EPR steering, Bell non-locality and entanglement in systems of identical massive bosons

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In previous work [1] quantum entanglement was treated for identical particle bipartite systems based on requiring the density operator to comply with the symmetrisation principle (SP) and with super-selection rules (SSR) prohibiting states with coherences between differing total particle numbers. The subsystems are distinguishable modes, the subsystem density operators for separable states also satisfying the SP and SSR for subsystem particle numbers. Spin squeezing in any spin component, two mode quadrature squeezing and a weak correlation test were shown to be new sufficiency tests for two mode entanglement with massive bosons. A test for the sum of Sx, Sy spin operator variances being less than half the mean boson number N [2] also applied.

Quantum states for composite systems are categorised as either separable or entangled, but states can also be divided differently into Bell local or Bell non-local states based on local hidden variable theory (LHVT) [3]. For Bell local states three cases occur depending on whether both, one of or neither of the LHVT subsystem probabilities are also given by a quantum probability involving sub-system density operators. Cases where one or both are given by a quantum probability are known as local hidden states (LHS) and such states are non-steerable [3]. All separable states are LHS, but some LHS are entangled.

Recently [4] we found that spin squeezing in any spin component, two mode quadrature squeezing and a weak correlation test show that the LHS model fails (including for the non-separable case) - hence the quantum state is steerable. A new spin variance test was also found for the sum of Sx, Sy spin operator variances, but now involving the means of both Sz and N.

In addition [4] we found a new test for Bell non-locality that applies when the measured quantities A, B have outcomes other than +1,-1 – such as for spin components.

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