

DDVCS Kinematics & Phase Space

➤ Physics phase space

$E_{Th.} = 2m_\mu \left(1 + \frac{m_\mu}{M}\right)$ is the **required minimum** (Q' dependent otherwise)

$Q_{max}^2 = \frac{4EM}{2E + M} \left[E - 2m_\mu \left(1 + \frac{m_\mu}{M}\right) \right]$ is the **maximum achievable** (Q' dependent otherwise)

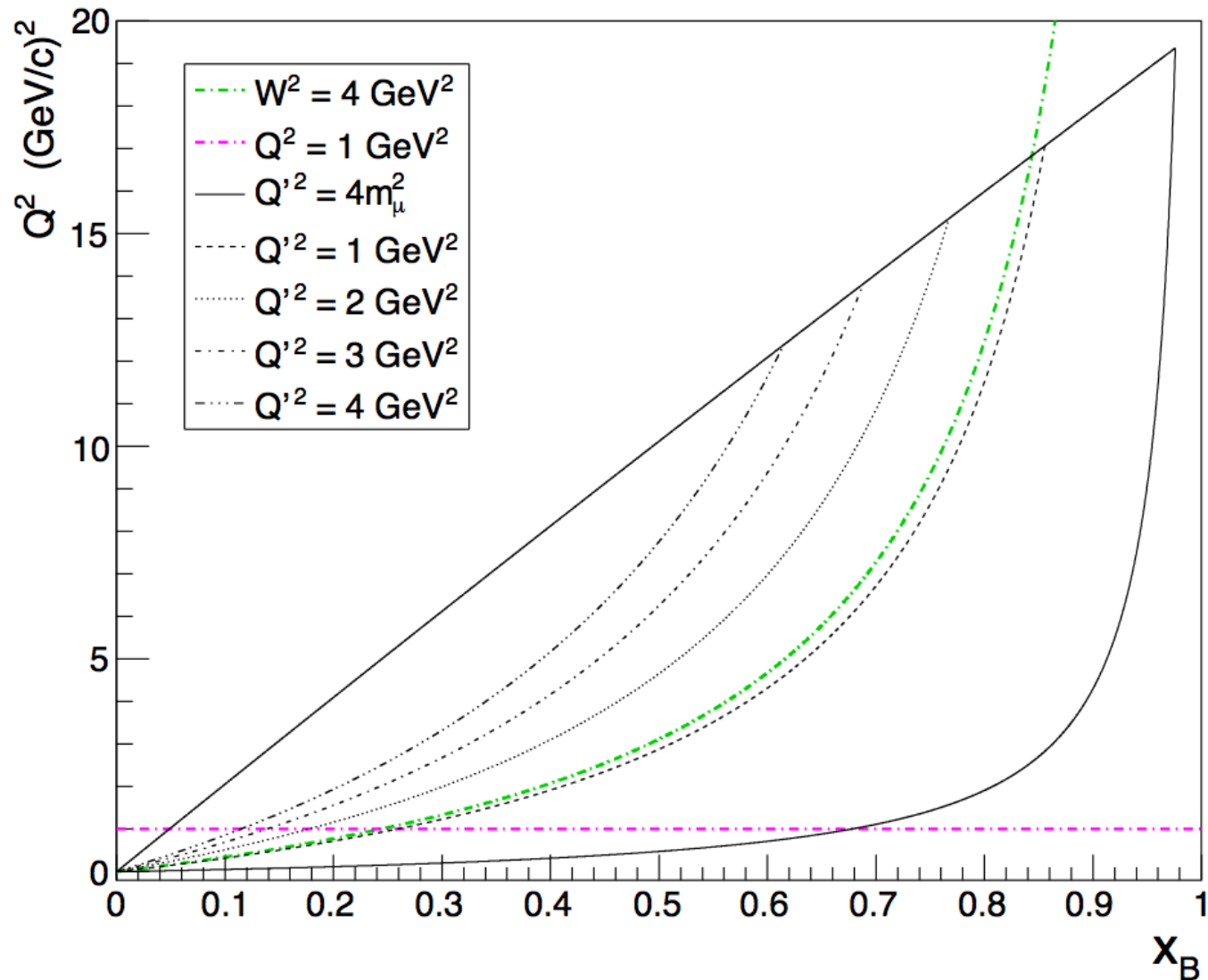
$Q'_{min} = 2m_\mu$ $Q'_{max} = M \left[\sqrt{\left(1 + \frac{2E}{M}\right) \left(1 - \frac{Q^2}{2EM}\right)} - 1 \right]$ is the **muon** phase space

