Heavy Photon Search Run and Results Update

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Motivation

Additional U(1) symmetry in nature -> new gauge boson!

\[ \epsilon \quad \text{“heavy photon”} \]

\[ \gamma \quad \text{kinetic mixing} \]

Kinetic mixing could be the leading interaction between the Standard Model and Dark Sector!

Experimental Signature

\[ e^- + ^{183}\text{W} \rightarrow A' + X \rightarrow e^+ + e^- + X \]

A' → Standard Model particles

Standard Model

\[ g \quad W^\pm, Z, \gamma \]

Dark Sector

forces + particles
dark matter?
Experimental Setup

Jefferson Lab, CEBAF

CEBAF max energy 2.2 GeV/pass (max 5 pass)
Simultaneously deliver beam to 4 halls

HPS is in the alcove of Hall B
Experimental Setup

**Analyzing Magnet**

**Electromagnetic Calorimeter (Ecal)**

- Triggers events
- Measures particle energy
- Resolution: 4%/\sqrt{E}

**Silicon Vertex Tracker (SVT)**

- Measures particle trajectories
- Momentum and vertex

**SVT active area**

0.5 mm from beam!
HPS Proposed Reach

Large $\epsilon$ coupling, prompt decay

Small $\epsilon$ coupling, $A'$ long-lived

Runs status to date:
Spring 2015: Engineering Run
1.05 GeV, 50 nA
Achieved 30% of proposed production data

Spring 2016: Physics Run
2.3 GeV, 200 nA
Achieved 77% of proposed production data
2016 Run: Ecal Performance

Cosmics for initial gain calibration

18 MeV/crystal

Time difference between 2 clusters

σ=330 ps

Beam bunch structure

Elastically-scattered e- peak in fiducial region

Timing offsets were calibrated using RF time from accelerator
2016 Run: SVT Performance

- Calibration in progress
- Initial data, prior to alignment, already consistent with proposal

Moller Mass, initial data

Elastically scattered e-, initial data

\[ \mu = 2.2181 \pm 0.0015 \]
\[ \sigma_p = 0.1687 \pm 0.0011 \]
\[ \sigma_p^2 = 7.61\% \]

\[ \mu = 2.17930 \pm 0.00069 \]
\[ \sigma_p = 0.16938 \pm 0.00076 \]
\[ \sigma_p^2 = 7.75\% \]
Invariant Mass

Searching for the Heavy Photon using a blinded analysis (10% of the data)

$e^+ e^- \text{ invariant mass}$

1.05 GeV beam

2.3 GeV beam

PRELIMINARY
1 GeV Analysis

![Graph showing Mass Resolution vs Invariant Mass](image)

- **A' Monte Carlo**
- **Moller data**
- **Moller Monte Carlo**

**Parameter** | **Proposal value** | **Measured value**
--- | --- | ---
Beam current | 50 nA | 50 nA
SVT occupancy | <1% | 1%
DAQ/trigg. rate | 18 kHz | 19 kHz
Pair mass res. @ 33 MeV/c² | 1.4 MeV | 1.4 MeV
Pair vertex res. @ 40 MeV/c² | 4.4 mm | 4.6 mm

**e+e- Vertex**

<table>
<thead>
<tr>
<th>Simulation</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>0.1917</td>
</tr>
<tr>
<td>Std Dev</td>
<td>4.595</td>
</tr>
</tbody>
</table>

Slice 36 copy

Entries 62034

Preliminary
1 GeV Analysis: Bump Hunt

- 10% of 2015 data, SVT at 0.5 mm
- Conservative cuts
- Fits 7th order polynomial background + $A'$ peak

- Fix $A'$ “peak” width, moving “peak” across spectrum to determine upper limits
1 GeV Analysis: Vertex search

- Search for long-lived $A'$ with separated vertex
Summary

• Successful very short runs in 2015 and 2016 with data taken for both bump hunt and vertex search for Heavy Photons
• 165 days still remain: We expect next physics runs in 2018 and later
• Instrumentation papers are in preparation for the beamline, SVT. Ecal NIM submitted this past week
• Finalizing analysis and expecting results in early 2017
HPS Running

Spring 2015 Running

Beam energy: 1.05 GeV

SVT at 1.5 mm

SVT at 0.5 mm

Nights + Weekends
Commissioning

Achieved: 2 of 7 proposed run days

Spring 2016 Running

Beam energy: 2.3 GeV

Commissioning

Achieved: 5 of 7 proposed run days

Beam energy:

Integrated current x life time (mC)

Horizontal profile

σ = 110 μm

Vertical profile

σ = 45 μm