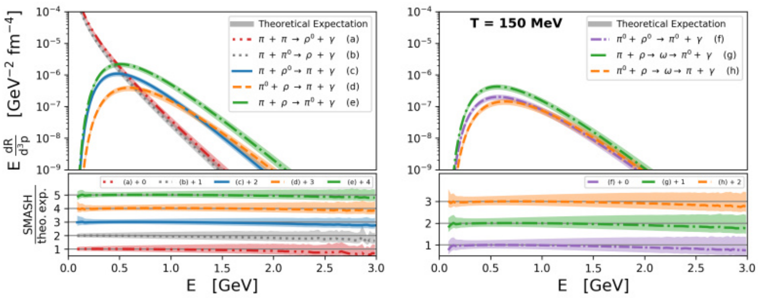
Hadronic Non-Equilibrium Photon Production



Introduction

The smallest constituents of matter and their properties are studied by means of relativistic heavy ion collisions. Photons serve as valuable probes carrying information from within the collision to the detector. The theoretical understanding of the properties of those photons is essential to understand the dynamics of heavy-ion reactions. This work contributes to the understanding of photons produced in the hadronic phase of heavy-ion collisions.

Methods

Complex theoretical models are necessary to dynamically simulate relativistic heavy-ion collisions. One possibility is the application of relativistic transport models which give access to the properties of each particle throughout the entire evolution. Within this project, the hadronic transport approach SMASH has been extended by the production of photons originating from hadronic scatterings. For this, the production cross sections have been derived from the underlying effective field theory. The corresponding production channels are implemented into SMASH and photons are produced during the evolution. It shall be noted that photons are produced rarely in heavy-ion collisions. This requires extremely high statistics, and therefore also high computing capacities, in order to obtain meaningful results.

Results

Before photons are studied in heavy-ion collisions the newly-implemented production processes are subject to a proof of concept. For this, the thermal photon rate of a cubic box, which is in thermal and chemical equilibrium, is compared to its semi-analytical expectation value (Fig. 1). Within errors a perfect agreement is found between the photon rates resulting from SMASH and the theoretical expectation for all eight processes implemented. In continuation, the effects on the thermal photon rate of additionally applying form factors is studied as well as the response to varying temperatures of the medium (Fig. 2). All

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Project Term
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Clusters
LOEWE CSC Cluster Frankfurt

Additional Software
SMASH

Institute
Institute of Theoretical Physics

University
Goethe Universität Frankfurt am Main

Partners
GSI Helmholtzzentrum für Schwerionenforschung, Stony Brook University, McGill University

of this is performed in a fully-equilibrated system.

Discussion

The photon production processes implemented can be divided into two groups characterized by their mediating particles, for which the application of form factors has different implications. While for (π, ρ, a_1)-mediated processes the thermal photon rate is reduced for all photon energies, the thermal photon rate for (ω)-mediated processes is reduced only for high photon energies, but enhanced else-wise. This attributes a higher importance to the (ω)-mediated processes in the region of low and intermediate photon energies. In addition, the temperature dependence of the thermal photon rate is studied. It is observed that photon production is enhanced for increasing temperatures and vice versa. This behavior is expected, as higher temperatures imply more interactions and therefore also more produced photons.

Outlook

Although photon production from hadronic scattering processes has been implemented, photons from bremsstrahlung processes are still missing to properly study photon production in relativistic heavy-ion collisions. The derivation of bremsstrahlung cross sections as well as the implementation of the corresponding processes in SMASH constitutes the next step. Once implemented, SMASH can be applied as an afterburner in hybrid models to study photon production in high-energy heavy-ion collisions.

Figures

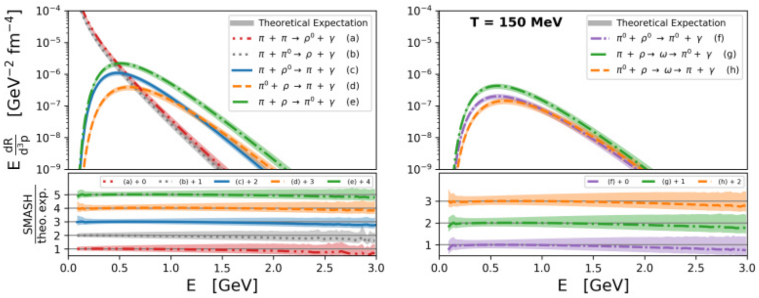

Figure 1: Thermal photon rate as obtained from SMASH (lines) as compared to theoretical expectations(bands) for all photon production channels in a thermal medium at T = 150 GeV.

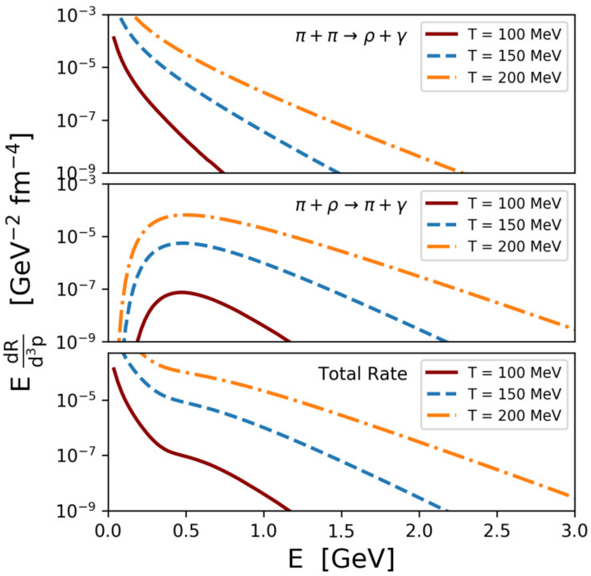

Figure 2: Temperature scaling of two groups of production channels (upper and middle panel) and of the total photon rate in a thermal medium between T = 100 GeV and T = 200 GeV.

Publications

Schäfer, A.; Torres-Rincon, J. M.; Rothermel, J.; Ehlert, N.; Gale, C.; Elfner, H.: Benchmarking a nonequilibrium approach to photon emission in relativistic heavy ion collisions. Phys. Rev. D, 99(11):114021, 2019. http://doi.org/10.1103/PhysRevD.99.114021

Schäfer, A.; Torres-Rincon, J. M.; Gale, C.; Elfner, H.: A Non-Equilibrium Approach to Photon Emission from the Late Stages of Relativistic Heavy-Ion Collisions. In 28th International Conference on Ultrarelativistic Nucleus-Nucleus Collisions, 2020. https://arxiv.org/abs/2001.03378

Oliinychenko, D.; Steinberg, V.; Weil, J.; Kretz, M.; Staudenmaier, J.; Ryu, S.; Schäfer, A.; Rothermel, J.; Mohs, J.; Li, F.; Elfner (Petersen), H.; Pang, L.G.; Mitrovic, D.; Goldschmidt, A.; Geiger, L.; Rose, J.-B; Hammelmann, J.; Prinz, L.: smash-transport/smash: SMASH-1.8, 2020. http://doi.org/10.5281/zenodo.3742965

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