SLAC-PUB-1604
July 1975
(T/E)

CONTRIBUTION OF THE LOW MASS DRELL-YAN LEPTON PAIRS TO THE OBSERVED ANOMALOUS LEPTONS*

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ABSTRACT

We show that a calculation of the Drell-Yan mechanism taking into account the transverse momenta of the lepton pairs reproduces the observed anomalous lepton production.

(Submitted to Phys. Lett.)

*Work supported by the U. S. Energy Research and Development Administration.

We have found recently[1] that the Drell-Yan contribution to lepton pairs is consistent with the measured cross section.[2] We calculate here the Drell-Yan contribution to the single leptons and compare with those observed in the FNAL experiment at 300 GeV/c.[3]

The single lepton contribution of a virtual photon of mass $\sqrt{Q^2}$, and c.m. momenta P_Q is:

$$\frac{E_\ell d\sigma}{d^3P_\ell}(pp \to \ell^\pm + x) = \frac{1}{4\pi}\int \frac{d^3P_Q}{E_Q^R}\left(\frac{E_Q d\sigma_Q}{d^3P_Q}\right)\frac{\delta\left(E_\ell^R - \frac{\sqrt{Q^2}}{2}\right)}{E_\ell^R} \qquad (1)$$

where E_ℓ^R is the energy of the lepton in the Q rest frame. Neglecting the transverse momenta of the quarks, gives Drell-Yan leptons too low by an order of magnitude when compared to the FNAL experiment. However, when we assume that the transverse momenta of the lepton pairs follow the distribution:

$$\left.\frac{E_Q d^3\sigma_Q}{dP_Q^3}\right|_{90^0} \propto \frac{1}{\left(P_{\perp Q}^2 + m^2\right)^4}$$

where $m \simeq 1\ \mathrm{GeV}/c^2$, the low mass lepton pairs[4] contribution accounts adequately for the anomalous single leptons in a large range of lepton transverse momenta.[5]

The invariant cross section $\rho_Q(\eta_Q) \equiv \frac{E_Q d^3\sigma_Q}{dP_Q^3}$ $\left(\eta \equiv P_{\perp Q}^2 + Q^2\right)$ of the dileptons with mass $\sqrt{Q^2}$ can be used to predict $\rho_\ell(\eta_\ell)$ of the single leptons[6]:

$$\rho_\ell(\eta_\ell) = \int d\eta_Q \frac{F\left(\frac{1}{2},\frac{1}{2};1;r^2\right)\rho_Q(\eta_Q)}{2\left[\eta_Q\eta_\ell\left(\eta_Q - Q^2\right)\left(\eta_\ell - m_\ell^2\right)\right]^{1/4}} \qquad (2)$$

where $r^2 \approx Q^4/16\eta_Q\eta_\ell$. In the region, $\eta_\ell >> Q^2$, if the dileptons distributions are

$$\rho_Q(\eta_Q) \rightarrow \left[\eta_Q^{-\alpha},\ e^{-\alpha\eta_Q},\ e^{-\beta\eta_Q^{1/2}}\right], \tag{3}$$

then the distributions of the single leptons are:

$$\rho_\ell(\eta_\ell) \rightarrow \left[\eta_\ell^{-\alpha},\ \frac{e^{-\alpha\eta_\ell}}{\alpha\eta_\ell},\ \frac{e^{-\beta\eta_\ell^{1/2}}}{\beta\eta_\ell^{1/2}}\right]. \tag{4}$$

