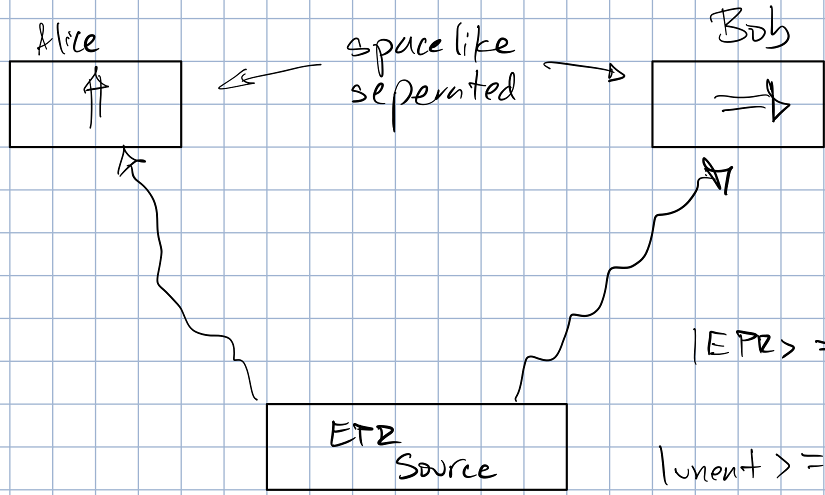
lot of wrong tings

tensor product vector space

2 detectors



$|EPR\rangle = \frac{1}{\sqrt{2}}\left(|R\rangle_A \otimes |L\rangle_B + |L\rangle_A \otimes |R\rangle_B \right)$

$|unent\rangle = |R\rangle_A \otimes |R\rangle_B$

eigenvalues

Alice & Bob can measure

$\sigma_3 = \begin{matrix} +1 & \hat{e}_x & \text{lin pol.} \\ -1 & \hat{e}_y & \text{lin. pol.} \end{matrix}$

$\sigma_2 = \begin{matrix} +1 & \text{RHCP} \\ -1 & \text{LHCP} \end{matrix}$

$\sigma_1 = \begin{matrix} +1 & 45^\circ \text{ wrt. x axis} \\ -1 & -45^\circ \;" \;\; " \end{matrix}$

we can't obtain definite answer for any pair of σ_i b/c $[\sigma_i, \sigma_j] \neq 0$ for $i \neq j$

You can simultaneously diagonalize 2 Hermitian matrices A & B iff $[A, B] = 0$
→ mutual eigenvalue

$[\sigma_2, \sigma_3] = i\,\sigma_1$

Alice has a photon $|R\rangle = \frac{1}{\sqrt{2}}\left(|\hat{x}\rangle + i\,|\hat{y}\rangle \right)$

if she measures $\sigma_2 \begin{pmatrix} +1 & R \\ -1 & L \end{pmatrix}$, gets $+1$ every time. Now in this state

now measure $\sigma_3 \begin{pmatrix} +1 & |\hat{x}\rangle \\ -1 & |\hat{y}\rangle \end{pmatrix}$, gets $\begin{matrix} +1 & 50\% \\ -1 & 50\% \end{matrix}$

Alice & Bob measure $\sigma_2(R, L)$ or $\sigma_3(\hat{e}_x, \hat{e}_y)$ for photons $|EPR\rangle$ or $|\text{unent}\rangle$

start w/ $|\text{unent}\rangle = |R\rangle_A \otimes |R\rangle_B$

Alice measures σ_2 she gets $+1$ every time
Bob " " " -1 " "

Alice measures σ_3 she gets $\frac{1}{2}(|\hat{x}\rangle_A + i|\hat{y}\rangle_A) \otimes (|\hat{x}\rangle_B + i|\hat{y}\rangle_B)$

$$- \frac{1}{2}\left(|\hat{x}\rangle_A |\hat{x}\rangle_B + i|\hat{y}\rangle_A |\hat{x}\rangle_B + i|\hat{x}\rangle_A |\hat{y}\rangle_B - |\hat{y}\rangle_A |\hat{y}\rangle_B\right)$$

