Heavy Photon Search

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The Heavy Photon Search collaboration is performing an experiment aimed at discovering a hidden-sector heavy (or dark) photon - a $U(1)$ vector boson. Heavy photons (or A's) couple to electric charge through kinetic mixing with the Standard Model photon, with production analogous to bremsstrahlung radiation. They may also mediate dark matter interactions. The Heavy Photon Search experiment (HPS) has recently performed two successful engineering runs, first in spring of 2015 and later in the winter of 2016 with a higher beam energy. HPS is expected to take significantly more data during 2019. The experiment is composed of a six-layer silicon microstrip vertex tracker and a $PbWO_4$ crystal calorimeter.

Motivation

Anomalies from cosmic rays [1], as well as dark matter distributions in galactic haloes [2], provide theoretical motivation for a heavy photon in the 0.1 to 1.0 GeV range. Such a particle could be produced in a laboratory setting, and identified through its decay products.

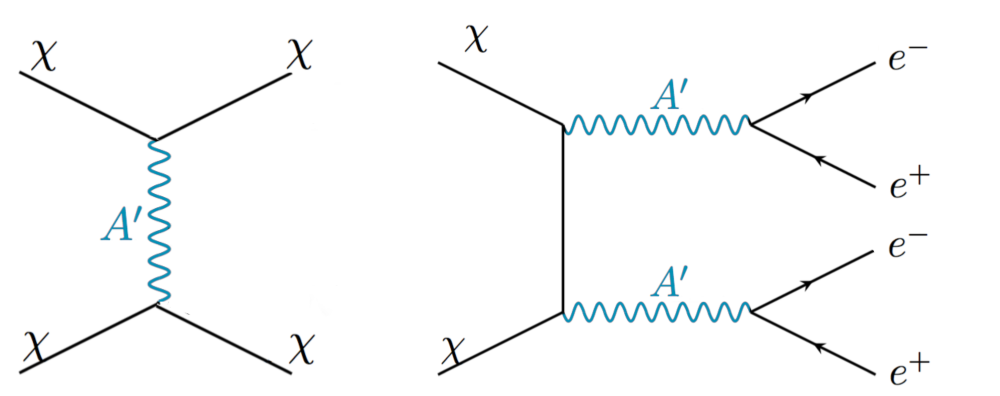

Figure 1: *(left) Dark matter self-interaction, which may solve "core-cusp" anomalies in galactic haloes. (right) Dark matter annihilating into leptons through A', as a solution to cosmic-ray anomalies.*

Signals and Backgrounds

Heavy Photon Signal

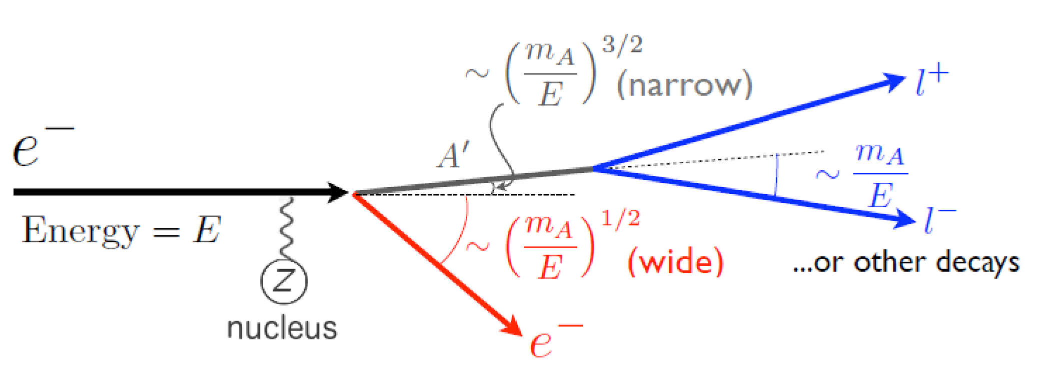

Figure 2: *Topology and kinematics of an A' production as an incoming electron scatters off a nucleus with atomic number Z, and then decays.*

A' particles are generated in electron collisions on a fixed target by a process analogous to ordinary photon bremsstrahlung.

