ELASTIC SCATTERING OF 650-MeV PROTONS

V M. GUZHAVIN, G. K. KLIGER, V. Z. KOLGANOV, A. V. LEBEDEV, K. S. MARISH, M. A. MUSIN, Yu. D. PROKOSHKIN, V. T. SMOLYANKIN, A. P. SOKOLOV, L. M. SOROKO, and TS'UI WA-CH'UANG

Joint Institute for Nuclear Research

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A liquid-hydrogen bubble chamber was used to record 1767 elastic pp scattering events at 650 MeV. The angular distribution of the scattered protons was obtained.

THE EXPERIMENT

THE elastic scattering of protons at energy near 650 MeV was investigated in many studies[1-5], essentially with the aid of scintillation counters. The angular distribution of the protons at small and large angles was investigated in these studies by various methods. The purpose of the present investigation was to measure the angular distribution of elastically scattered protons in a broad angle interval by an identical procedure, so as to eliminate possible systematic errors. The experiments were performed with the liquid-hydrogen bubble chamber of the Institute of Theoretical and Experimental Physics, in a beam of (650 ± 5) MeV protons[6].

The 25,000 stereo photographs obtained by irradiating the chamber were scanned three times with a diascope. Particular attention was paid in the second and third scannings to protons scattered through very small angles. The plane of the projection screen was inclined 70° to the diascope axis. As a result, the visible kink angles in the tracks at the scattering point were increased fourfold, thus greatly enhancing the efficiency of observation of small-angle scattering events.

The proton scattering angles θ were measured with the reprojector of the Institute of Nuclear Problems[7]. In cases when the recoil proton was stopped inside the chamber the scattering angles were determined also from the recoil-proton range. The mean-square error of the determined angle θ was 0.5° and was principally connected with the curving of the tracks. The azimuthal scattering angle was measured with a reprojector accurate to 1.5°.

The events selected for final processing were those with scattering angle $-70° < \varphi < 70°$, registered in the central region of the chamber. An analysis of the azimuthal distribution of the selected events $N(\varphi)$ has shown that for angles θ in the interval from 7 to 90° this distribution does not depend on φ and the registration efficiency is close to 100%. Both tracks of the scattered protons are observed reliably in this angle interval. With further decrease in θ, the distribution $N(\varphi)$ begins to drop off in the region of large φ, and the registration efficiency is accordingly reduced (Fig. 1).

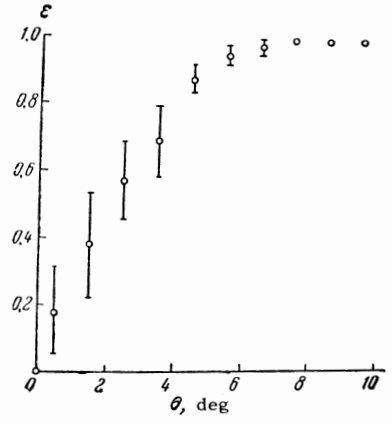

FIG. 1. Angular dependence of the proton elastic scattering registration efficiency ϵ.

Comparison of the cases of scattering into the upper and lower hemispheres has shown that there is no false asymmetry in the distribution $N(\varphi)$:

$$N(-70° < \varphi < 0) / N(0 < \varphi < 70°) = 1.01 \pm 0.05.$$

ANGULAR DISTRIBUTION OF SCATTERED PROTONS

In determining the differential proton elastic scattering cross section, we singled out the central part of the chamber in order to avoid errors connected with losses during scanning. A total of

