Description of the X(4260) and X(4360) Mesons as a $\rho D\bar{D}$ Molecular State

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XIIth Quark Confinement and the Hadron Spectrum, 02/09/2016

OVERVIEW

- Motivation and Introduction
- Formalism
- Results and Discussion
- Summary

MOTIVATION and INTRODUCTION

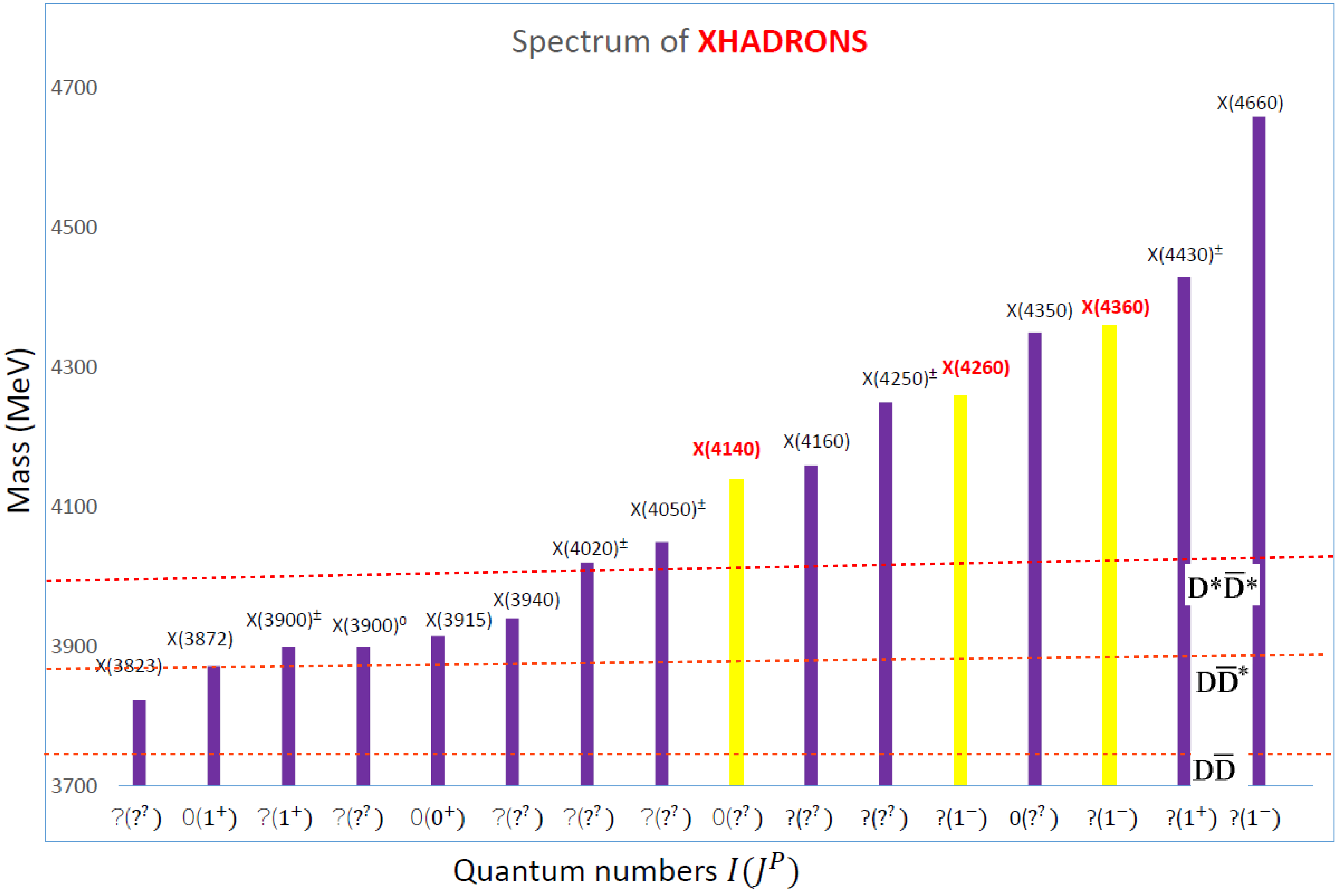
- *Recently, the large number of new states found in the hadron experiments*

- *The properties of some of them are still not easy to explain within the quark model spectrum*

- *There are no compelling theoretical pictures that provide an unquestionable description of what is seen in the experiments*

- *The Quarkonium Working Group (QWG) concluded: there are still a lot of surprises and puzzles in the studies of heavy quarkonium*

- *The motivation of the this talk:*
  → *understand the properties of the particles found in the hadron experiments (structure ect...)*
  → *search for new states of the hadron spectroscopy theoretically*



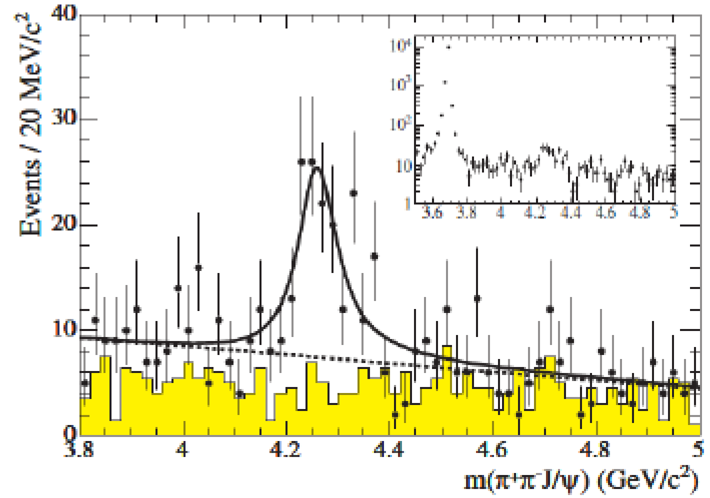
Spectrum of XHADRONS
Mass (MeV)
4700
4500
4300
4100
3900
3700
X(3823)
X(3872)
X(3900)±
X(3900)0
X(3915)
X(3940)
X(4020)±
X(4050)±
X(4140)
X(4160)
X(4250)±
X(4260)
X(4350)
X(4360)
X(4430)±
X(4660)
D*D̄*
DD̄*
DD̄
?(??) 0(1+) ?(1+) ?(??) 0(0+) ?(??) ?(??) ?(??) 0(??) ?(??) ?(??) ?(1−) 0(??) ?(1−) ?(1+) ?(1−)
Quantum numbers I(J^P)

$X(4260)$ $I^G(J^{PC})=?^?(1^{--})$

- In 2005, BABAR, the process $e^+e^- \to \pi\pi J/\Psi$ cross section

(B. Aubert et al. [BaBar Collaboration], Phys Rev. Lett. 95,142001, 2005)

m~ 4260 MeV/c^2
Γ~ 90MeV/c^2



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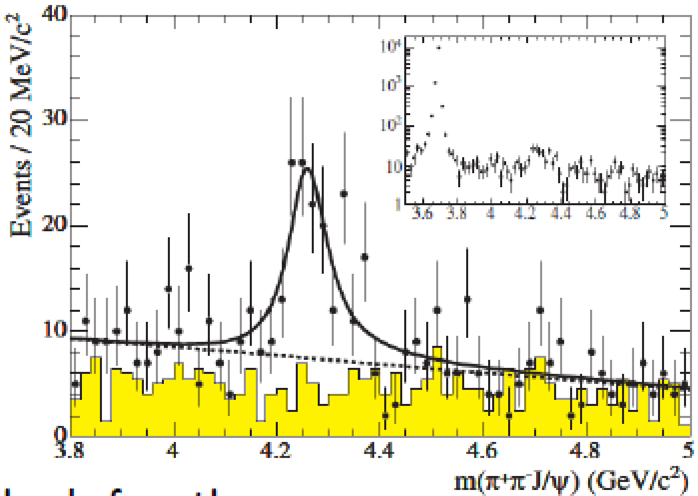

