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Slope-Mass-Correlation in Diffractive Dissociation Reactions

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Abstract We present in this paper a set of new results of new Three Component Deck Model for Diffractive Dissociation Reactions. These new results are confronted with recently published ones to obtain a general view of the model, its predictions and comparison with experimental results. Two kinds of correlations and amplitudes are given: the slope-mass-cos θ^{GJ} and slope-mass-partial wave correlations.

1. INTRODUCTION

One of the most important parts of high energy scattering is the Inelastic diffractive component or diffraction dissociation. The Three Component Deck Model (TCDM) gives a very good description of the dlffractive dissociation phenomena. We have made[1] applications of the model to severa1 reactions, with very good results. Other applications are presented in the present paper, giving a certain universalizationto the model. In this paper we confront the previous results with the new appllcatlons of the TCDM, exhibiting a general view of its main properties. For a general review of all diffractive aspects of scattering, see reference 2.

Similarly to other aspects of the scattering process, the inelastic part has also soft and hard components in the physical regions. While the soft component has been very much studied and is described by good models, the hard component appears at high energies and very large momentum transfers, and is due to the interactionsofthe hadron constituents. It is an apen subject.

In this paper we limit ourselves to the diffractive dissoclation soft component and specifically to the TCDM [2a]. We have shown

that this model reproduces the maln aspects of the diffractive dissoclatlon reactions (DDR). Here, we put together all new and published results for different reactlons, giving a systematic description of the spin-parity structure. The TCDM is the only model describing, among the maln properties of the data, the mass-slope-cos θ^{GJ} and mass-slope--partial-wave correlatlons. A summary of the improvements, derlvations, spln-parity structures for each reactlon, approximations and hypothesls are given In the next sections. Section 2 is dedicated to the model and the main aspects of its derivation. In section 3 we give the applicatlons of the TCDM to severa1 reactlons with different spin and parity structure in the a + P → i + 2 subreaction (here $\underline{a}$ is the beam-particie, P is the Pomeron exchanged In the complete inelastic reaction and 1 + 2 represents the subsystem in which we study the effective mass distributions and general properties). Partial wave amplitudes for each reactlon are glven in section 4. Finally in section 5 we present the discusslon and conclusions from our study.

2. THREE COMPONENTS DECK MODEL

We present now the general description, propertles and maln parts of the derivations of the TCDM.

In all cases, we have considered a general reaction $a+b\to(1+2)+3$, see fig.1, where b = 3 = nucleon, atvery highenergy, where the diffractlve phenomena are dominant. In TCDM the diffractive character is represented by the Pomeron ($\mathbb{P}$) exchange. The dissociation of the hadron (a) into a pair (1+2) is descrlbed by the coherent sum of the Born terms of the exchange amplitudes of the (a), (1) and (2) particles or the s, u and t channel respectively of the subreaction a + $\mathbb{P}$ → 1 + 2 (see fig. 2). We use a standard parametrlzation of the Pomeron exchange, as described belo~.The two parameters b and σ_T, the slope and the high energy

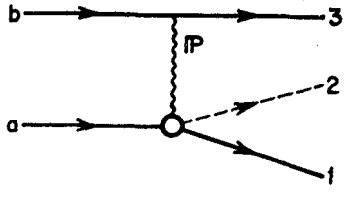

Fig.1 - Single Pomeron exchange in the a + b → (1 + 3) + 2 reaction at high energy.

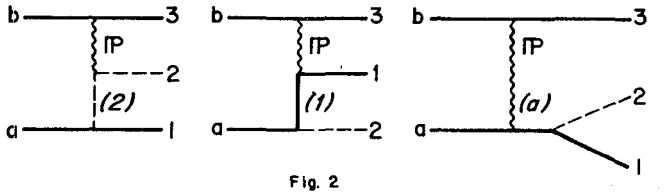

Fig. 2

Fig.2 - The three components of the (TDCM), representing the t_1-channel, u_1-channel and s_1-channel of the a + b → (1+2) + 3 reaction.

total cross section are in general experimentally known. But in ourcase the subreactions $(\underline{2}) + (b) \to (2) + (3{=}b)$, $(\underline{1}) + (b) \to (1) + (3{=}b)$ and (a) + (b) → $(\underline{a})$ + (3=b) are off-mess-shell in the sense that $(\underline{2})$, $(\underline{1})$ and (a) are off-mass-shell particles. Then we must correct theoff-shell problem by changing sllghtly the b and σ_T in each case. This isthe best way to consider indirectly a form *factor* without breaking some other important properties, as the interferences among the three terms.

The well known Gribov-Morrison rule[3], $\Delta P = (-1)^{\Delta J}$, where ΔP and A J are the parity and spin balance between the particles In the diffractive vertex, is automatically satisfied in elastic diffractive subreactlons, which appear In the TCDM.

To obtain the hadronic current coupled to the Pomeron, in TCDM, we assume the vector coupling hypothesis (VCH). On the current constructed with this hypothesis we impose the s-channel helicity conservation (SCHC)*, which simplifies the form of the coupling, and reduces the coupling constants to only one. It is a well known experimental result that in the elastlc dlffractive reactions, dominated by the Pomeron exchange, the Pomeron couples only to the *s*-channel helicity conserving hadronic vertex .

In the high energy approximation (HEA), defined in Appendix A, the current, for a vertex $a(p,\lambda)$ **P** $b(p',\lambda')$ obtained with (VCH), has the general form[5]

$$J^{\beta}_{\lambda'\lambda}(p',p) \underset{\sim}{} (-t)^{|\lambda'-\lambda|/2}\, V(\lambda',\lambda) P^{\beta} \qquad (1)$$

where $t = (p'-p)^2$, $P = (p'+p)/2$ and $V(\lambda',h)$ are functions of the coupling constants, the masses m_a, m_b and the momentum transfer t.

Imposing the SCHC on these currents, they become[1d]

$$J^{\beta}_{\lambda'\lambda}(p',p) \simeq 2g_{a\mathbb{P}b}\, P^{\beta}\, \delta_{\lambda'\lambda} \qquad (2)$$

In the diffractive reglon, dominated by the Pomeron exchange, the hellcity amplitudes are essentially imaginary. For a generic diffractive reaction,

$$a(p,\lambda_a) + b(q,\lambda_b) \rightarrow a(p',\lambda'_a) + b(q',\lambda'_b)$$

the hellcity amplitudes may be written as

$$A(s,t)_{\lambda_a,\lambda_b,\lambda'_a,\lambda'_b} = \frac{i}{2}\, e^{Bt/2}\, J_{\beta;\lambda'_a\lambda_a}\, J^{\beta}_{\lambda'_a\lambda_b} \qquad (3)$$

The relation among the coupling constants, which appear in the currents, and the total cross sectlon is given by the optical theorem

$$g_{aa\mathbb{P}}\, g_{bb\mathbb{P}} = \sigma^{ab}_{\mathrm{Tot}}(s) \qquad (4)$$

Off mass shell corrections must be introduced in the diffractlve amplitudes contained in the TCDM. It is important to emphasize the Inconvenienceof introducing newform factors totake intoaccount off mass shell effects. The complications duetothepresenceofthese form factors could destroy the possible Interferences among the components of TCDM.

The most convenient way to Introduce the off-mann shell effects Is vla small variations of the experimental diffractive slopes (B_{2b},B_{1b} and B_{ab}) and the cross sections values ($\sigma^{2b}_{\mathrm{Tot}}(s_2)$,$\sigma^{1b}_{\mathrm{Tot}}(s_3)$ and $\sigma^{ab}_{\mathrm{Tot}}(s)$).

In the HEA, the general form of the common vertex $b\mathbb{P}3$, conslderlng that b = 3, is given by

$$J^{\beta}_{\lambda_3\lambda_b} \simeq 2g_{b\mathbb{P}}\, R^{\beta}\delta_{\lambda_3\lambda_b} \qquad (5)$$

where $R = (p_b + p_3)/2$.

The factorization property of the pomeron permits to factorize thls common vertex in the TCDM. Thls factorization may be represented as in flg. (3).

A consequence of thls property in the case of the TCDM is that the splns of the $b\mathbb{P}3$ vertex do not affect the general structure of the TCDM. Then, at the HEA, the spins of the particles b and 3 may be neglected, and the current in eq. (5) may be written as

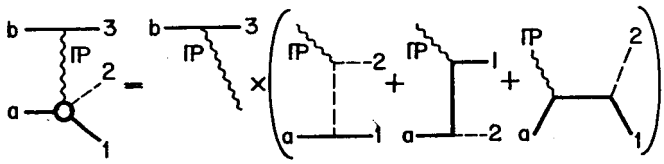

Fig. 3

Fig.3 - Graphical representation of the Pomeron factorization property.

$$J^{\beta} \simeq 2g_{b\mathbb{P}}\, R^{\beta} \tag{6}$$

To materialize the problem and to introduce a standard notation for our applications of TCDM, let us consider a particular type of reaction in which the particle b = 3 is a nucleon and a, 1 and 2 are spinless hadrons.

The amplitudes for each component of the TCDM, represented in fig. (2), with the kinematics defined in Appendix A, are

$$A^{(t)} = \frac{i}{2}\, e^{B_{2b}t_2/2}\,(2g_{b\mathbb{P}}R^{\beta})\,(2g_{2\mathbb{P}}Q_{\beta})\,\frac{1}{t_1-m_2^2}\,g_{a12} \tag{7a}$$

$$A^{(u)} = \frac{i}{2}\, e^{B_{1b}t_2/2}\,(2g_{b\mathbb{P}}R^{\beta})\,(2g_{1\mathbb{P}}P_{\beta})\,\frac{1}{u_1-m_1^2}\,g_{a12} \tag{7b}$$

and

$$A^{(s)} = \frac{i}{2}\, e^{B_{ab}t_2}\,(2g_{b\mathbb{P}}R^{\beta})\,(2g_{a\mathbb{P}}K_{\beta})\,\frac{1}{s_1-m_a^2}\,g_{a12} \tag{7c}$$

To simplify these expressions we define

$$g^{t}(t_2) = \sigma_{tot}^{2b}(s_2)\,e^{B_{2b}t_2/2}$$

$$g^{u}(t_2) = \sigma_{tot}^{1b}(s_3)\,e^{B_{1b}t_2/2}$$

and

$$g^{s}(t_2) = \sigma_{tot}^{ab}(s)\,e^{B_{ab}t_2/2} \tag{8}$$

where, according eq. (4),

$$\sigma_{tot}^{2b}(s_2) = g_{b\mathbb{P}}g_{2\mathbb{P}}\ ,\quad \sigma_{tot}^{1b}(s_3) = g_{b\mathbb{P}}g_{1\mathbb{P}}$$

and

$$\sigma_{tot}^{ab}(s) = g_{b\mathbb{P}} g_{a\mathbb{P}}$$

and also

$$T = ig_{a12} g^{t}(t_2)/(t_1 - m_2^2)$$

$$U = ig_{a12} g^{u}(t_2)/(u_1 - m_1^2) \qquad (9)$$

and

$$S = ig_{a12} g^{s}(t_2)/(s_1 - m_a^2)$$

At the HEA in eq. (A.9), using eq. (A.10) and the definitons above, the components in eq. (7) become

$$A^{(t)} = T = s_2 . T$$

$$A^{(u)} = U = s_3 . U \qquad (10)$$

and

$$A^{(s)} = S = s . S$$

The scattering amplitude is the coherent sum of the three components

$$A = A^{(s)} + A^{(t)} + A^{(u)}$$

Then for reactions with spinless particles in the dissociative vertex,

$$\delta_a = \delta_1 = \delta_2 = 0$$

the TCDM yields

$$A = S + T + U = ig_{a12} \left\{ \frac{s . g^{s}(t_2)}{s_1 - m_a^2} + \frac{s_2 . g^{t}(t_2)}{t_1 - m_2^2} + \frac{s_3 . g^{u}(t_2)}{u_1 - m_1^2} \right\} \qquad (11)$$

The general forms of the components, considering the spin factors, are

$$A^{(s)} = F^{(s)} . S, \quad A^{(t)} = F^{(t)} . T$$

and

$$A^{(u)} = F^{(u)} U$$

where

$$F^{(s)}, \ F^{(t)} \text{ and } F(u)$$

are tunctions of the masses and Invariants in eq. (A.3). It is clear that for splnless particles $F^{(s)} = s$, $F^{(t)} = s_2$ and $F^{(u)} = s_3$.

The components of the TCDM summed up coherently may interfere destructively in some klnematical regions. This interference is the mechanism which gives rise to the correlation among three variables: the diffractlve slope B, the effectlve mass $M_{12} = \sqrt{s_1}$ of the dissociated system, and the polar coordlnate θ^{GJ} of a dissociated particle momentum $\vec{p}_1$ relative to the inclident beam momentum $\vec{p}_a$ in the GJS.

Another feature of thls correlation is the slope-mass-partial wave correlation, which will be studied in section 4. A direct consequence of the Interferences above mentioned is the large slopes and/or the dips obtained in the $d\sigma/dt_2$ distributions.

