Heavy Photon Search

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The Heavy Photon Search (HPS) 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 HPS experiment 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 experimental apparatus is composed of a six-layer silicon microstrip vertex tracker and a PbWO$_4$ crystal calorimeter.

Motivation

Anomalies in dark matter distributions in galactic haloes [1] provide motivation for a heavy photon in the 0.1 to 1.0 GeV range. This particle is an example of a vector portal between Standard Model particles and the dark matter sector. Depending on its parameters, it could be produced in a laboratory setting, and identified through its decay products.

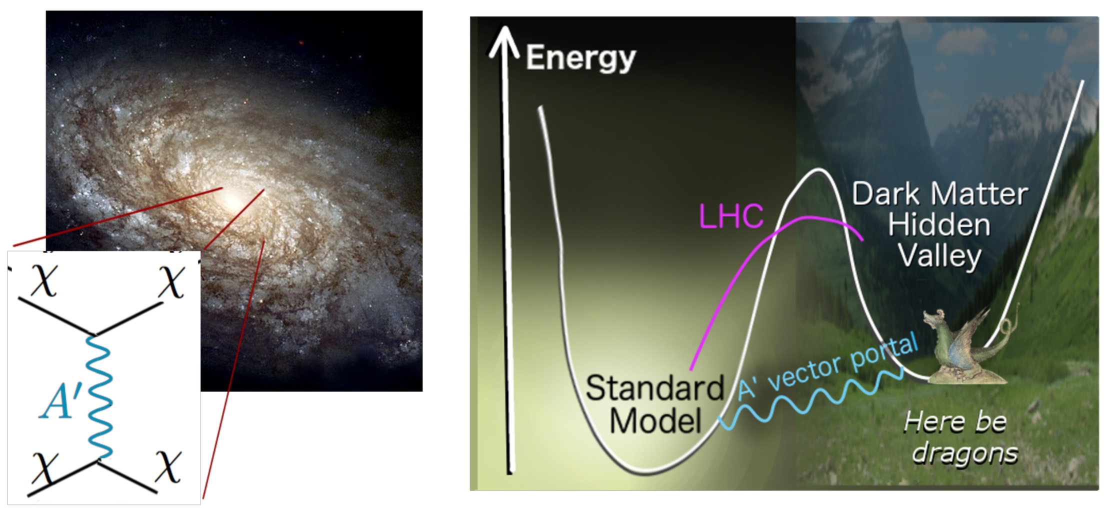

Figure 1: *(left) Dark matter self-interaction, mediated by A', which may solve "core-cusp" anomalies in galactic haloes. (right) The heavy photon as a "vector portal" between the Standard Model and a "hidden vector" dark sector.*

Signals and Backgrounds

Heavy Photon Signal

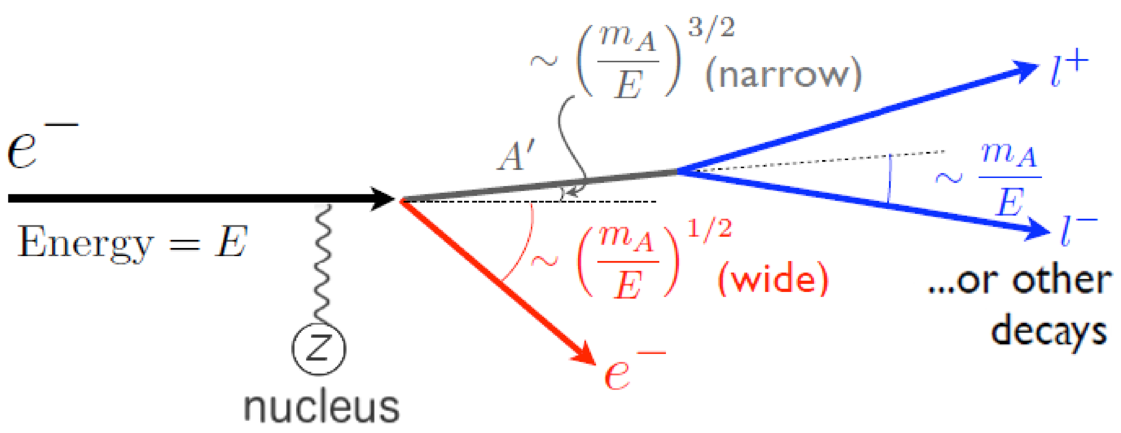

Figure 2: *Topology and kinematics of an A' production as an incoming electron scatters off a nucleus with atomic number Z, and then decays.*

