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Measurement of the Λ_c^+ Transverse-Momentum Production Distribution in pp Interactions at $\sqrt{s} = 62$ GeV.

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Introduction. – Detailed studies of charmed-particle production in high-energy proton-proton interactions are of particular interest. The experiments performed so far have measured the total cross-section for inclusive ($pp \to D^+X$, $pp \to \Lambda_c^+X$) [1-4] or associated ($pp \to \Lambda_c^+e^-X$, $pp \to e^-D^0X$, $pp \to \bar{\Lambda}_c^-e^+X$) production [5,6]. In these processes no direct measurement is available on the production distributions of the charmed particle.

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(1) D. DRIJARD, H. G. FISCHER, W. GEIST, R. GOKIELI, P. G. INNOCENTI, V. KORBEL, A. MINTEN, A. NORTON, R. SOSNOWSKI, S. STEIN, O. ULLALAND, H. D. WAHL, P. BURLAND, M. DELLA NEGRA, G. FONTAINE, P. FRENKIEL, C. GHESQUIÈRE, D. LINGLIN, G. SAJOT, H. FREHSE, E. E. KLUGE, M. HEIDEN, A. PUTZER, J. STIEWE, P. HANKE, W. HOFMANN, M. PANTER, K. RAUSCHNABEL, J. SPENGLER and D. WEGENER (CCHK COLLABORATION): *Phys. Lett. B*, **81**, 250 (1979).

(2) K. L. GIBONI, D. DIBITONTO, M. BARONE, M. M. BLOCK, A. BÖHM, R. CAMPANINI, F. CERADINI, J. EICKMEYER, D. HANNA, J. IRON, A. KERNAN, H. LUDWIG, F. MULLER, B. NAROSKA, F. NAVACH, M. NISSBAUM, J. O'CONNOR, C. RUBBIA, D. SCHINZEL, H. SEEBRUNNER, A. STAUDE, R. TIRLER, G. VAN DALEN, R. VOSS and R. WOJSLAW (ACHMNR COLLABORATION): *Phys. Lett. B*, **85**, 437 (1979).

(3) W. LOCKMAN, T. MEYER, J. RANDER, P. SCHLEIN, R. WEBB, S. ERHAN and J. ZSEMBERY (UCLA-SACLAY COLLABORATION): *Phys. Lett. B*, **85**, 443 (1979).

(4) D. DRIJARD, H. G. FISCHER, W. GEIST, P. G. INNOCENTI, V. KORBEL, A. MINTEN, A. NORTON, S. STEIN, O. ULLALAND, H. D. WAHL, P. BURLAND, G. FONTAINE, P. FRENKIEL, C. GUESQUIÈRE, G. SAJOT, P. HANKE, W. HOFMANN, M. PANTER, K. RAUSCHNABEL, J. SPENGLER, D. WEGENER, H. FREHSE, E. E. KLUGE, M. HEIDEN, W. HERR, A. PUTZER, M. DELLA NEGRA, D. LINGLIN, R. GOKIELI, R. SOSNOWSKI and M. SZEPTYCKA (ACCDHW COLLABORATION): *Phys. Lett. B*, **85**, 452 (1979).

(5) M. BASILE, G. CARA ROMEO, L. CIFARELLI, A. CONTIN, G. D'ALI, P. DI CESARE, B. ESPOSITO, P. GIUSTI, T. MASSAM, F. PALMONARI, G. SARTORELLI, G. VALENTI and A. ZICHICHI: *Measurement of associated charm production in* pp *interactions at* $\sqrt{s} = 62$ GeV, to be published in *Nuovo Cimento*.

(6) J. IRION, H. SEEBRUNNER, M. BARONE, M. M. BLOCK, A. BÖHM, R. CAMPANINI, F. CERADINI, D. DI BITONTO, K. L. GIBONI, D. HANNA, H. LUDWIG, F. MULLER, B. NAROSKA, F. NAVACH, M. NUSSBAUM, C. RUBBIA, D. SCHINZEL, A. STAUDE, R. TIRLER and R. VOSS (ACHMN COLLABORATION): preprint CERN-EP/80-229 (1980).

In the field of $D\bar{D}$ production there was only one indirect measurement (coming from μ-production studies) of the transverse-momentum distribution of the charmed mesons in the reaction $pp \to D\bar{D}X$ at $\sqrt{s} = 27$ GeV (7).

The purpose of this paper is to report the first measurement of the transverse-momentum production distribution of the Λ_c^+ charmed baryon in the reaction

$$pp \to \Lambda_c^+ + e^- + \text{anything} \tag{1}$$

at a centre-of-mass energy of $\sqrt{s} = 62$ GeV, the Λ_c^+ being identified via its decay mode $\Lambda_c^+ \to pK^-\pi^+$.