In the spinless cases it is possible to obtain relatlons that give the positions of the dips and show clearly the correlation among M_{12}, $\cos\theta^{G.J.}$ and t_2.

At HEA, $s \simeq s_2 + s_3$, taking this into the eq. (11) and equal to zero the coefficients of s_2 and s_3, we obtain

$$\begin{aligned} Z_{st} &\equiv g^s(t_2)(t_1-m_2^2) + g^t(t_2)(s_1-m_a^2) = 0 \\ Z_{su} &\equiv g^s(t_2)(u_1-m_1^2) + g^u(t_2)(s_1-m_a^2) = 0 \end{aligned} \tag{12}$$

Some observatlons may be made about these equations:

a) they may be satlsfied In the physical region, slnce In this region $s_1-m_a^2$ is positlve whereas $t_1-m_2^2$ and $u_1-m_1^2$ are negative.

b) they may be rewrltten as

$$\begin{aligned} \cos\theta^{GJ} &= f_1(t_2) \\ M_{12} &= f_2(t_2) \end{aligned} \tag{13}$$

which show clearly the correlation among the three variables M_{12}, $\cos\theta^{GJ}$ and t_2, predlcted by this model.

c) the factorlzation of the elastic vertex $bP3$ In the TCDM, according to fig. (3), shows that the position (M_{12}, $\cos\theta^{GJ}$, t_2) of the zero in the amplitude, or of the dlp in $d\sigma/dt_2$, is independent of the hadron b.

d) the parameters that fix the position of the zeros of the amplitudes are the total crors sectlons $\sigma_{tot}^{ib}(s)$ and the elas-

tic slopes B_{ib} $(i = a,1,2)$.

Dual Reggeization of TCDM

In the present form of the TCDM, each component is the Born term of the amplitudes for exchange of the particles a, 1 and 2. The validity of the model is restricted to the effective mass $M_{12} = (\sqrt{s_1})$ range between the threshold and the resonances of the dissociated subsystem 1+2.

The need for reggelzation has been known since the beglnning of the DDR fenomenology development,

The reggeization of the TCDM must be done with some care. The components of exchange of particles a, 1 and 2 must be handled in a symmetric way, because the interferences that generate the slope-mass-cose[G-] correlation must not be lost in the course of the process.

The solution of this problem is given by duality, which provides a Regge behaviour for the three channels, avoiding double counting and treating all channels in a symnetric way[ia].

The procedure for dual reggelzation of the TCDM in the spinless case has been performed[iia] using the Venezlano formula

$$A = ig_{a12}\left\{s_3 Z_{su}\frac{\Gamma(-\alpha_s)\Gamma(-\alpha_u)}{\Gamma(1-\alpha_s-\alpha_u)} + s_2 Z_{st}\frac{\Gamma(-\alpha_s)\Gamma(-\alpha_t)}{\Gamma(1-\alpha_s-\alpha_t)}\right\} \qquad (14)$$

where

$$a_s = s_1 - m_a^2, \quad \alpha_t = t_1 - m_2^2 \quad \text{and} \quad a_u = u_1 - m_1^2$$

3. APPLICATIONS OF TCDM TO SEVERAL TYPES OF DDR

In thls sectlon we collect several results of the applicatlons of TCDM. The DDR studled here have different configurations of spin and parlty in the dissociatlve vertex (a → 1 + 2). These configuratlons will be denoted as $\delta_a^P \to \delta_1^P, \delta_2^P$.

The followlng configurations are analysed here

$$A - (0^- \to 0^+, 0^-)$$

$$B - (0^- \to 1^-, 0^-)$$

$$C - (1/2^+ \to 1/2^+, 0)$$

and

$$D - (1/2^+ \to 3/2^+,\ 0^-)$$

Some examples of reactions that correspond to these structures of spin and parity are

$$A - \pi + p \to (\varepsilon + a) + p$$

$$K + p \to (\kappa + \pi) + p$$

$$B - \pi + p \to (\rho^0 + \pi) + p$$

$$K + p \to (K^* + \pi) + p$$

$$C - p + p \to (n + \pi^+) + p$$

$$p + p \to (\Lambda + K^+) + p$$

$$D - p + p \to (\Delta^{++} + \pi^-) + p$$

The TCDM amplitudes for DDR of type A have already been obtained in the precedent section.

For reactions of type B, using the kinematics of Appendix A the components of TCDM are

$$A^{(t)}_{\lambda_1} = \frac{i}{2} e^{B_{b2} t_2/2} (2g_{b\mathbb{P}} R^\beta)(2g_{2\mathbb{P}} Q_\beta) \frac{1}{t_1 - m_2^2} g_{a12}\, \varepsilon^*_\mu(p_1,\lambda_1) p_a^\mu$$

$$A^{(s)}_{\lambda_1} = \frac{i}{2} e^{B_{ab} t_2/2} (2g_{b\mathbb{P}} R^\beta)(2g_{a\mathbb{P}} K_\beta) \frac{1}{s_1 - m_a^2} g_{a12}\, \varepsilon^*_\mu(p_1,\lambda_1) p_2^\mu \qquad (15)$$

$$A^{(u)}_{\lambda_1} = \frac{i}{2} e^{B_{1b} t/2} (2g_{b\mathbb{P}} R_\beta) \varepsilon^*_\mu(p_1,\lambda_1) \Gamma^{\mu\beta\nu} \frac{(-g_{\nu\sigma} + k_\nu k_\sigma/k^2)}{u_1 - m_1^2} g_{a12} (p_a + p_2)^\sigma/2$$

where $\varepsilon_\mu(p_1,\lambda_1)$ is the wave function for spin 1 particles and

$$\Gamma^{\mu\beta\nu} = 2g_{1\mathbb{P}} \left[2(g^{\mu\beta} p^\nu + p^\mu g^{\beta\nu}) - g^{\mu\nu} p^\beta \right] \qquad (16)$$

is the s-channel helicity conserving coupling in the vertex $1^-\mathbb{P}1^-$.

In the HEA, using the notation introduced in section 2, those components may be written as

$$A^{(t)}_{\lambda_1} \underset{\sim}{=} T\, \varepsilon^*_\mu(p_1,\lambda_1) p_a^\mu$$

$$A^{(s)}_{\lambda_1} \underset{\sim}{=} S\, \varepsilon^*_\mu\, p_1,\lambda_1\, p_2^\mu$$

and

$$A_{\lambda_1}^{(u)} \sim \left[U p_a^\mu + s\, U (p^\mu - p_a^\mu) - U R^\mu (s_1 + m_a^2 - m_2^2 - t_1)/4 \right] \varepsilon_\mu^*(p_1, \lambda_1) \qquad (17)$$

In the G.J.S. we have

$$p_a^\mu = E_a E^\mu + |\vec{p}_a| Z^\mu \text{ and } p^\mu = \sqrt{s_1}\, E^\mu \qquad (18)$$

and for HEA

$$R^\mu \sim \frac{s}{2\sqrt{s_1}} (E^\mu + \sin a\, X^\mu + \cos \alpha\, Z^\mu) \qquad (19)$$

where

$$E^\mu = , \qquad X^\mu = \begin{pmatrix} 0 \\ 1 \\ 0 \\ 0 \end{pmatrix} \text{ and } Z^\mu = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \end{pmatrix} \qquad (20)$$

Taking these results into eqs.(17) and summing up the components, the helicity amplitudes read

$$\begin{aligned} A_{\lambda_1} = {} & \{\sqrt{s_1}\, S + E_a T + E_a U + s\, U(m_1^2 + m_2^2 - m_a^2 + t, - u_1)/4\sqrt{s_1}\} \varepsilon_\mu^*(p_1, \lambda_1) E^\mu \\ & + \{s_2 |\vec{p}_a| \tau + s\, U[|\vec{p}_a| - (s_1 + m_a^2 - m_2^2 - t_1)\cos \alpha/4\sqrt{s_1}]\}\, \varepsilon_\mu^*(p_1, \lambda_1) Z^\mu \\ & - [s\, U(s_1 + m_a^2 - m_2^2 - t_1)\sin \alpha/4\, \sqrt{s_1}] \varepsilon^*(p_1, \lambda_1) X^\mu \end{aligned} \qquad (21$$

The spin 1 wave functions are

$$\varepsilon^{\mu *}(p_1, 0) = \frac{1}{m_1} \begin{pmatrix} p_1 \\ E_1 \sin\theta \cos\phi \\ E_1 \sin\theta \sin\phi \\ E_1 \cos\theta \end{pmatrix} \qquad (22)$$

$$\varepsilon^{\mu *}(p_1, \pm 1) = \frac{e^{\mp i\phi}}{\sqrt{2}} \begin{pmatrix} 0 \\ \mp \cos\theta \cos\phi - i \sin\phi \\ \cos\theta \sin\phi + i \cos\phi \\ \pm \sin\theta \end{pmatrix}$$

and the helicity amplitudes in eq. (21) are written explicitly

$$A_{\lambda_1=0} = |\vec{p}_1|\{\sqrt{s_1}\,S + E_a T + E_a U + s\,U(m_1^2 + m_2^2 - m_a^2 + t_2 - u_1)/4\sqrt{s_1}\}/m_1 - E_1\{s_2|\vec{p}_a|T + s\,U[|\vec{p}_a| - (s_1 + m_a^2 - m_2^2 - t_1)\cos\alpha/4\sqrt{s_1}]\}\cos\theta/m_1 - s\,U\,E_1(s_1 + m_a^2 - m_2^2 - t_1)\sin\alpha\,\sin\theta\cos\phi/(4m_1\sqrt{s_1}) \quad (23)$$

and

$$A_{\lambda_1=\pm1} = \mp e^{\mp i\phi}\{\{s_2|\vec{p}_a|T + s\,U[|\vec{p}_a| - (s_1 + m_a^2 - m_2^2 - t_1)\cos\alpha/4\sqrt{s_1}]\}\sin\theta - s\,U(s_1 + m_a^2 - m_2^2 - t_1)\sin\alpha(\cos\theta\,\cos\phi \pm i\,\sin\phi)/4\sqrt{s_1}\}/\sqrt{2} \quad (24)$$

The possible zeros in these amplitudes may not be determined by simple equations like those for spinless reactions. In this case, the zeros must be found numerically.

Reactions of type C have the following components for the TCDM:

$$A^{(t)}_{\lambda_1\lambda_a} = 2TR.Q\bar{u}(p_1,\lambda_1)\gamma_5 u(p_a,\lambda_a)$$

$$A^{(u)}_{\lambda_1\lambda_a} = U\,\bar{u}(p_1,\lambda_1)\not{R}(\not{k} + m_1)\gamma_5 u(p_a,\lambda_a) \quad (25)$$

and

$$A^{(s)}_{\lambda_1\lambda_a} = S\,\bar{u}(p_1,\lambda_1)\gamma_5(\not{p} + m_a)\not{R}u(p_a,\lambda_a)$$

The helicity amplitudes, obtained summing these components, may be written as

$$A_{\lambda_1\lambda_a} = R_\beta\bar{u}(p_1,\lambda_1)\{2(T + S)p_2^\beta\gamma_5 - (U + S)\gamma^\beta\not{p}_2\gamma_5\}u(p_a,\lambda_a) \quad (26)$$

where we have assumed $m_1 = m_a$.

There may occur zeros in these amplitudes, due to interferences among the components, if

$$T + S = 0 \quad \text{and} \quad U + S = 0 \quad (27)$$

in the physical region. The equations for the zeros are

$$Z_{st} = (s_1 - m_a^2)g^t(t_2) + (t_1 - m_2^2)g^s(t_2) = 0$$
$$Z_{su} = (s_1 - m_a^2)g^u(t_2) + (u_1 - m_1^2)g^s(t_2) = 0 \qquad (28)$$

These equations are the same as those (eq.(12)) obtained for *spinless* reactions.

For the reaction $pp \to n\pi p$, [1a], from eqs. *(28)* and using the relation

$$s_1 + t_1 + u_1 = 2m_N^2 + m_\pi^2 + t_2$$

we obtain

$$t_1(\text{dip}) = m_\pi^2 + t_2$$

and

$$s_1(\text{dip}) = m_N^2 - t_2 . e^{\Delta . t_2} . \delta \qquad (29)$$

where

$$\delta = \sigma_{NN}/\sigma_{\pi N} \quad \text{and} \quad A = (B_{NN} - B_{\pi N})/2$$

These equations describe correctly the behaviour of the zero in the amplitudes, or the dip in $d\sigma/dt_2$.

