Dimuon radiation at the CERN SPS within a hybrid evolution model

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Introduction

- l^+l^- are **messengers of the hot and dense phase** of the collision
- l^+l^- allow us to investigate **medium effects** on hadron properties
- Finding: ρ spectral function is modified in the medium (CERES,NA60, ...)
- Finding: **Sudden steepening** of the $\mathbf{m_T}$ spectra above the ρ (NA60)
  - ▷ emission from early times? early times $\equiv \mathbf{q\bar{q}} \to \mu^+\mu^+$?
  - ▷ Interpretation requires realistic transverse dynamics

Dynamics of thermal dileptons: effort and aims

We let the in-medium e.m. correlator shine from a full (3+1)d hydrodynamical calculation

- seek for **fingerprints of the dynamical evolution** of the fireball throughout the $(\mathbf{T}, \mu_\mathbf{B})$ plane and the different phases of matter
- investigate **importance of non-thermal contribution**. Explore consequences of an eventual continuous slow decoupling

Emission rates

- $\rho^* \to \mathbf{ll}$

$$\frac{d^8N_{\rho^*\to ll}}{d^4x d^4q} = -\frac{\alpha^2 m_\rho^4 L(M^2)}{\pi^3 g_\rho^2 \; M^2} f_B(q_0;T)\,\mathrm{Im}\,D_\rho(M,q;T,\mu_B)$$

with ρ spectral function in-medium modified

▷ Spectral density for the ρ meson in a heat bath of **N** and π re-derived from [1] and tabulated

- $4\pi \to \mathbf{ll}$ rate from the reverse process measured in $\mathbf{e^+e^-}$ annihilation

$$i\frac{d^8N_{4\pi\to ll}}{d^4x d^4q} = \frac{4\alpha^2}{(2\pi)^2} e^{-q_0/T} \frac{M^2}{16\pi^3\alpha^2}\sigma(e^+e^- \to 4\pi)$$

$\sigma(\mathbf{e^+e^-} \to 4\pi)$ from BaBar data [2]

- $\mathbf{q\bar{q}} \to \mathbf{ll}$ in LO [3]

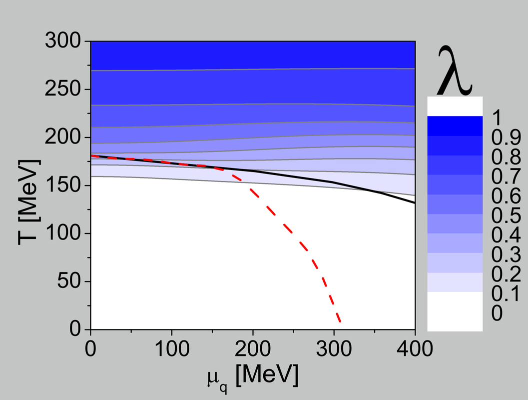
Evolution model [4]

UrQMD → SHASTA → UrQMD

- Non-equilibrium initial conditions via UrQMD
- 3+1 ideal hydrodynamical evolution for the hot and dense stage of the reaction
- Time-span for decoupling in dilute stage modelled via hadronic cascade

EoS [5]

- Obtained from coupling the Polyakov loop to a chiral hadronic flavor-SU(3) model, adding quark d.o.f.
- describes chiral restoration and deconfinement phase transition
- contains the correct asymptotic d.o.f. (quarks ↔ hadrons)



