In-medium Modifications of Hadrons and the NA60 dimuon measurements

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Outline

Why Electromagnetic Probes?

Models for dilepton production in HIC’s

Comparison to NA60 di-muon data
Why Electromagnetic Probes?

- $\gamma, \ell^\pm$: no strong interactions
- reflect whole “history” of collision

Fig. by A. Drees
Vector Mesons and chiral symmetry

- dilepton rates $\Leftrightarrow$ electromagnetic current-correlation functions
- probes chiral vector current
- hadronic em. current $\Leftrightarrow$ spectral properties of vector mesons
- study medium modifications of hadrons in HIC’s

![Graph showing spectral functions of vector mesons and charged current models.](image)

- $\rho$ (770) + cont.
- $a_1$ (1260) + cont.

Dropping Masses?

Melting Resonances?

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Medium Modifications of Hadrons and NA60
Models

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Models

- confront different models for low-mass region with di-muon data in 158 GeV In-In Collisions
  [NA60 Collaboration]
  1. Hadronic Many Body Theory
     for medium modifications of \( \rho \) mesons [Rapp, Wambach 99] + chiral vector-axial-vector mixing [HvH, Rapp 06]
  2. Virial expansion within chiral reduction formalism
     [Steele, Yamagishi, Zahed 97]
  3. Scenario with (parameterized) dropping \( \rho \) masses
  4. \( \rho \)-spectral function from Hidden Local Symmetry
     [Harada, Sasaki 06]

- medium described with thermal fireball parametrization compatible with hydro models
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Hadronic Many-Body Theory + Chiral Mixing

▸ intermediate mass range: Mixing of $\Pi_V$ with $\Pi_A$
(Dey, Eletsky, Ioffe '90)

$$\Pi_V^{(T)} = (1 - \epsilon) \Pi_V + \epsilon \Pi_A,$$
$$\epsilon = \frac{1}{2} \frac{\mathcal{T}_{\pi}(T, \mu_\pi)}{\mathcal{T}_{\pi}(T_c, 0)} \propto \omicron$$

▸ Fireball model $\Rightarrow$ time evolution
▸ absolute normalization!
▸ good overall agreement with data
▸ consistent with $\omega$ and $\phi$
▸ $\omega$: similar model as for $\rho$
▸ $\phi$: less well known; width assumed $\approx 80$ MeV

[HvH, R. Rapp, PRL 97, 102301 (2006)]
Hadronic Many-Body Theory + Chiral Mixing

- $2\pi$ contributions + $\rho B$ interactions from Rapp+Wambach '99
- intermediate mass range: Mixing of $\Pi_V$ with $\Pi_A$

$$\Pi^{(T)}_V = (1 - \epsilon)\Pi_V + \epsilon\Pi_A, \quad \epsilon = \frac{1}{2} \frac{T\pi(T, \mu\pi)}{T\pi(T_c, 0)} \propto$$

- same absolute normalization!
Chiral Reduction Formalism (Virial Expansion)

[HvH, Rapp hep-ph/0604269] [Dusling, Teaney, Zahed 06]

- underestimates medium effects on the $\rho$
  (due to low-density approximation no broadening!)
- intermediate masses: mixing less pronounced
- indication of chiral restoration?
- results with fireball parametrization consistent with hydro!
Dropping $\rho$ masses/HLS?

$$m^*_\rho = m_\rho \left(1 - c\rho_B/\rho_0\right) \left[1 - (T/T_c)^2\right]^\alpha$$

- **Naive** mass dropping not favored by NA60 data
- **Hidden local symmetry** [Harada, Sasaki 06]
- dropping mass + narrowing of $\rho$ also not favored by data
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Hadronic Many Body Theory (semicentral)

missing yield at high $p_T$: "Corona effect"?
Hadronic Many Body Theory (semicentral)

include cocktail and freeze-out $\rho$
contribution from Drell-Yan?
work in progress
[Strong, HvH, Rapp 06]
Hadronic Many Body Theory (semicentral)

work in progress [Strong, HvH, Rapp 06]
Conclusions

- chiral symmetry: important feature to connect QCD↔hadronic effective models
- important property of (s)QGP: How is chiral symmetry restored?
- electromagnetic probes may provide most direct insight
- models vs. data: broadening of $\rho$, small mass shifts
  no $\rho$-mass dropping observed
- a lot to do for theory
  - consistent chiral scheme for hadrons
  - self-consistent treatment of (axial-) vector particles
  - equation of state including in-medium modifications vs. statistical models with “free hadron properties”