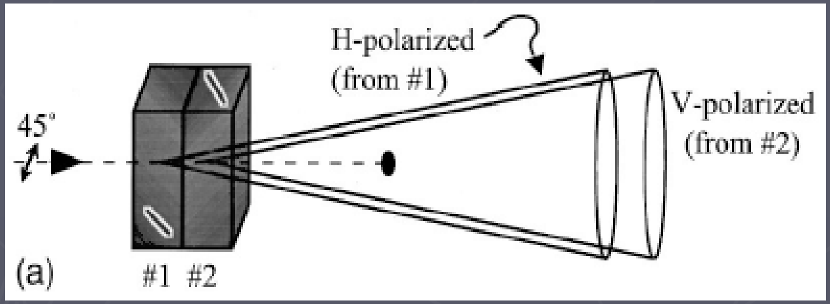
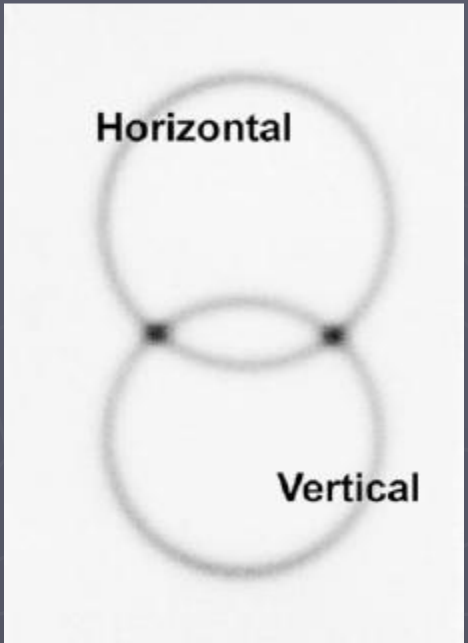
Entanglement on demand

Gershoni, Lindner, Akopian, Berlatzky, Poem

On demand



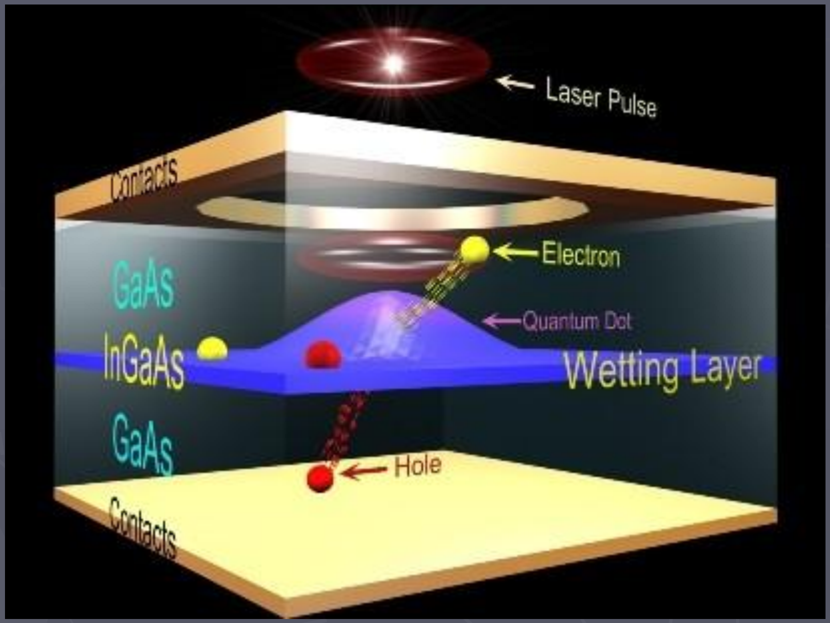


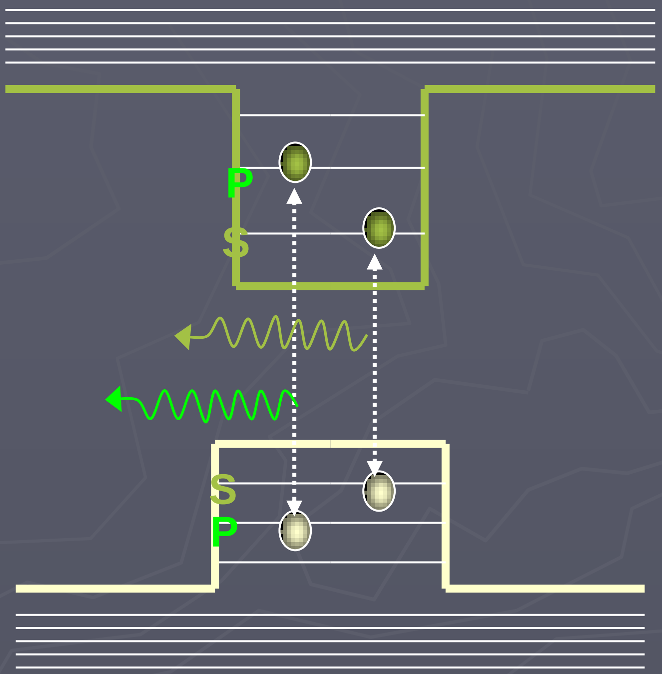
$$|0\rangle \otimes |0\rangle + \varepsilon(\,|V\rangle \otimes |H\rangle + |H\rangle \otimes |V\rangle\,)$$