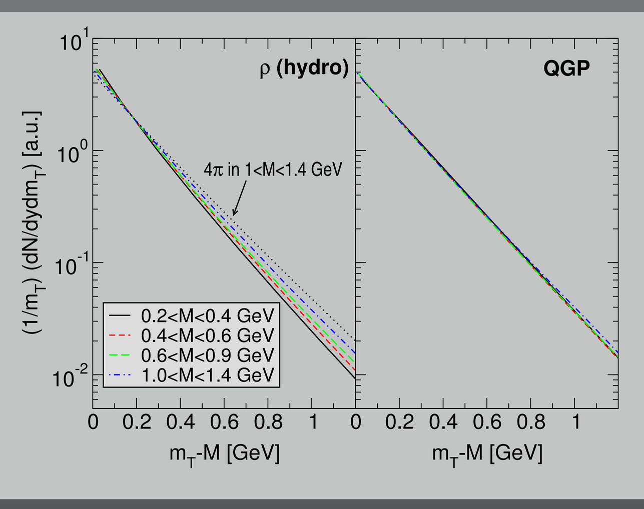
λ : **fraction of QGP**

- λ increases with increasing **T**
- large coexistence phase
- "weight" hadronic and QGP rates with λ

$$\frac{d^8N_{ll}}{d^4x d^4q} = [1-\lambda]\left(\frac{d^8N_{4\pi\to ll}}{d^4x d^4q} + \frac{d^8N_{\rho\to ll}}{d^4x d^4q}\right) + \lambda\frac{dN_{q\bar{q}\to ll}}{d^4x d^4q}$$

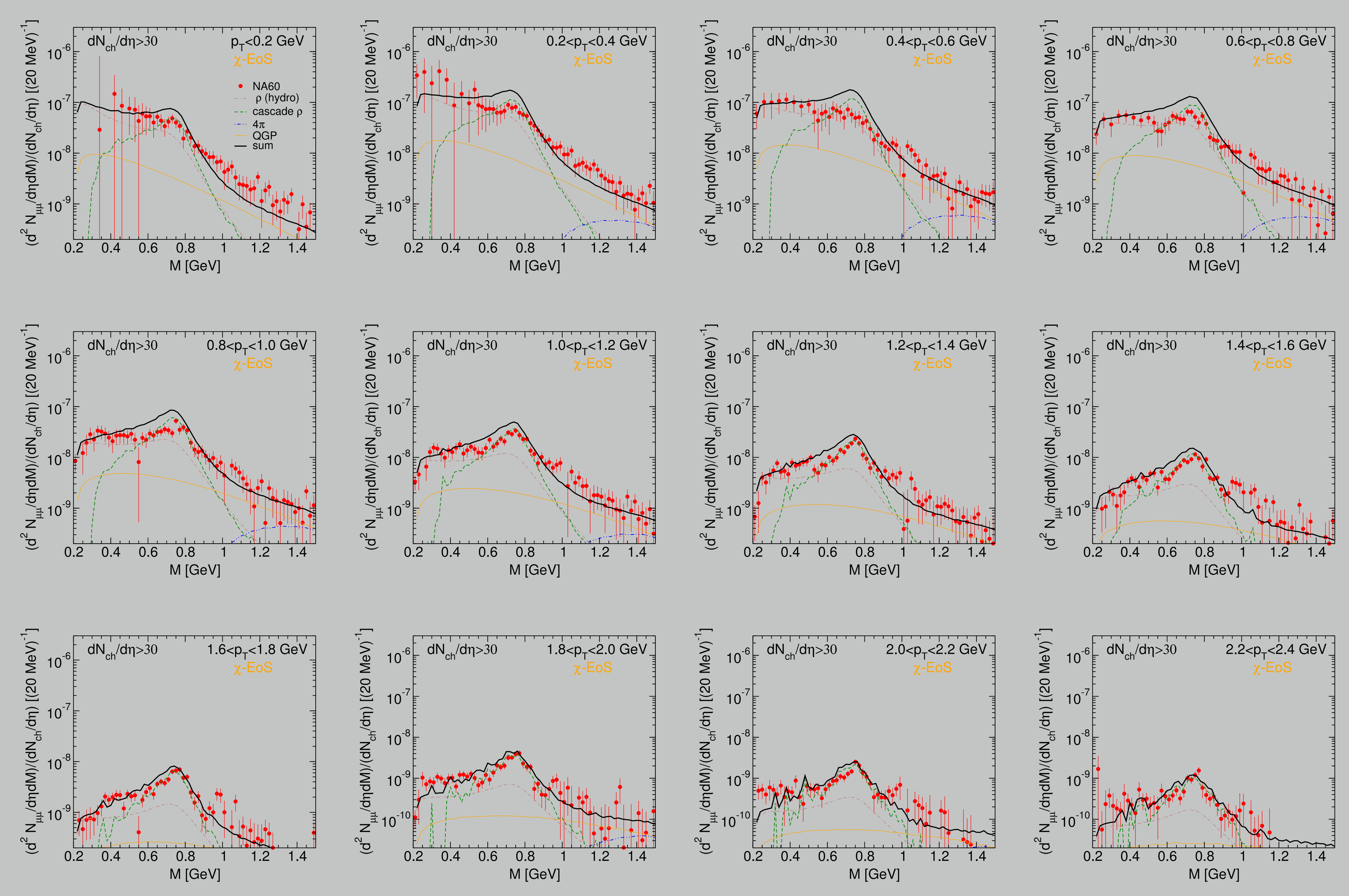
Results: Transverse dynamics of thermal dileptons