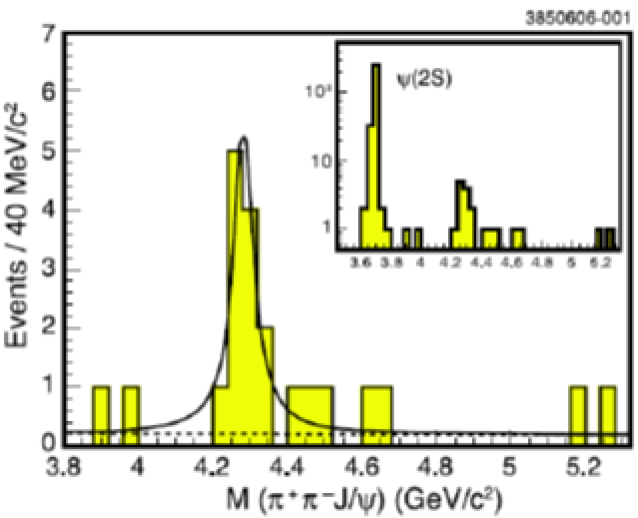

- The Cleo Collaboration searched for the new resonances X(4260)

(Q. He et al. [CLEO Collaboration], Phys Rev. D 74, 091104, 2006)

m~ 4284^{+17}_{-16} (stat) $\pm$ 4 (syst)MeV/c^2
Γ~ 73^{+39}_{-25} $(stat) \pm 5$ $(syst)$MeV/c^2

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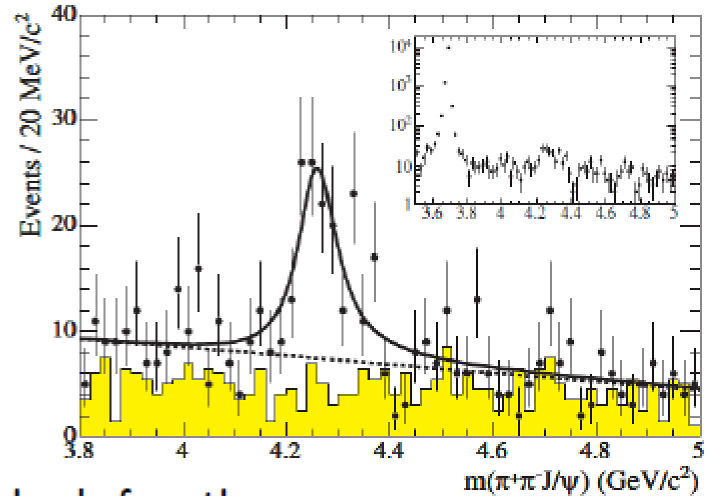

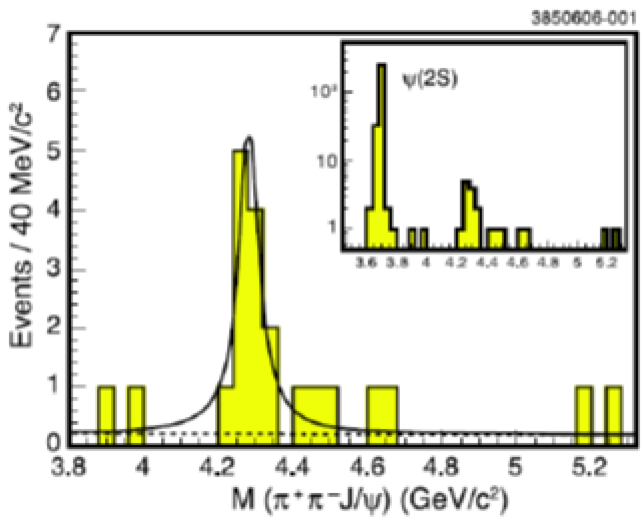

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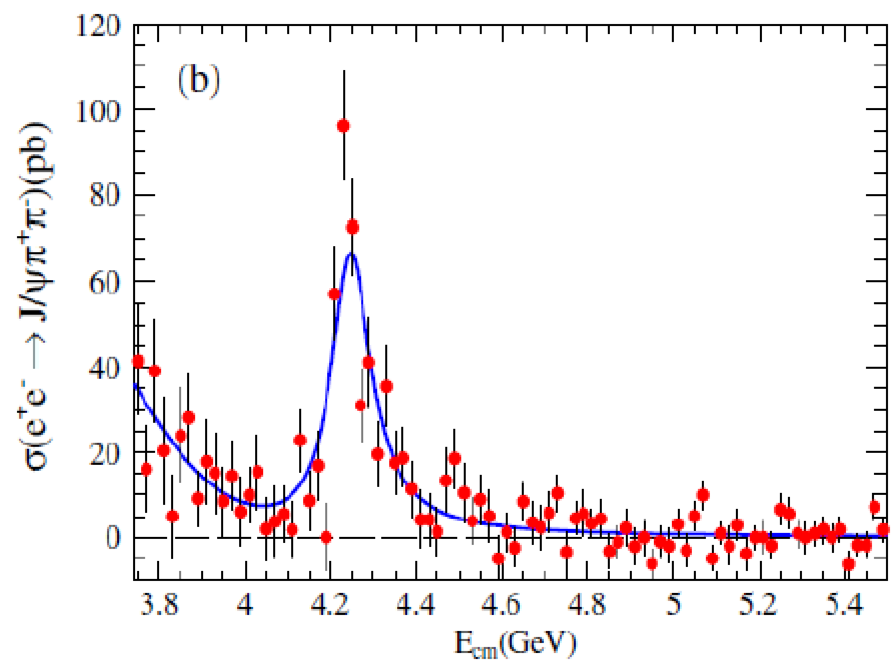
(Q. He et al. [CLEO Collaboration], Phys Rev. D 74, 091104, 2006)

m~ 4284^{+17}_{-16} (stat) ± 4 (syst)MeV/c^2
Γ~ 73^{+39}_{-25} $(stat)$± 5 $(syst)$MeV/c^2

- Again, BABAR Collaboration studied $e^+e^- \to \pi\pi J/\Psi$ in the c.m. Energy range 3.74-5.50 GeV using ISR events

(J. P. Lesset al. [BaBar Collaboration], Phys Rev. D 86, 051102, 2012)

m~ 4245 ± (stat) ± 4 (syst) MeV/c^2
Γ~ 114^{+16}_{-15} $(stat)$ ± 7$(syst)$MeV/c^2



$X(4360)\quad I^G(J^{PC}) = ?^?(1^{--})$

- In 2007, BABAR observed a structure

(B. Aubert et al. [BaBar Collaboration], Phys Rev. Lett. 98,212001, 2007)

$$m \sim 4324.0 \pm 24\ \text{MeV}/c^2$$
$$\Gamma \sim 172 \pm 33\ \text{MeV}$$

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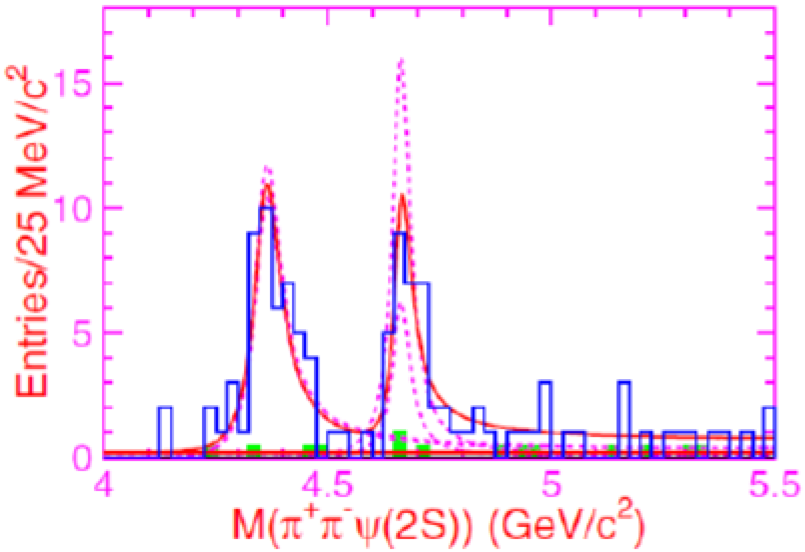
- Belle, measured $e^+e^- \to \pi\pi\Psi(2S)$ cross section between treshold and 5.5 GeV. This state is a good agreement with structure observed by BABAR in mass but with a much narrower width

