The HPS experiment

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Motivations for searching Heavy Photons
Description of HPS setup
2015 Engineering Run
Conclusions
Dark Matter and Dark Sector

- DM suggest a dark sector
- Standard Model should be ”blind” to new Dark Forces
- How to look for them?
The heavy photon $A'$

Consider a theory in which nature contains an additional Abelian gauge symmetry, $U(1)_D$ [Holdom, Phys. Lett. B166, 1986]

$$\mathcal{L} = \mathcal{L}_{SM} + \frac{1}{4} F'_{\mu\nu} F'_{\mu\nu} + m_{A'}^2 A'_{\mu} A'_{\mu} + \frac{\epsilon}{2} F^Y_{\mu\nu} F'_{\mu\nu} \quad (1)$$

This gives rise to a kinetic mixing term which produces an effective parity-conserving interaction $\epsilon e A'_{\mu} J^\mu_{EM}$ of the $A'$ to the electromagnetic current, suppressed relative to the electron charge $e$ by the parameter $\epsilon$, which can naturally be in the range $10^{-12} - 10^{-2}$
Search for A' - Current situation

Fixed Target

$e^- \rightarrow A' \rightarrow l^+ l^-$

$Z \rightarrow \sigma \sim \frac{\alpha^3 Z^2 e^2}{m^2} \sim O(10 \text{ pb})$

$O(\alpha_b^{-1}) \text{ per day}$

- Flavor Factories
- Rare Meson Decays
- Fixed target experiments
- Precision Measurements
- Beam dump experiments

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A’ search: Bump-Hunt and Vertexing

A’ takes most of the incident energy, produced very forward

**Large coupling regime:**
A’ decays in target \(\therefore\) constrain \(e^+e^-\) to originate from beamspot
Search for peak in invariant mass plot

**Small coupling regime:**
A’ decays outside of target \(\therefore\) constrain A’ to originate from beamspot
Search for displaced vertex + mass peak

Including recoil e- along with \(e^+e^-\) pair would improve mass resolution
The Heavy Photon Search (HPS) experiment

- 1 to 6 GeV, 200 nA $e^-$ on 1% R.L. W target
- 6 layer Silicon Vertex Tracker (SVT)
- Electromagnetic Calorimeter (ECal)

Heavy Photon Search Beamline and Detectors
HPS Construction

- Conceived, built and installed HPS detector in about 14 months
- The HPS test detector [NIM A, Volume 777, 21 March 2015, Pages 91-101]
- Upgrade $PbWO_4$ Ecal installed September 2014
- Improved six-layer Si Vertex Tracker installed February 23, 2015
2015 Engineering Run

- 2015 Engineering Run
- in HallB at Jefferson Lab
- 1.1 GeV, 200 nA beam
- Commissioned HallB beamline, SVT, ECAL, trigger, DAQ
- took data with SVT at $\pm 1.5$ mm and $\pm 0.5$ mm from beam
Beam Quality

HPS requires high-quality, stable beam.
Small beam size:

- $\sigma_x \approx 300$ to $500 \, \mu m$
- $\sigma_y \approx 15$ to $50 \, \mu m$

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Took over 5 billion events with single electron and pairs triggers

Detector and data acquisition system performed as expected

Currently analyzing a 10% of the data to calibrate the detector response
  - Time
  - Energy
  - Position
$e^+e^-$ Pairs Mass Distribution

Tiny fraction of all data. Very preliminary look!
Expected HPS Reach

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Conclusions

- HPS is a new experiment at JLAB, dedicated to searching for heavy photons with masses 10-200 MeV and couplings $10^{-3} < \epsilon < 10^{-5}$ in unexplored regions of parameter space.
- Invariant mass and vertexing signatures let HPS achieve sensitivity to very small values of the $A'$ coupling. Using invariant mass alone, HPS covers $\epsilon^2 > \text{few} \times 10^7$ for $10 < m_{A'} < 200$ MeV.
- HPS is installed in Hall B at JLAB and recently completed a successful engineering run, exercising all aspects of the experiment.