- Mass ordering observed for hadronic contribution, but not for dileptons emitted in the QGP
- In the QGP phase, no significant radial flow has developed yet



Results: Invariant mass spectra

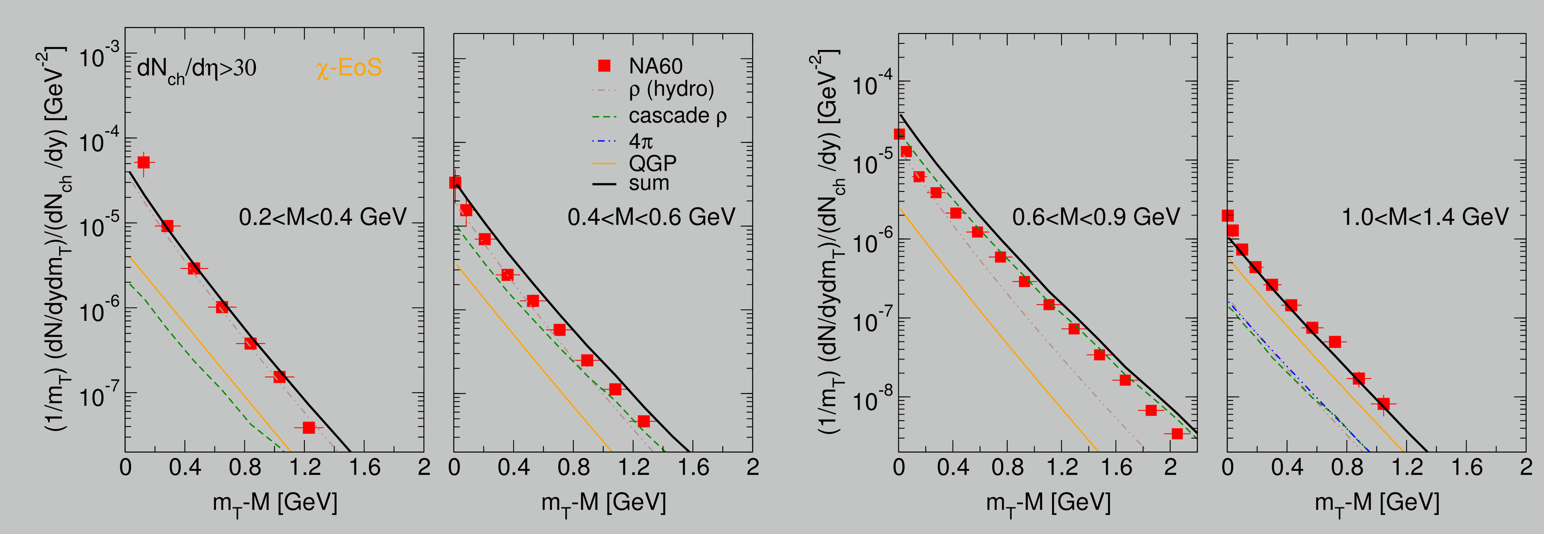
- Excess IMS calculated for 12 $\mathbf{p_T}$ bins and compared to NA60 [6] data



