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AXIAL VECTOR MESON PRODUCTION

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A B S T R A C T

Recently available differential cross-section and density matrix information on $\pi^- p \to B^- p$ at 4 GeV/c are successfully described in terms of t channel exchanges and s channel absorptive effects. The s channel helicity amplitude which is dominant at small $|t|$ (zero net helicity flip ω exchange) is found to have a zero at $-t = 0.2$ GeV^2. SU(3) and higher symmetries are used to predict cross-sections for further axial vector meson production processes, in particular non-diffractive A_1 production. The importance of these processes with regard to Regge phenomenology and meson spectroscopy is emphasized.

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1. - INTRODUCTION

Of the two axial vector meson nonets $(B, K_B, h, h'; J^{PC} = 1^{+-})$ and $(A_1, Q_A, D, D'; J^{PC} = 1^{++})$ whose existence is suggested by the quark model, the B meson alone is well established [1)-5)]. A recent determination of the J^P, polarization and cross-section of the B as produced in 4 GeV/c $\pi^- p$ interactions [1),5)] enables a more detailed study of axial vector production amplitudes than has hitherto been possible. Previous studies [6)] have been forced, through lack of direct experimental information, to consider relatively crude models derived from pseudoscalar and vector meson production via naive quark model results. These last, however, do not describe correctly the more subtle features of axial meson couplings (e.g., the dominantly transverse $B \rightarrow \omega\pi$ decay [7)]). Another study [8)] exploited semi-local duality for Reggeon-particle scattering to successfully relate $\pi N \rightarrow \eta N$ and $\pi N \rightarrow BN$ though only in a spin averaged sense [*)].

In the case of $\pi N \rightarrow BN$ we are fortunately in a position to tackle the problem directly. Together with knowledge (through factorization) of the Regge exchange couplings to nucleons, the differential cross-section and density matrix elements [5)] yield enough information to estimate the separate Regge pole exchanges (ω and A_2) and their associated cut corrections. In so doing we are able to test to what extent recent ideas on Regge phenomenology [10)] apply to this new domain. Previous studies of meson Regge exchanges have involved production of pseudoscalar and vector mesons only. Natural parity exchanges, in the latter processes, couple only to helicity-one mesons, while in axial vector production a richer spin structure is possible with both helicity states populated. The negligible rôle played by unnatural parity pole exchange in 1^+ production also contributes to a rather clean study of ω and A_2 exchange.

Having estimated the PVA couplings $(J^{PC}(A) = 1^{+-})$ the cross-sections for B production by charge exchange (CEX) and hypercharge exchange (HYCEX) may be predicted as a cross-check of this Regge decomposition. We reinvestigate the failure of a previous model [6)] for the relative A_2 and B production cross-sections. A comparison of the $A_2\,\rho\pi$ couplings obtained in a recent analysis of A_2 production [11)] and our $B\omega\pi$ coupling is found to be in accord with theoretical estimates.

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*) A recent analysis [9)], details of which were received after completion of the present work, attempts to predict B production assuming (unrealistically) only absorbed ω exchange. Predictions for the B decay parameters are made but are invalidated by the failure to perform the necessary crossing from s to t channel helicity quantization (see Appendix).

The higher symmetry ℓ broken $SU(6)_W$, which satisfactorily describes the ω helicity in B decay also gives the decay $A_1 \to \rho\pi$ [12] and hence yields a prediction for the non-diffractive production of A_1 in terms of B production. Studies of A_1 production by vacuum quantum number exchange have so far failed to isolate a resonant state with $J^P = 1^+$ [3]. We re-emphasize [6] the merits of searching for a resonant A_1 state produced by CEX or HYCEX and we present predictions.

Section 2 contains a description of our model and a discussion of the available B production data. Predictions of related processes including non-diffractive A_1 production are discussed in Section 3. Concluding remarks are in Section 4.

2. - MODEL FOR B PRODUCTION

We define s channel helicity amplitudes $N^{\lambda B}_{\lambda_N'\lambda_N}$, $U^{\lambda B}_{\lambda_N'\lambda_N}$ of definite exchange naturality (natural and unnatural parity exchange asymptotically)

$$\begin{aligned} N^0_{\lambda'\lambda} &= H^0_{\lambda'\lambda} \\ N^1_{\lambda'\lambda} &= \frac{1}{\sqrt{2}}\left(H^1_{\lambda'\lambda} - H^{-1}_{\lambda'\lambda} \right) \\ U^1_{\lambda'\lambda} &= \frac{1}{\sqrt{2}}\left(H^1_{\lambda'\lambda} + H^{-1}_{\lambda'\lambda} \right) \end{aligned} \tag{2.1}$$

