A Precision Measurement of the Neutral Pion Lifetime via the Primakoff Effect

Experiment E99-014

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We will perform a precise measurement of the neutral pion lifetime using the small angle coherent photoproduction of π^o's in the Coulomb field of a nucleus, i.e. the Primakoff effect. The $\pi^o \to \gamma\gamma$ decay proceeds primarily via the chiral anomaly and represents one of the most definitive tests of confinement scale QCD. This measurement will be a state-of-the-art experimental determination of the lifetime with a precision better than 1.5%, which is commensurate with the theoretical uncertainty.

Three general experimental techniques have been used to access the neutral pion decay width: direct measurement of the lifetime through decay in flight, $\gamma\gamma$ collisions, and the Primakoff effect. The result obtained from the most recent experiment, a direct decay measurement at CERN in 1985, is nearly two standard deviations below the value predicted by ChPT if the statistical and systematic errors are added in quadrature. Loop corrections at the 1-2% level, however, tend to increase the predicted width. The present experimental knowledge of the π^o lifetime is at the $\cong 10\%$ level. We will measure the lifetime to 1.4% and thereby fill this important experimental gap.

The primary experimental equipment required by this measurement includes: the Hall B photon tagger; 5% radiation length solid π^o production targets (^{12}C, ^{116}Sn, and ^{208}Pb); a pair production luminosity monitor located just downstream of the π^o production target; a highly segmented hybrid electromagnetic calorimeter for π^o decay photons composed of lead glass modules and a high resolution insertion in the central region near the beam; an array of scintillators for charged particle veto.

The high intensity, high energy Hall B tagged photon facility will enable a measurement which will hold two distinct advantages over previous experiments involving bremsstrahlung beams. First, the quasi-monochromatic nature of the tagged beam will enable a clean kinematical separation of the Primakoff mechanism from various background processes. Second, the tagging technique will enable significantly better control of systematic errors associated with the photon flux normalization.

We will take data with sufficient angular resolution to check the shape of the Primakoff peak after the coherent nuclear and nuclear-Primakoff interference amplitudes, which will be determined empirically by larger angle data, have been subtracted. Three spin zero targets will be used in this experiment. These have form factors which have been well studied by electron scattering measurements and can be used to test the Z^2 dependence of the cross section. Additionally, the strong energy dependence of the cross section will be measured from 4.6 to 5.7 GeV. The study of the Primakoff peak as a function of angle, atomic number, and photon energy will add a great deal of confidence to the measurement and can be used to empirically determine the systematic errors.