ISTITUTO NAZIONALE DI FISICA NUCLEARE
Laboratori Nazionali di Frascati

LNF-82/10

M. Basile et al. : THE LONGITUDINAL-MOMENTUM DISTRIBUTION OF CHARM MESONS PRODUCED IN (pp) INTERACTIONS AT $\sqrt{s}$ = 62 GeV

Estratto da:
Lett. Nuovo Cimento 33, 33 (1982)

Servizio Documentazione
dei Laboratori Nazionali di Frascati

LETTERE AL NUOVO CIMENTO VOL. 33, N. 2 9 Gennaio 1982

The Longitudinal-Momentum Distribution of Charm Mesons Produced in (pp) Interactions at $\sqrt{s} = 62$ GeV.

M. BASILE, G. CARA ROMEO, L. CIFARELLI, A. CONTIN, G. D'ALÍ
P. DI CESARE, B. ESPOSITO, P. GIUSTI, T. MASSAM, R. NANIA
F. PALMONARI, G. SARTORELLI, G. VALENTI and A. ZICHICHI

CERN - Geneva, Switzerland
Istituto di Fisica dell'Università - Bologna, Italia
Istituto di Fisica dell'Università - Perugia, Italia
Istituto Nazionale di Fisica Nucleare - Sezione di Bologna, Italia
Istituto Nazionale di Fisica Nucleare, LNF - Frascati (Roma), Italia

(ricevuto il 12 Ottobre 1981)

Summary. – 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.

1. *Introduction.* – We have recently observed (1,2) the production of charm mesons, D^0 and D^+, in the reaction $pp \to De^-X$ 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.

---

(1) M. BASILE, G. CARA ROMEO, L. CIFARELLI, A. CONTIN, G. D'ALÍ, P. DI CESARE, B. ESPOSITO, P. GIUSTI, T. MASSAM, R. NANIA, F. PALMONARI, G. SARTORELLI, G. VALENTI and A. ZICHICHI: *Nuovo Cimento A*, **65**, 457 (1981).
(2) M. BASILE, G. CARA ROMEO, L. CIFARELLI, A. CONTIN, G. D'ALÍ, P. DI CESARE, B. ESPOSITO P. GIUSTI, T. MASSAM, R. NANIA, F. PALMONARI, G. SARTORELLI, G. VALENTI and A. ZICHICHI: *Measurement of* $(D^+\bar{D})$ *charm-meson pair production in* (pp) *interactions at* $\sqrt{s} = 62$ GeV, preprint CERN-EP/81-125 (1981) and *Nuovo Cimento*, in press.

Details concerning the apparatus, the prompt $e^{\pm}$ selection and the hadron identification procedure can be found elsewhere [3-6].

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 semi-leptonic decay from the associated antimeson ($\overline{D}$). The results on ($D^0\overline{D}$) and ($D^+\overline{D}$) pair productions are presented separately.

3. *Results.*

3.1 The D^0 longitudinal distribution. The D^0-meson was observed in the reaction

$$pp \to D^0 + (e^-K^+_{TOF}) + X , \quad D^0 \to K^-\pi^+ \tag{1}$$

where the semi-leptonic decay of the antimeson was signalled by the presence not only of an e^-, but also of a positively charged kaon in the final state [1]. This was identified in the TOF hodoscope and is labelled as K^+_{TOF}. The e^- was required to have $p_T \geqslant 0.5$ GeV/c. The ($K^-\pi^+$) invariant mass was derived for any negative track not identified by TOF as a $\overline{p}$ 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 $\Delta p/p \leqslant 30\%$. For the electron this limit was twice as low, $\Delta p/p \leqslant 15\%$.

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 ($e^+K^+_{TOF}$), ($e^-K^-_{TOF}$) or ($e^+K^-_{TOF}$), there was clearly no evidence for any effect [1]. 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 semi-leptonic 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

---

(3) M. BASILE, G. CARA ROMEO, L. CIFARELLI, A. CONTIN, G. D'ALÌ, P. DI CESARE, B. ESPOSITO, L. FAVALE, P. GIUSTI, T. MASSAM, F. PALMONARI, G. SARTORELLI, G. VALENTI and A. ZICHICHI: *Nucl. Instrum. Methods*, **179**, 477 (1981).

