Experimental test of nonclassicality without fair sampling assumption nor any additional conditions

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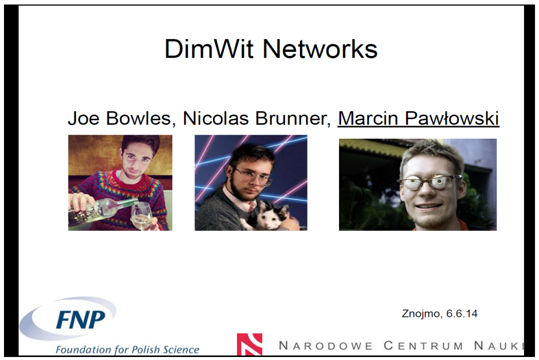
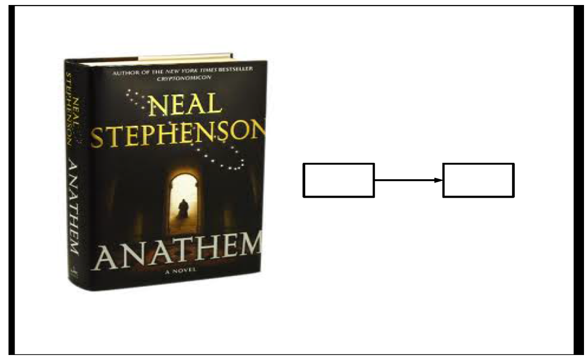
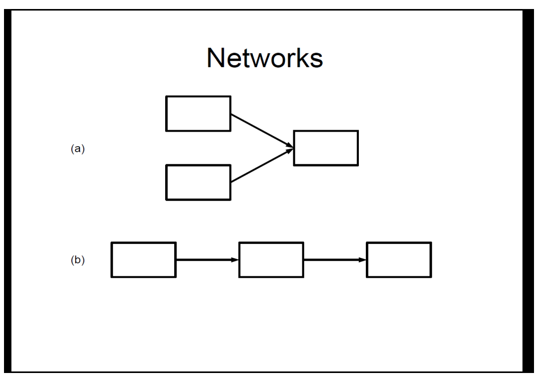
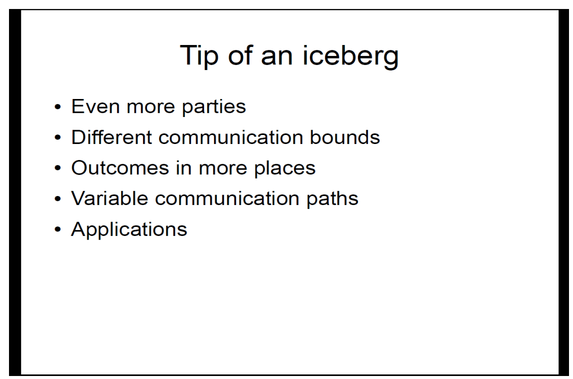
Previously on CEQIP.....

