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Modification of the Chew-Low Formula for the $(3/2, 3/2)$ π -N Resonance

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The theory of Chew and Low for π -N scattering results in a formula, containing two parameters, which may be used to fit the observed phase shifts. It is most useful in the case of the $T=3/2$, $J=3/2$ state which contains the well-known resonance at approximately 200 MeV (lab.). The usual form ¹⁾ is :

$$\frac{\eta^3}{\omega^*} \cot \alpha_{33} = \frac{3}{4f^2} \left(1 - \frac{\omega^*}{\omega_0} \right) \quad (1)$$

where $\eta = \frac{p}{m_\pi c}$ and p is the pion c.m. momentum, $(m c^2 \omega^*)$ is the π -N c.m. energy less one nucleon mass, ω_0 is the resonance value and f is the coupling constant. For $\omega^* < \omega_0$ the straight line form of (1) agrees well with experiment but for $\omega^* > \omega_0$ there is serious disagreement, as one might expect for a theory derived in a low energy approximation. However, it is possible to obtain good agreement with the data by noting that (1) actually ²⁾ should contain $\eta^3 [V(k)]^2$ in place of η^3 . As explained by Wick

$$V(k) = \int e^{i\vec{k} \cdot \vec{x}} \rho(\vec{x}) d\vec{x} \quad (2)$$

where K is the wave number ($K = \eta \left(\frac{\hbar}{m_\pi c} \right)$) and $\rho(\vec{x})$ is the "extended source distribution" for the nucleon. In formula (1) $V(K)=1$ and $\rho(\vec{x})=\delta(\vec{x})$. Actually, in a convergent theory one must introduce a cutoff. Instead of the usual sharp cutoff at $\omega^* = M/m_\pi$ (M = nucleon mass), I have considered the following :

$$\rho(\vec{x}) = \frac{a^2 e^{-ar}}{4\pi r} \quad (3)$$

This is a Yukawa source distribution, and yields a smooth cutoff for $V(K)$ or $V(\eta)$:

$$V(K) = \frac{1}{1 + K^2 a^2} \quad (4)$$

Introducing this into (1) it is possible to fit the data with $a^{-1} = 0.38$ f ($0.27 \frac{\hbar}{m_\pi c}$ or $1.8 \frac{\hbar}{Mc}$). The other constants are approximately in agreement with those of Johnson and Camac ³⁾ :

$$r^2 = 0.087$$

$$\omega_0 = 2.17$$

Since the Chew-Low theory is for a non-relativistic static nucleon problem and relies on the assumption that a complicated integral expression ⁴⁾ can be approximated as a constant effective range (or equivalently ω_0), the agreement achieved with (4) may be fortuitous. Nevertheless it is interesting to note that the simple application of a more "realistic" nucleon source of approximately nucleonic dimensions brings theory and experiment together, as shown in the figure.

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FIGURE CAPTION

A Chew-Low plot for two values of $V(K)$ is shown above. The points are from the data of references ^{5),6),7)} and ⁸⁾. The straight line is for $f^2 = 0.087$, $\omega_0 = 2.17$.