Baryon bound states of three hadrons with charm and hidden charm

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Outline

1. Introduction

2. Formalism

3. Results

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1. Introduction

The Faddeev equations under the Fixed Center Approximation (FCA) is an effective tool to deal with multi-hadron interaction, seen in:

[1] L. Roca and E. Oset, Phys. Rev. D 82, 054013(2010).
[2] J. Yamagata-Sekihara, L. Roca and E. Oset, Phys. Rev. D 82, 094017 (2010).
[3] J. J. Xie, A. Martinez Torres, E. Oset and P. Gonzalez, Phys. Rev. C 83, 055204 (2011).

Three body system with charm has not been explored. We take KbarDN, KDN, NDK and NDDbar systems for our investigation.

?Why

2. Formalism

The idea of FCA:

1) There is a cluster of two bound particles;

2) Third particle interacts with cluster.

Known two body clusters:

1) KD+coupled channels--->D^*_{s0}(2317)

[1] J. Hofmann, M. F. M. Lutz, Nucl. Phys. A733, 142-152 (2004)
[2] F. -K. Guo, P. -N. Shen, H. -C. Chiang, R. -G. Ping, Phys. Lett. B641, 278-285 (2006).
[3] D. Gamermann, E. Oset, D. Strottman, M. J. Vicente Vacas, Phys. Rev. D76, 074016 (2007).

2) DN+coupled channels--->$\Lambda_c(2595)$

[1] J. Hofmann, M. F. M. Lutz, Nucl. Phys. A763, 90-139 (2005).
[2] T. Mizutani, A. Ramos, Phys. Rev. C74, 065201 (2006).
[3] L. Tolos, A. Ramos, T. Mizutani, Phys. Rev. C77, 015207 (2008).
[4] C. Garcia-Recio, V. K. Magas, T. Mizutani, J. Nieves, A. Ramos, L. L. Salcedo, L. Tolos, Phys. Rev. D79, 054004 (2009).

3) DDbar+coupled channels--->Hypothetical X(3700)

[1] D. Gamermann, E. Oset, D. Strottman, M. J. Vicente Vacas, Phys. Rev. D76, 074016 (2007).

Possible structures:

- N-KD
- K-DN
- Kbar-DN
- N-DDbar

Example N-DK--->one needs t_1 for ND, t_2 for NK.

The amplitudes t_1 and t_2 are represented in diagrams of the Bethe-Salpeter equation.

$$T = V + VGT$$

t_1

t_2

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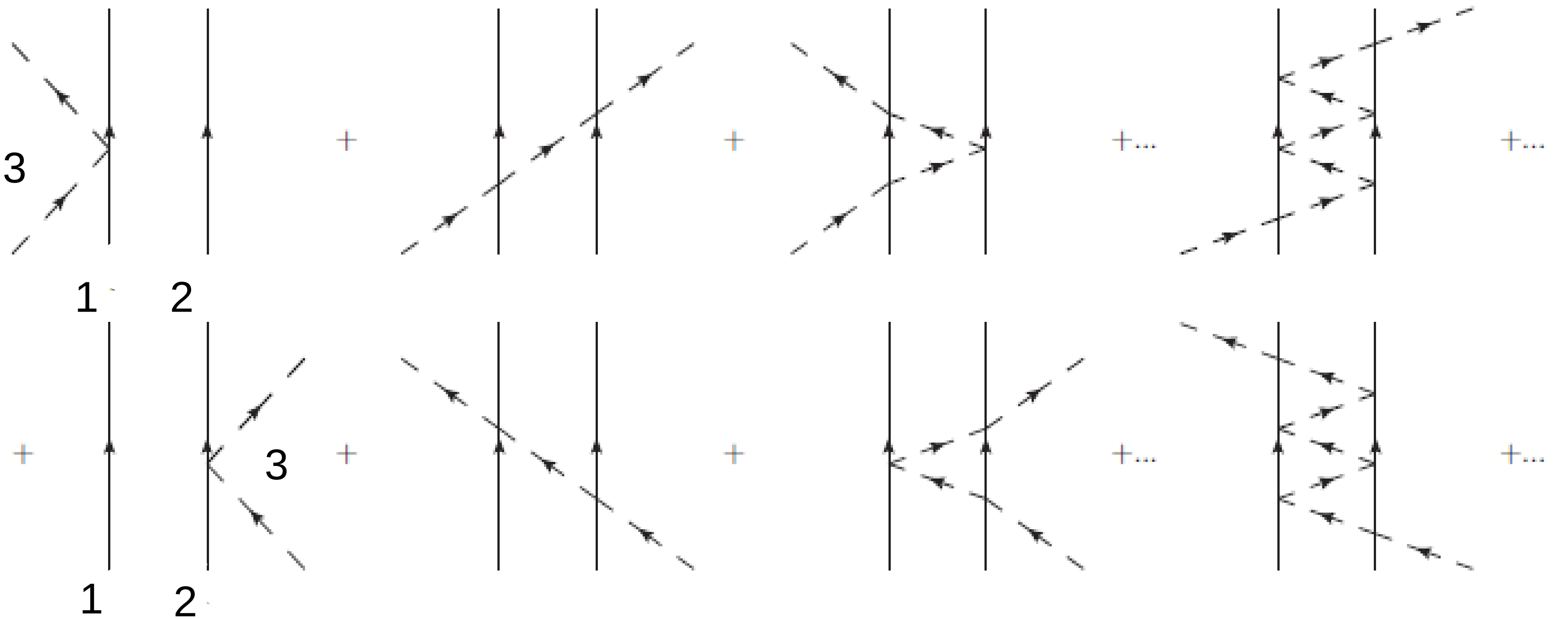
The FCA is represented in diagrams:



