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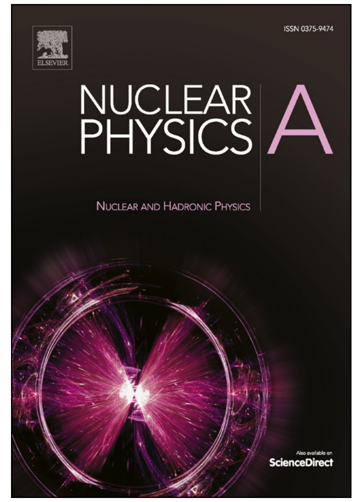

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Quantum diffusion of electromagnetic fields of ultrarelativistic spin-half particles

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We compute electromagnetic fields created by a relativistic charged spin-half particle in empty space at distances comparable to the particle Compton wavelength. The particle is described as a wave packet evolving according to the Dirac equation. It produces the electromagnetic field that is essentially different from the Coulomb field due to the quantum diffusion effect.

I. INTRODUCTION

It has been known for a while that very intense electromagnetic fields are created in ultra-relativistic hadronic and nuclear collisions [1–5]. However, no convincing experimental evidence of their impact on the scattering dynamics has been observed. In recent years, a renewed interest to this subject was motivated by the relativistic heavy-ion collision experiments. The electromagnetic fields are intense enough to modify the properties of the nuclear matter produced in these collisions. In order to evaluate the impact of these fields on the nuclear matter, it is crucial to know their space-time structure. In [6–12] production of the electromagnetic fields was studied using the hadron transport models, neglecting the nuclear medium electric and magnetic response and flow. In [9, 11, 12] it was pointed out that the quantum nature of the nucleus wave function gives rise to strong field fluctuation, so that even in central collisions the r.m.s. does not vanish. In [13–16] it is argued that due to the finite electric conductivity of nuclear matter, the lifetime of the electromagnetic field is significantly longer than in vacuum. Anomalous transport can also affect the field producing oscillations [17–19] and even forcing the field into the topologically non-trivial configurations [20–25]. The electromagnetic field in the nuclear medium, unlike that in vacuum, strongly depends on the initial conditions [26]. The nuclear medium produced in relativistic heavy-ion collisions is well described by the relativistic hydrodynamics. Relativistic magneto-hydrodynamic calculations were done in [27–29] in the ideal limit (infinite electrical conductivity).

In a recent publication [30] we argued that one can treat the sources of the electromagnetic field, i.e. the valence quarks, neither as point particles (classical limit) nor as plane waves, which have infinite spatial extent. This is because the interaction range, the quark wave function size