Entanglement

сцепленность
перепутанность

$\alpha|\text{лев}\rangle + \beta|\text{прав}\rangle$

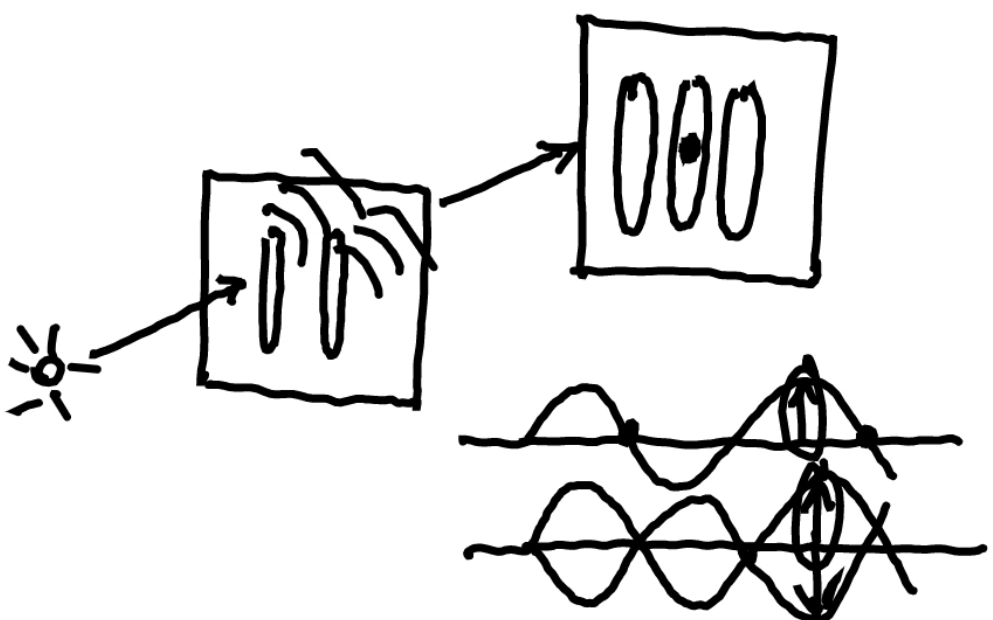
$\alpha|\text{орел}\rangle + \beta|\text{решка}\rangle$