Backgrounds

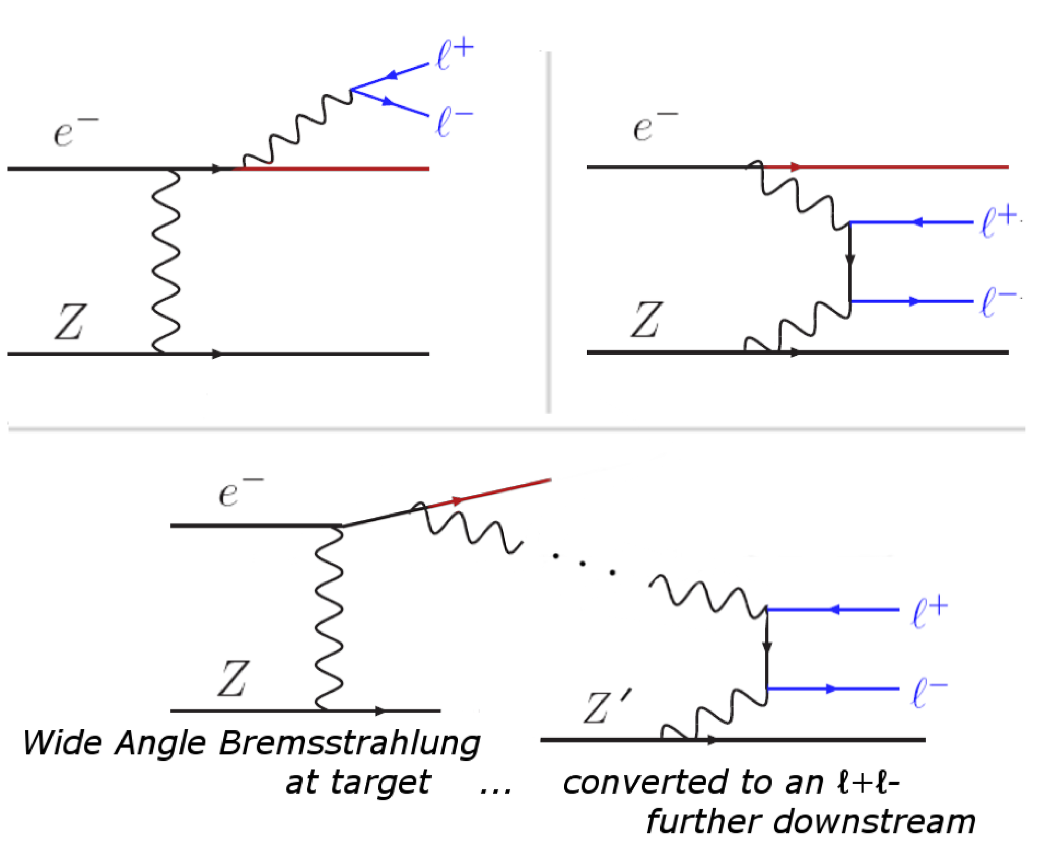

Figure 3: *Sample diagrams of (top left) radiative trident (γ^*), (top right) Bethe-Heitler trident, and (bottom) converted wide-angle bremsstrahlung reactions, that comprise the primary QED background to $A' \to l^+l^-$ search channels.*

In addition to the background sources shown above, beam background is non-negligible due to our high beam current.

