7.6 γp cross section determination

For quasi-real photons, the photoproduction cross section $\sigma_{\gamma p}$ is derived from the electroproduction cross section $\sigma_{ep}(y_1, y_2)$(detector acceptance corrected) by

$$\sigma_{\gamma p} = \frac{\sigma_{ep}(y_1, y_2)}{\Delta F} \tag{71}$$

where

$$\Delta F = \int_{y1}^{y2} f_{\gamma/e}(y)\, dy \tag{72}$$

is the ratio of the γp luminosity to the ep luminosity. We may ask a question: where does $\sigma_{\gamma p}$ lie on the $\sigma_{\gamma p} \sim y$ curve? Note that this is not the same as the question: what is the average value of y? According to the mean value theorem of calculus, y^* can be uniquely determined from the following equation if $\sigma_{\gamma p}(y)$ is a monotonous function of y in the range $y_1 < y < y_2$:

$$\begin{aligned} \sigma_{ep}(y_1, y_2) &= \int_{y_1}^{y_2} \sigma_{\gamma p}(y)\, f_{\gamma/e}(y)\, dy \\ &= \int_{F(y_1)}^{F(y_2)} \sigma_{\gamma p}(F)\, dF \\ &= \Delta F \sigma_{\gamma p}(F(y^*)) \end{aligned} \tag{73}$$

where y^* depends on function forms of $F(y)$ and $\sigma_{\gamma p}(F)$,

$$F(y) = \int^{y} f_{\gamma/e}(y')\, dy' \tag{74}$$

$$\sigma_{\gamma p}(F(y^*)) = \frac{1}{\Delta F} \int_{F(y_1)}^{F(y_2)} \sigma_{\gamma p}(F)\, dF \tag{75}$$

However, while $F(y)$ is a known function, $\sigma_{\gamma p}(F)$ is to be determined experimentally. The uncertainty in y^* is about the width of a y bin. We arbitrarily take the average of $\log(y_1)$ and $\log(y_2)$ as y^*. The motivation is explained as following. If $\sigma_{\gamma p}(F)$ is a linear function of F,

$$\sigma_{\gamma p}(F) = a_0 + a_1 F \tag{76}$$

then the solution of Eq. (75) is

$$F(y^*) = \frac{(F(y_1) + F(y_2))}{2} \tag{77}$$

Since $F(y) \sim \log(y)$ for small y, Eq. (77) leads to

$$y^* = \sqrt{y_1 y_2} \tag{78}$$

or equivalently

$$W^* = \sqrt{W_1 W_2} \tag{79}$$

Eq. (76) is approximately equivalent to assuming $\sigma_{\gamma p} \approx \log(s_{\gamma p})$, which is not far from experimental data.

For $F(y)$ calculation, $Q^2_{\max}$ was calculated with the rear beampipe cut at 176°(see Eq. (28) and Figure 7(d) in Chapter II).

Start from data in Table 19, photoproduction cross section can be calculated. Results of the photoproduction cross section are summarized in Table 20, where the errors are statistical. J/ψ background (mostly from diffractive process) is not subtracted.

Table 20: Nominal cross sections

W range(GeV)	40-140	40.0-71.3	71.3-140.0
$\Delta F = F(y_2) - F(y_1)$	0.112	0.058	0.054
mean W^* (GeV)	74.8	53.4	99.9
nominal $\langle\epsilon\rangle$	0.35 ± 0.01	0.35 ± 0.01	0.35 ± 0.01
$N_{J/\psi}$	61 ± 11	28 ± 7	35 ± 8
$\sigma_{ep}(y_1, y_2)$ (nb)	6.0 ± 1.1	2.8 ± 0.7	3.4 ± 0.8
$\sigma_{\gamma p} = \frac{\sigma_{ep}}{\Delta F}$ (nb)	53 ± 10	47 ± 12	64 ± 15

7.7 Systematic errors

Systematic errors come from five sources.

1. Luminosity error. This error affects comparison of the cross sections measured by the ZEUS experiment and other experiments, but does not affect comparisons between the ZEUS results of different leptonic decay modes and different W regions.
2. $J/\psi \to e^+e^-$ branching ratio error. This error causes a little inconvenience in comparison of the cross sections measured by the ZEUS experiment and other experiments if different nominal branching ratio values are used.
3. Theoretical uncertainty. This is the error in the differential cross section $d\sigma/dx$. This error arises from incorrect modeling of the signal and background processes. For the signal process, this includes the uncertainty in the gluon distribution, t dependence of pomerons, and polarization of J/ψ. For background processes, this includes the uncertainty in the parameter n in $d\sigma/dM_x^2 \sim M_x^{-n}$ of the proton diffractive process. Theoretical uncertainty affects $\langle\epsilon\rangle$ determination.
4. Acceptance error. This is the error in local acceptance $\epsilon(x)$. This error is due to incorrect modeling of the detector and the beam conditions, e.g., discrepancy between the detector hardware and its simulation, such as calibration of the CAL energy scale and the CTD wire