Open-charm mesons in hot and dense matter

L. Tolos[1], A. Ramos[2] and T. Mizutani[3]

[1]FIAS (University of Frankfurt)

[2]Universitat de Barcelona

[3] Virginia Polytechnic Institute and State University

1. Motivation
2. Self-consistent coupled-channel approach: $\Lambda_c(2593)$ and $\Sigma_c(2770)$
3. Open-charm mesons in hot dense matter
4. Conclusions & Outlook

Hadron07, Frascati, 8-13 October 2007

Motivation

Experimental scenarios..

- J/Ψ suppression M.Gonin et al. (NA50), NPA 610 (1996) 404c

initially predicted by color screening in QGP T.Matsui and H.Satz, PLB 178 (1986) 416

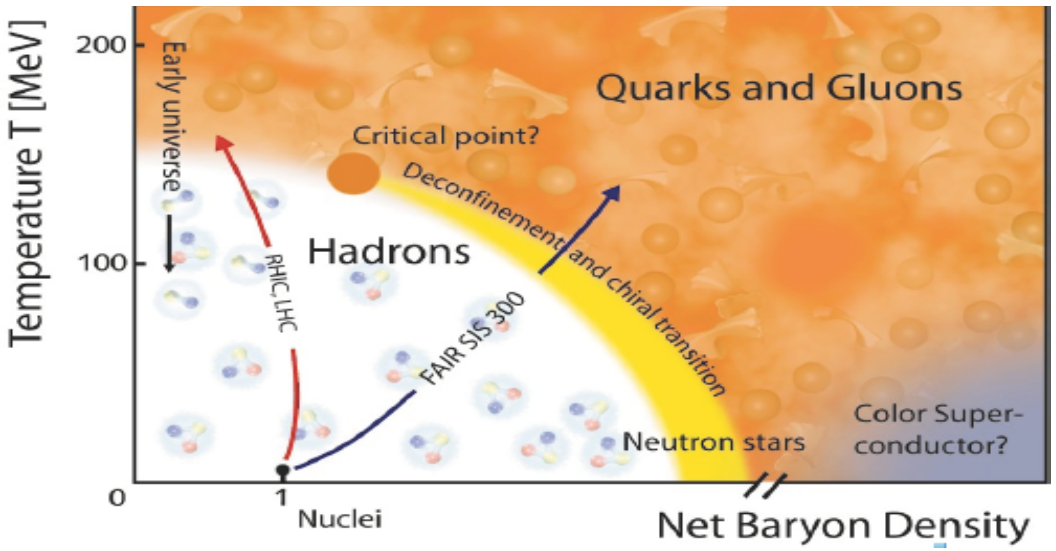
but also due to comover scattering $J/\Psi + \pi, \rho \rightarrow \bar{D} + D$

several authors: A. Capella, R. Vogt, X.N. Wang, W. Cassing, O. Linnyk, A. Andronic..

- Open-charm enhancement Abreu et al. (NA50), EPJC14 (2000) 443

but recent debate because of dimuon production by NA60 Scomparin, talk@QM2005

- CBM@FAIR



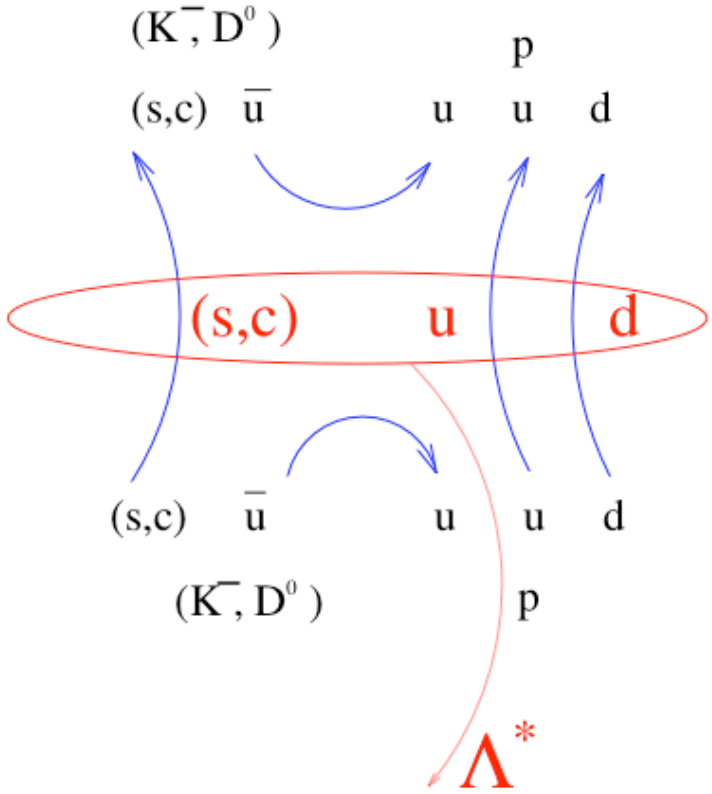
From the theoretical side..