This is summed in terms of partitions T_1 and T_2.

T_1: all diagrams beginning with interaction in particle 1.

T_2: all diagrams beginning with interaction in particle 2.

The FCA to Faddeev equations for the three body interaction system read

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

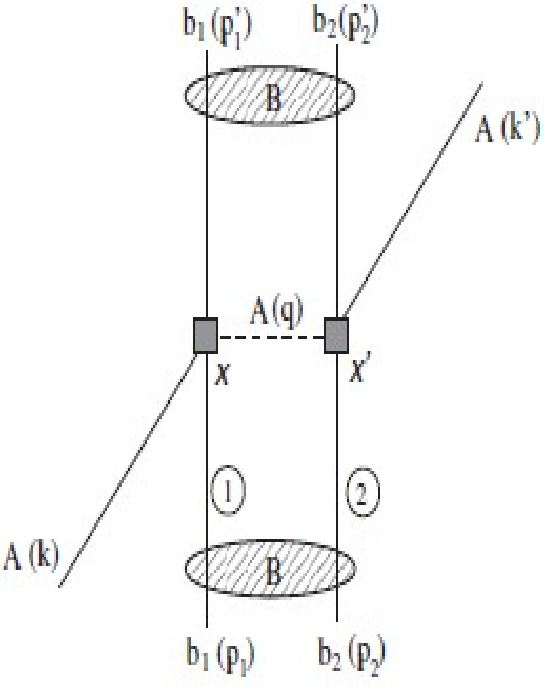
$$\Rightarrow \quad T = \frac{\tilde{t}_1 + \tilde{t}_2 + 2\,\tilde{t}_1\,\tilde{t}_2\,G_0}{1 - \tilde{t}_1\,\tilde{t}_2\,G_0^2},$$

We must take into account the isospin structure of the cluster for the t_1 and t_2 amplitudes.

$$t_1 = \frac{3}{4}\ t_{31}^{I=1} + \frac{1}{4}\ t_{31}^{I=0},$$
$$t_2 = \frac{3}{4}\ t_{32}^{I=1} + \frac{1}{4}\ t_{32}^{I=0},$$

Besides, there are weight factors for normalization of these amplitudes to make the normalization the same for mesons and baryons. For the KbarDN and KDN systems, we have

$$\tilde{t_1} = \frac{1}{2m_1}\ t_1, \qquad \tilde{t_2} = t_2,$$



In the NDK and NDDbar systems, we get

$$\tilde{t_1} = \frac{2m_R}{2m_1}\ t_1, \qquad \tilde{t_2} = \frac{2m_R}{2m_2}\ t_2,$$

Now, in the first two cases, the loop function $G_0(s)$ is given by

$$G_0(s) = \int \frac{d^3\vec{q}}{(2\pi)^3} F_R(q) \frac{1}{q^{02} - \vec{q}^{\ 2} - m_3^2 + i\ \epsilon},$$

