Self-testing from the perspective of nonclassicality

Is the work of a physicist based on trust? Imagine that two scientists, Alice and Bob, want to perform an experiment together. They are located in two separate laboratories. They need someone who will prepare a specific quantum system and send its constituent parts to them. Then, scientists will perform certain operations on this system. Alice and Bob decide to buy the research equipment needed for the experiment. Each of them receives a black box that contains that contains the experimental set-up. There are several buttons on the boxes, with which you can control the experiment settings, and a screen on which the results of the experiment are displayed. Although Alice and Bob do not know what is inside the boxes, the producer promises them that they perform the tasks they want: perform specific operations on a specific quantum system. This is very important for Alice and Bob. If the boxes perform different measurements, or the quantum system delivered to the boxes is not the expected one, the experiment will fail. Do Alice and Bob just have to trust the apparatus manufacturer?

It turns out that Alice and Bob can check whether the black-boxes perform the promised operations. This procedure is called self-testing. Alice and Bob need to check how the results on the black-box screen change upon changing the apparatus settings. This way, they can collect the statistical data produced by the devices. This procedure is illustrated in Figure 1. Some statistics can only be produced by performing specific operations on a particular quantum system. After observing such statistics, Alice and Bob are sure that the producer did not lie to them. In other words, self-testing allows one to verify whether a given device uses a declared quantum system and performs declared operations on it.

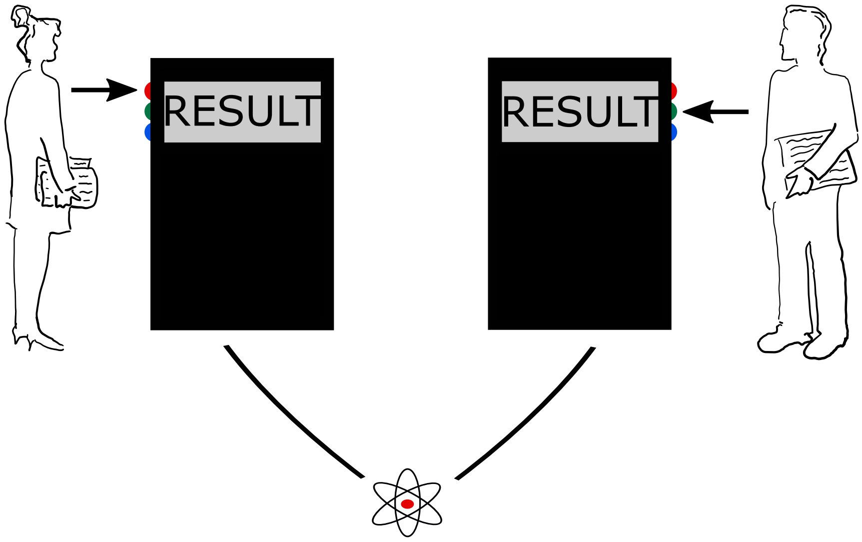

Figure 1: Self-testing protocol. Alice and Bob observe the black-box results as they change the settings. In the figure, the colorful buttons symbolize various settings.

Self-testing is an important topic in quantum physics. Self-testing studies provide a better understanding of quantum systems and how they differ from the classical ones. Moreover, self-testing is an important protocol in quantum information processing.

In this research project, I will develop a theoretical formalism for studying self-testing. It will be based on two different notions of nonclassicality: contextuality and LOSR-nonclassicality. This formalism will be applicable to experiments such as the one described above, but also to others. For example, it will allow for self-testing when Alice prepares a quantum system and sends it to Bob. Moreover, I will investigate robust self-test protocols. This means that even if Alice's and Bob's black-boxes experience experimental noise, self-testing will still be possible. The formalism developed in this project will unify already known results. I also intend to use this formalism to search for new results in the field of self-testing.