junk

Entangled piece

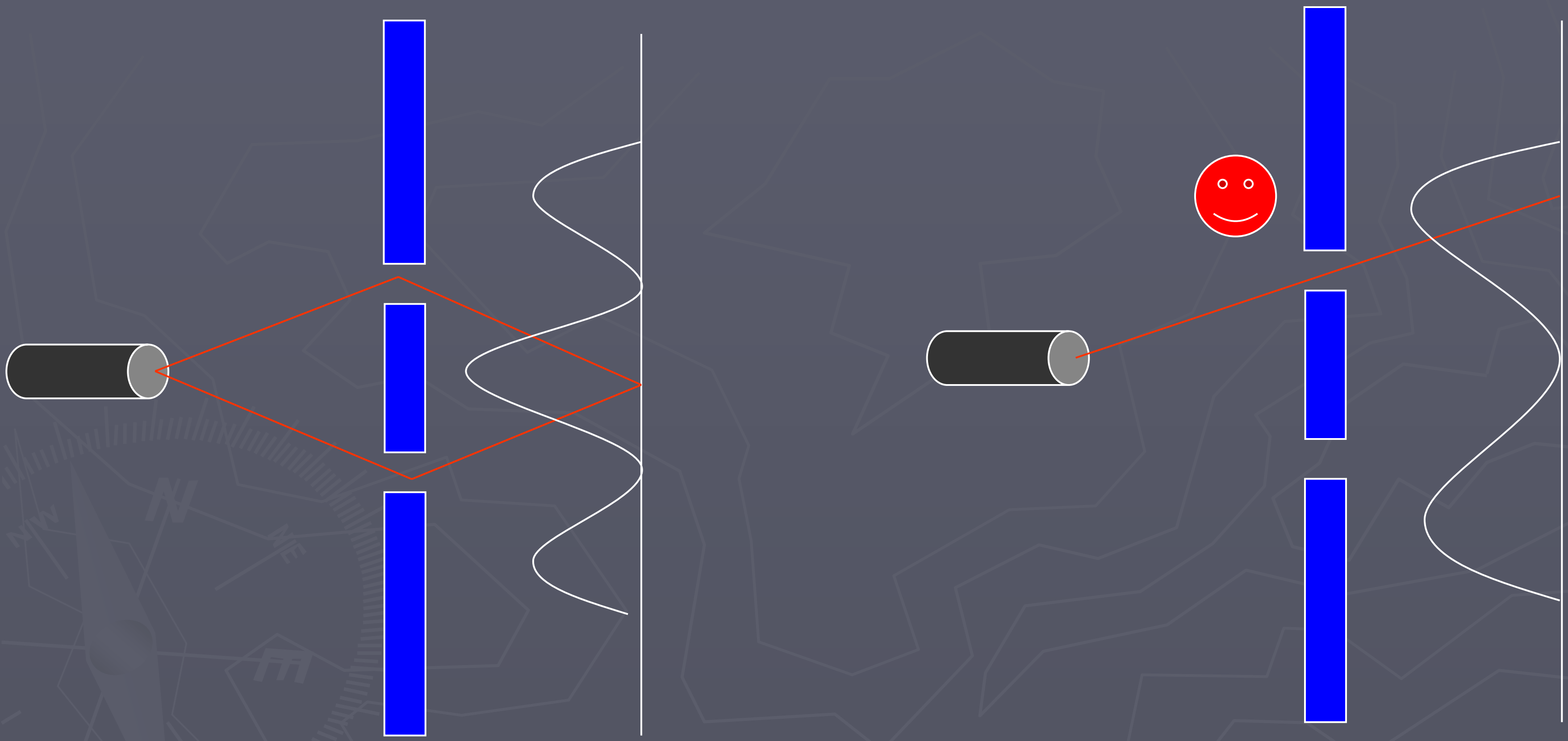
Quantum dots





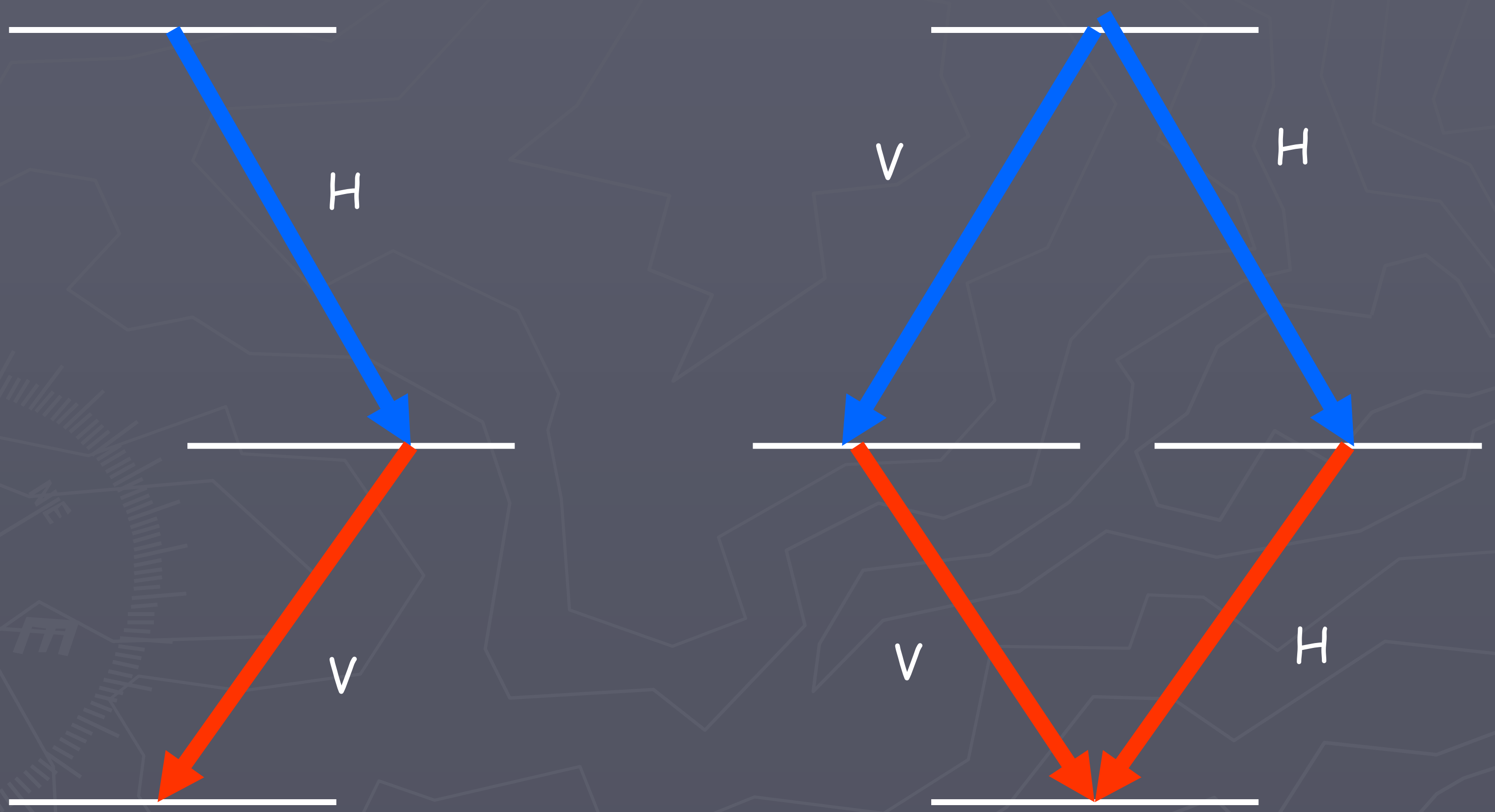
$$|incoming\ photon\rangle \rightarrow |photon\ pair\rangle$$

