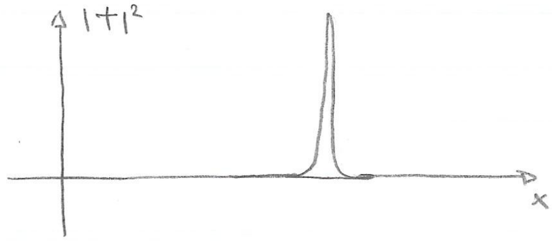
In a position measurement the particle can be found at any localization, where the probability density is not equal to zero. Once the position of the particle has been measured, the probability density must be concentrated around the measured localization

After position measurement:



Based on our previous analysis; we have

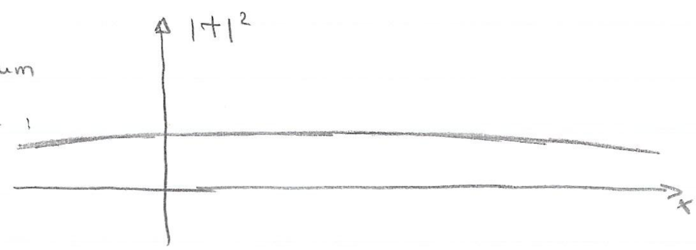
→ small uncertainty in position

→ large uncertainty in momentum

described by a strongly localized wave packet

Next, after some time we measure the momentum of the particle. Once the momentum is measured, the probability density must look like

After momentum measurement:



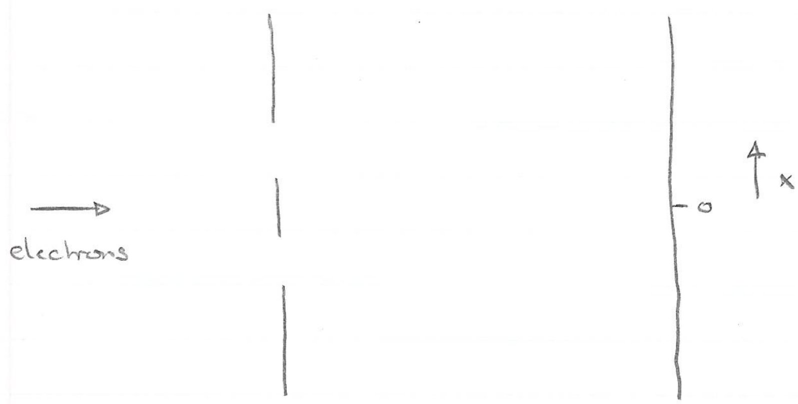
Now, we have a small uncertainty in momentum but a large uncertainty in position of particle, described by a plane wave.

Remarks :

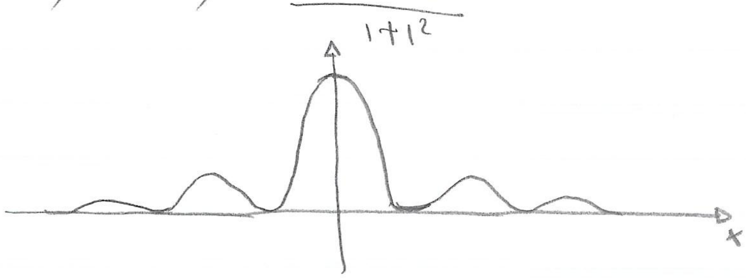
- In each step (before measurement, after position measurement, after momentum measurement) the probability density $|\Psi|^2$ belongs to a different wave function Ψ.
  → act of measurement changes the wavefunction of the particle.

- Schrödinger equation describes the evolution of the particle before and after the measurement but it does not capture the act of the measurement itself.
  → measurement is a discontinuous process.

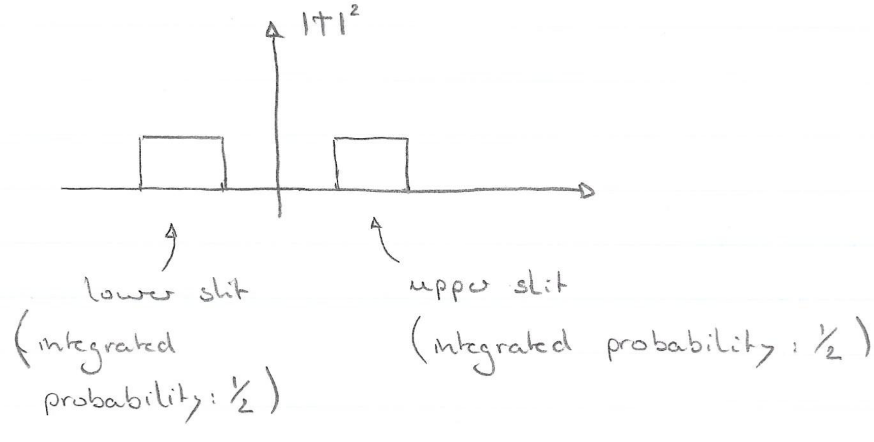
Let's look back to the double slit experiment, and see how a measurement process changes the outcome of the experiment.