(4) H. FREHSE, F. LAPIQUE, M. PANTER and F. PIUZ: *Nucl. Instrum. Methods*, **156**, 87 (1978); H. FREHSE, M. HEIDEN, M. PANTER and F. PIUZ: *Nucl. Instrum. Methods*, **156**, 97 (1978).

(5) M. BASILE, G. CARA ROMEO, L. CIFARELLI, A. CONTIN, G. D'ALÌ, P. GIUSTI, T. MASSAM, F. PALMONARI, G. SARTORELLI, G. VALENTI and A. ZICHICHI: *Nucl. Instrum. Methods*, **163**, 93 (1979).

(6) M. BASILE, G. CARA ROMEO, L. CIFARELLI, A. CONTIN, G. D'ALÌ, P. DI CESARE, B. ESPOSITO, P. GIUSTI, T. MASSAM, F. PALMONARI, G. SARTORELLI, G. VALENTI and A. ZICHICHI: *Nuovo Cimento A*, **65**, 421 (1981).

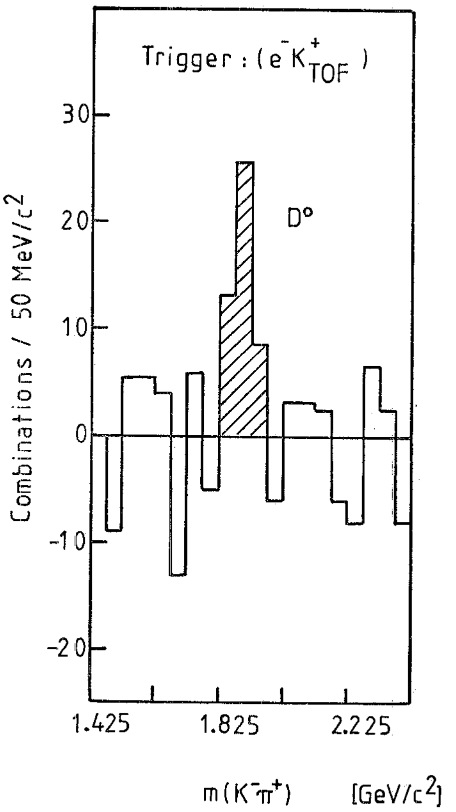

Fig. 1. – ($K^-\pi^+$) invariant-mass spectrum obtained for ($e^-K^+_{TOF}$)-triggered events and showing a D^0 signal of ~ 50 mass combinations, corresponding to ~ 4 standard deviations. The « event mixing » background is subtracted.

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.

