GOETHE UNIVERSITÄT FRANKFURT AM MAIN

DAAD

Phenomenology of (open and hidden) charmed mesons in a chiral symmetric model

Walaa I. Eshraim

in collaboration with

Francesco Giacosa and Dirk H. Rischke

FAIRness 2014, Salerno, Italy, Sept. 24 , 2014

Introduction

DAAD

- Quantum Chromodynamics: QCD

- Symmetries of the QCD Lagrangian.

  if all quark massless then we have chiral $U(4)_r \times U(4)_l$ symmetry

$$U(N_f)_r \times U(N_f)_l = SU(N_f)_r \times SU(N_f)_l \times U(1)_V \times U(1)_A$$

- Spontaneous breaking of chiral symmetry by quark condensates
- Explicit breaking of a global chiral symmetry by quark masses and chiral anomaly
-Effective chiral models of QCD.

• Charm quark???

Motivation

- Linear sigma model with vector and axial vector degrees of freedom.
- Inclusion of the charmed mesons into the linear sigma model (extended Linear Sigma Model - eLSM).
- Extension from low-energy to high-energy mesons.
- Study of the model for $T = \mu = 0$ (spectroscopy in vacuum).

GOETHE UNIVERSITÄT FRANKFURT AM MAIN

DAAD

Fields in the model

- **Mesons: quark-antiquark states ($q\bar{q}$)**

$$4N_f^2 + 2 \text{ fields}$$

- **For $N_f = 4$ there are *66* mesons: *64* quark-antiquark fields + one pseudoscalar glueball $\tilde{G}$ +one scalar glueball *G***

Quantum numbers (J^{PC})

Pseudoscalar mesons: 0^{-+}	Scalar mesons: 0^{++}	Vector mesons: 1^{--}	Axial-vector mesons: 1^{++}
D^0	$D_0^{*0} \Rightarrow D_0^*(2400)^0$	$D^{*0} \Rightarrow D^*(2007)^0$	$D_1^0 \Rightarrow D_1(2420)^0$
$D^\pm$	$D_0^{*\pm} \Rightarrow D_0^*(2400)^\pm$	$D^{*\pm} \Rightarrow D^*(2010)^\pm$	$D_1^\pm \Rightarrow D_1(2420)^\pm$
$D_s^\pm$	$D_{S0}^{*\pm} \Rightarrow D_{S0}^*(2317)^\pm$	$D_S^\pm$	$D_{S1}^\pm \Rightarrow D_{S1}(2536)^\pm$
$\eta_C \Rightarrow \eta_C(1S)$	$\chi_{c0} \Rightarrow \chi_{c0}(1P)$	$J/\psi \Rightarrow J/\psi(1S)$	$\chi_{c0} \Rightarrow \chi_{c0}(1P)$

W. I. Eshraim, PoS QCD -TNT-III (2014) 049 [arXiv:1401.3260 [hep-ph]]; W. I. Eshraim, F. Giacosa, and D. H. Rischke , [arXiv:1405.5861 [hep-ph]].

DAAD

Including charm degree of freedom

1) Scalar fields:

$$S=\frac{1}{\sqrt{2}}\begin{pmatrix} \frac{\sigma_N+a_0^0}{\sqrt{2}} & a_0^+ & K_S^+ \\ a_0^- & \frac{\sigma_N-a_0^0}{\sqrt{2}} & K_S^0 \\ K_S^- & \bar{K}_S^0 & \sigma_S \end{pmatrix} \Longrightarrow S=\frac{1}{\sqrt{2}}\begin{pmatrix} \frac{1}{\sqrt{2}}(\sigma_N+a_0^0) & a_0^+ & K_0^{*+} & D_0^{*0} \\ a_0^- & \frac{1}{\sqrt{2}}(\sigma_N-a_0^0) & K_0^{*0} & D_0^{*-} \\ K_0^{*-} & \bar{K}_0^{*0} & \sigma_S & D_{S0}^{*-} \\ \bar{D}_0^{*0} & D_0^{*+} & D_{S0}^{*+} & \chi_{c0} \end{pmatrix}$$