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

Backgrounds

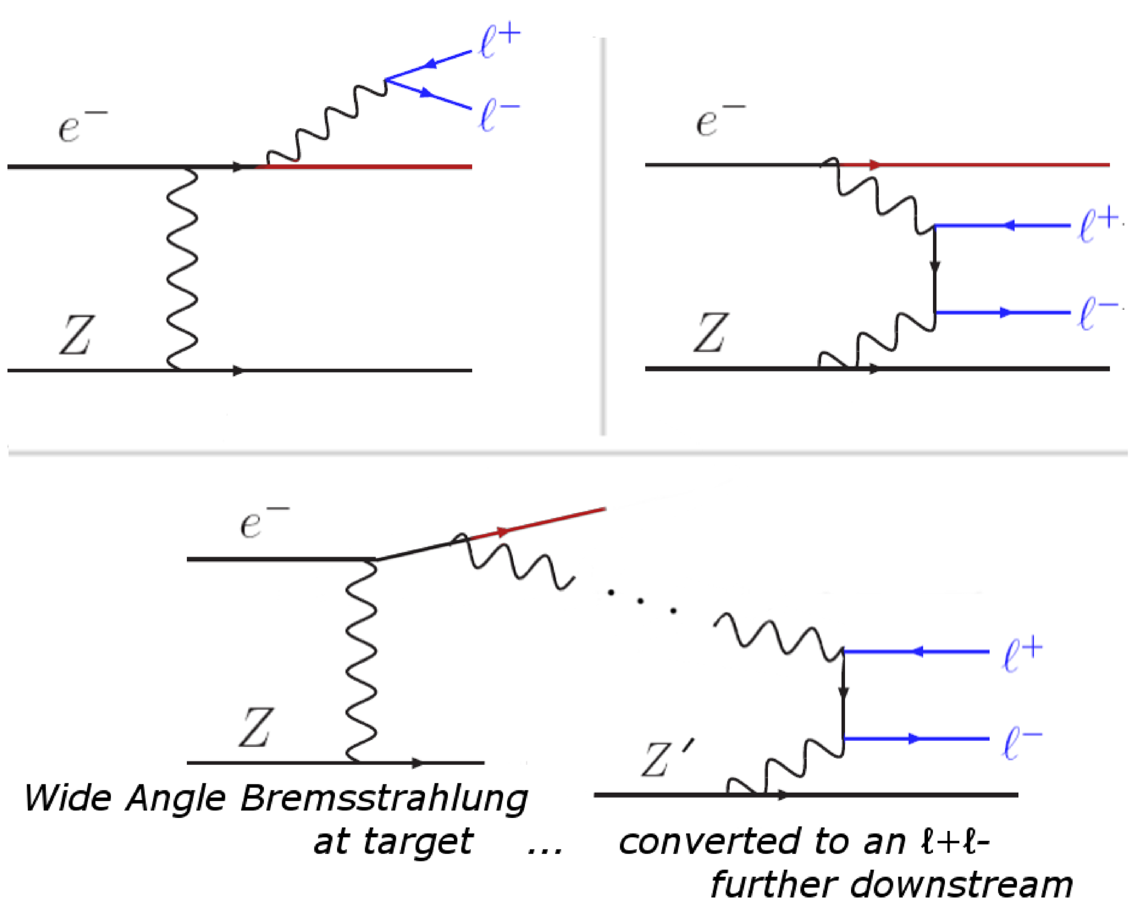

Figure 3: *Sample diagrams of QED background events: (top-left) radiative trident (γ^*), (top-right) Bethe-Heitler trident, and (bottom) converted wide-angle bremsstrahlung reactions*

