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

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Summary. – The transverse-momentum distributions of the charm mesons, D^0 and D^+, have been measured in high-energy (pp) collisions. The best fit to the data expressed in terms of $\exp[-bp_T]$ gives for the exponent the value $b = 2.35 \pm 0.47$, in excellent agreement with theoretical predictions.

Introduction. – Since the discovery of open charm states in high-energy (pp) interactions, the measurement of their production distributions is the new crucial point, in view of acquiring a deeper understanding of the processes involved. In the present paper we will report the first measurement of the transverse-momentum distribution of charm mesons (D^0 and D^+), observed at $\sqrt{s} = 62$ GeV in the reaction $pp \to De^-X$.

Data analysis. – The experiment was performed at the CERN Intersecting Storage Rings (ISR). The apparatus consisted of the Split-Field Magnet (SFM) spectrometer, equipped with a single-electron or positron detector in the 90° region. This detector was made of gas threshold Čerenkov counters and electromagnetic shower counters, plus an additional « dE/dx » chamber placed very near to the interaction region. A detailed description of the various elements of such a detector and of the single-electron (positron) selection procedure has already been reported elsewhere [1-3]. A time-of-

(1) M. BASILE, G. CARA ROMEO, L. CIFARELLI, A. CONTIN, G. D'ALÍ, 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).
(2) 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).
(3) 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: *Nuovo Cimento A*, **65**, 421 (1981).

flight (TOF) counter hodoscope was also installed to perform charged-hadron identification in the low-momentum range ($p \leqslant 2$ GeV/c) over about 10% of the solid angle [4].

The purpose of the present experiment was to study the associated production of open charm states. The selection power of the set-up was based on the detection of a prompt electron produced in the semi-leptonic decay of the anticharm state. The associated charm state was in turn searched for, via its hadronic decay mode, by applying an invariant-mass analysis to the events having the « right charge » electron signature. The events with the « wrong charge » positron signature were used for background studies.

The charm mesons, D^0 and D^+, were observed in the following reactions:

$$\text{(1)} \qquad pp \to D^0 \;(\to K^-\pi^+) + (e^- K^+_{TOF}) + \text{anything}$$

and

$$\text{(2)} \qquad pp \to D^+ \;(\to K^-_{TOF}\pi^+\pi^+) + (e^-) + \text{anything}\,.$$

We refer the reader elsewhere for details about the analysis [5-6]. This will be briefly recalled as follows. For reaction (1):

i) the trigger e^-, coming from $\bar{D}$ semi-leptonic decay, was required to have a transverse momentum $p_T \geqslant 500$ MeV/c;

ii) a further trigger condition was imposed, namely the presence of a K^+, also originating from $\bar{D}$ decay, identified by the TOF system and labelled as K^+_{TOF};

iii) the $(K^-\pi^+)$ final state consisted of any negative track not identified via TOF as a $\bar{p}$ or a π^-, plus any positive track not identified as a p or a K^+ and having $x_L < 0.3$ (*) (where $x_L = 2p_L/\sqrt{s}$ is the longitudinal fractional momentum).

For reaction (2):

i) The $\bar{D}$ semi-leptonic decay trigger was based only on the e^-, again with $p_T \geqslant 500$ MeV/c.

(4) M. Basile, G. Cara Romeo, L. Cifarelli, A. Contin, G. D'Alí, P. Giusti, T. Massam, F. Palmonari, G. Sartorelli, G. Valenti and A. Zichichi: *Nucl. Instrum. Methods*, **163**, 93 (1979).

(5) 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).

(6) 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.

(*) Above this value, the contamination from fast protons cannot be neglected, owing to the exponential increase with x_L of the p/π^+ ratio.

ii) The three-body ($K^-\pi^+\pi^+$) system was selected with a K^-, identified in the TOF hodoscope (K^-_{TOF}), and any two positively charged particles, having the same characteristics as specified for the π^+ of reaction (1). Moreover, a high-p_T cut, $p_T(K^-_{TOF}\pi^+\pi^+) \geqslant 0.7$ GeV/c, was applied. This cut efficiently reduced the combinatorial background level in the invariant mass-spectrum.

All the particles in reactions (1) and (2) were required to originate from the reconstructed event vertex, within ± 5 cm, and not to be affected by a momentum error greater than 30% (15% for the electron).

The D^0 and D^+ signals obtained from this analysis are shown in fig. 1 and 2, respectively, after subtraction of the standard « event mixing » normalized background.

