A light particle loop-effect on heavy particle propagator

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Outline

Model

- Lagrangian

$$\begin{aligned}\mathcal{L} =& \frac{1}{2}\partial_\mu\phi\partial^\mu\phi - \frac{m_\phi^2}{2}\phi^2 - \frac{\Lambda_3}{6}\phi^3 - \frac{\lambda_{4\phi}}{24}\phi^4 \\ &+ \partial_\mu\chi^\dagger\partial^\mu\chi - m_\chi^2\chi^\dagger\chi - \frac{\lambda_{4\chi}}{4}(\chi^\dagger\chi)^2 \\ &+ i\bar{\psi}_1\partial\!\!\!/\psi_1 + i\bar{\psi}_2\partial\!\!\!/\psi_2 - m_{\psi_1}\bar{\psi}_1\psi_1 - m_{\psi_2}\bar{\psi}_2\psi_2 \\ &- T_1\phi\chi^\dagger\chi - \frac{\tau_2}{2}\phi^2\chi^\dagger\chi - Y_1\phi\bar{\psi}_1\psi_1 - Y_2\phi\bar{\psi}_2\psi_2.\end{aligned}$$

  (sign convention: $+,-,-,-$)
- No operators with higher than 4 mass dimension $\Longrightarrow$ renormalisable $\Longrightarrow$ No hard limit on parameters.

- Dimensionless parametrisation

$$\begin{aligned}\mathcal{L}_{\text{scalar}} =& \frac{1}{2}\partial_\mu\phi\partial^\mu\phi - \frac{m_\phi^2}{2}\phi^2 - \frac{\lambda_3 m_\phi}{6}\phi^3 - \frac{\lambda_{4\phi}}{24}\phi^4 \\ &+ \partial_\mu\chi^\dagger\partial^\mu\chi - c^2 m_\phi^2\chi^\dagger\chi - \frac{\lambda_{4\chi}}{4}(\chi^\dagger\chi)^2 \\ &- \tau_1 m_\phi\phi\chi^\dagger\chi - \frac{\tau_2}{2}\phi^2\chi^\dagger\chi.\end{aligned}$$

- To make perturbative expansion work:

$$\lambda_3, \lambda_{4\phi}, \lambda_{4\chi}, \tau_2 \ll 1, \quad \tau_1 \ll c.$$

Resonance Structure in One-Loop Order

One-loop diagrams

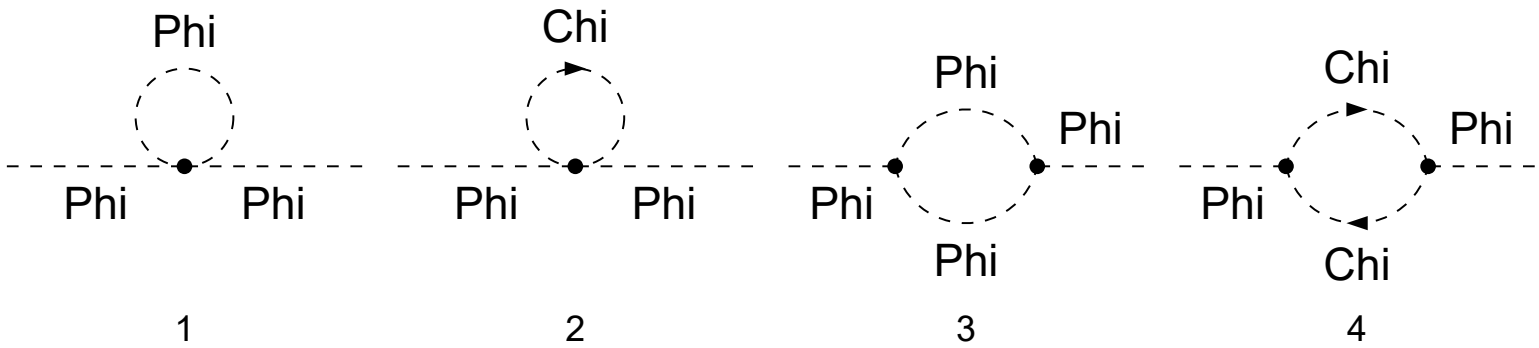
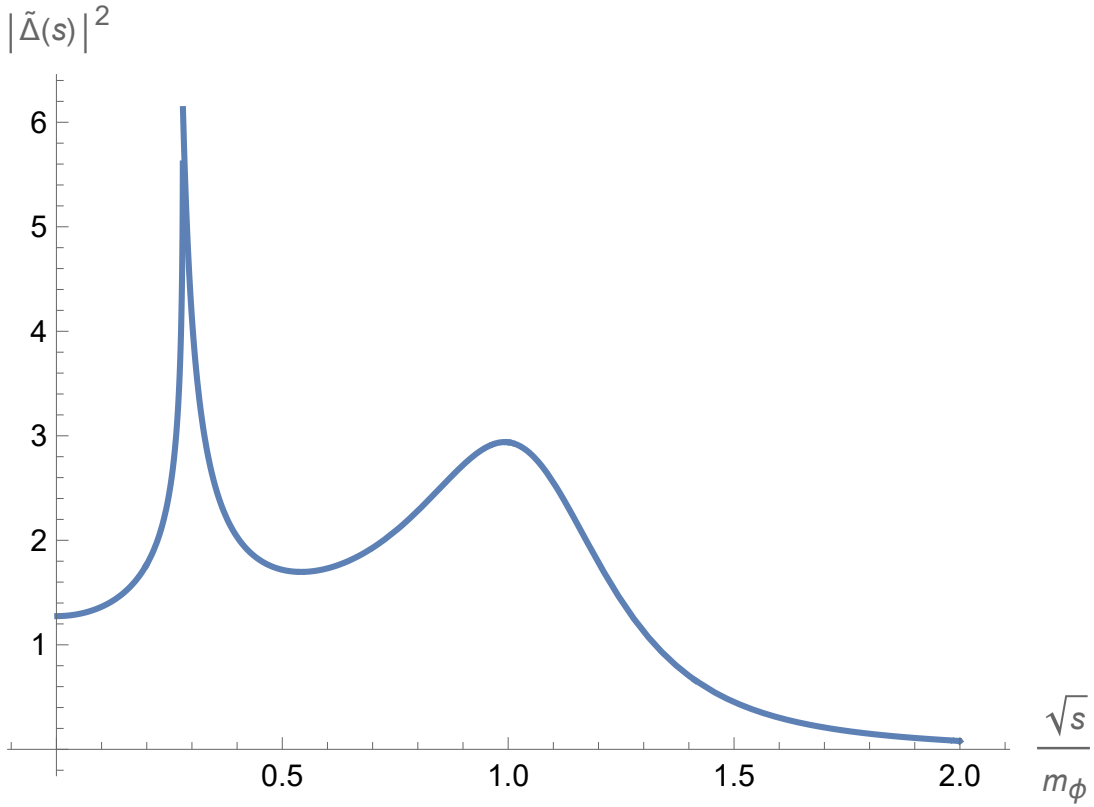