(X. L. Wang et al. [Belle Collaboration], Phys. Rev. Lett., 99, 142002,2007)

$$m \sim 4361.0 \pm 9 \pm 9 \text{ MeV}/c^2$$
$$\Gamma \sim 74 \pm 15 \pm 15 \text{ MeV}/c^2$$

$$m \sim 4664.0 \pm 11 \pm 5 \text{ MeV}/c^2$$
$$\Gamma \sim 48 \pm 15 \pm 3 \text{ MeV}/c^2$$



X(4260)* and *X(4360)* $\to \rho D\bar{D}$ *!!

$\rho\, D\bar{D}$ Three Body System

Fixed Center Approximation (FCA) to the Faddeev equations is an effective tool to deal with the three-body hadronic interactions.

This method is technically simple and accurate when dealing with bound states.

$\bar{K}NK,\ \bar{K}NN,\ DNN,\ \text{multi-}\rho,\ \cdots$ (M.Bayar, J. Yamagata, L. Roca, C.W.Xiao, J.J.Xie, A. Martines Torres, W.H. Liang, E. Oset: PRC84(2011)015209, PRD84(2011)0340037, NPA833(2012)57, PRD82(2010)054013, PRD82(2010094017.)

$\pi(\Delta\rho)\ \Rightarrow$ solved the $\Delta_{\frac{5}{2}^+}(2000)$ puzzle (J.J. Xie, A. Martines Torres, E. Oset, PRC83(2011)055204)

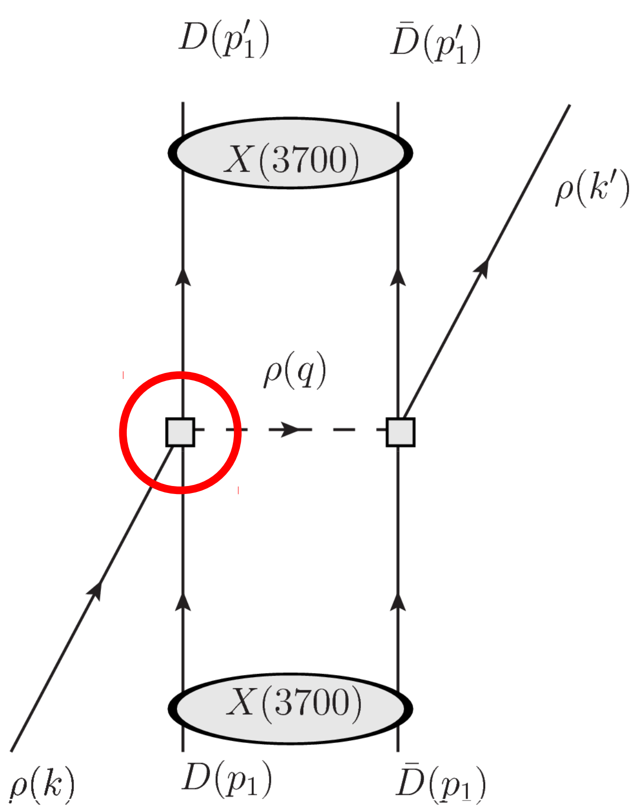
Limits to the FCA to the Faddeev equations (A. Martines Torres, E.J. Garzon, E. Oset PRD83(2011)116002; M.Bayar, J. Yamagata, E. Oset PRC84(2012)015209.)

THREE BODY INTERACTION

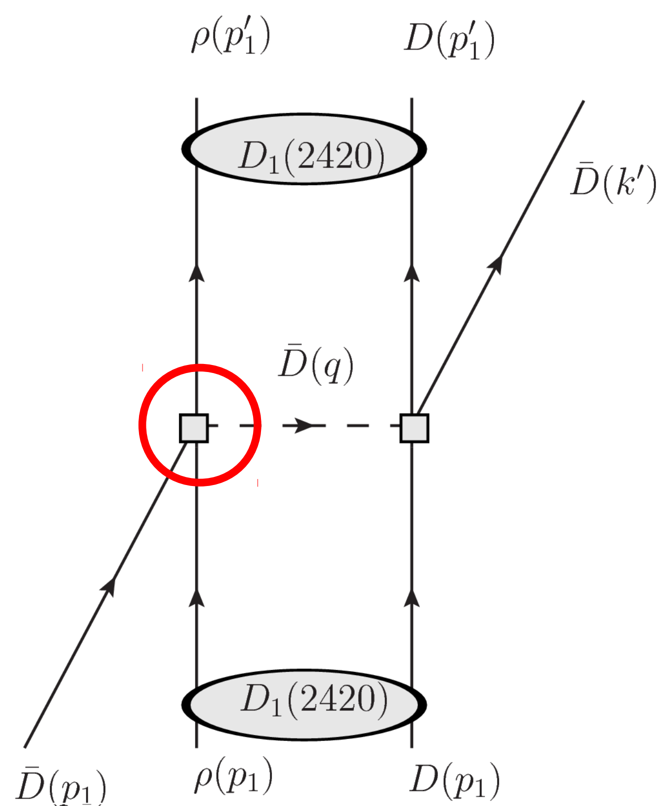
the $\rho D\bar{D}$ system

- ***A cluster of two bound particles $D\bar{D}$, (I=0), X(3700) and ρD, (I=1/2), D_1(2420)***
- ***Third particle interacts with the cluster***

the $\rho - X(3700)$



the $\bar{D} - D_1(2420)$



ρD and DDbar Unitarized Amplitude:

The Bethe-Salpeter (BS) equation in coupled channels

$$T = [1 - V\,G]^{-1}\,V$$

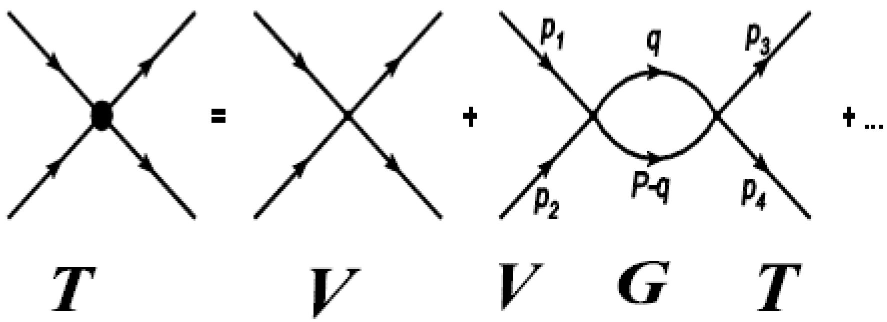


Fig: Diagrammatic representation of the Bethe Salpeter equation

G ⟶ *the diagonal matrix of the loop function of two mesons in the i-channel*

V ⟶ *the potential of the two-body interaction which is obtained from the Lowest Langrangian.*

ρD (vector - pseudoscalars mesons) two body scattering :

Channel content in each sector for the pseudoscalar vector meson interaction D. Gamermann and E. Oset Eur. Phys. J. A 33, 119–131 (2007)

