Charm and Hidden Charm Scalar Resonances in Nuclear Matter

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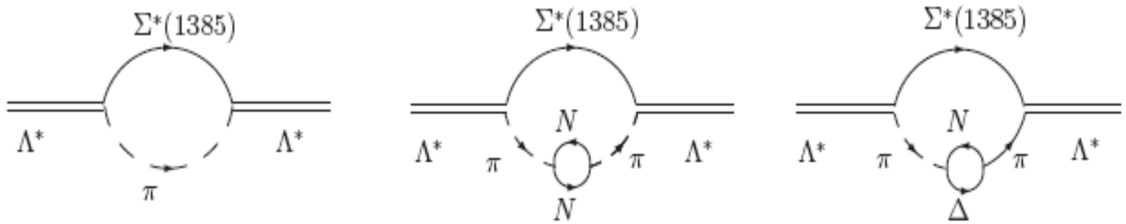
Motivation

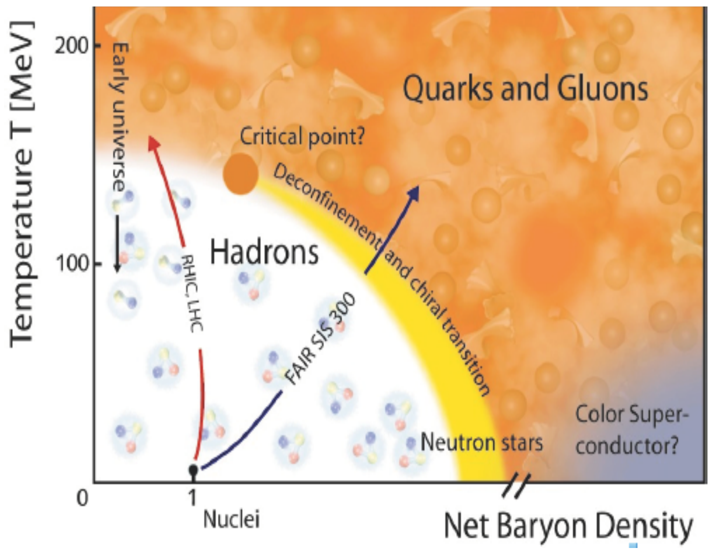
The modification of the properties of elementary particles in nuclei give us information about the excitation mechanisms in the nucleus as well as the nature of those particles

ex. Λ**(1520)** resonance: width at nuclear matter density is five times bigger than the free one

$$\Lambda^*(1520) + p \rightarrow \Sigma^*(1385) + n$$



Kaskulov and Oset, PRC 73 (2006) 045213

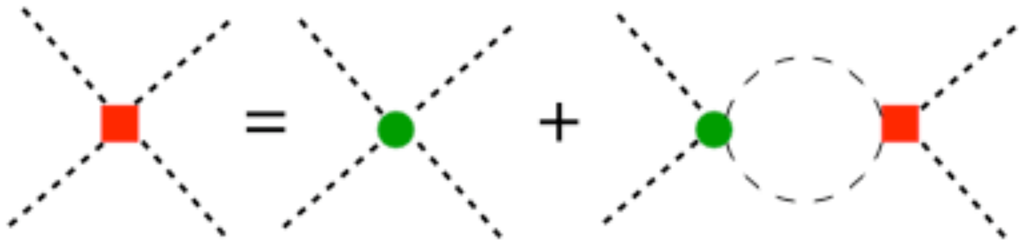


FAIR will extend the GSI program for in-medium modifications of hadrons in the light sector to the heavy one

http://www.gsi.de/fair/

$D_{s0}(2317)$, $D_0(2400)$ and $X(3700)$

Charm and hidden charm scalar resonances are generated dynamically from the interaction of coupled channels of two pseudoscalars*



$T_{ij} \;=\; V_{ij} \;+\; V_{il}\; G_l\; T_{lj}$

with **G** the **two-meson loop**

$$G_l(P) = i \int \frac{dq^4}{(2\pi)^4} \frac{1}{q^2 - m_1^2 + i\epsilon} \frac{1}{(P-q)^2 - m_2^2 + i\epsilon}$$