$\bar{n}n \propto \bar{u}u+\bar{d}d$

$\bar{s}s$

$\bar{c}c$

2) Pseudoscalar fields

$$P=\frac{1}{\sqrt{2}}\begin{pmatrix} \frac{\eta_N+\pi^0}{\sqrt{2}} & \pi^+ & K^+ \\ \pi^- & \frac{\eta_N-\pi^0}{\sqrt{2}} & K^0 \\ K^- & \bar{K}^0 & \eta_S \end{pmatrix} \Longrightarrow P=\frac{1}{\sqrt{2}}\begin{pmatrix} \frac{1}{\sqrt{2}}(\eta_N+\pi^0) & \pi^+ & K^+ & D^0 \\ \pi^- & \frac{1}{\sqrt{2}}(\eta_N-\pi^0) & K^0 & D^- \\ K^- & \bar{K}^0 & \eta_S & D_S^- \\ \bar{D}^0 & D^+ & D_S^+ & \eta_c \end{pmatrix}$$

$$\eta=\eta_N\cos\phi+\eta_S\sin\phi$$

$$\eta'=-\eta_N\sin\phi+\eta_S\cos\phi$$

with mixing angle $\phi=-44.6^o$

[W. I. Eshraim; S. Janowski; F. Giacosa; D. H. Rischke. Phys.Rev. D87 (2013) 054036 [arXiv: 1208.6474 [hep-ph]].

The multiplet of the scalar and pseudoscalar quark-antiquark states: $\Phi=S+iP$

GOETHE UNIVERSITÄT

3) Vector fields:

$$V^\mu = \frac{1}{\sqrt{2}} \begin{pmatrix} \frac{w_N^\mu + \rho^{\mu 0}}{\sqrt{2}} & \rho^{\mu +} & k^{*\mu +} \\ \rho^{\mu -} & \frac{w_N^\mu - \rho^{\mu 0}}{\sqrt{2}} & k^{*\mu 0} \\ k^{*\mu -} & \bar{k}^{*\mu 0} & w_S^\mu \end{pmatrix} \Longrightarrow V^\mu = \frac{1}{\sqrt{2}} \begin{pmatrix} \frac{1}{\sqrt{2}}(\omega_N + \rho^0) & \rho^+ & K^*(892)^+ & D^{*0} \\ \rho^- & \frac{1}{\sqrt{2}}(\omega_N - \rho^0) & K^*(892)^0 & D^{*-} \\ K^*(892)^- & \bar{K}^*(892)^0 & \omega_S & D_S^{*-} \\ \bar{D}^{*0} & D^{*+} & D_S^{*+} & J/\psi \end{pmatrix}^\mu$$

4) Axial vector fields:

$$A^\mu = \frac{1}{\sqrt{2}} \begin{pmatrix} \frac{f_{1N}^\mu + a_1^{\mu 0}}{\sqrt{2}} & a_1^{\mu +} & k_1^{\mu +} \\ a_1^{\mu -} & \frac{f_{1N}^\mu - a_1^{\mu 0}}{\sqrt{2}} & k_1^{\mu 0} \\ k_1^{\mu -} & \bar{k}_1^{\mu 0} & f_{1S}^\mu \end{pmatrix} \Longrightarrow A^\mu = \frac{1}{\sqrt{2}} \begin{pmatrix} \frac{1}{\sqrt{2}}(f_{1,N} + a_1^0) & a_1^+ & K_1^+ & D_1^0 \\ a_1^- & \frac{1}{\sqrt{2}}(f_{1,N} - a_1^0) & K_1^0 & D_1^- \\ K_1^- & \bar{K}_1^0 & f_{1,S} & D_{S1}^- \\ \bar{D}_1^0 & D_1^+ & D_{S1}^+ & \chi_{c,1} \end{pmatrix}^\mu$$

The left-handed matrix: $L^\mu = V^\mu + A^\mu$ and the right-handed matrix: $R^\mu = V^\mu - A^\mu$

W. I. Eshraim, PoS QCD -TNT-III (2014) 049 [arXiv:1401.3260 [hep-ph]]; W. I. Eshraim; Giacosa; and D. H. Rischke; [arXiv:1405.5861 [hep-ph]]