The experimental set-up. – The experiment was performed at the CERN Intersecting Storage Rings (ISR), by using the split-field magnet (SFM) detector (8), with the addition of Čerenkov counters and electromagnetic shower detectors (EMSD) (9) to trigger on electrons produced at 90°, and a large area time-of-flight system (TOF) (10) for particle identification. A schematic plan of the experimental set-up is shown in fig. 1.

A multiwire proportional chamber (MWPC) with analog read-out (« dE/dx » chamber (11)), placed near the intersection region, was used at the software level to reduce the background, from electrons produced in the π^0 and η Dalitz decay and in γ conversions, down to about 50% level. The contamination from charged hadrons simulating electrons was reduced to the 2% level, after a software refinement of the trigger conditions.

Data analysis. – From the sample of selected events, a clear signal of Λ_c^+ decaying into $pK^-\pi^+$ (5) was obtained. Let us briefly recall how the analysis was performed. (For full details, see ref. (5).)

The events were first required to have at least one positive particle with $x_L \simeq 2p_L/\sqrt{s} > 0.3$ and an error on the measured momentum $\Delta p/p < 30\%$. The positive particle, with the highest x_L, was assumed to be a proton (the π^+ contamination on the proton sample ranges from 20% to 2%, exponentially decreasing with increasing x_L). In the invariant mass $pK^-\pi^+$, the $K^-(\pi^+)$ is any negative (positive) track not identified as $\bar{p}$ or π^- (p or K^+) by the time of flight. All possible combinations (the ratio combinations-to-events is only 1.15) were entered into the mass plot, provided they satisfied the following conditions:

a) all particles were fitted to the vertex (within ± 5 cm) and had a momentum uncertainty $\Delta p/p < 30\%$;

b) both K^- and π^+ were in the same rapidity hemisphere as that of the proton;

c) the rapidity of both the K^- and the π^+ was greater than 1.0.

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(7) K. W. BROWN, B. C. BARISH, J. F. BARTLETT, A. BODEK, M. G. SHAEVITZ, E. J. SISKIND, A. M. DIAMANT-BERGER, J. P. DISHAW, M. FAESSLER, J. K. LIU, F. S. MERRITT and S. G. WOJCICKI: *Phys. Rev. Lett.*, **43**, 410 (1979).

(8) R. BOUCLIER, R. C. A. BROWN, E. CHESI, L. DUMPS, H. G. FISCHER, P. G. INNOCENTI, G. MAURIN, A. MINTEN, L. NAUMANN, F. PIUZ and O. ULLALAND: *Nucl. Instrum. Methods*, **125**, 19 (1975).

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

(10) M. BASILE, G. CARA ROMEO, L. CIFARELLI, A. CONTIN, G. D'ALI, 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).

(11) 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).