DN interaction: similar features as $\bar{K}N$ interaction. In the charm sector we also find a subthreshold I=0 resonance, the $\Lambda_c(2593)$ (udc) with a strong resemblance to the $\Lambda(1405)$ (uds).

$$\overline{K}=\begin{pmatrix}\bar{K}^0 & \bar{d}\,s\\ -K^- & \bar{u}\,s\end{pmatrix} \qquad s=-1$$

$$D=\begin{pmatrix}D^+ & \bar{d}\,c\\ D^0 & \bar{u}\,c\end{pmatrix} \qquad c=1$$

$$I(J^P)=1/2\ (0^-)$$



May the $\Lambda_c(2593)$ be generated also dynamically?

- Predictions for the ***mass shift*** in mean-field models:

  $U_{D+}(\rho_0) \sim -60$ to -200 MeV and $U_{D-}(\rho_0) \sim 20$ to -140 MeV

  - QMC model K.Tsushima et al. PRC 59 (1999) 2824, A. Sibirtsev et al. EPJ 6 (1999) 351
  - QCD sum-rule model A.Hayashigaki PLB 487 (2000) 96, [2]W. Weise Hirschegg'01 (2001) 249
  - Chiral model A. Mishra et al. PRC 69 (2004) 015202

- ***Spectral function*** in self-consistent coupled-channel approach:
  - D meson self-energy with a SU(3) separable potential for u-,d- and c-content as bare interaction

    LT, J. Schaffner-Bielich and A. Mishra PRC 70 (2004) 025203;
    LT, J. Schaffner-Bielich and H. Stoecker PLB 635 (2006) 85 (finite T!)

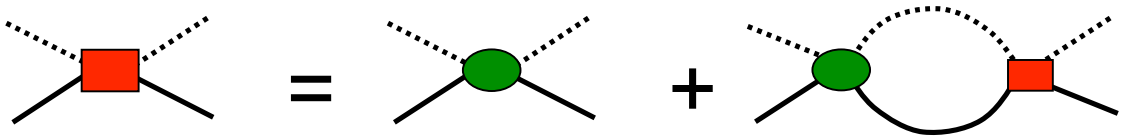
  - D and $\bar{D}$ meson self-energy with an improved bare interaction by extension to SU(4) M.F.M. Lutz and C.L. Korpa PLB 633 (2006) 43

  - D meson self-energy using a revised SU(4) interaction + scalar-isoscalar attractive Σ_{DN} term T. Mizutani and A. Ramos PRC 74 (2006) 065201

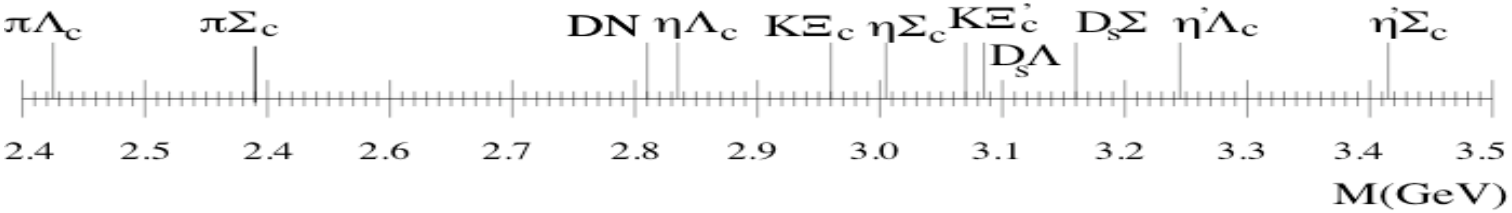
HERE: we extend the model to $\bar{D}$ mesons and implement finite T effects

Self-consistent coupled-channel approach: $\Lambda_c(2593)$ and $\Sigma_c(2880)$

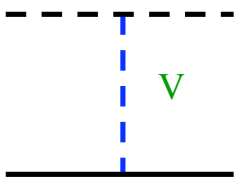
To solve the Bethe-Salpeter equation in coupled channels