Charm	Strangeness	$I^G(J^{PC})$	Channels
1	1	$1(1^+)$	πD_s^*, $D_s\rho$ KD^*, DK^*
		$0(1^+)$	DK^*, KD^*, ηD_s^* $D_s\omega$, $\eta_c D_s^*$, $D_s J/\psi$
	0	$\frac{1}{2}(1^+)$	πD^*, $D\rho$, KD_s^*, $D_s K^*$ ηD^*, $D\omega$, $\eta_c D^*$, DJ/ψ
	−1	$0(1^+)$	DK^*, KD^*
0	1	$\frac{1}{2}(1^+)$	πK^*, $K\rho$, ηK^*, $K\omega$ $\bar{D}D_s^*$, $D_s\bar{D}^*$, KJ/ψ, $\eta_c K^*$
	0	$1^+(1^{+-})$	$\frac{1}{\sqrt{2}}(\bar{K}K^* + c.c.)$, $\pi\omega$, $\eta\rho$ $\frac{1}{\sqrt{2}}(\bar{D}D^* + c.c.)$, $\eta_c\rho$, $\pi J/\psi$
		$1^-(1^{++})$	$\pi\rho$, $\frac{1}{\sqrt{2}}(\bar{K}K^* - c.c.)$, $\frac{1}{\sqrt{2}}(\bar{D}D^* - c.c.)$
		$0^+(1^{++})$	$\frac{1}{\sqrt{2}}(\bar{K}K^* + c.c.)$, $\frac{1}{\sqrt{2}}(\bar{D}D^* + c.c.)$, $\frac{1}{\sqrt{2}}(\bar{D}_s D_s^* - c.c.)$
		$0^-(1^{+-})$	$\pi\rho$, $\eta\omega$, $\frac{1}{\sqrt{2}}(\bar{D}D^* - c.c.)$, $\eta_c\omega$ $\eta J/\psi$, $\frac{1}{\sqrt{2}}(\bar{D}_s D_s^* + c.c.)$, $\frac{1}{\sqrt{2}}(\bar{K}K^* - c.c.)$, $\eta_c J/\psi$

ρD, $(I=1/2)$, $D_1(2420)$

TABLE II. The C^I coefficients in Eq. (2) for the $I = 3/2$ case.

Channels	πD^*	$D\rho$
πD^*	1	1
$D\rho$	1	1

ρD (vector - pseudoscalars mesons) two body scattering :

$$T = -(\hat{1} + V\hat{G})^{-1} V \vec{\epsilon}.\vec{\epsilon}'$$

The Lagrangian:

$$\mathcal{L}_{PPVV} = -\frac{1}{4f^2} Tr\left(J_\mu \mathcal{J}^\mu\right)$$

The potentials, projected over s-wave:

$$V^I_{ij}(s) = \frac{1}{2}\int_{-1}^{1} d(cos\theta)\tilde{V}^I_{ij}(s, t(s, cos\theta), u(s, cos\theta))$$

The loop function:

$$G_l = i\int \frac{dq^4}{(2\pi)^4} \frac{1}{q^2 - m_l^2 + i\epsilon} \frac{1}{(P-q)^2 - M_l^2 + i\epsilon}$$

$$= \frac{1}{16\pi^2}\left(\alpha_i + \text{Log}\frac{m_l^2}{\mu^2} + \frac{M_l^2 - m_l^2 + s}{2s}\text{Log}\frac{M_l^2}{m_l^2} + \frac{p}{\sqrt{s}}\left(\text{Log}\frac{s - M_l^2 + m_l^2 + 2p\sqrt{s}}{-s + M_l^2 - m_l^2 + 2p\sqrt{s}} + \text{Log}\frac{s + M_l^2 - m_l^2 + 2p\sqrt{s}}{-s - M_l^2 + m_l^2 + 2p\sqrt{s}}\right)\right)$$

μ → the regularization scale

α_i → a subtraction constant

(the only free parameter in our calculation)

The Unitarized T-matrix for $D\bar{D}$

D. Gamermann, E. Oset, D. Strottman and M. J. Vicente Vacas, Phys. Rev. D 76, 074016 (2007)

$D\bar{D}$, $K\bar{K}$, $\pi\bar{\pi}$, $\eta\eta$, $\eta_c\eta$, $D_s\bar{D}_s$, in the $I=0$

$D\bar{D}$, $K\bar{K}$, $\pi\bar{\pi}$, $\pi\eta$, $\eta_c\pi$, in the $I=1$ case

Bethe-Salpeter equation for $D\bar{D}$:

$$T = (\hat{1} - V\hat{G})^{-1}V$$

the pseudoscalar-pseudoscalar mesons loop function:

The Lagrangian:

$$\mathcal{L}_{PPPP} = \frac{1}{12f^2}\,\mathrm{Tr}(J_\mu J^\mu + \Phi^4 M).$$

The amplitudes in charge base:

9. C = 0, S = 0

States	Amplitude
$D_s^+ D_s^- \to D_s^+ D_s^-$	$-\frac{1}{3f^2}(\psi_3(s+t-2u) + 2m_D^2 + 2m_K^2 - 2m_\pi^2)$
$\to D^+ D^-$	$-\frac{1}{6f^2}(\psi_5(t-u) + s - u + 2m_D^2 + m_K^2 - m_\pi^2)$
$\to D^0 \bar{D}^0$	$-\frac{1}{6f^2}(\psi_5(t-u) + s - u + 2m_D^2 + m_K^2 - m_\pi^2)$
$D^+ D^- \to D^+ D^-$	$-\frac{1}{3f^2}(\psi_3(s+t-2u) + 2m_D^2)$
$\to D^0 \bar{D}^0$	$-\frac{1}{6f^2}(\psi_5(t-u) + s - u + 2m_D^2)$
$D^0 D^0 \to D^0 D^0$	$-\frac{1}{3f^2}(\psi_3(s+t-2u) + 2m_D^2)$
$K^+ K^- \to K^+ K^-$	$-\frac{1}{3f^2}(s+t-2u+2m_K^2)$
$\to K^0 K^-$	$-\frac{1}{6f^2}(s+t-2u+2m_K^2)$
$\to \pi^+ \pi^-$	$-\frac{1}{6f^2}(s+t-2u+m_K^2+m_\pi^2)$
$\to \pi^0 \pi^0$	$-\frac{1}{12f^2}(2s-t-u+2m_K^2+2m_\pi^2)$
$\to \pi^0 \eta$	$-\frac{1}{12\sqrt{3}f^2}(3(2s-t-u)+2m_K^2+2m_\pi^2)$
$\to \eta\eta$	$-\frac{1}{12f^2}(3(2s-t-u)+6m_K^2-2m_\pi^2)$

