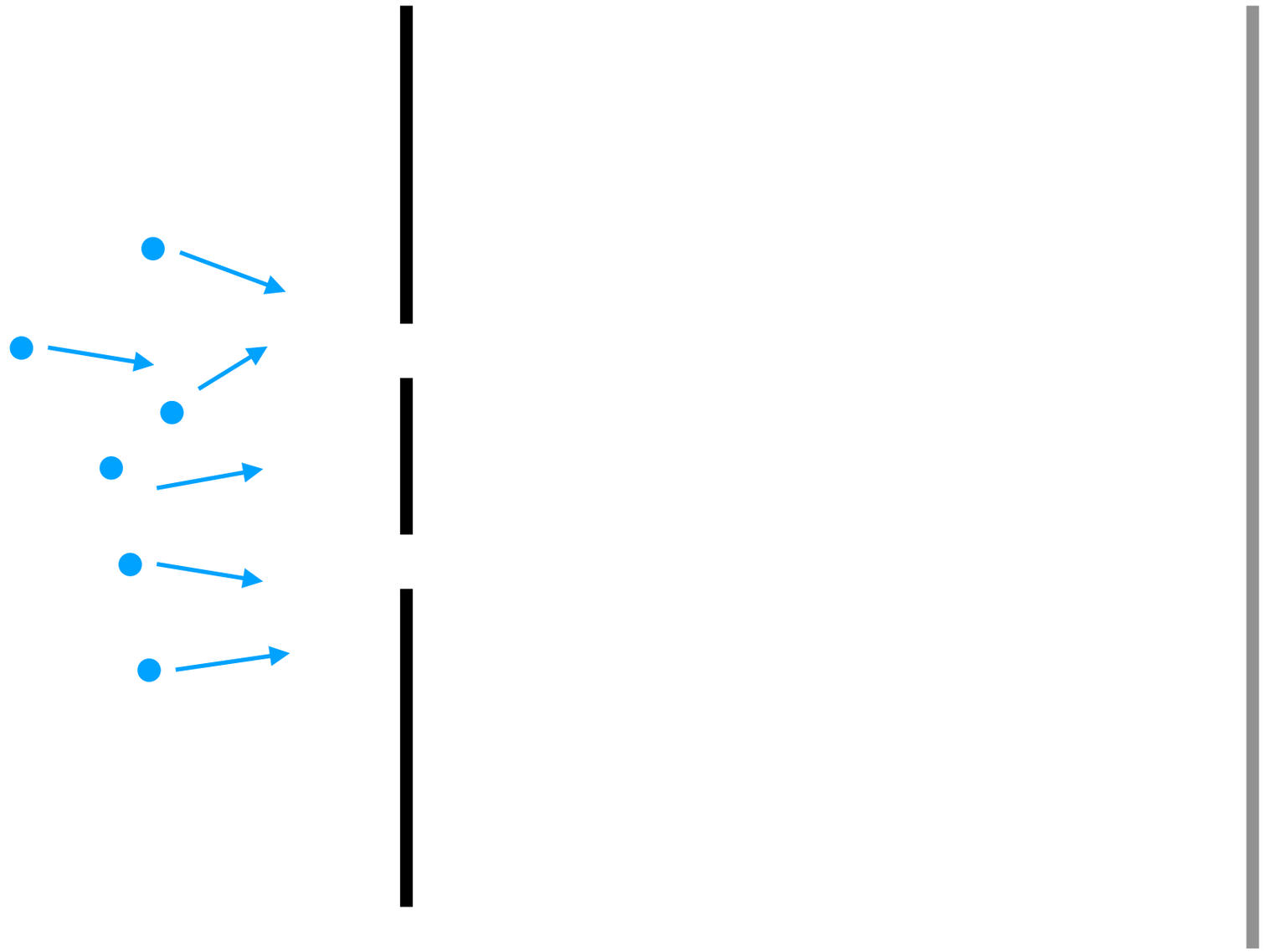
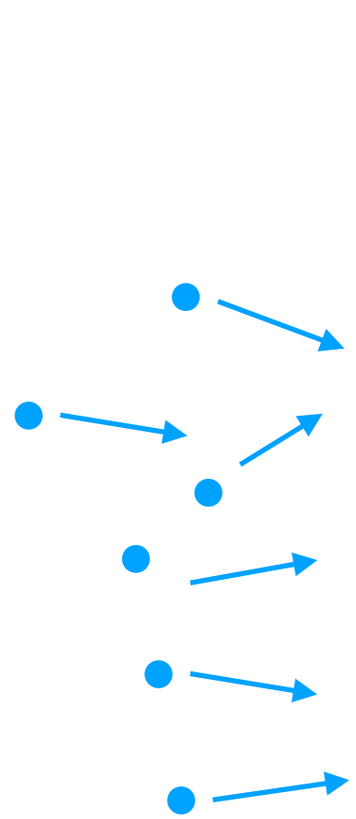
Complementarity and the 2-slit experiment

