Are the X(4260) and X(4360) Molecular State?

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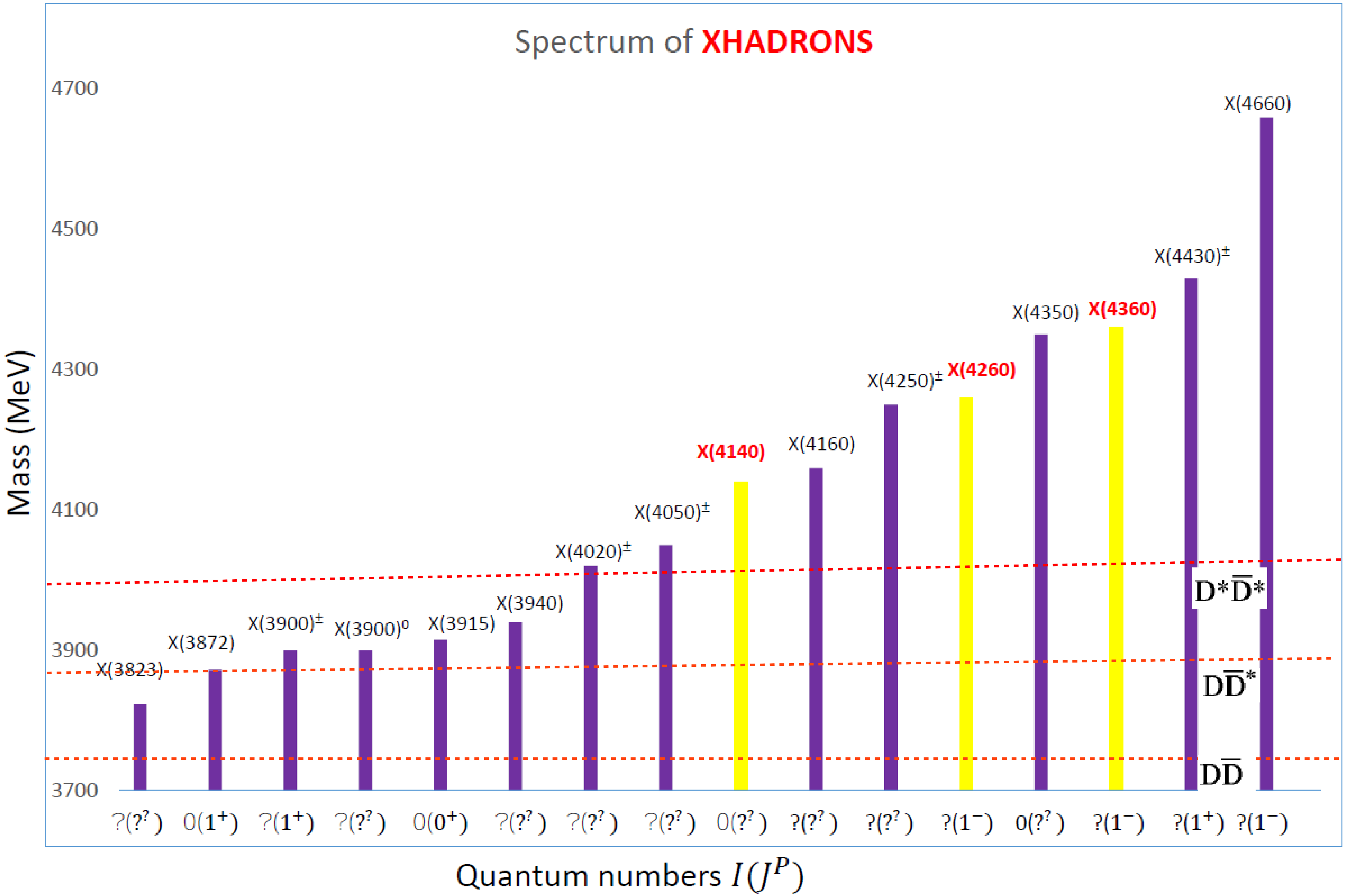
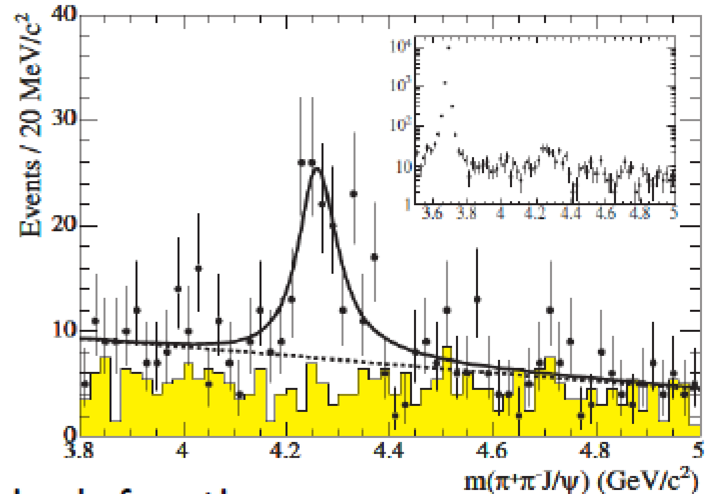
OVERVIEW

