

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

M. Sarsour<sup>a</sup>, T. Peterson<sup>a</sup>, M. Planinic<sup>a</sup>, S.E. Vigdor<sup>a</sup>, C. Allgower<sup>a</sup>, B. Bergenwall<sup>b</sup>, J. Blomgren<sup>b</sup>, T. Hossbach<sup>a</sup>, W.W. Jacobs<sup>a</sup>, C. Johansson<sup>b</sup>, J. Klug<sup>b</sup>, A.V. Klyachko<sup>a</sup>, P. Nadel-Turonski<sup>b</sup>, L. Nilsson<sup>b</sup>, N. Olsson<sup>b</sup>, S. Pomp<sup>b</sup>, J. Rapaport<sup>c</sup>, T. Rinckel<sup>a</sup>, E.J. Stephenson<sup>a</sup>, U. Tippawan<sup>b</sup>, S.W. Wissink<sup>a</sup> and Y. Zhou<sup>a</sup>

<sup>a</sup> Indiana University Cyclotron Facility, Indiana University, Bloomington, IN, USA

<sup>b</sup> Uppsala University, Uppsala, Sweden

<sup>c</sup> Ohio University, Athens, OH, USA

We report preliminary results of a double-scattering experiment applying the technique of neutron tagging to measure the absolute differential cross section for np scattering in an energy and angle region where earlier experiments have shown serious discrepancies among themselves and with energy-dependent partial wave analyses.

The np scattering database at intermediate energies is marred by significant shape inconsistencies and absolute normalization errors in differential cross section measurements [1,2]. These problems have led to controversy [2,3] over the selection criteria for data in partial wave analyses [4] and over extracted values of the charged  $\pi$ NN coupling constant. We report preliminary results of an np scattering experiment designed to give better control over systematic errors, and thus to resolve discrepancies in the database. The tagged neutron technique we apply differs extensively from previous methods, and can provide absolute cross section precision approaching  $\pm 1\%$ .

The experimental setup is illustrated in Fig. 1. The neutron production reaction  $p+d \rightarrow n+2p$  is induced by a 203 MeV electron-cooled, stored proton beam on a  $D_2$  gas jet target (GJT) in the IUCF Cooler [5]. Energy, time, and two-dimensional position measurements for both recoil protons in the tagger determine the 4-momentum of each produced neutron on an event-by-event basis. The tagger comprised an array of four  $6.4 \times 6.4$  cm<sup>2</sup> silicon double-sided strip detectors (DSSD) with 480  $\mu$ m readout pitch, each followed by a silicon pad (backing) detector of the same area. Fast front-end electronics for the DSSD's permitted a tagger-based event trigger on neutron candidates, regardless of whether they interacted in the forward target and/or detectors. The forward setup included a solid secondary scattering target of  $CH_2$  or C, a forward array of plastic scintillators for triggering and energy information, and a set of  $(x, y, u)$  multi-wire proportional chambers (MWPCs) to track forward protons from np scattering events.

Tagged neutron events were recorded in three mutually exclusive event streams, triggered by a two-particle hit pattern in the tagger in anti-coincidence with scintillators (LUV, SUV) used to veto charged particles produced upstream of the secondary target,

and coupled with (a) no forward coincidence (for neutron flux monitoring); (b) both  $\Delta E$  scintillator and rear hodoscope in coincidence (for np scattering candidates); or (c) rear hodoscope but not  $\Delta E$  in coincidence (for evaluating the neutron detection efficiency of the hodoscope). Neutron beam properties were defined by identical cuts for all three event streams, so that associated systematic uncertainties would cancel in the ratios from which the absolute np scattering cross section was extracted. Among the common cuts was one on particle identification in the tagger, requiring either that both recoil particles stop in the DSSD's ("2-stop" events) or that one of the two be consistent with a proton stopping in its backing detector ("1-punch" events). Other common cuts defined the area on the secondary target within which acceptable tagged neutrons had to impinge.

The analysis used additional cuts to define np free-scattering very sparingly, relying instead on accurate background subtraction via frequent switching between the precisely matched  $\text{CH}_2$  and C targets. This removed not only p-C quasifree scattering events, but also background from other sources, such as scattering from the aluminum support frame for the secondary target, or protons produced in the GJT that passed above the top of the LUV and SUV scintillators. The success of the subtraction is illustrated in Fig. 2, which shows the vertical position ( $y_{tag}$ ) of neutrons on the secondary target, as reconstructed from the tagger information. Background-subtracted spectra were used to evaluate efficiencies for the few non-common cuts imposed to select free-scattering events, including ones on  $\Delta E$  vs.  $\theta_p^{scat}$  and on the MWPC proton track quality. Cuts on  $E_{hodoscope}$ , and associated sensitivity to the reaction tail in this thick scintillator, were avoided.

