QCD Sum Rules for the D-Meson at finite Density

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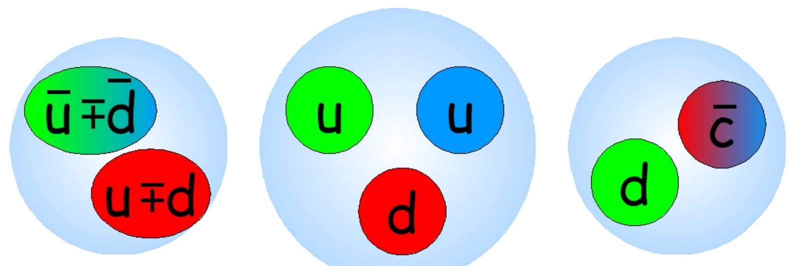
QCD-Condensates and medium-modified Hadrons

- Hadrons are composite objects of quark and gluons.



$\omega/\rho-Meson$ $Nukleon$ $D-Meson$

$m_u \approx m_d \ll m_c$

- Quarks and gluons are described by the theory of strong interaction (QCD).
- Hadrons emerge as excitations of the QCD ground state (= vacuum). → This vacuum is characterized by condensates:

$$\langle \bar{q}q \rangle \,,\ \langle \frac{\alpha_s}{\pi} G^2 \rangle \,,\ \langle \bar{q} g_s (\sigma G) q \rangle \,,\ \langle \bar{q} \hat{A} q \bar{q} \hat{B} q \rangle$$

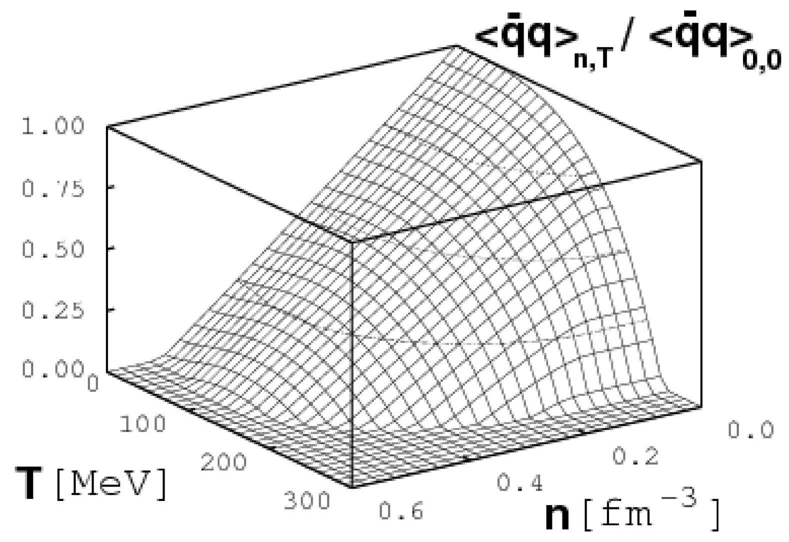
- Condensates account for the complex dynamical non-perturbative structure of the QCD vacuum.
- Hadron masses are understood in terms of condensates:

$$m_{\mathrm{Hadron}} = \mathcal{F}(\langle \bar{q}q \rangle, \ldots).$$

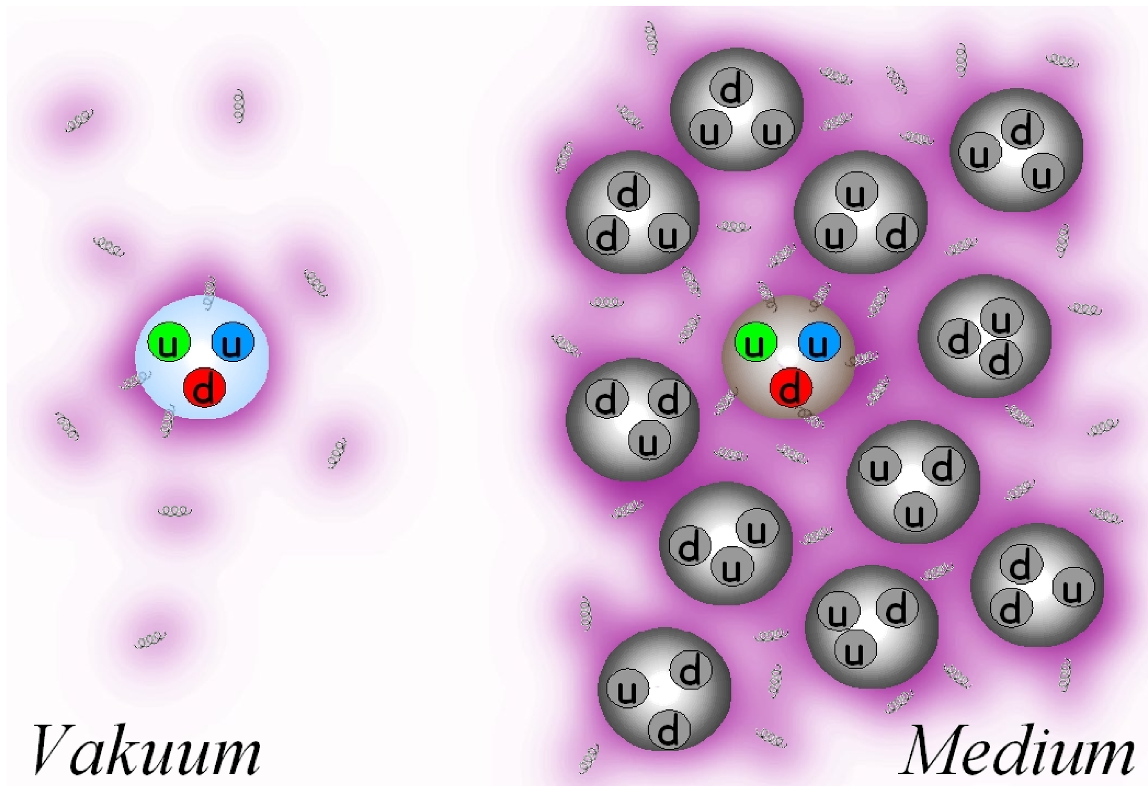
- Condensates change within strongly interacting matter, e.g. nuclear matter.

→ Expectation: masses and other properties of hadrons change when embedded in nuclear matter.

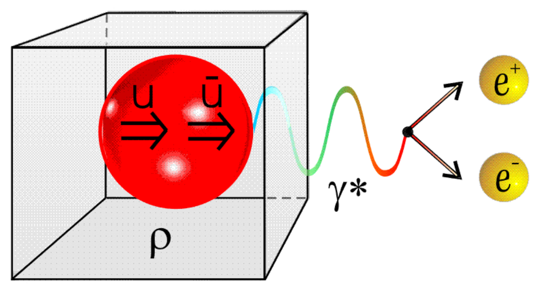
- Analogy → Stark- and Zeeman effects.



- $\langle \bar{q}q \rangle$ is an order parameter of chiral symmetry related to a fundamental symmetry principle of strong interaction; chiral symmetry is spon-taneously broken in vacuum; expected to be restored in dense (n) + hot (T) nuclear matter.



- How to measure medium modifications of hadrons?



- Probing spectral properties by direct electromagnetic decays of vector mesons = goal of HADES