The helicity amplitudes for this type of reaction may be written in a form more convenient for calculations. Summing the components in eq. (25), we obtain in the HEA

$$A_{\lambda_1\lambda_a} = (S + T + U)\bar{u}(p_1\lambda_1)\gamma_5 u(p_a\lambda_a) - i s |\vec{p}_a| (S+U)\sin\alpha\, \bar{u}(p_1\lambda_1)(\sigma^{31}$$
$$- \cos\alpha\, \sigma^{01} + \sin\alpha\, \sigma^{03})\gamma_5 u(p_a\lambda_a)/2\sqrt{s_1} \qquad (30)$$

This gives explicitly

$$A_{\pm 1/2,\pm 1/2} = \pm \{(S + T + U)G_- \cos(\theta/2)$$
$$- s|\vec{p}_a| (S+U)\sin\alpha [E_+ \sin\alpha \cos(\theta/2) - e^{\mp i\phi}(G_+$$
$$+ E_+ \cos\alpha)\sin(\theta/2)]/2\sqrt{s_1} \} \qquad (31)$$

and

$$A_{\mp 1/2,\pm 1/2} = -e^{\pm i\phi} \{(S + T + U)G_+ \sin(\theta/2)$$

$$+ s|\vec{p}_a|(S+U)\sin a [E_- \sin a \sin(\theta/2) - e^{\cdots}(\sim$$

$$+ E_- \cos a)\cos(\theta/2)]/2\sqrt{s_1}\} \qquad (32)$$

where

$$E_\pm = (E_1+m_1)^{1/2}(E_a+m_a)^{1/2} \pm (E_1-m_1)^{1/2}(E_a-m_a)^{1/2}$$
$$G_\pm = (E_1+m_1)^{1/2}(E_a-m_a)^{1/2} \pm (E_1-m_1)^{1/2}(E_a+m_a)^{1/2} \qquad (33)$$

Dual Resonance Parametrization

The TCDM for the reactions of type C may be reggeized and dualized. The helicity amplitudes in eq. (26) may be written as

$$A_{\lambda_1\lambda_a} = \bar{u}(p_1\lambda_1)\left\{\frac{2R.p_2 Z_{st}\gamma_5}{(s_1-m_a^2)(t_1-m_2^2)} - \frac{Z_{su}\not{R}\not{p}_2\gamma_5}{(s_1-m_a^2)(u_1-m_1^2)}\right\} u(p_a,\lambda_a) \qquad (34)$$

The prescription for dual resonance **parametrization** (DRP) consists in performing in eq. *(34)* the substitutions

$$1/(s_1-m_a^2)(t_1-m_2^2) \rightarrow \frac{\Gamma(-\alpha_a(s_1))\Gamma(-\alpha_2(t_1))}{\Gamma(1-\alpha_a(s_1)-\alpha_2(t_1))} \qquad (35)$$

and

$$1/(s_1-m_a^2)(u_1-m_1^2) \rightarrow \frac{\Gamma(-\alpha_a(s_1))\Gamma(-\alpha_1(u_1))}{\Gamma(1-\alpha_a(s_1)-\alpha_1(u_1))} \qquad (36)$$

The Regge **trajectories** are parametrized by

$$\alpha_1(u_1) = u_1 - m_1^2 \;, \quad \alpha_2(t_1) = t_1 - m_2^2$$
and
$$\alpha_a(s_1) = s_1 - m_a^2 + i\lambda(s_1 - (m_1+m_2)^2)^{1/2} \qquad (37)$$

where the parameter h controls the resonance width.

The TCDM has been applied to the reaction $pp \rightarrow A^* \bar{p}$, which is of type D. Its amplitudes are given in reference 1d.

4. PARTIAL WAVE AMPLITUDES

In this section we project the helicity amplitudes, obtained in section 3, into partial waves.

For reactions of type A, $(0^- \to 0^+, 0^-)$, the partial wave amplitudes are given by eq. (B.5), for $\lambda_a = 0$ and $N_{12} = -1$. We then have

$$A^{JM,-} = ((2J+1)/4\pi)^{1/2} \int d\Omega e^{-iM\phi} d^J_{M0}(\theta) A(\theta,\phi)$$

and

$$A^{JM,+} = 0 \tag{38}$$

and the parity of these amplitudes is $P = -(-1)^J$.

The amplitude $A(\theta,\phi)$, given by eq. (11), may be written as

$$A(\theta,\phi) = A^{(1)}(\theta) + A^{(2)}(\theta).\cos\phi \tag{39}$$

where

$$A^{(1)}(\theta) = ig_{a12}\left[sg^s(t_2)/(s_1-m_a^2) + a_2 g^t(t_2)/(t_1-m_2^2) + a_3 g^u(t_2)/(u_1-m_1^2)\right] \tag{40}$$

$$A^{(2)}(\theta) = ig_{a12} b\left[g^t(t_2)/(t_1-m_2^2) - g^u(t_2)/(u_1-m_1^2)\right] \tag{41}$$

For HEA we have

$$\begin{aligned} a_2 &\underset{\sim}{=} s(E_2 + |\vec{p}_1|\cos\alpha\cos\theta)\sqrt{s_1} \\ a_3 &\underset{\sim}{=} s(E_1 - |\vec{p}_1|\cos\alpha\cos\theta)/\sqrt{s_1} \\ b &\underset{\sim}{=} s|\vec{p}_1|\sin\alpha\ \operatorname{sen}\theta/\sqrt{s_1} \end{aligned} \tag{42}$$

and

The integration over ϕ shows that there are non-vanishing amplitudes only for $M=0$ and $M=\pm 1$, and that

$$A^{J,M=-1,-} = -A^{J,M=+1,-}$$

We introduce the notation

$$A(L^P_J)_M = A^{J,M,-} \tag{43}$$

where $J=L$, and the S, P and D partial wave amplitudes are given by

$$A(S_0^-)_0 = \pi^{1/2} \int_{-1}^{1} d(\cos\theta) d^0_{00}(\theta) A^{(1)}(\theta)$$

$$A(P_1^+)_0 = (3\pi)^{1/2} \int_{-1}^{1} d(\cos\theta)\, d^1_{00}(\theta)\, A^{(1)}(\theta)$$

$$A(P_1^+)_1 = ((3\pi)^{1/2}/2) \int_{-1}^{1} d(\cos\theta)\, d^1_{10}(\theta) A^{(2)}(\theta) \qquad (44)$$

$$A(D_2^-)_0 = (5\pi)^{1/2} \int_{-1}^{1} d(\cos\theta) d^2_{00}(\theta) A^{(1)}(\theta)$$

$$A(D_2^-)_1 = ((5\pi)^{1/2}/2) \int_{-1}^{1} d(\cos\theta) d^2_{10}(\theta) A^{(2)}(\theta)$$

for reactions of type B $(0^- \to 1^-, 0^-)$, the helicity amplitudes in eqs. (23) and (24) have the form (see eq. B.1)

$$A_{\lambda_1}(\theta,\phi) = e^{-i\lambda_1} \overset{\gamma}{A}_{\lambda_1}(\theta,\phi) \qquad (45)$$

and the partial wave amplitudes are given by eqs. (B.2) and (B.5), for $\lambda_a = \lambda_2 = 0$ and $N_{12} = -1$:

$$A^{JM,\pm}_{\lambda_1} = ((2J+1)/8\pi)^{1/2} \int d\Omega e^{-iM\phi} \{d^J_{M\lambda_1}(\theta)\overset{\gamma}{A}_{\lambda_1}(\theta,\phi) \mp d^J_{M,-\lambda_1}(\theta)\overset{\gamma}{A}_{-\lambda_1}(\theta,\phi)\} \qquad (46)$$

for $\lambda_1 = \pm 1$

$$A^{JM,-}_{\lambda_1} = ((2J+1)/4\pi)^{1/2} \int d\Omega e^{-iM\phi}\, d^J_{M0}(\theta) A_0(\theta,\phi) \qquad (47)$$

and

$$A^{JM,+}_{\lambda_1} = 0 \quad \text{for} \quad \lambda_1 = 0$$

The parities of these amplitudes are given by

$$P = \pm (-1)^J$$

From eqs. (23) and (24) we see that the expressions for $\overset{\gamma}{A}_{\lambda_1}(\theta,\phi)$ have the form

$$\overset{\gamma}{A}_{\lambda_1}(\theta,\phi) = A^{(1)}_{\lambda_1}(\theta) + A^{(2)}_{\lambda_1}(\theta)\cos\phi + A^{(3)}_{\lambda_1}(\theta)\sin\phi \qquad (48)$$

where, $A^{(3)}_0(\theta) = 0$, for $h_1 = 0$ and $A^{(1)}_{-1}(\theta) = -A^{(1)}_1(\theta)$ and $A^{(2)}_{-1}(\theta) = -A^{(2)}_1(\theta)$ for $\lambda_1 = \pm 1$. The coefficients $A^{(i)}_{\lambda_1}(\theta)$ $(i = 1,2,3)$ may be obtained from eqs. (23) and (24).

The integrations on ϕ in eqs. (54) and (55) show that only the values M=O and $M=\pm 1$ correspond to non-vanishing amplitudes.

As we are seeking for possible interferences among the components of TCDM, we choose $M=0$, which selects the coefficients $A^{(1)}_{\lambda_1}(\theta)$. The coefficient $A^{(1)}_{n}$ (8) is the only one that contains the three components of TCDM, and is the more probable to gives rise to strong interferences.

From eqs. (54) and (55) we obtain, for M=O

$$A^{J,M=0,-}_{\lambda_1=0} = (\pi(2J+1))^{1/2} \int_{-1}^{1} d(\cos\theta) d^{J}_{00}(\theta) A^{(1)}_{0}(\theta) \tag{49}$$

$$A^{J,M=0,-}_{\lambda_1=1} = (2\pi(2J+1)^{1/2} \int_{-1}^{1} d(\cos\theta) d^{J}_{01}(\theta) A^{(1)}_{1}(\theta) \tag{50}$$

$$A^{J,M=0,-}_{\lambda_1=-1} = A^{J,M=0,-}_{\lambda_1=1}$$

and

$$A^{J,M=0,+}_{\lambda_1} = 0$$

The amplitudes for well defined orbital angular momentum are given by eq. (B.10). Using the notation

$$A(L^{P}_{J}) = A^{J,M=0}_{(L)} \tag{51}$$

the S, P and D partial wave amplitudes are, for M=O

$$A(S^{+}_{1}) = (1/3)^{1/2} \left(2A^{J=1,M=0,-}_{\lambda_1=1} + A^{J=1,M=0,-}_{\lambda_1=0}\right)$$

$$A(P^{-}_{0}) = - A^{J=0,M=0,-}_{\lambda_1=0}$$

$$A(P^{-}_{2}) = (2/5)^{1/2} \left(\sqrt{3}\, A^{J=2,M=0,-}_{\lambda_1=1} + A^{J=2,M=0,-}_{\lambda_1=0}\right) \tag{52}$$

$$A(D^{+}_{1}) = (2/3)^{1/2} \left(A^{J=1,M=0,-}_{\lambda_1=1} - A^{J=1,N=0,-}_{\lambda_1=0}\right)$$

$$A(D^{+}_{3}) = (1/7)^{1/2} \left(2\sqrt{2}\, A^{J=3,M=0,-}_{\lambda_1=1} + \sqrt{3}\, A^{J=3,M=0,-}_{\lambda_1=0}\right)$$

The helicity amplitudes for reactions of type C also factorize similarly to eq.(B.1). The partial wave amplitudes are given by eq.(B.2), for $\lambda_2 = 0$ and $N_{12} = -1$ as

$$A^{JM,\pm}_{\lambda_1\lambda_a} = ((2J+1)/8\pi)^{1/2} \int d\Omega e^{-i(M-\lambda_a)\phi} \{d^J_{M\lambda_1}(\theta) \overset{\gamma}{A}_{\lambda_1\lambda_a}(\theta,\phi) \mp d^J_{M,-\lambda_1}(\theta) \overset{\gamma}{A}_{-\lambda_1,\lambda_a}(\theta,\phi)\} \tag{53}$$

and the parities of these amplitudes are

$$P = \pm(-1)^{J-1/2} \tag{54}$$

From the helicity amplitudes shown in eqs. (31) and (32) we see that

$$\overset{\gamma}{A}_{\lambda_1\lambda_a}(\theta,\phi) = A^{(1)}_{\lambda_1\lambda_a}(\theta) + A^{(2)}_{\lambda_1\lambda_a}(\theta).\cos\phi + A^{(3)}_{\lambda_1\lambda_a}(\theta) e^{-i2\lambda_a\phi} \tag{55}$$

where the coefficients $A^{(i)}_{\lambda_i\lambda_a}(\theta)$ may be obtained from those amplitudes.

