Abstract

This proposal describes a measurement of the weak pion-nucleon coupling constant to a high level of accuracy using moderate beam time in a theoretically "clean" process. We propose to measure the parity-violating asymmetry in pion photoproduction off the proton, $\vec{\gamma}p \to n\pi^+$. This asymmetry is expected to be $\sim 2.3 \times 10^{-7}$, and can be measured to statistical uncertainty of $\sim 0.5 \times 10^{-7}$ at Jefferson Lab in Hall A. The systematic errors are expected to be smaller than the statistical errors. The asymmetry is related to the weak isovector pion-nucleon coupling, h^1_π, with no uncertainty due to nuclear structure. h^1_π will be determined with uncertainty of 1.0×10^{-7}, 20% of its expected value, 4.6×10^{-7}. At present there are two experiments; photon circular polarization for ^{18}F ($|h^1_\pi| = 0.28^{+0.89}_{-0.28} \times 10^{-7}$) and the anapole moment of ^{133}Cs ($h^1_\pi = 9.5 \pm 2.1\,[\text{exp.}] \pm 3.5\,[\text{theor.}] \times 10^{-7}$) that have been interpreted to give very different values of h^1_π. The disagreement in the extraction of h^1_π from ^{18}F and ^{133}Cs systems could be a reflection of poor understanding of many-body physics. This experiment will be the first attempt to measure the weak pion-nucleon coupling constant in the single nucleon system. A reliable measurement of h^1_π provides a crucial test of the meson-exchange picture of the weak nucleon-nucleon interaction. Such a test of the meson-exchange picture will shed light on low energy QCD.

1 Introduction

Parity invariance has played a critical role in the evolution of our understanding of the weak interaction. It was the experiment of Wu *et al.* [1] motivated by the suggestion of Lee and Yang [2] that led to reexamination of the symmetry properties of all interactions. In 1958, Feynman and Gell-Mann introduced the $V - A$ interaction for charged currents [3], which, when combined with Weinberg's introduction of the neutral current a decade later [4], essentially completed our picture of the weak force. Since that time careful experimental work has led to verification of nearly every aspect of the proposed weak interaction structure:

1. in the leptonic sector, $\mu^- \to e^-\nu_\mu\bar{\nu}_e, \tau^- \to e^-\nu_\tau\bar{\nu}_e$,
2. in the $\Delta S = 0, 1$ semi-leptonic sector, $n \to pe^-\bar{\nu}_e, \Lambda \to pe^-\bar{\nu}_e$,
3. in the $\Delta S = 1$ non-leptonic sector, $\Lambda \to p\pi^-, K^+ \to \pi^+\pi^0$.

However, there is one area missing from this itemization: The $\Delta S = 0$ non-leptonic nucleon-nucleon (NN) interactions, $NN \to NN$. Obviously there is nothing in the identity of the particles involved to reveal the difference between this weak interaction and the ordinary strong $NN \to NN$ process. In fact the weak NN component is masked by the much larger strong NN force but is detectable by the property of parity violation.

On the experimental side, the first search for parity violation in the NN interaction was carried out by Tanner [5] in 1957, but it was not until 1967 that convincing evidence