Which path and interference



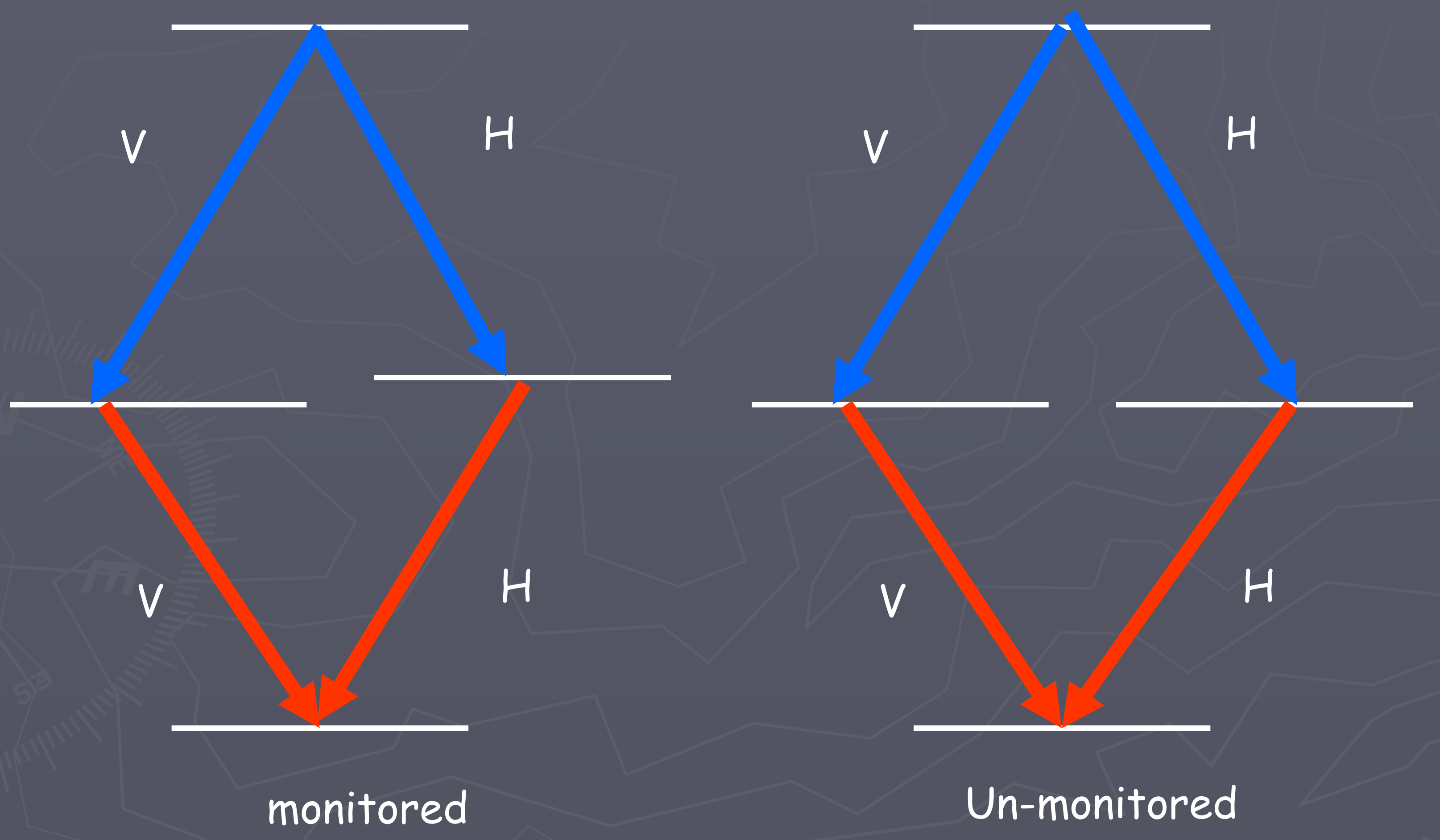
Monitoring the path kills interference

Which path and entanglement

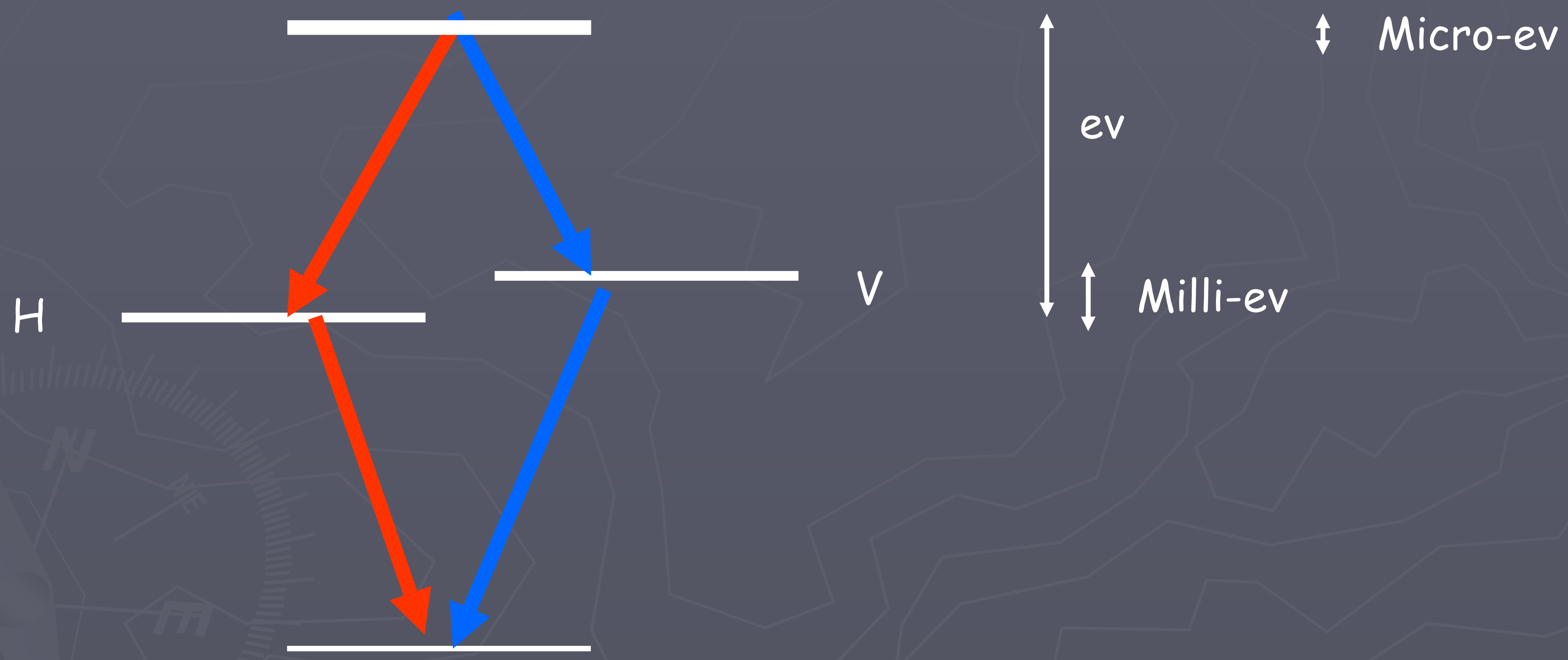


Entanglement: A 2 photon analog of interference

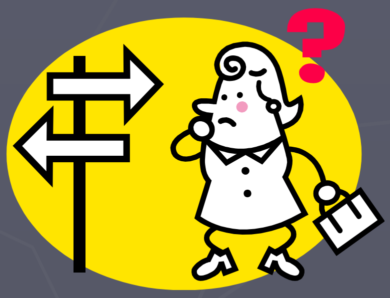
Monitoring a cascade



Scales

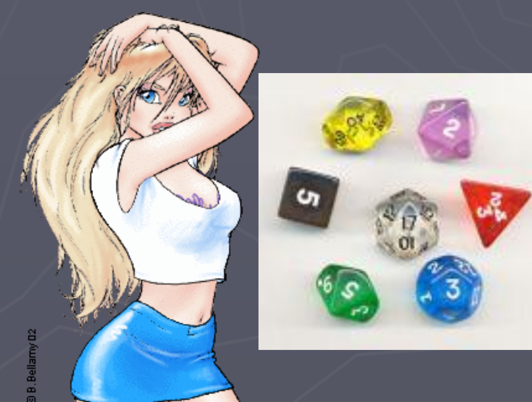


classical correlations



Independence and correlations

independence $$P_{ab}(x,y) = P_a(x)P_b(y)$$



Correlations due to common source

$$P_{ab}(x,y) = \sum_j p_j\, P_a^j(x) P_b^j(y)$$

Separable states

$$\rho_S = \sum p_j \, \rho_j^A \otimes \rho_j^B, \qquad p_j > 0$$

Entangled states= Unseparable

