Radially excited vector mesons: a Bethe-Salpeter-Schwinger-Dyson approach

Fredy F. Mojica[1] Carlos E.Vera[2]
Eduardo Rojas[3] Bruno El-Bennich[4]

Universidad del Tolima

[1]fremo22@gmail.com, [2]cvera@ut.edu.co, [3]eduro4000@gmail.com,
[4]bruno.bennich@cruzeirodosul.edu.br

December 2, 2016

Index

Motivation

1. The value of masses of vector resonances can provide information about the interaction vertex between quarks and gluons.
2. Currently, there are low energy experiments about spectroscopy.*

Motivation

1. The value of masses of vector resonances can provide information about the interaction vertex between quarks and gluons.
2. Currently, there are low energy experiments about spectroscopy.*

Motivation

*

- Jefferson Lab [1]
- Japan Proton Accelerator Research Complex [2]
- The PANDA Experiment [3]
- The Mainz Microtron [4]
- COMPASS COmmon Muon Proton Apparatus for Structure and Spectrocopy [5]

---

[1] https://www.jlab.org/
[2] https://www.j-parc.jp/index-e.html
[3] http://www.oeaw.ac.at/smi/research/hadron-physics/b-factory-at-kek-and-panda-at-fair/the-panda-experiment/
[4] http://www.kph.uni-mainz.de/eng/108.php
[5] http://wwwcompass.cern.ch/compass/

Schwinger - Dyson equations

Schwinger-Dyson equations (SDE) are a set of non-perturbative coupled integral equations that relate different Green functions and which allow to study the MDG.

$$S_F^{-1}(p) = S_F^{0\,-1}(p) - 4\pi i\alpha \int \frac{d^d k}{(2\pi)^d}\gamma^\mu S_F(k)\gamma^\nu \Delta^0_{\mu\nu}(q)\ , \qquad (1)$$

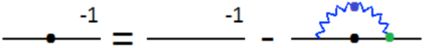

Figure: Schwinger - Dyson diagram for the inverse fermion propagator.

Bethe - Salpeter equations

It's an integral equation for the wave function of quark-antiquark ground state, it means, describes the interaction between two particles.

$$\left(\frac{1}{2}\gamma^{\mu}P_{\mu}+\gamma^{\mu}p_{\mu}-m\right)_{\alpha\alpha'}\left(\frac{1}{2}\gamma^{\nu}P_{\nu}-\gamma^{\nu}p_{\nu}+m\right)_{\beta'\beta}\chi^{ab}_{\alpha'\beta'}(P,p)$$
$$=-\int d^4p'\bar{K}^{ab}_{\alpha\beta;\eta'\xi'}(p,p';P)\chi^{ab}_{\eta'\xi'}(p',P), \tag{2}$$

for the amplitude of the pion,

$$\Gamma^{ab}_{\alpha\beta}=\left(S^{-1}(p_{+})\chi^{ab}(P,p)S^{-1}(p_{-})\right)_{\alpha\beta} \tag{3}$$

Bethe - Salpeter equations

where $p_{\pm} = p \pm \frac{1}{2}P$ and $S^{-1}(k) = \not{k} - m$. Deleting indexes and in abbreviated form use we can write

$$\chi(P,p) = S(p_+)\Gamma^{ab}(P,p)S(p_-). \tag{4}$$

Γ is known as the Bethe-Salpeter amplitude:

$$\lambda(P^2)\Gamma^{ab}(P,p) = \int d^4p' \bar{K}^{ab}(p,p';P)S(p'_+)\Gamma^{ab}(P,p')S(p'_-), \tag{5}$$

Taking into account that,

$$\Gamma^V_\mu(q;P) = \sum_{i=1}^{8} T^i_\mu(q;P)F_i(q^2,q.P;P^2) \tag{6}$$

Tensorial base for the amplitude of Bethe-Salpeter[a]