For the last two cases, $G_0(s)$ read

$$G_0(s) = \frac{1}{2m_R} \int \frac{d^3\vec{q}}{(2\pi)^3} F_R(q) \frac{m_3}{E_3(\vec{q})} \frac{1}{q^0 - E_3(\vec{q}) + i\ \epsilon}.$$

where F_R (q) is the form factor of the cluster of particles 1 and 2, given by

$$F_R(q) = \frac{1}{\mathcal{N}} \int_{|\vec{p}|<\Lambda, |\vec{p}-\vec{q}|<\Lambda} d^3\vec{p} \frac{1}{2E_1(\vec{p})} \frac{1}{2E_2(\vec{p})} \frac{1}{M_R - E_1(\vec{p}) - E_2(\vec{p})}$$

$$\frac{1}{2E_1(\vec{p}-\vec{q})} \frac{1}{2E_2(\vec{p}-\vec{q})} \frac{1}{M_R - E_1(\vec{p}-\vec{q}) - E_2(\vec{p}-\vec{q})},$$

$$\mathcal{N} = \int_{|\vec{p}|<\Lambda} d^3\vec{p} \left(\frac{1}{2E_1(\vec{p})} \frac{1}{2E_2(\vec{p})} \frac{1}{M_R - E_1(\vec{p}) - E_2(\vec{p})}\right)^2,$$

[1] J. Yamagata-Sekihara, L. Roca and E. Oset, Phys. Rev. D 82, 094017 (2010).

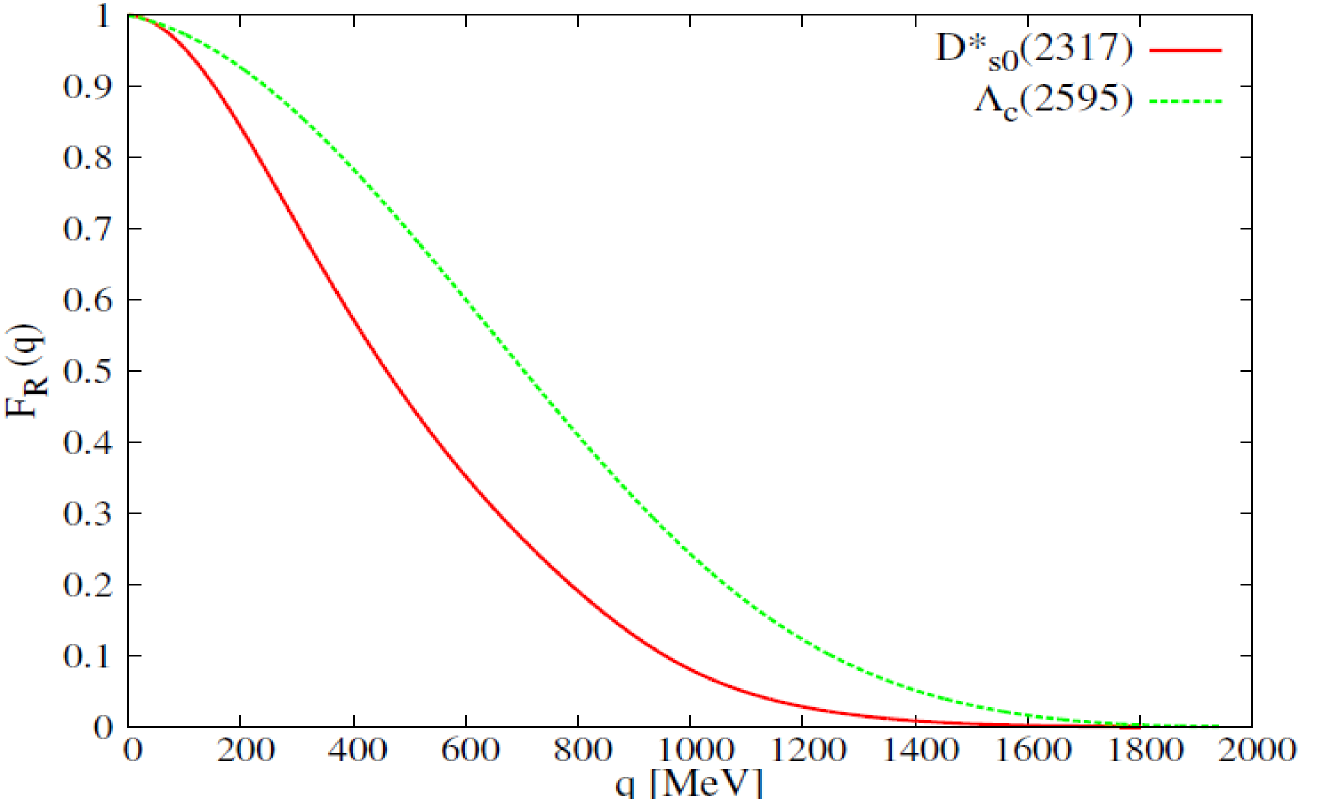
Λ is cut off needed to regularize loops in the study of the cluster in the unitary approach.

