MULTIPLE CHARM AND HIDDEN CHARM MESONS WITH STRANGENESS

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INTRODUCTION

Present understanding of QCD:

Doubly charmed mesons and baryons T_{cc}, Ξ_{cc}^{+}, Ξ_{cc}^{++}, Ω_{cc}^{+}

Triple charm meson-baryon and baryon-baryon states

$$\Xi_{cc}D,\ \Xi_{cc}D^* \quad \Xi_{cc}\Lambda_c,\ \Xi_{cc}\Sigma_c$$

Three-body states with double/triple charm/bottom,

$$BD\bar{D}, BDD, BBB^*$$

Doubly charmed and single strangeness three-body states

“Now that we all agree on the agenda, a show of hands on how many want to keep it hidden.”

M. Mattson et al., PRL89, 112001 (2002);
S. Zouzou, et al., Z. Phys. C30, 457 (1986).
R. Chen, A. Hosaka, and X. Liu, PRD96,114030 (2017), PRD97,114011(2018)
J. M. Dias et al., PRD96, 094007 (2017).
L. Ma, Q. Wang, U. G. Meissner, Chin. Phys. C43, 014012 (2019).
M. Sanchez, L. S. Geng, J. X. Lu, et al., PRD98, 054001 (2018).

INTRODUCTION

There is lot of Work to do!

Particle Data Group:

$K(3100)$

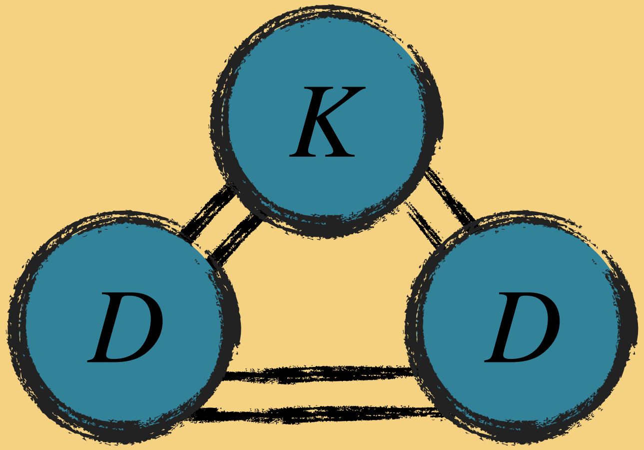
vast unexplored

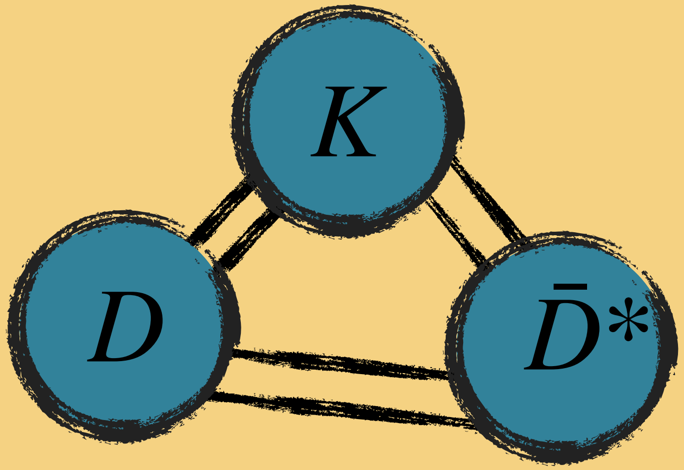
energy region

There are no experimental data available on Heavy K or K^* mesons!