such that the 1^+ meson observables are

$$\begin{aligned} \sigma^0_N &\equiv \rho^H_{00}\cdot d\sigma/dt = |N^0_{++}|^2 + |N^0_{+-}|^2 , \\ \sigma^1_N &\equiv (\rho^H_{11} - \rho^H_{1-1}) . d\sigma/dt = |N^1_{++}|^2 + |N^1_{+-}|^2 , \\ \sigma^1_U &\equiv (\rho^H_{11} + \rho^H_{1-1}) . d\sigma/dt = |U^1_{++}|^2 + |U^1_{+-}|^2 , \\ \sqrt{2}\, \mathrm{Re}\,\rho^H_{10}\cdot d\sigma/dt &= \mathrm{Re}\left(N^1_{++} N^{0*}_{++} + N^1_{+-} N^{0*}_{+-}\right) . \end{aligned} \tag{2.2}$$

Pole Exchanges

To obtain a model of maximum simplicity compatible with the data we consider initially, natural parity Regge exchanges only - ω and A_2. Guided by Regge pole phenomenology [13] we retain only the ω_{++} and A_{2+-} contributions, and estimate their relative baryon couplings from $\pi(K)N \to \pi(K)N$ analyses. We take

$$\omega^0_{++} = g . e^{bt} . \Gamma(1-\alpha(t)) . (1-e^{-i\pi\alpha(t)}) . (s/s_0)^{\alpha(t)-1} \tag{2.3}$$

and

$$A^0_{2+-}/\omega^0_{++} = -R_{A\omega} . \sqrt{-t'} . i \cot\left(\frac{\pi\alpha(t)}{2}\right) \tag{2.4}$$

where $\alpha(t) = 0.5 + 0.86t$ (exchange-degenerate ρ-A_2-f-ω trajectory) and $s_0 = 1$ GeV^2. $R_{A\omega}$ (estimated to be about -1) is the product of the ratio of the meson vertex couplings (+1 by exchange degeneracy) and the ratio of the baryon couplings [13]. In the following, we take $R_{A\omega} = -1$.

For the helicity-one contributions, we write

$$A^1_{2+-}/A^0_{2+-} = \omega^1_{++}/\omega^0_{++} = R^s_{10} . \sqrt{-t'}/m_\omega \quad . \tag{2.5}$$

The value of R_{10} in the t channel may be estimated from the helicity couplings of the ω produced in B decay :

$$\frac{T_{\lambda_\omega=1}(B\to\omega\pi)}{T_{\lambda_\omega=0}(B\to\omega\pi)} = \frac{T_{\lambda_B=1}(\omega\to B\pi)}{T_{\lambda_B=0}(\omega\to B\pi)} = i . R^t_{10} \tag{2.6}$$

where $T\lambda_B(\omega\to B\pi)$ is the helicity amplitude for ω decay (virtually) into $B\pi$. For our purposes it is of course necessary to cross R^t_{10} to R^s_{10} and to continue from the ω pole to negative t. This is done explicitly in the Appendix.

The angular momentum factor $\sqrt{-t'}/m_\omega$ in Eq. (2.5) is that which would occur in a dual model for the continuation from $t = m_\omega^2$ to negative t. Data on B decay [1),2)] suggest R^s_{10} is in the region of $1.3 \to 1.5$ but since an unknown continuation is involved, we will determine R^s_{10} from the B production data and compare with its value on the B pole.

Cut Contributions

ω and A_2 contributions alone cannot describe the non-zero, albeit structureless, σ^1_u seen in the data (Fig. 1). Studies of pseudo-scalar and vector meson [10)] production have indicated the presence of cut (background) contributions at least in amplitudes of zero s channel net helicity flip. Such a cut in N^o_{++} would produce, if geometrical ideas have any validity, a dip in σ^o_N near $t = -0.2$ GeV^2 as, in fact, seen in the data. We parametrize

$$C^0 = -g_{c^0} \cdot e^{b_c t} \cdot i e^{-i\left(\frac{\pi\alpha}{2} + \phi_0 t\right)} \cdot (s/s_0)^{\alpha_c(t)-1}$$

$$C^1 = +g_{c^1} \cdot e^{b_c t} \cdot e^{-i\left(\frac{\pi\alpha}{2} + \phi_1 t\right)} \cdot (s/s_0)^{\alpha_c(t)-1} \qquad (2.7)$$

where $\alpha_c = 0.5 + 0.43\, t$ and ϕ_o and ϕ_1 allow the cuts to vary away from being antiparallel to their respective poles (ω and A_2).

