FEW NUCLEON SYSTEMS

STATUS OF THE SEARCH FOR CHARGE SYMMETRY BREAKING IN n-p SCATTERING

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The experimental search[1] for charge symmetry breaking (CSB) in n-p scattering at E_n=188 MeV is now on the verge of production running — the first such run being scheduled for March of 1986. Although there has been a relatively small overlap of reliable polarized target operation with reliable cyclotron operation during the past year, nonetheless, considerable progress has been made during this period in the many areas crucial to the production running mode of this experiment. A few highlights are summarized below.

The polarized neutron facility (PNF) and detector arrays for the CSB experiment have been complete for some time and have been used to acquire n-p scattering data in a number of preliminary runs.[2] One major purpose of these runs has been the development of extensive diagnostics and in-beam calibration techniques for the equipment. The data acquisition software now continually checks incoming events for a wide variety of anomalies suggestive of hardware problems, allowing much more rapid identification of equipment failures than was possible previously. In addition, more elaborate calculations involving sorted event data and scalar ratios are performed at regular intervals (e.g., every 10-15 minutes of running) to check for the possibility of more subtle problems with the data being written to magnetic tape.

An extensive set of startup procedures has been developed and carefully documented. In addition to the usual shakedown and debugging of the CSB and polarimeter electronics, there are procedures utilizing the secondary neutron and proton beams available in the PNF, scattering from plastic scintillator and CD_2 targets, which provide for automatic matching of the pulse height and timing responses from the 192 liquid scintillator neutron detector cells. At the same time we obtain an absolute angle calibration for the detector arrays and a cell-by-cell efficiency calibration for the neutron detectors. These checks and calibrations are performed at the beginning of every running period, and in conjunction with the shakedown and tuneup of the electronics, take on the order of two days (6 shifts) of machine time.

From our now extensive experience replaying data from the preliminary runs, we are learning how to extract free n-p scattering yields with optimal efficiency, while minimizing the chance of introducing possible subtle, spin-dependent biases in the analysis. We have found that it is helpful to calculate several new transformed variables in order to reduce the correlations among the various parameters to which we then apply software cuts. Other software improvements relate to increasing the sorting speed and further reduction of troublesome bugs. We have found that the most reliable discrimination against quasifree scattering background events is performed by a series of relatively conservative cuts on raw and in some cases calculated kinematic variables, coupled with subtraction of quasifree data acquired with a hydrogen-free "dummy" target. A rather elaborate dummy target has been made from hydrogen-free compounds that closely simulate the components and construction of the polarized proton target.

In a typical opening-angle spectrum the residual background, after subtraction of the "dummy" target spectrum, accounts for $\lesssim 0.1\%$ of the free-scattering peak area (this is adequate for the level of statistical accuracy we hope to reach). From the free-scattering yields for the left and right detectors, determined as a function of beam and target spin projections (eight pieces of information all together), we will be able to extract information which is sensitive to the presence of a CSB analyzing power difference $\Delta A(\theta) \equiv A_n(\theta) - A_p(\theta)$. With the expected beam and target polarizations and counting times, we should be able to determine ΔA to a statistical precision of $\leqslant \pm 0.001$ in each of six angle bins spanning the range $60° \leqslant \theta_{cm} \leqslant 120°$. More precisely, the quantitiy we extract is[3]

$$X(\theta) \equiv \frac{P_b A_n(\theta) - P_t A_p(\theta)}{P_b A_n(\theta) + P_t A_p(\theta)} \approx \frac{1}{2}\left[\frac{\Delta P}{P} + \frac{\Delta A(\theta)}{A(\theta)}\right],$$

where $\Delta P = P_b - P_t$ and $P = (P_b + P_t)/2$, and where P_b and P_t are the beam and target polarizations, respectively. X may be be calculated directly from the various spin dependent free scattering yields (L_{++}, L_{+-}, etc.) and relative neutron fluxes (I_{++}, I_{+-}, etc.) (In fact there are several ways to extract X; the various methods having different sensitivities to certain systematic errors.) Since $\Delta P/P$ is independent of Θ, any dependence of $X(\Theta)$ on angle is a signature of CSB. This method of extracting the CSB information does not require accurate knowledge of P_b or P_t. Shown in the top panel of Fig. 1 are calculations of $\Delta A(\theta)$ arising from both electromagnetic (spin-orbit) and strong interaction sources, according to first-order Born approximation predictions of Gersten.[4] Indicated in the lower panel of Fig. 1 are corresponding calculations of $X(\Theta)$. Also shown in the figure are "mock" data points for $X(\Theta)$, which indicate the statistical accuracy we expect to achieve in the experiment (corresponding to a total of 4×10^7 detected free n-p scattering events summed over all angles and spin states).