- *Introduction*
- *Formalism*
- *Results and Discussion*
- *Summary*



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)

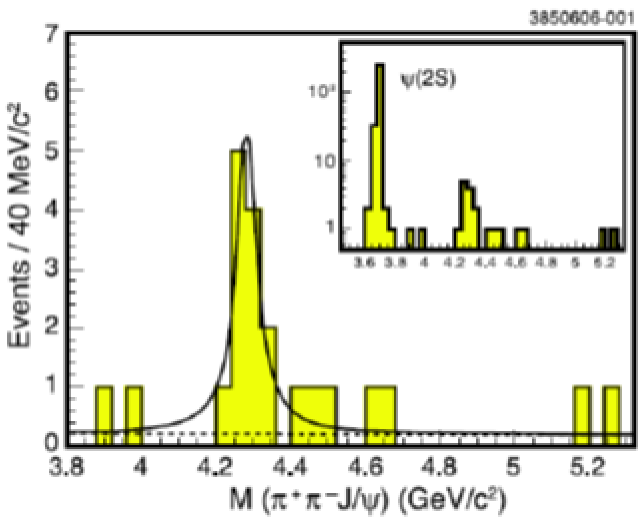
$X(4260)$ $I^G(J^{PC}) = ?^?(1^{--})$



- 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)

$$m \sim 4260\ \text{MeV}/c^2$$
$$\Gamma \sim 90\text{MeV}/c^2$$



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

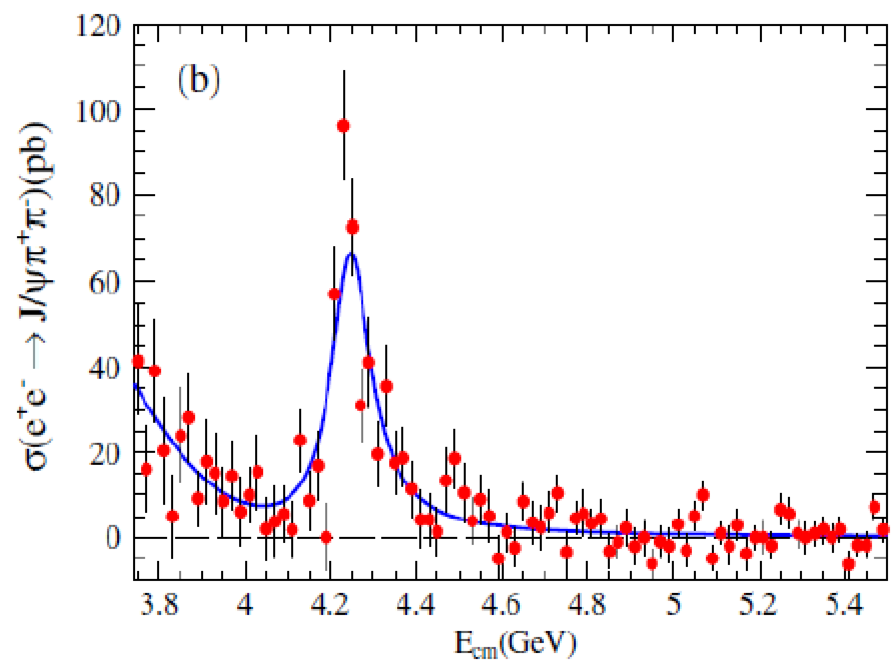
(Q. He et al. [CLEO Collaboration], Phys Rev. D 74, 091104, 2006)

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

- 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)

$$m \sim 4245 \pm (\text{stat}) \pm 4\ (\text{syst})\ \text{MeV}/c^2$$
$$\Gamma \sim 114^{+16}_{-15}\ (stat) \pm 7(syst)\text{MeV}/c^2$$



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

- In 2007, BABAR observed a structure

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

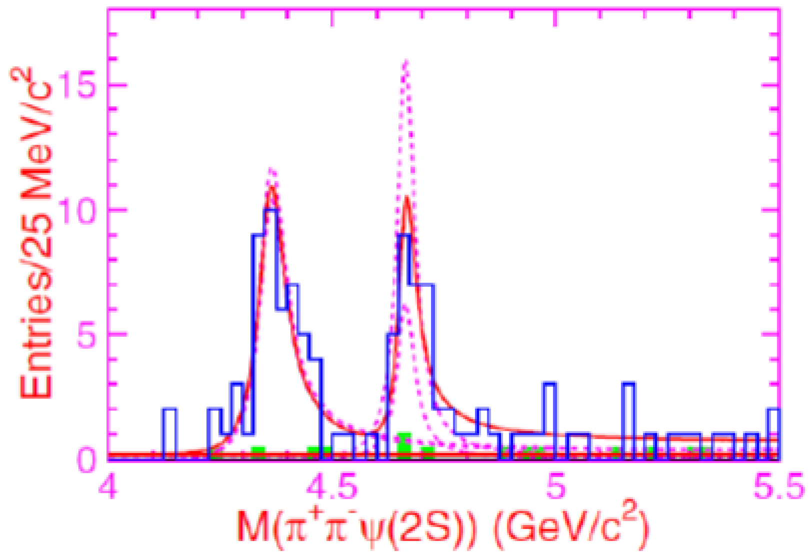
$$m \sim 4324.0 \pm 24 \text{ MeV}/c^2$$
$$\Gamma \sim 172 \pm 33 \text{ MeV}$$

- 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 $X(4360)$ → Molecular State??