Our Model

The model for B production is then

$$N^0_{++} = \omega^0_{++} + C^0 \qquad N^0_{+-} = A^0_{2+-}$$

$$N^1_{++} = \omega^1_{++} \qquad N^1_{+-} = A^1_{2+-} + C^1 \qquad (2.8)$$

$$U^1_{++} = 0 \qquad U^1_{+-} = C^1 \quad .$$

It may be seen that ρ_{00} determines g_{c0}/g and $b - b_c$; $d\sigma/dt$ determines g and b ; g_c1/g is fixed by $\rho_{11} + \rho_{1-1}$; R^s_{10} is determined by $(\rho_{11} - \rho_{1-1})/\rho_{00}$. $\mathrm{Re}\,\rho_{10}$ is a cross-check. The cut phase parameters ϕ_i are only weakly constrained (by the depth of the dips in ρ_{00} and $\mathrm{Re}\,\rho_{10}$) to be near zero. A fit to the 4 GeV/c $\pi^- p \to B^- p$ data with $\phi_1 = \phi_0 = 0$ is shown in Fig. 1, and the parameters are

$$\begin{aligned} &g = 51.9 \;, \quad g_{c0} = 49.4 \;, \quad g_{c1} = 25.3 \\ &b = 1.45 \;, \quad b_c = 1.02 \\ &R^s_{10} = 1.48 \quad (|F_0|^2 = 0.16) \end{aligned} \tag{2.9}$$

$[\chi^2/\mathrm{NDF} = 7.8/(19-6) \sim 0.6]$. In the fit the large value of ρ_{00} is explained at small $-t$ by ω exchange, the dip at $t = -0.2$ is due to pole/cut cancellation ("peripheral" ω exchange) and to the rising contribution of A_2 exchange $(\sim\sqrt{-t'})$ which also explains the ρ_{00} values at large $-t$: $\rho_{11} + \rho_{1-1}$ is pure A_2 cut. At $t' = 0$ N^1_{+-} is pure cut and falls in value as A^1_{2+-} begins to cancel C^1 (zero near $t = -0.2$ GeV^2). It is left to $\omega^1_{++}(\sim\sqrt{-t'})$ to give a strong contribution near $t = -0.2$ and produce the shape of $\rho_{11} - \rho_{1-1}$ observed. A cross-check of the zero structure of N^0_{++} and N^1_{+-} is provided by $\mathrm{Re}\,\rho_{10}$ whose two terms $\mathrm{Re}(N^1_{++}N^{0*}_{++})$ and $\mathrm{Re}(N^1_{+-}N^{0*}_{+-})$ go from positive to negative and negative to positive, respectively as $-t$ increases through 0.2 GeV^2. Only the sign of R^s_{10} needs to be determined by the data. The double zero structure in $\mathrm{Re}\,\rho_{10}$ is a direct consequence of the pole/cut cancellation properties of non-evasive $(\omega^0_{++} \sim \text{const.})$ and evasive $(A^1_{2+-} \sim -t')$ poles.

The value $R^s_{10} = 1.48$ corresponds (see Appendix) to the B decay parameter $|F_0|^2$ $[= 1/(1+|g_+/g_0|^2)]$ of 0.16 while experimental values vary from 0.10 ± 0.06 [1] to 0.16 ± 0.04 [2]. In view of the extrapolation involved, the comparison is very satisfactory *).

Predictions for B Production

Also shown in Fig. 1 are the data and model predictions for $d\sigma/dt$ $(\pi^+ p \to B^+ p)$ at 5 GeV/c. Since the $I = 0(\omega)$ and $I = 1(A_2)$ exchanges occur in amplitudes of different baryon helicity, the model predicts equal meson observables $(\sigma, d\sigma/dt, \rho_{mm'})$ for $\pi^+ N \to B^+ N$ and $\pi^- N \to B^- N$. The available

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*) The sign of g_+/g_0 (positive) is also in agreement with the data.

data for σ *) and for $d\sigma/dt$ is consistent with this [5),15)]. We expect the comparison of $\pi^{\pm}p \to B^{\pm}p$ differential cross-sections in Fig. 1 to be realistic since the background subraction methods used in each case are similar.

Since the $I=1$ component in our model for $\pi N \to BN$ is dominated by A_2 quantum number exchange with baryon helicity flip couplings only, it is possible to predict from it the cross-section for $\pi N \to B\Delta$ by scaling with the coupling ratio $(g_{A_2\bar{N}\Delta}/g_{A_2\bar{N}N})^2 \underset{\mathrm{EXD}}{\equiv} (g_{\rho\bar{N}\Delta}/g_{\rho\bar{N}N})^2$, deduced from $d\sigma/dt$ $(\pi^- p \to \pi^0 n)$ and $d\sigma/dt$ $(\pi^+ p \to \pi^0 \Delta^{++})$ data to be ≈ 2 [16)]. The prediction for $\sigma(\pi^- n \to B^- \Delta^0)$ at 7 GeV/c is 35-40 μb depending on the strength of the cuts present. The experimental measurement is [17)] 26 ± 10 μb suggesting that the strength of A_2 exchange is in accordance with the nucleon and delta production data and exchange degeneracy expectation. Conflicting evidence is, however, provided by the 5 GeV/c measurement [15)] $\sigma(\pi^+ p \to B^0 \Delta^{++}) = 15 \pm 12$ μb which is equivalent to $\sigma(\pi^- n \to B^- \Delta^0) = 20 \pm 16$ μb at 5 GeV/c. The more directly related process $\pi^+ n \to B^0 p$ is simple to predict ($\sigma \approx 90$ μb at 4 GeV/c) but not to measure experimentally since there are two neutrals in the final state.

