QUARK SPIN-FLIP IN POMERON EXCHANGE

A. DONNACHIE

School of Physics and Astronomy, University of Manchester,
Manchester M13 9PL, England

Abstract

It has been shown \cite{1} that the energy-dependence of the reaction $\gamma p \to b_1(1235)$ requires a contribution from pomeron exchange. This necessitates spin-flip at the quark level as the transition is from a $^3S_1$ state to a $^1P_1$ state. The same mechanism occurs in the reaction $\pi p \to a_1(1260)p$, which is a $^1S_0$ to $^3P_1$ transition.

Preliminary H1 data \cite{2} on $\gamma p \to (\omega \pi^0)X$ at $\langle W \rangle = 200$ GeV were provisionally interpreted as diffractive $b_1(1235)$ production:

$$\sigma(\gamma p \to b_1X) = 790 \pm 200 \pm 200 \text{ nb.}$$

(1)

This interpretation seems unlikely as the transition $\gamma \to b_1(1235)$ does not satisfy the Gribov-Morrison rule \cite{3,4} $P_{out} = (-1)^{J-P_{in}}$ and is from a $q\bar{q}$ spin-triplet state (photon) to a spin-singlet state ($b_1(1235)$), while it is well-established that helicity-flip amplitudes are small for pomeron exchange.

There is evidence from the Omega Photon Collaboration (CERN) \cite{5} that the transition is not dominated by pomeron exchange as, for $20 \leq E_\gamma \leq 70$ GeV ($\langle W \rangle = 8.6$ GeV) they find the energy dependence to be

$$\sigma(E_\gamma) = \sigma(39) \left(\frac{39}{E_\gamma}\right)^\alpha,$$

with

$$\sigma(39) = 0.86 \pm 0.27 \mu b, \quad \alpha = 0.6 \pm 0.2.$$  

(2)

(3)

This implies a combination of Regge exchange ($\sim 1/E_\gamma$) and pomeron exchange ($\sim E_\gamma^{2\epsilon}$, $\epsilon \approx 0.08 - 0.1$).

The CERN data are consistent with predominant $b_1(1235)$ production with $\sim 20\%$ $J^P = 1^-$ background, a result confirmed by SLAC \cite{6} at $E_\gamma = 20$ GeV ($\langle W \rangle = 6.2$ GeV). If we assume non-interfering Regge exchange (responsible for producing the $b_1(1235)$) and pomeron exchange (responsible for producing the $J^P = 1^-$ background) the cross section can be represented by

$$\sigma(s) = As^{2\epsilon} + Bs^{-2\eta}$$

with $\epsilon = 0.08$, $\eta = 0.4525$, $A = 0.107 \mu b$, $B = 29.15 \mu b$. At $E_\gamma = 39$ GeV the pomeron-exchange contribution is 25% of the total. Extrapolating to $W = 200$ GeV, this gives 584 nb which becomes $\sim 730$ nb after including a factor for nucleon dissociation.

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The $J^P = 1^-$ component can be estimated using simple VMD arguments:

$$
\frac{d^2\sigma_{\gamma p \rightarrow Vp}(s, m^2)}{dt \, dm^2} = \frac{\sigma_{e^+e^- \rightarrow V(m^2)} \, d\sigma_{Vp \rightarrow Vp}(s, m^2)}{4\pi^2\alpha}.
$$

Using the optical theorem to relate the amplitude at $t = 0$ to the total cross section for $Vp$ scattering and integrating over $t$ gives

$$
\frac{d\sigma_{\gamma p \rightarrow Vp}(s, m^2)}{dm} = \frac{m\sigma_{e^+e^- \rightarrow V(m^2)}(\sigma_{Vp \rightarrow Vp}^{\text{Tot}}(s))^2}{32\pi^3\alpha b},
$$

where $b \approx 5 \text{ GeV}^{-2}$ is the slope of the near-forward differential cross section.