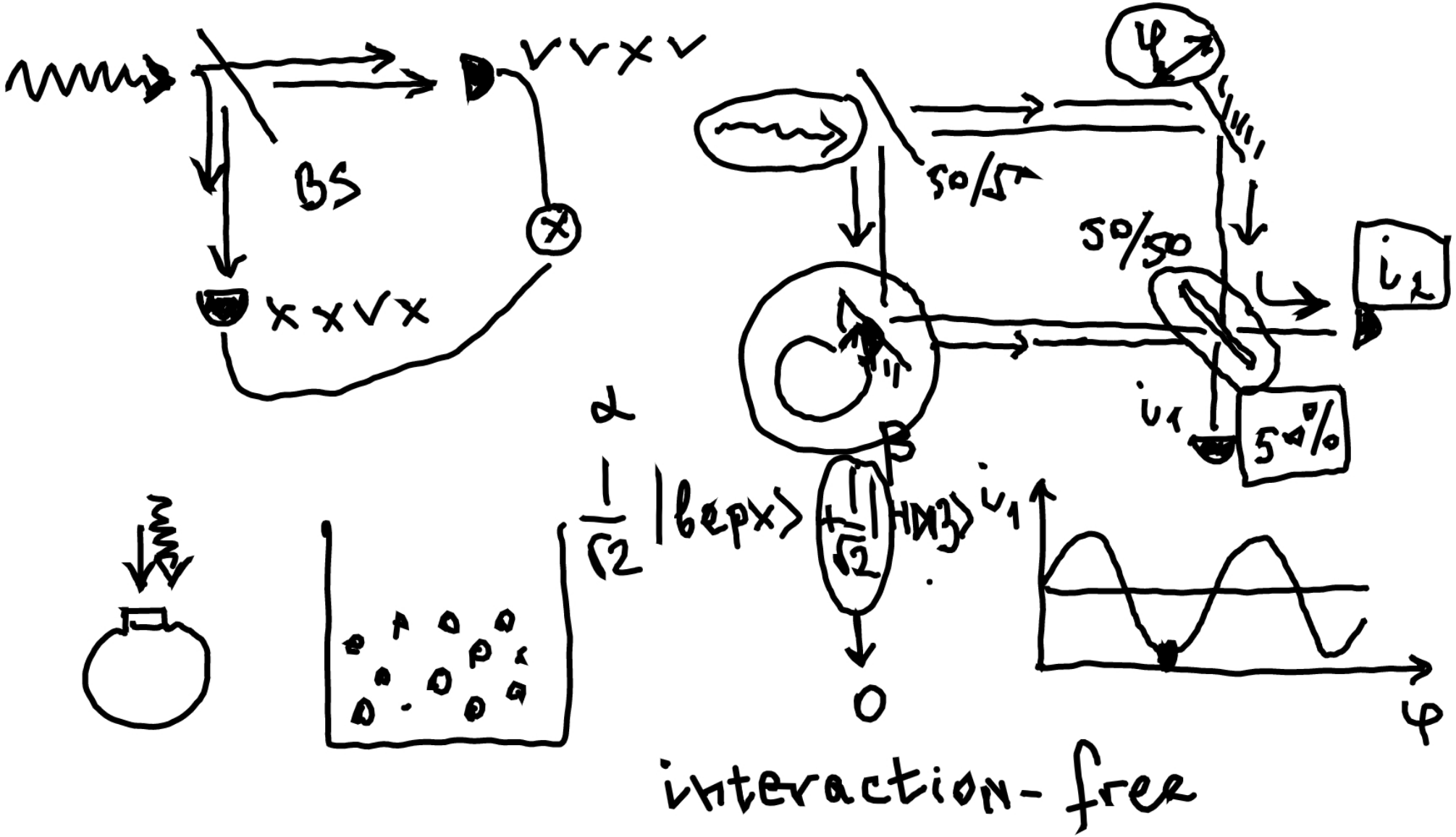
$\alpha, \beta \in \mathbb{C}$

$|\alpha|^2$ – вер-ть "орел"

$|\beta|^2$ – вер-ть "решка"

$|\alpha|^2 + |\beta|^2 = 1$

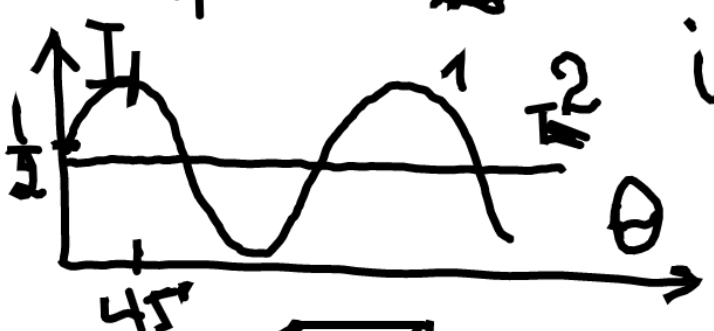


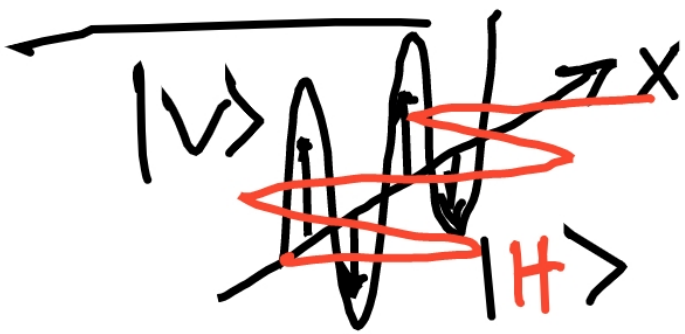

BS
50/50
50/50
i_2
i_1
54%
α
$\frac{1}{\sqrt{2}}|bepx\rangle + \frac{1}{\sqrt{2}}|HM3\rangle$
i_1
0
φ
interaction-free

