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

Authors
Ahmadzadeh, Akbar
Leader, Elliot.

Publication Date
1964-01-08

UCRL-11192

University of California

Ernest O. Lawrence Radiation Laboratory

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

Berkeley, California

Non-Standard Phys. Rev. Letters

UCRL-11192

UNIVERSITY OF CALIFORNIA

Lawrence Radiation Laboratory
Berkeley, California

AEC Contract No. W-7405-eng-48

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

Akbar Ahmadzadeh and Elliot Leader

January 8, 1964

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

Akbar Ahmadzadeh and Elliot Leader

Lawrence Radiation Laboratory
University of California
Berkeley, California

January 8, 1964

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 $N\bar{N} \rightarrow N\bar{N}$ 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 $N\bar{N}$ (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

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

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

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

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

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:

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

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.[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

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

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

σ_{pp}^{-}, we expect that σ_{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.

ACKNOWLEDGMENT

The authors are indebted to Professor Geoffrey Chew for suggestions and encouragement.

FOOTNOTES AND REFERENCES

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

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.