Probability density at screen:

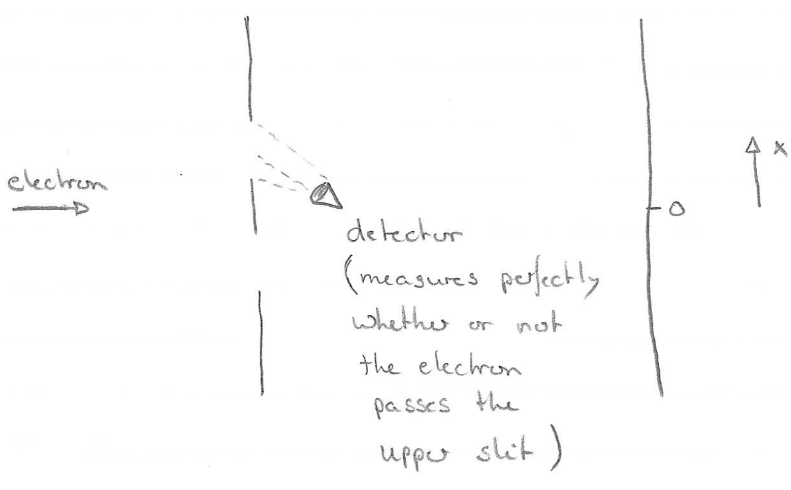


Probability density at slits:

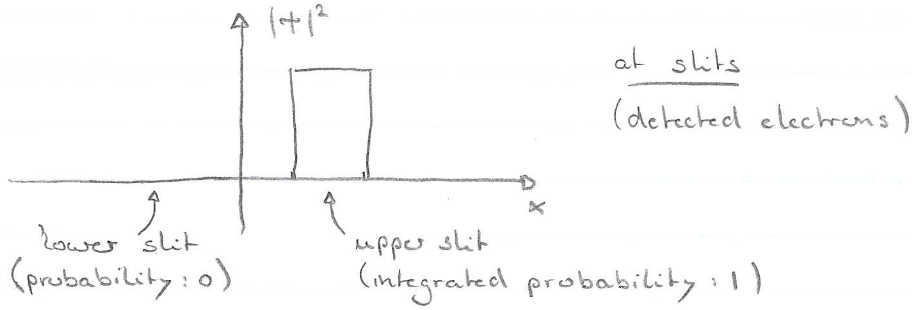


This reflects that the electron passes (with equal probability) through both slits and interferes with itself after the slit to generate the observed interference pattern at the screen.

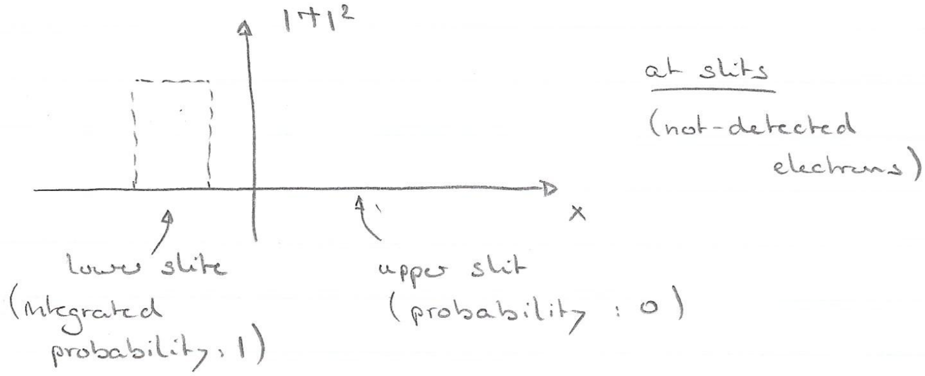
Now we place a detector after one of the two slits that detects whether or not the electron passes this slit.



For the electrons that are <u>detected</u>, we know that they have passed through the upper slit and these electrons are described by the following probability density

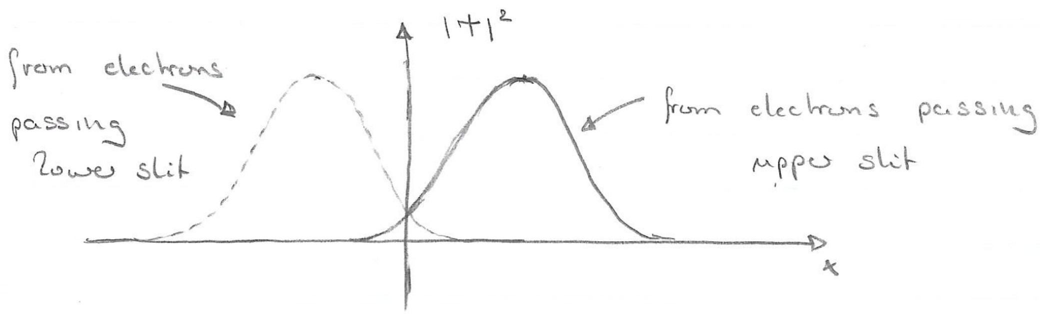


and for the electrons that are <u>not detected</u>, we know that they have passed through the lower slit



Thus, the measurement changes the wave function at the slits either to reproduce the upper probability density or the lower one.

As a consequence: The observation at the screen also changes (to a non-interference pattern)



Since position and momentum of the particle cannot be measured simultaneously with complete precision, these variables are called

complementary variables.

In quantum mechanics there are other complementary variables, namely

- the components of the orbital angular momentum L_x, L_y and L_z
- the components of the spin angular momentum S_x, S_y and S_z

We will study the measurement process for complementary variables further for the components of the spin angular momentum.

To this end, we first need to study the Stern-Gerlach experiment, which will us show

- that atoms have a quantized magnetic moment
- the magnetic moment arises due to orbital and spin angular momentum.