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PARITY VIOLATION IN PROTON-PROTON SCATTERING
AT INTERMEDIATE ENERGIES

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ABSTRACT

Results of a measurement of parity nonconservation in the \vec{p} - p total cross section at 800-MeV are presented. The dependence of transmission on beam properties and correction for systematic errors are discussed. The measured longitudinal asymmetry is $A_L = (+2.4 \pm 1.1(\text{statistical}) \pm 0.1(\text{systematic})) \times 10^{-7}$. A proposed experiment at 230 MeV is discussed.

INTRODUCTION

An experiment has been carried out to search for parity nonconservation (PNC) in the scattering of 800 MeV longitudinally-polarized protons from an unpolarized hydrogen target. In the experiment, PNC appears as a small helicity dependence in the total cross section when the helicity of incoming protons is reversed. A longitudinal asymmetry A_L is defined: $A_L = (\sigma_+ - \sigma_-)/(\sigma_+ + \sigma_-)$ where σ_+ (σ_-) is the total cross section for positive (negative) helicity protons on the target.

PNC arises from an interference between the strangeness-conserving weak interaction and the strong interaction. Meson-exchange calculations¹⁻³ of the parity-violating amplitudes give predictions that agree with experimental measurements^{4,5} at energies of 15 and 45 MeV. However, at higher energies (6 GeV), the meson-exchange predictions⁶ do not explain the large experimental result.⁷ Other theoretical models,^{8,9} designed to be valid in the high-energy region, have predictions that agree with the 6-GeV results. In the intermediate energy region of 800-MeV, it is not clear which existing models correctly describe PNC effects. I will discuss results from a parity measurement at 800 MeV that is the highest energy p - p measurement to date, achieving a sensitivity in its result comparable to that of the low-energy experiments.

EXPERIMENTAL SETUP

The experiment was performed with the Clinton P. Anderson Meson Physics Facility (LAMPF) polarized H^- beam. Polarized H^- ions were produced in a Lamb-shift-type ion source.¹⁰ Neutral hydrogen atoms, initially polarized in the spin-filter region of the source, had their polarization reversed at 30 Hz by a weak magnetic field. Beam pulses were of 500- μ s duration with a 120-Hz repetition rate. The proton-beam intensity ranged from 1 to 5 nA, and average polarization was 70%.

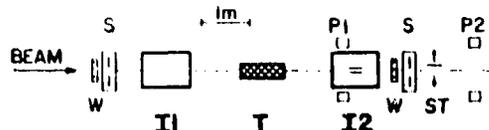


FIG. 1. Experimental setup

The layout of the apparatus is shown in Fig. 1. The transmission of protons through a one-meter long liquid-hydrogen target was measured by integrating ion chambers, I1 and I2, located upstream and downstream of the target. Detector noise due to nuclear spallation reactions in ion-chamber surfaces was a significant factor in determining the final statistical sensitivity of the measurement. To reduce

spallation effects, special ion chambers¹¹ were used.

A major concern of the experiment were changes in beam properties that occur synchronous to the helicity reversal (beam systematics). Such changes could give rise to a spurious PNC signal. Detectors used to monitor the beam properties on a pulse-by-pulse basis are shown in Fig. 1. Integrating multi-wire ion chambers,¹² W, monitored beam position and size. A four-arm polarimeter, P1, used the LH_2 target as an analyzer to measure net transverse polarization (T_{pol}). The upstream ion chamber of the transmission measurement recorded intensity variations of the incident beam. Lastly, a second polarimeter utilized a narrow moving target, ST, to sample the transverse-polarization distribution across the beam profile every two minutes. The first moment of transverse polarization across the beam profile, C_{pol} , can result in an unwanted contribution to Z even if both $T_{pol} = 0$ and the beam is on the symmetry axis.^{4,13} A dual-loop feedback system (not shown) stabilized the beam in position as well as angle.

The helicity-dependent fractional change in transmission, Z, was determined from the analog difference of the I1 and I2 signals. For each group of four beam pulses (quad), the quantity $Z_q = (T_+ - T_-) / (T_+ + T_-)$ was calculated, where T_+ (T_-) is the average transmission for a pair of +(-) helicity pulses. The helicity reversal pattern for each quad was + - - + in order to reduce the effects of drifts and to remove 60-Hz effects. After the accumulation of $\sim 10^5$ quads, an average, Z, and a statistical uncertainty in Z were computed from the individual Z_q and their fluctuations. The longitudinal asymmetry A_L can be

calculated from the transmission asymmetry:

$$A_L = Z/(P \ln T)$$

where P is the beam polarization and T is the average transmission of the target. For this experiment a P = 0.7 and T = 0.85 resulted in a value of $1/(P \ln T)$ of -8.8. Hence to reach a sensitivity in A_L of 10^{-7} , Z had to be measured to nearly one part in 10^8 .