$\rho D\bar{D}$ *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)

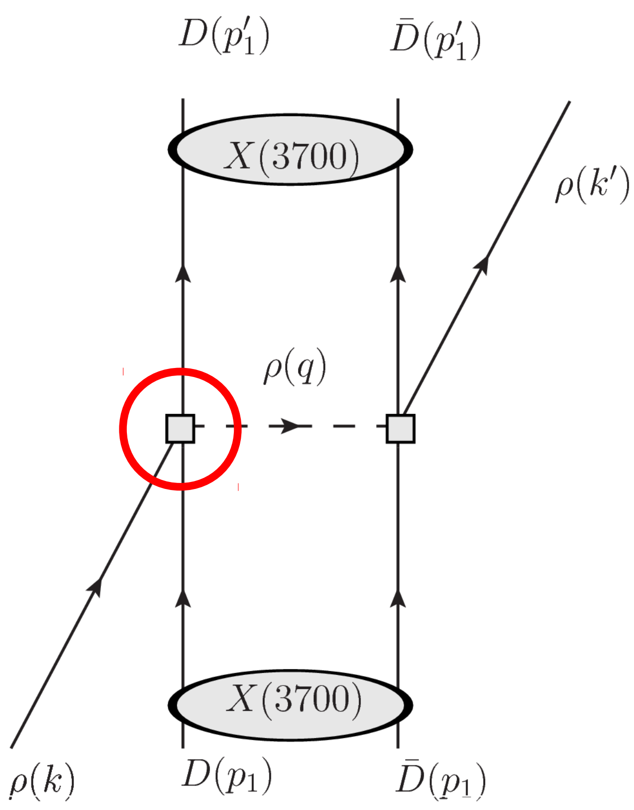
Limits to the FCA to the Faddeev equations (A. Martines Torres, E.J. Garzon, E. Oset PRD83(2011)116002; M.Bayar, J. Yamagata, E. Oset PRC84(2012)015209.)

THREE BODY INTERACTION

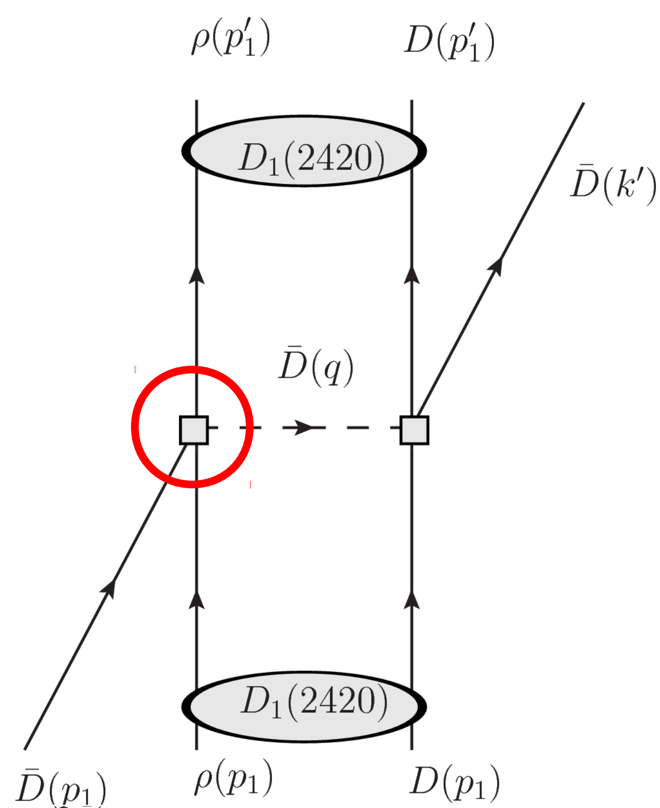
the $\rho D\bar{D}$ system

- *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 (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)*