Linear Sigma Model Lagrangian with (axial-)vector mesons

$$\mathcal{L} = \mathcal{L}_{dil} + \mathrm{Tr}[(D^\mu\Phi)^\dagger(D^\mu\Phi)] - m_0^2\left(\frac{G}{G_0}\right)^2 \mathrm{Tr}(\Phi^\dagger\Phi) - \lambda_1[\mathrm{Tr}(\Phi^\dagger\Phi)]^2 - \lambda_2\,\mathrm{Tr}(\Phi^\dagger\Phi)^2$$
$$+ \mathrm{Tr}\left\{\left[\left(\frac{G}{G_0}\right)^2\frac{m_1^2}{2} + \Delta\right]\left[(L^\mu)^2 + (R^\mu)^2\right]\right\} + \mathrm{Tr}[H(\Phi+\Phi^\dagger)] - 2\,\mathrm{Tr}[\varepsilon\Phi^\dagger\Phi]$$
$$- \frac{1}{4}\mathrm{Tr}[(L^{\mu\nu})^2 + (R^{\mu\nu})^2] + c(det\Phi - det\Phi^\dagger)^2 + i\tilde{c}\,\tilde{G}\left(\det\Phi - \det\Phi^\dagger\right) + i\frac{g_2}{2}\{\mathrm{Tr}(L_{\mu\nu}[L^\mu, L^\nu])$$
$$+ \frac{h_1}{2}\mathrm{Tr}(\Phi^\dagger\Phi)Tr[(L^\mu)^2 + (R^\mu)^2] + h_2\,\mathrm{Tr}[(\Phi R^\mu)^2 + (L^\mu\Phi)^2] + 2h_3\mathrm{Tr}(\Phi R_\mu \Phi^\dagger L^\mu) + \mathrm{Tr}(R_{\mu\nu}[R^\mu, R^\nu])\} + \ldots,$$

where $\mathcal{L}_{dil}$ is the dilaton Lagrangian,

$$\mathcal{L}_{dil} = \frac{1}{2}(\partial_\mu G)^2 - \frac{1}{4}\frac{m_G^2}{\Lambda^2}\left(G^4 \ln\frac{G^2}{\Lambda^2} - \frac{G^4}{4}\right)$$

D.Parganlija, P.Kovacs, G.Wolf, F.Giacosa and D.H. Rischke, Phys. Rev. D 87 (2013) 014011 [arXiv:1208.0585 [hep-ph]];
W. I. Eshraim, PoS QCD -TNT-III (2014) 049 [arXiv:1401.3260 [hep-ph]].

Spontaneous Symmetry Breaking (SSB)

Shifting the fields

$$G \to G + G_0, \quad \sigma_N \to \sigma_N + \phi_N, \quad \sigma_S \to \sigma_S + \phi_S$$

where,

$$\phi_N = Z_\pi f_\pi \qquad \phi_S = \frac{2 Z_k f_k - \phi_N}{\sqrt{2}}$$

D. Parganlija, P. Kovacs, G. Wolf, F. Giacosa and D. H. Rischke, Phys. Rev. D 87 (2013) 014011 [arXiv:1208.0585 [hep-ph].

For $N_f = 4$ new shift

$$\chi_{C0} \to \chi_{C0} + \phi_C$$

where

$$\phi_C = \frac{2 Z_D f_D - \phi_N}{\sqrt{2}} = \sqrt{2} Z_{D_s} f_{D_s} - \phi_S = \frac{Z_{\eta_C} f_{\eta_C}}{\sqrt{2}}$$

W. I. Eshraim, PoS QCD -TNT-III (2014) 049 [arXiv:1401.3260 [hep-ph]];W. I. Eshraim, F. Giacosa and D. H. Rischke, , arXiv:1405.5861 [hep-ph]].

There are 29 eqs. of square masses of mesons with 15 unknown parameters.

