$$ct' = \gamma\,(ct + \beta x) \qquad ct' \pm x' = \gamma\,[ct + \beta x \pm (x + \beta ct)] \qquad (1.)$$

$$x' = \gamma\,(x + \beta ct) \qquad = \gamma\,[(1 \pm \beta)\,ct \pm (1 \pm \beta)\,x]$$

$$x^{\pm\prime} = \gamma(1 \pm \beta)\,x^{\pm} \qquad = \gamma\,(1 \pm \beta)\,[ct \pm x]$$

$$x^{+\prime} = \gamma\,(1+\beta)\,x^{+} \qquad x^{+\prime}x^{-\prime} = x^{+}x^{-}$$

$$x^{-\prime} = \gamma\,(1-\beta)\,x^{-}$$

$$d^4k\,\delta(k^2 - m^2)\,\theta(k^0) = dk^0\,d^3k\,\delta(k^{0\,2} - \vec{k}^{\,2})\,\theta(k^0) = \frac{d^3k}{2|\vec{k}|} = \frac{1}{2}\,dk^-\,dk^+\,d^2k^\perp\,\delta(k^+k^- - k^{\perp 2})\,\theta(k^+)$$

$$= \frac{1}{2k^+}\,dk^+\,d^2k^\perp$$

$\uparrow$ 0 dla gluonów

$$\int[123] = \int \frac{dk_1^+ \, dk_2^+ \, dk_3^+}{2k_1^+ \; 2k_2^+ \; 2k_3^+ \; (2\pi)^3 \, (2\pi)^3 \, (2\pi)^3}$$

$\hat{H}_{A^3}$ zawiera człon

$$\int[123] \; ig \partial_\alpha A^a_\beta \left[A^\alpha, A^\beta\right]^a$$

(2.)

$$(2\pi\hbar)^3 = h^3$$

$$\hbar = 1$$

$\hat{H}_{A^3}$ zawiera $\displaystyle\int \frac{dk_1^+ \, dk_2^+ \, dk_3^+}{2k_1^+ \; 2k_2^+ \; 2k_3^+} \; 2(\pi)^3 \delta^3(k_1 + k_2 + k_3) \; a_1^\dagger a_2^\dagger a_3^\dagger$, ale tego wyrazu nie ma w $\hat{P}^-$.

$$k^+ = k^0 + k^3 = \sqrt{k^{1\,2} + k^{2\,2} + k^{3\,2}} + k^3 \geq 0$$

$$k_1^+ + k_2^+ + k_3^+ > 0 \qquad \delta(k_1^+ + k_2^+ + k_3^+) = 0$$

③

$$g_t = g_0 + g_0^3 \frac{1}{2\cdot 48\pi^2} 11 N_c \ln\frac{s^2}{s_0^2} = g_0 + g_0^3 \frac{11N_c}{96\pi^2} \ln\frac{s^2}{s_0^2}$$

$$\frac{\partial}{\partial s^2} g_t = \frac{g_0^3}{s^2} \frac{11N_c}{96\pi^2} \qquad ' = \frac{d}{dx}, \quad x = s^2$$

$$g_t^3 = \left(g_0 + g_0^3 \frac{1}{96\pi^2} 11N_c \ln\frac{s^2}{s_0^2}\right)^3 = g_0^3 + O(g_0^4), \quad g = g_0 + O(g^3)$$

$$\frac{g'}{g^3} = \frac{1}{x} \frac{11N_c}{96\pi^2}, \quad \frac{1}{2}\left(-\frac{1}{g_t^2} + \frac{1}{g_{t_0}^2}\right) = \frac{11N_c}{96\pi^2} \ln\frac{s^2}{s_0^2} \qquad g_t^2 = \frac{g_{t_0}^2 = g_0^2}{1 - g_0^2 \frac{11N_c}{48\pi^2} \ln\frac{s^2}{s_0^2}}$$

$s \to 0 < s_0$

$$g_t \sim \frac{1}{\frac{11N_c}{48\pi^2} \ln\frac{s_0^2}{s^2}} \xrightarrow[s\to 0]{} 0$$

$\boxed{AF}$

FIN