Correlations of conserved charges at finite density

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Motivation

- Can evolution of susceptibilities be extracted from experiment (including $\langle \delta\varepsilon\delta\varepsilon\rangle = C_v$, $\langle \delta Q_a \delta Q_b\rangle = \chi_{ab}$, $\langle \delta P_i \delta P_j\rangle = (P+\varepsilon)T\delta_{ij}$, $\langle \delta Q_a \delta E\rangle = \cdots$)?
- Can one simultaneously consider all conserved charges $\{E, P_x, P_y, P_z, B, Q, S\}$?

Approach

I. Calculate background hydrodynamic 1-D evolution at $\rho_B \neq 0$. This provides $\langle \delta A \delta B\rangle_{\rm eq}$ a function of τ. (A, B) refer to 7 conserved quantities: $(E, P_x, P_y, P_z, B, Q, S)$. Calculations here assumed $T(\tau_f) = 150$ MeV and $\rho_B(\tau_f) = 8\rho_0/11$, $\rho_Q = 0.4\rho_B$.
II. Assuming *local* correlations are equilibrated, find source function for *balancing* correlations, $c_{AB}(\Delta\eta)$.

$$C_{AB}(\eta_1-\eta_2,\tau) = \langle \delta A(\tau,\eta_1)\delta B(\tau,\eta_1)\rangle_{eq}\frac{\delta(\eta_1-\eta_2)}{\tau} + c_{AB}(\tau,\eta_1,\eta_2), \quad (1)$$

$$c_{AB} = \int d\tau_j \tau_j d\eta_j G_{AA'}(\eta_1-\eta,\tau_1,\tau_j)G_{BB'}(\eta_2-\eta,\tau_2,\tau_j)\times \left(\partial_{\tau_j}+\frac{1}{\tau_j}\right)\langle \delta A(\tau_j,\eta_1)\delta B(\tau_j,\eta_1)\rangle. \quad (2)$$

Balancing part comprised of contributions from different τ. Each contribution is proportional to the rate at which susceptibility changes at that τ. Rate is sensitive to the equation of state (see Fig.(1-2)).
III. Find Green's functions by solving for evolution of linearized perturbations:

$$\partial_\tau \delta\varepsilon = -\frac{1}{\tau}\delta(\varepsilon+P) - \partial_\eta \frac{\varepsilon+P-\frac{8\eta_s}{3\tau}}{\tau}u^\eta, \quad (3)$$

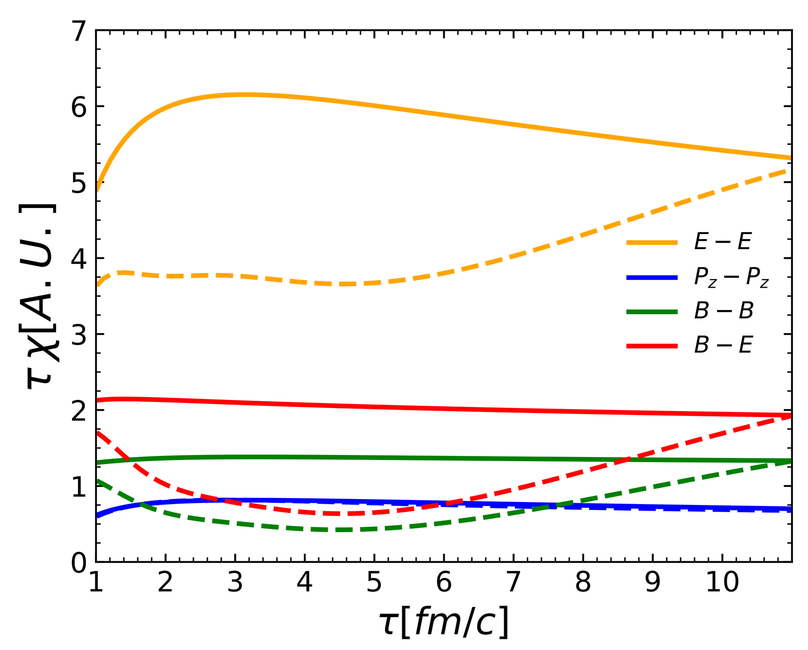
$$\partial_\tau\left(\varepsilon+P-\frac{4\eta_s}{3\tau}\right)\delta u^\eta = -\frac{2}{\tau}\left(\varepsilon+P-\frac{4\eta_s}{3\tau}\right)\delta u^\eta - c_\rho^2\frac{\partial_\eta\delta\varepsilon}{\tau} - \partial_\rho P\frac{\partial_\eta\delta\rho}{\tau}+\frac{4\eta_s\partial_\eta^2\delta u^\eta}{3\tau^2}, \quad (4)$$

