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Abelian anomaly and neutral pion production[1]

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The process $\gamma^*\gamma \to \pi^0$ is fascinating because in order to explain the associated transition form factor within the Standard Model on the full domain of momentum transfer, one must combine, using a single internally-consistent framework, an explanation of the essentially nonperturbative Abelian anomaly with the features of perturbative QCD. The case for attempting this has received a significant boost with the publication of data from the BaBar Collaboration [Phys. Rev. D **80**, 052002 (2009)] because, while they agree with earlier experiments on their common domain of squared-momentum-transfer [CELLO - Z. Phys. C **49**, 401 (1991); CLEO - Phys. Rev. D **57**, 33 (1998)], the BaBar data are unexpectedly far *above* the prediction of perturbative QCD at larger values of Q^2. I will elucidate the sensitivity of the $\gamma^*\gamma \to \pi^0$ transition form factor, $G_{\gamma^*\gamma\pi}(Q^2)$, to the pointwise behaviour of the interaction between quarks; and use existing Dyson-Schwinger equation calculations of this and the kindred $\gamma^*\gamma^* \to \pi^0$ form factor to characterize the Q^2-dependence of $G_{\gamma^*\gamma\pi}(Q^2)$. It will become apparent that in fully-self-consistent treatments of pion: static properties; and elastic and transition form factors, the asymptotic limit of the product $Q^2 G_{\gamma^*\gamma\pi^0}(Q^2)$, which is determined *a priori* by the interaction employed, is not exceeded at any finite value of spacelike momentum transfer: the product is a monotonically-increasing concave function. Studies exist which interpret the BaBar data as an indication that the pion's distribution amplitude, $\phi_\pi(x)$, deviates dramatically from its QCD asymptotic form, indeed, that $\phi_\pi(x) =$constant, or is at least flat and nonvanishing at $x = 0, 1$. I will explain that such a distribution amplitude characterises an essentially-pointlike pion; and show that, when used in a fully-consistent treatment, it produces results for pion elastic and transition form factors that are in striking disagreement with experiment. A bound-state pion with a pointlike component will produce the hardest possible form factors; i.e., form factors which become constant at large-Q^2. On the other hand, QCD-based studies produce soft pions, a valence-quark distribution amplitude for the pion that vanishes as $\sim (1-x)^2$ for $x \sim 1$, and results that agree well with the bulk of existing data. It can thus be argued that the large-Q^2 BaBar data is inconsistent with QCD and also inconsistent with a vector current-current contact interaction; and hence that the large- Q^2 data reported by BaBar is not a true representation of the $\gamma^*\gamma \to \pi^0$ transition form factor.

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