- Region $\mathbf{M < 0.5}$ GeV dominated by **in-medium** radiation at low $\mathbf{p_T}$; resonable $\mathbf{p_T}$ scaling
- Cascade emission saturates the region $\mathbf{M \sim m_\rho}$
- Sum of thermal and cascade emission results in overestimation of the $\mathbf{M \sim m_\rho}$ region for $\mathbf{p_T \lesssim 1}$ GeV ⇒ presence of a long-lasting cascade emission in which the ρ meson can be approximated by its vacuum properties disfavoured by experimental data
- In region $\mathbf{1 < M < 1.5}$ GeV emission from QGP accounts for about half of the yield; reasonable $\mathbf{p_T}$ scaling

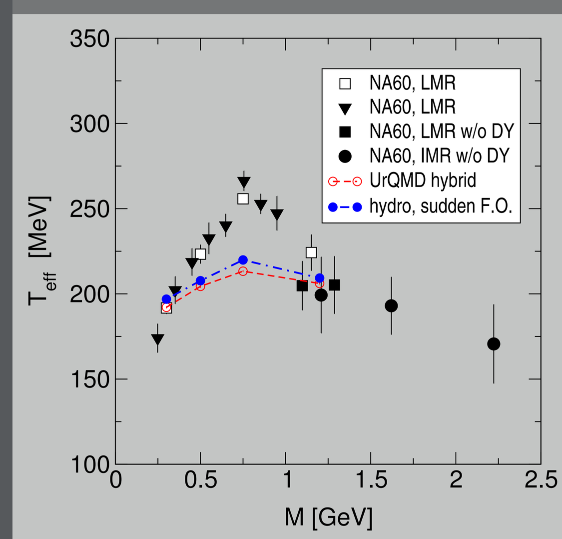
Results: Transverse mass spectra

- Excess TMS calculated for 4 **M** bins and compared to NA60 [6] data



- Hardest contribution from non-thermal sources, max coupling to flow at transition hydro→UrQMD
- agreement for $\mathbf{0.2 < M < 0.4}$ GeV and $\mathbf{1 < M < 1.4}$ GeV, discrepancies for $\mathbf{0.4 < M < 0.9}$ GeV

Results: T_{eff}



- increase of $\mathbf{T_{eff}}$ up to $\mathbf{m_\rho}$ followed by drop naturally emerged, however quantitative discrepancies found
- $\mathbf{T_{eff}}$ underestimated for $\mathbf{0.4 < M < 0.9}$ GeV, reproduced for $\mathbf{1 < M < 1.4}$ GeV and $\mathbf{0.2 < M < 0.4}$ GeV
- refinement of late-stage decoupling needed?

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References

[1] V. L. Eletsky *et al.*, Phys. Rev. C64 (2001) 035202.
[2] B. Aubert *et al.* [BABAR Collaboration], Phys. Rev. D71 (2005) 052001; V. P. Druzhinin, arXiv:0710.3455.
[3] J. Cleymans, J. Fingberg and K. Redlich, Phys. Rev. D35 (1987) 2153.
[4] D. H. Rischke *et al.*, Nucl. Phys. A595 (1995) 346-382; *ibid.* 383; H. Petersen *et al.*, Phys. Rev. C78 (2008) 044901.
[5] J. Steinheimer *et al.*, J. Phys. G38 (2011) 035001.
[6] R. Arnaldi *et al.* [NA60 Collaboration], Eur. Phys. J. C61 (2009) 711.

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