respectively. Namely, the distributions of the single leptons are identical or <u>steeper</u> than the distributions of the dileptons, depending on the P_Q distributions. The observed constancy of the $\frac{\ell}{\pi}$ ratio over a large range of $P_{\perp\ell}$ in this experiment indicates that the single lepton distribution is of the form $1/(m^2+P_{\perp\ell}^2)^4$. Theoretically, it could be obtained from Eq. (2) for a known $\rho_Q(\eta_Q)$. The distribution of the dileptons can be calculated[5] by integrating the product of the leading quark distribution function $(1\text{-}x)^3/(m^2+k_\perp^2)^4$ and the nonleading antiquark distribution function $(1\text{-}x)^7/\left[(P_{\perp Q}-k_\perp)^2+m^2\right]^8$ over the quark fractional momentum x and transverse momentum $k_\perp$. The distribution of these leptons is mainly $1/(m^2+P_{\perp Q}^2)^4$. We notice that, from Eq. (3) and Eq. (4), a power law in the η_Q results in a power law in η_ℓ distribution function. Since both leptons and π's have the same power law, the constancy of $\frac{\ell}{\pi}$ in $P_{\perp\ell}$ is easily understood from this picture. We notice that, without folding in the transverse momentum distribution of the quarks, one cannot explain this constant ratio $\frac{\ell}{\pi}$. It is interesting to note that for a pion beam, where the dilepton distribution is not longer $1/(m^2+P_{\perp Q}^2)^4$, but is changed to $A/(m^2+P_{\perp Q}^2)^2 + B/(m^2+P_{\perp Q}^2)^4$, the ratio $\frac{\ell}{\pi}$ increases with $P_{\perp\ell}$.[7]

In Fig. 1 we show $d\sigma/dP_{\perp\ell}$ for several cases. Curve A is the Drell-Yan contribution assuming no quarks transverse momentum, and the angular distributions of the leptons are only transverse to the c.m. direction, i.e., $d\sigma/dP_\perp = d\sigma/d\frac{Q}{2}$. Curve B is the contribution when all distributions are folded in.

In Fig. 2, we show the new Drell-Yan contribution with $Q > 2m_\mu$ and the measured data (we assume no colors for quarks). This mass cutoff should be different for electron pairs and muon pairs. One should expect the ratio $\frac{e}{\pi}$ to be larger than the ratio $\frac{\mu}{\pi}$ at low $P_\perp$ where the mass threshold is most important. This in fact has been observed in recent prompt electron and prompt muon experiments.[8,9] We understand that the Drell-Yan calculation is not valid for low mass lepton pairs and the agreement to the data should be taken with reservations.

We wish to thank R. Mozley, L. Wang and other members of our group at SLAC for discussions. We also appreciate the conversations with R. Blankenbecler, S. Brodsky, J. Bjorken and S. Drell of the Theory Group. Critical advice from G. Farrar and M. Davier is appreciated.

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7. We thank R. Blankenbecler for explaining the physics of quarks transverse momentum distribution.

