Thermal photon emission from the $\pi\rho\omega$ system

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Ultra-relativistic heavy-ion collisions produce fireballs of strongly-interacting matter at high temperatures and densities. Understanding the phases of this matter is at the forefront of nuclear physics research [1]. Hadronic probes of these fireballs undergo multiple rescatterings, thus losing much of the information from the interior of the fireball. Photons, however, do not interact via the strong nuclear force. Since their electromagnetic mean free paths are much larger than the fireball size, they escape relatively unaltered, carrying valuable information on the properties of the strongly-interacting matter from which they were emitted.

The collision zone in non-central heavy-ion collisions has an initial spatial anisotropy which gets converted into a momentum anisotropy, known as elliptic flow (v_2). There currently exists a discrepancy between state-of-the-art calculations and experimental data of direct photon spectra and v_2 [2]. In particular the large v_2, which takes time to develop, suggests that the expanding fireball contains strong thermal photon sources from the later, hadronic stages of its evolution. In Ref. [3] it was conjectured that there exist additional as-of-yet unidentified sources of thermal photons. In that work it was shown that enhancing the thermal photon emission by hand significantly alleviated the discrepancy between experimental data and calculations of direct photon spectra and v_2.

In the present work [4] we have identified a novel source of thermal photons from a system composed of π, ρ, and ω mesons. We have calculated thermal photon emission rates from scattering processes of $\pi\rho \to \gamma\omega$, $\pi\omega \to \gamma\rho$, and $\rho\omega \to \gamma\pi$ using both thermal field theory (TFT) and relativistic kinetic theory (KT). In our KT calculations for $\pi\omega \to \gamma\rho$ we encountered a singularity in the pion exchange associated with the $\omega \to \pi^0\gamma$ radiative decay, which has already been accounted for in previous works [5]. By using TFT, we both avoided the singularity and identified a criterion to avoid double-counting the ω radiative decay. In addition, we confirmed the equivalence of the frameworks of TFT and KT in thermal photon rate calculations.

Our resulting total rates from the $\pi\rho\omega$ system are shown in Fig. 1 and compared to existing calculations. We see that our rates are comparable to those from an ω t-channel exchange in $\pi\rho \to \gamma\pi$ scattering, which were earlier found to be significant [5]. Also shown are the rates from $\pi\pi$ scattering Bremsstrahlung [6,7], which are significant for the lower range of photon energies.

This identification of a novel source of thermal photons directly supports the conjecture from Ref. [3] of unaccounted-for hadronic sources of thermal photons which contribute to both photon spectra and v_2. Calculations of photon spectra and v_2 have been conducted which support our expectation of a significant contribution of our rates [8,9], thus helping to resolve discrepancies with current experimental data.
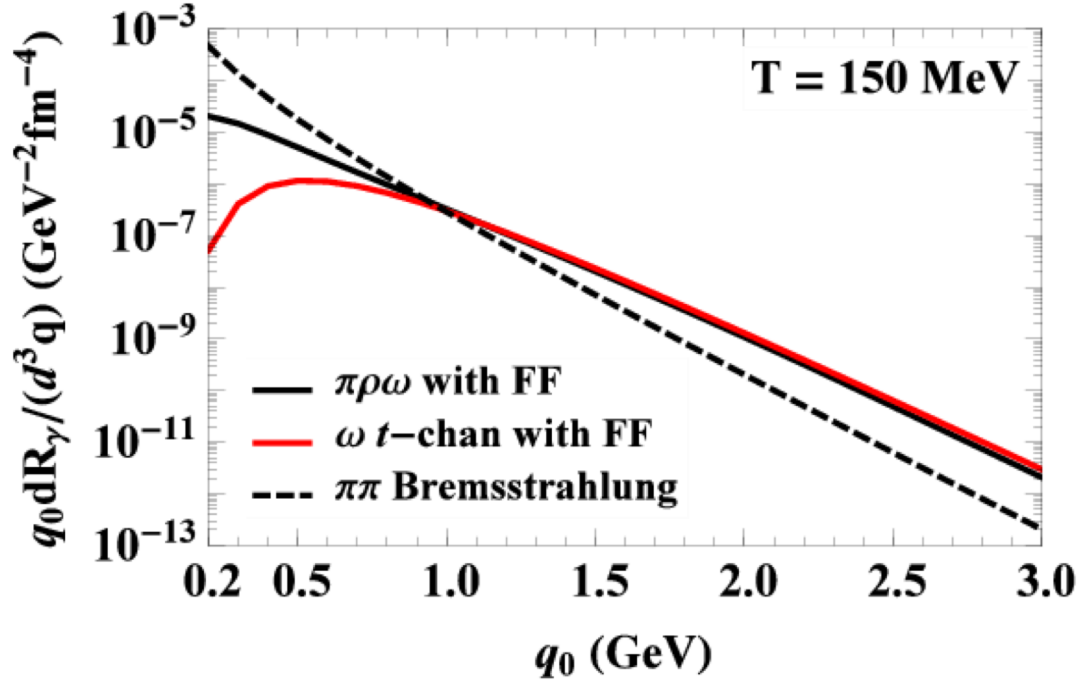
FIG. 1. Thermal photon rates at a temperature of T = 150 MeV from the $\pi\rho\omega$ system [4] compared to ω t-channel exchange in $\pi\rho \to \gamma\pi$ scattering [5] and $\pi\pi$ Bremsstrahlung [6,7].

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