the peak and require that the ratio of the time-of-flight weights for the chosen combination to that for the combination in which the K and π have been interchanged be greater than 3.[6] Out of 38 $D^0\pi^+$ events 26 survive and out of 11 $D^0\pi^-$ events 3 survive. These latter 3 events are consistent with coming from backgrounds. We expect 1.4 events from uncorrelated combinations of particles and 0.6 events from $K\pi$ double misidentification. Thus, at the 90% confidence level, the fraction of the time that a D^0 decays as if it were a $\bar{D}^0$ (e.g., to $K^+\pi^-$ instead of $K^-\pi^+$) is less than 16%.[7]

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Large-Angle Neutron-Proton Elastic Scattering from 5 to 12 GeV/c*

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Neutron-proton differential cross sections have been measured with good statistics for four-momentum transfers $0.14 < -t \lesssim 19.0$ (GeV/c)^2 at laboratory momenta ranging from 4.5 to 12.5 GeV/c. The experiment was carried out in a neutron beam at the Argonne National Laboratory zero-gradient synchrotron. These results in conjunction with previous n-p charge-exchange data provide almost complete elastic-scattering angular distributions in this momentum range.

We report measurements of neutron-proton elastic scattering which extend from small angles out to about 145° in the c.m. system. At the highest energies this corresponds to $0.14 < -t \lesssim 19$ (GeV/c)^2. The only previous n-p measurements above 1 GeV/c which extend to large angles were made by our group at the Lawrence Berkeley Laboratory Bevatron[1] some years ago. We have now extended these measurements to higher momenta and larger angles with greatly improved statistics. Our data in conjunction with the n-p charge-exchange data of Miller *et al.*[2] provide nearly complete elastic-scattering angular distributions in this momentum range.

A schematic diagram of the experimental layout is shown in Fig. 1. A neutron beam with a continuous spectrum of momenta up to 12.5 GeV/c was produced by steering the internal proton beam of the Argonne National Laboratory zero-gradient synchrotron onto a beryllium target. Collimators were used to define the beam and two sweeping magnets removed charged particles. Lead filters reduced the γ-ray contamination to a negligible value. The K^0's and $\bar{n}$'s in the beam were also negligible. An intensity of 2.3×10^{12} circulating protons yielded $\sim 3\times 10^6$ neutrons over a spill length of 550 msec.

The neutron beam was incident on a liquid-hy-

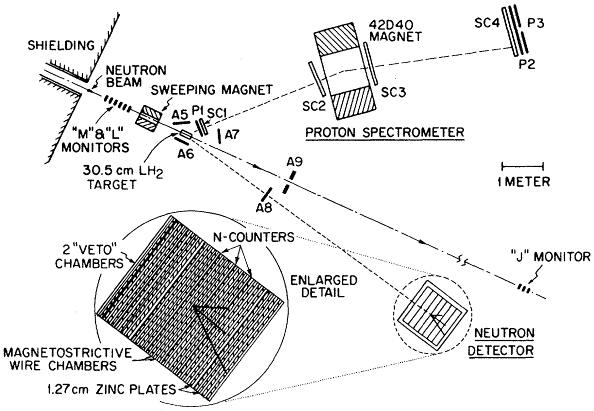

FIG. 1. Layout of the experimental apparatus.

drogen target 30.5 cm long and 5.1 cm in diameter. The recoil proton was momentum-analyzed and its scattering angles were measured by a spectrometer consisting of four magnetostrictive chambers each with x-y-u-v readout planes and a 42D40 analyzing magnet with a 6-in. gap. A fast coincidence between scintillation counters $P1$, $P2$, and $P3$ was part of the event trigger which required that a charged particle pass through the spectrometer. The scattered-neutron trajectory was determined by requiring that the neutron interact in a detector consisting of thirty wire spark chambers, twenty-eight zinc plates, and six scintillation counters. The interaction point was found with a spatial resolution of 1.5 mm full width at half-maximum.[3] The scattering angle of the neutron was then found by connecting the interaction point in the neutron detector to a point in the liquid-hydrogen target on the proton trajectory. Numerous veto counters, $A1$–$A9$, were used to reduce the trigger rate from inelastic interactions. The trigger requirement was a fast coincidence between counters $P1$, $P2$, and $P3$ in the proton arm and two or more of the neutron counters with no vetoes.

All kinematic variables were measured except the momenta of the incident and scattered neutrons. Thus momentum and energy conservation allowed a two-constraint fit to n-p elastic scattering. The fitting program calculated χ^2 for the fit and the unmeasured momenta. Events with a good χ^2 were considered to be elastic and were binned according to the incident momentum and square of the four-momentum transfer.

