Measurement of the Absolute Differential Cross Section for np Elastic Scattering Near 200 MeV

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In one of the final experiments carried out on the IUCF Cooler (CE71), we utilized a tagged neutron beam to make high-precision absolute cross section measurements for intermediate-energy np elastic scattering. The aim was to resolve back-scattering discrepancies in the database that bear on the extraction of a charged pion-nucleon coupling constant [1] and that have led to rejection of the majority of data in partial wave analyses [2]. The tagging not only allowed accurate determination of the incident neutron flux, but also offered a host of other, less obvious, advantages important to a precise experiment: (1) accurate relative normalization of data taken with the CH_2 production target and with a carefully matched C target used for quasifree background subtraction; (2) event-by-event determination of neutron energy, impact point and incidence angle on the secondary target, with the latter measurement being especially important for cross section measurements very near 180° c.m. scattering angle; (3) three-dimensional location of background sources displaced from the secondary target; (4) precise measurement of the detector acceptance for np scattering events; (5) methods to tag np scattering event subsamples that should yield identical cross section results but different sensitivity to various sources of systematic error.

The results of the measurement, shown in Fig. 1, were published in Letter form early in 2005 [3]. The absolute normalization uncertainty was held under ±1.5% and the angle-dependent systematic uncertainties are typically less than half the size of the statistical error bar in each angle bin. The comparison in Fig. 1 with PWA calculations from the Nijmegen group (which have not been adjusted with the present results included in the database), and with earlier experimental results from Uppsala [4], reveal a systematic problem affecting the angular shape of the latter data. The present results agree much better with the PWA calculations than do the Uppsala data, but still show ~2% systematic deviations explored in more detail in Fig. 2. These deviations are well outside our estimated experimental systematic errors, but appear no larger than present PWA uncertainties, judged by comparison of different solutions in Fig. 2.

Continuing data analysis during 2005 has concentrated on two issues: (1) trying to understand possible sources of the discrepancy near 180° between the present results (and the PWA) vs. those from Uppsala [4] and an independent measurement made by a Freiburg group at PSI [5]; and (2) investigating a possible additional source of systematic normalization uncertainty in the present experiment, associated with conceivable hydrogen buildup on the C target used for quasifree background subtraction. In addressing the first issue, it occurred to us that cross section measurements with a secondary neutron beam of sizable angular divergence could be susceptible to systematic overestimation of yields in small solid-angle bins centered near 0° laboratory proton angles, due to significant contributions from incident neutrons deviating appreciably from the mean neutron direction. We therefore reanalyzed the CE71 data purposely ignoring the neutron incidence angle information provided event-by-event from the tagging. The results shown in Fig. 3 confirm that the absence of such incidence angle information in more conventional experiments is a concern in comparing cross sections at the largest c.m. angles.

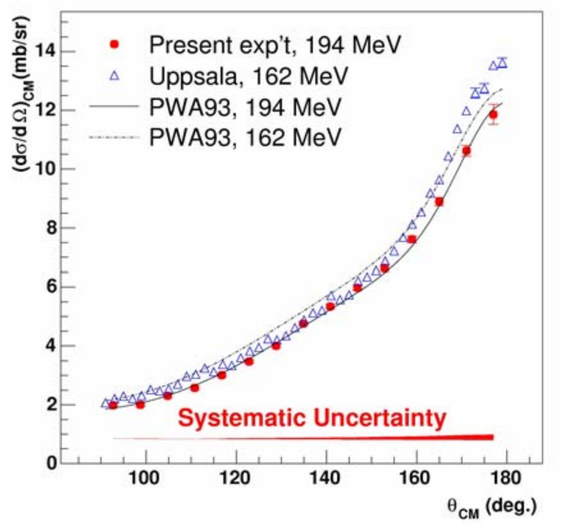

Figure 1. *Absolute differential cross section from the present experiment, compared with data from Ref. [4] and with PWA calculations at two relevant energies [6]. Error bars on the present results are statistical (including background subtraction), while the shaded band represents all systematic uncertainties, including on the overall normalization.*

