CHAPTER VIII
SUMMARY AND OUTLOOK

The cross section of elastic photoproduction of J/ψ has been measured extensively over the last two decades in fixed target experiments with photon-proton center of mass energy $\sqrt{s_{\gamma p}}$ up to 28GeV. The ZEUS and H1 measurements of this process† in 1993, the first achieved in a collider experiment, extended the $\sigma_{\gamma p \to J/\psi p}$ data to $\sqrt{s_{\gamma p}} = 100$GeV region. Benefited from its superior calorimeter first level trigger, ZEUS was able to collect a much larger sample of elastic $J/\psi \to e^+e^-$ candidates as well as a large sample of elastic $J/\psi \to \mu^+\mu^-$ to determine $\sigma_{\gamma p \to J/\psi p}$ in two $\sqrt{s_{\gamma p}}$ bins and in both leptonic decay modes. The 1993 measurement of the cross section of elastic photoproduction of J/ψ in its e^+e^- decay mode has been presented in this thesis.

8.1 Summary

The cross section $\sigma_{\gamma p \to J/\psi p}$ determined by this analysis is compared with low energy data, the ZEUS preliminary results[82] and H1 result[83] in Figure 57(b) and with cross sections for inclusive photoproduction and elastic photoproduction of light vector mesons in Figure 57(a). Cross sections measured at HERA by ZEUS and H1 converge well and clearly demonstrate a fast rise of the cross section with $\sqrt{s_{\gamma p}}$, as compared with $\sqrt{s_{\gamma p}}$ dependence of elastic ρ production and inclusive photoproduction cross sections.

The fast rise of $\sigma_{\gamma p \to J/\psi p}$ has important implications. It comes down to how the photon is modeled. In Figure 57(a), the theoretical predictions of $\sigma_{\gamma p}^{total}$ and $\sigma_{\gamma p \to \rho p}$,

† The H1 measured photoproduction of J/ψ at $z > 0.95$ and estimated that the major contribution was due to diffractive photoproduction instead of elastic photoproduction.

based on the vector-meson-dominance model(VMD) of the photon and Reggeon exchange model of diffractive scattering, decribe data from low energy to HERA data quite well.[†] It indicates that inclusive photoproduction and ρ production are dominated by the nonperturbative process which up to this day can only be described by phenomenological VMD model of the photon and Regge theory of the scattering. In contrast, calculation based on the VMD like model fails to describe the J/ψ photoprodution as shown in Figure 57(a) and (b) by the dotted curve.[88] The solid curve that well describes the J/ψ data is derived from the QCD inspired model by M. Ryskin,[60] according to which photoproduction of J/ψ is to a large extent a perturbative process, where the virtual photon fluctuates into $c\bar{c}$ pair, instead of hadronizing into a J/ψ vector meson, which interacts with the proton through a color singlet of two gluons with self-interaction up to leading logarithm approximation (LLA). A recent calculation[90] using the color dipole model[91] as a solution of the generalized BFKL equation[92] gives a similar prediction. The rising cross section for J/ψ photoproduction was also predicted by J. Pumplin's subtractive quark model.[94] Common to these QCD inspired models is that the cross section is proportional to square of the gluon distribution if the scattering is in the perturbative regime. Note that it is far from obvious that the gluon distribution can be probed in elastic scattering where proton is intact and only slightly deflected. The fast rise of elastic photoproduction of J/ψ is consistent with the observed steep rise of the F_2 structure function at small x (Bjorken variable) by ZEUS and H1.[93] In the nonperturbative regime, the cross section is basically determined by the size of the hadron. A coherent description of the photon and proton is emerging from HERA measurements of $\sigma_{\gamma p\to J/\psi p}$, $\sigma_{\gamma p}^{total}$, $\sigma_{\gamma p\to\rho p}$ and F_2 structure function at small x.

[†] This conclusion itself is one of the major results obtained at HERA by ZEUS and H1.

