Available online at www.sciencedirect.com
SCIENCE DIRECT®
Physics Letters B 611 (2005) 255–259
PHYSICS LETTERS B
www.elsevier.com/locate/physletb

Evidence for quark spin-flip in pomeron exchange

A. Donnachie

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

Received 9 December 2004; received in revised form 18 February 2005; accepted 19 February 2005

Editor: G.F. Giudice

Abstract

Spin-parity analyses of the $\omega\pi$ system in the reaction $\gamma p \to (\omega\pi)p$ for photon laboratory energies from 20 to 70 GeV have shown that production of the $J^P = 1^+$ $b_1(1235)$ meson dominates, with a $J^P = 1^-$ background at the level of 20%. Using vector-meson dominance arguments, this background is shown to be consistent with the data on $e^+e^- \to \omega\pi$. The energy dependence of the data imply that the mechanism is a combination of reggeon and pomeron exchange. Assuming that the latter is relevant only for the $J^P = 1^-$ component and extrapolating to $W = 200$ GeV, it is argued that this accounts for most of the preliminary $\omega\pi$ signal observed by the H1 Collaboration in the same reaction. A residual peak can be ascribed to the $b_1(1235)$, which requires a quark spin-flip from pomeron exchange. Precisely the same mechanism occurs in the reaction $\pi p \to a_1(1260)p$.

Preliminary data from the H1 Collaboration [1] on the reaction $\gamma p \to (\omega\pi^0)X$ at $\langle W\rangle = 200$ GeV and $\langle W\rangle = 210$ GeV was provisionally interpreted as diffractive $b_1(1235)$ production. After subtraction of the non-resonant background predicted by Pythia, the cross section for $\gamma p \to b_1(1235)X$ is

$$\sigma\big(\gamma p \to b_1(1235)X\big) = 790 \pm 200(\text{stat}) \pm 200(\text{syst})\ \text{nb}. \tag{1}$$

At first sight it is unlikely that the $b_1(1235)$ can be produced by pomeron exchange, which this interpretation requires. The transition $\gamma \to b_1(1235)$ does not satisfy the Gribov–Morrison rule [2,3] which relates the change in spin ΔJ to the change in parity between the incident particle and the outgoing resonance by $P_{\text{out}} = (-1)^{\Delta J} P_{\text{in}}$. Further it is well known experimentally that pomeron exchange conserves helicity to a good approximation, so that helicity-flip amplitudes are small. This is in agreement with the phenomenological γ_μ coupling of the pomeron to quarks [4]. The $q\bar{q}$ pair from a photon are in a spin-triplet state, as exemplified by vector-meson dominance, but the quarks in the $b_1(1235)$ meson are in a spin-singlet state so quark helicity flip is required for the $\gamma \to b_1(1235)$ transition. There is also experimental evidence, at

E-mail address: ad@a35.ph.man.ac.uk (A. Donnachie).

0370-2693/$ – see front matter
doi:10.1016/j.physletb.2005.02.036

lower energy, that the reaction $\gamma p \to (\omega\pi^0)p$ is not dominated by pomeron exchange.

The Omega Photon Collaboration [5] at CERN performed a spin-parity analysis of the $\omega\pi^0$ enhancement photoproduced in the energy range 20 to 70 GeV, with $\langle W\rangle = 8.6$ GeV. They concluded that the enhancement is consistent with predominant $b_1(1235)$ production, with $\sim 20\%$ $J^P = 1^-$ background. This conclusion was confirmed by a SLAC experiment [6] at an energy of 20 GeV, $W = 6.2$ GeV, with a polarised beam. It should be noted that a spin-parity analysis of the H1 data cannot be performed because of limited acceptance. It was possible to measure the energy dependence of the reaction in the CERN experiment, with the result

$$\sigma(E_\gamma) = \sigma(39)\left(\frac{39}{E_\gamma}\right)^\alpha, \quad 20 \leqslant E_\gamma \leqslant 70 \text{ GeV} \tag{2}$$

with

$$\sigma(39) = 0.86 \pm 0.27 \ \mu\text{b}, \qquad \alpha = 0.6 \pm 0.2. \tag{3}$$