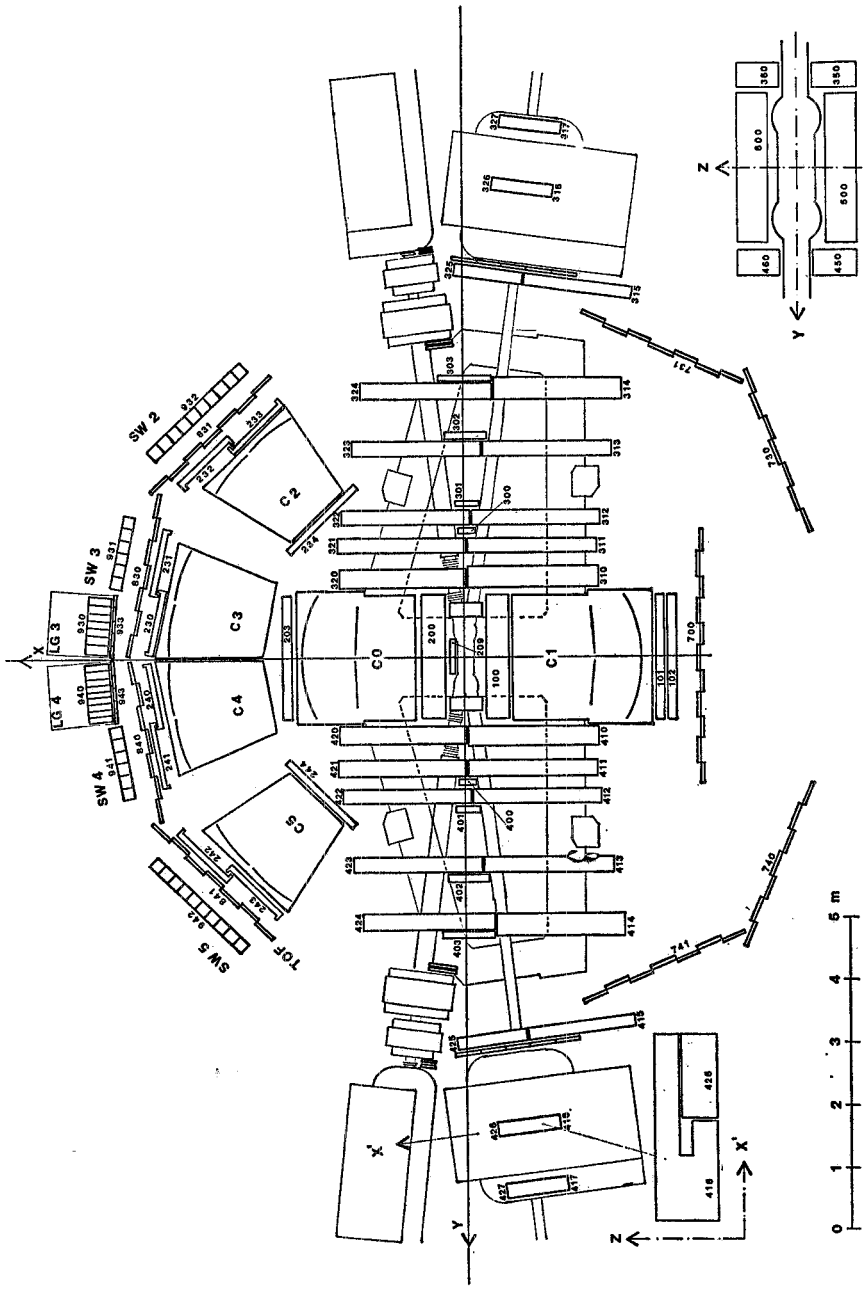

Fig. 1. – Top view of the SFM detector, showing the MWPCs and the external apparatus for particle identification (TOF). C_i ($i=0, \ldots, 5$) are the gas threshold Čerenkov counters. The electromagnetic shower detectors (EMSD) are of two types, lead/scintillator sandwiches and lead glass, indicated as SW_i ($i=2, \ldots, 5$) and LG_i ($i=3, 4$), respectively. Only the coincidences C_0C_3 or C_0C_4, associated with a minimum energy release greater than 500 MeV in the EMSDs, were used in the « electron » trigger. The « dE/dx » chamber is indicated by the number 209.

In order to enhance the Λ_c^+ signal, the following conditions were imposed on the hemisphere opposite to that of the Λ_c^+: either the presence of a leading system of charged particles with $x_{tot} = \sum_{i=1}^{n} (x_{i_L}) > 0.5$, or a signature for a leading system escaping detection, *i.e.* $x_{tot} < 0.1$. The above sum was extended to all particles fitted to the vertex and with $\Delta p/p < 30\%$. The results are shown in fig. 2. Here the mass spectrum

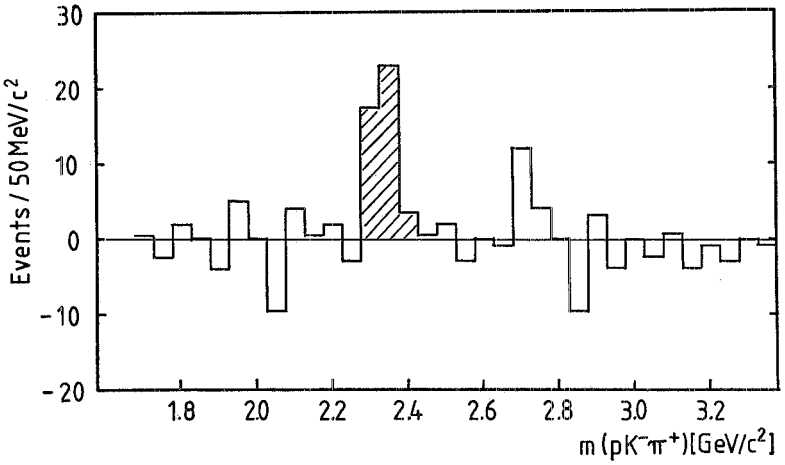

Fig. 2. – Difference between the $pK^-\pi^+$ invariant mass spectrum associated with e^--triggered events and the same mass combination relative to e^+-triggered events.

for e^--triggered events was subtracted from the mass spectrum for e^+-triggered events. The presence of a « signal » in only the e^--triggered events is the proof that the enhancement in the $pK^-\pi^+$ mass plot corresponds to a charmed baryon produced in association with an anticharmed particle decaying semi-leptonically. This is the source of the e^- triggers. The « signal » is therefore identified as the charmed baryon Λ_c^+, first discovered by SAMIOS and collaborators ([12]).

