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# On the Tests of Relativistic Time Dilation in the CERN Muon Storage Ring

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*Abstract.* In a recent paper Huang has suggested that the tests of relativistic time dilation carried out by the muon g-2 experiments have not confirmed the effect in a precise quantitative way. This claim is shown to be without foundation.

Measurements carried out in the CERN muon storage ring on the lifetime of muons in flight with a relativistic $\gamma$ factor of $\approx 29.3$ have verified the relativistic time dilation factor: $\tau/\tau_0 = \gamma$ to a precision of $\leq 2 \times 10^{-3}$ at the 95 % confidence level [1]. Huang [2] has suggested that errors and inconsistencies exist in the results presented in Ref.[1]. Huang re-analysed the bunch structure of the circulating muons in the time period from 6-10 $\mu$s after injection, as presented in Fig.2 of Ref.[1] (or Fig.18 of Ref.[3]). This figure was included for illustrative purposes only, and is not drawn accurately enough to perform the quantitative analysis necessary to derive the mean rotation period to the accuracy claimed in Ref.[2]. Huang claims, by inspection of this figure, that the mean rotation period T is 148.15ns as compared to the fitted value [4] of: T=149.910±0.019 ns, a 0.8% difference, which is 65 times the estimated error of Ref.[1,4]. A direct measurement (after magnification) of Fig.2 of Ref.[1] reveals that the figure is not drawn with an accuracy of better than $\approx 1$ %, so that to determine T from it, with a precision of $7 \times 10^{-5}$, as implied by the last significant figure of Huang's estimate, is impossible. Actually the ratio of the distance between the gradations on the abscissa indicating 6, 8$\mu$s to that between those indicating 8, 10$\mu$s is 1.009±0.003, of the same order as the difference between Huang's estimate of T and the fitted value.

Huang goes on to claim that, from his estimate of T, together with the measured mean radius of the orbits of the circulating muons of r = 7.0059 m [1], and taking into account the errors on the mean radius and T, that the relativistic $\gamma$ factor must lie in the range 6.015 to 11.458, much lower than the value of $\approx$ 29.3 quoted in Ref.[1]. The Lorentz equation, used in Huang's analysis, leads to the well-known relation between the radius of curvature r (m) of the circular orbit of a particle of mass m (GeV) moving perpendicularly to to a uniform magnetic field of strength H (T):

$$\gamma\beta m = 0.299979 Hr \tag{1}$$

The magnetic field of the g-2 storage ring, 1.4745 T [3], and Haung's estimate for $\gamma$, then imply that r must lie in the range from 1.43-2.76 m. The vacuum tank of the muon storage ring, however, extends only over the region from 6.94-7.06 m (see Fig. 7 of Ref.[3]). The simple requirement that the muons must be *somewhere* in this region already implies that $\gamma$ = 29.3$\pm$0.25, incompatible with Huang's estimate of 6.015-11.458.

Huang's error is to use the relation:

$$T = 2\pi r/v \tag{2}$$

to calculate the velocity $v$ (and hence $\gamma$) without noticing that the essential feature of the muon storage ring is a uniform magnetic field, and that due to the Lorentz equation (1), r is not constant when T,$v$ change.

In summary, Huang has produced no substantial argument against the validity of the high precision tests of time dilation presented in Ref.[1].

# References

[1] J.Bailey et al., Nature 268 (1977) 301.

[2] Y.-S. Huang, Helv. Phys. Acta, Vol. 66 (1993) 346.

[3] J.Bailey et al., Nucl. Phys. B150 (1979) 1.

[4] F.Combley et al., Phys. Rev. Lett. (1979) 1383.