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MODIFICATION OF THE GLAUBER FORMULA FOR VIOLATION OF THE POMERANCHUK THEOREM

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The total cross section for scattering of a given particle by neutrons is usually extracted from the proton and deuteron scattering data by means of the Glauber formula[1]

$$\sigma_d = \sigma_p + \sigma_n + \delta\sigma , \qquad (1)$$

$$\delta\sigma = -\frac{\langle r^{-2} \rangle}{4\pi} \sigma_p \sigma_n (1 - a_p a_n), \qquad (2)$$

where a_N is the ratio of the real to imaginary part of the forward scattering amplitude f_N ($N = n, p$) and $\langle r^{-2} \rangle$ is the mean inverse square radius of the deuteron. The additional terms which can appear in eq. (2) to take charge-exchange processes into account[2] do not affect the considerations of this paper and are therefore omitted for simplicity.

There have been recent speculations concerning a possible violation of the Pomeranchuk theorem[3] for certain processes[4-6], although the evidence for the violation has also been questioned[7,8]. Such a violation would imply an asymptotic behaviour[3], $a_N = C_N \ell n\, k$ for some constant C_N , where k is the c.m. momentum. Under this condition eq. (2) would lead to an unphysical logarithmic growth of $\delta\sigma$. Let us consider why this formula breaks down in this case.

Equation (2) is derived from the more general Glauber formula /1/

$$\delta\sigma = \frac{2}{k^2} \mathrm{Re} \int S(q) f_n(q) f_p(q) d^2 q , \quad (3)$$

where $S(q)$ is the deuteron form factor for momentum transfer q, by assuming that $f_N(q)$ is slowly varying within the peak of $S(q)$ at $q = 0$. However, a logarithmic growth of a_N implies a shrinkage of the diffraction peak in $d\sigma/dt$ /5/, since $\sigma_{e\ell} = \int (d\sigma/dt) dt \le \sigma$. Such a shrinkage would invalidate the derivation of eq. (2) at sufficiently high energies. In this case, on the other hand, as $k \to \infty$ eq. (3) reduces instead to

$$\delta\sigma = \frac{2}{k^2} \int \mathrm{Re}\, f_n(q)\, \mathrm{Re}\, f_p(q) d^2 q , \quad (4)$$

using $S(0) = 1$ and assuming no variation of the phase of f_N within the diffraction peak.

For definiteness, let us assume that the diffraction peak remains exponential in form even at asymptotic energies, so that $d\sigma_N/dt = g_N(k) \exp[-a_N(k) t]$. From the above considerations it follows that asymptotically

$$g_N(k) = \frac{C_N^2 \sigma_N^2}{16\pi} \ell n^2 k , \quad a_N(k) = \frac{\gamma_N C_N^2 \sigma_N}{16\pi} \ell n^2 k , \quad (5)$$

where $\gamma^{-1} = \sigma_{e\ell}/\sigma$. Substituting eqs. (5) into (4), we obtain

$$\delta\sigma = \frac{4 C_p C_n \sigma_p \sigma_n}{\gamma_p C_p^2 \sigma_p + \gamma_n C_n^2 \sigma_n} [1 + O(k^{-2})] . \quad (6)$$

If we assume the Okun-Pomeranchuk theorem[9] concerning the asymptotic equality $f_p = f_n$, which is already well satisfied at present accelerator energies, then eq. (6) simplifies asymptotically to

$$\delta\sigma = 2\,\sigma/\gamma = 2\sigma_{e\ell} \,. \qquad (7)$$

We note that in (7) $\delta\sigma > 0$, in contrast with the usual result $\delta\sigma < 0$. This difference is due to the fact that in eq. (3) each amplitude f_N is mainly real in our case, but mainly imaginary in the usual case. Under the more restrictive assumption of the dominance of f_N by the exchange of the Pomeranchuk trajectory, and hence of the validity of the Pomeranchuk theorem, the asymptotic behaviour $\delta\sigma \to 0^-$ was established in[10] independently of $\gamma(k)$. In our case, on the other hand, the asymptotic limit of $\delta\sigma$ is positive, since $\lim \sigma_{e\ell} \neq 0$[11,12].

If the Pomeranchuk theorem is violated, the logarithmic growth of a_N, and consequently the applicability of eq. (6), becomes effective only at energies very much higher than those of existing accelerators[6]. Thus, although one would expect to observe a practically constant value of σ_d in the large energy region in which σ_N is already constant and eq. (2) is valid, σ_d would attain its asymptotic value only at much higher energies.

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