$$\rho = |\psi\rangle \langle\psi|, \qquad |\psi\rangle = \frac{|1\rangle \otimes |0\rangle - |0\rangle \otimes |1\rangle}{\sqrt{2}}$$

Negative probabilities

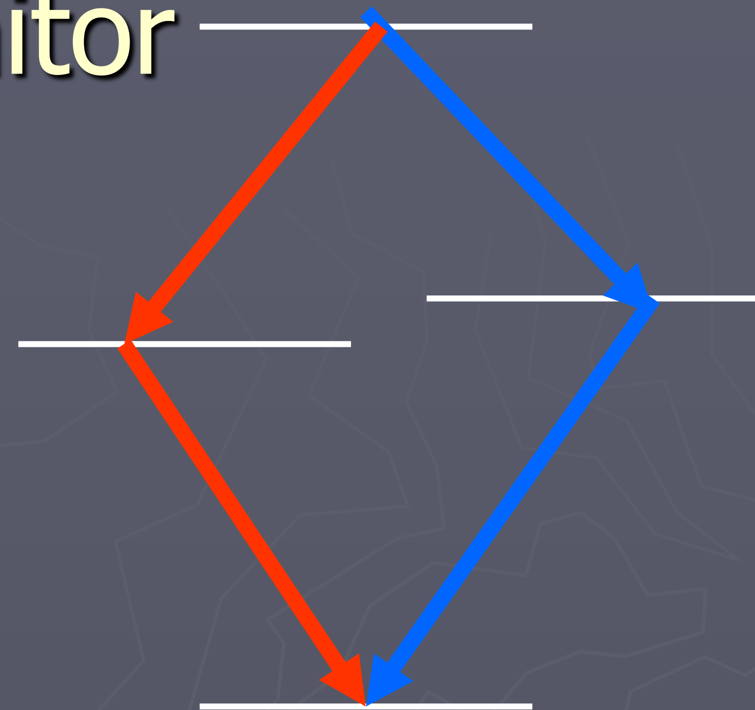
Peres test

$$\rho = \begin{pmatrix} A & B \\ B^* & C \end{pmatrix}, \quad \rho^P = \begin{pmatrix} A & B^* \\ B & C \end{pmatrix}$$

If transform has negative eigenvalue state is entangled

$$\rho = \frac{1}{2}\begin{pmatrix} 0 & 0 & 0 & 0 \\ 0 & 1 & -1 & 0 \\ 0 & -1 & 1 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix} \qquad \rho^P = \frac{1}{2}\begin{pmatrix} 0 & 0 & 0 & -1 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ -1 & 0 & 0 & 0 \end{pmatrix}$$