BEAM SYSTEMATICS

To correct for beam systematics, the sensitivity of Z to each beam systematic was determined in a separate measurement. Subsequently, beam properties were recorded during the transmission measurement, and corrections to Z were later applied in the off-line analysis. Pulse-by-pulse corrections were made for beam intensity, position, and size. Corrections for T_{pol} were made for each quad. Corrections for C_{pol} and for unwanted electrical couplings were applied on a run-by-run basis.

Contributions from transverse polarization were minimized by locating the beam along the symmetry-axis of the transmission detectors. The servo-loop system maintained the beam on the symmetry axis during data taking. The sensitivity of Z to intensity modulations was determined using an apparatus¹⁴ consisting of a set of stripper grids that were moved in and out of the H^- beam path to produce a 10% intensity modulation at 30 Hz. At each transmission detector, position scans were performed to measure the sensitivity of Z to position. Small corrections for size variations were calculated from the quadratic components in the position dependence of Z. 30-Hz electrical pickup in the difference signal was minimized by using a 15-Hz digital signal to transmit the helicity-reversal information from the polarized source to the experiment. Care was also taken to insert either optical or analog isolators in all important signal paths.

To cancel contributions to A_L from changes not correlated to the beam helicity, the experiment was run for equal time periods in two different operating configurations (N and R)¹⁵ of the spin filter¹⁰ in the polarized source. Data taken in the two configurations can be combined in two ways: $PNC = (Z_N - Z_R)/2$ measures the longitudinal asymmetry while canceling some systematic effects; $HI = (Z_N + Z_R)/2$ is expected to be zero and serves as a test for unidentified systematic errors. Unidentified systematic errors were also addressed by analyzing the data using a shift in the quad grouping that eliminates helicity dependence from the calculated A_L . The resultant value, A_L (shift), was consistent with zero.

The final PNC and HI values of A_L , along with corrections made to A_L for each systematic, are given in Table I. Within each data run, pulse-to-pulse fluctuations in A_L are smaller for the corrected data than for the uncorrected data. This decrease occurs because correlations between Z and various beam systematics are removed by the corrections. In addition, testing the data from all runs for the hypothesis that $HI = 0$ and that PNC has a definite value produces a χ^2 value for corrected data which is nearly a factor of 2 smaller than that for uncorrected data.

TABLE I. Results for A_L and beam-systematic corrections. Both statistical and systematic contributions to uncertainty are given.

Quantity	PNC($\times 10^7$)			HI($\times 10^7$)		
	Value	Stat	Sys	Value	Stat	Sys
Corrections to A_L						
Position	0.3	0.3	0.1	-2.7	0.3	0.4
Intensity	-0.8	0.5	0.1	7.7	0.5	0.8
Size	-0.1	0.0	0.1	0.2	0.0	0.1
Polarization	<0.1	0.0	0.0	<0.1	0.0	0.0
C_{pol}	-0.1	0.4	0.0	-0.2	0.4	0.0
Electrical pickup	0.0	0.0	0.0	0.6	0.0	0.0
A_L (uncorrected)	3.0	1.2		-5.0	1.2	
A_L (corrected)	2.4	1.1	0.1	0.2	1.1	0.9
A_L (shift)	-0.7	1.1		-0.3	1.1	

The measured longitudinal asymmetry at 800 MeV is $A_L = (+2.4 \pm 1.1(\text{statistical}) \pm 0.1(\text{systematic})) \times 10^{-7}$. The corrected HI result is consistent with zero.

FUTURE EXPERIMENTS

An improved experiment by the Simonius group is being conducted at SIN, and new results will be presented in another talk at this conference. No independent verification of the large ZGS result exists. Therefore, an experiment utilizing the 30-GeV polarized beam at Brookhaven would be desirable. However, at this time a proposal has yet to be submitted.

In the intermediate energy range, a \vec{p} - p experiment at 230 MeV has been proposed at TRIUMPF by a Manitoba/ Alberta/ TRIUMPF/ LANL/ Washington/ Irvine collaboration. At this energy the $^1S_0 - ^3P_0$ PV transition amplitude does not contribute to A_L because of kinematics and strong-interaction phases.¹⁶ As a result other PV amplitudes dominated by ρ -meson exchange become significant, and there is promise for a determination of h_ρ . Finally, a letter of intent has been submitted by the TRIUMPF Collaboration to perform a 2.8 GeV measurement at Saturne.

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