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



where **V** built from the meson-baryon Lagrangian at lowest order

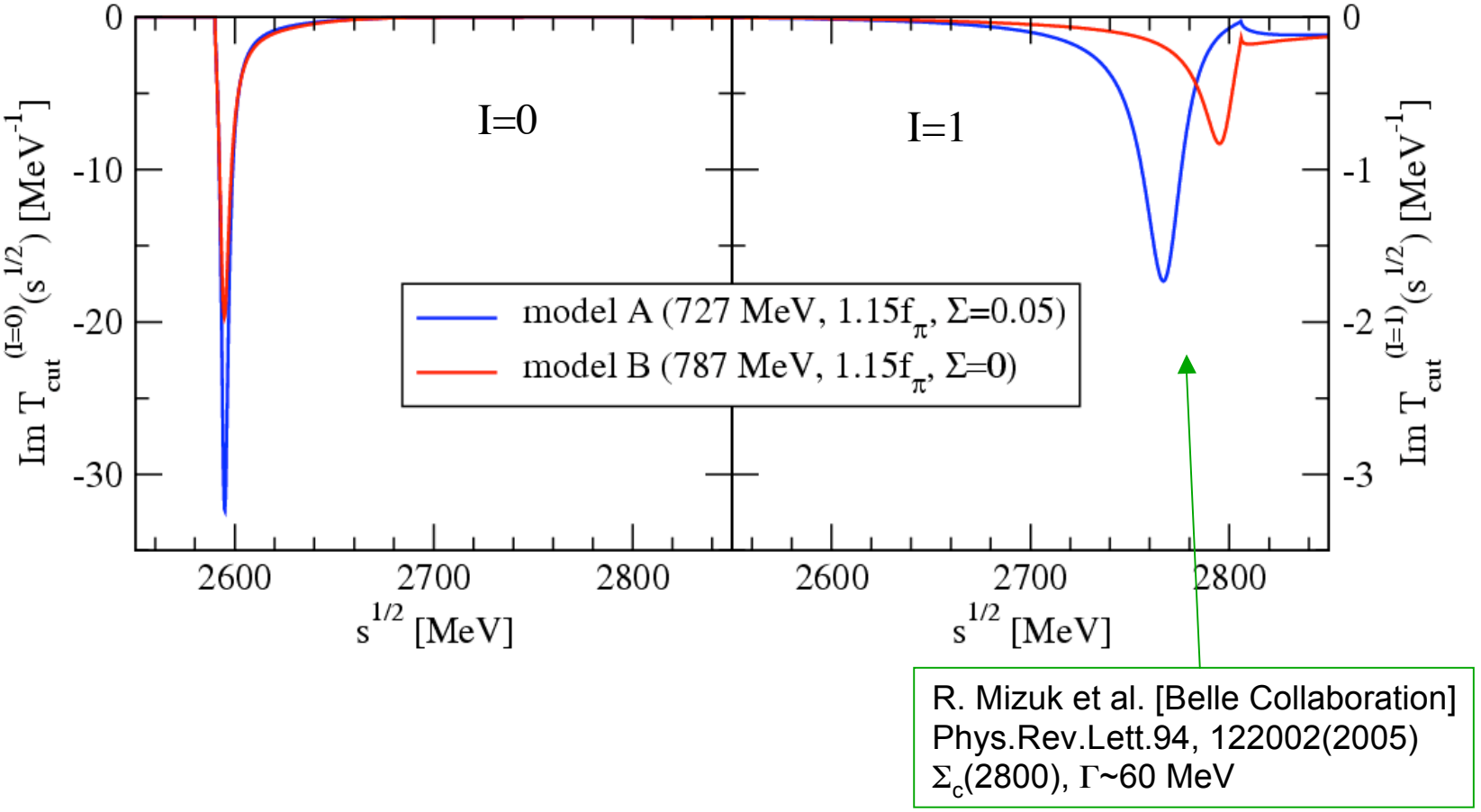


$$V_{ij} = -\kappa C_{ij} \frac{1}{4f^2}(2\sqrt{s} - M_i - M_j)\left(\frac{M_i + E}{2M_i}\right)^{1/2}\left(\frac{M_j + E'}{2M_j}\right)^{1/2}$$

broken SU(4) by the physical masses

and supplemented by a scalar-isoscalar interaction (Σ_{DN} term)