Color as path monitor



Photons wave packet

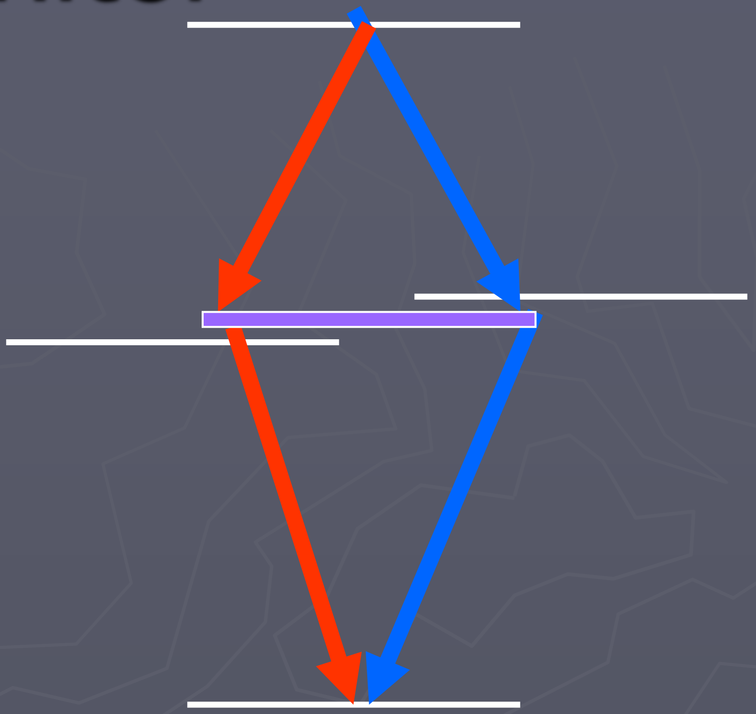
$$|\psi\rangle = \alpha\,|HH\rangle \otimes \overbrace{|p_H\rangle} + \beta\,|VV\rangle \otimes |p_V\rangle$$

$$\rho = \begin{pmatrix} |\alpha|^2 & 0 & 0 & \gamma \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ \gamma & 0 & 0 & |\beta|^2 \end{pmatrix}$$

$$\gamma = \alpha\bar{\beta}\langle p_H|p_V\rangle$$

Monitors of the decay path kill the entanglement

Eliminating the monitor



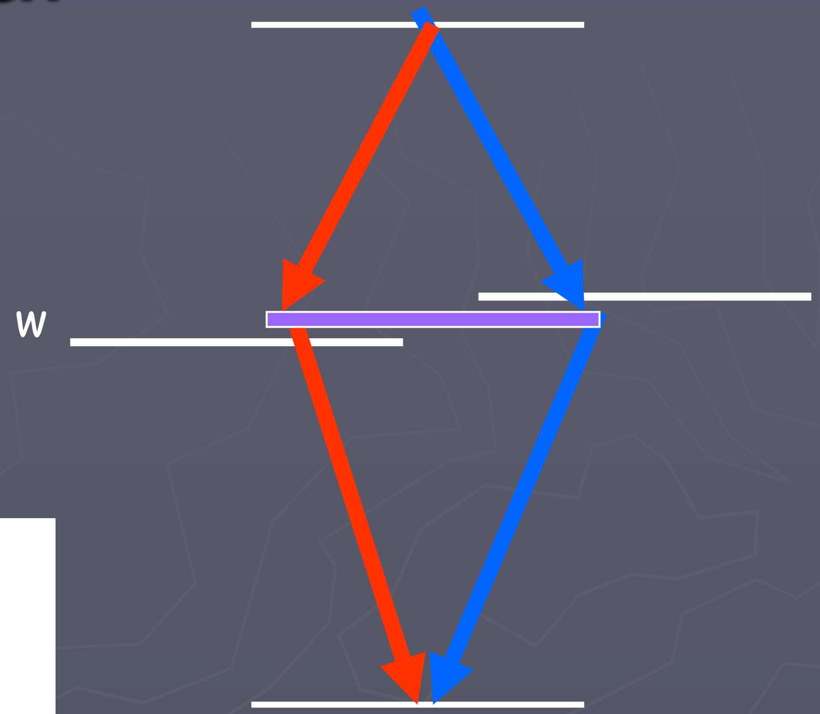
$$|\psi\rangle$$

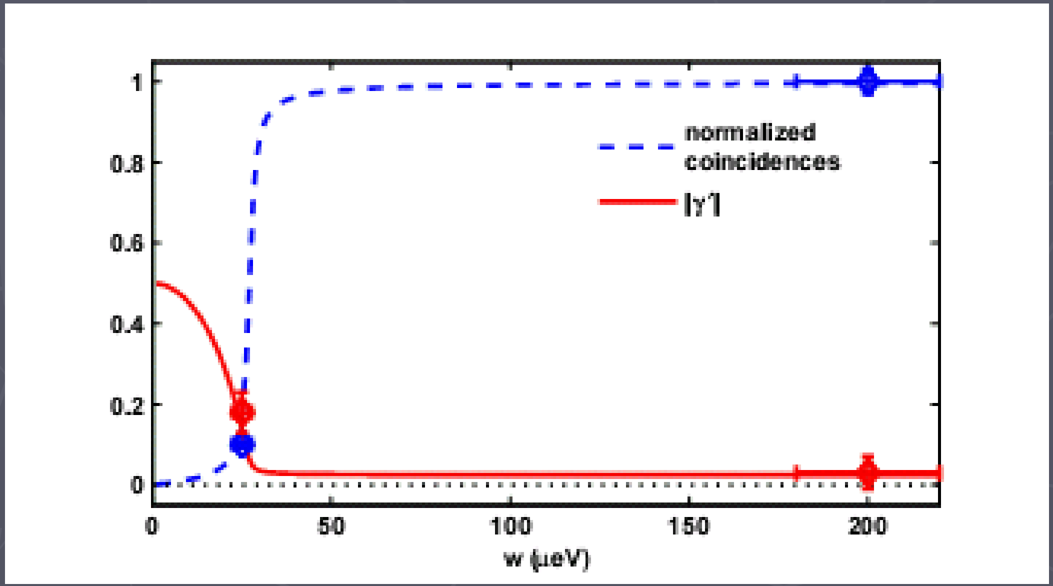
$$\rightarrow \Big(|HH\rangle + |VV\rangle\Big) \otimes |p\rangle$$

$$\rho = \frac{1}{2}\begin{pmatrix} 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 1 \end{pmatrix}$$

