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HIGH-MASS MUON PAIRS PRODUCED IN π^-Be COLLISIONS AT 150 AND 175 GeV/c

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ABSTRACT

An analysis of 500 high-mass, high-resolution $\mu^+\mu^-$ pairs produced in π^-Be collisions at 150 and 175 GeV/c indicates departure from the simple Drell-Yan production mechanism with coloured quarks.

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The production of high-mass $\mu^+\mu^-$ pairs in hadron-hadron collisions is expected to occur by quark-antiquark annihilation into a time-like virtual photon[1]. Using the Drell-Yan formalism for this process and the known nucleon quark momentum distributions, one can determine the pion quark structure function. We have done this analysis using approximately 500 $\mu^+\mu^-$ pairs with masses $\geq$ 3.8 GeV produced in π^-Be collisions at the CERN Super Proton Synchrotron (SPS). The beam momentum was 150 GeV/c for 60% of our data and 175 GeV/c for the rest. The charged final-state particles were analysed in a large-acceptance, high-resolution spectrometer which has been described elsewhere[2].

The Drell-Yan cross-section with coloured quarks[3] is

$$\frac{d^2\sigma}{dMdx_F} = \frac{8\pi\alpha^2}{9M^3\sqrt{x_F^2 + 4M^2/s}} f^\pi(x_1)g^N(x_2) \ , \qquad (1)$$

where $f^\pi(x_1) = x_1\bar{u}^\pi(x_1)$ and $g^N(x_2) = (4/9)x_2u^N(x_2) + (1/9)x_2\bar{d}^n(x_2)$. Here, $\bar{u}^\pi(x_1)$ is the distribution function of $\bar{u}$ quarks in the π^- and $u^N(x_2)$ and $\bar{d}^N(x_2)$ are the nucleon u and $\bar{d}$ quark distribution functions, respectively. We take the nucleon structure function from the analysis of Buras and Gaemers[4].

We determine $f(x_1)$ by fitting our data in x_F – M space in the region $-0.1 \leq x_F \leq 0.8$ and 3.8 GeV $\leq$ M $\leq$ 7.8 GeV [5]. Our good mass resolution ($\Delta M/M = 0.015$) allows us to fit all the way down to 3.8 GeV and still avoid contamination from the ψ'. The results to the fit are shown in Fig. 1. The smooth curve is a fit to the form $f^\pi(x_1) = a\sqrt{x_1}(1 - x_1)^b$. We find a = 2.59 ± 0.33 and b = 1.56 ± 0.18, with χ^2 = 30 for 52 degrees of freedom. The data points in Fig. 1 arise from a fit in which $f^\pi(x_1)$ is allowed to assume different values in each 0.1 bin in x_1. These data points show that the kinematic domain of our experiment is such that we are not sensitive to the regions $x_1 \lesssim 0.2$ or $x_1 \gtrsim 0.85$. Thus, we are not probing the pion sea quark distribution. Also shown on Fig. 1 (dashed curve) is the result from a similar analysis done on data from π^-N interactions at 225 GeV/c [3].

Our pion structure function implies that approximately 49% of the π^- momentum comes from the $\bar{u}$ valence quark. Also, $\int_0^1 [f(x_1)/x_1]\, dx_1 = 3$. These values are both about three times higher than expected[6]. Thus, in contrast to the 225 GeV/c results[3], our data are in apparent disagreement with the simple Drell-Yan model. Reconciliation between our data and the Drell-Yan mechanism could occur if the quarks were colourless, which would reduce our f(x) by a factor of three. Also, QCD corrections to the Drell-Yan mechanism, as suggested by Altarelli, Ellis and Martinelli[7], could be important.

Drell-Yan, like other quark-antiquark annihilation mechanisms, predicts a scaling behaviour for $M^3 d\sigma/dM$. For example, when Eq. (1) is integrated over x_F, the scaling prediction is made that $M^3 d\sigma/dM$ is a function only of M^2/s. To test this prediction we plot in Fig. 2 our data from the two beam momenta 150 and 175 GeV/c. We used a linear A dependence to scale our Be target data to cross-sections per nucleon[8]. Data from these two momenta are consistent with scaling. As before, we restrict our analysis to the 2μ mass data above 3.8 GeV to avoid resonance mechanisms or changes in $\langle p_T \rangle$ dependences. Figure 2 also contains the 225 GeV/c data from Ref. 3. These data lie considerably below the two sets of data from this experiment. Thus, there is an apparent violation of the scaling prediction.

REFERENCES AND FOOTNOTES

1) S.D. Drell and T.-M. Yan, Phys. Rev. Lett. 25, 316, 902 (E) (1970) and Ann. Phys. 66, 578 (1971).