$t_{\pm} = -2M \left[\frac{(\omega + M)(W^2 + M^2 - Q'^2)}{2W^2} \pm \frac{q}{2W^2} \sqrt{\left[W^2 - (Q' + M)^2 \right] \left[W^2 - (Q' - M)^2 \right]} - M \right]$

is the **nucleon** phase space where (ω, q) refers to the initial virtual photon and W is the center of mass energy of the initial γ^*N system

➤ Electron view

Phase Space of $ep \rightarrow ep\mu^+\mu^-$ at $E_0 = 11$ GeV





... corresponding limits and relations

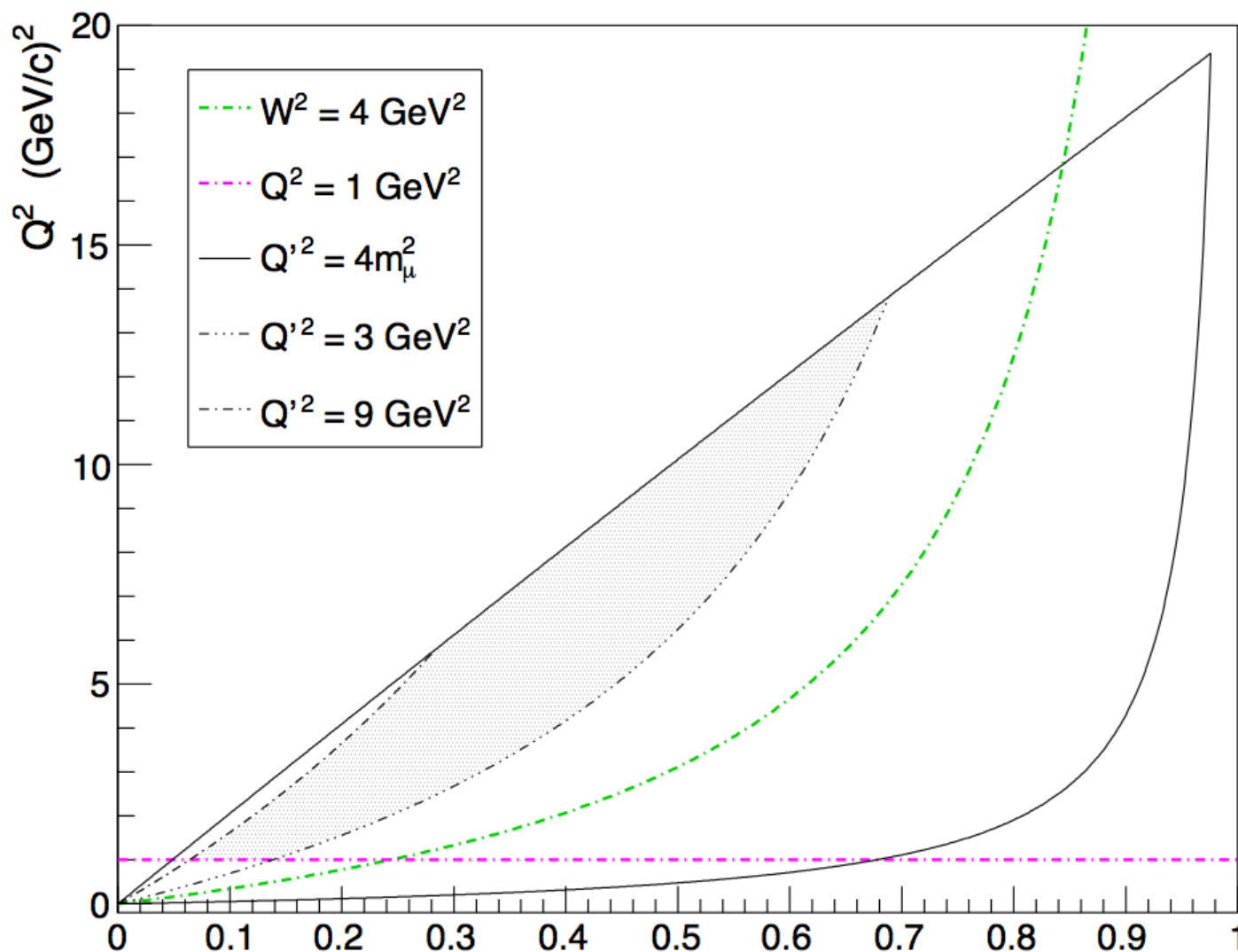
$$Q_{\min}^2(x) = \frac{Q'(Q'+2M)x}{1-x} \quad Q_{\max}^2(x) = \frac{4E^2Mx}{2E+Mx}$$

