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Probing early time dynamics and QGP transport properties with photons in relativistic heavy-ion collisions

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We present the first study quantifying the sensitivity of hadron and photon observables to the early-time evolution in heavy-ion collisions which implements a realistic pre-equilibrium stage with effective QCD kinetic theory [1, 2] and a state-of-the-art hybrid (IP-Glasma + MUSIC + UrQMD) framework [3]. We calculate photon emission from the pre-equilibrium phase by folding the system's energy momentum-tensor with thermal photon emission rates including their viscous corrections. By changing switching time and coupling parameters inherent to the pre-equilibrium evolution, we study how the non-equilibrium phase influences the hadron and photon flow coefficients in Pb+Pb, Xe+Xe, and O+O collisions at 5 TeV. Because the space-time volume scales differently from the number of binary collisions from O+O to Xe+Xe and Pb+Pb collisions, a systematic system size comparison of photon production can further shed light on the relative contributions from thermal and prompt sources and provide further insight into early time QGP dynamics.

Recent Bayesian extractions of the QGP bulk viscosity using hadronic observables alone [4] cannot disentangle easily a large narrow peak temperature dependence of bulk viscosity from a broader $\zeta/s(T)$ with a lower maximum value. Utilizing the power of photons as clean and penetrating probes, we demonstrate how thermal photon production and its flow coefficients can improve constraints on QGP bulk viscosity owing to its sensitivity to early stages of the QGP evolution.

[1] A. Kurkela, A. Mazeliauskas, J.F. Paquet, S. Schlichting, and D. Teaney, "Matching the Nonequilibrium Initial Stage of Heavy Ion Collisions to Hydrodynamics with QCD Kinetic Theory," Phys. Rev. Lett. 122, no. 12, 122302 (2019)

[2] A. Kurkela, A. Mazeliauskas, J.F. Paquet, S. Schlichting, and D. Teaney, "Effective kinetic description of event-by-event pre-equilibrium dynamics in high-energy heavy-ion collisions," Phys. Rev. C 99, no. 3, 034910 (2019)

[3] S. McDonald, C. Shen, F. Fillion-Gourdeau, S. Jeon and C. Gale, "Hydrodynamic predictions for Pb+Pb collisions at 5.02 TeV," Phys. Rev. C 95, no. 6, 064913 (2017)

[4] J.F. Paquet, C. Shen, G. Denicol, S. Jeon and C. Gale, "Phenomenological constraints on the bulk viscosity of QCD," Nucl. Phys. A 967, 429 (2017).

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