CHAPTER X

STUDY OF INDIVIDUAL REGGE TRAJECTORIES

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It is known that if the photoproduction amplitude $T$ can be written in the form

$$(10.1) \, T = A^\mu < | j^{\mu}^{2\text{.m.}} | >$$

where $J^{\text{em.}}$ is the electromagnetic part of the total hadronic current and $A^\mu$ denotes the electromagnetic field and the matrix element is to be taken between only the hadronic states, the current can be decomposed in terms of an isoscalar and an isovector part

$$(10.2) \, j^{\mu}^{\text{2.m.}} = j^{(s)} \mu + j^{(v)} \mu$$

which transforms under $G$ parity in the following way:

$$(10.3) \, G \, j^{(s)} \, G^{-1} = -j^{(s)} \mu$$

$$(10.4) \, G \, j^{(v)} \, G^{-1} = j^{(v)} \mu$$

We are interested to find which are the possible exchanged particles, between $\gamma (\eta, \eta', \xi, \omega, \phi, \rho, \rho')$ and $\bar{NN}$ pair (Diagram 1) where each particle in the bracket corresponds to different photoproduction process:
To determine the exchanged particles we demand the C-parity and isospin invariances. For example, let us find the exchanged mesons in $\pi^0$ photoproduction. If $j_\mu = j^{(a)}_\mu$, then for the right-hand vertex in the diagram 1

$$\langle \pi^0 | j^{(a)}_\mu | x \rangle$$

will be nonzero only for those exchanged particles whose C-parity is +1 and isospin 1 because for $\pi^0$, C=+1 and I=1. The particles with $G=+\frac{3}{2}$ and I=1 are $B$ and $\phi$. Thus we find that $B$ and $\gamma$ exchanges contribute only to the isoscalar part of the photoproduction amplitude. Similarly, for

$$j_\mu = j^{(b)}_\mu, \quad \langle \pi^0 | j^{(b)}_\mu | x \rangle$$

will be nonzero only for those exchanged particles for which C=−1 and I=0. The particles having these quantum numbers are $\omega$ and $\phi$. Thus $\omega$ and $\phi$ exchanges will contribute only to the isovector part of the amplitude.

In a similar way we can find the possible exchanged
particles corresponding to the photoproduction of \( \eta^\pm, \omega^0, \phi^0, \eta^0, \rho^0 \) and \( \rho^\pm \) mesons. In Table 12 we give the list of all these exchanged particles.

Regge pole model claims that the objects being exchanged in these different processes are not the mesons, but instead something which are related to the meson trajectories \( \alpha^0 \) for which \( \text{Re} \, \ell \) (\( \ell = \text{meson mass} \)) = spin of the particle thus introducing a moving spin of the exchanged particle.

Further, in Regge theory the various trajectories and the residues of the poles are unknown functions, the values of which are to be obtained by comparing theory with experiment. This comparison is made difficult by the fact that, in any particular reaction several trajectories contribute in general to the photoproduction amplitude. In consequence, our present knowledge of the Regge trajectories are quite meagre. However, as early as 1964 Kramer and Stichsel (1) made an interesting remark that in the case of \( \pi^0 \) photoproduction the contribution out of the

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(1) G. Kramer and P. Stichsel, Zeits. fur Physik 178 (1964) 519.
four trajectories $\omega$, $\phi$, $\rho$ and $\pi$ could be separated by pion photoproduction on nuclei with isotopic spin zero. This has also been emphasized by V.A. Tsyarev in a recent preprint (2) where he has observed that by measuring the cross-section of photoproduction of pion on nuclei it is possible to study the Regge trajectories of $\omega$-meson assuming the $\gamma\phi\pi$ coupling to be weak.

Stichel (3) has shown that at high energy limit ($e \rightarrow \infty$), the experiment with photons polarized perpendicular to the production plane select out amplitude due to the natural spin-parity ($P(-1)^J = +1$) whereas photons polarized parallel to the production plane select out the amplitude due to the unnatural spin-parity ($P(-1)^J = -1$).

