Recent results in the extended linear sigma model: (axial)vector meson in-medium masses and finite volume effects

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Vector and axial vector meson **E**xtended Polyakov **L**inear **S**igma **M**odel.
Effective model to study the phase diagram of strongly interacting matter at finite T and μ.
Phys. Rev. D 93, no. 11, 114014 (2016)

- "Simple" quark-meson model with four meson nonets (axial) vectors included
- Mesonic Lagrangian with chiral symmetry + Constituent quarks ($N_f = 2 + 1$)

Thermodynamics: **Mean field level** effective potential:

- Classical potential.
- Fermionic one-loop correction with vanishing fluctuating mesonic fields.
  Properly renormalized functional integration over the fermionic fields.
- Polyakov loop potential.

$$\Omega(T, \mu_q) = U_{Cl} + \mathrm{tr} \int_K \log\left(iS_0^{-1}\right) + U(\Phi, \bar{\Phi})$$

Field equations by minimizing in the order parameters ϕ_N, ϕ_S, Φ and $\bar{\Phi}$.

Parametrization of the model at $T = 0,\ \mu = 0$ with ≈ 30 physical quantities.

Curvature meson masses are calculated from the grand potential

$$M_{ab}^2 = \frac{\partial^2 \Omega}{\partial \varphi_a \partial \varphi_b}\bigg|_{\{\varphi_i\}=0} = m_{ab}^2 + \Delta m_{ab}^2 + \delta m_{ab}^2$$

Besides the tree-level meson masses, fermion one-loop corrections are taken into account.
Mixing at tree-level between S-V and P-A $\Rightarrow$ "wave function renrom." factor in S, P masses.
Fermion determinant by functional integration of the fermionic Lagrangian

$$\mathcal{L}_Y = \bar{\psi}\left(i\gamma^\mu \partial_\mu - g_F(S - i\gamma_5 P) - g_V \gamma^\mu (V_\mu + \gamma_5 A_\mu)\right)\psi$$

In the 2016 version $g_V = 0$ was used. **Phys. Rev. D 104, 056013 (2021)**

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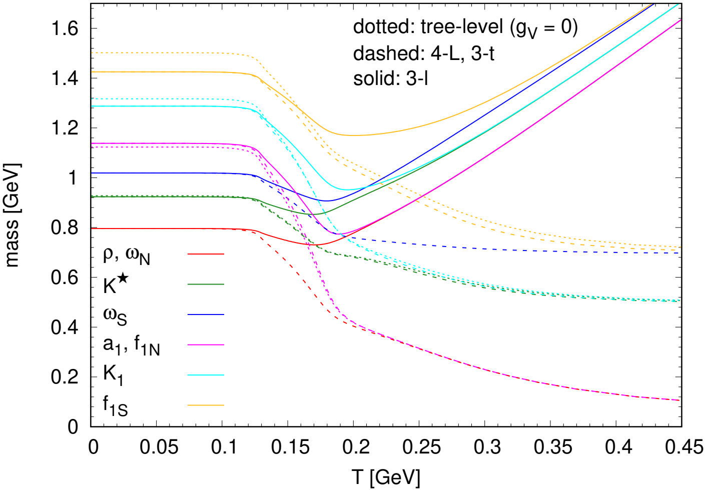
Including $g_V \neq 0 \quad \Rightarrow \quad$ fermionic contribution for (axial) vectors!
It can be calculated as the one-loop **fermionic self-energy** at vanishing external momentum

$$\Pi^{\mu\nu}(K=0) = \sum_{x=l,t,L} \Pi_x(0) P_x^{\mu\nu}, \qquad \Pi_{L,t,l}(0) = \Pi_{\text{vac}}(0) + \Pi_{L,t,l}^{\text{mat}}(0)$$

Gaussian approximation to separate the physical modes and find their masses.
The modes at $T \neq 0$: non-propagating 4-longitudinal (L), 3-longitudinal (l), 3-transversal (t)

Mass of A/V modes with $g_V \neq 0$



II. Volume dependence

Why to suty finite size effects?

Field theoretical models in the thermodyn. limit, and objects like compact stars: infinite/large volume, fireball at HIC: small volume.

- General considerations in statistical physics: Finite-size scaling theory (FSS).
- Specially for strongly interacting systems: Studying the volume effects in our models.

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Models with **infinite volume**: How to mimic the volume effects?

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Models with **infinite volume**: How to mimic the volume effects?

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- Discretization: $\int dp \to \sum_n$
- Low momentum cutoff: $\int_0^\infty dp \to \int_\lambda^\infty dp$

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Tested also in HRG model:
Karsch, Morita and Redlich: Phys. Rev. C 93, no.3, 034907 (2016)

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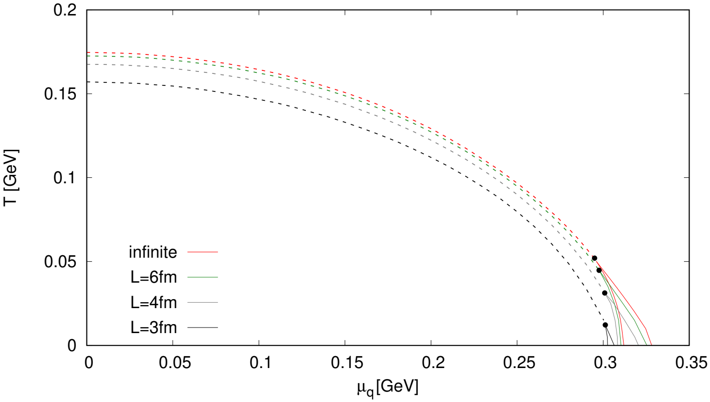
Other effects – eg. surface – are not taken into account.

Volume dependence of the CEP



Thank you!