Experimental Setup

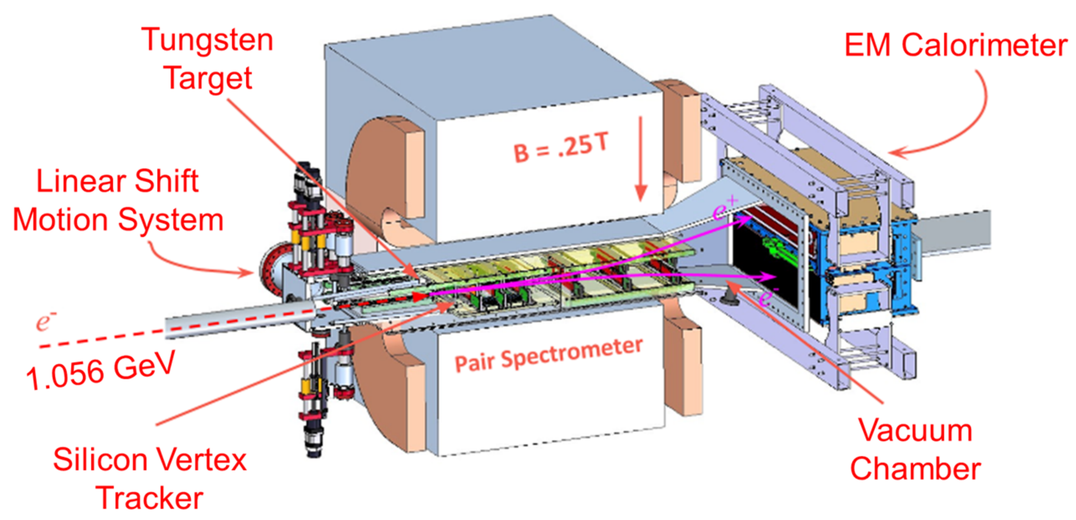

Figure 4: *Schematic view of the HPS detector.*

The near-continuous duty cycle of the CEBAF beam at Jefferson Lab, along with fast detectors and electronics, allows us to run with short time windows and reduce occupancies.

Silicon Vertex Tracker

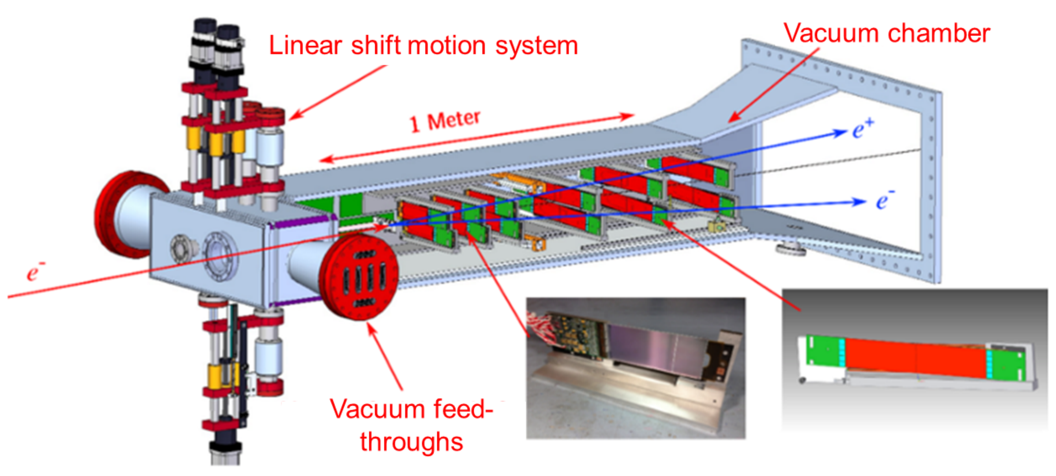

Figure 5: *Renderings of the target assembly and silicon planes inside their support box.*

The tracker is made up of six measurement layers. Each layer has two closely spaced planes of silicon microstrip sensors to measure both X and Y coordinates for momentum measurement and track identification. [3]

