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Interference effects in the ionization loss of high-energy particles. Theory and CERN SPS experiments

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When a charged particle moves in a medium it loses part of its energy on ionization and excitation of atoms. This part is known as ionization energy loss. Experimentally, it is often convenient to measure not the total value of the particle ionization loss, but just a part of it due to collisions with relatively small momentum transfers (distant collisions), which is known as restricted ionization loss (RIL). When a high-energy particle enters a target from vacuum, a transformation of the electromagnetic field around the particle occurs in a thin boundary layer of the target, which leads to the change of RIL along the particle path. There has been an attempt to investigate such a boundary effect at SPS accelerator at CERN [1]. Though, due to a large target thickness, almost no effect has been observed. In the present report we propose a different experiment in which an analogous effect is expected to be significant due to the particle's field transformation not in the medium, but in a vacuum. We consider a process in which a high-energy electron consecutively traverses two targets situated on some distance l from each other: a thick upstream one and an ultrathin downstream one. It is shown that evolution of the particle's field after its passage of the upstream target should result in a considerable modification of the particle RIL in the downstream target [2, 3] and its dependence on l. Such an effect results from the inteference of the electron's proper field and the field of transition radiation, which evolves as a result of the particle passage through the upstream target. Such interference makes the electron 'half-bare', which results in the change of its RIL. For electron energies of about 100 GeV, achievable at SPS, the discussed effect can take place within a macroscopically large distance between the tagrets, of the order of several tens of meters.

Another type of interference effect in RIL, known as the Chudakov effect, takes place for high-energy electron-positron pairs. It results from the destructive interference (mutual screening) of the electron's and positron's proper electromagnetic fields in the vicinity of the pair creation point in a medium, and leads to suppression of the pair RIL in this region. In [4, 5] the first accelerator-based experimental investigation of this effect at SPS has been reported. In this experiment the most probable value E_{MP} of the pair RIL in thin silicon detectors has been measured. The results were noticeably different from the predictions of all existing theories of Chudakov effect (which describe the average value E_{AV} of the pair RIL in the target per unit path). In the present work we obtain the probability distribution function for the value of the pair RIL in a thin target and calculate the quantity E_{MP} [6]. It is shown that the Chudakov effect of RIL suppression is stronger manifested for E_{MP} than for E_{AV} and the developed theory better coinsides with the experimental results [4, 5] than the mentioned theories for E_{AV}.

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