Baryonic sources of thermal photons

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Electromagnetic radiation from high-energy heavy-ion collisions is an excellent observable to investigate the microscopic properties of QCD matter produced in these reactions (e.g., the in-medium spectral functions of vector mesons, revealing a transition to quark-gluon degrees of freedom, and mechanisms of chiral-symmetry restoration) as well as the bulk properties of the expanding fireball (such as its temperature, lifetime and collective behavior) [1]. Since leptons and photons traverse the fireball without significant re-interactions, they can probe the conditions deep inside the hot and dense medium. The emission from the hadronic phase plays an essential role in the finally observed spectra. In particular, baryons and anti-baryons have been found to be strong catalysts for electromagnetic radiation, even at collider energies where the baryon chemical potential is small [2,3] but both baryons and anti-baryons are rather abundant.

In the present work, we have conducted a systematic analysis of π- and ω-meson-induced reactions off a large set of baryon states (ca. 30 nucleon, Δ and hyperon states). The interaction vertices are based on effective hadronic Lagrangians where the parameters are quantitatively constrained by empirical information from vacuum decay branchings (both hadronic and radiative) and scattering data (including πN scattering and nuclear photoabsorption); gauge invariance is maintained by suitable regularization procedures. The thermal emission rates are computed using kinetic theory but can be directly compared to previous calculations using hadronic many-body theory, see Fig. 1.

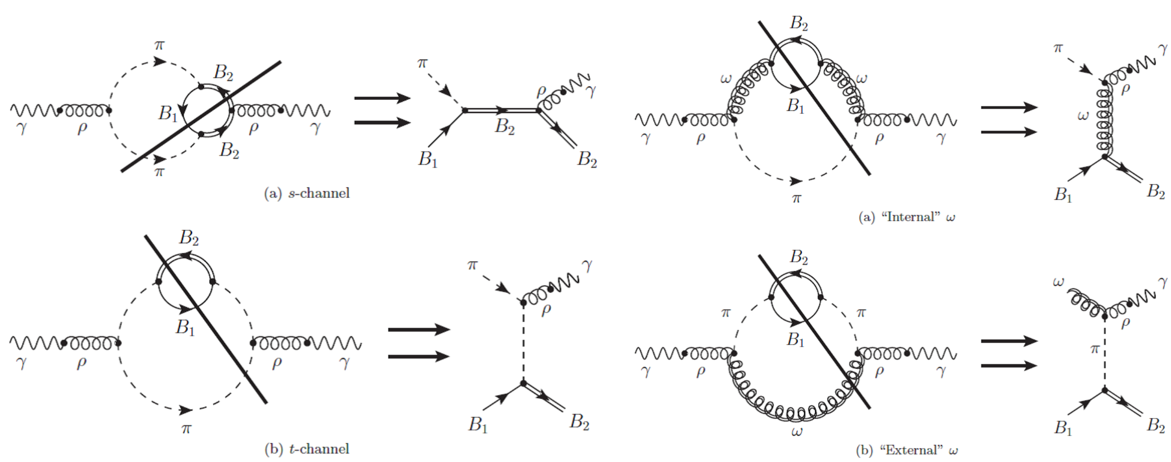

Fig. 1. Examples of the Feynman diagrams for photon production processes involving baryons considered in this work and their relation to cuts of the ρ-meson selfenergy; Left panel: pion-induced; right panels: processes involving the πρω vertex.

Our results for pion-indued processes (cf. Fig. 2) show that the emissions rates at photon energies below ~1 GeV are dominated by P-wave processes, with the largest individual contributions stemming from the N(939) and Δ(1232) couplings. At higher energies, D-wave processes take over, in particular NN(1520) and ΔΔ(1620) couplings. We also find that a previously used approximation for the ρ -

selfenergy, where only N and Δ couplings were considered but with an effective upscaled baryon density (nucleon density plus half the density of all excited states) [4], appears to be a fair approximation to the explicitly calculated rates.

