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A. I. MUKHIN, I. V. POPOVA, and G. N. TENTYUKOVA

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Abstract

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A. I. MUKHIN, I. V. POPOVA, and G. N. TENTYUKOVA

PHASES OF MESON-NUCLEON SCATTERING IN THE ENERGY REGION UP TO 310 MeV

(Presented by Academician L. A. Artsimovich on 14 IX 1956)

The interaction of π^+-mesons with hydrogen in the energy interval below 200 MeV has been studied in more or less detail by a number of authors. In the energy region from $\sim$ 200 to $\sim$ 300 MeV, the study of meson–nucleon scattering is of interest because here there may arise the possibility of observing the interaction of mesons with the proton not only in S- and P-, but also in D-states.

At the same time, phase analysis at these energies can still be carried out by comparatively simple means, owing to the small cross section of inelastic processes.

In the present brief communication we give the results of an analysis of data on the scattering of π^+-mesons by hydrogen, carried out both under the assumption that the contribution to the scattering from D-states is negligibly small, i.e., that the scattering occurs only in S- and P-states (S-P analysis), and under the assumption that the contribution of D-states may prove appreciable (S-P-D analysis).

In the case where the interaction of π^+-mesons with hydrogen occurs only in S- and P-states, the angular distribution of the scattered mesons in the center-of-mass system may be written in the form

$$\lambda^{-2}\frac{d\sigma}{d\Omega} = A + B\cos\theta + C\cos^2\theta.$$

Distributions of this type, with coefficients found by the least-squares method for energies of 176, 200, 240, 270, and 307 MeV, are shown in Fig. 1 by solid lines together with the experimentally measured values of the cross sections $(^1)^*$.

In the S-P analysis, with the aid of an electronic computer the differential cross sections were expressed in terms of the three phase shifts α_3, α_{31}, and α_{33}. The minimum of the quantity

$$M = \sum_i \left\{ \frac{f_i(\alpha_3, \alpha_{31}, \alpha_{33}) - \sigma_i}{\Delta\sigma_i} \right\}^2,$$

which characterizes the degree of deviation of the scattering curve $f_i(\alpha_3, \alpha_{31}, \alpha_{33})$, calculated from the phases, from the experimentally measured cross-section values σ_i with error $\Delta\sigma_i$, was sought. In the calculations, as a first approximation, the phases in turn, beginning with α_3, were varied within specified limits in steps of one degree; this cycle was repeated several times until M ceased to decrease. Then the variations were made in steps of one half

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* A detailed description of the experimental side of the study of the scattering of π^+-mesons by hydrogen was given in a recently published article (JETP, **31**, 371 (1956)), which, however, did not present the complete results of the phase analysis at all energies.

degrees, etc., until the prescribed accuracy of the calculations was reached. The "optimal" scattering phases obtained in this way are also given in Table 1.

If one relies on the validity of the S-P analysis up to energies of $\sim$ 300 MeV, then it follows from what has been said above that the linear dependence of the phase α_3 on the momentum is not preserved at energies above 200-240 MeV.

On the other hand, despite the fact that there is no strong experimental indication of the necessity of this*, it is interesting to see whether the linear dependence of the S phase on the meson momentum is preserved when higher angular momenta ($l = 2$) are included in the analysis. In view of this, the experimental data of Ref. ([1]), as well as of Refs. ([3–7]), were reanalyzed with the aid of a high-speed electronic computer, under the assumption that, for the description of π-meson scattering, along with S and P waves it is also necessary to take D waves into account (S-P-D analysis).

Table 1

S-P analysis. Phases of scattering of π^+-mesons by protons (in degrees)

Meson energy (MeV)	α_3	α_{31}	α_{33}
126	−10.6	−19.5	69.0
200	−9.1	10.0	102.0
240	−18.1	−2.6	114.7
270	−20.2	−6.7	129.3
307	−23.3	−8.4	133.2

Fig. 1. Angular distributions of positive pi mesons elastically scattered by hydrogen.

Figure 1: Fig. 1. Angular distributions of positive pi mesons elastically scattered by hydrogen.

If S, P, and D waves participate in the scattering, then, in addition to the three phase shifts already enumerated above, α_3, α_{31}, and α_{33}, the phase shifts δ_{33} and δ_{35}, corresponding to D states with total angular momentum 3/2 and 5/2, are also different from zero.

Fig. 1. Angular distributions of positive π-mesons elastically scattered by hydrogen.
a) $E = 176$ MeV, b) $E = 200$ MeV, c) $E = 240$ MeV, d) $E = 270$ MeV, e) $E = 307$ MeV

In the calculations, as in the case of the S-P analysis, the minimum of the quantity

$$M = \sum_i \left\{ \frac{f_i(\alpha_3, \alpha_{31}, \alpha_{33}, \delta_{33}, \delta_{35}) - \sigma_i}{\Delta\sigma_i} \right\}^2,$$

where $f_i(\alpha_3, \alpha_{31}, \alpha_{33}, \delta_{33}, \delta_{35})$

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* Only the data at an energy of 307 MeV indicate some difficulty in approximating the observed angular distribution by a function of the type $A + B\cos\theta + C\cos^2\theta$, i.e., by a function with only three free parameters.

function expressing the cross section in terms of five phase shifts, and σ_i is the experimentally measured cross section with error $\Delta\sigma_i$.

The "optimal" scattering phases obtained in the S-P-D analysis are given in Table 2.

Of course, it is difficult to assert anything reliably about the magnitude of the phase shifts of the D waves on the basis of only the "optimal" solution presented in Table 2. A tendency for them to increase (at least δ_{35}) with increasing meson energy is visible, which is an indirect argument—though certainly not proof—in favor of the fact that already at energies of the order of 300 MeV the contribution of D-waves cannot be neglected.

Table 2

S-P-D analysis. Scattering phases of π^+-mesons by protons (in degrees)

Meson energy (MeV)	α_3	α_{31}	α_{33}	δ_{33}	δ_{35}
113	−12.0	−1.0	27.2	−1.6	0.6
120	−11.2	−1.3	32.5	0.9	0
165	−18.0	−6.0	62.2	1.0	−5.7
176	−16.6	−15.2	68.8	1.7	−2.3
189	−12.5	−7.0	96.5	−3.0	−3.7
200	−6.7	8.9	102.7	7.0	−0.3
240	−14.0	−2.0	114.4	3.0	−5.0
270	−13.6	−4.3	128.8	4.3	−6.9
307	−13.0	−4.0	133.6	9.5	−10.0
310	−16.8	−2.0	129.6	2.6	−6.5

In conclusion, the authors express their gratitude to the director of the Computing Center of the Academy of Sciences of the USSR, Academician A. A. Dorodnitsyn, for providing the opportunity to carry out the computations on the BESM, and also to B. Pontecorvo and L. I. Lapidus for discussions.

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Note: Figure translations are in progress. See original paper for figures.