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To cite this version:
A. Gersten. DISCRETE AMBIGUITIES AND SOME PECULIARITIES OF N-N AMPLITUDES. Journal de Physique Colloques, 1985, 46 (C2), pp.C2-471-C2-473. <10.1051/jphyscol:1985258>. <jpa-00224574>

HAL Id: jpa-00224574
https://hal.archives-ouvertes.fr/jpa-00224574
Submitted on 1 Jan 1985
DISCRETE AMBIGUITIES AND SOME PECULIARITIES OF N-N AMPLITUDES

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Abstract - The applications of the zeros method are reviewed. The reconstruction of the n-p amplitudes and amplitude regularities are discussed.

The method of zeros\(^1\)\(^,\)\(^2\) is a useful tool of studying ambiguities of phase shift analyses. It had direct applications in the case of scattering of spin zero particles\(^3\), spin \(\frac{1}{2}\) on spin zero particles\(^1\)\(^1\)\(^1\)\(^1\) and in \(NN \rightarrow \pi\pi\) scattering\(^5\)\(^,\)\(^6\).

The case of elastic N-N scattering was studied by Manolessou-Grammaticou\(^7\) and by Grebenyuk, Komarov and Shklyarevskii\(^8\) who had done a detailed analysis of elastic p-p scattering. The relation of the ambiguities to the transversity amplitudes was pointed out in Ref. 9. In the above papers the ambiguities are based on the 5 observables \(\sigma = \sigma/d\Omega, P_{AA}, D_{NN}, C_{NN}, K_{NN}\) and on 3 total cross sections. The application of the method of zeros to the above set of observables is rather limited because usually other observables are measured (Wolfenstein parameters) and there are constraints on the residues at the pion and photon poles. In ref. 8 are presented two ambiguous sets of p-p phase shifts at energies approaching 1 GeV.

The application to the study of the existence of the dibaryon resonances is also limited because of the very large background and because of a lack of an evidence of Regge trajectories passing through the suspected dibaryon resonances and through states of lower angular momenta as well (\(3P_1\) before \(3P_3\) and \(1S_0\) before \(1D_2\), although the antibound \(1S_0\) state can be considered as a Regge pole).

I would like to present here a formula which greatly facilitates the computation of zeros and ambiguities for any spin using the variable \(\phi = e^{i\theta}\). Let a helicity amplitude \(\phi(\theta)\) be given in the form
Then usually the ambiguities are obtained by complex conjugation of the zeros of transversity amplitudes in the $\omega$ plane. The transversity amplitudes are linear combinations of the helicity amplitudes and in this case the use of formula (2) simplifies greatly the computations.

At present there are not enough experiments available for a unique determination of the n-p amplitudes above 500 MeV. It is of interest to point out that with the knowledge of isospin 1 amplitudes (from p-p scattering) and the 5 mentioned observables for n-p scattering, it would be possible (within some sign ambiguities) to determine the n-p amplitudes.

We shall present the results for the transversity amplitudes using the notation of ref. 10. We shall also use the notation $T_j^I(\theta) \equiv T_j^I j=1,..,5$; $I=0, 1$ (isospin), $A_\parallel \equiv a$, $A_2 \equiv A_2$, $A_3 \equiv \omega_3$, $A_4 \equiv A_4$ (for n-p observables) and $T_j^I(\theta) = |T_j^I(\theta)| \exp [i\alpha_j^I(\theta)]$.

The results for the transversity amplitudes $T_j^O$ are:

$$|T_j^O|^2 = |T_j^I|^2 + \sum_k B_{jk} A_k(-\theta) + \sum_k C_{jk} A_k(\pi-\theta)$$

(3)

$$2|\tau_j^O|\tau_j^I \cos [\alpha_j^O(\theta) - \alpha_j^I(\theta)] = \sum_k B_{jk} A_k(-\theta) - \sum_k C_{jk} A_k(\pi-\theta)$$

(4)

where

$$\begin{pmatrix} B_{jk} \end{pmatrix} = \begin{pmatrix} 1 & 4 & 1 & 1 & 1 \\ -1 & 4 & 1 & 1 & 1 \\ 1 & 0 & 1 & -1 & -1 \\ 1 & 0 & 1 & -1 & 1 \\ 1 & 0 & -1 & 1 & -1 \end{pmatrix} \quad \begin{pmatrix} C_{jk} \end{pmatrix} = \begin{pmatrix} 1 & -4 & 1 & 1 & 1 \\ 1 & 4 & 1 & 1 & 1 \\ 1 & 0 & -1 & 1 & -1 \\ 1 & 0 & -1 & 1 & 1 \\ 1 & 0 & 1 & -1 & -1 \end{pmatrix}$$

The amplitude ambiguities could be further reduced if regularities or constraints can be found. It seems to me that the N-N repulsive core should be better understood and explored in phenomenological and high energy models. An attempt in this direction is the no-exchange model (NEM). I will present here a generalization of the model for any spin, starting from the representation

$$\frac{2}{q^2 \mu^2} \int_0^\infty j_\nu(qr) k_\nu(\mu r) r^2 dr,$$

(5)

where $j_\nu$ and $k_\nu$ are spherical Bessel functions, $q = \sqrt{-t}$, $t$ is the 4-momentum transfer squared, $\nu = (\lambda_1 - \lambda_2) - (\lambda_3 - \lambda_4)$; $\lambda_1, \lambda_2$ are initial helicities and $\lambda_3, \lambda_4$ are
final helicities. The NEM consists of replacing the one particle exchange term of eq (5) by

$$\frac{q^\nu}{q^2+\mu^2} \xrightarrow{\text{NEM}} 2\mu^+ \int\limits_{-\infty}^{\infty} j^v(qr)k^v(\mu r)r^2d_r$$

$$= 2\mu^+ R \left[ u^Rj^v(qR)k^v(\mu R) - qRj^v(qR)k^v(\mu R) \right].$$

The physical meaning of eq (6) is that particles are exchanged only outside the radius $R$. The real parts of the double spin flip N-N helicity amplitudes are described quite well with this model with $R=1.1$ fm assuming the pion exchange for lab energies above 100 MeV up to energies where phase shift analysis is being done.

Very fruitful discussions with D. V. Bugg are highly appreciated.

References
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