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Estimation of the dimension of classical and quantum systems

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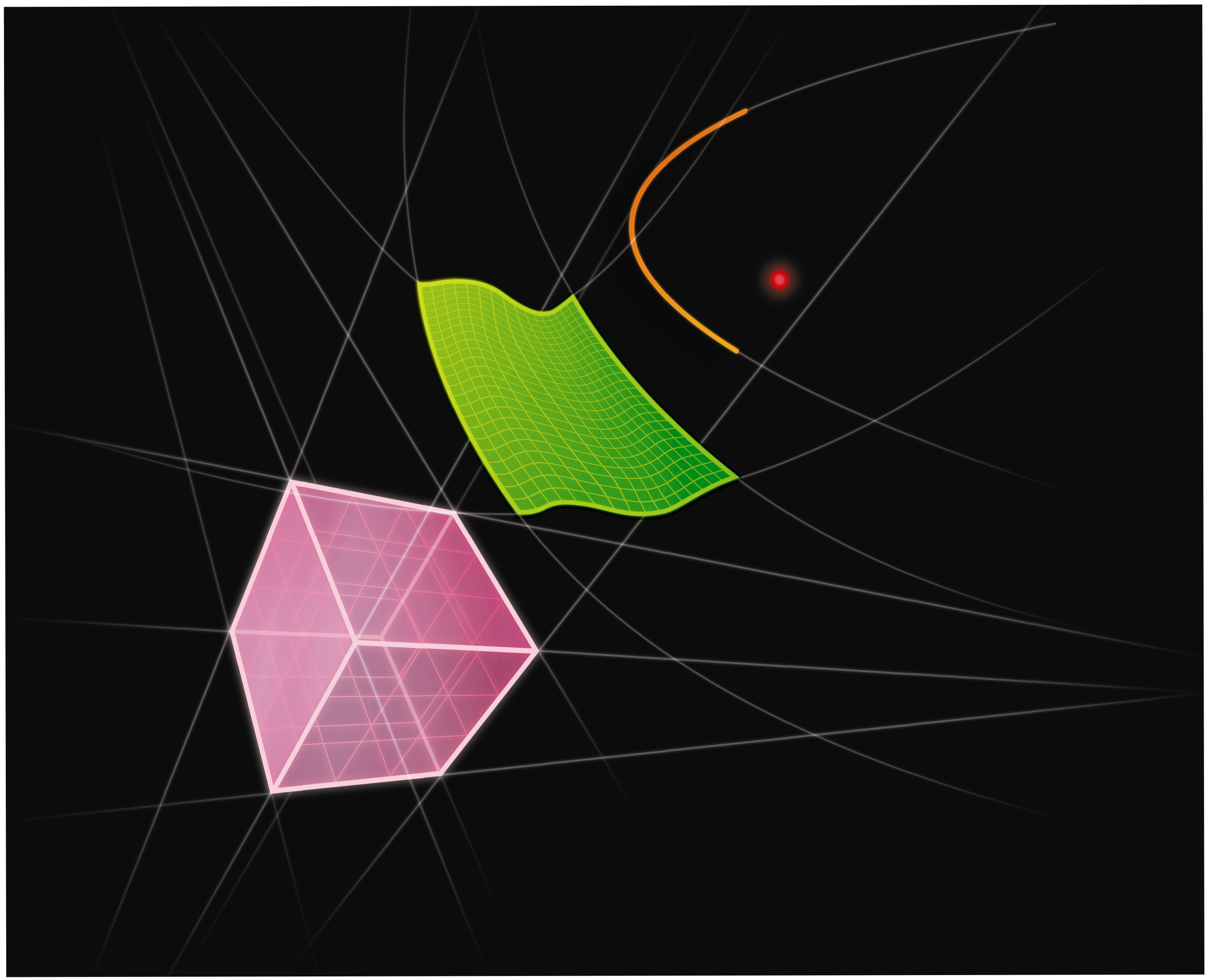
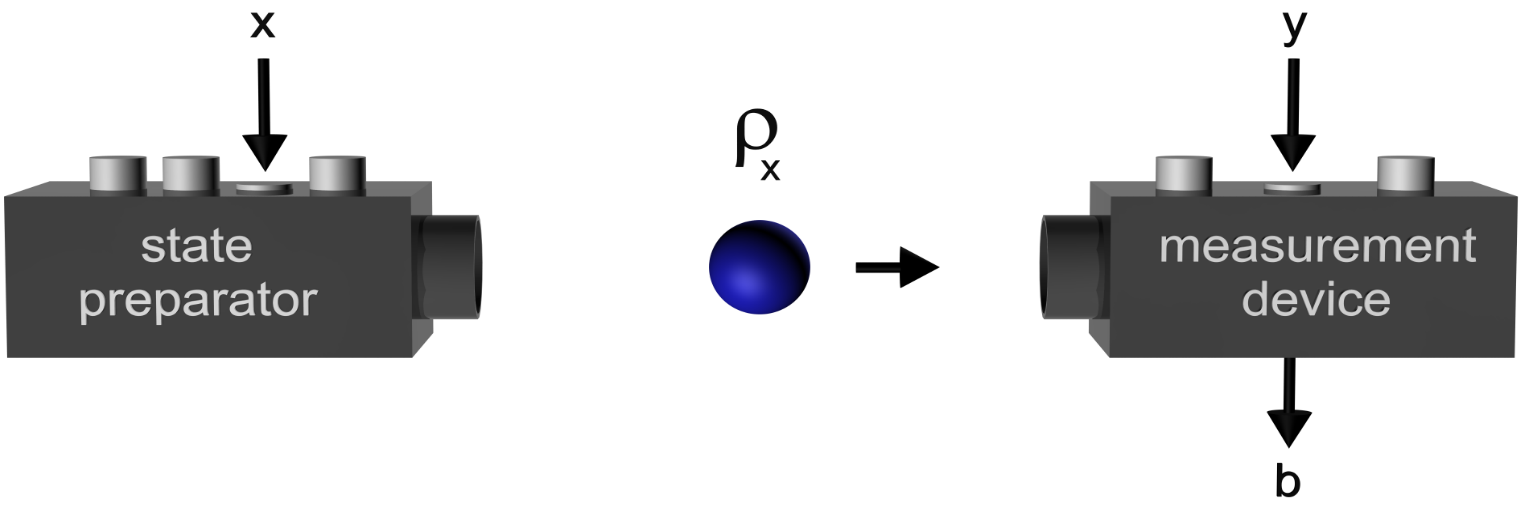
Measuring the dimension