$$x_{\max} = \frac{2E}{M} \frac{2EM - Q'(Q'+2M)}{4E^2 + Q'(Q'+2M)} \quad Q_{\max}^2 = \frac{4EM}{2E+M} \left[E - Q' \left(1 + \frac{Q'}{2M} \right) \right]$$

$$Q^2(W^2, x) = \frac{(W^2 - M^2)x}{1-x}$$

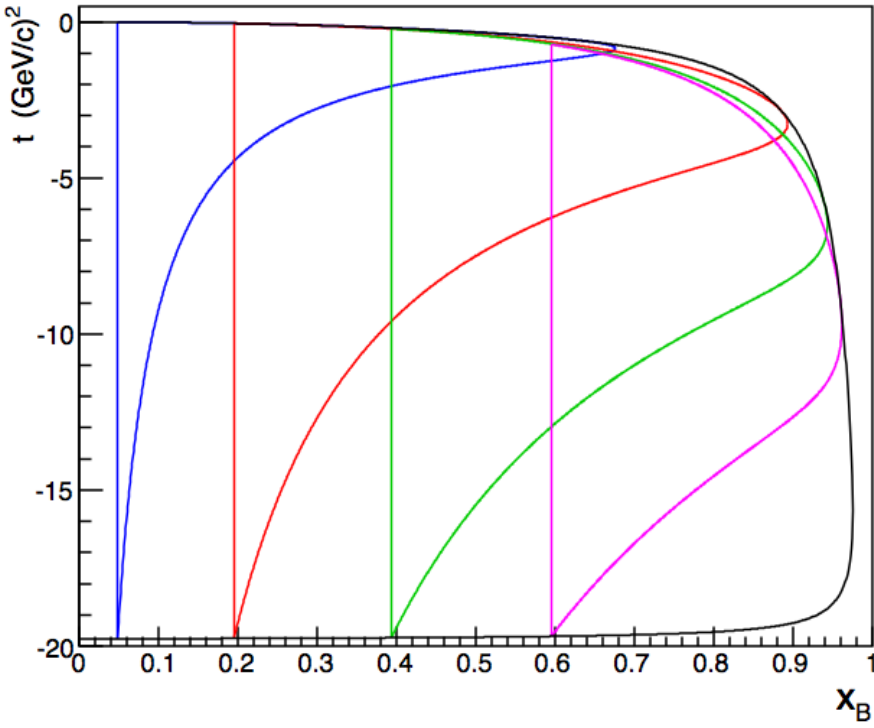


Phase Space of $ep \rightarrow ep\mu^+\mu^-$ at $E_0 = 11$ GeV

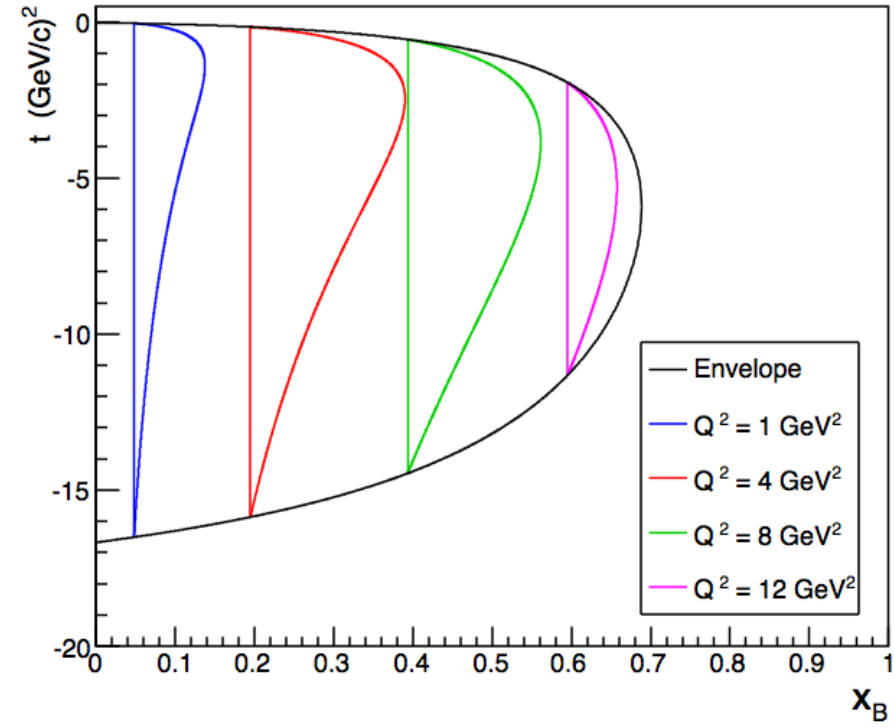


➤ Nucleon view

Phase Space of $ep \rightarrow e\mu^+\mu^-$ at $E_0 = 11$ GeV and $Q^2 = 4m_\mu^2$



