DOUBLY DIFFERENTIAL INELASTIC CROSS-SECTION CURVE FITS FOR $J/\psi$ PHOTOPRODUCTION

E160

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Inelastic $J/\psi$ Kinematics

- Beam Energy in the Center of Mass Frame
- The momentum of the $J/\psi$ perpendicular to the beam line’s axis of propagation (z-axis): $p_t^2 = p_x^2 + p_y^2$
- Fraction of the initial beam energy that the $J/\psi$ carries: $z = \frac{E_{\psi}}{E_{\gamma}}$
Phenomenological Form for $\frac{d^2\sigma}{dp_t^2 dz}$

- Assume that we are dealing with a separable function

\[
\frac{d^2\sigma}{dp_t^2 dz} = f(z)g(p_t^2)h(W)
\]  

(1)

- First find a form for each of the functions

- Make a linear fit to the data from H1 and ZEUS using the model $d^2\sigma/dp_t^2 dz = \alpha \cdot X$

- The compiled data contained values for the doubly differential cross-section over various ranges of the kinematic variables.

- For example $\frac{d^2\sigma}{dp_t^2 dz} = 22.6\text{GeV}$ when $W = 150\text{GeV}, p_t^2 = 1.54\text{GeV}^2, z = 0.83$

- Once we found the form of Eq. 1, it was our task to plug in the numbers for each value and fit using ROOT to find the slope, $\alpha$
Beam Energy (W) Dependence

Figure 1: Observed total cross section of inelastic $J/\psi$ production at energies ranging from near-threshold to 200 GeV.

- Only included data with $z < 0.9$
- Eq. 2 from our fits for the total cross-sections of the elastic data was applied holding $\alpha_2$ and $\alpha_3$ fixed to values obtained from elastic data

$$\sigma = \alpha_1 \cdot (1 - \frac{W^2}{W_{th}^2})^{\alpha_2} \cdot W^{\alpha_3} \quad (2)$$
Transverse Momentum ($p_t^2$) Dependence

Figure 2: An example of the fit used to determine the exponent $n$.

- An equation for the $p_t^2$ dependence was found in the H1 paper we extracted the inelastic data from (C. Adloff, et al., H1 Collaboration, hep-ex/0205064)

$$ (p_t^2 + M_{\psi}^2)^{-n} $$

- Where $M_\psi$ is the mass of the $J/\psi$ and $n$ is some variable with $z$ dependence
Figure 3: The exponential of the $p_t^2$ dependence is plotted over the range of $z$ and fit to a line

$$n = \alpha_0 + \alpha_1 z$$ \hspace{1cm} (4)

- We fit a line to $n$ vs. $z$ using data included in the H1 paper to measure $n$'s dependence on $z$ but this needed some adjustment for our double differential cross-section fit - more to come on this
Energy Ratio (z) Dependence

![Graph showing dσ/dz vs z]

Chi2 / ndf = 67.64 / 36  
Prob = 0.0006762  
p0 = 17.13 ± 11.23  
p1 = 0.193 ± 0.3632  
p2 = 3.634 ± 1.299

Figure 4: Data for dσ/dz from various sources normalized to the H1 value for z ≈ 0.7

- We normalized the data to the H1 value for z ≈ 0.7 and fit to an equation of the form:

\[ \alpha_6(1 + \alpha_4e^{\alpha_5z}) \]  

(5)

- The fit in Figure 4 may not represent what happens for high z values, but it was assumed adequate for our purposes.
Figure 5: The calculated X values for the EMC data are out of line with the H1 data - leading us to believe that the factor $M_\psi$ is too large for such low values of $p_t^2$ (this is for $\gamma = 1$)

- We now have a function we believe should fit the data for the doubly differential cross-section that takes into account all three kinematic variables

$$\frac{d^2\sigma}{dp_t^2dz} = \alpha_6 \frac{(1 - \frac{W_{th}^2}{W^2})^{\alpha_2} W^{\alpha_3}}{(p_t^2 + \frac{M_\psi^2}{\gamma})^{\alpha_0 + \alpha_1 z}}(1 + \alpha_4 e^{\alpha_5 z}) = \alpha_6 \cdot X$$

(6)
• We tried values for this factor $1 \leq \gamma \leq 10$ and found that the best line was formed by a factor $\gamma = 2.5$

• Now back to the method used to find $\alpha_0$ and $\alpha_1$. The mass parameter was divided by 2.5 and the new best fit for n vs. z was calculated. Using these values for the parameters in Eq. 6 we found that the best fit for X was now $\gamma = 5.0$

• Turn the crank again and obtain the fit shown in Fig. 6 for our doubly differential cross-section

• Now that we have a good phenomenological representation of the data we should check to see how it compares with theoretical predictions.

• See references and more detail at the following website
Figure 6: The distribution for $\gamma = 5$, $\alpha_0 = 2.165$ and $\alpha_1 = 0.8434$. Note the $\chi^2$/degrees of freedom is lower because of the recalculated exponential parameters.