2) M. Abolins, R. Barate, P. Bareyre, P. Bonamy, P. Borgeaud, J.C. Brisson, M. David, J. Ernwein, F.X. Gentit, G. Laurens, Y. Lemoigne, J. Pascual, J. Poinsignon, A. Roussarie, G. Villet, S. Zaninotti, P. Astbury, A. Duane, G.J. King, D.P. Owen, D. Pittuck, D.M. Websdale, M.C.S. Williams, A. Wylie, J.G. McEwen, B. Brabson, R. Crittenden, R. Heinz, J. Krider, T. Marshall, R. McIlwain and T. Palfrey, Phys. Lett. 82B, 145 (1979).

3) C.B. Newman et al., Phys. Rev. Lett. 42, 951 (1979).

4) A.J. Buras and K.J.F. Gaemers, Nucl. Phys. B132, 249 (1978). Averaging over the neutrons and protons in our ^{9}Be target we find

$$g^{N}(x) = 0.877\ x^{0.594}(1-x)^{3.08} - 0.455\ x^{0.706}(1-x)^{3.84} + 0.567\ x^{0.706}(1-x)^{3.84} + 0.201\ (1-x)^{14.4}.$$

The first two terms arise from proton valence u quarks, the third term from neutron valence u quarks, and the fourth term from u and $\bar{d}$ sea quarks. We have taken a fixed $\mu^{+}\mu^{-}$ mass of 4.65 GeV.

5) The data were normalized by comparing the yield with the ψ yield. We measured the ψ yield to be 95 nb at 150 GeV/c. From this and other ψ yields, we deduce a total cross-section of 110 nb for ψ production at 175 GeV/c. A study of like-sign muon pairs suggests that the background in our $\mu^{+}\mu^{-}$ data above 3.8 GeV is negligible. However, we cannot exclude the possibility that some background of unknown origin is present. See M.A. Abolins, R. Barate, P. Bareyre, P. Bonamy, P. Borgeaud, J.C. Brisson, M. David, J. Ernwein, F.X. Gentit, G. Laurens, Y. Lemoigne, J. Pascual, J. Poinsignon, A. Roussarie, G. Villet, S. Zaninotti, P. Astbury, A. Duane, J. King, D.P. Owen, D. Pittuck, D.M. Websdale, M.C.S. Williams, A. Wylie, J.G. McEwen, B. Brabson, R. Crittenden, R. Heinz, J. Krider, T. Marshall and P. Palfrey, preprint D.Ph.P.E. 78-05, Communication at the 19th Int. Conf. on High Energy Physics, Tokyo, August 1978.

6) R.D. Field and R.P. Feynman, Phys. Rev. D 15, 2590 (1977).

7) G. Altarelli, R. Ellis and G. Martinelli, submitted to Nuclear Physics B.

8) This is in contrast to the $A^{1.12}$ of Ref. 3. Using an $A^{1.12}$ dependence lowers our data points by a factor of 0.77.

Figure captions

Fig. 1 : The smooth curve and data points represent fits to the pion structure function using our data. The dashed curve is from a similar analysis at 225 GeV/c (see Ref. 3).

Fig. 2 : $M^3 d\sigma/dM$ is plotted against the scaling variable $\tau = M^2/s$. The solid points come from Ref. 3. The two data points with the largest τ values come from the region of the upsilon.

