ELASTIC SCATTERING OF 6.2-GeV PROTONS BY DEUTERONS

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We investigated elastic pd scattering at 6.2 GeV, using photographic emulsions impregnated with heavy water. The incident proton beam was perpendicular to the plane of the emulsion. Altogether, 267 elastic pd scattering events and 39 pp scattering events were found. The differential cross section is given in the c.m.s. angle interval 2—9.5°. The elastic scattering cross section is $\sigma_{el} = 12.6 \pm 1.4$ mb. The effective radius of pd interaction is $R = (2.0 \pm 0.1) \times 10^{-13}$ cm.

THIS is a continuation of an earlier investigation[1] of elastic scattering of protons by deuterons at 6.2 GeV, and is aimed at increasing the statistical accuracy.

A stack of 29 type NIKFI-BR pellicles of initial thickness 400μ was used. Three pellicles were impregnated with heavy water, and the remainder with ordinary water. The thickness of the impregnated layers was 1000μ. The chamber was irradiated perpendicular to the emulsion surface by the internal proton beam of the proton synchrotron of the Joint Institute for Nuclear Research. During the irradiation one cm^3 of heavy-water-impregnated emulsion contained 4.78×10^{22} atoms of deuterium.

The emulsions were area-scanned with an emersion objective at 630× magnification. Altogether 20.16 cm^2 of material was scanned (including the previously used material[1]). Inasmuch as the intensity of the primary beam was uneven over the area (beyond the limits of statistical errors), the scanned area was subdivided during the course of reduction of the experimental data into three sections of area 9.49, 5.93, and 4.74 cm^2. The average intensity of the primary beam in these sections was respectively $(4.34 \pm 0.03) \times 10^5$, $(3.91 \pm 0.03) \times 10^5$, and $(3.40 \pm 0.03) \times 10^5$ protons/cm^2. To determine the scanning efficiency and to increase the reliability of the results, the entire area was scanned twice.

The procedure used to measure the kinematic parameters and the criteria for selecting cases of proton elastic scattering were described in detail by Lyubimov et al.[2]

Altogether 849 two-prong stars were found; 507 were measured, and the remainder patently did not satisfy the elastic-scattering criteria. The analysis did not include events at distances less than 50μ from the upper or lower surfaces of the developed emulsion.

The mean error in the measurement of the recoil deuteron scattering angle was ~ 2°, and that of the fast scattered proton ~ 7′. The range-energy curve which we obtained earlier[11] from 33 measured cases, was refined in the present work on the basis of 159 cases. An event was classified as an elastic scattering if it satisfied the elastic-scattering kinematics within the limits of triple deviations. A total of 267 of elastic pd scattering and 39 cases of inelastic pp scattering was found.

The efficiency ϵ of the double scanning, the number n of the obtained elastic pd scattering cases, and the c.m.s. differential cross section in the corresponding angle intervals are listed in Table I. The scanning efficiencies were determined following Lim et al.[3], while the errors in the efficiencies were calculated in accordance with the paper of Podgoretskiĭ et al.[4]

Table I

θ_{cms}, deg	n	ε	$d\sigma/d\Omega$, mb/sr
2.0—3.5	88	0.90±0.03	359±41
3.5—5.5	103	0.90±0.03	186±20
5.5—7.5	53	0.89±0.04	70±10
7.5—9.5	16	0.87±0.07	22±6
>9.5	7		

In the first and second angle intervals, it is sometimes difficult to distinguish between pp and pd scattering within the limits of triple deviations. In such cases the events were classified as pd or pp scattering depending on which of the kinematics was better satisfied. The error introduced in such a manner in the number of pd scattering was less

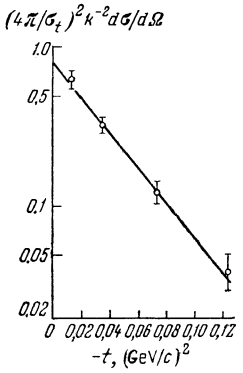
than 7% for the first interval and less than 3% for the second. The contribution of the quasi-elastic scattering and of other background events was ~ 5% for all angle intervals.

Table II lists data for the 39 cases of elastic pp scattering which we observed; they are compared with the earlier results[5]. The differential cross sections for the corresponding intervals coincide, within the limits of statistical errors.

Table II

θ_{cms}, deg	n	ε	$d\sigma/d\Omega$, mb/sr	$d\sigma/d\Omega$, mb/sr[5]
2.5	6			
2.5—6.5	15	0.90	58.5±15	65.7±9
6.5—10.5	12	0.74	30.1±9	33.8±5
>10.5	6			

The figure shows the quantity $(4\pi/\sigma_t)^2 k^{-2} d\sigma/d\Omega$ as a function of $-t$. Here σ_t —total pd-scattering cross section, k —c.m.s. wave number, and $-t$ — square of 4-momentum transfer.



For 6.2 GeV we have $\sigma_t = 78.9 \pm 0.8$ mb[6]. It is seen from the figure that the data satisfy the relation

$$(4\pi/\sigma_t)^2 k^{-2} d\sigma/d\Omega = \exp(b + At). \quad (1)$$

The coefficients b and A, determined by least squares, are $b = -0.20 \pm 0.15$ and $A = 25.3 \pm 2.5$ $(GeV/c)^{-2}$. Our value of b does not contradict the value which follows from the optical theorem: $b \geq 0$.

The total cross section for elastic scattering, $\sigma_{el} = 12.6 \pm 1.4$ mb, was obtained by extrapolating our data to $t = 0$ and $t = -0.3$ $(GeV/c)^2$ (b was assumed equal to zero and $A = 25.3$ $(GeV/c)^{-2}$).

Relation (1) is similar to that obtained for pp scattering at $|t| \leq 0.4$ $(GeV/c)^2$. It can be derived for pp scattering at high energies either within the framework of the optical model of the nucleon[7] or on the basis of the Regge theory[8]. Of course, the optical model can be used also to describe pd interaction. For example, for a black sphere or a black disc at $R \approx 2 \times 10^{-13}$ cm and $|t| \leq 0.08$ $(GeV/c)^2$, we obtain approximately

$$(4\pi/\sigma_t)^2 k^{-2} d\sigma/d\Omega = \exp[-(R/2\hbar)^2 t], \quad (2)$$

where R —effective interaction radius. From (1) and (2) we get $R = 2\hbar A^{1/2}$. The effective radius for the pd interaction at 6.2 GeV is therefore $R = (2.0 \pm 0.1) \times 10^{-13}$ cm.

The differential cross section for elastic scattering of one particle by another, neglecting spins, can be analyzed as a function of the Lorentz-invariant variables s and t (where s —square of the total energy in the c.m.s.). A detailed analysis for pd scattering at high energies can be made if experimental data are available for different values of the energy s and for both small and large values of the momentum transfer t.

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