Free space DN amplitudes

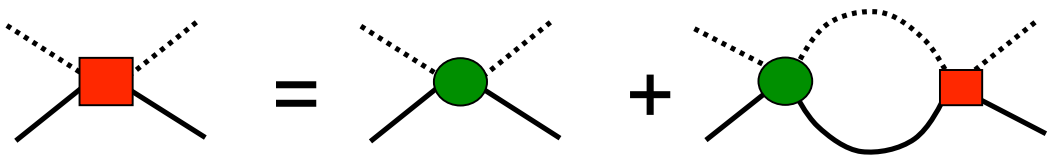


R. Mizuk et al. [Belle Collaboration]
Phys.Rev.Lett.94, 122002(2005)
$\Sigma_c(2800)$, Γ~60 MeV

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

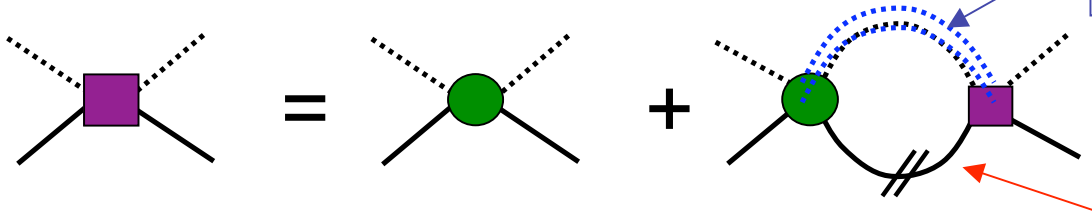
In-medium DN interaction at finite temperature:
selfconsistent coupled-channel procedure

Free space



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

Medium



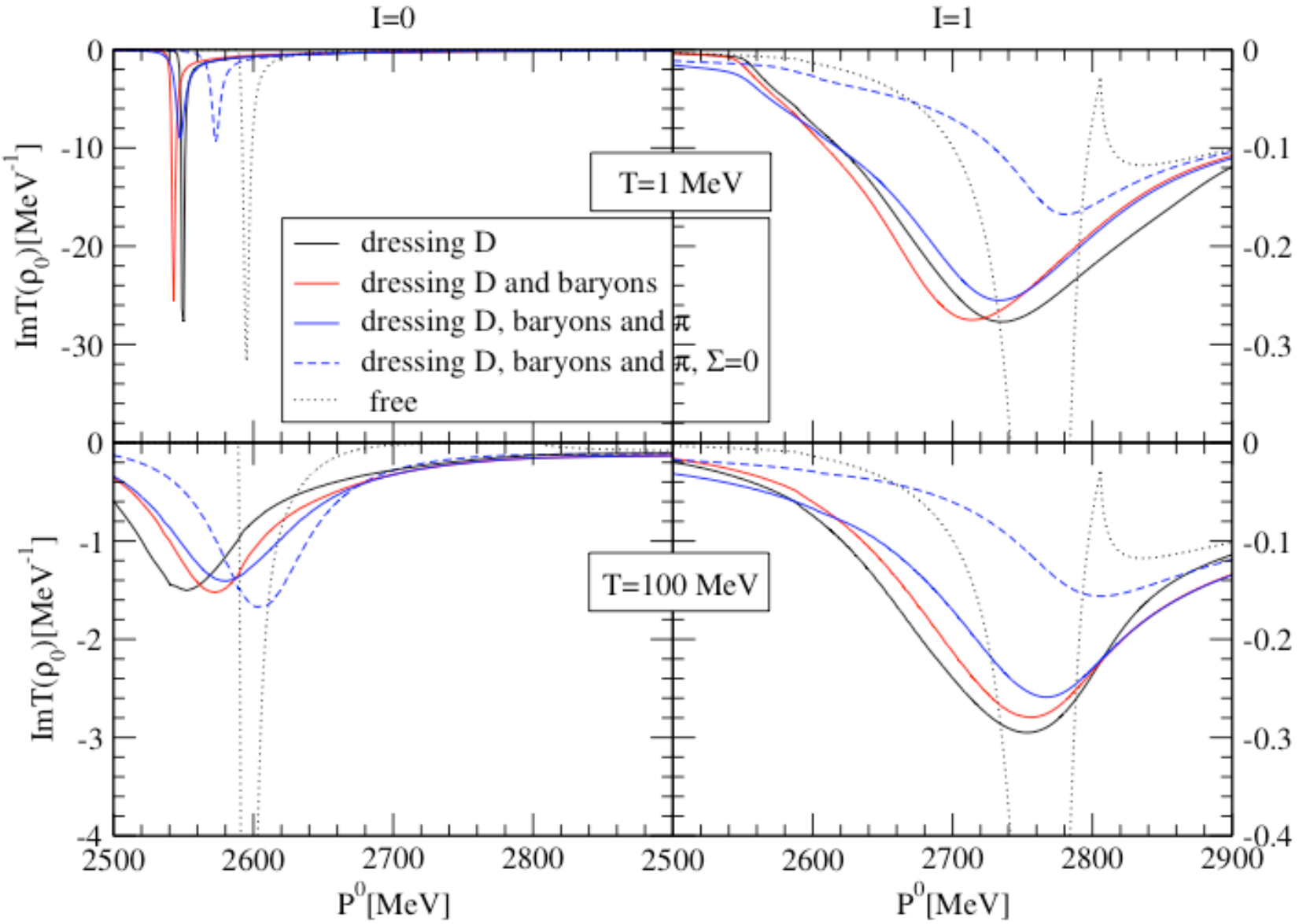
$T_{ij}(\rho) = V_{ij} + V_{il}\, G_l(\rho)\, T_{lj}(\rho)$