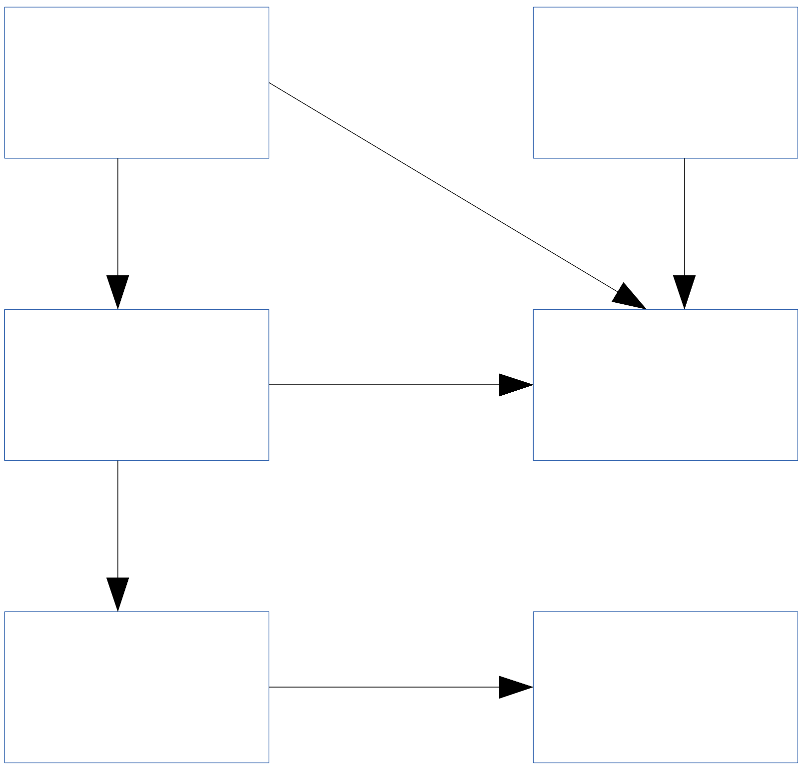


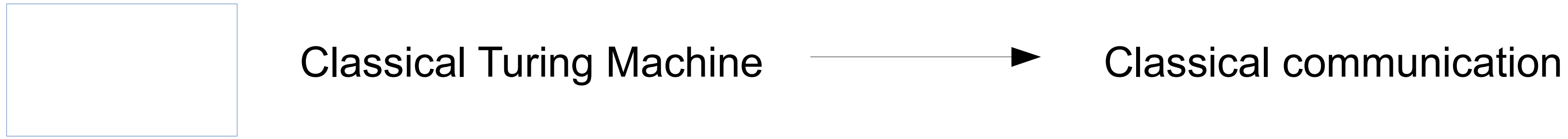




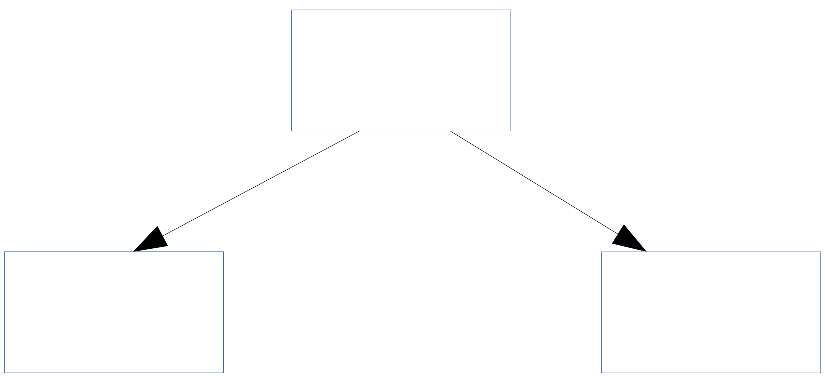


What is a test of nonclassicality?





Two types of tests:



Bell scenario

Device Independent protocols

Prepare-and-measure scenario

Semi Device Independent protocols

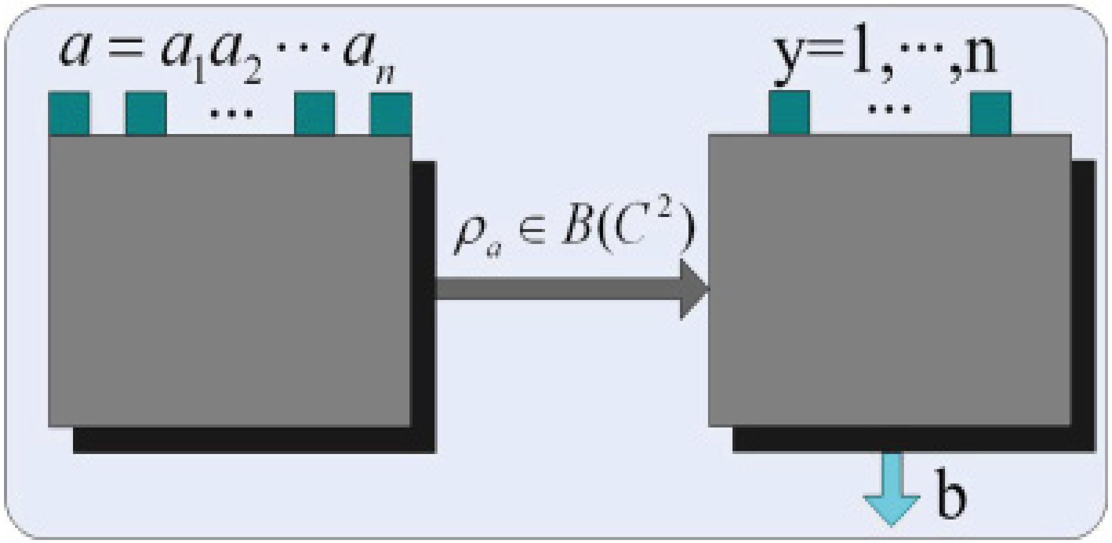
Semi Device Independent protocols

Examples: Quantum key distribution, random number generation, communication complexity tasks.

