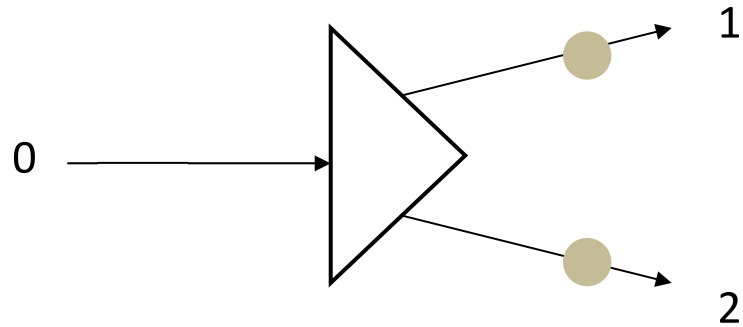
Spin half particle represented by a wavepacket χ passes through a Stern-Gerlach Apparatus



$|\psi_0\rangle = |\chi_0\rangle(|\alpha\rangle \cos\theta + |\beta\rangle \sin\theta)$

$\rho_0 = |\psi_0\rangle\langle\psi_0|$

$= \cos^2\theta\, |\chi_0\rangle\langle|\chi_0||\alpha\rangle\langle\alpha| + \sin^2\theta\, |\chi_0\rangle\langle|\chi_0||\beta\rangle\langle\beta| + \cos\theta \sin\theta\, |\chi_0\rangle\langle|\chi_0||\alpha\rangle\langle\beta| + hc$

$|\psi\rangle = |\chi_1\rangle|\alpha\rangle \cos\theta + |\chi_2\rangle|\beta\rangle \sin\theta$

$\rho = |\psi\rangle\langle\psi|$

$= \cos^2\theta\, |\chi_1\rangle\langle|\chi_1||\alpha\rangle\langle\alpha| + \sin^2\theta\, |\chi_2\rangle\langle|\chi_2||\beta\rangle\langle\beta| + \cos\theta \sin\theta\, |\chi_1\rangle\underbrace{\langle\chi_2|}_{=0}\alpha\rangle\langle\beta| + hc$

Add a decohering environment

$$\rho = \cos^2\theta\ |\chi_1\rangle\langle\chi_1|\ |E_1\rangle\langle E_1|\ |\alpha\rangle\langle\alpha| + \sin^2\theta\ |\chi_2\rangle\langle\chi_2|\ |E_2\rangle\langle E_2|\ |\beta\rangle\langle\beta|$$

$$+ \cos\theta\ \sin\theta\ |\chi_1\rangle\langle\chi_2|\ |E_1\rangle\langle E_2|\ |\alpha\rangle\langle\beta| + hc$$

Trace over environment variables and add a detector, which may include an observer

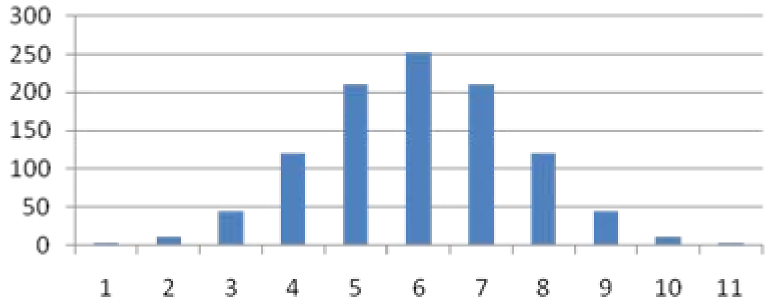
$$\rho = \cos^2\theta\ |D_1\rangle\langle D_1|\ |\chi_1\rangle\langle\chi_1|\ |\alpha\rangle\langle\alpha| + \sin^2\theta\ |\chi_2\rangle\langle\chi_2|\ |D_2\rangle\langle D_2|\ |\beta\rangle\langle\beta|$$

The physical development of each spin and associated detector is independent of θ.

Consider outcome of performing a number, *N,* identical SG measurements
In a given branch, *M* positive and *N* – *M* negative spins are observed

Total number of branches with *M* positive spins = ${}^{N}C_{M}$

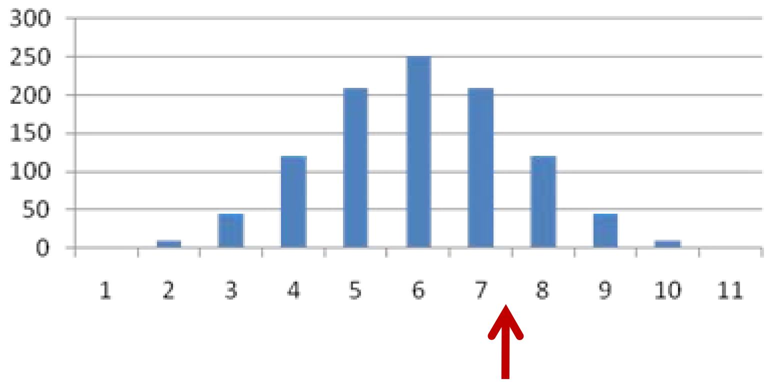
E.g, with *N* = 10



This has a maximum when *N = M,* but unless $\theta = 45^0$, the expected result does not correspond with this maximum
Also, this distribution is unaffected by θ, which is consistent with the earlier argument

So how can detection probability depend on θ?

Suppose $\theta = 30^0$, $N = 10$. then $N\cos^2\theta = 0.75$.



We expect to observe $M = 7$ or 8, but there will be branches with all possible values of M.

Consider two of these: one with $M = 7$ and one with $M = 3$.

An observer should expect to be on the first branch rather than the second. That is, her "state of expectation" is influenced by the value of θ

But this state is part of her quantum state, which we have seen is independent of θ in the absence of interference.

Can this question be resolved?

Consider a situation where the observer has no prior knowledge of θ and tries to deduce this from her measurements:

⑥⑥⑥ ⑨⑨⑨⑨⑨⑨⑨ 😐 I have no idea what θ is 😐

⑨⑨⑨ ⑥⑥⑥⑥⑥⑥⑥ 😐 I have no idea what θ is 😐

Observer's state of expectation depends only on *M* and is independent of the actual value of θ.

BUT any observer who understood this could not logically form any expectation about the value of θ.