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BACKWARD PRODUCTION OF THE B MESON

IN K^-p INTERACTIONS AT 4.2 GeV/c

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ABSTRACT

The backward production of the B(1235) meson is studied in the reaction $K^- p \rightarrow \Sigma^- \pi^+ \omega$. This reaction is observed in the final state $\Sigma^- \pi^+ \pi^+ \pi^- \pi^0$. A $\pi^+ \omega$ mass enhancement is visible in the region of the B meson for events with small $|u|$ ($K^- \rightarrow \Sigma^-$) squared four-momentum transfer. The properties of the enhancement agree with those of the B meson. The cross section for $K^- p \rightarrow \Sigma^- B^+$ at 4.15 GeV/c incident K^- momentum is $(3.2 \pm 0.5) \mu\text{b}$. The backward production of the B meson is compared with similar baryon exchange productions of the A_1 and $C(Q_1)$ axial vector mesons observed in the same experiment.

The non-relativistic quark model predicts within the lowest radial excitation the existence of two 1^+ nonets of mesons with opposite C parity. So far the B meson is considered as the only well-established resonance in the 1^+ family, observed only in the $\pi\omega$ decay mode, mainly in $\pi^\pm p$, $\bar{p}p$ and K^-p [1-4] interactions. Among the other 1^+ candidates, the D_{1285} meson is now accepted as a resonance, the E_{1420} meson has still to be confirmed to have $J^P = 1^+$, and the A_1 , Q_1 , Q_2 mesons (the latter sometimes called C, C') are observed mainly in diffractive processes. This makes the observation and interpretation of the A_1 , Q_1 , Q_2 enhancements rather difficult. Recently, evidence was presented for backward production of the A_1 and Q_1 mesons [5-6].

In this letter we report the observation of an enhancement at 1208 ± 18 MeV produced backward in the reaction $K^-p \rightarrow \Sigma^- \pi^+ \omega$ at 4.2 GeV/c. The properties of the enhancement (mass, width, spin parity) agree with those of the B meson. The cross section and the slope of the differential cross section are comparable to those of the A_1 and Q_1 meson production at the same energy. The production mechanism is shown to be dominated by $I = \frac{1}{2}$ baryon exchange as for the A_1 meson.

The data come from a series of exposures of the CERN 2m hydrogen bubble chamber to K^- beams of momenta in the range 4.09 to 4.25 GeV/c, in which a total of 3.1 million pictures were taken corresponding to a sensitivity of 133 events/ μ b.

The events used in the present analysis come from the four-prong topology with a negative decay giving a 1C-fit to the reaction

$$K^-p \rightarrow \Sigma^- \pi^+ \pi^+ \pi^- \pi^0, \quad (1)$$

with a kinematical fit probability larger than 1% at the production vertex. 23 998 unweighted events are kept after selecting a restricted fiducial volume and after imposing that the projected length of the Σ^- be larger than 3 mm and that its projected decay angle be larger than 60 mrad. A weighting procedure is applied to correct for these geometrical cuts and gives an average weight of 1.27. The main ambiguity problem occurs when the V^- fits both a Σ^- and a K^- decay. The majority of these

events are good Σ^- events, as the K^- contamination is estimated to be less than 3% on the basis of phenomenological cross sections and particle lifetimes. In general, the treatment of ambiguities is not crucial for this investigation as we will be concerned only with events of the subreaction

$$K^- p \rightarrow \Sigma^- \pi^+ \omega \quad (2)$$

containing the narrow ω meson.

Fig. 1 shows the $\pi^+ \pi^- \pi^0$ mass distribution around the ω mass for events of reaction (1) and for $|u|(K^- \rightarrow \Sigma^-) < 1.2 \text{ GeV}^2$ (2422 weighted events). A clear ω signal is seen over the background. We define as ω events with a $\pi^+ \pi^- \pi^0$ mass in the interval $(0.74, 0.83) \text{ GeV}$. When both $\pi^+ \pi^- \pi^0$ combinations fall in this interval ($< 10\%$), we select the 3π mass closest to the ω mass of 0.7826 GeV . The prominent features of reaction (2) are $\Lambda(1405)$, $\Lambda(1520)$, $\Sigma^0(1660)$ and $\Lambda(1820)$ production observed in the $\Sigma^- \pi^+$ system (not shown) and production of a broad bump centred at a $\pi^+ \omega$ mass of $\sim 1.21 \text{ GeV}$. Fig. 2 shows the $\pi^+ \omega$ effective mass with the condition $|u|(K^- \rightarrow \Sigma^-) < 1.2 \text{ GeV}^2$. The bump is enhanced by the application of this condition which reduces the hyperon production but for the $\Lambda(1520)$ resonance known to be produced both in forward and backward directions [7]. We have checked that the enhancement observed in the $\pi^+ \omega$ mass spectrum is not a reflection of these hyperons.