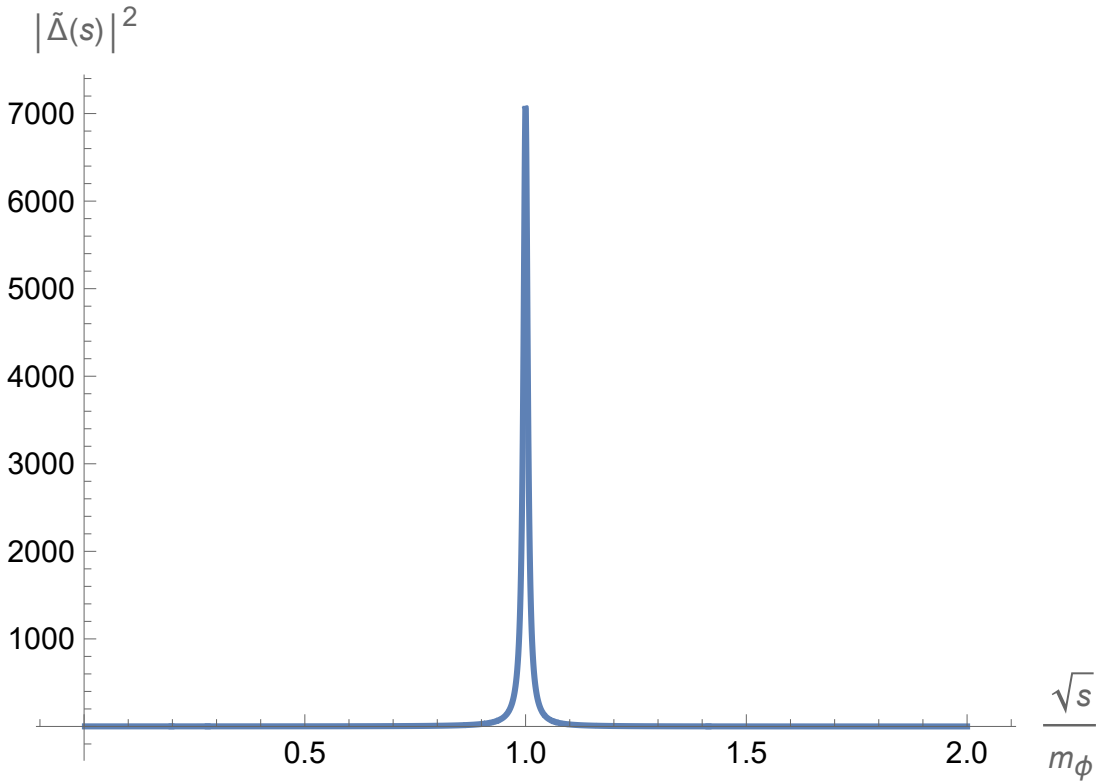
Diagram 1 and 2 have no effects in one-loop order.

