TEST OF THE SECOND POSTULATE OF SPECIAL RELATIVITY IN THE GeV REGION

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The second postulate of special relativity states that the velocity of electromagnetic radiation is independent of the motion of the source. In spite of recent experiments to test this postulate [1-5], the empirical evidences remain either of low accuracy or subject to different theoretical doubts [6-8]. For a detailed review of the situation, see, for example, ref. 2.

To compare experiments on this subject, it has been assumed for simplicity that the velocity of the radiation from a moving source is given by

$$c' = c + kv \, , \tag{1}$$

where v is the velocity of the moving source and k is a constant to be determined experimentally. Special relativity requires, of course, $k = 0$. The best value quoted from astronomical arguments, namely considerations concerning the orbits of close binary stars [9-11], is $k < 10^{-6}$, while for terrestrial tests the best results only give a k value of the order of $k < 0.1$. However, as there is no justification for the linear dependence assumed in eq. (1), this comparison of various experiments is evidently rather arbitrary.

In order to increase the accuracy of the terrestrial tests and in particular to search for a breakdown of special relativity for source velocities very close to c, a measurement has been made of the velocity of γ rays from the decay of π^0 mesons of energy >6 GeV [$\gamma = (1-\beta^2)^{-\frac{1}{2}} > 45$ according to special relativity]. The velocity of the γ rays was measured absolutely by timing over a known distance.

The measurement was performed with the CERN Proton Synchrotron (*PS*), running at a momentum of 19.2 GeV/c. The π^0's were produced in a Be target (ϕ = 1 mm, length = 20 mm) and the γ rays were observed at an angle of $\approx 6^\circ$ to the proton direction. Bending magnets close to the target were used to sweep away charged particles giving an essentially neutral beam, which passed through a 5 mm diameter lead collimator and a permanent magnet about 50 m from the target.

The γ rays were detected by means of a 4 mm thick Pb converter followed by a small plastic scintillator in coincidence with a lead-glass Čerenkov counter. The pulse height in this was used to select γ rays of energy ≥ 6 GeV. In front of the detector system a large plastic scintillator was used as an anticounter to eliminate residual charged particles in the beam.

The time measurement was based on the bunched structure of the PS beam. The circulating beam consists of bunches of a few nsec half-width and separation about 105 nsec. In order to conserve this bunch structure, the radio frequency voltage was maintained during the target irradiation (100 msec).

The start pulses for a time-to-pulse-height converter were taken from the small plastic scintillator, and the stop pulses were derived from the PS radio frequency. The pulses from the time-to-pulse-height converter were fed to a multichannel analyser.

To measure the velocity of the γ rays two detector positions A and B were used. The distance between these ($S = 31.450 \pm 0.0015$ m) was chosen to be very close to c/f, where f is the radio frequency during the target irradiation (9.53220 ± 0.00005 MHz). The γ ray velocity (c') is then found from

$$c' = S/(1/f + \Delta) \, , \tag{2}$$

where $\Delta = t_B - t_A$ and $t_{A,B}$ are the times recorded in positions A, B, respectively. With this choice of the distance S the two peaks appear almost in the same channels of the time sorter ($\Delta \ll 1/f$), and one obtains a very accurate velocity measurement insensitive to errors in the calibration and linearity of the timing electronics.

Fig. 1 shows the experimental arrangement together with sample time spectra recorded in detector positions A and B. For comparison, recordings for two other positions A' and B' are

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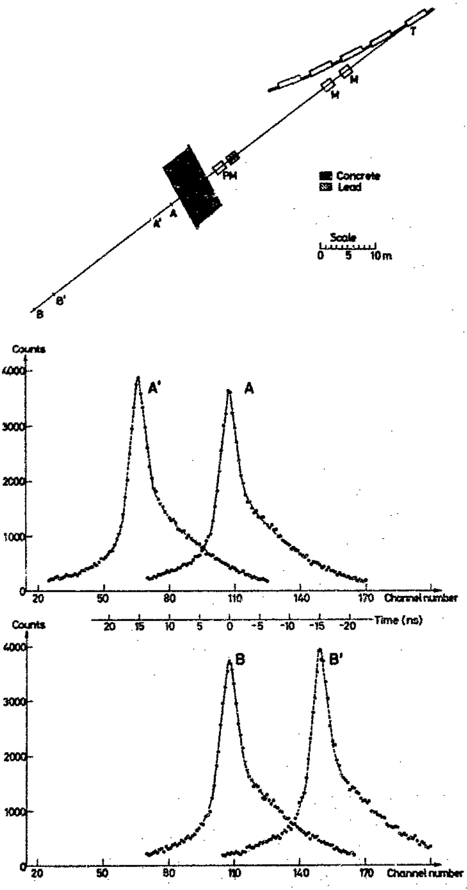

Fig. 1. The experimental arrangement and typical time spectra of the γ rays recorded in the four detector positions A, A', B, B'. Channel width 0.35 nsec. The measuring time for 100 000 counts in the peak was about 10 min.

also presented. A' and B' are located 4.5 m from A and B, respectively (as shown in fig. 1) and the expected shift of ± 15 nsec is well verified.

Although the peaks show an asymmetry originating in the PS, an accurate estimation of the peak positions can be obtained by utilizing the sharp left part of the curves. In spite of a slow drift in the peak positions (due in part to small changes in the PS itself), it was clear that there was no constant difference correlated with positions A and B. Choosing the most stable periods, and correcting for the linear drift, the mean value for the shift is found to be $\Delta = 0.005 \pm 0.013$ nsec.

The result for the velocity measurement of γ rays of energy ≥ 6 GeV from a source with $\beta = 0.99975$ (according to special relativity) as given by eq. (2) is

$$c' = (2.9977 \pm 0.0004) \times 10^{10}\ \mathrm{cm/sec}\ .$$

If we interpret this result using eq. (1) with $c = 2.9979 \times 10^{10}$ cm/sec, the corresponding value for k is:

$$k = (-3 \pm 13) \times 10^{-5}.$$

Note that the γ rays observed in this experiment pass through some beryllium, a thin mylar window and about 60 m of air before their velocity is measured. As this material is refractive, the extinction theorem implies that the original γ rays from the moving source will be slowly absorbed and replaced by similar radiation reemitted by the stationary medium, thus invalidating the experiment [7]. This effect becomes important if the phase delay due to the medium exceeds say $\lambda/2\pi$, where λ is the wavelength of the γ rays. Deriving the refractive index for γ rays from the forward scattering amplitude per electron $A = e^2/mc^2$, the maximum allowable distance becomes

$$d_{\max} = (\lambda n A)^{-1} \approx 5\ \mathrm{km\ of\ air}$$

for γ rays of 6 GeV, where n is the number of electrons per cm^3 of the medium. We conclude that reradiation by stationary material is a negligible effect in this experiment.

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RADIATIVE CORRECTIONS TO $e^+ + e^- \to \mu^+ + \mu^-$

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In this note we give an evaluation of the radiative corrections to the colliding beam reaction $e^+ + e^- \to \mu^+ + \mu^-$. We use Eriksson's work on the renormalization group in electrodynamics [1] to obtain a tentative estimate of the higher order corrections in α. Our results show that the higher order terms play a minor role for colliding beam experiments in the energy range of interest for the various projects now under development [2].

Our calculation of the two-photon contribu-