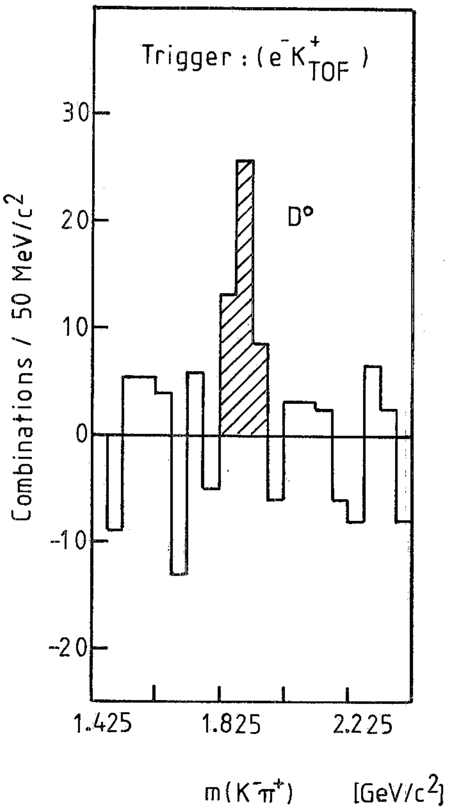

Fig. 1. – ($K^-\pi^+$) invariant-mass spectrum relative to ($e^-K^+_{TOF}$)-triggered events. A peak of ~50 mass combinations, corresponding to a ~ 4 standard-deviation effect, appears in the D^0 mass range. The background, derived via the usual « event mixing » technique, is subtracted.

An identical analysis was repeated for events carrying « wrong » triggers, such as ($e^+K^+_{TOF}$), ($e^+K^-_{TOF}$), or ($e^-K^-_{TOF}$) in the case of reaction (1). In the case of reaction (2), the « wrong » trigger was (e^+). These triggers could obviously not be due to the decay of a $\bar{D}$-meson. The « wrong » triggers produced no evidence for any D^0 or D^+ effect [5-6]. This proves that the correct selection on the antimeson trigger leads to the observation of the associated production of ($D^0\bar{D}$) and ($D^+\bar{D}$) pairs.

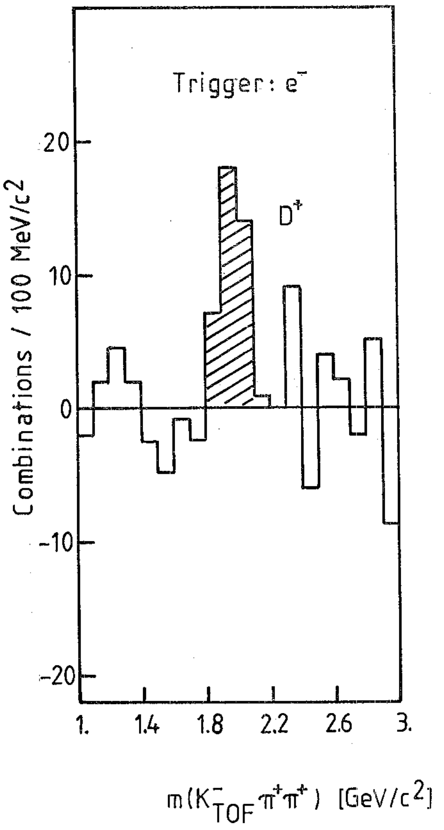

Fig. 2. – ($K^-_{TOF}\pi^+\pi^+$) invariant-mass spectrum obtained with the (e^-) trigger and the condition $p_T(K^-_{TOF}\pi^+\pi^+) \geqslant 0.7$ GeV/c, after « event mixing » background subtraction. A D^+ signal of ~ 40 mass combinations (~ 3.5 standard deviations) is observed.

Results. – The $(1/p_T)(\Delta N/\Delta p_T)$ distribution, relative to either the D^0 or the D^+ meson, was derived via the « in-out » procedure. This consisted in the definition of two regions of the invariant-mass spectrum where the D-meson appeared:

i) the « in » region, *i.e.* the mass interval where the peak itself is observed;

ii) the « out » region, *i.e.* the sum of the region below this peak and the one above it, each as wide as the « in » region.

The p_T distributions of the events falling into the « in » and « out » regions were determined separately and corrected for the apparatus acceptance. The « out » region provided the background distribution. This was normalized to the number of background events contained under the D-meson peak inside the « in » region. Finally, the « in-out » difference was worked out. It is worth mentioning that the shapes of the « in » and « out » distributions were not the same: the « out » distribution fell more rapidly with increasing p_T.

