Radiative Widths of Light Pseudoscalar Mesons at 11 GeV via the Primakoff Effect

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In the limit of massless u, d, and s quarks, the classical QCD Lagrangian exhibits a $SU(3)_L \times SU(3)_R \times U(1)_A$ symmetry. In full quantum theory, the $U(1)_A$ symmetry is explicitly broken, leading to the effect of chiral anomaly in QCD [1]. On the other hand, the $SU(3)_L \times SU(3)_R$ symmetry is spontaneously broken, giving rise to eight massless pseudoscalar Goldstone bosons. The effects of $SU(3)$ and isospin breaking by the u, d, and s quark masses lead to important mixing effects among the light pseudoscalar mesons. Understanding the electromagnetic properties of these mesons are, therefore, fundamentally important in probing QCD at the confinement scale. One of the most interesting systems in low-energy QCD is represented by the three neutral light pseudoscalar mesons, π^0, η, and η', the first two being Goldstone bosons. The study of two-photon partial decay widths of π^0, η, and η' and their transition form factors at very small Q^2 are of fundamental importance in determining the mixing angle of the η–η' system, the light quark mass ratios [2], and one $\mathcal{O}(p^6)$ low-energy constant in the chiral Lagrangian. Thus, providing a stringent test of the low energy limit of QCD.

The PrimEx collaboration at Jefferson Laboratory has a comprehensive program to perform a high precision ($\sim$1.4%) measurement of the neutral pion lifetime using the small angle coherent photoproduction of π^0's in the Coulomb field of a nucleus, *i.e.*, the Primakoff effect [3]. The primary experimental equipment for this measurement includes a high resolution electromagnetic hybrid calorimeter (HYCAL), with Pb-glass modules and a central insertion of high resolution $PbW0_4$ crystals, together with the Hall B photon tagger, and a pair production luminosity monitor.

With the planned upgrade of the CEBAF beam energy to 11 GeV, the current development of the high precision measurement of the $\pi^0 \to \gamma\gamma$ decay width will be extended to include the $\eta \to \gamma\gamma$ and the $\eta' \to \gamma\gamma$ channels [4]. These measurements of the radiative decay widths, together with the electromagnetic transition form factor measurements, will provide one of the most fundamental tests of both QCD and QCD inspired models.

References:

[1] J.F. Donoghue, E. Golowich, and B.R. Holstein, *Dynamics of the Standard Model*, Cambridge University Press (1992).

[2] H. Leutwyler, *The ratios of light quark masses*, Phys. Lett. B378, 1996, 313-318.

[3] Jefferson Lab Proposal E99014, 1999 (url:www.jlab.org/primex).

[4] Pre-Conceptual Design Report (pCDR) for the 12 GeV Upgrade of CEBAF, March, 2003.