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The quantum theory of time: from formalism to experimental test

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The violation of the discrete symmetries of charge conjugation (C), parity inversion (P), and time reversal (T) observed in high energy physics are clearly fundamental aspects of nature. A new quantum theory [1,2] has been introduced to demonstrate the possibility that the violations have large-scale physical effects. The new theory does not assume any conservation laws or equations of motion. In particular, if T violation is turned off, matter is represented in terms of virtual particles that exist momentarily only. However, with T violation turned on, what was the mathematical structure of a virtual particle now traces out an unbounded world line that satisfies conservation laws and an equation of motion. The theory is then analogous to the 5 dimensional "proper time" formalism introduced by Feynman [3], extended by Nambu [4] in the 1950's, and developed as "parameterized relativistic quantum theories" [5]. The important point here is that time evolution and conservation laws are not built into the new theory, but rather they emerge *phenomenologically* from T violation. In other words, the new theory proposes that T violation is the *origin of dynamics and conservations laws.* It has experimentally testable predictions and offers new insight into the quantum nature of time.

The talk will include an analysis of the nature of the T violation from known and expected sources such as mesons, neutrinos, and a Higgs-like scalar field. In appropriate parameter regimes, the commutator of the time-reversed versions of the associated T violating Hamiltonian, $\hat{H}_F$ and $\hat{H}_B$, is found to approach the canonical form $[\hat{H}_F, \hat{H}_B] = i\lambda\hat{1}$ where $\hat{H}_B = \hat{T}\hat{H}_F\hat{T}^{-1}$, $\hat{T}$ is Wigner's time reversal operator, $\hat{1}$ is the identity operator, and $\lambda = \langle i[\hat{H}_F, \hat{H}_B]\rangle$ represents the amount of T violation.

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