Results. – To study the transverse-momentum (p_T) dependence of the produced Λ_c^+, the $pK^-\pi^+$ mass spectrum was divided into two different mass ranges: the « IN » region ($2.28 \leqslant m(pK^-\pi^+) < 2.38$ GeV/c²) and the « OUT » region ($2.18 \leqslant m(pK^-\pi^+) < 2.28$ GeV/c², $2.38 \leqslant m(pK^-\pi^+) < 2.48$ GeV/c²). The events in the « OUT » region have been used to give the shape of the background to the events in the « IN » region. The p_T distribution of the Λ_c^+ was thus determined by subtracting, the « OUT » p_T distribution from the « IN » p_T distribution. The « OUT » p_T distribution was normalized to the total number of background events in the « IN » region. The corrections for the apparatus acceptance were applied to the real events, using single-track acceptance tables computed by means of a Monte Carlo simulation program.

Figure 3 shows the apparatus acceptance, as a function of p_T, for $pK^-\pi^+$ events in the invariant mass range between 2.18 GeV/c² and 2.48 GeV/c².

([12]) E. G. CAZZOLI, A. M. CNOPS, P. L. CONNOLLY, R. I. LOUTTIT, M. J. MURTAGH, R. B. PALMER, N. P. SAMIOS, T. T. TSO and H. H. WILLIAMS: *Phys. Rev. Lett.*, **34**, 1125 (1975).

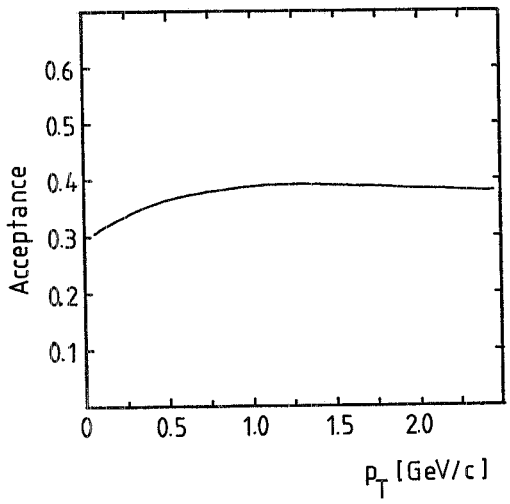

Fig. 3. – Apparatus acceptance as a function of p_T for $pK^-\pi^+$ combinations in the mass range between 2.18 GeV/c^2 and 2.48 GeV/c^2.

The experimental data are shown in fig. 4. They have been fitted with an exponential function of the form: $(1/p_T)(\Delta N/\Delta p_T) \propto \exp[-bp_T]$. The best fit gives for the exponent the following result:

$$b = 2.5 \pm 0.4 .$$

The fit is indicated by the dashed line in fig. 4.

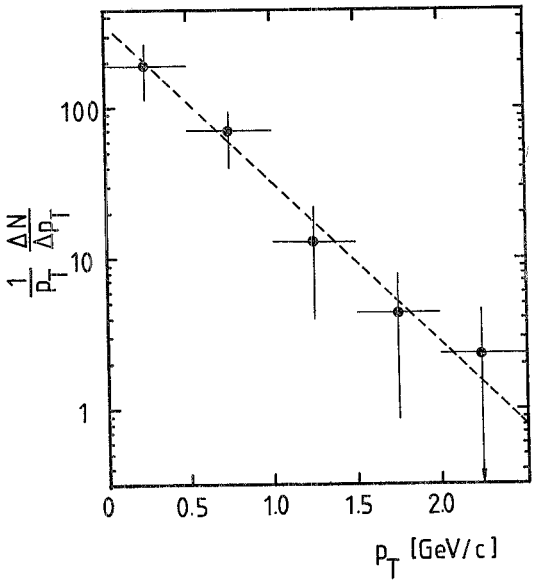

Fig. 4. – Experimental p_T distribution of the Λ_c^+ events. The dashed line is the best fit.

Recent QCD calculations by MARGOLIS and collaborators [13], using two-gluon annihilation as the main process for open charm production in pp collisions, lead to a value

$$b = 2.28 ,$$

which is in excellent agreement with our experimental result.

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[13] Y. AFEK, C. LEROY and B. MARGOLIS: *Phys. Rev. D*, **22**, 86 (1980).