Parameters

The values of the $N_f = 3$ parameters :

Parameter	Value	Parameter	Value
m_1^2	0.413×10^6 MeV^2	m_0^2	-0.918×10^6 MeV^2
$\phi_C^2 c/2$	$450 \cdot 10^{-6}$ MeV^{-2}	δ_S	0.151×10^6MeV^2
g_1	5.84	h_1	0
h_2	9.88	h_3	3.87
ϕ_N	164.6 MeV	ϕ_S	126.2 MeV
λ_1	0	λ_2	68.3

[D. Parganlija, P. Kovacs, G. Wolf, F. Giacosa and D. H. Rischke, Phys. Rev. D 87 (2013) 014011 [arXiv:1208.0585 [hep-ph]].

→ χ^2 /d.o.f = 1.23

The new three parameters for $N_f = 4$ are $\phi_C, \delta_C, \varepsilon_C$.

By fit with χ^2 /d.o.f = 1 :

$$\phi_C = (176 \pm 28)\ \text{MeV},\ \ \delta_C = (3.91 \pm 0.36) \times 10^6\ \text{MeV}^2,\ \varepsilon_C = (2.23 \pm 0.71) \times 10^6\ \text{MeV}^2 .$$

[W. I. Eshraim, F. Giacosa and D. H. Rischke, , arXiv:1405.5861 [hep-ph]].

Results

Masses of light mesons:

Observable	our Value [MeV]	Experimental Value [MeV]
$m_{f_{1N}}$	1186	1281.8 $\pm$ 0.6
m_{a_1}	1185	1230 $\pm$ 40
$m_{f_{1S}}$	1372	1426.4 $\pm$ 0.9
m_{K^*}	885	891.66 $\pm$ 0.26
m_{K_1}	1281	1272 $\pm$ 7
m_{σ_1}	1362	(1200-1500)-i(150-250)
m_{a0}	1363	1474 $\pm$ 19
m_{σ_2}	1531	1720 $\pm$ 60
m_{w_N}	783	782.65 $\pm$ 0.12
m_{w_S}	975	1019.46 $\pm$ 0.020
m_ρ	783	775.5 $\pm$ 38.8
m_η	509	547.853 $\pm$ 0.024
m_π	141	139.57018 $\pm$ 0.00035
$m_{\eta'}$	962	957.78 $\pm$ 0.06
$m_{K_0^*}$	1449	1425 $\pm$ 50
m_K	485	493.677 $\pm$ 0.016

W. I. Eshraim, PoS QCD -TNT-III (2014) 049 [arXiv:1401.3260 [hep-ph]; D. Parganlija, P. Kovacs, G. Wolf, F. Giacosa and D. H. Rischke, Phys. Rev. D 87 (2013) 014011 [arXiv:1208.0585 [hep-ph].

Masses of (open and hidden) charmed mesons:

Resonance	Quark content	J^P	Our Value [MeV]	Experimental Value [MeV]
D^0	$u\bar{c}, \bar{u}c$	0^-	1981 ± 73	1864.86 ± 0.13
$D_S^\pm$	$s\bar{c}, \bar{s}c$	0^-	2004 ± 74	1968.50 ± 0.32
$\eta_c(1S)$	$c\bar{c}$	0^-	2673 ± 118	2983.7 ± 0.7
$D_0^*(2400)^0$	$u\bar{c}, \bar{u}c$	0^+	2414 ± 77	2318 ± 29
$D_{S0}^*(2317)^\pm$	$s\bar{c}, \bar{s}c$	0^+	2467 ± 76	2317.8 ± 0.6
$\chi_{c0}(1P)$	$c\bar{c}$	0^+	3144 ± 128	3414.75 ± 0.31
$D^*(2007)^0$	$u\bar{c}, \bar{u}c$	1^-	2168 ± 70	2006.99 ± 0.15
D_s^*	$s\bar{c}, \bar{s}c$	1^-	2203 ± 69	2112.3 ± 0.5
$J/\psi(1S)$	$c\bar{c}$	1^-	2947 ± 109	3096.916 ± 0.011
$D_1(2420)^0$	$u\bar{c}, \bar{u}c$	1^+	2429 ± 63	2421.4 ± 0.6
$D_{S1}(2536)^\pm$	$s\bar{c}, \bar{s}c$	1^+	2480 ± 63	2535.12 ± 0.13
$\chi_{c1}(1P)$	$c\bar{c}$	1^+	3239 ± 101	3510.66 ± 0.07

W. I. Eshraim, F. Giacosa and D. H. Rischke, [arXiv:1405.5861 [hep-ph]];
W. I. Eshraim, PoS QCD -TNT-III (2014) 049 [arXiv:1401.3260 [hep-ph].

