EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN/EP 80-48
17 April 1980

MEASUREMENT OF THE K^-/π^- STRUCTURE FUNCTION RATIO USING THE DRELL-YAN PROCESS.

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ABSTRACT

The first measurement of the kaon to pion structure function ratio has been performed in a high integrated luminosity experiment studying the production of massive muon pairs. The ratio $\bar{u}_K/\bar{u}_\pi$ clearly deviates from 1 for values of $x_1 \geq 0.7$. A theoretical model comparison is also briefly discussed.

(Submitted to Physics Letters)

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We have measured the ratio $R(x_1) = \bar{u}_K(x_1)/\bar{u}_\pi(x_1)$ of the up quark distribution in the K^- meson to the up quark distribution in the π^- meson, as a function of the quark fractional momentum x_1, by studying simultaneously in a beam dump experiment the reactions :

$$\left.\begin{matrix} K^- \\ \pi^- \end{matrix}\right\} + \text{Nucleus} \rightarrow \mu^+\mu^- + X \qquad (1)$$

at 150 GeV/c incident beam momentum.

In the framework of the Drell-Yan model, the event distribution

$\left.\frac{dN}{dx_1}\right|_{K,\pi}$ can be written as :

$$\left.\frac{dN}{dx_1}\right|_{\pi} = K_\pi \frac{\sigma_0 L_\pi}{3x_1{}^2}\left[\bar{u}_\pi(x_1)\ I(x_1) + d_\pi(x_1)\ J(x_1)\right] \qquad (2a)$$

$$\left.\frac{dN}{dx_1}\right|_{K} = K_K \frac{\sigma_0 L_K}{3x_1{}^2}\left[\bar{u}_K(x_1)\ I(x_1) + s_K(x_1)\ \frac{J(x_1)}{2}\right] \qquad (2b)$$

where :

- $\sigma_0 = \frac{4\pi\alpha^2(\hbar c)^2}{3s}$, s being the total c.m.s. energy squared
- $L_\pi(L_K)$ is the integrated luminosity for pions (kaons)
- K_π, K_K are the ratios of the measured cross section of reaction (1) to its predicted value by the D.Y. model. K_π and K_K are assumed to be identical in value and from our previous measurements[(1)] they are compatible with being constant in the (x_1, x_2) range of our experimental acceptance
- $I(x_1)$ and $J(x_1)$ are integrals over the target variable x_2, involving the nucleon structure function and the calculated acceptance of the apparatus $A(x_1, x_2)$.

For a platinum target (Z/A = 0.4) :

$$I(x_1) = \int \frac{1}{9x_2{}^2}\left[1.6\ u_p(x_2) + 2.4 d_p(x_2) + 4 S_p(x_2)\right] A(x_1, x_2)\ dx_2$$

$$J(x_1) = \int \frac{1}{9x_2{}^2}\ S_p(x_2)\ A(x_1, x_2)\ dx_2$$

assuming for the sea quark in the nucleon $\bar{u}_p = \bar{d}_p = S_p$; $\bar{s}_p = \frac{S_p}{2}$,where S and s are the light quarks and the strange quark sea distributions respectively. In equation (2) the contribution of the meson sea is neglected since our experimental data correspond to values of $x_1 \geq 0.2$. Using $\bar{u}_\pi = d_\pi$, as imposed by isospin invariance, and (2a) and (2b)

$$R(x_1) = \frac{L_\pi}{L_K} \frac{\left.\frac{dN}{dx_1}\right|_K}{\left.\frac{dN}{dx_1}\right|_\pi} C(x_1) \quad \text{with} \quad C(x_1) = \frac{1 + \frac{J(x_1)}{I(x_1)}}{1 + \frac{1}{2}\frac{J(x_1)}{I(x_1)}\frac{s_K(x_1)}{\bar{u}_K(x_1)}} \qquad (3)$$

The ratio $J(x_1)/I(x_1)$ computed using the CDHS[2] parametrization of the nucleon structure function at $Q^2 = -20\ \text{GeV}^2$ is always less than 5% (see fig.2). In equation (3), the ratio $s_K(x_1)/\bar{u}_\pi(x_1)$ is at present unknown; however, assuming $s_K/\bar{u}_K \leq 10$ for $x_1 > 0.9$, the maximum deviation of $C(x_1)$ from 1 is 15%. For the present analysis and taking into account our statistical error, we approximate R to be :

$$R(x_1) = \frac{L_\pi}{L_K} \frac{\left.\frac{dN}{dx_1}\right|_K}{\left.\frac{dN}{dx_1}\right|_\pi} \qquad (4)$$