Such an energy dependence is not consistent with dominance of pomeron exchange, which would require an increasing cross section, nor is it consistent with pure Regge exchange, which would require a somewhat faster decrease with increasing energy. A natural interpretation is that the observed energy dependence arises from a combination of pomeron and reggeon exchange. As a simple first approximation, consider the cross section to be given by non-interfering reggeon and pomeron exchanges, the former relating primarily to $b_1(1235)$ production and the latter relating entirely to the production of the $J^P = 1^-$ state. The energy dependence of the cross section (2) can be well reproduced by

$$\sigma(s) = As^{2\epsilon} + Bs^{-2\eta}, \tag{4}$$

where ϵ and η have the standard values [7] 0.08 and 0.4525 respectively and

$$A = 0.107 \ \mu\text{b}, \qquad B = 29.15 \ \mu\text{b}. \tag{5}$$

At $E_\gamma = 39$ GeV the pomeron contribution to the cross section is 25%, in good agreement with what is observed for the $J^P = 1^-$ component in the data. Extrapolating the pomeron part of (4) to HERA energies gives a cross section of 584 nb. As the HERA data include diffraction dissociation of the nucleon, the result extrapolated from the fit to the CERN data should be increased by a factor of about 1.25 giving 730 nb, compatible with the cross section observed. The reggeon part of the cross section is negligible at this energy.

What is the origin of this $J^P = 1^-$ component? An estimate can be made using simple vector-meson dominance arguments. For a vector final state V, the cross section for $\gamma p \to Vp$ is related to that for $e^+e^- \to V$ by [8]

$$\frac{d^2\sigma_{\gamma p\to Vp}(s,m^2)}{dt\,dm^2} = \frac{\sigma_{e+e-\to V}(m^2)}{4\pi^2\alpha}\frac{d\sigma_{Vp\to Vp}(s,m^2)}{dt}. \tag{6}$$

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

$$\frac{d\sigma_{\gamma p\to Vp}(s,m^2)}{dm} = \frac{m\sigma_{e+e-\to V}(m^2)}{32\pi^3\alpha b}\left(\sigma^{\text{Tot}}_{Vp\to Vp}(s)\right)^2, \tag{7}$$

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

The cross section for $\gamma p \to \pi^+\pi^-\pi^+\pi^- p$ over the same energy and four-pion mass ranges as the $\omega\pi$ photoproduction data has been compared with the data on $e^+e^- \to \pi^+\pi^-\pi^+\pi^-$ by the Omega Photon Collaboration [9]. This gave the result

$$\sigma^{\text{Tot}}_{Vp\to Vp} = 16.7 \pm 3.4 \text{ mb}. \tag{8}$$

Three models were considered in the spin-parity analysis [5] of the $\gamma p \to \pi^+\pi^-\pi^+\pi^- p$ data: $\omega\pi$ states with $J^P = 1^+, 1^-, 0^-$, $J^P = 1^+, 1^-$ and $J^P = 1^+, 1^-$ with the 1^- constrained to be s-channel helicity conserving. It is the third one that we use here.

The data [10–12] for $e^+e^- \to \omega\pi$ are shown in Fig. 1(a) and the comparison with $d\sigma/dm$ in Fig. 1(b). The errors arising from (8) have not been included. The normalisation in this comparison is absolute and shows that the model produces the same $J^P = 1^-$ cross section as the reggeon plus pomeron fit, within the admittedly large errors.

A similar comparison can be made with the HERA data and this is shown in Fig. 2 after converting the preliminary H1 data from events/bin to $d\sigma/dm$ assuming 790 nb as the integrated cross section. At the upper end of the mass range the agreement is reasonably good, perhaps surprisingly so given the overall errors in the procedures we are using. However the