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ELASTIC SCATTERING OF 300-Mev NEGATIVE PIONS BY HYDROGEN

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The elastic scattering of 300-Mev negative pions from hydrogen was studied with the aid of a hodoscopic system with pulse-fed counters. Equation (1) gives the angular distribution for the elastic scattering under the hypothesis that the fundamental contribution to the scattering comes from the S and P waves.

IN the present work, a hodoscopic system with an adjustable pulse feed for the counters[1,2] was used to study the elastic scattering of 300-Mev negative pions. The experimental setup is shown in Fig. 1. Negative pions formed by the bombardment of a beryllium target by 670-Mev protons from the internal beam of the synchrocyclotron of the Joint Institute for Nuclear Research were bent in the magnetic field of the accelerator and were incident on a collimator set into a four-meter concrete shield. On the other side of the collimator stood a magnet which cleared the beam of particles with other momenta.

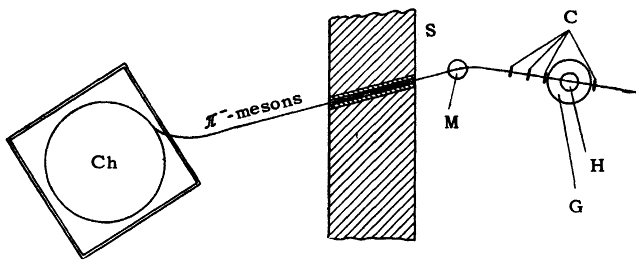

FIG. 1. Diagram of the arrangement of the apparatus: Ch – synchrocylotron chamber, S – shielding wall, M – deflecting magnet, C – scintillation counters, G – hodoscopic system, H – liquid hydrogen target.

The energy of the beam of pions was determined by measuring their range in copper, after taking into account corrections for multiple scattering of the mesons in copper and for slowing-down losses in the walls of the hydrogen target, and was equal to (300 ± 7) Mev, where the energy spread was obtained from the absorption curve. The admixture of negative muons in the pion beam was equal to 4%. The pion beam was picked out by a scintillation counter telescope and was incident on a polystyrene foam target in liquid hydrogen. The intensity of the meson beam, which was detected by the telescope, was about 13,000 particles/minute. The pion scattering process in the hydrogen target was separated by the hodoscope control system which

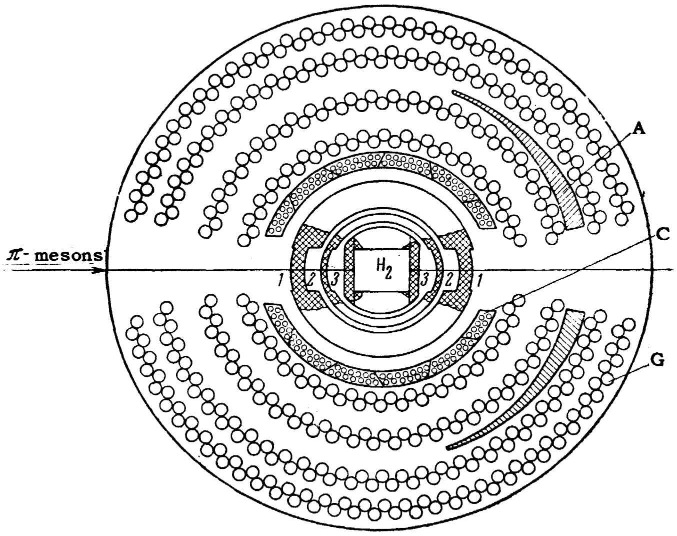

FIG. 2. Setup of the counters in the hodoscopic system: C – counters of the control system, G – hodoscopic system, A – copper absorber, 1, 2, 3 are the walls of the polystyrene foam target with the liquid hydrogen.

contained, besides the scintillation counter telescope, gas-discharge counters with small dead times, set in front of the hodoscope counters.

Figure 2 shows the arrangement of the counters in the hodoscopic system. The counters detected negative pions scattered in the whole angular interval from 20° to 160° in the laboratory system. In the angular interval from 20° to 70° relative to the incident beam, a copper absorber whose thickness varied with angle was set between the second and third rows of counters to separate the recoil proton from the scattered pions. When the scattered pions went into the solid angle determined by the controlling gas-discharge counters, a high voltage pulse was generated which passed through all the counters in the hodoscopic system. A gas discharge, displayed by MTX-90 neon bulbs, was produced by the pulse feed in those counters through which particles passed. A motion picture camera recorded the lighted neon bulbs.

