Heavy-Light Mesons in a Contact Interaction

Marco Antonio Bedolla, Elena Santopinto

INFN Sezione di Genova

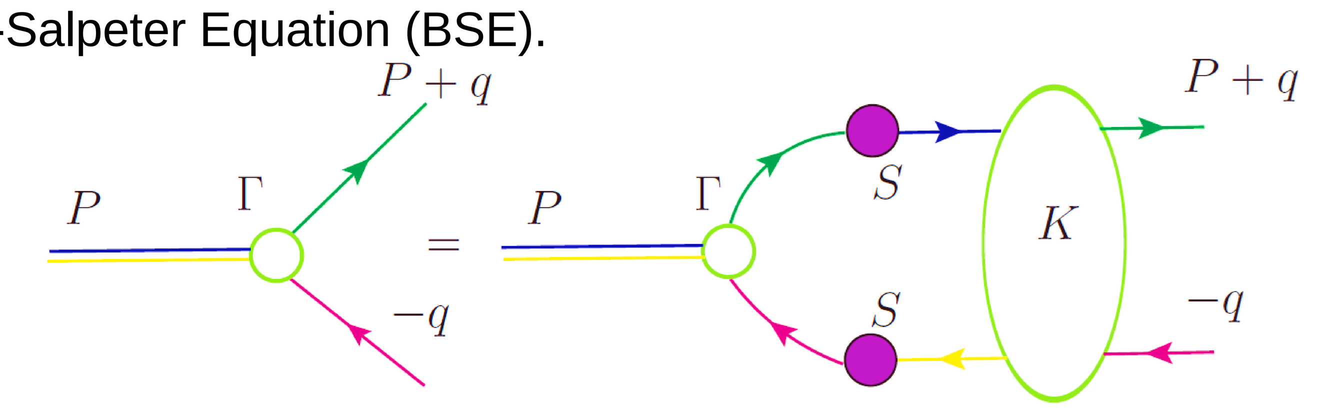
vía Dodecaneso 33, 16146 Genova, Italia.

Abstract

We present a unified formalism for the analysis of mesons provided by a symmetry-preserving Schwinger-Dyson-Bethe-Salpeter-equation (SDBSE) treatment of a vector-vector contact interaction. The contact interaction (CI) model provides a simple-to-implement alternative to perform exploratory studies of QCD within the SDBSE framework. Within the limitations of this model, we calculate observables that can be compared and contrasted with experimental data, lattice QCD and other SDBSE calculations involving sophisticated interaction kernels.

The SDBSE Formalism

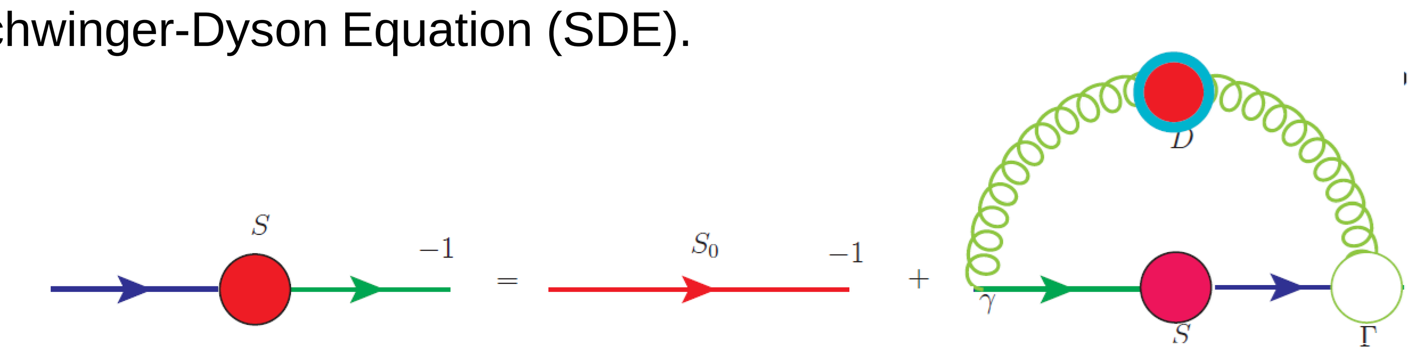
A meson appears as a pole in the quark-antiquark Green function or Bethe-Salpeter Equation (BSE).