Motivation: There's no such thing as full device independence.

Big problem: Detection efficiency

First solution: RAC with independent devices



$b=a_y$

N=2 Classical average success probability 0.75

Worst case 0.5

Quantum in both cases 0.85

Simple cheating strategy

Classical devices share a string of random numbers R:

Sender:
+ R=1 sends a_1
+ R=2 sends a_2

Receiver:
+ R=y returns a_y
+ R≠y returns a random number

First lesson: Use whole probability distribution!

Independent devices and inefficient detectors

Each round when the detector does not produce any outcome choose a random value.

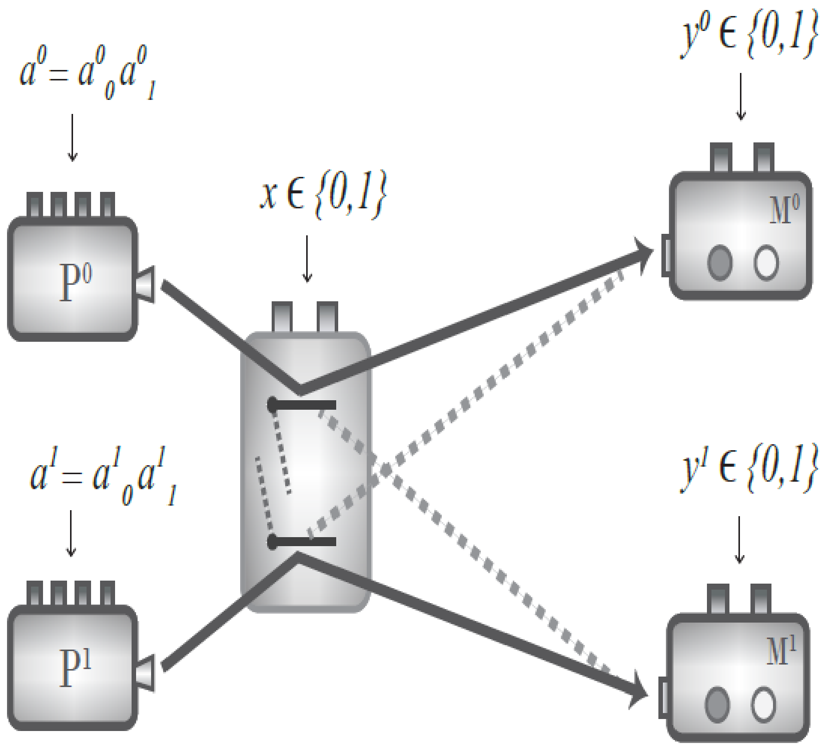
If the system is quantum then the success probability can be:

$$0.85p+0.5(1-p)>0.5$$

Probability that the detector clicks

Does not matter if the system is imperfect

New solution, new network



Two parallel RACs

Sender:
+ R=1 sends a_1
+ R=2 sends a_2

Receiver:
+ R=y returns a_y
+ R≠y returns a random number

Let's use the simple cheating strategy:

All parties have access to the same R

Let's assume that both receivers got the same input

If receiver 0 is successful then probability that R=y is 0.75 and the probability that receiver 1 is successful is 0.875.

If receiver 0 is not successful then probability that R=y is 0.25 and the probability that receiver 1 is successful is 0.625.

We observe correlations which should not be present.

Let's impose independence

1. For every possible input $i = (a^0, a^1, y^0, y^1, x)$ the success probability of guessing the correct bit is the same for both the measurement devices,

$$P(b^0 = a_{y^0}^{0\oplus x}|i) = P(b^1 = a_{y^1}^{1\oplus x}|i) = T. \tag{2}$$

We use this assumption so that we have a value of T which we can optimize instead of a set of 128 pairs of success probabilities.

