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THE LONGITUDINAL MOMENTUM DISTRIBUTION OF CHARM MESONS
PRODUCED IN (pp) INTERACTIONS AT $\sqrt{s} = 62$ GeV

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ABSTRACT

The longitudinal momentum distributions of the charm mesons D^0 and D^+ , observed in high-energy proton-proton collisions, have been measured. The data provide evidence for a dominant charm-meson production in the central region.

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1. INTRODUCTION

We have recently observed^{1,2)} the production of charm mesons, D^0 and D^+ , in the reaction $pp \rightarrow D e^- X$ at a centre-of-mass energy $\sqrt{s} = 62$ GeV. The purpose of the present paper is to report on the longitudinal momentum distributions of the observed D mesons. These distributions are particularly relevant for the understanding of charm production mechanisms in high-energy proton-proton interactions.

2. ANALYSIS

The experiment was performed at the Split-Field Magnet (SFM) spectrometer of the CERN Intersecting Storage Rings (ISR). In the 90° region, the spectrometer was equipped with a system consisting of a "dE/dx" chamber, gas Čerenkov counters, and electromagnetic shower counters, to achieve a clean single-electron or positron detection. A time-of-flight (TOF) hodoscope was installed around the intersection region in order to provide some (π , K, p) identification up to about 2 GeV/c momentum.

Details concerning the apparatus, the prompt $e^\pm$ selection, and the hadron identification procedure can be found elsewhere³⁻⁶⁾.

The data were analysed in order to recognize the charm meson (D) via its hadronic decay products, in coincidence with a prompt electron, this being the "signature" of the semileptonic decay from the associated antimeson ($\bar{D}$). The results on $(D^0 \bar{D})$ and $(D^+ \bar{D})$ pair productions are presented separately.

3. RESULTS

3.1 The D^0 longitudinal distribution

The D^0 meson was observed in the reaction

$$pp \rightarrow D^0 + (e^- K_{\text{TOF}}^+) + X, \quad (1)$$
$$\quad \quad \quad \downarrow$$
$$\quad \quad \quad K^- \pi^+$$

where the semileptonic decay of the antimeson was signalled by the presence not only of an e^- , but also of a positively charged kaon in the final state¹⁾. This

was identified in the TOF hodoscope and is labelled as K_{TOF}^+ . The e^- was required to have $p_T \geq 0.5$ GeV/c. The $(K^- \pi^+)$ invariant mass was derived for any negative track not identified by TOF as a $\bar{p}$ or a π^- and any positive track not identified as a p or a K^+ . For the π^+ , the condition $|x_L| < 0.3$ (where $x_L = 2p_L/\sqrt{s}$ is the longitudinal fractional momentum) was also imposed in order to reduce the contamination from fast protons, which grows exponentially with increasing $|x_L|$. Finally, all tracks in reaction (1) were required to fit the reconstructed event vertex (within ± 5 cm) and to have a momentum error $\Delta p/p \leq 30\%$. For the electron this limit was twice as low, $\Delta p/p \leq 15\%$.

The D^0 signal ensuing from this analysis is shown in Fig. 1, where the $(K^- \pi^+)$ invariant mass is plotted after background subtraction (this was determined by the standard "event mixing" technique). In the same invariant mass distribution, obtained with "wrong" triggers such as $(e^+ K_{\text{TOF}}^+)$, $(e^- K_{\text{TOF}}^-)$ or $(e^+ K_{\text{TOF}}^-)$, there was clearly no evidence for any effect¹⁾. This proves that the D^0 was indeed detected in association with its antimeson, which generates both the electron and the positive kaon via its semileptonic decay.

The longitudinal momentum distribution of the D^0 was then obtained by subtracting from the $|x_L|$ distribution of the events giving at least one $(K^- \pi^+)$ mass combination inside the observed peak, the $|x_L|$ distribution of the events outside the peak, i.e. in the two mass intervals below and above, each as wide as the D^0 mass interval itself.

The "in" and "out" distributions have been corrected for the apparatus acceptance. The "out" distribution was normalized to the level of background events observed in the $(K^- \pi^+)$ invariant mass spectrum under the peak of the "in" region.

The result is illustrated in Fig. 2, where the D^0 production appears to be dominant at small $|x_L|$ values. However, in order to get a more precise analysis, the data were compared with a Monte Carlo, where the D^0 production was simulated according to three different mechanisms:

- "central" production (model I): $E(d\sigma/d|x_L|) \sim (1 - |x_L|)^3$,

- "flat-y" production (model II): $d\sigma/d|y| = \text{const}$,
- "flat- x_L " production (model III): $d\sigma/d|x_L| = \text{const}$,

where x_L is the previously defined longitudinal fractional momentum and $y = \frac{1}{2} \ln [(E+p_L)/(E-p_L)]$ is the rapidity.

