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Search for Faster-Than-Light Particles*

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An experimental search for the existence of charged particles that propagate with velocities always greater than that of light in a vacuum has been performed. Subject to some assumptions regarding the behavior of such particles, it is found that the photoproduction cross section in lead is less than 1.7×10^{-33} cm^2.

INTRODUCTION

THE possibility of the existence of particles that propagate with velocities that are always greater than the velocity of light in vacuum has been discussed by several authors.[1-5] An early search[6] for such particles placed an upper limit of 3 μb on the photoproduction cross section in lead with 800-keV photons. This paper reports a continuation of that search with an improved detector and with photons of slightly higher energy. The properties of faster-than-light particles have been discussed at great length in Refs. 1, 2, and 6. Only those properties essential to this experiment will be mentioned here.

In order to conduct an experimental search for these particles, called tachyons,[2] it is necessary to assume that they interact with ordinary particles and fields. It is then possible to look for the Čerenkov radiation that charged tachyons emit in a vacuum.

As discussed in Ref. 6, when a tachyon passes through an electrostatic field in a vacuum, it will gain energy from the field but lose energy through Čerenkov radiation. The net energy gain per unit path length s can be expressed

$$\frac{dE}{ds}=-\frac{Z^2e^2}{2\hbar^2c^2}E^2+Ze|\epsilon|\,, \tag{1}$$

where E is the total energy of the tachyon, Ze is the charge, and $|\epsilon|$ is the magnitude of the electric field. For a stationary energy state, $dE/ds=0$, yielding a stationary energy of

$$E=\left(\frac{2\hbar^2c^2}{Ze}|\epsilon|\right)^{1/2}. \tag{2}$$

If $Z=1$ and $|\epsilon|=3$ kV/cm, a tachyon would reach a stationary energy state of 3.8 eV in a path length of less than 10^{-2} cm. At this energy, a large portion of the Čerenkov radiation is in the visible range and can be detected by a photomultiplier.

EXPERIMENTAL RESULTS

The experimental apparatus designed to detect such Čerenkov radiation is shown schematically in Fig. 1. γ rays from a 129-mCi Co^{60} source [main γ-ray components[7]: 1.332 MeV (99+%) and 1.172 MeV (99+%)] were assumed to photoproduce tachyon pairs in a lead shield 15.5 cm thick. This shield was thick enough to prevent any significant number of γ rays from reaching the detection equipment directly. The tachyons then entered the first of two identical detectors. Each detector consisted of two parallel plates, 8.9×6.3 cm, between which an electrostatic field was maintained, and an RCA 8575 photomultiplier which looked at the region between the plates. The plates were in a vacuum of approximately 5×10^{-5} Torr. The photomultiplier was located perpendicular to the direction of the electric field to utilize the fact that the Čerenkov radiation would be emitted close to 90° with respect to the direction of motion.

The plate separation was 4 cm and the potential difference between them was 12 kV. From Eq. (2), this corresponds to a stationary energy state of 3.8 eV if $Z=1$. Each tachyon was assumed to radiate 12 keV of energy in Čerenkov radiation during its passage between the plates, with the energy distributed equally over the region 0–3.8 eV. The average number of photons produced by each tachyon would then be 6300, of which 7.7% or 485 would be in the solid angle sub-

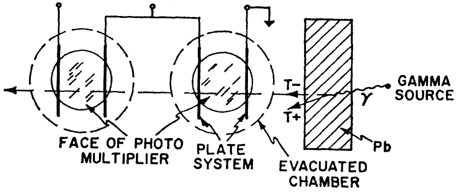

FIG. 1. Schematic representation of the detector system. $T^{\pm}$ represents tachyons which would be photoproduced in the lead shield.

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tended by the photomultiplier. The maximum sensitivity of the photomultiplier was for photons with energies between 2.5 and 3.5 eV. Only 26% of the photons produced would fall in this energy range. Thus, there would be 125 photons of the right energy reaching the photomultiplier for each tachyon.

The photomultiplier was calibrated in the following manner. Using a radioactive source, a plastic scintillator (Pilot B) and data on the number of photons emitted per keV transferred to the scintillator, a known number of photons could be sent into the photomultiplier. The calibration was checked using a NaI(Tl) crystal in a similar manner. The voltage on the photomultiplier was adjusted so that the minimum number of photons that would trigger the photomultiplier's discriminator was 60. This number was chosen to decrease triggers on dark current.

In order to reduce the counting rates in each detector due to small corona points on the high-voltage plates, the plates were covered with opaque paper, 5 mils thick. This paper did not significantly affect the field between the plates.

Coincidences between the two detectors were counted for a period of 10^4 sec with the source present and for 10^4 sec without the source. The total number of counts was seven counts with the source and seven counts without the source. In each case, the number of counts was consistent with the expected accidental rate. Therefore, with 90% confidence, the counting rate R from tachyons is

$$R < 4.8\times 10^{-4} \text{ counts/sec}. \tag{3}$$

The counting rate from tachyons in our apparatus is

$$R = n\sigma L\Omega N_\gamma, \tag{4}$$

where n is the number of lead atoms/cm^3 in the lead shield, L is the mean length traveled by the photons in the lead, N_γ is the number of γ rays/sec produced by the source, Ω is the fraction of the solid angle subtended by the detector, and σ is the tachyon photoproduction cross section in lead. In our calculation of the cross section, we use $n = 3.3\times 10^{22}$ atoms/cm^3, $L = 1.2$ cm, and $\Omega = 7.6\times 10^{-4}$. Since the experiment cannot distinguish between the two energies of γ rays emitted by the source, N_γ is taken to be $2\times 129\times (3.7\times 10^7)$ γ rays/sec, and the average of the two energies is used. Thus, the cross section for tachyon photoproduction in lead by photons of 1.2 MeV is

$$\sigma < 1.67\times 10^{-33} \text{ cm}^2. \tag{5}$$

CONCLUSION

This search for faster-than-light particles has reduced the upper limit for the photoproduction cross section in lead to less than 2 nb with photon energies of 1.2 MeV with 90% confidence.

This limit holds for tachyons having charges in the range 0.5*e* to 1.9*e*. If the tachyon charge is much larger than 1.9*e*, the stationary energy level and therefore the Čerenkov radiation falls below the sensitive region of the photomultiplier. If the charge becomes too small, the stationary energy level rises but the number of photons in the sensitive region decreases until the number drops below the minimum necessary to trigger the detector.

Since tachyons may exist with finite momentum and zero total energy, they can be produced with any "mass" with zero energy input. Thus, this limit is valid for charged tachyons of any "mass."

It is interesting to note that this limit is over eight orders of magnitude smaller than the cross section for photoproduction of electron-positron pairs at the same energy.

The validity of this limit depends quite strongly on assumptions regarding the behavior of tachyons. These assumptions, discussed in great detail elsewhere,[6] include the following: (1) that tachyons gain energy in an electrostatic field in the same manner as ordinary particles; (2) that the emission of Čerenkov radiation in a vacuum is not suppressed by selection rules; (3) that tachyons do not have a large probability of being captured in matter; and (4) that if tachyons decay into ordinary particles, the lifetime for such decays is at least 10^{-15} sec or greater, allowing them to pass through the detection apparatus.

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