Phase Space of $ep \rightarrow e\mu^+\mu^-$ at $E_0 = 11$ GeV and $Q^2 = 3$ GeV²

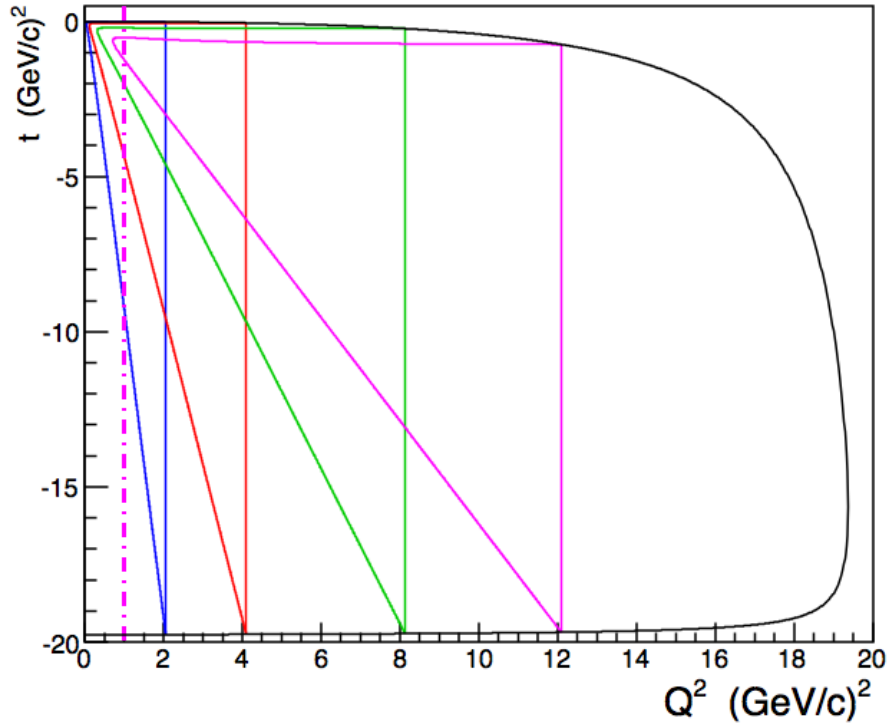


... corresponding limits and relations

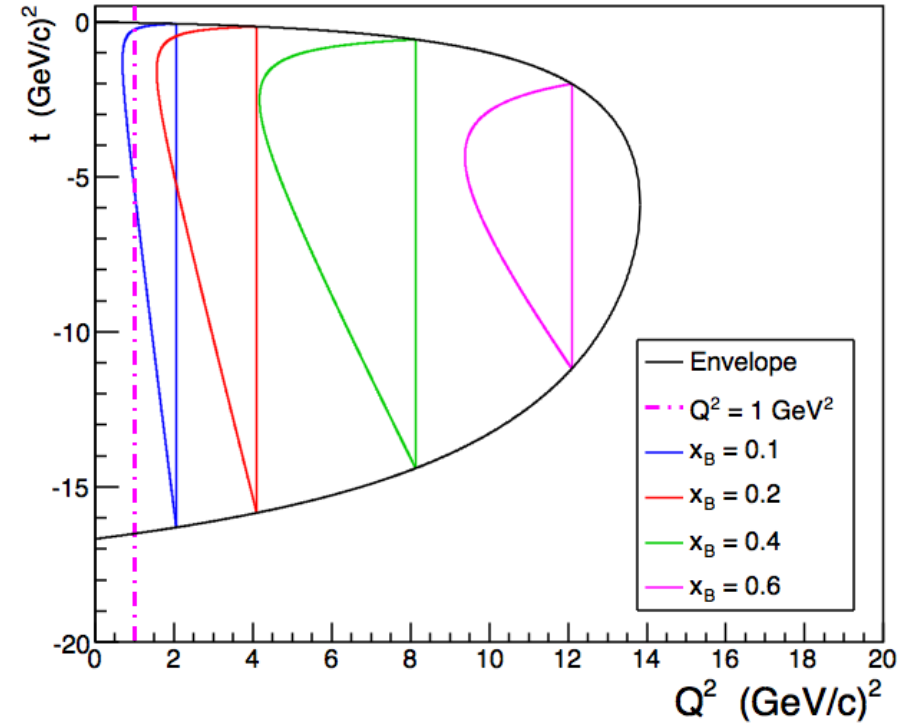
$$t_{\max} = t_+ \left(Q^2 = \frac{4E^2 Mx}{2E + Mx} \right)$$



Phase Space of $ep \rightarrow ep\mu^+\mu^-$ at $E_0 = 11$ GeV and $Q^2 = 4m_\mu^2$



Phase Space of $ep \rightarrow ep\mu^+\mu^-$ at $E_0 = 11$ GeV and $Q^2 = 3$ GeV²