We show in fig. 3 the Chew Low plot for the $\pi^+ \omega$ system produced in reaction (2). ω events have been required to fall in the central region of the ω decay Dalitz plot (if $\lambda_\omega = (\vec{p}_+ \times \vec{p}_-)^2 / (\vec{p}_+ \times \vec{p}_-)^2_{\text{max}}$, $\lambda_\omega > 0.5$). One sees an accumulation of events around a mass of 1.21 GeV at small $|u|$ values. The cut $|u|(K^- \rightarrow \Sigma^-) < 1.2 \text{ GeV}^2$ preserves most of these events and will be systematically applied in what follows.

Since a large fraction of the cross section of reaction (2) is due to hyperon production channels, the first step of our analysis consists of a series of multi-channel likelihood [8] fits to find the fractions with which these channels contribute. We assume no interference between

the channels and represent each resonance by an appropriate ℓ -wave Breit-Wigner function. Omitting the $\Sigma^- B^+$ channel in our fit, the $(\Sigma^- \pi^+)$ and $(\Sigma^- \omega)$ mass spectra are well reproduced. This is not the case of the $(\pi^+ \omega)$ mass spectrum (fig. 2, curve A). We are therefore led to introduce the channel

$$K^- p \rightarrow \Sigma^- B^+ \quad (3)$$

with the B^+ meson decaying into $\pi^+ \omega$ and having a mass and width fixed at 1208 and 163 MeV respectively (see below). The $(\pi^+ \omega)$ mass spectrum is now also well described in fig. 2, curve B. The $\Sigma^- B^+$ contribution represents $(19 \pm 2.5)\%$ of the sample with $|u| < 1.2$ GeV and corresponds to (360 ± 45) unweighted events.

We now turn to a study of the spin-parity content of the $\pi^+ \omega$ enhancement. The limited available statistics forces us to restrict ourselves to the analysis of the decay angular correlations of the $(\pi^+ \omega)$ system. We follow the Zemach method applied to the spin-parity determination of the B particle [9]. This analysis involves maximum likelihood fits of the angle between the normal to the ω decay plane and the ω line-of-flight in the $(\pi^+ \omega)$ system for different $(\pi^+ \omega)$ mass regions. The absolute square of the amplitude is assumed to be an incoherent sum of terms describing the $(\pi^+ \omega)$ system in different spin-parity states and terms describing the background.

Owing to the narrow width of the ω , interference effects due to the presence of two π^+ in reaction (1) can be neglected. Interference terms must however be introduced for states of the same spin-parity but of different orbital momentum ℓ . We limited ourselves to the following spin-parity assignment:

$$0^-, 1^+ S, 1^+ D, 1^-, 2^- P, 2^+.$$

The background representation consists of a constant term describing the non ω events and of appropriate ℓ -wave Breit-Wigner functions accounting for the hyperon background. We further selected the events lying in the central region of the ω decay Dalitz plot to reduce the background from non ω events.

Fig. 4 shows the results of the partial wave analysis for the terms contributing significantly. The $1^+ S (\pi^+ \omega)$ amplitude is recognized as the most important and seen to peak in the B region. The $1^+ D (\pi^+ \omega)$ contribution is small and featureless. In the B region the D/S amplitude ratio is consistent with the Particle Data Group (PDG) value of 0.25 [10]. The background of non ω events is small as expected from the selection procedure explained above. The background of hyperon shows both in size and shape the expected contribution. As a check of our method, we repeated the spin analysis on the large forward B^- meson production observed in the reaction $K^- p \rightarrow \Sigma^+ \pi^- \omega^0$ [4]. We got results for all the $(\pi^- \omega)$ waves very similar to those of the $(\pi^+ \omega)$ waves in the present reaction. We conclude that the $\pi^+ \omega$ enhancement has a spin parity $J^P = 1^+$.