$$B \to J/\psi K\pi\pi$$

INTRODUCTION





$D - D_{s0}^*(2317)$

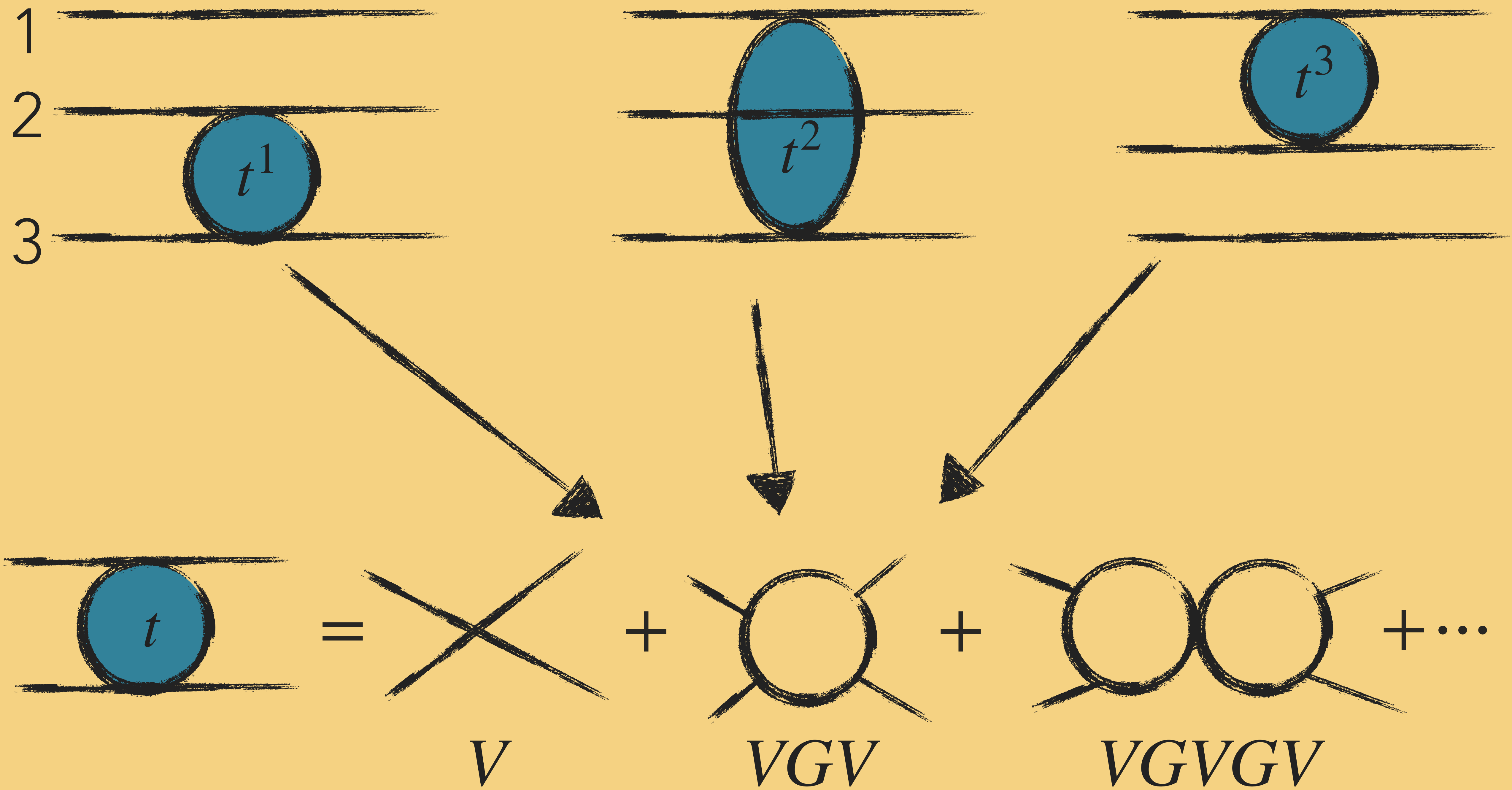
$D\bar{D}^*K$

Kaon Exchange Potential
Isospin 0, 15-50 MeV

Pion Exchange Potential
~ 4318 MeV

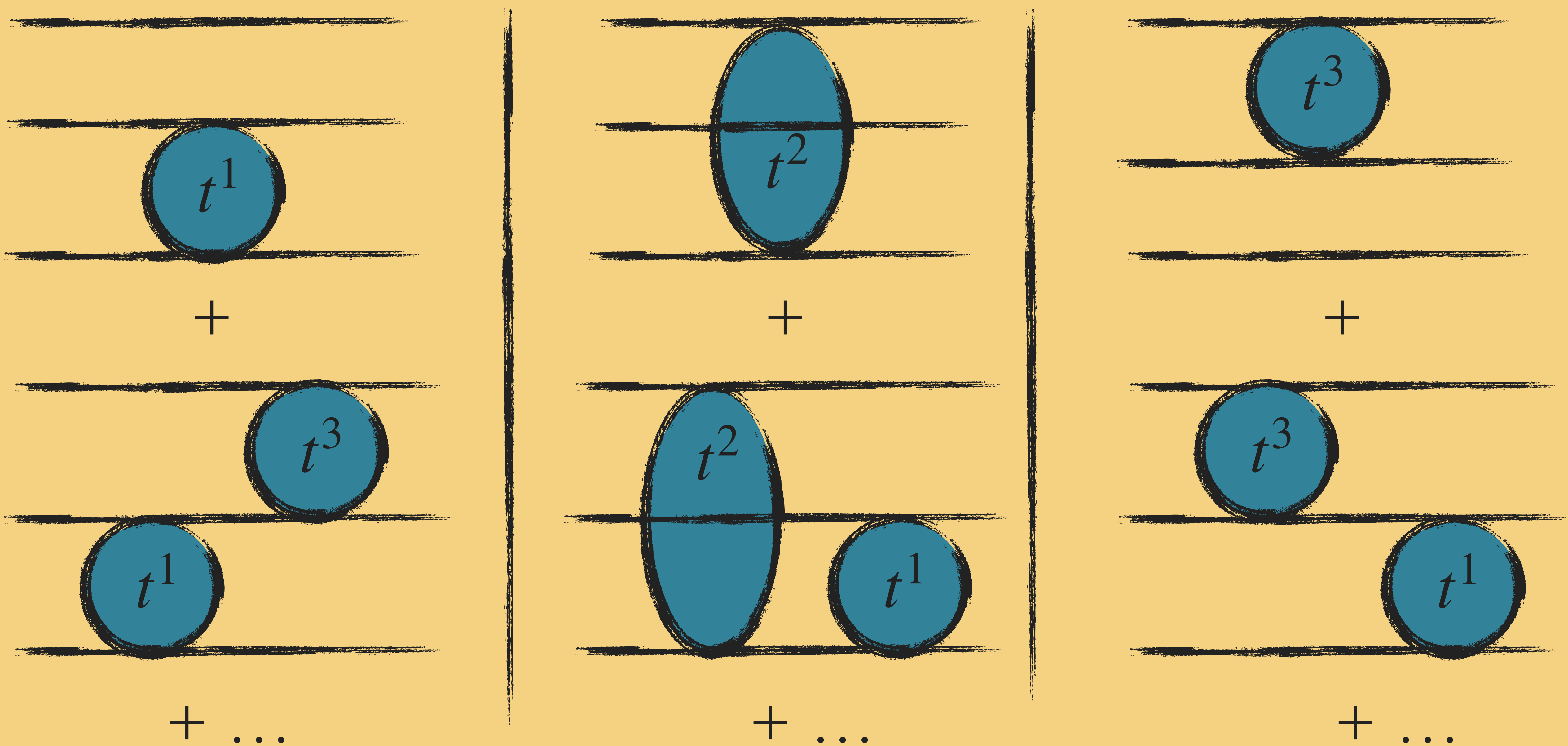
M. Sanchez, L. S. Geng, J. X. Lu, Hyodo, Valderrama, PRD98, 054001 (2018).
L. Ma, Q. Wang, U. G. Meissner, Chin. Phys. C43, 014012 (2019).

FORMALISM

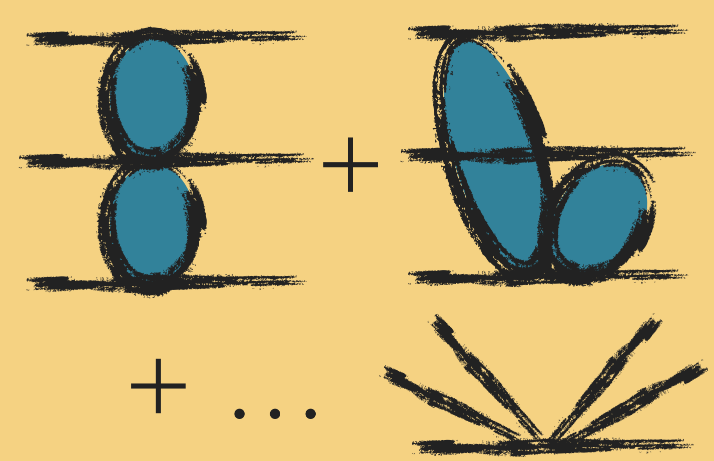


$$t = V + VGt = [1 - VG]^{-1}V$$

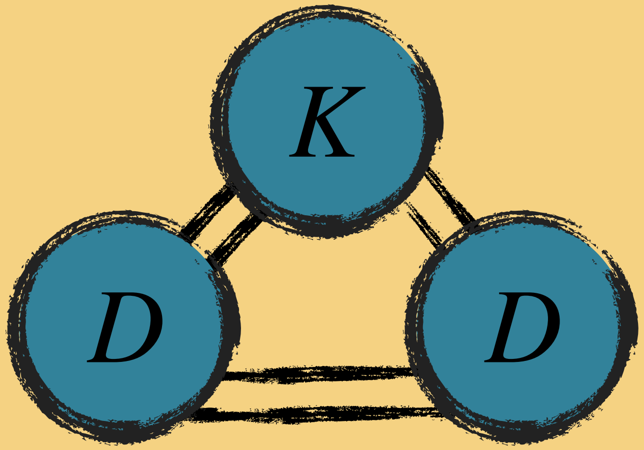
FORMALISM



$$
\left.
\begin{aligned}
T^1 &= t^1 + t^1 G(T^2 + T^3) \\
T^2 &= t^2 + t^2 G(T^1 + T^3) \\
T^3 &= t^3 + t^3 G(T^1 + T^2)
\end{aligned}
\right\}
$$