$$T^1_\mu(q;P) = \gamma^T_\mu,$$
$$T^2_\mu(q;P) = \frac{6}{q^2\sqrt{5}}[q^T_\mu(\gamma^T.q) - \frac{1}{3}\gamma^T_\mu(q^T)^2],$$
$$T^3_\mu(q;P) = \frac{2}{qP}[q^T_\mu(\gamma.P)],$$
$$T^4_\mu(q;P) = \frac{i\sqrt{2}}{qP}[\gamma^T_\mu(\gamma.P)(\gamma^T.q) + q^T_\mu(\gamma.P)],$$
$$T^5_\mu(q;P) = \frac{2}{q}q^T_\mu,$$
$$T^6_\mu(q;P) = \frac{i}{q\sqrt{2}}[\gamma^T_\mu(\gamma^T.q) - (\gamma^T.q)\gamma^T_\mu],$$
$$T^7_\mu(q;P) = \frac{i\sqrt{3}}{P\sqrt{5}}(1-\cos^2\theta)[\gamma^T_\mu(\gamma.P) - (\gamma.P)\gamma^T_\mu] - \frac{1}{\sqrt{2}}T^8_\mu(q;P),$$

$$T^8_\mu(q;P) = \frac{i2\sqrt{6}}{q^2P\sqrt{5}}q^T_\mu(\gamma^T.q)(\gamma.P),$$
$$V^T_\mu = V_\mu - \frac{P_\mu(P.V)}{P^2},$$
$$\frac{1}{12}Tr_D[T^i_\mu(q;P)T^j_\mu(q;P)] = f_i(\cos\theta)\delta_{ij},$$
$$f_1(z) = 1$$
$$f_i(z) = \frac{4}{3}(1-z^2); i = 3,4,5,6$$
$$f_i(z) = \frac{8}{5}(1-z^2)^2; i = 2,7,8$$

[a] arXiv:nucl-th/9905056

Qin-Chang-Liu-Roberts-Wilson interaction model

$$D^{ab}_{\mu\nu}(q) = \delta^{ab}\left(g_{\mu\nu} - \frac{k_\mu k_\nu}{q^2}\right)\frac{\Delta(q^2)}{q^2} \tag{7}$$

$$Z_1 g^2 D_{\mu\nu}(q)\Gamma_\mu(k,p) \longrightarrow Z_2^2 \frac{\mathcal{G}(q^2)}{q^2} T_{\mu\nu}(q)\gamma_\mu \tag{8}$$

$$\frac{\mathcal{G}(q^2)}{q^2} = \frac{8\pi^2}{\omega^4} De^{\left(-\frac{q^2}{\omega^2}\right)} + \frac{8\pi^2\gamma_m \mathcal{F}(q^2)}{ln\left[\tau + \left(1 + q^2/\Lambda^2_{QCD}\right)^2\right]} \tag{9}$$

where $\gamma_m = 12/(33 - 2N_f)$, $N_f = 4$, $\Lambda^2_{QCD} = 0.234GeV$, $\tau = e^2 - 1$ y
$\mathcal{F}(q^2) = \left[1 - e^{(-q^2/4m_t^4)}\right]/q^2, m_t = 0.5GeV.$ [6]

[6] arXiv:1407.3598

Results Model 1

$\omega = 0.4$ y $D = (0.8)^3/\omega$

MESON	$m_v(Gev)$	$f_v(Gev)$	Exp. m_v	Exp. f_v
$\rho_{(770)}$	0.7419	0.2314	0.770	0.2203
$\phi_{(1020)}$	1.0868	0.2994	1.0194	0.2276
$\phi_{(1680)}$	1.2955	0.1037	1.6593	
J/ψ	3.1144	0.4349	3.0969	0.4162
$\psi_{(2s)}$	3.3931	0.2186	3.6891	0.2962

Results Model 2

$\omega = 0.6$ y $D = (1.1)^3/\omega$

MESON	$m_v(Gev)$	$f_v(Gev)$	Exp. m_v	Exp. f_v
$\phi_{(1020)}$	1.3456	0.3926	1.0194	0.2276
$\phi_{(1680)}$	1.6593	0.1377	1.6593	
J/ψ	3.3834	0.5697	3.0969	0.4162
$\psi_{(2s)}$	3.8153	0.1977	3.6891	0.2962

Conclutions

- The program calculate values very close to the experimental value of the masse and decay constant of vector mesons.
- We can perform a prediction of the masses and decay constants of the resonances of vector mesons that have not yet been measured in the experiment.
- The next step in our calculation is to estimate the optimal value for the parameters ω and D, in order to reproduce simultaneously the experimental values of the masses and decay constants of the vector mesons.

!Thanks for your attention!