meson dressing
(D and π)

Pauli blocking
and
baryon dressing
($N,\Lambda,\Sigma,\Lambda_c,\Sigma_c$)

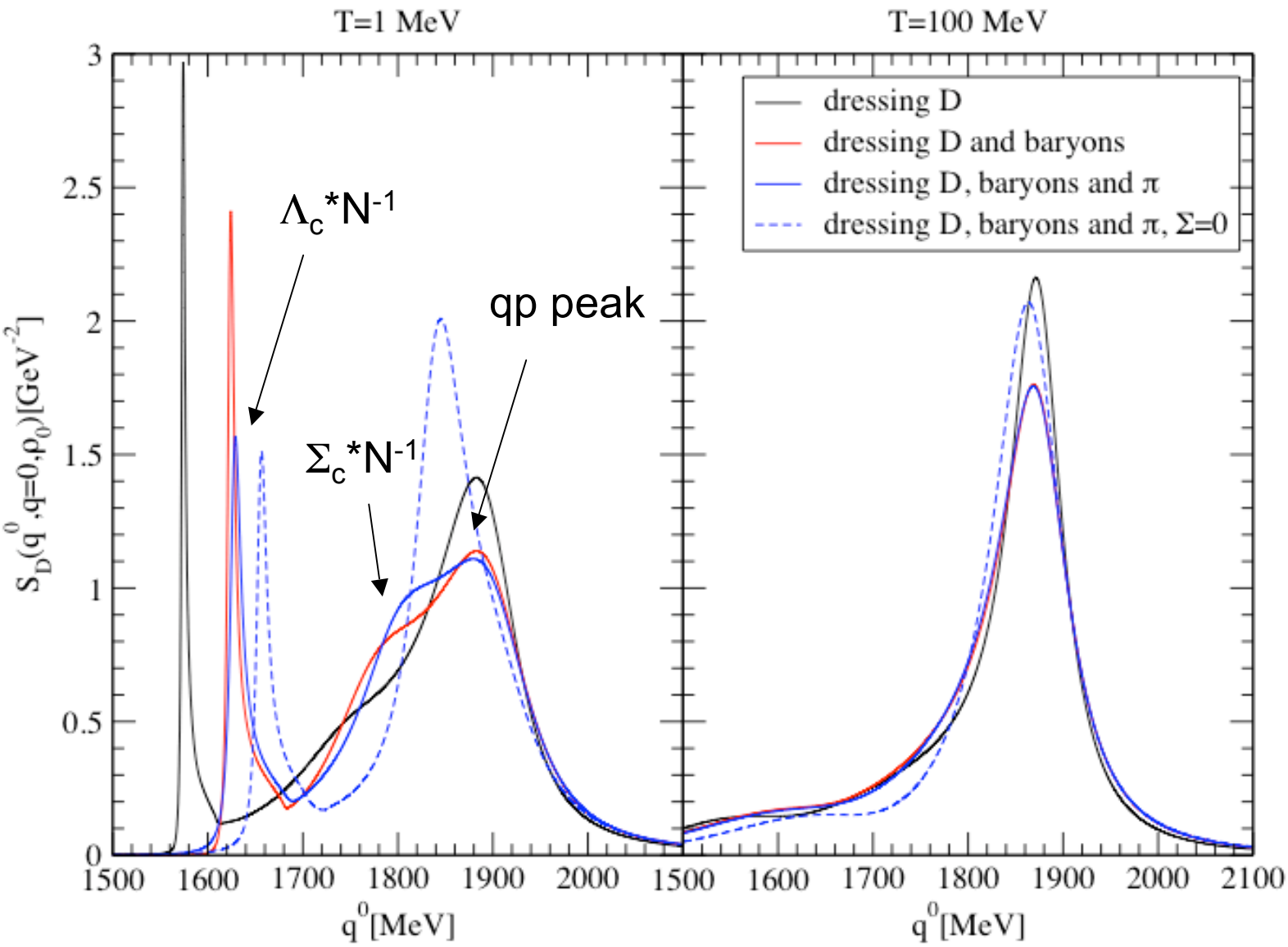
Dressed D meson Self-consistently:

Open-charm mesons in hot dense matter

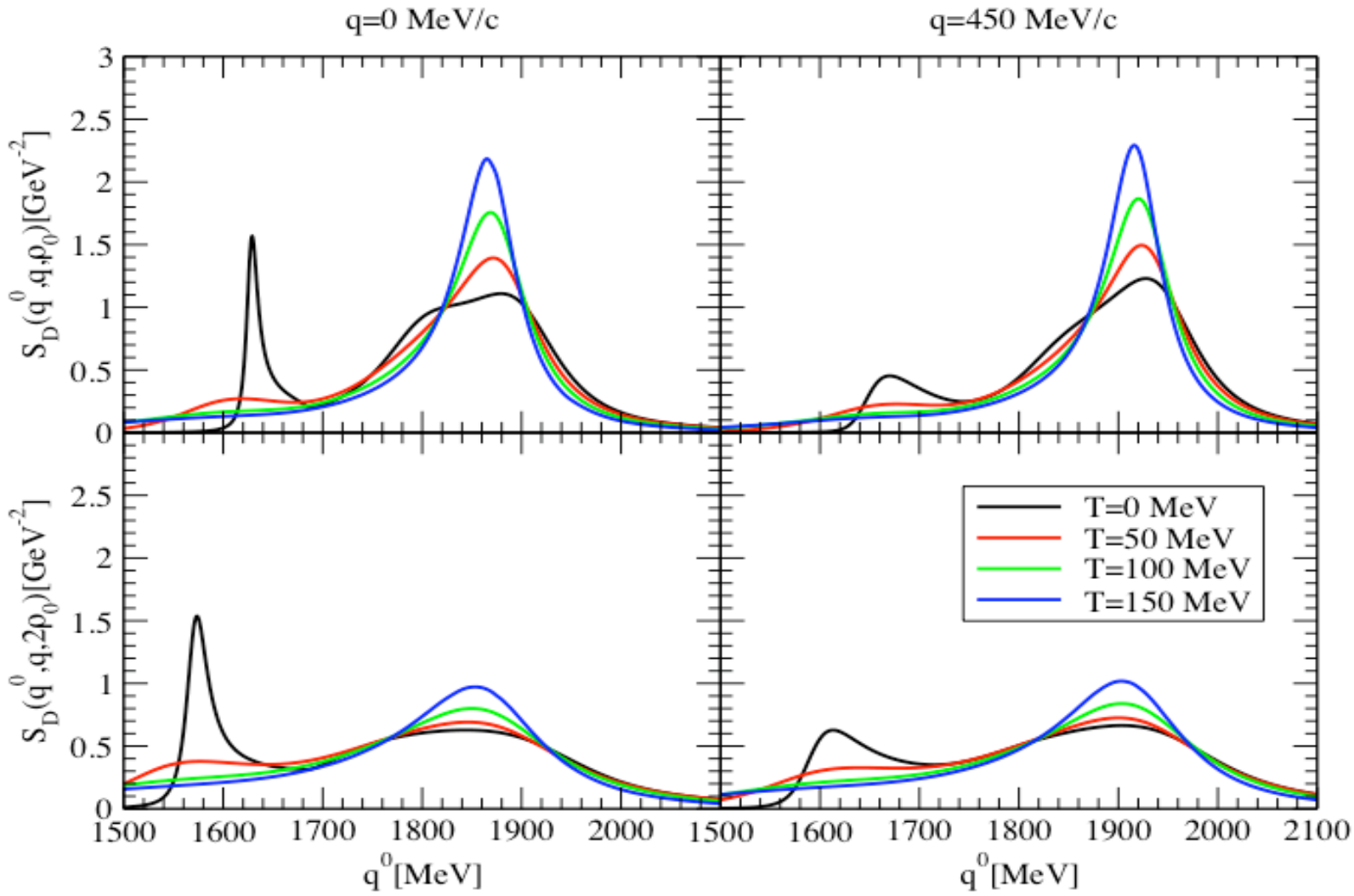


In-medium $\Lambda_c(2793)$ & $\Sigma_c(2880)$ at finite temperature

D meson spectral function at finite temperature



Evolution with density and temperature of the D spectral function



Similar trend to previous finite temperature results

LT, J. Schaffner-Bielich and H. Stoecker PLB 635 (2006) 85

