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UNUSUAL PRODUCTION FEATURES OF ISO-SCALAR MESONS IN PROTON DIFFRACTIVE DISSOCIATION AT THE CERN-ISR

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Abstract: D(1285) and E/iota(1422) are observed in the diffractive dissociation process, $pp \rightarrow (p K^0 K^\pm \pi^\mp)p$, with $\sqrt{s} = 63$ GeV. The D(1285) is produced with dominant ± 1 helicity. Several unusual features of the data suggest that the mesonic states result from gluonic interactions in the collision.

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As part of a search for glueball candidates in high energy proton-proton interactions with $\sqrt{s} = 63$ GeV at the CERN Intersecting-Storage-Rings (ISR), we are studying a number of final states which result from diffractive dissociation of protons. In the strange particle diffractive process:

$$p + p \rightarrow [p + K^0 + K^\pm + \pi^\mp] + X \quad (1)$$

we have observed^[1] pronounced signals in the $K^0 K^\pm \pi^\mp$ invariant mass spectrum corresponding to the production of a state at 1422 MeV (see below) and the well known D(1285) with $J^P = 1^+$. There are very unusual production features of these states which are significant in their own right and form the main subject of this Letter. They suggest that, in the dissociation, $p \rightarrow p + \text{iso-scalar meson}$, the meson is produced from gluons in the initial proton.

In Reaction (1), the $pK^0 K^\pm \pi^\mp$ system enters a forward spectrometer with its total momentum approximately equal to the beam momentum; the low-mass system X recoils in the opposite arm. No attempt is made to detect the system X, although it is known from an earlier analysis^[2] of similar diffractive systems at the ISR, that X is a proton 88% of the time and, moreover, that the properties of the system in the forward spectrometer are independent of the nature of X (factorization).

The equipment used to obtain the results reported here is the forward spectrometer^[3,4] of experiment R608 at the ISR, which was sensitive to particles produced with polar angles in the range $23 < \Theta < 150$ mrad. In addition to the wire chamber tracking system, the spectrometer contains a two-threshold (16 cells each) gas Cerenkov counter system for particle identification. During data taking, a set of veto counters covered most of the solid angle outside the spectrometer acceptance, but allowed the recoil system X to emerge into an aperture of approximately ± 400 mrad. The trigger required that 5 or more tracks traverse the forward spectrometer but made no requirements on the recoil system X. For many of the events, a recoil proton remained in the vacuum pipe and no signals were seen in counters outside the spectrometer aperture. Although a beam-beam interaction signature was not required during data acquisition, the multi-track vertex distribution of Reaction 1 corresponds to the beam-beam crossing region with beam-gas background less than 0.1%.

For the data reported here, which constitutes 40% of our total data sample of this type, 10.7×10^6 triggers were recorded with an integrated luminosity of $\int L dt = 9.5$ events/pbarn. 3.2×10^6 of these triggers have 5 tracks with total charge +1 and total longitudinal momentum peaking near Feynman $x_F \approx 1$, one of the characteristics of diffraction dissociation

processes at high energy.

There are 52,416 events with identified $pK^0K^\pm\pi^\mp$. Figure 1(a) shows the distribution in total longitudinal momentum, P_{total} , for these events. A pronounced diffractive peak is seen near the beam momentum of 31.4 Gev/c. There are 39,880 events with P_{total} in the range 30-33 Gev which we identify as examples of Reaction (1). An inset shows the K^0 signal before the K^0 mass selection, for the events in Figure 1(a).

The $pK^0K^\pm\pi^\mp$ invariant mass distribution for Reaction (1) is shown in Fig. 1(b). The distribution is quite smooth, with a peak near 2.9 Gev, and shows no evidence for diffractive excitation of resonant states. The fall to threshold is due to our small angle acceptance cutoff, while the shape at high mass is dominated by the fall-off typical of diffractive excitation. The dashed line in Fig 1(b) corresponds to the $pD(1285)$ component of Reaction 1 discussed below and also shows no resonant structure.

The invariant mass distributions for the $K^0K^\pm\pi^\mp$ and $K^0K^\pm\pi^\mp$ systems in Reactions 1 are summed together and shown in Fig. 2(a). There are two pronounced signals, the first of which is the $D(1285)$ meson with decay mode: $D \rightarrow \delta(980)^\pm\pi^\mp$. The second signal at 1422 Mev is in a mass region where there is, at present, considerable confusion concerning the number of different states and their spin-parity assignments. For this reason, we tentatively refer to this state as $E/\text{iota}(1422)$. A spin-parity analysis of this signal will be reported elsewhere.