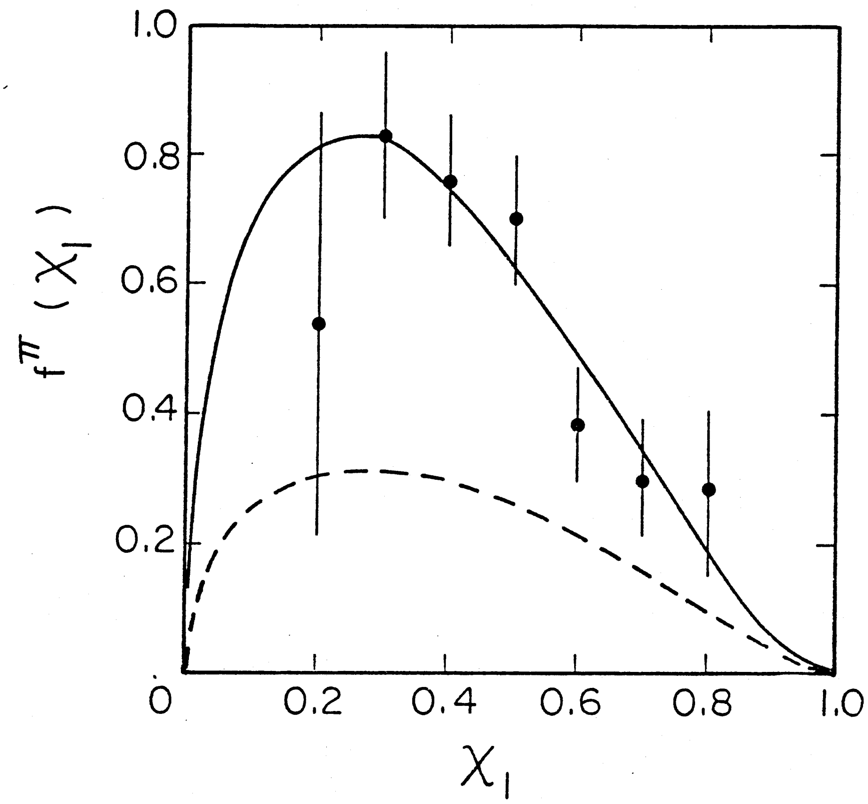
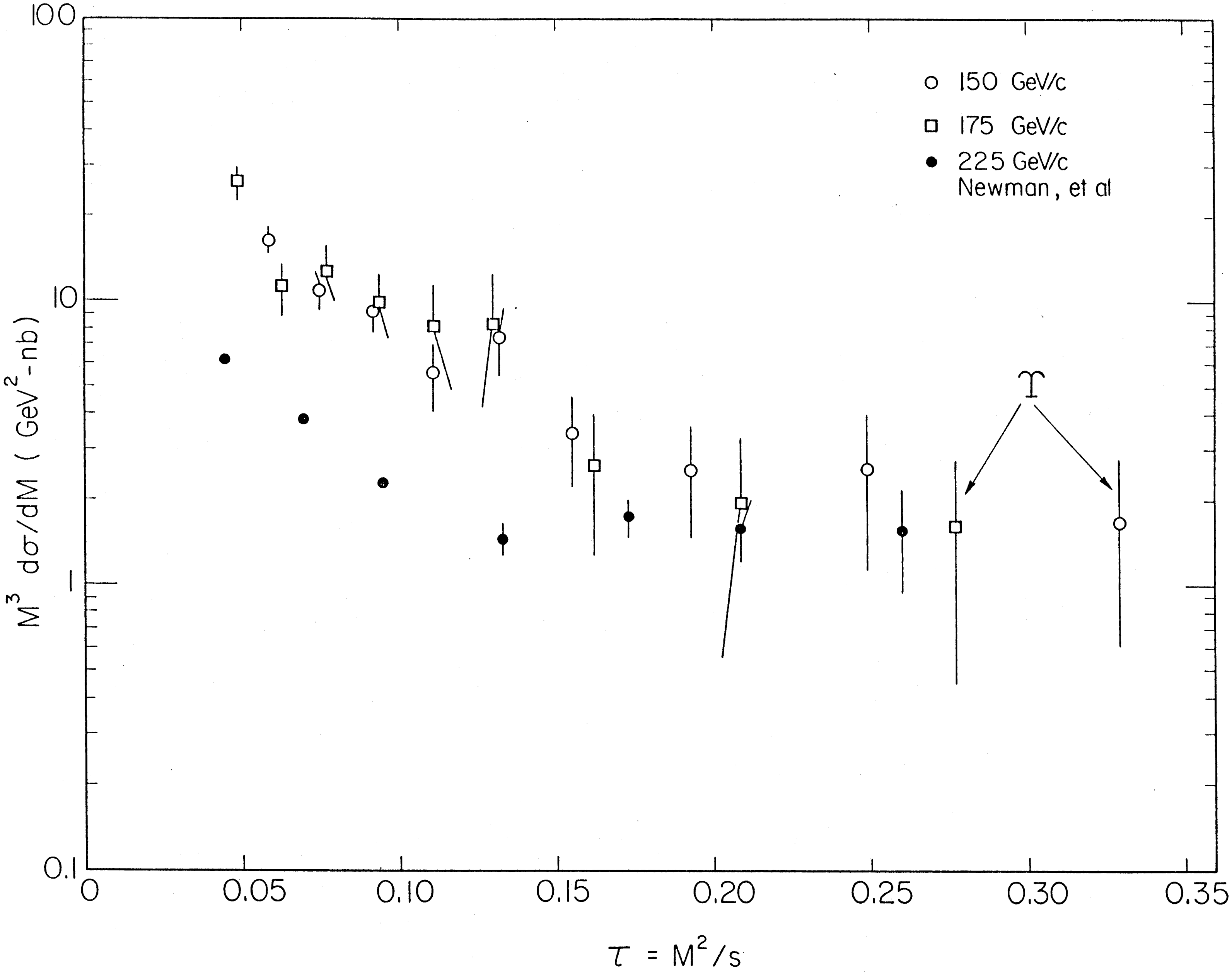


Fig. 1



100
10
1
0.1
0
0.05
0.10
0.15
0.20
0.25
0.30
0.35
$M^3\ d\sigma/dM$ (GeV^2-nb)
$\tau = M^2/s$
○ 150 GeV/c
□ 175 GeV/c
● 225 GeV/c
Newman, et al
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Fig. 2