NEUTRON-DEUTERON ELASTIC SCATTERING FROM 6 TO 12.5 GeV/c ☆

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The differential cross section for neutron-deuteron elastic scattering was measured for four-momentum transfers $0.3 < -t < 2.0$ $(\mathrm{GeV}/c)^2$ with incident neutron momenta between 6 and 12.5 GeV/c. The measurement was made with spark chambers at the Argonne ZGS. Results are compared with proton-deuteron elastic scattering at compara-able energies as a test of isospin invariance in strong interactions and with the predictions of the Glauber multiple scattering theory. Very good agreement is found.

Experimental tests of charge symmetry and charge independence in hadron reactions have been confined to low energies and small momentum transfers [1]. Nucleon-deuteron reactions are especially suitable for such tests since they can proceed only through the isospin states $|I, I_3\rangle = |\frac{1}{2}, \frac{1}{2}\rangle$ for proton-deuteron, and $|I, I_3\rangle = |\frac{1}{2}, -\frac{1}{2}\rangle$ for neutron-deuteron elastic scattering. Disagreement between the neutron-deuteron and proton-deuteron differential cross sections would indicate a violation of charge independence in strong interactions while equality of the cross section would serve as a basic check of the assumed charge symmetry of nuclear forces. We present results of a study of neutron-deuteron elastic scattering for an extended range of momentum transfers with incident neutron momenta between 6 and 12.5 GeV/c. Our measurements are relative and not absolute. Previous tests have verified charge symmetry at small momentum transfers. Thus our n-d differential cross sections have been normalized at small momentum transfers to p-d data at comparable energies. The experiment thus tests charge symmetry by comparing the *t-dependence* of n-d and p-d differential cross sections out to large momentum transfers. Proton-deuteron differential cross sections have previously been measured for similar ranges of momentum transfer at 6.37 GeV/c, 9.7 GeV/c, and 12.8 GeV/c [2, 3].

A schematic view of the experimental arrangement is shown in fig. 1. The ZGS proton beam was incident on an internal beryllium target. A neutron beam was taken off at an angle of about 0.5° with respect to the circulating proton beam. Charged particles were removed from the beam by means of two sweeping magnets. Lead filters placed ahead of the sweeping magnets removed γ's from the beam. Contamination due to K^o's and $\bar{n}$'s in the beam was negligible. The flux in the beam varied from 2×10^5 to 10^6 neutrons per burst with a typical burst length of 550 ms.

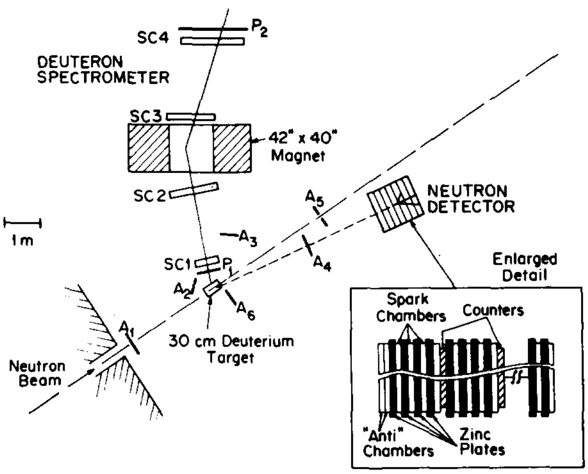

Fig. 1. Experimental arrangement

The neutron beam was incident on a 30 cm long deuterium target. The scattered neutron was detected by its interaction in an array of zinc plates and wire spark chambers. The array consisted of 28 zinc plates, each 1.2 cm thick, interspersed with 30 spark chambers with magnetostrictive readout. Six scintillation counters in the array were used in the trigger. A veto counter preceeding the array insured that a neutral particle interacted in the array. The neutron angles were determined with an accuracy of about ±2.5 mr