The Omega Photon Collaboration [5] compared $\gamma p \rightarrow (\pi^+\pi^-\pi^+\pi^-)p$ with $e^+e^- \rightarrow \pi^+\pi^-\pi^+\pi^-$ over same energy and 4-pion mass ranges as their $\omega\pi$ data, giving $\sigma_{Vp \rightarrow Vp}^{\text{Tot}}(s) = 16.7 \pm 3.4 \text{ mb}$. It is now possible to predict $d\sigma/dm$ for the CERN and H1 data, given the data on $e^+e^- \rightarrow \omega\pi$. These data are shown in figure 1(a) and the prediction is compared with the CERN data in figure 1(b).

The predicted cross section is in good agreement with the H1 [2] at the upper end of the mass range, but there is an apparent excess of the data at the lower-mass end, as can be seen in figure 2. Is this indicative of some diffractive production of $b_1(1235)$ and, if so, is this reasonable?

An analogous reaction is $\pi^-p \rightarrow a_1(1260)p$. Although this does satisfy the Gribov-Morrison rule it requires spinflip at the quark level (singlet to triplet). Fitting the cross section data [11] with a single effective power, $\sigma = As^\alpha$, gives $\alpha = -0.52$, close to the value found for $\gamma p \rightarrow b_1(1235)p$ implying the same interpretation of Regge plus pomeron exchange, but now we must allow for interference. A fit to the cross section data with

$$
\sigma = As^{2\epsilon} + Bs^{\epsilon-\eta} + Cs^{-2\eta}
$$

Figure 1: (a) The cross section for $e^+e^- \rightarrow \omega\pi$. The data are from Novosibirsk [8] (horizontal bars), CLEO [9] (crosses) and the DM2 Collaboration [10] (stars) (b) The $J^P = 1^-$ component of the $\omega\pi$ mass distribution in the reaction $\gamma p \rightarrow \omega\pi p$ at $\sqrt{s} = 8.5$ GeV. The data are from the Omega Photon Collaboration [5] (crosses) and from the application of vector meson dominance to the data in (a) (horizontal bars).
Figure 2: The $\omega \pi$ mass distribution in the reaction $\gamma p \rightarrow \omega \pi p$ at $\sqrt{s} = 200$ GeV. The data (preliminary) are from the H1 Collaboration[2] (crosses) and from the application of vector meson dominance to the data in figure 1(a) (horizontal bars).

Given $A = 7.87$ $\mu$b, $B = 98.6$ $\mu$b, $C = 1231$ $\mu$b.

Comparing the spin-flip pomeron-exchange contribution to the $\pi^- p \rightarrow a_1(1260)p$ cross section with the non-spin-flip pomeron-exchange contribution to the $\pi p$ elastic scattering cross section shows the latter is a factor of $\sim 130$ larger. A similar comparison of $\gamma p \rightarrow b_1(1235)p$ with $\gamma p \rightarrow \rho(770)p$ gives a ratio of the same order of magnitude.

![Figure 3: The cross section for $\pi^- p \rightarrow a_1(1260)p$. The data are from the ACCMOR Collaboration and the curve is the fit using the interfering Regge plus pomeron parametrization](image)

There are several reactions in which one would expect to see similar effects. Photoproduction of the isoscalar counterpart of the $b_1(1235)$, namely the $h_1(1170)$, should occur at about 10% of the photoproduction cross section so would be of the order of 50 to 100 nb at HERA energies. The mechanism allows diffractive photoproduction of the unconfirmed hidden-strangeness $h_1(1380)$, which should occur at the level of 1% of the $\phi$ photoproduction cross section, so we expect about
10nb at HERA energies. In the strange sector, the $K_1(1270)$ and $K_1(1400)$ are nearly equal mixtures \cite{12} of the $K_{1A}(1^3P_1)$ and the $K_{1B}(1^1P_1)$ so we would expect the $1^3P_1$ component of the $K_1(1270)$ and $K_1(1400)$, as the analogue of the $a_1(1270)$, to be produced diffractively in high-energy $Kp$ interactions.

Spin-flip coupling of the pomeron has been discussed extensively in the context of proton-proton scattering at small $t$ \cite{13}, proton-proton scattering at large $t$ \cite{14} and in vector-meson and $Q\bar{Q}$ production in deep inelastic scattering \cite{15,16}.

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