The 2-slit experiment

Classical particles with random velocities



The 2-slit experiment

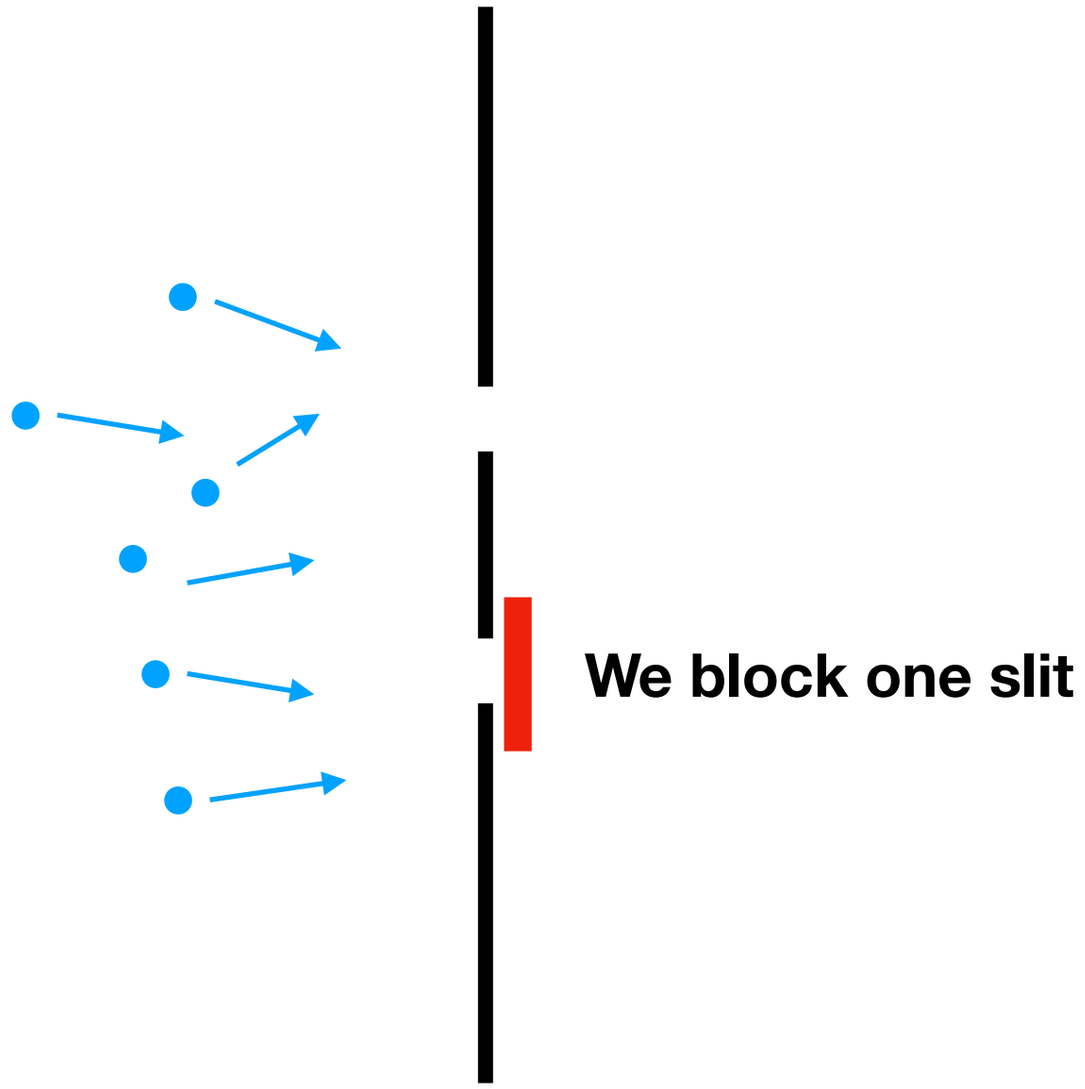


Classical particles with random velocities

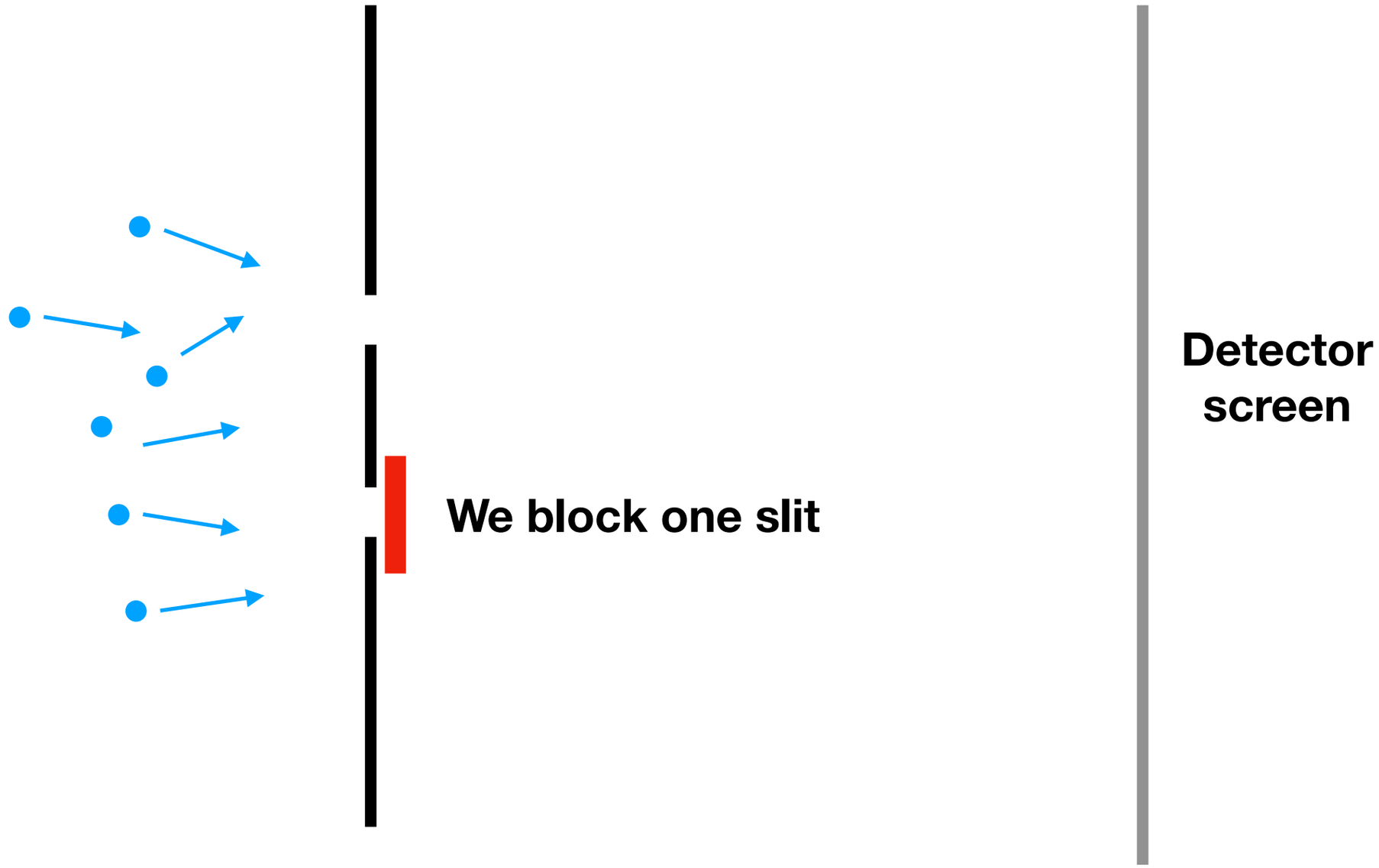
Screen with 2 slits

Detector screen

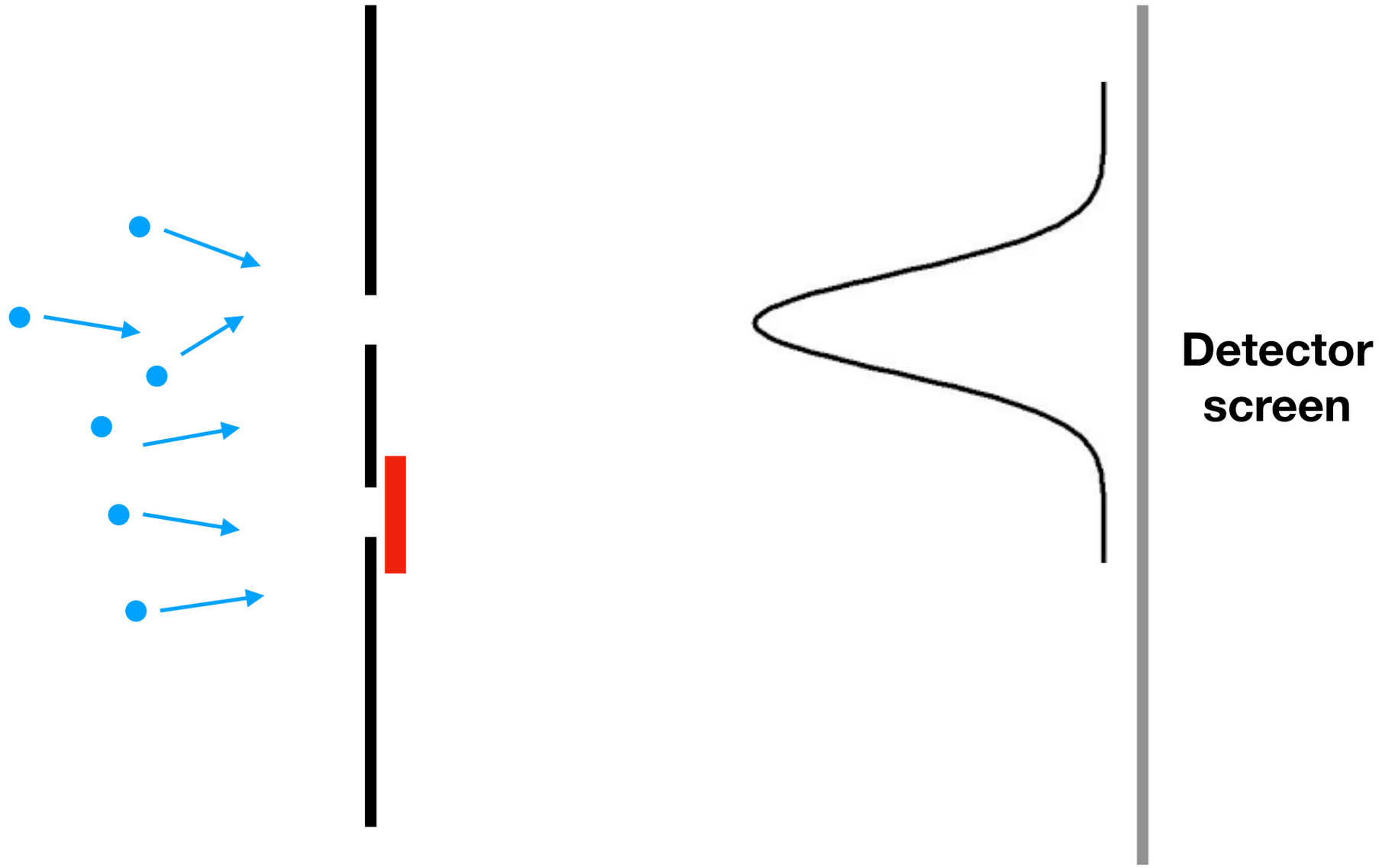
The 2-slit experiment

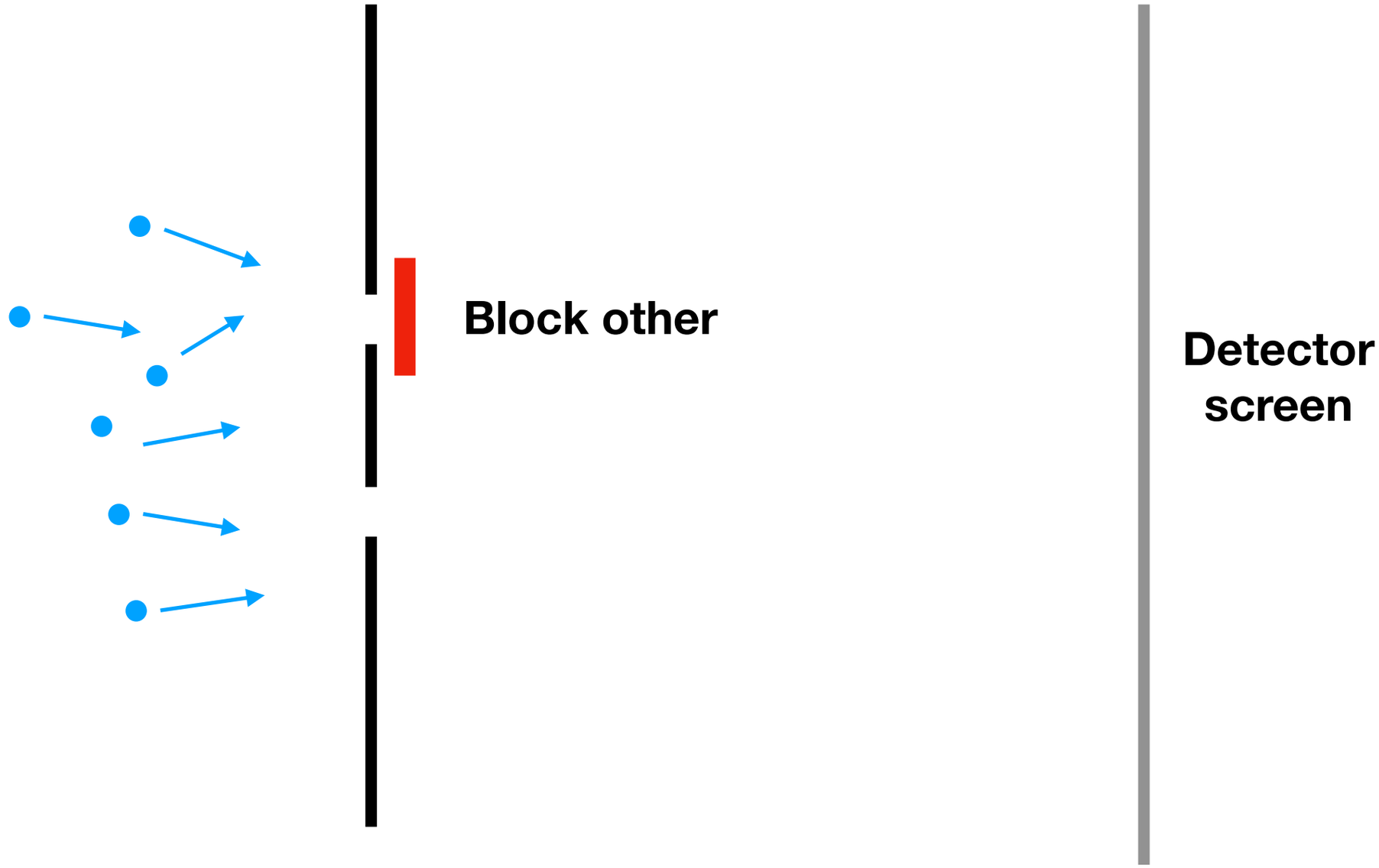


The 2-slit experiment

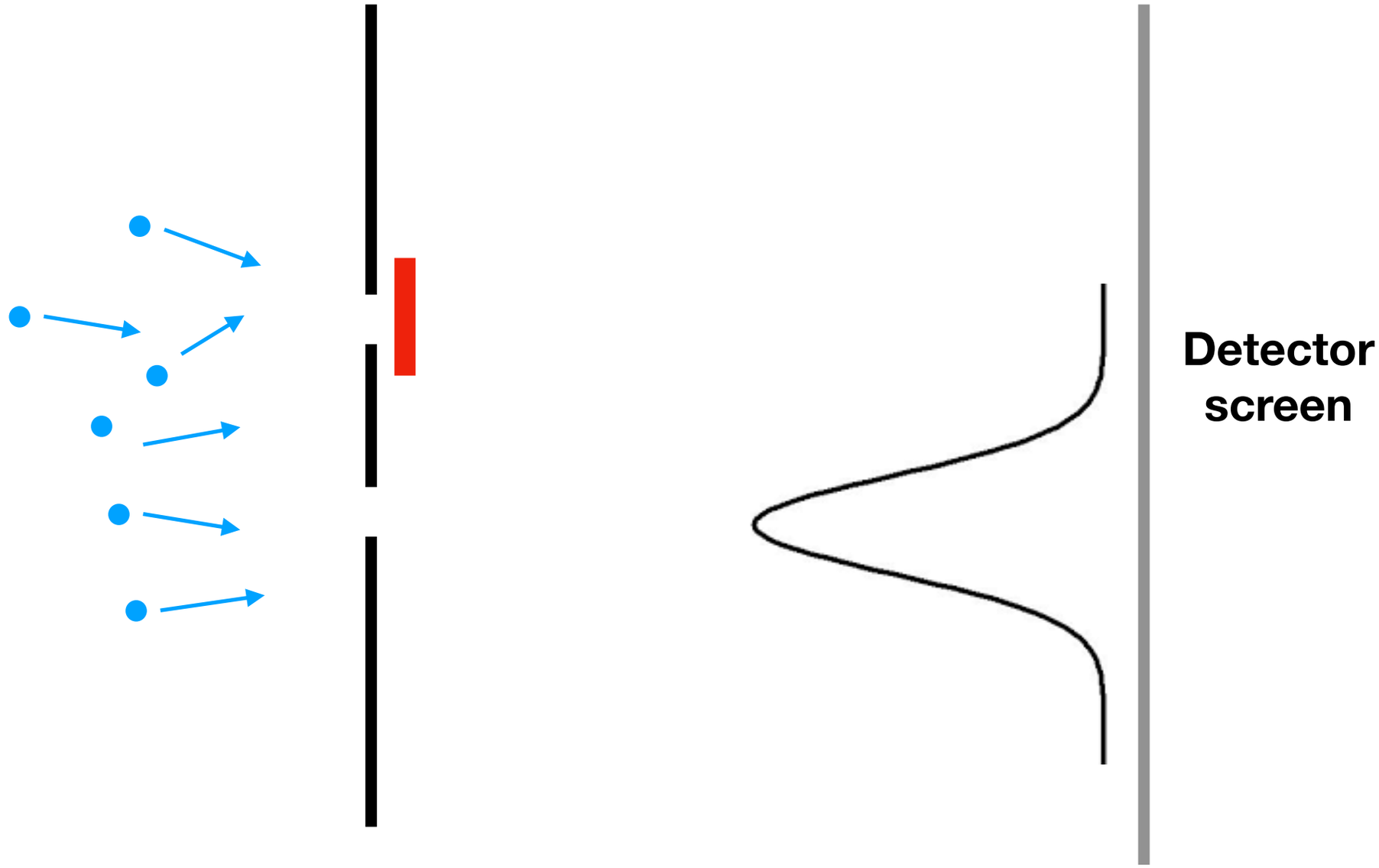


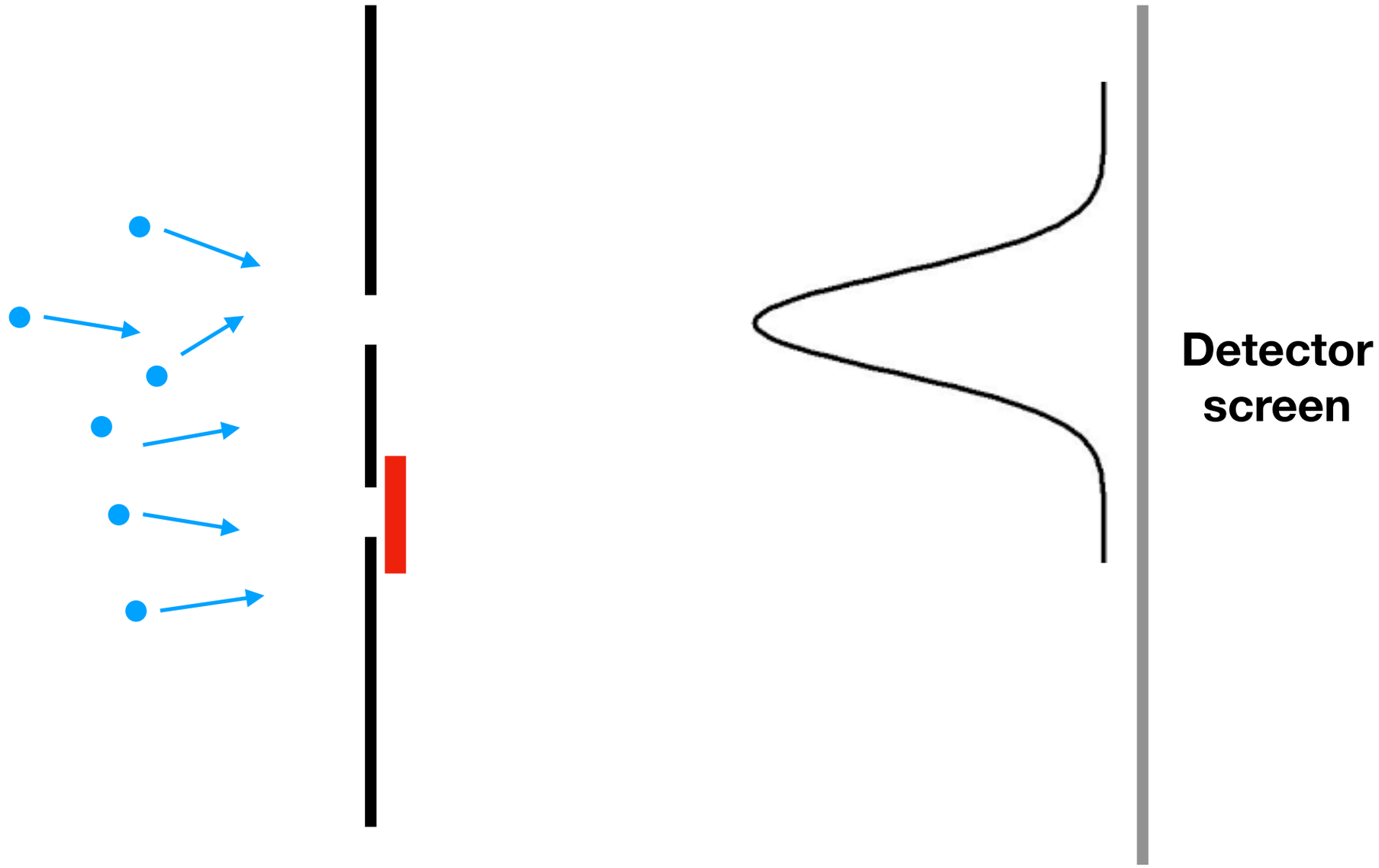
What distribution of particle hits on the detector screen do we measure?

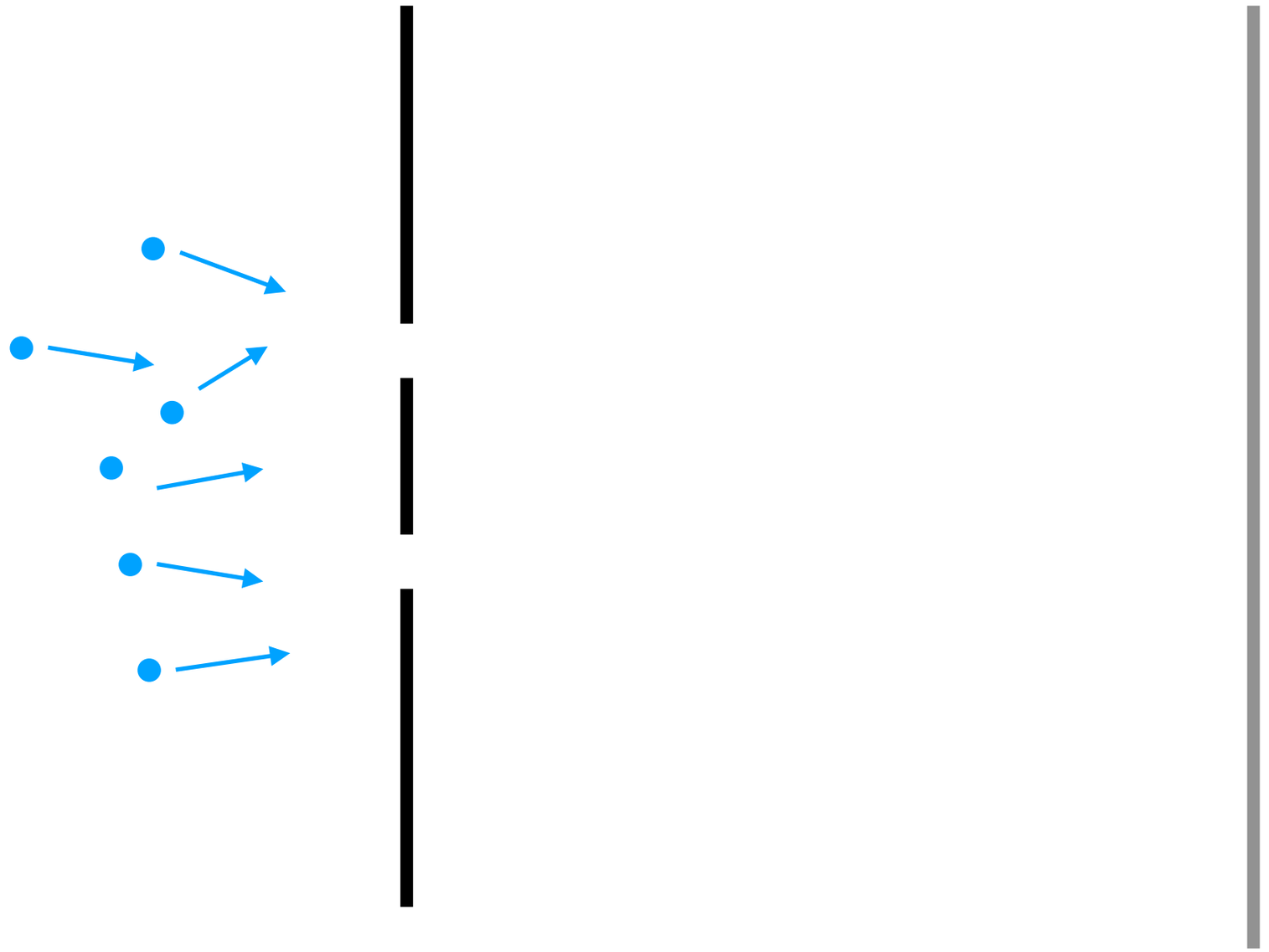

Detector
screen



What distribution of particle hits on the detector screen do we measure?

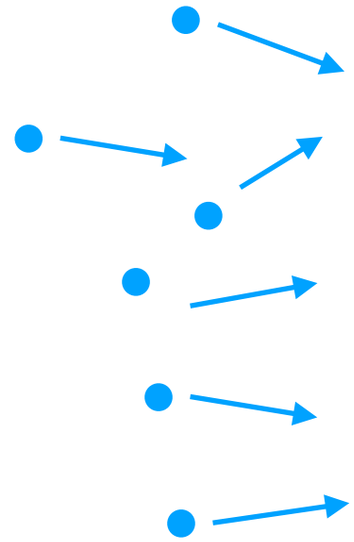

Detector
screen

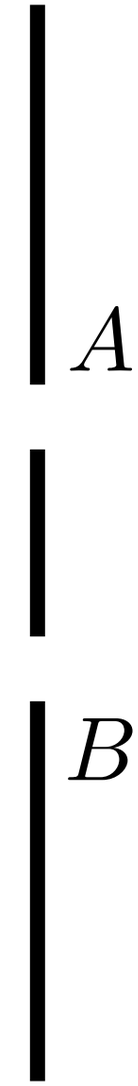

Detector
screen

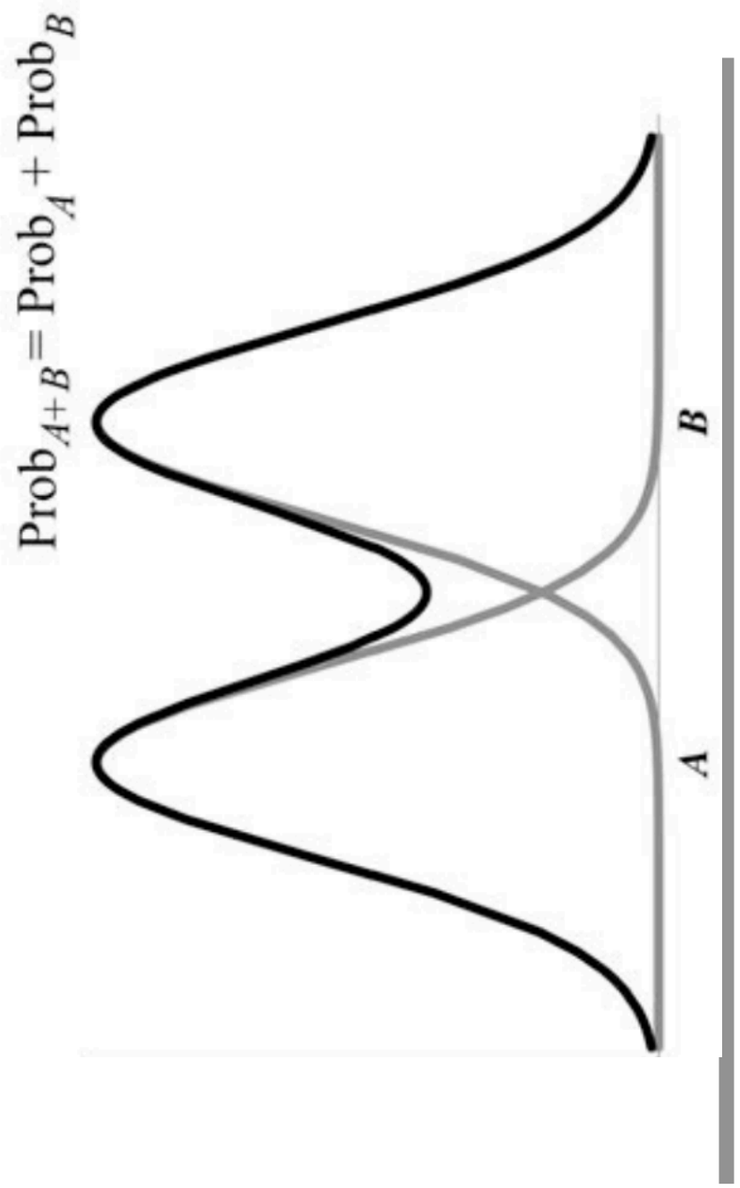


Both slits open? What pattern on screen?

