# ELASTIC SCATTERING OF HIGH-ENERGY PIONS AND NUCLEONS

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It is shown that, under some very general assumptions, the cross section for large-angle elastic scattering of strongly interacting particles should decrease as $1/E_0$ ($E_0$ is the incident particle energy in the laboratory system).

THE c.m.s. elastic scattering amplitude without allowance for spin effects can be written in the form

$$A(\vartheta) = \frac{i\lambda}{2}\left\{\sum_{l=0}^{\infty}(2l+1)(1-\beta_l)P_l(\cos\vartheta)\right\}, \quad (1)$$

where $\beta_l = e^{2i\eta_l}$; $\eta_l$ is a complex phase shift.

If the wavelength $\lambda$ is sufficiently small in comparison with the interaction range of the particles, then the quantity $\beta$ can be considered as a smooth function of the quantum number $l$. Under this assumption, we obtain for the forward scattering

$$A(0) = \frac{i\lambda}{2}\sum_{l=0}^{\infty}(2l+1)(1-\beta_l)\Delta l$$

$$\rightarrow \frac{i\lambda}{2}\int_0^{\infty} 2l\,dl\cdot(1-\beta_l) = \frac{i\lambda}{2}(1-\bar{\beta}_L)L^2, \quad (2)$$

where $\Delta l = 1$, L is the upper limit of the orbital number $l$ for which the quantity $(1-\beta_l)$ is already small, $\bar{\beta}_L$ is the mean value of $\beta_l$ in the interval $0 < l < L$. The differential cross section for forward scattering is then

$$(d\sigma/d\Omega)_0 = \tfrac{1}{4}\lambda^2|(1-\bar{\beta}_L)|^2L^4 = \tfrac{1}{4}|(1-\beta_L)|^2R^2(R/\lambda)^2, \quad (3)$$

where $R = \lambda L$ is the radius of the interaction sphere of the particles.

For scattering backward at $\vartheta = \pi$, we obtain

$$A(\pi) = \frac{i\lambda}{2}\sum_{l=0}^{\infty}(2l+1)(1-\beta_l)(-1)^l$$

$$= \frac{i\lambda}{2}\left\{\sum_{s=0}^{\infty}(4s+1)(1-\beta_{2s}) - \sum_{s=0}^{\infty}(4s+3)(1-\beta_{2s+1})\right\}$$

$$= \frac{i\lambda}{2}\left\{\sum_{s=0}^{\infty}(4s+1)(\beta_{2s+1}-\beta_{2s}) - 2\sum_{s=0}^{\infty}(1-\beta_{2s+1})\right\}. \quad (4)$$

Further,

$$\beta_{2s+1} - \beta_{2s} = \frac{d\beta}{dl}\Delta l + \cdots$$

($\Delta l = 1$), and we assume that the second derivative is negligible (smoothness condition). Inserting these values into (4) we obtain

$$A(\pi) \rightarrow \frac{i\lambda}{2}\left\{\int_0^{\infty}(2l+1)\frac{d\beta}{dl}\frac{dl}{2} - \int_0^{\infty}(1-\beta_l)\,dl + \int_0^{\infty}\frac{d\beta}{dl}dl\right\}$$

$$= \frac{i\lambda}{2}\frac{3}{2}(1-\beta_0). \quad (5)$$

Hence

$$\left(\frac{d\sigma}{d\Omega}\right)_\pi = \frac{\lambda^2}{4}\frac{9}{4}|(1-\beta_0)|^2, \quad (6)$$

where $\beta_0$ corresponds to the value of $\beta$ for $l = 0$. Hence the expected dependence of the backward scattering on the particle energy (if $\beta_0$ is already small, i.e., for large absorption) will be $\sim 1/E^2$, or, in the laboratory system, $\sim 1/E_0$.

Comparison with the available experimental data indicates qualitative agreement with formula (6). Thus, $(d\sigma/d\Omega)_\pi = 0.10$ mb/sr for 2.5-BeV pions [1] and 0.02 mb/sr for (7–8)-BeV pions. [2]

For $|1-\beta_0| = 0.7$, the corresponding theoretical values, according to (6), are 0.10 and 0.03 mb/sr. Of course, we can obtain formula (6) in more accurate form if we take the sum for the first few phase shifts and later replace it by an integral, as was done in the derivation of formula (6). At this stage, however, it is desirable to compare (6) with the experimental data over a broader interval.

If the dependence $(d\sigma/d\Omega)_\pi \sim E^{-2}$ is confirmed, then this would signify that the absorption inside the nucleon depends weakly on the energy. It is also important to compare the behavior of $\pi$N and NN backward scattering, since a difference in the results of such scattering can be an indication of a difference between the core of a nucleon and of a pion.

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[1] Lai, Jones, and Perl, Phys. Rev. Lett. 7, 125 (1961).

[2] Arkhipov, Grishin, Sil'vestrov, and Strel'tsov, Joint Institute for Nuclear Research, Preprint R-765, Dubna, 1961.

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