NUCLEON-NUCLEON AND FEW BODY SYSTEMS

PROGRESS ON THE CHARGE-SYMMETRY-BREAKING EXPERIMENT

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During 1987, the experimental search for charge symmetry breaking (CSB) in $\vec{n}$-$\vec{p}$ scattering at E_n = 183 MeV entered the production running phase. An earlier short production run in March, 1986 had provided a sufficient statistical sample of $\vec{n}$-$\vec{p}$ data (a little over one million free-scattering events) to yield meaningful information about some systematic errors, allow considerable development of our replay software, and produce the most precise spin correlation ($C_{NN}(\theta)$) measurements ever made for n-p scattering. The latter results, bearing a much stronger similarity to predictions made with the Bonn, than with the Paris, one-boson-exchange potential, have now been published.[1] We have now, as discussed below, acquired significantly more data. The resulting $C_{NN}(\theta)$ distribution (with greater statistical precision in smaller angle bins) is displayed, along with the C200 phase shift solution calculated with SAID,[2] in the accompanying figure.

The second half of 1986 and the first half of 1987 were devoted largely to substantial improvements in the hardware and software for the CSB experiment. The charged-particle sweeping magnet in the polarized neutron beam line was replaced by one with much greater field capability, to allow ±90° precession of horizontal components in the neutron beam polarization. This was necessary to provide sufficient cancellation of systematic errors in the CSB measurement arising from spin correlations between possible in-plane components in the beam and target polarizations. For the same reason, we fabricated a warm-bore rotating Hall probe assembly for the polarized proton target (PPT) dewar, to permit measurement and cancellation of horizontal components in the ($\sim$ 600 G) PPT holding field to an accuracy $\sim \pm 1$ G.

More accurate cancellation of magnetic fields was also a concern for the neutron-detector phototubes. The March, 1986 data had indicated an appreciable systematic error arising from gain shifts, and hence neutron detection efficiency shifts, when the PPT spin was flipped by reversal of the holding field direction. The installation of correction coils wound on the detector arms, together with additional mu-metal shielding of all the phototubes, has now reduced the field change at the phototubes to typical values $\lesssim \pm 0.02$ G, at which level the attendant CSB systematic errors are no longer a concern.