Classical particles with random velocities



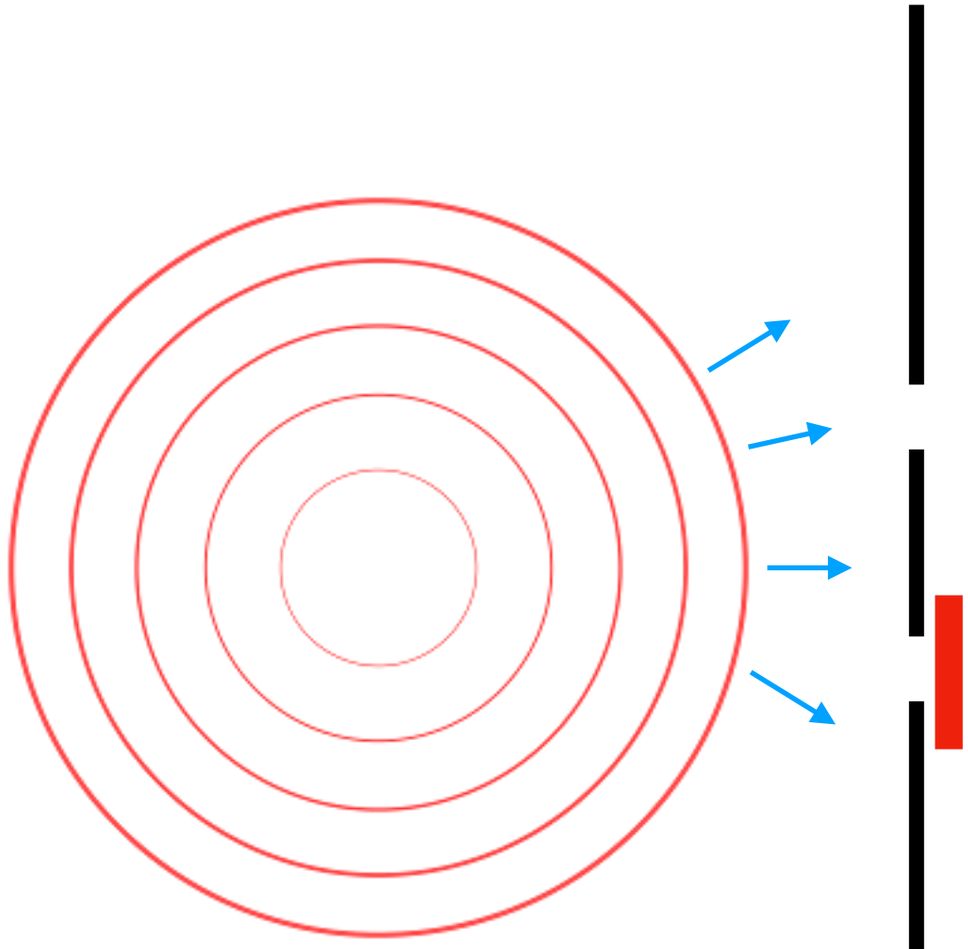




Detector screen

Double-peaked distribution of particles

Now with sound waves

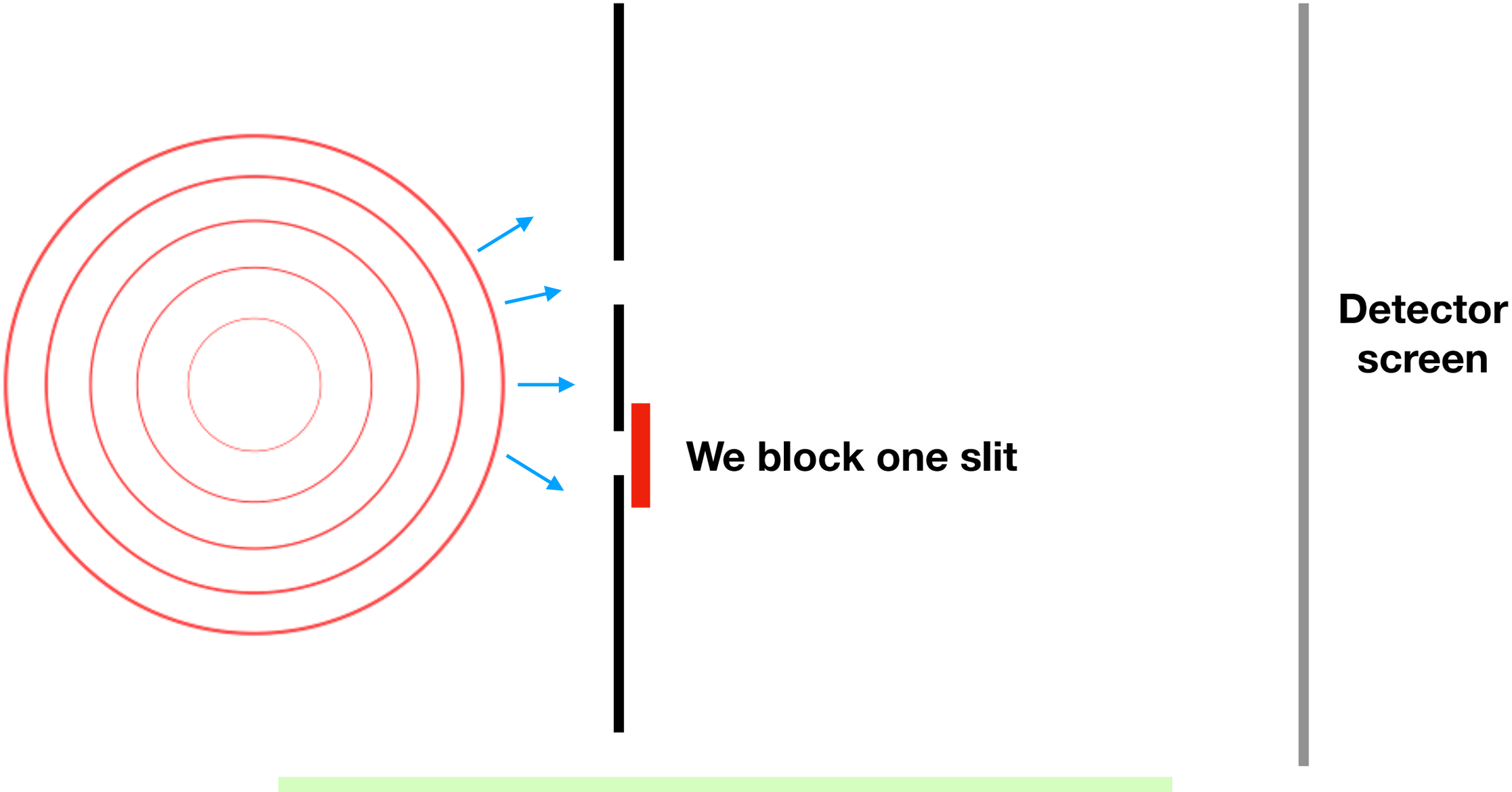


We block one slit

Detector screen

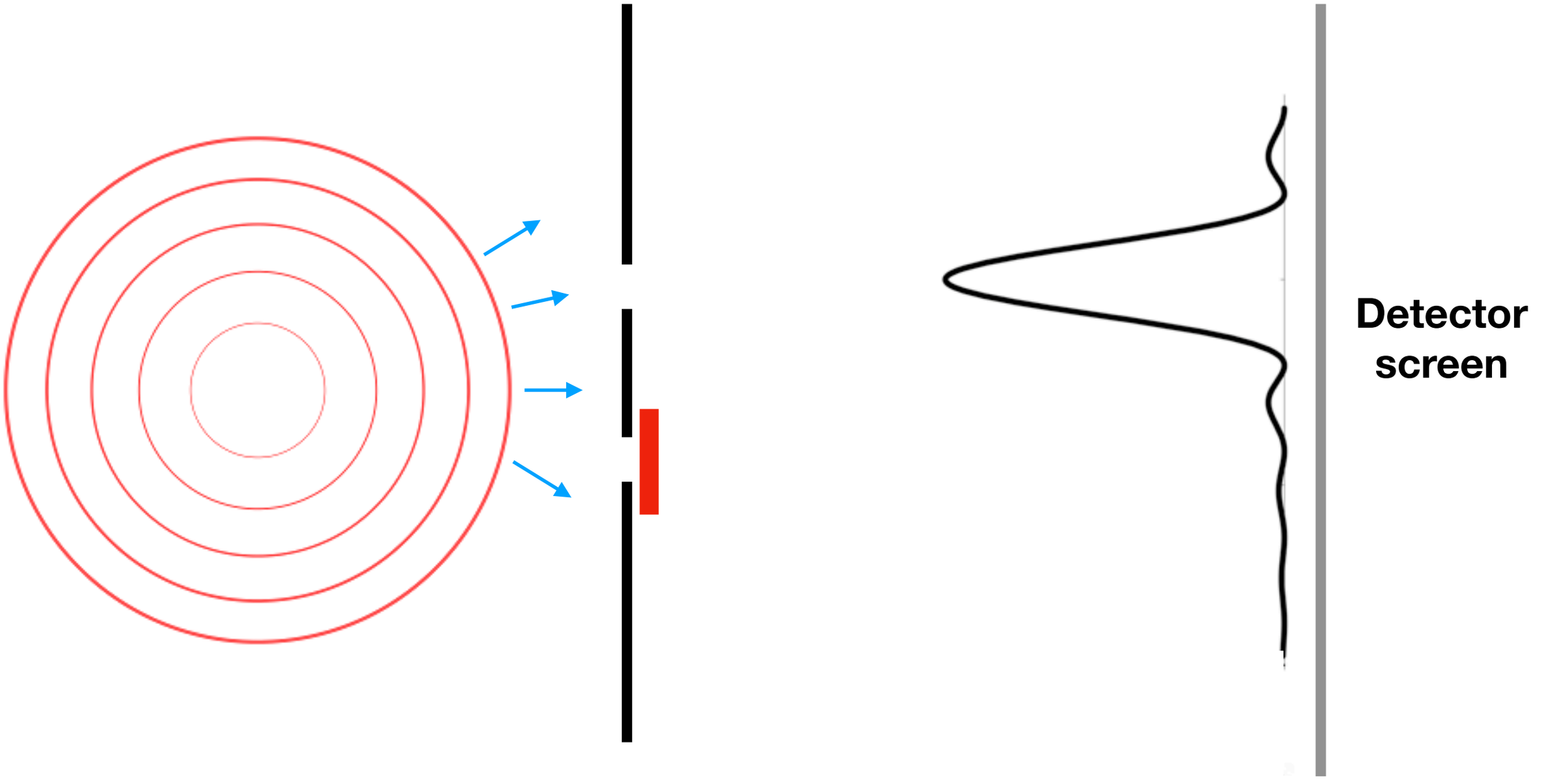
$$\text{Wavelength } = \lambda$$

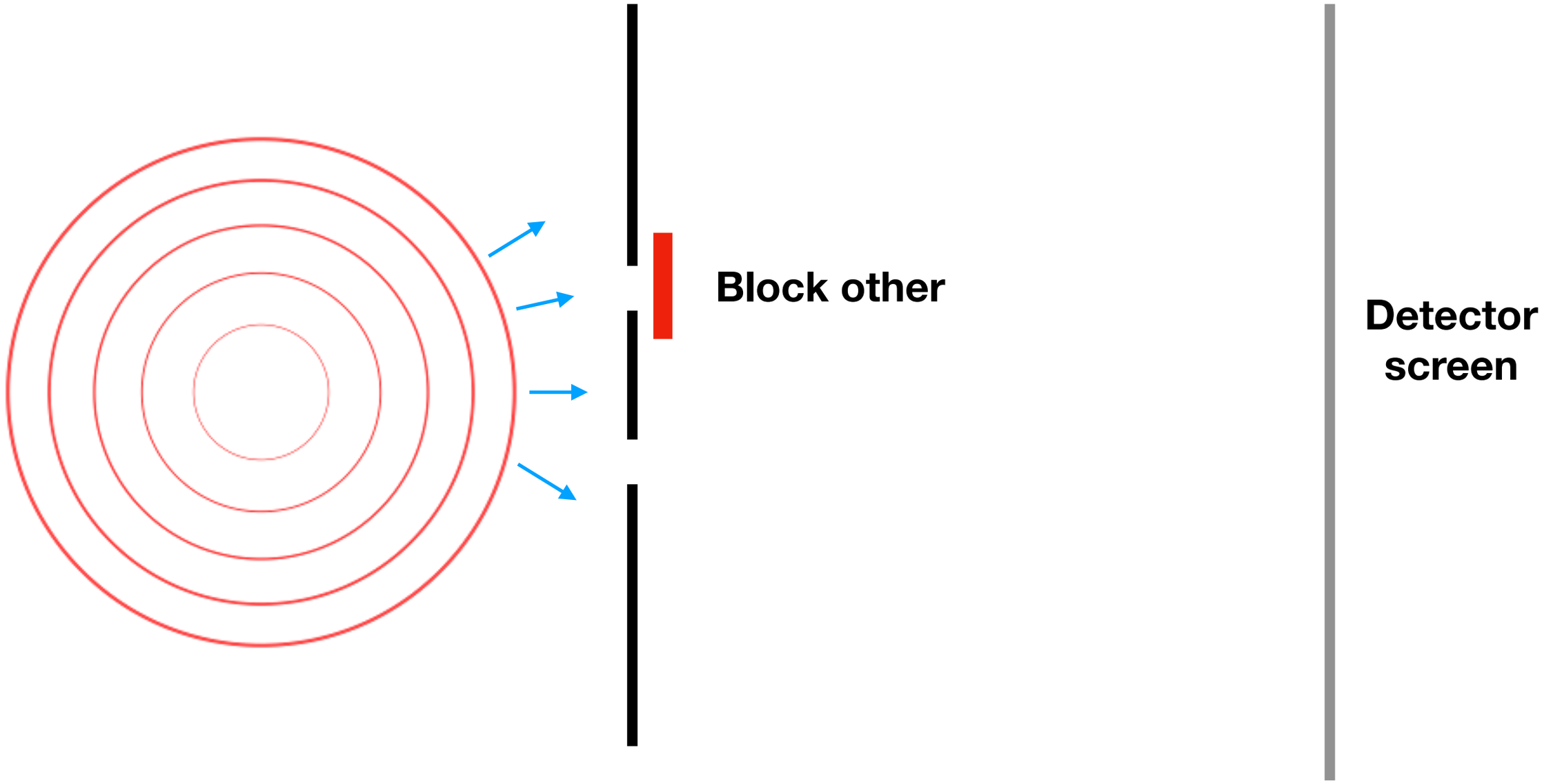
Now with sound waves



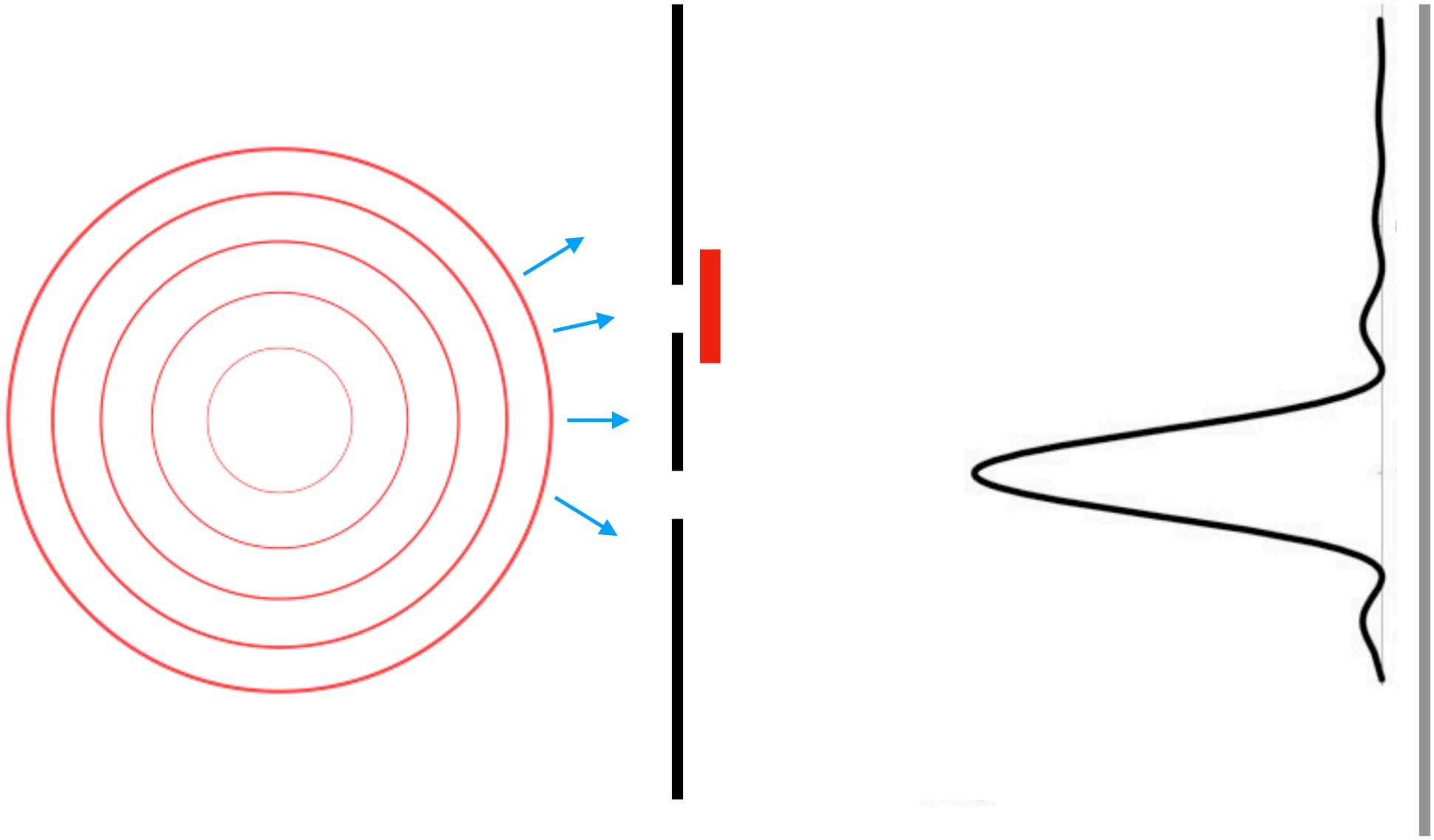
What is intensity profile on detector screen?

Now with sound waves

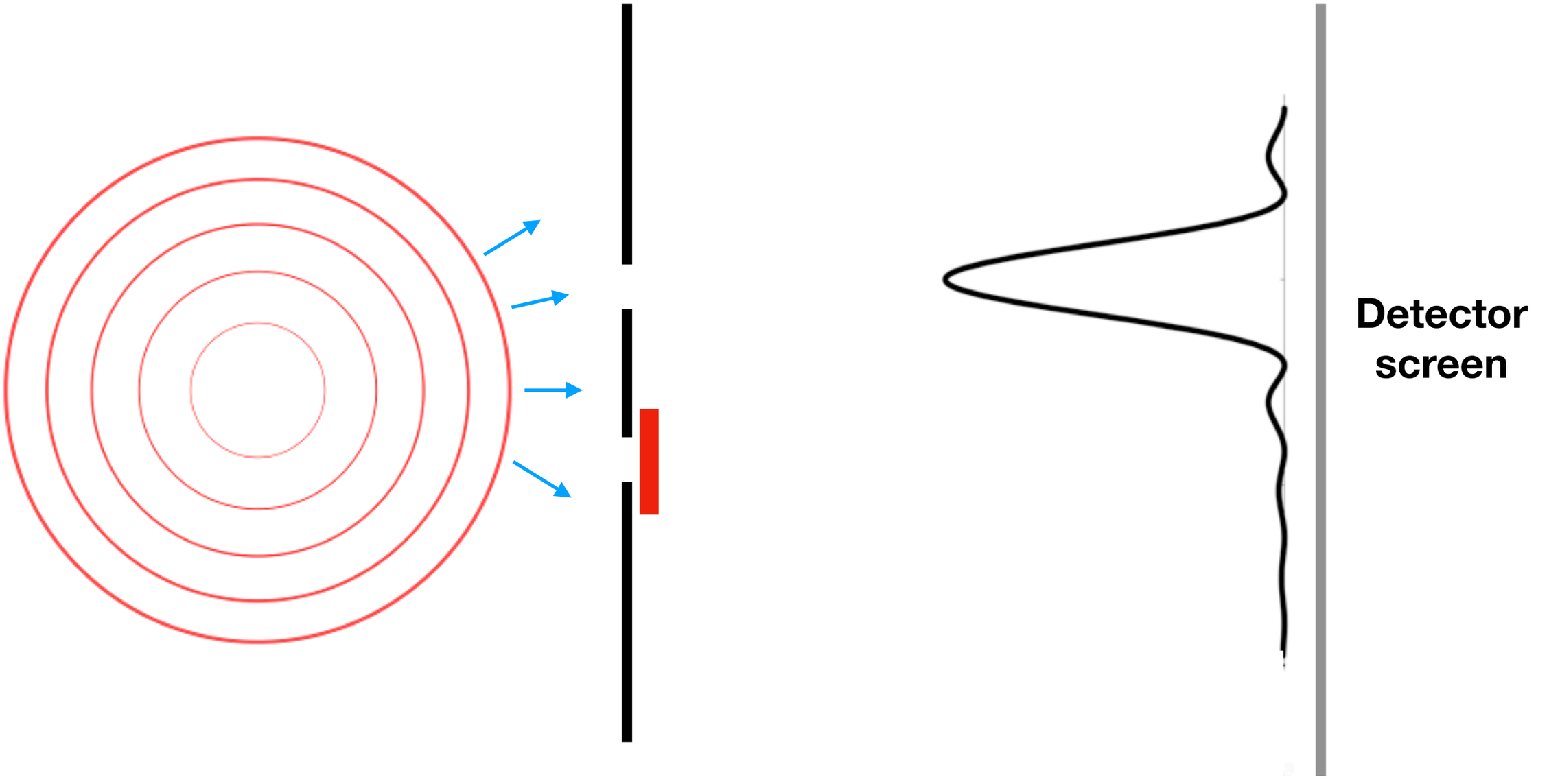




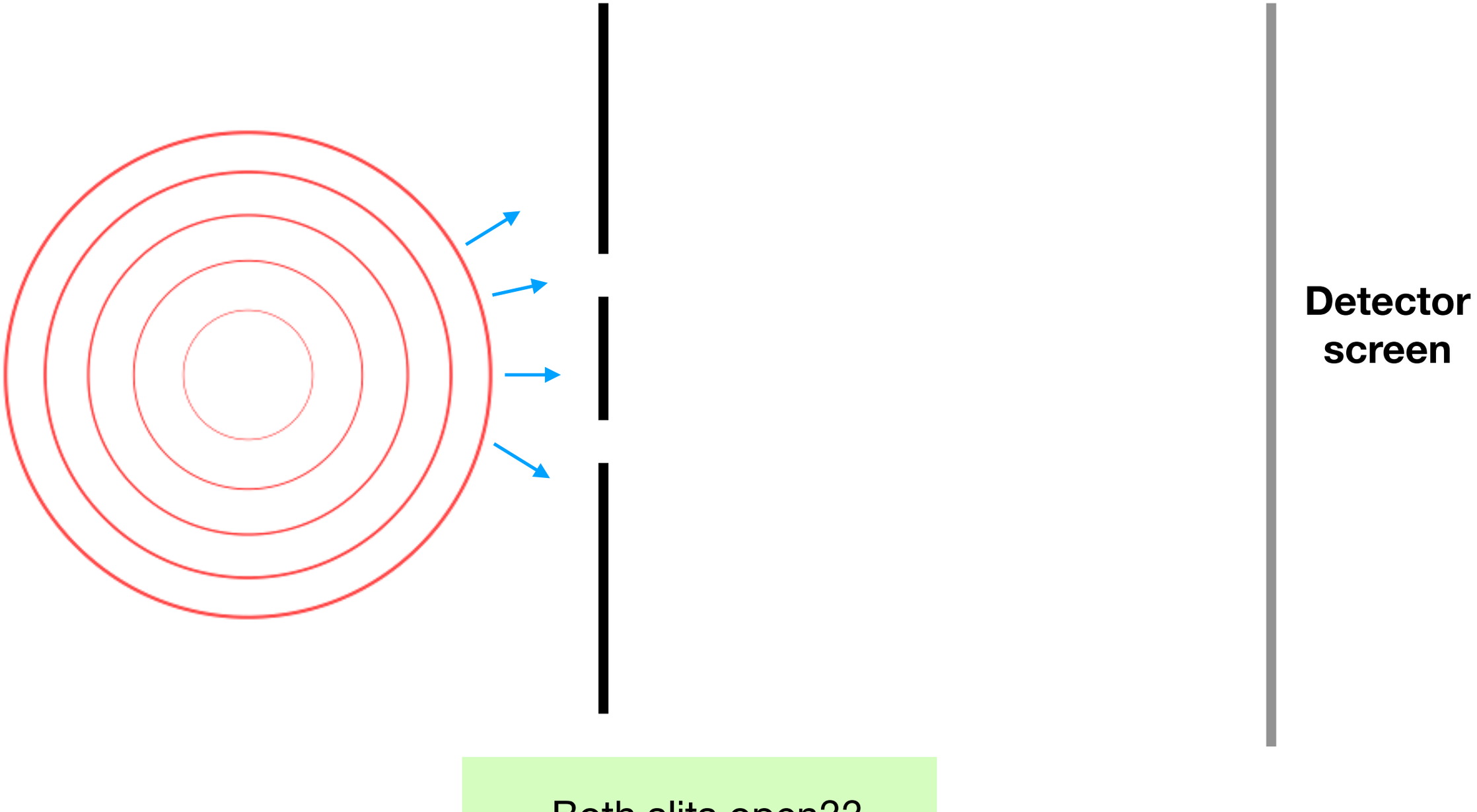
What intensity profile do we measure?