The Integration on ϕ shows that the non-vanishing amplitudes correspond to $M = \pm\lambda_a$ and $M = \lambda_a \pm 1$. We choose $M = \lambda_a$ because this condition selects the coefficients $A^{(1)}_{\lambda_1\lambda_a}(\theta)$. Only these coefficients contain the three components of TCDM, and are the most probable source of the interferences we are seeking for. From eqs. (62) and (64) we obtain for $M=\lambda_a$ that

$$A^{J,M=\lambda_a,\pm}_{\lambda_1\lambda_a} = (\pi(J+1/2))^{1/2} \int_{-1}^{1} d(\cos\theta) \left[d^J_{\lambda_a\lambda_1}(\theta)\, A^{(1)}_{\lambda_1\lambda_a} \mp d^J_{\lambda_a,-\lambda_1}(\theta)\, A^{(1)}_{-\lambda_1,\lambda_a}(\theta)\right] \tag{56}$$

The partial wave amplitudes for well defined orbital angular momentum L, according to eq. (8.10), are

$$A^{J,M=\lambda_a,-}_{(L=J-1/2)\lambda_a} = 2(2J/(2J+1))^{1/2}\, C^{J-1/2,1/2,J}_{0,1/2,1/2}\, A^{J,M=\lambda_a,-}_{1/2,\lambda_a}$$

$$A^{J,M=\lambda_a,+}_{(L=J+1/2)\lambda_a} = 2(2(J+1)/(2J+1))^{1/2}\, C^{J+1/2,1/2,J}_{0,1/2,1/2}\, A^{J,M=\lambda_a,+}_{1/2,\lambda_a}$$

$$A^{J,M=\lambda_a,+}_{(L=J-1/2)\lambda_a} = 0$$

and

$$A^{J,M=\lambda_a,-}_{(L=J+1/2)\lambda_a} = 0 \tag{57}$$

and satisfy the relations

$$A^{J,-1/2,\pm}_{(L=J\pm1/2),-1/2} = \pm\, A^{J,1/2,\pm}_{(L=J\pm1/2),1/2} \tag{58}$$

Introducing the notation

$$A(L^P_J)_{1/2} \equiv A^{J,M=1/2,\pm}_{(L)1/2} \tag{59}$$

the S, P and D for $M = \lambda_a = 1/2$, are written

$$\begin{aligned}
A(S^-_{1/2})_{1/2} &= \sqrt{2}\; A^{J=1/2,M=1/2,-}_{\lambda_1=1/2,\lambda_a=1/2} \\
A(P^+_{1/2})_{1/2} &= -\sqrt{2}\; A^{J=1/2,M=1/2,+}_{\lambda_1=1/2,\lambda_a=1/2} \\
A(P^+_{3/2})_{1/2} &= \sqrt{2}\; A^{J=3/2,M=1/2,-}_{\lambda_1=1/2,\lambda_a=1/2} \\
A(D^-_{3/2})_{1/2} &= -\sqrt{2}\; A^{J=3/2,M=1/2,+}_{\lambda_1=1/2,\lambda_a=1/2} \\
A(D^-_{5/2})_{1/2} &= \sqrt{2}\; A^{J=5/2,M=1/2,-}_{\lambda_1=1/2,\lambda_a=1/2}
\end{aligned} \tag{60}$$

The partial wave amplitudes for reactions of type $D_s(1/2^+ \to 3/2^+, 0^-)$, are given by[1d]

$$\begin{aligned}
A(S^-_{3/2})_{1/2} &= A^{3/2,1/2,+}_{3/2,1/2} + A^{3/2,1/2,+}_{1/2,1/2,} \\
A(P^+_{1/2})_{1/2} &= -\sqrt{2}\; A^{1/2,1/2}_{1/2,1/2} \\
A(P^+_{3/2})_{1/2} &= -(1/5)^{1/2}\; (3\, A^{3/2,1/2,-}_{3/2,1/2} + A^{3/2,1/2,-}_{1/2,1/2})
\end{aligned}$$

$$A(P^{+}_{5/2})_{1/2} = (1/5)^{1/2}(2\,A^{5/2,1/2,+}_{3/2,1/2} + \sqrt{6}\,A^{5/2,1/2,+}_{1/2,1/2})$$

$$A(D^{-}_{1/2})_{1/2} = \sqrt{2}\,A^{1/2,1/2,-}_{1/2,1/2}$$

$$A(D^{-}_{3/2})_{1/2} = A^{3/2,1/2,+}_{3/2,1/2} - A^{3/2,1/2,+}_{1/2,1/2}$$

$$A(D^{-}_{5/2})_{1/2} = -(2/7)^{1/2}(\sqrt{6}\,A^{5/2,1/2,-}_{3/2,1/2} + A^{5/2,1/2,-}_{1/2,1/2})$$

$$A(D^{-}_{7/2})_{1/2} = (1/7)^{1/2}(\sqrt{5}\,A^{7/2,1/2,+}_{3/2,1/2} + 3\,A^{7/2,1/2,+}_{1/2,1/2}) \qquad (61)$$

5. RESULTS AND DISCUSSIONS

In this paper we analyse the TCDM applications to several types of (DDR). We put together all spin-parity structures of the subreaction $a + P \to 1 + 2$. These amplitudes can be useful for a complete understanding to the DDR phenomenology. In this sense the model is universal, describing the multiple aspects of the data. The TCDM is a natural consrquence of the earlier Drell-Hiida-Deck-Model[6]. This model described thr DDR untll the dlscovery of the slope (B), mass (M_{12}), angular ($\cos\theta^{G.J.}$) and the slope-mass-partial waves correlations.

The applicatlon of TCDM to these dlfferent types of reactions permits us to test the model In those reactions for which there are experimental results, and to give a theoretical prediction for the others.

The DDR studied here have different spin and parlty structures In the subreactlons ($a + P \to 1 + 2$).

The reactions studied here have the following spin and parity rtructures in the dissociative process ($a \to 1 + 2$), ($J^P_a a \to J^P_1 1 + J^P_2 2$): A-$(0^- \to 0^+, 0^-)$, B-$(0^- \to 1^-, 0^-)$, C- $(1/2^+ \to 1/2^+, 0^-)$ and D-$(1/2^+ \to 3/2^+, 0^-)$.

We choose only one reactlon of each type to apply the TCDM. The reactlons chosen are respectively:

$$A\text{-}:\ K + p \to (k+\pi) + p$$

B^-: $K + p \to (K^* + \pi) + p$

C-: $p + p \to (n + \pi^-) + p$

and

D^-: $p + p \to (\Delta^{++} + \pi^-) + p$

We now discuss the results obtained for eachofthese reactions.

The reactlons of type A have the simplest spin and parity structure. The TCDM for these reactlons may be reggeized, what extends the valldity of the model beyond the region of resonances In the dis-sociated sybsystem (1+2).

The partia1 wave amplitudes for the reaction $K + p \to (k + \pi) + p$ are given by eq. (44). A slope-mass correlation may be observed in the Swave. Flg.(4) shows the theoretical dlstributions for the S wave In the effective mass ranges $1.25 \leq M_{k\pi} \leq 1.35$ GeV and $1.35 \leq M_{k\pi} \leq 1.50$ GeV respectively.

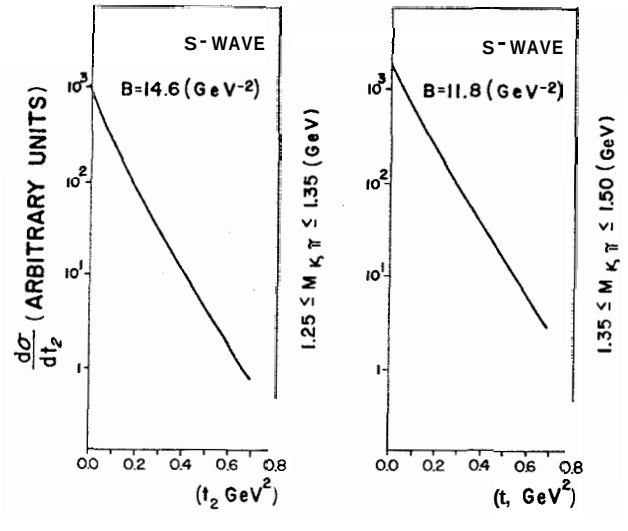

Fig.4 - Partia1 wave (0^-S) t_2-distributions and slopes of the reaction $Kp \to (k\pi)p$, for two effective mass ranges.

The slopes of these distributions, calculated in the interval $0 \leq |t_2| \leq 0.002$ GeV^2, are respectively B = 14.6 GeV^{-2} and B = 11.8GeV^{-2}. These results may be compared with the experimental ones[a], shown in fig. (8).

The parameters of TCDH used to obtain the results above are $\sigma_{tot}^{\pi N}$ = 23 mb, σ_{tot}^{KN} = 20 mb, σ_{tot}^{kN} = 24 mb, $B_{\pi N}$ = 7 GeV^{-2}, B_{KN} = 6.5GeV^{-2} and B_{kN} = 6.5 GeV^{-2}.

The reaction of type B studied here is $K + p \to (K^*+\pi) + p$. The helicity amplitudes and the partial wave amplitudes are given by eqs. (23) and (52) respectively.

A slope mass correlation may be observed in the S and P waves. In figs. (5,6,7) we see the distributions for 1^+ S and 0-P waves, restricted by M=0, in the effective mass ranges $1.04 \leq M_{K^*\pi} \leq 1.20$ GeV, $1.20 \leq M_{K^*\pi} \leq 1.35$ GeV and $1.35 \leq M_{K^*\pi} \leq 1.50$ GeV.

The slopes of these distributions calculated in the interval $0 \leq |t_2| \leq 0.02$ GeV^2, are given in those figures.

The results for the two higher mass intervals may be compared with the experimental distributions[8] and slopes of fig. (8).

The TCDM parameters used to find these experimental slopes are $\sigma_{tot}^{\pi N}$ = 22 mb, $\sigma_{tot}^{K^*N}$ = 18 mb, σ_{tot}^{KN} = 21 mb, $B_{\pi N}$ = 9.0 GeV^{-2}, B_{K^*N} = 4.5 GeV^{-2} and B_{KN} = 3.0 GeV^{-2}.

As may be observed in fig. 5, there exists a strong interference in the 0^- P wave, whose slope is much higher than that of the 1^+ S wave. As a consequence of that interference there appears a dip in the 0^- P wave. The dip naves slowly to higher values of $|t_2|$ as $M_{K^*\pi}$ increases.

It must be remembered however that in the mass intervals where the data are given, mainly in the higher ones, there exist $K^*\pi$ resonances.

The dip in the 0^- P wave, predicted by the model, is not seen in the data. Possibly it is covered by resonance effects, or the large errors near t_2 = - 0.3 GeV^2 do not permit to observe the dip.

The reaction of type C, $p + p \to (n+\pi^+) + p$, allows an excellent test for the TCDM. This reaction has the bestdataamong the DDR. A clear slope-mass-cos θ^{GJ} correlation may be observed in these data. This reaction has some spin complications. However the TCDM may be reggeized

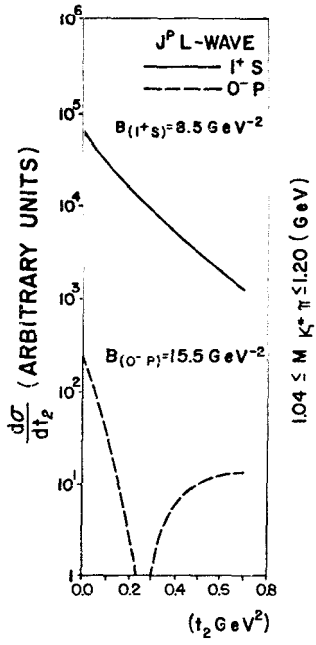

Fig.5 - (1^+S) and (0^-P) partial wave distributions and slopes of the reaction $Kp \to (k\pi)p$, in the effective mass range $1.04 \leq M_{K^*\pi} \leq 1.20$ (GeV).

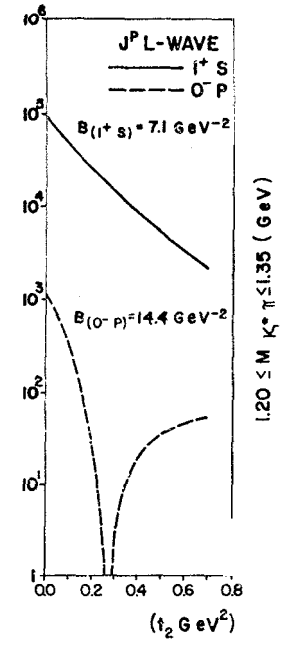

Fig.6 - The same as fig. (5) for $1.20 \leq M_{K^*\pi} \leq 1.35$ (GeV).

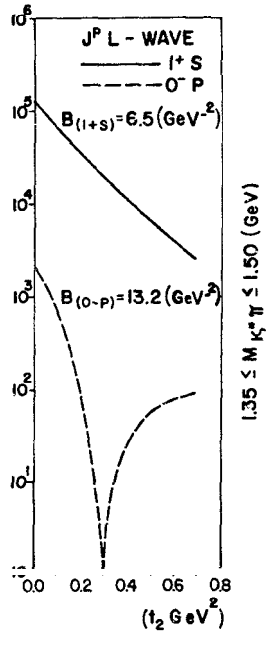

Fig.7 - The same as fig. (5) for $1.35 \leq M_{K^*\pi} \leq 1.50$ (GeV).