Electromagnetic Calorimeter

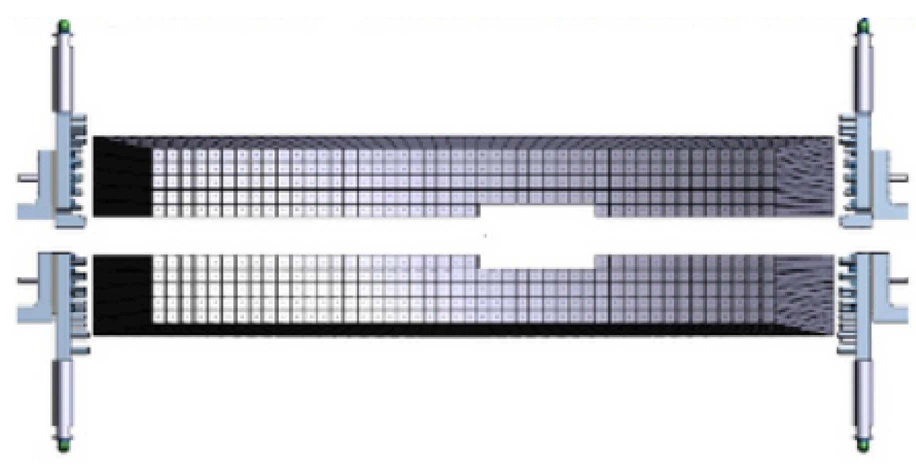

Figure 6: *A rendering of the electromagnetic calorimeter (Ecal) setup looking down the beam line.*

The Ecal contains 442 lead tungstate ($PbWO_4$) crystals and covers the full acceptance region of the silicon tracker. It provides the trigger for data acquisition and also is used for electron identification during the data analysis. [4]

References

[1] D. P. e. a. Finkbeiner, JCAP **1105**, 002 (2011), 1011.3082.

[2] M. e. a. Vogelsberger, Mon. Not. Roy. Astron. Soc. **423**, 3740 (2012), 1201.5892.

[3] P. Hansson Adrian (HPS), in *Proceedings, 2015 IEEE Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC 2015): San Diego, California, United States* (2016), p. 7581862, 1511.07844.

[4] I. e. a. Balossino (HPS), Nucl. Instrum. Meth. **A854**, 89 (2017), 1610.04319.

Experimental Reach

The search channel for this experiment is $A' \to e^+e^-$, with or without a displaced vertex, depending on the coupling α':

- A resonance search is sensitive at large values of α'/α, where the A' production rate is high.
- A displaced vertex search is sensitive at lower α', where decay lengths are longer than the the tails of the vertex distribution of prompt tridents.

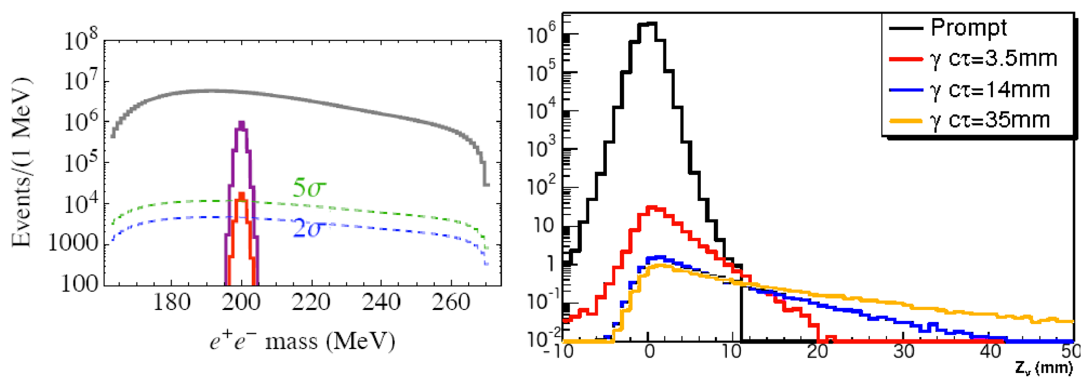

Figure 7: *Example signals and backgrounds for (left) a resonance search and (right) a vertexing search.*

