Diagnosing quantum relays by means of collective entanglement witnesses

Karol Bartkiewicz[1,2] Antonín Černoch[1], and Karel Lemr[1]

[1] Faculty of Science, Palacký University in Olomouc, Czech Republic

[2] Faculty of Physics, Adam Mickiewicz University, Poznań, Poland

MULTIPHOTON QUANTUM LAB

@ RCPTM, PALACKÝ UNIVERSITY

multiphoton.upol.cz

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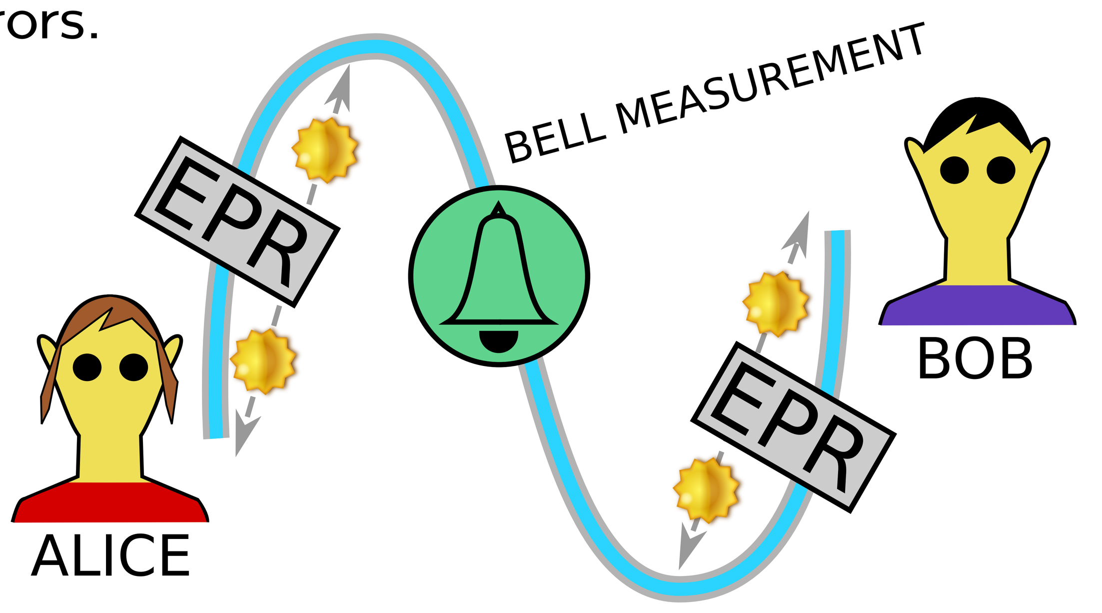
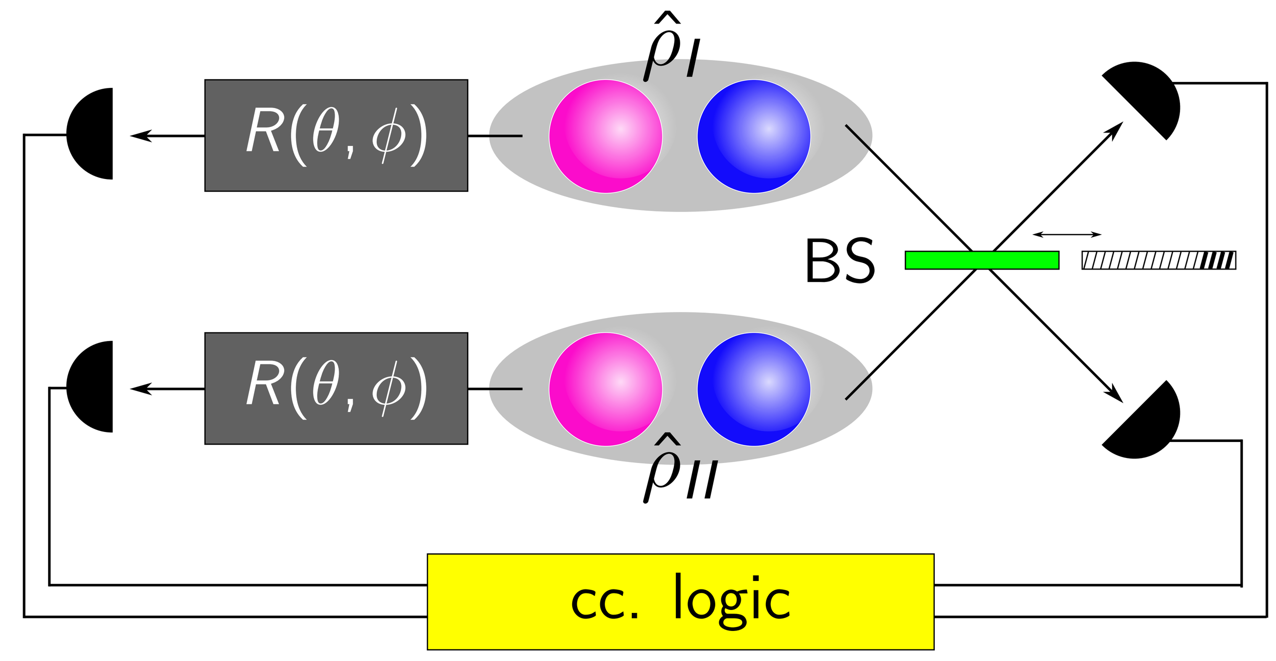
QUANTUM RELAYS

