The Relationship Between the Possibility of a Hidden Variable in Time and the Uncertainty Principle

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In this paper we will discuss the relationship between the possibility of a hidden variable in time and the uncertainty principle. The discussion consists in a fundamental look at the decay time processes of unstable elementary particles. As will be argued, the hidden variable in time possibility may result in a possible way to bypass the energy-time uncertainty principle. Therefore energy and time information may be known simultaneously in the decay time process. A fundamental and general experimental way to test the above is suggested.

1 Introduction

In this paper we investigate the connection between the possibility of a hidden variable in time and the uncertainty principle. In [1] the process of $e^+e^- \to \mu^+\mu^-$ was discussed and it was questioned how come under what appears to be identical local initial conditions we get a distribution of decay time values for the μ^+ and the μ^-. In[1] there was no discussion about the muon mass width that in fact means that the muons are in principle not completely identical to each other and therefore the local initial conditions are not completely identical between the different events. In [1] it was assumed that the muon mass width could not explain (at least not by itself) the exponential decay time distribution of the muons. Therefore the suggestion was that there exists another internal property within the muons that is responsible for generating the muon decay time distribution.

However this could not be the complete explanation as the muons do have a narrow distribution of mass values and therefore there are slightly different local initial conditions in this process between different events. This fact has to be taken into account in a complete explanation for the decay time distribution in this process. As the muon mass width is part of the uncertainty principle, in this paper we will discuss the connection of the uncertainty principle to the hidden variable in time possibility and attempt to incorporate the two. Moreover we will discuss how the existence of a hidden variable in time could help to bypass the energy-time aspect of the uncertainty principle. Finally an experimental way to test the above is discussed.

This paper is organized as follows. Section 2 discusses the theoretical background. Section 3 describes a possible experimental way to bypass the energy-time uncertainty principle in case a hidden variable in time do exist. The conclusions are presented in section 4.

2 Theoretical discussion

2.1 Background

In this paper we investigate the connection between the possibility of a hidden variable in time and the uncertainty principle. The hidden variable in time possibility first presented in [1] gives a deterministic approach that attempts to explain the distribution in decay time as a result of a compatible distribution in an additional internal property within the particles. The suggestion was that this additional internal property is related to the frequency of the virtual boson emission and absorption and therefore as it is related to time and affects the decay time of particles it was termed a hidden variable in time (f_r). However even if the above is correct this could not be a complete explanation as we have to take into account a known distribution in the initial decaying particles which is the distribution in their mass.

In [1] it was assumed that this mass distribution of for example the muon particles can not solely explain the muon exponential decay time distribution. More specifically it was assumed that the Breit-Wigner distribution of the mass value could not be translated in a deterministic, unique and logical way, using the Standard Model, into the exponential decay time distribution that we observe. One could convince oneself intuitively that this is the case by considering the peaks of the two distributions which are at $m = M_{mean}$ for the Breit-Wigner case and $t = 0$ for the exponential decay case and also the tails which are for the mass Breit-Wigner case at $m = 0$, and at $m = \infty$ (two tails) and for decay time case at $t = \infty$.

Therefore one can not get a logical connection between the two distributions because one could not associate the process initial and final condition logically considering what we know from the Standard Model. That is if we start from the two peaks as the most common and popular initial conditions where most of the events are then we get two different initial conditions for the mass value at the tails ($m = 0,\ m = \infty$) that give a single final condition which is the tail of the exponential at $t = \infty$.

This does not give a logical and deterministic explanation as logically under different initial conditions we should get different final conditions considering the dependence of the decay time on the mass as described in the Standard Model and the experimental decay time results, i.e the higher the mass is the shorter the decay time is. Therefore the mass distribution could not generate deterministically and logically using the Standard Model, the observed muon decay time distribution, and we need an alternative explanation. Perhaps in the form of the hidden variable f_r.