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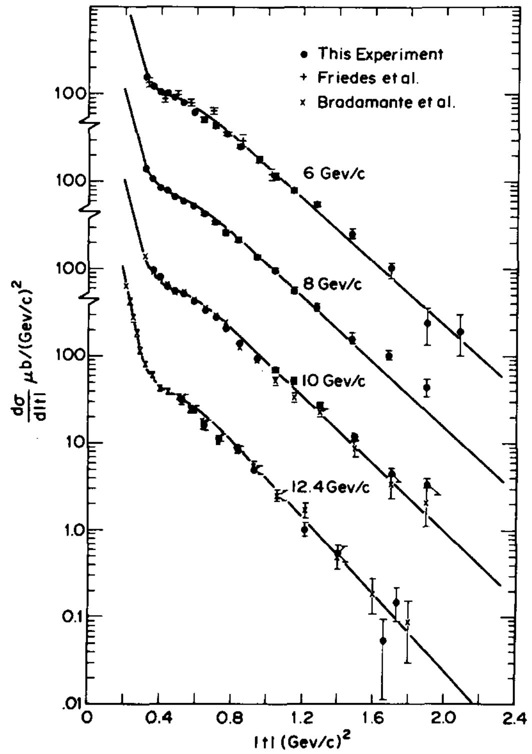

Fig. 2. Cross sections for nucleon-deuteron elastic scattering. The curves are Glauber theory calculations. The data of Bradamante et al. at 12.8 GeV/c, which had a normalization error of ± 50%, have been scaled by a factor of 0.65.

by connecting the vertex of the neutron-induced shower in the chambers with the deuteron track extrapolated into the deuterium target.

The momentum and angle of the recoil deuteron were measured in a wire-spark-chamber spectrometer.

The triggering requirement was a fast coincidence between counters P1, P2 and any two counters in the neutron array with no vetoing pulse from the veto counters. The trigger did not discriminate between deuterons and protons produced in deuteron break-up reactions. Deuterons were cleanly separated from protons in the analysis by a calculation of particle mass based on the measured momentum and time-of-flight between counters P1 and P2.

For each event, since only the incident and scattered neutron momenta are unknown, a two-constraint fit to elastic scattering was possible. Events that gave satisfactory fits were binned according to incident neutron momentum and four-momentum transfer. Bins in incident neutron momentum were 1.0 GeV/c wide. The effective solid angle for each incident momentum and four-momentum transfer was determined by Monte Carlo calculation.

The data have been corrected for inelastic background contamination and nuclear absorption. Target empty corrections were negligible. The corrections range from 16% absorption and 1% inelastic background at small $|t|$ to 6% absorption and 2% inelastic background at large $|t|$. Uncertainties assigned to the cross sections include statistical errors and estimated errors in the background subtraction and nuclear absorption correction.

In fig. 2 we plot the differential cross sections for n-d and p-d [2, 3] elastic scattering as functions of $|t|$. Over the range of energies and momentum transfers studied, we find them to be in excellent quantitative agreement. In particular, at large $|t|$ the n-d and p-d cross sections are equal as required by charge symmetry.

The curves in fig. 2 represent Glauber-theory calculations of the neutron-deuteron differential cross sections [4]. The basic nucleon-nucleon amplitudes have been parameterized by the phenomenological form $f = (k\sigma_T/4\pi)(i + \alpha)\exp(bt/2)$. For the deuteron form factors, $S_0(q)$ and $S_2(q)$, we have used the analytical representations given by Alberi et al. [5] for the deu-

Table 1
Nucleon-nucleon parameters used in theoretical calculation of cross sections shown on fig. 2

P (GeV/c)	α_n	α_p	σ_n (mb)	σ_p (mb)	b_n (GeV/c)$^{-2}$	b_p (GeV/c)$^{-2}$
6	−0.47 [6]	−0.42 [7]	41.4 [8]	41.0 [8]	8.7	8.7
8	−0.43	−0.38	39.9	40.2	8.8	8.8
10	−0.4	−0.34	39.6	39.8	9.2	9.2
12.4	−0.37	−0.31	39.3	39.5	10.4	10.4

teron wave functions of Bressel, Kerman, and Rouben. The curves agree well with the data over the range of measured momentum transfers. Table 1 lists the nucleon-nucleon parameters used in the calculations.

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