The events in the tail below the $x_F \approx 1$ peak in Fig. 1(a) arise mainly from the reaction:

$$p + p \rightarrow [p + K^0 + K^\pm + \pi^\mp + \pi^0] + X \quad (2)$$

where the π^0 has escaped detection. Because of the resolution of our detector, some of this component forms a background under the diffractive peak in Fig. 1(a). To determine what fraction of the signals in Fig. 2(a) may be associated with Reaction (2), the $K^0K^\pm\pi^\mp$ invariant mass spectrum for P_{total} in the 25-29 Gev/c range is shown in Fig. 2(b). Both the $D(1285)$ and $E/\text{iota}(1422)$ signals are seen to be much smaller with respect to the non-resonant background in Fig. 2(b) than in Fig. 2(a).

A comparison between the signal/background ratios in Figs. 2(a) and 2(b), respectively, allows us to conclude that both signals dominantly result from a 2-body dissociation (i.e., $p \rightarrow p + D$ and $p \rightarrow p + E/\text{iota}$) and that the cross section ratio $\sigma(p \rightarrow p D \pi^0)/\sigma(p \rightarrow p D)$ is less than 20% of the corresponding ratio for the non-resonant background. We observe^[5] the same effect for production of other isoscalar states, namely $p \rightarrow p + \phi(1020)$ and $p \rightarrow p + \omega(783)$, although the effect is not seen for production

of the iso-vector $\rho(770)$ meson in $p \rightarrow p + \rho^0$. A likely explanation of these observations is that, in the diffractive dissociation process, $p \rightarrow p +$ isoscalar boson, the boson dominantly materializes from gluon interactions and the valence quarks in the beam proton are not directly involved. Iso-vector meson states could not be made in this way.

Next we examine the internal structure of the forward-going $pD(1285)$ system in Reaction (1). We find that as the pD invariant mass increases, the angular distribution of the final state proton becomes sharply peaked forward with respect to the beam proton. The acceptance-corrected distribution in this Gottfried-Jackson angle, θ_{GJ} , for pD mass in the range 2.5-3.1 Gev is shown in Fig. 3(a). A tendency is also observed for the pD "breakup" plane to be coplanar with the production plane. Therefore a selection on this Treiman-Yang angle, $\phi_{TY} = \pi \pm \pi/2$, is also made in plotting Fig. 3(a)

Fig. 3(b), shows the $K^0 K^\pm \pi^\mp$ invariant mass for the same $pK^0 K\pi$ mass and ϕ_{TY} selections used in Fig. 3(a), but with $\cos \theta_{GJ} > 0.3$. The signal to background ratios for the E/ι is substantially improved. The solid curve in Figs. 3(b) is a fit to the mass spectrum using two Breit-Wigner functions folded with our experimental resolution^[6] and a polynomial background. For the data in Fig. 3(b) the resonance parameters found are 1286 ± 1 and $\Gamma = 24 \pm 3$ Mev for the D meson, and 1422 ± 3 and $\Gamma = 47 \pm 10$ Mev for the E/ι .

We now consider other aspects of $D(1285)$ production. We concentrate here on the D , because background corrections are smaller than for the E/ι and because the acceptance corrections are simpler for the almost pure $D \rightarrow \delta\pi$ final state. Fig. 4(a,b) show the acceptance- and background-corrected distributions of four-momentum transfer from each beam proton to its respective final state proton, as defined in the insert diagram of Fig. 4. Since P_{2f} and D together carry the initial beam momentum, t_1 corresponds to the "soft" pomeron characteristic of diffractive processes. In contrast, however, t_2 is "hard" with an average value larger than 1 Gev². Its relatively flat distribution shows the inherent asymmetry between the two sides of the diagram in Fig. 4. The absence of events at small t_2 corresponds to the acceptance loss for very forward protons seen in Fig. 3(a). Both t distributions appear to have two components with exponents given in the figure caption.