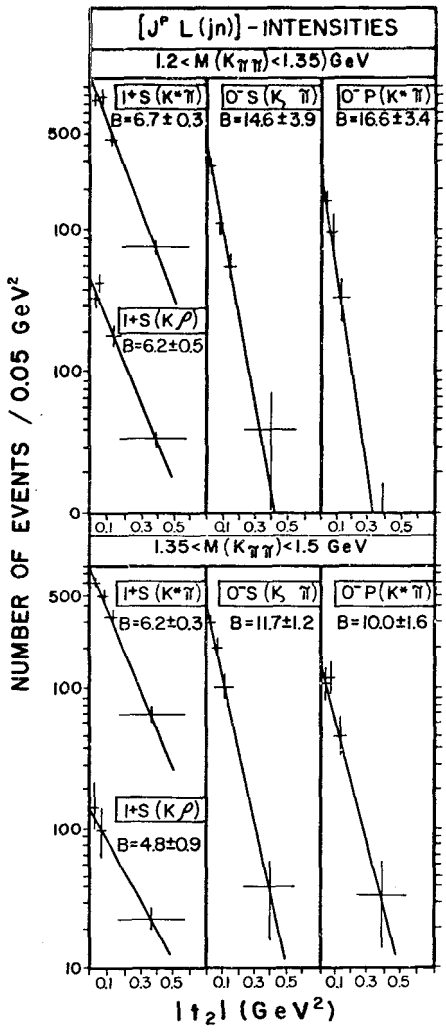

Fig.8 - Experimental results of the partial wave cross sections for the reactions $Kp \to (k\pi)p$ - $(0^- S)$ and $Kp \to (K^*\pi)p$ - $(1^+S$ and $0^-P)$, in two effective mass range[8].

and dualized. Two parametrizations have been obtained for the dualized TCDM. The dual resonance parametrization (DRP) is obtained according to the Veneziano ansatz. We cannot expect that the theoretical mass spectrum fits well the experimental one with this rigid parametrization.

A more flexible parametrization to describe the resonances is the dual reggeized Deck parametrizatlon. In this case the Veneziano functions are replaced by their Regge limits.

The fits of these parametrizations to the data are shown in figs. (9) to (16). The values of the (TCDM) parameters (which are the same for the two cases) are $\sigma_{tot}^{\pi p} = 25$ mb, $\sigma_{tot}^{np} = 30$ mb, $\sigma_{tot}^{pp} = 40$ mb, $B_{\pi p} = 10\ \mathrm{GeV}^{-2}$, $B_{np} = B_{pp} = 9\ \mathrm{GeV}^{-2}$ and $h = 0.3$ GeV.

The total mass spectrum, fig. (9), fixes the overall normalizations for the two parametrizations. Fig. (10) shows the $d\sigma/dt_2$ distributions for some windows in $M_{n\pi}$ and $\cos\theta^{GJ}$. These windows appear in fig. (11), where the zeros of the amplitudes, determined by eqs. (29), are located. Fig. (12) shows the net diffractive slope (B) as a function of the effective mass and the good fitting of the slope predicted by the DRP.

There is a satisfactory agreement of the parametrizations with the $\cos\theta^{GJ}$ and ϕ^{GJ} distributions, shown in fig. (13). The dualized TCDM reproduces well the turnover of the $\cos\theta^{GJ}$ distributions at $\cos\theta^{GJ} = +1$.

Although there are no experimental results to be confronted with, it is interesting to see how the slope mass correlation appears in partial waves. Figs (14,15,16) show the S, P and D waves distributions, restricted by $M = \lambda_a$. It may be seen that the strongest interferences occur in the P and D waves, in which there appear dips and turnovers.

Another reaction, of the same type, which is very well described by the dualized TCDM is $p + p \to (\Lambda + K^+) + p$. See figures (17-21) taken from references 1c, where the comparison with the experimental data was made.

The reaction of type D analyzed here, $p + p \to (\Delta^{++} + \pi^-) + p$, has helicity amplitudes ahd partial wave amplitudes given in reference 1d. The complexity of these amplitudes does not permit to derive simple equations to determine the positions of possible zeros. But the numerical calculations of $d\sigma/dt_2$ show that there exists slope-mass corre-

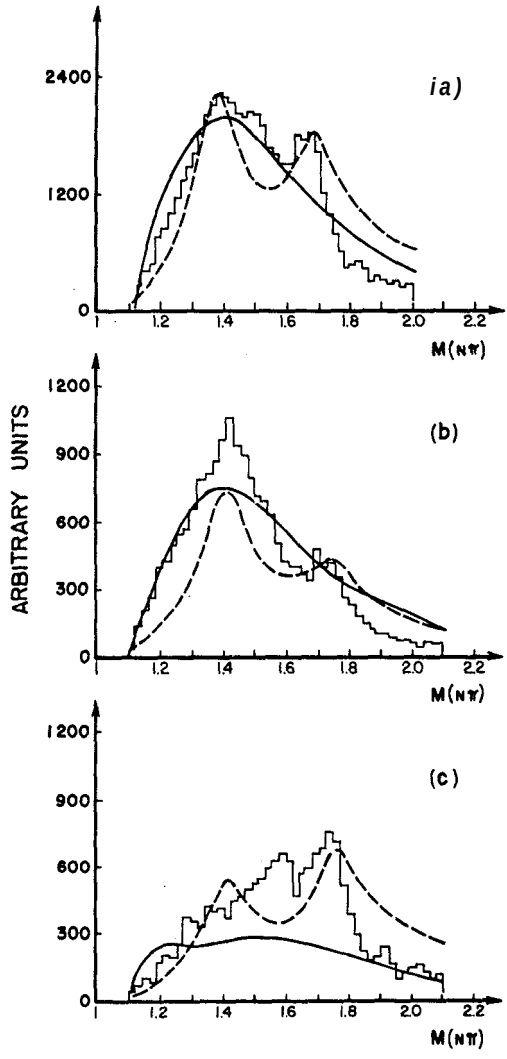

Fig.9 - Effective mass ($M_{N\pi}$) distributions of the reaction $Np \to (N\pi)p$ for (a) $-0.1 < t_2 < 0.02$; (b) $-0.08 < t_2 < -0.02$ and (c) $-1.0 < t_2 < -0.2$. The full line represents the dual Deck parametrization and the dotted line represents the dual resonance parametrization[1a].

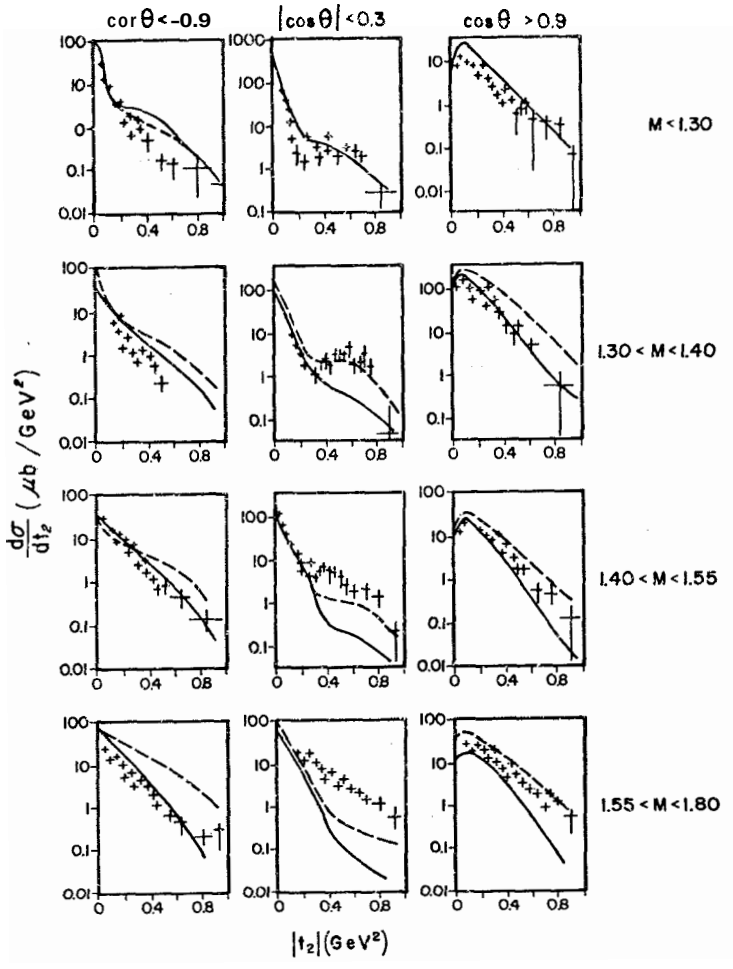

Fig.10 - t_2 distributions integrated in several regions of $M_{N\pi}$ and cos θ^{GJ}.

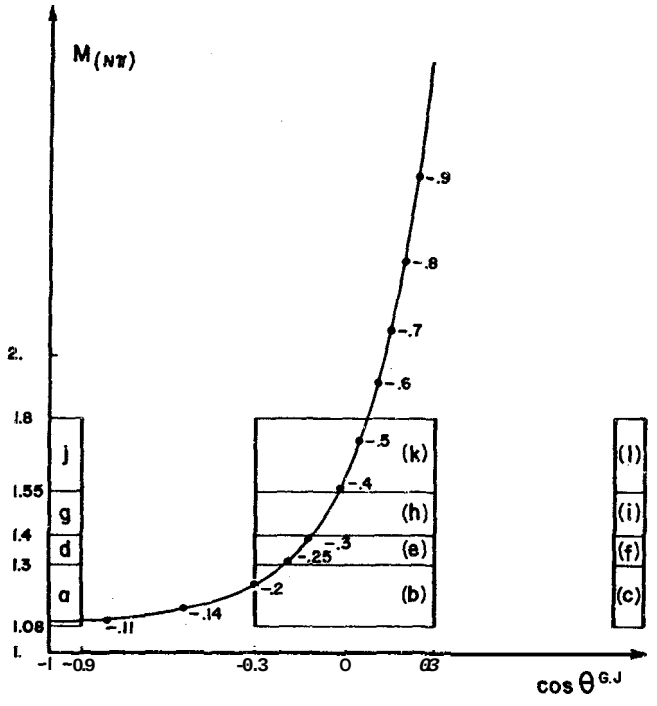

Fig.11 - The location of the zero of the amplitude for $Np \to (N\pi)p$, as a function of cos θ^{GJ}, $M_{N\pi}$ and t_2. The rectangles labelled from (a) to (R) are the regions in cos θ^{GJ} and $M_{N\pi}$ in which the t_2 distributions of fig. (10) are Integrated.

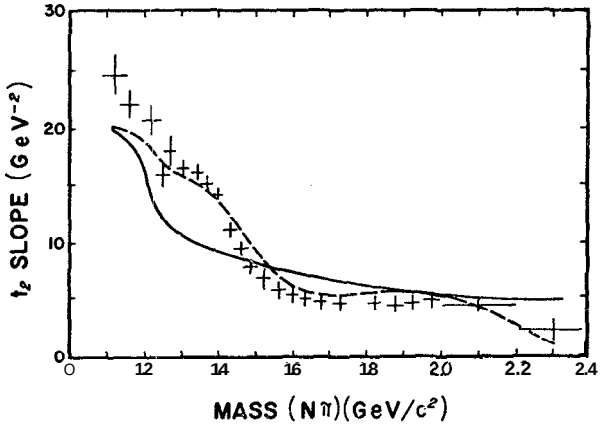

Fig.12 - The t_2 slope as a functlon of $M_{N\pi}$.

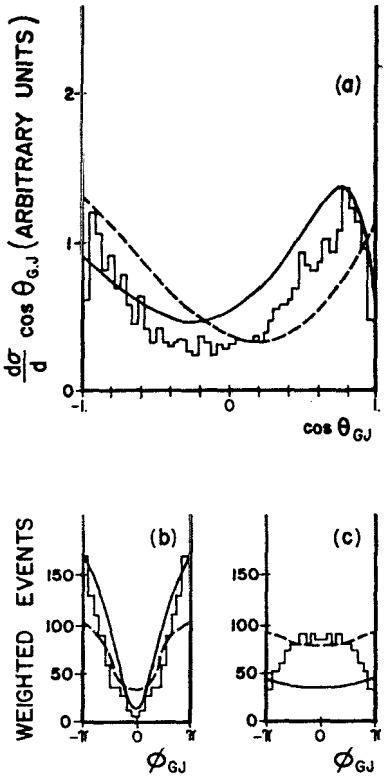

Fig.13 - (a) $\cos\theta^{GJ}$ distribution for $1.08 < M_{N\pi} < 1.4$ (GeV) and $-0.23 < t_2 < 0$. (b) ϕ^{GJ} distribution for $1.2 < M_{N\pi} < 1.375$ (GeV), $-0.2 < t_2 < -0.02$ and $0.8 < \cos\theta^{GJ} < 1$. (c) The same as (b) except

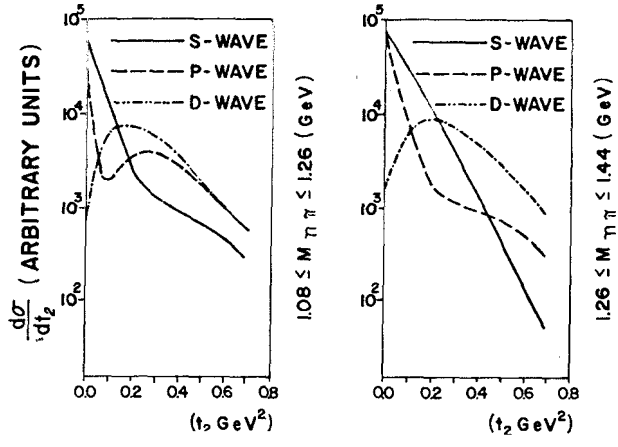

Fig.14 - S, P and D partial wave t_2 distributions for the reaction $Np \to (N\pi)p$ integrated in two effective mass range, and restricted to $(M = \lambda_a)$.