Quantum relays are designed to distribute quantum entanglement across large distances by implementing the **entanglement swapping** operation on the inner nodes of an entanglement distribution chain [Jacobs2002]. Their role is to combat quantum channel losses and errors.



COLLECTIVE WITNESSES

Collective entanglement witnesses are designed to detect entanglement by using a joint measurement on multiple copies of the investigated state. Particular example of such a witness is the **collectibility** [Rudnicki2011].



Experimental implementation: [Lemr2016].

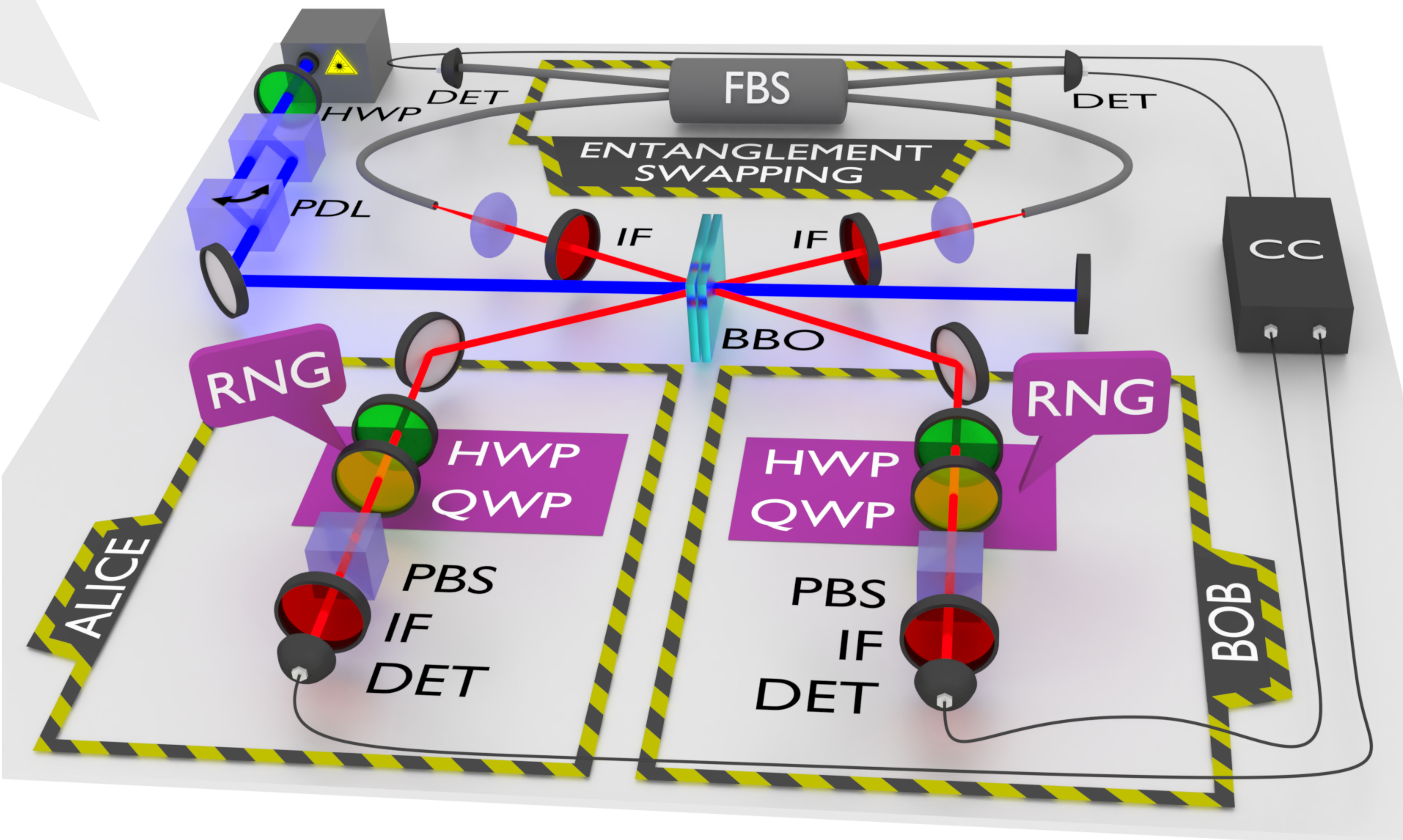
Q: What do they share in common?