A relativistic s-wave Breit-Wigner function has been fitted to the enhancement using a polynomial of fourth order for the background. We find

$$M = (1.208 \pm 0.018) \text{ GeV} \quad \Gamma = (0.163 \pm 0.050) \text{ GeV} .$$

The cross section for reaction (1) was found to be $(187 \pm 15) \mu\text{b}$, all corrections for scanning and measuring losses being included. Using the results of the multi-channel fit and correcting for the undetected decay modes (10%) of the ω meson we get the cross section at 4.15 GeV/c incident K^- momentum

$$\sigma(\Sigma^- B^+) = (3.2 \pm 0.5) \mu\text{b} \text{ for } |u|(K^- \rightarrow \Sigma^-) < 1.2 \text{ GeV}^2 .$$

Repeating the multi-channel fit for successive $|u|$ intervals, we have measured the differential cross section of the $\Sigma^- B^+$ channel. A fit of the function $d\sigma/du = a \exp(-b|u|)$ gives

$$b = (2.0 \pm 0.2) \text{ GeV}^{-2} .$$

Both $I = \frac{1}{2}$ and $I = 3/2$ neutral baryon exchange can contribute to the production of the B meson in reaction (2). If it were $I = 3/2$, one should observe a B^- signal nine times larger in the reaction

$$K^- p \rightarrow \Sigma^+ B^- ,$$

in which we observe a large forward B^- but no backward signal. The upper limit for backward B^- production was estimated to be $2 \mu\text{b}$ in [4] at a sensitivity level of 97 events/ μb . It can now be put down to $1 \mu\text{b}$ at the final sensitivity level of 133 events/ μb . Thus the exchange mechanism seems to be dominantly $I = \frac{1}{2}$ baryon exchange.

We conclude that we have obtained evidence for a significant backward production of a $1^+ \pi^+ \omega$ enhancement that we identify as the B^+ meson. The fact that the well established B meson ($J^P = 1^+$) is also seen to be produced backward strengthens the evidence for backward production of the more controversial A_1 and $Q_1(C)$ 1^+ mesons in this experiment. Indeed, the properties of the reactions $K^- p \rightarrow \Sigma^- A_1^+$, $\Xi^- C^+$ and $\Sigma^- B^+$ have several common features: cross sections of 3-7 μb , $d\sigma/du$ slopes $\sim 2 \text{ GeV}^{-2}$ and production via $I = \frac{1}{2}$ baryon exchange for both the A_1 and the B

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FIGURE CAPTIONS

- Fig. 1 $\pi^+ \pi^- \pi^0$ mass distribution from $K^- p \rightarrow \Sigma^- \pi^+ \pi^+ \pi^- \pi^0$,
 $|u| (K^- \rightarrow \Sigma^-) < 1.2 \text{ GeV}^2$, one combination per event, the closest
to the ω mass.
- Fig. 2 $\pi^+ \omega$ mass distribution for the reaction $K^- p \rightarrow \pi^- \omega^+$ and
 $|u| < 1.2 \text{ GeV}^2$. Curve A shows the result of the multi-channel
likelihood fit when no $\Sigma^- B^+$ amplitude is introduced. Curve B
shows the effect of adding the $\Sigma^- B^+$ channel.
- Fig. 3 Chew-Low plot for the $\pi^+ \omega$ system produced in reaction $K^- p \rightarrow \pi^- \omega^+$.
 ω events have been required to fall in the central region of the
 ω decay Dalitz plot ($\lambda_\omega = (\vec{p}_+ \times \vec{p}_-)^2 / (\vec{p}_+ \times \vec{p}_-)^2_{\text{max}}$ in ω c.m.
system > 0.5).
- Fig. 4 Results of the partial wave analysis of the $\pi^+ \omega$ system
($\lambda_\omega > 0.5$).

Fig. 1

Fig. 2

Fig. 3

$M(\pi^+\pi^-\omega)$ GeV

Fig. 4