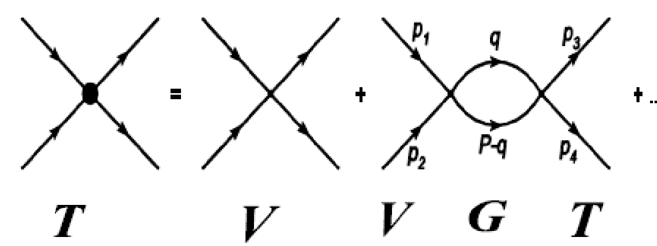
Charm	Strangeness	$I^G(J^{PC})$	Channels
1	1	$1(1^+)$	πD_s^*, $D_s\rho$ KD^*, DK^*
		$0(1^+)$	DK^*, KD^*, ηD_s^* $D_s\omega$, $\eta_c D_s^*$, $D_s J/\psi$
	0	$\frac{1}{2}(1^+)$	πD^*, $D\rho$, KD_s^*, D_sK^* ηD^*, $D\omega$, $\eta_c D^*$, DJ/ψ
	−1	$0(1^+)$	DK^*, KD^*
0	1	$\frac{1}{2}(1^+)$	πK^*, $K\rho$,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

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, (I=1/2), $D_1(2420)$

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



ρD (vector - pseudoscalars mesons) two body scattering :

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:

$$G_l = i\int \frac{dq^4}{(2\pi)^4}\frac{1}{q^2 - m_l^2 + i\epsilon}\frac{1}{(P-q)^2 - M_l^2 + i\epsilon}$$
$$= \frac{1}{16\pi^2}\left(\alpha_i + \text{Log}\frac{m_l^2}{\mu^2} + \frac{M_l^2 - m_l^2 + s}{2s}\text{Log}\frac{M_l^2}{m_l^2}\right.$$
$$\left. + \frac{p}{\sqrt{s}}\left(\text{Log}\frac{s - M_l^2 + m_l^2 + 2p\sqrt{s}}{-s + M_l^2 - m_l^2 + 2p\sqrt{s}} + \text{Log}\frac{s + M_l^2 - m_l^2 + 2p\sqrt{s}}{-s - M_l^2 + m_l^2 + 2p\sqrt{s}}\right)\right)$$

The Unitarized T-matrix for DD

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 DD :

