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A SYSTEMATIC APPROACH TO THE ANALYSIS OF EN AND NN TOTAL CROSS SECTIONS

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Berkeley, California

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Akbar Ahmadzadeh and Elliot Leader

January 8, 1964

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A SYSTEMATIC APPROACH TO THE ANALYSIS  
OF NN AND  $\bar{N}\bar{N}$  TOTAL CROSS SECTIONS\*

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We wish to point out a general, rigorous and extremely simple method of analyzing NN and  $\bar{N}\bar{N}$  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  $\bar{N}\bar{N}$  scattering in the s-channel.

Examination of the s-channel-to-t-channel crossing matrices indicates that the total (unpolarized) NN or  $\bar{N}\bar{N}$  cross section (s-channel) can be expressed in terms of only one of the five  $\bar{N}\bar{N} \rightarrow \bar{N}\bar{N}$  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

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

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

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

Here  $f_2$  is one of the  $\bar{N}N$  (t-channel) spin-triplet transition amplitudes.<sup>1</sup>

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

$$\begin{aligned} \sigma_{pp} &= \frac{2\pi}{p\sqrt{s}} \{g(+, 0) - g(-, 0) - g(-, 1) + g(+, 1)\}, \\ \sigma_{pn} &= \frac{2\pi}{p\sqrt{s}} \{g(+, 0) - g(-, 0) + g(-, 1) - g(+, 1)\}, \\ \sigma_{\bar{p}p} &= \frac{2\pi}{p\sqrt{s}} \{g(+, 0) + g(-, 0) + g(-, 1) + g(+, 1)\}, \\ \sigma_{\bar{p}n} &= \frac{2\pi}{p\sqrt{s}} \{g(+, 0) + g(-, 0) - g(-, 1) - g(+, 1)\}. \end{aligned} \quad (3)$$

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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  $\bar{N}\bar{N}$  amplitudes of definite parity and isospin. Inversion of Eq. (3) provides a unique set of four functions directly related to four experimental quantities, namely:

$$\begin{aligned}
 g(+, 0) &= \frac{p\sqrt{s}}{8\pi} \left[ \sigma_{pp} + \sigma_{pn} + \sigma_{\bar{p}\bar{p}} + \sigma_{\bar{p}\bar{n}} \right] \\
 g(-, 0) &= \frac{p\sqrt{s}}{8\pi} \left[ -\sigma_{pp} - \sigma_{pn} + \sigma_{\bar{p}\bar{p}} + \sigma_{\bar{p}\bar{n}} \right] \\
 g(-, 1) &= \frac{p\sqrt{s}}{8\pi} \left[ -\sigma_{pp} + \sigma_{pn} + \sigma_{\bar{p}\bar{p}} - \sigma_{\bar{p}\bar{n}} \right] \\
 g(+, 1) &= \frac{p\sqrt{s}}{8\pi} \left[ \sigma_{pp} - \sigma_{pn} + \sigma_{\bar{p}\bar{p}} - \sigma_{\bar{p}\bar{n}} \right]. \quad (4)
 \end{aligned}$$

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.<sup>1,2</sup>

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

$$\begin{aligned}
 g(+, 0) &\longrightarrow \text{Pomeranchuk family} \\
 g(-, 0) &\longrightarrow \omega \quad \text{family} \\
 g(-, 1) &\longrightarrow \rho \quad \text{family} \\
 g(+, 1) &\longrightarrow R \quad \text{family.}
 \end{aligned}$$

Note that of the twelve possible sets of trajectory quantum numbers coupled to the  $\bar{N}N$  system,<sup>3</sup> only the above four contribute to  $f_2$  and therefore to the total s-channel cross sections. The R-trajectory<sup>4</sup> has not usually been included in Regge-pole analyses, since there is no known resonance with its quantum numbers,  $I(J^{PG}) = 1(J_{\text{even}}^{--})$ . 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

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

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

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



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$\sigma_{pp}$ , we expect that  $\sigma_{pn}$  should increase 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

- \* Work done under the auspices of the U. S. Atomic Energy Commission.
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