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DIFFRACTION SCATTERING OF FAST PARTICLES

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THE structure of elementary particles can be determined by studying the elastic scattering of some type of beam by these particles. In the application to nuclei and nucleons, the only example of such a beam up to present is the well known work of the group of Hofstadter with electron scattering, which makes it possible to determine the form factors of the electric charge and of the magnetic moment.[1] However, analysis of the elastic scattering of other types of particles also makes it possible to obtain valuable information about the structure of nucleons and of the nucleus.* By way of example, we consider the scattering of π^- mesons by nucleons.[3,4]

For simplicity, we disregard the spin-dependence of the interaction and neglect the process of charge exchange. We assume also that the real part of the phase shift, $\mathrm{Re}\,\eta_l = 0$, which is in good agreement with experiment for energies $E_\pi \geq 1$ Bev.[2,5] A rigorous solution of the problem will be published later.

In Fig. 1 the solid lines show the quantity

$$\mathrm{Im}\,\eta_l = -\frac{1}{2}\ln\left\{1 - \lambda\!\!\!^{-}{}^{-1}\int_0^{\pi}\sqrt{(d\sigma_d(\theta)/d\Omega)}\,P_l(\cos\theta)\sin\theta\,d\theta\right\}$$

for the case of scattering of 1.3-Bev π^- mesons.

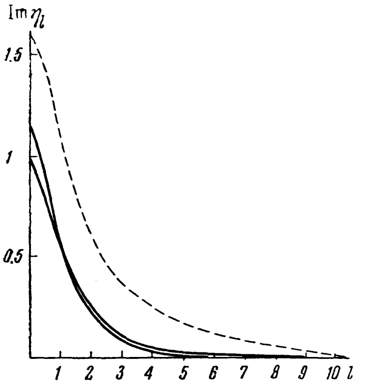

FIG. 1

In order to calculate these functions, curves of least and greatest curvature were constructed between the limits of the experimental values of the differential cross section for elastic scattering ($\sigma_d \approx \sigma_{el}$) from reference 3. The curves in Fig. 1 were drawn through the centers of the rectangles of the corresponding histograms. The dashed line in Fig. 1 gives the values of $\mathrm{Im}\,\eta_l$ calculated from the mean experimental data from reference 4 for the scattering of 5-Bev π^- mesons.

At high energies, where the wavelength $\lambda\!\!\!^{-}$ becomes substantially smaller than the dimensions of the scattering system, and the relative change in the absorption coefficient K over a wavelength $\lambda\!\!\!^{-}$ is small, the quasi-classical approximation can be employed with a high accuracy. Taking $\mathrm{Im}\,\eta_l$ from Fig. 1, we obtain from well-known formulas[6] the values: $\sigma_{in} = (25.5 \pm 1.5)$mb, $\sigma_d = 7.4 \pm 0.1$)mb for E = 1.3 Bev and $\sigma_{in} \approx 23$ mb, $\sigma_d \approx 5$ mb for E = 5 Bev. The good agreement of these quantities, as well as that of the angular distribution we calculated for the elastically scattered particles, with the data of references 3 and 4 is one of the justifications of the following applications of the quasi-classical approximation.

In Fig. 2 we give the values K = K(r) (where r is the distance from the center of the nucleon)

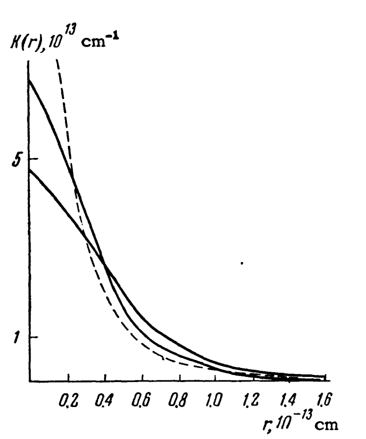

FIG. 2

for E = 1.3 Bev (solid curves) and E = 5 Bev (dotted curve). These values were obtained from a numerical solution of the integral equation

$$2\,\mathrm{Im}\,\eta_l = \int\limits_0^{\sqrt{L^2-l^2}} K(\sqrt{l^2+s^2})\,ds,$$

where $L = l_{max}$ and $\mathrm{Im}\,\eta_l$ is taken from Fig. 1.

Values of K(r) in the region of small r are not unambiguously determined and depend on the way in which the cross section for diffraction scattering is approximated in the region of large angles. As a consequence of the large experimental errors in reference 4, the rise in the values of K(r) upon going from E = 1.3 Bev to E = 5 Bev in the region $r \sim 0$ is also not completely reliable.

The mean square 'pion' radius of the nucleon calculated from the curves of K(r) in Fig. 2 is equal to $(0.82 \pm 0.06) \times 10^{-13}$ cm, and its value at E = 5 Bev is, within the limits of experimental error, the same.

The example considered is a particular case of the solution of the so-called inverse problem of scattering: given the scattered wave, determine completely the interaction potential.

It is our pleasant duty to thank K. Danilov for help in the numerical calculations.

*The work of reference 2 is devoted to a detailed consideration of this problem.

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