Outline

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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. $\Lambda(1520)$ 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

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

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

\[
\mathcal{L} = \frac{1}{12f^2} \left( \text{Tr} \left( J_{88\mu} J_{88}^{\mu} + 2J_{33\mu} J_{88}^{\mu} + J_{3\bar{3} \mu} J_{33}^{\mu} \right) + \frac{8}{3} \gamma J_{31\mu} J_{13}^{\mu} + \frac{4}{\sqrt{3}} \gamma \left( J_{31\mu} J_{83}^{\mu} + J_{38\mu} J_{13}^{\mu} \right) + 2\gamma J_{38\mu} J_{83}^{\mu} + \psi_5 J_{33\mu} J_{33}^{\mu} + \mathcal{L}_{\text{mass}} \right)
\]

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^- \\
\bar{K}^0 - \frac{2\eta}{\sqrt{6}} \\
K^-
\end{pmatrix},
\quad
\phi_3 = \begin{pmatrix}
\bar{D}^0 \\
D^- \\
D_s^-
\end{pmatrix},
\quad

\psi_5 = -\frac{1}{3} + \frac{4}{3} \left( \frac{m_L}{m_{J^\psi}} \right)^2,
\quad
\phi_1 = \eta_c
\]

Gamermann, Oset, Strottman, Vicente-Vacas, PRD 76 (2007) 074016
Close to a pole (2nd Riemann sheet), the amplitude is

where $\text{Re } z_R$ is the mass of the resonance, $\text{Im } z_R$ the half width and $g_i$ gives the coupling of the resonance to a given channel.

D_{s0}(2317)

<table>
<thead>
<tr>
<th>Channel</th>
<th>Chiral model res (GeV)</th>
<th>Phenom. model res (GeV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$DK$</td>
<td>10.21</td>
<td>10.36</td>
</tr>
<tr>
<td>$D_2\eta$</td>
<td>6.90</td>
<td>6.00</td>
</tr>
<tr>
<td>$D_2\eta_c$</td>
<td>0.48</td>
<td>1.52</td>
</tr>
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</table>

D_{0}(2400)

<table>
<thead>
<tr>
<th>Channel</th>
<th>Chiral model res (GeV)</th>
<th>Phenom. model res (GeV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$D\pi$</td>
<td>8.91</td>
<td>10.87</td>
</tr>
<tr>
<td>$D\eta$</td>
<td>1.36</td>
<td>3.77</td>
</tr>
<tr>
<td>$D_2\bar{K}$</td>
<td>5.71</td>
<td>8.52</td>
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</table>

X(3700)

<table>
<thead>
<tr>
<th>Channel</th>
<th>$f_0$ res (GeV)</th>
<th>$\sigma$ res (GeV)</th>
<th>X(3700) (GeV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\pi\pi$</td>
<td>1.96</td>
<td>4.23</td>
<td>0.21</td>
</tr>
<tr>
<td>$K\bar{K}$</td>
<td>3.82</td>
<td>1.28</td>
<td>0.03</td>
</tr>
<tr>
<td>$\eta\eta$</td>
<td>4.47</td>
<td>0.47</td>
<td>0.00</td>
</tr>
<tr>
<td>$D\bar{D}$</td>
<td>0.71</td>
<td>4.08</td>
<td>10.41</td>
</tr>
<tr>
<td>$D_2\bar{D}_2$</td>
<td>3.73</td>
<td>0.49</td>
<td>6.73</td>
</tr>
<tr>
<td>$\eta\eta_c$</td>
<td>2.07</td>
<td>1.04</td>
<td>0.29</td>
</tr>
</tbody>
</table>
Two meson loop in the medium

\[ \tilde{T}_{ij} = V_{ij} + V_{il} G_l \tilde{T}_{lj} \]

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

\[ = i \int \frac{d^4q}{(2\pi)^4} \int_0^\infty d\omega \frac{S_D(\omega, \bar{q}, \rho)}{q^0 - \omega + i\eta} \left( P^0 - q^0 - \bar{q}^2 - m_D^2 \right) + i\eta \]
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

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 $\rho_0$, 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