We wish to suggest that if we consider inelastic photoproduction processes leading to appropriately chosen excited state of the nuclear system using linearly polarized photons we can isolate different Regge trajectories entering into the amplitude of the

(2) V.A. Tsyarev, Yadernaya Fizika 10 (1969) 375.
(3) P. Stichel, Zeit. fur. Physik 180 (1964) 170.
different photoproduction reactions; thus we can better study the individual Regge trajectories by studying nuclear photoproduction phenomena. However, to isolate the trajectories let us replace the N-Reggeon $\bar{N}$ vertex in diagram 1 by A-Reggeon $\bar{A}$, as in diagram 2:

![Diagram 2](image)

where $A$ is a nucleus with isospin, $I=0$. For example, if we take $^{12}$C or $^{16}$O to be the nucleus and consider inelastic photoproduction of $\pi^0$ meson leading to any one of the so many excited levels that exist with $I=1^+$, out of the four $\phi, \omega, \rho, B$ trajectories isospin conservation will restrict only $\gamma$ and $B$ trajectories to be exchanged. We find that $\rho$ has natural parity $(F=\pi(-1)^J=1)$ whereas the $B$ trajectory has unnatural parity $(F=\pi(-1)^J=-1)$. Therefore, if we make an experiment with photon polarized perpendicular to the

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production plane the $\rho$ trajectory gets isolated whereas if we make an experiment with photon polarized parallel to the production plane, the $B$ trajectory gets isolated.

Similarly if we look at the Table 12 we find that in the case of photoproduction of $\rho$ or $\phi$ meson $A_1$, $A_2$, $\pi$, $X^0$, $f_1$, $f_2$, $D$, $\gamma$, $\eta$ are the possible exchanges. As we did before, if we take the target to be a nucleus like $^{12}\text{C}$ or $^{16}\text{O}$, and consider inelastic transitions leading to the excited levels with $I=1$, $A_1$, $A_2$ and $\pi$ trajectories can only contribute due to isospin conservation. Out of these three $A_1$, $A_2$ and $\pi$ trajectories $A_2$ possesses natural parity ($P^i=P(-1)^{z+1}$) whereas $A_1$ and $\pi$ have unnatural parity ($P^i=P(-1)^{z-1}$) thus, the experiment with photons polarized perpendicular to the production plane will isolate the $A_2$ trajectory whereas experiment with photon polarized parallel to the production plane will separate the $A_1$ and $\pi$ trajectories. Now the problem remains to isolate $A_1$ and $\pi$. If, in particular, we consider the photoproduction of $\phi$ meson in the above discussion we can isolate the $A_1$ trajectory because of the very
weak $\gamma\pi\phi$ coupling at the meson vertex in diagram 2.

We give below the processes which isolate different trajectories:

<table>
<thead>
<tr>
<th>Process</th>
<th>Isolated trajectory</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\gamma + A (I=0) \to \pi^0 + A (I=0)$</td>
<td>$\omega$</td>
</tr>
<tr>
<td>$\gamma + A (I=0) \to \pi^0 + A^* (I=1)$</td>
<td>$\gamma$</td>
</tr>
<tr>
<td>$\gamma + A (I=0) \to \pi^+ + A^* (I=1)$</td>
<td>$B$</td>
</tr>
<tr>
<td>$\gamma + A (I=0) \to \phi + A^* (I=1)$</td>
<td>$A_2$</td>
</tr>
<tr>
<td>$\gamma + A (I=0) \to \phi + A^* (I=1)$</td>
<td>$A_1$</td>
</tr>
</tbody>
</table>
Table 12

The exchanged particles in the t-channel in the reaction $\gamma p \rightarrow \text{meson} + N$

<table>
<thead>
<tr>
<th>Final state</th>
<th>Exchanged particles contributing to isoscalar amplitude</th>
<th>Exchanged particles contributing to the isovector part of the amplitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>$N\pi^0$</td>
<td>$B^0, \rho^0$</td>
<td>$\omega, \phi$</td>
</tr>
<tr>
<td>$N\pi^\pm$</td>
<td>$B^\pm, \gamma^\pm$</td>
<td>$A^\pm, A^\pm, \pi^\pm$</td>
</tr>
<tr>
<td>$N\gamma^0$</td>
<td>$\omega, \phi$</td>
<td>$B^0, \rho^0$</td>
</tr>
<tr>
<td>$N\omega^0$</td>
<td>$E, D, X^0, f^0, f, \eta, \eta$</td>
<td>$A_1^0, A_2^0, \pi^0$</td>
</tr>
<tr>
<td>$N\phi^0$</td>
<td>$\sim$</td>
<td>$\sim$</td>
</tr>
<tr>
<td>$N\phi^0$</td>
<td>$A_1^0, A_2^0, \pi^0$</td>
<td>$E, D, X^0, f^0, f, \eta, \eta$</td>
</tr>
<tr>
<td>$N\phi^\pm$</td>
<td>$A_1^+, A_2^+ , \pi^\pm$</td>
<td>$B^\pm, \phi^\pm$</td>
</tr>
</tbody>
</table>