Entanglement at a price

Fat is beautiful

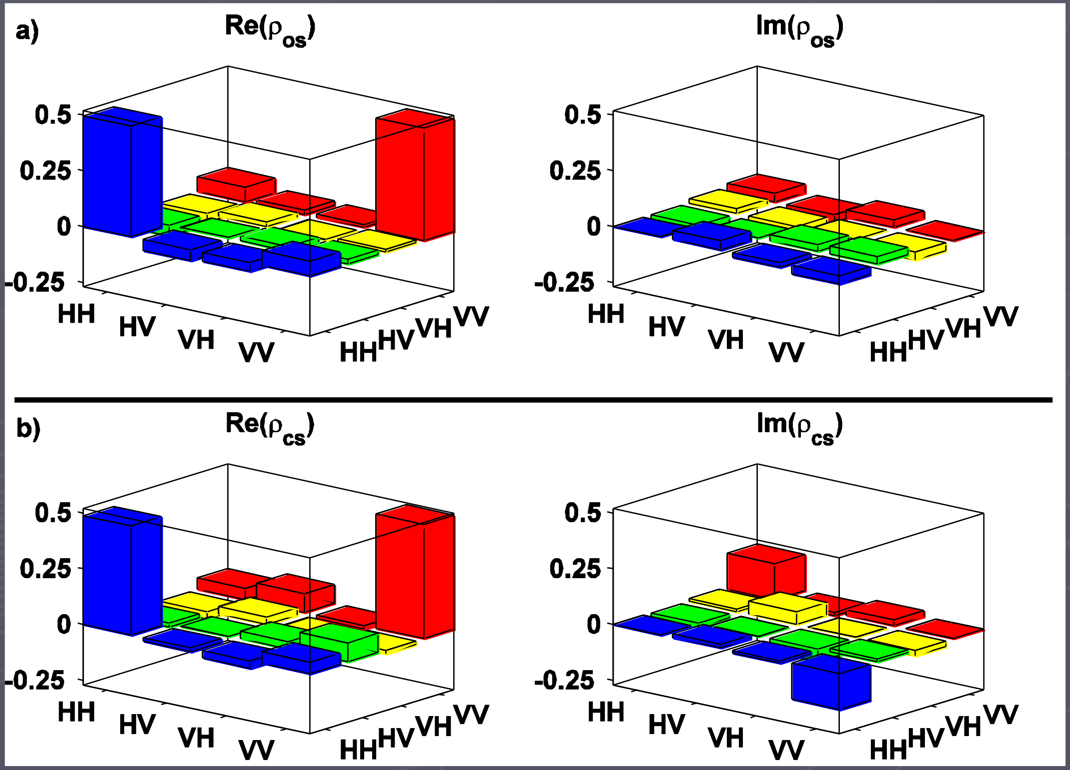




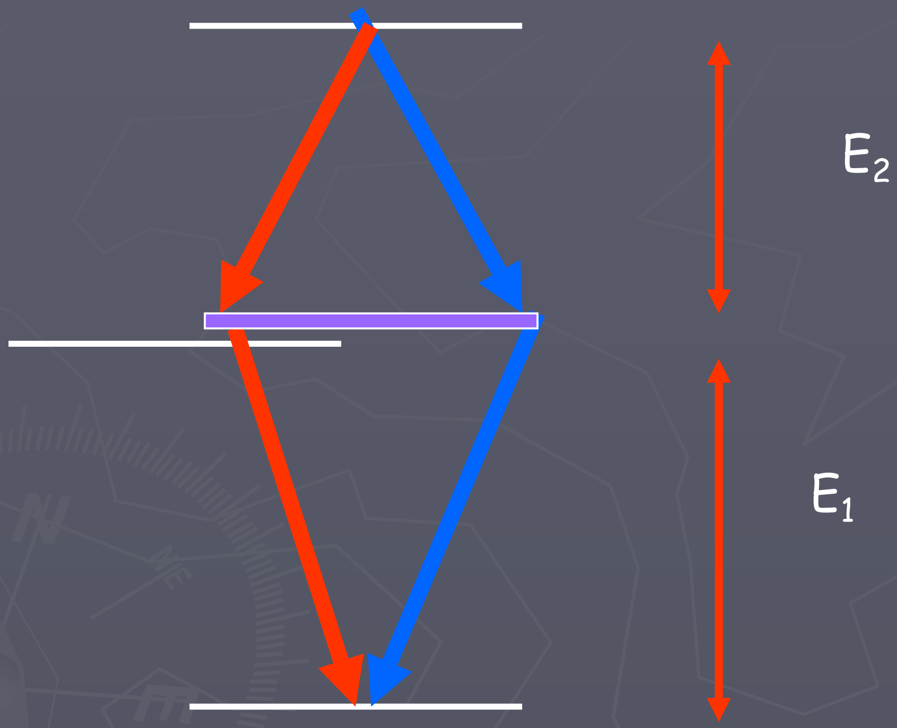
Tomography

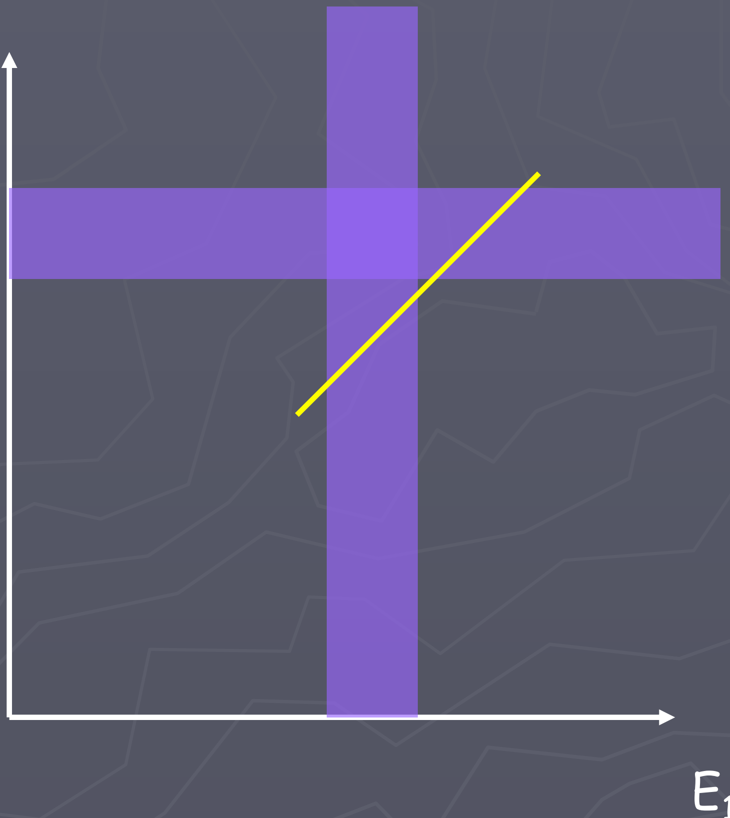
