The Scattering of 40-Mev Positive Pions by Hydrogen*,†

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DIFFERENTIAL scattering cross sections of hydrogen for 40 $\pm$3-Mev positive pions have been measured at laboratory angles of 45, 60, 90, 120, and 140 degrees.

After analysis and focusing both by the cyclotron fringing field and by a deflecting magnet, the pion beam was further defined and counted by a double coincidence telescope consisting of the scintillation counters 1 and 2 shown in Fig. 1. The beam so defined was quite parallel but contained a 3 percent muon-electron contamination, as was determined from range measurements, and a 1 percent contribution due to random coincidences between counters 1 and 2. Polyethylene and carbon scatterers were placed behind counter 2 and a larger counter, 5 the pulses of which were in anticoincidence with those from the defining telescope, was placed behind the scatterers. Since the energy of pions scattered by hydrogen is a function of the scattering angle, different scatterer thicknesses were used at each angle, and the geometries

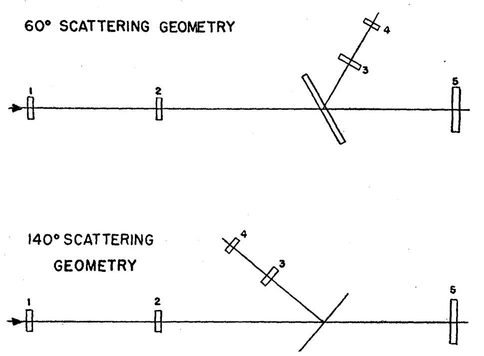

FIG. 1. Elevation drawings of the 60° and the 140° setups illustrating the transmission geometry used in the forward hemisphere and the reflection geometry used in the backward hemisphere.

illustrated by Fig. 1 were used. The scatterers were made sufficiently thin so that the scattered pions had enough energy to traverse the detecting telescope which consisted of the counters 3 and 4.

Because of the large background counting rate due to elastic scattering and star production by carbon, the pulse heights in counter 3, corresponding to particles passing through the detecting telescope in time coincidence with a pion in the incident beam, were recorded. By restricting the CH_2-carbon subtraction to that region of pulse height in which hydrogen-scattered pions were expected, reasonable signal-to-noise ratios were attained.

The results, corrected for beam contamination and for the inefficiency of a fast coincidence circuit used, are given in Table I. θ_0 is the nominal scattering angle; θ_{max} and θ_{min} are, respectively, the maximum and minimum scattering angles accepted by the detecting telescope; and Ω_{eff} is the effective solid angle which was

TABLE I. The results expressed in the laboratory system and in the center-of-mass system. θ_{max} and θ_{min} give the total angular spreads and Ω_{eff} is the effective solid angle.

Scattering angles laboratory θ_0 (deg)	θ_{min} (deg)	θ_{max} (deg)	c.m. Θ (deg)	Ω_{eff} (sterad)	Hydrogen cross section (10^{-27} cm²/sterad) laboratory	c.m.
45	35	58	53	0.0773	0.14 $\pm$0.43	0.11 $\pm$0.34
60	48	73	69	0.0942	0.49 $\pm$0.18	0.42 $\pm$0.15
90	76	110	100	0.110	0.89 $\pm$0.34	0.91 $\pm$0.35
120	101	135	129	0.0863	1.18 $\pm$0.30	1.44 $\pm$0.37
140	125	150	147	0.0702	1.63 $\pm$0.55	2.20 $\pm$0.74

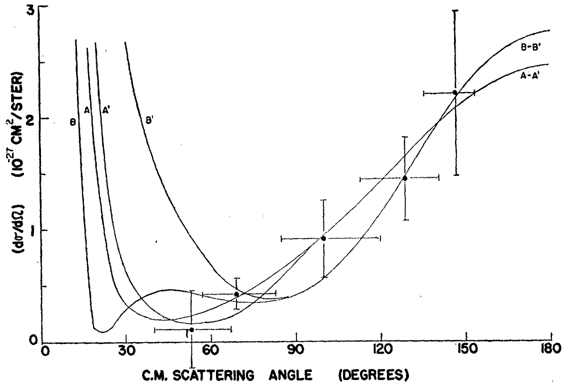

FIG. 2. The center-of-mass angular distribution of $\pi^+ + p \to \pi^+ + p$ at 40 Mev. For Curve A the phase shifts are $\alpha_3 = -5.7°$, $\alpha_{33} = +4.1°$, $\alpha_{31} = -0.1°$. For Curve B: $\alpha_3 = -2.0°$, $\alpha_{33} = +6.0°$, $\alpha_{31} = +0.7°$. Curves A' and B' correspond, respectively, to A and B with reversed signs of the phases.

calculated taking into account the known distribution of incident beam intensity across the scatterer. The errors are standard deviations and include uncertainties in the corrections and in the solid angles as well as those due to counting statistics.

Because of the large uncertainties, the data can be reproduced by several sets of phase shifts. The curves of Fig. 2 represent two such sets: Curve A, $\alpha_3 = -5.7°$; $\alpha_{33} = +4.1°$; $\alpha_{31} = -0.1°$; Curve B: $\alpha_3 = -2.0°$; $\alpha_{33} = +6.0°$; $\alpha_{31} = +0.7°$. α_3, α_{33}, and α_{31} are, respectively, the phase shifts for the $S_{\frac{1}{2}}$, $P_{\frac{3}{2}}$, and $P_{\frac{1}{2}}$ states. The curves A' and B' correspond, respectively, to A and B with reversed signs. The Coulomb interference was calculated from the equation given by Van Hove[1] to lowest order in his expansion of the Coulomb amplitude. It is apparent that if the magnitude of α_{33} is large compared to α_3 (Curves B and B') that the negative sign for α_3 is favored by the data. The test is not so crucial when α_3 and α_{33} are about equal in magnitude (Curves A and A'), but again the set with negative α_3 gives a somewhat better fit.[2]

The integrated total cross section is $(10.9\pm3)\times10^{-27}$ cm², in agreement with the most recent value[3] reported by this laboratory from an attenuation measurement.

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[1] L. Van Hove, Phys. Rev. 88, 1358 (1952).
[2] See R. E. Marshak and A. E. Woodruff (to be published).
[3] C. E. Angell and J. P. Perry, Phys. Rev. 90, 724 (1953).

Evidence for a Region of Extra Nuclear Stability between the 82- and 126-Neutron Shells*

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A NUMBER of new atomic mass measurements have been made in this laboratory in the region $82<N<126$. These masses have been used to study nuclear stability in this region. A previous study[1] of nuclear stability, in the region $28<N<50$ and $28<Z<40$, indicated no unusual stability; especially lacking was the existence of subshell effects in this lighter region.

A useful method of representing the data in order to locate mass effects is to plot the neutron number against the difference between the semi-empirical mass values of Metropolis and Reitweisner[2] and the experimental masses. Since the semi-empirical mass formula has no compensating factors which allow for shell