$|\alpha| e^{i\varphi_\alpha} |H\rangle + |\beta| e^{i\varphi_\beta} |V\rangle$

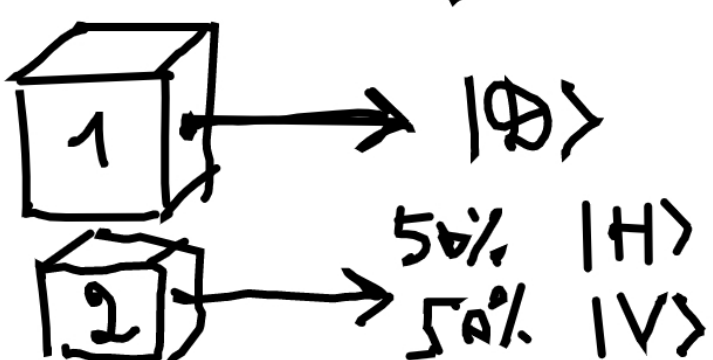
$e^{i\varphi}$

i_1 – темный





$\alpha |H\rangle + \beta |V\rangle$



$|D\rangle = \frac{1}{\sqrt{2}} |H\rangle + \frac{1}{\sqrt{2}} |V\rangle \quad e^{i\varphi}$

$|A\rangle = \dots -$

1 монета: $|\text{орел}\rangle$ $|\text{решка}\rangle$

$\alpha|0\rangle + \beta|1\rangle$

2 монеты: $\alpha|0,0\rangle+\beta|0,1\rangle+\gamma|1,0\rangle+\delta|1,1\rangle$

$\alpha,\beta,\gamma,\delta \in \mathbb{C}$ $|\alpha|^2+|\beta|^2+|\gamma|^2+|\delta|^2=1$

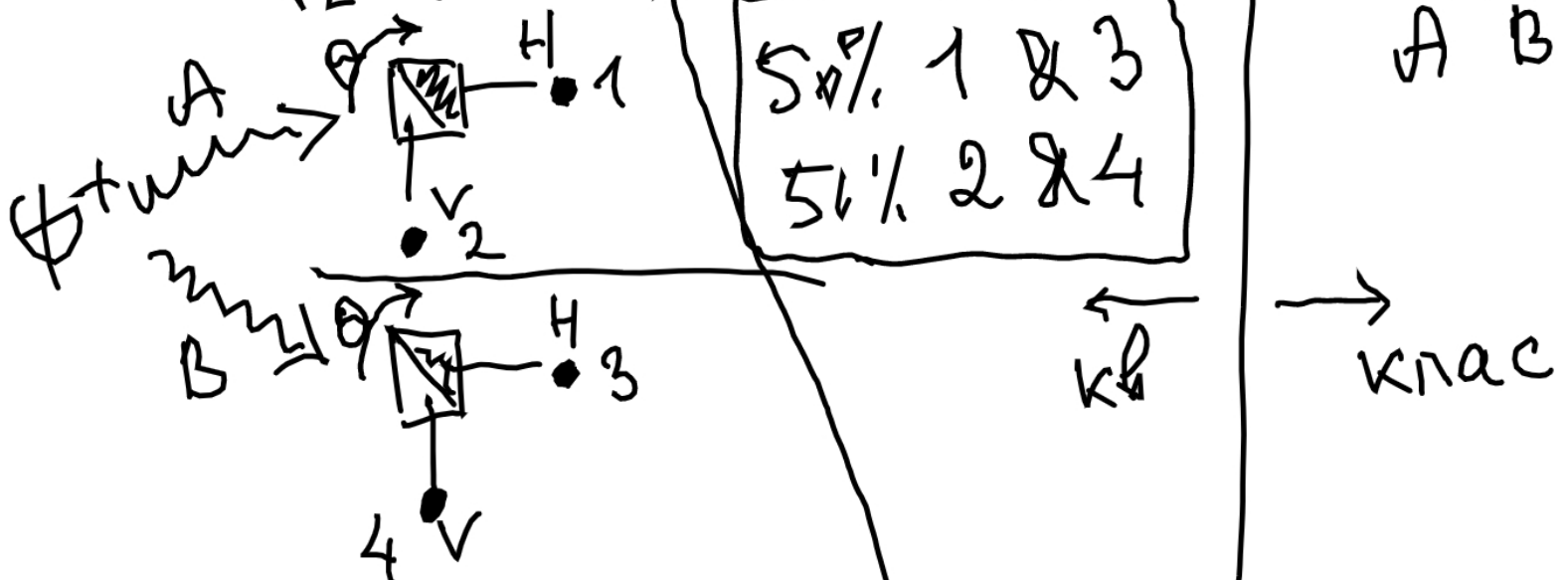
$|H,H\rangle_{AB}$ $|H\rangle_A \otimes |H\rangle_B$ $|HH\rangle$