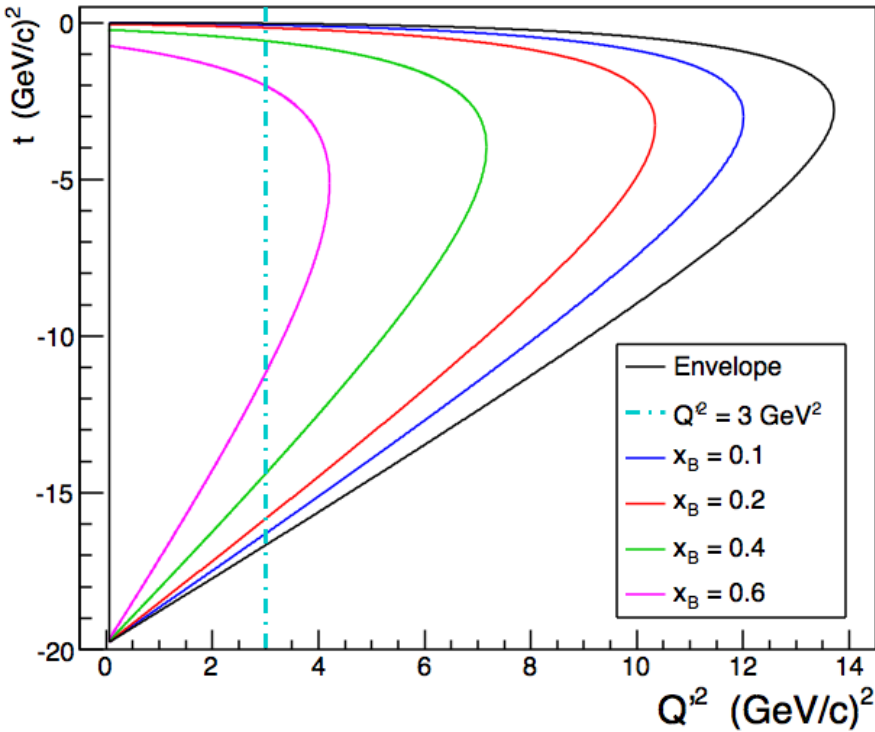


... corresponding limits and relations

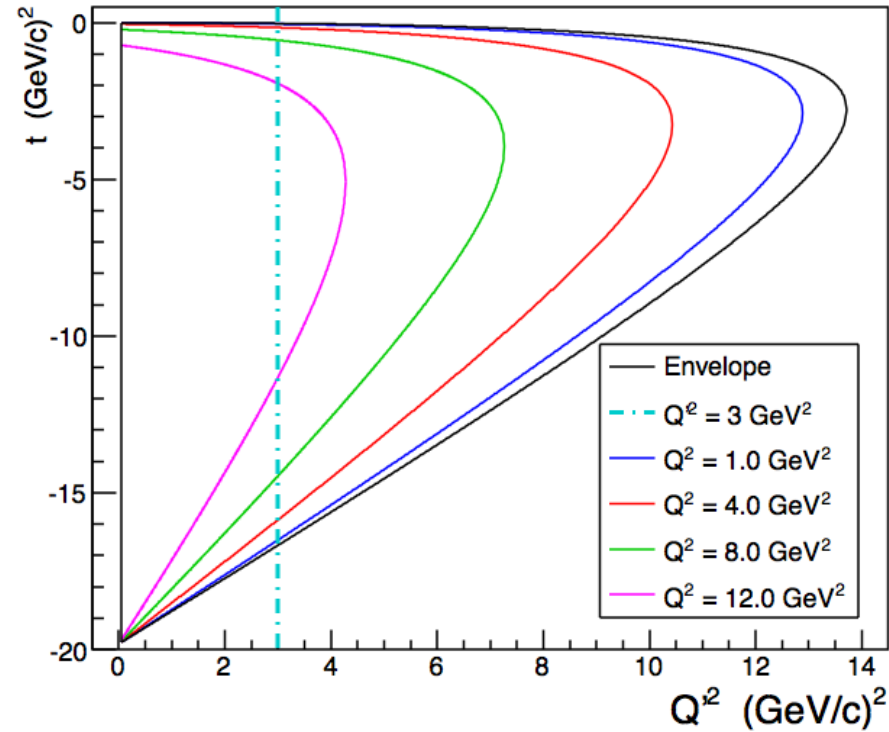
$$t_{\min} = t_- \left(x = \frac{1}{M} \frac{2EQ^2}{4E^2 - Q^2} \right) \quad t_{\max} = t_+ \left(x = \frac{1}{M} \frac{2EQ^2}{4E^2 - Q^2} \right)$$