The standard model does however, give a general link between the Breit-Wigner shape and the exponential decay time shape for a given particle which narrows down the uncertainty by telling us the favorite mass value of the particles is M_{mean} and that an enhanced fraction of them will decay almost instantly after they are born. For example if 40% of the masses are at a bin around M_{mean} then $40 * 40 = 16\%$ of them will decay in the first decay time bin in the decay time distribution.

That is if we measure a specific mass to be on the mean value then we know that there is a 16% probability that the particle would decay in the first decay time bin. This is compared to what we know from the uncertainty principle, where knowing exactly the mass value yields a complete uncertainty on the decay time. Therefore the Standard Model reduces the uncertainty with respect to the uncertainty principle by allowing us to calculate the Breit-Wigner and the exponential decay time distributions.

2.2 $\Delta m, \Delta t$ and f_r

The distribution of Δm is known from the Breit-Wigner but the distribution of Δt is experimentally unknown (we do not know how to deduce it from the exponential decay distribution), we only know the maximum value of it from the knowledge of Δm and the boundaries given by the uncertainty principle.

According to [1], if one knows the true particle decay $T1$, time then one may know f_{r1} from Fig. 1. In this case this particular f_{r1} has two possible mass value $M1, M2$ as shown in Fig. 2. These two mass values may have the same value of f_{r1} but with very different mean lifetimes given for example in the muon case, from the known Standard Model formula:

$$\tau_{\mu(1,2)} = \frac{192\,\pi^3 h^7}{G_f M(1,2)^5_\mu\, c^4}\,. \tag{1}$$

where G_f is the Fermi coupling constant. In the case when f_r exists, one may have a deterministic link between $\Delta m, \Delta t, f_r$ and t which may cancel the uncertainty limitations as will be discussed later on. Without f_r there is no deterministic link between a specific mass $M1$ and a specific decay time $T1$.

If f_r exists the exponential shape is the slope of the f_r depending on the mean lifetime which gives a deterministic description for a specific event using extra information in the form of f_r.

2.3 Mathematical relationship between f_r and the exponential and Breit-Wigner distributions

Putting the above into a mathematical form gives us two expressions for f_r:

$$f_{r(i)} = f(m_i)\,A_i = f(m_i)\,\exp\left(-\frac{t_i}{\tau_i}\right) \tag{2}$$

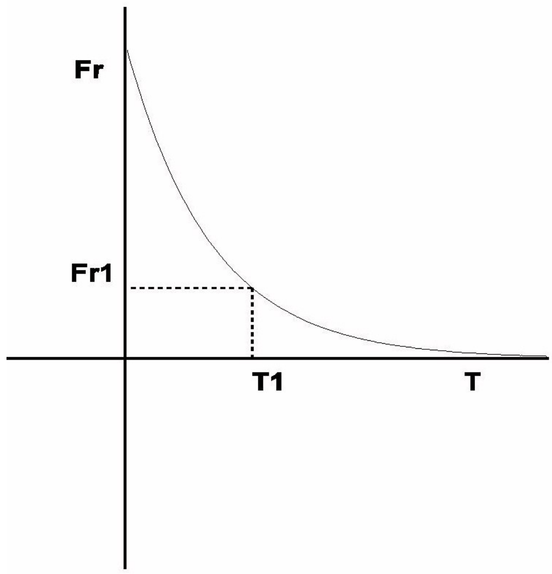

Fig. 1: f_r versus the distribution of the particles decay time.

$$f_{r(i)} = f(m_i)\,f(E_i) = f(m_i)\,\frac{k_1}{(E_i^2 - M_{mean}^2)^2 + M_{mean}^2\,\Gamma_i^2} \tag{3}$$

where $f(m_i)$ is the mass amplitude and $E_i = m_i\,c^2$. One possibility for $f(m_i)$ may be: $f(m_i) = M_{mean} + (m_i - M_{mean})\,k_2$ where k_1 and k_2 are parameters with yet unknown values. The above relationship suggests the following:

For mass measured close to the muon mean mass values Δm is small and Δt is large (but we cannot be sure at this stage how large as we do not know how to deduce the uncertainty Δt from the exponential muon decay time distribution). We can only get the maximum value for Δt for small Δm using the uncertainty principle. From Fig. 2 we can see that small Δm values correspond to high f_r values and therefore, as can be seen from Fig. 1 to short decay time values.