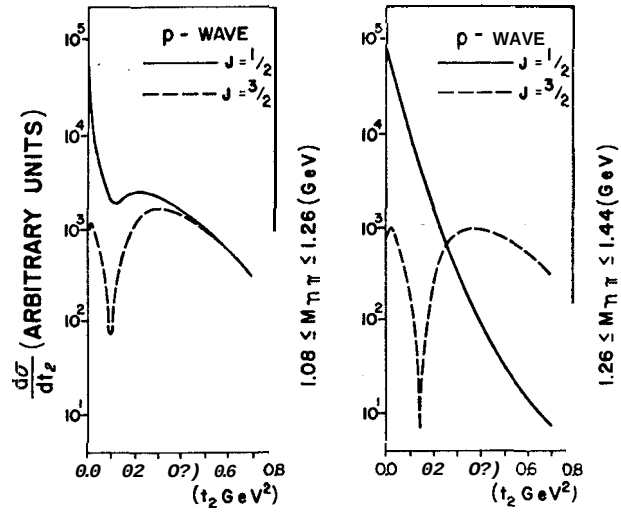

Fig.15 - $P_{(J=1/2)}$ and $P_{(J=3/2)}$ partial wave t_2 distributions.

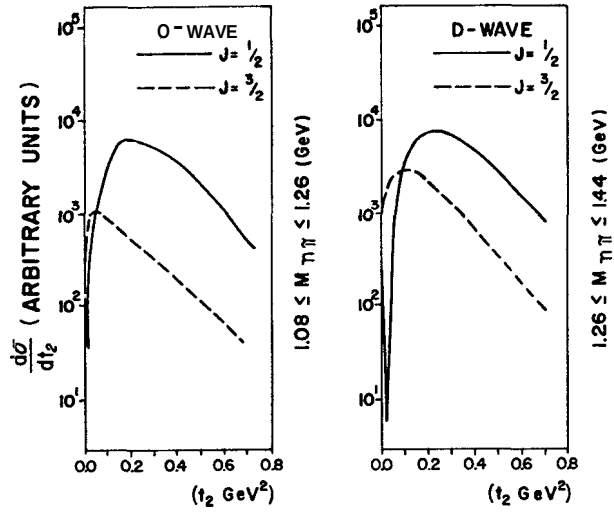

Fig.16 - $D_{(J=3/2)}$ and $D_{(J=5/2)}$ partial wave t_2 distributions.

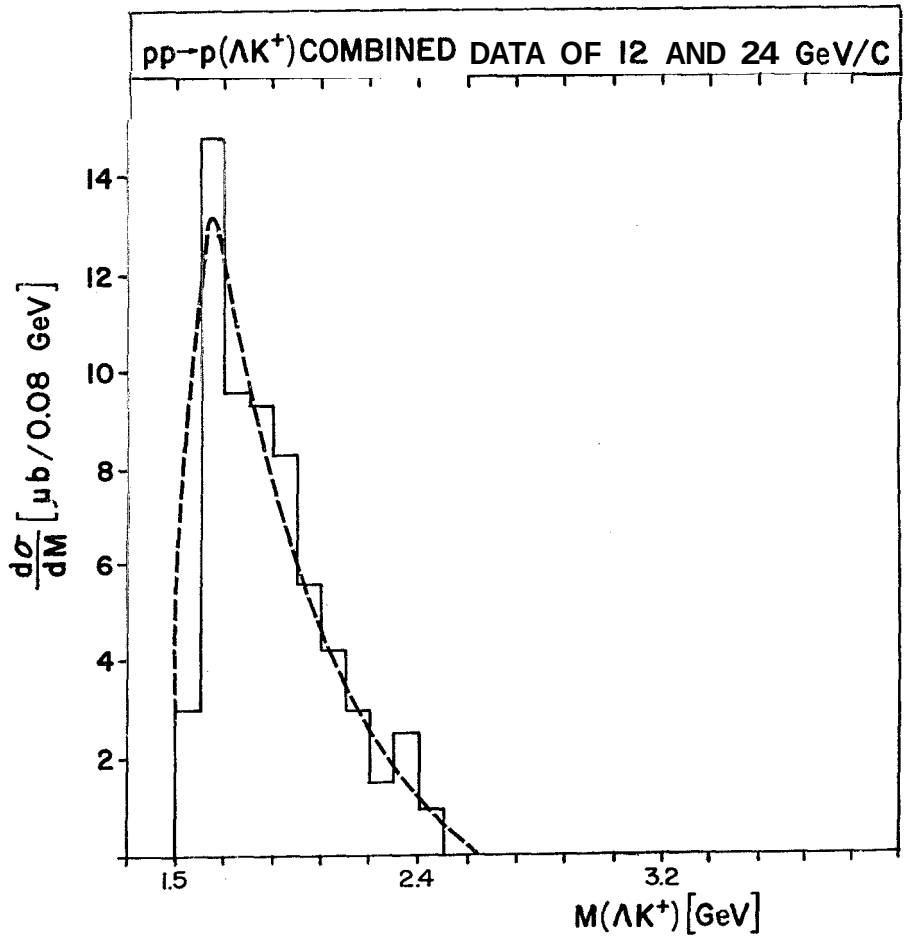

Fig.17 - The mass distribution of the (ΛK^+) system. The full line shows the results of the $(TCDM)^{1c}$.

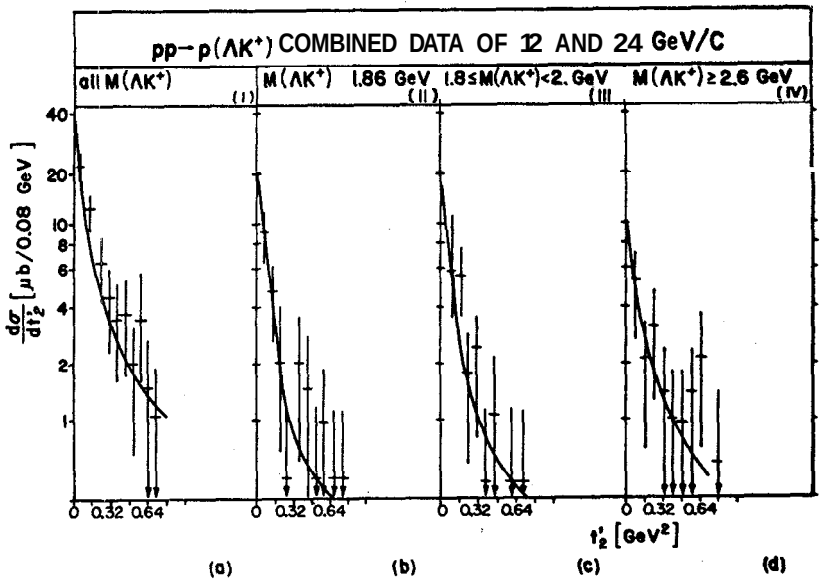

Fig.18 - $d\sigma/dt_2$ distributions for various $M(\Lambda K^+)$ intervals, integrated over all $\cos\theta^{GJ}$ and ϕ^{GJ}. (a) for all $M(\Lambda K)$ masses, (b) for $1.61 \leqslant M(\Lambda K) \leqslant 1.8$ GeV, (c) for $1.8 \leqslant M(\Lambda K) \leqslant 2.0$ GeV, (d) for $2.0 \leqslant M(\Lambda K) \leqslant 2.5$ GeV.

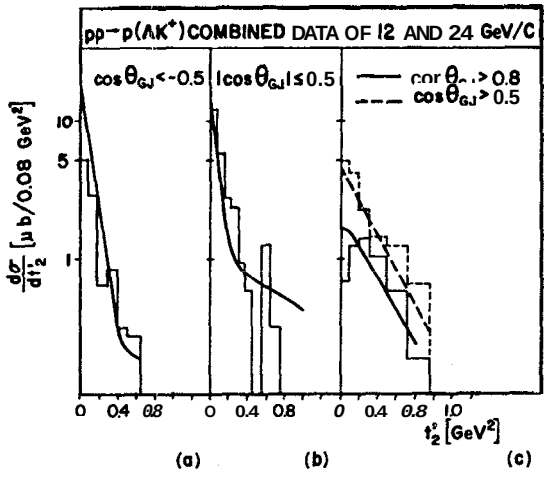

Fig.19 - $d\sigma/dt_2$ distributions for some $\cos\theta^{GJ}$ regions, for all masses of ΛK^+ system and integrated over all ϕ^{GJ} (a) in the interval $\cos\theta^{GJ} < -0.5$; (b) for $|\cos\theta^{GJ}| \leqslant 0.5$; (c) $\cos\theta^{GJ} \geqslant 0.8$ (full line), $\cos\theta^{GJ} \geqslant 0.5$ (dotted line).

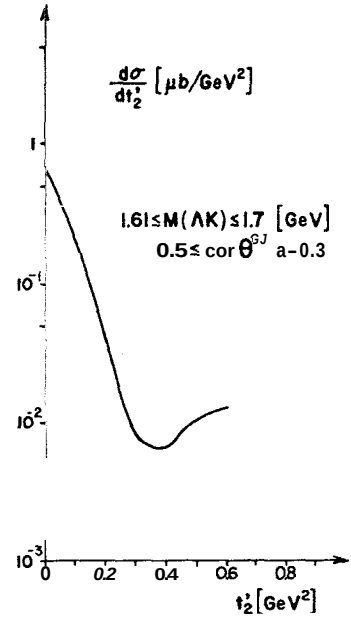

Fig. 20-a

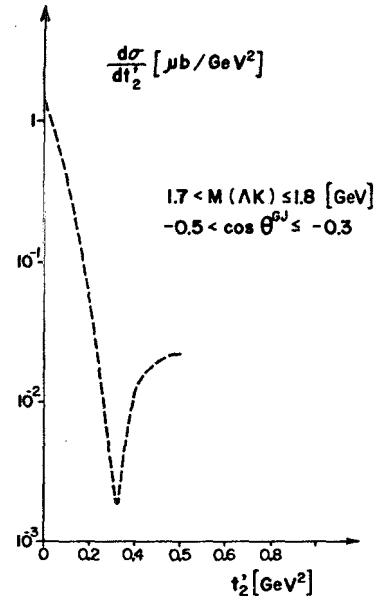

Fig. 20-b

Fig.20 - Theoretical $d\sigma/dt_2$ distributions calculated by (TCDDM). (a) In the intervals $1.61 \leqslant M(\Lambda K) \leqslant 1.7$ (GeV) and $-0.5 \leqslant \cos\theta^{GJ} \leqslant -0.3$. (b) In the intervals $1.7 \leqslant M(\Lambda K) \leqslant 1.8$ (GeV) and $-0.5 \leqslant \cos\theta^{GJ} \leqslant -0.3$.

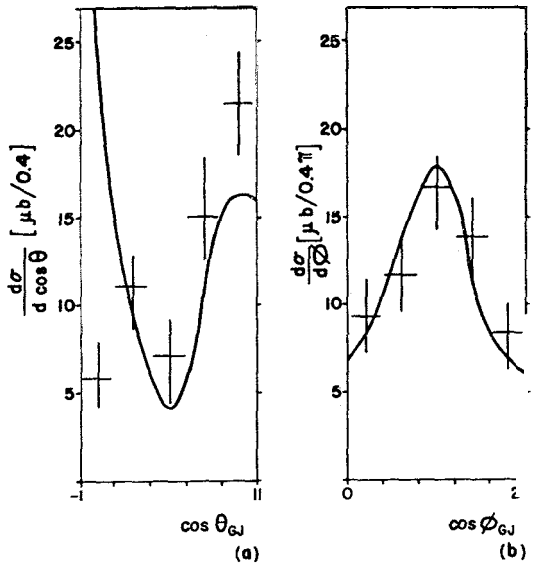

Fig.21 - Gottfried-Jackson angle distributions for all masses $M(\Lambda K)$ and for $0 \leqslant |t_2| \leqslant 1$. (a) $\cos\theta^{GJ}$ distribution integrated over all ϕ^{GJ}. (b) ϕ^{GJ} distribution integrated over all $\cos\theta^{GJ}$.

lations in the distributions for that reaction. In fig. (22) we see that the slope decreases as the effective mass increases. Fig. (23) shows how the slope depends on the effective mass and on the $\cos\theta^{GJ}$ intervals

The set of parameters of TCOM used in these calculations are $\sigma_{tot}^{\pi N} = 25$ mb, $\sigma_{tot}^{NN} = 40$ mb, $\sigma_{tot}^{N\Delta} = 50$ mb, $B_{\pi N} = 10\ GeV^{-2}$, $B_{NN} = 9\ GeV^{-2}$ and $B_{N\Lambda} = 8\ GeV^{-2}$, and the slopes are calculated in the interval $0 \leq |t_2| \leq 0.02\ GeV^2$.