N normalization factor to make F_R(**q**=0)=1.

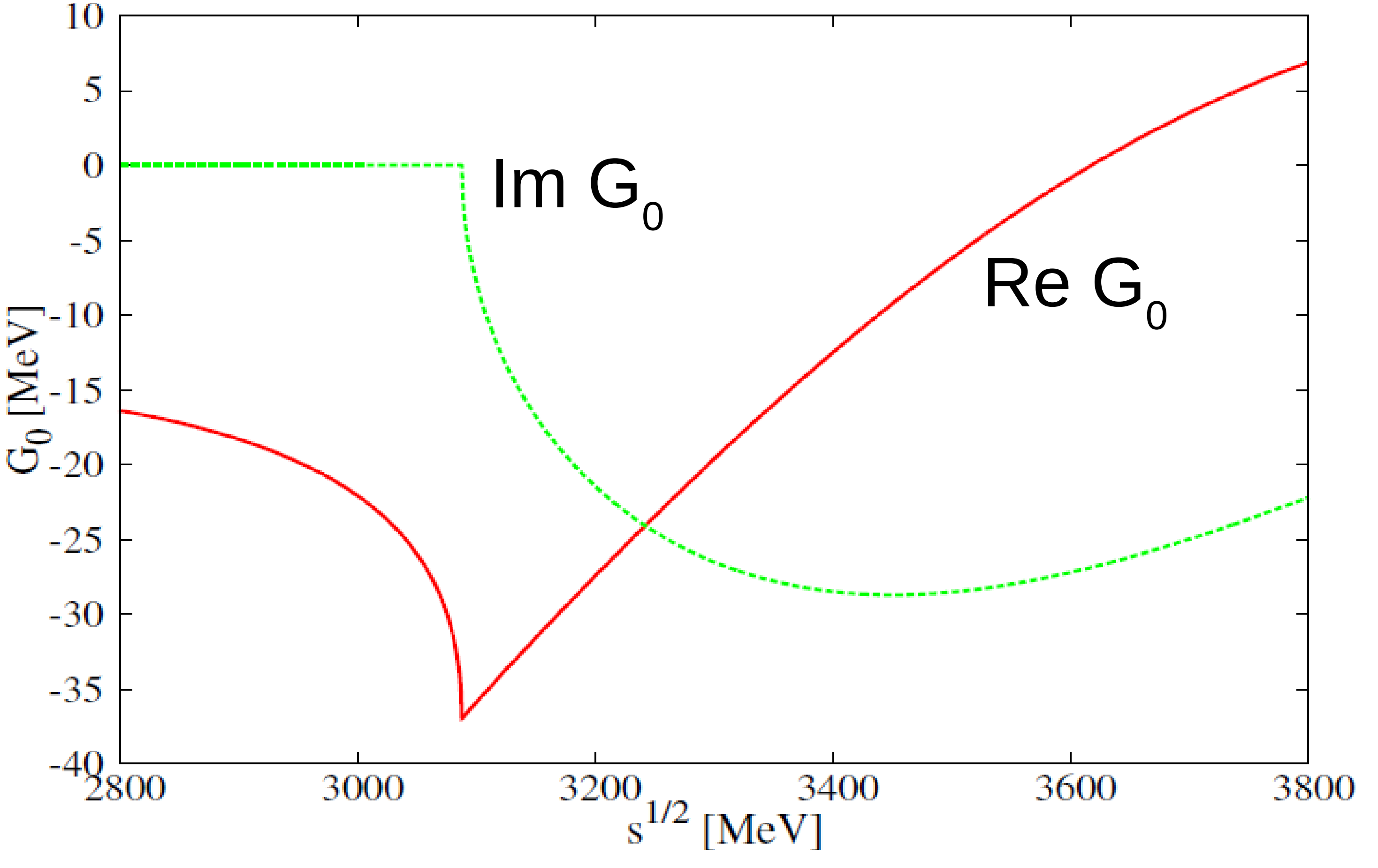
3. Results

(1) The case of KbarDN interaction

Form factors for $D^*_{s0}(2317)$ and $\Lambda_c(2595)$:



In the next step we evaluate G_0



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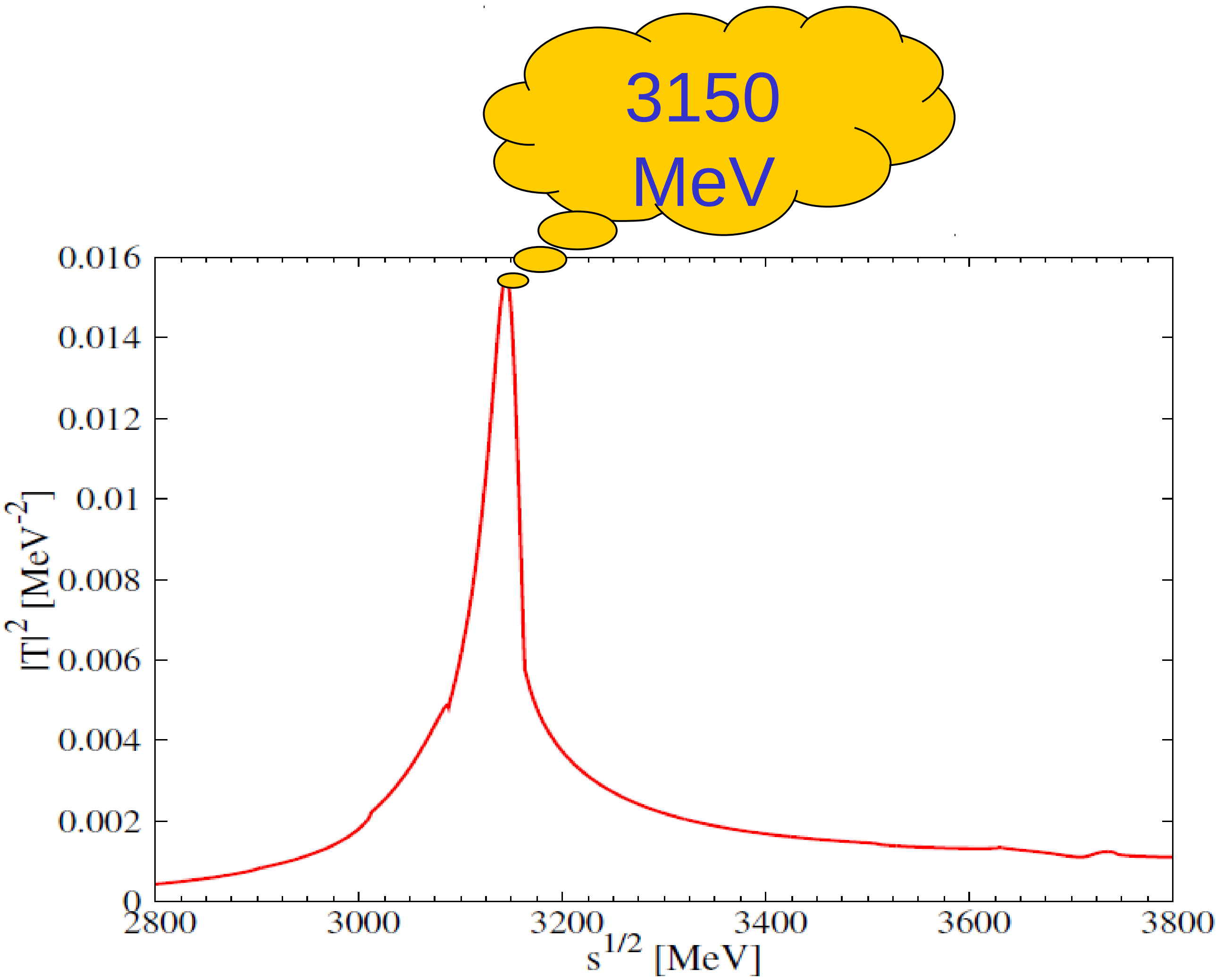
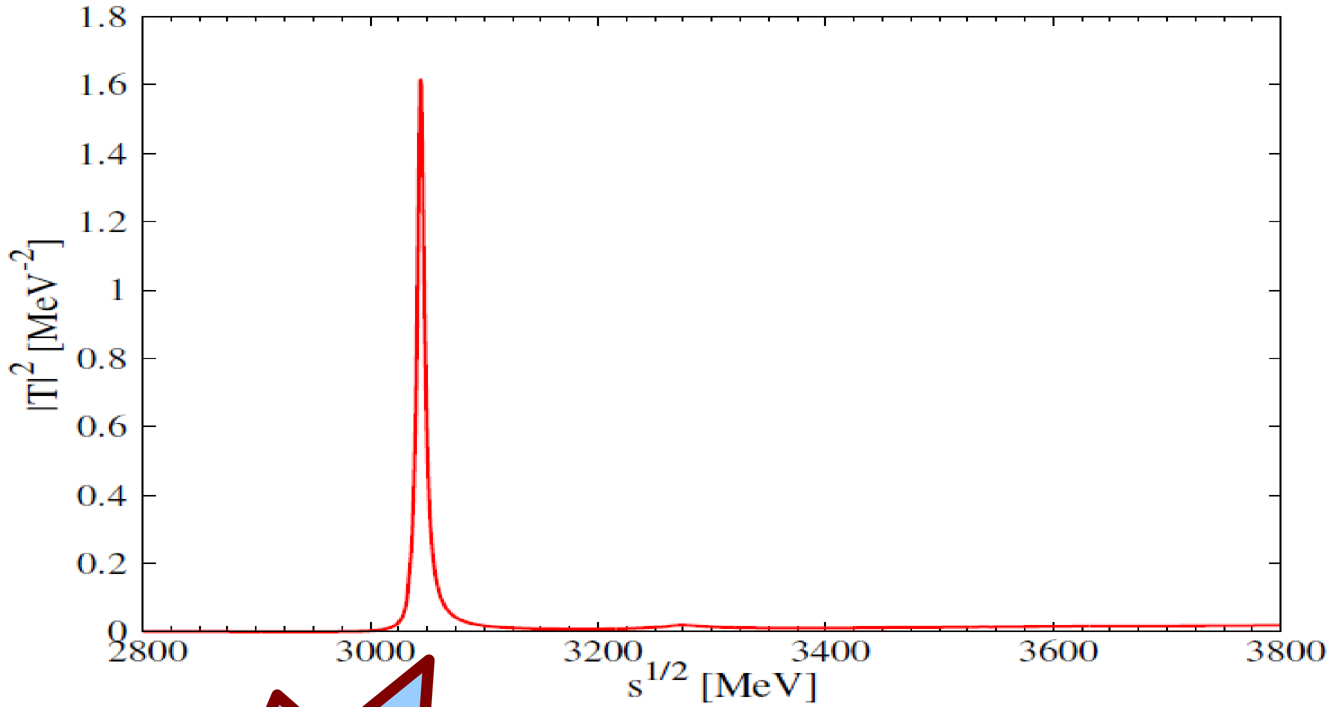
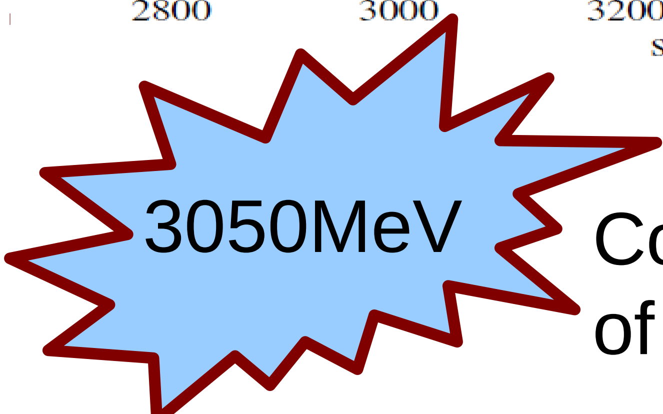
Finally we get the total scattering amplitude T of the Kbar DN interaction, shown as



(2) The N DK system





Corresponds to an exotic state of positive strangeness.