Phase Space of $ep \rightarrow e\mu^+\mu^-$ at $E_0 = 11$ GeV



Phase Space of $ep \rightarrow e\mu^+\mu^-$ at $E_0 = 11$ GeV



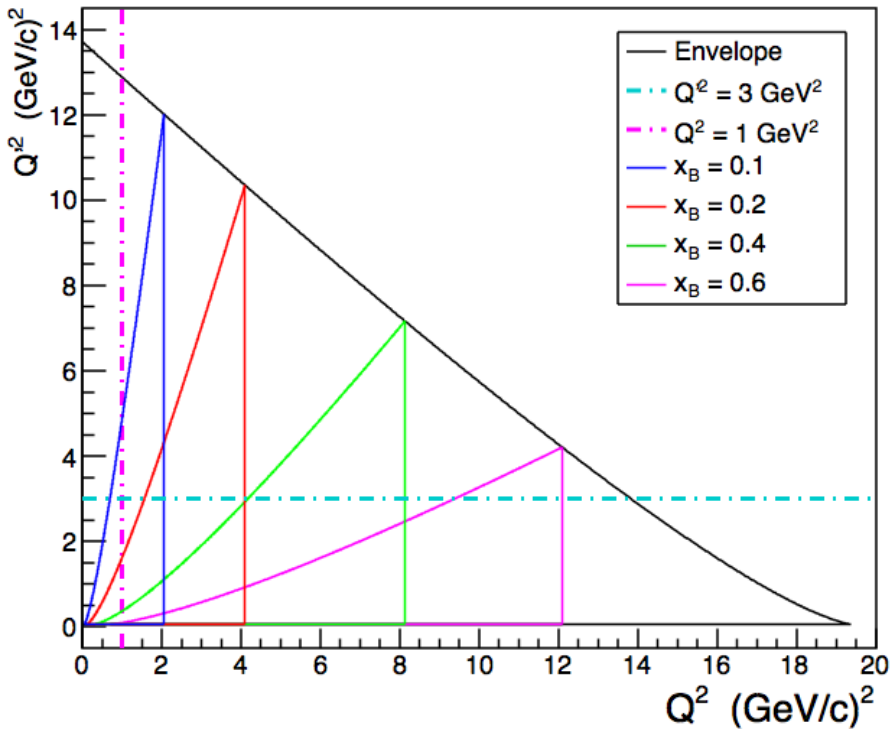
... corresponding limits and relations

$$t_{\min} = \lim [Q^2 \rightarrow 0] t_- \left(x = \frac{1}{M} \frac{2EQ^2}{4E^2 - Q^2} \right)$$

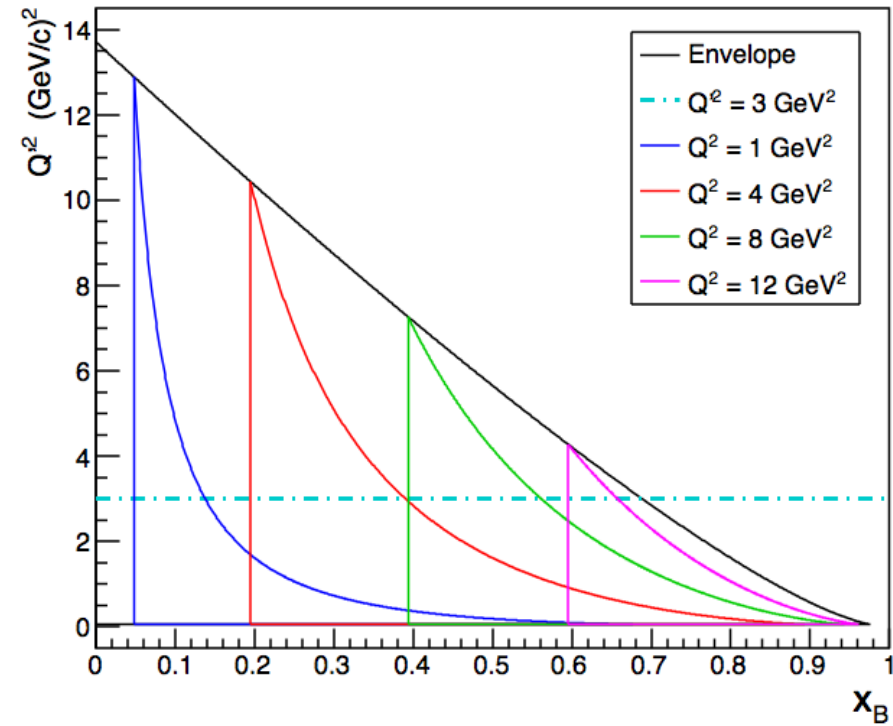
$$t_{\max} = \lim [Q^2 \rightarrow 0] t_+ \left(x = \frac{1}{M} \frac{2EQ^2}{4E^2 - Q^2} \right)$$

➤ Final virtual photon view

Phase Space of $ep \rightarrow e\mu^+\mu^-$ at $E_0 = 11$ GeV



Phase Space of $ep \rightarrow e\mu^+\mu^-$ at $E_0 = 11$ GeV



... corresponding limits and relations

$$Q'_{\min} = 2m_{\mu} \quad Q'_{\max} = M \left[\sqrt{1 + \frac{Q^2}{M^2} \frac{1-x}{x}} - 1 \right]$$