With monitor

Without monitor

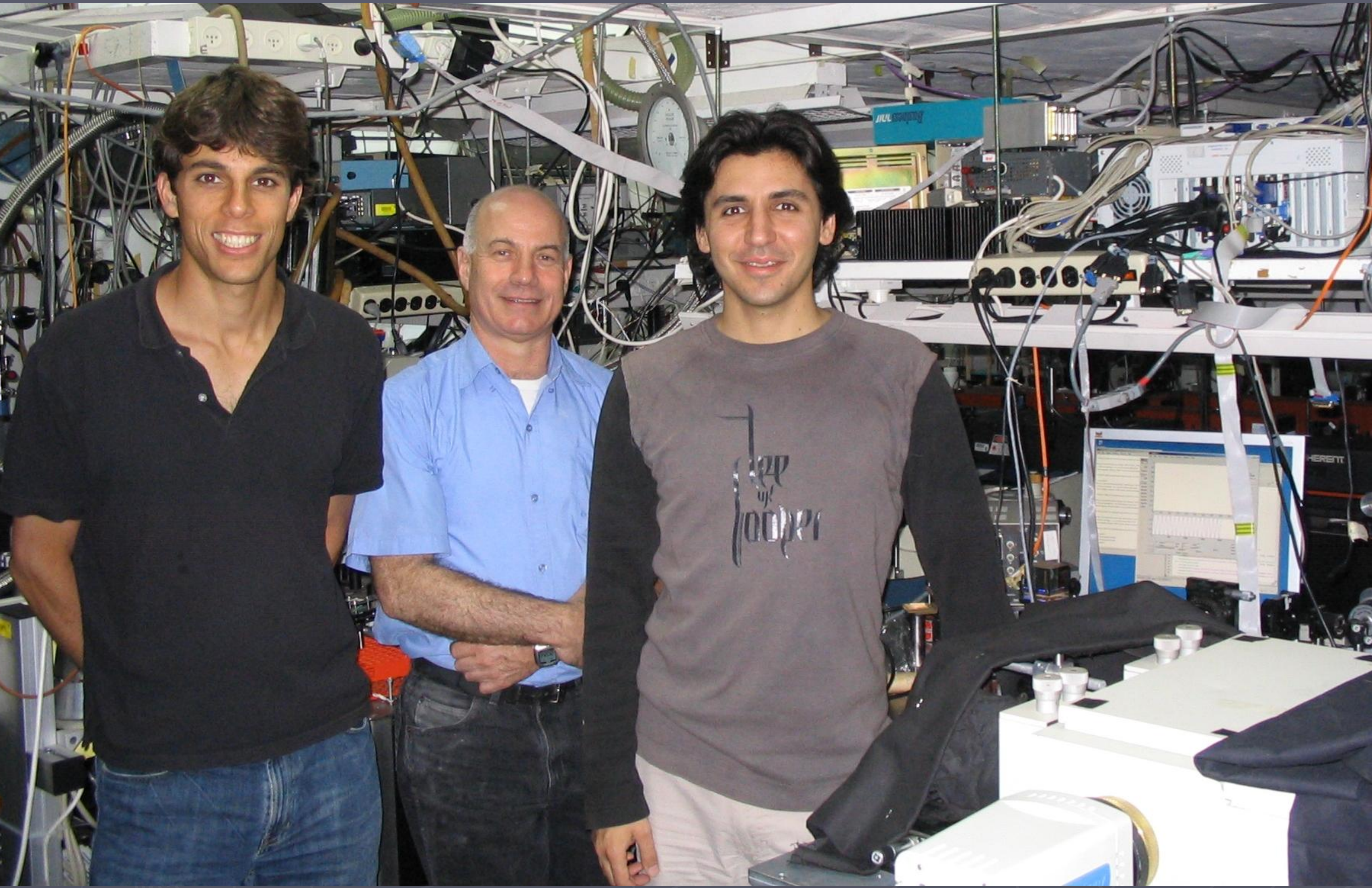


Serendipity





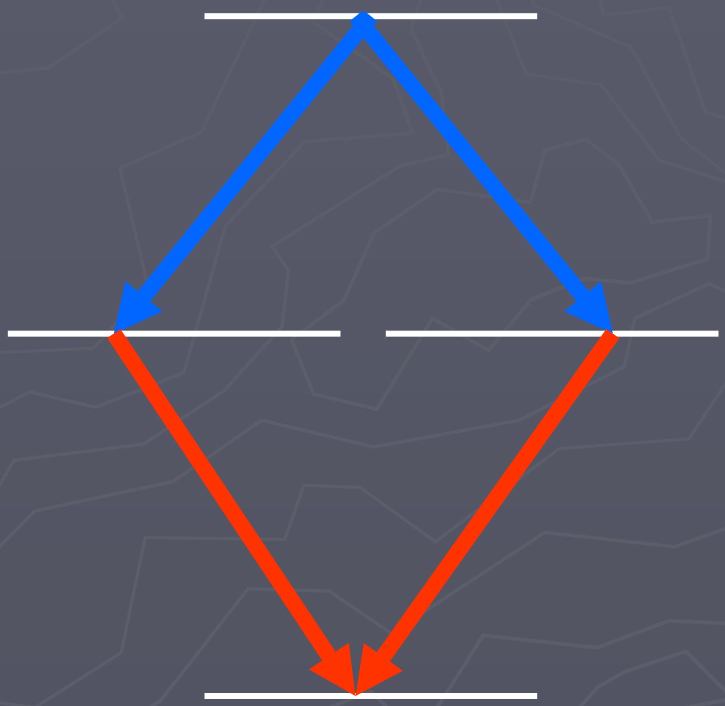
The levels meander together with fixed splitting