Mass difference and decay constants

The mass difference of the squared charmed (axial-)vector mesons:

mass difference	theoretical value MeV^2	experimental value MeV^2
$m^2_{D_1} - m^2_{D^*}$	$(1.2 \pm 0.6) \times 10^6$	1.82×10^6
$m^2_{\chi_{C1}} - m^2_{J/\psi}$	$(1.8 \pm 1.3) \times 10^6$	2.73×10^6
$m^2_{D_{S1}} - m^2_{D^*_S}$	$(1.2 \pm 0.6) \times 10^6$	1.97×10^6

Weak decay constant of *D*, *D*s, and f_{η_C} .

$$f_D = (254 \pm 17)\ \text{MeV}\ ,\ f_{D_S} = (261 \pm 17)\ \text{MeV}\ ,\ f_{\eta_C} = (222 \pm 28)\ \text{MeV}$$

[Exp. value = 206.7 ± 8.9] *MeV*, [Exp. value = 260.5 ± 5.4] *MeV*, [Exp. value = 335 ± 75] *MeV*

W. I. Eshraim, F. Giacosa and D. H. Rischke, arXiv:1405.5861 [hep-ph].

Decay widths of open charmed mesons:

Decay Channel	Theoretical results [MeV]	Experimental results [MeV] (from [6])
$D_0^*(2400)^0 \to D\pi$	139^{+243}_{-114}	$D^+\pi^-$ seen; full width $\Gamma = 267 \pm 40$
$D_0^*(2400)^+ \to D\pi$	51^{+182}_{-51}	$D^+\pi^0$ seen; full width: $\Gamma = 283 \pm 24 \pm 34$
$D^*(2007)^0 \to D^0\pi^0$	0.025 ± 0.003	seen; < 1.3
$D^*(2007)^0 \to D^+\pi^-$	0	not seen
$D^*(2010)^+ \to D^+\pi^0$	$0.018^{+0.002}_{-0.003}$	0.029 ± 0.008
$D^*(2010)^+ \to D^0\pi^+$	$0.038^{+0.005}_{-0.004}$	0.065 ± 0.017
$D_1(2420)^0 \to D^*\pi$	65^{+51}_{-37}	$D^{*+}\pi^-$ seen; full width: $\Gamma = 27.4 \pm 2.5$
$D_1(2420)^0 \to D^0\pi\pi$	0.59 ± 0.02	seen
$D_1(2420)^0 \to D^+\pi^-\pi^0$	$0.21^{+0.01}_{-0.015}$	-
$D_1(2420)^0 \to D^+\pi^-$	0	not seen; $\Gamma(D^+\pi^-)/\Gamma(D^{*+}\pi^-) < 0.24$
$D_1(2420)^+ \to D^*\pi$	65^{+51}_{-36}	$D^{*0}\pi^+$ seen; full width: $\Gamma = 25 \pm 6$
$D_1(2420)^+ \to D^+\pi\pi$	0.56 ± 0.02	seen
$D_1(2420)^+ \to D^0\pi^0\pi^+$	0.22 ± 0.01	-
$D_1(2420)^+ \to D^0\pi^+$	0	not seen; $\Gamma(D^0\pi^+)/\Gamma(D^{*0}\pi^+) < 0.18$

W. I. Eshraim, F. Giacosa and D. H. Rischke, arXiv:1405.5861 [hep-ph].

- The decay widths of charmonium state depend on the parameters λ_1 and h_1.

