LA-UR -84-2481

CONF-840757--7

LA-UR--84-2481

DE84 016483

Los Alamos National Laboratory is operated by the University of California for the United States Department of Energy under contract W-7405-ENG-36

TITLE PARITY NONCONSERVATION IN PROTON-PROTON AND PROTON-WATER SCATTERING AT 1.5 GeV/c

AUTHOR(S) R. E. Mischke, J. D. Bowman, R. Carlini, D. MacArthur, D. E. Nagle, H. Frauendfelder, R. W. Harper, V. Yuan, A. B. McDonald, R. L. Talaga

SUBMITTED TO XXII International Conference on High Energy Physics, Leipzig, DDR, July 18-25, 1984

Los Alamos National Laboratory
Los Alamos, New Mexico 87545

PARITY NONCONSERVATION IN PROTON-PROTON AND PROTON-WATER SCATTERING AT 1.5 GeV/c

R. E. Mischke, J. D. Bowman, R. Carlini, D. MacArthur, D. E. Nagle,
Los Alamos National Laboratory, Los Alamos, New Mexico 87545

H. Frauenfelder, R. W. Harper, V. Yuan
University of Illinois, Urbana, Illinois 61801

A. B. McDonald
Princeton University, Princeton, New Jersey 08540

and

R. L. Talaga
University of Maryland, College Park, Maryland 20742

Experiments searching for parity nonconservation in the scattering of 1.5 GeV/c (800 MeV) polarized protons from an unpolarized water target and a liquid hydrogen target are described. The intensity of the incident proton beam was measured upstream and downstream of the target by a pair of ionization detectors. The beam helicity was reversed at a 30-Hz rate. Auxiliary detectors monitored beam properties that could give rise to false effects. The result for the longitudinal asymmetry from the water is $A_L = (1.7 \pm 3.3 \pm 1.4) \times 10^{-7}$, where the first error is statistical and the second is an estimate of systematic effects. The hydrogen data yield a preliminary result of $A_L = (1.0 \pm 1.6) \times 10^{-7}$. The systematic errors for p-p are expected to be $< 1 \times 10^{-7}$.

This paper describes two experiments searching for parity nonconservation in p-p and p-H_2O scattering at 1.5 GeV/c (800 MeV). The experiments measure a longitudinal asymmetry $A_L = (\sigma_+ - \sigma_-)/(\sigma_+ + \sigma_-)$, where $\sigma_+(\sigma_-)$ is the total cross section for positive (negative) helicity protons on an unpolarized target. A value of A_L is expected to occur at the level of 10^{-7} from the interference between the strong and weak scattering amplitudes. If the strong part of the interaction is known, these experiments can help determine the strangeness conserving weak interaction between hadrons.

The present experiments are at an energy intermediate to previous measurements.[1-4] When extended to the energy of the present experiment, calculations[5,6] provide conflicting predictions for p-p scattering of $|A_L| < 2 \times 10^{-7}$ and $A_L \simeq 1.8 \times 10^{-6}$. An experimental determination of the asymmetry at 1.5 GeV/c gives new information on the energy dependence of A_L and tests the range of validity of theoretical models for parity nonconservation.

The experiments were performed at the Clinton P. Anderson Meson Physics Facility (LAMPF) utilizing longitudinally polarized protons produced in a Lamb-shift-type ion source.[7] A transverse magnetic field in the source reversed the proton helicity at a rate of 30 Hz. The reversal frequency was chosen to minimize noise due to random fluctuations in beam properties. The beam was accelerated to 1.5 GeV/c as H^- atoms and reached the apparatus in "macropulses" of 500 μsec duration with a 120-Hz repetition rate. The beam intensity was typically between 2 and 5 nA and the average polarization was $|\vec{P}| = 0.70 \pm 0.03$.

The layout of the experiment during the H_2O run is presented in Fig. 1. The stripper foil was located 50 m upstream; an aperture in the foil defined the ... size and removed beam halo. The beam position was stabilized by steering magnets, which were controlled by feedback systems from detectors that sensed the beam position. Two identical low-noise ion chambers,[8] IC1 and IC2, were used to determine the cross section by measuring the transmission, Z, of the polarized beam through the target. The aperture of the ion chambers was 10 × 10 cm and the active length was 30 cm. A 10-cm thick H_2O target had a transmission of 85% and was placed 2 m upstream of IC2. A Pb target, used in the experiment as a control, was

1.6 mm thick and had a transmission of 98%. The thickness of the Pb target was chosen to give the same multiple Coulomb scattering as the H_2O target but with a factor of ten fewer nuclear interactions. Data were also taken with no target.