FORMALISM

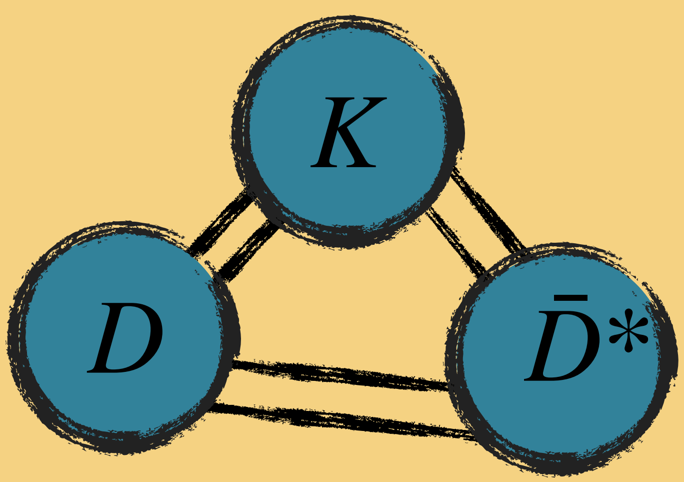


$DK,\ D_s\eta,\ D_s\pi \longrightarrow D^*_{s0}(2317)$

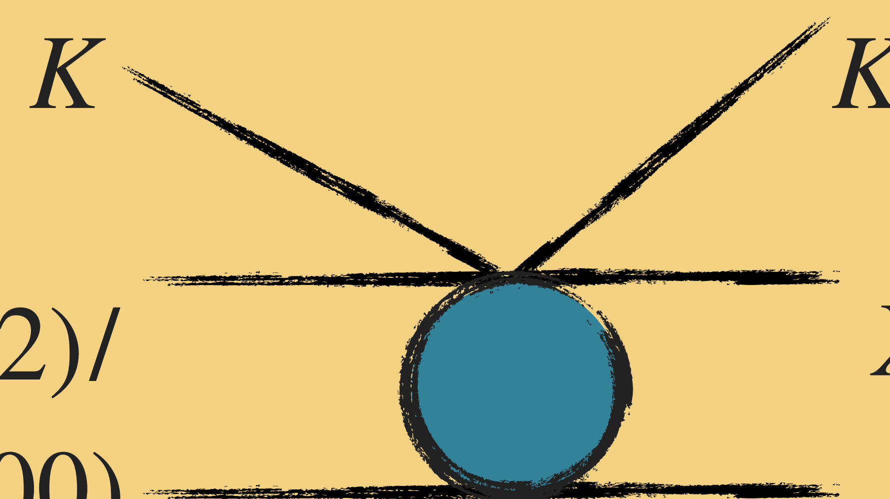
DD, DD_s $\longrightarrow$ Vector meson exchange t, u channels

$DDK,\ DD_s\eta,\ DD_s\pi$

Dimensional regularization



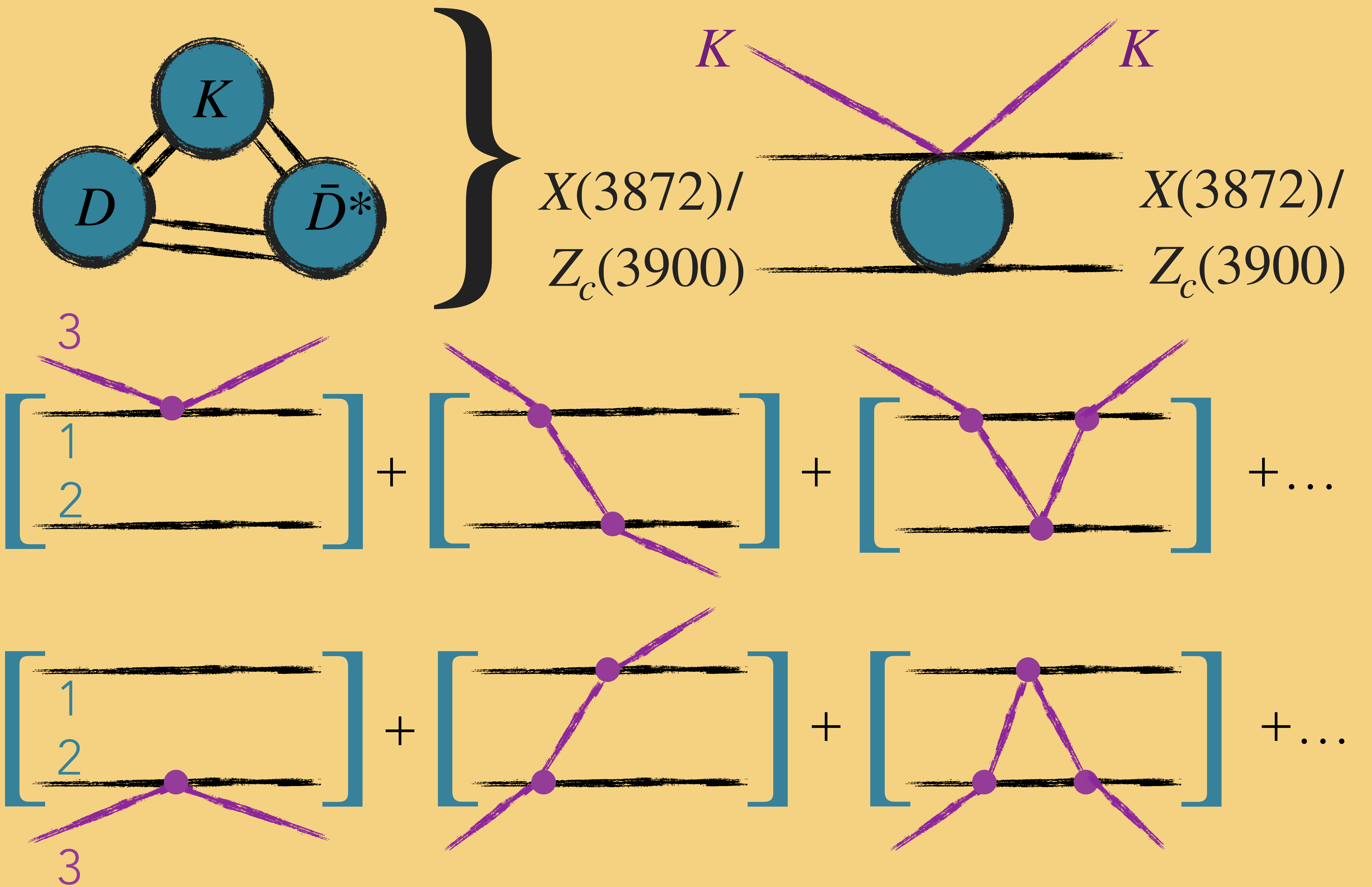
$X(3872)/$
$Z_c(3900)$



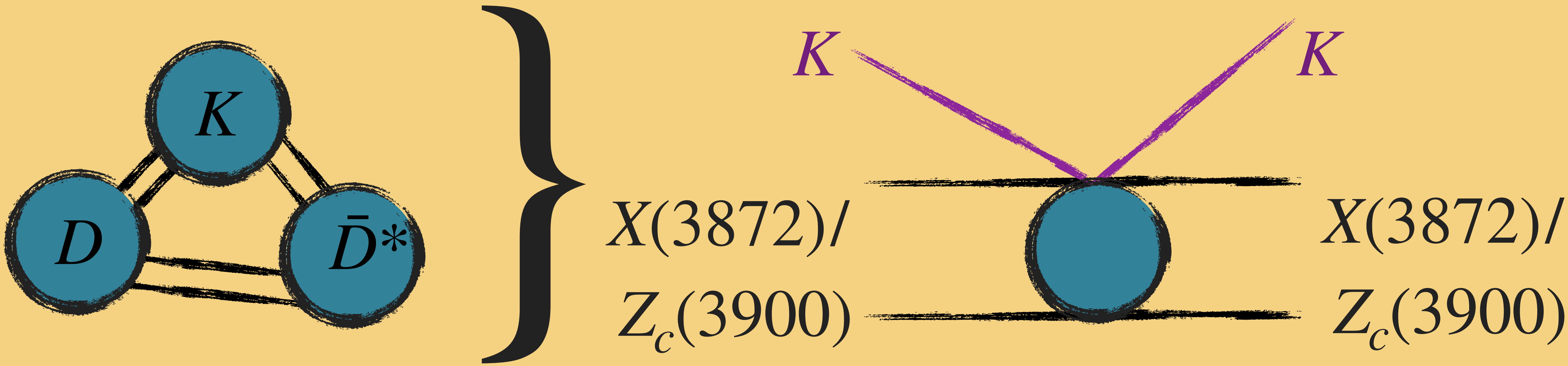
$X(3872)/$
$Z_c(3900)$

F. K. Guo, P. N. Shen et al., PLB641, 278 (2006); D. Gamermann, E. Oset, D. Strottman, M. J. Vicente Vacas, PRD76, 074016 (2007)
S. Sakai, L. Roca. E. Oset, PRD96, 054023 (2017).