*Kolomeitsev and Lutz, PLB 582 (2004) 39; Hofmann and Lutz, NPA 733 (2004) 142; Guo, Shen, Chiang, Ping, PLB 641 (2006) 278; Gamermann, Oset, Strottman, Vicente-Vacas, PRD 76 (2007) 074016 and **V** the **potential,** from the generalization of the meson-meson SU(3) chiral lagrangian to the strongly broken SU(4) sector mostly due to the explicit consideration of the masses of the exchanged vector mesons

$$\mathcal{L} = \frac{1}{12f^2}\Big(Tr\big(J_{88\mu}J_{88}^{\mu} + 2J_{\bar{3}3\mu}J_{88}^{\mu} + J_{3\bar{3}_\mu}J_{3\bar{3}}^{\mu}\big) + \frac{8}{3}\gamma J_{\bar{3}1\mu}J_{13}^{\mu} + \frac{4}{\sqrt{3}}\gamma\big(J_{\bar{3}1\mu}J_{83}^{\mu} + J_{\bar{3}8\mu}J_{13}^{\mu}\big) + 2\gamma J_{\bar{3}8\mu}J_{83}^{\mu} + \psi_5 J_{\bar{3}3_\mu}J_{\bar{3}3}^{\mu} + \mathcal{L}_{mass}\Big)$$

f_π or f_D

with currents and mesons fields,

$$j_{ij}^{\mu} = (\partial^\mu\phi_i)\phi_j - \phi_i(\partial^\mu\phi_j)$$

$$\phi_8 = \begin{pmatrix} \frac{\pi^0}{\sqrt{2}} + \frac{\eta}{\sqrt{6}} & \pi^+ & K^+ \\ \pi^- & \frac{-\pi^0}{\sqrt{2}} + \frac{\eta}{\sqrt{6}} & K^0 \\ K^- & \bar{K}^0 & \frac{-2\eta}{\sqrt{6}} \end{pmatrix} \quad \phi_3 = \begin{pmatrix} \bar{D}^0 \\ D^- \\ D_s^- \end{pmatrix}$$

$$\phi_{\bar{3}} = \begin{pmatrix} D^0 & D^+ & D_s^+ \end{pmatrix} \qquad \phi_1 = \eta_c$$

and parameters

light vector meson

$$\gamma = \left(\frac{m_L}{m_H}\right)^2$$

heavy vector meson

$$\psi_5 = -\frac{1}{3} + \frac{4}{3}\left(\frac{m_L}{m_{J_\psi}}\right)^2$$

Gamermann, Oset, Strottman, Vicente-Vacas, PRD 76 (2007) 074016

Close to a pole (2nd Riemann sheet), the amplitude is

$$T_{ij} \approx \frac{g_i g_j}{z - z_R}$$

where Re z_R is the mass of the resonance, Im z_R the half width and g_i gives the coupling of the resonance to a given channel

$D_{s0}(2317)$

Channel	Chiral model res (GeV)	Phenom. model res (GeV)
DK	10.21	10.36
$D_s\eta$	6.40	6.00
$D_s\eta_c$	0.48	1.52

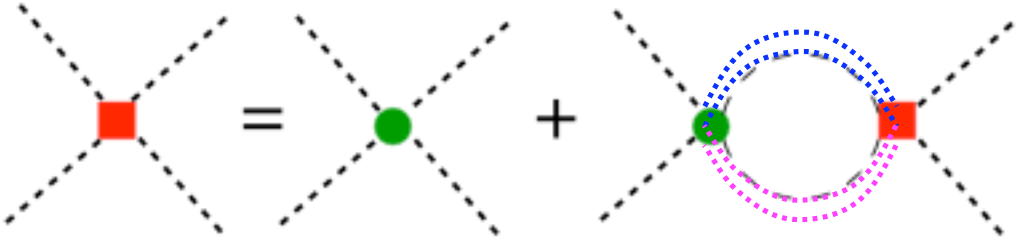
$D_0(2400)$

Channel	Chiral model res (GeV)	Phenom. model res (GeV)
$D\pi$	8.91	10.87
$D\eta$	1.36	3.77
$D_s\bar{K}$	5.71	8.52

X(3700)

