CERN-EP/84-14

February 7th, 1984

STUDY OF THE LOW MASS DIMUON CONTINUUM PRODUCED IN HADRONIC INTERACTIONS

NA3 Collaboration

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ABSTRACT

We present here the analysis of low mass dimuon events
($1.8 \text{ GeV} < M_{\mu\mu} < 2.6 \text{ GeV}$) produced by positive and negative pion and
proton beams at 200 GeV/c. Using the difference between the π^- and the
 π^+ cross sections, and comparing to the Drell-Yan model, we find a
K-factor of 2.47 ± 0.5 . Only about 1/2 of the events can be attributed
to the Drell-Yan mechanism. If the remaining events are attributed to
muonic decays of D mesons we find an upper limit for the cross section of
charmed meson production of $40 \mu\text{b}$ at a 90% confidence level.

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The high mass dimuon continuum ($4.2 \text{ GeV} < M_{\mu\mu} < 8.5 \text{ GeV}$), produced in hadronic interactions is well described by the Drell-Yan [1] model. However the cross section must be renormalized by a scale factor (K-factor) as we have shown in previous publications [2]. We analyse presently the low mass ($1.8 \text{ GeV} < M_{\mu\mu} < 2.6 \text{ GeV}$) dimuon events produced by pions and protons on a platinum target, at 200 GeV/c [3]. If one uses only a π^- or a π^+ beam, it is very difficult to compare the data with the predictions of the Drell-Yan model : this mass region is indeed contaminated by muon pairs coming from hadronic sources (ρ' , ω' , $D\bar{D}$ meson leptonic decays). The cleanest way to suppress all these contributions is to subtract the π^+ from the π^- data, using an isoscalar target : then all hadronic contributions vanish. We have collected data at 200 GeV/c with positive and negative pion beams, using the NA3 spectrometer. The muon pairs are produced on a 6 cm platinum[†]) target and analysed by our magnetic spectrometer. The apparatus and the trigger logic as well as the experimental methods are described elsewhere [4].

The spectrometer and the trigger properties have been optimized to have a good efficiency for high mass dimuon pairs (in the J/ψ region and above), giving a good acceptance (of the order of 35% at $M > 7 \text{ GeV}$). For masses below the J/ψ , the acceptance is much poorer. The trigger requirements on the vertical component of the transverse momentum P_{TV} (either one of the two muons with $P_{TV} > 1 \text{ GeV/c}$ or both muons with $P_{TV} > 0.7 \text{ GeV/c}$) select at low dimuon mass a definite topology, with both muons almost in the vertical plane, one muon pointing up and the other pointing down.

†) The platinum nucleus is not isoscalar. However, we have measured the J/ψ cross section induced by a π^- and a π^+ beam, and we have found that they are equal within 2%. We assume the same result for the other hadronic cross sections.

The total acceptance of the apparatus for these low mass dimuons is about 5%, increasing rapidly with $M_{\mu\mu}$ and P_T . This value is obtained by assuming decay angular distributions of the type : $1 + \cos^2\theta^*$ and ϕ^* isotropic for the polar and azimuthal angles respectively, as defined in the Collins Soper frame.

It should be noticed that the result of this calculation depends strongly on the parameters of the transverse momentum distribution, $P_T \exp(-bP_T)$, used as input in the Monte-Carlo simulation. To avoid this problem, it seems natural to choose only those events with topological properties corresponding to good trigger acceptance. For this purpose we select events satisfying the following cuts :

$$|\phi^* - \phi_d| \leq \pi/6 \text{ or } \pi - \pi/6 \leq \phi^* - \phi_d \leq \pi + \pi/6$$

$$|\cos\theta^*| < 0.5$$

where ϕ_d is the azimuthal angle of the dimuon in the laboratory frame. The event distributions as a function of $\phi^* - \phi_d$ and $\cos\theta^*$ are shown in fig. 1. The dashed area corresponds to the event selection for the present analysis.