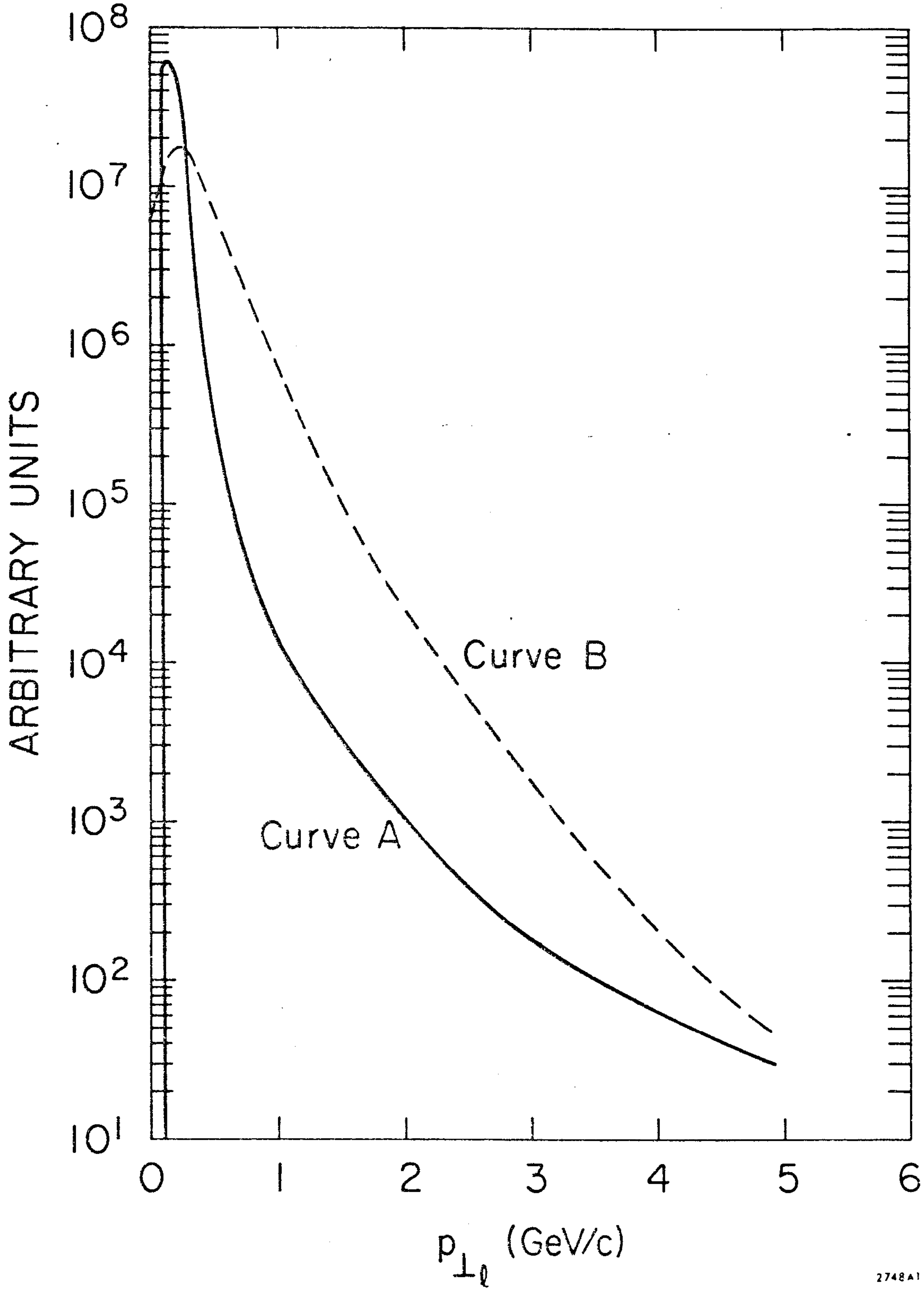
8. James W. Cronin, Review of Direct Lepton Production in Nucleon-Nucleon Collisions, Lecture prepared for the International School of Subnucleon Physics, Erice, July 11, 1975. We have not used K. Winter's point due to the reasons mentioned in J. W. Cronin's review paper.

9. L. Lederman, Talk presented at the 1975 International Symposium on Electron and Photon Interactions at High Energy, Stanford University. The new data from CHORM group at low $P_{\perp}$ support this threshold argument.