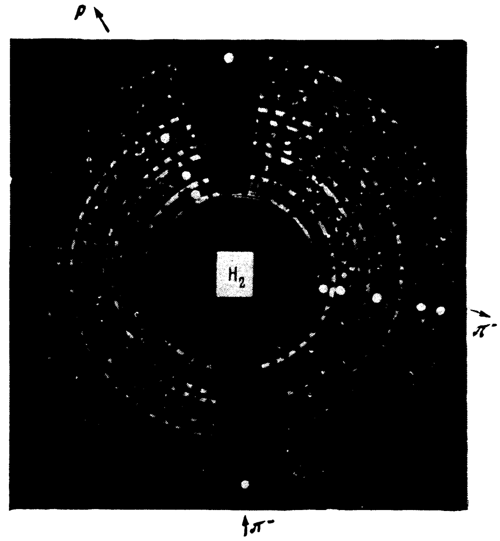

FIG. 3,

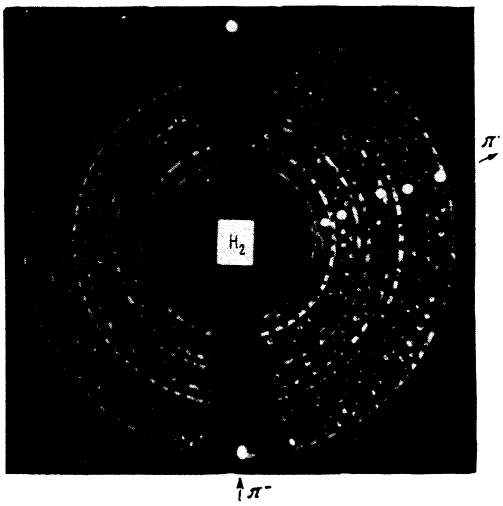

FIG. 4

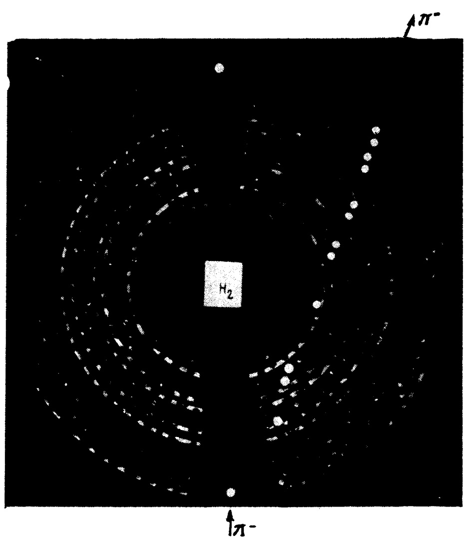

FIG. 5

To investigate negative pion scattering from hydrogen, measurements were carried out with the target first filled with hydrogen and then empty. The analysis of the exposures obtained was carried out in two steps. First the pellicles were examined with a D-1A diascope, and the scattering events were marked. Next each scattering event was analyzed in detail. To do this the activated counters recorded on the photographs were examined on a diagram showing the location of the hodoscopic counters.

In processing the plates only those cases were examined in which simultaneous counts were made in the four rows or in three arbitrary rows when the trajectory of the particle could be described.

All the trajectories obtained were broken down into several groups according to the following criteria:

1. A single photograph shows two trajectories whose angles of scattering relative to the incident beam of negative pions are connected by an angular correlation corresponding to energy and momentum conservation laws. These trajectories represent the tracks of the scattered meson and the recoil proton.

2. Trajectories of particles which can be described by a) scattering in the hydrogen or in the walls of the hydrogen target, b) scattering in the walls of the hydrogen target (1, 2, figure 2), c) scattering in the crystal of the scintillation counter, or d) accidental coincidences.

The photographs (Figs. 3 — 5) show the trajectories of the particles corresponding to groups 1, 2a, and 2c, respectively.

The hodoscope made it possible to discriminate, in a large angular interval, between the scattering events in the hydrogen or in the walls 3 (Fig. 2) and those scattering events in walls 1 and 2, which fact improved the statistical accuracy of the difference methods of measuring.

In analyzing the plates, about 1500 scattering events were found whose trajectories could be attributed to types 1 and 2a. Measurements without hydrogen showed that the scattering events with type 2a trajectories make up about a third of all the cases. Thus the number of events of scattering from hydrogen was about 1000. All the scattering events were broken down into angular intervals of 10°, and the differential cross sections were computed by the formula

$$(d\sigma(\theta)/d\Omega)_{\text{lab}} = (N_{\text{with H}} - N_{\text{without H}})/N_{\text{H}}\Omega(1-\alpha)N_{\pi}\varepsilon,$$

where $(N_{\text{with H}} - N_{\text{without H}})$ is the number of pions scattered from hydrogen, N_H is the number