It was important to measure the properties of the beam during each pulse. Split-plate ion chambers, SIC1 and SIC2, measured the position and angle of the beam. IC1 monitored beam intensity changes. A four-arm polarimeter determined residual transverse polarization in both the horizontal and vertical planes. The polarimeter was also used with an alternate target that was moved repeatedly through the beam to map the distribution of residual transverse polarization across the beam profile. A circulating component of polarization, CPOL, can cause a helicity correlated change in the amount of scattered beam passing through the aperture of IC2 even if the net transverse polarization is zero.

The transmission for each macropulse was determined from the amplified analog difference of the IC1 and IC2 signals to keep the least count in the digitized number from becoming a limiting factor in signal noise. The transmission and the other measured beam properties for each pulse were written on magnetic tape and later analyzed for helicity correlated variation.

Correlations with the 30-Hz helicity reversal were sought by analyzing groups of four beam pulses. The helicity pattern of the group, + − − +, was chosen to reduce the effects of drifts; it also suppressed 60 Hz effects. For each group the quantity $\Delta Z/2Z = (Z_+ - Z_-)/(Z_+ + Z_-)$ was calculated where $Z_{+(-)}$ is the average of the two +(−) helicity pulses. From each run, which consisted typically of 10^5 four-pulse groups, an average was calculated and a statistical uncertainty was computed from the variance of the measurements.

Contributions to $\langle \Delta Z/2Z \rangle$ due to 30-Hz signals carried by beam properties were determined by measuring the effect of each contributing beam property. The sensitivities of $\langle \Delta Z/2Z \rangle$ to position and transverse polarization were determined from sets of calibration runs (each set called a sweep) interspersed among the data runs. In these sweeps, beam position was systematically varied to determine the functional dependence of transmission on changes in these beam properties. Sweeps taken with the polarization fully transverse determined the dependence of $\langle \Delta Z/2Z \rangle$ on transverse polarization. The position of the beam for which these corrections vanished is called the neutral axis. CPOL was measured during target-out runs. The dependence of $\Delta Z/2Z$ on intensity was determined from the correlation between the 30-Hz component of intensity and $\Delta Z/2Z$ during each data run.

Electrical couplings of any 30-Hz signals into the data channels were suppressed by paying careful attention to signal path and component isolation. The 30-Hz reversal signal used at the polarized source was divided down to 15 Hz before transmission to the apparatus. The 15 Hz was isolated and coded into a frequency modulated signal as an additional measure to eliminate any 30 Hz pickup.

As a check on other unidentified systematics not directly related to the helicity of the beam, data were taken in two configurations (N and R) of the polarized source.[7] In both configurations protons exiting the source were longitudinally polarized but the spin directions for the N and R configurations are opposite with respect to the transverse spin-flip field of the source. Hence, the combination (N-R)/2 cancels the effects of helicity-independent systematics and is interpreted as a PNC signal. The combination (N+R)/2 is a measure of the presence of helicity-independent systematics and is called a "null" signal.

A total of 18.0×10^{15} protons were incident on the H_2O target in twenty-eight runs. The data with the Pb target consist of eleven runs with 6.1×10^{15} protons and 4.5×10^{15} protons were taken with no target in nine runs. The position and intensity corrections were computed for each run by multiplying the average 30-Hz component of intensity or position by the appropriate sensitivity. The CPOL corrections for H_2O and Pb runs were made by interpolating the values from nearby target-out runs. A fitting program determined the sensitivity of $\langle \Delta Z/2Z \rangle$ to polarization and the position of the effective neutral axis of the experiment for all targets simultaneously. The weighted average values of $\langle \Delta Z/2Z \rangle$ for the PNC and null combinations were computed for each target. These values are presented in Table I before and after the corrections are applied. The values of each correction are also given in Table I. Uncertainties in the determination of the sensitivities have been included in the statistical uncertainties. Contributions to $\langle \Delta Z/2Z \rangle$ from electrical pickup were measured in beam-off runs to be $(0.1 \pm 0.7) \times 10^{-8}$. This correction has been applied to the null values for each target.