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

FIXED-CENTER FORMALISM FOR THE THREE BODY SYSTEM

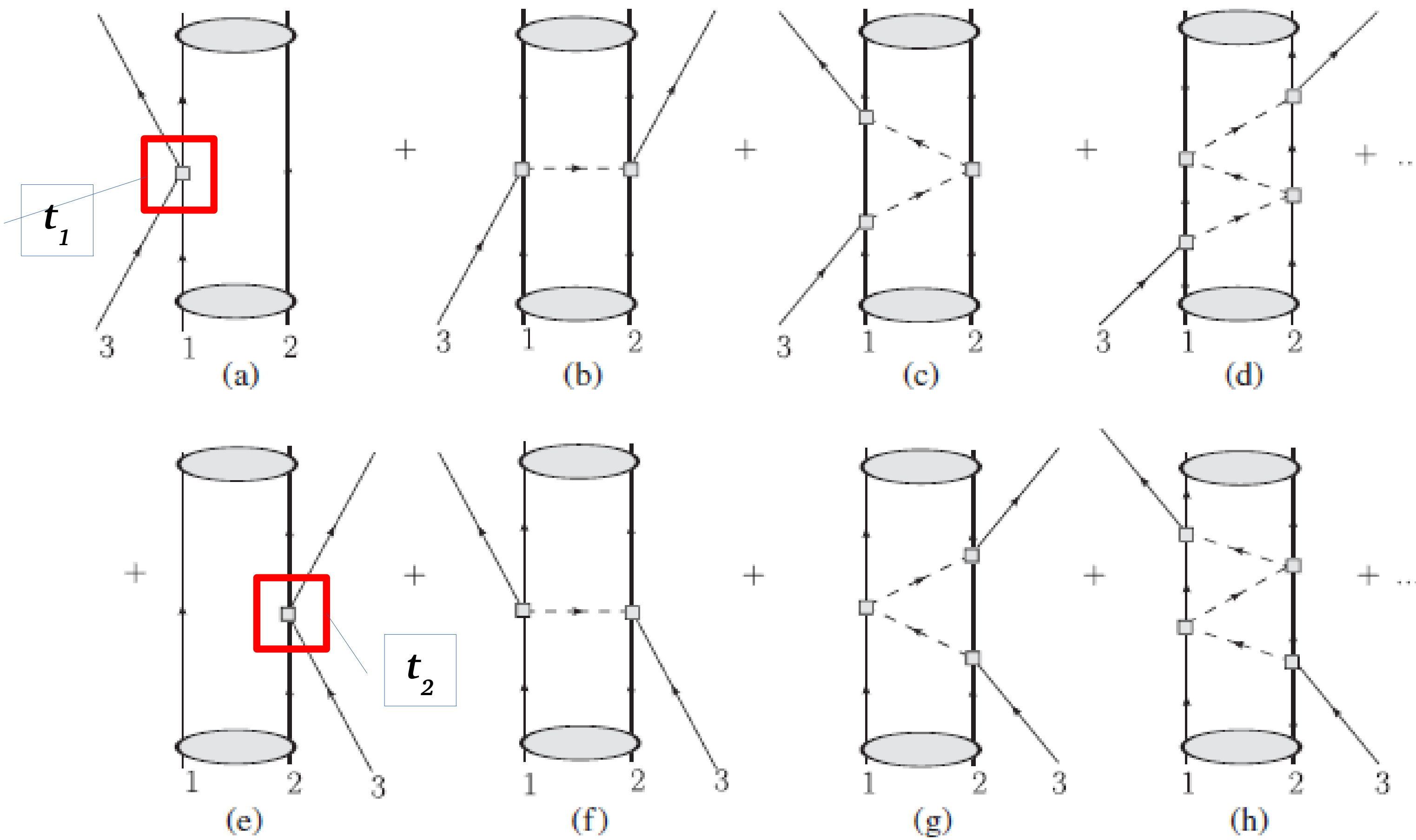


FIG. Diagrammatic representation of the fixed-center approximation to Faddeev equations

- **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:

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

S-matrix for the double scattering:

$$S^{(2)} = -i(2\pi)^4 \frac{1}{\mathcal{V}^2} \delta^4(k_3 + k_{\rm cls} - k_3' - k_{\rm cls}') \times \frac{1}{\sqrt{2\omega_3}} \frac{1}{\sqrt{2\omega_3'}} \frac{1}{\sqrt{2\omega_1}} \frac{1}{\sqrt{2\omega_1'}} \frac{1}{\sqrt{2\omega_2}} \frac{1}{\sqrt{2\omega_2'}} \times \int \frac{d^3q}{(2\pi)^3} F_{\rm cls}(q) \frac{1}{q^{02} - \vec{q}^{\,2} - m_3^2 + i\epsilon} t_1 t_2,$$

The full three-body scattering:

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

Using the low energy reduction

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

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

For the normalization

The S-matrix for the single scattering:

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

S-matrix for the double scattering:

$$S^{(2)} = -i(2\pi)^4 \frac{1}{\mathcal{V}^2} \delta^4(k_3 + k_{\text{cls}} - k'_3 - k'_{\text{cls}}) \times \frac{1}{\sqrt{2\omega_3}} \frac{1}{\sqrt{2\omega'_3}} \frac{1}{\sqrt{2\omega_1}} \frac{1}{\sqrt{2\omega'_1}} \frac{1}{\sqrt{2\omega_2}} \frac{1}{\sqrt{2\omega'_2}} \times \int \frac{d^3q}{(2\pi)^3} F_{\text{cls}}(q) \frac{1}{q^{02} - \vec{q}^{\,2} - m_3^2 + i\epsilon} t_1 t_2,$$

The full three-body scattering:

$$S = -iT \frac{1}{\mathcal{V}^2}(2\pi)^4 \delta^4(k_3 + k_{\text{cls}} - k'_3 - k'_{\text{cls}}) \times \frac{1}{\sqrt{2\omega_3}} \frac{1}{\sqrt{2\omega'_3}} \frac{1}{\sqrt{2\omega_{\text{cls}}}} \frac{1}{\sqrt{2\omega'_{\text{cls}}}}.$$

Using the low energy reduction

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

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

we get:

$$T = T_1 + T_2 = \frac{\tilde{t}_1 + \tilde{t}_2 + 2\tilde{t}_1\tilde{t}_2 G_0}{1 - \tilde{t}_1\tilde{t}_2 G_0^2}.$$

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 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 $\vec{P}_{2(1)}$,