Detector screen

Now with sound waves

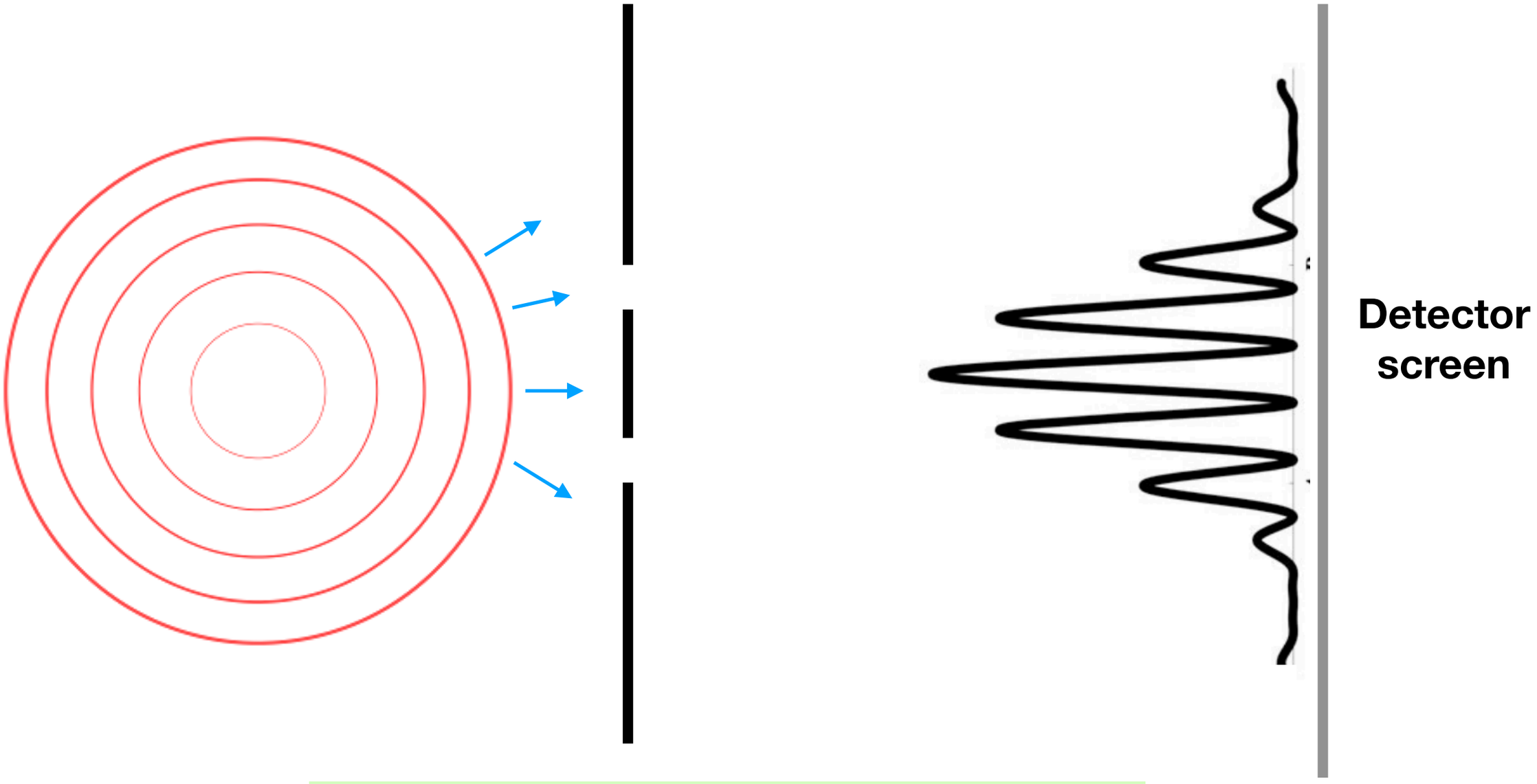


Now with sound waves



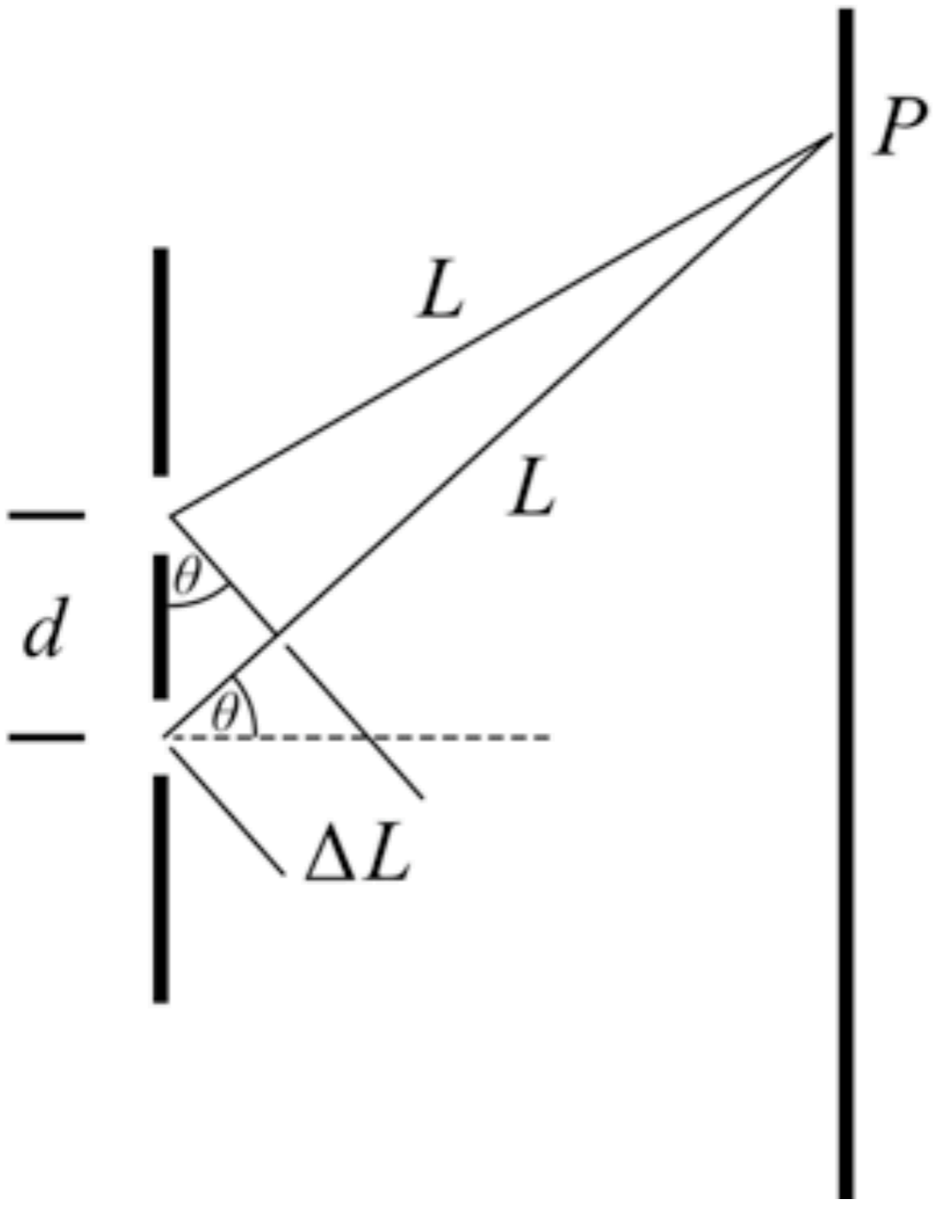
Both slits open??