Experimental Setup

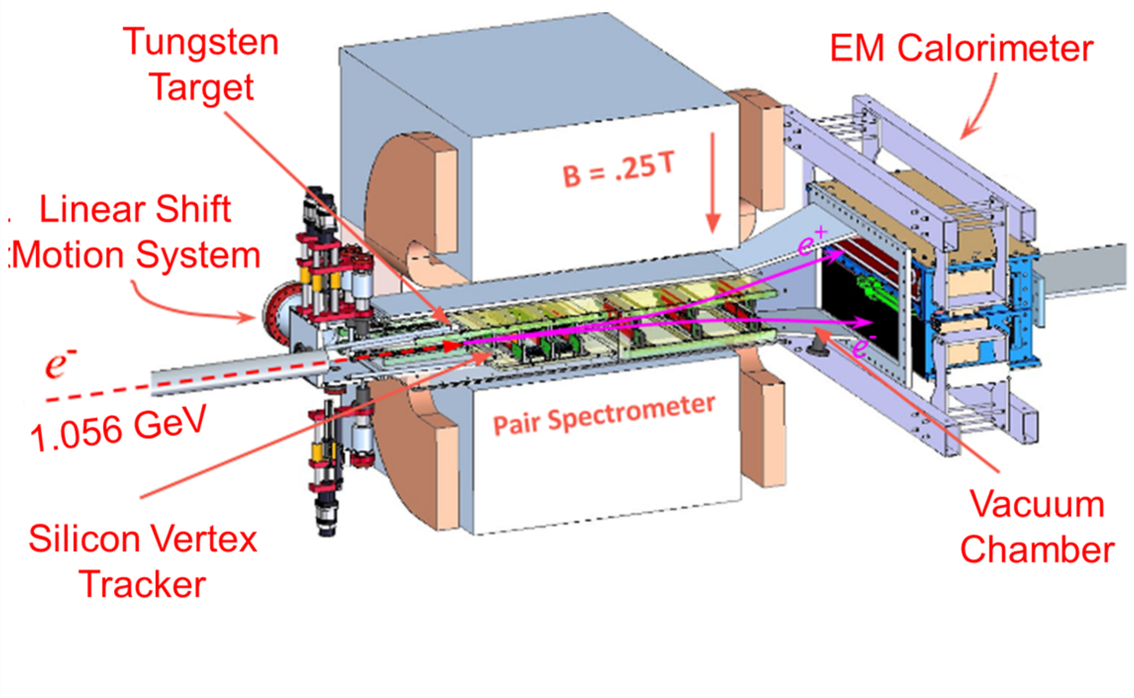

Figure 4: *Schematic view of the HPS detector.*

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

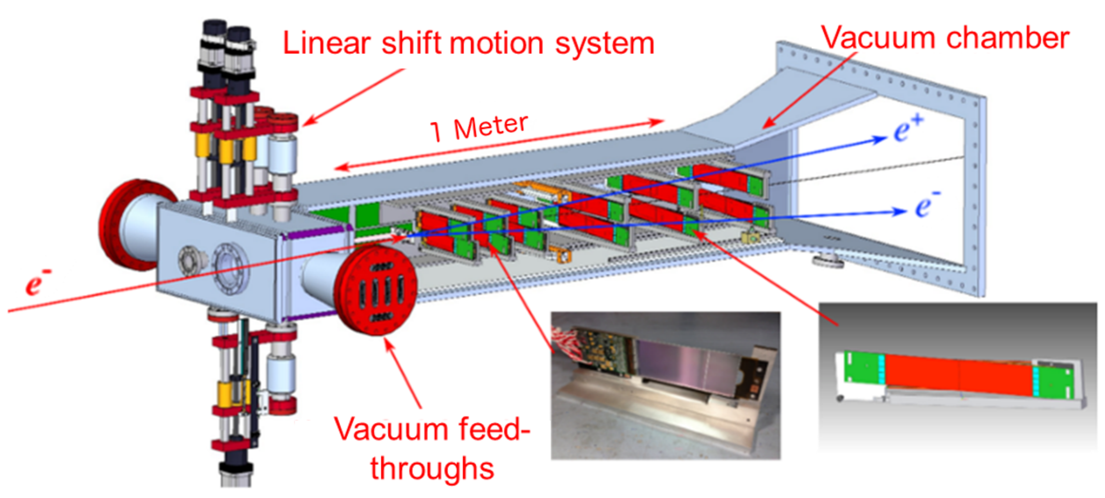

Figure 5: *Renderings of the target assembly and silicon planes inside their support box.*

Each of the SVT's six measurement layers has two closely-spaced planes of silicon microstrip sensors to measure both X and Y coordinates for momentum measurement and track identification. [2]

Electromagnetic Calorimeter

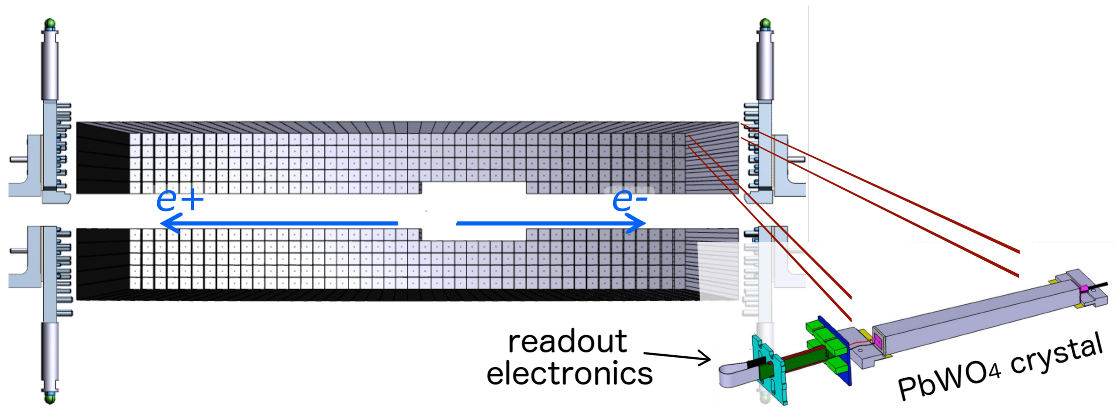

Figure 6: *A rendering of the electromagnetic calorimeter (Ecal) setup looking down the beam line.*

