# THE DRELL-YAN DILEPTON CROSS SECTION 

 IN THE HIGH MASS REGION*Minh Duong-van<br>Stanford Linear Accelerator Center Stanford University, Stanford, California 94305


#### Abstract

With specific assumptions, we show that the calculated Drell-Yan dilepton cross section agrees with the recent high mass measurement of the Columbia-Stony Brook-FNAL group.


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[^0]The recent report on the Upsilon ${ }^{1}$ adds to the list of new excitements in particle physics．It is natural to study the background in its vicinity。 We try to understand the measured background of the dileptons in the high mass， $\mathrm{Q}>4.5 \mathrm{GeV}$ ，region，using the Drell－Yan process．${ }^{2}, 3$ Several assumptions are made：

1．The production of high mass pairs is assumed to be similar to the produc－ tion of high $P_{\perp}$ hadrons，where the A dependence is roughly linear．This may be substantiated by the measured ratio of $\frac{\sigma_{\psi}}{\sigma_{\rho}}=A^{\circ} 35$ 。
2．The $x$－distribution of the dileptons $\left(x \equiv P_{\|}^{c_{0}} m^{\rho} / P_{\|}^{c_{0}} m_{\circ}\right)$ is a function of $Q^{2} / \mathrm{s}$ in the Drell－Yan model．It flattens as $Q^{2} / \mathrm{s}$ increases．Fig．1a shows the predicted $x$－distribution compared with the data on the $x$－distribution of the di－ leptons at $\psi$（and its vicinity）at Serpukov。 ${ }^{4}$ ．Since we predict that the shape at $\frac{Q^{2}}{\mathrm{~S}} \simeq \frac{36}{2 \mathrm{M} \times 400}$（FNAL）is almost similar to that at $\frac{\mathrm{Q}^{2}}{\mathrm{~S}} \simeq \frac{9}{2 \mathrm{M} \times .70}$（Serpukov）， we use the x －distribution of the $\psi$ and its vicinity measured by Antipov et al．to estimate the cross section in the high mass region．（No appreciable difference in the distribution at the $\psi$ and off the $\psi$ was observed．）To extract the high mass dilepton cross section，the Columbia－Stony Brook－FNAL group have used the parametrization ${ }^{1}$

$$
\frac{E d^{3} \sigma}{d P^{3}} \propto(1-|x|)^{4.3} e^{-1.6 P_{\perp}}
$$

Estimated from the measured low $x$ region（ $x<.1$ ），the cross section calculated using this．$(1-|x|)^{4.3}$ parametrization is a factor of 2.5 smaller than that es－ timated using the measured $x$－distribution（Fig。1a）．From Fig。1b，if a is the area measured from $x=x_{B}$ to $x=1$ ，where $x_{B}$ is the value where the distribu－ tion breaks from a flat distribution and A is the total area under the curve，the ratio $\xi$ is：

$$
\xi=\frac{\mathrm{a}}{\mathrm{~A}}=\frac{1}{1+\left(5 \mathrm{x}_{\mathrm{B}}\right) /\left(1-\mathrm{e}^{-5\left(1-\mathrm{x}_{\mathrm{B}}\right)}\right)}
$$

The measured ratio $\xi_{\min }=\frac{\sigma\left(|x| \geq x_{\min }\right)}{\sigma(-1 \leq x \leq 1)}$ for $\psi$ production ${ }^{4}$ is plotted in Fig．2。 Set $\mathrm{x}_{\mathrm{B}}=\mathrm{x}_{\min } ; \xi_{\mathrm{B}}$ is also plotted in Fig．2．The intersection at $\mathrm{x}_{\mathrm{B}}=$ $x_{\min } \approx .3$ ．The factor of 2.5 can be evaluated：

$$
\frac{\int_{0}^{.3} d x+\int_{.3}^{1} e^{-5(x-03)} d x}{\int_{0}^{1} e^{-5 x} d x} \simeq 2.5
$$

（We have assumed $\mathrm{e}^{-5 \mathrm{x}} \approx(1-\mathrm{x})^{4.3}$ ．）To test the validity of this method of ex－ trapolation，we have used the Serpukov data for all $x$ and at $E=70 \mathrm{GeV}$ to pre－ dict the $\psi$ cross section ${ }^{5}$ for $\mathrm{x}>.32$ and at $\mathrm{E}=240 \mathrm{GeV}$ 。 From scaling pre－ diction，the energy difference would give a factor of 2 in cross section．From Fig。2，at $x_{\min }=.32, \xi_{\min }=.38, \sigma_{\text {predicted }}(|x|>.32, E=240)=$ $\left(3.5 \times 10^{-32} \mathrm{c}_{\mathrm{c}} \mathrm{m}_{\mathrm{o}} /\right.$ nucleon $) \times 2 \times .38=26 \mathrm{nb} /$ nucleon．The measured cross section at FNAL ${ }^{5}$ is also $26 \mathrm{nb} /$ nucleon．