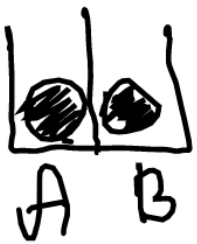
Сост-ния Бэлла Bell states

$|\Phi^{\pm}\rangle = \frac{1}{\sqrt{2}}(|HH\rangle \pm |VV\rangle)$ $|\Psi^{\pm}\rangle = \frac{1}{\sqrt{2}}(|HV\rangle \pm |VH\rangle)$

$\langle \Phi^+ | \Phi^- \rangle = 0$ $\langle \Phi^+ | \Psi^+ \rangle = 0$

$$|\Phi^+\rangle = \frac{1}{\sqrt{2}}\left(|HH\rangle + |VV\rangle\right)$$





$$|D\rangle = \frac{1}{\sqrt{2}}\left(|H\rangle + |V\rangle\right)$$
$$|A\rangle = \frac{1}{\sqrt{2}}\left(|H\rangle - |V\rangle\right)$$

$$|H\rangle = \frac{1}{\sqrt{2}}\left(|D\rangle + |A\rangle\right)$$
$$|V\rangle = \frac{1}{\sqrt{2}}\left(|D\rangle - |A\rangle\right)$$

$$|\Phi^+\rangle = (D+A)(D+A) + (D-A)(D-A) = DD + AA$$

$$|\Psi^-\rangle = \frac{1}{\sqrt{2}}\left(|HV\rangle - |VH\rangle\right) = \frac{1}{\sqrt{2}}\left(|\alpha\rangle|\tilde{\alpha}\rangle - |\tilde{\alpha}\rangle|\alpha\rangle\right)$$