$$[\Gamma_H(p;P)]_{tu} = \int \frac{d^4q}{(2\pi)^4} K_{tu;rs}(p,q;P)\chi(q;P)_{sr}$$

$$S_f^{-1}(p) = i\gamma \cdot p + m_f + \Sigma_f(p)$$

The quark propagator is represented by its equation of motion, or its Schwinger-Dyson Equation (SDE).



$$\chi(q;P) = S_f(q_+)\Gamma_H(q;P)S_g(q_-)$$

$$\Sigma_f(p) = \int \frac{d^4q}{(2\pi)^4} g^2 D_{\mu\nu}(p-q)\frac{\lambda^a}{2}\gamma_\mu S_f(q)\Gamma^a_\nu(p,q)$$

Contact Interaction

We assume that the quark-gluon interaction is led by symmetry-preserving vector-vector contact interaction; here, we consider that the interaction between quarks is not mediated via massless bottom exchange, but instead through the interaction defined by:

$$g^2 D_{\mu\nu}(k) = \frac{4\pi\alpha_{IR}}{m_g^2}\delta_{\mu\nu} \equiv \frac{1}{m_G^2}\delta_{\mu\nu} \qquad m_g = 800\text{ MeV} \qquad \alpha_{IR} = 0.93\pi$$

After considering the rainbow-ladder approximation for the vertex, in the CI model the kernel reads:

$$\Gamma^a_\mu(p,q) = \frac{\lambda^a}{2}\gamma_\mu$$

$$K(p,q;P)_{tu;rs} = -\frac{1}{m_G^2}\delta_{\mu\nu}\left[\frac{\lambda^a}{2}\gamma_\mu\right]_{ts}\left[\frac{\lambda^a}{2}\gamma_\nu\right]_{ru}$$

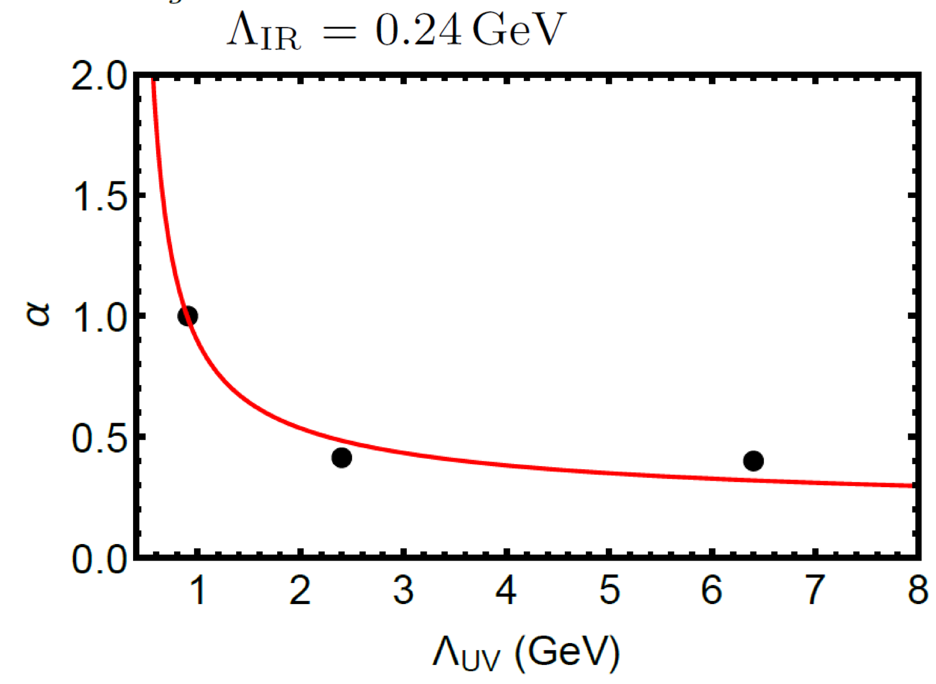
To solve the integrals, we use the proper time regularization method. We introduce an infrared cutoff to implement confinement, and an ultraviolet cutoff to setup the dimensioned quantities. In previous papers[1-5], we study the light, charm and bottom sector, and found out that, in order to study each region, we required a different set of parameters:

quark	$\hat{\alpha}_{IR}$ [GeV^{-2}]	Λ_{UV} [GeV]	α	Ratio
u, d, s	4.565	0.905	3.739	1
c	0.228	2.400	1.547	0.414
b	0.035	6.400	1.496	0.400