Nucleon polarization observables involve interference between $I=0$ and $I=1$ exchanges. Although not likely to be measured in the near future, we give our (mirror symmetric) predictions for the polarization to be expected in $\pi^{\pm}p \to B^{\pm}p$ at 4 GeV/c (Fig. 2). The sign change near $-t = 0.2$ GeV^2 is a direct consequence of the zeros in the $n=0$ amplitudes of meson helicity zero and one which were inferred from the ρ_{00} and $\mathrm{Re}\,\rho_{10}$ data :

$$P\,d\sigma/dt = -2.\,\mathrm{Im}\left[(\omega^0_{++} + C^0).A^{0\,*}_{2+-} + \omega^1_{++}(A^1_{2+-} + C^1)^*\right] . \qquad (2.10)$$

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*) For a data compilation, see Ref. 14)

The Regge model expectation for the momentum dependence of σ (integrated for $|t| < 1\ \mathrm{GeV}^2$) is $\sigma \sim p_L^{-0.7}$ *). The available data, however, fall more steeply ($p_L^{-1.6}$) [14),18)]. Part of this discrepancy may be explained by the fact that the data are integrated over all production angles and therefore contain contributions from other exchange mechanisms. Baryon exchange, for example, would contribute to a steeper energy dependence of the data. High energy, high statistics B production studies using the same methods of analysis as used at 4 GeV/c would provide a stringent test of our Regge interpretation of the data.

Unnatural Parity Exchange

Possible unnatural parity exchanges are the $\delta(980)$ (a very low-lying trajectory) and the A_1 whose coupling to nucleons is thought to be weak [19),11)]. Interference effects between these and a natural parity cut could appear in σ_u^1. In view of the above remarks and the small structureless σ_u^1 seen experimentally, we do not regard inclusion of unnatural parity poles as necessary at the present level of sophistication and cannot blame such contributions for the steep energy dependence of the data.

3. - RELATED PROCESSES

Hypercharge Exchange B Production

From the ω and A_2 exchange couplings in $\pi^- p \to B^- p$ one may estimate the (exchange degenerate) K* Regge pole exchange in $K^- n \to B^- \Lambda$ e.g.,

$$\frac{K^{*0}_{++}(890)}{\omega^0_{++}} = -\lambda \cdot \frac{1}{\sqrt{6}} \cdot \frac{1 + 3(F/D)_{++}}{3(F/D)_{++} - 1} \tag{3.1}$$

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*) This behaviour is not easily related to $\alpha_{eff}(t \approx 0)$ since at low energy σ is more kinematically depleted by the cuts ($t_{min} > |t| < 1\ \mathrm{GeV}^2$) than at high energies.

where

$$\lambda = \frac{\Gamma(1-\alpha_{K^*})}{\Gamma(1-\alpha)} \cdot (s/s_0)^{\alpha_{K^*}-\alpha} \quad ; \alpha_{K^*} = 0.35 + 0.86t \tag{3.2}$$

is an SU(3) breaking factor [20]. The K^*_{+-}(890 and 1420) may be similarly related to the A_{2+-}

$$\frac{K^{*0}_{+-}(1420)}{A^0_{2+-}} = \lambda \cdot \frac{1}{\sqrt{6}} \cdot \frac{1 + 3(F/D)_{+-}}{1 + (F/D)_{+-}} \quad . \tag{3.3}$$

Since the SU(3) properties of cut corrections are not well understood it is only possible to predict the Regge pole contributions and so give a rough estimate *) of the $K^- n \to B^- \Lambda$ cross-section [using $(F/D)_{++} = -5$, $(F/D)_{+-} = 2/3$]. At 4.9 GeV/c we predict $\sigma \approx 24$ μb as compared with the experimental value [21] of $\sigma = 29 \pm 8$ μb (all $-t$).