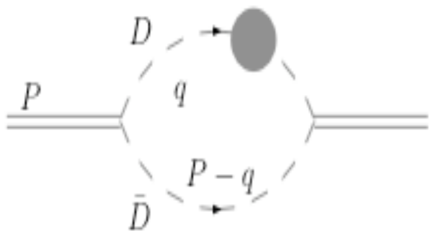
Channel	f_0 res (GeV)	σ res (GeV)	X(3700) (GeV)
$\pi\pi$	1.96	4.23	0.21
$K\bar{K}$	3.82	1.28	0.03
$\eta\eta$	4.47	0.47	0.00
$D\bar{D}$	0.71	4.08	10.41
$D_s\bar{D}_s$	3.73	0.49	6.73
$\eta\eta_c$	2.07	1.04	0.29

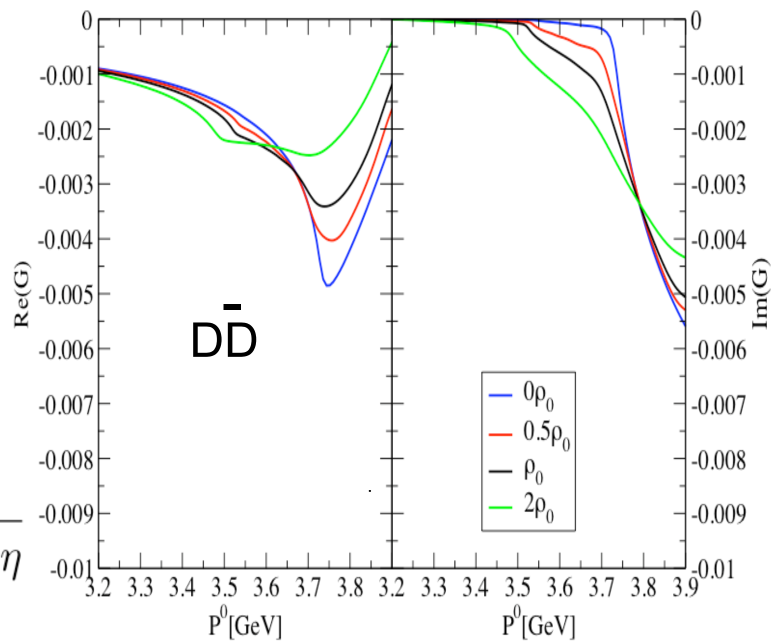
Two meson loop in the medium



$$\tilde{T}_{ij} = V_{ij} + V_{il}\,\tilde{G}_l\,\tilde{T}_{lj}$$

X(3700)





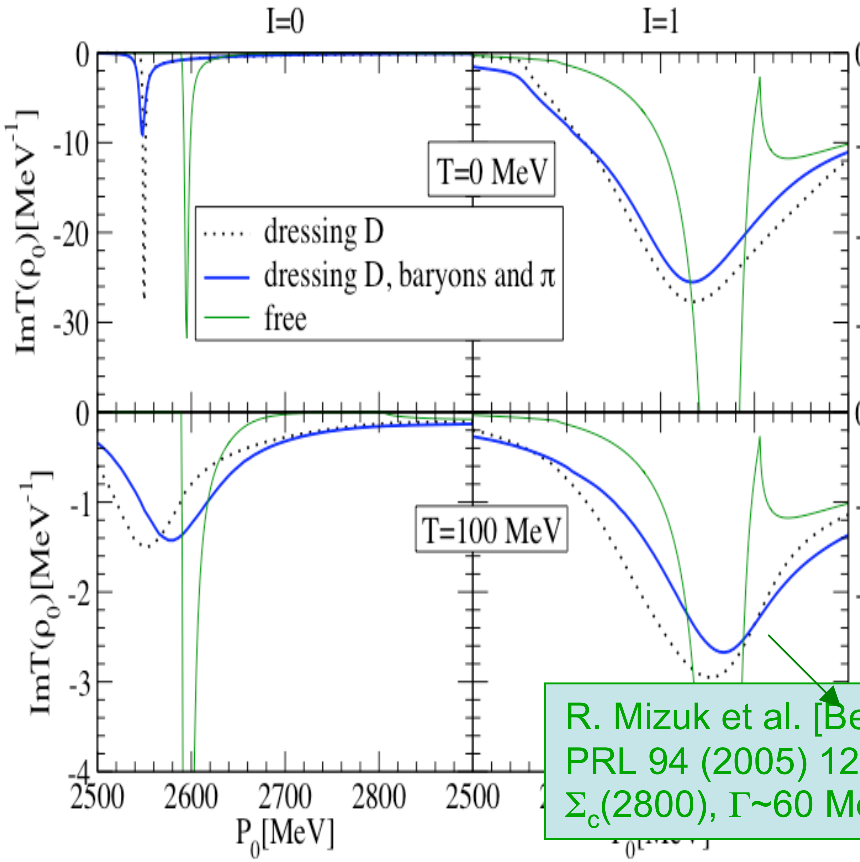
$$\tilde{G}(P^0,\vec{P},\rho) = i\int \frac{d^4q}{(2\pi)^4} D_D(q,\rho) D_{\bar{D}}(P-q,\rho)$$