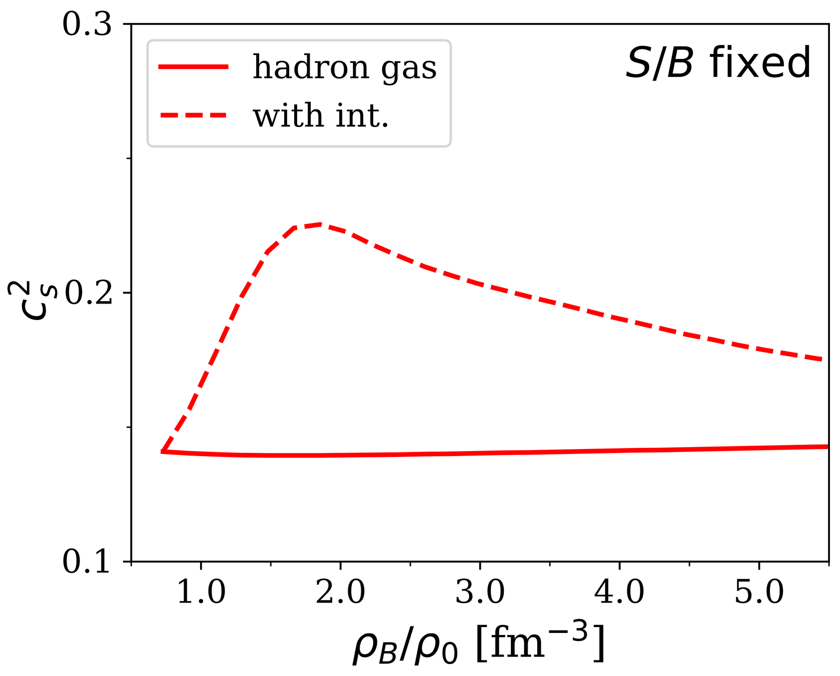
$$\partial_\tau\delta\rho = -\frac{\delta\rho}{\tau}+\frac{\rho+D\partial_\tau\rho}{\tau}\partial_\eta\delta u^\eta + \frac{D}{\tau^2}\partial_\eta^2\delta\rho. \quad (5)$$

Correlations sensitive to non-diagonal susceptibilities of conserved charges as ρ_B increases due to convection terms present in Eq.(5). At high ρ_B, the evolution of Q, B, S correlations cannot be separated from energy-momentum correlations (see Eqs.(3-5)).
Green's functions convoluted with source in Eq. (2) to generate $c_{AB}(\tau_f, \Delta\eta)$.
IV. Project correlations onto final state. In Cooper-Frye