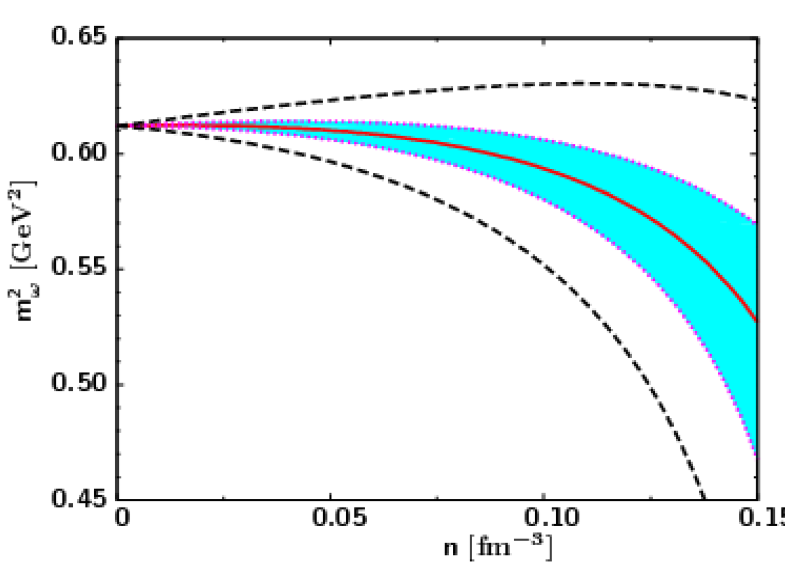
QCD-Sum Rules

- Using an ansatz for the spectral function, medium modifications of corresponding parameters can then be extracted (example: change of an effective mass). Vice versa, experimental knowledge of such in-medium effects can be utilized to constrain the hitherto unknown density dependence of particular QCD condensates.

⟶ successfully describe the hadron mass spectrum in vacuum and accomplish directly the correspondence of modifications of hadron properties to changes of QCD condensates. Based on analytical properties of the hadron Green's function (describing hadron propagation), integral representations can be found (dispersion relations). They relate integrals of the hadronic spectral function to parameters of QCD, especially to QCD condensates (technique: operator product expansion).

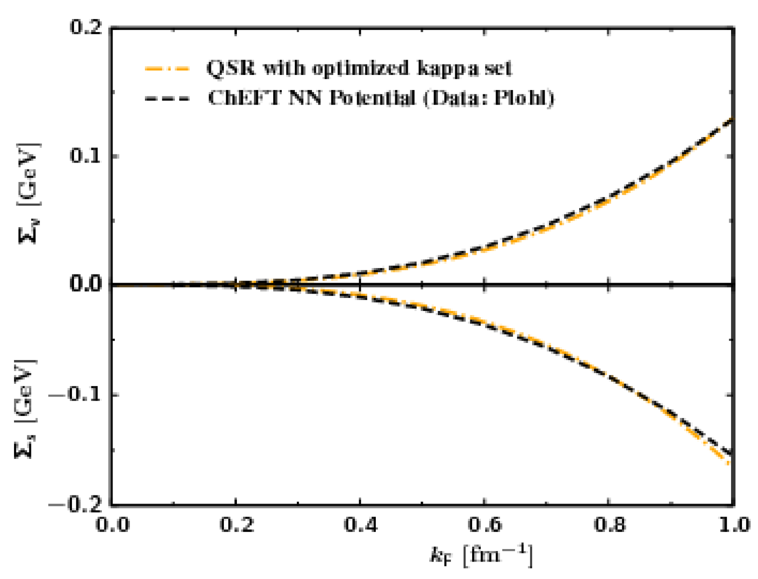
$$\underbrace{\frac{1}{\pi}\int_{-\infty}^{\infty} \frac{\Delta \Pi_H(s,\vec{q})}{s-q_0}}_{\text{Spectral integral of hadrons H}} - \sum_{n=0}^{N} a_n q_0^n = c_0(q) + \underbrace{c_1(q)\langle \bar{q}q \rangle + c_2(q)\langle \frac{\alpha_s}{\pi} G^2 \rangle + c_3(q)\langle \bar{q} g_s(\sigma G) q \rangle + c_4(q)\langle \bar{q}\hat{A}q\bar{q}\hat{B}q \rangle + \ldots}_{\text{Condensates as higher power corrections to the leading perturbative contribution } (\sim 1/q^{2n})}$$

ω - Meson
qq - light quark system
experimental data:
CB - TAPS, further data expected from HADES



