

## Truth and Beauty: Quantum Entanglement Theory and Its Generic Searches at the Colliders

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The quantum entangled state, which does not violate the Bell non-locality, can violate the Bell non-locality due to the super-activation. Thus, the quantum entanglement is indeed one of the most important properties of quantum mechanics, i.e., Truth of Nature. We shall propose the quantum entanglement theory from mathematical point of view, i.e., Beauty of Theory. For pure states, considering a general quantum system with  $N$  particles, we show that the quantum space (the total spin polarization parameter space) is complex projective space, and the classical space (the spin polarization parameter space for classical theory) is the cartesian product of the complex projective spaces. Thus, the classical space is the (generalized) Sagre variety in the quantum space, and the quantum entanglement space is the difference of these two spaces. For mixed states, the sufficient and necessary conditions for quantum entanglement can be given as a set of algebraic equations, which are simple and can be solved easily for physical systems. In addition, we propose a generic method to calculate the quantum range and classical range for the expectation value of any physics observable at the collider, and thus we can probe the quantum entanglement spaces which the previous ways cannot. However, there is a circular argument issue. Furthermore, we will briefly explain how to probe the quantum entanglement consistently in high energy physics by determining the spin analyzing powers and excluding the local hidden variable theory, i.e., evade the circular argument issue and solve the no-go theorem problem.

**Presenter:** LI, Tianjun (Henan Normal University)

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