This points can be expressed in terms of the ultraviolet cutoff only, and can be fitted nearly with a logarithmic curve, as a reminiscent of the QCD coupling constant:

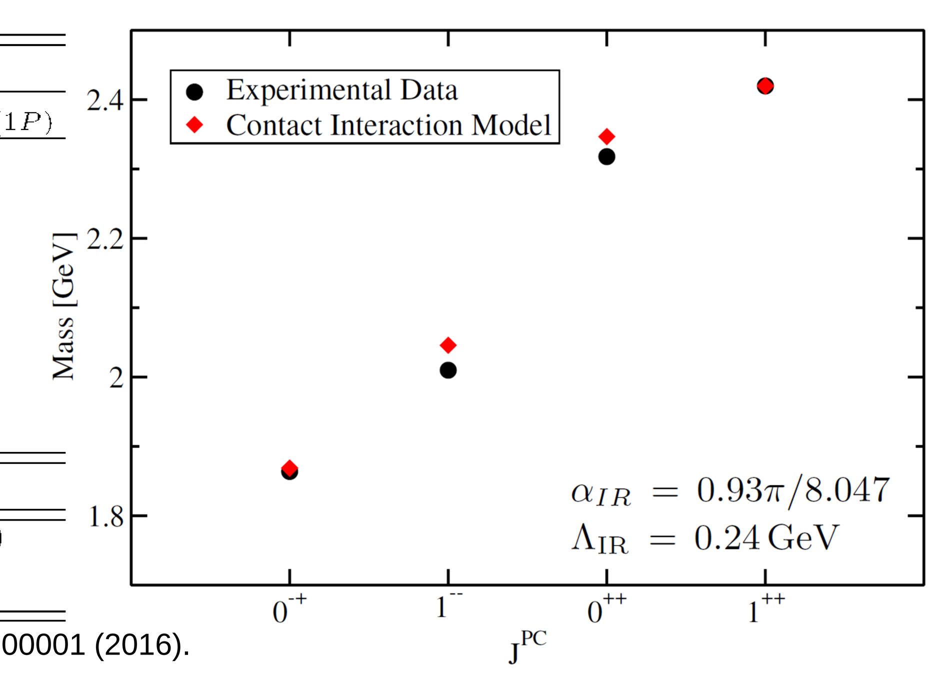
$$\alpha = \frac{\alpha_{IR}}{m_g^2}\Lambda_{UV}^2 \qquad \alpha(\Lambda_{UV}) = a\ln^{-1}(\Lambda_{UV}/\Lambda_0)$$

$$\Lambda_{IR} = 0.24\,\text{GeV}$$



With the help of this fit, we adjust Λ_{UV} to obtain the experimental value of the pseudoscalar mesons, and the rest of results are predictions of the model