The Ecal covers almost the full acceptance region of the SVT and is used for the data acquisition trigger, and also electron identification during the data analysis. [3]

References

[1] M. Vogelsberger, J. Zavala, and A. Loeb, Mon. Not. Roy. Astron. Soc. **423**, 3740 (2012), 1201.5892.

[2] 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.

[3] I. Balossino et al. (HPS), Nucl. Instrum. Meth. **A854**, 89 (2017), 1610.04319.

Experimental Reach

Our experiment searches for $A' \to e^+e^-$, with or without a displaced vertex, depending on the coupling α':

- A resonance search is sensitive at large values of α', 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.

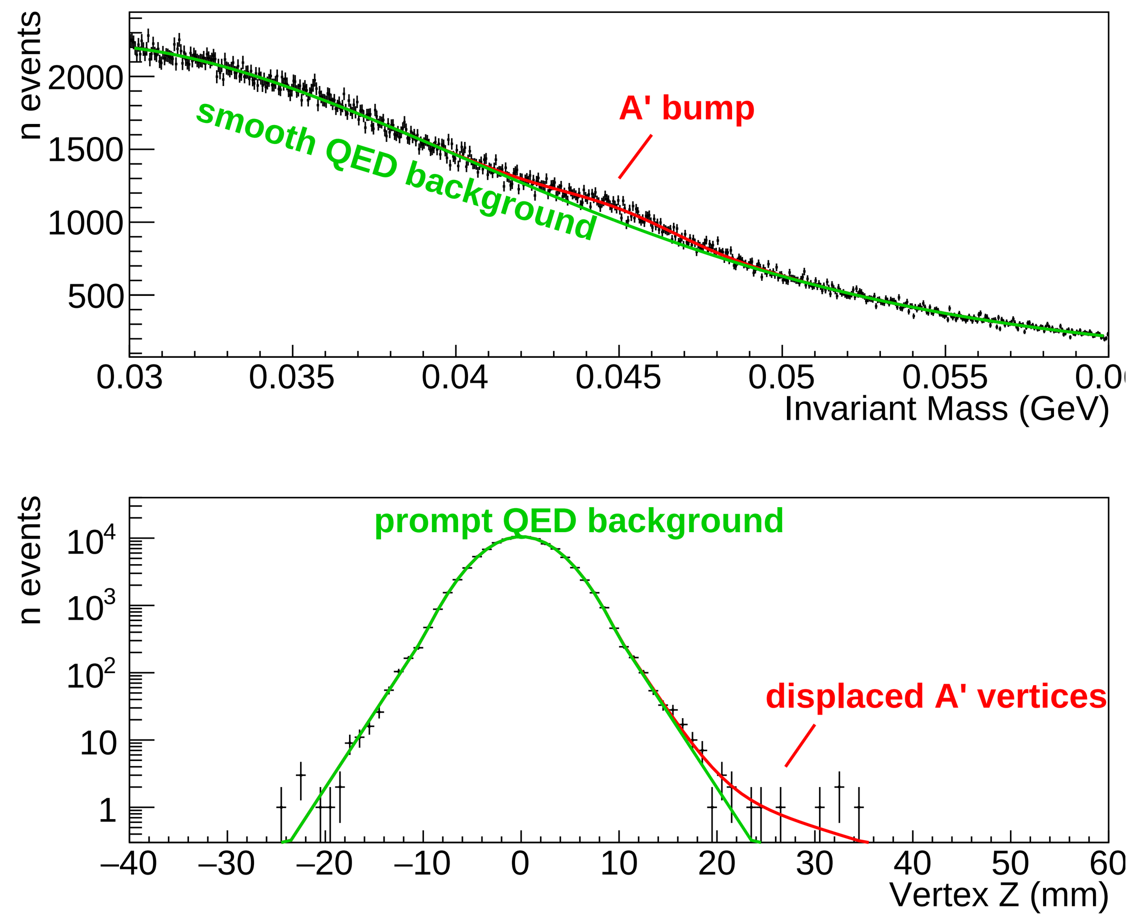

Figure 7: *Example signals and backgrounds for (top) a resonance search and (bottom) a displaced-vertex search, with $\approx 5\sigma$ significance.*