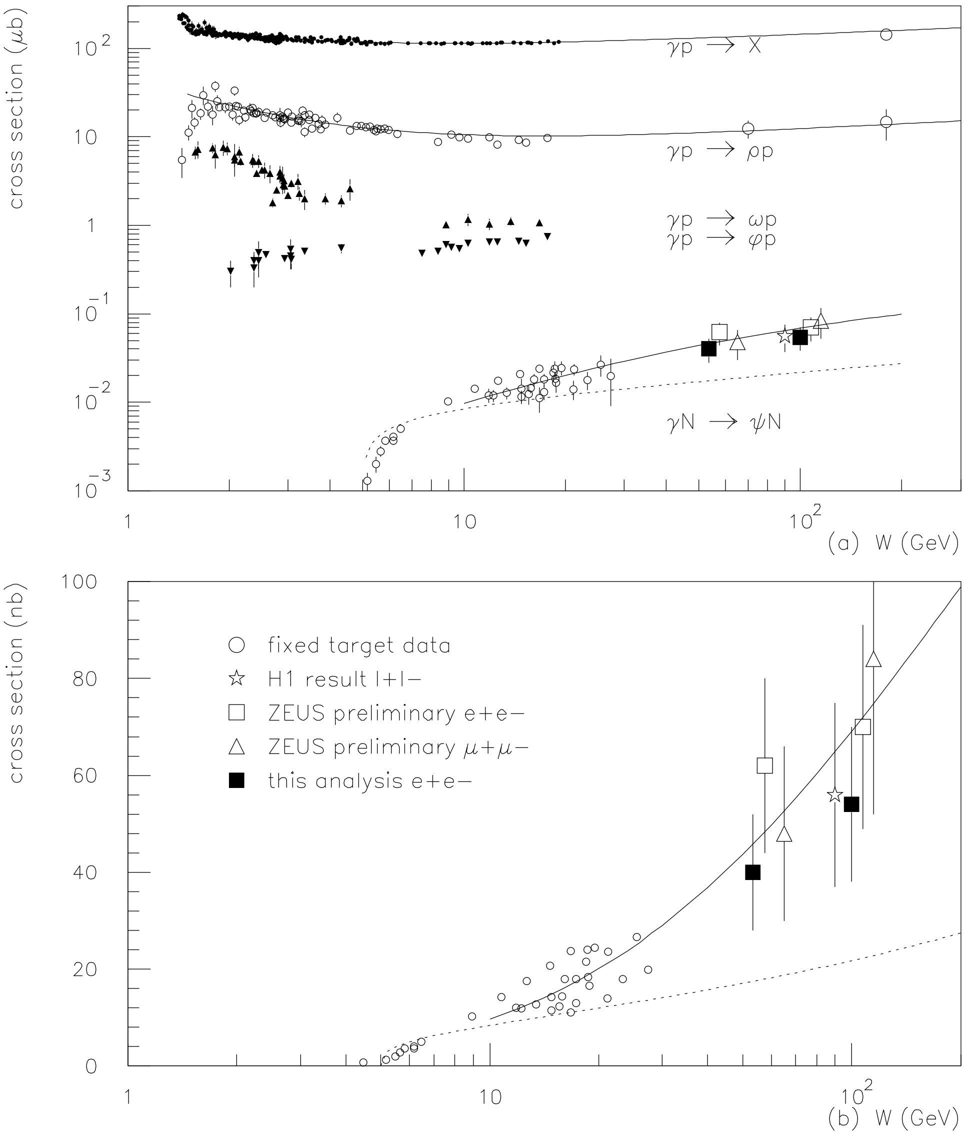

Figure 57: Comparison of photoproduction cross sections. (a) Energy dependence of the cross sections for inclusive photoproduction and elastic vector meson productions measured in fixed target experiment and at HERA. Theoretical predictions are also shown. (b) For better view, energy dependence of the cross section for elastic J/ψ photoproduction is shown in linear-log scales. Solid line is calculated from a perturbative QCD model by Ryskin.[60] Dotted line is calculated from a VMD model.[89]