FORMALISM



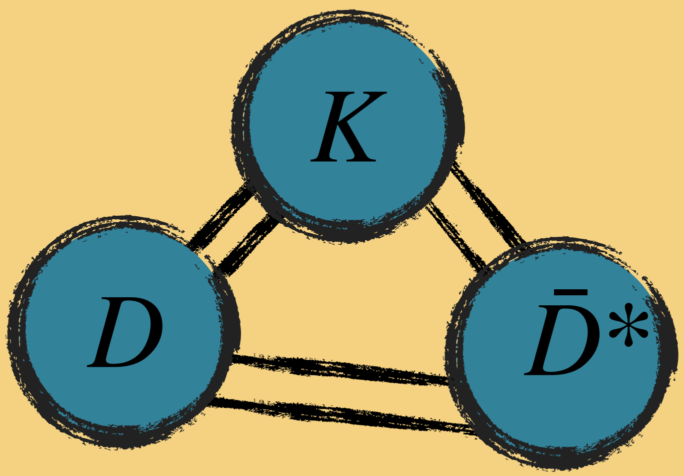
FORMALISM



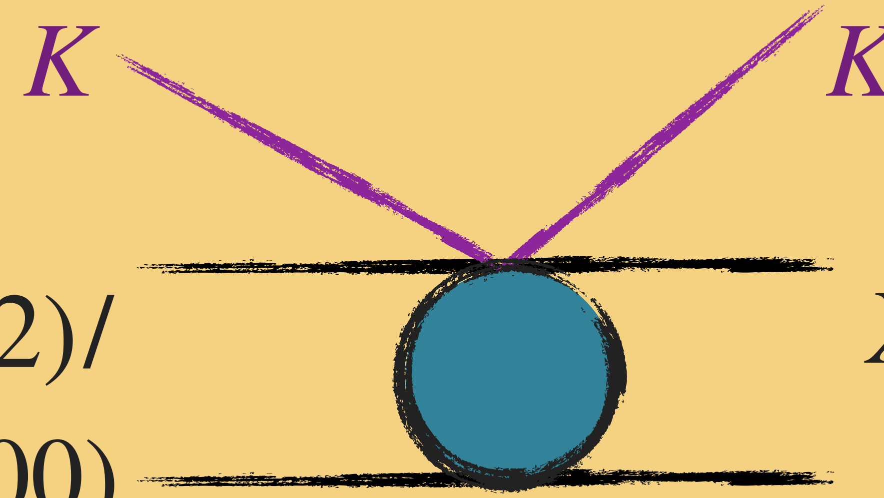
$$T_{31} = t_{31} + t_{31} G T_{32}$$
$$T_{32} = t_{32} + t_{32} G T_{32}$$

$$|KX; 1/2, 1/2\rangle = |K^+; 1/2, 1/2\rangle \otimes |D\bar{D}^*; 0, 0\rangle = \left| I_z^K = \frac{1}{2} \right\rangle \otimes \left[\left| I_z^D = \frac{1}{2}, I_z^{\bar{D}^*} = -\frac{1}{2} \right\rangle - \left| I_z^D = -\frac{1}{2}, I_z^{\bar{D}^*} = \frac{1}{2} \right\rangle \right]$$

FORMALISM



$$\left.\right\}$$ $X(3872)/$ $Z_c(3900)$



$X(3872)/$ $Z_c(3900)$

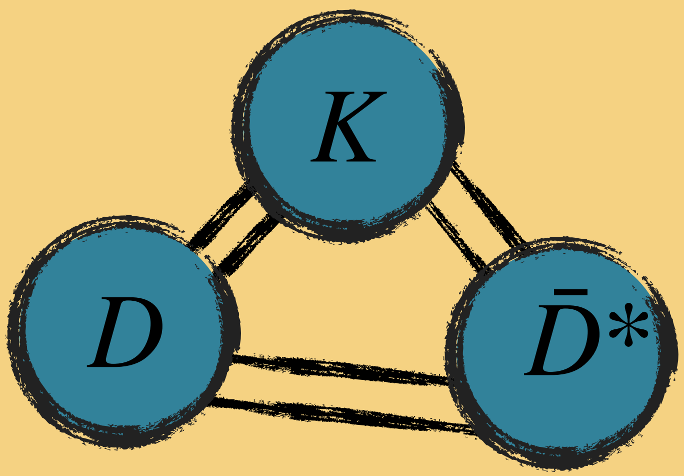
$$T_{31} = t_{31} + t_{31} G T_{32}$$

$$T_{32} = t_{32} + t_{32} G T_{32}$$

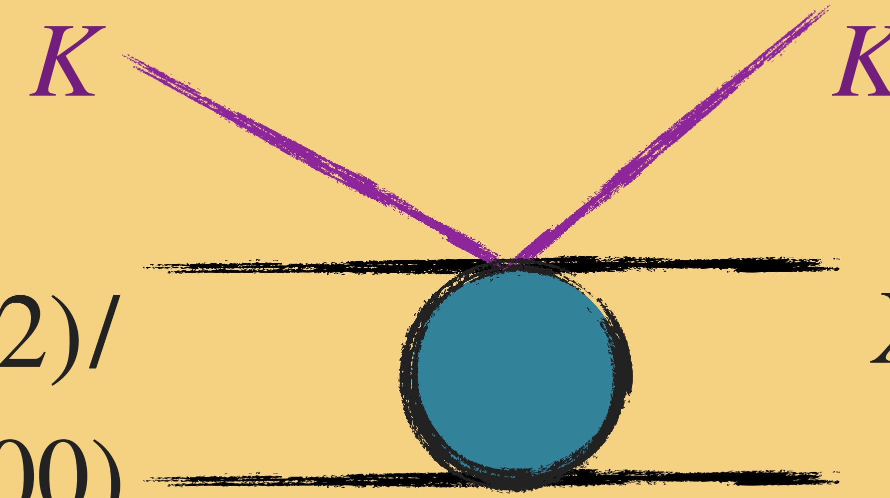
$$t_{31} = \begin{bmatrix} (t_{31})_{11} & (t_{31})_{12} \\ (t_{31})_{21} & (t_{31})_{22} \end{bmatrix} \qquad t_{32} = \begin{bmatrix} (t_{32})_{11} & (t_{32})_{12} \\ (t_{32})_{21} & (t_{32})_{22} \end{bmatrix}$$

$$(t_{31})_{12} = \frac{\sqrt{M_X M_Z}}{m_D} \frac{\sqrt{3}}{4} (t^{I=1}_{KD} - t^{I=0}_{KD}) \qquad (t_{32})_{12} = -\frac{\sqrt{M_X M_Z}}{m_{\bar{D}^*}} \frac{\sqrt{3}}{4} (t^{I=1}_{K\bar{D}^*} - t^{I=0}_{K\bar{D}^*})$$

