The A' Experiment (APEX)
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1 Goal of experiment

New forces could have escaped detection only if their mediators are either heavier than $\mathcal{O}$(TeV) or quite weakly coupled. The latter possibility can be tested by precision colliding-beam and fixed-target experiments. A new abelian gauge boson, A', can acquire a small coupling to charged particles if it mixes kinetically with the photon [11]. Indeed, quantum loops of heavy particles with electric and $U(1)'$ charges can generate kinetic mixing and an effective interaction $\epsilon e A'_\mu J^\mu_{\rm EM}$ of the A' to the electromagnetic current J^μ_{EM}, suppressed relative to the electron charge e by $\epsilon \sim 10^{-2} - 10^{-6}$ [10]. This mechanism motivates the search for very weakly coupled gauge bosons. Anomalies related to dark matter [3] and to the anomalous magnetic moment of the muon [14] have motivated interest in the possibility of an A' with MeV- to GeV-scale mass. Gauge bosons in the same mass range arise in several theoretical proposals [9], and their couplings to charged matter, $\alpha' \equiv \epsilon^2\alpha$ ($\alpha = e^2/4\pi$), are remarkably weakly constrained [7].

The A' Experiment (APEX) is designed to search for sub-GeV mediators of weakly coupled new forces. APEX will probe charged particle couplings with new forces as small as $2 \times 10^{-4} e$ and masses between $65\ \mathrm{MeV}$ and $525\ \mathrm{MeV}$.

2 Experimental setup

The proposed experiment will study e^+e^- production off an electron beam incident on a high-Z target as illustrated in Figure 1. The beam will pass through a target consisting of narrow strips of tungsten foil, with total thickness between 0.5% and 10% X_0 for each running configuration. The beam will be rastered in both directions: horizontally by $\pm$0.25 mm and vertically by $\pm$2.5 mm. The e^+e^- pair components will be detected in the HRS spectrometers. The detector package in each HRS includes two vertical drift chambers (VDC), the single-PMT trigger scintillator counter (S0), the Gas Cherenkov counter, the segmented high-resolution scintilator hodoscope, and the double-layer lead-glass shower counter.

The experiment will measure the invariant mass spectrum of e^+e^- pairs produced by an incident beam of electrons on a tungsten target, in four kinematic settings. The search for an A' peak will be done in the mass range from $\sim$ 65 MeV

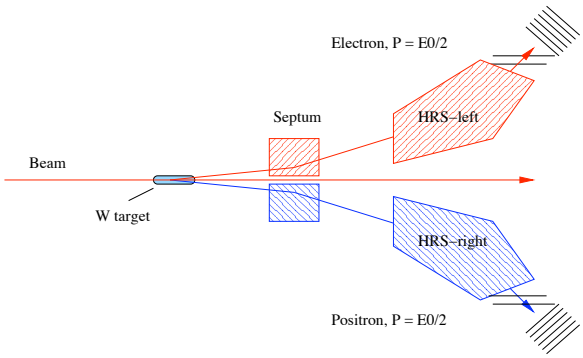

Figure 1: The layout of the experimental setup.

to 525 MeV. The experiment will be performed in Hall A at JLab using two high-resolution spectrometers [1] together with a septa magnet constructed for the PREX experiment [12]. The electron beam with a current of $\lesssim 80\ \mu A$ will be incident on a solid target located on a standard target ladder in a standard scattering chamber. The target will be made of a set of 10 tungsten strips strung vertically with their planes orthogonal to the beam direction. The beam will be rastered by ± 0.25 mm in the horizontal and ± 2.5 mm in the vertical direction.

The electron will be detected in the left HRS (HRS-L) and the positron will be detected in the right HRS (HRS-R). The trigger will be formed by a coincidence of two signals from the S2m counters of the two arms with a signal from the gas Cherenkov counter of the HRS-R (positive polarity arm). A timing window of 20 ns will be used for the first coincidence and 40 ns for the second coincidence. The resulting signal will be used as a primary trigger of DAQ.

