Letters to the Editor

Elastic Scattering in High Energy and Impulse Approximation

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April 9, 1958

In 1950, Chew\(^1\) first presented the impulse approximation as an useful method to treat high energy nucleon-nucleus scatterings. However, in those days, our knowledge on elementary scatterings was limited to the cross sections and decisive information on the phase shifts was hardly given. So from elementary scatterings we could not get any information on the interference terms in nucleon-nucleus scatterings. This made it difficult to put the impulse approximation to practical use.

Recently, the increasing knowledge on \(n-p\) and \(p-p\) scatterings made it possible to get an insight into elementary scatterings in the energy region up to 310 Mev phenomenologically and up to about 150 Mev theoretically. As a result, we can choose a few sets of phase shifts concerning elementary scatterings.

On the other hand, Wolfenstein et al.\(^4\) analysed the spin matrix of elementary scatterings between particles of spin 1/2, and Wright\(^5\) related it to phase shifts.

We can make use of these results in applying the impulse approximation to estimate high energy scatterings. Especially, as Chew pointed out, one can expect to get satisfactory results applying the approximation to high energy \(n-d\) or \(p-d\) scatterings.

Along this line, we calculate the cross
Fig. 1. Angular distribution of \( n-d \) elastic scattering at 90 Mev.

The experimental result is due to Stern et al.\(^6\) This experiment was done on the elastic scatterings of 190 Mev deuterons by protons. This is equivalent to 95 Mev in the c.m. system.

The curves are the calculated results upon the impulse approximation, using phase shifts of elementary scattering due to Otsuki et al.\(^5\) (curve I), and due to Gammel and Thaler\(^4\) (curve II), and using cross-sections of elementary scatterings with an assumption that the interference term is some constant times of the sticking factor at all angles (curve III). Curve III is due to Chew.\(^1\)

section of the elastic scattering of 90 Mev neutrons by deuterons. As the deuteron ground state we use the wave function of the Hulthén type with \( \alpha = \sqrt{eM/\hbar^2} = 0.232 \times 10^{13} \text{ cm}^{-1} \) and \( \beta = 7\alpha \), for S-state. In this paper we neglect the contributions from D-state. For the phase shifts of elementary scattering, we use those due to Gammel and Thaler\(^2\) which are determined phenomenologically and are characterized by a strong \( L-S \) force, and those due to Otsuki, Tamagaki and Watari\(^1\) which are suggested theoretically from meson theory and are characterized by the strong tensor potentials.

Experimental result of 190 Mev deuterons scattered by protons due to Stern et al.\(^6\) is compared with our calculated results. This energy is equivalent to 95 Mev in the c.m. system. At such high energies as 90 Mev, we can disregard the difference between \( n-d \) and \( p-d \) scatterings except for very small angles. Also we may neglect the difference between 90 Mev and 95 Mev. Hence we calculate the cross section for the scatterings of 90 Mev neutron by deuteron and compare to the experimental result cited above.

The agreement between experimental and calculated results is satisfactory for both sets of phase shifts\(^3,4\) (See curve I and curve II in Fig. 1.)

The sticking factor which decreases monotonically with increasing magnitude of momentum transfer implies that the forward scattering is favored. This result
was shown by Chew. (See curve III in Fig. 1.) Besides, the destructive interference terms between \( n-n \) and \( n-p \) scatterings play an important role, especially in large angles. Along with the nature of sticking factor this fact gives reasonable agreement with experimental values for angles of less than about 110°.

Authors wish to express their sincere thanks to Professor M. Kobayasi for his interest in this work and to Messrs. S. Hatano and M. Yasuno for discussions. They are indebted to Mr. R. Tamagaki and others for showing the results of their calculations on the phase shifts in nucleon problems prior to publication.

1) G. F. Chew, Phys. Rev. 80 (1950), 196; 84 (1951), 710; 84 (1951), 1057.
5) S. Otsuki, R. Tamagaki and W. Watari, private communication.