The χ^2 for the fit to the data runs after all corrections is 39 with 42 degrees of freedom. The change in χ^2 due to each correction was determined by removing each correction with all the others applied. The χ^2 is expected to decrease as each correction is added, corresponding to an improved internal consistency of the data. The only significant exception is the position correction for Pb, which resulted in an increase in χ^2 of 3.7.

The PNC values for the two control targets are consistent with zero as are the null values for all targets. This is a strong test for the presence of systematic errors, which may arise from imperfect characterizations of the corrections. Two plausible sources of systematic error are the time dependence of the CPOL values and the uncertainty in the effective neutral axis affecting the polarization correction. There is an additional contribution to the systematic error estimate for Pb due to the increase in χ^2 when the position correction is included. The separate systematic error estimates have been combined quadratically and the total is given in Table I for each target.

For the H_2O target, the PNC value can be related to A_L by the factor $1/(|\vec{P}| \ln Z) = -8.8$. The net corrected value of A_L for H_2O is $(1.7 \pm 3.3 \pm 1.4) \times 10^{-7}$, where the first error is statistical and the second is an estimate of systematic effects.

The hydrogen experiment differed from the water run in several important respects. A second polarimeter was added to monitor the residual polarization from the transmission target. This allowed the moving polarimeter target that scanned across the beam to be operated continuously. New detectors were added to measure the beam position on a pulse by pulse basis with greater linearity than available from the split ion chambers. A device was built to modulate the beam intensity at a 30-Hz rate. With this tool we were able to understand the sensitivity of the system to intensity changes at a much better level. These changes, a realignment of the transmission detectors, and a breakthrough in our understanding of the position and polarization sensitivity of the detectors were important in reducing the sources of systematic error in the hydrogen run to correspond to the higher statistical precision of the data.

The liquid hydrogen target was 1 m long, which corresponds to Z = 0.85. The data consist of 74 runs with the source in the N configuration and 83 runs of the R type. At this time the analysis of the p-p result is not complete. The preliminary result is based on the raw data, corrected only for position and intensity. The value for A_L is $(1.0 \pm 1.6) \times 10^{-7}$. We have not evaluated the systematic errors but believe they will be $< 1 \times 10^{-7}$.

Previous measurements of A_L at low energies yield non-zero results in good agreement with theoretical predictions based on a meson-exchange model[9-11] and a hybrid quark model.[12] In contrast, the high-energy experiment has reported a value for an H_2O target that is more than an order of magnitude larger than meson-exchange predictions[5] for N-N scattering. Recent theoretical work[13] treating the quark constituents of nucleons has predicted a value of $A_L \sim 2 \times 10^{-6}$ at 6 GeV/c, in good agreement with the experimental result. Another calculation,[14] involving a parity violating admixture in the nucleon wave function, has predicted a similar result.[15]

The result for H_2O is consistent with the expectation from meson exchange calculations that $A_L \sim 1 \times 10^{-7}$ but it is clearly smaller than the prediction[6] of $A_L \sim 1.8 \times 10^{-6}$. A rapid increase in the magnitude of A_L between 1.5 and 6 GeV/c is consistent with the quark-level calculation although its validity is not expected to extend down to 1.5 GeV/c. The hydrogen result is also consistent with zero. When final, it will have two important advantages over the H_2O result. First, it will not involve a nucleus and thus will be exempt from questions about nuclear structure. Second, the statistical precision will be a factor of three better. The H_2O result does give some information about the magnitude of PNC effects in p-n scattering but this result will be superceded by a new experiment just completed that uses a deuterium target and also has a statistical precision at the level of 1×10^{-7}.

We wish to acknowledge the contributions of C. M. Hoffman, J. M. Potter, C. Barnes, and J. Zyskind to early phases of this experiment. The entire LAMPF staff is commended for accomodating the severe demands this experiment has made on the LAMPF operation. O. van Dyck made important contributions to the beam-line design and to servo control of the beam position; E. P. Chamberlain was responsible for the ion source design and operation. J. Novak designed the liquid hydrogen target. This work was supported by U. S. Department of Energy and by the National Science Foundation, contract NSF PHY81-03317.