We would like to stress the merit of our analysis which consists of comparing two sets of data, for kaons and pions respectively, which have been collected simultaneously by the same experimental set up. In particular, the experimental acceptance, trigger efficiencies and beam conditions are the same for π and K events. The only relevant systematic error in expression (4) affects the luminosity ratio L_π/L_K and it is estimated to be less than 10%. It originates from deadtime losses which have been partially corrected and efficiency variations of the CEDAR counter arising from the high instantaneous rate of the beam; in addition the absorption of the beam particles in the 6 cm platinum target has not been corrected for.

The experiment was performed with the NA3 spectrometer[3] at the CERN SPS using an unseparated negative beam (π^-, K^-, $\bar{p}$) of momentum 150 GeV/c. Kaons and antiprotons were identified by two differential Cerenkov counters CEDAR[4]. The beam composition at the experimental target was measured at low intensity ($\sim 10^6$ part./sec) and was found to be 1.3% of antiprotons, 3.2% of kaons and 95.5% of pions. Under these conditions the probability of a π^- to simulate a K^- is 10^{-4} as can be deduced from a pressure scan of the CEDAR counter. At high intensity (5×10^7 part./burst) the detection efficiency, taking into account dead time effects, has been measured by comparing the two CEDAR's both tuned on K^- and is equal to 97%. Thus the contamination of K^- in π^- events is quite negligible . The signals of the 8 photomultipliers of each CEDAR were recorded on T.D.C's and the reference time was provided by a counter hodoscope mounted on the downstream face of the beam dump. We used the average time of those 6 photomultipliers closest to the mean value given by the 8. The resulting time distribution for the kaon detecting CEDAR is shown in fig.1. More than 95% of the K^- induced events are within a 4 nsec time interval. The random events under the peak are assumed to be produced by pions and represent a contamination level of 20%. Their contribution has been subtracted bin per bin in the dN/dx_1 distribution.

We have selected a sample of dimuon events produced on the 6 cm long platinum target and with a mass cut $4.1 \leqslant M \leqslant 8.5$ GeV in order to eliminate the resonance regions (ψ, ψ', Υ). The resulting statistics consists of approximately 700 events produced by kaons and 21200 events produced by pions. We plot the ratio R of equation (4) as a function of x_1, in fig.2. It appears that for values of $x_1 > 0.7$ the momentum spectrum of the $\bar{u}$ quark in the kaon decreases faster than the corresponding one for the $\bar{u}$ in the pion. This can also be expressed by parametrizing the data with the analytic form $R \propto (1-x)^A$, giving $A = 0.18 \pm 0.07$.

In fig.2, we compare our data with the theoretical models based on Regge considerations, proposed by P.V. Chliapnikov et al.(5) and A. El Hassouni et al.(6). These models limit the value of A in the range 1/8 to 1/2. Recently a non relativistic calculation(7) of the pion and kaon structure function in the framework of Q.C.D has been performed assuming for the quark mass ratio m_s/m_u the value : 540/336. The corresponding $\bar{u}_K/\bar{u}_\pi$ ratio can be deduced from this model and be compared to our experimental data. This is shown in fig.2 by the solid curve which seems to agree satisfactorily with the data.

We would like to acknowledge the efficient operation of the SPS accelerator and the strong support provided to the running of the beam line by the SPS Experimental Area group. We also express our deep appreciation to the technical staff of the collaboration for the continuous effort during the preparation and the running of the experiment. Finally, interesting discussions with F. Martin on the theoretical interpretation of the data are kindly acknowledged.

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The ratio $\bar{u}_K/\bar{u}_\pi$ is computed using α_ϕ = 0.17 instead of 0.
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FIGURE CAPTIONS

Fig. 1 Time spectrum of the CEDAR counter for K^- identification : plotted is the time mean value of 6 photomultipliers. More than 95% of the kaon are in a 4 nsec interval.

Fig. 2 The data points represent

$$\frac{L_\pi}{L_K} \frac{\left.\frac{dN}{dx_1}\right|_K}{\left.\frac{dN}{dx_1}\right|_\pi}$$ as defined by equation (4).