FIGURE CAPTIONS

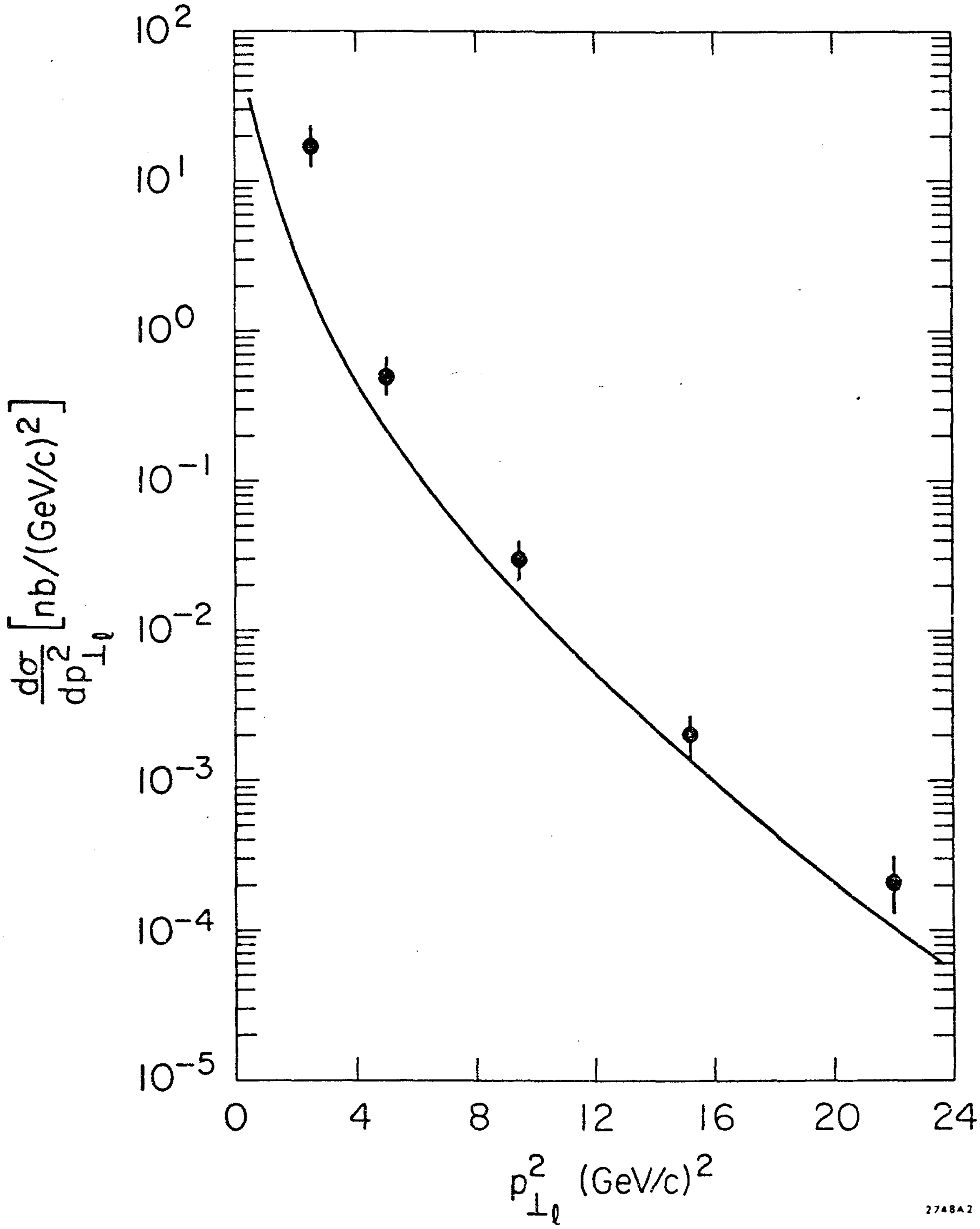
1. Curve A is the Drell-Yan contribution assuming no quarks transverse momentum, and the angular distributions of the leptons are only transverse to the direction; i.e., $d\sigma/dP_{\perp} = d\sigma/d\frac{Q}{2}$. Curve B is the contribution when all distributions are folded in.

2. The new Drell-Yan contribution with $Q > 2m_{\mu}$ and the measured data.



ARBITRARY UNITS
10^8
10^7
10^6
10^5
10^4
10^3
10^2
10^1
0
1
2
3
4
5
6
$p_{\perp_\ell}$ (GeV/c)
Curve A
Curve B
2748A1

Fig. 1



10^2
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
$\frac{d\sigma}{dp^2_{\perp_\ell}}$ $\left[nb/(GeV/c)^2\right]$
0
4
8
12
16
20
24
$p^2_{\perp_\ell}$ $(GeV/c)^2$
2748A2

Fig. 2