region of the HPS test run setup. At the HPS target asymmetric beam profile $\sigma_X = 300\mu m$ and $\sigma_Y = 20\mu m$ can be achieved with existing B-line optics.

3. Diagnostics and Trajectory

Control The HPS test run will use the Hall-B beam line as is. Beam position and current will be controlled by two sets of cavity beam position monitors (BPM) that are located in upstream tunnel. There are sets of corrector dipoles and quadrupoles that are routinely used to tune the beam for Hall B. Pair of BPMs will define the incoming trajectory of the beam and are in the fast feedback loop. Readings from these BPMs will be used to maintain stable beam position and current.

The beam profile will be measured using two wire scanners, one installed in front of the first chicane dipole, another about 8 meters upstream. These two profilers will be used to establish the required beam parameters. There will also be a wire scanner mounted on the target ladder to check the beam profile at the target location.

There will be set of beam halo counters mounted along the beam line in order to provide fast monitoring of the beam conditions. These counters are like those used for beam profile measurements. They are also included in the machine fast shutdown system (FSD) in order to terminate beam in the event of beam excursions.

4. Targets

Thin tungsten foil will be used for the target. High Z material is chosen to minimize the hadronic production relative to the trident and A production, since the ratio of QED to hadronic processes goes as (Z2/A). The target will be located 10 cm in front of the first plane of silicon strip detectors. The primary target will be 0.125% of a radiation length (approximately 4 microns tungsten). A foil of 0.25% radiation length will also be available for some of the data taking, adjusting the beam current as appropriate.

It is intended to operate with beam currents up to 200 nA, which will produce strong local heating in the target. The strength of tungsten drops by an order of magnitude with temperature increases in the range of 1000 C. In addition, the material re-crystallizes above this range, which increases the tendency for cracking where thermal expansion has caused temporary dimpling. For these reasons, we plan to keep the temperature rise below about 1000 degrees. This can be accomplished by keeping the beam Gaussian width above 70 microns for a round beam spot. However, a strongly elliptical beam spot will be an advantage for constraining the vertex during data analysis. A spot of, for example, 20 by 250 microns would achieve the same limitation of the temperature rise. The combination of vacuum, magnetic field and potential radiation damage have to be borne in mind in the design, and suitable materials must be used. The device additionally has to be compatible with the silicon strip detector system and its cable and cooling plant, as well as beam line diagnostic equipment. A vertical linear motion mechanism will allow the foil to be positioned on or off the beam line. The foil material will be mounted on a 3-sided frame, the upper edge being free-standing. That will be the leading edge when the foil is moved up on to the beam line, and so the move can be made without inhibiting the beam delivery, which would be necessary if a full rectangle were to be used for the frame. Alignment relative to the beam is thus easily accomplished. Between the supports, the surface of the foil will be 5 mm tall by 20 mm wide. By providing position control, further advantages can be realized. Lower on the same C-frame, separated by 1 millimeter, will be a second foil of probably 8 microns (0.25% radiation length) to further test scaling of the detector performance against thickness and beam current. However, in addition, a set of tungsten wires will be installed on extensions of the arms of the support frame. The wires, of about 12 microns diameter, will in fact be the first material to encounter the beam during insertion. They will be used as a fairly conventional wire scanner. In particular they would be able to provide information about the minor and major axes, and the tip angle (roll), of a strongly elliptical beam spot. Wires mounted at 6 and horizontal would be ideal for this purpose. They will be spaced to avoid overlap between scan profiles for the largest beams they are required to measure. There is adequate room for this. Positioning resolution of 5-10 microns will be provided for scanning. It is intended to read out scatter signals from the wires by using some of the calorimeter crystals. If these signals are not within range, a simple counter will be installed for the purpose at the downstream end of the vacuum tank.

5. Scattering chambers

One of the critical elements on the beam line is a scattering chamber between the top and bottom parts of the ECal. In order to keep calorimeter coverage close to the beam, maintain required thickness of the thermal insulation for ECal, and maintain as wide as possible vacuum gap, the top and bottom plates of the scattering chamber must be quite thin. At the locations of primary beams (e- and ?) the openings in the chamber must be even bigger.In Figure 2.2.5.1 a conceptual design of the scattering chamber is shown. Front flange of the chamber matches to the exit flange of the vacuum box inside the analyzing magnet. Vacuum is maintained only on the electron side (beam right). Two wider openings are for electron and photon beams. This design allows crystals to be at 20 mm from the beam plane. After the crystals, some where at half a length of the chamber, vacuum chamber plates will be thicker since there is no need for electronics to be at the same level as the crystals.Figure 2.2.5.2 shows this arrangement with the crystals at 20 mm of the beam, and in between the thermal shield of the ECal surrounding the chamber wall and reinforcement rib closed to the elliptical shape. Figure 2.2.5.1. A conceptual design of the scattering chamber.Figure 2.2.5.2. Special arrangement to fit the scattering chamber with the ECAL.In order to validate the conceptual design physics simulations and mechanical analysis are performed. The proposed chamber can be made of aluminum 5083 H111 or stainless steel 304 L. In Figure 2.2.5.3 stress analysis performed with an aluminum chamber, which follows the CODAP design rules is shown. In Figure 2.2.5.4, the deformation in the middle is shown. One of possible solution to avoid the deformation can be inserting an aluminum honeycomb in the scattering chamber. Further physics simulations and mechanical optimization are foreseen. Figure 2.2.5.3. The stress analysis of the proposed scattering chamber made of aluminum 5083.Figure 2.2.5.4. Deformation of the top and bottom plates of the vacuum chamber.