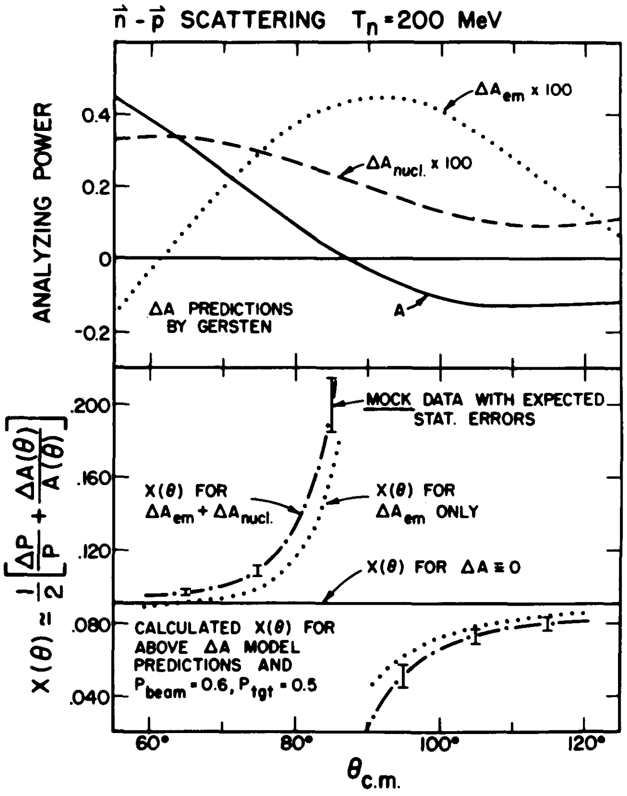

Figure 1. Theoretical calculations of $A(\theta)$, $\Delta A(\theta)$ (top panel), and the CSB variable $X(\theta)$ (bottom panel) over the angle range covered in the experiment. The isospin-mixing parameters[4] include several strong-interaction contributions which partially cancel to give ΔA_{nucl} shown. The "data points" plotted are representative of the results we hope to attain!

In order to efficiently extract such numbers from the data, a considerable effort has gone into considering the various extraction schemes (5 at latest count) for $X(\Theta)$, and to writing an extensive analysis program (POLOC) to perform the appropriate calculations from the spin-dependent free scattering yields obtained either on-line or from subsequent replay of event data tapes. In addition POLOC permits one to calculate the neutron beam polarization (either directly from the neutron polarimeter, or indirectly from the incident beam polarization as measured with a polarimeter located in the high energy beam switchyard), PPT polarization (under the assumption that $\Delta A = 0$), the analyzing powers and spin correlation coefficients as a function of angle, and many other quantities of interest. When applied to on-line data (every few event tapes or so) the program printout provides many additional ways of checking the quality of the data being acquired during the run.

We have also devoted considerable time to devising schemes for measuring and minimizing sensitivity to a variety of sources of systematic error in the CSB experiment. The main concern are spurious angle-dependent left-right asymmetries that exactly simulate ΔA, in that they change sign with a flip of one, but not the other, of the interacting nucleon spins. Such an effect arises, for example, from the bending of protons traversing the PPT holding field. To keep the consequent $\Delta A_{false} \lesssim 1 \times 10^{-4}$, we must correct the measured proton angle for the bend (typically ~ 1°) to an accuracy better than 0.04° over the entire angular range of the detectors. We have recently developed a new and improved version of the angle correction software which is based on detailed realistic field maps. The actual angle deflections are parameterized in a way that permits the corrections to be made rapidly on an event-by-event basis.

The reliability of this procedure can be tested (and parameters adjusted), for example, by checking the accuracy with which we can measure the $A_y(\theta)$ zero-crossing angle for p-p scattering (which must cross at precisely 90° in the c.m.) of a secondary proton beam from the PPT.