Fig. 4(c) contains the differential cross section (corrected for all decay modes) in Feynman- x of the D alone. It shows that the D is produced preferentially at smaller Feynman- x , $x_F(D)$, despite the fact that it is more massive than the proton. To obtain $d\sigma/dx_F(D)$, the function $\exp(bP_t)$ was fitted to the acceptance- and background-corrected transverse momentum

distributions for D production, in different bins of $x_F(D)$. b was found to be independent of $x_F(D)$ with a mean value of -2.5 GeV^{-2} . The $d\sigma/dx_F(D)$ points shown in Fig. 4(c) are obtained by integrating the distributions over P_t . The cross section is $(3.5 \pm 0.7) \text{ } \mu\text{b}$ per hemisphere for $pp \rightarrow \{pD\}X$ with $0.35 < x_F(D) < 0.7$. The solid curve in Fig. 4(d) is a fit of $(1-x_F)^n$ to the data points with $n = 2.0 \pm 0.2$. If this form is assumed to be valid over the entire region of $x_F(D)$, the total cross section for $pp \rightarrow \{pD\}X$ is $14.1 \text{ } \mu\text{b}$ per hemisphere, corresponding to about 3×10^{-3} of the total single proton diffractive excitation cross section.

Finally, we examine the spin state of $D \rightarrow \delta^+\pi^-$ ^[7]. The spherical harmonic moments of the π direction in the D rest frame are determined for events in the D signal (1.24-1.32 GeV) which have $\text{Mass}(K^0K^+) < 1.08 \text{ GeV}$, $x_F(D) = 0.4-0.6$ and $P_t = 0.5-1.1 \text{ GeV}/c$. Fig. 5 shows the acceptance-corrected $\cos \theta$ projection using the direction of motion of the D as the z-axis. The curve is the fitted spherical harmonic expansion. The negative value found for the $\langle Y_{20} \rangle$ moment, -0.070 ± 0.012 , implies that the dominant helicity of the D(1285) is ± 1 . After correcting for a 10% s-wave background under the D in the data sample used for the moment analysis, the ± 1 helicity content is found to be $(87.2 \pm 3.5)\%$.

In summary, we have shown that the diffractive dissociation of $p \rightarrow p + D(1285)$ has several unusual features: (1) Production of the iso-vector state $\pi^0 D(1285)$ is suppressed; the iso-vector/iso-scalar production ratio, $\pi^0 D/D$, is much smaller than the same ratio for the non-resonant background. The same effect is observed for $E/\text{iota}(1422)$ production; (2) Although the D(1285) is more massive than the proton, $d\sigma/dx_F(D)$ peaks at small values; (3) the D is produced with its spin mainly aligned along its direction of motion. (1) and (2) suggest that the D(1285) does not contain valance quarks from the beam proton, but rather results from a (multi-) gluon component of the proton via a process (see Fig. 4) analogous to the Drell-Hiida-Deck mechanism^[8], but with a (proton + color-singlet gluon system) instead of a $p\pi$ system interacting with the pomeron. (3) may be telling us something about the spin structure of this interaction.

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FIGURE CAPTIONS

1. (a) Total longitudinal momentum (P_{tot}) of events identified as $pK^0K^\pm\pi^\mp$. The inset shows the K^0 mass spectrum for all events (before the K^0 mass selection).
 (b) Invariant mass of all $pK^0K^\pm\pi^\mp$ events in the $x_F \approx 1$ peak.
2. $K^0K^\pm\pi^\mp$ mass spectra for events with total longitudinal momentum in the ranges: (a) 30-33 GeV/c, (b) 25-29 GeV/c.
3. (a) Gottfried-Jackson angle ($\cos(\theta_{\text{GJ}})$) of final-state proton in pD(1285) events with pD(1285) mass in range 2.5-3.1 GeV and with $\phi_{\text{TY}} = \pi \pm \pi/2$.
 (b) $K^0K\pi$ mass spectra for events with $\cos(\theta_{\text{GJ}}) > 0.3$ and the same $pK^0K\pi$ mass and ϕ_{TY} selections as in (a).
4. Momentum transfer distributions, (a) t_1 and (b) t_2 for pD(1285) events. The inset defines t_1 and t_2 .
 Exponents in (a) are $-(5.8 \pm 0.2)$ and $-(2.4 \pm 0.3)$ GeV⁻².
 Exponents in (b) are $-(0.7 \pm 0.1)$ and $-(1.8 \pm 0.2)$ GeV⁻².
 (c) $d\sigma/dx_F$ distribution (per hemisphere) of D(1285) in the reaction $pp \rightarrow \{pD\}X$.
5. D(1285) decay angle $\cos \theta$ projection as described in text.
 The $m = 0$ moments are shown.

Figure 1

Figure 2

Figure 3

Figure 4

Figure 5