C. Tracking and Vertexing system

D. Electromagnetic Calorimeter

E. Electronics and DAQ

3. SIMULATIONS AND RECONSTRUCTION

4. SETUP FOR PARASITIC RUN

5. PERFORMANCE OF THE TEST RUN APPARATUS

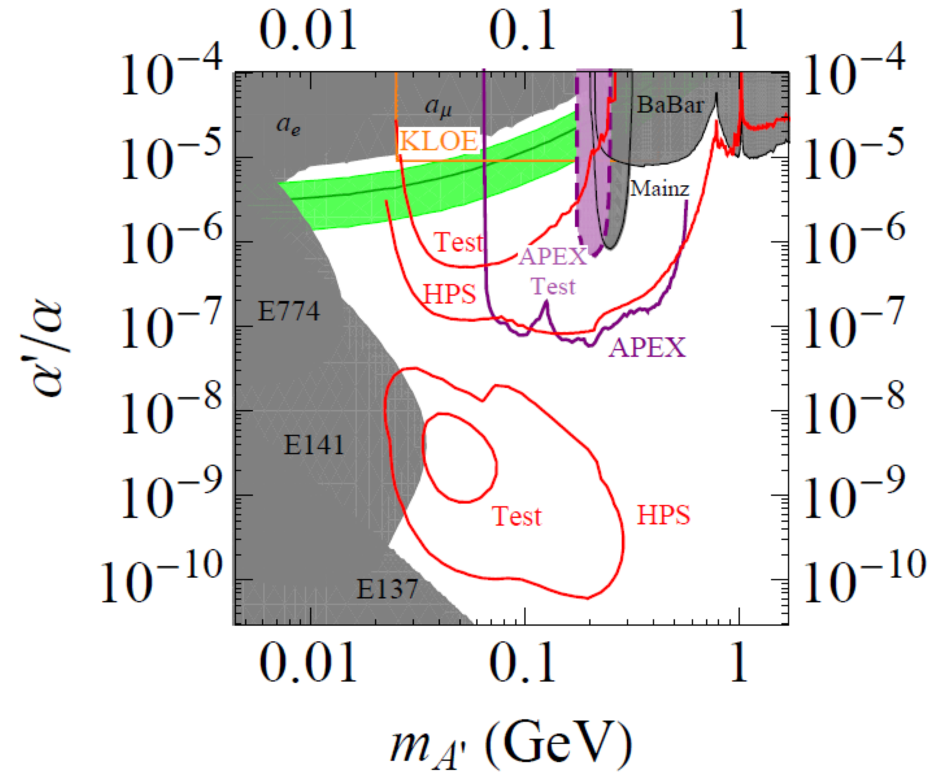

FIG. 1: Anticipated reach in $\alpha'/\alpha = \epsilon^2$ for the Heavy Photon Search (HPS) experiment at Hall B in JLab (red lines) with existing constraints on an A' from electron and muon anomalous magnetic moment measurements, a_e and a_μ (see [3, 4]), the BaBar search for $\Psi(3S) \to \gamma\mu + \mu^-$ [5], three beam dump experiments, E137, E141, and E774 [**?**] (see [2]), and a limit from a test run of a fixed target experiment at MAMI (Mainz) [9].A preliminary limit from a search by KLOE for decays $\Phi \to \eta A' \to \gamma e^+e^-$ is shown as an orange curve. Note that the limit on a_μ is 5σ, the limit from MAMI is 90%, while the other limits are 95%.The green shaded band shows the $\pm 2\sigma$ preferred region for an A' to explain the discrepancy between the observed and Standard Model predicted value for a?. Also shown are estimates of potential 2σ sensitivities for A' searches in existing data (thin dashed lines), assuming optimal sensitivity as described in the full version of this proposal: KTeV $\pi^0 \to \gamma A' \to \gamma e^+e^-$, (green dashed curve) and Belle $e^+e^- \to \gamma A' \to \gamma\mu^+ mu^-$ (gray dashed curve). In addition, we show the projected 2σ sensitivities for the proposed APEX experiment in JLab Hall A (purple) [8], the 2σ projected sensitivity achievable with the APEX test run (purple dashed), and the 5σ sensitivity taken from [9] of the proposed DarkLight experiment using the JLab Free-Electron Laser (FEL) (blue). The HPS lines show the combined 2σ sensitivity of two 9×10^6 second runs, with a 6.6 GeV, 450 nA (2.2 GeV, 200 nA) electron beam incident on a 0.25% (or 0.125%) radiation length tungsten target. The Test lines show the 2σ sensitivity of the test run with 0.5×10^6 seconds of beam time. The upper (lower) red curves denote sensitivity of thefull resonance search (vertex-based resonance search).The latter lines correspond to 2.4 signal events expected after imposing a vertex requirement that reduces background to 0.5 expected events per resolution-limited mass window.The full detector, trigger, and vertexing efficiencies have been included in these estimates.

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