$$= i\int \frac{d^4q}{(2\pi)^4}\int_0^\infty d\omega \frac{S_D(\omega,\vec{q},\rho)}{q^0-\omega+i\eta}\ \frac{1}{(P^0-q^0)^2-\vec{q}^{\,2}-m_{\bar{D}}^2+i\eta}$$

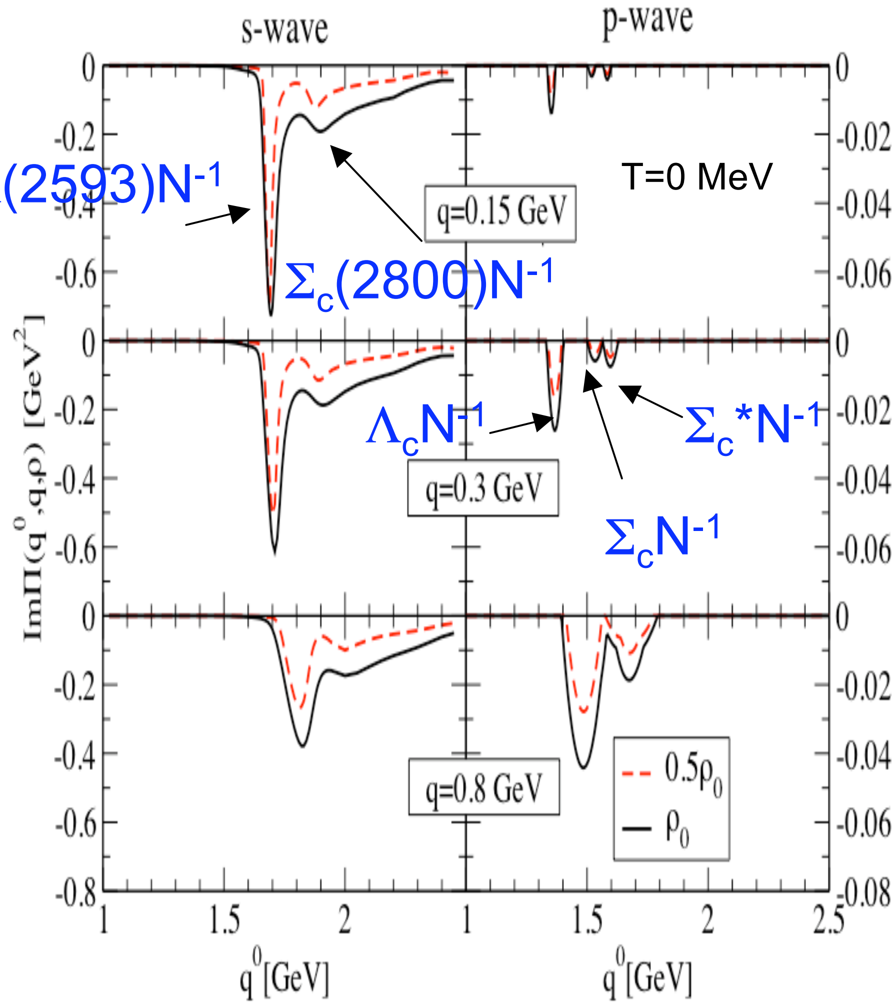
The self-energy of the D meson

The I=0 $\Lambda_c(2593)$ and another resonance in I=1 around the nominal $\Sigma_c(2800)$ are generated