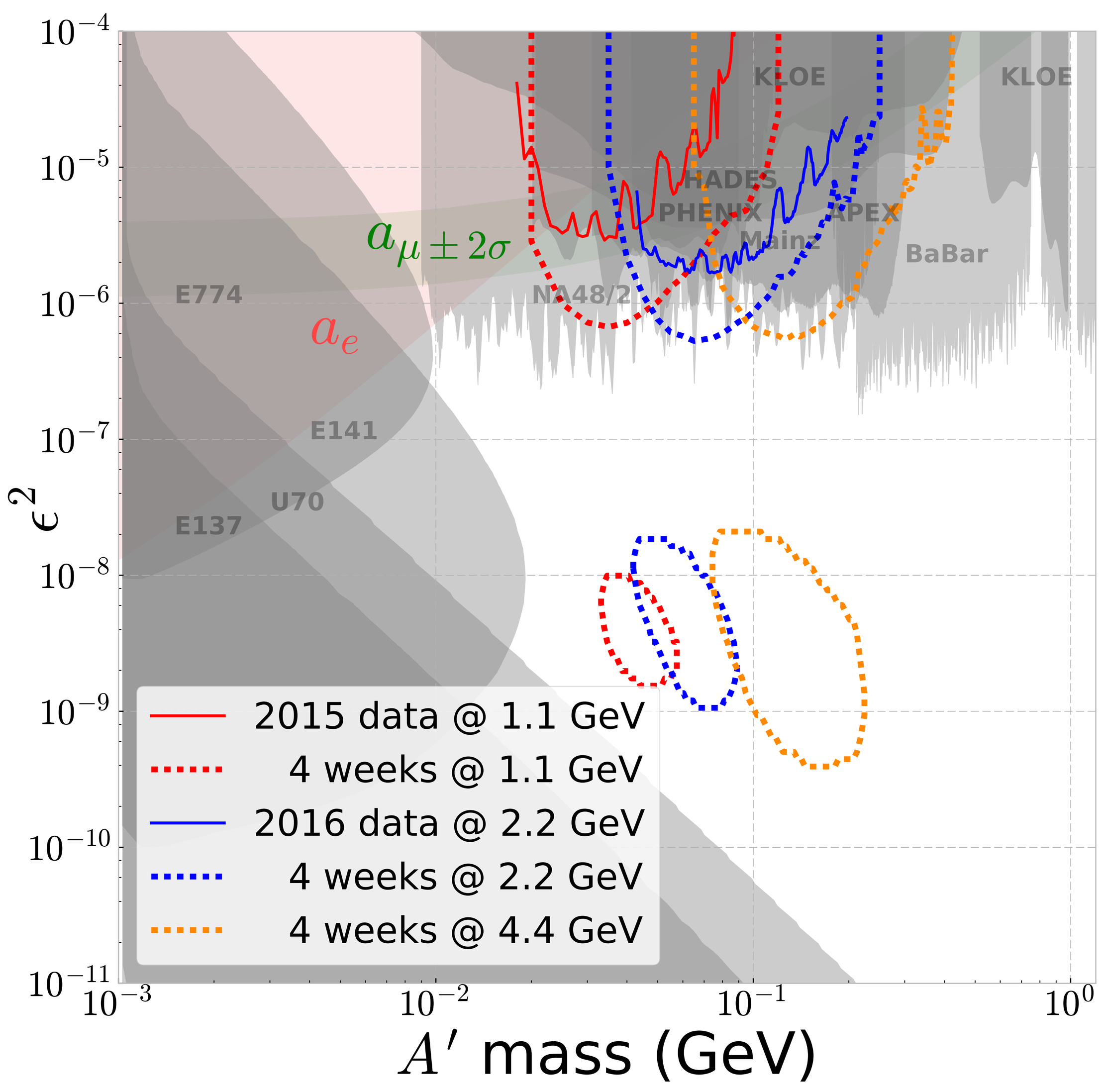

Figure 8: *Anticipated reach in $\alpha'/\alpha = \epsilon^2$ for HPS using existing data samples (solid lines) and larger future data samples (dashed).*

Existing constraints on the A' come 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, with several proposed upgrades to improve the reach of the experiment through improved resolution and acceptance:

- Add a tracking "layer 0" to the SVT, between the target and the existing layer 1.
- Add a hodoscope for an additional positron-only trigger.