θ	ϑ (c.m.s)	dσ/dΩ, 10^{-27} cm²/sr	θ	ϑ (c.m.s.)	dσ/dΩ, 10^{-27} cm²/sr
0°30′	1°08′	32 ±29	21°30′	49°14′	3.6±0,5
1°30′	3°09′	21 ±12	22°30′	51°26′	4.4±0,6
2°30′	5°57′	16 ± 6	23°30′	53°38′	3.6±0,5
3°30′	8°14′	12 ± 4	24°30′	55°50′	3.5±0,5
4°30′	10°31′	12 ± 2	25°30′	58°01′	2,8±0,4
5°30′	12°47′	9,7± 1.7	26°30′	60°13′	2.6±0,4
6°30′	15°07′	7,3± 1,2	27°30′	62°22′	3,7±0,5
7°30′	17°32′	8,6± 1,2	28°30′	64°32′	3.5±0,5
8°30′	19°45′	8,6± 1.2	29°30′	66°40′	2,8±0,4
9°30′	22°09′	7,4± 1,0	30°30′	68°09′	3,5±0,5
10°30′	26°19′	5,0± 0.8	31°30′	70°56′	3,2±0,4
11°30′	26°43′	6,1± 0.9	32°30′	73°03′	3.0±0,4
12°30′	28°55′	6,0± 0.8	33°30′	75°09′	2.6±0,4
13°30′	31°12′	6,6± 0,8	34°30′	77°15′	2.3±0,4
14°30′	33°30′	5,8± 0,8	35°30′	79°30′	2,4±0,4
15°30′	35°45′	5,2± 0,7	36°30′	81°24′	1,7±0,3
16°30′	38°01′	4,4± 0.6	37°30′	83°28′	2.4±0,4
17°30′	40°17′	4,4± 0.6	38°30′	85°32′	2,1±0,4
18°30′	42°31′	2,6± 0,5	39°30′	87°30′	2,6±0,4
19°30′	44°47′	3,8± 0.6	40°30′	89°35′	2.0±0,4
20°30′	46°59′	4,0± 0.6			

1767 elastic-scattering events was registered in this region.

For the selected events we plotted the c.m.s. distribution relative to the sum of the scattering angles $\vartheta_1 + \vartheta_2$. The average value of the sum was 180°. The variance of the distribution was 1.5°, corresponding to the indicated accuracy of the angles θ. Such an angular resolution leads to an uncertainty in the discrimination between the elastic and inelastic processes, amounting to (8 ± 3) events or 0.5% of the elastic-scattering events.

The differential proton elastic-scattering cross sections $d\sigma/d\Omega$, normalized to the total elastic scattering cross section,[6]

$$\sigma_s = (25.1 \pm 0.8) \cdot 10^{-27} \text{ cm}^2,$$

are listed in the table.

In the scattering angle interval $\vartheta > 15°$, the errors are determined only by the statistics, and in the region of smaller angles the error in determining the registration efficiency becomes significant.

The angular dependence of the differential cross section, averaged over angle intervals $\Delta\theta = 3°$, is shown in Fig. 2. In the angle region $\vartheta > 10°$, where Coulomb interaction can be neglected, the data obtained are approximated by the polynomial

$$d\sigma / d\Omega = [(2.02 \pm 0.15) + (3.2 \pm 0.8)3\cos^2\vartheta - (4.6 \pm 1.4)5\cos^4\vartheta + (3.1 \pm 0.8)7\cos^6\vartheta] \times 10^{-27} \text{ cm}^2/\text{sr}.$$

A statistical comparison of our data with earlier results shows that the present results and those of [1,2] agree with a probability of 80%. This probability amounts to 18% in the case of the work of Bogomolov et al.[3]

In conclusion we take the opportunity to thank M. P. Balandin for help with the reprojector and microscope measurements and L. I. Lapidus for a discussion of the results.

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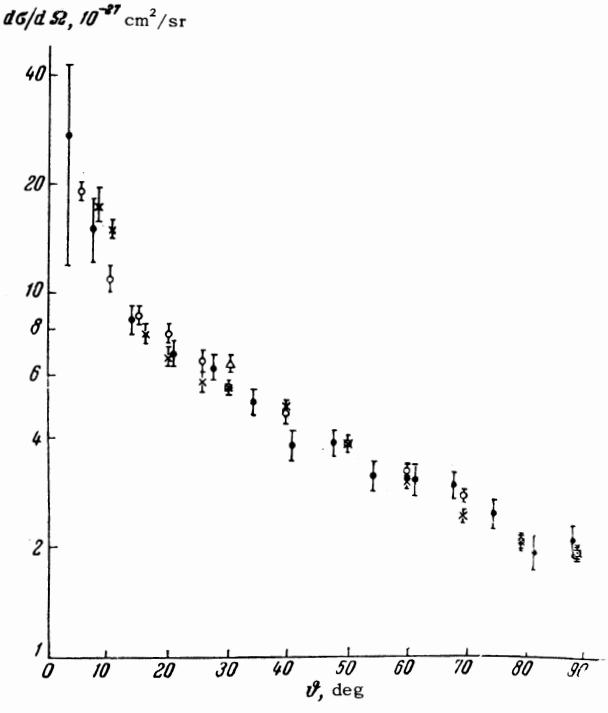

FIG. 2. Differential cross sections of elastic pp scattering: ● – present work; earlier data: ○ – [2], × – [3], △ – [4].

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