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Y. N. Srivastava

Northeastern University

A. Widom

Northeastern University

E. Sassaroli

Massachusetts Institute of Technology; University of Perugia, Italy

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Comment on “EPR without ‘collapse of the wave function’ ”

Y. N. Srivastava and A. Widom

Physics Department, Northeastern University, Boston MA, USA

Physics Department & INFN, University of Perugia, Perugia, Italy

and

E. Sassaroli

Center for Theoretical Physics, Massachusetts Institute of Technology, Cambridge MA

Physics Department & INFN, University of Perugia, Perugia, Italy

ABSTRACT

The implications of the many proper time amplitudes for the process $\Phi \rightarrow K^o + \bar{K}^o$ was discussed in a recent letter of B. Kayser and L. Stodolsky who predicted a small correction ($\sim 5\%$) to the usually predicted phase oscillation frequency for forthcoming Φ factory experiments. Based on previous work (also using the many proper times formalism), we predicted a much larger correction factor ≈ 2 . This correction factor is important in that it allows for a crucial future $D\Phi NE$ experimental test of the many proper times amplitude formalism.

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In a recent letter[1], B. Kayser and L. Stodolsky discussed issues concerning quantum interference of amplitudes and their conclusions (*bar one*) are remarkably similar to those of our previous work[2 – 8].

The issues are as follows: (i) The notion of the “collapse of the wave function” (or equivalently the so called “projection postulate”) is not generally valid for reasons of Lorentz symmetry, and (ii) Each internal propagator of a Feynman diagram requires its own proper time (many proper time amplitudes)[†](1).

The above ideas were applied to the $DA\Phi NE$ process

$$\Phi \rightarrow K^0 + \bar{K}^0. \quad (1)$$

An example of two interfering common channel (secondary vertex) amplitudes are shown below; i.e.

$$\begin{array}{ccc} \begin{array}{c} \pi^0 \\ \swarrow \\ \pi^0 \end{array} & - & \begin{array}{c} K_{S,left} \\ \tau_{S,left} \end{array} & - & \Phi & - - & \begin{array}{c} K_{L,right} \\ \tau_{L,right} \end{array} & - - & \begin{array}{c} \pi^+ \\ \nearrow \\ \pi^- \end{array}, \end{array} \quad (2a)$$

and

$$\begin{array}{ccc} \begin{array}{c} \pi^0 \\ \swarrow \\ \pi^0 \end{array} & - & \begin{array}{c} K_{L,left} \\ \tau_{L,left} \end{array} & - & \Phi & - - & \begin{array}{c} K_{S,right} \\ \tau_{S,right} \end{array} & - - & \begin{array}{c} \pi^+ \\ \nearrow \\ \pi^- \end{array}. \end{array} \quad (2b)$$

Note that *four* proper times are required to describe these *two* interfering amplitudes. The resulting total amplitude (K_L and K_S are virtual) has the form

$$\begin{aligned} \text{Amp}(\Phi \rightarrow (\pi^0 \pi^0)_{left} + (\pi^+ \pi^-)_{right}) = \\ A(K_L \rightarrow \pi^+ \pi^-) A(K_S \rightarrow \pi^0 \pi^0) \exp(-i\bar{M}_S \tau_{S,left} - i\bar{M}_L \tau_{L,right}) \\ - A(K_S \rightarrow \pi^+ \pi^-) A(K_L \rightarrow \pi^0 \pi^0) \exp(-i\bar{M}_S \tau_{S,right} - i\bar{M}_L \tau_{L,left}), \end{aligned} \quad (3)$$

where $\bar{M}_{L,S} = (M_{L,S} - (i/2)\Gamma_{L,S})$. The interference phase between the processes in Eqs.(2) is given by

$$\theta = M_S \tau_{S,left} + M_L \tau_{L,right} - M_S \tau_{S,right} - M_L \tau_{L,left}. \quad (4)$$

With

$$M = (1/2)(M_L + M_S), \quad \Delta M = (M_L - M_S), \quad (5a)$$

$$\tau_{right} = (1/2)(\tau_{S,right} + \tau_{L,right}), \quad \tau_{left} = (1/2)(\tau_{S,left} + \tau_{L,left}), \quad (5b)$$

and

$$\Delta \tau_{right} = (\tau_{L,right} - \tau_{S,right}), \quad \Delta \tau_{left} = (\tau_{L,left} - \tau_{S,left}), \quad (5c)$$

we previously found that

$$\theta = \Delta M(\tau_{right} - \tau_{left}) + M(\Delta\tau_{right} - \Delta\tau_{left}). \quad (6)$$

Kayser and Stodolsky erroneously neglected the second term on the right hand side of Eq.(6). The error turns out to be crucial. If one neglects the second term on the right hand side of Eq.(6), then there is no difference between using four times or using the two times conventionally employed previous to our work. In fact, it is the second term on the right hand of Eq.(6) that provides a forthcoming clear experimental *DAΦNE* test of the many time amplitude formalism. The kinematics are as follows: (i) In the center of mass frame (i.e. the $e^+ + e^- \rightarrow \Phi$ rest frame at *DAΦNE*) we have $\mathbf{p}_L + \mathbf{p}_S = \mathbf{0}$ so that $p = |\mathbf{p}_L| = |\mathbf{p}_S|$. (ii) For a long or short K meson $\tau_{L,S} = (M_{L,S}d/p)$ where d is the center of mass frame distance that the K meson travels. (iii) Thus $\tau_L - \tau_S = ([M_L - M_S]d/p)$, or equivalently $\Delta\tau \approx (\Delta M/M)\tau$. (iv) Finally

$$M(\Delta\tau_{right} - \Delta\tau_{left}) \approx \Delta M(\tau_{right} - \tau_{left}), \quad (7)$$

and the two terms on the right hand side of Eq.(6) are approximately equal. With proper units restored,

$$\theta \approx (2c^2\Delta M/\hbar)(\tau_{right} - \tau_{left}). \quad (8)$$

We note in passing that the interference phase in Eq.(8) contains light speed c (relativity). Any attempt to derive θ using purely non-relativistic quantum mechanics will be inadequate.

FOOTNOTE

- (1) Compare footnote 9 of[1] with Eq.(48) of[6].

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