FIXED-CENTER FORMALISM FOR THE THREE BODY SYSTEM

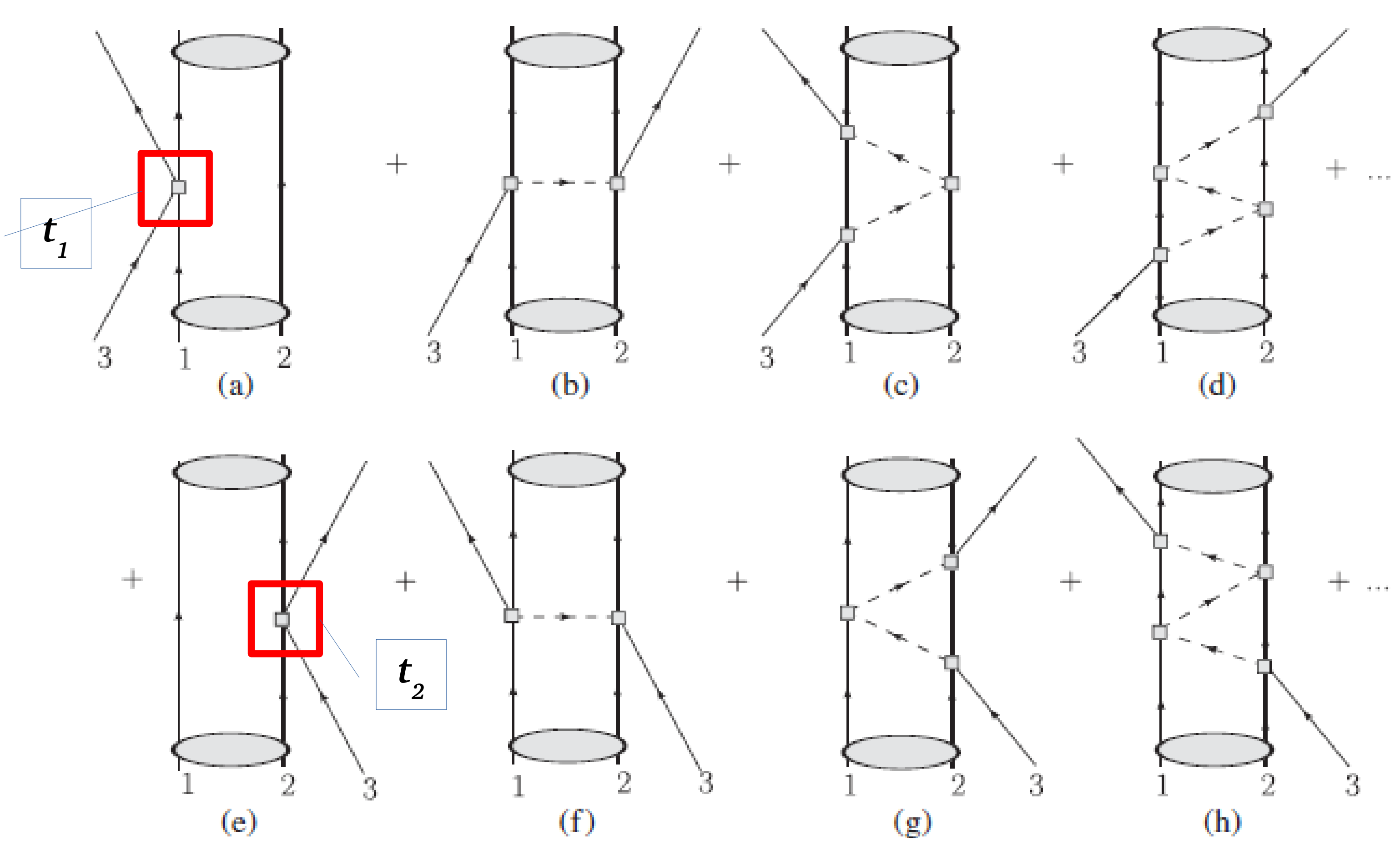


FIG. Diagrammatic representation of the fixed-center approximation to Faddeev equations

- ***T1:*** *all diagrams beginning with interaction in 1 meson.*
- ***T2:*** *all diagrams beginning with interaction in 2 meson.*

$$T_1 = t_1 + t_1 G_0 T_2,$$
$$T_2 = t_2 + t_2 G_0 T_1.$$

$$T = T_1 + T_2$$

For the normalization

The S-matrix for the single scattering:

$$S_1^{(1)} = -it_1 \frac{1}{\mathcal{V}^2}(2\pi)^4\delta^4(k_3 + k_{\rm cls} - k_3' - k_{\rm cls}') \times \frac{1}{\sqrt{2\omega_3}}\frac{1}{\sqrt{2\omega_3'}}\frac{1}{\sqrt{2\omega_1}}\frac{1}{\sqrt{2\omega_1'}},$$

Using the low energy reduction

$$\sqrt{2\omega} \sim \sqrt{2m}$$

$$\tilde{t}_1 = \frac{m_{\rm cls}}{m_1}t_1, \qquad \tilde{t}_2 = \frac{m_{\rm cls}}{m_2}t_2$$

S-matrix for the double scattering:

$$S^{(2)} = -i(2\pi)^4\frac{1}{\mathcal{V}^2}\delta^4(k_3 + k_{\rm cls} - k_3' - k_{\rm cls}') \times \frac{1}{\sqrt{2\omega_3}}\frac{1}{\sqrt{2\omega_3'}}\frac{1}{\sqrt{2\omega_1}}\frac{1}{\sqrt{2\omega_1'}}\frac{1}{\sqrt{2\omega_2}}\frac{1}{\sqrt{2\omega_2'}} \times \int\frac{d^3q}{(2\pi)^3}F_{\rm cls}(q)\frac{1}{q^{02} - \vec{q}^{\,2} - m_3^2 + i\epsilon}t_1t_2,$$

The full three-body scattering:

$$S = -iT\frac{1}{\mathcal{V}^2}(2\pi)^4\delta^4(k_3 + k_{\rm cls} - k_3' - k_{\rm cls}') \times \frac{1}{\sqrt{2\omega_3}}\frac{1}{\sqrt{2\omega_3'}}\frac{1}{\sqrt{2\omega_{\rm cls}}}\frac{1}{\sqrt{2\omega_{\rm cls}'}}.$$

For the normalization

The S-matrix for the single scattering:

$$S_1^{(1)} = -it_1 \frac{1}{\mathcal{V}^2}(2\pi)^4\delta^4(k_3 + k_{\rm cls} - k'_3 - k'_{\rm cls}) \times \frac{1}{\sqrt{2\omega_3}}\frac{1}{\sqrt{2\omega'_3}}\frac{1}{\sqrt{2\omega_1}}\frac{1}{\sqrt{2\omega'_1}},$$

S-matrix for the double scattering:

$$S^{(2)} = -i(2\pi)^4\frac{1}{\mathcal{V}^2}\delta^4(k_3 + k_{\rm cls} - k'_3 - k'_{\rm cls}) \times \frac{1}{\sqrt{2\omega_3}}\frac{1}{\sqrt{2\omega'_3}}\frac{1}{\sqrt{2\omega_1}}\frac{1}{\sqrt{2\omega'_1}}\frac{1}{\sqrt{2\omega_2}}\frac{1}{\sqrt{2\omega'_2}} \times \int\frac{d^3q}{(2\pi)^3}F_{\rm cls}(q)\frac{1}{q^{02} - \vec{q}^{\,2} - m_3^2 + i\epsilon}t_1t_2,$$

The full three-body scattering:

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Using the low energy reduction

$$\sqrt{2\omega} \sim \sqrt{2m}$$

$$\tilde{t}_1 = \frac{m_{\rm cls}}{m_1}t_1, \qquad \tilde{t}_2 = \frac{m_{\rm cls}}{m_2}t_2$$

we get:

$$T = T_1 + T_2 = \frac{\tilde{t}_1 + \tilde{t}_2 + 2\tilde{t}_1\tilde{t}_2G_0}{1 - \tilde{t}_1\tilde{t}_2G_0^2}.$$

The function G_0 is the meson exchange propagator

The Function G_0

$$G_0 = \frac{1}{2m_{\rm cls}} \int \frac{d^3q}{(2\pi)^3} F_{\rm cls}(q) \frac{1}{q^{0\,2} - \vec{q}^{\,2} - m_3^2 + i\epsilon}$$

the energy carried by particle 3

The Form factor:

$$F_{\rm cls}(q) = \frac{1}{\mathcal{C}} \int_{\substack{p<k_{\rm max} \\ |\vec{p}-\vec{q}|<k_{\rm max}}} d^3p \frac{1}{2\omega_1(\vec{p})} \frac{1}{2\omega_2(\vec{p})} \frac{1}{m_{\rm cls} - \omega_1(\vec{p}) - \omega_2(\vec{p})} \times \left(\frac{1}{2\omega_1(\vec{p}-\vec{q})}\right) \left(\frac{1}{2\omega_2(\vec{p}-\vec{q})}\right) \frac{1}{m_{\rm cls} - \omega_1(\vec{p}-\vec{q}) - \omega_2(\vec{p}-\vec{q})},$$

$$\mathcal{C} = \int_{p<k_{\rm max}} d^3p \left[\frac{1}{2\omega_1(\vec{p})} \frac{1}{2\omega_2(\vec{p})} \frac{1}{m_{\rm cls} - \omega_1(\vec{p}) - \omega_2(\vec{p})}\right]^2$$