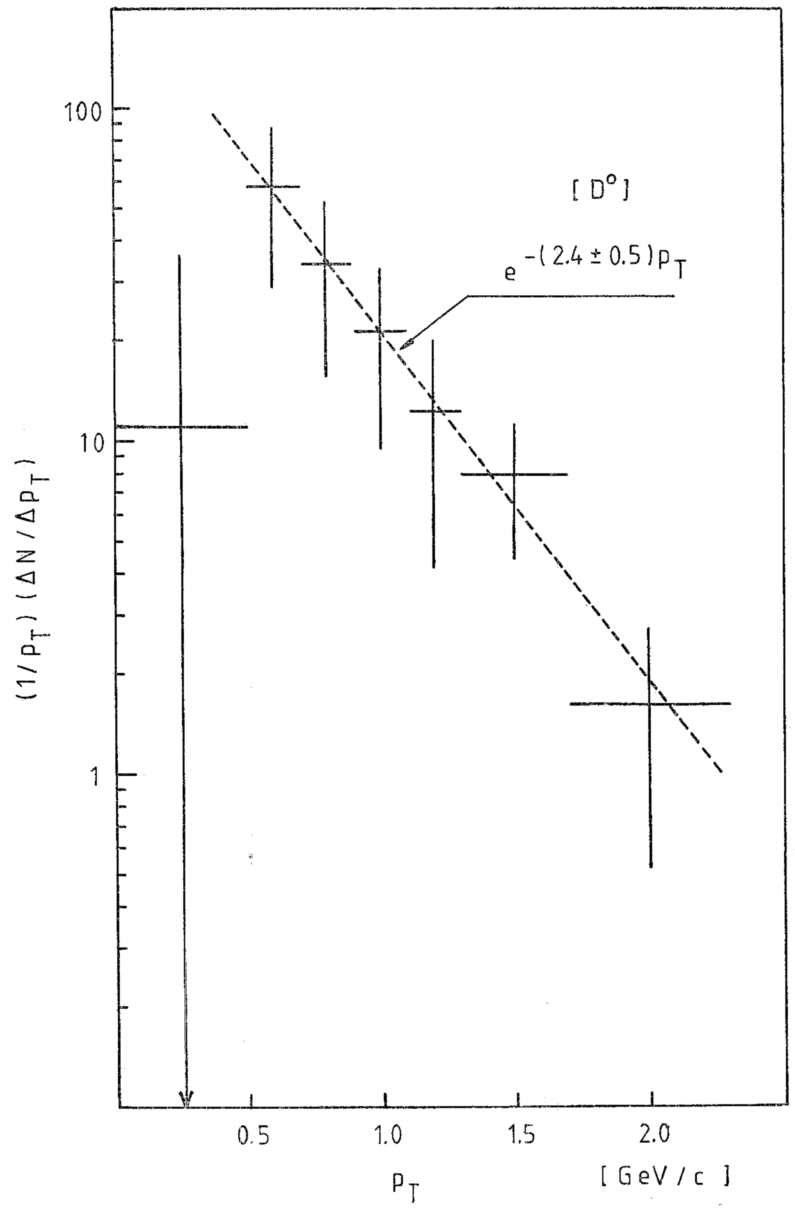

Fig. 3. – $(1/p_T)(\Delta N/\Delta p_T)$ distribution of D^0 events, derived via the « in-out » technique. The D^0 peak in the $(K^-\pi^+)$ mass spectrum defined the « in » region. The « out » region covered the two mass intervals below and above the D^0 peak, each as wide as the « in » interval. The best fit to this distribution (for $p_T \geqslant 0.5$ GeV/c), is also shown as a dashed line.

