Reply to “Comment on ‘Entangled entanglement’ ”

Günther Krenn
Atom Institut der Österreichischen Universitäten, Schützstraße 115, A-1020 Wien, Austria

Anton Zeilinger†
Institut für Experimentalphysik, Universität Innsbruck, Technikerstraße 25, A-6020 Innsbruck, Austria
(Received 27 May 1997)

Expounding an argument that we have stated in Sec. IV of our paper [Phys. Rev. A 54, 1793 (1996)], we demonstrate that according to our understanding Schafir’s conclusion [preceding Comment, Phys. Rev. A 56, 4335 (1997)] is based upon a premise that is not tenable. [S1050-294797035105]

PACS number(s): 03.65.Bz

In our paper [1] we consider a three-particle system described by the Greenberger-Horne-Zeilinger state [2,3] proposed by Mermin [4]. Spin measurements with two possible outcomes (+ and −) are performed on the particles along arbitrary directions. By the results of the measurements on one particle, say, particle 3, two subensembles of the results of the measurements on particles 1 and 2 are defined in the following way. Whenever the result of a measurement on particle 3 is + (−) the corresponding results of the measurements on particles 1 and 2 are assigned to subensemble + (−). Analyzing the characteristics of the correlations of the results within these subensembles, we have shown, that it essentially depends on the measurement performed by observer 3 whether or not the correlations can be interpreted classically, i.e., whether or not Bell’s inequality is violated.

In his Comment Schafir [5] argues that, because of the nonlocality of the three-particle system as a whole, it is impossible to select a subensemble of the results of the measurements on particles 1 and 2 in such a way that the same results (e.g., results 1,3,4,6,... of a specific experimental run) are selected independently of the measurements performed on particles 1 and 2. Therefore, he concludes that it is inadmissible to apply the considerations implicated in the use of Bell’s inequality as a criterion for locality. Only if the same results are considered in the four experimental situations represented in Bell’s inequality is a decision on the kind of correlations possible by evaluating the inequality.

It is our understanding that the premise of Schafir’s conclusion is not tenable. As stated in Sec. IV of our paper, the measurements performed on particles 1 and 2 can be totally independent from the measurement performed on particle 3. Therefore, we can choose any arbitrary temporal order for the measurement on particle 3 relative to the measurements on the other two particles. Specifically, the measurement on particle 3 can be performed long before the measurements on particles 1 and 2 take place. In such a way the results assigned to subensembles + and −, respectively, are defined independently of the experimental situation that is chosen for particles 1 and 2 (e.g., with regard to Bell’s inequality). Whatever is going to be measured on particles 1 and 2, in any case the same subsequences will be assigned to subensembles + and −, respectively, because the results of observer 3 already have been registered long before.

Thus we cannot agree with Schafir’s statement that “the subsequences considered by observers 1 and 2 will in general be different if they choose different measurement angles.” In fact, the selection to which subsequence (+ or −) certain results of observers 1 and 2 belong is done long before these measurement angles are chosen and therefore cannot depend on a specific choice of these angles. Yet Schafir is certainly correct in stating that there exists nonlocality for the three-particle system as a whole. Entangled entanglement is one of its manifestations.

This work was supported by the Austrian Science Foundation FWF Project No. 6502.