constraint to represent a 95% C.L. upper bound, we find the constraint depicted in Figure 1. For $m_{A'} \gtrsim 2m_\mu$, this requires $\alpha'/\alpha \gtrsim 10^{-5}$, while the constraint weakens at higher masses, especially near the ρ-resonance. See [87] for a comparison of our sensitivity estimate to those previously published.

We caution that systematic uncertainties in the A' limit beyond those quoted in [75] may slightly weaken the resulting limit, which should therefore be taken as a rough approximation unless further analysis is done. First, A' production in B-factories is more forward-peaked than the $\Upsilon(3S)$ decay mode considered in [75], so that the signal acceptance is more uncertain. In addition, background distributions in [75] are derived from smooth polynomial fits to data collected on the $\Upsilon(4S)$ resonance, which is assumed to contain no signal. This assumption is not correct for A' production, though the resulting systematic effects are expected to be small.

D. Sensitivity of Potential Searches using Existing Data

Several past and current experiments have data that could be used to significantly improve current limits on α'/α, as discussed in [4, 8, 27]. Here, we estimate the potential sensitivity of searches in three channels ($\pi^0 \to \gamma A' \to \gamma e^+e^-$, $\phi \to \eta A' \to \eta e^+e^-$, and $e^+e^- \to \gamma A' \to \gamma\mu^+\mu^-$), considering only the statistical uncertainties and irreducible backgrounds. These are likely overestimates, as we are unable to include either systematic uncertainties or significant instrumental backgrounds such as photon conversion in the detector volume.

BaBar, BELLE, and KTeV (E799-II) have produced and detected large numbers of neutral pions, of order 10^{10}, of which roughly 1% decay in the Dalitz mode $\pi^0 \to e^+e^-\gamma$. These experiments can search for the decay $\pi^0 \to \gamma A'$ induced by A'–photon kinetic mixing, which would appear as a narrow resonance over the continuum Dalitz decay background. KTeV has the largest π^0 sample, and its e^+e^- mass resolution can be approximated from the reported measurement of the $\pi^0 \to e^+e^-$ branching fraction [76] to be roughly 2 MeV. This paper also reports the measured mass distribution of Dalitz decays above 70 MeV, from which we estimate potential sensitivity to α'/α as small as 5×10^{-7} for $70 < m(e^+e^-) \lesssim 100$ MeV, as shown by the orange shaded region in Figure 3.

Similarly, KLOE can search for the decay $\phi \to \eta A'$, likewise induced by A' kinetic mixing with the photon, in a sample of 10^{10} ϕ's. An analysis of this data is ongoing [77]. We have taken the blue dashed curve in Figure 3 from [4], which assumes that mass resolution σ_m is dominated by KLOE's 0.4% momentum resolution. We have adjusted the contours from [4] to determine a 2σ contour and enlarged the bin width used to determine signal significance from σ_m in [4] to $2.5\sigma_m$. Above the muon threshold, ϕ decays are not competitive with B-factory continuum production.

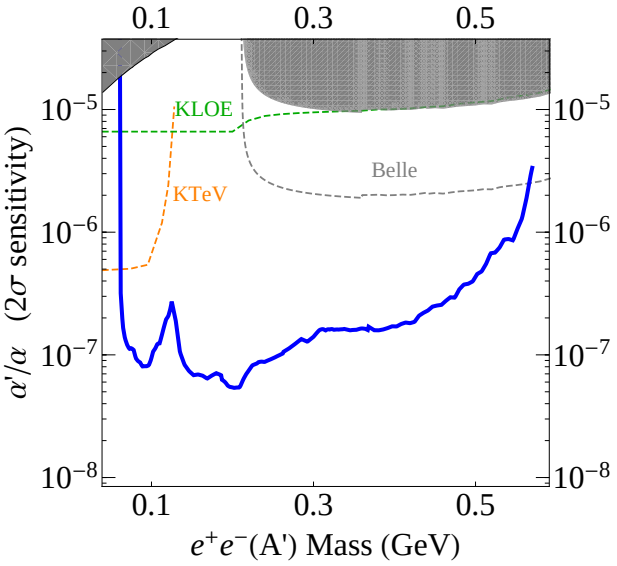

FIG. 3: Anticipated 2σ sensitivity in $\alpha'/\alpha = \epsilon^2$ for the A' experiment (APEX) at Hall A in JLab (thick blue line), compared with current limits and estimated potential 2σ sensitivity for A' searches in existing data (dashed lines), assuming optimal sensitivity as described in the text. From left to right: KTeV $\pi^0 \to \gamma A' \to \gamma e^+e^-$ (orange dashed curve), KLOE $\phi \to \eta A' \to \eta e^+e^-$ (green dashed curve) and Belle $e^+e^- \to \gamma A' \to \gamma\mu^+\mu^-$ (gray dashed curve). Existing constraints are as in Figure 1.

In addition, BaBar and Belle can search for the continuum production mode $e^+e^- \to \gamma A' \to \gamma\mu^+\mu^-$ in their full datasets. For example, an analysis of the Belle $\Upsilon(4S)$ data set would increase statistics by a factor of ~ 24 relative to the BaBar $\Upsilon(3S)$ search that we have interpreted as a limit above. We have derived the expected sensitivity (shown as a black dashed line in Figure 3) simply by scaling the $\Upsilon(3S)$ estimated reach by $\sqrt{24}$. These searches have not been extended below the muon threshold because of large conversion backgrounds.

III. A' PRODUCTION IN FIXED TARGET INTERACTIONS

A' particles are generated in electron collisions on a fixed target by a process analogous to ordinary photon bremsstrahlung, see Figure 4. This can be reliably estimated in the Weizsäcker-Williams approximation (see [3, 78–80]). When the incoming electron has energy E_0, the differential cross-section to produce an A' of mass