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

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

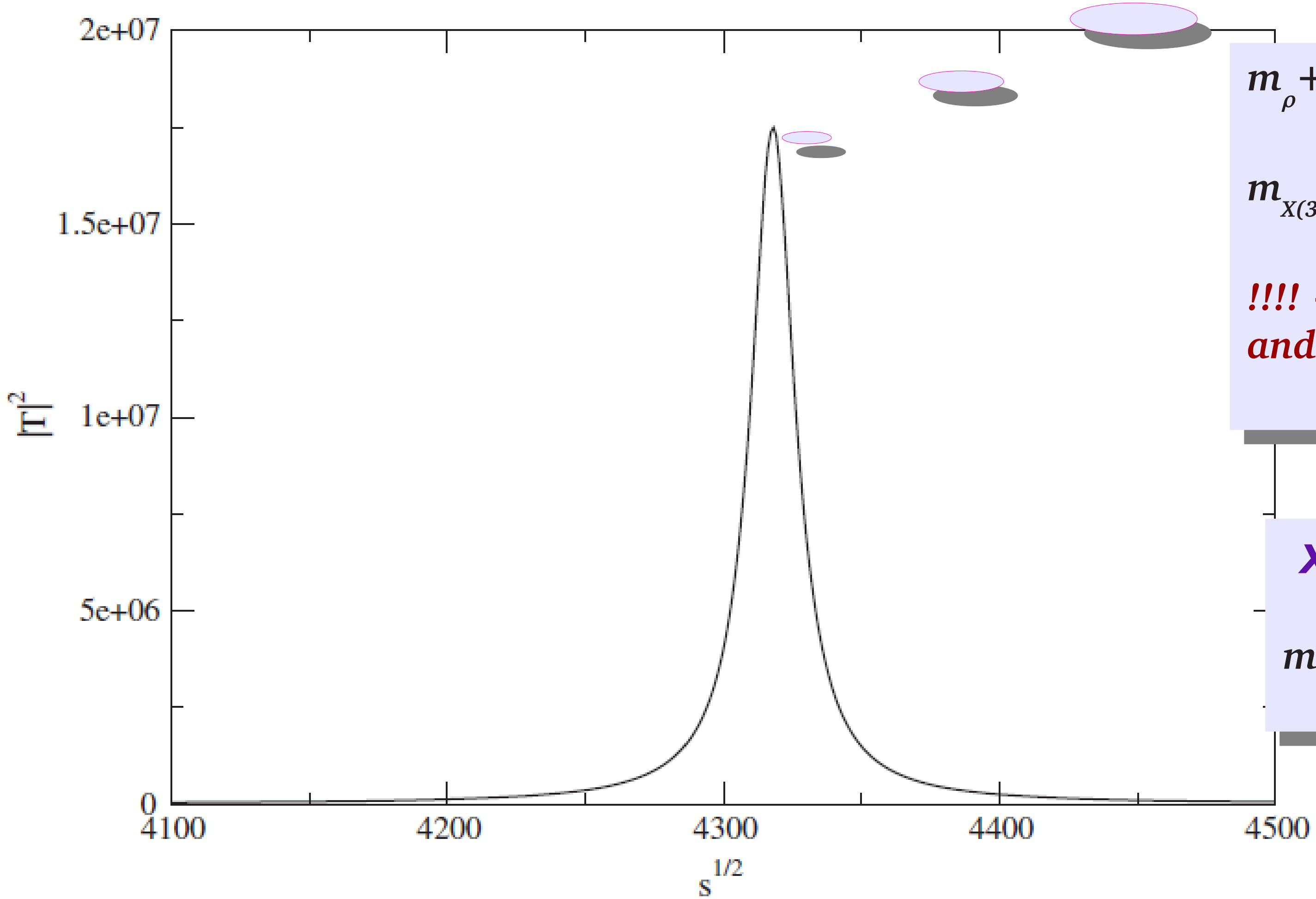


FIG. 2. Modulus squared of the $\rho(D\bar{D})_{X(3700)}$ scattering amplitude with total isospin $I = 1$.