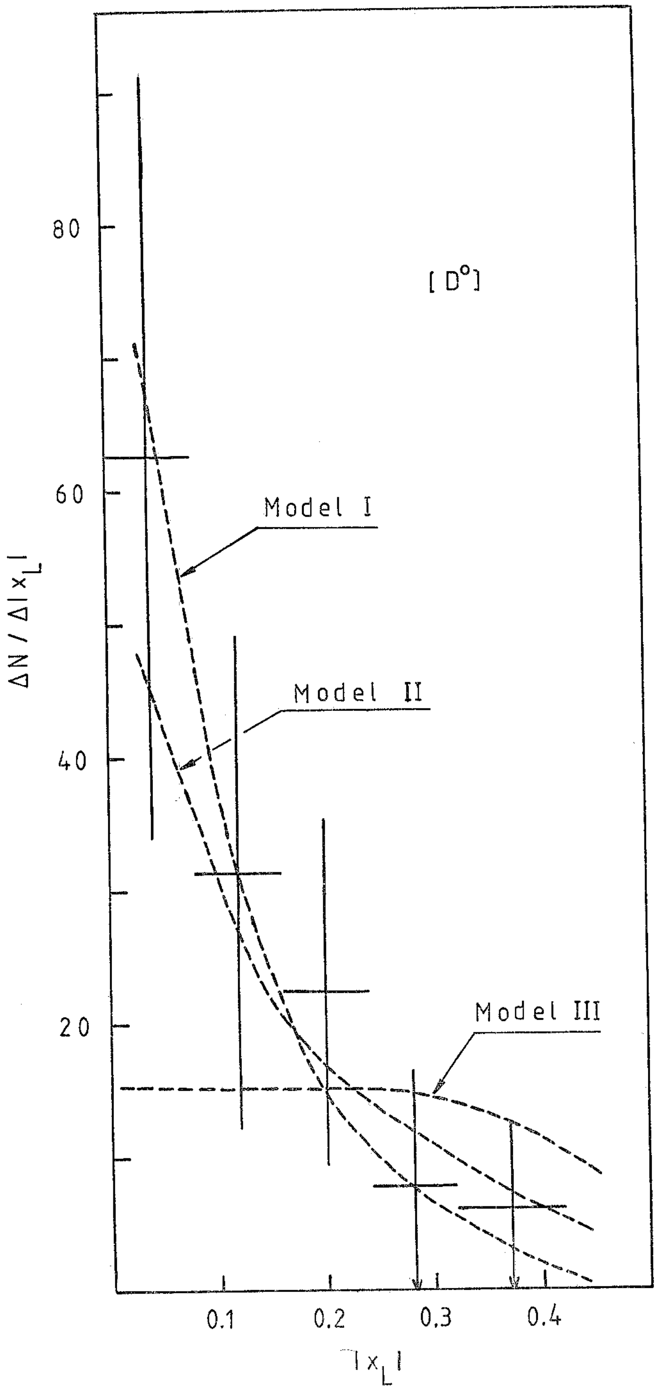

Fig. 2. – $|x_L|$ distribution of D^0 events, obtained via the « in-out » technique. The dashed-line curves show the Monte Carlo distributions obtained for different production hypotheses: « central » (model I), « flat-y » (model II), and « flat-x_L » (model III).

3.2. The D^+ longitudinal distribution. The charged meson D^+ was also observed in this experiment (2), via the reaction

$$pp \to D^+ + e^- + X . \quad \hookrightarrow K^-_{TOF}\pi^+\pi^+ \tag{2}$$

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 part 3.1. Again, the condition $p_T \geqslant 0.5$ GeV/c was imposed on the e^- from the antimeson decay. Moreover, a high-p_T requirement, $p_T(K^-_{TOF}\pi^+\pi^+) \geqslant 0.7$ GeV/c, was applied. This cut was in fact very efficient for reducing the background level in the $(K^-_{TOF}\pi^+\pi^+)$ invariant-mass spectrum. The resulting D^+ signal is shown in fig. 3, after background subtraction. It has been checked (2) that the $(K^-_{TOF}\pi^+\pi^+)$ 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 part 3.1). The difference was made between the $|x_L|$ distributions

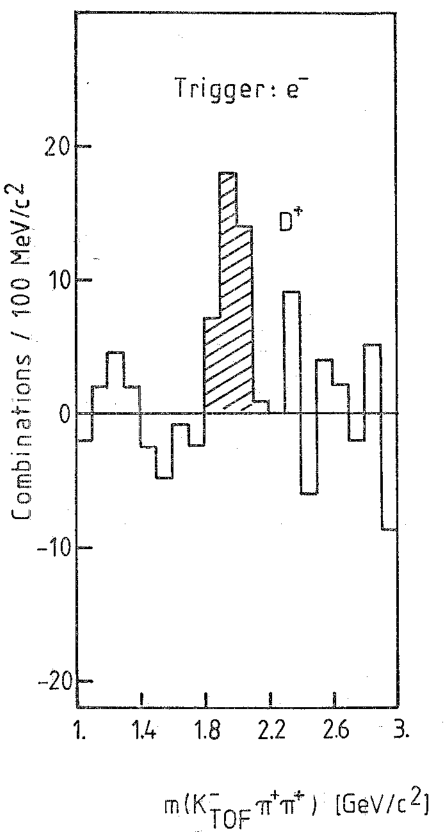

Fig. 3. – $(K^-_{TOF}\pi^+\pi^+)$ invariant-mass spectrum obtained with the e^- trigger, after the « event mixing » background subtraction. The D^+ shows up with ~ 40 mass combinations, corresponding to a ~ 3.5 standard-deviation effect.