The best way to see the slope mass correlation inthis reaction is to look at the partial wave dlstributions. It must be remembered that the partlal wave distrlbutions are here restricted by the condition M=A$_a$. This condition has the advantage of simplifying the calculations and is enough to exhibit a possible slope-mass-partial wave correlatlon.

In fig. (24) we see the S, P and D wave distributlons for two effective mass intervals. The S wave shows a strong interference, with a dip at $t_2 \simeq -0.35$ GeV .

The examination of each amplitude $A(L_J^P)_{1/2}$, for P and D wave distrlbutions, allows us to seek for interference structures not seen in fig. (24).

Fig. (25) shows the $A(P_{1/2}^{+})_{1/2}$, $A(P_{3/2}^{+})_{1/2}$ and $A(P_{5/2}^{+})_{1/2}$ distributlons. Among these, the $A(P_{3/2}^{+})_{1/2}$ is the one that shows the strongest interference, with a dip at $t_2 \simeq -0.1\ GeV^2$.

The relative normalizatlon in fig. (25) shows that the partial wave $A(P_{1/2}^{+})_{1/2}$ is two orders of magnltude larger than $A(P_{3/2}^{+})_{1/2}$, where the strongest interference occurs. For this reason the total Pwave distributlons, showed in fig. (24), do not present dips.

The D wave spectrum for each J, i.e., the $A(D_{1/2}^{-})_{1/2}$, $A(D_{3/2}^{-})_{1/2}$ $A(D_{5/2}^{-})_{1/2}$ and $A(D_{7/2}^{-})_{1/2}$ wave distrlbutions are shown in fig. (26). We remark that only the $A(D_{1/2}^{-})_{1/2}$ and $A(D_{7/2}^{-})_{1/2}$ waves present dips at $t_2 \simeq -0.6\ GeV^2$ and $t_2 \simeq -0.4\ GeV^2$ respectively. The total D wave dlstribution, showed in fig. (24) does not present dips because all the contributions from different J values are added.

The net slopes for each wave, calculated in the interval $0 \leq |t_2| \leq 0.02$ GeV , are shown In tables 1 and 2. In table 2 we remark that all waves, but $P_J = 3/2$, present an expected mass- slope--partlal wave correlation, that is, the slope decreases as the effective mass $M_{\Lambda\pi}$ Increases.

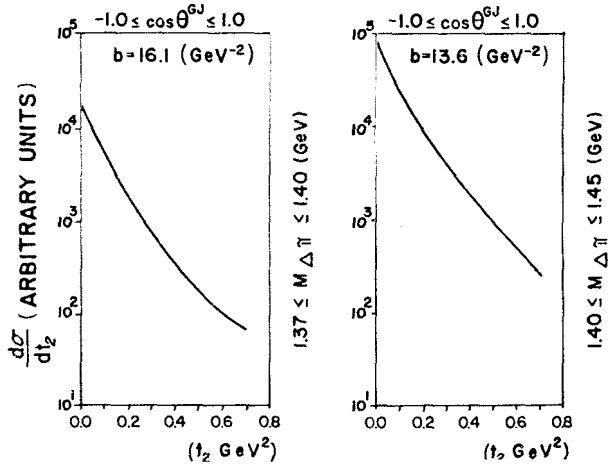

Fig.22 - t_2 distributions and slopes, for reaction $pp \to (\Delta^{++}\pi^-)p$, integrated in two effective mass ranges.

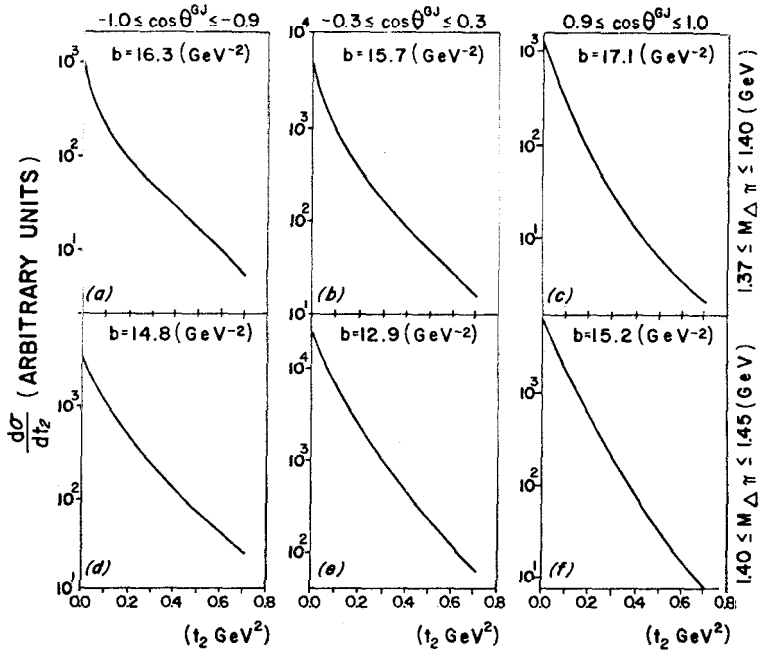

Fig.23 - t_2 distributions and slopes for $pp \to (\Delta^{++}\pi^-)p$, integrated in two intervals of $M_{\Delta\pi}$ and three intervals of $\cos\theta^{GJ}$.

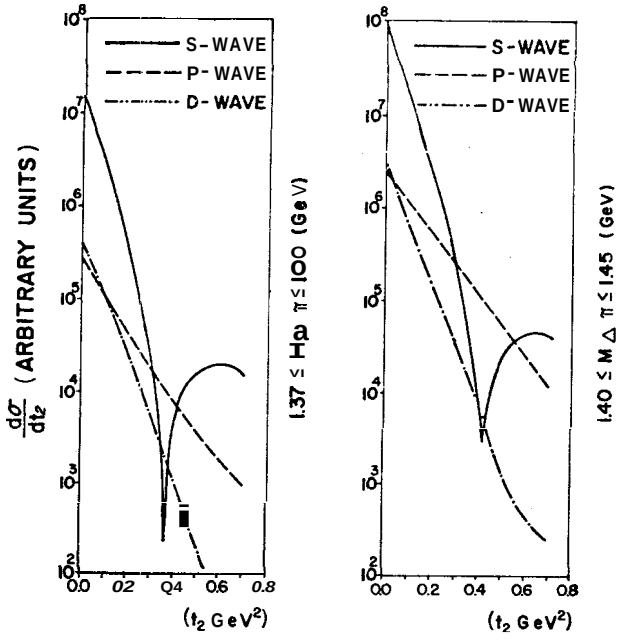

Fig. 24 - S, P and D partial wave t_2 distributions, restricted to $(M = \lambda_a)$

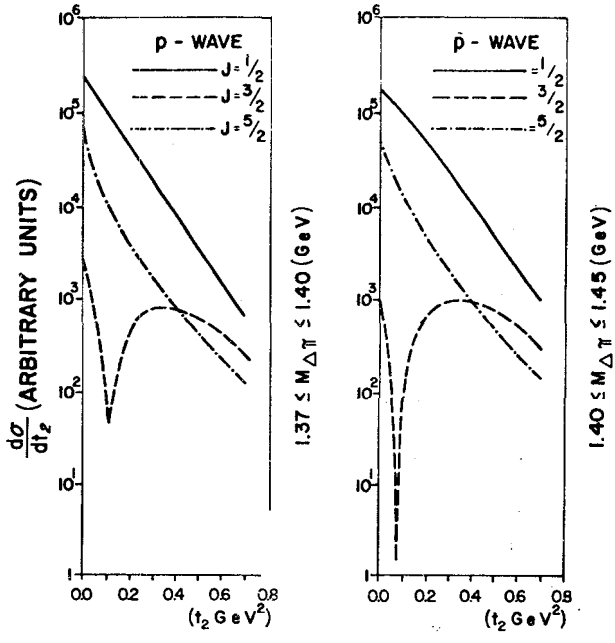

Fig. 25 - $P_{(J=1/2)}$, $P_{(J=3/2)}$ and $P_{(J=5/2)}$ partial wave t_2 distributions, restricted to $(M = \lambda_a)$.

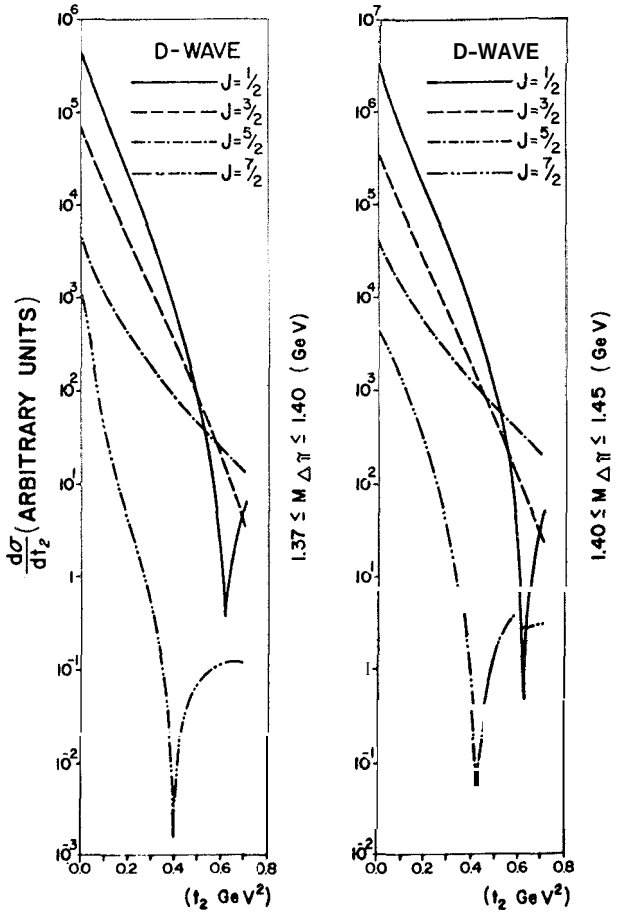

Fig. 26 - $D_{(J=1/2)}$, $D_{(J=3/2)}$, $D_{(J=5/2)}$ and $D_{(J=7/2)}$ partial wave t_2 distributions, restricted to $(M = \lambda_a)$.

The abnormal behaviour of the $P_{J=3/2}$ happens because the zero occurs for smaller $|t_2|$ when s_1 Increases.

The reactions of type A and B are analised with combined data from experiments at 10, 14 and 16 GeV incident K^- momenta. And for the reactions of type C and D the data come from experiments at 12 and 24 GeV incident proton momenta. It was observed that there is no significant variation of the cross sections in the energy Intervals analised.

L	$1.37 \leq M_{\Delta\pi} \leq 1.40$ GeV	$1.40 \leq M_{\Delta\pi} \leq 1.45$ GeV
S	$B = 19.5$	$B = 17.4$
P	$B = 9.7$	$B = 7.3$
D	$B = 16.7$	$B = 16.1$

Table 1 - Values in GeV^{-2} of the slopescorresponding to the curves $d\sigma/dt_2$ shown at fig. 24.

L	J	$1.37 \leq M_{\Delta\pi} \leq 1.40$ GeV	$1.40 \leq M_{\Delta\pi} \leq 1.45$ GeV
P	1/2	$B = 7.1$	$B = 4.5$
	3/2	$B = 24.2$	$B = 33.2$
	5/2	$B = 22.8$	$B = 18.1$
,	1/2	B = 17.2	$B = 16.4$
	3/2	$B = 13.4$	$B = 13.0$
	5/2	$B = 18.9$	$B = 13.2$
	7/2	$B = 43.2$	$B = 34.7$

Table 2 - Values in GeV^{-2} of the slopes for each wave with well defined L and J values, shown in figs. 25 and 26.

APPENDIX A

This appendix contains a summary of the kinematical variables and expressions used in this paper.

The DDR $a + b \to (1+2) + 3$ may be represented as in fig. (1), and the TCDM which describes these reactions has the diagrams of fig. (2).