FORMALISM



$X(3872)/$
$Z_c(3900)$



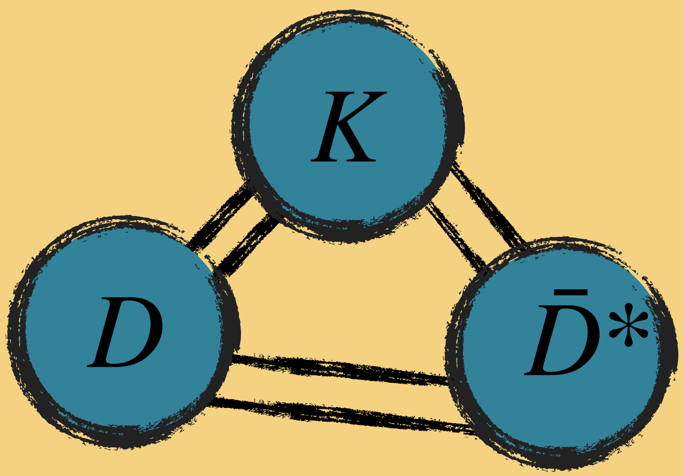
$X(3872)/$
$Z_c(3900)$

$$T_{31} = t_{31} + t_{31} G T_{32}$$
$$T_{32} = t_{32} + t_{32} G T_{32}$$

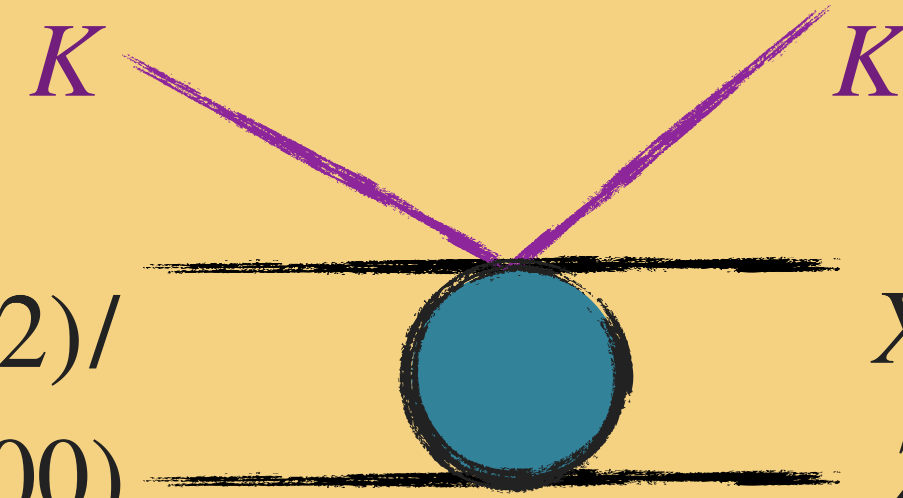
$$\langle K C_a; I, I_z | G_0 | K C_a; I, I_z \rangle$$
$$= \frac{1}{2M_a} \int \frac{d^3\boldsymbol{q}}{(2\pi)^3} \frac{F_a(\boldsymbol{q})}{q^{0\,2} - \boldsymbol{q}^2 - m_K^2 + i\epsilon}$$

$$F_a(\boldsymbol{q}) = \frac{1}{\mathcal{N}} \int_{|\boldsymbol{p}|,\ |\boldsymbol{p}-\boldsymbol{q}|<\Lambda} d^3\boldsymbol{p}\, f_a(\boldsymbol{p}) f_a(\boldsymbol{p}-\boldsymbol{q}),$$
$$f_a(\boldsymbol{p}) = \frac{1}{\omega_D(\boldsymbol{p})\omega_{\bar{D}^*}(\boldsymbol{p})} \frac{1}{M_a - \omega_D(\boldsymbol{p}) - \omega_{\bar{D}^*}(\boldsymbol{p})},$$

FORMALISM



$X(3872)/$
$Z_c(3900)$

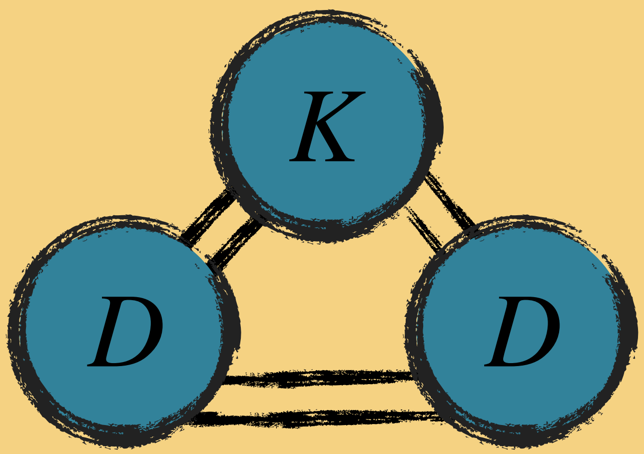


$X(3872)/$
$Z_c(3900)$

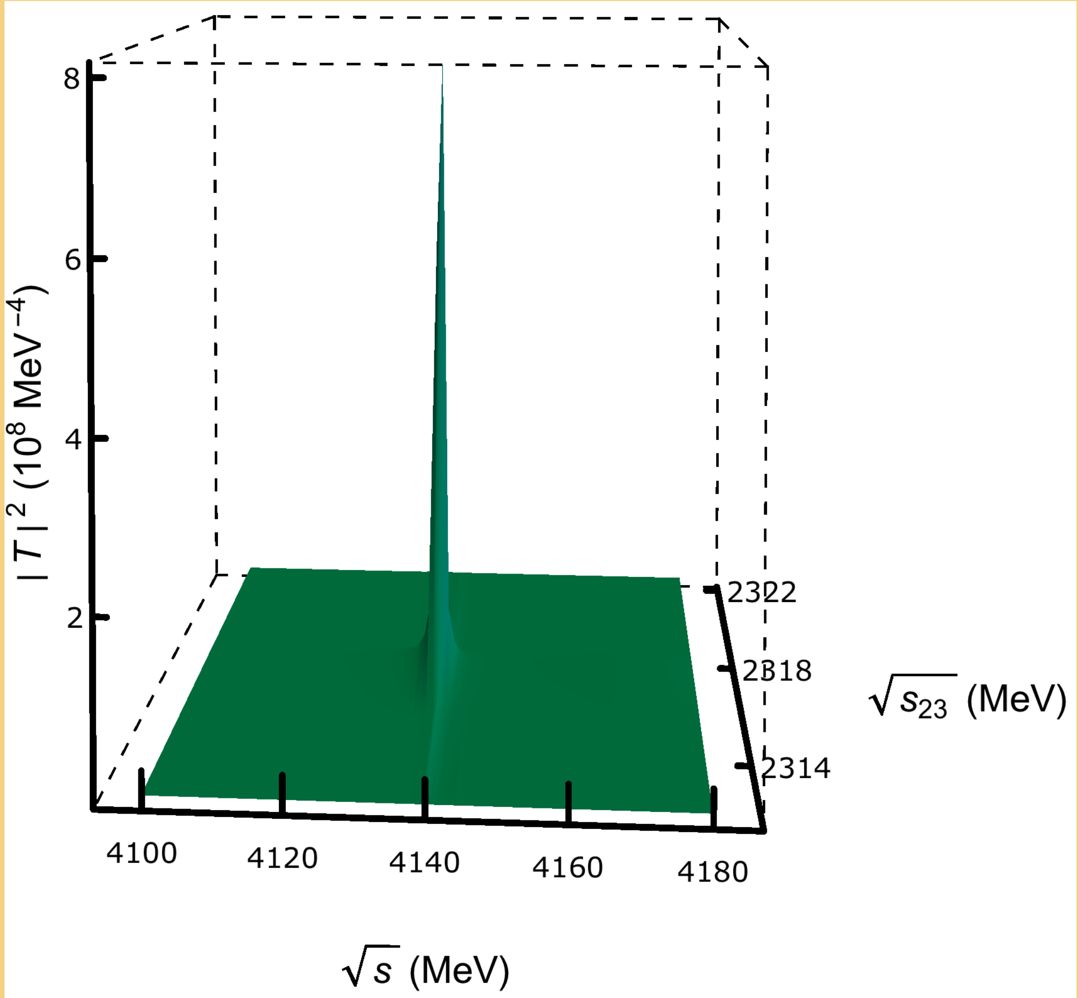
$$T_{31} = t_{31} + t_{31} G T_{32}$$
$$T_{32} = t_{32} + t_{32} G T_{32}$$

$$G_0 = \begin{bmatrix} (G_0)_{11} & 0 \\ 0 & (G_0)_{22} \end{bmatrix}$$

RESULTS



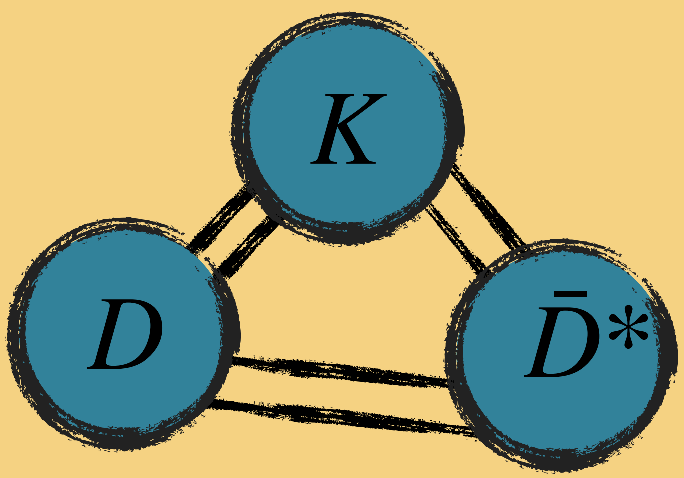
Phys. Rev. D99, 076017 (2019)



I=1/2, 4140 MeV

Wu, Liu, Geng, Hiyama, Valderrama, Gaussian Expansion Method, arxiv: 1906.11995 [hep-ph].