The arguments of the three body amplitude T(s) and two body amplitudes $t_j(s_j)$

- *s → the total invariant mass of the three body system*
- *s_j → the invariant masses of the two body systems*

➡ *the binding energy among the three particles, proportionally to their masses:*

$$E_1 = \frac{\sqrt{s}}{(m_{\rm cls} + m_3)} \frac{m_1 m_{\rm cls}}{(m_1 + m_2)}$$

$$E_2 = \frac{\sqrt{s}}{(m_{\rm cls} + m_3)} \frac{m_2 m_{\rm cls}}{(m_1 + m_2)}$$

$$E_3 = m_3 \frac{\sqrt{s}}{(m_{\rm cls} + m_3)}.$$

the total energy of the two body system:

$$s_{1(2)} = (p_3 + p_{1(2)})^2 = \left(\frac{\sqrt{s}}{m_{\rm cls} + m_3}\right)^2 \left(m_3 + \frac{m_{1(2)} m_{\rm cls}}{m_1 + m_2}\right)^2 - \vec{P}^2_{2(1)}$$

with an approximate value of $\vec{P}_{2(1)}$,

$$\frac{\vec{P}^2_{2(1)}}{2m_{2(1)}} \simeq B_{2(1)} \equiv \frac{m_{2(1)} m_{\rm cls}}{(m_1 + m_2)} \frac{(m_{\rm cls} + m_3 - \sqrt{s})}{(m_{\rm cls} + m_3)},$$

$B_{2(1)}$ → the binding energy of particle 2 (1)

The Isospin

the $\rho - X(3700)$ *the cluster of X(3700),* $I_{D\bar{D}} = 0$

$$|D\bar{D}\rangle^{I=0} = \frac{1}{\sqrt{2}}\left|\frac{1}{2}, -\frac{1}{2}\right\rangle - \frac{1}{\sqrt{2}}\left|-\frac{1}{2}, \frac{1}{2}\right\rangle$$

with the nomenclature $|I_{z_1}, I_{z_2}\rangle$ for the $D\bar{D}$ system

The total isospin of the three body system $I_{\rho(D\bar{D})} = 1$

$$\langle \rho D\bar{D}|t|\rho D\bar{D}\rangle = \langle \rho^+(D\bar{D})^{I=0}|(\hat{t}_{\rho D} + \hat{t}_{\rho\bar{D}})|\rho^+(D\bar{D})^{I=0}\rangle$$

with nomenclature $|D\bar{D}, I, I_z\rangle \otimes |\rho, I, I_z\rangle$

$$= -\langle 1, +1| \otimes \frac{1}{\sqrt{2}}\left(\left\langle\frac{1}{2}, \frac{1}{2}\right|\left\langle\frac{1}{2}, -\frac{1}{2}\right| - \left\langle\frac{1}{2}, -\frac{1}{2}\right|\left\langle\frac{1}{2}, \frac{1}{2}\right|\right)(\hat{t}_{\rho D} + \hat{t}_{\rho\bar{D}})$$

$$\times \frac{1}{\sqrt{2}}\left(\left|\frac{1}{2}, \frac{1}{2}\right\rangle\left|\frac{1}{2}, -\frac{1}{2}\right\rangle - \left|\frac{1}{2}, -\frac{1}{2}\right\rangle\left|\frac{1}{2}, \frac{1}{2}\right\rangle\right) \otimes (-)|1, +1\rangle$$

$$= \left(\frac{2}{3}t_{\rho D}^{I=3/2} + \frac{1}{3}t_{\rho D}^{I=1/2}\right) + \left(\frac{2}{3}t_{\rho\bar{D}}^{I=3/2} + \frac{1}{3}t_{\rho\bar{D}}^{I=1/2}\right)$$

The Isospin

the $\rho - X(3700)$

the cluster of X(3700), $I_{D\bar{D}} = 0$

$$|D\bar{D}\rangle^{I=0} = \frac{1}{\sqrt{2}}\left|\frac{1}{2}, -\frac{1}{2}\right\rangle - \frac{1}{\sqrt{2}}\left|-\frac{1}{2}, \frac{1}{2}\right\rangle$$

with the nomenclature $|I_{z_1}, I_{z_2}\rangle$ for the $D\bar{D}$ system

The total isospin of the three body system $I_{\rho(D\bar{D})} = 1$

$$\langle \rho D\bar{D}|t|\rho D\bar{D}\rangle = \langle \rho^+(D\bar{D})^{I=0}|(\hat{t}_{\rho D} + \hat{t}_{\rho\bar{D}})|\rho^+(D\bar{D})^{I=0}\rangle$$

with nomenclature $|D\bar{D}, I, I_z\rangle \otimes |\rho, I, I_z\rangle$

$$= -\langle 1, +1| \otimes \frac{1}{\sqrt{2}}\left(\left\langle\frac{1}{2}, \frac{1}{2}\right|\left\langle\frac{1}{2}, -\frac{1}{2}\right| - \left\langle\frac{1}{2}, -\frac{1}{2}\right|\left\langle\frac{1}{2}, \frac{1}{2}\right|\right)(\hat{t}_{\rho D} + \hat{t}_{\rho\bar{D}})$$

$$\times \frac{1}{\sqrt{2}}\left(\left|\frac{1}{2}, \frac{1}{2}\right\rangle\left|\frac{1}{2}, -\frac{1}{2}\right\rangle - \left|\frac{1}{2}, -\frac{1}{2}\right\rangle\left|\frac{1}{2}, \frac{1}{2}\right\rangle\right) \otimes (-)|1, +1\rangle$$

$$= \left(\frac{2}{3}t_{\rho D}^{I=3/2} + \frac{1}{3}t_{\rho D}^{I=1/2}\right) + \left(\frac{2}{3}t_{\rho\bar{D}}^{I=3/2} + \frac{1}{3}t_{\rho\bar{D}}^{I=1/2}\right)$$

the $\bar{D}(\rho D)_{D_1(2420)}$ system

$I_{\rho D} = \frac{1}{2}$

$I_{\bar{D}(\rho D)} = 0$

$I_{\bar{D}(\rho D)} = 1$

$$t = (t_{D\rho}^{I=1/2}) + (t_{D\bar{D}}^{I=1})$$

$$\langle \rho D\bar{D}|t|\rho D\bar{D}\rangle = \langle \bar{D}(\rho D)^{I=1/2}|(\hat{t}_{D\rho} + \hat{t}_{D\bar{D}})|\bar{D}(\rho D)^{I=1/2}\rangle$$

$$= \frac{1}{\sqrt{2}}\left\langle\frac{1}{2}\right| \otimes \left(\frac{1}{\sqrt{3}}\left\langle 0, -\frac{1}{2}\right| - \sqrt{\frac{2}{3}}\left\langle -1, \frac{1}{2}\right|\right) + \frac{1}{\sqrt{2}}\left\langle -\frac{1}{2}\right| \otimes \left(\sqrt{\frac{2}{3}}\left\langle 1, -\frac{1}{2}\right| - \frac{1}{\sqrt{3}}\left\langle 0, +\frac{1}{2}\right|\right)(\hat{t}_{D\rho} + \hat{t}_{D\bar{D}})$$

$$\times \frac{1}{\sqrt{2}}\left|\frac{1}{2}\right\rangle \otimes \left(\frac{1}{\sqrt{3}}\left|0, -\frac{1}{2}\right\rangle - \sqrt{\frac{2}{3}}\left|-1, \frac{1}{2}\right\rangle\right) + \frac{1}{\sqrt{2}}\left|-\frac{1}{2}\right\rangle \otimes \left(\sqrt{\frac{2}{3}}\left|1, -\frac{1}{2}\right\rangle - \frac{1}{\sqrt{3}}\left|0, +\frac{1}{2}\right\rangle\right)$$

