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ENTANGLEMENT IN PARTICLE PHYSICS

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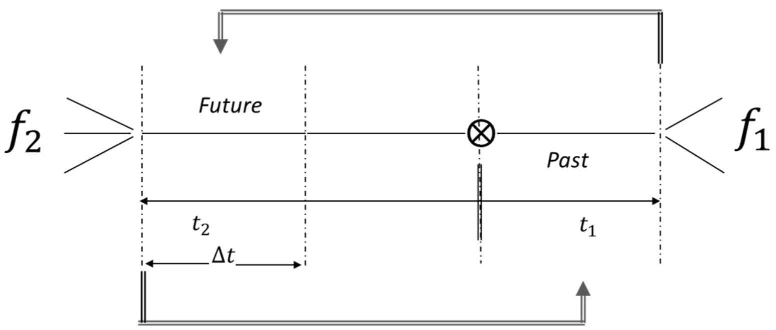
The Entanglement of a pair of nutral mesons (K0-K0bar, B0-B0bar), actually obtained in the PHI and B-factories, offers many novelties beyond Entanglement in quantum optics: particle-antiparticle mixing, CP violation and, most important, non-trivial time evolution of the system. In its time history, it covers the production, entangled, interference and decoherence regimes. It provides effects in its two aspects: (1) as a tool for a BYPASS of (otherwise) NO-GO arguments in particle physics; (2) for the discovery of novel quantum phenomena, such as a surviving correlation-in-time from the future to the past between the two partners.

The Conundrum of Time Reversal Symmetry for unstable particles was considered to be an undefined transformation, the decay being irreversible. Entanglement and the consideration of the decay as a Filtering measurement allow the BYPASS to this NO-GO by the construction of the Transition Probability between the tagged and filtered states of the living partner between the two decays, and so the corresponding Asymmetry. Using this conceptual basis, BABAR observed Time Reversal Violation in the B-system with an impressive significance.

In the K-system, the two states of definite time evolution (KL, KS) cannot be tagged by any decay channel, due to CP Violation. Whereas KL beams can be constructed by means of their very distinct lifetimes, and its rare decays studied with controlled precision, the tagging problem of KS has been with us in the last 58 years. Recently it has been proved that the reach of the decoherence regime in the entangled K-system maintains a surviving correlation-in-time which becomes definite from the observation of the future second decay to the past-decayed state tagged as KS. This fact opens a new avenue in particle physics studies, including direct tests of CPT symmetry.

In correspondence with the known EPR correlation between the two partners of the entangled K-system, leading to the tag of the living partner and its future time evolution, one may ask whether there is a novel quantum effect from the observation of the future fate of the living partner, when the system is no longer entangled, on the past-decayed state when the system was entangled. The post-diction of quantum mechanics is most surprising: the answer is positive and definite and depends on what and WHEN (an indisputable free will of the experimentalist!) the future decay is observed. KLOE-2 has obtained a preliminary result confirming this "spooky" quantum effect by comparing the two time distributions of the first decay correlated with two identical observations of the future second decay at two very distinct times. The reader probably would agree that this post-tag and its dependence on the future observation time opens an epistemological discussion on the role of time in quantum mechanics and the instant reality in nature.



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