Using fit including the decay widths of charmonium state χ_{C0}, we obtain

$$\lambda_1 = -0.16 \quad \text{and} \quad h_1 = 0.046.$$

W. I. Eshraim, F. Giacosa and D. H. Rischke, in preparation, preliminary!

Mixing matrix of the three scalar fields (σ_N, σ_S, G)

$$\begin{pmatrix} f_0(1370) \\ f_0(1500) \\ f_0(1710) \end{pmatrix} = \begin{pmatrix} 0.94 & -0.17 & 0.29 \\ 0.21 & 0.97 & -0.12 \\ -0.26 & 0.18 & 0.95 \end{pmatrix} \begin{pmatrix} \sigma_N \equiv (\bar{u}u + \bar{d}d)/\sqrt{2} \\ \sigma_S \equiv \bar{s}s \\ G \equiv gg \end{pmatrix}$$

where G is a scalar glueball.

S. Janowski, F. Giacosa and D. H. Rischke, in preparation.

Decay widths of hidden charmed mesons:

1) Decay widths of (axial-)vector charmonium states:

$$\Gamma_{J/\psi} = 0 \quad \text{and} \quad \Gamma_{\chi_{c1}} = 0$$

2) Decay widths of scalar charmonium state (η_C):

W. I. Eshraim, F. Giacosa and D. H. Rischke, in preparation preliminary!

Decay Channel	theoretical result [MeV]	Experimental result [MeV]
$\Gamma_{\eta_c \to \overline{K}_0^* K}$	0.01	-
$\Gamma_{\eta_c \to a_0 \pi}$	0.01	-
$\Gamma_{\eta_c \to f_0(1370)\eta}$	0.00018	-
$\Gamma_{\eta_c \to f_0(1500)\eta}$	0.006	-
$\Gamma_{\eta_c \to f_0(1710)\eta}$	0.000032	-
$\Gamma_{\eta_c \to f_0(1370)\eta'}$	0.027	-
$\Gamma_{\eta_c \to f_0(1500)\eta'}$	0.024	-
$\Gamma_{\eta_c \to f_0(1710)\eta'}$	0.0006	-
$\Gamma_{\eta_c \to \eta\eta\eta}$	0.052	-
$\Gamma_{\eta_c \to \eta'\eta'\eta'}$	0.0023	-
$\Gamma_{\eta_c \to \eta'\eta\eta}$	0.44	-
$\Gamma_{\eta_c \to \eta'\eta'\eta}$	0.0034	
$\Gamma_{\eta_c \to \eta K \overline{K}}$	0.15	0.32±0.17
$\Gamma_{\eta_c \to \eta' K K}$	0.41	
$\Gamma_{\eta_c \to \eta\pi\pi}$	0.12	0.54±0.18
$\Gamma_{\eta_c \to \eta'\pi\pi}$	0.08	1.3±0.0.6
$\Gamma_{\eta_c \to K K \pi}$	0.095	-

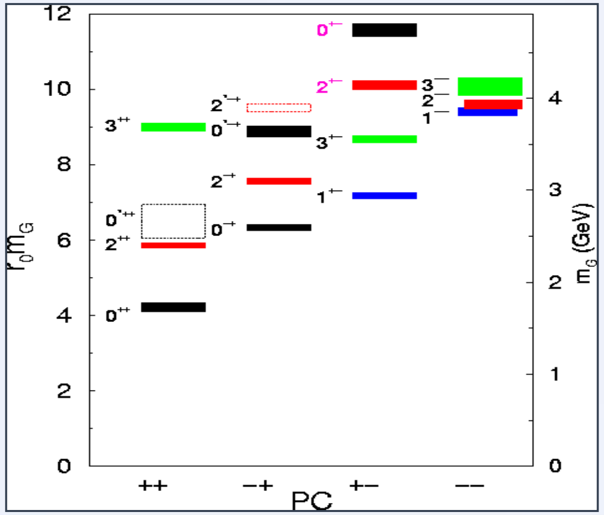
Decay width of η_C into a pseudoscalar glueball

BESIII: $m_{\tilde{G}} = 2370\ MeV$

$$\Gamma_{\eta_{C\to\tilde{G}\pi\pi}} = \begin{cases} = 0.16\ MeV \\ = 0.124\ MeV \end{cases}$$