$+1$ prob $= 2 \times \frac{1}{4} = \frac{1}{2}$

if she gets $+1$ for σ_2, state

$|\ \rangle_A$ now $@ |\hat{x}\rangle_A$

$$\frac{1}{\sqrt{2}}\left(|\hat{x}\rangle_A \otimes |\hat{x}_B\rangle + i|\hat{x}\rangle_A \otimes |\hat{y}\rangle_B\right)$$

Bob gets $+1$ 50% -1 50%

Alice can predict Bob's measurement of σ_2 exactly, but no idea for σ_3

Bob's photon being R or L is element of physical reality
" " " $\hat{e}_x$ or $\hat{e}_y$ is not " " "

Now start w/ epr $|EPR\rangle = \frac{1}{\sqrt{2}}(|R\rangle_A \otimes |L\rangle_B + |L\rangle_A \otimes |R\rangle_B)$

Alice measures $\sigma_2 (R, L)$ she gets R w/prob 50% $\frac{1}{2}$
" " L " "

suppose she got $|R\rangle$, new state $\rightarrow$ $|R\rangle_A \otimes |L\rangle_B$

now, Bob always gets -1 for σ_2 (left)
if she got L, he gets 1

for $|EPR\rangle$, R or L is element of Bob's physical reality

Lets have Alice & Bob measure σ_3 $(\hat{e}_x, \hat{e}_y)$

$$|EPR\rangle = \frac{1}{\sqrt{2}}\Big(\underbrace{\left(\tfrac{1}{\sqrt{2}}(|\hat{x}\rangle_A + i|\hat{y}\rangle_A)\right)}^{|R\rangle_A} \otimes \overbrace{\left(\tfrac{1}{\sqrt{2}}(|\hat{x}\rangle_B - i|y\rangle_B)\right)}^{|L\rangle_B}$$

FOIL

$$+ \frac{1}{\sqrt{2}}\Big(\overbrace{\left(\tfrac{1}{\sqrt{2}}(|\hat{x}\rangle_A - i|\hat{y}\rangle_A)\right)}^{|L\rangle_A} \otimes \overbrace{\left(\tfrac{1}{\sqrt{2}}(|\hat{x}\rangle_B + i|y\rangle_B)\right)}^{|R\rangle_B}\Big)$$

$$= \frac{1}{\sqrt{2}}\Big(\frac{1}{2}\big(|\hat{x}\rangle_A \otimes |\hat{x}\rangle_B + \cancel{|\hat{x}\rangle_A \otimes -i|\hat{y}\rangle_B} + \cancel{i|\hat{y}\rangle_A \otimes |\hat{x}\rangle_B} + |\hat{y}\rangle_A |\hat{y}\rangle_B\big)$$

$$+ \frac{1}{2}\big(|\hat{x}\rangle_A \otimes |\hat{x}\rangle_B + \cancel{|\hat{x}\rangle_A \otimes i|\hat{y}\rangle_B} - \cancel{i|\hat{y}\rangle_A \otimes |\hat{x}\rangle_B} + |\hat{y}\rangle_A |\hat{y}\rangle_B\big)\Big)$$

$$= \frac{1}{\sqrt{2}}\Big(\frac{1}{2}\big(|\hat{x}\rangle_A \otimes |\hat{x}\rangle_B + |\hat{y}\rangle_A \otimes |\hat{y}\rangle_B\big)$$

$$+ \frac{1}{2}\big(|\hat{x}\rangle_A \otimes |\hat{x}\rangle_B + |\hat{y}\rangle_A \otimes |\hat{y}\rangle_B\big)\Big)$$

$$= \frac{1}{\sqrt{2}}\left(|\hat{x}\rangle_A \otimes |\hat{x}\rangle_B + |\hat{y}\rangle_A \otimes |\hat{y}\rangle_B \right)$$

if Alice measure $\sigma_3 = +1$ (pol. $|\hat{x}\rangle$) she can predict Bob measures same $+1$ ($|\hat{x}\rangle$ pol.)

same for -1

polarization along $\hat{e}_x, \hat{e}_y$ is also an element of physical reality for $|EPR\rangle$

wait, they don't commute, so can't simultaneously measure

Alice can decide what is Bob's element of physical reality

EPR: QM is incomplete