It is interesting in the near future to know how well the Drell－Yan dileptons scale．However it would be dangerous to compare the cross section extrapolated from $x>.3$ and from $x=0$ data if the $x$－distribution is not exactly known．A factor of $(2.5)^{2}$ errors may result if $(1-|x|)^{4.3}$ distribution is assumed． 3．We assume the quarks have colors．We define $f_{i}^{p}(z)$ as the probability of finding a parton of type $i$ and charge $e_{i}$ carrying a fraction $z$ of the proton $p_{0}$ The distribution of $f_{i}^{p}(z)$ is taken from the work of $T_{\text {。 Goldman }}^{\circ}{ }^{3,6}$ It is listed as follows：

$$
\begin{gathered}
f_{u}^{p}(z)=\frac{.2(1-z)^{7}}{z}+1.89 \frac{(1-z)^{7}}{\sqrt{z}}+\left\{\begin{array}{l}
90.2 z^{3 / 2} e^{-7.5 z} \\
5(1-z)^{3}
\end{array}\right\} \begin{array}{l}
z<.35 \\
z \geq .35
\end{array} \\
f_{d}^{p}(z)=\frac{.2(1-z)^{7}}{z}+1.3 \frac{(1-z)^{7}}{\sqrt{z}}+.7(1-z)\left\{\begin{array}{l}
90.2 z^{3 / 2} e^{-7.5 z} \\
5(1-z)^{3}
\end{array}\right\} \begin{array}{l}
z<.35 \\
z \geq .35
\end{array} \\
f_{\vec{u}}^{p}(z)=f_{\frac{d}{p}}^{p}(z)=f_{s}^{p}(z)=f_{\frac{p}{p}}^{p}(z)=f_{c}^{p}(z)=f_{\frac{p}{p}}^{p}(z)=\frac{.2(1-z)^{7}}{z}
\end{gathered}
$$

With these assumptions, we can calculate the Drell-Yan cross sections: Call $\mathrm{x}=\frac{2 \mathrm{P}_{\|}^{\mathrm{c}} \cdot \mathrm{m} .}{\sqrt{\mathrm{s}}}$ the fraction of the longitudinal $\mathrm{c}_{0} \mathrm{~m}_{0}$ momentum of the dileptons, the differential cross section for a parton $q_{i}$ having longitudinal momentum $\frac{z \sqrt{s}}{2}$ to annihilate with an anitparton $\bar{q}_{i}$ of momentum $\frac{-\bar{z} \sqrt{s}}{2}$ producing a virtual photon of mass $Q$ weighted by the probability distribution of finding a quark $q_{i}$ with a fraction $z$ in $A, \bar{q}_{i}$ of a fraction $\bar{z}$ in $B$, is:
where

$$
\begin{aligned}
& \frac{d \sigma}{d Q d x}=\frac{1}{3} \frac{4 \pi \alpha^{2}}{3 Q^{2} s} \cdot 2 Q \cdot \int_{0}^{1} d z \int_{0}^{1} d \bar{z} \delta\left(z \bar{z}-\frac{Q^{2}}{s}\right) \delta(z-\bar{z}-x) G^{\prime}(z, \bar{z}, x) \\
& e \\
& G^{\prime}(z, \bar{z}, x)=\sum_{i} e_{i}^{2}\left[f_{i}^{A}(z) f_{i}^{B}(\bar{z})+f_{\bar{i}}^{A}(\bar{z}) f_{i}^{B}(z)\right]
\end{aligned}
$$

The factor $\frac{1}{3}$ is due to colors.
The longitudinal momentum and energy conservations are constrained by $\delta(\mathrm{z}-\overline{\mathrm{z}}-\mathrm{x})$ and $\delta\left(\mathrm{z} \overline{\mathrm{z}}-\mathrm{Q}^{2} / \mathrm{s}\right)$. Upon integration,

$$
\frac{d \sigma}{d Q d x}=\frac{1}{3} \frac{4 \pi \alpha^{2}}{3 Q^{4}} \cdot 2 Q \cdot \sum_{i} e_{i}^{2} \frac{z^{2}}{z_{A}+z_{B}}\left\{\left\{\left[f_{i}^{A}\left(z_{A}\right) f_{i}^{B}\left(z_{B}\right)+f_{\bar{i}}^{A}\left(z_{A}\right) f_{i}^{B}\left(z_{B}\right)\right]\right\}\right.
$$

where

$$
\begin{aligned}
& \mathrm{z}_{\mathrm{A}}=\frac{1}{2}\left[\mathrm{x}+\left(\mathrm{x}^{2}+4 \mathrm{Q}^{2} / \mathrm{s}\right)^{\left.\frac{1}{2}\right\rceil}\right. \\
& \left.\mathrm{z}_{\mathrm{B}}=\frac{1}{2}-\mathrm{x}+\left(\mathrm{x}^{2}+4 \mathrm{Q}^{2} / \mathrm{s}\right)^{\frac{1}{2}}\right]
\end{aligned}
$$

The cross section $\frac{d \sigma}{d Q}$ is obtained after x is integrated out. Fig. 3 shows the
calculated Drell－Yan cross section．The agreement with data is surprisingly good considering the calculation has no free adjusted parameters．

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## FIGURE CAPTIONS

1. a) The measured $x$-distribution from Ref. 4 (Serpukov).

$$
\frac{d \sigma}{d x} \sim \int_{0}^{1.5(\mathrm{GeV} / \mathrm{c})^{2}} \frac{\mathrm{~d}^{2} \sigma}{\mathrm{dxdP}_{\perp}^{2}}, \text { where } \mathrm{x}=\frac{\mathrm{P}_{\|}^{\mathrm{c} \cdot \mathrm{~m} .}}{\mathrm{P}_{\max }^{\mathrm{c}_{\mathrm{o}} \mathrm{~m}_{\mathrm{o}}}}, \mathrm{P}_{\max }^{\mathrm{c} \cdot \mathrm{~m}_{\mathrm{o}}}=5.2 \mathrm{GeV} / \mathrm{c} .
$$

The dotted curve is the predicted distribution from Drell-Yan model.
b) Simple suggested parametrization of the x-distribution.
2. The area ratio $\xi_{\min }(x)$ and $\xi_{B}(x)$ defined in the text, plotted versus $x_{\text {min }}{ }^{\circ}$
3. The measured cross section by the Columbia-Stony Brook-FNAL group, corrected by a factor of 2.5 (see text). The dotted curve is the Drell-Yan calculation with colors.


Fig. 1


Fig. 2


Fig. 3


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