Now with sound waves



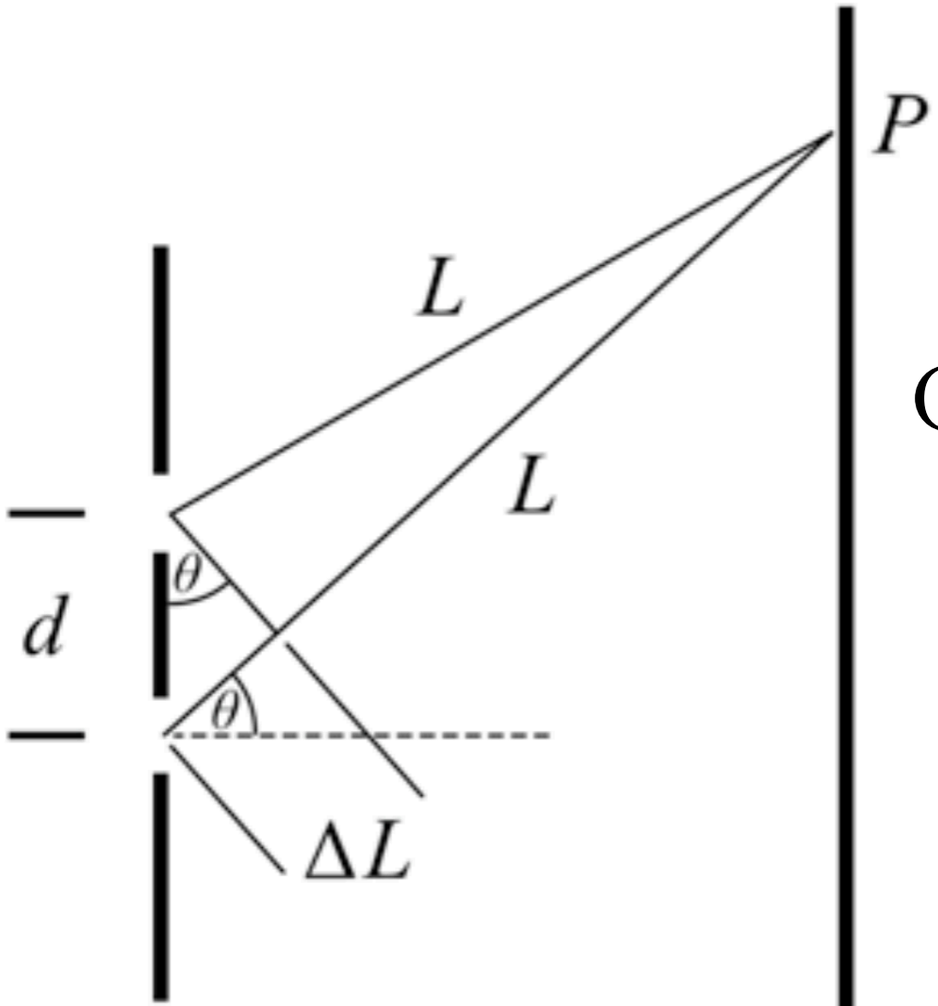
Constructive + Destructive interference

Interference theory



Slit separation $= d$

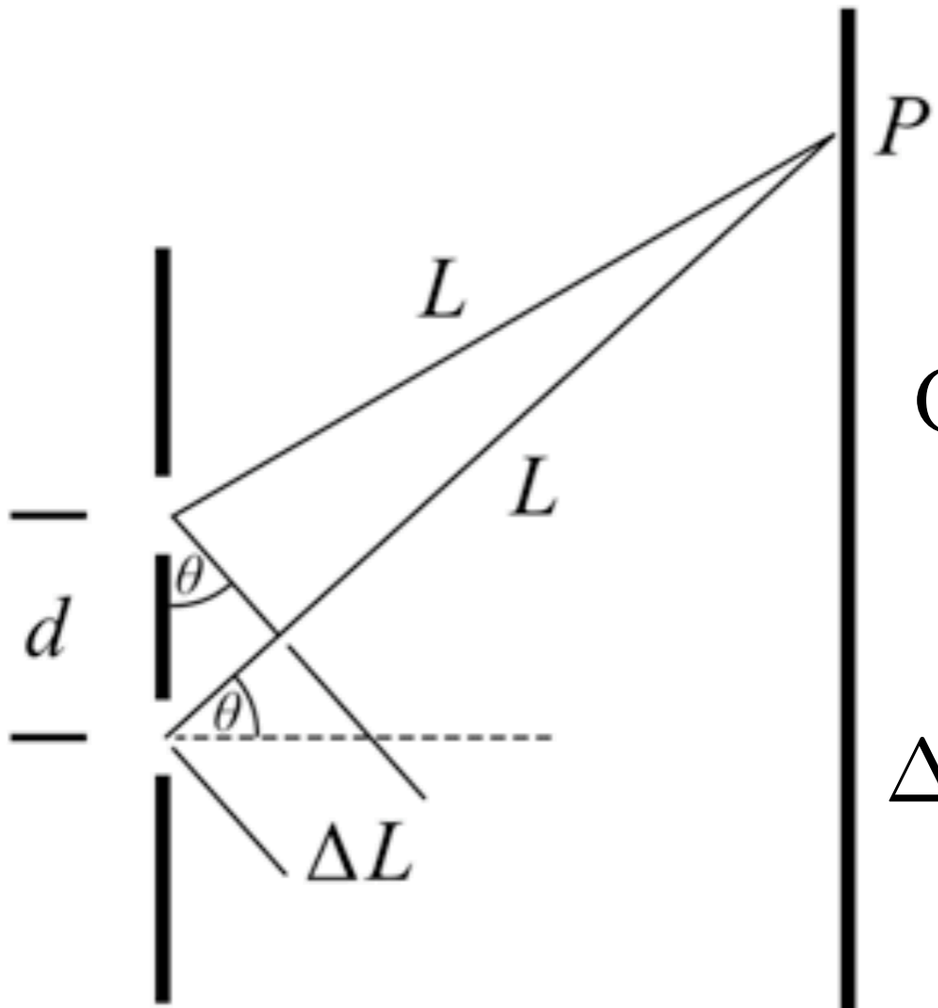
Interference theory



Slit separation $= d$

Consider a point P on screen at angle θ from lower slit

Interference theory



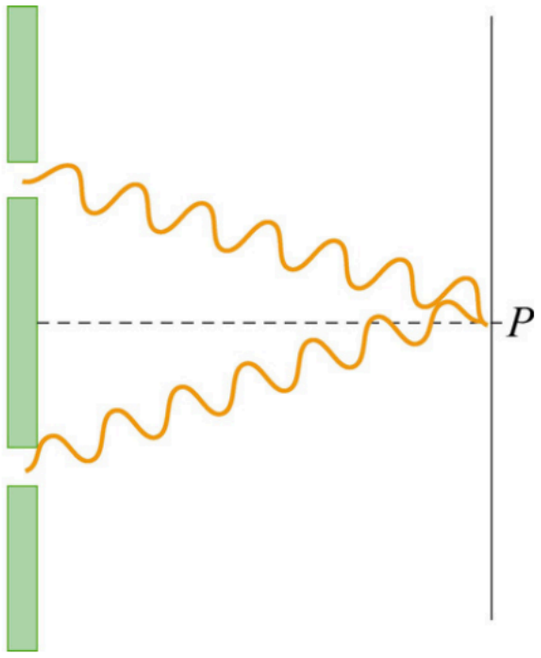
Slit separation $= d$

Consider a point P on screen at angle θ from lower slit

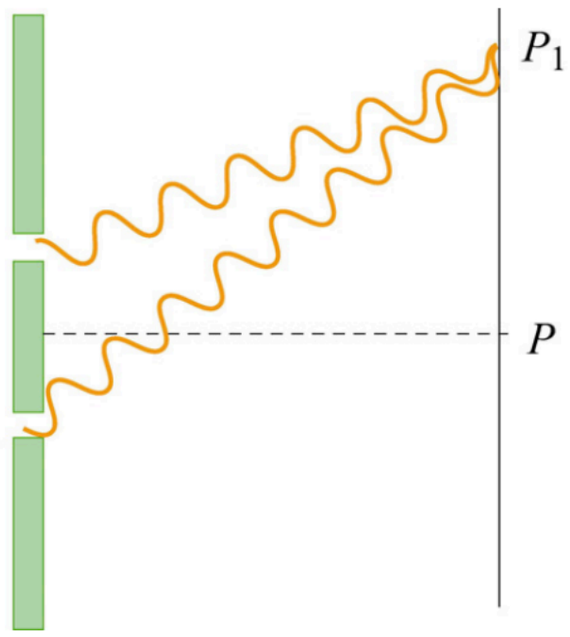
$\Delta L =$ difference in path lengths

$$\Delta L = d \sin \theta$$

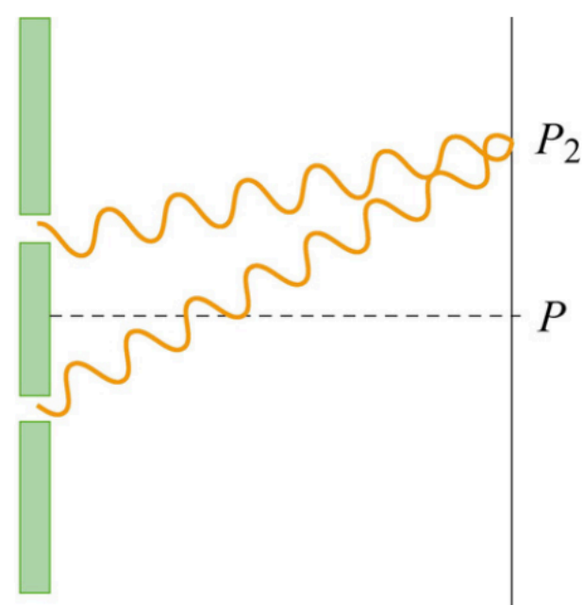
Interference theory



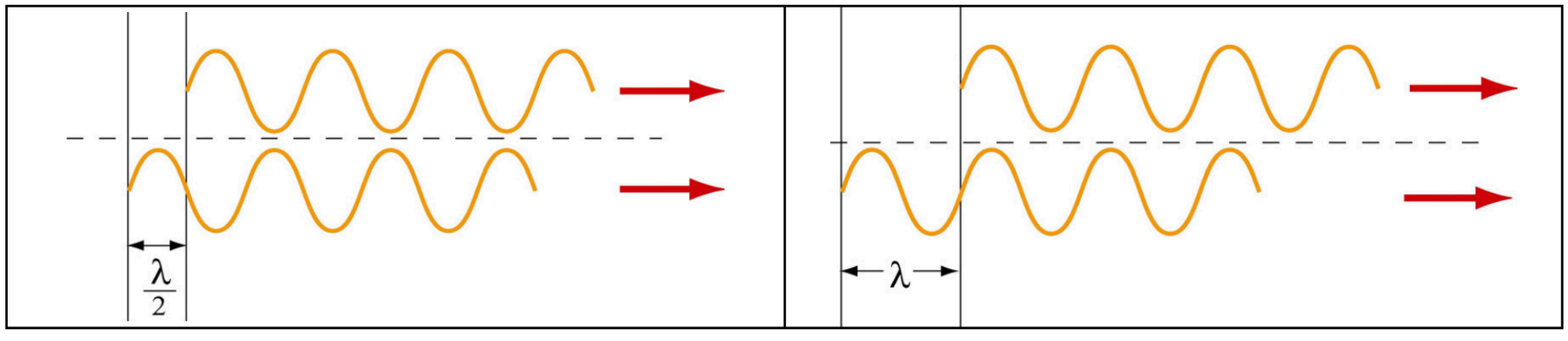
Constructive interference



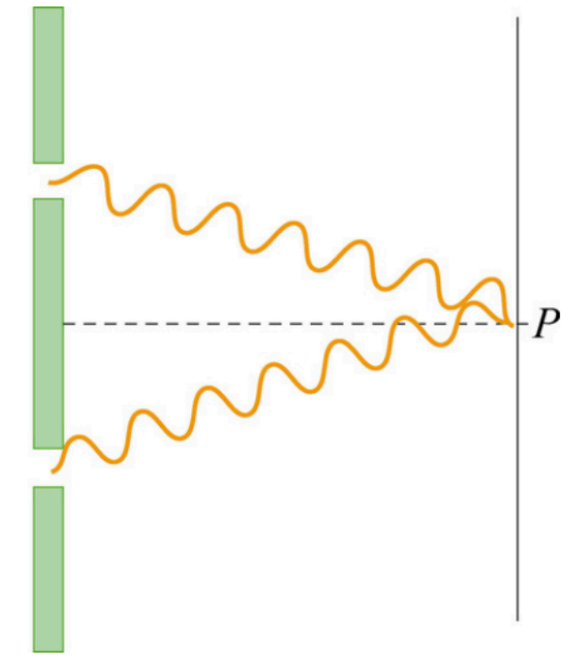
Constructive interference



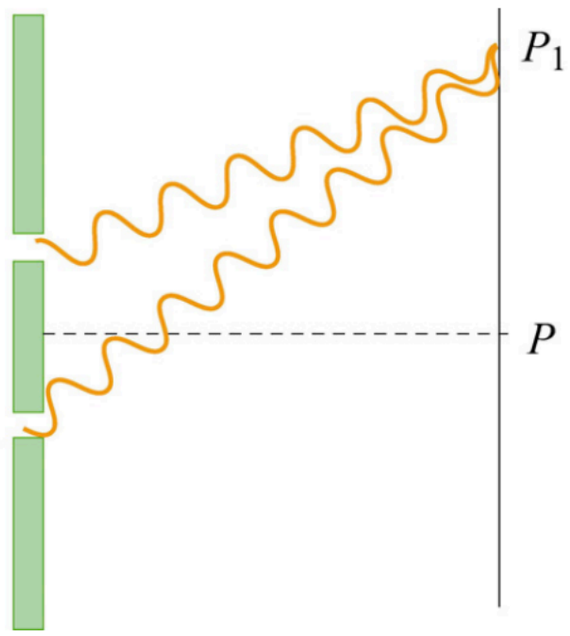
Destructive interference



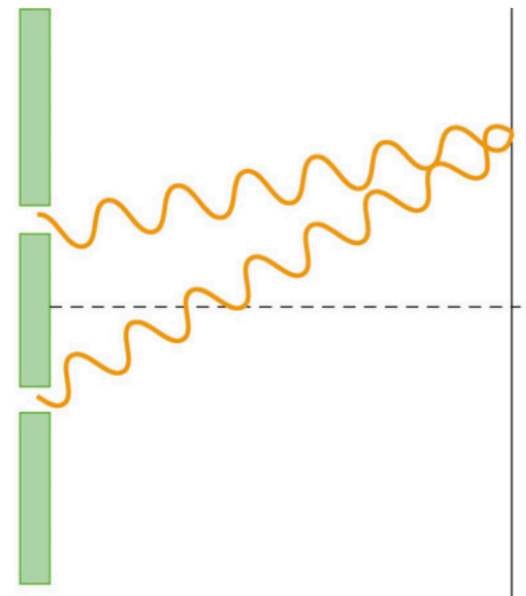
Interference theory



Constructive interference



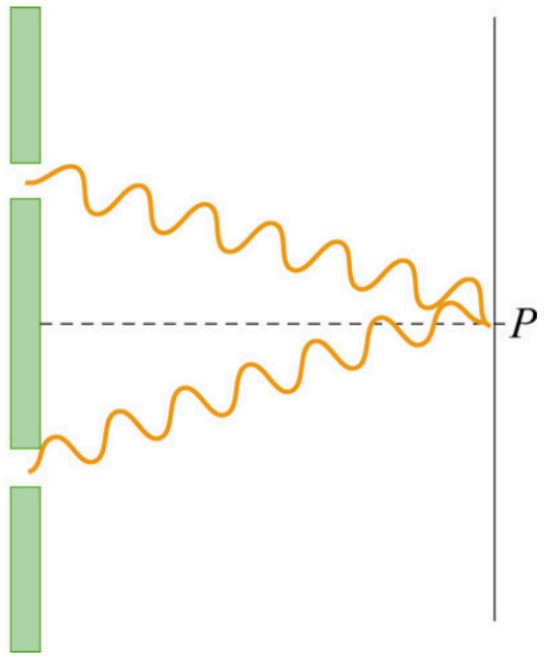
Constructive interference



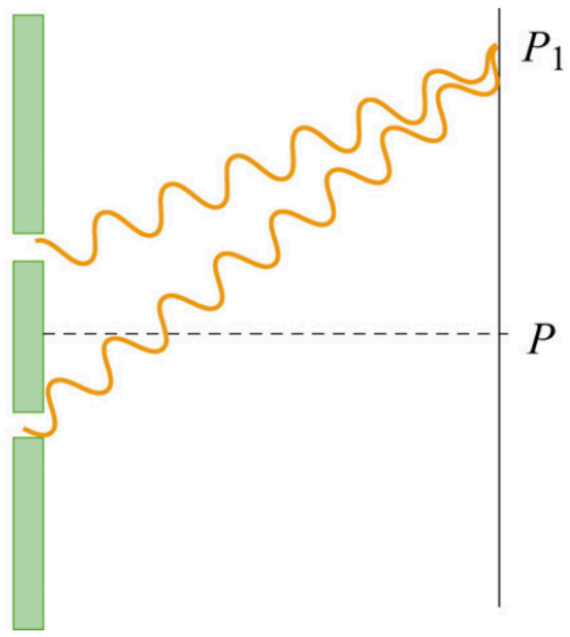
Destructive interference

Constructive: path difference is **integer multiple** of wavelength
Destructive: path difference is **half-integer multiple** of wavelength.

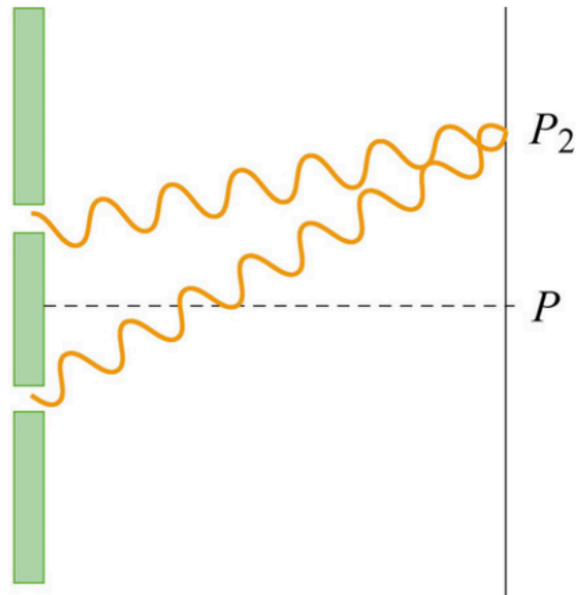
Interference theory



Constructive interference



Constructive interference

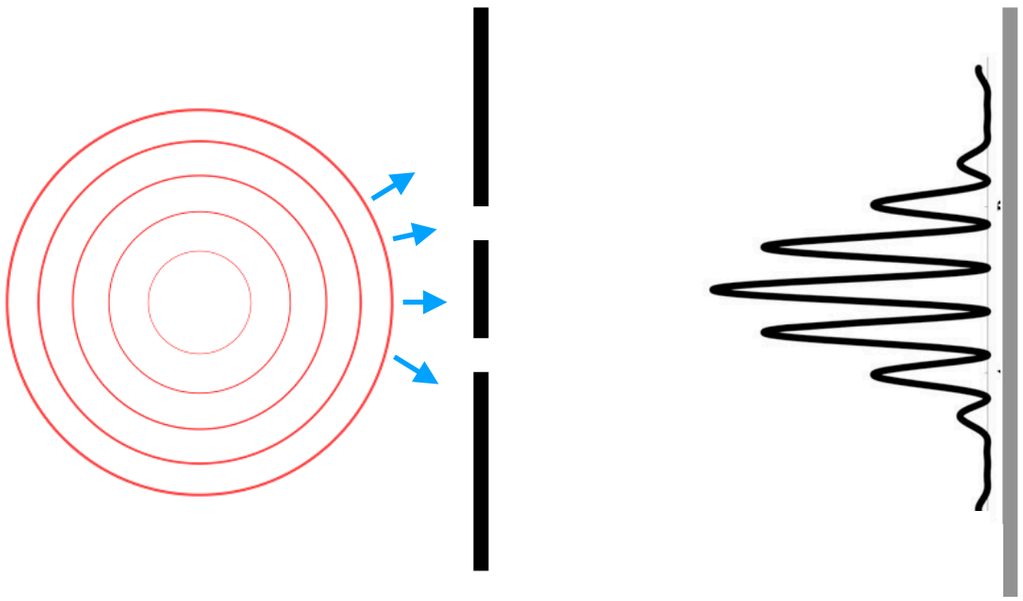


Destructive interference

Constructive: $\Delta L = n\lambda \text{ with } n = 0, \pm 1, \pm 2, \pm 3, \ldots$

Destructive: $\Delta L = \frac{1}{2} n\lambda \text{ with } n = \pm 1, \pm 2, \pm 3, \ldots$

Peaks in profile



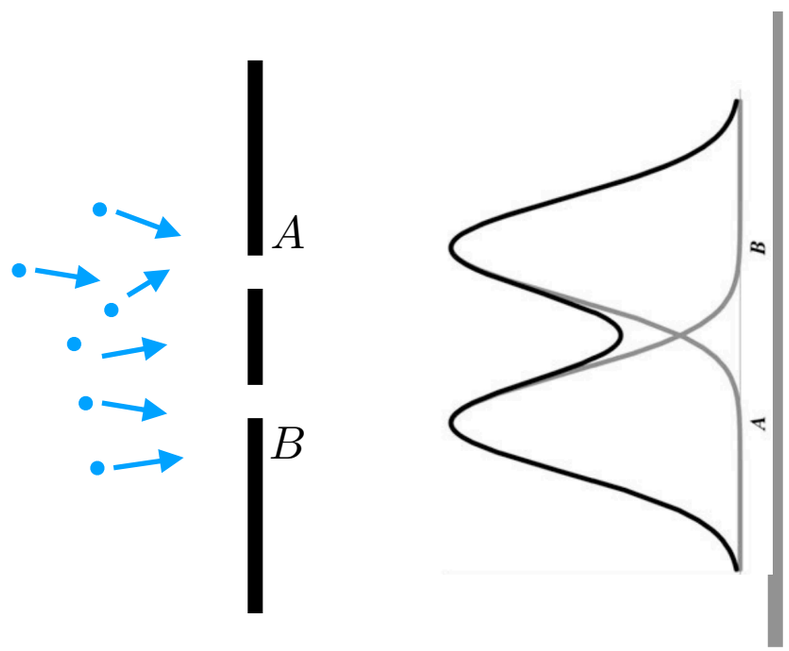
$$\Delta L = n\lambda \text{ with } n = 0, \pm 1, \pm 2, \pm 3, \ldots$$

$$\Delta L = d \sin\theta$$

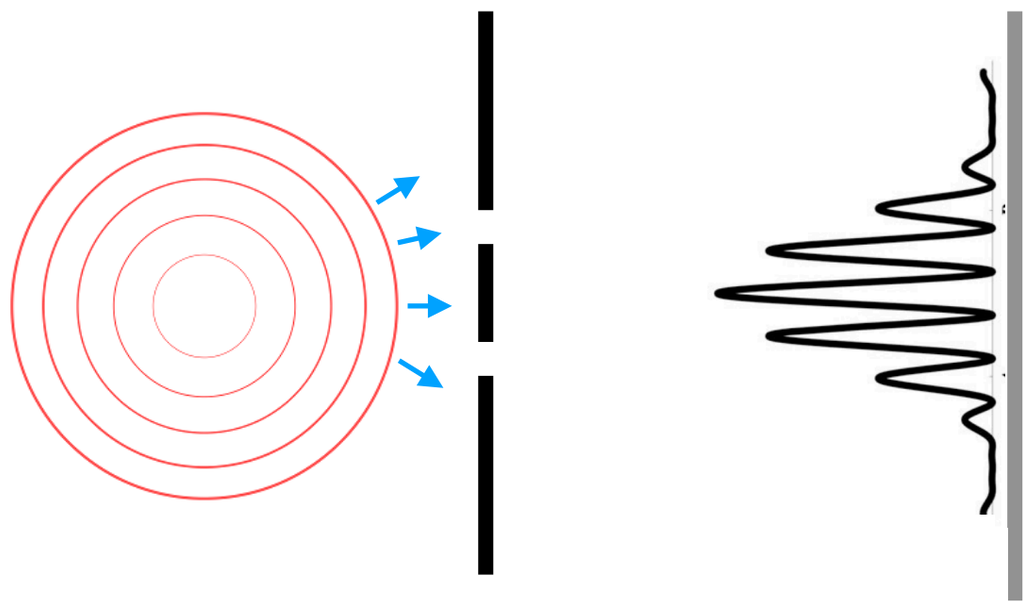
this implies peaks when: $n\lambda = d \sin\theta$