A: **Their geometry.**

Q: Why should we care?

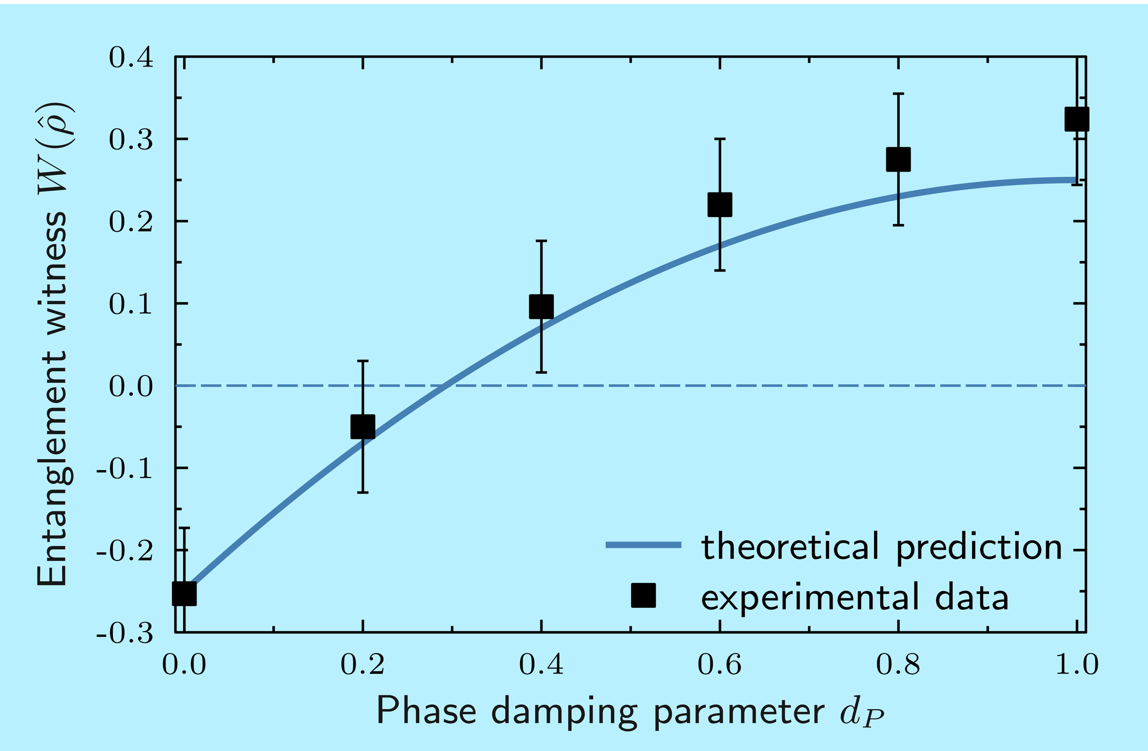
A: **Because collective entanglement witnesses can be used for easy and fast diagnostics of quantum relays.**