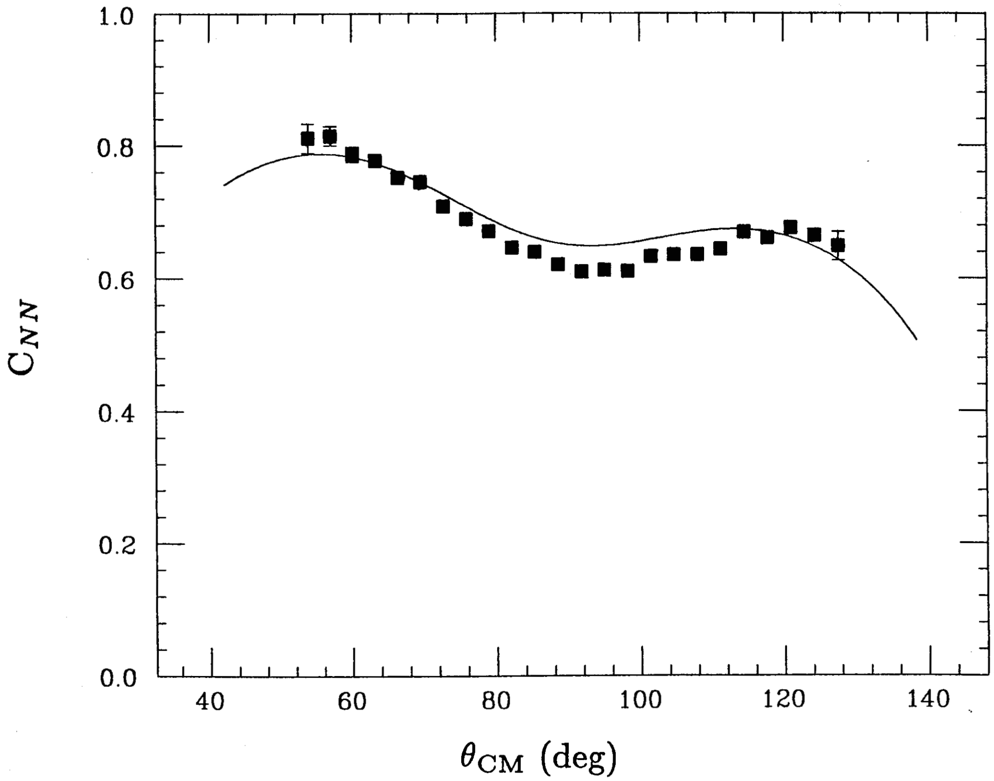

Figure 1. Spin correlation $C_{NN}(\theta)$ data, a byproduct of recent CSB production running, shown with typical statistical error bars of ± 0.006 with the data summed in 1.6° laboratory angle bins. There is an overall normalization uncertainty of at least ± 8% in the C_{NN} measurement (see Ref. 1). The curve is the single energy phase shift prediction of Arndt as described in the text.

Considerable additional effort was devoted to improving the reliability of the neutron detectors and multiwire proportional chambers and to developing software to allow VAX replay of the data at an order of magnitude greater speed than was possible with the Harris acquisition computer and software.

A major focus of attention during 1986-87 was on improving the "spin refrigerator"[3] PPT performance. In March, 1986 we had attained peak target polarizations $\simeq 0.42$, corresponding to a value $\simeq 0.36$ averaged over the $\vec{n}$-$\vec{p}$ running time. These values were consistent with expectations based on the operating conditions achieved at that time: the (yttrium ethyl sulfate, YES) target crystals were polarized by rotating them at a rate of ~ 40 Hz and a temperature of ~ 0.67 °K in a 9.5 kG polarizing field. The superconducting magnet assembly for the PPT was replaced in July, 1987 with a commercial one obtained from C.C.L. (London) that has allowed us to run reliably at polarizing fields of 12 kG. Other improvements aimed at reducing the heat load generated by the spinning target allow us now to operate at T $\simeq$ 0.53 °K for rotation rates of 35-40 Hz. With these improved operating conditions, we expected (based on calculations which had always been capable previously of reproducing the measured target polarizations) peak polarizations in excess of 0.60. However, the values actually attained have been typically $\simeq$ 0.45, leading to time-averaged values of $\simeq$ 0.39 during production runs in Fall, 1987. Measurements of target polarization buildup as a function of spinning time reveal that the initial rate of increase is consistent with expectations, but the expected final polarization is never reached. We cannot now reproduce target polarizations measured under earlier operating conditions with the same crystals. Despite extensive testing of the physical parameters, temperature, rotation rate, and magnetic field, we have not yet succeeded in understanding the source of the low polarization. Our last speculation is that the crystals "age" after some period of time, perhaps in 9 months. For this reason we are presently in the process of growing new YES crystals, and hope to have them ready for at least half of the production running planned for summer, 1988. On the positive side of PPT performance, we have found that radiation damage to the crystals, which can lead to significant deterioration in the PPT spin relaxation time (τ_{relax}) over the course of a 3-week run, can be annealed rather quickly by cycling the target up to liquid nitrogen temperature. The annealing process restores the initial value $\tau_{relax} \gtrsim$ 150 hours at a holding field of 600 G.

In two long, very successful production runs during Fall, 1987 we acquired a total of $\sim 15 \times 10^6$ free $\vec{n}$-$\vec{p}$ scattering events over the angular range $60° \leq \theta_{cm}(n) \leq 120°$. With the average target polarization of 0.39 and the average neutron beam polarization of 0.56 attained during these runs, the data yield statistical uncertainties in the CSB variable $\Delta A(\theta)$ of $\sim \pm$ 0.0022 in 4° wide (laboratory angle) bins. With the larger bin size used in the recent TRIUMF 477 MeV $\vec{n}$-$\vec{p}$ scattering experiment,[4] we already have somewhat better statistical precision than they achieved for ΔA at the zero-crossing angle of the n-p analyzing power. However, measurement of the angular dependence of ΔA remains our major focus. We have planned two 5-week runs for Summer, 1988 to add up to 25×10^6 free $\vec{n}$-$\vec{p}$ events to our data. The final statistical precision achieved will depend on whether or not the new YES crystals are available for the summer runs, and on whether they allow us to attain higher target polarizations. In any case, we hope to determine ΔA in ~8 angle bins with typical statistical precision of at least ± 0.0014.