corresponding to the « in » and « out » regions of the $(K^-_{TOF}\pi^+\pi^+)$ 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 require-

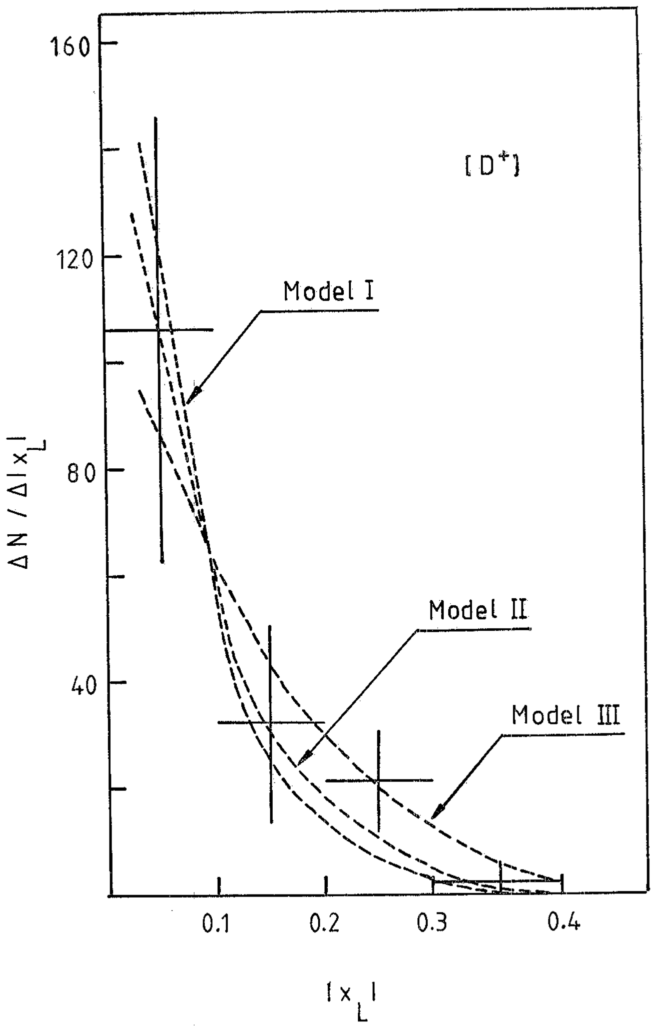

Fig. 4. – $|x_L|$ distribution of D^+ events, derived via the « in-out » difference. The dashed-line curves are relative to Monte Carlo events and simulate three different production mechanisms: « central » (model I), « flat-y » (model II) and « flat-x_L » (model III).

ment 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 part 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 mechanism (7). Such a result significantly differs from the one relative to the charm baryon Λ_c^+ distribution, measured in the same experiment (8). 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.

---

(7) A preliminary result has recently been reported on the D-meson longitudinal distribution measured in a bubble chamber experiment (LEBC-EHS) with a 360 GeV/c π^- beam at the CERN Super Proton Synchrotron. The $|x_L|$ distribution, relative to 11 $D^\pm$ and 8 D^0 events, appears to be compatible with a $(1-|x_L|)^3$ behaviour, in good agreement with our findings. (S. REUCROFT: *Charm production and lifetime using bubble chamber techniques*, talk given at the *International Conference on High-Energy Physics* (Lisbon, 1981)).

(8) M. BASILE, G. CARA ROMEO, L. CIFARELLI, A. CONTIN, G. D'ALÍ, P. DI CESARE, B. ESPOSITO, P. GIUSTI, T. MASSAM, F. PALMONARI, G. SARTORELLI, G. VALENTI and A. ZICHICHI: *Lett. Nuovo Cimento*, **30**, 487 (1981).