Particles vs Waves

Particles incident



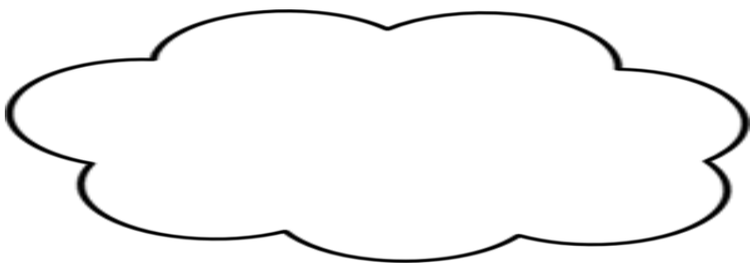
Wave incident



$$n\lambda = d\sin\theta$$

Electron incident

Single electron
With sharp momentum

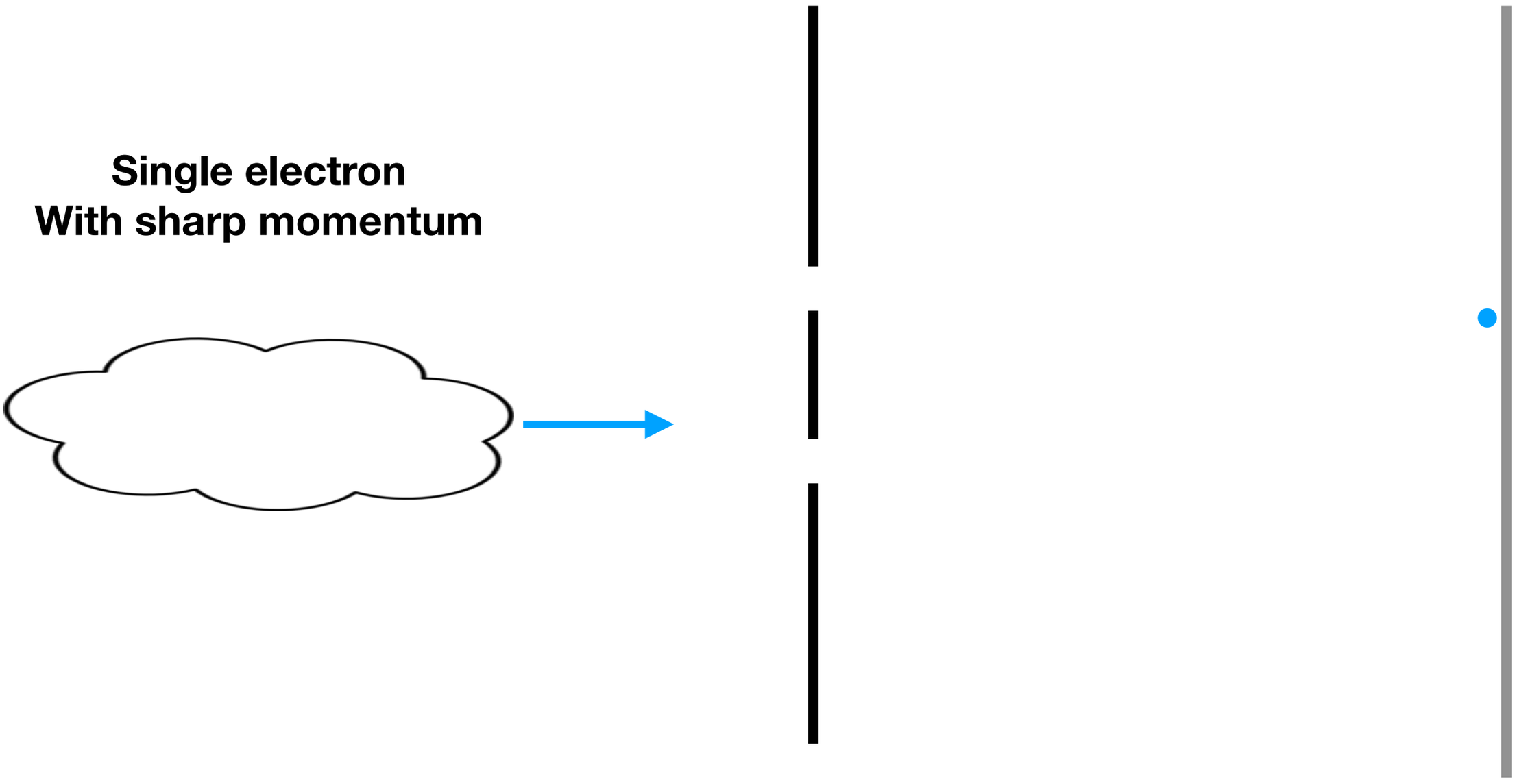


Detector screen

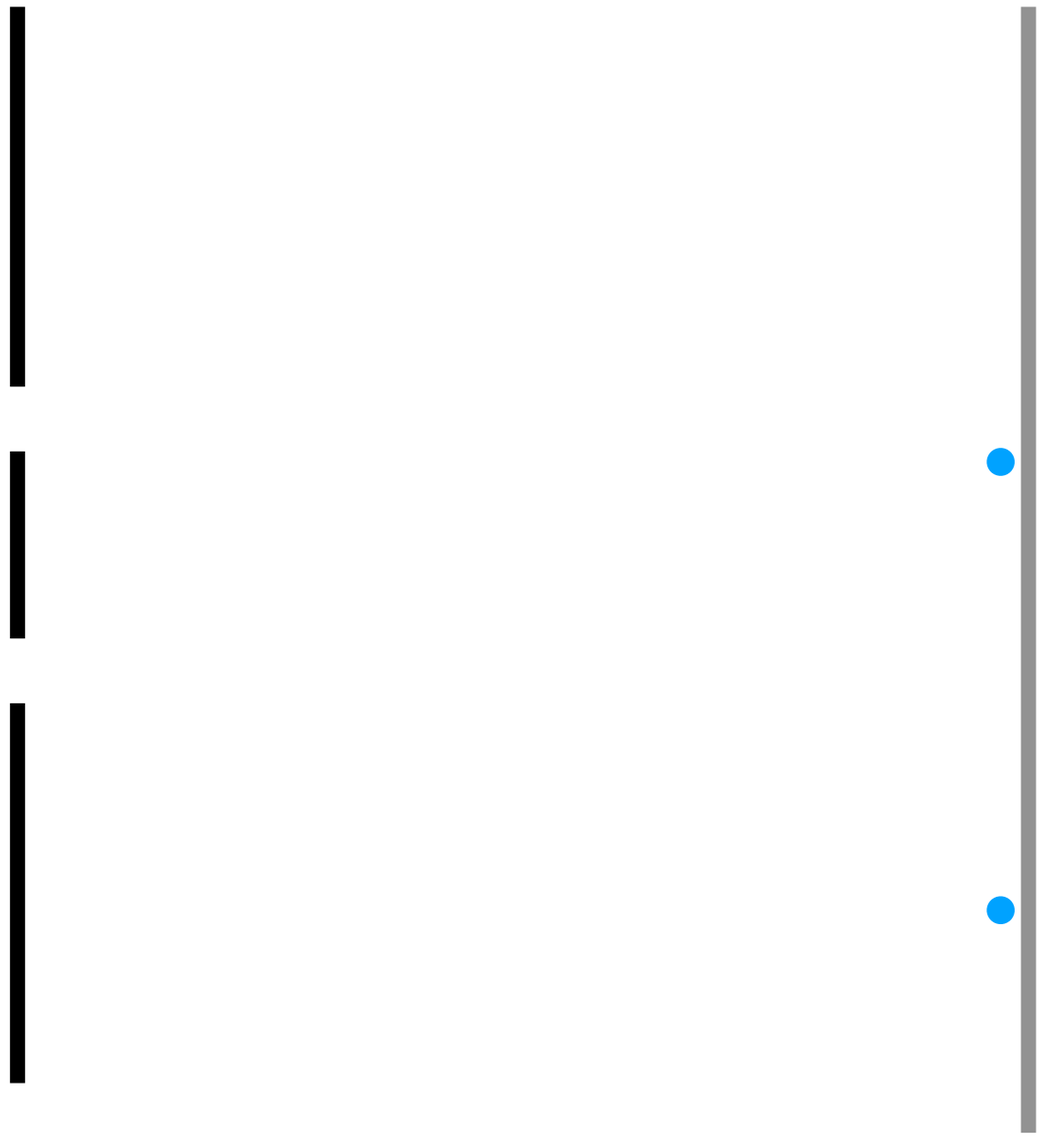
Electron incident

Electron incident

Single electron
With sharp momentum

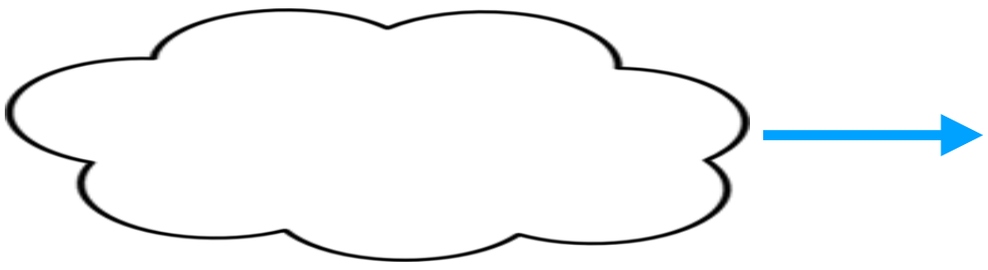


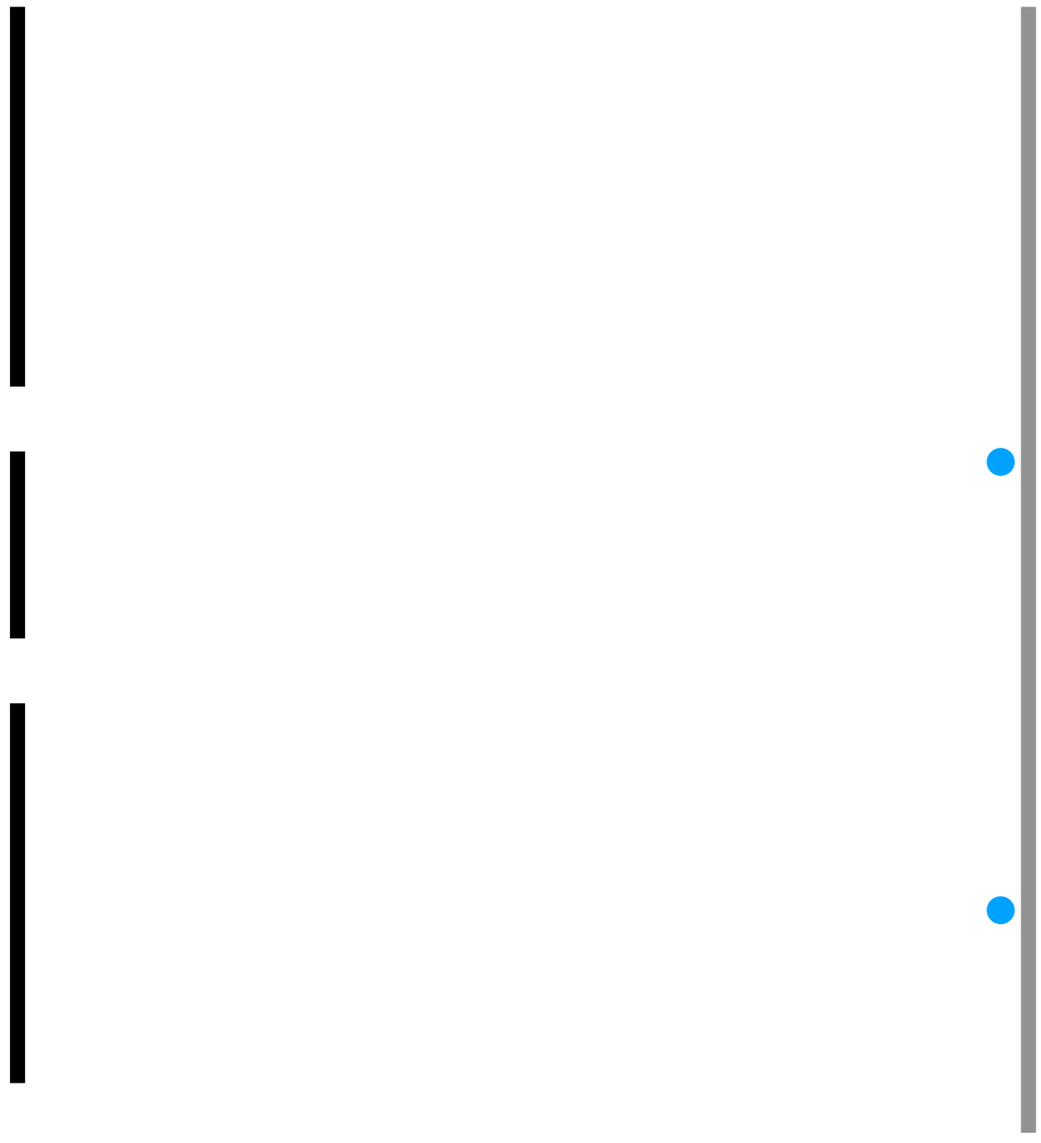
Electron incident



Electron incident

Repeat many times

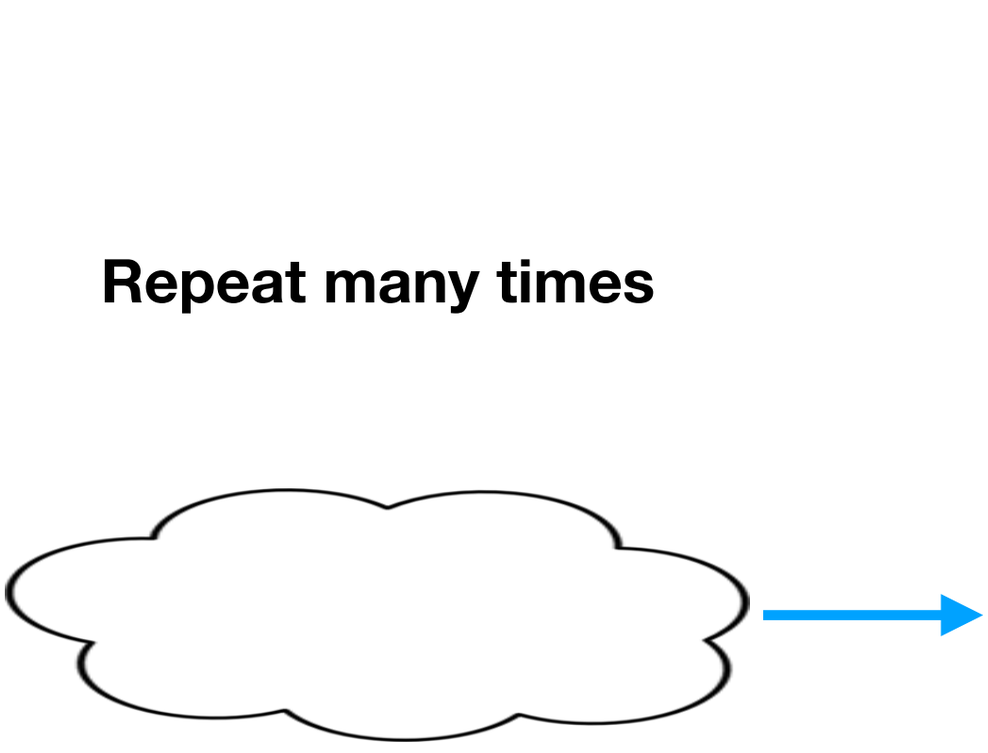


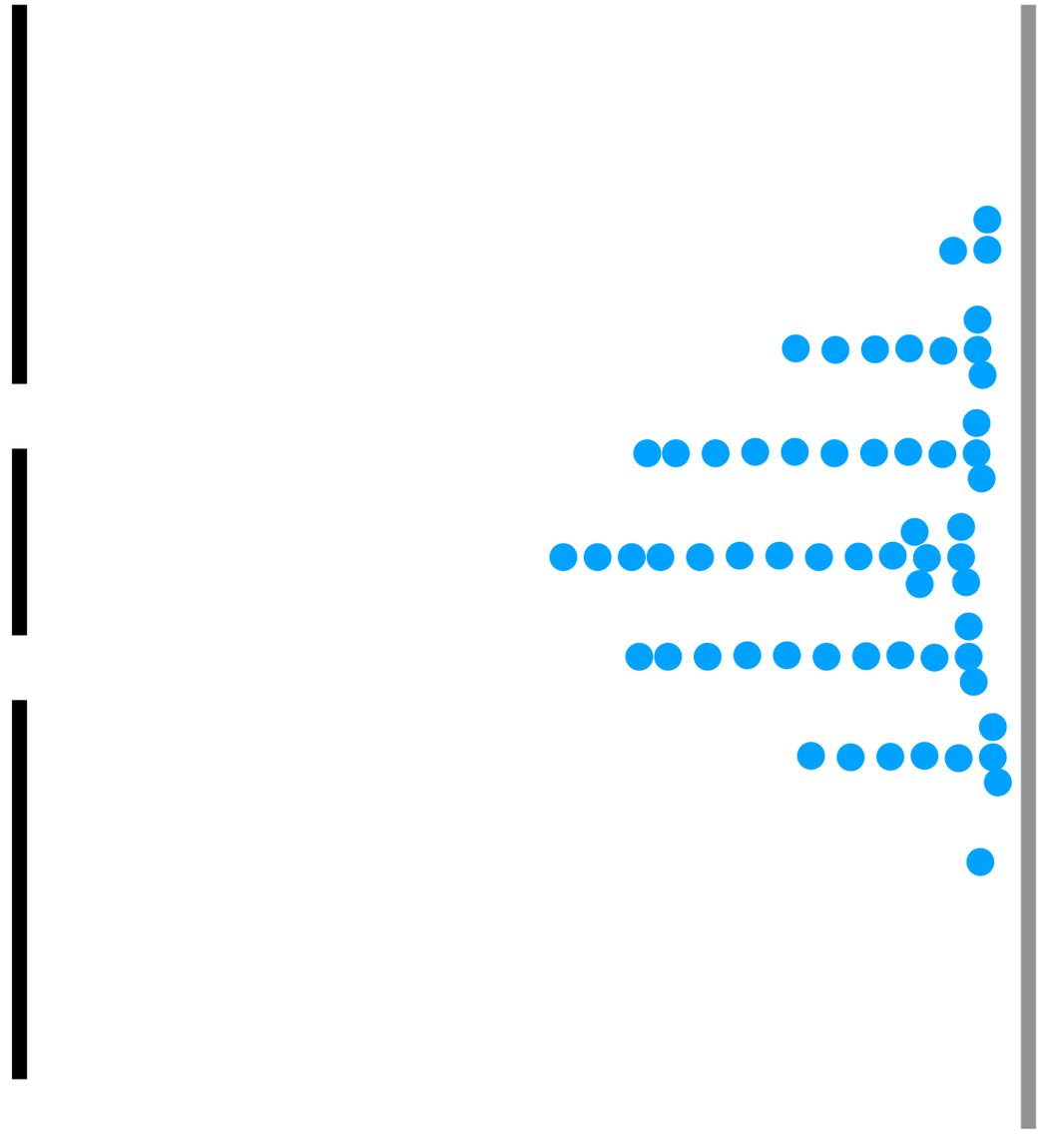


detection!