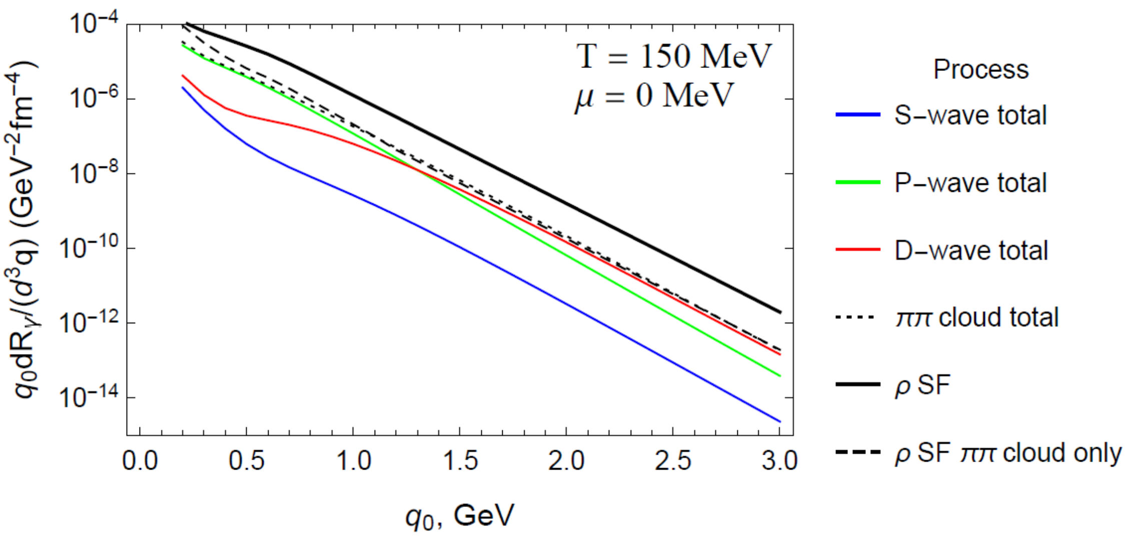

Fig. 2. Thermal photon rates from $\pi + B_1 \rightarrow \gamma + B_2$ reactions with pion exchange calculated in this work in the S-wave (blue line), P-wave (green line) and D-wave (red line) channels, and their sum (black dotted line), compared to the pion cloud contribution from the ρ SF [25] including only N and Δ states but using an effective nucleon density (black dashed line), and the total rate from the ρ spectral function (black solid line).

The second part of our study was devoted to processes with ω-meson-baryon couplings, most of which constitute novel sources of thermal photon production. These turn out to be significant relative to the pion cloud contributions for photon energies of around 1 GeV (several tens of percent), and exceed those for energies above ~1.5 GeV, cf. Fig. 3; ω-induced rates also have a potential for additional

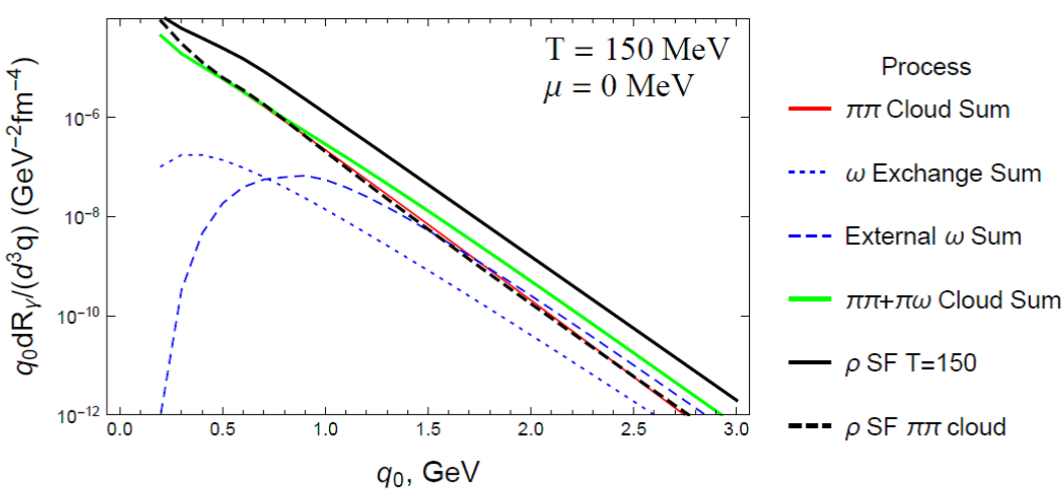

Fig. 3. Total thermal photon rates at T = 150MeV and vanishing baryon chemical potential calculated in this work from the ππ cloud (red line) and the πω cloud (blue dotted and dash-dotted lines); their sum (green solid line) is compared to the total rate from the in-medium ρ SF [4] (solid black line) as well as its ππ cloud component only (black dashed line).

contributions, as many of their manifestations in baryon decay branchings are not well established or not known at all to date. The additional sources found here may help to mitigate some of the tension that currently exists between theoretical calculations of thermal photon spectra and experimental data, especially at RHIC energies [5,6].

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