Replay of the Fall, 1987 data is presently concentrating on the analysis and understanding of systematic errors. Information about these is available from several sources. The production $\vec{n}$-$\vec{p}$ running was divided up so that (over and above the periodic reversal of beam and target spins) half of the data were obtained with the PPT spin parallel, and half with it anti-parallel, to the PPT holding field. Comparison of the data from these two halves provides information on systematic errors arising from PPT <u>field</u> (as opposed to spin) reversal. Similarly, half the data were acquired with +90°, and half with −90°, precession of horizontal beam polarization components, allowing determination of the sensitivity to systematic errors associated with in-plane spin correlations.

In addition to the normal running with beam and target simultaneously polarized, a roughly equal amount of time was devoted to specific systematic error tests. Runs with the target unpolarized, but with the holding field coils on (and flipping) at a larger than normal current, provide further information on spurious ΔA signals associated with the PPT field reversal. Runs with the RF transition power turned off at the polarized source, and the sweeping magnet field reduced, allow us to search for systematic errors associated with the procedures for reversing the beam spin. Runs with a secondary sideways-polarized proton beam incident on the polarized target provide enhanced sensitivity to horizontal components in the PPT polarization. Runs with a normally polarized proton beam scattering from the polarized target allow a general null test of the experiment design and equipment, and can hopefully reveal unexpected sources of error. We expect that a complete digestion of all this information will require at least a year of replay and analysis after the data acquisition is completed. As of this writing we have, after substantially increasing the number of diagnostic histograms into which we sort, and correcting several software bugs, replayed all the $\vec{\mathrm{n}}$-$\vec{\mathrm{p}}$ data taken so far. We have eliminated apparent systematic error effects, observed during on-line analysis of the data in Fall, 1987, arising from incomplete software correction for the bending of protons in the PPT holding field. At the present level of the replay, it appears that systematic errors in the CSB observable $\Delta A(\theta)$ are no larger than the statistical uncertainties. We hope to convince ourselves that they are in fact much smaller, by more detailed analysis of the auxiliary measurements designed to enhance potential systematic errors.

Finally, it is worth noting that the theoretical interest in our CSB measurement has increased since publication[4] of the TRIUMF result. As has been stressed recently by A.W. Thomas,[5] at the single angle and energy of the TRIUMF measurement, ΔA should be dominated by the effect of the n-p mass difference on the one-pion-exchange potential, on which there is now good agreement among different calculations. The TRIUMF datum is, however, insensitive to the contribution from $\rho^\circ - \omega^\circ$ meson mixing, whose magnitude scales with the poorly known ρNN and ωNN couplings. Indeed, recent valence quark models of the NN interaction, which attempt to replace ω-exchange with quark interchange diagrams as an explanation for the short-range repulsion, would give <u>no</u> comparable contribution to ΔA, since one requires the 1^- quantum numbers of the vector mesons (or else of $q\bar{q}$ sea quark pairs) to get an appropriate spin-dependence in the CSB part of the potential.[5] The <u>angular distribution</u> of $\Delta A(\theta)$ which we are measuring is sensitive to the $\rho - \omega$ mixing calculation, and may thereby provide unique insight into the nature of the short-range NN interaction.

1. J. Sowinski et al., Phys. Lett. B **199**, 341 (1987).
2. R.A. Arndt et al., Phys. Rev. D **35**, 128 (1987).
3. J. Sowinski and L.D. Knutson, to be published in Phys. Rev. B., June 1988.
4. R. Abegg et al., Phys. Rev. Lett. **56**, 2571 (1986).
5. A.W. Thomas, lectures presented at the school on "Quarks in Hadrons and Nuclei" (Erice, 1987), to be published in Prog. Nucl. Part. Phys. **20**.