The availability of the secondary proton beam also plays a crucial role in limiting systematic errors associated with the spin correlation of horizontal polarization components in the beam and target. The neutron beam has an unavoidable horizontal component [arising from the $^2H(\vec{p},\vec{n})$ production reaction polarization], and consequently these errors are most easily eliminated by insuring that the horizontal components of the target polarization are negligible. This will be done by measuring the PPT horizontal polarization and using correction coils to cancel the corresponding horizontal components of the magnetic field at the target. For this purpose, we have built and tested room temperature coils which hug the PPT dewar wall at 90° to the beam (left and right) to provide cancellation of the transverse fields. The polarizing magnet internal to the PPT will be used to cancel out longitudinal components. These additonal fields, controlled by the PPT microprocessor, may have either polarity and/or different magnitudes for the two different orientations of the main PPT holding field.

In order to determine how to set the correction fields we will make measurements of the asymmetries produced in p-p scattering initiated on the PPT by a sideways-polarized secondary proton beam. In preparation for this type of running we have modified the beam switchyard polarimeter ($p + {}^{12}C$ scattering) to include left-right as well as up/down detectors. The overall performance of the switchyard polarimeter has been improved by replacing the NaI scintillators with telescopes consisting of a thin plastic "trigger" scintillator, followed by an Al absorber block (reducing the scattered proton energy from 200 to 100

MeV), and a plastic stopping detector. The "trigger" scintillator serves to reduce the very large number of background events which would normally occur in such a spectrum by giving some degree of directionality as well as ensuring that a scattered charged particle initiates the detected event rather than a high energy (background) neutron. Further additions to the analysis program POLOC (described above) have been incorporated in order to handle these new measurements with sideways polarized beams. In order to provide the sideways polarized proton beam (by elastic scattering of a sideways-polarized primary beam from a spin-zero nucleus) we have recently installed and tested with beam a superconducting spin-precession solenoid (borrowed from Prof. F.D. Becchetti at the University of Michigan) in the high energy PNF beam line.

Besides the installation of the above superconducting solenoid, the major equipment development during the past year has involved improvements to the "spin refrigerator" PPT. The superconducting polarizing field magnet has been rewound, and more recently, one of the holding magnet coils also had to be rewound. Numerous modifications have been made to improve the trapping of contaminant gases in the ^{3}He line and to improve the flow of cooling liquid to the target. Improvements in the design of the target crystal holder, the addition of bearing cooling fans and baffles, and improved procedures for dynamical balancing of the target as well as for cleaning the shaft bearings, have all helped to reduce the heat load created by spinning the target during polarization. A new batch of Yb doped yttrium ethyl sulfate (YES) crystals has been grown and a new large area (5 x 7 cm^2) target assembled. The polarization buildup times (3-4 hours starting from P = 0) and the spin relaxation times (~ 60 hours in a 0.10 T holding field) for the new crystals are both much better than for previous batches. These changes have led to substantial advances in all aspects of target performance. In a PPT test in September, 1985 we achieved a target polarization ≃ 0.40 in a 1.0 T polarizing field with a crystal rotation rate of 50 Hz (at a temperature of 0.75 K).

Efforts to make further improvements in the performance of the polarized target are continuing. Higher polarizing fields would clearly be beneficial, and we are currently looking into the possibility of obtaining commercially wound magnets which would reliably produce fields of up to 1.25 T. We are also pursuing modifications to the cooling system which may lead to further improvements in the temperature achieved while polarizing the target.

1) S.E. Vigdor et al., Proc. Fifth Int'l. Symp. on Polarization Phenomena in Nuclear Physics (Sante Fe, August, 1980), edited by G.G. Ohlsen et al., (AIP, New York, 1981) Vol. II, p. 1455.

2) S.E. Vigdor et al., IUCF Scientific and Technical Report 1978, p.15; 1979, p. 118; 1981, p. 52; 1982, p. 101; 1983, p. 57 and 1984, p. 38.

3) W.W. Jacobs et al., Proc. Sixth Int'l. Symp. on Polarization Phenomena in Nuclear Physics (Osaka, Japan, 1985), p. 233.

4) A. Gersten, Phys. Rev. C 24, 2174 (1981).