Non-Diffractive A_1 Production

It has been a great challenge for higher symmetry schemes to account for the transverse decay $B \to \omega\pi$. Apparently successful (though largely untested) symmetries such as ℓ broken $SU(6)_W$, in doing this also relate the two pionic decays $B \to \omega\pi$ and $A_1 \to \rho\pi$, where by A_1 we mean the $J^{PC} = 1^{++}$ (supposedly) resonant state sought in 3π final states. The ℓ broken $SU(6)_W$ predictions [12]

$$\frac{g_0(A)}{g_0(B)} = \frac{g_+(B)}{g_0(B)} \quad \left[\equiv -\sqrt{2}\, R^t_{10}(B)\right] \tag{3.4}$$

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*) Cuts would be expected to reduce (increase) the differential cross-section at small (large) $-t$. Using $\pi N \to BN$ as a guide, we estimate that all natural parity cross-sections predicted in this section could be multiplied by 2/3 to simulate the effect of cuts. All integrated cross-sections predicted in this work refer to $|t| < 1.0$ GeV^2.

and

$$- R^{t}_{10}(A) \equiv \frac{1}{\sqrt{2}} \cdot \frac{g_{+}(A)}{g_{0}(A)} = \frac{1}{2}\left[\frac{\sqrt{2}}{g_{+}(B)/g_{0}(B)} + 1\right] \qquad (3.5)$$

relate the $B^{-} \to \omega\pi^{-}$ and $A_{1}^{-} \to \rho^{0}\pi^{-}$ helicity decay couplings $g_{\lambda_{\omega}}(B)$ and $g_{\lambda_{\rho}}(A)$ which, as shown explicitly in the Appendix, in turn relate the s channel helicity couplings of B and A_1 production. Thus $R^{s}_{10}(B) = 1.48$ [Eq. (2.9)] corresponds [Eq. (A.5)] to $R^{t}_{10}(B) = -1.61$ and hence $g_{+}(B)/g_{0}(B) = 2.28$. Equations (3.4) and (3.5) then give $g_{0}(A)/g_{0}(B) = 2.28$ and $R^{t}_{10}(A) = -0.81$. The s channel quantities of interest, $T^{s}_{0}(A)/T^{s}_{0}(B) = -1.26$ and $R^{s}_{10}(A) = 0.40$, are calculated from these by means of the crossing Eqs. (A.1) and (A.5).

Assuming exchange degeneracy, it is then a simple matter to calculate from Eqs. (2.8) the f^{0} and ρ exchange contributions to A_1 production, e.g.,

$$\frac{f^{0}_{++}(A)}{\omega^{0}_{++}(B)} = -i\left[T^{s}_{0}(A)/T^{s}_{0}(B)\right] . \cot\left(\frac{\pi\alpha(t)}{2}\right) ,$$

$$\frac{\rho^{0}_{+-}(A)}{A^{0}_{2+-}(B)} = i\left[T^{s}_{0}(A)/T^{s}_{0}(B)\right] . \tan\left(\frac{\pi\alpha(t)}{2}\right) . \qquad (3.6)$$

Provided the phase space properties of the decays $B \to \omega\pi$ and $A_1 \to \rho\pi$ are comparable, we can predict a non-diffractive cross-section of

$$\sigma(\pi^{-}p \to \underset{\hookrightarrow \rho^{0}\pi^{-}}{A_{1}^{-}}\, p)_{\text{non-diff.}} \approx 75\,\mu b \qquad (3.7)$$

at 7.5 GeV/c, as compared with the experimental value

$$\sigma(\pi^{-}p \to \rho^{0}\pi^{-}p) \approx 460 \pm 50\,\mu b \;(m_{\rho\pi} < 1.5\,\text{GeV}; J^{P} = 1^{+}) .^{*)} \qquad (3.8)$$

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*) estimated value from Ref. 22).

Since there are unknown Pomeron and cut contributions to be added to Eq. (3.7), and Deck effect contributions included in Eq. (3.8), this comparison has little significance. It is potentially of more value, to study the A_1 produced by HYCEX or CEX. Since the SU(3) properties of B and A_1 are identical, equations analogous to (3.1)-(3.3) can be used to relate K*(890 and 1420) exchange to ρ and f^0 exchange in A_1 production. We thus predict (at 4 GeV/c)

$$\sigma(K^-p \to A_1^0\Lambda) \approx 16\,\mu b \quad . \tag{3.9}$$

Analogously to B production, we may estimate the cross-section for the CEX process $\pi^-p \to A_1^0 n$ to be around 20 μb. However, in this case the allowed unnatural parity exchanges B and Z $(J^P I^G = 2^- 1^+)$ are expected [11] to couple much more strongly to nucleons (in U^1_{+-} and U^1_{++}, respectively) than would A_1 exchange in B production. Since we have no estimate of the (helicity flip) $B\pi A_1$ and $Z\pi A_1$ couplings we may only predict a CEX A_1 natural parity cross-section $\sigma_N \approx 20$ μb.