REFERENCES

1. D. E. Nagle et al., in High Energy Physics with Polarized Beams and Targets, edited by G. H. Thomas, AIP Conference Proceedings No. 51, (American Institute of Physics, New York, 1978), p. 224.
2. R. Balzer et al., Phys. Rev. Lett. 44, 699 (1980).
3. M. Simonius, in High Energy Physics with Polarized Beams and Targets, edited by C. Joseph and J. Soffer, Experientia Supplementum No. 38, (International Symposium, Lausanne, 1980), p. 355.
4. N. Lockyer et al., Phys. Rev. Lett. 45, 1821 (1980).
5. E. M. Henley and F. R. Krejs, Phys. Rev. D 11, 605 (1975).
6. G. Nardulli, E. Scrimeri, and J. Soffer, Z. Phys. C 16, 259 (1983).
7. J. McKibben, in Polarization Phenomena in Nuclear Physics, edited by G. G. Ohlsen et al., AIP Conference Proceedings No. 69, (American Institute of Physics, New York, 1980), p. 830.
8. J. D. Bowman et al., Nucl. Instrum. Methods. 216, 399 (1983).
9. V. R. Brown, E. M. Henley, and F. R. Krejs, Phys. Rev. C 9, 935 (1974). Note that the asymmetry defined there is $2A_L$ as here defined.
10. M. Simonius, Nucl. Phys. A220, 269 (1974)
11. B. Desplanques, J. F. Donoghue, and B. R. Holstein, Ann. Phys. 124, 449 (1980).
12. L. S. Kisslinger and G. A. Miller, Phys. Rev. C 27, 1602 (1983).
13. T. Goldman and D. Preston, Nucl. Phys. B217, 61 (1983).
14. G. Nardulli and G. Preparata, Phys. Lett. 117B, 445 (1982).

15. This calculation is controversial, see J. F. Donoghue and B. R. Holstein, Phys. Lett. 125B, 509 (1983); B. H. J. McKellar, Phys. Lett. 138B, 6 (1984).

TABLE I. Summary of the raw and corrected results for $\langle \Delta Z/2Z \rangle \times 10^8$ and the correction for each type of false effect.

Target:	H_2O			Pb			none		
Raw	$\langle\frac{\Delta Z}{2Z}\rangle$	±stat	±sys	$\langle\frac{\Delta Z}{2Z}\rangle$	±stat	±sys	$\langle\frac{\Delta Z}{2Z}\rangle$	±stat	±sys
PNC	3.3	±3.5		7.1	±7.3		-6.6	±6.1	
null	2.6			17.1			-7.6		
Corrected									
PNC	-1.9	±3.7	±1.6	8.9	±7.4	±1.8	-9.2	±6.1	±0.0
null	-5.2	±3.8		-3.6			3.1		

	PNC	null	PNC	null	PNC	null
Corrections for						
Position	-0.9	-6.8	1.8	-10.1	0.0	0.0
Polarization	-0.7	0.4	0.7	0.6	0.0	0.2
Intensity	-1.9	-0.2	-1.0	-11.0	-2.7	10.4
CPOL	-1.9	-1.3	0.3	-0.3	0.2	0.1

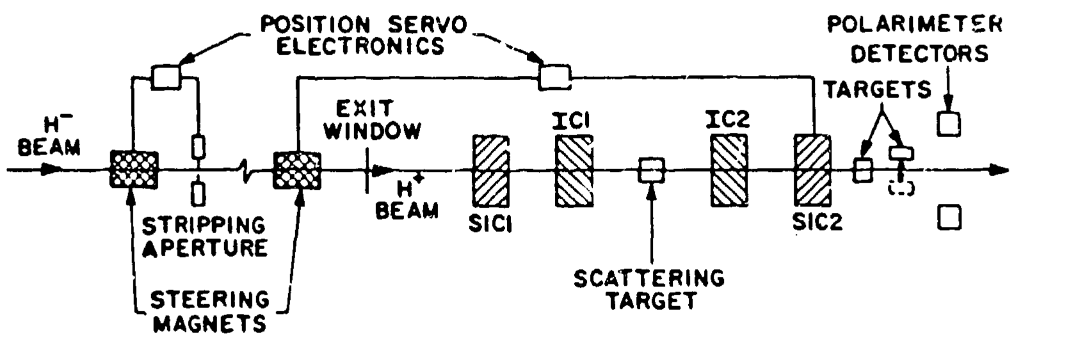

Fig. 1 Experimental layout. Beam position is monitored by split ion chambers, SIC1 and SIC2. Feedback systems keep the beam centered on the stripping aperture and SIC2. Ion chambers, IC1 and IC2, measure the transmission of the scattering target. The polarimeter can be used with a stationary or a moving target to measure average transverse beam polarization or its distribution across the beam profile.