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The Theory of Ionization and the Emission of Cerenkov Radiation.

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The latest experimental results (*) of VOYVODIC at Bristol and WILSON at Manchester show that the present form of the theory of the ionization loss of relativistic charged particles is not satisfactory. The present form of the theory is based on a combination of classical and quantum computations, along the lines given by FERMI (1), the contribution, of the close collisions being taken from the Bethe-Bloch quantum treatment and the effects of the polarization of the medium being computed classically. It was shown by FERMI (1) that the Cerenkov radiation is included in the part of the energy loss associated to polarization effects. A. BOHR (2), SCHÖNBERG (3,4) and MESSEL and RITSON (5) have shown that the part of the increase of the loss in the relativistic region associated with polarization effects is due to the emission of Cerenkov radiation, in classical theory. The latest experimental results show that the increase of ionization agrees approximately with the theoretical predictions for the total loss, including Cerenkov radiation. If the present theory were correct, this would mean that the Cerenkov radiation is almost completely absorbed in the immediate neighbourhood of the track. Experimental values of the absorption coefficients are not available for all the range of frequencies of intense Cerenkov radiation. An estimate, based on theoretical values and extrapolation of the known absorption coefficients, gives an absorption of the Cerenkov radiation considerably lower than we should have to assume to explain the observed ionization increase after the minimum.

It is unlikely that the Cerenkov radiation should be so strongly absorbed as the interpretation of the latest experimental data would require. It is more satisfactory to conclude that the distribution of the loss between direct ionization and excitation and the emission of Cerenkov radiation predicted by the present theory is not correct, there being less Cerenkov radiation and more (2) direct ionization-excitation. We have already pointed out that the Cerenkov spectrum given by classical theory requires important quantum corrections (refer. 3, pg. 27) and also that the con-

(*) Private communication.

(1) E. FERMI: *Phys. Rev.*, **57**, 485 (1940).

(2) A. BOHR: *Det. Kgl. Dans. Vid. Sels.*, **24**, n. 19 (1948).

(3) M. SCHÖNBERG: *Bull. Cent. Phys. Nucl. Bruxelles.*, n. 20 (1950).

(4) M. SCHÖNBERG: *Nuovo Cimento*, **8**, 159 (1951).

(5) H. MESSEL and D. M. RITSON: *Phil. Mag.*, **41**, 1129 (1950).

clusion that the increase of the loss associated to polarization effects in the relativistic region consists mostly of Cerenkov radiation might not hold in a quantum treatment (ref. 3, pg. 4). A quantum treatment of the polarization effects is not available to the author, but it is possible to discuss in a qualitative way some of the features of the mechanism of the loss of energy and to gain some insight into the reasons of the limitations of the existing classical treatment.

The classical theory predicts that the most intense Cerenkov bands correspond in general to frequencies of the order of the ionization potentials of the intermediate shells of the atoms of the ionized medium. The mechanism of the eventual emission of such photons is not exactly known, but it seems plausible to assume that they are due to single electron jumps. The emission of the most intense Cerenkov bands would then require jumps between levels of the continuous spectrum and discrete levels, i.e. jumps corresponding to a previous ionization of atoms of the medium. Thus we see that the emission of the most intense Cerenkov bands predicted by the present classical theory could hardly occur, since they would require probably the previous ionization of atoms. Instead of direct emission of high frequency Cerenkov radiation we may expect to have ionization.

Thus we can under stand the experimental results.

It follows from the preceding considerations that the most insatisfactory feature of the existing classical treatment of the energy loss in the relativistic region is the model of the atoms of the medium as formed by systems of harmonic oscillators, since such harmonic oscillators can vibrate with any amplitude without ejection of electrons. It is interesting to remark that in the present classical theory the Cerenkov radiation flows from the immediate neighbourhood of the trajectory of the ionizing particle — as we have shown in references 3 and 4 — and, since it is well known that quantum corrections are important in the description of close interactions, this circumstance indicates also that the classical theory of the emission of Cerenkov radiation is not satisfactory. The classical result that the Cerenkov radiation flows right from the trajectory of the ionizing particle suggests that the Lorentz transformed Coulomb field in the neighbourhood of the ionizing particle is modified in a non negligible way by the polarization of the medium, so that the Bethe-Bloch treatment of the close collisions may require some corrections.

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