Currently, the analysis of the absolute differential cross sections is done for the "2-stop" events to  $\sim \pm 5\%$  systematic uncertainty, while the total flux of "1-punch" events is still being evaluated. The two event classes give completely consistent angular distribution shapes - an important crosscheck on the reliability of the experiment and analysis, because these events come from complementary regions of the tagged beam profile and energy distribution - but for now the 1-punch absolute cross section has simply been normalized to that for 2-stop events. The present results, averaged over the 2-stop and normalized 1-punch samples, are shown in Fig. 3 as filled circles and compared with the J. Rahm et al. [2] results at 162 MeV and the Nijmegen partial wave analysis (PWA93) at neutron energy  $TLAB = 194$  MeV [6]. Our results are so far reasonably consistent with PWA93, within systematic uncertainties of  $\sim \pm 5\%$ . Both the statistical and systematic errors should improve significantly as the analysis is completed.

## REFERENCES

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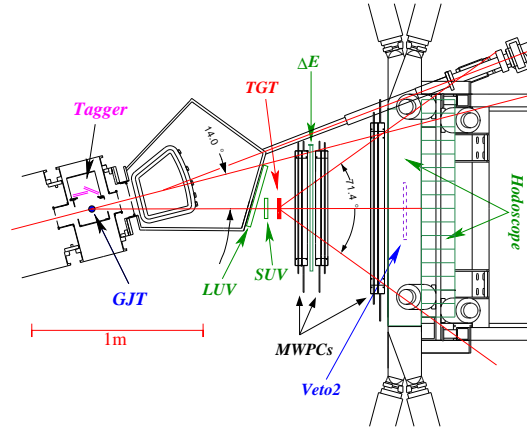


Figure 1. A top view of the experimental setup for the np scattering experiment.

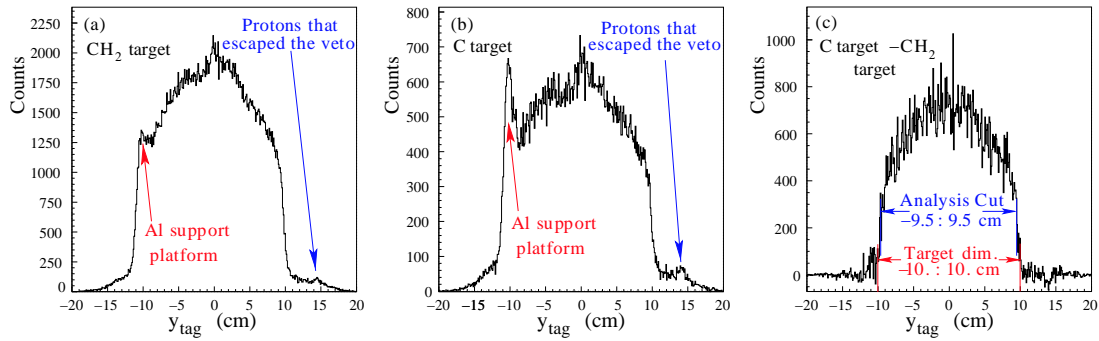


Figure 2.  $y_{tag}$  distributions for (a)  $\text{CH}_2$ , (b) C, and (c) the difference between them.

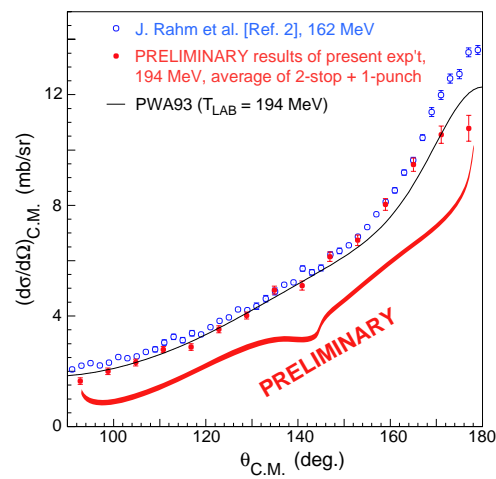


Figure 3. Preliminary cross section results (statistical errors only) from the present experiment.