It is perhaps interesting to note that in our model for non-diffractive $\pi^\pm N \to A_1^\pm N$ the dominant amplitude is the helicity zero f^0 exchange ($\rho^H_{00} \gtrsim 0.95$ for $|t| < 0.5$ GeV^2) ; $R^s_{10}(A) = 0.40$ which corresponds to a high degree of s channel helicity conservation [in the t channel $R^t_{10}(A) = -0.81$]. Thus if, as sometimes suggested [23),24)], the Pomeron couples through the f^0 we might also expect s channel helicity conservation in diffractively produced A_1. Estimates [23)] of the universal Pomeron to f coupling ratio ($\approx$ 2.9 in amplitude at 7.5 GeV/c) would, however, yield an estimate of the total diffractive and non-diffractive cross-section for $\pi N \to A_1 N$ of $\sigma \approx 1.4$ mb, thus casting doubt on the quantitative validity of such arguments.

A_1 Decay Parameters

The ℓ broken $SU(6)_W$ equations (3.4) and (3.5), together with $g_+(B)/g_0(B) = 3.0$ [1)] and $\Gamma_{B\to\omega\pi} = 135$ MeV, yield a value for the A_1 partial width : $\Gamma_{A_1\to\rho\pi} = 170$ MeV [130 MeV if we had taken $g_0(B) = 0$] *).

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*) The PCAC prescription for relating the pionic decay coupling constants to the partial widths has been used [12)].

The quantity $R^t_{10}(A_1)$ may be expressed in terms of the more usual D/S decay amplitude ratio (defined in the Appendix). This gives $D/S = -0.15$ $[-0.35$ for $g_o(B) = 0]$.

A_2 Production

In an attempt to describe simultaneously the basic features of all resonance production, Fox et al. [6] found difficulty in relating the differential cross-sections for $\pi N \to BN$ and $\pi N \to A_2 N$ - the measured B/A_2 ratio was 10 times smaller than predicted by their naive quark model relations. This comparison involved the charged A_2 cross-section data which in principle has some (unknown) Pomeron exchange contribution. A more realistic comparison may be made using the ρ exchange component estimated in a recent analysis of charge-exchange A_2 production [11] and the ω exchange component found here. We find at $t \approx m_\rho^2 \approx m_\omega^2$ the ratio of meson vertex couplings to be

$$\frac{\omega^{\lambda_B = 1+}}{\rho^{\lambda_{A_2} = 1+}} = 3.2 \tag{3.10}$$

while from the ratio of B and A_2 decay widths $(\Gamma_{B\to\omega\pi}/\Gamma_{A_2\to\rho\pi} = 135/72)$

$$\frac{\omega^{\lambda_B = 1+}}{\rho^{\lambda_{A_2} = 1+}} = 1.7 \; . \tag{3.11}$$

The existing non-diffractive A_2 and B production data are therefore not inconsistent with an estimate based on the resonance widths *). This B/A_2 comparison is more favourable than that of Fox et al. since (we believe) a) ω exchange in B production is larger than the data suggest (due to cut-pole cancellation) and b) charged A_2 data yield an overestimate of the Regge pole A_2 couplings (Pomeron exchange may well be present [24]).

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*) ℓ broken $SU(6)_W$ also relates B and A_2 decay parameters. It is consistent with the experimental widths $\Gamma_{B\to\omega\pi} = 135$, $\Gamma_{A_2\to\rho\pi} = 72$ MeV and a dominantly transverse B decay.

4. - CONCLUSIONS

This first study of B meson production data has yielded valuable insight into the production mechanisms of axial vector mesons. In particular, we note the following points.

a) - The available differential cross-section and density matrix data for $\pi N \rightarrow BN$ hold few surprises for simple ideas of Regge phenomenology viz. exchange degenerate ω and A_2 Regge poles with corrections in $n = 0$ amplitudes such as to yield cross-over zeros at $t = -0.2$ GeV^2.

b) - There are no compelling indications of important unnatural parity pole exchanges in B production.

c) - Meagre charge and hypercharge exchange data lend support to our B production model.

d) - The model's $B\omega\pi$ helicity couplings are in good agreement with the measured B decay parameters and with simple estimates based on A_2 production.

e) - We predict equal differential cross-section and density matrix elements for $\pi^+ p \rightarrow B^+ p$ and $\pi^- p \rightarrow B^- p$. Their respective nucleon polarizations are predicted to have a single zero at $-t = 0.2$ GeV^2 and be mirror symmetric.

f) - Ignoring normalization and background uncertainties, the energy dependence of the B production cross-section taken at face-value is more rapid than that of a Regge pole model. Cleanly separated B production data at higher energies are needed to clarify this point.

g) - As compared with previous models, that of Section 2 allows a simpler and more realistic estimate of the production properties of the B meson nonet (i.e., the K_B and h mesons).

h) - ℓ broken $SU(6)_W$ allows predictions of non-diffractive A_1 production. A 16 μb cross-section for $K^- p \rightarrow A_1^0 \Lambda$ at 4 GeV/c is predicted. This process offers an attractive opportunity of isolating a resonant 1^+ signal in a situation free of ambiguities due to Pomeron couplings and/or Deck mechanisms.