LT, Ramos, Mizutani, PRC 77 (2008) 015207

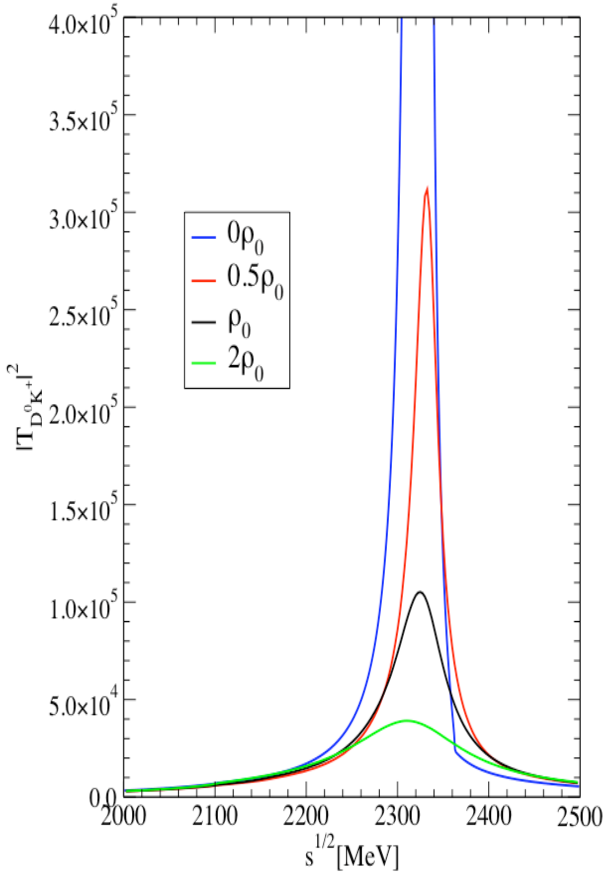


R. Mizuk et al. [Belle]
PRL 94 (2005) 122002:
$\Sigma_c(2800)$, Γ~60 MeV



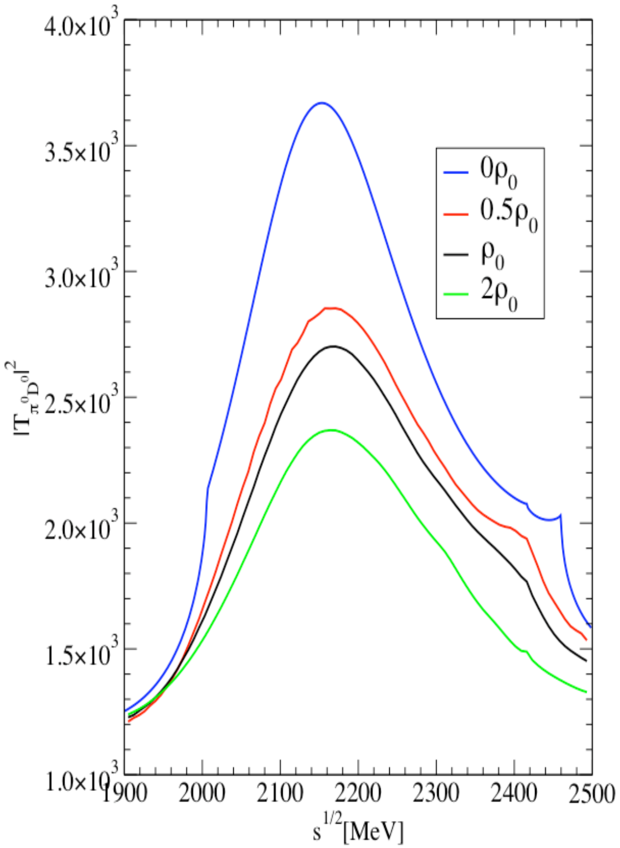
D-meson: s-wave much more important than p-wave