An additional logic will be arranged for a coincidence in the S2m counters in the HRS-L and HRS-R. This second type of trigger will be prescaled by a factor of 200 for DAQ. Single-arm triggers using the S0 counters will be used to calibrate and adjust the delays for individual PMTs in the S2m and the gas Cherenkov counters.

3 Accelerator or Lab Facility

APEX will use Jefferson Laboratory's Continuous Electron Beam Accelerator Facility and two High Resolution Spectrometers (HRSs) in Hall A.

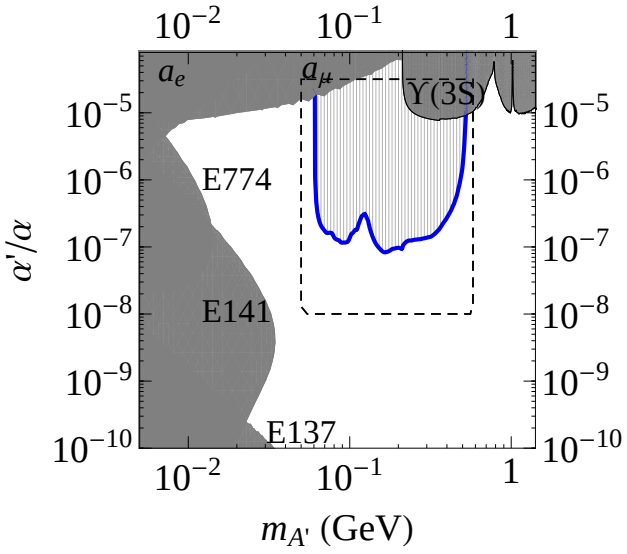

Figure 2: Anticipated 2σ sensitivity for the proposed experiment (thick blue line), with existing constraints on an A' from electron and muon anomalous magnetic moment measurements, a_e and a_μ (see [14]), the BaBar search for $\Upsilon(3S) \to \gamma\mu^+\mu^-$ [5], and three beam dump experiments, E137, E141, and E774 [6, 16, 8] (see [7]). The a_μ and $\Upsilon(3S)$ limits assume equal-strength couplings to electrons and muons. Note that the sensitivity curve is the combined sensitivity from runs at four different energy settings – the decrease in the sensitivity between $100 - 200$ MeV could be removed by choosing a different setting.

4 Physics Reach

The proposed experiment will be sensitive to new gauge bosons with couplings $\epsilon e \gtrsim 3 \times 10^{-4} e$, corresponding to cross-section suppression $\alpha'/\alpha \gtrsim 9 \times 10^{-8}$ – see Figure 2. This is about a factor of 10–30 times lower in ϵ than existing constraints (which assume that the A' couples also to muons), and corresponds to 100–1000 times smaller cross-sections.

This parameter range is interesting for several reasons. This region of mass and coupling is compatible with A''s explaining the annual modulation signal seen by the dark matter direct detection experiment DAMA/LIBRA, and also with dark matter annihilating or decaying into A''s, which explains a myriad of recent cosmic-ray and other astrophysical anomalies. The region is also compatible with A''s explaining the discrepancy between the Standard Model predicted and mea-

sured value of the anomalous magnetic moment of the muon, $(g-2)_\mu$. In addition, and independently of any connection to dark matter, the proposed experiment would be the first to probe A's of mass $\sim 100\,\mathrm{MeV}$ with gauge kinetic mixing below $\epsilon \sim 10^{-3}$, the range most compatible if the Standard Model hypercharge gauge group is part of a Grand Unified Theory.

5 Status and Schedule

APEX completed a test run in July 2010. The experiment is currently approved by PAC 37 (pending a radiation review). APEX is currently preparing for the possibility of running in March 2012. More likely, the full APEX run will occur in 2014 after the CEBAF 12 GeV upgrade is complete.

6 Future Plans

We are preparing additional equipment to improve the quality of the HRS optics calibration for the full run using a scintillating fiber detector.

7 Collaborating Institutions and Collaborators

For a list of collaborators and collaborating institutions, please see [2].

References

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