The resulting acceptance of $\sim 4\%$ is almost independent of $M_{\mu\mu}$ and P_T and hence much less sensitive to the input distributions used in the Monte Carlo^{†)}.

The cross section difference for the $\pi^- - \pi^+$ on a platinum target, assuming a linear A dependence [6], can be written as :

$$\frac{d\Delta\sigma}{dx_1 dx_2} = \sigma_0 \frac{1}{3} \cdot \frac{1}{9} \frac{V(x_1)}{x_1^2 x_2^2} [u(x_2) + 2d(x_2)]$$

$$\text{where : } \sigma_0 = 4\pi\alpha^2/3s \text{ and } \Delta\sigma = \sigma(\pi^-) - \sigma(\pi^+) \quad (1)$$

†) If we assume the angular distribution of the form :
 $d\sigma/d\phi^* d\cos\theta^* \propto 1 + \cos^2\theta^* + A \sin^2\theta^* + B \cos\phi^* \sin 2\theta^* +$
 $C \sin^2\theta^* \cos 2\phi^*$ as in ref. [5] with $A = 2C$, $B = -0.6 P_T/M$ and $C = 1.5 P_T^2/M^2$ the acceptance increases only by about 12%.

u and d are the up and down valence structure functions of the nucleon and V_π the valence structure function of the pion. The contributions of the sea quarks have been eliminated by the subtraction.

We define the K factor as usually :

$$K = (d\Delta\sigma/dM)_{\text{exp.}} / (d\Delta\sigma/dM)_{\text{th.}}$$

where $(d\Delta\sigma/dM)_{\text{th}}$ is computed using Eq.(1) in which the valence structure function of the nucleon comes from Deep Inelastic Scattering experiments : we have taken the results of the CDHS neutrino experiment [7] at $Q^2 = 5 \text{ GeV}^2$, corresponding to the mean value of $M_{\mu\mu}^2$ for our events. For the pion structure function, we use our results at 200 GeV/c for $\langle M^2 \rangle = 25 \text{ GeV}^2$ [8]. We then take into account the scaling violations predicted by the Altarelli Parisi evolution equations, to obtain the pion structure function at $Q^2 = 5 \text{ GeV}^2$ (Table 1). We have checked that all following results are insensitive to the numerical value of the QCD Λ parameter; in fact they would have been unchanged with Q^2 - independent structure functions. In this way we obtain the K factor for the low mass region :

$$K = 2.47 \pm 0.5 \quad (1.8 \text{ GeV} < M < 2.6 \text{ GeV})$$

Notice that this new value of K is consistent with all previous determinations [2,9] performed at relatively higher value of $\tau = M^2/S$ in πN interactions. The error takes into account the systematic uncertainties on the pion structure function (8%), on the luminosity (12%), and on the acceptance (5%).

Using this factor, one can compute the Drell-Yan contribution to the dimuon yield from incident p , π^+ or π^- . This contribution is compared to the data on Fig. 2a and 2b; the dashed area corresponds to the uncertainty on the cross section due to the error on the determination of the pion sea. One can remark that the cross section induced by $\pi^- \pi^+$ or p separately is not fully explained by the Drell Yan mechanism, when we include the sea contribution, multiply by the K factor and add the contribution of the π and K decays, estimated from the like-sign muon pairs to be 8%. The Drell-Yan mechanism contributes only to about 1/2 of the dimuon cross section.

A possible explanation for the remaining events is the muonic decay of D mesons, following the scheme :

Two models for D production, have been used to compute the acceptance for such a process. In the first model we guess that the D mesons are produced by the isotropic desintegration of a composite mass M. The M distribution is taken to be

$$d\sigma/dM \propto 1/M^3 \exp(-0.55M) \quad \text{ref. [10]} \quad (2)$$

and the corresponding P_T and x_F distribution :

$$E \, d\sigma/dP_T^2 \, dx_F \propto (1 - |x_F - 0.2|)^3 \exp(-2.3P_T) \quad (3)$$

The event generation is limited to masses between the $D\bar{D}$ threshold and 4.2 GeV. In the second model the $D\bar{D}$ are generated without correlations with a P_T and x_F like in equation (3). These two models give a $D\bar{D}$ cross section of the order of about 20 μb if the whole excess of events is attributed to $D\bar{D}$.