$$\delta N_h = n_{ha}q_{ha}\chi^{-1}_{ab}\delta Q_b, \quad (6)$$

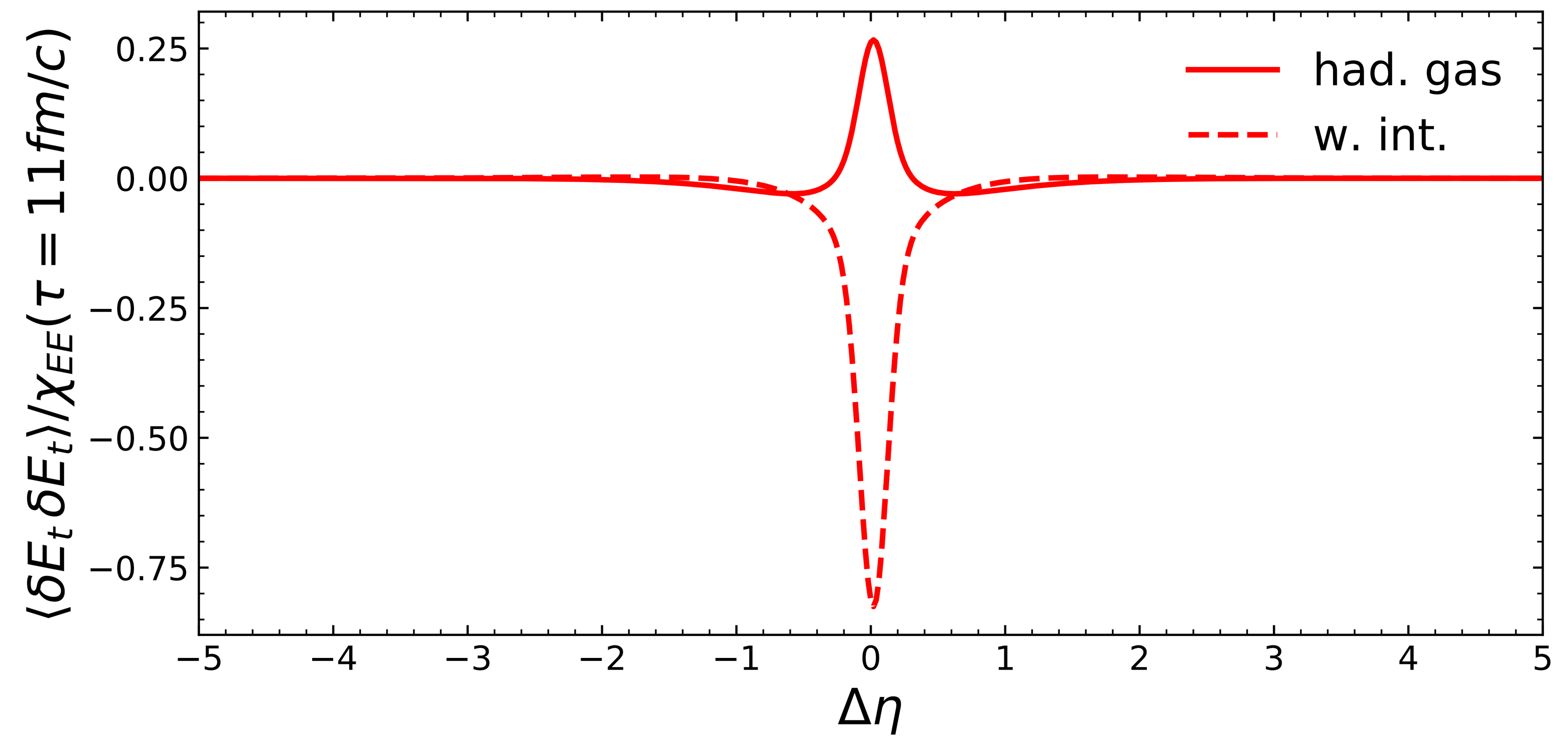
Thermal quantities



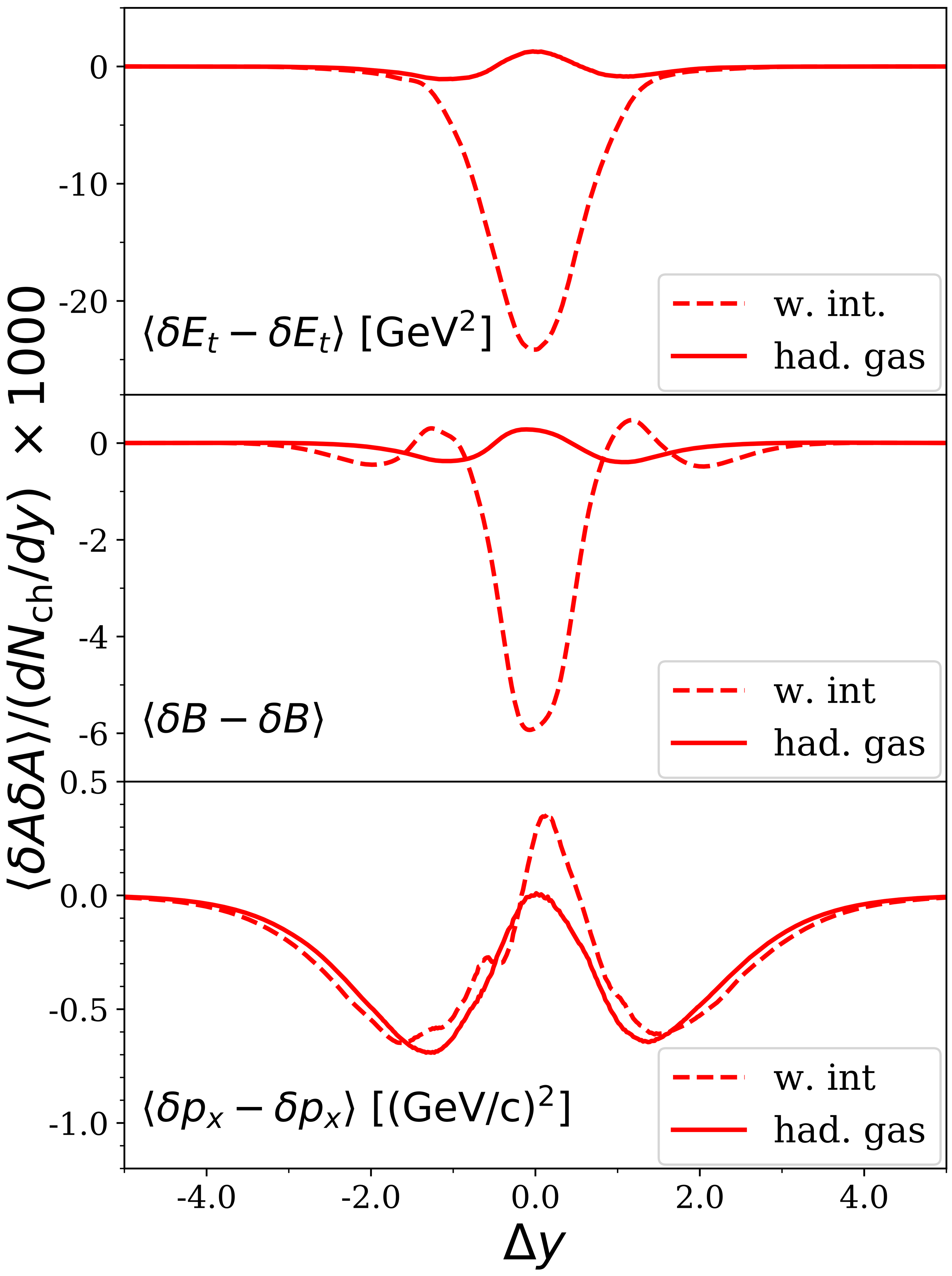


Results

Energy-energy correlations before projection onto final state particles:



Correlations after projection onto final state particles:



Conclusions

- Final state correlations $\langle\delta E_t(0)\delta E_t(\eta)\rangle$,$\langle\delta P_x(0)\delta P_x(\eta)\rangle$,$\langle\delta B(0)\delta E_t(\eta)\rangle$,... sensitive to EoS!
- Thermal smearing is significant but not fatal.
- Biggest challenge is initial state correlations.

Acknowledgements

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Bibliography

References

[1] S. Pratt, and C. Young, "Relating measurable correlations in heavy ion collisions to bulk properties of equilibrated qcd matter", Phys. Rev. C **95**, 054901 (2017).