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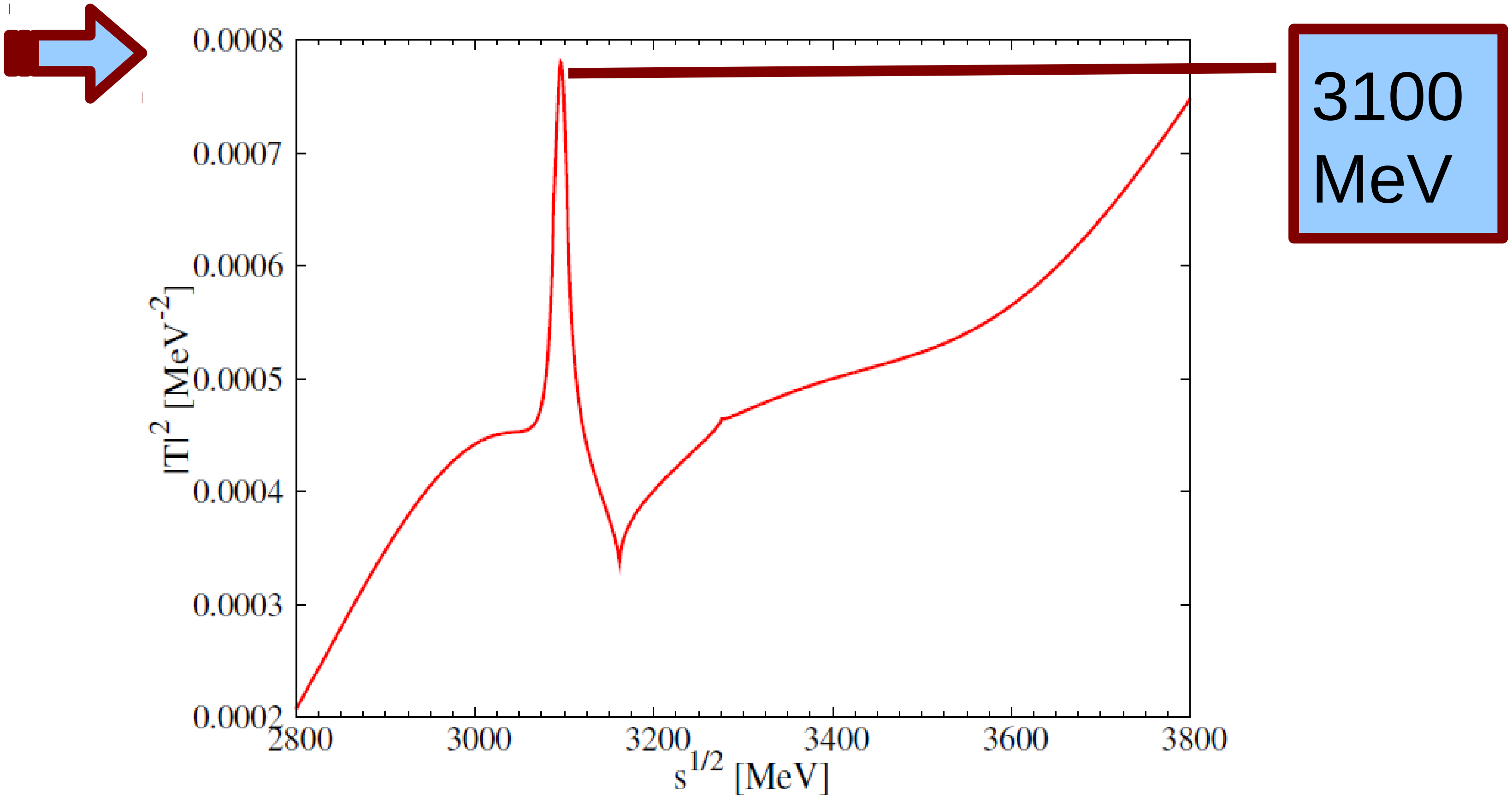
(3) The K DN system



Irrelevant, strength very small compared to NDK configuration. So it is not a relevant configuration.

