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50 years of Bell's theorem and Weak Interaction Processes

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John St. Bell was known and hired as a "particle physicist" when he came up with his work on hidden parameters. The aim of this talk is to discuss whether his theorem can be brought back to those systems that do not build up ordinary matter and light. Indeed, entanglement can be witnessed in decay processes governed by the weak interaction, e.g., in flavour oscillating systems or hyperon systems, BUT: Can an experimentally conclusive test be found proving the existence of correlations that are stronger than those allowed by classical physics?

It is not straightforwardly to apply Bell's theorem to unstable systems. For neutral entangled K-mesons finally Bell's theorem could be generalized without spoiling the conclusiveness [1] and allows for an experimental test, however, for the entangled Lambda-Antilambda system such a solution has not yet been found [2].

The findings [1] turned out to be also surprising from the theoretical point of view since a connection between the violation of Bell's theorem and the tiny violation of the CP symmetry (C..charge conjugation, P…parity) has been found. Herewith, e.g. the security of quantum cryptography protocols gets related to the small difference between a world of matter and antimatter that itself can be attributed to the unsolved problem why we live in a universe dominated by matter.

In the last part of the talk I point out, why weakly decaying systems are a unique laboratory to study foundations of quantum mechanics, e.g. for testing decoherence models or collapse models [3] or for quantum information theoretic tasks [2].

[1] Hiesmayr et al., "Revealing Bell's Nonlocality for Unstable Systems in High Energy Physics", EPJ C , Vol. 72, 1856 (2012).

[2] Hiesmayr, "Weak Interaction Processes: Which Quantum Information is revealed?", arXiv:1410.1707

[3] Brahami et al., "Are collapse models testable with quantum oscillating systems? The case of neutrinos, mesons, chiral molecules", Nature:Scientific Reports 3, 1952 (2013).

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