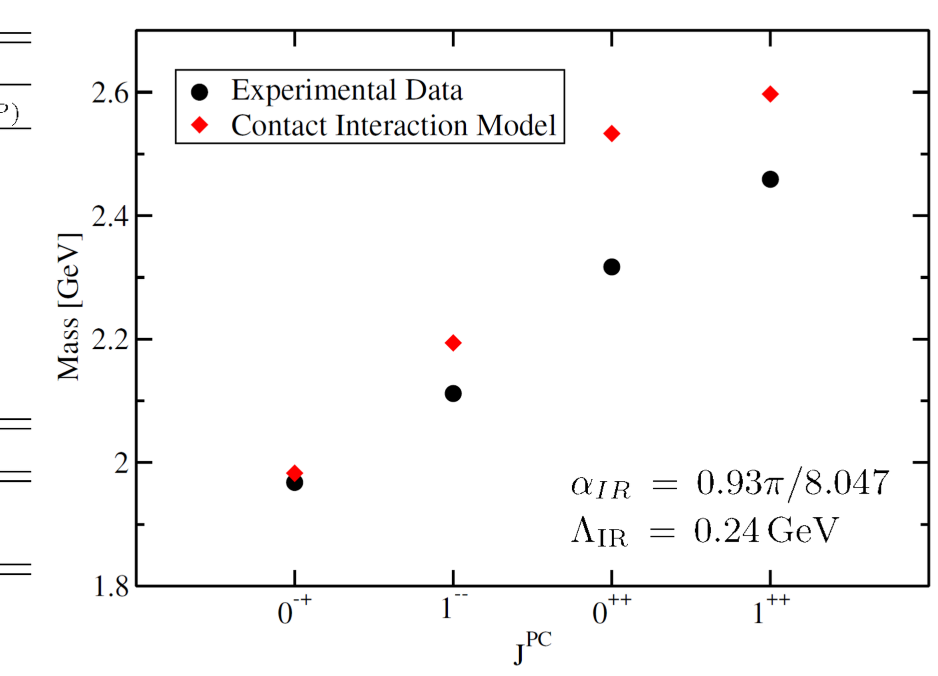
$m_u = 0.007$ GeV	masses and decay constants [MeV]			
$m_c = 1.09$ GeV	$(m,f)_{D(1S)}$	$(m,f)_{D^*(1S)}$	$m_{D_0(1P)}$	$m_{D_1(1P)}$
Experiment [60]	(1864, 149)	(2010, 196)	2318	2420
CI	(1869, 425)	(2046, 182)	2347	2422
CI-subtr [61]	(1869, 146)	(2011, 169)	–	–
NST1 [43]	(1850, 108)	(2040, 113)	–	–
NST2 [43]	(1880, 183)	–	–	–
HGKL1 [45]	(1868, 228)	–	–	–
HGKL2 [45]	(1869, 678)	–	–	–
	amplitudes			
E_H	4.292	0.592	0.073	0.039
F_H	0.064	—	—	—



[60] C. Patrignani et al. [Particle Data Group], Chin. Phys. C 40, no. 10, 100001 (2016).

[61] F. E. Serna et al., EPJ Web Conf. 137, 13015 (2017).

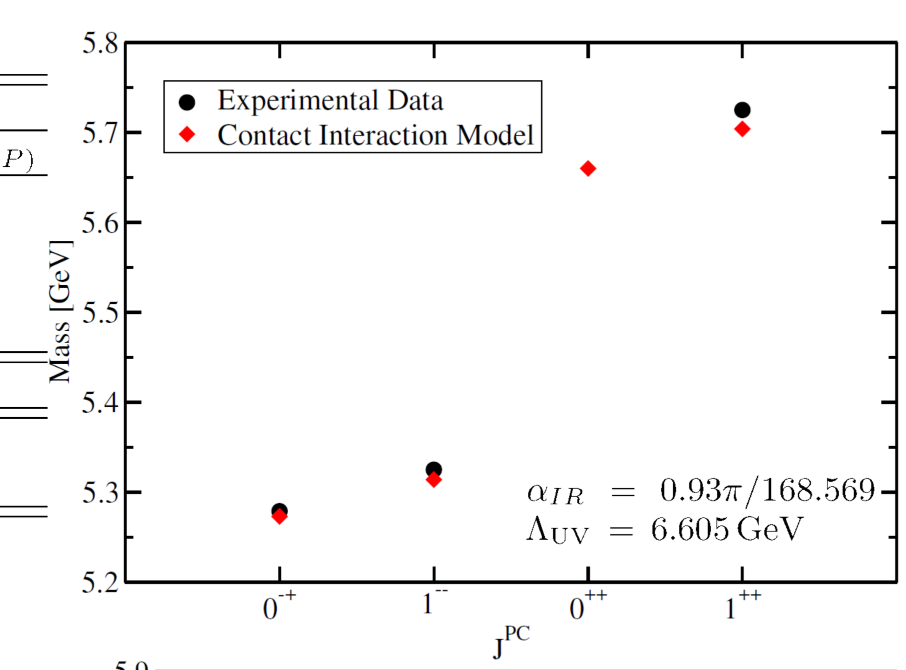
$m_s = 0.17$ GeV	masses and decay constants [MeV]			
$m_c = 1.09$ GeV	$(m,f)_{D_s(1S)}$	$(m,f)_{D_s^*(1S)}$	$m_{D_{s1}(1P)}$	$m_{D_{s1}(1P)}$
Experiment [60]	(1968, 176)	(2112, 227)	2317	2459
CI-	(1983, 247)	(2194, 192)	2442	2487
CI-subtr [61]	(1977, 169)	(2098, 195)	–	–
NST1 [43]	(1970, 139)	(2040, 113)	–	–
NST2 [43]	(1900, 194)	–	–	–
HGKL1 [45]	(1872, 190)	(2175, 125)	2265	2354
HGKL2 [45]	(1802, 208)	(2011, –)	2211	–
	amplitudes			
E_H	2.450	0.670	0.069	0.037
F_H	0.301	—	—	—



