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Akbar Ahmadzadeh and Elliot Leader

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We wish to point out a general, rigorous and extremely simple method of analyzing NN and $N\bar{N}$ total cross sections and, as an example, to indicate its application in Regge-type models. Because in this analysis we must know the $\bar{p}n$ total cross section, a primary aim of this letter is also to encourage the experimental measurement of $\sigma_{\bar{p}n}$.

I. Consider NN or $N\bar{N}$ scattering in the s-channel. Examination of the s-channel-to-t-channel crossing matrices indicates that the total (unpolarized) NN or $N\bar{N}$ cross section (s-channel) can be expressed in terms of only one of the five $N\bar{N} \to N\bar{N}$ spin-transition amplitudes (f_1 through f_5 in the notation of Ref. 1) in the t-channel. This transition can take place with parity $P = \pm 1$ and isospin $I' = 0$ or 1. Specifically, one finds

$$\sigma^I \begin{pmatrix} NN \\ \\ N\bar{N} \end{pmatrix} = \frac{4\pi}{p\sqrt{s}} (-1)^I \sum_{\substack{I'=0,1 \\ P=\pm 1}} B^{II'} \begin{pmatrix} P \\ \\ 1 \end{pmatrix} g(P, I'; s) , \tag{1}$$

where $B^{II'}$ is an element of the well-known isospin crossing matrix,[1] and we have $s = 4m^2 + 2m\,T$, $p = \left(\frac{mT}{2}\right)^{1/2}$ (T is the laboratory kinetic energy), and

$$g(P,\ I;\ s) = -P\ \mathrm{Im}\ f_2\ (P,\ I;\ s,\ t = 0)\ . \tag{2}$$

Here f_2 is one of the $N\overline{N}$ (t-channel) spin-triplet transition amplitudes.[1]

Thus the four independent experimental cross sections can be expressed in terms of the four functions $g(P,\ I)$ as

$$\sigma_{pp} = \frac{2\pi}{p\sqrt{s}}\,\{g(+,\ 0) - g(-,\ 0) - g(-,\ 1) + g(+,\ 1)\},$$

$$\sigma_{pn} = \frac{2\pi}{p\sqrt{s}}\,\{g(+,\ 0) - g(-,\ 0) + g(-,\ 1) - g(+,\ 1)\},$$

$$\sigma_{\overline{p}p} = \frac{2\pi}{p\sqrt{s}}\,\{g(+,\ 0) + g(-,\ 0) + g(-,\ 1) + g(+,\ 1)\},$$

$$\sigma_{\overline{p}n} = \frac{2\pi}{p\sqrt{s}}\,\{g(+,\ 0) + g(-,\ 0) - g(-,\ 1) - g(+,\ 1)\}. \tag{3}$$

The above results are generally valid and apply at all energies. They are particularly useful in the high-energy region since almost all theoretical models of high-energy scattering calculate, as primary quantities, the t-channel $N\bar{N}$ amplitudes of definite parity and isospin. Inversion of Eq. (3) provides a unique set of four functions directly related to four experimental quantities, namely:

$$g(+, 0) = \frac{p\sqrt{s}}{8\pi}\left[\sigma_{pp} + \sigma_{pn} + \sigma_{\bar{p}p} + \sigma_{\bar{p}n}\right]$$

$$g(-, 0) = \frac{p\sqrt{s}}{8\pi}\left[- \sigma_{pp} - \sigma_{pn} + \sigma_{\bar{p}p} + \sigma_{\bar{p}n}\right]$$

$$g(-, 1) = \frac{p\sqrt{s}}{8\pi}\left[- \sigma_{pp} + \sigma_{pn} + \sigma_{\bar{p}p} - \sigma_{\bar{p}n}\right]$$

$$g(+, 1) = \frac{p\sqrt{s}}{8\pi}\left[\sigma_{pp} - \sigma_{pn} + \sigma_{\bar{p}p} - \sigma_{\bar{p}n}\right] . \qquad (4)$$

Once the energy dependence of the functions $g(P, I)$ is known, these functions can be analyzed in terms of any specific model under consideration. The contribution of any model to the $g(P, I)$ can be obtained directly if it is expressed in terms of the quantum numbers of the t-channel, or by an application of the known crossing matrices.[1,2]

II. We illustrate here the use of these equations in the Regge model. In the Regge model the correspondence with the four trajectory families is

$g(+, 0) \longrightarrow$ Pomeranchuk family

$g(-, 0) \longrightarrow \omega$ family

$g(-, 1) \longrightarrow \rho$ family

$g(+, 1) \longrightarrow R$ family.

Note that of the twelve possible sets of trajectory quantum numbers coupled to the $N\bar{N}$ system,[3] only the above four contribute to f_2 and therefore to the total s-channel cross sections. The R-trajectory[4] has not usually been included in Regge-pole analyses, since there is no known resonance with its quantum numbers, $I(J^{PG}) = 1(J^{--}_{even})$. However, in a systematic analysis it should be included, and Eqs. (4) would indicate whether its effect is negligible or not.

Considering the relatively high-energy region, we expect that only t-channel contributions are significant. Then from Eq.(2) the contribution of any Regge pole to the g(P, I) of its family is

$$B_{P,I}\,(2\alpha_{P,I} + 1)\,P_{\alpha_{P,I}}\left(\frac{m + T}{m}\right), \tag{5}$$

where $B = \beta e^{i\pi\alpha}$ is the modified residue of the trajectory.

Incidentally, note that from Eqs.(3), in contrast to

$\sigma_{\overline{pp}}$, we expect that $\sigma_{\overline{pn}}$ should <u>increase</u> towards its asymptotic value.

In conclusion, Eq.(4) offers a simple and systematic scheme for analyzing theoretical models in terms of the experimental cross sections.

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FOOTNOTES AND REFERENCES

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1. M. L. Goldberger, M. T. Grissaru, S. W. MacDowell, and D. Y. Wong, Phys. Rev. 120, 2250(1960).

2. The crossing matrices are implicit in Ref. (1). A complete account of these matrices will be given in a subsequent paper.

3. I. J. Muzinich, Phys. Rev. 130, 1571(1963).

4. A. Pignotti, Lawrence Radiation Laboratory Report UCRL-11152, December 3, 1963, submitted to Phys. Rev. Letters; A. Ahmadzadeh, Lawrence Radiation Laboratory Report UCRL-11164, December 16, 1963, submitted to Phys. Rev. Letters.