The dashed curves represent the limits of the ratio

$$\frac{\bar{u}_K(x_1)}{\bar{u}_\pi(x_1)} \times \frac{1}{C(x_1)}$$ where :

- $C(x_1)$ is defined in equation (3)
- $\bar{u}_K/\bar{u}_\pi$ and $s_K/\bar{u}_K$ are taken from ref(5), and the $J(x_1)/I(x_1)$ ratio is shown in the insert. The upper (lower) curve corresponds to A = 1/8 (A = 1/2)

The dotted and solid curves represent $\bar{u}_K/\bar{u}_\pi$ ratio from ref.(6) and ref.(7) respectively.

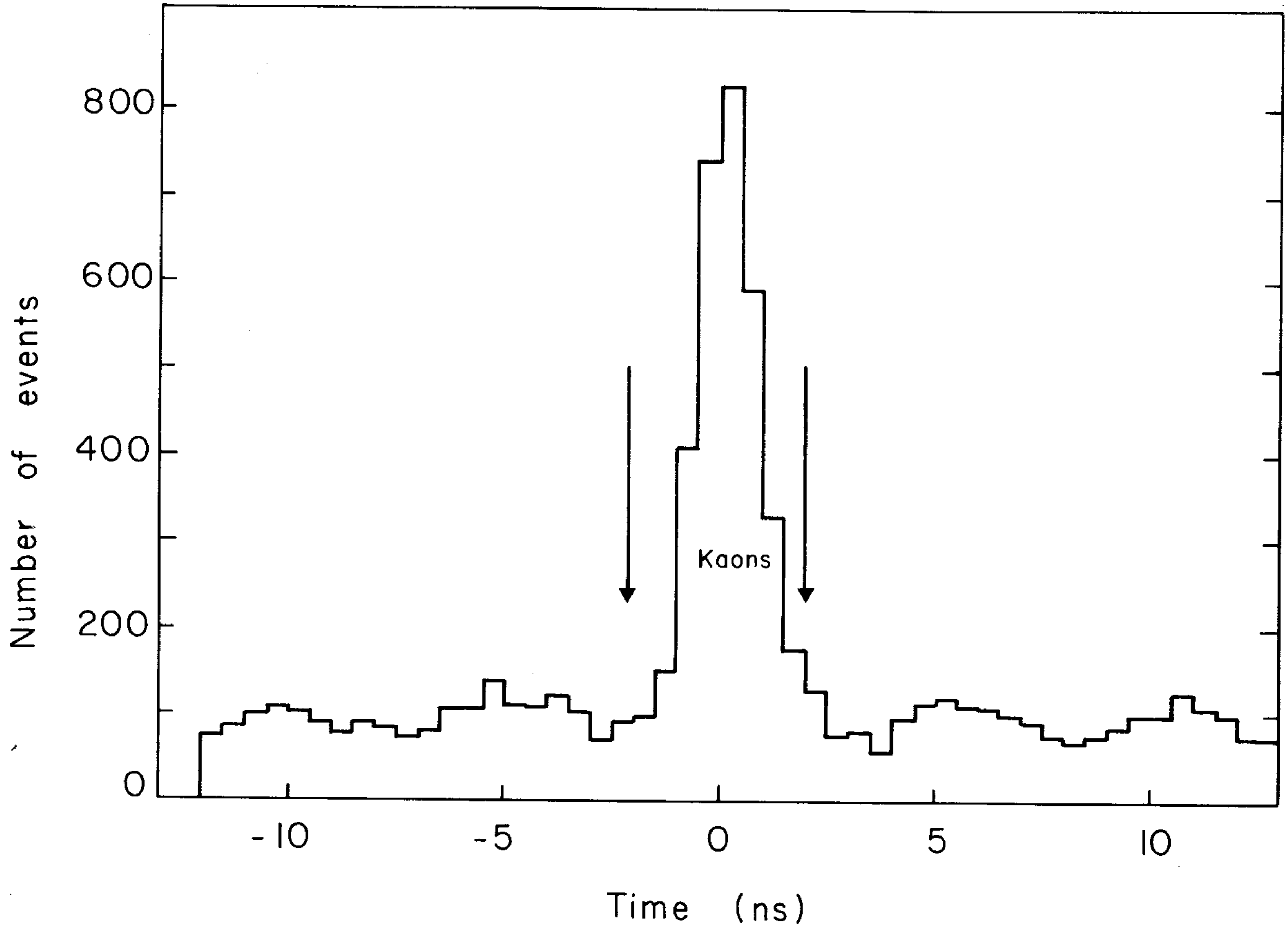

FIG. 1

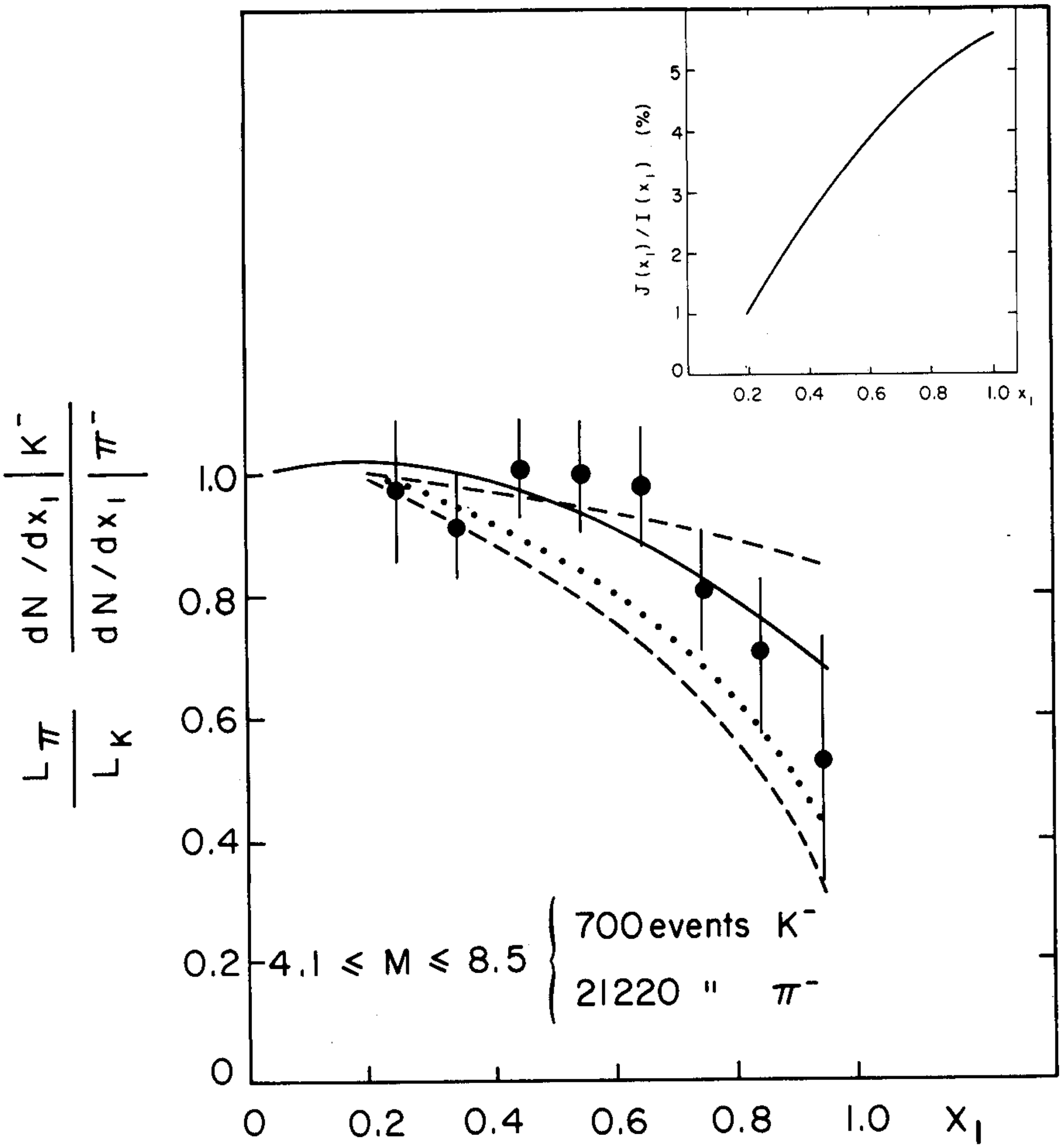
$\frac{L_\pi}{L_K} \frac{dN/dx_1|K^-}{dN/dx_1|\pi^-}$
1.0
0.8
0.6
0.4
0.2
0
0
0.2
0.4
0.6
0.8
1.0
x_1
4.1 ≤ M ≤ 8.5
700 events K^-
21220 " π^-
$J(x_1)/I(x_1)$ (%)
0
1
2
3
4
5
0.2
0.4
0.6
0.8
1.0
x_1

FIG. 2