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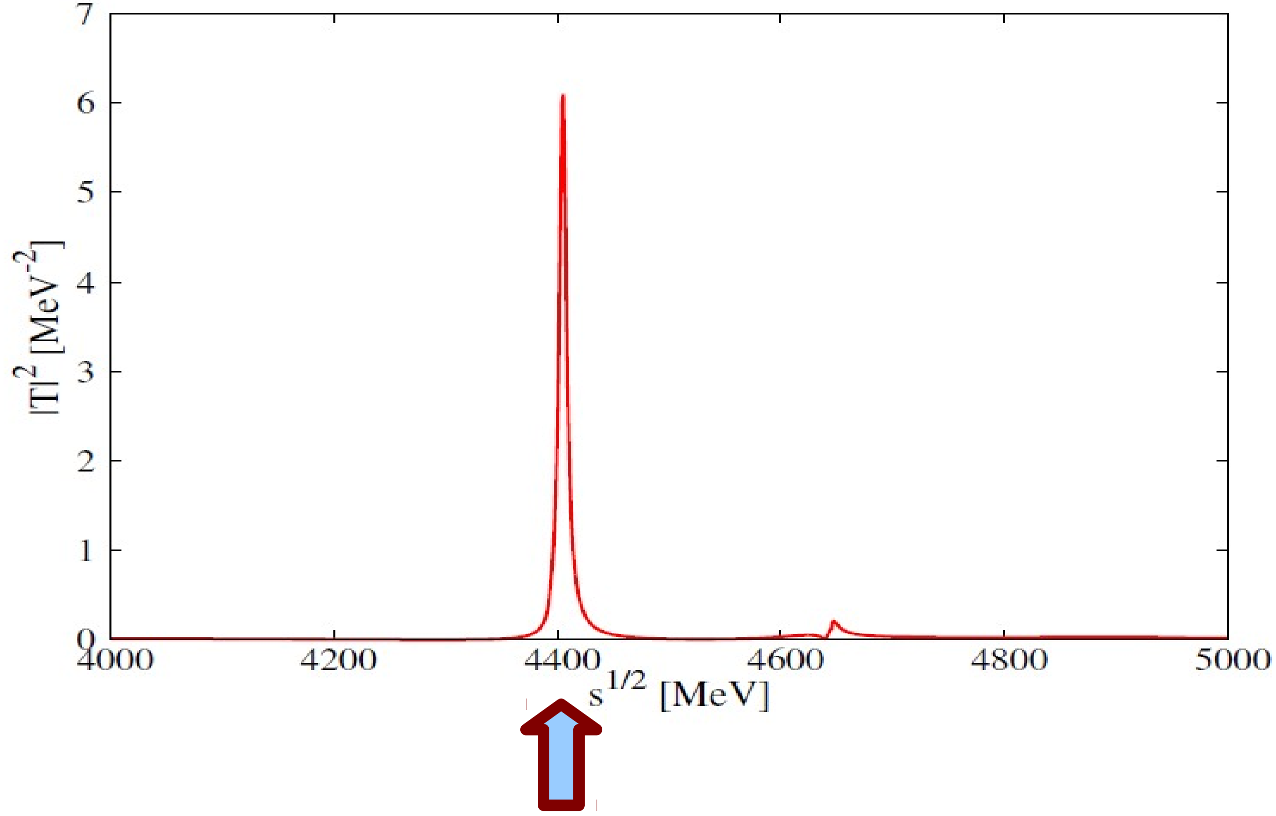
(4) The N DDbar interaction



This would be a hidden charm baryon state of positive parity. Analogies to NKKbar system at 1920 MeV([1] D. Jido and Y. Kanada-En'yo, Phys. Rev. C 78, 035203 (2008). [2] A. Martinez Torres, K. P. Khemchandani, U. G. Meißner, and E. Oset, Eur. Phys. J. A 41, 361 (2009). [3] A. Martinez Torres and D. Jido, Phys. Rev. C 82, 038202 (2010).).

4. Conclusion

We have investigated these three body systems, as KbarDN , N DK (K DN) and N DDbar. In all cases we find bound or quasibound states:

1) Kbar DN system, S=-1, C=1 : at 3150 MeV;
2) N DK system, S=1, C=1 : at 3050 MeV, Exotic;
3) N DDbar system, S=0,C=0 : at 4400 MeV, Hidden charm.

And all of them are $J^P = 1/2^+$ states.

Call for independent calculations.

Call for measurement in future Facilities of FAIR, or the BELLE upgrade.

Thank you