DECAYS IN QFT - WS 2012/2013

Sheet 10 **25/1/2013**

Exercise 1: Three-body decay with intermediate virtual state (14 points = 3 + 4 + 4 + 3)

Consider the Lagrangian

$$\mathcal{L} = \mathcal{L}_0 + \mathcal{L}_1 \tag{1}$$

where

$$\mathcal{L}_0 = \frac{1}{2}\left[(\partial_\mu P)^2 - M_P^2 P^2\right] + \frac{1}{2}\left[(\partial_\mu S)^2 - M_S^2 S^2\right] + \sum_{i=1,2,3} \frac{1}{2}\left[(\partial_\mu \varphi_i)^2 - m_i^2 \varphi_i^2\right] , \tag{2}$$

$$\mathcal{L}_1 = \alpha P S \varphi_3 + g S \varphi_1 \varphi_2. \tag{3}$$

For simplicity we set $m_3 = 0$.

1. If $g = 0$ the particle S is stable. Evaluate the two-body decay width $\Gamma_{P \to S\varphi_3}$.
2. If $\alpha = 0$ only the decay $S \to \varphi_1\varphi_2$ takes place. Determine $\Gamma_{S\to\varphi_1\varphi_2}$. The spectral function of S in the relativistic Breit-Wigner approximation is given by

$$d_S(x) = N \frac{\theta(x - m_1 - m_2)}{\left(x^2 - M_S^2\right)^2 + \left(M_S \Gamma_{S\to\varphi_1\varphi_2.}\right)^2}. \tag{4}$$

   Which is the equation which determines the normalization constant N?
3. For $\alpha \neq 0$, $g \neq 0$ the three-body decay takes place. Write down the expression of $\Gamma_{P\to\varphi_1\varphi_2\varphi_3}$ using the results of points 3.1 and 3.2. The final solution should be expressed in the integral form

$$\Gamma_{P\to\varphi_1\varphi_2\varphi_3} = \int_a^b F(x)dx \tag{5}$$

   where $x = m_{12}$ and $F(x)$ is non-vanishing for $a < x < b$. Determine a, b, and $F(x)$.
4. Discuss the limit in which g is very small.

Exercise 2: Virtual particle in the 1-3 channel (6 points)

Consider a three-body decay $P \to \varphi_1\varphi_2\varphi_3$ described by the Lagrangian

$$\mathcal{L} = \mathcal{L}_0 + \mathcal{L}_1 \tag{6}$$

with

$$\mathcal{L}_1 = \alpha P S \varphi_2 + g S \varphi_1 \varphi_3. \tag{7}$$

How do we 'see' the existence of the particle S in the usual Dalitz plot as function of the two variables m_{12}^2 and m_{23}^2?