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APPENDIX

We collect together the pole extrapolation formulae used. Consider for simplicity, the ω exchange contribution in $\pi\pi \to B\bar{B}$ scattering. The crossing matrix for the factorized (1^- exchange) $B\omega\pi$ vertex is

$$T_0^s = T_0^t . \cos\chi - T_+^t . \sin\chi$$
$$T_+^s = T_0^t . \sin\chi + T_+^t . \cos\chi \qquad (A.1)$$

where $T_+ = \sqrt{2} T_{\lambda_B = 1}$.

Now for large s,

$$\sin\chi = \frac{2 m_B . q_t . \sin\theta_t}{s} \qquad (A.2)$$

where

$$q_t = \left\{ \left[t - (m_\pi - m_B)^2\right] . \left[t - (m_\pi + m_B)^2\right] / 4t \right\}^{1/2} . \qquad (A.3)$$

The t channel helicity amplitude vertices $T^t_{\lambda_B}$ are related to the $\omega \to B\pi$ amplitude couplings g_{λ_B} by

$$i R_{10}^t \equiv \frac{T_+^t}{T_0^t} = \frac{d^1_{10}(\cos\theta_t)}{d^1_{00}(\cos\theta_t)} . \frac{g_+}{g_0} = - \frac{1}{\sqrt{2}} . \frac{\sin\theta_t}{\cos\theta_t} . \frac{g_+}{g_0} \qquad (A.4)$$

where $g_+ \equiv \sqrt{2} g_1$.

To evaluate the contributions of the $\omega \to B\pi$ couplings to the s channel vertices we evaluate the crossing matrix (A.1) at $t = m_\omega^2$ and s (or $\cos\theta_t$) $\to \infty$, i.e.,

$$R_{10}^s \equiv \frac{T_+^s}{i . T_0^s} = \frac{\tan\chi/i + R_{10}^t}{1 + (\tan\chi/i) . R_{10}^t} \tag{A.5}$$

where, by Eq. (A.4)

$$R_{10}^t = -\frac{1}{\sqrt{2}} \cdot \frac{g_+}{g_0} . \tag{A.6}$$

We note that the continuation to $t = m_\omega^2$ and s large must be consistent for $\sin\theta_t$ (and hence $\sin\chi$) in Eqs. (A.2) and (A.4). In this way $\tan\chi$ is calculated $(s \to +\infty)$ to be $+i\ 0.913$ and the sign in Eq. (A.6) as shown. This also fixes the sign of the negative $-t$ continuation

$$\frac{T_+^s}{T_0^s} = + R_{10}^s . \sqrt{-t'}/m_\omega \tag{A.7}$$

where R_{10}^s is defined in Eq. (A.5).

Data for B decay are often expressed in terms of

$$|F_0|^2 \equiv 1/(1 + |g_+/g_0|^2) . \tag{A.8}$$

Equation (2.6) of the text indicates that g_+/g_0 is the same for $B \to \omega\pi$ and for $\omega \to B\pi$ since their decay amplitudes are simply related by a Lorentz boost (no Wigner rotation is necessary). The ratio of D wave to S wave (D/S) may also be used to characterize axial vector decays :

$$\begin{aligned} g_0 &= \frac{1}{\sqrt{3}} (S - \sqrt{2} . D) \\ g_+ &= \frac{1}{\sqrt{3}} (\sqrt{2} . S + D) . \end{aligned} \tag{A.9}$$