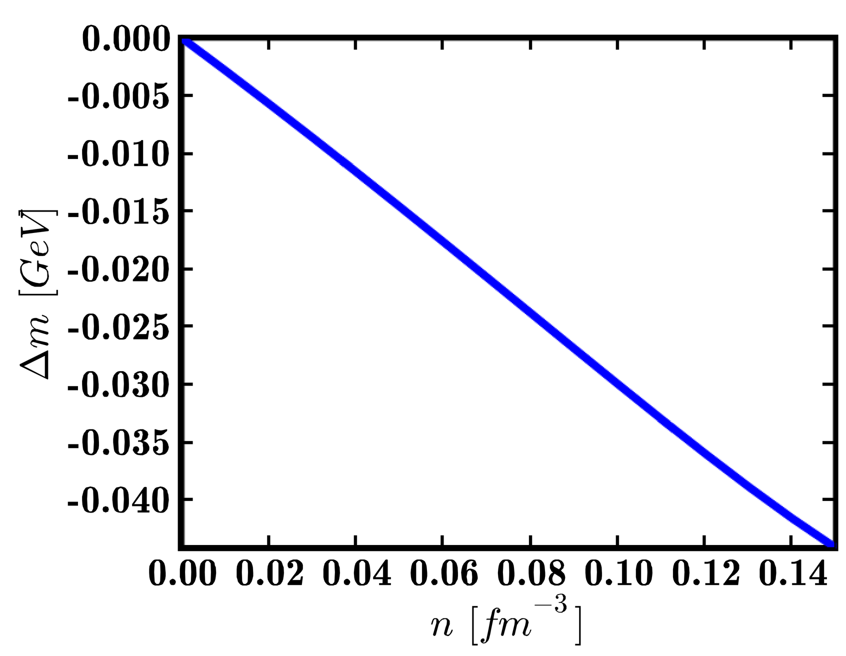
R. Thomas, S. Zschocke, B. Kämpfer, Phys. Rev. Lett. (2005)

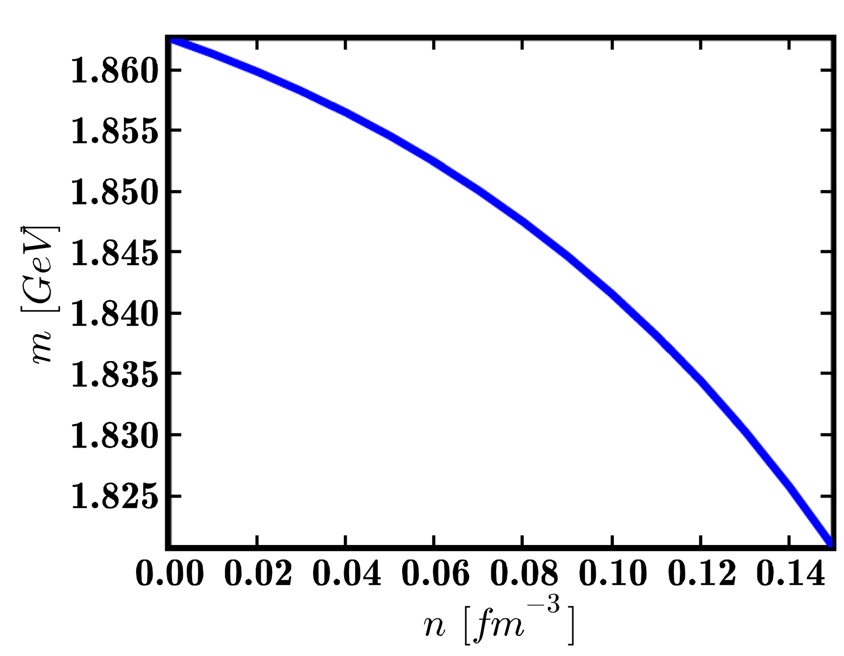
Nucleon
qqq - light quark system
experimental data: ground state of nuclei + Dirac phenomenology



R. Thomas, T. Hilger, B. Kämpfer, Nucl. Phys. A (2007)

D - Meson
Qq - heavy-light quark systems
experimental data: expected from CBM + PANDA @ FAIR





ω

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