

Measurement of the Polarization Parameter in np Charge-Exchange Scattering from 2 to 12 GeV/c*

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We have measured the polarization parameter in neutron-proton charge-exchange scattering for incident neutron momenta of 2–12 GeV/c and $0.01 \leq |t| \leq 1.0$ (GeV/c)². Results based on 300 000 events show a negative polarization whose magnitude increases monotonically with $|t|$ approaching 60% for $|t| \sim 0.6$ and which has little energy dependence.

In order to study the spin dependence of nucleon-nucleon scattering over a wide range of incident momenta and momentum transfers, we have measured the polarization parameter in neutron-proton charge exchange for $2 \leq p_{\text{lab}} \leq 12$ GeV/c and $0.01 \leq |t| \leq 1.0$ (GeV/c)².

The experimental layout is shown in Fig. 1 and is similar to that used in recent np charge-ex-

change cross-section measurements at Argonne.¹ The neutrons were produced at an angle of $\frac{3}{4}^\circ$ from an internal Be target in the zero-gradient synchrotron and collimated to a 2.5×3.0 -cm² spot on a vertically polarized ethylene-glycol target.² The typical beam intensity was 10^6 neutrons per machine pulse with a slow spill of 500 msec. The broad spectrum of the neutron beam

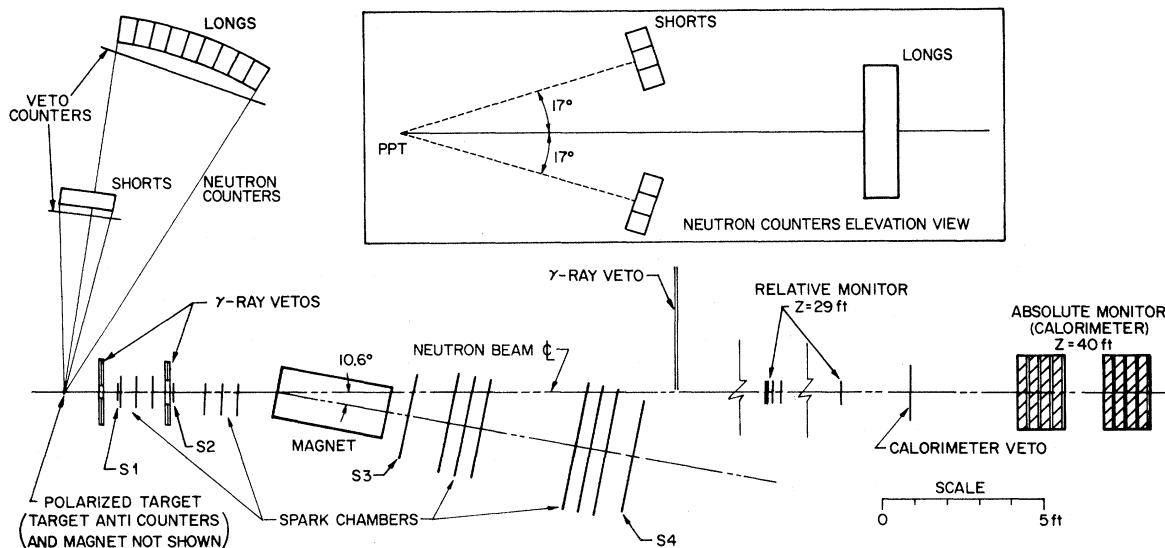


FIG. 1. Plan view of the experimental apparatus with inset showing neutron-counter elevation view.

allowed us to collect data simultaneously at all momenta between 2 and 12 GeV/c with an approximately constant event yield per momentum interval. Two independent monitors of beam intensity (one absolute and one relative) downstream of the target provided normalization for the experimental data.

The event trigger demanded that one and only one charged particle from the target pass through the magnetic spectrometer and that at least one neutron counter fire within a specified time gate. A fourfold coincidence of the scintillation counters S_1, S_2, S_3, S_4 signaled the presence of a proton whose momentum and direction were determined by the wire chamber and magnet spectrometer system. Target anticounters and pulse height cuts on S_1 and S_2 reduced the triggers from wide-angle charged particles and higher-multiplicity events. The slow recoil neutron was detected in one of two banks of thick scintillation counters, each covering different regions of $|t|$ but with sufficient overlap to check consistency. The identity of the counter that fired and end-to-end timing between photomultiplier tubes on each end of that counter determined the neutron's direction; time of flight relative to the first counter in the proton arm determined its energy. The neutron counters were protected from room background by a concrete bunker and from charged particles originating near the target by thin veto counters.

When the trigger requirements in both arms were satisfied, the spark chambers were pulsed and data were transferred to an on-line DDP-24 computer. Between beam spills the computer analyzed 50% of the events and wrote records of the raw and analyzed data onto magnetic tape. The trigger rate was typically 20 per pulse and about 1 of 35 triggers was a usable charge-exchange event from a free proton. 10^7 triggers were recorded from a polarized target with an average polarization of 40%.³

To separate out the elastic events, the on-line analysis program tested whether events satisfied constraints on opening angle and horizontal and vertical momentum balance. The last constraint proved particularly sensitive and, when a histogram was made, revealed a clean elastic peak above a flat background (Fig. 2).