Q: Is it be possible to assess the dimension of a completely unknown system only from the results of measurements performed on it?

A: Yes, but we can establish only lower bounds on the dimension of an unknown system in a device independent way.

Our scenario



- 4 possible preparations (x)
- 3 measurements (y)
- Possible outcomes b=±1

Our scenario

Dimension witness is:

$I_4 \equiv E_{11}+E_{12}+E_{13}+E_{21}+E_{22}-E_{23}+E_{31}-E_{32}-E_{41}$

$E_{xy}=P(b=+1|x,y)-P(b=-1|x,y)$

Classical and quantum bounds for the dimension witness I_4:

	C_2 (bit)	**Q_2 (qubit)**	**C_3 (trit)**	**Q_3 (qutrit)**	**C_4 (quart)**
I_4	5	6	7	7,97	9

Experiment

- Photon pairs are generated in SPDC.
- We use polarization and orbital angular momentum.
- Our orthogonal vectors are:

$$|H,\pm1> \text{ and } |V,\pm1>.$$

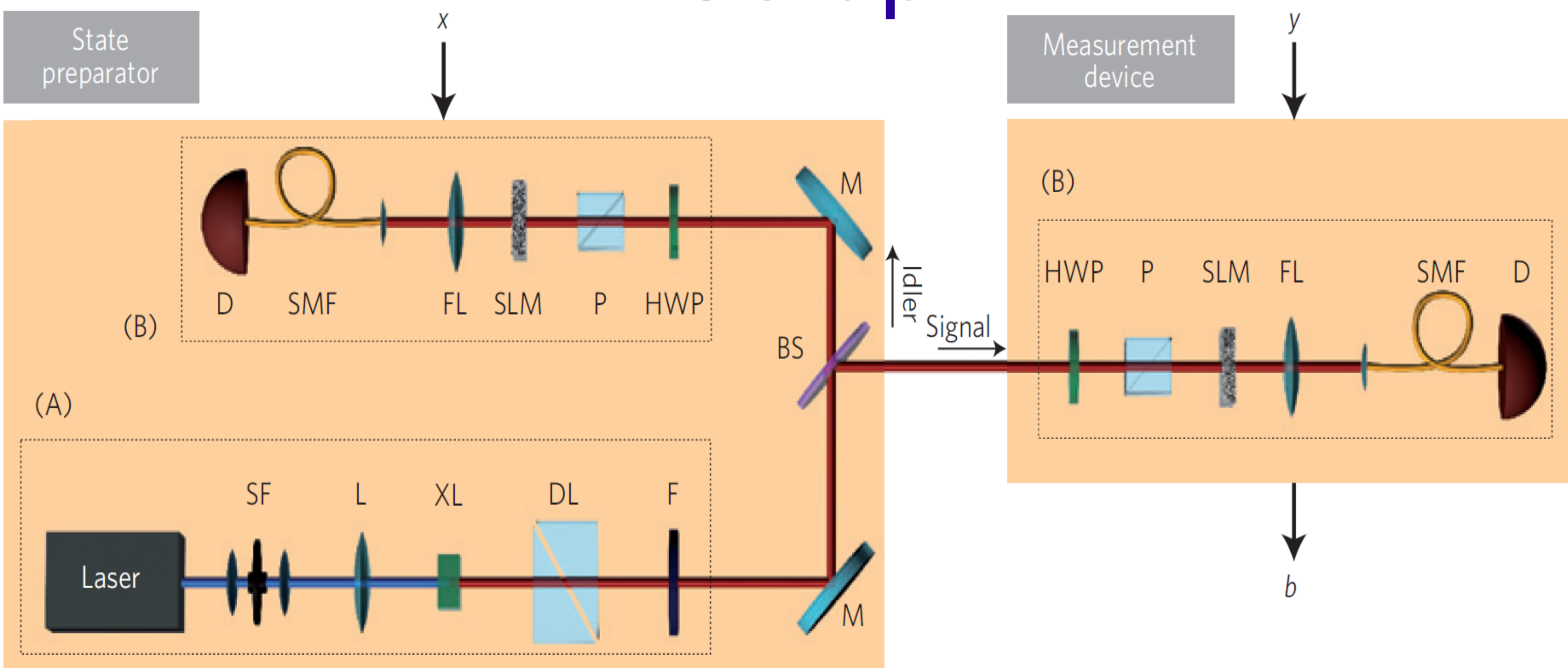
- Our entangled state is:

$$|\Psi^{-}>_{POL} \otimes |\Psi^{-}>_{OAM} ,$$

where $|\Psi^{-}>_{POL}$ =(1/Sqrt[2])($|H>_s|V>_i-|V>_s|H>_i$) and

$|\Psi^{-}>_{AOM}$ =(1/Sqrt[2])($|m=1>_s|m=-1>_i-|m=-1>_s|m=1>_i$)

Setup



Qubit:

$|\phi_1\rangle = \cos\frac{\pi}{8}|H,+1\rangle + \sin\frac{\pi}{8}|V,+1\rangle$

$|\phi_2\rangle = \cos\frac{\pi}{8}|H,+1\rangle - \sin\frac{\pi}{8}|V,+1\rangle$

$|\phi_3\rangle = |H,+1\rangle$

$|\phi_4\rangle = |V,+1\rangle$

Qutrit:

$|\phi_1\rangle = \cos\frac{\pi}{8}|H,+1\rangle + \sin\frac{\pi}{8}|V,+1\rangle$

$|\phi_2\rangle = \cos\frac{\pi}{8}|H,+1\rangle - \sin\frac{\pi}{8}|V,+1\rangle$

$|\phi_3\rangle = |H,-1\rangle$

$|\phi_4\rangle = |V,+1\rangle$

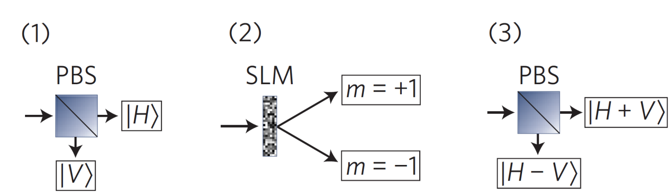
Quart:

$|\phi_1\rangle = |H,+1\rangle$

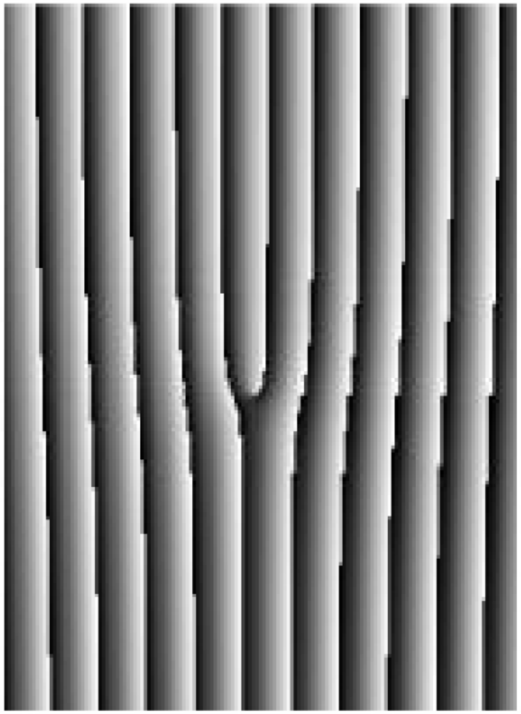
$|\phi_2\rangle = |H,-1\rangle$

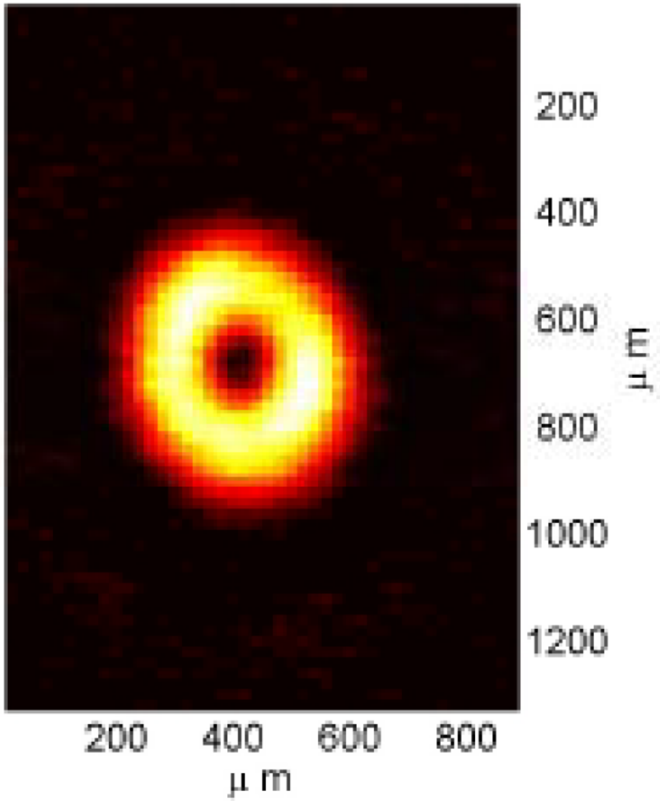
$|\phi_3\rangle = |V,+1\rangle$

$|\phi_4\rangle = |V,-1\rangle$

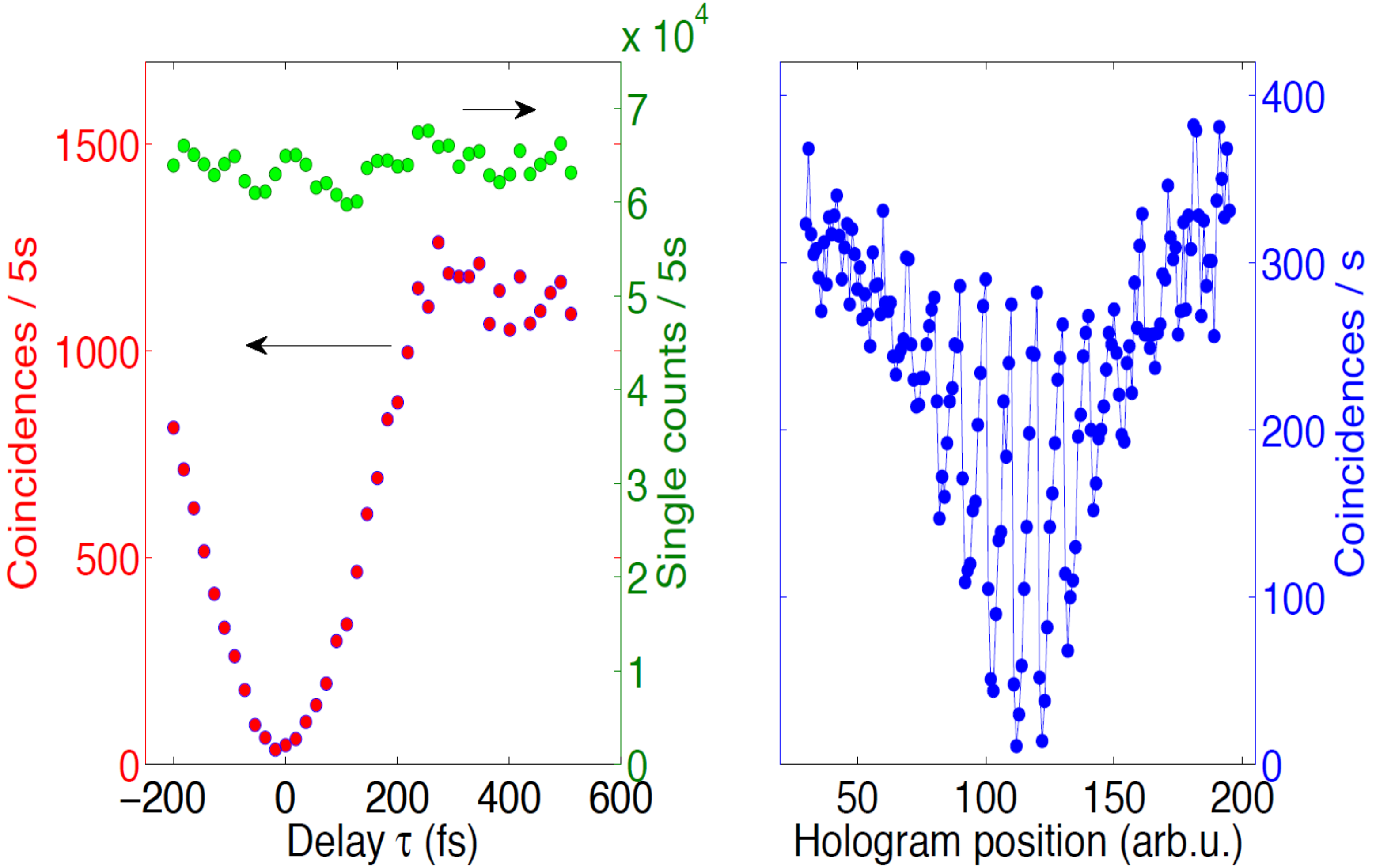


Results



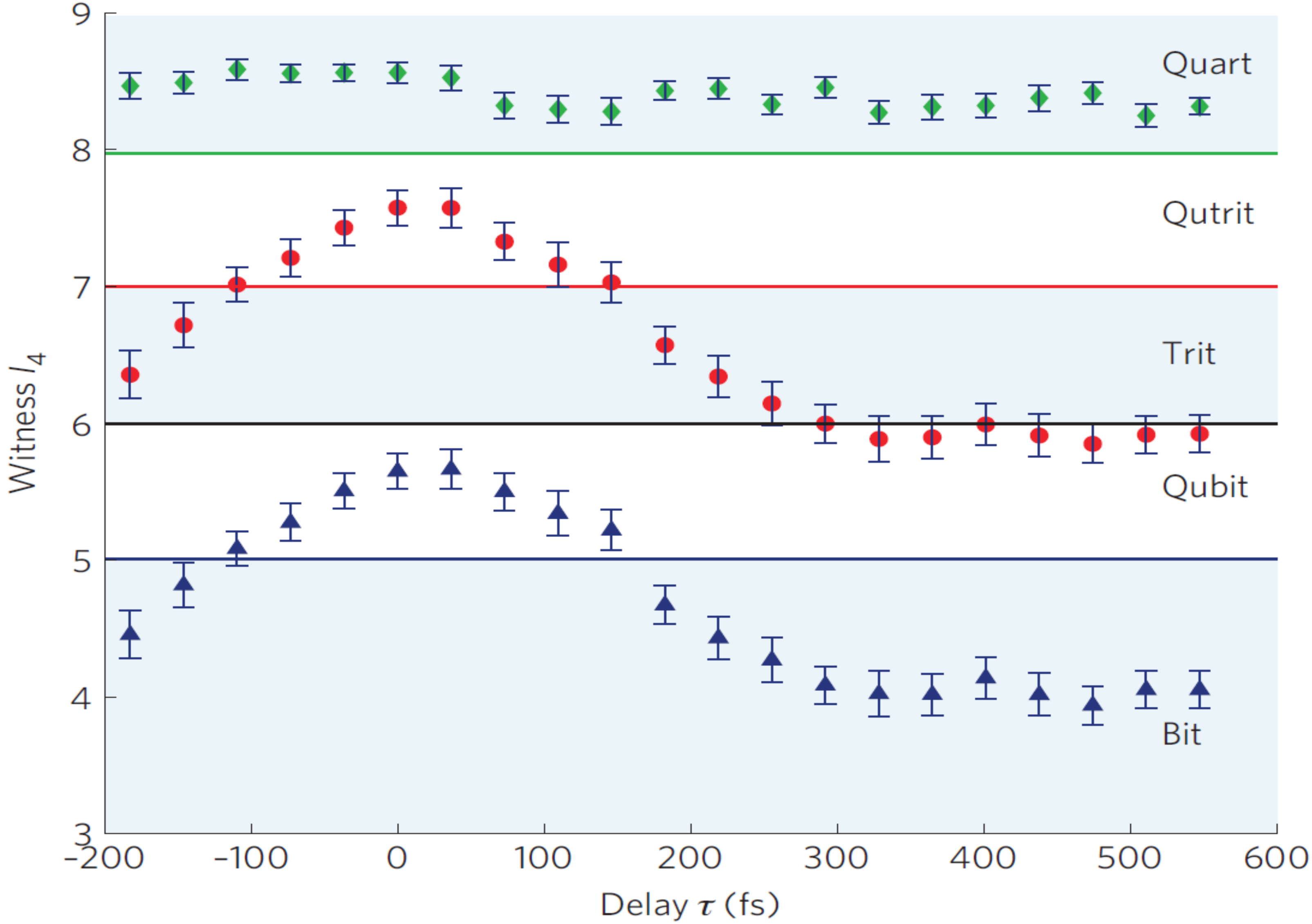


Results



x 10^4
Coincidences / 5s
Single counts / 5s
Delay τ (fs)
0
500
1000
1500
0
1
2
3
4
5
6
7
−200
0
200
400
600
Coincidences / s
Hologram position (arb.u.)
0
100
200
300
400
50
100
150
200

Results



Quart
Qutrit
Trit
Qubit
Bit
Witness I_4
Delay τ (fs)
9
8
7
6
5
4
3
−200
−100
0
100
200
300
400
500
600

Thank you for your attention.