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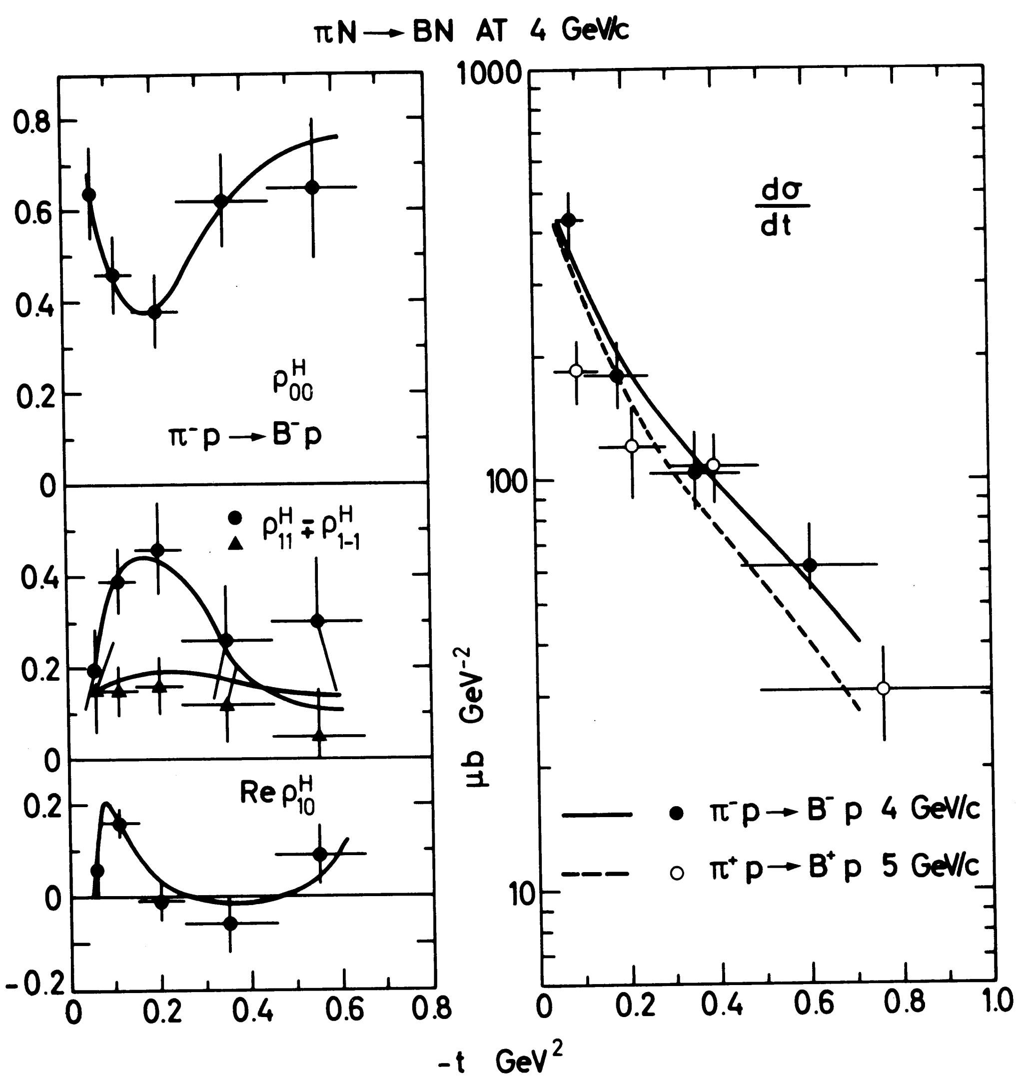
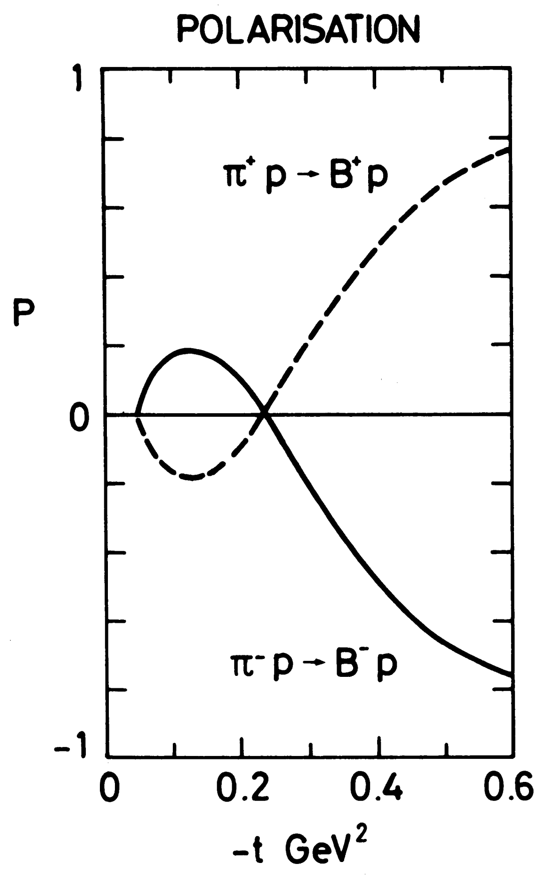


$\pi N \rightarrow BN$ AT 4 GeV/c
ρ_{00}^{H}
$\pi^- p \rightarrow B^- p$
$\rho_{11}^{H} \mp \rho_{1-1}^{H}$
$\mathrm{Re}\,\rho_{10}^{H}$
$\frac{d\sigma}{dt}$
$\mu b\ GeV^{-2}$
$\pi^- p \rightarrow B^- p$ 4 GeV/c
$\pi^+ p \rightarrow B^+ p$ 5 GeV/c
$-t\ GeV^2$

FIG.1



POLARISATION
P
$\pi^+ p \rightarrow B^+ p$
$\pi^- p \rightarrow B^- p$
$-t\ GeV^2$

FIG. 2