Estimates of the quasielastic background in our data were obtained by subjecting the events to a full kinematic fit with three degrees of freedom and comparing the resulting χ^2 distribution with that obtained from a sample of 2×10^6 events

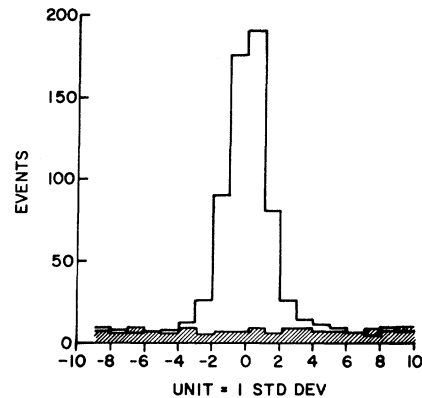


FIG. 2. Vertical-momentum balance constraint showing the elastic peak for a typical set of data. Graphite dummy target data are shaded.

where the ethylene glycol in the target was replaced by graphite. After normalization, the χ^2 distribution of events from the graphite runs was virtually the same as that of the glycol for $10 \leq \chi^2 \leq 100$. Within the elastic peak ($\chi^2 \leq 10$) the graphite data gave typical backgrounds of $\sim 25\%$ for the short and $\sim 5\%$ for the long neutron counters. Only events with $\chi^2 \leq 10$ were used in the polarization determination.

The data were subjected to the following consistency checks. It was found that within statistics the polarization was independent of the χ^2 cut (for $\chi^2 \leq 10$), independent of the participating neutron counters in their region of overlapping $|t|$, independent of event origin in the glycol target, and independent of calendar time in the six months during which the data were accumulated. The polarization for a sample of background events ($15 \leq \chi^2 \leq 100$) was $(-1.5 \pm 1.5)\%$ overall and did not depend on $|t|$. The experimental $|t|$ resolution was always much smaller than the bin size used to plot the polarization.

The results of the experiment based on 300 000 elastic events are shown in Fig. 3 where the polarization parameter⁴ is plotted as a function of $|t|$ for several values of incident beam momentum. The vertical error bars include counting statistics and background subtraction, but do not include the error in absolute calibration of the target polarization.^{3, 5, 6}

The main features of the data are as follows: The magnitude of the polarization increases monotonically with $|t|$ to large momentum transfers; for fixed momentum transfer there is little energy dependence exhibited; in the region where the data overlap those of the previous ex-

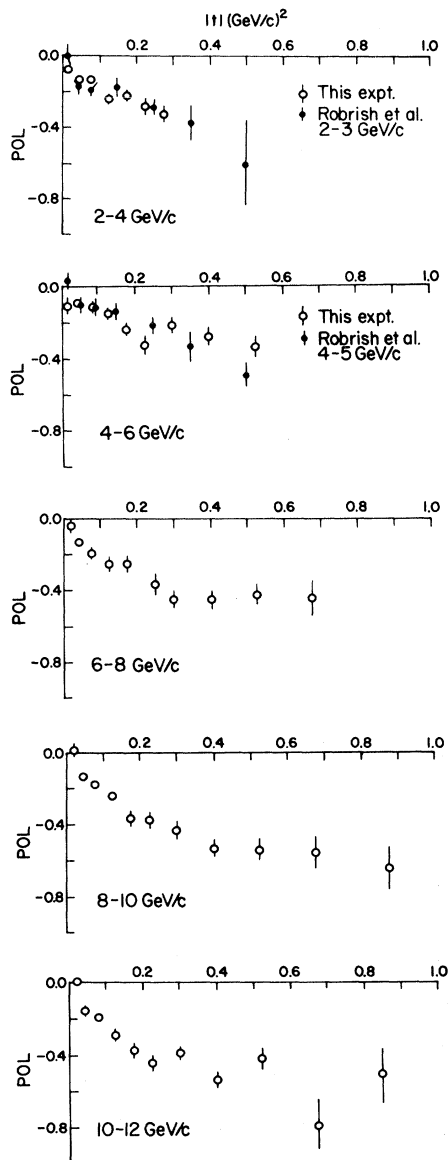


FIG. 3. Polarization parameter for five laboratory-momentum bins. Data of Ref. 7 shown for comparison.

periment⁷ the results are in agreement.

Within the framework of exchange models the sharply forward-peaked cross section for np charge exchange indicates the predominance of the pion.^{1,8,9} However, to generate the large polarization magnitude seen in this experiment, considerable contributions from other exchanges (such as ρ and A_2) must be present. Current strong- and weak-cut absorption models which incorporate these exchanges are unable to fit both the cross section and polarization data with-

out using special absorption functions or additional vertex form factors.^{10,11}

All present np charge-exchange data show a cross-section shape and a polarization which are independent of energy.^{1,7-9} It is interesting to speculate whether this situation will persist at arbitrarily high energies.

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²Argonne polarized-target facility PPT-II.

³Relative to absolute calibration by a double-scattering experiment, the NMR system determined the target polarization to be $(40 \pm 3)\%$ [see G. Bureson, D. Hill, S. Kato, P. F. M. Koehler, T. B. Novey, A. Yokosawa, D. Eartly, K. Pretzl, B. Barnett, A. Laasenen, and P. Steinberg, Phys. Rev. Lett. **26**, 338 (1971); D. Hill, P. F. M. Koehler, T. B. Novey, B. Sandler, H. Spinka, A. Yokosawa, D. Eartly, K. Pretzl, G. Bureson, and H. Davis, Phys. Rev. Lett. **27**, 1241 (1971)].

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⁵Bureson *et al.*, Ref. 3.

⁶Hill *et al.*, Ref. 3.

⁷Robrish *et al.*, Ref. 4.

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¹¹E. Gotsman and U. Maor, Nucl. Phys. **46B**, 525 (1972).