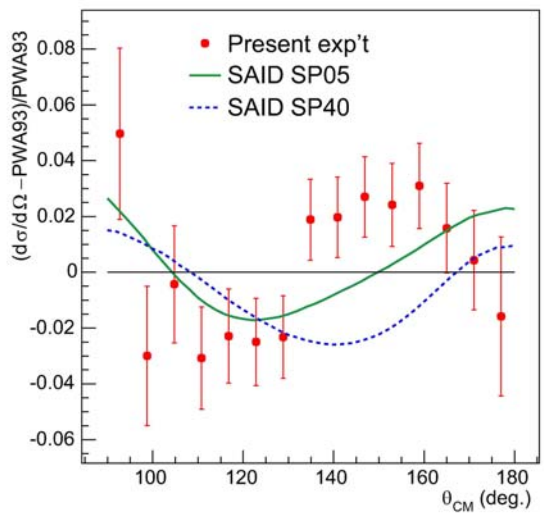

Figure 2. *The relative differences of the present absolute np scattering differential cross sections and of two SAID PWA solutions [7] from the Nijmegen PWA93 solution [2,6], all at E_n = 194 MeV. The SP40 solution is from a 2003 analysis of the database from 0-400 MeV, while SP05 is the current SAID solution, fitted over the range 0 – 3.0 GeV, including the present data in the fit.*

In order to search for any evidence of hydrogen buildup on the carbon target used for subtractions, we had to search for events with a clean signature of free vs. quasifree scattering. These were not available in the sample used for data analysis to date, since that sample involved detection of only the forward-going proton from the np scattering. However, the trigger logic used for the experiment also permitted simultaneous collection of events in which a forward-going neutron converting in the thick hodoscope mounted at the rear of the detector array would fire in coincidence with a large-angle proton that traversed the ΔE scintillator following the CH_2 or C target and only the first two of three multi-wire proportional chambers in the forward array. Such events correspond to c.m. scattering angles near or below 90°, but they allow clear observation of the free-scattering opening-angle peak between outgoing neutron and proton. As seen in Fig. 4, this previously unanalyzed event sample reveals no evidence of a free-scattering peak from the C target, permitting us to place an upper limit on the amount of hydrogen in that target.

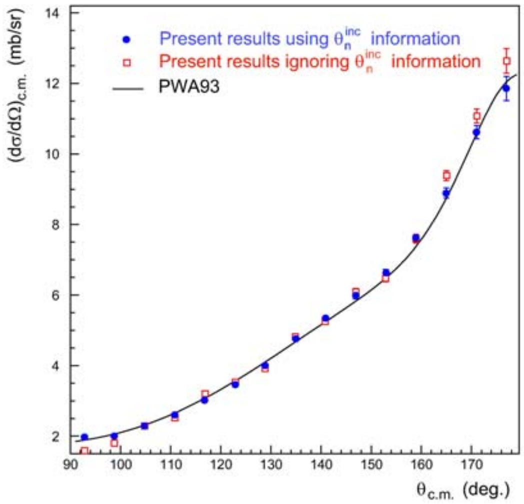

Figure 3. *The effect on the present analysis of neglecting the tagger information about the neutron incidence angle in the reconstruction of the np scattering angle for each event. The closed circles represent the final results, while the open squares are those when the scattering angle is estimated only with respect to the central neutron beam direction. The neglect of neutron incidence angle information gives rise to a systematic error near 180° quite comparable to that uncovered in the results of non-tagger experiments from Refs. [4] and [5].*

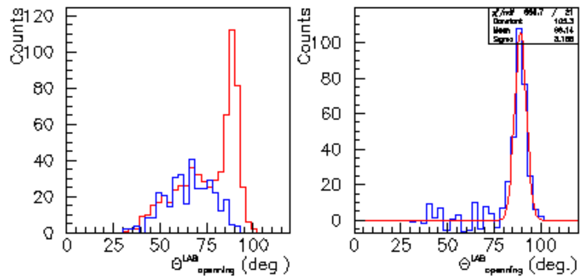

Figure 4. *np scattering opening angle spectra reconstructed for events where the detected proton fires only two of the three wire chambers and a forward neutron appears to fire the rear scintillator hodoscope. For such coincidence events, a clear free-scattering peak is seen with the CH_2 production target (red histogram in left frame), while no hint of such a peak is seen for the C target (blue histogram). The subtracted spectrum is shown on the right, with a fitted Gaussian peak. This analysis allows us to place an upper limit on the amount of hydrogen contamination of the graphite background target.*

A long paper reporting the detailed results from this experiment, with emphasis on the analysis of various systematic error sources, will be submitted for publication in early 2006, completing CE71.

References

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