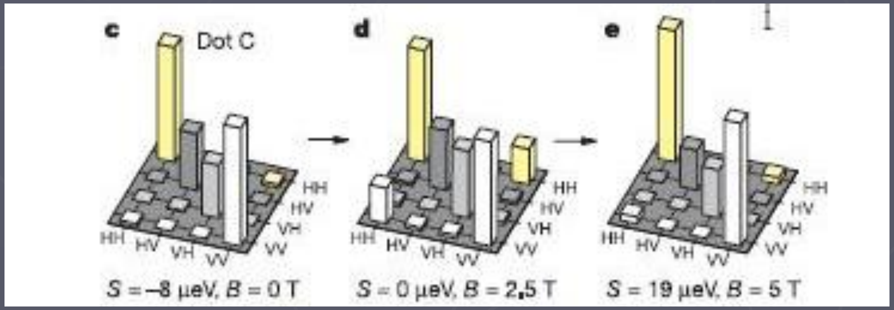
Grad students Netanel Lindner and Nika Akopian with Prof. Dudi Gershoni

Toshiba experiment

Forced degeneracy by annealing
And magnetic fields



Is degeneracy sufficient?



split

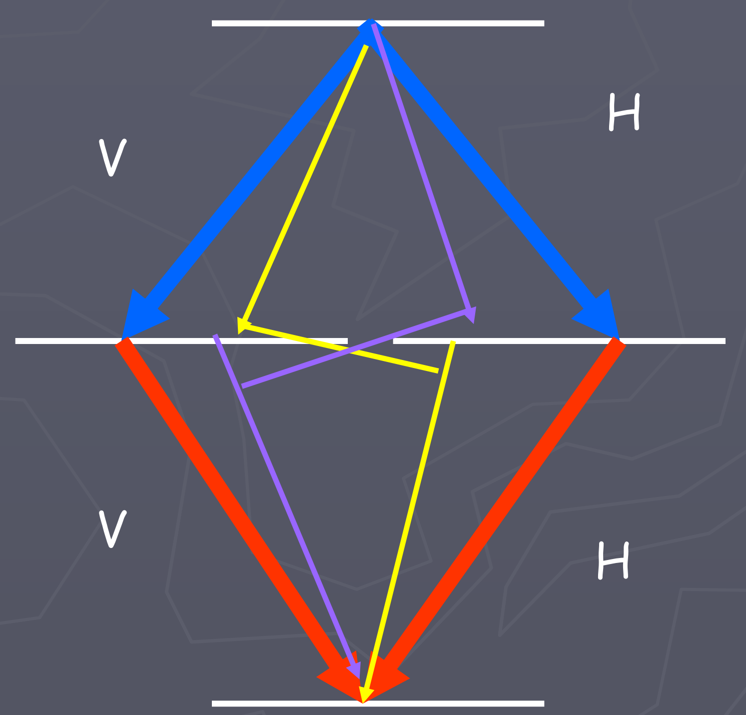
degenerate

split

Shields et. al. Nature 439 (2006)

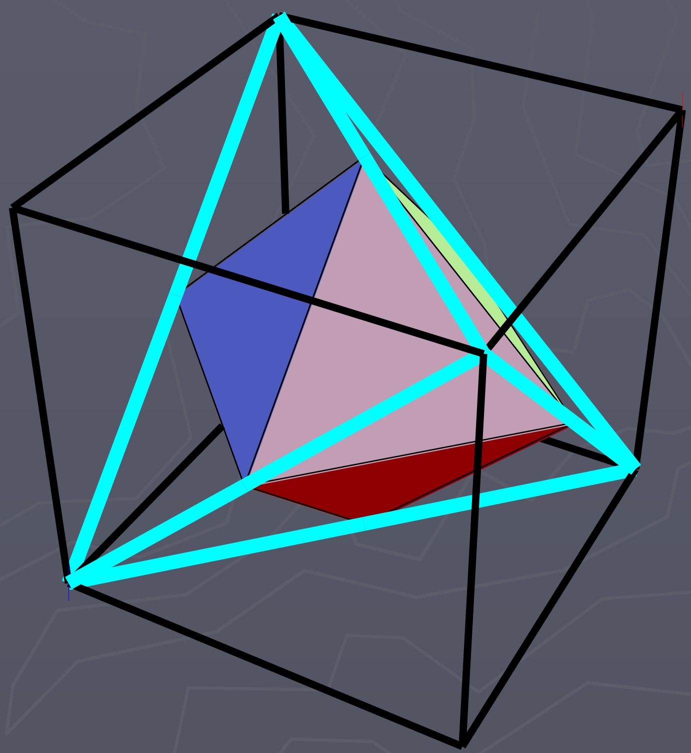
Separable by Peres test

What went wrong



2 qubits Peres is iff

Octahedron=separable
Tetrahedron=all states
Cube= witnesses
Peres=reflection



Leinaas Myrheim Uvrom, Kenneth Avron

Local Operations

$$\text{dim}\rho = 15$$

$$\rho \to (U_a \otimes U_b)\,\rho\,(U_a^\dagger \otimes U_b^\dagger)$$

$$U \in SU(2) \qquad dim(U_a \otimes U_b) = 9$$

$$U \in SL(2,C) \qquad dim(U_a \otimes U_b) = 12$$

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