Electron incident

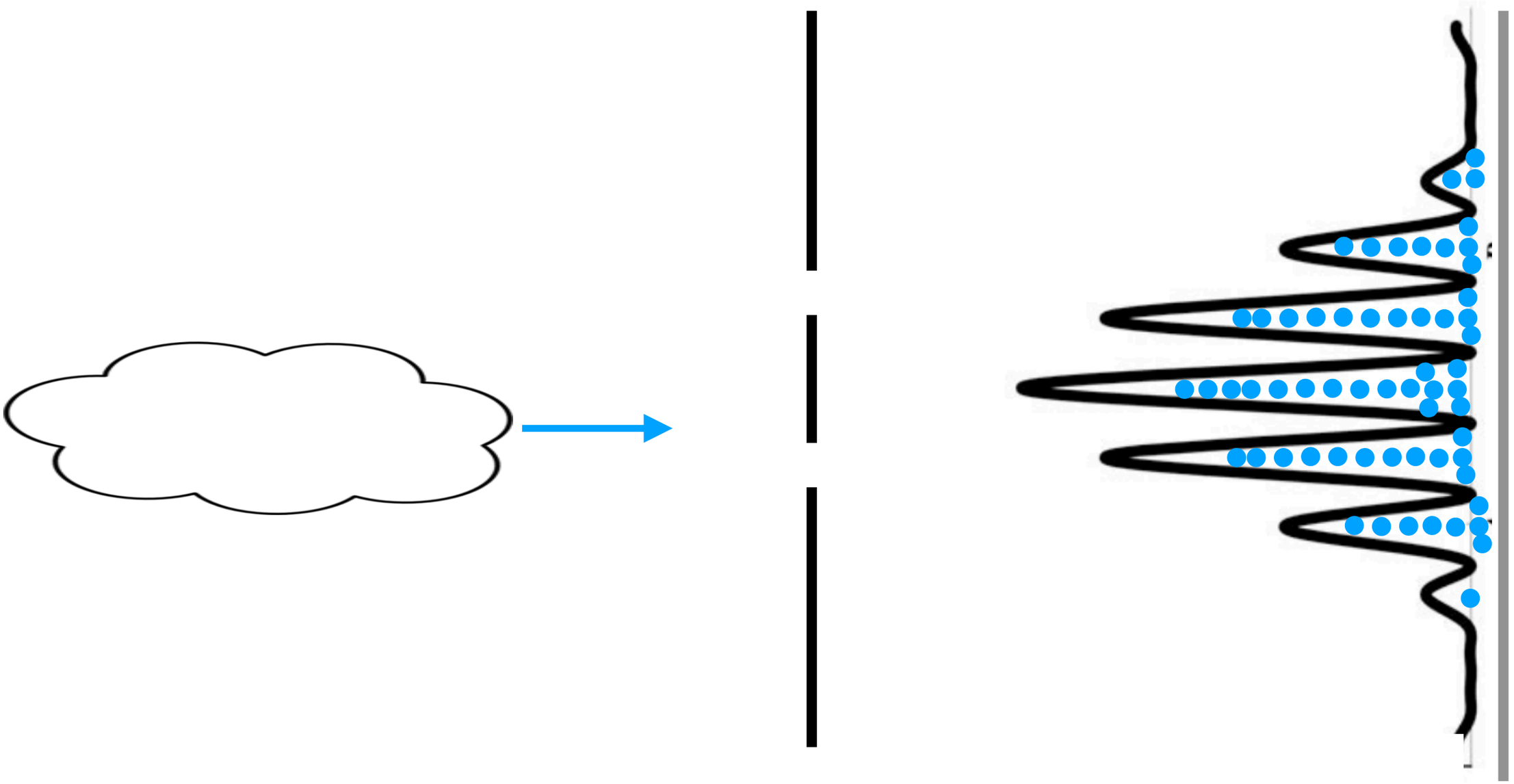
Repeat many times





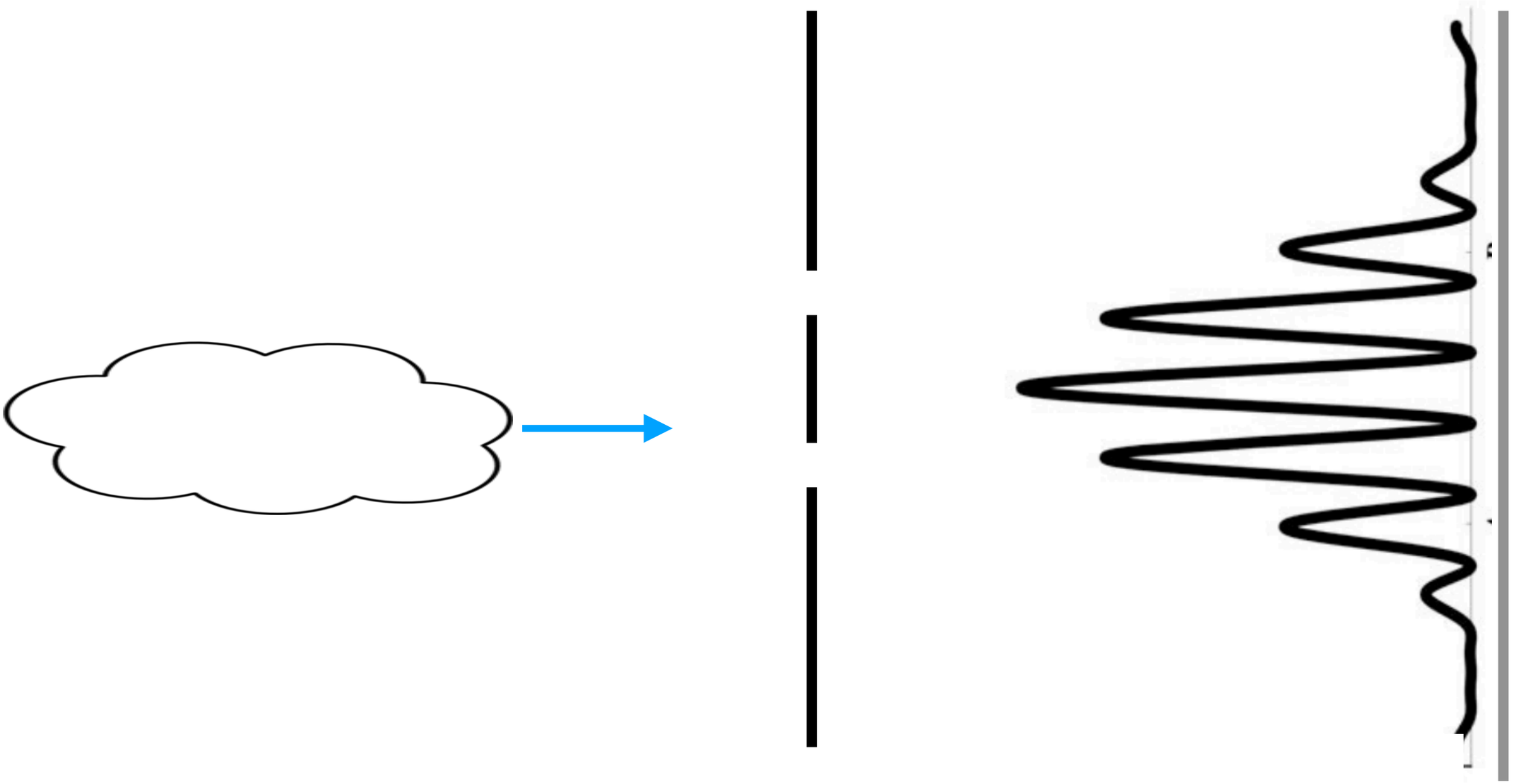
Multiple peaks!

Electron incident



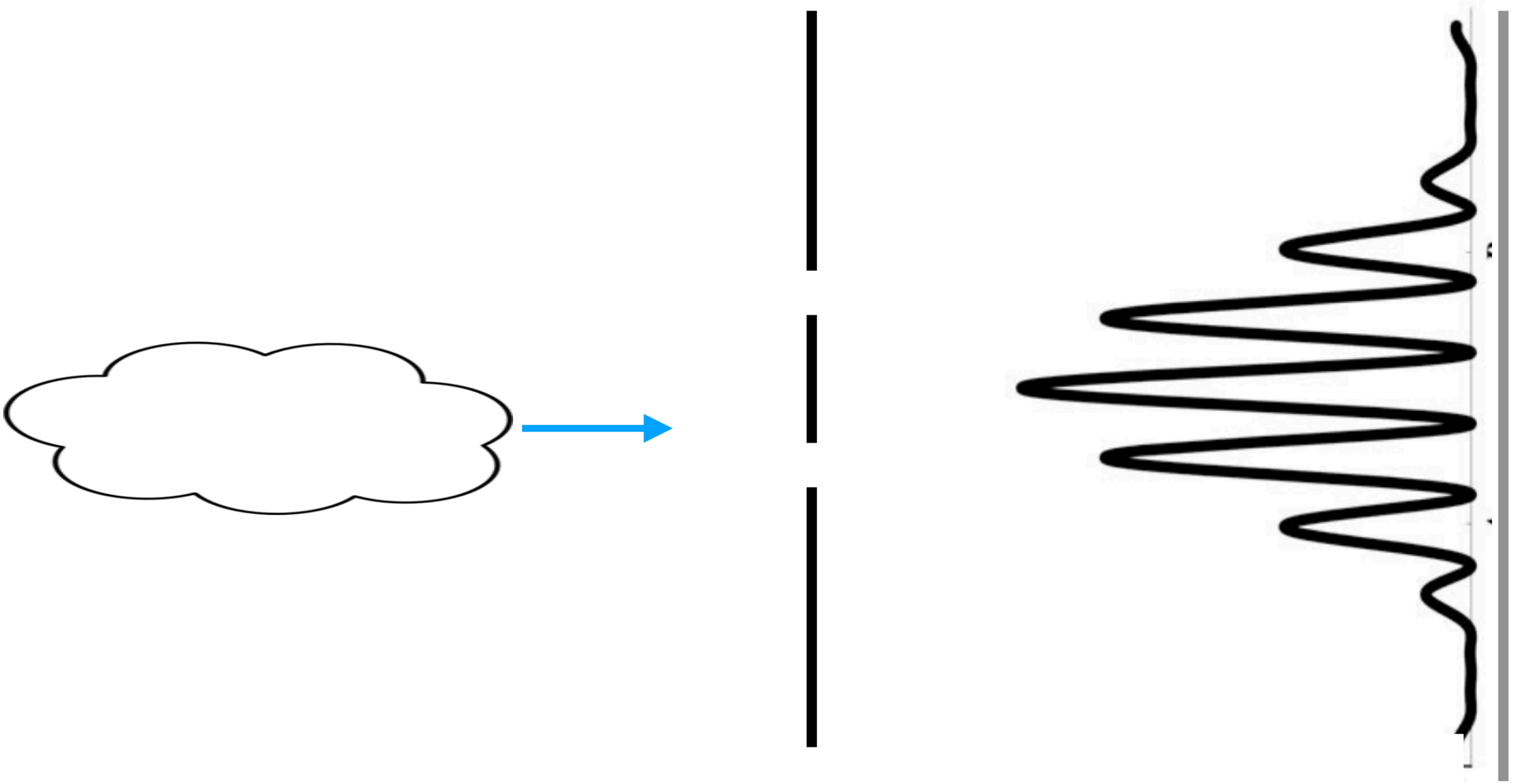
Wavelike pattern!

Electron incident

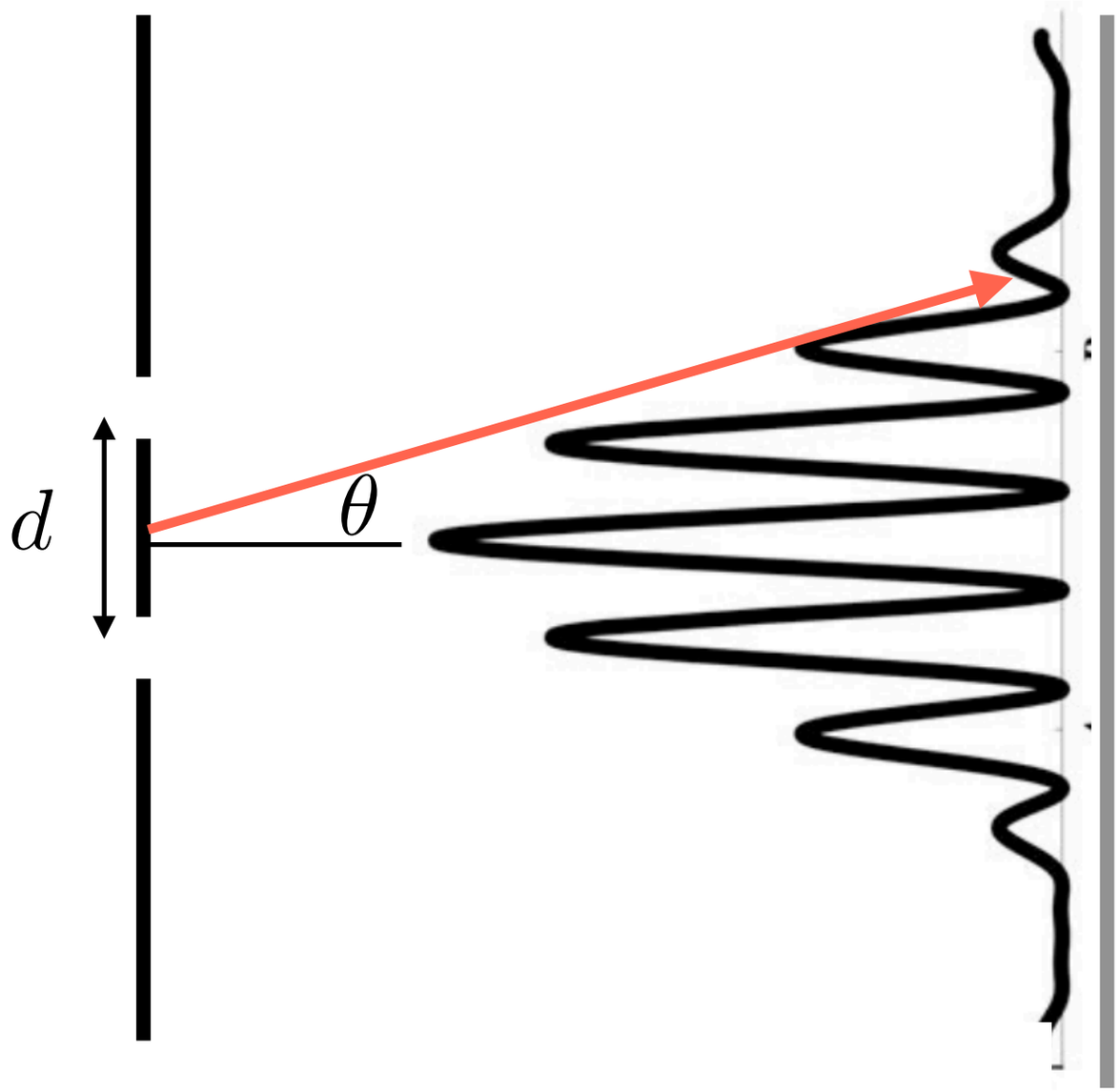


Wavelike pattern!

Electron incident



Peaks in distribution



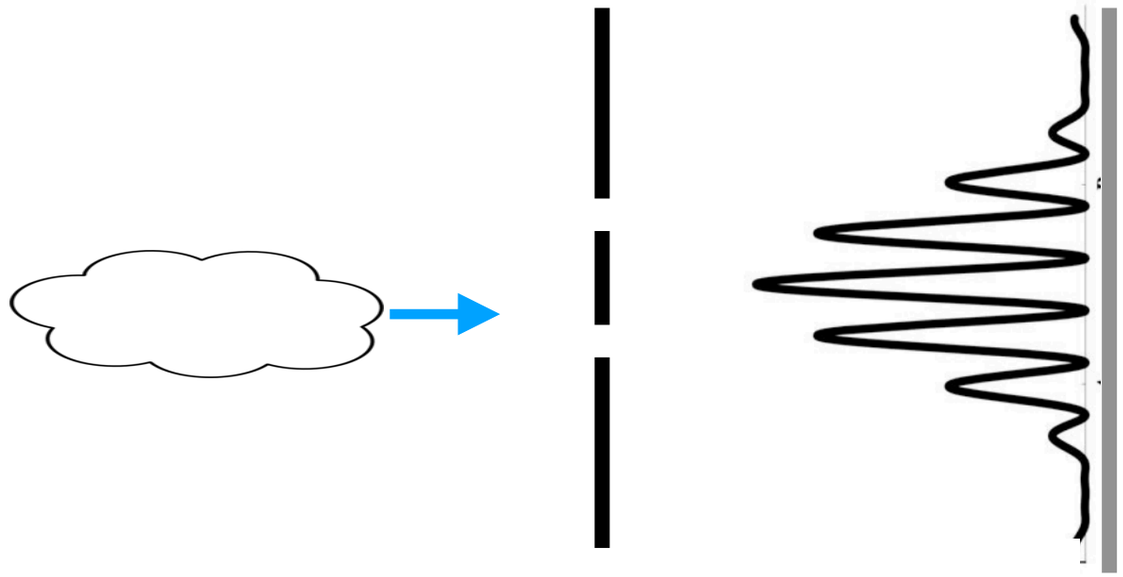
$$n\lambda_{dB} = d\sin\theta$$

de Broglie wavelength

Example calculation

Slit separation: $d = 0.4mm$

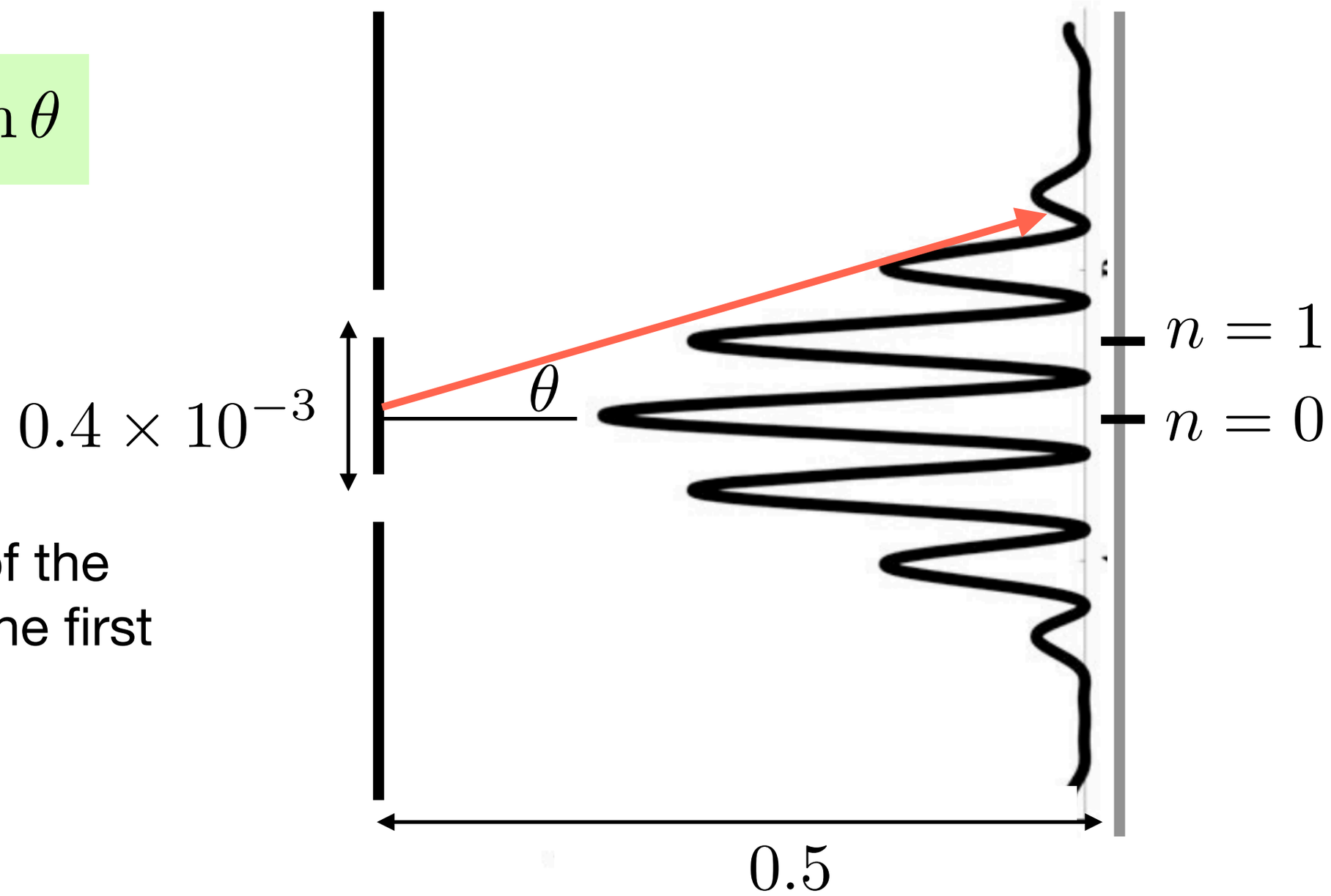
Distance to screenn: $L = 0.5m$



The separation of the central peak to the first peak is 0.05m
What is the de Broglie wavelength?