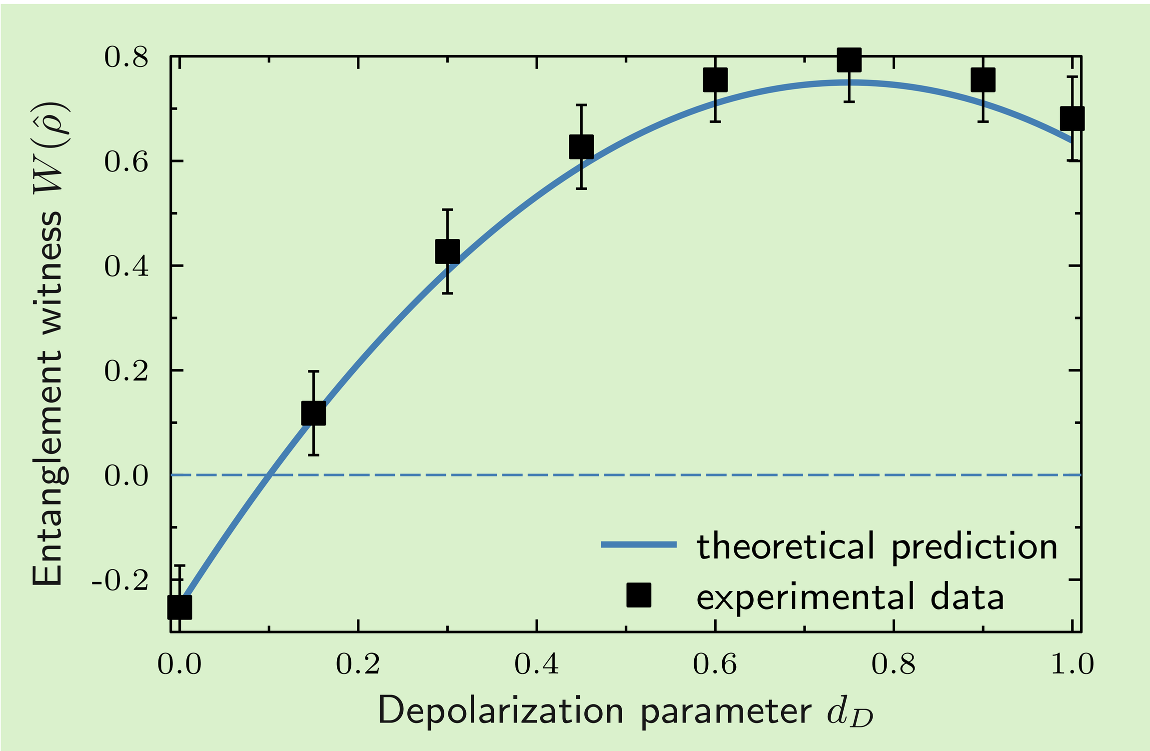
ONLY 4 MEASUREMENT SETTINGS ARE NEEDED

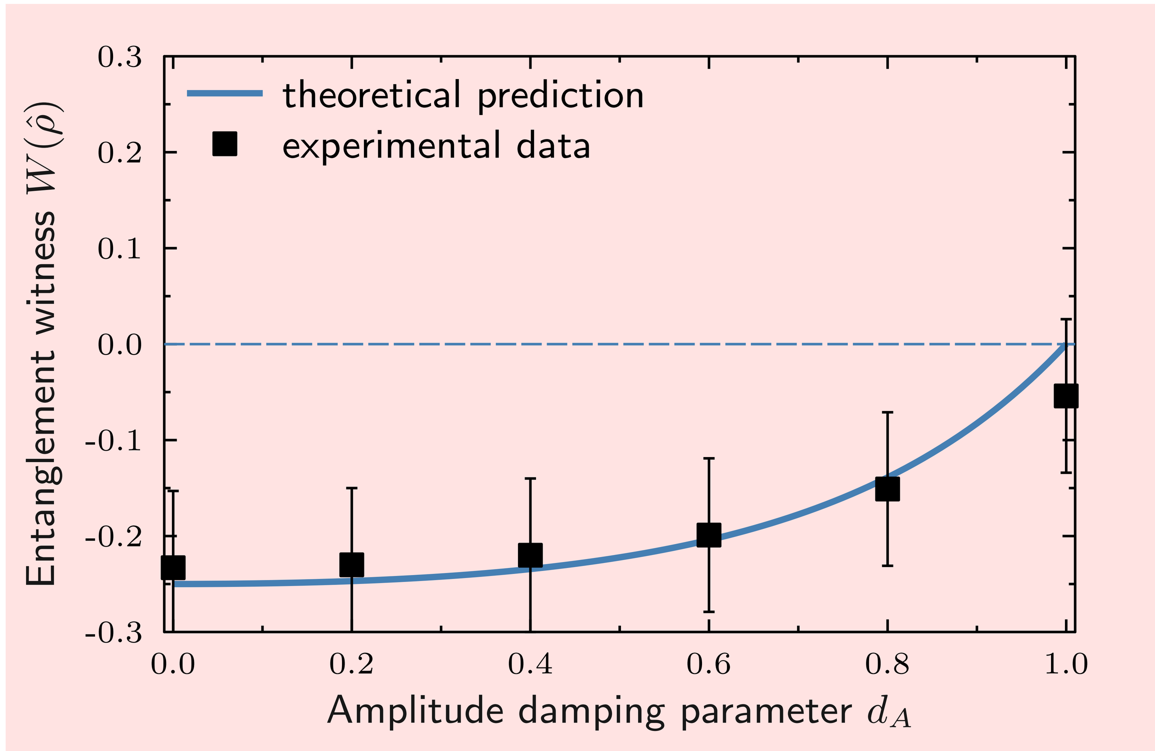


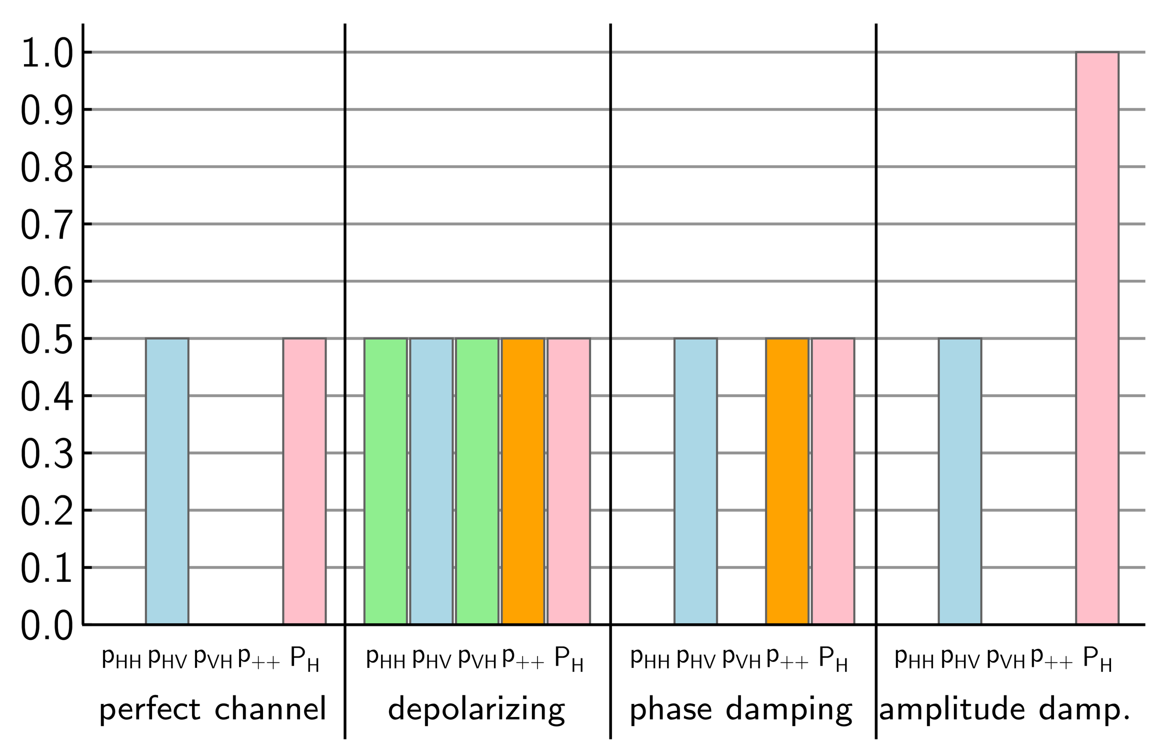
Three error channels were implemented:

- phase damping:
  $M_0 = \sqrt{1-\frac{p}{2}}\hat{1}, M_1 = \sqrt{\frac{p}{2}}\hat{\sigma}_z$
- depolarizing:
  $M_0 = \sqrt{1-p}\hat{1}, M_1 = \sqrt{\frac{p}{3}}\hat{\sigma}_x,$
  $M_2 = \sqrt{\frac{p}{3}}\hat{\sigma}_y, M_3 = \sqrt{\frac{p}{3}}\hat{\sigma}_z$
- amplitude damping:
  $\hat{\rho} \to \begin{pmatrix} 1 & 0 \\ 0 & \sqrt{1-p} \end{pmatrix} \hat{\rho} \begin{pmatrix} 1 & 0 \\ 0 & \sqrt{1-p} \end{pmatrix}$









Channel errors were simulated by randomly applying polarization transformations together with the required local projections. Each error deviates the collectibility from its theoretical minimum. By observing individual outcomes of respective measurement settings, one can identify the type of occurring error (each channel has a characteristic fingerprint).

[Jacobs2002] B. C. Jacobs, T. B. Pittman, and J. D. Franson, Phys. Rev. A **66**, 052307 (2002)
[Rudnicki2011] Ł. Rudnicki, P. Horodecki, and K. Życzkowski, Phys. Rev. Lett. **107**, 150502 (2011)
[Lemr2016] K. Lemr, K. Bartkiewicz, A. Černoch, Phys. Rev. A **94**, 052334 (2016)

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