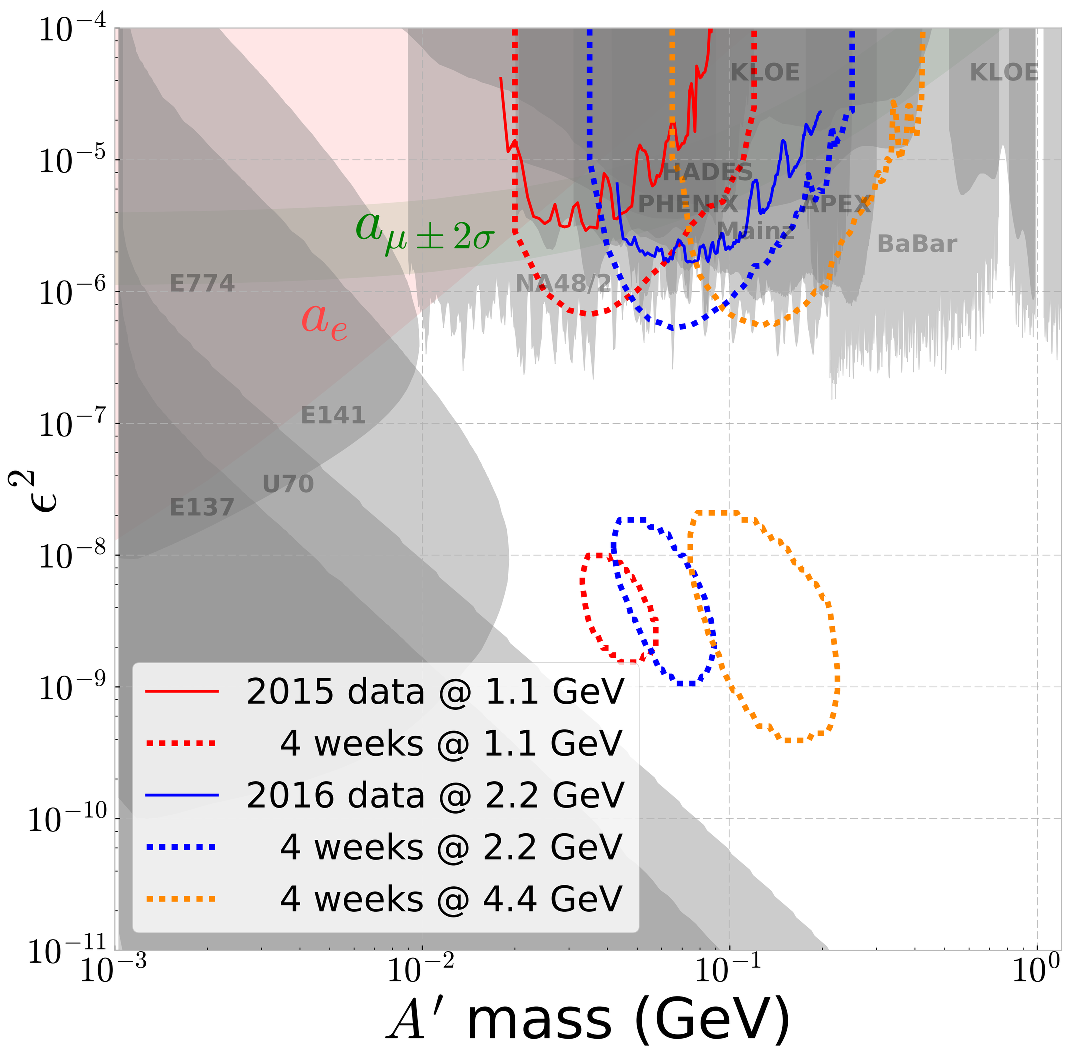

Figure 8: *Anticipated reach in $\alpha'/\alpha = \epsilon^2$ for the HPS experiment using existing data samples (solid lines) and larger future data samples (dashed).*
Shaded regions represent existing constraints on the A' from various other experiments, including beam-dumps, other resonance searches and anomalous magnetic moments of electrons and muons.

Future of HPS

The major physics results of HPS will result from the 2019 running. Several upgrades have been proposed in order to improve the reach of the experiment through improved resolution and acceptance:

- Including an additional layer to the Silicon Vertex Tracker, halfway between the target and the existing first layer of the tracker.
- Adding a hodoscope for an additional positron-only trigger.