(2.19) $$P_{B,b} = \left(\frac{m_{B,T}}{\sqrt{2}} e^{y_{B,b}}, \frac{M_{B,T}}{\sqrt{2}} e^{-y_{B,b}}, -z_N \vec{q}_T \right) = \left(P_B^+, P_B^-, P_{BT} \right)$$

$$k_i^b = \left(\frac{Q}{\hat{x}_N \sqrt{2}}, \frac{\hat{x}_N (k_i^2 + k_{iT}^2)}{\sqrt{2} Q}, k_{iT} \right) = \left(k_i^+, k_i^-, k_{iT} \right)$$

$$k_f^b = \left(\frac{k_{fT}^2 + k_f^2}{\sqrt{2} \hat{z}_N Q}, \frac{\hat{z}_N Q}{\sqrt{2}}, k_{fT} \right) = \left(k_f^+, k_f^-, k_{fT} \right)$$

$$R_1 = \frac{P_B \cdot k_f}{P_B \cdot k_i} = \frac{①}{②}$$

$m_{B,T} = \sqrt{m_B^2 + P_{BT}^2}$ (2.19 ↓)

$k_{fT} = \left(\delta k_T \cos\phi - \hat{z}_N q_T, \delta k_T \sin\phi \right)$

$k_{iT} = \left(k_{iT} \cos\phi_i, k_{iT} \sin\phi_i \right)$

① $$P_B \cdot k_f = P_B^+ k_f^- + P_B^- k_f^+ - P_{BT} k_{fT}$$

$$= \left(\frac{\sqrt{m_B^2 + z_N^2 q_T^2}}{\sqrt{2}} e^{y_{B,b}} \right) \left(\frac{\hat{z}_N Q}{\sqrt{2}} \right) + \left(\frac{\sqrt{m_B^2 + z_N^2 q_T^2}}{\sqrt{2}} e^{-y_{B,b}} \right) \left(\frac{k_{fT}^2 + k_f^2}{\sqrt{2} \hat{z}_N Q} \right)$$

$$- \left(-z_N q_T \right) \left(-\hat{z}_N q_T + \delta k_T \cos\phi_f \right)$$

From Sterlings R_1 derivation eqn (13)

$$k_{fT}^2 = \delta k_T^2 - 2 \delta k_T \cos\phi \, \hat{z}_N q_T + \hat{z}_N q_T^2$$

② $$P_B \cdot k_i = P_B^+ k_i^- + P_B^- k_i^+ - P_{BT} k_{iT}$$

$$= \left(\frac{\sqrt{m_B^2 + z_N^2 q_T^2}}{\sqrt{2}} e^{y_{B,b}} \right) \left(\frac{\hat{x}_N (k_i^2 + k_{iT}^2)}{\sqrt{2} Q} \right) + \left(\frac{\sqrt{m_B^2 + z_N^2 q_T^2}}{\sqrt{2}} e^{-y_{B,b}} \right) \left(\frac{Q}{\hat{x}_N \sqrt{2}} \right)$$

$$- \left(-z_N q_T \right) \left(k_{iT} \cos\phi_i \right)$$

$$k_{iT}^2 = k_{iT}^2 \cos^2\phi_i + k_{iT}^2 \sin^2\phi_i = k_{iT}^2$$

(4.2) $$\hat{x}_N = \frac{x_N}{\text{zeta}}, \quad \hat{z}_N = \frac{z_N}{x_i}$$