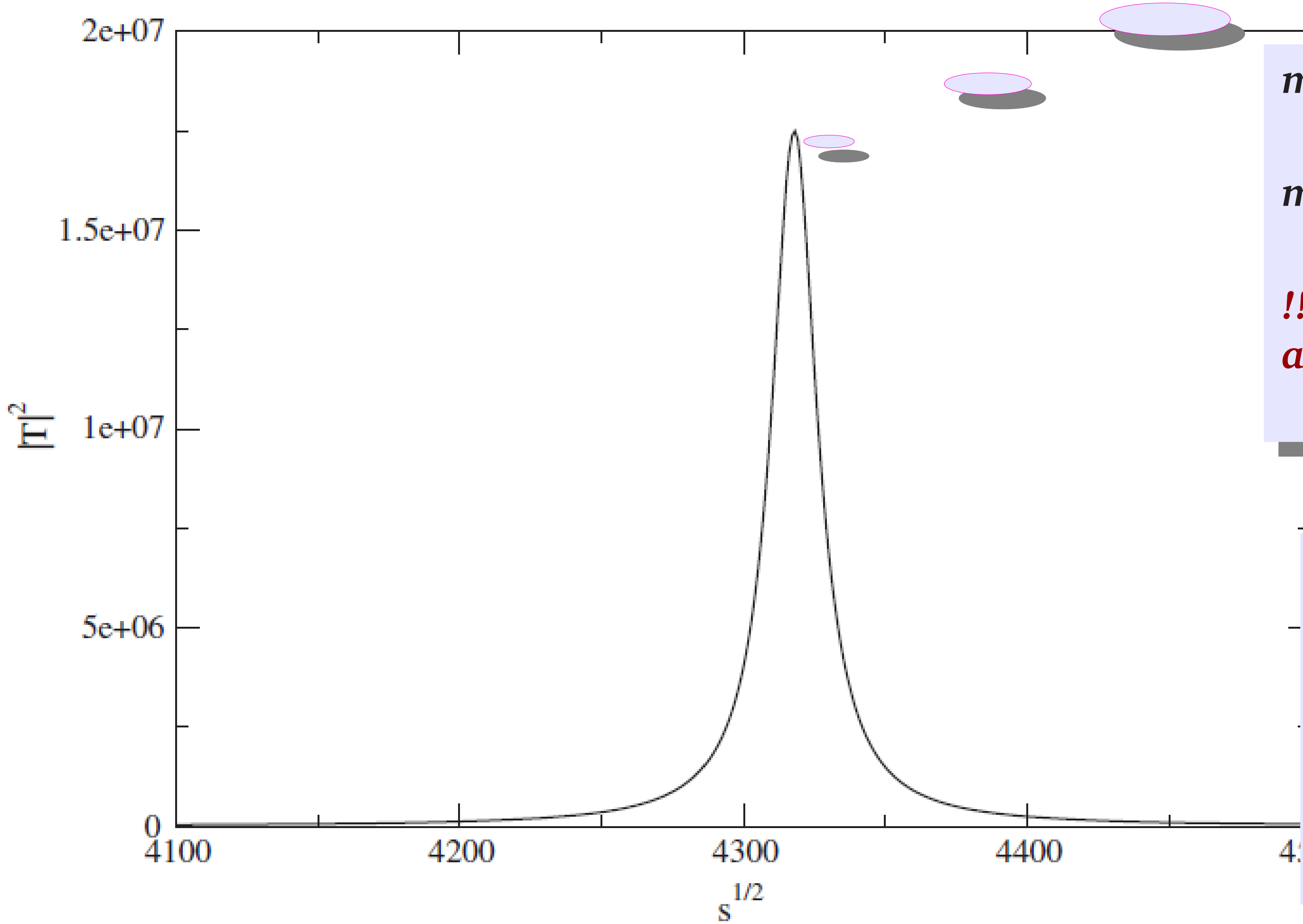
$$= \left(\frac{8}{9}t_{\bar{D}\rho}^{I=3/2} + \frac{1}{9}t_{\bar{D}\rho}^{I=1/2}\right) + \left(\frac{2}{3}t_{D\bar{D}}^{I=1} + \frac{1}{3}t_{D\bar{D}}^{I=0}\right)$$

with the nomenclature $|\rho\bar{D}, I_{z_1}, I_{z_2}\rangle \otimes |D, I_z\rangle$

RESULTS AND DISCUSSION

B. Durkaya and M. Bayar, Phys. Rev. D 92, 036006 (2015)

m~4320 MeV, Γ~25 MeV



$m_\rho + m_D + m_D$ = 4535 MeV

$m_{X(3700)} + m_\rho$ ~ 4475 MeV

!!!! ~160 MeV below the X(3700) and ρ meson threshold

X(4360) $I^G(J^{PC}) = ?^?(1^{--})$

m~4361 MeV, Γ~74 MeV

X(4260) $I^G(J^{PC}) = ?^?(1^{--})$

m~4251 MeV, Γ~120 MeV

FIG. 2. Modulus squared of the $\rho(D\bar{D})_{X(3700)}$ scattering amplitude with total isospin $I = 1$.

