

Asymmetric Bell Experiment with Inefficient Detectors

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Let us imagine an experimentalist, who has maximally entangled photons and wants to violate Bell's inequality in his laboratory. Among many obstacles he has to overcome, two of them are the most significant. Firstly, he has to avoid exchanging information about the measurement settings between the particles. Secondly, he has to detect particles with a high enough probability, because if the detection efficiency is too low, one can reproduce quantum correlations using a LHV (Local Hidden Variables) model. These two problems are known in the literature, respectively, as the locality loophole [1] and the detection loophole [2, 3]. Fortunately, it is possible to close the locality loophole using photons in the experiment [4, 5, 6, 7, 8]. However, closing the detection loophole is still an object of study. The authors of [9] showed that for the CHSH inequality, the lower bound for detector efficiency needed to close the loophole is 82.8% for maximally entangled states. This bound was lowered to 66.7% by Eberhard [10]. Furthermore, the detector efficiency has been studied for other Bell inequalities [11, 12, 13, 14, 15, 16].

In our research, we are trying to answer the following question: If we prepare a Bell experiment and we have two detectors, having different efficiencies both smaller than 100%, which detector should each party receive? And also: Which representation of the chosen Bell inequality should we consider? These are very crucial questions, which arise in laboratories. Hence, we hope that our results will be useful for experimentalists. We focus on the I_{3322} inequality [17], which is a natural candidate for testing, because of its asymmetry [14, 18]. We consider the case of a post-selection strategy, which consists in rejecting all the rounds in the Bell experiment when one of the detectors does not click. We used numerical optimisation methods to find both the best classical strategy for Alice and Bob and the best detector clicking strategy. Thus, we have found minimal efficiencies of the detectors of Alice and Bob needed to violate I_{3322} . We made the same studies also for symmetric representations of I_{3322} [19]. Our results show that the minimal efficiencies of Alice and Bob's detectors of the asymmetric representation of I_{3322} is lower than in case of the symmetric one [20]. It is work in progress, and we are examining other post-selection methods as well as other Bell inequalities. We want to consider also the case when non-maximally entangled states are used in Bell experiments.

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