2.5 Equivalent photon approximation

Photoproduction at ep collider can be described in terms of a quasi-real photon scattering with a proton. In order to measure $\sigma_{\gamma p}$ from ep collisions, the number of signal events should be normalized by γp luminosity($\mathcal{L}_{\gamma p}$), instead of ep luminosity($\mathcal{L}_{ep}$). A relationship between $\mathcal{L}_{\gamma p}$ and $\mathcal{L}_{ep}$ can be calculated.

A virtual photon has four degrees of freedom. With the constraint $m_{e'} = m_e$, rotation symmetry about ep beam axis, and Q^2 integrated out, only one degree of freedom is left for γ, usually chosen as $y(y = (s_{\gamma p} - m_p^2)/\tilde{s})$. Then ep and γp cross sections are formally related by(longitudinal term is neglected):

$$\frac{d\sigma_{ep}(y)}{dy} = \sigma_{\gamma p}(y) \frac{1}{\mathcal{L}_{ep}} \frac{d\mathcal{L}_{\gamma p}(y)}{dy} \tag{25}$$

The ratio of γp luminosity and ep luminosity is calculable and expressed by the equivalent photon approximation(EPA):[13]

$$\begin{aligned} f_{\gamma/e}(y) &= \frac{d\mathcal{L}_{\gamma p}}{\mathcal{L}_{ep} dy} \\ &= \frac{\alpha}{2\pi y}\left(\left(1 + (1-y)^2\right)\log\frac{Q^2_{\max}}{Q^2_{\min}} - 2(1-y)\left(1 - \frac{Q^2_{\min}}{Q^2_{\max}}\right)\right) \end{aligned} \tag{26}$$

where

$$\begin{aligned} Q^2_{\min} &= \left(\sqrt{\left(\frac{s + m_e^2 - m_p^2}{2\sqrt{s}}\right)^2 - m_e^2} - \sqrt{\left(\frac{s + m_e^2 - W^2}{2\sqrt{s}}\right)^2 - m_e^2}\right)^2 - \left(\frac{W^2 - m_p^2}{2\sqrt{s}}\right)^2 \\ &\approx m_e^2 \frac{y^2}{1-y} \qquad (y \ll 1) \end{aligned} \tag{27}$$

$$Q^2_{\max} = 4E_e^2(1-y)\frac{(1+\cos\theta_{\max})}{(1-\cos\theta_{\max})} \tag{28}$$

$\theta_{\max}$ is the boundary of the rear beampipe.

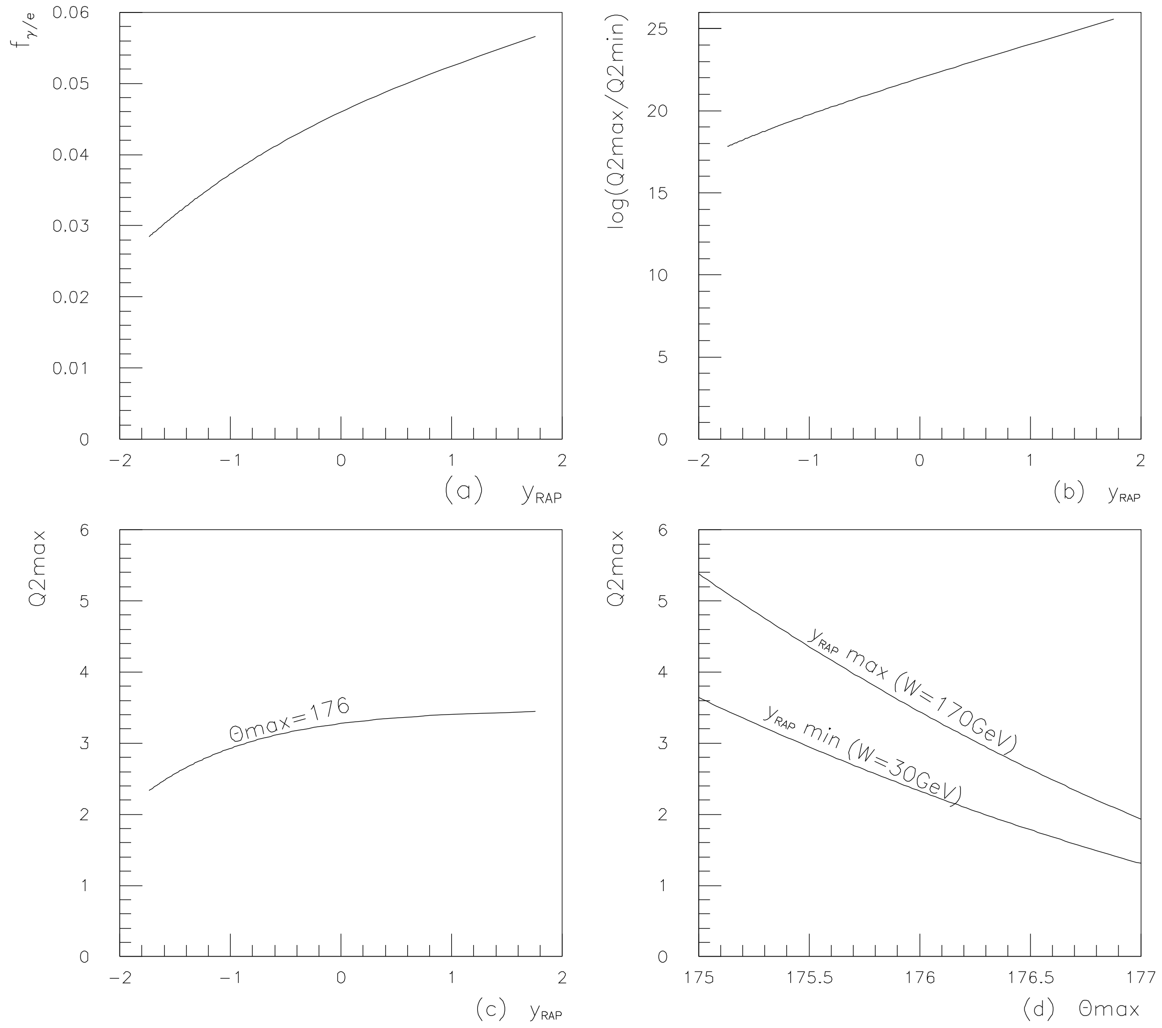

Figure 7: (a) $y_{\rm rap}$ spectrum of the equivalent photon flux. (b-d) show that $Q^2_{\rm max}$'s variation with $y_{\rm rap}$ and uncertainty of rear beampipe boundary is inconsequential.

Instead of using y, we also use $y_{\rm rap}$, rapidity of J/ψ defined in Eq. (31)(next Section), for this degree of freedom. $f_{\gamma/e}(y_{\rm rap}) = 2y f_{\gamma/e}(y)$ does not change much over the detector accessible range of $y_{\rm rap}$, as shown in Figure 7(a).