For mass measured far from the mean muon mass value (lower or bigger), we know that Δm is large and Δt is small. Again we cannot be sure for a particular event how small is Δt, however we only know that it has to be small as Δm is large in order to satisfy the uncertainty principle. From Fig. 2 we can see that large Δm corresponds to low f_r values and therefore, as can be seen from Fig. 1, to long decay time values.

Therefore the effect of the uncertainty principle assuming the existence of f_r, on the decay process is that it associates a particular and different uncertainty on each decay time and mass values. This is where masses around M_{mean} are assumed to have short decay times and have small Δm and large Δt, and masses that are away from M_{mean} (smaller or greater) are assumed to have larger decay times and larger Δm and smaller Δt.

This is where the limitation associated by the uncertainty principle of knowing simultaneously the exact mass and de-

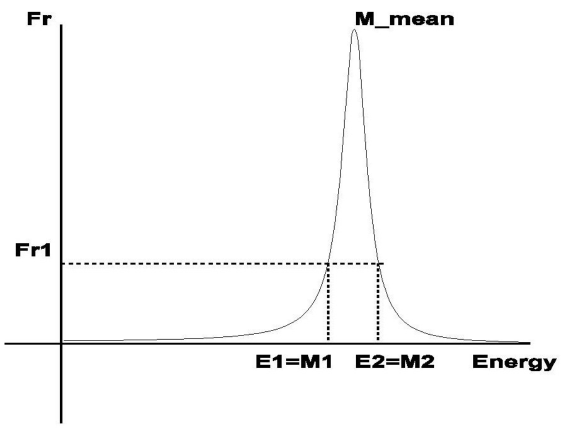

Fig. 2: f_r versus the distributions in the particles mass.

cay time of a particle still remains. In the next section we will discuss how this limitation could be bypassed.

3 Possible bypass of the energy-time uncertainty principle

The possibility of a hidden variable in time opens up a new way to fundamentally bypass the above limitation on the simultaneous knowledge of the muon mass and decay time values. This could be expressed by the following measurement that may be done by known detectors [2]:

As measuring the muon mass exactly is experimentally difficult due to the missing energy of the neutrino involved, we may turn to measuring exactly its decay time.

Therefore, if we measure a specific muon decay time $t1$, we know its f_r from Fig. 1. Therefore we could know its two associated masses $m1$ and $m2$ from Fig. 2 and its mass uncertainty Δm. From the uncertainty principle we could then also know its maximum Δt uncertainty. Therefore this gives us three possible decay time $t1$, $t1 - \Delta t$, $t1 + \Delta t$ and six possible masses that are associated to these three decay times. Now we need to decide which pair of decay time and mass values is the correct one for that particular event. We can attempt to do that by measuring exactly the muon electric charge Q in that event from:

$$\frac{M V^2}{r} = Q V B \tag{4}$$

where B is the external magnetic field, M is the muon mass and we can measure the momentum from the curvature r and the velocity V from the Cherenkov detector. Therefore after knowing the charge we may deduce the factor $A = \exp(-t/\tau)$ according to [3]. This A value corresponds to a part of the particles f_r in that particular event where $f_{r(i)} = f(m_i)\, A_i$ as shown in (2). Now all we need to do is to see which pair of mass and decay time values is closest in value to the measurement of the factor A and find the correct initial mass and final decay time in that particular event, thereby bypassing the uncertainty principle.

4 Conclusion

The implication of a hidden variable in time on the energy-time uncertainty principle was discussed. A fundamental way was presented to bypass the uncertainty principle through measuring the decay time and charge value in a specific $e^+e^- \rightarrow \mu^+\mu^-$ event, thereby knowing the exact value of the initial muon mass and decay time.

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