$|\tilde{\mathbf{\Delta}}(s)|^2$ in terms of s:



Parameters: $c = 0.14$, $\lambda_3 = 0.15$, $\tau_1 = 0.13$.
(Somewhat unrealistic in the sense that $\tau_1/c \approx 1$.)

More natural parameter settings:



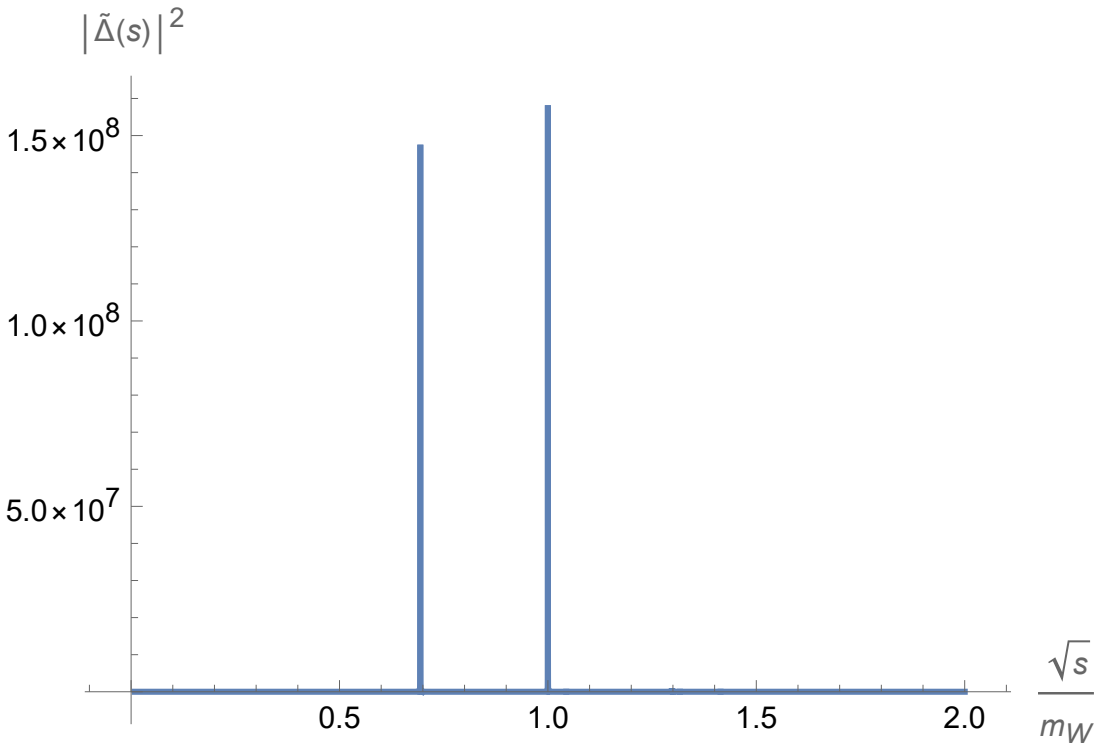
Parameters: $c = 0.14$, $\lambda_3 = 0.15$, $\tau_1 = 0.02$.
It appears to follow the Breit-Wigner distribution again.
(The shape is highly dependent of τ_1.)

Series expansion of $\Pi(s)$:

$$\pi^2 m_\phi^2 \left[\frac{5\sqrt{3}\pi - 27}{18}\lambda_3^2 - 3\tau_1^2 - \frac{\tau_1^2(1-6c^2)}{\sqrt{1-4c^2}} \log\left(\frac{1-\sqrt{1-4c^2}}{2c^2} - 1 \right) \right]$$
$$+ \pi^2 s \left[\frac{21 - 4\sqrt{3}\pi}{36}\lambda_3^2 + \frac{\tau_1^2}{6}(6 + c^{-2}) - \frac{2c^2\tau_1^2}{\sqrt{1-4c^2}} \log\left(\frac{1-\sqrt{1-4c^2}}{2c^2} - 1 \right) \right]$$
$$+ \frac{\pi^2 s^2}{120 m_\phi^2}\left(\lambda_3^2 + \frac{2\tau_1^2}{c^4} \right) + \frac{\pi^2 s^3}{840 m_\phi^4}\left(\lambda_3^2 + \frac{2\tau_1^2}{c^6} \right) + O(s^4).$$

We have $c^2 m_\phi^2 = m_\chi^2$-suppression.

Alternative Model: Weak with Light Higgs



Parameters: $m_H/m_W = 0.3$, $g_W = 0.6$.