An error of 33% is due to the uncertainty on the Drell-Yan contribution (20% on the K-factor and an uncertainty of 26% due to the pion sea distribution). An other 50% systematic error can be attributed to the production model.

This leads to an upper limit of 40 $\mu\text{b}/\text{nucleon}$ at the 90% confidence level for $D\bar{D}$ production. This is consistent with the $D\bar{D}$ production cross section recently measured by LEBC [11] at higher energies ($\sigma(D\bar{D}) = 40 \mu\text{b}$ from 350 GeV/c π^-).

Another indication of this mixing of Drell-Yan and $D\bar{D}$ in the low-mass dimuons is given by the transverse momentum distributions (Fig. 3). For incoming protons and pions we obtain the same mean P_T value : $\langle P_T \rangle = 880 \text{ MeV}/c$, which is intermediate between what is expected from pure $D\bar{D}$ (around 500 MeV/c) and from Drell-Yan (around 1.2 GeV/c, from ref. 12).

CONCLUSION

Using the difference between π^- and π^+ induced dimuons, we have found that the Drell-Yan mechanism at low mass ($\langle M^2 \rangle \sim 5 \text{ GeV}^2$) gives the same K factor than at higher masses ($\langle M^2 \rangle \sim 25 \text{ GeV}^2$) in the π -nucleon interactions. However, in the mass region studied in this letter, the Drell-Yan mechanism explains only 50% of the dimuon yield, the other events being compatible with associated production of charmed mesons.

ACKNOWLEDGEMENTS

We are very grateful to the members of the SPS operating crew and the Experimental Areas group. We finally would like to express our deep gratitude to the engineering and technical staff of our collaboration for the outstanding contribution in the design, construction and operation of our apparatus.

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TABLE 1

Pion structure functions	Nucleon structure functions
$V_{\pi}(x) \propto x^{0.41-0.065\bar{s}} (1-x)^{0.95+0.072\bar{s}}$	$u(x) \propto x^{0.52-0.16\bar{s}} (1-x)^{2.79+0.77\bar{s}}$
$\theta_{\pi}(x) = 0.11 (1-x)^{8.4}$	$d(x) \propto x^{0.52-0.16\bar{s}} (1-x)^{3.79+0.77\bar{s}}$
$\bar{s} = \log \frac{\log Q^2/0.50^2}{\log 25/0.50^2}$	$\theta_N(x) = (0.26 + 0.18\bar{s})(1-x)^{8.1}$
	$\bar{s} = \log \frac{\log Q^2/0.50^2}{\log 20/0.50^2}$

FIGURE CAPTIONS

Fig. 1 Event distributions for the angular variables $\phi^* - \phi_d^*$ and $\cos\theta^*$.

Fig. 2 a) Cross section difference

$$\left(\frac{d\sigma}{dM}\right)_{\pi^-} - \left(\frac{d\sigma}{dM}\right)_{\pi^+}$$

at 200 GeV as a function of dimuon mass.

b) Cross section $d\sigma/dM$ for $\pi^- \pi^+$ and p at 200 GeV as a function of dimuon mass. The solid lines represent the predictions of the Drell-Yan model multiplied by $K = 2.47$

The dashed areas around the pion curves represent the uncertainty on the predicted Drell-Yan yield, coming from the poor knowledge of the pion sea.

Fig. 3 P_T distribution of the low mass events.

FIG. 1

FIG. 2a

FIG. 2b

FIG. 3