Metric description of hadronic interaction from Bose–Einstein correlation

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We discuss the problem of second-order correlation in pion production in high-energy processes (commonly known as Bose–Einstein correlation) by means of the concept of nonlocality and its mathematical realization via the isotopy of Hilbert and Minkowski spaces. Such a nonlocal approach allows one to describe the spatial shape of the source where pions are produced ("fireball"), and to account also for the correlation in phase. The correlation function obtained by this method does not contain free "*ad hoc*" parameters. Moreover, a test of this nonlocal correlation function performed on UAI experimental data is as good as that given by the conventional treatment. Such an approach suggests an interpretation of the pion production as a decay process of the fireball whose mean lifetime can be explicitly evaluated. Using the data of the UAI ramping run, we find an expression for the metric parameters as functions of the energy. They provide an effective dynamical description of the hadronic interaction in terms of a deformation of the Minkowski metric. The related parameters of the fireball admit of future experimental verification at DELPHI. The law of deformation of time in the presence of a hadronic field is derived. Its behavior with energy allows one to give an appealing picture of confinement and asymptotic freedom of hadronic constituents.
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1. INTRODUCTION

The phenomenon of second-order interference in pion production from high-energy collisions[1] was widely discussed in its formulation as a Bose–Einstein (BE) correlation among identical particles[2] by borrowing concepts from interferometry in radio astronomy.[3] Previously, it was merely considered as an unexpected and unforeseen correlation in the production of pions.[4]

The so-called BE correlation was later recognized as common to widely disparate processes, such as hadronic (also involving nuclei and heavy ions) and hadro-leptonic reactions, as well as pair annihilations and $\gamma\gamma$-reactions (for an experimental as well as theoretical review, see, e.g., Ref. 5).

From a phenomenological viewpoint, the effect is that pairs of identical bosons show a higher probability of emission at small opening angles—or, equivalently, at small relative momenta—than pairs of nonidentical particles. As already mentioned above, it was first interpreted, for equally charged pions, as a manifestation of their BE statistical properties.[4] The BE correlation picture of this phenomenon originates, of course, in the quantum-mechanical interference of the wave functions of the particles and the consequent requirement of a total wave function symmetric under particle exchange.[5]

Note that at the macroscopic level (for instance, in radio astronomical interferometry), the interference—and therefore the correlation—occurs in the space near the detector. This implies a coherent source. In contrast, at the microscopic level, we have to look for correlation, i.e., interference, in the spatial region near the source, which, *a priori*, is not expected to be coherent. This is the very reason for the unpredictability of the correlation effect first observed for pions: classically, the interference (and therefore the correlation) of the detected bosons is a strict consequence of source coherence. Although the principles at the very basis of the BE interpretation are, of course, of universal validity, we think that there is a difference in their application to the microscopic case as compared to the macroscopic one.

In our opinion, the inadequacy of BE correlation in the microscopic case is due to the model of source coherence used in deducing the correlation function.

To see this, let us critically review the main lines of the classical procedure of deriving the second-order correlation function $C_{(2)}$ defined by

$$C_{(2)}=\frac{P(p_1,p_2)}{P(p_1)P(p_2)}, \tag{1.1}$$

where $P(p_1,p_2)$ is the two-particle probability density subjected to BE symmetrization and $P(p_i)$ is the corresponding single-particle quantity for a particle with four-momentum p_i. In practice, one often uses the simplified expression

$$C_{(2)}=\frac{P(p_1,p_2)}{P_0(p_1,p_2)}, \tag{1.2}$$

where the reference probability density $P_0(p_1,p_2)$ is essentially the same as $P(p_1,p_2)$ apart from its lack of BE symmetrization.

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