Charm resonances in nuclear matter



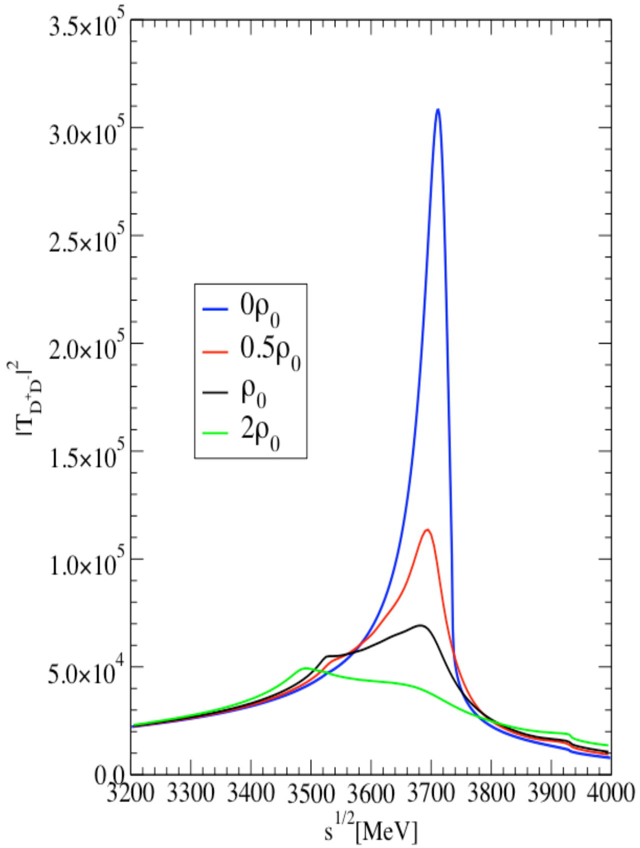
$D_{s0}(2317)$:

$D^0K^+ \rightarrow D^0K^+$



$D_0(2400)$:

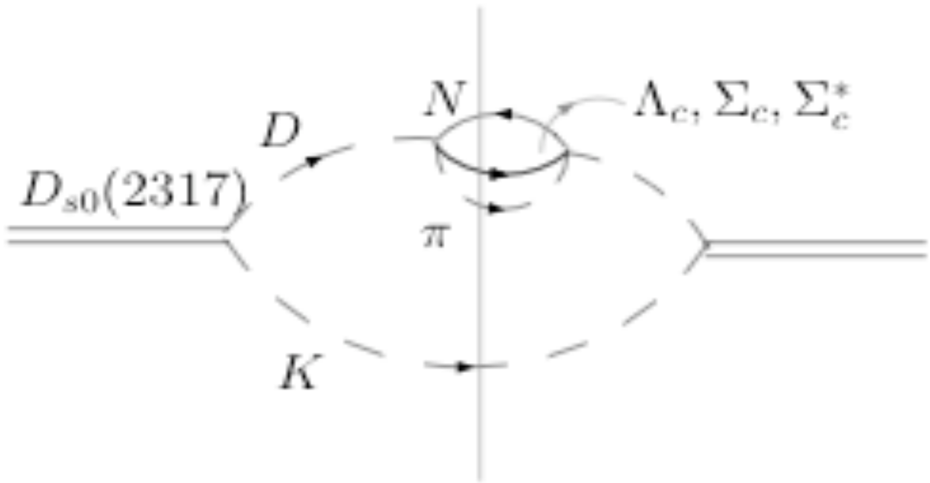
$D^0\pi^0 \rightarrow D^0\pi^0$



$X(3700)$:

$D^0\bar{D}^0 \rightarrow D^0\bar{D}^0$

Experimental analysis of the resonances in nuclear medium via, for example, the transparency ratio*: test of the D meson interaction in nuclei and the nature of those charm scalar resonances



*ω: Kaskulov, Hernandez and Oset, EPJA 31 (2007) 245

ϕ: Cabrera, Roca, Oset, Toki and Vicente-Vacas, NPA 733 (2004) 130

Conclusions & Outlook

We generate dynamically charm and hidden charm scalar resonances via a unitarized coupled-channel calculation of two pseudoscalars in nuclear matter

- $D_{s0}(2317)$, $D_0(2400)$ and X(3700) are generated dynamically. While $D_{s0}(2317)$ and X(3700) develop a width of 100 or 200 MeV at ρ_0, the width $D_0(2400)$ changes less comparatively.
- Experimental analysis of the renormalized resonances in nuclear medium (via transparency ratios) is a valuable test of the dynamics of D meson interaction in nuclei and the nature of those charm and hidden charm scalar resonances.
- In particular, FAIR is an optimal hadron facility to investigate charm physics in a dense and hot medium

Molina, Gamermann, Oset and LT, arXiv:0806.3711