$\bar{D}N$ scattering lengths & $\bar{D}$ meson potential

$$a_{\bar{D}N} = -\frac{1}{4\pi}\frac{M_{\bar{D}N}}{\sqrt{s}}T_{\bar{D}N\to\bar{D}N}$$

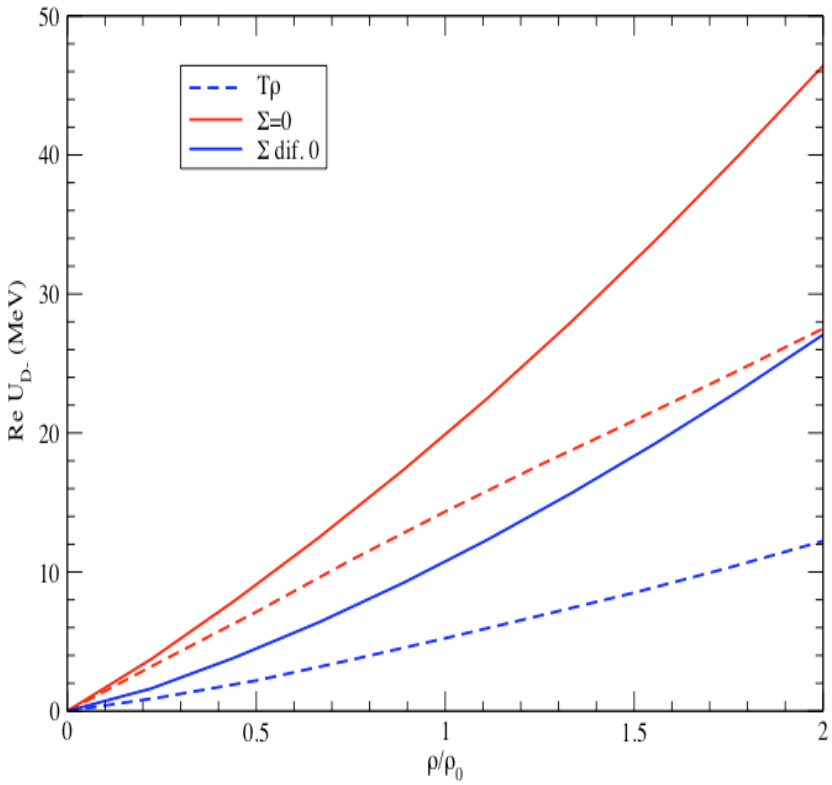
$$U_{\bar{D}}(\vec{q}) = \frac{\Pi_{\bar{D}}(E_{qp}(\vec{q}),\vec{q})}{2\sqrt{m_{\bar{D}}^2+\vec{q}^{\,2}}}$$

in contrast with LK

Table 1: $\bar{D}N$ scattering lengths (fm)

