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A MEASUREMENT OF  $C_{NN}$  IN n-p SCATTERING AT 188 MeV

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The charge symmetry breaking (CSB) experiment is designed to make a very precise measurement of the analyzing power difference  $\Delta A = A_n - A_p$  for n-p scattering, where  $A_{p(n)}$  is the analyzing power measured with polarized protons (neutrons). In performing these measurements we use a neutron beam and proton target simultaneously polarized normal to the scattering plane. As a byproduct of these measurements two n-p elastic scattering observables can also be extracted from the same data. These are the usual analyzing power,  $A = 1/2(A_n + A_p)$ , and the spin correlation parameter,  $C_{NN}$  (also called  $A_{NN}$  or  $A_{yy}$ ). The parameter  $C_{NN}$  is particularly interesting since the Bonn and Paris microscopic nucleon-nucleon potential models give

quite different predictions for this observable in the angle range covered by the CSB experiment.

In the past year, as part of the early production running for the CSB experiment, we obtained sufficient statistical precision on  $C_{NN}(\theta)$  measurements to constrain significantly our understanding of the n-p interaction. Since the measurement and analysis procedures are the same as for the CSB experiment itself, we refer the reader to CSB contributions in this and earlier reports<sup>1,2</sup> for a detailed discussion of most of the experimental techniques.

The measurement of  $\Delta A$  is designed to be insensitive to absolute beam and target polarization magnitudes. For measurements of  $C_{NN}$  and  $A$ , however, we

would like to have good independent, absolute calibrations of the polarizations. Since the expected CSB effects are quite small ( $|\Delta A| \sim 0.001$ ) and our  $\vec{n}-\vec{p}$  measurements span an angular range where  $|A|$  reaches 0.4, if one (beam or target) polarization can be accurately and absolutely determined, the other can be inferred to high precision from the CSB data assuming charge symmetry holds. We hope in the future to be able to tie down the target polarization to the 1% level through accurate measurements of the analyzing power for  $p-p$  scattering.<sup>3</sup> In the meantime, however, we have chosen to normalize the data presented here directly to  $n-p$  analyzing powers calculated from phase shifts. The neutron polarization is determined by comparing asymmetries measured while flipping the neutron beam spin,  $a_n(\theta)$ , to the phase shift prediction of  $A(\theta)$  as a function of angle (see Fig. 1(b)). Then a comparison of the  $a_p(\theta)$  distribution (the asymmetry measured by flipping the proton target spin) with  $a_n(\theta)$  fixes the proton-to-neutron polarization ratio. With this normalization technique we can still extract significant information concerning the angular dependence of  $C_{NN}(\theta)$  and the consistency of the absolute magnitudes of  $A$  and  $C_{NN}$  given by the phase shift solutions. For the data to be presented here the average neutron polarization was determined to be  $0.44 \pm 0.01$  and the average proton polarization  $0.37 \pm 0.02$ , with the errors representing statistical uncertainties only. These values are consistent with less precise determinations from knowledge of the primary proton beam polarization and the production reaction spin transfer coefficients, and from NMR measurements of the target polarization. Both of these polarizations should be considerably improved in future CSB runs.

The  $A_n$  and  $C_{NN}$  data, which were measured over a continuous angle range, are shown in Fig. 1 collected into  $4.8^\circ$  lab angle bins. The curves are generated with the program and data compilation SAID,<sup>4</sup> and have been averaged over the same angular bin size as the data. The error bars plotted with the data points are purely statistical, with typical values of  $\pm 0.01$  for  $A_n$  and  $\pm 0.03$  for  $C_{NN}$ . The phase shift solution chosen for the normalization is Arndt's SM86 global solution (solid line). When the normalization procedure described above is followed to determine the target and beam polarizations, the statistical uncertainties in the  $a_n$  and  $a_p$  asymmetries propagate to

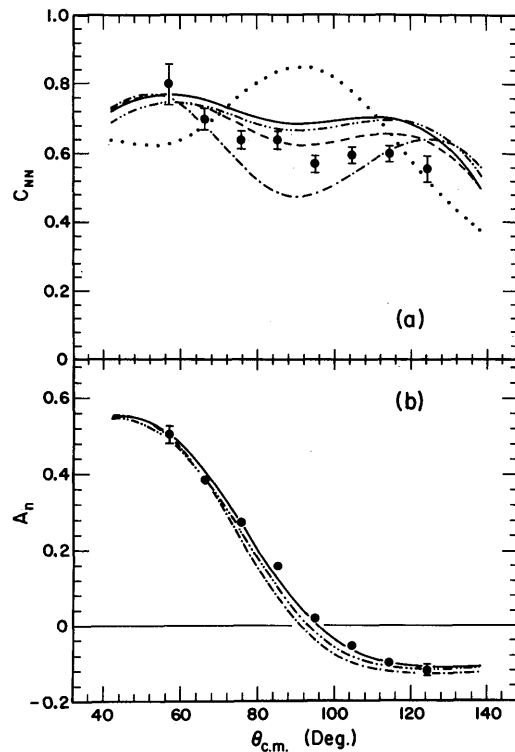


Figure 1. (a) The  $n-p$  elastic scattering spin correlation parameter  $C_{NN}$  at 188 MeV. The curves correspond to Arndt's global phase shift solution SM86 (solid), Arndt's single energy solution C200 (dash), the Saclay 260 solution (dots), the Bonn potential (dash-double-dot) and the Paris potential (dash-dot). (b) The  $n-p$  elastic scattering analyzing power at 188 MeV. The data have been normalized to the phase shift solution SM86. The key to the curves is the same as in (a).

yield an overall normalization uncertainty of +/-7% for the  $C_{NN}$  data.

The most striking observation in comparing the data to the curves is that the Paris potential and the Saclay phase shifts do not predict the correct shape for  $C_{NN}(\theta)$ . Although the SM86 prediction for  $C_{NN}$  is closer to the right shape, it would require a 13% renormalization to reproduce the measurements. The same is true for the Bonn potential prediction. The latter two curves are also not quite as asymmetric about  $90^\circ$  as the data. Arndt's C200 single-energy solution produces approximately the correct asymmetry and in fact would give a quite good fit to the data with a 6% renormalization, within the  $C_{NN}$  uncertainty mentioned above.

$C_{NN}$  over this angle range is sensitive to the  $^3S_1$ ,  $^3D_1$  and  $^3D_2$  phase shifts and hence these new data should further constrain these parameters. The disagreement between the Paris potential prediction and the data near  $90^\circ$  seems to be associated mainly with the  $^3D_2$  phase shift. For the Paris potential this phase shift differs by about 15% from that of the C200

solution. This failure of the Paris potential to reproduce a spin observable in n-p scattering is an important observation considering the increasing use of this potential in Faddeev calculations and to generate effective N-nucleus interactions. It may, in particular, be relevant to systematic problems noted for spin-dependent isoscalar parts of effective interactions.<sup>5</sup> It is also worth noting that these data correspond to only a small fraction of the total number of events eventually to be acquired for CSB. When the experiment is finished the statistical errors on  $C_{NN}$  and  $A_n$ , for the same angular bin width, should be less than a tenth the present size.

- 1) See contributions to this report on p. 1 and p. 162.
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