Could be measured in

Lattice QCD calculations:



$m_{\tilde{G}} = 2600\ MeV$

W. I. Eshraim, F. Giacosa and D. H. Rischke, in preparation preliminary!

DAAD

Decay width of χ_{c0}

3) Decay widths of a pseudoscalar charmonium state (χ_{c0}):

Decay Channel	theoretical result [MeV]	Experimental result [MeV]
$\Gamma_{\chi_{c0}\to a_0 a_0}$	0.004	-
$\Gamma_{\chi_{c0}\to k_1 \overline{K}_1}$	0.005	-
$\Gamma_{\chi_{c0}\to \eta\eta}$	0.022	0.031±0.0039
$\Gamma_{\chi_{c0}\to \eta'\eta'}$	0.02	0.02±0.0035
$\Gamma_{\chi_{c0}\to \eta\eta'}$	0.004	<0.0024
$\Gamma_{\chi_{c0}\to K^* K_0^*}$	0.00007	-
$\Gamma_{\chi_{c0}\to \rho\rho}$	0.01	-
$\Gamma_{\chi_{c0}\to f_0(1370) f_0(1370)}$	0.005	<0.003
$\Gamma_{\chi_{c0}\to f_0(1500) f_0(1500)}$	0.004	<0.0005
$\Gamma_{\chi_{c0}\to f_0(1370) f_0(1500)}$	0.000004	<0.001
$\Gamma_{\chi_{c0}\to f_0(1370) f_0(1710)}$	0.0003	0.0069±0.004
$\Gamma_{\chi_{c0}\to f_0(1500) f_0(1710)}$	0.00004	<0.0007
$\Gamma_{\chi_{c0}\to K_0^* K\eta}$	0.008	-
$\Gamma_{\chi_{c0}\to K_0^* K\eta'}$	0.004	-
$\Gamma_{\chi_{c0}\to f_0(1370)\eta\eta}$	0.0004	-
$\Gamma_{\chi_{c0}\to f_0(1500)\eta\eta}$	0.003	-
$\Gamma_{\chi_{c0}\to f_0(1370)\eta'\eta'}$	0.0027	-
$\Gamma_{\chi_{c0}\to f_0(1370)\eta\eta'}$	0.000089	-
$\Gamma_{\chi_{c0}\to f_0(1500)\eta\eta'}$	0.011	-
$\Gamma_{\chi_{c0}\to f_0(1710)\eta\eta}$	0.00008	-
$\Gamma_{\chi_{c0}\to f_0(1710)\eta\eta'}$	0.00003	-

Decay Channel	theoretical result [MeV]	Experimental result [MeV]
$\Gamma_{\chi_{c0}\to \overline{K}_0^{*0} K_0^{*0}}$	0.01	0.01±0.0047
$\Gamma_{\chi_{c0}\to K^- K^+}$	0.059	0.061±0.007
$\Gamma_{\chi_{c0}\to \pi\pi}$	0.089	0.088±0.0092
$\Gamma_{\chi_{c0}\to \overline{K}^{*0} K^{*0}}$	0.0175	0.017±0.0072
$\Gamma_{\chi_{c0}\to ww}$	0.01	0.0099±0.0017
$\Gamma_{\chi_{c0}\to \phi\phi}$	0.004	0.0081±0.0013
$\Gamma_{\chi_{c0}\to k_1^+ K^-}$	0.005	0.063±0.0233

W. I. Eshraim, F. Giacosa and D. H. Rischke, in preparation,

preliminary!

Conclusions and Outlook

1. Linear sigma model with $N_f = 4$ and vector and axial-vector mesons.
2. Masses of (open and hidden) charmed mesons.
3. Charm-anticharm condensate and decay constants.
4. Decay widths of (open and hidden) charmed mesons.

I. Light tetraquark nonet and its extension to $N_f = 4$ (on going).

II. Mixing of axial- and pseudo-vectors charmed mesons (on going).

III. Inclusion of isospin breaking (on going).

IV. Extension to non-zero temperature and density.

Thank You