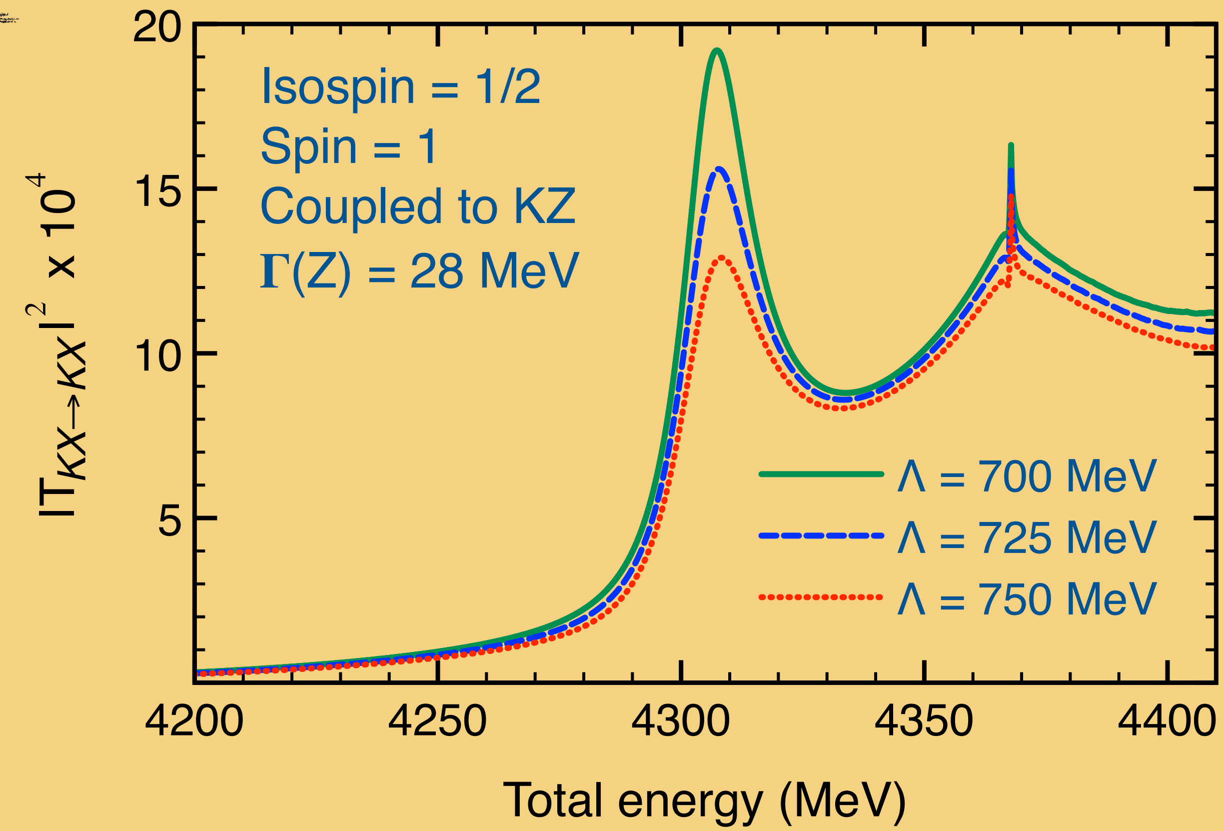
RESULTS

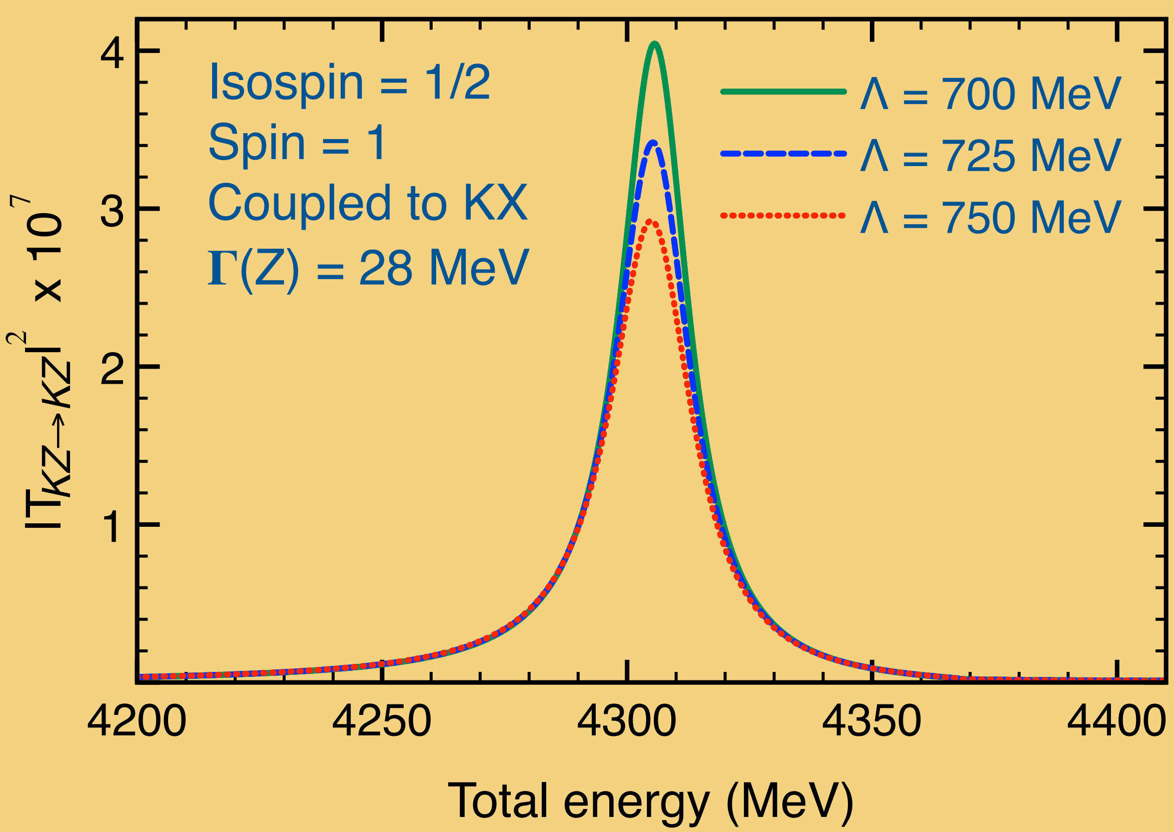


I=1/2, 4307 MeV,

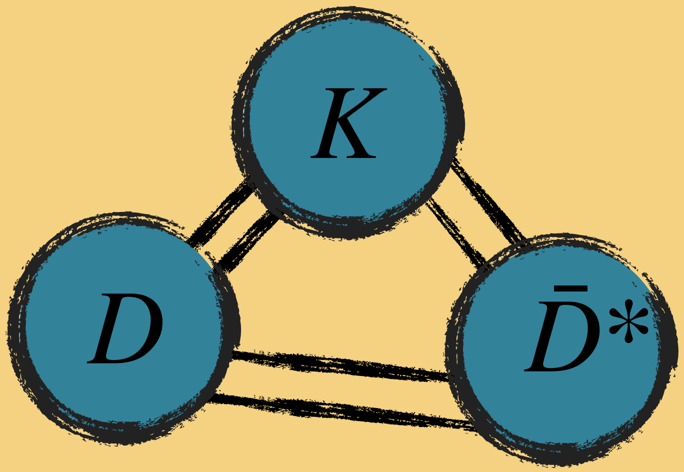
$\Gamma \sim 18$ MeV

Phys. Lett. B785, 112-117(2018)