$\bar{D}D_1(2420)$ system

m~4256 MeV, Γ~25-30 MeV

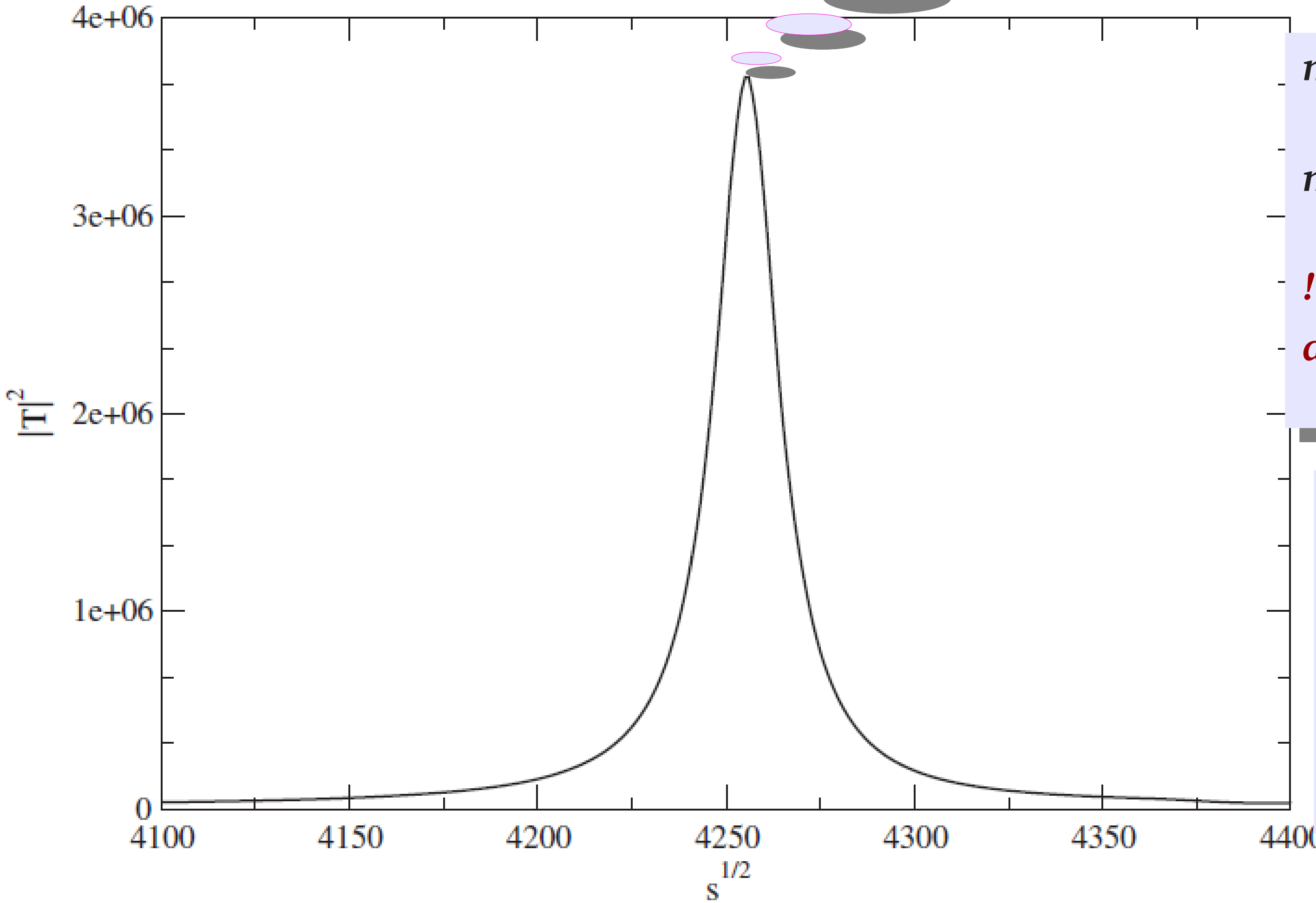


FIG. 3. Modulus squared of the $\bar{D}(\rho D)_{D_1(2420)}$ scattering amplitude with total isospin $I = 1$.

$m_\rho + m_D + m_D = 4535$ MeV

$m_{D1(2420)} + m_D \sim 4290$ MeV

!!!! ~40 MeV below the $D_1(2420)$ and D meson threshold

X(4360) ***$I^G(J^{PC}) = ?^?(1^{--})$***

m~4361 MeV, Γ~74 MeV

X(4260) ***$I^G(J^{PC}) = ?^?(1^{--})$***

m~4251 MeV, Γ~120 MeV

m~4241 MeV, Γ~20 MeV

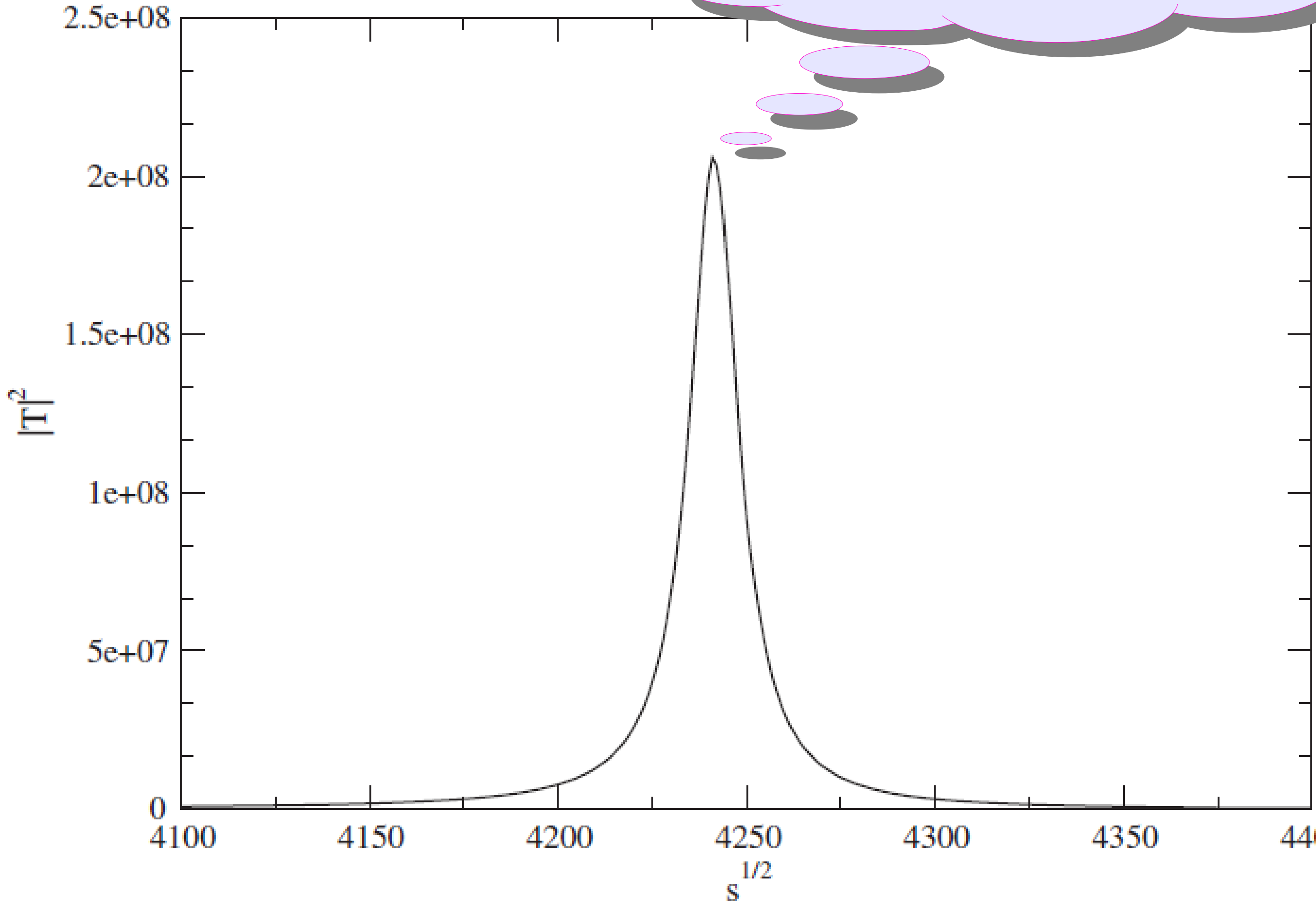


FIG. 4. Modulus squared of the $\bar{D}(\rho D)_{D_1(2420)}$ scatterin amplitude with total isospin $I = 0$.

$m_\rho + m_D + m_D = 4535$ MeV

$m_{D1(2420)} + m_D \sim 4290$ MeV

!!!! ~60 MeV below the $D_1(2420)$ and D meson threshold

!! Could be the $X(4250)^{\pm}$
m~4248 MeV, Γ~177 MeV
$I(J^P) = ?(?^?)$

!! or the X(4140)
m~4159 MeV , Γ~20 MeV
$I^G(J^{PC}) = 0^+(?^{?+})$

➡ ***A New State ....***

SUMMARY

- Chiral dynamics is a good tool to deal with hadron interaction.

- Its combination with nonperturbative unitary techniques allows to study the interaction of hadrons. Poles in amplitudes correspond to dynamically generated resonances. Many known resonances can be described in this way.

- The interaction of vector mesons with other mesons or baryons plays an important role in many hadronic reactions

- We investigate the three-body systems of $\rho D\bar{D}$ by taking the fixed center approximation to Faddeev equations, and find

  - A bound states around 4320 MeV and 4256 MeV associated to **X(4360) and X(4260) with I=1**
  - Predict a new state: mass about 4241 MeV with I=0

Thank you for your attention!