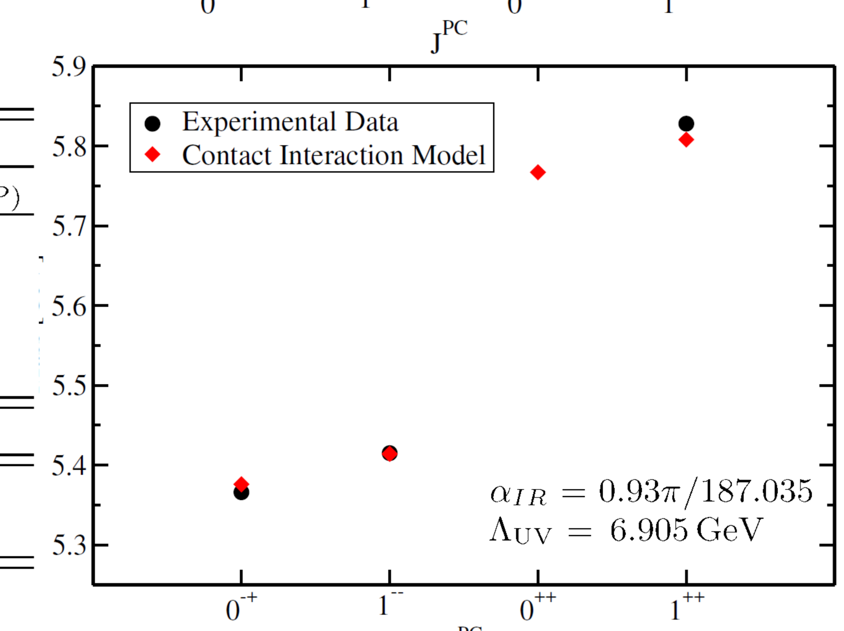
[43] T. Nguyen et al., AIP Conf. Proc. 1361, 142 (2011).

[45] T. Hilger et al., Eur. Phys. J. A 53, no. 10, 213 (2017).

$m_u = 0.007$ GeV	masses and decay constants [GeV]			
$m_b = 3.8$ GeV	$(m,f)_{B(1S)}$	$(m,f)_{B^*(1S)}$	$m_{B_0(1P)}$	$m_{B_1(1P)}$
Experiment [60]	5279	5325	–	5725
CI	(5273, 129)	(5314,371)	5660	5704
NST1 [43]	(5270, 74)	(2040, 113)	–	–
NST2 [43]	(5150, 187)	–	–	–
	amplitudes			
E_H	0.143	0.149	0.002	0.001
F_H	0.000	—	—	—



$m_s = 0.17$ GeV	masses and decay constants [MeV]			
$m_b = 3.8$ GeV	$m_{B_s(1S)}$	$m_{B_s^*(1S)}$	$m_{B_{s0}(1P)}$	$m_{B_{s1}(1P)}$
Experiment [60]	5366	5415	–	5828
CI	(5376, 178)	(5414, 384)	5767	5808
NST1 [43]	(5380, 101)	(5420, 113)	–	–
NST2 [43]	(4750, 115)	–	–	–
	amplitudes			
E_H	0.176	0.141	0.002	0.001
F_H	0.007	—	—	—



Conclusions

- We calculated the spectrum and decay constants of D and B mesons.
- Our results are in good agreement with experimental data and those from other models.
- In the bottom region, the coupling of the model is to sensitive to the value of the ultraviolet cutoff.
- In this way, the CI model could be a reliable tool to provide exploratory studies of QCD.

References

[1] L. Xiomara Gutiérrez, et. al., Phys. Rev. C81, 065202 (2010).

[2] C. Chen, et. al., Few Body Syst. 53, 293 (2012).

[3] M.A. Bedolla, et. al, Phys. Rev. D 92, 054031 (2015).

[4] M.A. Bedolla, et. al, Phys. Rev. D 93, 094025 (2016).

[5] K. Raya, et. al, arXiv:1711.00383 [nucl-th].