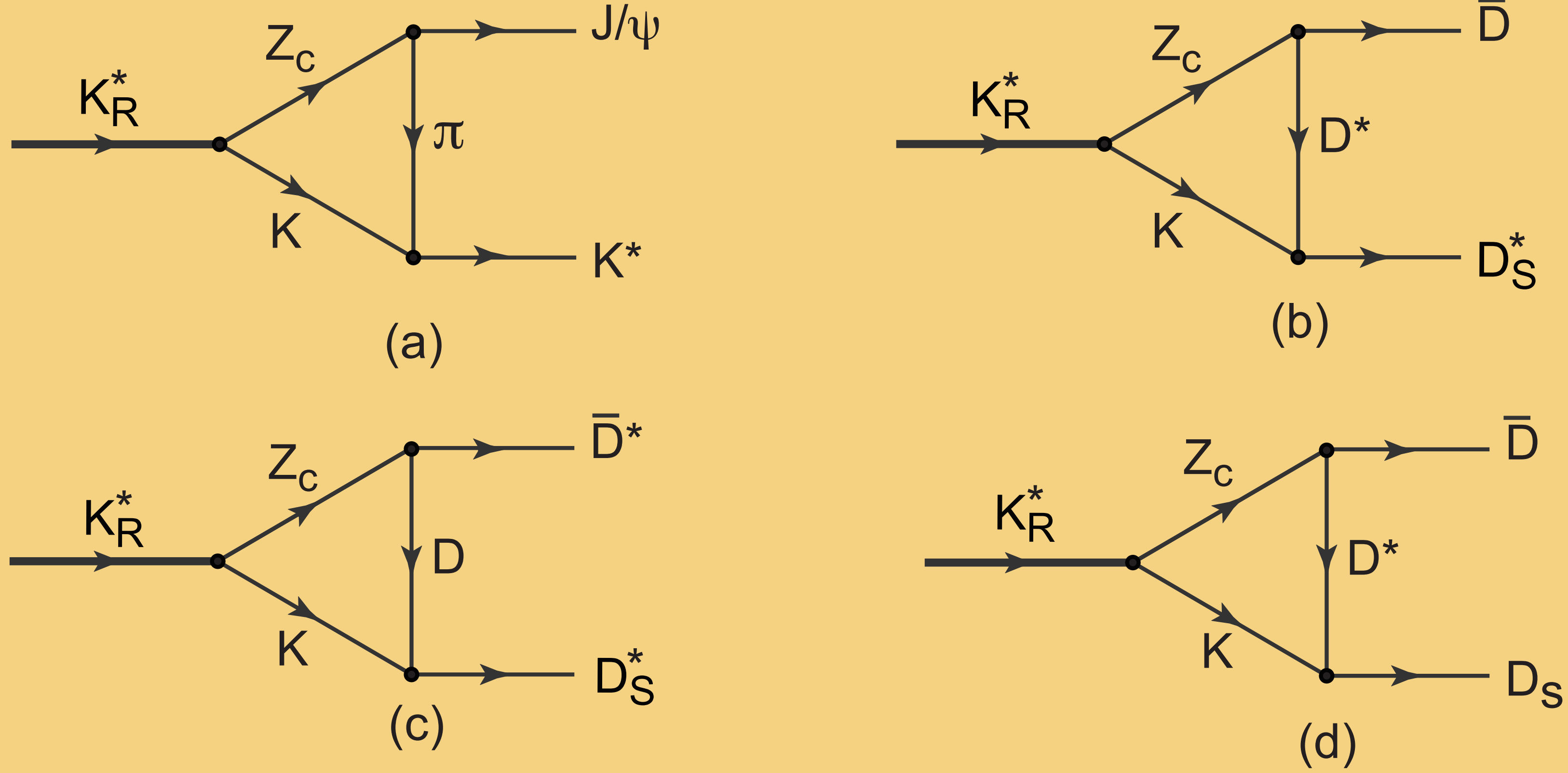


RESULTS



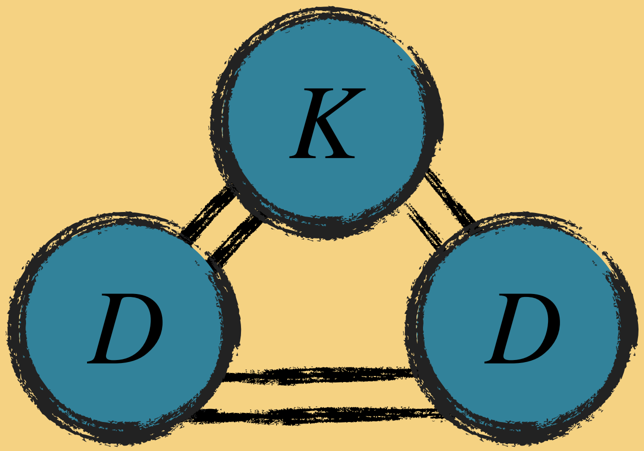
I=1/2, 4307 MeV,
$\Gamma \sim 18$ MeV

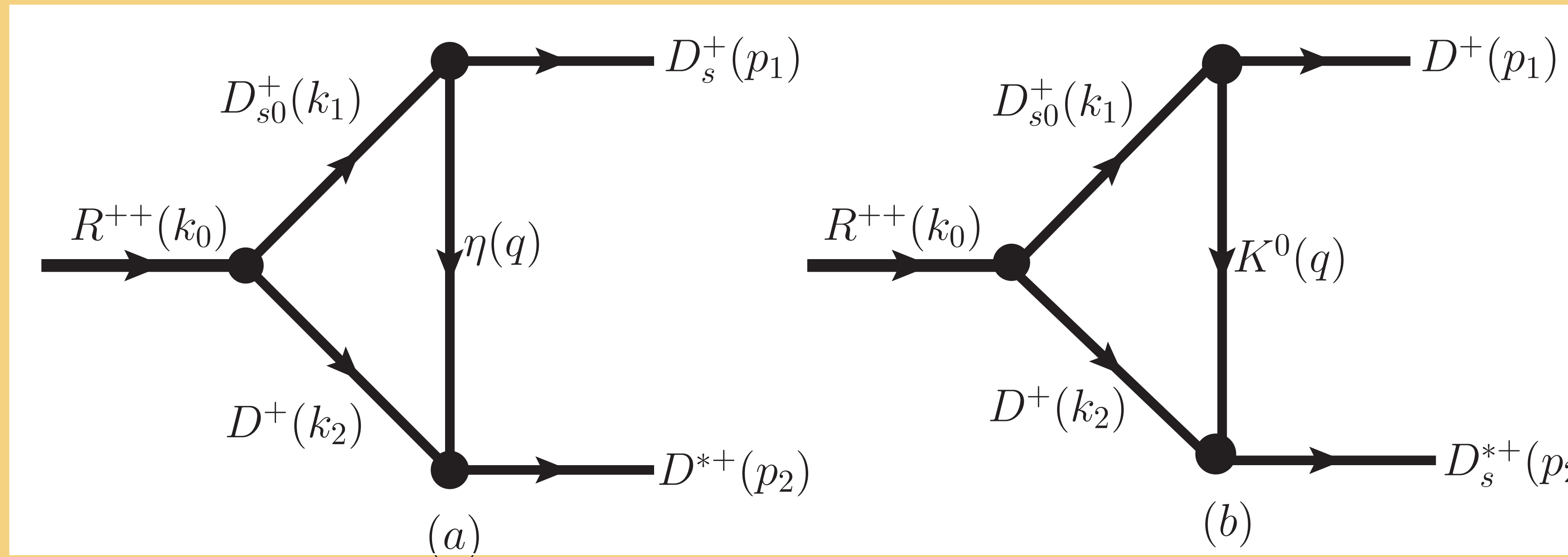
JHEP 1905, 103 (2019)

