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Unruh gamma radiation at RHIC?

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ABSTRACT

Varying the proposition that acceleration itself would simulate a thermal environment, we investigate the semiclassical photon radiation as a possible telemetric thermometer of accelerated charges. Based on the classical Jackson formula we obtain the equivalent photon intensity spectrum stemming from a constantly accelerated charge and demonstrate its resemblances to a thermal distribution for high transverse momenta. The inverse transverse slope *differs* from the famous Unruh temperature: it is larger by a factor of π. We compare the resulting direct photon spectrum with experimental data for Au–Au collisions at RHIC and speculate about further, analytically solvable acceleration histories.

1. Thermal looking classical radiation from accelerating source

It has been a puzzle to understand why thermal models supposing global equilibrium, and hydrodynamics assuming local equilibrium are so successful in describing single particle observables in high energy heavy ion and even in elementary particle reactions. Neither is it easy to understand intuitively how accelerating frames produce "thermal vacua", with quanta distributed as if they were connected to a heat bath — a proposition first formulated by Unruh [1] and soon analyzed in relation to black hole thermodynamics by Bekenstein [2] and Hawking [3,4]. Spectra of photons from a black hole was obtained by Page [5]. These early analyses in the seventies were followed by numerous attempts to harvest the merits of this idea in relation with possible ways to quantum gravity [6]. In the present Letter we calculate measurable consequences of this idea in photon spectra observed in high energy heavy ion collisions. The observation that transverse momentum spectra of direct gammas, measured perpendicular to the beam line in collider experiments, are well fitted by exponential distributions [7], are suggestive of "thermal" heat bath sources in high energy nuclear collisions. Theoretical calculations assuming the applicability of thermodynamic concept are phenomenologically successful in describing heavy ion experimental data [8–16]. Statistical predictions based on the assumption of a thermal source for also *pp* collisions at the LHC have recently been made by Becattini et al. [17,18]. Alternatively, the proposition that the thermal spectra in $p+p$ and in heavy ion $A+A$ collisions were due to accelerating frame concepts akin to the Unruh temperature of field theoretic vacua was made by Satz and Kharzeev [19–22]. However, a dynamical calculation demonstrating how thermal looking spectra emerge from accelerating systems was not provided. In Ref. [23] quantum field theory pair-creation in an electric-like field was shown to mimic one-particle thermal distributions and that it is sometimes difficult to distinguish a real thermal equilibrium system from a coherent quantum state with a reduced density matrix approximating a one-particle thermal distribution.

In this Letter we demonstrate in an exactly soluble model that basic *classical* electromagnetic bremsstrahlung from uniformly accelerating valence quark charges along a "beam" direction can also appear to be similar, though not identical, to radiation from a boost invariant perfect hydrodynamic fluid. This calculation is entirely classical with the Planck constant entering solely by converting the intensity distribution in terms of the number distribution of equivalent photons as each carrying the energy $\hbar\omega$. Beyond this we do not need to refer to field theory, quantization procedure or the vacuum state at all. The trajectory of point-like classical charges and the radiated photon field are calculated in the framework of special relativity, without any actual reference to a general frame and related Killing vectors.

We consider a simple point charge undergoing constant acceleration. We calculate the classical bremsstrahlung distribution using the text book [24] formula for the radiation field amplitude:

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