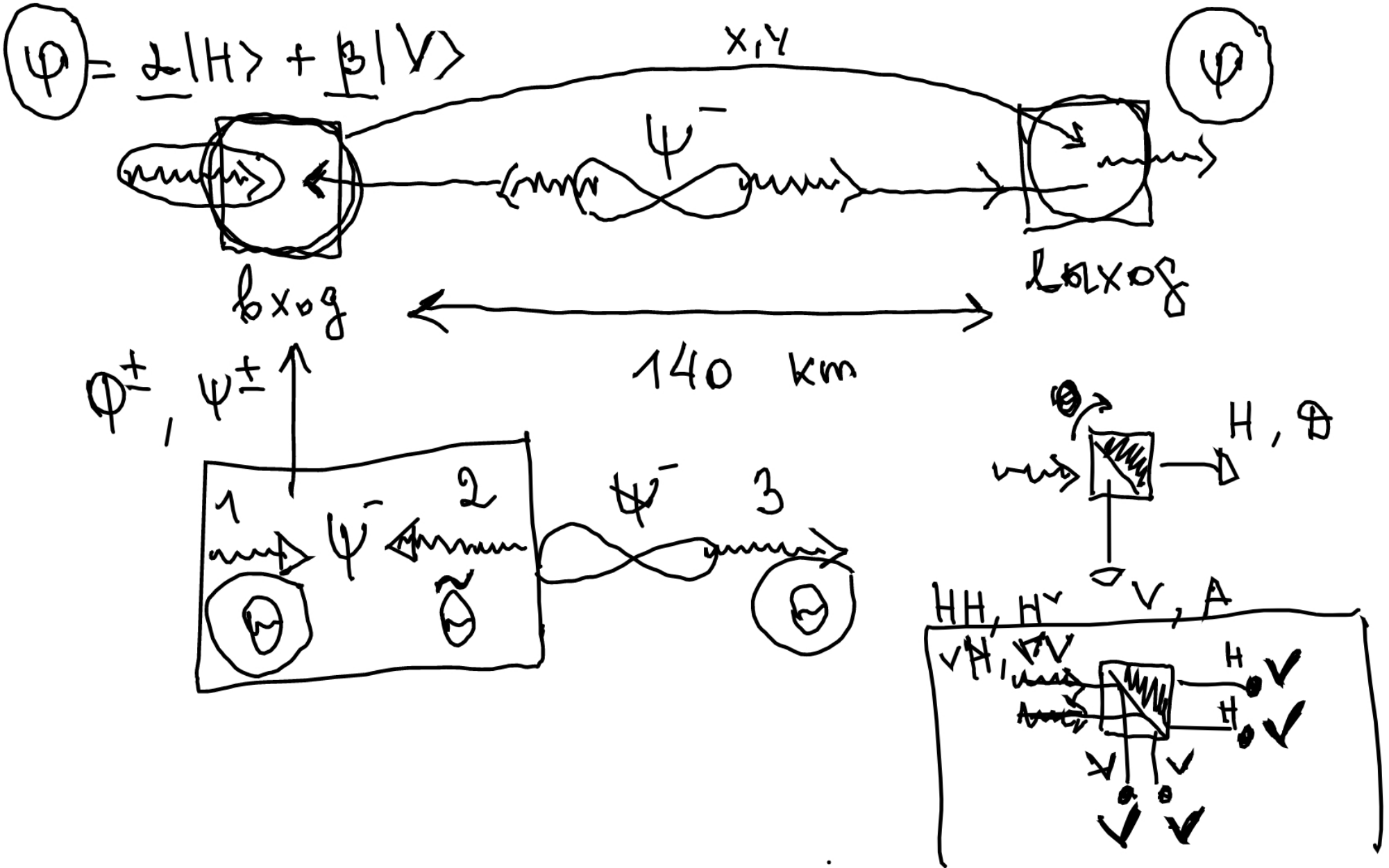
$|\theta\rangle|\theta+\frac{\pi}{2}\rangle$ $\quad$ $|\theta+\frac{\pi}{2}\rangle|\theta\rangle$

Φ/3

	H/V	D/A	R/L	
Φ^+	+	+		
Φ^-				
Ψ^+				
Ψ^-	−	−	−	

$$|R\rangle = \frac{1}{\sqrt{2}}\left(|H\rangle + e^{\pm i\frac{\pi}{2}}|V\rangle\right)$$

L $\quad$ $\pm i$


$\varphi = \alpha|H\rangle + \beta|V\rangle$
x, y
ψ^-
φ
Bob
Alice
140 km
$\Phi^\pm, \psi^\pm$
1
2
3
ψ^-
$\tilde{\psi}^-$
H, D
HH, HV
VH, VV
V, A
H
H
V
V

1, 2, 3 :

$|\varphi\rangle = \alpha|H\rangle + \beta|V\rangle$

$|\psi^-\rangle = \frac{1}{\sqrt{2}}(|HV\rangle - |VH\rangle)$

$|\Phi^+\rangle = \frac{1}{\sqrt{2}}(|HH\rangle + |VV\rangle)$

$|\psi^-_{1,2}\rangle \otimes |\varphi_3\rangle \rightarrow \frac{1}{\sqrt{2}}(\alpha|H\rangle + \beta|V\rangle)(|HV\rangle - |VH\rangle)$

$|HH\rangle = \frac{1}{\sqrt{2}}(|\Phi^+_{1,2}\rangle + |\Phi^-_{1,2}\rangle)$

$|HV\rangle$

$|VH\rangle$

$|VV\rangle$

$\alpha|H\rangle_1|H\rangle_2|V\rangle_3$