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

$m_{X(3700)}+m_\rho\sim4475$ MeV

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

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

m~4361 MeV, Γ~74 MeV

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

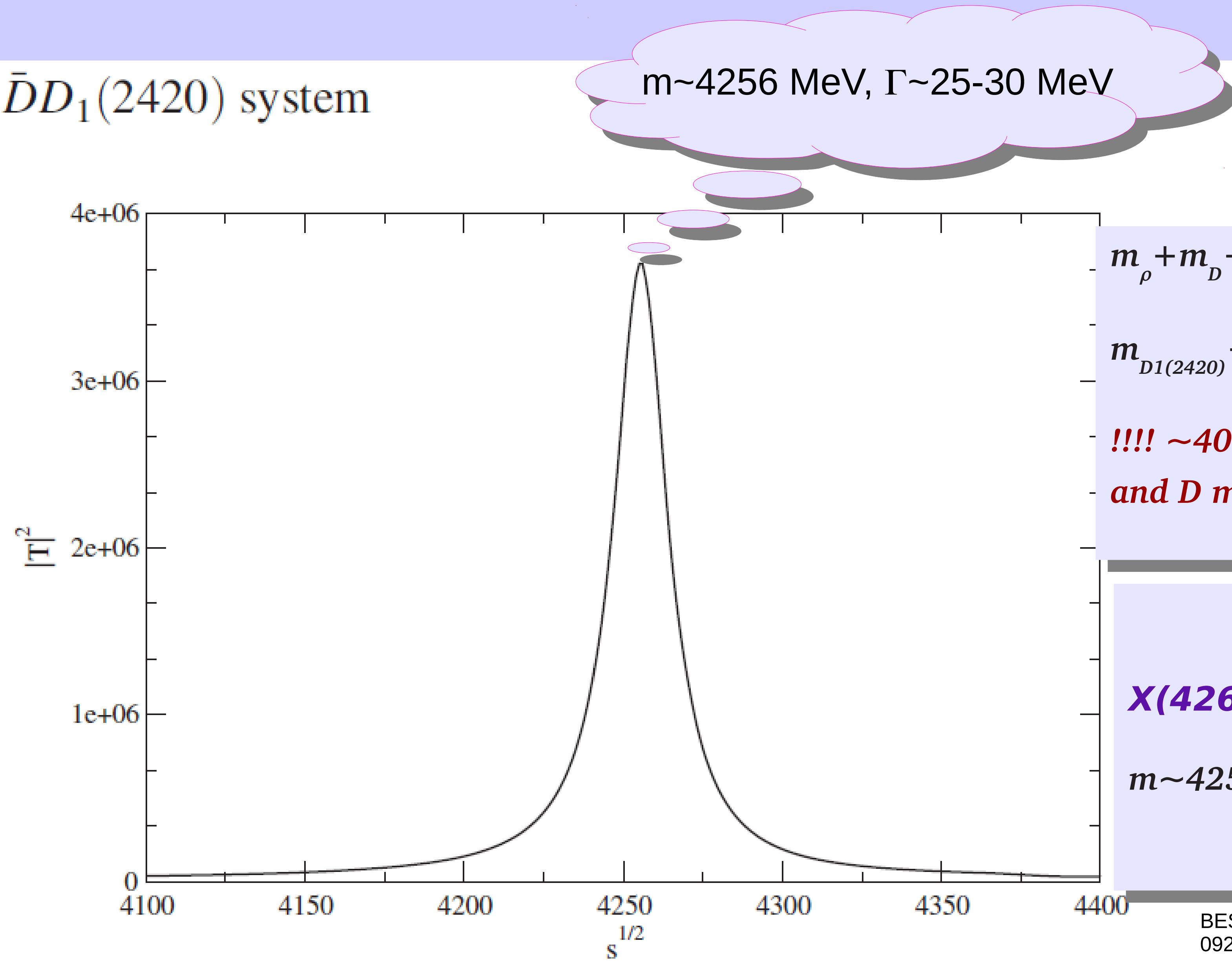


FIG. 3. Modulus squared of the $\bar{D}(\rho D)_{D_1(2420)}$ scattering amplitude with total isospin $I = 1$.

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

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

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

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

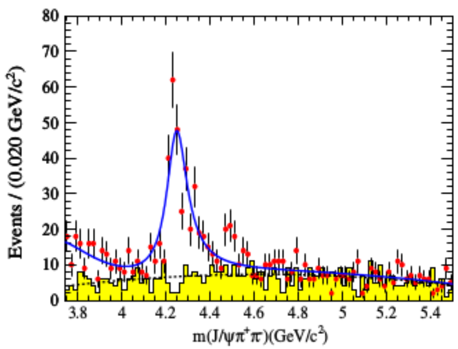
m~4251 MeV, Γ~44 MeV

BESIII, Phys.Rev.Lett. 118 (2017) no.9, 092001

(4) $e^+e^- \to \pi^+\pi^- J/\psi$, $\pi^+\pi^-\psi(2S)$, $\pi^+\pi^- h_c$ and the "Y" States

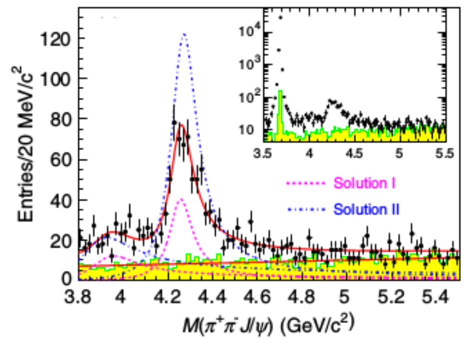
$e^+e^- \to \pi^+\pi^- J/\psi$ using ISR at BaBar

PRD 86, 051102(R) (2012)



$e^+e^- \to \pi^+\pi^- J/\psi$ using ISR at Belle

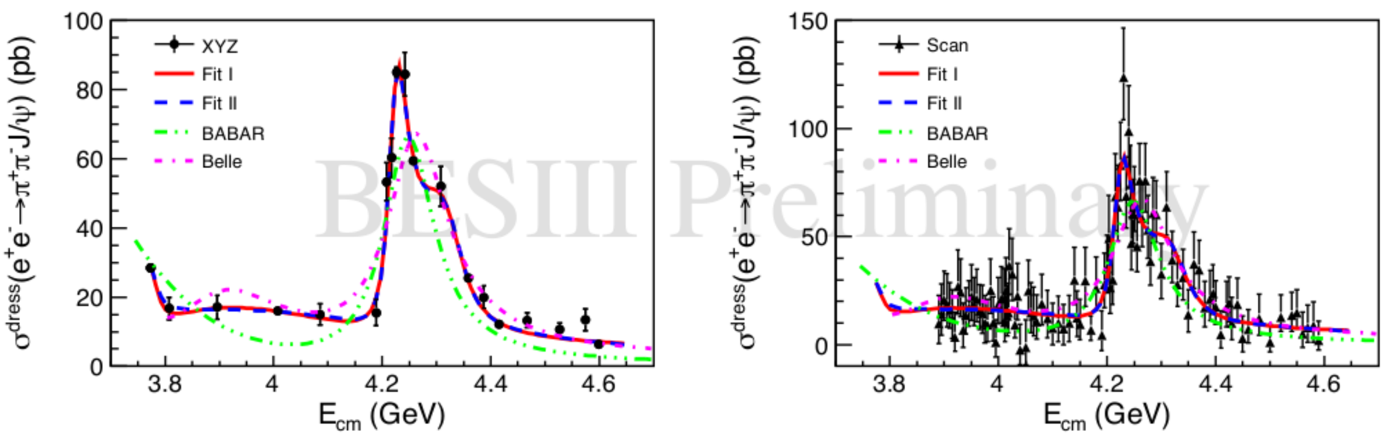
PRL 110, 252002 (2013)



⇒ asymmetric shape?
a low-mass peak ("Y(4008)")?

