Practical guide to Lab reports

Quantum Information and Computing course
A.A. 2024/25

1 CHSH inequality violation

1. Describe the setup and the aim of the experiment
2. Calibration of waveplates: data analysis. The `Waveplate_A.csv` file contain a table with the registered counts in function of the waveplate angle.
3. The datasets has 16 files such as `x0a1y0b1.txt`: each row represents the timestamps of each detection, together with the information of which detector fired. In each row, the first column is the timestamp (expressed in units of 81ps) of the detection measured from the turning-on of the time-tagger, the second column the channel that fired. Each file represents a different measurement set and outcome. In particular
   - $x = 0$ represent the choice of the operator A_0 on Alice side
   - $x = 1$ represents the choice of the operator A_1 on Alice side
   - $a = 0$ represents the outcome $+1$ on the Alice measurement
   - $a = 1$ represents the outcome -1 on the Alice measurement
   - $y = 0$ represent the choice of the operator B_0 on Bob side
   - $y = 1$ represents the choice of the operator B_1 on Bob side
   - $b = 0$ represents the outcome $+1$ on the Bob measurement
   - $b = 1$ represents the outcome -1 on the Bob measurement

   The notation `x1a0y0b1` represents the configuration $x = 1$, $a = 0$, $y = 0$, $b = 1$. Based on the above information it is necessary to calculate the coincidences based on the raw data. In particular it is useful to evaluate the histogram of the differences between the time of arrival of the two photons. Based on such histogram, a temporal window must be chosen to call two events "coincident".
4. Calculate the CHSH parameter and its corresponding error based on the Gaussian Error Propagation model. Consider Poissonian errors on the measured coincidences.

2 Quantum State Tomography

For a detailed description of Quantum State Tomography see PHYSICAL REVIEW A 64, 052312 (2001).

1. Describe the setup and the aim of the experiment
2. Determine the density matrix by liner inversion from the obtained data and check for positivity
3. Perform the Maximum-Likelihodd estimation
4. Evaluate Fidelity, Von-Neumann entropy and Concurrence for the obtained density matrices
5. Evaluate statistical errors by simulation. Consider each obtained count as a Poissnian random variable with mean value the obtained experimental data. Generate an ensemble of simulated density matrices ($>$100) with the above statistic. Determine for each ρ the Fidelity and Concurrence. Calculate the statistical errors as the standard deviations of the simulated results.