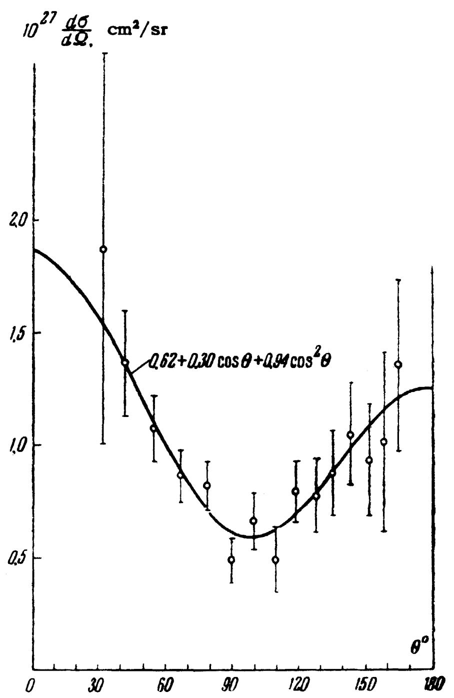

FIG. 6. Angular distribution for elastic scattering of 300-Mev negative pions from hydrogen.

of hydrogen atoms in 1 cm^2, Ω is the solid angle determined by the gas-discharge control counters, α is the fraction of negative muons and electrons in the beam, N_π is the number of π^- traversals through the hydrogen target (a correction for the dead time of the control system of the hodoscope was made in getting this number), and ϵ is the efficiency of detecting the pions. The efficiency of pion detection was determined, first, by the efficiency of the gas-discharge control system, second, by the efficiency of the hodoscopic counters, and third, by nuclear absorption in the copper absorber. The efficiency of the guide counters was·98%.[3]

For the chosen constant potential,[2] $V_0 = 1$ volt on the hodoscopic counters, the detection efficiency for each row was 85% for a high-potential pulse length of 0.8 μsec. For an individual counter efficiency of 85%, the probability is 52.3% that a particle would be recorded by four rows simultaneously, 36.8% by three, 9.8% by two, 1% by one, and 0.05% by none. The detection efficiency for a markedly higher selection of scattering cases was 89%. To measure the nuclear absorption in the copper absorber, the hodoscopic chamber (Fig. 2) was rotated about the vertical axis so that mesons passed through the copper filter. The energy of the pions was lowered to equal the energy of the pions scattered at the given angle. These measurements were carried out at several angles.

The angular distribution obtained of the differential scattering cross section is shown in Fig. 6, in the center-of-mass system. The errors shown in the differential cross sections are statistical. If it is conceded that the basic contribution to the scattering comes from S and P waves, then the angular distribution of the elastically-scattered pions in hydrogen can be given in the form

$$d\sigma / d\Omega = [(0.62 \pm 0.06) + (0.30 \pm 0.09) \cos\theta + (0.94 \pm 0.19) \cos^2\theta] \cdot 10^{-27} \text{ cm}^2/\text{sr} \quad (1)$$

To find the phase shifts in states with isotopic spin $T = 1/2$, we used the data from the present work on the elastic scattering of negative pions and the results of Mukhin and Pontecorvo for the elastic scattering of positive pions at 307 Mev.[4] The phase analysis was carried out with the aid of the "Strela" electronic computer. The phase shifts obtained by the Ashkin-Vosko graphical methods were used for initial data.

Two sets of phase shifts (see table) were found which gave a minimum value to the quantity

$$M = \sum (\Delta_i / \varepsilon_i)^2,$$

where Δ_i is the deviation of the calculated from the experimental values, and ϵ_i is the experimental error in the cross section. The expectation value of the quantity M was 19.

The introduction into the computer of initial data which differed from those obtained by the graphical method in both the values and signs of α_1, α_{11}, and α_{13} produced two sets of phase shifts, close to the sets given below.

The first set of phases are in satisfactory agreement with those obtained by Zinov and Korenchenko.[5] A better choice between the two sets can probably be made upon completion of the measurement, now in progress, of the polarization of the recoil protons in π^--p scattering.

In conclusion, the authors have the pleasant duty of expressing their thanks to A. A. Tyapkin for his guidance and help in the work and to N. I. Polumordvinova for help in carrying out the phase analysis.

	α_3	α_{31}	α_{33}	α_1	α_{11}	α_{13}	M
Set 1	—23.2°	—8.6°	133.3°	26.6°	10.7°	—3.1°	19.2
Set 2	—22.9°	—8.2°	133.3°	—11.6°	—2.4°	20.1°	18.5

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[2] V. V. Vishnyakov and A. A. Tyapkin, Атомная энерния (Atomic Energy) No. 10, 298 (1957).

[3] I. M. Vasilevskiĭ and V. V. Vishnyakov, Приборы и техника эксперимента (Instruments and Meas. Engg.), in press.

[4] A. I. Mukhin and B. Pontecorvo, JETP **31**, 550 (1956), Soviet Phys. JETP **4**, 373 (1957).

[5] Transactions of the International Conference on High Energy Physics, report of Prof. B. Pontecorvo, Kiev 1959.

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