Entanglement, decoherence and Bell inequalities in particle physics.

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Schladming Lectures

Abstract

1. Lecture:
We give a brief introduction into the features of entangled quantum states and explain the significance of Bell inequalities.
Our aim is to apply Bell inequalities and related topics to particle physics and concentrate for explicit demonstration on the strangeness of entangled K-meson systems which exhibit a rich quantum structure.
We describe the quantum mechanics of K-mesons and work out the analogies and differences to the entangled photon systems.

2. Lecture:
Respecting the unitary time evolution we derive Bell inequalities for K-meson systems, in particular we show their connections to CP-violation.
Next we introduce a phenomenological parameter for the decoherence of a quantum system which we determine from experimental data.

3. Lecture:
A theoretical model with convenient physical features is presented to explain the decoherence of a quantum state.
We introduce a standard measure of entanglement, which is frequently used in quantum information theory and is based on the entropy of the quantum state. We show that the entanglement loss equals precisely the phenomenological decoherence parameter introduced before.

4. Lecture:
We also consider geometric phases, like the Berry phase, and investigate their influence on entangled states and on a Bell inequality respectively. We propose an experiment within neutron interferometry to test our predictions.
Finally, we discuss socalled generalized Bell inequalities, entanglement witnesses, which can discriminate between entangled and separable states. We study their geometric properties and give examples of spin-1/2 particles.