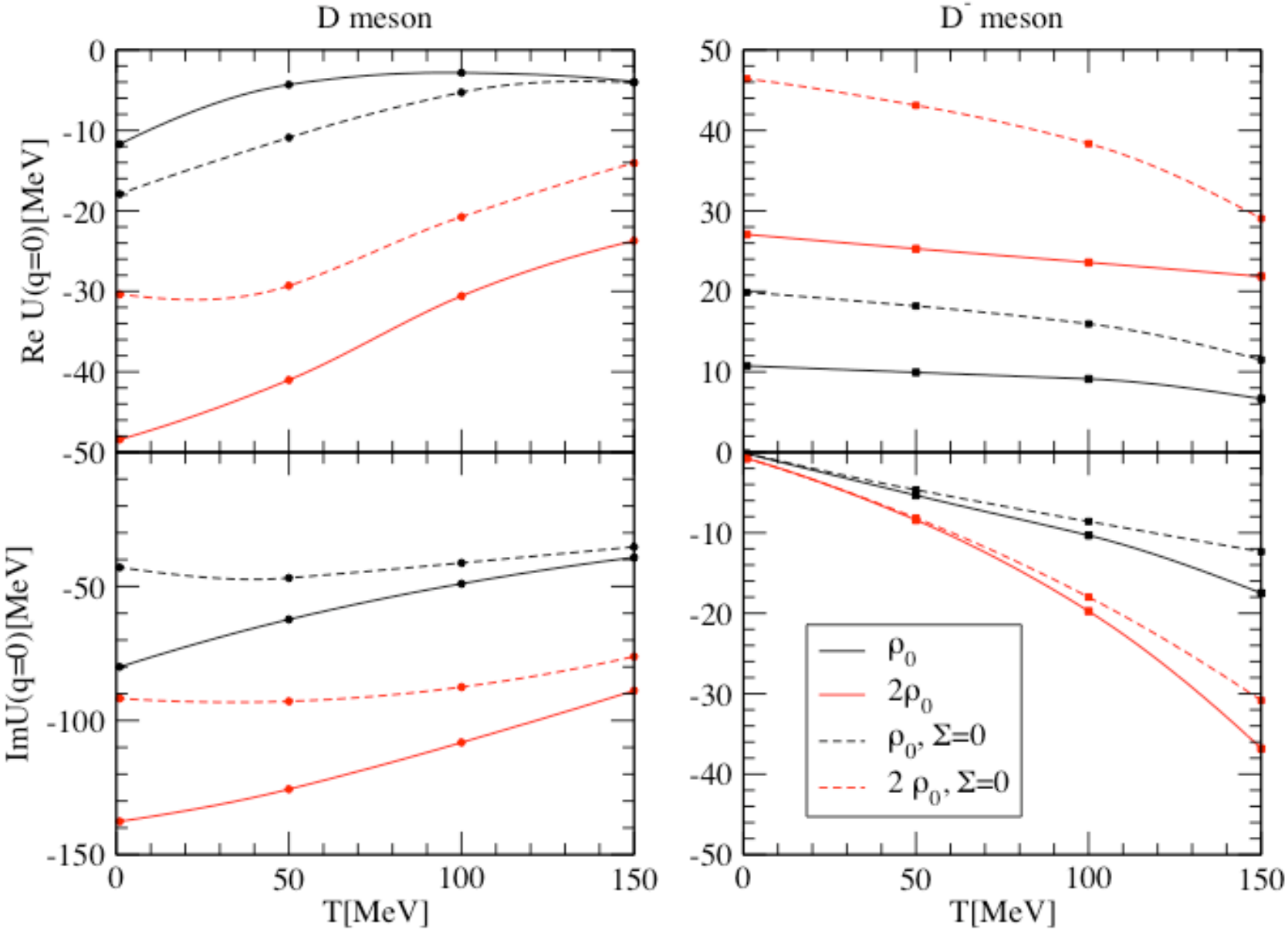
	Model A	Model B
$I=0$	0.607	0
(Born approx.)	0.262	0
$I=1$	-0.264	-0.289
(Born approx.)	-0.614	-0.876

similar to LK but half of HKMS



LK: M.F.M. Lutz and C.L.Korpa, PLB 633 (2006) 43
HKMS: J.Haidenbauer et al., EPJA 33 (2007) 107

D and $\bar{D}$ meson potentials



Conclusions & Outlook

We perform a self-consistent coupled-channel calculation of the D and $\bar{D}$ self-energies in symmetric nuclear matter at finite temperature taking, as bare interaction, the SU(4) TW contribution supplemented by Σ_{DN} term

✓In hot dense matter, $\Lambda_c(2593)$ and $\Sigma_c(2800)$ stay close to their free position but develop a remarkable width

✓The D meson spectral density shows a single pronounced peak at finite temperature that melts with increasing density

✓The low-density theorem is a not good approximation for the $\bar{D}N$, where the repulsive I=1 component dominates

✓ Temperature induces a stronger change in the mass of D than $\bar{D}$ meson and different behavior of the imaginary part due to distinct resonant structure

Open questions?

- J/Ψ suppression
- Open-charm enhancement
- D-mesic nuclei

Some answers expected at CBM @ FAIR

Working along these lines…

- Dressed charmed baryons beyond mean-field
- In-medium charmed cross sections
- ….

LT, A. Ramos and T. Mizutani, in preparation