In all these three models the same transverse momentum production mechanism was assumed, namely $\exp(-2p_T)$. The results are shown by the dashed curves in Fig. 2.

Notwithstanding the large errors, the comparison of the data with the Monte Carlo allows us to conclude that a "flat- x_L " behaviour is the least likely. Hence the D^0 longitudinal production is compatible with either a "central" or a "flat-y" mechanism.

3.2 The D^+ longitudinal distribution

The charged meson D^+ was also observed in this experiment²⁾, via the reaction

$$pp \rightarrow D^+ + e^- + X \quad (2)$$

$$\quad \quad \quad \downarrow$$

$$\quad \quad \quad K_{\text{TOF}}^- \pi^+ \pi^+$$

In this case, the K^- from D^+ decay was required to be identified in the TOF hodoscope, whilst the π^+ 's were selected as described in Section 3.1. Again, the condition $p_T \geq 0.5 \text{ GeV/c}$ was imposed on the e^- from the antimeson decay. Moreover, a high- p_T requirement, $p_T(K_{\text{TOF}}^- \pi^+ \pi^+) \geq 0.7 \text{ GeV/c}$, was applied. This cut was in fact very efficient for reducing the background level in the $(K_{\text{TOF}}^- \pi^+ \pi^+)$ invariant mass spectrum. The resulting D^+ signal is shown in Fig. 3, after background subtraction. It has been checked²⁾ that the $(K_{\text{TOF}}^- \pi^+ \pi^+)$ distribution obtained with the "wrong" e^+ trigger did not show any effect in the D^+ mass region, as expected, since the e^+ could not originate from the associated $\bar{D}$.

The D^+ longitudinal momentum distribution was worked out in the same way as for the D^0 (see Section 3.1). The difference was made between the $|x_L|$ distributions corresponding to the "in" and "out" regions of the $(K_{\text{TOF}}^- \pi^+ \pi^+)$ spectrum. The "out" region events provided the background reference distribution. The $|x_L|$ distribution of the D^+ , shown in Fig. 4, is consistent with that of the D^0 (see Fig. 2): the production in the low $|x_L|$ range again appears to be favoured.

However, the comparison with Monte Carlo simulated events is much less sensitive in this case. In fact, the requirement of a TOF identification for the K^- contributing to the invariant mass, implied a severe phase-space limitation for this particle ($p < 1.5$ GeV/c) and, consequently, for the three-body system itself. The Monte Carlo distributions relative to the already quoted production models, "central" (model I), "flat-y" (model II), and "flat- x_L " (model III) (see section 3.1) are shown in Fig. 4, where it appears that the present analysis was indeed too strongly $|x_L|$ biased to allow a definite distinction among these models. It should, however, be noticed that the Monte Carlo curve which agrees the least with the data is again the one corresponding to the "flat- x_L " hypothesis.

4. CONCLUSION

The first measurement of the longitudinal momentum distribution of charm mesons, either D^0 or D^+ , produced in (pp) collisions has been reported. Evidence has been found for a rather "central" D-meson production mechanism⁷⁾. Such a result significantly differs from the one relative to the charm baryon Λ_c^+ distribution, measured in the same experiment⁸⁾. This appeared to be rather "flat in $|x_L|$ ", as expected from the existence of the "leading" baryon effect.

Hence our studies on charm production in (pp) interactions indicate that charm phenomena follow two different mechanisms. The production of (meson-antimeson) pairs is preferentially "central". The production of (baryon-antimeson) pairs is "flat in $|x_L|$ " for the baryon and "central" for the antimeson.

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Figure captions

- Fig. 1 : $(K^- \pi^+)$ invariant mass spectrum obtained for $(e^- K_{TOF}^+)$ triggered events and showing a D^0 signal of ~ 50 mass combinations, corresponding to ~ 4 standard deviations. The "event mixing" background is subtracted.
- Fig. 2 : $|x_L|$ distribution of D^0 events, obtained via the "in-out" technique. The dashed-line curves show the Monte Carlo distributions obtained for different production hypotheses: "central" (model I), "flat-y" (model II), and "flat- x_L " (model III).
- Fig. 3 : $(K_{TOF}^- \pi^+ \pi^+)$ invariant mass spectrum obtained with the e^- trigger, after the "event mixing" background subtraction. The D^+ shows up with ~ 40 mass combinations, corresponding to an ~ 3.5 standard deviations effect.
- Fig. 4 : $|x_L|$ distribution of D^+ events, derived via the "in-out" difference. The dashed-line curves are relative to Monte Carlo events and simulate three different production mechanisms: "central" (model I), "flat-y" (model II) and "flat- x_L " (model III).

Fig. 1

Fig. 2

Fig. 3

Fig. 4