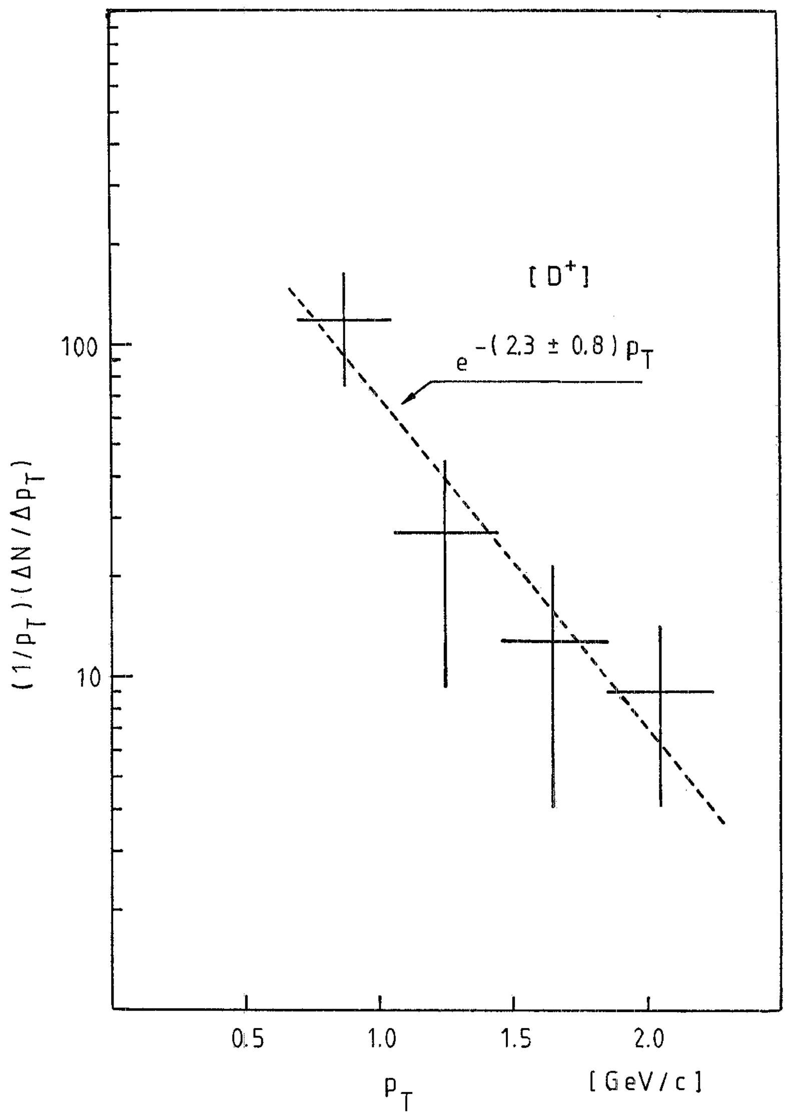

Fig. 4. – $(1/p_T)(\Delta N/\Delta p_T)$ distribution for D^+ events having $p_T \geqslant 0.7$ GeV/c. This was obtained by subtracting from the « in » distribution, relative to the $(K^-_{TOF}\pi^+\pi^+)$ invariant-mass interval where the D^+ peak was observed, the « out » distribution which corresponded to the mass intervals below and above the D^+, each as wide as the « in » interval. The best fit to the data (dashed line) is superimposed.

The p_T distributions obtained in this way for D^0 and D^+ events are shown in fig. 3 and 4 (7). The best fits to the data, of the form $(1/p_T)(\Delta N/\Delta p_T) \propto \exp[-bp_T]$, gave the following results:

$$b = (2.4 \pm 0.5) ,$$

for the D^0 (*), and

$$b = (2.3 \pm 0.8)$$

for the D^+. These fits are superimposed in fig. 3 and 4 (dashed lines). An average slope parameter was thus computed from the two above measurements: $\langle b \rangle = (2.35 \pm 0.47)$. This value is in excellent agreement with the slope measured for the Λ_c^+ baryon, observed in the same experiment (8).

Hence the results reported show that in high-energy (pp) interactions, the production of open charm states, such as D^0, D^+ and Λ_c^+, occurs at relatively high p_T, as expected from existing QCD theoretical predictions (9).

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(7) The average transverse momentum of D-mesons produced in (π^-p) interactions at lower energy has been recently measured to be $\langle p_T \rangle \simeq 800$ MeV/c. The data refer to a bubble chamber experiment (LEBC-EHS) with a 360 GeV/c π^- beam at the CERN SPS, where ~ 20 D decays were observed. (S. REUCROFT: *Charm production and lifetime using bubble chamber techniques*, talk given at the *International Conference on High-Energy Physics* (Lisbon, 1981)). This $\langle p_T \rangle$ value is consistent with our results ($\langle p_T \rangle \simeq 900$ MeV/c, as derived from the data in fig. 3), once the energy increase is taken into account.

(*) The fit was applied to the region above $p_T = 0.5$ GeV/c.

(8) 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: *Lett. Nuovo Cimento*, **30**, 481 (1981).

(9) See, for instance, Y. AFEK, C. LEROY and B. MARGOLIS: *Phys. Rev. D*, **22**, 86 (1980).