$e^+e^- \to \pi^+\pi^- J/\psi$ at BESIII (direct)

BESIII Preliminary (NEW!)



Conclusion 1: The cross section is inconsistent with a single peak for the Y(4260)!

Two peaks are favored over one peak by > 7σ.

Conclusion 2: The Y(4008) is not needed to describe the BESIII data.

Fit I with a wide low-mass Breit-Wigner is equivalent to
Fit II with an interfering non-resonant exponential shape.

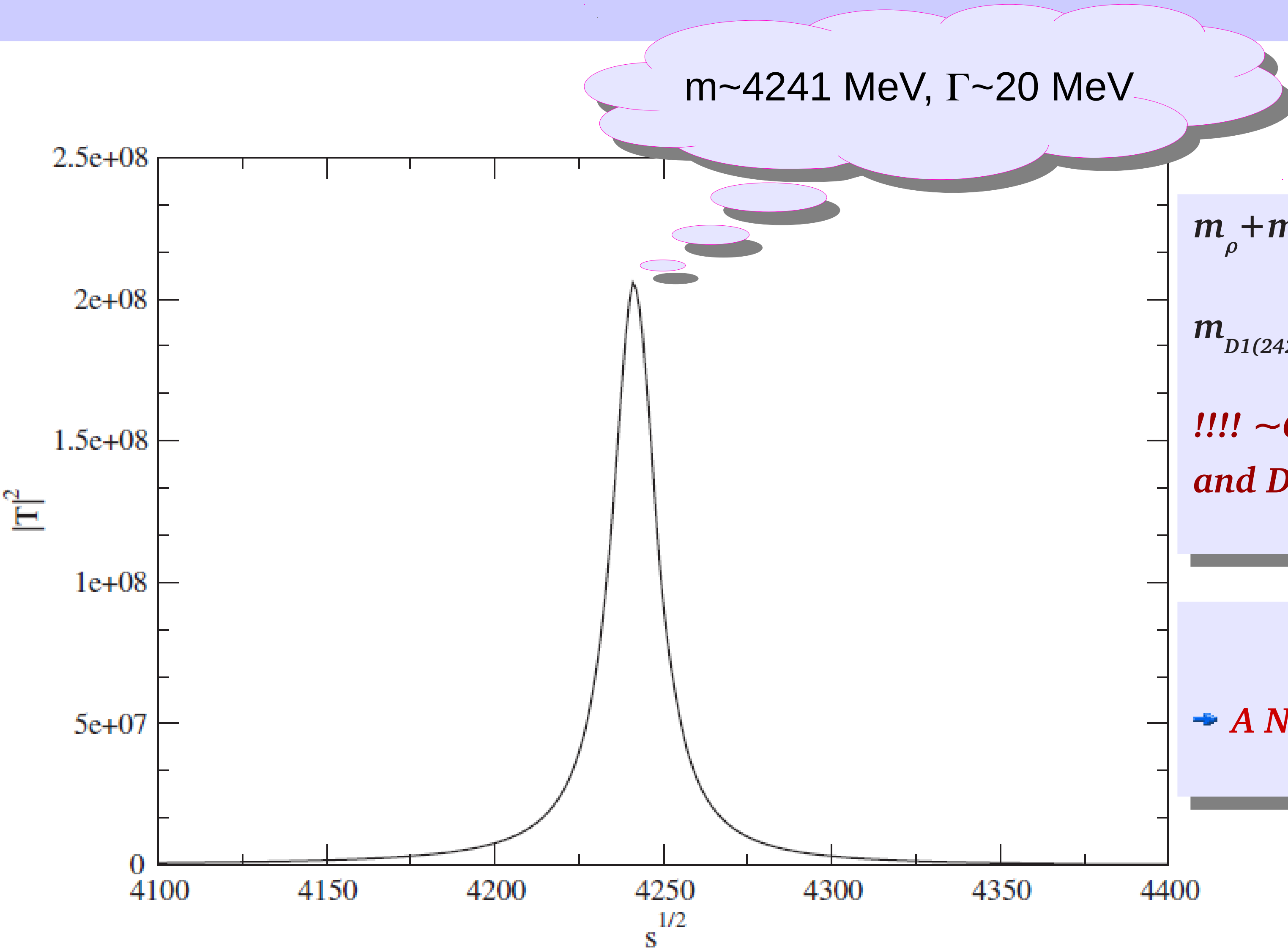


FIG. 4. Modulus squared of the $\bar{D}(\rho D)_{D_1(2420)}$ scattering amplitude with total isospin $I = 0$.

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

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

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

➨ ***A New State ....***

SUMMARY

- *We investigate the three-body systems of ρDD 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!