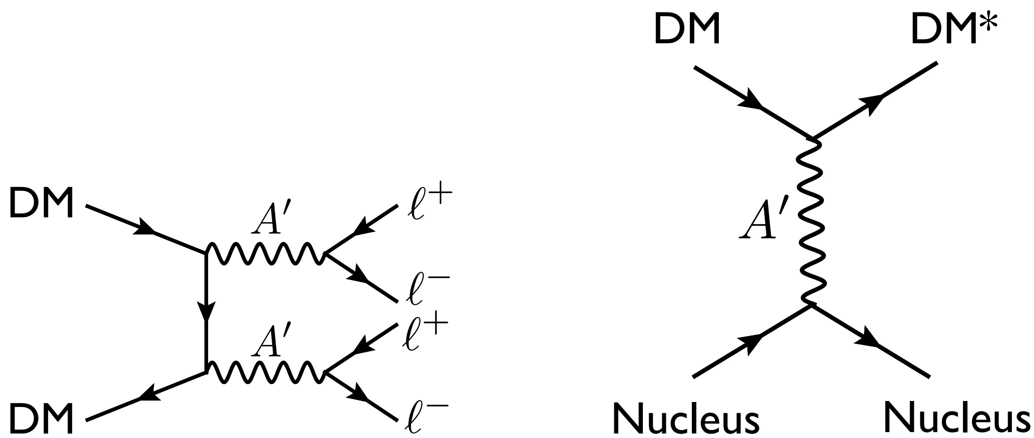

FIG. 2: **Left:** Dark matter annihilation into the dark photon A', which decays into charged leptons such as electrons and/or muons, can explain the cosmic-ray electron and/or positron excesses seen by PAMELA, Fermi, ATIC, HESS, and other experiments. **Right:** Dark matter scattering into an excited state off nuclei through A' exchange in direct dark matter detection experiments can explain the annual modulation signal observed by DAMA/LIBRA, and the null results of other direct detection experiments.

ing is dominated by an inelastic process,

$$\chi\, N \to \chi^*\, N, \tag{9}$$

in which the dark matter χ scatters off a nucleus N into an excited state χ^* with mass splitting $\delta \approx 100$ keV [67]. The kinematics of these reactions is also remarkably consistent with all the distinctive properties of the nuclear recoil spectrum reported by DAMA/LIBRA. In addition, the INTEGRAL telescope [71] has reported a 511keV photon signal near the galactic center, indicating a new source of $\sim$ 1-10 MeV electrons and positrons. This excess could be explained by collisions of $\mathcal{O}$(100 GeV-1 TeV) mass dark matter into $\mathcal{O}$(MeV) excited states in the galaxy [72] — dark matter excited by scattering decays back to the ground state by emitting a soft e^+e^- pair. The 511keV excess then arises from the subsequent annihilation of the produced positrons.

The existence of an A' may also help explain various other particle physics anomalies [27] such as the anomalous magnetic moment of the muon ($(g-2)_\mu$) [73] and the HyperCP anomaly [74].

While these experimental hints provide an urgent motivation to look for an A', it is important to emphasize the value of these searches in general. There has never been a systematic search for new GeV-scale force carriers that are weakly coupled to Standard Model particles. Nothing forbids their existence, and their discovery would have profound implications for our understanding of nature. A relatively simple experiment using the facilities available at, for example, Jefferson Laboratory and Mainz will probe a large and interesting range of A' masses and couplings.

C. Current Limits on Light $U(1)$ Gauge Bosons

Constraints on new A''s that decay to e^+e^- and the search reach of an experiment using the spectrometers of Hall A at Jefferson Laboratory are summarized in Figure 1. Shown are constraints from electron and muon anomalous magnetic moment measurements, a_e and a_μ [27], the BaBar search for $\Upsilon(3S) \to \gamma A' \to \gamma\mu^+\mu^-$, and three beam dump experiments, E137, E141, and E774 [3]. The constraints from a_μ and the BaBar search assume that the A' couples to muons — this is the case, for example, if it mixes with the photon. If it only couples to electrons, then the constraints on α'/α and $m_{A'}$ in the region to which the proposed experiment is sensitive are weaker than $\alpha'/\alpha \lesssim 10^{-4}$.

We refer the reader to [3, 27] for details on existing constraints. Here, we briefly review the constraint on $e^+e^- \to \gamma A' \to \gamma\mu^+\mu^-$ derived from the BaBar search [75]. If the A' couples to both electrons and muons, this is the most relevant constraint in the region probed by the proposed experiment. The analysis of [75] was in fact a search for $\Upsilon(3S)$ decays into a pseudoscalar a, $\Upsilon(3S) \to \gamma a \to \gamma\mu^+\mu^-$, but can be interpreted as a limit on A' production because the final states are identical. Using $\mathcal{L}_{\rm int} \sim 30$ fb^{-1} of data containing $\sim 122 \times 10^6$ $\Upsilon(3S)$ events, a 90% C.L. upper limit of roughly $(1-4)\times 10^{-6}$ on the $\gamma\mu^+\mu^-$ branching fraction was found for $m_{A'} \sim 2m_\mu - 1$ GeV. This search would thus be sensitive to about $\sim 100-500$ events with $e^+e^- \to \gamma A' \to \gamma\mu^+\mu^-$. Requiring that $\sigma(e^+e^- \to \gamma A') \times BR(A' \to \mu^+\mu^-) \times \mathcal{L}_{\rm int} \lesssim 500$, where $BR(A' \to \mu^+\mu^-) = 1/(2 + R(m_{A'}))$ for $m_{A'} > 2m_\mu$ with $R = \frac{\sigma(e^+e^- \to \text{hadrons};\, E=m_{A'})}{\sigma(e^+e^- \to \mu^+\mu^-;\, E=m_{A'})}$, and rescaling the resulting