The four-momenta corresponding to the external lines are $p_i (i = a,b,1,2,3)$ and for the internal lines we define

$$q = p_a - p_1, \quad k = p_a - p_2 \quad \text{and} \quad p = p_1 + p_2 \tag{A.1}$$

At the diffractive vertices the following four-momenta are used

$$\begin{aligned} P &= (p_1+k)/2 \quad , \; Q = (p_2+q)/2 \\ K &= (p_a+p)/2 \quad , \; R = (p_b+p_3)/2 \end{aligned} \tag{A.2}$$

The invariants constructed with these 4-vectors are

$$\begin{aligned} &s = (p_a+p_b)^2, \quad s_1 = (p_1+p_2)^2, \quad s_2 = (p_2+p_3)^2 \\ &s_3 = (p_1+p_3)^2, \quad t_1 = (p_a-p_1)^2, \quad u_1 = (p_a-p_2)^2 \\ &t_2 = (p_b-p_3)^2 \end{aligned} \tag{A.3}$$

The energies E_i and the momenta $|\vec{p}_i|$ $(i=a,b,1,2,3)$ aredefined in the Gottfried-Ickson frame for $\vec{p}_1 + \vec{p}_2 = 0$ the $1 + 2$ rest system, see fig. 27. The expressions of E_i and $|\vec{p}_i|$ are given by

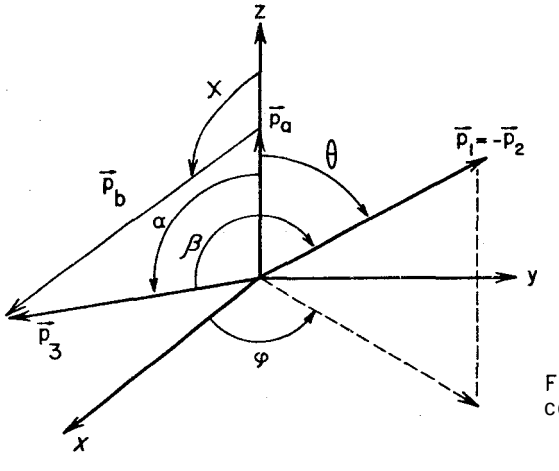

Fig. 27 - Gottfried - Jackson coordinates for $R12(\vec{p}_1+\vec{p}_2=0)$.

$$E_a = (s_1+m_a^2-t_2)/2\sqrt{s_1} \quad , \quad E_b = (s_1-m_a^2-m_3^2+t_2)/2\sqrt{s_1}$$

$$E_1 = (s_1+m_1^2-m_2^2)/2\sqrt{s_1} \quad , \quad E_2 = (s_1+m_2^2-m_1^2)/2\sqrt{s_1}$$

$$E_3 = (s-s_1-m_3^2)/2\sqrt{s_1} \quad , \quad |\vec{p}_a| = \lambda^{1/2}(s_1,m_a^2,t_2)/2\sqrt{s_1}$$

$$|\vec{p}_b| = \lambda^{1/2}(s_1,m_b^2,t_{a3})/2\sqrt{s_1}, \quad |\vec{p}_3| = \lambda^{1/2}(s_1,m_3^2,s)/2\sqrt{s_1}$$

and

$$|\vec{p}_1| = |\vec{p}_2| = \lambda^{1/2}(s_1,m_1^2,m_2^2)/2\sqrt{s_1} \tag{A.4}$$

where

$$t_{a3} = s_1 - s - t_2 + m_a^2 + m_b^2 + m \tag{A.5}$$

and $\lambda(x,y,z)$ is defined by

$$\lambda(x,y,z) = x^2+y^2+z^2-2(xy+xz+yz) \tag{A.6}$$

The angular coordinates for the momenta are

$$\vec{p}_1 = \vec{p}_1(\theta,\phi), \quad \vec{p}_b = \vec{p}_b(\chi,0) \quad \text{and} \quad \vec{p}_3 = \vec{p}_3(\alpha,0) \tag{A.7}$$

The angles in GJS are related by

$$\cos\beta = \cos a \cos\theta + \sin\alpha \operatorname{sen}\theta \cos\phi \tag{A.8}$$

High energy approximation (HEA)

These approximations correspond to

$$s,s_2,s_3 >> s_1,|t_1|,|u_1|,|t_2|,m_i^2 \quad (i=a,b,1,2,3) \tag{A.9}$$

Using eq. (A.9) we obtain

$$2Q.R \simeq s_2 \ , \ 2P.R \simeq s_3, \ 2K.R \simeq s \tag{A.10}$$

$$\cos a \simeq -(s_1-m_a^2+t_2)/\lambda^{1/2}(s_1,m_a^2,t_2)$$

$$\sin a \underset{\sim}{\simeq} 2\sqrt{s_1}\,\sqrt{-t_2}\,/\lambda^{1/2}\,(s_1, m_a^2, t_2) \qquad \text{(A.11)}$$

$$s_2 \underset{\sim}{\simeq} s(E_2 + |\vec{p}_1|\cos\beta)/\sqrt{s_1} \quad \text{and} \quad s_3 \underset{\sim}{\simeq} s(E_1 - |\vec{p}_1|\cos\beta)/\sqrt{s_1} \qquad \text{(A.12)}$$

For very small values of $|t_2|$ eq.(A.8) becomes

$$\cos\beta \underset{\sim}{\simeq} -\cos\theta + (2\sqrt{s_1}\,\sqrt{-t_2}\,/(s_1 - m_a))\sin\theta\cos\phi \qquad \text{(A.13)}$$

then, carrying into eq. (A.12) we obtain

$$s_2 \underset{\sim}{\simeq} s(E_2 - |\vec{p}_1|\cos\theta)/\sqrt{s_1} + (2s\,|\vec{p}_1|\,\sqrt{-t_2}/(s_1 - m_a^2))\sin\theta\cos\phi$$

and

$$s_3 \underset{\sim}{\simeq} s(E_1 + |\vec{p}_1|\cos\theta)/\sqrt{s_1} - (2s\,|\vec{p}_1|\,\sqrt{-t_2}/(s_1 - m_a^2))\sin\theta\cos\phi \qquad \text{(A. 14)}$$

In the same approximatlons we have

$$(t_1 - m_2^2) \underset{\sim}{\simeq} -(s_1 - m_a^2)(E_2 - |\vec{p}_1|\cos\theta)/\sqrt{s_1}$$

and (A.15)

$$(u_1 - m_1^2) \underset{\sim}{\simeq} -(s_1 - m_a^2)(E_1 + |\vec{p}_1|\cos\theta)/\sqrt{s_1}$$

From eqs. (A. 14) and (A.15) we obtain

$$\frac{s_3}{u_1 - m_1^2} \underset{\sim}{\simeq} -\frac{s}{s_1 - m_a^2}\left[1 - \frac{2|\vec{p}_1|\sqrt{s_1}\,\sqrt{-t_2}\sin\theta\cos\phi}{(s_1 - m_a^2)(E_1 + |\vec{p}_1|\cos\theta)}\right]$$

and (A. 16)

$$\frac{s_2}{t_1 - m_2^2} \underset{\sim}{\simeq} -\frac{s}{s_1 - m_a^2}\left[1 + \frac{2|\vec{p}_1|\sqrt{s_1}\sqrt{-t_2}\sin\theta\cos\phi}{(s_1 - m_a^2)(E_2 - |\vec{p}_1|\cos\theta}\right]$$

and at the limit $t_2 = 0$, we have the relation

$$\frac{s_2}{t_1 - m_2^2} \underset{\sim}{\simeq} \frac{s_3}{u_1 - m_1^2} \underset{\sim}{\simeq} -\frac{s}{s_1 - m_a^2} \qquad \text{(A.17)}$$

For a three particles final state reaction the cross-section is given by

$$d\sigma = C \int \frac{\lambda^{1/2}(s_1, m_1^2, m_2^2)}{s_1} ds_1 dt_2 d\cos\theta d\phi |A|^2 \qquad (A.18)$$

where

$$C = 1/(2^{10}\pi^4 \lambda(s, m_a^2, m_b^2))$$

APPENDIX B

In this appendix we collect some results useful for the projection into partial waves of the helicity amplitudes, obtained throughthe TCDM, for the DDR.

Neylectlng the spin structure of ($b\bar{b}3$) vertex, due to the factorizatlon property, the helicity amplitude, given by the TCDM for the DDR $a + b \to (1+2) + 3$, in the GJS, making use of the Jacob-Wick convention, has an explicit phase

$$A_{\lambda_1\lambda_2\lambda_a}(s, s_1, t_2; \theta, \phi) = e^{-i(\lambda - \lambda_a)\phi} A_{\lambda_1\lambda_2\lambda_a}(s, s_1, t_2; \theta, \phi) \qquad (B.1)$$

where $h = \lambda_1 - \lambda_2$.

The helicity amplitudes for total angular momentum J of the dissociated sybsystem (1+2) and its projection M, on the Incident beam direction $\vec{p}_a$, and normality $\pm$, are given by

$$A^{JM\pm}_{\lambda_1\lambda_2\lambda_a}(s, s_1, t_2) = [(2J+1)/8\pi]^{1/2} \int d\Omega\, e^{-i(M-\lambda_a)\phi} \times \{ d^J_{M\lambda}(\theta)\, \tilde{A}_{\lambda_1\lambda_2\lambda_a}(\theta, \phi) \pm N_{12}\, d^J_{M,-\lambda}(\theta)\, \tilde{A}_{-\lambda_1,-\lambda_2,\lambda_a}(\theta, \phi) \} \qquad (B.2)$$

where

$$N_{12} = \eta_1 \eta_2 (-1)^{\delta_1 + \delta_2 - v_{12}} \qquad (B.3)$$

In the above expresslon η_1 and $_{r)}$, and δ_1 and δ_2 aretheintrinslc paritles and spins of the particles 1 and 2 respectively; $v_{12} = 0$ for integer J and $v_{12} = 1/2$ for half integer J.

The paritles of the amplitudes are given by

$$P = \pm(-1)^{J - v_{12}} \qquad (B.4)$$

For $\lambda_1 = \lambda_2 = 0$ instead of eq. (8.2) we have

$$A^{JM,N_{12}}_{00,\lambda_a} = ((2J+1)/4\pi)^{1/2} \int d\Omega\, e^{-i(M-\lambda_a)\phi}\, d^J_{M0}(\theta) A_{00\lambda_a}(\theta,\phi) \tag{B.5}$$

From parity conservation we obtain the relation

$$A^{J,-M,\pm}_{-\lambda_1,-\lambda_2,-\lambda_a} = \eta(-1)^{M-\lambda_a} A^{JM,\pm}_{\lambda_1\lambda_2\lambda_a} \tag{B.6}$$

where

$$\eta = \eta_1\eta_2\eta_a(-1)^{\delta_1+\delta_2-\delta_a} \tag{B.7}$$

The amplitudes in eq. (8.2) also satisfy

$$A^{JM,\pm}_{-\lambda_1,-\lambda_2,\lambda_a} = \pm N_{12} A^{JM,\pm}_{\lambda_1\lambda_2\lambda_a} \tag{B.8}$$

The amplitudes for well defined J, M, orbital angular momentum L, spin $\vec{\delta} = \vec{\delta}_1 + \vec{\delta}_2$ and normality $(\pm)$, of the subsystem 1+2 are given by

$$A^{JM,\pm}_{(L,\delta)\lambda_a} = ((2L+1)/(2J+1))^{1/2} \sum_{\lambda_1\lambda_2} C^{L\delta J}_{0\lambda\lambda}\, C^{\delta_1\delta_2\delta}_{\lambda_1,-\lambda_2,\lambda}\, A^{JM,\pm}_{\lambda_1\lambda_2\lambda_a} \tag{B.9}$$

where $C^{L\delta J}_{0\lambda\lambda}$ and $C_{\lambda_1,-\lambda_2,\lambda}$ are the Clebsh-Gordan coeficients. In thecases for which $\delta_2 = 0$, $\delta = \delta_1$, the amplitudes in eq. (B.9) become

$$A^{JM,\pm}_{(L)\lambda_a} = ((2L+1)/(2J+1))^{1/2} \left[1 \pm N_{12}(-1)^{J-L-\delta_1}\right] \sum_{|\lambda_1|} C^{L\delta_1 J}_{0|\lambda_1||\lambda_1|} A^{JM,\pm}_{|\lambda_1|,\lambda_a} \tag{B.10}$$

From the eqs. (6.6) and (B.8) we obtain

$$A^{J,-M,\pm}_{(L),-\lambda_a} = \pm N_{12}.\eta(-1)^{M-\lambda_a} A^{J,M,\pm}_{(L)\lambda_a} \tag{B.11}$$

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Resumo

Neste artigo apresentamos um conjunto de novos resultados de Reações de Dissociação Difrativa, no contexto do Modelo Deck a Três Componentes. Estes novos resultados são confrontados com outros recentemente publicados para apresentar uma visão geral do modelo, suas predições e comparações com resultados experimentais. Dois tipos de amplitudes e correlações são observadas. A correlação inclinação difrativa-massa-cos θ^{GJ} e a inclinação difrativa-massa-ondas parciais.