Six overlapping settings of the proton spectrometer and the neutron detector were used to collect data over the entire kinematic range. The scattered neutrons ranged in momenta from about 1.0 to 12.0 GeV/c. Thus it was necessary to measure the momentum dependence of the neutron-detection efficiency. This was done by taking data in the small-angle region with the neutron-counter requirement removed from the event trigger. It was then possible to select a sample of elastic events from the proton information alone. From these a sample of events in which the scattered neutron should pass through the neutron detector was chosen. The ratio of the neutron conversions observed in the detector to those expected in the detection efficiency. The measured efficiency was constant at 65% for momenta greater than 6.0 GeV/c and dropped to 40% at 2.0 GeV/c and to zero at 0.8 GeV/c.[3]

Three sets of counter telescopes (M, J, and L in Fig. 1) monitored the incident neutron beam flux and were used to provide a relative normalization of data taken at different settings of the apparatus. The absolute normalization was done by fitting the data for $|t| < 0.8$ (GeV/c)^2 with a quadratic exponential in $|t|$, extrapolating to $|t| = 0$, and adjusting the intercept to the optical-theorem point given by

$$(d\sigma/dt)_{t=0} = (16\pi)^{-1}\sigma_T^{\,2}(1+\rho^2).$$

The values of σ_T used were calculated from a fit of n-p total-cross-section data given by Murthy *et al.*[4] The ratio of the real to imaginary part of the forward-scattering amplitude, ρ, was assumed to vary linearly with momentum, with ρ equal to -0.5 at 4.0 GeV/c and -0.4 at 12 GeV/c.[5] The uncertainty in this normalization is estimated to be ± 10%.

Various corrections have been applied to the data. The geometric acceptance of the detectors was calculated using Monte Carlo methods. Inelastic background corrections, as estimated from the χ^2 distributions, amounted to less than 20% in the large-angle and backward regions, and less than 10% in the forward region. Corrections for nuclear absorption of the recoil proton ranged from 2 to 4%. Target-empty corrections were negligible. Corrections for the energy dependence of the detection efficiency of the scattered neutron were also applied.

The differential cross sections are presented in Fig. 2 for eight incident-momentum bins in intervals of 1 GeV/c. The quoted errors include statistical uncertainties and uncertainties due to each of the corrections. The incident momentum attached to each graph is that of the center of the bin.

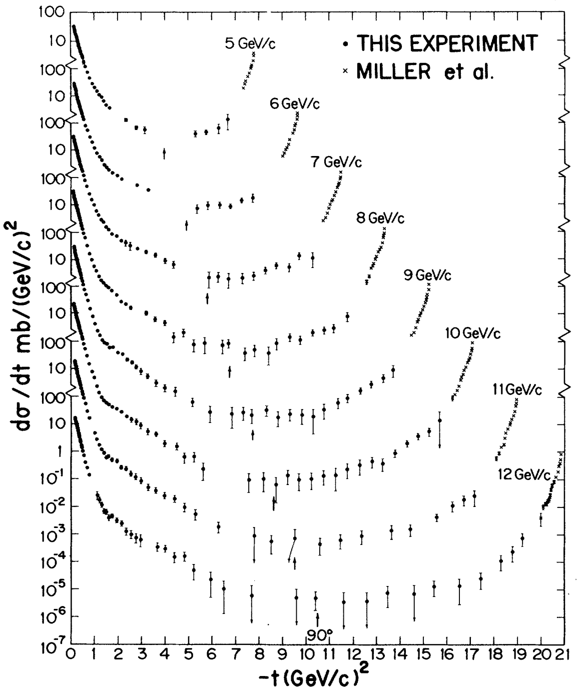

FIG. 2. Neutron-proton differential cross sections. The † indicates the position of 90° in the c.m. systems.

The data show a nearly exponential diffraction peak with the onset of a shoulder at $-t \sim 1.5$ (GeV/c)^2 for momenta above 7 GeV/c. This structure becomes more pronounced as the energy increases and eventually becomes the dip observed in p-p data above 100 GeV/c. We see evidence for additional structure at lower $|t|$ with a steepening of the logarithmic slope for $|t| \lesssim 0.18$ (GeV/c)^2. At large $|t|$ the cross sections flatten and reach a minimum near 90° in the c.m. system where the differential cross section is 4.28 μb/(GeV/c)^2 at 5 GeV/c and 4.3 nb/(GeV/c)^2 at 12 GeV/c. In the backward direction the cross sections rise monotonically and join smoothly with the charge-exchange data of Miller *et al.*[2] Our results are compared with available p-p data and with theory in the following Letter.[6]

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Comparison of Neutron-Proton Elastic-Scattering Data with Theory*

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We examine some features of neutron-proton elastic-scattering data over the laboratory momentum range 4.5 to 12.5 GeV/c. Comparisons with proton-proton elastic scattering data and with theory are made in both the small- and the large-angle–scattering regions.

In the preceding Letter[1] we have reported new data on neutron-proton elastic scattering covering an angular range extending to about 145° in the c.m. system over a laboratory momentum range of 4.5 to 12.5 GeV/c. We discuss here some special features of that data at both small and large scattering angles and make comparisons with proton-proton data and with theory.

Recently there has been a great deal of interest in large-transverse-momentum processes.[2] It is believed that at large momentum transfers the pointlike or constituent structure of hadrons becomes important and the main contribution to the differential cross section is due to the basic quark interaction. The additive quark model, for example, assumes that large-$|t|$ collisions between two hadrons result from the collisions between two constituent quarks whose interaction is indepen-