Example calculation

$$n\lambda_{dB} = d\sin\theta$$

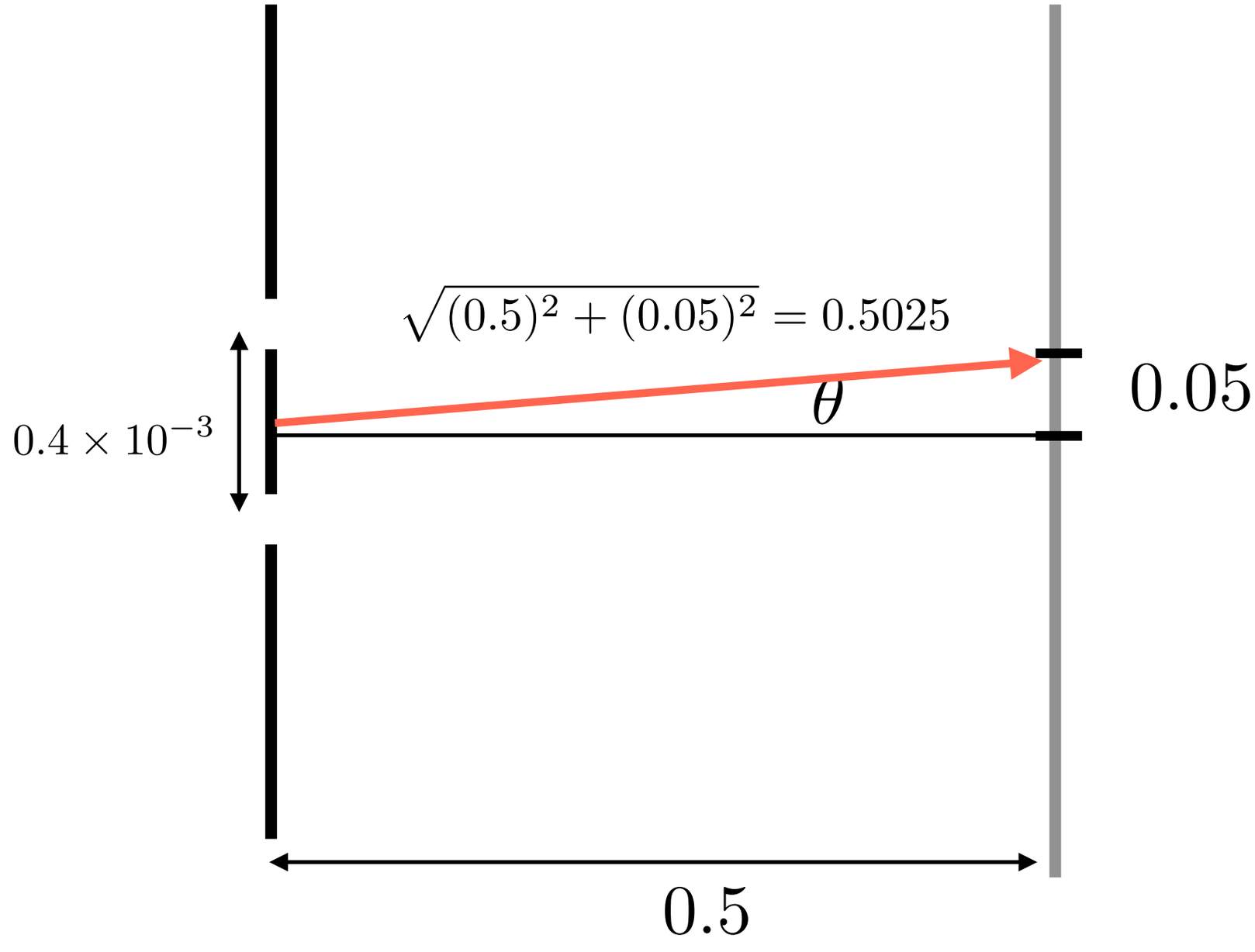


The separation of the central peak to the first peak is 0.05m

Example calculation

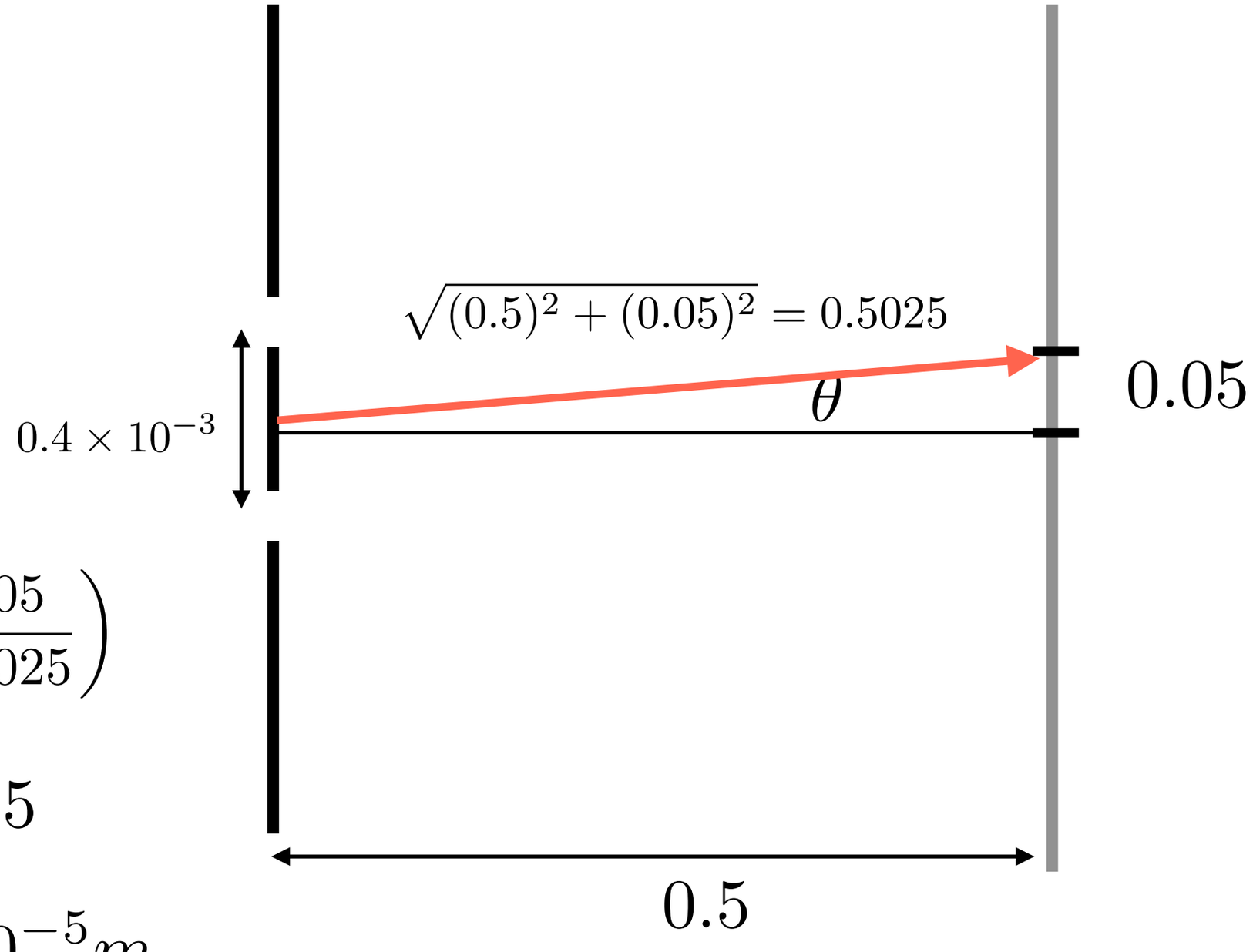
$$n\lambda_{dB} = d\sin\theta$$

$n = 1$



Example calculation

$$n\lambda_{dB} = d\sin\theta$$



$$\lambda_{dB} = (0.4 \times 10^{-3})\left(\frac{0.05}{0.5025}\right)$$

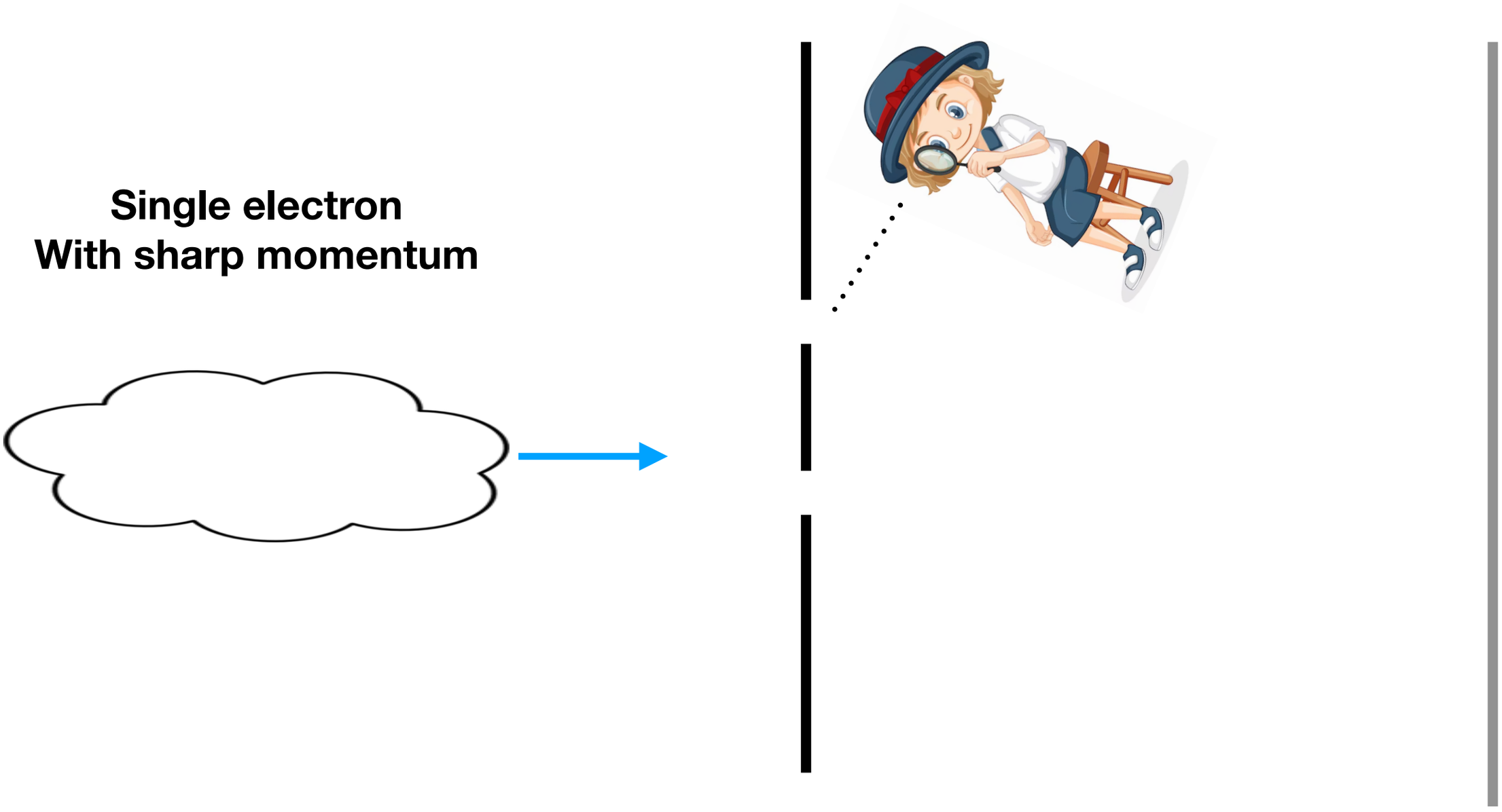
$$= 0.0000398015$$

$$= 3.98015 \times 10^{-5} m$$

Complementarity

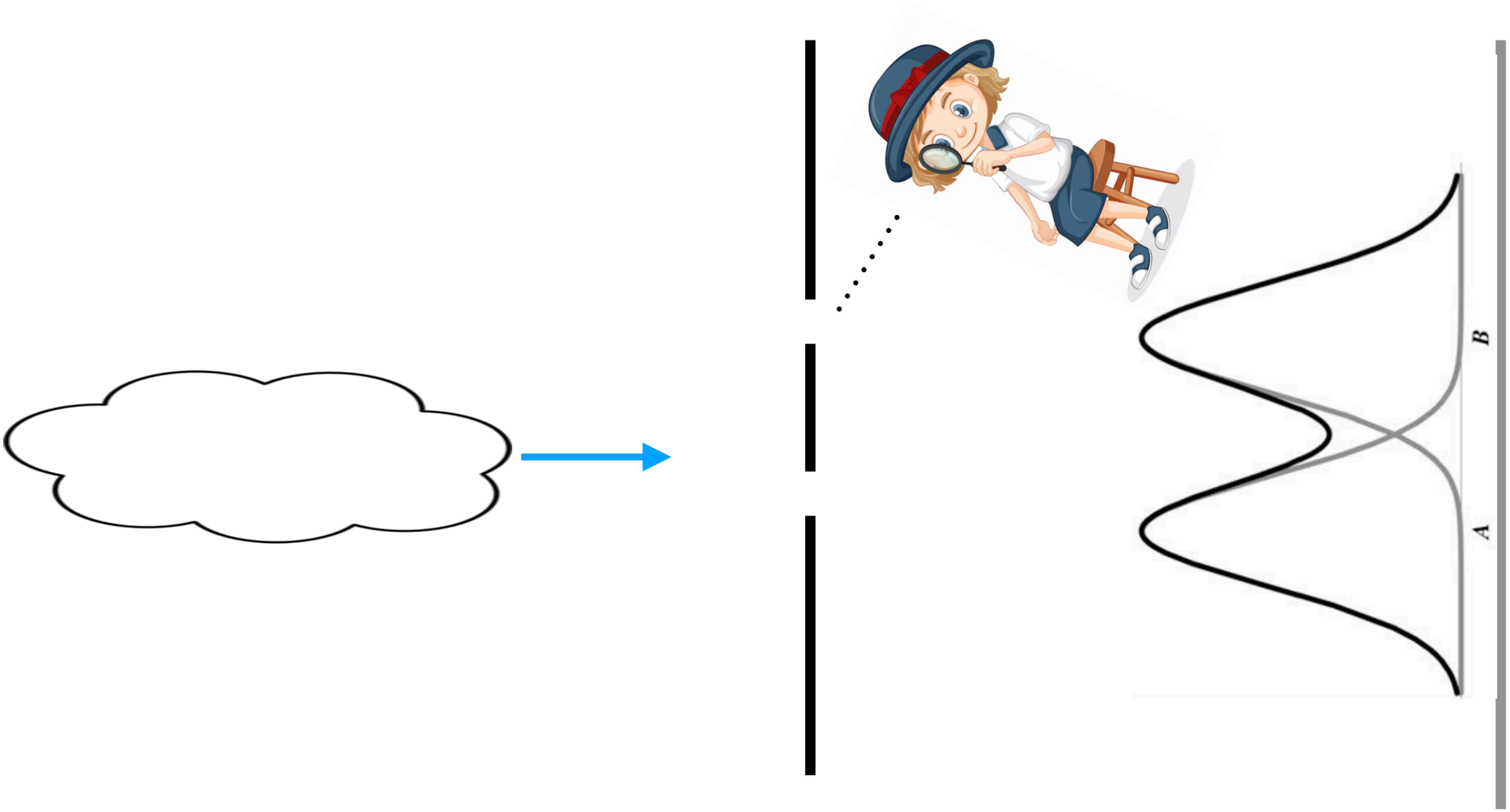
Probing the matter

Single electron
With sharp momentum



A person monitors one slit with really gentle detector

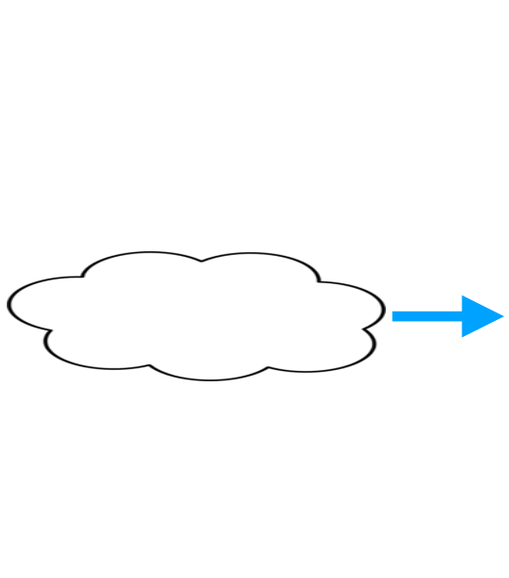
Probing the matter



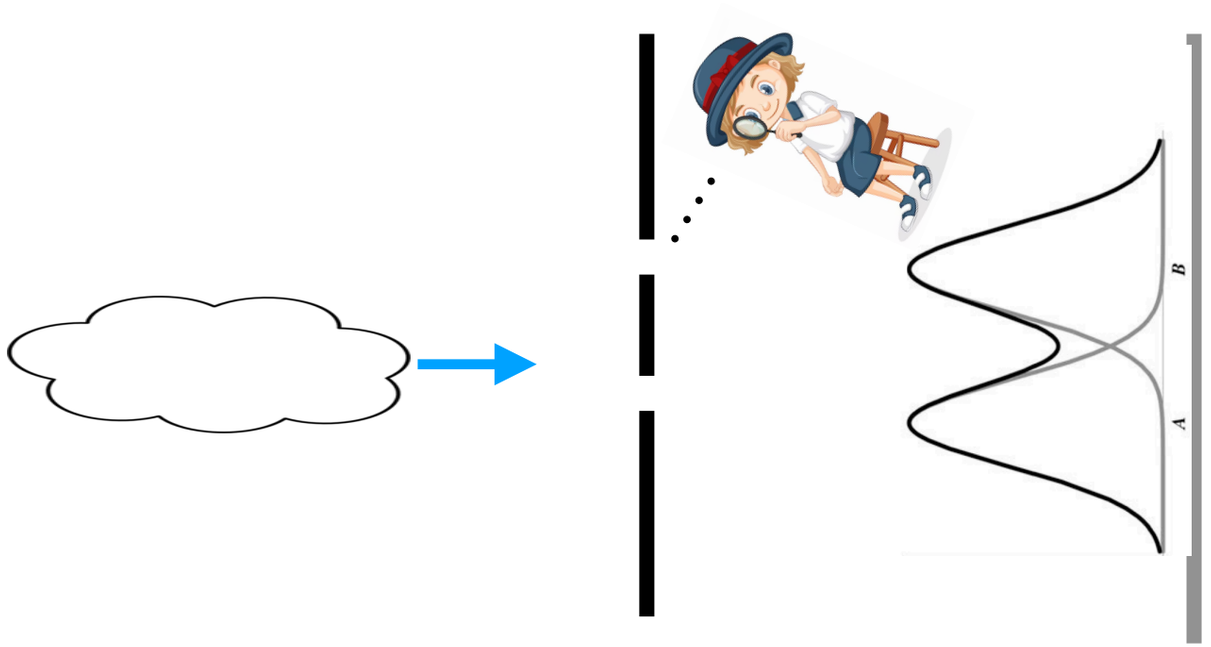
Double peaked distribution!!

Complementarity

Electron with sharp momentum.
Wave-like properties.
Interference pattern.

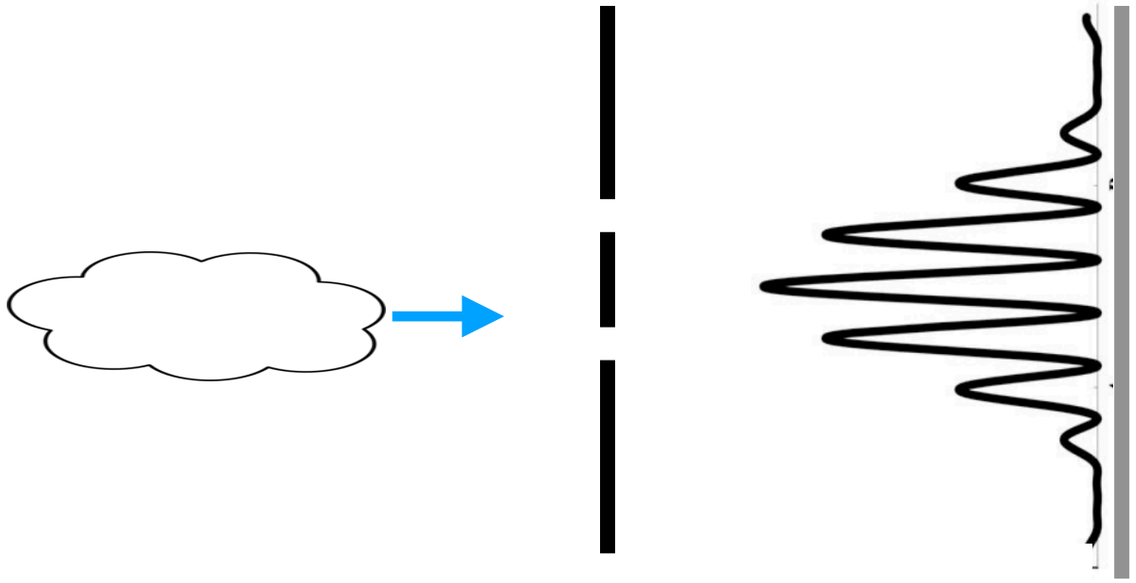


Learn information on position.
Becomes *particle-like*.
No interference pattern.



Complementarity

Electron with sharp momentum.
Wave-like properties.
Interference pattern.



Complementarity: “Wave-particle Duality”

Learn information on position.
Becomes *particle-like*.
No interference pattern.