2. For every input $i = (a^0, a^1, y^0, y^1, x)$, the probability distributions of b^0 and b^1 are independent,

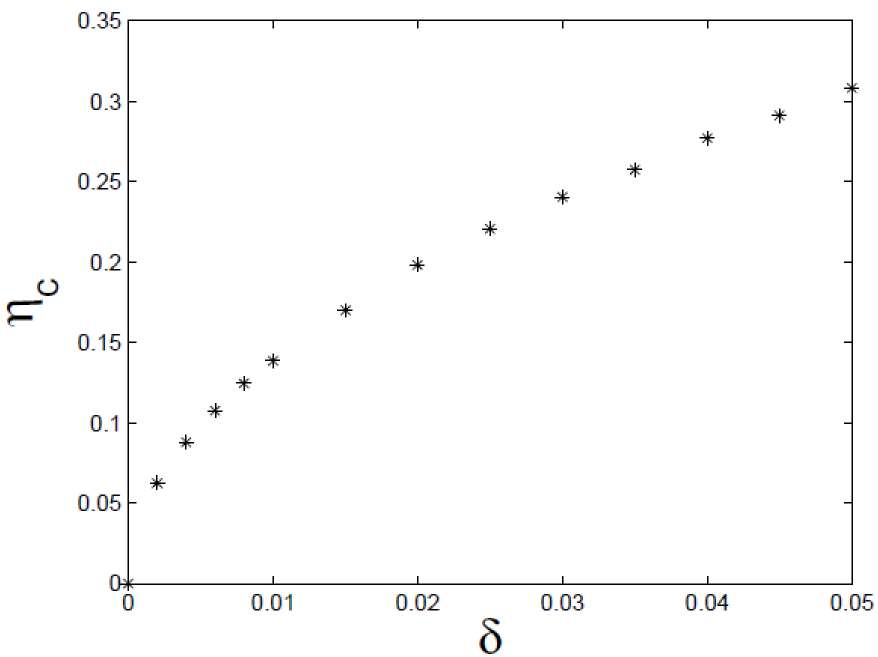
$$\begin{aligned} &P(b^0 = a_{y^0}^{0\oplus x}|b^1 = a_{y^1}^{1\oplus x}) = P(b^0 = a_{y^0}^{0\oplus x}|b^1 \neq a_{y^1}^{1\oplus x}) \\ &\implies P(b^0 = a_{y^0}^{0\oplus x}, b^1 = a_{y^1}^{1\oplus x})(1 - T) \\ &\quad = P(b^0 = a_{y^0}^{0\oplus x}, b^1 \neq a_{y^1}^{1\oplus x})T. \end{aligned} \tag{3}$$

Using linear programming we find that the only T compatible with classical models is 0.5!

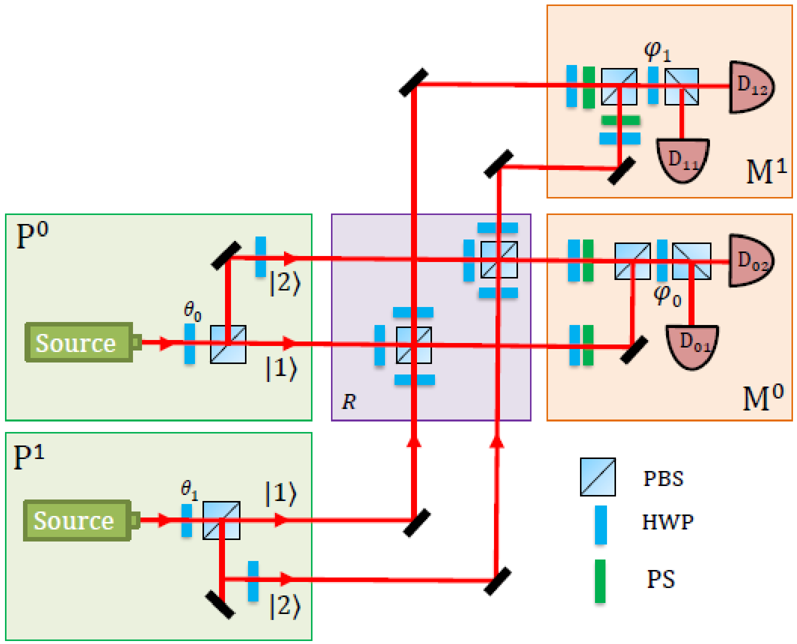
Imperfect independence

$$\forall i = (a^0, a^1, y^0, y^1, x),$$
$$P(b^0 = a^{0\oplus x}_{y^0} | b^1 \neq a^{1\oplus x}_{y^1}) + \delta \geq P(b^0 = a^{0\oplus x}_{y^0} | b^1 = a^{1\oplus x}_{y^1})$$
$$\geq P(b^0 = a^{0\oplus x}_{y^0} | b^1 \neq a^{1\oplus x}_{y^1}) - \delta$$

0.85p+0.5(1-p)>0.5



The experiment



We simply fed estimated probabilities into linear programming algorithm and kept adding standard deviations until they became compatible with classical model.

We could add 13 standard deviations so the probability that the communication was classical is negligible.