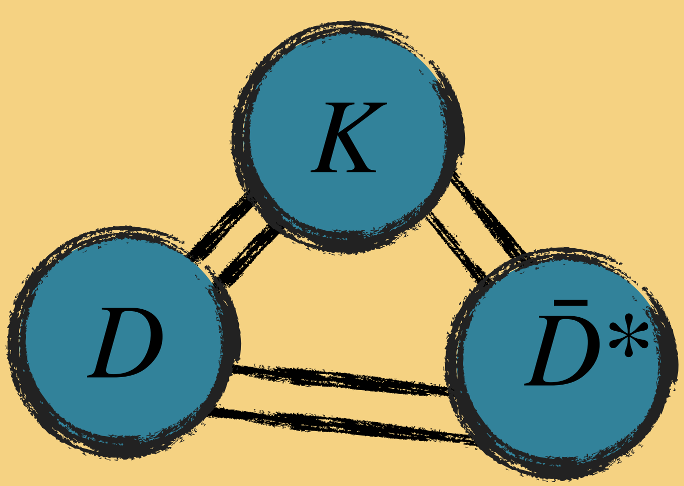


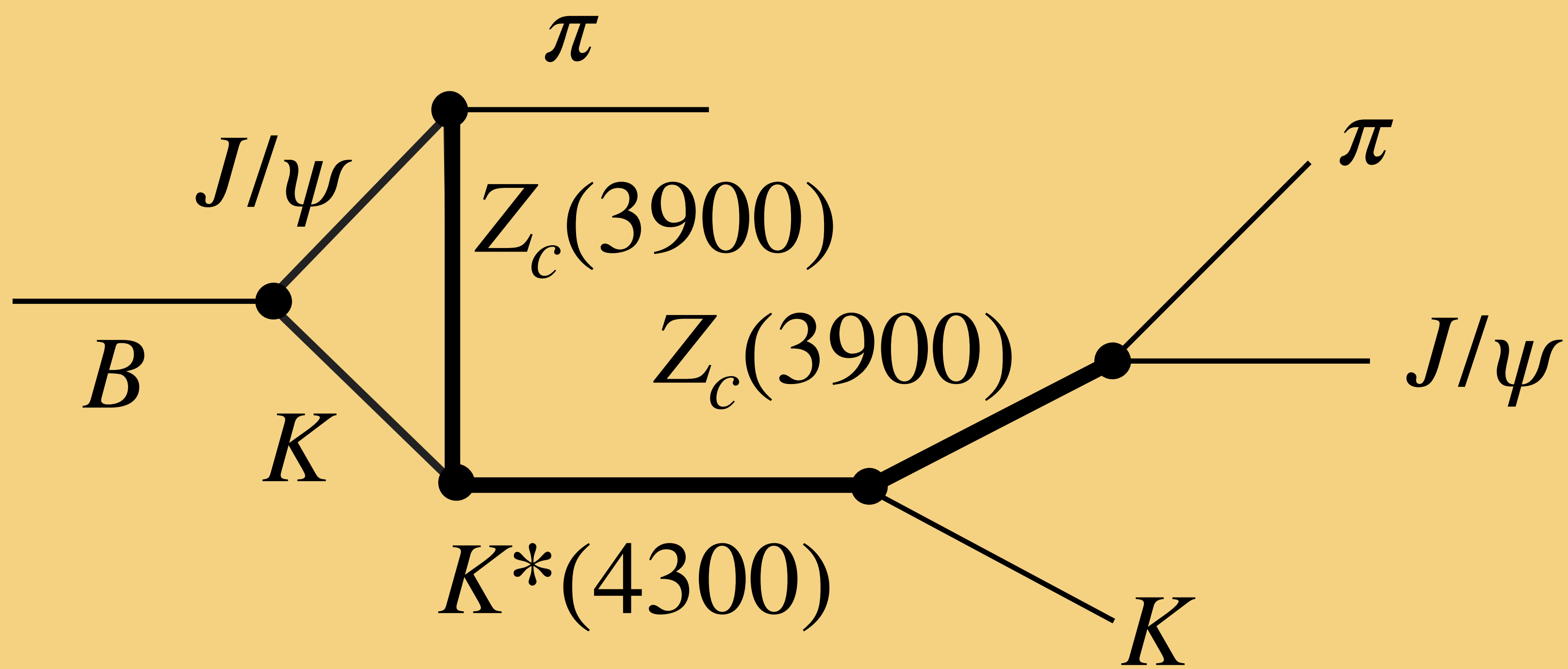
$\Gamma_a \sim 7$ MeV, $\Gamma_b \sim \Gamma_c \sim 0.5$ MeV,
$\Gamma_d \sim 1$ MeV

WORK ON PROGRESS

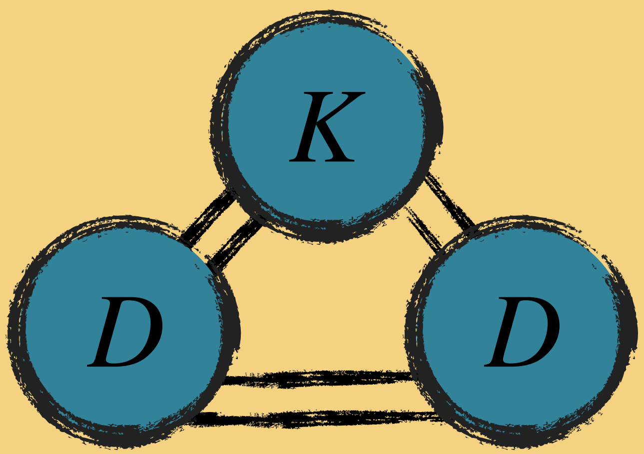








SUMMARY

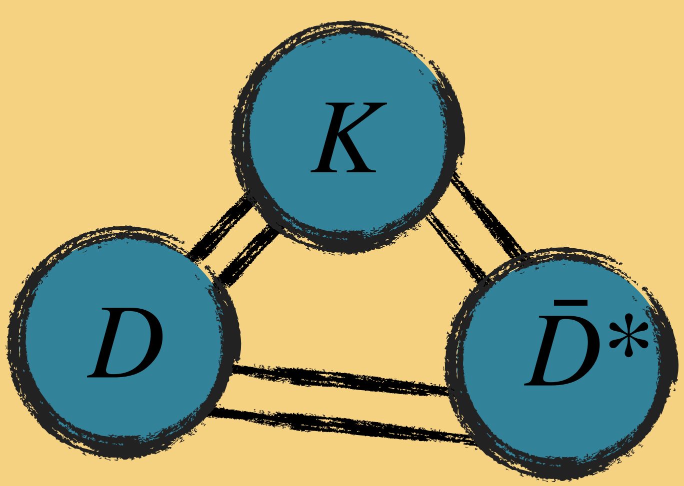


Faddeev Equations

I=1/2, 4140 MeV

$D_{s0}^*(2317)$

Decay modes: $D_s D^*$, DD_s^*



FCA to Faddeev Equations

I=1/2, 4307 MeV

$D_{s0}^*(2317), X(3872)/Z_c(3900)$

Invariant mass distribution

$B \to J/\psi \pi\pi K$